Document Title:	**Detailed Specification of the Cooling System of the Quadrupole Modules in the Straight Sections of SIS100**
Description:	This document represents the detailed specification for the manufacturing and testing of the liquid helium cooling system of the quadrupole doublet modules in the straight sections of the SIS100 synchrotron.
Division/ Organization:	GSI-PBMT
Field of application:	Project FAIR@GSI

Document History:

Version	Prepared by:	Checked, Date	Released, Date	Comment
V 1.1	A. Bleile 18.10.2013			Draft version
V 1.2	A. Bleile [2]2.01.2014			new template
V 1.3	A .Bleile 03.07.2015			
V 1.4	A .Bleile 26.10.2016			
V. 1.5	A. Bleile 30.01.2017			

EDMS **1346794 v.4** status **Released** access **Restricted**
F-DS-MT-79e-SIS100_Cooling-QP-Modules-Straight-QM_v1.5.pdf modified **2017-01-31 10:36**

Abstract

This document represents the detailed specification for the manufacturing and testing of the liquid helium cooling system of the quadrupole doublet modules for the straight sections of the SIS100 synchrotron. The quadrupole doublet modules can be divided into four groups regarding the cryogenic flow schemes: regular arc modules, arc termination modules, modules in the straight sections of the SIS100 and special modules for injection / extraction. This document is related to the modules in the straight sections only; all other modules are specified in dedicated detailed specifications. The document includes the cryogenic flow schemes of the quadrupole doublet modules as well as the flow schemes of the quadrupole units.

Table of Contents

1. Purpose and Classification of the Document....5
2. Abbreviations, Terms and Definitions 5
3. Scope of the technical System....6
   3.1. System Overview....6
   3.2. Content of Delivery 7
   3.2.1. Quadrupole units....7
   3.2.2. Quadrupole doublet modules 8
3.3. Spare Parts 8
4. System Specification 8
   4.1. System Environment and Constraints 8
   4.2. Cryogenic Flow Scheme of the Straight QP Modules....9
   4.3. Flow Schemes of the Quadrupole Units 10
   4.4. System Components (technical requirements)....10
5. Quality Assurance, Tests, and Acceptance....11
6. Documentation 11
7. Related Documents 14

List of Tables:

Table 1: Actively cooled devices of the QP doublet modules in the straight sections of the SIS100.7

List of Figures:

Figure 1: SIS100 cryogenic layout 6
Figure 2: Helium connections of the quadrupole modules 2.123 / 1.23s 9
Figure 3: Flow scheme of the QP modules 2.123 and 2.13s 12
Figure 4: Upstream unit QD*B 13
Figure 5: Upstream unit SF1*/2* 13

1. Purpose and Classification of the Document

The purpose of this document is to specify the technical requirements for the 4 K cryogenic system of the quadrupole doublet modules in the straight sections of the SIS100 synchrotron. The related modules are listed in the Table 1.

The cooling systems of the QP modules in the arc sections are described in the related detailed specifications and are not part of this document.

This document is not related to the cooling system of the thermal radiation shield, cold-warm transitions, thermal intercepts of the support structures and other items cooled at 50K.

Where ever requirements are specified in the General Specifications, Technical Guidelines, Common Specifications or Detailed Specifications they are only referenced in this document.

2. Abbreviations, Terms and Definitions

The definitions used in this document are given in [2], section 3.1.

Besides that, this document uses following abbreviations:

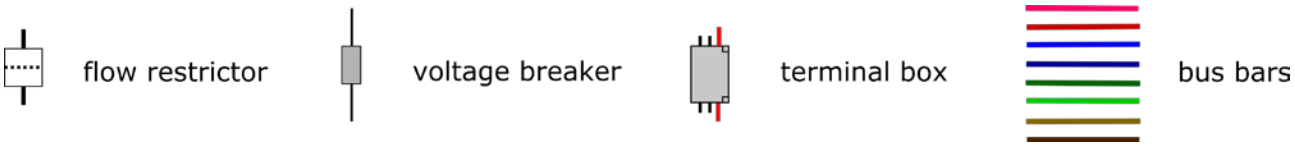
QP	quadrupole magne
QD	defocusing quadrupole magnet
F1 / F2	focusing quadrupole magnet, type 1 and 2
ST	steering magnet
CL	current leads of the corrector magnets
VC	beam vacuum chamber
P	cryo sorption pump
CWT	cold-warm transition
VB	voltage breaker

The cooling channel M1 is the cooling circuit of the magnets in the upstream quadrupole unit.

