Detailed Experimental Characterization of an Ionization Profile Monitor

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Outline

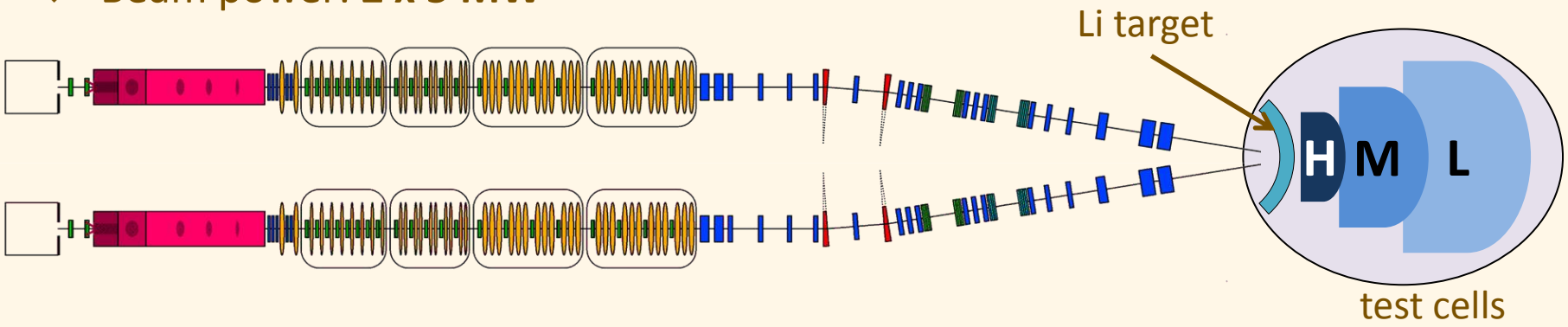
- IFMIF-EVEDA Accelerator
- IPM – Characteristics
- IPM-Prototype
  - Design at CEA Saclay
  - Test at GSI Darmstadt
  - Test at CEA Saclay
- Conclusion

IFMIF Accelerator

IFMIF: International Fusion Material Irradiation Facility

- Beam current: **2 x 125 mA** cw deuterium
- Energy: 40 MeV
- Beam power: **2 x 5 MW**

neutron source: **10^{17} n/s**



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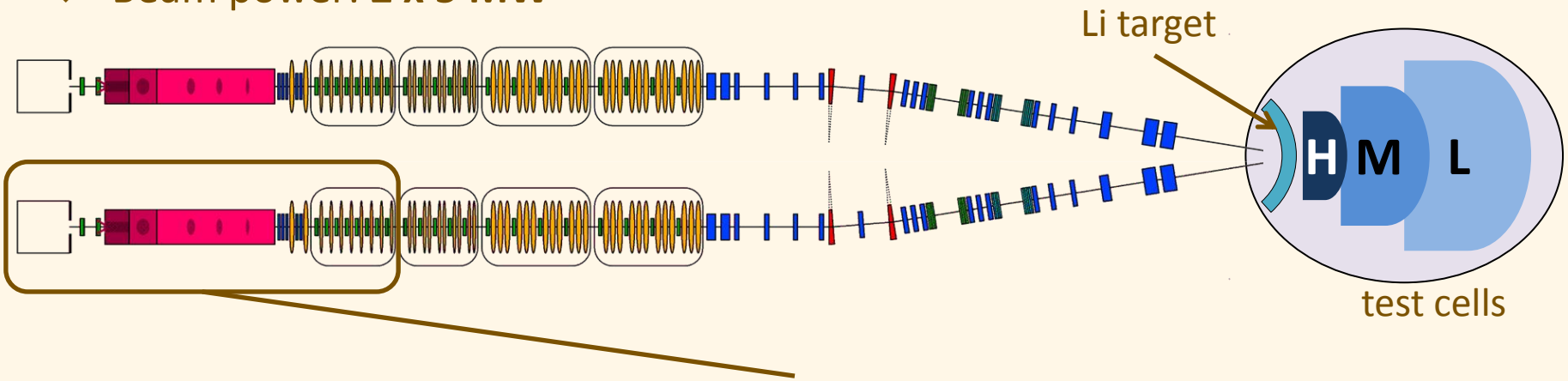
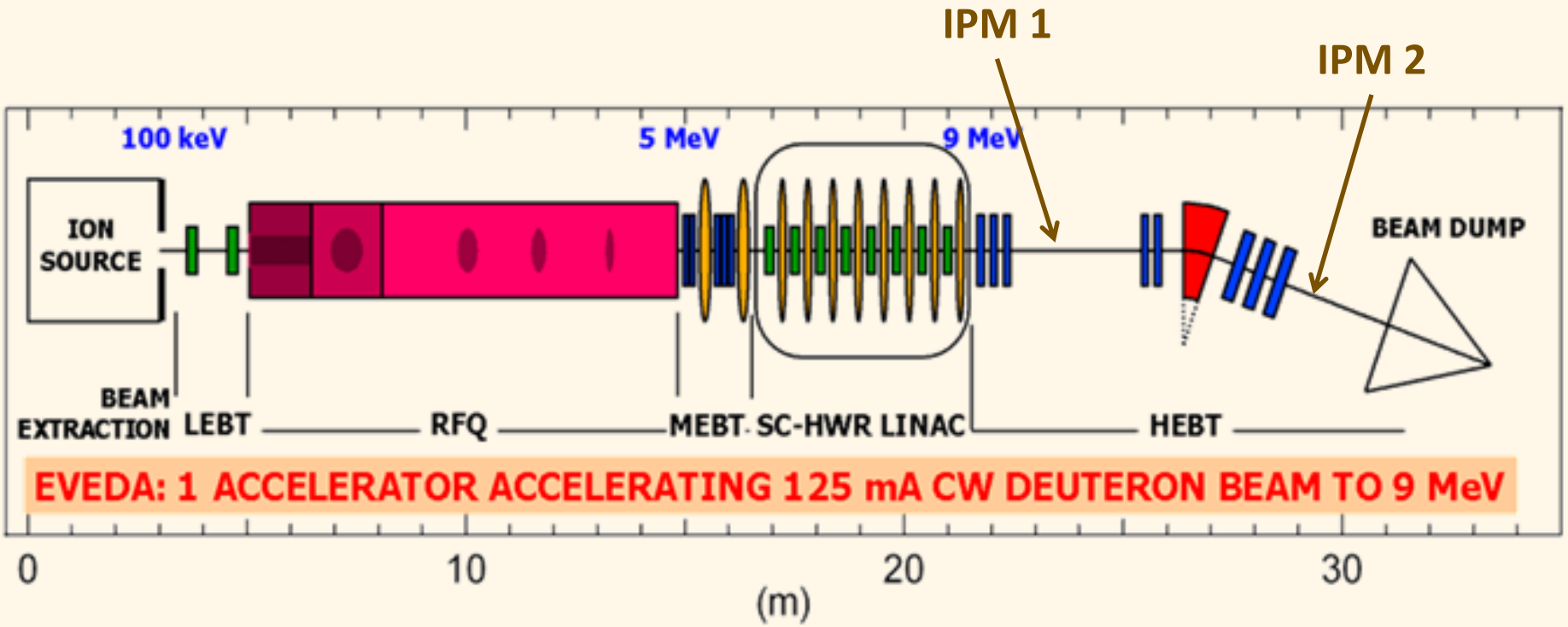


