Laser-driven hadron sources for materials science : assessing experimental feasibility

POLITECNICO MILANO 1863

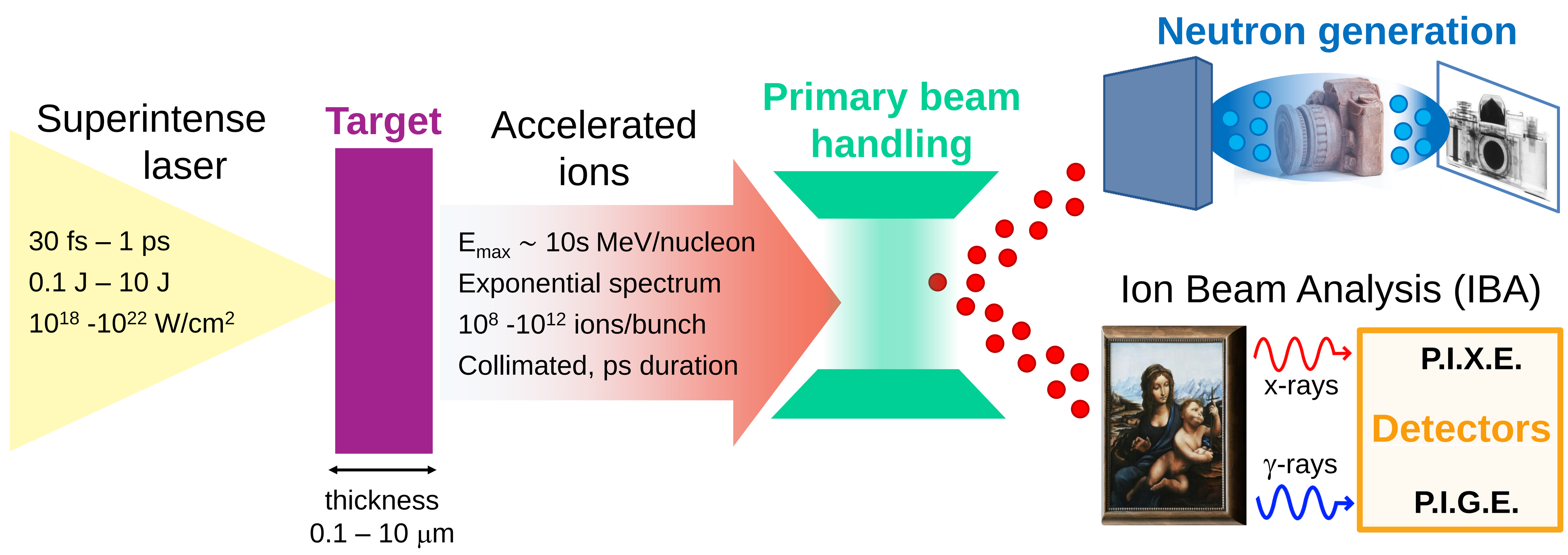
A. Maffini, F. Mirani, A. Formenti, L. Fedeli, A. Tentori, F. M. Arioli, A. Pazzaglia, D. Dellasega, V. Russo, M. Passoni

Dipartimento di Energia, Politecnico di Milano, Milan, Italy

NanoLab

erc ERC-2014-CoG No. 647554

Laser-driven hadron beams



Towards **a cheaper, portable alternative** to conventional accelerators

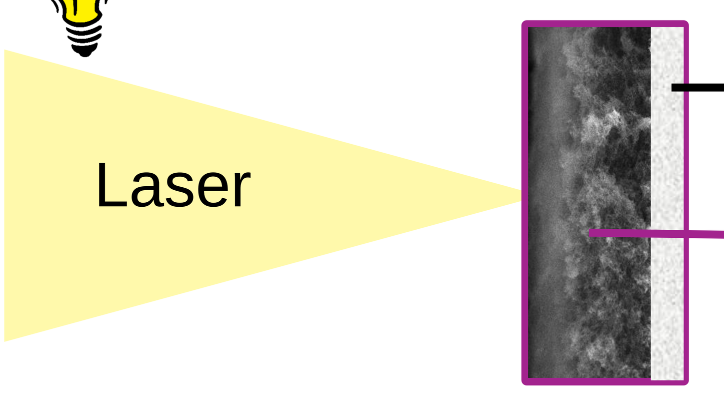
Laser-driven hadron beams for material science

Unconventional features to be explored:

- ✓ Non-monochromatic, tunable ion energy
- ✓ Pulsed, short duration of ion bunch
- ✓ Same laser, different applications

