

Configuration Management and Documentation	Document Type Detailed Specification	Document Number F-DS-BEA-en-BD_0140_IFC_40_Development-V002	Date 27.07.2026
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Document Title	Detailed Specification Current-to-Frequency Converter
Description	This document specifies the development of current-to-frequency converters as part of the beam diagnostics for FAIR and GSI
Division/ Organization	Commons / Beam Diagnostics Department (BEA)
Field of Application	FAIR GmbH and GSI GmbH

Document History

Version	Prepared/Checked by	Date	Date of Release	Comments
V001	M. Schwickert	27 th July 2026		Version 1 for EDMS approval, checked by C. Müller, C. Andre, P. Kowina, A. Reiter
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Abstract

This document describes services to be supplied to the existing GSI and future FAIR accelerator facility concerning the development, production and delivery of dedicated electronic hardware for the readout of particle detectors, i.e. current-to-frequency converters (IFC). This specification provides an overview of all deliverables and the type of technical development required.

This document covers all items of psp-code 2.8.6.5.1.8, 2.8.11.2.1 and 2.8.11.1.

This document covers all items of AID:0005291, AID:0005292, AID:0005293, AID:0005294 and AID:0005295.

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1. Purpose and Classification of the Document

This document is mandatory as technical description for the development and production contract drawn up in this context. All commercial and organisational conditions are specified in the commercial part of the contract in question.

The scope of application for this document is a subset of diagnostic equipment for FAIR and existing GSI upgrade activities, related to the beam instrumentation subsystems.

Brief descriptions of the FAIR project, the facility for anti-proton and ion research, and beam diagnostics are given in the following section.

This Detailed Specification describes technically the following AIDs:

AID:0005291	SIS100 IFC 4.0 Single
AID:0005292	SIS100 IFC Single Power Supply
AID:0005293	SIS100 IFC 4.0 Multiple
AID:0005294	SIS100 IFC-Crate
AID:0005295	SIS100 IFC Central Power Supply

1.1. Introduction to FAIR and Beam Diagnostics

Currently the international accelerator facility FAIR, one of the largest research projects worldwide, is being built in Darmstadt, Germany. At FAIR, matter that usually only exists in the depth of space will be produced in a lab for research. Scientists from all over the world will be able to gain new insights into the structure of matter and the evolution of the universe from the Big Bang to the present. FAIR will be one of the largest and most complex accelerator facilities in the world.

The FAIR accelerator facility will have the unique ability to provide particle beams of all the chemical elements (or their ions), as well as antiprotons (after full project completion). The particles will be accelerated to almost the speed of light in the FAIR accelerator facility and made available for scientific experiments. FAIR will generate particle beams of a previously unparalleled intensity and quality. At the heart of the facility is a superconducting underground ring accelerator with a circumference of 1,100 metres. There are also additional experimental rings and experimental stations with several kilometres of beam lines in total.

The existing accelerator facility of the GSI Helmholtzzentrum für Schwerionenforschung will serve as the injector for the new FAIR facility and will be technically upgraded for consistent integration. For more information on the FAIR project the reader is referred to the project website: <https://www.gsi.de/en/researchaccelerators/fair>.

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The task of the beam diagnostic system of FAIR is to provide all relevant physical information on the ion beam to the operations team of the facility. The common specification for beam instrumentation [1] provides an overview of the types of devices and their system layout. Generally, all beam diagnostic systems can be structured in five layers:

1. Detector with front-end analogue electronics and drive mechanics
2. Signal transmission via long cables
3. Signal acquisition and analysis in digitizer systems, typically ADCs with specific FPGA code, with front-end controllers (FEC) and read-out software (FESA classes)
4. Data accumulation in data concentrators and high-level software
5. Slow control systems for detector infrastructure or subsystems (drive control, gas flow measurement, etc.)

