EUROPEAN
PLASMA RESEARCH
ACCELERATOR
WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA activity report

Massimo Ferrario
On behalf of the EuPRAXIA collaboration

Sci-Com 19/11/2024

Scicom Recommendations about EuPRAXIA

1) *The delays of EuPRAXIA@SPARCLAB have to be taken into account for the overall strategy for research activities at LNF, since a sufficient portfolio of other scientific activities has to be maintained until the science program at EuPRAXIA@SPARCLAB starts. This has to be kept in balance with sufficient technical resources for EuPRAXIA@SPARCLAB design and project execution.*

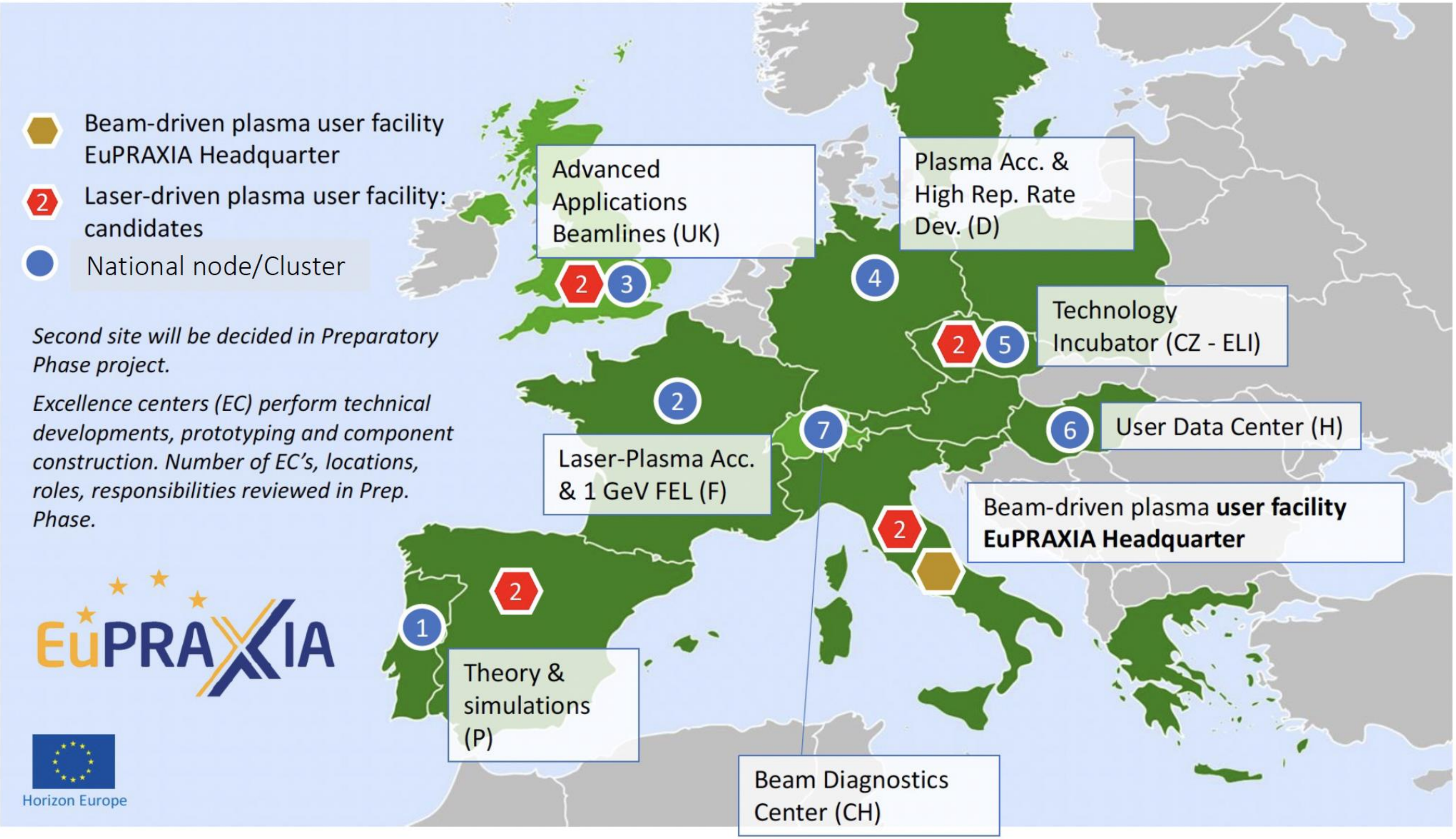
2) The SC re-iterates its recommendation from the last three reports that radiation lev-els and shielding dimensions for the drive bunch collimation and/or dump need to be computed. At a beam energy of more than 1 GeV and a mean beam current in the order of 0.1 μA this shielding may need considerable space and has to be known before building specifications are frozen!

3) To avoid further delays the open design question for the TDR need to be solved with high priority by studies, simulations and appropriate experiments in SPARCLAB.

4) Component procurement should start as soon as the TDR is finalized, otherwise inflation will drive the overall cost even higher.

5) The LNF and EuPRAXIA management has to develop a strategy how to cope with the cost overrun. Either additional financial resources have to be found, or a project descoping, or a phased approach has to be decided.

EuPRAXIA Consortium Networking



A large collection of the best European know-hows in accelerators, lasers and plasma technologies

Network organization
- **Sites (PWFA/LWFA)**
- **National nodes**
- **Technology clusters**

4 candidates for LWFA:
- CLPU, Salamanca
- CNR-INO, Pisa
- ELI ERIC, Prague
- EPAC-RAL, UK

EuPRAXIA Flagship Goals

Funded by the European Union

EuPRAXIA is the first European project that develops a dedicated particle accelerator research infrastructure **based on novel plasma acceleration** concepts **driven by innovative laser and linac technologies**.

EuPRAXIA Conceptual Design Report', W. Assmann et al., Eur. Phys. J. Special Topics 229, 3675 – 4284 (2020).

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 footprint.

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 duration of 20–90 picoseconds on the sample, allowing time-resolved studies. Here, EuPRAXIA will advance the capabilities of existing positron sources in flux and time resolution.

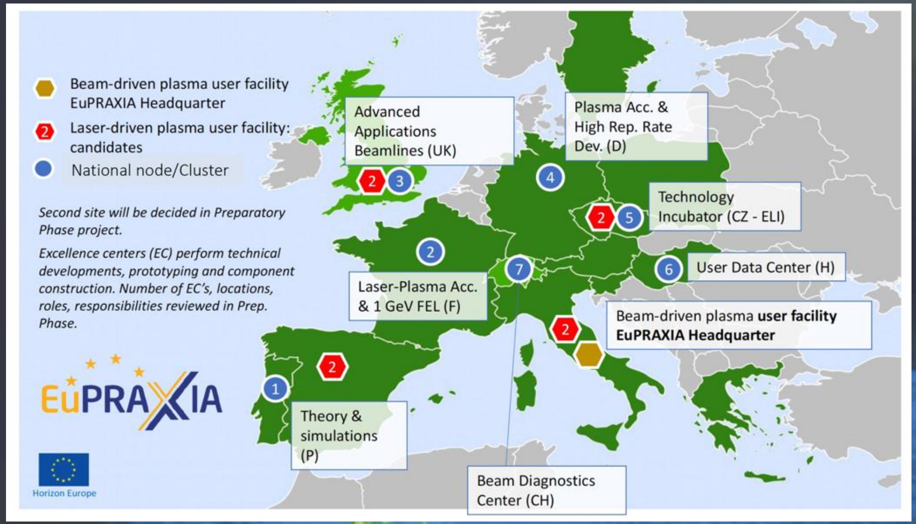
Flagship Science Goal 4: EuPRAXIA will deliver electron and positron beams at energies from a few 100 MeV up to 5 GeV for high-energy-physics-related R&D (detectors, linear collider topics). R&D goals include the demonstration of a linear collider stage, a "tabletop" HEP test beam, and studies on positron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

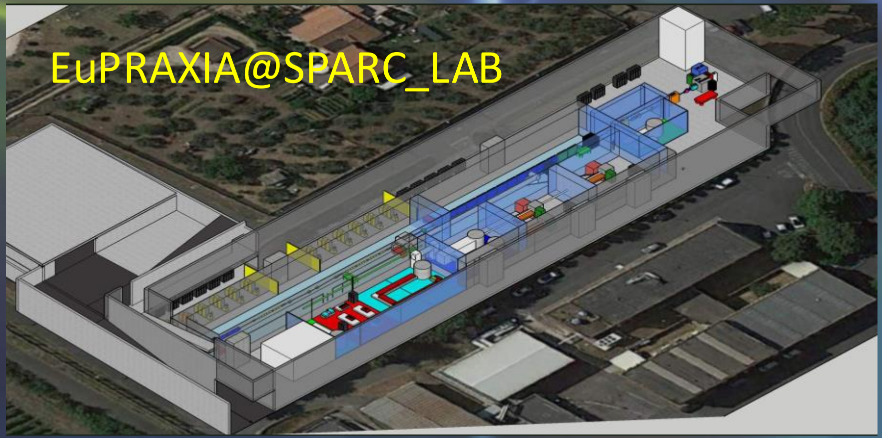
Flagship Science Goal 5: EuPRAXIA will deliver photons from an inverse Compton scattering (ICS) source. The photons of up to 600 MeV and with a narrow-band spectrum will enable precision nuclear physics and highly penetrative radiography for users.

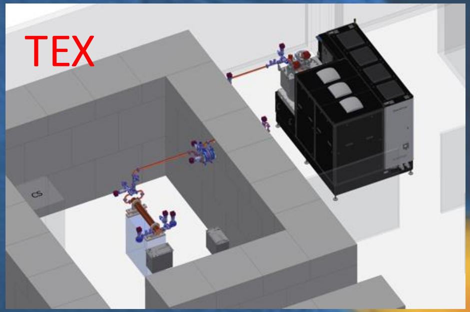
Flagship Science Goal 6: EuPRAXIA will provide access to a multi-stage high-repetition-rate plasma accelerator in the GeV range to users from accelerator science. This R&D platform will allow the testing of novel ideas and concepts, the full optimisation of a plasma collider stage, certain fixed target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

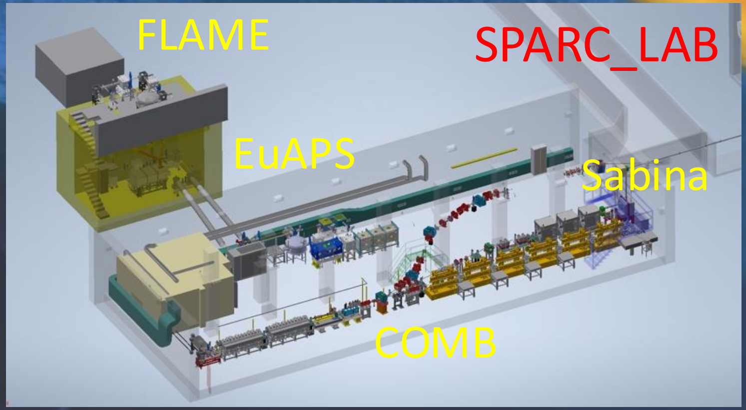
Flagship Science Goal 7: EuPRAXIA will provide access to cutting-edge laser technology with short pulse length in combination with high-energy photon pulses and short electron/positron bunches. Novel schemes of pump probe configurations and ultra-precise timing will be researched, feeding back into laser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

EuPRAXIA LNF Eco-System









EuPRAXIA Preparatory Phase Organisation

Funded by the European Union

Coll. Board
M. Ferrario INFN

Steering Committee

Scientific and Technical Advisory Board

Board of Financial Sponsors

WP1 - Coordination & Project Management
P. Campana, INFN
M. Ferrario, INFN

WP2 - Dissemination and Public Relations
C. Welsch, U Liverpool
S. Bertellii, INFN

WP3 - Organization and Rules
A. Specka, CNRS
A. Ghigo, INFN

WP4 - Financial & Legal Model. Economic Impact
A. Falone, INFN

WP5 - User Strategy and Services
F. Stellato, U Tor Vergata
E. Principi, ELETTRA

WP6 - Membership Extension Strategy
B. Cros, CNRS
A. Mostacci, U Sapienza

WP's on coordination & implementation as ESFRI RI (organization, legal model, financing, users)

WP7 - E-Needs and Data Policy
R. Fonseca, IST
S. Pioli, INFN

WP8 - Theory & Simulation
J. Vieria, IST
H. Vincenti, CEA

WP9 - RF, Magnets & Beamline Components
S. Antipov, DESY
F. Nguyen, ENEA

WP10 - Plasma Components & Systems
K. Cassou, CNRS
R. Shalloo, DESY

WP11 - Applications
G. Sarri, U Belfast
E. Chiadroni,U Sapienza

WP12 - Laser Technology, Liaison to Industry
L. Gizzi, CNR
P. Crump, FBH

WP13 - Diagnostics
A. Cianchi, U Tor Vergata
R. Ischebeck, EPFL

WP14 - Transformative Innovation Paths
B. Hidding, U Dusseldorf
S. Karsch, LMU

WP15 - TDR EuPRAXIA @SPARC-lab
C. Vaccarezza, INFN
R. Pompili, INFN

WP16 - TDR EuPRAXIA Site 2
A. Molodozhentsev, ELI-Beamlines
R. Pattahil, STFC

WPs on technical implementation and sites

EuPRAXIA_PP Consortium & ancillary EU programs

Funded by the European Union

Recent membership entries (CB decision in March):
- PSI (associate), CH
- GSI-FAIR Darmstadt & Uni. Dusseldorf, DE
- AMPLITUDE, FR

Formal acceptance by EU-PO completed.
No further members foreseen.

