A pixelated Faraday Cup for proton beam diagnostic

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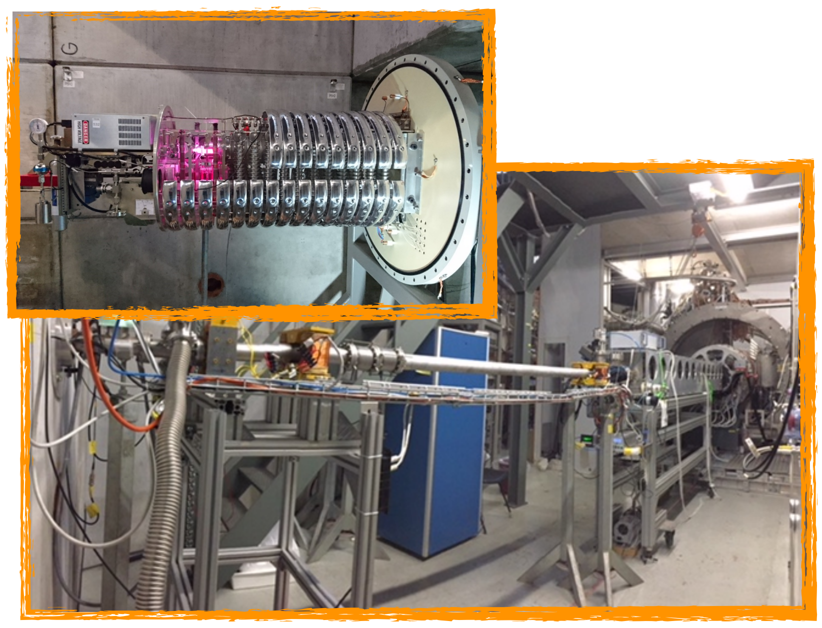
Introduction

Diagnostics tools are largely used to tune and set particle beams in a vast range of applications. They include particle and nuclear physics, medical physics up to material science and biology, just to mention a few.

The requirements of the detectors used to monitor the beam change accordingly with the specific case.

We present here a so called pixelated Faraday cup we built and used with the peculiar characteristic of measuring simultaneously a proton beam profile (beam spot and position) and intensity.
The detector covers a large range of current from a hundred μA down to a few nA perfectly matching the range of the proton beam intensity delivered by a Cockcroft-Walton accelerator which the detector will be coupled to.
The pixel size allows for a beam position determination better than 1 mm.

The Cockcroft-Walton accelerator and the proton beam line



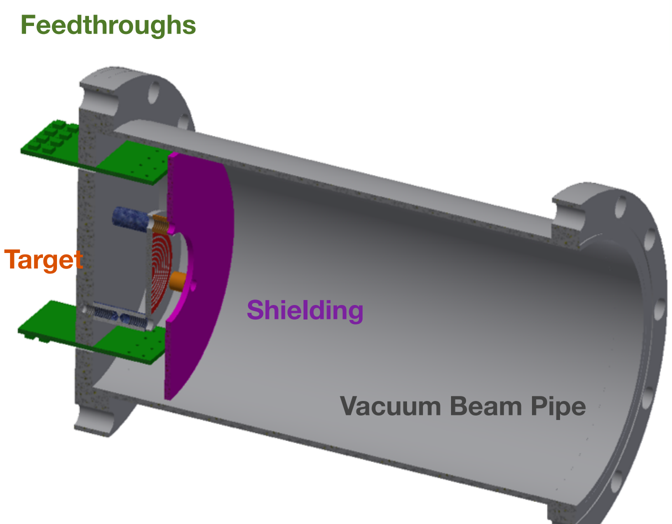
Main CW accelerator characteristics [1,2]

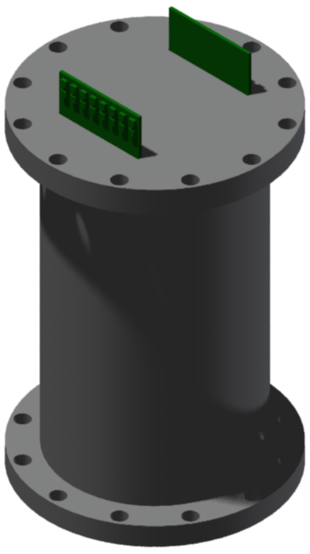
- Base vacuum level: < 10^{-6} mbar
- Terminal voltage range: 100 - 1000 kV
- Terminal voltage ripple: 500 V_{RMS}
- Beam current intensity range: 1 -100 μA
- Typical focused spot size (immediately after the CW Gate Valve): 1 x 1 cm² (FWHM)
- Angular divergence: 5 x 5 mad (FWHM)
- Current stability: < 10% (4 hours)
- Used gas: Hydrogen

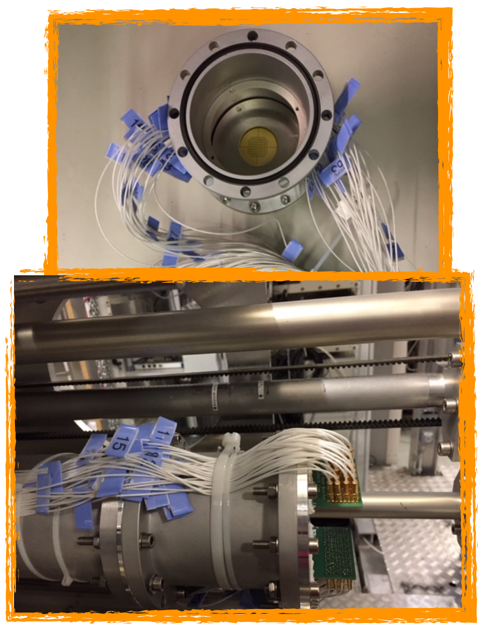
Proton beam line

- Base vacuum level: ~10^{-6} mbar
- Total length: ~ 10 m
- Extensible beam line via non magnetic bellows: Maximum stroke ~ 2.3 m
- Beam line end: Inside a magnetic field at 1.25 T