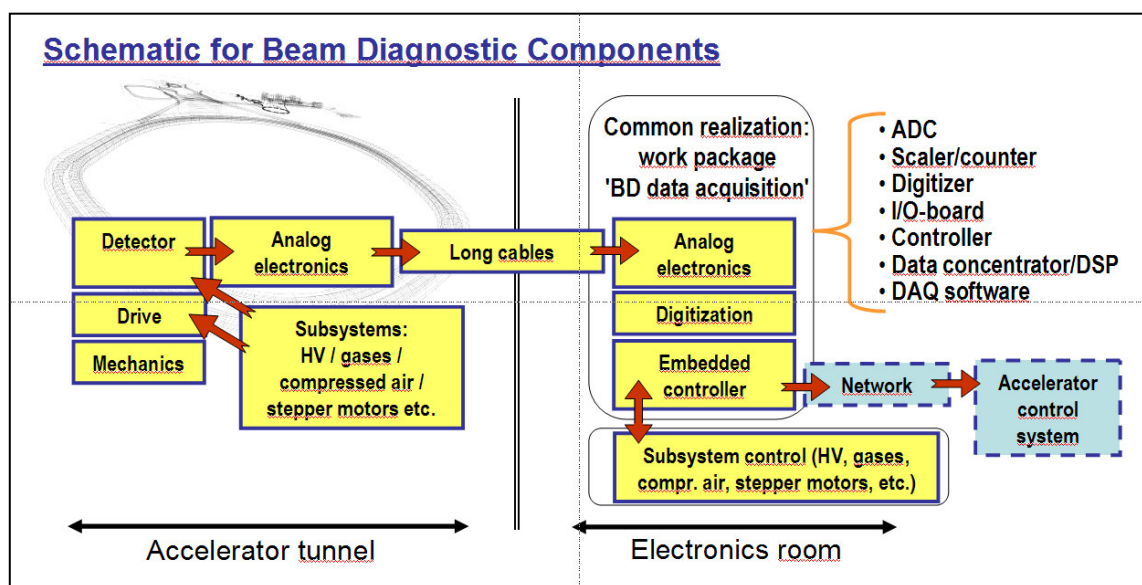


Figure 1: Schematic overview of general system layout

The scope of delivery in this contract is restricted to layer 1, the front-end analogue electronics, and aims to complete already existing instrumentation systems of the present GSI facility, serving the current “FAIR phase-0” experiment program, and to extend planned systems for the future FAIR facility.

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2. Abbreviations, Terms and Definitions

Table 1: List of Abbreviations

BEA	Beam Instrumentation Department
BI	Beam Instrumentation
BD	Beam Diagnostics
DAQ	Data Acquisition
DIN	Deutsche Industrie Norm
DS	Detailed Specification
EDMS	Engineering & Equipment Data Management Service
FAIR	Facility for Antiproton and Ion Research
FAT	Factory Acceptance Test
FESA	Front-End Software Architecture
GS	General Specification
GSI	GSI Helmholtzzentrum für Schwerionenforschung GMBH
HEBT	High Energy Beam Transport
IFC	I/f converter or current-to-frequency converter
I/O	Input / Output
LED	Light Emitting Diode
PSP	Project Structure Plan (code number in cost book)
QIPP	Quality-Inspection and Production Plan
R&D	Research & Development
SAT	Site Acceptance Test
SIS100	FAIR Synchrotron
SI-System	International System of Units
TCP/IP	Transmission Control Protocol/Internet Protocol
TG	Technical Guideline

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3. Scope of the Technical System

3.1. System Overview

The current-to-frequency converter (IFC) is a device for the measurement of small currents in the range from a few nA to 10 μ A, e.g. from ionisation chambers or secondary electron monitors, with high resolution and fast response time. The converter exploits the principle of pulsed charge balance and uses special opto-couplers as switched current sources.

The following paragraph describes existing realization of the IFC, which serves as a starting point for the electronic development in this contract.

Important notice:

For clarity, the existing realization of the IFC will be referred to as 'IFC3' in the following. The novel product, i.e. the result of the device development described in this specification, will be referred to as 'IFC4'.

The existing realization of the instrument (IFC3) features three measurement ranges, i.e. 100 nA, 1 μ A, or 10 μ A. Measurement ranges, input current polarity and test current can be selected or activated via a remote interface.

Two frequency output signals (norm. and inverted NIM pulses) are available via the interface. To avoid ground loops and hence noise pickup, control inputs as well as status and signal outputs are separated from the device ground via opto-couplers or relays. The current input is protected against overload. For local readout negative NIM output pulses are available via a Lemo connector. A green and a red LED indicate the device status "pulsed operation" or "range overload", respectively. For test purposes, an internal circuit produces a signal current of 1% of the active measurement range upon activation either via the local push button or the remote interface. With 1 MHz maximum output frequency at full scale excitation, the test function creates a frequency of about 10 kHz.

