DITANET International Conference:
Accelerator Diagnostic Techniques
9-11 November 2011, Seville, Spain

Beam Diagnostics for Future Low Energy Storage Rings

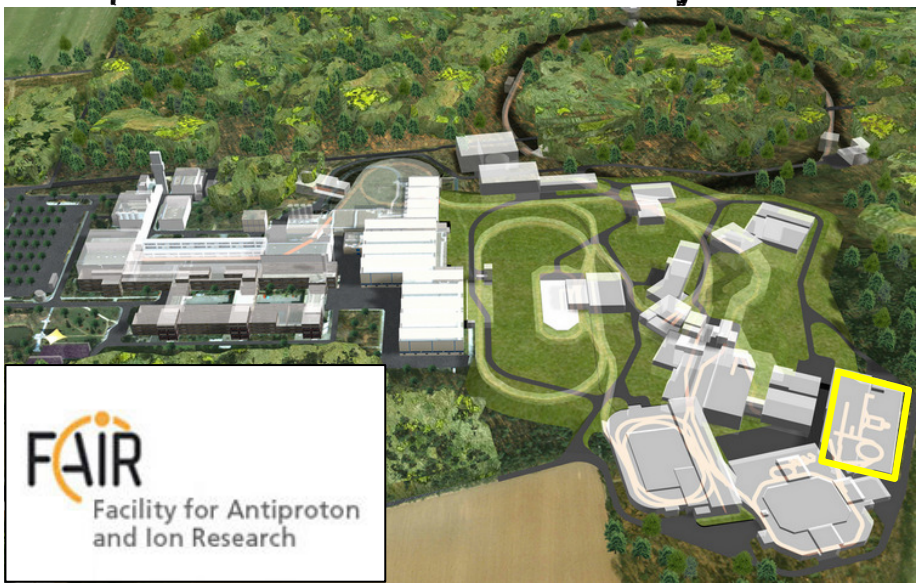
Janusz Harasimowicz

University of Liverpool
Cockcroft Institute

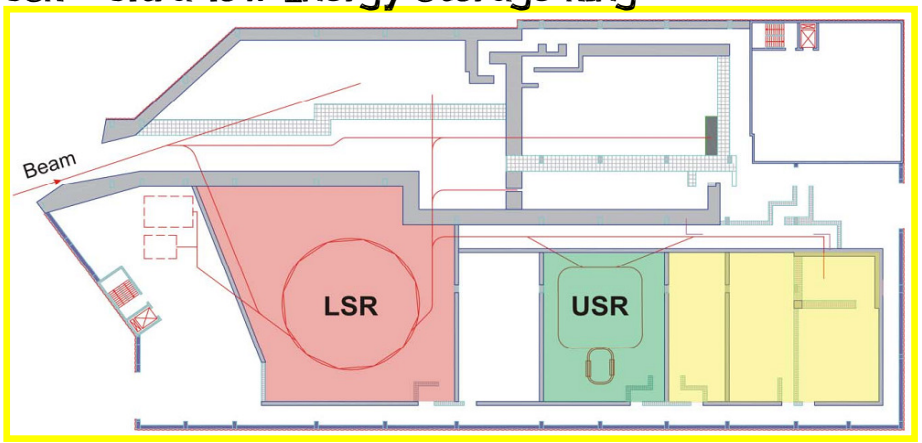
Challenges

- Energies
  MeV … keV … eV …
- Intensities
  µA … nA … pA … fA …
- Particles
  protons, ions,
  antiprotons …

Example: USR @ FAIR (GSI, Germany)



USR = Ultra-low Energy Storage Ring



30 MeV → 300 keV → 20 keV → ~rest

The Task

- Development of Novel Beam Instrumentation for Future Low Energy Storage Rings

The Task

> Development of Novel Beam Instrumentation for Future Low Energy Storage Rings

Position

Energy

Transverse profile

Intensity

Momentum

Emittance

Closed orbit

Tune

Longitudinal profile

Beam losses

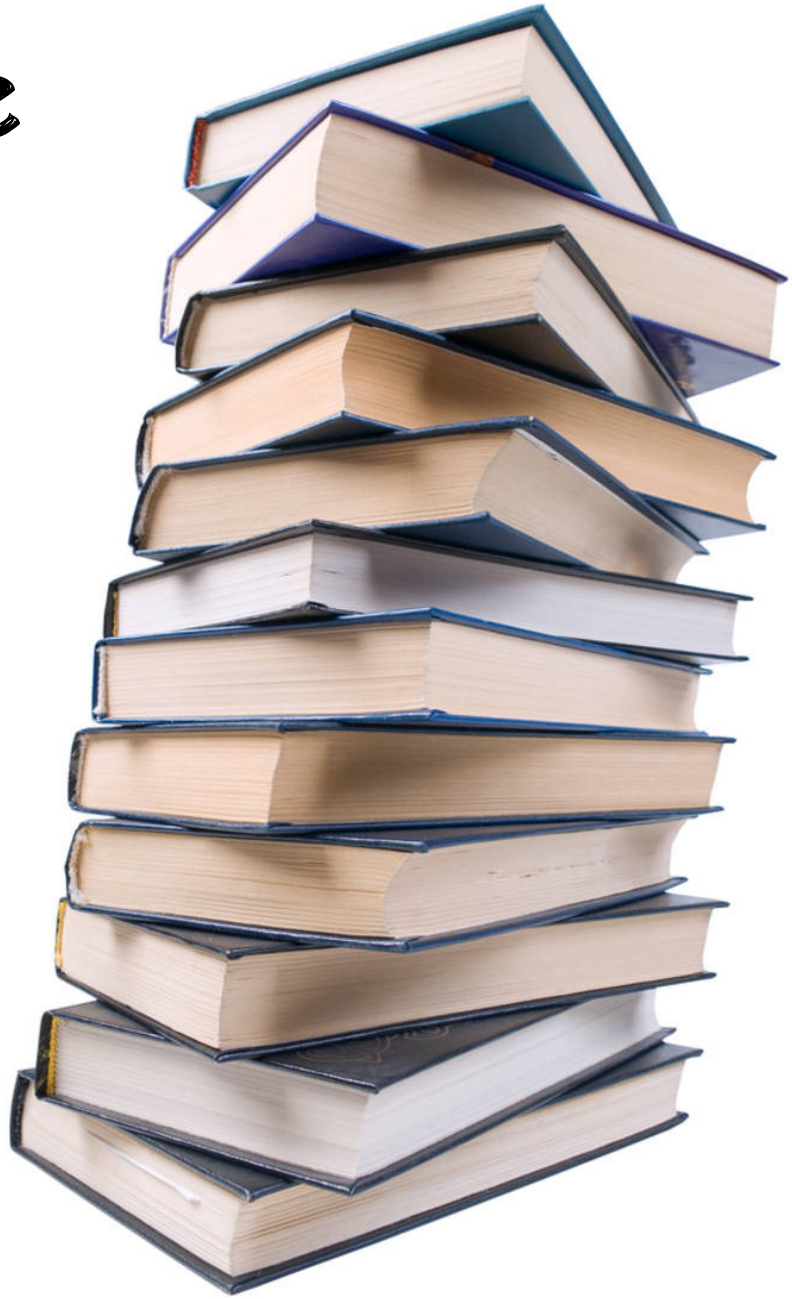
etc.

Reconnaissance

- **Intensity:**
  ~~Cryogenic Current Comparator~~
  Faraday Cup
  ~~Current Transformer~~
  ~~Capacitive Pick-Up~~

- **Position:**
  Capacitive Pick-Up

- **Transverse Profile:**
  Scintillating Screens
  Microchannel Plate
  Secondary Emission Monitor
  ~~Wire Scanner / Harp~~



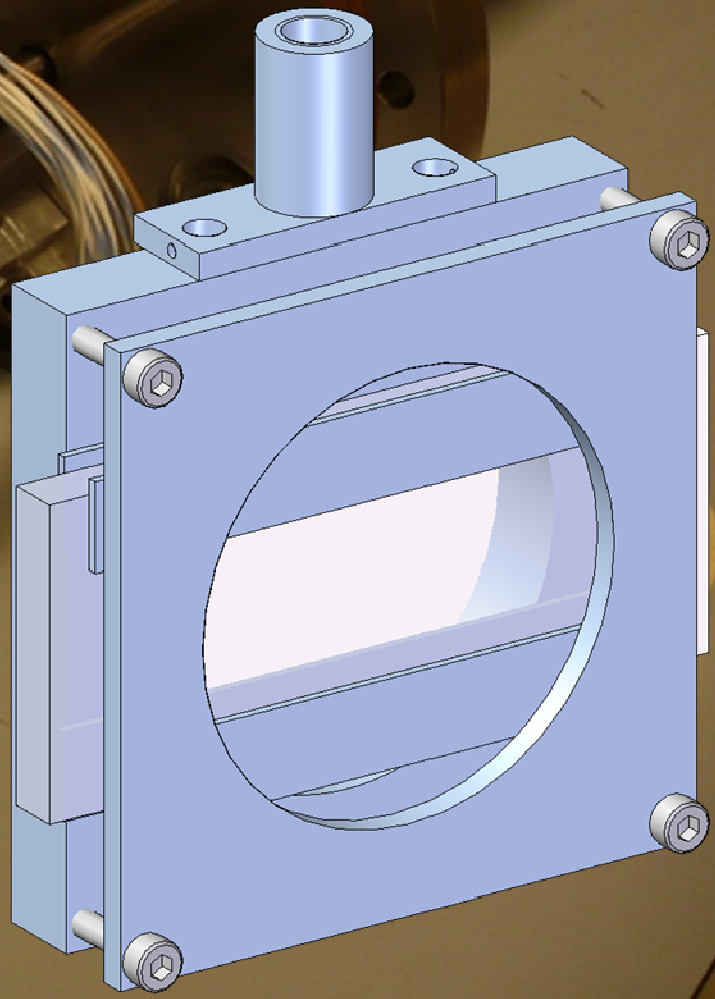
Legend: "strikethrough" = too much / too many for a PhD student!

