ELI Laser-Induced Fusion Kick-off Meeting

28-29th November 2023
Dolní Břežany,
Czech Republic

Introduction to ELI

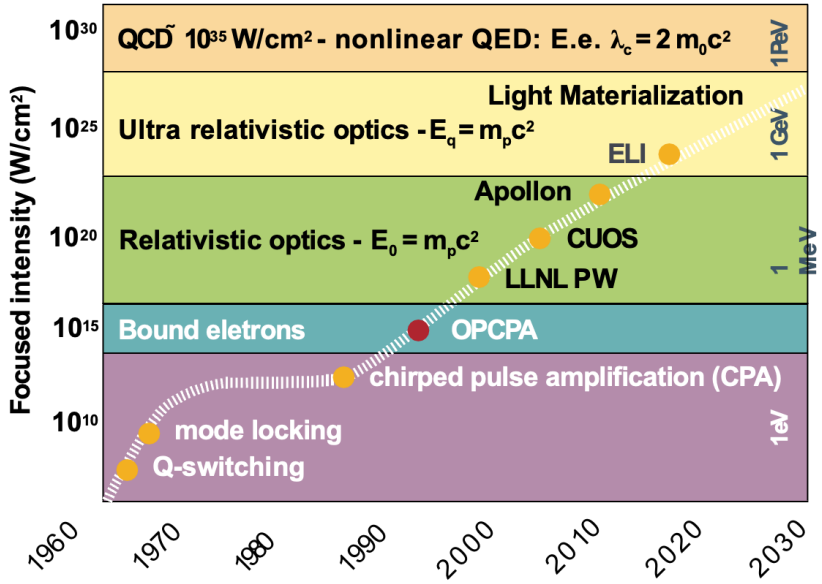
Andrew Harrison, ELI ERIC Director of Science

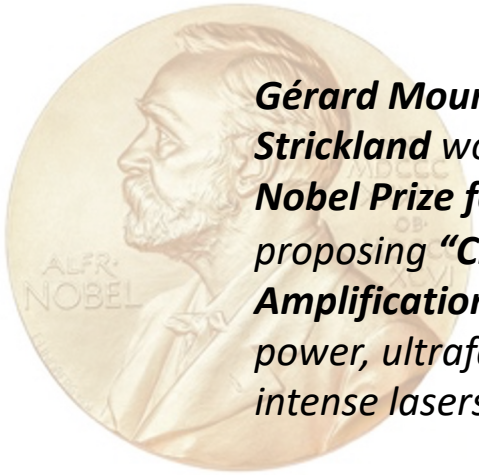
ELI Laser-Induced Fusion Kick-off Meeting

28-29 November 2023

From Nobel Prize to Extreme Light

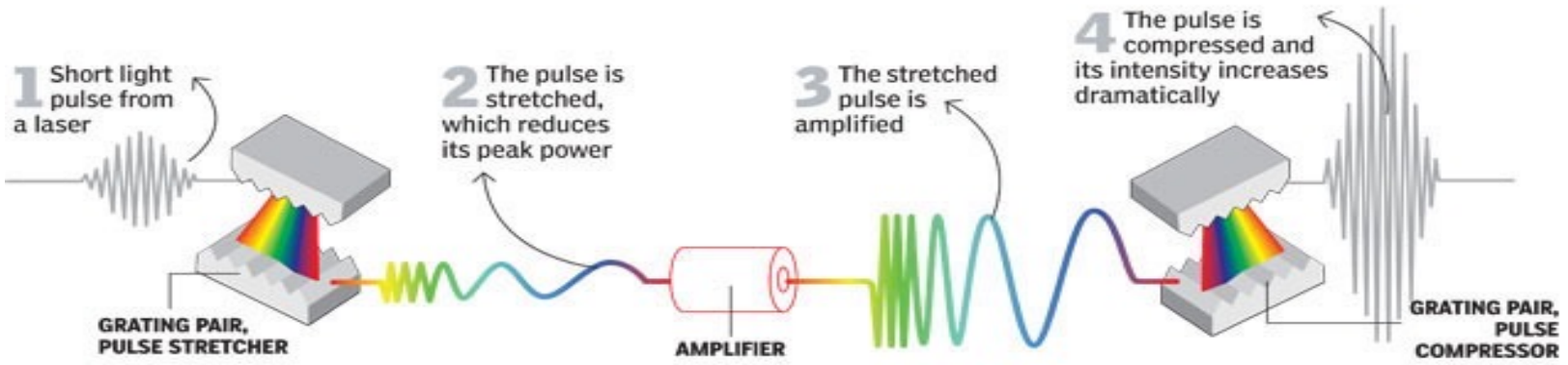
A Technological Breakthrough Enables ELI





Gérard Mourou and Donna Strickland *won the* ***2018 Nobel Prize for Physics*** *for proposing* ***"Chirped Pulse Amplification"*** *for high-power, ultrafast, extremely intense lasers.*

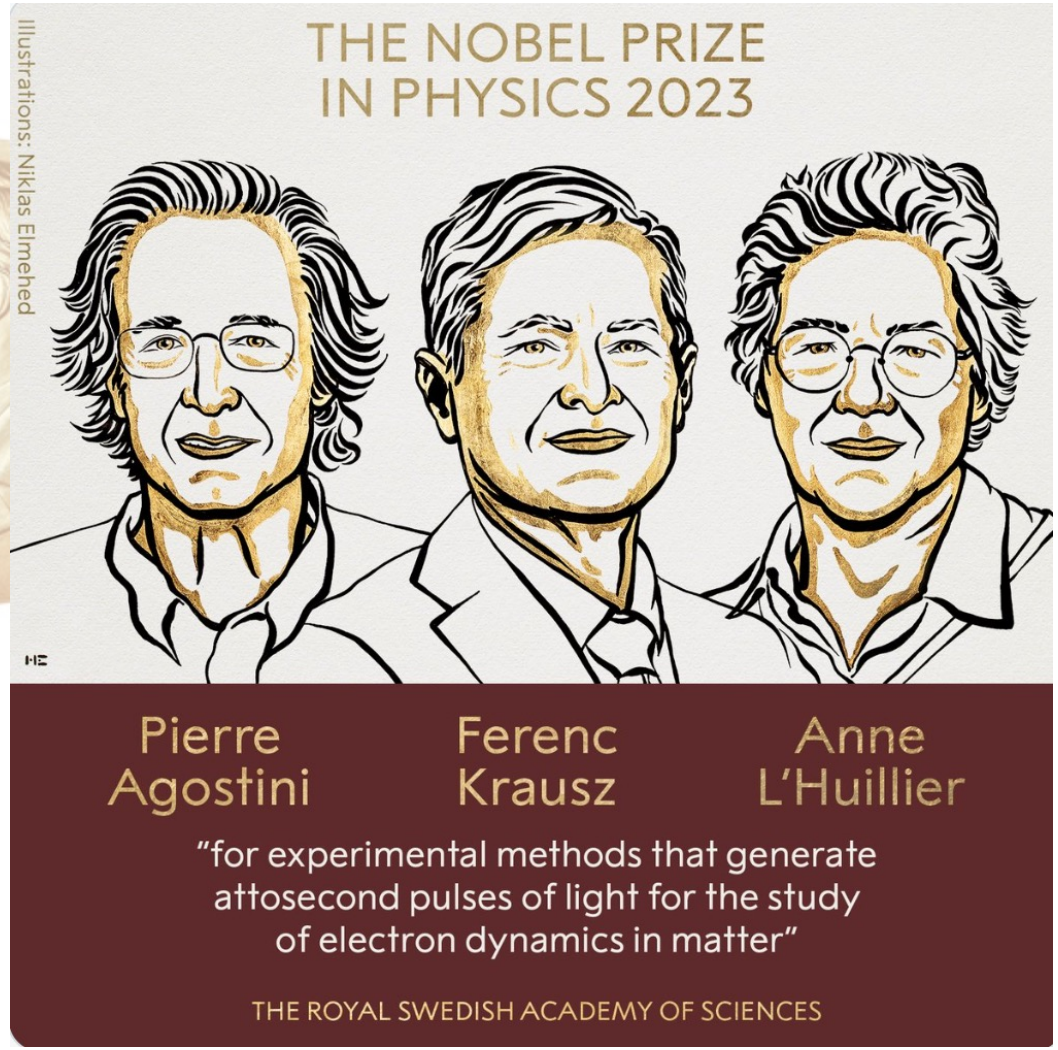
Chirped Pulse Amplification (CPA)

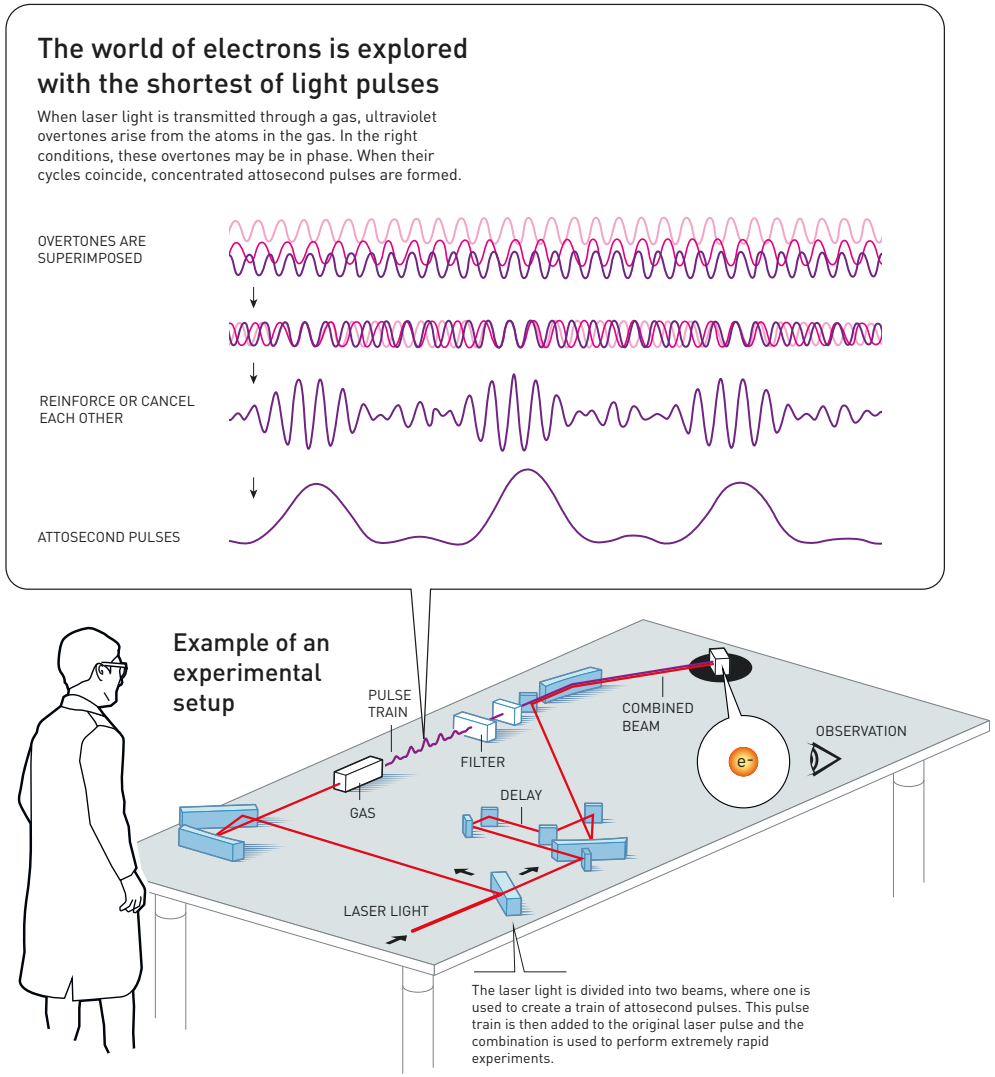


Mourou, et al proposed ELI in 2004, and from 2007-2010 initial reseach including 15 institutions and € 7.9M from the Seventh Framework Programme.

