EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS

6th European Advanced Accelerator Concepts Workshop
17–23 Sept 2023
Hotel Hermitage, La Biodola Bay, Isola d'Elba, Italy

EuPRAXIA

EuPRAXIA 2nd SITE

View from CNR

Leonida A. GIZZI,
CNR-INO and INFN, Pisa, Italy

This project has received funding from the European Union´s Horizon Europe research and innovation programme under grant agreement No. 101079773

CONTENTS

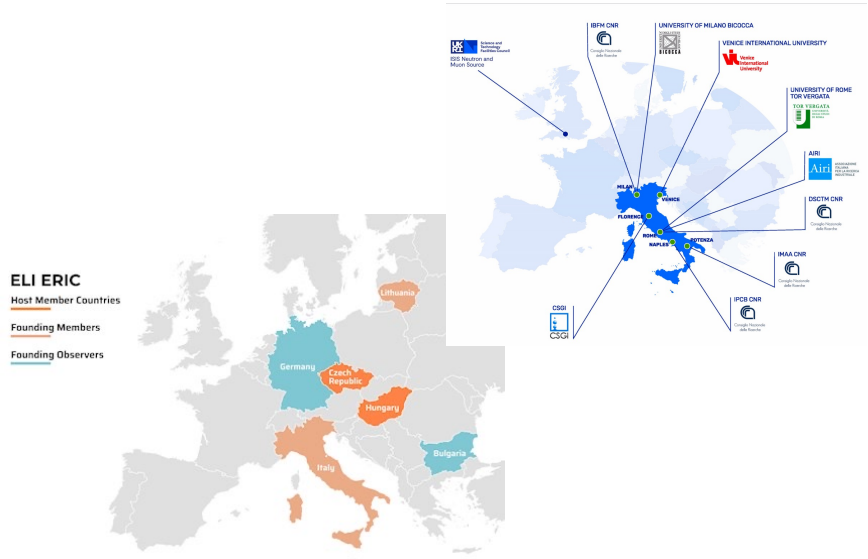
- **Motivation**
- **ID of host Institution (CNR)**
- **2nd site supporting Laboratory (ILIL): profile and topics**
- **Role in EuPRAXIA**
- **Ongoing developments towards 2nd site**
- **2nd site proposal institutional support**
- **Future actions**

MOTIVATION

- Long term engagement in high power laser and laser-plasma interactions;
- Strong multidisciplinary scientific potential;
- Emerging innovation and disruptive approaches;
- Leverage on national support to the field;
- Growing industrial impact of intense lasers.

Consiglio Nazionale delle Ricerche (CNR)

Funded by the European Union



Strong commitments to large scale facilities

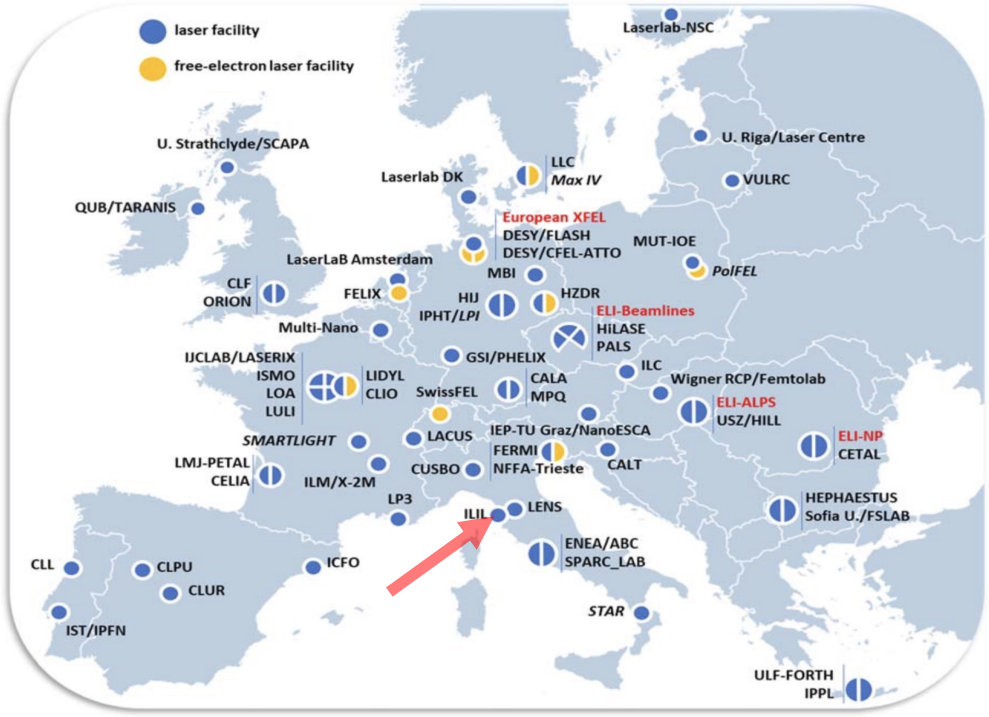
http://www.dsftm.cnr.it/large-scale-facilities/