Scintillating Screens

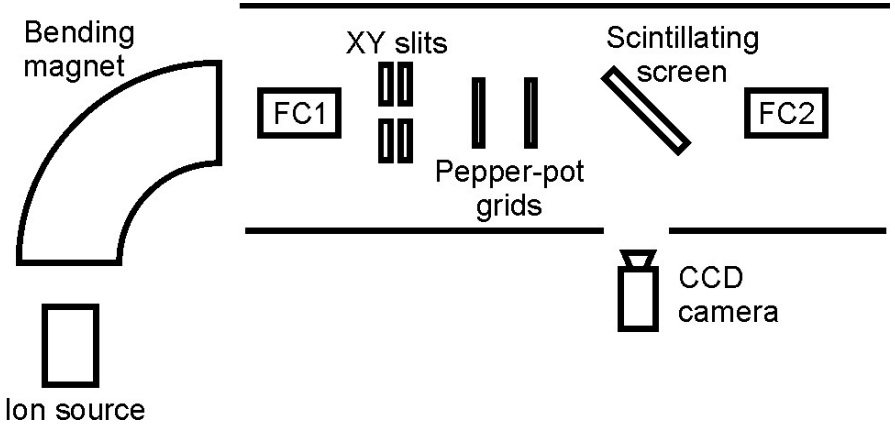
YAG:Ce

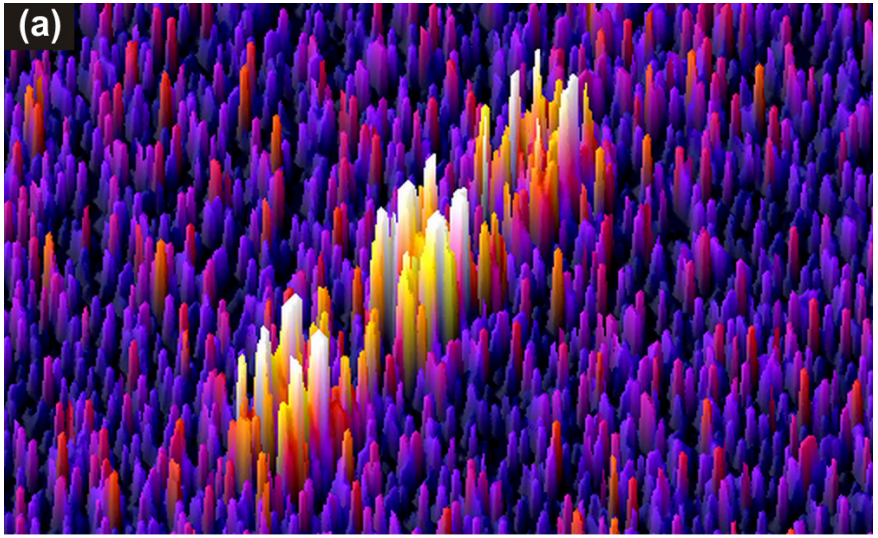
CsI:Tl

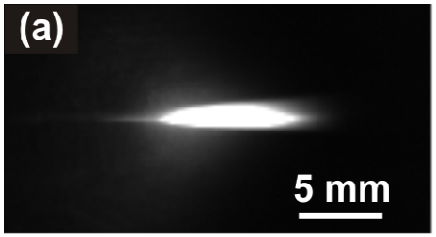
& Scint. Fibre Optic Plate

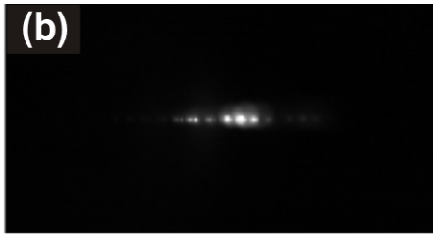


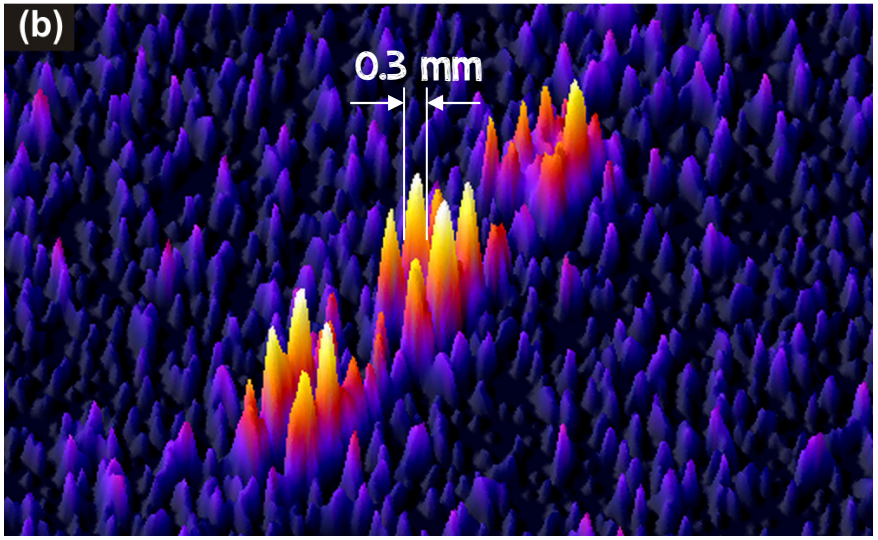
Measurements





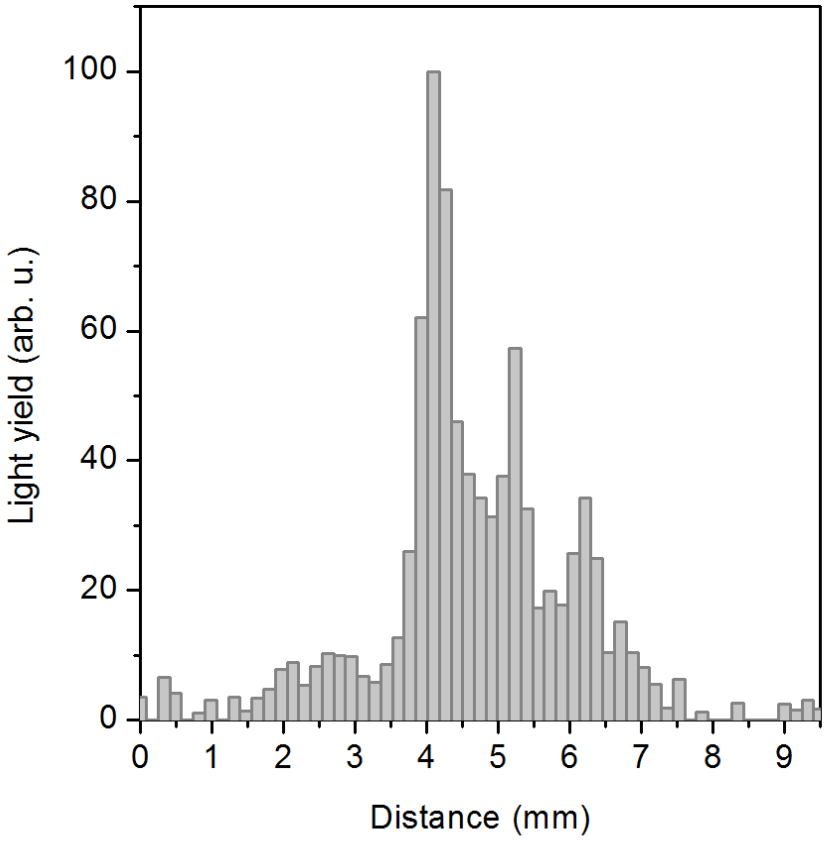


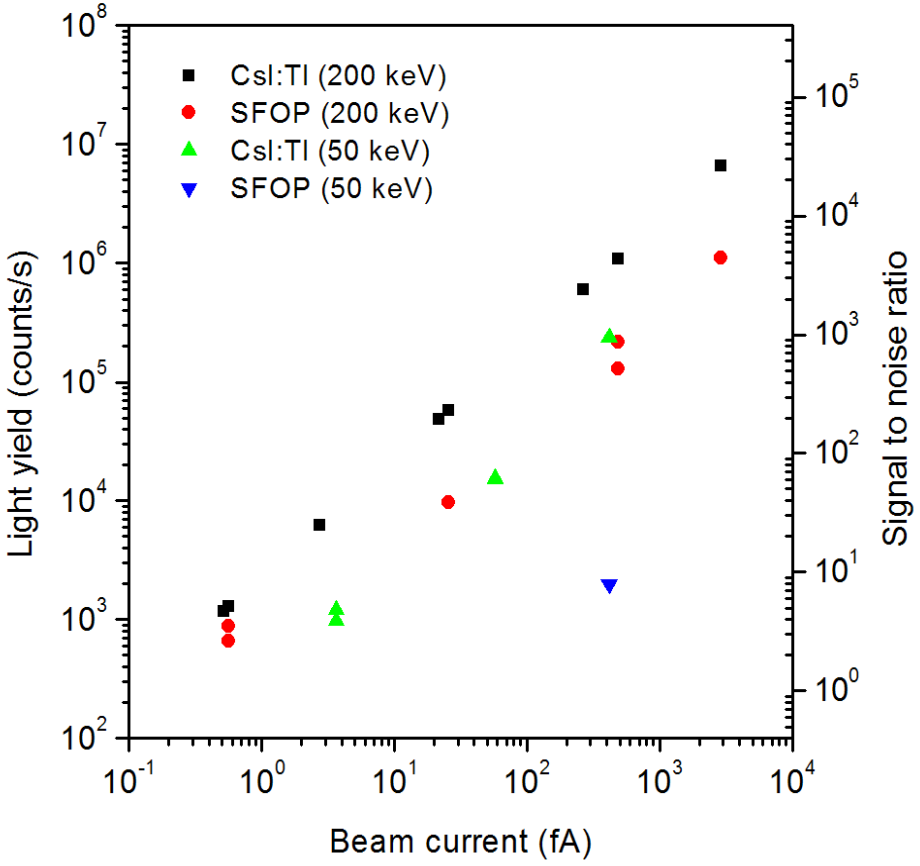




Measured with 200 keV and 50 keV protons at INFN-LNS, Catania, Italy

Resolution and Sensitivity

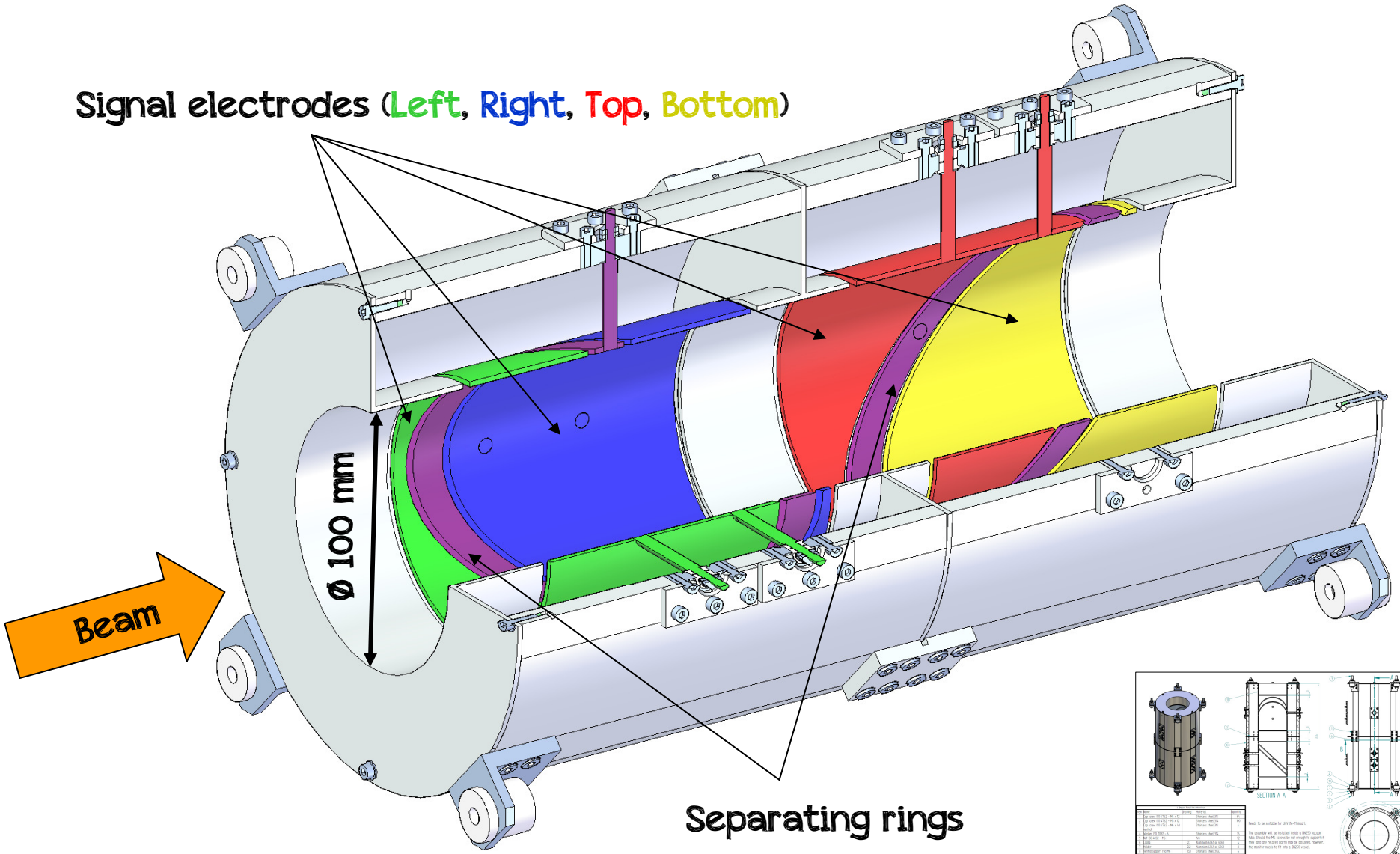




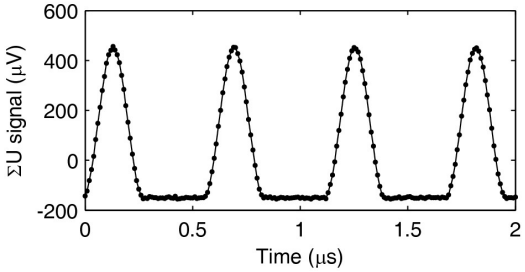
