EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA
Preparatory Phase

WP11: Update on XFEL beamline and applications at EuPRAXIA

Enrica Chiadroni, Sapienza University

EuPRAXIA_PP Annual Meeting 2024

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

WP11: Applications

Funded by the European Union

Work package number	11	Lead beneficiary			QUB		
Work package title	Applications						
Participant number	2	5	8	16	19	20	23	26
Short name of part.	CNR	UNIROMA1	CNRS	USZ	QUB	STFC	ELIBL	IASA
Person months per part.:	0 (+2)	12 (+6)	2 (+2)	0 (+6)	24 (+12)	0 (+6)	0 (+6)	0 (+8)
Start month	1			End month	48			

Objectives

Application development. Beamlines and delivery into user areas. Develop required structures in detail (excellence centers, scientific programs, R&D). Specify required funding needs. Propose EuPRAXIA funding programs. Steer scientific and technical progress towards EuPRAXIA implementation. Define specific parameters and modes of operation for beams in the user areas of interest.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

The WP11 is following up on the following work items coordinated by QUB and UNIROMA1, supported by the collaborating institutes with their extensive experience and knowledge base.

Whenever possible, the WP will also encourage preliminary tests of the beamlines, subject to funding and facility access. The WP will then work towards developing stations for secondary sources to be generated in the dedicated target areas and, in consultation with the potential user community, will develop a suite of diagnostics to be installed in each user area for each foresought application.

Milestones:

M11.1 Survey of Beam Parameters and identification of user applications (M12) ✓

M11.2 Survey of user facilities to test equipment and/or advanced concepts of beamlines (M18) ✓

MG.1 Update of concepts for EuPRAXIA, systems status report (M24)

M11.3 Design and project of transport beamlines, focusing on the preservation of beam parameters (M30)

Deliverables (brief description and month of delivery)

D11.1 Report on structures (centres, clusters) to be funded from national/bilateral/European levels (M12) ✓

D11.2 TRL report (M42)

Work Package Coordinators

Gianluca Sarri

Enrica Chiadroni

Work Package Participants

Contributions to WP11 Activity

Update on xfel beamline and applications at EuPRAXIA	*Enrica Chiadroni*
Hotel Hermitage, La Biodola Bay, Isola d'Elba, Italy	17:10 - 17:20
Update on schemes for secondary particle and photon sources at EuPRAXIA	*Gianluca Sarri*
Hotel Hermitage, La Biodola Bay, Isola d'Elba, