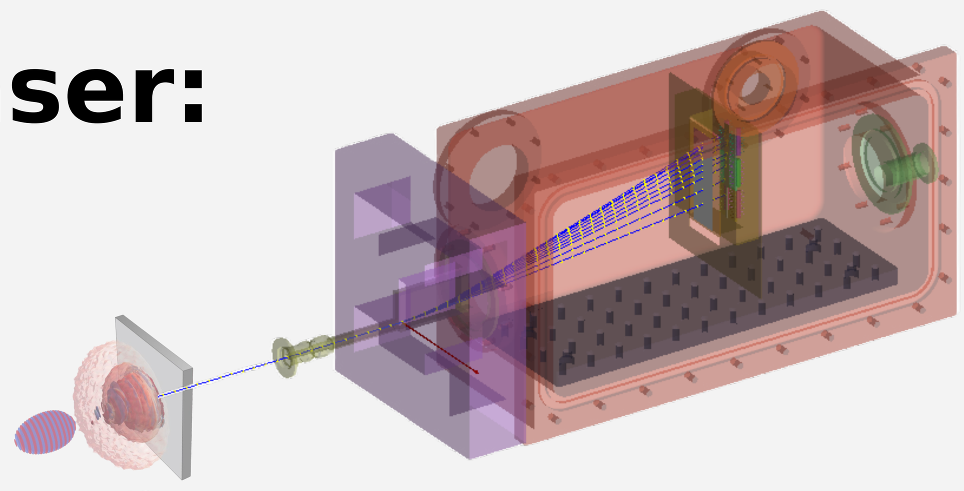
Experimental campaign on VEGA-3 laser: thin film targets investigation & magnetic spectrometer testing

F. Gatti[a]*, F. Mirani[a], A. Maffini[a], M.S. Galli De Magistris[a], M. Galbiati[a], K. Ambrogioni[a], D. Vavassori[a], D. Orecchia[a], D. Rastelli[b], A. Pola[a], J.L. Henares[c], A. Morabito[c], and M. Passoni[a]
[a]Department of Energy, Politecnico di Milano, Milano, Italy
[b]Raylab s.r.l., Caravaggio (Bergamo), Italy
[c]Centro de Láseres Pulsados, Salamanca, Spain
*francesco1.gatti@polimi.it

POLITECNICO MILANO 1863
ECLIM 2024 — 37TH EUROPEAN CONFERENCE ON LASER INTERACTION WITH MATTER
LISBON, PORTUGAL, 16-20TH OF SEPTEMBER 2024



Motivations and goals

Ion acceleration

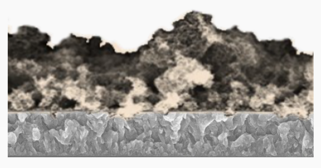
- **Short laser pulses** (10s fs) with **relativistic intensities** (10^{18}-10^{22} W/cm^2)

$$a_0 = \frac{eE_0}{m_e\omega_0 c} > 1$$

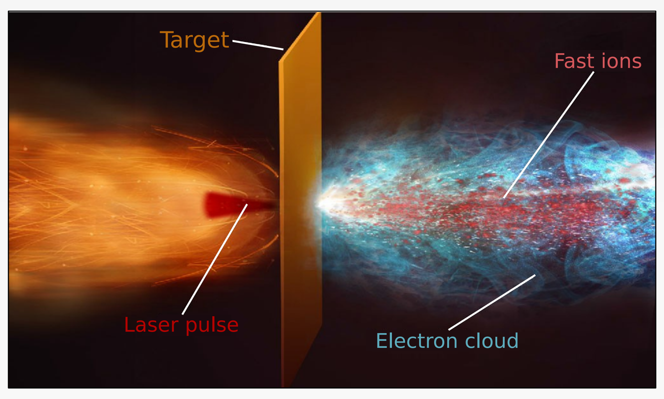
- Interaction with micrometric **solid foils**: Target Norma Sheat Acceleration (**TNSA**)
- **Plasma** generation: overdense regime $n_e > n_c$

