Beam Instrumentation for the Ultra-low Energy Storage Ring at FLAIR

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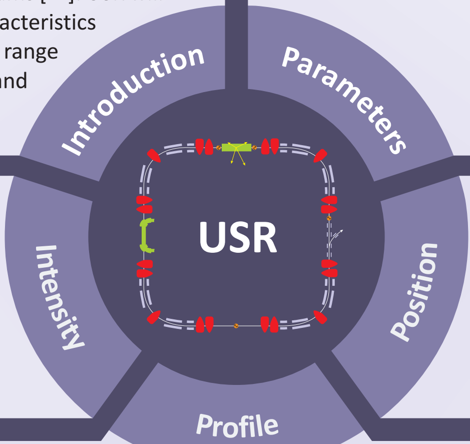
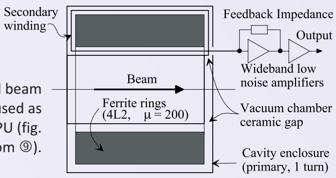
The future Facility for Low-energy Antiproton and Ion Research (FLAIR) will supply users with high-luminosity low-energetic beams of antiprotons for nuclear physics and atomic collision studies [①,⑨]. Antiprotons will be slowed down to 20 keV by a novel electrostatic Ultra-low energy Storage Ring (USR) which offers world-wide unique conditions for both in-ring studies and experiments requiring extracted slow beams [⑨]. USR will provide variable energies, intensities and beam characteristics (bunched or slowly extracted beams) making a wide range of low energy physics experiments with antiprotons (and possibly highly charge radioactive ions) feasible.

General parameters of the USR. For clarity, only the antiproton beams are presented.

Energy	20 – 300 keV
Velocity	0.006 c – 0.025 c
Number of particles	$< 2\cdot10^{7}$
Revolution frequency	46 – 177 kHz
Bunch length	1 ns – DC beam
Effective $\bar{p}$ rates for in-ring exp.	$10^{10} – 10^{12}$ pps
Average rates of extracted $\bar{p}$'s	$5\cdot10^{5} – 10^{6}$ pps

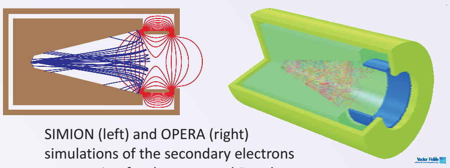


A set of longitudinal Schottky pick-ups, like those proposed for CERN AD and ELENA [⑨], is considered to be used as a non-destructive system for intensity, momentum spread and mean momentum measurements by FFT-based spectral analysis of Schottky signals.



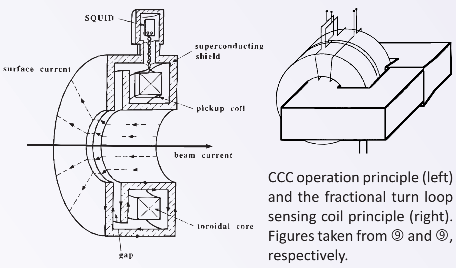
Ferrite loaded beam transformer used as a Schottky PU (fig. taken from ⑨).

In addition, a Faraday cup is considered to be used as a destructive monitor for absolute measurements. Although the charge can escape from it in a variety of ways (MeV-scale charged pions and recoil ions) and so it might not give exact values of the antiproton beam currents, it still can be used for the commissioning stage with protons or H^- ions.



SIMION (left) and OPERA (right) simulations of the secondary electrons suppression for the proposed Faraday cup.

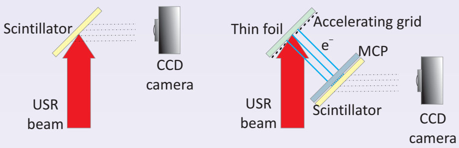
An interesting option is a SQUID-based cryogenic current comparator (CCC) for absolute, non-destructive in-ring measurements. However, an extensive R&D is required as there is still place for optimization, e.g. a fractional turn loop sensing coil may enhance a CCC sensitivity above that of a SQUID.