Measured with 200 keV and 50 keV protons at INFN-LNS, Catania, Italy

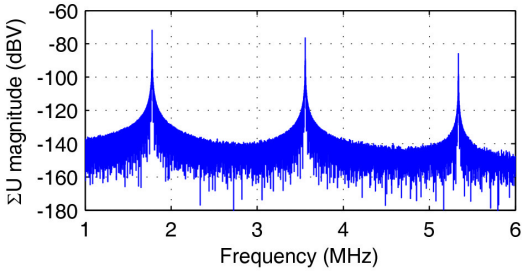
Capacitive Pick-Up

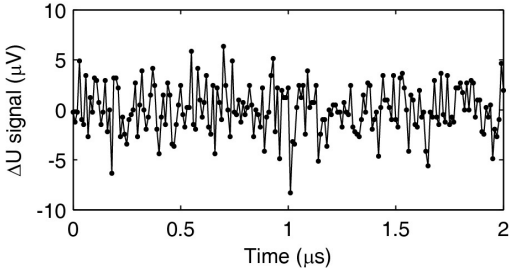
Capacitive Pick-Up

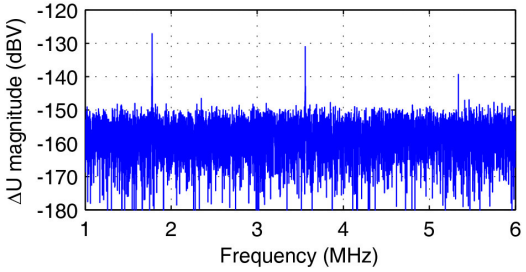


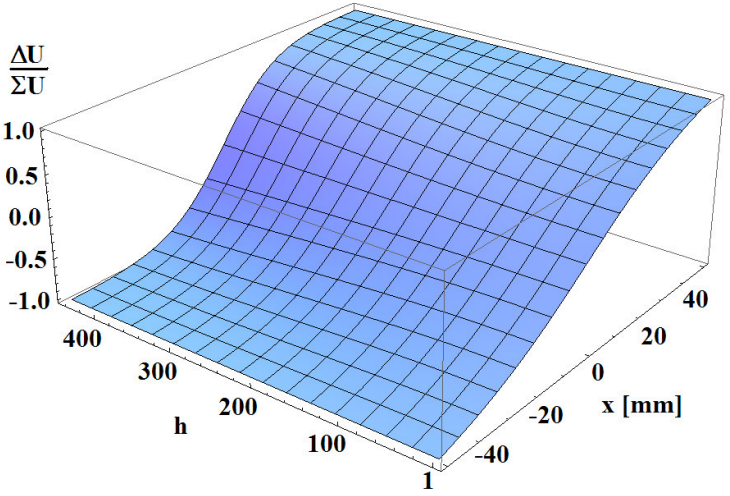
Modelling

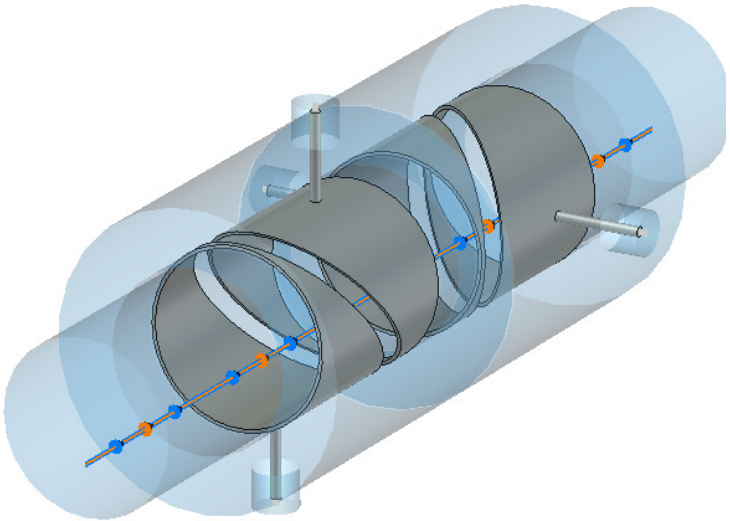


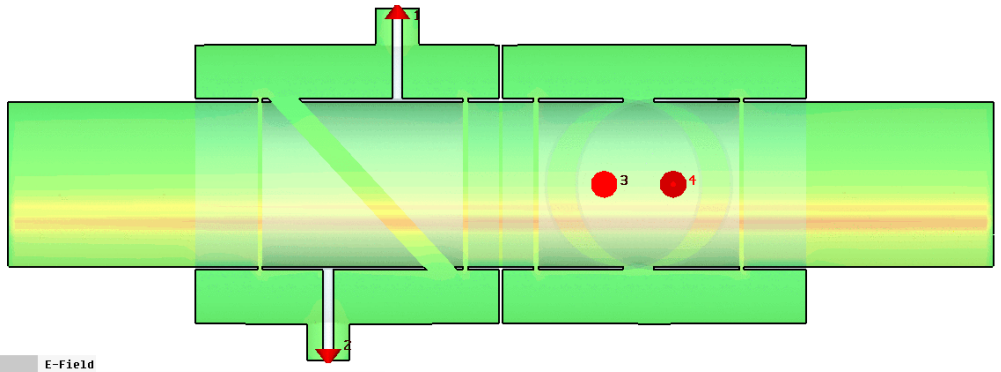










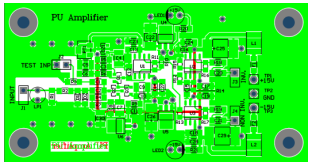


Type	E-Field
Monitor	e-field (t=5..20(0.2)) [pb]
Component	Abs
Plane at x	0
Maximum-2D	0.967828 V/m at -9.55193e-015 / -26.4 / -6.66667
Maximum Plot	

