EuPRAXIA@SPARC_LAB and related R&D

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2nd TDR Review Meeting, October 24, 2021

Istituto Nazionale di Fisica Nucleare

October 26

Session I – Introduction and General Topics

9:00 Registration starts
9:30 F. Bossi - Welcome (10')
9:40 R. Assmann – Prospects for EuPRAXIA in the framework of the ESFRI Road Map (20'+10')
10:10 M. Ferrario – The EuPRAXIA@SPARC_LAB Project and related R&D program (20'+10')
10:40 A. Falone – Project Management, (20'+10')

11:10 Coffee Break (20')

11:30 U. Rotundo – The Status of Infrastructures (20+10)
12:00 C. Vaccarezza – Start to End Simulations (20+10)
12:30 A. Ghigo – Machine Layout (20'+10')
13:00 Discussion (30')

13:30 Lunch Break (60')

Session II – Working Areas Reports

14:30 F. Stellato – The FEL Scientific Case (15+5)
14:50 L. Giannessi – The FEL schemes (15+5)
15:10 Discussion (20')
15:30 E. Chiadroni – The S-band Injector (15+5)
15:50 D. Alesini – The X-band Linac and related R&D Program(15+5)
16:10 A. Gallo – High Power RF Sources (15+5)
16:30 Discussion (20')

16:50 Coffee Break (20')

17:10 A Biagioni – The Plasma Section (15+5)
17:30 A. Cianchi – Electron beam diagnostics (15+5)

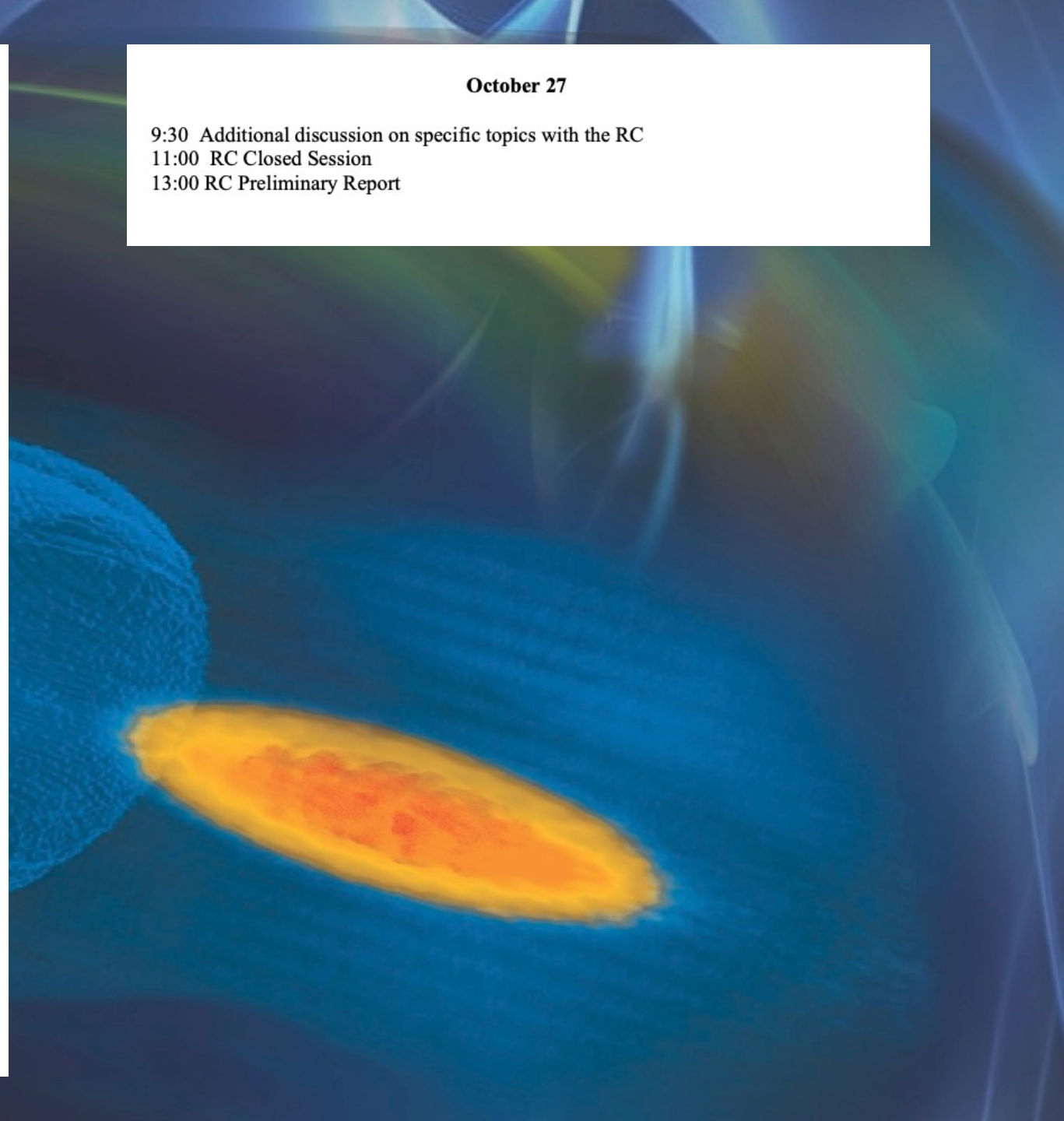
17:50 General Discussion (40')

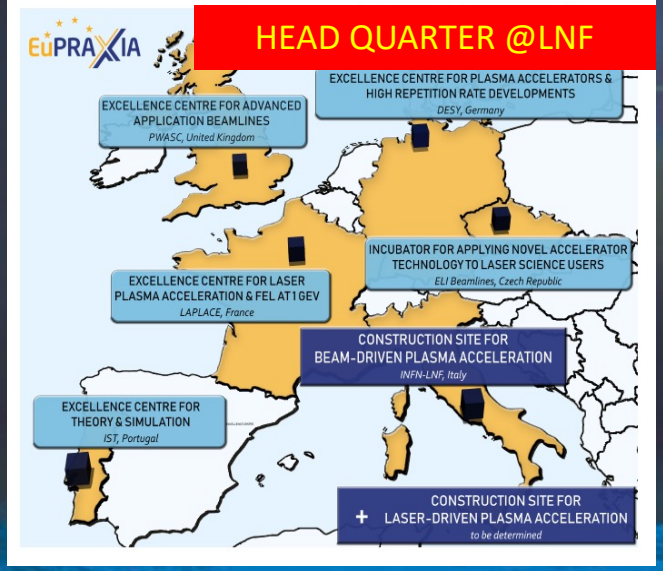
18:30 End of first day

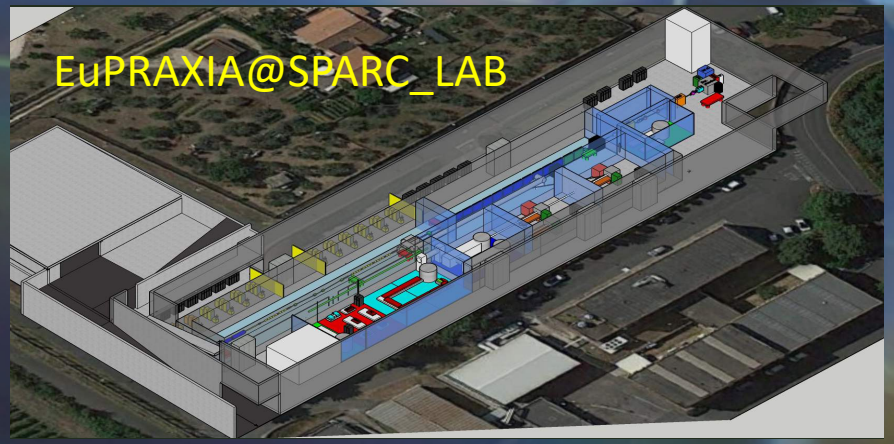
20:00 Social Dinner

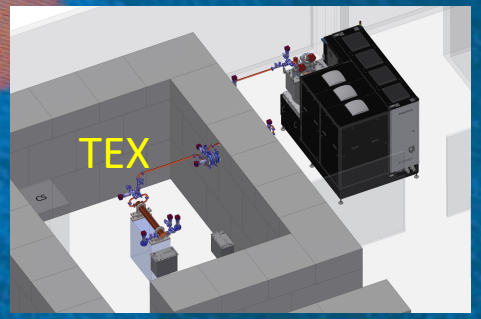
October 27

9:30 Additional discussion on specific topics with the RC
11:00 RC Closed Session
13:00 RC Preliminary Report



