ELI Beamlines cooperation with Poland and user offer

ELI ERIC Polish Information Day

Daniele Margarone
Director of Research and Operations
ELI Beamline Facility, The Extreme Light Infrastructure ERIC

Outline

- Introduction: ELI Beamlines Facility
- Scientific Cooperation with Poland
- ELI BL Operations and User Science Opportunities

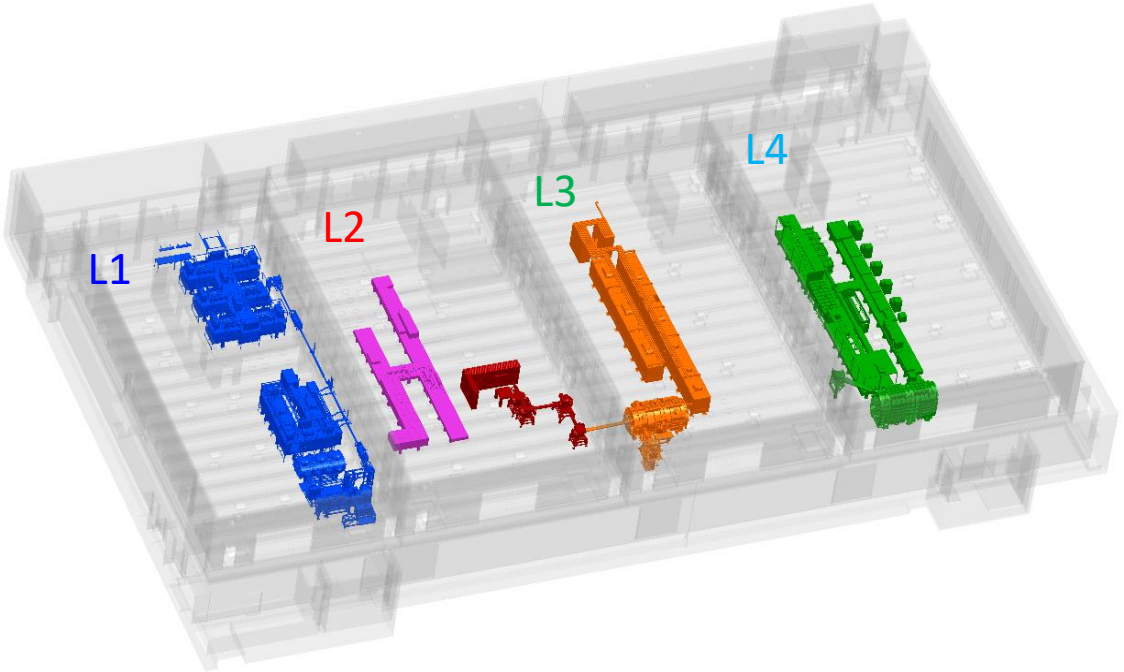
ELI Beamlines (mission profile)

Dolní Břežany, Czech Republic

- ✓ Provide unique tools to support scientific excellence worldwide
- ✓ Explore interaction of light with matter (plasma) at ultrahigh intensities (up to 10^{23} W/cm^2)
- ✓ Develop and operate four cutting edge, high-power femtosecond laser systems (L1, L2, L3, L4) with high energy, high repetition-rate capability (100mJ @1kHz, 2J @50Hz, 30J @10Hz, 1.5kJ @0.01Hz)
- ✓ Offer secondary sources (X-rays and accelerated particles) with unique capabilities to users
- ✓ Enable pioneering research not only in plasma physics, laboratory astrophysics, and material science, but also in biology, medicine, chemistry and other disciplines with strong multidisciplinary application potential