More technical details of the existing IFC3 can be found in the user manual **Fehler! Verweisquelle konnte nicht gefunden werden..**

It is important to mention that the IFC device requires a separate power supply. For the IFC4 two variants of power supplies are foreseen:

- A) 'single type' power supply (wall-plug unit) and
- B) 'multiple type' power supply (supply of IFCs from a remote central electronics room).

More details on the power supplies are given in section 4.3.1.

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3.2. Scope of Delivery

The following table gives a precise overview of all IFC devices, single (wall-plug) and multiple (central) power supplies to be delivered by the contractor. Calibration of IFC devices is part of the service prior to delivery.

Table 2: List of required devices.

SIS100 Detector / System	No. of pcs.	Type	Power Supply	Comment
Cryo collimators	60	rack-mount	central	„multiple type“
Ion halo collimators (foils)	3	rack-mount	central	„multiple type“
Proton halo collima-tors (absorber blocks)	12	rack-mount	central	„multiple type“
Halo collimator for slow extraction	6	rack-mount	central	„multiple type“
Beam Loss Monitors	198	rack-mount	central	„multiple type“
Beam Stopper	6	rack-mount	central	„multiple type“
Sum IFC central power supply	285	rack-mount	central	
Laser Cooling	10	single	wall-plug	„single type“
Spares	85	single	wall-plug	„single type“
Sum IFC single power supply	95	single	wall-plug	
Total no. of IFC units	380			

Power Supplies				
Single device	95			
Spares	10			
Central Power Supply	12			Two supply strings into six sectors each
Spares	2			
IFC-Crates	87			84 niches around SIS100 ring: IFC numbers require in three cases two crates
Spares	10			

3.3. Spare Parts

The number of spare parts is given in Table 2.

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4. System Specification

The following section specifies the technical parameters of the existing IFC3, which serves as a starting point for the device development towards the new IFC4. The required upgrades for IFC4 are described in section 4.2.

All component labelling has to be carried out according to [3], [3].

4.1. Technical Requirements for System Components

Main technical requirements of the current-to-frequency converter IFC3 are given in the following table. The IFC3 presented here is a result of a long-term development project at GSI. In order to achieve the required performance for precision measurements, the contractor has to strictly adhere to the given layout and a general willingness to perform quality assurance measures for various production steps is essential. For more technical details the reader is referred to **Fehler! Verweisquelle konnte nicht gefunden werden..**

Table 3: Technical requirements of IFC3

Req.-No.	Parameter	Value
R01)	Power supply	+5 V / 125 mA, -5 V / 100 mA stabilized power supply
R02)	Output frequency at full scale	1 MHz
R03)	Maximum output frequency, reduced linearity	2 MHz
R04)	Range A (default) / Range B / Range C	100 nA / 1 μ A / 10 μ A
R05)	Conversion factor A / B / C	100 fC / pulse ; 1 pC / pulse ; 10 pC / pulse
R06)	Equilibrium input current at 293 K	approx. 500 fA, adjustable
R07)	Equilibrium input current - drift	duplicates every $\sim$ 5 K
R08)	Temperature stability of conversion factor	approx. 0.1 % / K
R09)	Linearity ($f < 1$ MHz)	≤ 3 %
R10)	Input resistance, independent of range	1k Ω real, 60k Ω virtual
R11)	Acceptable detector/cable capacitance	≤ 300 pF
R12)	Response time	range dependent, < 3 periods
R13) ¹	Overload warning	> 90 % of full scale (see sec. 4.2)
R14) ¹	Time constant of overload response	10 ms
R15)	Current input socket	N jack (female)
R16)	Acceptable input load	< 20 mA / 20 Vrms
R17)	Polarity	selectable, default = negative

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R18) ¹	Local display LEDs	pulse = green; overload = red
R19)	Output pulse: local, not potential-free	negative NIM, tp = 250 ns
R20)	Test signal, via push button or remote	~1 % full scale

¹ Comment on R13, R14, R18: Overload signal will be dropped for IFC4, see next section.

