Secondary Emission Monitor for keV Ion and Antiproton Beams

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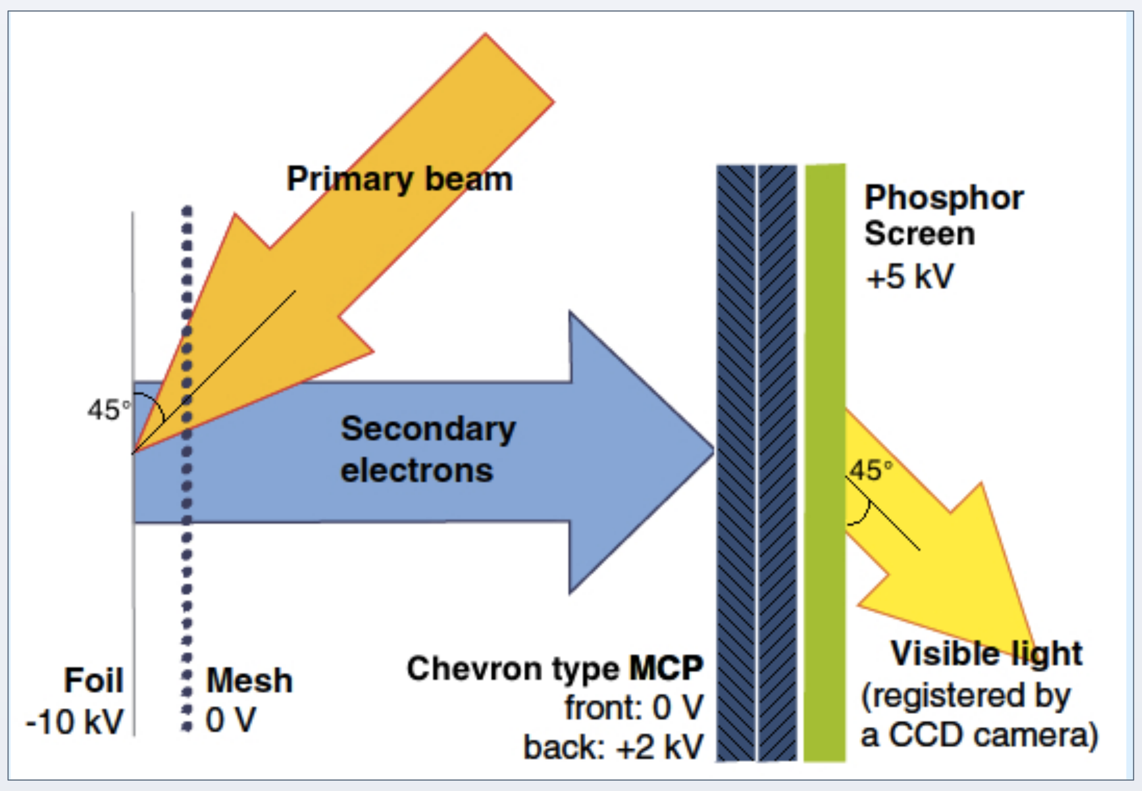
Abstract

