Operational status and current capabilities of the ELIMAIA-ELIMED experimental platform

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The **Extreme Light Infrastructure (ELI)** is the world's largest high-power laser research infrastructure. As an international user facility dedicated to multidisciplinary science and research applications of ultra-intense and ultra-short laser pulses, ELI provides access to world-class high-power, high-repetition-rate laser systems and laser-driven secondary particle and radiation sources. One of the available experimental platforms at ELI Beamlines is the *ELIMAIA* (ELI Multidisciplinary Applications of laser-Ion Acceleration) beamline, designed to provide characterized laser-driven ion beams for applications in physics, materials science, and medical research. The magnetic section of the beamline, called *ELIMED*, enables controlled, in-air sample irradiation at its end-station using laser-driven protons, currently with energies between 20 and 25 MeV.

Laser-driven ion accelerator

Can be arranged in two optical setups:

- ELIMAIA open station for ion acceleration research
  - Accommodates various target systems and detectors in different geometries
  - Suitable for improvement and development of laser-driven radiation sources
- Beam injection to ELIMED
  - Uses fixed optical setup to place the laser-target interaction with the ELIMED axis
  - Generates proton beams from standard solid targets
  - Offers limited options for online characterization of the interaction

Driven by the L3 HAPLS laser system:

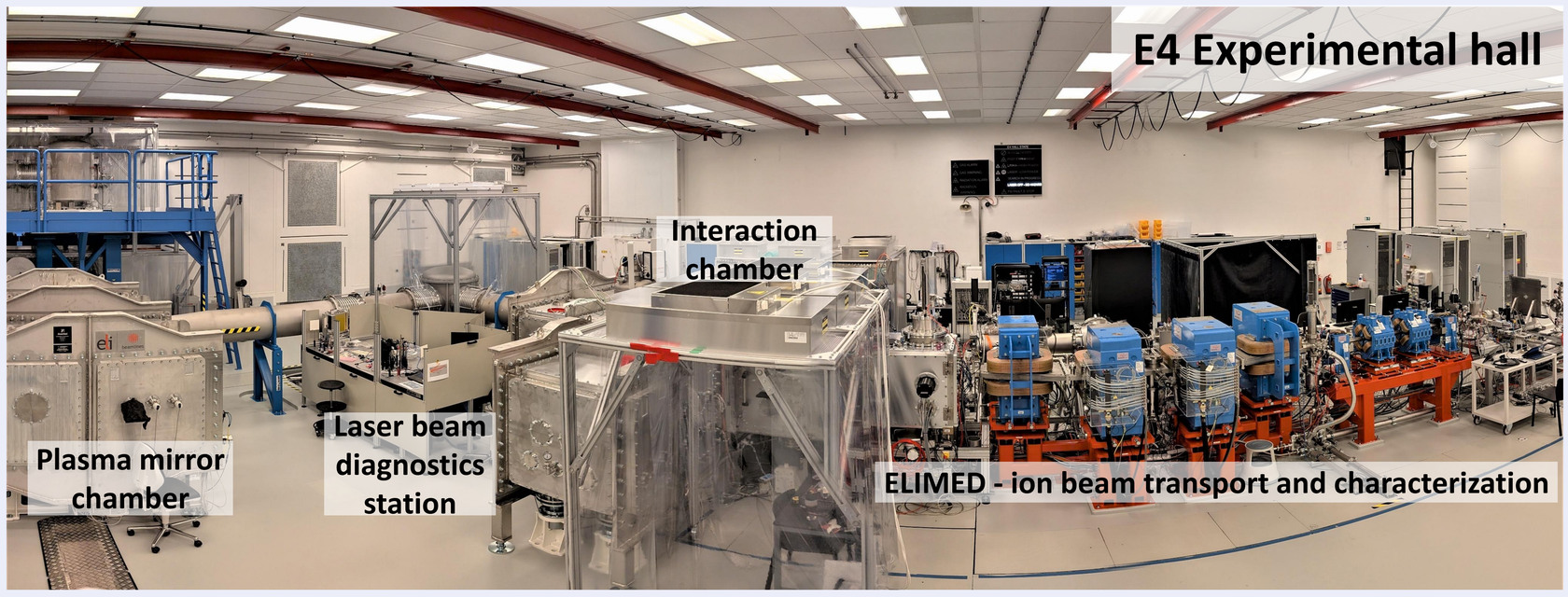
- **H**igh-repetition-rate **A**dvanced **P**etawatt **L**aser **S**ystem
- All-diode-pumped CPA Ti:sapphire laser system
- Designed for 30 J in 30 fs at 3.3/10 Hz
- Currently providing 15 J in 30 fs at 3.3 Hz
- On-target laser intensity (OAP 375 mm): $5 \cdot 10^{21}$ W/cm^2
- On-target pointing stability: 2.8 µrad RMS
- Contrast better than 10^{10} (to be re-measured)
- S-polarized beam on target

