

# STATUS OVERVIEW OF THE HESR BEAM INSTRUMENTATION

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## Abstract

The High Energy Storage Ring (HESR), within the Facility for Antiproton and Ion Research (FAIR), will provide proton and anti-proton beams for PANDA (Proton Antiproton Annihilation at Darmstadt) and heavy ion beams for SPARC (Stored Particles Atomic Physics Research Collaboration). With the beam instrumentation devices envisaged in larger quantities, e.g. BPM and BLM being in production, other BI instruments like Viewer, Scraper, or Ionization Beam Profile Monitor are in the mechanical design phase. An overview of the status is presented.

## INTRODUCTION

The HESR, part of the FAIR project in Darmstadt, Germany, is dedicated to the field of antiproton and heavy ion physics. The envisaged momentum range is 1.5 GeV/c to 15 GeV/c. The ring will be 574 m long in a racetrack shape. The planned beam instrumentation within the modularized start version is:

76	Diagonally Cut Beam Position Monitors (BPM)
118	Beam Loss Monitors (BLM)
2	Beam Current Transformers (BCT)
2	Ionization Beam Profile Monitor(IBM)
1	Wall Current Monitor (WCM)
1	Schottky Pick-up
1	Dynamical Tune-meter
1	Transverse Feedback System
5	Viewer
2	Scraper
73	Ion Clearing Chambers

## BPM SYSTEM

The pick-up design is based upon the COSY BPMs [1]. The length and diameter is shrunk by a common factor in order to keep the length to diameter ratio. Each BPM units consist of two diagonally cut pick-ups rotated by 90° around the beam axis in respect to each other. The setup is shown in Figure 1. The inner diameter of the pick-ups is 89 mm and the length 78 mm with a gap of 3 mm between the electrodes using an angle of 55.5°. The expected signal levels are depending on the capacitance of the pick-ups, the ion charge, the amount of ions, and the bunch length and can be calculated. The capacitance was calculated by means of COMSOL Multiphysics 5 simulations. This calculation resulted in a capacity to ground of 19 pF after optimization. For the lowest case, the first injection of antiprotons with  $10^8$  particles in the ring, the signal level was calculated to 0.5 mV. For the highest intensity case, with  $10^{11}$  antiprotons stored, the signal level is 390 mV.

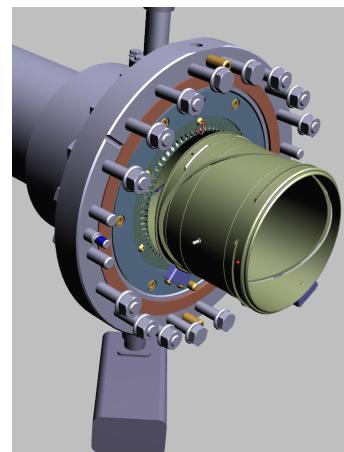


Figure 1: Schematic view on the BPM pick-up. Some parts of the assembly are not shown for better view on the pick-up.

## Signal Amplification

### Fixed Gain Head Amplifiers

Due to low amplitudes the HESR BPM signals require additional boosting prior to transmission over cables in order to achieve a better signal to noise ratio active head amplifiers with a high impedance low noise input were developed. At HESR the expected radiations levels are at a level an active solution could be taken into consideration. The amplifier itself is shown in Figure 2.

The specification of this amplifier is:

Amplification:	20 dB
Noise:	6 μV at 50 pF input capacitance and 10 MHz bandwidth
Bandwidth:	10 MHz default, configurable up to 70 MHz
Input Impedance:	500 kΩ
Power supply:	+8 V and -8 V
Output range:	± 1.5 V at 50 Ω

### Hadron Pre-Amplifier (HPA)

Within the FAIR project the decision was made early that a common amplifier solution should be found for all machines. Therefore the HPA was developed [2] in cooperation of the Gesellschaft für Schwerionenforschung (GSI) and Instrumentation Technologies, Slovenia.

The HPA amplifier has a gain range of +60 dB do -60 dB and is equipped with an overload protection which has been seen necessary especially for the SIS100. The HPA is equipped with a 50 Ω input.