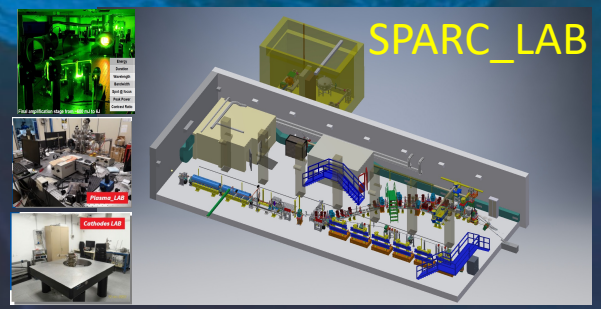






SABINA

REGIONE LAZIO



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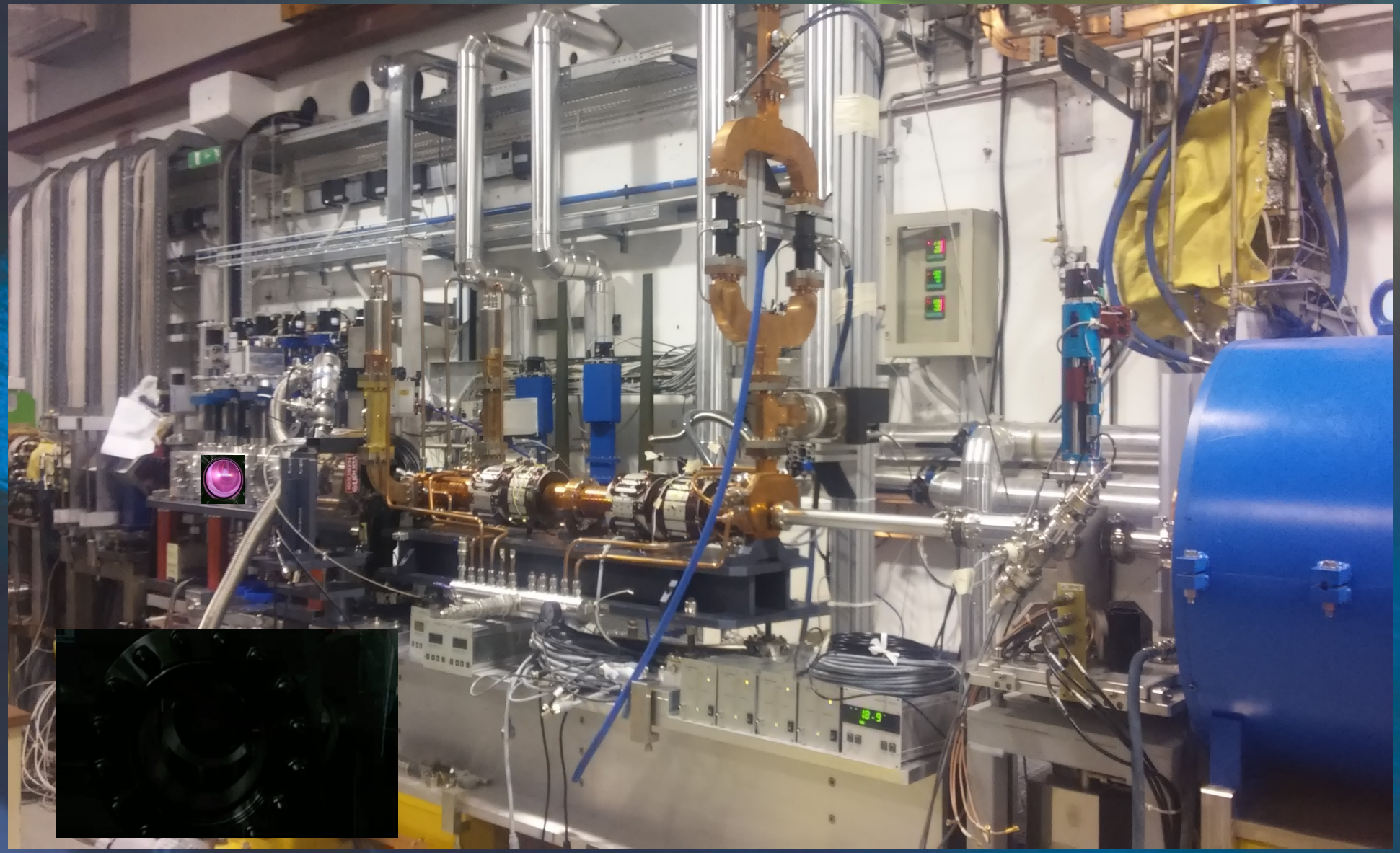
LNF–18/03
May 7, 2018

Technical Design Report

PWFA vacuum chamber at SPARC_LAB



Assisted Beam Loading Energy Spread Compensation

Achieved 4 MeV acceleration in 3 cm plasma with 200 pC driver

~133 MV/m accelerating gradient

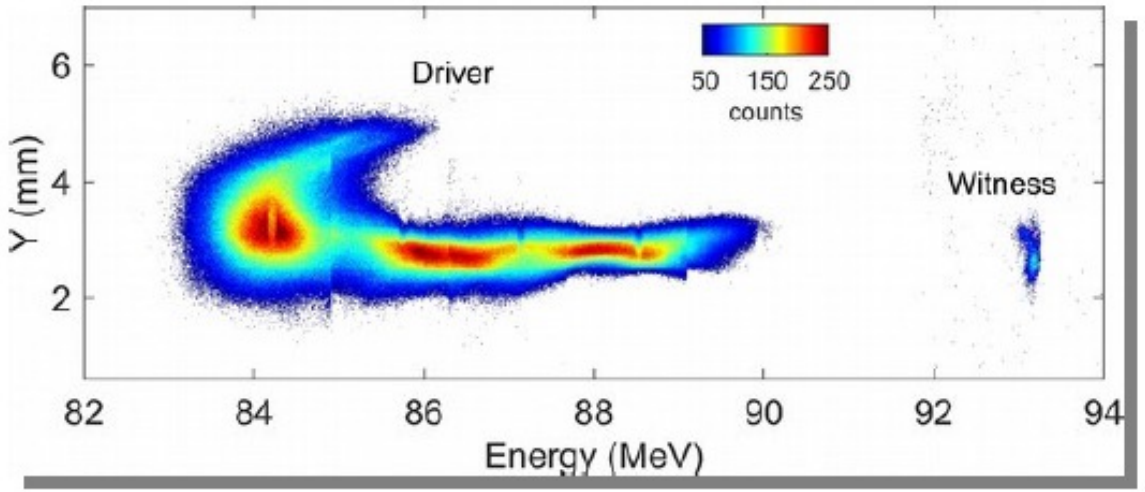
$2x10^{15}$ cm^{-3} plasma density

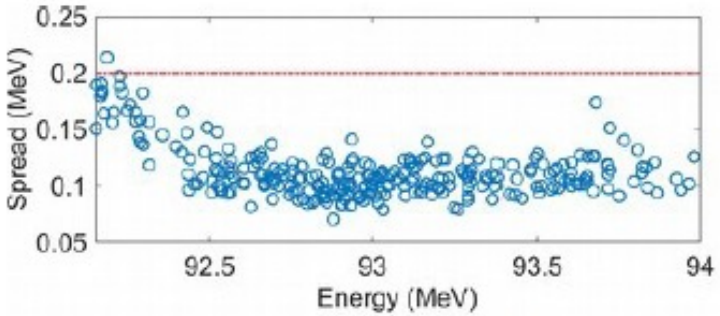
→ demonstration of energy spread compensation during acceleration

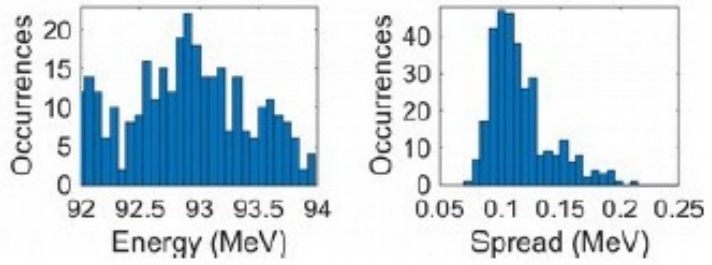
Energy spread reduced from 0.2% to 0.12%

99.5% energy stability

Can we use this technique also for EuPRAXIA ?

