PEPITES: Status and Plans

PEPITES = **P**rofil**E**ur **P**our **I**ons **T**hérapeutiques à **E**lectrons **S**econdaires

CNAO-IN2P3 Collaboration Meeting, 05/03/2026

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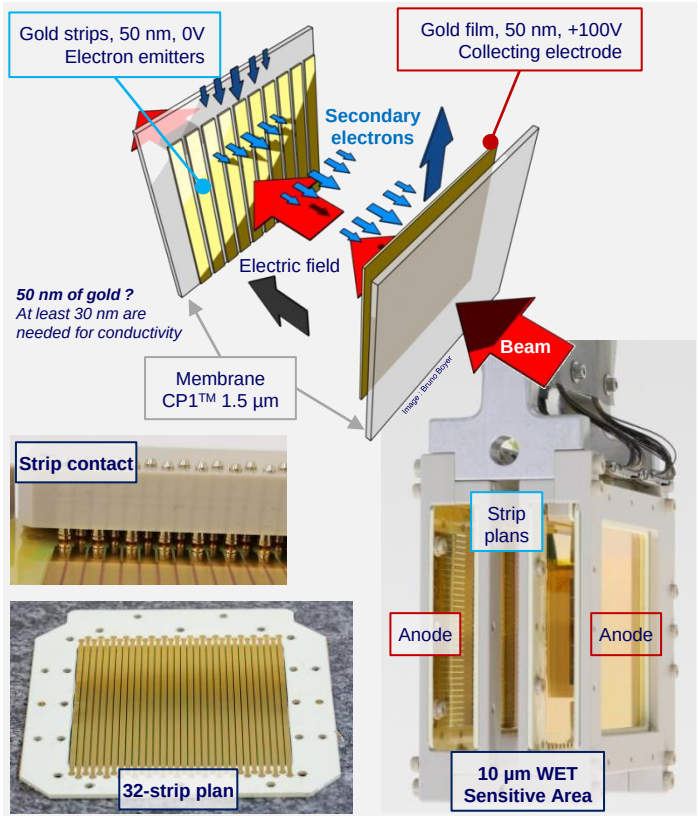
For the PEPITES Team

Overview

- PEPITES in a nutshell
- PEPITES @ CNAO: Main Target
- CNAO & LLR Team Activities
- Plans & Else

PEPITES in a nutshell

- **Secondary Electron Emission (SEE) beam profiler**
  - Why SEE for the signal ?
    - Only O(~10 nm) of material needed → Ultra-thin sensitive area
    - Very linear (well suited for Flash !)
  - Secondary e^-'s have low E (few eV) → Operate in vacuum
    - Fine for a beam monitor
  - Sensitive Area built with « Thin Film » techniques
    - Versatile techniques → Allows many variations



- **First version installed at ARRONAX**
  - In May 2022
    - Used since then for routine operations
  - **10 µm WET**
  - Low-noise & high-range readout elec.
    - Designed for continuous beam currents
    - By our CEA/DEDIP partner
  - 2 × 32 channels (X & Y beam sampling)

PEPITES @ CNAO: Main Target

PEPITES @ CNAO : Main Target

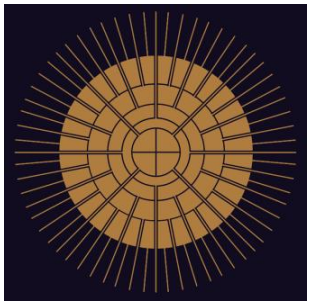
- **CNAO need for a distant monitor, 6.5 m from the patient**
  - Tolerable dispersion induced by the monitor : < 100 µrad
  - For a perfect beam entering the monitor, this translates into a
    beam size < 0.65 mm RMS at the patient level

- **Sensitive area options with PEPITES approach:**

Large cost increase

Geometry	CP1™ (1.5 µm) membranes	LuxFilm™ (0.1 µm) membranes
2 strip plans + 2 anodes plans = 4 plans in beam axis	~10 µm(*)	~2.5 µm
2 strip plans + 2 off axis anodes = 2 plans in beam axis	~5 µm(**)	~1.25 µm
2D pattern + off axis anode = 1 plan in beam axis	~2.5 µm	~0.63 µm

