EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA 2nd SITE @CNR

Status of preparation

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

EuPRAXIA-PP Annual Meeting
25 Sept 2024
Hotel Hermitage, La Biodola Bay, Isola d'Elba, Italy

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

CNR, Area della Ricerca del CNR, Pisa

Funded by the European Union

The *home* Laboratory

Funded by the European Union

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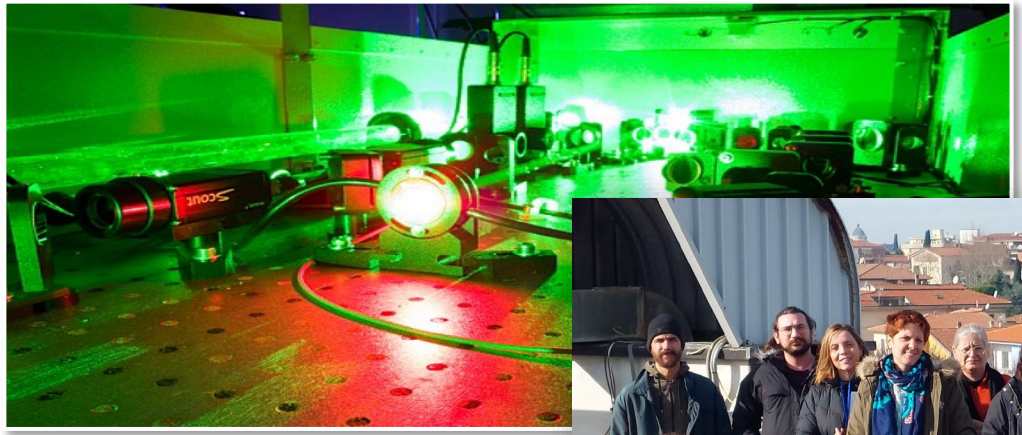
Simon VLACHOS (PhD)
Federico AVELLA (PhD)
Gianluca CELLAMARE (Associate)

Intense Laser Irradiation Laboratory

Istituto Nazionale di Ottica – Consiglio Nazionale delle Ricerche



http://www.ilil.ino.it

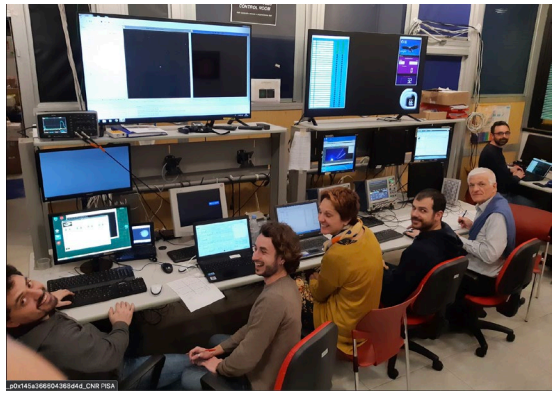
CNR-INO ISTITUTO NAZIONALE DI OTTICA CONSIGLIO NAZIONALE DELLE RICERCHE

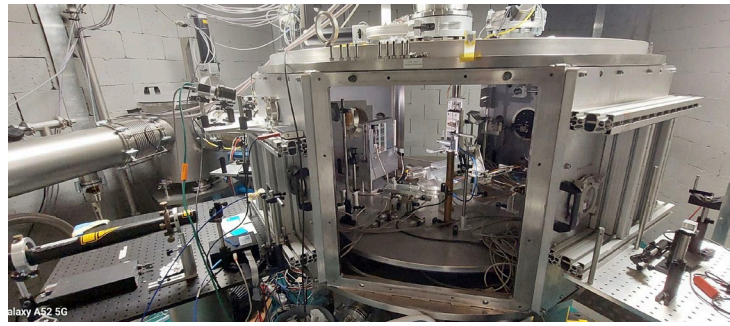
The *Intense Laser Irradiation Laboratory (ILIL)*

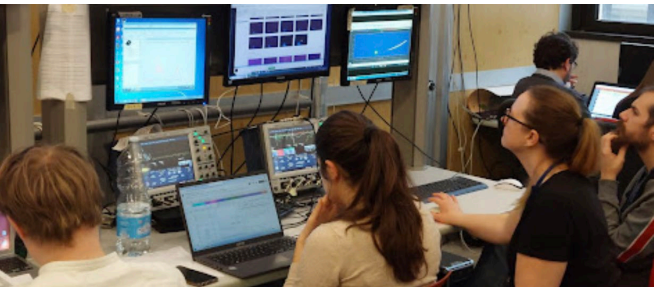
Funded by the European Union

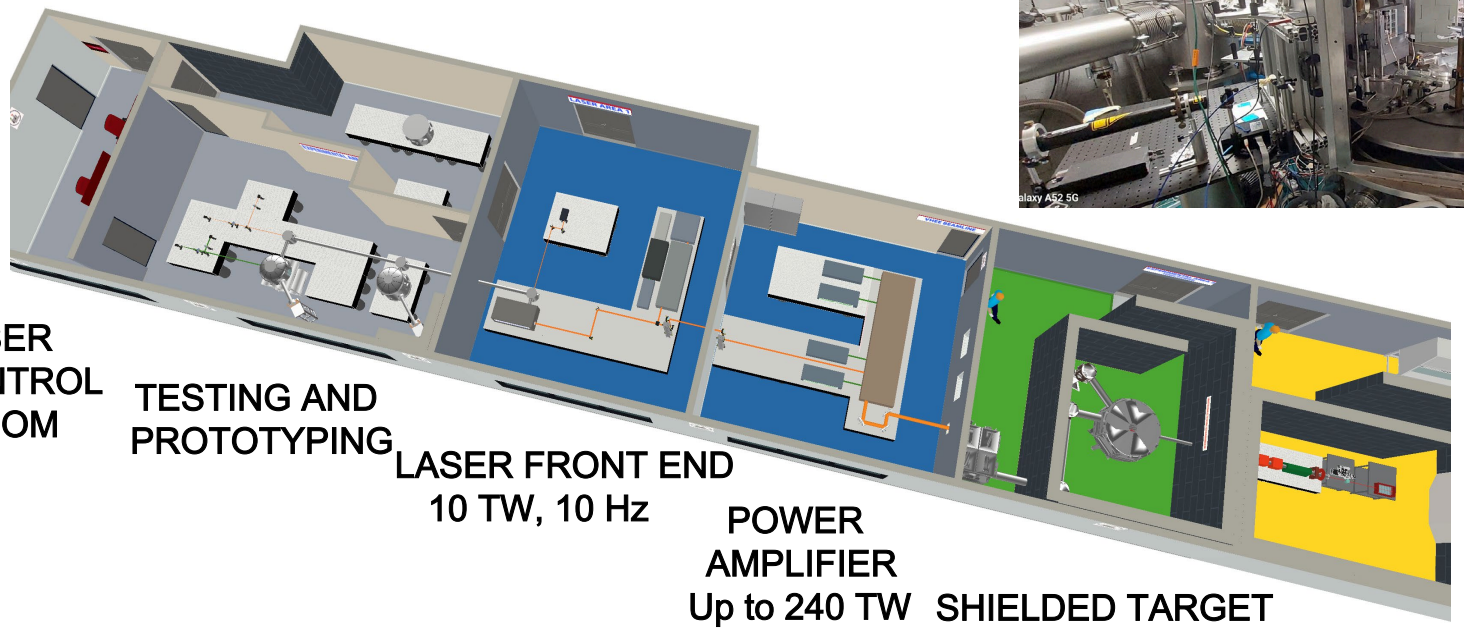
LASER CAPABILITIES:

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



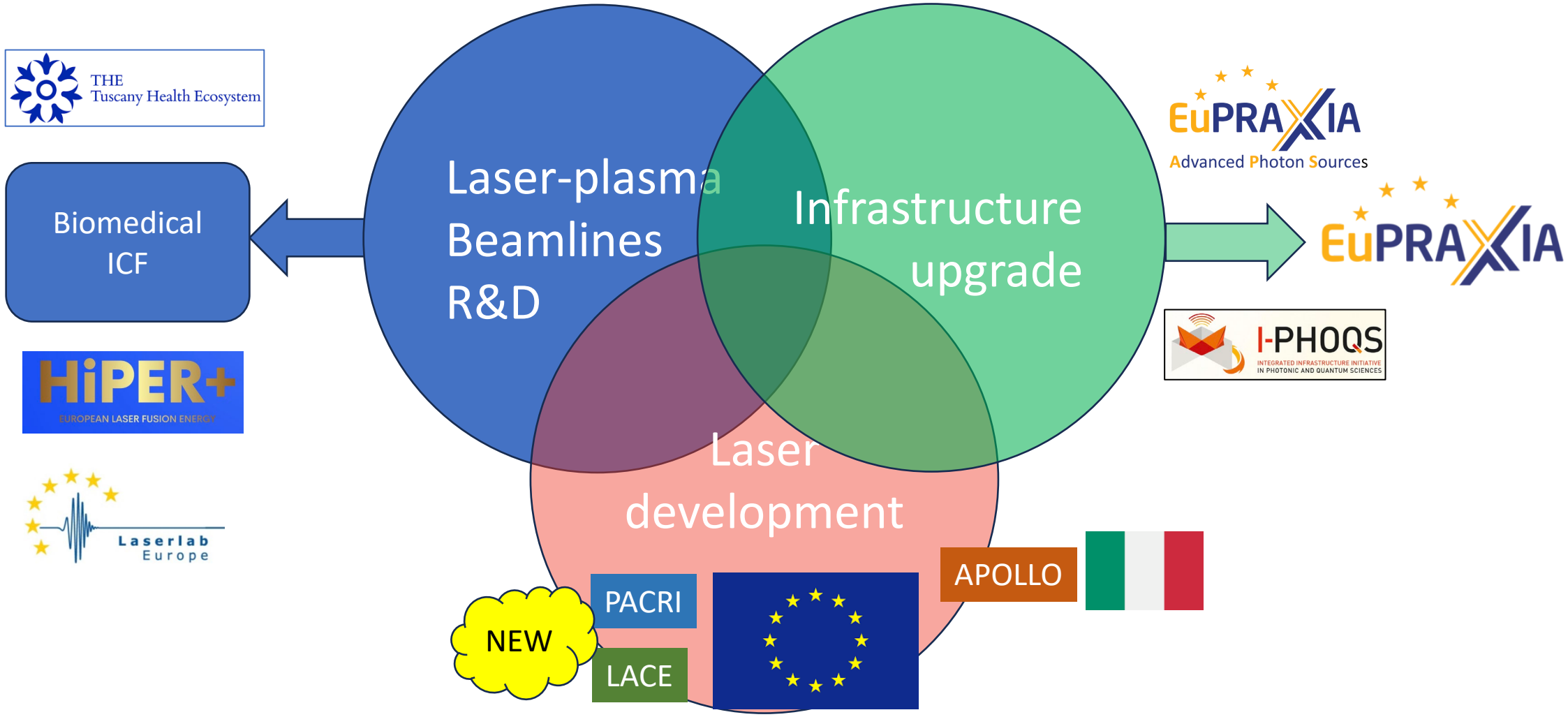






MAIN ACTIVITIES

Funded by the European Union



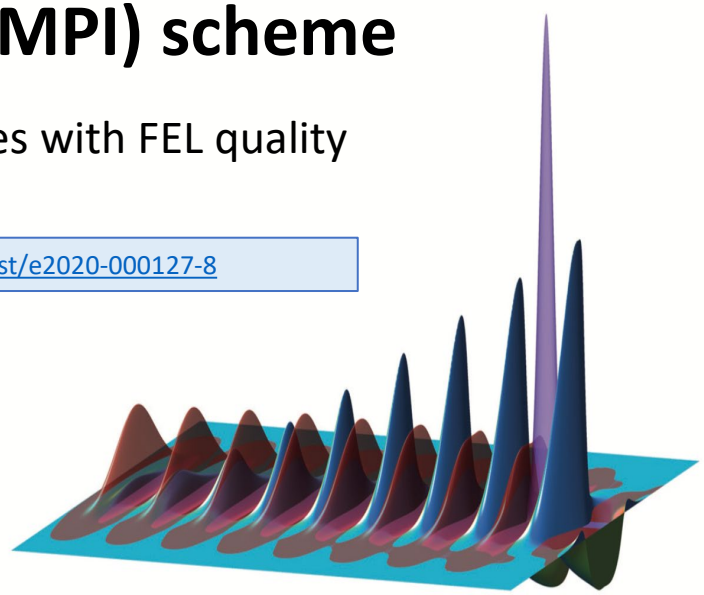
Funded by the European Union

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

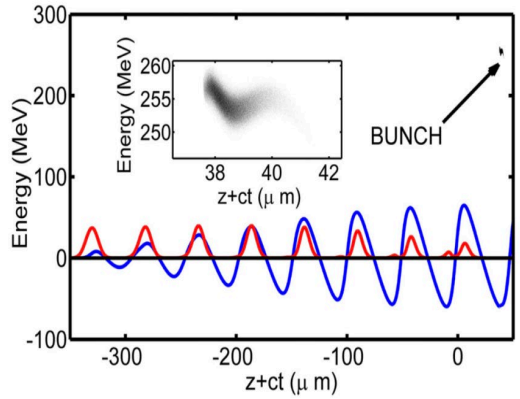
Bunch specifications - GOAL:	dE/E SLICE	ε_n SLICE	Q	I_{peak}
	<0.1%	**<0.1 mm mrad**	>30 pC	>2kA



- 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] P. Tomassini et al., *Physics of Plasmas 24, 103120 (2017)*

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

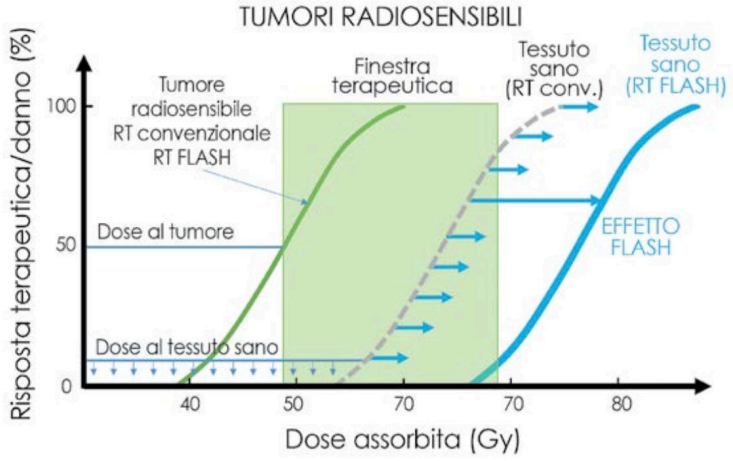


Close collaboration with ELI/P.Tomassini Pin-pointing experimental activity in progress

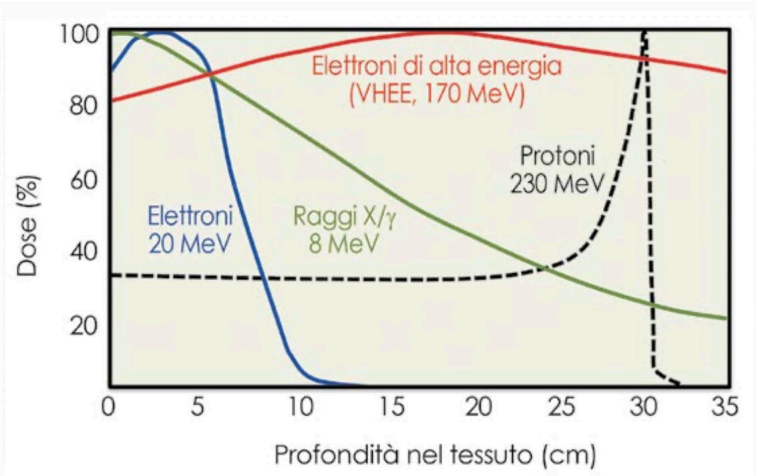
LPA-VHEE BEAM FOR RADIOTHERAPY

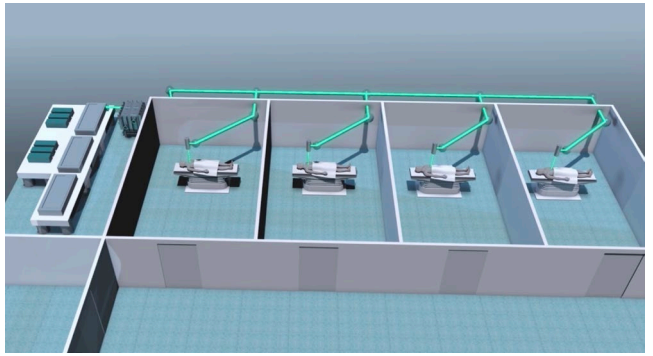
Funded by the European Union

High dose-rate radiobiology and the “FLASH effect”



