

Magnetic beam line to transport a few MeV laser-produced protons in air for PIXE applications



CNR-INO

ISTITUTO NAZIONALE DI OTTICA
CONSIGLIO NAZIONALE DELLE RICERCHE



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-) Introduction:

- 1) Particle induced X-ray emission (PIXE) with laser-accelerated particles
- 2) The LaserPIXE project

-) The 10 TW beam line Intense Laser Irradiation Laboratory

●-) Activities:

- 1) Pilot PIXE measurements in ambient air with laser driven source
- 2) Development of a compact magnetic beam line for few MeV protons

●-) Conclusions and Out-look

PIXE with laser-accelerated particles

PIXE is an Ion Beam Analysis technique to determine composition of near-surface layer(s) by characteristic X-ray emission using few MeV protons.

Motivation: few MeV protons can be efficiently generated by TNSA with ~ 10 TW laser allowing for compact PIXE apparatus.

Overview of PIXE related work with laser-accelerated particles:

-) *PIXE measurements* in vacuum from laser generated particles (protons+electrons)

[M. Barberio, S. Veltri, M. Scisciò & P. Antici, Scientific Reports, 7:40415, 2017]

-) *Simulation* of a beam line (quadrupoles+chicane) for PIXE with up to 20 MeV protons.

[M. Scisciò, M. Migliorati, L. Palumbo and P. Antici, Scientific Reports 8:6299, 2018]

-) *Simulation* PIXE experiments in *vacuum* with laser-accelerated protons

[M. Barberio and P. Antici, Scientific Reports 9:6855 2019]

-) *Simulation* PIXE experiments in *air* with laser-accelerated protons

[Passoni M, Fedeli L and Mirani F 2019 Sci. Rep. 9 9202]

-) *Simulation* experiment, highlighting the role of *laser-produced electrons* on PIXE signal

[M Passoni , FM Arioli, L Cialfi, D Dellasega , L Fedeli, A Formenti, AC Giovannelli, A Maffini , F Mirani , A Pazzaglia , A Tentori, D Vavassori, M Zavelani-Rossi and V Russo, 2020 Plasma Phys. Control. Fusion 62 014022]

The LaserPIXE project



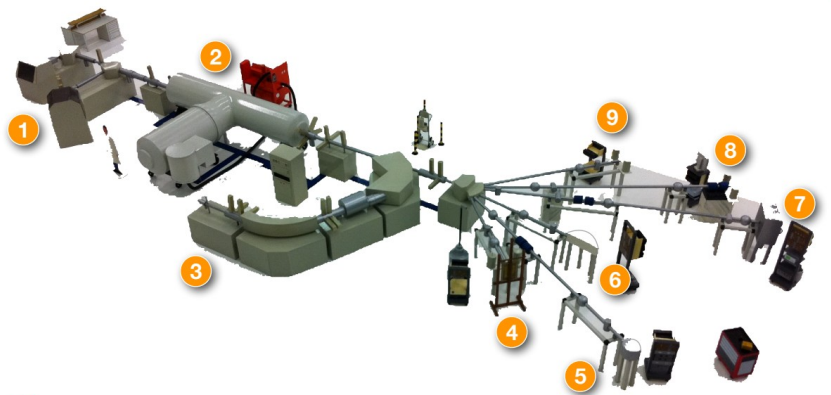
LaserPIXE is a technology Transfer project, co-funded by UE, through Regione Toscana, and VCS S.r.l (Parma-Italy), a company expert in custom vacuum chambers and components.

Research Partners: LABEC Laboratory (INFN-Florence), Institute of Clinical Physiology (CNR, Pisa).

Goal: design a *prototype proton laser-plasma accelerator* (up to ~ 3 MeV) to perform PIXE measurements in **ambient air**.