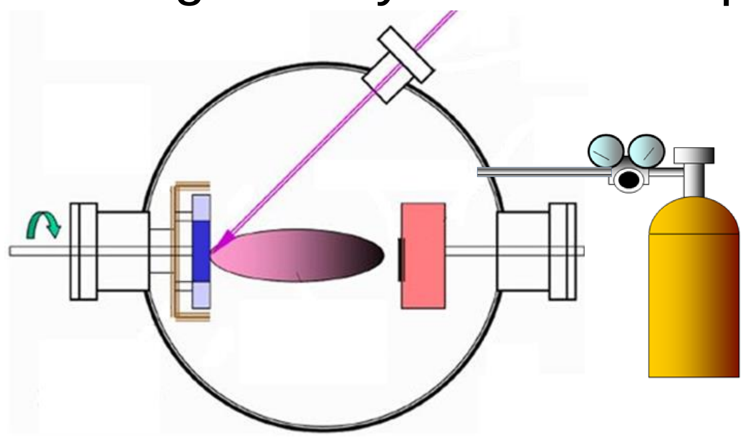
Advanced targets for laser-driven ions

idea: a **«near-critical»** layer to **enhance** laser-target **coupling**



$$\gamma \frac{m_e \omega^2}{4\pi e} \approx 6\ \mathrm{mg/cm^3}$$ (<10 x air density!!!)

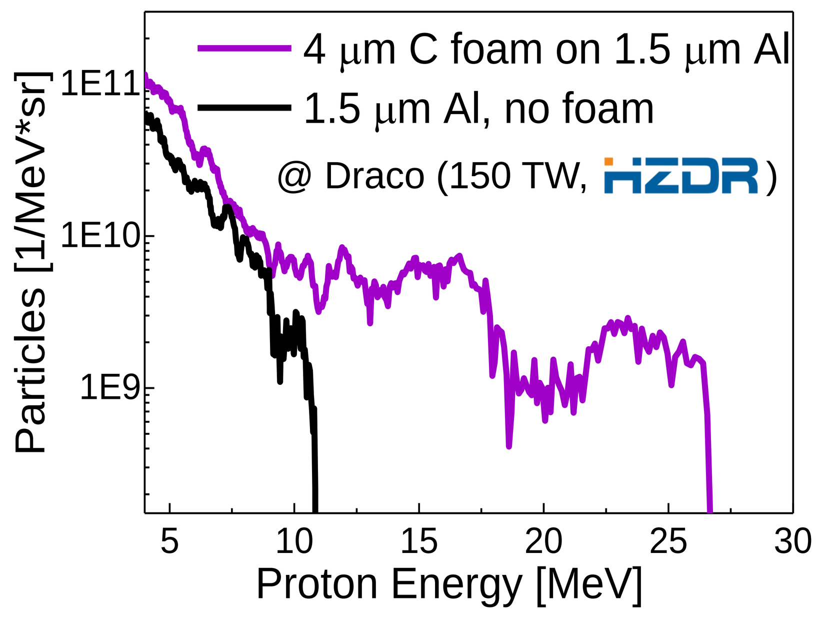
Foams grown by **PLD** technique



- ✓ Controlled nanostructure and composition
- ✓ Tunable density (6 – 100 mg/cm²)
- ✓ Virtually any kind of substrate

A. Zani et al., *Carbon* **56** (2013) 358-365

Foam-based targets do the job!