V. Favaudon et al., *Science Translational Medicine* **6**, 245ra93 (2014)

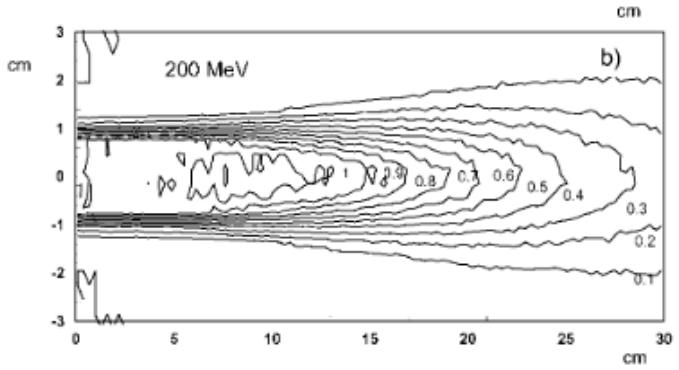




VHEE beams

- Same therapeutic effect on tumor tissue
- Sparing of healthy tisssue

Flash: dose to be delivered in a very short time <200 ms (to date)

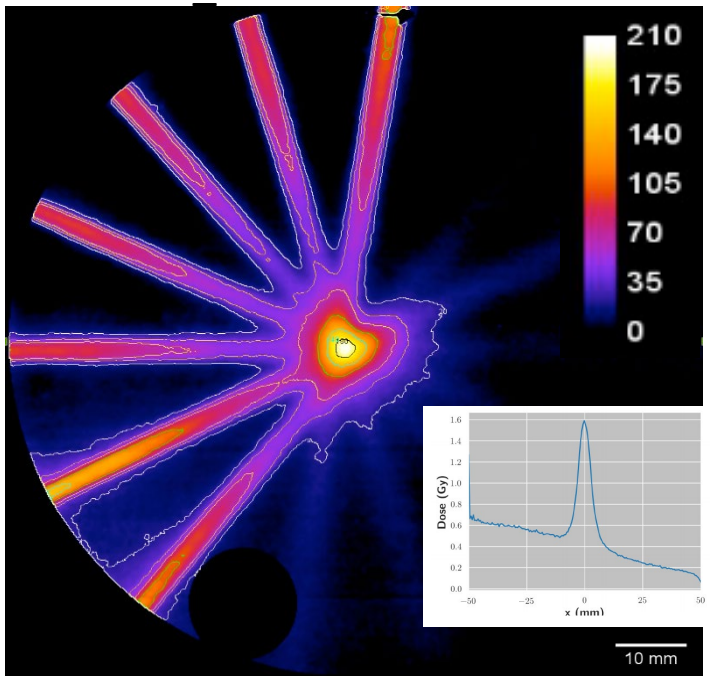


[1] C DesRosiers *et al* 2000 *Phys. Med. Biol.* **45** 1781,

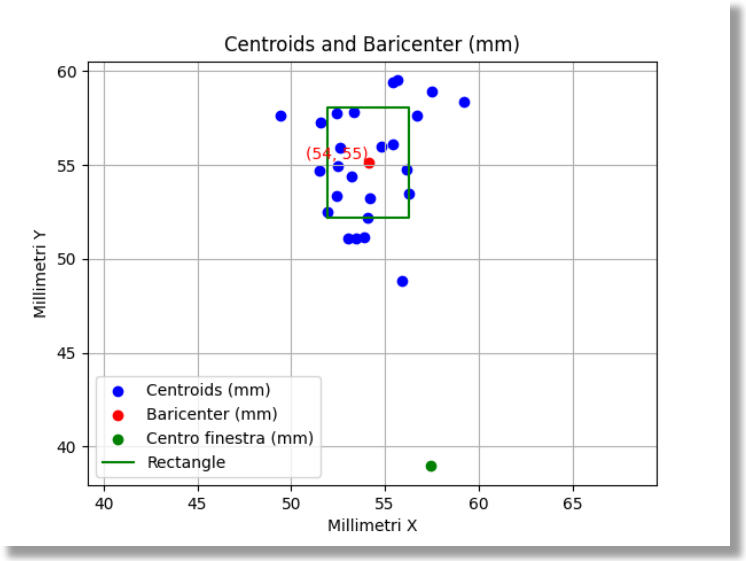
R&D for VHEE-RT beam: compliance

Funded by the European Union

MULTI_FIELD - 7-Fields irradiation



- **Increasing charge** and **focusing** can enable single pulse dose in the pencil beam at a few Gy per shot, very valuable for fundamental studies on the FLASH effect



- In perspective, FLASH-RT needs therapeutic doses **(tens of Gy)** in a short time (**in 200 ms)**
- This is challenging for all accelerators (including RF): LPA needs high repetition rate (kHz)

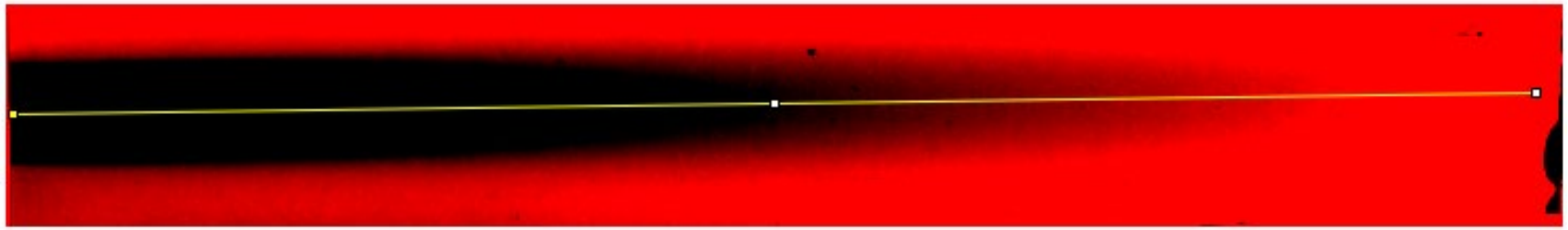
"THE" Tuscany Health Ecosystem

Also in: FRIDA (CSN5)

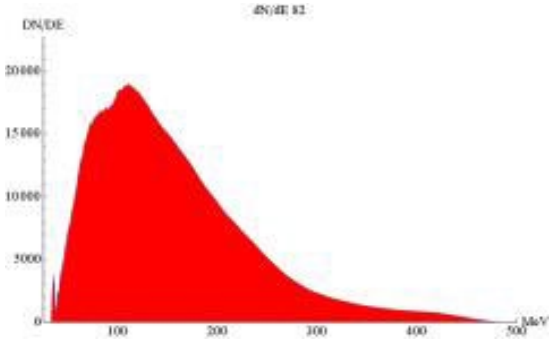
L. Labate et al., Scientific Reports 10, 17307 (2020)
A. Borghini et al., *Int. J. Mol. Sci. 25*(5), 2546 (2024)
C. Panaino et al., Phys. Med. Biol, (2024), Submitted

