Leonida A. Gizzi on behalf of:
M. Ferrario, INFN-LNF, WP6 coordinator

9 April 2025

WP6
Novel Particle Accelerators Concepts and Technologies

- **Ralph Assmann coordinated WP6 until end of August 23 when he left DESY**

- Task 1 (R.A. + M. Ferrario): **Novel Particle Accelerators Concepts and Technologies** (NPACT – **EuroNNAc4**)

  Sub-task leaders: ***B. Holzer*** *(CERN),* ***D. Minenna*** *(CEA),* ***A. Specka*** *(CNRS),* ***R. Walczak*** *(Oxford)*

- Task 2 (Leo Gizzi): **Lasers for Plasma Acceleration** (LASPLA)
- Task 3 (Cedric Thaury): **Multi-scale Innovative targets for laser-plasma accelerators** (MILPAT)
- Task 4 (Francois Mathieu): **Laser focal Spot Stabilization Systems** (L3S)

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iFAST/EuroNNAc Deliverables

Mission Accomplished

Deliverables related to WP6	
D6.1: EAAC workshops and strategies. *Report on the EAAC workshops as strategic forums for international accelerator R&D and resulting strategies*	M42 Nov. 2024
D6.2: LASPLA Strategy. *Report on a strategy for laser drivers for plasma accelerators.*	M46 Mar. 2025
D6.2: Electron acceleration experiments with new targets. *Report on electron acceleration with micro-scale target at a kHz repetition rate, and with long targets at the multi-Joule level.*	M24 April 2023
D6.4: Improvement of the laser intensity stability on target. *Report showing the stability on two laser facilities before and after improvement.*	M36 April 2024

iFAST

EAAC 2023

Ralph Assmann (GSI)
Massimo Ferrario (INFN)

EAAC 2013 has generated EuPRAXIA!

198 Participants

163 Delegates

35 Student Grants

EuroNNAc/iFAST provided funding to the EAAC workshop, in particular rooms, proceedings, student grants, van der Meer prize award, (about **350,000 € since 2013**, the first EAAC)

Changes for EAAC Ahead
good news

- The extension of the iFAST project until the end of October 2025 allow us to support also the **EAAC 2025** (September) **that is still sponsored by EuroNNAc/iFAST**

- EuroNNAc future beyond 2025 to be defined (founded in 2011 at CERN by RA), including **EU sponsoring for EAAC → We are looking for a proper Eu networking action to host EuroNNAC_5 (for example iFAST_2 ?)**

iFAST

Looking forward to seeing you at the

7th European Advanced Acceleration Conference

Elba, September 21-27, 2025

Pre-Registrations are now open

https://agenda.infn.it/event/46259/overview

	Sunday 21 Arrivals	Monday 22	Tuesday 23	Wednesday 24	Thursday 25	Friday 26	Saturday 27 Departures
9:00-10:30		Plenary	Plenary	Plenary	Plenary	Plenary	EuroNNAc4 Network Meeting
Break		Coffee Break 10:30-10:50					
10:50-12:30		Plenary	Plenary	Plenary	Plenary	Plenary	
Break		Lunch Break 12:30-16:00					
Break		Coffee Break 16:00-16:20					
16:20 18:45	Arrivals & Registration	Parallel Sessions	Parallel Sessions	Parallel Sessions	Parallel Sessions	Plenary	
19:00 20:30	Welcome Cocktail	Poster Session	Poster Session	Poster Session			
Evening	Dinner 20:30				Social Dinner	Dinner 20:30	

LPAW 2025 – Ischia Island – next week

https://agenda.infn.it/event/42311/

In addition the next Laser-Plasma Accelerators Workshop (LPAW205), Ischia 13-19 April, **will be partially supported by EuroNNAc/iFAST**

The Laser-Plasma Accelerators Workshop (LPAW) series is one of the leading workshops in the field of plasma-based acceleration and radiation generation. It started in the 1990s, with the first edition held in Kardamili, Greece.

	Sunday 13 Arrivals	Monday 14	Tuesday 15	Wednesday 16	Thursday 17	Friday 18	Saturday 19 Departures
9:00-10:40		Plenary Electron Acceleration	Plenary Secondary Radiation Sources	Plenary Plasma Sources	Plenary Diagnostics	Plenary Laser Technology	Departures
Break		Coffee Break 10:40-11:00					
11:00-12:40		Plenary Ion Acceleration	Plenary Applications	Plenary Theory and Simulations	Plenary Machine Learning	Plenary Facilities	
Break		Lunch Break 12:40-15:00					
15:00 16:40	Arrivals	Parallel Session Electron Acceleration; Parallel Session Ion Acceleration	Parallel Session Electron Acceleration; Parallel Session Ion Acceleration	Tour and Aperitivo Dinner	Parallel Session Secondary Radiation Sources; Parallel Session Applications	Plenary Facilities; Parallel Session Facilities; Parallel Session Laser Technology	
Break		Coffee Break 16:40-17:00			Coffee Break 16:40-17:00	Coffee Break 16:50-17:10	
17:00 18:40		Poster Session	Poster Session		Parallel Session Diagnostics, Plasma Sources; Parallel Session Machine Learning, Theory and Simulations	Plenary Facilities; Dawson Price	
Evening	Welcome Cocktail	Dinner 20:30			Social Dinner	Dinner 20:30	

EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA
Preparatory Phase

Recent news from the EuPRAXIA project

Funded by
the European Union

This project has received funding from the European Union´s Horizon Europe research and innovation programme under grant agreement No. 101079773. It is supported by in-kind contributions by its partners and by additional funding from UK and Switzerland.

A New European High-Tech User Facility

Funded by the European Union

1

Building a facility with very high field plasma accelerators, driven by lasers or beams
1 – 100 GV/m accelerating field

Shrink down the facility size
Improve Sustainability

2

Producing particles and photons to support several urgent and timely science cases

Drive short wavelength FEL
Pave the way for future Linear Colliders

https://www.eupraxia-facility.org/

FEATURE EuPRAXIA

Surf's up *Simulation of electron-driven plasma wakefield acceleration, showing the drive electron beam (orange/purple), the plasma electron wake (grey) and wakefield-ionised electrons forming a witness beam (orange).*

EUROPE TARGETS A USER FACILITY FOR PLASMA ACCELERATION

Ralph Assmann, Massimo Ferrario and Carsten Welsch describe the status of the ESFRI project EuPRAXIA, which aims to develop the first dedicated research infrastructure based on novel plasma-acceleration concepts.

Energetic beams of particles are used to explore the fundamental forces of nature, produce known and unknown particles such as the Higgs boson at the LHC, and generate new forms of matter, for example at the future FAIR facility. Photon science also relies on particle beams: electron beams that emit pulses of intense synchrotron light, including soft and hard X-rays, in either circular or linear machines. Such light sources enable time-resolved measurements of biological, chemical and physical structures on the molecular down to the atomic scale, allowing a diverse global community of users to investigate systems ranging from viruses and bacteria to materials science, planetary science, environmental science, nanotechnology and archaeology. Last but not least, particle beams for industry and health support many societal applications ranging from the X-ray inspection of cargo containers to food sterilisation, and from chip manufacturing to cancer therapy.

This scientific success story has been made possible through a continuous cycle of innovation in the physics and technology of particle accelerators, driven for many decades by exploratory research in nuclear and particle physics. The invention of radio-frequency (RF) technology in the 1920s opened the path to an energy gain of several tens of MeV per metre. Very-high-energy accelerators were constructed with RF technology, entering the GeV and finally the TeV energy scales at the Tevatron and the LHC. New collision schemes were developed, for example the mini "beta squeeze" in the 1970s, advancing luminosity and collision rates by orders of magnitudes. The invention of stochastic cooling at CERN enabled the discovery of the W and Z bosons 40 years ago.