4.2. IFC4 Functional Requirements (Parameter List)

The goal of the electronic developments in the frame of this project is the optimization of the existing IFC3 device. All further development works are based on the following decisions on functional requirements:

- Device development is based on the version IFC3, described in section 4.1
- In contrast to IFC3, for version IFC4 there is no electronic temperature compensation foreseen.
- In version IFC4 there will be no overload alarm anymore. In IFC3 the Overload Alarm indicates crossing of 90 % of range. But it was observed in IFC3, that this alarm introduces a jump in pulse output due to the sudden additional load requested from the power supply. Therefore, all related components for that group are NOT required anymore.
- Improvement of calibration: IFC3 has six internal adjustable CERMET 10 turn resistors (better new 20 turns): those are very important for calibration of each of the six measurement ranges in two polarities. However, IFC3 had the disadvantage that opening the calibration lid changes the carefully chosen calibration points when the lid is closed after calibration. Therefore, IFC4 will feature a special calibration feedthrough with plastic cover.
- A special plastic guidance is foreseen to ease the calibration with a calibration pen.
- An important disadvantage of the existing IFC3 is, that the discrete sender and receiver parts of the optical coupler are sometimes not well aligned. Due to this it is not possible to define a common pre-resistor per range for all individual IFCs, thus the values for several resistors (R32 / R35 / R37 / R39 / R42 / R44) vary. To improve this situation either a separate piggy board carrying sender and receiver shall be used, or a commercial sender/receiver combination shall be implemented.

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4.3. Interfaces

The following table lists all interfaces of the existing IFC3:

Table 4: IFC3 Interfaces

Interface	Task	Comment
N-Type (screw mount connector with fixed contact)	Measurement signal input	Important for small currents
Three pole screw terminal insulated from chassis	Power supply	New for IFC4
Sub-D connector insulated from chassis	Remote control and signal output	
Out NIM 1-pin Lemo socket	NIM-type signal output	Monitor output, used for local recalibration

For technical details of the interfaces see ref. **Fehler! Verweisquelle konnte nicht gefunden werden..**

4.3.1. Power Supply for IFC4

Each IFC device requires a separate power supply. In the case of the existing IFC3 only standard 230 V plug-in power supplies were used. However, for the requirements of the FAIR facility two variants of power supplies are needed for the IFC4:

- A) 'single type' power supply and
- B) 'multiple type' power supply.

4.3.1.1. Single-type Power Supply

The single-type power supply for the IFC is a standard wall-plug 230 V power supply.

The technical requirements are:

- stabilized power supply
- output voltage: +/- 5 V output voltage, low ripple, typ. 50 mVpp (max.)
- output current @ +5 V: max. 125 mA
- output current @ -5 V: max. 100 mA
- output connector type: 3-pin screw-plug terminal

4.3.1.2. Multiple-type Power Supply

This type of power supply acts as a central power supply for several IFCs. The schematic layout is presented in Figure 2.

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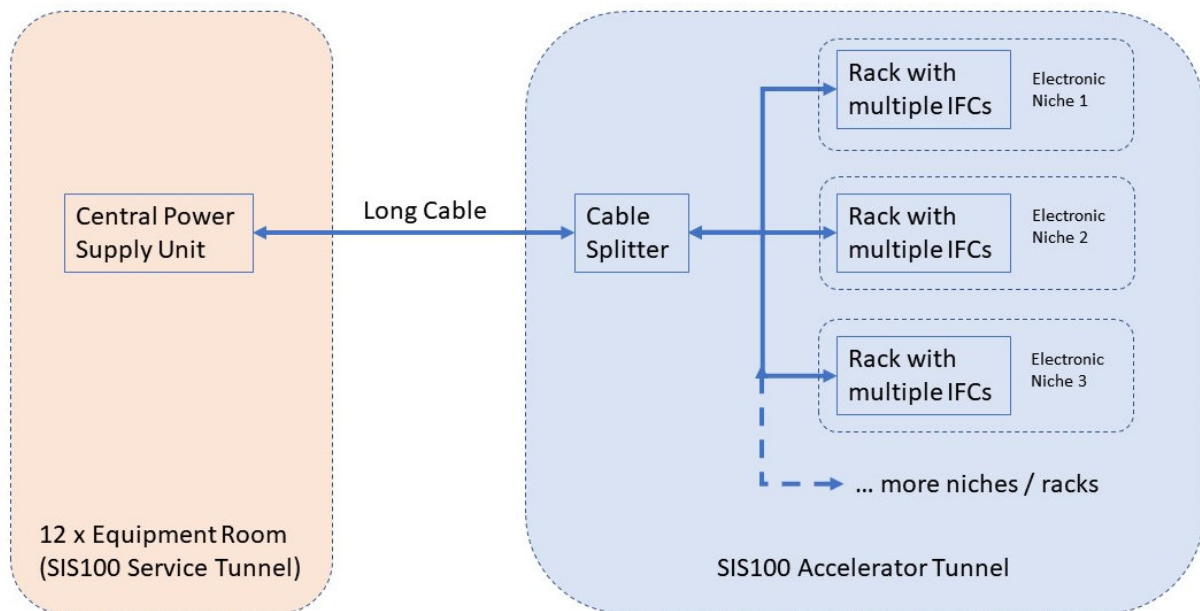