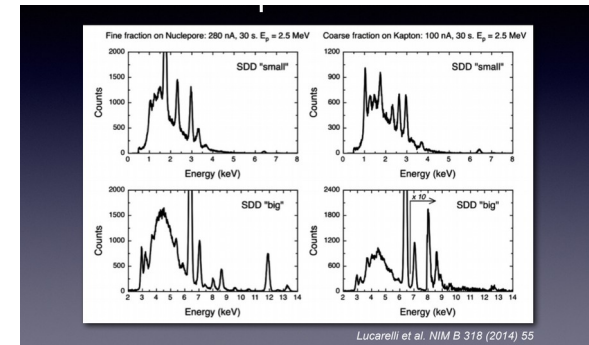


The LABEC laboratory in Florence



- 1 Ion sources
- 2 3MV Tandatron
- 3 AMS line
- 4 External beam (cultural heritage)
- 5 Scattering chamber (IBA)
- 6 Scattering chamber (nucl. physics)
- 7 Pulsed beam
- 8 External microbeam
- 9 External beam (aerosol)

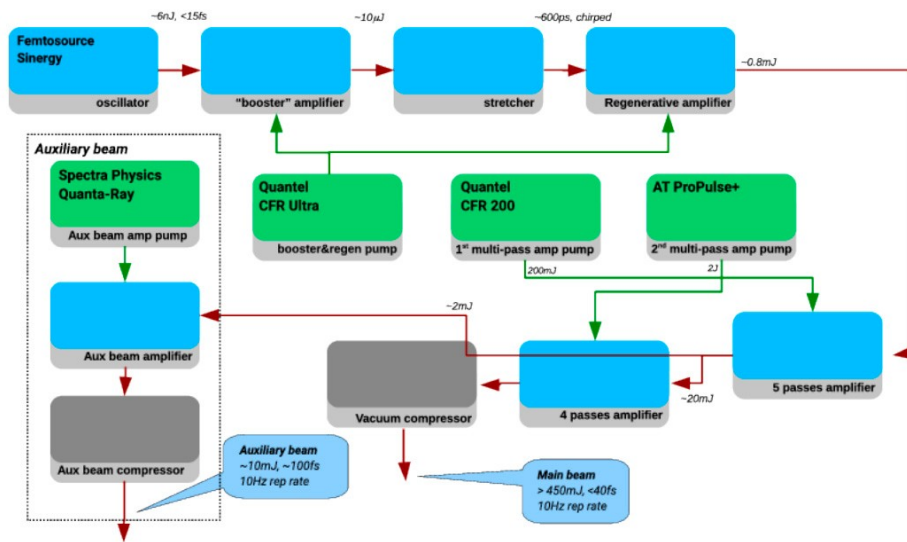
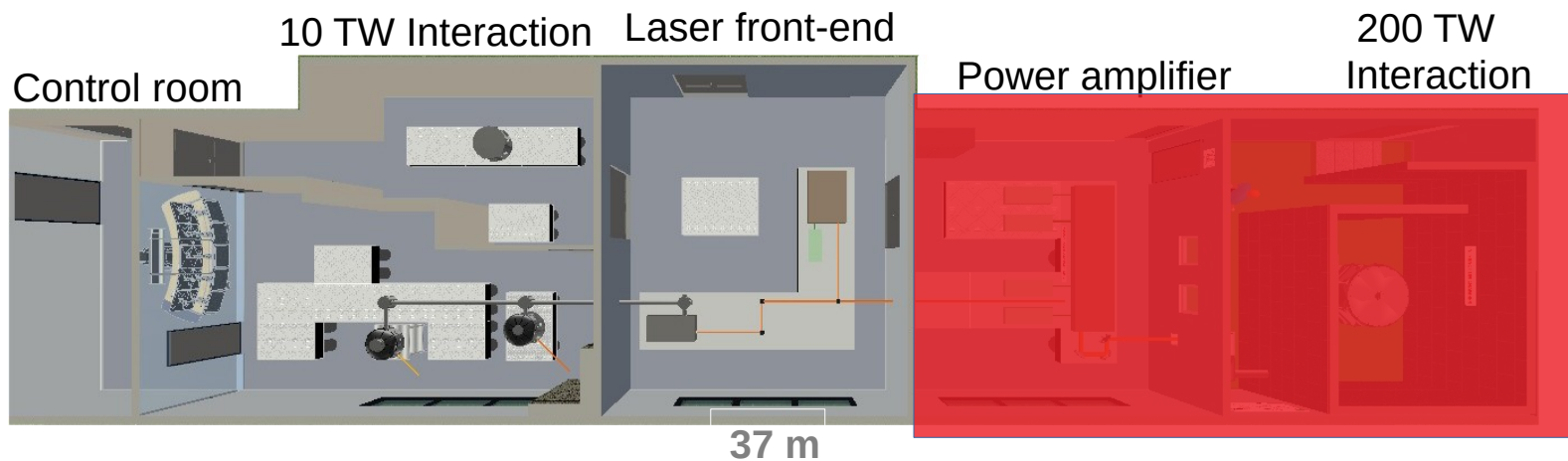
PIXE measurements at LABEC of aerosol from air quality monitoring stations.