Complemented by few institutes present in EuPRAXIA ESFRI consortium which did not sign the EuPRAXIA PP Grant Agreement, from FR, DE, PL, SE, UK, CN, JPN, US

EMPA*	CH
EPFL*	CH
PSI*	**CH**
DESY	DE
FBH Berlin	DE
FHG-ILT Aachen	DE
FZ Julich	DE
HZ Dresden	DE
LMU Muenchen	DE
HHU Dusseldorf	**DE**
GSI-FAIR Darmstadt	**DE**
ELI Beamline ERIC	CZ
CEA	FR
CNRS	FR
THALES	FR
AMPLITUDE	**FR**
IASA Athens	GR
WIGNER	HUN
Uni. Szeged	HUN
Uni. Pecs	HUN
CERN	INT. ORG.
H. Univ. Jerusalem	ISR
CNR	IT
ELETTRA Trieste	IT
ENEA Frascati	IT
INFN	IT
U. Roma Sapienza	IT
U. Roma Tor Vergata	IT
IST Lisbon	P
ALBA Cells	SP
CLPU Salamanca	SP
IC London*	UK
QU Belfast*	UK
STFC*	UK
U. Liverpool*	UK
U. Oxford*	UK
U. Strathclyde*	UK
UCLA*	US

* associate partners

UJT Shanghai (observer)	CN
HZ Jena (observer)	DE
U. Cote d'Azur Nice (observe	FR
NTUA Athens (observer)	GR
U. Milano Bicocca (observer)	IT
U. Palermo (observer)	IT
NCBJ Otwock (observer)	PL
U. Manchester (observer)	UK

38 members, 8 observers

ANCILLARY PROGRAMS

- EuPRAXIA Doctoral Network

This project has received funding from the European Union´s Horizon Europe research and innovation programme under grant agreement no. 101073480 and the UKRI guarantee funds.

- EuAPS

This publication has been made with the co-funding of European Union Next Generation EU.

PACRI (recently approved)

EuPRAXIA Workshop

23-27 September 2024
Elba

- EuPRAXIA_PP Annual Meeting [P. Campana, M. Ferrario] (23-24-25)
- **M15.2** Workshop on "EuPRAXIA@SPARC_LAB machine upgrade and additional beam lines" [C. Vaccarezza, Pompili] (26)
- **M6.1** Outreach Workshop [B. Cros, A. Mostacci] (27)

EuPRAXIA

Funded by the European Union

Sunday 22 – Arrivals

16:00	Arrivals
19:00 - 20:30	Welcome Cocktail
20:30	Dinner

Monday 23 – EuPRAXIA_PP

09:00	**Welcome**
09:10	**Opening talk: Recoil dominated electron-photon beam collisions...** (L. Serafini)
10:00	**EuPraxia Status** (P. Campana - M. Ferrario)
10:40	Coffee Break
11:00	**WP2 Dissemination and Public Relations** (C. Welsch - S. Bertelli)
11:50	**WP3 Organization and Rules** (A. Specka - A. Ghigo)
12:40	Lunch
16:00	Coffee Break
16:20	**WP4 Legal Framework, Financial Model and Socio-economic impact** (A. Falone)
17:10	**WP5 User Strategy and Services** (F. Stellato - E. Principi)
18:00	**WP6 Membership Extension Strategy** (B. Cros - A. Mostacci)
18:50 - 19:30	**General Discussion**
20:30	Dinner

Tuesday 24 – EuPRAXIA_PP

09:00	**Overview of Plasma based Linear Collider efforts** (J. Osterhoff)
09:50	**WP7 E-Needs and Data Policy** (R. Fonseca - S. Pioli)
10:40	Coffee Break
11:00	**WP8 Theory & Simulation** (J. Vieira - H. Vincenti)
11:50	**WP9 RF, Magnets & Beamline Components** (S. Antipov - F. Nguyen)
12:40	Lunch
16:00	Coffee Break
16:20	**WP10 Plasma Components & Systems** (K. Cassou - R. Shalloo)
17:10	**WP11 Applications** (G. Sarri - E. Chiadroni)
18:00	**WP12 Laser Technology and Liaison to Industry** (L. Gizzi - P. Crump)
18:50 - 19:30	**General Discussion**
20:00	Dinner
21:30 - 22:30	**Hollywood Physics** (C. Welsch)

Wednesday 25 – EuPRAXIA_PP

09:00	**Dielectric wakefield acceleration: application to linear colliders** (J. Rosenzweig)
09:50	**WP13 Diagnostics** (A. Cianchi - R. Ischebeck)
10:40	Coffee Break
11:00	**WP14 Transformative Innovation Paths** (B. Hidding - S. Karsch)
11:50	**WP15 TDR EuPRAXIA @SPARC_LAB (beam-driven plasma)** (C. Vaccarezza - R. Pompili)
12:40	Lunch
16:00	Coffee Break
16:20	**WP16 TDR EuPRAXIA Site 2 (laser-driven plasma)** (A. Molodozhentsev - R. Pattathil)
17:10	**Beyond EuPRAXIA_PP: the PACRI Project** (G. D'Auria)
17:40	**Final Discussion**
18:00 - 19:30	**Collaboration Board**
20:30	Social Dinner

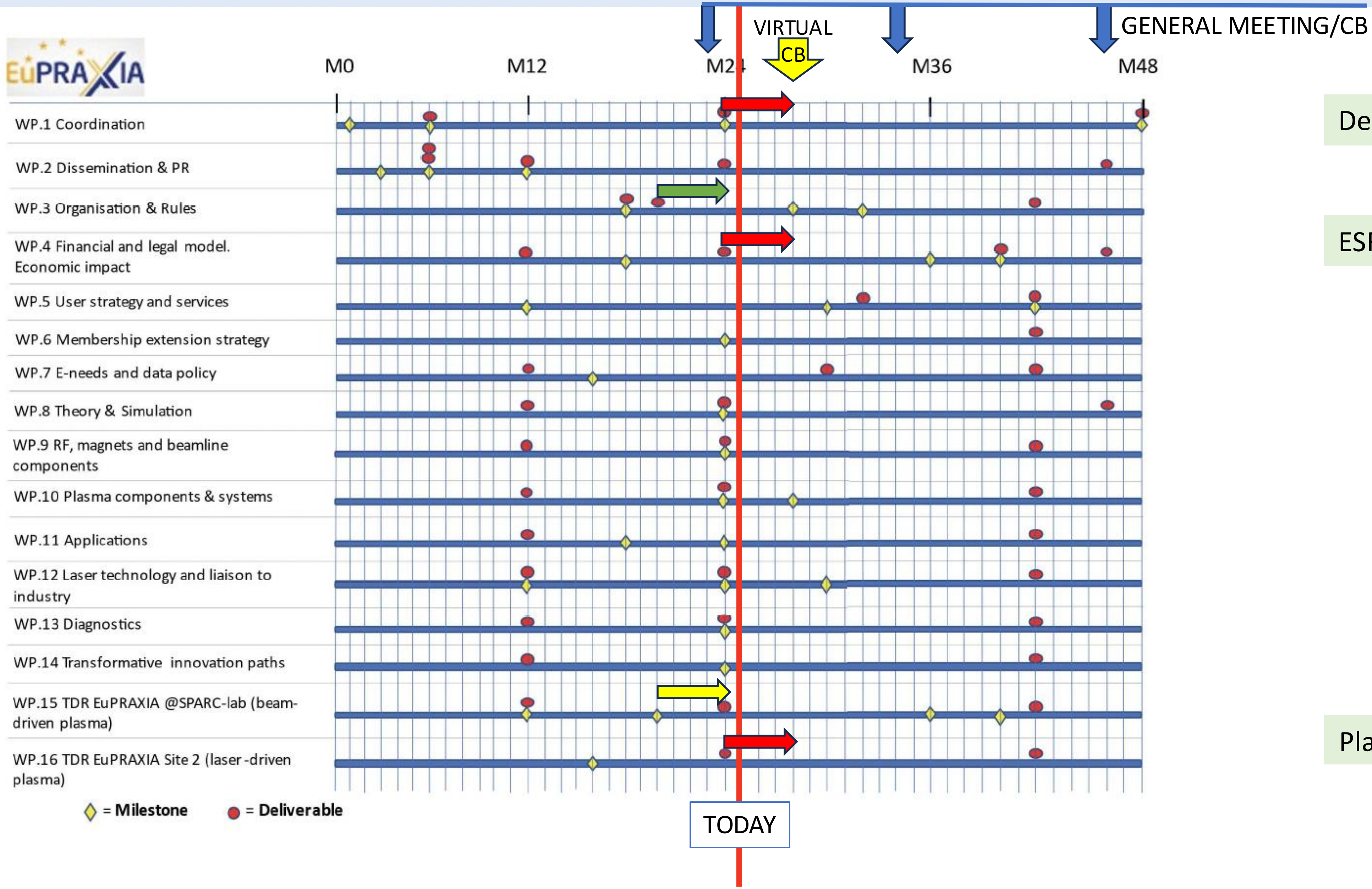
Thursday 26 – WORKSHOP

09:00	**EuPRAXIA@SPARC_LAB status short** (R. Pompili - C. Vaccarezza)
09:10	**Beam Driven Acceleration Scheme to 5 GeV Energy for EuPRAXIA@SPARC_LAB** (A. Giribono)
09:40	**EuPRAXIA@SPARC_LAB energy boosting to 5 GeV by LWFA and external injection** (A.R. Rossi)
10:10	**Plasma-Based Solutions for Beam Handling and Driver Extraction** (M. Carillo)
10:40	Coffee Break
11:00	**Stable Beam driven wakefield in structured plasmas** (A. Pukhov)
11:30	**Towards 400 Hz RF system for EuPRAXIA@SPARC_LAB** (F. Cardelli)
12:00 12:30	**High repetition rate C-band Photoinjector** (G. Silvi)
12:40	Lunch
16:00	**High Repetition rate Plasma sources** (L. Crincoli)
16:30	**Fully synchronized high repetition rate Petawatt laser driver for betatron beamline on EuPRAXIA@SparcLab machine** (A. Courjaud)
17:00	**Ultracold electron sources, kHz plasma injectors and strong THz fields** (S. Karsch)
17:30	Coffee Break
18:00	**VUV Applications at EuPRAXIA@SPARC_LAB** (F. Stellato)
18:30	**Theory and simulations for high K/γ regimes in undulator and ion channel devices** (A. Frazzitta)
19:00 - 19:30	**Closing Remarks & Discussion** (R. Pompili - C. Vaccarezza)
20:30	Dinner

