

# BEAM DIAGNOSTICS LAYOUT FOR THE FAIR PROTON LINAC

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## Abstract

The planned proton Linac for FAIR (Facility for Antiproton and Ion Research) will be – additionally to the existing GSI UNILAC – a second injector for the FAIR accelerator chain. It will inject a 70 MeV, (up to) 70 mA proton into the SIS18.

The beam diagnostics system for the proton Linac comprises nine current transformers for pulse current determination and fourteen BPMs for position, mean beam energy and relative current measurement. SEM-Grids and stepping motor driven slits will be used for profile as well as for emittance measurements. A wire based bunch shape monitor is foreseen, additionally a bending magnet will be used for longitudinal emittance determination during commissioning.

Presently main efforts are conducted concerning the BPM system. Detailed signal simulations with the finite element code CST are performed. An electronics board using digital signal processing is evaluated by detailed lab-based characterization and beam-based measurements at the UNILAC. In this paper we present the general layout and status of the diagnostics system as well as key results from our measurements and simulations.

## INTRODUCTION

The FAIR [1] facility, which is currently under construction at GSI/Darmstadt, is designed to provide antiproton and ion beams of worldwide unique intensity and quality for fundamental physics research.

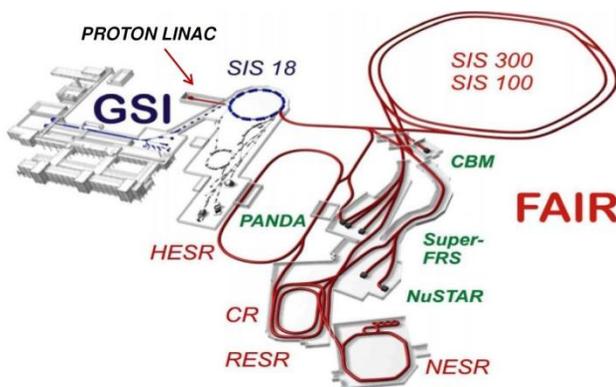


Figure 1: Layout of the FAIR facility.

The accelerator of FAIR comprises two injector Linacs, the existing UNILAC (including a separate high charge state injector) and the new proton Linac. Both Linacs inject into the SIS18 synchrotron, which is again an

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injector for the SIS100, the central accelerator component of FAIR.

Several upgrade steps of the UNILAC have already been performed or are currently under progress to match the beam requirements at FAIR. While the UNILAC can provide a unique variety of ions for nuclear and atomic physics, the proton Linac will provide the beam for the antiproton production chain. It will consist of an RFQ followed by two 10m sections of Cross Bar H-drifttube accelerators (CH structures). The first section includes six CH modules, which are pairwise rf-coupled. The second section consists of three separate modules, each one having its own klystron.

The proton Linac will deliver a beam current up to 70 mA at a macropulse length of 36  $\mu$ s and a typical bunch length of 100 ps. The design energy is 70 MeV [2,3]. Figure 2 shows a schematic of the proton Linac, including beam diagnostics.

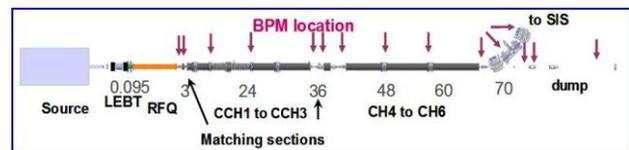


Figure 2: The FAIR proton Linac, showing the positions of the BPMs and particle energies.

## BEAM DIAGNOSTICS LAYOUT

The beam diagnostics system of the p-Linac will be - due to the compact structure of the two CH sections - concentrated in the LEPT, behind the RFQ (rebuncher section) and in a diagnostics/rebuncher beamline between the CH sections. Behind the accelerator, beam diagnostics elements are placed in the transfer line to the SIS18 as well as in a straight line in the beamdump. An exception to this rule are the Beam Position Monitors (BPMs). Four of them will be installed between the CH modules, together with the magnetic triplet lenses.

