# ELIMED at ELIMAIA: the first Users beamline dedicated to irradiation studies with laser-driven ion beams

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## State of the art

Laser-driven ion acceleration is a new physics field rapidly evolving, thanks to the continuous development of high power laser systems, allowing to investigate the interaction of ultra-intense laser (>$10^{19}$ W/cm$^2$ ) with matter. As a result of such interaction, extremely high electric and magnetic fields are generated. Such tremendous fields, allow to accelerate particles at relativistic energies in sub-millimetric dimensions Typically, these high energy ion beams are produced in thin solid targets and accelerated by a sheath field developed at the target-vacuum interface as a consequence of the generation of relativistic plasma electrons ("hot electrons") propagating into vacuum. Ion acceleration takes place until charge neutrality is restored and ultimately ions and electrons move together in a ballistic way. According to the state-of-the-art in laser-driven ion acceleration, proton energies up to 100 MeV have been experimentally demonstrated with a relatively high yield ($10^{10}$–$10^{12}$ protons/pulse) [1].

## Scientific Motivation

The mission of the laser-driven ion target area at the ELI-Beamlines facility (Dolní Brežany, CZ), called ELI Multidisciplinary Applications of laser-Ion Acceleration (ELIMAIA), is to provide stable, fully characterised and tuneable beams of particles accelerated by Petawatt-class lasers and to offer them to the Users' community interested in multidisciplinary applications. The ELIMAIA beamline has been designed and developed at the Institute of Physics of the Academy of Science of the Czech Republic (IoP-ASCR) in Prague in collaboration with the National Laboratories of Southern Italy of the National Institute for Nuclear Physics (LNS-INFN) in Catania (Italy). The beamline section dedicated to the final beam formation and absolute dosimetry is called ELIMED (ELI-Beamlins MEDical and multidisciplinary applications)


## Ion Acceleration by Lasers at ELI-Beamlines

The availability of ultra-high intensity lasers at ELI-Beamlines (>$10^{22}$ W/cm$^2$ ) will allow the acceleration with new acceleration regime, as the Radiation Pressure Acceleration (RPA). The generation of high-density ultra-short relativistic ion beams is, for example, predicted in the scheme called "laser piston regime", where the laser radiation pressure is dominant and the laser energy is efficiently transformed into ion energy.

Beam characteristics expected at the ELIMAIA beamline

| Ion Beam Features * | Phase 1 (L3) | Phase 2 (L3 or L4) |
|---|---|---|
| Energy range | 3–60 MeV/u | 3–300 MeV |
| Ions/shot | $10^9$ in 10%BW | $10^{10}$ in 10%BW |
| Bunch duration | 1–10 ns | 0.1–10 ns |
| Energy spread | 10% | 5% |
| Divergence | 1° | 0.5° |
| Ion spot size | 0.1–10 mm | 0.1–10 mm |
| Rep. Rate | 0.01–1 Hz | 0.01–10 Hz |

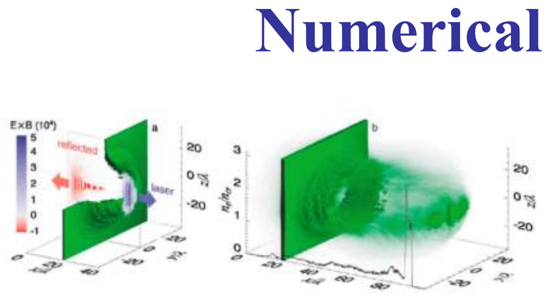
* Values are intended on an "user sample", i.e., at the very end of the ELIMED section.

## Dosimetry and Sample Irradiation

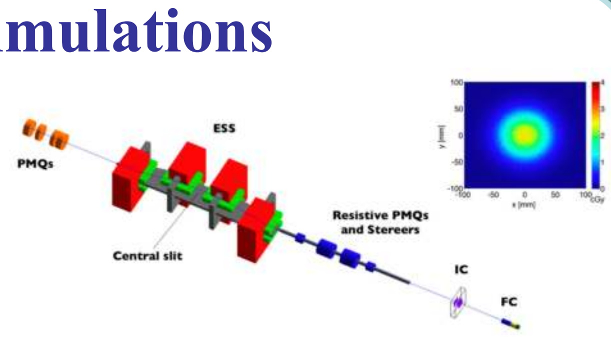
The ELIMED dosimetric system has been designed and realized to be dose rate independent, to work in laser-plasma environment and to allow real-time measurements with an accuracy of less than 5%.

A Secondary Electron Monitor (SEM) and a multi-gap Ionization Chamber (IC) will be calibrated against a Faraday Cup (FC) specifically designed to decrease uncertainties in the collected charge and to perform absolute dosimetry at the sample irradiation point [3]. Finally, a sample irradiation system (SIS) is installed in-air, at the end of ELIMED beamline and will allow the positioning of samples to be irradiated.

