PEPITES:

an Ultra-Thin Beam Profiler with Wide Dynamic Range for Charged Particle Beams

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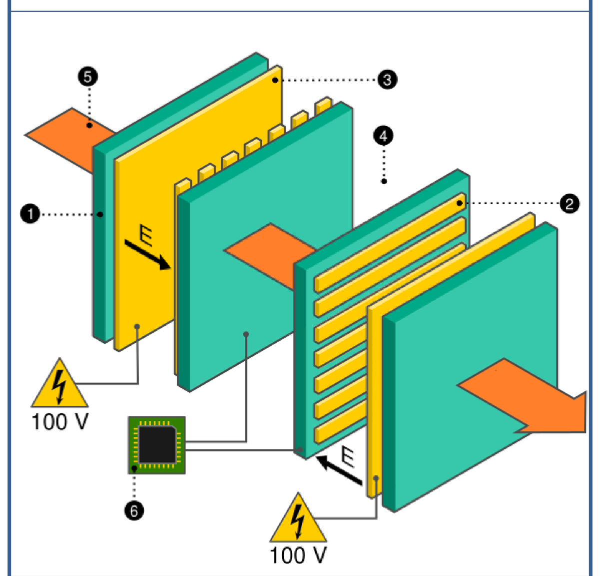
Hadrontherapy requires thin and radiation-hard profilers to monitor the beam during patient irradiation. A first 10 µm Water Equivalent Thickness (WET) PEPITES prototype was installed at **ARRONAX** (Saint-Herblain, France) in May 2022 and is used in routine operations. A second monitor is under development with the **CNAO** (Pavia, Italy) and is aimed at being used in clinic. The long detector-patient distance, 6.5 m, imposes a stringent material budget of O(5 µm) WET.
The new **FLASH** modality explores the biological response to high - ultra-high dose rates using beams in a wide range of durations (O(100 ms) – O(10 fs)). PEPITES withstands at least O(ms) ones; its usability is assessed down to ultra-short beams, O(30 fs), from laser-plasma acceleration.

PEPITES SENSITIVE AREA

Signal = Secondary Electron Emission (SEE) :
Only O(10 nm) of matter needed → Ultra-thin sensitive area
Very linear → Wide dynamic range
Thin film techniques used to built the sensitive area:
Versatile → allows for monitor variants (layer, strips, 2D pads…)

SEE ?
Ionization e^- produced so close to the surface they can leave the volume.
These are O(few eV) e^- → operate in vacuum. Fine for beam monitor.

Sensitive Area Sketch

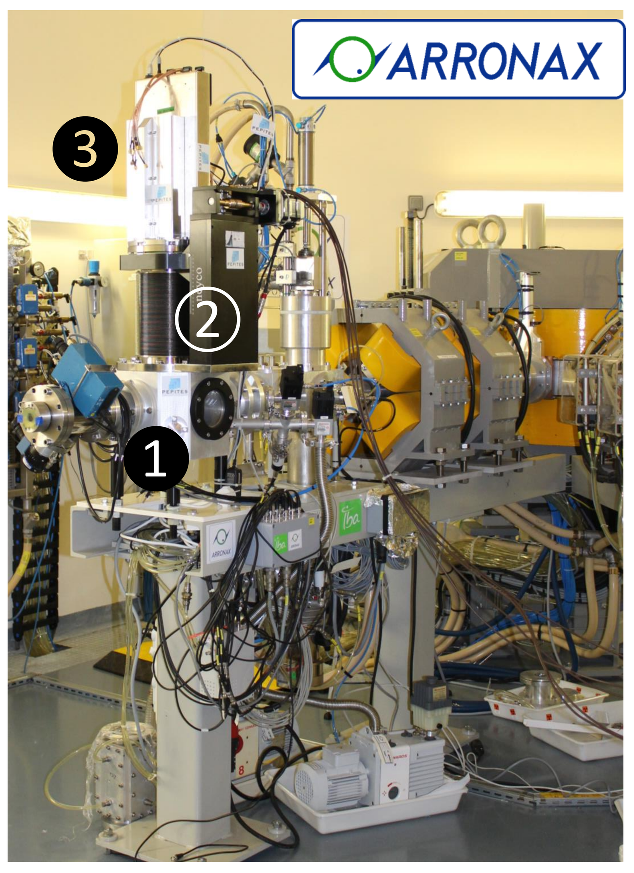


❶ 50 nm thick gold strip (e^- emitter)
❷ 1.5 µm CP1™
❸ 50 nm thick gold layer (e^- collector)
❹ Collection electric field
❺ Beam
❻ Readout, one channel per strip

