EuPRAXIA Project - Scientific Context

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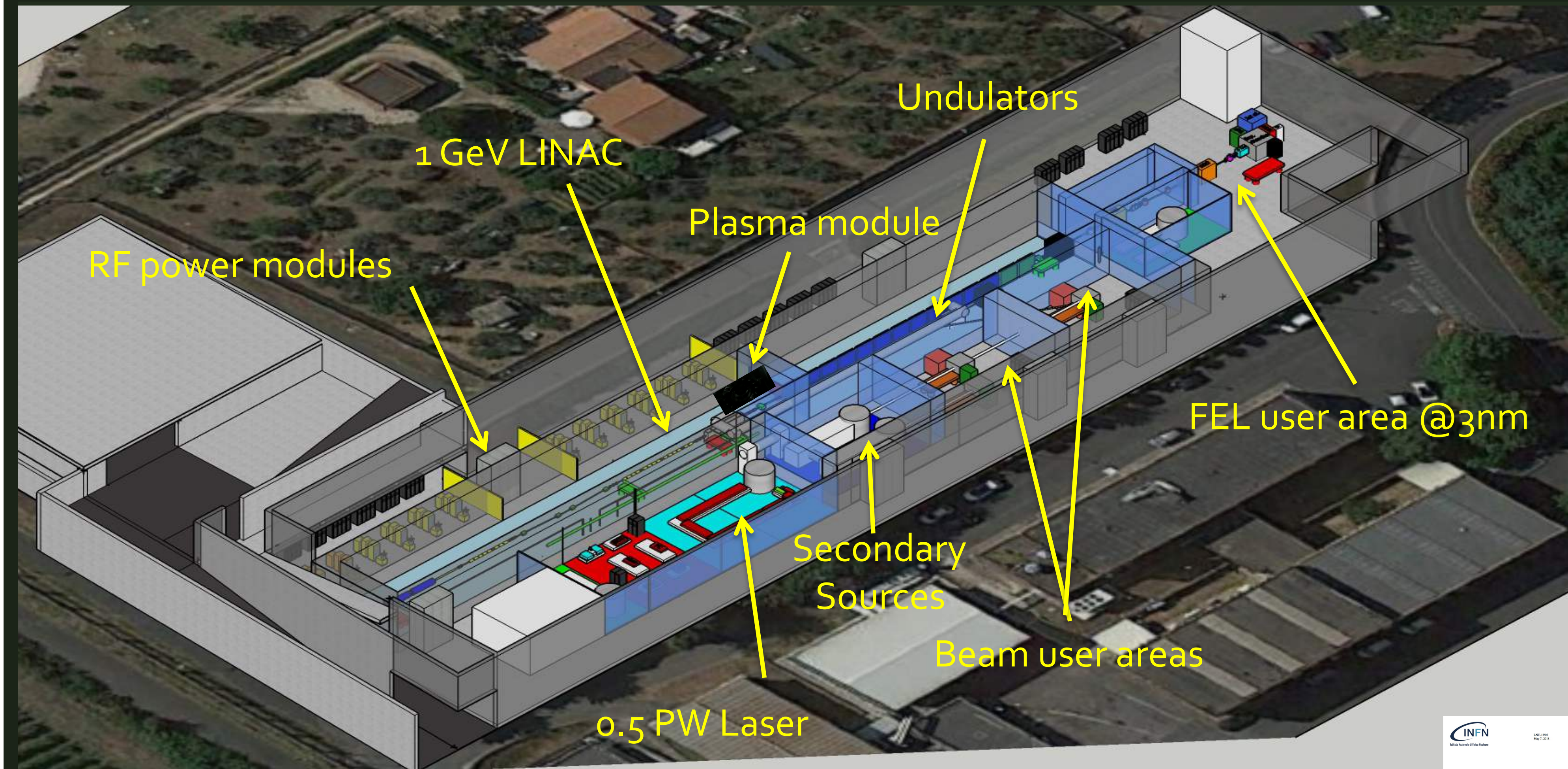
EuPRAXIA@SPARC_LAB



http://www.lnf.infn.it/sis/preprint/pdf/getfile.php?filename=INFN-18-03-LNF.pdf

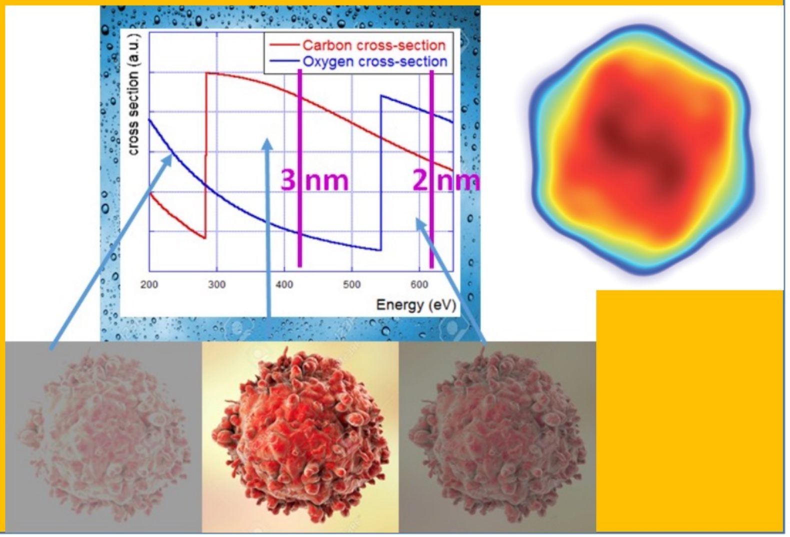
AQUA - Techniques & Samples @ 3 nm

Scientific case assembled and published.
Contributions from >15 different institutions
Balerna *et al.* Condensed Matter 4, 30 (2019)

Bio & Inorganic Samples

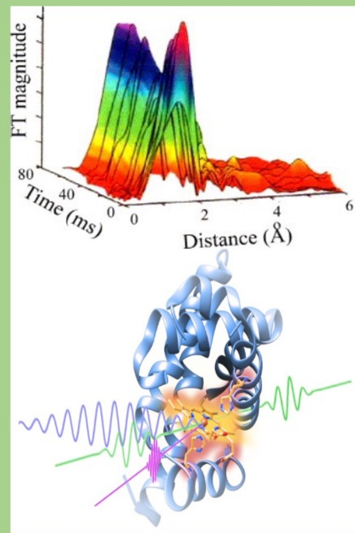
Proteins - Viruses
Bacteria- Cells
Metals – Magnetic materials
Superconductors -Semiconductors

Coherent imaging



X-ray absorption spectroscopy

Raman spectroscopy



ARIA - Techniques & Samples @ 50-180 nm

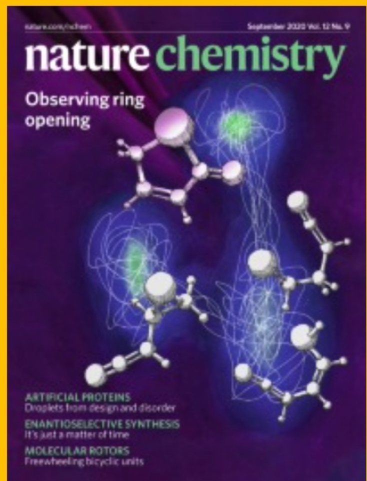
Scientific case in the DUV (DeepUV) and VUV (VacuumUV) is being assembled
Wavelength interval **complementary** with FEL1 @ Fermi

Samples & (techniques)

Gas phase & Atmosphere (Earth & Planets)
Aerosols (Pollution, nanoparticles)
Molecules & gases (spectroscopies, time-of-flight)
Proteins (spectroscopies)
Surfaces (ablation e deposition)

Photoemission Spectroscopy

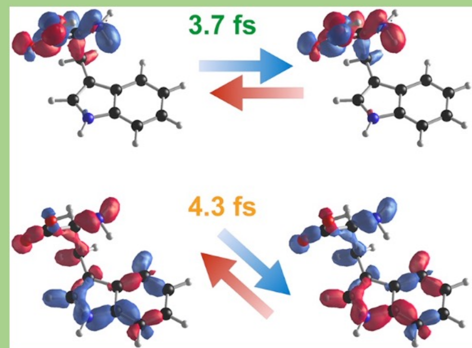
Ring opening in organic molecules
Pathak *et al. Nature Chemistry* 2020



Raman spectroscopy

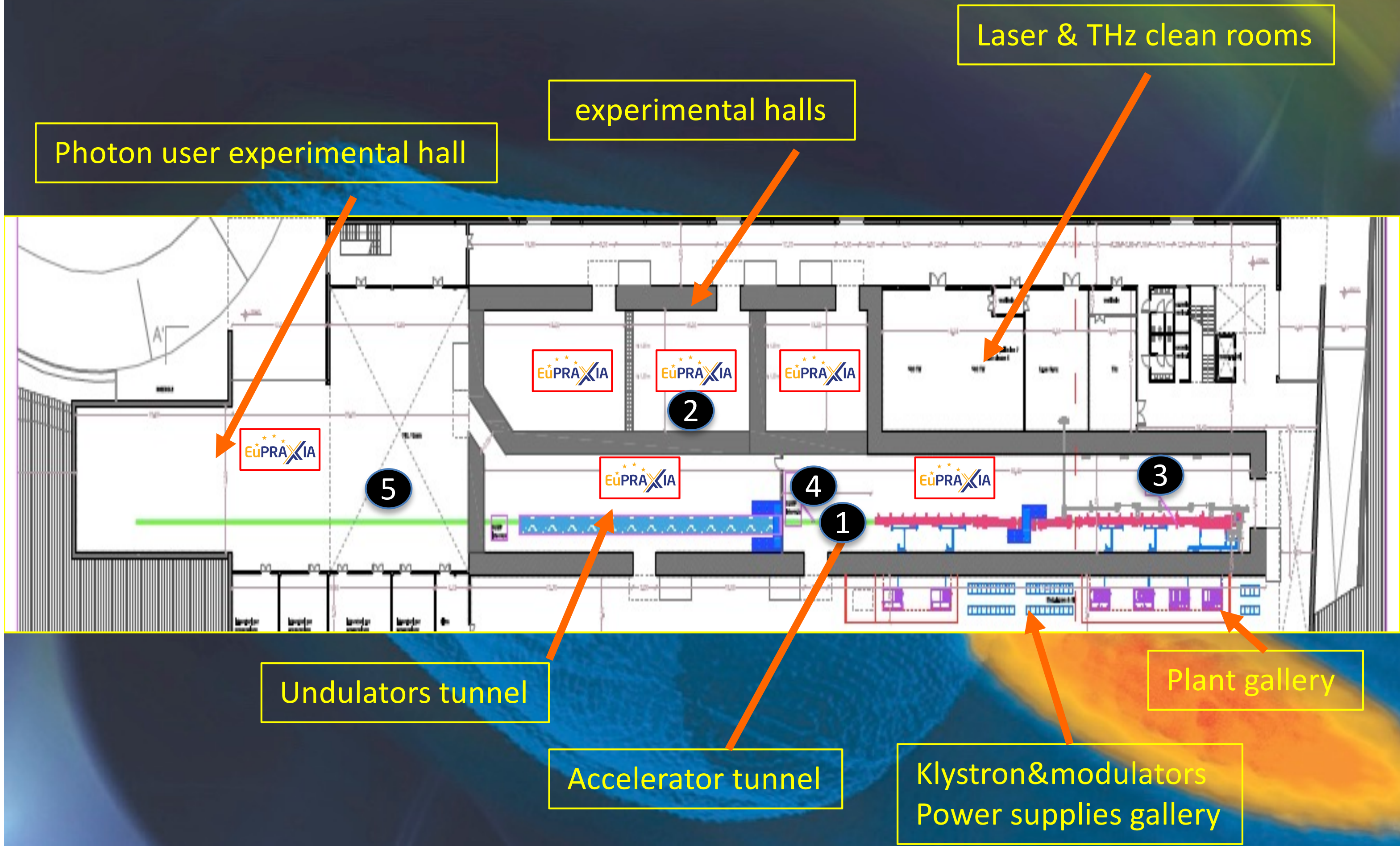
Photo-fragmentation of molecules

Ultrafast Quantum Interference in the Charge Migration of Tryptophan.
J Phys Chem Lett 2020