2023 Physics Nobel Prize

Experimental Methods Generating Attosecond Pulses





What is ELI ?

- ELI Beamlines, Czech Republic
- ELI Attosecond Light Pulses, Hungary
- ELI Nuclear Physics, Romania

Extreme Light Infrastructure for Europe

3 Complementary User Facilities:

- **High-Energy Beam Facility**, developing and applying ultra-short pulses of ultra-intense radiation to explore extreme conditions or produce high-energy particles and radiation
  (ELI Beamlines, Prague, CZ)
- **Attosecond Light Pulse Source**, offering unique time-resolved investigation possibilities for both nonrelativistic and relativistic interaction of light with all the four states of matter
  (ELI ALPS, Szeged, HU)
- **Nuclear Physics Facility** with ultra-intense lasers and brilliant gamma beams (up to 19 MeV) to produce and explore new nuclear states or generate neutron beams
  (ELI NP, Magurele, RO)

ELI is a big part Europe's strategy - advanced lasers intended for ***users***

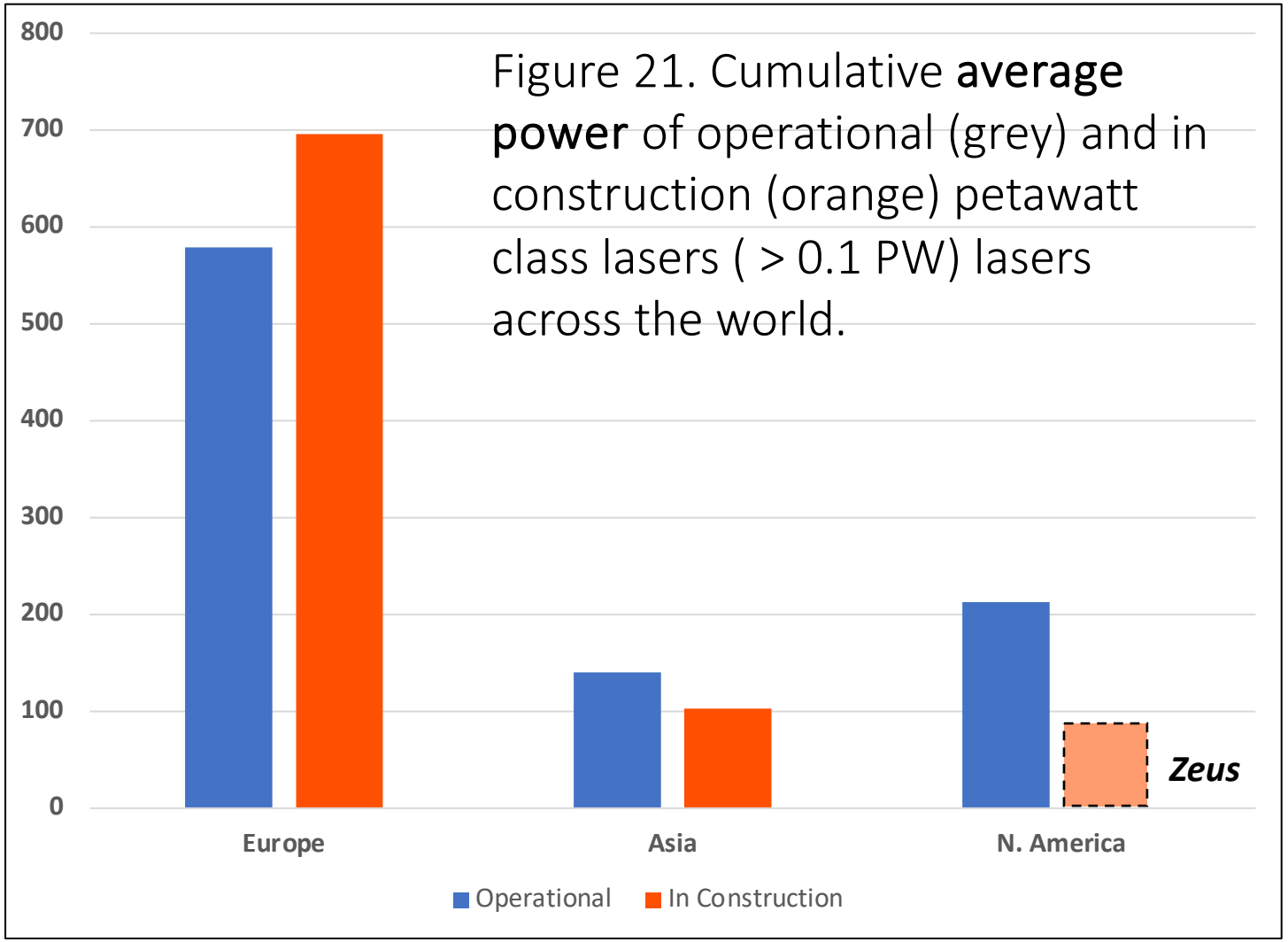


Figure 21. Cumulative **average power** of operational (grey) and in construction (orange) petawatt class lasers (> 0.1 PW) lasers across the world.

"Europe's investments, mainly through ELI, represent a massive increase in experimental productivity and focus on development of high-intensity laser applications."

Danson, C., Haefner, C., Bromage, J., Butcher, T., Chanteloup, J., Chowdhury, E., . . . Zuegel, J. (2019). Petawatt and exawatt class lasers worldwide. *High Power Laser Science and Engineering, 7*, E54. doi:10.1017/hpl.2019.36