$$n_c = \frac{m_e\omega_0^2\epsilon_0}{e^2}$$

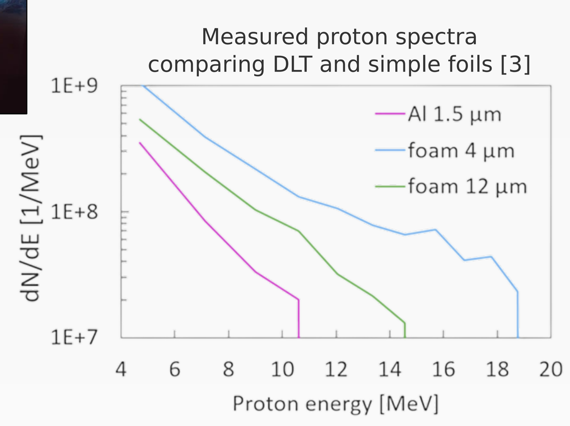
- **Acceleration** of high energy **e⁻** and **ions**: 1-10s MeV [1]
- **Enhanced TNSA** [2]: addition of **near-critical** material $n_e \approx n_c$
  - → **Double Layer Targets** (**DLTs**): few µm solid + ~10 µm low density
  - → **Volumetric** laser-plasma interaction
  - → Density: **few mg/cm³**



- **Control** and improve **energy and number of particles** [3]
- Potential **compact and flexible sources**
  - → Application in **materials science** (e.g. PIXE [4, 5]), **radioisotopes** production, ...

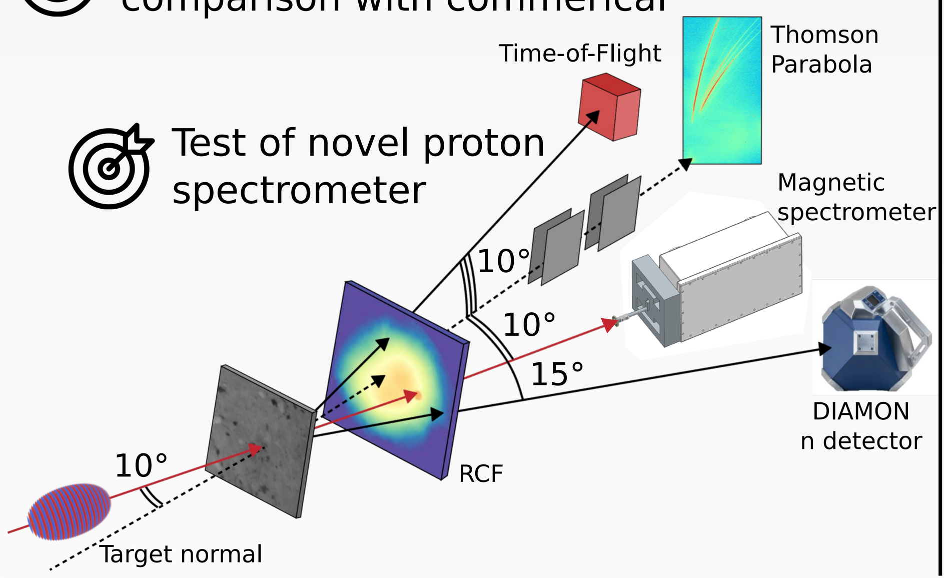


Need of **improved shot-to-shot stability** and **reliable diagnostics**



Experimental setup

- VEGA-3 laser:
  - 30-50 fs
  - 12 µm FWHM
  - 22 J (4 J in spot on target)
  - **~1.25x10²⁰ W/cm²**
- Test of deposited targets and comparison with commerical
- Test of novel proton spectrometer