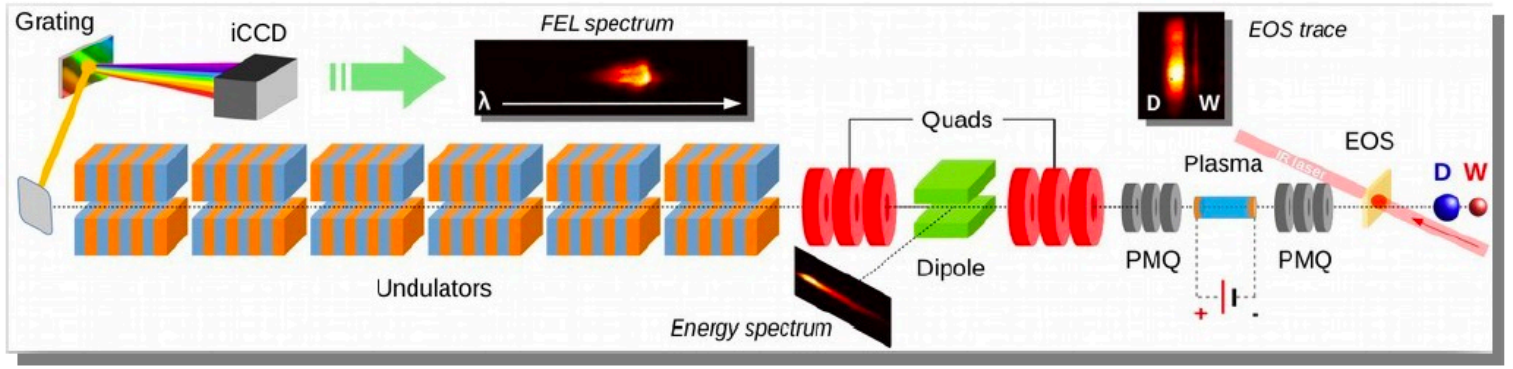


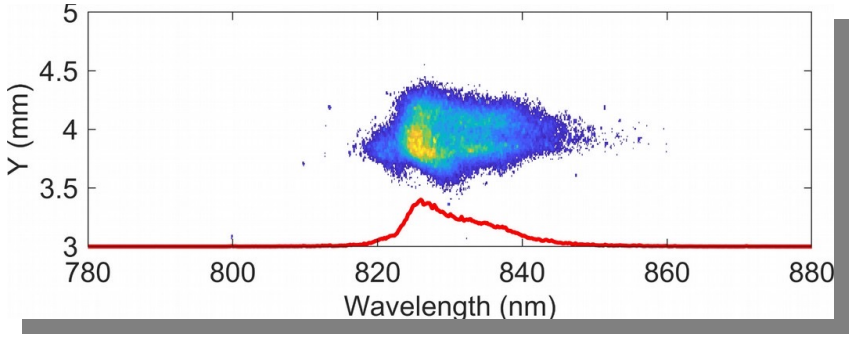


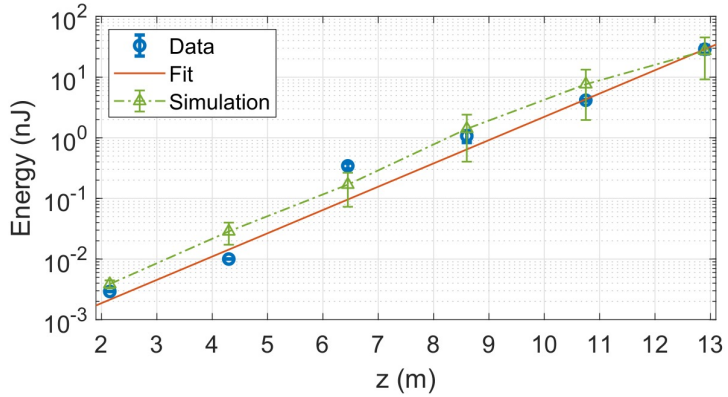


Pompili, R., et al. "Energy spread minimization in a beam-driven plasma wakefield accelerator." Nature Physics (2020): 1-5.

First Beam Driven SASE-FEL Lasing at SPARC_LAB (May 2021)