A European Research Infrastructure Consortium

A European International Organisation
Established in 2021

The Czech Republic,
Host of Seat

Hungary,
Host

Italian Republic

Lithuania

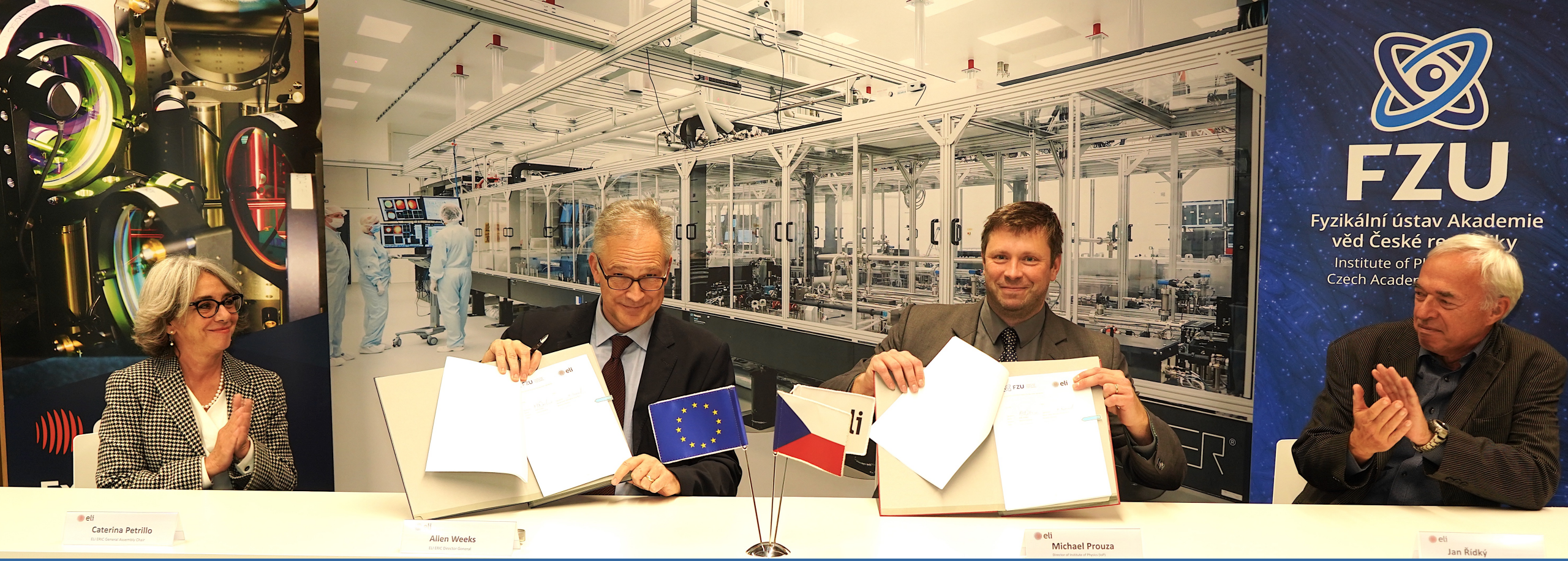
Federal Republic of Germany
Observer

Romania
Observer from 1 Jan 2024

Bulgaria
Observer

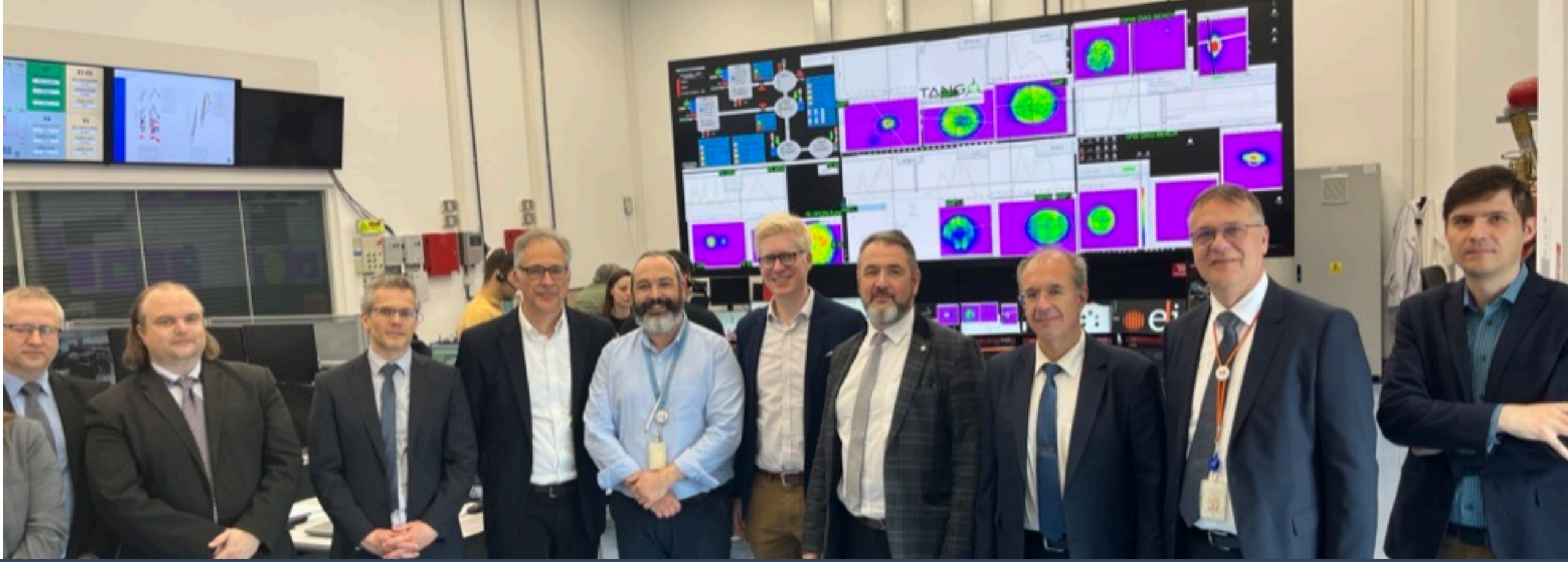
ELI ERIC is welcomes international partners for example with national agencies and/or institutions, which will contribute to the mission of ELI ERIC and support the involvement of their user communities and the operation of the ELI FACILITIES on a long-term perspective.

Member countries support ELI ERIC jointly with national funding.



Strategic Agreement with FZU Integrates ELI Beamlines into ELI ERIC from 1 January 2023

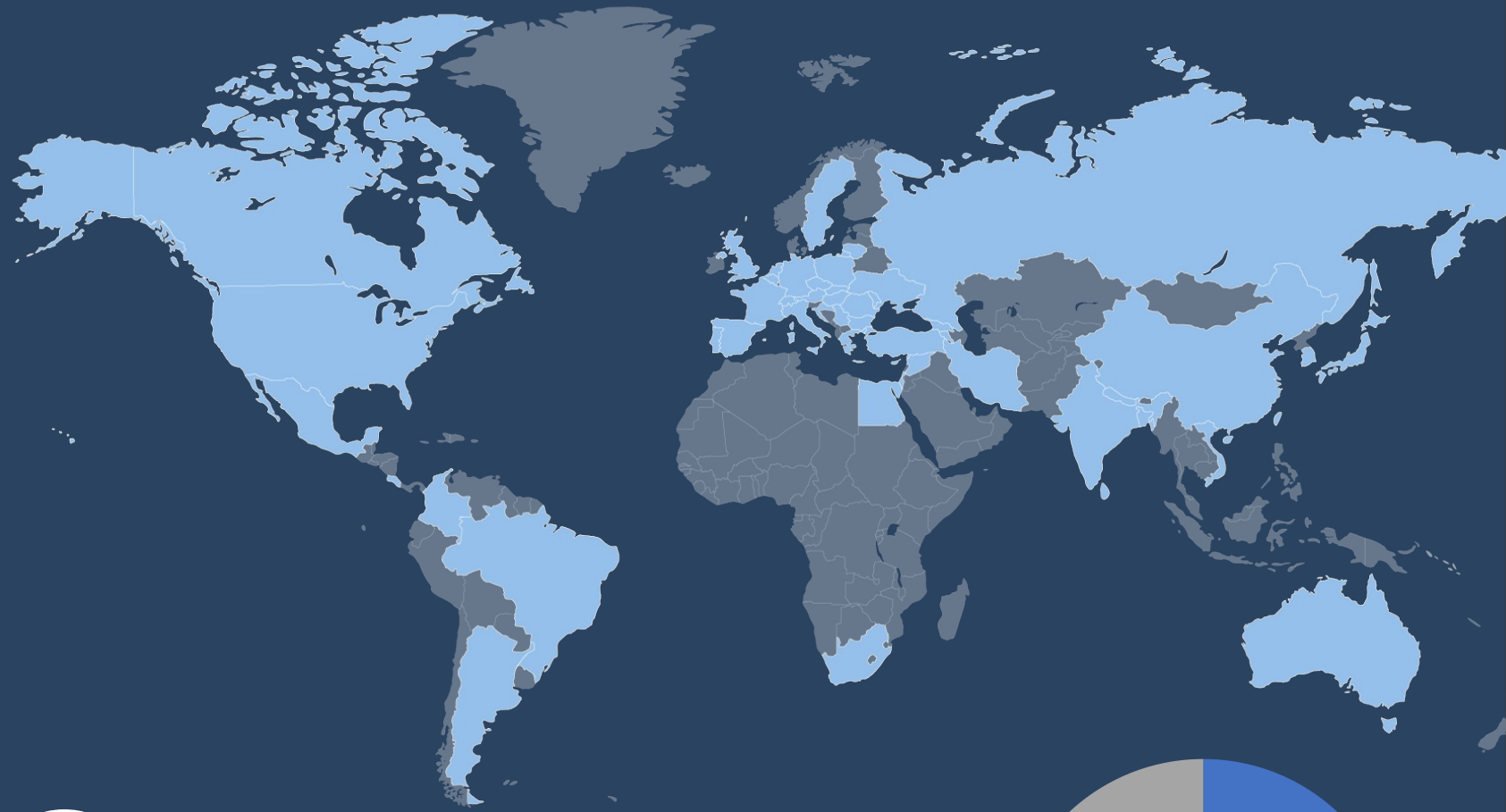
Strategic Agreement with University of Szeged Integrates ELI ALPS into ELI ERIC from 1 January 2024



High-Level Visit to the Romanian Ministry of Research and ELI NP took place in May 2023

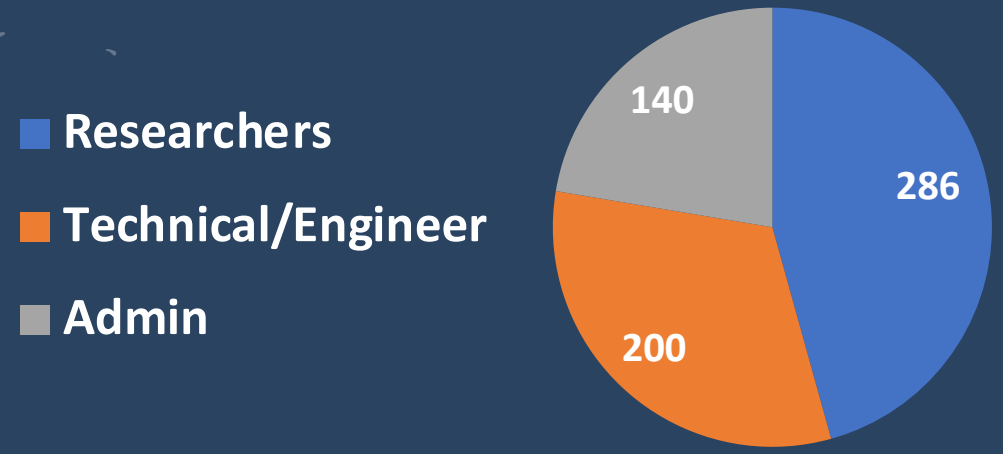
Romania accepted as Founding Observer from 1 January 2024

ELI ERIC
Facility Staff



47
Nationalities

627
Total Staff



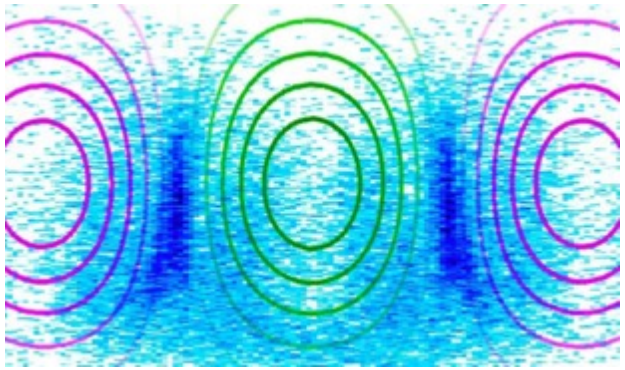
Democratising science using high-performance lasers

Applications in material science and biology – structure and dynamics to attoseconds

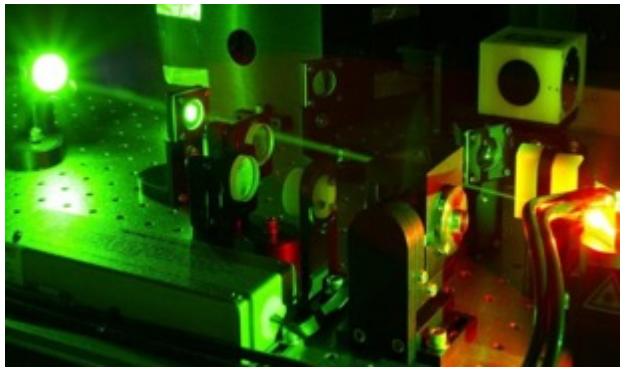
Particle acceleration
250 MeV ions accelerated by lasers

Radiation physics and electron acceleration- up to GeV electrons – for soft to hard x-rays