The cooling channel M2 is the cooling circuit of the magnets in the downstream quadrupole unit.

The cooling channel V is the common cooling circuit of the beam vacuum chambers in both upstream and downstream parts of the quadrupole doublet.

Symbols used in the flow diagrams:



3. Scope of the technical System

3.1. System Overview

The SIS100 synchrotron has six long straight sections with cryogenic quadrupole doublet modules. The gaps between modules are required to provide adequate space for warm accelerator components (Figure 1). Each straight section contains three cryogenic quadrupole doublet modules. As an exception the sector 5 (extraction) contains only two cryogenic quadrupole modules and two warm quadrupole magnets.

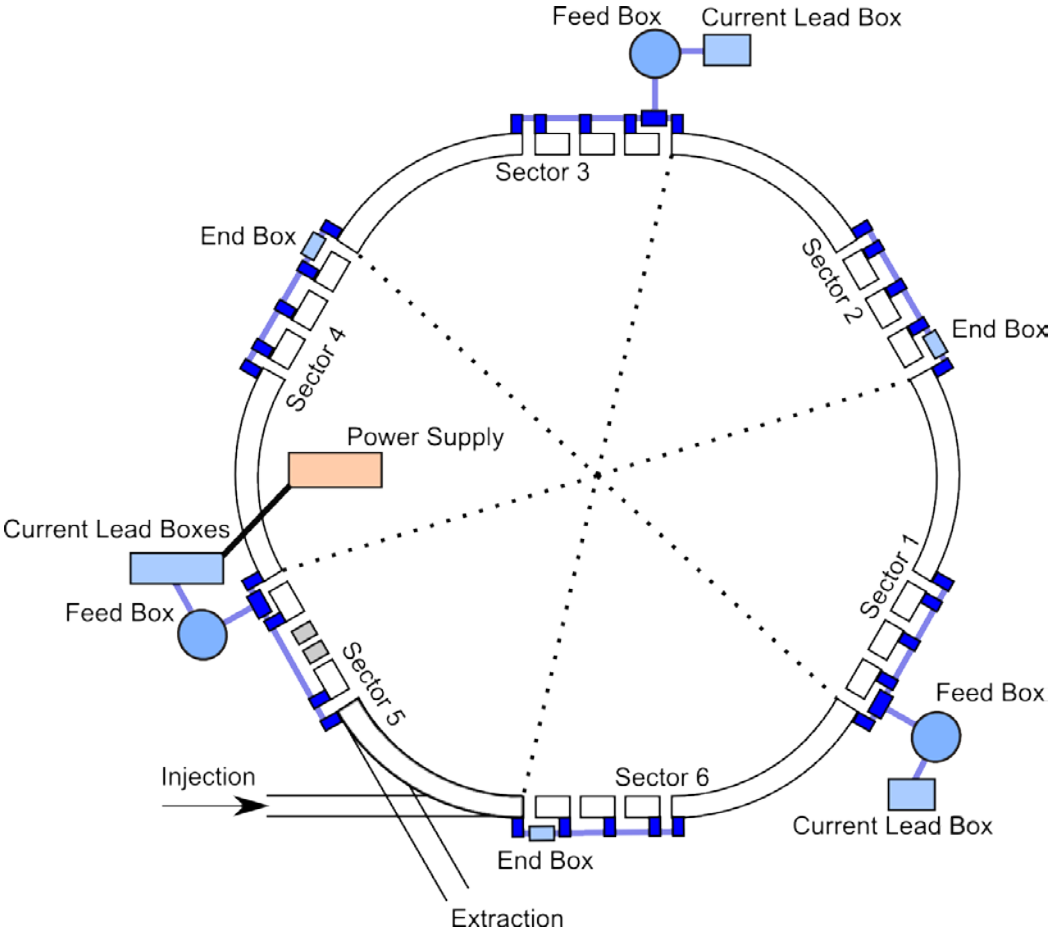


Figure 1: SIS100 cryogenic layout

All cryogenic quadrupole doublet modules are linked to the liquid helium headers and to the bus bar system in the by-pass lines [4].