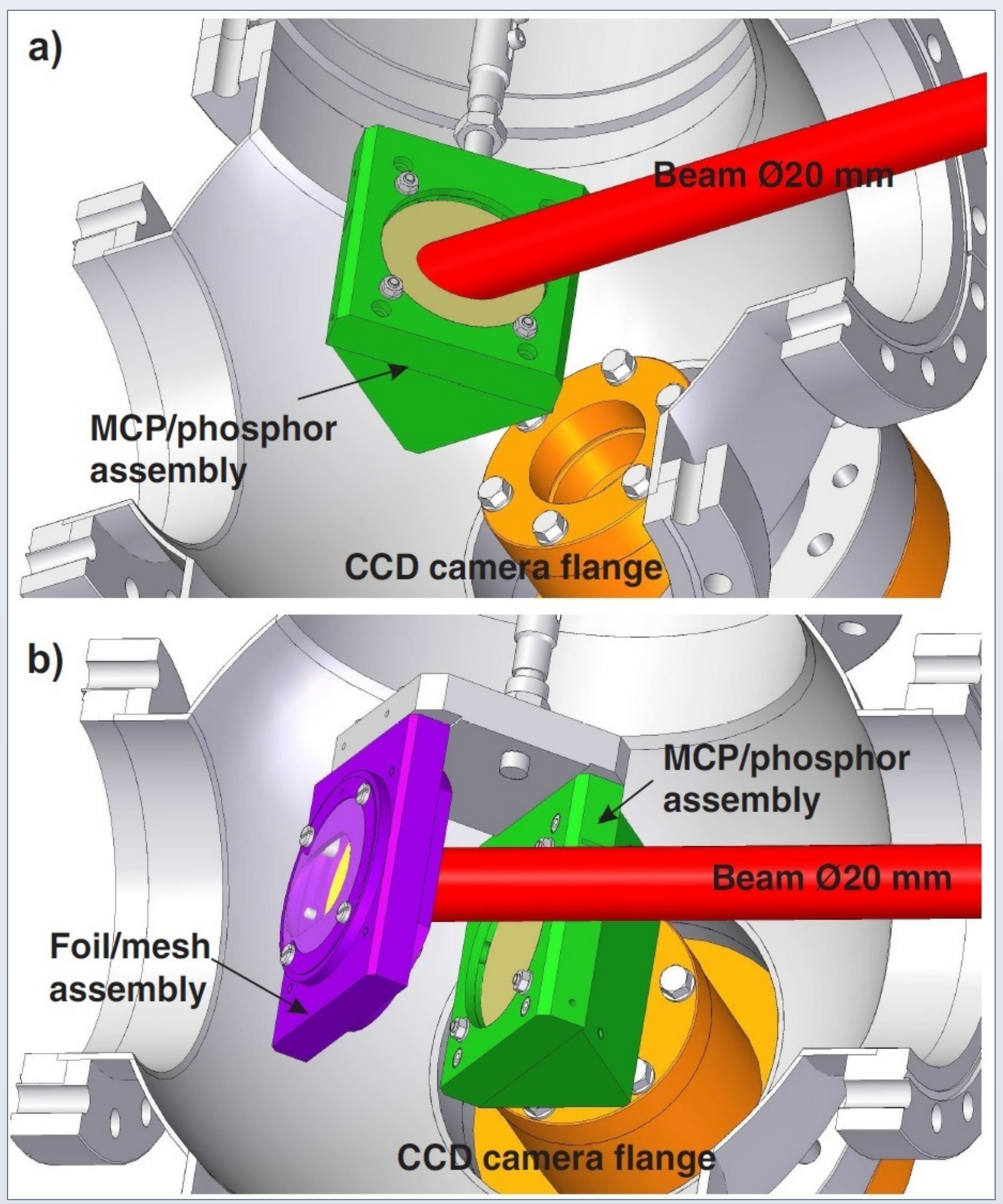
Beam profile monitoring of low intensity keV ion and antiproton beams remains a challenging task. A Secondary electron Emission Monitor (SEM) has been designed to measure profiles of beams with intensities below 10^7 and energies as low as 20 keV. The monitor is based on a two stage microchannel plate (MCP) and a phosphor screen facing a CCD camera. Its modular design allows two different operational setups. In this contribution we present the design of a prototype and discuss results from measurements with antiprotons at the AEgIS experiment at CERN. This is then used for a characterization of the monitor with regard to its possible future use at different facilities.

Detector Principle



- Primary beam hits the Al foil at 45°
- Secondaries emitted on the surface are accelerated through the mesh towards the MCP
- The two-stage MCP amplifies the e-signal with a gain of 10^6 @ 2 kV
- Phosphor screen converts e-signal into visible light registered by a CCD camera

Secondary Emission Monitor (SEM)