Friday 27 – WORKSHOP

	Presentation of Eupraxia
09:00	**EuPRAXIA accelerator and facility: a technical perspective** (M. Ferrario)
09:30	**EuPRAXIA Collaboration and its organisation** (A. Falone)
09:45	**Reason and directions of Membership Extensions** (P. Campana)
	Potential links in countries not yet represented in EuPRAXIA
10:00 10:30	**Pioneering experience on the development of accelerators from scratch: SESAME facility** (A. Lausi)
10:40	Coffee Break
11:00	**Research initiatives in INDIA and potential opportunities for EuPRAXIA** (R. Pattathil)
11:30	**Research initiatives in AFRICA and potential opportunities for EuPRAXIA** (C. Darve)
12:00 12:30	**The Latin American Synchrotron in the Greater Caribbean** (G. Violini)
12:40	Lunch
	EuPRAXIA framework for R&D
16:00	**Plasma based positron sources for testing positron acceleration at EuPRAXIA** (G. Sarri)
16:25	**Synergies for laser development between EuPRAXIA and other fields including fusion and industry** (L. Gizzi)
16:50	**Nuclear physics in plasma at EuPRAXIA** (P. Tomassini)
17:15	**EuPRAXIA possible contributions to the Linear Collider development** (J. Osterhoff)
17:40	Coffee Break
	Training and young researcher education
18:00	**The African School of Physics** (K. Adikle Assamagan)
18:20	**Tools for Students training in EU and funding opportunities** (C. Welsch)
	Discussion/Round table
18:40 - 19:30	**Strategy for linking Eupraxia to other worldwide similar accelerator activities** convener: B. Cros (K. Adikle Assamagan - C. Darve - A. Lausi - M. Ferrario - R. Pattathil - G. Violini)
20:30	Aperitivo Dinner

The tasks of the Preparatory Phase



Decision on 2nd site

ESFRI RI cost update

Plans for selected site 2

New Legal Entity Options – Comparison ERIC vs AISBL

European Research Infrastructure Consortium - ERIC

Positive Impact / Negative Impact; Internal Factors / External Factors

STRENGTHS	WEAKNESSES
Established by EU Regulation	Not preferred solution at institutional level
Specifically designed for European RI	National institutions as representing entities
Member State involvement	No flexible governance structure
No initial capital investment required	Process lengthy (2 steps submission and evaluation process by the EC)
Long term stability	Lack of political and institutional support
Specific exemption (VAT & Procurement directives)	

OPPORTUNITIES	THREATS
Higher Brand Reputation	Detached from host institution roadmap & strategy
ERIC Forum and networking	Higher financial risks
Cash and IKC possible	Membership fee as main funding model for operation
Ability to carry out economic activities	Unforeseen costs to be negotiated with member countries
Autonomy in defining procedures (procurement & hiring)	ERIC Model not applicable uniformly in all EU
Financial contribution based on financial tools	Several issues encountered by other ERICs

Association International sans but lucrative - AISBL

Positive Impact / Negative Impact; Internal Factors / External Factors

STRENGTHS	WEAKNESSES
Full Legal Personality	Headquarter to be placed in Belgium
Accepted by all members	Operational funding only through membership fee
Flexible and effective governance	Royal decree needed (lengthy process)
International dimension	Necessity of a notary act

OPPORTUNITIES	THREATS
International Brand Reputation	Long term sustainability somewhat critical
Ability for fund-raising (Eu Calls, National & Regional)	Large upgrade investment still needs full involvement of members institution.

Scientific and Technical Advisory Board

Committee formed by high level scientists, belonging to the area of particle physics, accelerators, plasma and laser technologies, with high expertise in governance of large programs / science policy

The goal is to provide advise to EuPRAXIA for the operation of the Consortium, both in the Preparatory Phase and in the (most important) Implementation Phase. They will have access to General Meetings material, and will be allowed to follow the CB, to get insights in the project

First, **introductory meeting on Sep. 12**; presentations on advancement of Preparatory Phase, technical aspects of beam and laser driven technologies, status of 2nd site choice, preparation of governance scheme

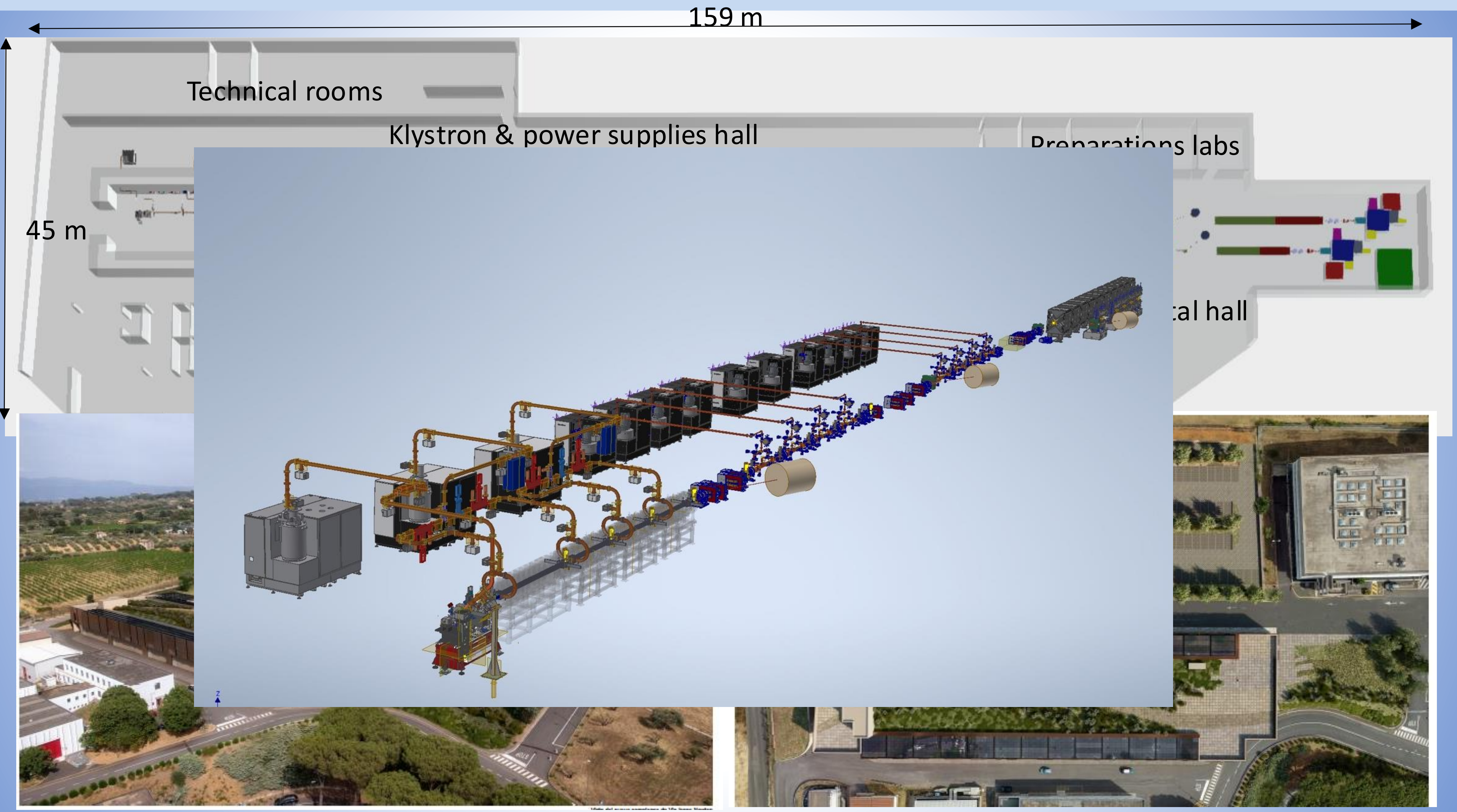
A second meeting is foreseen by early next year, with a more specific list of questions to which the Consortium will be asked to answer

→ Scientific strategy, technical choices,
2nd site, governance, funding, long term sustainability: the main items that will be discussed by STAB

- **Final list of members:**

* Lenny Rivkin - Chair	PSI/LEAPS
* Mike Dunne	SLAC
* Ursula Bassler	CNRS
* Sandro de Silvestri	Politecnico Torino
* László Veisz	UMU Sweden
* Fernando Ferroni	INFN
* Thomas Tschentscher	Eu. XFEL
* Hagen Zimer	Trumpf Laser CEO
* Roland Sauerbrey	ex HZDR director, retired

EuPRAXIA@SPARC_LAB Layout



Scicom Recommendations about EuPRAXIA

1) *The delays of EuPRAXIA@SPARCLAB have to be taken into account for the overall strategy for research activities at LNF, since a sufficient portfolio of other scientific activities has to be maintained until the science program at EuPRAXIA@SPARCLAB starts. This has to be kept in balance with sufficient technical resources for EuPRAXIA@SPARCLAB design and project execution.*

The recent introduction of the Project Management Office at LAB level is meant to address this recommendation. It will help the Lab management to harmonize the resources and suggest an alignment of resource allocation based on strategic objectives of the LAB.

EuPRAXIA@SPARC_LAB is the major project of the LAB and it currently absorbs a significant amount of resource especially in the Accelerator Division.

It will be essential that the resource allocation in the mid term will follow the natural evolution of the project and its requirements in terms of personnel and material resources.

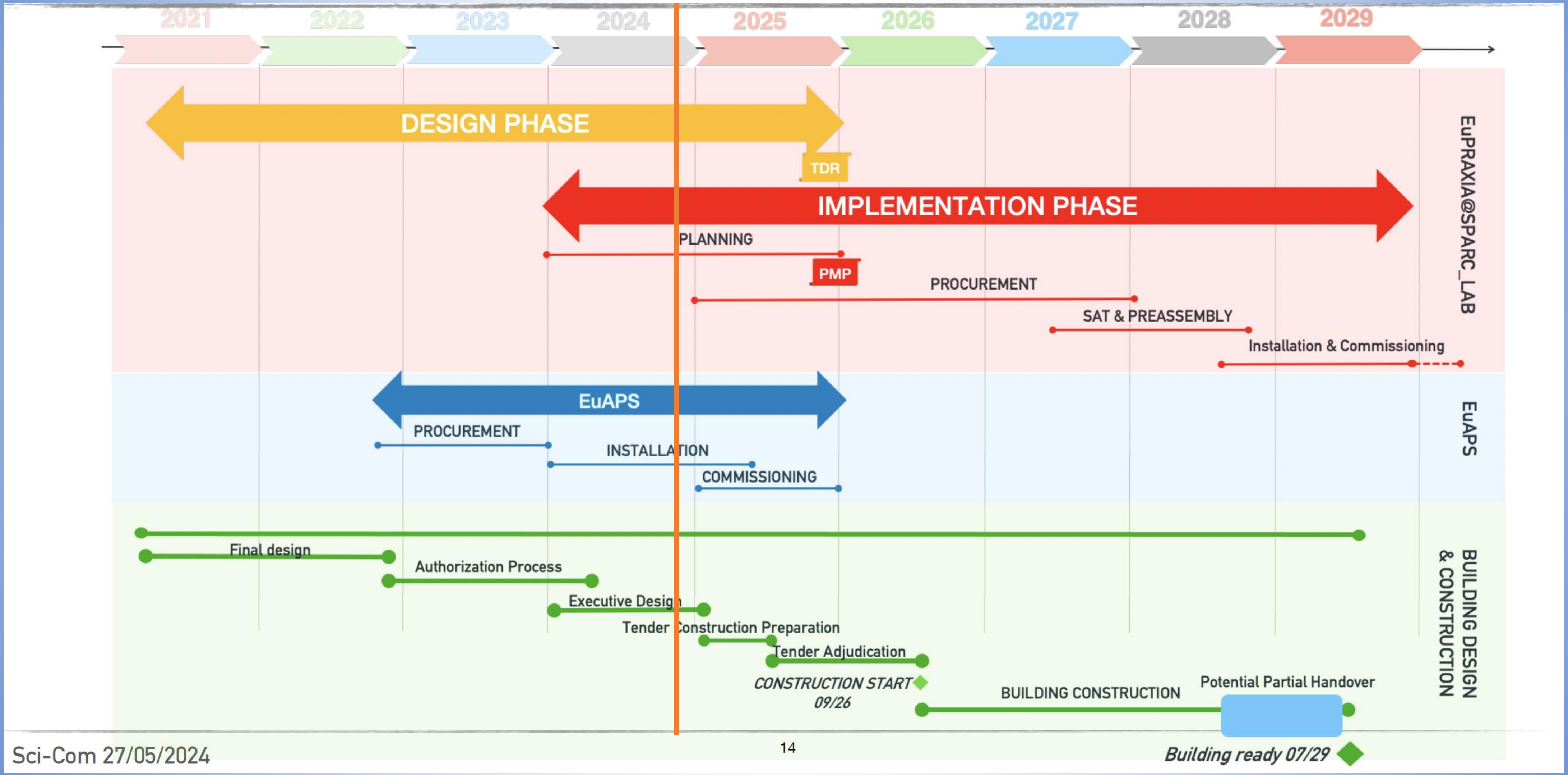
Scicom Recommendations about EuPRAXIA

4) Component procurement should start as soon as the TDR is finalized, otherwise inflation will drive the overall cost even higher.