The QP modules in the straight sections are listed in Table 1. Both types of modules are identical, except for the shape of the beam vacuum chamber. Two modules of the type 2.13s located in the sector 5 (beam extraction) and one module 2.13s in the sector 1 will have star shaped beam vacuum chambers while the modules 2.123 will have elliptical chambers.

The hydraulic flow diagrams of both QP module types 2.123 and 2.13s are identical. Each module consist of two parallel flow channels for the cooling of the quadrupole units and one flow channel for the cooling of one cryo sorption pump and two beam vacuum chambers.

Table 1: Actively cooled devices of the QP doublet modules in the straight sections of the SIS100.

Module type (short name)	Module type (full name)	Number of modules	Channel M1 (upstream unit)	Channel M2 (downstream unit)	Channel V
2.123	QD*B-TRP-SF1*/2*	14	QD	ST, F1 or F2	VC, P, VC
2.13s	QD*B-TRP-SF2*s	3			

3.2. Content of Delivery

Manufacturing of the cooling system of the QP modules is subdivided in two parts and is included in two different work packages. Section 3.2.1 describes the content of delivery for the contractor responsible for the manufacturing of the QP units. Section 3.2.2 describes the content of delivery for the contractor responsible for the integration of the QP doublet modules.

3.2.1. Quadrupole units

The Contractor responsible for the production of the quadrupole units has to accomplish all items listed below:

- Manufacturing of the flow restrictors for the cooling channels M1 and M2
- Assembly of the heaters for the cooling channels M1 and M2
- Integration of all components of the flow scheme (Figure 4, Figure 5)
- Installation of the temperature sensors on the helium lines according to the instrumentation list for QP units [5]
- Factory acceptance tests (FAT) including checking of the mass flow rate and possible adjustment of the flow restrictors for the cooling channels M1 and M2
- Documentation of all components of the cooling circuit of the QP unit according to the section 5 of [2]

All parts of the helium cooling circuit shall be manufactured and assembled according to the technical drawings provided by the Company. The set of the drawings for each type of the quadrupole unit is referenced in the Detailed Specification [3], section 3.3.

3.2.2. Quadrupole doublet modules

The Contractor responsible for the production of the quadrupole doublet modules has to accomplish all items listed below:

- Manufacturing of the flow restrictors for the cooling channel V
- Manufacturing and installation of the connection lines DN6 and DN15 (Figure 2)
- Integration of all components of the flow scheme according to Figure 3
- Installation of the remaining temperature sensors on the helium lines according to the instrumentation list for QP doublets [5]
- Factory acceptance tests (FAT) including checking of the mass flow rate and possible adjustment of the flow restrictor for the cooling channel V
- Documentation of all components of the cooling circuit according to the section 5 of [2]

All parts of the helium cooling circuit shall be manufactured and assembled according to the technical drawings provided by the Company. The set of the drawings for each type of the quadrupole module is referenced in the Detailed Specification [3], section 3.3.

3.3. Spare Parts

No spare parts are required for the 4K cooling system

4. System Specification

4.1. System Environment and Constraints

The limits of the system and environment are specified in [2], section 2.2.

All QP modules in the straight sections are connected to the cryogenic by-pass line [4]. The connection flange on the magnet cryostat is located at the downstream end of the magnet module.