ELI Beamlines Experimental Areas

"as built" lasers and experimental halls



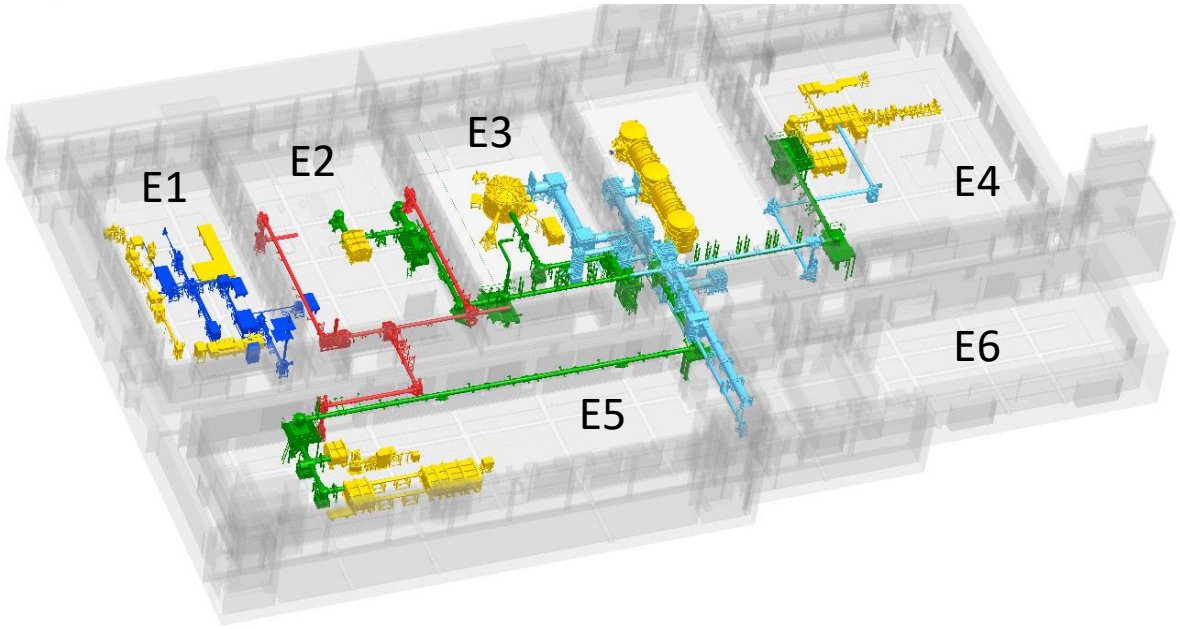
L1: 4TW, 15fs, 1kHz

L2: 100TW, 20fs, 50Hz

L3: 1PW, 30fs, 10Hz

L4: 10PW, 150fs, 0.01 Hz

L4n: 1.5kJ, 3ns, 0.01 Hz



E1: AMO, Material and Life sciences with kHz sources

E2: relativistic X-ray sources

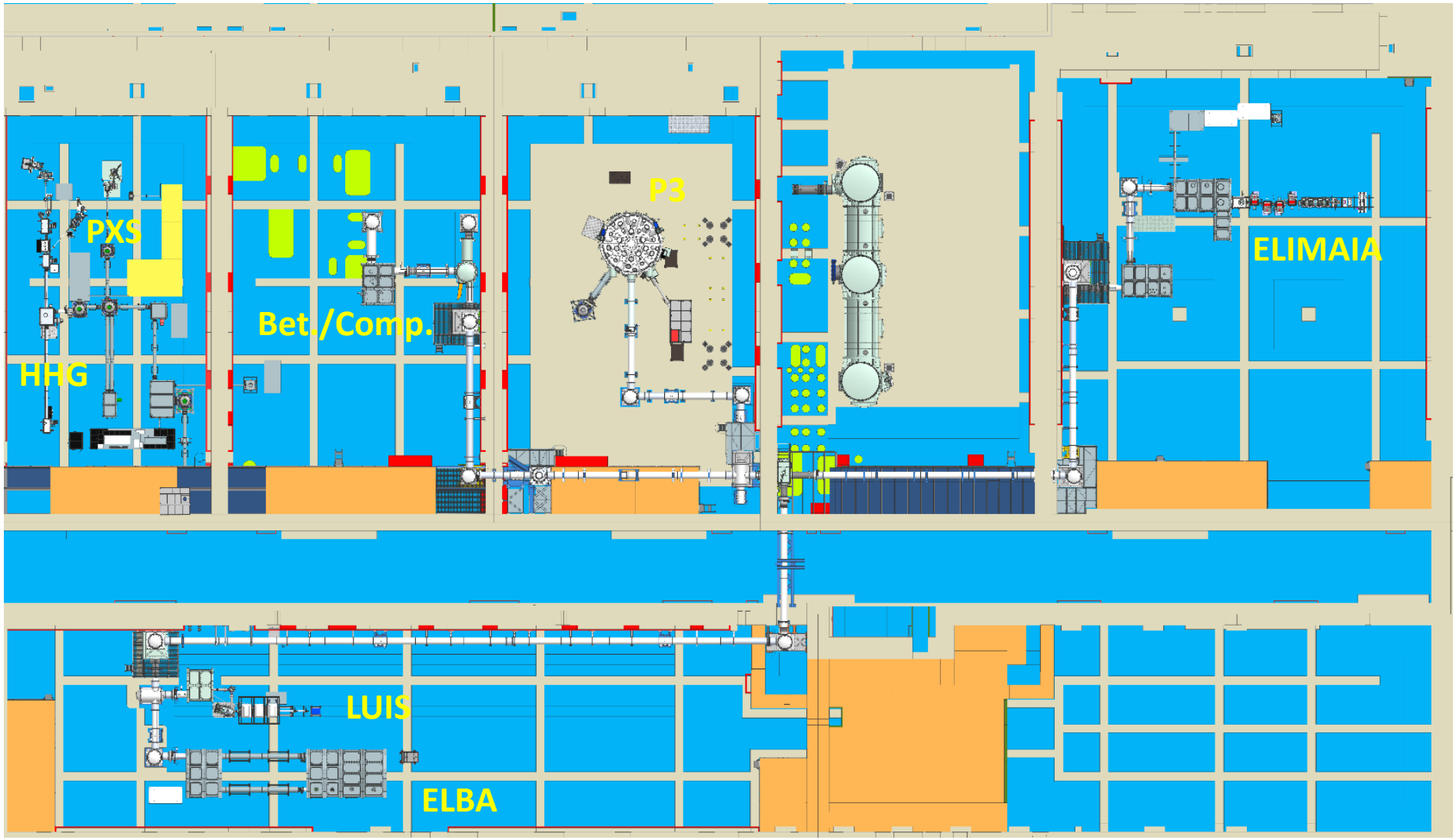
E3: Plasma Physics platform

E4: Ion Acceleration and Applications

E5: Electron Acceleration and Undulator Radiation

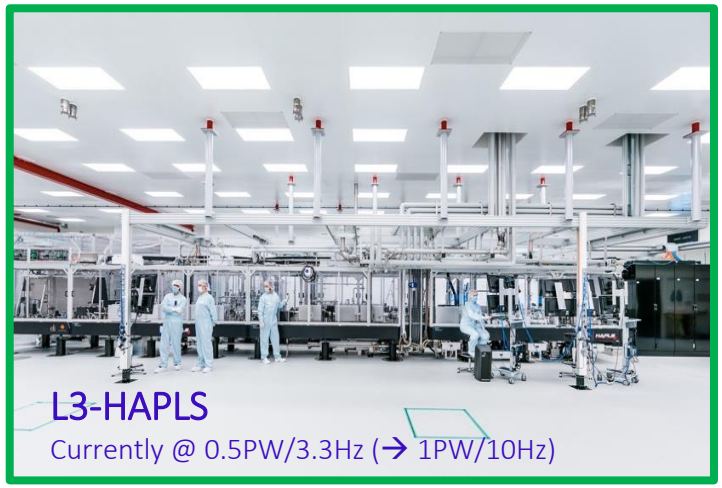
ELI Beamlines “Instruments”

secondary sources, end stations, experimental stations



Instruments currently in operation

L1-ALEGRA
Currently @ >3TW/1kHz (→ > 5TW/1kHz)

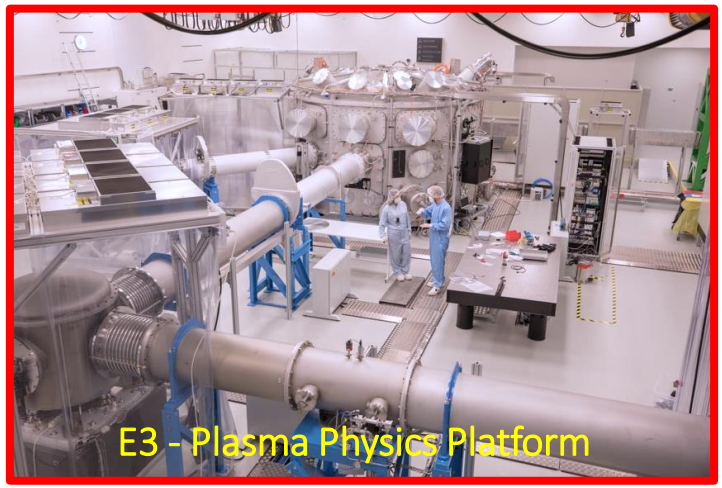


L3-HAPLS
Currently @ 0.5PW/3.3Hz (→ 1PW/10Hz)

L4-ATON
Currently @ 1.2kJ/0.55-10ns/0.01Hz (→ 10PW/0.01Hz)

E1: HHG&PXS + MAC/TREX/ELIps/SRS

E4 - ELIMAIA - ELIMED



E3 - Plasma Physics Platform

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PL Users: PALS Laser Facility in CZ

IPPLM-IoP(PALS) cooperation in laser-plasma physics since 2000

Laserlab Europe

PALS has paved the way for its spin-off baby: ELI Beamlines

Joint experiments at other facilities

IPPLM-ELI cooperation since 2015

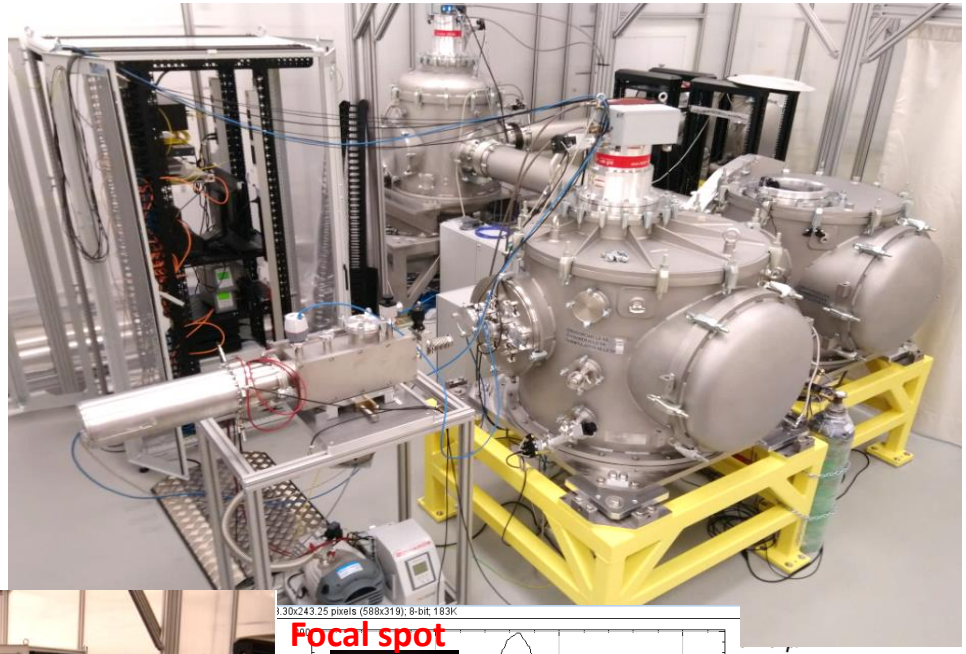
D. Margarone
ELI BL

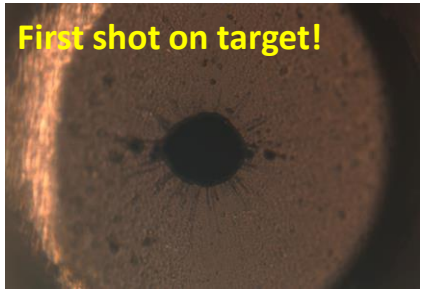
M. Rosinski
IPPLM

First shots at relativistic intensities

L3 HAPLS commissioning @ELI BL (ELI-IPPLM)

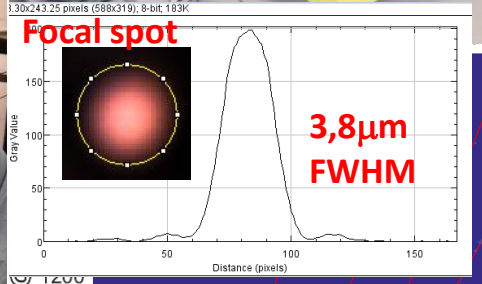
TERESA-L3
ELI Beamlines
Febr 2019

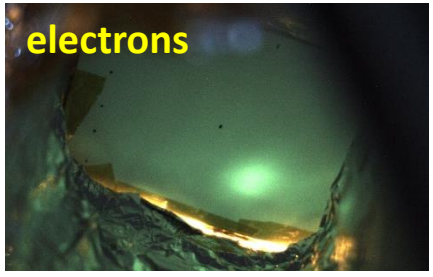




First ions and first electrons accelerated by the L3-HAPLS laser at ELI Beamlines

Plasma-based secondary sources have been generated at ELI Beamlines by the L3-HAPLS laser system for the first time. Two short experimental campaigns on ion and electron acceleration, respectively, have been carried out at the TERESA (TEstbed for high-REpetition-rate Sources of laser-Accelerated particles) target area.