Plasma physics and high energy density, astrophysics, nuclear photonics



Ultra high intensity interactions
High-field physics and theory



Laser development

ELI Attosecond Light Pulse Source

Szeged, Hungary

ELI ALPS Facility Layout

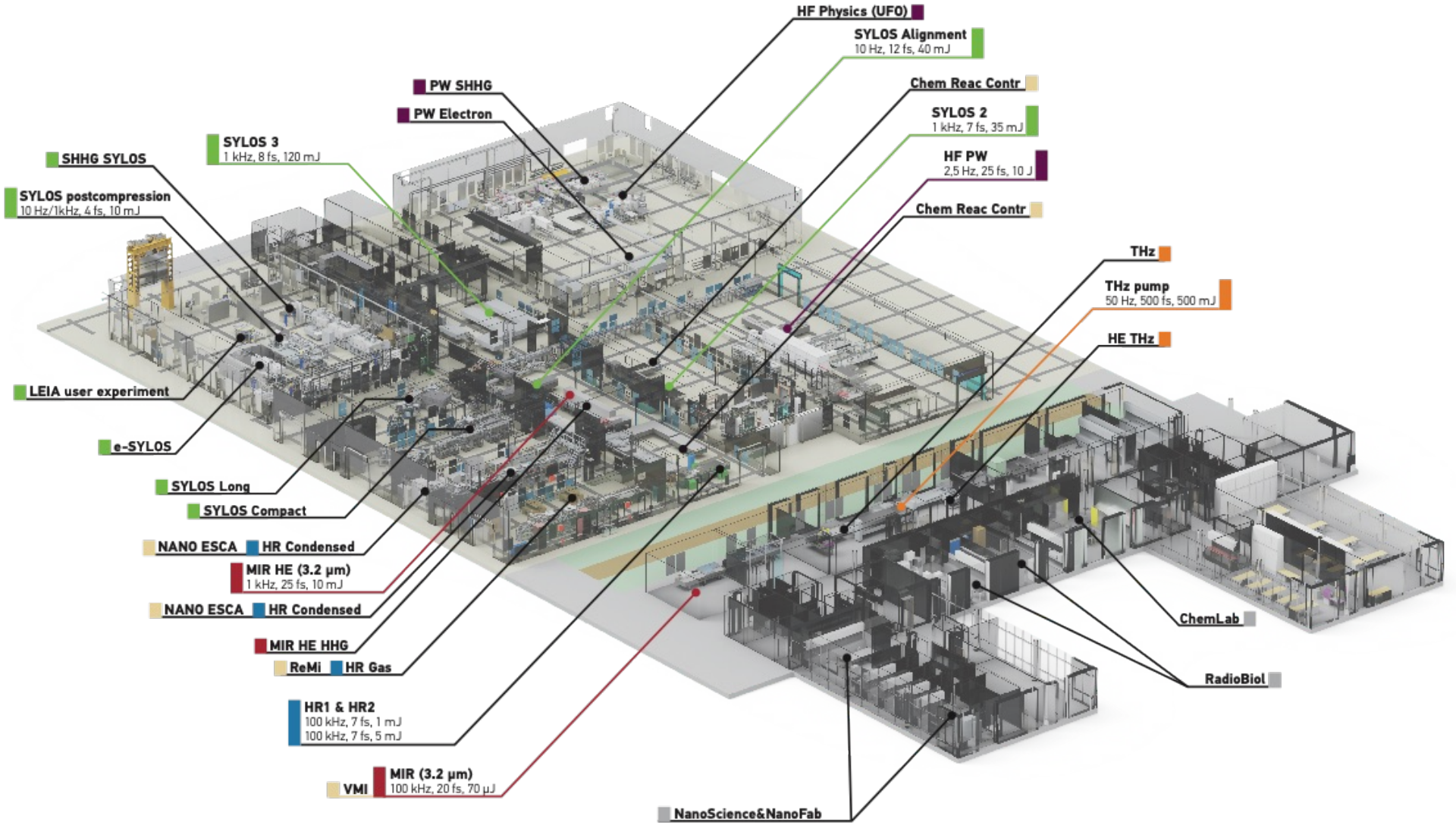
ELI ALPS

(Attosecond Light Pulse Source)

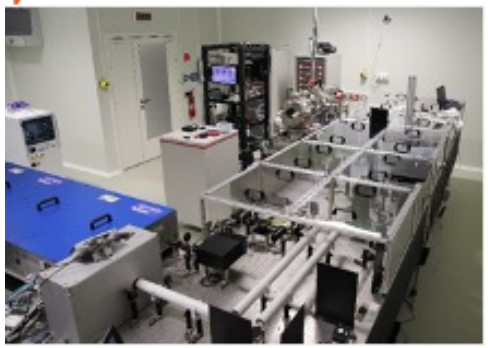
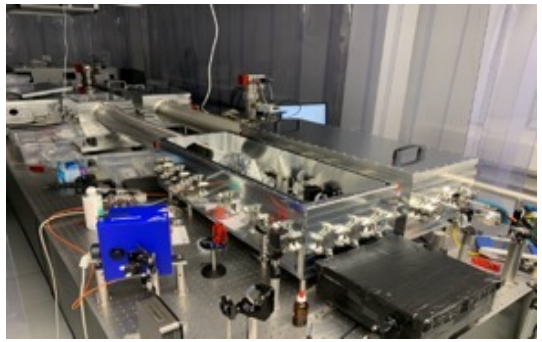
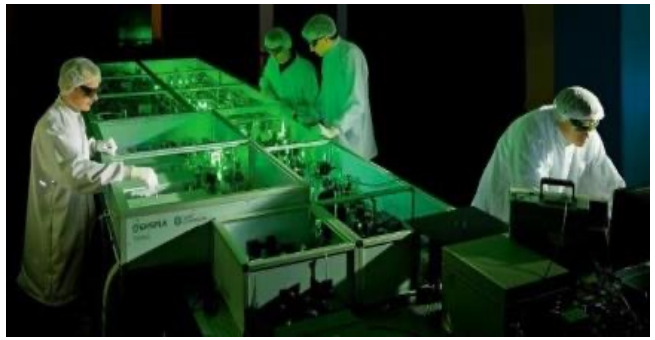
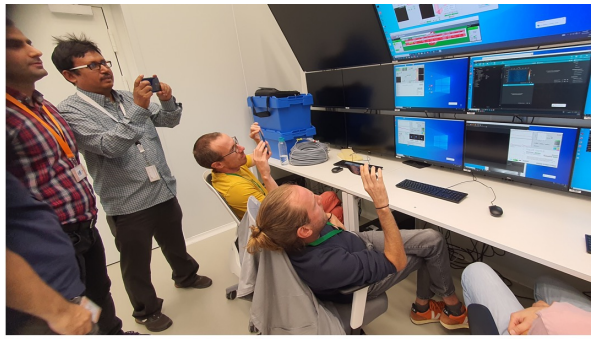
ELI ALPS is a leading research facility in ultrafast physical processes as well as a world-class centre for generating outstanding biological, chemical, medical and materials science results.

Research fields and applications:

- Development of attosecond light sources and measurement techniques
- Radiobiological applications
- Energy research: solar cells, artificial photosynthesis, transmutation of used nuclear fuels
- High-peak-power photonics
- Information technology, materials science and nanoscience
- Particle acceleration with few cycle laser pulses

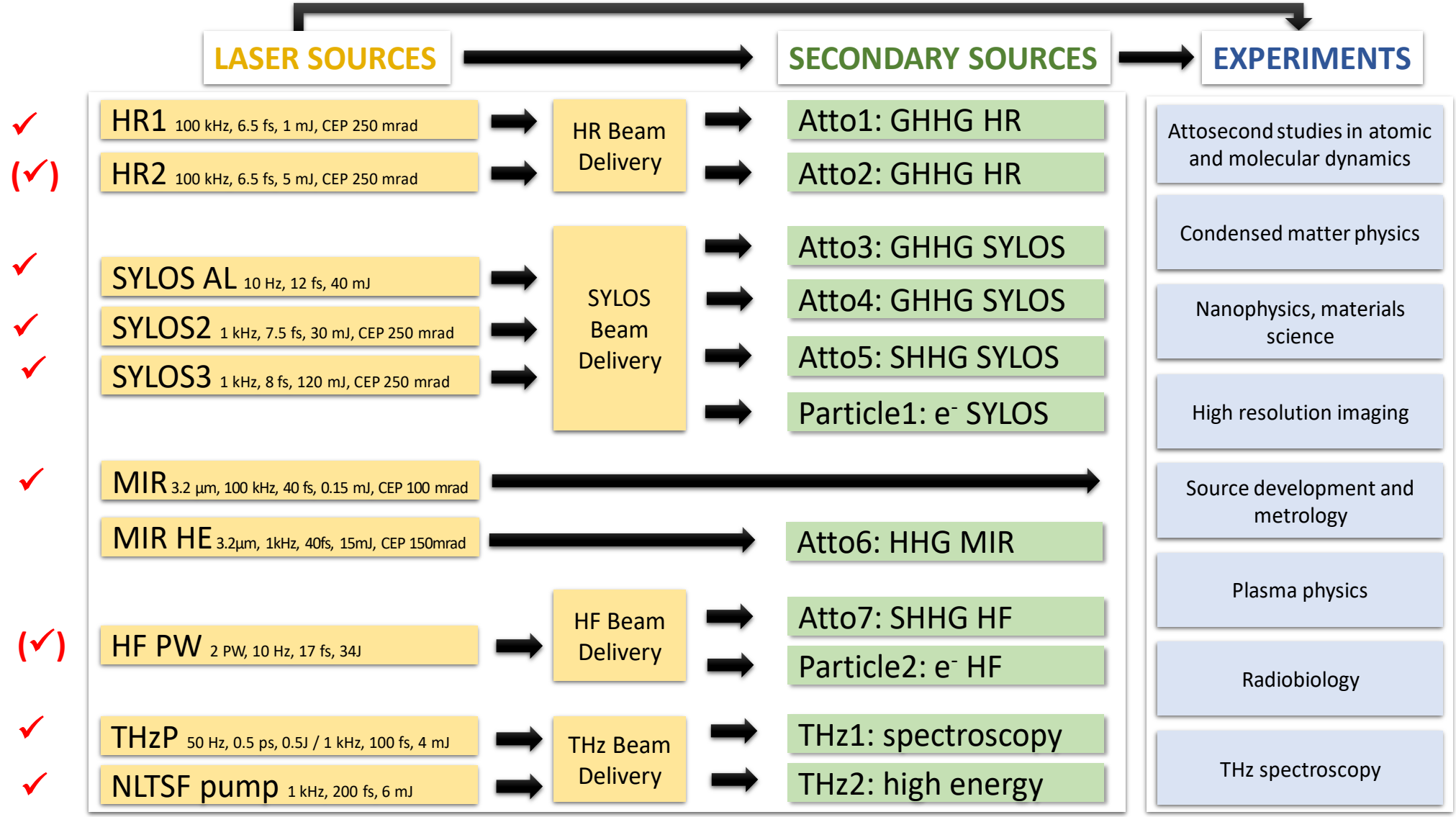


ELI ALPS laser systems

Primary laser	MIR	HR-1 (long/short pulse)	SYLOS (3)	HF PW (design)
Description	Mid-IR with OCPCA and CEP stabilisation	High Repetition Rate Yb-fiber laser, diode pumped	NOPCPA driven by diode-pumped Nd:YAG, CEP	OCPCA Ti:Sa , Nd:YAG amplifiers
Central wavelength	3200 nm (optimal)	1030 nm	825 nm	800 nm
Peak power	>2.4 GW	>25/140 GW	>15 TW	0.48 PW (2 PW)
Average power	12 W	up to 100 W	120 W	10 W (300 W)
Pulse energy	>120 µJ	1 mJ	120 mJ	4 J (28.9 J)
Repetition rate	100 kHz	100 kHz	1 kHz	2.5 Hz (10 Hz)
Pulse duration	<50 fs	<40 fs / <7 fs	<8fs	22 fs (<19 fs)