At the moment the inflation scenario seems to be not significant. On the other hand it is true that procurement especially for the critical items (e.g. RF power station) should start as soon as possible ideally even before the TDR completion. This is due to mitigate the risk of delays due to the procurement procedure.

For the RF power station case and the final validation of the CANON tubes, they will be tested during spring 2025 and the corresponding tender procedures can be triggered before the end of the year.

EuPRAXIA@SPARC_LAB baseline updating



TRD readiness: writing

X band linac	Civil infrastructures	Timing and synchronization	Free Electron Lasers	Plasma acc. module	Ele. and phot. diagnostics	Functionality saf. systems	Exp. end-stations	Laser systems	Control system	Photo-injector	Photon beamlines	System engineering	P. cost, time., management	Beam physics	EuPRAXIA in EU context	Scientific case	Machine layout	Magnets and power supp.	Int., impl., comm. strategy	Vacuum systems	Rad. saf. and beam dumps	Executive summary	EuPRAXIA@SPARC_LAB	RF systems	Conventional safety	Future upgrades
85	85	80	65	60	60	45	40	30	30	25	16	15	15	11	10	10	10	7	7	5	5	0	0	0	0	0

November 2024

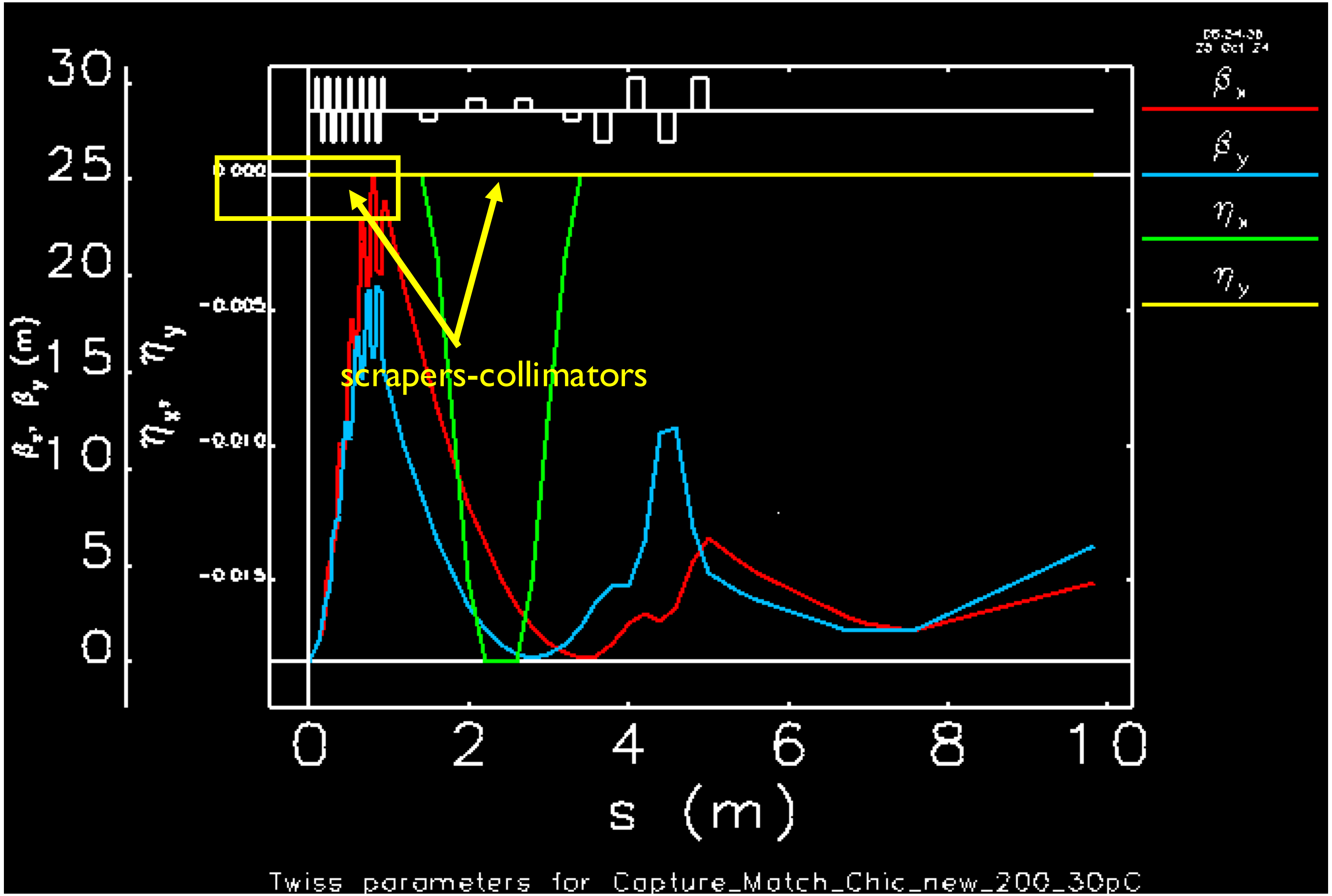
Scicom Recommendations about EuPRAXIA

2) The SC re-iterates its recommendation from the last three reports that radiation levels and shielding dimensions for the drive bunch collimation and/or dump need to be computed. At a beam energy of more than 1 GeV and a mean beam current in the order of 0.1 μA this shielding may need considerable space and has to be known before building specifications are frozen!

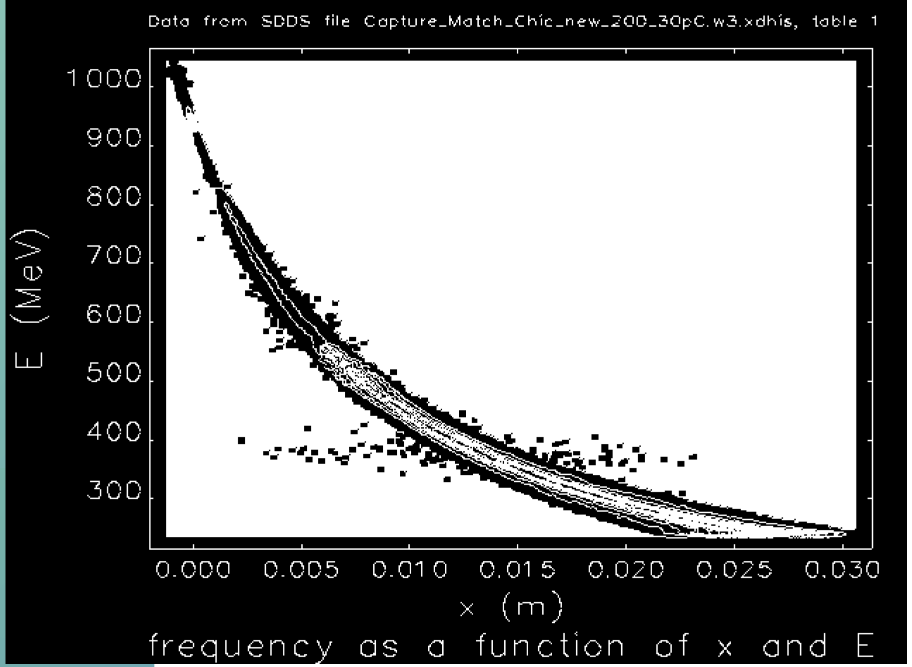
The simulation of the beam after the interaction with the plasma was done by evaluating its charge/energy distribution. The bulk of the charge, initially at 500 MeV, loses energy in the plasma and is distributed in the 2-300 MeV range.

A vacuum chamber with a septum that allows the beam to be extracted and dampened laterally is being considered, and the Radiation Protection Service is proceeding with the dimensioning of the dump.

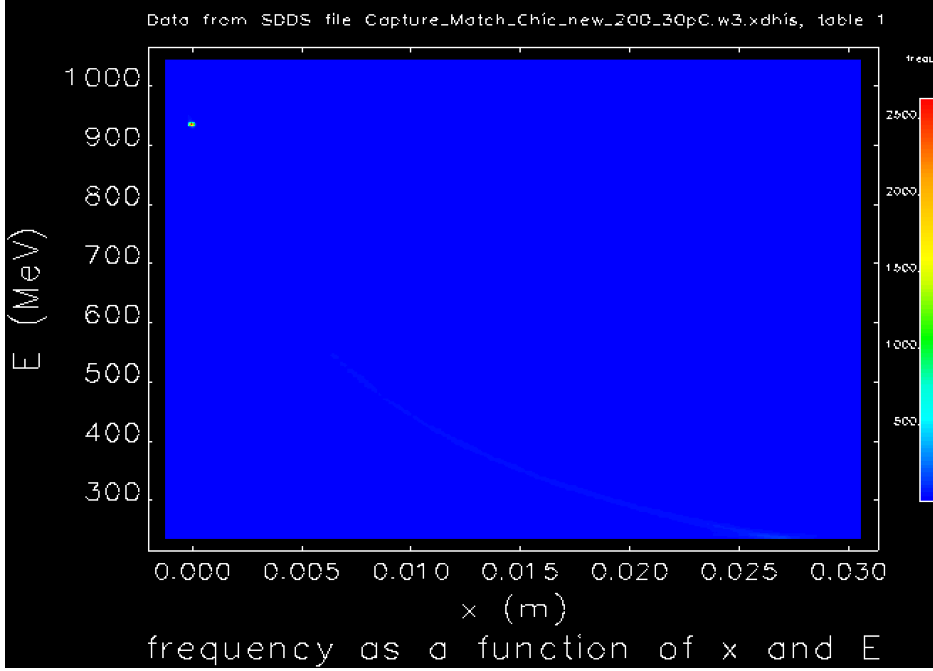
DRIVER WITNESS SEPARATION IN THE CHICANE



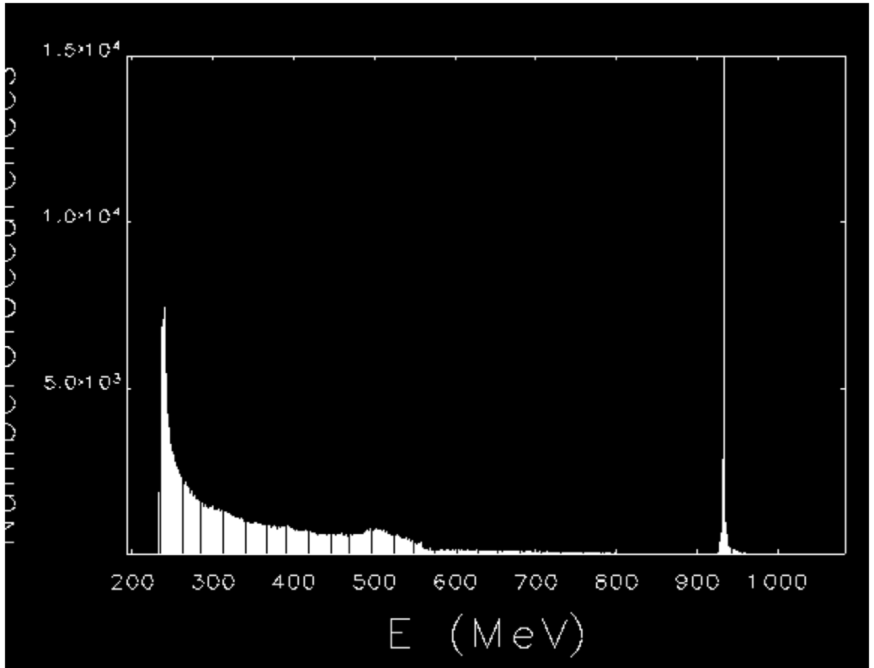
COMB BEAM ENERGY DISTRIBUTION BEFORE CUT



E (MeV) vs x (m) – contour plot



E (MeV) vs x (m) – contour plot with shade



E (MeV) histogram

Scicom Recommendations about EuPRAXIA

3) To avoid further delays the open design question for the TDR need to be solved with high priority by studies, simulations and appropriate experiments in SPARCLAB.

