Minimizing Disturbance in Ion Beam Profiling with PEPITES Monitor

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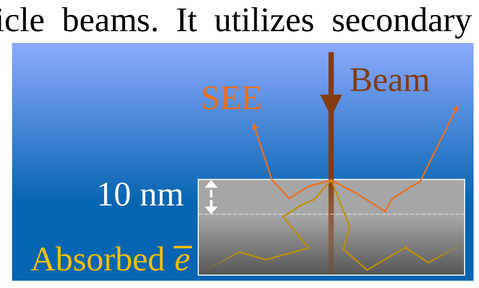
INTRODUCTION

PEPITES ultra-thin monitor has been developed to enable continuous and accurate beam profiling in hadron-therapy [1]. It is a novel beam diagnostic tool designed to measure the intensity and profile of charged particle beams. It utilizes secondary electron emission (SEE), for the signal as only *O* (10 nm) of matter is needed.



CHALLENGE

The PEPITES monitor was initially designed to be positioned 2 meters upstream of the patient. However, new constraints now require its placement at 6.5 meters upstream. To minimize any disturbance to the beam over this extended distance, it is essential to reduce the monitor's Water Equivalent Thickness (*WET*)

→ **Pushing beyond Ultra-thin design: *WET* from 10 µm to 5 µm.**

DESIGN

PEPITES consists of:

→ 2 segmented gold cathodes (32 strips, 1.84 mm wide, 0.35 mm interstrip), to measure *X* and *Y* profiles → $\boldsymbol{WET_{cathodes} \approx 5\ \mu m}$.

→ 2 biased anodes to collect the secondary electrons

Two distinct anode configurations were evaluated:

In-axis anode (original design):

2 gold electrodes, each 50 nm thick, deposited on 1.5 µm CP1 membrane → $\boldsymbol{WET_{anode} \approx 5\ \mu m}$

$\boldsymbol{WET_{PEPITES} = WET_{anode} + WET_{cathode}}$

$\boldsymbol{WET_{PEPITES} \approx 10\ \mu m}$

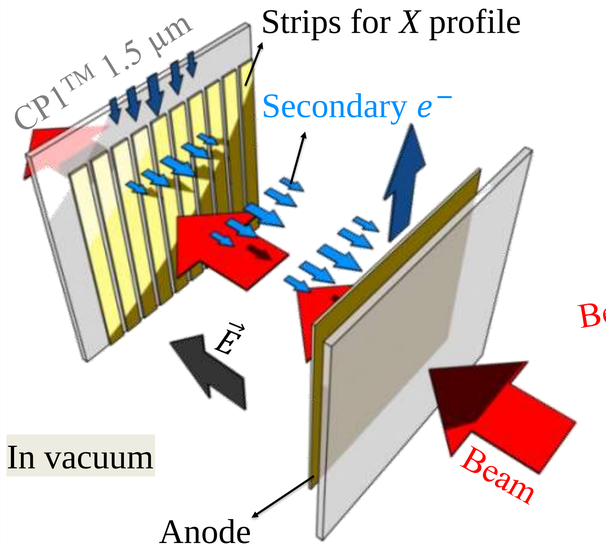
Anode-Cathode gap = 15 mm → parallel $\vec{E}$

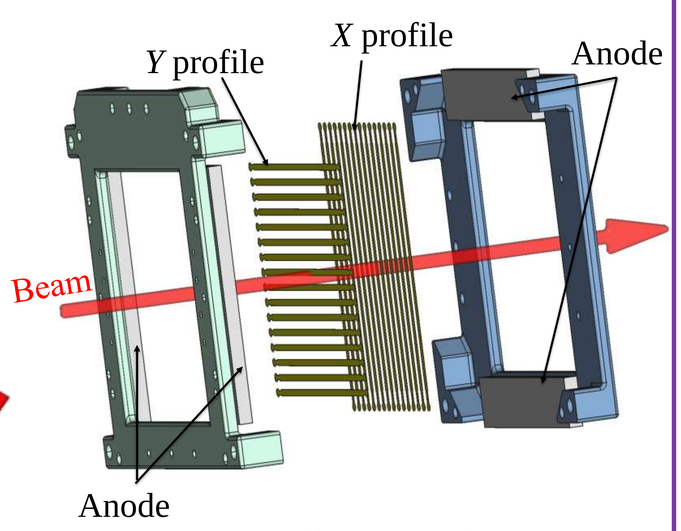
Off-axis anode (upgraded design):