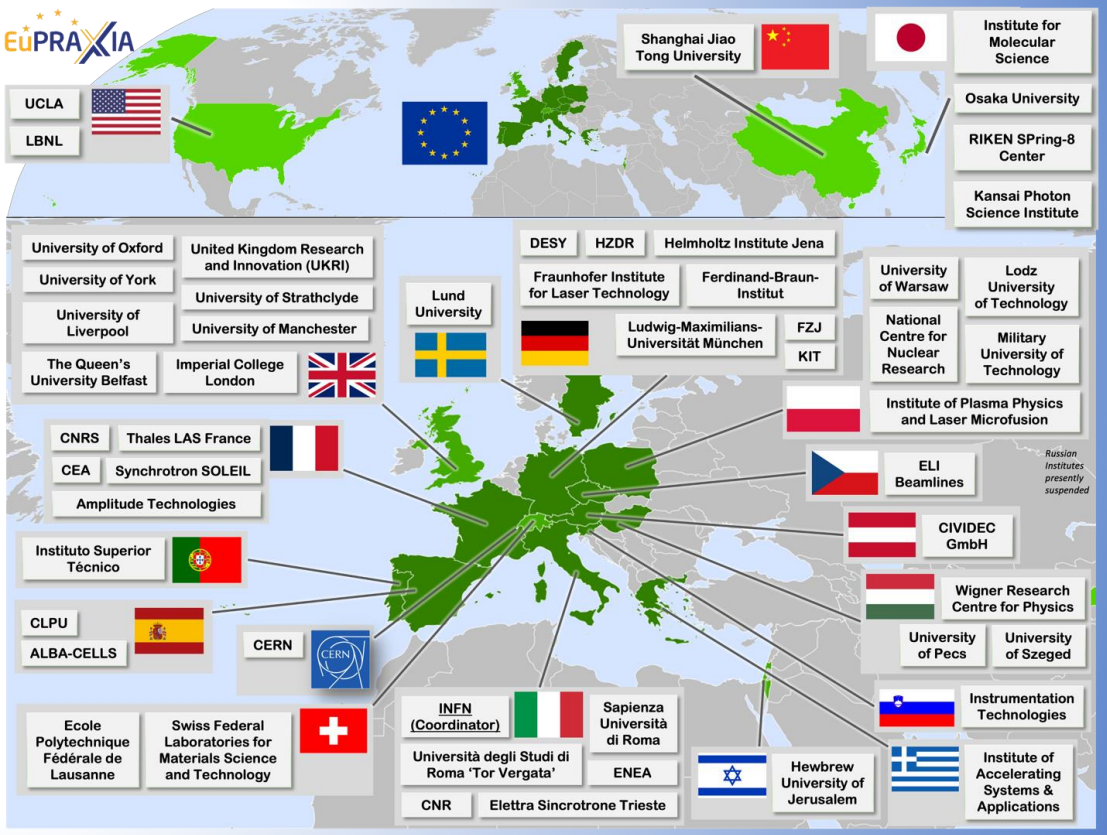
However, intrinsic technological and conceptual limits mean that the size and cost of RF-based particle accelerators are increasing as researchers seek higher beam energies. Colliders for particle physics have reached a

THE AUTHORS
Ralph Assmann *DESY and INFN*, **Massimo Ferrario** *INFN*, **Carsten Welsch** *University of Liverpool/INFN.*

CERN COURIER MAY/JUNE 2023 25

Wide International Collaboration

- The EuPRAXIA Consortium today: **54 institutes** from **18 countries** plus CERN
- Included in the **ESFRI** Road Map
- Efficient fund raising:
  - **Preparatory Phase** consortium (funding EU, UK, Switzerland, in-kind)
  - **Doctoral Network** (funding EU, UK, in-kind)
  - **EuPRAXIA@SPARC_LAB** (Italy, in-kind)
  - **EuAPS Project** (Next Generation EU)
  - **PACRI Project** (Funding EU)



EuPRAXIA Scientific Goals

Funded by the European Union

- **Free Electron Laser**
  [EuPRAXIA_MUR]
  [EuPRAXIA_PP]
  [EuPRAXIA_DN]
  [PACRI]
- **Betatron Source**
  [EuAPS_PNRR]
- **Positron Beams**
- **e+ / e- beams**
- **ICS Photon Beams**
- **High Rep. Rate LPA**
  [PACRI]
- **Laser Technology**
  [EuAPS_PNRR]

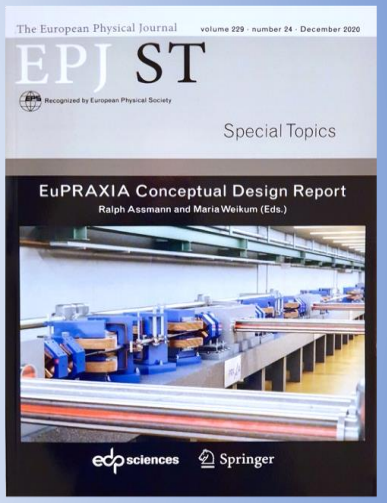
***Flagship Science Goal 1**: EuPRAXIA will deliver **free-electron laser** (FEL) X rays with 10^9-10^13 photons per pulse to user areas, covering wavelengths of 0.2 nm to 36 nm. The EuPRAXIA FEL pulses are naturally short (down to 0.4 fs) and will therefore provide users with tools for investigating processes and structures in ultra-fast photon science at a reduced facility foot print.*

***Flagship Science Goal 2:** EuPRAXIA will deliver **betatron X rays** with about 10^10 photons per pulse, up to 100 Hz repetition rate and an energy of 5-18 keV to users from the medical area. The much reduced longitudinal length of the X ray emission area (point-like emission) leads to an important improvement in image resolution compared to other techniques.*

***Flagship Science Goal 3**: EuPRAXIA will deliver **positron beams** at energies from 0.5 MeV to 10 MeV and a repetition rate of 100 Hz for material science studies. Per pulse about 10^6 positrons will be produced in a time duration of 20-90 picoseconds on the sample, allowing time-resolved studies. EuPRAXIA will here advance the capabilities of existing positron sources in flux and time resolution.*

***Flagship Science Goal 4**: EuPRAXIA will deliver **electron and positron beams** at energies from a few 100 MeV up to 5 GeV for high energy physics related R&D (detectors, linear collider topics). R&D goals include the demonstration of a linear collider stage, a "table top" HEP test beam and studies on positron transport and acceleration towards a linear collider.*

***Flagship Science Goal 5:** EuPRAXIA will deliver photons from an **inverse Compton scattering (ICS)** source. The photons of up to 600 MeV and with narrow-band spectrum will enable precision nuclear physics and highly penetrative radiography for users.*



600+ page CDR, 240 scientists contributed

***Flagship Science Goal 6**: EuPRAXIA will provide access to a **multi-stage, high-repetition rate plasma accelerator in the GeV range** to users from accelerator science. This R&D platform will allow the testing of novel ideas and concepts, full optimisation of a plasma collider stage, certain fixed target experiments (also in combination with lasers) and performance studies of conventional versus novel accelerator technology.*

***Flagship Science Goal 7**: EuPRAXIA will provide access to **cutting edge laser technology** with short pulse length in combination with high energy photon pulses and short electron/positron bunches. Novel schemes of pump probe configurations and ultra-precise timing will be researched, feeding back into laser science.*