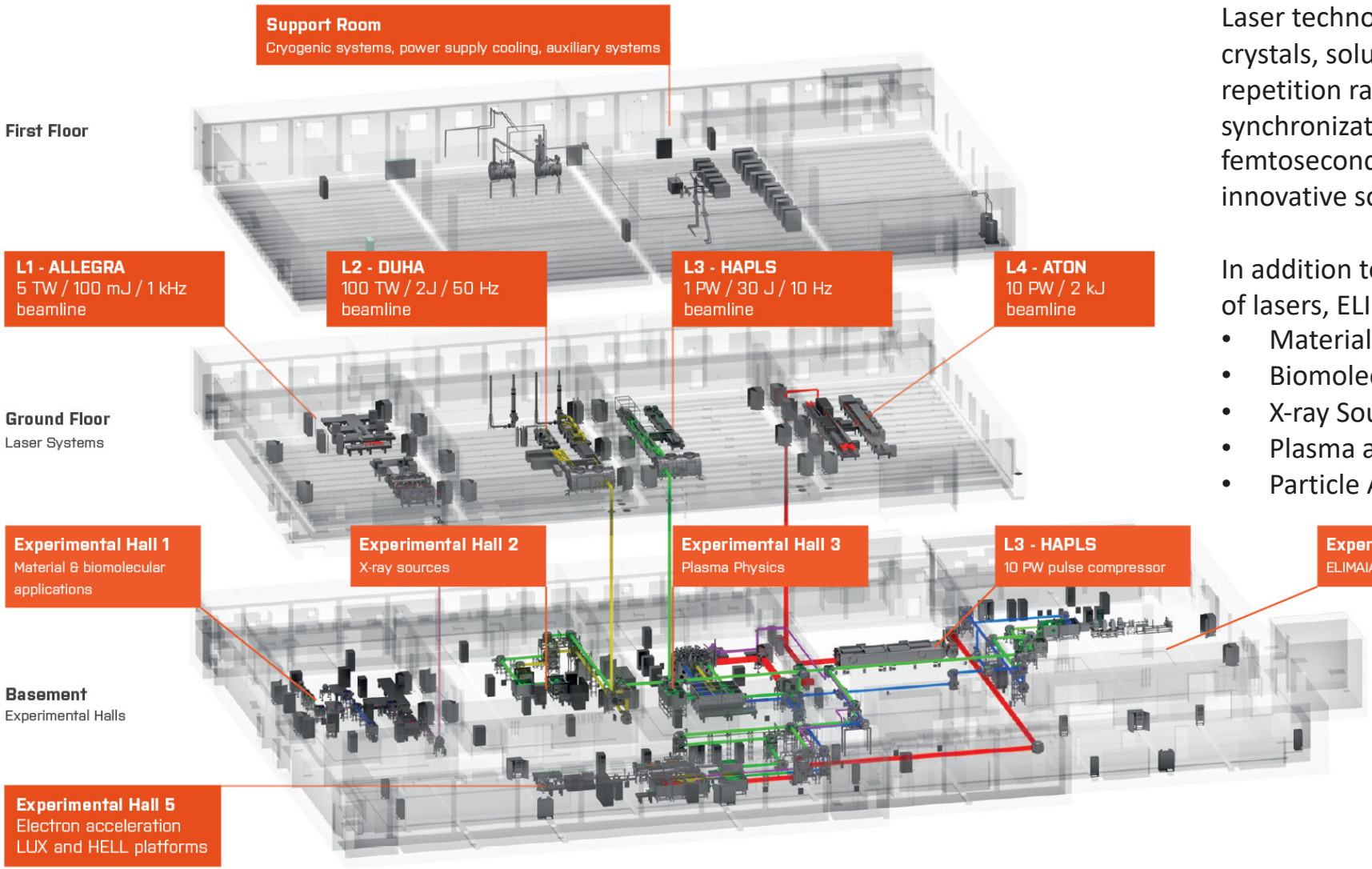
ELI ALPS experimental chains



ELI Beamlines

Dolní Břežany, Czech Republic

ELI Beamlines Facility Layout



ELI Beamlines

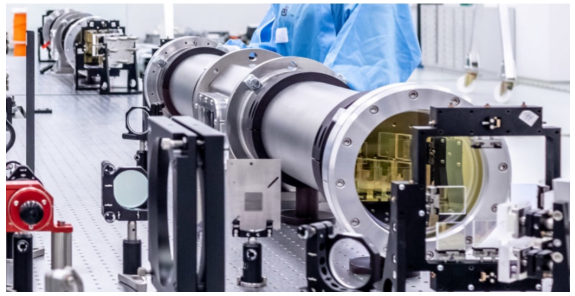
Laser technologies developing new techniques for laser crystals, solutions for the cryogenic cooling of high-power repetition rate laser amplifiers, femtosecond synchronization, advanced repetition rate diagnostics of femtosecond pulses, advanced control systems, and innovative solutions for petawatt (PW) pulse compressors.

In addition to basic research and development in the field of lasers, ELI Beamlines deals with research:

- Material science
- Biomolecular Applications
- X-ray Sources Driven by Ultrashort Laser Pulses
- Plasma and High-field Physics
- Particle Acceleration

Laser systems @ELI BL

including ramp-up/upgrades

Laser parameters	L1 - ALLEGRA	L2-DUHA	L3 - HAPLS	L4 - ATON
Description	OPCPA, Yb:YAG thin disks, diode pumping	OPCPA, Yb:YAG slabs,diode-pumped	CPA, Ti:Sa, diode pumping	CPA/OPCPA, Nd:glass, flash lamps pumping
Energy	**55 mJ** (100 mJ)	3 J	**13 J** (30 J)	**300 J @2w** (1.5 kJ @1w)
Pulse width	**15 fs**	**25 fs**	**27 fs**	**2-10 ns** (150 fs)
Peak Power	**>3 TW** (>6 TW)	>100 TW	**0.5 PW** (1 PW)	NA (10 PW)
Wavelength	840 nm	820 nm *(5mJ @2.2 □m)*	800 nm	530 nm (1060 nm)
Repetition rate	**up to 1 kHz**	50 Hz *(5mJ @1 kHz)*	**up to 3.3 Hz** (10 Hz)	**1/3min** (1/min)
Intensity contrast	10^{-10}	10^{-11}	10^{-11}	NA (10^{-11})

ELI-Beamlines Experimental Halls

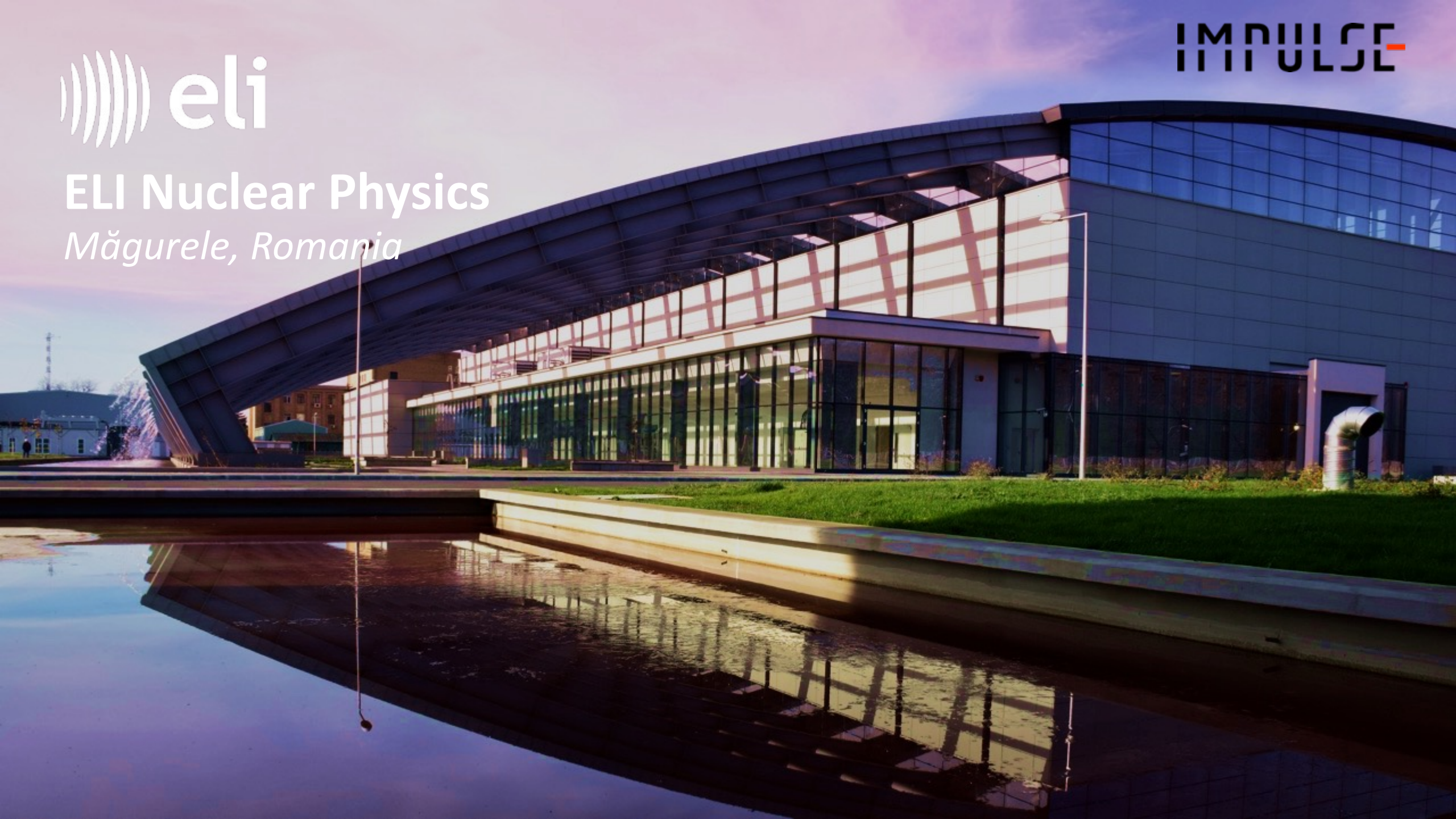
- Mid-IR to Hard X-rays @1kHz
- Pump-Probe techniques for
- fs-ms dynamics