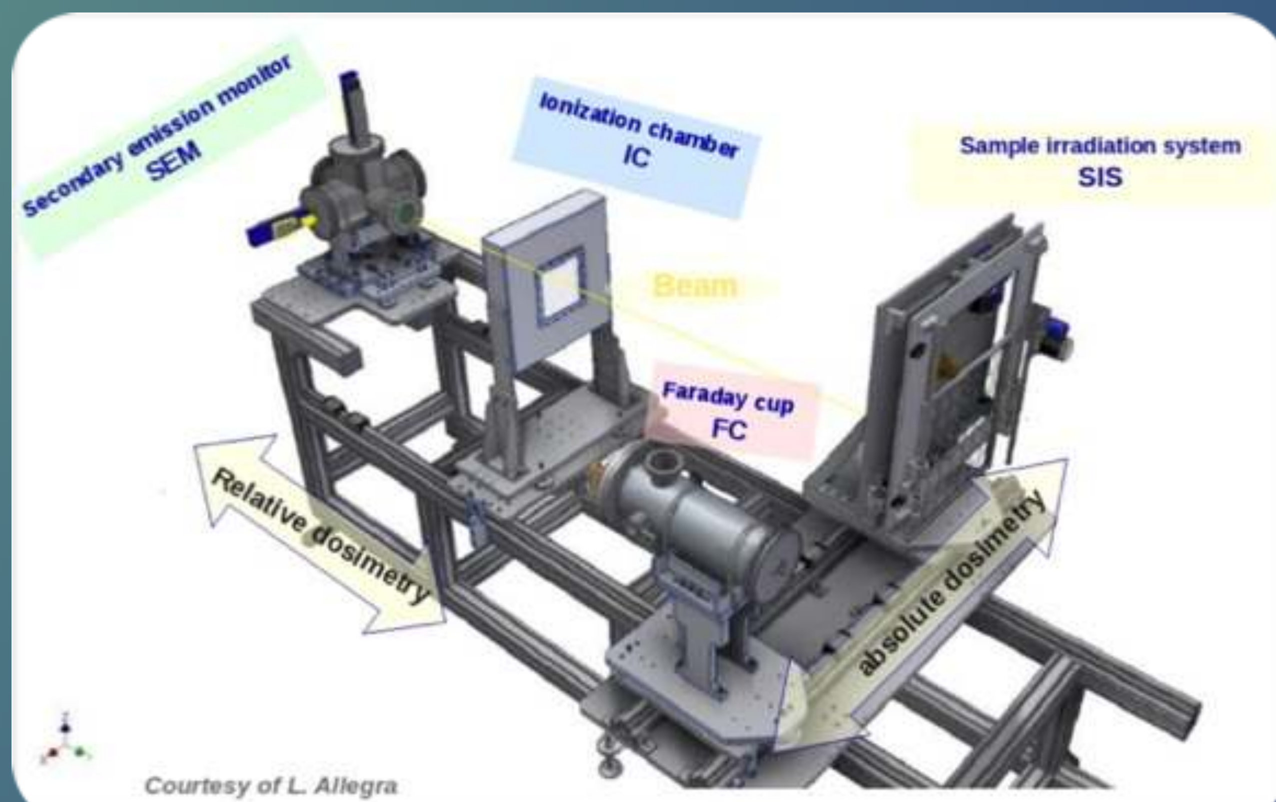
## Numerical simulations



A typical ion density distribution, in the radiation pressure acceleration (RPA) (laser piston) regime [2], generated when a laser hits a solid target.




Snapshot of the ELIMED simulation developed using the Geant4 toolkit [4]. Inset: 2D dose distributions at 2 m from the kapton window (at the user samples) [5]




[1] Higginson, A. and Gray, R. J. and King, M. and Dance, R. J. and Williamson, S. D. R. and Butler, N. M. H. and Wilson, R. and Capdessus, R. and Armstrong, C. and Green, J. S. and Hawkes, S. J. and Martin, P. and Wei, W. Q. and Mirfayzi, S. R. and Yuan, X. H. and Kar, S. and Borghesi, M. and Clarke, R. J. and Neely, D. and McKenna, P. Near-100 MeV protons via a laser-driven transparency-enhanced hybrid acceleration scheme(2018); [2] Esirkepov, T.; Borghesi, M.; Bulanov, S.V.; Mourou, G.; Tajima, T. Highly Efficient Relativistic-Ion Generation in the Laser-Piston Regime. (2004); [3] Schillaci, F.; Maggiore, M.; Andó, L.; Cirrone, G.A.P.; Cuttone, G.; Romano, F.; Scuderi, V.; Allegra, L.; Amato, A.; Gallo, G.; et al. Design of a large acceptance, high efficiency energy selection system for the ELIMAIA beam-line. J. Instrum. (2016); [4] Milluzzo, G.; Pipek, J.; Amico, A.G.; Cirrone, G.A.P.; Cuttone, G.; Korn, G.; Larosa, G.; Leanza, R.; Margarone, D.; Petringa, G.; et al. Geant4 simulation of the ELIMED transport and dosimetry beam line for high-energy laser-driven ion beam multidisciplinary applications. Nucl. Instrum. Meth. Phys. Res. A 2018,;[5] Milluzzo, G.; Pipek, J.; Amico, A.G.; Cirrone, G.A.P.; Cuttone, G.; Korn, G.; Larosa, G.; Leanza, R.; Margarone, D.; Petringa, G.; et al. Transversal dose distribution optimization with the Geant4 code for laser-accelerated proton beam multidisciplinary applications. Eur. J. Med. Phys. submitted.