A comprehensive review with the WP and WA leaders is now ongoing to resolve all the pending issues concerning the definition of the machine especially for beam dynamics, diagnostics and FEL configuration.

SPARC_LAB activities will remain the major benchmarking tool for the future of EuPRAXIA@SPARC_LAB even after the TDR completion. An intensive experimental program is drafted although during 2025 several upgrades must be concluded the the uptime of the machine will not be optimal.

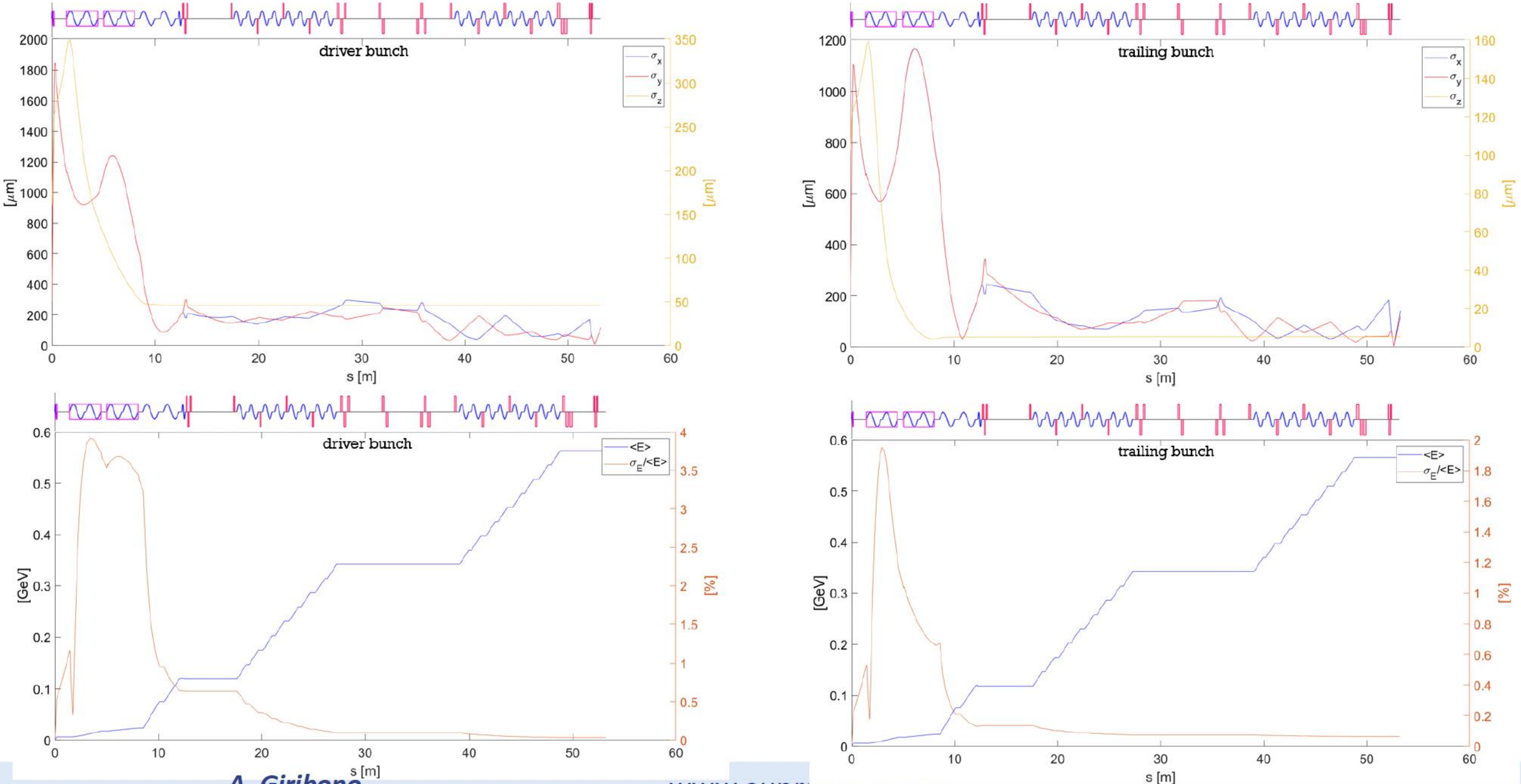
Goal parameters and design criteria

Funded by the European Union

Radiation Parameter	Unit	PWFA	Full X-band
Radiation Wavelength	nm	**3-4**	4
Photons per Pulse	$\times 10^{12}$	**0.1- 0.25**	1
Photon Bandwith	%	**0.1**	0.5
Undulator Area Length	m	30	
ρ(1D/3D)	$\times 10^{-3}$	**2**	2
Photon Brilliance per shot	$\left(\frac{s\ mm^2 mrad^2}{bw(0.1\%)}\right)$	$\mathbf{1{-}2\ \times 10^{28}}$	$1\ \times 10^{27}$

Electron Beam Parameter	Unit	PWFA	Full X-band
Electron Energy	GeV	**1-1.2**	1
Bunch Charge	pC	**30-50**	200-500
Peak Current	kA	**1-2**	1-2
RMS Energy Spread	%	**0.1**	0.1
RMS Bunch Length	μm	**6-3**	24-20
RMS norm. Emittance	μm	**1**	1
Slice Energy Spread	%	**≤0.05**	≤0.05
Slice norm Emittance	mm-mrad	**0.5**	0.5
Energy jitter	%	**≤0.05**	≤0.05
Driver-Witness Temporal jitter	fs	< 5	-

Beam Paramters



Machine Setup for VB based WoP1

Cathode Laser System			
	Witness	Driver	
Charge [Q]	30	200	pC
Time delay [Δt]	- 4.8	0	ps
Laser Spot size [σ_r]	175	300	µm
Laser Pulse length [σ_t]	0.30	0.40	ps

RF Gun		
RF Peak Voltage [V]	120	MV
RF Phase [ϕ]	-30	*Deg*
S-band Accelerating Sections		
RF Voltage (on average) [V]	21,21,35,35	MV
RF Phase [ϕ]	-92,-84,-10,-10	*deg*
X-band Accelerating Sections		
RF Voltage (on average) [V]	25	MV
RF Phase [ϕ]	-10	*deg*

Magnets			
S-band Photoinjector - Peak Field			
Type	B_{max} (T)	Length (m)	Energy (MeV)
Gun Solenoid	0.3	2 coils (SABINA like)	-
Acc. Structures solenoids	0.035, 0.075	*4triplets,3 triplets (SABINA like),0,0*	-
X-band Linac			
Type	g_{max} (T/m)	Length (m)	Energy (MeV)
Type A	10	0.010	100 - 350
Type B	13	0.015	330 - 550
Type C	20	0.020	550
PMQ in	300	0.005,0.009,0.005	550

Beam parameters from jitter studies (w/o X-band cavity) at the capillary entrance

RF Gun (rms)		
RF Voltage [ΔV]	± 0.02	%
RF Phase [Δϕ]	± 0.02	*deg*
S-band Accelerating Sections (rms)		
RF Voltage [ΔV]	± 0.02	%
RF Phase [Δϕ]	± 0.02	*deg*
X-band Accelerating Sections (rms)		
RF Voltage [ΔV]	± 0.02	%
RF Phase [Δϕ]	± 0.10	*deg*
Cathode Laser System		
Charge [ΔQ] (max)	± 1	%
Laser time of arrival [Δ*t*] (rms)	± 20	fs
Laser Spot size [Δσ]	± 1	%

	Witness		Driver		
	Without errors	With errors	Without errors	With errors	
Charge	30.00	30.00 ± 0.33	200.00	200.00 ± 2.00	pC
Energy	537.18	537.19 ± 0.31	539.29	539.29 ± 0.30	MeV
Energy spread	0.712	0.711 ± 0.003	0.92	0.92 ± 0.001	‰
Bunch length	19.88	19.97 ± 0.32	205.87	205.55 ± 0.87	fs
I_{peak}	1873	1643 ± 99	-	-	kA
Δt	0.53	0.53 ± 0.04	-	-	fs
$\varepsilon_{nx,y}$	0.562	0.562 ± 0.007	4.18	4.22 ± 0.15	mm mrad
$\sigma_{x,y}$	1.5	1.52 ± 0.18	5.85	5.89 ± 1.07	µm
$\beta_{x,y}$	4.3	4.5 ± 1.1	8.8	9.1 ± 3.3	mm
$\alpha_{x,y}$	1.2	1.2 ± 0.25	1.65	1.65 ± 0.30	

- Errors are intended as rms quantities
- Driver & Witness numerically separated on the longitudinal axes

List of proposed activities for 2024/25

1 New PMQ tests

2 High-gradient/high-quality PWFA beams & Injector working point

3 Filament experiment (A. Zigler)

4 Resonant multi-driver PWFA (L. Verra)

5 Commissioning of the SABINA beamline

6 Driver-Witness separation with APLs – 2 weeks (M. Carillo)

7 PWFA vs EOS (RF timing)-Plasma (density)-Laser (charge) jitter study (R. Pompili)

8 UV-Blue-IR photo-emission comparison for charge-jitter study (M. Galletti)

9 Plasma ramps parametric study (S. Romeo)

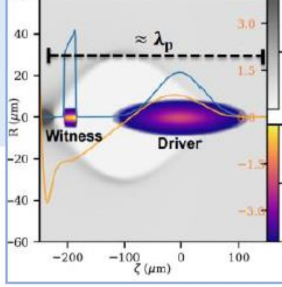
10 Commissioning of the EXIN beamline

11 FEL seeding with betatron radiation (A. Ghigo)

12 Ion motion recovery time

13 PWFA-FEL for attosecond pulses (M. Opromolla)

Comb beam generation at EuPRAXIA@SPARC_LAB

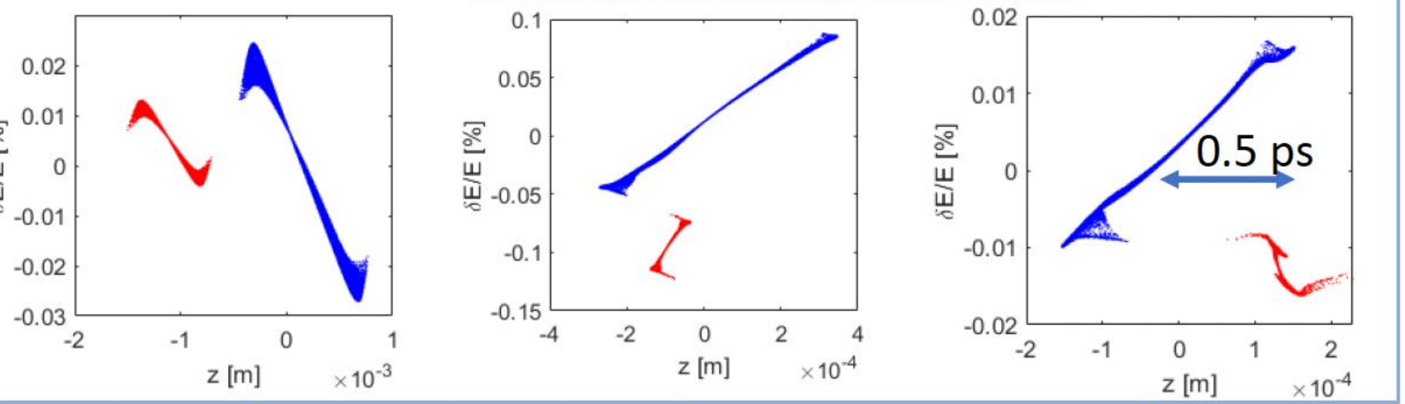


The **reference working point** is defined by the FEL performances and the plasma module