- Betatron combined with Inverse Compton Scattering for hard X-Rays

- kJ-class (2w), ns, high rep-rate, pulse-shaping capability
- Platform for HEDP, ICF, shock physics
- Dedicated targetry & diagnostics

- Ultrahigh intensity laser-matter interaction (>10^{21}W/cm^2)
- Laser-plasma p acc. (>35MeV)
- Tertiary sources (pitcher-catcher)

- ELBA: all-optical laser-electron collider
- LUIS: laser-driven FEL (350MeV; 45 eV photons)



ELI Nuclear Physics

Măgurele, Romania

ELI-NP Research Infrastructure

World-unique combination of instrumentation

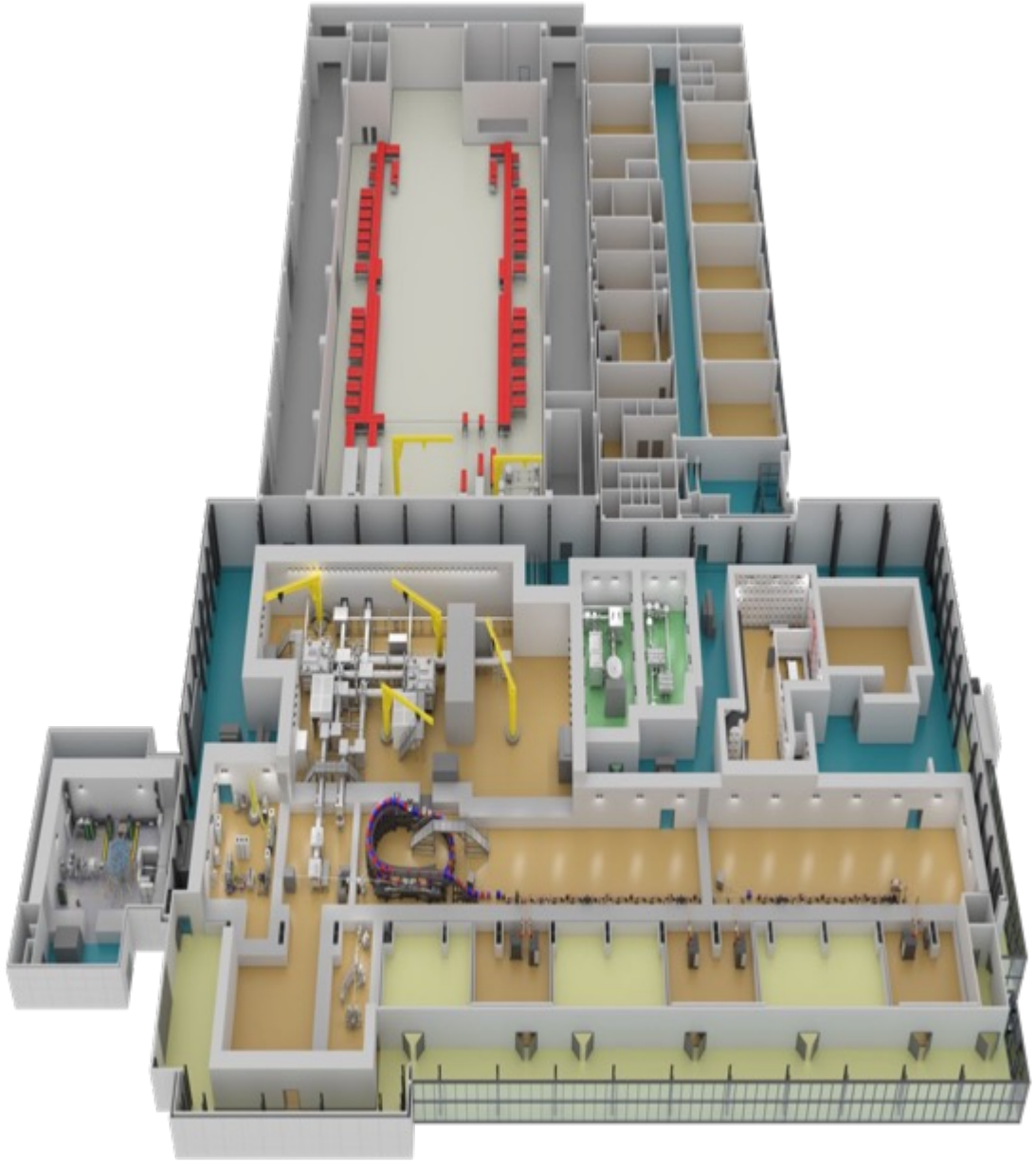
- 100 TW, 27 fs, 2.7 J @ 10Hz – available for users
- 1 PW, 24 fs-1 ps, 25J @ 1 Hz – available for users
- 10 PW, 25 fs, 250 J @ 1 shot/min - now operational and undergoing commissioning
- Optics and chambers for nuclear physics and ultra-high-field physics (QED)
- Monochromatic γ-beam (tunable 0.2 – 19.6 MeV) under development

Advanced studies in basic science

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

Developing technologies for:

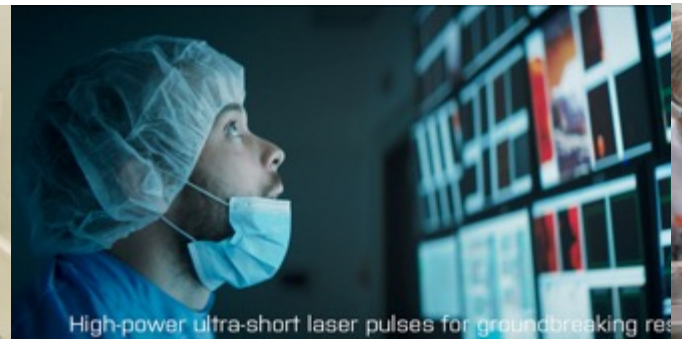
- medical applications (X-ray imaging, radioisotopes)
- industrial applications (non-destructive studies with!)
- material studies with positrons
- materials in high radiation fields



ELI ERIC is Open to the World

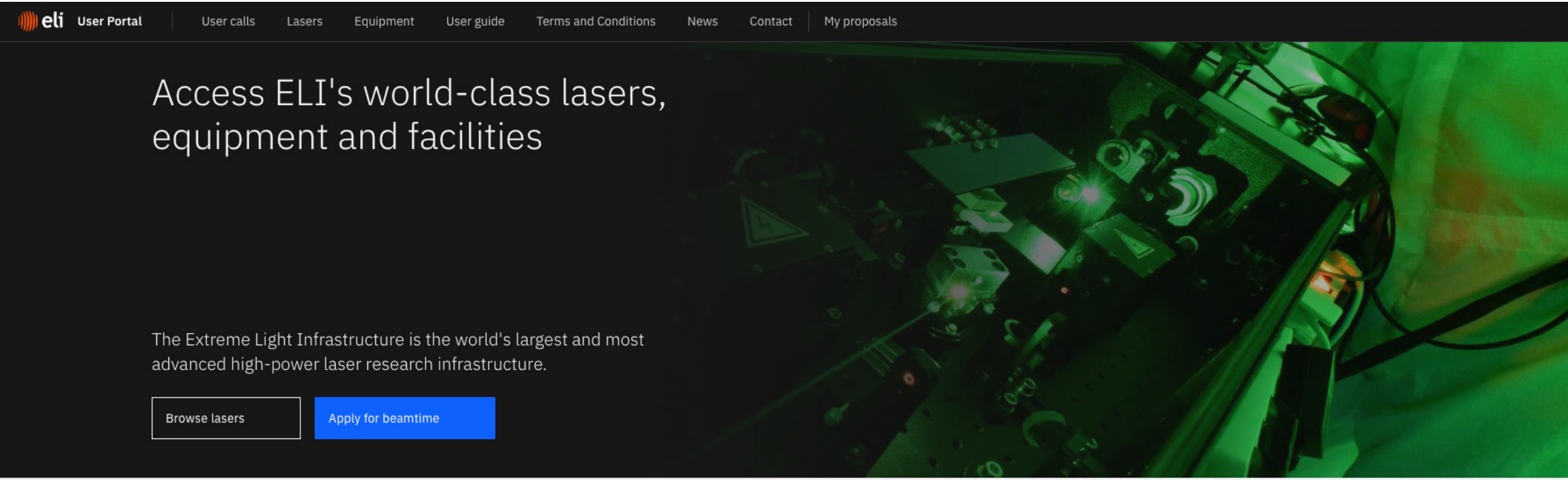
A user facility with three access modes

- **Excellence-Based Access** – Evaluation of proposals by international peer-review panels. ***Results of experiments published and open.***
- **Mission-Based Access** – Thematic research granted on the basis of scientific missions pursuing challenges. Proposals reviewed by international panels. ***Results published and open.***
- **Proprietary Access** – Paid access for industrial or other users. ***Results are retained by the user,*** consistent with ELI ERIC's Data and IPR Policy.