Time of Flight Spectroscopy

Opportunities for Collaborations at EuPRAXIA@SPARC_LAB



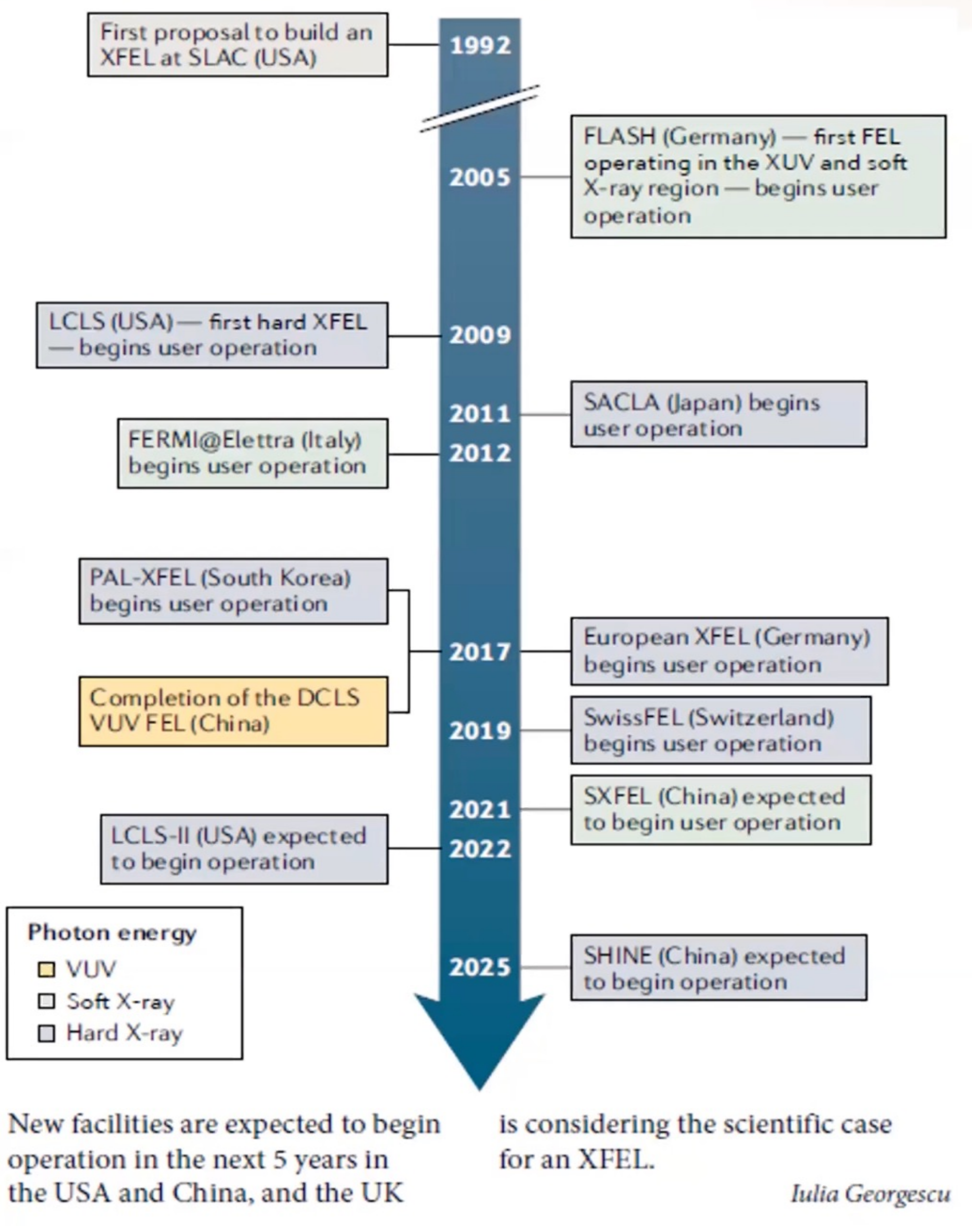
European interests & possible contributions to Frascati site:

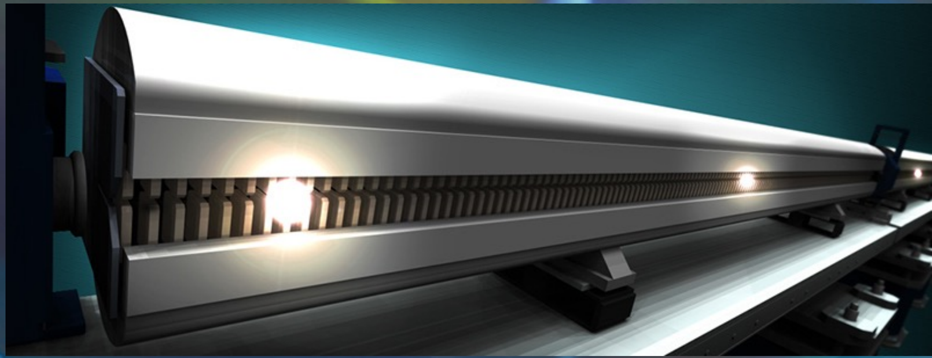
1. Plasma structure designs, devices
2. Compact positron source
3. HQ 150 MeV laser plasma injector
4. HQ laser driver
   - Hybrid concepts
   - Simulations
5. User experiments and lines

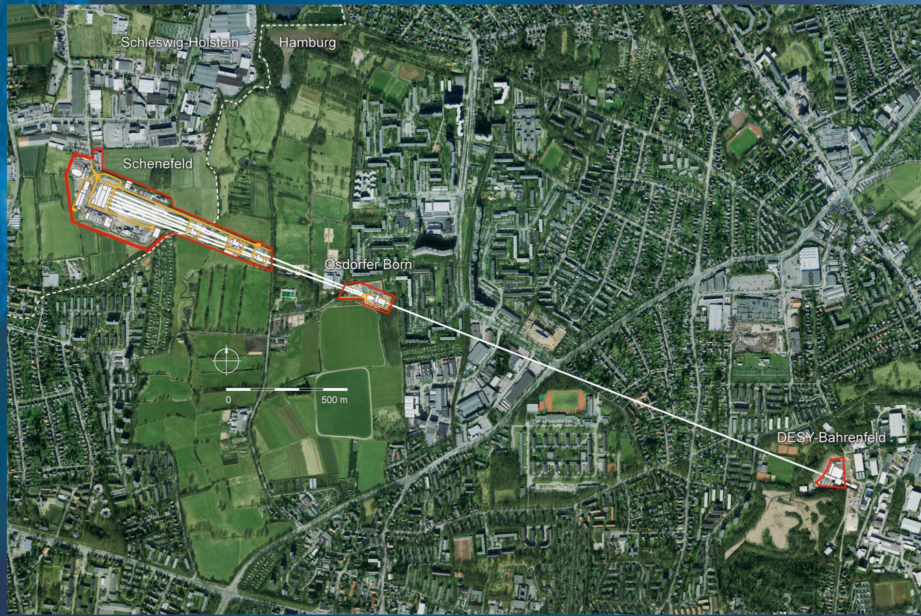
To be detailed in TDR phase.

FEL is a well established technology

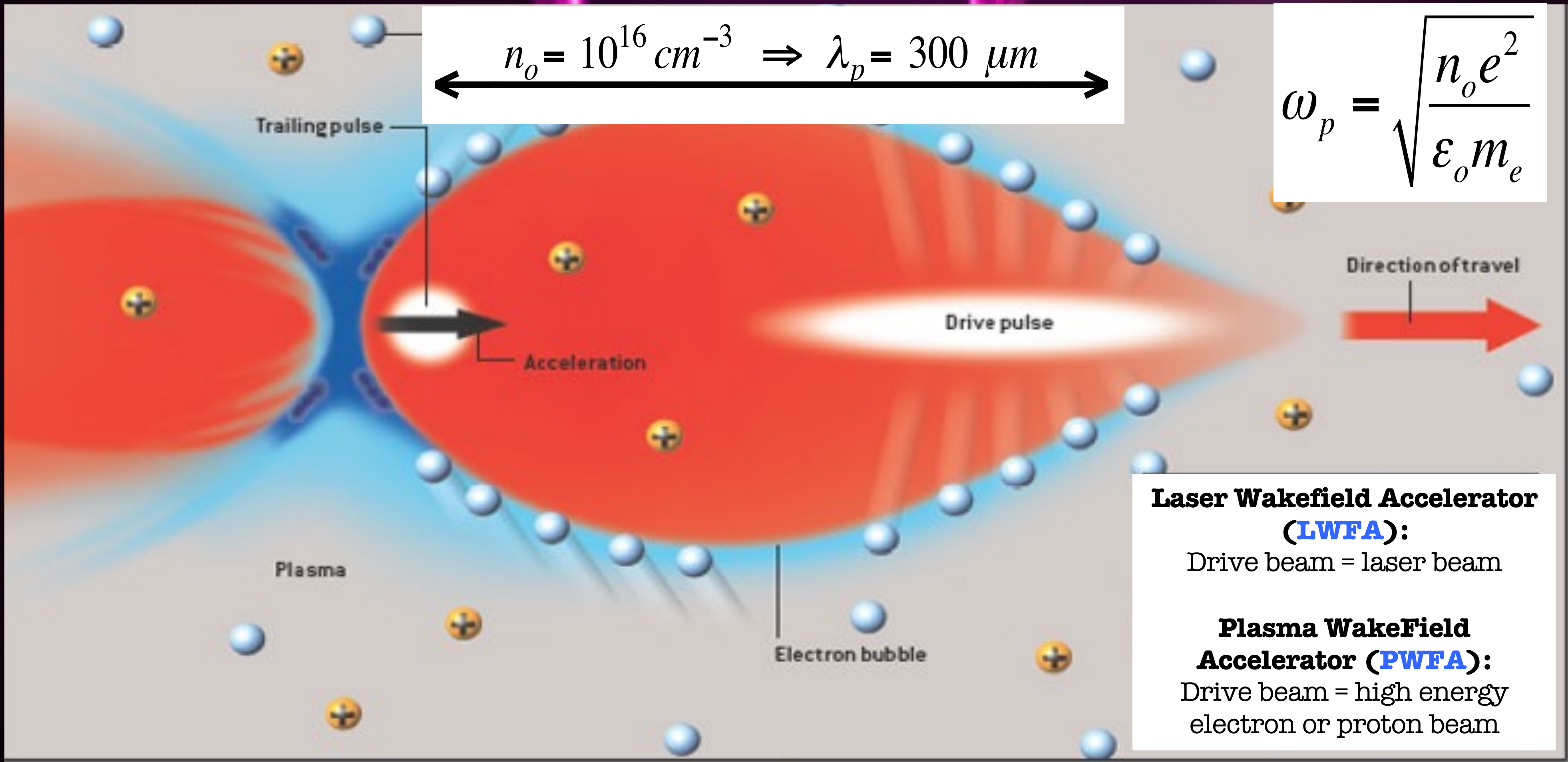
(But a widespread use of FEL is partially limited by size and costs)







