The Extreme Light Infrastructure

Joint Call for Users Webinar

ELI-NP status and laser beam-time allocation

Speaker Name: Domenico DORIA

Head of Department for Laser-Driven Experiments, ELI-NP

18 July 2022

eli

ELI-NP Infrastructure

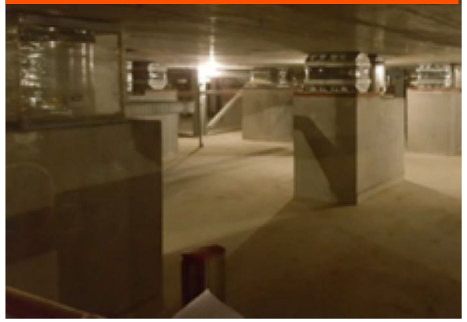
eli

ELI-NP is Operational since 2016

- Experiment building
- Office building
- Guesthouse
- Canteen
- Access control building

Over 32.000 sqm of built area and 270.000 cubic meter of air to condition

120,000 tons antivibration platform

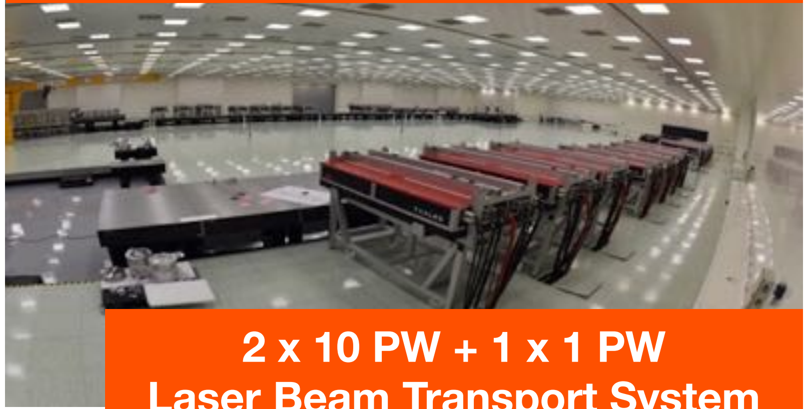


Clean rooms ISO6 - ISO7

For more info: https://www.eli-np.ro/

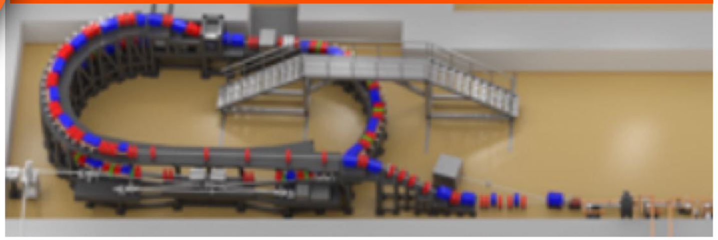
Largest geothermal system in Europe ~ 6 MW

2 x 10 PW High-Power Laser System

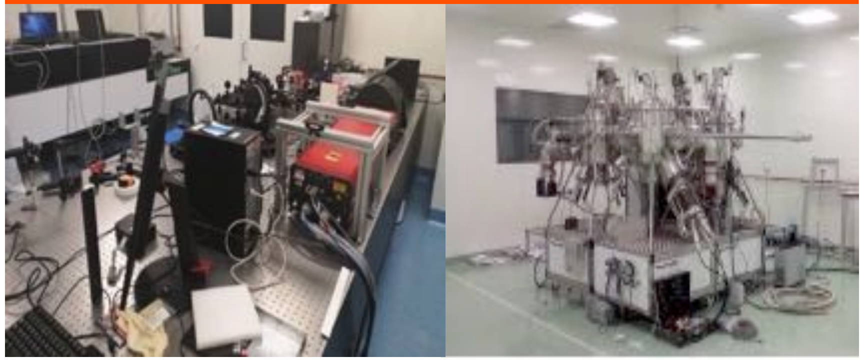


2 x 10 PW + 1 x 1 PW Laser Beam Transport System

Variable Energy Gamma System



Laboratories and workshops



9 Experimental areas

ELI-NP Research Infrastructure

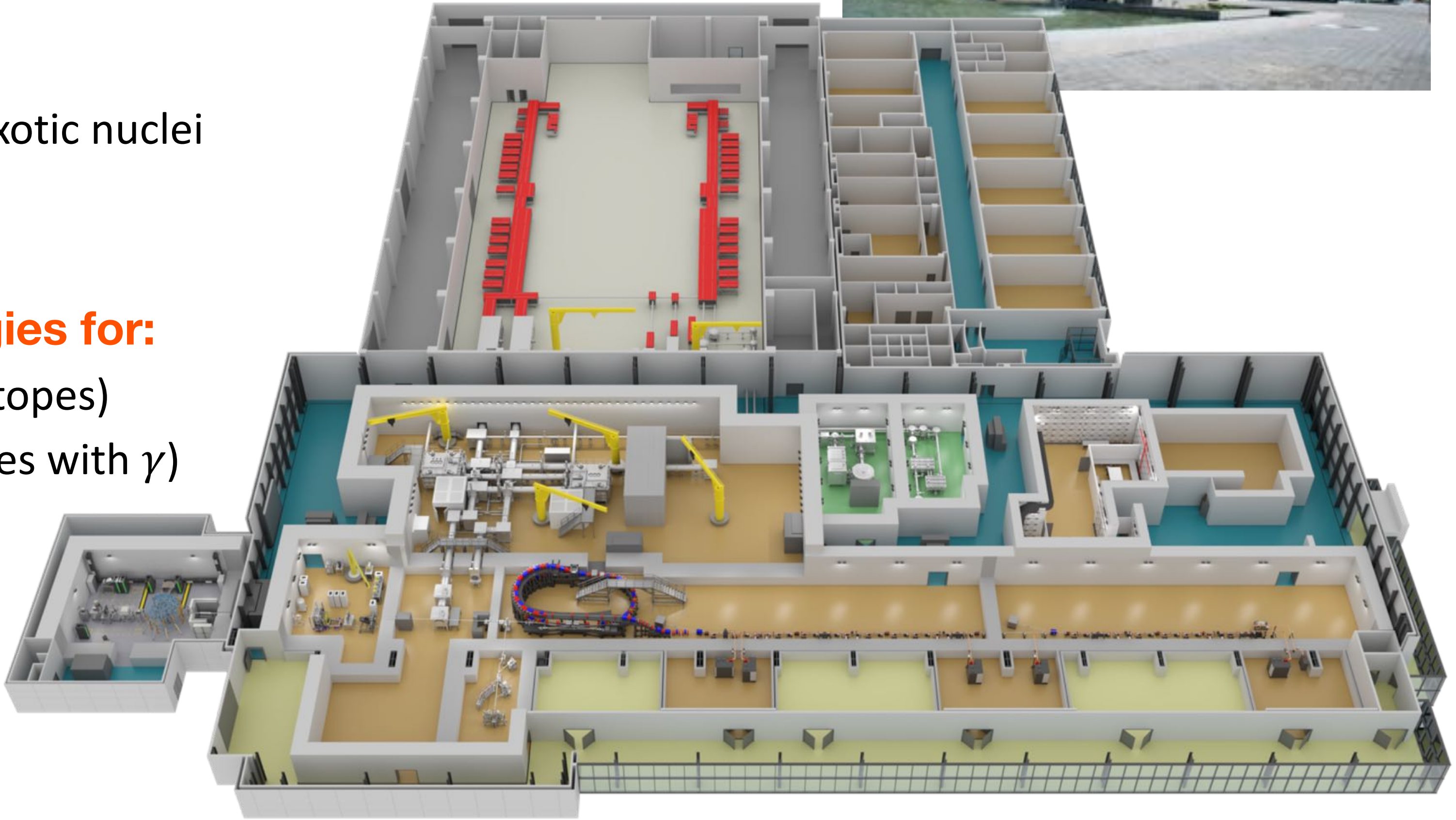
Advanced studies in basic science …

- characterization of laser-matter interaction with nuclear methods
- particle acceleration with high power lasers
- nuclear reactions in plasma
- photonuclear reactions, nuclear structure, exotic nuclei
- nuclear astrophysics and nucleosynthesis
- quantum electrodynamics (QED)

… and applications – developing technologies for:

- medical applications (X-ray imaging, radioisotopes)
- industrial applications (non-destructive studies with γ)
- material studies with positrons
- materials in high radiation fields

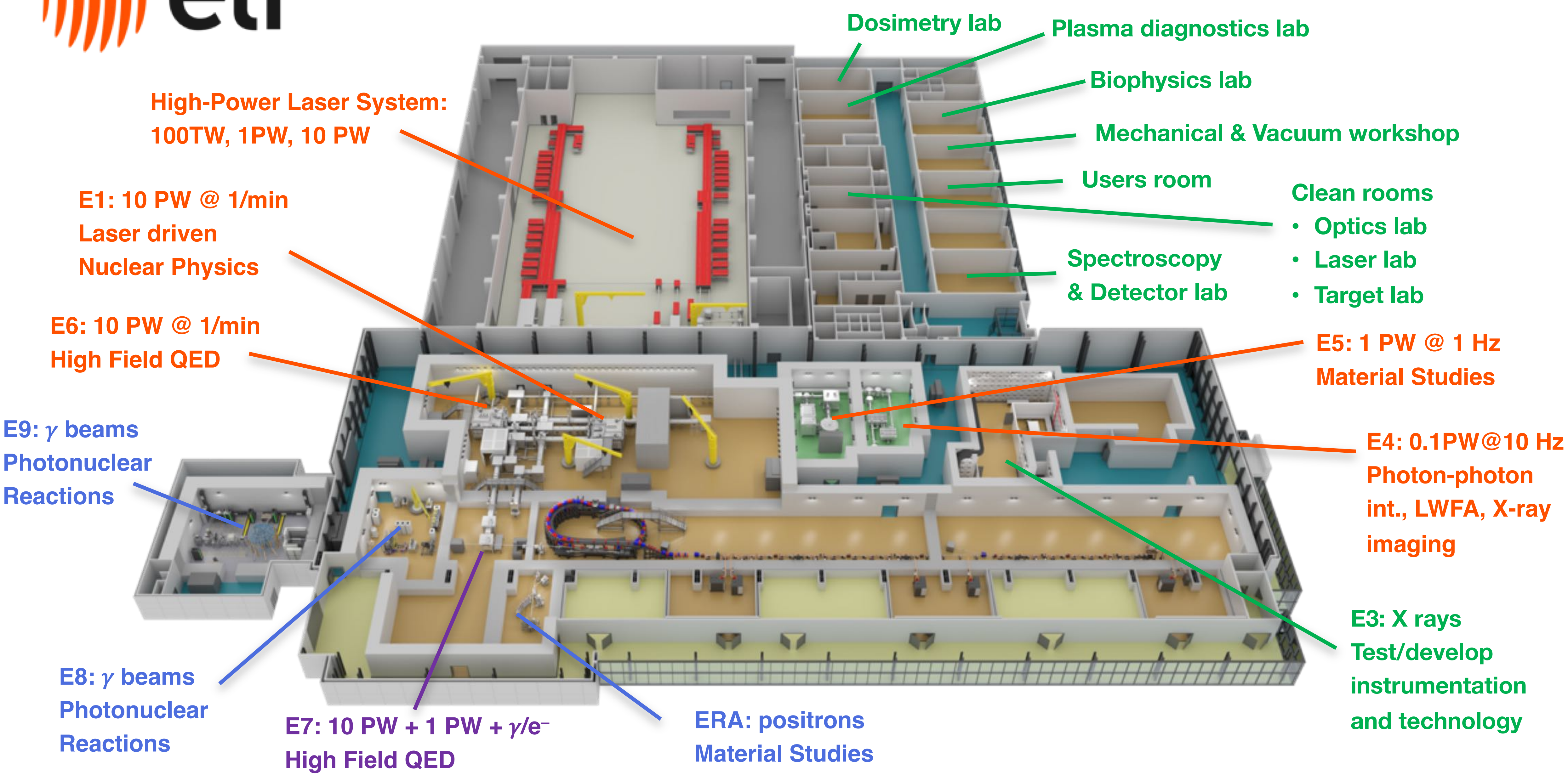
Experimental building



2015 Technical Design Reports assessed by ELI-NP ISAB

Rom. Rep. Phys. Vol. 68 (2016)

