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Document Title:	Detailed Specification of Particle Detector Combination for HEBT
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1. Purpose

The purpose of this document is to specify the technical requirements of the Beam Diagnostic (BD) component Particle Detector Combination (PDC) for the High Energy Beam Transfer Lines (HEBT) [2] of FAIR [1]. It is the most detailed document in the hierarchy of beam diagnostic documentation to specify all rules and information for the planned technical realization of this system.

The Detailed Specification serves as an entry point for third parties to get an overview of the required functionalities of a beam diagnostic component, to evaluate the scope of the instrument and to learn about the achievements reached with existing realizations at GSI.

Whenever regulations and requirements are specified in the General Specifications [3], Technical Guidelines or Common Specifications for Beam Diagnostics [4] they are only referenced in the present document. The related documents are listed in Appendix II.

No legal or contractual conditions are treated in this document. All related information is given in the General Specifications for FAIR [3]

Appendix III contains a list of abbreviations used in beam diagnostic documents.

2. Scope

The Particle Detector Combination system described here is intended for usage in the HEBT section of FAIR.

Throughout the FAIR project individual technical components are unambiguously identified by their unique psp-code (project structure plan). Moreover the sub-structure of beam diagnostic equipment is also reflected by detailed psp-codes for BD sub-components.

The present document covers the following psp-codes:

PSP	BD Component	FAIR Section
2.3.6.3	Particle Detector Combination	HEBT
2.3.6.3.1.1	Detector	HEBT
2.3.6.3.1.2	Vacuum Chamber	HEBT
2.3.6.3.1.3.1	Pressurized air drive	HEBT
2.3.6.3.1.3.2	Other	HEBT
2.3.6.3.1.4	Long Cables	HEBT
2.3.6.3.1.5.1	High-Voltage Supply	HEBT
2.3.6.3.1.5.2.	Pressurized air control	HEBT
2.3.6.3.1.5.3	Detector Gas	HEBT
2.3.6.3.1.6	Data Acquisition	HEBT

Civil construction and building issues are specifically **not** covered in the present document.

The PDCs are not connected to any kind of interlock or machine protection system.

3. Responsibilities

The responsibilities with respect to changes and modifications of the present document are entirely in the hands of the Beam Instrumentation Department (LOBI) of the GSI Helmholtz Centre for Heavy Ion Research GmbH (GSI) Darmstadt.

4. General Functionalities

4.1. Overview

The task of the Particle Detector Combination (PDC) detectors is to measure the beam intensity of slowly extracted beams. The PDC data will be used to determine, optimize and monitor the beam transmission and the temporal beam structure.

The complete range of possible beam intensities at FAIR cannot be covered by one detector type. At GSI the task was accomplished by a combination of three detectors, a plastic SCintillator (SC), an Ionization Chamber (IC) and a Secondary Electron Monitor (SEM). The working ranges for all three detector types are shown in Figure 1.

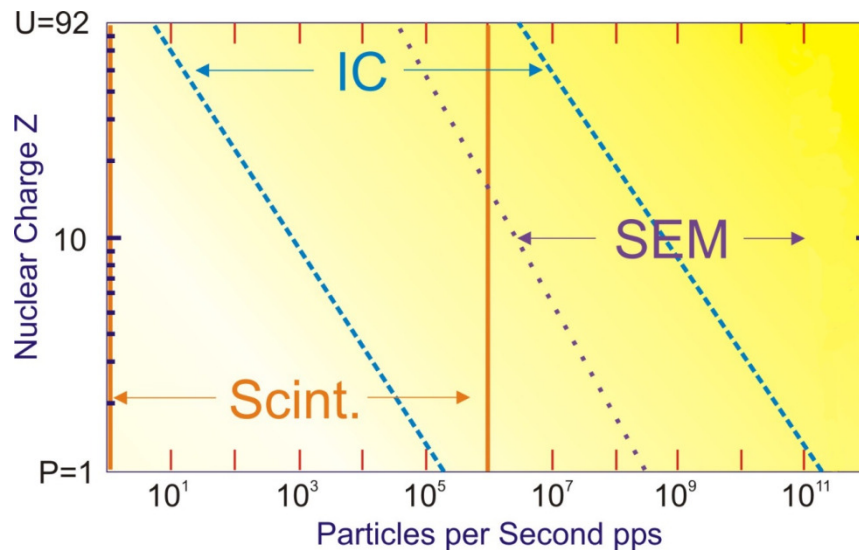


Figure 1: Working ranges of the GSI-PDC. The upper range of the SEM detector is about 10^{11} pps $^{238}\text{U}^{73+}$ @300 MeV/u, which is determined by the readout electronics.

There are multiple options for the realization of the PDC detectors. As the PDC will be used for the HEBT commissioning and standard operations, a solution close to the one established at GSI will be favored. The physical aspects of the PDC detectors are described in [302] and [303].

Since a Particle Detector Combination is 'defined' as three different detectors to measure the beam intensity over a wide range, the PDC detectors for HEBT are physically divided in two locations, due to mechanical reasons. The PDC is

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always located nearby the profile measurement device 'Multi Wire Proportional Chamber' (MWPC, [20]), where one installation contains the PDC-SC and PDC-SEM and a second contains the PDC-IC and the MWPC.

The PDC will measure all beam intensities expected at FAIR with accuracy of order of 5%.

4.1.1. Measured quantity

The PDC must measure the amount of particles passing through the active area of the detector as a function of time.

4.1.2. Physical Measurement Principle**PDC-SC**

The SC detector utilizes the interaction of the ion beam with a scintillator which creates scintillation light. A photomultiplier tube (PMT) converts the light into an electrical signal. Each beam particle creates one electrical pulse, which is counted by the Data Acquisition (DAQ) system [21].

PDC-IC

The IC detector uses an electrical field to collect ion-electron pairs formed in a known gas mixture by the ion beam. The beam current is calculated based on the measured ionization current and the calculated energy loss for a single beam ion into the IC active volume.

As described in 4.1, the PDC-IC part is installed on a separate drive, in combination with a MWPC, nearby the PDC-SC and PDC-SEM. The readout of the three PDC detectors is together described in this specification, the MWPC in a separate specification [20].

PDC-SEM

Many electrons are excited during the passage of charged particles through matter. Some of these electrons will have sufficient energy to migrate to the material surface and escape. The SEM detector measures the amount of these secondary electrons under controlled conditions. The beam current is calculated based on the measured secondary electron current and the calculated secondary electron yield for a single beam ion.

PDC-Self-Calibration

The SC detector produces one pulse for each detected ion. In contrast the IC and SEM detectors generate a current proportional to the beam intensity. The measured current is converted into beam intensity; the calculation requires details of the detector geometry (IC gap size, SEM foil thickness, etc.) and the beam energy, mass and charge. Systematic errors in the calculation of the beam current are removed by calibration of the IC versus a SC detector. Next, at higher beam intensities, the current determined by SEM is compared to the reading of

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the calibrated IC detector. This calibration procedure is called PDC-self-calibration.

Each PDC detector set consists of a SC, IC and a SEM detector, guaranteeing the possibility for self-calibration and detectors cross-checks.

4.2. Component Setup

In order to comply with the measurement task as described in the previous sections GSI LOBI Department defines the technical solution for installation at FAIR as described in the following sections.

The diagnostic component as specified in the present document is the product of on-going R&D work within GSI LOBI department. It is important to note that minor changes of the parameters given here might become necessary during the course of project realization. Any contributor shall account for the fact that limited alterations of the technical realization as described here will be communicated by GSI LOBI department (see section 3) as soon as the modification is approved by GSI and agreed upon by the responsible persons at FAIR.

The intent of the present specification is to give a coherent overview of the present planning for the BD component. Technical aspects and parameters, e.g. in sections 4.3 or 12, which are still under discussion are clearly marked as being preliminary throughout the document and the reader is requested to pay special attention to the list of open issues (see section 14).

4.2.1. PDC-SC

The BD component '**PDC-SC**' consists of the following parts:

- Detector: fast scintillator, e.g. NE102A/BC400/EJ-212 or similar, glued to a UV transparent light guide
- Photo Multiplier Tube (PMT) with magnetic shielding
- Active Voltage Divider (AVD) necessary for the PMT operation
- LED, attached to the light guide. It will be used for testing of the PMT-AVD-readout electronics chain. This functionality is referred to as self-test [320].
- Holding frame for the light guide, PMT and AVD
- Feed-through with pneumatic driven actuator
- Patch panel attached to the holding frame
- Cabling for the PMT signal and high voltage to the patch panel and from the patch panel to the corresponding electronics room
- Cabling for the test LED to the patch panel and from there to the corresponding electronics room
- Linear fan-in/fan-out, for splitting the analog signal from the detector
- Leading edge discriminator
- Latching scaler
- Counter interface for driving the self-test pulsed LED [320], [307]
- FEC (front-end computer), shared with other detectors
- Floating high voltage power supply.

Possibility for the following update should be foreseen:

- Additional latching scaler and discriminator for each PDC-SC.

4.2.2. PDC-IC

The BD component '**PDC-IC**' consists of the following parts:

- Detector: Gas filled ionization chamber (installed together with a Multi-Wire Proportional Chamber (MWPC) [20])
- Tubes mounted in the pocket, guiding the gas flow
- Quick release connectors for the gas supply
- Two tubes to the designated gas distribution panel
- Current to frequency converter (IFC) [308], grounded to the pocket body
- Holding frame, for detector mounting in the pocket
- High voltage RC filter, grounded to the pocket body
- Patch panel attached to the detector holding frame
- Cabling for the IC signal to the patch panel and from the panel to the IFC
- Cabling for the digital signals from the IFC to the corresponding counting room
- High voltage cables connecting the detector to the RC filter, through the patch panel, and the RC filter to the corresponding electronics room
- Counter interface (V-DIO [321]), for communication with the IFC
- Latching scaler
- FEC, shared with other detectors
- Floating High Voltage power supply

4.2.3. PDC-SEM

The BD component '**PDC-SEM**' consists of the following parts:

- Detector: secondary electron monitor, mechanically attached and grounded to the detector pocket
- Current to frequency converter (IFC) [308], grounded to the detector pocket
- Bakeable feedthroughs, for the detector signal and the high voltage
- Bakeable cables for the analogue and high voltage connections from the detector to the feedthroughs
- High voltage RC filter, grounded to the detector pocket
- Cable from the signal feedthrough to the IFC
- Cable/s for the IFC digital signals to the corresponding electronics room
- High voltage cable, from the RC filter to the corresponding electronics room
- Counter interface (V-DIO [321]), for communication with the IFC
- Latching scaler
- FEC, shared with other detectors
- Floating high voltage power supply

4.3. Basic Component Parameters

The PDC detector system should have:

- Active area covering a circle with diameter of 100 mm
- Operating ranges and measurement accuracy for the individual PDC-detectors equal or larger than the GSI and HIT-Heidelberg exemplary realization see Figure 1 and Table 1
- Time resolution better than 1 ms

The aimed measurement accuracy is 5% for all ions delivered by SIS18/SIS100.