Principle of plasma acceleration



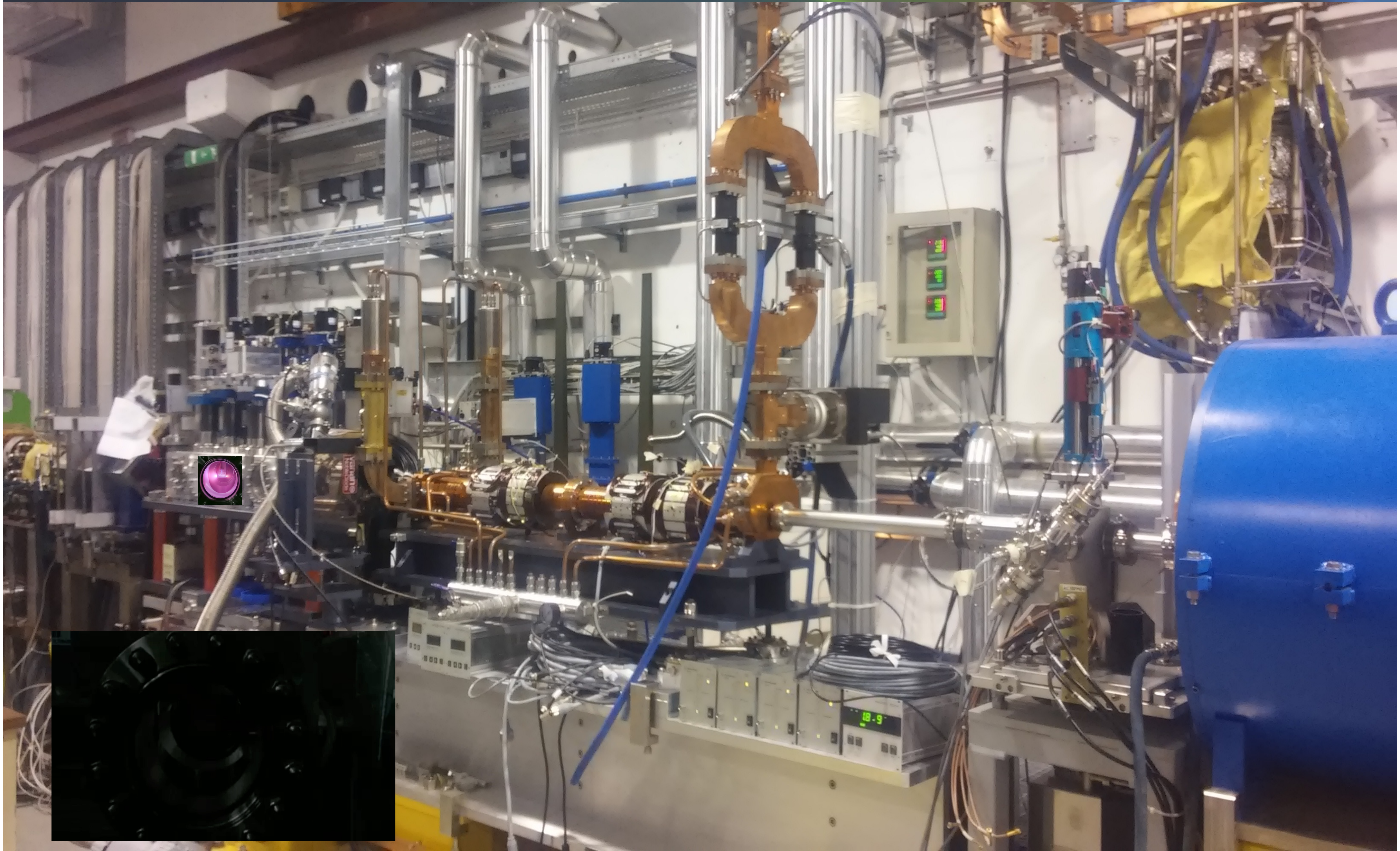
$$n_o = 10^{16}\ cm^{-3} \Rightarrow \lambda_p = 300\ \mu m$$

$$\omega_p = \sqrt{\frac{n_o e^2}{\varepsilon_o m_e}}$$

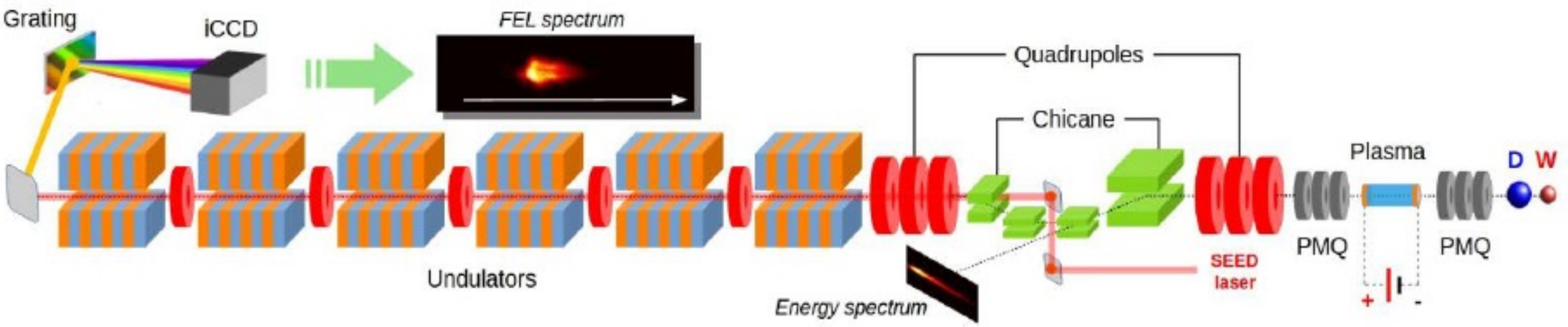
Laser Wakefield Accelerator (LWFA):
Drive beam = laser beam

Plasma WakeField Accelerator (PWFA):
Drive beam = high energy electron or proton beam

PWFA vacuum chamber at SPARC_LAB

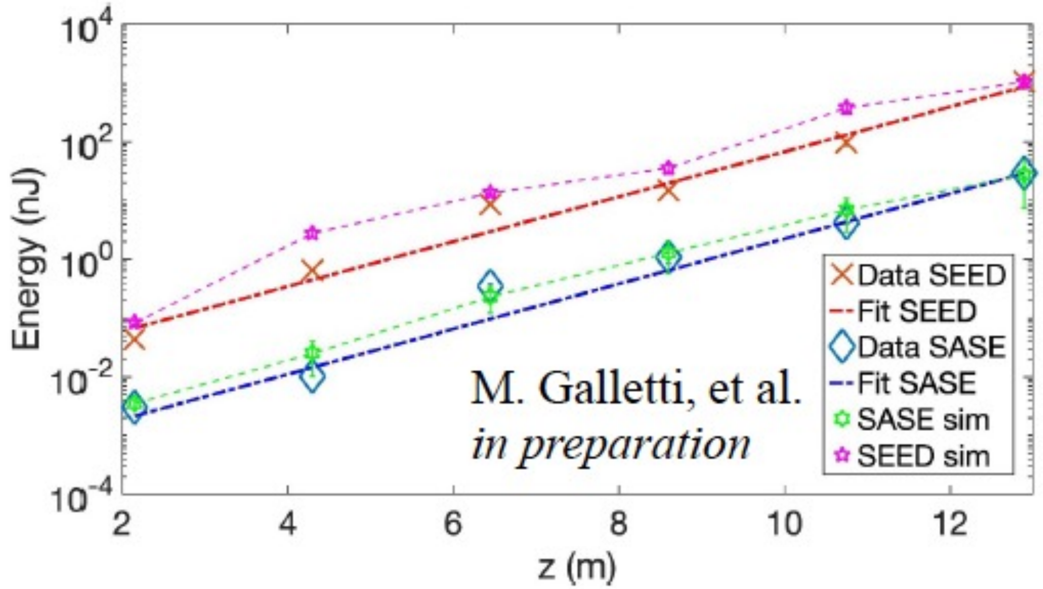


First Beam Driven SEEDED - FEL Lasing at SPARC_LAB (June 2021)

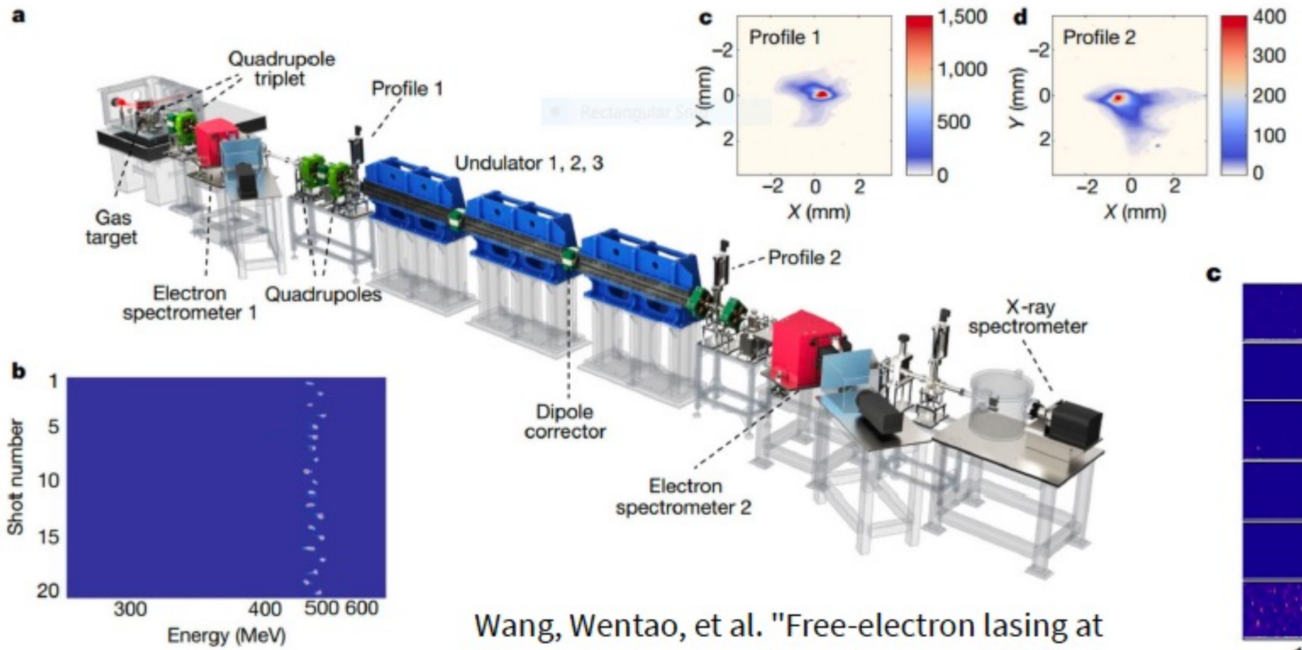


Seeded FEL radiation:

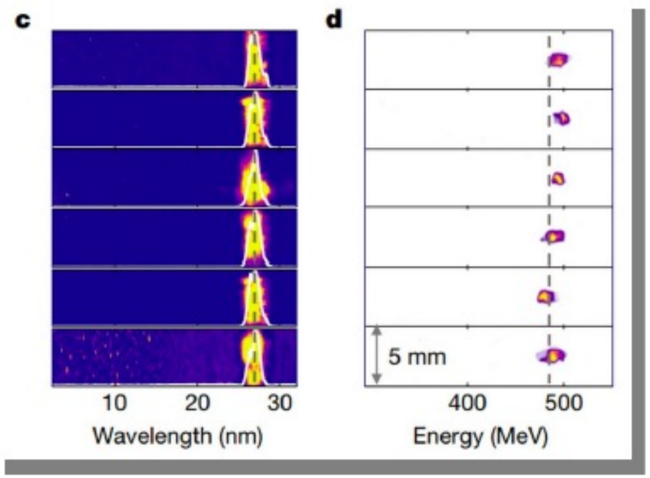
- part of the EOS laser was used as a seed;
- seed laser 795 nm, FEL peak still at 827 nm;
- pulse energy increase from ~30 nJ up to ~ 1 μJ;
- increased stability of radiation.



First Lasing with LWFA at SIOM



Wang, Wentao, et al. "Free-electron lasing at 27 nanometres based on a laser wakefield accelerator." Nature 595.7868 (2021): 516-520.



