Study of stray radiation at a laser-driven ion beamline

P4F Colloquium 2026

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ELI Beamlines

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- High-power laser interacts with a thin target
- Produces energetic ion beams
- Ultra-short, high-intensity pulses
- Compact alternative to large accelerators
- Target normal sheath acceleration (TNSA): most common and robust mechanism

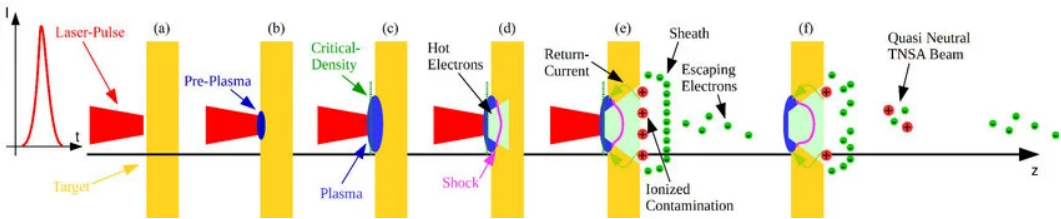
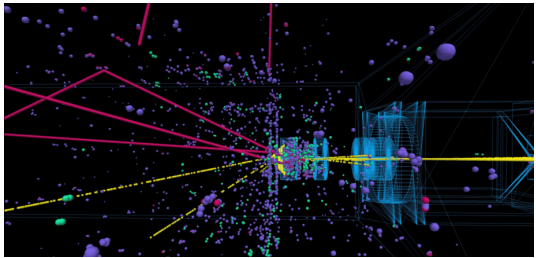


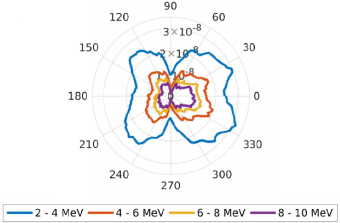
Figure: TNSA process leading to laser driven proton acceleration. [1]

Secondary Radiation Production

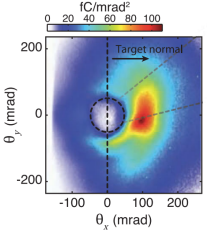
- Laser–target interaction generates prompt radiation
- Emission of photons (Bremsstrahlung) and electrons
- Additional radiation from beam interactions with beamline components
- Mixed, pulsed radiation field with broad energy distribution



PHOTON production [2]

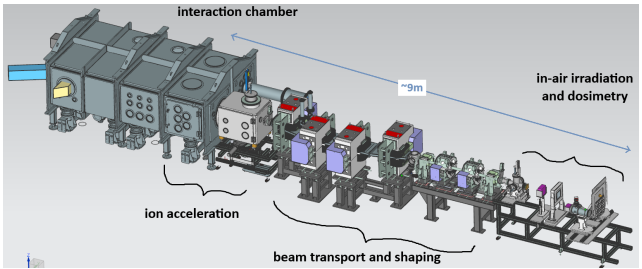


ELECTRON production [3]



ELIMED Beamline and Radiation Challenges

- Affects diagnostics and measurements
- Contributes to unwanted radiation dose
- Relevant for medical and research applications
- Requires accurate characterization

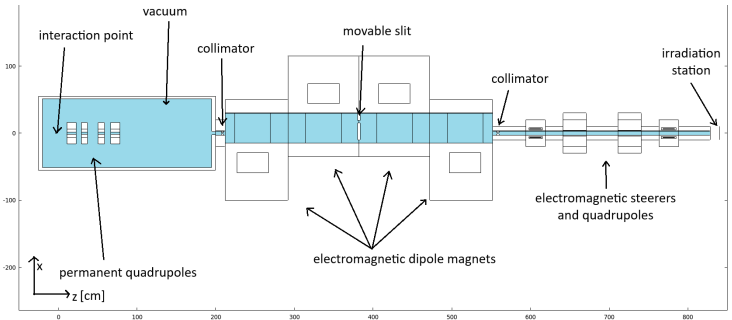


ELIMAIA-ELIMED:

- ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) at ELI Beamlines [4]
- ELIMED (ELI MEDical applications) [5]
- L3 HAPLS (The High-Repetition-Rate Advanced Petawatt Laser System) laser [6]
- ELIMAIA currently uses 10 J, 30 fs pulses at 0.2 Hz and provides proton beams with up to 40 MeV
- Used for studies in radiobiology, material science, cultural heritage

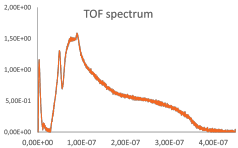
- Particle transport and interactions simulated
- Realistic ELIMED beamline geometry
- Includes ions, electrons, photons, and neutrons
- Beam source from PIC simulations, refined with experimental data
- Predicts radiation sources and spatial distribution

ELIMED beamline modeled in FLUKA [7,8]:

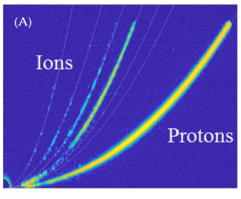


- Ion beam characterization:
  - Time-of-Flight (TOF) → energy spectrum
  - Thomson Parabola (TP) → ion species and charge states
- Radiation measurements:
  - Timepix → particle type, energy and timing
  - X-ray calorimeter → photon energy and count
- Measurements in pulsed, mixed radiation fields

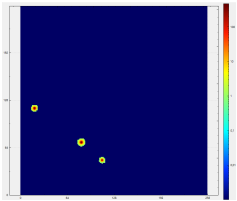
TOF signal:



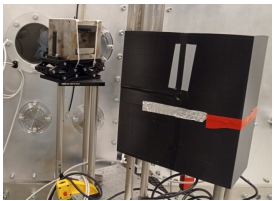
TP traces:



Timepix neutron signal:

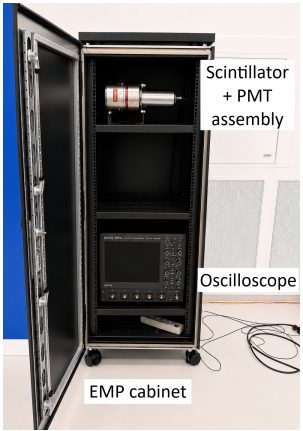


X-ray calorimeter detector:



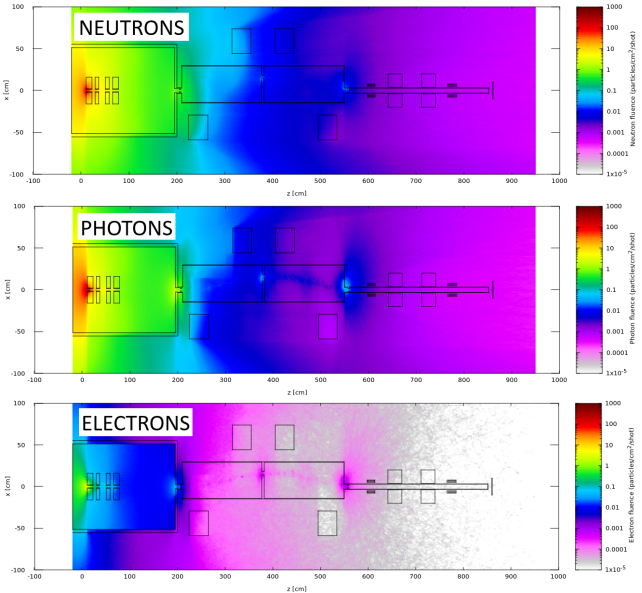
- Neutron Time-of-Flight (nTOF) system
  - Currently under experimental testing
  - Energy resolved neutron measurements
- Electron spectrometer
  - Design stage
  - Characterization of fast electron component
- Designed for pulsed, high-intensity environments
- Improved particle discrimination and coverage

→ Toward complete characterization of radiation field



Spatial Distribution of Secondary Radiation

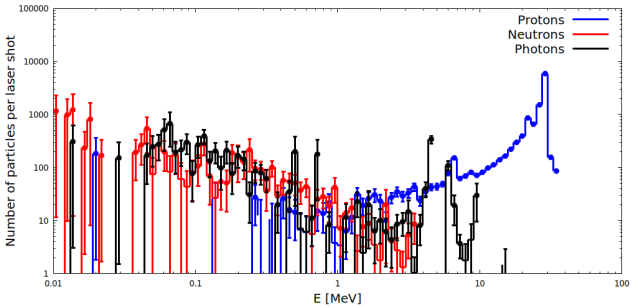
- Monte Carlo simulation of full ELIMED beamline
- Spatial distribution of: photons, neutrons, electrons
- Radiation intensity along and around beamline
- Identification of high-intensity regions



Radiation at Irradiation Point

- Fluence of particles at irradiation location
- Contributions from secondary radiation (photons, neutrons, electrons)
- Comparison with primary ion beam
- Secondary radiation as background to delivered dose

→ Impact on dosimetry and radiobiological studies



[1] Ehret, Michael. (2016). TNSA-Proton Beam Guidance with Strong Magnetic Fields Generated by Coil Targets. 10.13140/RG.2.1.3855.7847.
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[3] Chopineau, L., Leblanc, A., Blaclard, G., Denoeud, A., Thévenet, M., Vay, J., Bonnaud, G., Martin, P., Vincenti, H., & Quéré, F. (2019). Identification of Coupling Mechanisms between Ultraintense Laser Light and Dense Plasmas. Physical Review X, 9(1). https://doi.org/10.1103/physrevx.9.011050
[4] D. Margarone et al., "ELIMAIA: A Laser-Driven Ion Accelerator for Multidisciplinary Applications", Quantum Beam Science 2 (2018) 8.
[5] G.A.P. Cirrone et al., "ELIMED-ELIMAIA: The First Open User Irradiation Beamline for Laser-Plasma-Accelerated Ion Beams", Frontiers in Physics 8 (2020) 564907.
[6] Sistrunk, E. et al., "All Diode-Pumped, High-repetition-rate Advanced Petawatt Laser System (HAPLS)," in Conference on Lasers and Electro-Optics, OSA Technical Digest (online) (Optica Publishing Group, 2017), paper STh1L.2.
[7] Ahdida, C. et al., "New capabilities of the FLUKA multi-purpose code," Frontiers in Physics 9 (2022).
[8] Battistoni, G. et al., "Overview of the fluka code," Annals of Nuclear Energy 82 (8 2015).

Conclusion

- Stray radiation generated at target and along beamline
- Monte Carlo simulations map radiation propagation
- Photons, neutrons, electrons contribute to background
- Secondary radiation present at irradiation point
- Accurate characterization is essential for reliable beam use

Thanks to the team:

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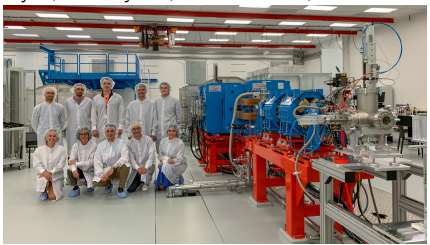

Thank you for your attention!