4.4. Installation Locations and Special Requirements

The present document covers the parameters for the BD component Particle Detector Combination as planned for installation in the High Energy Beam Transport (HEBT) line of FAIR.

The high radiation background in positions T1D1, T3D1 will lead to degradation of the plastic scintillator and the IFC electronics.

The number of components as well as special requirements can change due to modifications in the HEBT Topology.

It is required to set-up the IC-MWPC detectors gas infrastructure with respect to [26].

5. Mechanical Setup

5.1. Overview

The active area for all detectors is determined by the expected beam size (see Section 12). The PDC detectors will be mounted in/on two pockets [315]: one for the PDC-IC (and MWPC) and one for the PDC-SEM and PDC-SC, placed as close as the diagnostic chambers allow [23].

Accurate energy loss calculations can be performed for ions in equilibrium charge state. Hence, the system layout has to foresee at least one 50 μm stainless steel window in front of the first PDC detector with which the beam interacts.

Some of the detectors will be activated or will be operated in high radiation environment. To minimize exposure, patch panels should be provided, allowing quick mounting and dismounting of the cables and gas supply tubes.

Surface protection should be provided for the SEM and IC detectors. The detector covers will be used during transportation and storage.

5.2. PDC-SC

The PDC-SC consists of the following parts:

- Scintillator
- Light guide, glued to the scintillator
- Photomultiplier tube (PMT)
- Active Voltage Divider (AVD)
- Magnetic shield for the PMT
- Mechanics for pressing the PMT-AVD assembly against the light guide. Minimum pressure is required for a good optical contact between the light guide and the PMT
- LED, attached to the light guide
- Pocket, movable by pneumatic actuator. The pocket will be shared with the PDC-SEM. The pocket assembly should allow for the air flow which occurs when the PDC-SC is moved by the pneumatic drive
- Feed-through, movable by pneumatic driven actuator. The feed-through will move the PDC-SC out of the beam, when high beam intensities are measured with the PDC-SEM detector
- Light tight compartment, with patch panel, for the PMT-AVD assembly

The PDC-SC will be a rectangular panel with width of 105 mm, height of 109 mm and thickness of 2 mm. The scintillator will be glued to a light guide with thickness of 4 mm (e.g. glue NOA 61, produced by Norland Inc.). A 2.2 mm wide, 4 mm deep slot should be provided for gluing of the scintillator to the light guide. The light guide will be bent as shown in Figure 10. The plastic should not have bents larger than 40° in order to guarantee total internal reflection. The bend side of the light guide has to match the active area of a Hamamatsu R6427 PMT and

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should have an optical finish. The light guides for the PDC-SC detectors should be cut to the same length, within 2 mm, allowing for reproducible detector positioning.

A Hamamatsu R6427 PMT powered by a GSI in-house developed active voltage divider (AVD) [309] will be used to read the scintillator signal. Silicone pads will be installed on the PMT. The PMT-AVD assembly should be centered relative to the light guide and gently pressed against it, providing good optical contact.

The PMT should be covered by a conductive paint around the outside of the bulb, connected to the cathode potential and covered by isolating layer (HA coating). The HA coated PMT will be surrounded by magnetic shield. The shield has to be attached to the PMT-AVD assembly.

An LED will be attached to the light guide. It will be used for testing of the PMT-AVD-DAQ electronics chain (see Section 6). The cables powering the LED should be routed to the detector patch panel in a path which allows quick scintillator-light-guide exchange, without removal of the PMT-AVD.

Maximum space should be left in the pocket, where the SC detector will be installed, allowing for installation of additional/different particle counting detectors. The PDC-SC/PDC-SEM pocket, SC-patch panel and pneumatic actuators moving the detector pocket are indicated in Figure 2.

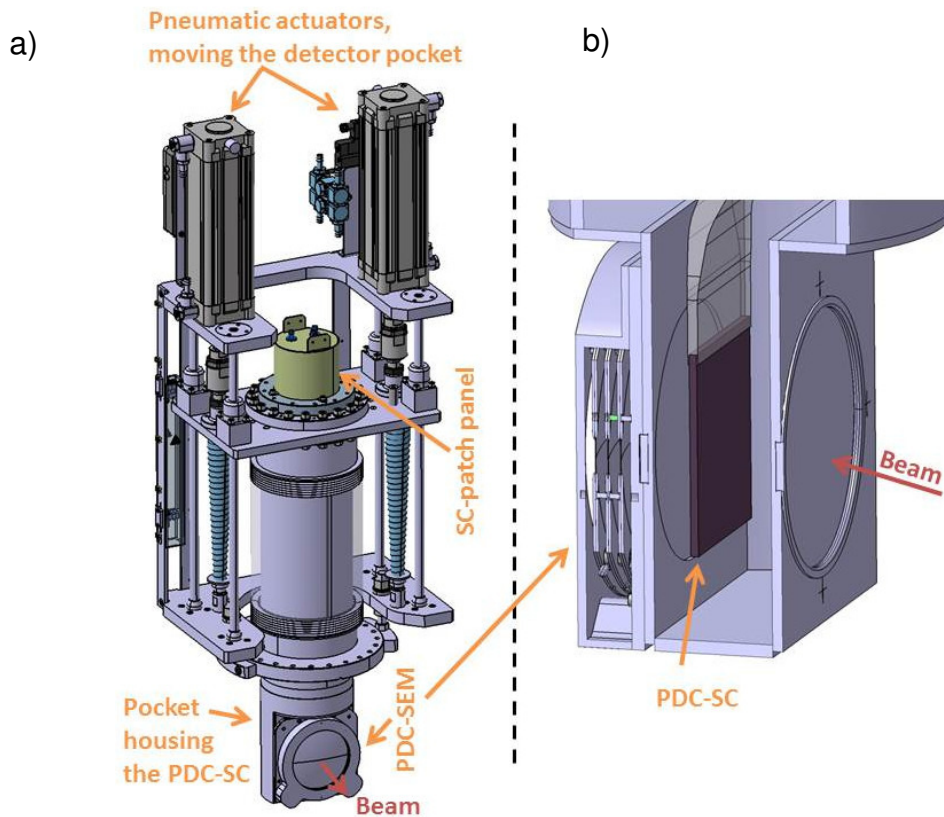


Figure 2: a) Schematics of the PDC-SC/PDC-SEM pocket. The pneumatic actuator driving the PDC-SC feed-through is not shown in the figure. b) A cut of the detector pocket, the PDC-SC and PDC-SEM are indicated.

5.3. PDC-IC

The PDC-IC consists of the following parts:

- Ionization chamber (combined with a MWPC [20])
- Detector pocket movable by pneumatic actuator
- Holding and positioning frame, fitted to the corresponding pocket
- RC high voltage filter, grounded to the pocket body
- Current to frequency converter (IFC) [308], grounded to the pocket body
- Patch panel with feedthroughs, sealing the pocket
- Pressure relief valve mounted on the patch panel
- Quick release self-sealing gas connectors
- Gas supply tubes with the corresponding fittings.

The PDC-IC will be built together with the MWPC [20] in one assembly at the GSI detector laboratory. It will be placed in the first detector pocket, with respect to the beam direction. The pocket has to be as long as feasible in order to provide possibilities for future updates.

Low noise operation requires appropriate grounding. The mechanical design should provide for common ground between the PDC-IC detector, the IFC and the RC filter.

A measurement of the beam intensity with PDC-IC relies on accurate energy loss calculation. The calculation will use the IC gas pressure to determine the gas density. The gas pressure/flow will be regulated and measured by the gas supply system [26]. Therefore, all connector and seals should be hermetic, sealing the detector pocket from the tunnel.

The materials in contact with the detector gas, gaskets, cable isolation etc., should not lead to polymerization, due to the strong electrical field created near the MWPC wires.

Quick release connections will be used for the gas supply. As the pocket may be over-pressured a pressure relief valve must be mounted on the patch panel. The relief pressure will be determined by the connector seals and must be a few times lower than the pressure at which the pocket windows break.

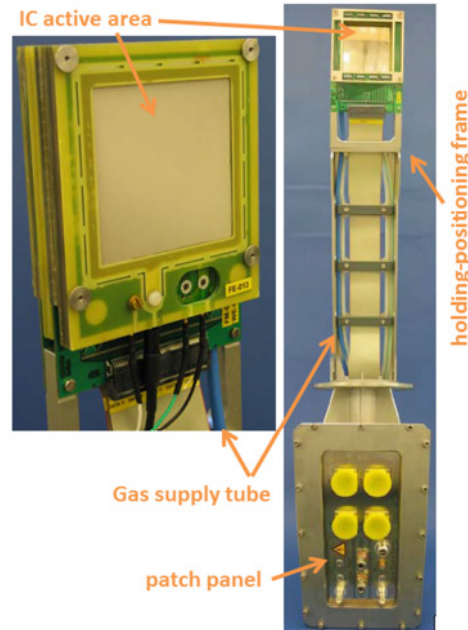


Figure 3: A photograph of the HIT Heidelberg MWPC-IC. It shows the holding structure, cabling and the pocket patch panel.

A MWPC-IC detector, used at HIT Heidelberg [318], is shown in Figure 3. The detector and its mechanics are similar to the one described in this section. The MWPC-IC detector at HIT Heidelberg ($\varnothing 70$ mm) has a smaller active area, compared to the HEBT MWPC-IC ($\varnothing 100$ mm).

5.4. PDC-SEM

The PDC-SEM will be operated in high vacuum and in ultra-high vacuum. It consists of the following parts:

- Three aluminum foils positioned and connected as shown in Figure 17
- Detector pocket shared with the PDC-SC, Figure 2
- Faraday cage grounded to the detector pocket
- Parts for attaching the detector to the pocket
- Signal and high voltage feedthroughs
- Shielded high voltage and signal cables
- RC high voltage filter, grounded to the detector pocket
- Current to frequency converter (IFC) [308], grounded to the detector pocket

The SEM-mechanics should conform to the following recommendations:

- Aluminum foils with minimum thickness should be used. The thickness will be determined by the stability to mechanical vibrations. Figure 4 shows a stack of three 24 μm Aluminum foils shaped by compressed air
- The detector surfaces have to be kept clean and free of unintended mechanical distortions
- The SEM foils should be mounted as close as mechanically reproducible
- The detector should be protected by a Faraday cage
- Shielded cables should be used for the signal and the high voltage
- The high voltage and the signal cables and Faraday cage should have the same ground



Figure 4: A photograph of a stack of three 24 µm thick Aluminum foils, shaped by compressed air.

The detector will be mounted on the pocket where the PDC-SC will be inserted. It will be placed behind the exit window of the pocket.

A SEM design consistent with the above requirements is shown in drawing [316]. Part of this drawing is shown in Figure 5. If a redesign is necessary, it has to be coordinated with the BI group.