Stretched Wire Test Stand

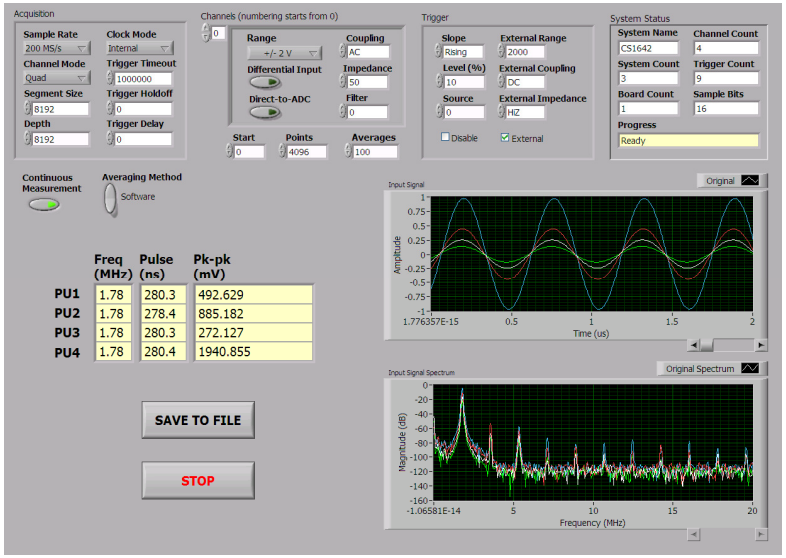
PU → amp → LP filter → ADC → LabView

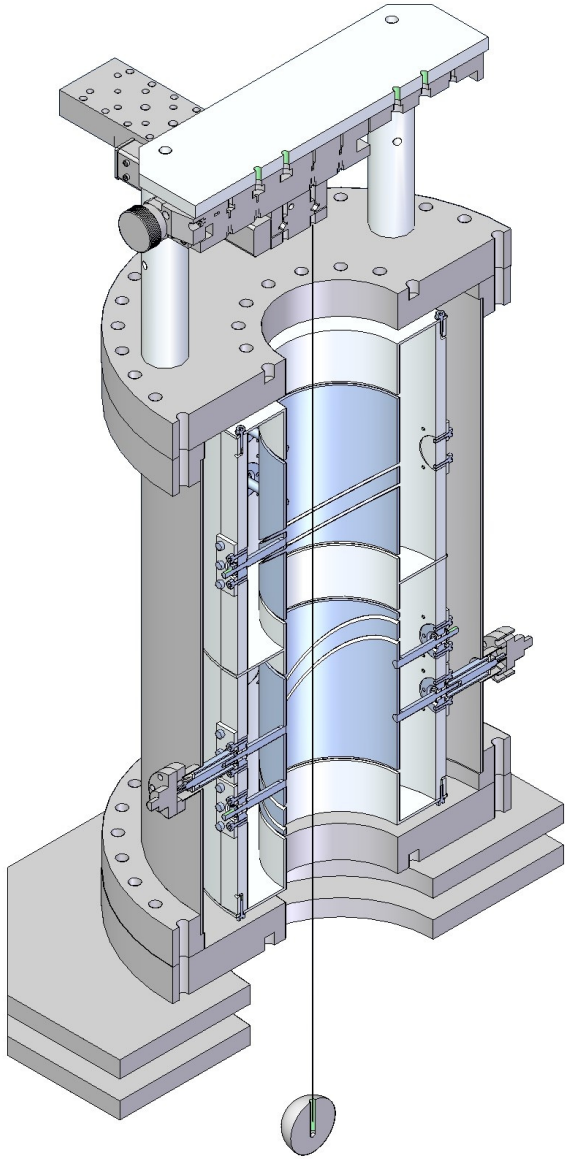
optional



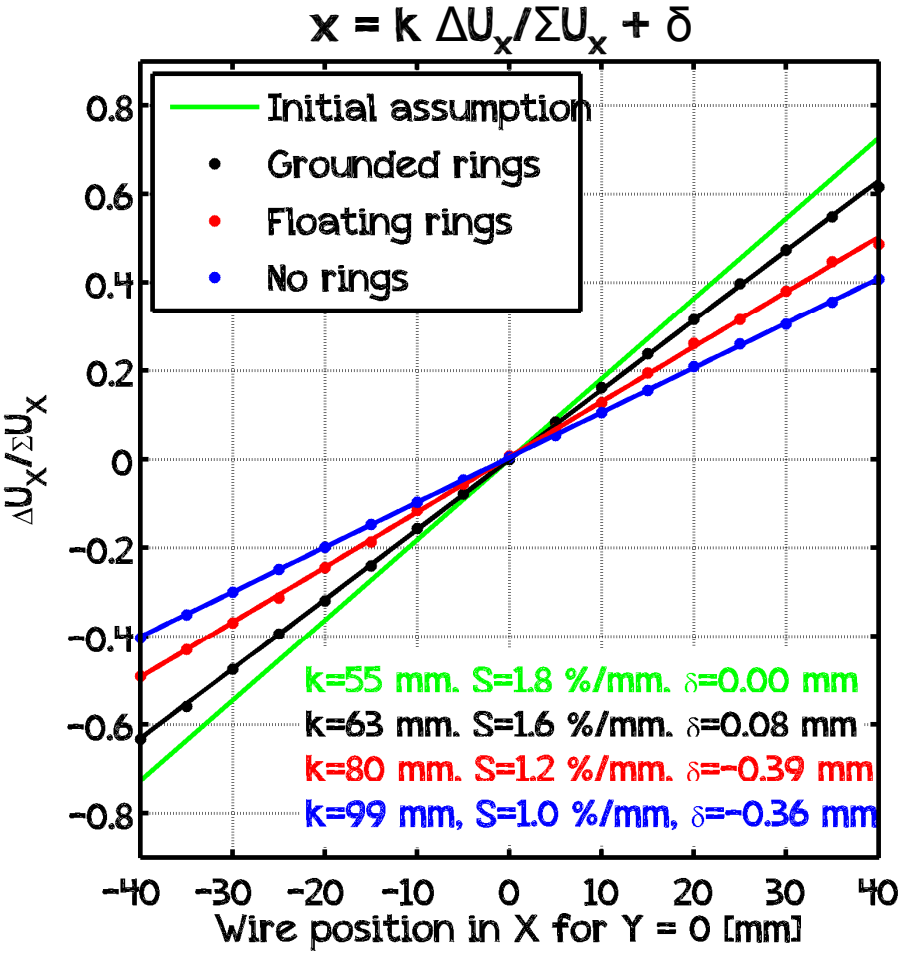
PU amps	SA-220F5	Custom
Input impedance	1 MOhm	5 MOhm
Input noise	0.5 nV/√Hz	0.9 nV/√Hz
Voltage gain	46 dB	54 dB

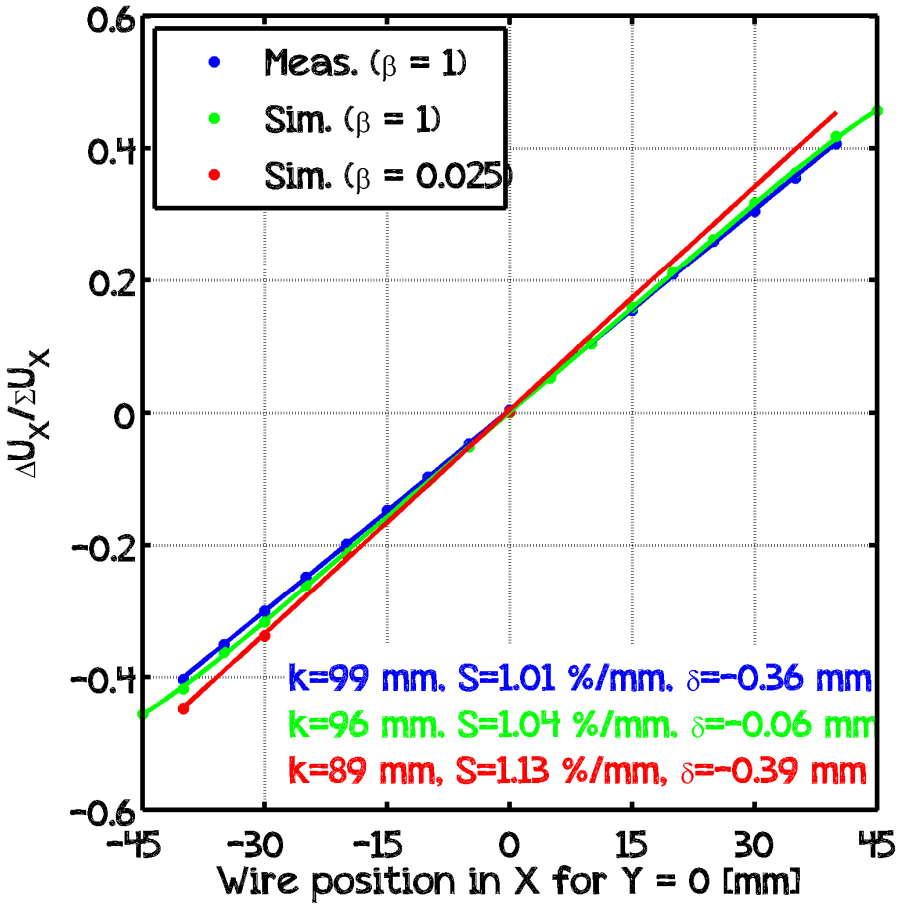
ADC	CS1642
Channels	4
Resolution	16 bit
Sampling	200 MS/s
Bandwidth	125 MHz
Memory	128 MB