Fourteen BPMs in total will be used for measurement of position, energy and relative current. The pulse current will be determined by nine current transformers. Secondary electron emission (SEM)-Grids and slits will be used for profile and emittance measurements. For determination of longitudinal emittance a wire based bunch shape monitor is foreseen in combination with a bending magnet (during commissioning).

In the LEPT charge state analysis will be performed with a Wien Filter, while the emittance is measured with an Allison scanner. Table 1 shows the diagnostics system at one glance.

Table 1: Elements of the Diagnostics System

Parameter	Device	#	Nondestr.	Remarks
Current	Transformer	9	Yes	Dynamic Transmission Control
	Faraday Cup	3	No	Mainly as Beam Dumps
Profile	SEM Grids	4	No	Standard
Transv. Emittance & Halo Scraping	Slit Grid	3	No	Standard
Position & Mean Energy	Button BPMs	14	Yes	Position, TOF & Relative Current
Bunch Shape	New BSM / Feschenko	1	Yes / No	Under Development
LEBT: Charge state	Wien Filter	1	No	Standard (CEA)
LEBT: Emittance	Allison Scanner	1	No	Standard (CEA)

**BPMs**

The BPM system will be used to measure the beam displacement with 0.1 mm spatial resolution as well as for determination of the mean beam energy from Time of Flight (TOF) and for measurement of the relative beam current using the sum signal.

The button type BPMs with a button diameter of 14 mm are either mounted between the CH modules (see Fig. 3) or in the beamline outside the CH tanks, therefore two different beam pipe apertures (30 mm and 50 mm) have to be taken into account. The basic layout of the BPM system and simulation calculations are presented in [4,5]. Currently a prototype of the BPM with 30 mm aperture is produced at CEA for tests with coaxial wire and background measurements on a CH prototype cavity at GSI.

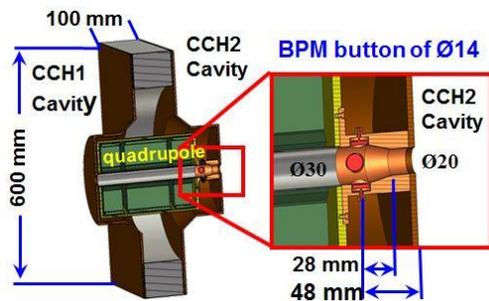


Figure 3: Button BPM mounted to a magnetic triplet in the ‘inter tank section’ between two CH modules.

The beam energy will be measured from the TOF of bunches between two successive BPMs with an accuracy of 8.5 ps corresponding to a phase difference of 1° at 325 MHz. For the processing of the BPM signals a digital system is considered, which is operated by undersampling technique, processing the data in an I/Q demodulation

scheme. The advantage of this Libera SPH [6] system is that there would be only one ‘combined’ electronics for digitization and (via FPGA) calculating relevant parameters, being directly connected to the control system network.

So far, the general functionality of the system was shown, its performance, in particular the accuracy of the phase measurement for TOF has to be investigated in more detail.

Beam tests at 108 MHz, using UNILAC pickups and a modified test version of the Libera resulted in some inconsistencies, which still have to be investigated. Fig. 4 shows the time domain measurement (red line) compared to the Libera SPH phase values and to FFT calculations for single bunches as well as for streams of bunches [4]. The values from the FFT calculations fit better to the time domain data, especially at lower amplitudes (negative zero crossing values). To better understand and solve this problem, the measurements will be repeated with a dedicated 108 MHz system.

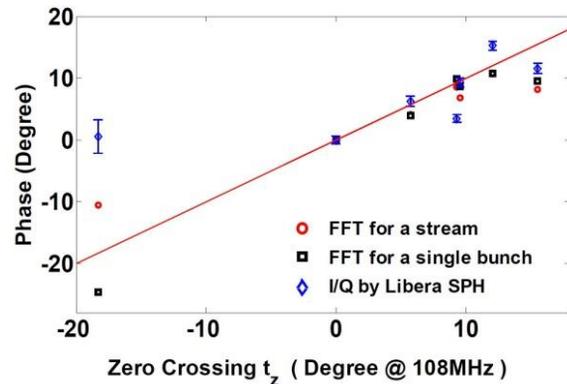


Figure 4: Time domain data compared to Libera SPH and FFT calculations for single bunch and streams of bunches.