R&D for VHEE-RT beam: dosimetry

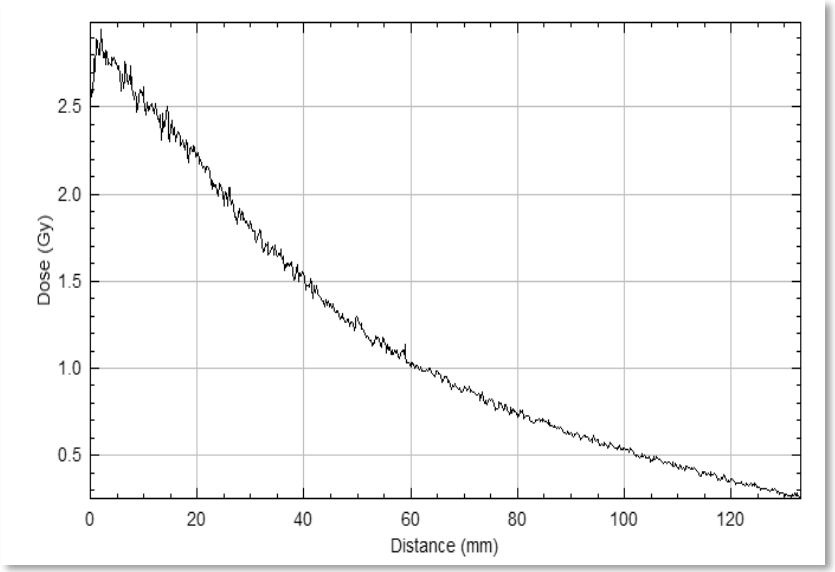
Funded by the European Union



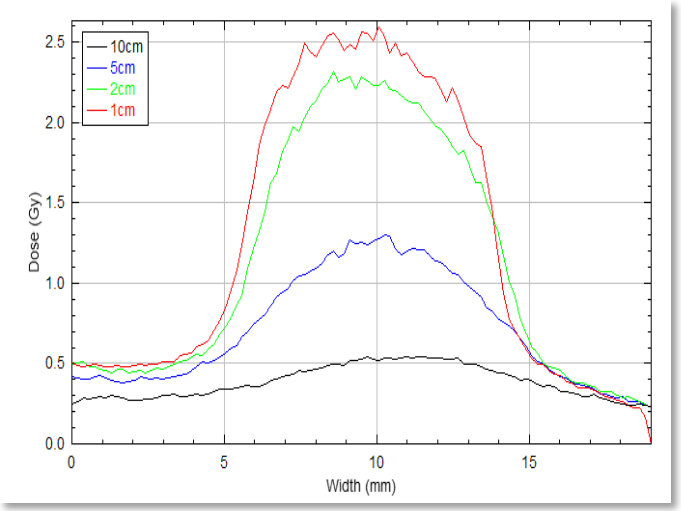
Longitudinal dose profile



Energy spectrum



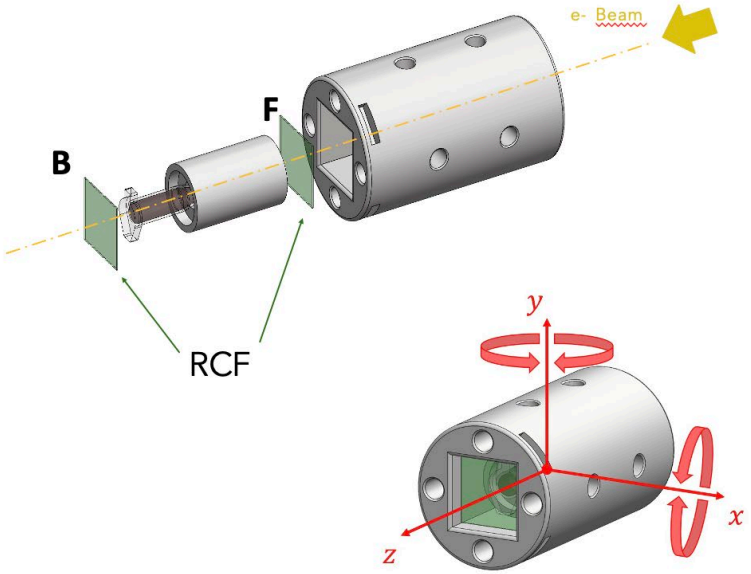
Transverse dose profile

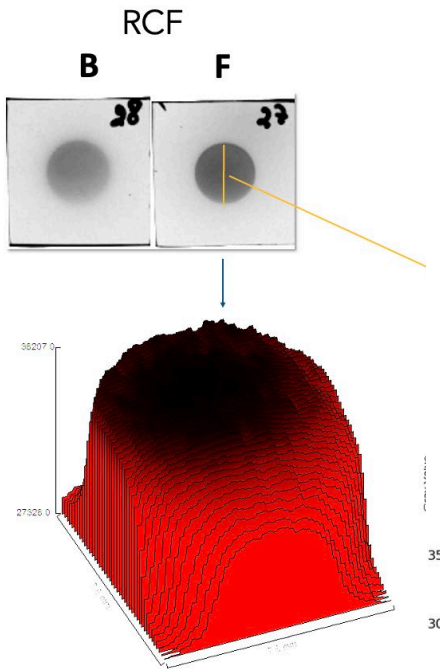


L. Labate et al., Scientific Reports 10, 17307 (2020)
A. Borghini et al., *Int. J. Mol. Sci. 25*(5), 2546 (2024)
C. Panaino et al., Phys. Med. Biol, (2024), Submitted

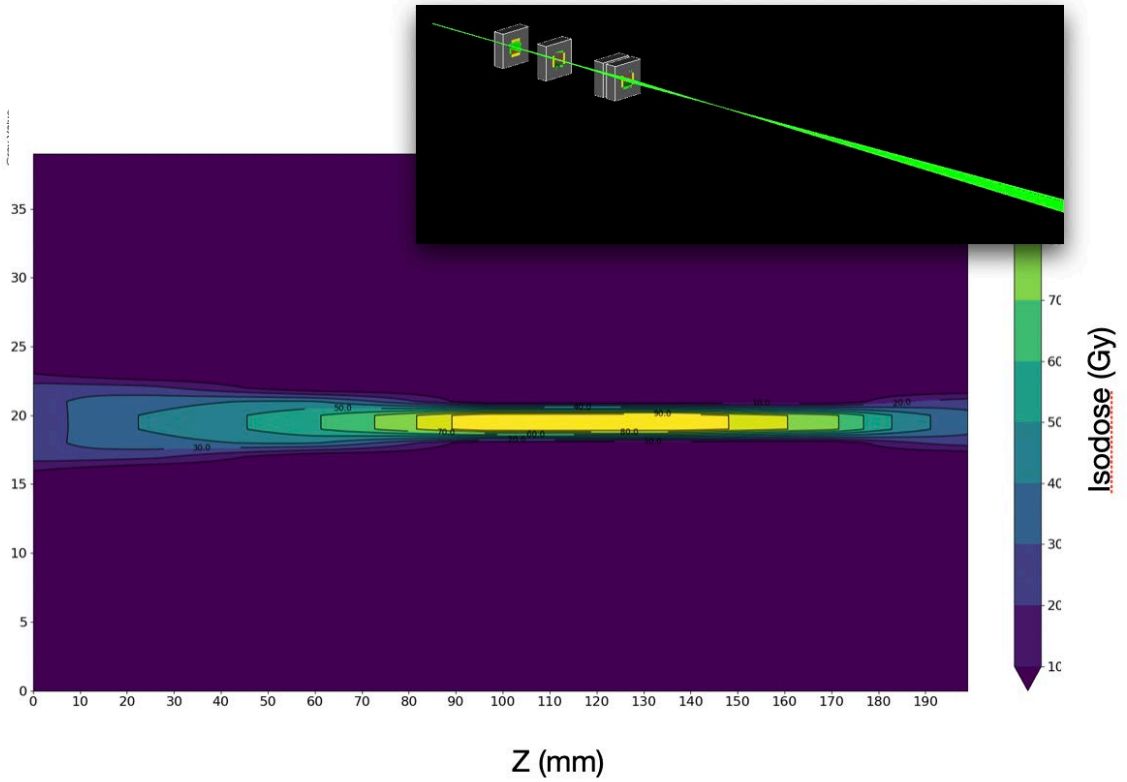
R&D for VHEE-RT beam: on sample

Funded by the European Union





Beam transport modelling



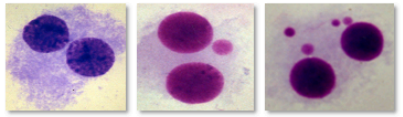
L. Labate et al., Scientific Reports 10, 17307 (2020)
A. Borghini et al., *Int. J. Mol. Sci. 25*(5), 2546 (2024)
C. Panaino et al., Phys. Med. Biol, (2024), Submitted