Detector



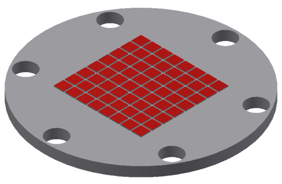




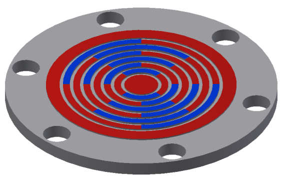
Main detector characteristics

- Base vacuum level: ~10^{-6} mbar
- Faraday cup insulated from the rest of the beam line
- All non-magnetic components
- Working inside a magnetic field of 1.25 T
- Simultaneous measurement of current and the position and size
- Large current range: 10 nA - 100 μA
- Precision on the beam position measurement: < 1 mm

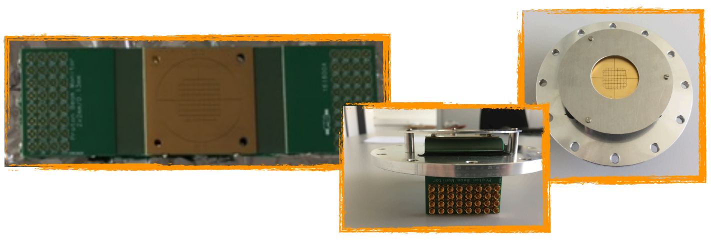
Target



Matrix: 8 x 8 channels
Pixel size: 2 x 2 mm²
Pixel pitch: 0.13 mm
Channels: 64

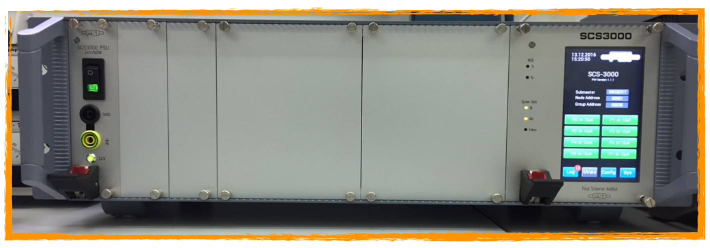


Annular rings: 8
Ring thickness: 2 (4) mm
4 portions/ring
Phase ring's portion: π/4
Number of channels: 26



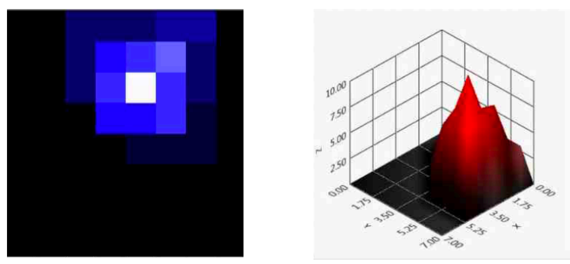
The Readout

- SCS3000 developed at Paul Scherrer Institut
- Maximum boards: 8
- Current meter boards
  - Current Range: 10 nA - 100 μA
  - precision: 0.5 nA
  - Offset: less then the resolution
  - 8 channels/board
- Touch screen and remote control
- Interface: Labview and Midas
- For more info: https://www.psi.ch/ltp-electronics/www-documents/



The Results

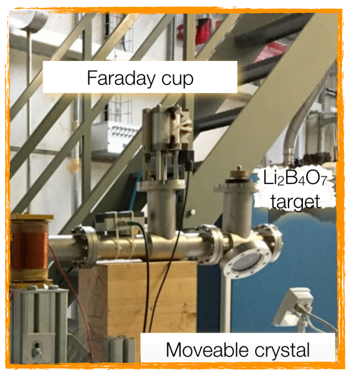
Pixelated Faraday cup



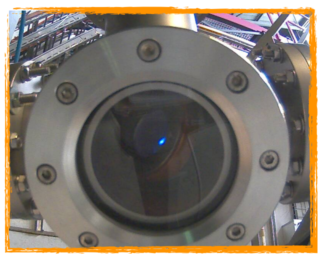
- Both the measured current and beam position (gravity centre) are consistent with what measured with other tools used to validate the detector performances (Used reference tools: normal Faraday cup and quartz crystal detector coupled to a camera)
- Total current: sum of all pixel current
- Beam position:
  - Coordinate (x,y) weighed mean
  - Asymmetry left-right
  - Asymmetry top-bottom

Reference detectors

Normal Faraday cup



Quartz crystal viewed by a camera



References

[1]: A. Papa, Il Nuovo Cimento **122** (2007) 627
[2]: J. Adam et al. (MEG collab.) NIM A **641** (2011) 19
[3]: A. M. Baldini et al. (MEG collab.) EPJC **73** (2013) 2365
[4]: A. M. Baldini et al. (MEGII collab.) EPJC **78** (2018) 380

Acknowledgements

We thank the Paul Scherrer Institut as host laboratory and for the technical support.
Grants: MIUR Montalcini D.M. 2014 n. 975
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Summary and Outlook

- A **first pixelated** Faraday Cup has been built, tested and successfully integrated into the MEGII Cockcrof-Walton beam line at the Paul Scherrer Institut [3,4]
- Its performance has been confirmed comparing the results obtained with that measured with other reference detectors
- The main new characteristics of this detector is the capability to measure **simultaneously** the beam current (**large current range** from 10nA to 100 μA) and the beam position (**better than 1 mm**)