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| Document Title: | **Detailed specification for Component Production, Cryostat Construction and Module Integration for the SIS100 Quadrupole Doublet Modules** |
| Description: | **PSP-Code: 02.08.02.10**<br><br>This documentation describes, respectively is referencing documents which describe the requirements on technical and procedural details of component production, cryostat construction, quality assurance, acceptance tests, packaging, transportation and shipment, documentation, deliverables for production, integration and delivery of Quadrupole Doublet Modules. |
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## Abstract

The document at hand is the specification for production and delivery of the full series of Quadrupole Doublet Modules for installation in the SIS100 accelerator, being part of the FAIR project. This documentation describes, respectively is referencing documents which describe the requirements on technical and procedural details of production of Quadrupole Doublet modules, quality assurance, acceptance tests, packaging, transportation and shipment, documentation, deliverables for production and delivery of Quadrupole Doublet Modules for operation at a test facility and in the SIS100 synchrotron. It defines the requirements on the production of a first of series (FoS) Quadrupole Doublet Module and the full series.

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## 1. Purpose and classification of the document

The document at hand is a specification for production, integration and delivery of 83 Quadrupole Doublet Modules (QDMs), showing several different configurations. This document specifies the cryostat systems, suspension and common girder systems and the module integration only. Any details on technical design of the integrated sub-systems as magnets, bus bars, beam pipe etc., are specified within their own dedicated detailed specifications.

The magnets respectively Quadrupole-magnet-units to be integrated into modules are *not* part of the delivery of the Contractor. The Quadrupole-magnet-units shall be supplied by the Company. Also any other components, not being part of the delivery by the contractor shall be supplied by the Company, respectively delivered by third parties, being assigned by the company. The responsibility for supply of non-Contractor components shall be at the Company. Also the installation of SIS100-QDM into the accelerator tunnel is *not* part of this specification.

For a detailed understanding of the structure of the full set of specification documents see figure 1-1 below.

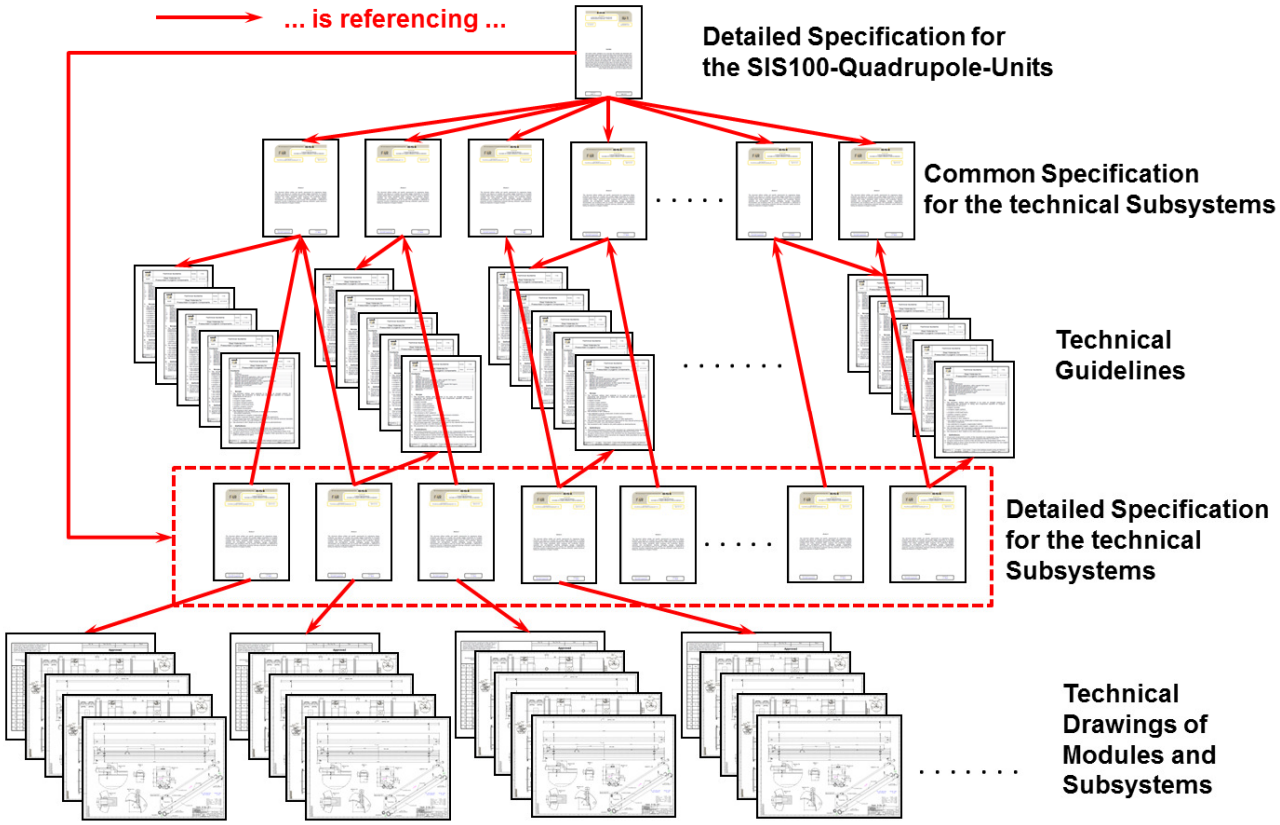



**Figure 1-1:** Document structure of the documentation set for the specification of the SIS100 QDMs

This documentation describes requirements, respectively is referencing documents which are describing requirements on

- technical design of QDMs,
- their production processes,
- the corresponding quality assurance,
- the corresponding testing processes,
- the packaging, transportation and shipment,
- the documentation,
- the deliverables

for production and delivery of QDMs. It defines the details and requirements for production of the modules, respectively the integration of involved functional components. Detailed procedural issues, relevant for named processes, are specified within this and other documents document being cited herein. This and other documents being cited herein, are building a basic set of information for the implementation of named processes. The general issues of legal rights, engineering, production, quality assurance and documentation of components for FAIR are defined by [1].

This document is valid for the SIS100 QDMs of all configuration types as described within a technical overview in section 3.1. Chapter 3.3 of this document is defining the scope of delivery by the Contractor and the Company, while later chapters are describing technical requirements of the individual types of QDMs. The production of QDMs shall be split into two deliveries, a first of series (FoS) device for the QDM – type 2.5 and the series production of this and all other types.

## 2. Abbreviations, terms and definitions

**Table 2-1:** List of abbreviations

| Abbreviation | Definition |
|---|---|
| BB | Bus Bar |
| BPM | Beam position monitor |
| CAP | Cryo-adsorption pump |
| CID | Component identification number |
| CH | Chromaticity Sextupole, horizontal focusing |
| COL | Cryo-Catcher |
| CV | Chromaticity Sextupole, vertical focusing |
| CWT | Cold-Warm-Transition |
| EC | End Cap |
| ECR | Engineering change request |
| EDMS | Engineering Data Management System |
| FAT | Factory acceptance test |
| F1 | Focusing Quadrupole, type F1 |
| F2 | Focusing Quadrupole, type F2 |
| f.i.o. | For information only |
| FoS | First of series |
| GHe | Gaseous Helium |
| IOL | Ion Optical Lattice |
| LCL | Local Current Lead |
| LD | Low current defocusing quadrupole magnet |
| LF | Low current focusing quadrupole magnet |
| LHe | Liquid Helium |
| MDR | Manufacturing Design Review |
| MLI | Multi Layer Insulation |
| NCR | Non conformity report |
| PED | Pressure Equipment Directive |
| QA | Quality Assurance |

| Abbreviation | Definition |
|---|---|
| QIPP | Qaulity Inspectiond and Production Plan |
| QP | Quadrupole |
| QDM | Quadrupole Doublet Module |
| QD | Defocusing Quadrupole |
| SAT | Site acceptance test |
| SC | Super conducting |
| ST | Steering magnet |
| UHV | Ultra High Vacuum |
| VC | Beam Vacuum Chamber |

**Table 2-2:** List of definitions.
These definitions apply to the SIS100-QDM systems and this document only. They may not be applied in general or to other technical systems of SIS100.

| Item | Definition |
|---|---|
| Bus Bar | An appropriate shaped piece of super conducting Nuclotron-cable, which witch is connected to the QP-coils, respectively is an additional electrical system supplying all Dipole magnets. These components are part of the cryogenic circuit of the magnet assemblies respectively are forming an integral part of Quadrupole coils. |
| QP-Magnet | An iron dominated superconducting quadrupole magnet assembly of the Nuclotron-type which is applied for beam focusing. It is built from a LHe-cooled yoke, a LHe-cooled coil of Nuclotron cable and includes its bus bar system. |
| Corrector-Magnet | An iron dominated superconducting magnet assembly of the Nuclotron-type which is applied for beam correction purposes. They are built from a LHe-cooled yokes and coils of Nuclotron-cable. They are not supplied by integral bus bars but need dedicated local current supply. |
| Steering-Magnet | An iron dominated superconducting magnet assembly of two dipole magnets of the Nuclotron-type which is applied for beam steering purposes. They are built from LHe-cooled yokes and coils of Nuclotron-cable. They are not supplied by the main global bus bar system but need dedicated local current supply. |
| QP-magnet-unit | An assembly of QP-magnets, partly with mounted corrector magnets. A fully assembled unit implies also UHV-beam vacuum systems, He-supply lines, cryogenic tuning systems, instrumentation and partly beam position monitors. QP-magnet-units do appear as pre-assembled components with magnets and cryogenic systems only, as well as fully assembled systems with added UHV components and instrumentation. |
| Common Girder | A mechanical framework, providing the connection, alignment and support structure for fully assembled QP-magnet-units and their He-supply-system. The common girder is cooled by integrated LHe-cooling pipes located at the exit of the magnet cooling circuits. |
| Cold Mass | A fully assembled structure, integrating two QP-magnet-units on a common girder being cooled by an integrated LHe-supply- and cooling system. |
| Thermal shield | A GHe-cooled (at 50 K – 80 K) metal shell structure, protecting an inside cold mass form thermal radiation. |

| Item | Definition |
|---|---|
| Insulation vacuum vessel | A stainless steel vessel of high mechanical stability, for keeping a high vacuum inside and providing mechanical interfaces for fixation of a cold mass. |
| Support system | A structure of mechanical components showing a minimum of thermal conductivity and high mechanical stability to provide a mechanically stable position for a cold mass. |
| Cryostat | An assembly of thermal shield and insulation vacuum vessel for the purpose of thermal insulation of a cold mass. |

## Important Notes

*The QDM type 2.5 might be named 3-F2 in some according technical drawings. Within the document at hand, only the naming 2.5 is in use. The type naming 3-F2, used in any technical drawings is out of date. This fact shall have no influence on any design detail.*

*Within this document, any figures of technical systems, in case they are marked with the abbreviation f.i.o., are FOR INFORMATION ONLY. Detailed engineering design, as defined by dedicated engineering design drawings of components and assemblies, might differ from such figures. The definitions and dimension in engineering drawings shall be valid.*

# 3. Scope of the technical system

## 3.1. **Overview on SIS100**

The Facility for Antiproton and Ion Research builds a new international accelerator facility for fundamental research with antiprotons and heavy ions. SIS100, the main accelerator of the research facility is a heavy ion synchrotron with a circumference of 1084 m is built in a tunnel, 12.5 m underground. It is designed for a magnetic rigidity of Bρ = 100 Tm. Its superconducting magnet technology is based on the design and experience of the Nuclotron accelerator witch is in operation at Joint Institute for Nuclear Research since 1993. SIS100 shows a six fold symmetry with six arc sections and long straight sections, providing space for injection-, extraction- and extended radio frequency acceleration systems. The ion optical lattice of a sextant is composed of 14 cells of 12.90 m in length. The ion optical lattice of one sextant consists of 10 lattice cells in the arcs, eight with two dipole magnets and one cell with only one dipole magnet at each end of an arc. A straight section shows four lattice cells of a total length of 51.60 m.

The SIS100 local cryogenic system, supplying the accelerator with liquid Helium, is principally divided into three sections. Each of these is fed from separate Feed Boxes. Each sixth of the ring consists of one cold arc and a straight warm section with three cold quadrupole doublets in between. A Bypass Line circumvents each of the six straight warm sections of SIS100 to supply liquid Helium and cold electrical connections to the superconducting quadrupole doublets within these sections.

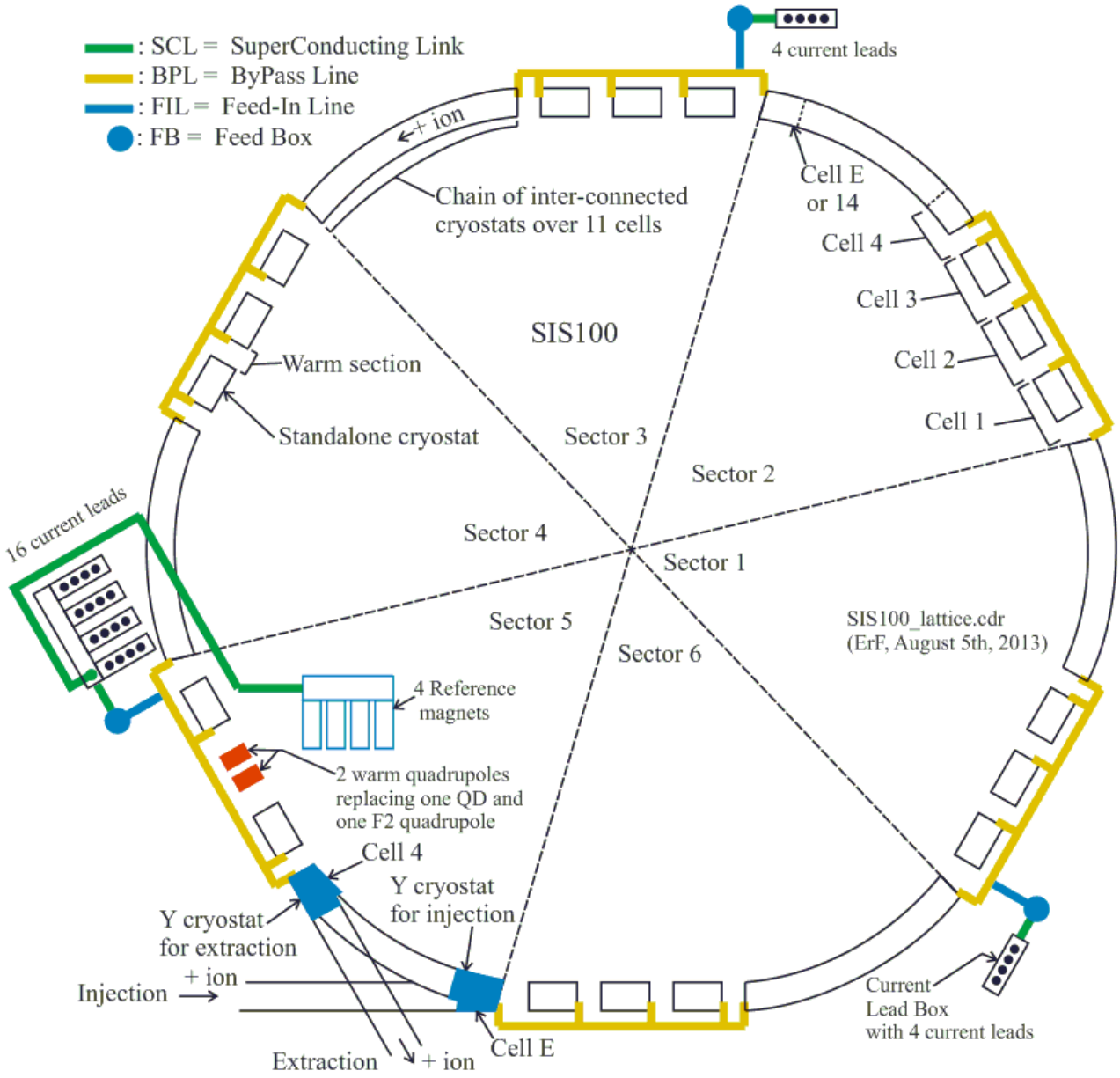



**Figure 3-1:** Schematic representation of the SIS100 accelerator showing the six sections of the synchrotron ring with its Bypass Lines and cryogenic and electrical supply systems.

**Figure 3-2:** Top view on a CAD model of SIS100 (with ion optical lattice shown) integrated in the tunnel building. The outer concrete tunnel houses the synchrotron machine itself and an inner tunnel provides space for all required electrical and cryogenic infrastructure being required for operation of SIS100.

## 3.2. System overview on the SIS100 QDM families and configurations

The components, being of functional effect in the ion optical lattice are focusing and defocusing quadrupole magnets, sextupole magnets, paired steering magnets, cryo-catchers and beam position monitors. These components are organized in different configurations within multiple types of QDMs. The full set of SIS100 QDMs splits into four families and 11 different configurations as defined by table 3-1 below.

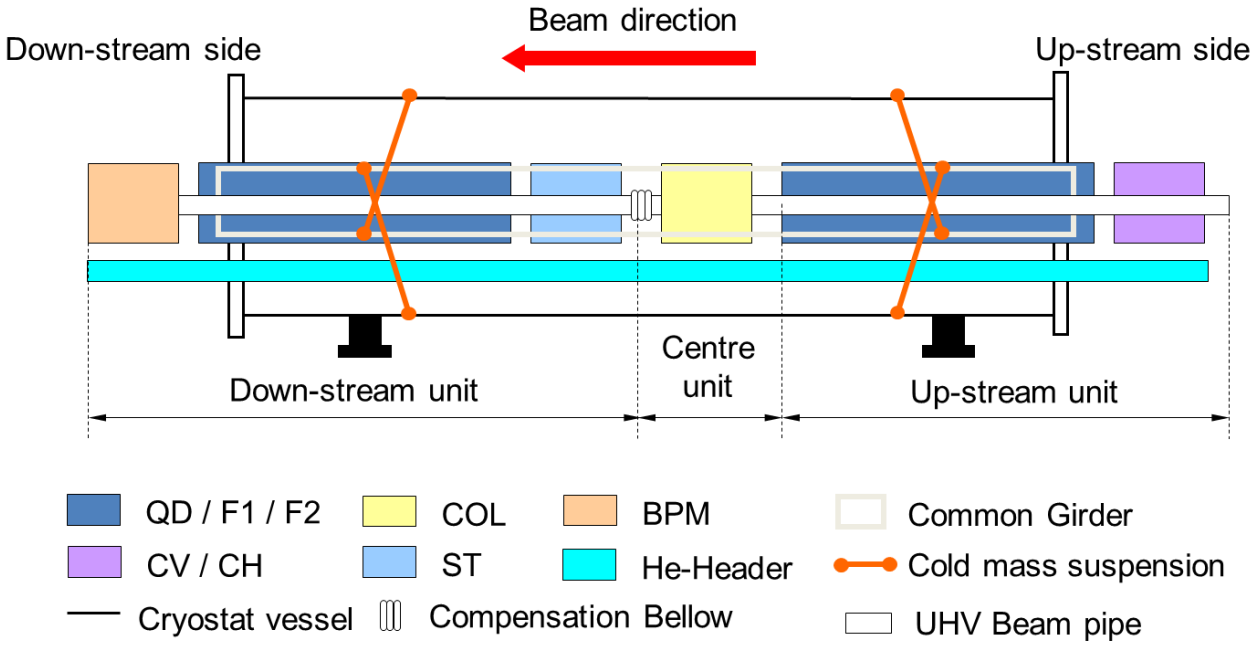



**Figure 3-3:** Schematic view of a SIS100 Quadrupole Doublet Module of the arc section type 2.5.

**Table 3-1:** Families and Configurations of SIS100 QDMs

| ***Configuration*** | | | | | ***Naming*** | | |
|---|---|---|---|---|---|---|---|
| **Module Family** | **Up-stream unit** | **Centre unit** | **Down-stream unit** | **IOL cell** | **Doublet name** | **Short name** | **Quantity** |
| Straight section | QD*B | -TRP- | SF2* | 1,2,3 | QD*B-TRP-SF2* | 2.123 | 14 |
| | QD*Bs | -TRP- | SF2*s | 1,3 | QD*Bs-TRP-SF2*s | 2.13s | 3 |
| Arc termination | QDBb | -T- | SF2Mb | 4 | QDBb-T-SF2M | 2.4 | 5 |
| Special | QDBx | -T- | SF2Mx | 4 | QDBx-T-SF2Mx [LD-P-LF] | 2.4x | 1 |
| | LD | -P- | LF | | | | |
| Arc section | VQD | -CR- | SF2B | 5 | VQD-CR-SF2B | 2.5 | 6 |
| | BQD | -C- | SF1H | 6, 10 | BQD-C-SF1H | 1.6A | 12 |
| | VQD | -CR- | SF1B | 7, 11 | VQD-CR-SF1B | 1.7B | 12 |
| | BQD | -C- | SF2H | 8, 12 | BQD-C-SF2H | 2.8C | 12 |
| | BQD | -CR- | SF2J | 9,13 | BQD-CR-SF2J | 2.9D | 12 |
| Arc termination | MQDb | -C- | SF1Bb | 14 | MQDb-C-SF1Bb | 1.E | 5 |
| Special | MQDi | -C- | SF1Bi | 14 | MQDi-C-SF1Bi [LD-P-LF] | 1.Ei | 1 |
| | LD | -P- | LF | | | | |

**Abbreviations in table** 3-1**:**

QD Defocusing quadrupole,
QD* Defocusing quad. type 1 in Module 2.123, 2.13s with reduced bus bar configuration
LD Low current defocusing quadrupole,
LF Low current focusing quadrupole,
F1 Focusing quad. type 1
F2 Focusing quad. type2
F2* Focusing quad. type 2 in Module 2.123, 2.13s with reduced bus bar configuration
J γ - t - jump quadrupole,
B Beam position monitor
V Vertical chrom. sextupole
H Horizontal chrom. sextupole
S Steering magnet
M Multipole corrector magnet
C Cryo-Catcher
T Drift tube
P Cryo-sorption-pump
R Roughing pump with CWT
b extended bus bars in the unit
i injection Y cryostat
x extraction Y cryostat
s Star shape chamber

**Additional explanations for table** 3-1**:**

The focusing and defocusing QP-magnets in the module types 2.123 and 2.13s are showing reduced bus bar configurations compared to the arc sections modules, thus they are marked with a * The F2*-type magnets will be powered by two different electrical circuits for F1- and F2-power supply, being installed in a cryogenic bypass-line. Basically the F2*-type QP-magnet is configured like an F2-type QP-magnet concerning its electrical power connection but is operating as an F2- respectively as an F1- type magnet, dependent of the configuration of its electrical power connection in the by-pass line.

The special modules in the ion optical lattice cells 4 and 14 (2.4x and 1.Ei) are integrating also the injection- respectively the extraction branches of SIS100. An identification of these additional assemblies is signed in in table 3-1 by square brackets.

### 3.2.1. Straight section modules

SIS100 implies two varieties of straight section modules, type 2.123 and 2.13s. Special star shaped VCs are installed in the QP units in the module type 2.13s compared to module type 2.123, where elliptical chambers are applied. The general structure of the module types 2.123 and 2.13s remains the same.

The general structure of a straight section module is shown in figure 3-4 to figure 3-6 to below by means of the example of module type 2.123.

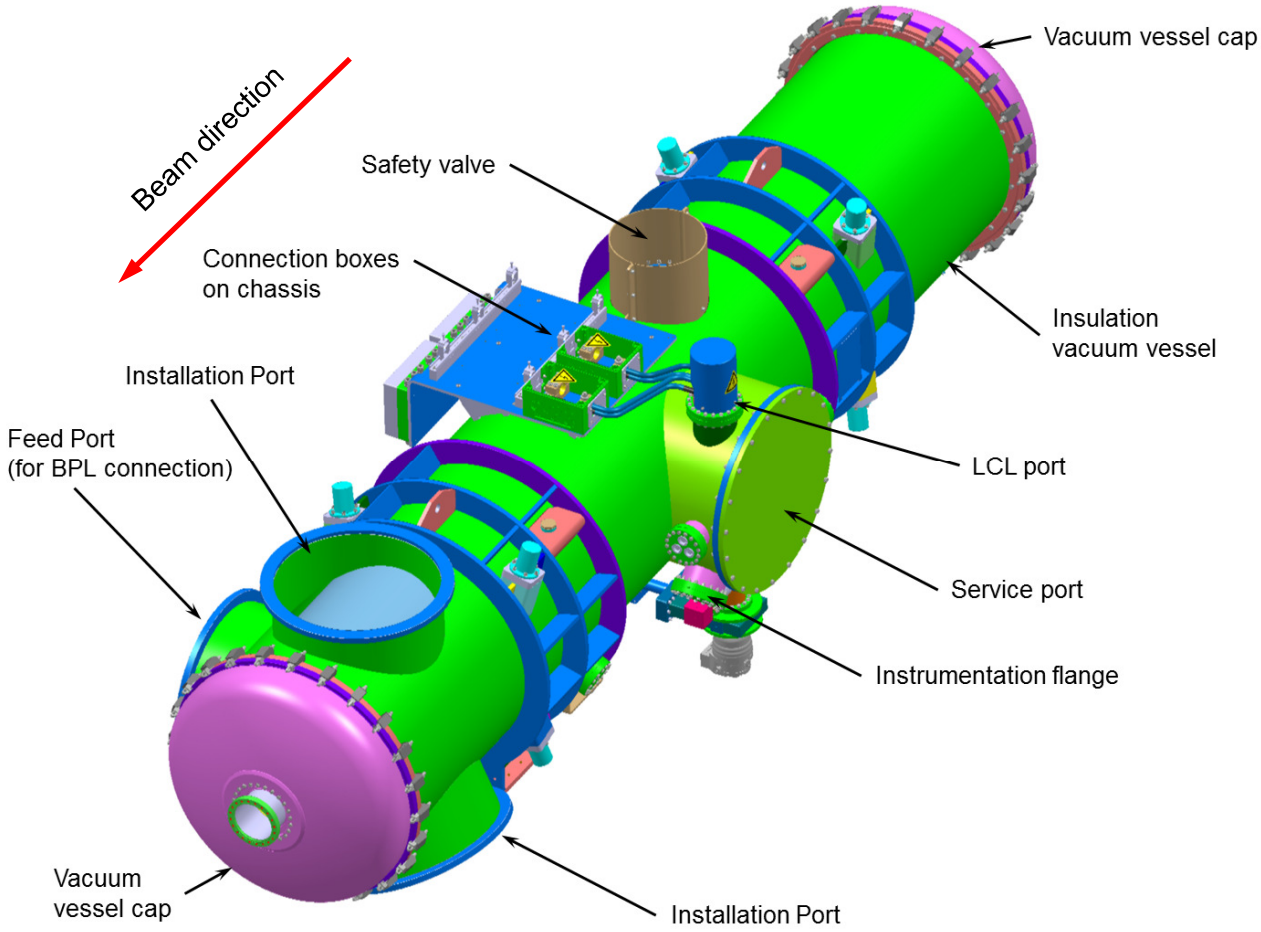



**Figure 3-4 f.i.o:** Complete SIS100-QDM, type 2.123 and 2.13s.

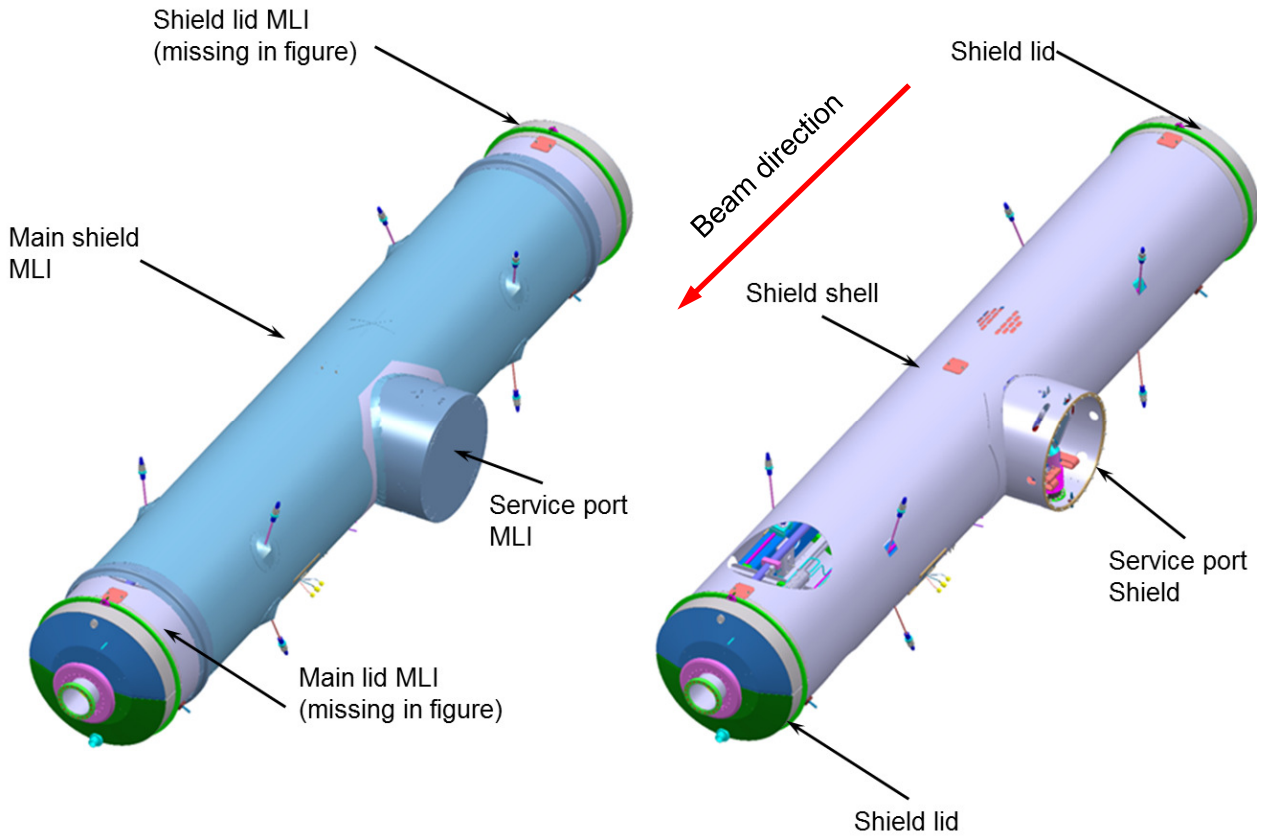



**Figure 3-5 f.i.o:** QDM cold mass surrounded by thermal shield with MLI (left) without MLI (right).

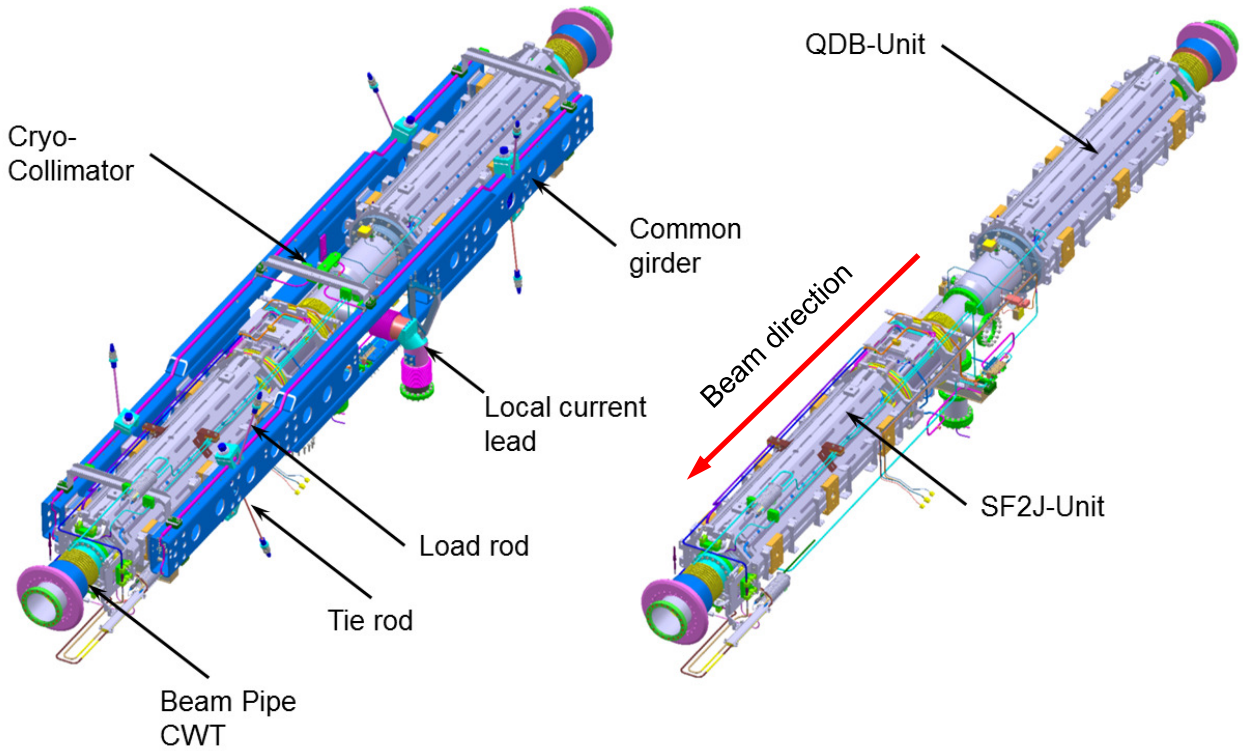



**Figure 3-6 f.i.o:** QDM cold mass: Integrated in the common Girder (left). upstream- and downstream-located units (right).

### 3.2.2. Arc termination modules

SIS100 implies two varieties of standard arc termination modules, the type 2.4 (upstream – located at the entrance of an arc section) and the type 1.E (downstream – located at the exit of an arc section). These modules imply dedicated end caps at their upstream – respectively downstream – end. Inside the ECs of these modules, the electrical and cryogenic supply of the SIS100 arc segments is fed out into the bypass line to provide continuity for the low temperature transport systems along the straight sections parllel to their warm installations. Due to high pressure forces, acting at the arc sector termination, these modules do need special support structures, stabilizing the arc termination modules in position.

The general structure of an arc termination module is shown in the figure 3-7 to figure 3-9 below by means of the example of module type 2.4.

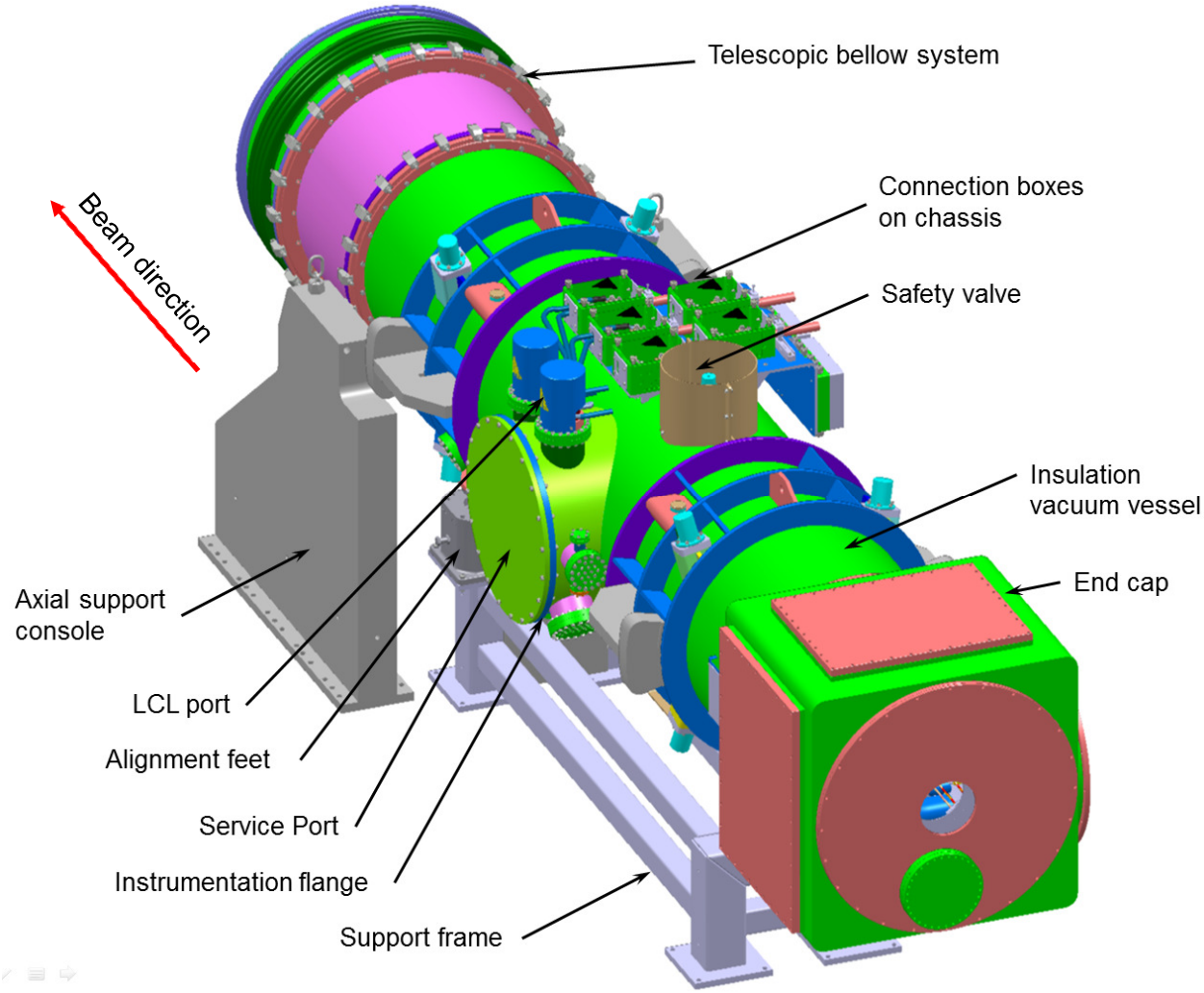



**Figure 3-7 f.i.o:** Complete SIS100-QDM, type 2.4 with support frame and axial support consoles. The support consoles only are installed at start and end of an arc-section only.

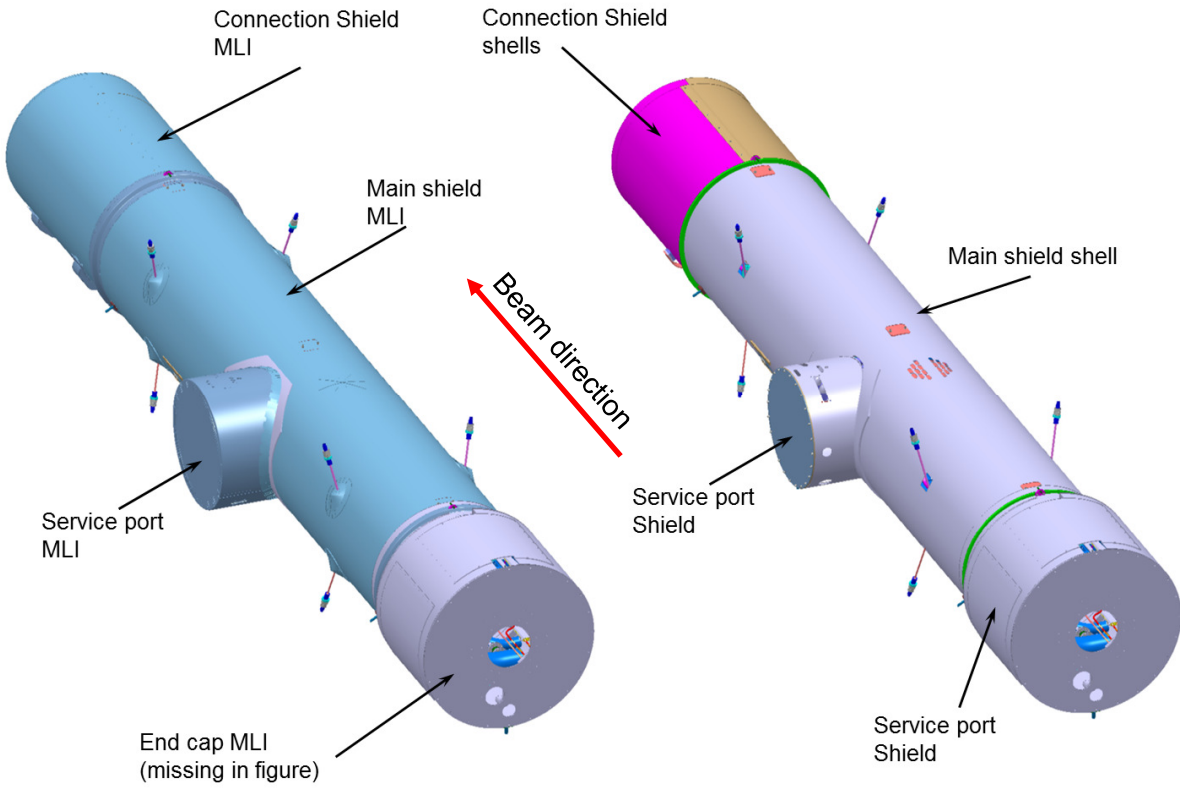



**Figure 3-8 f.i.o:** QDM, type 2.4 cold mass surrounded by thermal shield with MLI (left) without MLI (right).

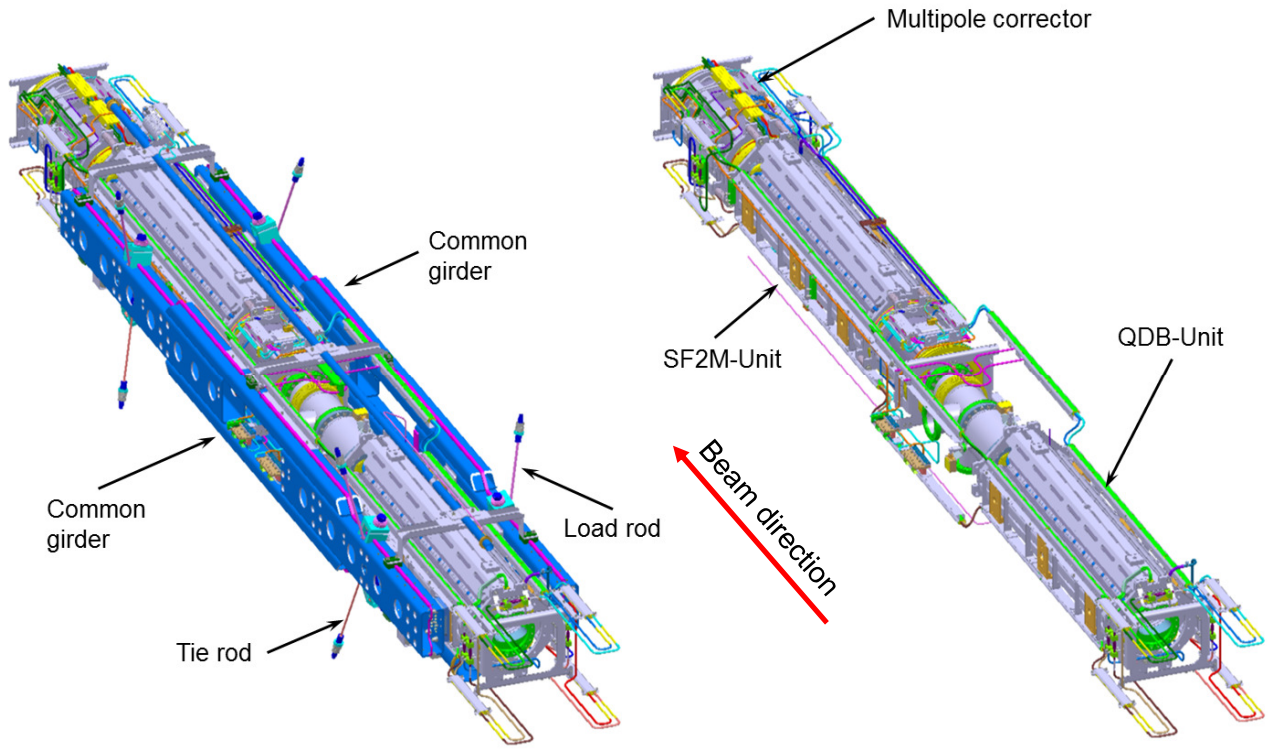



**Figure 3-9 f.i.o:** QDM, type 2.4 cold mass: Integrated in the common Girder (left). upstream- and downstream-located units (right).

### 3.2.3. Arc Section Modules

SIS100 implies five varieties of arc section modules, the types 2.5, 1.6A, 1.7B, 2.8C and 2.9D.

The general structure of an arc section module is shown in figure 3-10 to figure 3-13, by means of the module type 2.9D. All other configurations are showing the the same structures in general, but different configurations (seetable 3-1).

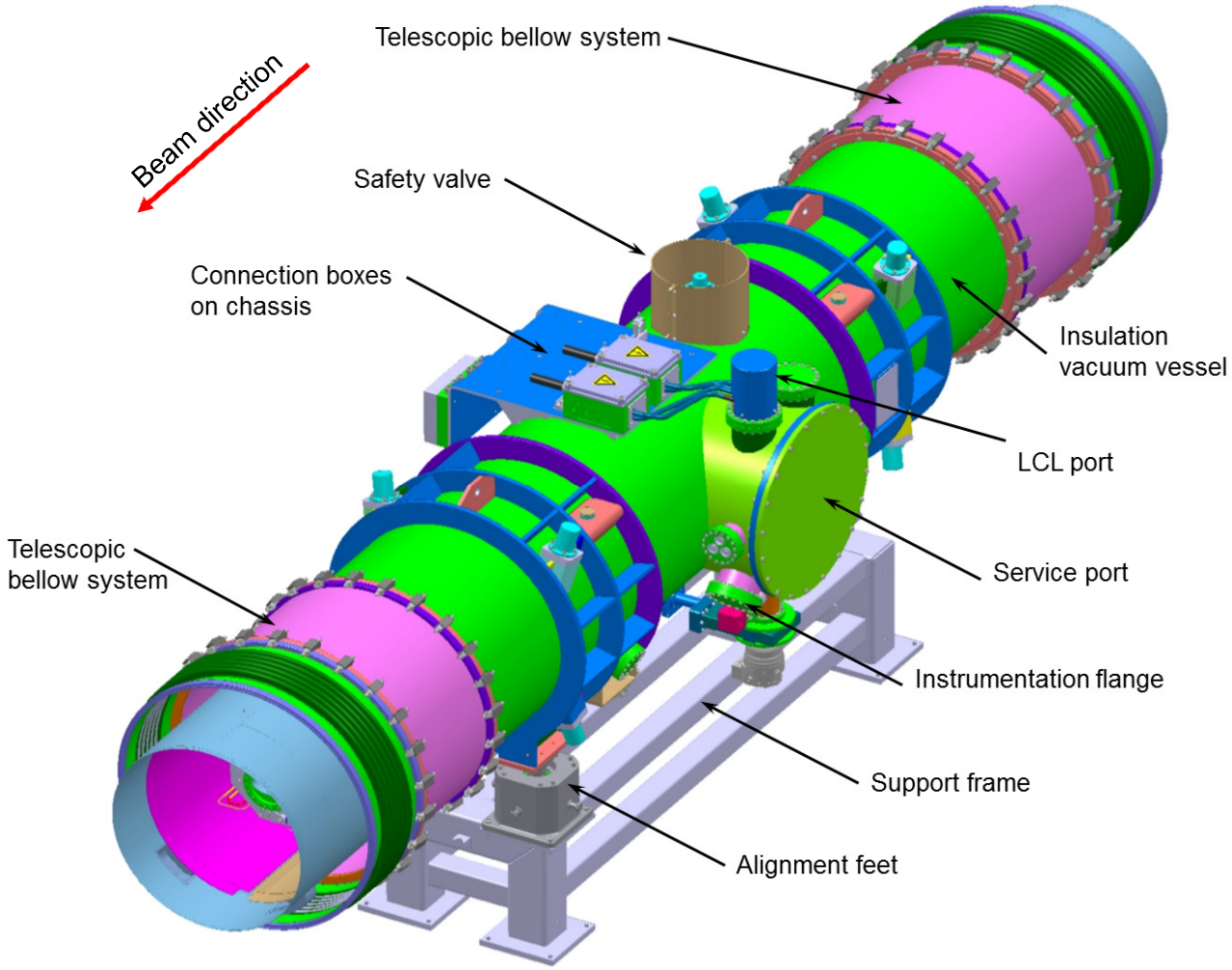



**Figure 3-10 f.i.o:** Complete SIS100-QDM, type 2.9D, mounted on support feet and support frame.

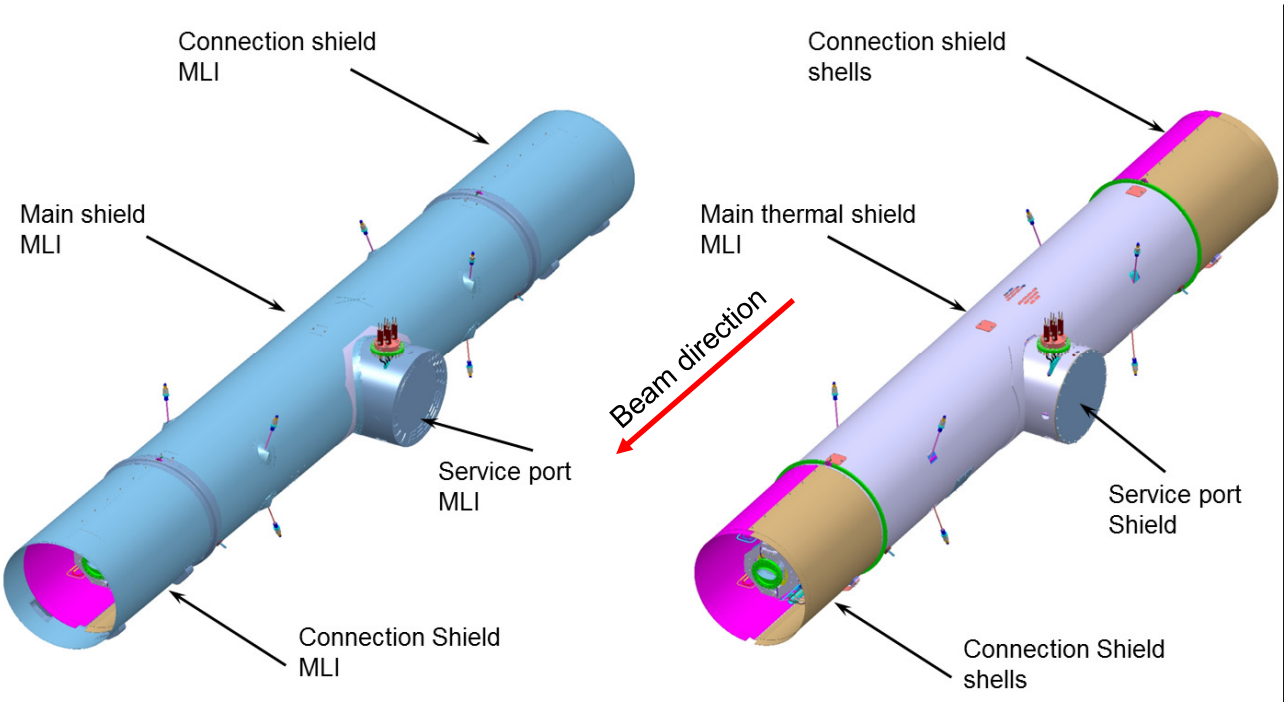



**Figure 3-11 f.i.o:** QDM cold mass surrounded by thermal shield with MLI (left) without MLI (right).

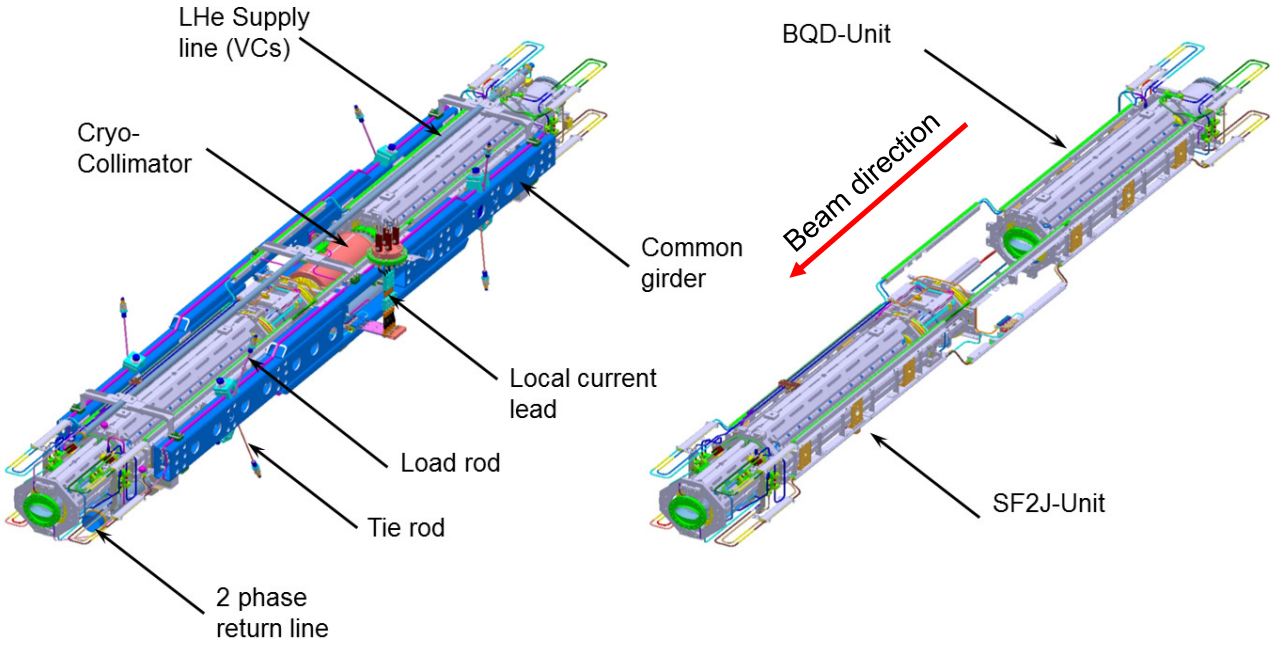



**Figure 3-12 f.i.o:** QDM cold mass (type 2.9D): Integrated in the common Girder (left). upstream- and downstream-located units (right).

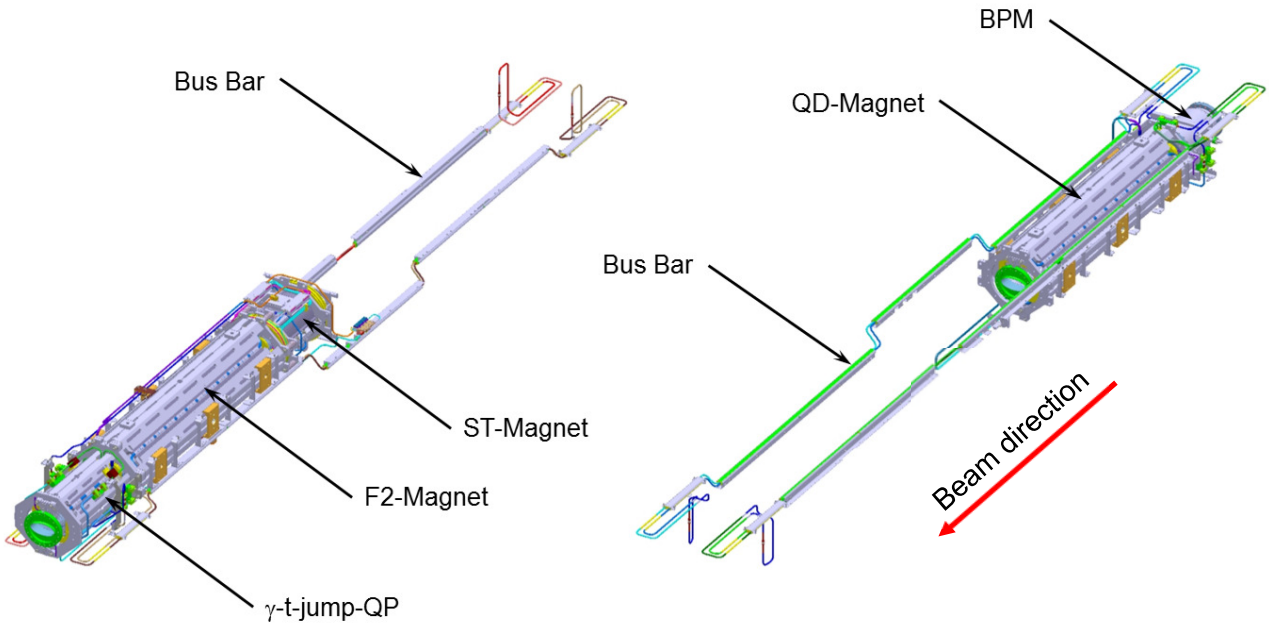



**Figure 3-13 f.i.o:** QDM cold mass: downstream-located SF2J-Unit (left). upstream-located BQD-Unit (right) in module type 2.9D.

Due to different types of arc section modules are required by the SIS100 IOL, various configurations of units and cold masses are to be built, as defined by table 3-1. The type QDM 2.9D is just one example. Design details of other types are defined in section 4.3.

### 3.2.4. Special modules

SIS100 implies two QDMs with special functionality for injection, respectively extraction of the heavy ion beam. Module type 1.Ei at the exit position of SIS100 sector 5 is designed as injection module and the type 2.4x at the entrance position of the sector 5 arc is designed as extraction module. The special modules are showing additional beam line branches to serve their dedicated function. The structure of the special modules is shown in the figure 3-14 to figure 3-19 below.

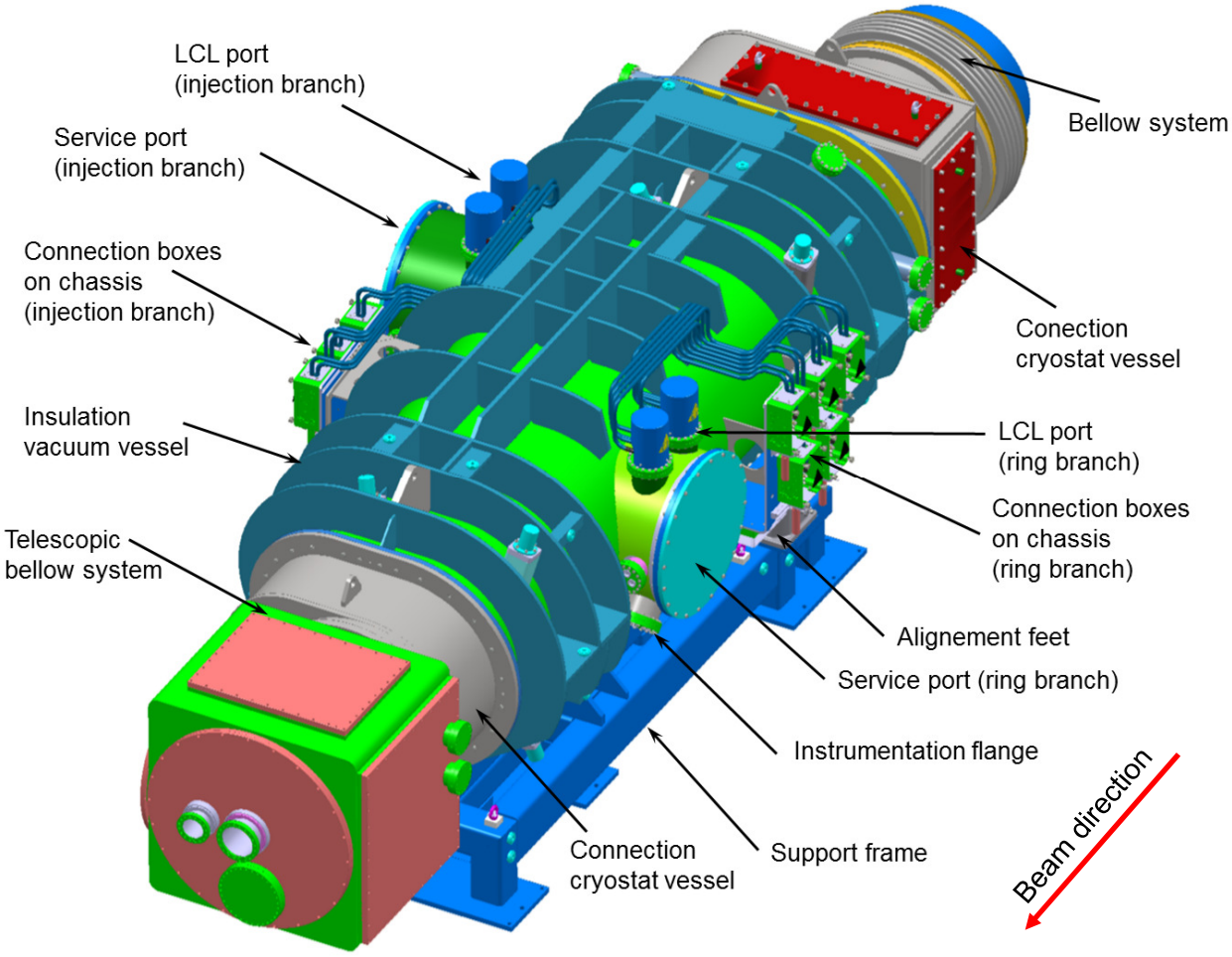



**Figure 3-14 f.i.o:** Complete SIS100-QDM, type 1.Ei, mounted on support feet and support frame.

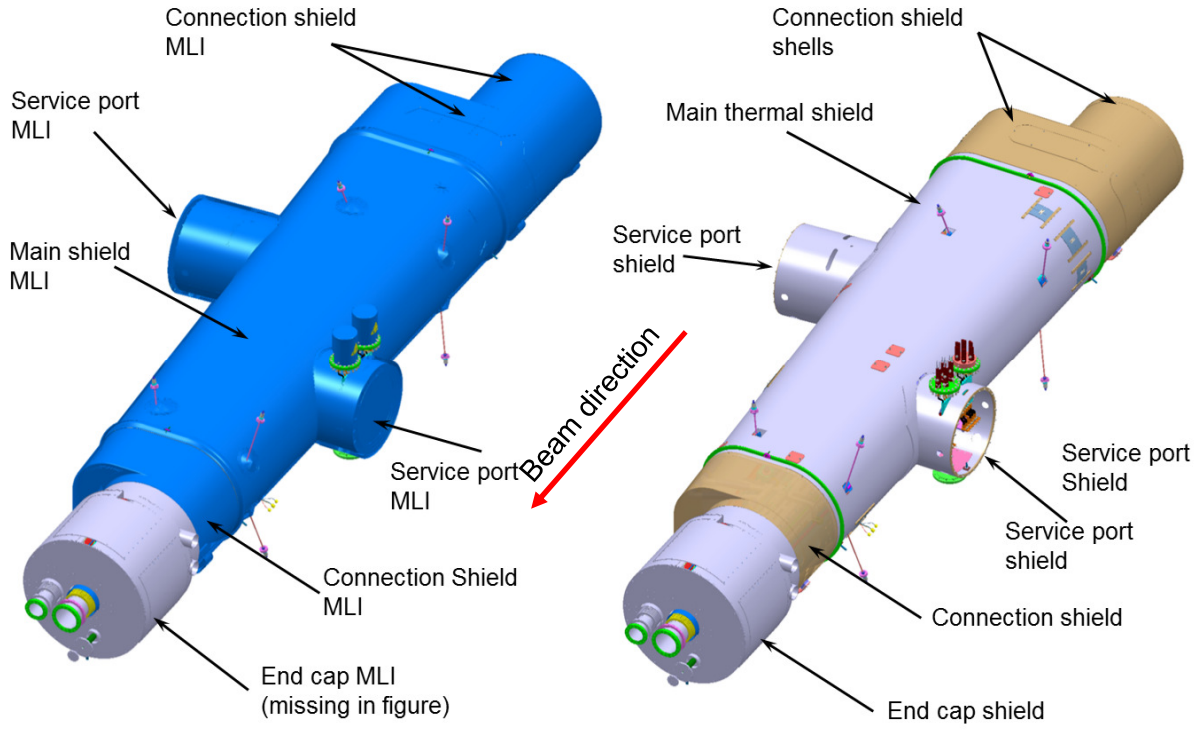



**Figure 3-15 f.i.o:** QDM cold mass surrounded by thermal shield with MLI (left) without MLI (right).

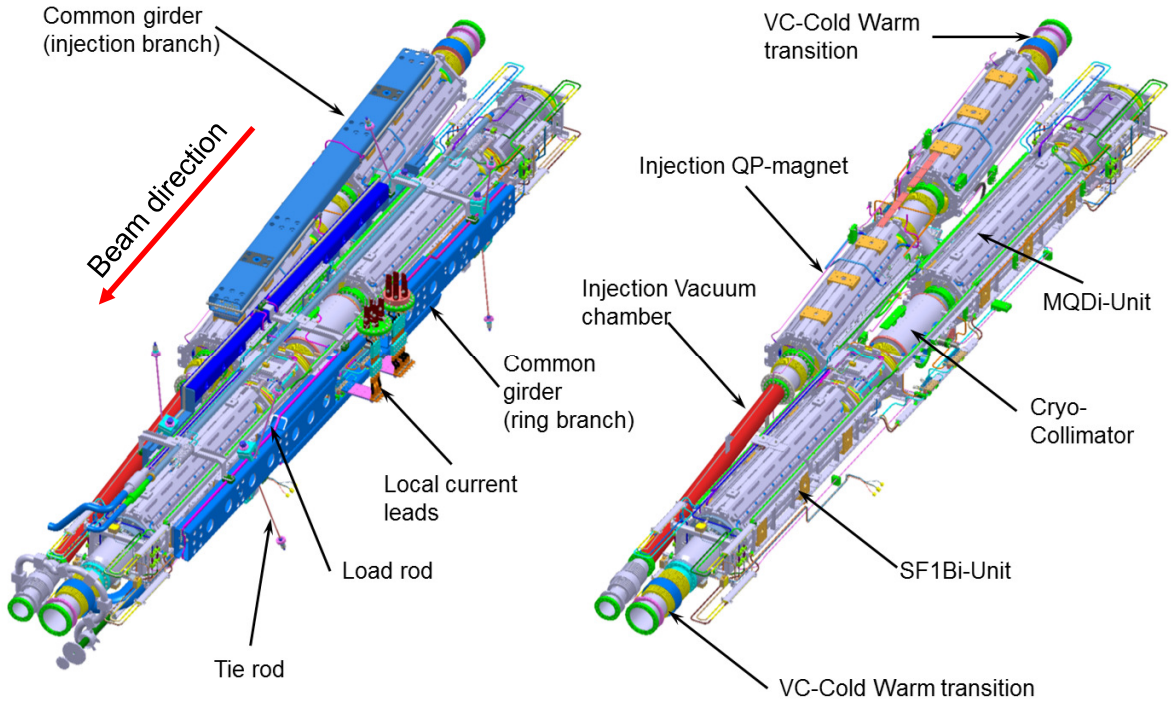



**Figure 3-16 f.i.o:** QDM cold mass (type1.Ei): Integrated in the common Girder (left). up-stream- and downstream-located units (right).

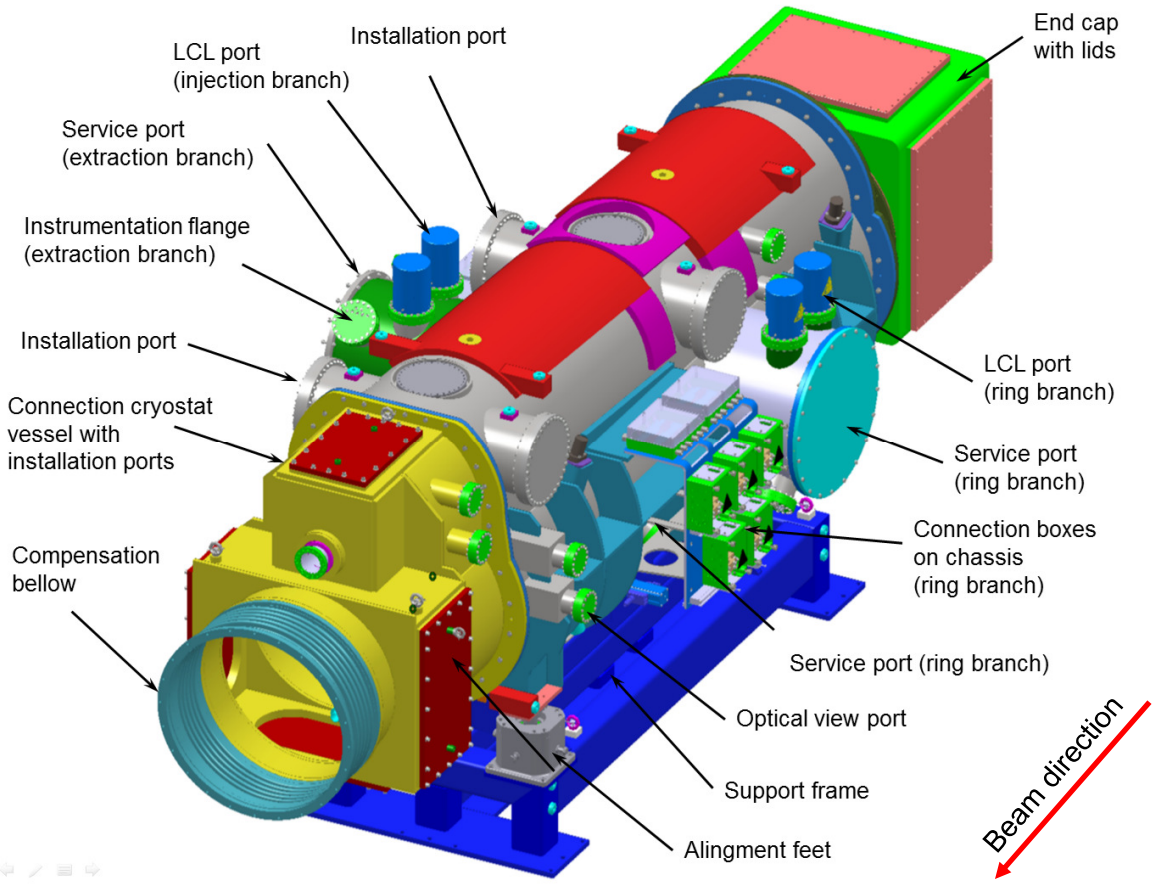



**Figure 3-17 f.i.o:** Complete SIS100-QDM, type 2.4x, mounted on support feet and support frame.

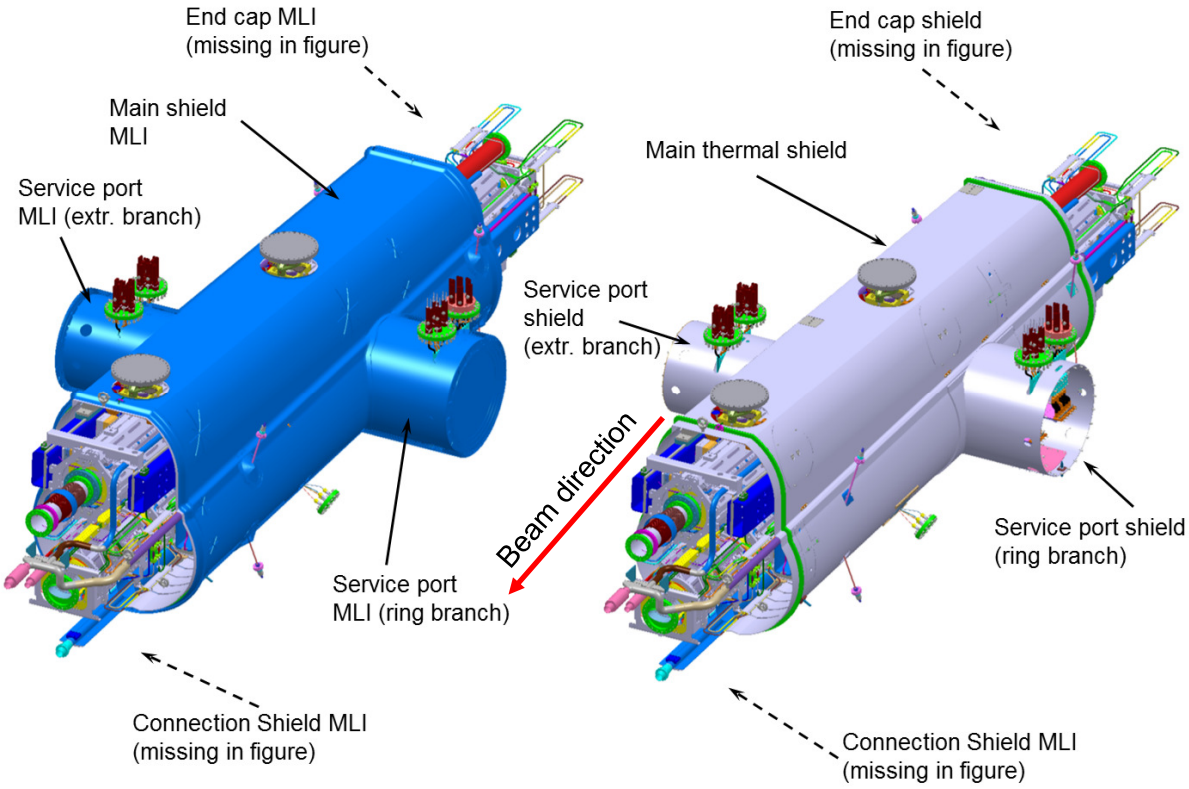



**Figure 3-18 f.i.o:** QDM Type 2.4x cold mass surrounded by thermal shield with MLI (left) without MLI (right).

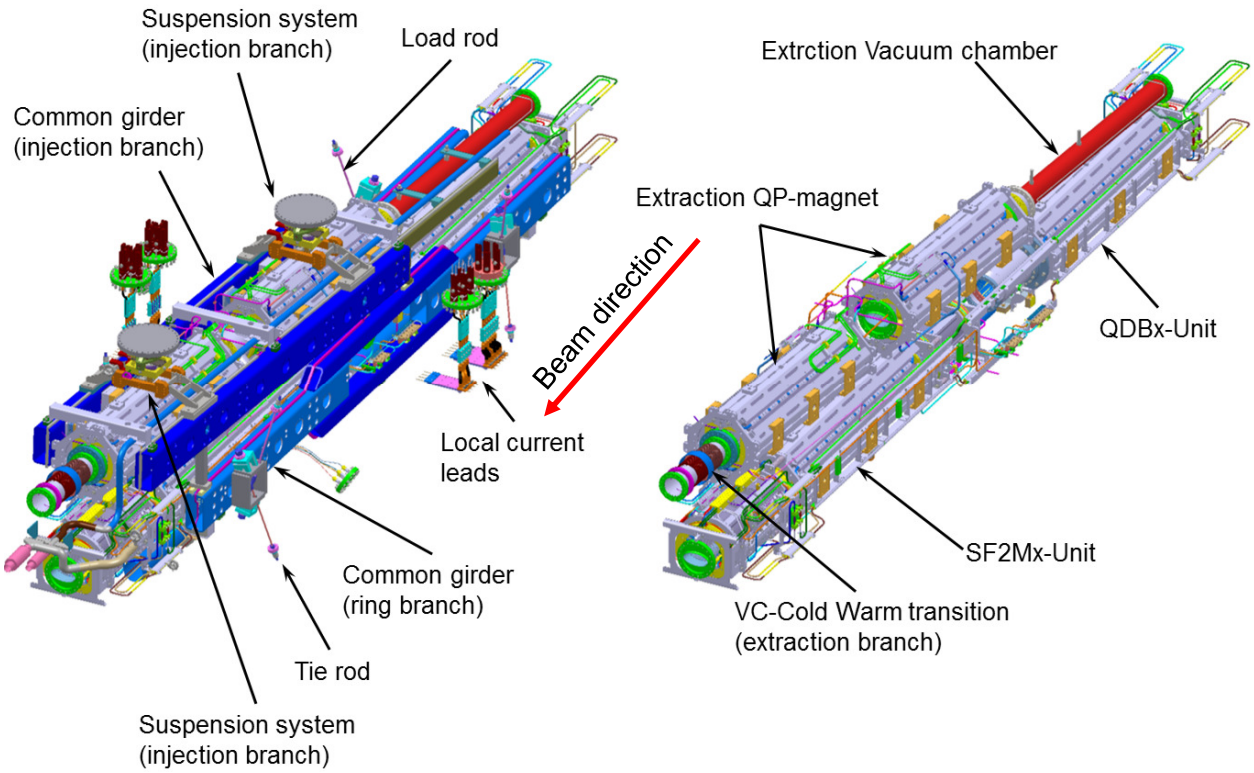



**Figure 3-19 f.i.o:** QDM cold mass (type 2.4x): Integrated in the common Girder (left). upstream- and downstream-located units of ring – and extraction branch (right).

### 3.3. **Content of Delivery**

Within this section, the deliverables by the Contractor as well as the provisions by the Company are defined. The full extent of deliverables by the Contractor comprises products (see section 0) and processes (see section 0).

**Important Note:**

*Most of the engineering drawings being referenced within this document are not completed at the time of start of the call for tender process. Thus, the Company will provide all assembly drawings in their status of development at the time being. These drawings may be signed as "For Information Only" since they will be changed in certain details during finalisation of the engineering process. As a substitute for missing engineering drawings, 3D-PDF data may be provided by the company.*

*At the time of awarding of contract a completed set of engineering drawings and an according 3D model for module type 2.5 shall be available and provided by the Company. The module type 2.5 is the module to be manufactured as a first of series (FoS) version. All other engineering drawings will be completed by the company after SAT of the FoS – module.*

*Since the complete sets of engineering drawings for all QDM are consisting of an extensive number of part- and assembly drawings, only the major assembly drawings are listed within the list of mandatory technical drawings [61] to [269]. Nevertheless, each single sheet of engineering drawing, being part of the full set of drawings shall be mandatory for the subject matter of this specification and the according contract.*

The SIS100-QDMs consist of multiple highly specialised technical sub-systems, being delivered by the company or suppliers being assigned by the company. The major tasks of the Contractor are

- checking incoming components,
- completion of QP-magnet-unit-assemblies,
  - installation of UHV – beam chambers,
  - installation of beam position monitors,
- manufacturing respectively procuring remaining components of the QDMs,
- installation and testing of remaining instrumentation,
- integration of components into QDMs,
- development and procurement of all testing setups,
- testing completed QDMs (at room temperature),
- safe packaging and shipment of QDMs.

A general overview on the delivery structure for module integration is given in the figure below.

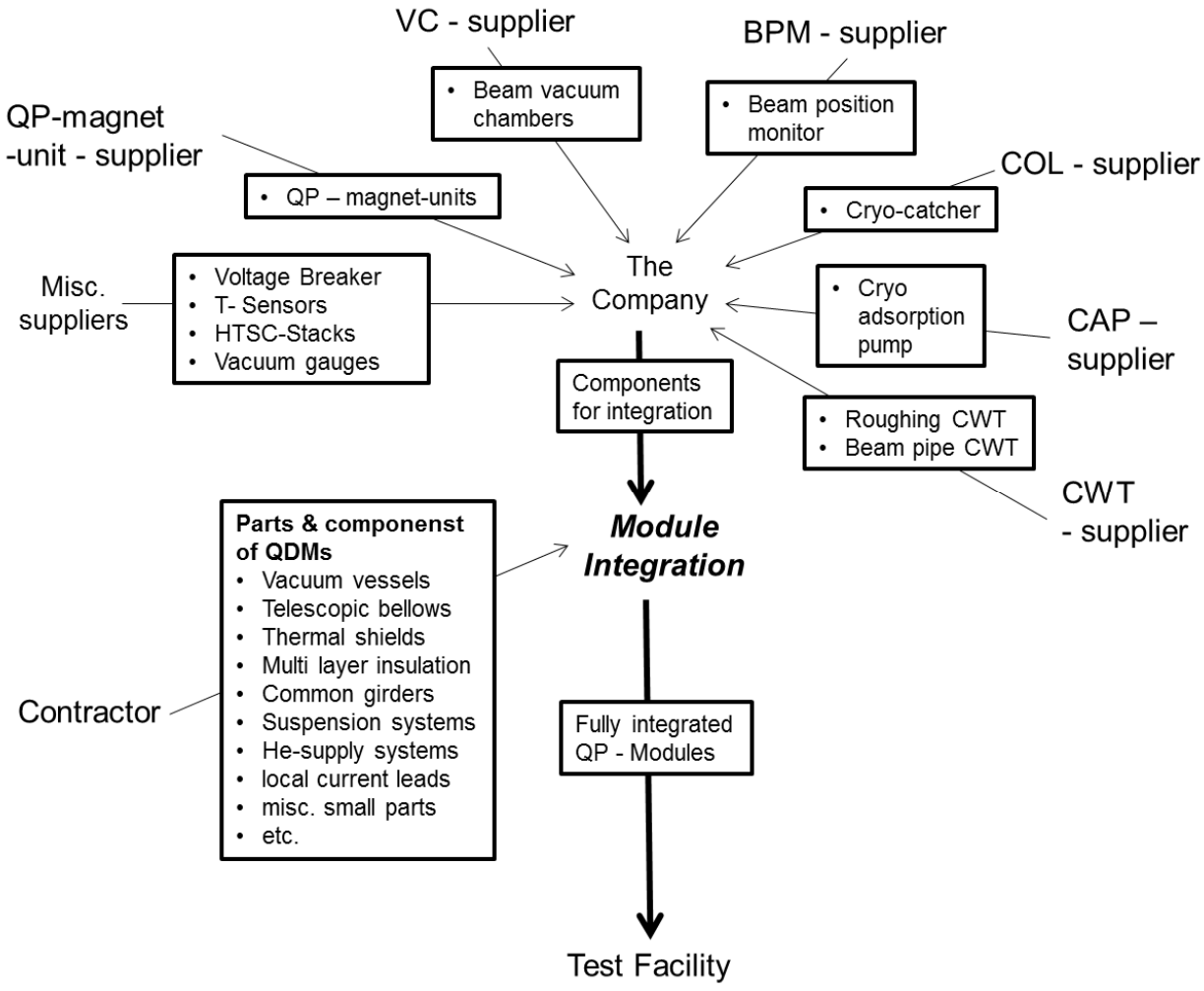



**Figure 3-20 f.i.o.:** Basic delivery scheme of components, participating to module manufacturing and integration.

***Important Note:***

*This scheme in figure 3-20 is for information only and without commitment for the Company. The responsibility for all non-Contractor supply is up to the Company and will be implemented by third party suppliers being assigned by the company. All other materials, parts and components, not being supplied by the Company are to be delivered by the Contractor.*

### 3.3.1. Delivery by the Contractor and supply by the Company

1) The contractor shall deliver all assemblies, components and parts build to print according to engineering design drawings, being supplied by the Company. Unless no design changes are requested by any party; the Contractor or the Company, and are approved by the Company, the effectual design drawings, supplied by the company are basis for production, integration and delivery of all SIS100-QDMs.
2) The Contractor shall provide all tooling, measurement and testing equipment, being required for production, integration and testing of all parts, components and assemblies which are manufactured by the contractor. This applies to all processes, being performed at the Contractor including FAT.
3) The Contractor shall provide all tooling and measurement equipment especially required and built for any testing, incoming goods inspection and quality assurance purposes including FAT.
4) All special tooling, measurement and testing equipment, being dedicated to the production, testing and quality assurance of SIS100-QDM being delivered by the Contractor shall be part of the final delivery. This applies also to special tooling and measurement equipment for any goods incoming inspection purposes.
5) The contractor shall deliver at least all documentation as defined by section 7 an all subsequent specifications and technical guidelines being referred to herein.
6) The delivery by the Contractor shall be split in delivery of a complete and fully integrated First of Series QDM of the type 2.5 and all remaining series QDM as complete and fully integrated assemblies.
7) The tables below concerning the delivery by the Contractor are listing the major assemblies and components only. All minor components, not being listed in detail within these tables, respectively within this document, are also part of the delivery by the Contractor. For a complete and detailed listing of assemblies, parts and components refer to the according parts- and instrumentation lists. The according parts- and instrumentation lists, as defined in [61] to [269], are defining the full extent of the delivery by the Contractor unless supplied by the Company.
8) Certain critical components and sub-assemblies will be supplied by the Company. All other Components, not being supply by the Company are to be produced or purchased by the Contractor and are part of the delivery by the Contractor for fulfilment of the according contract.
9) The completion of QP-units is one part of the subject matter of the contract.
10) The completion of fully assembled Quadrupole-Units shall be based on dedicated pre-staged assemblies, delivered by the Company. These assemblies will consist of
    - Quadrupole magnets with bus bars,
    - corrector magnets,
    - steering magnets,
    - LHe-supply lines,
    - restrictor assembly (hydraulic resistance) and heater assembly,

    being already pre-assembled into Quadrupole-Units when being supplied to the Contractor.
11) For completion of QP-Units the Company will deliver
    - UHV – beam chambers with CF – welding flanges,
    - components for assembly of beam position monitors,
    - mounting flanges for beam position monitors.

12) The manufacturing of the cold mass of QP-units is one part of the subject matter of the contract. The Company will deliver Cryo-Catchers for completion of QDM cold masses.
13) The manufacturing of the Local current Leads is one part of the subject matter of the contract The Company will deliver HTSC sub-units for integration into Local Current Leads.
14) The Company will deliver Temperature sensors with attached wires For installation and wiring in the cold mass- and QDM - assemblies.
15) The final integration of all SIS100 QDMs is one part of the subject matter of the contract.

***Important Note:***

*Drawing numbers, being cited in the tables below are tentative at the time of release of this document and may change during a design revision processes at the Company.*

**Module type:** Straight section module, type 2.123 including supports and alignment feet **Quantity:** 14 Pcs.

**Drawing No.:** 10000020624-E5A-000

**Parts list No.:** 10000020624-E5A-000

**Table 3-2:** *SUPPLY BY THE COMPANY* for all modules of type 2.123 (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit QD*B | 10000018323-E5A-000 | 14 | pre-assembled unit for completion |
| Unit SF2* | 10000018326-E5A-000 | 14 | pre-assembled unit for completion |
| QDB-Unit Vacuum Chamber (incl. CF-flange) | 10000018540-E5A-000 | 14 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF2-Unit Vacuum Chamber (incl. CF-flange) | 10000018538-E5A-000 | 14 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 14 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Roughing CWT | MG-1009622-A-000 | 14 | To be integrated with the UHV system of the module |
| Beam Pipe CWT | 10000018539-E5A-000 | 28 | To be integrated with the UHV chambers of the module |
| Cryo adsorption pump | CX-1019410-A-000 | 14 | To be integrated in cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-sub-units for LCL | MG-1023516-A-000 | 56 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-2.123 | | As defined by according Instrumentation list |

**Table 3-3:** *DELIVERABLES BY THE CONTRACTOR* for all modules of type 2.123 (essential sub-assemblies and components are listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Straight section module, type 2.123 mainly consisting of (see list as follows) | 10000018534-E5A-000 | 14 | The module has to be manufactured and assembled completely from all constituents as defined by according parts list. |
| Unit QD*B (fully assembled) | 10000018536-E5A-000 | 14 | Assembly and completion from supplied components. |
| Unit SF2* (fully assembled) | 10000018537-E5A-000 | 14 | Assembly and completion from supplied components. |
| Drift tube | 10000017459-E5A-000 | 14 | For integration into the UHV beam pipe system |
| Common Girder | 10000018354-E5A-000<br>10000018353-E5A-000 | 14 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | 10000018535-E5A-000 | 14 | incl. Common Girder and cryogenic system. To be integrated from all sub-assemblies. |
| Suspension system | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 14 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | 10000018331-E5A-000<br>10000018308-E5A-000<br>10000018309-E5A-000 | 14 | Including up- and down-stream closure and all required flanges. |
| Thermal shield | 10000018337-E5A-000<br>10000018313-E5A-000<br>10000018312-E5A-000 | 14 | Including service – and feed port shield and all required mounts. |
| Shield MLI | 10000018338-E5A-000<br>10000018340-E5A-000<br>10000018342-E5A-000 | 14 | A complete set of MLI including service port-, shield lid MLI and MLI for all mounts. |
| LCL-Assembly | MG-1010500-A-000_A<br>MG-1010000-A-000_A | 14 | Including all components from warm to cold terminal. HTSC sub-units will be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| Instrumentation (sensor installation and cabling) | PLI_SIS100_QDM-2.123 | 14 | Installation of one set for each module as listed by the according instrumentation list |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Support frame | MG-1009679-A-000 | 14 | |
| Alignment foot | 14047_001_01-001 | 42 | |
| Transportation locks | n/a | 14 | One set for each module required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 14 | One set for each module as required for safe and clean storage transportation. Engineering of protection caps and –materials must be performed by the Contractor. |

**Module type:** Straight section module, type 2.13s including supports and alignment feet **Quantity:** 3 Pcs.

**Drawing No.:** 10000020613-E5A-000

**Parts list No.:** 10000020613-E5A-000

**Table 3-4:** SUPPLY BY THE COMPANY for all modules of type 2.13s (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit QDB | 10000018323-E5A-000 | 3 | pre-assembled unit for completion |
| Unit SF2 | 10000018326-E5A-000 | 3 | pre-assembled unit for completion |
| QDB-Unit Vacuum Chamber (star-shaped cross section, incl. CF-flange) | 10000018325-E5A-000 | 3 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF2-Unit Vacuum Chamber (star-shaped cross section, incl. CF-flange) | 10000018330-E5A-000 | 3 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 3 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Roughing CWT | MG-1009622-A-000 | 3 | To be integrated with the UHV system the module |
| Beam Pipe CWT | 10000018539-E5A-000 | 6 | To be integrated with the UHV chamber of unit |
| Cryo adsorption pump | CX-1019410-A-000 | 3 | To be integrated with the UHV-system in the cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-sub-unit for LCL | MG-1023516-A-000 | 12 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-2.13s | | As defined by according Instrumentation List |

**Table 3-5:** *DELIVERABLES BY THE CONTRACTOR* to be manufactured or purchased by the Contractor for all modules of type 2.13s (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Straight section module, type 2.13s mainly consisting of (see list as follows) | 10000018304-E5A-000 | 3 | The module has to be manufactured and assembled completely from all constituents as defined by according parts list. |
| Unit QD*Bs (fully assembled) | 10000018324-E5A-000 | 3 | Assembly and completion from supplied components |
| Unit SF2*s (fully assembled) | 10000018329-E5A-000 | 3 | Assembly and completion from supplied components |
| Drift tube | 10000018359-E5A-000 | 3 | For integration into the UHV beam pipe system |
| Common Girder | 10000018354-E5A-000<br>10000018353-E5A-000 | 3 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | 10000018535-E5A-000 | 3 | incl. Common Girder and cryogenic system. To be integrated from all sub-assemblies. |
| Suspension system | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 3 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | 10000018331-E5A-000<br>10000018308-E5A-000<br>10000018309-E5A-000 | 3 | Including up- and down-stream closure and all required flanges. |
| Thermal shield | 10000018337-E5A-000<br>10000018313-E5A-000<br>10000018312-E5A-000 | 3 | Including service – and feed port shield and all required mounts. |
| Shield MLI | 10000018338-E5A-000<br>10000018340-E5A-000<br>10000018342-E5A-000 | 3 | i A complete set of MLI including service port-, shield lid MLI and MLI for all mounts. |
| LCL-Assembly | MG-1010500-A-000_A<br>MG-1010000-A-000_A | 3 | Including all components from warm to cold terminal. HTSC sub-units will be supplied by the Company. |
| Warm terminal boxes and connector cables | | | |
| Instrumentation (sensor installation and cabling) | PLI_SIS100_QDM-2.13s | 3 | Installation of one set of temperature sensors for each module as listed by the according instrumentation list |
| Support frame | MG-1009679-A-000 | 3 | |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Alignment foot | 14047_001_01-001 | 9 | |
| Transportation locks | n/a | 3 | One set for each module required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 3 | One set for each module as required for safe and clean storage transportation. Engineering of protection caps and –materials must be performed by the Contractor. |

**Module type:** Up-stream arc termination module, type 2.4 including endcap, interconnection bellows and shields, supports and alignment feet **Quantity:** 5 Pcs.

**Drawing No.:** 10000020601-E5A-000

**Parts list No.:** 10000020601-E5A-000

**Table 3-6:** *SUPPLY BY THE COMPANY* for all modules of type 2.4 (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit QDBb | 10000018195-E5A-000 | 5 | pre-assembled unit for completion |
| Unit SF2M | 10000018200-E5A-000 | 5 | pre-assembled unit for completion |
| QDBb-Unit Vacuum Chamber (incl. CF-flange) | 10000016296-E5A-000 | 5 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF2-Unit Vacuum Chamber (incl. CF-flange) | 10000016789-E5A-000 | 5 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 5 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Beam Pipe CWT | 10000018539-E5A-000 | 5 | To be integrated with the UHV chambers of the module |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-sub-units for LCL | MG-1023516-A-000 | 50 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-2.4 | | As defined by according Instrumentation List |

**Table 3-7:** *DELIVERABLES BY THE CONTRACTOR* for all modules of type 2.4 (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Arc termination module, type 2.4 mainly consisting of (see list as follows) | 10000018184-E5A-000 | 5 | The module has to be manufactured and assembled completely from all constituents as defined by according parts list. |
| Unit QDBb (fully assembled) | 10000018194-E5A-000 | 5 | Assembly and completion from supplied components |
| Unit SF2M (fully assembled) | 10000018199-E5A-000 | 5 | Assembly and completion from supplied components. |
| Drift tube | 10000018359-E5A-000 | 5 | For integration into the UHV beam pipe system |
| Common Girder | 10000018208-E5A-000<br>10000018207-E5A-000 | 5 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | 10000018188-E5A-000 | 5 | incl. Common Girder and cryogenic system. To be integrated from all sub-assemblies. |
| Suspension System | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 5 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | 10000016432-E5A-000 | 5 | including service port and all required mounts |
| Main thermal shield | 10000018205-E5A-000<br>10000018206-E5A-000 | 5 | including service –, feed port shield and supply line and all required mounts. |
| Main shield MLI | 10000015938-E5A-000 | 5 | A complete set of MLI including service port-, shield lid MLI and MLI for all mounts. |
| Telescopic bellow system | MG-1006650-A-000_A | 5 | Assembly including all clip bolts and gaskets. The bellows must not be installed for transportation processes. |
| Connection thermal shield | MG-1007568-A-000 | 5 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | 10000015960-E5A-000 | 5 | An MLI-jackets to be installed in the interconnection area between modules around the interconnection shielding. |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| LCL-Assembly | 10000018184_E5A_000 | 5 | Complete assemblies from arm to cold terminal. HTSC stacks to be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| End cap vacuum vessel | MG-1021004-A-000 | 5 | A cubic insulation vacuum vessel design including all required flanges, blanking flanges and clip-bolts. |
| End cap thermal shield | MG-1024996-A-000 | 5 | A cylindrical thermal shield design including all closures and mounts |
| End cap shield MLI | n/a | 5 | Complete set of MLI blankets for application around the end cap shield. |
| End Cap cryogenic piping | Multiple numbers | 1 each | Including thermal shield piping and 4K He piping and bellows |
| Instrumentation | PLI_SIS100_QDM-2.4 | | One set for each module as listed by the according instrumentation list |
| Support frame | MG-1009679-A-000 | 5 | |
| Alignment foot | SU-1009835-A-000 | 15 | |
| Support consoles | 10000016406-E5A-000 | 5x 2 | Five pairs are needed for SIS100 in all US-positions (Module type 2.4) where no special module is installed. |
| Transportation locks | n/a | 5 | One set for each module required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 5 | One set the module as required for safe and clean storage and transportation. Engineering of transportation locks must be performed by the Contractor. |

**Module type:** Extraction module, type 2.4x **Quantity:** 1 Pcs.
**Drawing No.:** not yet available
**Parts list No.:** not yet available

**Table 3-8:** SUPPLY BY THE COMPANY for the module of type 2.4x (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit QDBx | S911048-03-AY0001 | 1 | pre-assembled unit for completion |
| Unit SF2Mx | S911048-21-AY0001 | 1 | pre-assembled unit for completion |
| Extraction QP-Magnet (LD, LF) | S911048-24-AY0001 | 2 | pre-assembled unit for completion |
| QDBx-Unit Vacuum Chamber (incl. CF-flange) | S911048-81-SA1058 | 1 | To be integrated into a QP-unit. CF-flange to be welded to UHV-chamber. |
| SF2Mx-Unit Vacuum Chamber (incl. CF-flange) | S911048-81-SA1185 | 1 | To be integrated into a QP-unit. CF-flange to be welded to UHV-chamber. |
| Upstream-Extraction-QP-magnet-unit Vacuum Chamber (incl. CF-flange) | S911048-81-SA0611 | 1 | To be integrated with the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Downstream-Extraction-QP-magnet-unit Vacuum Chamber (incl. CF-flange) | S911048-81-SA0611 | 1 | To be integrated with the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Cryo-Adsorption pump | 10000016769-E5A-000 | 1 | To be integrated with the UHV system of the module |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 1 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Special Beam Pipe CWT | MG-1013714-A-000 | 1 | To be integrated with the UHV system of the module |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-Stacks for LCL | MG-1023516-A-000 | 14 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-2.4x | | As defined by according Instrumentation List |

**Table 3-9:** *DELIVERABLES BY THE CONTRACTOR* for the module of type 2.4x (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Extraction module 2.4x mainly consisting of (see list as follows) | S911048-75-AY0001 | 1 | The module has to be manufactured and assembled completely from all constituents as defined by according parts list. |
| Unit QDBx (fully assembled) | S911048-03-AY0000 | 1 | Assembly and completion from supplied components |
| Unit SF2Mx (fully assembled) | S911048-21-AY0000 | 1 | Assembly and completion from supplied components |
| Defocusing extraction QP-magnet-unit LD (fully assembled) | S911048-23-AY0000 | 1 | Assembly and completion from supplied components. |
| Focusing extraction QP-magnet-unit LF (fully assembled) | S911048-24-AY0000 | 1 | Assembly and completion from supplied components. |
| Drift tube, ring branch | S911048-81-SA1227 | 1 | For completion of UHV chambers of the ring branch. |
| Short drift tube, extraction branch | S911048-79-SA0005 | 1 | For completion of UHV chamber of the extraction branch |
| Long drift tube, extraction branch | S911048-79-SA0013 | 1 | For completion of UHV chamber of the extraction branch |
| Common Girder, ring branch | S911048-79-SA0002 | 1 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | S911048-79-AY0001 | 1 | incl. Common Girder and cryogenic system. To be integrated from all sub-assemblies. |
| Suspension System, ring branch | S911048-79-SA0001 | 1 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Common Girder, extraction branch | S911048-79-SA0004<br>S911048-79-SA0003 | 1<br>1 | Consisting of two single girder beams an traverses |
| Suspension System, extraction branch | S911048-79-SA0010,<br>S911048-79-SA0010 | 1<br>1 | Each one consisting of adjustable suspension pillar and suspension travers. |
| Main insulation vacuum vessel | S911048-77-AY0001 | 1 | Including all flanges, blanking flanges and mounts. |
| Main thermal shield | S911048-78-SA0001 | 1 | including service port shield at ring- and extraction branch |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Main shield MLI | S911048-78-SA0100 | 1 | A complete set of MLI including service port-, shield lids and MLI for all mounts. |
| Upstream-Connection cryostat vacuum vessel | n/a | 1 | One complete vacuum vessel fully assembled for connecting the main vacuum vessel with the End-Cap |
| End Cap vacuum vessel | n/a | 1 | One complete vacuum vessel fully assembled for connection to the main vacuum vessel. |
| End cap thermal shield | n/a | 1 | A cylindrical thermal shield design including all closures and mounts |
| End Cap shield MLI | n/a | 1 | Complete set of MLI blankets for application around the end cap shield including lid MLI. |
| End Cap cryogenic piping | Multiple numbers | | Including thermal shield piping and 4K He piping and bellows |
| Downstream-Connection cryostat vacuum vessel | S911048-37-SA0001 | 1 | One complete vacuum vessel fully assembled for connecting the main vacuum vessel with the following module. |
| Downstream-Connection shield MLI | n/a | 1 | An MLI jacket for insulating the connection thermal shield. |
| Connection bellow system | S911048-37-000043 | 1 | Assembly including all clip bolts and gaskets. The bellows must not be installed for transportation processes. |
| LCL-Assemblies | n/a | 2 | For low current supply of corrector magnets and extraction QP – magnets. Warm to cold terminal. HTSC stacks to be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| Instrumentation | PLI_SIS100_QDM-2.4x | | One set for each module as listed by the according instrumentation list |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Special support frame | S911048-76-AY0001 | 1 | |
| Special high load alignment foot | SU-1009835-A-000 | 3 | |
| Transportation locks | n/a | 1 | One complete set as required for safe transportation |
| Protection caps and -materials | n/a | 1 | One complete set as required for safe and clean storage and transportation |

**Module type:** Arc section module, type 2.5, ***First of Series*** including alignment feet and support frame **Quantity:** 1 Pcs.

**Drawing No.:** 1009705-A-000

**Parts list No.:** 1009705-A-000

**Table 3-10:** SUPPLY BY THE COMPANY for the module type 2.5, FoS (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit VQD | MAG-V04-E66.000.000-A-000_B | 1 | pre-assembled unit for completion |
| Unit SF2B | MAG-V08-E66.000.000-A-000_B | 1 | pre-assembled unit for completion |
| VQD-Unit Vacuum Chamber (incl. CF-flange) | MAG-V04-E66.011.000-A-000_B | 1 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF2B-Unit Vacuum Chamber (incl. CF-flange) | MAG-V08-E66.010.000-A-000_B | 1 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 1 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Roughing CWT | MG-1009622-A-000 | 1 | To be integrated with the UHV chambers of the module |
| Cryo-Catcher | MG-1004961-A-000_A | 1 | To be integrated in the UHV-system of the cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-Stacks for LCLs | MG-1023516-A-000 | 6 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-2.5_FoS | | As defined by according Instrumentation List |

**Table 3-11:** *DELIVERABLES BY THE CONTRACTOR* for the module type 2.5, FoS (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Arc section module, type 2.5, FoS<br>mainly consisting of (see list as follows) | MG-1005150-A-000_B | 1 | Fully assembled with all constituents. To be integrated with the UHV chambers of the module |
| Unit VQD (fully assembled) | MAG-V04-E66.000.000 | 1 | Assembly and completion from supplied components |
| Unit SF2B (fully assembled) | MAG-V08-E66.000.000 | 1 | Assembly and completion from supplied components |
| Common Girder | MG-1005838-A-000<br>MG-1005857-A-000 | 1 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | MG-1007850-A-000 | 1 | incl. Common Girder and cryogenic system |
| Suspension System | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 1 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | MG-1004655-A-000_B | 1 | Including all required flanges and mounts |
| Main thermal shield | MG-1005890-A-000_B<br>MG-1009754-A-000 | 1 | Including service port shield and all required mounts. |
| Main shield MLI | MG-1010422-A-000_B | 1 | A complete set of MLI including service port shield MLI and MLI for all mounts. |
| Telescopic bellow system | MG-1006650-A-000_B | 2 | Assemblies being applicable at upstream- and down-stream position. Not installed for transportation. |
| Upstream Connection thermal shield | MG-1007568-A-000 | 1 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Downstream Connection thermal shield | MG-1007545-A-000 | 1 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | MG-1013373-A-000_A | 2 | MLI-jackets to be installed around the interconnection shielding in the intercon-nection areas between modules. |
| LCL-Assembly | MG-1010500-A-000<br>MG-1010501-A-000 | 1 | Full assembly from warm to cold terminal. HTSC stacks to |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| | | | be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| Instrumentation, FoS | PLI_SIS100_QDM-2.5_FoS | | Complete set for the module as listed by according instrumentation list. |
| Support frame | MG-1009679-A-000 | 1 | |
| Alignment foot | 14047_001_01-001 | 3 | |
| Transportation locks | n/A | 1 | One set for the module, being required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 1 | One set the module as required for safe and clean storage and transportation. Engineering of transportation locks must be performed by the Contractor. |

**Module type:** Arc section module, type 2.5, series version including alignment feet and support frame **Quantity:** 5 Pcs.

**Drawing No.:** not yet available

**Parts list No.:** not yet available

**Table 3-12:** *SUPPLY BY THE COMPANY* for all modules of type 2.5 (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit VQD | MAG-V04-E66.000.000-A-000_B | 5 | pre-assembled unit for completion |
| Unit SF2B | MAG-V08-E66.000.000-A-000_B | 5 | pre-assembled unit for completion |
| VQD-Unit Vacuum Chamber (incl. CF-flange) | MAG-V04-E66.011.000-A-000_B | 5 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF2B-Unit Vacuum Chamber (incl. CF-flange) | MAG-V08-E66.010.000-A-000_B | 5 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 5 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Roughing CWT | MG-1009622-A-000 | 5 | To be integrated with the UHV chambers of the module |
| Cryo-Catcher | MG-1004961-A-000_A | 5 | To be integrated in the UHV-system of the cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-Stacks for LCLs | MG-1023516-A-000 | 30 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-2.5 | | As defined by according Instrumentation List |

**Table 3-13:** *DELIVERABLES BY THE CONTRACTOR* for all modules of type 2.5, (essential sub-assemblies and components listed only)

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Arc section module, type 2.5 mainly consisting of (see list as follows) | MG-1005150-A-000_B | 5 | Fully assembled with all constituents. To be integrated with the UHV chambers of the module |
| Unit VQD (fully assembled) | MAG-V04-E66.000.000 | 5 | Assembly and completion from supplied components |
| Unit SF2B (fully assembled) | MAG-V07-E66.000.000 | 5 | Assembly and completion from supplied components |
| Common Girder | MG-1005838-A-000<br>MG-1005857-A-000 | 5 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | MG-1007850-A-000 | 5 | incl. Common Girder and cryogenic system |
| Suspension System | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 5 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | MG-1004655-A-000_B | 5 | Including all required flanges and mounts. |
| Main thermal shield | MG-1005890-A-000_B<br>MG-1009754-A-000 | 5 | Including service port shield and all required mounts. |
| Main shield MLI | MG-1010422-A-000_B | 5 | A complete set of MLI including service port shield MLI and MLI for all mounts. |
| Telescopic bellow system | MG-1006650-A-000_B | 10 | One assembly applicable at upstream- and downstream position. Not installed for transportation. |
| Upstream Connection thermal shield | MG-1007568-A-000 | 5 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Downstream Connection thermal shield | MG-1007545-A-000 | 5 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | MG-1013373-A-000_A | 10 | MLI-jackets to be installed around the interconnection shielding in the intercon-nection areas between modules. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| LCL-Assembly | MG-1010500-A-000<br>MG-1010501-A-000 | 5 | Full assembly from warm to cold terminal. HTSC stacks to be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| Instrumentation | PLI_SIS100_QDM-2.5 | 5 | Complete set for the module as listed by according instrumentation list |
| Support frame | MG-1009679-A-000 | 5 | |
| Alignment foot | 14047_001_01-001 | 15 | |
| Transportation locks | n/A | 5 | One set for the module, being required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/A | 5 | One set the module as required for safe and clean storage and transportation. Engineering of transportation locks must be performed by the Contractor. |

**Module type:** Arc section module, type 1.6A, including alignment feet and support frame **Quantity:** 12 Pcs.

**Drawing No.:** not yet available

**Parts list No.:** not yet available

**Table 3-14:** SUPPLY BY THE COMPANY for all modules of type 1.6A (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit BQD | MG-1021461-A-000 | 12 | pre-assembled unit for completion |
| Unit SF1H | MG-1021571-A-000 | 12 | pre-assembled unit for completion |
| BQD -Unit Vacuum Chamber (incl. CF-flange) | MG-1021558-A-000 | 12 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF1H -Unit Vacuum Chamber (incl. CF-flange) | MG-1021392-A-000 | 12 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 12 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Cryo-Catcher | MG-1004961-A-000_A | 12 | To be integrated in the UHV-system of the cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-Stacks for LCLs | MG-1023516-A-000 | 72 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-1.6A | | As defined by according Instrumentation List |

**Table 3-15:** DELIVERABLES BY THE CONTRACTOR for all modules of type 1.6A (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Arc section module, type 1.6A mainly consisting of (see list as follows) | MG-1024015-A-000 | 12 | Fully assembled with all constituents. To be integrated with the UHV chambers of the module |
| Unit BQD (fully assembled) | MG-1021460-A-000 | 12 | Assembly and completion from supplied components |
| Unit SF1H (fully assembled) | MG-1021573-A-000 | 12 | Assembly and completion from supplied components |
| Common Girder | MG-1005838-A-000<br>MG-1005857-A-000 | 12 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | MG-1022248-A-000 | 12 | incl. Common Girder and cryogenic system |
| Suspension System | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 12 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | MG-1004655-A-000_B | 12 | Including service port shield and all required mounts. |
| Main thermal shield | MG-1005890-A-000_B<br>MG-1023122-A-000 | 12 | including service –, feed port shield and supply line |
| Main shield MLI | MG-1010422-A-000_B | 12 | A complete set of MLI including service port shield MLI and MLI for all mounts. |
| Telescopic bellow system | MG-1006650-A-000_A | 24 | One assembly applicable at upstream- and downstream position. Not installed for transportation. |
| Upstream Connection thermal shield | MG-1007568-A-000 | 12 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Downstream Connection thermal shield | MG-1007545-A-000 | 12 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | MG-1013373-A-000_A | 24 | MLI-jackets to be installed around the interconnection shielding in the intercon-nection areas between modules. |
| LCL-Assembly | n/a | 12 | Full assembly from warm to cold terminal. HTSC stacks to |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| | | | be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| Instrumentation | PLI_SIS100_QDM-1.6A | 12 | Complete set for the module as listed by according instrumentation list |
| Transportation locks | n/a | 12 | One set for the module, being required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 12 | One set the module as required for safe and clean storage and transportation. Engineering of transportation locks must be performed by the Contractor. |
| Support frame | MG-1009679-A-000 | 12 | |
| Alignment foot | 14047_001_01-001 | 36 | |

**Module type:** Arc section module, type 1.7B including alignment feet and support frame **Quantity:** 12 Pcs.

**Drawing No.:** not yet available

**Parts list No.:** not yet available

**Table 3-16:** SUPPLY BY THE COMPANY for all modules of type 1.7B (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit BQD | MAG-V04-E66.100.000-A-000_A | 12 | pre-assembled unit for completion |
| Unit SF2H | MG-1021603-A-000 | 12 | pre-assembled unit for completion |
| VQD-Unit Vacuum Chamber | MAG-V04-E66.011.000-A-000_B | 12 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF2B-Unit Vacuum Chamber | MAG-V08-E66.010.000-A-000_B | 12 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 12 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Cryo-Catcher | MG-1004961-A-000_A | 12 | To be integrated in the UHV-system of the cold mass. |
| Roughing CWT | MG-1009622-A-000 | 12 | To be integrated with the UHV chambers of the module |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-Stacks for LCLs | MG-1023516-A-000 | 72 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-1.7B | | As defined by according Instrumentation List |

**Table 3-17:** *DELIVERABLES BY THE CONTRACTOR* for all modules of type 1.7B (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Arc section module, type 1.7B mainly consisting of (see list as follows) | MG-1024017-A-000 | 12 | Fully assembled with all constituents. To be integrated with the UHV chambers of the module |
| Unit VQD (fully assembled) | MAG-V04-E66.000.000-A-000_B | 12 | Assembly and completion from supplied components |
| Unit SF1B (fully assembled) | MG-1021602-A-000 | 12 | Assembly and completion from supplied components |
| Common Girder | MG-1005838-A-000<br>MG-1005857-A-000 | 12 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | MG-1022468-A-000 | 12 | incl. Common Girder and cryogenic system |
| Suspension System | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 12 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | MG-1004655-A-000_B | 12 | Including all required flanges and mounts. |
| Main thermal shield | MG-1005890-A-000_B<br>MG-1023122-A-000 | 12 | Including service port shield and all required mounts. |
| Main shield MLI | MG-1010422-A-000_B | 12 | A complete set of MLI including service port shield MLI and MLI for all mounts. |
| Telescopic bellow system | MG-1006650-A-000_A | 24 | One assembly applicable at upstream- and downstream position. Not installed for transportation. |
| Up-stream Connection thermal shield | MG-1007568-A-000 | 12 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Down-stream Connection thermal shield | MG-1007545-A-000 | 12 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | MG-1013373-A-000_A | 24 | MLI-jackets to be installed around the interconnection shielding in the intercon-nection areas between modules. |
| LCL-Assembly | n/a | 12 | Full assembly from warm to cold terminal. HTSC stacks to |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| | | | be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| Instrumentation (incl. installation and wiring) | PLI_SIS100_QDM-1.7B | 12 | Complete set for the module as listed by according instrumentation list incl. installation, wiring and connectors |
| Support frame | MG-1009679-A-000 | 12 | |
| Alignment foot | 14047_001_01-001 | 36 | |
| Transportation locks | n/a | 12 | One set for the module, being required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 12 | One set the module as required for safe and clean storage and transportation. Engineering of transportation locks must be performed by the Contractor. |

**Module type:** Arc section module, type 2.8C including alignment feet and support frame **Quantity:** 12 Pcs.

**Drawing No.:** not yet available

**Parts list No.:** not yet available

**Table 3-18:** SUPPLY BY THE COMPANY for all modules of type 2.8C (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit BQD | MG-1021461-A-000 | 12 | pre-assembled unit for completion |
| Unit SF2H | MG-1021355-A-000 | 12 | pre-assembled unit for completion |
| BQD-Unit Vacuum Chamber (incl. CF-flange) | MG-1021558-A-000 | 12 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF2H-Unit Vacuum Chamber (incl. CF-flange) | MG-1021392-A-000 | 12 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 12 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Cryo-Catcher | MG-1004961-A-000_A | 12 | To be integrated in the UHV-system of the cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number as required for production will be supplied |
| HTSC-Stacks for LCLs | MG-1023516-A-000 | 72 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-2.8C | | As defined by according Instrumentation List |

**Table 3-19:** *DELIVERABLES BY THE CONTRACTOR* for all modules of type 2.8C (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Arc section module, type 2.8C mainly consisting of (see list as follows) | MG-1024018-A-000 | 12 | Fully assembled with all constituents. To be integrated with the UHV chambers of the module |
| Unit BQD (fully assembled) | MG-1021460-A-000 | 12 | Assembly and completion from supplied components |
| Unit SF2H (fully assembled) | MG-1021354-A-000 | 12 | Assembly and completion from supplied components |
| Common Girder | MG-1005838-A-000<br>MG-1005857-A-000 | 12 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | MG-1022233-A-000 | 12 | incl. Common Girder and cryogenic system |
| Suspension System | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 12 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | MG-1004655-A-000_B | 12 | Including all required flanges and mounts. |
| Main thermal shield | MG-1005890-A-000_B<br>MG-1023122-A-000 | 12 | Including service port shield and all required mounts. |
| Main shield MLI | MG-1010422-A-000_B | 12 | A complete set of MLI including service port shield MLI and MLI for all mounts. |
| Telescopic bellow system | MG-1006650-A-000_A | 24 | One assembly applicable at upstream- and downstream position. Not installed for transportation. |
| Upstream Connection thermal shield | MG-1007568-A-000 | 12 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Downstream Connection thermal shield | MG-1007545-A-000 | 12 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | MG-1013373-A-000_A | 24 | MLI-jackets to be installed around the interconnection shielding in the intercon-nection areas between modules. |
| LCL-Assembly | n/a | 12 | Full assembly from warm to cold terminal. HTSC stacks to |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| | | | be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| Instrumentation | PLI_SIS100_QDM-2.8C | 12 | Complete set for the module as listed by according instrumentation list |
| Support frame | MG-1009679-A-000 | 12 | |
| Alignment foot | 14047_001_01-001 | 36 | |
| Transportation locks | n/a | 12 | One set for the module, being required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 12 | One set for the module, being required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |

**Module type:** Arc section module, type 2.9D including alignment feet and support frame **Quantity:** 12 Pcs.

**Drawing No.:** not yet available

**Parts list No.:** not yet available

**Table 3-20:** *SUPPLY BY THE COMPANY* for all modules of type 2.9D (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit BQD | MG-1021461-A-000 | 12 | pre-assembled unit for completion |
| Unit SF2J | MG-1021652-A-000 | 12 | pre-assembled unit for completion |
| BQD-Unit Vacuum Chamber (incl. CF-flange) | MG-1021558-A-000 | 12 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF2J-Unit Vacuum Chamber (incl. CF-flange) | MG-1022235-A-000 | 12 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 12 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Roughing CWT | MG-1009622-A-000 | 12 | To be integrated with the UHV chambers of the module |
| Cryo-Catcher | MG-1004961-A-000_A | 12 | To be integrated in the UHV-system of the cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-Stacks for LCLs | MG-1023516-A-000 | 48 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-2.9D | | As defined by according Instrumentation List |

**Table 3-21:** *DELIVERABLES BY THE CONTRACTOR* for all modules of type 2.9D (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Arc section module, type 2.9D mainly consisting of (see list as follows) | MG-1024018-A-000 | 12 | Fully assembled with all constituents |
| Unit BQD (fully assembled) | MG-1021460-A-000 | 12 | Assembly and completion from supplied components |
| Unit SF2J (fully assembled) | MG-1021651-A-000 | 12 | Assembly and completion from supplied components |
| Common Girder | MG-1005838-A-000<br>MG-1005857-A-000 | 12 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | MG-1022235-A-000 | 12 | incl. Common Girder and cryogenic system |
| Suspension System | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 12 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | MG-1004655-A-000_B | 12 | Including all required flanges and mounts. |
| Main thermal shield | MG-1005890-A-000_B<br>MG-1023122-A-000 | 12 | Including service port shield and all required mounts. |
| Main shield MLI | MG-1010422-A-000_B | 12 | A complete set of MLI including service port shield MLI and MLI for all mounts. |
| Telescopic bellow system | MG-1006650-A-000_A | 24 | One assembly applicable at upstream- and downstream position. Not installed for transportation. |
| Upstream Connection thermal shield | MG-1007568-A-000 | 12 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Downstream Connection thermal shield | MG-1007545-A-000 | 12 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | MG-1013373-A-000_A | 24 | MLI-jackets to be installed around the interconnection shielding in the intercon-nection areas between modules. |
| LCL-Assembly | n/a | 12 | Full assembly from warm to cold terminal. HTSC stacks to be supplied by the Company. |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| Instrumentation | PLI_SIS100_QDM-2.9D | 12 | Complete set for the module as listed by according instrumentation list |
| Support frame | MG-1009679-A-000 | 12 | |
| Alignment foot | 14047_001_01-001 | 36 | |
| Transportation locks | n/a | 12 | One set for the module, being required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 12 | One set for the module, being required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |

**Module type:** Arc termination module, type 1.E including endcap, interconnection bellows and shields, supports and alignment feet **Quantity:** 5 Pcs.

