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Introduction

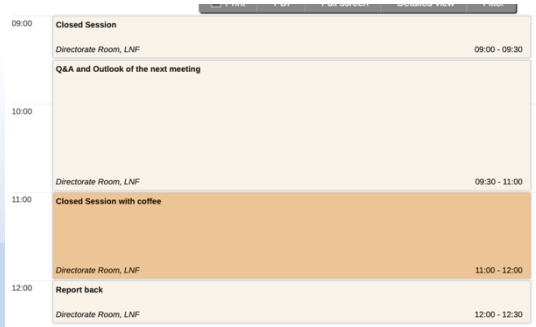
Massimo Ferrario,
On behalf of the EuPRAXIA collaboration

VIII TDR Review Meeting – LNF - 25/11/2024

Agenda

09:00	**Closed Session**	*Aula Touschek, LNF*	09:00 - 10:00
10:00	**Welcome from LNF Director**	*Paola Gianotti*	
	Aula Touschek, LNF		10:00 - 10:15
	Introduction	*Massimo Ferrario*	
	Aula Touschek, LNF		10:15 - 10:30
	EuPRAXIA Preparatory Phase Status	*Pierluigi Campana*	
	Aula Touschek, LNF		10:30 - 11:00
11:00	**Coffee Break**	*Aula Touschek, LNF*	11:00 - 11:30
	TDR Status	*Massimo Ferrario*	
	Aula Touschek, LNF		11:30 - 12:00
12:00	**Beam Dynamics S2E Simulations**	*Anna Giribono*	
	Aula Touschek, LNF		12:00 - 12:30
	Injector	*Enrica Chiadroni*	
	Aula Touschek, LNF		12:30 - 13:00
13:00	**Lunch Break**		

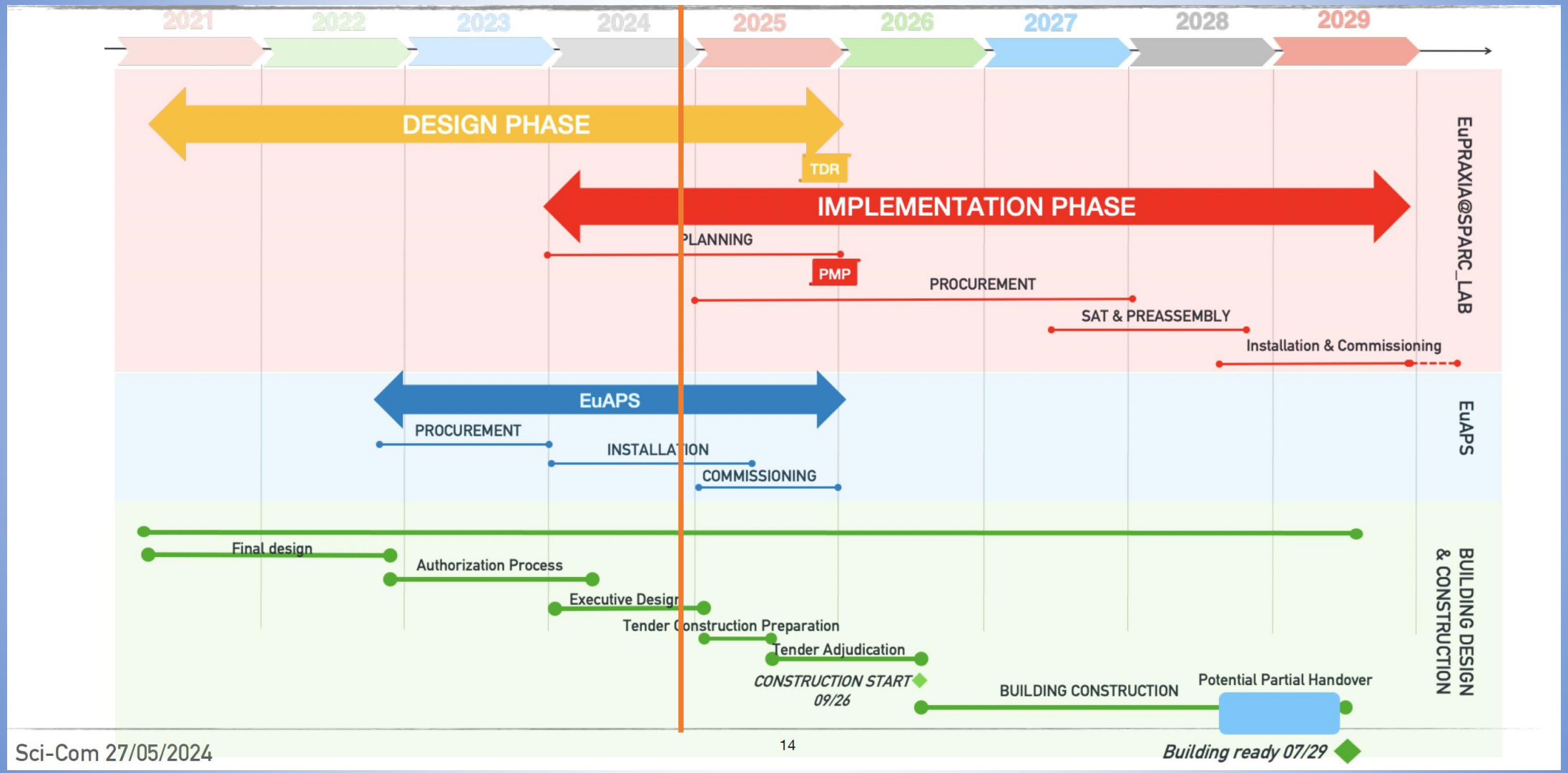
	Discussion		
	Aula Touschek, LNF		14:30 - 14:50
15:00	**LLRF and Synchronization System**	*Luca Piersanti*	
	Aula Touschek, LNF		14:50 - 15:10
	Vacuum System	*Andrea Liedl*	
	Aula Touschek, LNF		15:10 - 15:30
	Lasers	*Maria Pia Anania*	
	Aula Touschek, LNF		15:30 - 15:50
16:00	**Control System and Machine Protection**	*Stefano Pioli*	
	Aula Touschek, LNF		15:50 - 16:10
	Magnets	*Lucia Sabbatini*	
	Aula Touschek, LNF		16:10 - 16:30
	Coffee Break		
	Aula Touschek, LNF		16:30 - 17:00
17:00	**Plasma Source**	*Angelo Biagioni*	
	Aula Touschek, LNF		17:00 - 17:30
	Discussion		
	Aula Touschek, LNF		17:30 - 17:45
18:00	**Closed Session**		
	Aula Touschek, LNF		17:45 - 18:30



Building next steps

- Fire authorization received on April 2024
- Tender for Executive Project Verification:
  Provisional award on 06.21.2024
  Contract signature expected by the end of November 2024
- Completion of the executive design by the end of 2024
- The execution of the executive project verification should be completed by March 2025.
- Start of the tender procedure for the awarding of the works
- Construction site opening: September 2026

EuPRAXIA@SPARC_LAB baseline updating



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EuPRAXIA@SPARC_LAB TDR Status