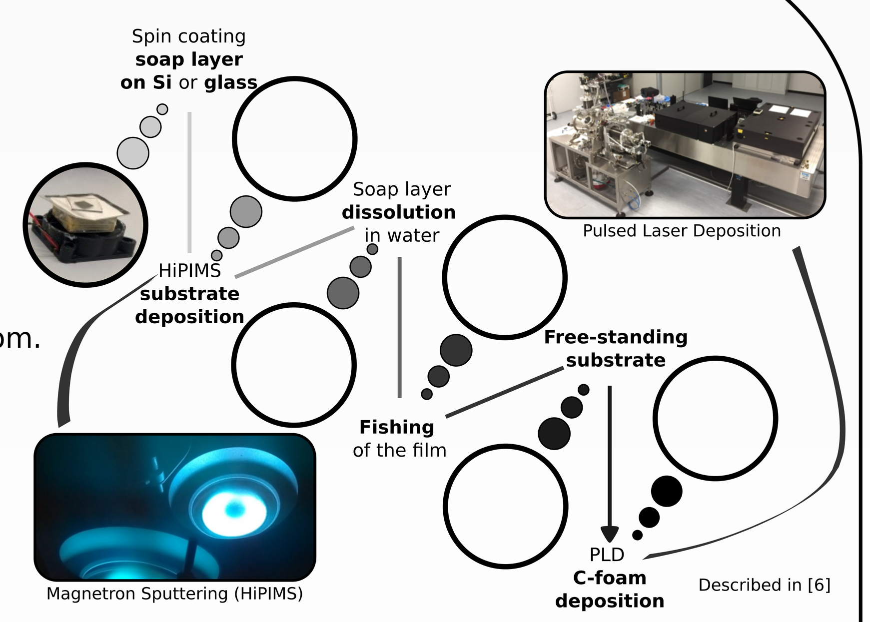


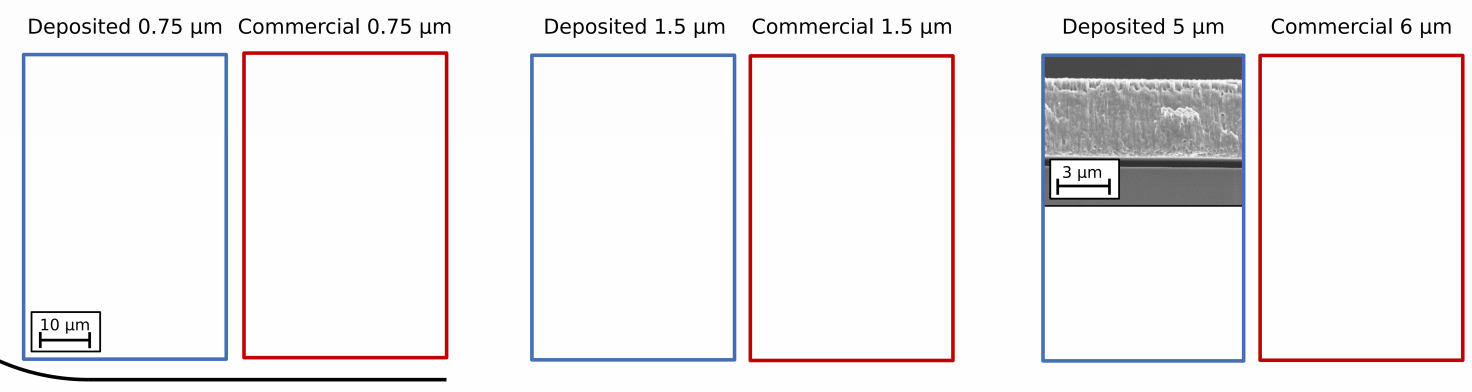
Targets characterization

- **Thickness** uniformity of Al targets assessed through EDXS maps in the range 750 **nm - 6 µm**

Deposited Al	Commercial Al
5% max deviation	25% max deviation & up to 40% difference from nom.