**Drawing No.:** 10000020599

**Parts list No.:** 10000020599

**Table 3-22:** *SUPPLY BY THE COMPANY* for all modules of type 1.E (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit MQD | 10000016427-E5A-000 | 5 | pre-assembled unit for completion |
| Unit SF21Bb | 10000016423-E5A-000 | 5 | pre-assembled unit for completion |
| MQD-Unit Vacuum Chamber (incl. CF-flange) | 10000016445-E5A-000 | 5 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| SF1Bb-Unit Vacuum Chamber (incl. CF-flange) | MAG-V08-E66.010.000-A-000_B | 5 | To be integrated into the pre-assembled unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 5 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Cryo-Catcher | MG-1004961-A-000_A | 5 | To be integrated with the UHV-system in the cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-Stacks for LCLs | MG-1023516-A-000 | 50 | To be integrated into the complete LCL assemblies. |
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-1.E | | As defined by according Instrumentation List |

**Table 3-23:** *DELIVERABLES BY THE CONTRACTOR* for all modules of type 1.E (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Arc termination module, type 1.E | 10000016400-E5A-000 | 5 | The module has to be manufactured and assembled completely from all constituents as defined by according parts list. |
| Unit MQD (fully assembled) | 10000016426-E5A-000 | 5 | Assembly and completion from supplied components |
| Unit SF1Bb (fully assembled) | 10000016422-E5A-000 | 5 | Assembly and completion from supplied components |
| Common Girder | MG-1005838-A-000<br>MG-1005857-A-000 | 5x<br>2 | Consisting of two single girder beams for assembly of the cold mass. |
| Integrated Cold Mass | 10000016407-E5A-000 | 5 | incl. Common Girder and cryogenic system. To be integrated from all sub-assemblies. |
| Suspension System | MG-1005752-A-000_A<br>MG-1005753-A-000_A | 5x<br>4 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Insulation vacuum vessel | 10000016432-E5A-000 | 5 | including service port and all required mounts |
| Main thermal shield | 10000016435-E5A-000<br>10000016436-E5A-000 | 5 | including service –, feed port shield and supply line and all required mounts. |
| Main shield MLI | 10000015938-E5A-000 | 5 | A complete set of MLI including service port-, shield lid MLI and MLI for all mounts. |
| Telescopic bellow system | MG-1006650-A-000_A | 5 | Assembly including all clip bolts and gaskets. The bellows must not be installed for transportation processes. |
| Connection thermal shield | MG-1007568-A-000 | 5 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | 10000015960-E5A-000 | 5 | An MLI-jackets to be installed in the interconnection area between modules around the interconnection shielding. |
| LCL-Assembly | MG-1010500-A-000_A,<br>MG-1010000-A-000_A<br>10000016470-E5A-000 | 5 | Complete assemblies from warm to cold terminal. HTSC stacks to be supplied by the |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| | 10000016303-E5A-000 | | Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |
| End cap, vacuum vessel | MG-1019541-A-000 | 5 | A cubic insulation vacuum vessel design including all required flanges, blanking flanges and clip-bolts. |
| End cap, thermal shield | MG-1023372-A-000 | 5 | A cylindrical thermal shield design including all closures and mounts |
| End cap, shield MLI | MG-1023383-A-000 | 5 | Complete set of MLI blankets for application around the end cap shield. |
| End cap, cryogenic piping | MG-1023374-A-000 | 5 | Including all 4K He piping and bellows |
| Instrumentation | PLI_SIS100_QDM-1.E | 5 | One set for each module as listed by the according instrumentation list |
| Support frame | MG-1009679-A-000 | 5 | |
| Alignment foot | SU-1009835-A-000 | 15 | |
| Support consoles | 10000016406-E5A-000 | 5x 2 | Five pairs are needed for SIS100 in all DS-positions (Module type 1.E) where no special module is installed. |
| Transportation locks | n/a | 12 | One set for each module required for safe transportation. Engineering of transportation locks must be performed by the Contractor. |
| Protection caps and -materials | n/a | 12 | One set the module as required for safe and clean storage and transportation. Engineering of transportation locks must be performed by the Contractor. |

**Module type:** Injection module, type 1.Ei including endcap, interconnection bellows and shields, supports and alignment feet **Quantity:** 1 Pcs.

**Drawing No.:** not yet available

**Parts list No.:** not yet available

**Table 3-24:** SUPPLY BY THE COMPANY for the module of type 1.Ei (essential sub-assemblies and components listed only).

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Unit MQDi | 10000017365-E5A-000 | 1 | pre-assembled unit for completion |
| Unit SF1Bi | 10000017363-E5A-000 | 1 | pre-assembled unit for completion |
| MQDi-Unit vacuum chamber (incl. CF-flange) | 10000016445-E5A-000 | 1 | To be integrated into a QP-unit. |
| SF1Bi-Unit vacuum chamber (incl. CF-flange) | MAG-V08-E66.010.000-A-000_B | 1 | To be integrated into a QP-unit. |
| Defocusing injection QP-magnet-unit | 10000017422-E5A-000 | 1 | To be completed with a vacuum chamber. CF-flange to be welded to UHV-chamber. |
| Focusing injection QP-magnet-unit | 10000017419-E5A-000 | 1 | To be completed with a vacuum chamber. CF-flange to be welded to UHV-chamber. |
| Defocusing injection QP-magnet-unit vacuum chamber (incl. CF-flange) | 10000016780-E5A-000 | 1 | To be integrated into a QP-unit. CF-flange to be welded to UHV-chamber. |
| Focusing injection QP-magnet-unit, vacuum chamber (incl. CF-flange) | 10000016780-E5A-000 | 1 | To be integrated into a QP-unit. CF-flange to be welded to UHV-chamber. |
| Beam Position Monitor (incl. mounting flange and signal cables) | STD-V05-D77.000.000 | 1 | To be integrated with the pre-assembled unit. Cabling to be installed during integration. |
| Cryo-Catcher | MG-1004961-A-000_A | 1 | To be integrated with the UHV-system in the cold mass. |
| Cryo-Adsorption pump | 10000016769-E5A-000 | 1 | To be integrated with the UHV system in the cold mass. |
| Voltage breaker | F559-013-002, F559-013-003 | | The full number, as required for production will be supplied |
| HTSC-Stacks for LCL | MG-1023516-A-000 | 14 | To be integrated into the complete LCL assemblies. |

| Component name | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Misc. Temperature Sensors incl. wires | PLI_SIS100_QDM-1.Ei | | As defined by according Instrumentation List |

**Table 3-25:** *DELIVERABLES BY THE CONTRACTOR* for the module of type 1.Ei (essential sub-assemblies and components listed only).

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Injection Module 1.Ei | 10000017337-E5A-000 | 1 | The module has to be manufactured and assembled completely from all constituents as defined by according parts list. |
| Unit MQDi (fully assembled) | 10000017364-E5A-000 | 1 | Assembly and completion from supplied components |
| Unit SF1Bi (fully assembled) | 10000017362-E5A-000 | 1 | Assembly and completion from supplied components |
| Defocusing injection QP-magnet-unit LD (fully assembled) | 10000017421-E5A-000 | 1 | Assembly and completion from supplied components |
| Focusing injection QP-magnet-unit LF (fully assembled) | 10000017419-E5A-000 | 1 | Assembly and completion from supplied components |
| Drift tube | 10000017458-E5A-000<br>10000017459-E5A-000 | 1<br>1 | One of each shall be delivered, assembled into the UHV-system. |
| Common Girder, ring branch | 10000017478-E5A-000,<br>10000017480-E5A-000 | 1<br>1 | Consisting of two single girder beams for assembly of the cold mass. |
| Common Girder, injection branch | 10000017481-E5A-000,<br>10000017482-E5A-000 | 1<br>1 | Consisting of two single girder beams for assembly of the cold mass. |
| Suspension System, ring branch | 10000017456-E5A -000 | 4 | Consisting of 4 load- and 4 tie rods for support of the cold mass in the module |
| Support pillar system, Injection branch | 10000017371_E5A_000<br>10000017372_E5A_000 | 1<br>1 | Each one consisting of adjustable suspension pillar. |
| Integrated Cold Mass, ring- and injection branch | 10000017351_E5A_000 | 1 | incl. Common Girder and cryogenic system. To be integrated from all sub-assemblies. |
| Main Insulation vacuum vessel | 10000017424-E5A-000 | 1 | Including all flanges, blanking flanges and mounts. |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Aux. insulation vacuum vessels | 10000017344-E5A-000<br>10000017345-E5A-000 | 1<br>1 | Two complete vacuum vessels fully assembled for connecting the main vacuum vessel. |
| End Cap vacuum vessel | MG-1021612-A-000 | | Including all flanges, blanking flanges and mounts. |
| End Cap cryogenic piping | MG-1023374-A-000 | 1 | Including all 4K He piping and bellows |
| End Cap thermal shield | MG-1025061-A-000 | | A cylindrical thermal shield design including all closures and mounts |
| End Cap shield MLI | MG-1023383-A-000 | | Complete set of MLI blankets for application around the end cap shield. |
| Main thermal shield | 10000017439-E5A-000 | 1 | Including two service port shields and supply lines and all required mounts. |
| Aux. thermal shields | 10000017376-E5A-000<br>10000017391-E5A-000 | 1<br>1 | including all required mounts |
| Main shield MLI | 10000017449-E5A-000 | 1 | A complete set of MLI including service port-, shield lid MLI and MLI for all mounts. |
| Aux. shield MLI | 10000017378-E5A-000<br>10000017393-E5A-000 | 1<br>1 | Two complete sets of MLI for the auxiliary thermal shield incl. all mounts. |
| Aux. Insulation vacuum vessels | 10000017345-E5A-000<br>10000017344-E5A-000 | 1<br>1 | Including all flanges, blanking flanges and mounts. |
| Compensation bellow | 10000022564_E5P_000 | 1 | Not installed for transportation. |
| Connection thermal shield | 10000022217-E5P-000 | 1 | A set of 2 Al-Shield wings with thermal coupling to the cooling line. Not installed for transportation processes. |
| Connection shield MLI | n/a | | An MLI-jackets to be installed in the interconnection area between modules around the interconnection shielding. |
| LCL-Assemblies | MG-1010500-A-000<br>10000016470 | 3<br>1 | Warm to cold terminal. HTSC sub-units to be supplied by the Company. |
| Warm terminal boxes and connector cables | Multiple drawing numbers | | Complete set of terminal boxes for connection to the power supplies and control cabinets |

| Component description | Drawing No. | Quantity | Remark |
|---|---|---|---|
| Instrumentation, injection (incl. installation and wiring) | PLI_SIS100_QDM-1.Ei | 1 | Complete set for the module as listed by according instrumentation list |
| Special support frame | 10000017350-E5A-000 | 1 | |
| Special high load alignment foot | SU-1009835-A-000 | 3 | |
| Transportation locks | n/a | 1 | One set for each module required for safe transportation |
| Protection caps and –materials | n/a | 1 | One set for each module as required for safe and clean storage transportation |

***Important Note:***

*For economic reasons all alignment feet as defined by drawing number 14047_001_01-001, being part of the deliverables by the contractor, shall be produced with cast steel housings instead of welded housings. This information may not be available in the set of drawings being supplied with the tender document at the time of call for tender.*

### 3.3.2. Deliverable processes

1) The Contractor shall be responsible for all processes, being required for procurement, respectively production of parts, components and assemblies being part of the delivery by the contractor as defined in this document and the according engineering drawings and instrumentation lists.
2) The Contractor shall be responsible for all processes being required for engineering and procurement, respectively production of all tooling and measurement equipment in production and testing of QDM and its parts, components and sub-assemblies.
3) In case, modifications of engineering design of any part, component or assembly of the QDMs is requested by the Contractor for any reason, the Contractor shall be responsible for such design changes as defined by section 5.1.
4) The following paragraphs are listing processes which are mandatory and at least must be performed by the Contractor during fulfilment of the order.
5) Major and super-ordinated processes are listed only. Processes not listed herein but found to be required for planning, production development, production, qaulity assurance and testing also must be developed, implemented and performed for production of the QDMs. Therefore the Contractor shall analyse all the full production and testing processes in detail.
6) For details of deliverable documentation see section 7.

**Review processes:**

- Design reviews in case of technical changes in component- or assembly design,
- Design review for special production-, test-, protection- and transportation tooling, (no engineering design will be provided by the company),
- Review of planning for procurement-, production-, test- and transportation processes,
- Review of quality assurance planning and documents.

**Development processes:**

- Redesign of detailed design solutions in case design changes are suggested by the Contractor,
- Design of special production-, testing-, protection- and transportation equipment and tooling,
- Planning and development of all required production- and assembly processes,
- Planning and development of required joining technologies according to applicable standards and European guidelines (e.g. brazing, welding, soldering etc.),
- Planning and development of the process for 3d-coordinate measurement and fiducialistation,
- Planning and development of all required quality assurance processes and measurement methods as long not defined in detail by technical guidelines or applicable standards,
- Planning and development of acceptance tests according to given requirements,
- Planning and developing all required transportation lock, transportation and storage protection and transportation data logging.

**Production, respectively procurement processes:**

Production, respectively procurement of all

- special tooling for production-, test-, protection- and transportation.
  No components or devices will be supplied by the Company.

Production, respectively procurement of all parts, components and assemblies

- for completion of the UHV systems,
- to complete and build all cold masses,
- to build cold mass suspension,
- to build and install the LCLs for SC- and NC-magnets,
- to build the cryostats, end caps, compensation bellow systems and connection cryostat systems, including thermal shields and MLI
- support frames and support feet,

as listed in the tables above and when not supplied by the Company.

Performing the

- completion of partly assembled QP-magnet-units with corresponding UHV components and BPMs by applying the required mechanical assembly, welding- and brazing processes,
- installation and alignment of QP-magnet-units into common girders to build the cold masses,
- completion of UHV-systems in the cold masses with corresponding UHV components by applying the required mechanical assembly processes and welding- and brazing processes,
- installation and completion of the cryogenic systems of the cold masses,
- installation and wiring of all instrumentation according to the instrumentation planning lists, specifications and technical gueidlines,
- assembly of all thermal shields and all cryostats,
- mounting, pre-alignment and pre-stressing of the cold masses in the cryostats,
- completion of the UHV system with CWTs,
- application of CID-labels to all component requiring a CID,
- assembly and installation of LCLs from electrical connection boxes to cold terminals,
- required cleaning processes, where ever needed.

**Testing and measurement processes:**

Performing all

- incoming goods inspection of all components for unit completion and QDM integration,
- required measurements and tests during production as defined by according QA-plans,
- survey of BPM-Position and orientation at QP-magnet-units w.r.t. the according QP-magnet,
- measurements for alignment of QP-magnet-units in the cold masses on the common girder,
- measurement and alignment of cold mass position and orientation of all QDMs during pre-alignment in the cryostat,
- testing of all instrumentation during and after installation,
- pre-assembly of the complete QDM-systems for installation test (including end caps, compensation bellow systems, support feet, support frames etc.),
- processes for 3D-coordinate measurement and fiducialistation (accuracy 0.1mm at 1σ),
- single processes in complete FATs for all QDMs and components as defined by according specifications and technical guidelines,
- inspection for correct CIDs assignment,
- checking of packaging and transportation protection before shipment release.

**Packaging and shipment processes:**

- application of all transportation locks and protection caps and materials,
- packaging of all QDMs and components ready for shipment,
- application of sensors and data loggers for permanent transportation data measurement (shock, humidity etc.),
- shipment of all QDMs and components,
- return of transportation frames to production site.

**Documentation processes:**

- Preparation and submission of ECRs in case any need for design, material or procedure changes is identified during any phase of the order fulfilment,
- documentation of production planning in detail for all production processes,
- documentation of all QA-planning in detail for all QA-processes,
- documentation for planning of joining technologies according to applicable standards,
- Complete documentation of CID assignment for the components of QDMs and complete modules,
- documentation as defined by according QA-planning,
- documentation as defined by corresponding technical guidelines and applicable standards,
- documentation as defined for complete FATs for all QDMs and components,
- collecting all datasheets and certificates of any material, applied for production- or cleaning processes of components and CDMs.
- documentation as defined by applicable CE-Standards, especially the pressure equipment directive 2014/68/EU.

**Documentation to be delivered:**

- Applicable documentation as defined by GS [1]
- Applicable Documentation as defined by CS [5]
- Design changes by the Contractor (when required)
- Production- and delivery schedule,
- QA-Planning,
- Complete documentation on completion of QP-magnet-units,
- Complete documentation on assembly and alignment of QP-magnet-units into cold mass,
- 3D-coordinate measurement and fiducialisation,
- Installation and testing of instrumentation,
- Pre-Alignment and pre-stressing of cold mass,
- CID – labeling and CID-registration,
- Packaging, shipment, transportation and storage,
- Quality assurance system of the Contractor,
- Incoming goods inspection,
- Tests and measurements during production,
- Non-Conformity-Reports,
- FAT of FoS,

- FAT of Series components,
- Reporting on production (every two working weeks),
- Documentation in Terms of CE, especially the pressure equipment directive 2014/68/EU.

### 3.3.3. Components not being part of the delivery

1) Within the technical drawings and parts lists, some components are listed, but are not part of the deliverables. These components are listed in the table table 3-26 below.
2) Temperature sensors shall be part of the Companies supply to the Contractor. The Contractor shall be responsible for incoming goods inspection of temperature sensors, installation and testing only.

**Table 3-26:** Components not being part of the deliverables by the contractor

| Name | Position number |
|---|---|
| Turbopump | 45 |
| UHV – valve | 46 |
| UHV – valve | 50 |
| Turbopump | 51 |
| NEG/IGP Pump | 52 |

### 3.3.4. Spare Parts

Each single spare part, respectively spare part assembly shall be packed properly and shall be ladled with its according drawing number.

**Spare parts: Insulation vacuum gaskets**

- Five complete sets of gaskets for the arc-section modules (e.g. Type 2.5) as listed in according parts lists.
- Two complete sets of gaskets for the straight-section modules (e.g. Type 2.123) as listed in according parts lists.
- Two complete sets of Insulation vacuum vessel gaskets, as defined in the according parts list for the arc-termination modules 1.E and 2.4. One set for each module.
- Two complete sets of Insulation vacuum vessel gaskets, as defined in the according parts list for each of the special modules 1.Ei and 2.4x. One set for each module.

**Spare parts for the Modules 2.4x and 1.Ei:**

- One complete set of spare parts shall be delivered for all G11-Components for both cold mass support feet of the injection branch in Injection module 1.Ei. Type and number of the dedicated components shall be taken from the according parts list.
- One complete set of spare parts shall be delivered for all G11-Components for the suspension pillar and traverse, Extraction module 2.4x. Type and number of the dedicated components shall be taken from the according parts list.

**MLI Spare parts:**

- One complete set of thermal shield MLI-blankets for the straight-section modules (e.g. Type 2.123) as listed in according parts lists.
- Two complete sets of thermal shield MLI-blankets for the arc-section modules (e.g. Type 2.5) as listed in according parts lists.

- Two complete sets of MLI-blankets as defined in the according parts list for the arc-termination modules 1.E and 2.4. One set for each module.
- 40 m of 10-layer uncut MLI-blanket hose for each type of 4K-He supply line (VC-supply-, magnet mass supply- and 2-phase-return line).

**Spare parts for Arc-section modules:**

- A set of spare parts shall be delivered by the Contractor as listed in table 3-27.

**Table 3-27:** List of required spare parts

| Name | Part number | Qty. (Pcs.) |
|---|---|---|
| DOVETAIL SLIDE | MG-1005887 | 8 |
| GIRDER OUTSIDE | MG-1005857 | 1 |
| GIRDER INSIDE | MG-1005838 | 1 |
| UPPER CURRENT LEAD CABLE | MG-1026635 | 20 |
| COLD TERMINAL CABLE | MG-1026152 | 20 |
| SUPPORT ROD UNIT | MG-1005753 | 8 |
| TIE ROD UNIT | MG-1005752 | 8 |
| DOVETAIL SLIDE CRYO CATCHER | MG-1008861 | 2 |
| Spacer sliding fixation 1 | MG-1010036 | 20 |
| Spacer sliding fixation 2 | MG-1010038 | 20 |
| Spacer sliding fixation 3 | MG-1010044 | 20 |
| Spacer sliding fixation 4 | MG-1010048 | 20 |
| Spacer sliding fixation 5 | MG-1010050 | 20 |
| Spacer center fixation 1 | MG-1010396 | 10 |
| Spacer center fixation 2 | MG-1010398 | 10 |
| Spacer center fixation 3 | MG-1010400 | 10 |
| Spacer center fixation 4 | MG-1010401 | 10 |
| Spacer center fixation 5 | MG-1010402 | 10 |
| Angular plate 0 | MG-1010370 | 20 |
| Angular plate 1 | MG-1009903 | 20 |
| Angular plate 2 | MG-1010063 | 20 |
| Angular plate 3 | MG-1010064 | 20 |
| Angular plate 4 | MG-1010065 | 20 |
| AXIAL SPHERICAL BEARING | MG-1013144 | 16 |
| CONNECTION BELLOW | MG-1006644 | 4 |
| ALINGMENT FOOT | SU-1009835 | 6 |

### 3.3.5. Delivery of documents by the Company

1) For the production of the FoS QDM, type 2.5, the Company provides a full set of engineering drawings.
2) For the production of the full series of SIS100-QDMs, the Company provides full sets of engineering drawings for each of the QDM-types, after finalisation of the FAT of FoS QDM, type 2.5.
3) The Company provides dedicated components for production of all QDMs as listed in the tables in section 0, named "*SUPPLY BY THE COMPANY".*

# 4. System Specification

## 4.1. **Parameter requirements (functional requirements)**

### 4.1.1. Operation parameter *(for Information only)*

1) The QDM is expected to be mainly operated under standard mode operation conditions as listed below while a failure mode operation must not be excluded. For Information on failure mode operation see [5], [283] and below.
2) Additional to the operation modes defined by [5] the following operation modes are applied, respectively may appear at a QDM:

***The operation cool down mode*** is defined by the following parameter:

- ≤ $10^{-6}$ mbar(absolute) inside the cryostat vacuum vessel
- 18 bar(absolute) GHe inside all shield cooling pipes
- Shield temperature is decreasing from room temperature to 50 K within 48 h (dT/dt is not constant and the temperature distribution is not homogenous)
- Cold mass temperature (TCM) is decreasing from room temperature to 4.5 K within 170 h (dT/dt is not constant and the temperature distribution is not homogenous)
- 18 bar(absolute) GHe inside all cold mass cooling pipes at $T_{CM}$ ≥ 70K
  < 18 bar(absolute) GHe inside all cold mass cooling pipes below $T_{CM}$ < 70K
  (dp/dt is not constant and the temperature distribution is not homogenous)

***The testing cool down mode*** is defined by the following parameter:

- ≤ $10^{-6}$ mbar(absolute) inside the cryostat vacuum vessel
- 18 bar(absolute) GHe inside all shield cooling pipes
- Shield temperature is decreasing from room temperature to 50 K within 12 h (dT/dt is not constant and the temperature distribution is not homogenous)
- Cold mass temperature (TCM) is decreasing from room temperature to 4.5 K within 24 h (dT/dt is not constant and the temperature distribution is not homogenous)
- 18 bar(absolute) GHe inside all cold mass cooling pipes at $T_{CM}$ ≥ 70K
- < 18 bar(absolute) GHe inside all cold mass cooling pipes below $T_{CM}$ < 70K
  (dp/dt is not constant and the temperature distribution is not homogenous)

***The cold mode*** is defined by the following parameter:

- ≤ $10^{-6}$ mbar inside the cryostat vacuum vessel
- 18 bar GHe inside all shield cooling pipes
- Shield temperature 50K ≤ $T_{Shield}$ ≤ 80 K
- 2.1 bar(absolute) LHe inside all cold mass cooling pipes

• Cold mass temperature is TCM = 4.5 K (at the inlet)

***The warm up mode*** is defined by the following properties:

- ≤ $10^{-6}$ mbar inside the cryostat
- 18 bar(absolute) GHe inside all shield cooling pipes
- Shield temperature is increasing from 50 K to room temperature within 24 h
- 18 bar(absolute) LHe inside all cold mass cooling pipes
- Cold mass temperature is increasing from 4.5 K to room temperature within 120 h

***Failure mode*** is defined by the following parameter:

- 1,013 (absolute) inside the cryostat vacuum vessel,
- 18 bar GHe inside all shield cooling pipes,
- Shield temperature rising from $T_{Shield} \geq 50K$,
- 20.4 bar(absolute) GHe inside the vacuum chamber cooling supply line,
- 19.3 bar(absolute) GHe inside the magnet cooling supply line,
- 17.7 bar(absolute) GHe inside the common return line
- Cold mass temperature is rising from TCM = 4.5 K.

#### 4.1.2. Requirements on the Insulation vacuum system

1) Requirements on the insulation vacuum system of QDMs are defined by [5].

#### 4.1.3. Requirements on the cryogenic systems

1) The basic requirements on the cryogenic system of a QDM are defined by [6].
2) Detailed requirements of specific technical systems of the QDMs are defined by [9], [10] and [11].

#### 4.1.4. Requirements on handling and installation of UHV-components

All rules of UHV state-of-the-art best knowledge and practice must be observed thoroughly and consistently during the assembly and integration of vacuum components. Failure to abide to these rules may result in severe vacuum performance impairments and may render the vacuum system ultimately unusable for UHV conditions. All vacuum components will be delivered in a clean condition, and utmost care must be taken to avoid any contamination.

1) To avoid that the vacuum chamber surfaces become contaminated, a clean environment for the vacuum chamber manufacturing is sufficient. A clean room (with clean room class) is advantageous, but is not necessarily required. However, covers shall be provided to keep the room dust-free. In general, the room shall be kept free from any oily and greasy objects at all times.
2) For the assembly of vacuum components (e.g. installation of a measuring device into a vacuum chamber), all necessary tools shall be cleaned prior to use, namely in such a way that they fulfil the same cleanliness standards as the component itself. Cleaning processes shall be documented so that possible impurities can be identified.
3) Vacuum facing surfaces must not come in contact with any greasy or oily substances (including bare hands leaving fingerprints), unless thorough cleaning follows immediately afterwards.
4) In order to avoid fingerprints and other contamination hazards, lint-free gloves must be worn by all personnel handling UHV components. All rules of best UHV practice and knowledge must be observed thoroughly and consistently.
5) In general, welding shall always be done in a clean environment and welding working places shall be always kept free from any oily and greasy objects.
6) Whenever access to UHV-related surfaces is not needed adequate covering of UHV-surfaces shall be provided (e.g. Al-foil or clean caps).
7) The following FAIR Technical Guidelines must be observed during integration of vacuum components:
   - Concerning welding: F-TG-V-3.1e [40], F-TG-V-3.9e [41]

- Concerning assembly: F-TG-V-3.42e [42], F-TG-V-13.1e [47]
- Concerning vacuum properties: F-TG-V-7.2e [43], F-TG-V-7.38e [44], F-TG-V-7.39e [45]
- Concerning transport and packaging: F-TG-V-9.1e [46]

## 4.2. **Interfaces**

The following chapters define the main interfaces, being relevant for assembly of complete SIS100-QDMs as well as the interfaces of the system attaching to the completed Modules. Due to the complexity of the full modules not all single interfaces are defined in detail.
Detailed information on interfaces must be extracted from the available technical drawings.

### 4.2.1. Pre-assembled Units

1) As shown in figure 3-20, only pre-assembled units and the required UHV components will be delivered to the Contractor for completion of assembly and integration into QDMs. The pre-assembled units are showing interfaces for assembly of
   - UHV components (VCs for all units),
   - Beam position monitors (where required).

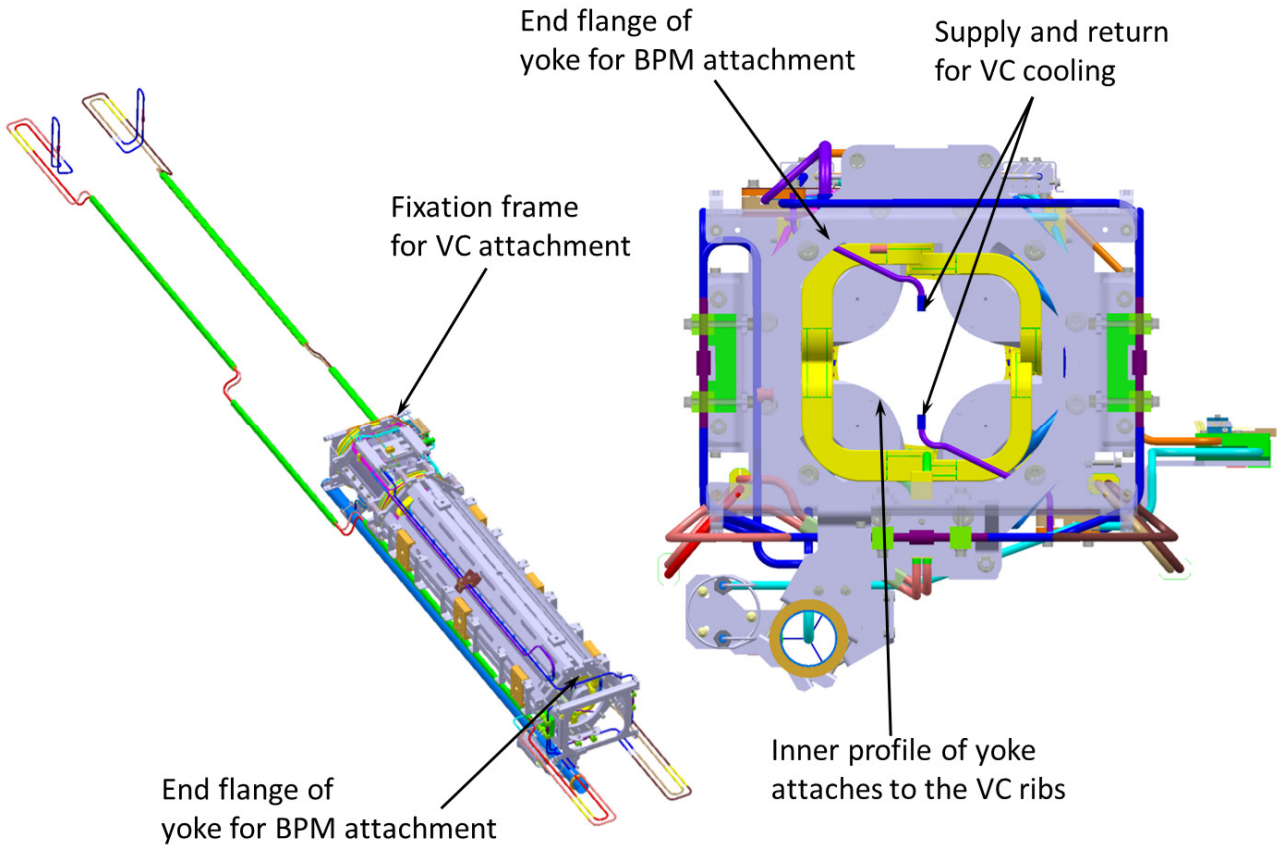



**Figure 4-1 f.i.o:** Pre-assembled SF1B-unit (left) without VC and BPM. Front view to SF1B-unit (right). Fixation fram in translucent display mode.

2) Other pre-assembled units do show similar interfaces in dependence of the components to be mounted. For detailed information on all pre-assembled units see according technical drawings.

***Drawings and part lists:***

See section 4.3.1.

### 4.2.2. Fully Assembled units

1) The fully assembled units are showing multiple interfaces to their surrounding components and assemblies. The units are attaching to
   - UHV components (VCs for all units, COL or drift tubes, CWTs),
   - Bus Bars of opposite unit,
   - Bus Bar clamps of opposite units,
   - Fixation frame of opposite units,
   - Local current leads for corrector magnets
   - Common Girder.
2) Half a LHe-supply line (of one full QDM) is part of each unit. Those lines shall be welded to each other during the cold mass integration. Within the assembled unit, they are fixed to a temporary fixation for transportation protection. This temporary fixation must be removed after assembly in the cold mass.

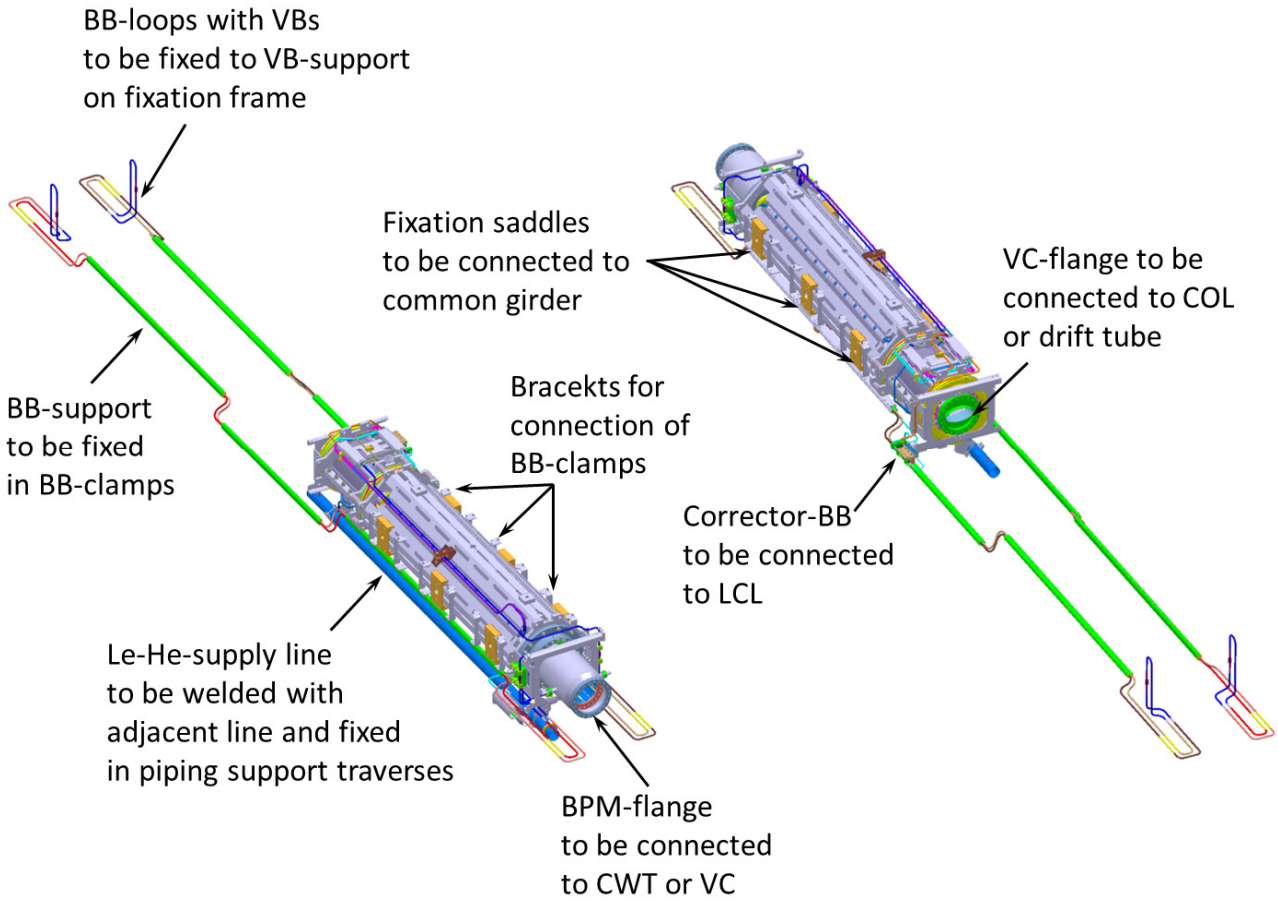



**Figure 4-2 f.i.o:** Assembled SF1B-unit (left) with VC and BPM. View to the VC flange of the SF1B-unit (right).

***Drawings and parts list defining the component interfaces:***

See section 4.3.1.

### 4.2.3. Common Girder

1) The Common Girder structure of the cold mass is mechanically integrating all cold mass components to one condensed mechanical system. Furthermore it provides the interfaces for its suspension in the cryostat system.
2) By means of dedicated bore matrices in the places where the common girders are connecting to the QP-magnets, an alignment appliance for aligning QP-magnet-units to each other is provided.
3) The common girder provides multiple mechanical and cryogenic interfaces, where integrated components
   - are attached to,
   - the cold mass is suspended by,
   - the common girder cooling is supplied with LHe.

   Interfaces are
   - Fixation plate for QP-magnet-units,
   - Alignment plate and bore matrices for unit alignment,
   - Terminal ledges for COL – fixation,
   - Suspension saddles for load- and tie rods,
   - Girder cooling connectors.

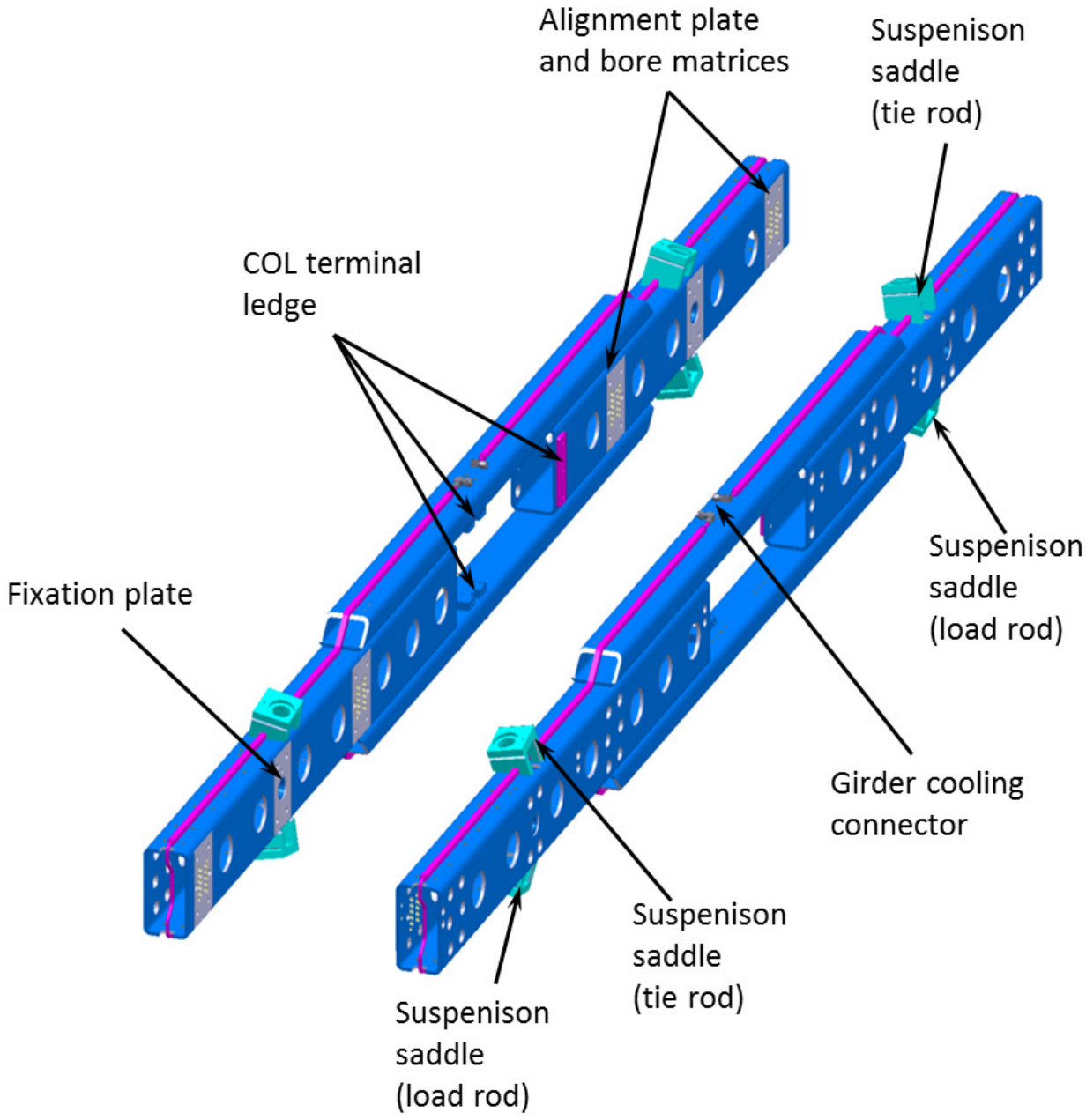



**Figure 4 2 f.i.o:** Common girder structure for integration of the cold mass.

4) Further interfaces are located on the top and lower planes of the common girders. Those are simple thread holes for attachment of traverses, carrying the LHe-supply systems.

***Drawings and part lists:***

See section 4.3.4to 4.3.7

### 4.2.4. Cold Mass

1) The cold mass provides mechanical-, electrical-, vacuum- and cryogenic interfaces, where
   - the cold mass is suspended in the cryostat,
   - the magnets in the QP-magnet-units are electrically connected,
   - the BPM – signals are read out of the device,
   - the beam vacuum chambers are connected to compensation bellows,
   - the cold mass is supplied by LHe.

   Interfaces are
   - suspension saddles,
   - main magnet Bus Bars,
   - BPM – signal transformers,
   - electrical terminals of corrector bus bars,
   - beam vacuum chamber- and BPM-flanges,
   - pipe ends of magnet supply, vacuum chamber supply and common return line.
2) The cold mass is built from two QP-magnet-units, integrated in one common girder.
3) The LHe cooling supply system and 2-phase-He-returnline is part of the integrated cold mass. The cryogenic system tubing provides the interfaces for connection of the cryogenic lines to the adjacent modules. This applies to the arc- and arc termination modules.
4) Within the straight section modules, cryogenic supply is realised by branch lines, fed in from the cryogenic by-pass-line.
5) Within the cold mass the cryogenic distribution system of the full QDM is implemented by multiple low cross section tubing, routed according to the flow schemes as defined by [9], [10] and [11]. This rooting generates multiple internal interfaces within the cold mass itself.
6) The cold mass is suspended in the cryostat by a mechanical system of crosswise oriented, low cross section suspension rods.

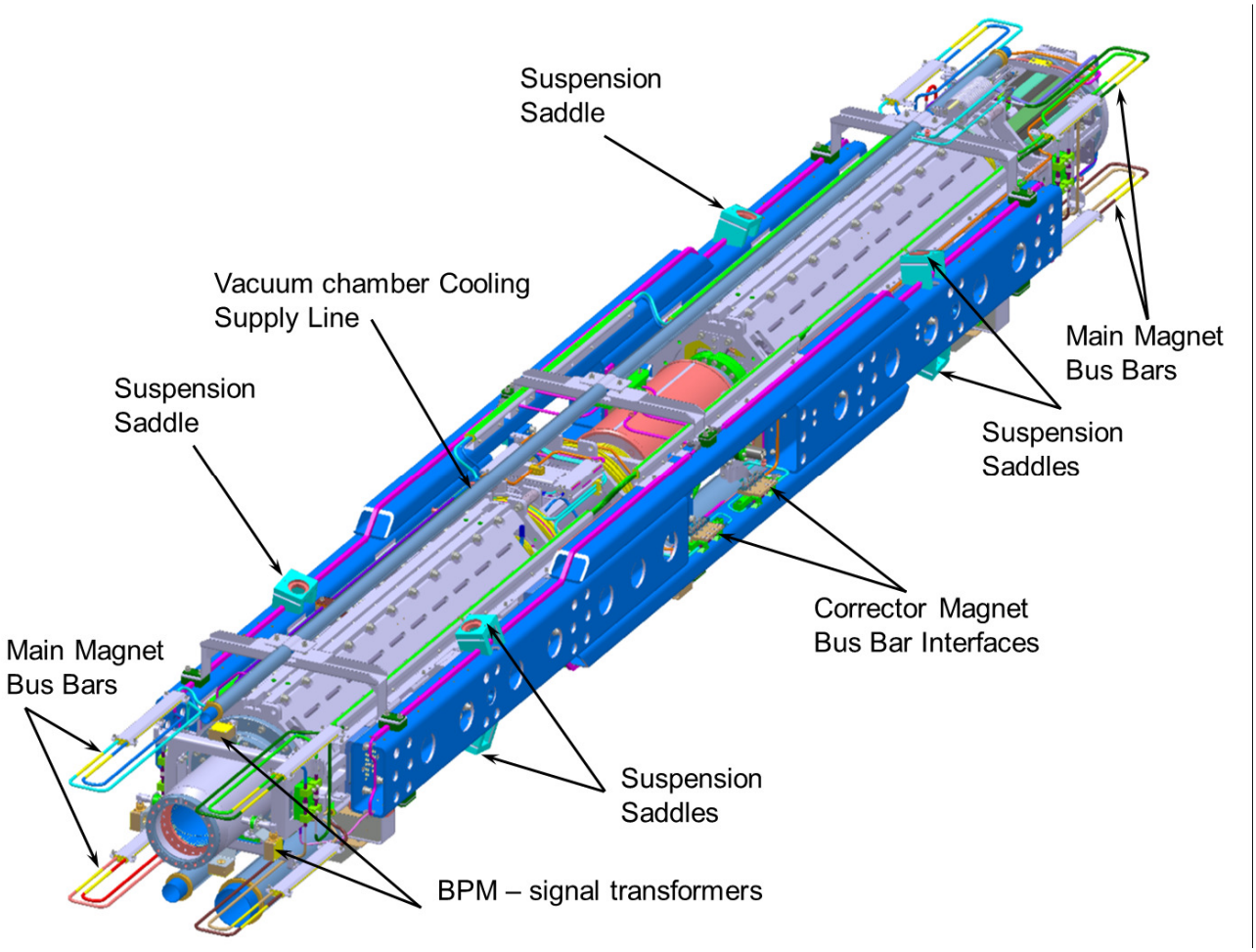



**Figure 4-3 f.i.o:** CAD-Model of a fully assembled cold mass, type 2.5 (isometric view).

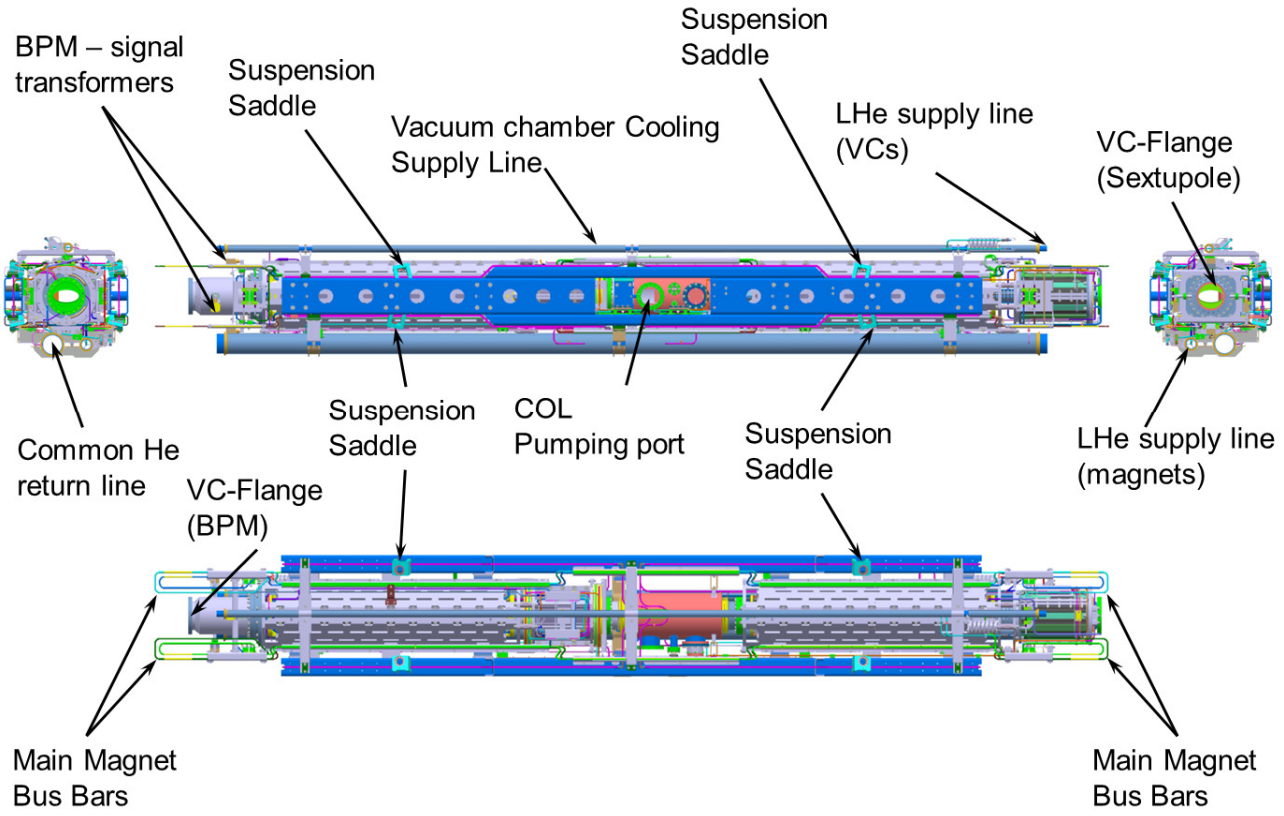



**Figure 4-4 f.i.o:** CAD-Model of a fully assembled cold mass, type 2.5 (projection views).

***Drawings and part lists:***

See section 4.3.2.

### 4.2.5. Suspension system

1) The demanding task of suspending and precisely stabilizing the QDM cold mass in the module is solved by a system of eight crosswise spanned load- and tie rods. The load rods are carrying the mass load of the cold mass and the additional span forces, applied by the tie rods.
2) For an optimum layout of the suspension system, a combination of Ti – alloy (Ti6Al4V) and stainless steel rods is required. These two components of one rod are screwed together by a connection thread.
3) The suspension system is fixed to the cold mass and the surrounding cryostat by tensioning the tie rods after pre-alignment of the cold mass in the cryostat.
4) For minimisation of the heat load to the cold mass, the suspension rods are thermally anchored by copper thermalisation straps.