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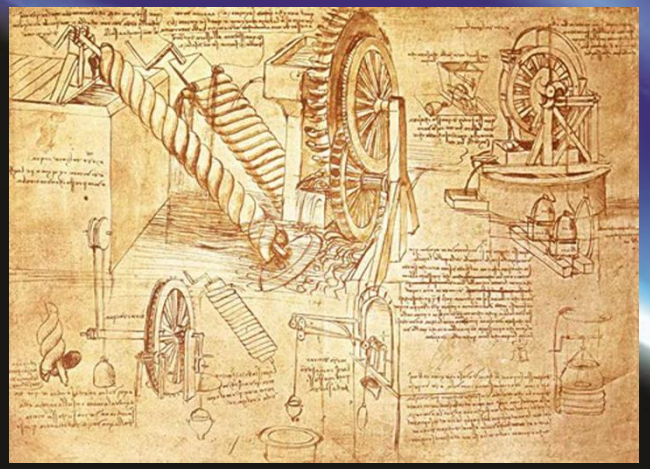
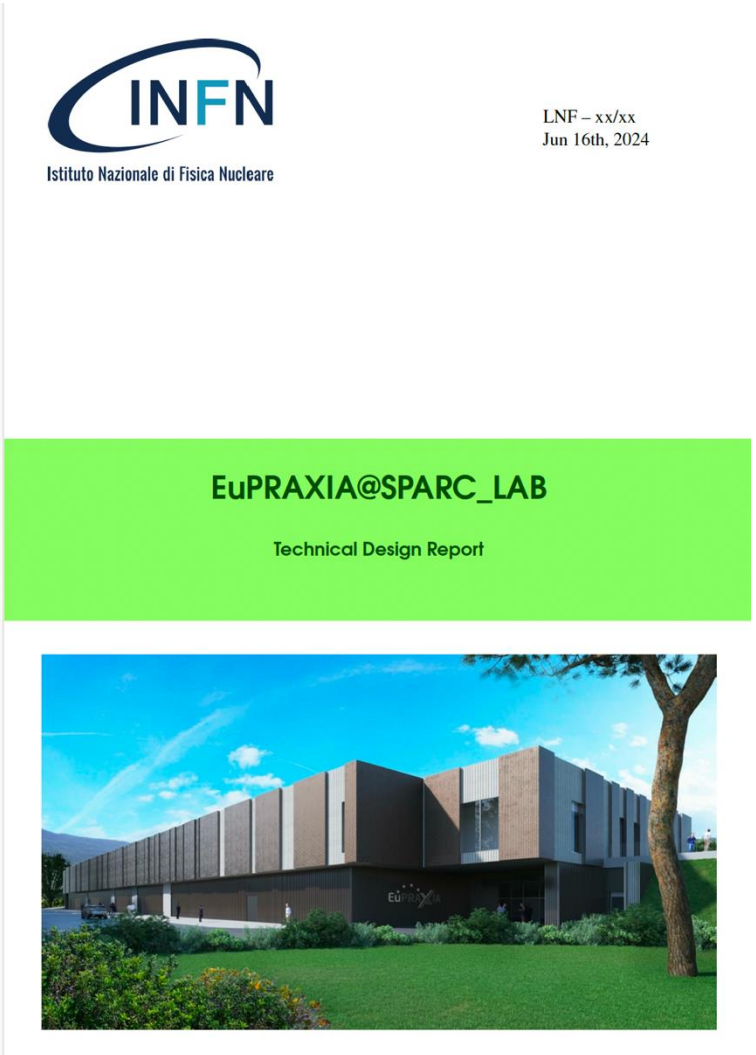


VIII TDR Review Meeting – LNF - 25/11/2024

TDR Index



1. Readiness
2. Executive Summary
3. EuPRAXIA in the European Context
4. EuPRAXIA@SPARC_LAB
5. Scientific Case

6. Beam Physics
7. Machine layout
8. RF Photo-Injector
9. RF X-band Linac and Compressor system
10. Plasma Accelerating Module
11. Free Electron Lasers
12. Photon Beam Lines
13. Experimental end-stations

14. Electron and Photon Diagnostics
15. Laser Systems
16. RF Systems
17. Timing and Synchronisation
18. Control system
19. Vacuum system
20. Magnets and Power Supplies
21. Functional Safety Systems
22. Civil Infrastructures

23. Conventional Safety
24. Radiation Safety and Beam Dumps
25. Integration, Implementation and Commissioning Strategy
26. System Engineering
27. Project Cost, timeline and Management Structure
28. Future Upgrades

https://www.overleaf.com/6441975428vfsgmvpctmph#ebe5ff

TDR Writing Status [%]

Editorial Board

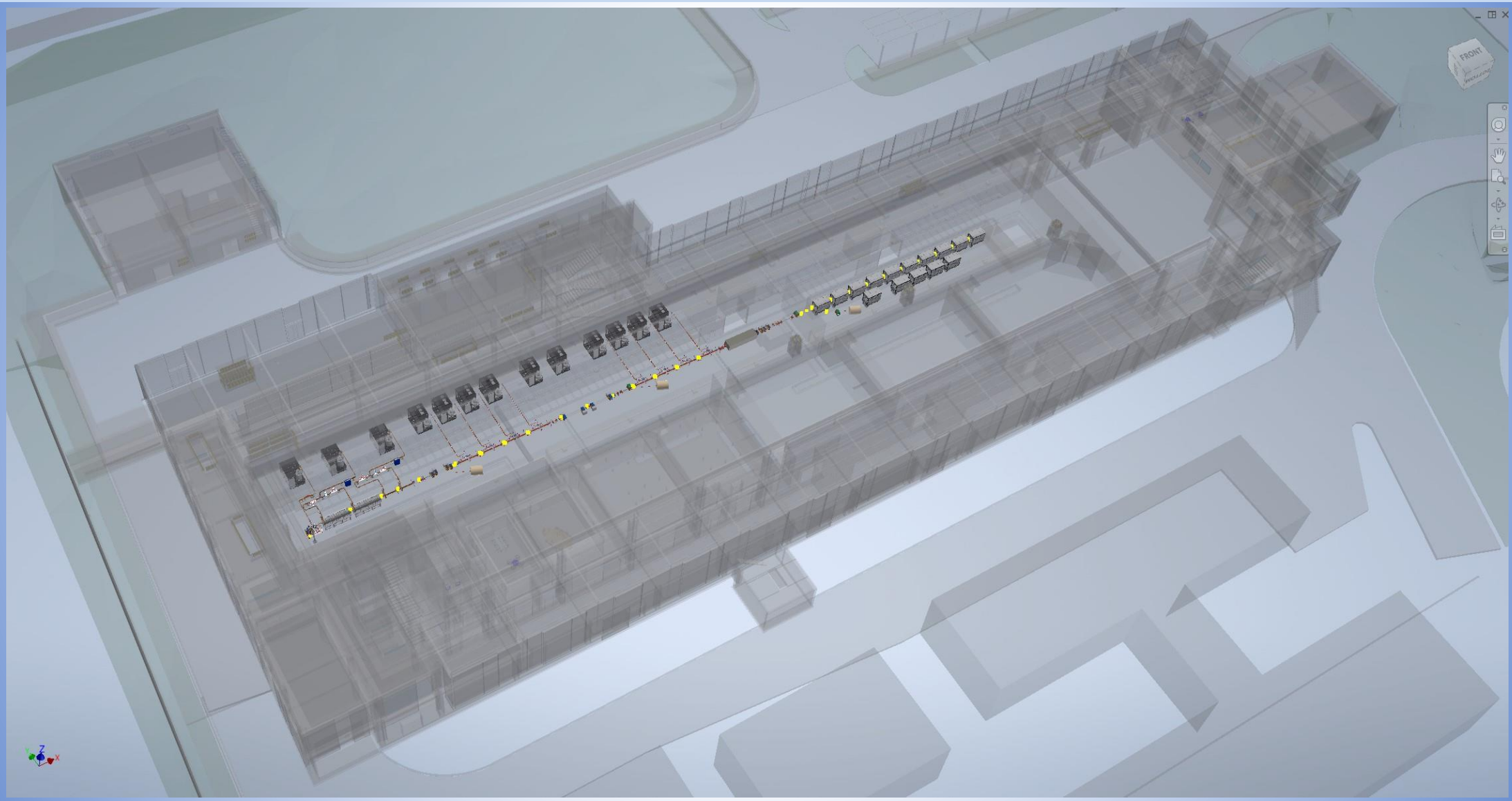
M. Ferrario
A. Gallo
A. Giribono
R. Pompili
F. Villa