Large design change



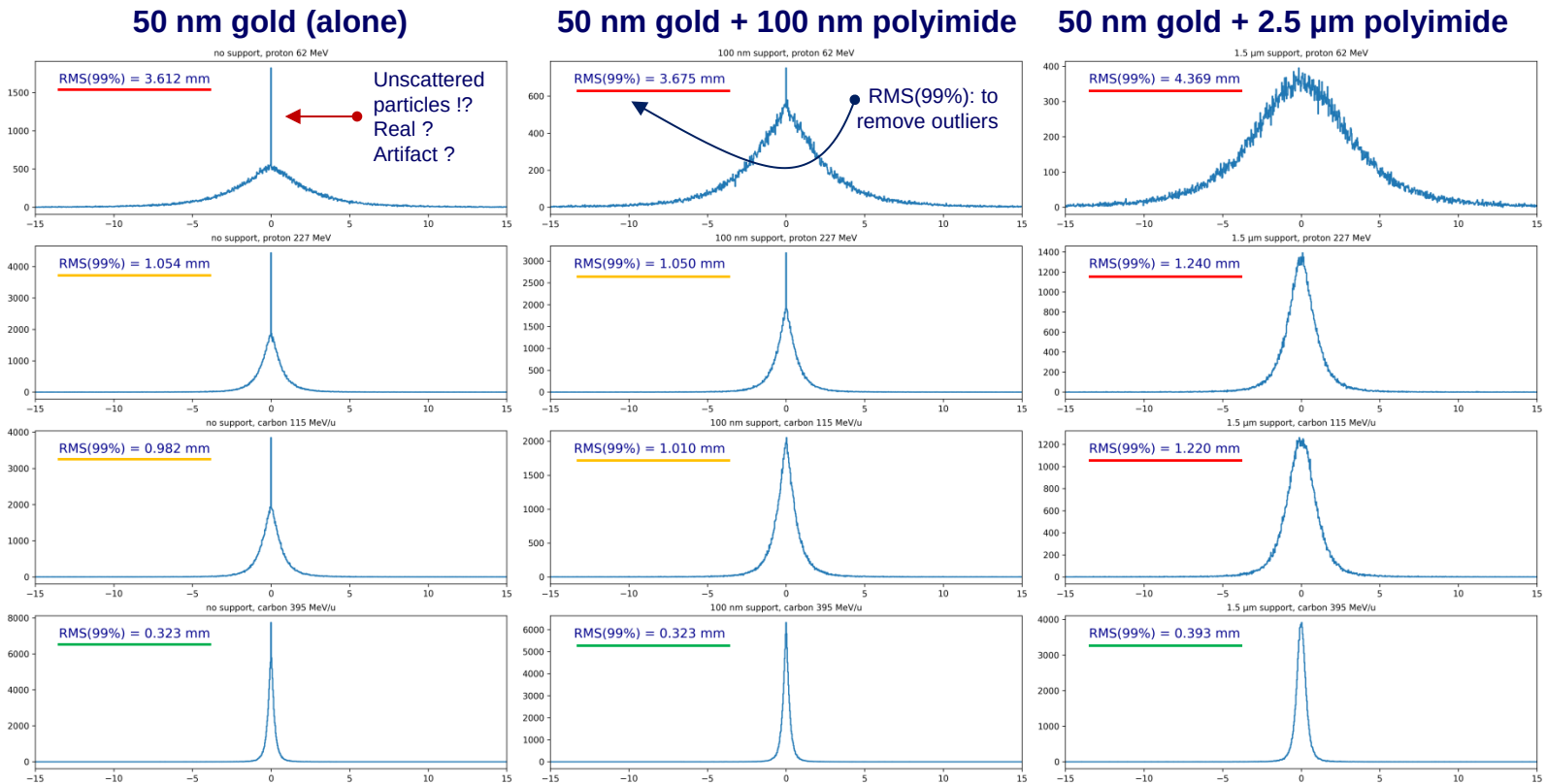
Example of a 2D pattern

- (*) The 10 µm WET version exists (ARRONAX)
- (**) The 5 µm WET version is discussed in this presentation

- We can simulate these various options to check the beam dispersion @ the patient level
  - Some simple Geant4 simulations shown after, Alessio Mereghetti has done similar simulations with FLUKA.
  - The difficulty: ultra-thin layers are not easy to simulate (few things to clarify, still…)