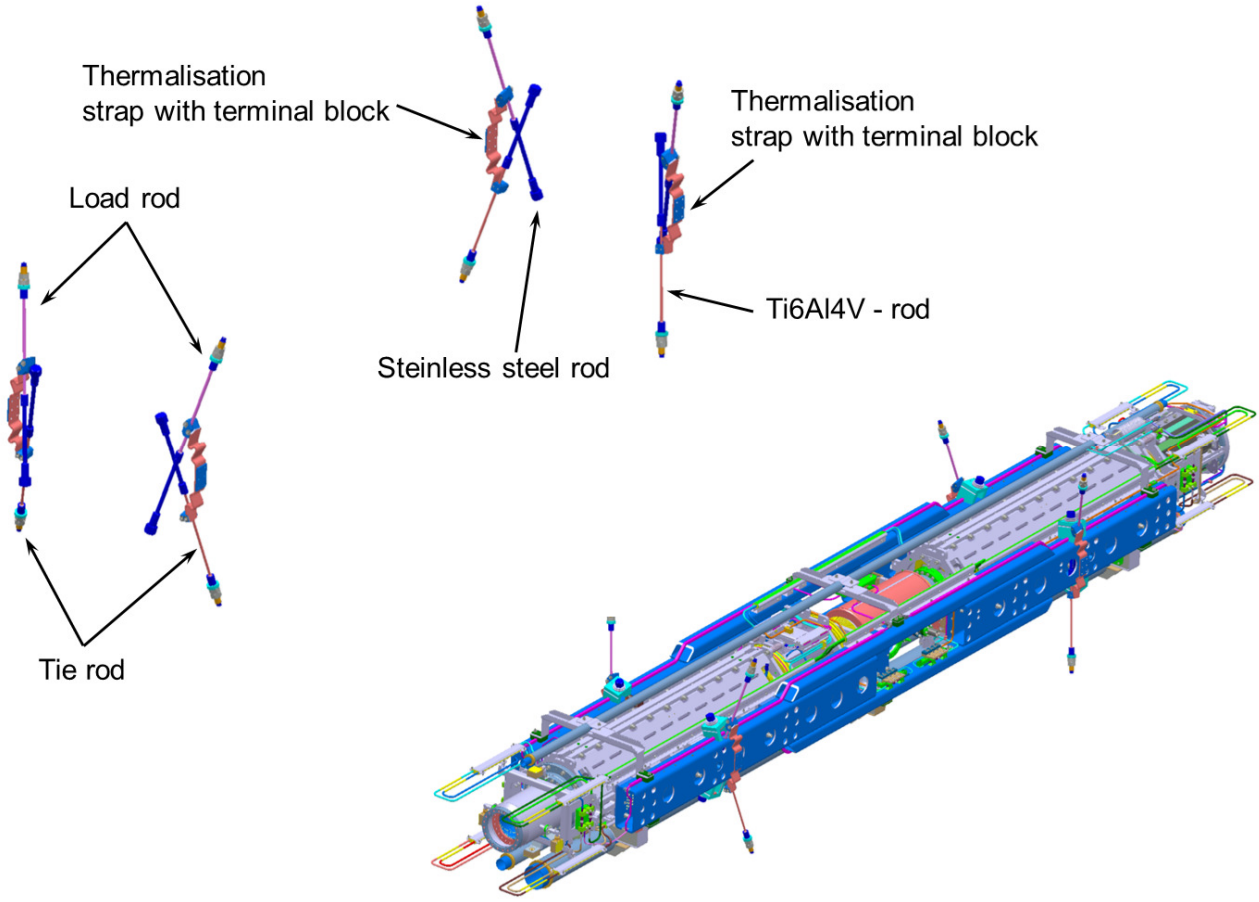



**Figure 4-5 f.i.o:** CAD-Model of the complete suspension system of an arc section module (top left). CAD-Model of the cold mass fixed in the suspension system (bottom right)

***Drawings and part lists:***

See section 4.3.4 to 4.3.7.

### 4.2.6. Local Current Leads

1) For electrical supply of corrector magnet systems (e.g. steering magnets, sextupole magnets, multipole corrector magnets) being installed in the cold mass of the QDM, local current leads are foreseen. LCLs are electrically conducting currents but thermally decoupling a warm terminal from a device at low temperatures.
2) An LCL provides electrical and thermal interfaces to their adjacent components. Those are
   - warm terminals for connection of the terminal boxes at room temperature,
   - thermal interception for the purpose of thermal anchoring,
   - cold terminals for connection to the super conducting bus bars of corrector magnets.
3) The SIS100 LCL consist of a normal-conducting Cu-part from the warm terminals to the HTSC-conductors and a high temperature – super-conductor for the connection to the low temperature super-conducting corrector bus bars.

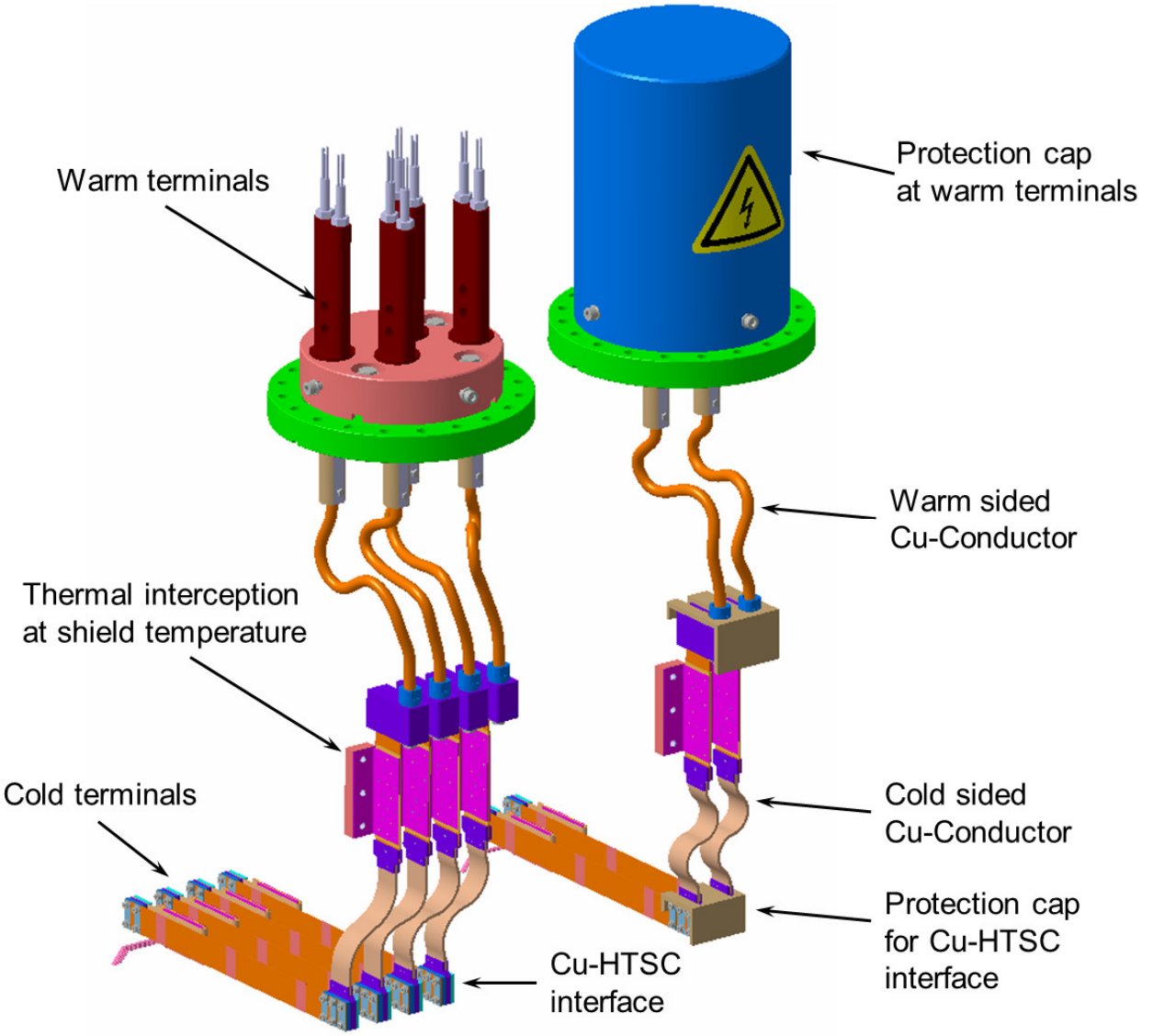



**Figure 4-6 f.i.o:** CAD-models of steering magnet LCLs (left) without protection caps shown and sextupole magnet LCLs (right) with protection caps shown.

***Detailed Specification:***
This document. A dedicated specification document is not yet available.

***Drawings and part lists:***
See section 4.3.3.

### 4.2.7. Thermal Shield

1) The thermal shield provides mechanical- and cryogenic interfaces, where
   - the MLI is located at
   - the thermal shield is supported on
   - the cryogenic supply is connected to
   - integrated systems are thermally intercepted
   - adjacent components are connected to each other

- the shield is axially centred in the insulation vacuum vessel
- instrumentation lead wires and cable are feed through
- over pressure is lead out (in accidental cases only)
- access to inner systems is provided

Those interfaces are

- the outer shield surface,
- the support pins,
- the shield supply and return line,
- the thermalisation blocks for instrumentation and support system
- bolting rivets along pitch circles and bolting ledgers,
- axial centring pins
- openings in the service port and cable windows,
- the blow-off grate
- service port shield

2) By adjusting the support and centring pins, the thermal shield can be axially and radially aligned in the insulation vacuum vessel.

***Drawings and part lists:***

See section 4.3.4 to 4.3.7.

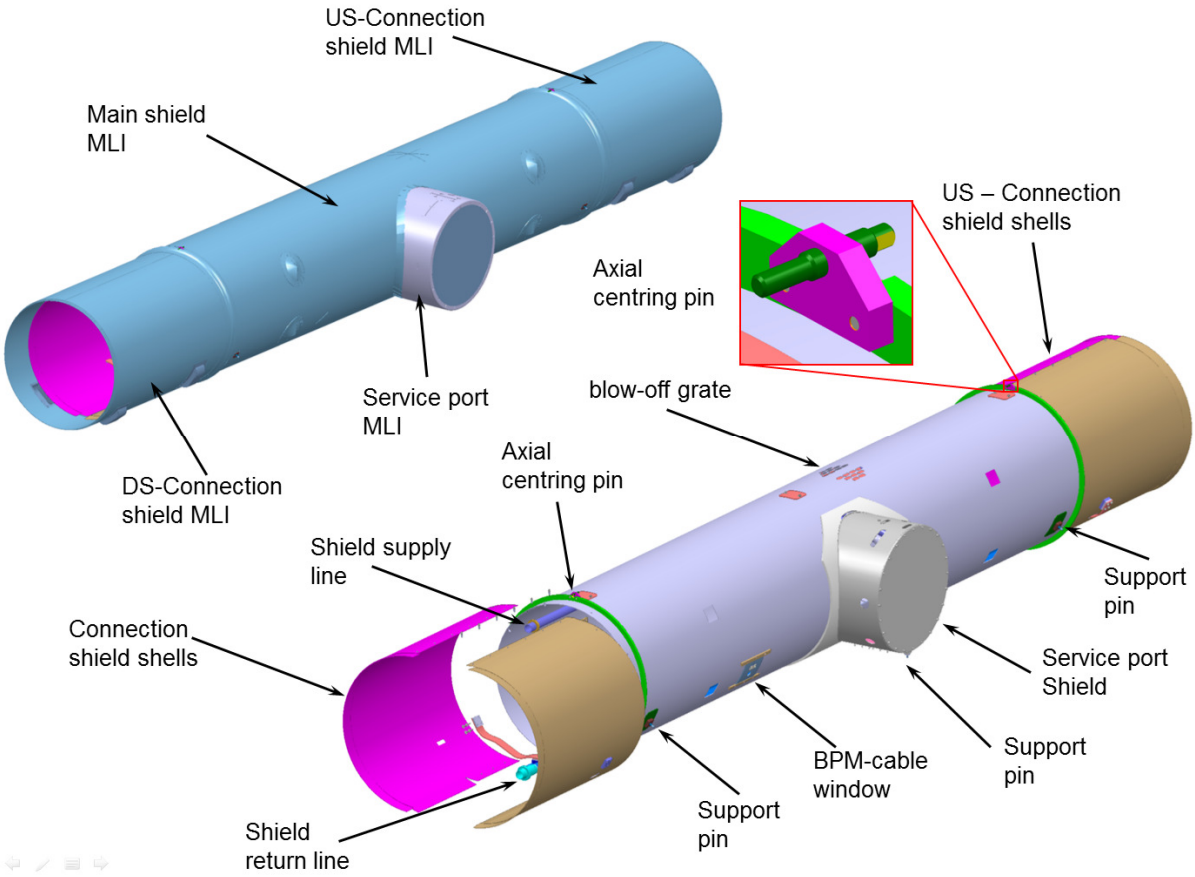



**Figure 4-7 f.i.o:** CAD-model of the thermal shield with the full set of MLI (top left) and without MLI (bottom right).

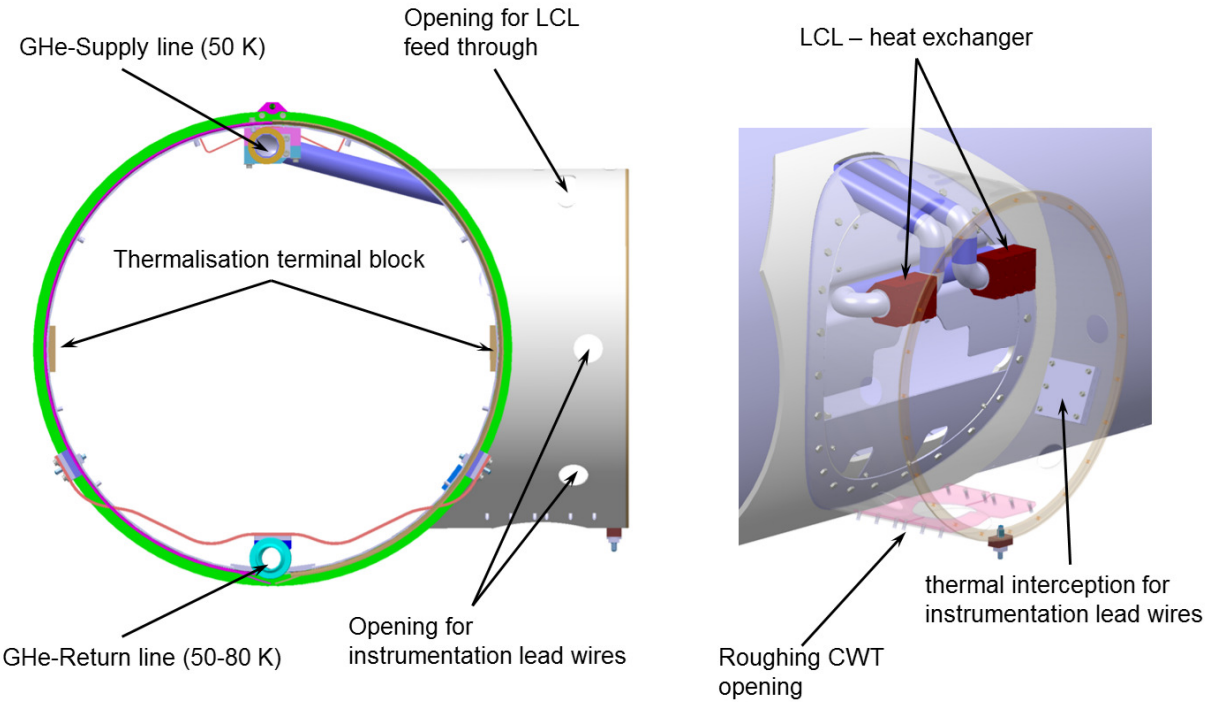



**Figure 4-8 f.i.o:** CAD-model of the thermal shield (left: view in axial direction). Detailed view onto the service port shield and the heat exchangers (left: translucent view).

### 4.2.8. Insulation vacuum vessel

1) The insulation vacuum vessels generally provides mechanical-, electrical and safety interfaces for multiple functions (see figures below):
   - Pos. 1.: Connection to adjacent modules for continuity of insulation vacuum
   - Pos. 2.: Connection to support- and support feet
   - Pos. 3.: Interface for floor-borne vehicles (Forklift)
   - Pos. 4.: Closure and access to service port for system maintenance
   - Pos. 5.: Mounting of the cold mass support system an access to adjustment screws for cold mass alignment
   - Pos. 6.: Connection for insulation vacuum pumps
   - Pos. 7.: Feed through for LCLs, local current supply of corrector magnets
   - Pos. 8.: Feed through for instrumentation signal lead wire connections (temperature sensors)
   - Pos. 9.: Feed through for quench detection signal lead wire connections (voltage taps sensors)
   - Pos. 10.: Carrying the electrical terminal boxes for connection of warm cables for local current supply of corrector magnets
   - Pos. 11.: Mounting fiducial targets for precision alignment purposes
   - Pos. 12.: Blowing off over pressure in case of broken He-supply systems
   - Pos. 13.: Mounting shackles for crane conveying
   - Pos. 14.: Feed through for BPM signal lead wire connections
   - Pos. 15.: Mount for a feed through flange for UHV-roughing pump connection
   - Pos. 16.: Retaining the thermal shield axial fixation bolts in cold operation mode
2) Other versions of QDMs are basically showing the same interfaces, but some might not exist due to a different design and application in SIS100. Especially for the special type modules 1.Ei and 2.4x (beam injection and extraction) this is the case.

**Drawings and part lists:**
See section 4.3.4 to 4.3.7.

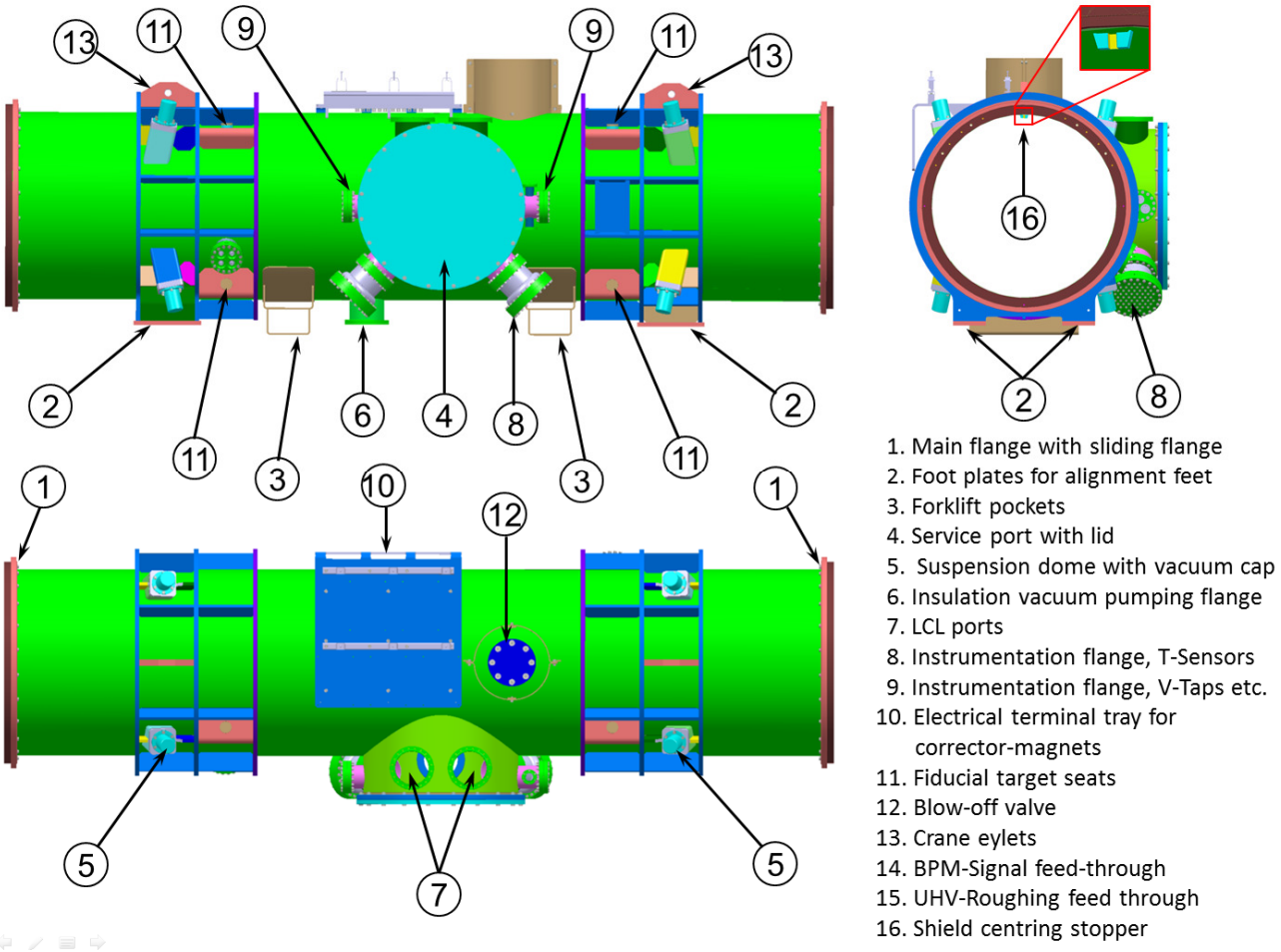



**Figure 4-9 f.i.o:** Projected views of the CAD-model of an arc type cryostat vacuum vessel without interconnection bellow system attached.

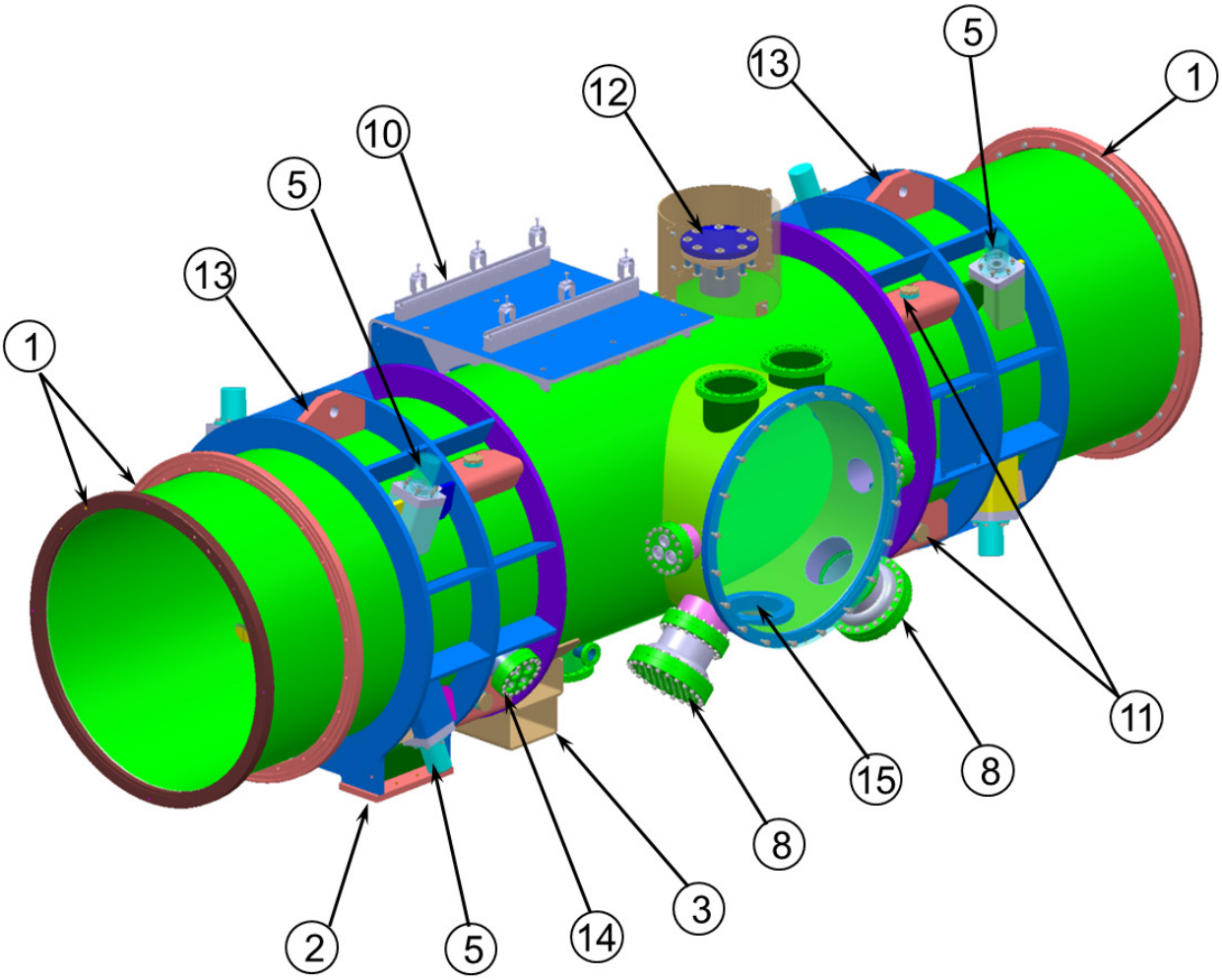



**Figure 4-10 f.i.o:** 3D view of the CAD-model of an arc type cryostat vacuum vessel without interconnection bellow system attached. Some components are displayed in translucent mode for a better vision onto details in the model.

### 4.2.9. Telescopic Bellow Systems

1) The telescopic bellow systems provide
   - the continuity of insulation vacuum,
   - a weak mechanical interconnection of magnet modules

   in a SIS100-arc section.
2) All required O-ring gaskets for vacuum tightness are integrated in the bellow-, tube and flange system. In case of leakage due to high radiation loads on elastomer gaskets, these seals will be exchanged against metal based gaskets (e.g. Helicoflex® or equivalent in design and performance) later on by the Company.
3) The bolting of the interconnection areas in-between the magnet modules shall be implemented by clip bolts, arranged in a collar around the connecting flanges.

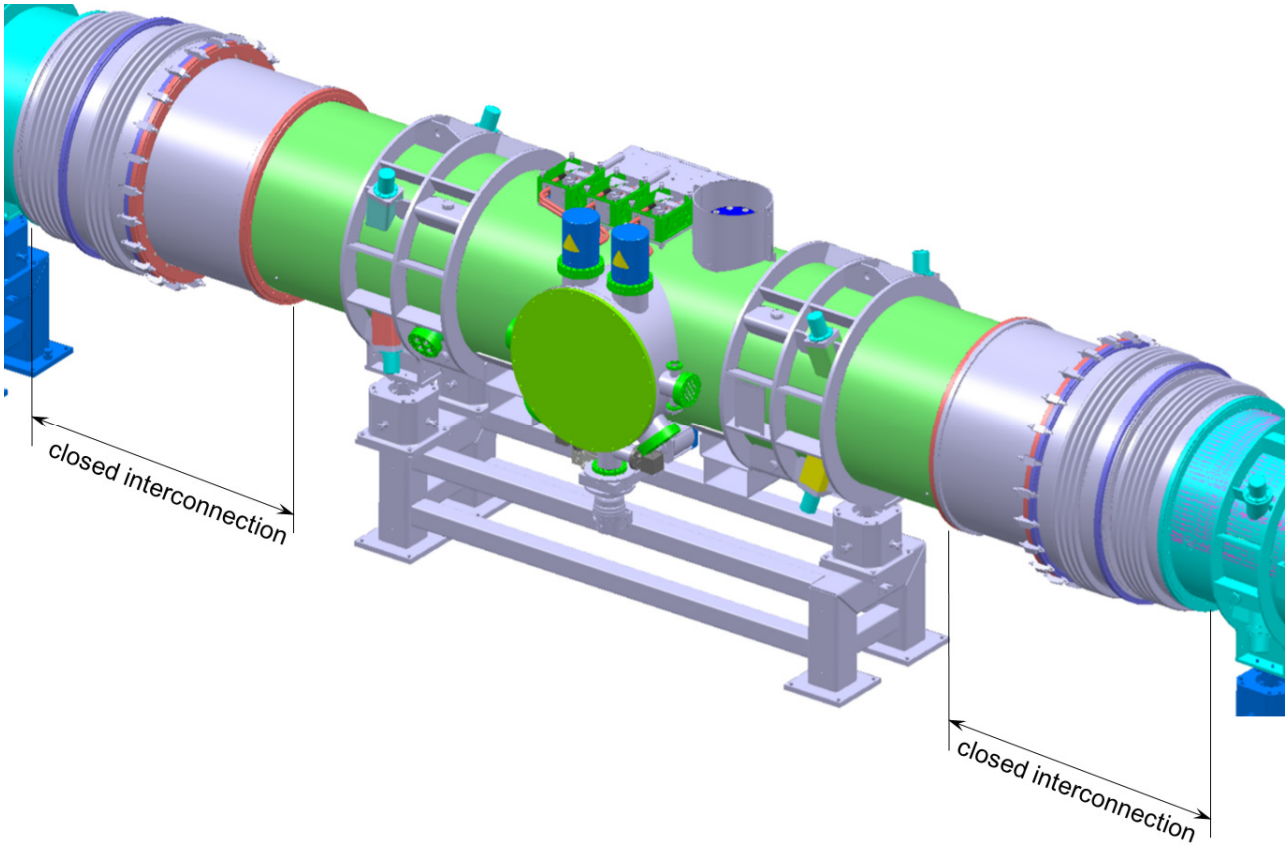



**Figure 4-11 f.i.o:** 3D view of a QDM, integrated in a SIS100-arc segment in between two DP-Modules. The module interconnections are closed.

**Important Note:**

*Figure 4-11 is for information only. Part of the delivery is the telescopic bellow systems of the SIS100-QDMs only. Neither the bellows of the adjacent modules or the installation in the tunnel are part of the delivery.*

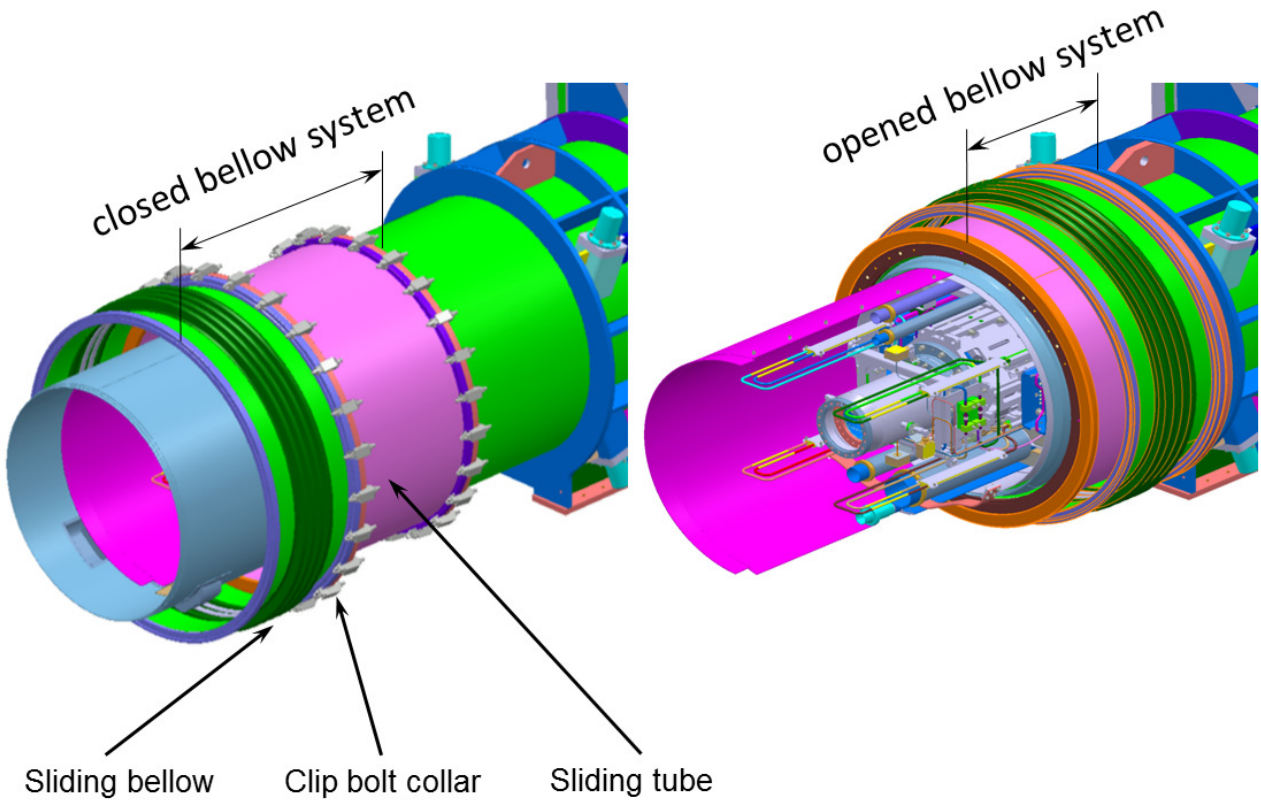



**Figure 4-12 f.i.o:** CAD-model of a closed telescopic bellow system (left) and an opened telescopic bellow system (right). The sliding bellow and tube is fully shifted onto the insulation vacuum vessel.

**Drawings and part lists:**
See section 4.3.4 to 4.3.7 .

### 4.2.10. Support frame and support feet

1) The support feet provide the required DOF for mechanical alignment of the QDM to the IOL of the SIS100. To this the QDM foot plates are bolted to the support feet top plates and the support feet are fixed to the subjacent support frame.
2) The interfaces of the support feet are
   - the top plate of the foot structure, connecting to the foot plate of the modules,
   - the base plate of the foot structure, connecting to the mounting plate of the support frame.
3) The support frame provides the rigid fixation of the full QDM to the concrete floor in the SIS100 ring tunnel in a certain heights over the floor level.
4) The interfaces of the support frame are
   - the mounting plates on top of the support frame, carrying the support feet at their base plates,
   - the base plates of the foot structure, connecting to the concrete floor in the SIS100.
5) The fully assembled modules, mounted to the support frames will be moved into position in the ring tunnel by the use of self-driving heavy duty rollers. The heavy duty rollers will be joined to the support frame at their lower horizontal rectangle profile beams.

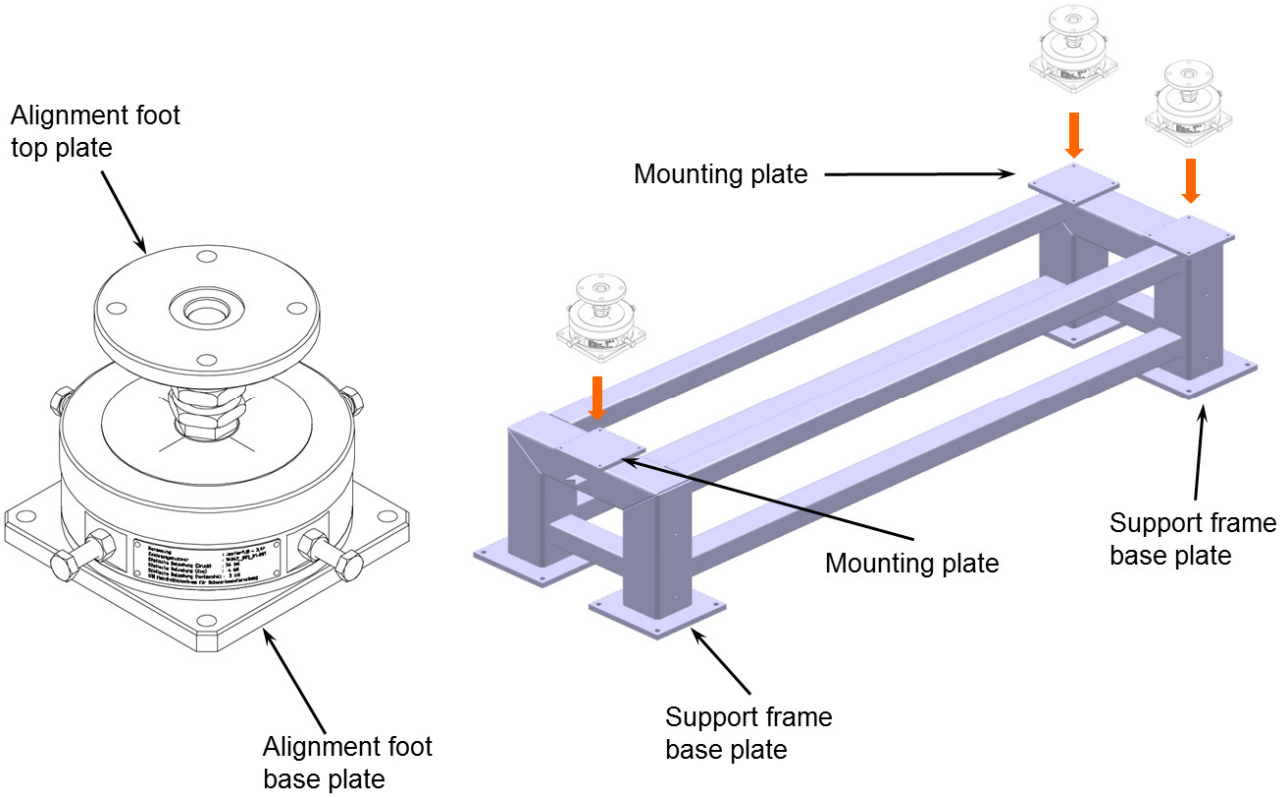



**Figure 4-13 f.i.o:** Isometric view of an alignment foot (left). Isometric view of an arc section support frame with support feet in assembling direction (right).

6) The support frame and foot as shown in figure 4-13 are not applicable to the special modules for injection and extraction. Those modules need special foot and support systems due to their exceptional high weight and shape. For details see section 4.2.13.

**Drawings and part lists:**
See section 4.3.8.

### 4.2.11. Arc Section Modules

1) The most important interfaces of arc section type modules are already listed by the previous sections in chapter 4.2. Their detailed definitions are determined by corresponding technical drawings as listed in these chapters.
2) Important main dimensions are shown in figure 4-14 through figure 4-16 below.
3) More detailed information are to be taken from according technical drawings.

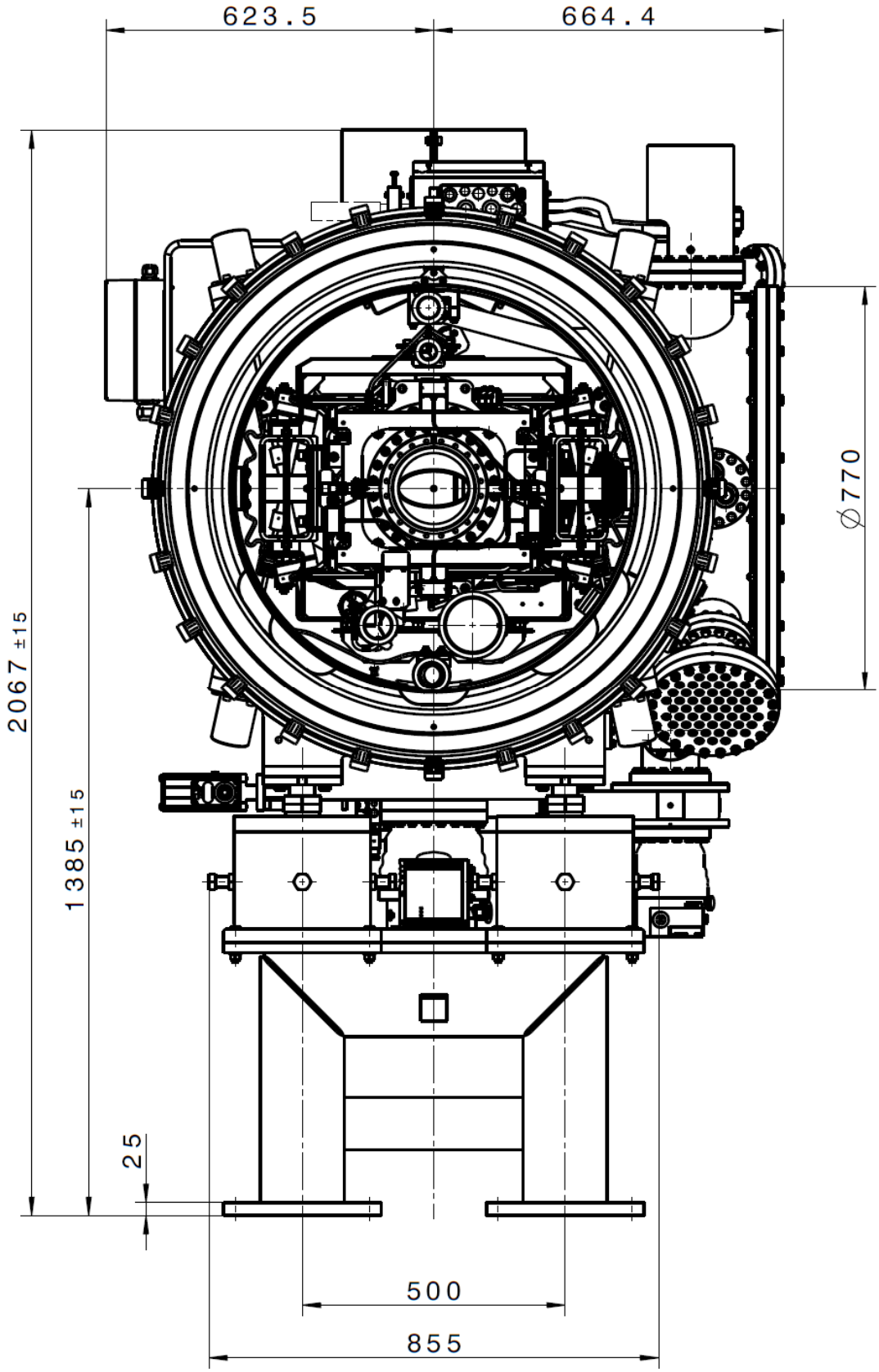



**Figure 4-14 f.i.o:** View to the down-stream-end of an arc section module, type 2.5 with main dimensions in mm

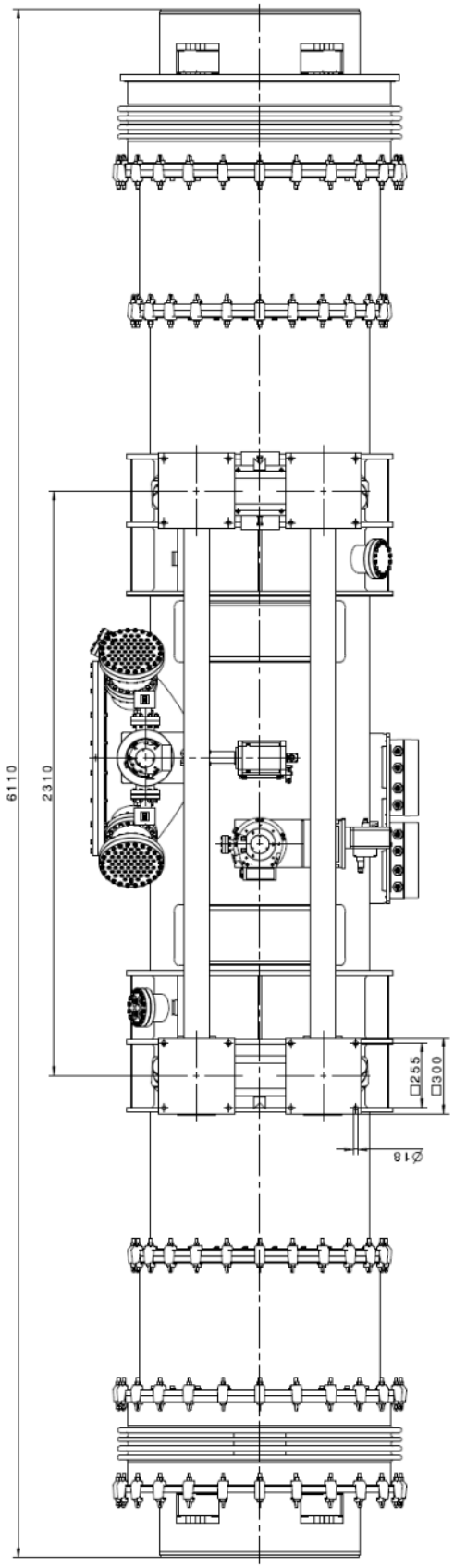



**Figure 4-15 f.i.o:** Bottom view to an arc section module of the type 2.5 with main dimensions in mm

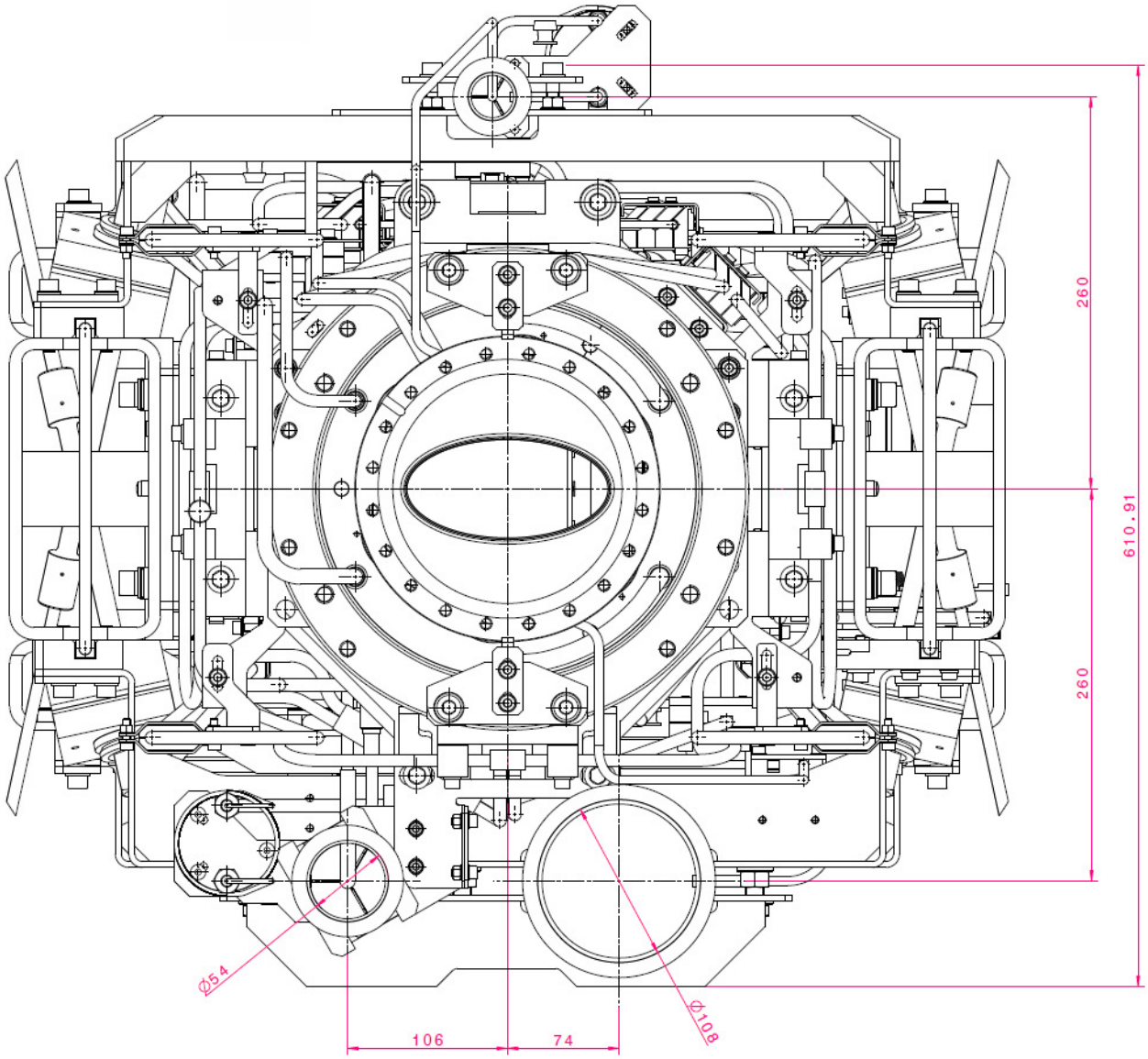



**Figure 4-16 f.i.o:** Downstream-View to the cold mass assembly of the arc module type 1.6A

4) The main dimensions (e.g. positions and dimensions of He-Supply lines) as stated in the figures above are equal for all arc section modules.
5) More detailed information are to be taken from according technical drawings.

**Drawings and part lists:**
See section 4.3.6.

4.2.12. Straight section modules

1) The most important interfaces of straight section type modules are already listed by the previous sections in chapter 4.2. Their detailed definitions are determined by corresponding technical drawings as listed in these chapters.
2) Important main dimensions are shown in figure 4-17 through figure 4-20 below.

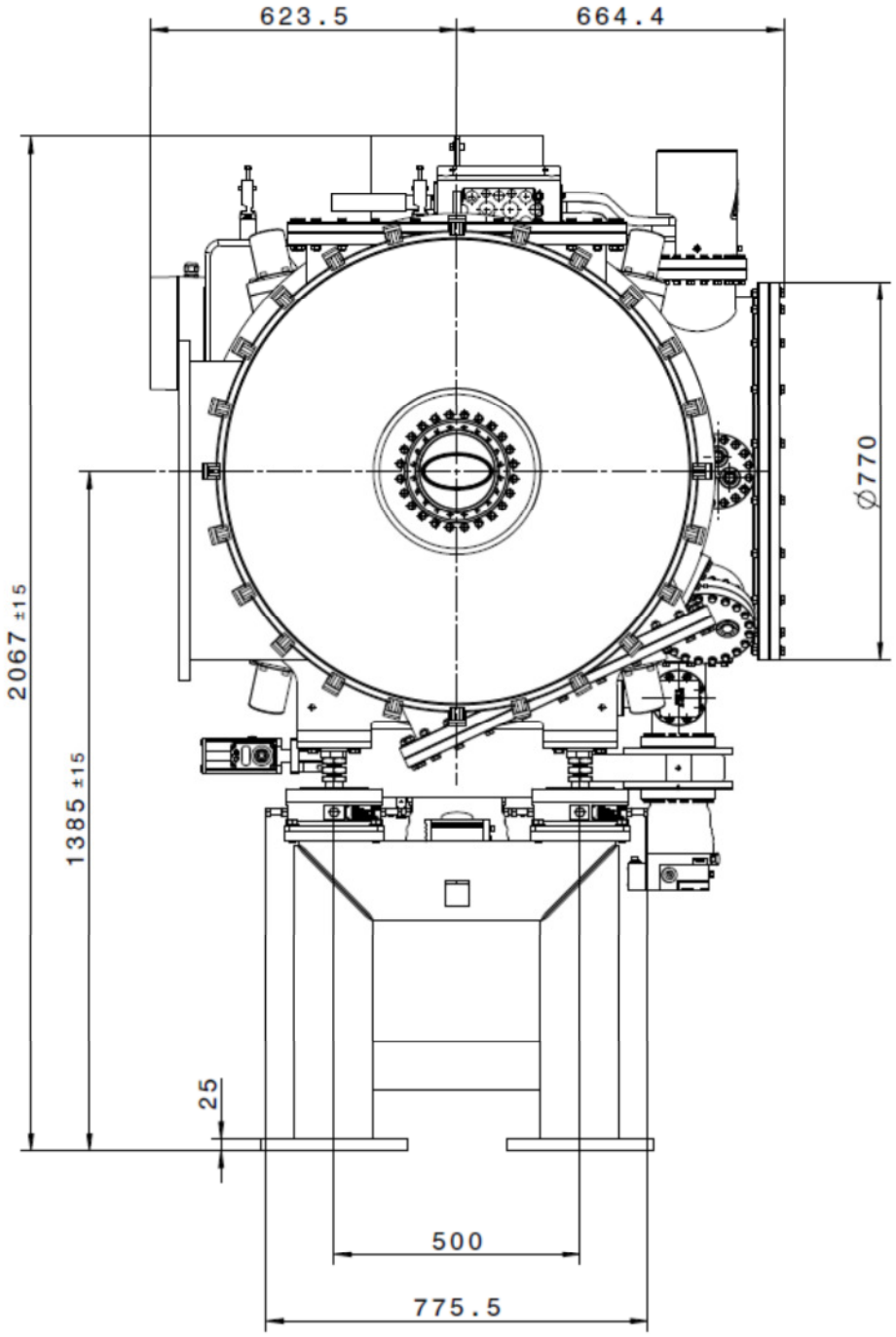



**Figure 4-17 f.i.o:** View to the downstream-end of a straight section module, type 2.123 and 2.13s with main dimensions in mm.

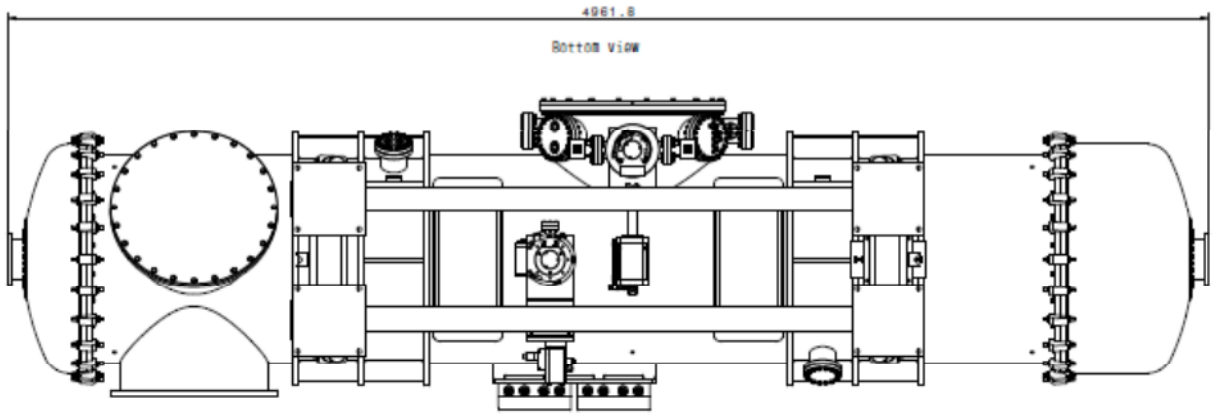



**Figure 4-18 f.i.o:** Bottom view to a straight section module of the type 2.123 and 2.13s with full length dimension in mm.