- **Carbon foam** [2] on **1.5 µm and 6 µm Al**:
  - **Avg. density** → ~6.4 mg/cm³ (1.2 n_c)
  - **Thickness** → 9, 18, 36, 54 µm (L_{sf})

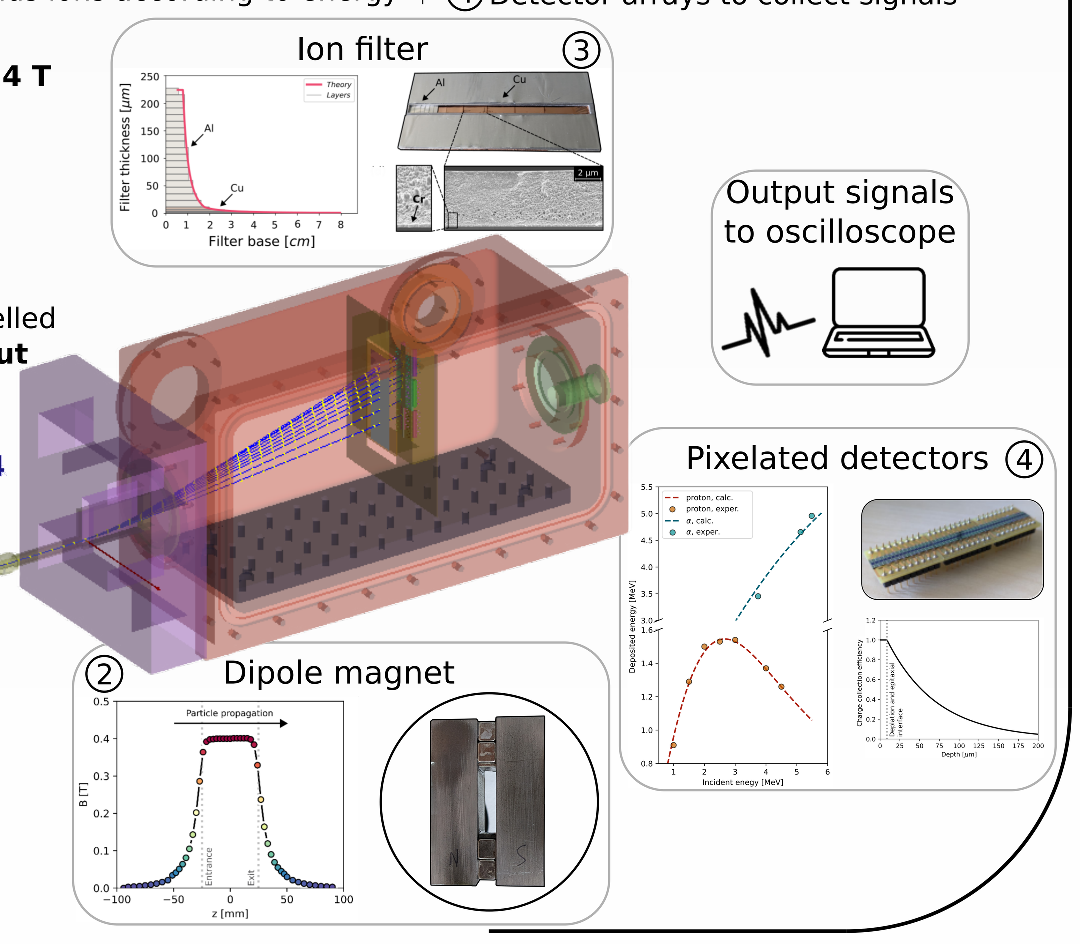


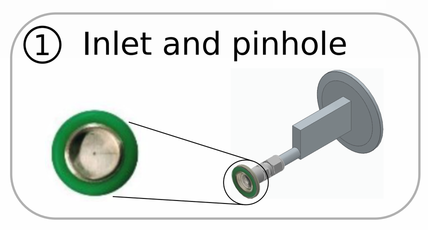


Spectrometer design

① Pinhole to select known small angle
② Magnet to spreads ions according to energy
③ Filter to remove heavy ions
④ Detector arrays to collect signals