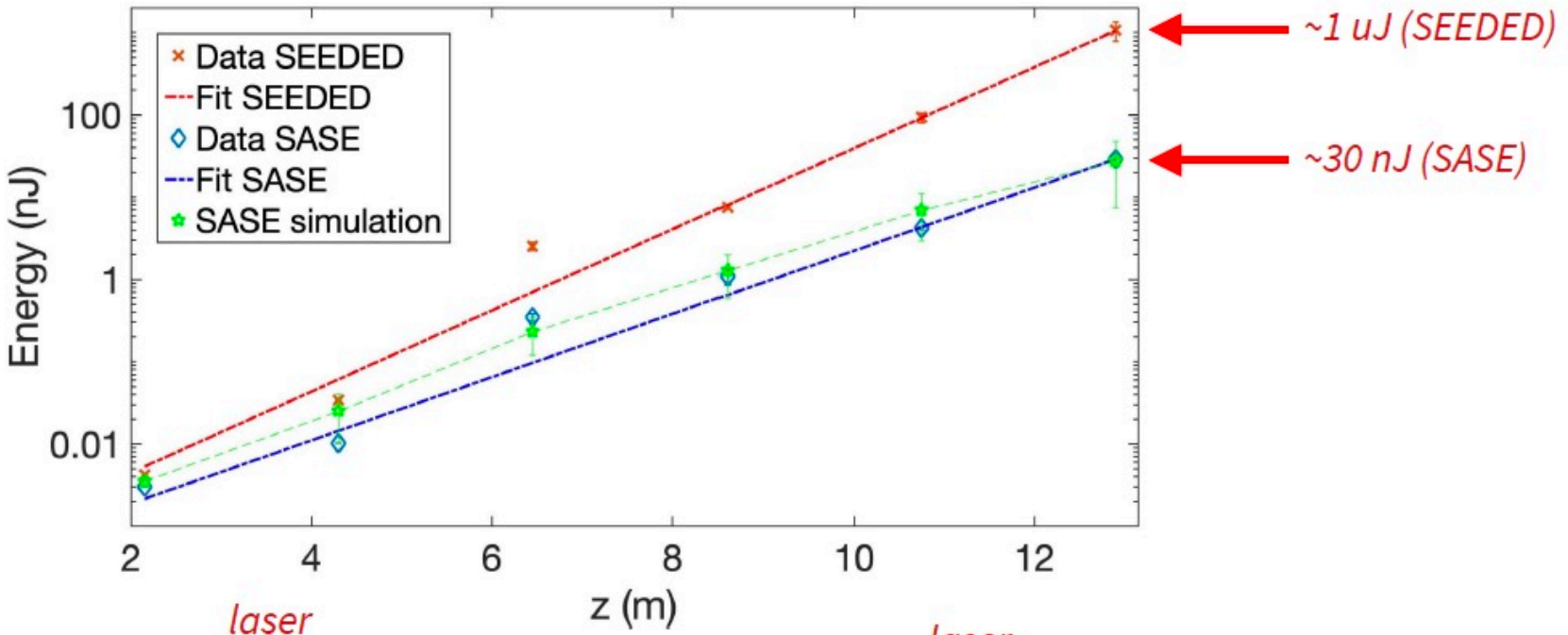


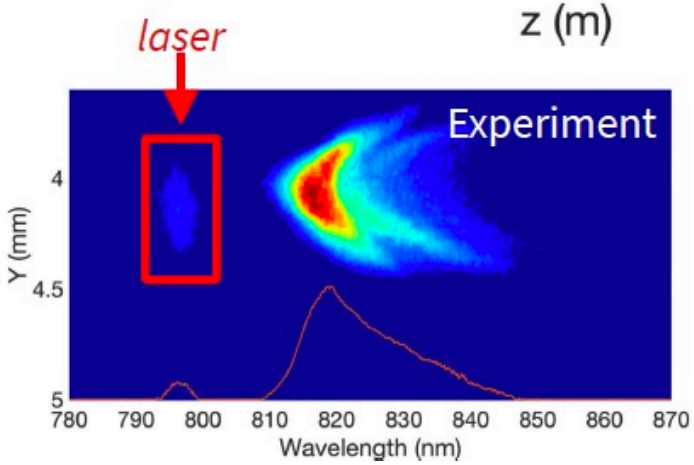


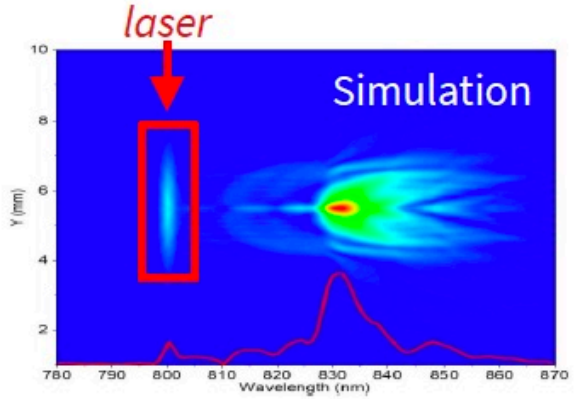


Submitted to Nature

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

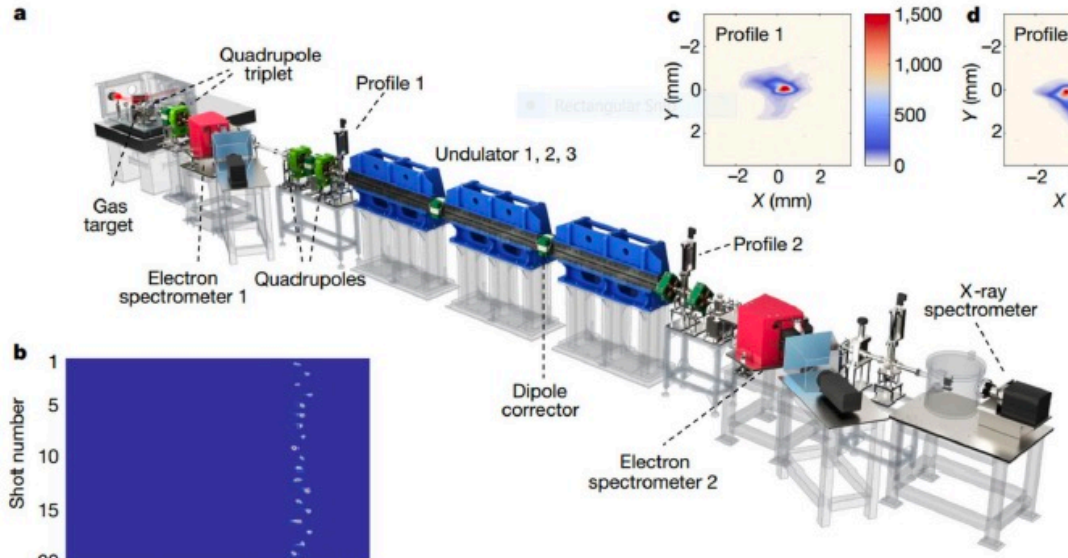


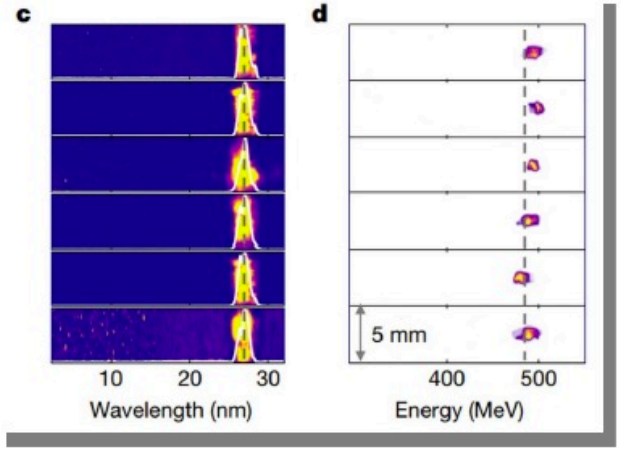




To Be Submitted to Nature

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 ($I \sim 4 \times 10^{18}$ W/cm^2) laser focused on a gas-jet

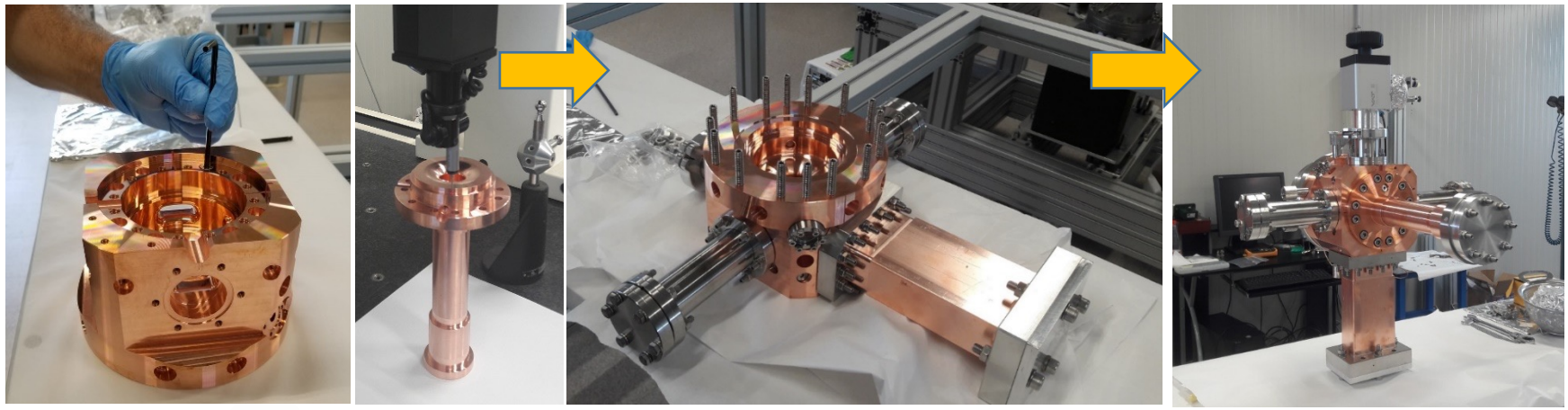
Peak energy ~ 490 MeV, 0.5% spread (measured), emittance 0.5 um (estimated)

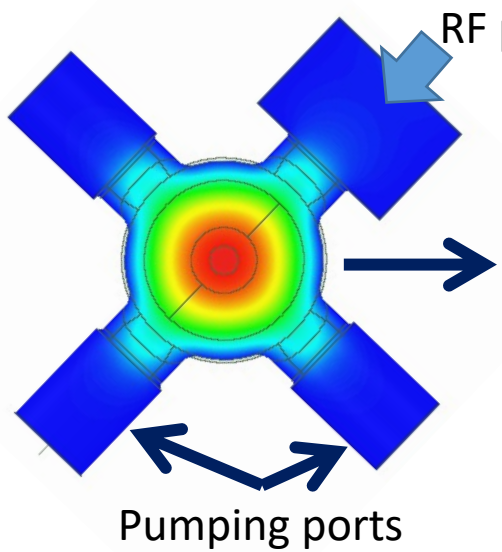
Radiation energy from 0.5 to 150 nJ

IMPROVEMENTS IMPLEMENTED IN THE NEW SPARC_LAB INJECTOR

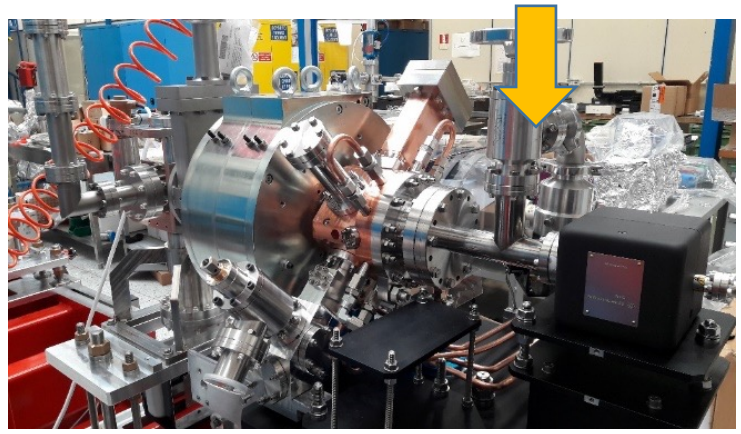
With respect to the “old” injector the new one:

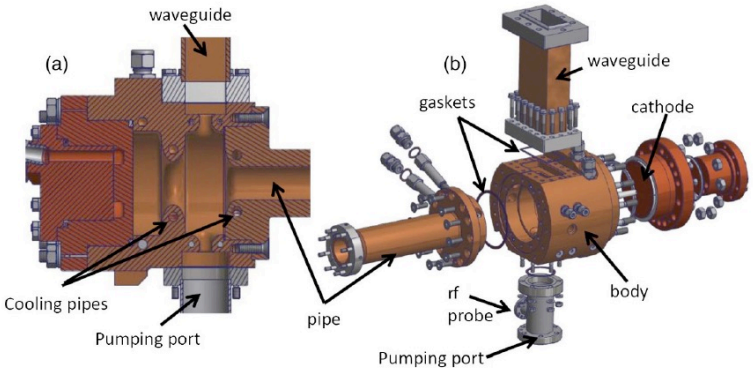
1) Integrate an RF gun fabricated with the **new brazing free technology**;
2) Integrate a **new solenoid** with a **remote control of the transverse position at the <+/-10 μm level;**
3) allows **on axis laser injection system** with the last mirror in air and not into the beam pipe;
4) Has been designed with the possibility of a **future integration of an X/C band cavity linearizer;**
5) Has a **variable skew quadrupole** after the gun for the compensation of residual quadrupole components
6) Has an electromagnetic design with a **full compensation of the quadrupole components**
7) Has an **improvement of the effective pumping speed** with two added pumping ports
8) **No cathode tuning is necessary**
9) **Overcoupling (β=2)**





