ELENA Beam Instrumentation

On behalf of many people

AD – ELENA transfer line

Position

Profile

(Intensity)

ELENA ring

Position

Tune

Profile

(Intensity)

Recombination rate

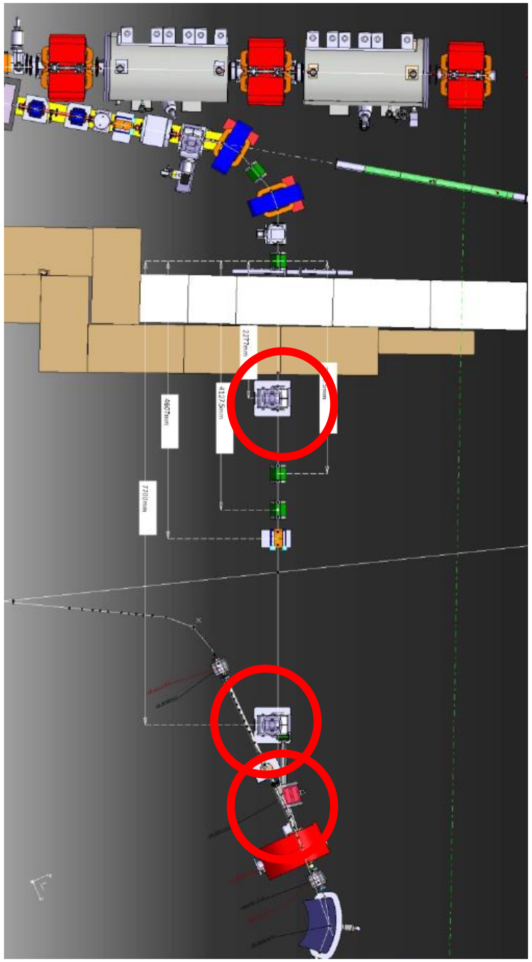
Experimental zones

Profile

(Intensity)

AD-ELENA transfer line

Modification of the existing 7000 line

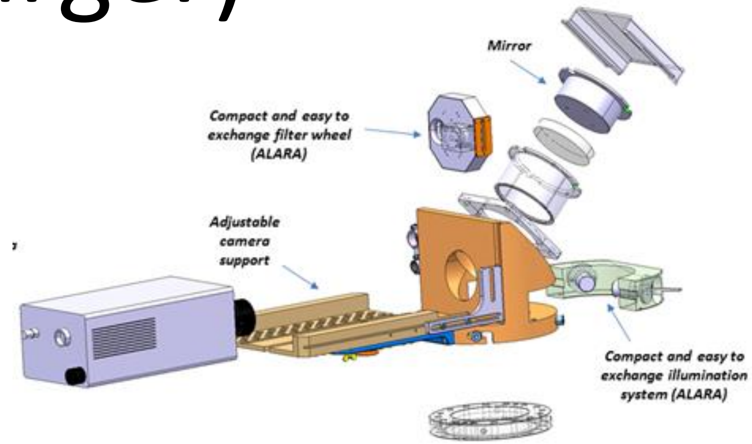


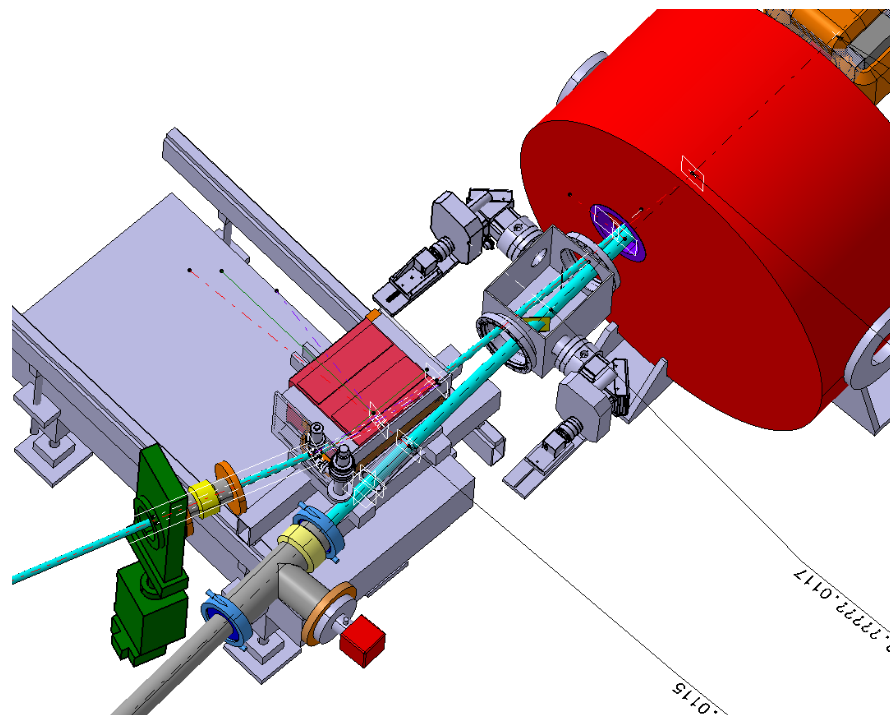
New line linking 7000 line to ELENA

BTV (S. Burger)

At present in the AD, Al_2O_3 scintillating screens are installed in the transfer lines and coupled to a CCD camera have provided information on the antiproton beam position and size. One such device will be moved from its current location in the 7000 line and will be installed after the second bending magnet that will deflect the antiproton beam from the AD to ELENA.

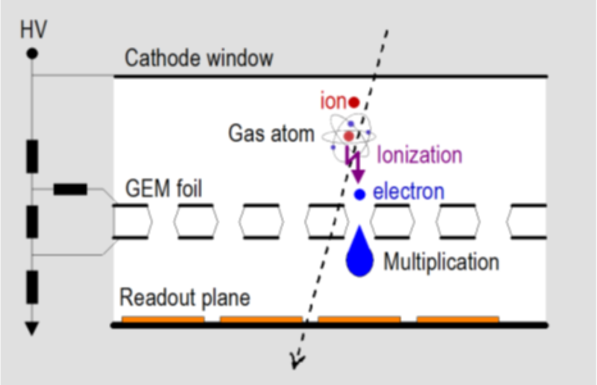
A new system is also being developed that will be capable of measuring the beam position and size just before the injection kicker and at the first turn in the ring. It consists of two distinct systems each incorporating a 6 cm x 4 cm screen, a CCD camera, filter wheel, optical elements and a pneumatic in/out movement.