Important Milestone Achieved

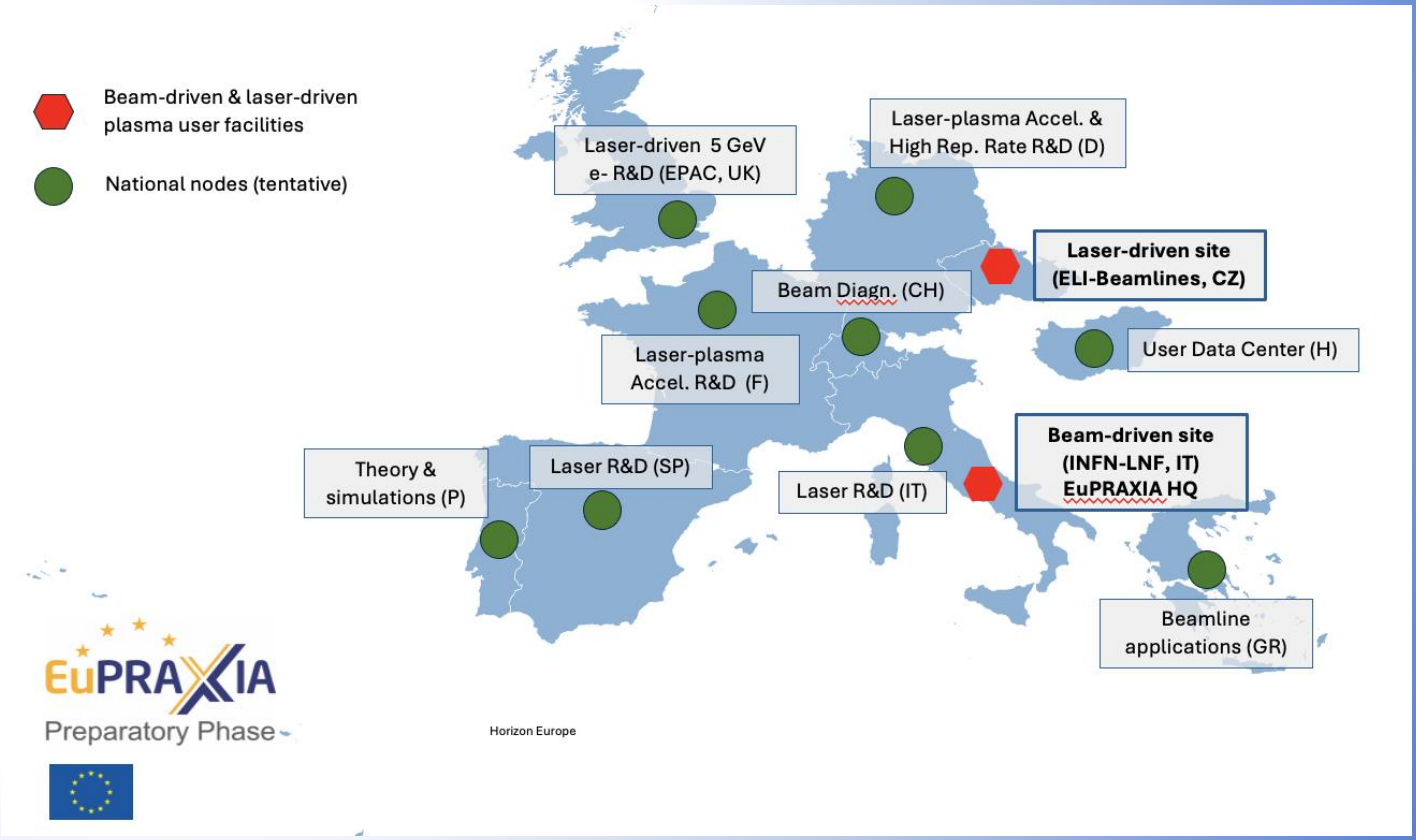
EuPRAXIA selects ELI for the Laser-Driven Accelerator Site

https://www.eupraxia-facility.org/post/eupraxia-selects-eli-for-second-laser-driven-accelerator-site

The EuPRAXIA Consortium selected the ELI Beamlines Facility in Dolní Břežany, Czech Republic, as the site for its laser-driven plasma accelerator pillar. ELI Beamlines was selected for its infrastructure readiness, state-of-the-art laser systems, and comprehensive technical expertise.

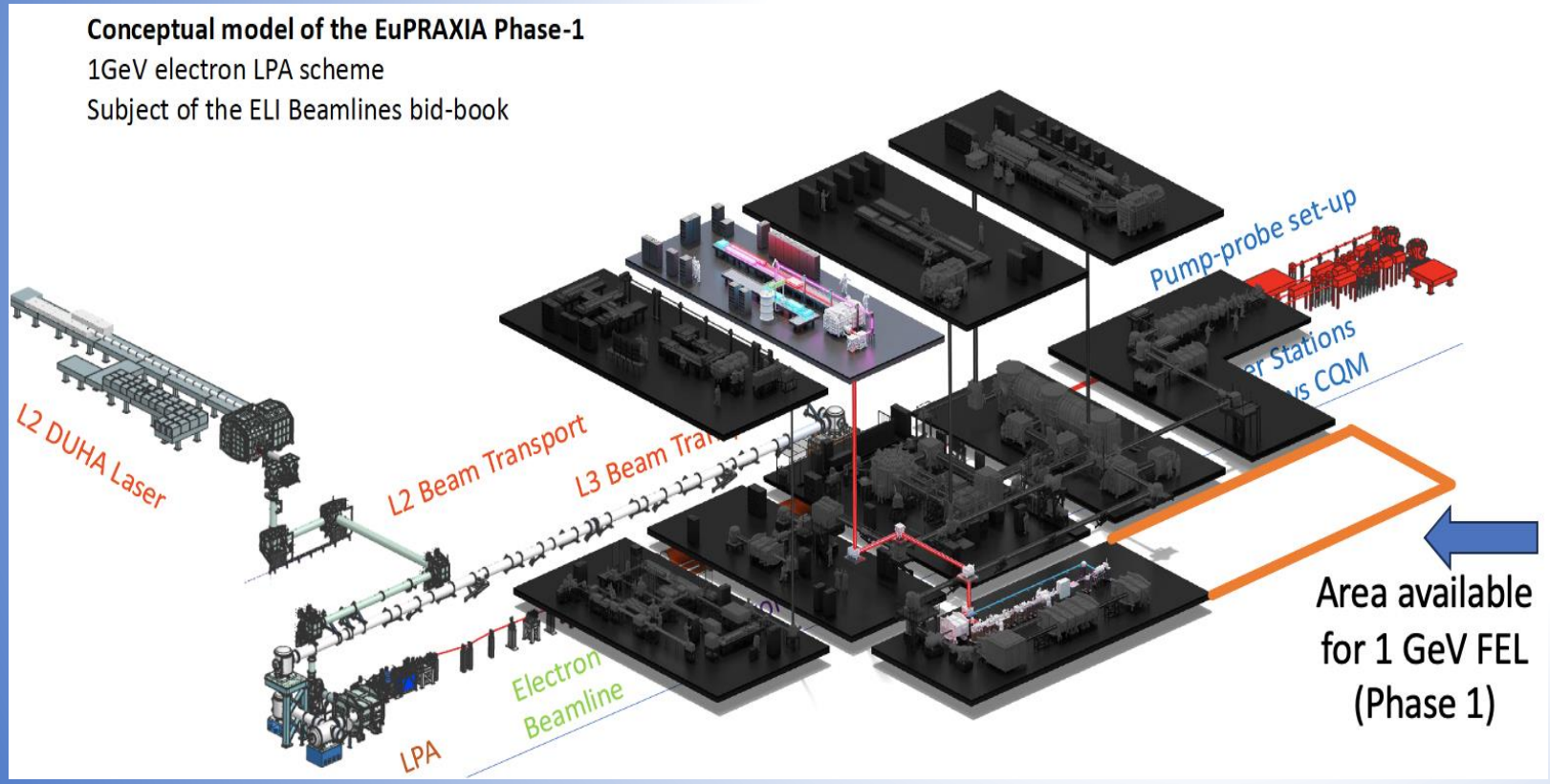
EuPRAXIA also recognises the important roles of the other candidates for the second site, EPAC and CNR-INO.