Design with full quadrupole field component compensation



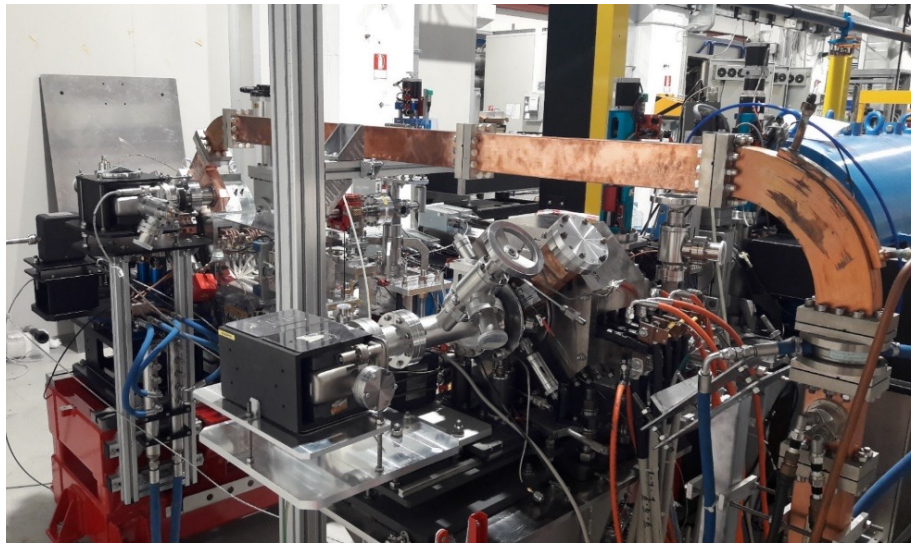


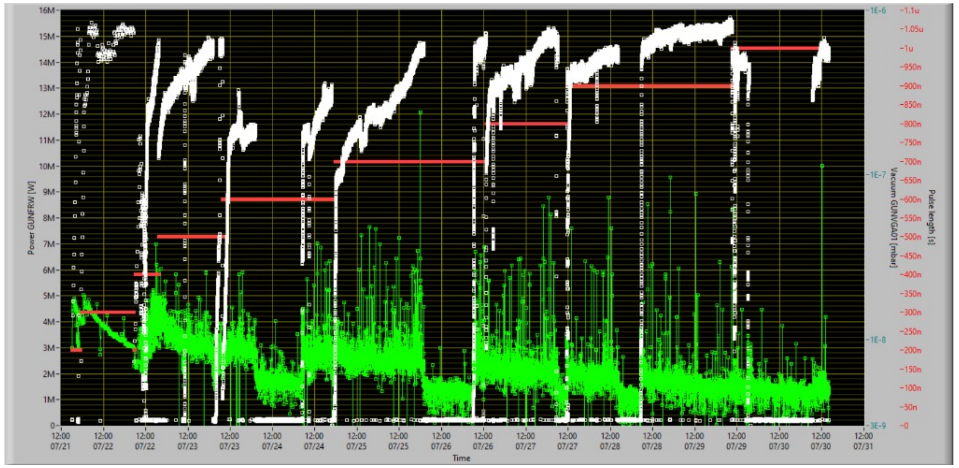
NEW SPARC_LAB INJECTOR STATUS

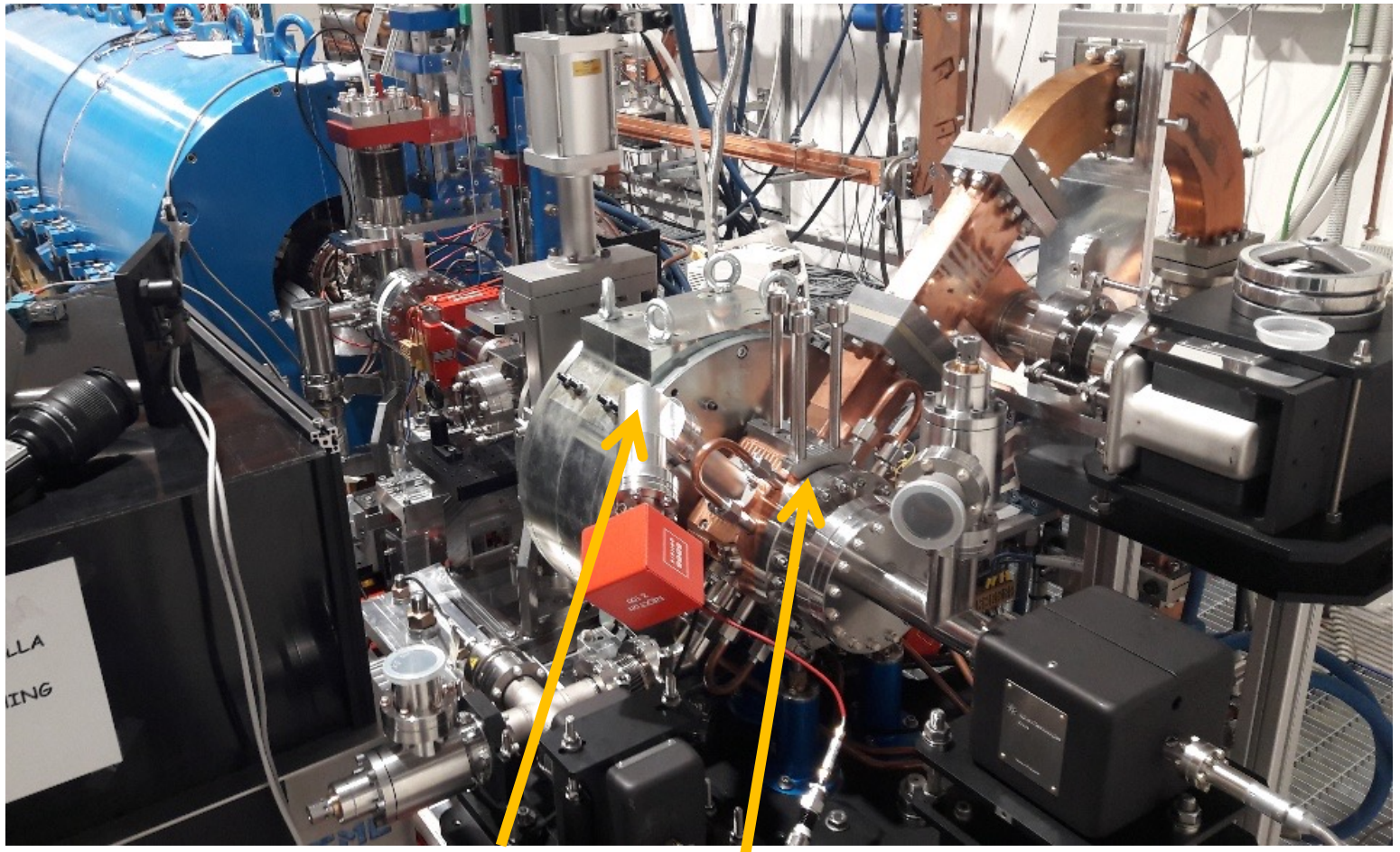
⇒ The injector has been **tested at high power on a RF parallel line**, reaching the **final performances in an incredible short time** (< 10 days)

⇒ The new injector has been **now inserted online** and RF test will start in these days following by electron generation and beam characterization

New injector under test on a parallel line







Tests of the EuPRAXIA Working Points will be also possible

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

What Next at SPARC_LAB?

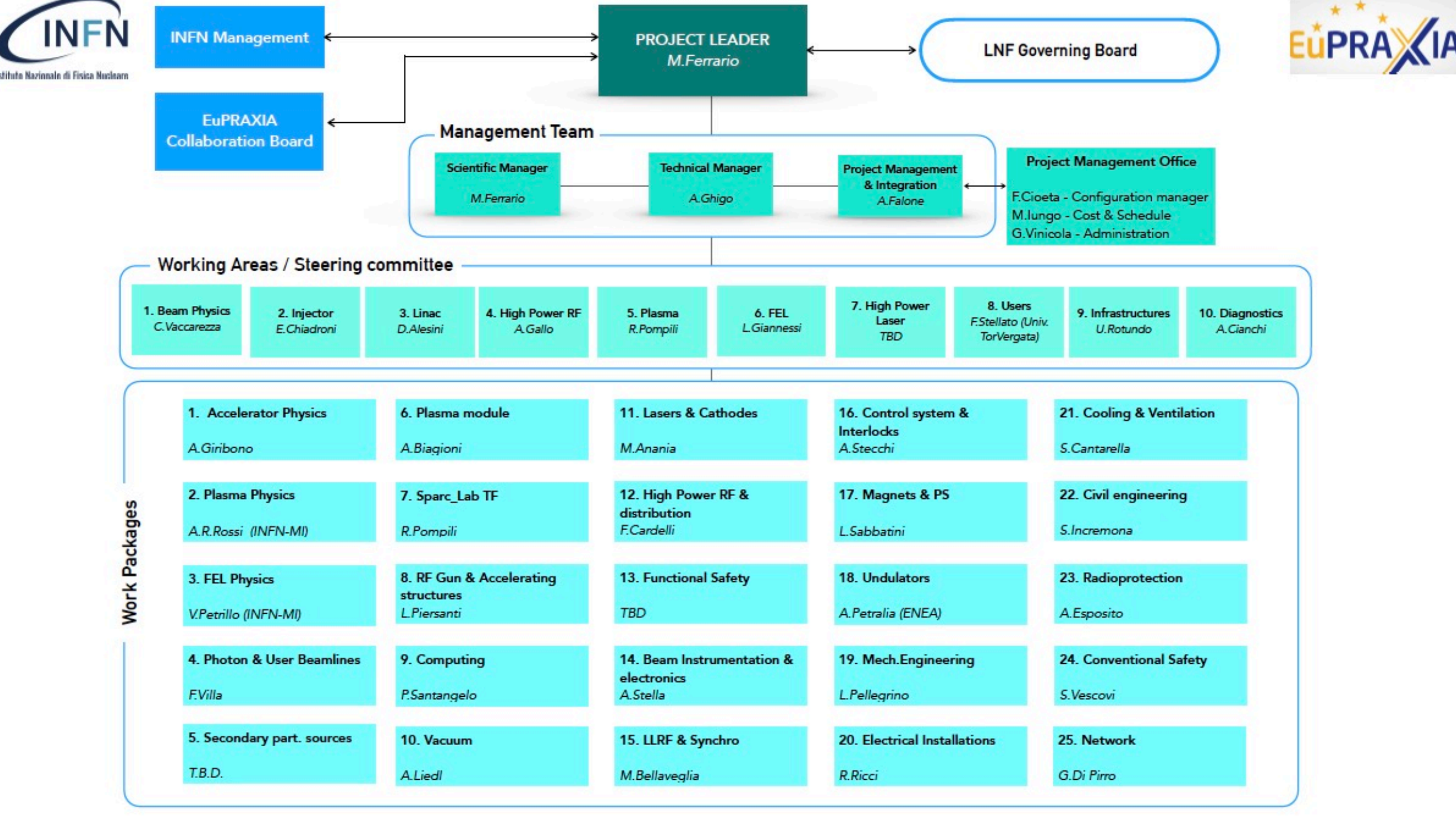
1. November - December 2021. Gun conditioning and characterization. We should have a fully operational machine before the Christmas 2021.