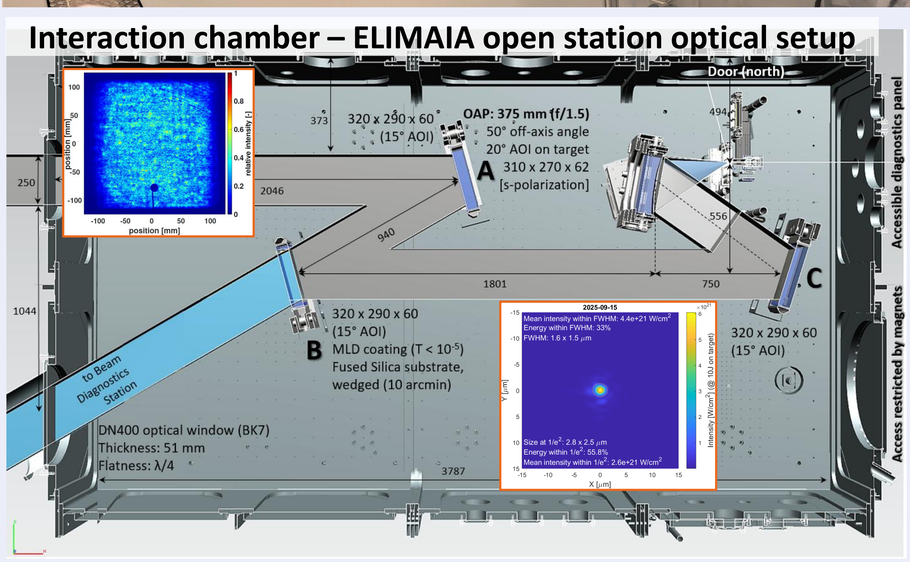
Currently provides the following ion beam parameters:

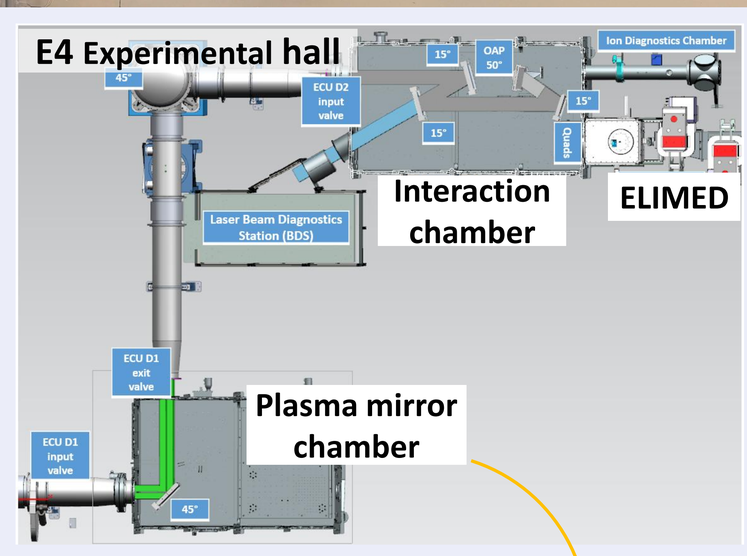
- Typical TNSA spectrum
- Proton cutoff energy: 40 MeV using 2 µm thick Cu targets
- Proton flux (total above 3 MeV)**:** 10^{11} sr^{-1}

Offers the following online diagnostics:

- Time-of-flight diamond detectors
- MCP-based Thomson parabola ion spectrometer
- Scintillator X-ray detector
- XUV spectrometer