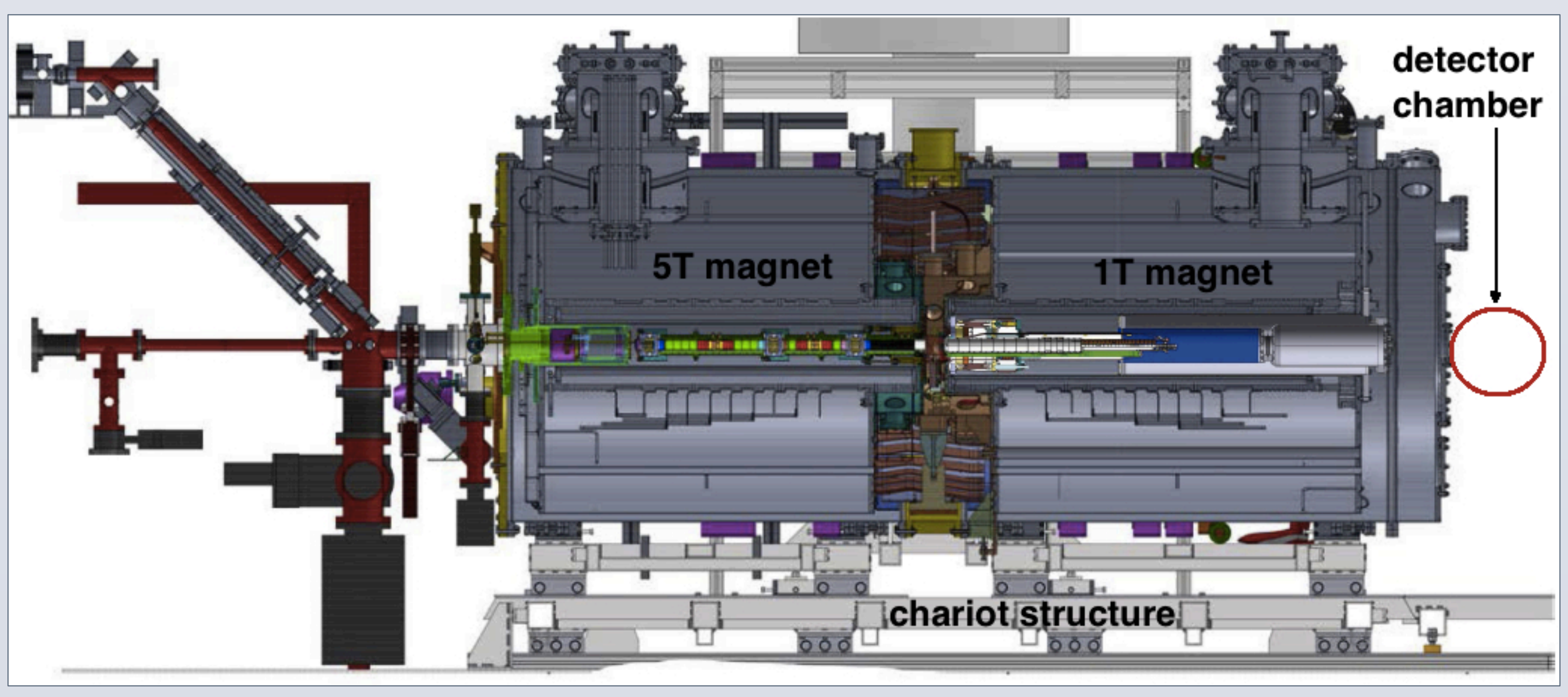


a) Stand-alone MCP configuration: both antiprotons and secondaries reach the MCP and phosphor screen.

b) Foil/mesh setup: -10 kV are applied to the metal foil where secondary e^- are produced, then accelerated through the grounded mesh towards the MCP and phosphor screen. Light produced in the phosphor screen is recorded by the CCD camera. Only negatively charged particles arrive to the MCP.

Note that the beam aspect ratio is maintained in both setups due to the 45° orientation of the device.