For the above listed arguments the HESR deviated from this concept by introducing active head amplifiers instead of the passive impedance transformer. Still the HPA remains part of the signal chain, as the head amplifier will have a fixed



Figure 2: Picture of the head amplifier developed for the HESR BPM system. The N-type plug is main signal input. In SMA a calibration signal input and the signal output is visible. The power is connected through the D-Sub plug.

gain. An adjustable gain amplifier is seen necessary to adapt for different beam properties. The electric power needed for the head amplifiers will be supplied from the HPA, as the necessary voltages are available in the inside its chassis and therefore additional power supplies and cables from the power supply rooms are not needed. On the downside, the HPA has to be modified and will thus not longer be a standard FAIR item.

The HPA consists of two modules stacked after each other: First an attenuator stage and second an amplifier stage. For low input signal levels, the attenuator will be switched to a total attenuation of 0 dB, but still adding a noise to the signal. As the modified version of the HPA will be a non standard item anyway, the attenuator modules will be removed from the HPA in order to achieve a better signal to noise ratio.

## BEAM LOSS MONITOR

For machine commissioning, routine operation and further beam optimization detailed beam loss data is very valuable. Unlike other accelerators, the HESR BLM data will not be used for an automated machine protection, as the stored total beam energy will not be high enough to damage the machine. Along the ring 118 BLMs will be used. The BLM will consist of a BC-400 plastic scintillator and a Hamamatsu photomultiplier (PMT). This solution is favored over e.g. an ion chamber type loss monitor because of the low expected loss rates. A prototype is shown in Figure 3. It was developed by GSI and will be used in other parts of FAIR as well, e.g. the High Energy Beam Transport (HEBT).

For the readout of the BLMs a  $\mu$ TCA system is planned utilizing scaler SIS8800 and counter SIS8980 from Struck Innovative Systeme GmbH. Both cards are connected to each other via the  $\mu$ TCA backplane and provide 16 channels per card. The BPM photomultiplier will be powered individually utilizing a multichannel HV system in order to be able to



Figure 3: BLM prototype based on a scintillator and PMT setup during tests in the COSY synchrotron.

compensate for the properties of the individual BLM detector and the individual location.

## IONIZATION BEAM PROFILE MONITOR

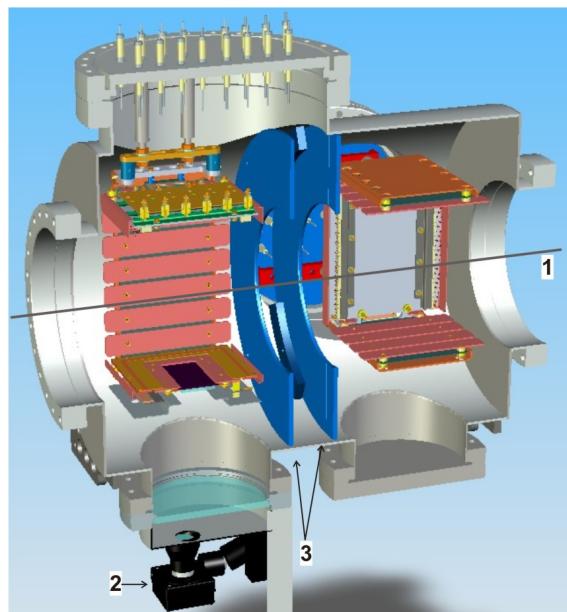


Figure 4: Drawing of the IPM prototype built together with the GSI [3]. The ion beam (1) ionizes residual gas which is accelerated towards a detector and read out by a standard GiGE camera (2). To minimize the effect of the electrical fields towards each other, shielding plates have been inserted between both devices.

An Ionization Beam Profile Monitor (IPM) (Figure 4) was built and tested in cooperation with the GSI in 2007 [4]. Since then it became a very valuable instrument in beam diagnostics at COSY and GSI [5]. Based on both experiences a similar device is under development for the

HESR. The HESR device will be a scaled down version, because of the smaller aperture. It is being designed in a size that would not only fit the HESR but also in the HEBT. Because of the delicate nature of the microchannel plates and the importance of the system, 2 systems will be installed, providing one backup system in case of failure. Together with the locations in the HEBT a FAIR wide number of 12 identical IPM installations is envisaged.