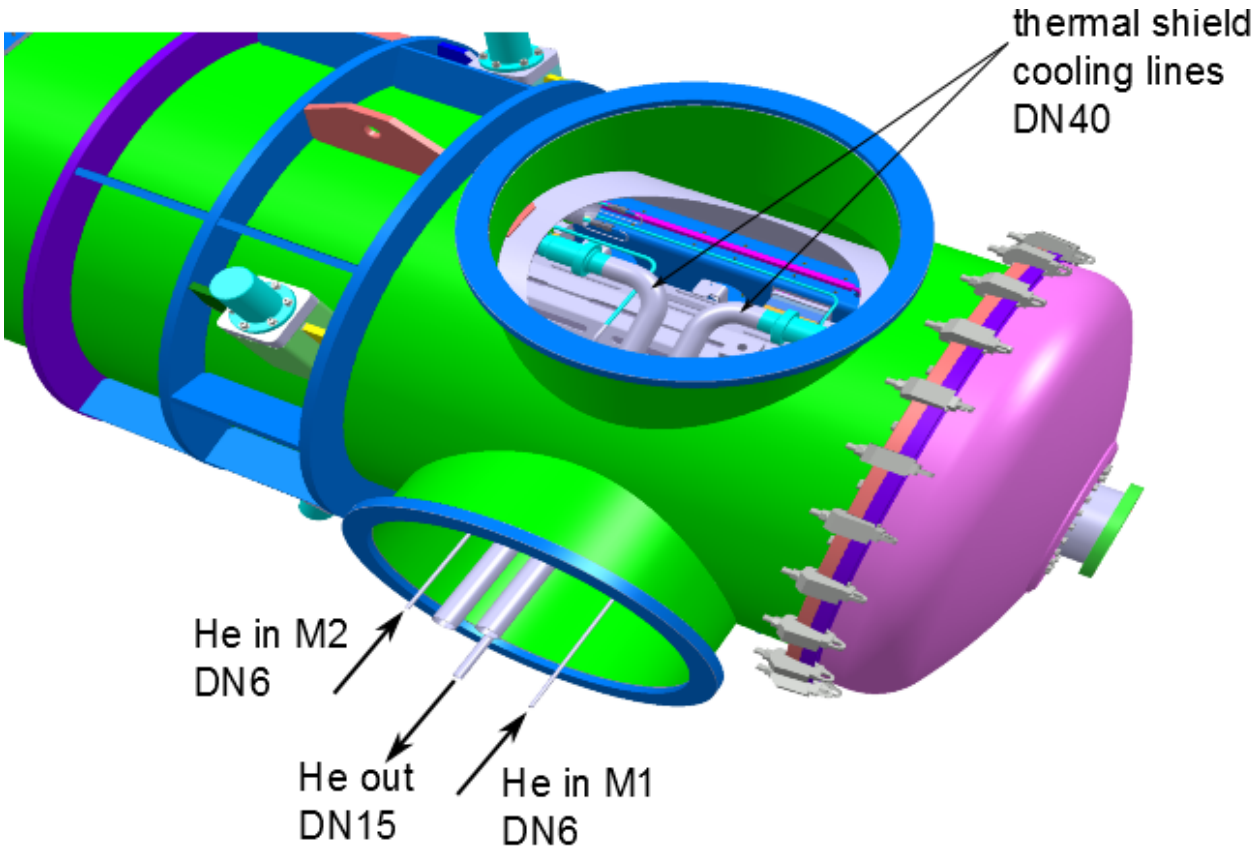


Figure 2: Helium connections of the quadrupole modules 2.123 / 1.23s

4.2. Cryogenic Flow Scheme of the Straight QP Modules

The 4K circuit of each module has two independent magnet cooling channels M1 (upstream QP unit) and M2 (downstream QP unit) and one cooling channel V for the beam vacuum chambers (see also [2], section 3.8).

As shown in Table 1, the actively cooled devices connected in series form two different types of the magnet cooling channels M1 / M2:

- Quadrupole only (unit QDB), 17 units
- Steerer + Quadrupole (units SF2 / SF2s), 17 units

The cooling channel V consists of two beam vacuum chambers and one cryo sorption pump connected in series.