IFMIF-EVEDA: Engineering Validation Engineering Design Activities

Prototype limited to 1 x 125 mA cw @ **9 MeV, 1.125 MW**

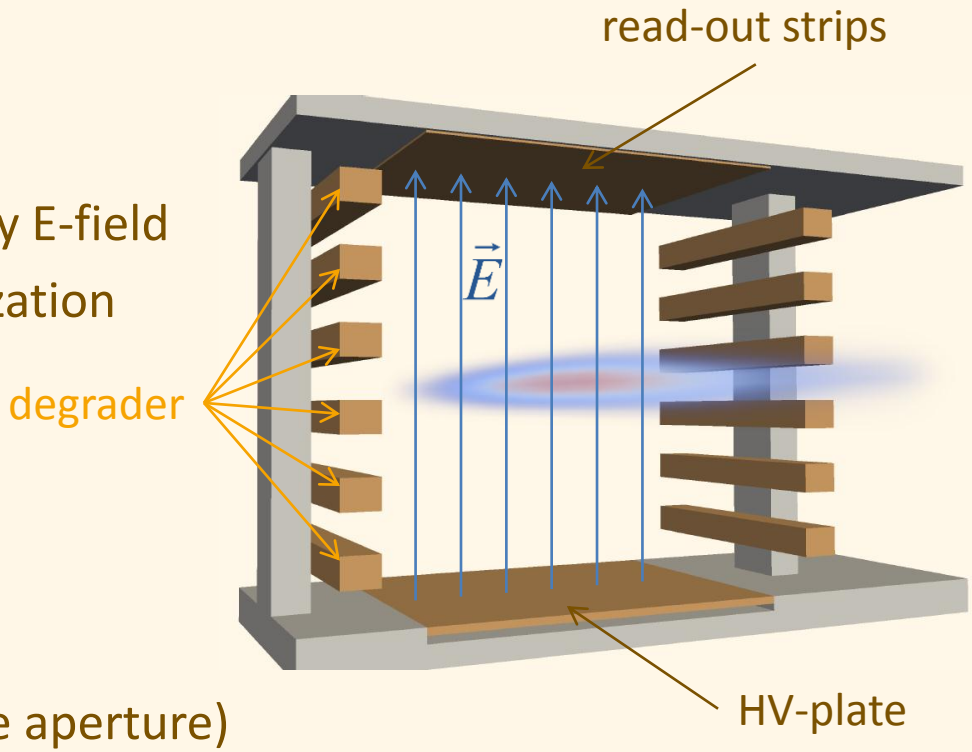
IPMs in IFMIF-EVEDA Accelerator



IPM – Characteristics

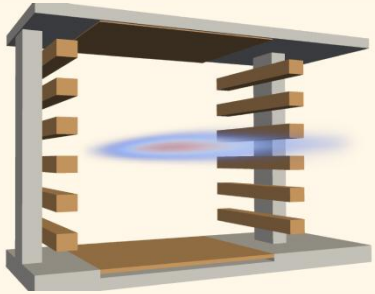
Principle of Operation:

- Beam ionizes residual gas
- Electrons / ions are extracted by E-field
- Beam profile derived from ionization current



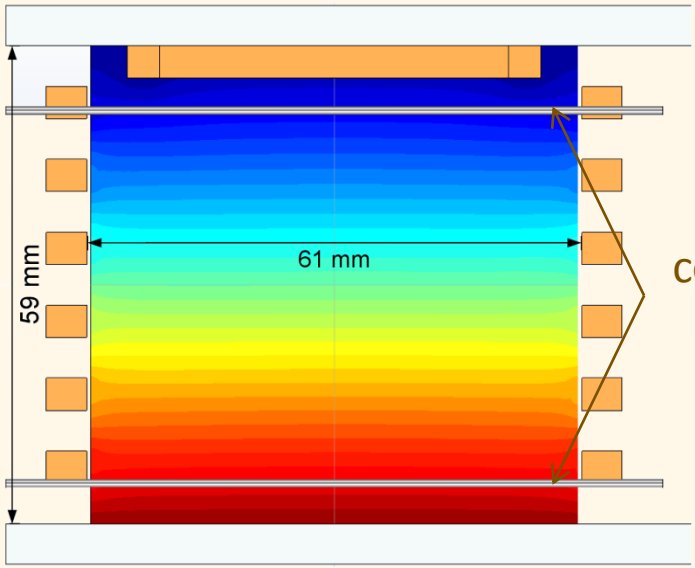
IFMIF-EVEDA Challenges:

