Transverse Emittance Measurement of a 2.5 MeV Proton Beam on LIPAc, IFMIF's Prototype

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Abstract

Beam commissioning of LIPAc accelerator at Rokkasho is in progress. This poster reports about emittance measurement of a 2.5 MeV proton beam using slits, steerers and a SEM grids. Attention is withdrawn on the following subjects:

- Profile measurement with the SEM grids and the secondary emission current
- Emittance measurement analysis and comparison beam dynamics simulations

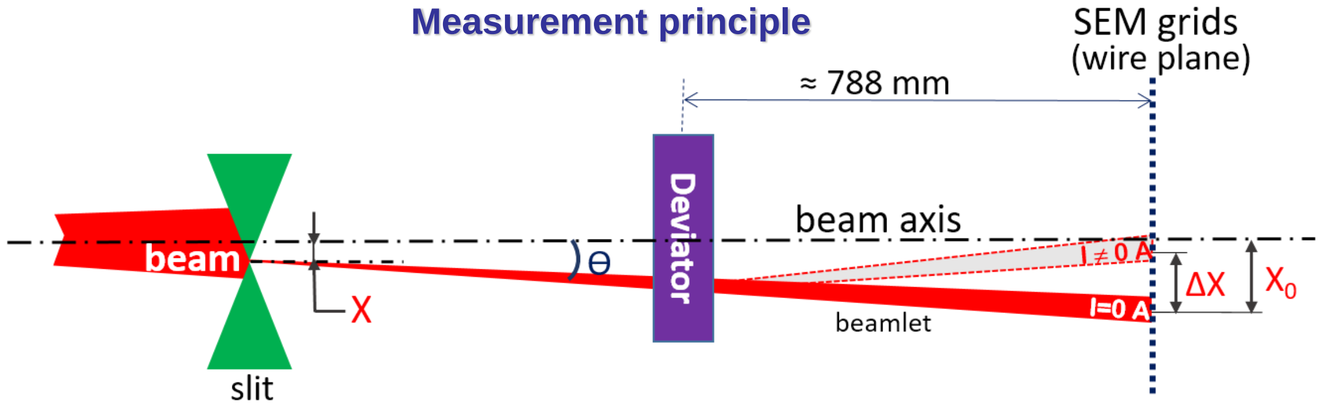
Principle

Why to use steerers?

- Read-out is a SEM-Grid
- Large gaps between wires (1, 2 and 3 mm), avoiding to measure accurately the beamlet profile

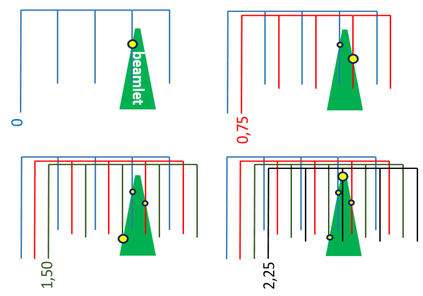
→ Steerers allow for sweeping the beamlet on few wires

Measurement principle



4 steerers currents are applied

4 points for the beamlet, instead of 1
→ insuring better reconstruction!



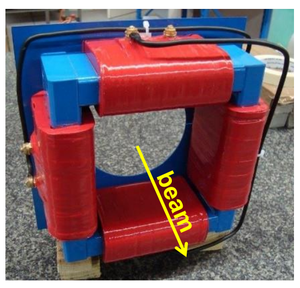
Instruments

Slits (CIEMAT Madrid & AVS, Spain)

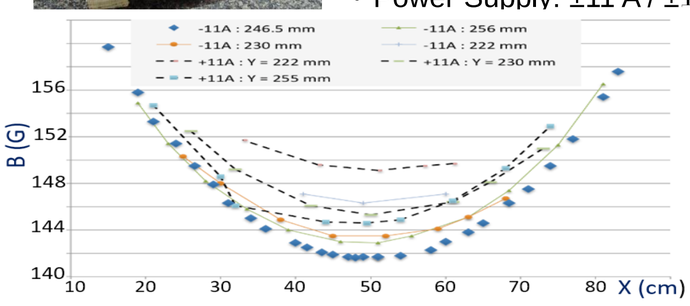
- 2 slits (H & V)
- Aperture 100 or 200 µm
- Graphite, then TMZ
- Water cooled
- Δt_{max} = 100 µs
  for D^+: 125 mA, 9 MeV
  σ_{beam} > 5-6 mm

talk MOB003, yesterday
D. Jimenez-Rey / I. Podadera-Aliseda.