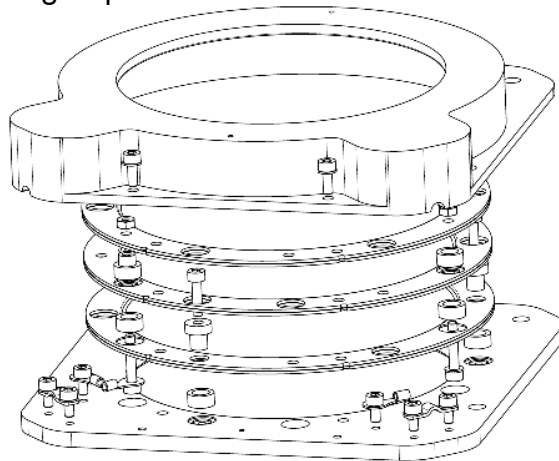


Figure 5: Exploded view of the PDC-SEM detector from drawing [316].

5.5. Vacuum Parts

For manufacturing and factory acceptance test of vacuum parts, all vacuum components e.g. chamber and stainless steel cylinder with gas volume and stainless steel foil windows have to fulfil the Vacuum Technical Guidelines [100], [101], [102], [103], [104], [105], [106], [107], [108], [109], [110], [111] and the requirements included in the Common Specification for FAIR Beam Diagnostics [4].

The PDC-SEM is a vacuum part and must be built according to the above specifications. The PDC-SC and PDC-IC will be operated under atmospheric pressure in the pockets.

The detectors will use two feedthroughs with pneumatic driven actuator. Each actuator will be mounted on DN200CF flange of the of BD vacuum chambers

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[23]. The actuators will drive two pockets mounted on DN150CF flanges. A photograph of a pocket prototype is shown in Figure 6.



Figure 6: Photograph of a prototype for the PDC detector pocket. The pocket windows are made from 50 µm stainless steel.

5.6. Mechanical Drive / Feed-through

The detectors will be moved in and out of the beam line by pneumatic drives. Three drives will be needed per PDC detector, one for the pocket with the PDC-IC and MWPC, a second for the pocket with the PDC-SC and PDC-SEM detectors and a third one for the PDC-SC feed-through. The pneumatic drives are described in the corresponding specifications [22], [25].

A 3D model of a PDC-IC pneumatic drive is shown in Figure 7. For dust protection, the pneumatic actuator must be enclosed in a protective box; a transparent material is preferred.

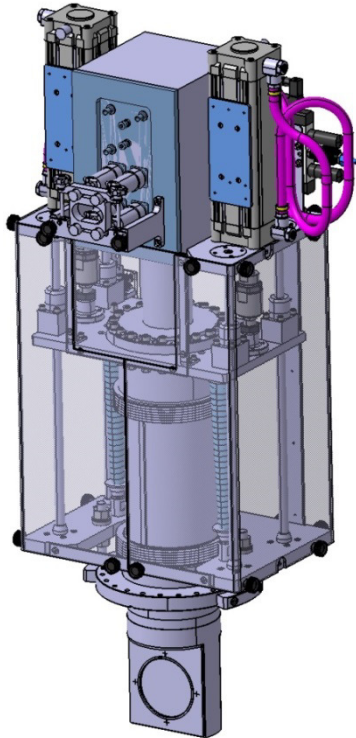


Figure 7: 3D model of pneumatic actuator for the PDC-IC detector.

5.7. Non-Vacuum Parts and Supports

The non-vacuum part of the PDC-IC consists of the detector head itself as well as its mounting structure inside the detector pocket, the break-out box with the patch panel providing the interfaces to the electrical and gas supplies as well as the detector signals.

The non-vacuum parts of the PDC-SC consists of the detector itself as well as its mounting structure inside the detector pocket, the patch panel providing the interfaces to the electrical supply as well as the detector signal.

The PDC-IC-IFC, PDC-SEM-IFC, PDC-IC-RC high voltage filter, PDC-SEM-RC high voltage filter, signal cables and high voltage cables are non-vacuum parts and can be removed for example during bake-out of the beam line (applicable only for the SIS100 extraction beam line, T1X1).

5.8. Exemplary Realization at GSI

Since many years PDC detectors are used at GSI to set-up the beam and to optimize beam transmission at the high energy beam transfer lines (HEBT). The installation was also demanded by the radiation safety department to survey beam intensities delivered to the experiments. A photograph of the PDC is shown in Figure 8.

In contrast to FAIR planning, the GSI PDC contains all three monitors (PDC-SC, PDC-IC, PDC-SEM) in the same spot. Whereas at FAIR HEBT, the three monitors plus a MWPC [20] are installed on two drives (PDC-SC & PDC-SEM; PDC-IC & MWPC) in different installation locations nearby.

At GSI all PDCs are equal with respect to the detector dimensions and types. The PDCs are not used to create any kind of interlock signals.

GSI-PDC parameters are listed in Table 1.

Device	Parameter	Value	Unit
Scintillator			
BC400	Size	75 x 79 x 1	mm ³
	Voltage	-1200 to -1800	V
	Photonis PMT shielded by mu-metal	XP2972	
Ionization chamber			
GSI type	Gap size	2 x 3.125	mm
	active area (diameter)	50	mm
	Detector gas flow	Ar/CO ₂ (80/20) 1.5	l/h
	Voltage	-1000	V
Secondary electron monitor			
GSI type	Size	70 x 70	mm ²

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	Material of foils	Aluminium	
	Number of electrodes	3	
	Voltage	+100	V
	Gap size	5	mm
	Thickness of foils	100	μm

Table 1: GSI-PDC parameters.

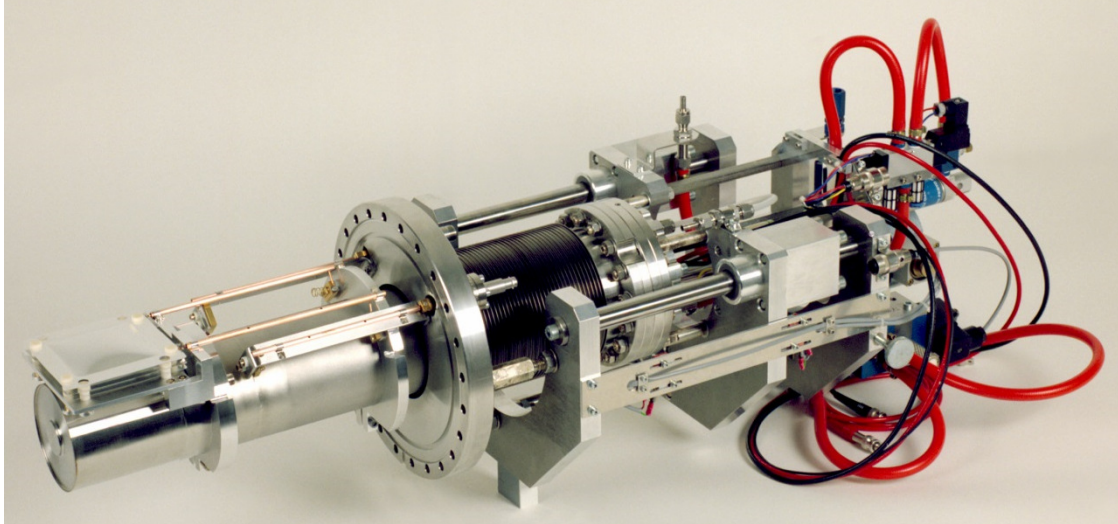


Figure 8: GSI-PDC with its complete feed-through and actuator mechanics.

5.8.1. GSI-SC

The scintillation light from a plastic scintillator has a decay constant of a few ns, hence the SC detector can be used for spill structure analysis. Due to the long signal cables at GSI, the time resolution reached by the GSI-SC detector was better than 100 ns.

A schematic view of the GSI-SC is shown in Figure 9. A BC400 plastic scintillator (manufactured by BICRON) is connected to a UV transparent PMMA light guide, Figure 10. A Photonis XP2972 PMT is attached to in-house developed active voltage divider (base). The PMT-Base assembly is pressed against the plastic light guide by springs. The detector operates in the vicinity of magnets; hence 1 mm thick magnetic shield is installed in the aluminum housing. An LED is mounted close to the photocathode, it is used to test the PMT and following electronics and data acquisition, see [320] and [307].

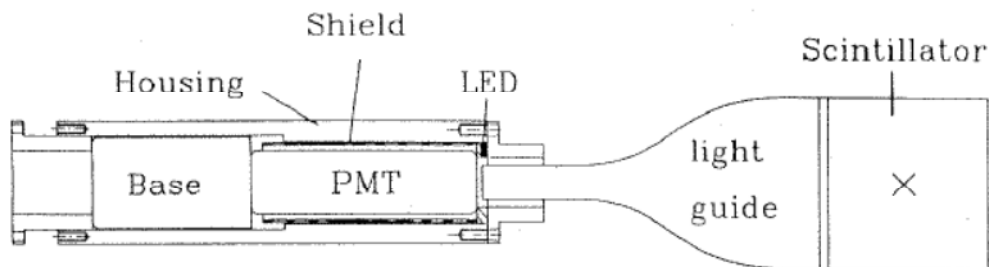


Figure 9: Schematic view of the SC detector.

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The thickness, size and optical coupling of the scintillator panel to the PMT limit the maximum counting rate of the detector and the ions which can be detected. The standard scintillator thickness at GSI is 1 mm. The scintillator is attached to the light guide with optical grease. Both of them are wrapped in Aluminum foil and black tape, Figure 11. This thickness is sufficient for the observation of ions heavier than carbon. Thicker scintillators or better light transition is needed for detection of lighter ions (see Subsection 14.1).

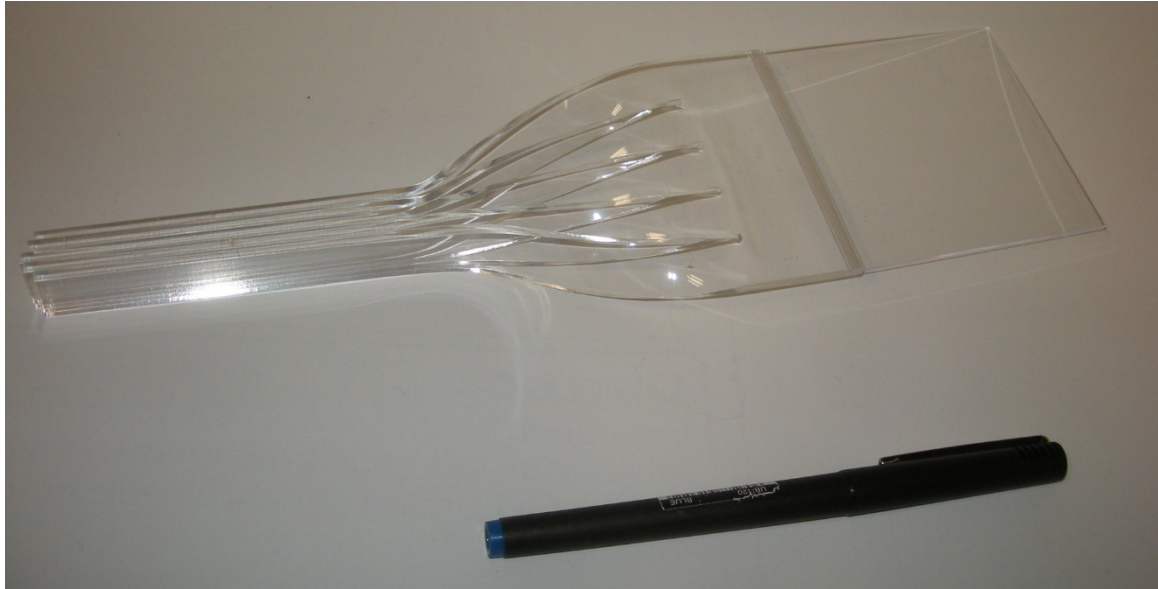


Figure 10: Rectangular plastic scintillator ($79 \times 75 \times 1 \text{ mm}^3$) with PMMA light-guide. On the left hand side the light guide will be cut, to appropriate length, and polished to optical quality.