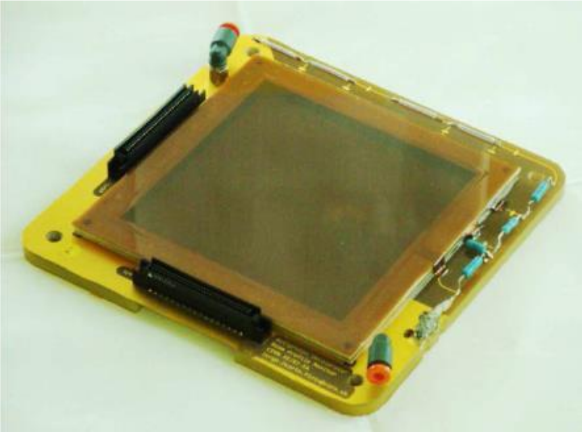


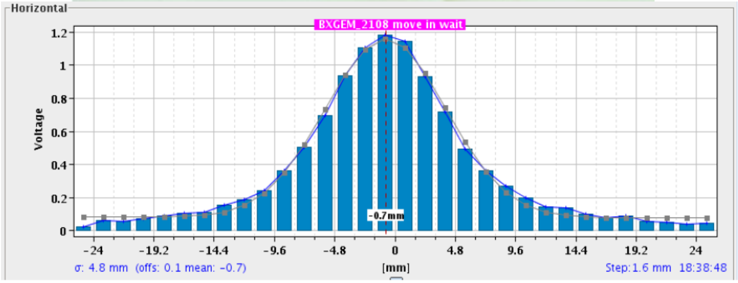
GEM (BI-EA)

GEMs have been deployed extensively in the present AD experimental areas and give excellent results for both position and profile measurements. Like multi-wire proportional chambers these detectors are also gas-filled, and essentially the same physical phenomenon is exploited to multiply ionization charge.

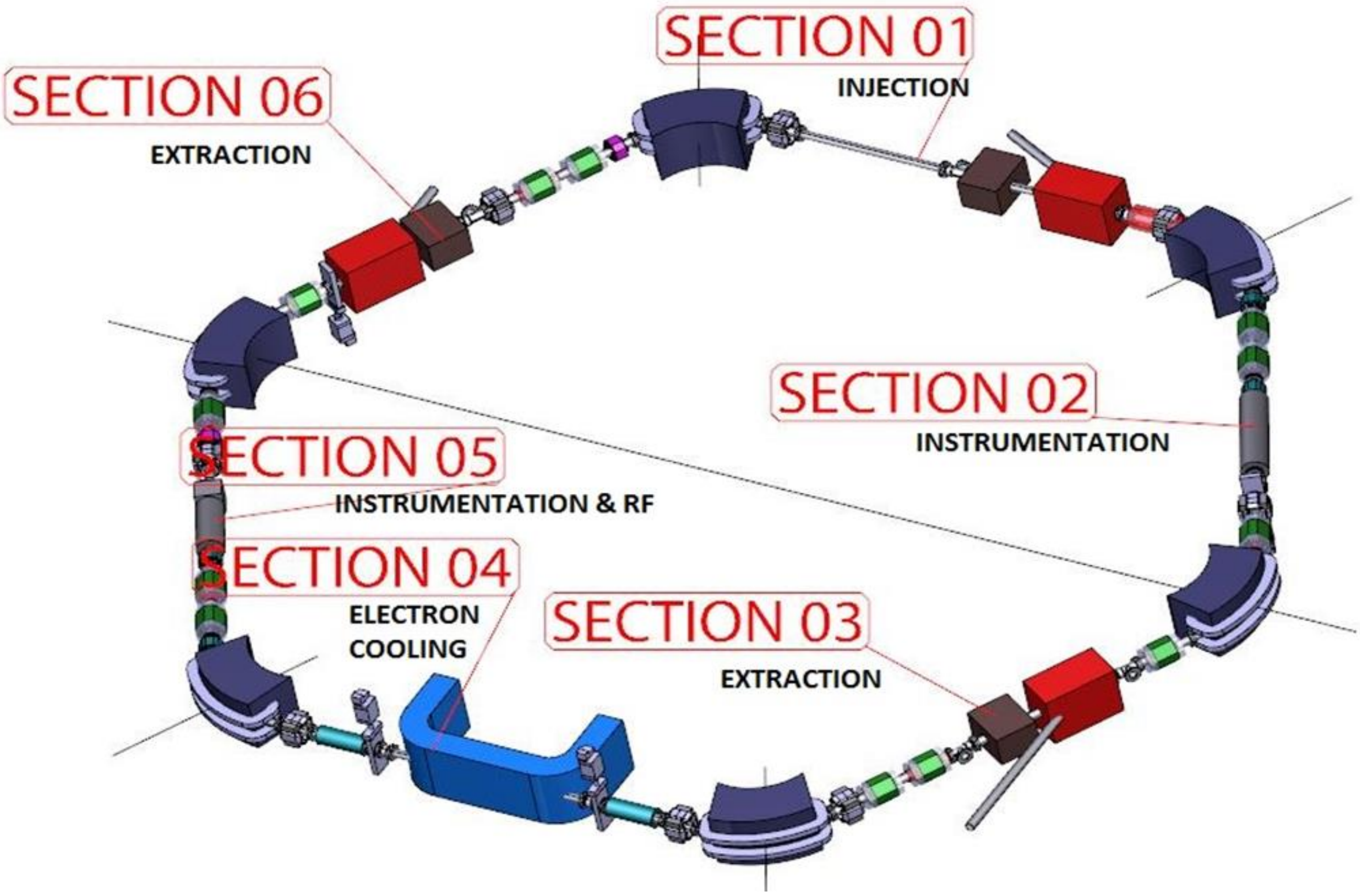


A GEM is a 50 µm thick foil of Kapton, copper clad on both sides, pierced with microscopic holes at a high density (our 10×10 cm² foils have about a million holes). A voltage of a few hundred volts applied to the top and bottom copper layers causes an electric field that focuses in the centre of these holes where it is just as strong as close to the wires of a wire chamber. Ionization electrons enter the holes from one side, are multiplied inside the holes, and then exit on the other side where they are collected by a strip pattern that integrates the charge and reads out the profile.





ELENA ring


SECTION 01
INJECTION
SECTION 06
EXTRACTION
SECTION 02
INSTRUMENTATION
SECTION 05
INSTRUMENTATION & RF
SECTION 04
ELECTRON
COOLING
SECTION 03
EXTRACTION

Beam Position (L. Soby)

The ELENA orbit measurement system will be based on 20 circular BPMs made out stainless steel with vacuum as dielectric, and mounted inside quadrupoles and dipoles.