Summary of IPPLM-IoP-ELI cooperation

laser plasma physics and applications (2000+)

- Joint **publications** (since 2000): **>70** based on **user access** @PALS (PI: J. Badziak, J. Wołowski, T. Pisarczyk, M. Rosinski, et al.)
- Number of IPPLM **user experiments** (since 2000): **>30 @PALS** (Laserlab access) and **1 @ELI-BL** (scientific collaboration, MoU)
- Number of ELI BL **R&D experiments @IPPLM -** High Power Laser Laboratory (since 2018): 2 exp. on electron acceleration (T. Levato et al.), 1 exp. on ion acceleration (A. Velyhan, D. Margarone), and 1 exp. on applications, i.e. PIXE (V. Kantarelou, S. Stancek, F. Schillaci)
- **Research topics** of mutual interest: laser-plasma particle acceleration, plasma diagnostics, applications, EMP, magnetic fields, ICF, and pB fusion)

Training of Polish Students @ELI BL

summer internship programme (not exhaustive list)

- ✓ 2019 (2 months): Michal Krakowsky, “Development of control systems for UHV power supplies”, Wroclaw University of Science and Technology
- ✓ 2020 (2 months): Michal Krakowsky, “Internship on the development of hybrid analogue-digital control systems for UHV power supplies and test of spectrometer prototype”, Wroclaw University of Science and Technology
- ✓ 2019 (2 months): Alicja Kwasny, “Development of cryogenic target system”, Wroclaw University of Science and Technology
- ✓ 2019 (2 months): Alicja Kwasny, “Application of machine learning for optimization of laser-matter interaction”, Wroclaw University of Science and Technology
- ✓ ……. **~20** just from Wroclaw University of Science and Technology!
- ✓ ~1-2 PhD students per year (experiments at PALS and ELI) since 2000

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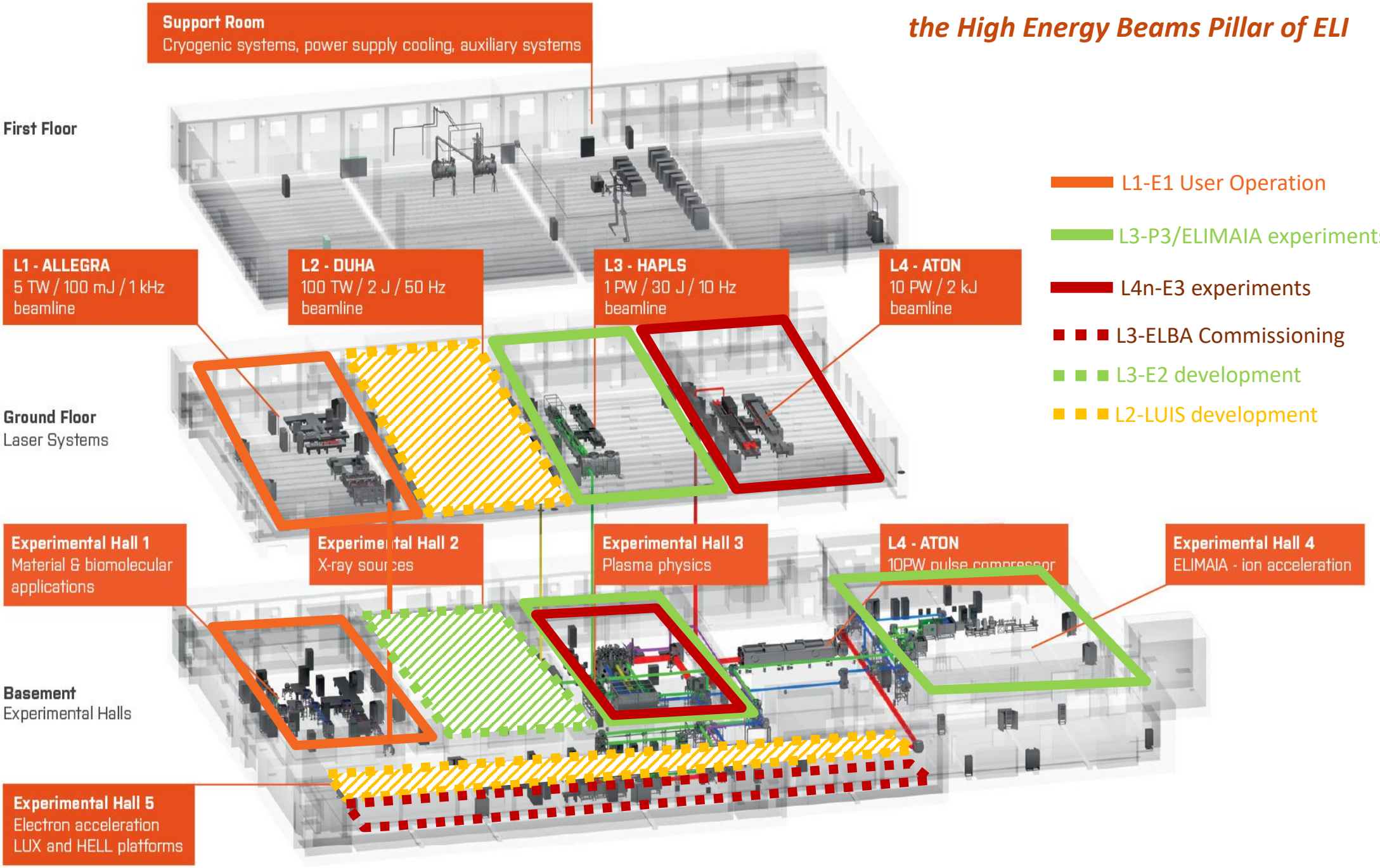
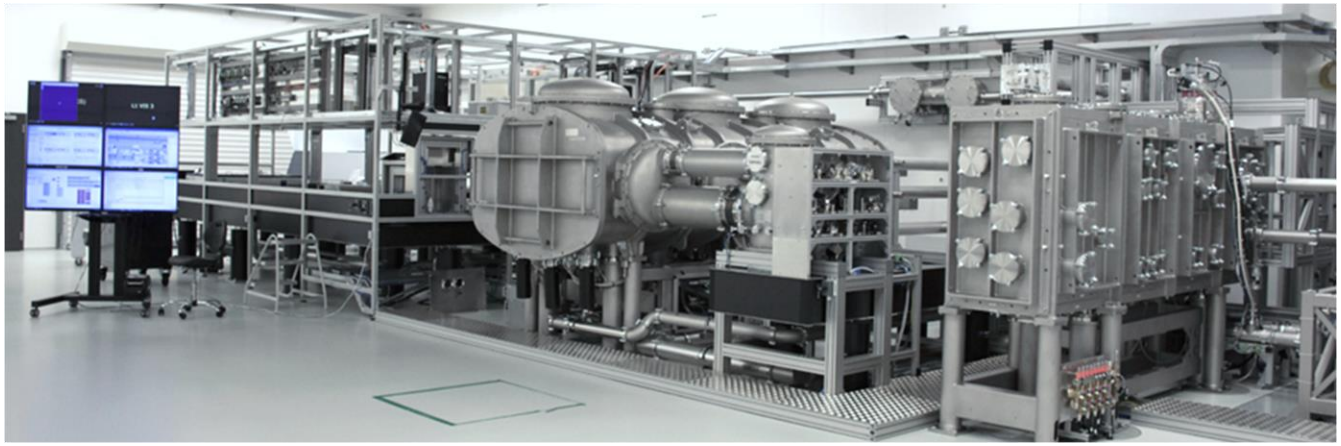
ELI Beamlines Facility

the High Energy Beams Pillar of ELI



L1 ALEGRA laser status

R. Antipenkov, P. Bakule, B. Rus (Dep.91)



- Picosecond OPCPA architecture: inherently high temporal pulse contrast
- System designed and built at ELI-Beamlines (using commercial thin-disk pump lasers)