CCC operation principle (left) and the fractional turn loop sensing coil principle (right). Figures taken from ⑨ and ⑨, respectively.

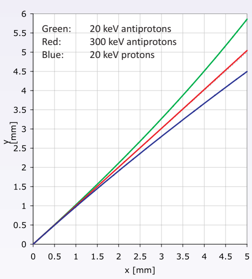
Other monitors, like activation or annihilation detectors, could make use of the advantage of antiprotons interaction with matter, but they would provide destructive, time consuming, relative and not highly accurate results only.

A simple scintillator-based device would deliver sufficient information on the beam profile. However, a problem of the light yield decrease due to the surface sputtering [⑨] and a possibly limited sensitivity are currently being investigated for a thin CsI:Tl scintillator in the collaboration with INFN-LNS, Italy.



Two concepts of beam profile monitoring: a scintillator-based device (left) and a secondary electron emission foil-based solution (right).

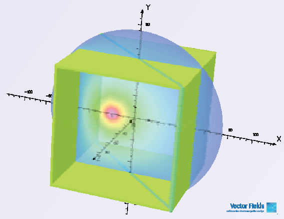
Another destructive device being studied is a secondary electron emission monitor. In this case an accelerating field is introduced and its influence on the initial beam should not be neglected.



Disturbance of different beams in the presence of the secondary electron emission monitor.

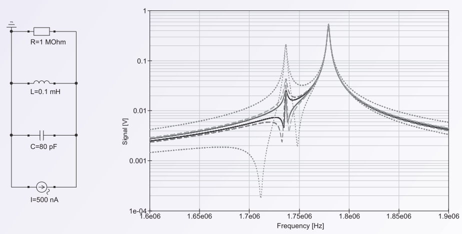
In addition, a micro-wire monitor successfully tested with 25 keV ÷ 5.3 MeV antiprotons and intercepting only 1% of the beam [⑨] could be acquired for the less perturbing diagnostics.

Capacitive pick-ups (PU) are foreseen for beam position monitoring. Due to a low number of particles and a low signal-to-noise ratio, a tuned resonant circuit is under investigation.



OPERA simulation of a misaligned beam (red spot) measured by a shoe-box type capacitive pick-up.

Different PU geometries have been studied and a great improvement of sensitivity to the beam displacement has been achieved by separating electrodes by a ring on the ground potential. However, preliminary studies of equivalent circuits showed that a coupling (parasitic) capacitance between two separate electrodes cannot be neglected as it results in a loss of information on beam position. Even for a small value of a coupling capacitance (a few pF) not only is a difference signal smaller by three orders of magnitude as compared to uncoupled electrodes, but also the frequency spectrum is distorted. The problem can be resolved by creating just one resonant circuit directly measuring the difference signal from two electrodes.



A resonant PU electrode equivalent circuit and resulting spectra for different beam displacements (solid line: ± 1 mm, dashed line: ± 2 mm, dotted line: ± 10 mm) for two electrodes coupled with a parasitic capacitance.

References

① Widmann E. *et al.*, FLAIR - Technical Proposal (2005), http://www.oeaw.ac.at/smi/flair/
⑨ Welsch C.P. *et al.*, Hyperfine Interact. 172 (2006) 71.
⑨ Welsch C.P. *et al.*, NIM A 546 (2005) 405.
⑨ Eriksson T. *et al.*, CERN AD Rep. 079 (2007).
⑨ Gonzalez C. *et al.*, PAC Proc. (1999) 474.
⑨ Tanabe T. *et al.*, NIM A 427 (1999) 455.
⑨ Sese J. *et al.*, IEEE Trans. Instrum. Meas. 48 (1999) 1306.
⑨ Sieber T. *et al.*, DIPAC Proc. (2007) 283.
⑨ Hori M., Rev. Sci. Instrum. 76 (2005) 113303.