Due to the different flow resistance of different types of cooling channels the helium mass flow has to be adjusted for each type by means of the flow restrictor (see [2], section 3.4.1). The final sizing of the flow restrictors for each type of the cooling channel will be done after the first cold test of the respective quadrupole unit. The Company will submit the detailed design parameter for the restrictors (length and diameter of capillary). The Contractor responsible for the integration of the

Quadrupole Doublet Modules shall manufacture the flow restrictor for the cooling channel V (cooling of the beam vacuum chambers). The flow restrictors for the magnet cooling channels M1, M2 will be manufactured by Contractor responsible for the manufacturing of the Quadrupole Units (see also section 3.2).

All QP modules listed in Table 1 have the same flow scheme (Figure 3). Only difference between modules 2.123 and 2.13s is the shape of the beam vacuum chamber ("s" denotes the star shape chamber).

Superconducting bus bars of the upstream unit will be connected to the electrical circuit of the defocusing quadrupoles QD.

Superconducting bus bars of the downstream unit will be connected either to the F1 or to the F2 electrical circuit. The selection of the electrical circuit will be done in the bypass line [4].

4.3. Flow Schemes of the Quadrupole Units

The flow scheme of the assembled unit QDB is shown in Figure 4.

The flow scheme of the assembled unit SF2 is shown in Figure 5.

4.4. System Components (technical requirements)

The most important components of the flow schemes like superconducting coils and bus bars, magnet yokes, beam vacuum chambers, voltage breakers etc. are described in appropriated specifications and will not be specified in this document.

The main helium supply and return headers A1, A2 and B (DN25, DN50 and DN100) are located in the by-pass line [4]. The connection of the flow channels M1, M2 and V to the helium headers is realized by three connection pipes:

- Ø8x1 for the connections to the supply headers A1
- Ø8x1 for the connections to the supply headers A2
- Ø18x1.5 for the connection to the return header B

The sizes of the tubes are fixed and must not be changed by Contractor.

Beside these components the main parts of the cooling system are:

- Flow restrictors [2], 3.4.1
- Connection pipes [2], 3.3
- Voltage breakers

Each cooling channel will be equipped with temperature sensors according to the instrumentation list of the quadrupole module [5]. The sensors will be mounted on the helium tubes and will operate in a vacuum environment.

Each magnet cooling channels M1 and M2 will be equipped with a heater ([2], section 3.10.2) according to the instrumentation list. The heaters are mounted on the helium tubes in vacuum and are located just before the flow restrictors (upstream).

5. Quality Assurance, Tests, and Acceptance

The Contractor responsible for the manufacturing of Quadrupole Units as well as the Contractor responsible for the integration of the Quadrupole Doublet Modules shall perform a series of acceptance and performance tests on the assembled cooling circuit as specified in [2], section 4.2):

1. Document compliance according to the Pressure Equipment Directive
2. Visual inspection
3. Dimensional inspection
4. Pressure test according to the Pressure Equipment Directive
5. Integral leak test
6. Flow rate tests and adjustment of the flow restrictors
7. Test of instrumentation installed on the piping (temperature sensors, heaters)

The Company will perform additional tests of the cooling circuit at helium temperature as described in [2], section 4.3 within the Site Acceptance Test of the magnet module.