Steerers (H & V)



- $\int \vec{B} \cdot \vec{dl}$ < 23.3 G.m
  → Δ=3 mm for 9 MeV deuteron
- Aperture 105 mm
- Rect. enameled conductor
  → 4.64×1.14 mm²
- Size ~ 80 × 185 mm²
- Power Supply: ±11 A / ±15 V



SEM-Grid

- 2 squared wire grids:
  - Tungsten golden plated wires
  - 47 wires H & V → Ø = 20 µm
  - Frames: Rogers 4350B
  - Aperture = 100 mm
  - Repeller (external wires +100 V)
- Integration time: 40 µs to 16 s
- Capacitor = 68 nF
- Vacuum flange CF DN200
- 1 actuator

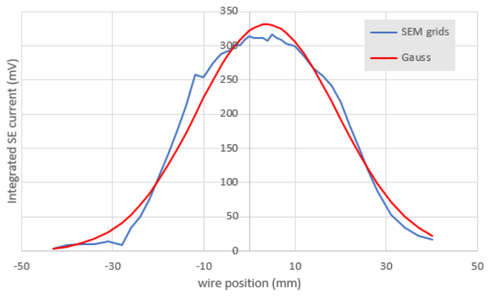
SEM-Grid model designed by Ganil:
J.L. Vignet et al., "the beam profile monitors for SPIRAL2", DIPAC09, Basel, 2009.

Profile measurement

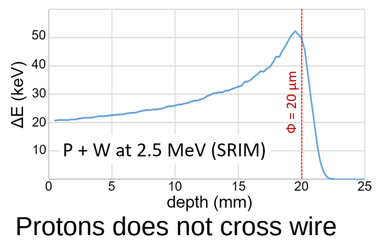
Secondary emission current:

→ Rule of thumb tells that only electron/ion pairs created in the superficial layer (1 nm) of the wire contribute to the current…

Proton 2.5 MeV, 24 mA, Δt = 800 µs/s, σ ~ 15 mm

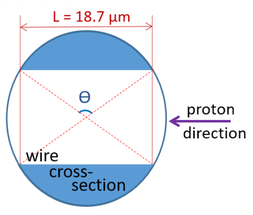


- SRIM → ΔE/Δx ~ 100 eV/nm
- Electron binding energy ~ 25 eV
- Expectation: if incident proton crosses the wire
  → **4** electrons / proton
- Measure
  → **2.26** electrons / proton!



Protons does not cross wire all the time

- protons stopped inside the wire (white)
- protons cross (blue)
  → 2.26 / 4
  → L = 18.7 µm



Ø 20 µm wire cross-section

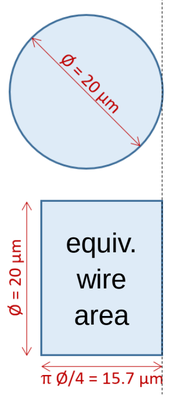
Deuteron 5 MeV, 118 mA, Δt = 200 µs/s, σ ~ 17.5 mm

SRIM
- range of D^+ in tungsten ~ 43 µm >> $Ø_{wire}$
- ΔE_W = 1.4 MeV
- ΔE/Δx = 89 eV/nm