User Portal

https://up.eli-laser.eu

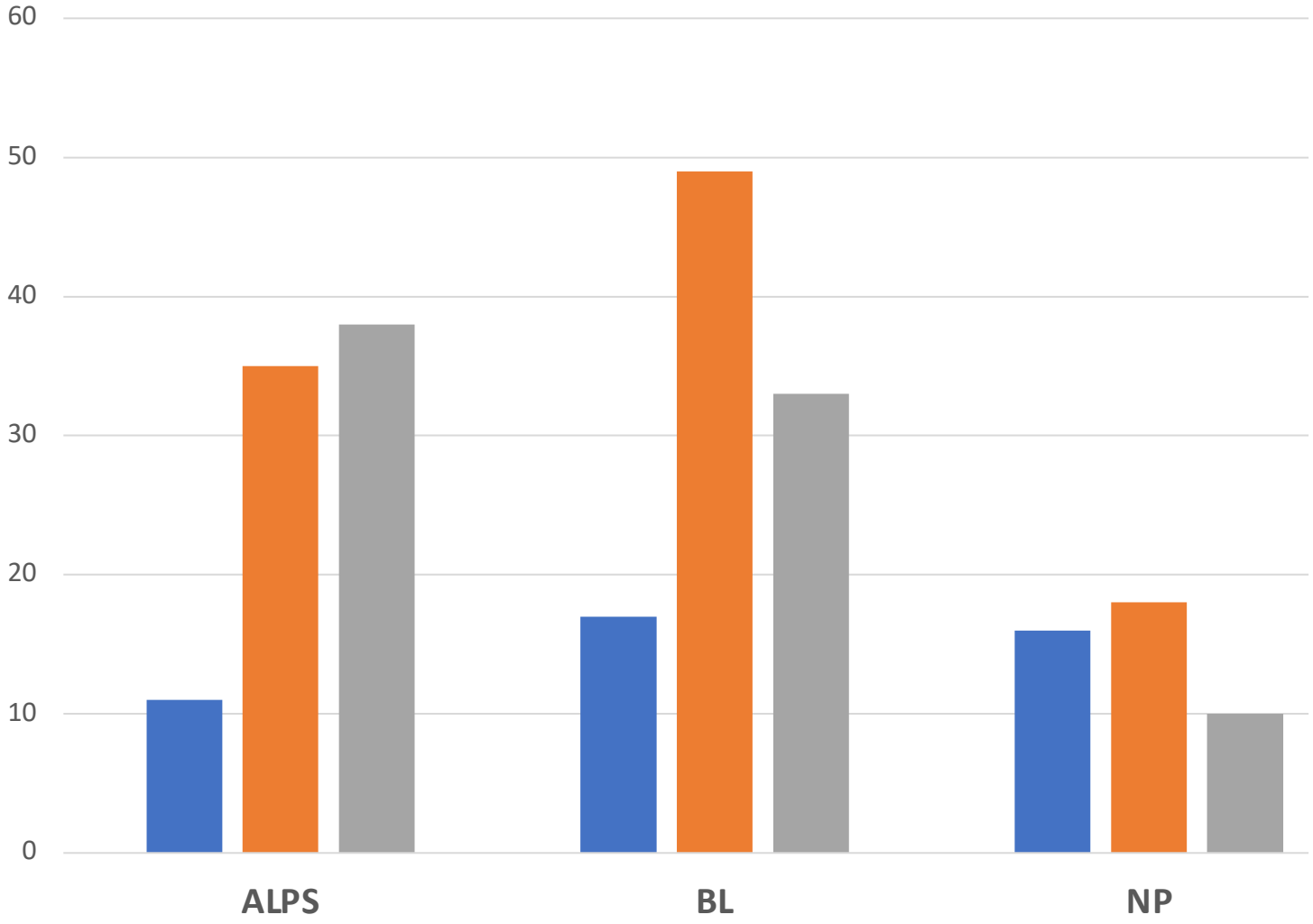


The Extreme Light Infrastructure is an international user facility dedicated to multi-disciplinary science and research applications of ultra-intense and ultra-short laser pulses. ELI provides access to world-class high-power, high-repetition-rate laser systems and a wide range of complementary equipment for cutting- edge research in physical, chemical, materials, and medical sciences, as well as breakthrough technological innovations.

Browse the available equipment and find more information below.

The First Three ELI User Calls Have 227 Proposals from 28 Countries

ELI User Call Proposals by Facility



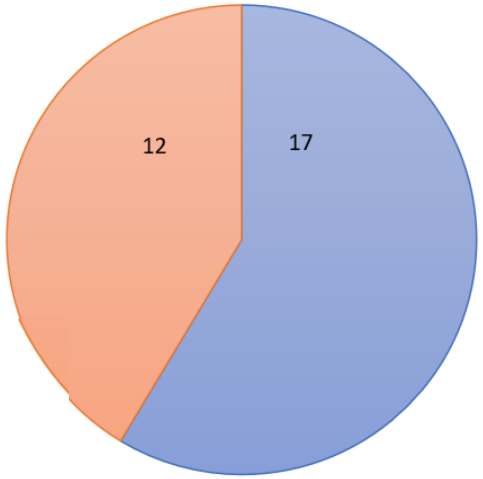
	Call 1	Call 2	Call 3
Instru-ments	*10*	*32*	*30*
ALPS	*11*	*35*	*38*
BL	*17*	*49*	*33*
NP	*16*	*18*	*10*
Total	**44**	**102**	**81**

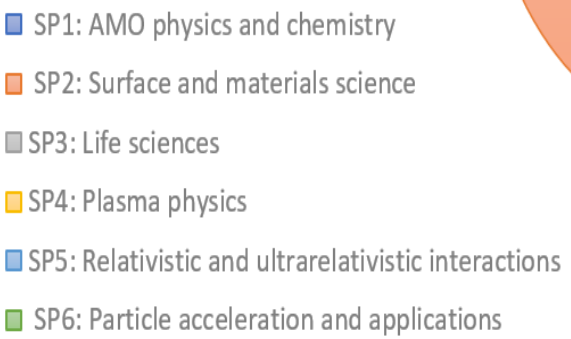
227 Proposals, > 500 scientists

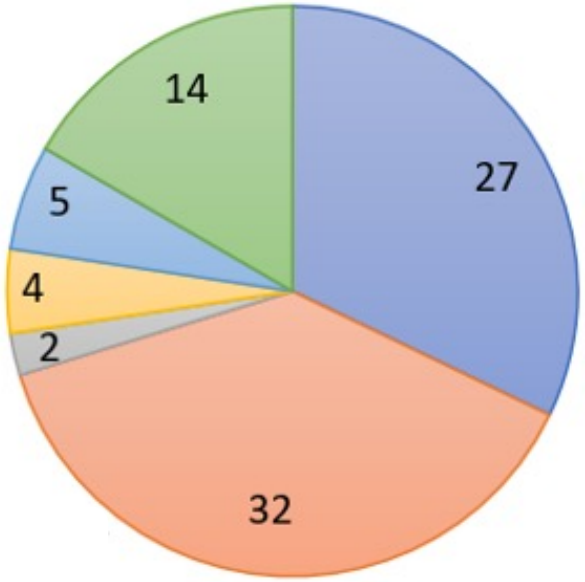
ELI User Calls - Evolution of Science Areas

For ELI ERIC - strong increase in ***Life Sciences*** and ***Particle Acceleration Applications*** from the 2nd to 3rd Call, as new accelerator facilities come online

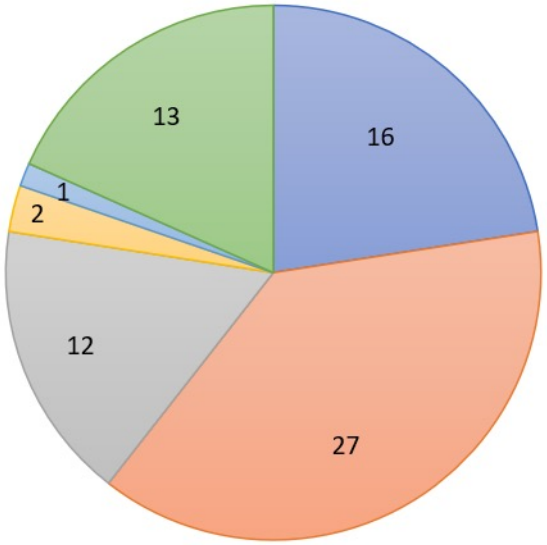
Call 1 - Summer 2022







Call 2 - Spring 2023



Call 3 - Autumn 2023

Some reduction in ***AMO and Chemistry*** and ***Surface and Materials Science*** due to lower availability of L1 instruments for this call

ELISS2023

ELI Summer School | 29 Aug – 1 Sep 2023

Dolní Břežany, Czech Republic

8th edition of the Joint ELI Summer School 2023

- 120 participants from 24 countries
- 4 day programme
- 32 speakers
- 38 Poster submissions

IMPULSE

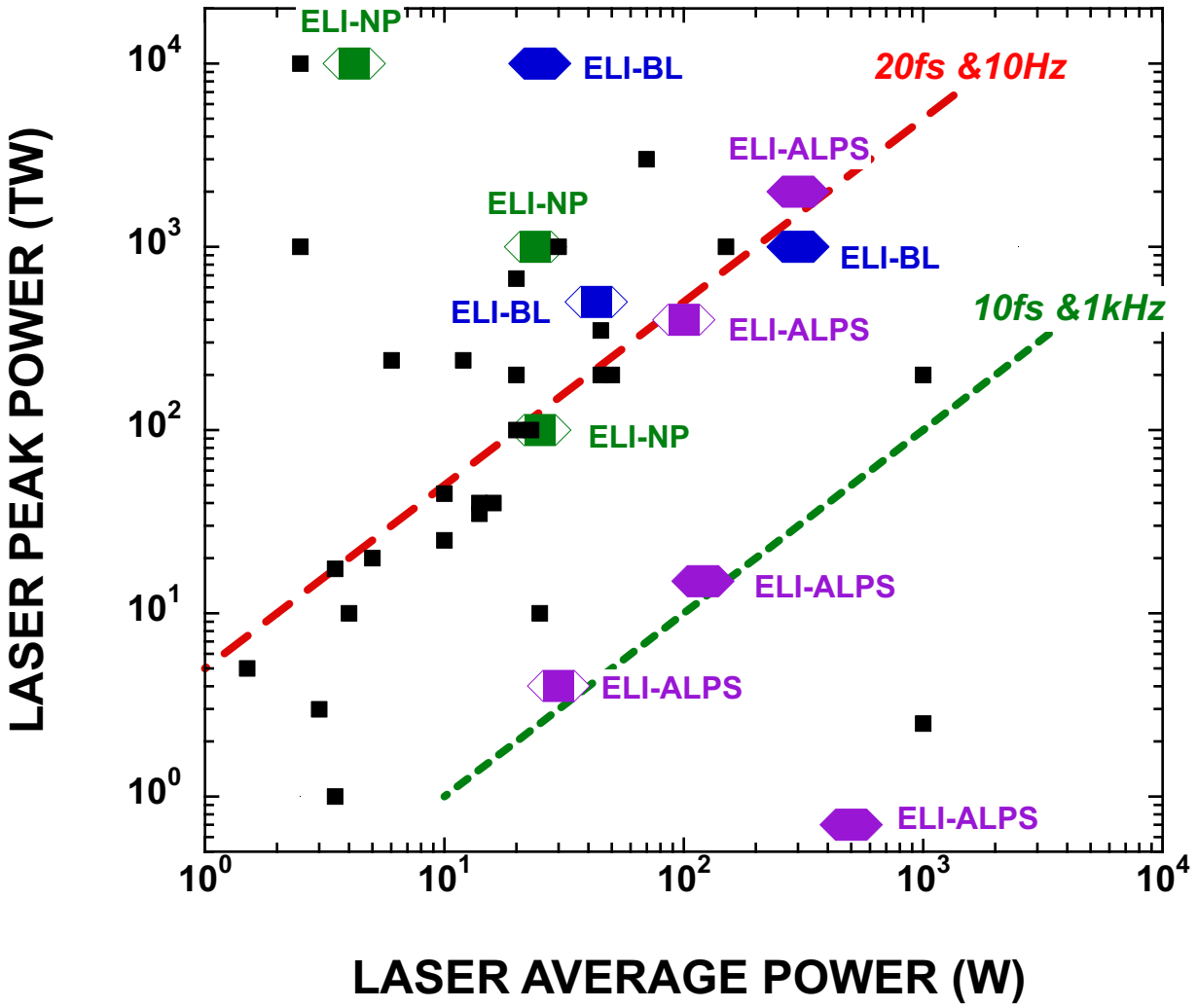
ELI ERIC Leads Innovation and Technology