R&D for VHEE-RT beam: radiobiological validation

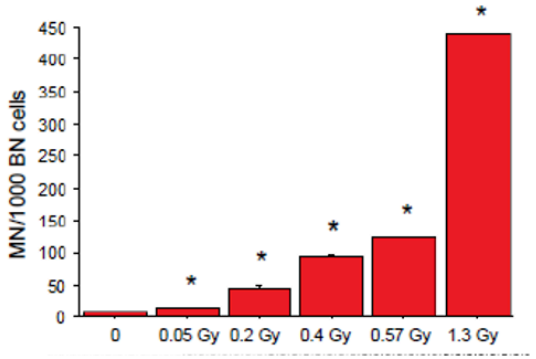
Funded by the European Union

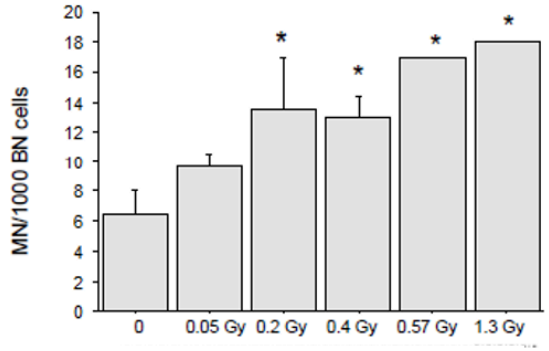
Biological endpoints

Micronucleus Assay



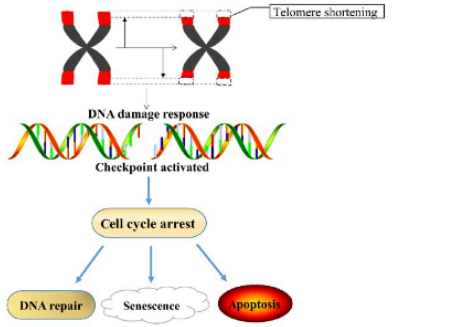
Targeted effect



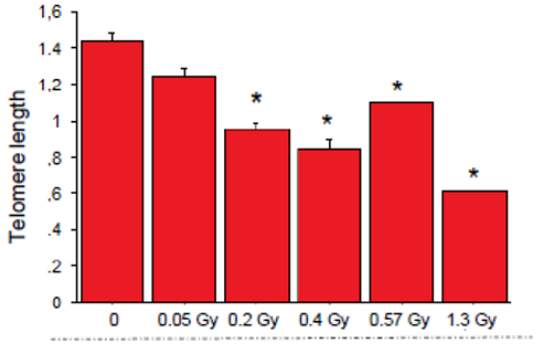


Bystander effect

Telomere Shortening



G. Wang et al DOI:10.3892/ol.2021.12757



Targeted effect

* All p<0.05 vs. control value

L. Labate et al., Scientific Reports 10, 17307 (2020)
A. Borghini et al., *Int. J. Mol. Sci. 25*(5), 2546 (2024)
C. Panaino et al., Phys. Med. Biol, (2024), Submitted

Ti:SA laser driver development

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 therma load transport

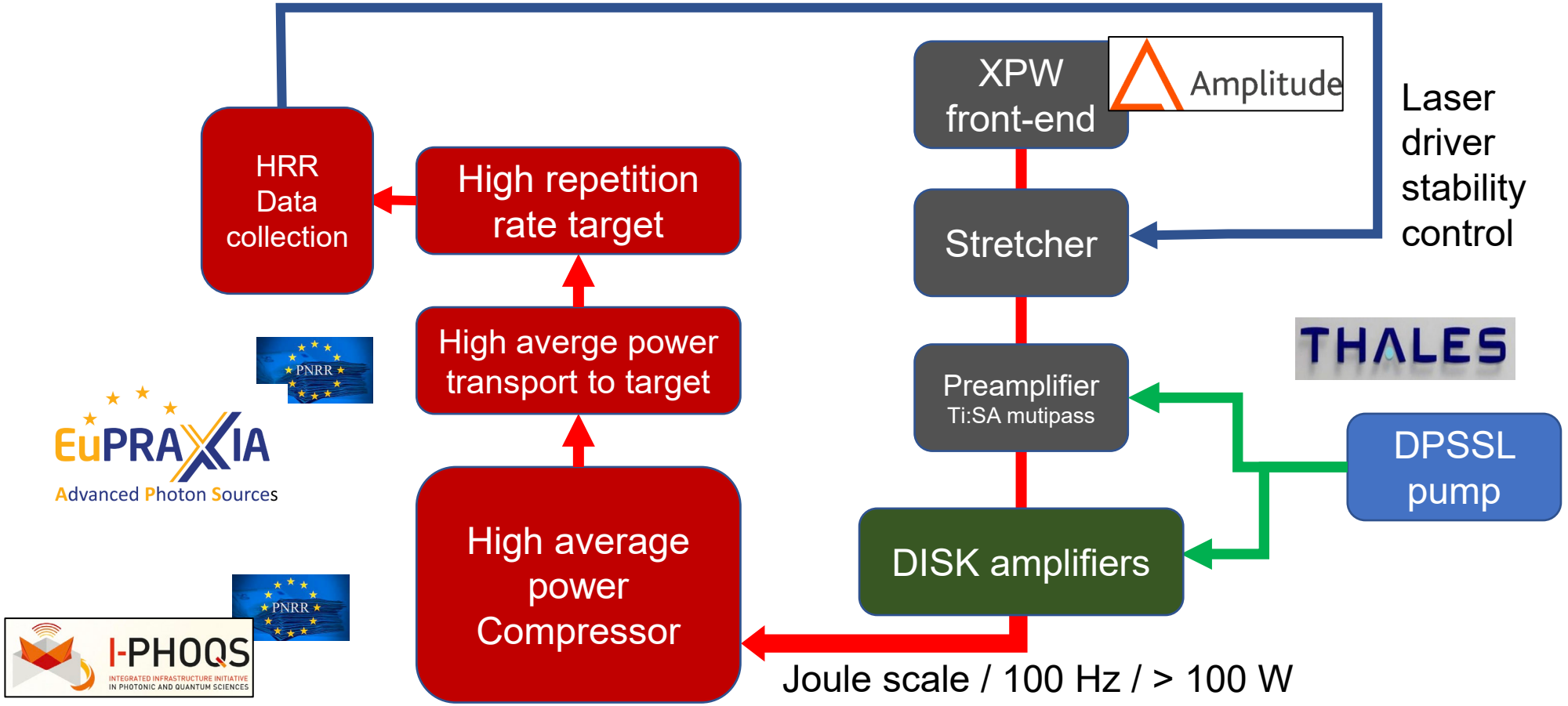
- **EuAPS@CNR-Pisa**
- > 40 TW peak power
- 100 Hz repetition rate
- 100 W average power
- Diode pumped
- Thermal load effects