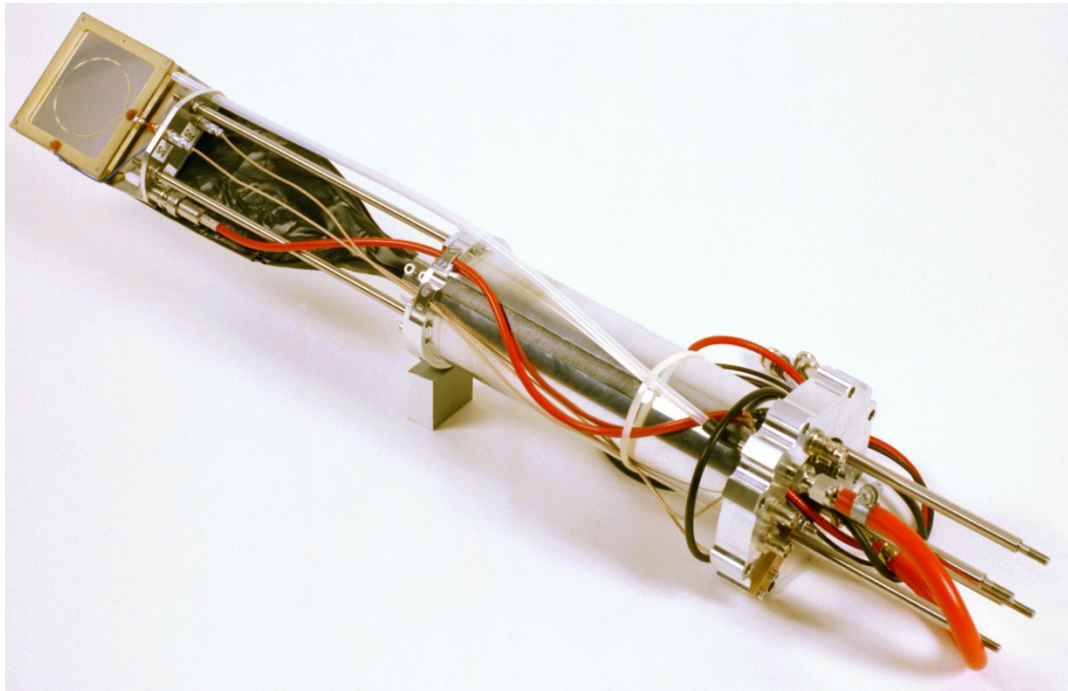


Figure 11: Removable inner part of the GSI-PDC with IC (older version) and SC, both are placed in 1 bar of Ar/CO_2 mixture circulated through the red tubes.

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The SC detector is sensitive to radiation damage and overload due to high beam intensity. Furthermore, particles which reacted with the pocket windows may have much lower charge than the beam, generating a signal below the detection threshold. These effects are shown in Figure 12, where ^{238}U beam at 300 MeV/u was detected by 1 mm scintillator. The blue curve is an amplitude spectrum of normally operating SC detector. The counts with smaller amplitudes are due to particles which reacted in the material in front of the SC detector.

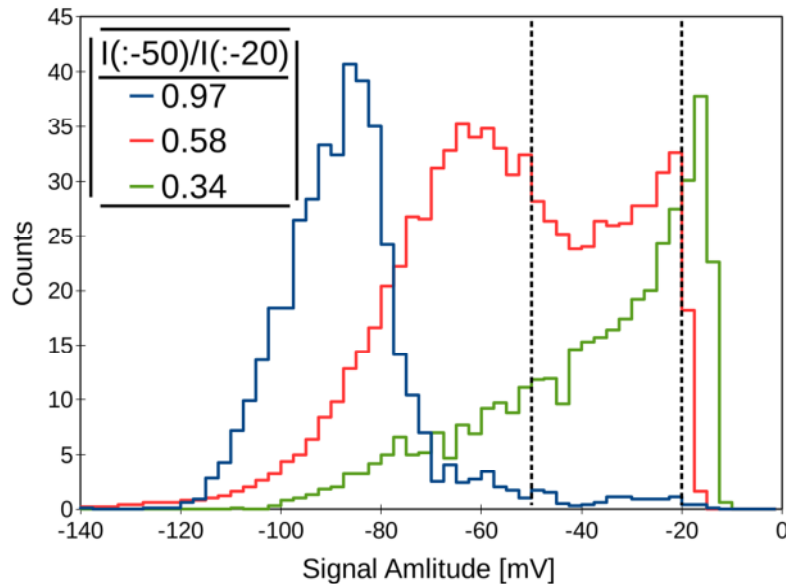


Figure 12: Signal amplitudes for normally operating PMT-AVD in blue, overloaded detector during parts of the spill in red and radiation damaged scintillator in green. The ratio of counts with amplitudes larger than 50 mV and 20 mV is shown in the inset.

The accuracy of the PDC-SC reading can be determined with different methods, e.g. measurement of the amplitude spectra, comparison of counts above two different thresholds, comparison to a calibrated IC, etc.

5.8.2. PDC-IC

The IC detector uses an electrical field to collect ion-electron pairs formed in a known gas mixture by the ion beam. The IC is operated in current mode, with a current to frequency converter (IFC) [308] attached by a short cable to the central electrode.

The GSI-IC consists of two IC chambers, mounted back to back as shown in Figure 13. Each chamber has a gap of 3.125 mm and is operated with Ar/CO₂ (80/20) gas mixture at 1 atm. A photo of the GSI-IC is shown in Figure 14. Figure 11 shows the GSI-IC attached to the corresponding detector feed-through.

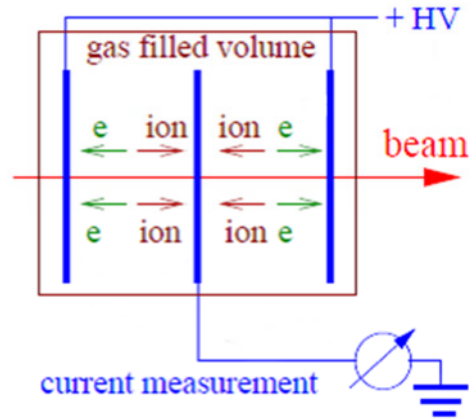


Figure 13: Schematic view of an Ionization Chamber (IC). The IC can be biased by positive or negative high-voltage.

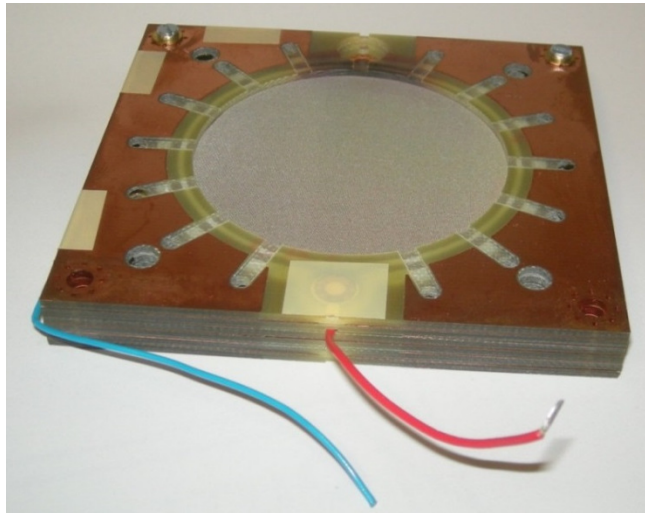


Figure 14: Two-gap GSI-IC with $d=50$ mm diameter.

The GSI-IC is powered by a negative high voltage. If positive high voltage is applied, the IFC will integrate the signal from the ions. At 1 kV/3.125 mm, the ions will be collected in approximately 50 μ s, which is about 10 times slower compared to electrons collection. The required time resolution for this detector is of the order of 1 ms or less, hence there is no difference if negative or positive voltage is used. The latter allows implementation of an IFC with the same polarity for the IC and the SEM detectors. Using the same IFC for both detectors is advantageous in terms of reliability, simplifying the IFCs and maintenance.

The maximum beam intensity measurable with the IC is determined by the charge recombination into the detector. The effect was measured in [312] and is illustrated in Figure 15. A software correction to the detector reading should be considered as a possibility to extend the IC operating range.

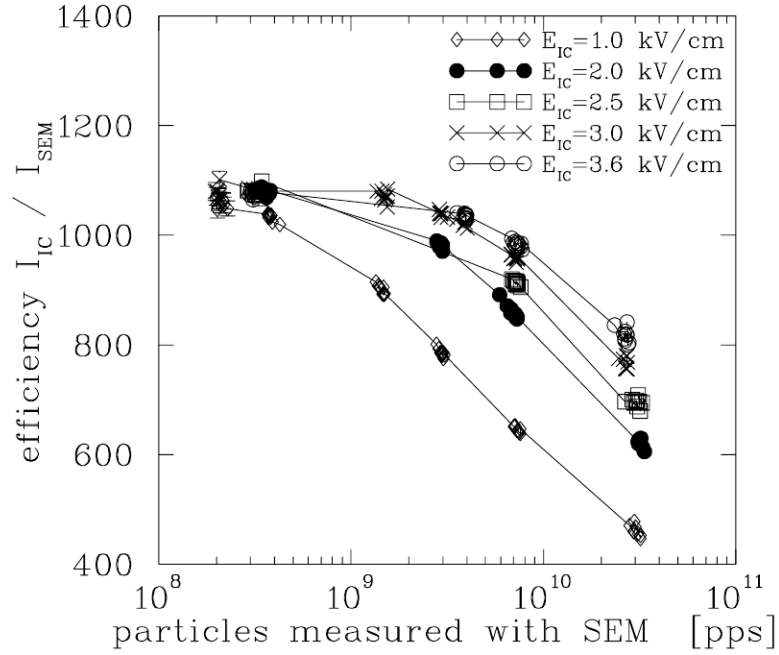


Figure 15: IC-current as a function of beam intensity measured for 300 MeV/u Ne beam. The IC-current is normalized to the non-saturated SEM detector, see in [312] for further details.