Training a new generation of scientists and experts

- **ELI welcomes doctoral and master level students from diverse fields**
- **There are over 30 students currently working at ELI and doing their research**

*ELI is very open to **industrial collaboration** to complement scientific collaboration, as well as looking **to increase the base of our qualified suppliers** from around the world.*

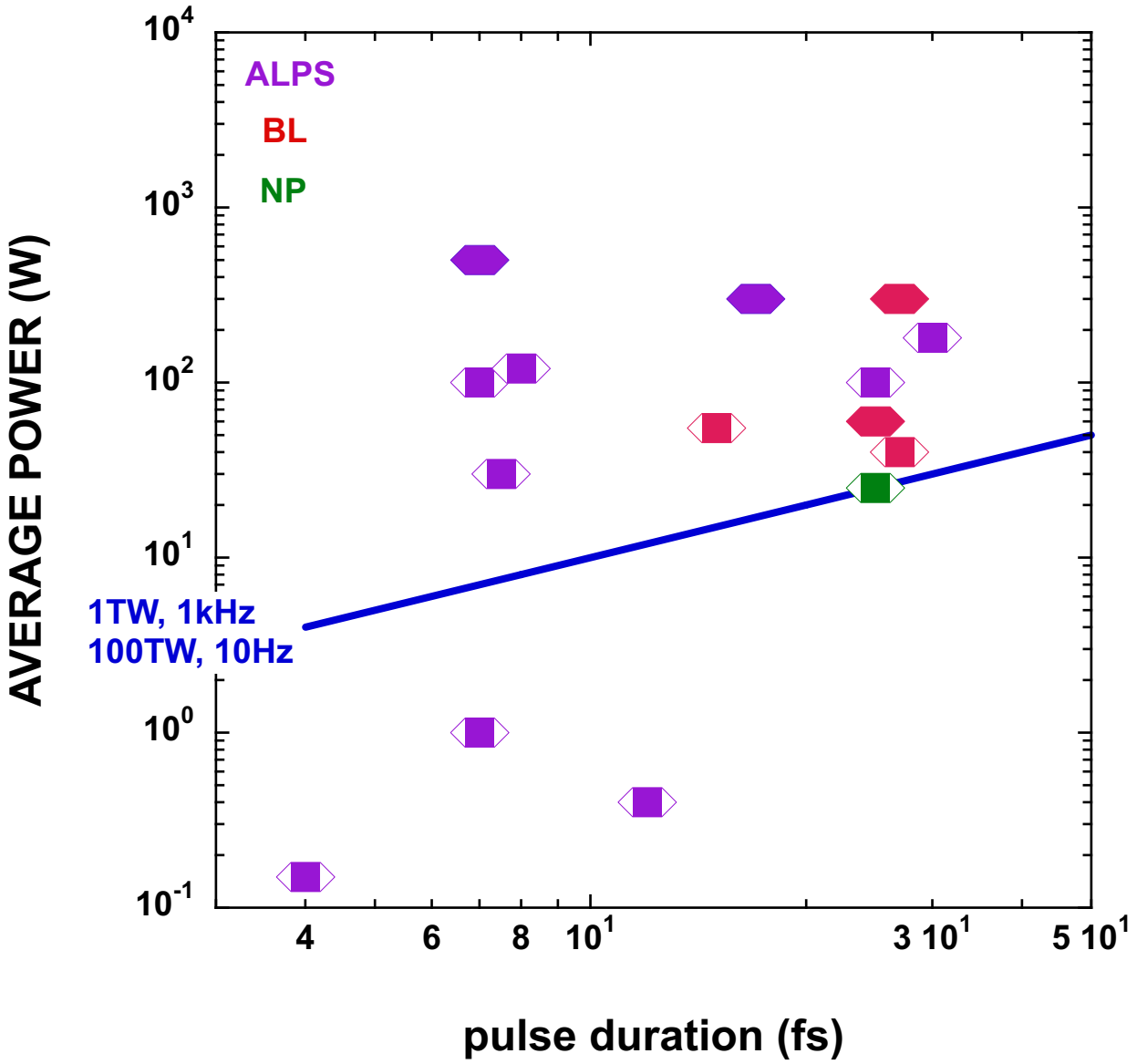
Technical standing



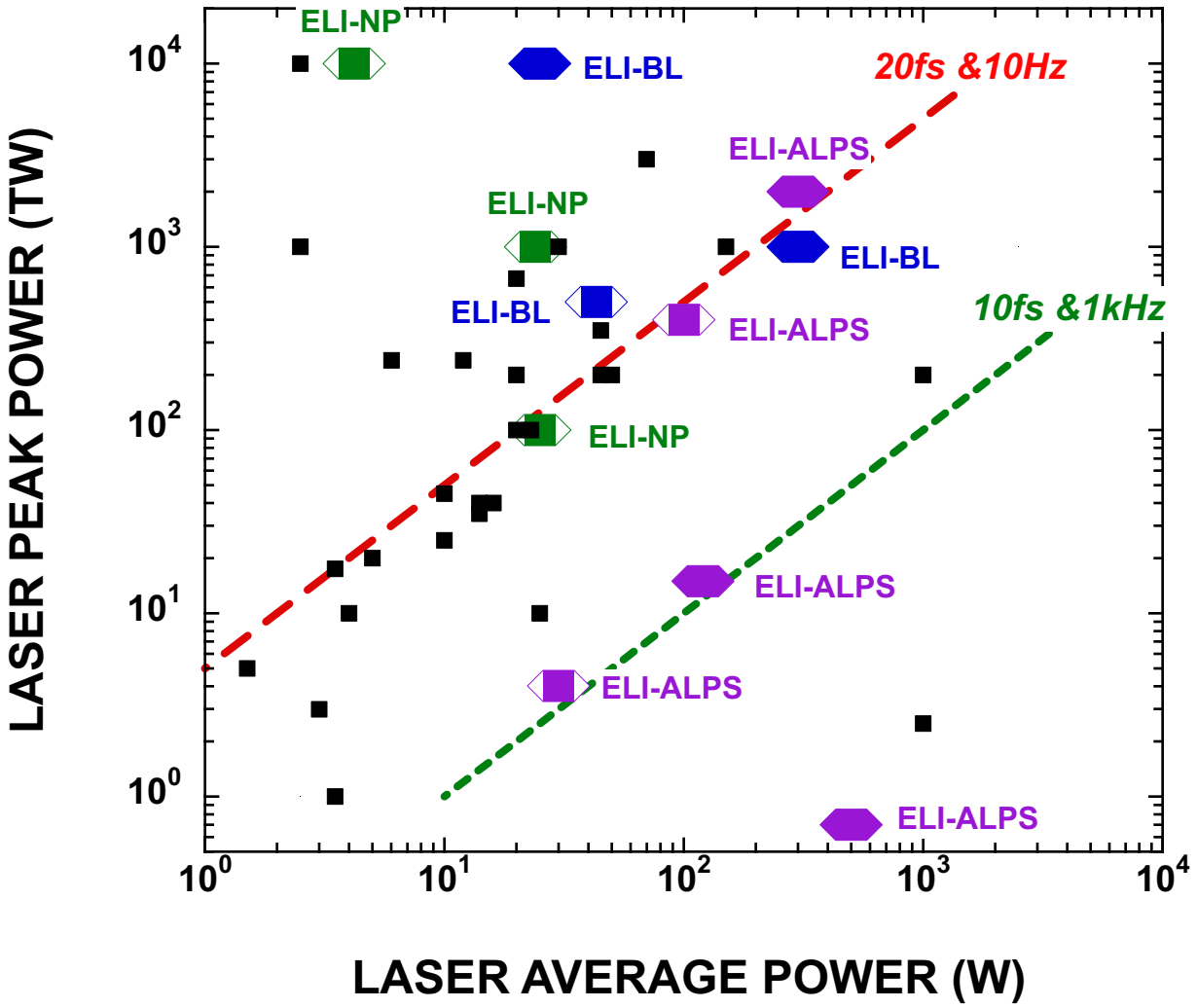
For ELI:
- Full: goal
- Half full: already achieved

Other laser facilities denoted by black squares

Technical standing



The bigger picture



- **ELI's success will ultimately be judged by the impact of the science it enables its user community to deliver**
- Laser performance provides USPs, but has to be complemented by experimental facilities adapted to the needs of experimentalists - chambers and diagnostics, secondary sources, data handling and computation, theory and simulation in partnership with users
- ELI cannot be excellent at everything – need to find areas of strategic focus, with targeted development and calls across 3 Facilities
- And to continue to develop technically to maintain technical edge

ELI Laser-Induced Fusion Kick-off Meeting

28-29th November 2023
Dolní Břežany,
Czech Republic