Experimental building



High-Power Laser System

LSD department (Head of LSD: Ioan Dancus)

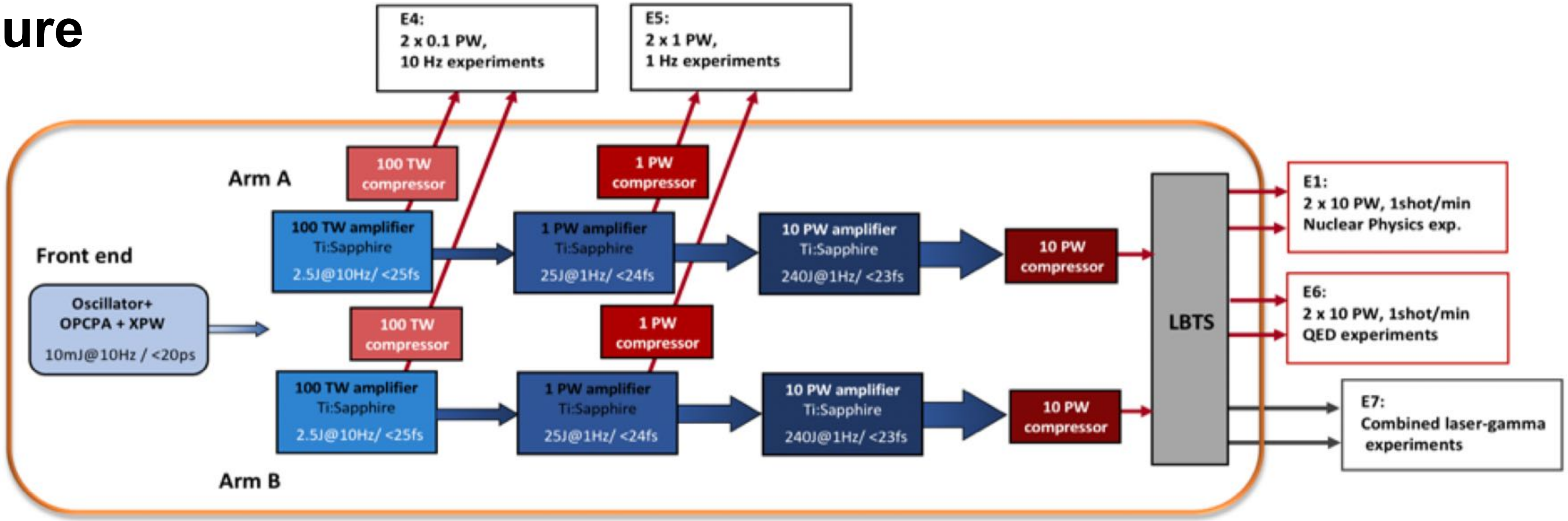
Measured parameters of the HPLS

Output type	100 TW	1 PW	10 PW
Pulse energy (J) *	2.5	24	242
Pulse duration (fs) **	< 25	< 24	<23
Repetition rate (Hz)	10	1	1/60
Calculated Strehl ratio from measured wavefront	> 0.9	> 0.9	> 0.9
Pointing stability (μrad RMS)	< 3.4	< 1.78	< 1.27
Pulse energy stability (rms)	< 2.6 %	< 1.8 %	< 1.8 %

*Calculated considering the transmission efficiency of temporal compressors
**Measured with attenuated input energy in the compressors

HPLS architecture

For this User call ELI-NP will offer the 100 TW and 1 PW laser beams

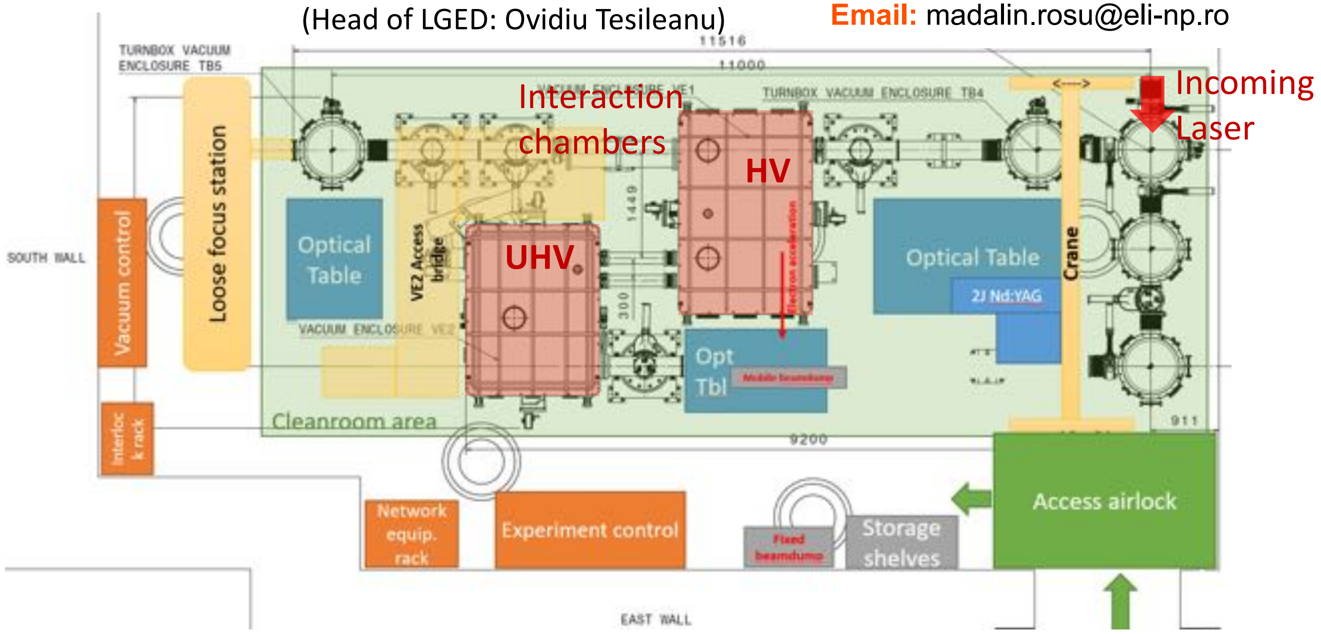


The 100 TW and 1 PW areas

E4: 100 TW

LGED department
(Head of LGED: Ovidiu Tesileanu)

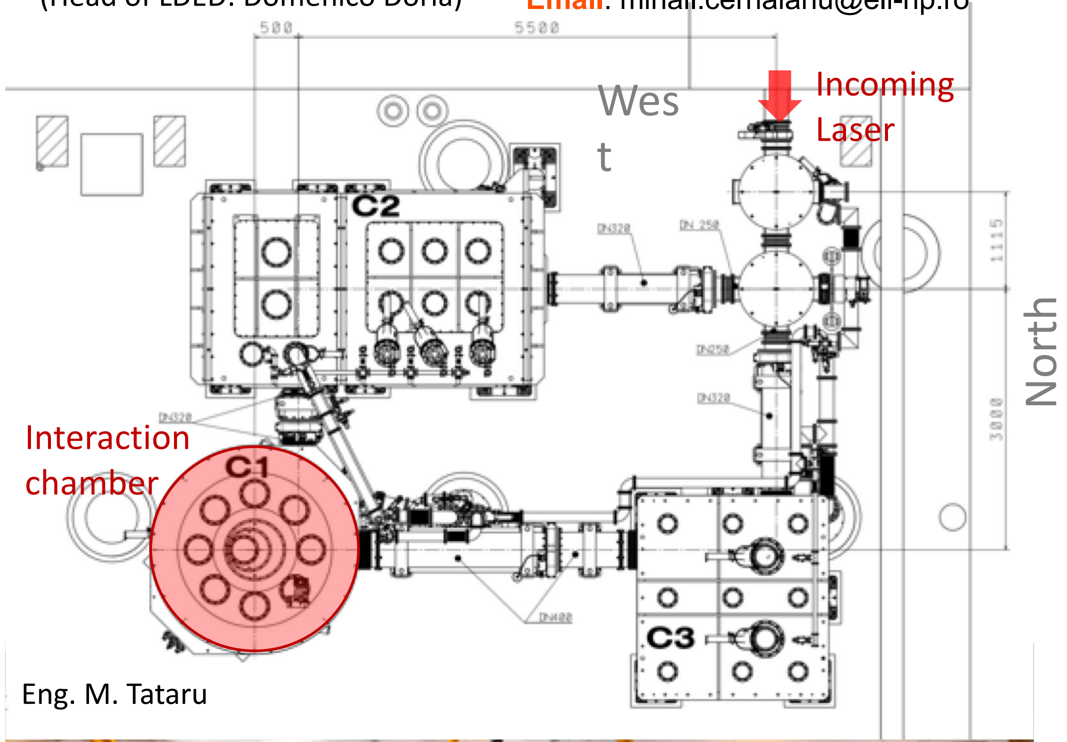
Contact Person: Madalin Rosu
Email: madalin.rosu@eli-np.ro