Observation of FEL radiation @ 27 nm using LWFA

Electron beam generated from a 200 TW (I~4x10^{18} W/cm^2) laser focused on a gas-jet

Peak energy ~ 490 MeV, 0.5% spread (measured), emittance 0.5 um (estimated)

Radiation energy from 0.5 to 150 nJ

EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA

EuPRAXIA Design Study started on Novemebr 2015

Approved as HORIZON 2020 INFRADEV, 4 years, 3 M€

Coordinator: Ralph Assmann (DESY)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653782.

http://eupraxia-project.eu

The EuPRAXIA Project

http://www.eupraxia-project.eu/

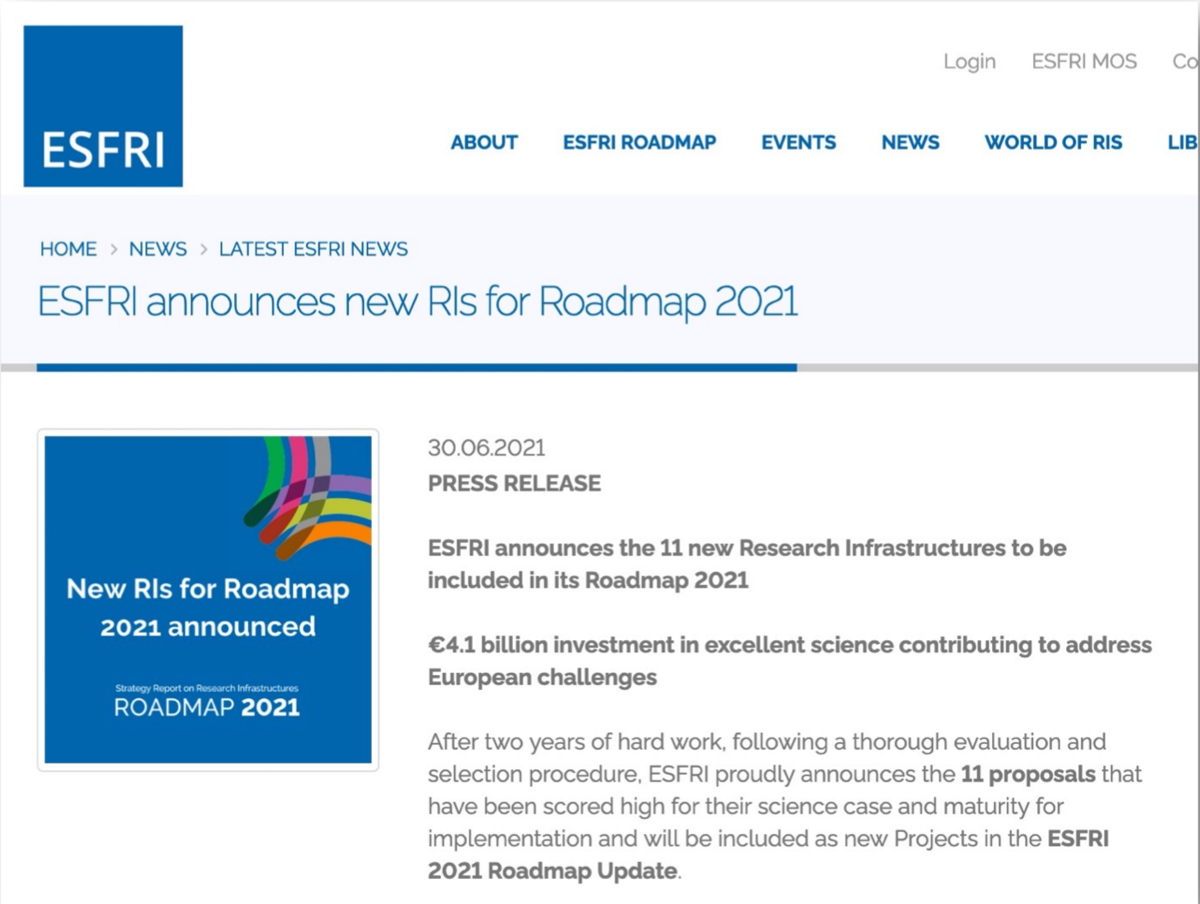
Horizon 2020

- First ever international design of a **plasma accelerator facility**.
- Challenges addressed by EuPRAXIA since 2015:
  - How **can plasma accelerators produce usable electron beams**?
  - **For what can we use those beams** while we increase the beam energy towards HEP and collider usages?
- **CDR for a distributed research infrastructure** funded by EU Horizon2020 program. Completed by 16+25 institutes.
- **Next phase consortium** with 40 partners, 10 observers.
- **Applied to ESFRI roadmap update 2021** with government support in Sep 2020.
- **Successful** and and placed on ESFRI roadma.

653 page CDR, 240 scientists contributed

Great News 30.6.2021

Building the first plasma accelerator facility



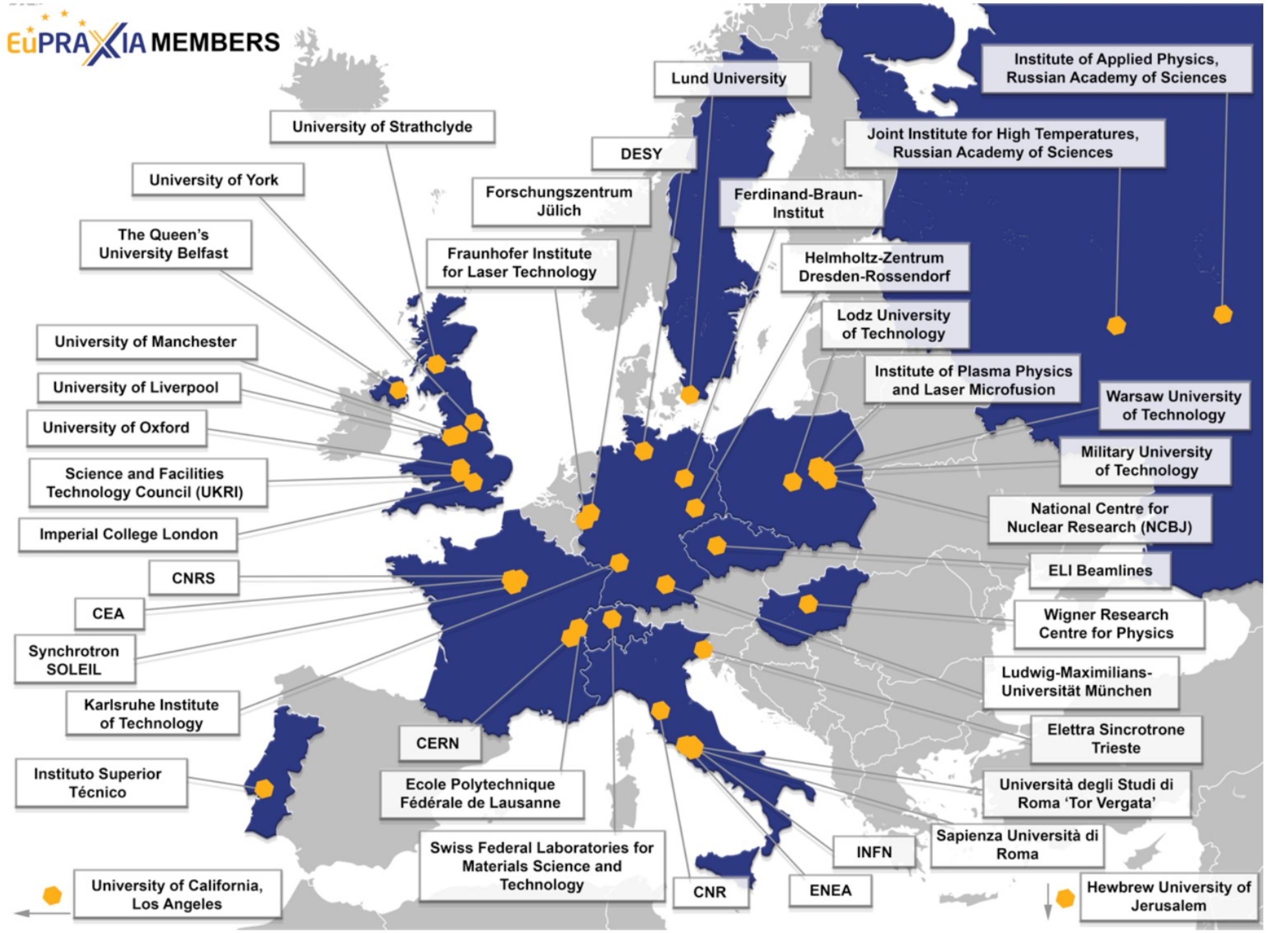
About the ESFRI Roadmap

ESFRI has established a European Roadmap for Research Infrastructures (new and major upgrades, pan-European interest) for the next 10-20 years, stimulates the implementation of these facilities, and updates the roadmap as needed. The ESFRI Roadmap arguably contains the best European science facilities based on a thorough evaluation and selection procedure. It combines ESFRI Projects, which are new Research Infrastructures in progress towards implementation, and ESFRI Landmarks successfully implemented Research Infrastructures enabling excellent science.

The Consortium Members for the Next Phase

(from 16 to 40)

Horizon 2020



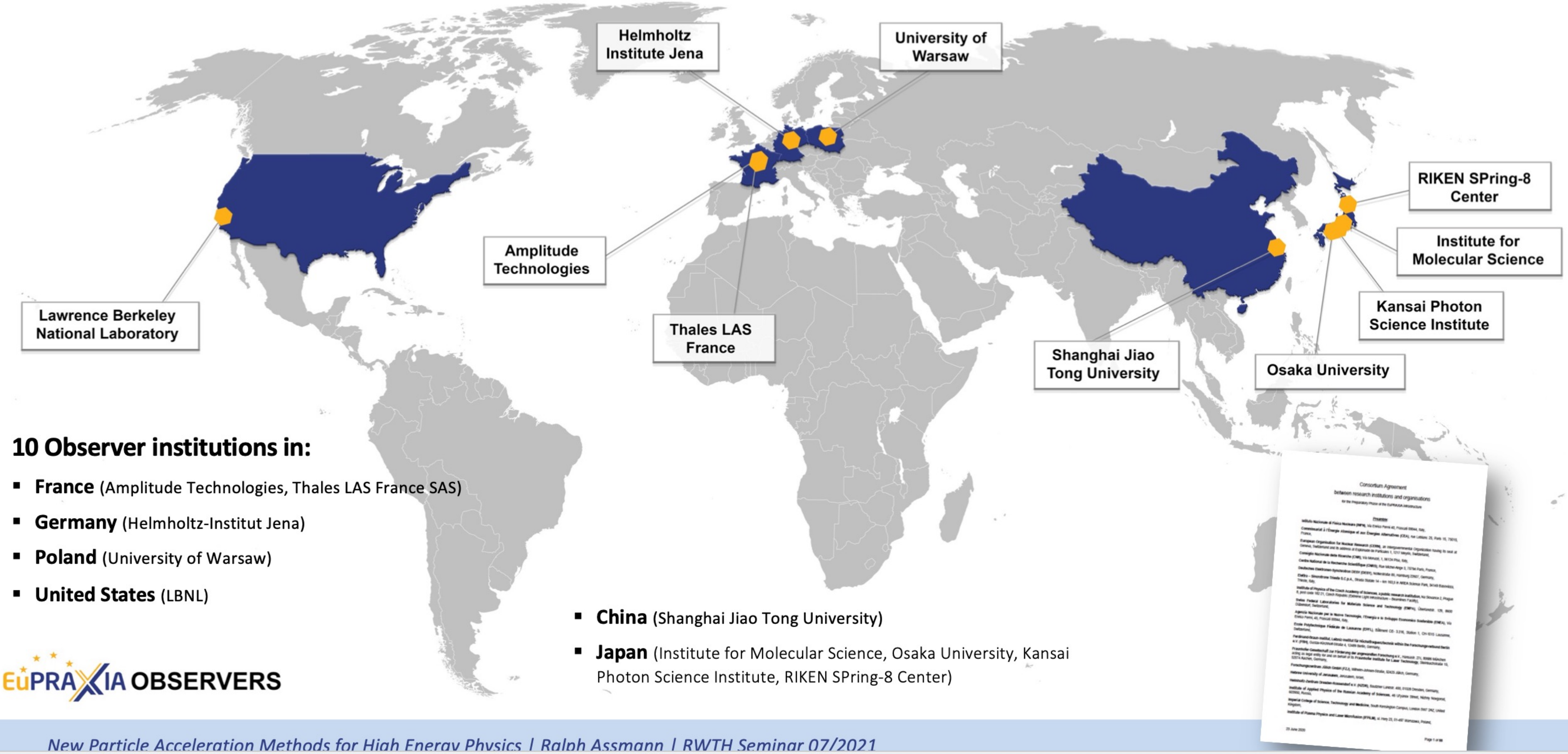
40 Member institutions in:

- **Italy** (INFN, CNR, Elettra, ENEA, Sapienza Università di Roma, Università degli Studi di Roma "Tor Vergata")
- **France** (CEA, SOLEIL, CNRS)
- **Switzerland** (EMPA, Ecole Polytechnique Fédérale de Lausanne)
- **Germany** (DESY, Ferdinand-Braun-Institut, Fraunhofer Institute for Laser Technology, Forschungszentrum Jülich, HZDR, KIT, LMU München)
- **United Kingdom** (Imperial College London, Queen's University of Belfast, STFC, University of Liverpool, University of Manchester, University of Oxford, University of Strathclyde, University of York)
- **Poland** (Institute of Plasma Physics and Laser Microfusion, Lodz University of Technology, Military University of Technology, NCBJ, Warsaw University of Technology)
- **Portugal** (IST)
- **Hungary** (Wigner Research Centre for Physics)
- **Sweden** (Lund University)
- **Israel** (Hebrew University of Jerusalem)
- **Russia** (Institute of Applied Physics, Joint Institute for High Temperatures)
- ***United States*** (UCLA)
- **CERN**
- **ELI Beamlines**

The Consortium Observers for the Next Phase

(from 25 to 10, Consortium Agreement signed)

Horizon 2020



10 Observer institutions in:

- **France** (Amplitude Technologies, Thales LAS France SAS)
- **Germany** (Helmholtz-Institut Jena)
- **Poland** (University of Warsaw)
- **United States** (LBNL)