Achieved 55 mJ / <15 fs pulses @ 1 kHz

Routine operation for users

- ~30 mJ on target in E1

- Availability in experimental halls: E1 hall
- available on average 6.8 hours per day for planned user experiments in E1 hall

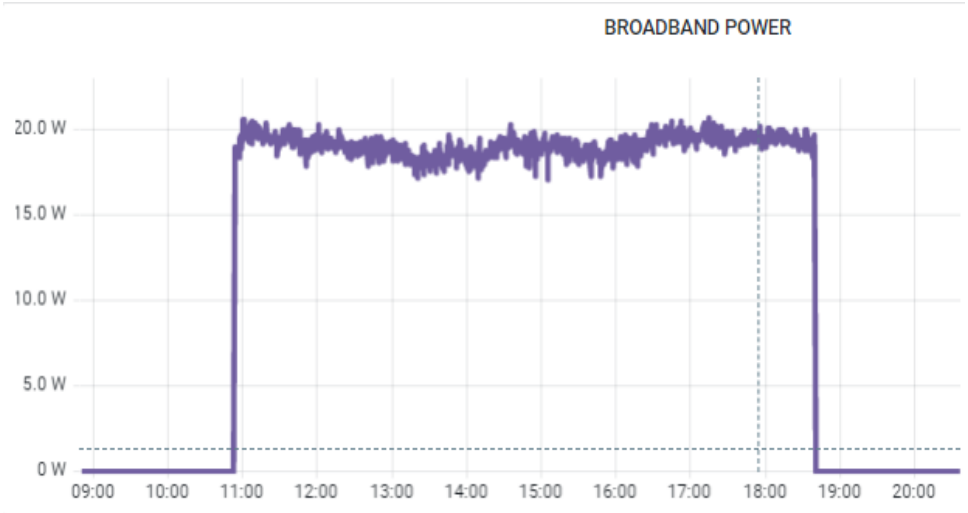
L1 ALLEGRA Major Upgrade completion dates

Jun 2023

- second beam >10mJ, 15 fs, synchronized with L1, any delay with <100fs precision

Dec 2023

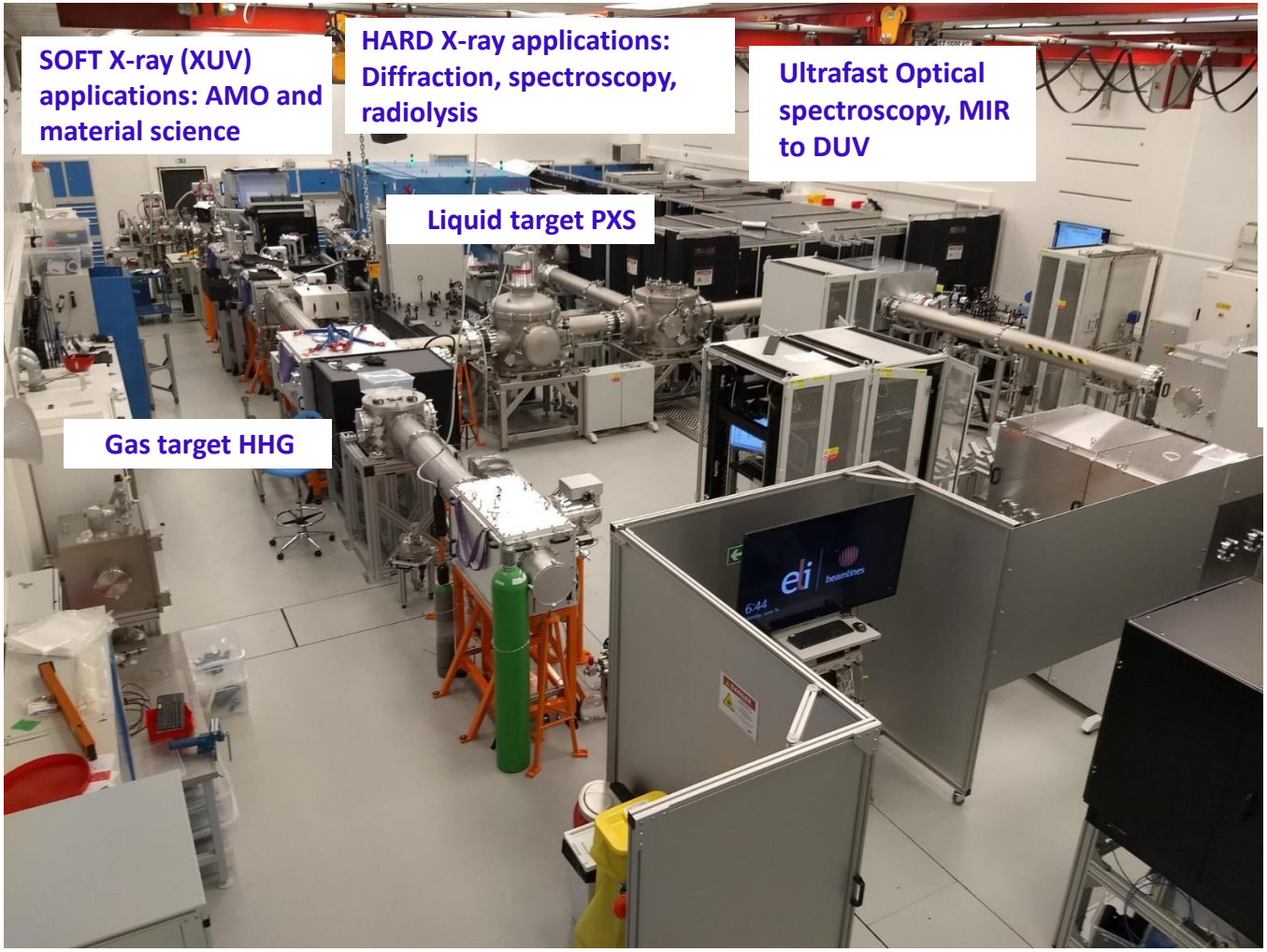
- 100 mJ, 15 fs output from L1 ALLEGRA (requires completion of 0.5 J, 1030 nm amplifier)

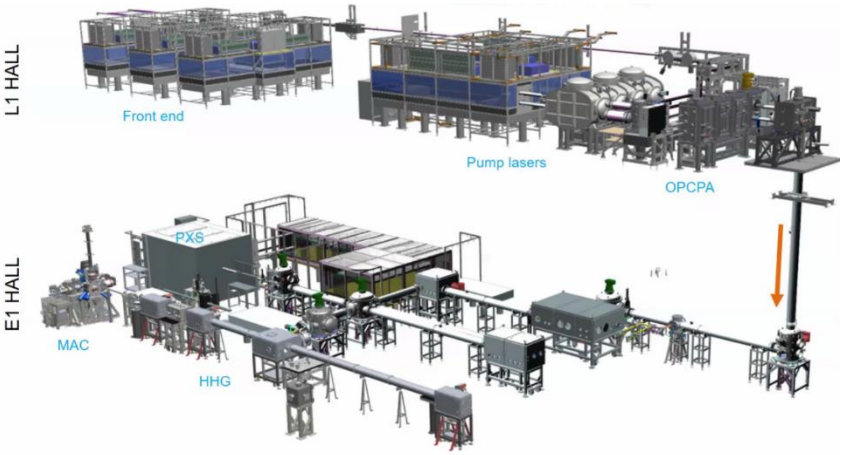


E1 Experimental hall

X-ray beamlines & end-stations

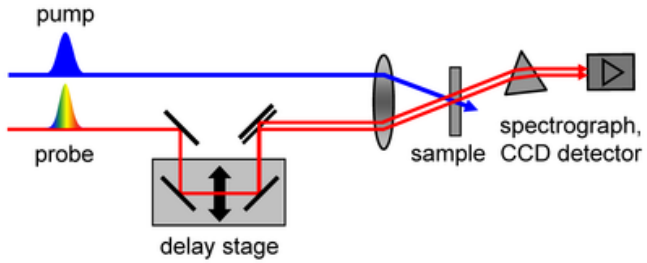
J. Andreasson et al. (Dep88), O. Hort, J. Nejdl (Dep.86)