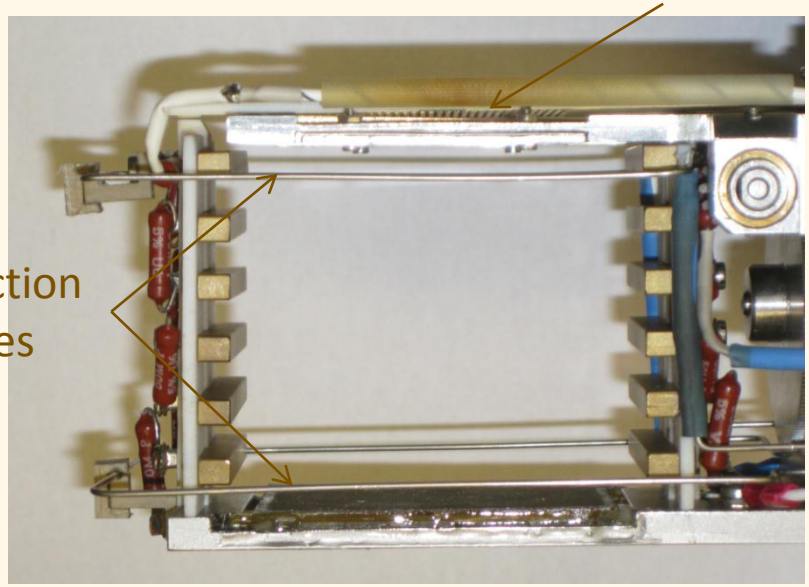
- Limited space
  - ⇒ Compact design (wrt. large aperture)
  - ⇒ no mag. guidance field possible
- High background radiation (~7 kSv/h close to the beam dump)



IPM Prototype Design

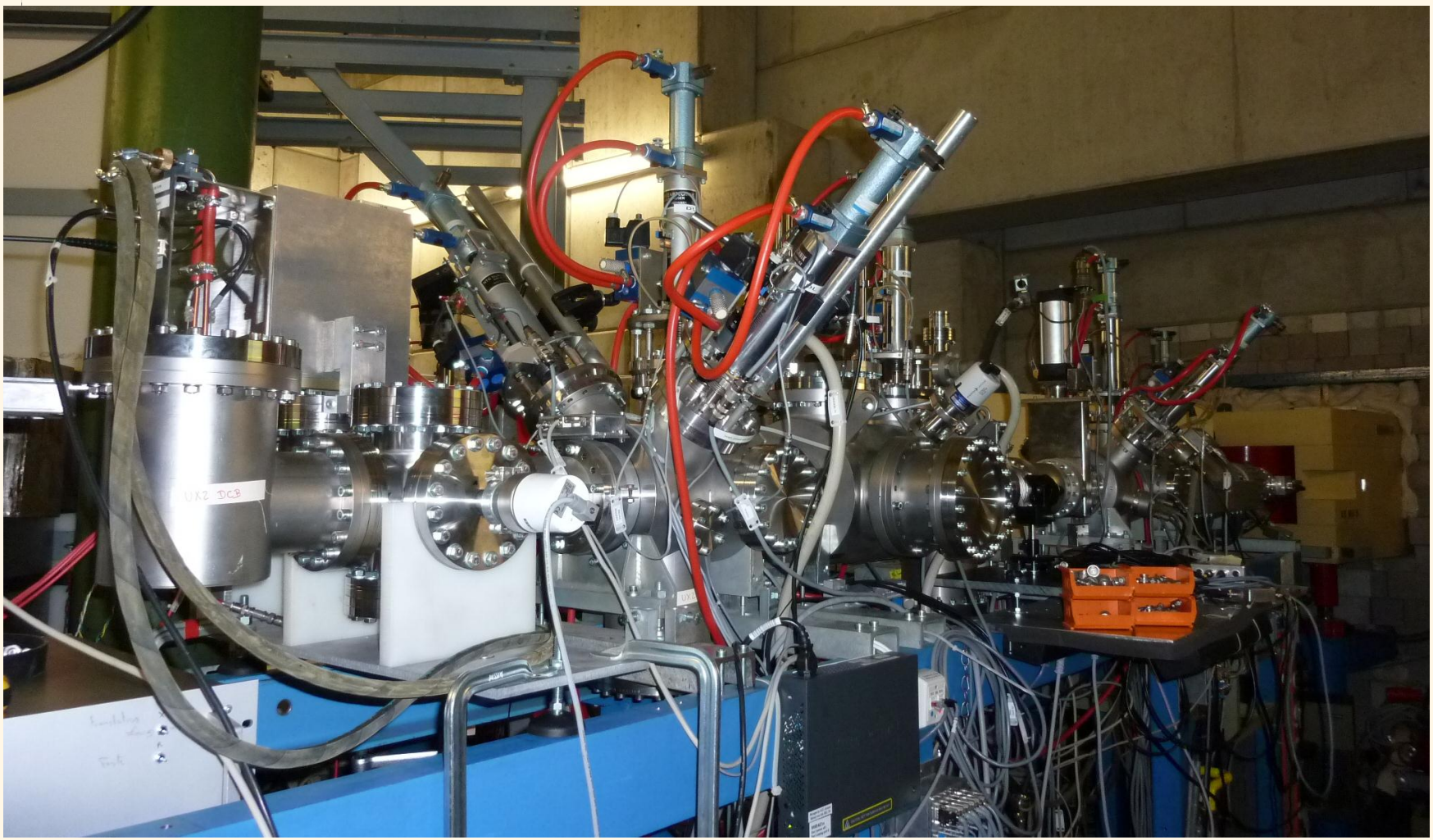
- Charge collected on 32 strips with 1.25 mm pitch
- Uniform electric field required to conserve beam profile
- Prototype designed based on FEM E-field simulations*
- Internal dimensions: 61 mm x 59 mm x 40 mm
- Voltage applied: 5000 V (E = 833 V/cm)