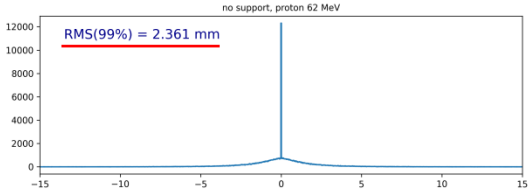
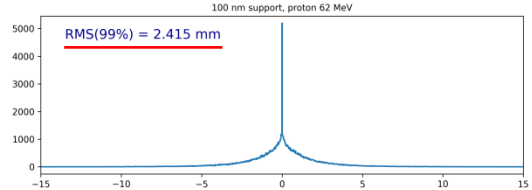
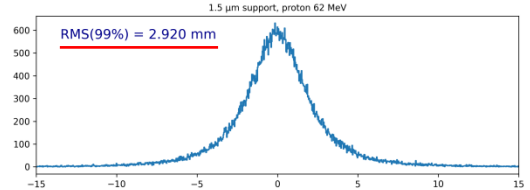
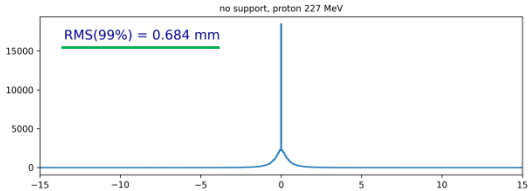
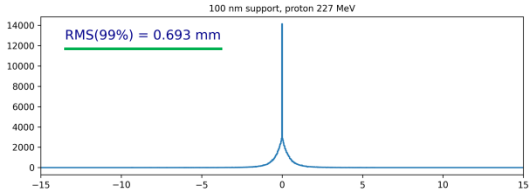
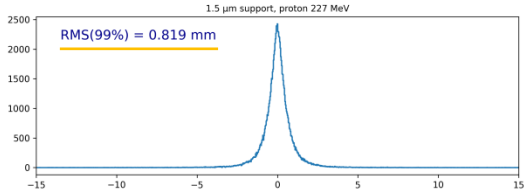
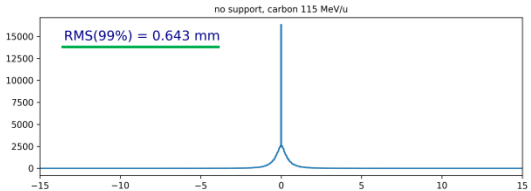
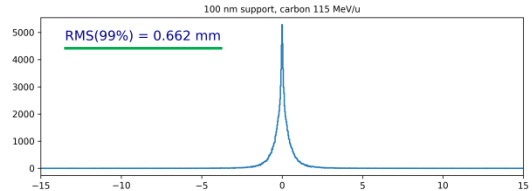
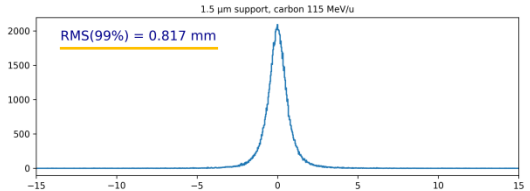
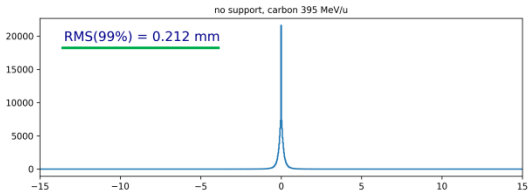
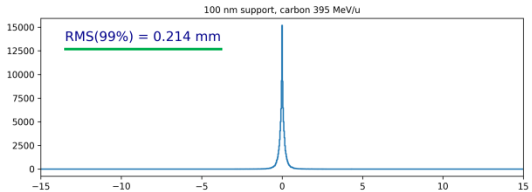
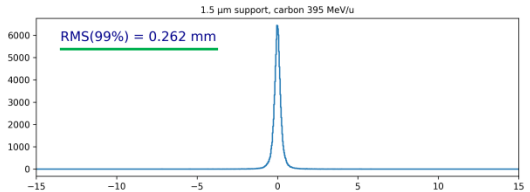
Beam Profile @ 6.5 m: 4 Plans in Beam