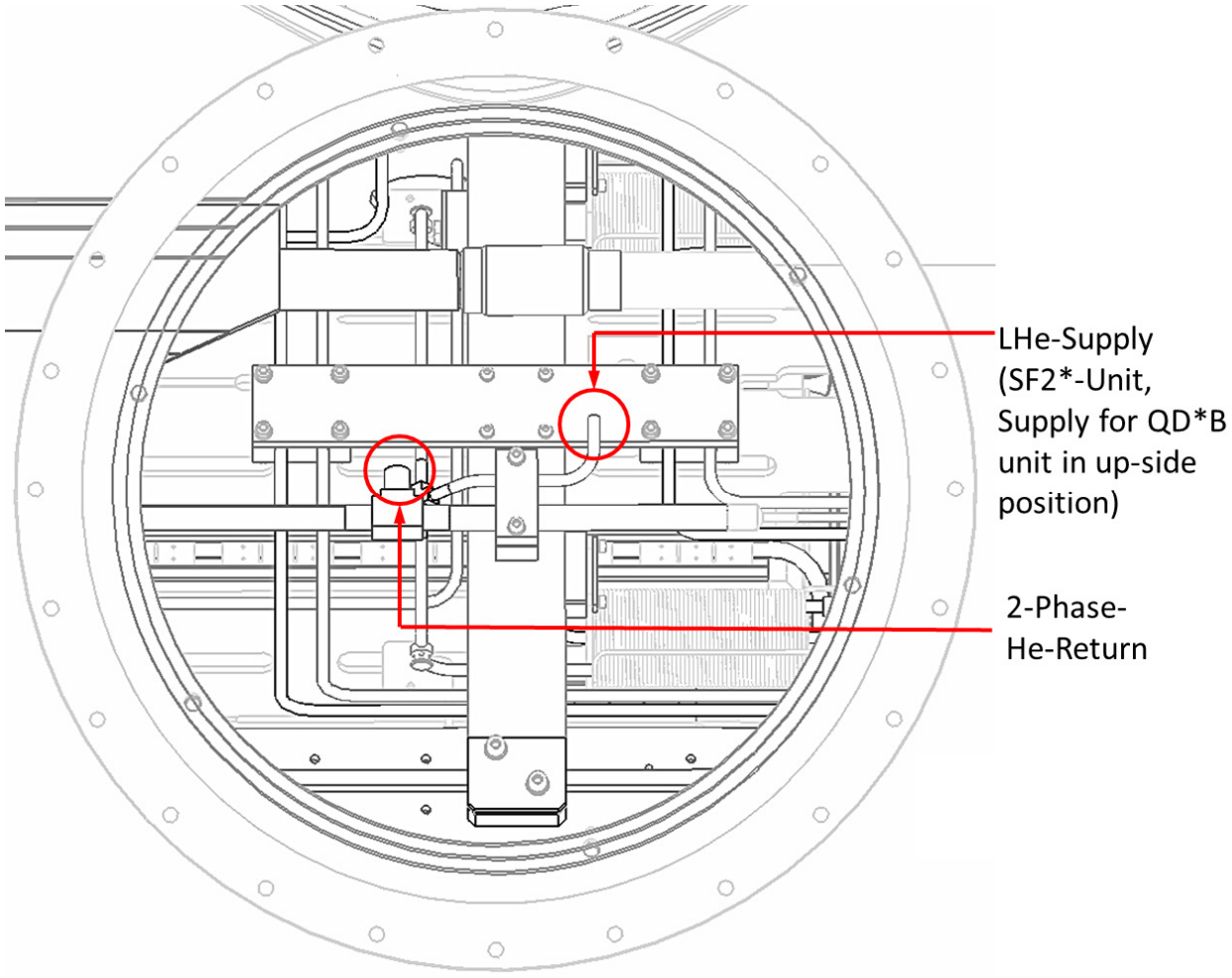



**Figure 4-19 f.i.o:** Front view to the feed-in port of straight section module type 2.123 and 2.13s (no dimensions stated). The weld flanges for connection of LHe lines fed in from the by-pass line are pointed out.

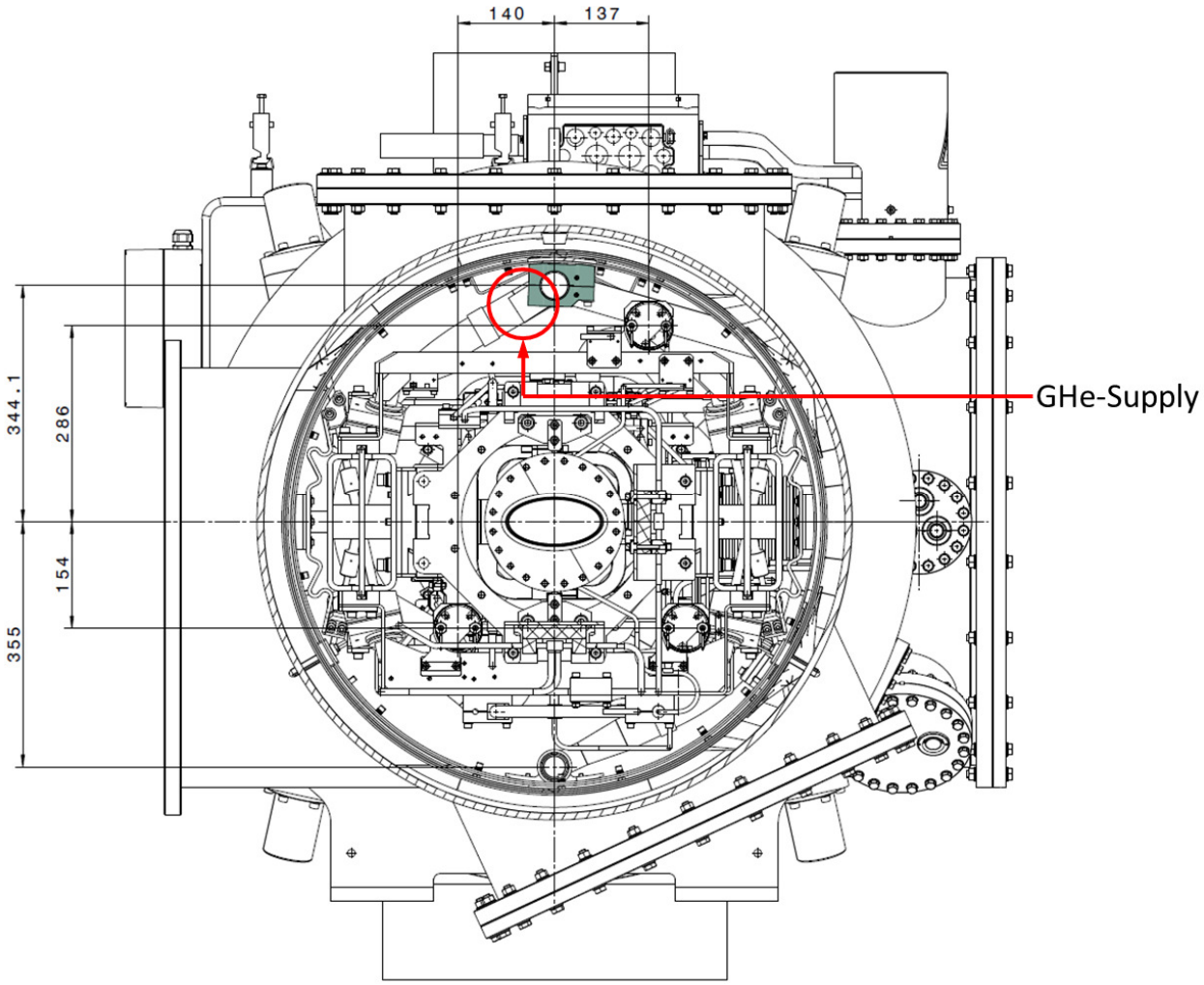



**Figure 4-20 f.i.o:** Section view to the front of straight section module type 2.123 and 2.13s pointed out weld flange for GHe-supply for thermal shield cooling.

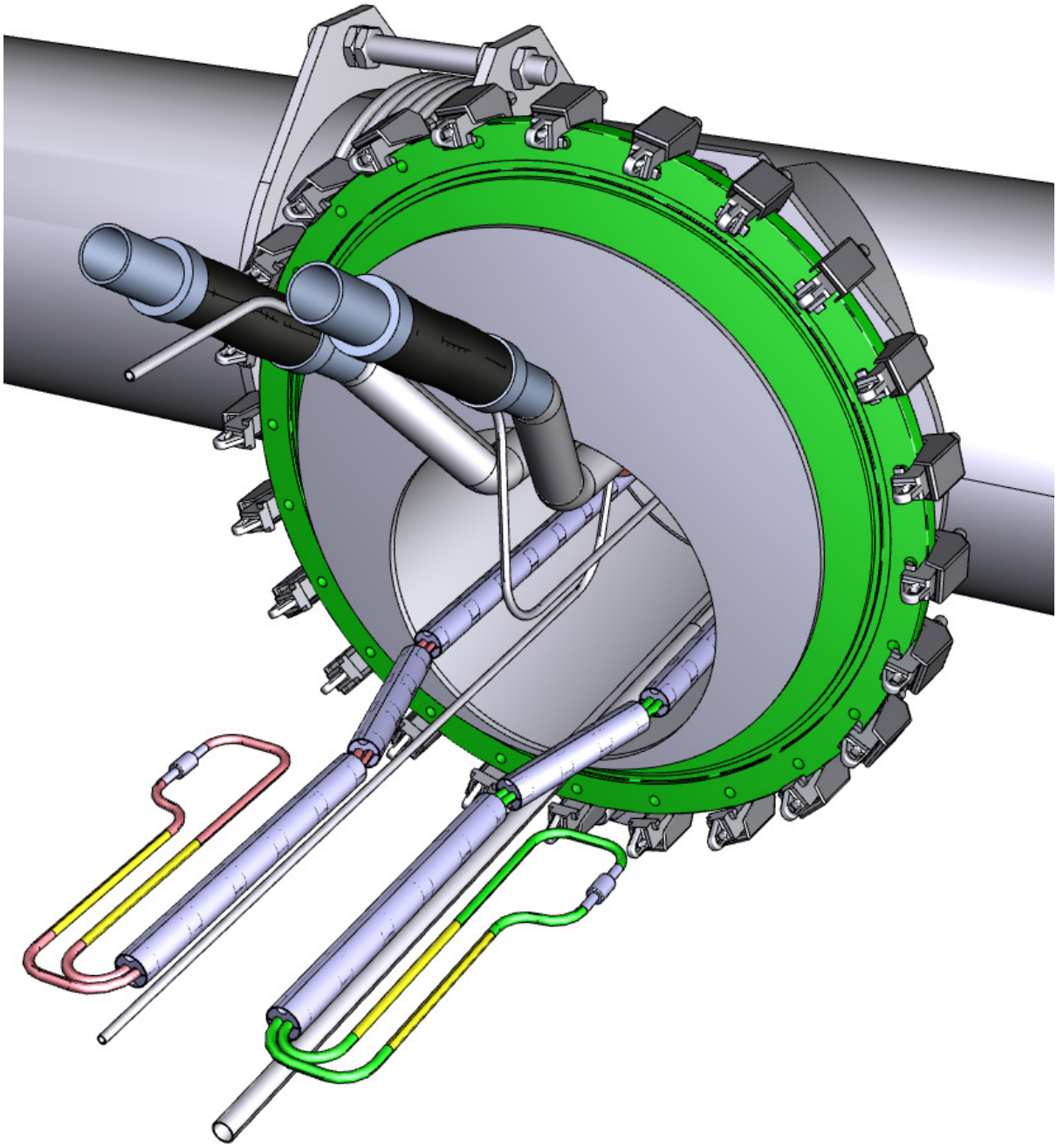


**Figure 4-21 f.i.o:** 3D-view to CAD-Model of the interface of the by-pass line for cryogenic and electrical supply of the straight section module type 2.123 and 2.13s (No components of the by-pass line are part of the contract).

***Important Note:***

*Figure 4-24 is FOR INFORMATION ONLY. No components of the by-pass line as shown in* figure 4-24 *are part of the delivery.*

**Drawings and part lists:**
See section 4.3.4.

### 4.2.13. Special modules

No detailed documentation available at the time of document release.

### 4.2.14. End Caps of arc termination modules

1) Important main dimensions of the interfaces of the arc termination modules of the type 2.4 and 1.E are shown in figure 4-22 through figure 4-25 below.
2) More detailed information is to be taken from according technical drawings.

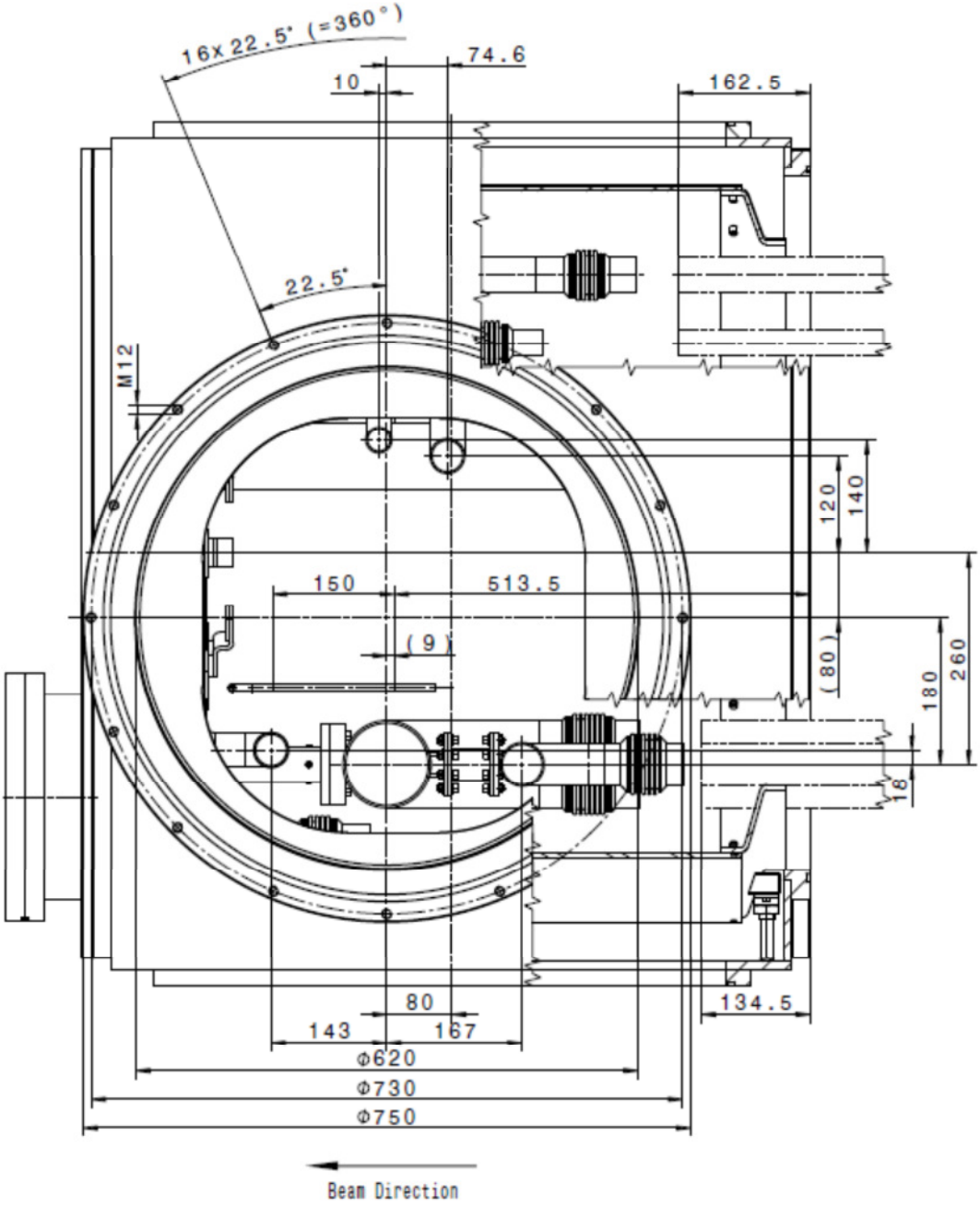



**Figure 4-22, f.i.o:** Design sketch of the side-view onto the feed-port of the End Cap of module type 2.4.

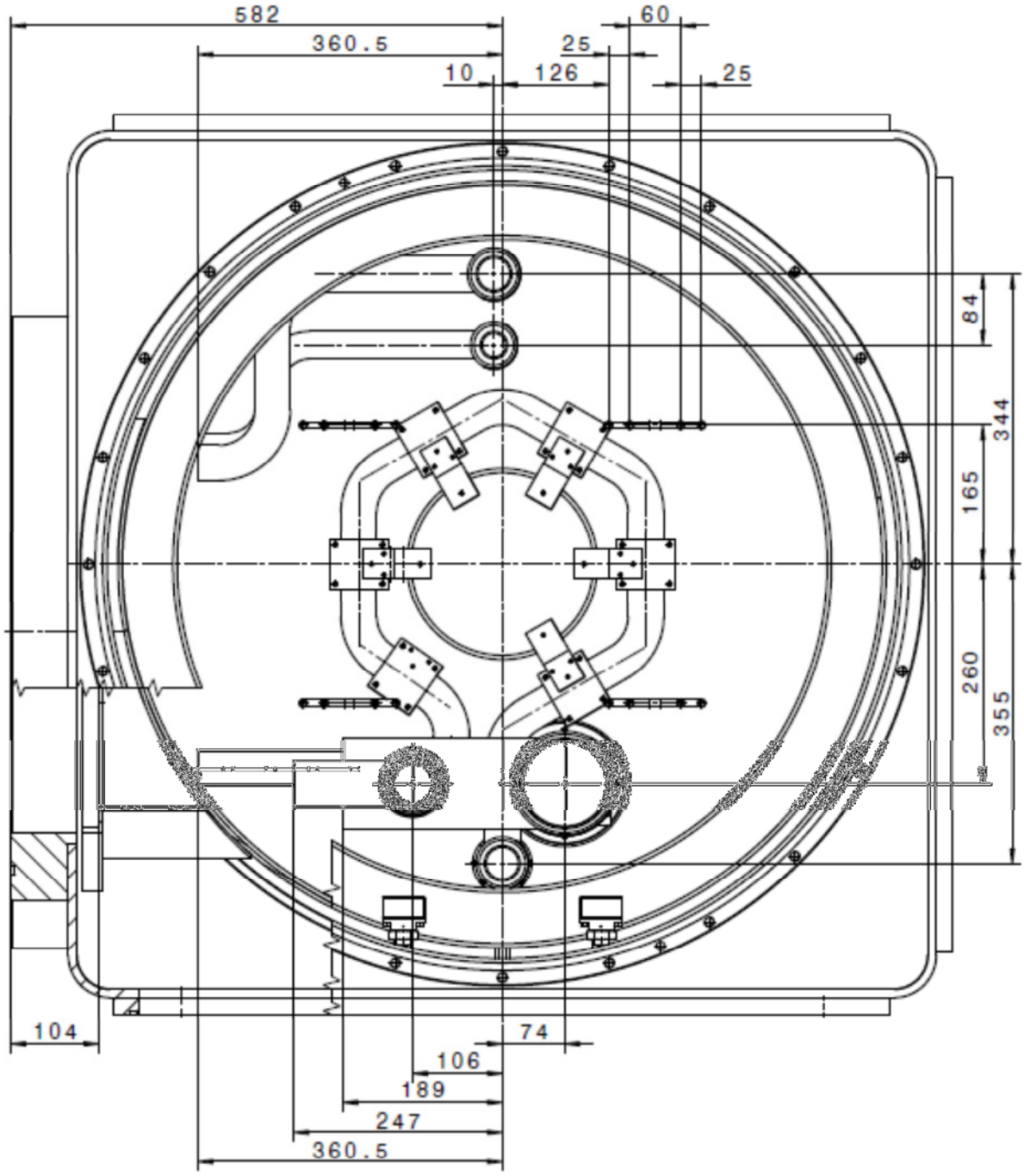



**Figure 4-23, f.i.o.:** Design sketch of the view onto the connection port of the End Cap towards the main module type 2.4.

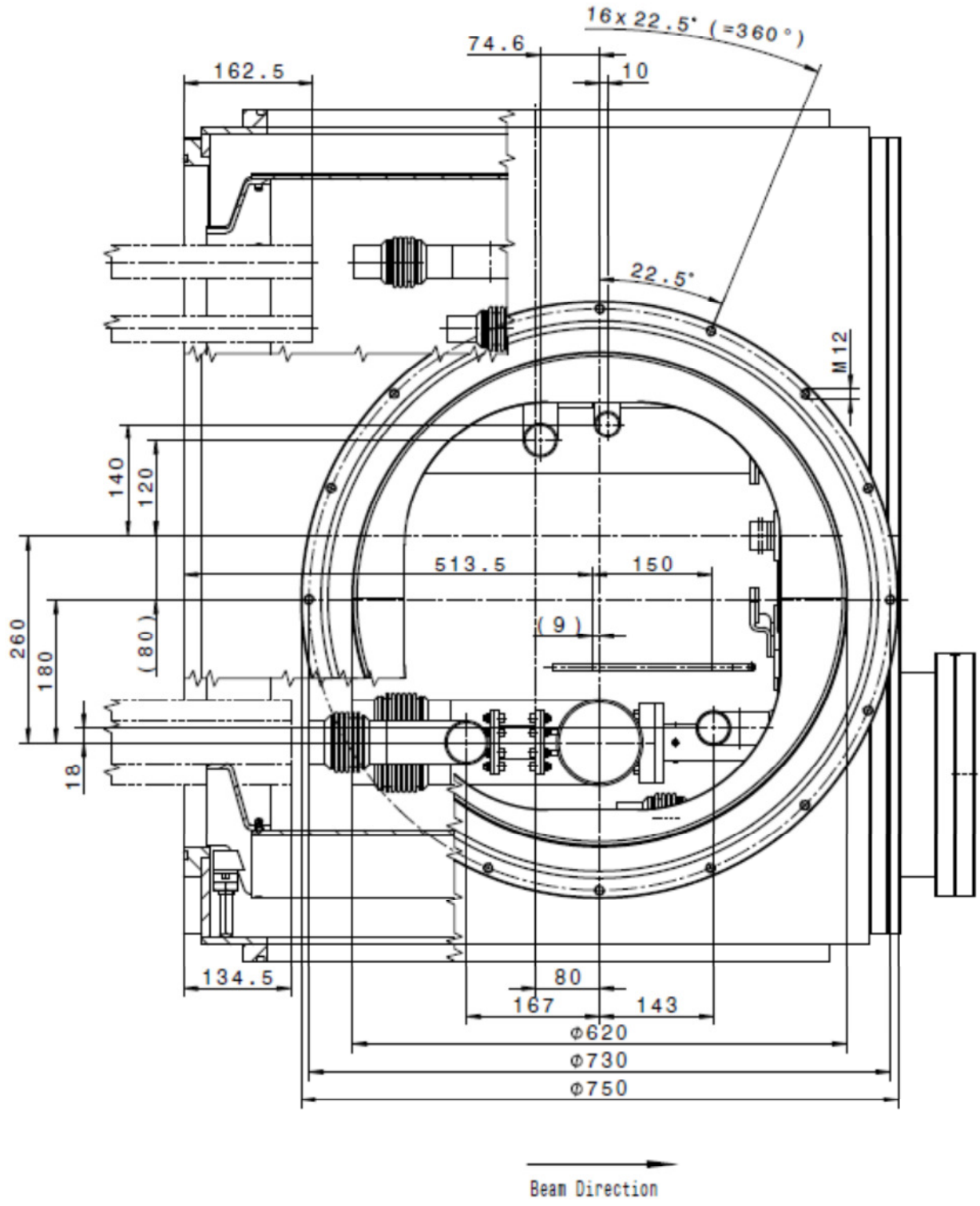



**Figure 4-24, f.i.o:** Design sketch of the side-view onto the feed-port of the End Cap of module type 1.E.

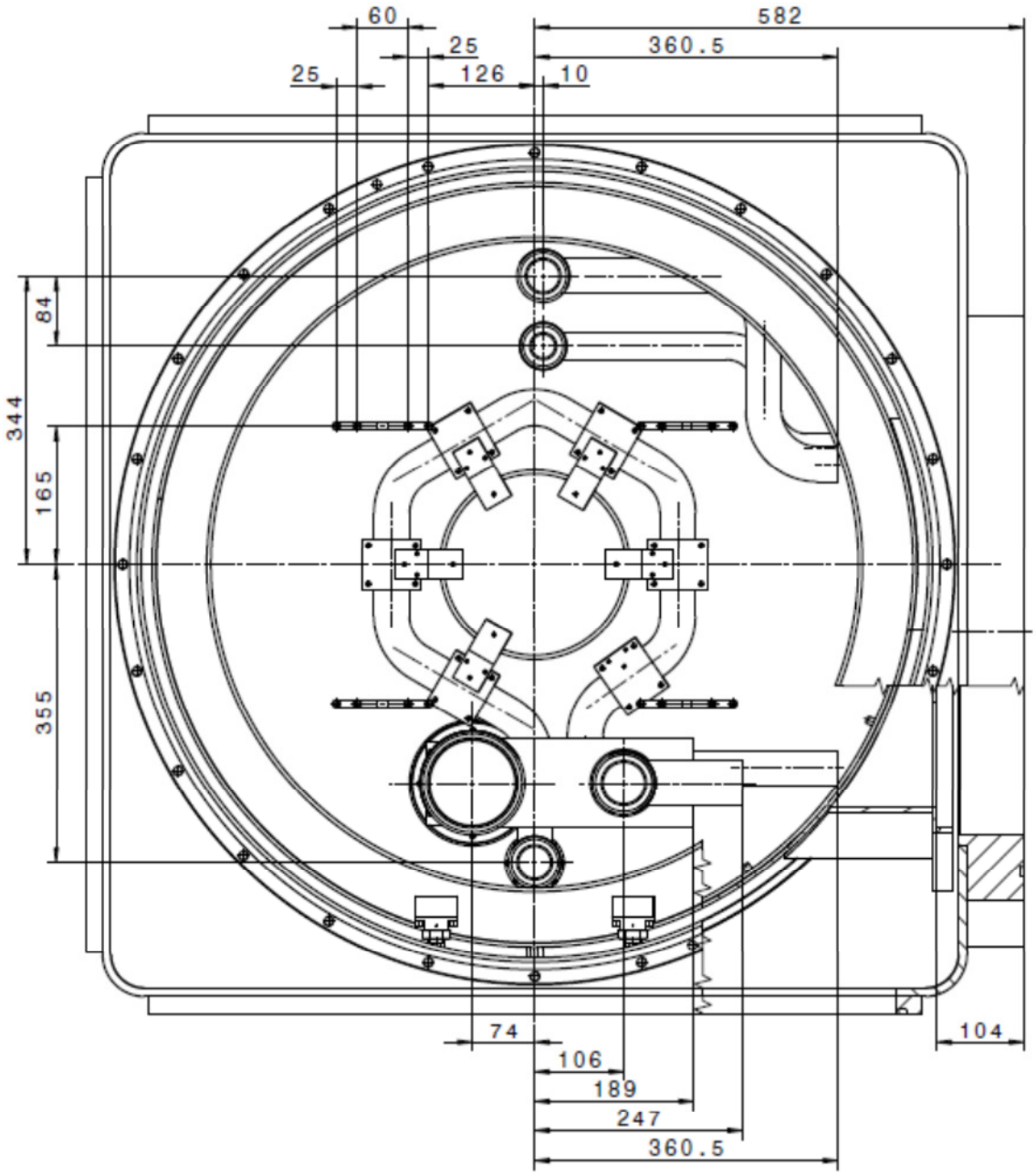



**Figure 4-25, f.i.o.:** Design sketch of the view onto the connection port of the End Cap towards the main module type 1.E.

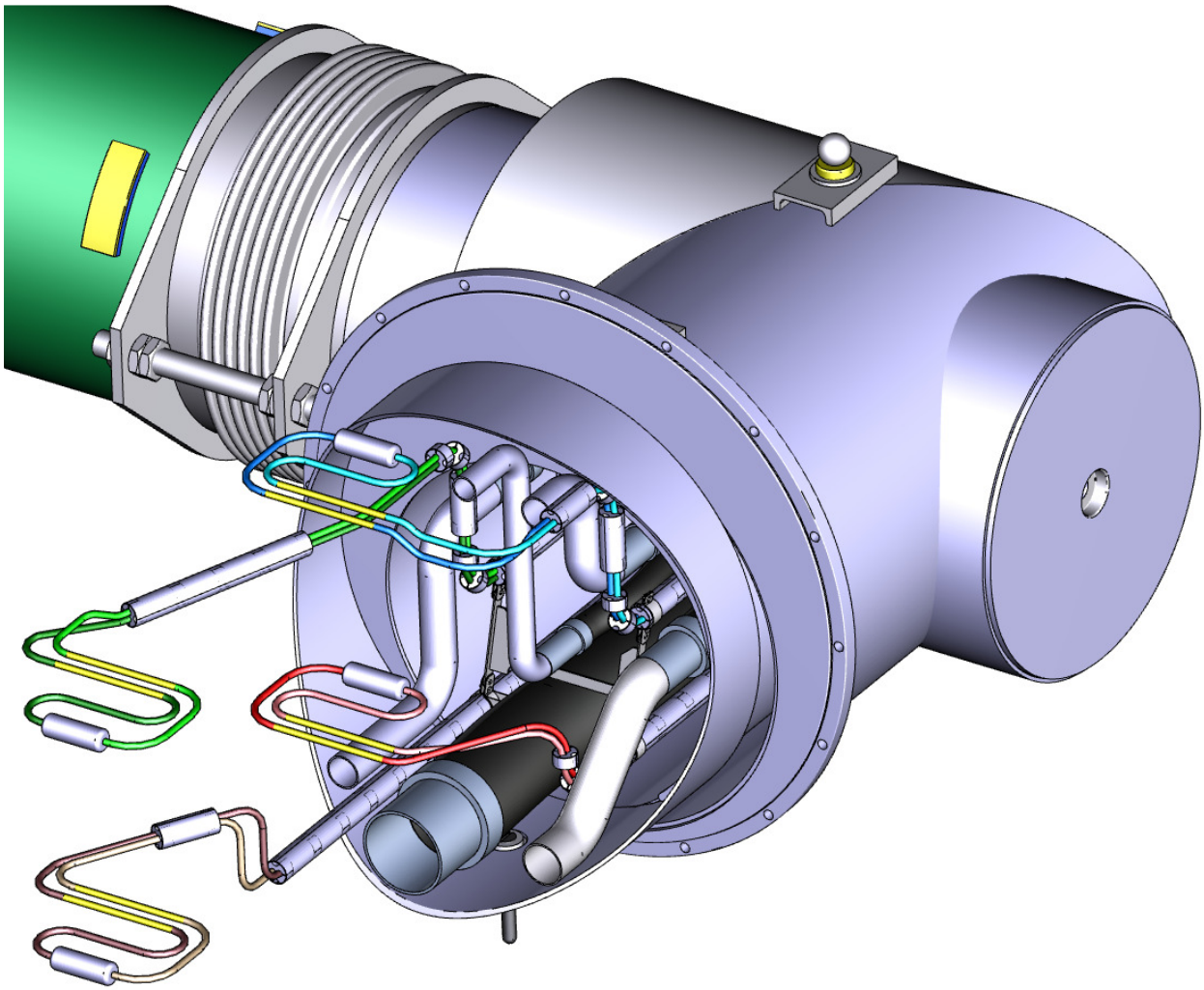


Figure 4-26, f.i.o.: 3D-view to CAD-Model of the interface of the by-pass line for cryogenic and electrical supply at the arc termination modules type 1.E.
Situation at other arc termination modules is similar.

***Important Note:***

*Figure 4-26 is FOR INFORMATION ONLY. No components of the by-pass line as shown in figure 4-26 are part of the delivery.*

**Drawings and part lists:**
See section 4.3.5.

## 4.3. System Components

1) Any drawing number, being cited in the tables below within section 4.3 is tentative at the time of release of this document and might change during a design up-date processes.
2) All dimensions and requirements to components and assemblies as defined by this engineering documentation must be adhered, verified and documented in terms of quality assurance and the requirements on documentation (see section 7).
3) For information on quantities for module production refer to section 0.

**Common Specifications:**

- F-CS-CR-01e, Common Specification for Cryostats of Cryogenic Modules in FAIR Accelerators [5]
-

**Detailed Specifications:**

- This document,
- F-DS-MT-108e_SIS100, Detailed specification of instrumentation for SIS100 Quadrupole-Modules [13]

### 4.3.1. Quadrupole Units

**Table 4-1:** Drawings and part lists for production of SIS100 QP-magnet-units

| In module type | Configuration | Drawing and parts list number | Instrumentation plan |
|---|---|---|---|
| 2.123 | QD*B | 10000018536-E5A-000 | PLI_SIS100_QDM-2.123 |
| 2.123 | SF2* | 10000018537-E5A-000 | PLI_SIS100_QDM-2.123 |
| 2.13s | QD*B | 10000018324-E5A-000 | PLI_SIS100_QDM-2.123 |
| 2.13s | SF2* | 10000018329-E5A-000 | PLI_SIS100_QDM-2.123 |
| 2.4 | QDBb | 10000018194-E5A-000 | PLI_SIS100_QDM-2.4 |
| 2.4 | SF2Mb | 10000018199-E5A-000 | PLI_SIS100_QDM-2.4 |
| 2.4x | QDBx | S911048-03-AY0000 | PLI_SIS100_QDM-2.4x |
| 2.4x | SF2Mx | S911048-21-AY0000 | PLI_SIS100_QDM-2.4x |
| 2.4x | LD | S911048-23-AY0000 | PLI_SIS100_QDM-2.4x |
| 2.4x | LF | S911048-24-AY0000 | PLI_SIS100_QDM-2.4x |
| 2.5, 1.7B | VQD | MAG-V04-E66.000.000 | PLI_SIS100_QDM-2.5 |
| 2.5 | SF2B | MAG-V07-E66.000.000 | PLI_SIS100_QDM-2.5 |
| 1.6A, 2.8C, 2.9D | BQD | MG-1021460-A-000 | PLI_SIS100_QDM-1.6A<br>PLI_SIS100_QDM-2.8C<br>PLI_SIS100_QDM-2.9D |
| 1.6A | SF1H | MG-1021573-A-000 | PLI_SIS100_QDM-1.6A |

| In module type | Configuration | Drawing and parts list number | Instrumentation plan |
|---|---|---|---|
| 1.7B | SF1B | MG-1021602-A-000 | PLI_SIS100_QDM-1.7B |
| 2.8C | SF2H | MG-1021354-A-000 | PLI_SIS100_QDM-2.8C |
| 2.9D | SF2J | MG-1021651-A-000 | PLI_SIS100_QDM-2.9D |
| 1.E | MQD | 10000016426-E5A-000 | PLI_SIS100_QDM-1.E |
| 1.E | SF1Bb | 10000016422-E5A-000 | PLI_SIS100_QDM-1.E |
| 1.Ei | MQDi | 10000017364-E5A-000 | PLI_SIS100_QDM-1.Ei |
| 1.Ei | SF1Bi | 10000017362-E5A-000 | PLI_SIS100_QDM-1.Ei |
| 1.Ei | LD | 10000017421-E5A-000 | PLI_SIS100_QDM-1.Ei |
| 1.Ei | LF | 10000017419-E5A-000 | PLI_SIS100_QDM-1.Ei |

### 4.3.2. Cold Mass

**able 4-2:** Drawings and part lists for production of integrated SIS100 QDM cold masses

| Module type | Drawing and parts list number | Instrumentation plan |
|---|---|---|
| 2.123 | 10000018535-E5A-000 | PLI_SIS100_QDM-2.123 |
| 2.13s | 10000018535-E5A-000 | PLI_SIS100_QDM-2.123 |
| 2.4 | 10000018188-E5A-000 | PLI_SIS100_QDM-2.4 |
| 2.4x | S911048-79-AY0001 | PLI_SIS100_QDM-2.4x |
| 2.5 | MG-1007850-A-000 | PLI_SIS100_QDM-2.5 |
| 1.6A | MG-1022248-A-000 | PLI_SIS100_QDM-1.6A |
| 1.7B | MG-1022468-A-000 | PLI_SIS100_QDM-1.7B |
| 2.8C | MG-1022233-A-000 | PLI_SIS100_QDM-2.8C |
| 2.9D | MG-1022235-A-000 | PLI_SIS100_QDM-2.9D |
| 1.E | 10000016407-E5A-000 | PLI_SIS100_QDM-1.E |
| 1.Ei | 10000017351_E5A_000 | PLI_SIS100_QDM-1.Ei |

### 4.3.3. Local Current Leads

This detailed description is for the integration and manufacturing of conduction cooled current leads with thermal anchors for a nominal current of 250 A DC needed for the superconducting corrector magnets in the SIS100 Quadrupole-Doublet-Modules. In the colder part high temperature superconductor (HTS) is employed.

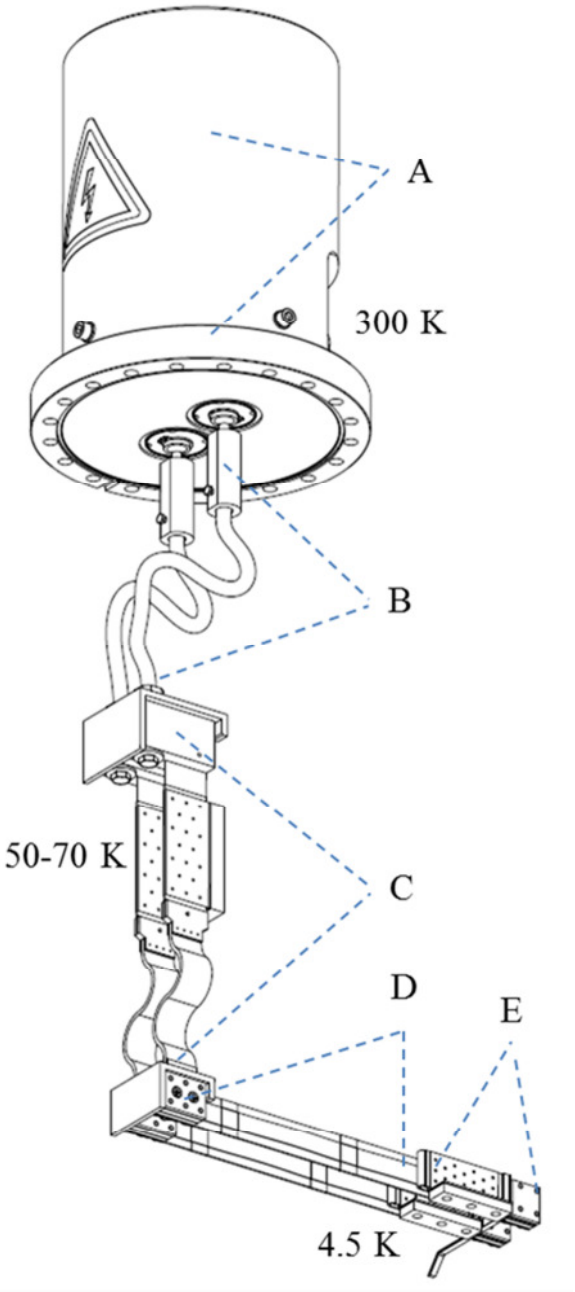



**Figure 4-27:** CAD-Model of a LCL assembly for supply of a SC Chromaticity Sextupole magnet. A - Top hermetic flange with worm terminals and cover. B - Top flexible copper lead between 300 K to top thermal anchor. C - Midle strip copper conductor with thermal anchor at 50-70 K. D - Low thermal conducting composite HTS&brass current lead. E - Cold terminal with thermal anchor and HTS&copper strip.

**Table 4-3:** Main specification of Local Current Leads. All values but the Insulation resistance are for information only.

| Property | Nominal Value | Comment |
|---|---|---|
| Nominal DC current | 250 A | dI/dt = 0 A/s |
| Cycling current | Max 300 A | dI/dt = 750 A/s |
| Cooling method | Thermal conducting | Epoxy Heat-sink |
| Heat load at 50-70 K | < 8.5 W<br>< 14 W | I = 0<br>I = 250 A |
| Heat load at 4.5 K | < 0.2 W<br>< 0.2 W | I = 0<br>I = 250 A |
| Insulation at 1.1 kV | R > 1 GΩ | to ground |
| Assembly method | Screwed flat terminals | Au-plated Cu surface |

As long as no detectable manufacturing error is causal for any deviation from specification values as defined in table 4-3, the Contractor shall not be responsible for the compliance of the specified values, but the insulation resistance to ground. This value must be proven within the FAT.

**Table 4-4:** Drawings and part lists for production of SIS100 QDM local current leads

| In module type | Configuration | Drawing and parts list number | Instrumentation plan |
|---|---|---|---|
| 2.123 | QDBs | n/a | PLI_SIS100_QDM-2.123 |
| 2.123 | SF2s | n/a | PLI_SIS100_QDM-2.123 |
| 2.13s | QDBs | n/a | PLI_SIS100_QDM-2.123 |
| 2.13s | SF2s | n/a | PLI_SIS100_QDM-2.123 |
| 2.4 | QDBb | n/a | PLI_SIS100_QDM-2.4 |
| 2.4 | SF2Mb | n/a | PLI_SIS100_QDM-2.4 |
| 2.4x | QDBx | n/a | PLI_SIS100_QDM-2.4x |
| 2.4x | SF2Mx | n/a | PLI_SIS100_QDM-2.4x |
| 2.4x | QDx | n/a | PLI_SIS100_QDM-2.4x |
| 2.4x | Fx | n/a | PLI_SIS100_QDM-2.4x |
| 2.5, 1.7B | VQD | n/a | PLI_SIS100_QDM-2.5 |
| 2.5 | SF2B | n/a | PLI_SIS100_QDM-2.5 |
| 1.6A, 2.8C, 2.9D | BQD | n/a | PLI_SIS100_QDM-1.6A<br>PLI_SIS100_QDM-2.8C<br>PLI_SIS100_QDM-2.9D |
| 1.6A | SF1H | n/a | PLI_SIS100_QDM-1.6A |
| 1.7B | SF1B | n/a | PLI_SIS100_QDM-1.7B |
| 2.8C | SF2H | n/a | PLI_SIS100_QDM-2.8C |
| 2.9D | SF2J | n/a | PLI_SIS100_QDM-2.9D |
| 1.E | MQD | n/a | PLI_SIS100_QDM-1.E |
| 1.E | SF1Bb | n/a | PLI_SIS100_QDM-1.E |
| 1.Ei | MQDi | n/a | PLI_SIS100_QDM-1.Ei |
| 1.Ei | SF1Bi | n/a | PLI_SIS100_QDM-1.Ei |

### 4.3.4. Straight section modules

All components and assemblies for the production of the SIS100 straight section modules shall be procured and manufactured according to the documentation as listed by table 4-5

**Table 4-5:** Drawings and part lists for production of SIS100 arc termination modules

| Module type | Configuration | Drawing and parts list number | Instrumentation plan |
|---|---|---|---|
| 2.123 | QDB-TRP-SF2 | 10000018534-E5A-000 | PLI_SIS100_QDM-2.123 |
| 2.13s | QDBs-TRP-SF2s | 10000018304-E5A-000 | PLI_SIS100_QDM-2.123 |

### 4.3.5. Arc termination modules

**Table 4-6:** Drawings and part lists for production of SIS100 arc termination modules

| Module type | Configuration | Drawing and parts list number | Instrumentation plan |
|---|---|---|---|
| 2.4 | QDBb-T-SF2M | 10000018184-E5A-000 | PLI_SIS100_QDM-2.4 |
| 1.E | MQD-C-SF1Bb | 10000016400-E5A-000 | PLI_SIS100_QDM-1.E |

### 4.3.6. Arc Section Modules

**Table 4-7:** Drawings and part lists for production of SIS100 arc section QDMs

| Module type | Configuration | Drawing and parts list number | Instrumentation plan |
|---|---|---|---|
| 2.5 | VQD-CR-SF2B | MG-1005150-A-000_B | PLI_SIS100_QDM-2.5 |
| 1.6A | BQD-C-SF1H | MG-1024015-A-000 | PLI_SIS100_QDM-1.6A |
| 1.7B | VQD-CR-SF1B | MG-1024017-A-000 | PLI_SIS100_QDM-1.7B |
| 2.8C | BQD-C-SF2H | MG-1024018-A-000 | PLI_SIS100_QDM-2.8C |
| 2.9D | BQD-CR-SF2J | MG-1024018-A-000 | PLI_SIS100_QDM-2.9D |

### 4.3.7. Special modules

**Table 4-8:** Drawings and part lists for production of SIS100 special modules

| Module type | Configuration | Drawing and parts list number | Instrumentation plan |
|---|---|---|---|
| 1.Ei | MQDi-C-SF1Bi | 10000017337-E5A-000 | PLI_SIS100_QDM-1.Ei |
| 2.4x | QDBx-T-SF2Mx | S911048-75-AY0001 | PLI_SIS100_QDM-2.4x |

### 4.3.8. Support frames and support feet

**Table 4-9:** Drawings and part lists for production of SIS100-QDM support frames

| | **Drawing and parts list number:** | | |
|---|---|---|---|
| **Frame type** | **Support frame** | **Alignment foot** | **Support console** |
| 2.123, 2.13s 2.5, 1.6A, 1.7B, 2.8C, 2.9D | 10000016266-E5A-000 | 14047_001_01-001 | |
| 1.E, 2.4 | 10000016266-E5A-000 | 14047_001_01-001 | 10000016406-E5A-000 |
| 2.4x | S911048-76-AY0001 | SU-1009835-A-000 | |
| 1.Ei | 10000017350-E5A-000 | SU-1009835-A-000 | |

### 4.3.9. BPM *(for information only)*

The SIS100 Beam Position Monitor will be supplied by the Company according to

**Drawing number:**

STD-V05-D77.000.000 – 000, BEAM POSITION MONITOR F. SIS100.

**Specification:**

F-DS-BD-67e, Detailed Specification of Beam Position Monitors (BPM) for SIS100 [274]

### 4.3.10. UHV Components *(for information only)*

Most UHV components for the integration into the SIS100 special modules will be delivered by the Company according to the documentation as listed in Table 4-10.

**Table 4-10:** Drawings and part lists for production of UHV-components for integration in the SIS100 QDM-Modules.

| Component | Drawing and parts list number | Specification |
|---|---|---|
| Vacuum Chambers | 10000018540-E5A-000, 10000018538-E5A-000, 10000018325-E5A-000, 10000018330-E5A-000, 10000016296-E5A-000, 10000016789-E5A-000, S911048-81-SA1058, S911048-81-SA1185, S911048-81-SA0611, MAG-V04-E66.011.000-A-000_B, MAG-V08-E66.010.000-A-000_B, MG-1021558-A-000, MG-1021392-A-000, MG-1022235-A-000, 10000016445-E5A-000, 10000016780-E5A-000, | F-DS-VC-15e, F-DS-VC-14e, |
| Drift Tube | 10000018359-E5A-000 | |
| Cryo Adsorption Pump | CX-1019410-A-000 | F-DS-VC-44e [275] |
| Roughing CWT | MG-1009622-A-000 | F-DS-VC-22e [278] |
| Beam Pipe CWTs | 10000018539-E5A-000, MG-1013714-A-000 | F-DS-VC-21e [279] |

### 4.3.11. Cryo-Catcher *(for information only)*

The SIS100 Cryo-Catcher will be supplied by the Company according to

**Drawing number:**

MG-1004961-A-000 – 000, CRYOCATCHER MODULE

**Specification:**

F-DS-SI-01e, Detailed Specification for a SIS100 Cryo-Catcher Unit [280]

### 4.3.12. Supports and alignment feet

**Table 4-11:** Drawings and part lists for production of support frames and alignment feet.

| Component | Drawing and parts list number | Specification |
|---|---|---|
| Standard support frame | MG-1009679-A-000 | F-DS-MT-55e, Detailed specification for stand for arc end Quadrupole doublet modules for SIS 100 [15], |
| Support consoles | 10000016406-E5A-000 | |
| Special support frame, 1.Ei | 10000017350-E5A-000 | |
| Special support frame, 2.4x | S911048-76-AY0001 | |
| Alignment foot | 14047_001_01-001 | Alignment feet for SIS 100 QP and DP [16] |
| Special high load alignment foot, 1.Ei, 2.4x | SU-1009835-A-000 | |

## 5. Procedure

### 5.1. **Design changes by the Contractor**

1) The Contractor might suggest changes in design, material or manufacturing method for any component or assembly of the SIS100-QDMs. In case, the Contractor shall submit a completely filled in Engineering Change Request to the Company in writing for each single change.
2) The Company shall reserve the right to reject any suggested change without a justification required.
3) Any change, suggest by the Contractor, shall be applied only after a written approval by the Company. Therefore, an Engineering Change Request, formally approved by the Company shall be the permission for application of changes.
4) In case of any changes applied, suggested by Contractor, the Contractor shall be comprehensively responsible for any effect, resulting from such change. No change of specified characteristics in performance and functionality of components or assemblies will be accepted.
5) In case the Contractor applies any changes, not formally being approved by the Company, the the Company shall reserve the right to reject the affected component without any further justification. In case, the Contractor shall replace such component or assembly immediately and without any additional costs for the Company.
6) In case any change in design, material or manufacturing method, was accepted by the Company, the Contractor shall perform all required processes (e.g. re-design, procurement of matrerial etc.) without additional charge.
7) In case of a suggested design change, the Contractor shall perform an according re-design, including all required documentation and design review procedures, free of charge for the company .
8) A final approval of the ECR shall be dependent of the evaluation result of the new and final design.

#### 5.1.1. Design phase and design release in case of ECR

1) In case any design change, suggested by the Contractor, is accepted by the Company to be prepared, the Contractor shall perform the detailed re-design of the affected components and assemblies. In case, the Contractor shall perform
   - a re-engineering of the affected components and assembly, including all required analysis, calculations and verifications, also in terms of CE.
   - a re-design of the CAD-Models,
   - a re-design of affected engineering drawings.
2) For the ECR release procedure, the Contractor shall perform important designed review stages CDR and MDR as defined by [19].
3) A decision on final release of a design change shall be stated by the Company earliest after approval of the review processes as defined.
4) Even though the Company releases any design change, prepared by the Contractor, the responsibility for any results out of its application shall remain at the Contractor.

#### 5.1.2. Stability requirements (***only in case of design changes by the contractor***)

1) In case of design changes, by request of the Contractor, are performed by the Contractor, the Contractor shall be responsible for the technical design of the SIS100-QDMs and the impact of the design changes to the stability of the cold mass as defined by.
2) The defined stability values (see table 5-1) are specifying the admitted tolerances between the warm and the cold status of the QDM cold mass.
3) All following definitions of stability are describing the magnet positions and orientation stability with respect to mechanical stresses, thermal contraction and the regular outer influences onto the QDMs as appearing during all standard operation modes as defined herein and by [5].
4) The structural mechanics and interaction of all mechanical cryostat-, girder and suspension components must provide sufficient stability to assure the x, y and z-position and orientation stability of the cold mass relative to the warm position of the magnets. Values are listed in.
5) The tolerance values for the z-position are composed of a first value which defined the unavoidable thermal contraction (+ for the upstream position and – for the downstream position) and a tolerance value resulting from tolerances of the involved mechanical parts.

**Table 5-1:** Allowed geometrical tolerances of magnet positions between warm and cold status (after cool down). ***These Values are for information only as long as no relevant design changes are introduced by the Contractor***.

| Magnet Type | Δx in µm | Δy in µm | Δz in mm | x-Rotation in mrad | y-Rotation in mrad | z-Rotation in mrad |
|---|---|---|---|---|---|---|
| QP (D, F1, F2) | ± 125 | ± 125 | +/-3.9 ± 1.2 | ± 0,0833 | ± 0,0833 | ± 0,14 |
| Sextupole | ± 175 | ± 175 | +5.6 ± 1.2 | ± 0,171 | ± 0,171 | ± 0.263 |
| Steering H/V Dipole | ± 175 | ± 175 | +6.2 ± 1.2 | ± 0,171 | ± 0,171 | ± 0.263 |

6) The structural mechanics and interaction of all mechanical cryostat- and suspension components must provide sufficient stability to assure the position and orientation stability of the outer fiducial target seats as follows:
   - Position stability of a single fiducial target seat: $\Delta x, \Delta y, \Delta z = \pm 50$ µm
7) Named stability requirements must be guaranteed for the status
   - after the cool down,
   - during operation,
   - during processes as defined by [5] and herein.
8) Named stability requirements must be also guaranteed for the relative stability of the magnets
   - for the processes of on-site conveying (crane and floor conveying),
   - for the process of closing the cryostat,
   - for the process pumping insulation vacuum.
9) In Case of design changes are performed by the Contractor, the Contractor shall prove the geometrical stability between warm and cold status of the QDM as defined by table 5-1.
**10)** The cold mass stability will be tested within at least one full thermal operation cycle during the site acceptance test (SAT).

### 5.2. **Review processes and releases**

1) The Contractor shall organise and arrange regular review processes with the Company for
   - Desing changes (only in case of changes are applied for),
   - Production planning,
   - QA-planning,
   - FAT planning,
   - Transportation planning.
2) The Contractor shall deliver a first plan for all review processes within the offering documents.
3) For the review processes, all documentation to be reviewed shall be delivered to the Company two working weeks in advance.
4) Even though the Company releases any document or process, prepared or planned by the Contractor, the responsibility for any results out of its application shall remain at the Contractor.

### 5.3. **Overview on production sequence**

The figures below are showing a schematic overview on the production sequences for integration of a typical QDM. Within these figures, not all detailed production processes are represented, but only the very general processes.

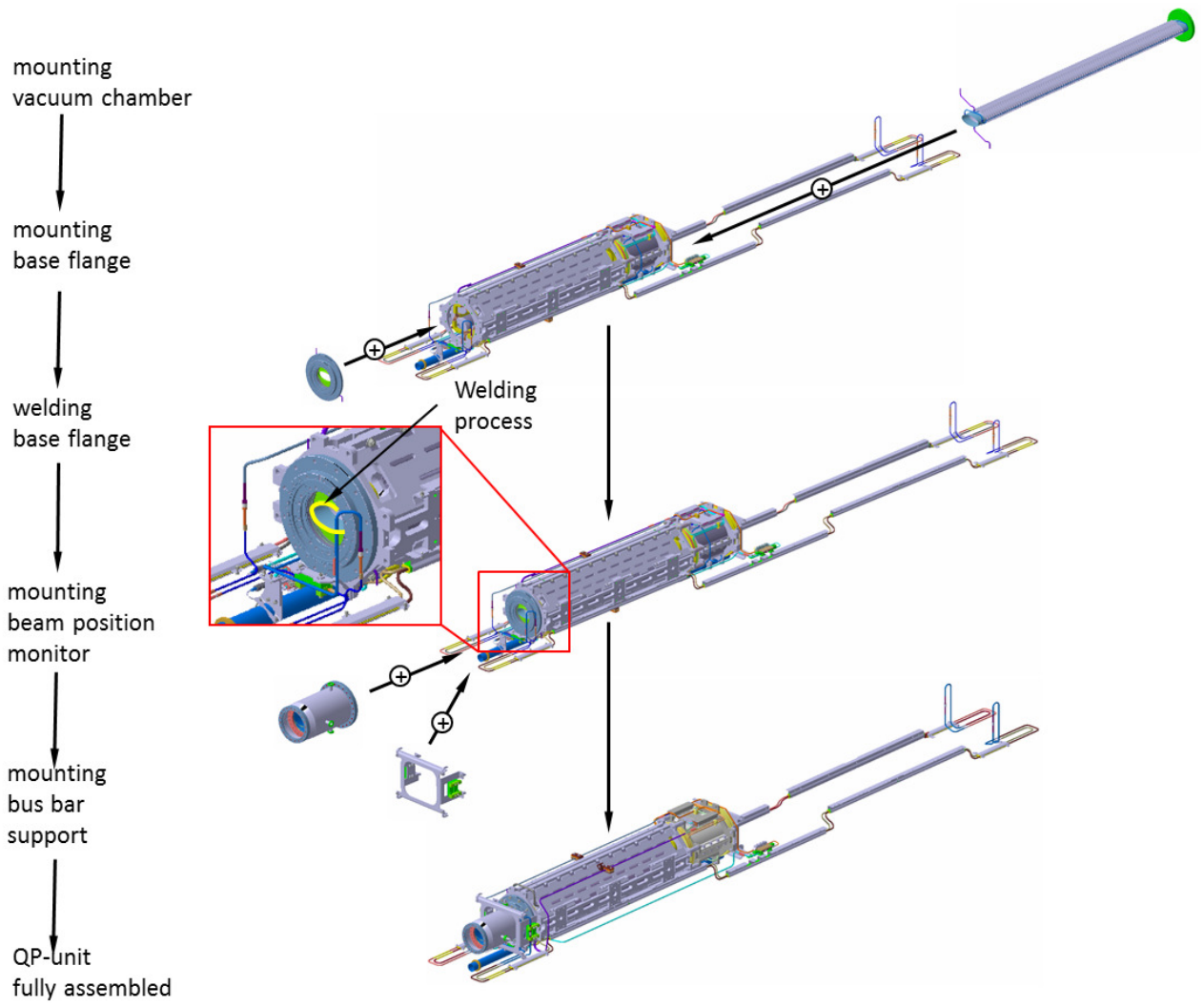



**Figure 5-1, f.i.o.:** Schematic view on the sequence of the QP-magnet-unit assembly for completion of the SF2B – Unit from a pre-staged unit to a completed QP-magnet-unit with vacuum chamber and beam position monitor.

