ELISS2023

ELI Summer School | 29 Aug – 1 Sep 2023

Dolní Břežany, Czech Republic

Overview of the Extreme Light Infrastructure-Nuclear Physics status and future perspectives

Domenico Doria

ELI-NP/IFIN-HH

29.08.2023

Dolní Břežany, Czech Republic

IMPULSE is funded by the European Union's Horizon 2020 programme under grant agreement No. 871161

Extreme Light Infrastructure Pillars

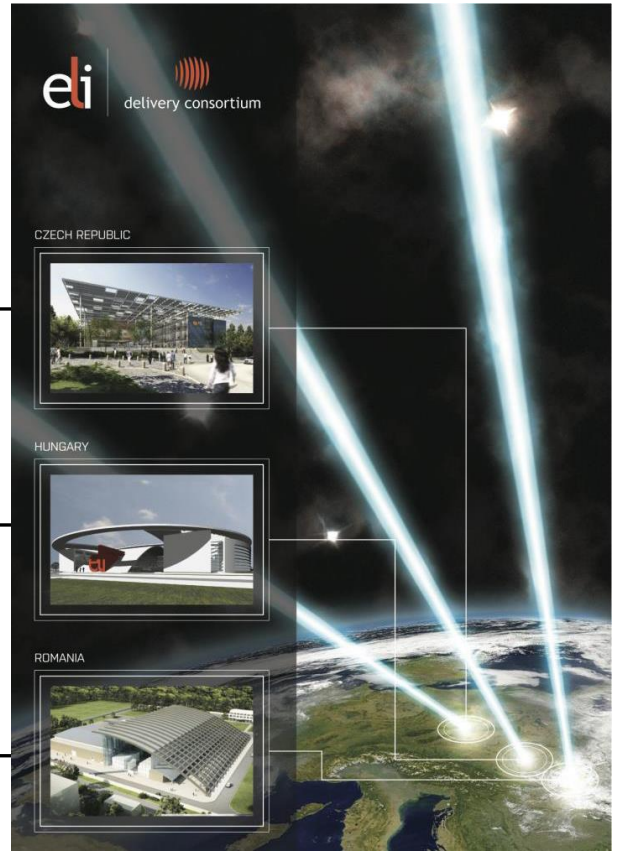
Extreme Light Infrastructure

https://eli-laser.eu/

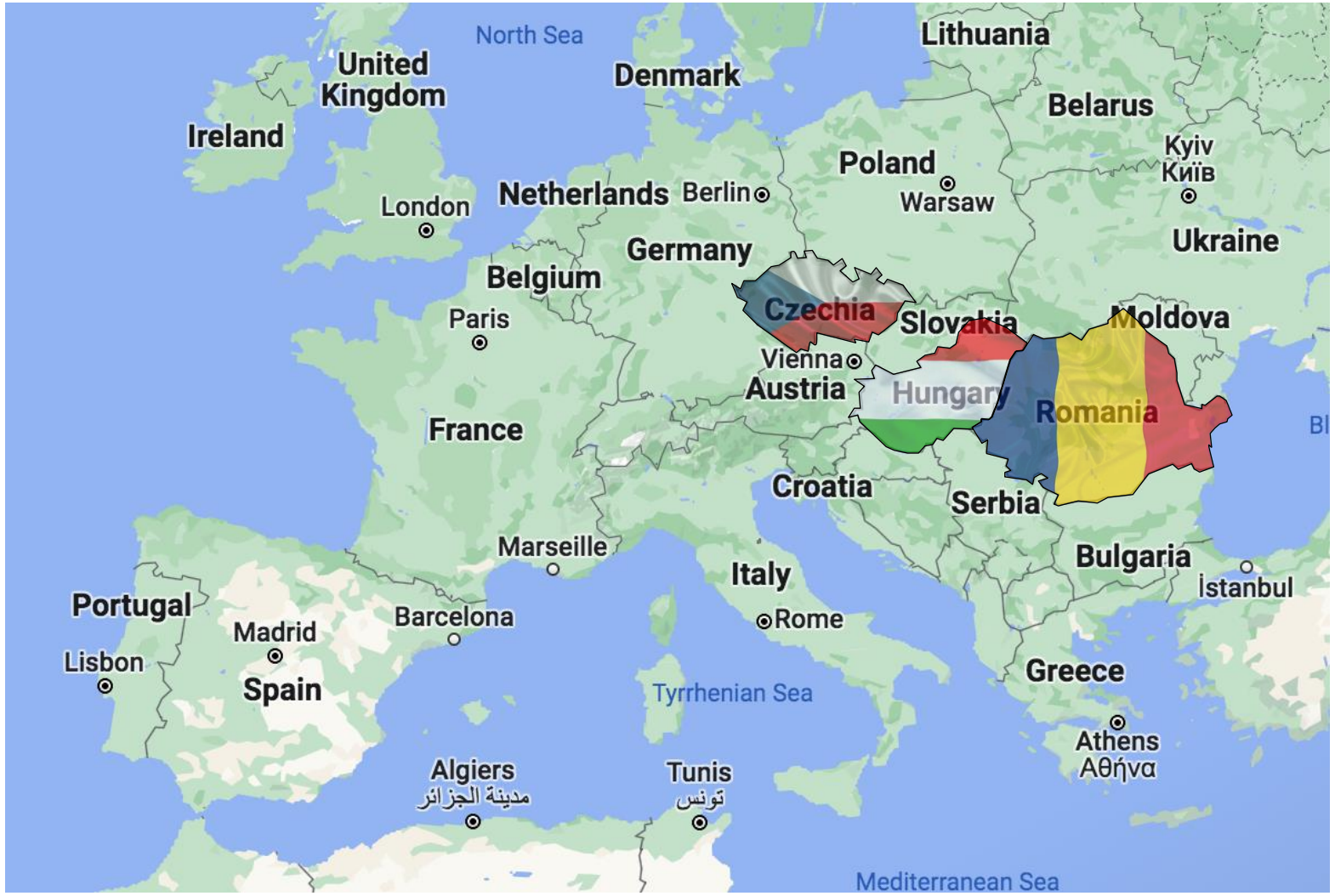
ELI-Beamlines
Prague, CZ

ELI-ALPS
Szeged, HU

ELI-NP
Bucharest, RO



Pan-European Research Center



The ELI-NP Infrastructure

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

Largest geothermal system in Europe ~ 6 MW

2 x 10 PW High-Power Laser System

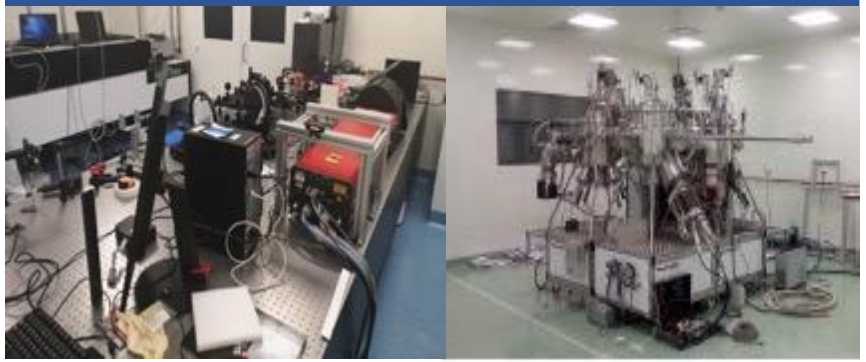
2 x 10 PW + 1 x 1 PW Laser Beam Transport System

Variable Energy Gamma System

120,000 tons antivibration platform

Clean rooms ISO6 - ISO7

Laboratories and workshops



9 Experimental areas

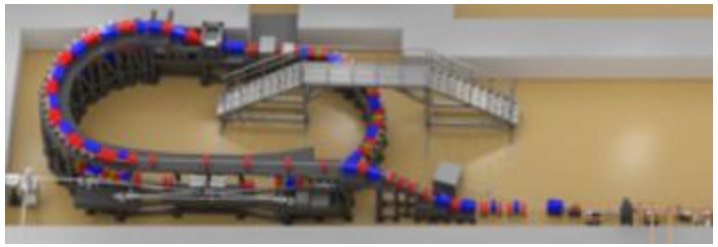
For more info: https://www.eli-np.ro/

The ELI-NP site

Overall implementation status: more than 85%

Major Components:

- **High power laser system (HPLS) + Laser beam transport system (LBTS)**
  100% – fully implemented and operational (**2019 HPLS, 2020 LBTS**)



- **Gamma beam system**
  45% - completion delayed

- **Experimental setups and laboratories**
  100% – fully implemented – **under final commissioning**

- **Civil constructions**
  100% – fully implemented and operational **(since 2016)**

ELI-NP Experimental activities

Advanced studies in basic science ...

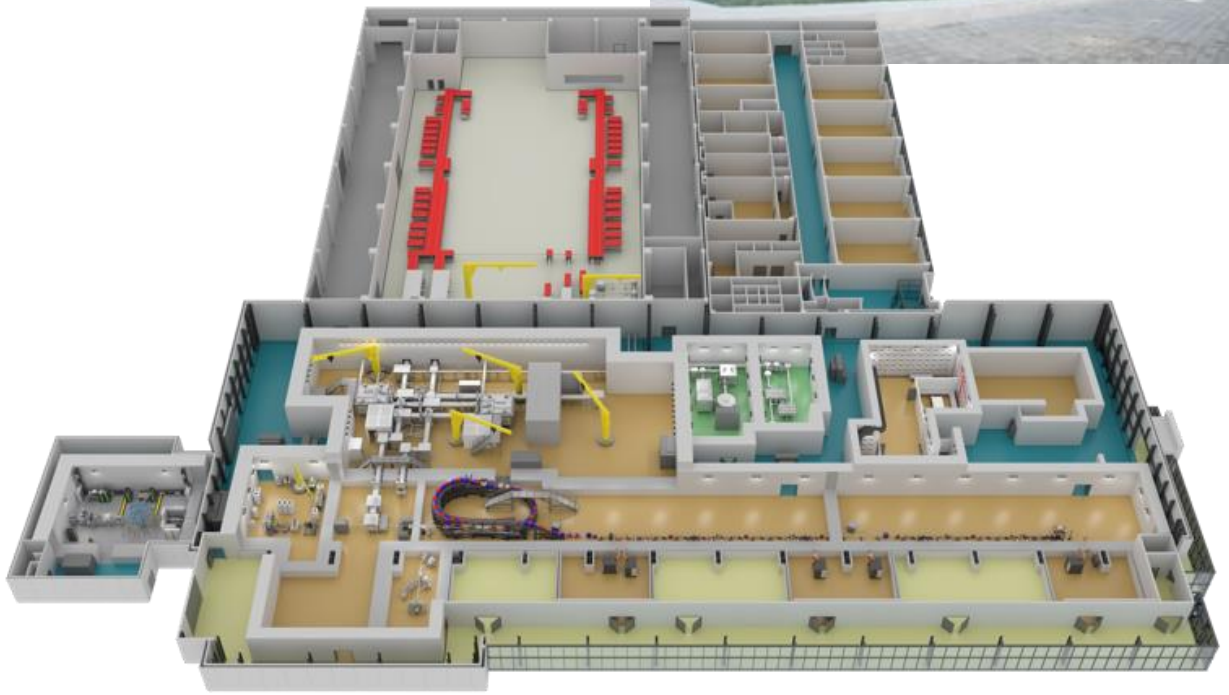
- characterization of laser-matter interaction with nuclear methods
- particle acceleration with high power lasers
- nuclear reactions in plasma
- photonuclear reactions, nuclear structure, exotic nuclei
- nuclear astrophysics and nucleosynthesis
- quantum electrodynamics (QED)

... 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

2015 Technical Design Reports
assessed by ELI-NP ISAB
Rom. Rep. Phys. Vol. 68 (2016)

Experimental building



K. A. Tanaka, *et al.*, *Current status and highlights of the ELI-NP research program, Matter and Radiation at Extremes*, **5** (2020) 024402.
D. Doria *et al., Overview of ELI-NP status and laser commissioning experiments with 1 PW and 10 PW class-lasers,* JINST **15** C09053 (2020)

ELI-NP Experimental building

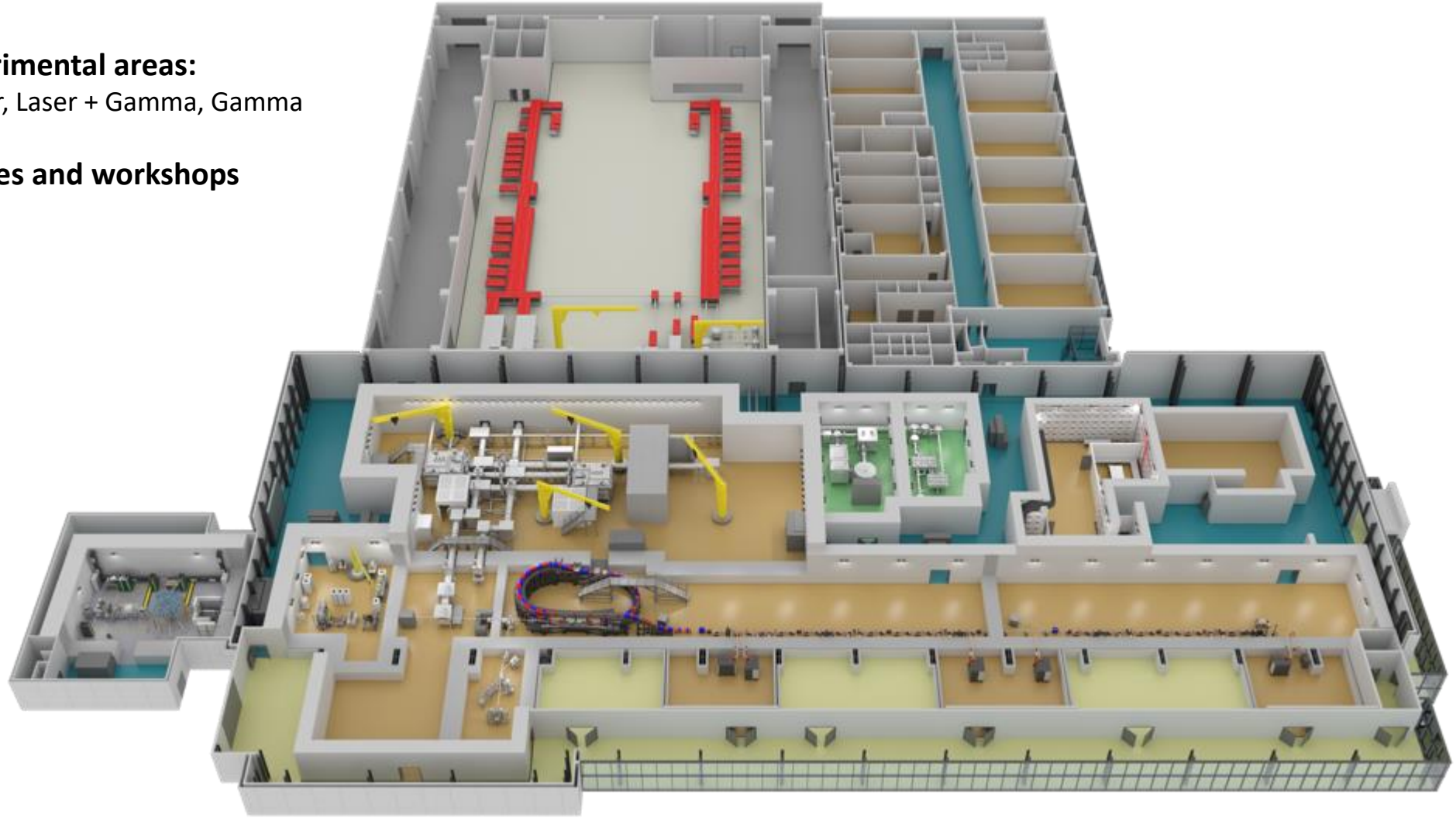
Two extreme light beam sources with unprecedented features:

1. High Power Laser System: 2 x 10 PW, 24 fs, synchronizable lasers
2. Gamma Beam System: 19.5 MeV, 0.5% rel. bwd, 5 x10^3 ph/s/eV, 95% lin. pol.

Nine experimental areas:

Laser + Laser, Laser + Gamma, Gamma

Laboratories and workshops



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ELI-NP Experimental building

Two extreme light beam sources with unprecedented features:

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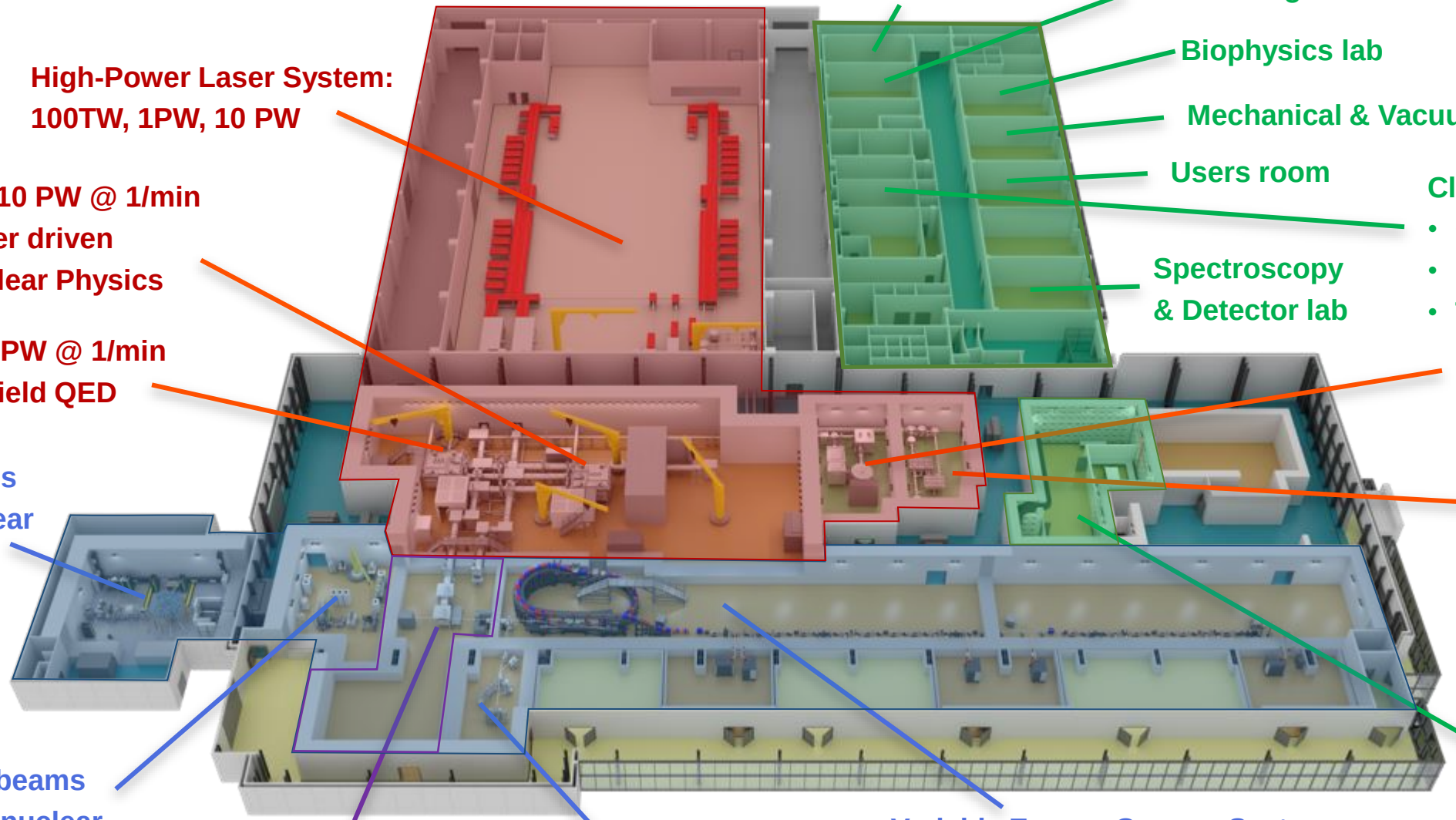


Dosimetry lab

Plasma diagnostics lab

Biophysics lab

Mechanical & Vacuum workshop

Users room

Clean rooms
- Optics lab
- Laser lab
- Target lab

Spectroscopy & Detector lab

High-Power Laser System:
100TW, 1PW, 10 PW

E1: 10 PW @ 1/min
Laser driven
Nuclear Physics

E6: 10 PW @ 1/min
High Field QED

E5: 1 PW @ 1 Hz
Material Studies

E9: γ beams
Photonuclear
Reactions

E4: 0.1PW@10 Hz
Photon-photon
int., LWFA, X-ray
imaging

E3: X rays
Test/develop
instrumentation
and technology

E8: γ beams
Photonuclear
Reactions

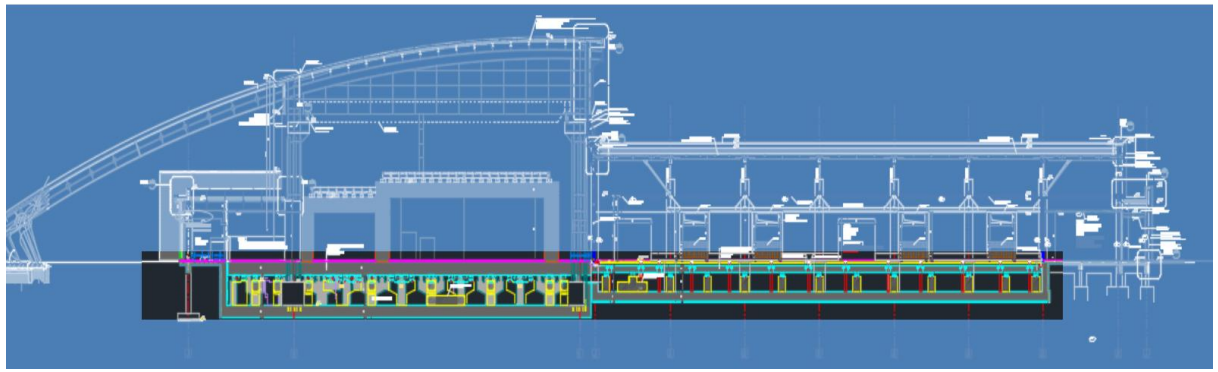
E7: 10 PW + 1 PW + γ/e^-
High Field QED

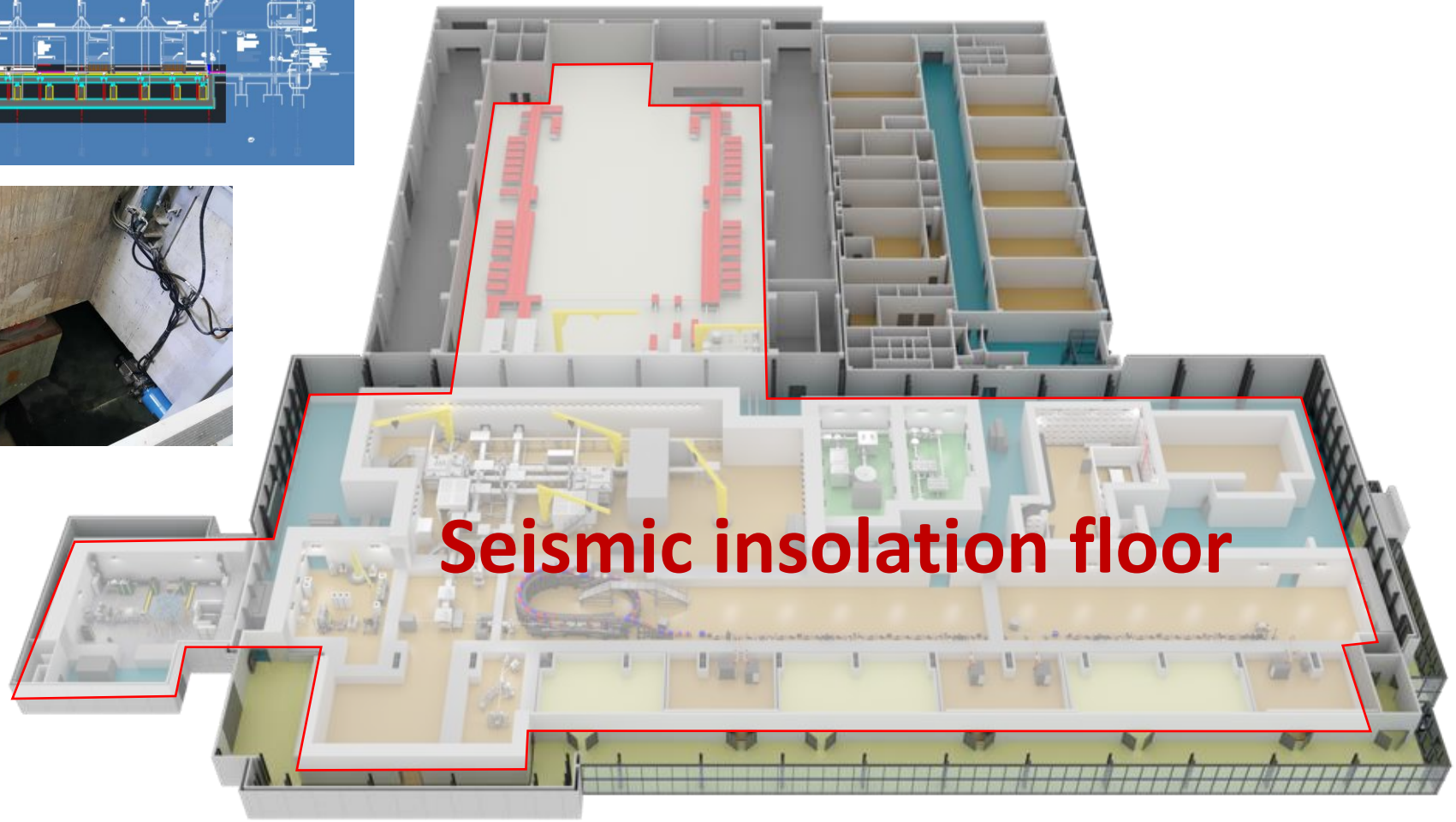
ERA: positrons
Material Studies

Variable Energy Gamma System:
γ up to 19.5 MeV,
Spectral density > 5000 photons/eV/s