	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
November 2024	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
June 2024	80	5	80	30	60	45	45	15	30	30	20	15	7	7	10	10	5	10	7	7	5	5	0	0	0	0	0
Progress	5	80		35		15		25			5	1	8	8	1		5										

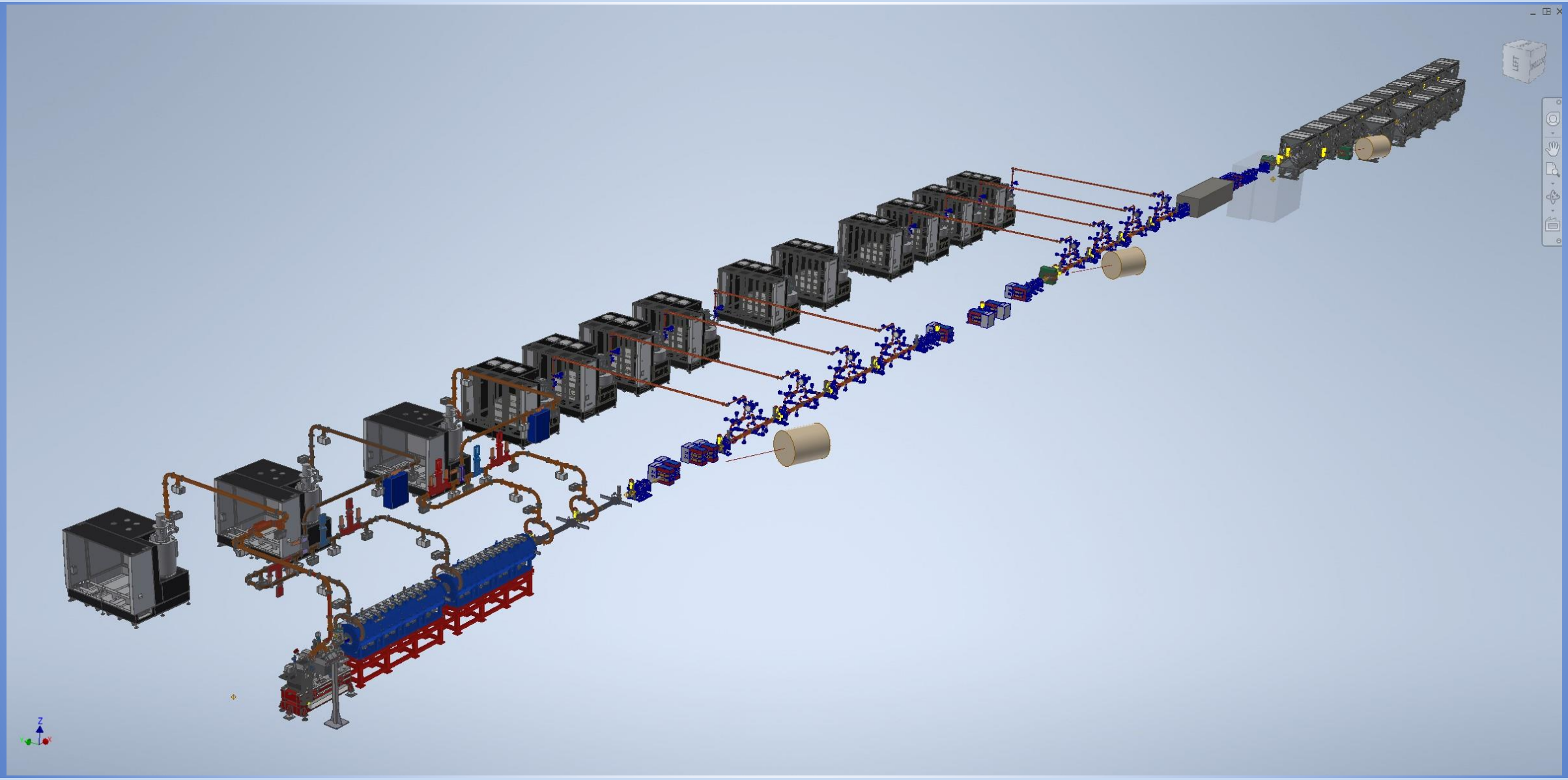
Warning: Writing status does not reflects the effective Project Design Advancement

Complete draft: April 2025 => Final version: October 2025 => INFN Approval: end 2025

Machine Layout



All Component included



EuPRAXIA@SPARC_LAB Functional Layout – V2.12

Istituto Nazionale di Fisica Nucleare

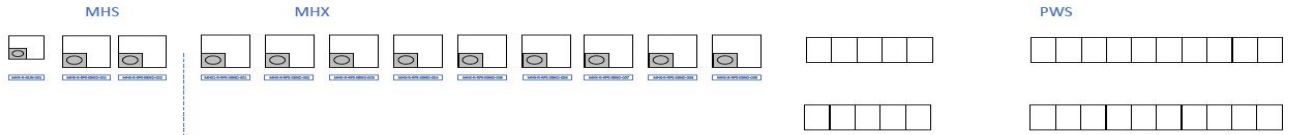
Areas	
LNT	Linac Tunnel
FTN	Fel Tunnel
USR	User Room
MHS	Modulator Hall S-Band
MHX	Modulator Hall X-Band
PWS	Power Supply Area

Module	
LA	Accelerating Module
LM	Magnetic Module

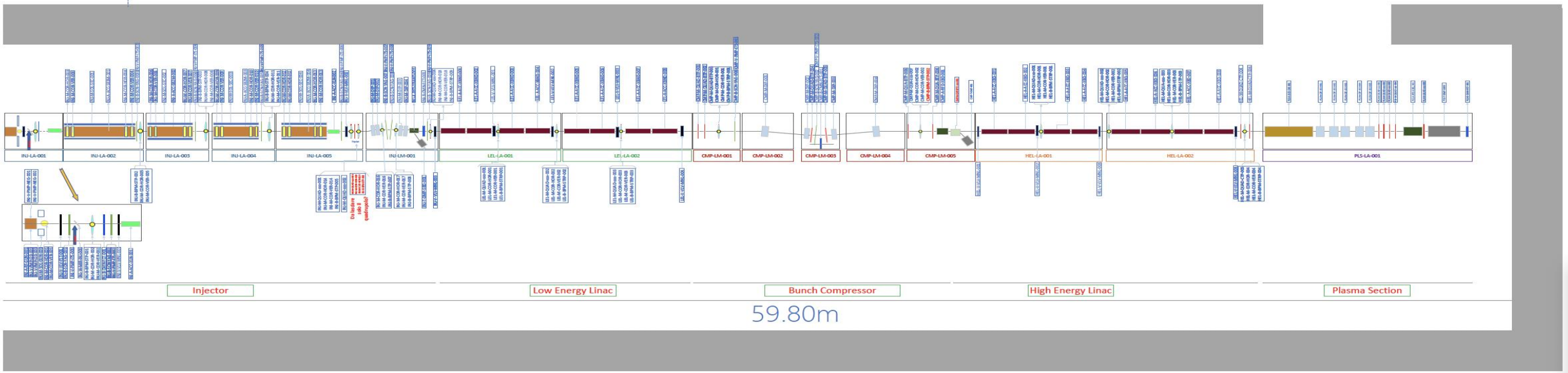
System Zones	
INJ	Injector
LEL	Low Energy Line
CMP	Bunch Compressor
HEL	High Energy Line
PLS	Plasma Section
FEL	Undulator Line