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

TDR: EuPRAXIA Ti:Sa front-end development *funded*

Funded by the European Union

100 Hz operation at Joule level pulse energy is outstanding and a unique opportunity to address HAP issues



Procurement and preparation in progress

CNR-INO
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CONSIGLIO NAZIONALE DELLE RICERCHE

Funded Laser development in *PACRI*

Funded by the European Union

Scaleup of collaborative TDR development of EuPRAXIA Laser

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

High repetition rate High power Ti:Sa amplifier module — PACRI WP10

↓

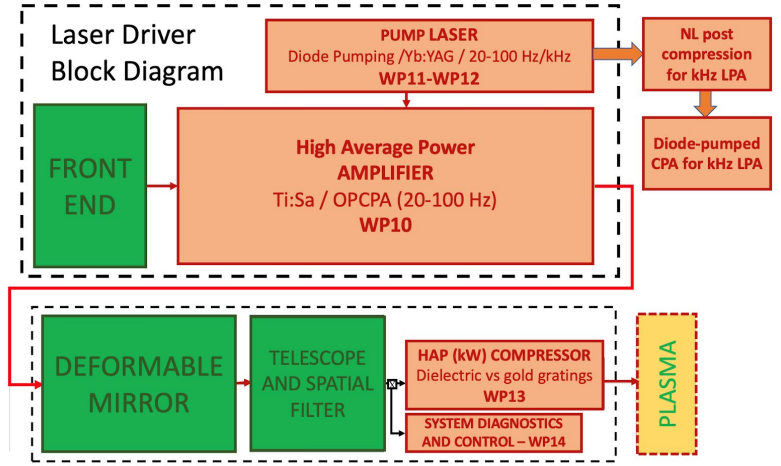
High repetition rate pump sources for laser drivers — PACRI WP12

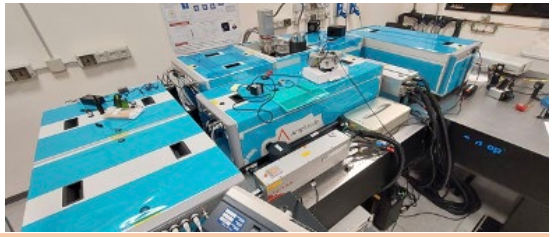
↓

Prototype of High average power optical compressor — PACRI WP13

↓

Laser driver System Architecture, transport and engineering — PACRI WP14





Efficient kHz laser driver modules for plasma acceleration

PACRI WP11

Project PACRI to start on March 1st, 2025

CNRINO Consiglio Nazionale delle Ricerche Istituto Nazionale di Ottica

Amplitude

THALES

UKRI Science and Technology Facilities Council — Central Laser Facility

Leibniz FBH Ferdinand Braun Institut

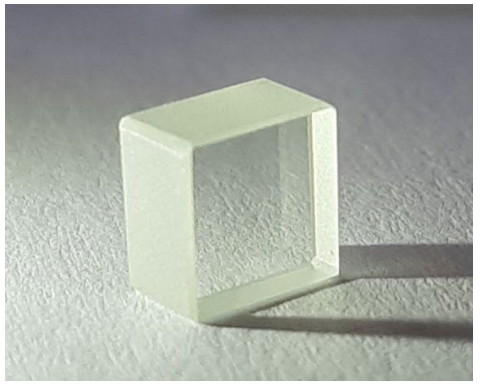
eli

LMU Ludwig-Maximilians-Universität München

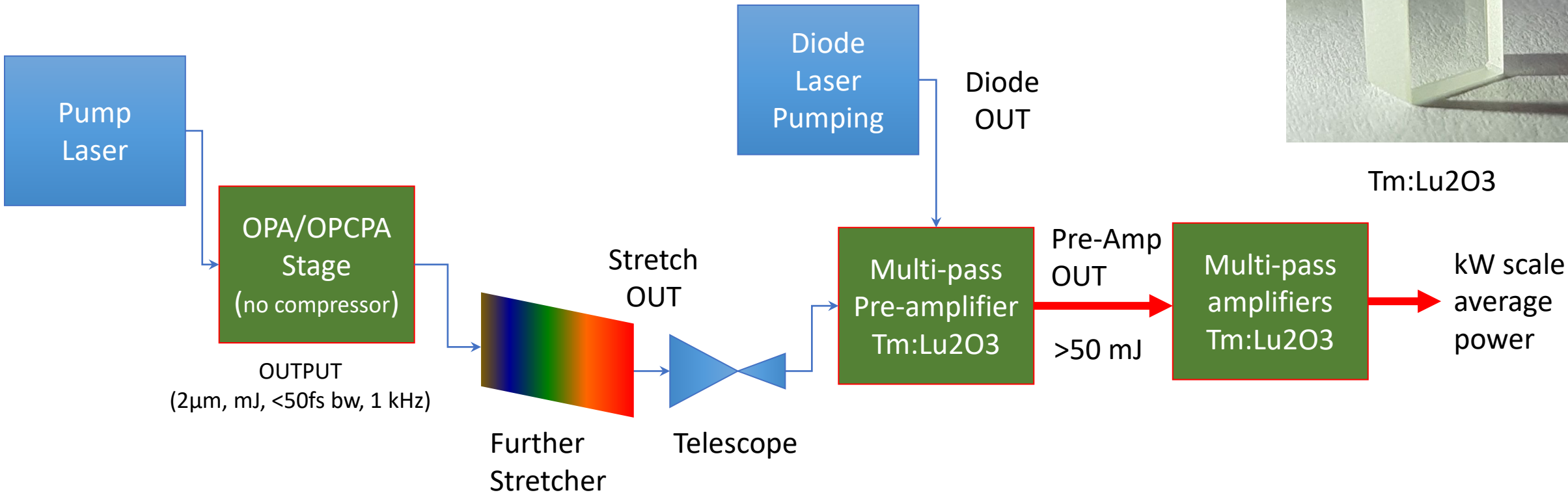
University of Oxford

CLPU Centro de Láseres Pulsados

Development of a new laser platform based on fully diode pumped, Thulium-doped CPA amplifiers



Tm:Lu2O3

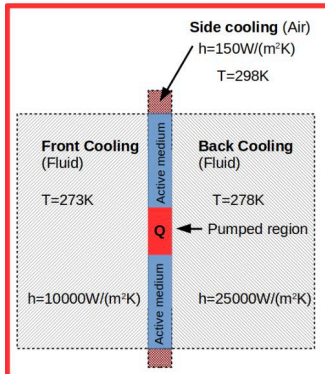


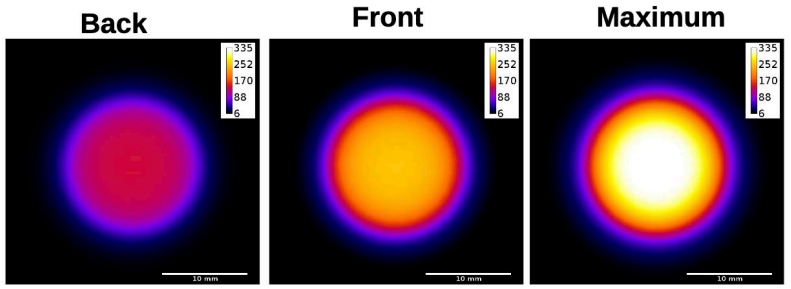
Main development effort in amplifier modules ”Apollo” project