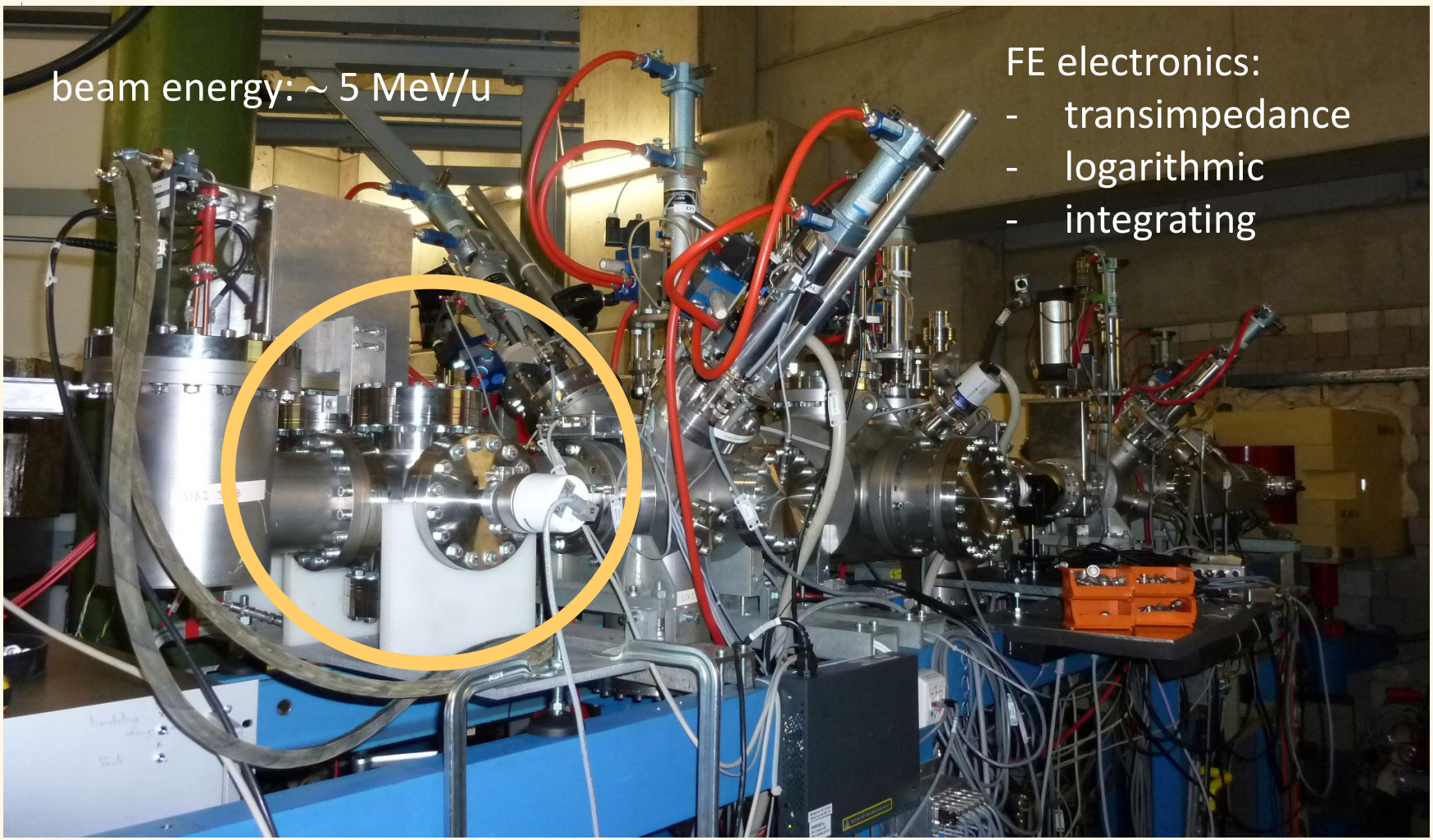
*Lorentz-E Particle Trajectory Solver Copyright © 1998 - 2010 Integrated Engineering Software Sales Inc.