Component Legend

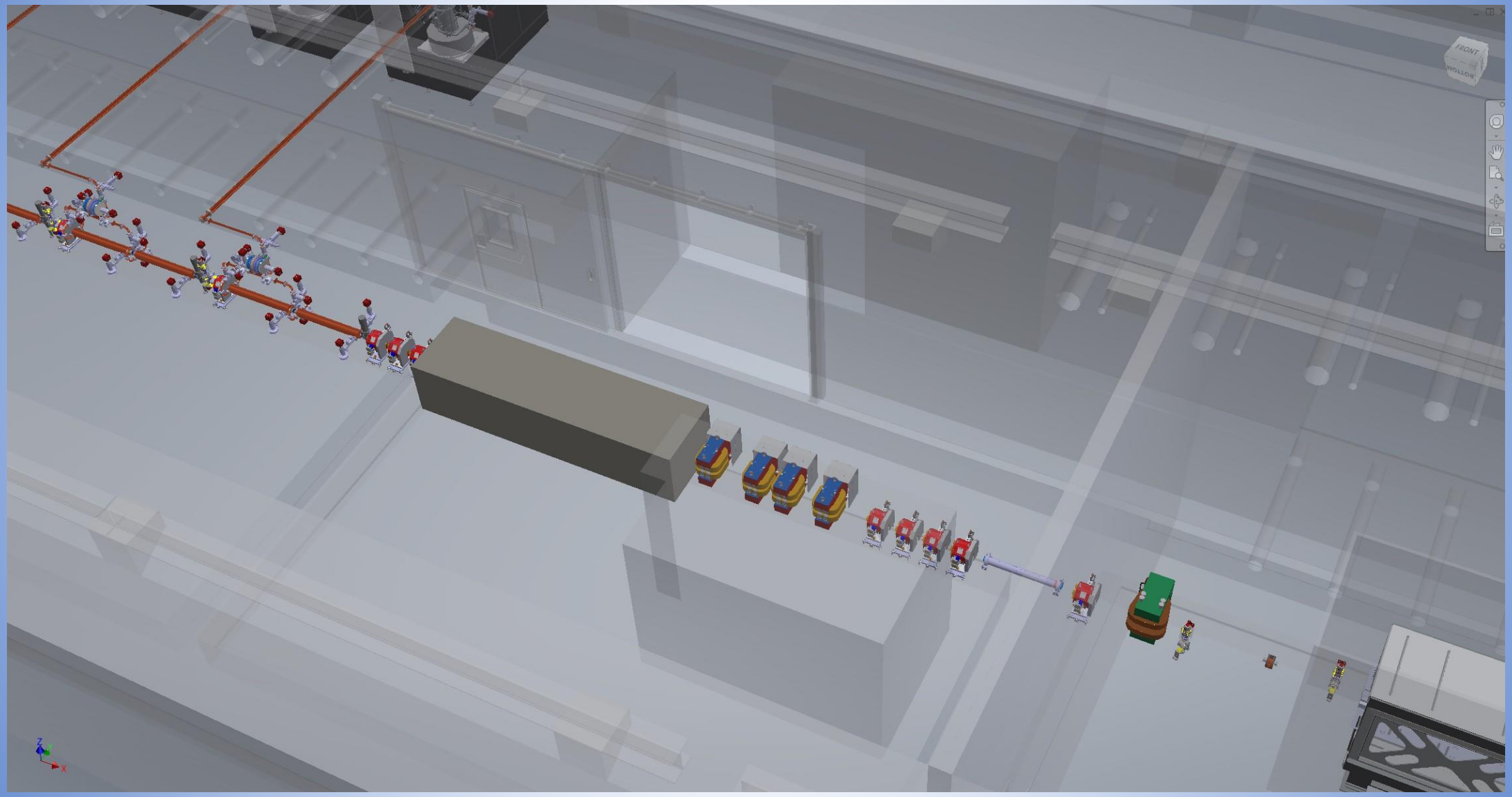
- BPM
- Corrector Magnet
- BPM with Corrector Magnet
- FAST Current Transformer (FCT)
- YAG/OTR Beam Screen
- Vacuum Valve
- S-Band Accelerating Structure
- X-Band Accelerating Structure
- Linearizer
- Quadrupole Magnet
- Transverse Deflecting Cavity
- Cavity Beam Position Monitor
- Sextupole Magnet
- Special Dipole
- Dipole Magnet
- Undulator
- Radiation Stop
- Beam Dump
- Phase Shifter
- Vacuum Chamber



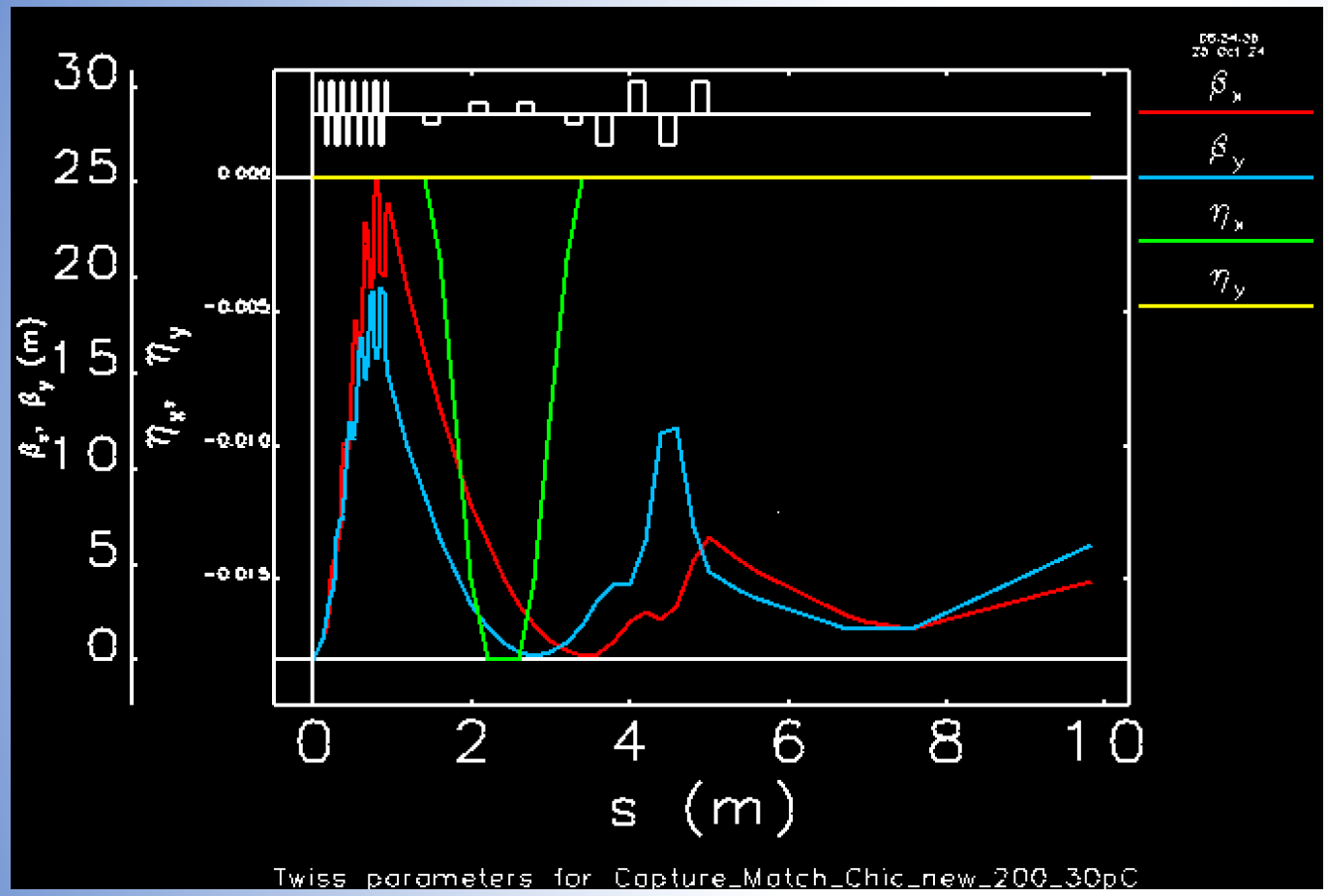
The RC noticed that communication between WP leaders needs substantial improvement.