Prototyping of amplifiers

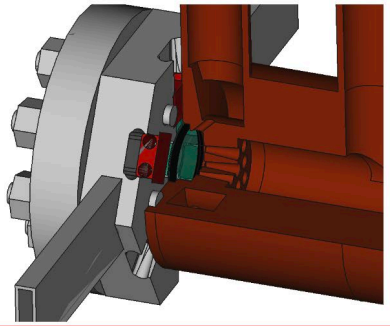
Funded by the European Union

Thermal & Fluid Studies

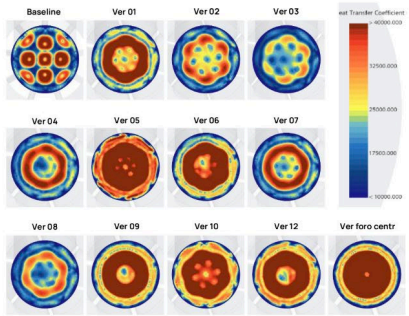




Conceptual Design

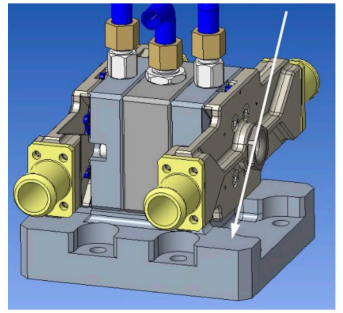


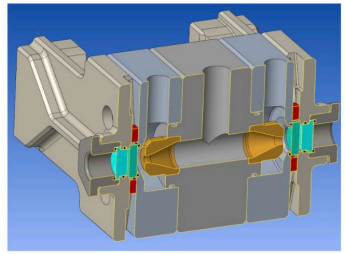
Turbolent Back Cooling

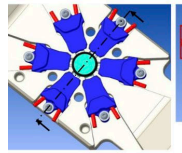


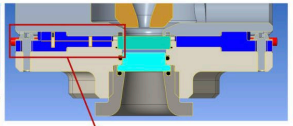
Laminar Front Cooling

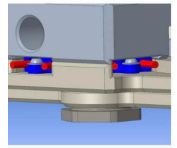
Final Design & Test

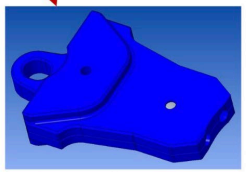




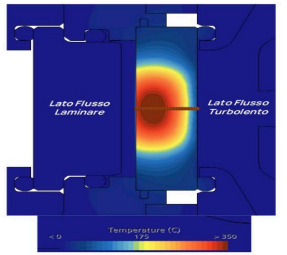


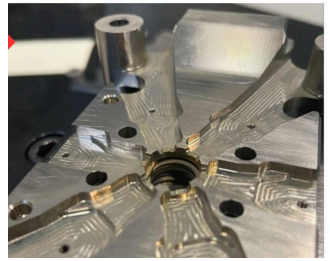


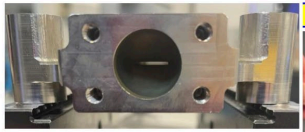


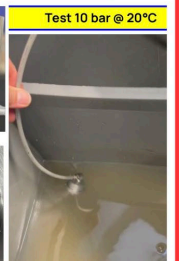


Thermo-fluid dynamic simulations





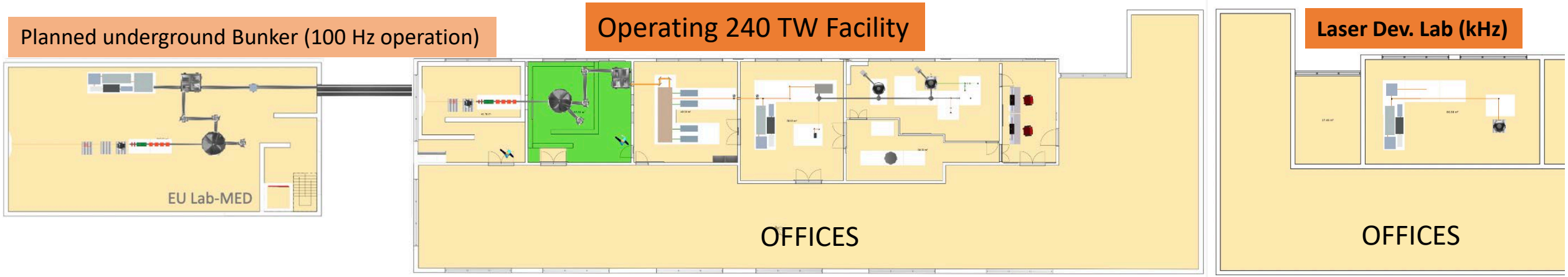




Next step: thermomechanical tests

ONGOING INFRASTRUCTURE DEVELOPMENTS

Funded by the European Union



ONGOING:

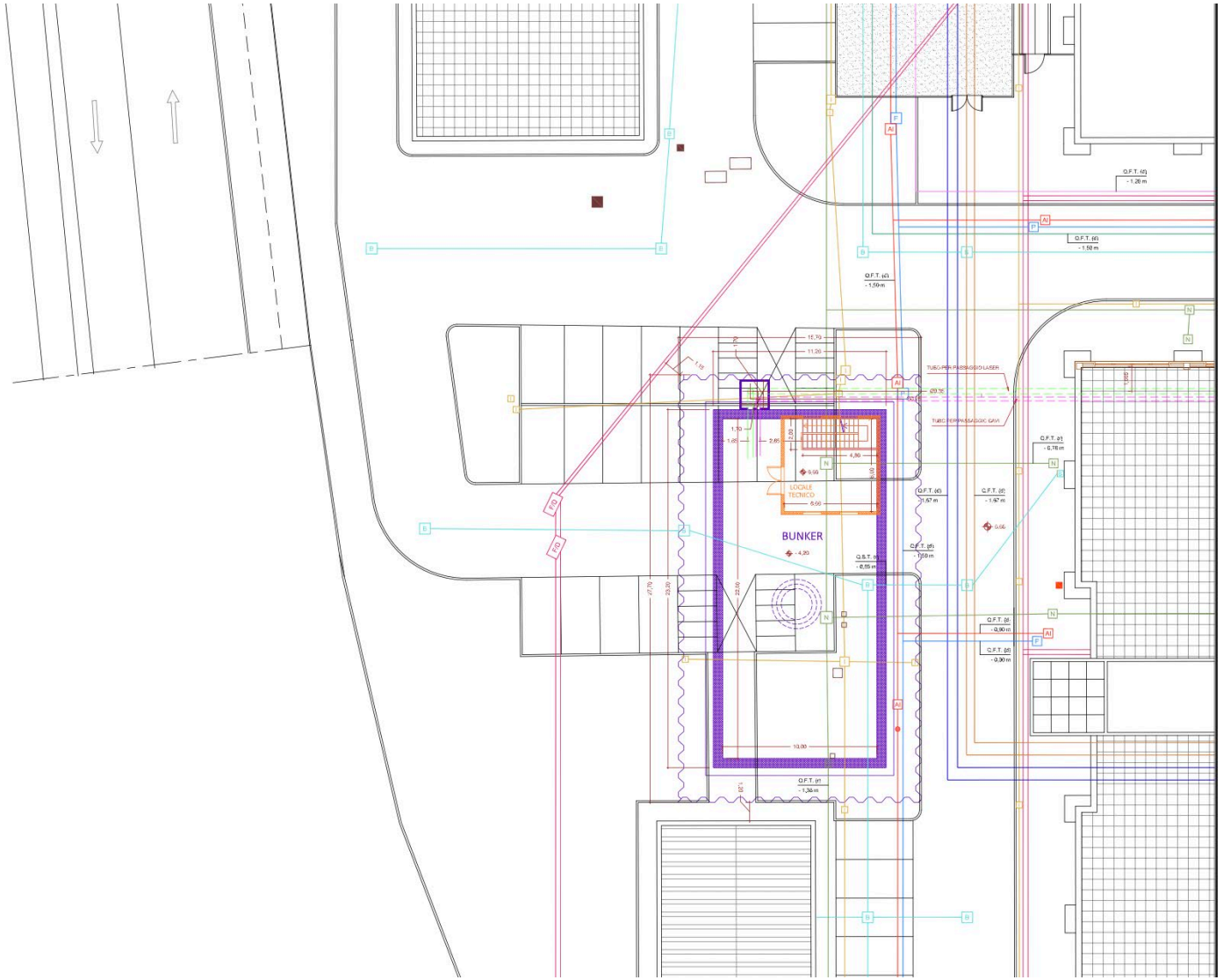
1. Upgrade of existing laser system (240 TW) for enhanced stability and control (100 Hz front-end)
2. New laser systems for high repetition rate operation (100 Hz-1J, 1kHz-20 mJ)
3. New Infrastructure develompent for user access to beamlines

Part of :

Part of :