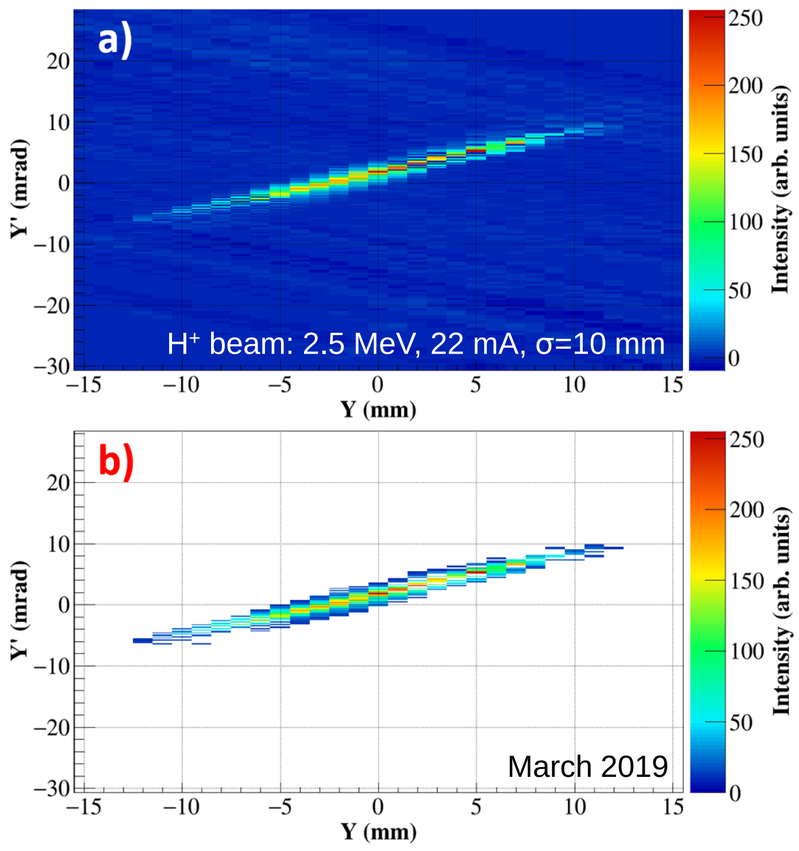
→ 89/25 = **3.6** electrons / deuteron

Profile measurement
→ **3.3** electrons / incident deuteron

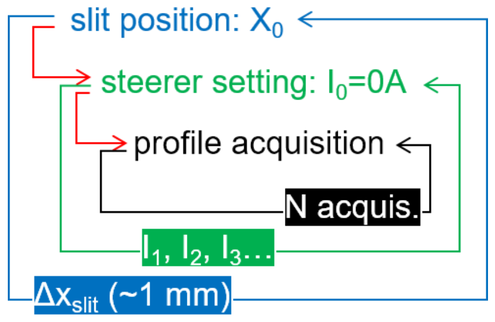
Conclusion: the rule of thumb may be really convenient for sizing electronics.



Emittance measurement



Measurement synopsis



Analysis (Python script)

- Use of TraceWin[1] and the magnetic field map for simulating the beamlet shifts
- Analysis using Raw data (Fig. a)
- Final analysis (Fig. b): intensity below a certain threshold (10) is considered as background, and therefore removed.
  Unfortunately, analysis is a bit dependent of this threshold since the range of SEM-Grid read-out is not optimized.

→ The integrating capacitors of the RO will be decreased and changed for minimizing this effect, for the next beam campaign.

Results and simulation comparisons

- Really nice agreement for vertical emittance between measurements and beam dynamics simulations, except for point 4 (the latter will be investigated with simulations and post analysis).
- Agreements are also acceptable for the deduced Twiss parameters.

Measurement	1	2	3	4
SOL1 [A]	135	135	135	131
SOL2 [A]	160	160	162	162
V_{RFQ} [kV]	66	62	70	70
Norm. ε_{exp} / ε_{sim} [π mm mrad]	0.24 / 0.24	0.24 / 0.24	0.22 / 0.23	0.24 / 0.28
β_{exp} / β_{sim} [mm/π mrad]	7.1 / 7.5	8.0 / 8.1	6.6 / 6.3	6.5 / 6.0
α_{exp} / α_{sim}	-4.8 / -5.5	-5.4 / -6.0	-4.3 / -4.3	-4.4 / -4.5

[1] *D. Uriot, and N. Pichoff, "Status of Tracewin code", in Proc. IPAC'15, Richmond, VA, USA, 2015.*

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