IPM Test at GSI



X2 branch at GSI

IPM Test at GSI



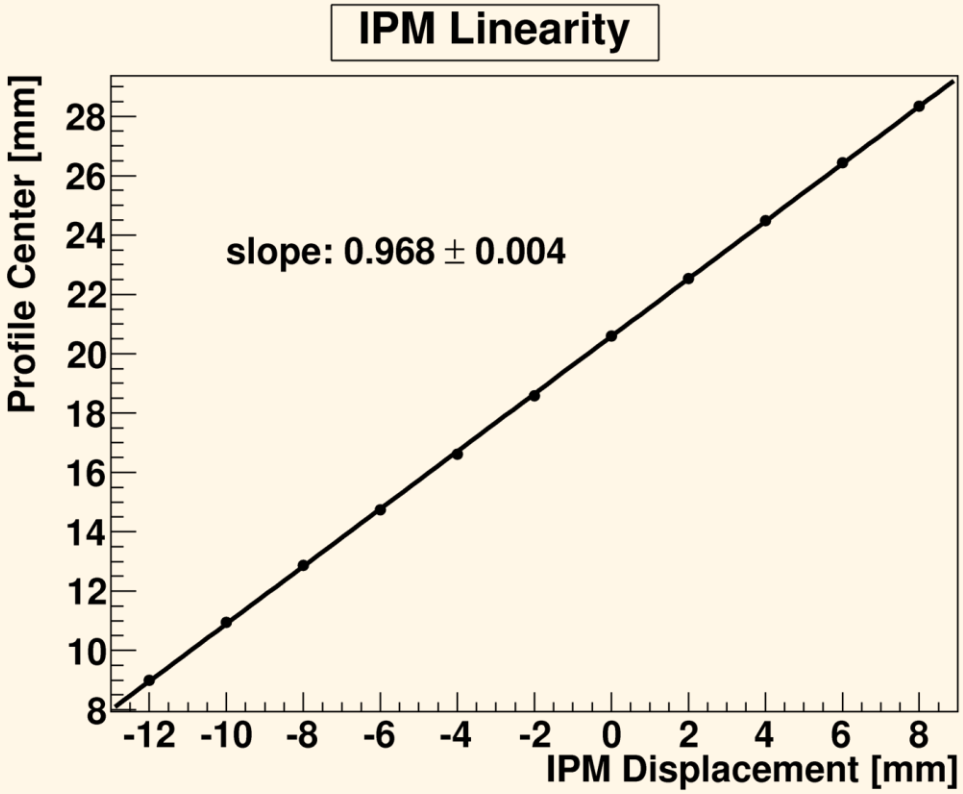
X2 branch at GSI

Field Uniformity Test

- Move IPM in 2 mm steps perpendicular to the beam
- Plot profile center versus IPM position

- Linear response over all active area

Good field uniformity

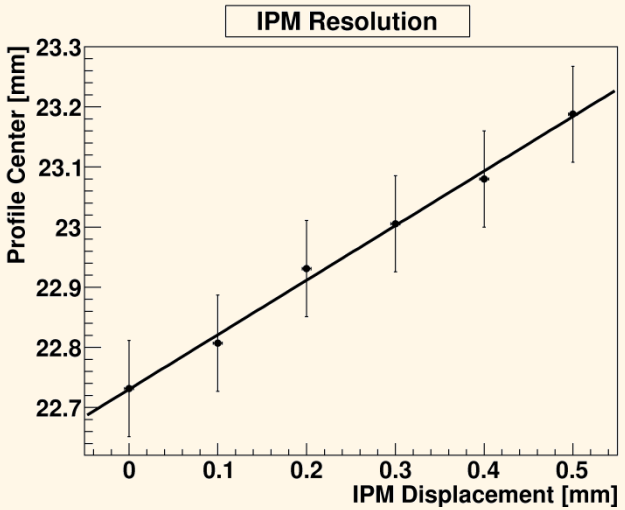


Beam: 30 µA Ca^{10+}

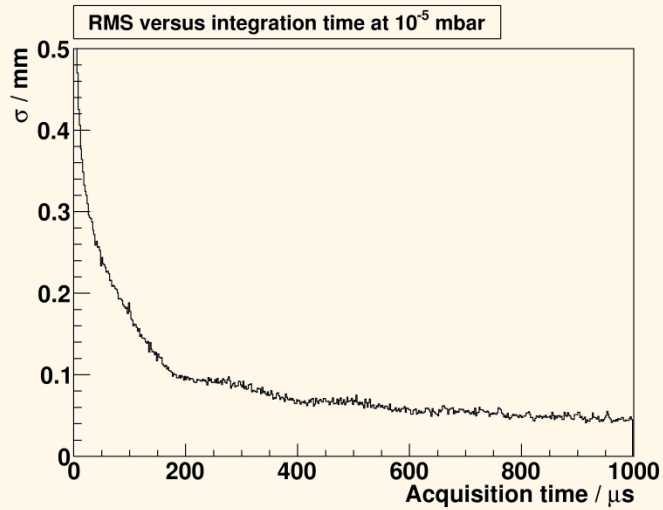
Position Resolution

- Move IPM in 100 µm steps perpendicular to the beam
- Averaged over 60 ms (16.7 Hz)
- Plot profile center versus IPM position

IPM resolves well 100 µm profile shifts



- Fluctuation of beam center versus data acquisition time
- 120 µA Xe^{21+}, 10^{-5} mbar N_2
- Plateau of < 100 µm at ~1kHz