The PDC-IC will be built together with the MWPC [20] in one assembly at the GSI detector laboratory. A photograph of a similar detector, with active area of 75x75 mm², is shown in Figure 16.

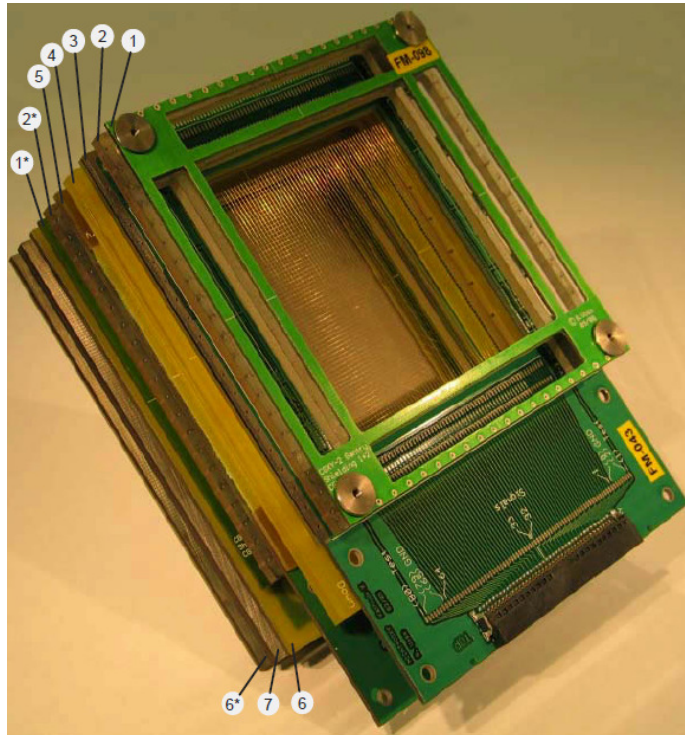


Figure 16: Photograph of the MWPC-IC [318] detector built for HIT Heidelberg. The numbers correspond to the layers described in Table 2.

Part	Layer	Component	Material & Pitch	Thickness
MWPC	1,1*	Shielding foil	Aluminized Polyimide	25 μm
	1-3; 5-1*	'dead' gap	Ar/CO ₂	c.a. 4.9 mm
	3,5	Signal (x,y)	W/Au wires 1.1 mm	50 μm 0°, 90°
	3-4; 4-5	'active' gap	Ar/CO ₂	c.a. 4.8 mm
	4	High voltage layer	W/Au wires 2mm	20 μm 45°
IC	1*-6	'dead' gap	Ar/CO ₂	2.1 mm
	6, 6*	High voltage layer	PE/Ni mesh	57 μm
	6-7; 7-6*	'active' gap	Ar/CO ₂	c.a. 3.4 mm
	7	Signal layer	PE/Ni mesh	57 μm

Table 2: HIT Heidelberg MWPC-IC layers (see also Figure 16 and [318]).

5.8.3. PDC-SEM

A schematic and a photograph of the GSI-SEM detector are shown in Figure 17. Three 100 μm aluminum foils were mounted on ceramic isolators. The foils are shaped in order to remove mechanical vibrations. The outer foils were positively biased, collecting the secondary electrons created by the ion beam. The central foil was connected via a short cable to the IFC described in [308] and [313].

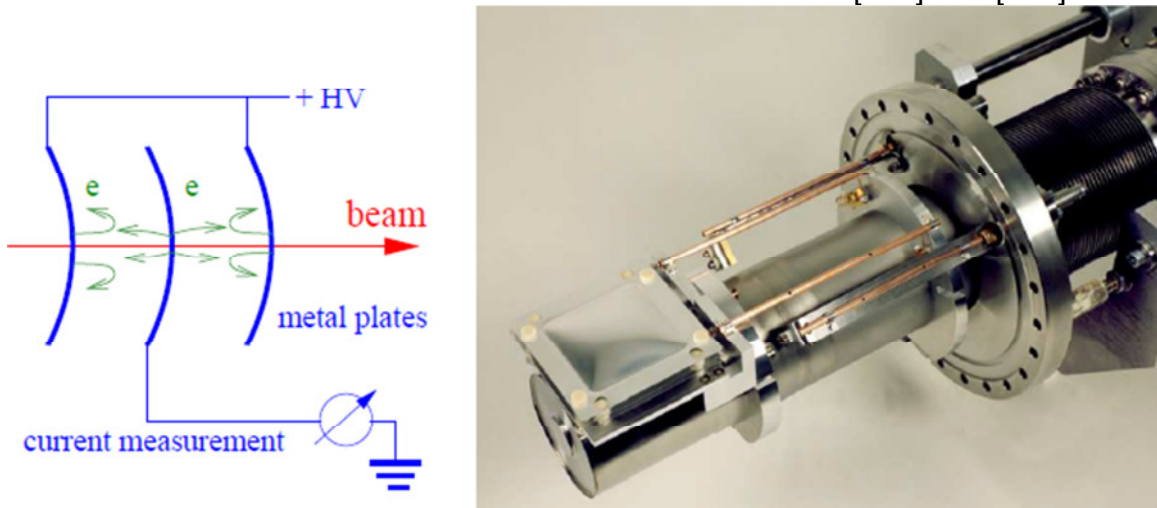


Figure 17: Schematic view of the Secondary electron monitor (SEM).

Provided that all SEM foils were installed in the same condition their electron yield will be similar. For the batch of foils used for the GSI-SEM detectors this yield was about 27.5 electrons per $\text{MeV}/(\text{mg}/\text{cm}^2)$ [304].

The assumption is that the surface of all foils is saturated with defects created during manufacturing, shaping and cleaning. For a given batch of foils one expects similar yield and low sensitivity to radiation damage, as long as the density of defect around the surface does not change. Such a change may be introduced by long exposure to high beam intensities. For instance focused

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^{238}U @ 300 MeV/u beam at 10^{10} particle per second will heat the aluminum foils, annealing the foils around the beam spot.

6. Electronics and Data Acquisition

6.1. Overview

The PDCs belong to the group of particle counting detectors. The PDC-SC generates a pulse for each particle interacting with the scintillator, while the PDC-IC and PDC-SEM generate a current proportional to the beam current. The IC/SEM signal is measured by a current to frequency converter (IFC [308]). Schematic of the PDC electronics is shown in Figure 18.

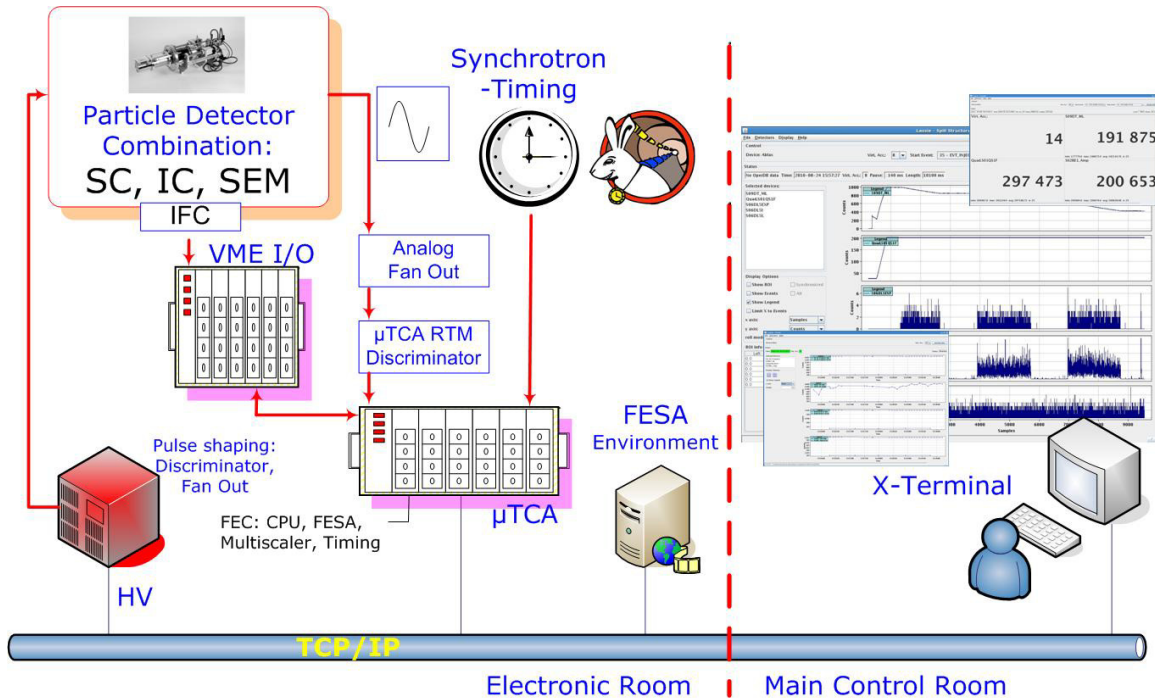


Figure 18: Signal and data flow diagram for the PDC detectors.

The detectors require remotely controlled high voltage power supply. This is realized with Ethernet based HV hardware.

The PDC-SC delivers analogue signals to an Analog Fan-In/Fan-out for multiplication, which is followed by a discriminator. The standard readout will be through μ TCA-discriminators, which will be realized as a RTM board attached to a μ TCA scaler.

The signals induced by the PDC-IC and PDC-SEM will be directly converted by the IFCs [308] to digital pulses with frequency proportional to the input current. The frequency of the signals generated by the IFCs will be measured with the μ TCA or VME scalers [305].

The FESA-DAQ software will be implemented on a diskless FEC, which will provide data to the users, e.g. the main control room, for visualization and evaluation (see Chapter 8).

In addition, the IFCs will generate a status signal when the input is in overage.

6.2. Beam line Electronics

PDC-SC

A PMT and an AVD [309] will be used to convert the light from the scintillator to electrical pulses. With an amplifier attached to the AVD the PMT can be operated at a lower gain, allowing for higher counting rates.

A system “self-test” will be performed with an LED [320], installed in front of the PMT. It will be attached to the detector light guide.

PDC-IC

An IFC module has to be installed close to the IC. The IFC should be grounded to the same point as the IC. The IFC requires ± 5 V DC.

A passive high voltage RC-filter will be installed close to the detector. The filter and the high voltage should:

- Not increase the recovery time of the detector after overload
- Protect the IFC from damage due to high leakage current
- Limit the maximum current in case of an accidental short (for instance during detector service)

Example schematics of an RC-filter and its frequency response are shown in Figure 19. The filter is based on a 5 M Ω resistor and a 100 nF capacitor. The capacitance and resistance have to be as large as possible. The maximum resistor value is limited by the voltage drop over the resistor at the maximum current at which the IC will be operated. The maximum current which the IFC can digitize is 10 μ A. With 5 M Ω the voltage drop over the resistor will be 50 V at 10 μ A, which is acceptable. The 120 k Ω resistor protects the IFC from short circuit, as the IFC will be able to withstand 20 mA DC current [308].