ELETTRA and FERMI (beamlines),
ESRF (beamlines)
ILL, ISIS, ESS, NFFA, XFEL, ELI

CNR, Area della Ricerca del CNR, Pisa

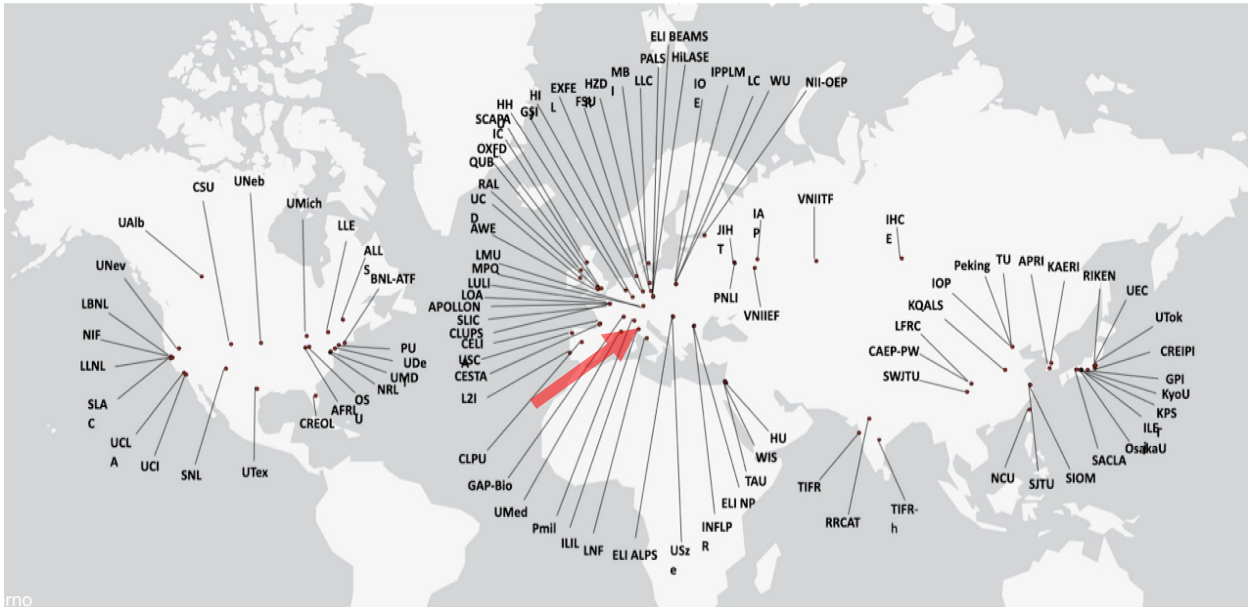
Facilities and infrastructures

Funded by the European Union



*Overview of **laser** and **light** sources infrastructures obtained by a recent LASERLAB-ELI-ERIC joint study.*

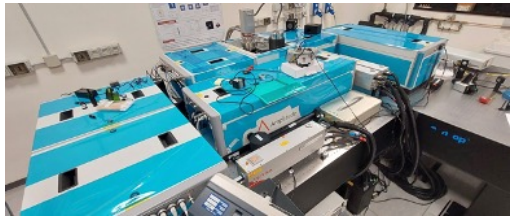
Fast growing research and technology
Emerging new installations



ICUIL World map of lasers with peak power >100 TW, G. Mourou Nobel Lecture: Extreme light physics and application", Rev. Mod. Phys., 91, 030501 (2019).