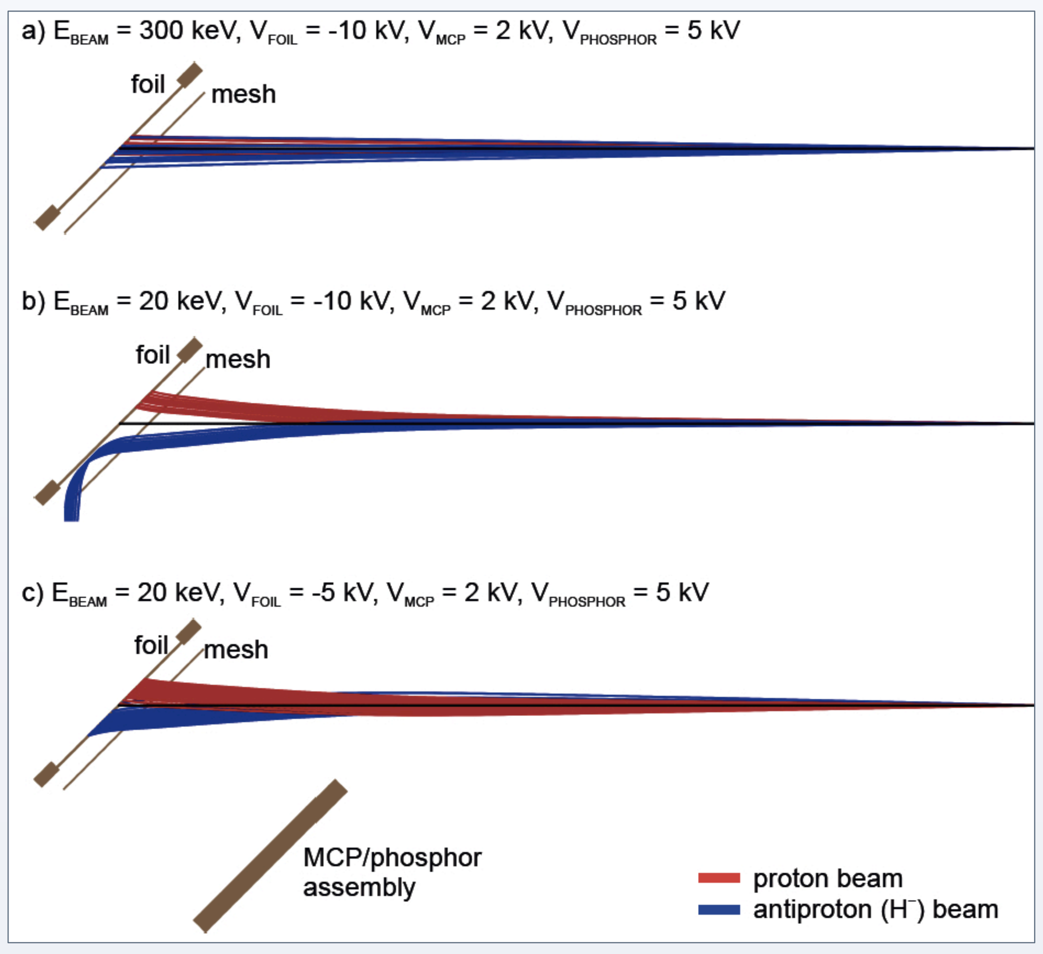
Experimental Setup



AEgIS Beam Parameters:

Beam Energy:	300 keV/u
Beam Intensity:	~3x10^7 pps per shot
Repetition time:	110 s
Bunch length:	120 ns

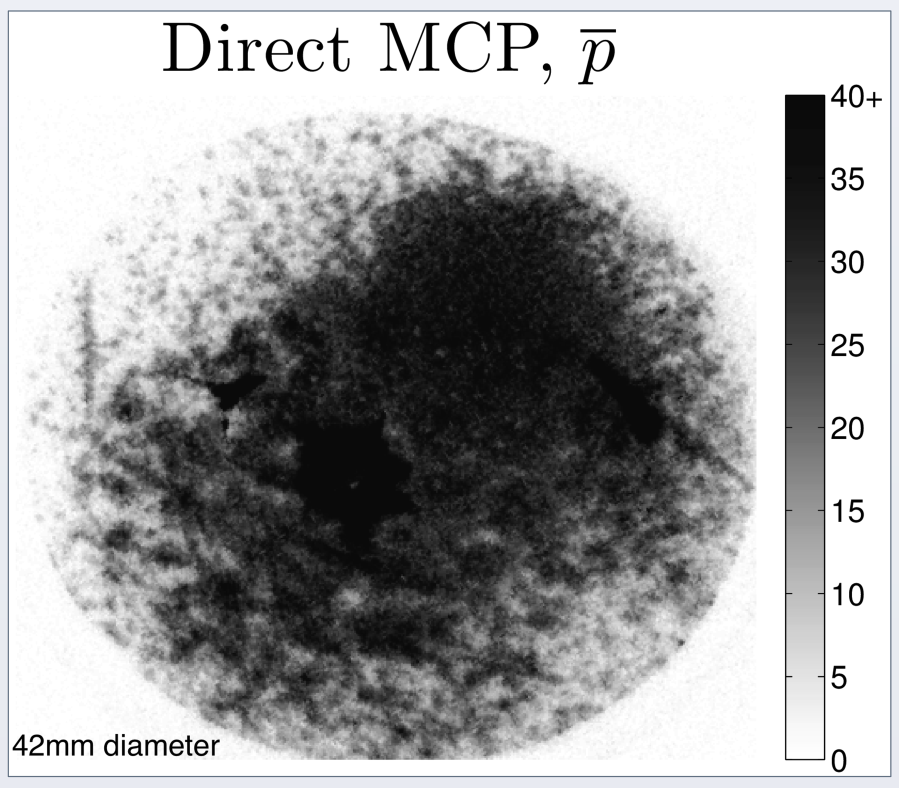
The SEM was installed in a purpose-built detector chamber downstream of the AEgIS 5 T and 1 T magnets at the Antiproton Decelerator (AD) [1] hall at CERN. It shared space with other detector technologies, such as nuclear emulsions [2].