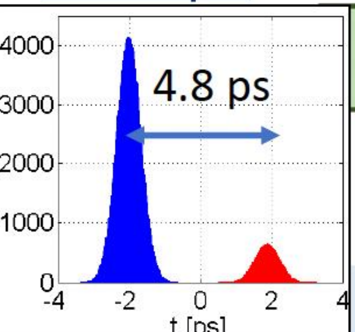
- Witness brightness → I_{peak} = 2 kA, ε_{nx} < 1μmrad, δE/E < 0.1 %
- Witness energy jitter < 1 %
- Accelerating gradient of the order of GV/m
- Weakly non-linear regime (bubble with resonant behaviour)

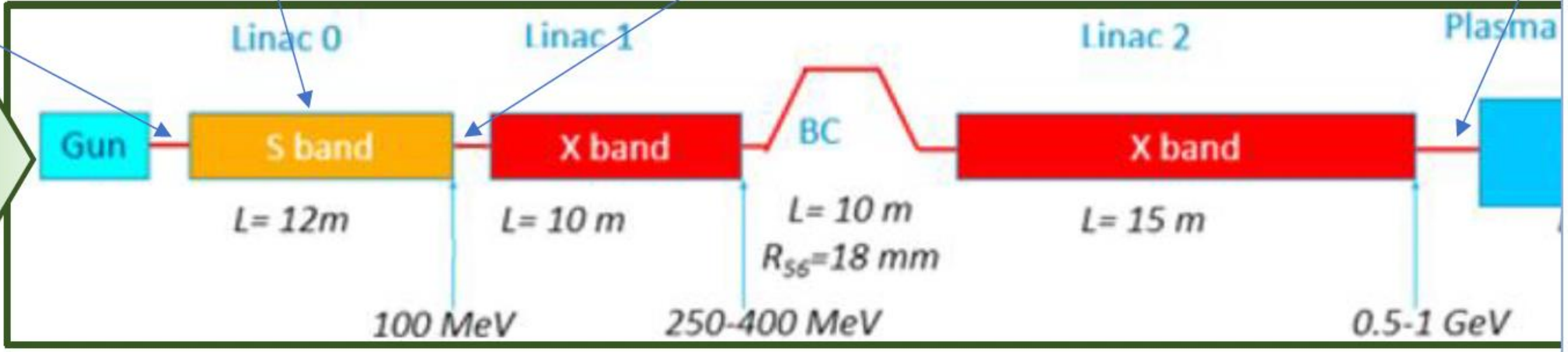
1. **200** (500) pC driver + **30** (50) pC witness
2. plasma density of the order of $10^{16}\ cm^{-3}$ (λ_p = 334 μm)
3. Driver-witness separation of around $\lambda_p/2$ → **0.5 ps** (1 ps)
4. Driver and witness bunches of **50** (24) and **6** μm rms
5. Driver and witness spot size of **4** and **1** μm with α=1

Velocity bunching technique

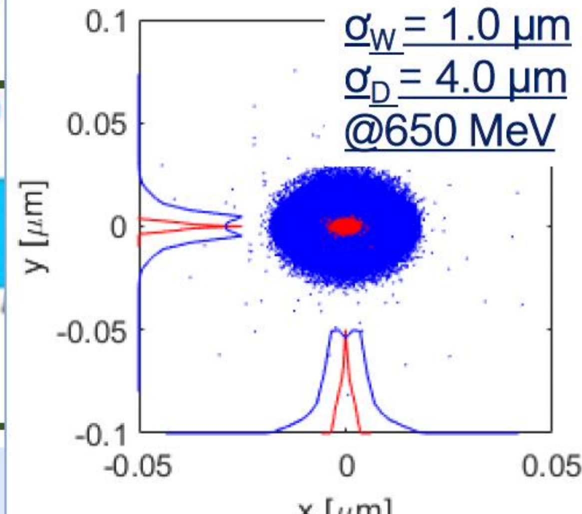


Laser comb technique





Strong focusing system



A. Giribono

Preliminary results obtained at SPARC_LAB

In May 2023 we tested a preliminary version of the intra-pulse feedback on the C-band klystron with very good results
Preliminary data have been parasitically collected during machine restart in October 2024 for the S-band power plants

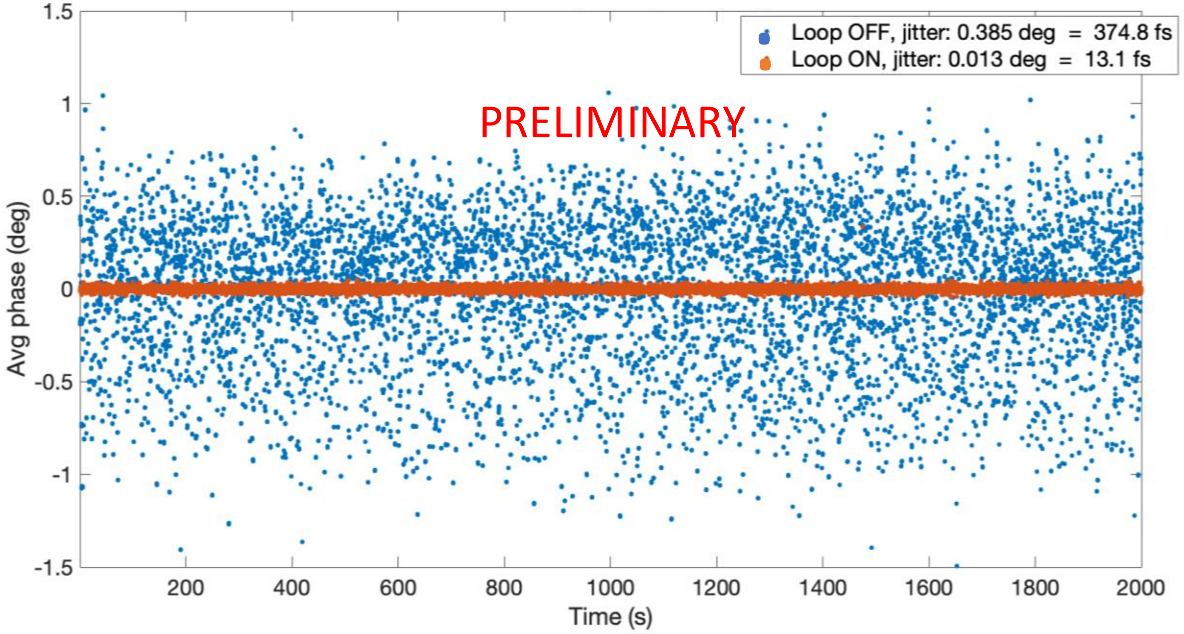
TO DO:
The performance achieved on both S and C band power plants are very promising but must be still optimized and consolidated:

- Reach the same stability of K1 also on K2
- Further optimize the intra-pulse feedback system (Xianghe Fang Ph.D. student from Eupraxia DN just started his activity with the RF group on this topic)

PC-laser locking electronics performance can be improved
Test of the intra-pulse feedback system on the X-band power plant at TEX

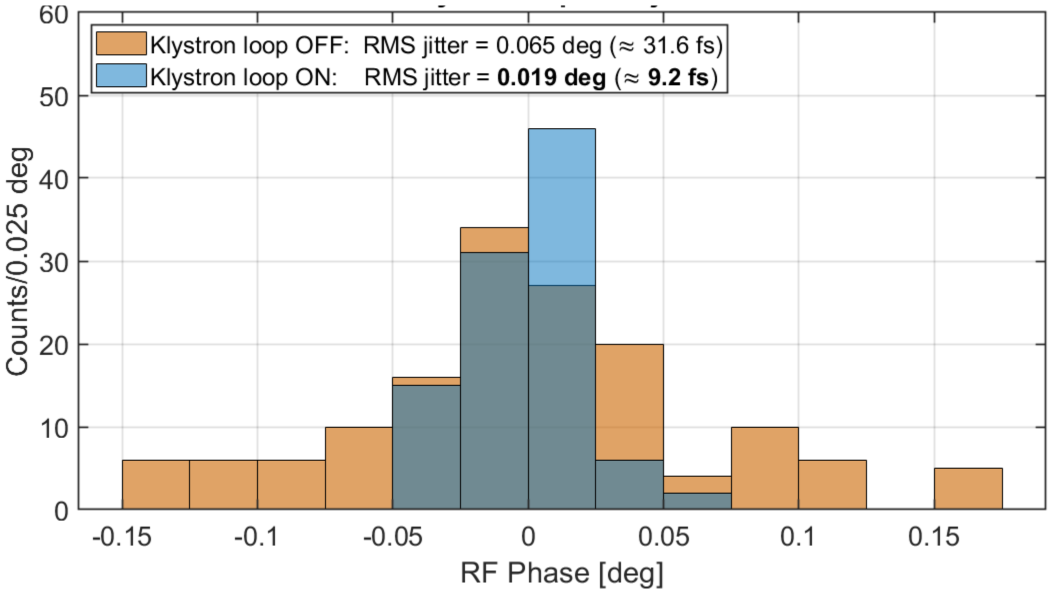
S-BAND

RF-Gun phase jitter compression
from 0.385 deg down to 0.013 deg (**13.1 fs**)



C-BAND

K3 phase jitter compression
from 0.065 deg down to 0.019 deg (**9.2 fs**)



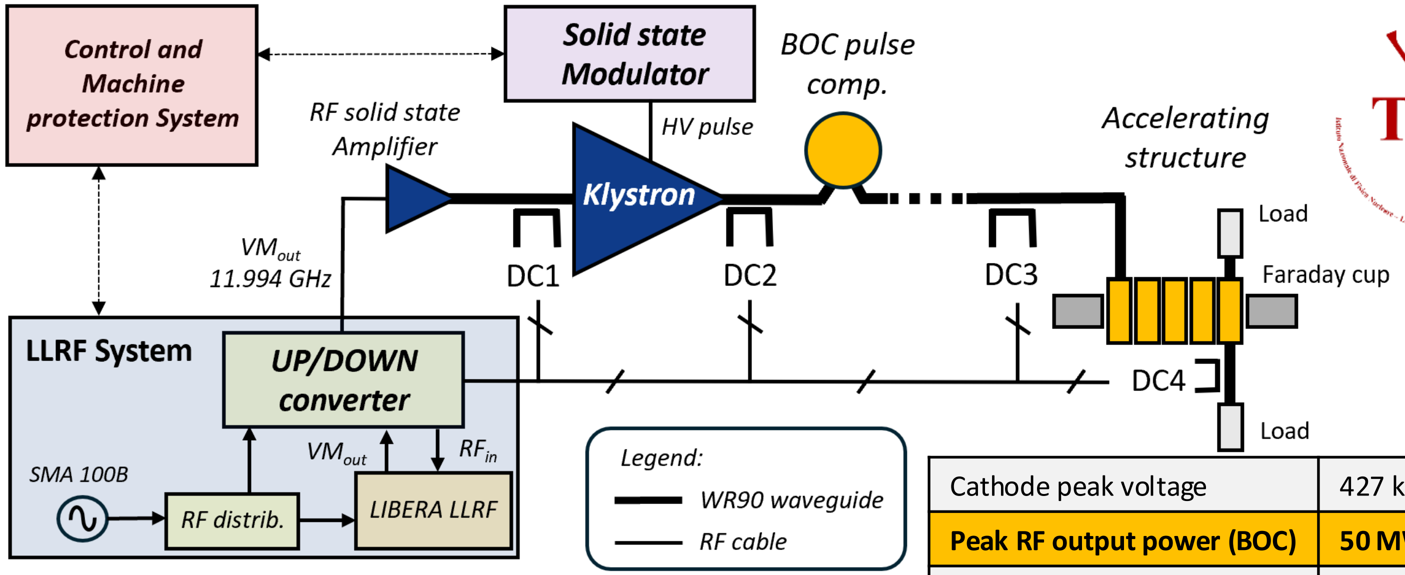
L. Piersanti et al. *Photonics* **2024**, *11*(5), 413