2. January – February 2022: external users.

3. March 2022: the new C-band modulator will be here by the end of the February 2022, thus the whole March will be dedicated to installations. By the last week of the March we should have a fully operation machine again.

4. April - July 2022. The plasma season. - to reach the 1 GeV/m acceleration gradient. To do so we have a new injection/focusing system for the electron train. If we can achieve 1 GeV/m quick enough, the FEL experiments must be planned in this period as as the High Transformer Ration experiments

5. September - December 2022. SABINA project installations.


INFN
Istituto Nazionale di Fisica Nucleare
INFN Management
PROJECT LEADER
M.Ferrario
LNF Governing Board
EuPRAXIA
EuPRAXIA Collaboration Board
Management Team
Scientific Manager
M.Ferrario
Technical Manager
A.Ghigo
Project Management & Integration
A.Falone
Project Management Office
F.Cioeta - Configuration manager
M.Iungo - Cost & Schedule
G.Vinicola - Administration
Working Areas / Steering committee
1. Beam Physics
C.Vaccarezza
2. Injector
E.Chiadroni
3. Linac
D.Alesini
4. High Power RF
A.Gallo
5. Plasma
R.Pompili
6. FEL
L.Giannessi
7. High Power Laser
TBD
8. Users
F.Stellato (Univ. TorVergata)
9. Infrastructures
U.Rotundo
10. Diagnostics
A.Cianchi
Work Packages
1. Accelerator Physics
A.Giribono
2. Plasma Physics
A.R.Rossi (INFN-MI)
3. FEL Physics
V.Petrillo (INFN-MI)
4. Photon & User Beamlines
F.Villa
5. Secondary part. sources
T.B.D.
6. Plasma module
A.Biagioni
7. Sparc_Lab TF
R.Pompili
8. RF Gun & Accelerating structures
L.Piersanti
9. Computing
P.Santangelo
10. Vacuum
A.Liedl
11. Lasers & Cathodes
M.Anania
12. High Power RF & distribution
F.Cardelli
13. Functional Safety
TBD
14. Beam Instrumentation & electronics
A.Stella
15. LLRF & Synchro
M.Bellaveglia
16. Control system & Interlocks
A.Stecchi
17. Magnets & PS
L.Sabbatini
18. Undulators
A.Petralia (ENEA)
19. Mech.Engineering
L.Pellegrino
20. Electrical Installations
R.Ricci
21. Cooling & Ventilation
S.Cantarella
22. Civil engineering
S.Incremona
23. Radioprotection
A.Esposito
24. Conventional Safety
S.Vescovi
25. Network
G.Di Pirro

R&D Financial Requests

Tab.4: Detailed list of equipment to be procured

Working Area	Family items	Year	Amount (k€)	Note
1 - Beam Physics	Computing cluster	2021	250	Needed for full 3D Simulations
2 – Injector	Upgrade Photocathode laser	2021	725	To be implemented at SPARC_LAB
	Upgrade LLRF	2021	100	
	Upgrade Synch System	2021	100	
	Timing system upgrade	2021	50	
	RF Gun prototype	2022	25	
	S-Band modulator	2022	550	
3 - Linac	Heat treatment chamber	2021	70	
	X-Band mech prototype	2021	60	
	X-Band RF prototype	2021	80	
	Magnetic measurement lab upgrade	2021	130	
	Quadrupole prototype	2022	80	
	Procurement vacuum components	2022	60	
	Local heater	2022	10	
	RF/ Vacuum components	2022	50	
	WG Circular mode converter	2022	80	
	HP Waveguide components	2022	150	
	X-band Full Prototype	2022	200	
	BOC prototype (x2)	2023	200	
4 – Integration	CPI High efficiency klystron	2021	1300	
	X-Band solid state amplifier	2021	100	
	Warranty extension	2021	35	
	TEX Setup	2021	195	Needed for the SAT of the X-band RF System
	2nd Klystron full specs	2023	750	
5 – Plasma	Realization of long capillary	2022	970	
6 – FEL	Prototype Apple X	2022	100	
	Intraondulator diagnostics prototype	2023	260	
8 - User	Optical elements protytpe	2022	225	
9 – Infrastructure	Radioprotection studies	2022	50	
	High stability cooling skid	2022	50	
10 – Diagnostics	High precision charge measurement	2021	80	
	Stripline BPM Prototype	2022	60	
	Beam Loss Monitor prototype	2023	30	
	Compact diagnostic chamber prototype	2023	60	

EuPRAXIA Organisation Chart

EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS

Advisory & Oversight Boards
- Open Innovation Forum
- Scientific & Technical Advisory Committee
- User Meetings & Program Committees
- Resource Review Board
- Quality Assurance Panel
- Ethical Advisory Board

Collaboration Board
1 representative per Member & Observer
1 Chair and 1 Deputy Chair

Project Coordinator + Management Team

Steering Committee

Central EuPRAXIA Management

Construction Site Frascati

INFN EU

EuPRAXIA @ SPARC_LAB Collaboration Board

PROJECT LEADER *M.Ferrario*

LNF- Steering Committee
- Chair - *A.Falone*
- Project Leader - *M.Ferrario*
- Technical Manager - *A.Ghigo*
- Lab.Director *F.Bossi-*
- Div.Directors - *A.Gallo, U. Rotundo, P.Gianotti*
- Administration - *T. Ferro*
- Conventional safety - *S.Vescovi*
- Radioprotection - *A.Esposito*
- Sparc_Lab - *G.Di Pirro*

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- Technical Manager *A.Ghigo*
- Project Management & Integration *A.Falone*
- Project Management Support Office

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2. Injector *E.Chiadroni*
3. Linac *D.Alesini*
4. Integration *B.Buonomo*
5. Plasma *R.Pompili*
6. FEL *L.Giannessi*
7. High Power Laser *TBD*
8. Users *F.Stellato (Univ. TorVergata)*
9. Infrastructures *U.Rotundo*

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Construction Site
(tbd in 2023)

Local Project Team

Laser-driven plasma accelerator
Delivers FEL light, X rays, electrons, positrons
Life sciences, medicine, materials

Four candidate sites described in conceptual design report

Excellence Centres

Local Project Teams
- *Plasma Simulations & Theory*
- *Laser-Plasma Acceleration & FEL Developments*
- *Plasma Acceleration & High-Rep-Rate Developments*
- *Advanced Application Beamlines*
- *Technology Incubator to Laser Science Users*

Technical design tests, prototyping, production

EuPRAXIA user e-needs infrastructure

Project Clusters (WPs)
- *Theory & Simulation*
- *Laser Technology*
- *Plasma Components & Systems*
- *RF Technology*
- *Magnets & Other Beamline Components*
- *Diagnostics*
- *Applications*
- *Transformative Innovation Paths*
- *Training, Outreach & Dissemination*
- *Implementation & Layout*

Technical Design Report

National projects and facilities

Individual groups at universities and laboratories

Organization for initial Preparatory Phase in dark blue

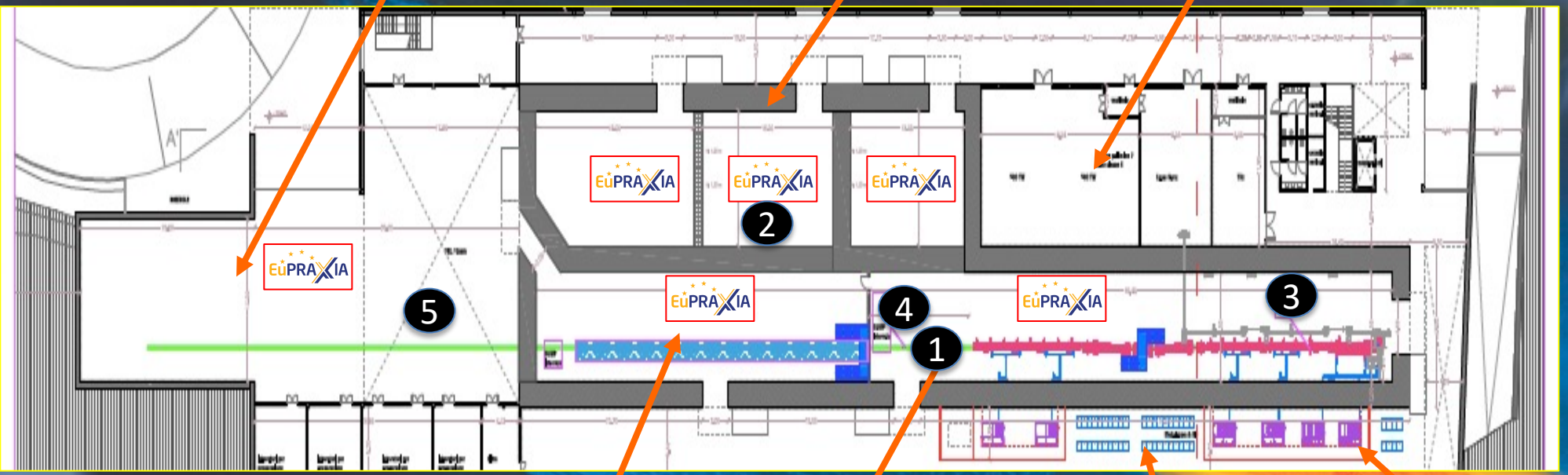
Features to be added with decision on second site or in later phases are indicated in lighter shades