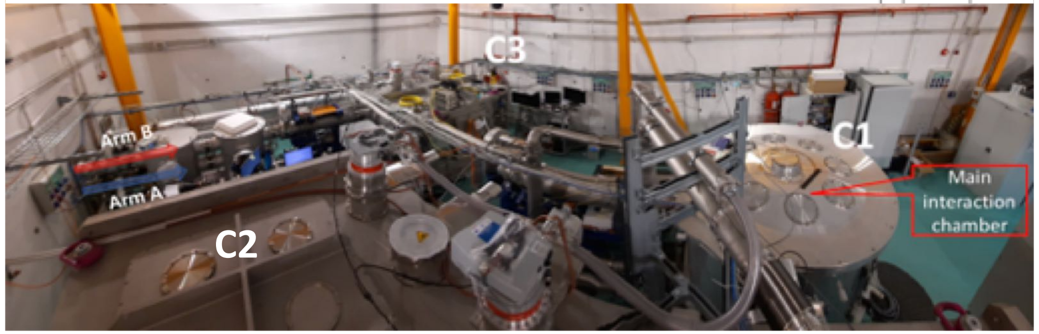


E5: 1 PW

LDED department
(Head of LDED: Domenico Doria)

Contact Person: Mihail Cernaianu
Email: mihail.cernaianu@eli-np.ro





For more info at https://users.eli-np.ro/

100 TW Laser Experimental area (E4)

100 TW area infrastructures

- 2 interaction chambers in stainless steel (HV – VE1 and UHV – VE2)
- 5 turning boxes
- 10 turbomolecular pumps (maglev), 1 cryo-pump
- Integrated control system, automatic / manual modes
- VE1 typical pump time: 60 mins; venting + opening: 45 mins
- Possibility to control and maintain the vacuum level up to 10^{-3} mbar
- Large soft-wall cleanroom – equiv. ISO7

Large Optics available

- 6” flat mirrors w/ motorized mounts
- F = 1500mm off-axis parabola, AOI = 6.25°
- F = 520mm off-axis parabola, AOI = 7.5°

Other components for the setup

- movement stages and detectors, optical tables, optical diagnostics available on-site

The 100 TW Laser features

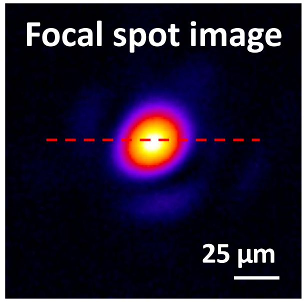
100 TW laser beam features

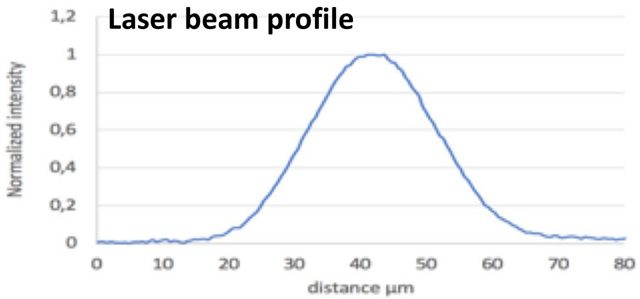
- Energy: < 2.5 J
- Pulse duration: < 25 fs
- Central wavelength: ~ 810 nm
- Beam diameter: ~ 54 mm
- Laser pointing fluctuation on target: ~ ±7 µrad
- Energy stability: <2.5%

- **For this user call only experiments with gas target (gas jet or gas cell) or no target will be offered**
- **No BR issues foreseen**

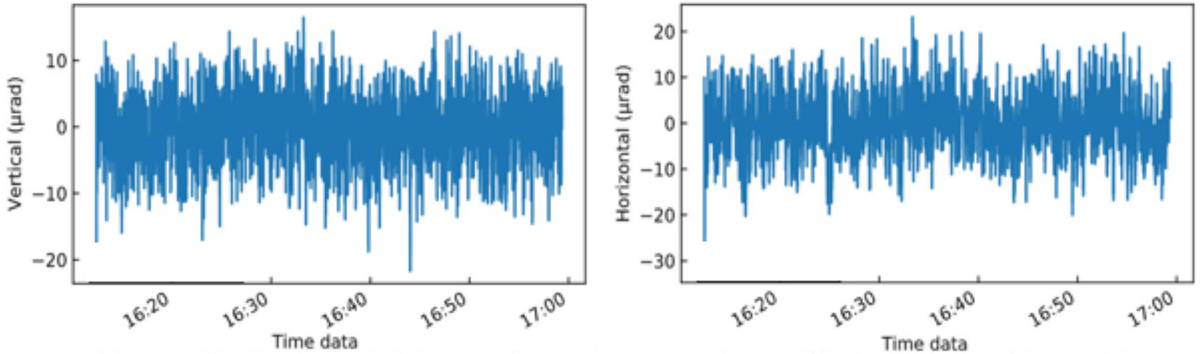
Example of focus properties

- Parabolic mirror: 1.5 m focal length (F# ~28)
- Spot size diameter: ~ 22±2 µm at FWHM
- Encircled energy ~ 70% @ $1/e^2$





- Laser pointing stability



Laser pointing stability representing the laser far-field horizontal and vertical pointing fluctuation as function of time. The r.m.s. of the fluctuations is ±7 µrad.

Diagnostics available in the 100 TW area

List of diagnostics provided

Light detectors

- Energy meters:
  10µJ-2.5mJ: Gentec QE95LP-S-MB-QED-D0,
  1mJ-250J: QE8SP-B-BL-D0
- Wavefront sensor: Phasics SID4-H
- CMOS cameras: Basler acA2440-20gm, daA3840-45uc
- Photomultipliers 300-700 nm:
  Hamamatsu H10721-110, H10721-20
- Fast photodiodes 200-1100 nm:
  Thorlabs DET025A/M, DET10A2, DET08C/M, Alphalas UPD-35-UVIR-P
- Optical Spectrometers in visible and near-infrared: Ocean Optics HR4000 CG-UV and NQ512-1.7
- Optical plasma probe (as a pick-up from the main laser beam): 1w, 1/2'' dia. and up to 100 mJ with pulse duration as the main laser beam, for Interferometry and Shadowgraphy.

Charged particle diagnostics

- Thomson parabola
- Stack detector
- Electron spectrometer
- ICT

Nd:YAG laser available in E4:

- Litron LPY 7864G-10
- Single Longitudinal Mode, 2nd and 3rd harmonic modules available
- Synchronization with HPLS main laser via Stanford Research Systems DG645 delay generator
- Max. 2.75 J, pulse width 12-15 ns

The 1 PW Laser Experimental area (E5)

1 PW area infrastructures

- 1 main interaction chamber (C1) in Aluminium
- 2 turning boxes + 2 large chambers (C2, C3) in stainless steel
- 9 turbomolecular pumps (1 cryo-pump on demand may be possible)
- Integrated control system, automatic / manual modes
- C1 typical pump time: 90 mins; venting + opening: 60 mins
- Vacuum level up to 10^{-6} mbar
- Small soft-wall cleanroom – equiv. ISO7

Large Optics available

- 12”x8’’ rectangular flat mirrors w/ motorized mounts
- F = 5000mm off-axis parabola, AOI = 45°
- F = 707mm off-axis parabola, AOI = 22.5°

Other components for the setup

- movement stages and detectors, optical tables, optical diagnostics available on-site

1 PW Laser features

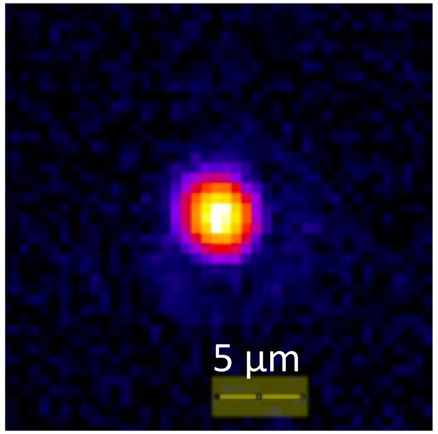
1 PW laser beam features

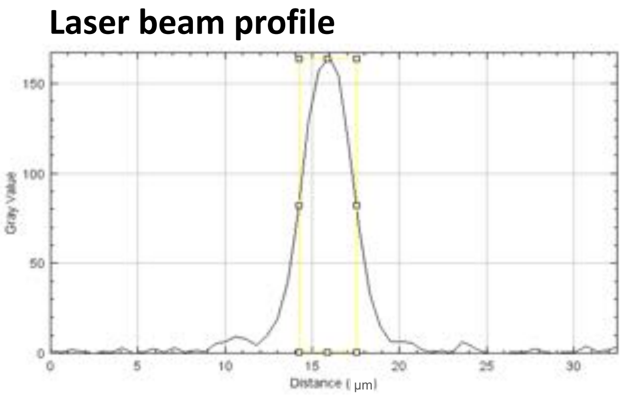
- Energy: < 24 J
- Pulse duration: < 24 fs
- Central wavelength: ~ 810 nm
- Beam diameter: ~ 190 mm
- Laser pointing fluctuation on target: ~ ±1.5 µrad
- Energy stability: <2.5%

- **For this user call only experiments with solid target and short focal will be offered, SPM can be set on request**
- **To avoid BR issues, the angle of incidence on target must be > 1/F# (i.e. >22.5˚) w/o PM and > 1/2F# with PM.**

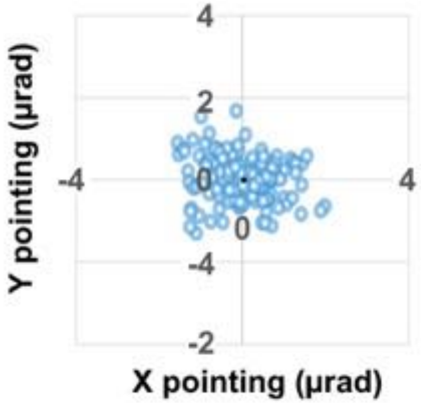
Example of focus properties

- Parabolic mirror: 707 mm focal length (F# ~3.7)
- Spot size diameter: ~ 3.6 ± 2 µm at FWHM
- Encircled energy ~ 65% @ $1/e^2$





- Laser pointing stability



Diagnostics available in the 1 PW area

List of diagnostics provided

Light detectors

- Energy meters Gentec: a few, from µJ to 100s J level
- Wavefront sensor: Shack-Hartmann sensor λ/100 r.m.s. 32x40 px
- CMOS cameras: several Basler, 2 x ANDOR ICCD, 2 x PCO
- Fast photodiodes 200-1100 nm
- Optical Spectrometers in visible and near-infrared: Ocean Optics, ANDOR Shamrock (VIS)
- Laser Diagnostics: (FF, NF, laser energy at full power, FROG, back-reflection)
- Several Optical fiber bundles available
- Optical plasma probe/pump (as a pick-up from the main laser beam): 1w or 2w, 1'' dia. up to 400 mJ with pulse duration as the main laser beam, (e.g., Interferometry, Shadowgraphy)
- Streak camera VIS (1 ps temporal resolution)

