PEPITES for Beams From Laser-Plasma Acceleration ?

TRF/LhARA Collaboration Meeting #5
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Overview

- PEPITES & related projects
- PEPITES-UltraFash : PEPITES vs Laser-Plasma Beams

PEPITES & related projects
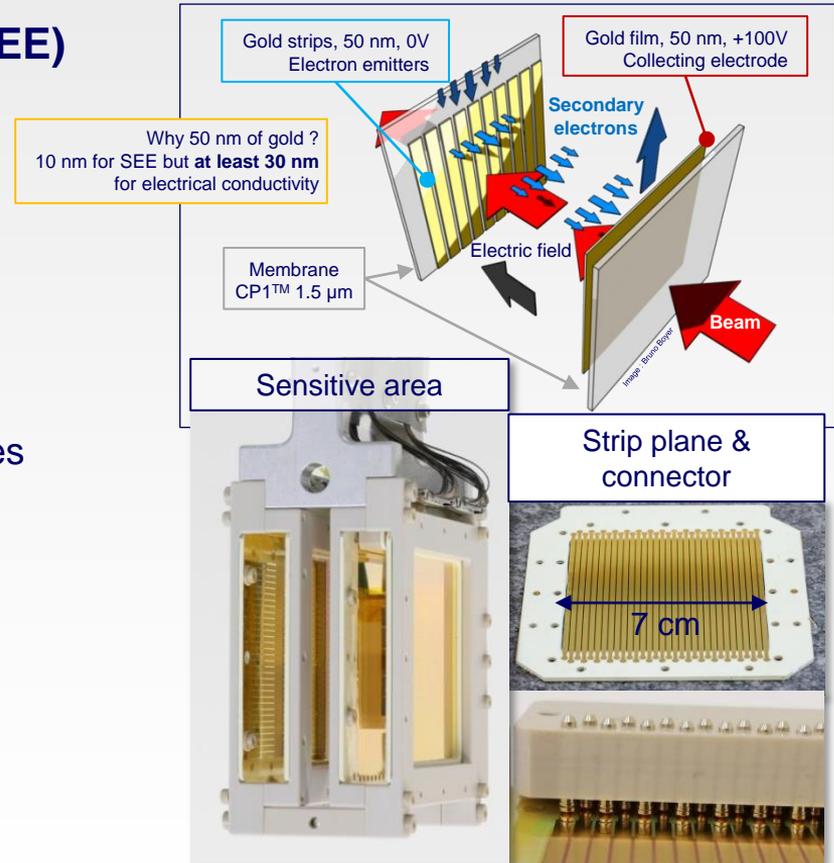
PEPITES in a Nutshell