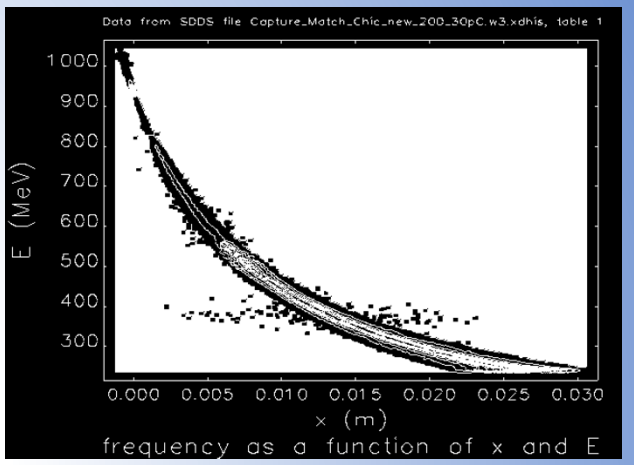


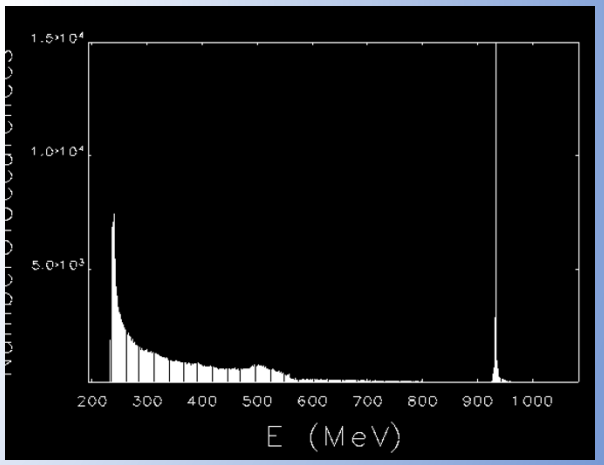
Driver/Witness Separator (Chicane)

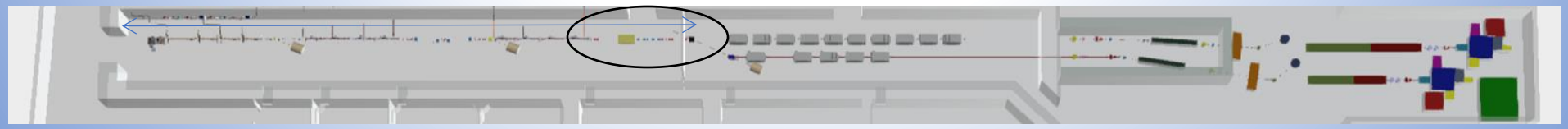


Driver Witness Separation in the final Extraction Chicane









Courtesy C. Vaccarezza and the BD team

Goal parameters and design criteria (100 Hz)

Funded by the European Union

The RC strongly recommends that the preparation of the list of the machine parameters is given priority as it is fundamental for the coherent preparation of the TDR.

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	$\left(\frac{s\ mm^2 mrad^2}{bw(0.1\%)}\right)$	$\mathbf{1-2 \times 10^{28}}$	1×10^{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**	-

- The TDR shall include a chapter on risk management that covers the risks, the eventual mitigating measures, and their associated cost.

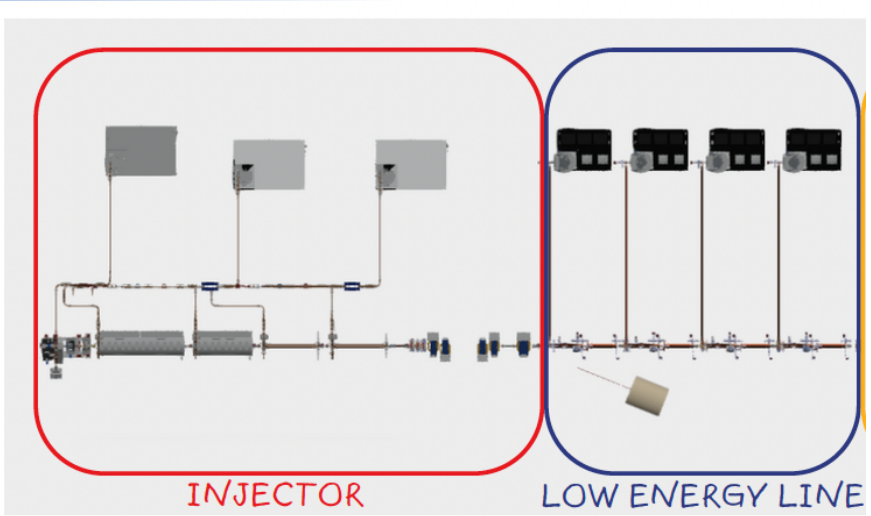
Functional Area	Estimated Cost (€)
Injector	10.999.880
Low Energy Line	9.596.380
Bunch Compressor	1.180.400
High Energy Line	9.761.760
Plasma Module	2.096.000
AQUA FEL	15.520.000
AQUA Beam Lines	7.095.900
ARIA FEL	6.004.000
ARIA Beam Lines	6.374.900
General Elements	3.940.740
Building	48.082.992
Hi-Tech utilities	6.000.000
TOTAL	**126.652.952**

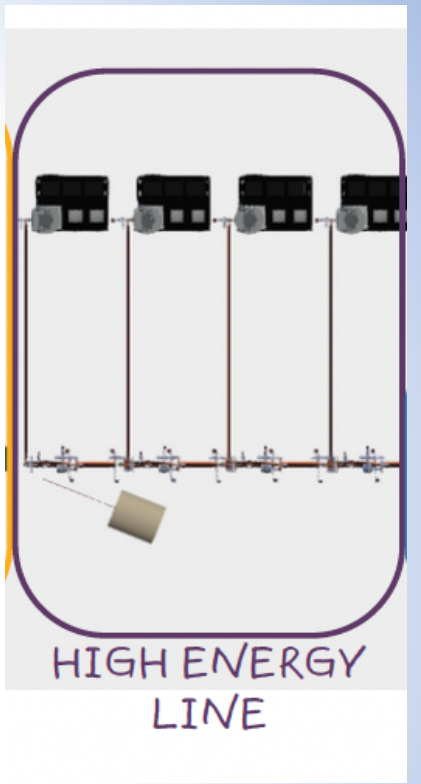
Table 2: Aggregated cost per functional area

- The TDR shall include a chapter on environmental sustainability.