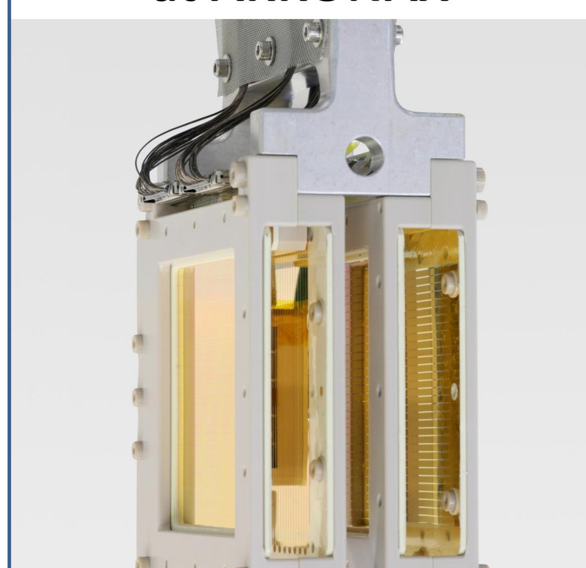
Why gold ?
It is a good SEE emitter (depends on Z) and is easy to handle
Why 50 nm instead of the 10 nm needed for SEE ?
Below 30 nm, metals are not metallic, they form disconnected spots. We use 50 nm to have 30 nm + 20 nm of safety margin.

PEPITES @ ARRONAX

Installed permanently on AX3 beam line
❶ In beam host vacuum chamber
❷ Translation stage, driven by a linear actuator, moves the monitor in/off the beam axis
❸ Readout electronic box
Low-noise dedicated ASIC
Read current from strips
one channel per strip
Removable box
(high intensity operations)



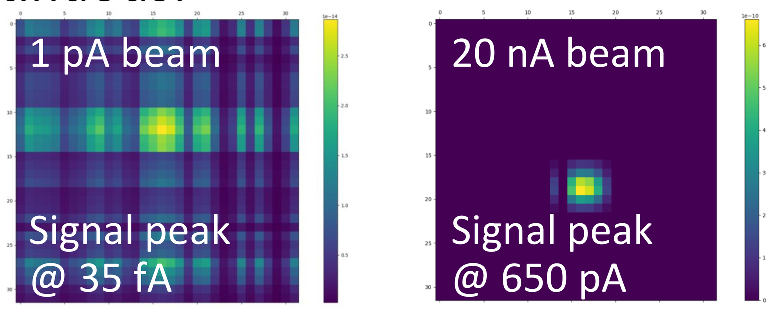
Sensitive Area in Use at ARRONAX



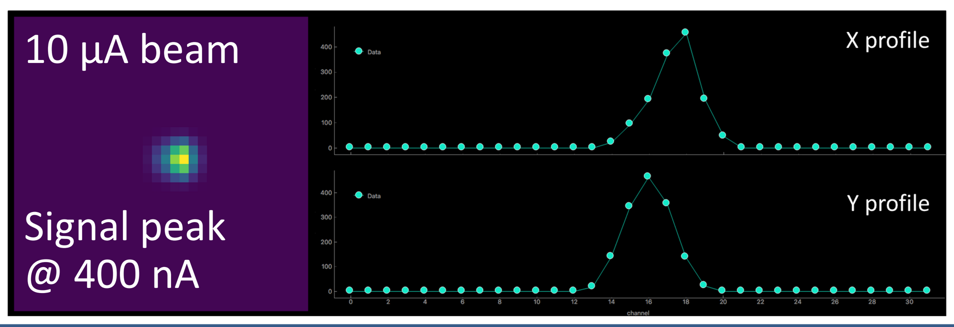
7×7 cm²
32 channels in X & Y

68 MeV Proton Beam

Continuous:

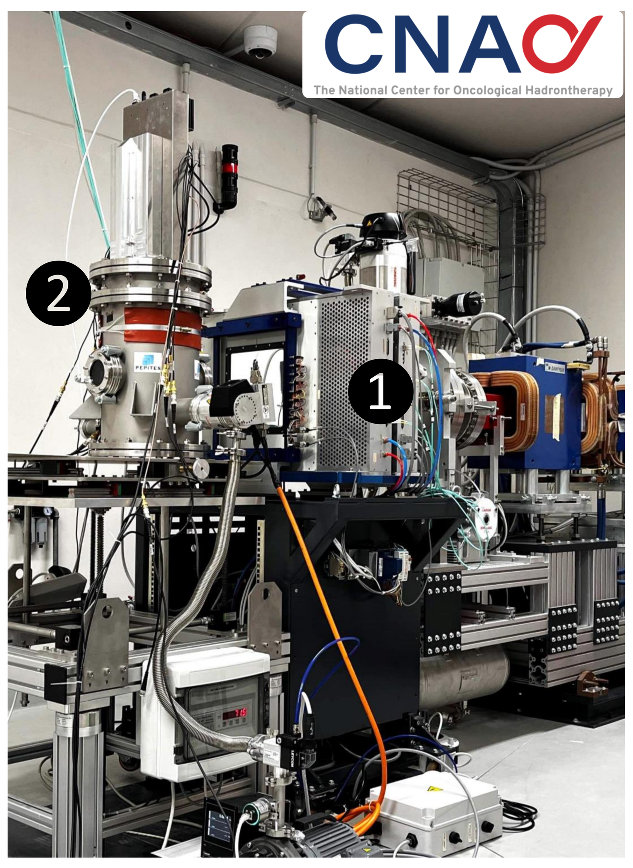


FLASH, 10 ms duration:

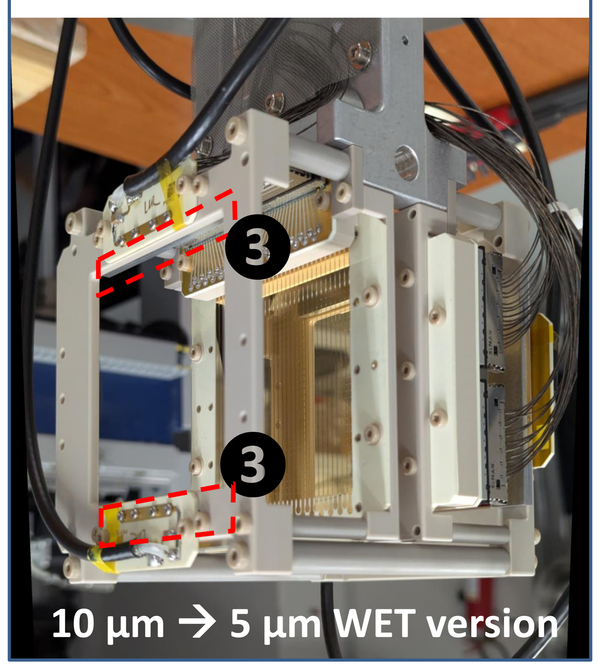


PEPITES @ CNAO

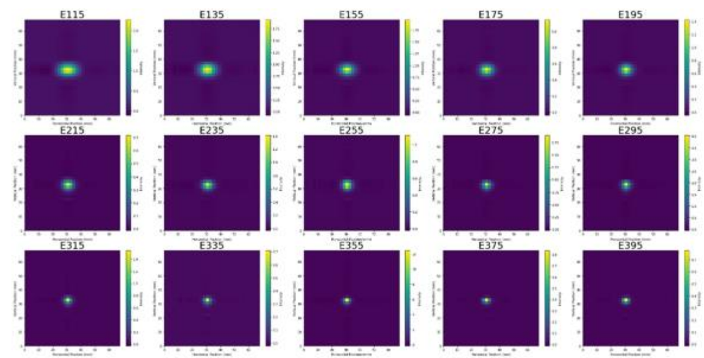
Use standalone "PEPITES NOMAD":
a copy of PEPITES & readout electronic
❶ CNAO test beam line
❷ Standalone vacuum chamber
hosting the copy of PEPITES
(no translation stage)
❸ Off axis anodes:
metallic bars (hidden by frame)
E collection field not parallel nor uniform anymore !
→ Effect on measured profiles ?