Strong link with

UNDERGROUNG BUNKER



New layout finalized.
Now engaging tendering process for construction

Full 2nd site development

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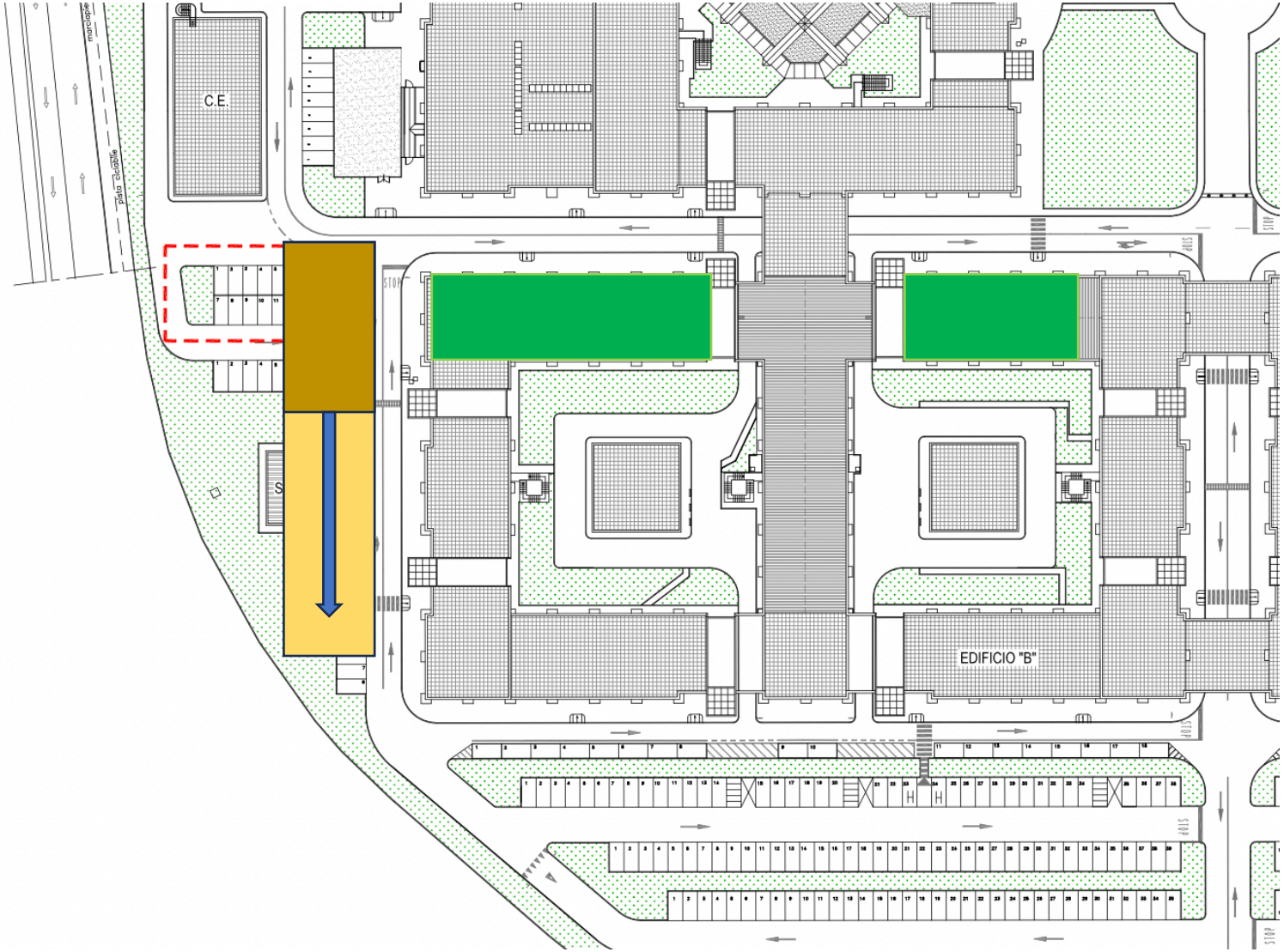
New layout: further extension of underground bunker is now possible



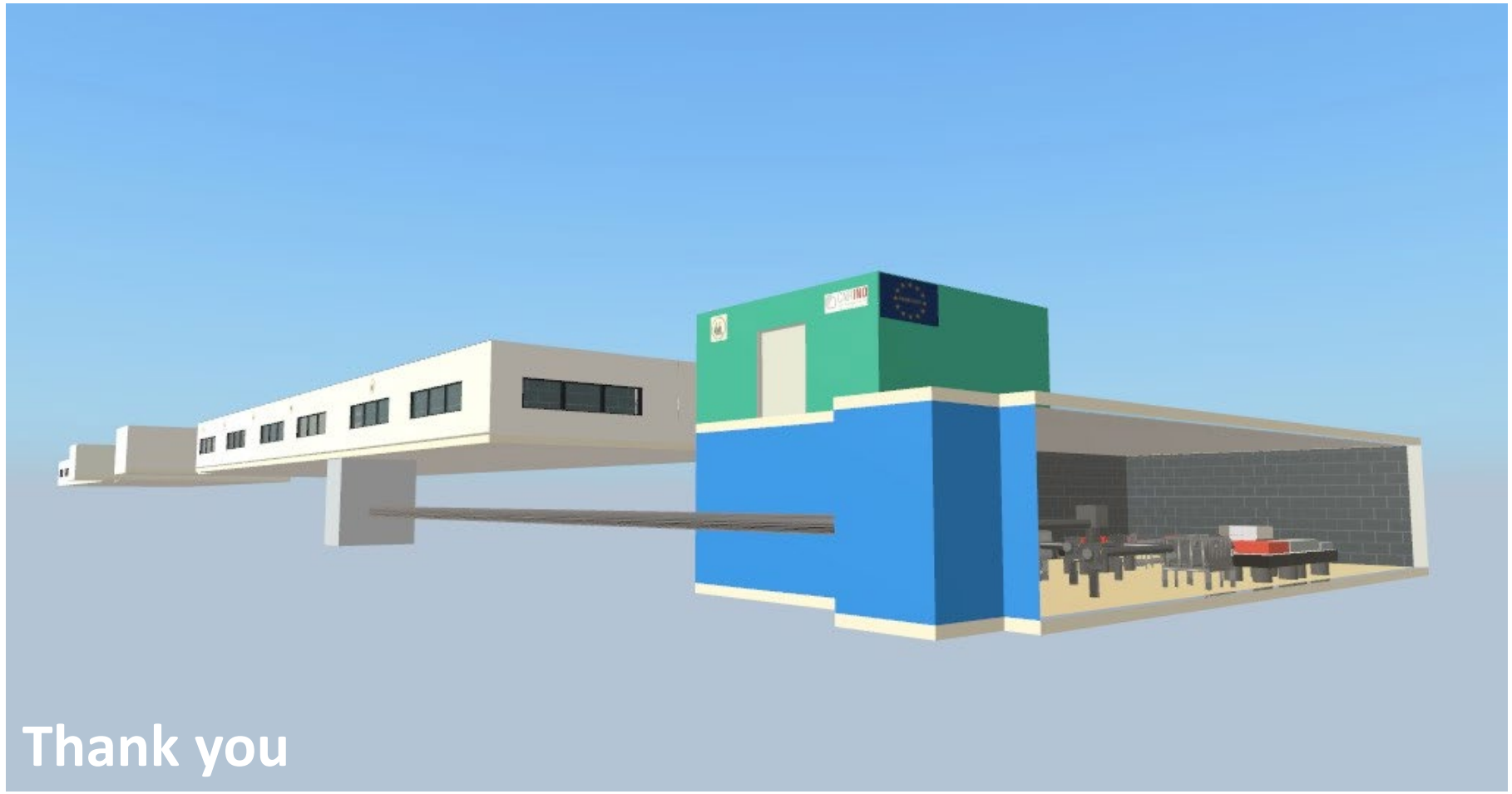
Summary

Funded by the European Union

- Building the 2nd site case on scientific and technological development;
- Following the success of the PP and the significant additional funding from new proposals, higher level support is emerging;
  - National (PNRR) RI are speeding up the establishment of the national cooperation and infrastructure upgrade;
  - CNR headquarters have been engaged with positive feedback;
  - Higher level (ministerial) engagement on hold for discussion on ET.

THE END

Funded by the European Union



THE Tuscany Health Ecosystem

EuPRAXIA Advanced Photon Source

I-PHOQS INTEGRATED INFRASTRUCTURE INITIATIVE IN PHOTONIC AND QUANTUM SCIENCES