Opportunities for Collaborations at EuPRAXIA@SPARC_LAB

Laser & THz clean rooms

experimental halls

Photon user experimental hall



Undulators tunnel

Accelerator tunnel

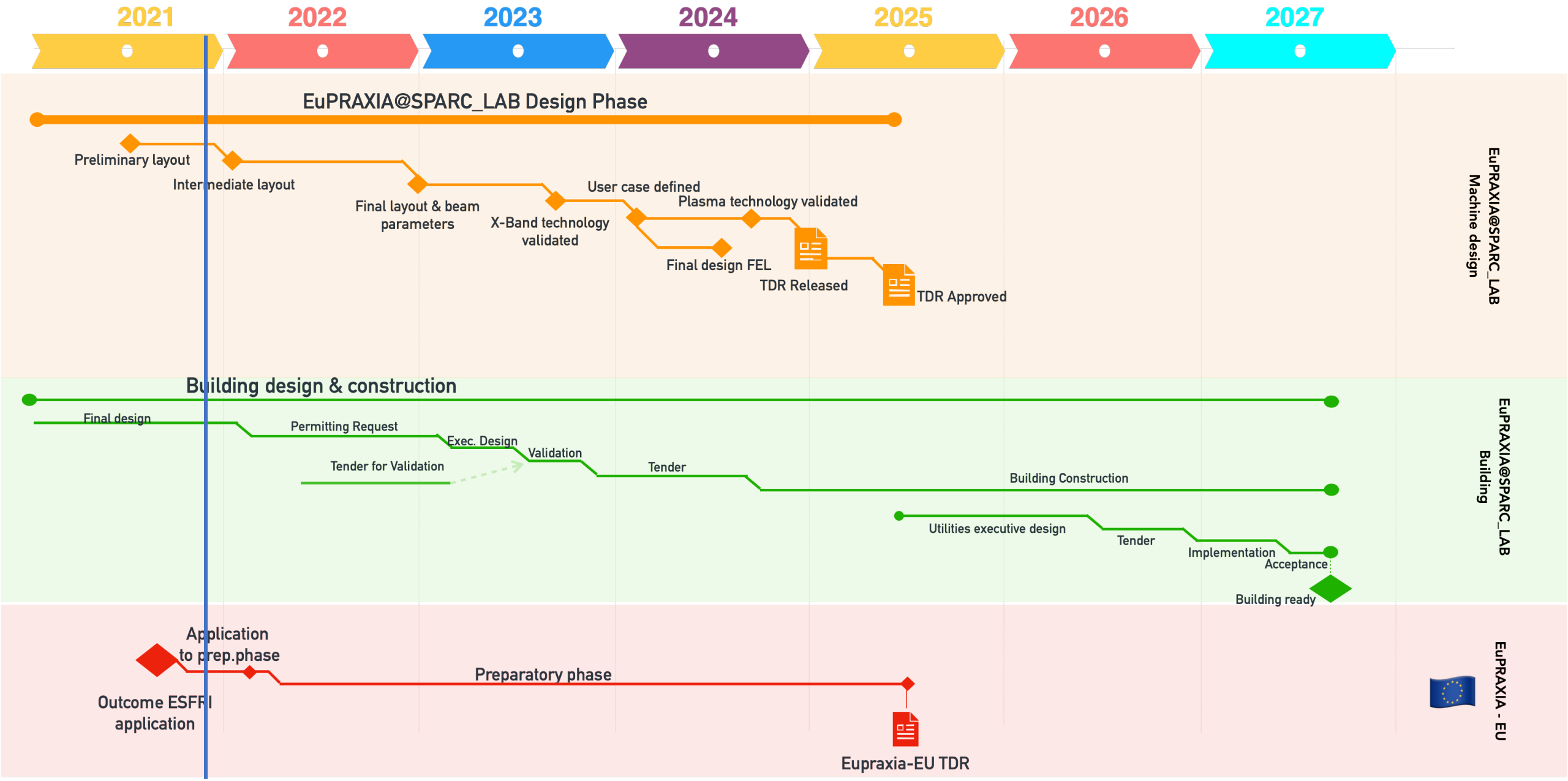
Klystron&modulators
Power supplies gallery

Plant gallery

European interests & possible contributions to Frascati site:

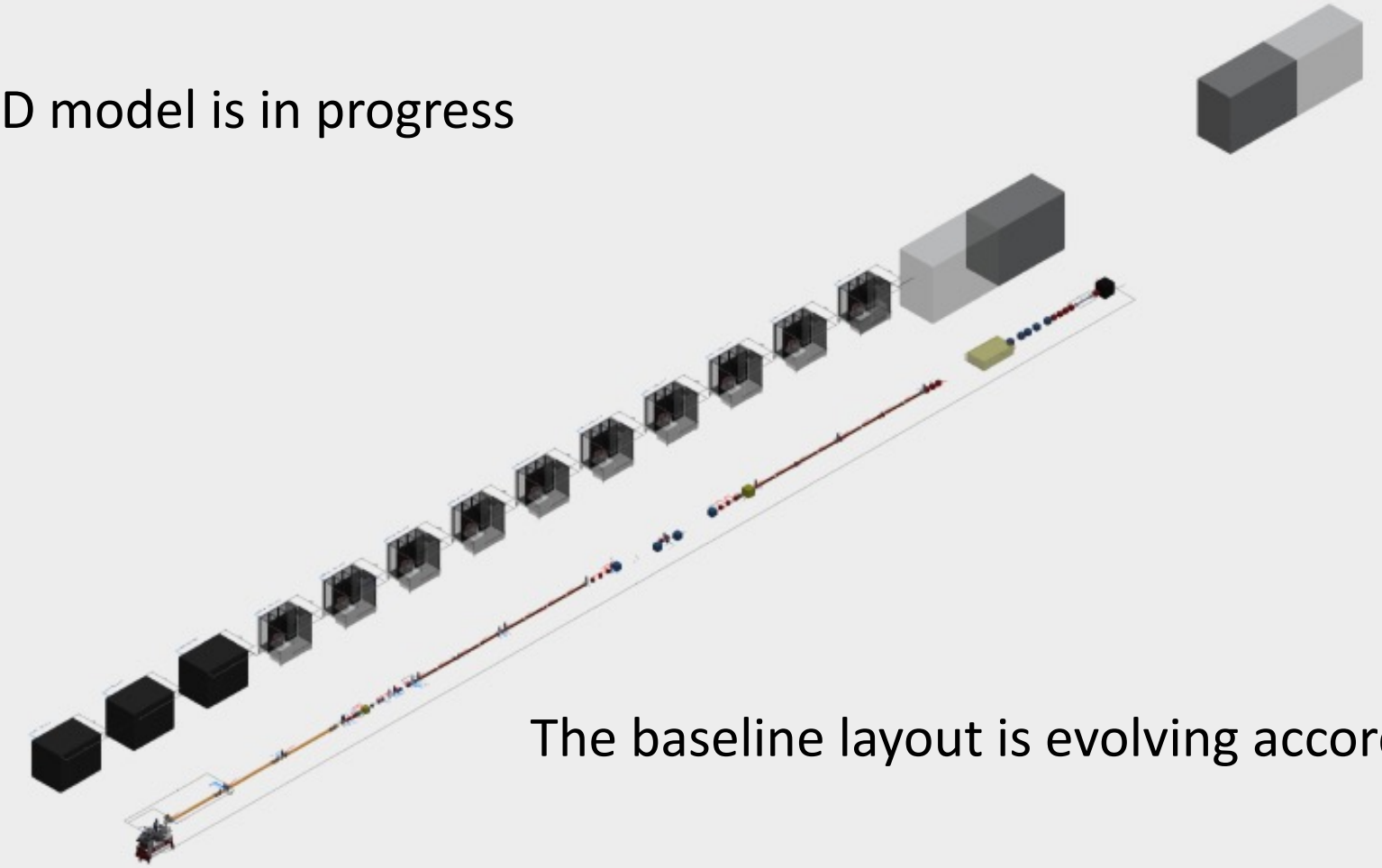
1. Plasma structure designs, devices
2. Compact positron source
3. HQ 150 MeV laser plasma injector
4. HQ laser driver
   - Hybrid concepts
   - Simulations
5. User experiments and lines

To be detailed in TDR phase.