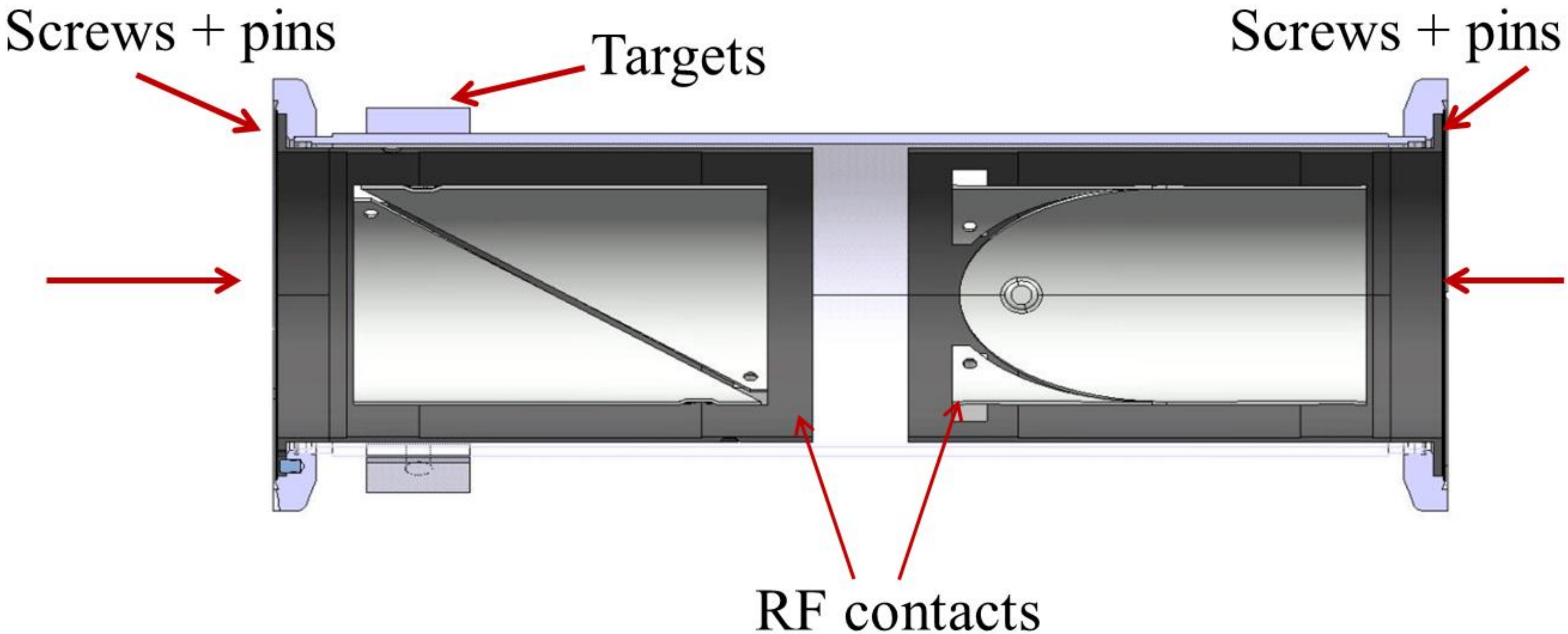
Design of PU, analogue electronics as well as digital acquisition is optimized in view of using the 20 BPMs as one big Schottky PU.

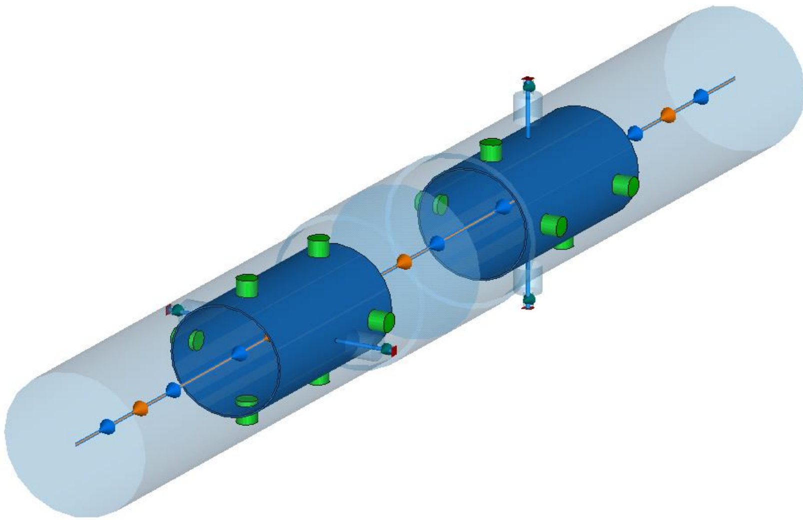
The proposed design is based on a stainless steel body containing 2 diagonal cut BPMs. Two such elements will be inserted in to a vacuum tank, 100mm diameter, in order to have a position measurement in both planes. The sum and difference signals will be generated in the head amplifier.

After amplification of the signals, by low noise amplifiers located very near to the BPMs, the signals will be transported by ~50m cables, digitized and processed using digital Δ/Σ normalization for the position calculations.

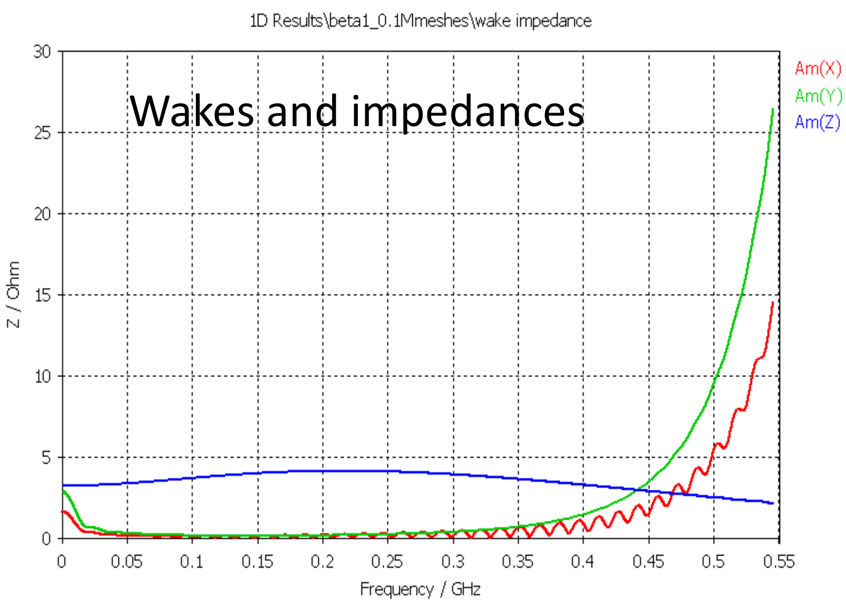
Resolution	0.1mm
Accuracy	0.3-0.5mm
Precision	0.1mm
Max. beam displacement	33mm
Time resolution	~10ms
Revolution frequencies	1050-145kHz
Overall maximum length	400mm
Inner diameter	66mm
Bake out temperature	250°C
Vacuum	3×10^{-12} Torr