***Function* is fundamentally related to dynamics!**
Beamlines and end stations for **photon science experiments in the mid IR to Hard X-ray range at kHz**

These are used for **time resolved experiments** using **pump-probe** techniques to study **femtosecond** to millisecond dynamics



L3 HAPLS laser status

High repetition rate Advanced Petawatt Laser System

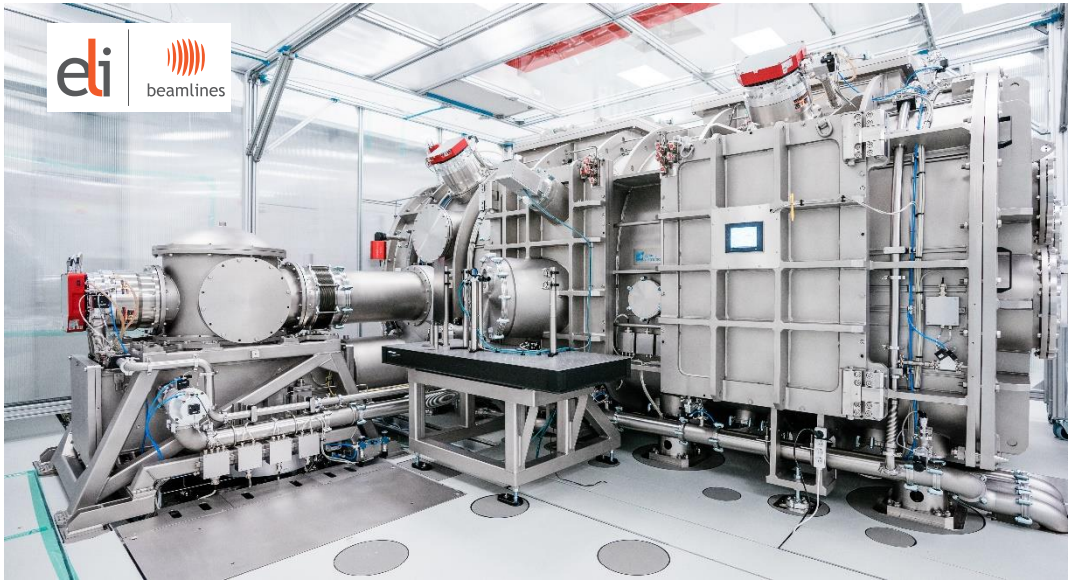
J. Cupal, B. Rus (Dep.91)

- 1 PW 10 Hz repetition rate beamline
- Nd:glass helium-cooled DPSLL pump laser
- Ti:sapphire short-pulse chain, helium-cooled power amplifier
- World's highest peak power laser diode arrays
- High level of automation

Design performance: 1 PW / 10 Hz
30 J / <30 fs

Current performance: 0.5 PW / 0.5 Hz, 3.3 Hz
13.3 J / 27.3 fs

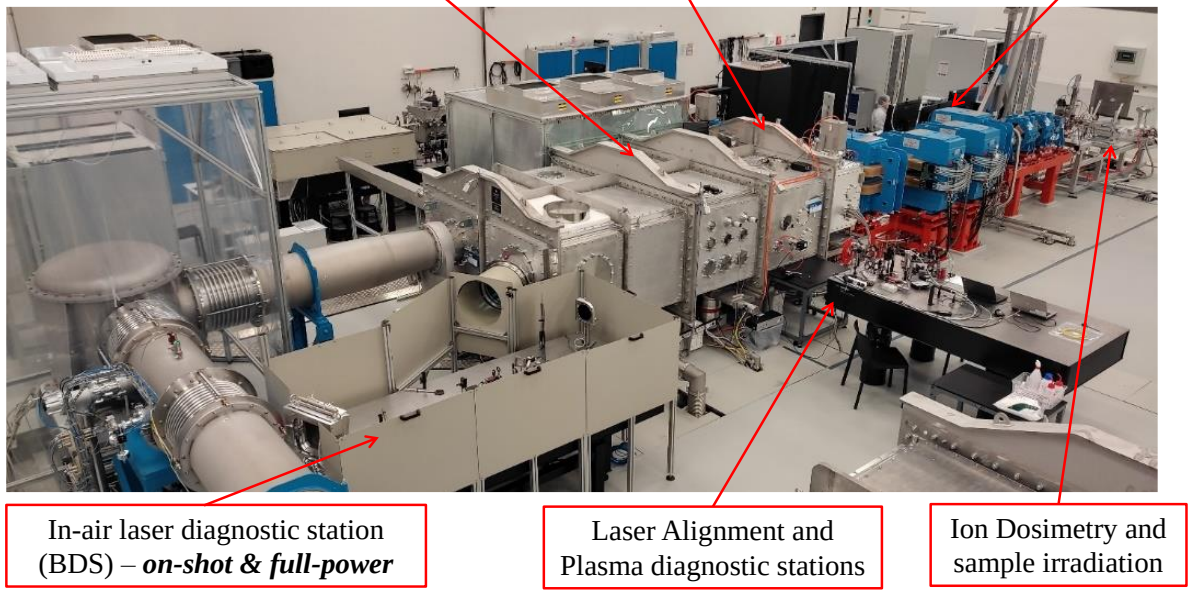
Ramping to PW / 10 Hz in progress:
- 1 PW / 0.5 Hz 2023
- 1 PW / 3⅓ Hz 2024
- 1 PW / 10 Hz 2025



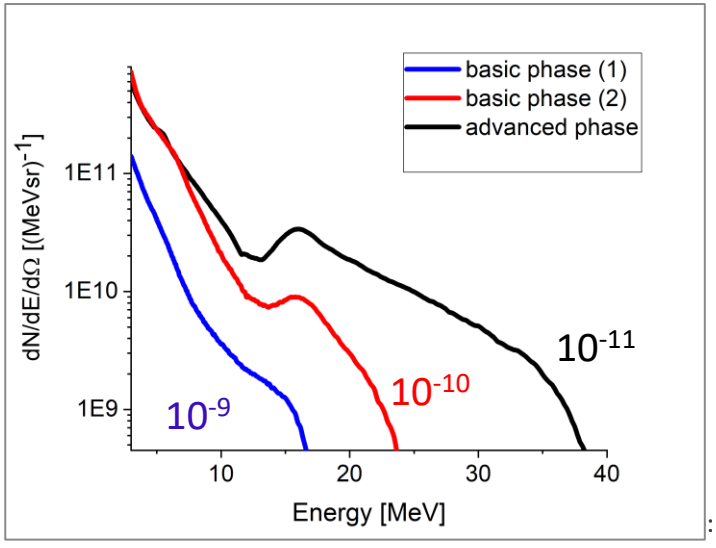
ELIMAIA beamline (E4)

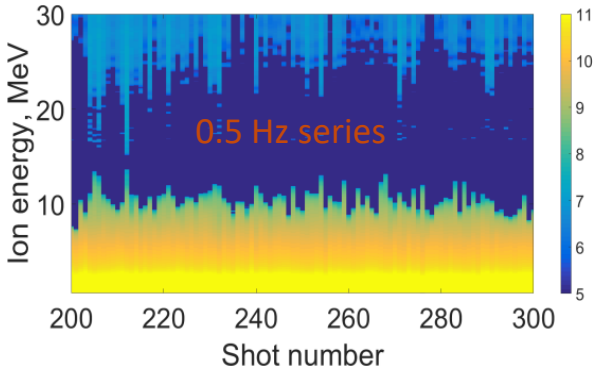
Ion Acceleration and multidisciplinary applications (ELIMED end-station)

F. Schillaci, L. Giuffrida (Dep.87)



Ion Accelerator	Available	Design
Laser intensity	$2 \cdot 10^{21}$ W/cm^2	$5 \cdot 10^{21}$ W/cm^2
Laser energy	>10J	30J
Laser pulse width	<30 fs	<30 fs
Repetition rate	up to 0.5 Hz	10 Hz
Proton energy cutoff	40 MeV	100 MeV
Proton flux (>3 MeV)	~ $1 \cdot 10^{10}$/sr	~ $1 \cdot 10^{11}$/sr