Figure 2: Schematic layout for multiple-type power supplies.

The multiple-type power supplies are designed for the requirements of the SIS100 synchrotron. Here 12 equipment rooms are available for the installation of the accelerator infrastructure. Inside each electronic equipment room several of the Central Power Supply Units will be installed. Each central power supply unit provides the operating voltage for several crates with multiple IFCs.

In the SIS100 service tunnel each of the 6 straight sections will feature 1 branch for the central power supply of IFCs. Identically, each of the 6 bent sections will feature 1 branch for the central power supply of IFCs.

In the bent sections there are 10 niches with 3 IFCs each. In the straight sections there are 4 niches with variable numbers of devices, ranging from 2 to 13 IFCs.

The delivery for the multiple-type power supplies consists of two parts:

1) Central Power Supply Unit

- 19-inch rack mount chassis, 3 height units
- stabilized power supply
- Output voltage: +/- 9 - 12 Volts (to compensate for voltage drops between power supply and IFC crate)
- Output current: 5A (operating current estimated up to 4 A – operating at limit is not desired)
- Output connector type: 3+1 pol screw terminal or round power connector i.e. Sourial M12
- 3 unit 19" frame with modular replaceable supply units with standard VG interface preferred

2) IFC-Crate

- 19-inch rack mount chassis, 3 height units
- sliders / slots for up to 7 IFCs
- mechanical design in such a way that the standard IFC housings fit inside the crate sliders
- slider length: 220 mm

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- sub-D connectors with cutting and clamping technology (male)
- backplane with DIN rail (Hutschiene)
- good access to IFC from front-side is necessary to allow for individual IFC calibration
- Input connector type: 3-pin screw-plug terminal
- potential common power stabilization per crate to +/-5V

The exact quantities for the Central Power Supply Units and IFC-crates will be determined as the project progresses. The following numbers may serve as a first estimate:

Central Power Supply Units: 12 pcs.

IFC-crates: 87 pcs.

4.4. System Environment and Constraints

Environmental constraints of the IFC4 housing

Parameter	Value	Comment
Size	16 cm x 4 cm x 8 cm	
Temperature	+15° to +40° C	
Front side current Input	N type	
Front side local NIM out	LEMO 00 size connector	Sometimes local calibration is required!
Insulated 15 pol Sub-D control connector male back side		Slide out of crate partly for calibration requires crate internal flat ribbon connection to back side connector!

Environmental constraints of the power supply crate

Parameter	Value	Comment
Size	19 inch, 3U, rack-mount	
Temperature	+15° to +40° C	

Environmental constraints of the IFC crate

Parameter	Value	Comment
Size	19 inch, 3U, rack-mount	
Temperature	+15° to +40° C	
Modular replaceable power unit with standard crate internal H15 interface	H15 interface	In case of defect a fast replacement must be possible to ensure functionality and minimize down-time!

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5. Procedure

The realization process for FAIR hardware components is split into two phases: design and production. Each phase is concluded by a quality gate, i.e. a review or acceptance test.

For general information the reader is referred to the General Specification [2], for details on conceptual and final design reviews, CDR and FDR, see [4].

Detailed information can be found in Common Specifications for Beam Diagnostics (chapter 5) [1].