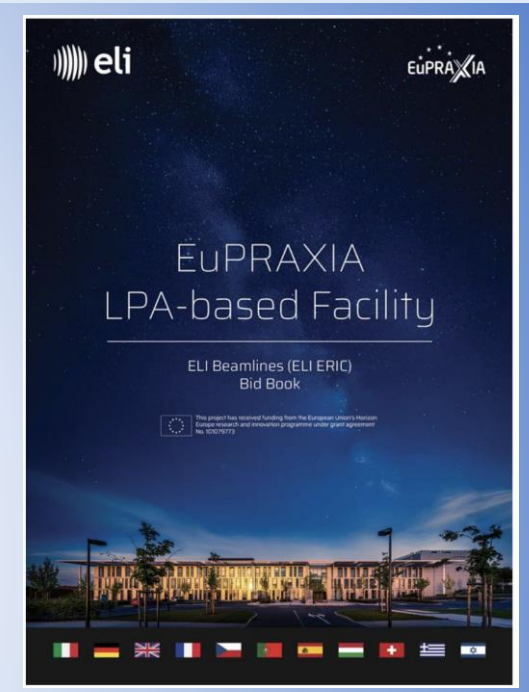
EPAC will contribute to EuPRAXIA as a centre for R&D, focusing on advancing research towards achieving a high-quality 5 GeV electron beam. While **CNR-INO** will function as EuPRAXIA's National Node in Italy and laser test facility.



EuPRAXIA@ELI LPAW based facility

With it's advanced high-power, high-repetition-rate laser systems, including the newly developed L2 DUHA laser (aiming to 200 TW, 100 Hz) , and versatile experimental setups, ELI is ideally equipped to implement and operate the Laser-Plasma-Accelerator-based 1-GeV Free-Electron Laser (FEL) envisioned by EuPRAXIA.





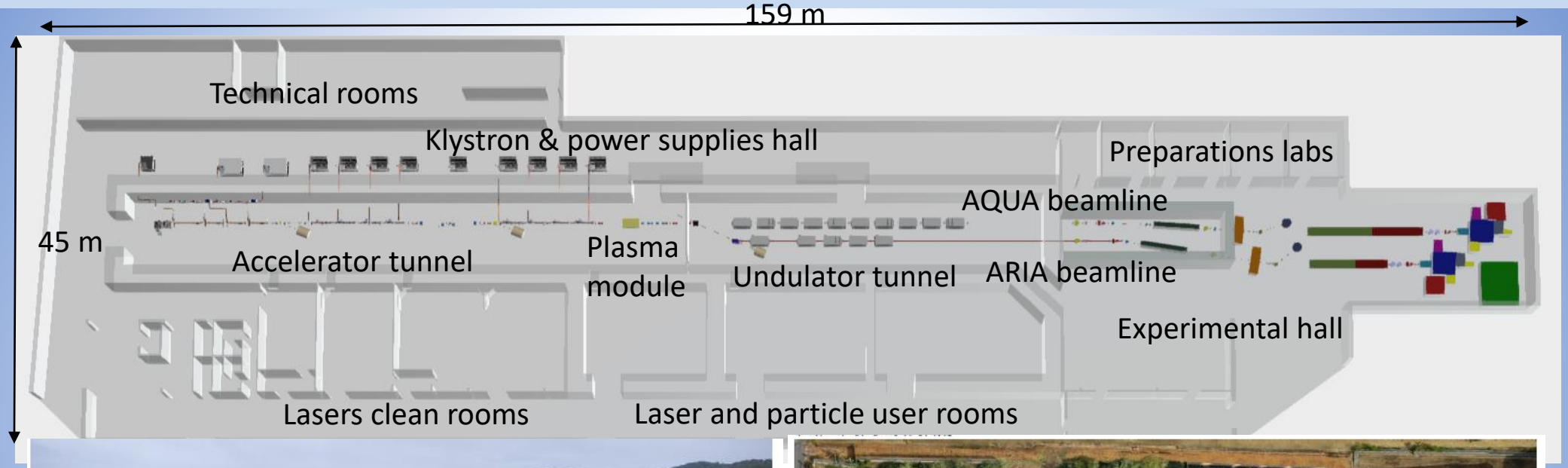
PHASE-1		
Soft X-ray FEL (W_e = 1GeV)	~ 4 nm / 100 Hz	L2-laser
Low-energy POSITRON source	YES / 1000 Hz	ALLEGRO laser
PHASE-2		
Hard X-ray FEL (W_e ~ 2 GeV)	~ 0.3 nm / 100 Hz	L2-laser
High-energy electron beam Up to 5 GeV	YES 100 Hz	**NOVEL** PW-class laser system

Headquarter and Site 1: EuPRAXIA@SPARC_LAB

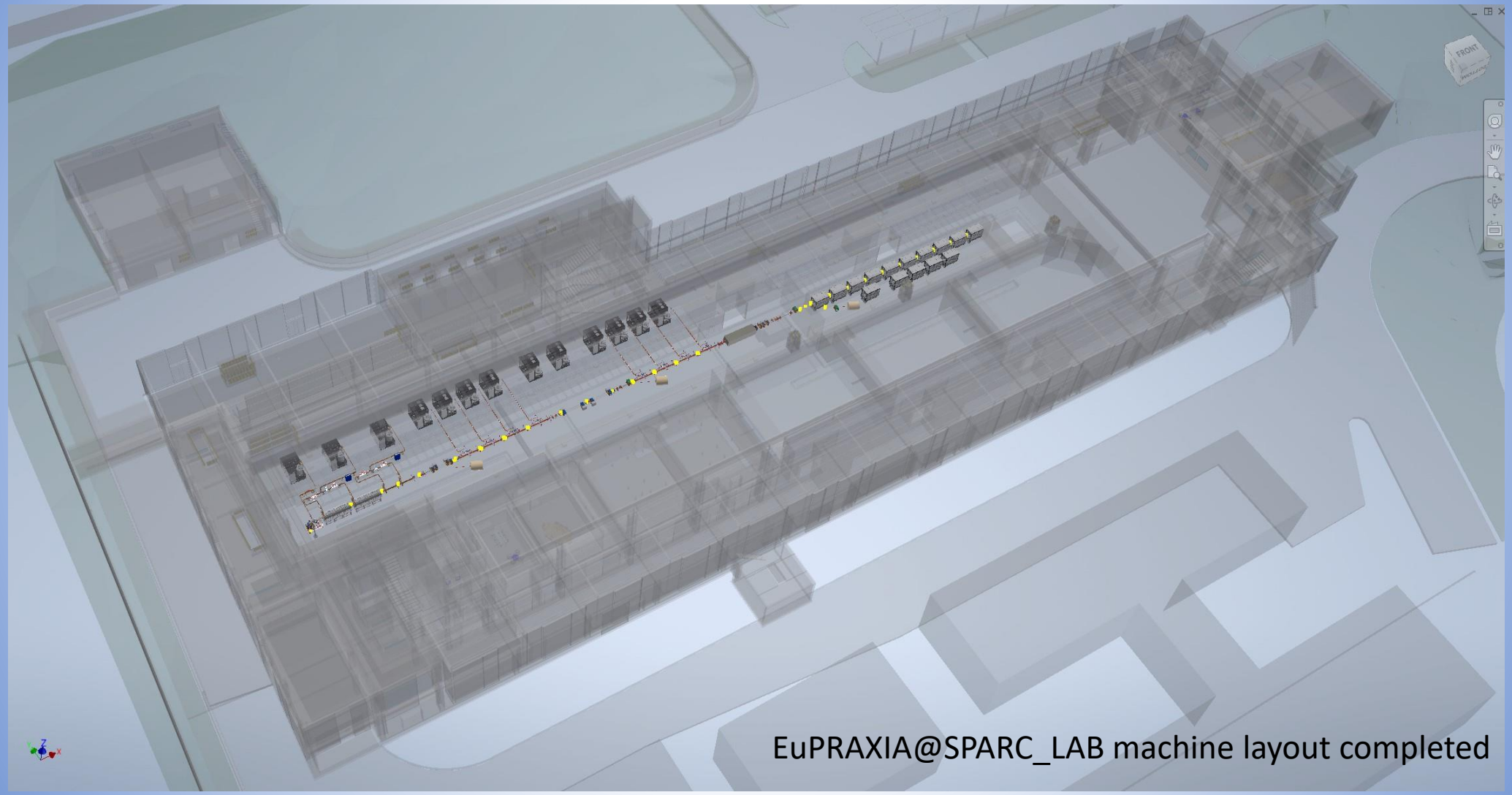
- Frascati`s future facility
- > 130 M€ invest funding
- Beam-driven plasma accelerator
- Europe`s most compact and most southern FEL
- The world`s most compact RF accelerator (X band with CERN)

