Current Neutron Studies @ ELI Beamlines

Kickoff meeting SwissELITE Detector Project 3

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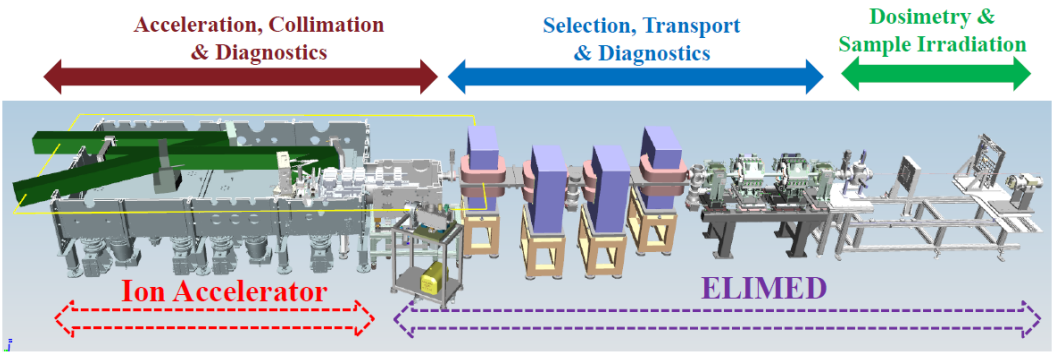
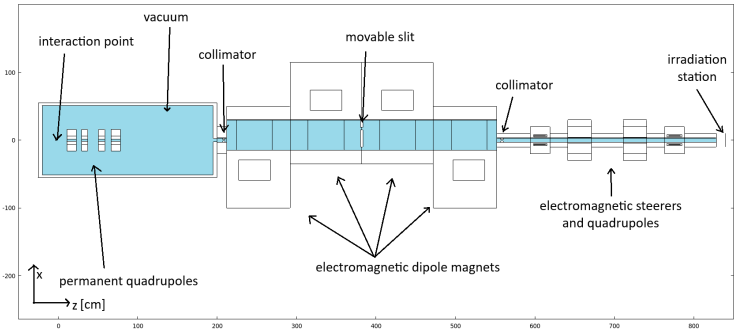
ELI Beamlines

September 3, 2025



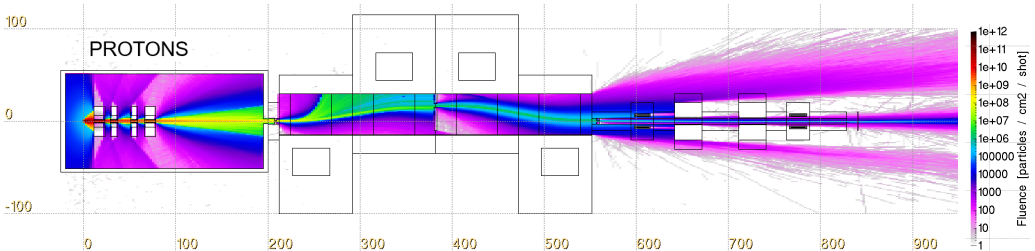
- ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) at ELI Beamlines
- ELIMED (ELI MEDical applications)
- L3 HAPLS (The High-Repetition-Rate Advanced Petawatt Laser System) laser
- ELIMAIA currently uses 10 J, 30 fs pulses at 0.2 Hz and provides proton beams with up to 40 MeV
-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

Simulation setup



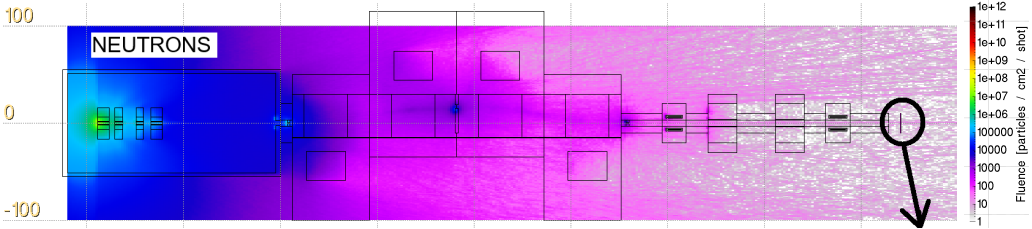
- Simulation prepared in FLUKA
- Source: 3D PIC simulations (updated to match experimental results) with 10^{11} primary protons simulated
- Proton beam: energies 0-40 MeV, up to 20° angular divergence
- Up to 4% transmission efficiency