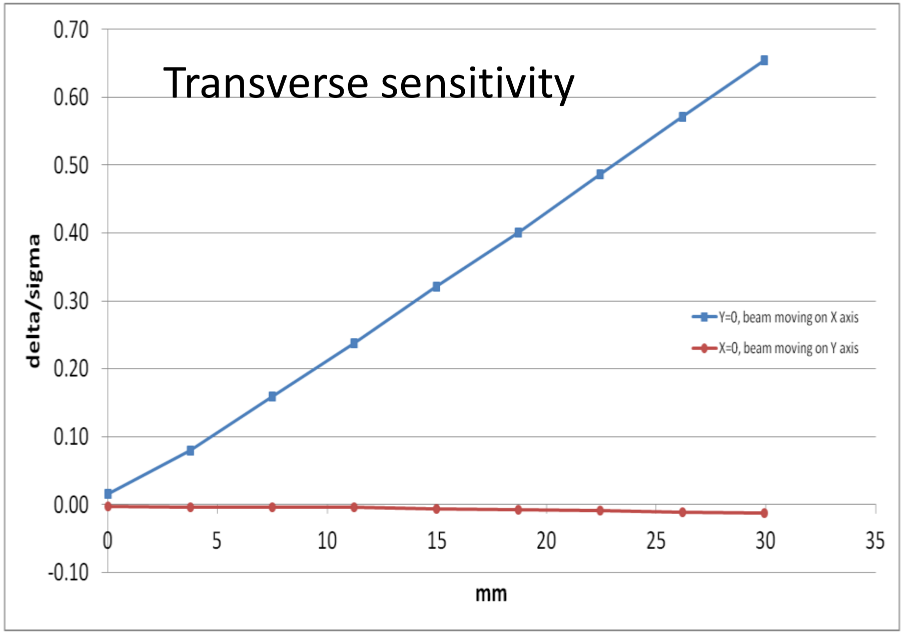
- **BPM (electrodes + support tube slides into vacuum chamber**
- **Two different lengths of vacuum chambers**
- **After NEG coating and mounting they go to metrology**
- **Then measurement on our test bench**

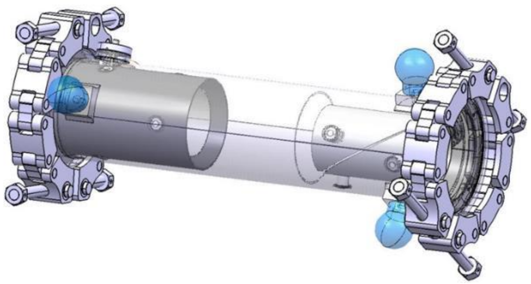


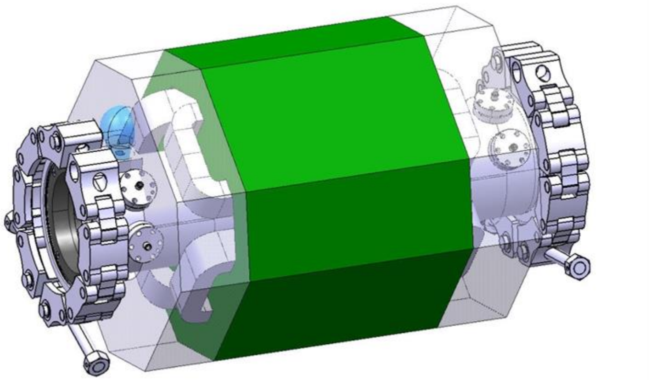


Electrode length	120mm
Electrode area	1.24E-02 m^2
Electrode capacitance	17pF
Cable capacitance (20cm, 75Ω)	10pF
Amplifier input capacitance	~20pF
Number of charges	1E7
Bunch length	1.5m
Bunching factor	20
Max. input signal amplitude	**3.0mV**
Transverse sensitivity	**~90µV/mm**