Lucarelli et al. NIM B 318 (2014) 55

Courtesy of Massimo Chiari, INFN LABEC laboratory Florence

The laser system: 10 TW beam line

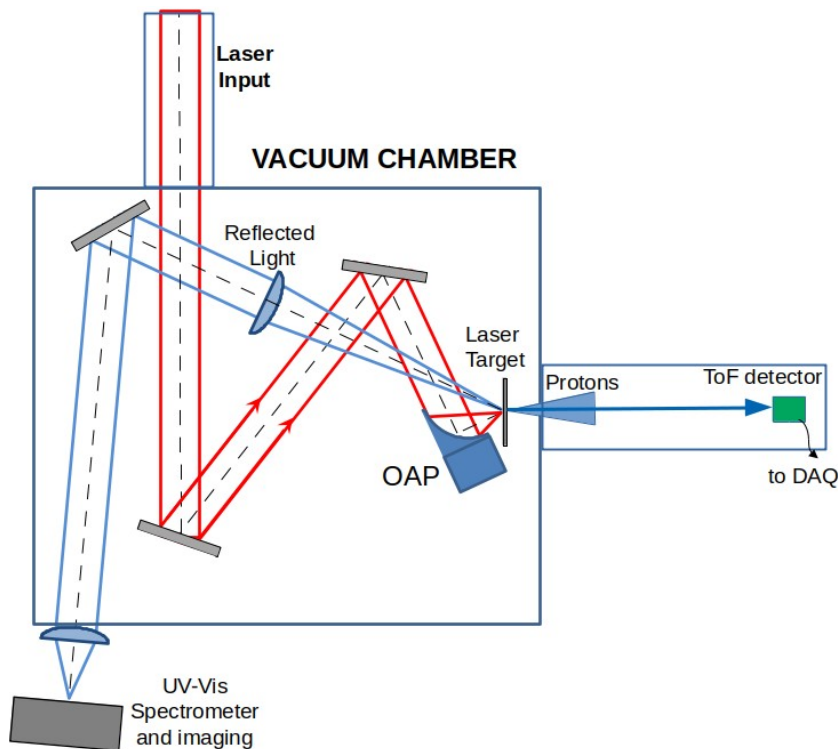


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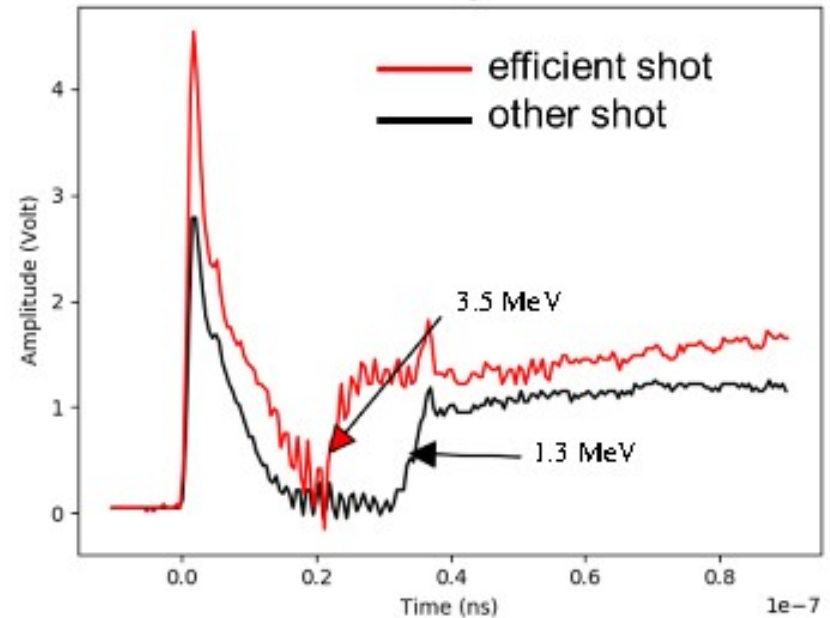