For a perfect (point-like, no divergence) beam entering the monitor



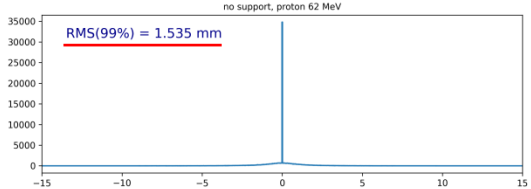
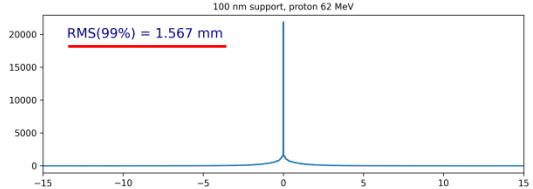
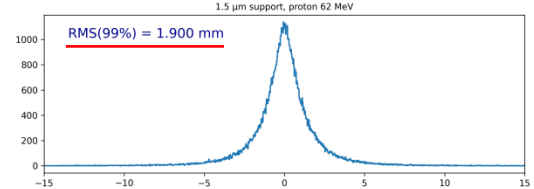
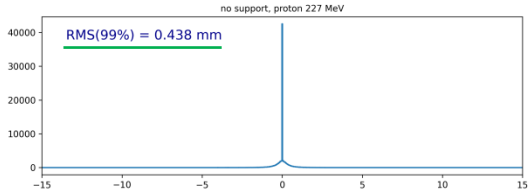
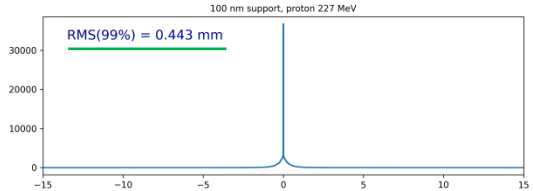
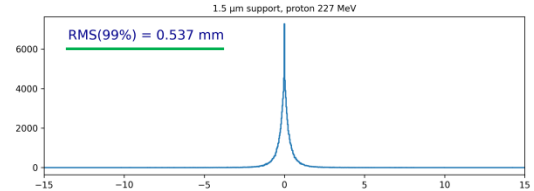
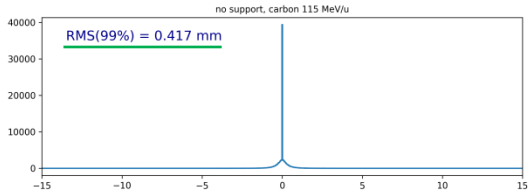
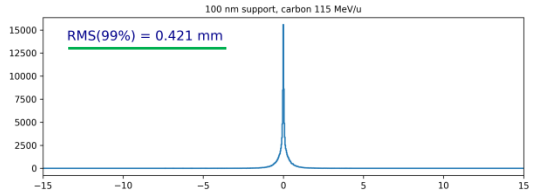
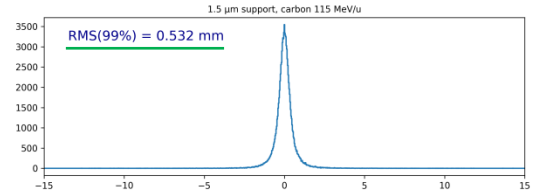
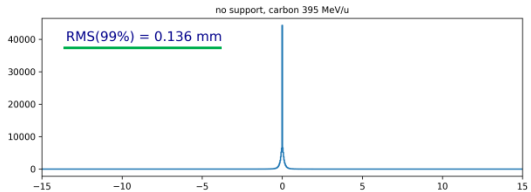
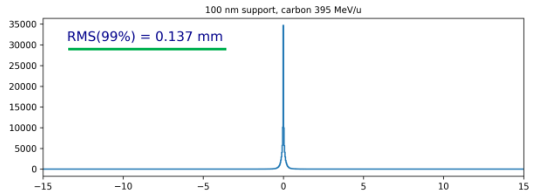
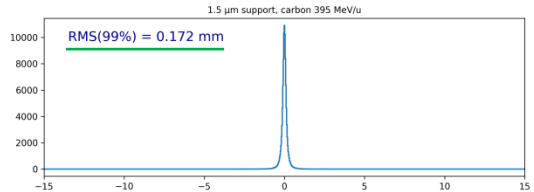
Beam Profile @ 6.5 m: 2 Plans in Beam