RF/Plasma - Cost Comparison

600 MeV (RF)

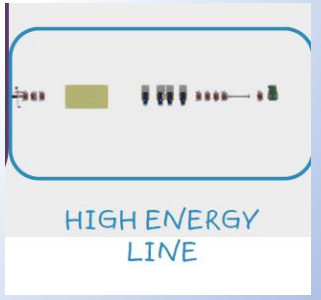




+500 MeV
(RF)

Assuming we have an RF injection system up to 600 MeV, compare an upgrade of +500 MeV with:

- X-ban RF structures only
- Plasmamodule only

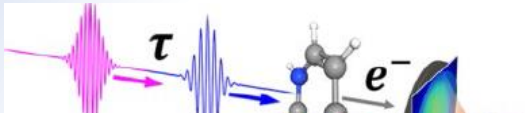


+500 MeV
(Plasma)

ARIA beamline scientific case

Not included in the TDR

Photoemission



Gas phase & Atmosphere

During the last weeks negotiations with local government (Reg.Lazio) have been intensified and we are close to finalize an agreement for an additional 10 M€ funding for the second beam line (ARIA).

This is a co-funding (10M€ Reg.Lazio + 10M€ INFN).

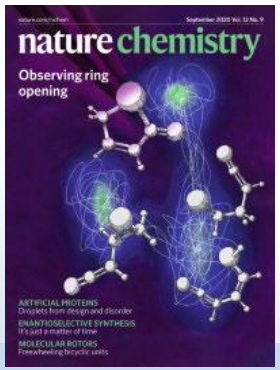
This is exclusively for an additional beam line (thus cannot be used for the original baseline) and has some constraints in terms of financial accounting.

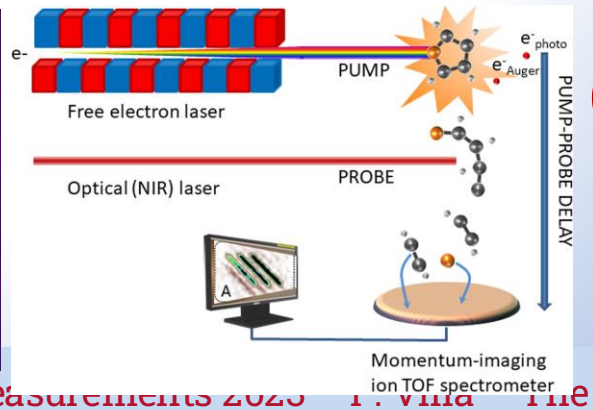
The second beamline must be completed in 2029 (although is not mandatory to have it fully operational).

Surfaces

(ablation & deposition)

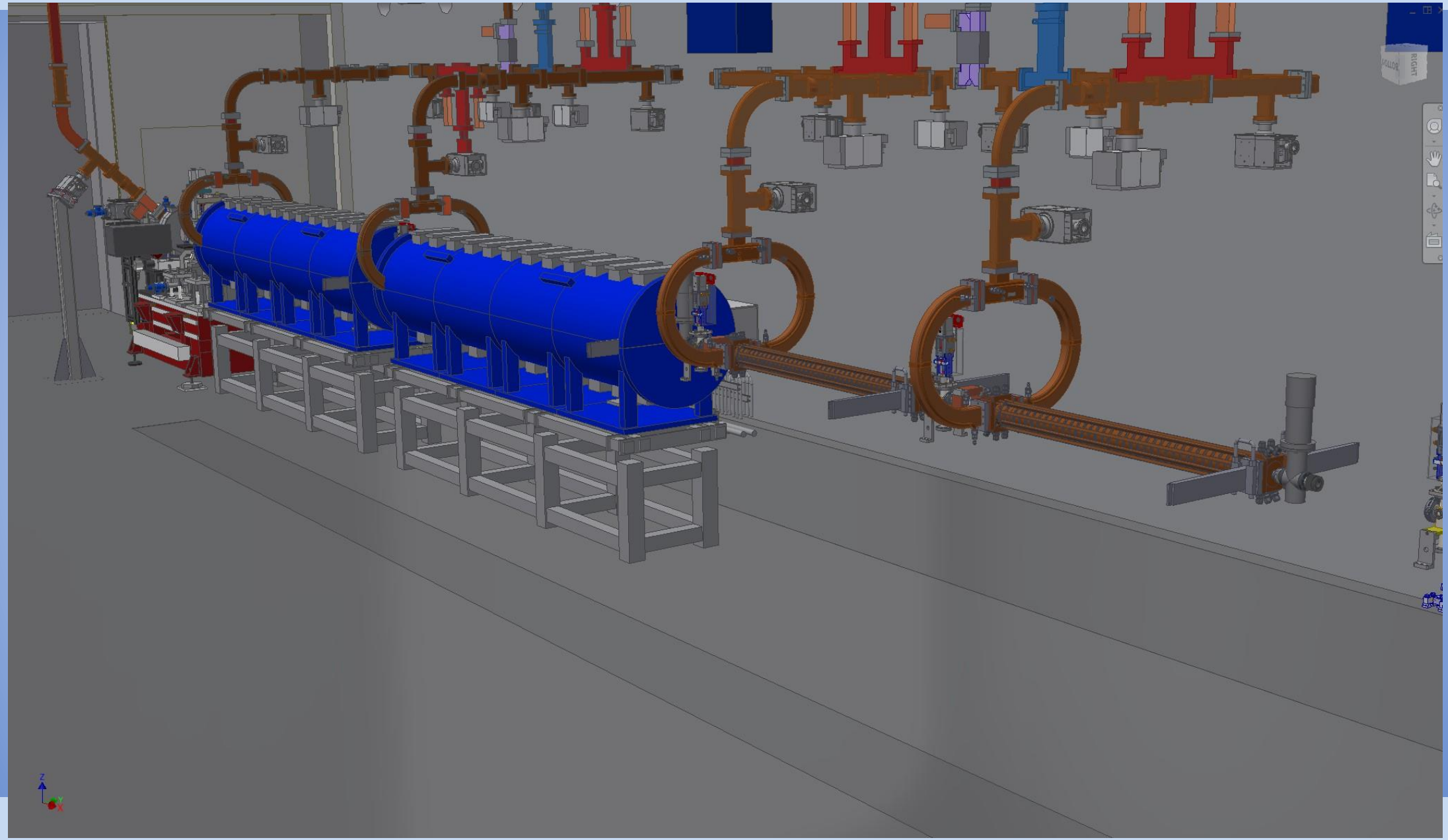
Photo-fragmentation of molecules
Time of Flight Spectroscopy