- **Ultra-thin Secondary Electron Emission (SEE) beam profiler:**
  - Assets of SEE as signal:
    - Tiny amount of material needed (~10 nm)
      - **→ Very thin sensitive area possible**
    - Very linear at least up to O(A) beams
      - **→ Wistands conventional and FLASH irradiations**
  - Secondary electron energy low (O(eV))
    - Must operate in vacuum
    - **→ suited for beam monitors inside beam line**
  - Sensitive Area built using « Thin Film » techniques
    - Versatiles techniques **→ many variants possible**
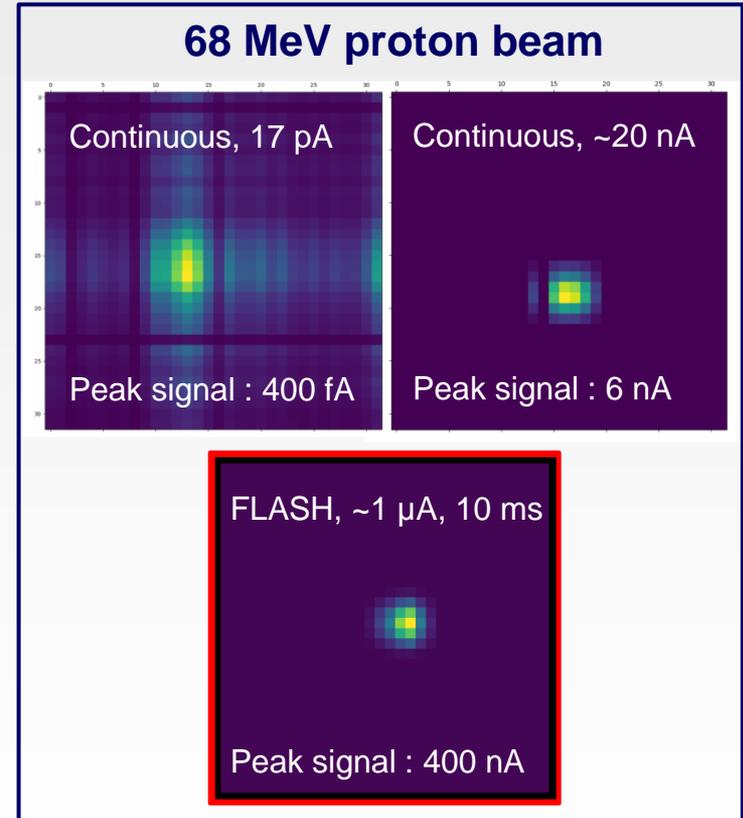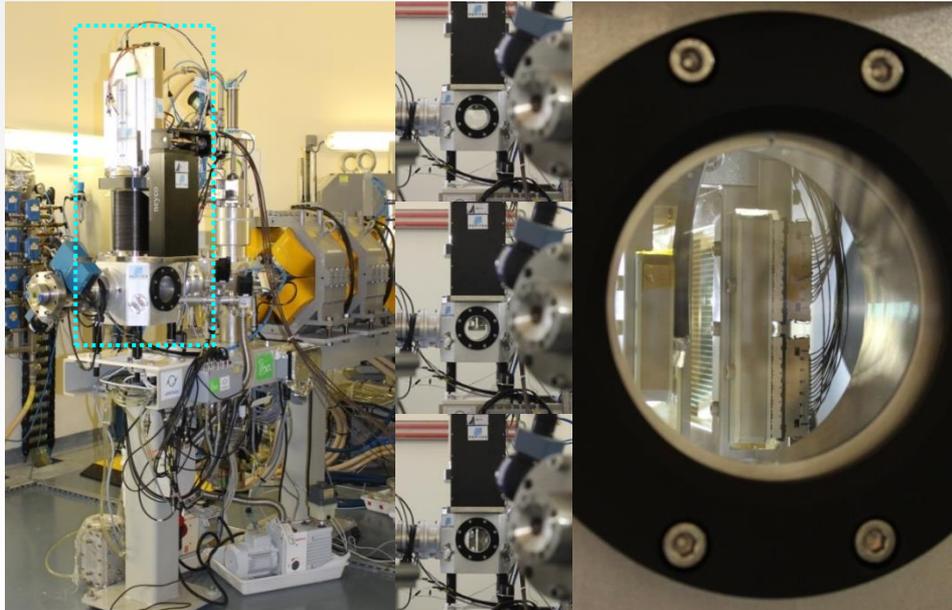
- **Current version:**
  - **10 µm WET**
  - **Low noise & high range read-out electronic**
    - For continuous current beams
    - Designed by our CEA partner
  - 2 × 32 channels (X & Y beam sampling)

Gold strips, 50 nm, 0V
Electron emitters

Gold film, 50 nm, +100V
Collecting electrode

Secondary electrons

Why 50 nm of gold ?
10 nm for SEE but **at least 30 nm** for electrical conductivity

Electric field

Membrane CP1™ 1.5 µm

Beam

Image Bruno Boyer

Sensitive area

Strip plane & connector

7 cm

PEPITES @ ARRONAX (St Herblain/Nantes, France)

- Installed on May 2022 (ANR-17-CE31-0015)
  - Provides feed-back on "daily" usage
- **Used 80% of time for FLASH !**
 - While initially designed for continuous beams…