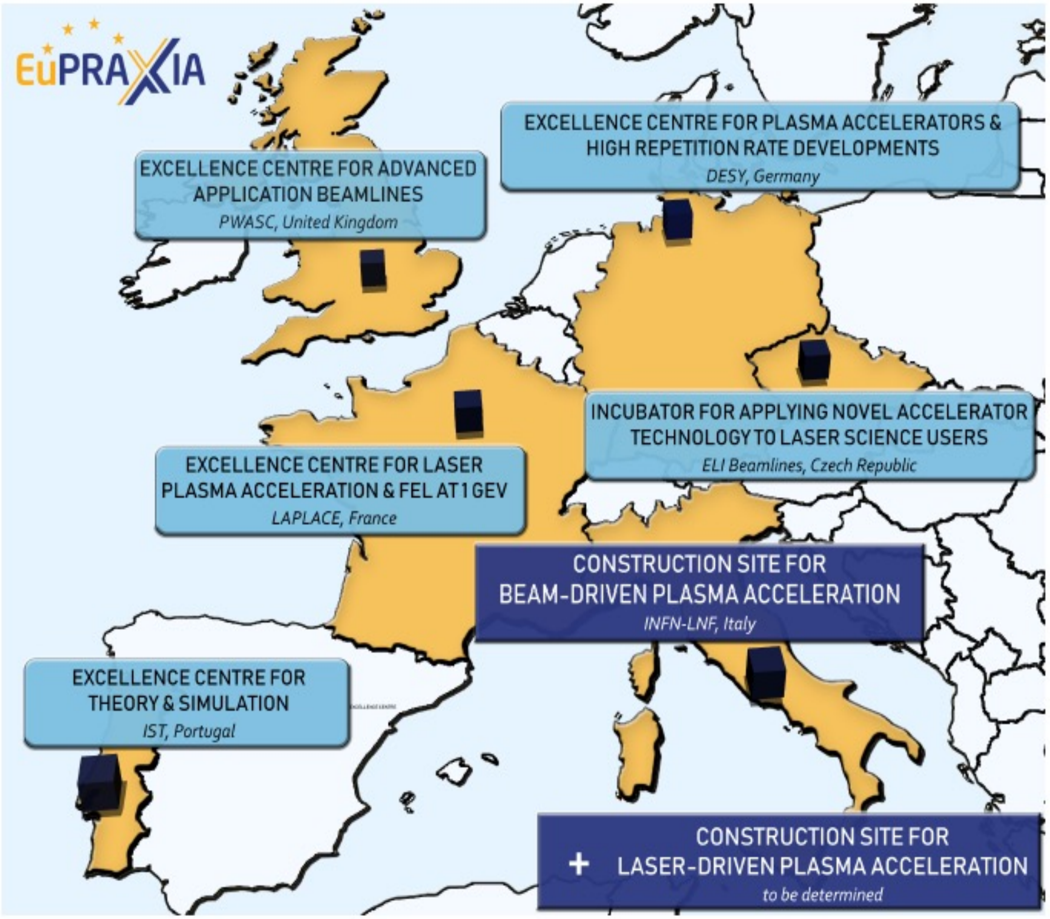
- **China** (Shanghai Jiao Tong University)
- **Japan** (Institute for Molecular Science, Osaka University, Kansai Photon Science Institute, RIKEN SPring-8 Center)

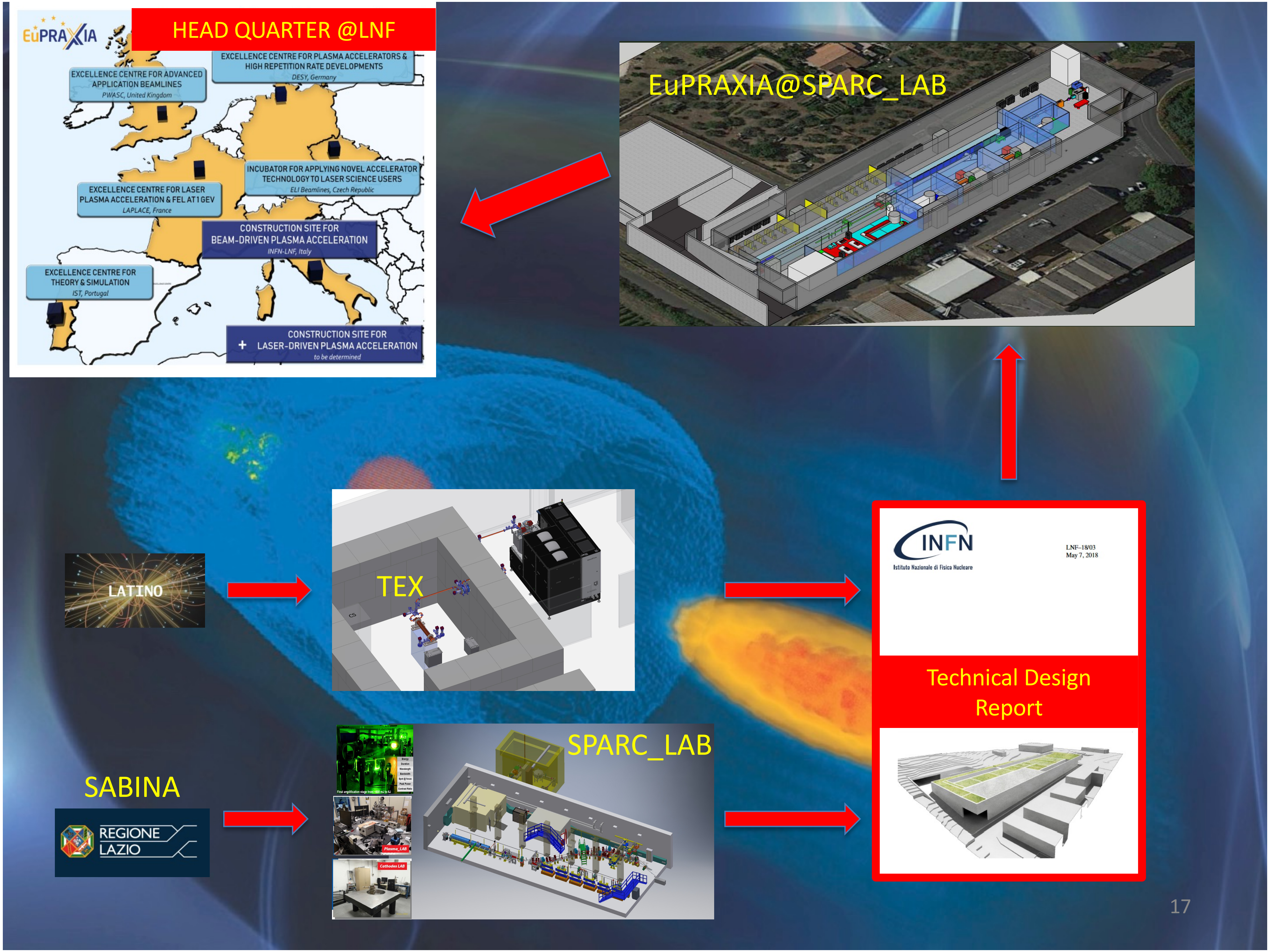
EuPRAXIA OBSERVERS

… and Builds a European Distributed Facility

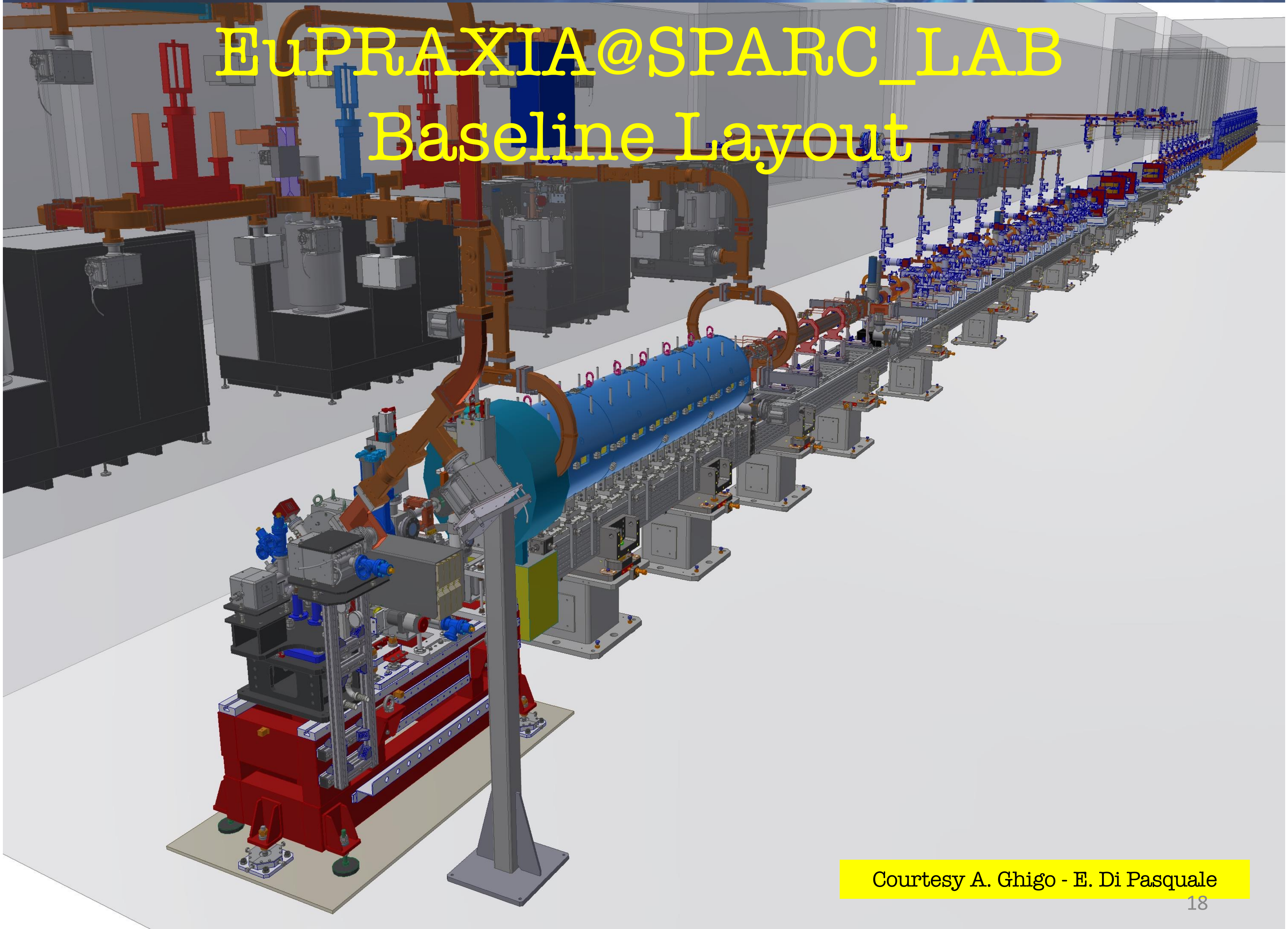
Position Europe as a Leader in the Global Context

1. Lean overall **EuPRAXIA management**
2. **Ten clusters:** Collaborations of institutes on specific problems, developing solutions, technical designs, driving developments with EuPRAXIA generated funding → **expertise of Helmholtz centers required - opportunities**
3. **Five excellence centers** at existing facilities: Using pre-investment, support tests, prototyping, production with EuPRAXIA generated funding → **DESY excellence center**
4. **One or two construction sites** at existing facilities with EuPRAXIA generated funding:
   - **Beam-driven** at Frascati (Italy).
   - **Laser-driven** at CLF/STFC (UK), CNR/ INFN (Italy) or ELI-Beamlines.