6. Documentation

The requirements for the documentation are specified in [2], section 5

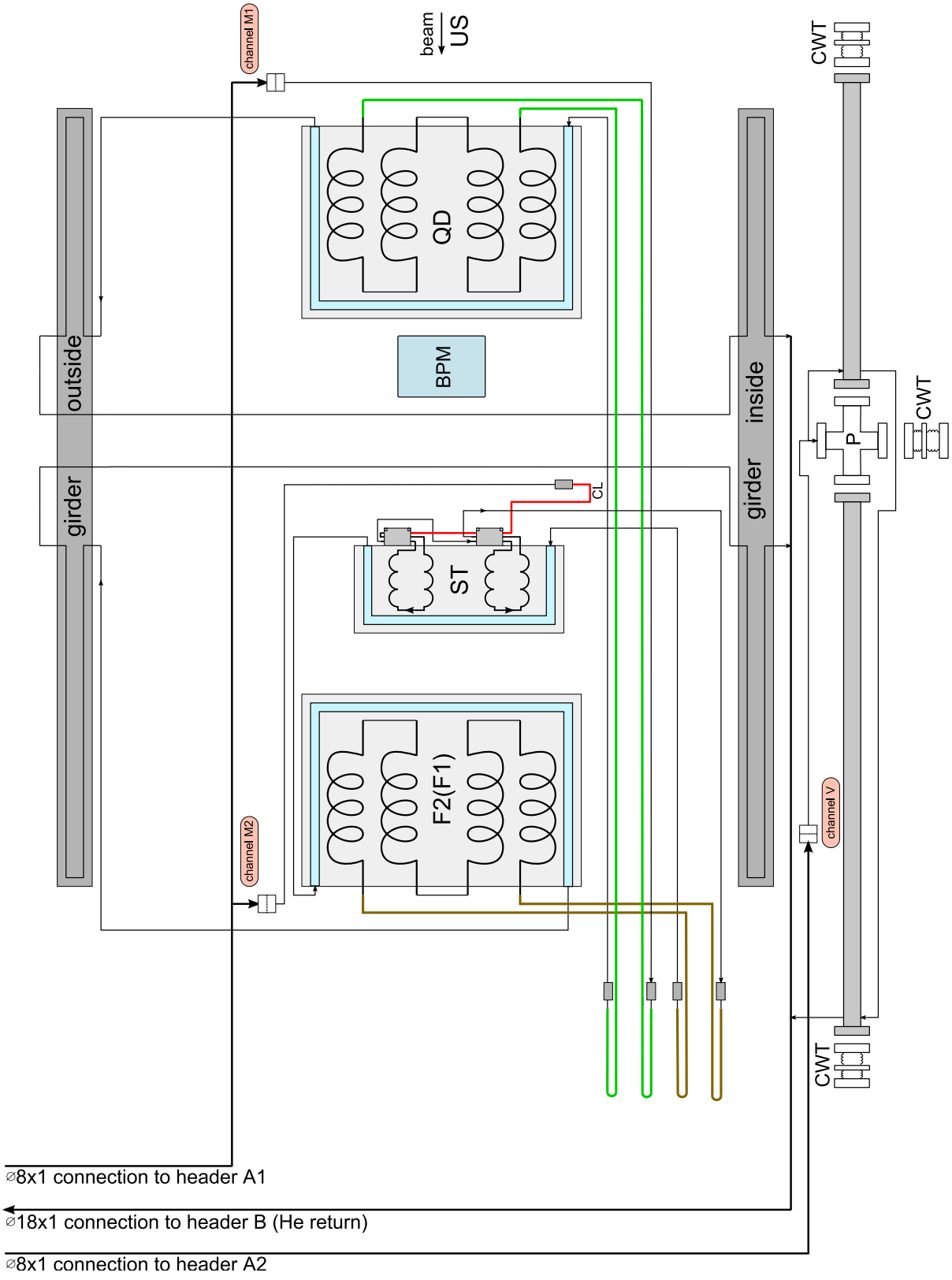


Figure 3: Flow scheme of the QP modules 2.123 and 2.13s

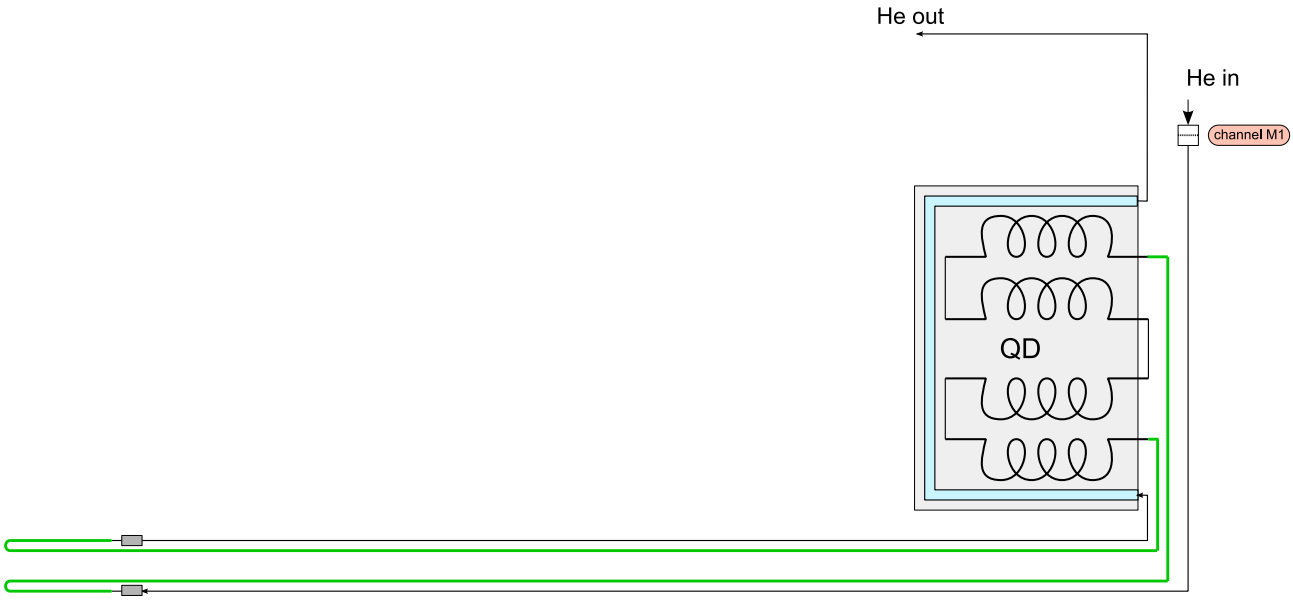


Figure 4: Upstream unit QD*B

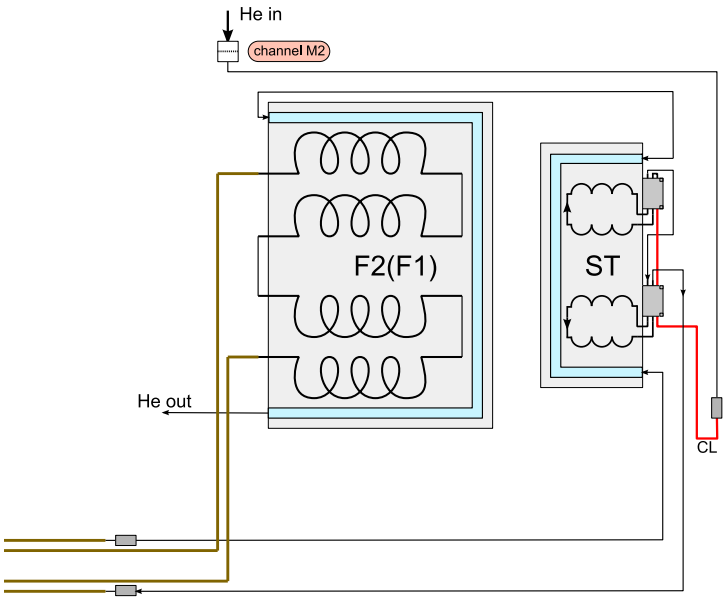


Figure 5: Upstream unit SF1*/2*

7. Related Documents

[1] F-GS-F-01e, General Specification for the FAIR Accelerator Facility Project, EDMS Nr. 1365092

[2] F-CS-MT-04e, Common Specification of the cooling system of the superconducting SIS100 magnets, EDMS Nr. 1274168

[3] Detailed specification for Component Production, Cryostat Construction and Module Integration for the SIS100 Quadrupole Doublet Modules F-DS-MT-107e, EDMS Nr. 1533009

[4] F-DS-K-20e, Detailed Specification of the Local Cryogenic By-Pass System for SIS100, EDMS Nr. 1261140

[5] F-DS-MT-108e, Detailed specification of instrumentation for SIS100 Quadrupole-Modules, EDMS Nr. 1561225