Beam: 1 mA Xe^{21+}

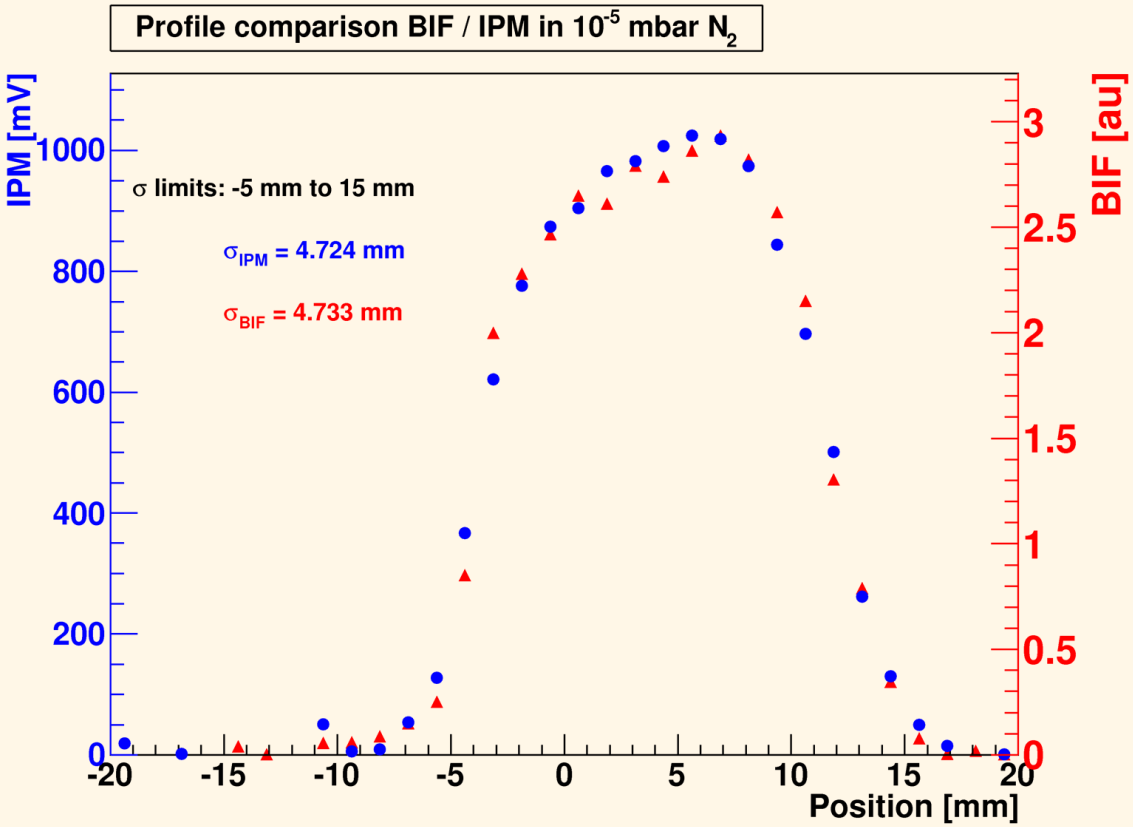
BIF Comparison

10^{-5} mbar N_2

BIF: Beam Induced Fluorescence

BIF Monitor based on light emitted by atoms excited by the beam

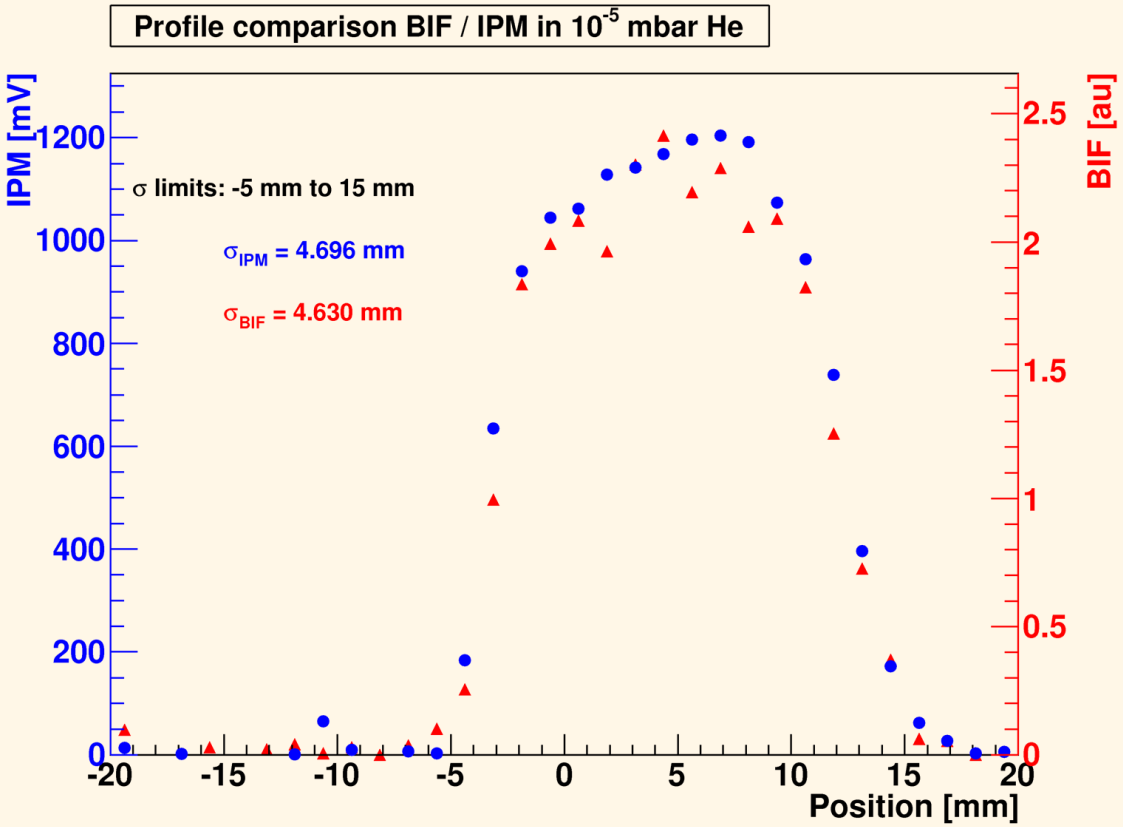
BIF profiles acquired by *Frank Becker, GSI*