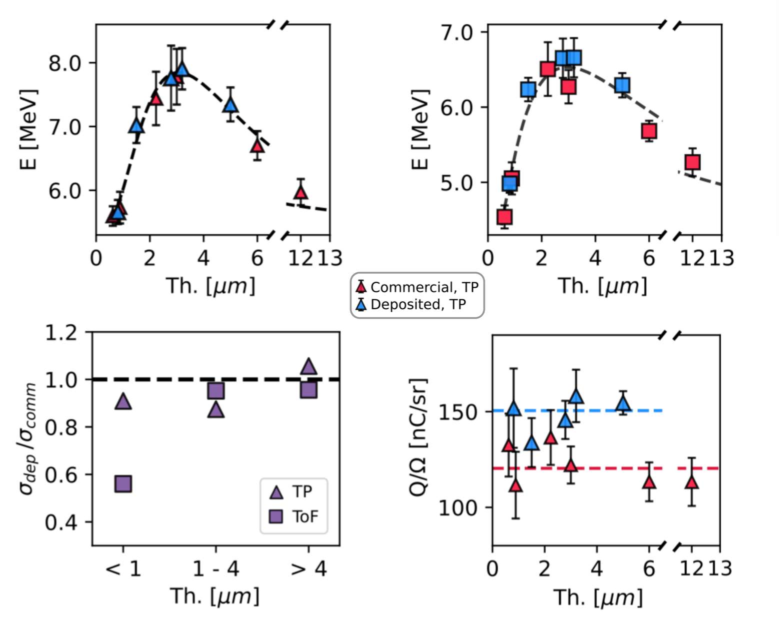
- Total size **< 50 cm**, with **5 cm, 0.4 T**
- Energy range and resolution: **0.40±0.01** - 72±15 MeV (Ref. value: **10.2±0.8** MeV)
- Detectors' **pixels** ~2 mm^2
  Charge Collection Efficiency modelled
  Voltage pulses amplitude **readout**
  → **Real time**
- **Response matrix** from Geant4
  → **Absolute calibration**





Ion acceleration results

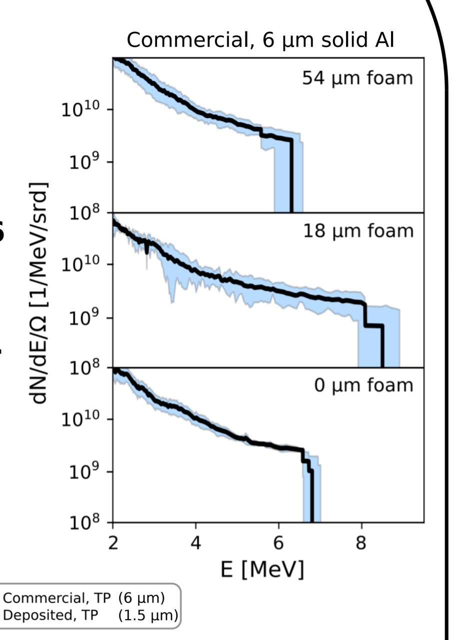
Deposited vs commercial

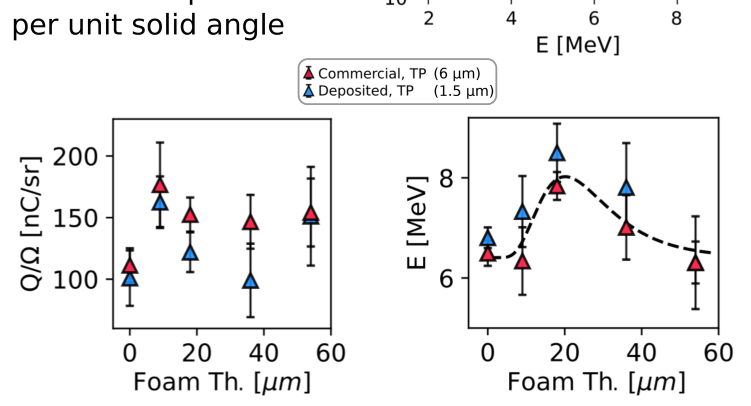


- Same E_{max} trend with thickness, peaked at **~3 µm**
- Very **similar cutoff** energy
- **Higher** shot-to-shot **reproducibility**
- About **30% more** accelerated protons per unit solid angle