Charged particle diagnostics

- Thomson parabola
- Stack detector
- Electron spectrometer
- ICT
- Fast Oscilloscopes

Other tools

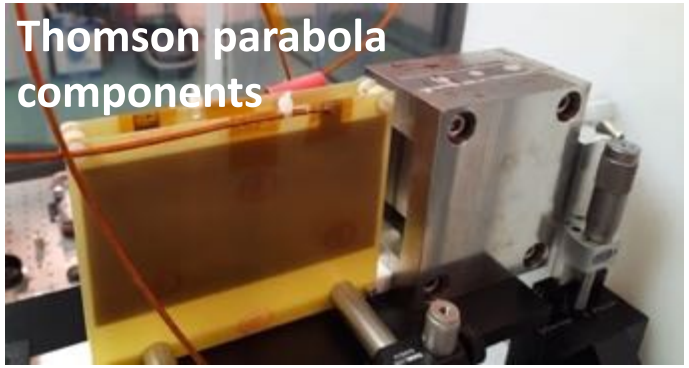
- Internal Injection Alignment Laser: CW 632-800nm, 110mm dia.
- Linear/Circular Polarization: large Mica waveplates
- 5X –40X objectives alignment system,
- Alignment system: 1µm spatial resolution motion
- Deformable Mirror

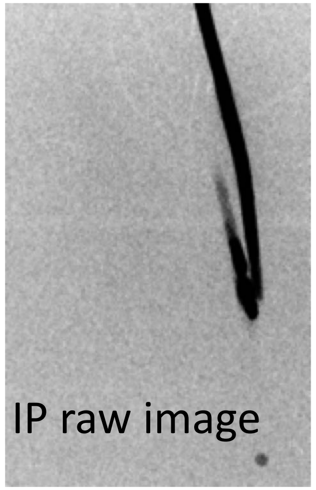
Thomson parabola

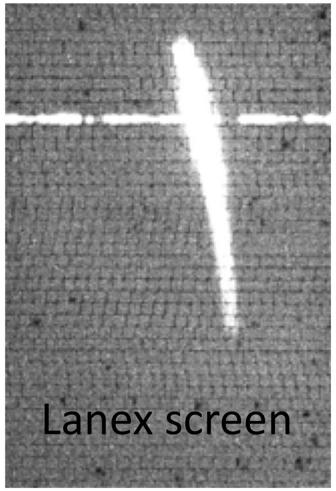
Ion Energy spectra resolution

Key parameters

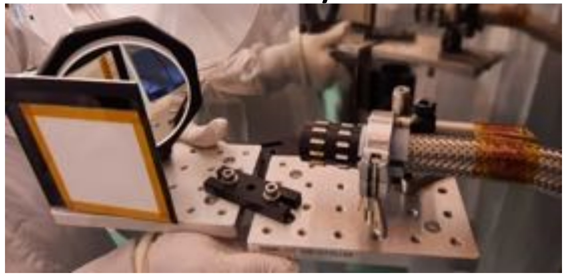
- Modus operandi : off-line or on-line
- Energy and ions vs flux discrimination, small solid angle resolution
- (H^{+}<100 MeV, C^{6+}<50 MeV/n, 3% res. @ 60 MeV p)
- High voltage for electrostatic deflector (≤ 20 kV)
- Permanent dipole magnet (~1 T)
- Dipole dimensions: 1 cm gap, 5-10cm length
- Electric plates: 1 cm gap, 10-15 cm length
- Image Plate (16 positions) and/or Scintillator type Lanex
- 2 TP units are available







Lanex readout system

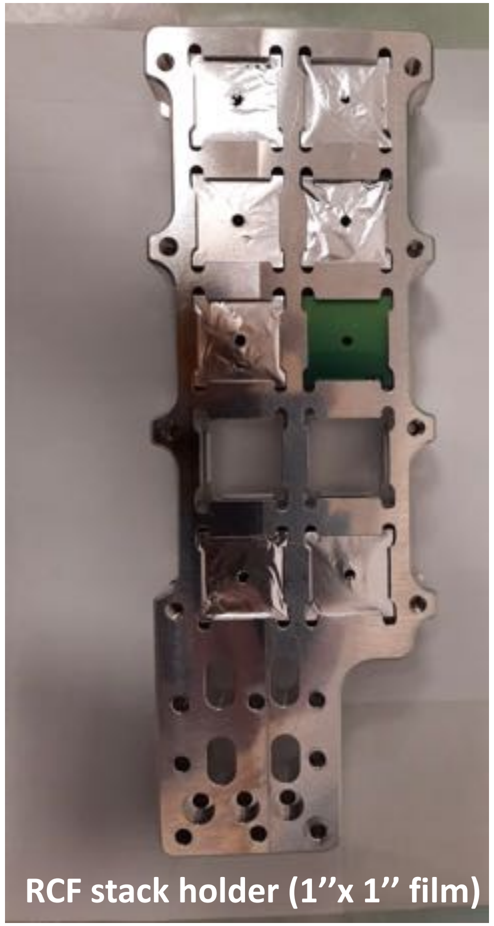


Stack detector

Proton Energy spectrum resolution

Key parameters

- Modus operandi : off-line
- Proton energy (and somewhat ions) vs flux discrimination, angular distribution resolution (H^+<100 MeV, typically a few MeV energy res.)
- Stack of detectors (RCF, CR39, IP)
- Stack dimensions: 25x25 mm^2 or 50x50 mm^2
- A matrix of stacks is available in a shot cycle.
- Sensitivity: Single particle sensitivity with CR39 and IP, and minimum measurable dose of ~cGy with RCF)
- A few matrices are available to help replacement during shot cycles



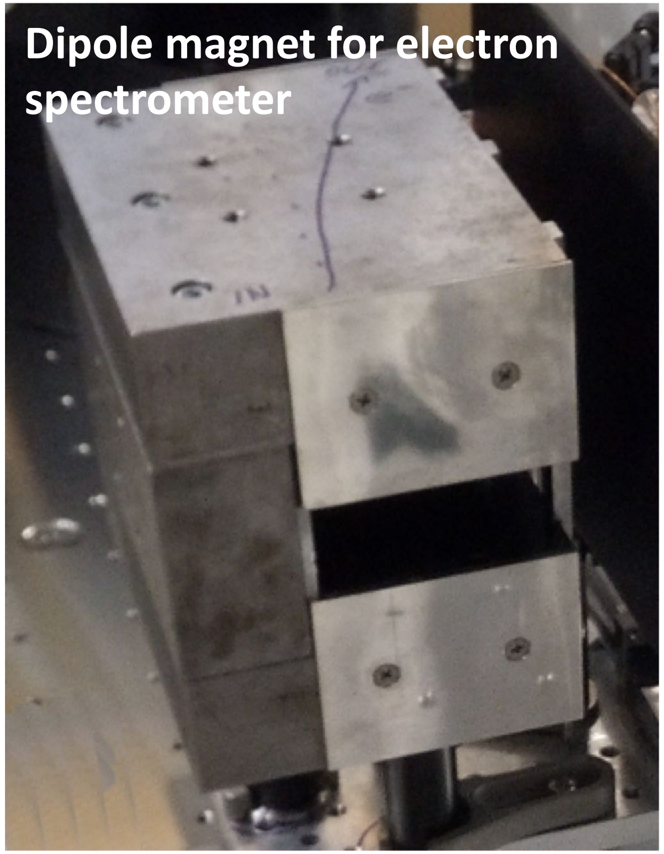
RCF stack holder (1"x 1" film)

Electron Spectrometer

Electron Energy spectrum resolution

Key parameters

- Modus operandi : on-line (or off-line)
- electron flux vs energy discrimination, small angle resolution
- (e^- energy of 100s MeV, i.e. res. 5% @ 300 MeV)
- Permanent dipole magnet (~0.7 T)
- Dipole dimensions: 3 cm gap, 16cm length
- Scintillator type Lanex or Image Plate
- 1 magnet available for such energies, other small dipoles are available for 10s MeV energy resolution



Laboratory support

Laboratory available

Target Laboratory
Optics Laboratory
Laser Experiments Diagnostics Laboratory
Biophysics and Biomedical Applications
Dosimetry laboratory
Mechanical and Electrical workshop

Bio Laboratory (P. Vasos)

Laser Experiments Diagnostics Laboratory (V. Nastasa)

A laboratory support for testing and setting up diagnostics, and processing/analyzing detectors/films (e.g., CR39 etching)

LP14 laboratory

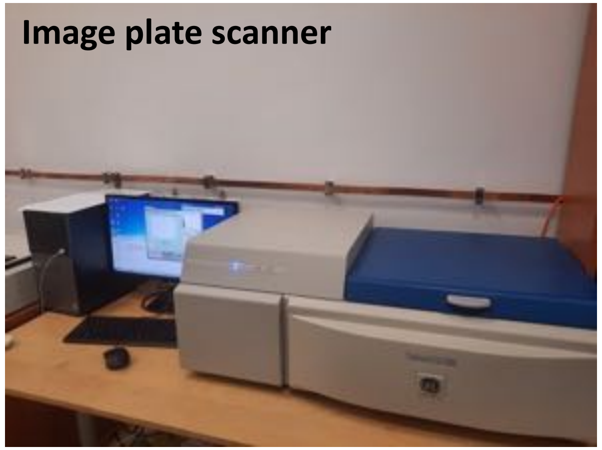


Image plate scanner

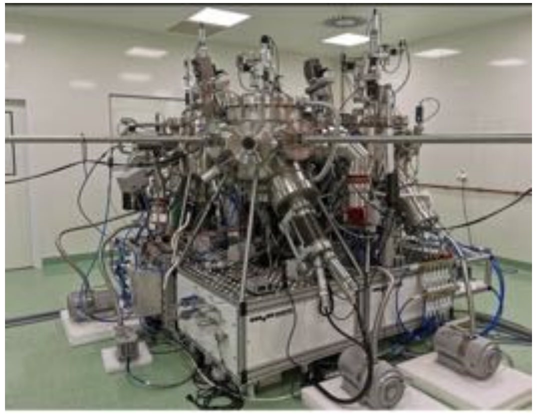
Laser cutter machine for RCF and CR39

Testing vacuum chamber

RCF scanner

Target Laboratory (V. Leca)

A target laboratory support for fabrication and characterisation of solid targets