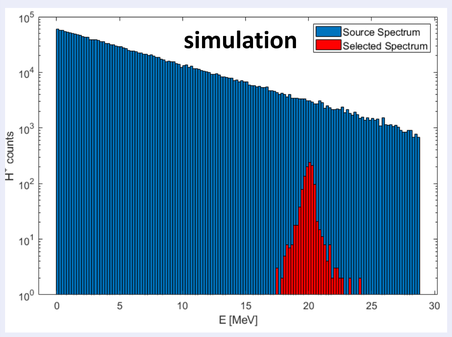


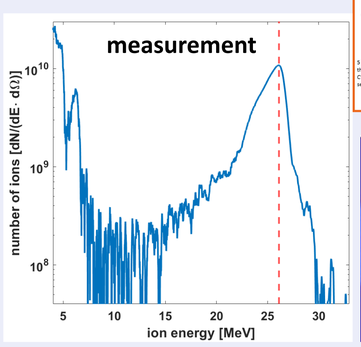


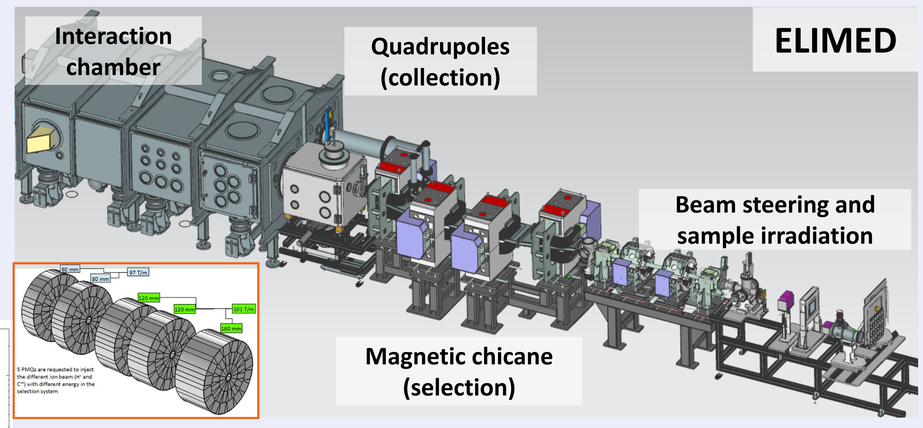
ELIMED output parameters

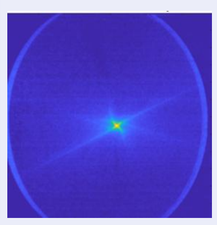
Current performance:

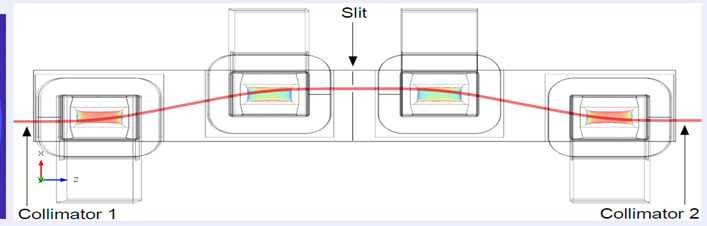
- Proton output energy: from 20 to 25 MeV
- Transmission efficiency: 4% (verified)
- Energy spread: 10-15% (to be verified)
- Output beam size (nominal): 0.1-10 mm
- Proton bunch duration: 10 ns
- Dose: 30 mGy/shot at the entrance to the Bragg peak