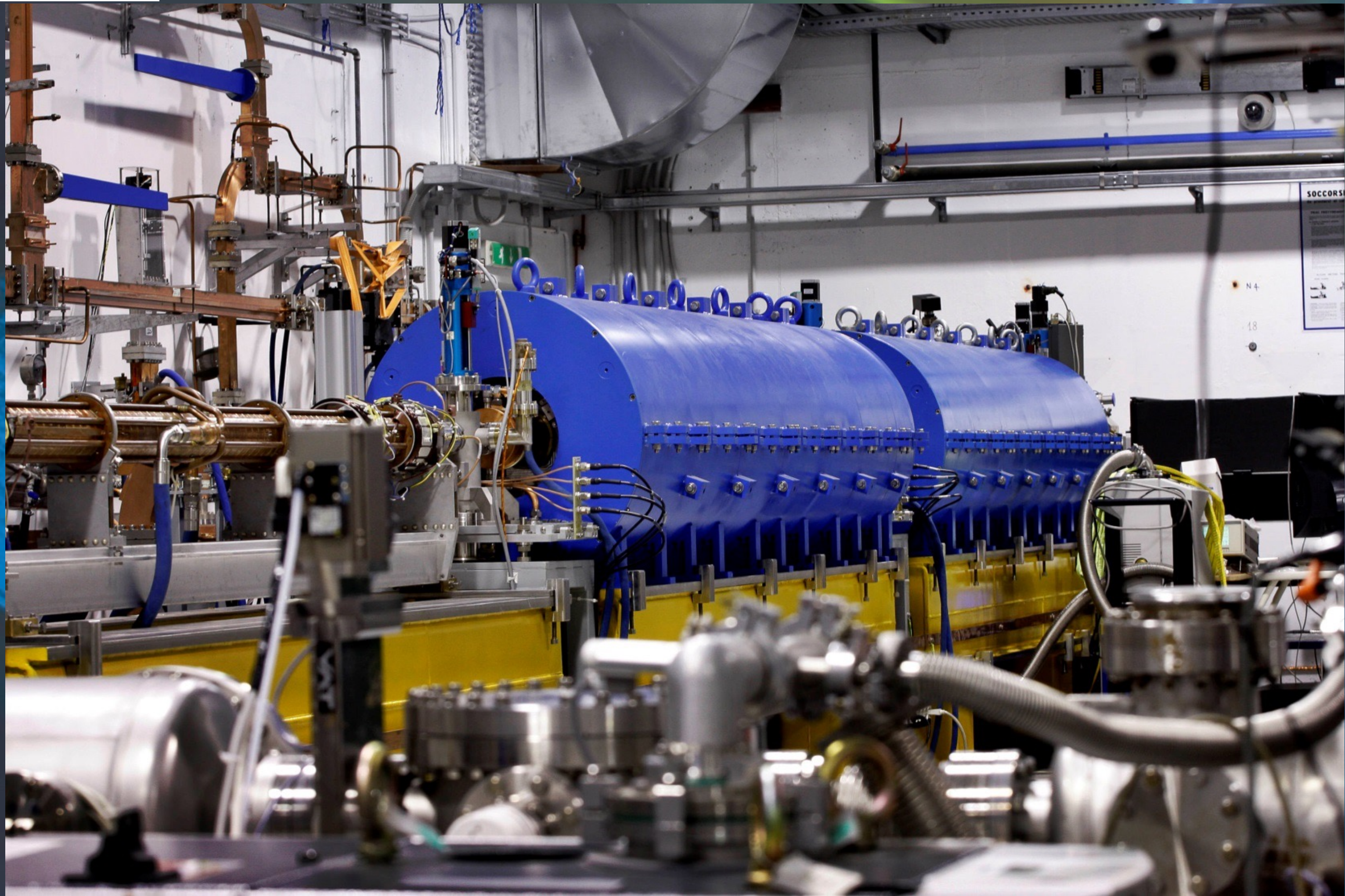

HEAD QUARTER @LNF
EuPRAXIA
EXCELLENCE CENTRE FOR PLASMA ACCELERATORS & HIGH REPETITION RATE DEVELOPMENTS
DESY, Germany
EXCELLENCE CENTRE FOR ADVANCED APPLICATION BEAMLINES
PWASC, United Kingdom
INCUBATOR FOR APPLYING NOVEL ACCELERATOR TECHNOLOGY TO LASER SCIENCE USERS
ELI Beamlines, Czech Republic
EXCELLENCE CENTRE FOR LASER PLASMA ACCELERATION & FEL AT 1 GEV
LAPLACE, France
CONSTRUCTION SITE FOR BEAM-DRIVEN PLASMA ACCELERATION
INFN-LNF, Italy
EXCELLENCE CENTRE FOR THEORY & SIMULATION
IST, Portugal
CONSTRUCTION SITE FOR LASER-DRIVEN PLASMA ACCELERATION
to be determined
EuPRAXIA@SPARC_LAB
LATINO
TEX
SABINA
REGIONE LAZIO
SPARC_LAB
INFN
Istituto Nazionale di Fisica Nucleare
LNF–18/03
May 7, 2018
Technical Design Report

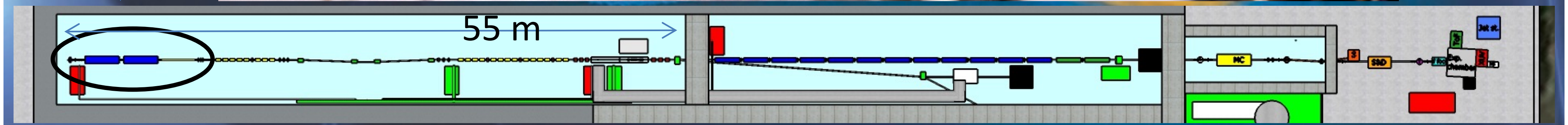
EuPRAXIA@SPARC_LAB Baseline Layout



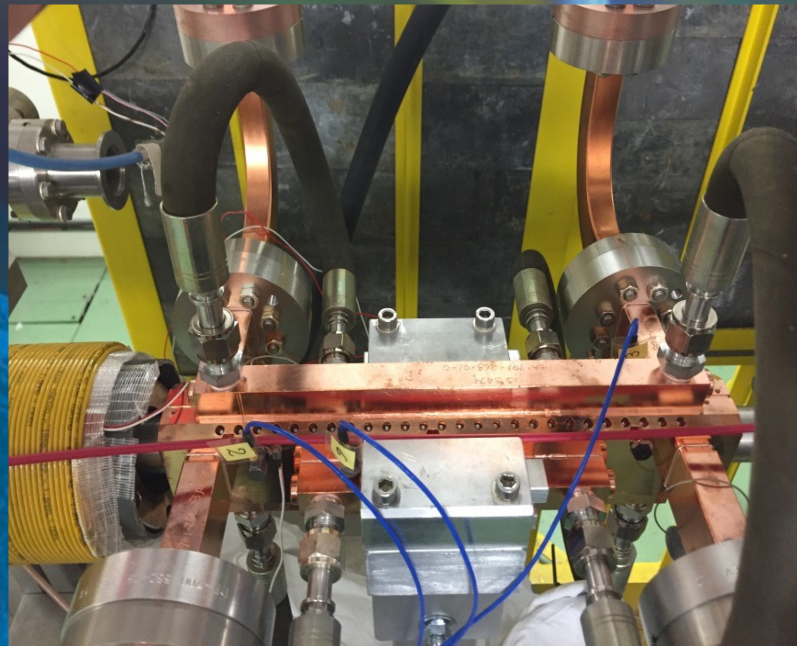
Courtesy A. Ghigo - E. Di Pasquale

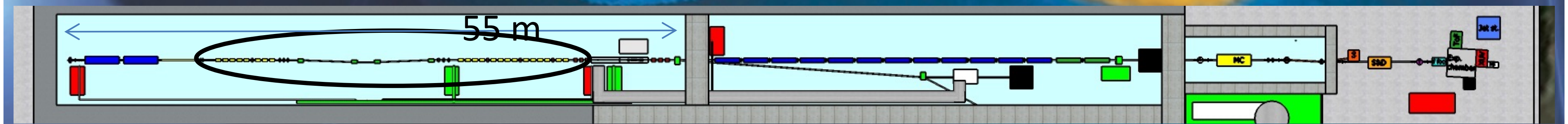
SPARC_LAB HB photo- injector





X-band Linac





TEX facility – TEst stand for X-band at Frascati

- The *TEst-stand for X-band* (**TEX**) is a facility conceived for R&D on high gradient X-band accelerating structures and waveguide components in view of Eupraxia@SPARC_LAB project.
- It has been co-funded by Lazio regional government in the framework of **the LATINO project** (*Laboratory in Advanced Technologies for INnOvation*). The setup has been done in **collaboration with CERN** and it will be also used to test CLIC structures.
- TEX is located in bld. 7 of LNF, which is being fully refurbished and upgraded to host the high gradient facility and other labs.