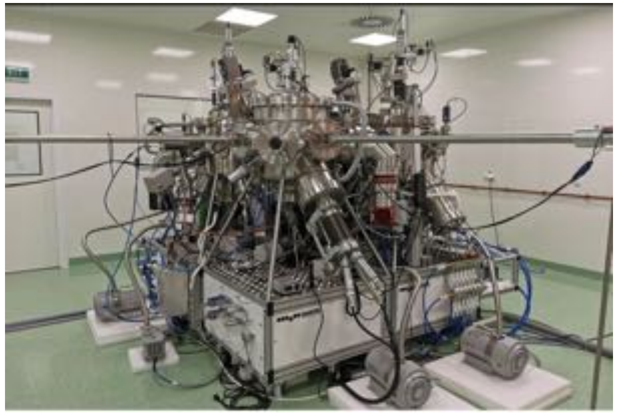


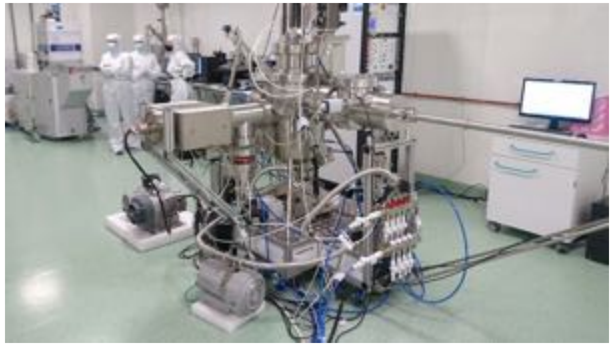
ELI-NP Target Laboratory support infrastructure

(V. Leca)

Target Laboratoy support

Capabilities:	Tools:
Fabrication of (ultra)thin/thick films (free-standing or supported)	RF/DC sputter deposition, e-beam evaporation, spin-coating, electro-chemical synthesis.
Micro/nano-structuring (gratings, nanoparticles, nano-wires, nano-pillars, low density (porous) materials	Electron-Beam Lithography, photolithography, Reactive Ion Etching, Ar-ion milling, chemical methods
Characterization (Surface characterization, elemental composition, morphology and topography, roughness, interface analysis)	X-ray diffraction, Atomic Force Microscopy, Scanning Electron Microscopy with Energy-Dispersive X-Ray Spectroscopy and Electron Backscatter Diffraction, optical profilometry and microscopy
Surface treatments	Thermal treatments, polishing, surface reconditioning, plasma surface cleaning
Micromechanical and micro assembly	Wafers cutting, targets frames, micromachining





0.1 and 1 PW theory and simulation support

(P. Tomassini, A. Berceanu)

Currently available computational resources include

- 1x128CPU Xeon 8358, 1Tb RAM
- 2x48CPU AMD Ryzen 3960X, 250Gb RAM
- 2x24CPU Xeon 8268, 1.5TB RAM
- 8x16CPU AMD Rome 7282, 256GB
- 2xA100 GPU, 160Gb, Nvlink
- 16xV100 GPU SXM3, 512GB, Nvlink
- 16x10TB SATA, HDD

Available codes include

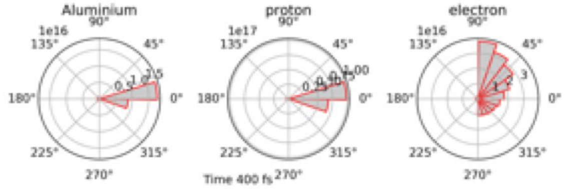
- EPOCH 2D (laser-solid, LWFA)
- Smilei 2D (laser-solid, LWFA)*
- PIConGPU (laser-solid, LWFA)*
- FB-PIC** quasi-3D (laser-solid with normal incidence, LWFA)
- Qfluid 2D cyl (LWFA)
- TSST (Nonlinear Thomson backscattering)
- RelNTS (Nonlinear Thomson Scattering at arbitrary angles and with structured pulses)

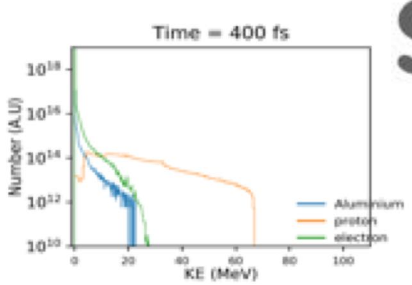
Typical computational time

*2-3 days of computational time for a standard TNSA simulation with 15nm of resolution

**4-6h of computational time for a quasi-3D simulation of LWFA in the bubble regime, 1cm of propagation

Laser solid with standard and structured pulses



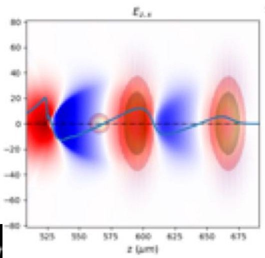


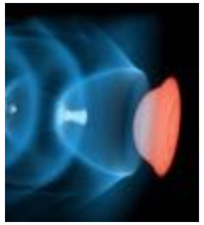
Smilei

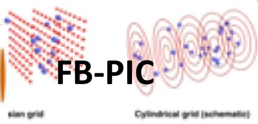
EPOCH

PIConGPU

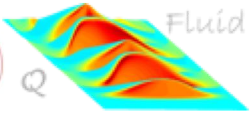
LWFA with standard and structured pulses





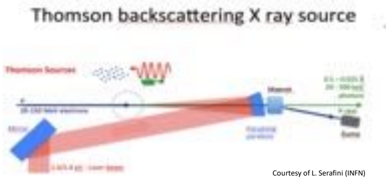


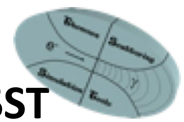
FB-PIC



QFluid

Nonlinear Thomson Scattering with standard and structured pulses





TSST

RelNTS

Hydrodynamical simulations

FLASH CENTER

Thank you for your attention

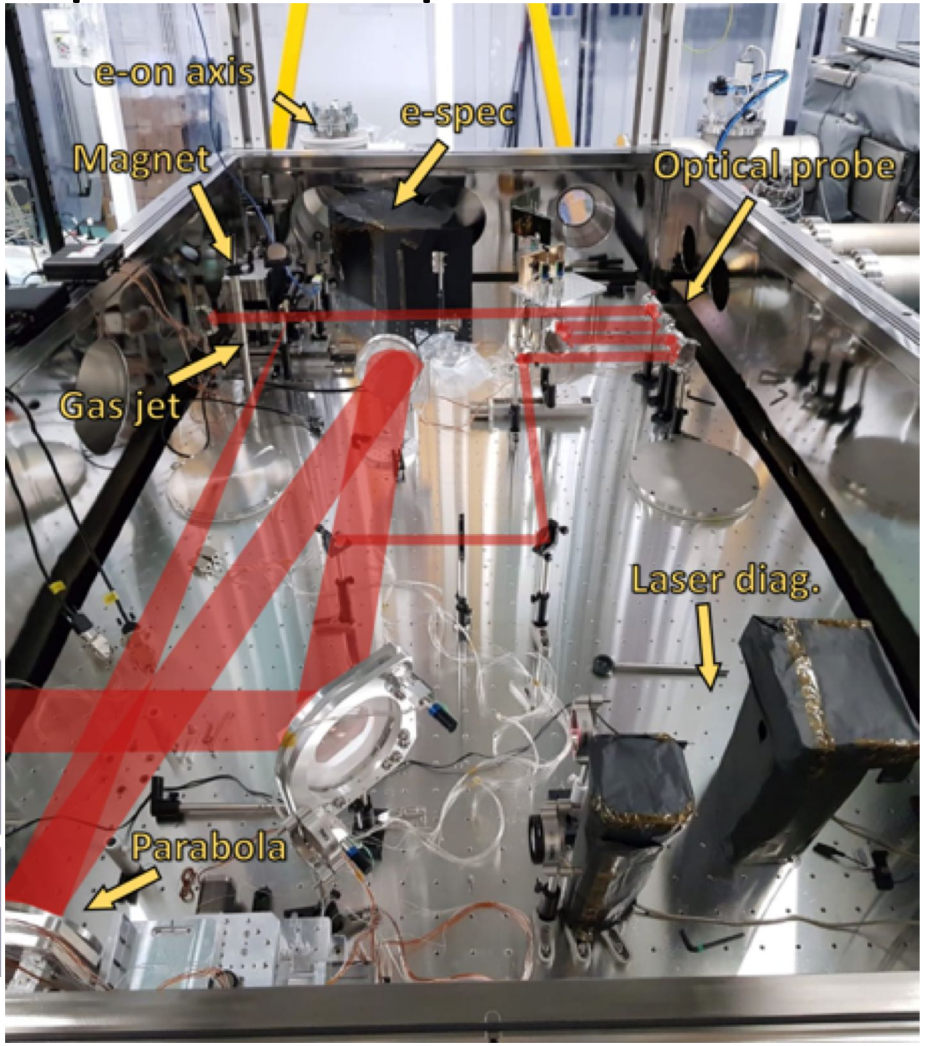
Commissioning results

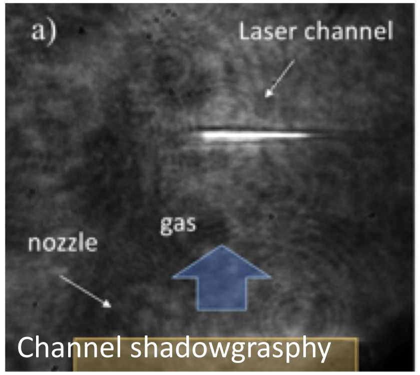
The 100 TW LWFA results

First operation in 2020 – Electron acceleration in gas targets (P.I. D. Doria)

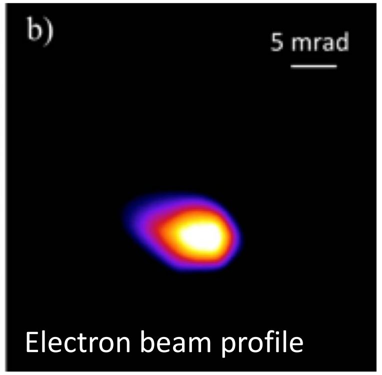
- Gas jet target 2mm long
- SourceLab valve with controller SL-Smartshot (fast solenoid valve driver LX-03R and electro-magnetic valve A2-6443)
- Pure He and mixture He +2% N_2 were used
- F=1500mm parabola
- Max. electron energy attained with Helium gas ≈220 MeV with an energy spectrum having a certain degree of monochromaticity
- Max. electron energy reached using the gas mixture ≈ 320 MeV with a continuum energy spectrum, as expected when using a dopant such as N_2
- Electron diagnostics: spectrometer (up to 500 MeV) – 16 cm long dipole magnet with 3 cm gap and ~0.7 T B-field, and a Lanex screen