2 Al. bars positioned perpendicular to the segmented cathodes, outside the beam axis → $\boldsymbol{WET_{anode} = 0\ \mu m}$ **!**

$\boldsymbol{WET_{PEPITES} \approx 5\ \mu m}$

Finite element method simulations → compromise between compactness and deviation from parallel $\vec{E}$ field.





To enhance visualization → schematic shown for *X* profile only

X profile: Forward emission.

Y profile: Backward emission.

The signal is read on every strip via two 32-channel ASIC designed by CEA.

SETUP

For this test at CNAO, a 115 MeV/u carbon ion beam is used.

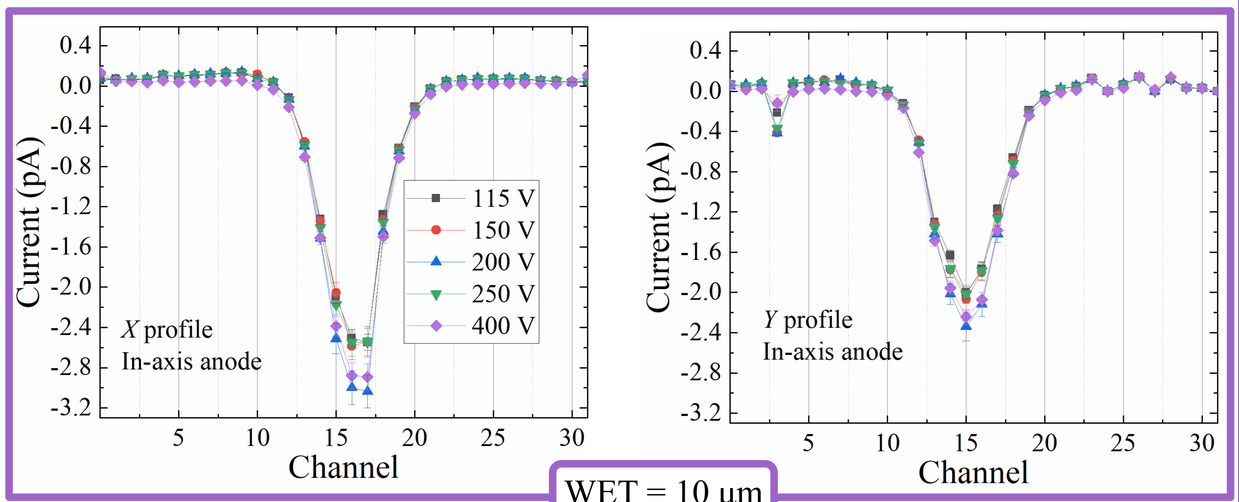
• **Positional scanning:** The detector was scanned by moving the beam across it in a 5×5 regular grid, covering a 42 mm range in both *X* and *Y* directions.

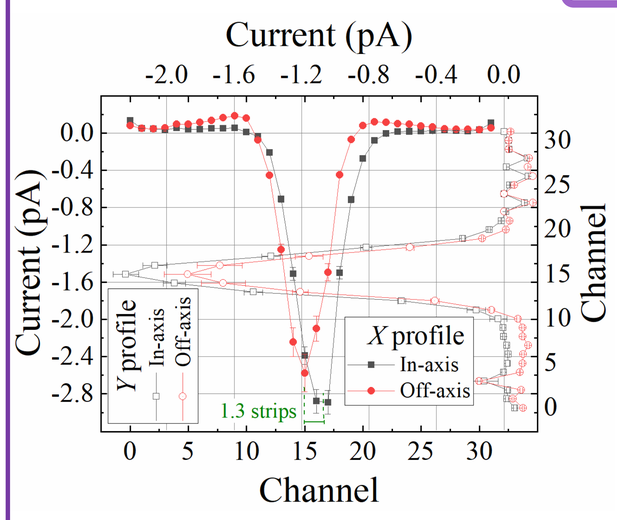
• **Voltage-dependent characterization:**

– *In-axis anode*: 115 V, 150 V, 200 V, 250 V, and 400 V.