TEX (Test stand for X-band) facility

- The **TEst-stand for X-band (TEX)** is conceived for R&D and test on high gradient X-band accelerating structures, RF components, LLRF systems, Beam Diagnostics, Vacuum system and Control System
- It has been co-funded by Lazio region 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**
- The installation and commissioning of the whole system have been completed by the end of 2022.
- **Then started the testing activity:**

Period	Device tested at high power
Jan. - Feb. 2023	**3D printed Spiral RF loads** and wg
May - Oct. 2023	X-band **T24 CLIC structure (CERN)**
Nov. - Dec. 2023	X-band **Mode converter** and **circular wg**
Jan. - Feb. 2024	X-band RF **waterload (PSI)**
March 2024	**20 cells first EuPRAXIA RF prototype**

F. Cardelli et al., in Proc. IPAC'22, Bangkok, Thailand. (2022) paper TUPOPT061
L. Piersanti et al. Photonics 2024, 11(5), 413.
F. Cardelli et al., in Proc. IPAC'24, Nashville, TN (2024) paper TUPR02



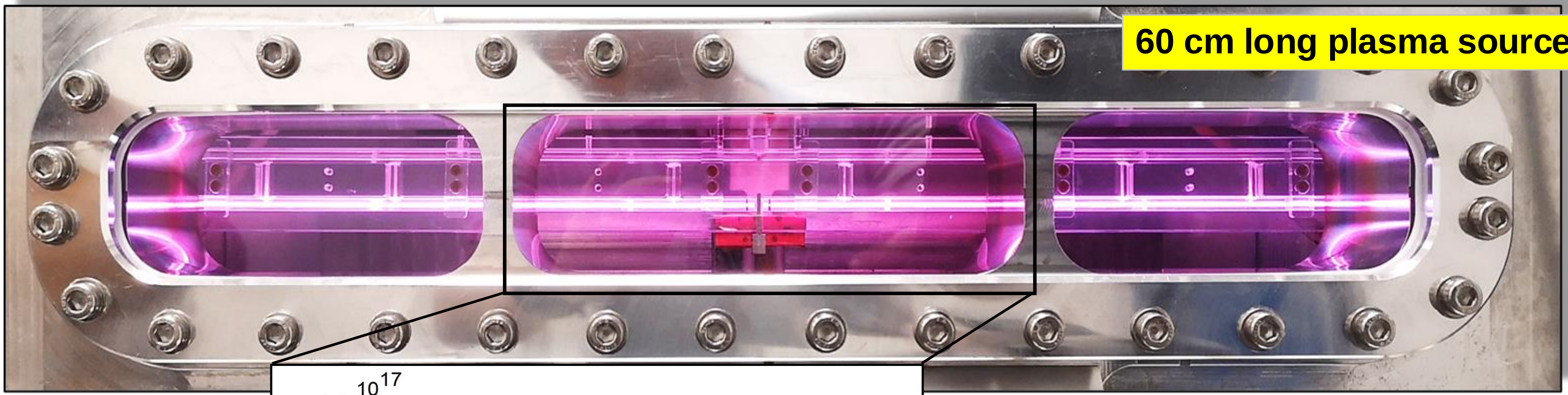
Cathode peak voltage	427 kV
Peak RF output power (BOC)	**50 MW - 200 MW**
Pulse length	100 ns - 1.5 us
Repetition Rate	**50 Hz**
RF output amplitude stability	< 0.09 %
RF output phase stability	20.9 fs

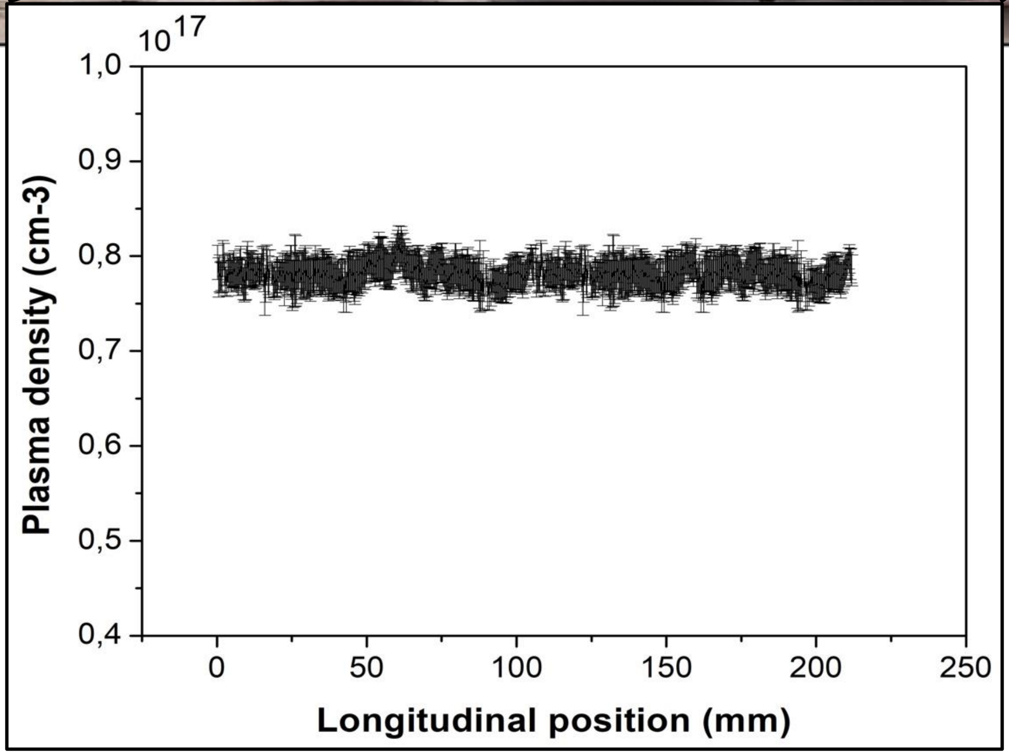
LLRF system

50 MW RF Source

Bunker

CPI Klystron





Preliminary tests:

- Middle section
- First 3D plastic prototype (ceramics for the future)

1.1 GeV (1 GV/m 600 MeV in **60cm** long capillary - density 10^{16} cm-3):

- Fabrication by machining
- 10 increasing diameter
- Density range 10^{16} -10^{17} cm^{-3}
- 13 kV with 500 A
- **100 Hz rep Rate (ceramic materials)**

Scicom Recommendations about EuPRAXIA

5) The LNF and EuPRAXIA management has to develop a strategy how to cope with the cost overrun. Either additional financial resources have to be found, or a project descoping, or a phased approach has to be decided.

A comprehensive cost review has been done during the year. Significant savings have been found due to a better definition of the machine. At the moment the cost scenario is the following:

An additional funding line of 10M€ is at advanced stage of negotiation with Regional Government.

A 10% over budget is still there, however:

- Minimum scope is now fully funded.
- The cost estimation includes contingencies and savings are expected from the building tender.
- A phasing approach will be adopted.
- The funding attractiveness is remarkably high.

Functional Area	Estimated Cost (€)
Injector	10.999.880
Low Energy Line	9.596.380
Bunch Compressor	1.180.400
High Energy Line	9.761.760
Plasma Module	2.096.000
AQUA FEL	15.520.000
AQUA Beam Lines	7.095.900
ARIA FEL	6.004.000
ARIA Beam Lines	6.374.900
General Elements	3.940.740
Building	47.945.500
Hi-Tech utilities	6.000.000
TOTAL	**126.515.460**

Board of Financial Sponsors

Funded by the European Union

Committee formed by representatives from Funding Agencies of countries present in EuPRAXIA to advise/support/endorse/control the operation of the Consortium, both in the Preparatory Phase and in the (most important) Implementation Phase

BoFS is expected to ratify 2nd site choice, legal framework, governance, funding scheme (in-kind & cash), together with general EuPRAXIA layout and operation (sites + national nodes + technical clusters).
Quite inhomogeneous National Funding Schemes: National Institutes (IT, FR, UK), Ministerial levels, CERN IGO, ELI-ERIC, etc... Difficult recollection of concerned people. 1st meeting expected within year's end

Country	Name	other info
CERN	Steinar Stapnes	CERN
Czech Rep	Radka Wildova	Director General for Higher Education, Science and Research section
	Marek Vysinka	Research Infrastructures Department
France	Antoine Rousse	CNRS-LOA
	Catalin Miron	CEA-Research Infrastructures
Germany	to be comunicated	
Greece	Emmanuel Varvarigos	Vice-Rector of NTUA
Italy	Sandra Malvezzi	INFN Executive Board
	to be comunicated	Italian Research and University Ministry
Portugal	Marta Fajardo	IPT
Spain	Rebeca Frías Antolín	Grandes Instalaciones Científicas - Ministerio de Ciencia, Innovación y Universidades
UK	John Collier	CLF Director and Executive Director of Laserlab Europe
Hungary	Peter Racsko	NRDIO officier

Plasma Accelerators for Compact Research Infrastructures (PACRI)

Funded by the European Union

- **HORIZON-INFRA-2024-TECH-01-01: R&D for the next generation of scientific instrumentation, tools, methods, solutions for RI upgrade**

- **Budget ~10 MEuro**

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

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 Accelerators for Compact Research Infrastructures (PACRI)