Experimental setup

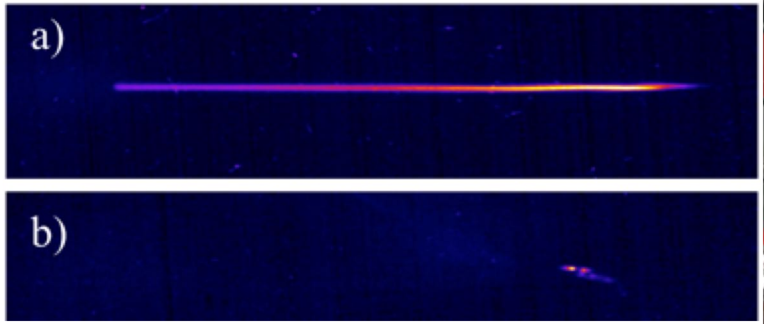




Channel shadowgrasphy



Electron beam profile



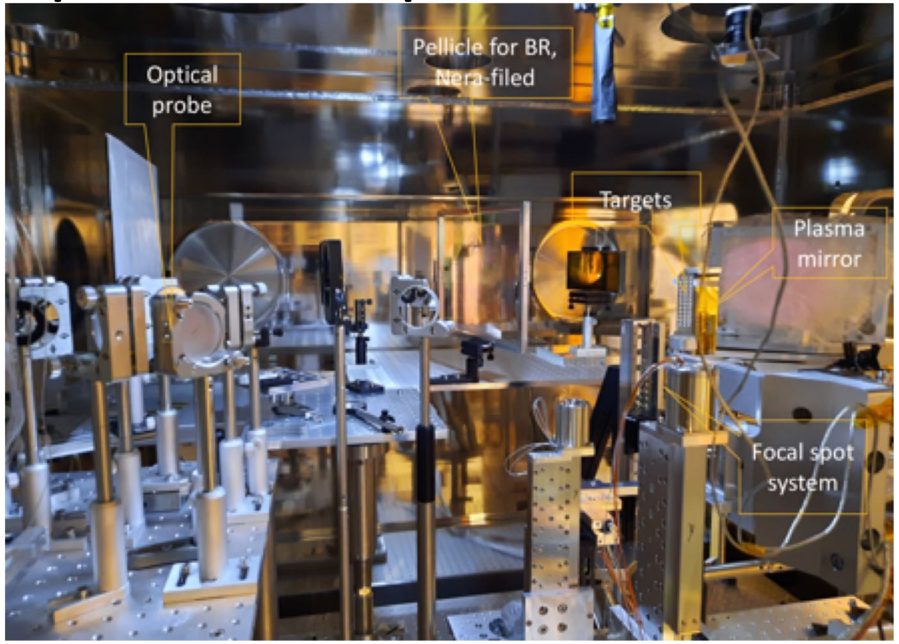
Electron spectrometer raw images: a) signal with admixture, b) with pure He.

The 1 PW TNSA results

First operation in 2021 – ion acceleration from solid targets (P.I. M. Cernaianu)

- Thick and thin foils (e.g. Al, CH, DLC)
- F=710mm parabola
- Max. proton energy attained of 50 MeV with SPM
- Max. ion energy attained: carbon ion 15 MeV/n from DLC target by using a SPM.

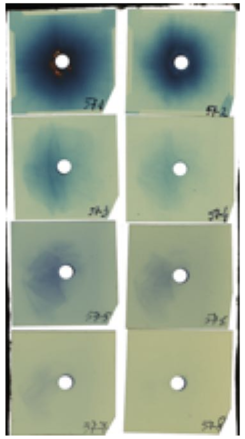
Experimental setup



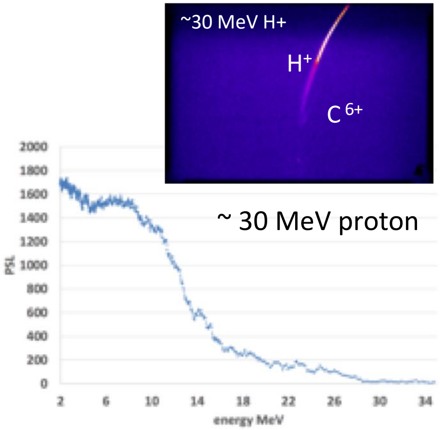
Shot parameters with plasma mirror

Laser beam power:
23.1 J, ~26 fs ➔ 880 TW
Intensity on target: ~ 4 x10^{21} W/cm^2
Target: 1.5 µm Al foil

Radiochromic film stack

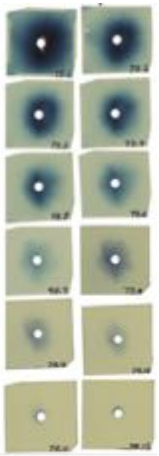


Thomson parabola data

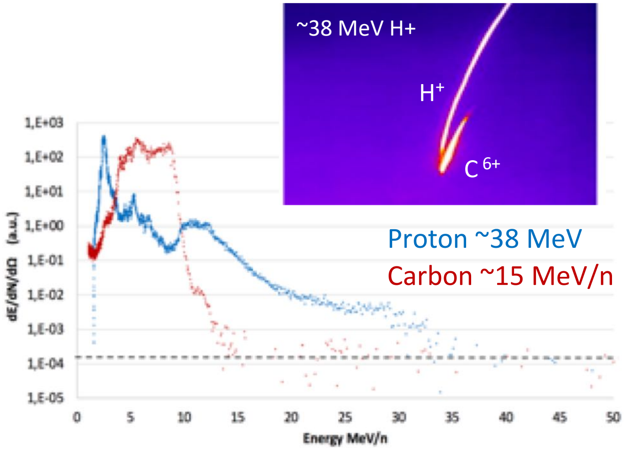


Laser beam power:
19 J, ~75 fs ➔ 250 TW
Intensity on target: ~ 1 x10^{21} W/cm^2
Target: 380nm DLC (built in house)

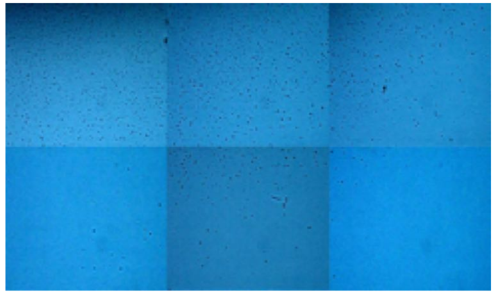
Radiochromic film stack



Thomson parabola



CR-39 show E_p > 50 MeV



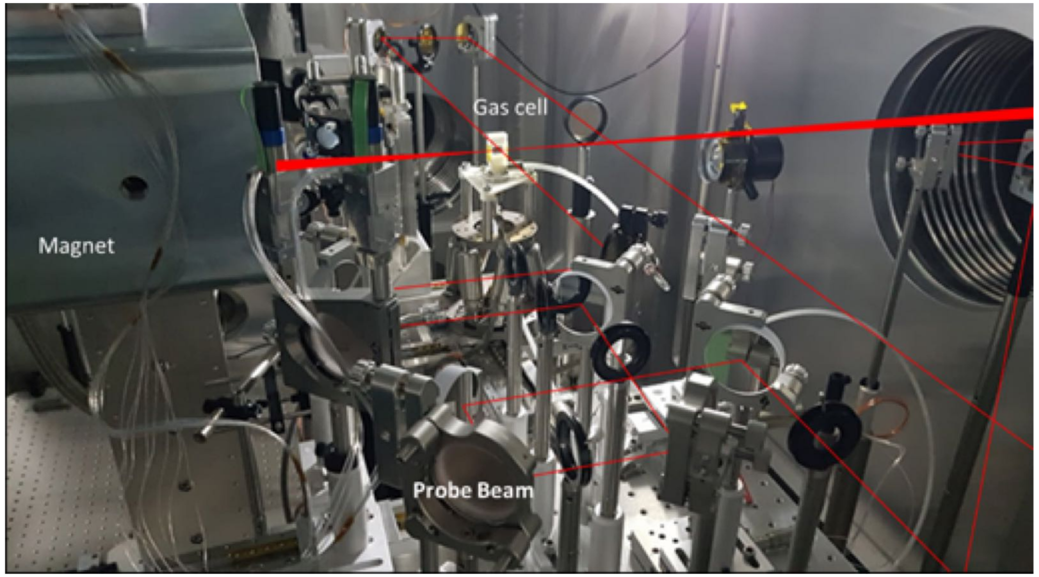
Proton density ~ 10^3 protons /cm^2

The 1 PW LWFA results

First operation in 2021 – Electron acceleration in gas targets (P.I. P. Ghenuche)

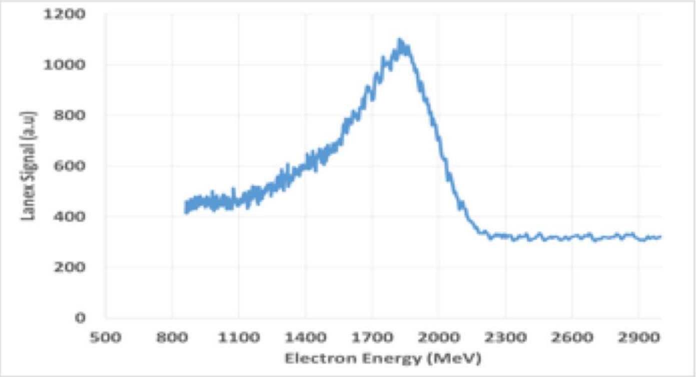
- Gas jet target and gas cell from 2mm to 2 cm long
- SourceLab variable metal gas cell, fix 3D printed gas cell, 2 mm metal gas jet
- Pure He and mixture He +2% N_2 were used
- F=5000mm parabola
- Max. electron energy attained with both Helium gas and admixture of ≈ 2 GeV
- Electron diagnostics: spectrometer (up to 3 GeV) – 30 cm long dipole magnet with 3 cm gap and ~1 T B-field, and a Lanex screen

Experimental setup

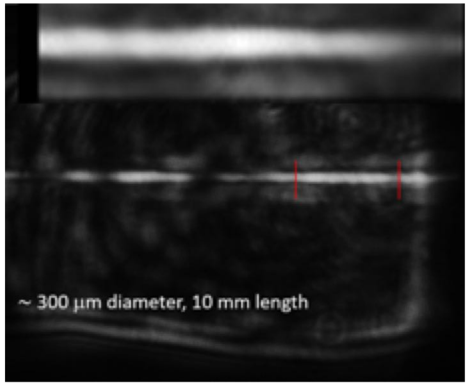


zero point

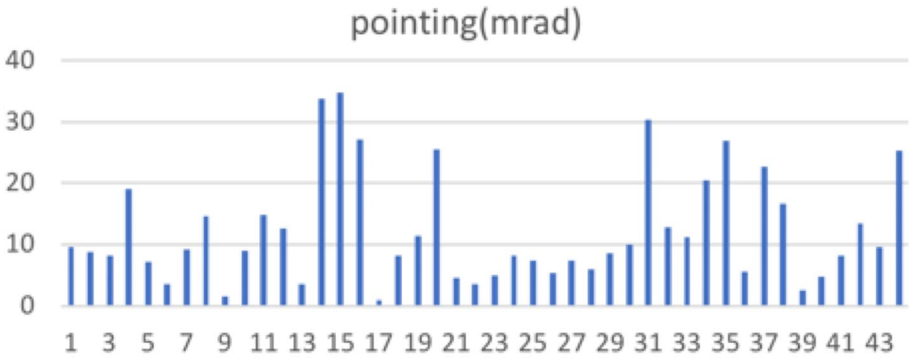
Electron deviation on lanex



Electron Beam Energy Spectra for pure He



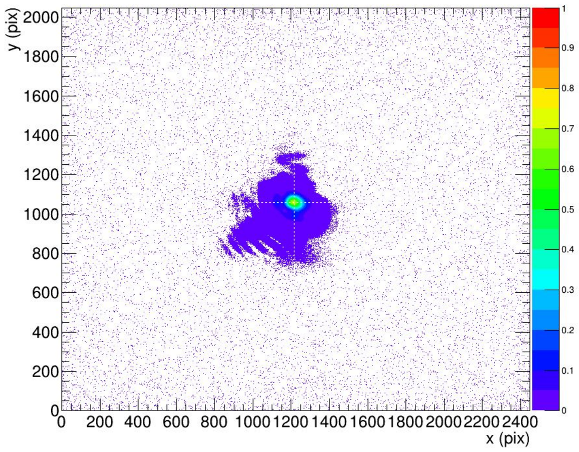
Shadowgraphy and WFS (plasma channel)