68 MeV proton beam

Continuous, 17 pA

Peak signal : 400 fA

Continuous, ~20 nA

Peak signal : 6 nA

FLASH, ~1 µA, 10 ms

Peak signal : 400 nA

PEPITES @ CNAO

## Centro Nazionale di Adroterapia Oncologica (Pavia, Italy)

- Project started in 2023, subject to a specific CNRS – CNAO agreement
- CNAO's need : beam monitor **6.5 m from the patient used during therapeutic irradiation → very thin monitor needed !**
- **First test beam in November 2023**, with **"PEPITES NOMAD"**, **carbon ion beams:**
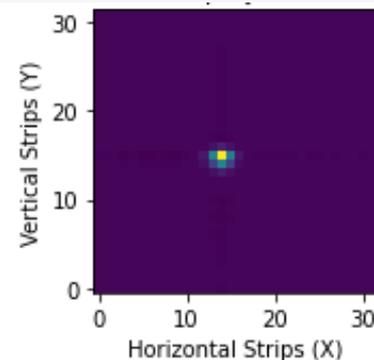

2023.11

PEPITES NOMAD (copy of ARRONAX PEPITES)
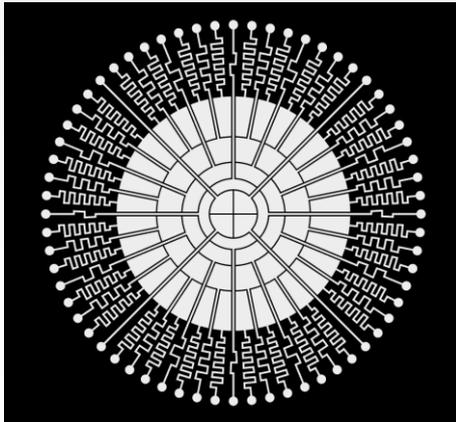
CNAO beam line
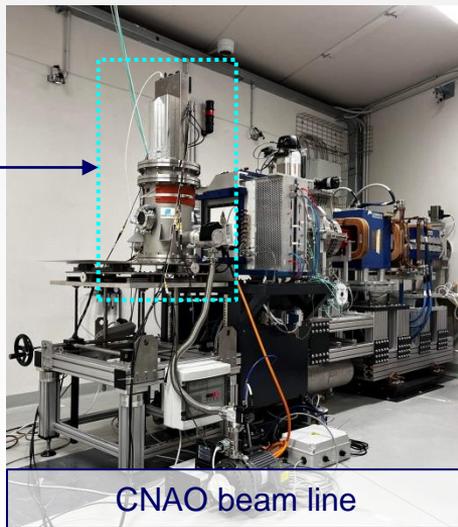
Y and X measured profiles
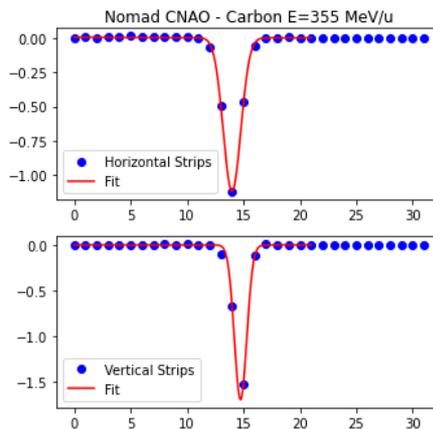
2D reconstructed profile

Options for Thinner Monitor

| Geometry	CP1™ (1.5 µm) membranes Cost : moderate	LuxFilm™ (0.1 µm) membranes Cost : +++
2 strip planes + 2 anodes planes	~10 µm	~2.5 µm
2 strip planes + 2 off axis anodes	~5 µm	~1.25 µm
2D pattern + off axis anode	~2.5 µm	~0.63 µm

2D pattern

Third variant, under patent process…
So, no details here !