For a perfect (point-like, no divergence) beam entering the monitor

	50 nm gold (alone)	50 nm gold + 100 nm polyimide	50 nm gold + 2.5 µm polyimide
62 MeV p			
227 MeV p			
115 MeV/u ^{12}C			
395 MeV/u ^{12}C			

Beam Profile @ 6.5 m: 1 Plan in Beam

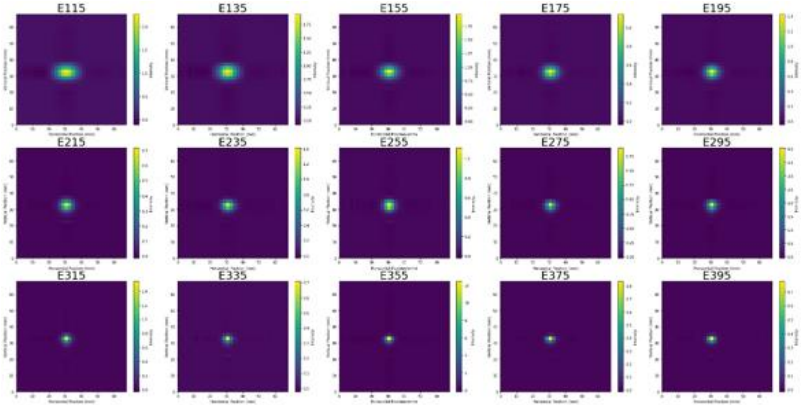
For a perfect (point-like, no divergence) beam entering the monitor

	50 nm gold (alone)	50 nm gold + 100 nm polyimide	50 nm gold + 2.5 µm polyimide
62 MeV p (Low E part difficult to deal with)			
227 MeV p			
115 MeV/u ^{12}C			
395 MeV/u ^{12}C			

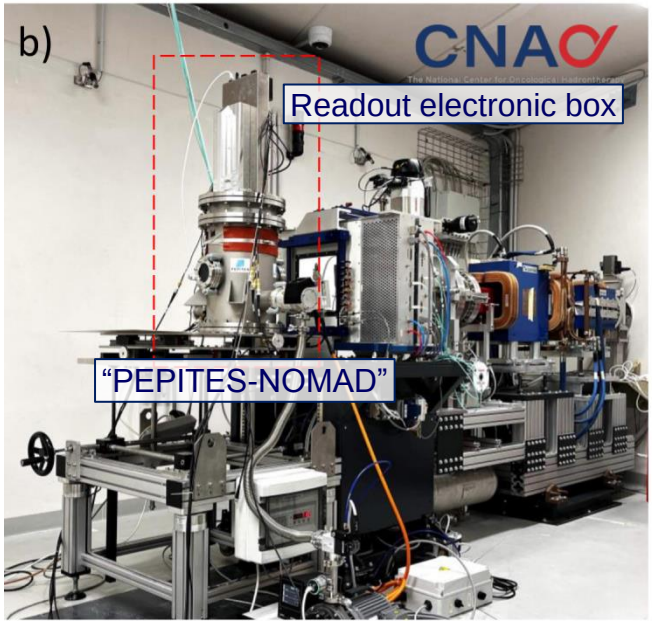
CNAO & LLR Team Activities

1st Test Beam, November 2023: First Carbon Ions measured by PEPITES

- Done with “PEPITES-NOMAD”
  - Copy of the ARRONAX PEPITES
    - With a copy of the readout electronic too
    - But with a standalone vacuum chamber
      - With 250 µm Kapton beam entrance and exit windows
- Performed energy scan with carbon ion beams
  - 115 – 395 MeV/u

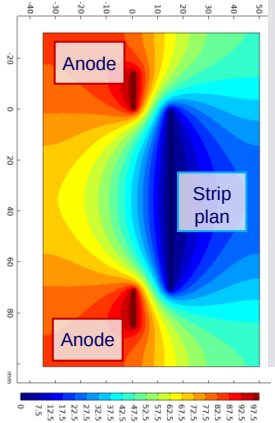


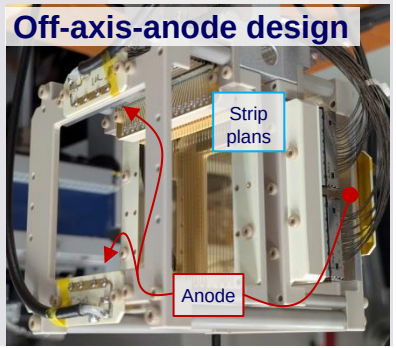
2D reconstructed beam transverse profiles