- Fluence of primary proton beam, scored in region: x=±0.5m, y=±1cm and z=0-10m, results normalized per laser shot:

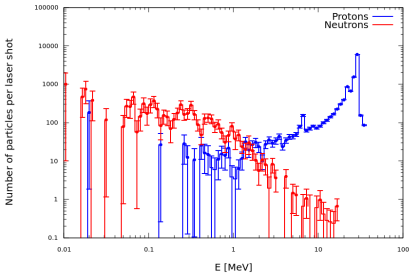


- Protons are focused, small energy range is selected, then steered and prepared for irradiation of samples

Simulation results - neutrons

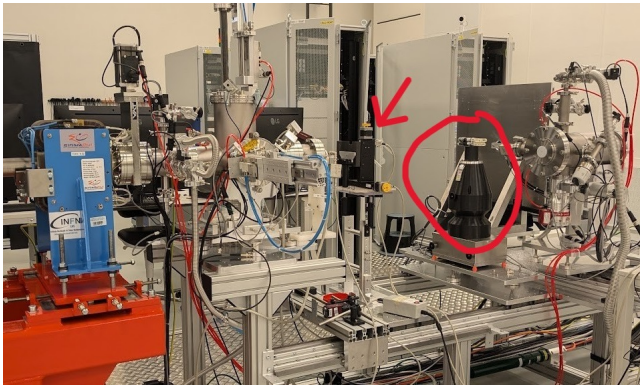


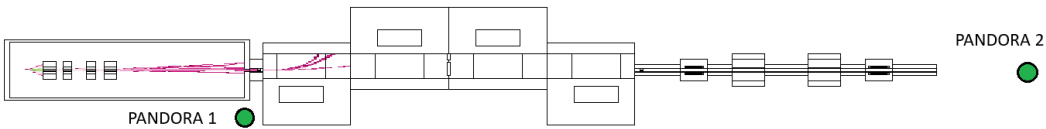
- Neutrons are created when primary particle interacts with elements with critical locations: focusing quadrupole section and collimators throughout the beamline
- Simulation shows neutrons in small doses with energies up to $\sim 20\,\mathrm{MeV}$



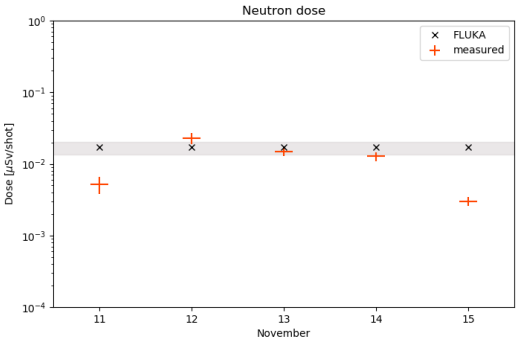
Measurement techniques:

- Dose readers (Berthold LB 6419 detectors, bubble detectors)
- TimePix detector
- Neutron time-of-flight scintillator detector
  (in development)