Concrete shielded Bunker and Modulator Cage

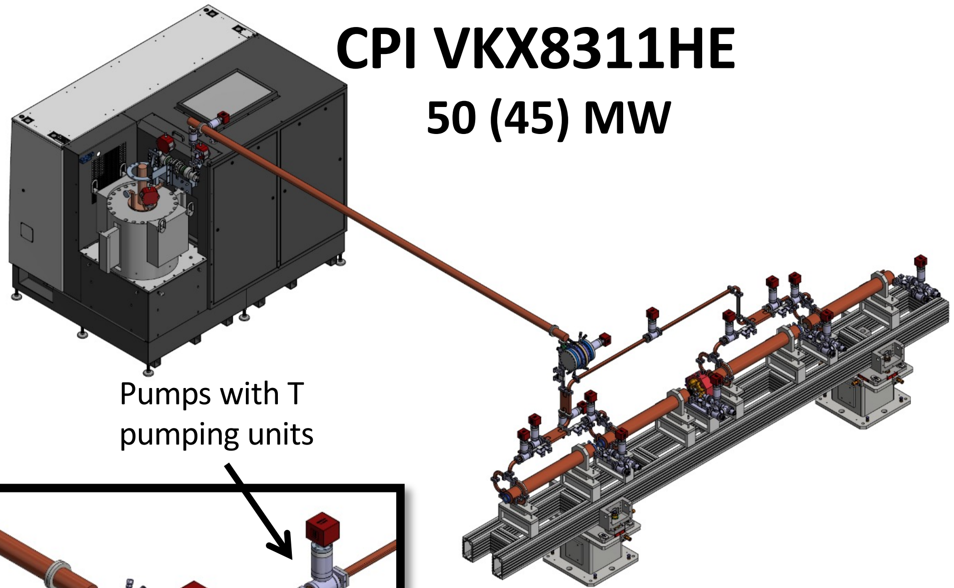
Control room and Rack room

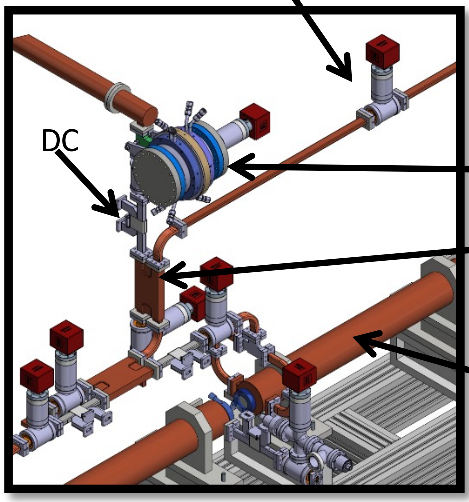
Courtesy S. Pioli

RF MODULE LAYOUT

CPI VKX8311HE

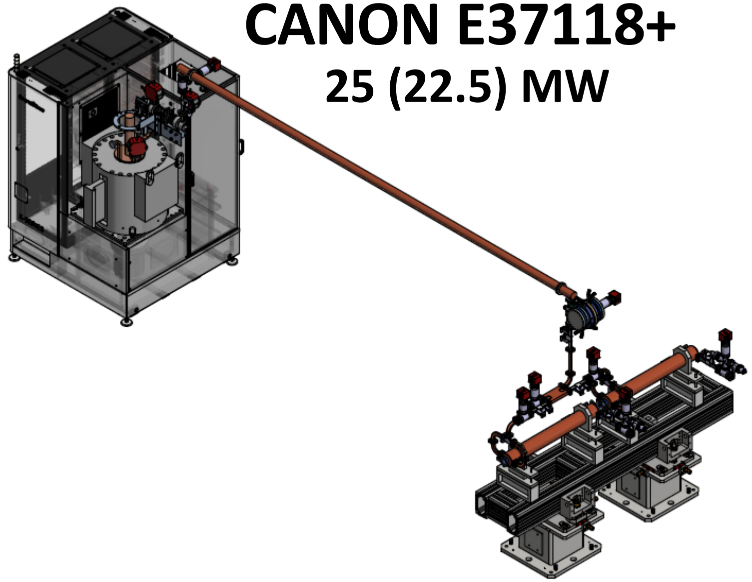
50 (45) MW





CANON E37118+

25 (22.5) MW



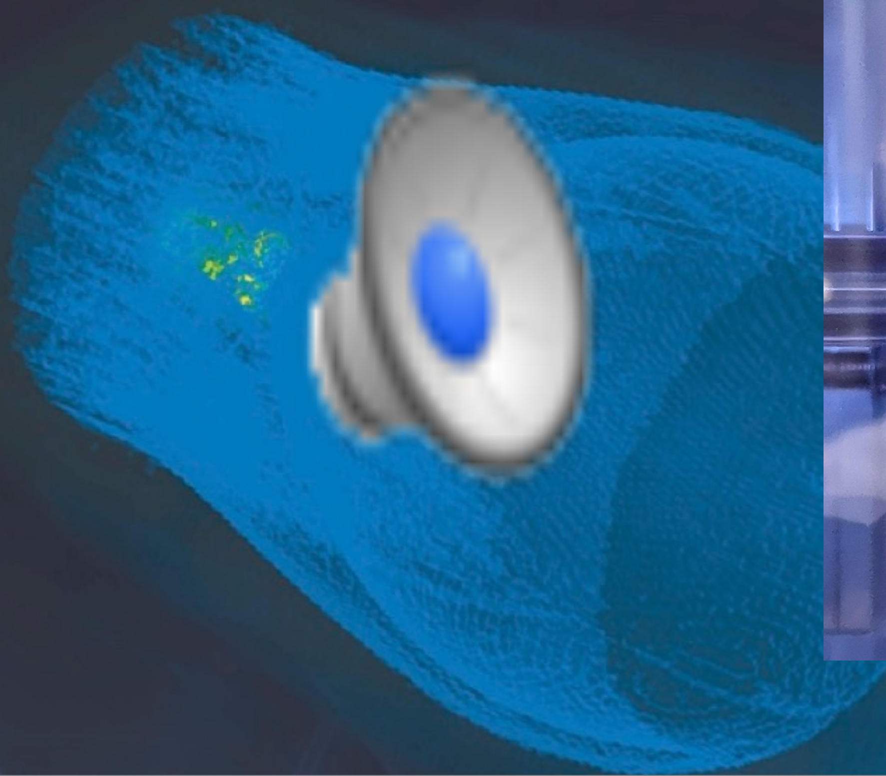
Courtesy G. Di Raddo, E. Di Pasquale, F. Cardelli

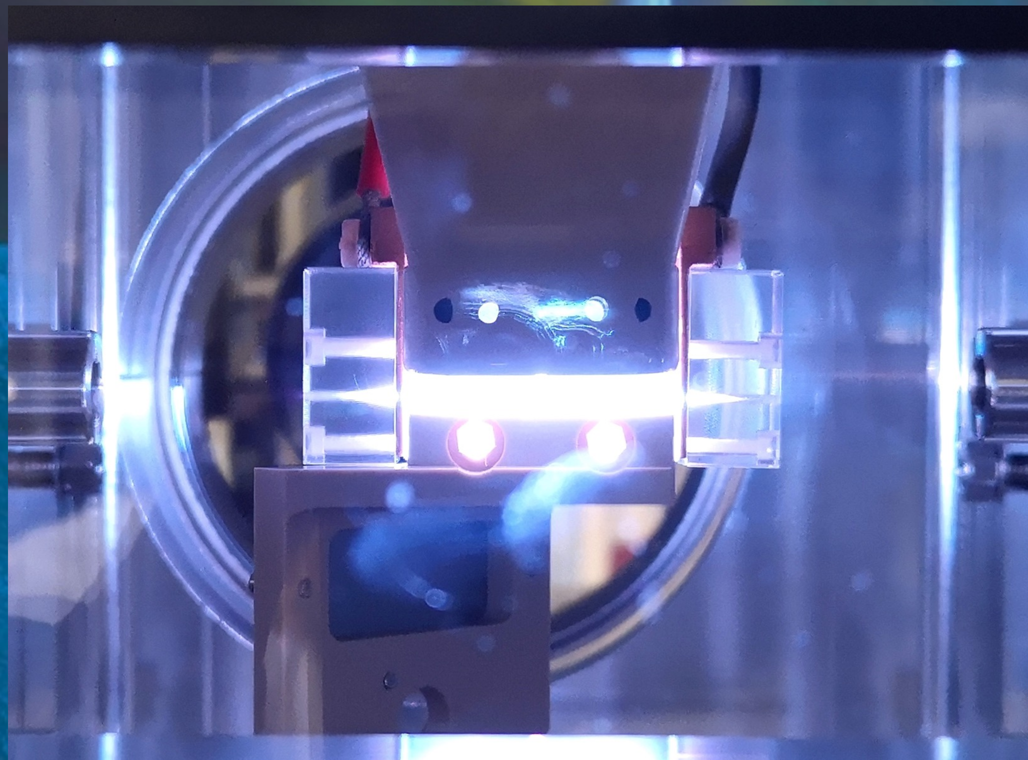
⇒ **Waveguide components** (DC, T pumping, hybrids,…) **CERN design** but there are some components for which we have to fix the design (circular-rectangular waveguide mode converter, pumping unit on circular waveguide)

⇒ **Pulse compressor: BOC (PSI) or INFN Design**

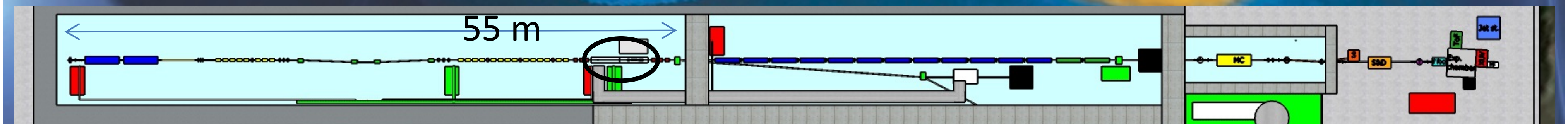
⇒ **Asymmetric waveguide distribution system to take into account the RF propagation time**

Plasma WakeField Acceleration

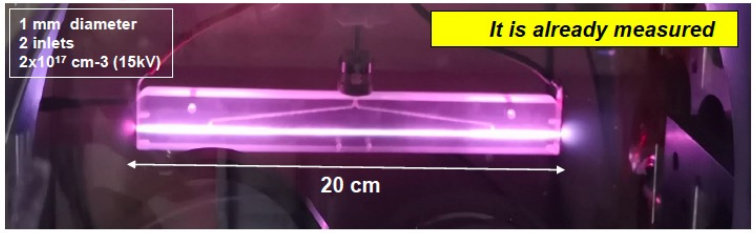




Capillary discharge at SPARC_LAB

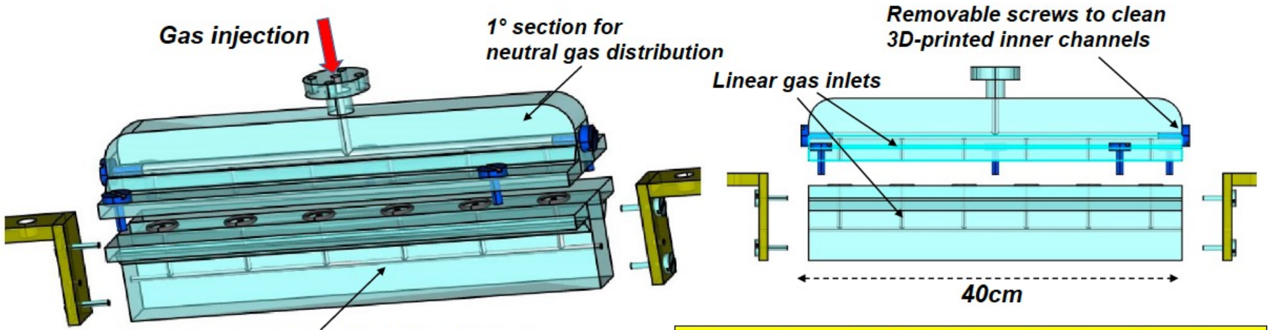


40 cm-long Gas-filled discharge-capillary



Paschen curves (50 mbar)

Length	*Density*	*Vb*
3 cm	$4x10^{16}$ cm-3	3 kV
10 cm	$4x10^{16}$ cm-3	8 kV
20 cm	$4x10^{16}$ cm-3	14 kV
40 cm	$4x10^{16}$ cm-3	23 kV

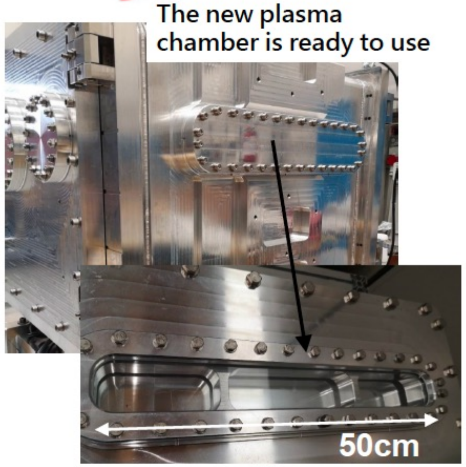


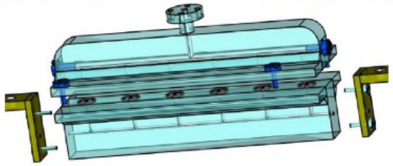
Linear channel/inlets allow us to clean them from printing residuals

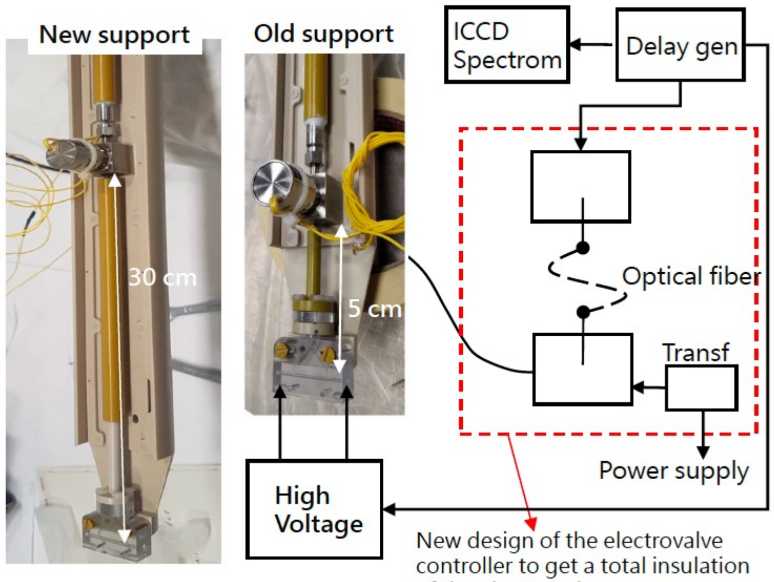
40cm-long Gas-filled discharge-capillary

The new plasma chamber is ready to use

A crucial point to produce a gas discharge is the insulation of others components of the plasma module with respect to the HV pulse

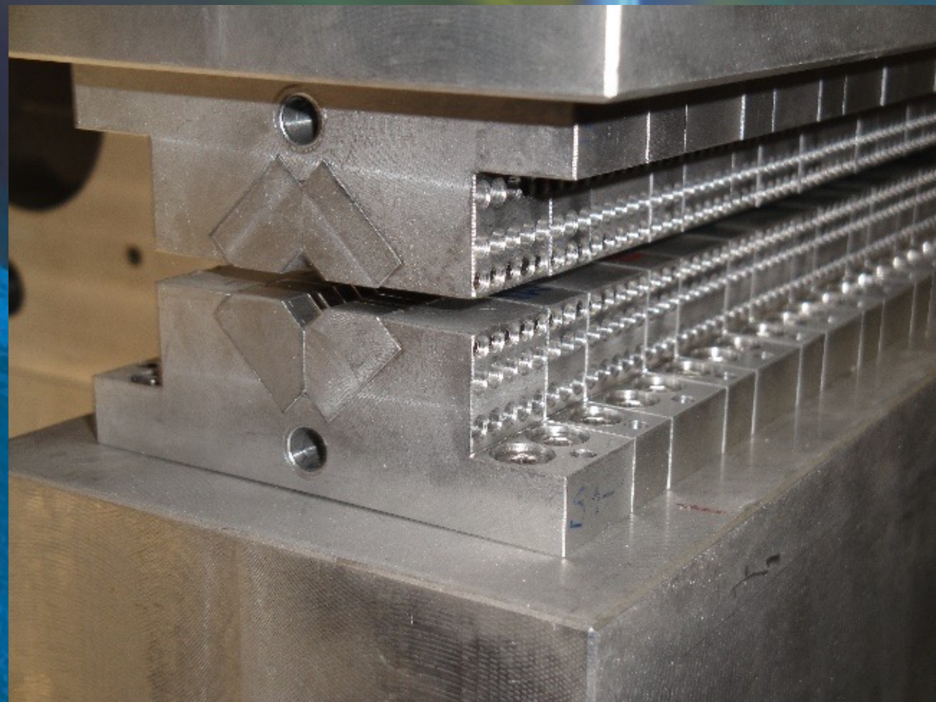




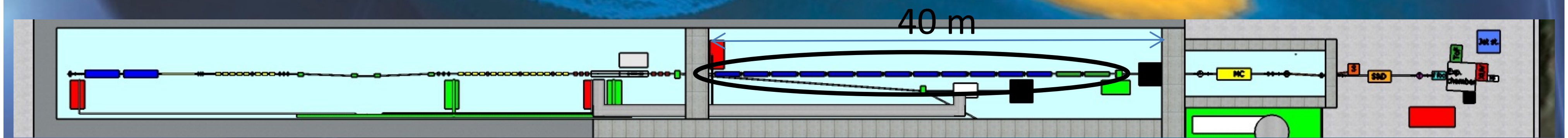


New design of the electrovalve controller to get a total insulation of the electro valve