5.1. Design Phase

Conceptual Design Review (CDR): At this stage the concept of a component must be established. This includes e.g. all required simulations, estimates and calculations or the integration of the component into its working environment. Further, it includes a review of all safety relevant aspects.

Final Design Review (FDR): The final review establishes the production readiness of a component. At this stage all relevant information must be available. All documents needed for the production (drawings, concerted inspection plans, etc.) and operation (instruction manuals, etc.) are provided by the supplier.

5.2. Production Phase

For general information the reader is referred to the General Specification [2]. The contractor must prepare a comprehensive Quality Plan (Q-Plan) based on ISO 10005 (a standard assigned to ISO9001) and submit it for approval.

All FAIR components are tagged with a Component Identification Number (CID) according to, [3]. These numbers will be provided by the Beam Instrumentation Department prior to production. All reports and documents of a single component must refer to its unique CID.

A first of series component (FoS) will be produced and its quality checked during factory acceptance tests (FAT). After transport to GSI, all or parts of the tests will be repeated during site acceptance tests (SAT). Successful results on the FoS define the start of the series production. All tests are documented in writing. Raw data files in a common format like ACSII, CSV or similar are part of the delivery.

Special attention must be paid to calibration and linearity measurements in all 6 measurement ranges (3 ranges, 2 current polarities). Given the large number of units, a dedicated test bench with precision current source and frequency counter is required with possibility to modify and automatize software FAT procedures. Beam Instrumentation Department will assist this development.

Series production of IFC4 units must be divided into a pre-series of about 10% of the total number in order to verify the production process and the quality of the devices. This pre-series must be tested and analysed according to the FAT procedure established for the FoS unit. Documentation and data must be sent to GSI for formal approval in writing prior to the production of the full series. Finally, the FAT procedure is carried out on all series units.

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6. Quality Assurance, Tests and Acceptance

For general information the reader is referred to the General Specification [2]. Detailed information can be found in the Common Specifications for Beam Diagnostics (chapter 5) [1].

6.1. Quality Assurance System of the Contractor

The Q-plan of the manufacturer and acceptance test documentation summarise all information to assure the requested component quality.

For details on factory and site acceptance tests, FAT and SAT, see [5]. General requirements must be tailored to the needs of each individual project type: software, mechanical hardware or electronics.

6.2. Factory Acceptance Test (FAT)

Detailed information can be found in the Common Specifications for Beam Diagnostics (chapter 5) [1]. Prior to production, the FAT procedure must be agreed by manufacturer and Beam Diagnostics Department in writing.

6.3. Site Acceptance Test (SAT)

Detailed information can be found in the Common Specifications for Beam Diagnostics (chapter 5) [1]. Prior to delivery, the SAT procedure must be agreed by manufacturer and Beam Diagnostics Department in writing. Beam Instrumentation Department will repeat FAT tests at GSI on an existing test bench for the FoS unit, all units of the pre-series and a subset of the full series.

7. Documentation

For general information the reader is referred to the General Specification [2]. Detailed information can be found in the Common Specification for Beam Diagnostics (chapter 5) [1].

A complete list of documents must be compiled for each component and agreed upon by manufacturer and Beam Diagnostics Department in writing. The documentation includes all technical information, instruction manuals, drawings, circuits, part and component lists.

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8. Related Documents

MANDATORY:

- [1] EDMS-ID: 1174185 F-CS-BD-01e Common Specifications Beam Diagnostics
- [2] EDMS-ID: 1365092 F-GS-F-01e General_Specification
- [3] EDMS-ID: 1229368 F-TG-B-05e Component-ID_Barcode_System
- [4] EDMS-ID: 1514206 Q-VA-QA-0006 Design Reviews (CDR and FDR)
- [5] EDMS-ID: 1514174 F-VA-QUA-en-0025 Acceptance Tests (FAT and SAT)

RECOMMENDED / INFORMATION:

- [6] EDMS-ID: 1563284 F-DS-BD-27e Detailed Specification HEBT Particle Detector Combination
- [7] EDMS-ID: 1179710 F-DS-BD-13e Detailed Specification for Secondary Electron Emission Grid (SEM-Grid) for HEBT
- [8] User Manual: „Gebrauchsanweisung IFC3, Strom-Frequenz-Wandler“, Fa. Seleon, 2003