Beam: 1 mA Xe^{21+}

BIF Comparison

10^{-5} mbar Helium



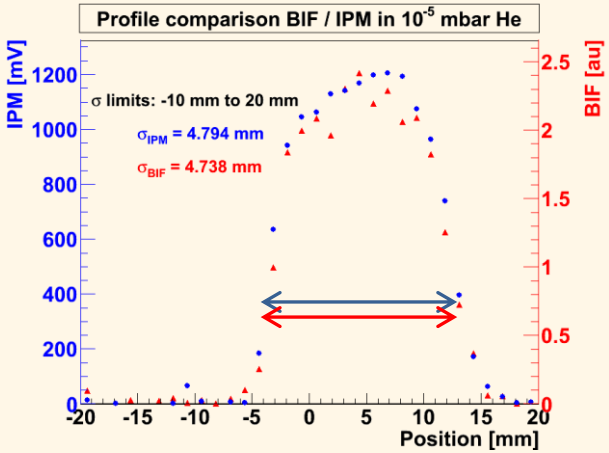
BIF profiles acquired by *Frank Becker, GSI*

Beam: 1 mA Xe^{21+}

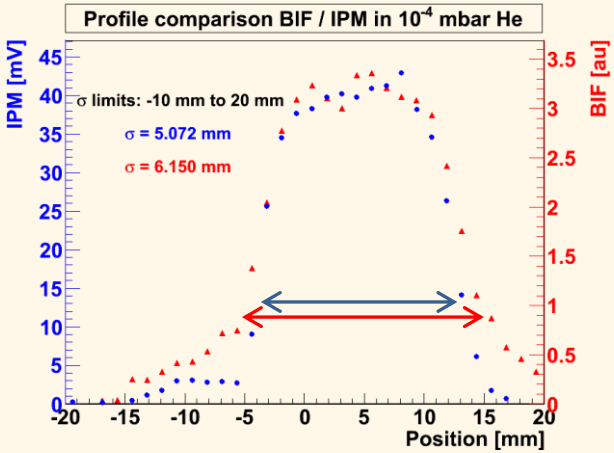
BIF Comparison

High pressure Helium

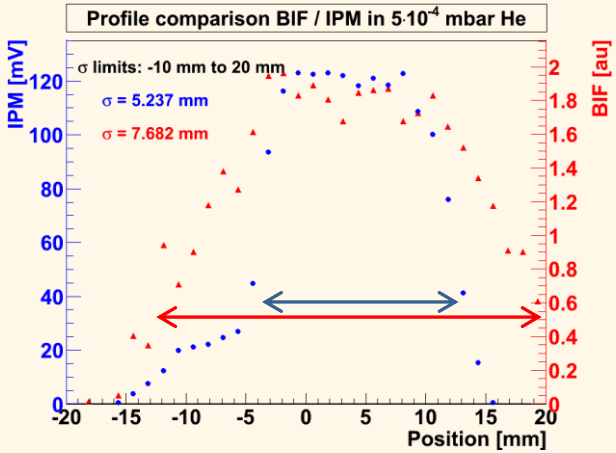
10^{-5} mbar



10^{-4} mbar



$5 \cdot 10^{-4}$ mbar



Profile broadening of BIF not observable

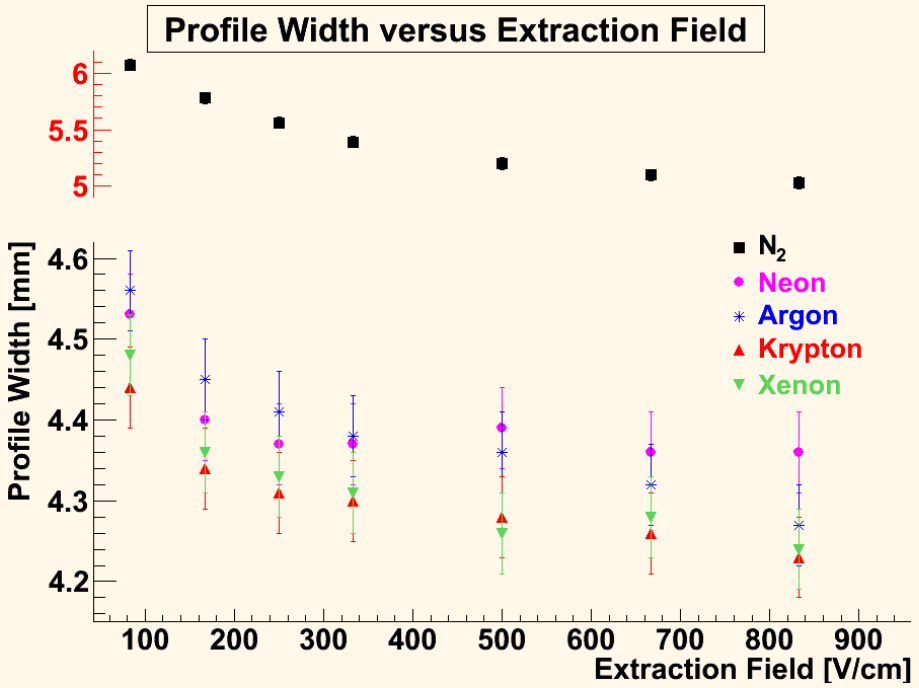
BIF profiles acquired by *Frank Becker, GSI*

Beam: 1 mA Xe^{21+}

Electric Field Strength

- Profile width decreases with higher extraction fields
- Plateau at a few kV
- Effect stronger for molecular N_2 than for atomic noble gases