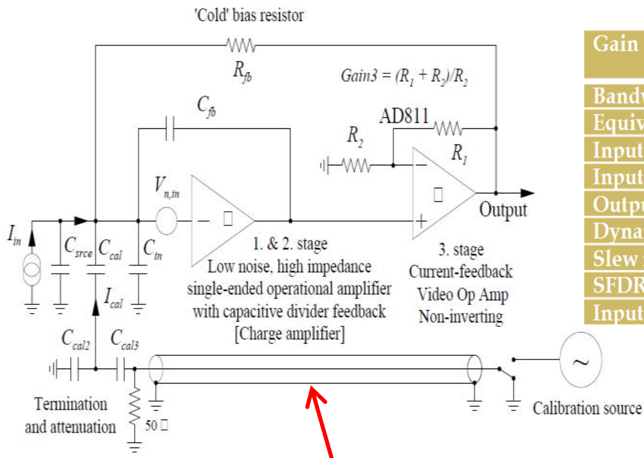




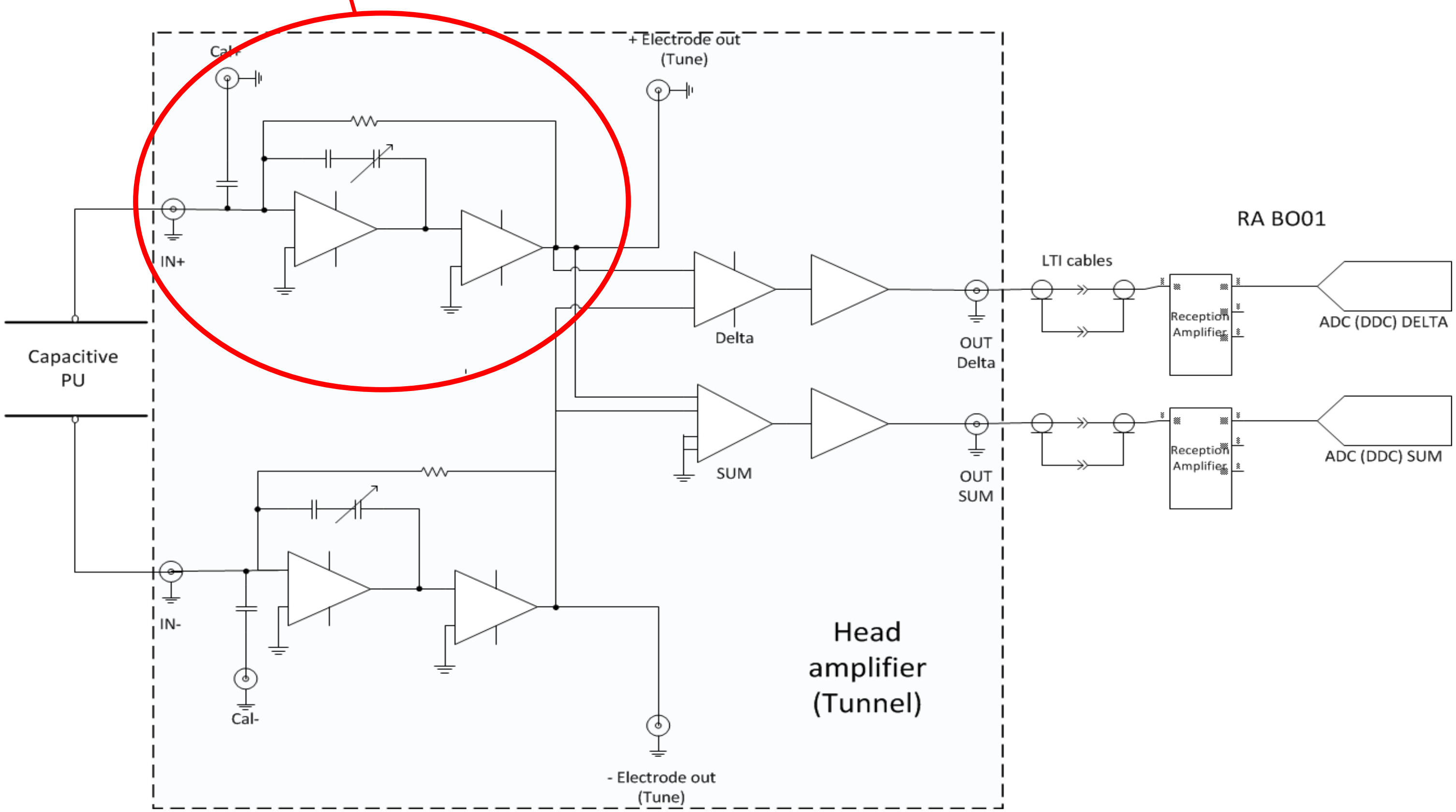




BPM	Magnet	Length	Comments
LNR.BPMEA0110	LNR.MDCAY.0105	340.5mm	Dipole
LNR.BPMEA.0125	LNR.MDCAY.0130	340.5mm	Dipole
LNR.BPMEA.0215	LNR.MQNLD.0210	432.5mm	Quadrupole
LNR.BPMEA.0240	LNR.MQNLD.0235	432.5mm	Quadrupole
LNR.BPMEA.0320	LNR.MQNLD.0315	432.5mm	Quadrupole
LNR.BPMEA.0415	LNR.MDCAY.0405	340.5mm	Dipole
LNR.BPMEA.0430	LNR.MDCAY.0435	340.5mm	Dipole
LNR.BPMEA.0520	LNR.MQNLD.0515	432.5mm	Quadrupole
LNR.BPMEA.0555	LNR.MQNLD.0550	432.5mm	Quadrupole
LNR.BPMEA.0625	LNR.MQNLD.0620	432.5mm	Quadrupole



Gain	48dB	Same gain in diff. and sum ch.
Bandwidth	DC- 40MHz	1dB cut-off and pass band ripple
Equivalent input noise	0.4nV/sqrt(Hz)	
Input resistance	3GΩ	
Input capacitance	20pF	
Output impedance	50Ω	
Dynamic range	4Vpp	
Slew rate	500V/µs	
SFDR	>120dB	Spurious Free Dynamic Range
Input connectors	SMA	

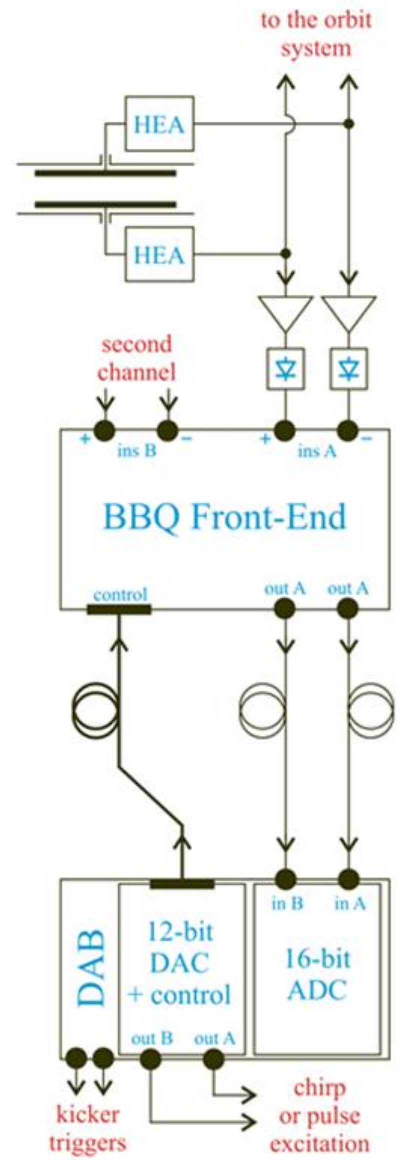


Tune (M. Gasior)

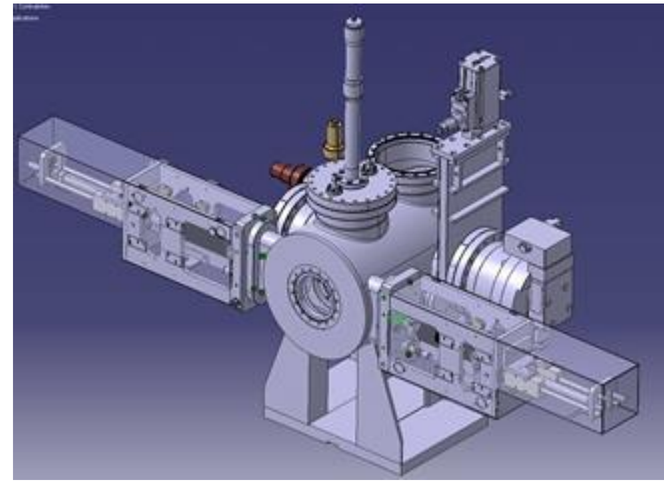
Base-Band Tune (BBQ) measurement systems are highly sensitive and based on a direct diode detection principle. The AD will soon be equipped with such a system and it is planned to use a similar setup for ELENA.

As with all BBQ setups the system will consist of:

- Diode detectors, converting beam-induced pulses from electrodes of a position pick-up to slower varying signals, from which DC offsets corresponding to the beam orbit is removed with series capacitors.
- An analogue front-end amplifying and filtering the detector signals.
- Two 16-bit ADC for parallel acquisition of horizontal and vertical betatron oscillation signals.
- A VME, FPGA based Digital Acquisition Board (DAB) providing the read-out and processing of the ADC samples, spectra calculation, data buffering and storing for subsequent transmission through the VME bus to a front-end computer.
- Two 12-bit DACs implemented as a DAB mezzanine, used to generate signals for beam chirp excitation, independently for horizontal and vertical machine planes; the DAB can also provide tune kicker triggers synchronised with the acquisition.