## VIEWER

There will be 5 viewers installed in the HESR. One at the beginning and end of each telescope and an additional one directly after the injection septum magnet. As shown in Figure 5, the viewer consists of a scintillation screen mounted at 45° and will be moved by a pneumatic drive. As a speciality, if the viewer is not used an RF cage will be moved into its place. This is done in order to minimize the overall impedance of the ring. If the RF cage is in it's place, a second pneumatic drive will move RF springs in their position to ensure an optimal electrical conduction. Before moving the RF cage out, these springs will be pulled back.

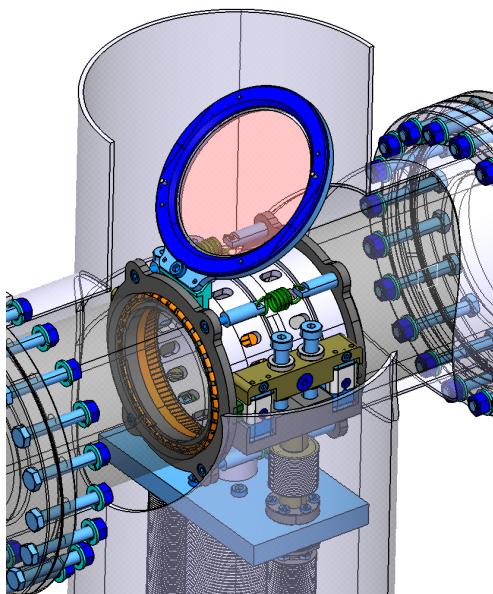


Figure 5: Drawing of the viewer. A scintillator screen is moved into the beam with 45°. While being moved out, a RF cage will be moved into it's position.

## SCRAPER

The scraper system is shown in Figure 6. There will be 2 scraper systems being installed in the HESR. Each system consists of 2 vertical and 2 horizontal jaws. Each jaw of 10 copper rods which are placed in an alternating manner and are each 25 mm in diameter. This layout assures a particle will be slowed down by at least 50 mm of material while the structure will have a minimal effect on the RF impedance while being on it's out position. Each jaw can move in farther than the middle of the beam pipe. As a safety measurement the jaws are therefore placed not directly facing

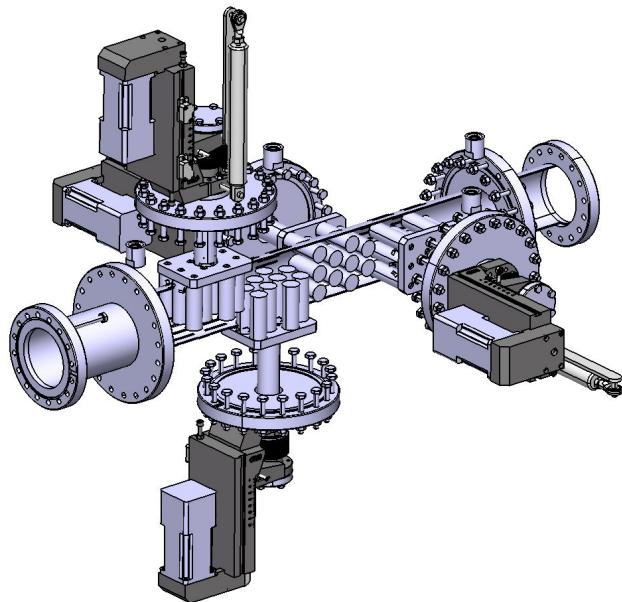


Figure 6: Drawing of the scraper. On each side of each plain the scraper consists of 10 rods of 25 mm diameter. The scraper can move in further than the middle of the beam pipe. To avoid damage opposing rods are moved in longitudinal position.

each other but longitudinally behind one another. If both jaws are moved in fully they will not touch each other and so not being damaged.

## OUTLOOK

At this point in time the BPM pick-ups are in the early production phase. The ion clearing system is currently in the bidding phase, so that both systems are considered being ready during 2019. The other presented systems, namely IPM, scraper and viewer are in the late design phase, so that the production will start within the next months. Other systems like the Wall Current Monitor, Schottky Pick-up, Dynamical Tune-meter, and Transverse Feedback System are in an early design phase, the design is envisaged to be finished within 2018.

## REFERENCES

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