- Simple portable system to **measure both conventional and FLASH beam** intensities

- **Proof of principle obtained beginning of April !**
  - Using an electron-flash machine @ Institut Curie, Orsay, France
  - 7 MeV e$^-$, O(nC), pulses 1 – 5 µs

2024.04
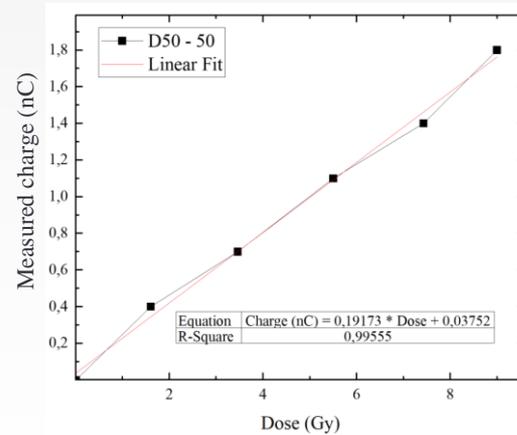
It works ! ;)

PEPITES-UltraFash : PEPITES vs Laser-Plasma Beams
PUFF : PEPITES for UltraFlash Facilities

PEPITES & Laser-Plasma Beams ?

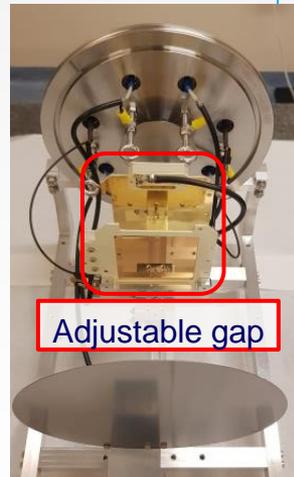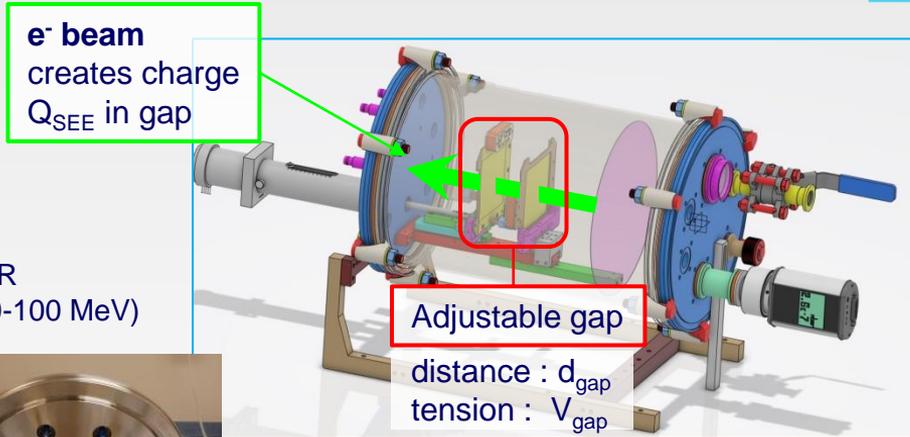- **SEE withstands "classical" FLASH beams**

- **What about "UltraFlash" ones ?**

- Creation of project **PEPITES-UltraFlash**
  - Supported by French MITI
- Joint LLR – LOA project
  - **LOA = Laboratoire d'Optique Appliquée**, next to LLR
  - LOA operates e⁻ beam, laser-plasma accelerated, O(0-100 MeV)
  - Has several rooms with beams

- **Driving work items:**
  - **Observe the signal**
  - **Assess its linearity/non-linearity**

- **Dedicated apparatus PUFF**
  - **Two parallel planes, with variable distance**
    - To verify signal understanding
  - 1ˢᵗ version to be mounted on LOA chamber
  - 2ⁿᵈ version, standalone

- **Main limitation: access to beam !**

e⁻ beam creates charge Q_{SEE} in gap

Adjustable gap

distance : d_{gap}
tension : V_{gap}

Adjustable gap

(*) For typical values:
- d_{gap} = 1 cm
- V_{gap} = 100 V
- Q_{SEE} = 1 nC

$i_{max} = v_{max} \cdot Q_{SEE}/d_{gap}$

$\sim 0.59\ A$ (*)

$t_{gap} = d_{gap} \cdot \sqrt{2 \cdot m_e/(q_e \cdot V_{gap})}$

$\sim 3.4\ ns$ (*)

Expected Signal Shape

To Scale Drawing !