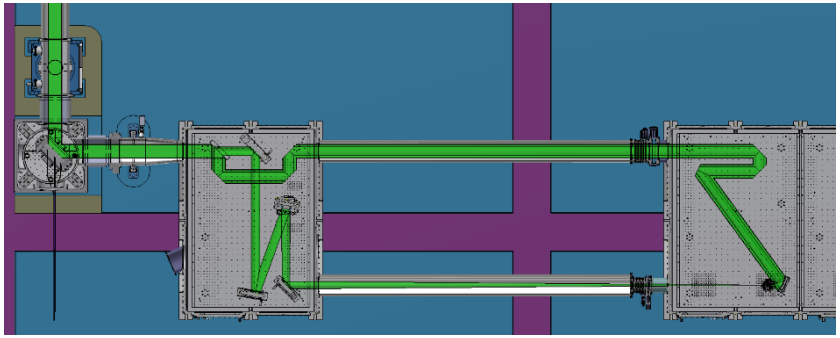
ELIMED Station	Design parameters @ user sample
Proton energy	5-60 MeV
Ions/shot	$1 \cdot 10^{8}$-$1 \cdot 10^{10}$/sr
Bunch duration	1-10 ns (>10^9 Gy/s)
Ion beam aperture	~ 1deg (FWHM)
Ion beam spot size	0.1-10 mm (FWHM)
Repetition rate	Possible active modulation (1Hz)

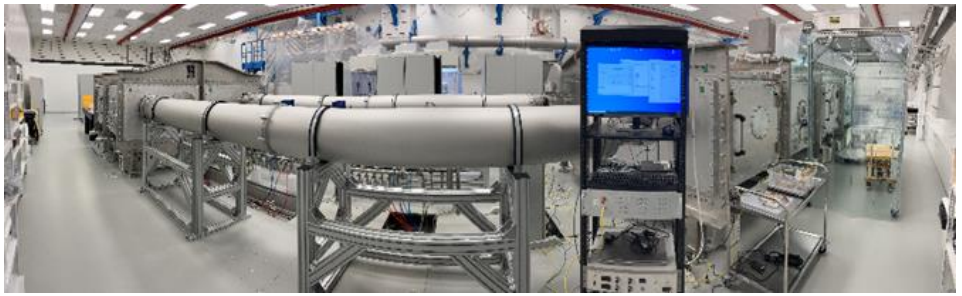
ELI-ELBA beamline (E5)

status and plan

G. Grittani, S.V. Bulanov (Dep.86)

- Electron acceleration line installed
- Counter Propagation line procured, installation in March 2023
- Set-up accommodates different beam splitter configuration (split ratio can be varied based on user requirements)
- User contribution to experimental diagnostics, data analysis, and modeling





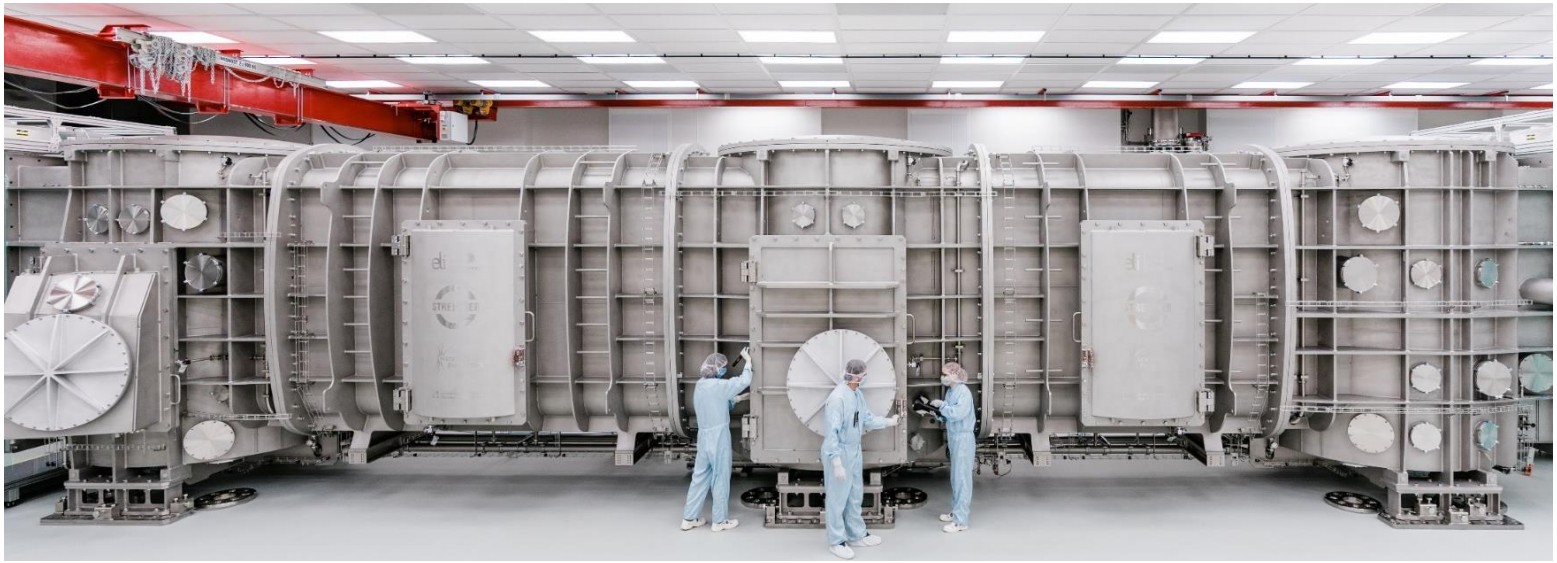
First Light (Spring 2022) — Laser Electron Collider (2023)

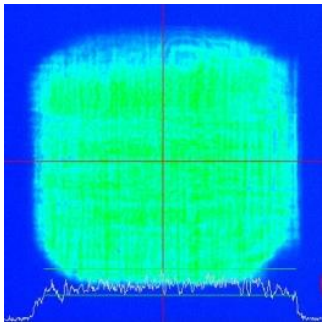
LWFA Accelerator (Winter 2022)

L4 ATON laser

kJ CPA system to provide 10 PW peak power

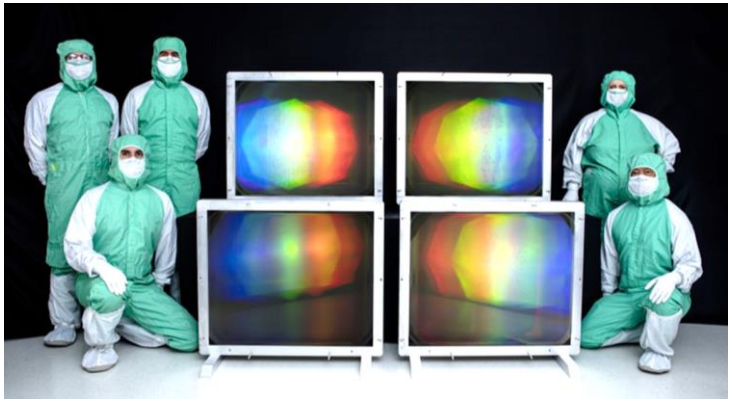
P. Trojek, B. Rus et al. (Dep.91)





PA2 Beam size

- **323x323 mm kJ LP**
- **620x620 mm 10 PW**



Parameter	Achieved value
CPA pulse energy	1512 J significant headroom, higher energy possible
Bandwidth FWHM	~14 nm Gaussian fit non-optimized compressibility 154 fs
Long pulse (LP) energy	1180 J significant headroom, higher energy possible
Pulse width / temporal shaping	<0.5-10 ns 125 ps with 60 ps rise time
Current shot rate	1 per 2 minutes (high beam wavefront quality) 1 per minute (moderate quality)