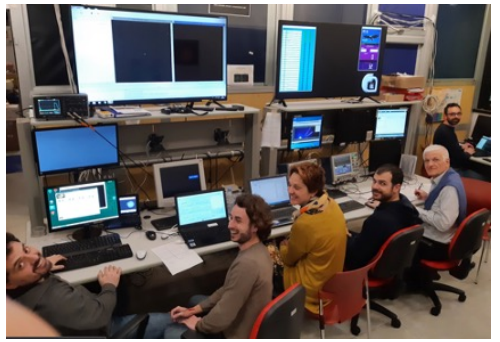
The Intense Laser Irradiation Laboratory (ILIL)

Funded by the European Union



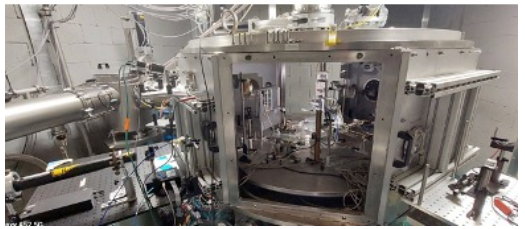
LASER CAPABILITIES:

- 240 TW, Ti:Sa, up to 5 Hz, 27 fs;
- 1kHz, >20 mJ, Ti:Sa + OPA
- 100 Hz, >1J, TiSA (procurement in progress)



NEW HAP LASER DEV. LAB

A member of Laserlab-Europe-AISBL



USER CONTROL ROOM

TESTING AND PROTOTYPING

LASER FRONT END 10 TW, 10 Hz

POWER AMPLIFIER Up to 240 TW

SHIELDED TARGET AREA FOR PARTICLE ACCELERATION

NEW BEAMLINE for PRE-CLINICAL STUDIES

NEW HIGH DOSE UNDERGROUND BUNKER

Laserlab Europe

THE Tuscany Health Ecosystem

iFAST

I-PHOQS INTEGRATED INFRASTRUCTURE INITIATIVE IN PHOTONIC AND QUANTUM SCIENCES

eli

ESFRI

PNRR

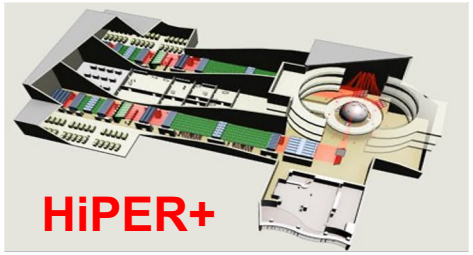
EuPRAXIA Advanced Photon Source

MAIN SCIENTIFIC ENGAGEMENTS @ ILIL

Funded by the European Union

High intensity laser-plasma interaction physics and applications

- **Laser-plasma acceleration**
  - High quality GeV electron beamline design
  - VHEE beamline for medical applications
  - Advanced laser-target interaction for proton beamline and applications
- **Laser-fusion studies**
  - LPI studies for Inertial Fusion (HiPER+)
  - kJ, laser concept development
  - Material studies
- **Laser development**
  - 100 Hz beamline
  - kHz laser technology development for high efficiency operation



HIGH QUALITY GEV SCALE LWFA

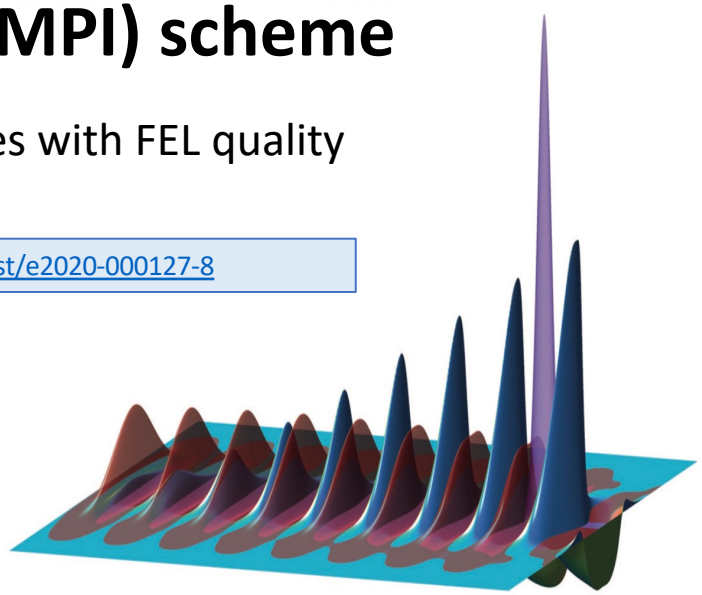
Funded by the European Union

The REsonant Multi-Pulse Ionization Injection (REMPI) scheme

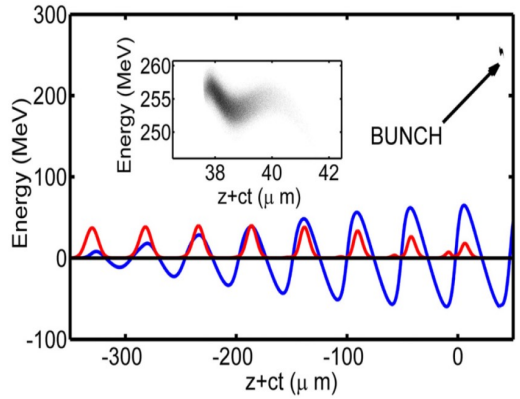
Motivation: Within the EuPRAXIA project we aim at generating 4.5/5GeV bunches with FEL quality