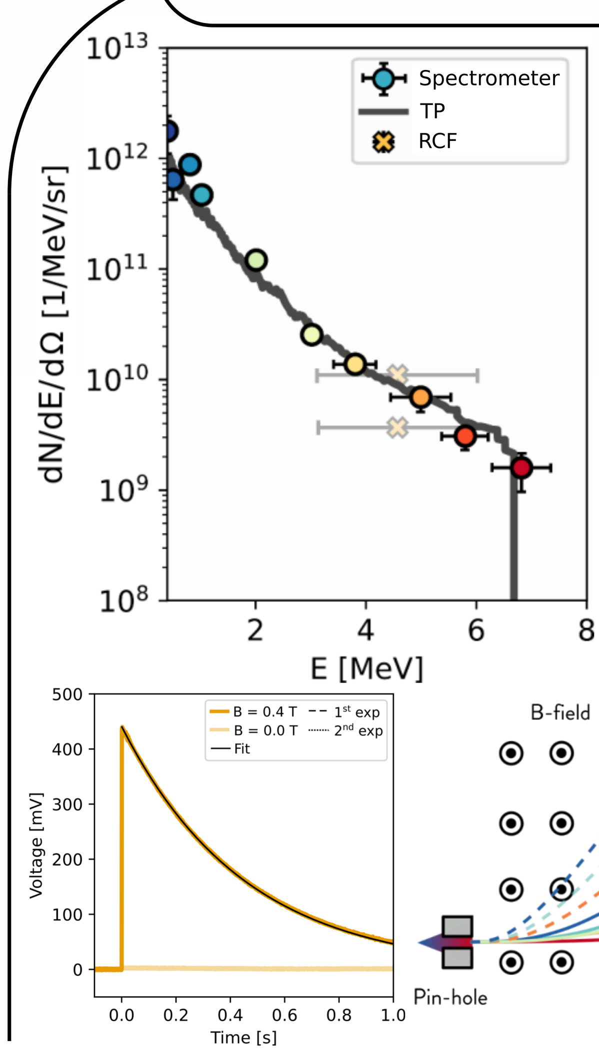
Single vs double layer

- Trend of E_{max} independent of substrate
- **Peak** between **18-36 µm foam thickness**
- About **2 MeV higher** cutoff energy
- About **70% more** accelerated protons per unit solid angle