In parallel to the measurements extensive simulations with the CST Microwave Studio® have been performed to investigate the properties of the button BPM system. Besides calculations for signal strength optimization, background reduction and accuracy mapping (at different geometries and pickup sizes) some effort has been spent to check the effect of beam displacement on the phase measurement. Results will be presented in [7].

**Beam Transformers**

The AC beam transformers (ACCTs) will be the main tool for pulse to pulse loss detection and transmission measurements. The ‘standard’ transformers used at GSI are an in-house development [8]. Typical parameters of these transformers are shown in Table 2.

For application in the p-Linac however some additional features would be desirable, such as an adjustable sensitivity range and a larger bandwidth (~2 MHz) for identification and investigation of fast effects from the chopper or the rf- system. For that purpose a collaboration with Bergo Instrumentation is currently discussed.

Table 2: Parameters of the GSI ACCTs

Core radius	$r_i=30$ mm, $r_o=45$ mm
Core thickness	25 mm
Core material	(CoFe)70%(MoSiB)30% Vitrovac 6025
Number of windings	2x10
Resolution	0.2 $\mu$ A for full BW
Bandwidth	500 kHz
Droop	0.5% for 5ms pulses

The data acquisition for the transformers will be done with a commercial VME based ADC in connection with a FESA application software, as it is to become standard for the FAIR facility [9].

### SEM-Grids and Slits

The beam profile of the proton beam will be measured by secondary electron emission (SEM) grids, stepping motor driven units will be combined with slits for emittance measurements.

Both devices are well established standards at GSI. An innovative element here is the employment of a Charge to Frequency Converter (CFC) and digitizer ASIC [10]. This DAQ system has been tested successfully at UNILAC during the latest experimental runs.

### Bunch Shape Monitor

A prototype of a non-destructive Bunch Shape Monitor (BSM) is currently installed in the transfer line of the SIS18 and tested with beam [11]. The main difference between this BSM (schematically shown in Fig. 5) and the so called 'Feschenko Type' [12] is that the secondary electrons are produced from collisions with the residual gas instead of using a wire on high voltage.

As a consequence an extraction voltage for the electrons (similar to an IPM) is required as well as an energy separator in front of the rf-deflector to make sure that the detected electrons originate from the equipotential plane of the region of interest.

So far, the optimization process of the device is going on. Averaging over a number of bunches is necessary to obtain good bunch shapes. It is not yet decided which type of BSM will be used. To have a backup solution with a traditional 'Feschenko' BSM, a collaboration for the production of such a device at the Institute of Nuclear Research (INR), Moscow, is established.

### SUMMARY

The beam diagnostics system of the p-Linac consists from front end hardware point of view of 'State of the Art' components. Exceptions are the BSM and the BPM preamplifiers. The innovative part of the system lies on the electronics and DAQ side. Here an advanced electronics for the ACCTs, the digital system for BPM

signal processing and the CFCs for the SEM-grids are challenging developments.

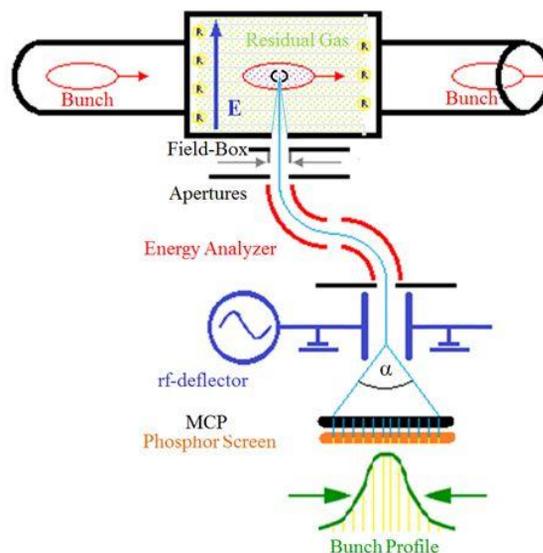


Figure 5: Non-destructive BSM prototype.

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