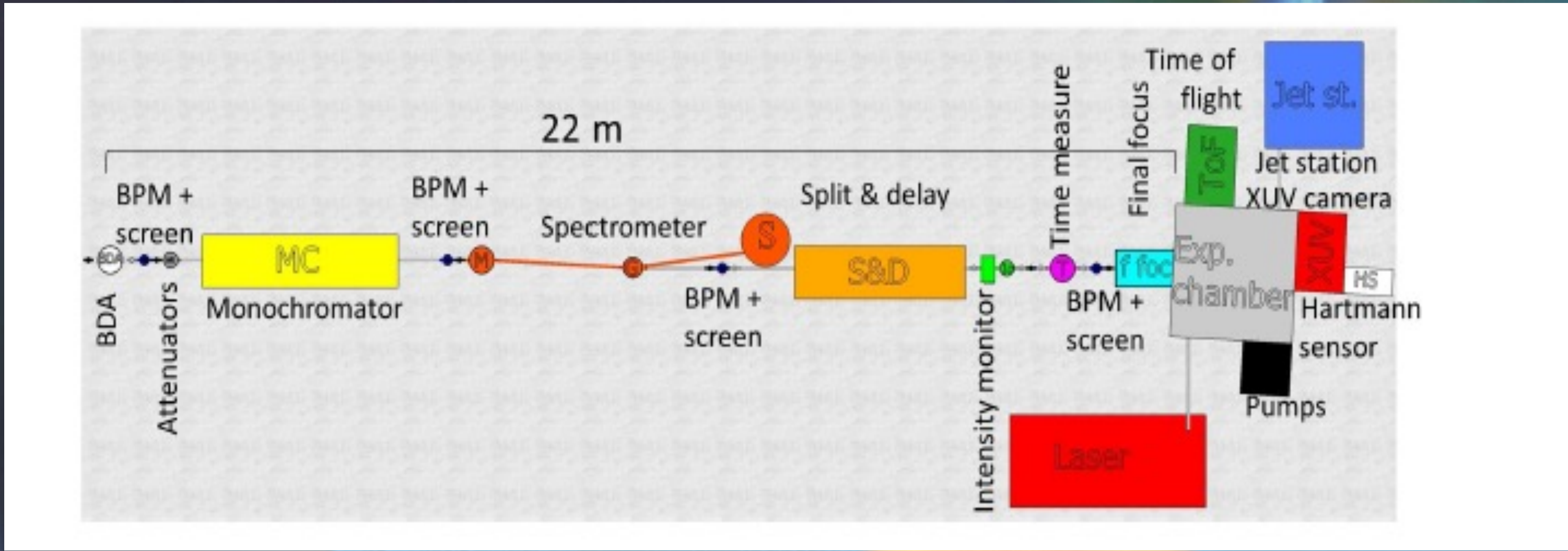
Undulators

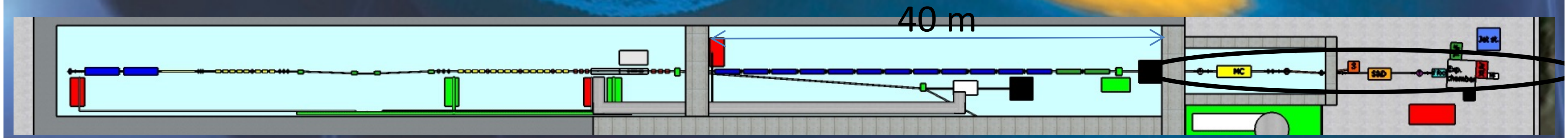


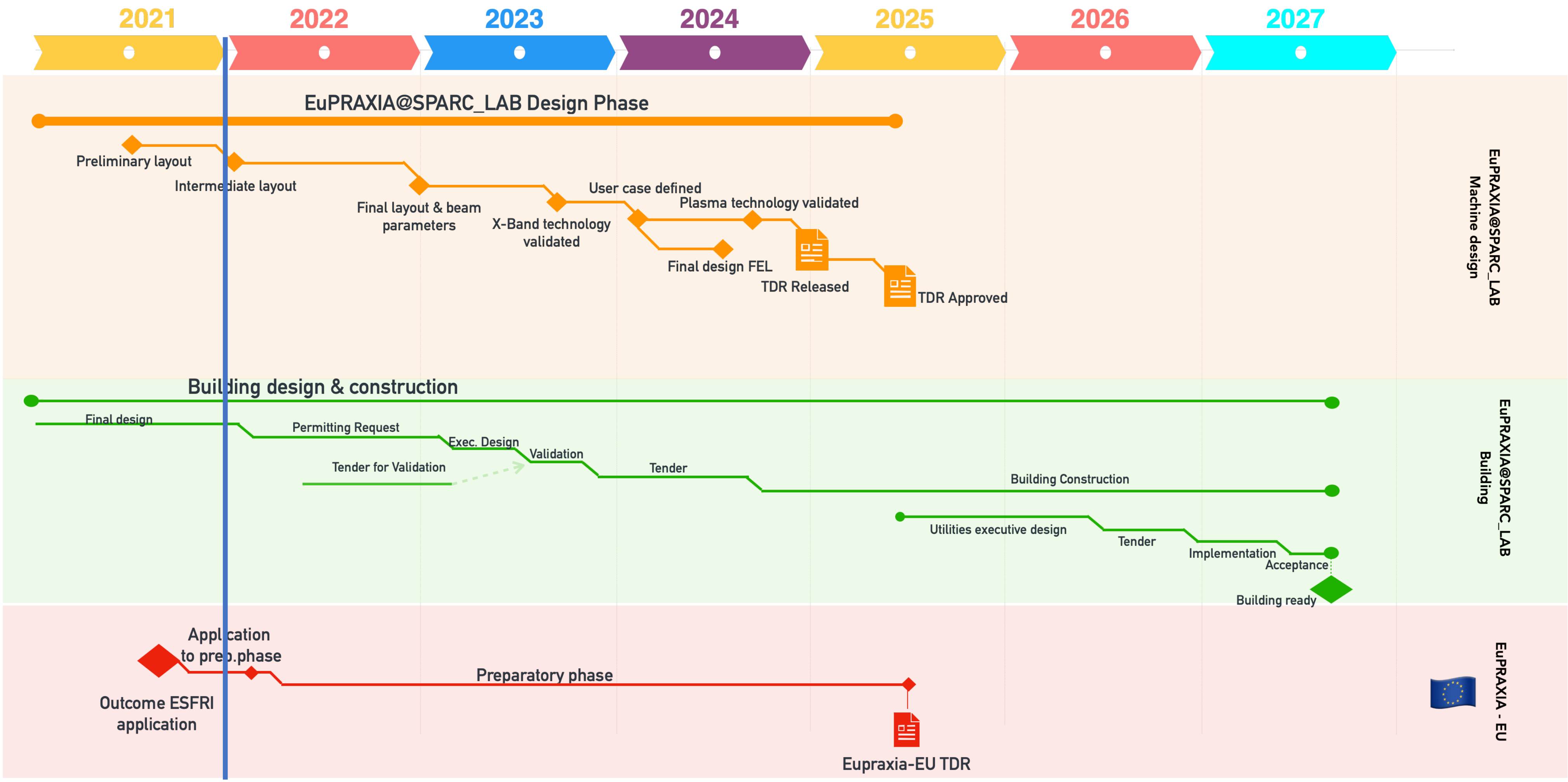
KYMA Δ udulator at SPARC_LAB: λ=1.4 cm, K1



Photon beam line

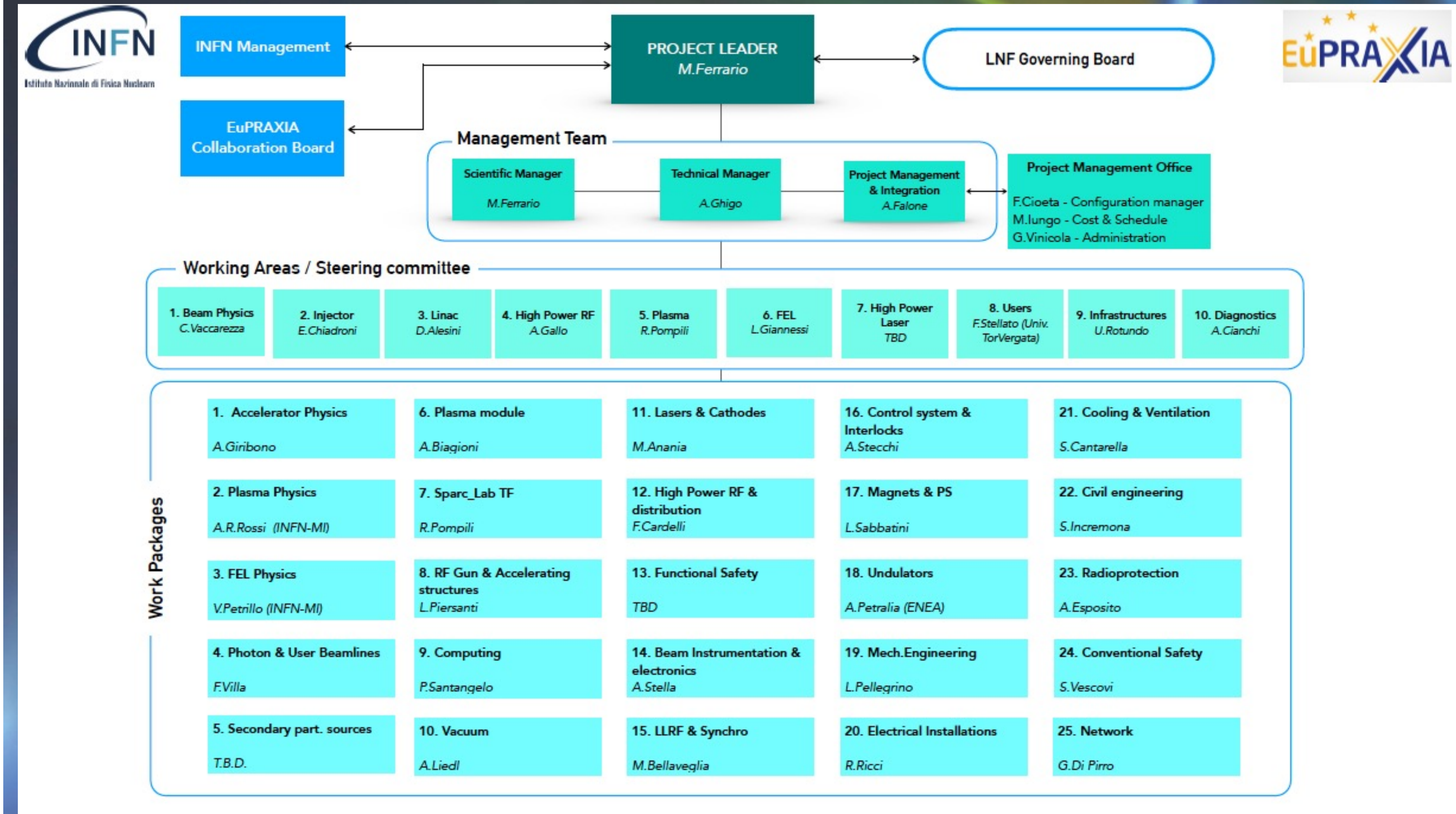






Courtesy A. Falone

Acknowledgements



Thank for your attention