- Construction site opening: September 2026

EuPRAXIA@SPARC_LAB Layout



Technical Design Report to be submitted by June



EuPRAXIA@SPARC_LAB machine layout completed

PACRI
Kick-off meeting

Trieste, Italy | 12 – 14 March 2025

EuPRAXIA eli

12–14 mar 2025
Trieste, Hotel NH

https://indico.elettra.eu/event/52/

PACRI – 101188004 – Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Coordination and focus

Funded by
the European Union

1. Compact & efficient plasma accelerators (M. Ferrario - INFN)

With focus on the **high rep-rate plasma modules**, as required for the **EuPRAXIA project,** extending its scientific domain to high average brightness radiation sources and possible future applications to high energy physics.

2. Compact & efficient X-band technology for accelerators (G. D'Auria - ELETTRA)

With focus on normal conducting RF technology for linacs (**X-band**), **improving** their **efficiency and power consumption** and extend their operating capabilities **up to the kHz regime.**

3. Efficient & high repetition rate Lasers (L. Gizzi - CNR).

With focus on **high power laser technology**, to drive high-gradient and high-repetition-rate Laser Plasma Acceleration (LPA) related to the above-mentioned applications.

PACRI

PACRI Work Packages

Funded by the European Union

WP No.	Work Package Title	Lead Partic. Short Name
1	Coordination and project management	ELETTRA
2	Scientific and industrial exploitation	ULIV
3	Plasma accelerator theory and simulations	IST
4	High repetition rate plasma structures	INFN
5	Plasma acceleration diagnostics and instrumentation	CNRS
6	High efficiency RF generator	Thales-MIS
7	High repetition rate modulator	Scandinova
8	X-band RF Pulse Compressor (BOC)	INFN
9	RF tests and validation	CERN
10	High repetition rate high power Ti:Sa amplifier module	UKRI
11	Efficient kHz laser driver modules for plasma acceleration	CNR
12	High-rep rate pump sources for laser drivers	ELI-ERIC
13	Prototype of high average power optical compressor	Thales-LAS
14	Laser Driver System Architecture,transport and engineering	CNRS

Plasma

X-band

Lasers

25 Members
+
1 Associated partner

19 Universities
and Scientific Labs.
+
7 Industries

#	Partner	Acronym
1	Elettra - Sincrotrone Trieste SCpA (Coordinator)	ST
2	European Organization for Nuclear Research	CERN
3	Istituto Nazionale Fisica Nucleare	INFN
4	University of Liverpool	ULIV
5	Thales-MIS	Th-MIS
6	Scandinova Systems AB	SCND
7	VDL ETG Technology & Development BV	VDL
8	COMEB	COMEB
9	United Kingdom Research and Innovation	UKRI
10	Consiglio Nazionale delle Ricerche	CNR
11	Extreme Light Infrastructure ERIC	ELI-ERIC
12	Centre National de la Recherche Scientifique CNRS	CNRS
13	Thales LAS France SAS	Th-LAS
14	Amplitude	Amplitude
15	Centro de LÁSERES Pulsados	CLPU
16	Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Hoechstfrequenztechnik	FBH
17	Associacao do instituto superior Tecnico para a Investigacao e Desenvolvimento	IST
18	Università degli Studi di Roma La Sapienza	USAP
19	Heinrich-Heine-Universitaet Duesseldorf	UDUS
20	Deutsches Elektronen-Synchrotron DESY	DESY
21	The Chancellor, Masters and Scholars of the Univ. of Oxford	UOX
22	Ludwig-Maximilians-Universitaet Muenchen	LMU
23	GSI Helmholtz Centre for Heavy Ion Research	GSI
24	Università degli Studi di Roma Tor Vergata	UTOR
25	SourceLAB	SourceLAB
26	Paul Scherrer Institut **(Associated partner)**	PSI

Leonida A. GIZZI – CNR-INO (Task Leader)

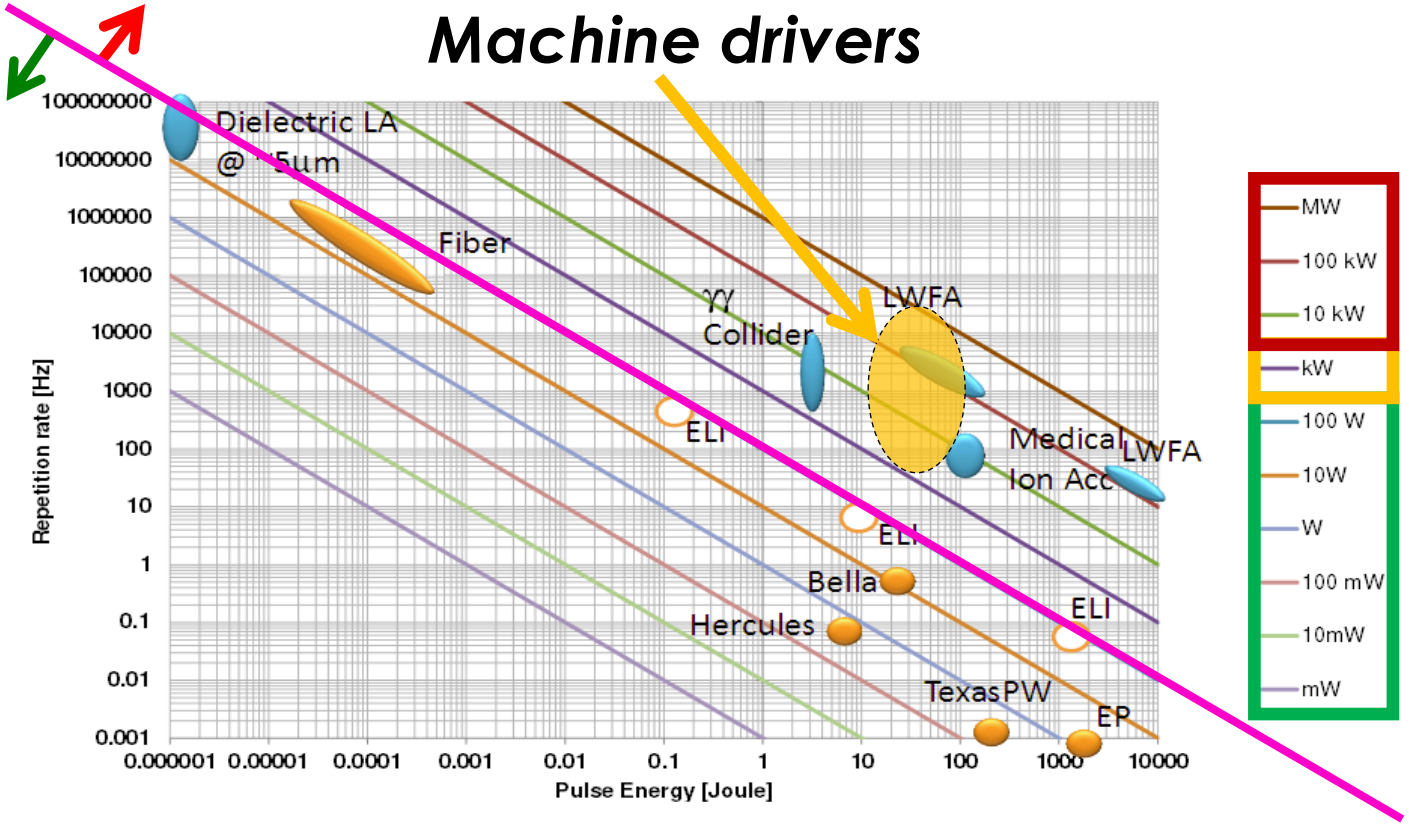
4th iFAST Annual Meeting, Krakow, Poland, 9 April 2025