– *Off-axis anode*: 0 V, 10 V, 20 V, 50 V, 100 V, 200 V, 300 V, and 400 V.

PRELIMINARY RESULTS



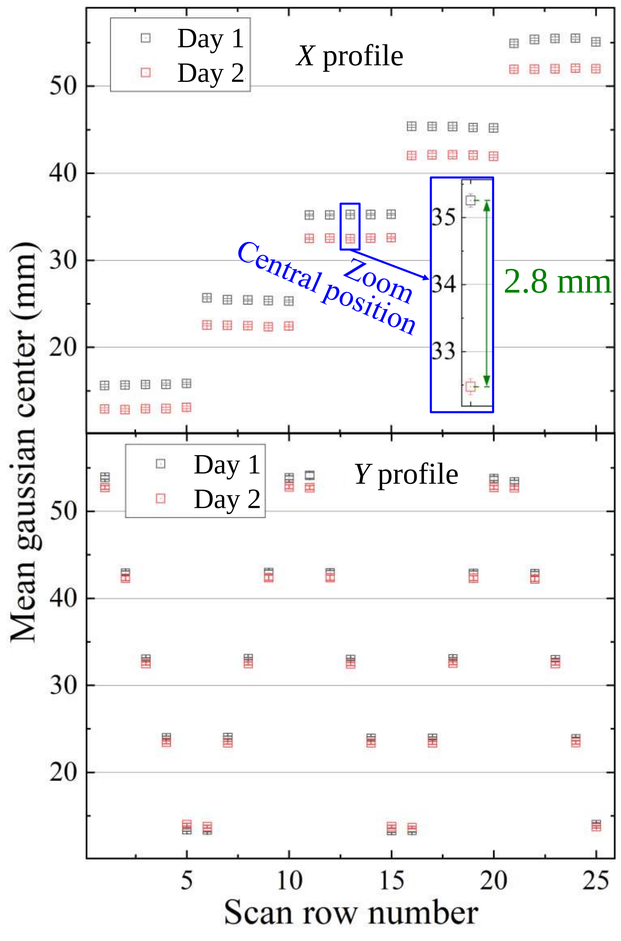


• Off-axis design shows lower current → linked to electrode geometry. Can be corrected via calibration, with no impact on performance.

• As expected, SEE favors forward emissions over backward emissions.

Sigma values in mm

PEPITES *In-axis anode*		PEPITES *Off-axis anode*	
X profile	*Y* profile	*X* profile	*Y* profile
4.05 ±0.23	4.26 ±0.23	3.85 ±0.18	3.75 ±0.27



• A 2.8 mm shift in the *X* profile position was observed → likely due to a difference in the manual positioning of the setup, following the replacement of the anodes.

• Stable peak positions and sigma values confirm measurement reproducibility.

• The low-WET Off-axis design remains effective for precise beam diagnostics.

SUMMARY

- An upgraded version of PEPITES profiler with half the WET (5 µm) was tested and validated at CNAO facility.
- Despite a non-parallel electric field, the detector maintains accurate measurements of beam parameters.
- Reduced material thickness minimizes beam scattering, enabling lower energy and longer monitor–target distance applications.
- Future developments include a single-electrode design for both *X* and *Y* profiles. Integration of deep learning optimization is planned to enhance beam parameter extraction.

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References

[1] C. Thiebaux *et al.*, "First results of PEPITES a new transparent profiler based on secondary electron emission for charged particle beams", 11th International Beam Instrumentation Conference.