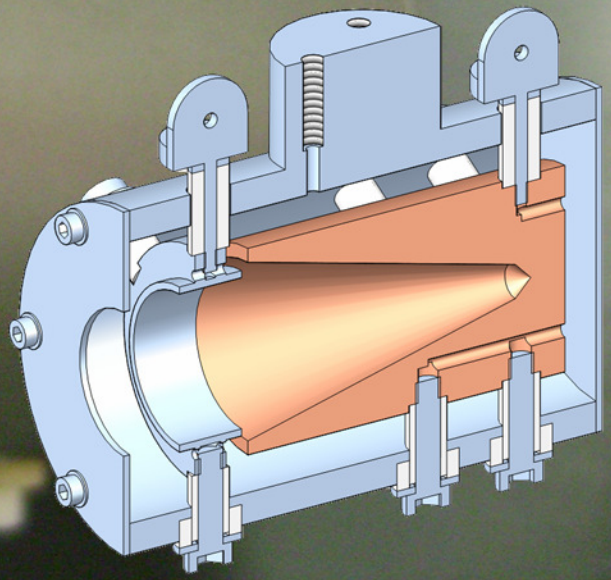


Measurements vs. Simulations

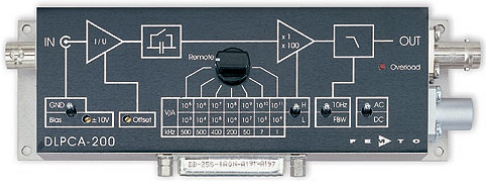




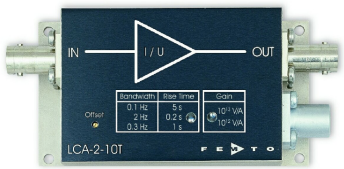
Faraday Cup

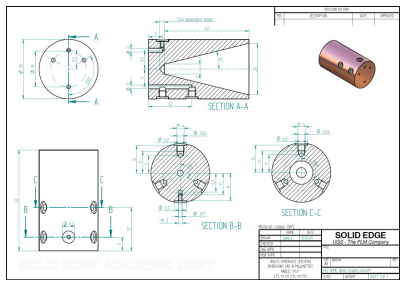


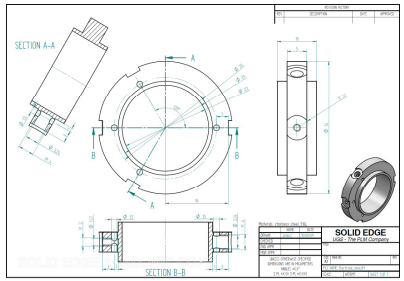
Faraday Cup

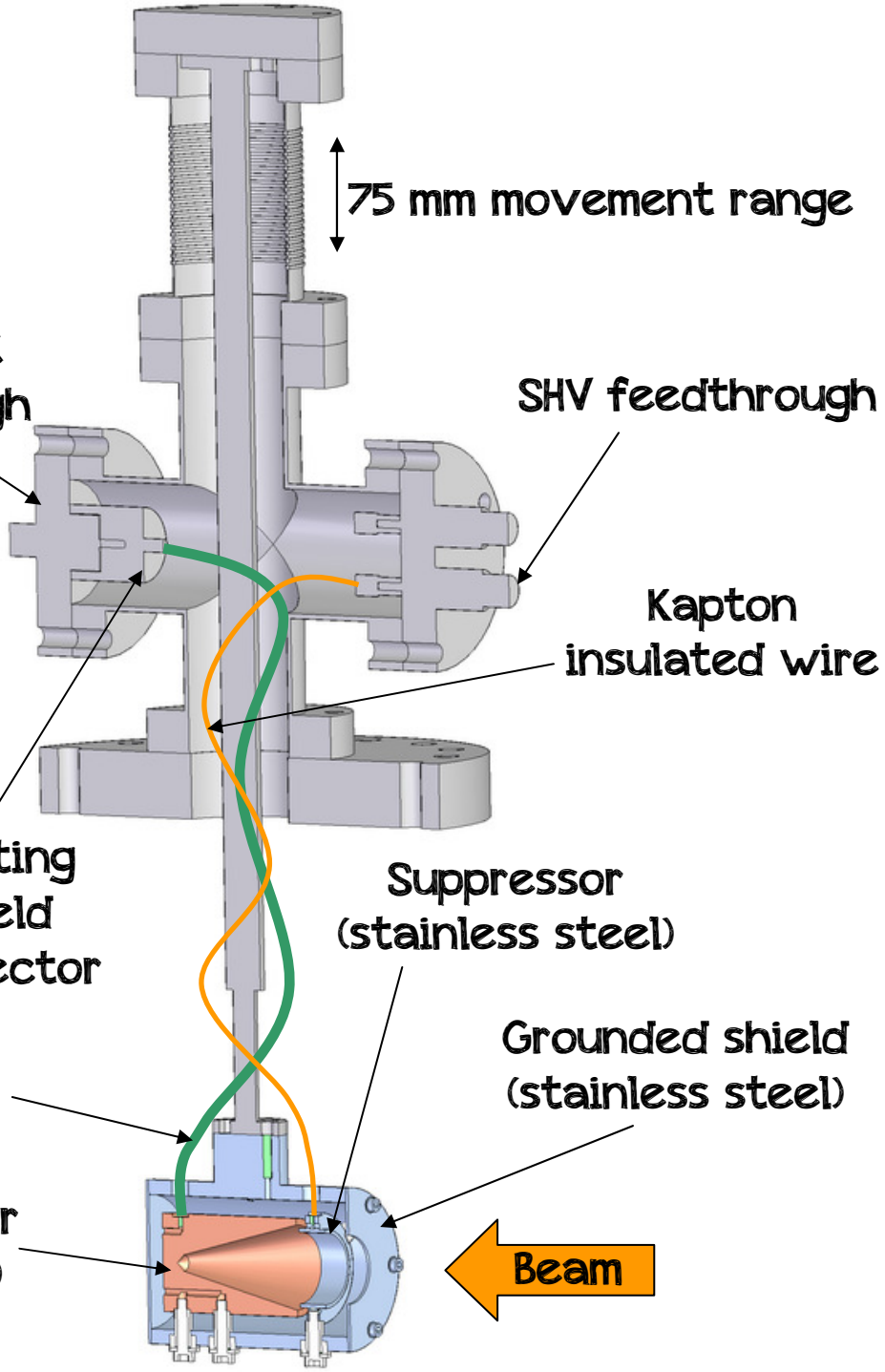


Trans-impedance amplifiers

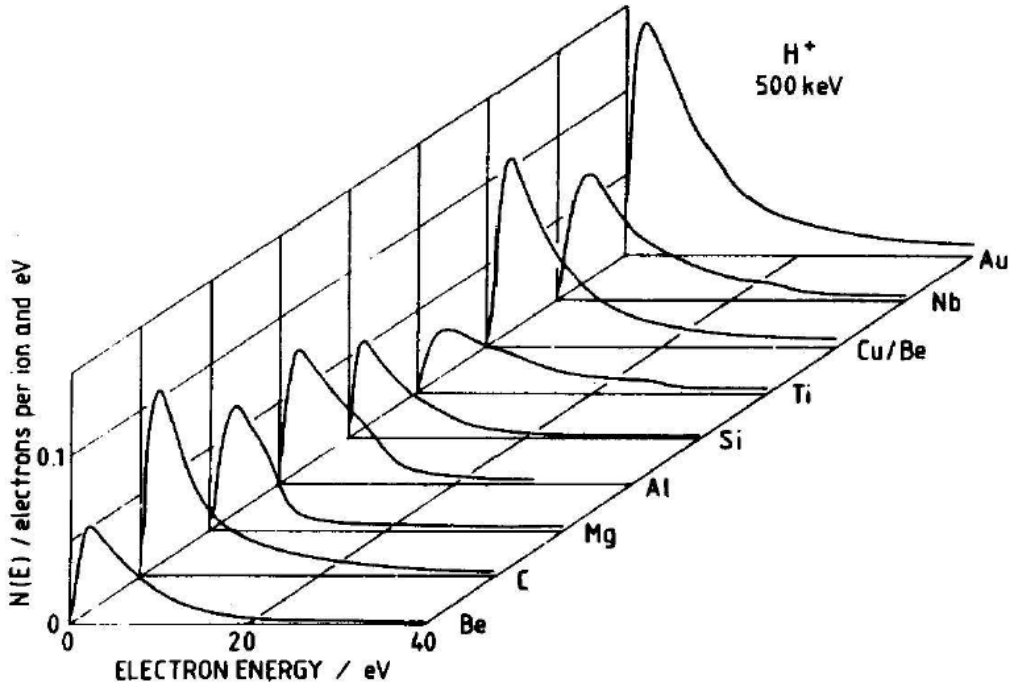


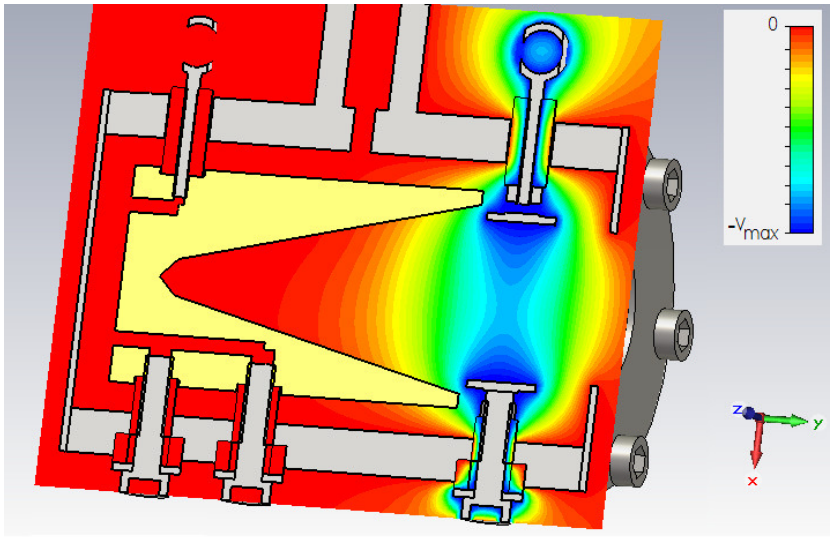