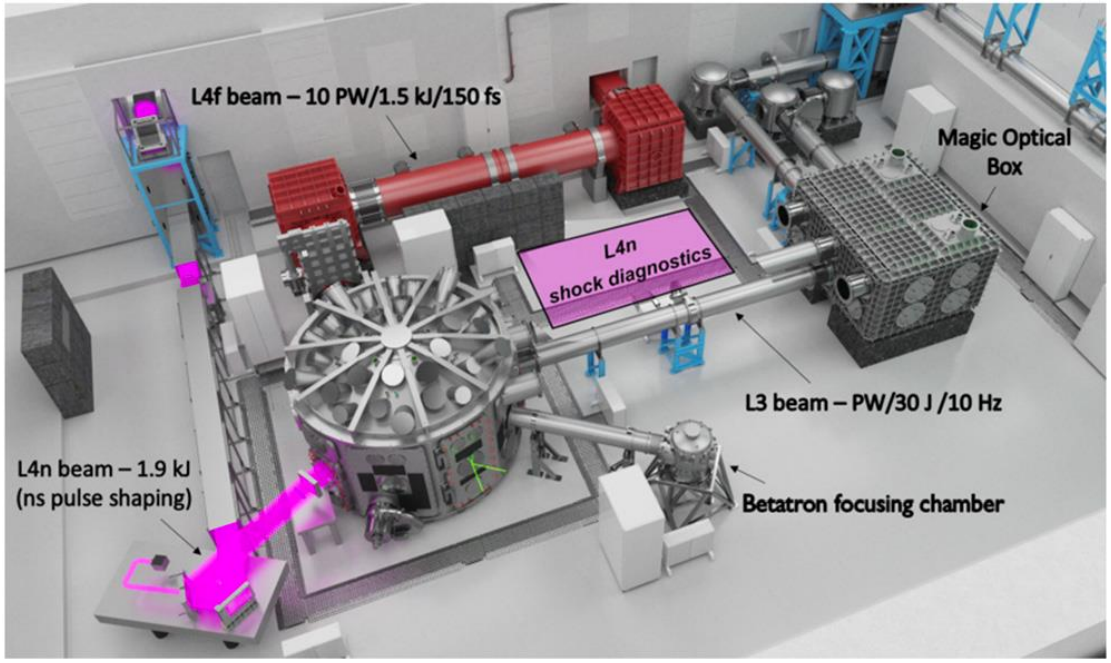
Date:

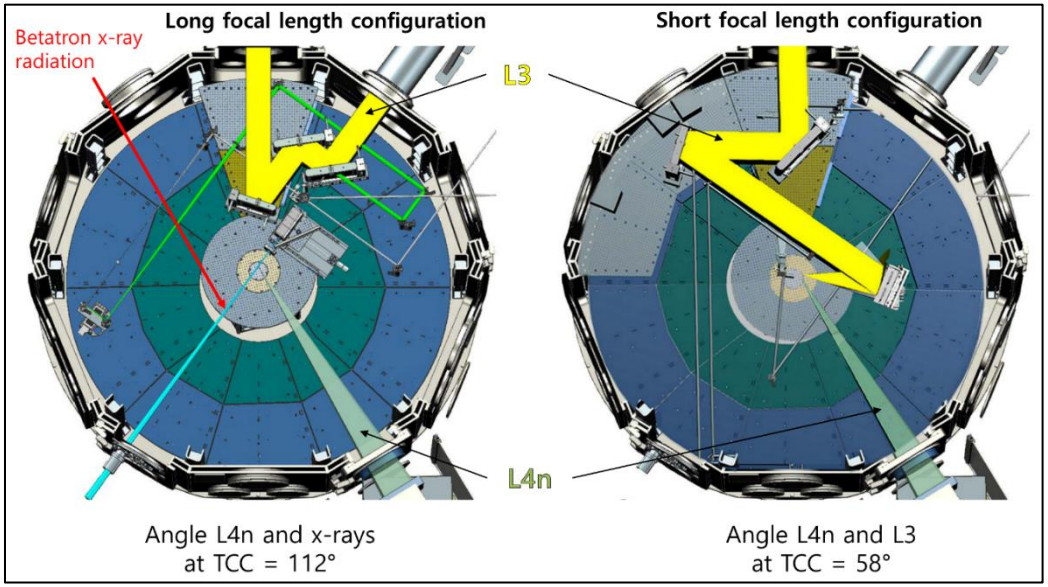
P3 experimental platform (E3)

L4-ns + L3

S. Weber et al. (Dep.89)

- ➔ **L4n as driver** (to generate **ICF** relevant plasma, e.g. shocks or WDM) & **L3 as diagnostic** tool
- ➔ **L3-SFL**: energetic protons (radiography), K-alpha, gammas (few MeVs); f/3 OAP, focal length 0.75 m
- ➔ **L3-LFL**: betatron broadband radiation, potentially electrons (?!); f/20 spherical mirror, focal length ~5 m



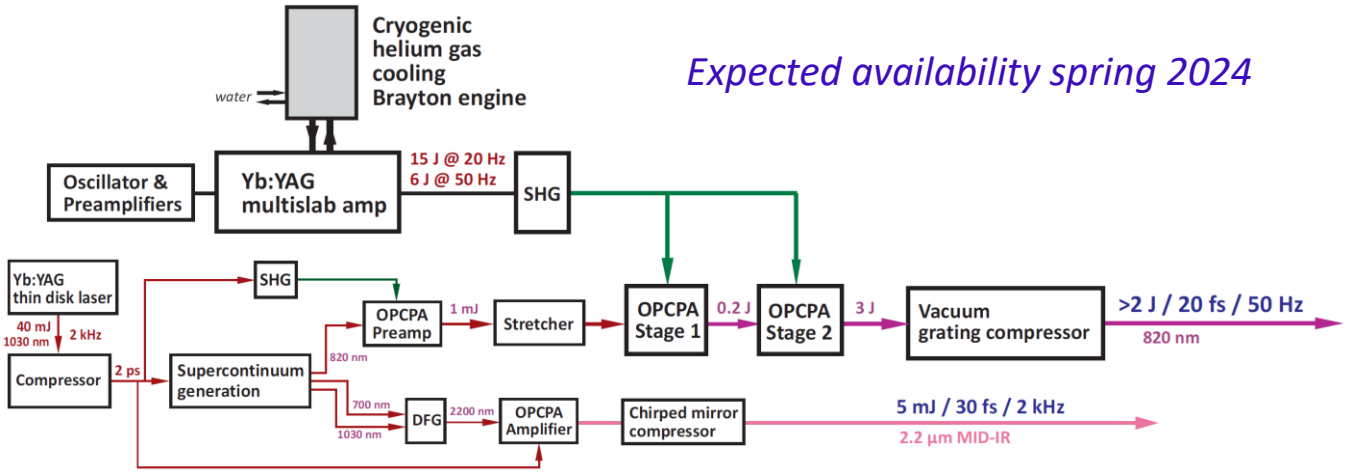


➔ L4n and L3 can be synchronized with a jitter of ~20 ps at present

L2 DUHA (R&D – ADONIS)

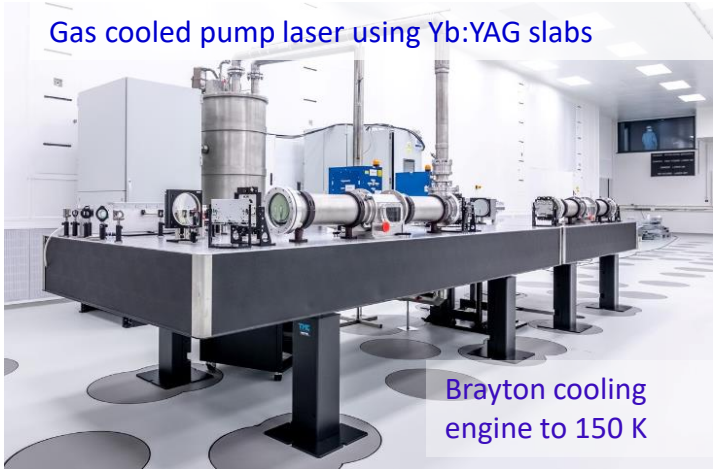
>100 TW, 50 Hz system with mid-IR aux beam

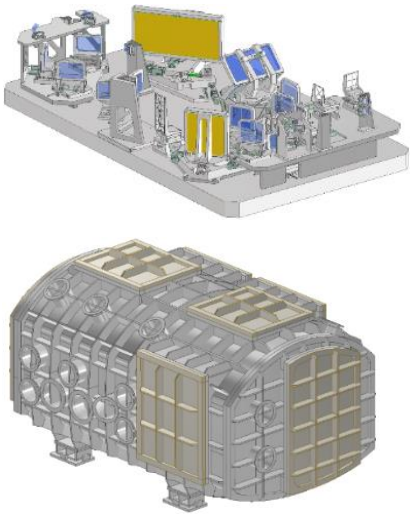
J.T. Green, B. Rus (Dep.91)