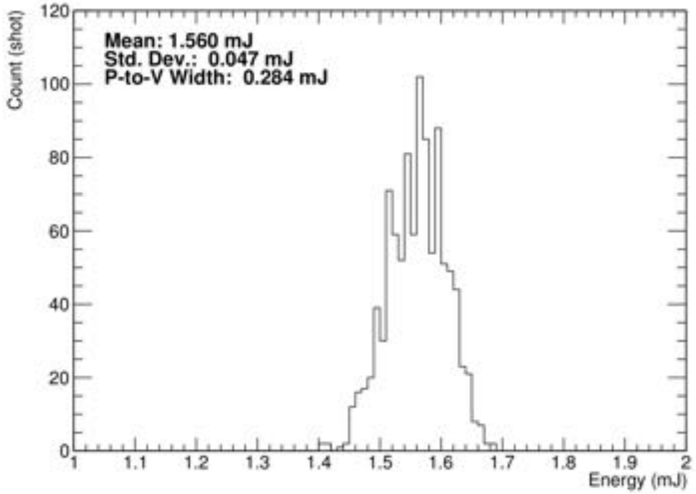
Electron Beam Pointing in a typical day from gas admixture

The 100 TW short focal

Focal spot optimization with the F=520mm OAP

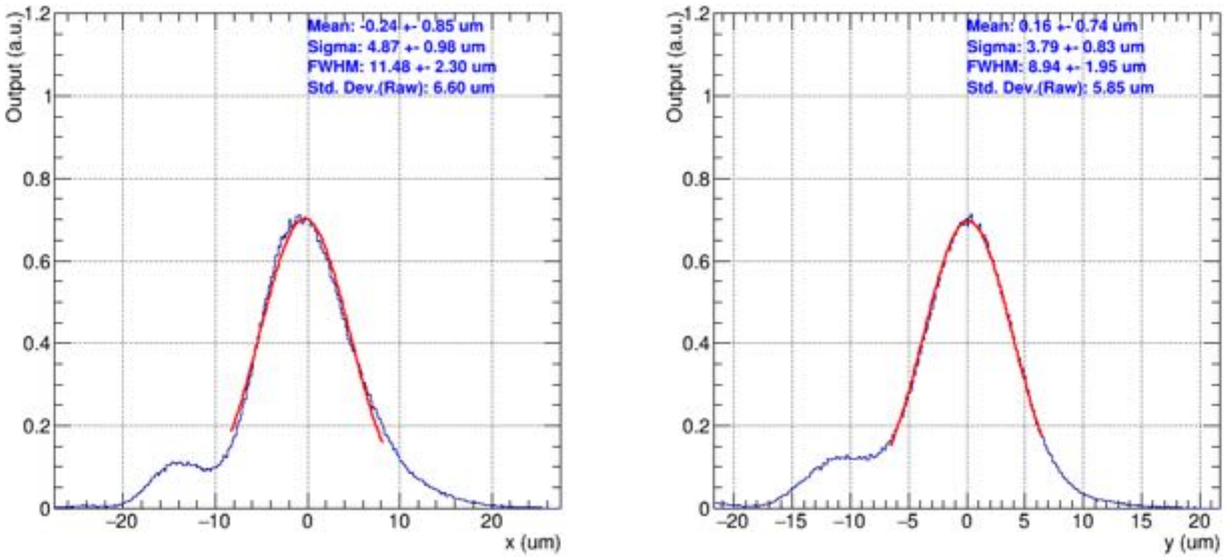


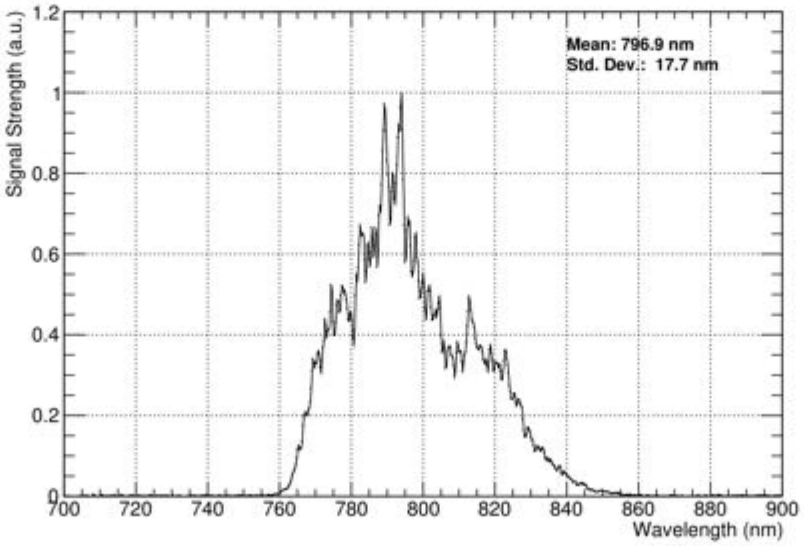
Energy Stability at focus



Spectrum before OAP
(100 shots averaged)