Seismic insolation floor

Anti–vibration platform: ±1 µm @ < 10 Hz





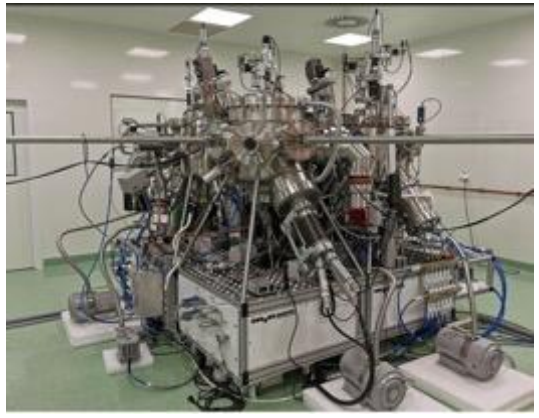
Laboratories available

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

Bio Laboratory (P. Vasos)

Target Laboratory (V. Leca)

A target laboratory support for fabrication and characterization of solid targets



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

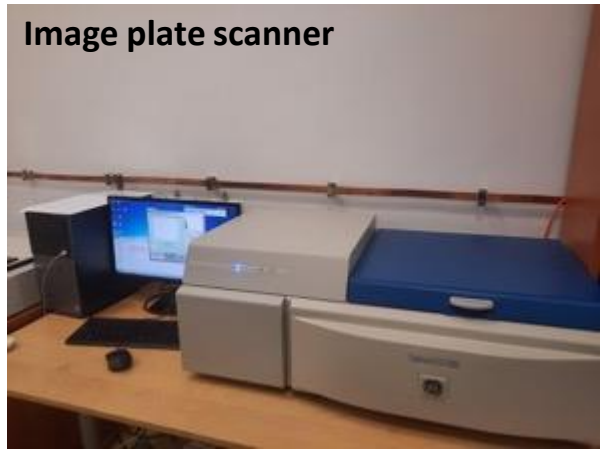


Image plate scanner

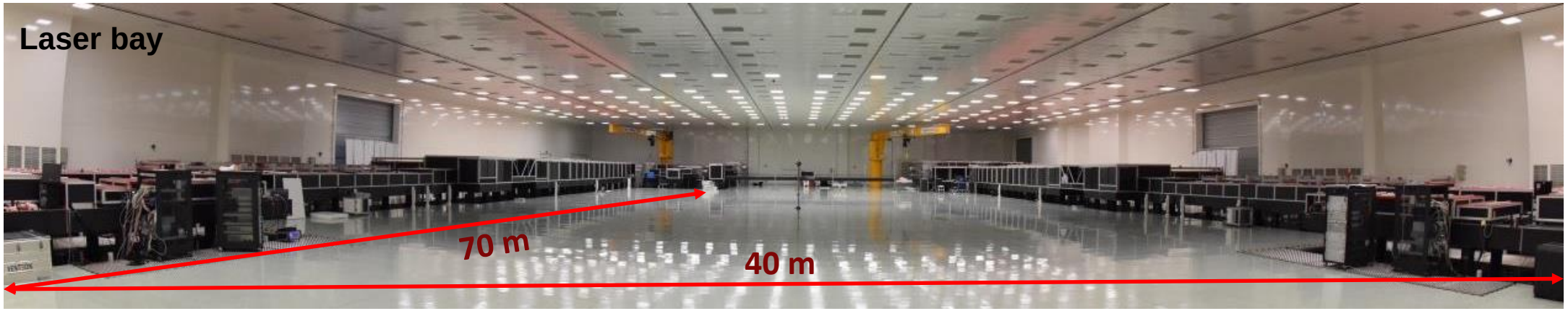

Laser cutter machine for RCF and CR39

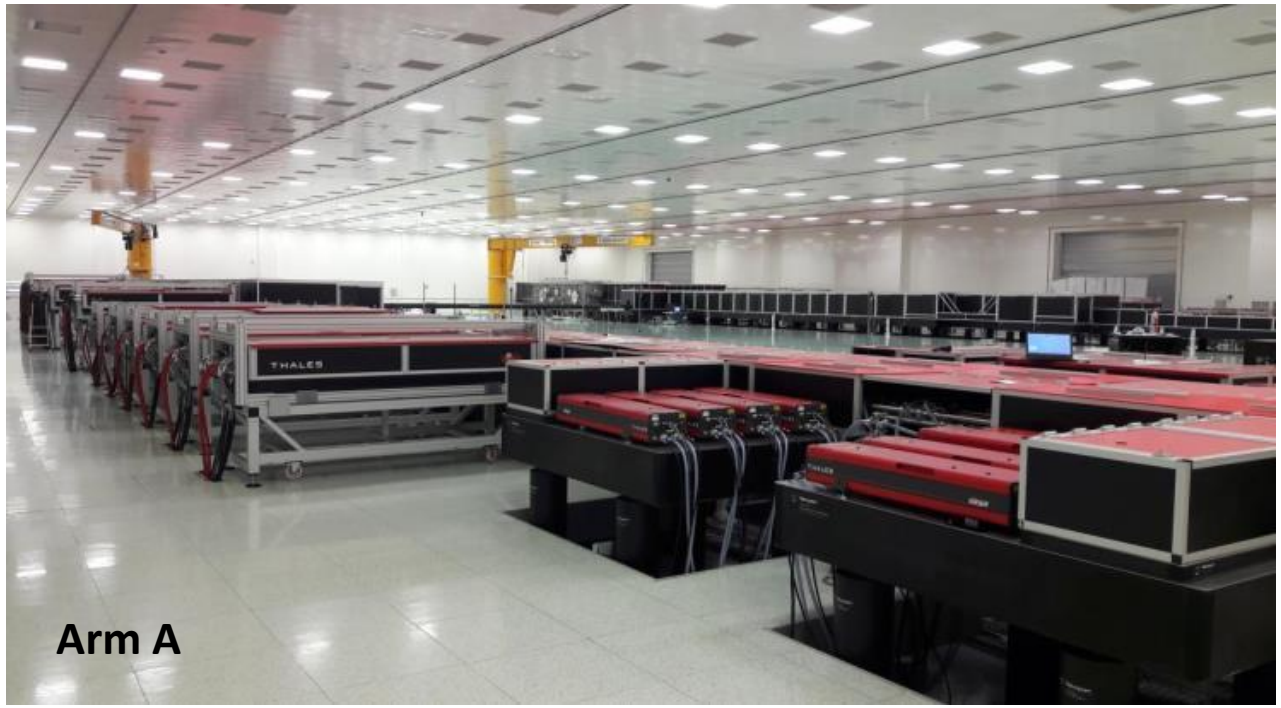

Testing vacuum chamber


RCF scanner

The ELI-NP High-Power Laser System (HPLS)

The ELI-NP high-power laser system





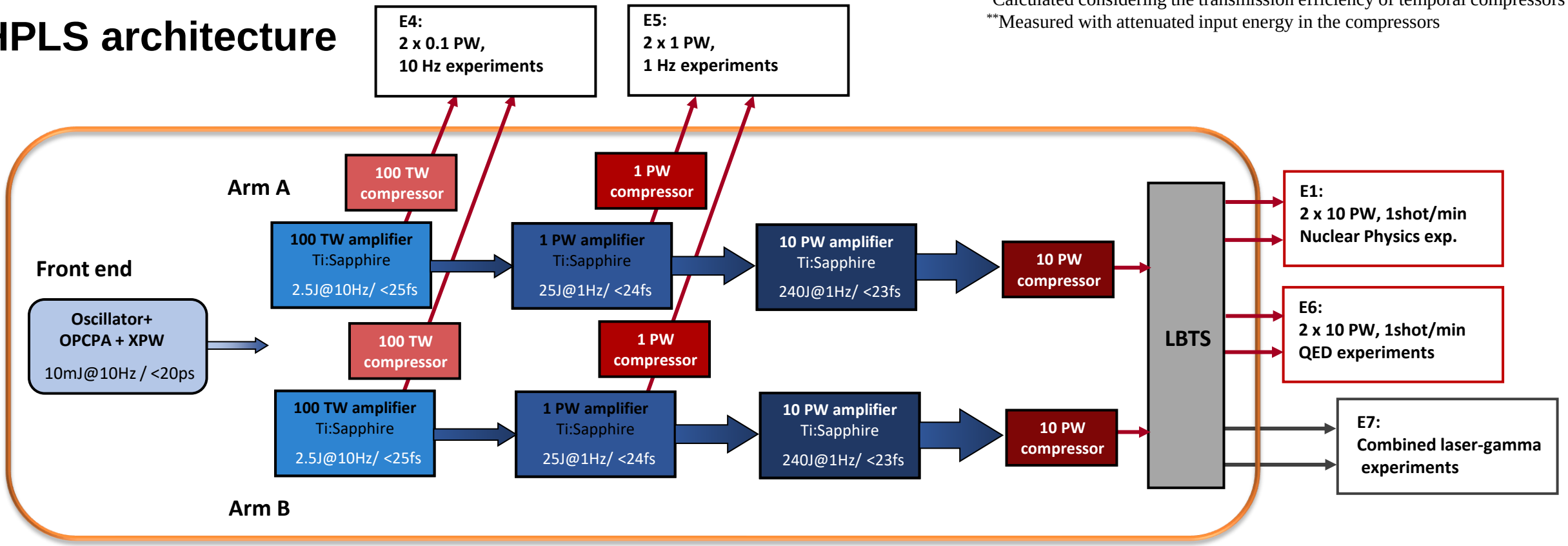
The ELI-NP high-power laser system

Measured parameters of the HPLS

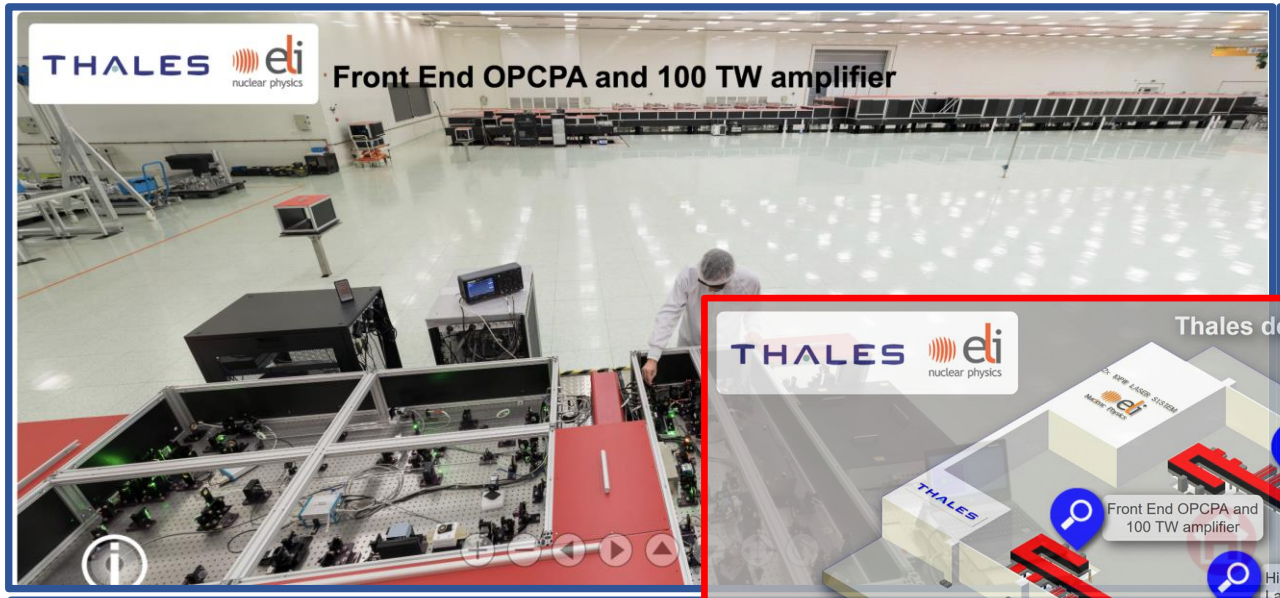
Output type	100 TW	1 PW	10 PW
Pulse energy (J) *	2.7	25	242
Pulse duration (fs) **	< 25	< 24	<23
Repetition rate (Hz)	10	1	1/60
Calculated Strehl ratio from measured wavefront	> 0.9	> 0.9	> 0.9
Pointing stability (µrad RMS)	< 3.4	< 1.78	< 1.27
Pulse energy stability (rms)	< 2.6 %	< 1.8 %	< 1.8 %

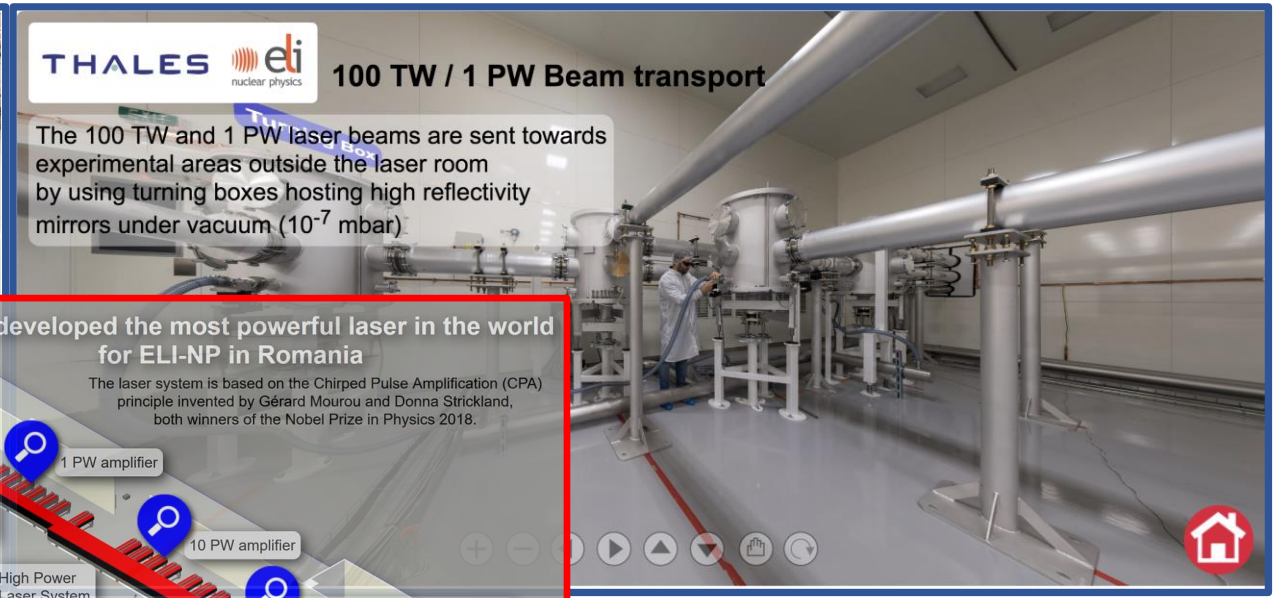
*Calculated considering the transmission efficiency of temporal compressors
**Measured with attenuated input energy in the compressors