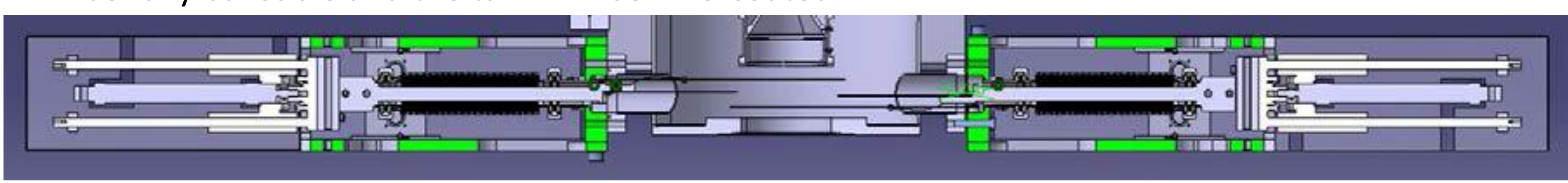


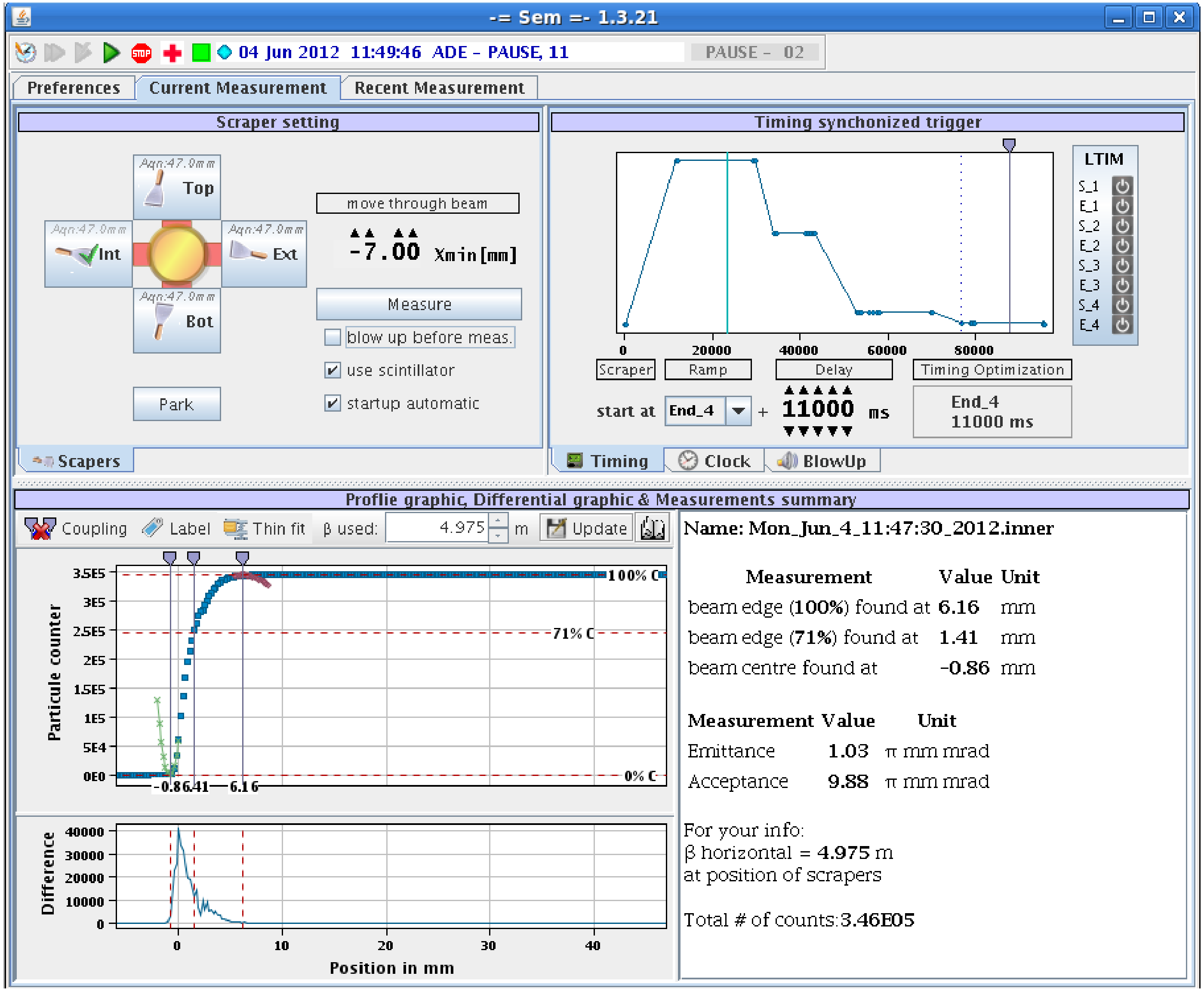
Beam Profile (R. Folch & BI-EA)



The profile of the circulating beam will be measured destructively using a scraper system. In this device a blade is moved quickly across the beam and creates a particle shower due to the interaction of the beam with the blade. A simultaneous detection of the intensity of the particle shower outside the vacuum chamber with a scintillator/photomultiplier assembly and the blade position gives an image of the beam profile.

For ELENA, 4 scraper blades (2 horizontal and 2 vertical) will be installed in a vacuum tank in section 5 of the ring . Their design is based on the Linac 4 beam stopper and will consist of a 50 mm X 20 mm aluminium plate fixed on a rigid arm which is moved into the beam by a stepping motor or a pneumatic jack. A stroke of approximately 40 mm is required to completely kill the circulating beam and the plate has to move to the IN beam position in about 1 second. The exact position is read via LVDT sensors and end switches. The movement control will be done using standard PLC based controls. All external components of the tank will be enclosed in a frame and protected by a cover to avoid any damage and for human safety. The components under vacuum will be fully bakeable and the tank will be NEG-coated.




-= Sem =- 1.3.21
04 Jun 2012 11:49:46 ADE - PAUSE, 11
PAUSE - 02
Preferences
Current Measurement
Recent Measurement
Scraper setting
Top
Int
Ext
Bot
move through beam
-7.00 Xmin[mm]
Measure
blow up before meas.
use scintillator
startup automatic
Park
Scrapers
Timing synchonized trigger
LTIM
S_1 E_1 S_2 E_2 S_3 E_3 S_4 E_4
0 20000 40000 60000 80000
Scraper
Ramp
Delay
Timing Optimization
start at End_4 + 11000 ms
End_4
11000 ms
Timing
Clock
BlowUp
Proflie graphic, Differential graphic & Measurements summary
Coupling
Label
Thin fit
β used: 4.975 m
Update
Particule counter
100% C
71% C
0% C
-0.86 1.41 6.16
Difference
Position in mm
Name: Mon_Jun_4_11:47:30_2012.inner
Measurement Value Unit
beam edge (100%) found at 6.16 mm
beam edge (71%) found at 1.41 mm
beam centre found at -0.86 mm
Measurement Value Unit
Emittance 1.03 π mm mrad
Acceptance 9.88 π mm mrad
For your info:
β horizontal = 4.975 m
at position of scrapers
Total # of counts:3.46E05

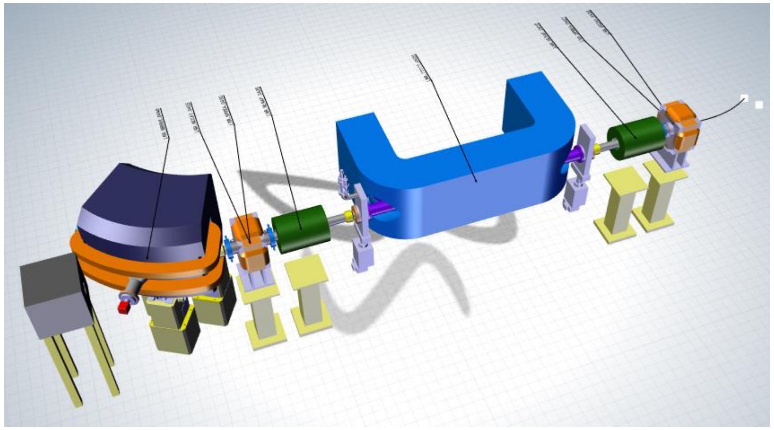
Recombination Monitor (BI-EA)

For commissioning at 100 keV with the proton source, optimisation of the electron cooler can be performed by measuring the recombination rate of electrons with the circulating protons. The choice of detector depends on the required information.