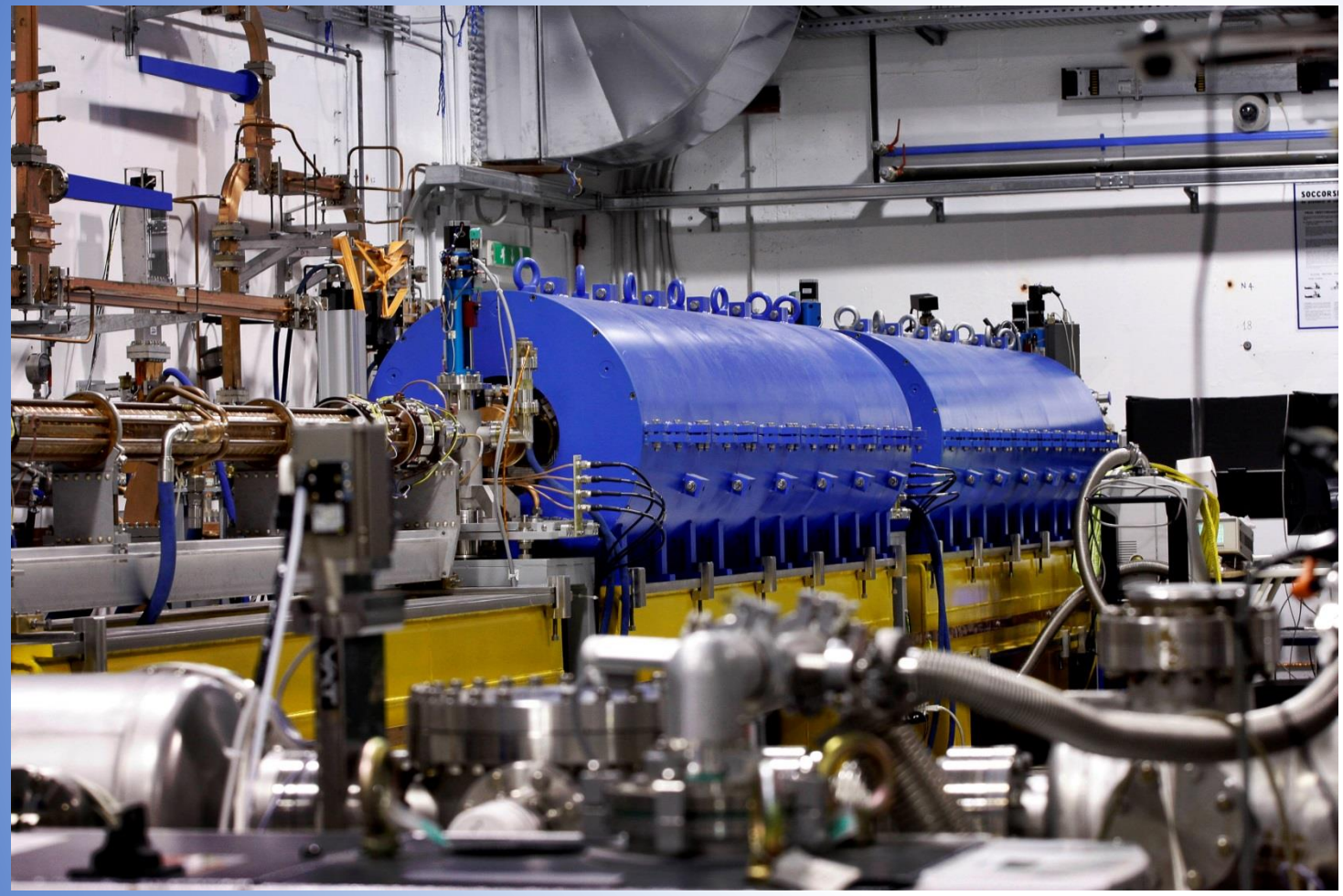


Courtesy F. Stellato

Injector

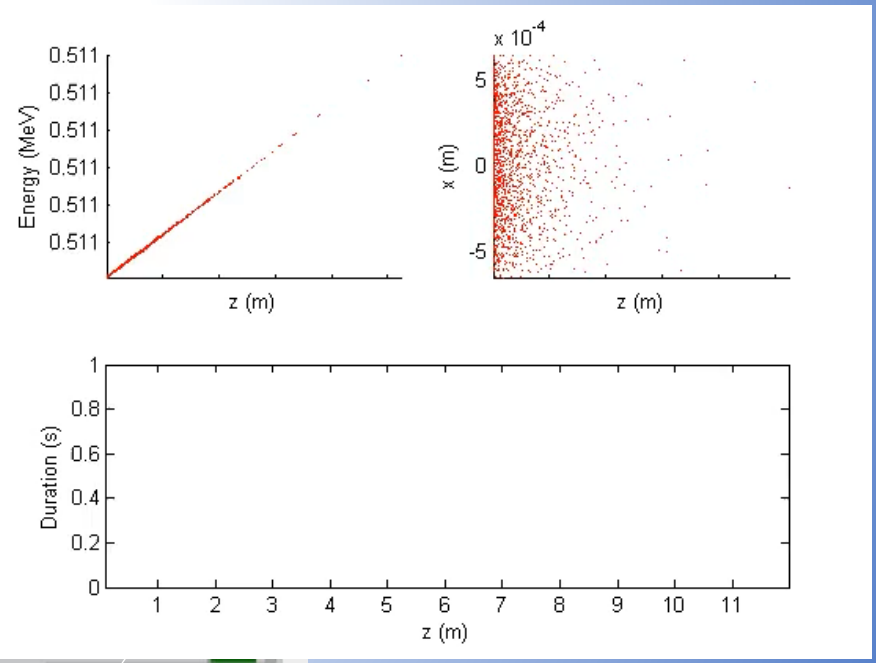


Injector test at SPARC_LAB planned (2025)



Parameter	Unit	Witness	Driver
Charge	pC	30	200
Energy	MeV	101.5	103.2
RMS energy spread	%	0.15	0.67
RMS bunch length	fs	12	20
RMS norm. emittance	mm mrad	0.69	1.95
Rep. rate	Hz	10	10

Table 7.2: Driver and witness beam parameters at the end of photo-injector.