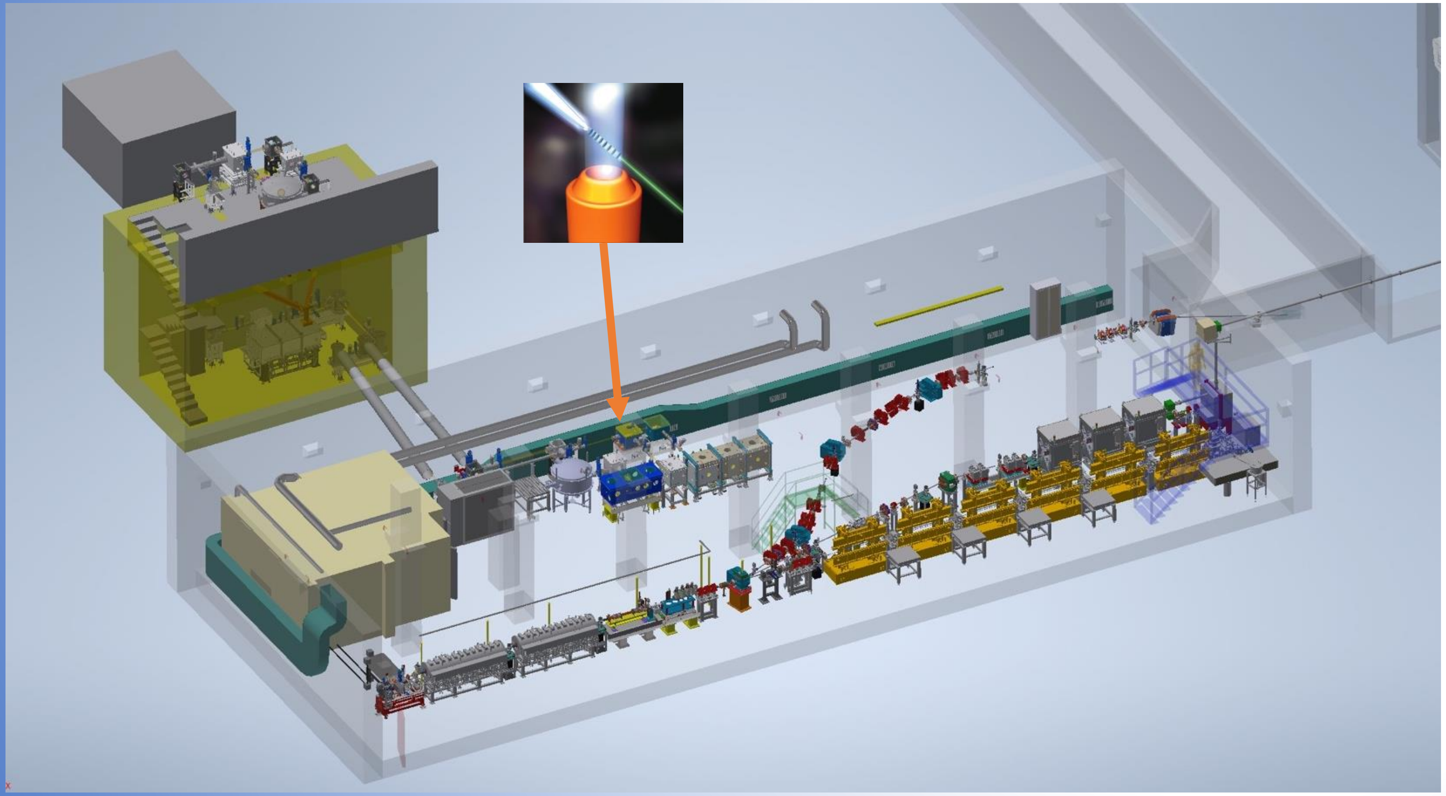
Funded by the European Union

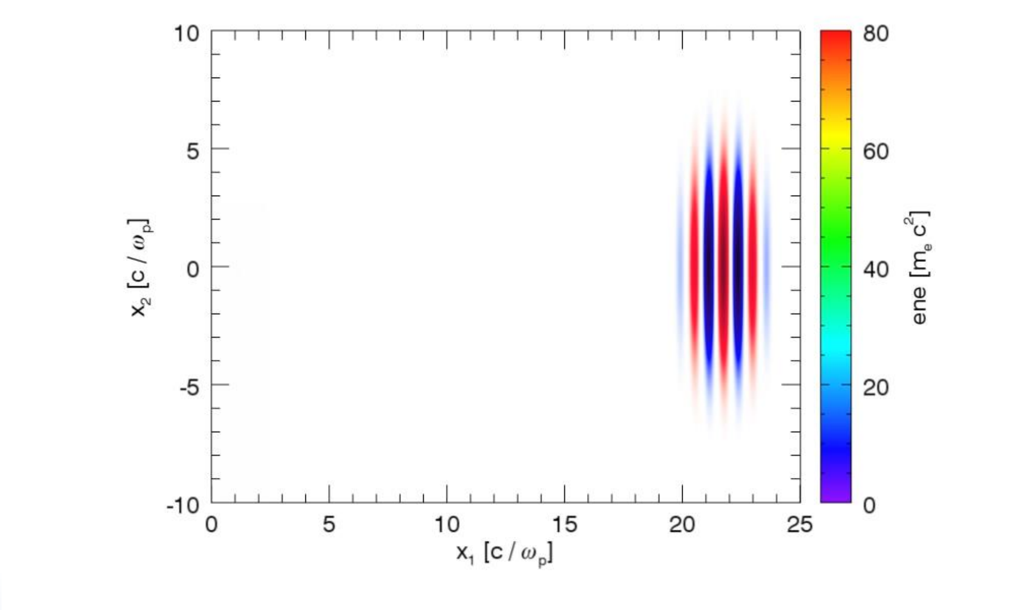
The objective of the **PACRI** project is to develop innovative breakthrough technologies, increasing their Technology Readiness Level (TRL) for electron accelerators while taking energy consumption, resource efficiency, costs, and environmental impact into due account. This includes the following draft non-exclusive goals:

- **developing high rep-rate plasma modules,** as required for the EuPRAXIA project, extending its scientific domain from high average brightness radiation sources up to high energy physics;
- **developing key laser components required to upscale high-power high repetition rate Laser technology** as required by the EuPRAXIA and ELI Research Infrastructure.
- **improving the performance of normal conducting technology for X-band linac drivers,** extending them to the kHz regime, with focus on efficiency and energy consumption;
- **supporting development towards compact linear colliders and nuclear physics facilities;**
- **developing compact advanced undulator modules,** in order to reduce the overall size of the future FEL facilities.
- **supporting the availability of compact X-ray facilities (FELs, ICSs, Betatron)** to serve a larger number of users in many scientific fields, industry and society;

Betatron Radiation Source at SPARC_LAB

Electron beam Energy [MeV]	50-800
Plasma Density [cm^{-3}]	10^{17} - 10^{19}
Photon Critical Energy [keV]	1 - 10
Nuber of Photons/pulse	10^{6} – 10^{9}

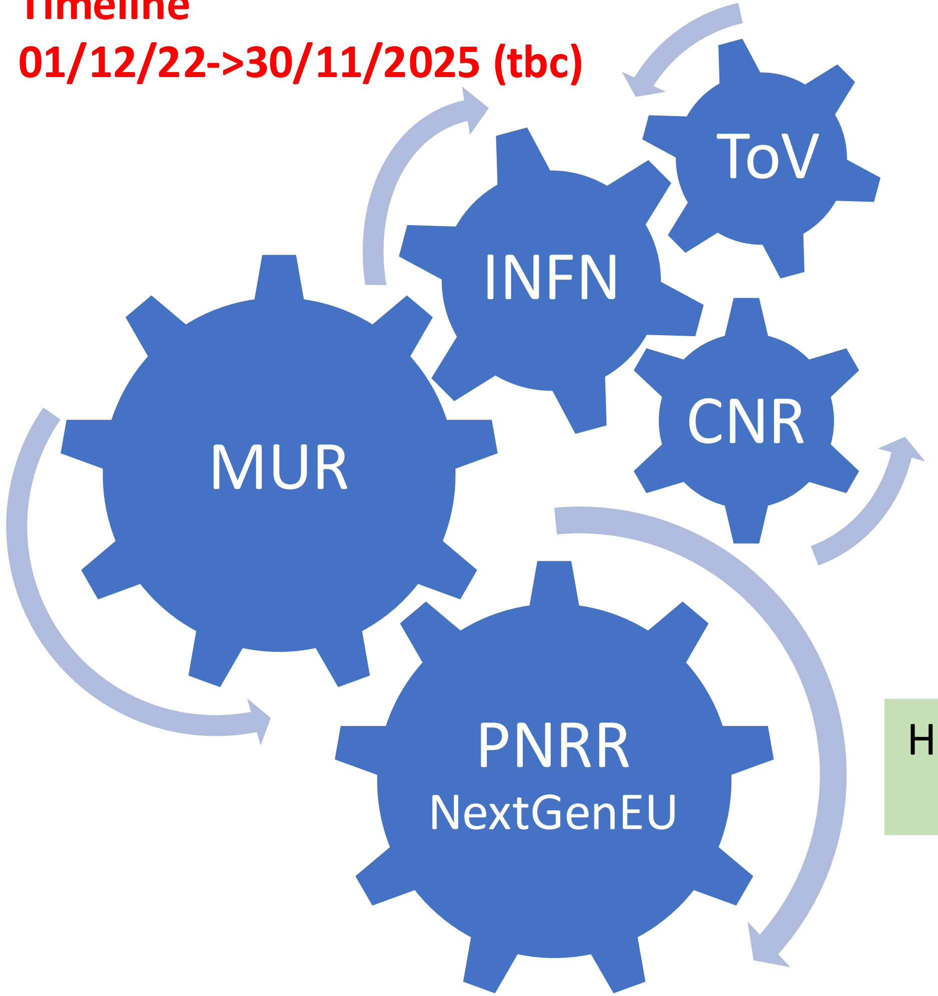




Courtesy J. Vieira, R. Fonseca/GoLP/IST Lisbon

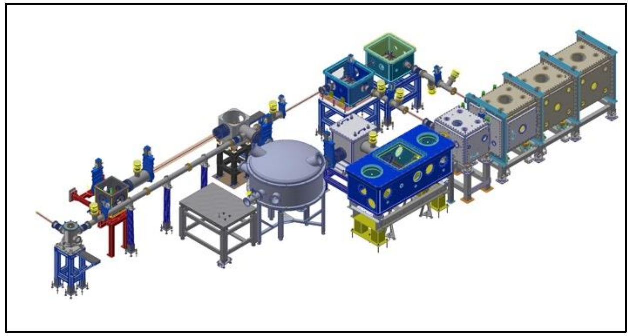
EuAPS is one the INFN-led PNRR projects: investment 22.350.588 Euro

Timeline
01/12/22->30/11/2025 (tbc)

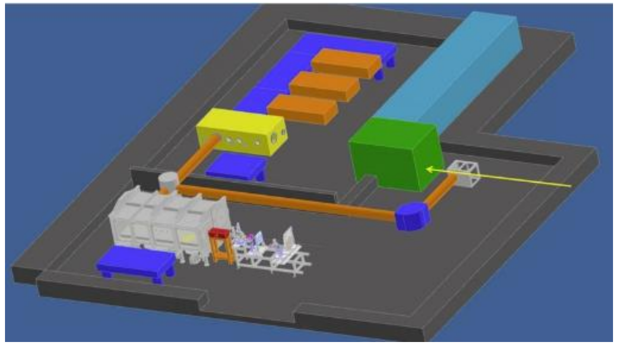


Management&Dissemination
165.850 Euro (WP1)

Betatron Radiation source at LNF
9.457.088 Euro (WP2)



High Power Laser beamline at LNS
7.864.500 Euro (WP3)



High repetition rate beam Laser at CNR-INO (Pisa)
4.863.150 Euro (WP4)

EuAPS – Financial status

Direct costs:
Personnel costs – all limited duration contracts are ongoing

Sections	Requested grant €	Committed+Paid €	Spending factor	Personnel Contracts (2y)
INFN-LNF	5.668.400,00	5.414.190,98	95,5%	3
LNS	7.387.812,47	6.610.792,65	89,5%	2
INFN-MI	267.000	237.438,39	88,9%	2
Total	**13.323.212,47**	**12.262.422,02**	**92%**	**7**

Scientific instrumentation + civil infrastructures (see tables)

Sections	Requested grant €	Committed+Paid €	Spending factor	Personnel Contracts (2y)
UniTov	585.158,36	569.293,00	97,2%	1

Sections	Requested grant €	Committed+Paid €	Spending factor	Personnel Contracts (2y)
CNR	5.804.986,00	5.428.827,67	**93,5%**	4

*Indirect costs = 7% on direct costs
225.000 already allocated for Intellera consulting.

Fundamental research and applications with the EuPRAXIA facility at LNF

4–6 Dec 2024
LNF
Europe/Rome timezone

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EuPRAXIA@SPARC_LAB is a cutting-edge research project that will be realized in the INFN Frascati National Laboratories in Italy, focusing on advanced accelerator technologies. It is part of the broader EuPRAXIA initiative, aimed at developing the world's first plasma-based accelerator with user applications.

Given the advance in the project development, we are focusing our effort on the potentiality of the new facility in a wide scientific perspective, including FEL applications, but extending to other fields in which our photon and particle sources can contribute. To this end, LNF is organizing a Workshop on "Fundamental research and applications with the EuPRAXIA facility at LNF", to be held at Laboratori Nazionali di Frascati of INFN on December 4-6, 2024.

Funded by the European Union


Thank for your attention