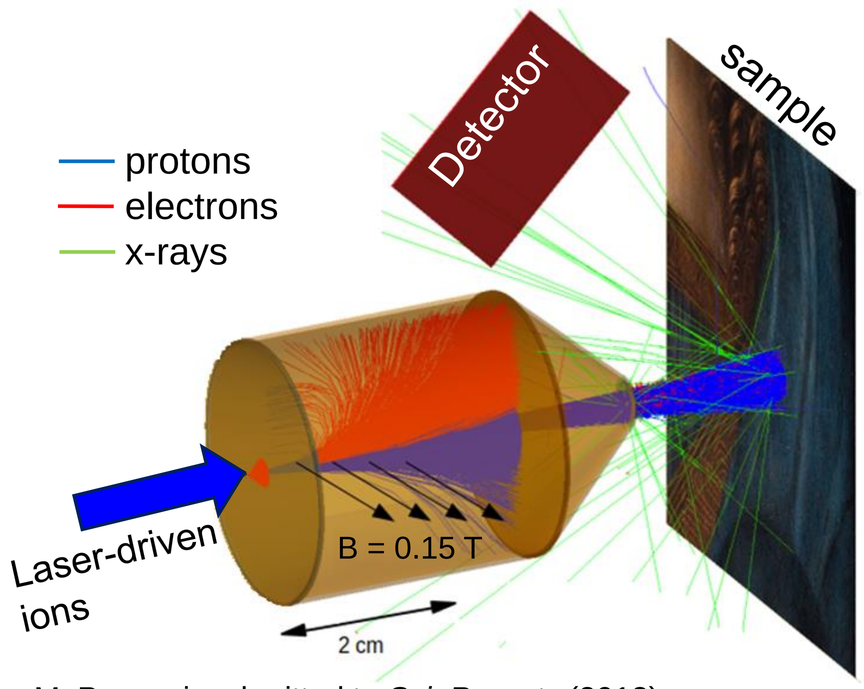


M. Passoni et al., *Phys. Rev. Accel. Beams* **19**, 061301(2016)

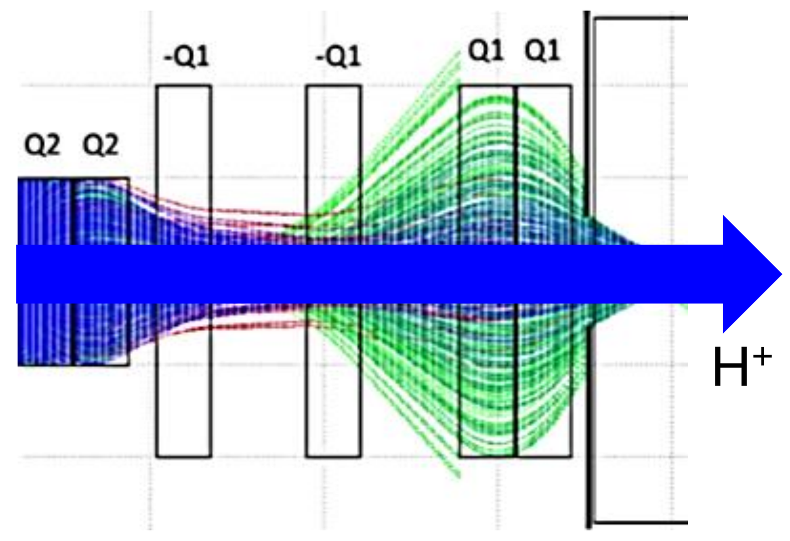
Primary beam handling

➢ Magnetic **dipole**
- ✓ Simplest and cheapest setup
- × No collimation of the beam
- × Spatial energy spread

➢ **Quadrupole** system
- ✓ Charge separation plus collimation
- × Expensive, difficult to plug-in
- × Optimized for a specific spectrum



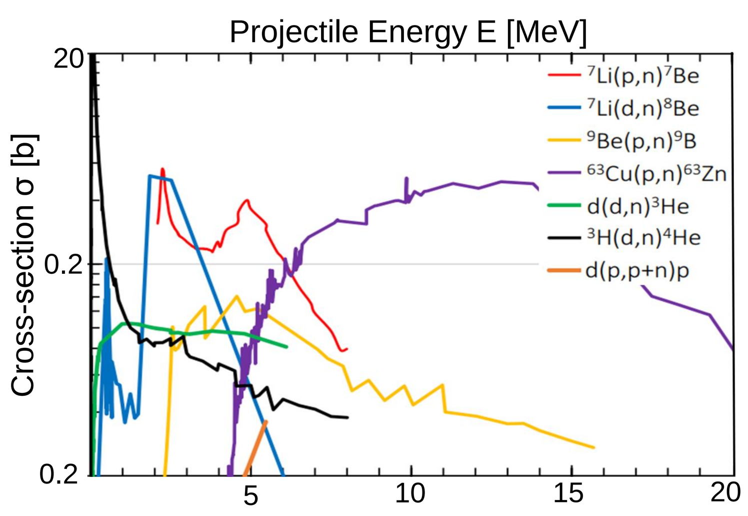
M. Passoni, submitted to *Sci. Reports* (2018)



M Sciscìo et al., *Sci. Reports* **8** (2018), 6299.

Neutron conversion engineering

Pitcher-Catcher reactions

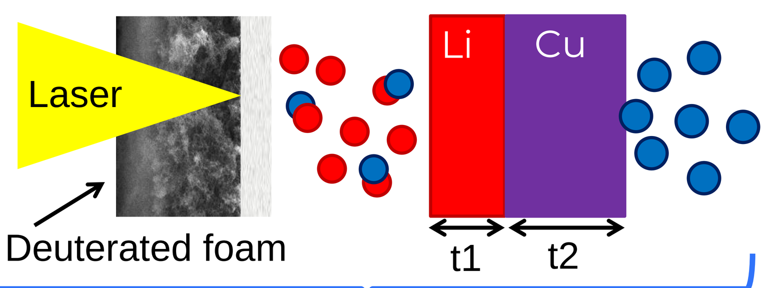


adapted from: A. Alejo et al., *Il Nuovo Cimento* **38 C** (2015) 188

Material choice

	Pros	Cons
Li	High σ at low energy Both (p,n) and (d,n)	Explosive Low melting point
Be/ BeO	Acceptable σ at moderate energy	Highly toxic Hydrogen embrittlement
Cu	High, broad σ for E>5 MeV Easy manufacturing Excellent heat conduction	Very low σ for E<4 MeV

Advanced configuration



Theoretical / numerical investigation!