All IFCs should be connected to the Clean Power Supply [112].

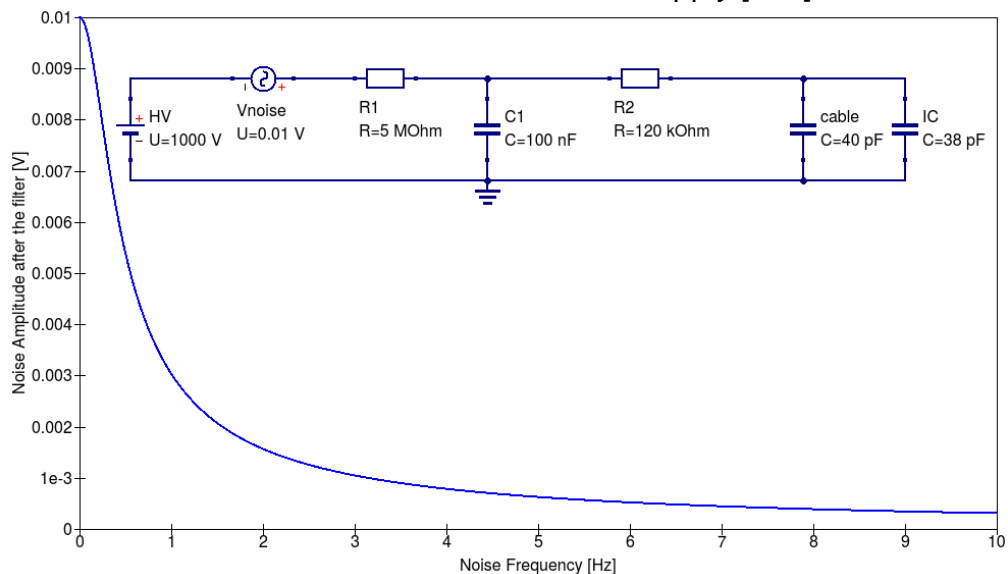


Figure 19: Example realization of a High voltage RC-filter.

PDC-SEM

An IFC module and a high voltage RC-filter will be installed close to the detector. The requirements for the IFC power and the RC-filter are the same as for the PDC-IC electronics.

IFC

The IFC connector to the V-DIO [321] module, which will be placed in the electronics room, should be TE Industrial Mini IO.

6.3. Parts in Electronic Rooms**PDC-SC**

- Cables for all analogue signals providing N-type feed-through connectors
- Leading edge discriminator in conformance with [21]. The discriminator input characteristics and general performance should match or outperform the one of the Phillips Scientific PS 710 discriminator
- Linear Fan-In/Fan-Out, min. 3 output channel, similar in performance to the Phillips Scientific PS 748 Fan-In/Fan-Out
- μ TCA Multichannel Latching scaler
- Counter interface for self-test option
- Carrier for additional FMC boards, e.g. ADC/TDC, or a mobile DAQ, for detailed amplitude spectra and spill structure analysis (min, one unit, to be move between the electronics rooms)

The analogue PMT signal will be transported to a nearby electronics room. It will be split by a Linear FAN-IN/FAN-OUT and discriminated by two leading edge discriminators. The digital signals from the level discriminators will be sent to latching scalers. The scalers are a part of the DAQ system, which is described in the Detailed Specification of the FAIR Beam Diagnostic Data Acquisition System [21].

The two discriminators will have different thresholds and will be used to detect detector overload and radiation damage.

The self-test LED will be connected to a counter interface, generating a burst of light pulses in defined time slots [320], [307].

PDC-IC and PDC-SEM

- IFC interface to the V-DIO [321] module. The module will distribute the IFC output data, status signal and parameters, control the range setting and the self-test function of the IFC
- μ TCA Multichannel Latching scaler

The current generated by the PDC-IC and PDC-SEM detectors will be fed into IFCs. The output signals will be connected to a counter interface via a multi-wire control cable. The V-DIO interface will be placed into the closest electronic room.

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It will receive the digital signal from the IFCs, the pulses with frequency proportional to the beam current will be fed into a latching scaler. The PDC-IC and PDC-SEM DAQ must be in conformance with [21].

6.4. Cabling

Cable relieves and guides must be provided in order to avoid accidents during actuator movement, mounting and dismounting.

PDC-SC

This device requires:

- 50 Ohm signal cable, from the detector patch panel to the electronics room, the SC signal should be attenuated less than 2 times, e.g. RG214, N-type connector
- 50 Ohm LED-test cable, from the detector patch panel to the electronics room, e.g. RG58, BNC/Lemo connector
- High voltage cable, from the detector patch panel to the electronics room, up to 9 kV, e.g. LEMO 106330, SHV connectors

A patch panel should be installed on the detector holding structure. The cables from the detector and the “self-test” LED will be connected to the patch panel. The patch panel has to be light tight.

PDC-IC

This device requires:

- 50 Ω signal cable, from the detector to the pocket feedthrough panel, e.g. RG214, N-type connector
- 50 Ω signal cable from the pocket feedthrough panel to the IFC, e.g. RG214, N-type connector
- Multi-pole signal and control cable, e.g. Canon 15 or 25 pins (to be defined) from the IFC to the V-DIO interface in the electronics room
- High voltage cables, connecting the IC detector to the RC filter, e.g. LEMO 106330, SHV connectors
- High voltage cable, up to 9 kV, e.g. LEMO 106330, SHV connectors. From the RC-filter to the high voltage module in the electronics room
- IFC $\pm 5V$ DC, multi-pin cable

A patch panel should be installed on the top of the detector pocket. The cables from the detector and the gas system tubes will be connected to the patch panel. The patch panel has to seal hermetically the IC-MWPC into the detector pocket.

PDC-SEM

This device requires:

- UHV Polyimide cable, from the detector signal to the pocket feedthroughs
- 50 Ω signal cable from the pocket feedthrough to the IFC, e.g. RG214, N-type connector

- Multi-pole signal and control cable, e.g. DSub 15 or 25 pins (to be defined) from the IFC to the V-DIO interface in the electronics room
- UHV Polyimide cable, from the detector high voltage to the pocket feedthrough. The cable should be rated for more than 100 V
- High voltage cable from the pocket feedthrough to the RC-filter, rated to at least 100 V, e.g. LEMO 106330, SHV connectors
- High voltage cable, up to 9 kV, e.g. LEMO 106330, SHV connectors. For the RC filter to the high voltage module in the electronics room
- IFC ± 5 V DC multi-pin cable

Two vacuum feedthroughs for signal and high voltage.

6.5. Exemplary Realization at GSI

PDC-SC

The analogue signals of the PDC-SC are transported via long RG214 cables into the electronic room. The cables are mounted on a cable terminal plate as interconnection point. The analogue signal is fed into a NIM PS748 Fan Out and then into a NIM discriminator PS710, 8-channel, 150 MHz (Phillips Scientific, Canberra GmbH, D-65428 Rüsselsheim). The digital pulses were connected to the VME DAQ system ABLASS [305], "A Beam Loss measurement and Scaling System". The signal counting is done with a VME SIS3820, 32-Channel Multiscaler, 32-Bit, 200 MHz input frequency. NIM/Lemo and ECL/flat ribbon cable versions of the scaler are used. An in-house designed counter interface handled the self-test option.

PDC-IC and PDC-SEM

The analogue signals of the PDC-IC and the PDC-SEM were transported to IFCs via 50 cm long RG214 cables. The converters are connected via 15 pin control cables to an in-house developed counter interface, placed into the electronic room. The counter interface controlled the IFCs self-test function, range and provided access to the device ID. It obtained timing information via a MIL bus. This counter interface cannot be used with the new FAIR control system. Hence, a new development or replacement by COTS solutions is foreseen. The digital signal from the counter interface was fed into a SIS3820 scaler (see above). The scalars were read by the ABLASS system [305].

Highly resolved spill structure analysis

The PDC signals from the NIM PS748 Fan-In Fan-Out were sent to a second set of discriminators and scalars identical to the one described above. An expert system called ABLAX (ABLAAss-eXpert) [306] analyzed these data. ABLAX is able to read a subset of channels at 1 MHz samplings frequency, which is 1000 times faster than ABLASS.

7. Timing Requirements

The FAIR timing system will be based on the White Rabbit protocol [27]. The DAQ system must include a timing receiver compatible with the form factor of the DAQ hardware (see chapter 6). The software running on the FEC will correlate the timing events with the PDC data stream (see chapter 8 and [21]).

8. Data Acquisition Software

The PDC DAQ will be realized with the FESA architecture. The system will be trigger-less, continuously acquiring data. It must register all accelerator timing events, relating them to the acquired data. The complete chain of data acquisition must be in conformance with [21]. The following information and operation modes should be provided by the DAQ:

- Parallel readout of all PDCs in one accelerator timing domain. Minimum latching frequency of 1 kHz must be reached, with selected channel in a μ TCA capable to be read at latching frequency of 1 MHz (at least 4 channels)
- Particle-rate as a function of time
- Particle sum (integral of the particle-rate over the cycle) at the end of a cycle, defined by accelerator timing events
- For cycles longer than 1 s, periodical partial update of the output data stream must be foreseen
- Mechanism for data record of selected channels to disk should be foreseen

8.1. General Requirements

Beam diagnostic data acquisition software shall be based on the CERN-built FESA system including the GSI-specific extensions. The FESA version to be used should be the latest actual version released at GSI. For details of the FESA system see Detailed Specification for Data Acquisition [21].

The FESA classes will interact directly with the hardware, handle hardware settings and publish acquired data to remote clients (i.e. graphical user interfaces). The interface to the FESA classes must comply with the 'Guideline for designing FESA equipment software at the GSI and the FAIR facility' [300] and the 'Guideline for Connecting new Equipment to the Accelerator Control System' [301]. The latter guideline, details the naming conventions and interface parts (like Status, Setting and Acquisition properties) which are mandatory for the software. Furthermore, the GSI-FESA template classes have to be used as base for the class development. They are provided to ensure seamless integration of the FESA class into the control system.

The concept of the FESA based DAQ systems shall be discussed and agreed on with GSI experts before the main programming work has started. In addition a code review before final integration into the Accelerator Control System (ACS) should be performed. An iterative development style based on frequent feedback and demonstration of the present status of work is mandatory.

The following list gives a broad but not necessarily exhaustive overview over the general requirements of the FESA classes (the final version 'Guideline for designing FESA equipment software at the GSI and the FAIR facility' will specify the binding requirements).

- Property data should be as far as possible self-contained, which means it should contain all information needed to use the data for different purposes without access to other data-sources e.g. databases, FESA classes, etc. The data purposes include:
 - Displaying
 - Archiving
 - Correlation
- Property data should represent values in SI units if applicable (i.e. Ampere, Volt, Particles/sec, etc.). The physical unit should be sent with the data
- Acquisition data must contain information on the timing context (cycle stamp (timestamp of cycle start), cycle name, acquisition time) at which it was acquired
- Measurement values should have information about their quality. An alarm when leaving a tolerance band must be raised
- Supervision of the device status must be supported
- FESA classes must provide all functionality to integrate with other parts of the control system like:
 - Alarm system
 - Post-mortem system
 - Data archiving and logging

If applicable, the FESA classes for beam diagnostics must control the:

- Equipment self-test
- Equipment calibration
- Logging and archiving for offline analysis of all data (in general to disk) on demand either manual or triggered by ACS independent on the above mentioned archiving and logging system of the ACS

8.2. General Functionality

The PDC system will measure the beam intensity as a function of time during slow beam extraction.