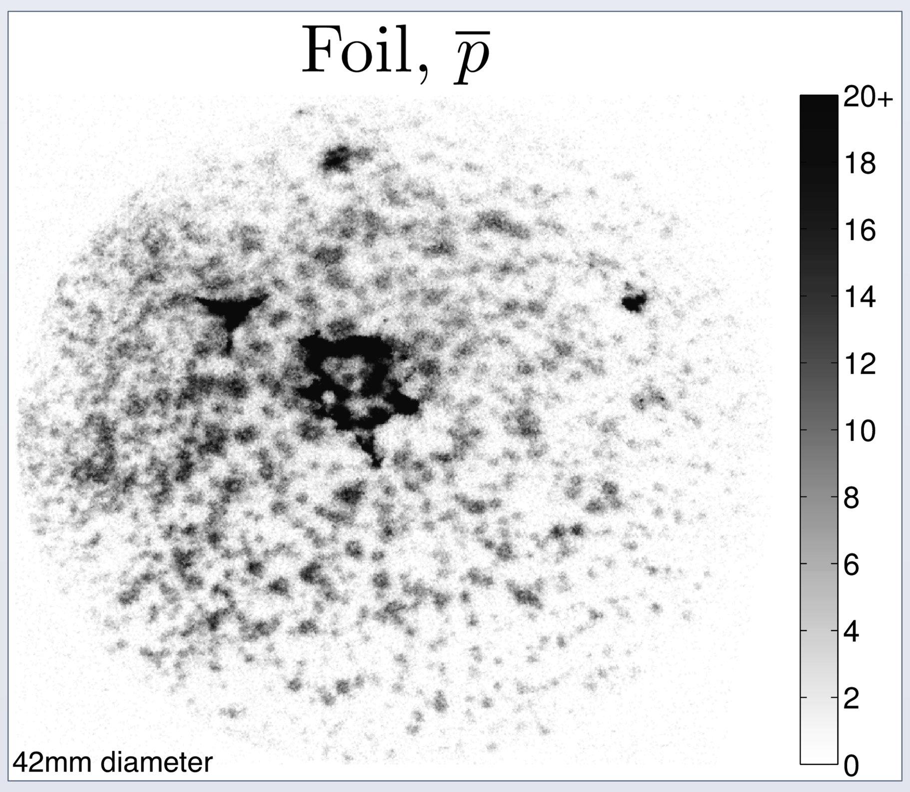
SIMION [3] simulations of the SEM performance with low-energy proton and antiproton beams indicate the best voltage parameters to work with a given beam energy.

The effect of foil voltage could lead to a distortion of 4 mm and 5 mm for protons and antiprotons, respectively [4].

Experimental Results



Annihilation events can be seen when the MCP/Phosphor is exposed directly to the antiproton beam at AEgIS. Black spots correspond to damages on the monitor due to high voltage sparks. The active area of the phosphor screen shown in these images is 42 mm, which one could to eventually calculate beam size. This was not possible in these tests as the antiproton beam was very defocused after the 5 T and 1 T AEgIS magnets.



In the second setup (foil/mesh), only secondary particles arrive to the monitor, yielding a more indirect image of the beam. No significant improvement of the image was achieved by changing the voltage of either the MCP or the phosphor screen. Closing the gate valve upstream of the monitor allowed high energy particles (pions) to reach the monitor, despite its thickness. This confirmed that the beam seen in the foil/mesh setup is mostly antiprotons.

Conclusion

These measurements are destructive for either configuration of the device. No collimator tests were performed, but previous studies account for <2 mm spatial resolution for the foil-based configuration [4]. For the first time, the stand-alone MCP configuration was successfully tested, showing clear beam images, but introducing some background noise from high energy secondary particles.

The SEM was the only online monitor in the latest AEgIS run and the only one sensitive enough for the initial (low intensity) beam steering. This monitor has proven to work both with protons and antiprotons, yielding promising results as a detector for future installations such as the accelerator FLAIR at GSI, Darmstadt [5]. More studies are needed in order to fully characterize the SEM capabilities as a permanent monitor for low energy ion and antiproton beams.

References

[1] Baird, S., et al., Nuclear Instruments and Methods in Physics Research A, 391, (1997) 210-215.
[2] S Aghion et al. JINST 8 P08013 (2013)
[3] Inc. Scientific Instrument Services. SIMION: ion and electron optics simulator. http://simion.com/, (2009)
[4] Harasimowicz, J., Welsch, C. P., Cosentino, L., Pappalardo, A., and Finocchiaro, P., Physical Review Special Topics-Accelerators and Beams, 15(12), 122801, (2012)
[5] Welsch, C. P., et al., Nuclear Instruments & Methods in Physics Research A, 405-417, (2005)

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