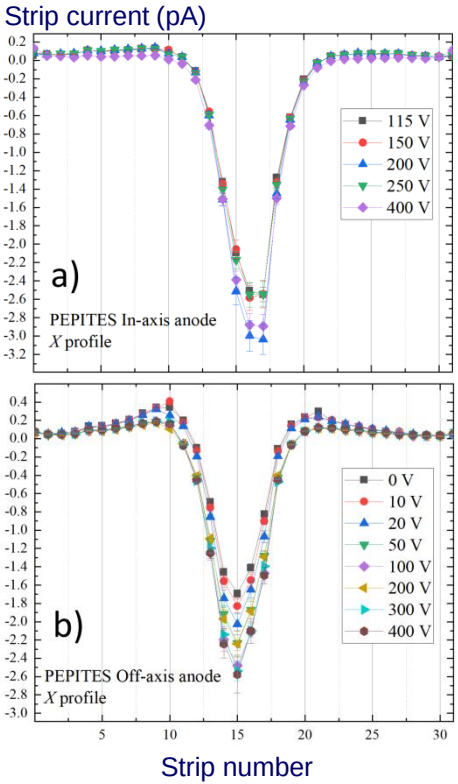


2nd Test Beam, September 2024: Test of “Off-Axis-Anode” Design

- Test of the “off-axis-anode” design:
  - Golden plan anodes removed
  - And replaced by metallic bars, placed outside the beam axis
- WET change: **10 → 5 µm**
- **But collection E field: uniform & parallel → ~~uniform & parallel~~**
- Effect on profiles ?
  - Topic of 2nd test beam
  - Moderate effect, because readout is on emission side



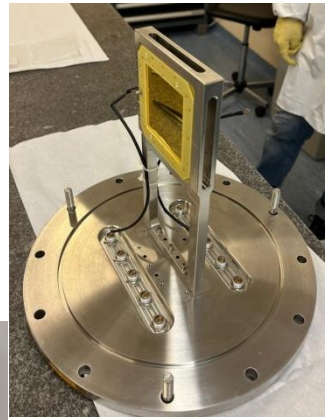


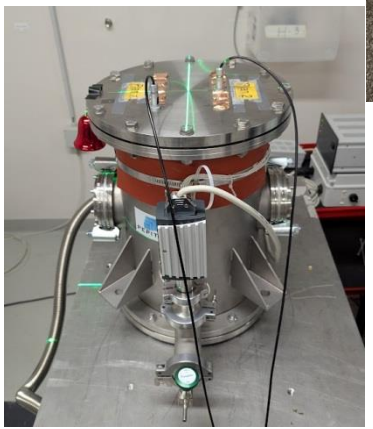


3rd Test Beam, April 2025: Electronic Tests & SEE Rate Meas.

- **Technical cross-check of readout**
  - Borrow ARRONAX' electronic box…
  - ..and compare results with NOMAD one
  - Some small differences seen
    - Slightly higher in the middle of profiles..
  - **Note:** during the past year, a test bench @ LLR has been brought up & running
    - Will allow to investigate such effects
    - Will allow to verify/calibrate the readout
- **SEE rate measurement**
  - SEE data at "high" (> 10 MeV) are scarce / do not exist
    - But needed for PEPITES to understand the signal
    - No data with "high E" carbon ions, to our knowledge
  - Dedicated apparatus to measure SEE rate
    - Two plain plans facing each other
    - Installed in the same NOMAD vacuum chamber

Sensor for SEE rate: Two plain plans facing each other, with a 1.5 cm gap.