Status of laser driver development

Current reqirement for LPA driver: PW-class system, with high repetition rate (≈kHz)

Demanding high average power

Machine drivers



LASPLA Objectives

Establish a roadmap to foster delivery of **advanced industrial laser drivers** with high-repetition rate and higher efficiency, for the first user laser-plasma based accelerators.

Establish a **coordination activity with networking** and training of **main laser labs and industrial partners**, focused on laser-driver R&D.

Major effort required to fill the gap between **existing** and **required** laser technology

L.A. Gizzi et al., A viable laser driver for a user plasma accelerator, NIM **A 909 , 58 (2018); https://doi.org/10.1063/1.4984906

LASPLA Strategy

Report on a strategy for laser drivers for plasma accelera

- High TRL Ti:Sa, 100 Hz, multi Joule scale (EuPRAXIA-Like) - 1-10 kW
- Coherent combination of multi-J-scale beams
- High TRL – Industrial development in progress at J level

- Short-medium term solution
- Proof-of-principle user laser accelerator
- Needs components testing

Existing "Commercial"
100 Hz,<100 W, J-SCALE front-end
&
Efficient diode laser technology

- Diode pumped, direct CPA, kHz, multi- Joule scale
- **High efficiency** with **advanced lasing materials (DPSSL)**
- Optical parametric **chirped pulse amplification (OPCPA)** with diode pumping
- Post-compression of thin-disk lasers
- Coherent combination of fibers

- Longer term solution
- Scalable, efficient
- Needs high brightness, lower cost diode lasers for pumping
- Needs materials and components R&D

iFAST

LASPLA Strategy

Report on a strategy for laser drivers for plasma acceleration (D.6.2)

1 Introduction
2 Pillars of strategy
2.1 Overview
2.2 Key Technologies
- 2.2.1 Cooling architectures
- 2.2.2 Pump lasers
- 2.2.3 High Quality Front-end
- 2.2.4 100 Hz Ti:Sa Technology
- 2.2.5 Diode laser technology
- 2.2.6 Thulium doped gain media
- 2.2.7 Exploitation of industrial kHz systems

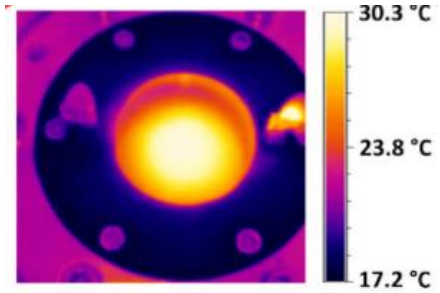
3 Planned developments
3.1 Funded Laser Activities
- 3.1.1 Ti:Sa amplifier modules
- 3.1.2 Efficient kHz laser drivers
- 3.1.3 High Rep-rate pump sources
- 3.1.4 High average power compressors
- 3.1.5 System Architectures

4 Future plans / Conclusion / relation to other IFAST work

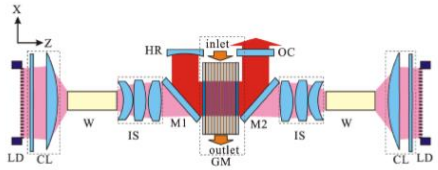
Underpinning EuPRAXIA-like Laser driver

Funded by the European Union

THERMAL MANAGEMENT OF POWER AMPLIFIERS



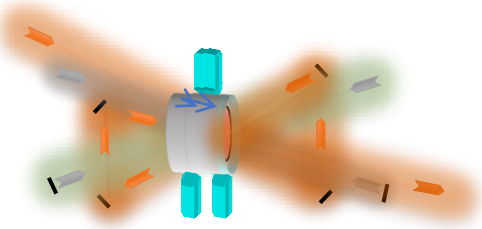
WATER/GAS COOLING



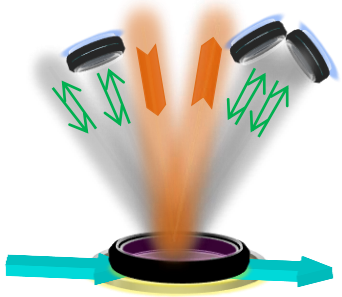
Prototyping needed

AMPLIFIER GEOMETRY TRANSMISSION VS. REFLECTION

Multipass transmission

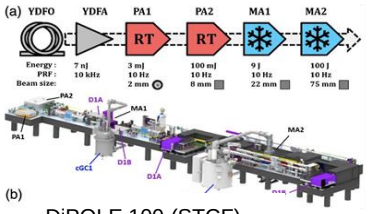


Multipass reflection

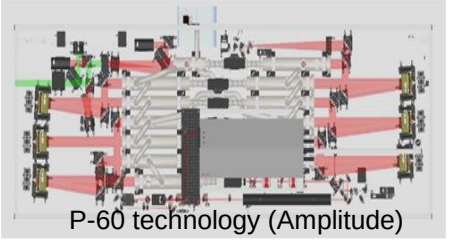


Prototyping needed

DPSSL PUMP SOURCES TECHNOLOGY



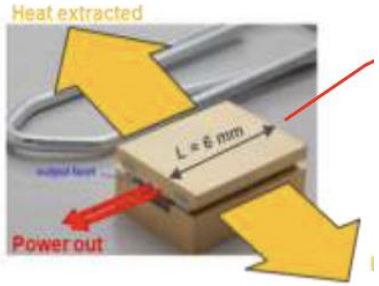
DiPOLE 100 (STCF)

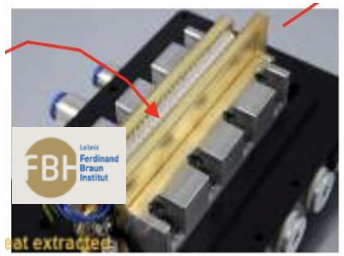


P-60 technology (Amplitude)