R. Assmann et al., "EuPRAXIA Conceptual Design Report" The European Physical Journal Special Topics **229**, 3675–4284 (2020); https://doi.org/10.1140/epjst/e2020-000127-8

Bunch specifications - GOAL:	dE/E SLICE	ε_n SLICE	Q	I_{peak}
	<0.1%	**<0.1 mm mrad**	>30 pC	>2kA



- This is a very challenging working point for a plasma-based accelerator.
- We developed a laser-driven scheme, the *Resonance Multi-Pulse Ionization Injection scheme (REMPI [1])*
- The REMPI scheme combines the most advanced concepts conceived to date in LWFA to deliver high quality electron beam to drive an X-ray FEL.



[1] Test platform: P. Tomassini et al., "The resonant multi-pulse ionization injection," Physics Of Plasmas 24, 103120, 2017.

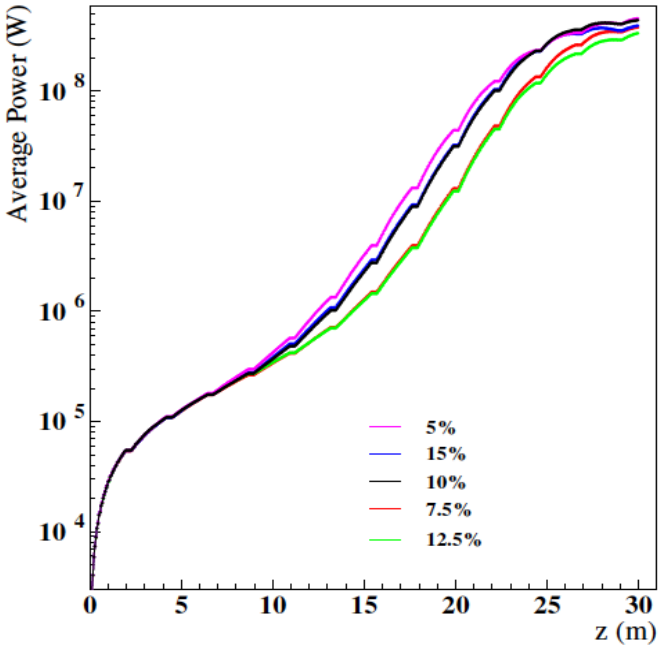
FEL MODELLING of REMPI BEAM

Funded by the European Union

Laser-plasma REMPI SCHEME → TRANSPORT to undulator → FEL emission

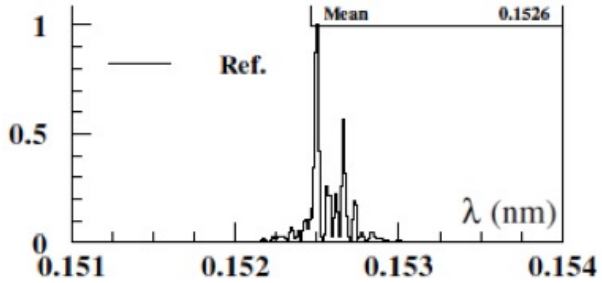
Up to 39 m planar undulator line with period λ_u = 14 mm, with $E_{beam} \approx 4.5$ GeV, the resonant wavelength of 1.5 Å.