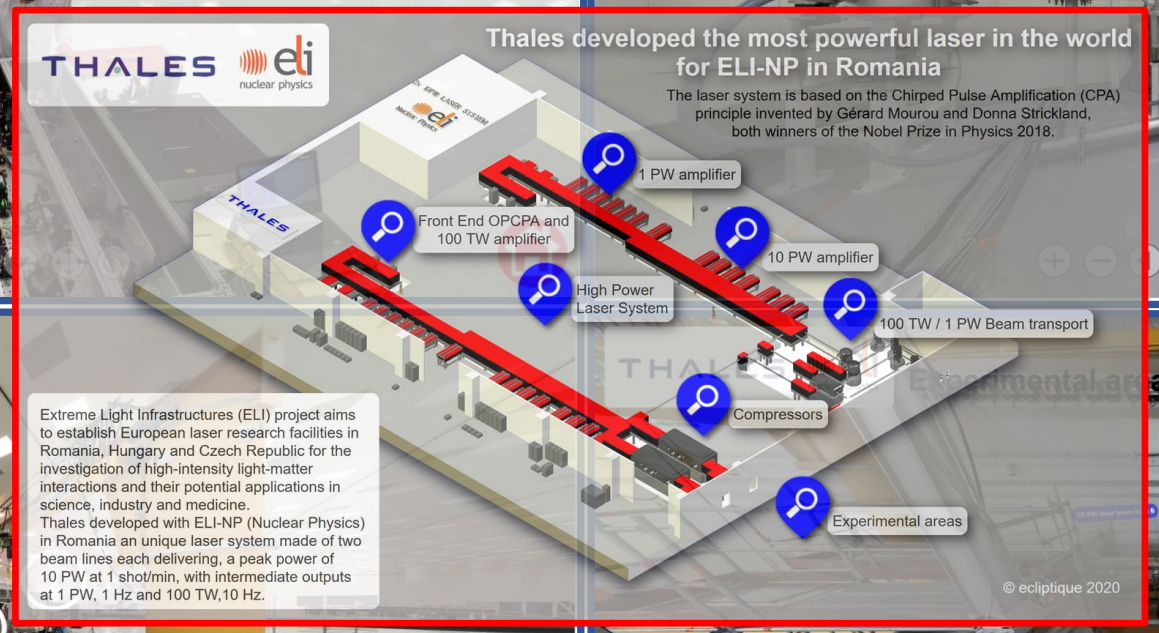
HPLS architecture

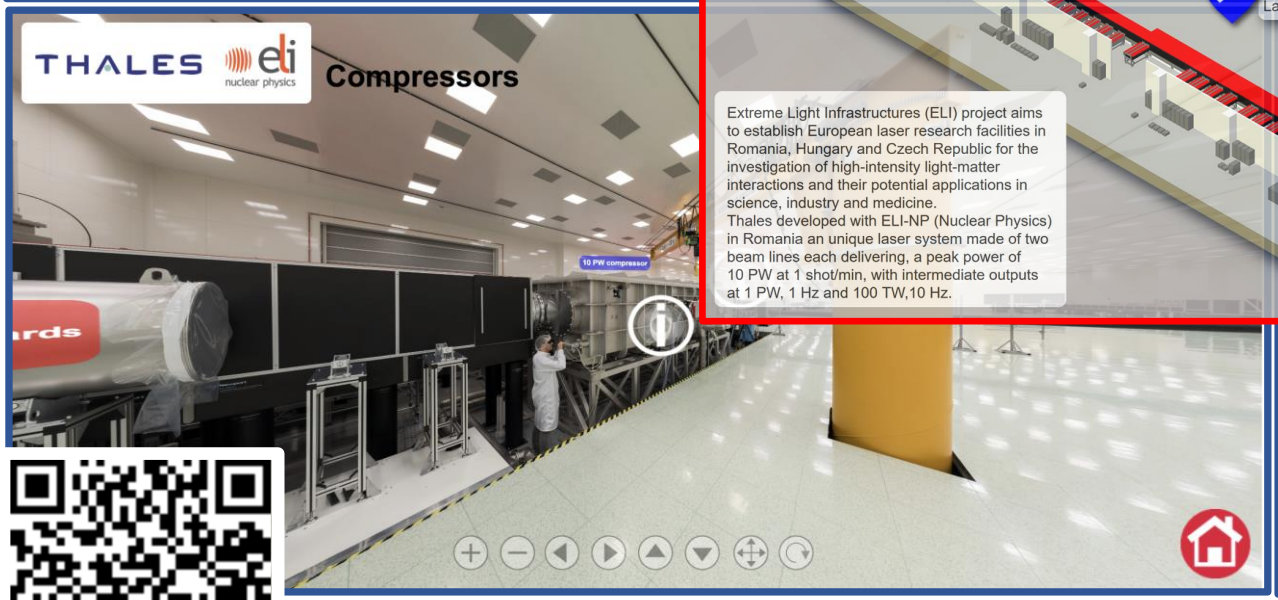


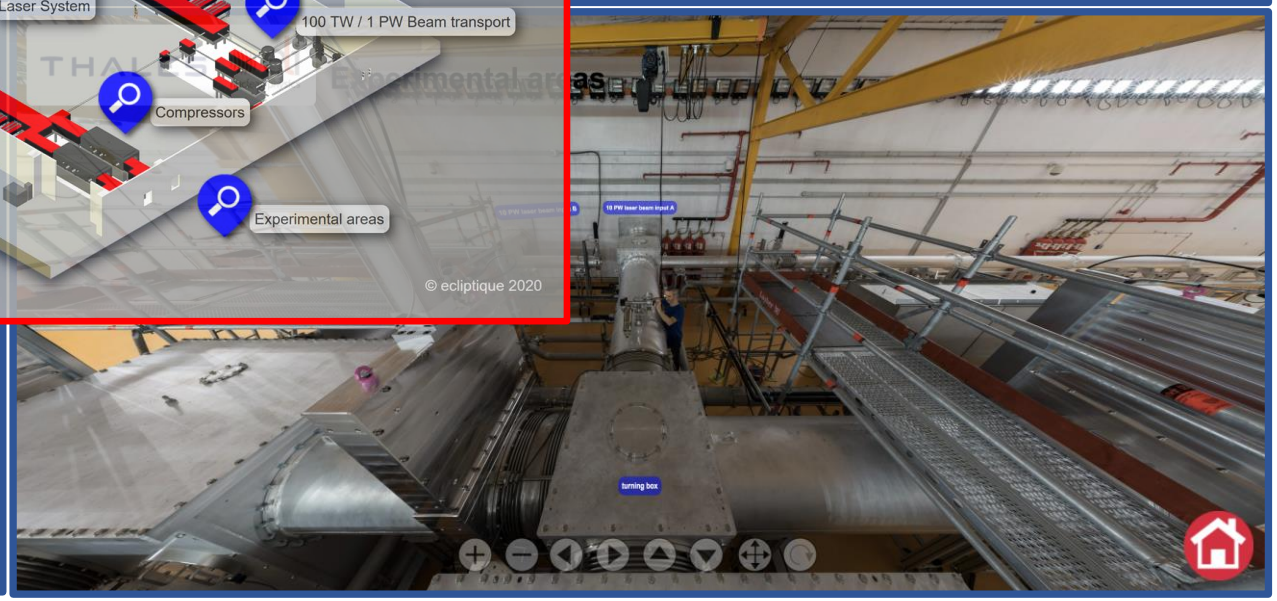
Virtual tour of the ELI-NP HPLS





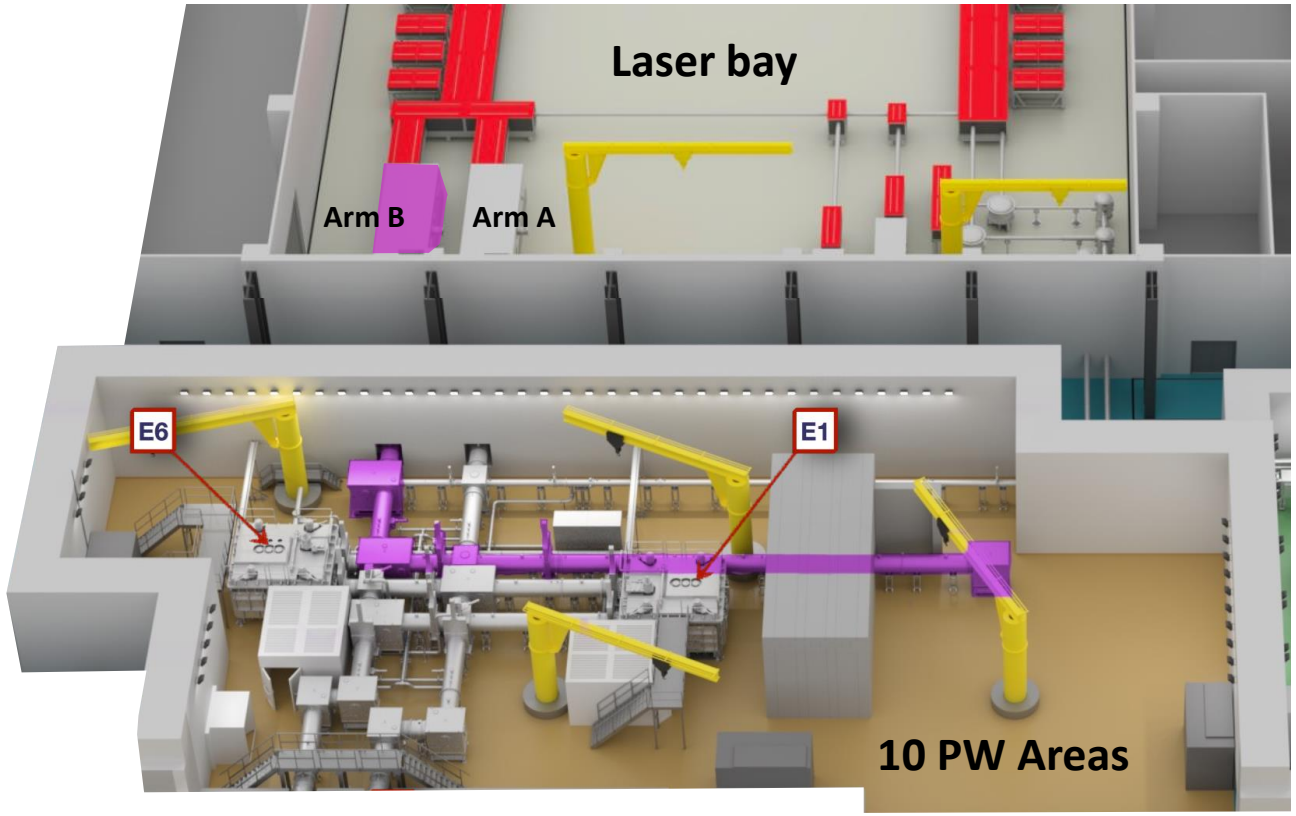






Virtual tour of the ELI-NP laser system
https://www.eli-np.ro/thales_eli-np.php

The High-Power Laser System inaugural day

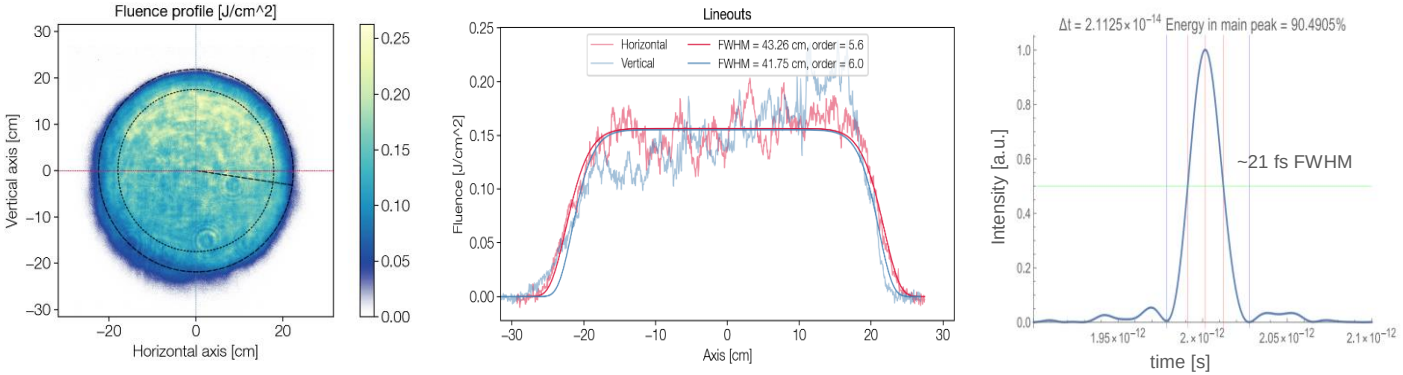


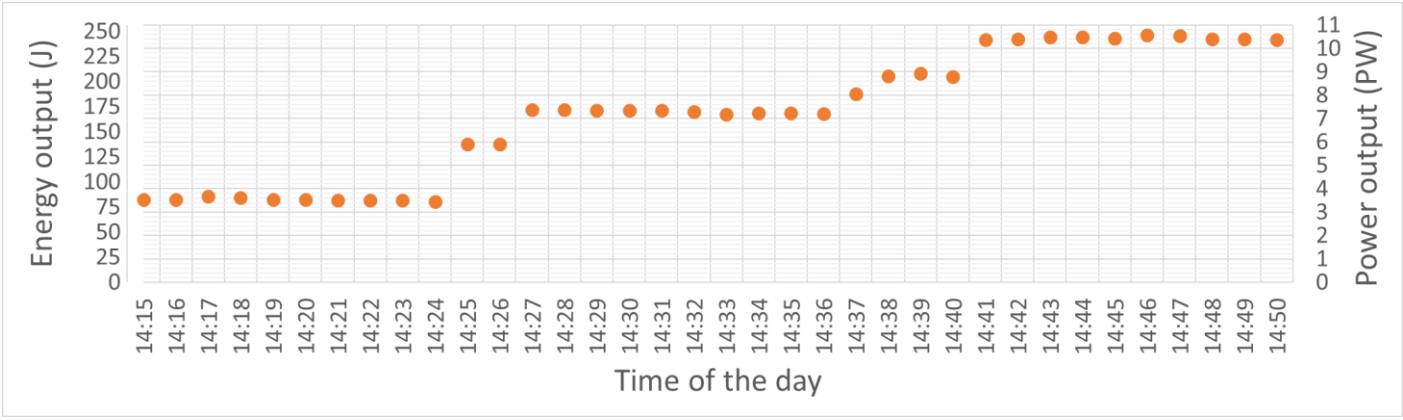
Control room of the HPLS

High power Joule meter

The High-Power Laser System inaugural day

Calculated peak power = 243 J / 23,4 fs = 10.4 PW





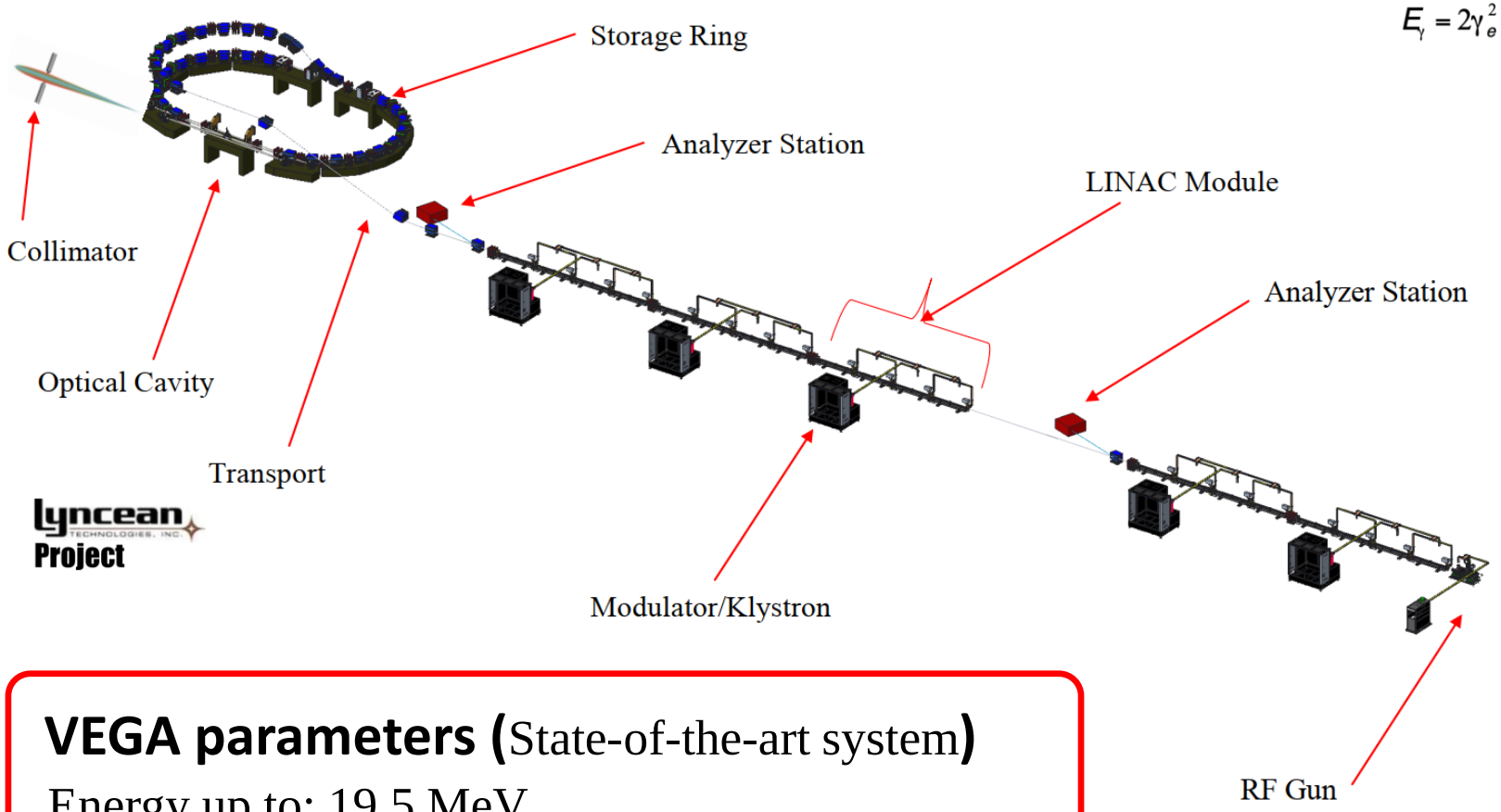
Control room of the HPLS

High power Joule meter

The ELI-NP Variable Energy Gamma System (VEGA)

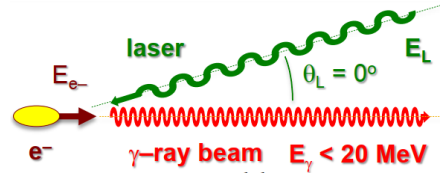
The ELI-NP Variable Energy Gamma System

The ELI-NP Variable Energy Gamma System (VEGA)
GSD department



IR and Green laser light for the inverse Compton scattering

$$E_\gamma = 2\gamma_e^2 \cdot \frac{1+\cos\theta_L}{1+(\gamma_e\theta_\gamma)^2 + a_0^2 + \frac{4\gamma_e E_L}{mc^2}} \cdot E_L$$



VEGA Main components

- **Injector system:**
  - RF electron source
  - 800 MeV warm LINAC (S-band)
- **Storage ring:**
  - top-up mode
  - bunch frequency (71.4 MHz)
- **High-gain optical cavity (71.4 MHz)**
  - IR laser (1030 nm) for E_γ = 1-10 MeV
  - green laser (515 nm) for E_γ = 2-19.5 MeV
- **Gamma-ray beam interface:**
  - collimator station

VEGA parameters (State-of-the-art system**)**

Energy up to: 19.5 MeV

Quasi-monochromatic: < 0.5 % relative bandwidth

High spectral density: > 5000 photons/eV/s

High-degree of linear polarization: > 95 %

Implementation completion taken over by ELI-NP

⟹ **delayed to 2026**

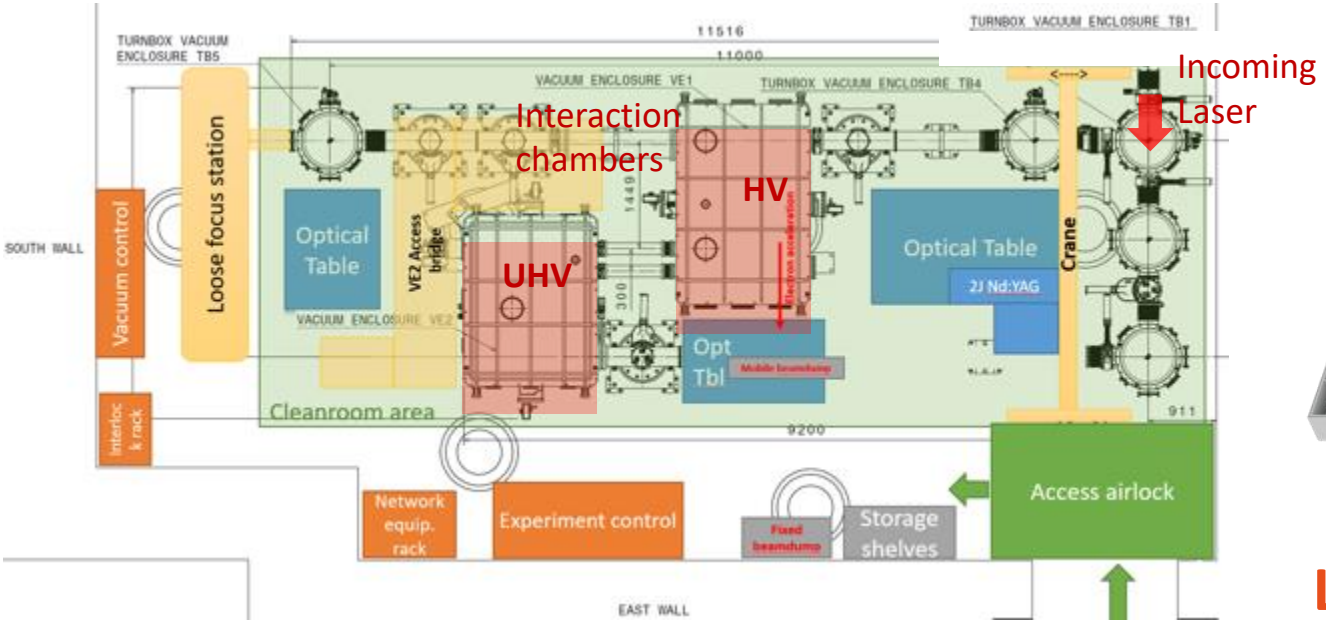
The HPL experimental areas

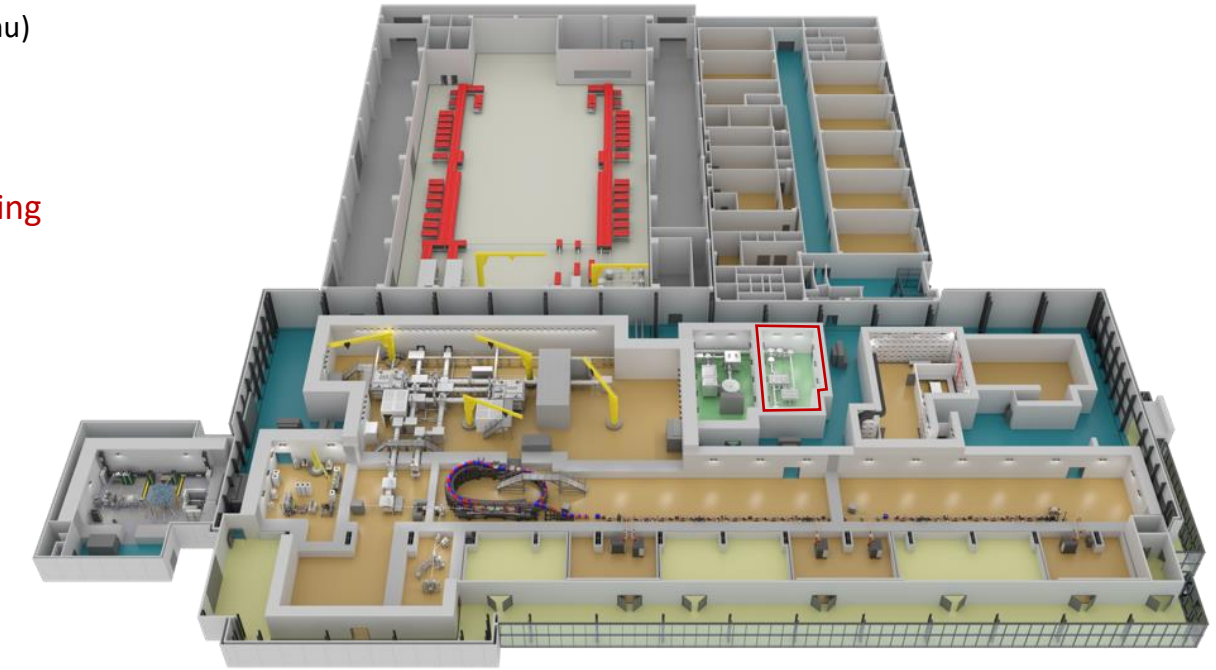
The 100 TW experimental area

E4: 100 TW experimental area

HPL: 2 arms of 2.5 J, 25 fs, 10 Hz

LGED department
(Head of LGED: Ovidiu Tesileanu)
Contact Person: Madalin Rosu
Email: madalin.rosu@eli-np.ro





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°

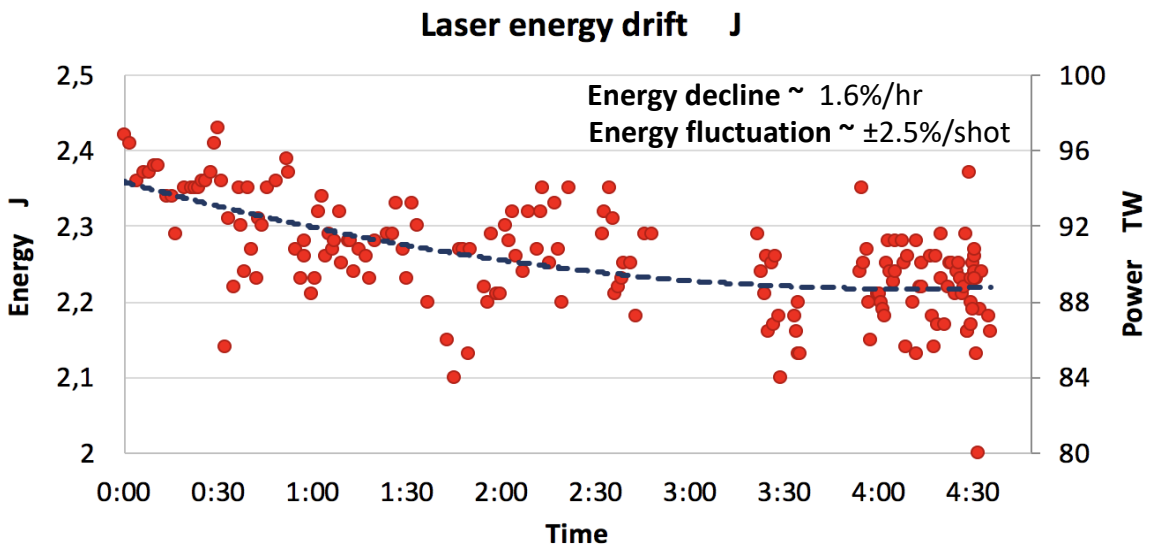
High Vacuum Chambers

- UHV with pressure down to 10^{-9} mbar
- HV with pressure down to 10^{-6} mbar

The 100 TW Laser features

100 TW laser beam features

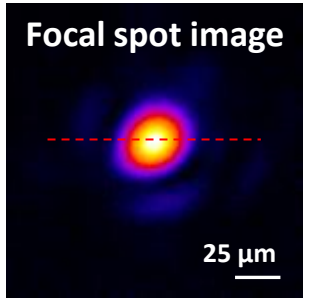
- Energy: < 2.5 J
- Pulse duration: < 25 fs
- Central wavelength: ~ 810 nm
- Beam diameter: ~ 54 mm
- Laser pointing fluctuation on target: ~ ±7 µrad
- Energy stability: <2.5%

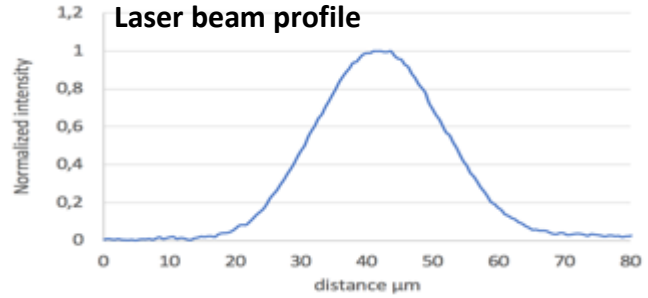


Stability of the laser pulse energy as function of time. The corresponding power is represented on the right axis.