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

DIODE LASERS EFFICIENCY, BRIGHTNESS AND LIFETIME



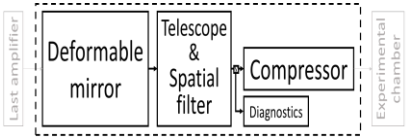


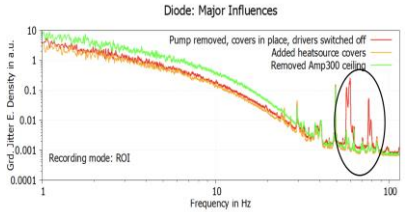
Needs development

COMPRESSOR AND TRANSPORT: THERMAL AND MECHANICAL

Gold -> MD, MLD, MMLD

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





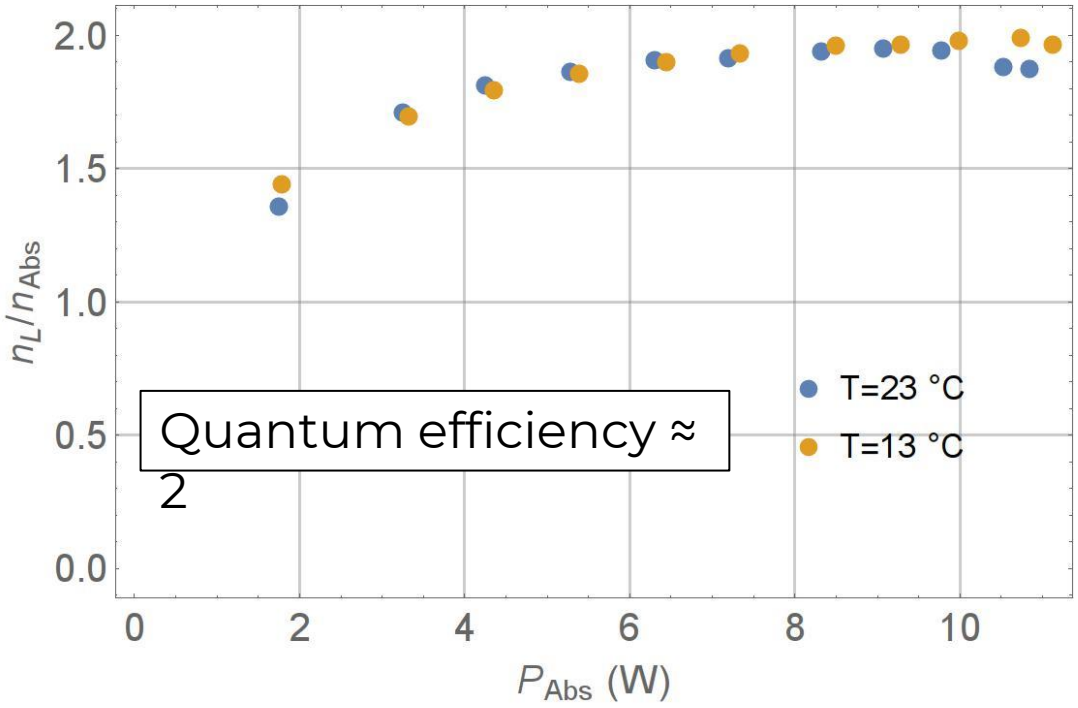
Main challenges: large optics, mechanical stability, beam quality control, pointing stability

CNR-INO ISTITUTO NAZIONALE DI OTTICA CONSIGLIO NAZIONALE DELLE RICERCHE

Forward looking high efficiency solutions

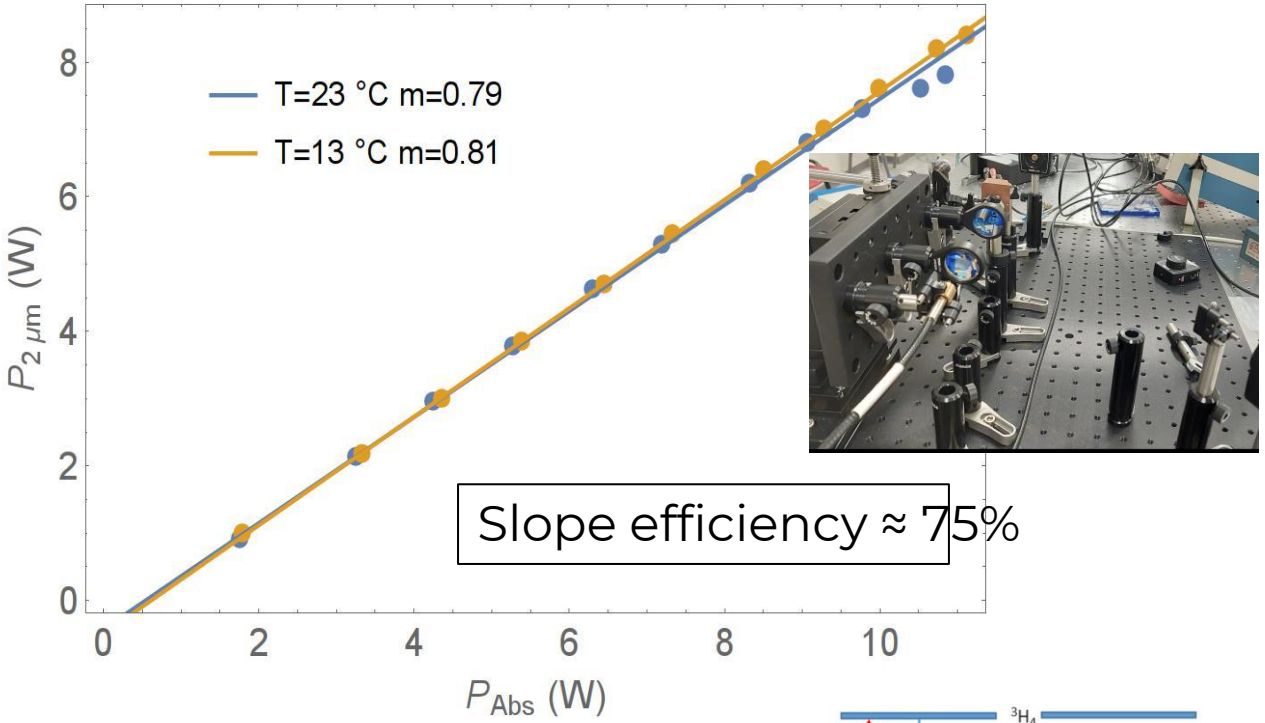
Accurate characterizaton of absorbed pump energy to measure quantum ef
Measures for two different temperatures of 13 and 23°C

Quantum efficiency

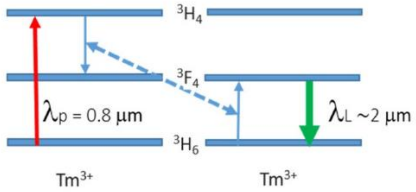


Quantum efficiency ≈ 2

Slope efficiency



Slope efficiency ≈ 75%



Preliminary: quantum efficiency close to 2 : **Evidence of strong cross relaxation**

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A. Fregosi, F. Brandi, L. U. Labate1, F. Baffigi, G. Cellamare, M. Ezzat, D. Palla, G. Toci, A. Whitehead, and L. A. Gizzi, *A study of cross-relaxation and temporal dynamics of lasing at 2 microns in Thulium doped ceramic*, HPLSE, 2025

PACRI LASER WORK AHEAD

Funded by the European Union

Funding for scaleup of collaborative EuPRAXIA TDR development (within Infratech proposal PACRI)