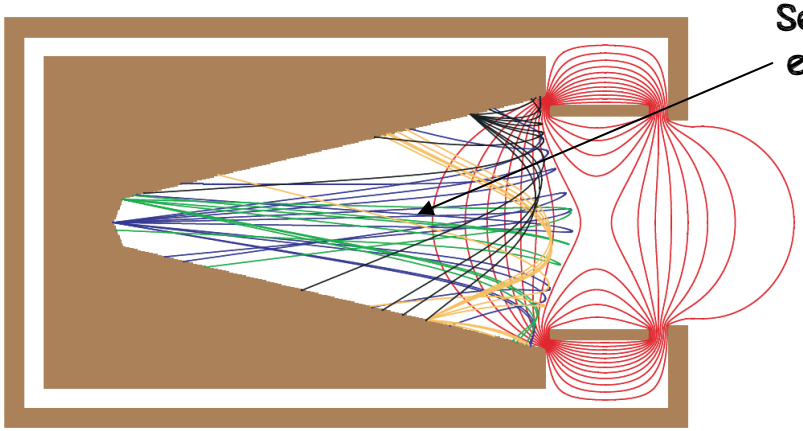




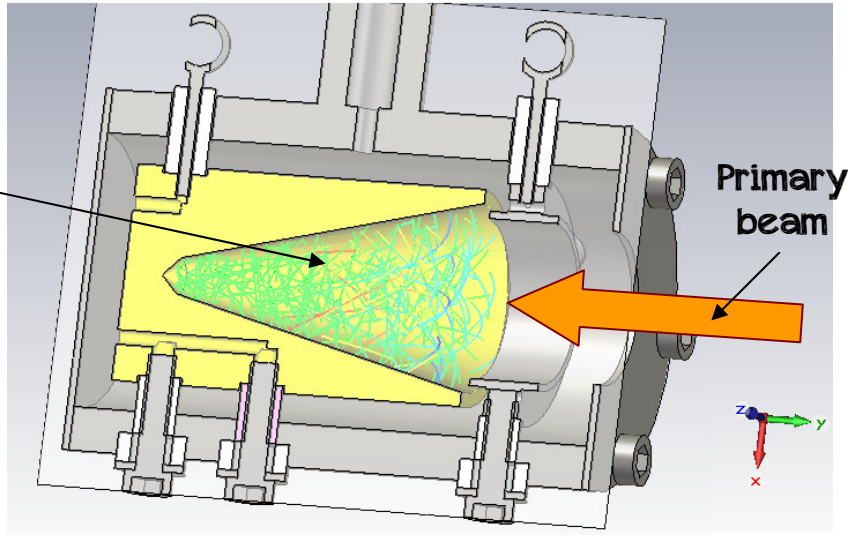
Modelling



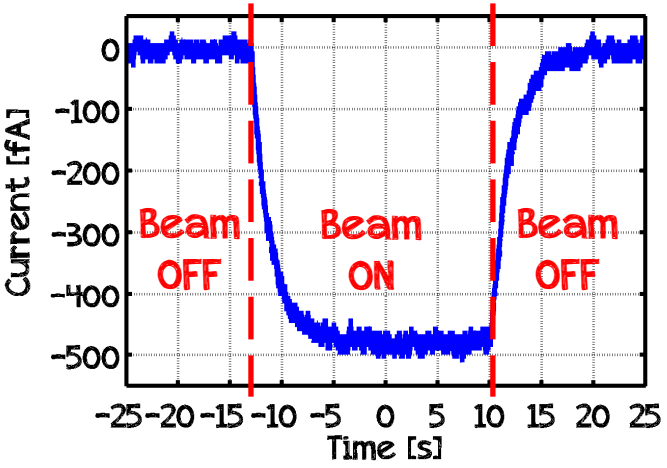


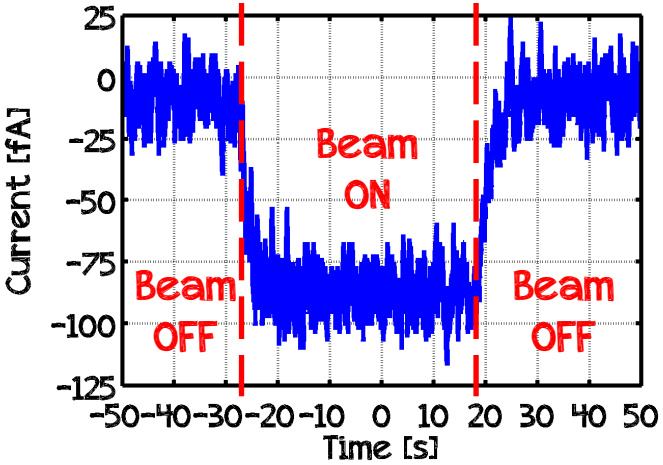


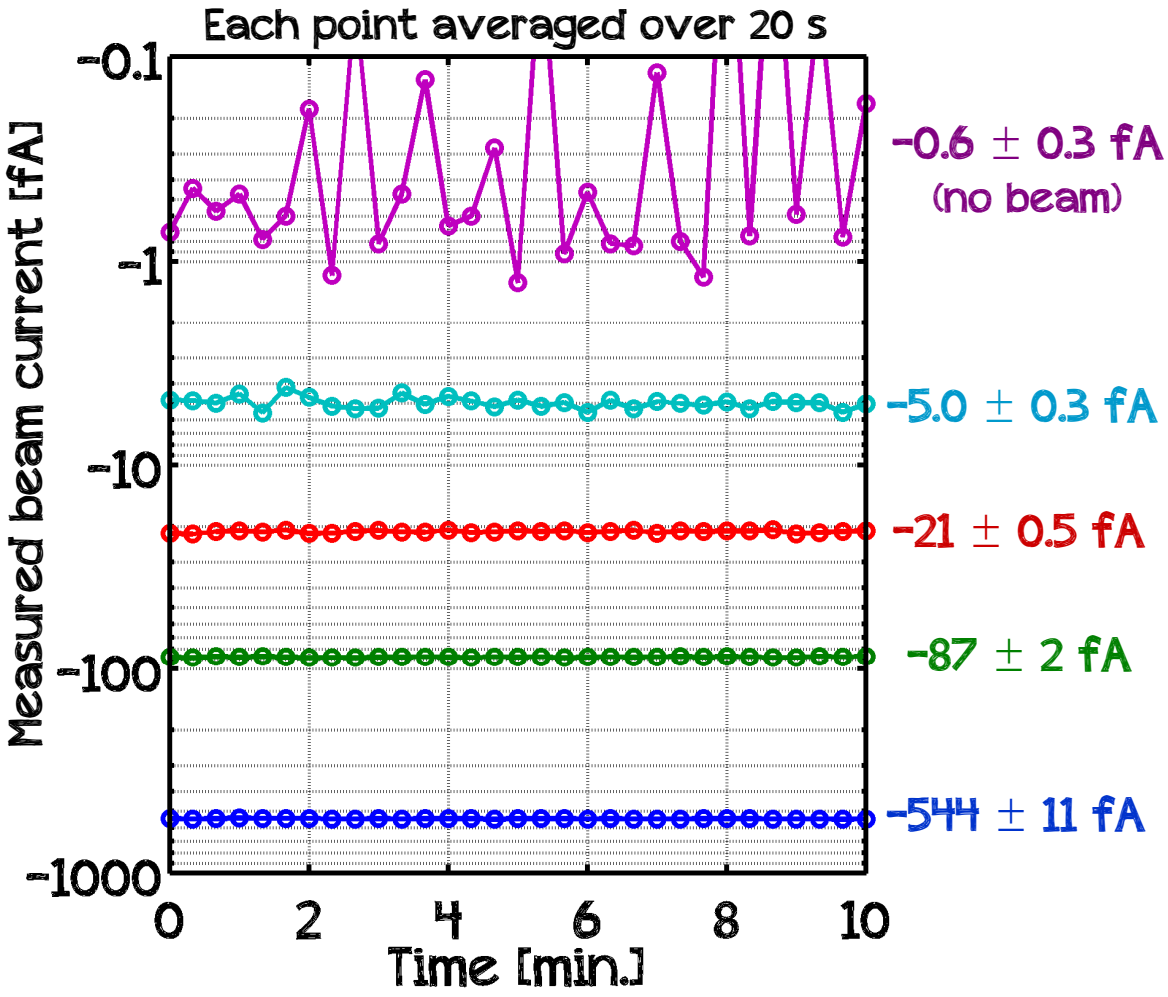
Secondary electrons



Measurements

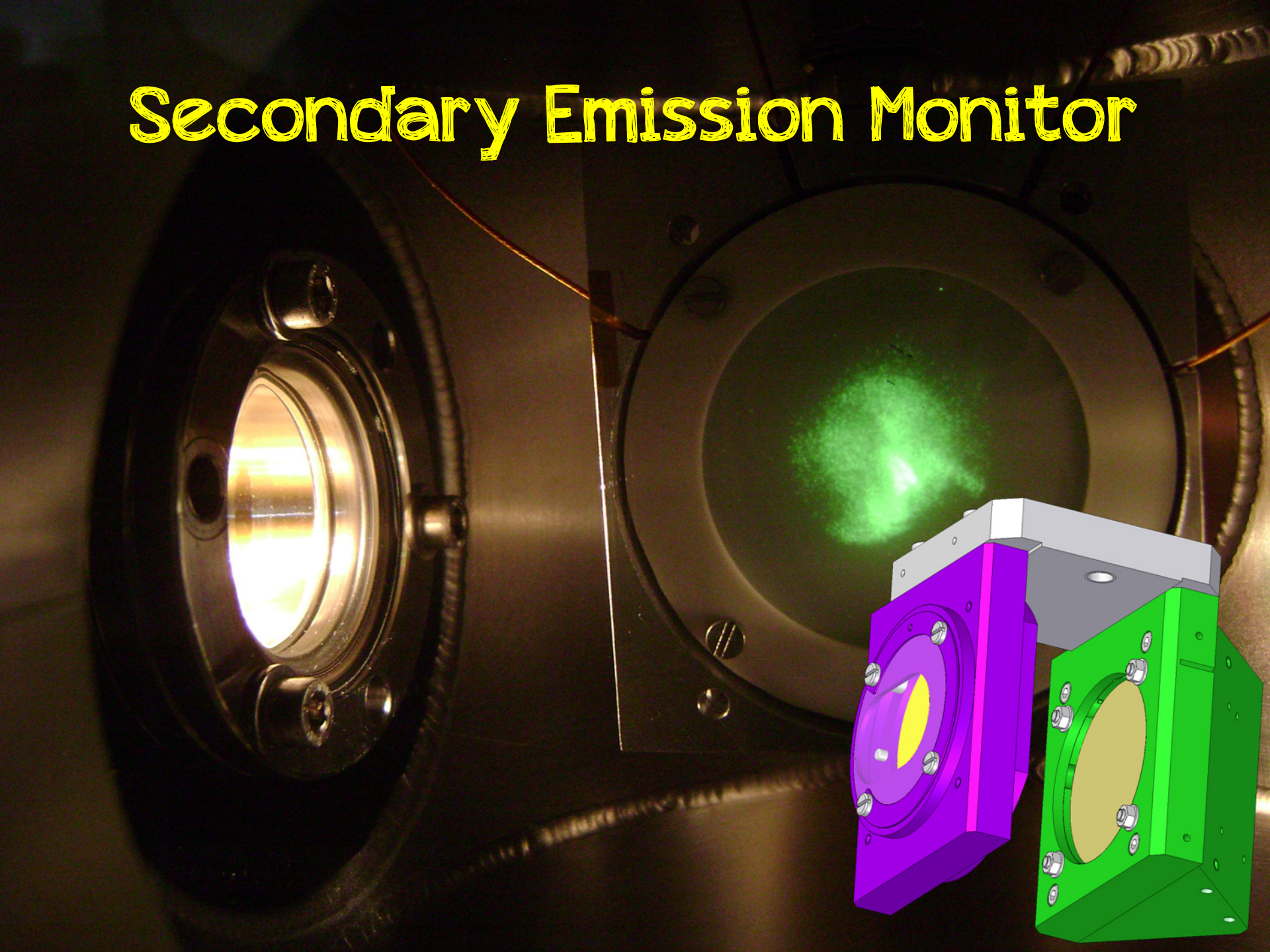




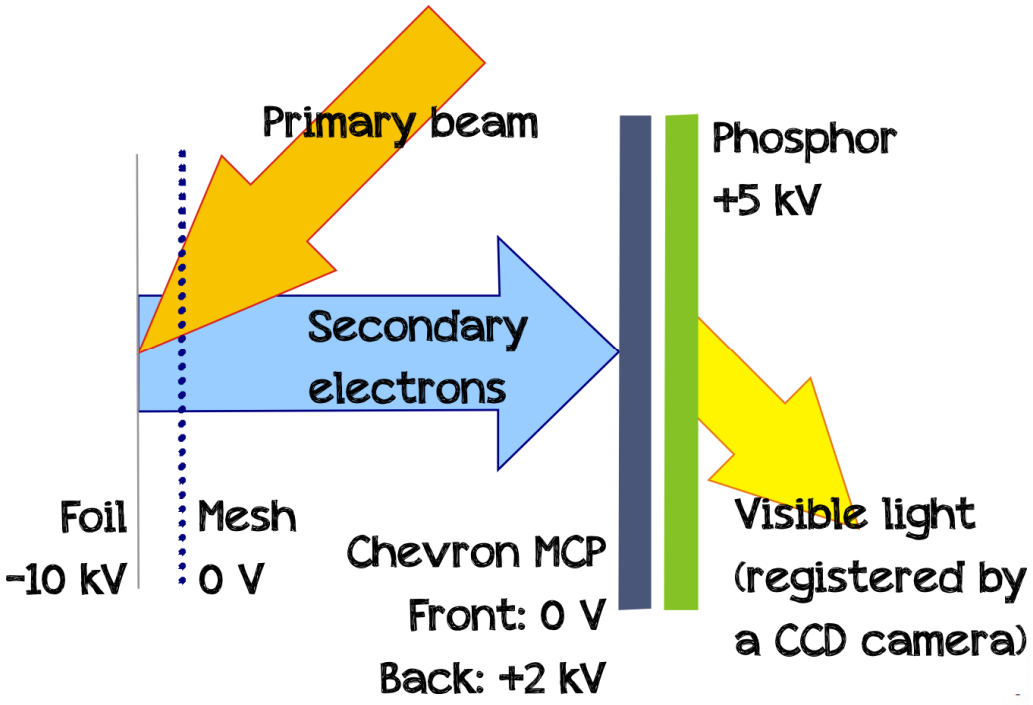


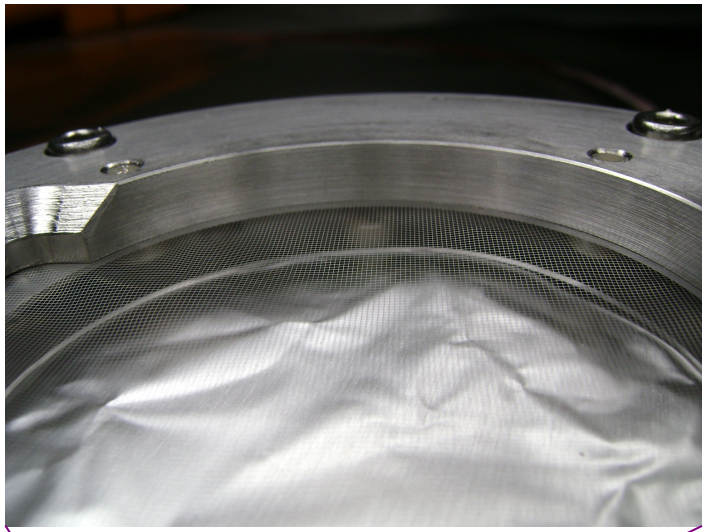
Measured with 200 keV protons at INFN-LNS, Catania, Italy