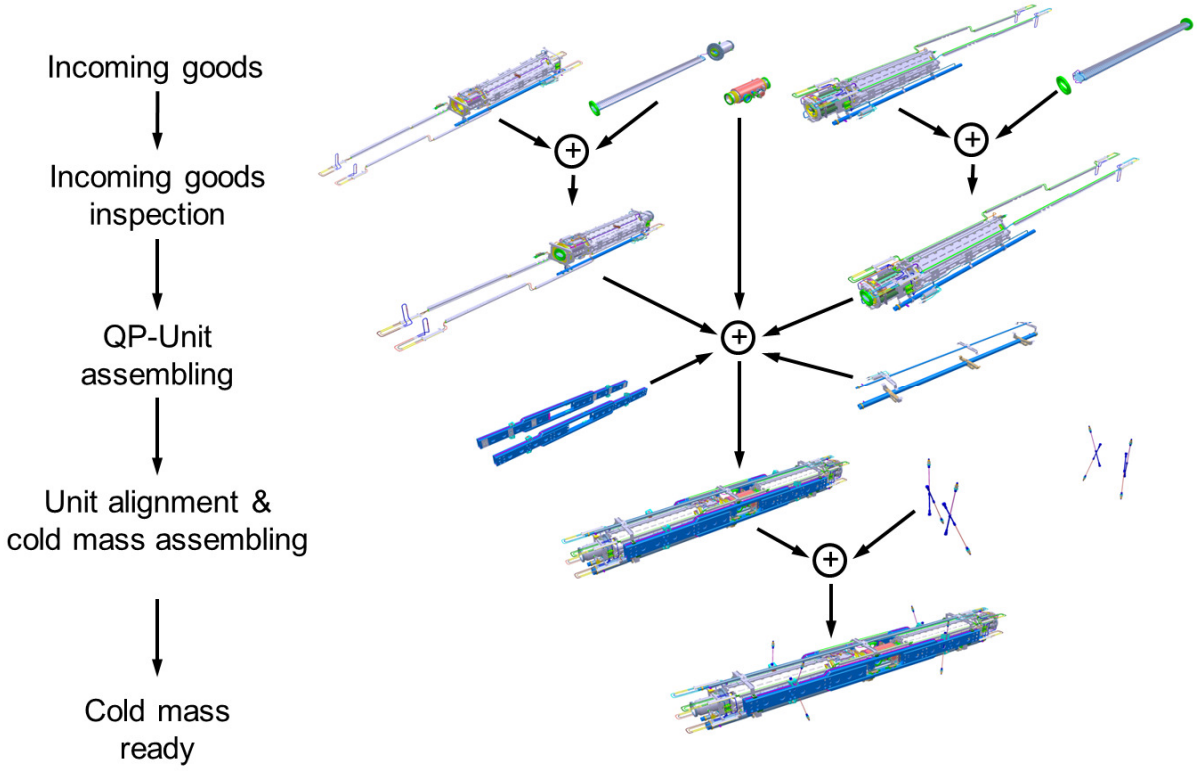



**Figure 5-2, f.i.o.:** Schematic view on the sequence of the QP-magnet-unit and cold mass integration process by the example of the arc section module type 2.5.

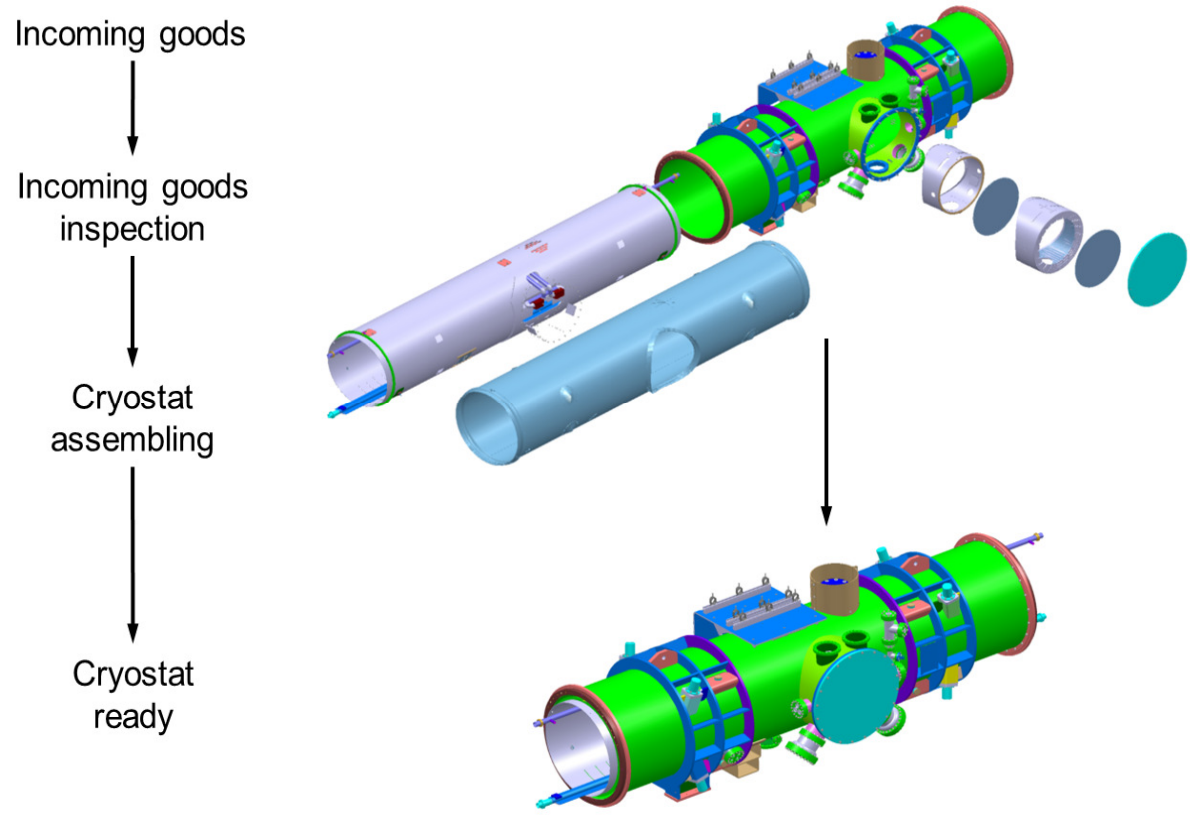



**Figure 5-3, f.i.o.:** Schematic view on the sequence of the QDM-cryostat integration process by the example of the arc section module type 2.5.

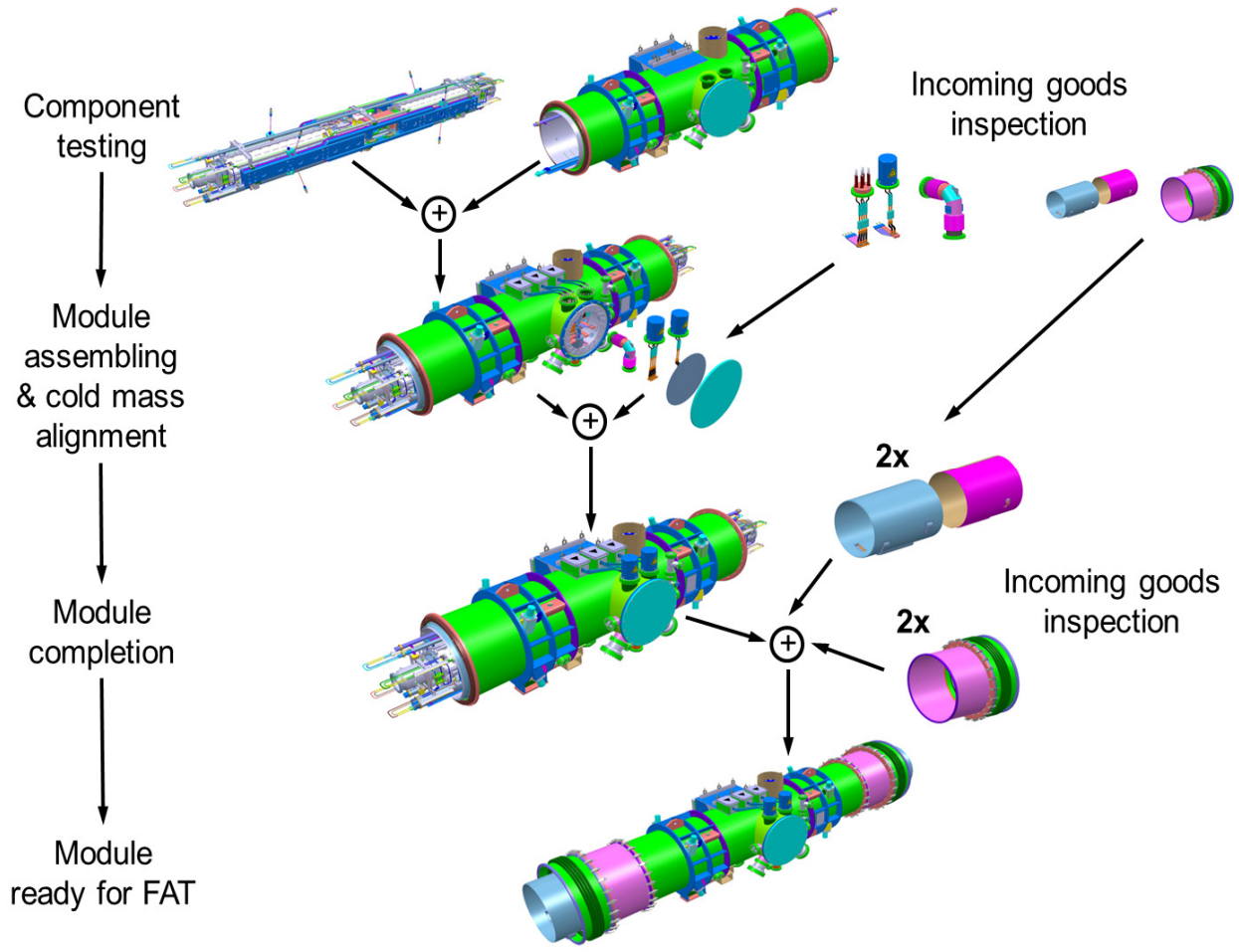



**Figure 5-4, f.i.o.:** Schematic view on the sequence of the QDM integration process by the example of the arc section module type 2.5.

## 5.4. **Production- and delivery schedules**

*Delivery schedules for QDM production, FoS and series shall be part of the contract.*

Due to a supply structure (see figure 3-20) and the unique boundary conditions of the FAIR project, the precise planning of a delivery schedule for all components, being supplied by the Company, is not yet finished at the time of completion of this document. Nonbinding information on a preliminary delivery schedule for the supply by the Company is available in [285].

1) The production of QDM shall be split in two major production phases
   - 1st the production of a First of Series QDM, type 2.5
   - 2nd the series production after SAT release of the FoS-type.
2) A first version of a delivery sequence, as expected by the Company, is given by section 5.4.2.
3) A first approach of production planning shall consider the information on the delivery schedule for all sub-components, being the supply by the Company as defined by [285].
4) A detailed delivery schedule for the supply by the Company shall be submitted by the Company, as soon as all contracts for supply of sub-components, being supply by the Company, are signed.

5) The Contractor shall be aware of the possible appearance of changes in the supply schedule for the supply by the Company. In case of changes in this supply schedule, due to what reason ever, the Contractor shall provide the flexibility to implement such changes into the production planning.

### 5.4.1. Delivery schedule for First of Series production

1) The delivery time schedule for production and delivery of the FoS SIS100 – QDM, type 2.5 shall be agreed with the Company in writing and shall become part of the contract.
2) The Contractor shall deliver a detailed production schedule for FoS production within the bidding documents. This schedule shall cover the production, respectively procurement of all major components for integration, major production processes but at least:
   - common girder,
   - suspension system,
   - thermal shield,
   - insulation vacuum vessel,
   - telescopic compensation bellow system, incl. bracket screws,
   - production tooling,
   - transportation locks,
   - transportation data logging,
   - QP-magnet-units,
   - unit-assembly with UHV-components
   - production of cryogenic system,
   - cold mass assembly,
   - alignment of units in cold mass,
   - module integration,
   - pre-alignment of cold mass,
   - transportation.

### 5.4.2. Delivery schedule for series Production

1) A schedule for production and delivery of SIS100 – QDM series modules shall follow a delivery sequence of integrated SIS100-QDM as listed in table 5-2. This sequence is tentative for the time being when this document is finished. Changes may appear and shall be agreed with the Company.

**Table 5-2:** Expected delivery sequence for supply of integrated SIS100-QDM

| Delivery sequence | Short name | Up-stream unit | Centre unit | Down-stream unit | Beamline doublet | Count |
|---|---|---|---|---|---|---|
| 1 | 2.5 | VQD | CR | SF2B | | 6 |
| 2 | 1.7B | VQD | CR | SF1B | | 12 |
| 3 | 1.6A | BQD | C | SF1H | | 12 |
| 4 | 2.8C | BQD | C | SF2H | | 12 |

| Delivery sequence | Short name | Up-stream unit | Centre unit | Down-stream unit | Beamline doublet | Count |
|---|---|---|---|---|---|---|
| 5 | 2.9D | BQD | CR | SF2J | | 12 |
| 6 | 2.4 | QDBb | T | SF2Mb | | 5 |
| 7 | 1.E | MQDb | C | SF1Bb | | 5 |
| 8 | 2.123 | QD*B | TRP | SF2* | | 14 |
| 9 | 2.13s | QD*Bs | TRP | SF2*s | | 3 |
| 10 | 2.4X | QDBx | T | SF2Mx | LD-P-LF | 1 |
| 11 | 1.Ei | MQDi | C | SF1Bi | LD-P-LF | 1 |

2) The Contractor shall deliver a conceptual version of a production schedule for series production.
3) The production schedule shall cover the production, respectively procurement and delivery time ranges of all major components for integration, major production processes but at least:
   - common girder,
   - suspension system,
   - thermal shield,
   - insulation vacuum vessel,
   - telescopic compensation bellow system, incl. bracket screws,
   - production tooling,
   - transportation locks,
   - transportation data logging,
   - QP-magnet-units,
   - unit-assembly with UHV-components
   - production of cryogenic system,
   - cold mass assembly,
   - alignment of units in cold mass,
   - module integration,
   - pre-alignment of cold mass,
   - transportation.

   Within this planning, the Contractor shall define the time ranges for delivery of dedicated QP-magnet-unit types to the Contractor. Such planning is required for advanced production planning at the manufacturer of QP-magnet-units.

### 5.5. **Production or purchase of UHV – components**

1) For production or purchase of UHV – components (e.g. Drift Tube) the technical guidelines, listed as follows are to be applied:
   - F-TG-V-2.5e, Vacuum Firing for Hydrogen Degassing of Materials and UHV Chambers [50]
   - F-TG-V-2.6e, Material for Bakeable CF Flanges [51]
   - F-TG-V-2.25e, Forged Blanks for Vacuum Applications Material 1.4429 / ESU [52]
   - F-TG-V-2.28e, Stainless Steel for Beam Vacuum Chambers at Cryogenic Temperatures [53]
   - F-TG-V-3.4e, Manufacturing of CF Knife-Edge Flanges [54]
   - F-TG-V-5.1e, Surface Properties of Vacuum Chambers [55]
   - F-TG-V-6.1e, Cleaning of UHV Components of Stainless Steel [56]
   - F-TG-V-7.1e, Mechanical Acceptance Test for Beam Vacuum Components [57]
   - F-TG-V-7.15e, Record for Factory Acceptance Test (FAT) of Vacuum Components [58]
   - F-TG-V-7.25e, Vacuum Properties Acceptance Tests for Cryogenic Beam Vacuum Components [59]

### 5.6. **Storage of provisions and components**

1) The Contractor shall be responsible for storage of provisions and components, being needed for production of all QDMs.
2) The Contractor shall provide sufficient storage space and an applicable storage management for storage of 20% of all components, provided by the Company or any sub-Contractor.
3) In case of finished QDMs cannot directly be accepted at the Company, for whatever reason, the Contractor shall provide sufficient storage space to store at least 10% of the full production amount (min. 8 pcs. of QDMs) for at least 6 month.
4) In case of shortage in storage space, the Contractor shall announce the situation in writing to the Company.

### 5.7. **Completion of QP-magnet-units**

1) All QP-magnet-units will be delivered to the Contractor in an incomplete pre-assembled state. Missing components for completion are at least
   - UHV-Vacuum chambers,
   - Beam position monitors,

   dependent of the unit configuration.
2) The company shall be responsible for the supply of the main components for completion of QP-magnet-units. Main components for completion of QP-magnet-units will be delivered to the Contractor by suppliers being assigned by the Company respectively by the Company itself.
3) Main components for completion of QP-magnet-units will be delivered according to:
   - F-DS-VC-15e: Detailed Specification for SIS100 Quadrupole Chambers with Elliptical Cross-Section
   - F-DS-VC-14e: Detailed Specification for SIS100 Quadrupole Chambers with Star-shaped Cross-Section

- F-DS-BD-67e: Detailed Specification of Cold section BPM Detector SIS100

4) Prior to installation, the Contractor shall perform an incoming goods inspection according to section 6.3 for
   - QP-magnet-units,
   - UHV-Vacuum chambers,
   - Beam position monitors.

### 5.7.1. Assembly of UHV-Vacuum chambers

All beam vacuum chambers required for integration into the quadrupole units are rib-stiffened, thin-walled chambers which will be provided by the Company. The chambers must be inspected immediately upon receipt for any transport damages. If damage is found, the Company must be informed immediately. A damaged chamber must not be installed. Generally, installing the chambers must always be made with utmost caution, cleanlyness and skill.
The outer rib shape of all chambers is adapted to the aperture shape of the quadrupole yokes and adjacent beamline components, respectively. Most of the quadrupole chambers will be used simultaneously as common chambers for sextupole, multipole, and steerer magnets. Therefore, the length of the VCs varies depending on the quadrupole module type.
Three basic chamber types will be used in the quadrupole units:

- quadrupole chambers with elliptical cross sectional aperture to be installed in the modules 2.123, 2.4, 2.4x, 2.5, 1.6A, 1.7B, 2.8C, 2.9D, 1.E, 1.Ei;
- quadrupole chambers with star-shaped cross sectional aperture to be installed in module 2.13s;
- quadrupole chambers with elliptical cross sectional aperture to be installed in the modules 2.4x and 1.Ei, more specifically, in the injection and extraction branches of the Y cryostat.

An overview of all VCs can be found in Tables 5-1, 5-2, and 5-3. Each unit includes one vacuum chamber. Due to installation reasons, each VC is equipped with a fixed DN160CF flange on one side, and with a vacuum-tight end cap on the opposite side. Basically, the VC installation may only commence when the cold mass of the magnet units is precisely aligned in the girder.

The installation of the vacuum chambers in the units must be carried out in the sequence as follows.

1) Prior to inserting the vacuum chamber into the quadrupole units, the elliptic end cap has to be removed using an appropriate, dedicated cutting tool which will be provided by the Company. Its application will be detailed to the Contractor by the Company in a corresponding instruction manual. The removal of the elliptic end cap must be carried out in such a way that all UHV cleanliness specifications must be observed. During removal of the end cap, all surrounding vacuum, magnet and cryostat components must be protected. No filings or dust may come into contact with the surroundings; an appropriate local air extraction system is recommended. In general, all state-of-the-art rules of best vacuum practice and knowledge must be observed thoroughly.

2) After removal of the elliptic end cap, the correctly chosen vacuum chamber type shall be carefully inserted, i.e. cautiously pushed, into the quadrupole magnet unit yoke with all auxiliary magnets assembled (steerer, sextupole, multipole corrector, where applicable). When

pushing through, it is essential to ensure that the chamber does not become wedged, otherwise structural damage may occur to the magnet yoke or to the vacuum chamber. With the exception of chamber type U2, all VCs are to be inserted exclusively in beam direction. The chamber type can be found on the corresponding QR code label of the appropriate VC.

3) After the chamber has been successfully pushed through the yoke, first the connecting tube (cf. Technical Drawings and table 5-3, connecting tube) *must be brazed* in order to interconnect the cooling tube circuit of the individual chamber. Brazing instructions are given in the Technical Drawings of the appropriate VC. Afterwards, the leak tightness of the closed LHe cooling circuit must be checked.

4) Once the leak test has been completed and the absence of leaks is confirmed, the cooling tube circuit of the chamber must be connected to the LHe supply and return lines of the quadrupole unit. These connections are to be made utilizing a suitable orbital welding tong.

5) The subsequent mounting step depends on the specific chamber type:
   a) *Vacuum chamber of type U1, U2, D1, D5, SU*. These chamber types are adjacent to a Beam Position Monitor (BPM) and are to be connected to it by means of a special adapter flange (see Technical Drawing STD-V05-D077.002.001). Therefore, these chambers will be delivered only with one CF-type flange. According to Figure 5-1, the open end of the VC must be welded vacuum-tight to the adapter flange. Prior to welding, an appropriate elliptically shaped protective plastic cap must be inserted into the beam tube in order to protect the VC from contaminations due to welding. TIG welding technique should be applied. During and after welding all UHV cleanliness requirements must be observed. Utmost care must be taken that the VC does not become contaminated due to welding. After welding, first the welding seam shall be inspected to ensure that there are no welding defects which might render it unfit for UHV application. Afterwards, the welding seam and the chamber segment, which was not protected during welding by the protective cap, must be cleaned thoroughly using isopropanol or ethanol. Any discolouration or annealing colours in the vicinity of the welding seams must be removed beforehand with a soft wire brush. After cleaning, the protective plastic cap must be removed from inside the tube and flushed thoroughly with dry $GN_2$ (at least 99.995% purity = nitrogen 4.5). Subsequently, the floating bearing of the chamber (drawing No.: MAG-V07-E066.022.001 and MAG-V07-E066.022.002) must be installed onto the retaining plate (see MAG-V07-E066.023.001), and the entire chamber must be aligned carefully in the magnet yoke.

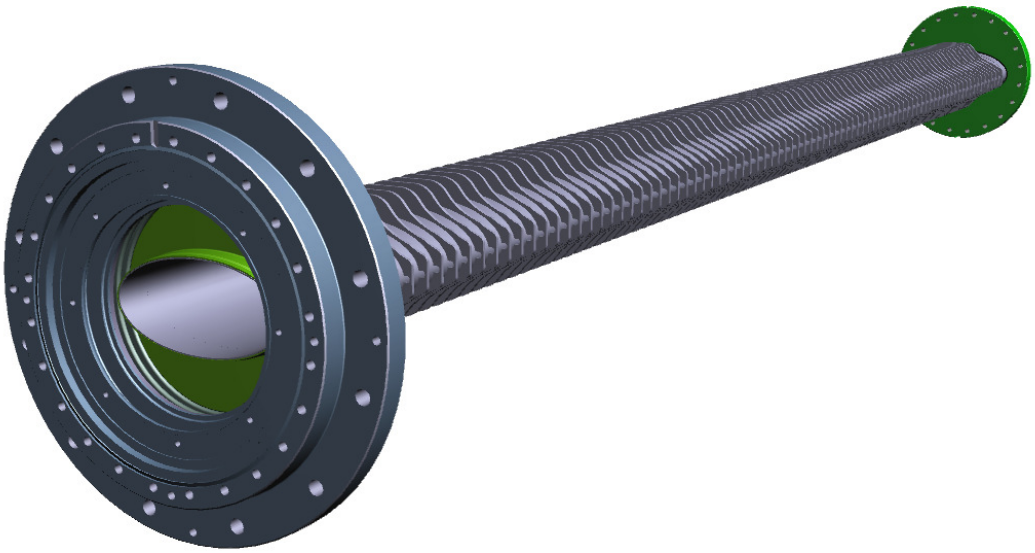


**Figure 5-5:** Special adapter flange DN200CF (cf. Technical Drawing STD-V05-D077.002.001)

b) *Vacuum chamber of type U3, U4, D2, D3, D4, D6, SD, IX.* These chamber types will be delivered with a loose CF-type flange. This loosely supplied CF-type flange must be welded to the open chamber end. The same welding instructions and cleaning rules are to be applied and observed as detailed under 5a). It is essential to ensure the precise orientation of the CF-type flanges in relation to the chamber. If the welding work has been completed, the fixed and movable bearing must be installed in accordance with the technical drawings.

After welding of the DN160CF flange to the vacuum chamber, a dedicated leak check of the vacuum chamber is mandatory in order to ashure the successful welding procedure. In genral, the sequence of necessary leak checks during assembly must be agreed with the company in writing, during definition of QA-procedures.

Once the chambers have been successfully integrated into the magnet units, the subsequent mounting of the BPM, the Cryo-Catcher, the CAP and the RCWT can be commenced, depending on the quadrupole module type.

**Table 5-3:** SIS100 quadrupole chamber types with elliptical cross section

| Chamber type | Chamber type | To be installed in module | Pcs. | Length at RT [mm] | DN160CF option | | Inserting direction for mounting | LHe supply connection side |
|---|---|---|---|---|---|---|---|---|
| | | | | | Upstream side (US) | Downstream side (DS) | | |
| U1 | Chamber for Defocusing Quadrupole (- BPM) | 15 × 2.123<br>5 × 2.4<br>1 × 2.4x | 21 | 1419 | fixed | no | In beam direction | DS |
| U2 | (BPM -) Chamber for Defocusing Quadrupole | 12 × 1.6A<br>12 × 2.8C<br>12 × 2.9D | 36 | 1419 | no | fixed | In opposite beam direction | US |

| Chamber type | Chamber type | To be installed in | Pcs. | Length at RT | DN160CF option | | Inserting direction for | LHe supply |
|---|---|---|---|---|---|---|---|---|
| U3 | Common chamber for Chromaticity Sextupole Vertical Focusing and Defocusing Quadrupole | 6 × 2.5<br>12 × 1.7B | 18 | 1985 | fixed | loose | In beam direction | US |
| U4 | Common chamber for Multipole Corrector and Defocusing Quadrupole | 5 × 1.E<br>1 × 1.Ei | 6 | 2213,2 | fixed | loose | In beam direction | US |
| D1 | Common chamber for Steerer and Focusing Quadrupole 1 ( - BPM) | 12 × 1.7B<br>5 × 1.E<br>1 × 1.Ei | 18 | 1879 | fixed | no | In beam direction | DS |
| D2 | Common chamber for Steerer, Focusing Quadrupole 1 or 2, and Chromaticity Sextupole Horizontal Focusing | 12 × 1.6A<br>12 × 2.8C | 24 | 2414 | fixed | loose | In beam direction | DS |
| D3 | Common chamber for Steerer, Focusing Quadrupole 2, and Jump Quadrupole | 12 × 2.9D | 12 | 2489 | fixed | loose | In beam direction | DS |
| D4 | Common chamber for Steerer and Focusing Quadrupole 2 | 15 × 2.123 | 15 | 1884 | fixed | loose | In beam direction | DS |
| D5 | Common chamber for Steerer and Focusing Quadrupole 2 (- BPM) | 6 × 2.5 | 6 | 1875 | fixed | no | In beam direction | DS |
| D6 | Common chamber for Steerer, Focusing Quadrupole 2 and Multipole Corrector | 5 × 2.4<br>1 × 2.4x | 6 | 2699,2 | fixed | loose | In beam direction | DS |
| | **Sum** | | **162** | | | | | |

**Table 5-4:** SIS100 Quadrupole chambers types with star-shaped cross section and different lengths

| | | | | | Upstream side (US) | Downstream side (DS) | | |
|---|---|---|---|---|---|---|---|---|
| SU | Chamber for Defocusing Quadrupole (- BPM) | 2.13 | 2 | 1419 | fixed | no | In beam direction | DS |
| SD | Common chamber for Steerer and Focusing Quadrupole 2 | 2.13 | 2 | 1884 | fixed | loose | In beam direction | DS |
| | **Sum** | | **4** | | | | | |

**Table 5-5:** SIS100 chamber types for injection and extraction branches with elliptical cross section

| Cham-ber type | Chamber type | To be installed in module | Pcs. | Length at RT [mm] | DN160CF option | | Inserting direction for mounting | LHe supply connection side |
|---|---|---|---|---|---|---|---|---|
| | | | | | Upstream side (US) | Downstream side (DS) | | |
| IX | Chamber for Injection and Extraction Quadrupoles | 2 × 1.Ei<br>2 × 2.4x | 4 | 1269 | fixed | loose | In beam direction | DS |
| | **Sum** | | **4** | | | | | |

### 5.7.2. BPM assembly and survey

1) The following steps are describing the most important processes of BPM assembly into the QP-Units as well as preceding preparation:
   - Insert quadrupole vacuum chamber in the quadrupole unit,
   - Mount the Main Flange to quadrupole yoke,
   - Adjust position and tilt of the Main Flange using the dowel pins,
   - Weld Main Flange to the quadrupole chamber,
   - Mount ceramic pipe and fix it position with dowel pins,
   - Perform transfer measurements as specified below in paragraph 4),
   - Assemble BPM chassis following special requirements as defined below in paragraph 2),
   - Assemble contact pins, signal feed-throughs and matching transformers retaining plates,
   - Install and connect matching transformers,
   - Install and connect cryogenic cables to matching transformers,
   - fix cryogenic cables in thermal anchor,
   - pull cryogenic cables through relevant flange
   - mount isolation-vacuum flange
   - Verification of electrical continuity of the BPM-Cable and electrical feed-troughs.
2) Since any incline of the chassis in respect to the main reference flange can exceed tolerances between guard rings and inner part of the BPM chassis, the special attention has to be paid during assembly.
   - fastening of the screws holding chassis must strictly follow technical guide line F-TG-V-13.1 [47].
   - Exception for last fastening: torque must not exceed 22 Nm.
   - The slit of CF 200 connection between chassis and main flange has to be controlled using slip gauge (see Figure 5-6). The maximum difference must not exceed 0.1mm.

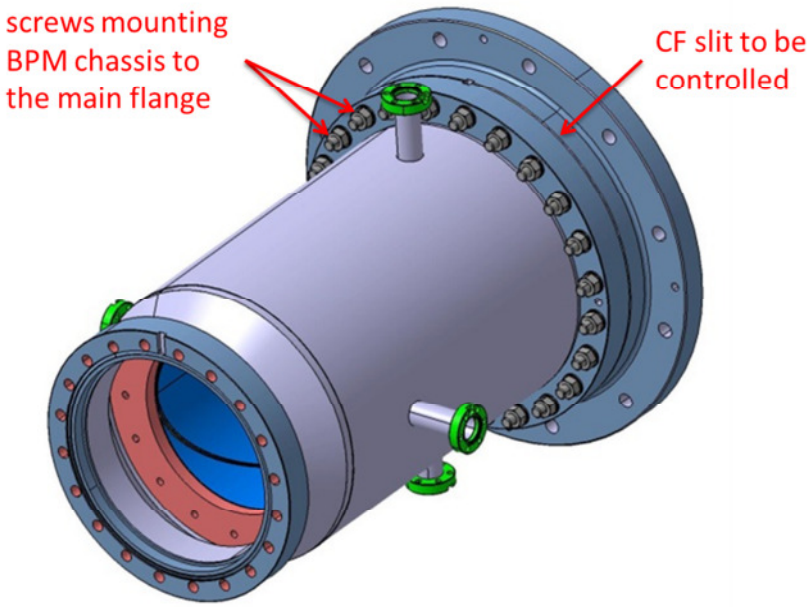



**Figure 5-6:** Screws mounting BPM chassis to the main flange and slit to be controlled.

3) Surveying shall be performed after assembly of a QP-Unit, welding of its main flange to the vacuum chamber and installing the ceramic beam pipe on the main flange but before installation of the BPM chassis.
4) The BPM survey procedure is to be performed according the following description:
   - Referenced holes and/or worked-over planes at the positions specified in figure 5-7 shall be applied as reference targets, respectively as fixture bores for fiducial targets.
   - Each single reference target position at the BPM shall be determined relative to each single reference target position of the QP-Magnet with the precision of 0.05 mm or better.
5) Based on the survey results, the position of the BPM relative to quadrupole axes shall be calculated within a tolerance 0.2 mm.

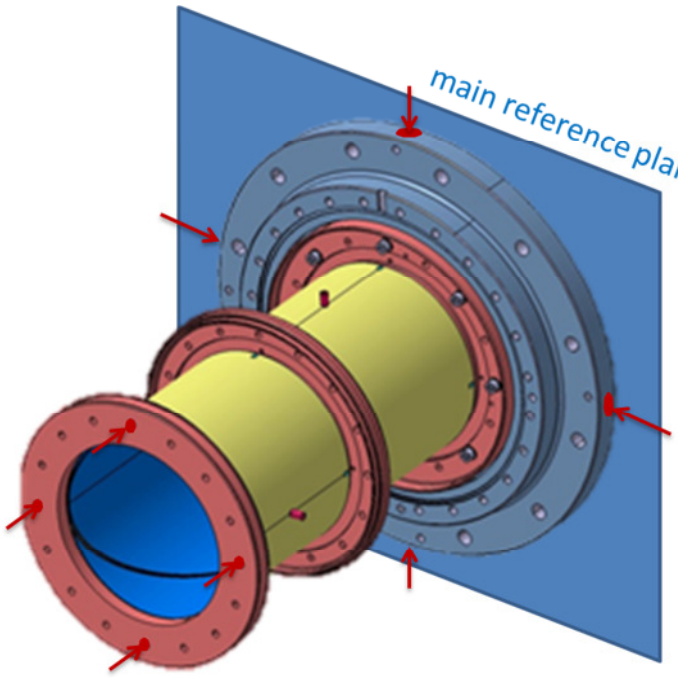


**Figure 5-7:** Position of the referenced holes and/or worked-over planes for fiducials on the main flange and ceramic cylinder.

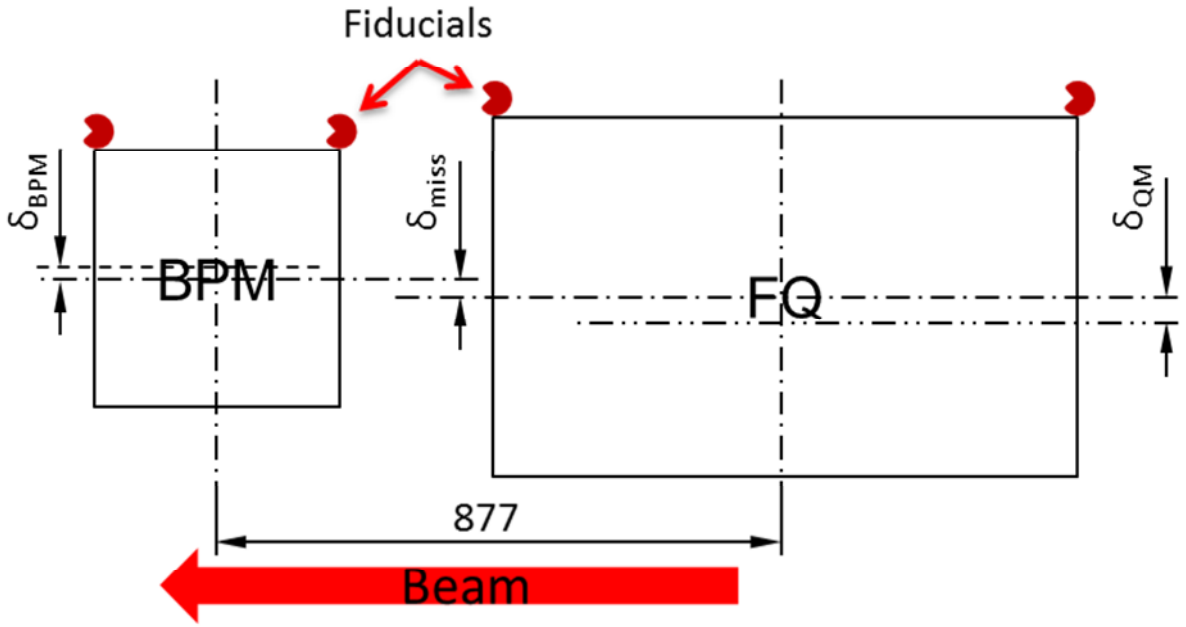



**Figure 5-8:** Definition of the offsets between geometrical axes (dashed-dotted line), electrical center of BPM (dashed line) and magnetic axis of the neighbouring quadrupole magnet (dashed-double-dotted line).

6) All results, from geometrical measurement and calculation shall be documented within an according protocol.

## 5.8. **Cold Mass assembly and alignment**

### 5.8.1. Assembly and Alignment of QP-magnet-units

1) The Contractor shall develop the process for assembly of the QDM - cold mass but not the algorithm and application for correction of QP-magnet axis in the cold mass.
2) The process for unit axis alignment in the cold mass is defined by section 5.8.2. and shall be implemented into the assembly process in detail without any change to calculation or application.
3) The Contractor shall prepare a detailed documentation on the assembly and alignment process, disclosing all technical details of applied procedures. This documentation shall be submitted to the Company latest 8 working weeks in advance to the planned start of production.
4) The Contractor shall be responsible for the correct assembly of the cold mass and the alignment of the units to each other under application of the procedure as defined by section 5.8.2 below.

### 5.8.2. Algorithm and application for correction of QP-magnet axis

The descriptions as follows are defining the process of adjusting of the quadrupole magnets „D“ and „F“ within the common girder of the cold mass in a SIS100-QDM.

Quadrupole principles:

The „fiducials“ on each quadrupole are 1380 mm apart, i.e. 690 mm from the magnet`s center. The loose bearings are 500mm from the magnet`s center. The distance from quadrupol center to quadrupol center is 2607 mm. (All dimensions are “warm” dimensions.)

At all bearings we may alter intermediate pieces from none to 1 mm in steps of 0.1 mm in horizontal ($Y_{mcs}$) direction or change the position of bolts from -0.5 mm to +0.5 mm also in steps of 0.1 mm in vertical ($Z_{mcs}$) direction. Hence the maximum correctible offset is 0.5 mm x 1.38 [690 mm / 500 mm] = 0.69 mm.

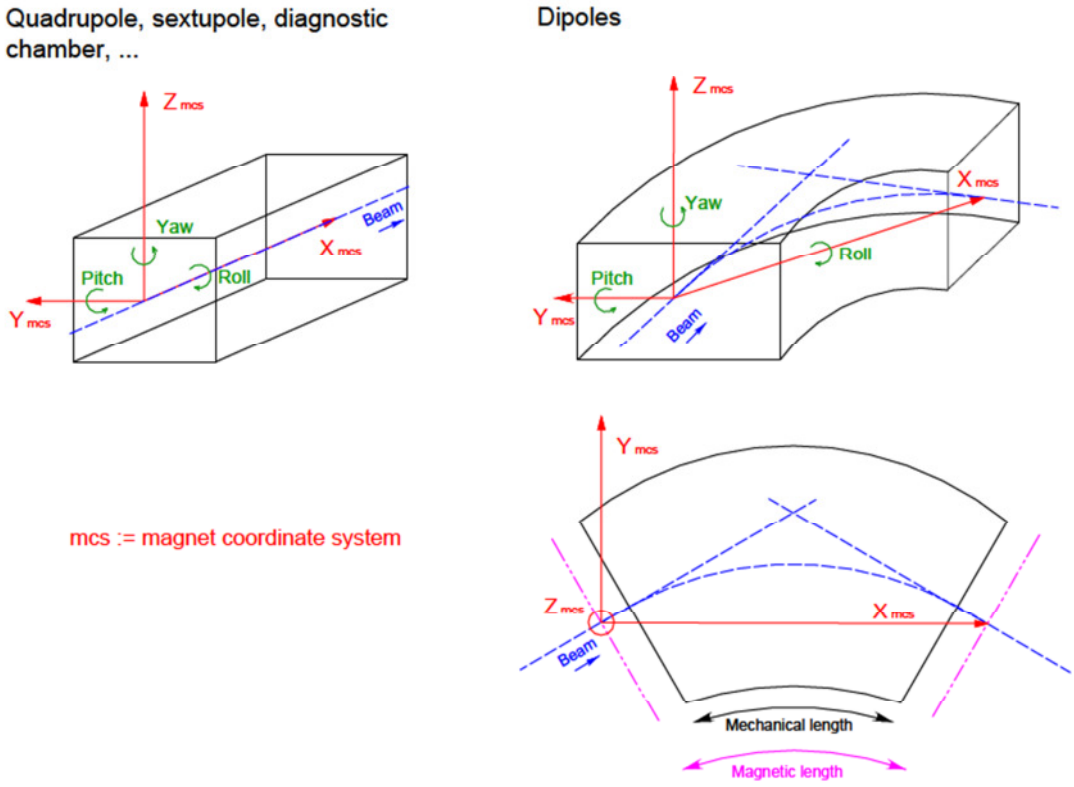



**Figure 5-9:** Coordinate system according to F-TG-3.68e [20]

**Basic configurations** (part numbers in parts list MG-1007850-A-000 [139])

In the basic configuration (magnetic axe = geometric axe) the quadrupoles are centered (direction $Y_{mcs}$) within the girder and there is one 0.5 mm spacer (part 59) each at J1 and J5, at J2 and J6 there are two spacers 0.2 mm and one spacer 0,1 mm each (parts 62 and 63). At the two fix points are spacer 0.5 mm (part 70) at J3 plus two spacers 0.2 mm (part 73) and one spacer 0.1 mm (part 74) at J4. One (zero degree) angular plate (part 64) is with each loose bearing (direction $x_{mcs}$). Furthermore there are two tapped dowel pins (direction $Z_{mcs}$; part 131) mounted in the drill „0“ at each loose bearing. All.

Each quadrupol is held on six points. The two spherical plates (fix points J3 and J4) at the magnet`s center, two dovetail (loose) bearings J1 and J2 at beam entrance (up-stream) and another two J5 and J6 at beam exit (down-stream).

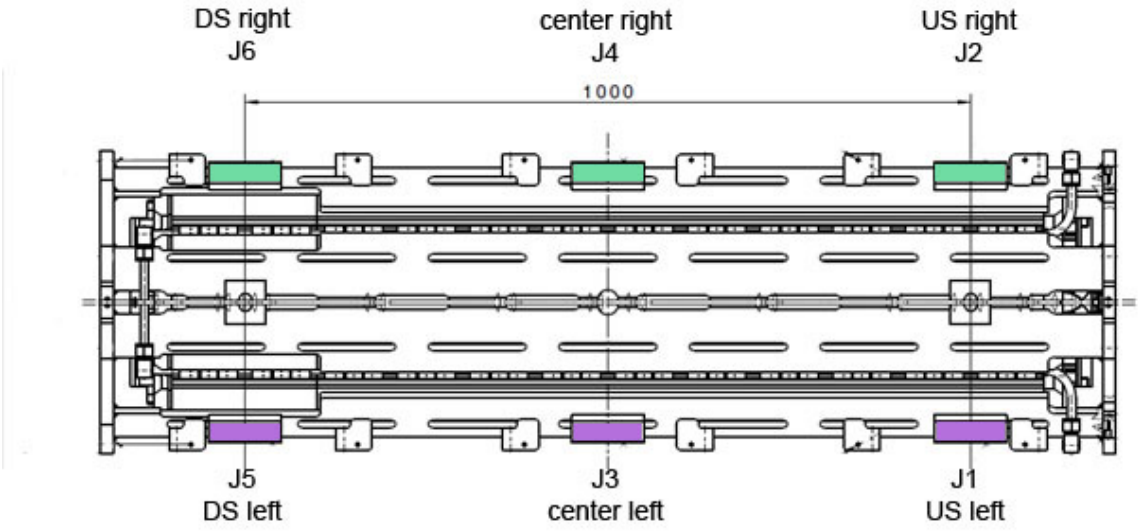



**Figure 5-10:** Top view on a QP-magnet with definition for the naming of support interfaces.

### Fiducialisation

For calculating the necessary corrections to get the magnets measured magnetic axis aligned to the girder`s geometric axis there is a xlsx-file (Mounting&Alignment_QP_Units_TEMPLATE.xlsx [270]). Therein the calculation for the horizontal ($Y_{mcs}$ Pitch) and vertical ($Z_{mcs}$ Yaw) offsets plus the offset for a possible rotation ($X_{mcs}$ Roll) is done.

In the xls-file`s „Reference geometry“ the measured values are written into the orange „Input“-fields.

The calculated values are given in the grey “Calculated”-fields.

Note:

If the resulting centerline of the two quadrupoles cannot get aligned to the girder`s geometrical axis, the cryostat has to be placed in the beamline adjacent to this remaining offset.

### Allignment of quadrupol magnets within the girder

(part numbers in parts list MG-1007850-A-000 [139])

Corrections in the „Y“-direction are done by changing the spacers from one side to the other. There must always be all spacers (one part 59, two parts 62 and one part 63) in use at one bearing (upstream, center and downstream)!

In direction „Z“ the positioning of the quadrupoles is done by putting the pins at the dovetail bearings into the adjacent holes.

To correct a possible offset around the „X”-axe four angular plates (from parts 65-69) have to replace the four parts 64 at the dovetail bearings.

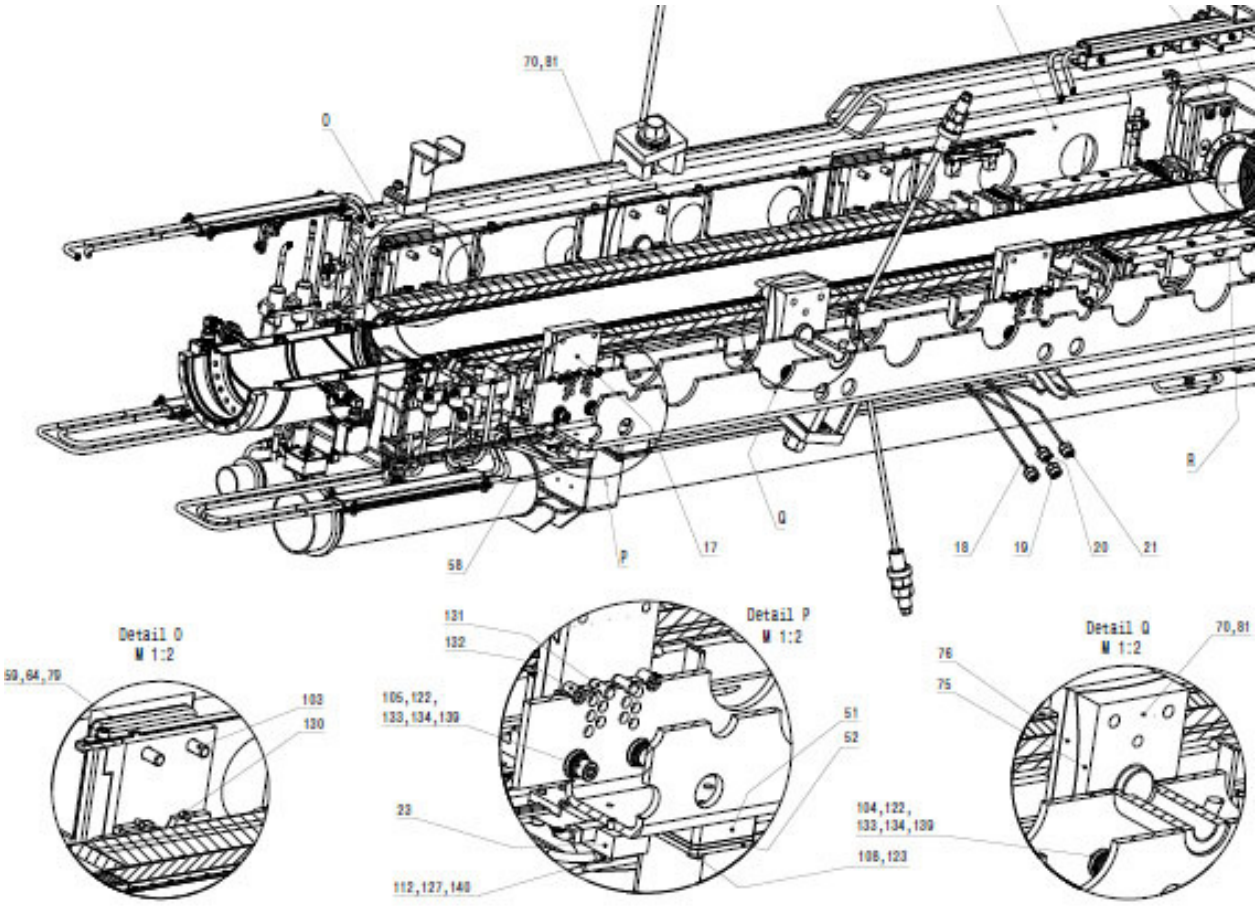



**Figure 5-11:** Partial view from MG-1007850-A-000 sheet 4

**Table 5-6:** References to parts lists and assignment of components to application in the cold amss assembly of SIS100-QDM of the type 2.5.

| Part | | Name | Drawing number | Bearing | Kind |
|---|---|---|---|---|---|
| 59 | 4 | Spacer sliding fixation; 0.5mm | MG-1010050-P-000 | J1; J5 | Dovetail |
| 62 | 8 | Spacer sliding fixation; 0.2mm | MG-1010038-P-000 | J2; J6 | Dovetail |
| 63 | 4 | Spacer sliding fixation; 0.1mm | MG-1010036-P-000 | J2; J6 | Dovetail |
| 64 | 4 | Angular plate 0° | MG-1010370-P-000 | J1; J2; J5; J6 | Dovetail |
| 65 | 4 | Angular plate 0.03° | MG-1009903-P-000 | J1; J2; J5; J6 | Dovetail |
| 66 | 4 | Angular plate 0.06° | MG-1010063-P-000 | J1; J2; J5; J6 | Dovetail |
| 67 | 4 | Angular plate 0.09° | MG-1010064-P-000 | J1; J2; J5; J6 | Dovetail |
| 68 | 4 | Angular plate 0.12° | MG-1010065-P-000 | J1; J2; J5; J6 | Dovetail |
| 69 | 4 | Angular plate 0.15° | MG-1010066-P-000 | J1; J2; J5; J6 | Dovetail |
| 70 | 1 | Spacer center fixation; 0.5mm | MG-1010402-P-000 | J3 | Spherical |
| 73 | 2 | Spacer center fixation; 0.2mm | MG-1010398-P-000 | J4 | Spherical |
| 74 | 1 | Spacer center fixation; 0.1mm | MG-1010396-P-000 | J4 | Spherical |

| Part | | Name | Drawing number | Bearing | Kind |
|---|---|---|---|---|---|
| 75 | 2 | Female spherical plate | MG-1009871-P-000 | J3; J4 | Spherical |
| 76 | 2 | Male spherical plate | MG-1009872-P-000 | J3; J4 | Spherical |

***Safety advice:***

*To replace or change any of the above mentioned spacers, angular plates or tapped dowel pins after a primary setup had been done, one has to observe that the quadrupol is secured in its place to prevent personal injury and/or material damages.*

### 5.8.3. Processing BPM components for cold mass assembly

1) Prior to the installation of the matching transformers measure the capacitances of the BPM electrodes against ground by means of LRC-meter or Network Analyzer. This procedure prove the proper assembly and BPM structure integrity:
   - Connect an LRC-meter to one of four N-type signal feeds of BPM,
   - Terminate all other feeds with 50 Ohm,
   - Measure the capacitance (90 pF ± 15 pF),
   - Repeat measurement for all other feeds,
     *Comment:* If 4 port network-analyzer is in use this measurement can be done in one single measurement whereas the capacity is to be extracted from S11-scattering parameter.
   - If capacitance measured at any feed-through diverge from 90 pF ± 15 pF recheck connections of the signal pins and feed-through and repeat measurement.
2) The following steps are describing the most important processes of further BPM assembly during integrating the completed QP-Units into the cold mass assembly:
   - Install matching transformers:
   - Connect four 90 degree N-type adapter on BPM feeds,
   - Connect matching transformer to the adapter,
   - Mount matching transformer body to holders,
   - Install four cryogenic semi-rigid cables and fix them to the common girder for cold mass integration into the QDM.
3) The following steps are describing the most important processes of further BPM assembly after integrating cold mass into the QDM assembly:
   - After completing cold mass assembly into the cryostat, pull cryogenic cables through relevant flanges in the thermal shield and the cryostat vacuum vessel,
   - Install electrical feed-throughs in CF-flange,
   - Mount isolation-vacuum flange at the cryostat vacuum vessel.
   - Perform electrical test of BPM system.
4) An integral electric test of all BPM connections shall be performed using a network-analyzer:
   - Connect 4-port network-analyzer to N-type outputs of Isolation-Vacuum flange,
   - Measure response function by S21 and S34-scattering parameters.

### 5.8.4. Handling and application of ceramic Voltage Breakers (VBs)

1) Avoid any kind of contamination of the VBs during unpacking, handling, assembly and welding or soldering processes.
2) Always handle clean VBs at all surfaces with clean, lint- and powder-free gloves only, e.g. vinyl-gloves. Even fingerprints will contaminate the components and reduce their insulation strength.
3) Mount and weld or solder in a clean room separated from the mechanical manufacturing.
4) Always wear clean, lint- and powder free gloves also during assembly.
5) Contact points with other materials (e.g. G11 epoxy glass laminate), which are hygroscopic can expose the voltage breaker to any kind of contamination have to be insulated by suitable insulation materials (e.g. Polyimide-tape).
6) If contamination occurred, clean the parts as described in chapter “Cleaning CMAs”.
7) Protect VBs from any impacts, bending and thermal stress.
8) Always take care to avoid undue stress on ceramic and brazing area all through full welding or soldering processes.
9) For each VB, installed in any assembly, the lot-number of the VB shall be documented in adequate construction documentation.

### 5.8.5. Assembly and alignment of the Cryo-Catcher

The Cryo-Catcher unit will be mounted between the two quadrupole vacuum chambers. The vacuum chamber is equipped with bellows to compensate longitudinal shrinking during cooldown and transversal offset due to the magnet alignment. The actual Cryo-Catcher is a block of copper, which will catch lost beam ions during operation in a controlled way, in order to stabilize the beam vacuum. The front part of this block is electrically insulated, but connected to the outside with a wire, such that the electrical current of incident ions can be measured. The surrounding chamber is plated with copper on the outside, to provide a homogeneous temperature distribution in order to get a high pumping speed. The complete block is kept at a higher temperature, than the surrounding cold chamber, to prevent pumping on the surface of incident beam ions. This higher temperature is achieved, by connecting the Cryo-Catcher thermally to the thermal shield of the cryostat with a thermalisation band. The support structure of the Cryo-Catcher block contains a bellow with high thermal resistance. The support structure also allows setting the Cryo-Catcher to individual distances, with respect to the beam axis. To prevent a damage of this construction, a transport bracket is installed, which will only be removed temporarily for cryogenic tests and after final placement of the quadrupole unit in the tunnel.

The Cryo-Catcher unit is equipped with a temperature sensor on the chamber, and a temperature sensor for the Cryo-Catcher block. Since the block is always required to be warmer than the surrounding chamber, especially during cooldown, a heater will be installed in the thermalisation band.

1) The Cryo-Catcher unit will be supplied by the Company. More details are described in its detailed specification [280].
2) When handling the Cryo-Catcher unit, and during assembly, special care has to be taken in order to not damage the bellows. The transportation bracket needs to be mounted.
   - The bellows upstream and downstream have to be compressed, when inserting the Cryo-Catcher-unit in between the vacuum chambers of the QP-magnet-units. They are designed such, that they are free of stress in the cryogenic operation mode, when the cold mass is contracted. All relevant Technical Guidelines have to be considered, when the UHV flanges are connected.

- The distance of the Cryo-Catcher block with respect to the beam axis has to be adjusted by the contractor. The company will provide a document, specifying the required distance for each individual QP-module. The adjustment is made by means of ceramic spacers, intended for this. The individual performed adjustment has to be noted in the documentation for the particular QP-module.
- The LHe pipes have to be connected by a suitable joining process, which has to be agreed with the company.
- The thermalisation strap of the Cryo-Catcher, which is mounted to the thermal shield, has to be equipped with a heater.
- After the cold mass has been installed into the cryostat, the Cryo-Catcher-support has to be connected to the thermalisation strap.
- The BNC-socket of the Cryo-Catcher chamber for the current measurement has to be connected to the corresponding socket of the cryostat.
- The temperature sensors have to be mounted and connected according to the instrumentation list.
- CAUTION: When performing a leak test of the UHV system, the bellows need to be supported, in order to prevent a collapse of the bellows by the vacuum force.

3) For the Cryo-Catcher-unit there are some specific tests which have to be conducted, apart from the vacuum tests. It has to be proven, that the cryo-catcher block's position after the module integration is correct. The distance to the beam axis and the tilting of its surface facing the beam have to be checked. Therefore the following tests are required.

4) Position measurement 1:

   The distance between the front edge of the cryo-catcher and the beam axis has to be measured and documented. The beam axis is represented by the magnetic axis of the upstream quadrupole magnet. The distance has to be 40 mm, within a tolerance of ±0.5 mm.