Hoping not having messed-up orders of magnitudes…

Longitudinal View	Transverse View

10 fs beam
(3 µm length)

CP1
1.5 µm

Gold strip
50 nm thick

500×500
gold atome^2

For a 1 nC pulse, on 1 cm^2, each 500×500 gold atome^2 is crossed by one track, in average.
This happens all at once !

A PEPITES gold strip is 2 mm wide
→ At this scale exceeds this building size ?

A 10 µs "classical" FLASH beam, is 3 km long !

Test Beam Attempts with LPA

1st Attempt, October 9th 2023

- e⁻ E distribution
- LOA chamber "Zita", in "Yellow Room"
- ☠ PVC flange
- ☠ EMP noise !
- PEPITES chamber
- Laser shield, before & after
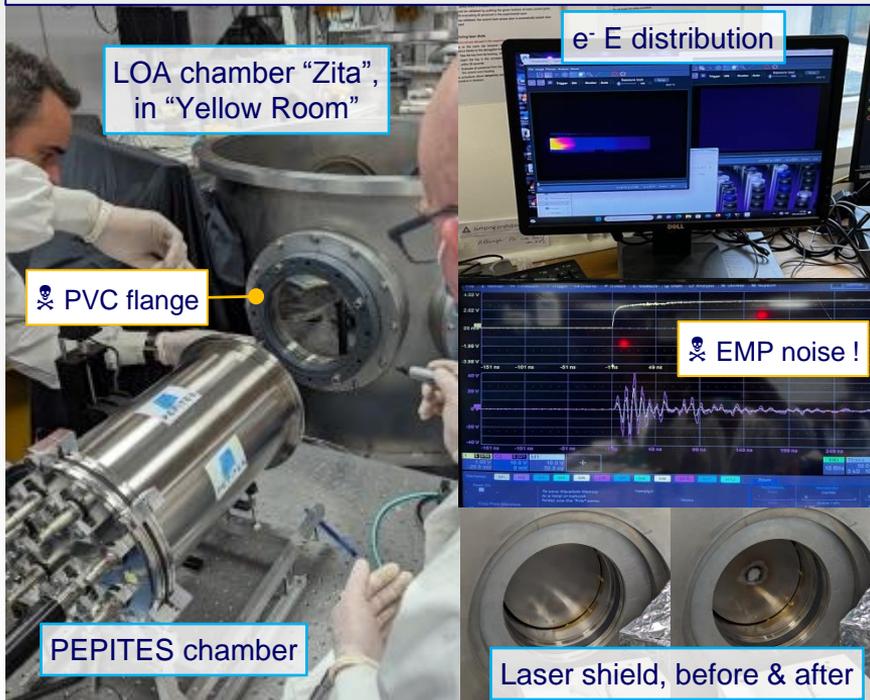
→ Drowned out by EMP background