Courtesy E. Chiadroni

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)

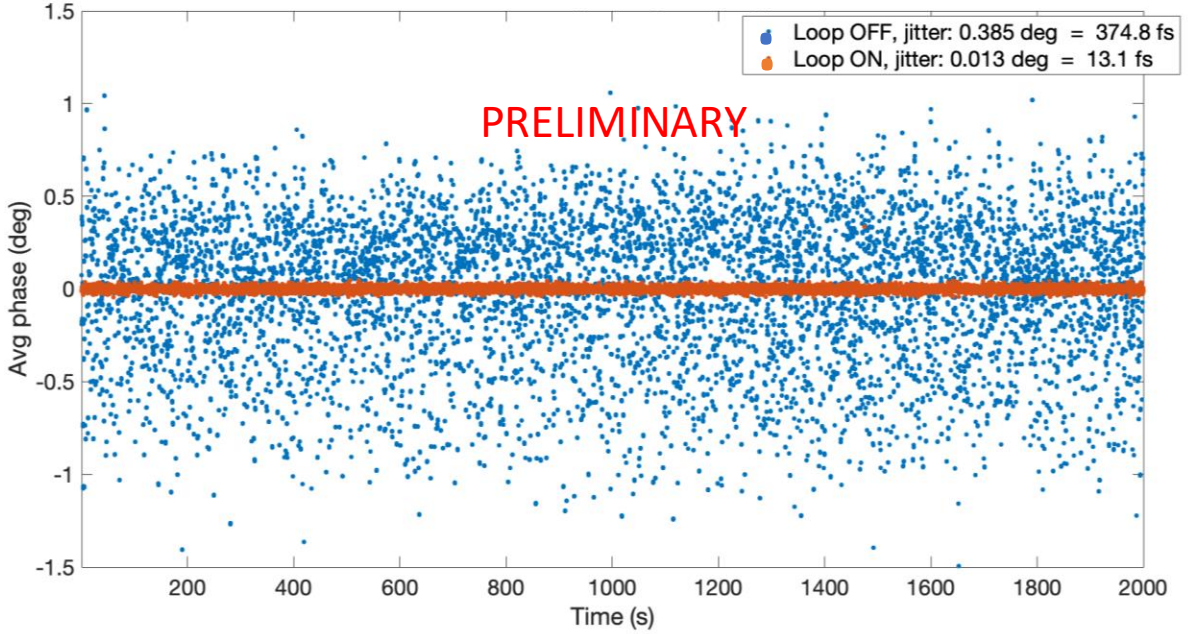
PC-laser locking electronics performance can be improved

Test of the intra-pulse feedback system on the X-band power plant at TEX

S-BAND

RF-Gun phase jitter compression

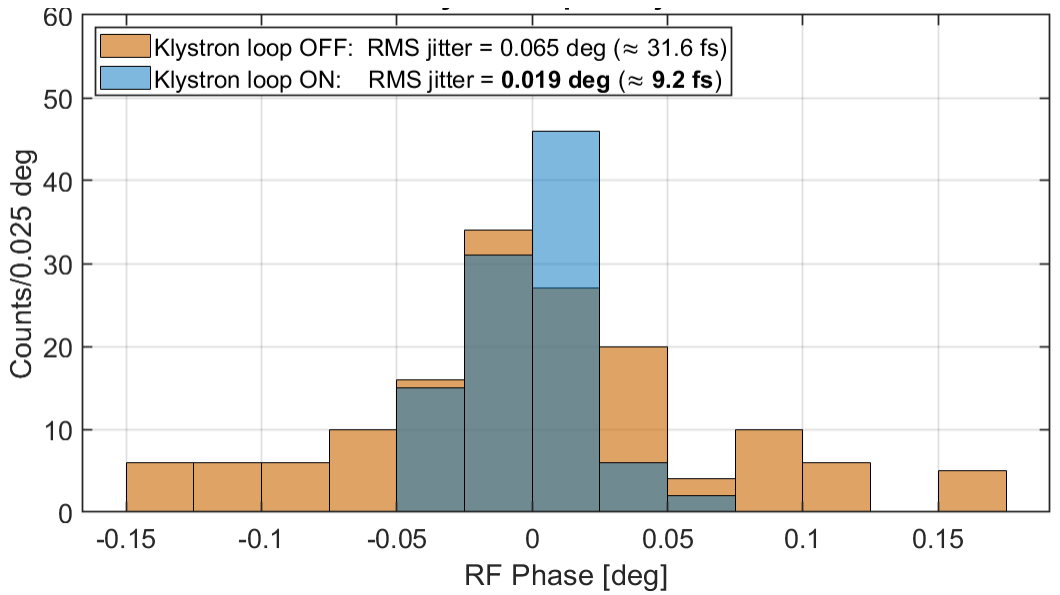
from 0.385 deg down to 0.013 deg (**13.1 fs**)



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

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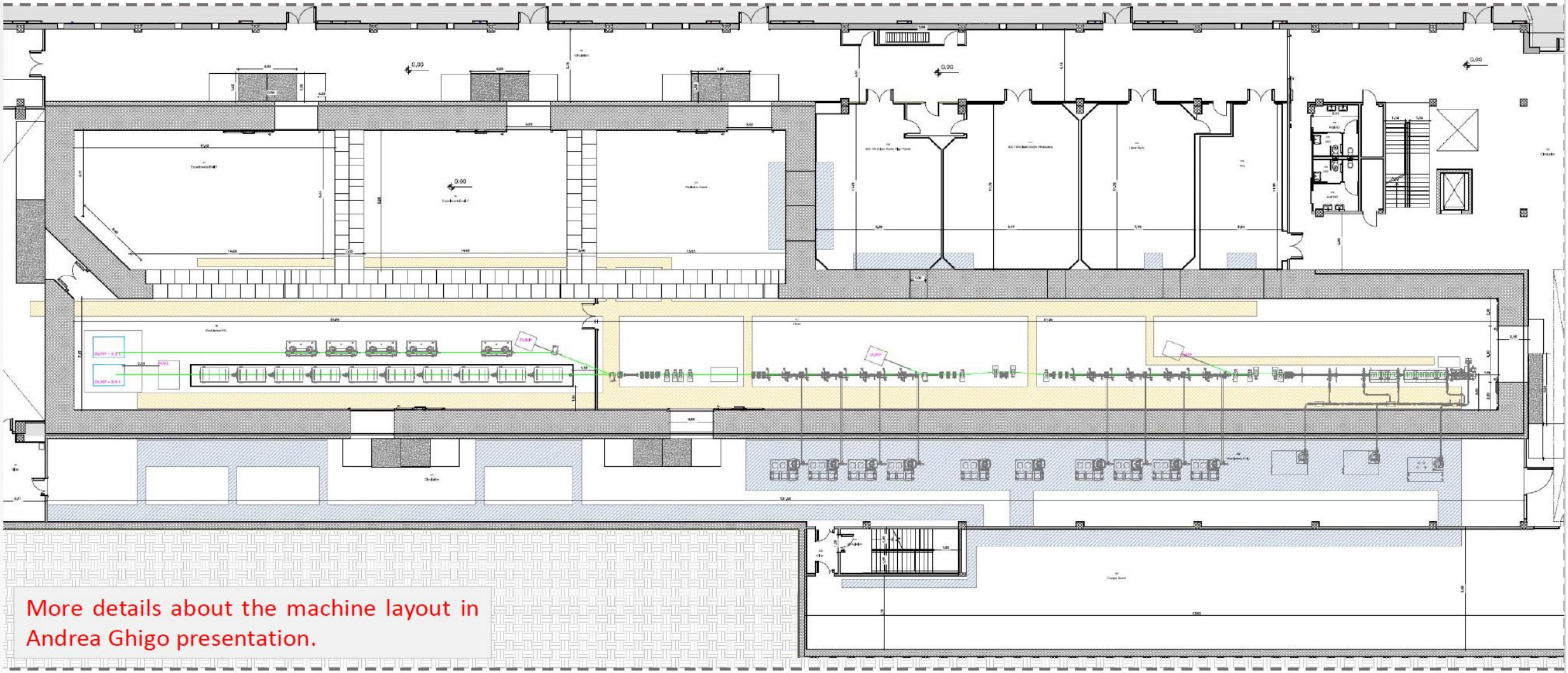
Thanks

Executive design – overlap with machine layout



More details about the machine layout in Andrea Ghigo presentation.