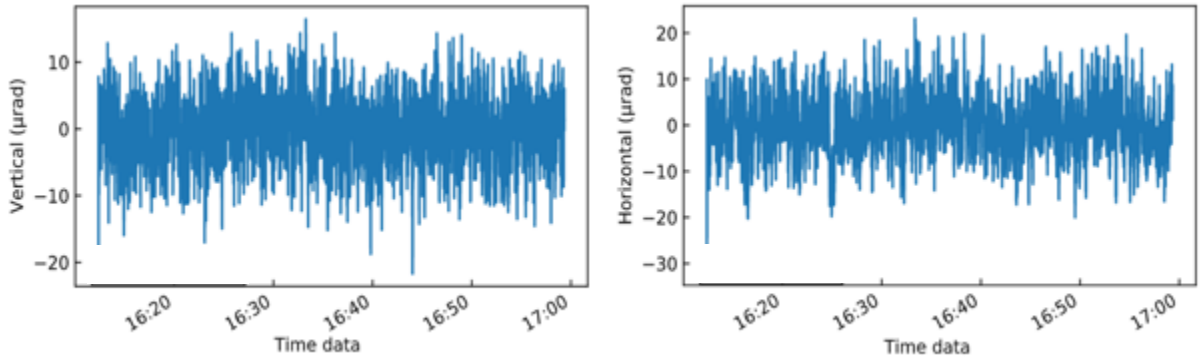
Example of focus properties

- Parabolic mirror: 1.5 m focal length (F# ~28)
- Spot size diameter: ~ 22±2 µm at FWHM
- Encircled energy ~ 55% @ $1/e^2$





- Laser pointing stability

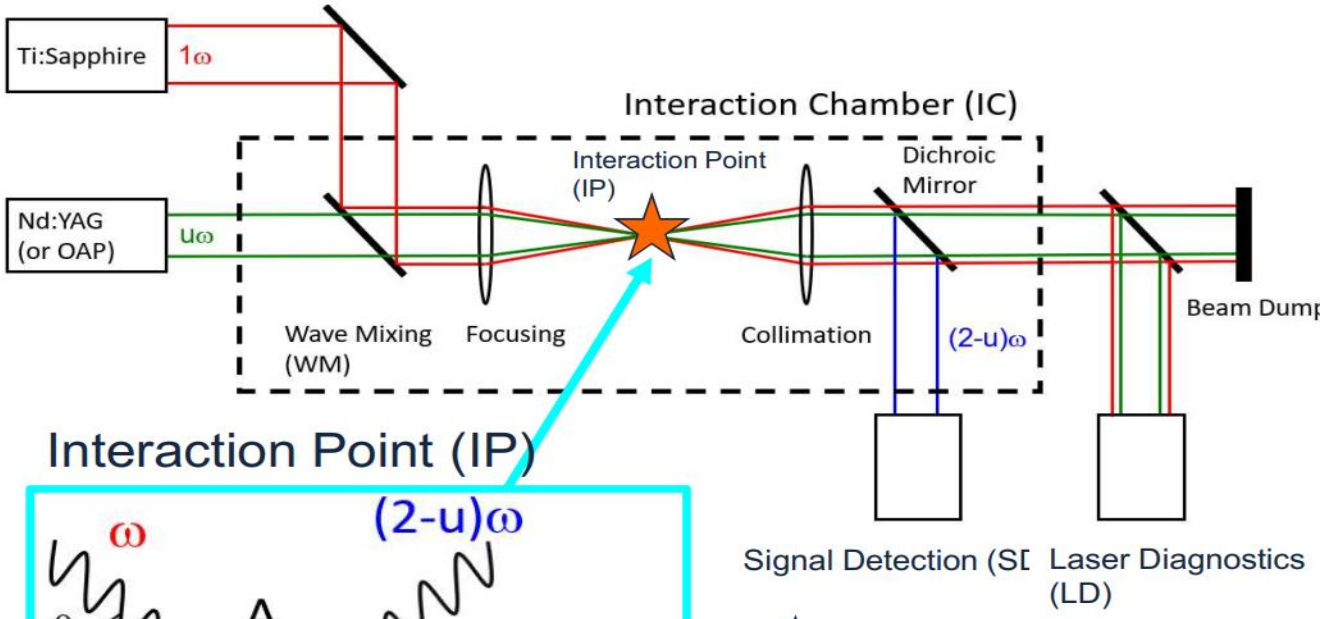


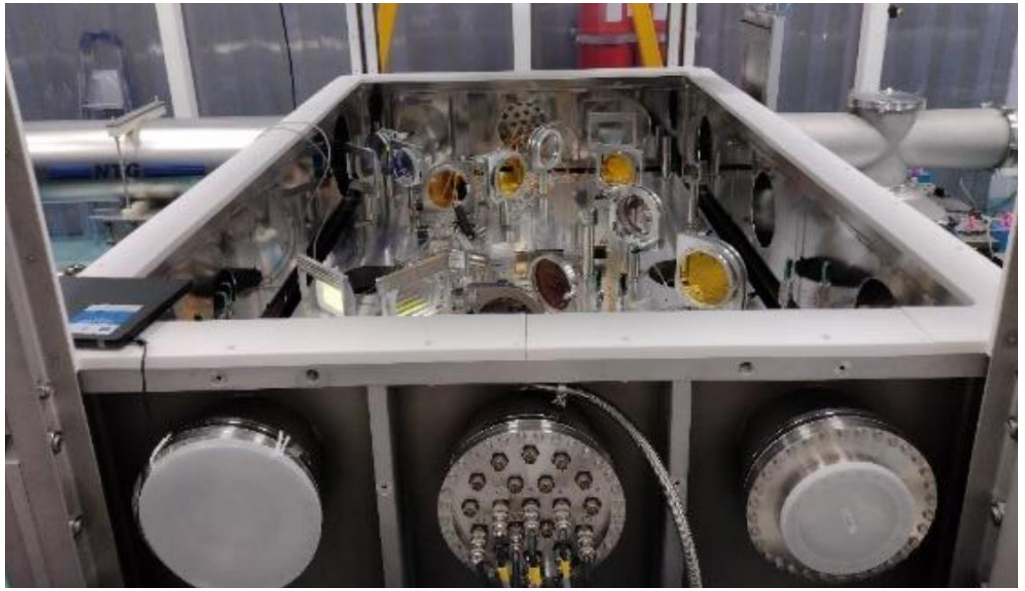
Laser pointing stability representing the laser far-field horizontal and vertical pointing fluctuation as function of time. The r.m.s. of the fluctuations is ±7 µrad.

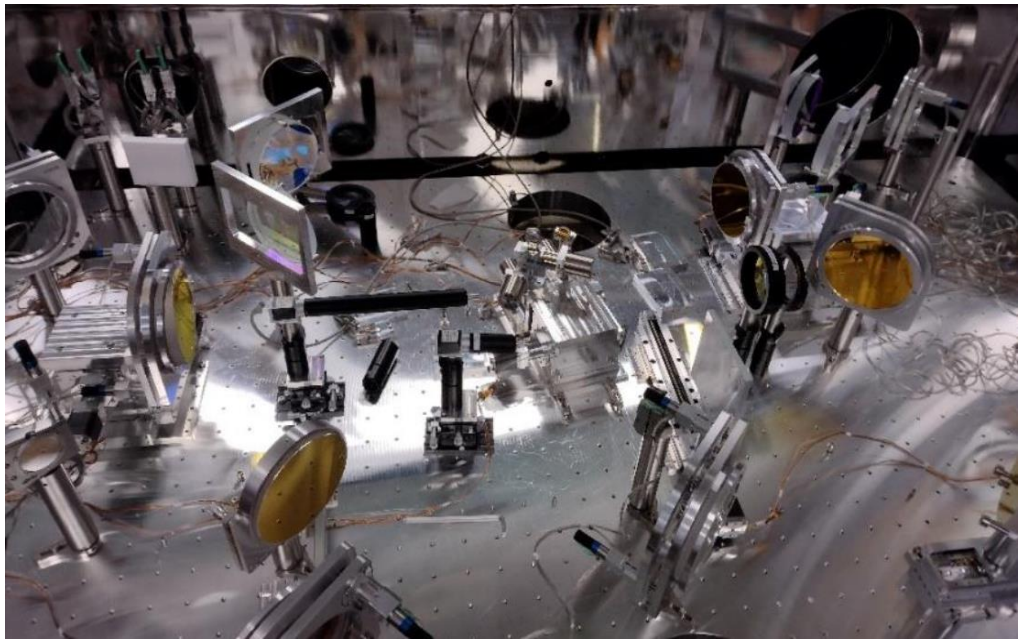
100 TW commissioning experiment of LGED department

Search for photon-photon interactions at sub-eV energies as possible candidates for light dark matter

Dark matter detection with two-color high-intensity lasers:
Four-wave mixing in “vacuum”







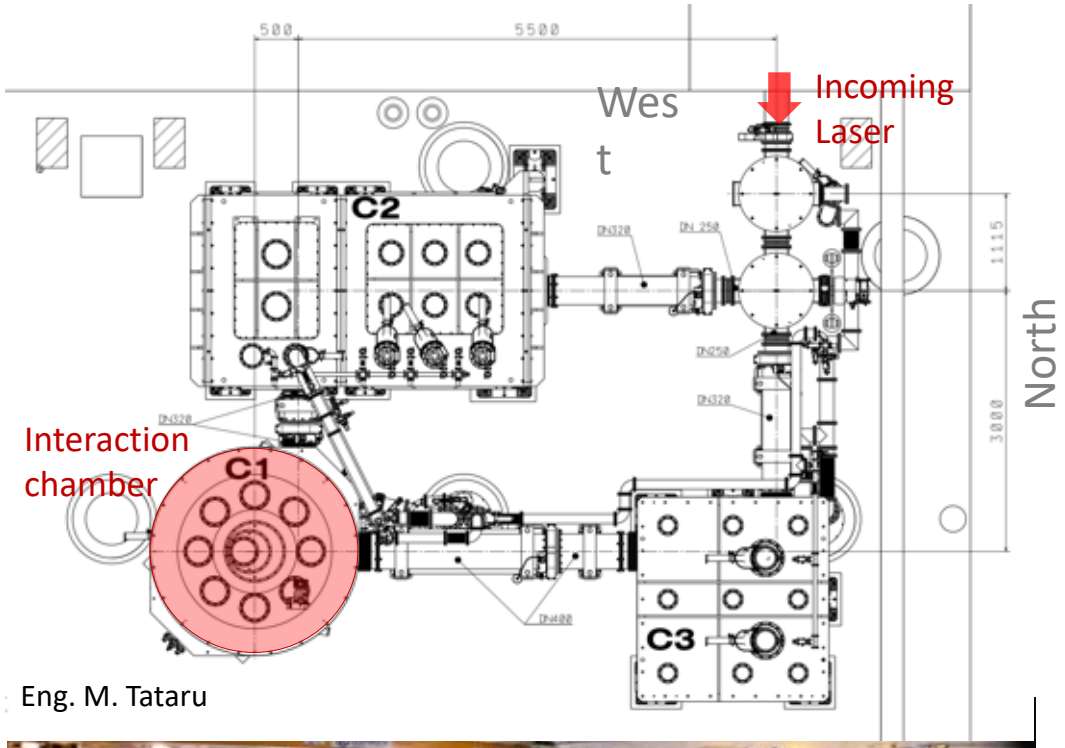
By Courtesy of Prof Homma (Hiroshima U.), S Sakabe (Kyoto U.) and LGED

The 1 PW experimental area

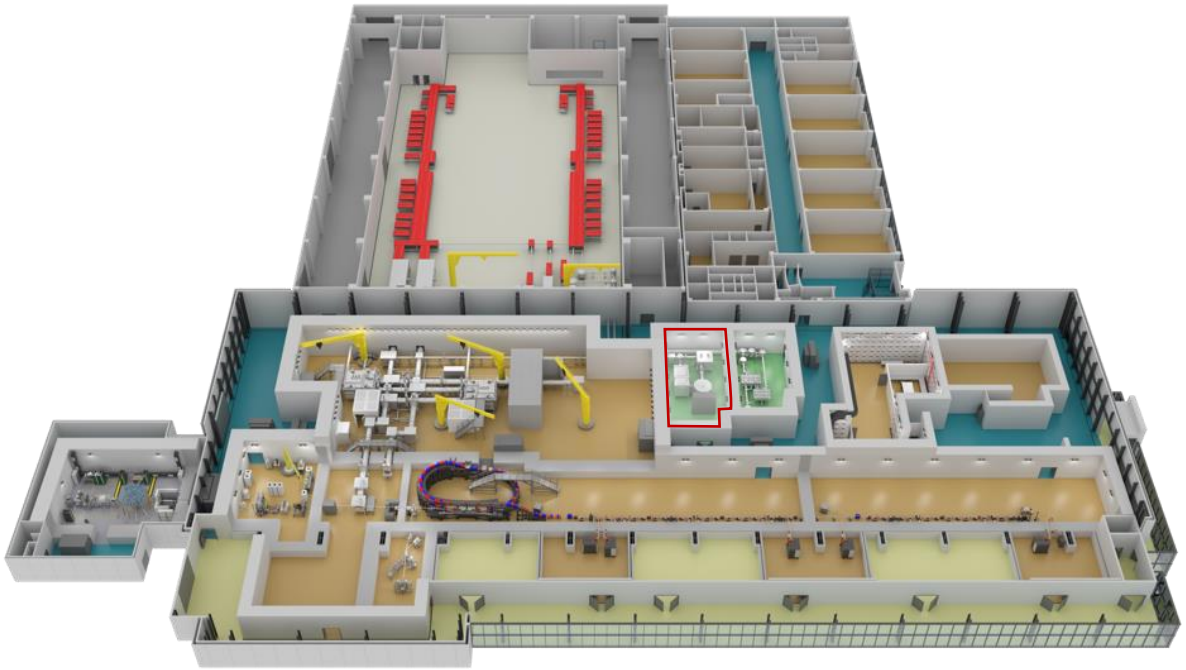
E5: 1 PW experimental area

HPL: 2 arms of 24 J, 24 fs, 1 Hz

LDED department
(Head of LDED: Domenico Doria)
Contact Person: Mihail Cernaianu
Email: mihail.cernaianu@eli-np.ro



Eng. M. Tataru



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°

High Vacuum Chambers

- 3 x HV with pressure down to 10^{-6} mbar

The 1 PW Laser features

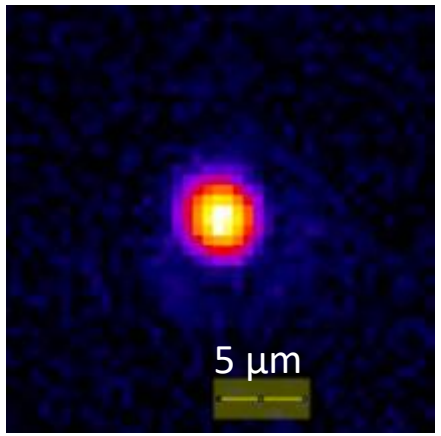
1 PW laser beam features

- 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%

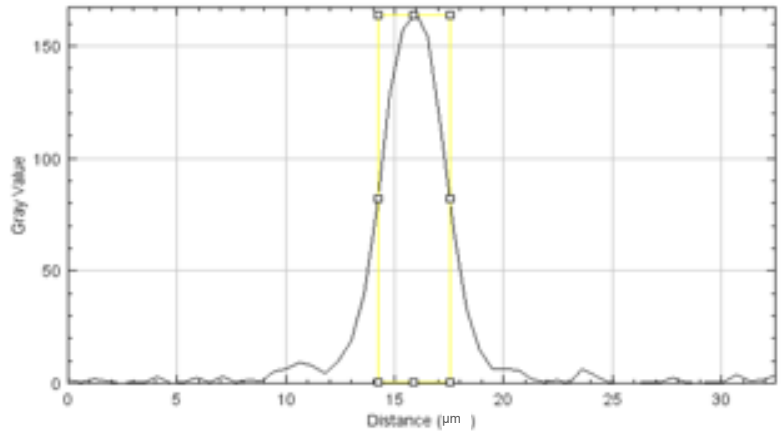
Example of focus properties

- Parabolic mirror: 707 mm focal length (F# ~3.7)
- Spot size diameter: ~ 3.6 ± 2 µm at FWHM
- Encircled energy ~ 50% @ $1/e^2e$
- Laser peak intensity: ~ $5x10^{21}$ Wcm^{-2}

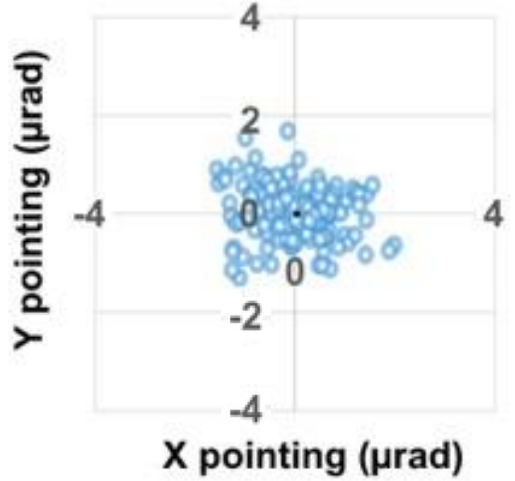
Shot focal (OAP)



Laser focal spot



Laser beam profile



Laser pointing stability

1 PW commissioning experiments (E5)

1 PW commissioning begun on 28 of June 2021

Goals of the 1 PW area commissioning

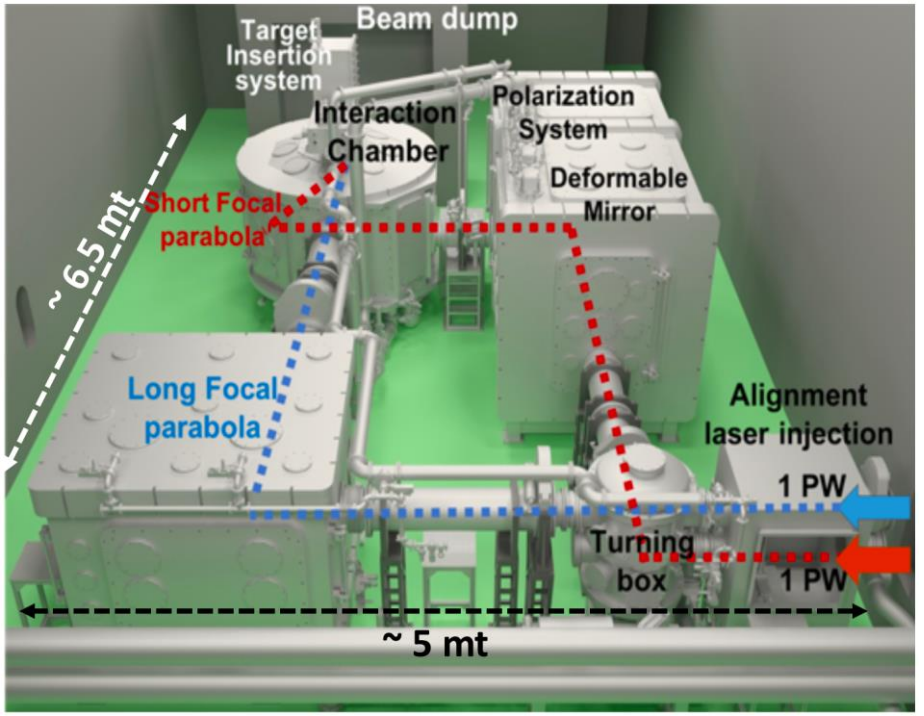
Phase 1 (P.I. M. O. Cernaianu/ F. Rotaru)

- **TNSA proton** acceleration, commissioning experiment to assess the HPLS 1 PW performance and test diagnostics, following the ELI-NP ISAB plan

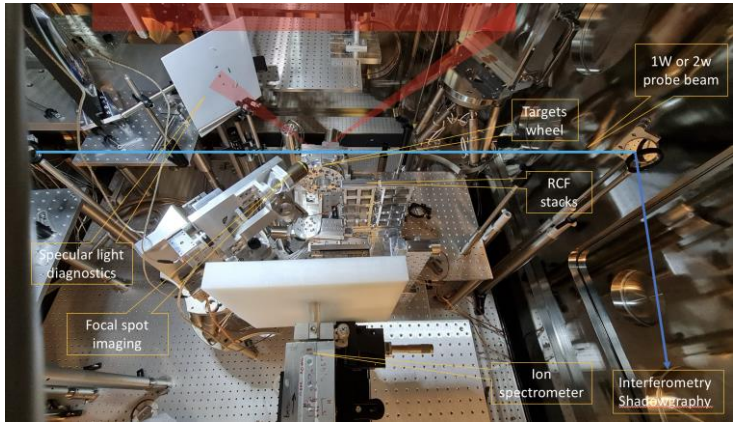
Phase 2 (P.I. P. Ghenuche/ B. Diaconescu)

- **LWFA** commissioning experiment at 1 PW by using gas cell and gas get targets.

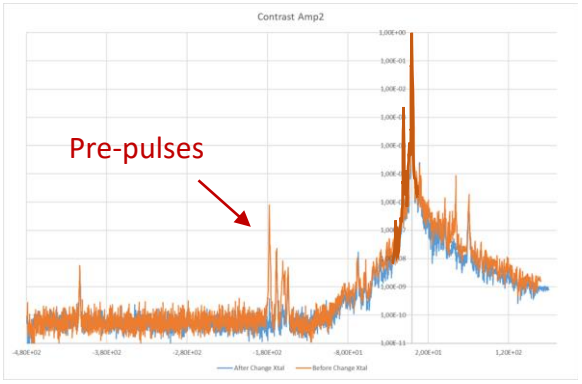
Isometric view of the 1 PW target area



Some outcome



Example of 1PW setup for solid targets (TNSA)



Most of prepulse have been solved during the first 3 weeks of commissioning.

Improved temporal contrast allowed for **the acceleration of protons up to 60 MeV** from ultra-thin films

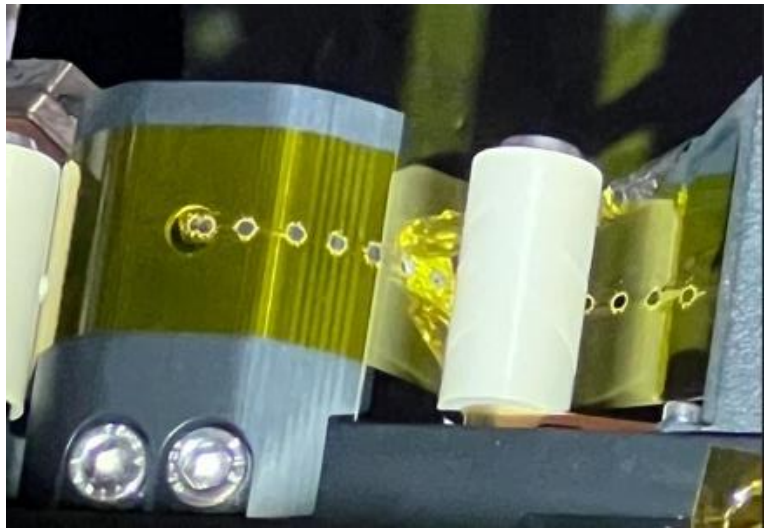
LWFA commissioning achieved **electron energy of ≈ 2 GeV** with both Helium gas and admixture

See talk of M. Cernaianu on Friday at 11.00

1 PW commissioning experiments (E5)

TNSA experiment at high repetition rate

Tape target system developed by STFC within the IMPULSE project tested at ELI-NP in collaboration with ELI Beamlines and STFC



Sequence of shots on the Kapton ribbon obtained shooting with 2 J laser energy and best laser pulse compression.

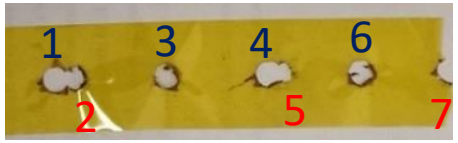
Ribbon moving at 11 mm/s

High laser energy shots

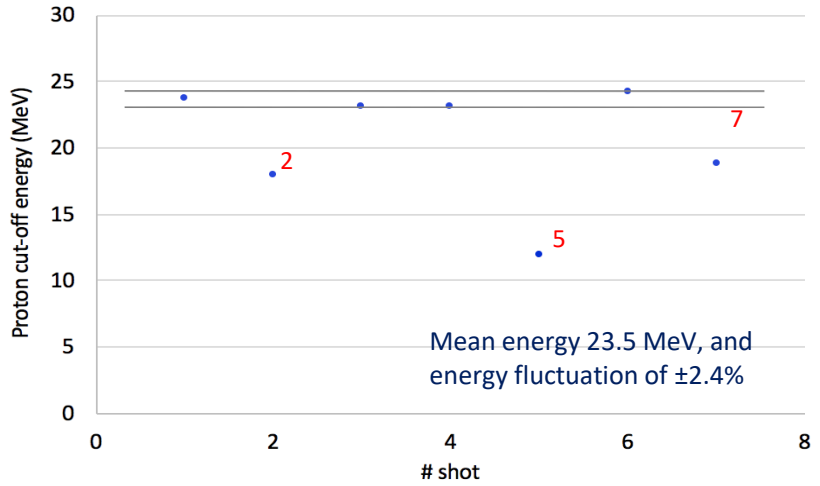
RAW image from Thomson parabola spectrometer

7 Proton traces on Image Plate

Damage on the Kapton after the shots



Shot on tape drive at 1Hz (20J, 200fs)

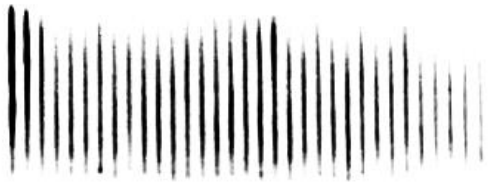


Maximum proton energy of 7 consecutive shots close obtained with the laser energy of 20J (close to maximum) and stretched laser pulse (~200fs) on a Kapton ribbon 13 µm thick.