PIXE with laser-plasma based accelerators: production of ~ 3 MeV cut-off protons

-) Off-the-shelf Au coated aluminum OAP: f/1, 90 degrees,
-) Laser-plasma acceleration targets: Al 10 micron, Ti 5 micron.
-) ToF detector: PIN diode



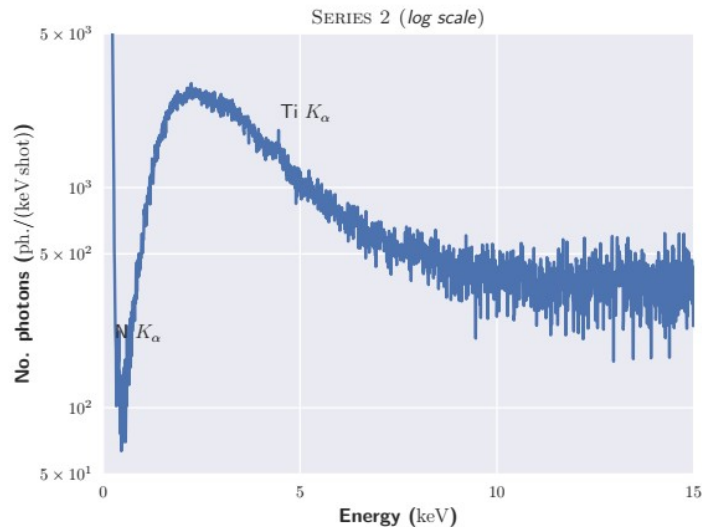
ToF measurements



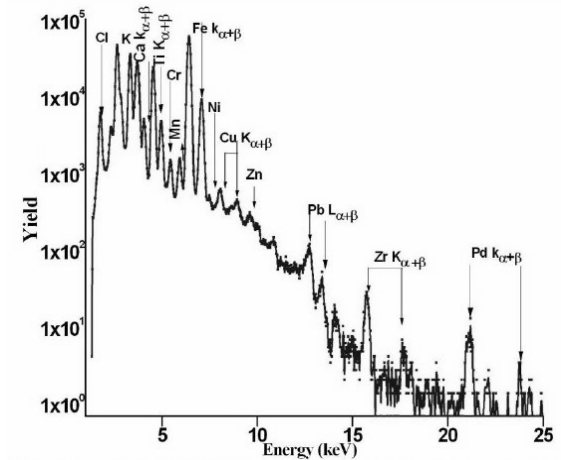
PIXE with laser-plasma based accelerators: pilot PIXE experiments in ambient air

Single photon Detection with a CCD X camera

Spectra averaging over 37 laser shots **Titanium**



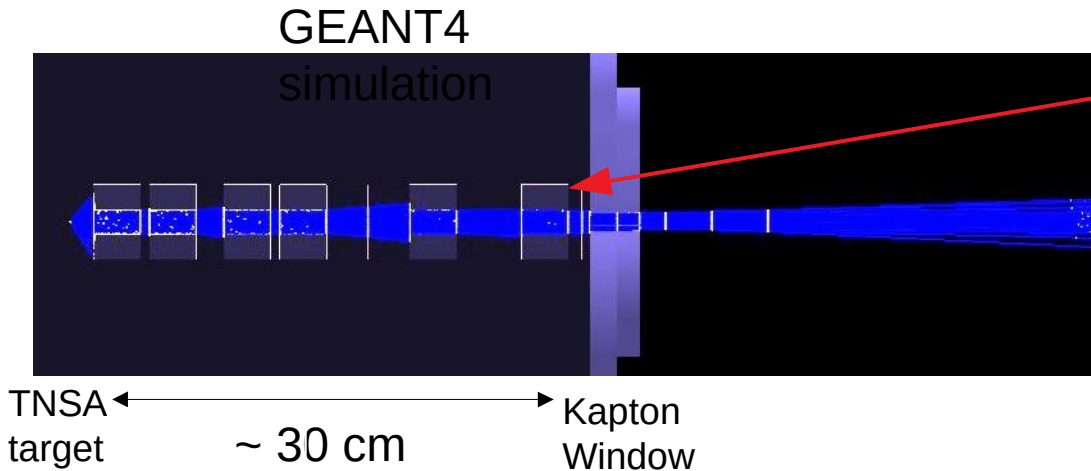
Protons air gap ~ 4 cm
X-ray photons air gap ~11 cm



A typical NIST reference esturine sediments sample PIXE spectra, Standard Reference Material 1646a. (International Journal of PIXE 21, 75, 2011), at 2 MeV.