Modified Sensitive Area Tested at CNAO

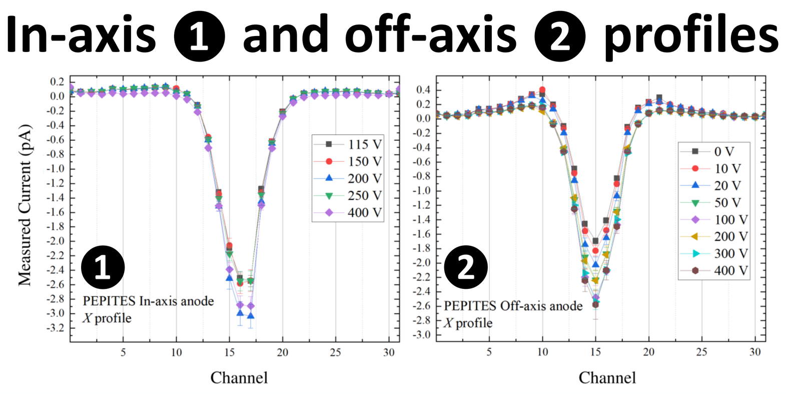


Carbon Ion Beam Energy Scan
with standard sensitive area



Shown for demonstration purpose of PEPITES measuring carbon ion beams

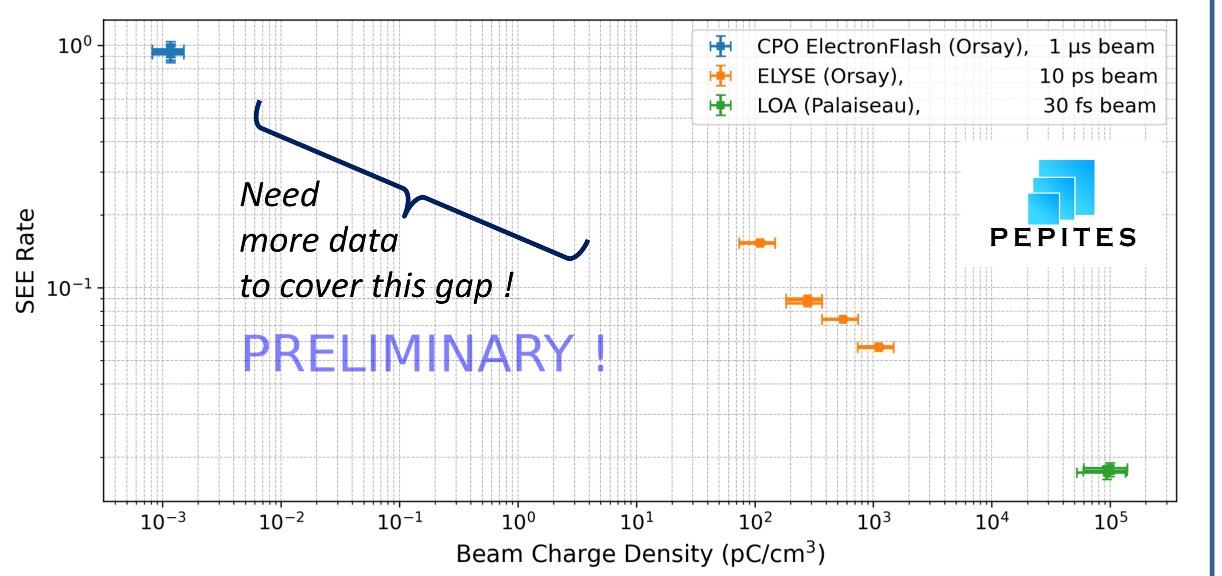
In-axis ❶ and off-axis ❷ profiles



Some undershoots but which essentially disappear at high HV

TOWARD ULTRA-HIGH DOSE RATES ?

Can SEE withstands the intense beams used in FLASH biomedical researches ?
No problem for O(ms) pulses (see ARRONAX FLASH above). But below ?
Series of SEE rate measurement with two parallel plans, 1 kV/cm, on several e^- machines
"Beam charge density" (= beam charge / beam volume) looks a relevant parameter
Strong SEE signal attenuation with beam charge density observed !
What mechanism ? Is there a "turning point" somewhere ?
Monitor doable ? Maybe with "calibration per domain" ?



FLASH ?
A biological effect observed with high dose rate irradiation: healthy tissues are better spared while tumor ones are still as damaged than with conventional, minutes long, irradiation of the same dose.

PEPITES is and ultra-thin, high dynamic range & versatile beam monitor.
A new topic emerged with the beam monitoring for ultra-high dose rates !

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