2nd Attempt, 2 w. March-April 2024

- LOA chamber in "SHERIL" Room
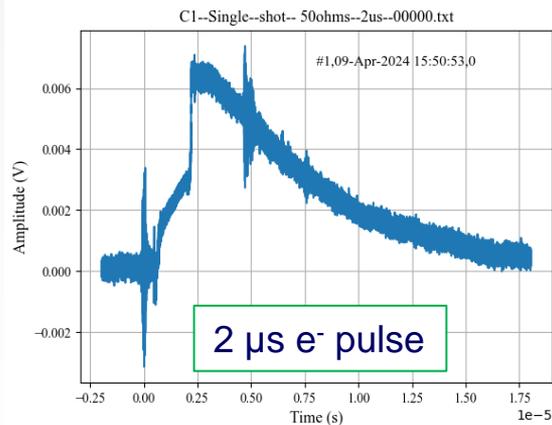- PEPITES chamber, decoupled from LOA chamber (closed)
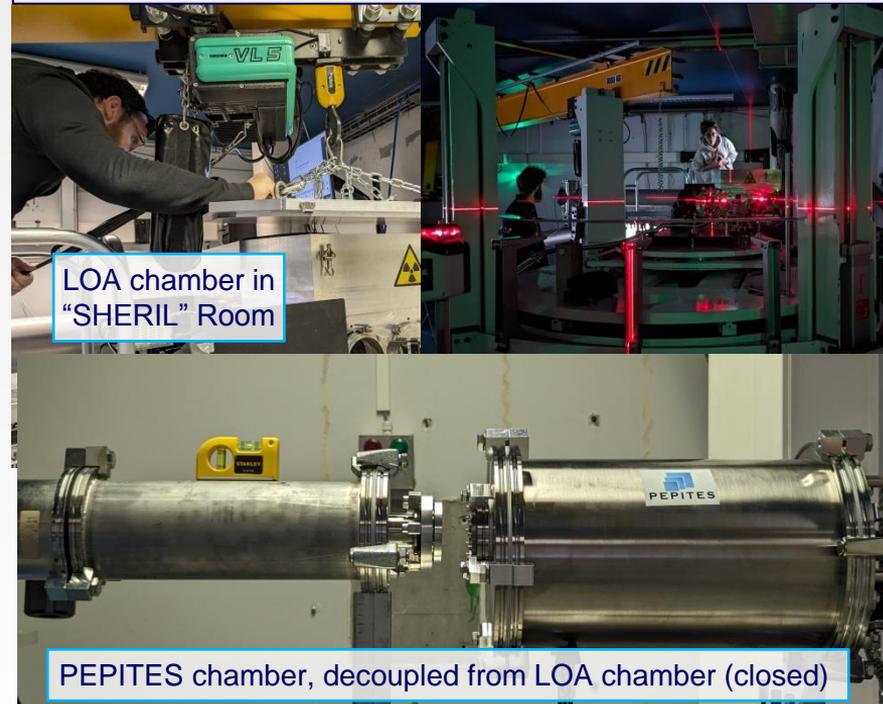
→ Line under development, no usable beam…

Short Test Beam @ Institut Curie, Orsay
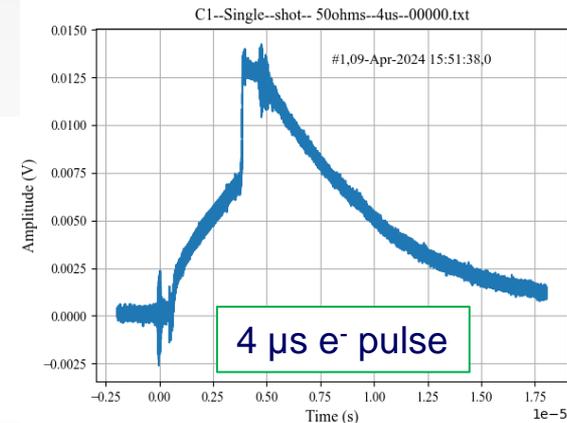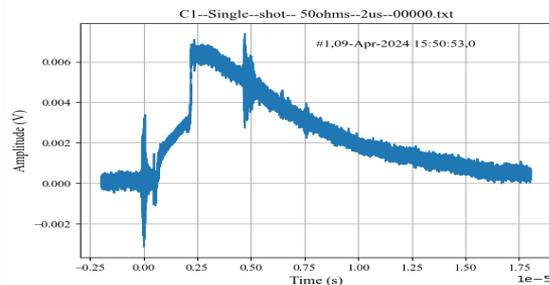
Electron-flash machine, April 2024

- On the same day   got its proof of principle, we took few minutes (in the rush) to see if PUFF is indeed alive
    - **It is !**
- Signals not to be taken at face…

2 µs e⁻ pulse

Same 2 µs e⁻ pulse, with same scale as 4 µs one

4 µs e⁻ pulse

Next Steps

- **Plan new test beam @ Institut Curie, Orsay**
  - To understand PUFF signal, with "classical" FLASH beams
  - And to measure SEE rate @ 7 MeV, from e- beam
    - Need a reference, to be usable also for UltraFlash
  - Candidate date in May
- **Go back to LOA for UltraFlash beams**
  - Possibly this fall
  - Re-hunt for the signal
  - If convincing, measure SEE rate, and compare with "classical" one
  - If *very lucky*, use usual PEPITES, in charge integrated mode, to profile a beam.

Thank you !