2021
2022
2023
2024
2025
2026
2027
EuPRAXIA@SPARC_LAB Design Phase
Preliminary layout
Intermediate layout
Final layout & beam parameters
X-Band technology validated
User case defined
Plasma technology validated
Final design FEL
TDR Released
TDR Approved
EuPRAXIA@SPARC_LAB Machine design
Building design & construction
Final design
Permitting Request
Exec. Design
Validation
Tender for Validation
Tender
Building Construction
Utilities executive design
Tender
Implementation
Acceptance
Building ready
EuPRAXIA@SPARC_LAB Building
Application to prep.phase
Preparatory phase
Outcome ESFRI application
Eupraxia-EU TDR
EuPRAXIA - EU

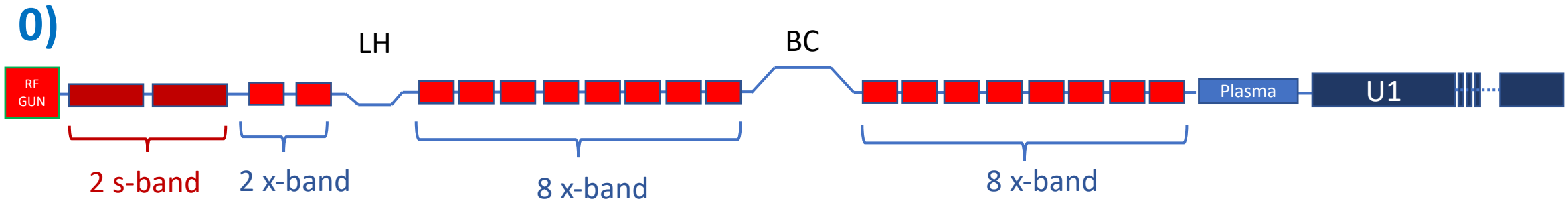
Preliminary baseline layout in progress

A detailed CAD model is in progress



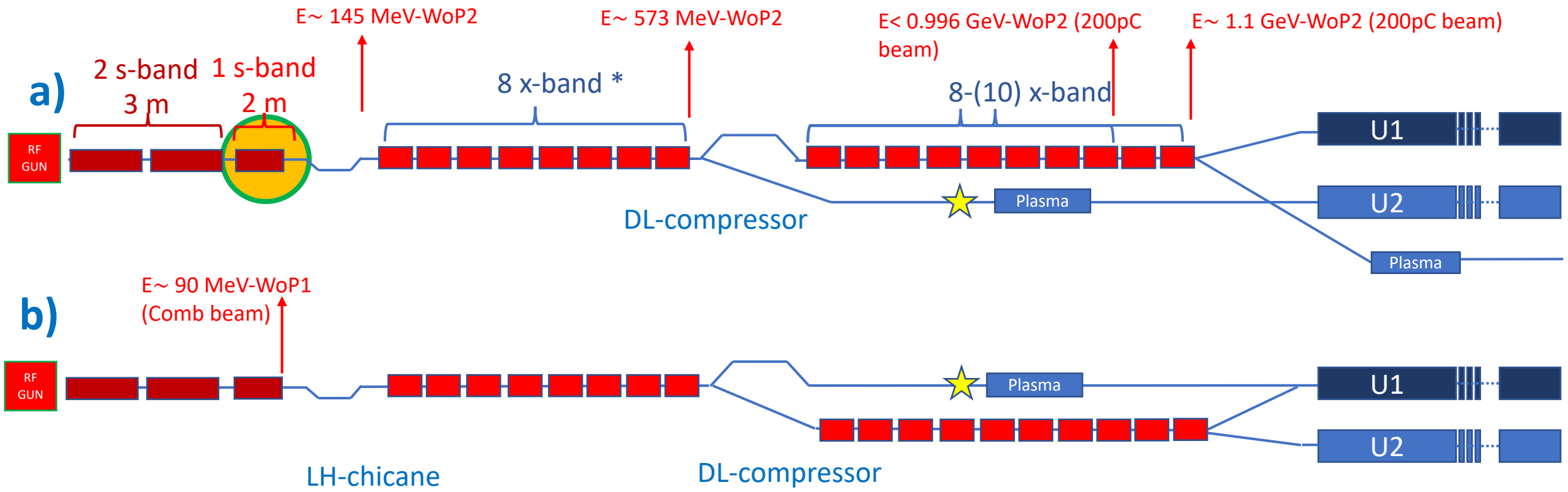
The baseline layout is evolving according to the BD results

The basic all-in-one layout Fall 2020



- Emax=1.03 GeV for all X-band configuration(w 10% contingency on Kly output power)
- Lmax =~ 60 m (ex. 59.52 m) from cathode + 1 m distance from the wall
  vs 59 m nominally available
- Extremely tight in:
  - plasma in&out matching
  - Diagnostic sections for characterization
  - No room for doglegs upstream the undulator

WA1-Beam Physics: two alternative layouts under comparison

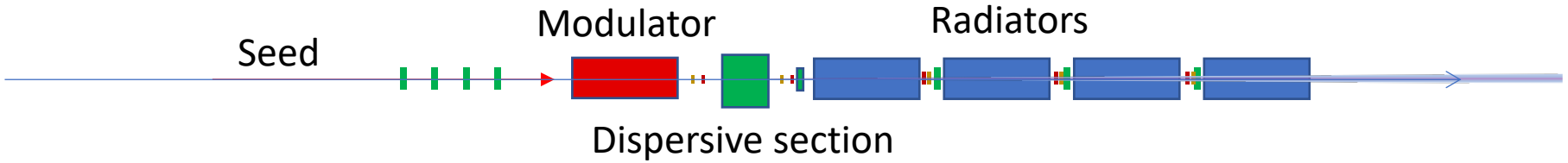


Operation at 400 Hz is under investigation

Investigating two FEL lines and their impact on the financial plan:

1) AQUA: Soft-X ray SASE FEL – Water window 4 nm shortest wavelength (baseline)

2) ARIA: VUV seeded HGHG FEL beamline for gas phase (not yet in the baseline)



Users Workshop done: https://agenda.infn.it/event/27926/

Previous RC Report – General Remarks

- The definition of personnel needs and availability is required to determine whether the various plans and activities are likely to be carried out successfully and on schedule. => Falone
- It was decided to appoint a new RC member to monitor the FEL scientific case and the FEL facility. => To be Done
- The RC recommends that a review of the building infrastructure and facilities be organized before the end of the year => Rotundo => December
- Particular effort and attention should be paid towards plasma density uniformity and reproducibility, already for the (500+500)MeV program. => Biagioni

Control framework definition

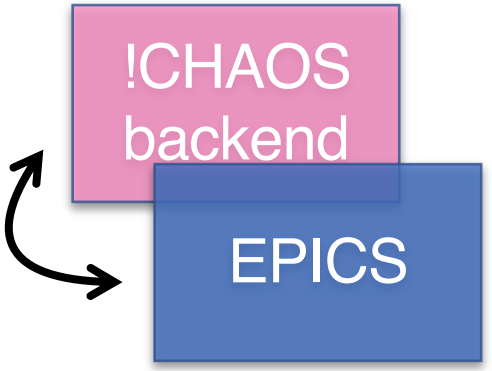
During the last review we said that the control framework would be finalized **by the end of 2021**.

The two hypotheses at stake were:

1. control **entirely made in !CHAOS**;
2. control **implemented in an already established framework** (EPICS, TANGO) **with !CHAOS as backend service** (PaaS, SaaS) for: storage, data analisys, data presentation, etc.

At the moment, the scenario that is being defined **is the second one**, using EPICS as control framework. This is going to be discussed with our management and defined within the set deadline.

An interfacement method between the two systems is under development and we are going to test it on the TEX facility.



WP16 • Control System
State of play

Training
Two courses (on EPICS and AGILE) – aimed at the EuPRAXIA@SPARC_LAB project – have been organized and attended

Survey on Work Packeges requirements
A first collection of specifications for machine hardware was completed

Activities planned in collaboration with others
Time synchronization and trigger distribution

Control framework definition
The final structure is being defined and will be discussed with management within the year (as stated in the previous review)


thanks for your attention

Estimation required additional manpower

WP	Description	Staff *	Post-Doc	Technician	Comment
1	Beam Physics		2		
2	Plasma Physics	1	1		
3	FEL Physics		1		INFN-MI
6	Plasma Module		1		
8	RF-Gun &				
10	Vacuum		1	2	
11	Laser & Cathodes	1	1		
14	Diagnostics	1	1		
15	LLRF & Synchronization	1			
16	Controls	2		2	
17	Magnets & PS		1		
18	Undulators		2		1 @ ENEA
19	Mech Engineer	1			
20	Electrical Installation			2	
21	Cooling & Ventilation			1	
22	Civil Engineering			1	
23	Radioprotection	1			
24	Conventional Safety	1			
25	Network	1			
PO	Project Office	1	2		
	TOTAL	**11**	**13**	**8**	
	TOT. FTE	**32**			

This would bring up to 90FTE allocated

- This does not take into account PhD students (around 10).
- Estimated cost/year = 1M€
- This allocation could come from different sources:
  - Already present in the Lab but working on other topics
  - Turnover
  - New hiring
  - In-kind contribution
- Request to be submitted at the INFN-Management.
- Strategy to be decided at management level