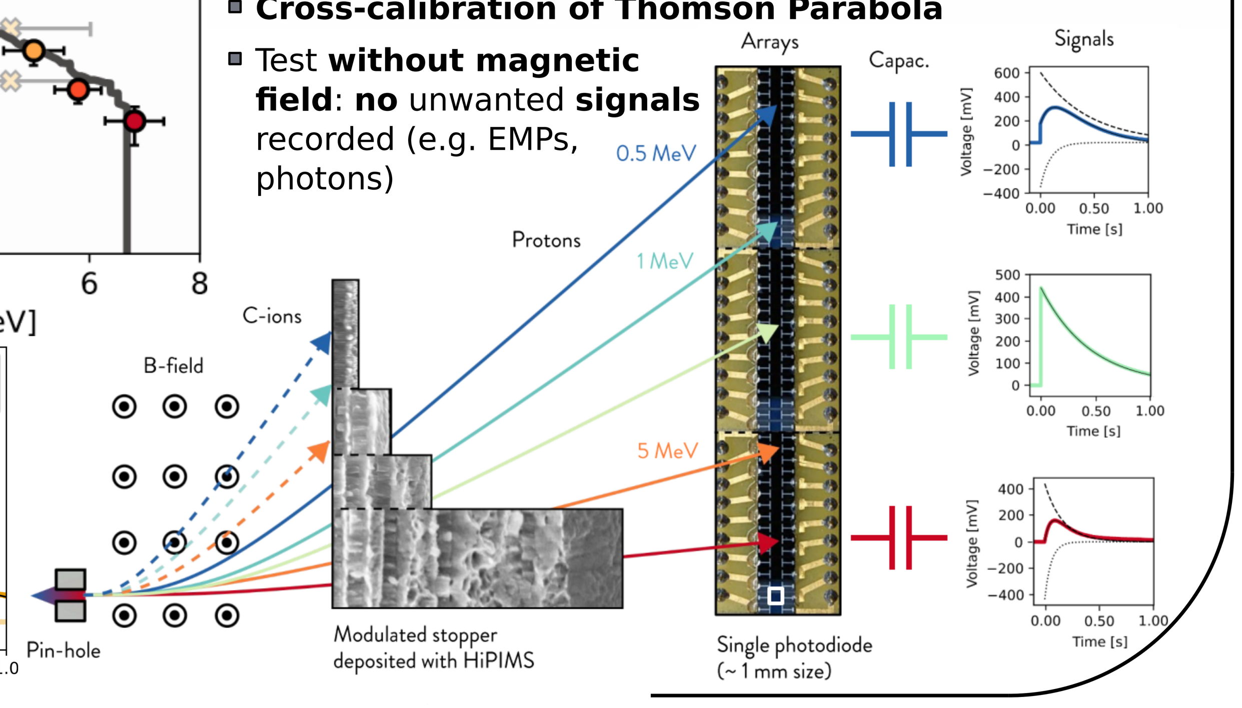




Measurements and comparisons



- **First test** in laser-driven acceleration experiment
- Front-end **electronics** sized **independently** for **each channel**
- Very good **qualitative agreement** with **Thomson Parabola** spectra
- **Quantitative agreement** with **RCFs** data
- **Cross-calibration of Thomson Parabola**
- Test **without magnetic field**: **no** unwanted **signals** recorded (e.g. EMPs, photons)



Conclusions and perspective

- **Commercial** rolled targets suffer of strong **fluctuation** of **thickness and surface quality**, with **detrimental effects** on accelerated ions
- **Optimized HiPIMS-deposited targets** can provide **better shot-to-shot stability** of accelerated protons
- **Carbon foams** of optimal thickness **enhanced** both **max energy and particle number**, while the solild layer is still of much relevance
- The developed **spectrometer** provided spectra in **accordance with the other diagnostics** employed
- The retrieved **proton numbers** were **in accordance with literature** results and were also **used to cross-calibrate the Thomson Parabola**

⇒

- Improvement in spectrometer **electronics and data**
- **Experimental campaign** @ eli scheduled for October

⇓

- Materials characterization with protons (**PIXE**)
- Use of both deposited **targets** and **spectrometer**

ERC-2022-PoC No. 101069171 PANTANI www.ensure.polimi.it
NanoLab
RAYLAB DETECTING INNOVATION
spin off
CLPU CENTRO DE LÁSERES PULSADOS

Bibliography:

[1] A. Macchi, et al., Rev. Mod. Phys. 85.2 (2013): 751.
[2] A. Maffini, et al., Appl. Surf. Sci. 599 (2022): 153859.
[3] I. Prencipe, et al., New J. Phys. 23.9 (2021): 093015.
[4] M. Passoni, et al., Sci. Rep. 9.1 (2019): 9202.
[5] F. Mirani, et al., Sci. Adv. 7.3 (2021): eabc8660.
[6] A. Maffini, et al., EPJ tech. instrum. 10.1 (2023): 15.
[7] F. Gatti, et al., IEEE Trans. Instrum. Meas., Accepted.