PACRI WP10

High repetition rate High power Ti:Sa amplifier module

PACRI WP12

High repetition rate pump sources for laser drivers

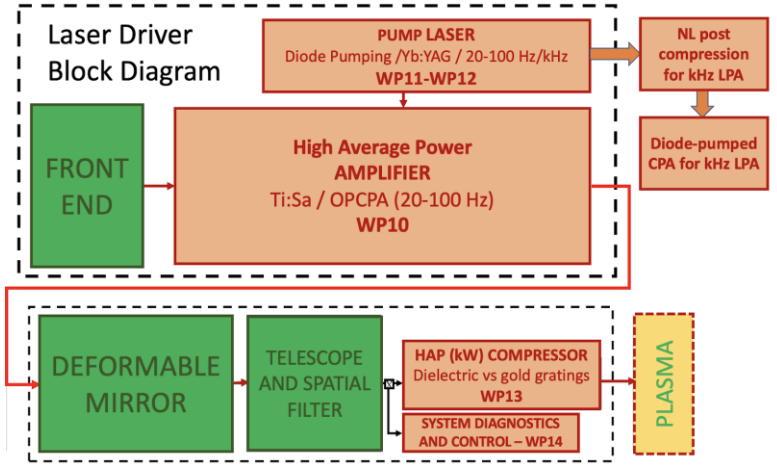
PACRI WP13

Prototype of High average power optical compressor

PACRI WP14

Laser driver System Architecture, transport and engineering

EuPRAXIA laser driver (100 Hz) and longer term options (1 kHz)



PACRI WP11

Efficient kHz laser driver modules for plasma acceleration

SAC Comments

Comments:

• The SAC finds the progress made in laser driver development very good and is pleased to see an increasing involvement of industry. This will be key to turn concepts into viable technologies.

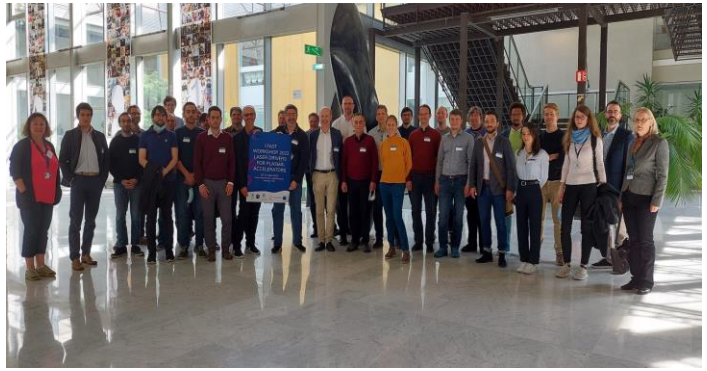
• It was not clear which of many future developments presented are to be achieved within the scope of I.FAST.

Suggestions:

• Since it was difficult to determine from this presentation the contributions from I.FAST, clearly indicate these in the future.

Strong IFAST contribution to the delivery of a STRATEGY for laser drivers for plasma accelerators

Outcome of IFAST for Strategy from **Workshop on *Laser Drivers for Plasma Accelerators*** held on 20-23 of April 2022 at the Ecole Polytechnique (Palaiseau, France) and more recently at the ***LASPLA Laser Technology* Workshop** held on 19-22 of September 2023 in the framework of the 6th EAAC 2023 at Elba, Italy.



Conclusions on LASPLA strategy

- **Intense laser technology is rapidly evolving;**
  - **Scientific lasers are being optimized for highest peak power;**
  - **Industrial lasers seeing laser-plasma acceleration as main application**
- **Limited scaling (thermal, wpe) for HEP accelerator drivers;**
- **New laser technology highlighted for high WPE and >kW average power;**
- **Strong motivation for efficient diode pumping to gradually replace flashlamps;**
- **New schemes and gain materials are emerging and under investigation.**

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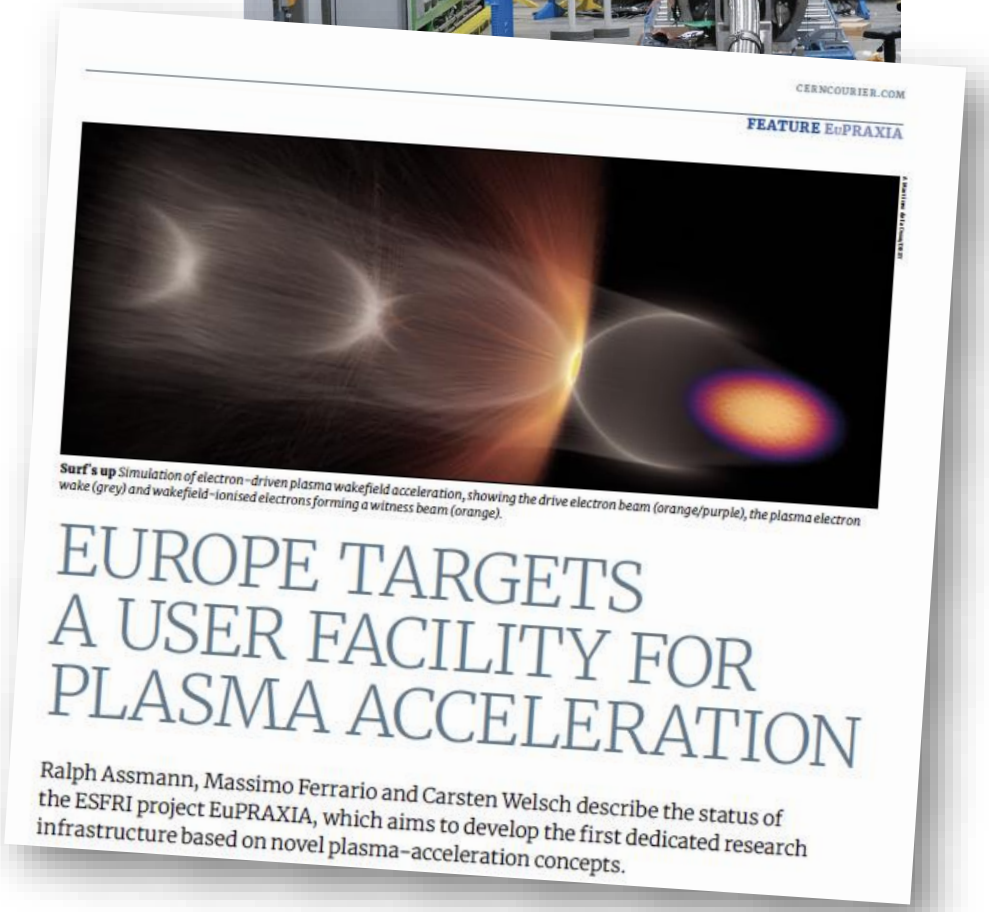
Overall Conclusions and Acknowledgements

Funded by the European Union

- Plasma accelerators have advanced considerably in beam quality, **achieving FEL lasing**.
- EuPRAXIA is an ESFRI project for a distributed European Research Infrastructure, **building two plasma-driven FEL´s in Europe**.
- EuPRAXIA FEL site in Frascati LNF-INFN is sufficiently funded for **first FEL user operation in 2029**.
- **Second EuPRAXIA FEL site has been recently selected**
- **Strong role of EuRONNAC in field development and consolidation of the Plasma Accelerator Community in EuROPE**
- **A warm thank to the IFAST project for supporting the EuRONNAC -> EAAC-> EuPRAXIA activities.**



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FEATURE EuPRAXIA

Surf's up Simulation of electron-driven plasma wakefield acceleration, showing the drive electron beam (orange/purple), the plasma electron wake (grey) and wakefield-ionised electrons forming a witness beam (orange).

EUROPE TARGETS A USER FACILITY FOR PLASMA ACCELERATION

Ralph Assmann, Massimo Ferrario and Carsten Welsch describe the status of the ESFRI project EuPRAXIA, which aims to develop the first dedicated research infrastructure based on novel plasma-acceleration concepts.