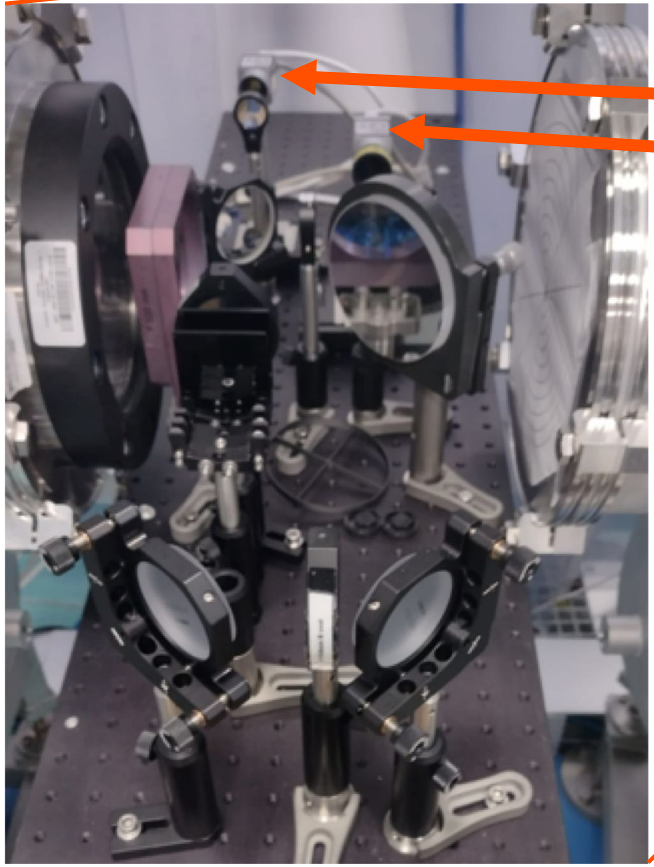
Crossline Sections





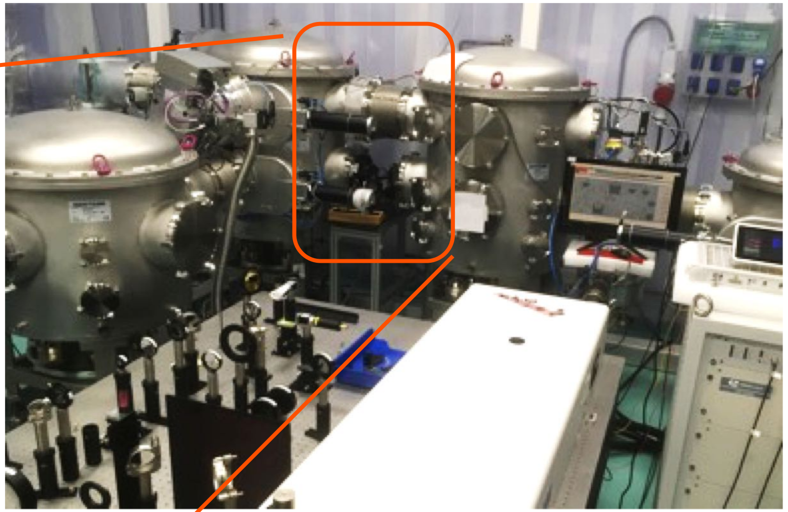
The 100 TW alignment systems

Laser diagnostics for daily alignment

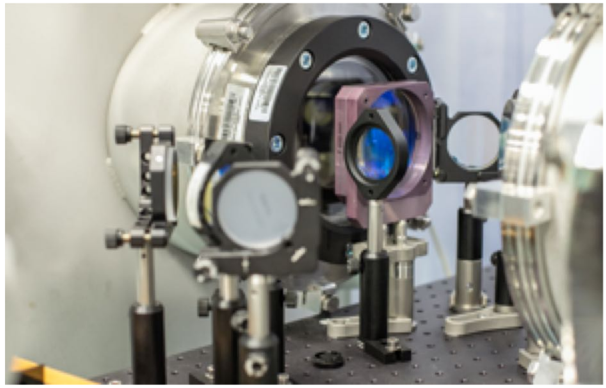


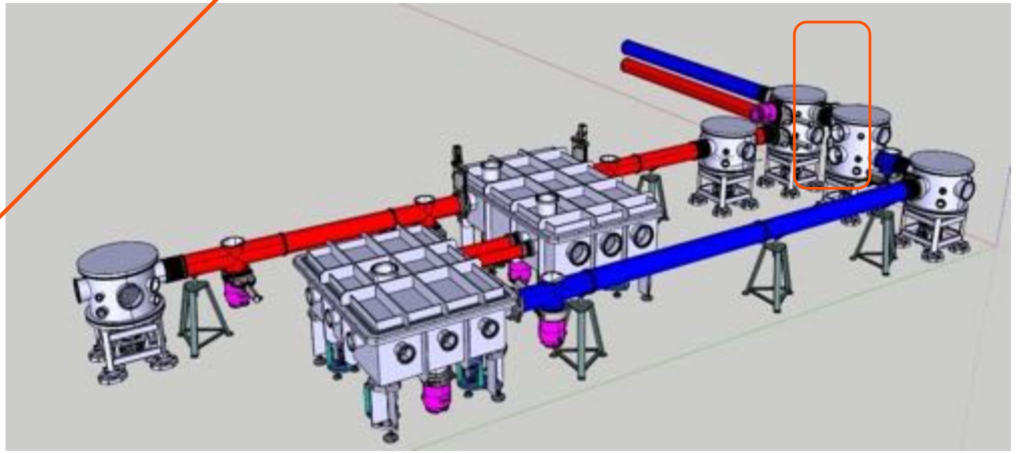
Near-field

Far-field



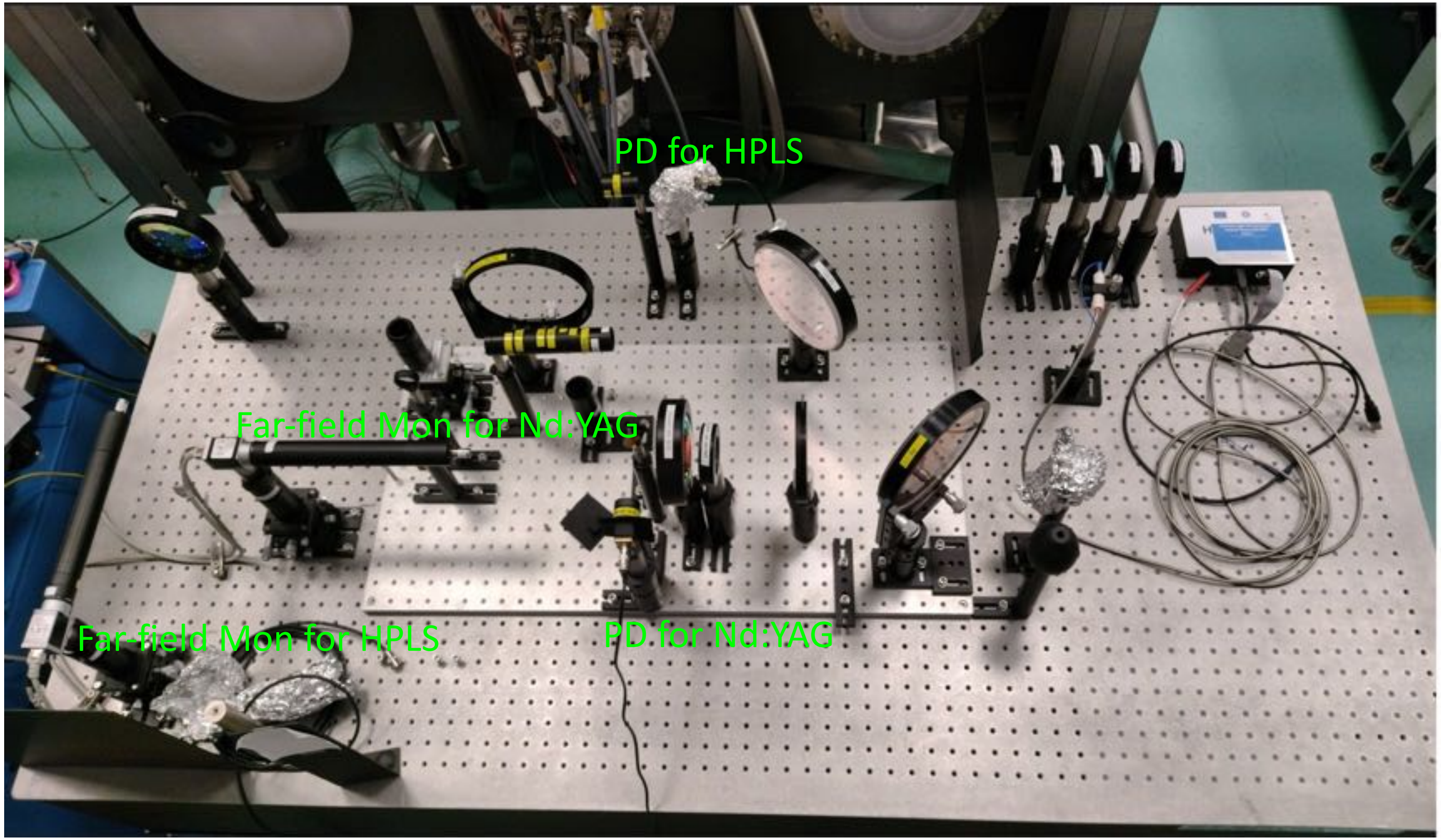
The diagnostics bench is located after the first turning box in the area



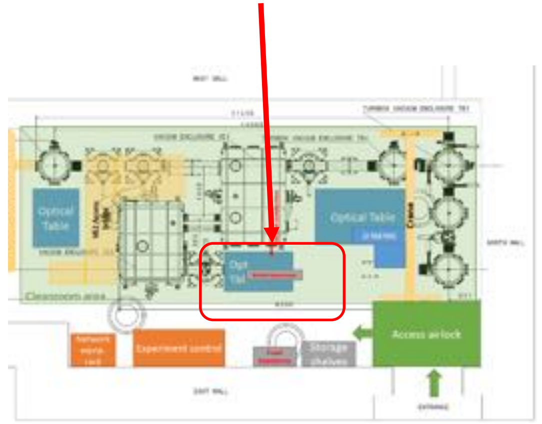


The 100 TW alignment systems

Pulse diagnostics for the experiment



Currently located near VE1



CMOS cameras for far-field mon.

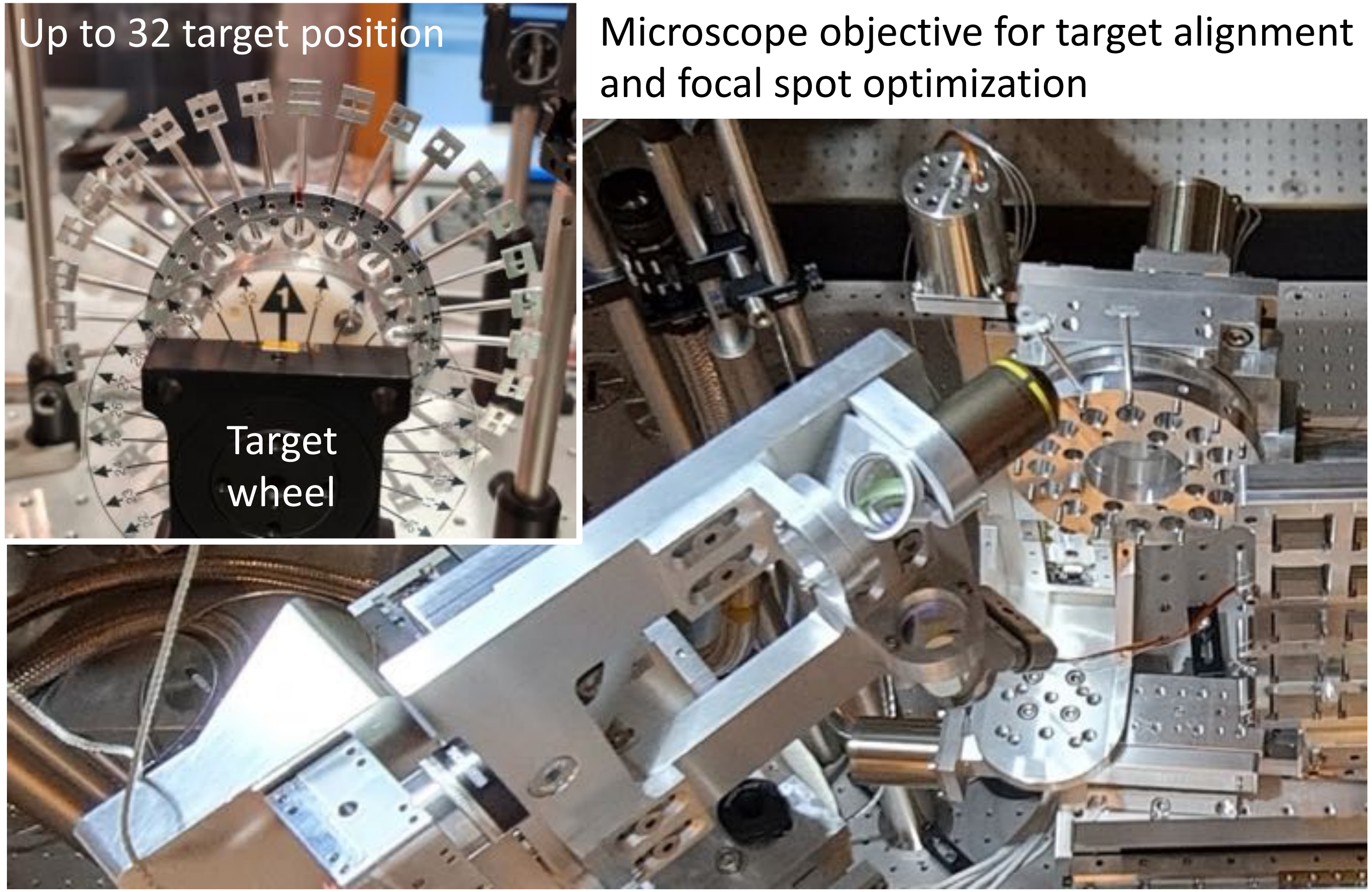
Fast photo-diodes

Pulse duration measurements can be performed in E4, on demand

The 1 PW alignment systems

Target alignment

Many targets loaded for a day of shooting

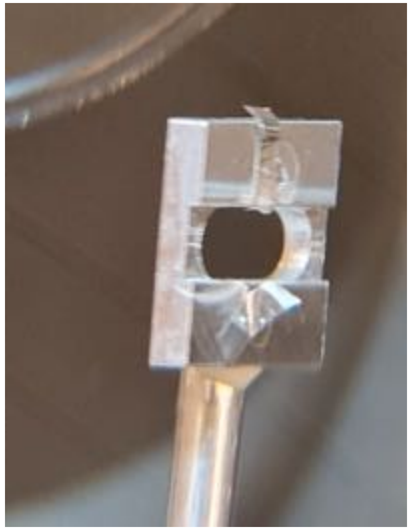


Microscope objective for target alignment and focal spot optimization

Target Al foils on holder

Before shot: intact

After shot: exploded



Target surface aligned before the shot: central region is in focus