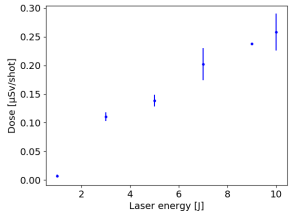


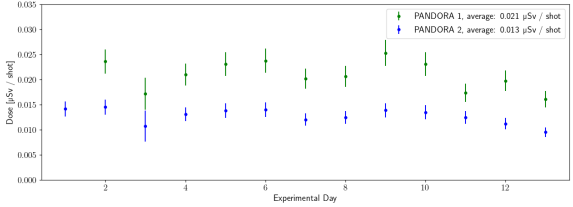
Measurements results

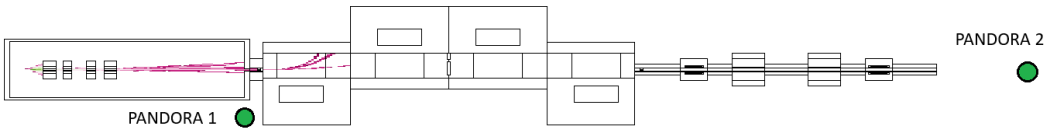


- Measurement of neutron dose with Berthold LB 6419 detector at irradiation location
- Results from 1 week of data taking - average 300 laser shots per day, laser intensity at FWHM $\sim 3 \times 10^{21}$ W/cm2
- Simulation results are normalized to the number of protons created per laser shot (1×10^{12}) including systematical error of 10% (shaded region)

- Additional data collected in Spring 2025 with 2 Berthold LB 6419 detectors
- Neutron dose is proportional to laser energy
- Dose decreases with distance from interaction point



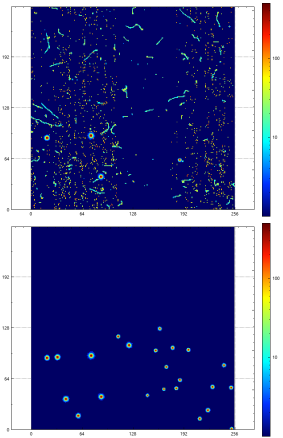




In other beamlines at ELI Beamlines, neutrons are generated as a by-product of high-energy particle production at increasing rate with planned laser upgrades.

E2/E5 halls

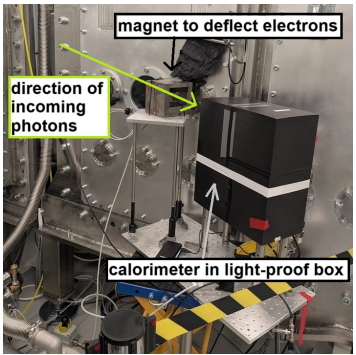
- Recently started using TimePix detector with neutron detection capabilities
- Data collection in progress

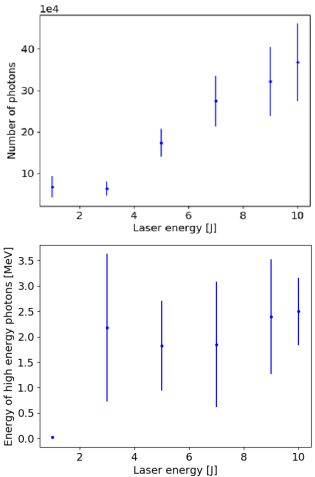


- Raw data showing different particle species

- Filtered only neutron events
- Detecting alpha particle

Recent ELIMAIA R&D project, now measuring Bremsstrahlung originating photons from laser interaction.





- X-rays from Bremsstrahlung radiation
- Using scintillator based detector to measure energy and number of photons
- Covers $\sim 30\,\mathrm{keV} - 10\,\mathrm{MeV}$ photon temperature

V. Istokskaia, et al., "Real-time bremsstrahlung detector as a monitoring tool for laser-plasma proton acceleration," https://doi.org/10.1017/hpl.2024.38

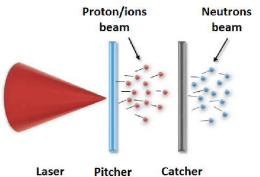
Good photon detectors are important for cross-checking neutron data.

Conclusion

- ELI Beamlines' experimental halls currently produce neutrons as by-products of high-energy particle beams
- Some simulations and very little measurements were done up to today
- Need for better diagnostics

Future plans:

- Generation of a neutron beam through the pitcher-catcher scheme
- Detectors will be needed for neutron beam quantification



Thank you!