A scintillator coupled to a photomultiplier can be used to measure the recombination rate from which the transverse energy of the electron beam can be evaluated. It will be a good means to correct any angular deviations between the electron and ion beams as the maximum signal is obtained when the beams are correctly aligned.

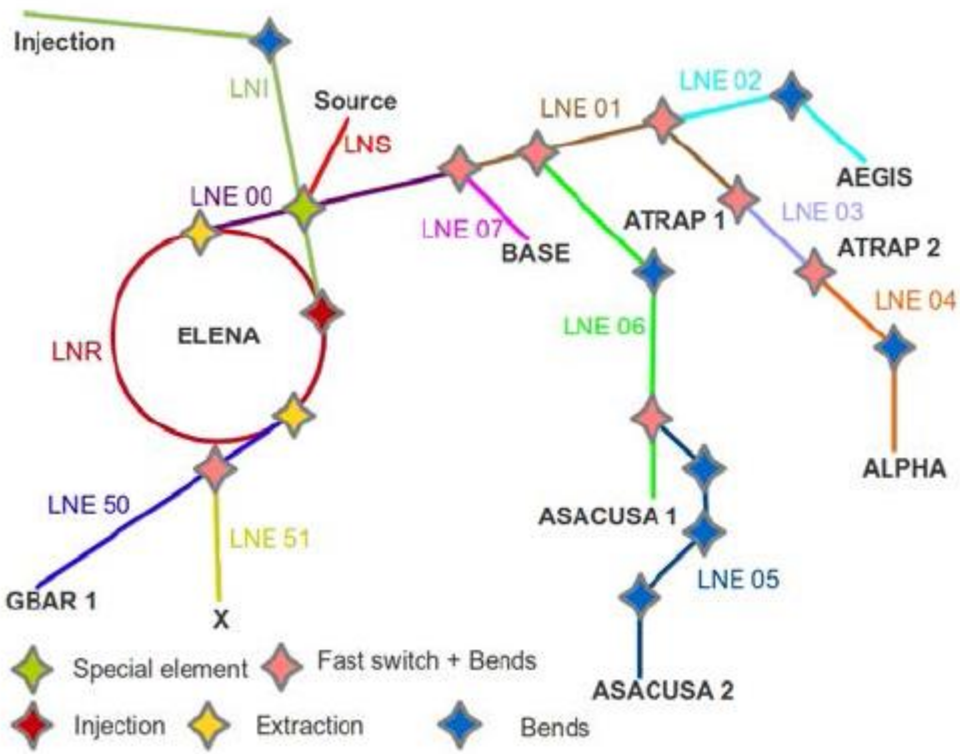
Using an imaging monitor (MCP with strip read-out) one can derive the profile and position of the ion beam from the profile and position of the recombined beam.

The detector will be installed in an extension of the bending magnet vacuum chamber downstream from the electron cooler. It’s design will be started soon.



Experimental Lines

The 100-keV antiproton beam extracted from ELENA will be transported to seven experiments using electrostatic beam lines of total length >100 m. The dipoles and quadrupoles comprising the beam lines must be precisely tuned to focus the antiprotons into the acceptance of the trap experiments.

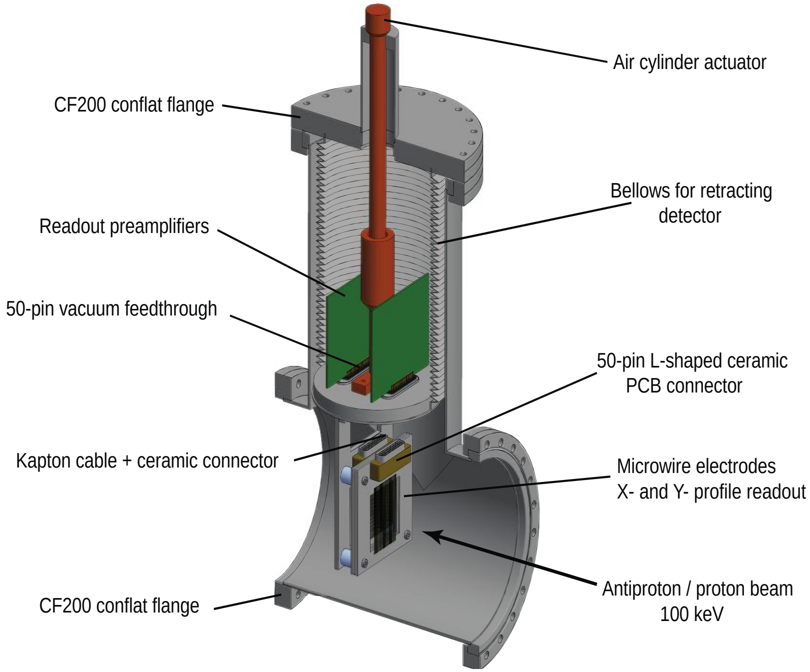


µWire Monitor (M. Hori)

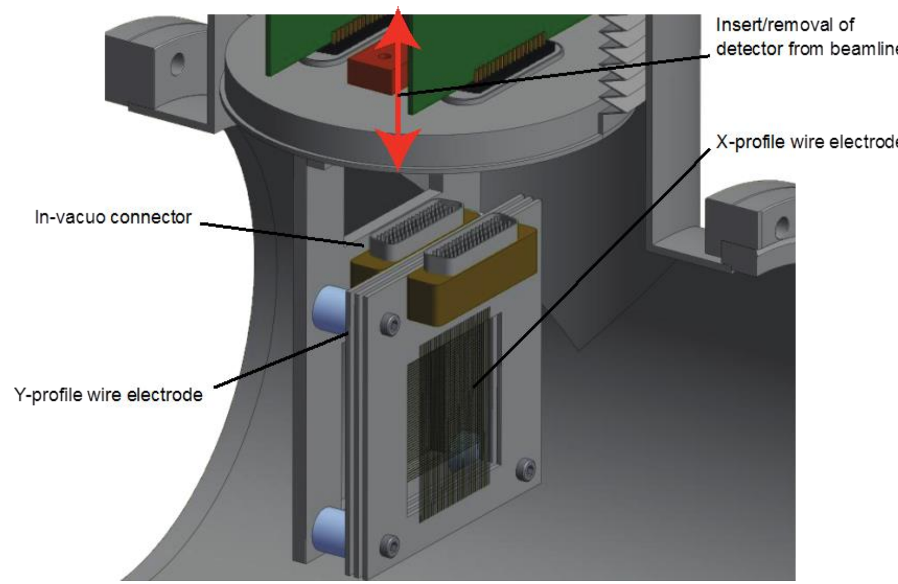
This monitor is based on the devices used by the ASACUSA collaboration since 1999 to measure 100-keV antiproton or proton beams that emerged from the Radiofrequency Quadrupole Decelerator (RFQD).