E-field dominant at 500 - 1000 V/cm



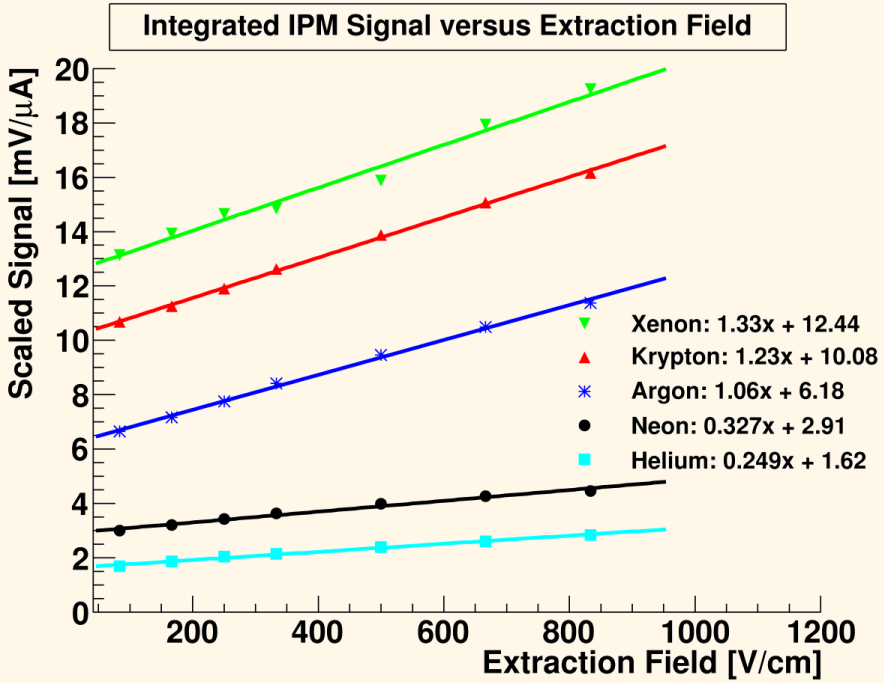
Beam: 1 mA Xe^{21+}

Signal Amplification

- Total strip current plotted versus extraction voltage
- Signal rises linearly

***Hypothesis*: Secondary electron emission during ion collection**

- $\left|\vec{E}\right| \propto E_{KIN} \propto SEM$



Beam: 1 mA Xe^{21+}

High Current Test

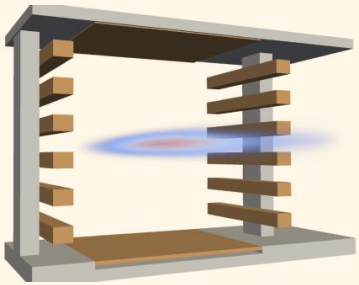
IPHI: Injecteur de Protons à Haute Intensité (I < 100 mA; E < 95 keV)

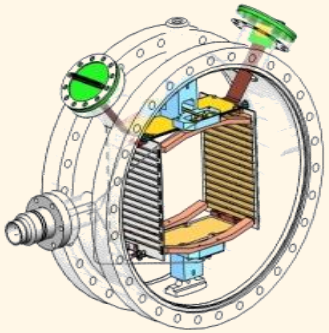
- Test at IPHI source
  - cw or pulsed
  - Low energy ⇒ high ionization cross section
  - No collimation ⇒ IPM is irradiated by beam

- IPM operational up to 10 mA cw (I_{Ioniz} comparable to IFMIF-EVEDA)
  - For I > 10 mA: tripping power supply probably due to primary particle bombardment
- IPM tested up to 20 mA in 10 % duty cycle

Conclusion

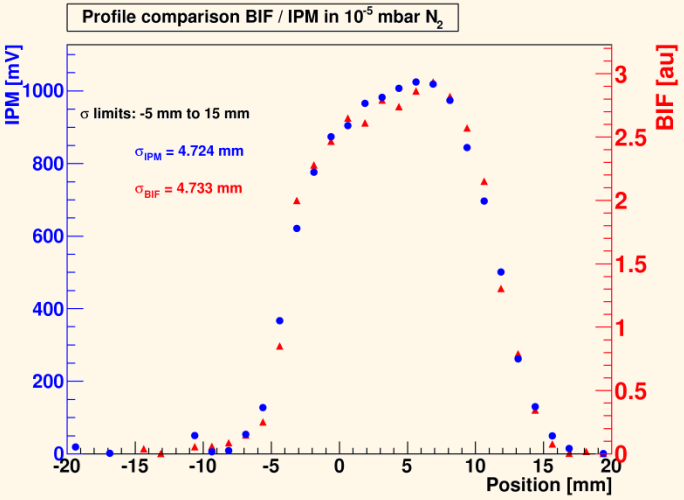
- Design based on FEM studies of extraction field
- No mag. guidance field due to lack of space
- Test at GSI:
  - Extraction field highly uniform
  - Profile shifts of 100 µm resolvable
  - Good agreement with BIF profiles
  - Signal amplification probably due to secondary electron emission
- Test at CEA Saclay:
  - Profile taking at high current cw beams
- Design for large aperture IPM is finalized

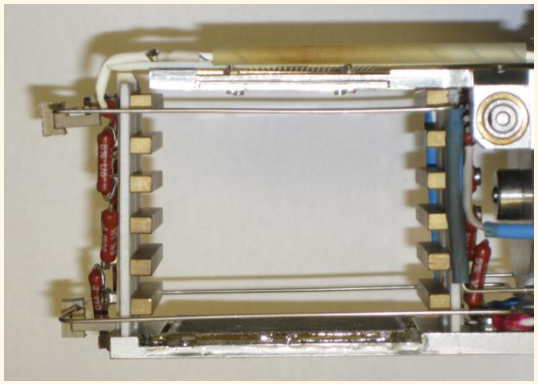




Acknowledgements

Sincere thanks to the GSI beam diagnostics staff and the IPHI group that made the test possible!





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