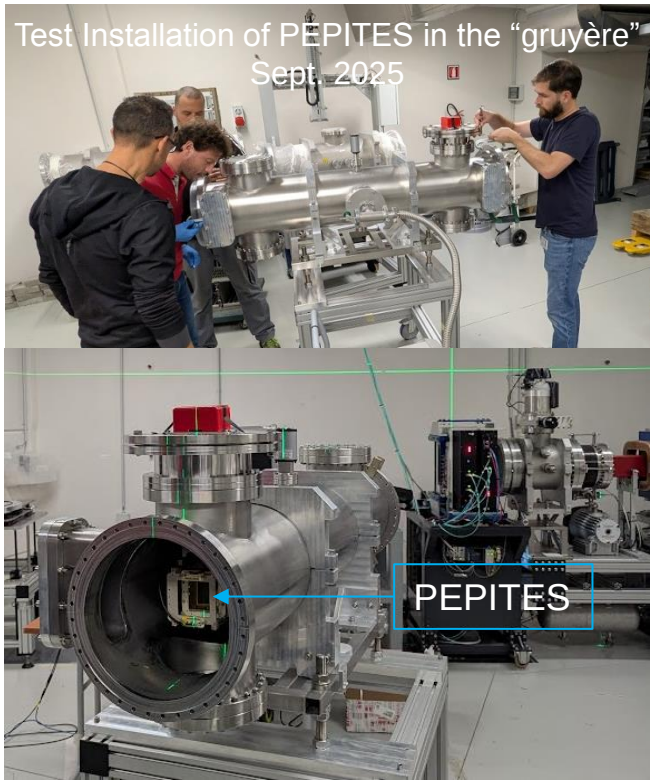
Sensor usage: Installed in the NOMAD vacuum chamber:
- one emitter plan
- one anode

Triax connection to Keithley

Next Test Beam: April 2026(*)
Alternative Readout & Realistic Conditions

- **Alternative Readout:**
  - The Torino group has developed a 64-channel charge measurement ASIC
    - That could be an alternative to the current PEPITES readout
  - Interface PCB built
    - to connect this electronic to PEPITES

- **Realistic Running Conditions:**
  - Up to now, PEPITES-NOMAD was used:
    - Ie, within the standalone vacuum chamber
  - So-called “gruyère” will be mounted on the experimental line
    - And will host PEPITES
  - Further tests are under discussion:
    - Measurement precision ?
      - Compare PEPITES meas. with known (how ?) profile coming on it
    - Dispersion measurement ?
      - On/off measurement to estimate the small dispersion du to PEPITES
      - But difficult meas.: additional sub-mm dispersion on a O(cm) beam !



(*) If budget allows !

Plans & Else

Plans

- **List of ongoing activities to pursue:**
  - Clarify the simulation
  - Discuss what to do with the low E part for protons
    - Removing PEPITES from the beam below some proton energy ?
  - Pending analyses (SEE rate, etc.)
  - State on Torino's electronic readout capability
  - Calibration test bench @ LLR
  - …
- **Going further:**
  - 2D sampling is put on the plate
    - New person, Emilia Becheva, at LLR, just starting using AI to reconstruct beam profiles with such sampling
    - One item: disentangle what is coming from the pads and what is coming from the connecting strips
  - Investing on ultra-thin (100 nm) polyimide ***will require significant support***
    - Not only the question of "buying it" (we will anyway ask the company to build the plans), it is also a question of getting experience and defining proper protocols to work with such advanced material
- Some good news:
  - In2p3 has offered a 2-year CNRS contract to PEPITES, to be filled from September

What Else ?

- The LLR PEPITES Team is also involved in:
  - **SPLIF/SPLASH:**
    - outreach projects for intensity/profile portable devices to work from continuous to Flash beams
    - Christophe is the PI
  - **BioALTO:**
    - Low E (few MeV – few tens of MeV) ions (p, He, ^{7}Li, ^{12}C, O) facility project in Orsay
    - Recently obtained a funding from “Région Ile-de-France”
      - With a part for providing a PEPITES-like monitor
    - Here also thinness is a challenge
      - Common issues with CNAO: opportunity for mutual benefit of projects ?
  - **SPARKS:**
    - An ANR project with LOA (Laboratoire d’Optique Appliquée, Palaiseau) and CEA/DEDIP which pre-proposal has just been accepted
      - Have to compete now for the proposal itself… response by this summer
      - Continuation of a CNRS-MITI project we had with LOA
    - A project for monitoring ultra-short (30 fs !!) beams from Laser-Plasma acceleration
      - Small beams, few mm^2, high cadency, LAPLACE facility
      - Ultra-ultra-thin (30 nm) Silicon Nitride may be an option to support the strips

Thank you !