The semi-non destructive monitor allows most of the antiprotons to pass through without any degradation, while the small portion (1-3%) intercepted by the wires produces the signal. The device is sensitive to antiproton, proton, and H^- beams of energies between 10 keV and 5.3 MeV. It consists of two position-sensitive photocathode grids providing the X and Y projections of the beam, sandwiched between three anode grids with a distance of 2 mm between them. Each grid consisted of between 32 and 48 gold-coated tungsten wires of diameter of 5–20 µm stretched over a ceramic frame, with a pitch 0.5–1.5 mm between neighbouring wires.

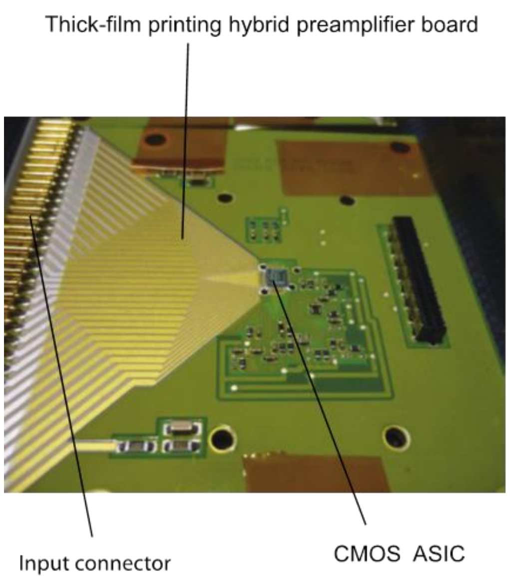
The cathode grids at ground potential are irradiated by the beam, and the secondary electrons emitted from them are accelerated toward the anode grids biased at 50 V. The beam profile is obtained by using charge-sensitive preamplifiers to measure the charge Q_i ejected from the cathode wires on the X- and Y-grids with high sensitivity.



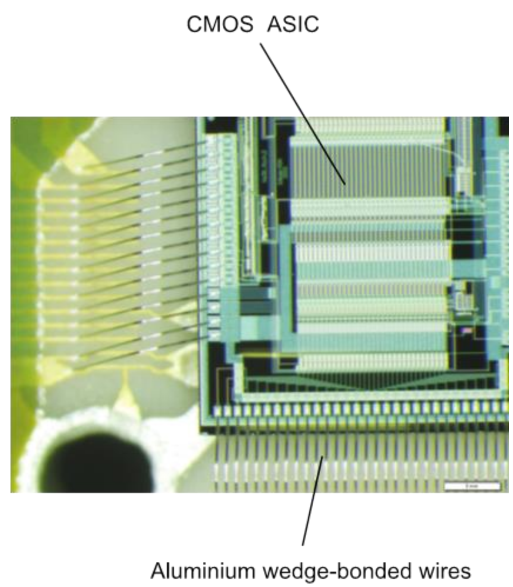
Air cylinder actuator
CF200 conflat flange
Bellows for retracting detector
Readout preamplifiers
50-pin vacuum feedthrough
50-pin L-shaped ceramic PCB connector
Kapton cable + ceramic connector
Microwire electrodes X- and Y- profile readout
Antiproton / proton beam 100 keV
CF200 conflat flange



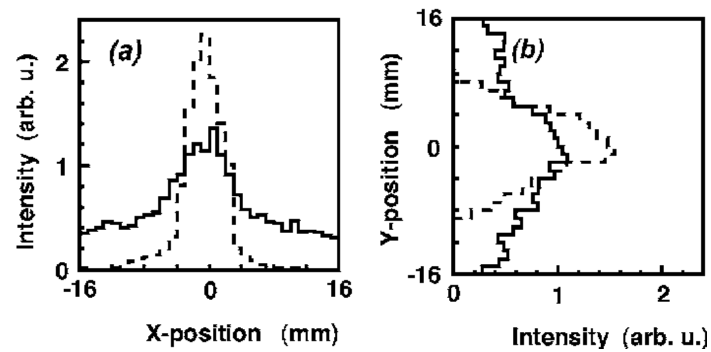
Insert/removal of detector from beamline
X-profile wire electrode
In-vacuo connector
Y-profile wire electrode



Thick-film printing hybrid preamplifier board
Input connector
CMOS ASIC



CMOS ASIC
Aluminium wedge-bonded wires



(a)
Intensity (arb. u.)
X-position (mm)
-16
0
16
0
1
2
(b)
Y-position (mm)
Intensity (arb. u.)
16
0
-16
0
1
2

Number of detectors	40 - 60
Beam type	Antiprotons, protons, H- ions
Beam energy	10 keV - 6 MeV (previously used in AD and RFQD)
Aperture	62 x 62 mm
Active area	48 x 48 mm (variable)
Spatial resolution	0.5 - 1.5 mm (variable)
Dynamic range	10000 (limited by charge-sensitive preamplifier)
Channels	64 or 92 channels parallel readout
Sensitivity	$>5 \times 10^5$ particles in a 300-ns-long bunch
Transmission	97-99% (depending on wire diameter and pitch) per detector
Chamber length along beam line	290 mm
Chamber diameter	200 mm
Flange and tube diameter	DN200CF
Materials	Stainless steel 316LN, alumina, gold, copper, Kapton ribbon insulator
Vacuum compatibility	$<10^{-10}$ mbar
Readout electronics	0.8 µm N-well CMOS ASIC (IDEAS VA32 or VA64)
Digitization	14-bit flash ADC
Calibration	In-situ calibration using DAC pulsar
Power	+/- 12 V DC, 4 A
Hardware interface	CERN standard VME64x backplane bus
Software interface	CERN standard PS control system

Future Developments

Use of BPM PUs for longitudinal Schottky measurements on de-bunched beams as well as intensity and position of bunched beams.

Cryogenic current comparator (CCC) based on a superconducting quantum interference device (SQUID) for the measurement of the circulating beam intensity.

Collaboration with GSI
Prototype to be tested in AD
If BPM summing successful then replace magnetic LPU and install CCC

Investigate the possibility to use residual gas ionisation or luminescence for circulating beam profile measurements.

To Do

- Finish integration of injection/1st turn BTV. Choose IN/OUT mechanism.
- Design/integrate strip-line kicker for tune measurement. Is there some space for a PU?
- Complete the integration of the scraper movement.
- Design recombination monitor.