The Self-Amplified Stimulated Emission (SASE) vs. pulse energy, gain length and resonant wavelength



e-beam	L_G [m]	$E_p(z_{exit})$ [μJ]	λ_{exit} [nm]
7.5%	1.753	9.28	0.152619
15%	1.781	9.60	0.152533
5%	1.912	11.15	0.152546
12.5%	1.756	8.22	0.152574
10%	1.791	10.78	0.152568
RMS	0.065	1.6	0.000033

Emission stable against plasma density variations (10%)



GENESIS 1.3 simulations by
Federico NGUYEN
(ENEA, Frascati)

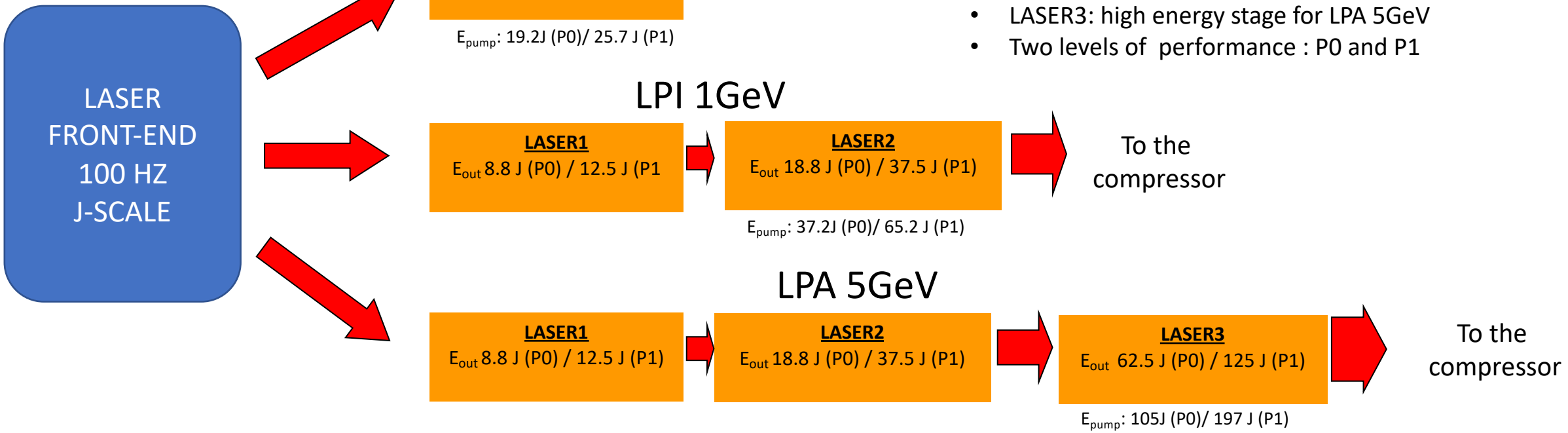
P. Tomassini, L. Giannessi, A. Giribono, F. Nguyen, and L. A. Gizzi, "Brilliant X-Ray Free Electron Laser Driven by Resonant Multi-Pulse Ionization Injection Accelerator", presented at the FEL2022, Triest, Italy, Aug. 2022, paper TUP17.

Now working on the proof of principle implementation and model refining

See WG1 talk today by Paolo Tomassini (ELI-NP)

TOWARDS EuPRAXIA LASER DEVELOPMENT

Funded by the European Union



- Three main modules: LASER1, LASER2, LASER3
- LASER1: stand-alone for LPI 150 MeV
- LASER2: output stage for LPI 1 GeV, second stage for LPA 5GeV
- LASER3: high energy stage for LPA 5GeV
- Two levels of performance : P0 and P1