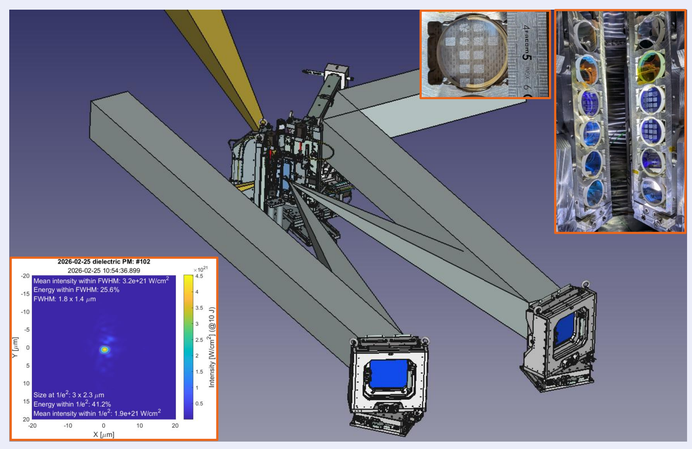




Upcoming upgrades

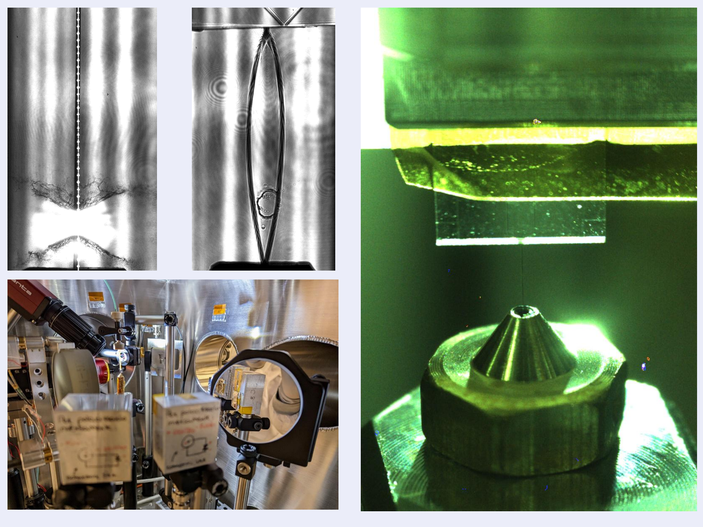
Double plasma mirrors:

- Dedicated optical setup in a separate chamber
- Ions produced from 25 nm thick targets
- To be commissioned by the end of 2026



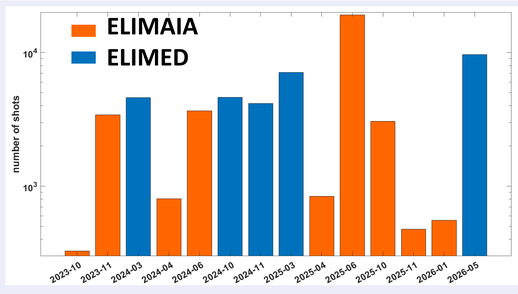
Continuously produced targets

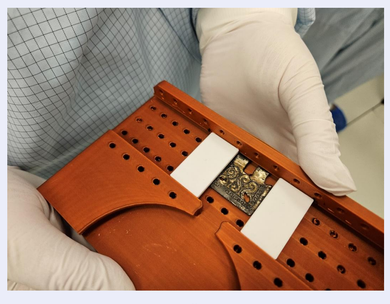
- Cylindrical and planar water jet
- Initial tests in progress



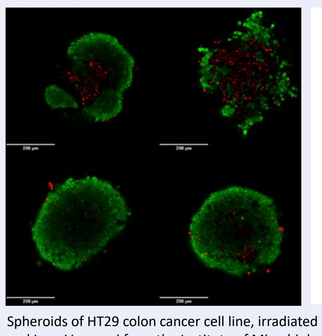
User operation highlights

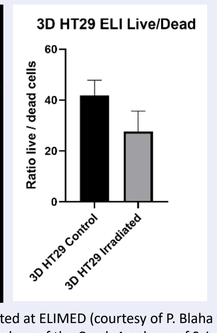
- 20 campaigns from October 2023 to June 2026 (10 with ELIMAIA, 10 using ELIMED)
- 164 days of high-power beamtime
- Over 52,000 high-power shots received (from 300 to 19,000 shots per campaign)
- Up to 1,000 shots on solid target per day
- Users' tape drive (Kapton 12 µm), water jet and H_2 cryogenic jet successfully deployed
- Pick-offs from the main laser beam (diameter of 3 in and 0.5 in) successfully implemented

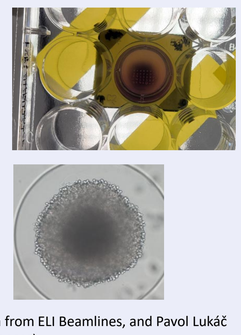




Silver buckle ornamented with niello and gold gilding, irradiated at ELIMAIA for PIXE (courtesy of M. Čechura from Archaeological Collections, Museum of Prague)







Spheroids of HT29 colon cancer cell line, irradiated at ELIMED (courtesy of P. Blaha from ELI Beamlines, and Pavol Lukáč and Luca Vannucci from the Institute of Microbiology of the Czech Academy of Sciences)

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[2] Cirrone, G. A. P., et al. (2020). ELIMED-ELIMAIA: The First Open User Irradiation Beamline for Laser-Plasma-Accelerated Ion Beams. *Frontiers in Physics*, 8, 564907.
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[4] Bláha, P., et al. (2025). ELIMAIA-ELIMED: A new user platform for radiobiological research utilizing laser-driven protons. *Frontiers in Physics*, 13, 1567622.
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Beamtime application on the ELI User portal up.eli-laser.eu