5) Position measurement 2:

   The surface of the Cryo-Catcher block, which is facing the beam axis, has to be tilted by 3° ±0.1°. The distance of the surface to the beam axis has to increase, while moving in beam direction. This angle has to be measured and documented. This can generally be measured by measuring the distance of the back edge facing the beam axis to the beam axis (again the magnetic axis of the quadrupole magnet upstream). Its distance to the beam axis has to be 55.7 mm ±0.5mm.

6) Electrical Measurement:

   - The electrical connection between the Cryo-Catcher head and the BNC socket at the outside of the cryostat (flange IF1) has to be proven and the electrical resistance has to be documented.
   - In order to measure this electrical connection, the Cryo-Catcher head needs to be connected electrically with a type of a lance through the beam pipe from the upstream entrance. The lance needs to be manufactured of a suitable material (e.g. stainless steel), in order to prevent a pollution of the UHV system. The material must be cleaned, such that no contamination can transferred into the UHV system, when the vacuum chamber walls are touched. For the measurement, the lance shall be placed on the top of the head of the Cryo-Catcher. It could have a bend tip, which connects to the Cryo-Catcher head.
   - The front of the Cryo-Catcher, facing the beam, must not get any scratches, in no case!
   - The measurement takes place between that lance and the BNC socket at the outside of the cryostat. The electrical resistance of the auxiliary equipment for the measurement, the measured resistance, and the thus resulting electrical resistance between Cryo-Catcher head and BNC socket have to be documented.

- Furthermore, the electrical insulation of the Cryo-Catcher head with respect to the cryostat's mass has to be proven. This can be done by a simple measurement of the electrical resistance at the BNC socket at the outside of the cryostat.

#### 5.8.6. Joining of low cross section cryogenic tubing (Stainless steel, CuNi30Mn1)

1) Low cross section cryogenic tubing is any tubing not belonging to the He-supply and –return system of diameters DN ≥ 25 (VC-, magnet-, thermal shield supply and common return).
2) Any interconnection of low cross section tubing, where no welding is applicable, shall be handled with special attention. In some cases, assembly space is very limited and sensitive components, e.g. a SC coils, are located close to the interconnection. Other cases are interconnections to sensitive components like ceramic voltage barkers or interconnection of stainless steel to CuNi30-material or copper is required.
3) The Contractor shall identify all interconnections of low cross section tubing and shall perform a detailed planning of joining technologies to be applied in close collaboration with the Company.
4) The Contractor shall propose applicable joining technologies and processes in detail, especially in terms of applied temperatures, filler metals, flux, tooling, forming gas etc..
5) In case of brazing is required as joining technology, solutions and processes as defined by [49] shall be applied if possible. In case, these solutions are not applicable, the Contractor shall inform the Company, justify in writing and shall suggest alternative solutions.
6) The application of appropriate forming gas shall be applied inside the tubing during brazing and welding processes.
7) When brazing or welding is applied close to super-conducting or organic components, e.g. SC cable or G11 used for SC coils, heating of these components to more than 100°C must be strictly avoided. The Contractor shall develop and apply adequate protection appliances (e.g. air-flow- or water-cooled copper plates with additional temperature resistive MLI) for heat protection of components.
8) During any joining process, the temperature of sensitive components shall be monitored and registered permanently with adequate temperature sensors, e.g. pt100, applied to the object close to the operation area.
9) For process qualification, the quality of joined connections shall be approved by polished micrograph sections of an adequate number of samples, prior to application in the production.
10) Any joining processes, to be applied to pressurised tubing must fulfil the requirements
    - of the European pressure equipment directive [7],
    - of applicable bulletins of AD 2000 [8].

    The Contractor shall proof the fulfilment of those requirements in writing as defined by named norms and standards.
11) Any joining process, not being approved by the Company shall not be applied. In case application without approval, components may be rejected without any further justification.
12) The Contractor shall remain responsible for correct application and functionality of joining technology and joints, even though a process was approved by the Company.
13) All planning and application of joining processes shall be documented in detail.

### 5.9. **Installation and testing of temperature sensors and instrumentation**

1) The basic requirements on instrumentation, sensor installation and cabling are defined by [13] and [5].

2) All instrumentation shall be applied in configurations as defined by the valid instrumentation list of the respective QDM module type as defined by [13].
3) Installation and testing of temperature sensors shall be applied according to the technical guidelines [25] and [22].
4) A CID-label shall be applied to each temperature sensor as defined by [17]. The registration of the CID shall be applied as defined by 5.13.2.

### 5.9.1. Thermal interception of instrumentation

1) All temperature sensor wiring and all voltage taps shall be thermally intercepted at the temperature level of the thermal shield. Therefore special thermal anchoring components shall be installed.

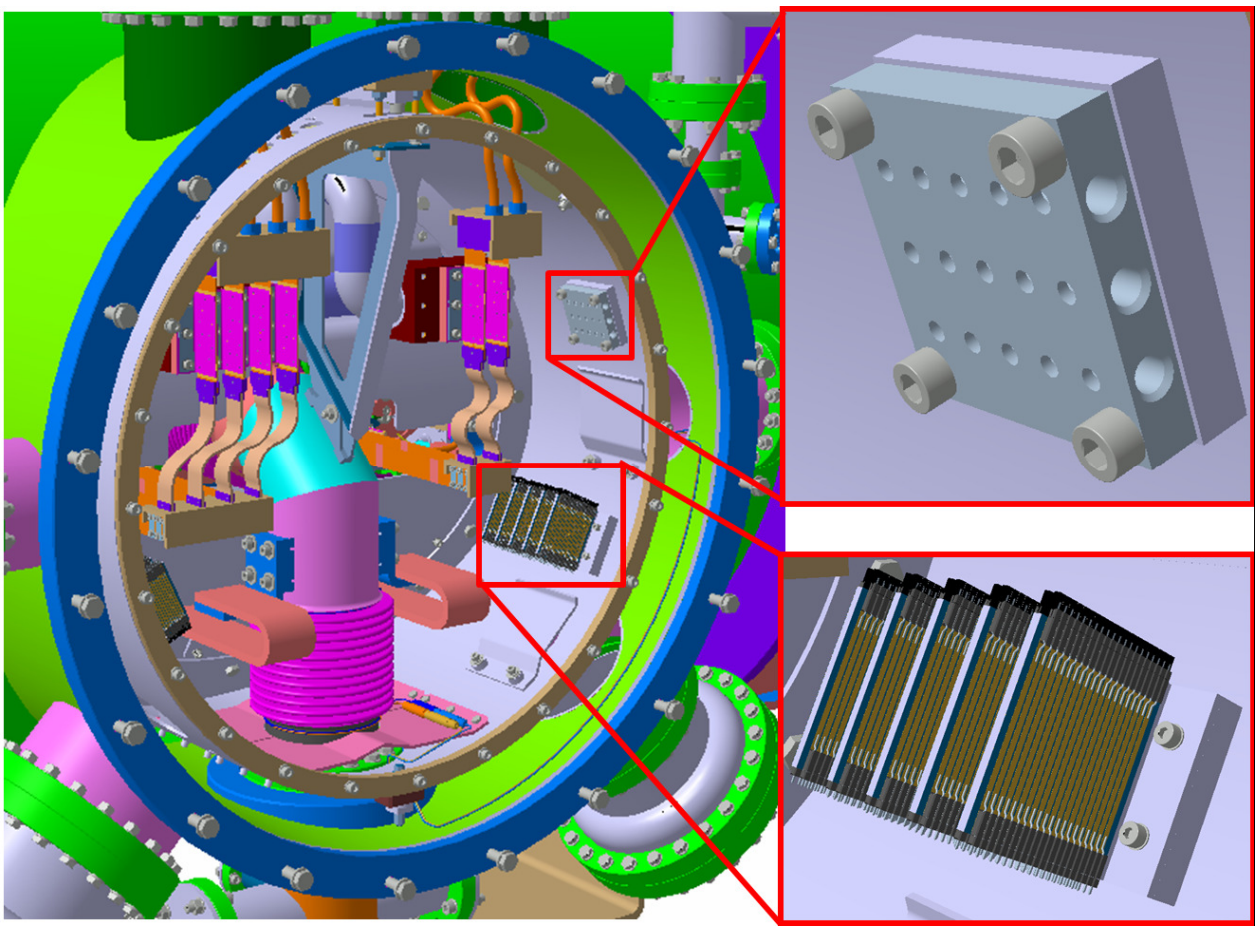


**Figure 5-12 f.i.o.:** CAD-model of the opened service port of a SIS100-QDM of the arc-section type with view on the thermal interceptions of temperature sensor wiring and voltage tap (left). Thermalisation block for voltage taps (top right). Thermalisation panels for temperature sensor wiring (bottom right).

2) The voltage taps must be feed through the thermalisation block after installation of the cold mass. For optimal thermal contact the wires must be infused by resin casting.
3) All thermalisation panels shall be fully prepared according the engineering drawing prior to installation in the service port shield. For thermalisation of the sensor wiring, plug connectors shall be applied at the sensor wiring and plugged to the thermalisation panels.

## 5.10. Module assembly and pre-alignment

### 5.10.1. Module assembly (arc section type)

1) Within this section, only a first proposal for a procedure of mounting the cold mass into the QDM-cryostat is given for the QDM-types 2.5, 1.6A, 1.7B and 2.9D.
2) The Contractor shall be responsible for development of the assembly- and pre-alignment procedure of cold mass in the QDM in all details.
3) Within the preparations for production, the process shall be documented in detail and shall be agreed with the Company.

**Overview:**

For assembly of cold mass into the cryostat, dedicated tooling and assembly field is needed. At first the cryostat vessel, including thermal shield, shall be arranged in line with the cold mass, located on a rail system, used to moved the cold mass shall into the cryostat vessel. After positioning of cold mass in the cryostat, four support rods are set in place. The Ti-alloy parts of load-rods shall be thightended in the inner tension screws which are located inside the common girders. After suspending cold mass on the load rods, the mounting sled must be retracted from the cryostat vessel and four tie-rods are set in place. Now the cold mass main axes shall be aligned correctly to the main axes of the cryostat vacuum vessel. In a final step all thermal contacts between thermal shield and cold mass shall be attached.

**General preparation an checks:**

1) Cryostat vacuum vessels and thermal shields must be manufactured, checked and approved according to applicable engineering drawings and specifications.
2) All surfaces of cryostat vacuum vessel and thermal shields clean and checked for cleanliness according the applicable technical guideline (see [5]).
3) All He-tubing of cold mass and thermal shield must have passed the required pressure tests.
4) All instrumentation must be properly installed at thermal shield and cold mass and must be proven for functionality. The cabling must be available at the cold mass in the region of the service port position.
5) For proper mounting of the cold mass in the cryostat, an adequate tooling or bench is required. Such device shall guarantee the possibility to move the cold mass straight into the cryostat along a 5 m runway with a maximum axial deviation of ≤ 2 mm

**Preparation of thermal shield:**

1) The service port shield must be detached from the main thermal shield. It cannot be mounted together with the main shield and must be attached later through the service port.
2) The He-supply line must be unlocked at bot rotation locks, upstream and downstream –side of the shield, and shall be swung inside the main shield.
3) The axial set screws must be removed from the shield.
4) Thermalisation straps must be fastened to their appropriate counterparts inside the thermal shield:
   - 2x Thermal interception outside downstream MG-1006417-A-000;
   - 2x Thermal interception inside downstream MG-1006438-A-000;
   - 1x Thermal interception Cryo-Catcher MG-1005269-A-000;
   - 1x Thermal interception pumping CWT downstream MG-1005160-A-000;
   - 1x Thermal interception pumping CWT upstream MG-1005152-A-000

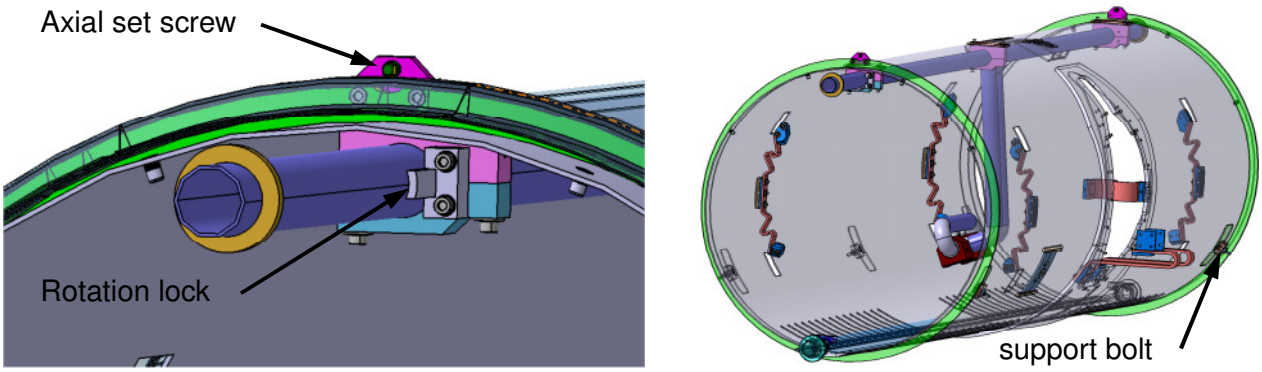



**Figure 5-13 f.i.o.:** (left) View to fixation lock and axial set screw at the downstream-end of the main thermal shield. (right) main thermal shield with He-supply swung in, thermalisation straps installed and service port shield detached.

5) The complete MLI-jacket, including service port shield MLI, shall be applied to the main thermal shield while the MLI-jacket of service port shall be pushed to the inside of the main shield for installation.
6) All support bolts at the bottom of the thermal shield must be set to their nominal setting dimensions as defined by the according engineering drawing.

**Assembly of cryostat:**

1) The cryostat consists of the cryostat insulation vacuum vessel with the thermal shield installed inside thermal shield and must be assembled in the next steps.
2) The thermal shield must be moved into the vacuum vessel. Carefully avoid abrasion of the bolts by scratching over the inner surface of the vacuum vessel.
3) Prior to mounting the service port thermal shield both supply cables for the heater jacket of the roughing CWT must be fixed inside the service port.
4) The inward folded MLI is pulled out of the main shield into the service port. Loose ends of MLI may be fixed with tape.
5) The service port shield shall be mounted and fastened to the main thermal shield.
6) The support bolt, downside of the service port shield must be fixed such, that the service port shield is centred in the service port.
7) The heat exchanger of the He-supply lines must be swung back into the service port opening and fixed with the support bolt.
8) The axial fixation bolts must be placed into position again (see figure 5-16) and 10mm clearance shall be set for thermal contraction compensation.

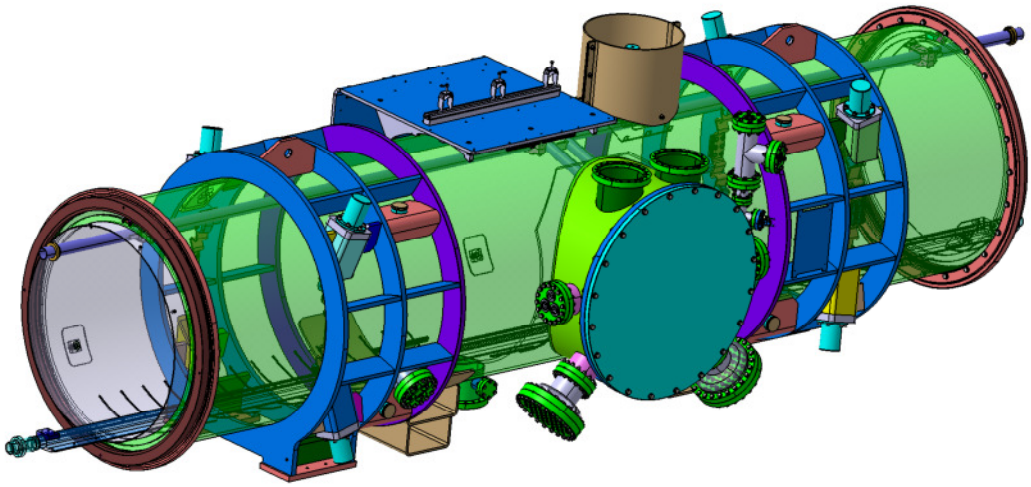


**Figure 5-14 f.i.o.:** Thermal shield installed in the insulation vacuum vessel. Service port flange is closed in this figure and instrumentation flanges are installed. These components must be removed for further work.

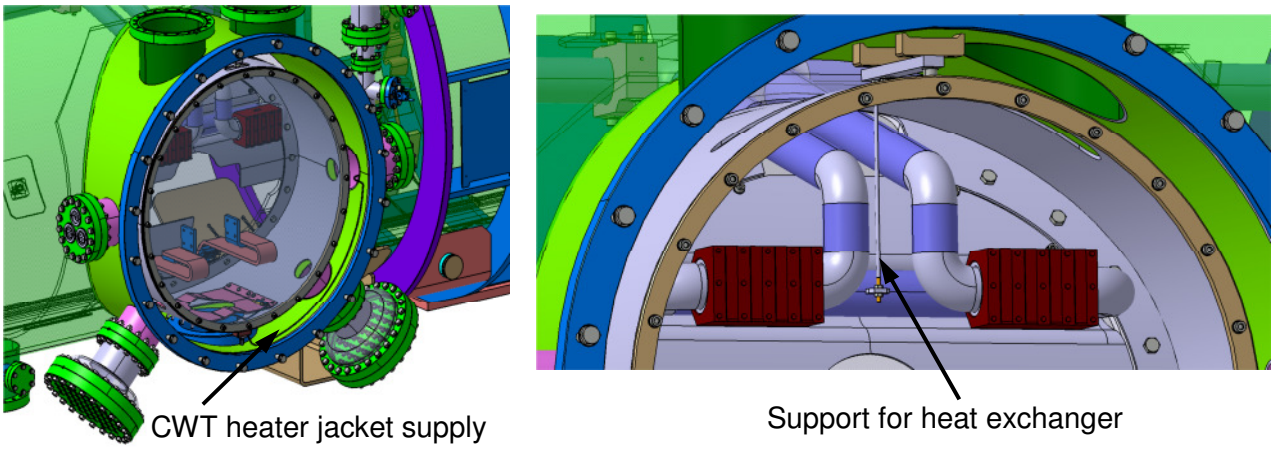



**Figure 5-15f.i.o. :** Thermal shield installed in the insulation vacuum vessel. Service port flange is closed in this figure and instrumentation flanges are installed. These components must be removed for further work.

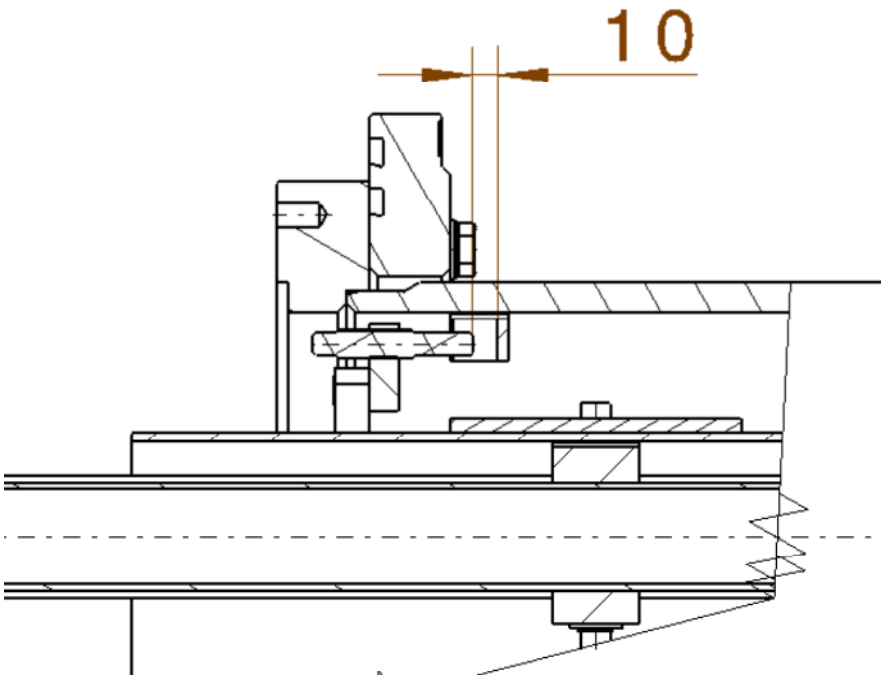



**Figure 5-16 :** Axial fixation in position with a 10 mm clearance being set.

**Preparations for cold mass installation:**

1) To clear the cryostat cross section for cold mass installation, all thermalisation straps of the support system must be pulled back into the hollow region of the support domes at the insulation vacuum vessel. To this, protection caps of support domes must be removed and all load- and tie-rods must be split. All thermalisation straps shall be fixed to their corresponding Ti-alloy-part of the according rod which shall be mounted in its dome, together with required bearings and washers.
2) For clearing the cryostat cross section, the suspension rods shall be pulled out at least 55 mm from the outer dome edge.
3) The fully assembled cold mass has to be checked for conformity according to its engineering drawings and all applying specifications.
4) Instrumentation must be checked for accordance to all applying specifications. The testing shall be performed according [13].
5) Electric systems must be checked for accordance to all applying specifications. The testing shall be performed according [31].
6) Hydraulic systems must be checked for accordance to all applying specifications. The testing shall be performed according [6], [9], [10], [11], [28], [29], [32] and [35].
7) The UHV-system must be checked for accordance with the applying specifications and carefully closed with clean closures [43], [44] and [45].
8) Sensor wires are to be bundled and reachable from the service port later on.
9) The four BPM signal wires must not be mounted yet.
10) In case of any non-acceptable deviation to any specification or engineering drawing, the cold mass must not be installed in the cryostat but must be rejected for revision.
11) The inner tensioning bolts shall be mounted, together with bearings and washers, into their saddles at the common girder. The bolts must be secured by rotation locks.

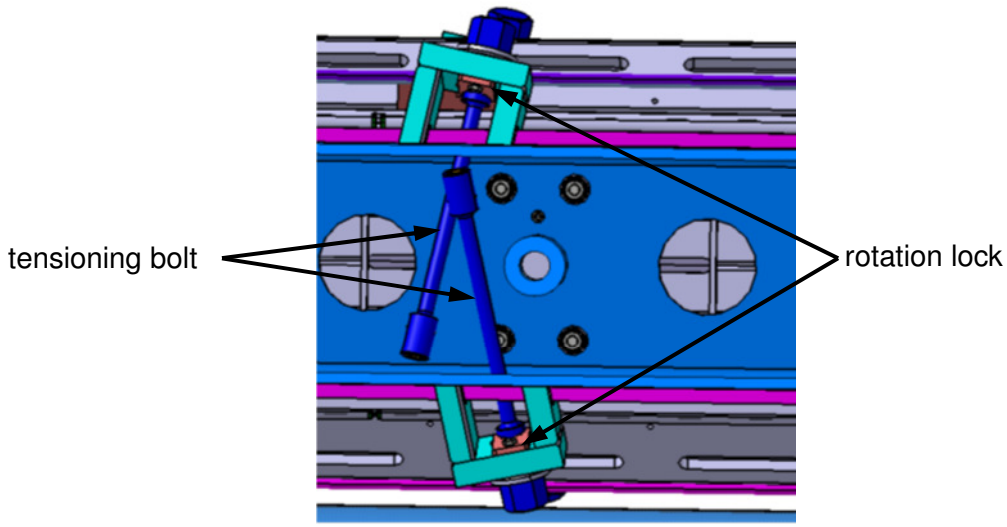



**Figure 5-17 f.i.o.:** Cut view of a common girder with tensioning bolts in position. Bearings, washers and rotation locks are installed.

Mounting the cold mass:

1) The cold mass must be installed properly onto a bench for module assembly.
2) The insertion of the cold mass into the cryostat must be done along the beam direction, starting at the upstream-position of the cryostat.
3) Due to small clearance in-between outer edges of the cold mass and the inner contour of the thermal shield, a permanent and careful check for any collisions must be performed during the mounting process.
4) The cold mass is to be moved into position in the cryostat.
5) When the cold mass reached its position, it must be fixed for mounting the suspension system.

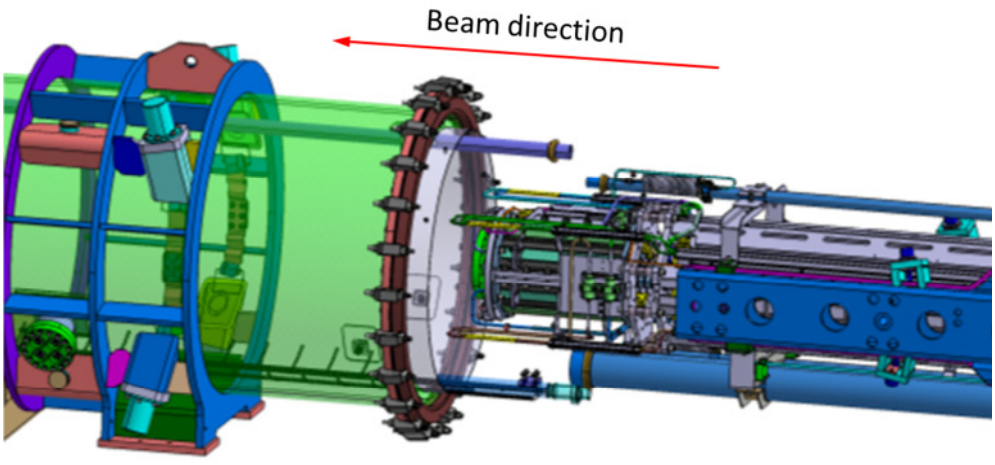



**Figure 5-18 f.i.o.:** Position of cold mass prior to process of insertion into the cryostat. The insertion must be done along the beam direction, starting at the upstream-position of the cryostat.

6) Fixations of support rod components, located in the domes of the vacuum vessel, shall be removed. The outer support rod components must be pushed into position for connection with inner components.

7) The outer Ti-alloy components of load-rods must be screwed into the inner rod components, at least 19 mm deep into the threaded hole of the steel part and must be fastened.
8) The support from the assembly tool to the cold mass can be removed, after the cold mass is securely fixed.
9) All tie-rods must be mounted in position without significant pre-tension.
10) It shall be considered to lift the cold mass for a certain amount to pre-compensate the lowering of cold mass during pre-stressing the support system. Therefore, the expected lowering shall be calculated precisely in advance.
11) The suspension system of the cold mass shall be pre-stressed and the cold mass shall be aligned according to requirements as defined by section 5.10.2.
12) All eight thermalisation straps of the suspension system shall be set in their correct positions as defined by according engineering drawings. For information see figures below. Real dimensions shall be taken from the according drawings.

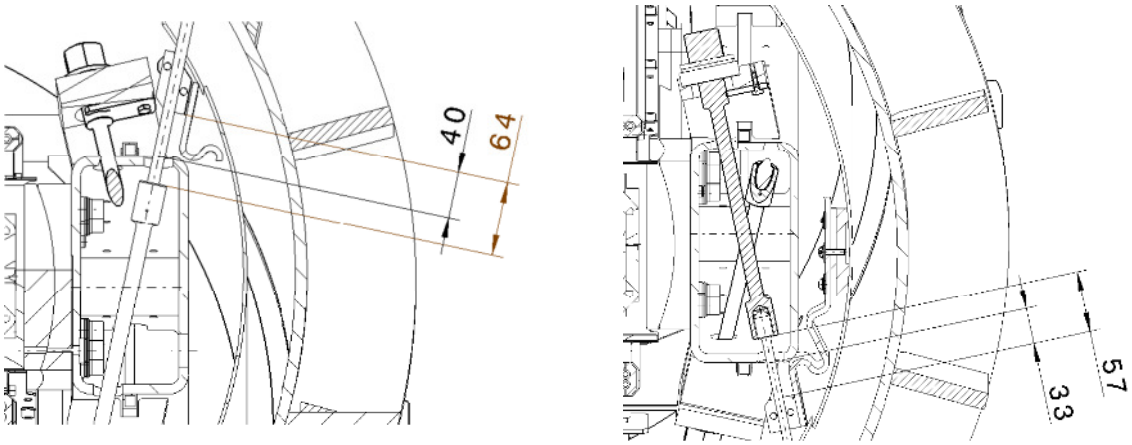



**Figure 5-19 f.i.o:** Cross section of a QDM at the position of a load-rod (left) respectively tie-rod (right) with required distances for fixation of thermalisation straps.

### 5.10.2. Pre-Alignment and pre-stressing of cold mass

Within the pre – alignment process the cold mass must be aligned within the cryostat that way, that later alignment processes of the QDM within the accelerator do not induce overstressing of any components which are connecting adjacent modules. Further on, the pre-alignment process must guarantee the correct settings of pre-stresses and suspension lengths to fulfil the stability requirements to the cold mass position stability.

1) Within the pre – alignment process
   - a reference point representing a midpoint,
   - a longitudinal reference axis,
   - a horizontal reference plane

   of the cold mass must be aligned to
   - a reference point representing a midpoint
   - a longitudinal reference axis,
   - a horizontal reference plane

   of the cryostat vacuum vessel.

Those references are kind of virtual objects, which must be defined by existing objects like end faces, split planes, reference bores, cylindrical surfaces of flanges or other suitable real geometries at the cold mass, respectively the cryostat vacuum vessel.

Pre-alignment and pre-stressing process:

1) During pre-alignment the pre-stress of all suspension rods must be applied and tuned to the required values (see pre-stressing and pre-alignment parameters) to guarantee the cold mass stability after cool down.
2) The pre-stress of the suspension system must be monitored with high accuracy (≤ 0.1% measurement accuracy) during the whole pre-alignment process.
3) All measured values of pre-stress and pre-alignment position must be documented in detail.
4) The pre-alignment process must be developed by the Contractor in detail. All details of the concept, the process and the planning of the complete measurement set-up must be documented and presented 8 Working weeks prior to the planned date of application in production. The according documentation must be handed over to the Company 5 working days prior to presentation.

Pre-stressing and pre-alignment parameters:

1) Reference elements for the magnetic axis and planes of the QP units shall be the 4 reference bores and surfaces at the endplates on both sides of the QP-Magnets.
2) Reference elements for the main axis, which is the ion optical axis, of the cold mass shall be the 4 reference bores and surfaces at the visible upstream- and downstream- located endplates of the QP-magnets of one cold mass.
3) Reference elements for the main axis of a cryostat vacuum vessel shall be the tolerated axis, and surfaces of upstream- and downstream- located main flanges of a QDM.
4) Reference elements for the main planes of a cryostat vacuum vessel shall be the 4 tolerated bores of upstream- and downstream- located main flanges of a QDM, identifying the lateral and vertical axis of a flange.
5) The pre-alignment precision must be at least less then
   - ± 0.5 mm in z – direction for deviation of cold mass center to QDM center on main axis,
   - 1 mm (as defined by [21], coaxiality tolerance of two axis) for deviation of cold mass reference axes to cryostat main axis,
   - 0.5 mm (as defined by [21], parallelism tolerance of two planes) for parallelism of cold mass horizontal reference planes to horizontal QDM main plain.
6) The pre-stress to be applied to a single suspension rod must be in the range of 10 to 11 kN. Due to non-uniform mass-distribution along the axis of the cold mass, different pre-stresses might be required for upstream- and downstream-suspension rods, dependent of the weight load at the according position. The Contractor shall calculate the required pre-stresses for the upstream- and downstream-positions of a module type for optimum horizontal orientation of the cold mass in the unit. Expectable values for upstream- and downstream-pre-stresses are 10 kN ≤ $\sigma_{pre}$ ≤ 11 kN.
7) The required pre-stresses, as calculated, must be applied with an accuracy of $\Delta F_{pre\text{-}stress}/F_{pre\text{-}stress} = \pm 2\%$.
8) A complete documentation of calculation and results for pre-stresses shall be submitted to the Company 8 weeks prior to the planned date of the first application of the pre-stressing and pre alignment process.

## 5.11. Assembly and installation of Local Current Leads

1) The contractor shall be responsible for development of the complete and detailed process of LCL-installation based on the existing technical drawings and the basic descriptions below.
2) The QP-Unit assembly, as supllied by the Company, adapts the cold terminal E to insulated Low Temperature Superconducting (LTS) wire of tubular bus-bar of the QP-unit. This terminal (E) is part of the QP-Unit and shall not be supplied by the Contractor.

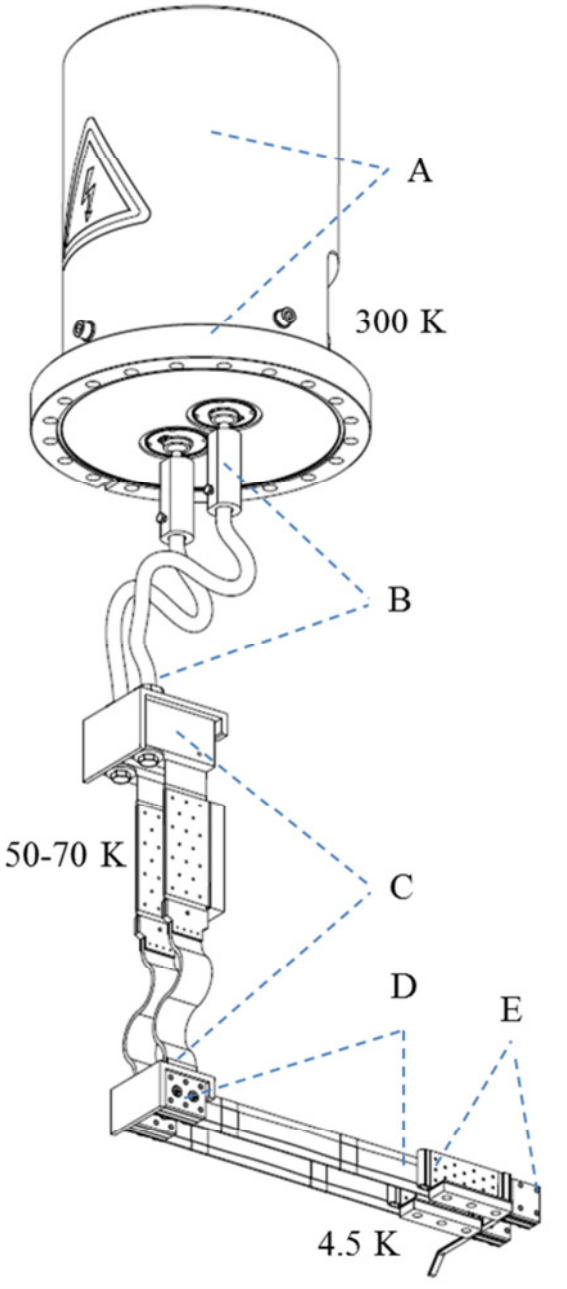



**Figure 5-20:** CAD-Model of a LCL assembly for supply of a SC Chromaticity Sextupole magnet. A - Top hermetic flange with worm terminals and cover. B - Top flexible copper lead between 300 K to top thermal anchor. C - Midle strip copper conductor with thermal anchor at 50-70 K. D - Low thermal conducting composite HTS&brass current lead. E - Cold terminal with thermal anchor and HTS&copper strip.

3) All sub-assemblies A-E (see figure 5-21) must be prepared in clean room and checked for high voltage application up to 1.1 kV (R > 1 GΩ). The electrical connection of sub- assemblies has to be made with screwed contacts of gold plated copper terminals. Gold plated terminals must be protected with adhesive Kapton®-tape before final assembly.
4) Top flange A shall be purchased respectively manufactured as separate part, according to drawing MG-1011668-A-000. All top hermetic insulators of this flange must be tested on vacuum leaks with background of ≤ $10^{-9}$mb*ltr/sec and for high voltage insulation R > 10 GΩ at 1.1 kV during 2 min.
5) The ends of the flexible copper cable B shall be soldered to the top copper fitting and bottom cone fitting, according to drawing MG-1026635-A-000. After soldering and cleaning the flexible copper cable must be wrapped with insulation adhesive Kapton®-tape, in half overlapping wrapping, and must be checked for insulation quality at 1.1 kV (R > 1 GΩ).
6) The intermediate copper part C must be assembled and soldered, according to drawing number MG-1026152-A-000. The heat-sink is made by glued copper strip with 50µm fiberglass cloth and blue epoxy Eccobond-286, cured 24 hrs at room temperature (see figure 5-21).

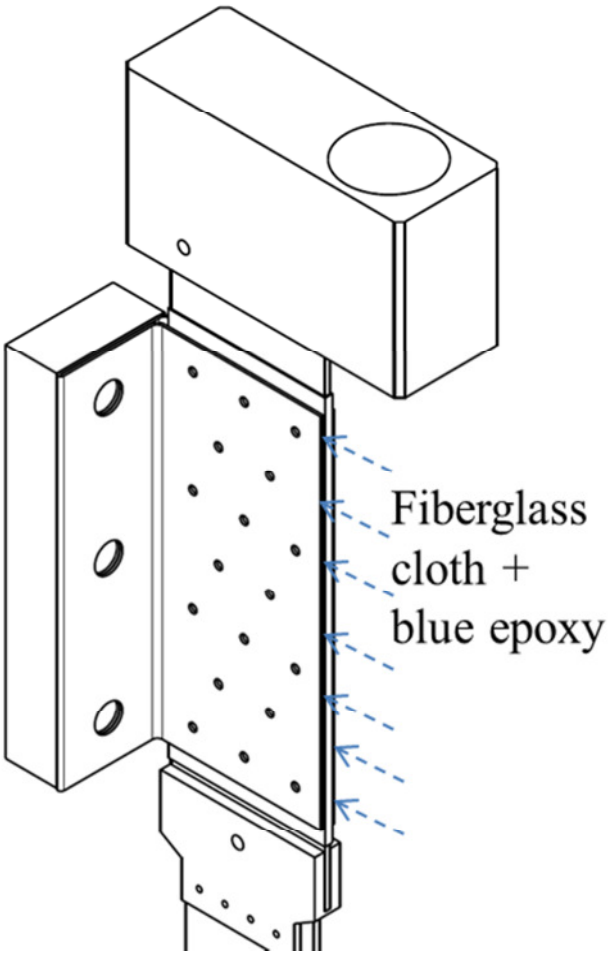



**Figure 5-21:** Heat-sink of copper conductor.

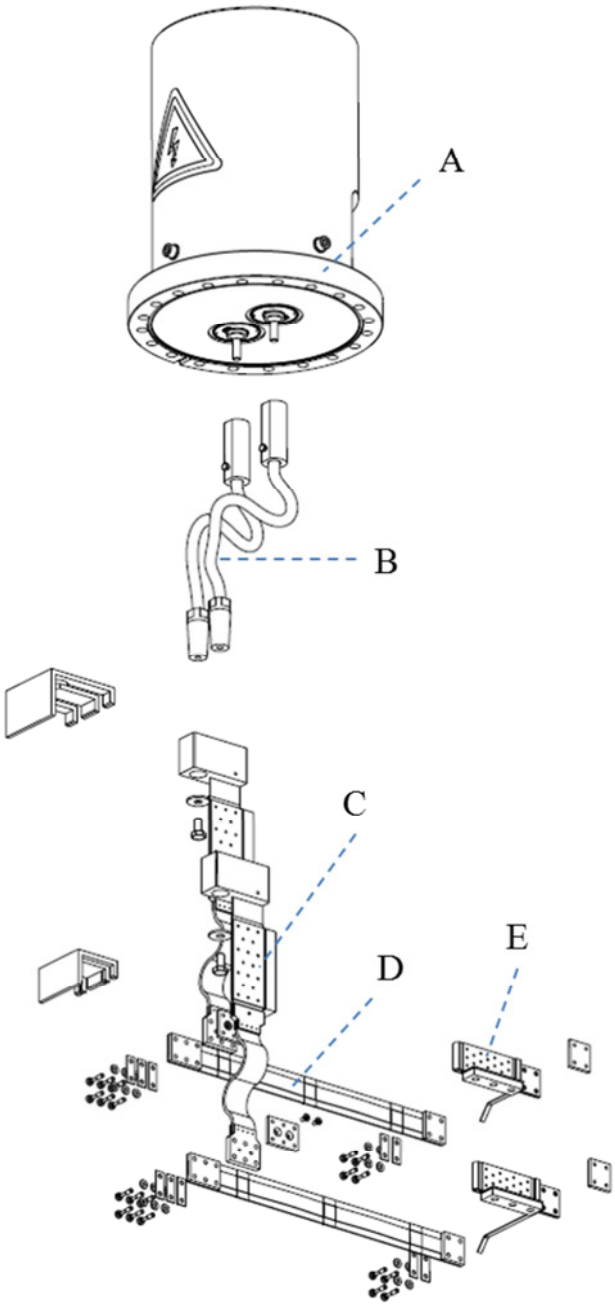



**Figure 5-22:** LCL sub-assemblies parts.

7) For assembly of LCLs, the contractor shall perform processes as follows.
   - Top flexible copper lead B shall be soldered to the finger of worm terminal at the bottom of hermetic flange A.
   - Midle strip copper conductor C will be bolted to the top heat-sink module 50-70 K via thermal pad. The top of the conductor end shall be bolted conical contact of part B.
   - Finally both terminals of HTSC – sub-unit D shall be screwed to the adequate terminals of parts C, E.
   - As final test the high voltage insulation up to 1.1 kV (R > 1 GΩ) shall be proven for each single LCL.

## 5.12. 3D-coordinate measurement and fiducialisation

1) The reference bore holes in the end plates of each single quadrupole magnet, as well in other magnets, hold the essential information about the position and orientation of its magnetic and mechanical axis. The Contractor is obliged to relate all reference bore holes of all magnets included into one cryostat
   a) to each other – *after* assembling and alignment of the quadrupole magnets et al on the common girder without thermal shield and cryostat vessel
   b) to the outer cryostat fiducials - *after* final installation and alignment of the girder into the cryostat vessel

   by precise 3D measurements, after unit assembling and alignment of the girder and after final integration into the cryostat, with an accuracy of 0.1mm (1σ). This shall be done by a laser tracker according to generally acknowledged rules of high precision measurement techniques. It is to be documented as a set of 3D coordinates for all reference bore holes of each magnet end plate and for all fiducials placed on the cryostat finally within one unique coordinate system (component coordinate system, see F-TG-A-3.68e [20]), valid for one single QDM.
2) The coordinate system to be used shall be agreed with the Company in writing.
3) All measured points must get names according to a defined system, which will be specified by the Company. This is essential to be able to process the data for alignment purposes in a useful way. The final naming must be given in a sketch that is included in the measurement protocol with the measured coordinates. Furthermore, the names of the points must be made visible by stickers at least for the cryostat fiducials.
4) Each individual QDM shall be processed as defined above.
5) After these measurements no changes of the position of magnets and girder with respect to the cryostat shall appear. The 3D information of the cryostat fiducials (and with this the position of the hidden quadrupole and other magnets) will be used for final alignment of the QDM within the SIS100 tunnel.
6) A written detailed work instruction including a template for the measurement protocol with work description, results and accuracies is to be submitted to the Company as early as possible but at the latest 4 weeks before starting these 3D measurements.
7) All measurement protocol for each QDM shall be submitted to EDMS (see section 7.3) right after individual measurements. It is not allowed to wait until final delivery of a QDM.

## 5.13. **Labeling**

### 5.13.1. Label plates for complete Modules

1) All SIS100-QDM must be equipped with a label plate. Such label plate has to show at least the following information:
   - all information according to the requirements of [5]
   - a CID-code as human readable number and as machine readable QR-Code according to the requirements of [17] and [18]
   - all required basic information on integrated active components (see figure 5-23)

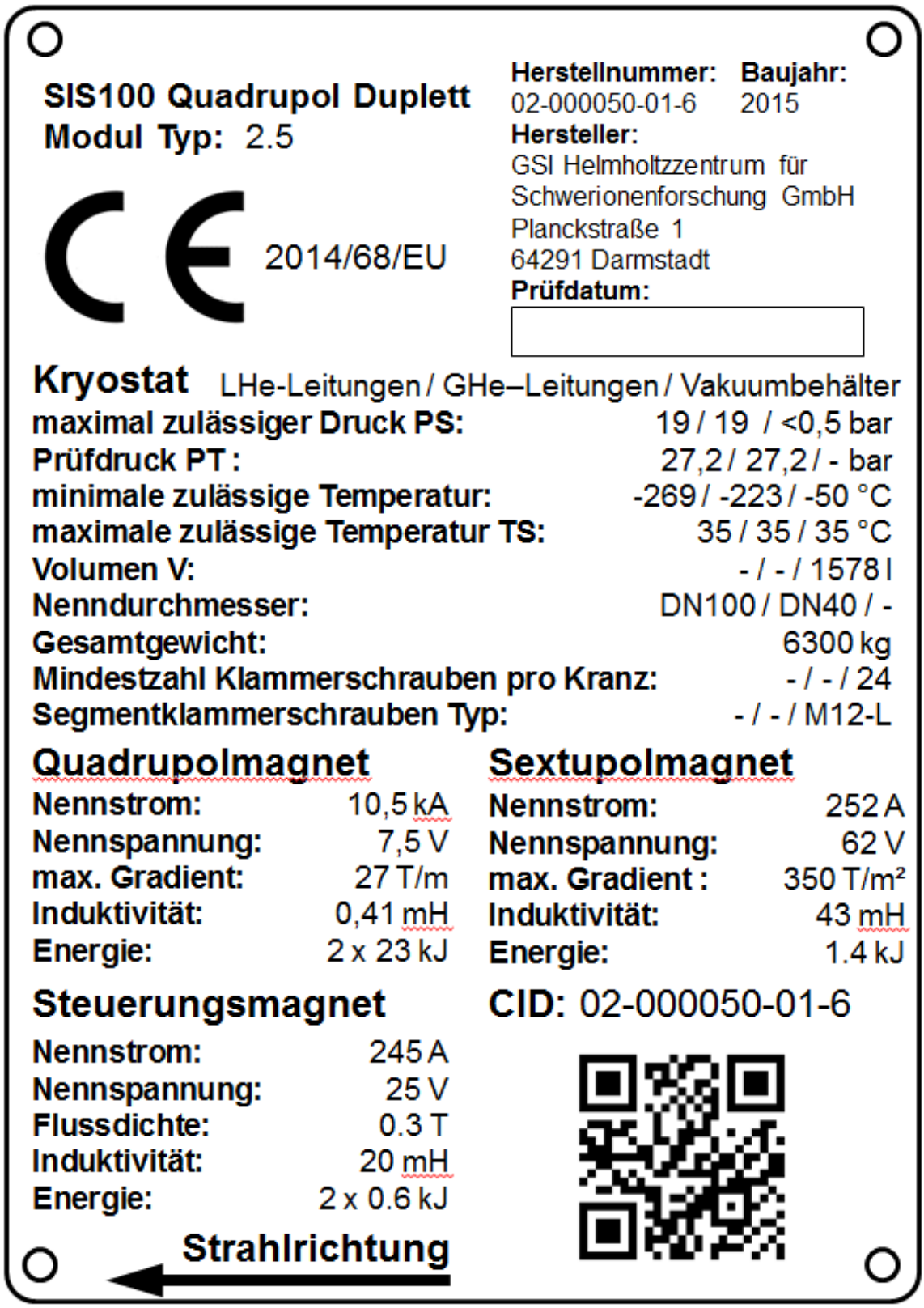



**Figure 5-23 f.i.o.:** Example for content of a label plate of a complete SIS100-QDM

2) The detailed content for basic information on all integrated components of a QDM shall be provided by the Company latest 3 month prior to application of the label to a module. The Contractor shall announce the date of for application of the label plate to the Company 4 month in advance to application.

### 5.13.2. CID – labeling and CID-registration

1) A dedicated and unique CID-Code shall be assigned to all completed QPMs. This CID code shall be applied at the outer label plate.
2) The CID-Codes of all components, installed in one QDM shall be registered in an adequate Structure for input into a component database at the Company. A typical tree-structure of CID-codes for a QDM is shown in figure 5-24

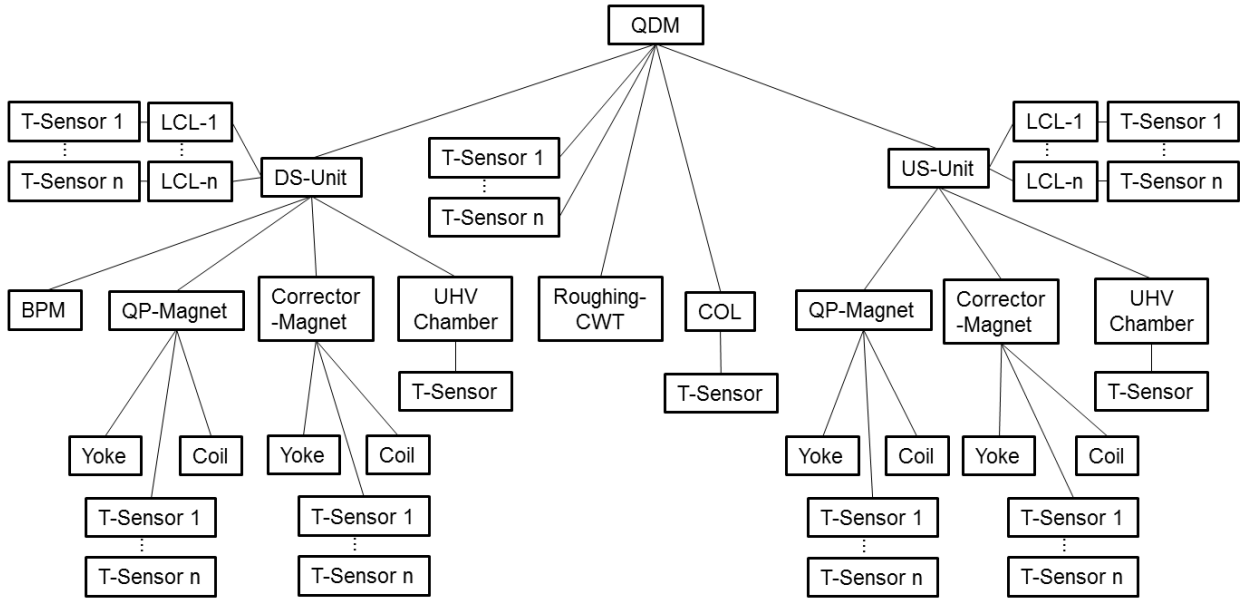



**Figure 5-24:** CID-Data structure of a complete QDM by example of an SIS100-arc-section module. Other configurations of SIS100-QDM are showing deviant CID-Data-trees.

3) The Contractor shall prepare a CID-data structure-tree for each configuration of SIS100-QDM. This structure must be applied to the according CID-data-file.
4) All components as defined by the CID-data structure and not being delivered with a CID-Code assigned, shall be marked with a CID-Label plate. For details see technical guideline [17].
5) For registration in a component data base at the Company, each single CID-Code, being assigned to all sub-components, shall be listed in the documentation file of the specific QDM.
6) A separate CID-Data-file shall be delivered for each single SIS100-QDM together with the complete documentation. The structure of the CID-Data-file shall be agreed with the Company prior to application.

### 5.14. Packaging, shipment, transportation and storage

1) The Contractor shall be responsible for safe packaging, shipment, transportation and storage of QDMs until the final transfer of perils.
2) The contractor shall fulfil at least the requirements as defined by [60].
3) The Contractor shall be responsible for the correct functionality of all applied transportation locks and safeguarding equipment for shipment, transportation and storage as long as applied correctly according to documentation and manuals, to be prepared by the Contractor.
4) The Contractor shall prepare a complete set off documentation in terms of packaging, shipment, transportation and storage according to the requirements of [5] and according technical guidelines being cited herein.
5) The following set of engineering drawings, respectively CAD-Models are proposals by the Company only. The Contractor shall be responsible for engineering, design, manufacturing and application of the components for packaging, shipment, transportation and storage.
   - Transportation lock - SIS 100 – QDM: KW-1014368-A-000
   - Internal transportation locks: KW-1017028-A-000
   - Protection Cap: KW-1016286-A-000
6) The Contractor shall deliver all documentation in terms of CE (machinery directive) , in case any transportation tooling shall be applied as lifting gear.
7) The transportation shall fulfil at least the following requirements:
   - All input loads (acceleration in m/s²), acting at the base of the transportation tooling shall, be damped to a max. remaining acceleration of $a_{max}$ <= 2*g = 2*9.81 m/s² in the centre of mass of the QDM for all directions (X, Y, Z).
   - The layout of the support system for dynamic damping-characteristics shall be based at least on the following data: acceleration of 1 g (= 9.81 m/s²), Vibration amplitude of 1.6 mm, vibration frequency range of 3 – 90 Hz.
   - For further information on support tooling layout for the SIS100-QDM, arc section types see [284].
8) In case the Contractor finds higher input loads within its risk-analysis, such shall be applied for the design of the transportation protection system.
9) In case any transportation tooling must not be applied as lifting gear, adequate design and labelling shall impede improper use.

## 6. Quality assurance, tests, and acceptance

### 6.1. Quality assurance system of the Contractor

1) The basic requirements to quality assurance at the Contractor are defined by [1], section 5.. Regulations as defined by [1] must be adhered without exception.

### 6.2. Quality inspection and production planning

1) Prior to any production, the Contractor shall prepare a detailed quality assurance plan for the whole production. By this QA-Plan, the contractor shall prove the reliability of all production and testing processes.
2) For planning and controlling all production processes so called Qaulity Inspection and Production Plans (for information see [286] and [287]) shall describe each single production

process (e.g. assembly, integration and testing e.g. BPMs) as detailed as required, to guarantee reliable and reproducible production for all QDMs.

3) QIPPs shall be prepared for all relevant processes and shall be applied during production to all products being built. The production of each product shall be documented within its production process by applying a QIPP for each product.
4) The QIPPs shall at least include all Basic information for a product (e.g. CID, serial number, drawing number etc.).
5) The QIPPs shall at least include all relevant single production steps and testing procedures, stating all important specified values of relevant parameter and the correlating test result as well as an adequate signing of workman and inspector. Further on, a QIPP shall define actions like notifications and reporting to the company, approval by the Company etc.
6) A QA-plan shall cover at least the following processes, with QIPPs for each process:
   - completion of partly assembled QP-magnet-units with corresponding UHV components and BPMs by applying the required mechanical assembly, welding- and brazing processes,
   - installation and alignment of QP-magnet-units into common girders to build the cold masses,
   - completion of UHV-systems in the cold masses with corresponding UHV components by applying the required mechanical assembly processes and welding- and brazing processes,
   - installation and completion of the cryogenic systems of the cold masses,
   - installation and wiring of all instrumentation according to the instrumentation planning lists, specifications and technical guidelines,
   - assembly of all thermal shields and all cryostats,
   - mounting, pre-alignment and pre-stressing of the cold masses in the cryostats,
   - completion of the UHV system with CWTs,
   - application of CID-labels to all component requiring a CID,
   - assembly and installation of LCLs from electrical connection boxes to cold terminals,
   - required cleaning processes, where ever needed.
7) All QIPPs shall be reviewed by the company. Production must not be started start without approval by the Company of the QA-Plan and all relevant QA-related documentations.

### 6.3. **Incoming goods inspection**

1) All components and assemblies, being delivered by the Company, are undergoing an acceptance test before delivery to the Contractor. Acceptance test or quality documentation (e.g. SAT-protocol or quality certificate) will be delivered to the Contractor together with components or assemblies.
2) The contractor shall apply an incoming goods inspection for all components and assemblies, at least as defined by 6.3.1.
3) To exclude transportation damage on coils and bus bars, the contractor shall apply testing of electrical integrity on coils and bus bars as defined by [31] at incoming goods inspection.
4) The contractor shall be responsible for planning and application of any further incoming goods inspection.
5) In case, further information on testing parameter for more detailed incoming goods inspection is needed, the Contractor may request such information at the Company in writing.
6) All applied incoming goods inspection must be documented in detail.

7) The planning of incoming goods inspection shall be introduced to the Company at least 8 weeks prior to start of production.

#### 6.3.1. General test procedures

1) The following checks must be performed in general for all deliveries:
   - transportation packaging shall be checked for visible damages and contamination,
   - transportation-data-logger or any tilt-, humidity-, shock-indicators must be readout,
   - number of delivered components must be checked for completeness,
   - documentation as specified for any supply shall be checked for completeness and correctness,
   - packaging shall be checked for integrity,
   - packaging shall be checked for cleanliness,
   - Visual check for overall integrity and undamaged functional elements,
   - CID-code of components shall be checked for correct assignment to serial-number (or equivalent).
2) In case of damaged or contaminated packaging or conspicuously high read-out of transportation-data (shock, tilt, humidity etc.) is registered, a very detailed inspection of affected components must be performed.
3) In case of any non-conformity is recognised during incoming goods inspection, the Contractor shall prepare according documentation and shall inform the Company as defined by section 6.5.