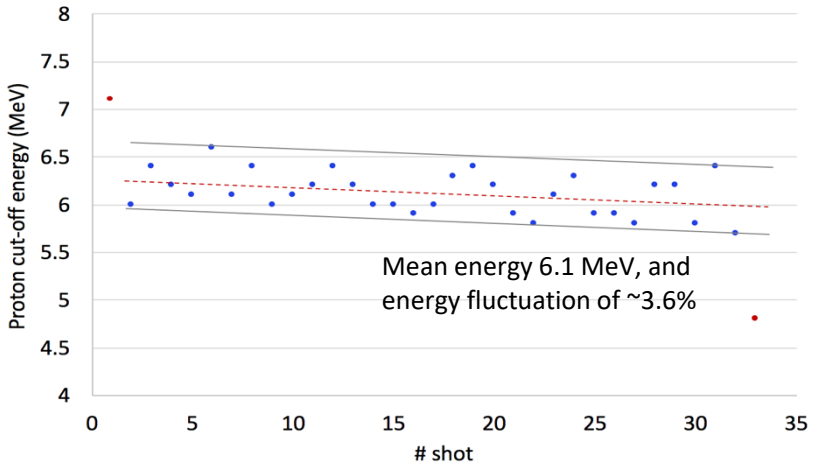
Low laser energy shots

RAW image from Thomson parabola spectrometer

33 Proton traces on Image Plate



Shot on tape drive at 1Hz (2J, 25fs)



Maximum proton energy of 33 consecutive shots at low energy (~2J) and best compression (~25fs) on a Kapton ribbon 13 µm thick.

ELI–NP as User Facility

1st Common Call for Users with ELI ERIC

Period: October 2022 – March 2023

ELI-NP **17 proposals**: 6 @ 100 TW & 11 @ 1 PW
(Romania, UK, Japan, France, Spain, Canada, Italy, Russia, Israel, India, Germany, Poland)

PAC Meeting: 3 – 4 October 2022

Grade A:	1 @ 100 TW, 2 @ 1 PW
Grade A-:	2 @ 100 TW, 4 @ 1 PW
Grade B:	3 @ 100 TW, 5 @ 1 PW

Successfully performed 2 exp. @ 100 TW and 2 exp. @ 1 PW

2nd Common Call for Users with ELI ERIC

Period: July 2023 – December 2023

ELI-NP **18 proposals**: 2 @ 100 TW & 16 @ 1 PW
(Romania, UK, Japan, USA, China, Israel, India, Germany, Poland)

PAC Meeting: 11 – 12 May 2023

Grade A:	5 @ 1 PW
Grade A-:	1 @ 100 TW, 6 @ 1 PW
Grade B:	1 @ 100 TW, 4 @ 1 PW
Grade C:	1 @ 1 PW

Scientific evaluation of experiment proposals
ELI-NP Program Advisory Committee (PAC)

Peter Thirolf (Chair)	Technische Universität München
Leonida Gizzi	INO-CNR Pisa
Karl Krushelnick	CUOS - University of Michigan
Paul McKenna	University of Strathclyde, Glasgow
Akifumi Yogo	ILE, Osaka University
Stuart Mangles	Imperial College of London
Antonino di Piazza	Max-Planck Institut für Kernphysik

User Office @ ELI-NP

Access based on the Terms & Conditions of Access with ELI ERIC
https://up.eli-laser.eu/downloads/Science-Call-TCA.pdf

Long Term Storage of Data

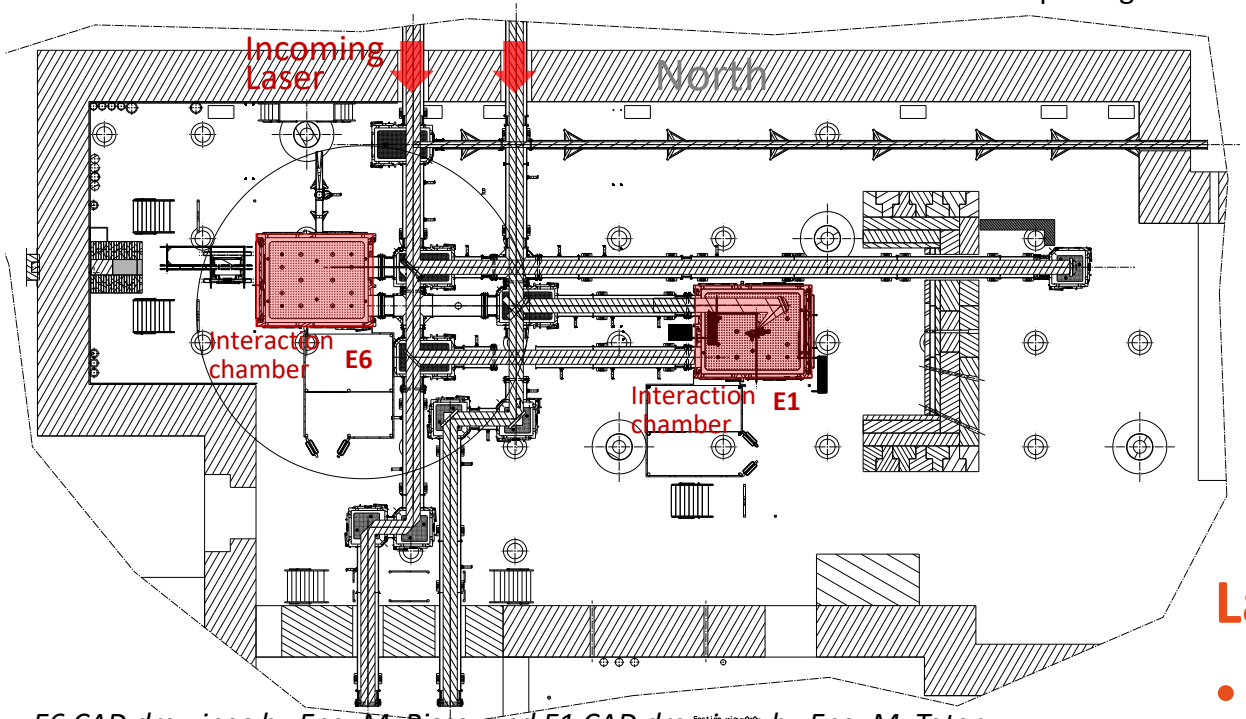
Access to ELI-NP Guesthouse and Canteen

The 10 PW experimental area

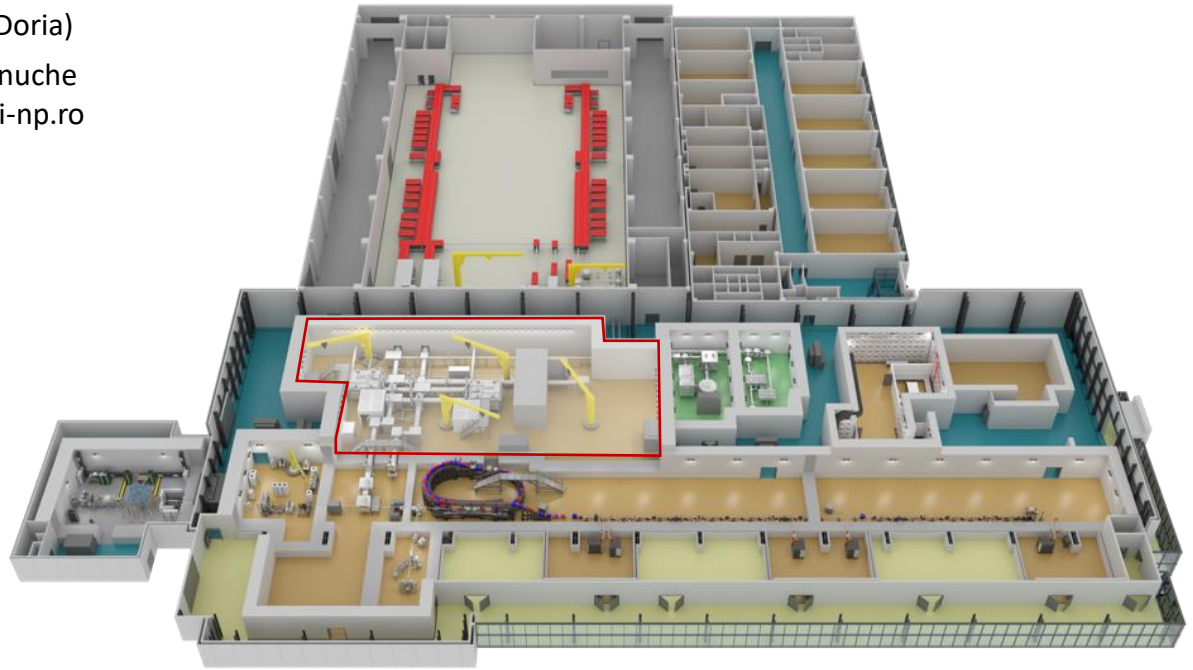
E1/E6: 10 PW experimental area

HPL: 2 arms of 235 J, 23 fs, 1 Hz

LDED department
(Head of LDED: Domenico Doria)
Contact Person: Petru Ghenuche
Email: petru.ghenuche@eli-np.ro



E6 CAD drawings by Eng. M. Risca, and E1 CAD drawings by Eng. M. Tataru



Large Optics available

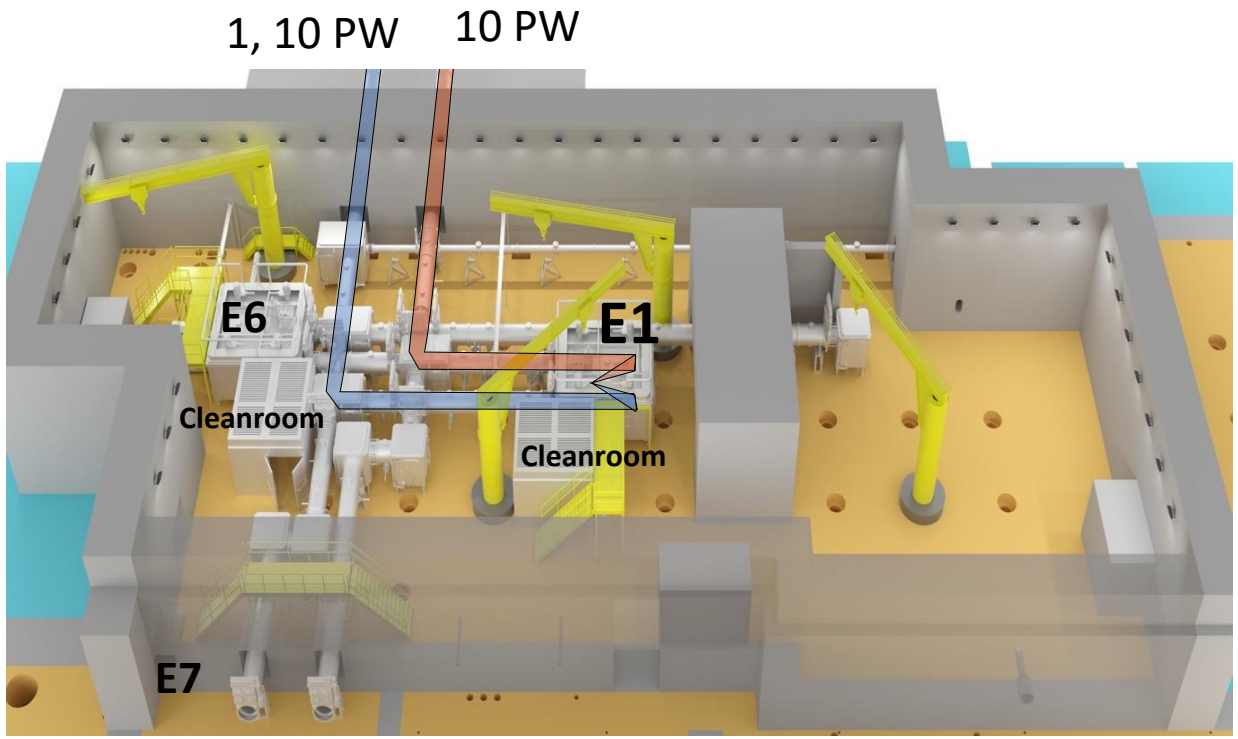
- ~34”x 24’’ rectangular flat mirrors w/ motorized mounts
- F = 30000mm off-axis spherical, AOI = 0°
- F = 1500mm off-axis parabola, AOI = 22.5°

High Vacuum Chambers

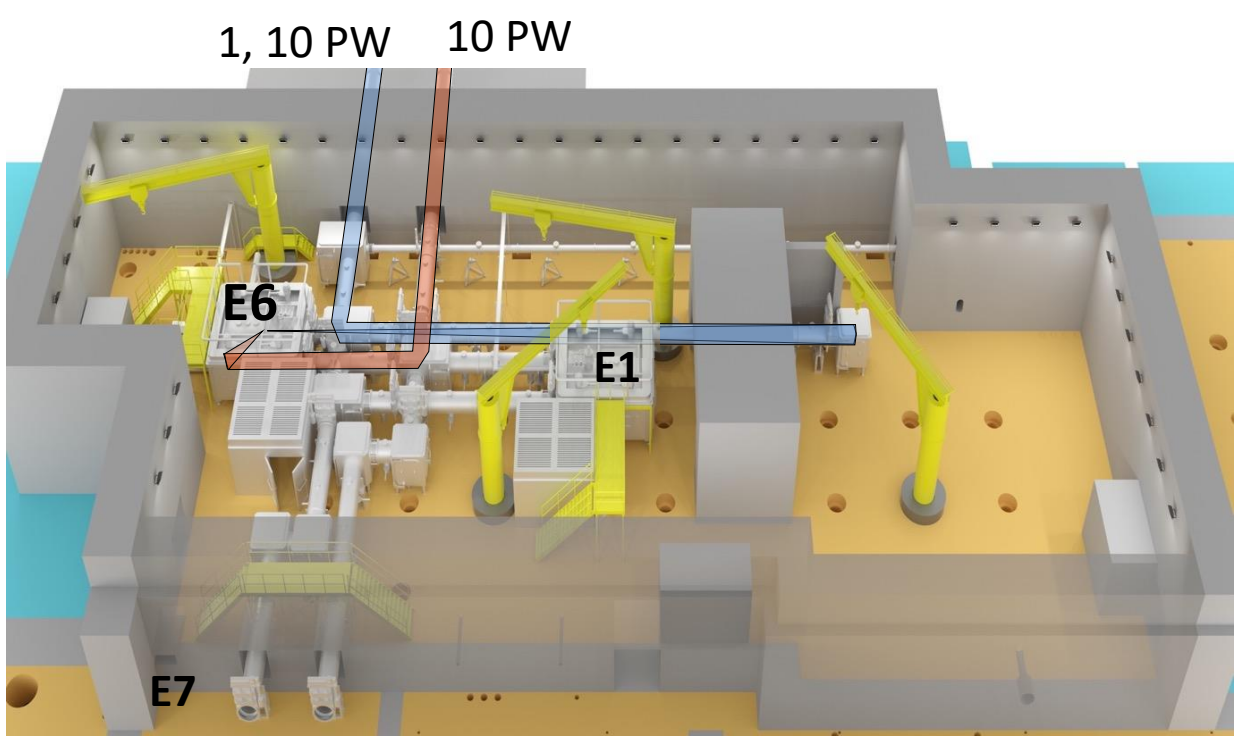
- 2 x large HV with pressure down to 10^{-6} mbar

10 PW experimental areas

E1 target area configuration (solid targets, nuclear physics)



E6 target area configuration (gas targets, QED)



E1 target area (solid target experiments)

- 2 x 10 PW laser beams: 240 J, 23 fs, 810 nm, ~ 45 cm dia. FWHM (or 10 PW @ 1/60 Hz and 1 PW @ 1 Hz)
- 2 Shot focal parabolic mirrors F2.7
- 1 Plasma mirror
- 1 Cleanroom
- Experimental chamber: L x W x H of 4000 x 3300 x 1780 mm^3

E6 target area (gas target experiments)

- 2 x 10 PW laser beams: 240 J, 23 fs, 810 nm, ~ 45 cm dia. FWHM (or 10 PW @ 1/60 Hz and 1 PW @ 1 Hz)
- 1 Shot focal - parabolic mirrors F2.7
- 1 Long focal ~30 mt. - spherical mirror F60 @ 10 PW (F150 @ 1 PW)
- 1 Plasma mirror
- 1 Cleanroom
- Experimental chamber: L x W x H of 4000 x 3300 x 1780 mm^3

10 PW experimental plan

10 PW commissioning with solid targets is started on Oct 2022

Goals of the 10 PW area commissioning

<u>E1 (solid targets)</u> P.I. Domenico DORIA

- Demonstrate **200 MeV proton** acceleration
- Demonstrate extreme focal intensity through laser-γ conversion ("**γ-flash**")
- **Dense heavy ion beams** for nuclear physics (time permitting)

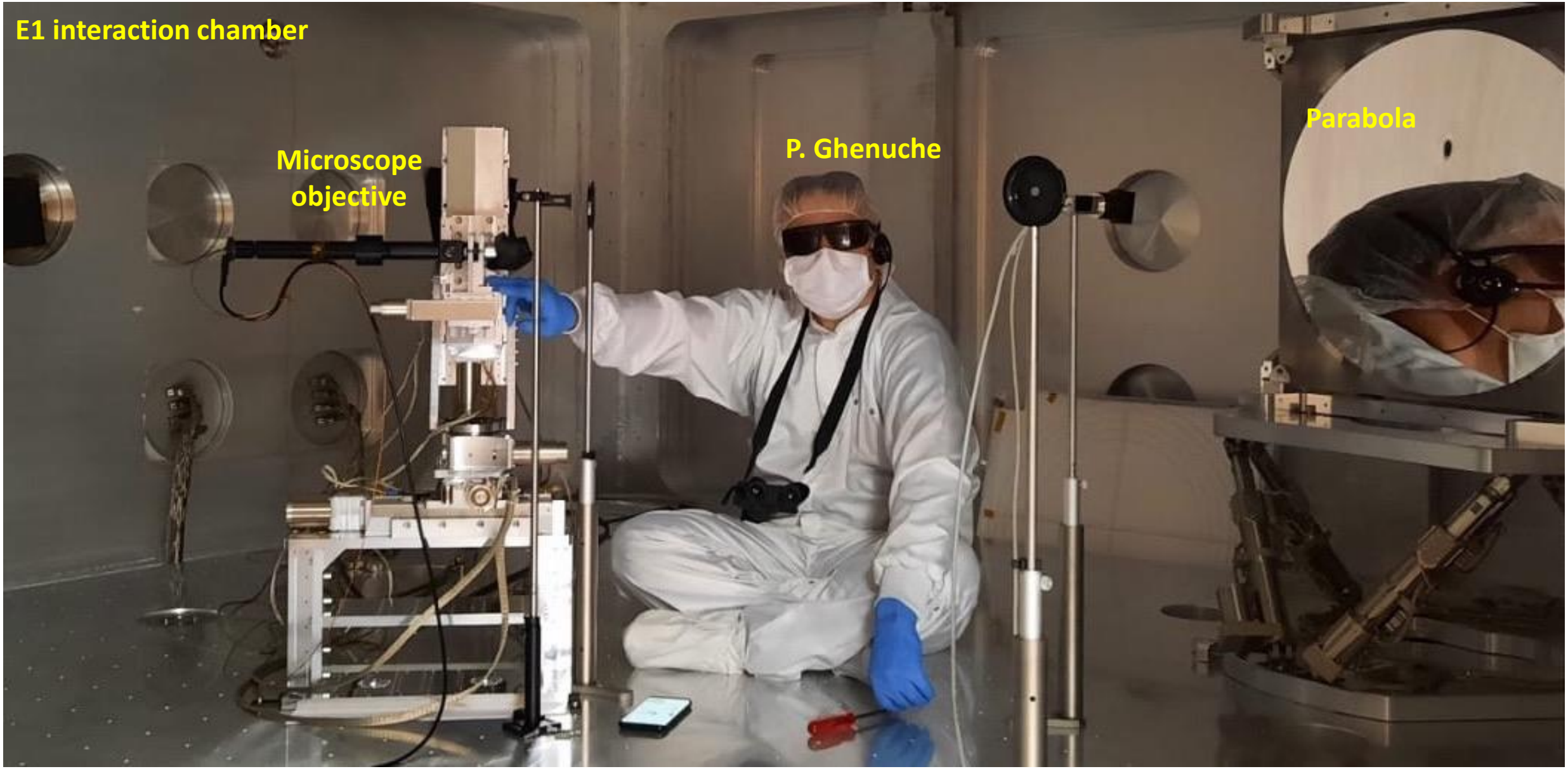
10 PW commissioning with gas targets is planned for Oct-Dec 2023

<u>E6 (gas targets)</u> P.I. Petru GHENUCHE

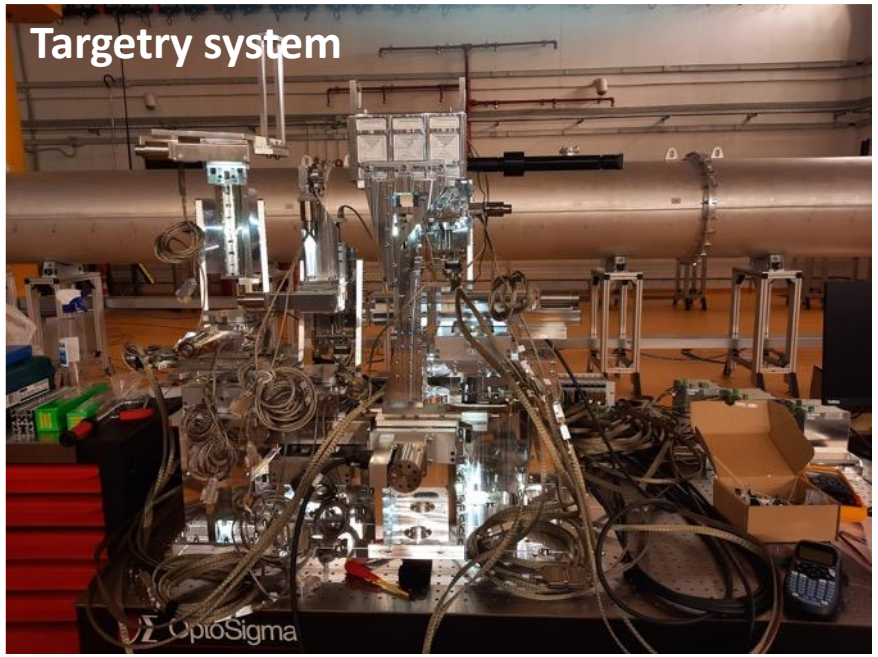
- 10 PW LWFA of **multi-GeV electron** beams