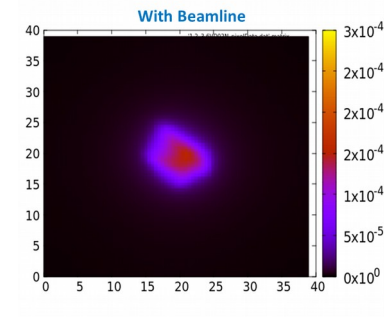
**The Kapton window gets damaged
and laser-generated electron are present**

Compact magnetic proton beam line between TNSA target and Kapton window: simulations



6 quadrupoles with permanent magnets

Spatial distribution



Over 1 cm diameter circle
at 1 cm from Kapton window
 $25 \cdot 10^6$ initial particles

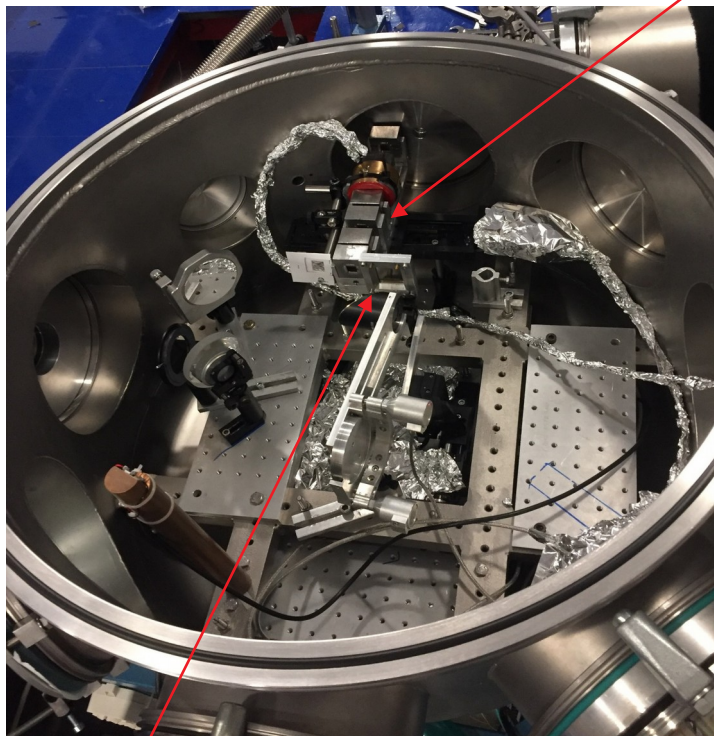
	2.4-2.6 MeV	2.9- 3.1 MeV
No. part. w/o Q	$5.7e+4$	$5.7e+4$
No. part. with Q	$2.1e+5$	$1.7e+5$

Compact magnetic proton beam line: experiments



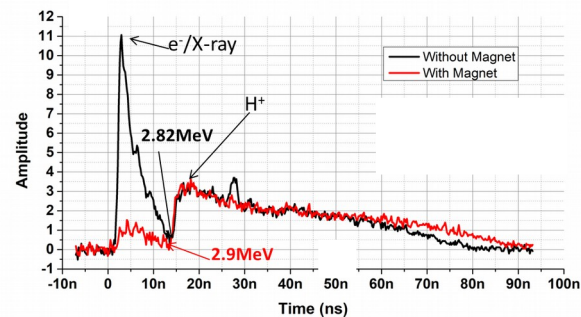
Experimental set-up

Magnetic quadrupoles



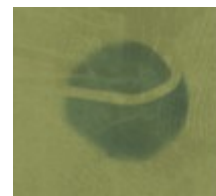
TNSA target

ToF measurements with PIN diode



EBT3 film

1 cm
After
Kapton



Conclusions



-) Pilot experiments have shown the feasibility of PIXE in air with laser-generated particles

-) A compact magnetic beam-line has been developed and tested

Out-look:

-) dosimetry of the proton beam in air.

-) PIXE experiments with proton beam in air.

Participants



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Thank You for the attention

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