### 6.4. **Tests and measurements during production**

1) The Contractor shall apply all required test and measurements as defined in according quality inspection plans.
2) Besides any tests and measurements as defined by section 4.3.12, further tests and measurements shall be applied during production, at least as defined within this section.
3) Results of these tests and measurements shall be documented in detail.
4) Sensitive components shall be tested also in between production processes for certain properties. In case any damage is recognised, a NCR according to section 6.5 shall be prepared.

#### 6.4.1. Electrical testing during production

1) Electrical integrity tests for
   - coil and bus bars,
   - instrumentation

   as defined by [31] and [22] shall be applied also during the integration processes.
2) Electrical integrity tests for coil and bus bars shall be applied
   - after brazing or welding close to temperature sensitive components was performed,
   - after mechanical integration into the cold mass.
3) Electrical integrity tests for instrumentation shall be applied
   - prior to cold mass integration of QP-magnet-units,

- after mechanical integration of QP-magnet-units into the cold mass,
- prior to final connection of signal cabling to feed through soldering pins,

#### 6.4.2. Dimensional tests of components and assemblies

1) All functional- and test dimensions of assemblies, built in the course of production, shall be tested and documented prior to further processing.
2) Components or assemblies, showing dimensions, deviant from specification or definitions in engineering drawings shall not be applied for further processing. Adequate measures, e.g. NCR or replacement, shall be applied.

#### 6.4.3. Cleanliness

1) During all single production steps, all components and assemblies shall be carefully protected from any contamination. The Contractor shall check all components for contamination prior to and after each production step.
2) In case of any contamination is registered, it must be removed residual-free.
3) In case a contamination cannot be removed residual-free, an NCR must be prepared according to section 6.5.

### 6.5. **Registration and Handling of non-conformities**

1) Each non-conformity according to
   - any specification,
   - any technical guideline,
   - any engineering drawing

   of
   - of any material,
   - any part, component or assembly,
   - any measurement,
2) shall be registered in an adequate form and shall be communicated immediately to the quality assurance department of the Company.
3) Contamination of any kind, which cannot be removed residual-free must be also handled as non-conformities.
4) For detailed requirements on handling non-conformities see section 4.2. in [26].

### 6.6. **Factory Acceptance Test (FAT)**

1) FAT as defined in following sections shall be applied to all QDM being manufactured within FoS- and series production.
2) For planning and preparation of FAT, the Contractor shall work through all relevant detailed specifications and technical guidelines to identify detailed requirements of FAT. All planning shall be based on the documentation referred to in these documents, all subsequent documentation, respectively technical guidelines cited herein.
3) The Contractor shall perform the development and procurement of required testing equipment. The company will not supply any setup for any testing procedure.

4) Any special design of test setups, being developed by the Contractor shall be presented and reviewed by the company, prior to procurement and application. Any test setup, not being released for application in FAT must not be applied for testing. For details on applicable review processes see [19].
5) FAT in terms of testing the cryogenic module shall be performed according [34] and subsequent documents.
6) The minimum requirements to the FAT are defined by Table 6-1 below.
7) A final version of the full definition of FAT shall be prepared during the negotiation in the tendering process and shall be defined as addendum to a contract.

**Table 6-1:** Overview table on FAT processes of a SIS100 QDM at the Contractor

| No. | Detailed description | Test value | In case of fail | Reference |
|---|---|---|---|---|
| | **Documentation** | | | |
| 1.1 | Documentation check for completeness of all documentation of integrated components (BPM, COL, VC, LCL, CAP, Instrumentation). | complete | reject, obtain documents | |
| 1.2 | Documentation check for completeness of all required documentation | complete | reject, obtain documents | [33] and subsequent |
| 1.3 | documentation check for completeness of documents in terms of CE | complete | reject, obtain documents | [5], [7], [8], [33] |
| 1.4 | Check of documentation of CID-Data for completeness and correctness | complete, correct | reject, complete, apply corrections | Section 5.13.2 |
| 1.5 | checking documentation of all joining processes (welding, soldering) applied | existing | reject, obtain documents | Section 5.8.6 |
| 1.6 | check documentation of QP-magnet-unit alignment in cold mass for completeness | complete, correct | reject, complete, apply corrections | Section 5.8.2 |
| 1.7 | Check documentation of 3D-coordinate measurement | complete, correct | reject, complete, apply corrections | Section 5.11. |
| | Completeness | | | |
| 2.1 | Visual check for completeness of module and components | complete | reject for rework | according assembly drawing and part lists |

| No. | Detailed description | Test value | In case of fail | Reference |
|---|---|---|---|---|
| | **Fiducialisation and pre-alignment** | | | |
| 3.1 | Proof of orientation and pre-stress of cold mass in vacuum vessel according section 5.11.:<br>error of koaxiality | according documentation.<br>1 mm (according [21], koaxiality) | reject, re-align | Section 5.10.2, [21] |
| 3.2 | Proof of fiducialisation measurement of cold mass<br>(AFTER UNIT ASSEMBLING AND ALIGNMENT ON THE GIRDER AND AFTER FINLA INTEGRATION INTO THE CRYOSTAT) | correct | reject, re-check | according protocol, Section 5.11. |
| | **Damages** | | | |
| 4.1 | Check for visual damages | not existent | reject for replacement | according assembly drawing and |
| 4.2 | Check accessible UHV sealing surfaces for damages | not existing | reject for replacement | |
| 4.3 | Check all flanges of insulation vacuum system for damages | not existing | reject for rework, replacement | |
| | **Cleanliness** | | | |
| 5.1 | cleanliness check of complete module | clean | reject for cleaning | [38] |
| 5.2 | Continuity check of thermal shield cooling system | free from blockage | reject for cleaning, replacement | |
| | **Electrical tests** | | | |
| 6.1 | Check of all temperature sensor instrumentation for warm resis-tance by 4 wire measure-ment | Resistance as prior to installation | reject for rework, replacement | [22] |
| 6.2 | Check for electrical integrity of Magnet and Bus Bar system:<br>Test voltage (max)<br>Resistance to ground | for details see [31] and [14] | reject for rework, replacement | [31], [14] |

| No. | Detailed description | Test value | In case of fail | Reference |
|---|---|---|---|---|
| | Duration period<br>(for details see [31] and [14]) | | | |
| 6.3 | Check temperature sensors for electrical insulation:<br>Test voltage<br>Resistance to ground<br>Duration period | = 100 VDC<br>≥ 100 MΩ<br>≥ 120 s | Reject for rework, replacement | section 4.9 in [31], |
| 6.4 | Check the LCL insulation resistance to ground | R > 1 GΩ at 1.1 kV | Reject for rework, replacement | Table 4-3 |
| | **Vacuum testing** | | | |
| 7.1 | Testing the UHV system:<br>Integral He-leak rate<br>ultimate pressure<br>residual gas composition<br>outgassing rate | ≤ $10^{-10}$ mbar*l/s<br>≤ $10^{-8}$ mbar<br>for Spectra see [43]<br>≤ $5*10^{-10}$ mbar*l/(s*cm$^2$) | reject for rework, replacement, cleaning | [32], [43] |
| 7.2 | Testing the insulation vacuum system:<br>Integral He-leak test<br>Single He-leak test<br>residual gas composition<br>Testing the cryogenic system | ≤ $10^{-7}$ mbar*l/s<br>≤ $10^{-9}$ mbar*l/s<br>for Spectra see [39] | reject for rework, replacement, cleaning | [39] |
| 8.1 | Flowrate test of the complete 4K-He-cooling system (magnet cooling, VC cooling) | Expected mass flow from calculation (to be agreed with Contractor) | reject for rework, replacement, cleaning | [29] |
| 8.2 | pressurised leak test of He-cooling system (4K-cooling system, shield cooling system):<br>design pressure PS<br>acceptable pressure drop | 20 bar(absolute)<br>≤ 20 mbar after 24 h | reject for rework, replacement | [30] |
| 8.3 | Integral He-leak test of He-cooling system (magnet- and VC-cooling):<br>Integral He-leak rate | ≤ $5*10^{-8}$ mbar*L/s | reject for rework, replacement | [39] |
| 8.4 | integral He-leak test of thermal shield-cooling system | ≤ $2*10^{-10}$ mbar*L/s | reject for rework, replacement | [28] |
| 8.5 | Residual moisture test of He-cooling systems (magnet-, VC-cooling and | 5ppm $H_2O$ | reject for cleaning | [35] |

| No. | Detailed description | Test value | In case of fail | Reference |
|---|---|---|---|---|
| | thermal shield cooling) | | | |
| 8.6 | Single He-Leak test of complete insulation vacuum system:<br>Singel He-leak rate: | ≤ $10^{-9}$ mbar*L/s | reject for rework, replacement | [36] |
| | **Tests in terms of CE** | | | |
| 9.1 | Check label plate for existence and correctness | Existing, correct | reject, install, replace | Section 5.13.1 |
| 9.2 | Pressure test of all pressurised systems in terms of CE<br>Test parameter: | according [7] and [8] | reject for replacement | [7], [8] |
| | **Packaging and transportation checks** | | | |
| 10.1 | Check for correct installation of transportation locks | complete, correct | reject for completion, rework | According engineering drawing, [37] |
| 10.2 | Check for correct application of desiccant | complete, correct | reject for completion, rework | According engineering drawing, [37] |
| 10.3 | check for complete and correct application of transportation protection caps | complete, correct | reject for completion, rework | According engineering drawing, [37] |
| 10.4 | check of correct application and activation of transportation data logging systems | correct, active | reject for correction, activate | [37] |

### 6.7. **Site Acceptance Test *(SAT, for information only)***

Site acceptance test will be performed at least with a certain amount of samples of all QDMs according to [281]. *Testing of modules will be performed by the company.* The site acceptance tests of modules imply at least the following tests and procedures:

- incoming goods inspection (warm testin),
- geometrical dimensions and toelrances (warm testing),
- leak rate of the helium cooling circuit (warm testing),
- static heat load (cold testing),
- electrical integrity of all power circuits (warm and cold testing),
- power tests of the corrector magnets (cold testing),

- power tests of the main quadrupoles (cold testing),
- electrical tests of the beam position monitor (warm and cold testing),
- measurement of the hydraulic resistance (warm and cold),
- validation of temperature sensors (warm and cold testing),
- tests of the cryo-catcher (warm and cold testing),
- vacuum tests of the beam chambers (warm and cold testing).

# 7. Documentation

1) All documentation must be prepared in German or English language.
2) Any documentation, required by an applicable CE – regulation (e.g. 2014/68/EU), must be unconditionally prepared and delivered in proper German language.
3) Any documentation not being prepared in German or English language will be rejected and must be delivered as a certified translation in German or English.
4) In case of any certificates (e.g. welder certificates) are existing in a language other than German or English, they must be delivered as certified translation into German or English.
3) During the processes of engineering, production and quality assurance all important developments and results must be documented in detail. Those documentations are part of the deliverables as listed by section 0.

## 7.1. **Deliverable documentation**

1) A complete set of applicable documentation as defined by [1] and [5] (and subsequent documents) shall be delivered without reservation.
2) In case any re-design of any component or assembly is required, a full set of documentation in terms of [1] and [5] shall be delivered for the design-change.
3) In case any re-design of any component or assembly is required, the regulations of [2], [3] and [4] must be adhered and applied.
4) A full set of documentation shall be delivered for each QDM for all
   - incoming goods inspection of each tested component of a QDM,
   - testing during completion of assembly of QP-magnet-units,
   - testing during assembly of the cold mass,
   - testing during installation and testing of instrumentation,
   - testing during production and assembly of thermal shield,
   - testing during production and assembly of complete cryostat,
   - testing during production and assembly of complete QDM,
   - certification of any purchased components for production of the QDM,
   - process documentation of all applied joining processes (welding, brazing, soldering, EMP-welding, gluing etc.)
   - process of pre-stressing the cold mass suspension system,
   - processes of alignment of QP-magnet-units within the cold mass,
   - 3D-measurements for fiducialisation of magnets, cold mass and QDM,
   - documentation an electronic data file of CID – labelling and CID-registration,
5) A full set of documentation on the FAT for each single QDM shall be delivered.

6) A full set of documentation on packaging, shipment, transportation, storage planning shall be delivered as defined by [37].
7) All data from data logging systems for monitoring of shipment processes shall be delivered for each single QDM.
8) A full Documentation in Terms of CE, especially in terms of PED 2014/68/EU [7] shall delivered for each single QDM.

#### 7.1.1. Requirements on engineering documentation

1) In case of any development and design must be performed by the manufacturer, the manufacturer shall deliver all relevant engineering documentation, as listed within the correlated common and detailed specifications, being relevant for such components.
2) All Engineering documentation of the component design must be delivered latest 2 weeks in advance to a planned design reviews.
3) The complete Engineering documentation for packaging and transportation system must be delivered completely 4 weeks in advance to the factory acceptance test.

#### 7.1.2. Requirements on production related documentation and QA documentation

1) A copy of all production documentation templates within their final status, such as e.g. control plans for dedicated components, must be delivered to the Company latest at 2 weeks in advance to the planned date of production start.
2) During production, the manufacturer shall prepare adequate reports for all testing and measurement processes to fulfil the requirements of quality assurance. All original versions of such test records must be collected in one folder; a production file; per QP-Doublet-Module must be delivered together with the corresponding QP-Doublet-Module, latest at the date of the FAT for the dedicated device.
3) Production files must be assigned to each QP-Doublet-Module by referencing the serial number of the dedicated QP-Doublet-Module.
4) Each production file must be well organised and must show a table of content. The organisation of the production files must be agreed with the Company.

#### 7.1.3. Requirements on testing and production process documentation

1) All testing before, during and after production must be documented in dedicated forms.
2) Testing forms must show at least
   - Date of testing / production,
   - serial number of tested / produced component,
   - CID number of tested / produced component (if existing),
   - reference number of process documentation for applied testing / production procedure,
   - name of testing / production personnel,
   - reference numbers of testing / production tools,
   - nominal values,
   - acceptance criteria,
   - measured values,
   - result of test evaluation,
   - signature of testing / producing personnel.

3) In case of contaminations or damages, documentation by photography must be prepared and taken to the production file.
4) All test results and raw data according to specified format of dedicated tests must be stored as digital data.

#### 7.1.4. Requirements on documentation of joining processes

1) For all joining processes at least the following information must be provided:
   - preparation of component interfaces prior to joining,
   - filler an auxiliary materials,
   - detailed process parameter.
2) For QA documentation of an interconnection
   - all nominal values and actual values of process parameter,
   - all test results for the interconnection,
   - producer, brand name and lot numbers of filler and auxiliary materials

   shall be documented in detail.
3) In case of interconnections of pressurised components and components, being part of a pressurised system, all documentation requirements in terms of [7] and [8] shall be documented in detail.

#### 7.1.5. Requirements on FAT documentation

1) The Contractor shall prepare a complete set of templates and a dummy sample of the folder as planned to be used for the FAT. Such folder shall be delivered, to the Company, 8 weeks in advance to the planned date of start of the very first FAT.
2) The structure of the templates and the folder shall be agreed with the Company in writing and shall be applied to all FAT processes.
3) In case a need for change of these structures is required by any party, this shall be announced by an ECR.

#### 7.1.6. Requirements on documentation in terms of CE

1) In case any component of a QDM or the complete QDM is subject to any CE directive, all documentation as defined by the corresponding CE directive must be delivered.
2) In case of engineering documentation, prepared by the Contractor, are requested by any CE regulation, the Contractor has to deliver these documents completely for the components which were designed by the Contractor.
3) At least the following documentation must be delivered for each QDM:
   - Welder certificates of all welders being involved in production,
   - Material certificates, as defined by DIN EN 10204, certificate type 3.1, for all materials in use for production.
   - a list of standards in terms of production, as referred to in pressure equipment directive 2014/68/EU, applied in full or in part, and a description of the solutions adopted to meet the essential requirements of the directive where the standards referred to have not been applied,
   - Test reports, especially for welding and pressure testing.

- Documentation, being delivered, must fulfil the requirements of the applicable CE directives and the applicable standards for the corresponding device or component (e.g. 2014/68/EU, AD2000).

#### 7.1.7. ECRs and NCRs

1) Each single engineering change request must be handled, documented and delivered as defined by [27]. As a document template for preparation of an Engineering Change Request, the template [271] shall be applied.
2) Each single non conformity report must be handled, documented and delivered as defined by [26]. As a document template for preparation of an Engineering Change Request, the template shall be applied. As a document template for preparation of a Non Conformity Report, the template [272] shall be applied.

### 7.2. **Planning and reporting on production**

3) The Contractor shall provide a production plan as MS-Project file with a monthly update.
1) The Contractor shall prepare a report on production every two working weeks, showing at least
   - statistics on production and procurement of sub-components, sub-assemblies and completed, respectively tested QDMs,
   - status of existing non-conformities,
   - current problems in production,
   - solutions for problems in production,
   - expected bottlenecks and solutions to overcome bottleneck situations,
   - current status of shipment of QDMs.

### 7.3. **Up-load of documentation to EDMS and release procedure at EDMS**

1) Beneath the documentation in writing, also an electronic copy of all documentation shall be up-loaded to the web-based data-management system EDMS.
2) The Company shall provide a number of EMDS accounts to the Contractor, for up-loading and organising data in EDMS.
3) The Company shall provide an appropriate project folder structure in EDMS for engineering and production data management.
4) The details on organisation of EDMS documents shall be agreed with the Company in writing.

#### 7.3.1. Document organization in EDMS

1) The Contractor shall perform an adequate organisation of documents in EDMS to guaranty, that all documentation according single components, assemblies or procedures can be found easily in EDMS during and after fulfilment of the contract. Therefor an adequate document management shall be applied by the Contractor.
2) For proper management of any documents in EDMS, the Contractor shall follow at least the these guidelines:
   - To each component or assembly, being processed during production, an EDMS-container shall be assigned to, as long as there is none,

- Each EDMS-container, a document is uploaded into, shall be marked with the according CID-code of the component it is dedicated to, if a CID-code is assigned to this object,
- Whenever components or assemblies are assembled to a resulting major assembly (completed unit, cold mass, thermal shield etc.), an EDMS-equivalent to this assembly shall be created in EDMS by creating an according container,
- All documents, respectively EDMS-containers representing real components shall be assembled, equivalently to the real assembly, by applying the EDMS-sub-document-feature.

3) Document management strategies and single procedures must be agreed with and approved by the Company.

#### 7.3.2. Document release in EDMS

1) The Contractor shall initiate an EDMS-based engineering-check, respectively adequate release-procedure for each set of documentation being delivered.
2) No set of documents will be accepted by the Company, which was not fully released in EDMS.

# 8. Related Documents

## 8.1. Mandatory specifications, norms and standards

[1] MANDATORY: FAIR General Specification, F-GS-F-01e, General Specification for the FAIR Accelerator Facility Project, EDMS-ID 1365092

[2] MANDATORY: FAIR Technical Guideline, Design Guideline of the Department Mechanical Design, EDMS-ID 1229367

[3] MANDATORY: FAIR Technical Guideline, Data Exchange Guideline of the Department Mechanical Design, Part 1: Basis Document, EDMS-ID 1229366

[4] MANDATORY: FAIR Technical Guideline, Data Exchange Guideline of the Department Mechanical Design, Part 2: Short Infos and Checklists, EDMS-ID 1259954

[5] MANDATORY: FAIR Common Specification, F-CS-CR-01e, Common Specification for Cryostats of Cryogenic Modules in FAIR Accelerators, EDMS-ID 1174184

[6] MANDATORY: FAIR Common Specification, F-CS-MT-04e, Common specification of the cooling system of the superconducting SIS 100 magnets, EDMS-ID 1274168

[7] MANDATORY: Directive 2014/68/EU of the European Parliament and of the council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment, European Parliament and Council, Brussels, Belgium, 2014-05-15, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0068&from=DE

[8] MANDATORY: AD 2000-Code, Beuth Verlag GmbH, Berlin, Germany, 2015

[9] MANDATORY: FAIR Detailed specification, F-DS-MT-71e, Detailed Specification of the Cooling System of the Regular Arc Quadrupole Modules for SIS100, EDMS-ID 1275675

[10] MANDATORY: FAIR Detailed specification, F-DS-MT-79e, Detailed Specification of the Cooling System of the Quadrupole Modules in the Straight Sections of SIS100, EDMS-ID 1346794

[11] MANDATORY: FAIR Detailed Specification, F-DS-MT-83e, Detailed Specification of the Cooling System of the Arc Termination Quadrupole Modules for SIS100, EDMS-ID 1532603

[12] MANDATORY: FAIR Detailed Specification, F-DS-MT-110e, Detailed Specification of SIS100 γ-t-Jump Quadrupole Current Leads

[13] MANDATORY: FAIR Detailed specification, F-DS-MT-108e, Detailed specification of instrumentation for SIS100 Quadrupole-Modules, EDMS-ID 1561225

[14] MANDATORY: FAIR Detailed Specification, F-DS-MT-80e, Bus-Bars and Voltage Taps in the SIS100 Quadrupole Modules, EDMS-ID 1173079

[15] MANDATORY: FAIR Detailed Specification, F-DS-MT-55e, Detailed specification for stand for arc end Quadrupole doublet modules for SIS 100, EDMS-ID 1357119

[16] MANDATORY: FAIR Detailed Specification, F-DS-MT-54e, Alignment feet for SIS 100 QP and DP, EDMS-ID 1178259

[17] MANDATORY: FAIR Technical Guideline, F-TG-MT-8.0e, Label plates used for designation of components in superconducting magnets, EDMS-ID 1382612

[18] MANDATORY: FAIR Technical Guideline, F-TG-B-0.5e, Permanent Tagging and Labelling of Components, EDMS-ID 1229368

[19] MANDATORY: FAIR Procedure, Q-VA-QA-0006, Design Reviews (CDR, PDR, FDR und MDR), EDMS-ID 1514206

[20] MANDATORY: FAIR Technical Guideline, F-TG-3.68e, FAIR related coordinate systems, EDMS-ID 1172944

[21] MANDATORY: DIN EN ISO 1101: Geometrical product specifications (GPS) - Geometrical tolerancing - Tolerances of form, orientation, location and run-out, Beuth Verlag GmbH, Berlin, Germany, 2015

[22] MANDATORY: FAIR Technical Guideline, F-TG-K-7.40e, Temperature sensor delivery and installation check, EDMS-ID 1562865

[23] MANDATORY: FAIR Technical Guideline, F-TG-K-3.52e, Temperature Sensors for Cryogenic Purposes, EDMS-ID 1172141

[24] MANDATORY: FAIR Technical Guideline, F-TG-K-3.56e, Low Power Cabling for Cryogenic Purposes, EDMS-ID 1172145

[25] MANDATORY: FAIR Technical Guideline, F-TG-K-13.5e, Temperature sensor Installation for cryogenic purposes, EDMS-ID 1172858

[26] MANDATORY: FAIR Procedure Document, Q-VA-QA-0030, Umgang mit Qualitätsabweichungen, EDMS-ID 1503121

[27] MANDATORY: FAIR Procedure, Q-VA-CM-0011, Change Management, EDMS-ID 1387517

[28] MANDATORY: FAIR Technical Guideline, F-TG-K-7.23e, He Leak Testing of Cryogenic Tubing, EDMS-ID 1172844

[29] MANDATORY: FAIR Technical Guideline, F-TG-K-7.26e, Flow Rate Test for Cryogenic Processing Pipes, EDMS-ID 1172846

[30] MANDATORY: FAIR Technical Guideline, F-TG-K-7.24e, Pressurised Leak Testing of Cryogenic Tubing, EDMS-ID 1172845

[31] MANDATORY: FAIR Technical Guideline, F-TG-MT-01e, DC High Voltage Insulation Tests for SC Magnets, EDMS-ID 1173079

[32] MANDATORY: FAIR Technical Guideline, F-TG-V-7.39e, Inverse Integral Leak Detection, EDMS-ID 1390815

[33] MANDATORY: FAIR Technical Guideline, F-TG-K-10.16e, Documentation and Certificates for Cryogenic Modules, EDMS-ID 1172856

[34] MANDATORY: FAIR Technical Guideline, F-TG-K-7.30e, Acceptance Test for the Cryogenics Related Quality of Cryogenic Modules, EDMS-ID 1172850

[35] MANDATORY: FAIR Technical Guideline, F-TG-K-7.27e, Residual Moisture Test for Cryogenic Processing Pipes, EDMS-ID 1172847

[36] MANDATORY: FAIR Technical Guideline, F-TG-K-7.19e, Vacuum Testing of Cryostat Vacuum Vessels, EDMS-ID 1172155

[37] MANDATORY: FAIR Technical Guideline, F-TG-K-9.11e: Packaging of Cryogenic Modules and Components, EDMS-ID 1172851

[38] MANDATORY: FAIR Technical Guideline, F-TG-K-7.18e, Testing the Cleanliness of Cryostat Insulation Vacuum Components, EDMS-ID 1172156

[39] MANDATORY: FAIR Technical Guideline, F-TG-K-7.28e, Vacuum Testing of Complete Cryogenic Modules, EDMS-ID 1172848

[40] MANDATORY: FAIR Technical Guideline, F-TG-V-3.1e, Constructive Design of Welding Seams for Vacuum Chambers, EDMS-ID 1172883

[41] MANDATORY: FAIR Technical Guideline, F-TG-V-3.9e, Welding of CF Flanges on Tubes, EDMS-ID 1172886

[42] MANDATORY: FAIR Technical Guideline, F-TG-V-3.42e, Copper Gaskets for CF Flanges, EDMS-ID 1172891

[43] MANDATORY: FAIR Technical Guideline, F-TG-V-7.2e, Vacuum Properties Acceptance Test without Bake-out, EDMS-ID 1506140, #120

[44] MANDATORY: FAIR Technical Guideline, F-TG-V-7.38e, Leak Detection of UHV Components, EDMS-ID 1390813

[45] MANDATORY: FAIR Technical Guideline, F-TG-V-7.39e: Inverse Integral Leak Detection, EDMS-ID 1390815

[46] MANDATORY: FAIR Technical Guideline, F-TG-V-9.1e, Transport and Packaging of Vacuum Components, EDMS-ID 1172926

[47] MANDATORY: FAIR Technical Guideline, F-TG-V-13.1e, Assembly Instructions for Knife-Edge UHV Flanges EDMS-ID 1172927

[48] MANDATORY: FAIR Technical Guideline, F-TG-V-2.37e, Bolts, Studs, Nuts and Washers for Cryogenic UHV Components, EDMS-ID 1172882

[49] MANDATORY: FAIR Technical Guideline, F-TG-S-3.33e, Soldering of connections, EDMS-ID 1172980

[50] MANDATORY: FAIR Technical Guideline, F-TG-V-2.5e, Vacuum Firing for Hydrogen Degassing of Materials and UHV Chambers, EDMS-ID 1172871

[51] MANDATORY: FAIR Technical Guideline, F-TG-V-2.6e, Material for Bakeable CF Flanges, EDMS-ID 1172872

[52] MANDATORY: FAIR Technical Guideline, F-TG-V-2.25e, Forged Blanks for Vacuum Applications Material 1.4429 / ESU, EDMS-ID 1172878

[53] MANDATORY: FAIR Technical Guideline, F-TG-V-2.28e, Stainless Steel for Beam Vacuum Chambers at Cryogenic Temperatures, EDMS-ID 1172880

[54] MANDATORY: FAIR Technical Guideline, F-TG-V-3.4e, Manufacturing of CF Knife-Edge Flanges, EDMS-ID 1172885

[55] MANDATORY: FAIR Technical Guideline, F-TG-V-5.1e, Surface Properties of Vacuum Chambers, EDMS-ID

[56] MANDATORY: FAIR Technical Guideline, F-TG-V-6.1e, Cleaning of UHV Components of Stainless Steel, EDMS-ID 1172894

[57] MANDATORY: FAIR Technical Guideline, F-TG-V-7.1e, Mechanical Acceptance Test for Beam Vacuum Components, EDMS-ID 1172905

[58] MANDATORY: FAIR Technical Guideline, F-TG-V-7.15e, Record for Factory Acceptance Test (FAT) of Vacuum Components, EDMS-ID 1172908

[59] MANDATORY: FAIR Technical Guideline, F-TG-V-7.25e, Vacuum Properties Acceptance Tests for Cryogenic Beam Vacuum Components, EDMS-ID 1172909

[60] MANDATORY: DIN EN 12195, Load restraining on road vehicles, Beuth Verlag GmbH, Berlin, Germany, 2010

## 8.2. **Mandatory engineering drawings (Essential assembly drawings listed only)**

*Due to the complete sets of engineering drawings for all QDM are consisting of an extensive number of part- and assembly drawings, only the essential assembly drawings are listed within the lists of mandatory engineering drawings. Never the less, each single sheet of engineering drawing, being part of the full set of drawings shall be mandatory for the subject matter of this specification and its according contract. Essential assembly drawings are listed as follows:*

- Support frames and alignment foot

[61] MANDATORY: Support frame, MG-1009679-A-000

[62] MANDATORY: Alignment foot, 14047_001_01-001

- Straight section module, type 2.123

[63] MANDATORY: Straight section module, including support, type 2.123, 10000020624-E5A-000 and sub-items

[64] MANDATORY: Straight section module, type 2.123, 10000018534-E5A-000 and sub-items and sub-items

[65] MANDATORY: Unit QDB (fully assembled), 10000018536-E5A-000 and sub-items

[66] MANDATORY: Unit SF2 (fully assembled), 10000018537-E5A-000 and sub-items

[67] MANDATORY: Drift tube, 10000018359-E5A-000 and sub-items

[68] MANDATORY: Common Girder, 10000018354-E5A-000, 10000018353-E5A-000 and sub-items

[69] MANDATORY: Suspension System, 10000018353-E5A-000 and sub-items

[70] MANDATORY: Integrated Cold Mass, 10000018535-E5A-000 and sub-items

[71] MANDATORY: Suspension system, MG-1005752-A-000_A, MG-1005753-A-000_A and sub-items

[72] MANDATORY: Insulation vacuum vessel, 10000018331-E5A-000, 10000018308-E5A-000, 10000018309-E5A-000 and sub-items

[73] MANDATORY: Thermal shield 10000018337-E5A-000, 10000018313-E5A-000, 10000018312-E5A-000 and sub-items

[74] MANDATORY: Shield MLI 10000018338-E5A-000, 10000018340-E5A-000, 10000018342-E5A-000 and sub-items

[75] MANDATORY: LCL-Assembly MG-1010500-A-000_A and sub-items, MG-1010000-A-000_A and sub-items

- Straight section module, type 2.13s

[76] MANDATORY: Straight section module, type 2.13s, including support, 10000020613-E5A-000 and sub-items

[77] MANDATORY: Straight section module, type 2.13s, 10000018304-E5A-000 and sub-items

[78] MANDATORY: Unit QDBs (fully assembled), 10000018324-E5A-000 and sub-items

[79] MANDATORY: Unit SF2s (fully assembled), 10000018329-E5A-000 and sub-items

[80] MANDATORY: Drift tube, 10000018359-E5A-000 and sub-items

[81] MANDATORY: Common Girder, 10000018354-E5A-000, 10000018353-E5A-000 and sub-items

[82] MANDATORY: Suspension System, 10000018353-E5A-000 and sub-items

[83] MANDATORY: Integrated Cold Mass, 10000018535-E5A-000 and sub-items

[84] MANDATORY: Suspension system, MG-1005752-A-000_A and sub-items, MG-1005753-A-000_A and sub-items

[85] MANDATORY: Insulation vacuum vessel, 10000018331-E5A-000 and sub-items, 10000018308-E5A-000 and sub-items, 10000018309-E5A-000 and sub-items

[86] MANDATORY: Thermal shield, 10000018337-E5A-000 and sub-items, 10000018313-E5A-000 and sub-items, 10000018312-E5A-000 and sub-items

[87] MANDATORY: Shield MLI, 10000018338-E5A-000 and sub-items, 10000018340-E5A-000 and sub-items, 10000018342-E5A-000 and sub-items

[88] MANDATORY: LCL-Assembly, MG-1010500-A-000_A and sub-items, MG-1010000-A-000_A and sub-items

- Upstream arc termination module, type 2.4

[89] MANDATORY: Support consoles, 10000016406-E5A-000 and sub-items

[90] MANDATORY: Arc termination module, type 2.4, 10000018184-E5A-000 and sub-items

[91] MANDATORY: Unit QDBb (fully assembled), 10000018194-E5A-000 and sub-items

[92] MANDATORY: Unit SF2M (fully assembled), 10000018199-E5A-000 and sub-items

[93] MANDATORY: Drift tube, 10000018359-E5A-000 and sub-items

[94] MANDATORY: Common Girder, 10000018208-E5A-000 and sub-items, 10000018207-E5A-000 and sub-items

[95] MANDATORY: Suspension System, MG-1005752-A-000_A and sub-items, MG-1005753-A-000_A and sub-items

[96] MANDATORY: Integrated Cold Mass, 10000018188-E5A-000 and sub-items

[97] MANDATORY: Insulation vacuum vessel, 10000016432-E5A-000 and sub-items

[98] MANDATORY: Main thermal shield, 10000018205-E5A-000 and sub-items, 10000018206-E5A-000 and sub-items

[99] MANDATORY: Main shield MLI, 10000015938-E5A-000 and sub-items

[100] MANDATORY: Telescopic bellow system, MG-1006650-A-000_A and sub-items

[101] MANDATORY: Connection thermal shield, MG-1007568-A-000 and sub-items

[102] MANDATORY: Connection shield MLI, 10000015960-E5A-000 and sub-items

[103] MANDATORY: LCL-Assembly, 10000018184_E5A_000 and sub-items

[104] MANDATORY: End cap vacuum vessel, MG-1021004-A-000 and sub-items

[105] MANDATORY: End cap thermal shield, MG-1024996-A-000 and sub-items

- Extraction module, type 2.4x

[106] MANDATORY: Special support frame, S911048-76-AY0001 and sub-items

[107] MANDATORY: Special high load alignment foot, SU-1009835-A-000 and sub-items

[108] MANDATORY: Extraction module, S911048-75-AY0001 and sub-items

[109] MANDATORY: Unit QDBx (fully assembled), S911048-03-AY0000 and sub-items

[110] MANDATORY: Unit SF2Mx (fully assembled), S911048-21-AY0000 and sub-items

[111] MANDATORY: Defocusing extraction QP-magnet-unit QDx (fully assembled), S911048-23-AY0000 and sub-items

[112] MANDATORY: Focusing extraction QP-magnet-unit (fully assembled), S911048-24-AY0000 and sub-items

[113] MANDATORY: Drift tube, ring branch, S911048-81-SA1227 and sub-items

[114] MANDATORY: Short drift tube, extraction branch, S911048-79-SA0005 and sub-items

[115] MANDATORY: Long drift tube, extraction branch, S911048-79-SA0013 and sub-items

[116] MANDATORY: Common Girder, ring branch, S911048-79-SA0002 and sub-items

[117] MANDATORY: Suspension System, ring branch, S911048-79-SA0001 and sub-items

[118] MANDATORY: Integrated Cold Mass, S911048-79-AY0001 and sub-items

[119] MANDATORY: Common Girder, extraction branch, S911048-79-SA0004 and sub-items, S911048-79-SA0003 and sub-items

[120] MANDATORY: Suspension System, extraction branch, S911048-79-SA0010 and sub-items, S911048-79-SA0010 and sub-items

[121] MANDATORY: Main insulation vacuum vessel, S911048-77-AY0001 and sub-items

[122] MANDATORY: Main thermal shield, S911048-78-SA0001 and sub-items

[123] MANDATORY: Main shield MLI, S911048-78-SA0100 and sub-items

[124] MANDATORY: Upstream-Connection cryostat vacuum vessel, n/a

[125] MANDATORY: End Cap vacuum vessel, n/a

[126] MANDATORY: End Cap MLI, n/a

[127] MANDATORY: Downstream-Connection cryostat vacuum vessel, S911048-37-SA0001 and sub-items

[128] MANDATORY: Downstream-Connection shield MLI, n/a

[129] MANDATORY: Connection bellow system, S911048-37-000043 and sub-items

[130] MANDATORY: LCL-Assemblies, n/a

[131] MANDATORY: End cap vacuum vessel, n/a

[132] MANDATORY: End cap thermal shield, n/a

[133] MANDATORY: End cap shield MLI, n/a

- Straight section module, type 2.5, ***First of Series***

[134] MANDATORY: Arc section module, FoS, MG-1005150-A-000_B and sub-items

[135] MANDATORY: Unit VQD (fully assembled), MAG-V04-E66.000.000 and sub-items

[136] MANDATORY: Unit SF2B (fully assembled), MAG-V07-E66.000.000 and sub-items

[137] MANDATORY: Common Girder, MG-1005838-A-000, MG-1005857-A-000 and sub-items

[138] MANDATORY: Suspension System, MG-1005752-A-000_A and sub-items, MG-1005753-A-000_A and sub-items

[139] MANDATORY: Integrated Cold Mass, MG-1007850-A-000 and sub-items

[140] MANDATORY: Insulation vacuum vessel, MG-1004655-A-000_B and sub-items

[141] MANDATORY: Main thermal shield, MG-1005890-A-000_B and sub-items, MG-1009754-A-000 and sub-items

[142] MANDATORY: Main shield MLI, MG-1010422-A-000_B and sub-items

[143] MANDATORY: Telescopic bellow system, MG-1006650-A-000_B and sub-items

[144] MANDATORY: Upstream Connection thermal shield, MG-1007568-A-000 and sub-items

[145] MANDATORY: Downstream Connection thermal shield, MG-1007545-A-000 and sub-items

[146] MANDATORY: Connection shield MLI, MG-1013373-A-000_A and sub-items

[147] MANDATORY: LCL-Assembly, MG-1010500-A-000 and sub-items, MG-1010501-A-000 and sub-items

- Arc-section module, type 2.5, Series

[148] MANDATORY: Arc section module, MG-1005150-A-000_B and sub-items

[149] MANDATORY: Unit VQD (fully assembled), MAG-V04-E66.000.000 and sub-items

[150] MANDATORY: Unit SF2B (fully assembled), MAG-V07-E66.000.000 and sub-items

[151] MANDATORY: Common Girder, MG-1005838-A-000 and sub-items, MG-1005857-A-000 and sub-items

[152] MANDATORY: Suspension System, MG-1005752-A-000_A and sub-items, MG-1005753-A-000_A and sub-items

[153] MANDATORY: Integrated Cold Mass, MG-1007850-A-000 and sub-items

[154] MANDATORY: Insulation vacuum vessel, MG-1004655-A-000_B and sub-items

[155] MANDATORY: Main thermal shield, MG-1005890-A-000_B and sub-items, MG-1009754-A-000 and sub-items

[156] MANDATORY: Main shield MLI, MG-1010422-A-000_B and sub-items

[157] MANDATORY: Telescopic bellow system, MG-1006650-A-000_B and sub-items

[158] MANDATORY: Upstream Connection thermal shield, MG-1007568-A-000 and sub-items

[159] MANDATORY: Downstream Connection thermal shield, MG-1007545-A-000 and sub-items

[160] MANDATORY: Connection shield MLI, MG-1013373-A-000_A and sub-items

[161] MANDATORY: LCL-Assembly, MG-1010500-A-000 and sub-items, MG-1010501-A-000 and sub-items

- Arc section module, type 1.6A

[162] MANDATORY: Arc section module, type 1.6A, MG-1024015-A-000 and sub-items

[163] MANDATORY: Unit BQD (fully assembled), MG-1021460-A-000 and sub-items

[164] MANDATORY: Unit SF1H (fully assembled),MG-1021573-A-000 and sub-items

[165] MANDATORY: Common Girder, MG-1005838-A-000 and sub-items, MG-1005857-A-000 and sub-items

[166] MANDATORY: Suspension System, MG-1005752-A-000_A and sub-items, MG-1005753-A-000_A and sub-items

[167] MANDATORY: Integrated Cold Mass, MG-1022248-A-000 and sub-items

[168] MANDATORY: Insulation vacuum vessel, MG-1004655-A-000_B and sub-items

[169] MANDATORY: Main thermal shield, MG-1005890-A-000_B and sub-items, MG-1023122-A-000 and sub-items

[170] MANDATORY: Main shield MLI , MG-1010422-A-000_B and sub-items

[171] MANDATORY: Telescopic bellow system, MG-1006650-A-000_A and sub-items

[172] MANDATORY: Upstream Connection thermal shield, MG-1007568-A-000 and sub-items

[173] MANDATORY: Downstream Connection thermal shield, MG-1007545-A-000 and sub-items

[174] MANDATORY: Connection shield MLI, MG-1013373-A-000_A and sub-items

[175] MANDATORY: LCL-Assembly, n/a

- Arc section module, type 1.7B

[176] MANDATORY: Arc section module, MG-1024017-A-000 and sub-items

[177] MANDATORY: Unit VQD (fully assembled), MAG-V04-E66.000.000-A-000_B and sub-items

[178] MANDATORY: Unit SF1B (fully assembled), MG-1021602-A-000 and sub-items

[179] MANDATORY: Common Girder, MG-1005838-A-000, MG-1005857-A-000 and sub-items

[180] MANDATORY: Suspension System, MG-1005752-A-000_A, MG-1005753-A-000_A and sub-items

[181] MANDATORY: Integrated Cold Mass, MG-1022468-A-000 and sub-items

[182] MANDATORY: Insulation vacuum vessel, MG-1004655-A-000_B and sub-items

[183] MANDATORY: Main thermal shield, MG-1005890-A-000_B and sub-items, MG-1023122-A-000 and sub-items

[184] MANDATORY: Main shield MLI, MG-1010422-A-000_B and sub-items

[185] MANDATORY: Telescopic bellow system, MG-1006650-A-000_A and sub-items

[186] MANDATORY: Upstream Connection thermal shield, MG-1007568-A-000 and sub-items

[187] MANDATORY: Downstream Connection thermal shield, MG-1007545-A-000 and sub-items

[188] MANDATORY: Connection shield MLI, MG-1013373-A-000_A and sub-items

[189] MANDATORY: LCL-Assembly n/a

- Arc section module, type 2.8C

[190] MANDATORY: Arc section module, MG-1024018-A-000 and sub-items

[191] MANDATORY: Unit BQD (fully assembled), MG-1021460-A-000 and sub-items

[192] MANDATORY: Unit SF2H (fully assembled), MG-1021354-A-000 and sub-items

[193] MANDATORY: Common Girder MG-1005838-A-000 and sub-items, MG-1005857-A-000 and sub-items

[194] MANDATORY: Suspension System, MG-1005752-A-000_A and sub-items, MG-1005753-A-000_A and sub-items

[195] MANDATORY: Integrated Cold Mass, MG-1022233-A-000 and sub-items

[196] MANDATORY: Insulation vacuum vessel, MG-1004655-A-000_B and sub-items

[197] MANDATORY: Main thermal shield, MG-1005890-A-000_B, MG-1023122-A-000 and sub-items

[198] MANDATORY: Main shield MLI, MG-1010422-A-000_B and sub-items

[199] MANDATORY: Telescopic bellow system, MG-1006650-A-000_A and sub-items

[200] MANDATORY: Upstream Connection thermal shield, MG-1007568-A-000 and sub-items

[201] MANDATORY: Downstream Connection thermal shield, MG-1007545-A-000 and sub-items

[202] MANDATORY: Connection shield MLI, MG-1013373-A-000_A and sub-items

[203] MANDATORY: LCL-Assembly, n/a

- Arc section module, type 2.9D

[204] MANDATORY: Arc section module, MG-1024018-A-000 and sub-items

[205] MANDATORY: Unit BQD (fully assembled), MG-1021460-A-000 and sub-items

[206] MANDATORY: Unit SF2J (fully assembled), MG-1021651-A-000 and sub-items

[207] MANDATORY: Common Girder, MG-1005838-A-000, MG-1005857-A-000 and sub-items

[208] MANDATORY: Suspension System, MG-1005752-A-000_A and sub-items, MG-1005753-A-000_A and sub-items

[209] MANDATORY: Integrated Cold Mass, MG-1022235-A-000 and sub-items

[210] MANDATORY: Insulation vacuum vessel, MG-1004655-A-000_B and sub-items

[211] MANDATORY: Main thermal shield, MG-1005890-A-000_B and sub-items, MG-1023122-A-000 and sub-items

[212] MANDATORY: Main shield MLI, MG-1010422-A-000_B and sub-items

[213] MANDATORY: Telescopic bellow system, MG-1006650-A-000_A and sub-items

[214] MANDATORY: Upstream Connection thermal shield, MG-1007568-A-000 and sub-items

[215] MANDATORY: Downstream Connection thermal shield, MG-1007545-A-000 and sub-items

[216] MANDATORY: Connection shield MLI, MG-1013373-A-000_A and sub-items

[217] MANDATORY: LCL-Assembly, n/a

- Arc termination module, type 1.E

[218] MANDATORY: Arc termination module, type 1.E, including support, 10000020599 and sub-items

[219] MANDATORY: Support consoles, 10000016406-E5A-000 and sub-items

[220] MANDATORY: Arc termination module, type 1.E, 10000016400-E5A-000 and sub-items

[221] MANDATORY: Unit MQD (fully assembled), 10000016426-E5A-000 and sub-items

[222] MANDATORY: Unit SF1Bb (fully assembled), 10000016422-E5A-000 and sub-items

[223] MANDATORY: Common Girder, MG-1005838-A-000, MG-1005857-A-000 and sub-items

[224] MANDATORY: Suspension System, MG-1005752-A-000_A, MG-1005753-A-000_A and sub-items

[225] MANDATORY: Integrated Cold Mass, 10000016407-E5A-000 and sub-items

[226] MANDATORY: Insulation vacuum vessel, 10000016432-E5A-000 and sub-items

[227] MANDATORY: Main thermal shield, 10000016435-E5A-000 and sub-items, 10000016436-E5A-000 and sub-items

[228] MANDATORY: Main shield MLI, 10000015938-E5A-000 and sub-items

[229] MANDATORY: Telescopic bellow system, MG-1006650-A-000_A and sub-items

[230] MANDATORY: Upstream Connection thermal shield, MG-1007568-A-000 and sub-items

[231] MANDATORY: Connection shield MLI, 10000015960-E5A-000 and sub-items

[232] MANDATORY: LCL-Assembly, MG-1010500-A-000_A, MG-1010000-A-000_A and sub-items, 10000016470-E5A-000 and sub-items, 10000016303-E5A-000 and sub-items

[233] MANDATORY: End cap vacuum vessel, MG-1019541-A-000 and sub-items

[234] MANDATORY: End cap thermal shield, MG-1023372-A-000 and sub-items

[235] MANDATORY: End cap shield MLI, MG-1023383-A-000 and sub-items

- Injection module, type 1.Ei, including support

[236] MANDATORY: Special support frame, 10000017350-E5A-000 and sub-items

[237] MANDATORY: Special high load alignment foot, SU-1009835-A-000 and sub-items

[238] MANDATORY: Special QDM, injection, 10000017337-E5A-000 and sub-items

[239] MANDATORY: Unit MQDi (fully assembled), 10000017364-E5A-000 and sub-items

[240] MANDATORY: Unit SF1Bi (fully assembled), 10000017362-E5A-000 and sub-items

[241] MANDATORY: Defocusing injection QP-magnet-unit (fully assembled), 10000017421-E5A-000 and sub-items

[242] MANDATORY: Focusing injection QP-magnet-unit (fully assembled), 10000017419-E5A-000 and sub-items

[243] MANDATORY: Drift tube, 10000017458-E5A-000 and sub-items

[244] MANDATORY: Common Girder, ring branch, 10000017478-E5A-000 and sub-items, 10000017480-E5A-000 and sub-items

[245] MANDATORY: Common Girder, injection branch 10000017481-E5A-000 and sub-items

[246] MANDATORY: Suspension System, ring branch 10000017456-E5A-000 and sub-items, 10000017924-E5P-000 and sub-items

[247] MANDATORY: Support pillar system, Injection branch 10000017337_E5A_000 and sub-items

[248] MANDATORY: Integrated Cold Mass, ring- and injection branch, 10000017337_E5A_000 and sub-items

[249] MANDATORY: Main Insulation vacuum vessel, 10000017424-E5A-000 and sub-items

[250] MANDATORY: Aux. insulation vacuum vessels, 10000017344-E5A-000, 10000017345-E5A-000 and sub-items

[251] MANDATORY: Main thermal shield, 10000017439-E5A-000 and sub-items

[252] MANDATORY: Aux. thermal shields, 10000017376-E5A-000 and sub-items, 10000017391-E5A-000 and sub-items

[253] MANDATORY: Main shield MLI, 10000017449-E5A-000 and sub-items

[254] MANDATORY: Aux. shield MLI, 10000017378-E5A-000 and sub-items, 10000017393-E5A-000 and sub-items

[255] MANDATORY: Aux. Insulation vacuum vessels, 10000017345-E5A-000 and sub-items, 10000017344-E5A-000 and sub-items

[256] MANDATORY: Compensation bellow, 10000017337_E5A_000 and sub-items

[257] MANDATORY: Upstream Connection thermal shield, 10000022217-E5P-000 and sub-items

[258] MANDATORY: LCL-Assemblies, 10000017337_E5A_000 and sub-items, 10000017337_E5A_000 and sub-items

### 8.3. **Mandatory instrumentation lists**

[259] MANDATORY: Instrumentation List, PLI_SIS100_QPM-2.123, Instrumentation planning list for SIS100-QDM, type 2.123

[260] MANDATORY: Instrumentation List, PLI_SIS100_QPM-2.13s, Instrumentation planning list for SIS100-QDM, type 2.13s

[261] MANDATORY: Instrumentation List, PLI_SIS100_QPM-2.4, Instrumentation planning list for SIS100-QDM, type 2.4

[262] MANDATORY: Instrumentation List, PLI_SIS100_QPM-2.4x, Instrumentation planning list for SIS100-QDM, type 2.4x

[263] MANDATORY: Instrumentation List, PLI_SIS100_QPM-2.5, Instrumentation planning list for SIS100-QDM, type 2.5

[264] MANDATORY: Instrumentation List, PLI_SIS100_QPM-1.6A, Instrumentation planning list for SIS100-QDM, type 1.6A

[265] MANDATORY: Instrumentation List, PLI_SIS100_QPM-1.7B, Instrumentation planning list for SIS100-QDM, type 1.7B

[266] MANDATORY: Instrumentation List, PLI_SIS100_QPM-2.8C, Instrumentation planning list for SIS100-QDM, type 2.8C

[267] MANDATORY: Instrumentation List, PLI_SIS100_QPM-2.9D, Instrumentation planning list for SIS100-QDM, type 2.9D

[268] MANDATORY: Instrumentation List, PLI_SIS100_QPM-1.E, Instrumentation planning list for SIS100-QDM, type 1.E

[269] MANDATORY: Instrumentation List, PLI_SIS100_QPM-1.Ei, Instrumentation planning list for SIS100-QDM, type 1.Ei

### 8.4. **Miscelleanous mandatory documents**

[270] MANDATORY: Document template, Mounting&Alignment_QP_Units_TEMPLATE.xlsx, EDMS-ID 1533009

[271] MANDATORY: Document template, Q-FO-QM-0008, Engineering Change Request, EDMS-ID 1276327

[272] MANDATORY: Document template, Q-FO-QA-0003, Non Conformity Report, EDMS-ID 1503137

### 8.5. **Recommended specifications and documents for information**

[273] RECOMMENDED: FAIR Detailed Specification, F-DS-MT-85e, Detailed Specification on Testing of Superconducting Quadrupole Doublet Modules for the SIS100, EDMS-ID 1366276

[274] FOR INFORMATION: FAIR Detailed Specification, F-DS-BD-67e, Detailed Specification of Cold section BPM Detector SIS100, EDMS-ID 1530448

[275] FOR INFORMATION: FAIR Detailed Specification, F-DS-VC-44e, Detailed Specification for SIS100 Cryo-Sorption Pumps, EDMS-ID 1405898

[276] FOR INFORMATION: FAIR Detailed Specification, F-DS-VC-15e, Detailed Specification for SIS100 Quadrupole Chambers with Elliptical Cross-Section, EDMS-ID 1273995

[277] FOR INFORMATION: FAIR Detailed Specification, F-DS-VC-14e, Detailed Specification for SIS100 Quadrupole Chambers with Star-shaped Cross-Section, EDMS-ID 1405897

[278] FOR INFORMATION: FAIR Detailed Specification, F-DS-VC-22e, Detailed Specification for the SIS100 Roughing Cold Warm Transitions, EDMS-ID 1539154,

[279] FOR INFORMATION: FAIR Detailed Specification, F-DS-VC-21e, Detailed Specification for the SIS100 Beam Pipe Cold Warm Transitions

[280] FOR INFORMATION: FAIR Detailed Specification, F-DS-SI-01e, Detailed Specifications SIS100 Cryo-Catcher Unit, EDMS-ID 1261923

[281] RECOMMENDED: FAIR Detailed Specification, F-DS-MT-85e, Detailed Specification on Testing of Superconducting Quadrupole Doublet Modules for the SIS100

[282] RECOMMENDED: FAIR Procedure, Q-VA-QA-0025e, Performing Factory Acceptance, Performing Factory Acceptance Test (FAT) oder Site Acceptance Test (SAT Aa, Ab, Ba, oder Bb), EDMS-ID 1514174

[283] FOR INFORMATION: FAIR Technical Guideline, F-TG-K-50.0e, Cryogenic Operation Parameter, EDMS-ID 1172859

[284] FOR INFORMATION: Design calculation for support tooling of SIS100-QDM, arc section type, Transportlagerung, Kurzform Rechenbericht, Sebert Schwingungstechnik GmbH, Kirchheim/Teck, Germany, 2014

[285] FOR INFORMATION: Preliminay delivery schedule for components being supply by the Company

[286] FOR INFORMATION: Quality Inspection Plan, Assembly Quadrupole Magnet FoS

[287] FOR INFORMATION: Template, Quality Inspection and Production Plan

8.6. **Engineering drawings for information**

[288] FOR INFORMATION: BEAM POSITION MONITOR F. SIS100, STD-V05-D77.000.000 – 000

[289] FOR INFORMATION: SIS100 Sektor 1 Gerade BG, Blatt 1, 1S-1S01-ST-0000025

[290] FOR INFORMATION: SIS100 Sektor 1 Gerade BG, Blatt 2, 1S-1S01-ST-0000025

[291] FOR INFORMATION: SIS100 Sektor 1 Bogen BG, 1S-1S01-ST-0000026

[292] FOR INFORMATION: SIS100 Sektor 2 Gerade BG, 1S-1S02-ST-0000020

[293] FOR INFORMATION: SIS100 Sektor 2 Bogen BG, Blatt 2, 1S-1S02-ST-0000021

[294] FOR INFORMATION: SIS100 Sektor 3 Bogen BG, Blatt 1, 1S-1S03-ST-0000009

[295] FOR INFORMATION: SIS100 Sektor 3 Bogen BG, Blatt 2, 1S-1S03-ST-0000009

[296] FOR INFORMATION: SIS100 Sektor 3 Gerade BG, Blatt 2, 1S-1S03-ST-0000021

[297] FOR INFORMATION: SIS100 Sektor 4 Gerade BG, Blatt 2, 1S-1S04-ST-0000020

[298] FOR INFORMATION: SIS100 Sektor 4 Bogen BG, Blatt 2, 1S-1S04-ST-0000021

[299] FOR INFORMATION: SIS100 Sektor 5 Gerade BG, Blatt 1, 1S-1S05-ST-0000034

[300] FOR INFORMATION: SIS100 Sektor 5 Gerade BG, Blatt 2, 1S-1S05-ST-0000034

[301] FOR INFORMATION: SIS100 Sektor 5 Bogen BG, Blatt 1, 1S-1S05-ST-0000038

[302] FOR INFORMATION: SIS100 Sektor 6 Gerade BG, 1S-1S06-ST-0000027

[303] FOR INFORMATION: SIS100 Sektor 6 Bogen BG, 1S-1S06-ST-0000028

[304] FOR INFORMATION: Isolierrohr, 559-013-002

[305] FOR INFORMATION: Isolierrohr, 559-013-003

[306] FOR INFORMATION: Transportation lock - SIS 100 – QDM, KW-1014368-A-000

[307] FOR INFORMATION: Internal transportation locks, KW-1017028-A-000

[308] FOR INFORMATION: Protection Cap, KW-1016286-A-000