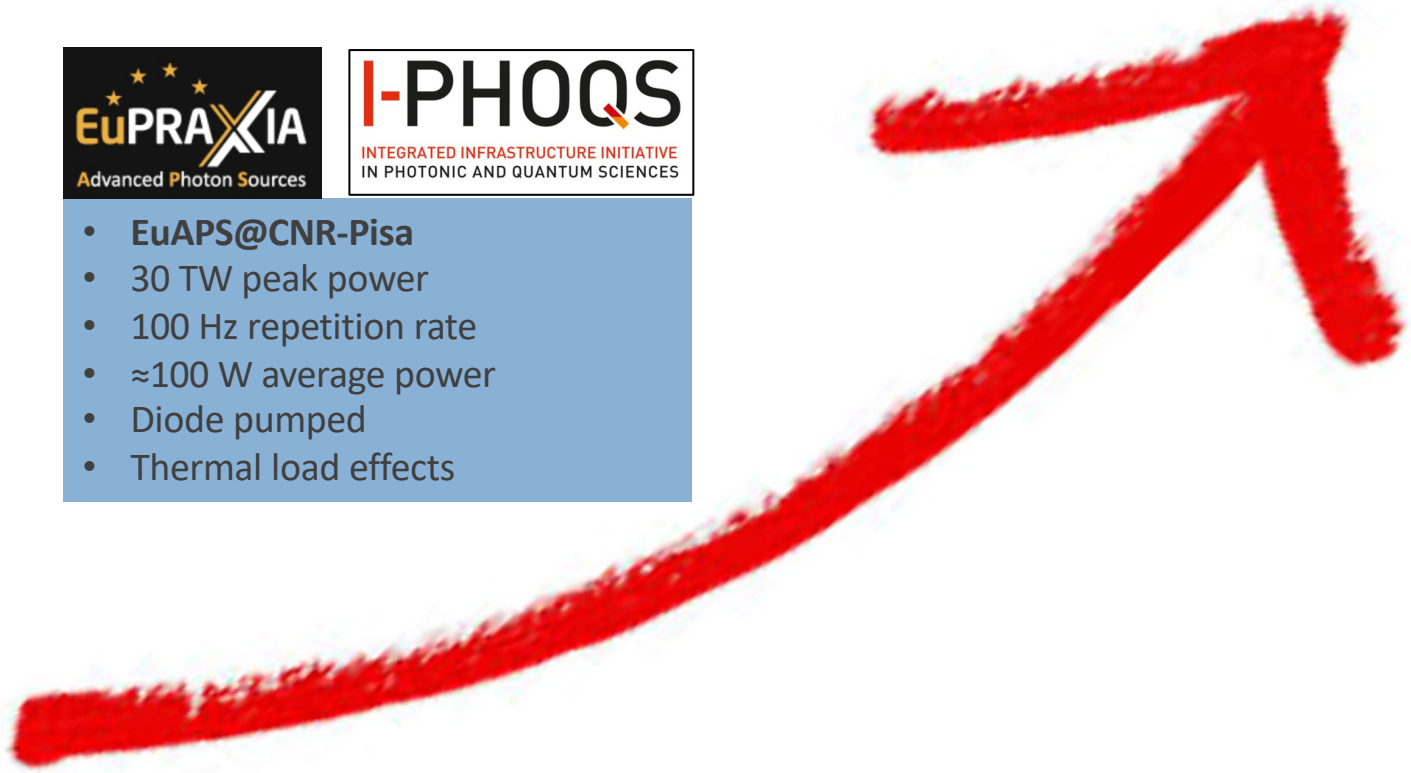
LASER: INTERMEDIATE MILESTONE

Funded by the European Union

Eupraxia laser development is aimed at delivering more efficient, kW-PW laser driver for plasma acceleration at >100 Hz rate

- **EuPRAXIA**
- PW class,
- 100 Hz repetition rate,
- multi kW average power,
- diode pumped
- Full thermal load transport

- **EuAPS@CNR-Pisa**
- 30 TW peak power
- 100 Hz repetition rate
- ≈100 W average power
- Diode pumped
- Thermal load effects



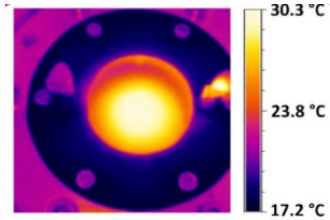
- **CURRENT**
- **PW class,**
- **Hz repetition rate,**
- **≈10 W average power**
- **flashlamp pumped**
- **No thermal load transport**

Underpinning EuPRAXIA Laser development

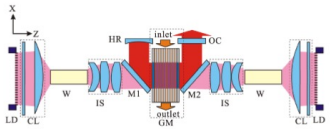
Funded by the European Union

High repetition rate (100 Hz) will speed up R&D of pending issues for Ti:Sa laser TDR

THERMAL MANAGEMENT OF POWER AMPLIFIERS



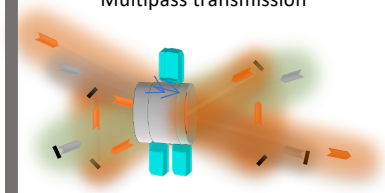
WATER/GAS COOLING



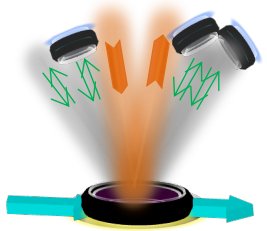
Prototyping needed

AMPLIFIER GEOMETRY TRANSMISSION VS. REFLECTION

Multipass transmission

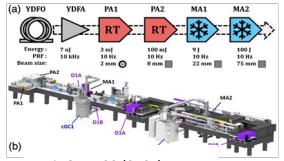


Multipass reflection

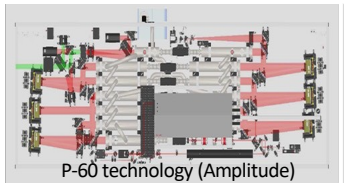


Prototyping needed

DPSSL PUMP SOURCES TECHNOLOGY



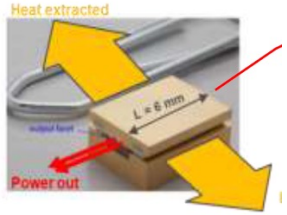
DiPOLE 100 (STCF)