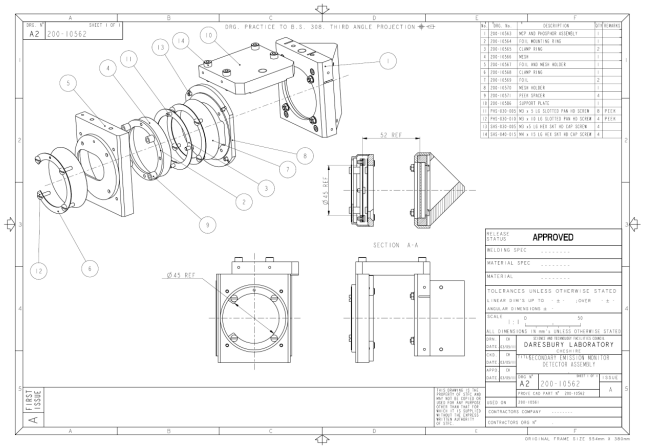
Secondary Emission Monitor

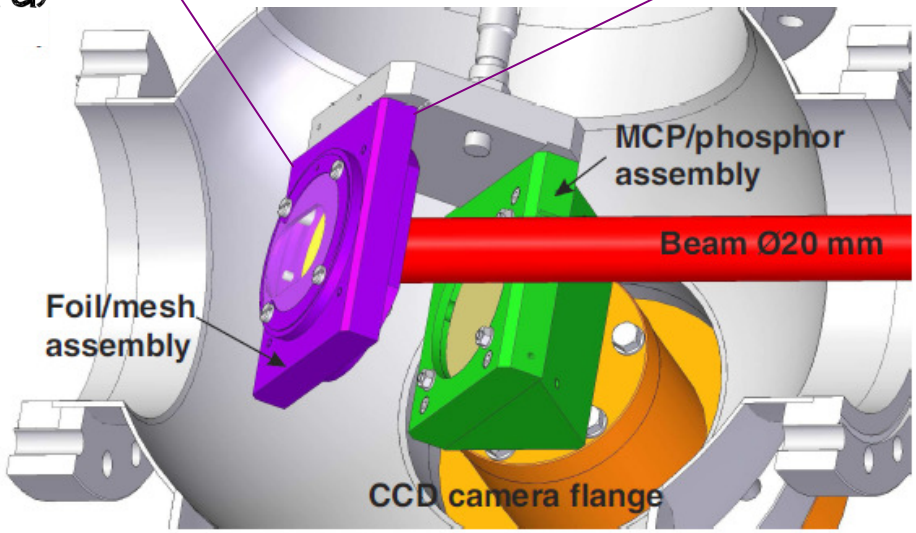


Secondary Emission Monitor

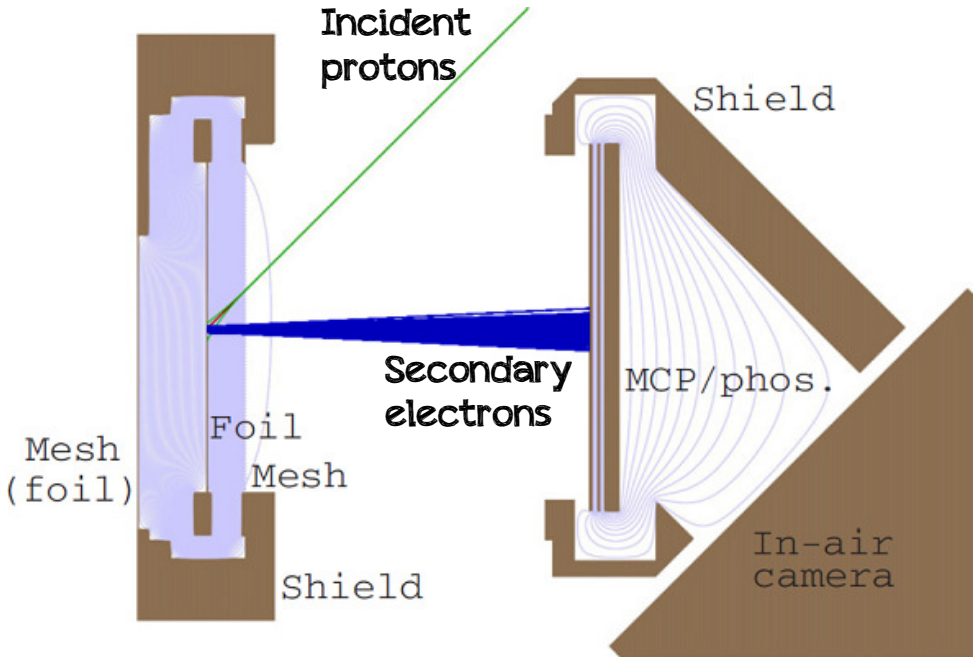


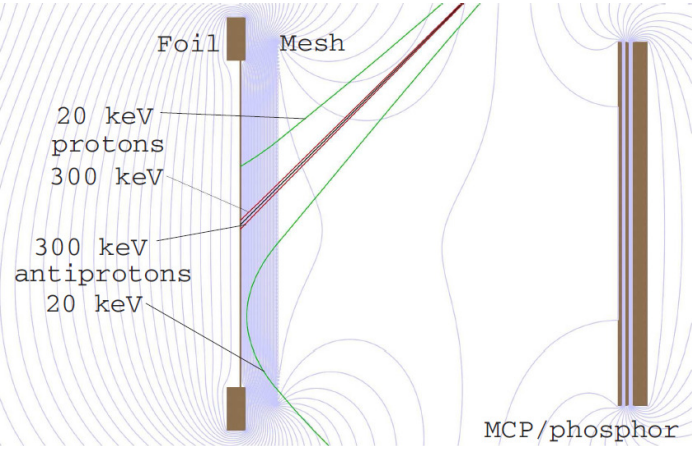


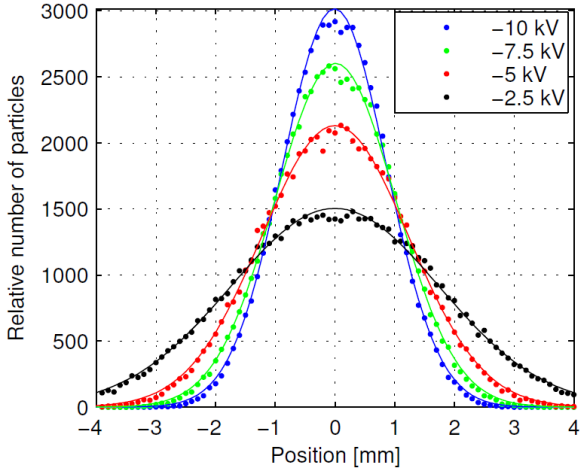


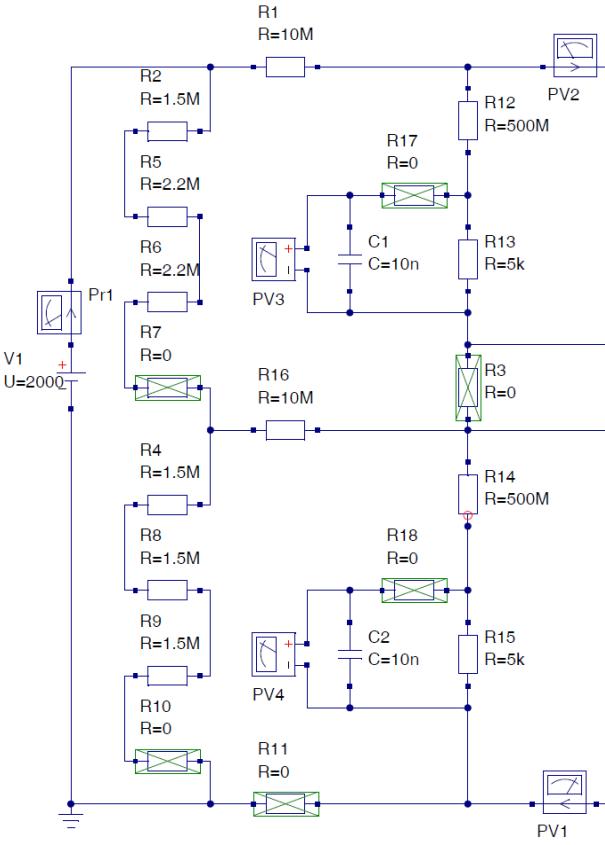


Modelling



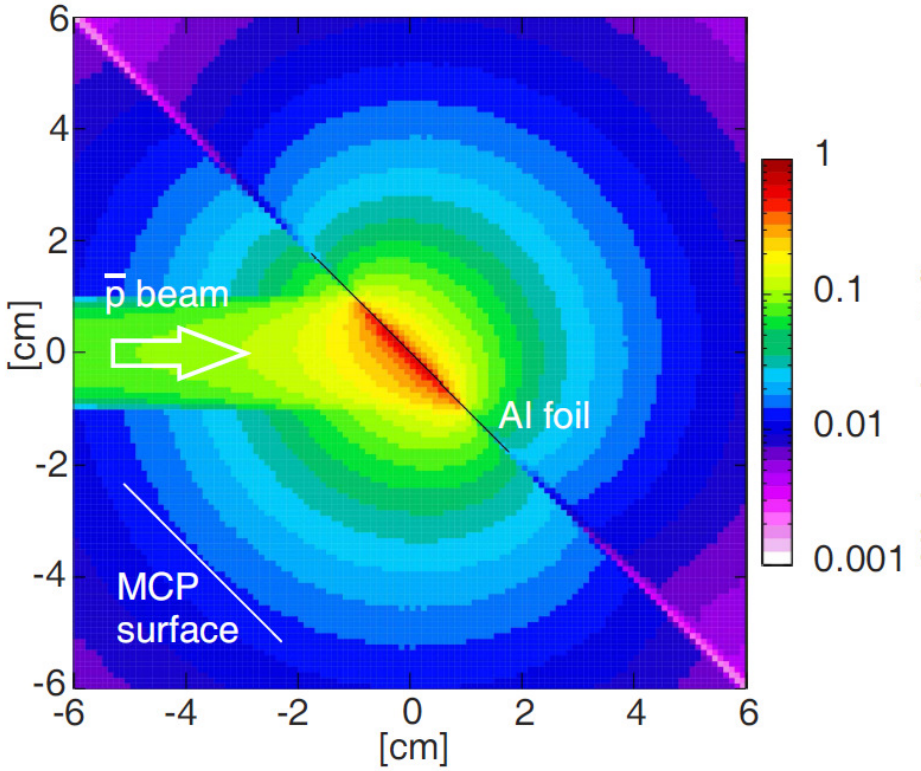




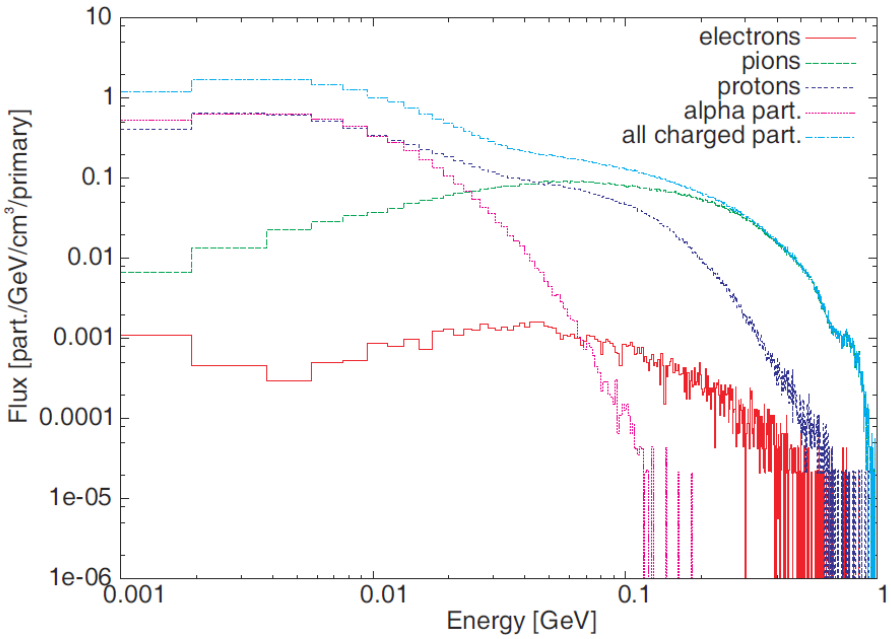


MCP voltage divider circuit

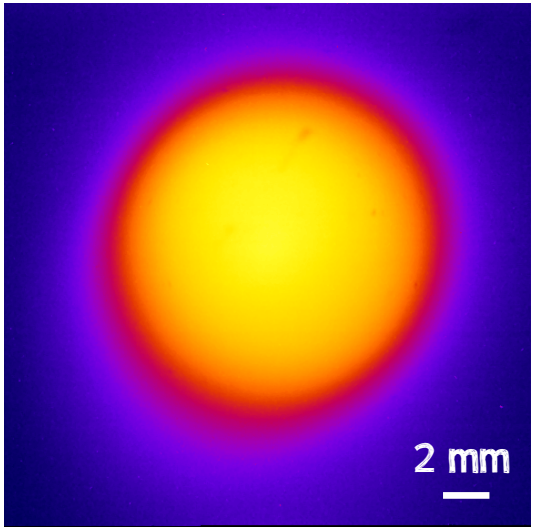
Modelling

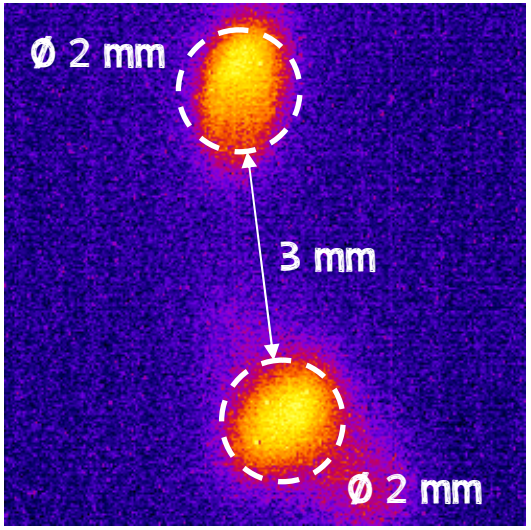


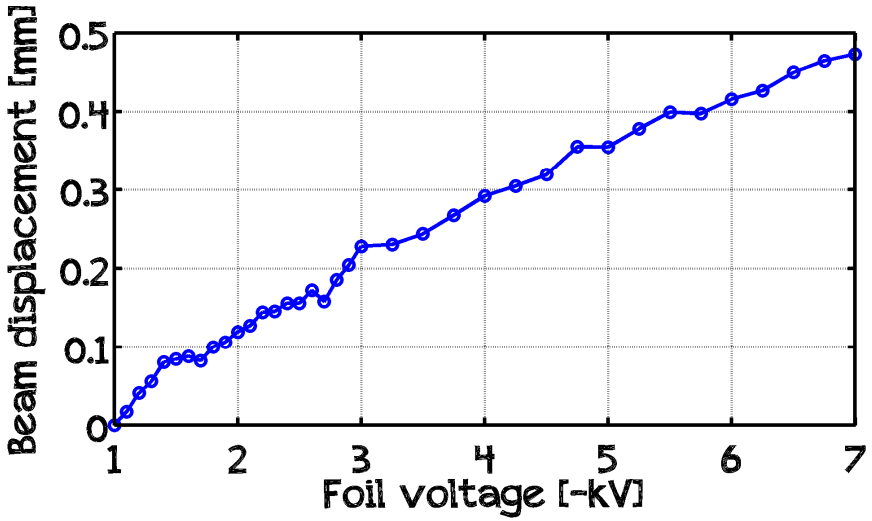
300 keV antiprotons

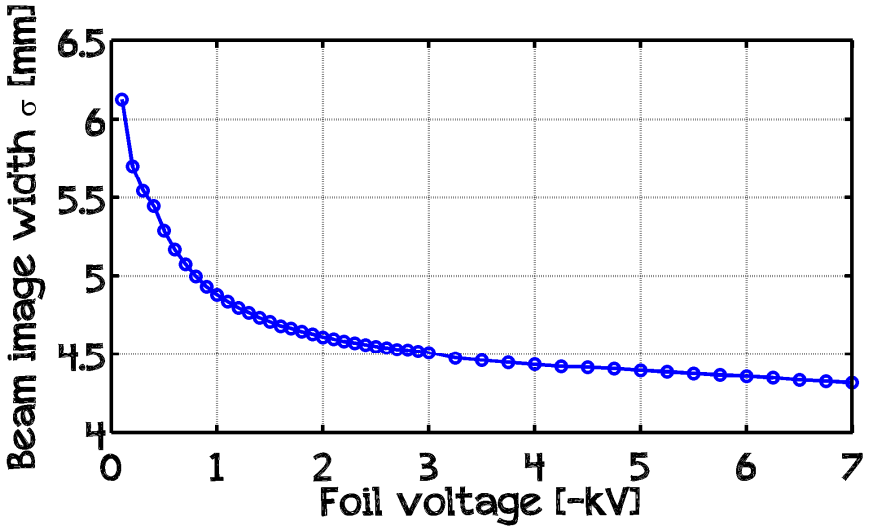


Measurements









Measured with 200 keV protons at INFN-LNS, Catania, Italy

Summary

- Scintillators
  - Sensitivity (CsI:Tl): ~fA for 200 keV protons
  - Resolution: at least 0.3 mm, no limits reached
- Capacitive Pick-Up
  - Linear response
  - Resolution: ~0.5 mm, possible improvement
  - Agreement with simulations: within 2.5%
- Faraday Cup
  - Sensitivity: few fA with 10-20 s averaging
- Secondary Emission Monitor
  - Sensitivity: at least fA, no limits reached
  - Resolution: at least 2 mm, no limits reached

References

1. Scintillating Screens Sensitivity and Resolution Studies for Low Energy, Low Intensity Beam Diagnostics, Rev. Sci. Instr. 81(10), 2010.
2. Beam Instrumentation for the Future Ultra-low Energy Electrostatic Storage Ring at FLAIR, Hyperfine Interact. 194, 2009.

3. Thin Foil-based Secondary Emission Monitor for Low Intensity, Low Energy Beam Profile Measurements, IPAC'11.
4. Experimental Results from Test Measurements with the USR Beam Position Monitoring System, IPAC'11.
5. Scintillating Screen Studies for Low Energy, Low Intensity Beams, IPAC'10.
6. Faraday Cup for Low-energy, Low-intensity Beam Measurements at the USR, BIW'10.
7. Beam Position Monitor Development for the USR, BIW'10.
8. Diagnostics for USR; Low Current BPMs, DITANET'09.
9. Optimisation Studies of a Resonant Capacitive Pick-Up for Beam Position Monitoring of Low Intensity, Low Velocity Antiproton Beams at FLAIR, DIPAC'09.
10. Beam Diagnostics for the USR, PAC'09.

More to follow