Thickness optimization

Thinner	Thicker
Not all ions converted	All ions converted
Less neutron scattering → More directional → Higher energy	More neutron scattering → More isotropic → Less energy
Easier to reach $T_{melting}$	Lower thermal stresses

Detectors for laser-driven PIXE

Detector requirements

"**Standard**" requirements
- ➢ High detection efficiency
- ➢ High X-ray energy resolution

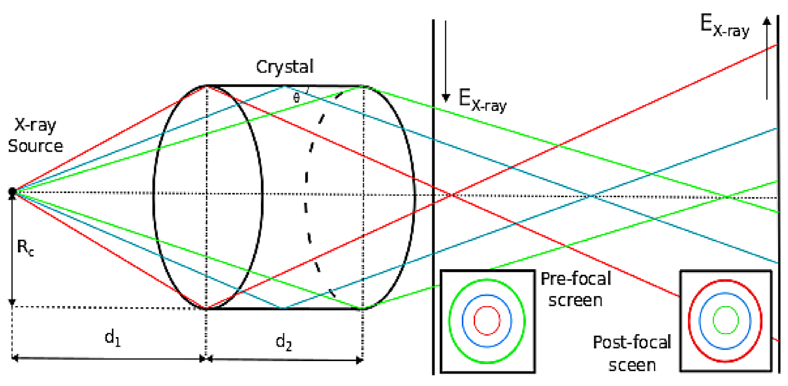
+

Laser-driven constraints
- ➢ Rejection of "noise" from laser-plasma
- ➢ Very short (few ns) x-rays / γ-rays burst

Conventional detectors **not** suited for **laser-driven PIXE**

Proposed solutions:

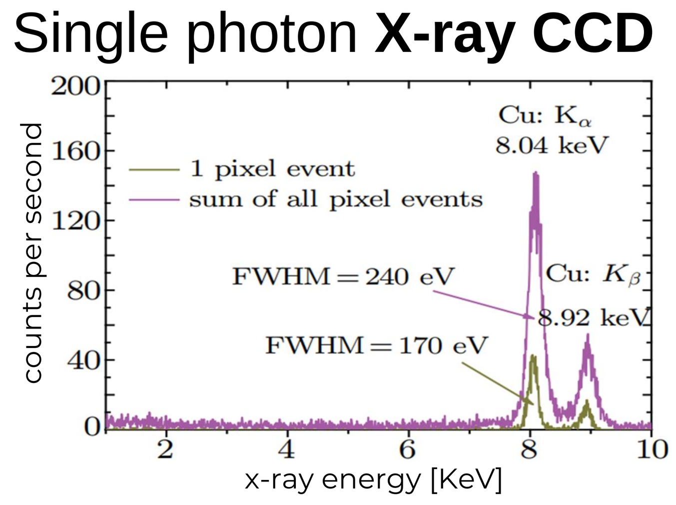
Von Hamos Spectrometer



- ❑ Passive detector
- ✓ High energy resolution
- × Low detection efficiency
- × Complex, expensive setup

L. Anklamm et al., *Rev. Sci. Inst* 85.5 (2014) 053110

Single photon **X-ray CCD**



- ❑ Active detector
- × Lower energy resolution
- ✓ Higher detection efficiency
- ✓ Relatively simpler & cheaper

Wei Hong et al., *Chin. Phys.* **B 26**, 025204 (2017)

Conclusion and perspectives

1) **Foam attached target**: to enhance the ion acceleration mechanism

2) **Beam handling:** dipoles & quadrupole to clean and collimate primary ions

3) **Neutron converter**: to be optimized also exploring unconventional solutions

4) **PIXE detector**: diffractive crystals and CCDs are best suited

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ERC-2014-CoG No. 647554 ENSURE — Assess the feasibility of a compact laser-driven proton source for material science applications

ERC-2016-PoC No.754916 INTER — Design of an Innovative Neutron source for non destructive TEsting and tReatments

SourceLAB CLPU

Experimental campaigns in preparation!