Expected availability spring 2024

- 2J / 20fs / 50 Hz (→ 4J / 100Hz)
- Nanosecond OPCPA
- Pump laser: 15 J @ 1030 nm DPSSL Yb:YAG
- Thin disk ps laser driving supercontinuum in bulk YAG: seed for high-energy OPCPA @ 820 nm & generation of 2.2 µm in DFG





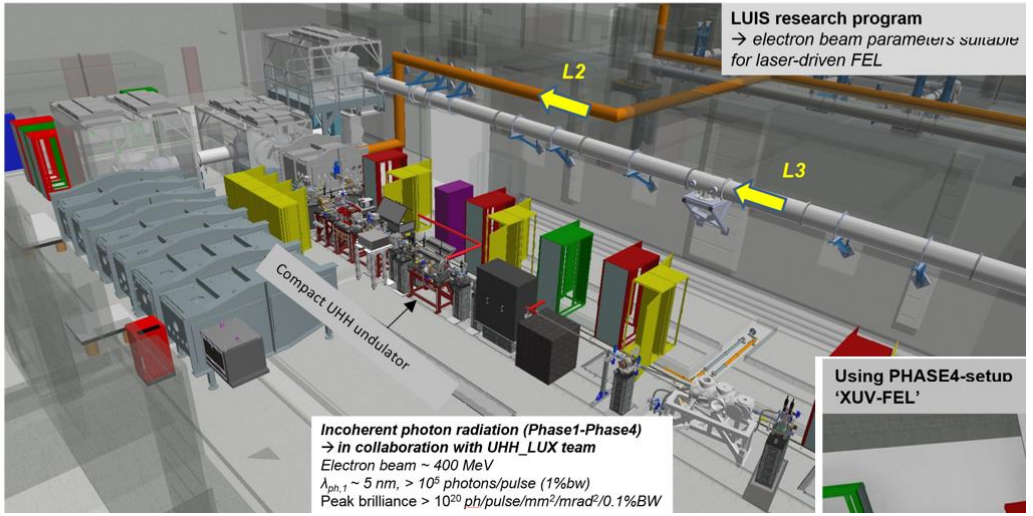
LUIS in E5 (R&D – ADONIS & EUPRAXIA)

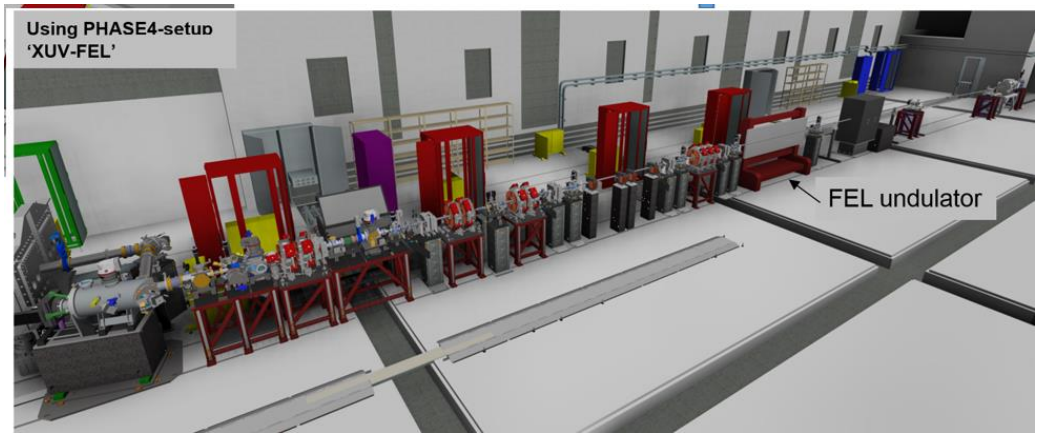
high quality LWFA electron beams for FEL with L2

A. Molodozhentsev, S.V. Bulanov (Dep.86)

LUIS technologies in the E5-experimental hall

from incoherent to coherent (FEL) photon radiation





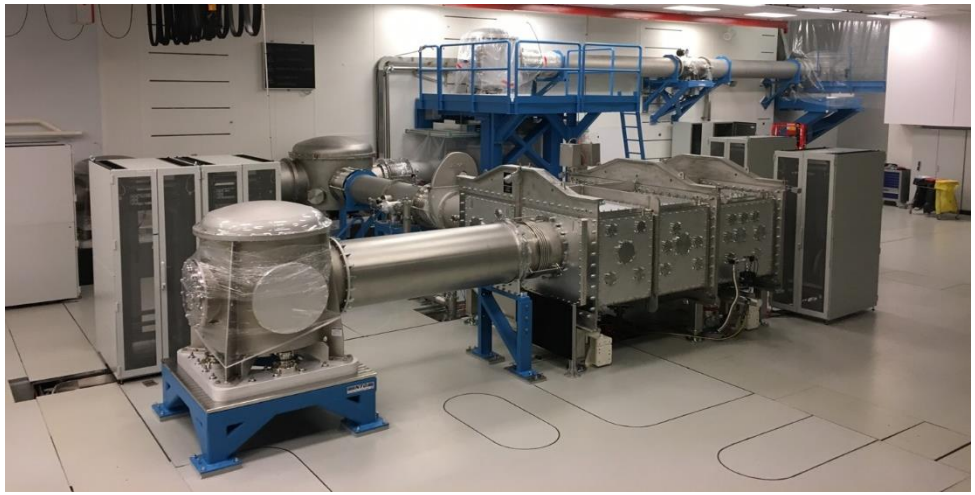
Gammatron beamline in E2 (R&D – ADONIS)

Betatron/Compton X-ray sources in E2/E3

U. Chaulagain, J. Nejdl, S.V. Bulanov (Dep.86)

Driven by L3 (or L2) @ 10Hz (or 50Hz)

	Betatron	Compton
photon energy	10- 100 keV	50 – 5000 keV
photons/shot	> 1E9	> 1E8
Source size	< 5 µm	< 5 µm
pulse duration	~30 fs	< 30 fs

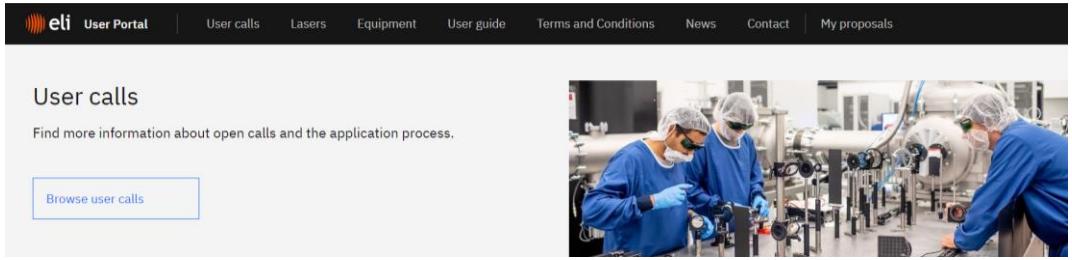


ELI Beamlines User Access

- ✓ **1st ELI ERIC Call** for User proposals, published in June 2022, experiments ongoing (L1-E1 kHz experimental chain)
- ✓ **ELI BL User Assisted Commissioning Calls**, published in October 2022, experiments planned in April-June 2023 (L3 @ELIMAIA-ELIMED, L4-ns @P3)
- ✓ **2nd ELI ERIC Call** for open-access proposals, published in February 2023, L1-E1 kHz chain and high power laser capabilities, i.e. L3 HAPLS (PW-class, 3.3 Hz) and L4 ATON (kJ-class, ns)

ELI Beamlines Call: User-assisted commissioning call for the P3 infrastructure at ELI-Beamlines, November 2022 – February 2023	
Issue Date	04.10.2022
Closing Date	05.11.2022
Status	closed

ELI Beamlines call: user-assisted commissioning of the ELIMAIA Ion Beam Transport section at high repetition-rate	
Issue Date	04.10.2022
Closing Date	05.11.2022
Status	closed



Thank you for your kind attention!

✓ ELI excellent teams
✓ User access (open)
✓ Young scientists
✓ Unique technologies

→ Unlimited User Science Opportunities →