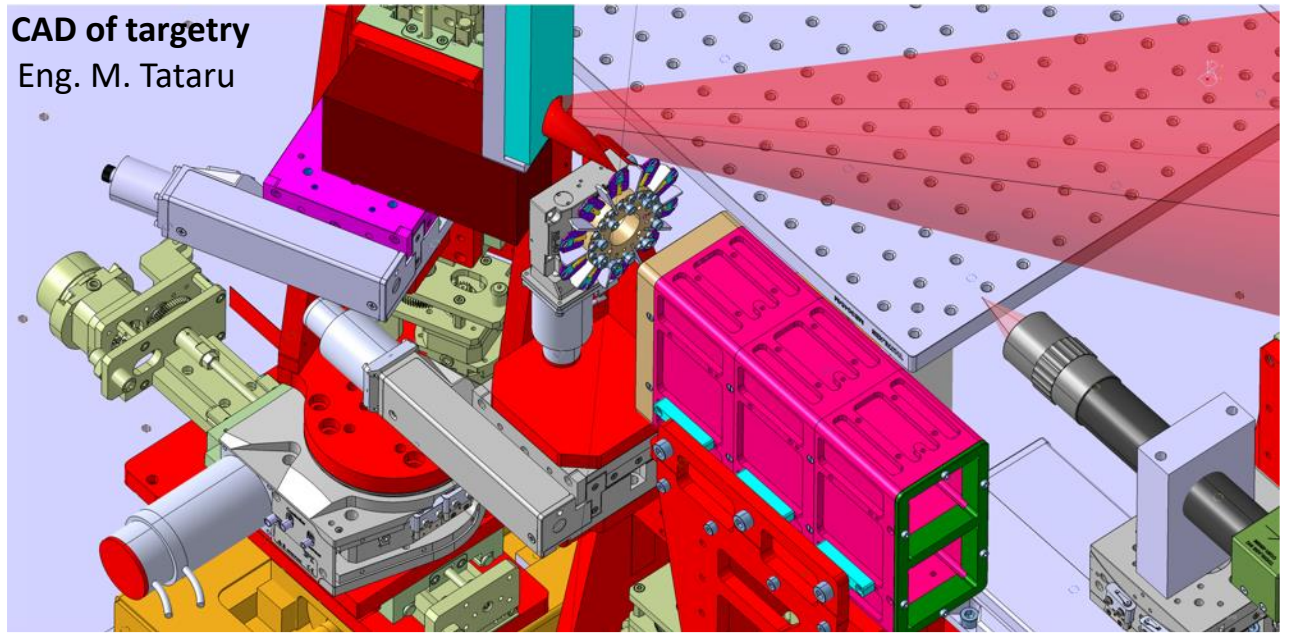
10 PW E1 experimental area commissioning (from Oct 2022)

Laser beam alignment and focal spot check



10 PW E1 experimental area commissioning (from Oct 2022)

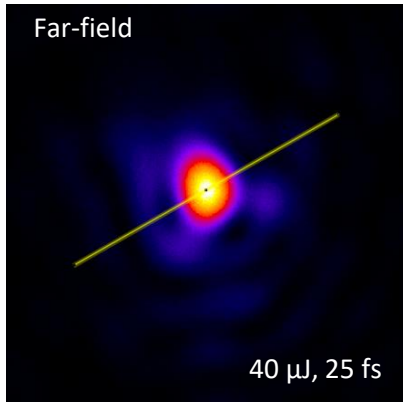


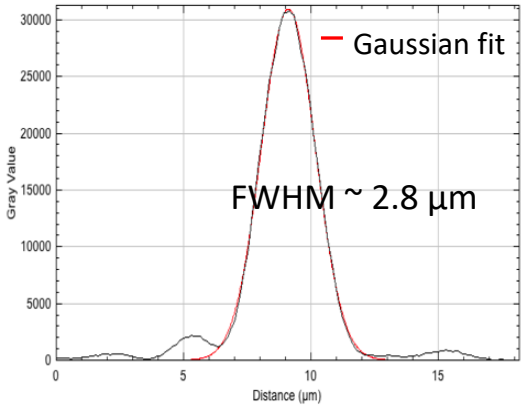


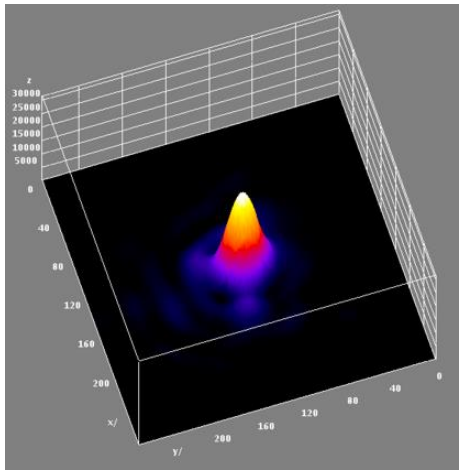
10 PW E1 experimental area commissioning

HPLS at low power

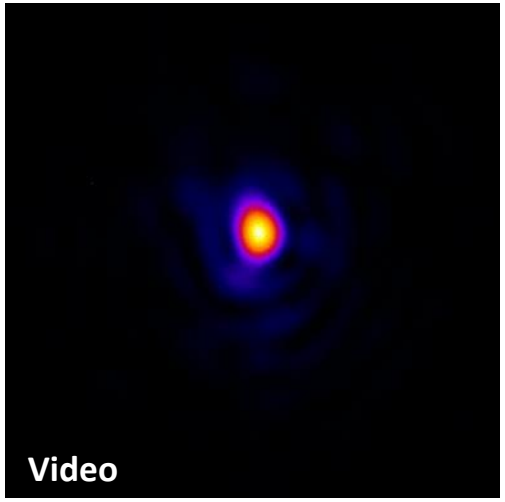
Best focal spot



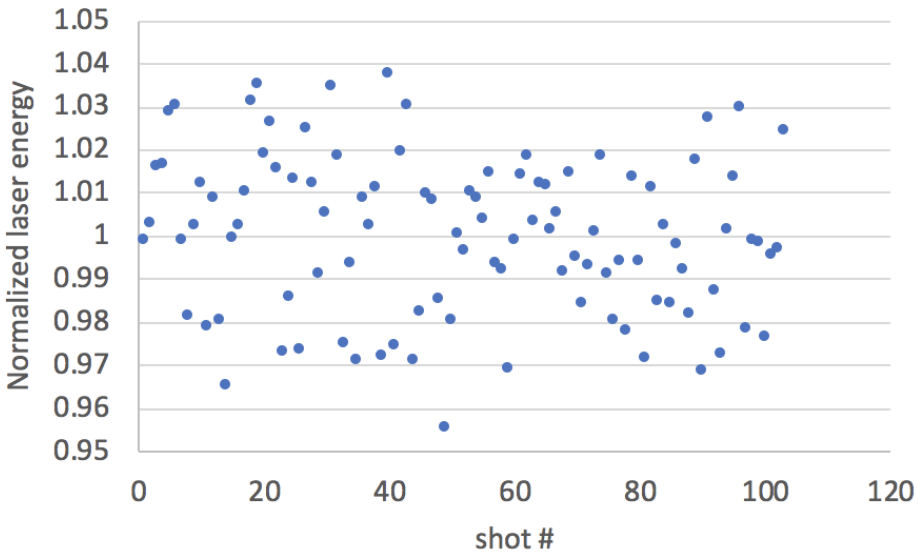




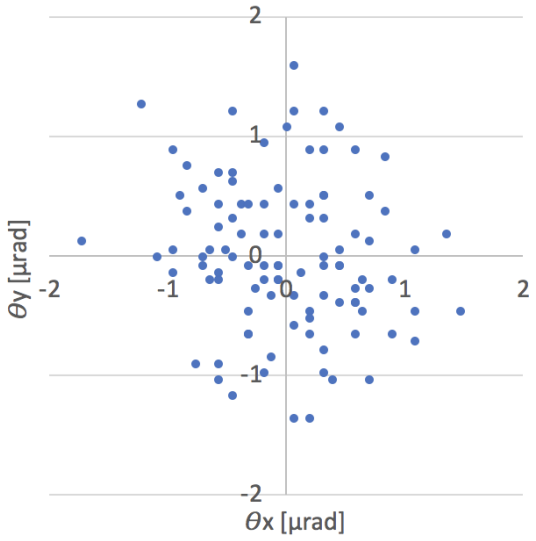
Movie of pointing fluctuation



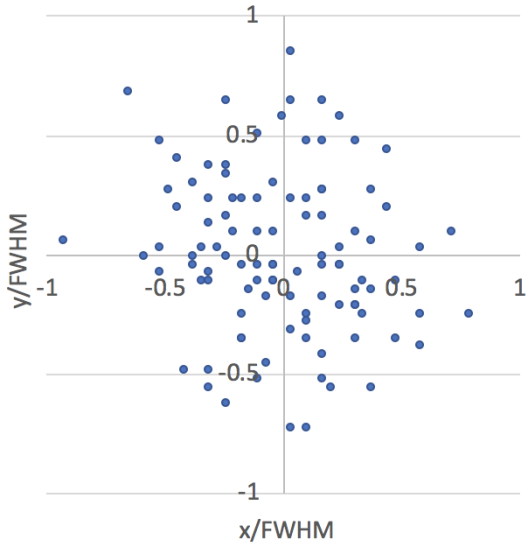
Laser energy fluctuation ~2%



Pointing fluctuation [µrad] ~1 urad

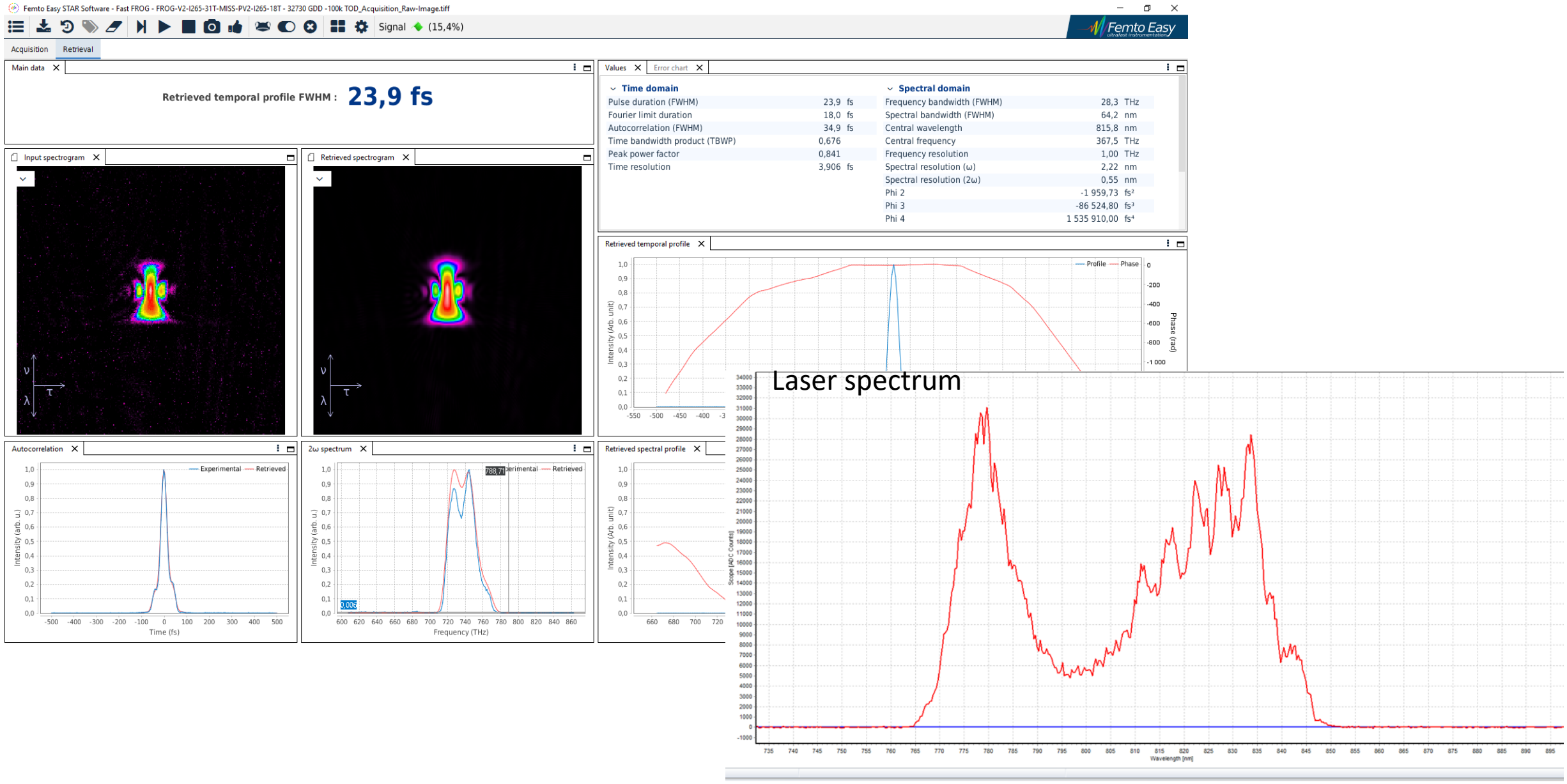


Pointing fluctuation (FWHM unit)



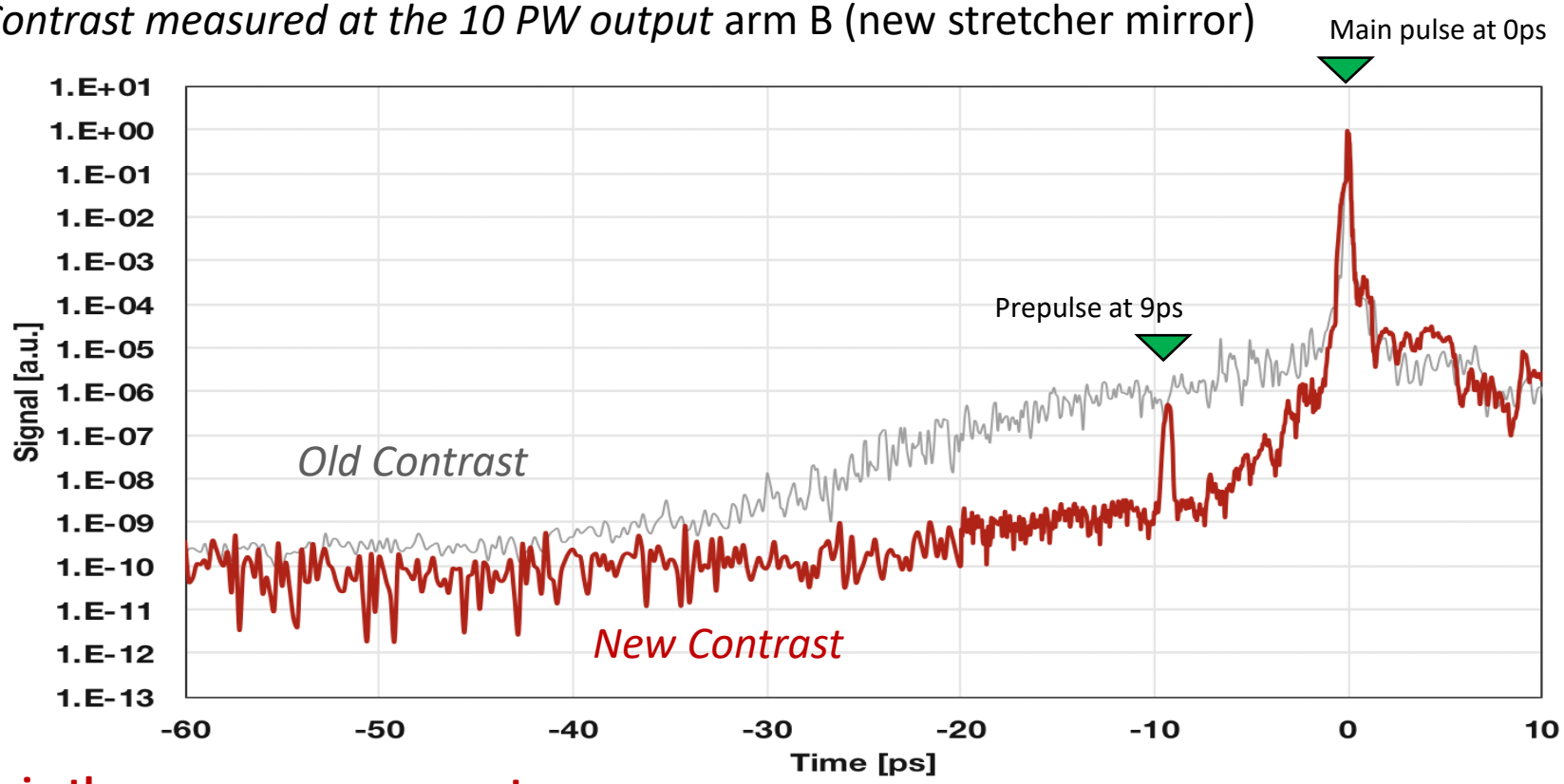
10 PW E1 experimental area commissioning

Laser pulse duration measurement with FROG



10 PW temporal contrast measurement

Improved Contrast measured at the 10 PW output arm B (new stretcher mirror)



A few pre-pulses in the ns range are present

Laser intensity

10 PW with 2.8 µm FWHM focal spot -> ~1.1 x 10^{23} Wcm^{-2}

with an encircled energy of ~ 55% -> ~6 x 10^{22} Wcm^{-2}

with PM ~ 75% reflectivity -> ~4.4 x 10^{22} Wcm^{-2}

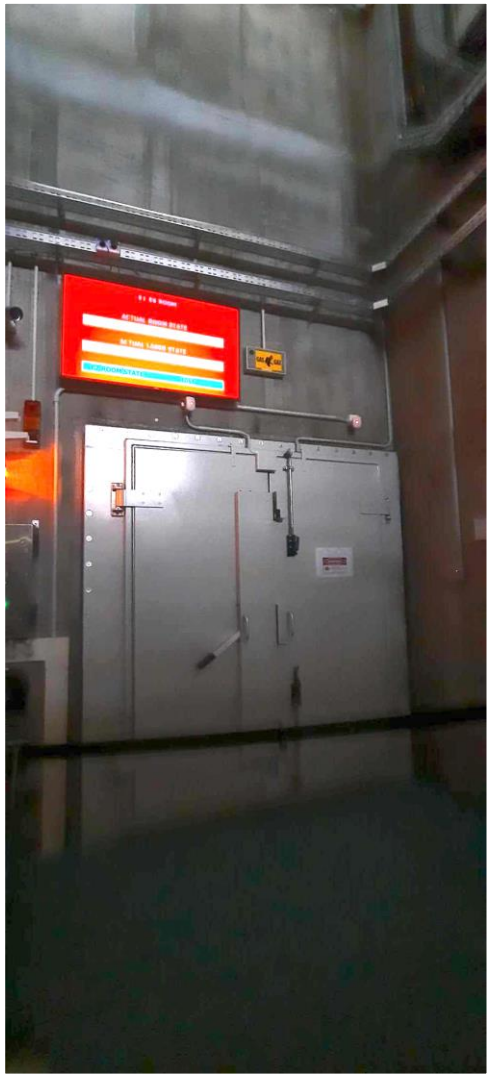
Temporal contrast

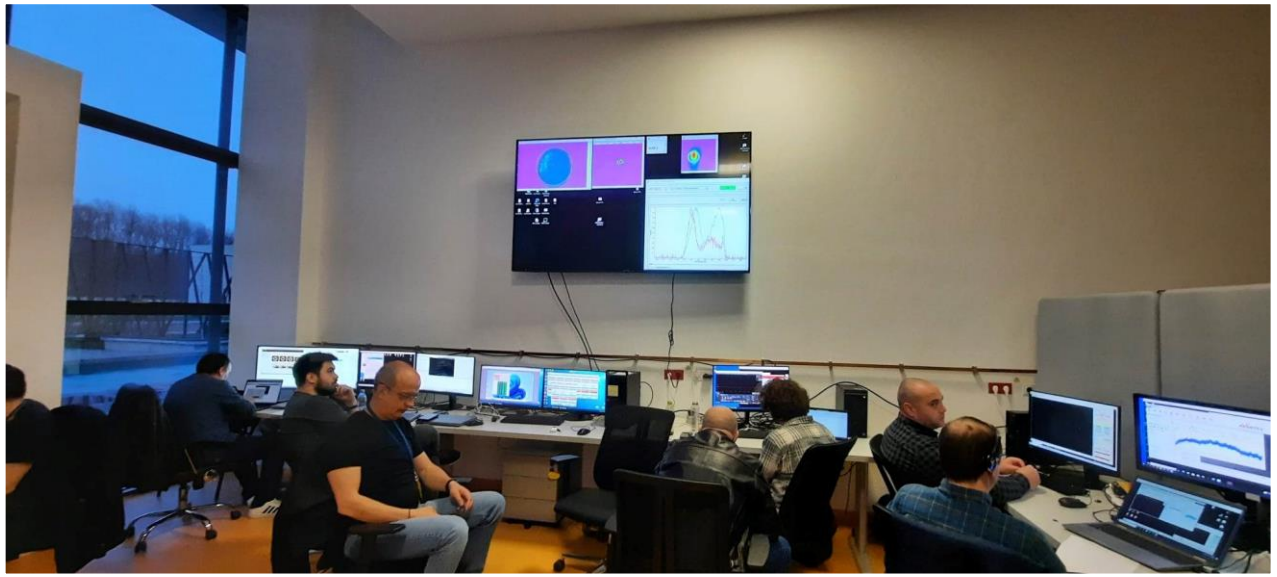
Without PM ~ 10^{-9} @ 10 ps, 10^{-6} @ 2 ps

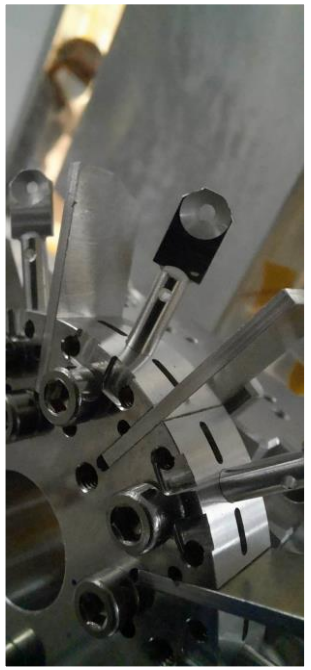
With PM < 10^{-11} @ 10 ps, < 10^{-8} @ 2 ps

10 PW E1 experimental area commissioning

On 13 Apr 2023 the first 10 PW shot was fired successfully on target







10 PW E1 experimental area commissioning (from 26 Sept 2022)

Commissioning goals:

TNSA >200 MeV protons,

RPA high-Z bulk acceleration

List of diagnostics of E1

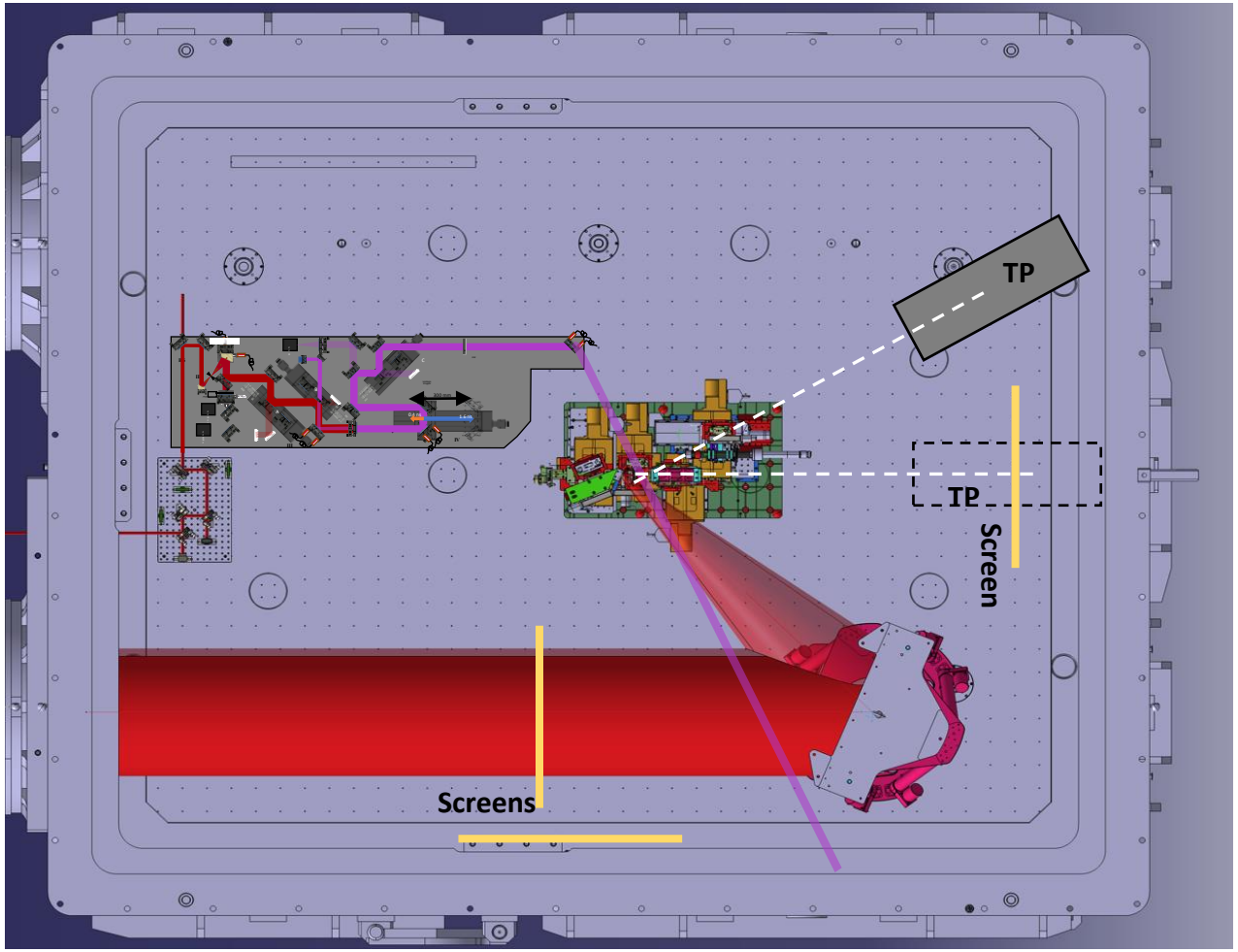
Laser Diagnostics

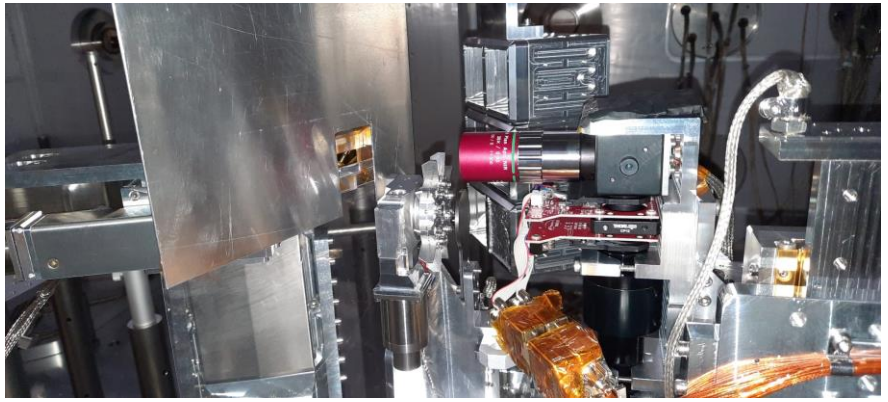
Targetry and Alignment System

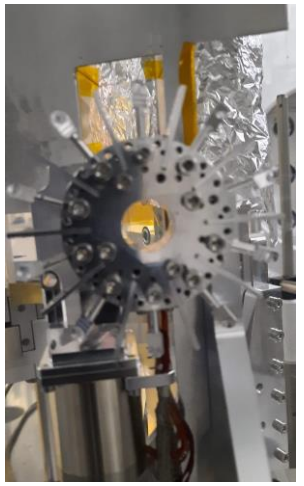
Radiochromic films stack, CR39 (< 200 MeV)

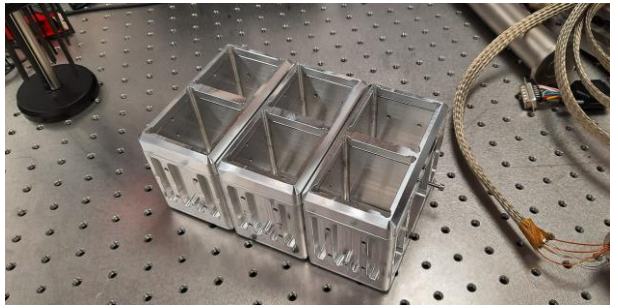
Thomson Parabola (~100 MeV and ~500 MeV proton)

Optical Probe/Pump (< 2 J)

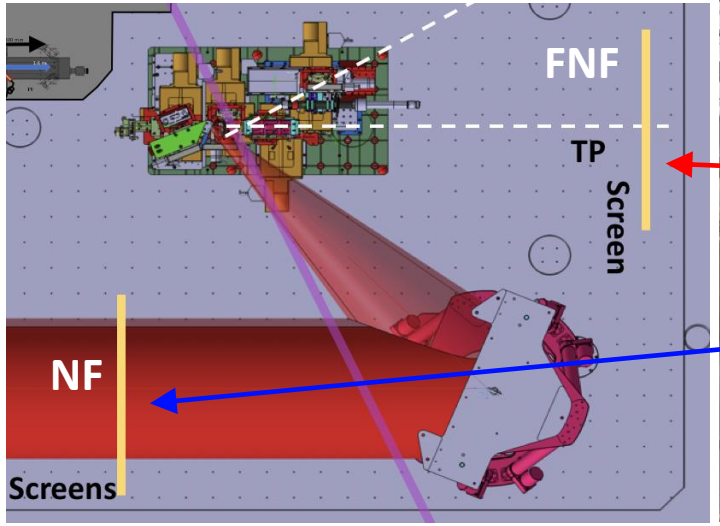


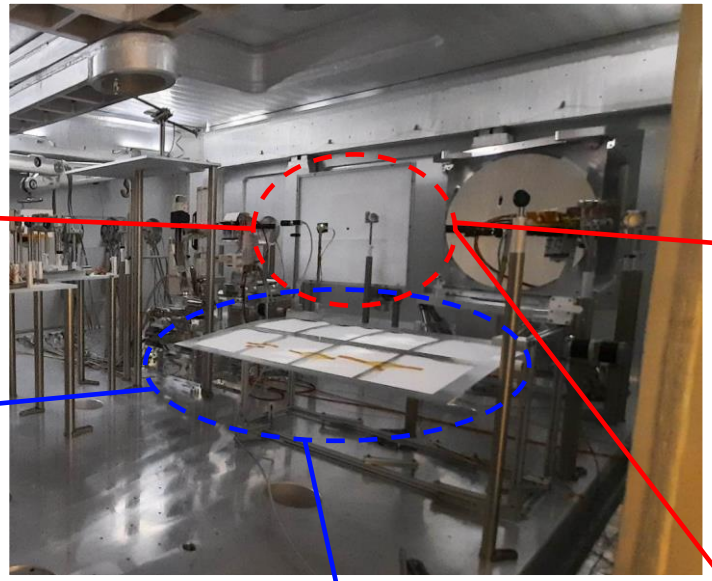


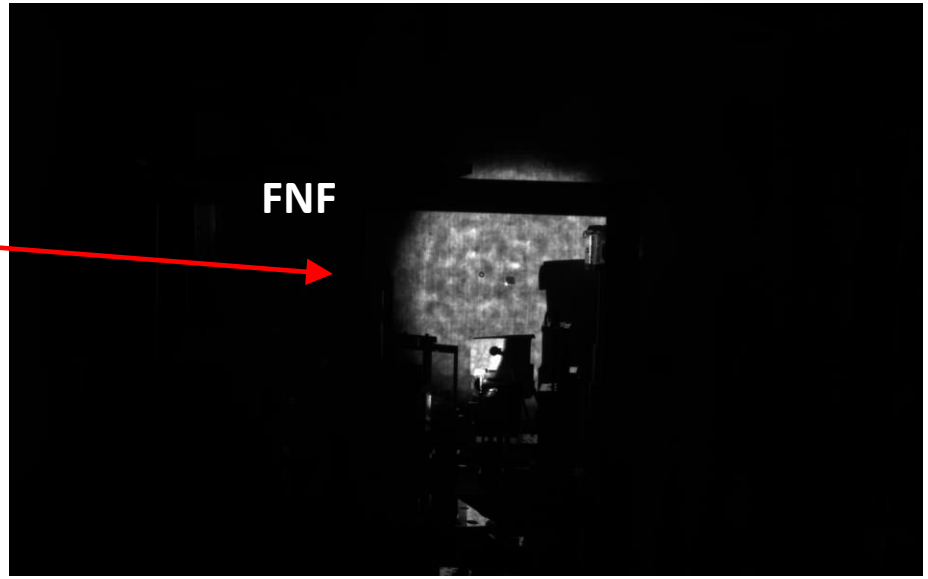




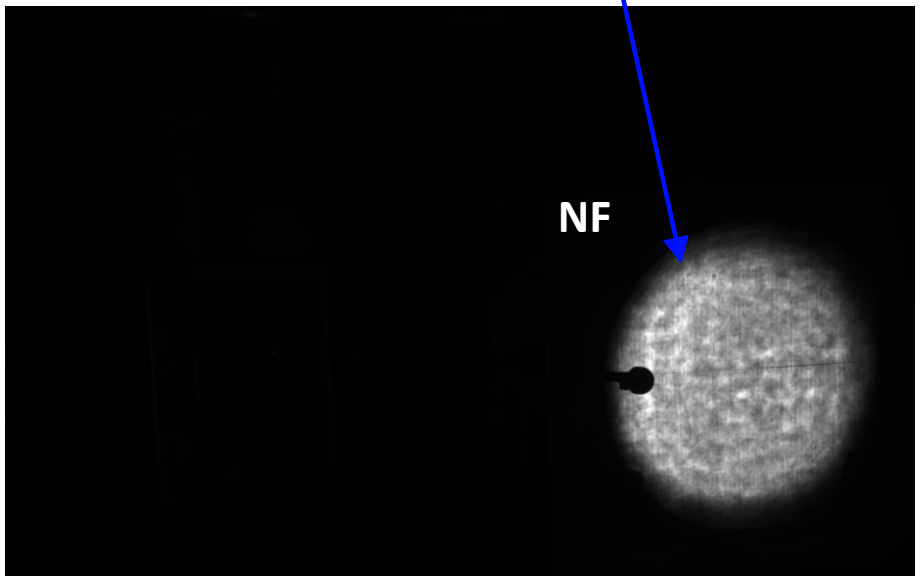
Single PM Calibration at 10 PW

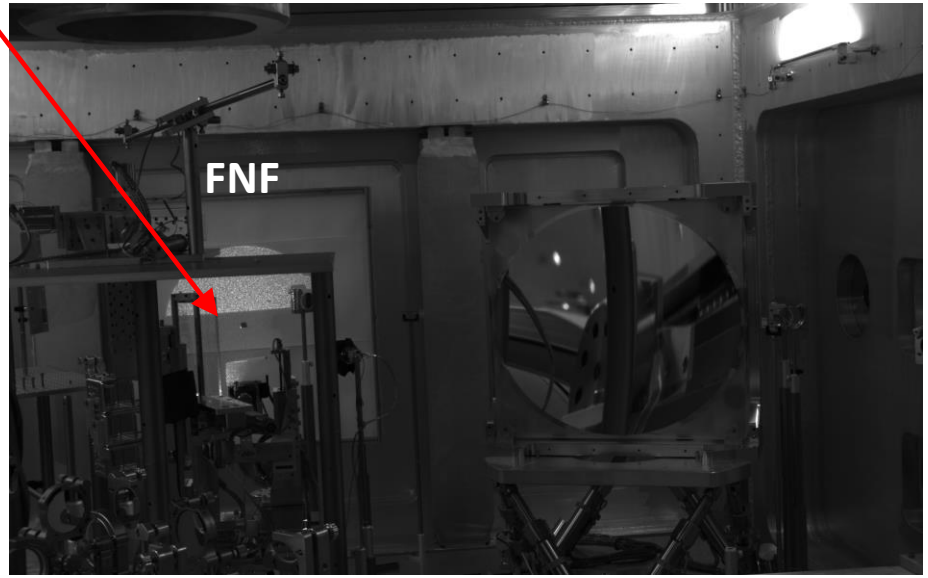






PM after shots

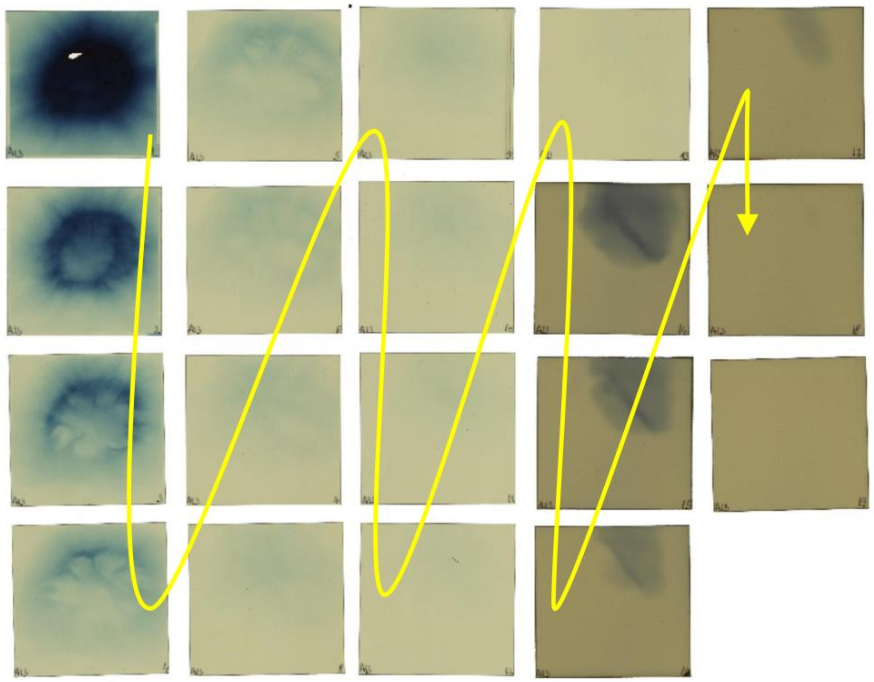




From a preliminary analysis the reflectivity seems to be ~ 70 – 80 % for an intensity on PM of ~3x10^{15} Wcm^{-2}

Some results from the 10 PW experiment

Proton acceleration to ~150 MeV (150nm Al)
First observation of H-like Lyα emission of Ni (Z=28) in laser produced plasmas
E1 Interaction Chamber: 10 PW Laser - Gamma rays conversion in dense targets with low Z (e.g. foams)



Al 0.4 microns Exceding 120MeV proton

200 nm approx. 100 MeV

100 nm approx 60 MeV

50 nm approx. 70 MeV

Al 0.4 microns Exceding 120MeV proton

About 10 shots per day on target

Ring structure ubiquitous (Energy, Pulse duration, Low field PM reflectivity)

Strong prepulse ? 2 ps candidates (9ps, postpulse in the last amp)

Double Plasma Mirror

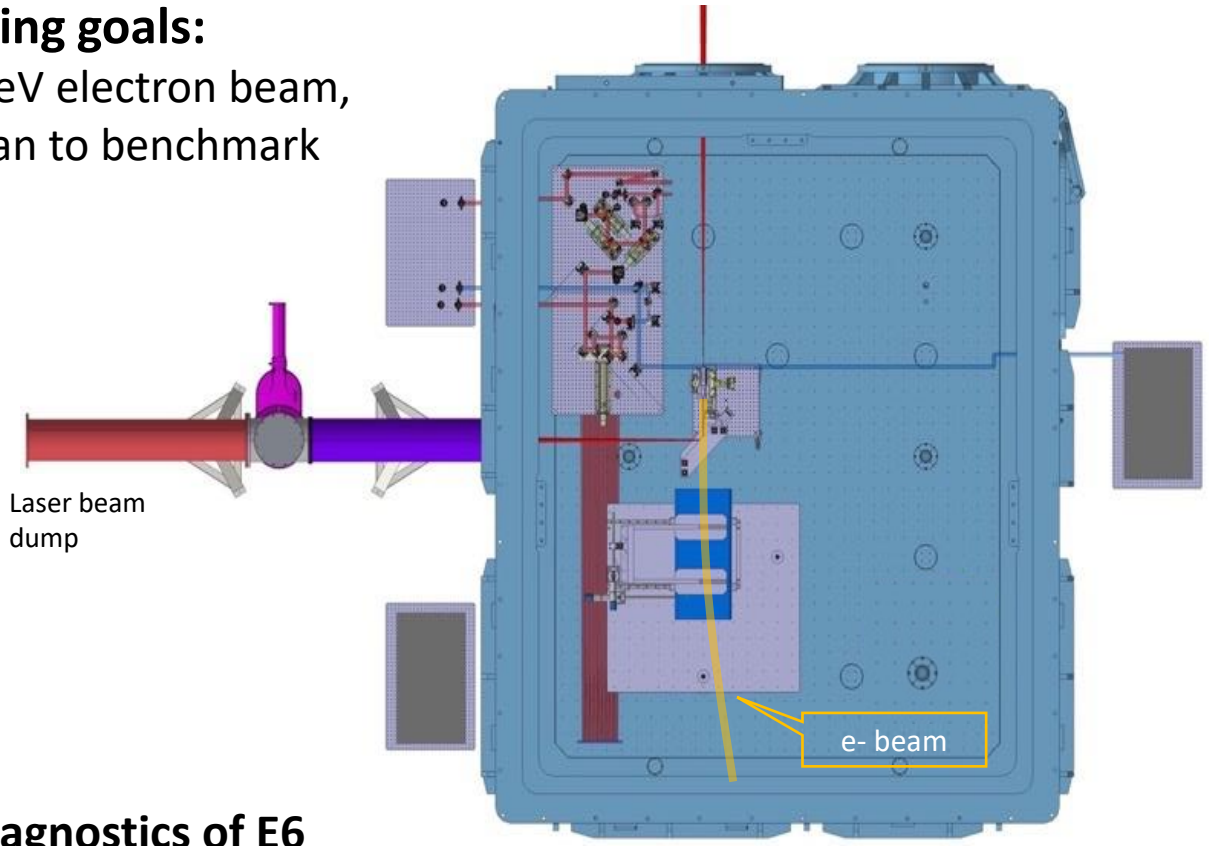
See talk of M. Cernaianu on Friday at 11.00

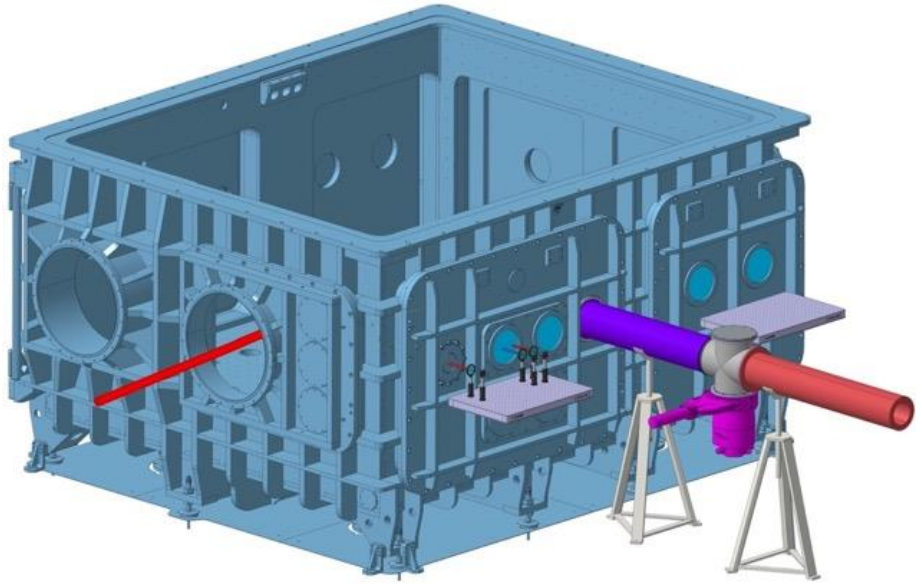
E6 experimental area commissioning

E6 10 PW commissioning starts in Oct 2023

Commissioning goals:

LWFA multi-GeV electron beam,
Parametric scan to benchmark





E6 CAD drawings by Eng. M. Risca

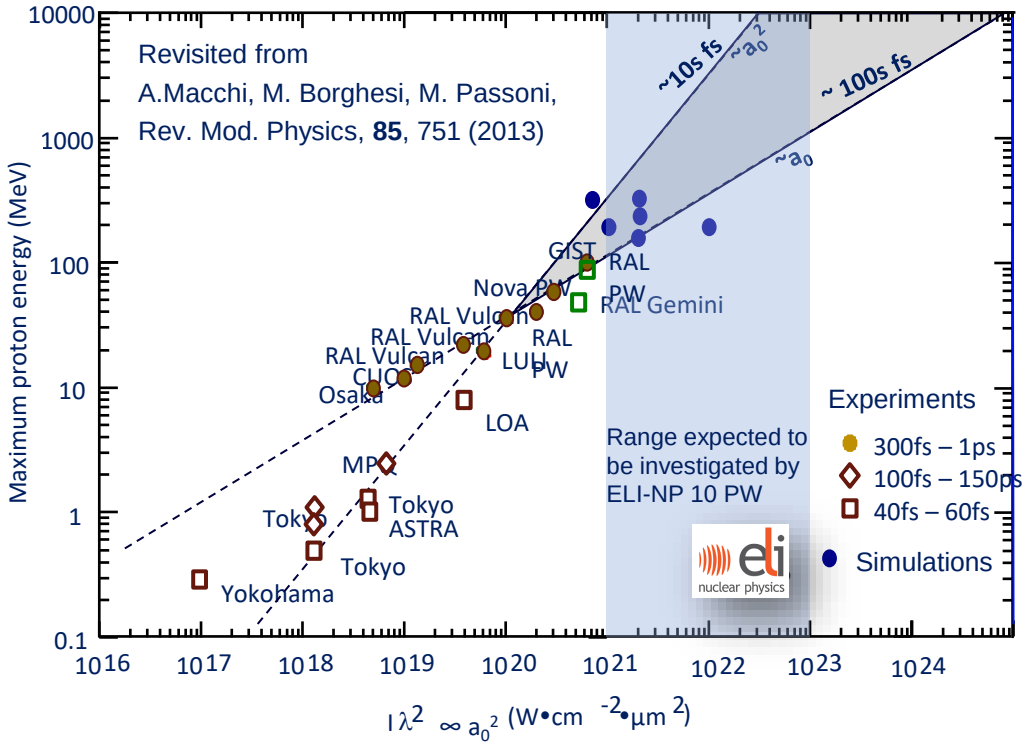
List of main diagnostics of E6

- Laser Diagnostics
- Targetry and Alignment Systems
- Laser Beam Dump
- e−/ e+ Pair Spectrometer
- e- spectrometer in vacuum up to 5GeV with planned upgrades to 20GeV
- Optical Probe/Pump