P-60 technology (Amplitude)

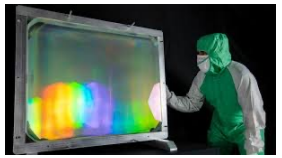
Currently no solution for full system specs (P1): development

DIODE LASERS EFFICIENCY, BRIGHTNESS AND LIFETIME



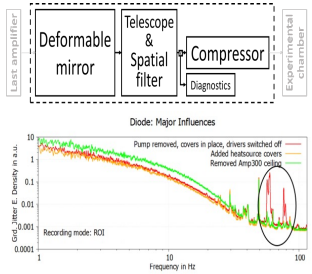
Needs development

COMPRESSOR AND TRANSPORT: THERMAL AND MECHANICAL STABILITY



Gold -> MD, MLD, MMLD

reduction of the thermal load
cooling of residual heat
control of thermal effects



Main challenges: large optics, mechanical stability, beam quality control, pointing stability

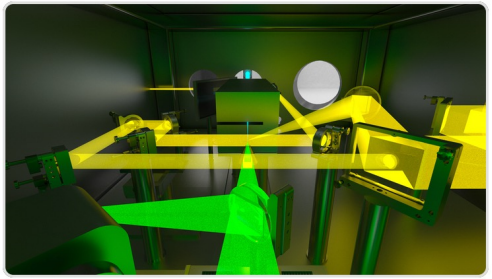
Cutting edge infrastructure: EUAPS

Funded by the European Union

Strong upgrade of existing labs and implementation of user access to unique laser and laser-plasma configurations

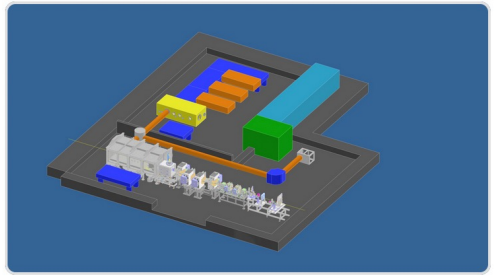
Research

The **EuPRAXIA Advanced Photon Sources** (**EuAPS**) project, led by INFN in collaboration with CNR and University of Tor Vergata, foresees the construction of a laser-driven "betatron" X Ray user facility at the LNF SPARC_LAB laboratory. EuAPS includes also the development of high power (up to 1 PW at LNS) and high repetition rate (up to 100 Hz at CNR Pisa) drive lasers for EuPRAXIA. EuAPS has received a financial support of 22.3 MEuro from the PNRR plan on "creation of a new RI among those listed in NPRI with medium or high priority" and has received the highest score for the action 3.1.1 of the ESFRI area "Physical Sciences and Engineering".



Betatron Radiation Source

READ MORE



High Power Laser Beamline

READ MORE

High Repetition Rate Laser Beamline

READ MORE

Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

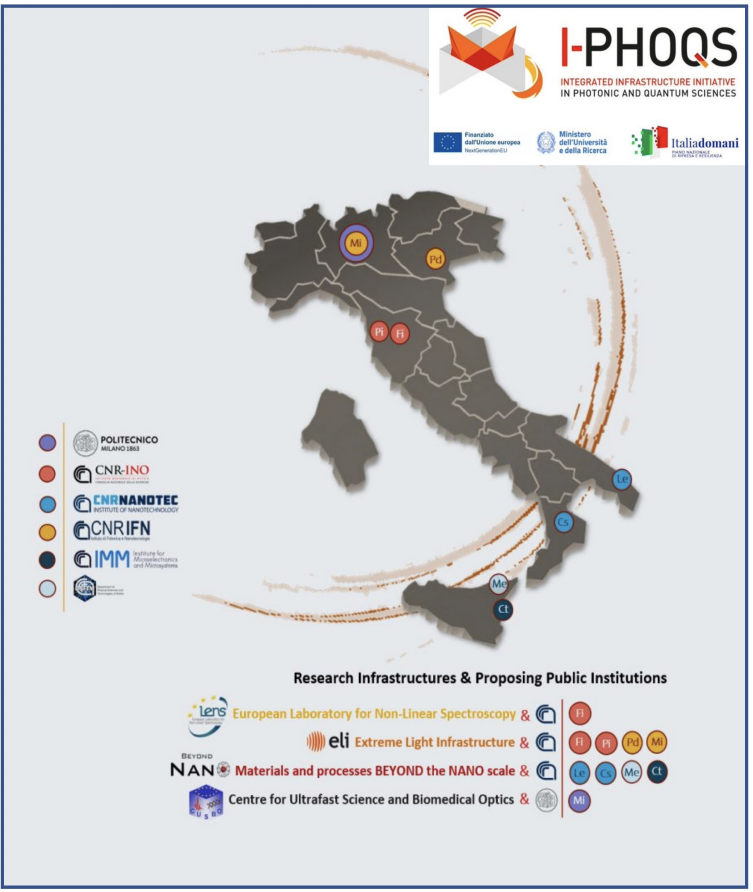
Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Strengthens the integration of national effort in the field and paves the way to further initiatives