A mechanism should be foreseen for optimization of the measurement accuracy and for detection of incorrect measurements, e.g. data logging, consistency checks, detectors overload and radiation damage detection.

The following data is required from the Data Acquisition Software:

- Particles number vs. time, with minimum time resolution of 1 ms
- Alarm/Interlock flag, generated when detector overload or detector damage conditions are detected

8.3. Operational Modes

The data acquisition software shall provide the following acquisition modes:

- Free-running mode
- Self-testing mode

8.4. Required I/O settings

To control the measurement setup the following I/O-channels have to be provided:

- Input/set: hardware and software parameters e.g. IFC gain, detector calibration factors, High Voltage settings etc.
- Input/set: acquisition mode, e.g. self-test mode

8.5. Required Beam Information

In order to provide the required functionality the following beam parameters have to be supplied to the DAQ system via LSA [29] or databases (not on front-end level):

- Ion charge state
- Ion species, defined by atomic number Z and atomic mass A
- Ion energy in units of MeV/u

The software will correlate the above information with the accelerator timing and the PDC data stream.

8.6. Online Display and Control

The FESA classes should provide data which allows for the control system to display the following information:

- Plot the spill structure and summed signal per cycle, displaying raw/calibrated data with time binning defined by the user
- Plot trending over multiple cycles, raw/calibrated data, displaying raw/calibrated data with time binning defined by the user
- Display of the complete device status
- Display of alarm when detector overload or detector damage conditions are detected
- Highlight the data in the spill and trend plots where the alarm was applicable
- Switching of operational modes, e.g. enable/disable self-test
- User control of the hardware and software parameters, e.g. IFC range, calibration parameters, etc.

An example FESA-Java based DAQ and Online Display System called LASSIE [319] is shown to the right of the red dotted line on Figure 18.

8.7. Data for Logging, Offline Analysis and Archiving

The DAQ should connect to the archiving and post-mortem services provided by the ACS.

For offline analysis the following functions are required:

- Generation of data files on demand (manual/automated by ACS)
- Recording in data format which can be read by supported and tested libraries/software

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A list of quantities to be archived/logged/post-mortem is given below. This is a list which will be modified based on the commissioning results. Data has to be recorded only for PDC inserted into the beam line.

Archiving

- At the beginning of the measurement or when changed:
 - o Detector ID
 - o Beam ion, beam energy, beam charge state, extraction time/length.
 - o Calculated energy loss in SC, IC, SEM
 - o Calculated calibration coefficients to be applied to the raw data
 - o IFCs range setting
 - o SC, IC and SEM voltage and current provided from the high voltage power supply
 - o Pneumatic actuators state: in/out
 - o Gas system status: ok/alarm
 - o Gas flow rate
 - o Operating mode, e.g. self-test state
- For each measured spill:
 - o Software alarms
 - o Integral number of particles in SIS18/100 at the beginning of the beam extraction (transformer reading)
 - o Raw and calibrated Integral, number of particles per spill, for the inserted PDC detectors

Logging

- Alarms, e.g. self-test failure

Post-mortem

- Detector ID
- Beam ion, beam energy, beam charge state, extraction time/length
- SC, IC and SEM voltage and current provided from the high voltage power supply
- Pneumatic actuators state: in/out
- integral number of particles in SIS18/100 at the beginning of extraction (transformer reading)
- Particles number vs. time, with maximum time resolution over the problematic spill

8.8. Special Issues and boundary Conditions

A mechanism for implementing the following features into the software should be foreseen:

- ACS can supply the predicted beam intensity, e.g. DC beam current transformer reading. Combining this information with thresholds, which will be determined based on beam type and beam energy, the software can recommend which PDC detector should be inserted
- The software can indicate to the operator when the PDC detector in use is overloaded, e.g. the IFC range is not optimal, or the beam intensity is too high for the detector in use

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- The ATIMA code [317] should be used for all energy loss calculations.
- The software can choose the optimal high voltage for the PMT/IC based on the expected energy deposition into the scintillator/IC in order to allow for maximum counting rate (to be implemented in the middle-ware)
- The software can correct the PDC-IC reading for charge recombination at high counting rates, see Sub-Section 5.8.2 and [314].
- The software can subtract the noise/background from the calibrated value. The background can be determined by summing the counts with no beam at the corresponding PDC location, e.g. the background integration can be started and stopped by ACS timing events

9. Related Subsystems

9.1. IFC interface

It may be necessary to connect the IFCs to a real-time field bus system in order to change ranges and perform self-tests at dedicated time slots. The subject "field-bus" will be handled in [21].

9.2. Pneumatic Drives with Control units

The PDC (with its three detectors) requires three pneumatic drives. There is one drive to move the first detector-pocket with the PDC-IC and the MWPC and a second drive to move the second detector-pocket with the PDC-SEM (also used for PDC-SC). The third drive moves the PDC-SC separately in and out of the beam inside the detector-pocket. For details see Detailed Specification for Mechanic Drives [22] and [25].

9.3. High-Voltage Supply

All PDCs detectors require high voltage. Detectors, at different locations, will share the same high voltage crate, which may lead to undesired ground loops. Hence, all high voltage channels should be isolated from each other and from the module ground (floating ground for all channels).

Each detector should be connected to a separate floating ground HV channel. It is recommended to use a modular system, e.g. CAEN SY1527, ISEG/Wiener mPod. The following HV parameters per channel will be sufficient:

- Polarity: changeable between plus and minus
- Maximum Voltage: 3 kV
- Maximum current: 3 mA

The remote control of the high voltage system must be in conformance with [21] and the detailed specification for the subsystem High Voltage Power Supply [24].

9.4. Detector Gas Supply

The ICs will use a gas mixture of 80% Ar and 20% CO₂ at standard atmospheric pressure [114]. The gas flow for each IC will be delivered by a detector gas supply system [26]. The exact gas pressure and temperature are not critical for the detector performance; the pressure variation should contribute less than 1% to the measurement accuracy.

10. Special requirements to the control system

In a multiplexed beam operation different beams can be delivered to a PDC. The pneumatic actuators can not guarantee that the PDC pockets will be inserted or removed quickly, compared to the acceleration cycle. Hence, the pocket actuators should not be moved by accelerator timing events. High beam intensity will damage the PDC-SC detector and will shorten the life of the MWPC [20], which will be installed together with the PDC-IC. Hence, the accelerator control system has to ensure that only the “measured” beam is delivered to a PDC detector.

If the control system allows, it is recommended to adopt the following procedure when a PDC-IC or PDC-SC insertion is requested:

- a) Inhibit inserting PDC components into the beam path, if fast extraction is set for the corresponding transfer line
- b) Switch the SEM-IFC to its most sensitive range
- c) Insert the PDC-SEM (most robust detector of PDC)
- d) If the PDC-SEM measures a value above a predetermined threshold, raise a warning and request a confirmation for the insertion of the PDC-IC or PDC-SC. Insert the PDC-IC (together with the MWPC) if there is no warning or the user confirms his desire
- e) If a PDC-SC measurement was requested, switch the IC-IFC to its most sensitive range to check again the intensity, before inserting the PDC-SC in the beam
- f) If the PDC-IC measurement is above a predetermined value raise a warning and do not allow the PDC-SC to be inserted into the beam

11. Quality Assurance, Tests, and Acceptance

All the information concerning Quality Assurance as well as FAT and SAT aspects are included in [4].

12. Technical Parameter List

PDC: Number of elements in HEBT		Total: 21 Module 0-3: 16
Aperture $\varnothing$	mm	100
Distance between the 2 PDC feedthroughs	mm	130
Overall length	mm	280
2 Detector pockets, stainless steal windows with thickness	μm	≤ 50
Detector pockets, windows area $\varnothing$	mm	≥ 100
2 pneumatic drives, manipulating the pockets, with Stroke	mm	≥ 200
1 pneumatic drives, manipulating the PDC-SC, with Stroke	mm	≥ 70
Scintillator		
Recommended scintillator material		BC400
Recommended scintillator thickness	mm	2
Active area $\varnothing$	mm	≥ 100
Recommended PMT [310], [311]		Hamamatsu R6427, with HA coating
Maximum High voltage	kV	- 2
Cathode Luminous Sensitivity	$\mu\text{A/lm}$	≥ 100
Anode Luminous Sensitivity (at -1500 V)	A/lm	300-700
Dark Current (at -1500 V)	nA	≤ 3
Active Voltage Divider with max. counting (100 mV output signal)	MHz	≥ 10
Ionization Chamber		
Active area $\varnothing$	mm	≥ 100
Recommended gap size	mm	Two gaps each c.a. 3
Maximum High voltage	kV	1.5
Detector gas		Ar/CO ₂ (80/20) 1 atm.
Gas pressure		c.a. Std. atm.
Gas pressure stability (if larger the pressure should be monitored)	mBar	$\leq 1\%$
Gas temperature variation (if larger the temperature should be monitored)	K	$\leq 1\%$
Gas flow	l/h	≤ 1.5
Current with no HV (noise)	pA	≤ 0.1
Leakage current, at 1500 V	pA	≤ 2
SEM		
Active area $\varnothing$	mm	≥ 100
Recommended foil thickness	μm	24 - 50
Recommended distance between the foils	mm	c.a. 5 or less
Max High voltage	V	200
Current with no High voltage (noise)	pA	≤ 0.1
Leakage current, at 100 V	pA	≤ 0.1
2xIFC		
Dynamic range	A	10^{-12} - 10^{-7}

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Polarity, switchable		Pos or Neg
Sensitivity	C/pulse	10^{-13}
Linearity	%	1
Temperature response measured with accuracy	%/K	0.2
Gain drift	%/Year	1
Overload detection		
DC Power	V	± 5
PDC DAQ		
Free-running		
Time slice for all channels	μs	$\leq 10^3$
Capable of reading at least 4 channels per crate with time slices (for SC spill structure analysis)	μs	1
For cycles longer than 1 s, partial update of the output data every	s	ca. 1
Maximum storage time/length for time dependent data	s	ca. 30

Table 3: PDC parameters.

13. Scope of Work and Delivery

Manufacturing and testing of the PDC has to be performed as described in the documents delivered by GSI/FAIR.

13.1. Scope of Work

Definition of the final setup in agreement with the GSI Beam Instrumentation (LOBI) department, regarding all requirements described in the detailed specification.