Topics of research with extreme light sources

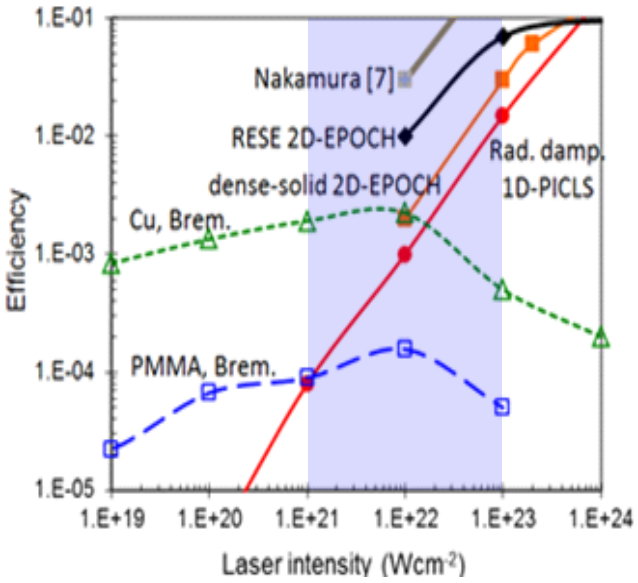
TNSA regime : accelerating protons above 200 MeV (E1)

TNSA scaling law and state-of–the-art



Ultra–intense gamma–ray source (E1)

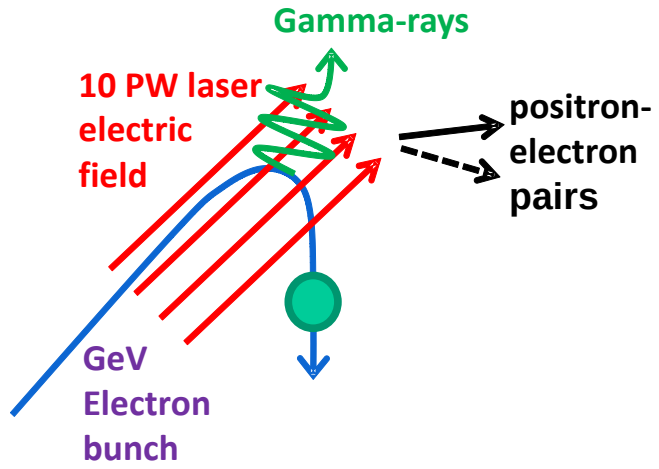
ELI-NP



P McKenna et al, ELI-NP TDR2

Tens of % laser-γ conversion efficiency in low-Z target ($\Longrightarrow$ PW gamma source)

Strong–field QED (E6)



Collision of multi-GeV e-beams with intense laser beams (>10^{22} W/cm^2)

- Synchrotron radiation or Nonlinear Compton:

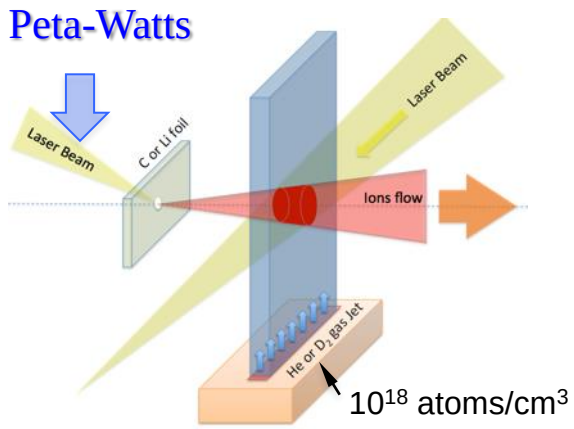
$$e^- + n\gamma_L \rightarrow e^- + \gamma_R$$

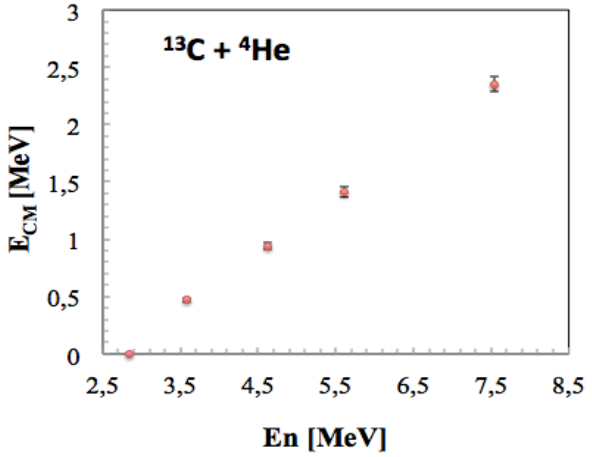
- Breit-Wheeler pair production:

$$\gamma_R + n\gamma_L \rightarrow e^- + e^+$$

Laser–Driven Nuclear Physics

Study of electron screening factor in nuclear reactions of astrophysical interest

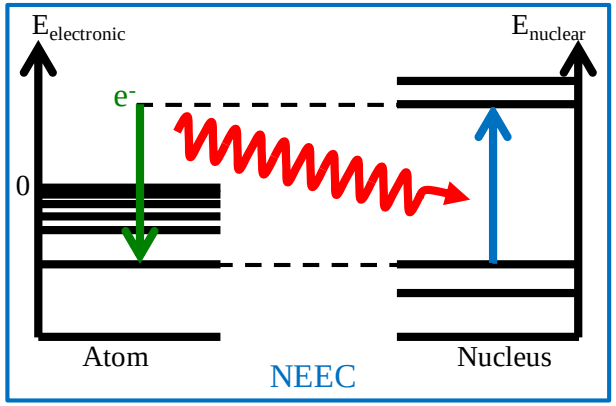




Nuclear reactions in hot plasma created by laser beams simulating stellar environments in the laboratory

S. Tudisco et al., INFN

Nuclear de-excitations in plasma



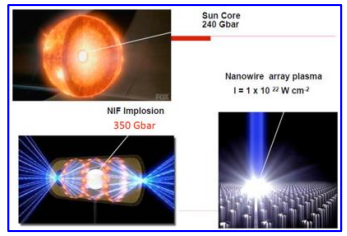
NEEC = Nuclear Excitation by Electron Capture

- ^{93m}Mo (E=2.4 MeV $t_{1/2}$=6.5 h) important case, NEEC claimed by Chiara *et al.*, Nature **554**, 216 (2018) release *via* 4.85 keV intermediate state.
  - Tandem accelerator ANL - NO real plasma conditions

Program at ELI-NP:

- Creating ^{93m}Mo *via* laser-induced proton reaction and exposing to REAL keV plasma with 1 & 10 PW system

Laser–driven bright neutron sources



Development of high-intensity short-pulsed laser-driven neutron source (LDNS)

- Photonuclear (γ,n) reaction at high-rep. rate
- Laser-induced implosion causing shock-compression on deuterated nanowires and 10's of Gbar pressure: 10^{19} W/cm^2, 60 fs, ultrahigh contrast >10^{11}, E_n = 2.45 MeV ⟶ n-flux = 2.2 x 10^6 n/J/shot, A. Curtis *et al.*, Nat. Comm. **9** 1077 (2018)
- Spallation or (p,n) reactions with laser-driven high-energy protons

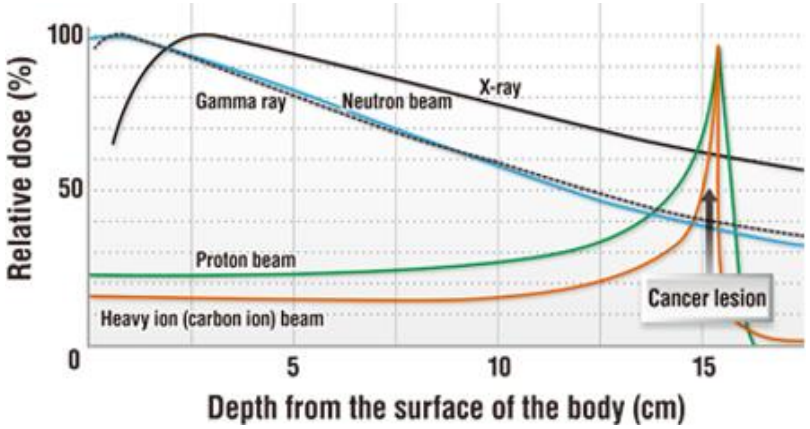
Program at ELI-NP:

- Radiography by a bright source of laser-driven thermal neutrons and X-rays, Yogo *et al.* 2021 Appl. Phys. Express **14** 106001 (2021)
- *N*- and maybe *2N* capture studies (long-term) of waiting-point nuclei in stellar evolution, Hill & Wu, PRC Phys. Rev. C **103**, 014602 (2021)

See talk of K. Spohr on Thursday at 10.40

Medical Applications of High–Power Lasers

Laser-driven C-ions for hadron therapy

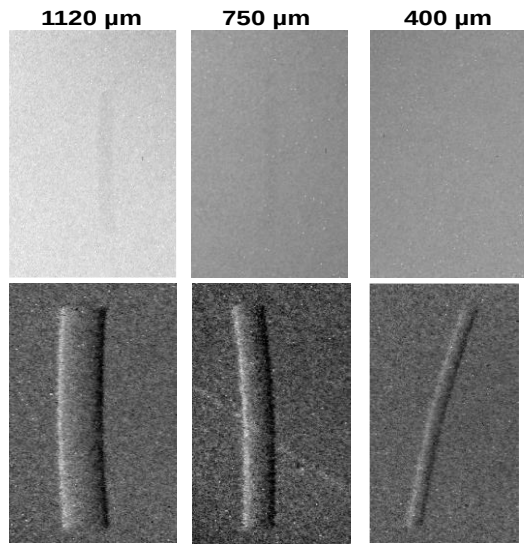


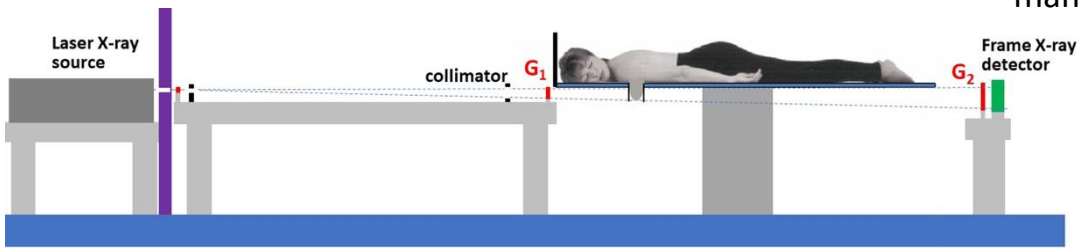
- **10 PW-class lasers have potential to accelerate heavy-ions to therapeutic energy and dose**, at ultrahigh dose rate, in few mm
- laser-driven ultra-high dose rate heavy-ion irradiation can enable **the FLASH effect** (healthy tissue sparring) (10^{10} Gy/s)
- Proposed medical focus on long term: **start from skin-level cancer, progressing to HNC and breast cancer** (#1 cause of cancer mortality for women)

Interferometric phase contrast X–ray imaging

- **Conventional**, absorption-contrast **X-ray imaging has poor visibility of soft tissue tumors**
- **Phase-contrast X-ray imaging investigated as alternative**
- Method requires intense, directional, short–pulse and spatially coherent X–ray source: **100 TW class lasers can do this**
- Proposed medical focus: **breast cancer and later lung cancer**

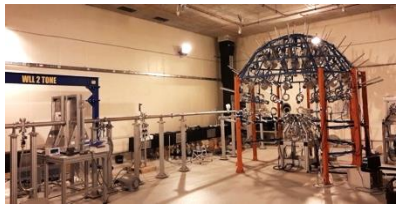
Fibrils simulating early breast cancer in mammographic accreditation phantom





N.Safca *et al*, Phys Med Bio 2022

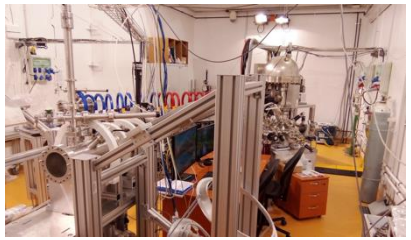
Gamma-Driven Experiments Areas by GDED



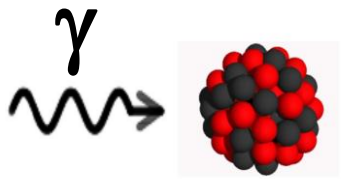
E9: γ beams
Photonuclear
Reactions

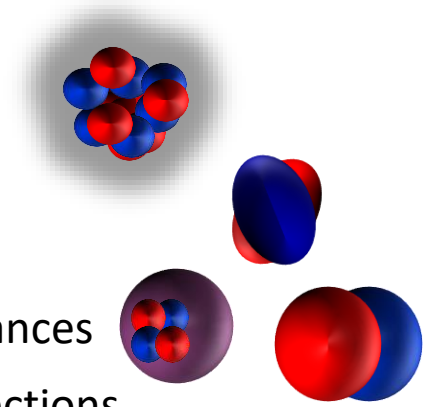
E8: γ beams
Photonuclear
Reactions

ERA: positrons
Material Studies



Physics Case: photonuclear reactions





Nuclear physics

- Nuclear structure
- e.m. dipole response of nuclei
- Pygmy and Giant Dipole Resonances
- Photonuclear reactions cross sections
- Nuclear astrophysics
- Photofission and exotic nuclei

Applications

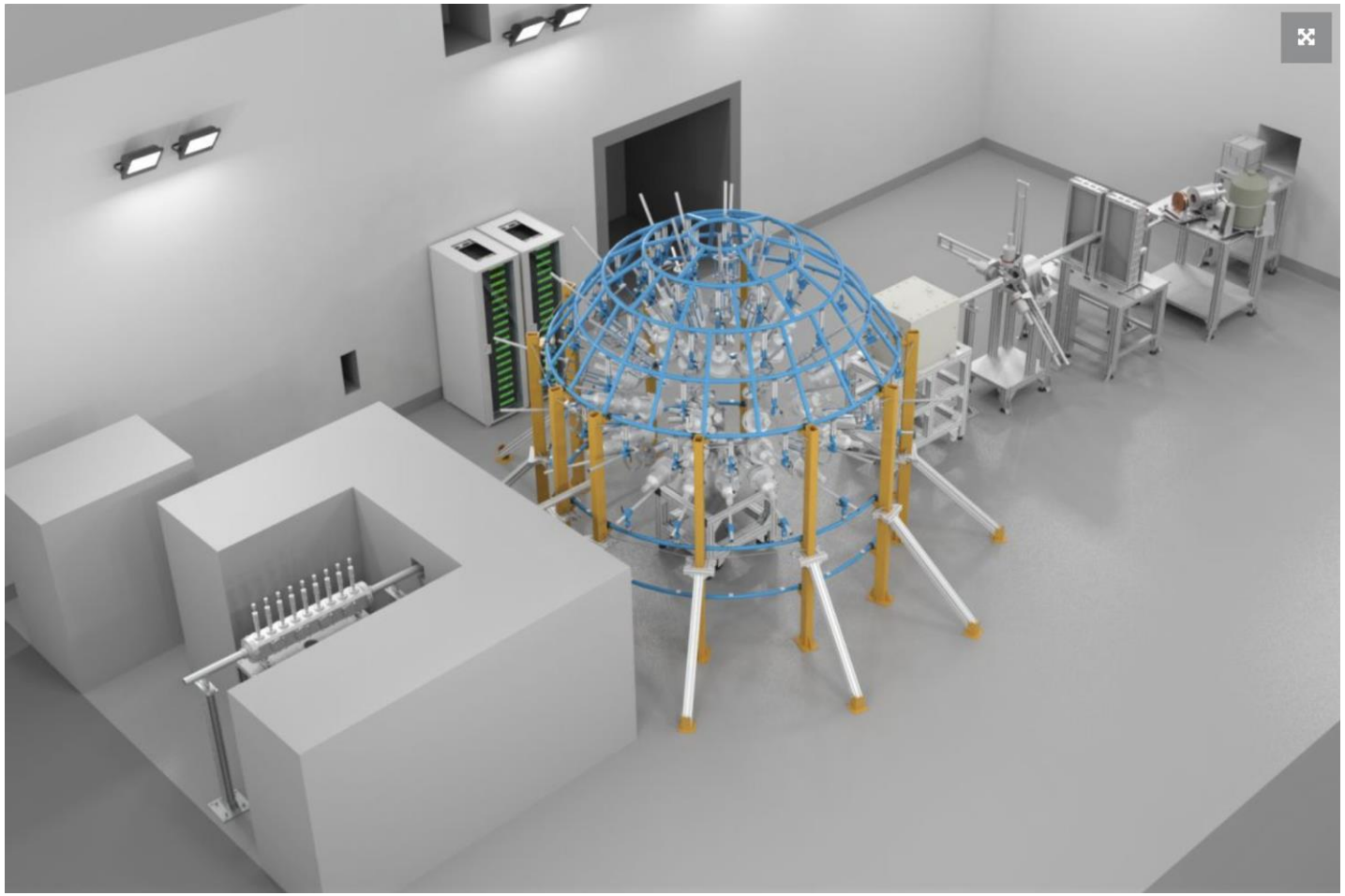
- Industrial imaging
- Radioisotopes generation
- Material studies with positrons

E9, VEGA experimental area by GDED

E9 area: ELIGANT-GN, -TN

study (γ,γ'), (γ, γn), (γ,n), and (γ,xn) reactions

Commissioned with High-energy neutrons from 252Cf



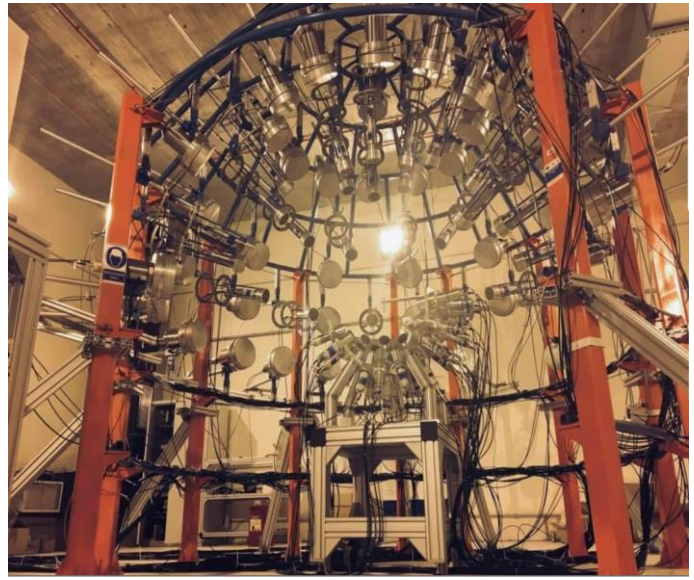
Responsible P.-A. Soederstroem

Detector array

15 3" x 3" LaBr3:Ce + Hamamatsu R11973
15 3" x 3" CeBr3 + Hamamatsu R6233+100
4 3" x 3" CeBr3 + Hamamatsu R11973

36 x 1.6 liter EJ-301 + Hamamatsu 4144 (liquid scint.)

25 x GS20 + ETL 9821 FKLB (^{7}Li glass)



- Combined high-energy gamma and neutron detection
- High-efficiency neutron counting
- Charged particle detection
- Neutron detector characterization
- Beam parameter monitoring and control

E8, VEGA experimental area by GDED

E8 area: ELIADE

Nuclear resonance fluorescence, nuclear astrophysics, photofission and industrial applications.

Commissioned ongoing

Responsible D. Testov

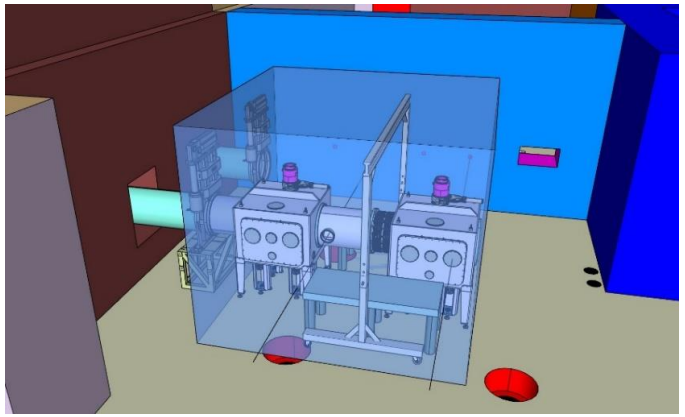
Detector array

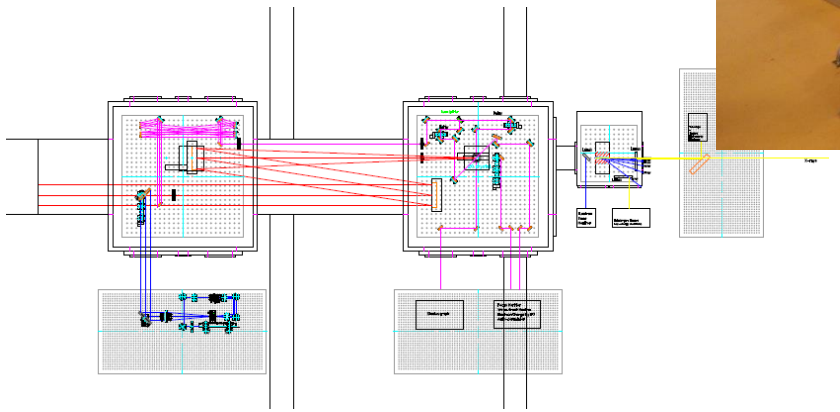
8 segmented clover HPGe detectors
4 LaBr3 detectors

NRF studies
Charge particle detection
Photofission studies
Industrial radiography and tomography
NRF-based elemental analysis
Gamma beam monitoring

Combined laser and gamma beams

- **First stage: 1 PW pulses @ 1 Hz**
- **Then: Multi-PW pulses + Electrons or gamma pulses from VEGA**
- Commissioning experiment endorsed by ISAB: PPEx – Production and photoexcitation of isomers
- Radiation reaction
- Pair creation in vacuum
- Vacuum birefringence
- All-optical vacuum birefringence: S. Ataman, Phys. Rev. A 97, 063811
- Vacuum system installed in the area, ongoing installation of the experimental setups; **To start commissioning experiments by the end of this year**





Center for High Power Optics

- A Centre for High Power Laser Optics adjacent and synergistic to the Extreme Light Infrastructure - Nuclear Physics (ELI-NP)
- Equipped with the technologies to carry out manufacture and/or repair of the high-power optical components used at the ELI-NP research infrastructure (**polishing system for large optical components, spectral technology for metrology, thin layer coating deposition system**)
- A green energy efficient building at the very highest standards, equipped with the latest technologies (air to water heat pump units, solar power system)
- **Collaboration with Osaka University and Okamoto Optics**

MINISTERUL DEZVOLTĂRII, LUCRĂRILOR PUBLICE ȘI ADMINISTRAȚIEI

Summary

- **ELI–NP Laser system fully operational on all outputs at nominal parameters**
- **Experimental areas E4 (100 TW) and E5 (1 PW) installed and commissioned**
  - First results – demonstrate good performance of the system
  - Available for users
- **Experimental areas E1, E6 (10 PW) are under commissioning in 2023**
- **VEGA System implementation is delayed to 2026**
- **Experimental setups for gamma beam experiments installed and commissioned**
- **User experiments with high power lasers**
  - First user experiments – started in November 2022
- **A large number of possible applications emerges from the use of laser-driven secondary sources and monochromatic gamma beams**
- **In June 2023 Romania was accepted as Founding Observer of ELI ERIC**

The ELI-NP team

260 employees

- 41 foreign researchers and engineers
- More than 100 young researchers below 35
- 58 Students PhD, master and bachelor

EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2014-2020

Project co-financed by the European Regional Development Fund through the Competitiveness Operational Programme "Investing in Sustainable Development"

Extreme Light Infrastructure-Nuclear Physics (ELI-NP) - Phase II

Thank you !

www.eli-np.ro