Cutting edge infrastructure: IPHOQS

Funded by the European Union

A new network of priority national RI with a broad view on photonics and related fields, including **high field photonics**



I-PHOQS is a network of leading national research infrastructures (RIs), focused on Photonics and Quantum Sciences and Technologies, providing a unique integrated, cross-domain and multi-faceted approach to complex scientific and technological questions.

I-PHOQS

INTEGRATED INFRASTRUCTURE INITIATIVE
IN PHOTONIC AND QUANTUM SCIENCES

Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Will provide a platform for coordinated user access to the most advanced labs and facilities

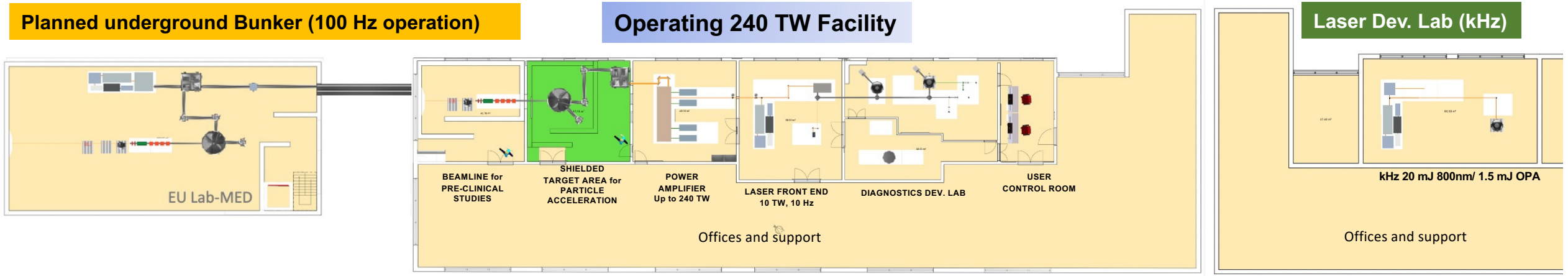
ILIL LAB UPGRADES IN PROGRESS

Funded by the European Union

Planned underground Bunker (100 Hz operation)

Operating 240 TW Facility

Laser Dev. Lab (kHz)



UPGRADE OF ILIL FACILITY FOR:

1. Upgrade of existing laser system (240 TW) for enhanced stability and control;
2. New laser systems for high repetition rate operation (100 Hz-1J, 1kHz-20 mJ);
3. New Infrastructure development, including underground bunker for user access to beamlines;

All upgrades funded and in progress – completion expected by mid-2026.

ROADMAP for 2nd Site: Institutional Support

Funded by the European Union

- So far a bottom-up approach was followed, building the case on scientific and technological development;
- Following the success of the PP application and the outcome of significant funding proposals, higher level support is emerging;
  - National (NGE-PNRR) RI are speeding up the establishment of the national cooperation;
  - CNR headquarters have been engaged with positive feedback;
  - Scientific council is being involved;
  - Contact established with ESFRI delegate;
  - Higher level (ministerial) engagement is in progress;
- Engagement of the National (INFN, Universities …) partners for synergic approach;
- Discussion of EuPRAXIA partners and collaborators ongoing.

THE END

Funded by the European Union

THE Tuscany Health Ecosystem

Advanced Photon Source

I-PHOQS
INTEGRATED INFRASTRUCTURE INITIATIVE IN PHOTONIC AND QUANTUM SCIENCES