- Final definition of the system details, according to mechanics, electronics and data acquisition (system realization in agreement with GSI LOBI department)
- Manufacture and tests of the parts, as described in Chapter 5 and 11.
- Delivery of all purchase components (e.g. detectors, mechanical components, electronics components, DAQ including software)
- Develop and produce special electronics (e.g. IFC, IFC-interface, LED counter interface)
- Assembly of pre-series and tests, according to Chapter 11
- Assembly of the complete setups and tests, according to Chapter 11
- Commissioning of the setups and software in the FAIR facility

13.2. Scope of Delivery

The scope of delivery is the complete PDC setup, consisting of all components described in the detailed specification, concerning:

- Detectors
- Vacuum Chamber
- Pneumatic Drives
- Compressed Air Control
- Detector Gas supply
- Cables
- High Voltage Supply
- Data Acquisition & Electronics (IFC etc.) & Software

The components have to be delivered to GSI. The PDC setups have to be assembled, tested and integrated into the FAIR HEBT beam line, as well as commissioned with the software.

Each PDC component should be labelled with component ID (CID) codes provided by GSI, see [113].

14. Open Issues / Questions

Reaching measurement accuracy of 5 % under standard operating conditions, without performing “self-calibration”, has to be demonstrated.

14.1. Development / Prototyping

- The standard PDC-SC thickness will be 2 mm. If this is too thin for proton counting, a 5 mm scintillator will be used with proton beams
- The design of the detector pockets has to be finalized
- The cable paths/gas tubes and their management has to be finalized
- The size of the RC-filter box has to be determined depending on the capacitor which will be used and the box has to be integrated in the mechanical design of the system
- Redesign of the AVD with built-in amplifier, removing the limitation on minimum gain due to the attenuation between the PDC-SC and electronics room (hence increasing the maximum counting rate)
- The cable type which will be used for the SC signal has to be defined
- The IFC mentioned in this document is a subject of a re-design [308]. The I/O should be connected to a V-DIO [321] module
- Depending on the developments for the FAIR field bus access, the control and signal lines of the IFC will be separated. The signals will be carried over fiber-optic cable
- The IFCs temperature coefficient has to be optimized
- The aging of the IFCs components with radiation has to be investigated
- Investigating IFC powered by a power supply placed in the electronics room
- Integrating the IFC overload detection in the data acquisition (latch/reset)
- For locations where the distance between the PDC detectors and the electronics room is larger than 200 m special solution should be found for the SC and IFC signal transport.
- μ TCA latching scaler and discriminator are under design

I. Attached Documents

No documents attached

II. Related Documentation

General Documents [1..19]

- [1] INFORMATION: FAIR Baseline Technical Report
- [2] INFORMATION: EDMS 1332223 Technical Design Report HEBT
- [3] MANDATORY: EDMS 1365092 F-GS-F-01e General Specification of the FAIR Accelerator Facility Project
- [4] MANDATORY: EDMS 1174185 F-CS-BD-01e Common Specifications Beam Diagnostics for FAIR

Detailed Specifications Beam Diagnostics [20..99]

- [20] INFORMATION: EDMS 1179709 F-DS-BD-12e ElecProfile+MWPC_T
- [21] INFORMATION: EDMS 1179740 F-DS-BD-40e DAQ
- [22] INFORMATION: EDMS 1179743 F-DS-BD-43e Mech+MechanicalDrives
- [23] INFORMATION: EDMS 1179744 F-DS-BD-44e Mech+VacuumChambers
- [24] INFORMATION: EDMS 1179746 F-DS-BD-46e SubSys+HighVoltage
- [25] INFORMATION: EDMS 1179747 F-DS-BD-47e SubSys+PneumaticDrive
- [26] INFORMATION: EDMS 1501126 F-DS-BD-66e Detector-Gas Supply
- [27] INFORMATION: EDMS 1176029 F-DS-C-05e_General-Machine-Timing-System
- [28] INFORMATION: EDMS 1176030 F-DS-C-06e_Timing-Receivers
- [29] INFORMATION: EDMS 1176027 F-DS-C-03e_Settings-Management-System

Technical Guidelines [100..199]

- [100] MANDATORY: EDMS 1172876 F-TG-V-2.24e Materials in UHV
- [101] MANDATORY: EDMS 1172873 F-TG-V-2.7e Ceramics for Vacuum Applications
- [102] MANDATORY: EDMS 1172887 F-TG-V-3.11e Bolts for Use in Vacuum
- [103] MANDATORY: EDMS 1172904 F-TG-V-6.10e Cleaning Assemblies and Sub-Assemblies in Vacuum
- [104] MANDATORY: EDMS 1172894 F-TG-V-6.1e Cleaning of UHV Components Stainless Steel
- [105] MANDATORY: EDMS 1172895 F-TG-V-6.2e Cleaning of Vacuum Components
- [106] MANDATORY: EDMS 1172897 F-TG-V-6.4e Cleaning of Ceramics for Use in UHV
- [107] MANDATORY: EDMS 1172898 F-TG-V-6.5e Cleaning of Aluminium Components
- [108] MANDATORY: EDMS 1172905 F-TG-V-7.1e Mechanical Acceptance Test for UHV Components
- [109] MANDATORY: EDMS 1172869 F-TG-V-2.1e Stainless Steel for Beam Vacuum Chambers
- [110] MANDATORY: EDMS 1172906 F-TG-V-7.2e Vacuum Properties Acceptance Test without Bakeout
- [111] MANDATORY: EDMS 1172907 F-TG-V-7.3e Vacuum Properties Acceptance Test with Bakeout
- [112] MANDATORY: EDMS 1172862 F-TG-ET-01e_Electrical_Design_Rules_and_Regulations
- [113] MANDATORY: EDMS 1229368 F-TG-B-0.5e_CID_and_Barcode
- [114] INFORMATION: EDMS 1172865 F-TG-BD-01e_Detector_Gas-Supply

Special Documents and Technical Notes [300...]

- [300] INFORMATION: EDMS 1235310 F-DG-C-01e FESA development guideline
- [301] INFORMATION: EDMS 1235721 F-DG-C-04e Equipment Integration Guideline
- [302] INFORMATION: "Lecture Notes on Beam Instrumentation and Diagnostics", Peter Forck, GSI, www.gsi.de
- [303] INFORMATION: "Radiation Detection and Measurements", Glenn F. Knoll, ISBN 0-471-07338-5
- [304] INFORMATION: P. Forck, P. Heeg, A. Peters, "Intensity measurement of high-energy heavy ions at the GSI facility", AIP Conf. Proc. 390, 422 (1997)
- [305] INFORMATION: T. Hoffmann, D. A. Liakin and P. Forck "A Fast VME Data Acquisition System for Spill Analysis and Beam Loss Measurement", BIW 2002, Upton, N.Y. (USA), 2002, p. 329-336, www.gsi.de
- [306] INFORMATION: T. Hoffmann, P. Forck and D. A. Liakin "New Spill Structure Analysis Tools for the VME Based Data Acquisition System ABLASS at GSI", BIW 2006, Batavia, Illinois (USA), www.gsi.de
- [307] INFORMATION: Technical Note SCI- Self Test, P. Boutachkov TN_SCI-SelfTest_2015-03.doc

Document Title: Particle Detector Combination for HEBT

- [308] INFORMATION: Technical Note, EDMS 1179766 F-TN-BD-001e_IFC_for_FAIR; Current to Frequency Converter (IFC), H. Reeg
- [309] INFORMATION: Technical Note, Active Voltage Divider (AVD), P. Boutachkov *et al.*, (not available yet)
- [310] INFORMATION: P. Boutachkov, *et al.*, "Bench Tests of PMTs and Voltage Dividers for Counting Applications at FAIR", GSI Scientific Rep. (2014), www.gsi.de
- [311] INFORMATION: P. Boutachkov, *et al.*, "In-beam Tests of PMTs and Voltage Dividers for Particle Detectors at FAIR", GSI Scientific Rep. (2014), www.gsi.de
- [312] INFORMATION: P. Forck, T. Hoffmann, A. Peters, "Detectors for Slowly Extracted Heavy Ions at the GSI Facility", DIPAC (1997), www.gsi.de
- [313] INFORMATION: H. Reeg, "A Current Digitizer for Ionisation Chambers/SEMs with high Resolution and fast Response", DIPAC99, Chester, p. 147 (1999), www.gsi.de
- [314] INFORMATION: M. Boutillon, "Volume recombination parameter in ionization chambers", Phys. Med. Biol. **43**, 2061 (1998)
- [315] INFORMATION: Drawings of the PDC detector pockets (not available yet)
- [316] INFORMATION: Assembly Drawing of the PDC-SEM detector: BD-1023295-A-000 and the related drawings
- [317] INFORMATION: ATIMA, code for energy loss calculation: web-docs.gsi.de/~weick/atima/
- [318] INFORMATION: B. Voss, A. Heinz, H. Risch, "Beam Monitors for the High-Energy Beam Line of HIT", GSI Scientific Rep. (2005), www.gsi.de
- [319] INFORMATION: T. Hoffmann, H. Bräuning, R. Haseitl, "LASSIE: THE LARGE ANALOGUE SIGNAL AND SCALING INFORMATION ENVIRONMENT FOR FAIR", ICALEPCS 2011, Grenoble, France
- [320] INFORMATION: Spec_SCI-SelfTest_2015-02
- [321] INFORMATION: V-DIO VME Boards, manufactured by MagentaSys, Switzerland, www.magentasys.com

III. Abbreviations

μTCA	Micro Telecom Computing Architecture
ABLASS	A Beam Loss measurement And Scaling System
ACS	Accelerator Control System
ADC	Analog to Digital Converter
AVD	Active Voltage Divider
BD	Beam Diagnostic
CERN	Conseil Européen pour la Recherche Nucléaire
COTS	Commercial (available) Off-The-Shelf
DAQ	Data Acquisition
FAIR	Facility for Antiproton and Ion Research
FEC	Front-end computer
FESA	Front-end Software Architecture
GSI	GSI Helmholtzzentrum für Schwerionenforschung GmbH
GUI	Graphical User Interface
HA	Conductive coating around a the PMT, connected to the cathode potential
HEBT	High Energy Beam Transport
I/O	Input/Output
IC	Ionization Chamber
ID	IDentification
IFC	Current to frequency converter
LED	Light Emitting Diode
LHC	Large Hadron Collider
LOBI	Linac and Operations - Beam Instrumentation
LSA	LHC Software Architecture
MWPC	Multi-Wire Proportional Chamber
NIM	Nuclear Instrumentation Module/Standard
PDC	Particle Detector Combination
PMT	Photo Multiplier Tube
PSP	Project Structure Plan (code number in cost book)
R&D	Research and Development

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RTM	Rear Transition Module
SC	Plastic Scintillator
SEM	Secondary Electron Emission
SIS18/100	Heavy Ion Synchrotron with maximum bending power of 18/100Tm
SHV	Safe High Voltage connector
TCP/IP	Transmission Control Protocol/Internet Protocol
TDC	Time to Digital Converter
TG	Technical Guideline
TTL	Transistor-Transistor Logic
UHV	Ultra-High Vacuum
VME	Versa Module Eurocard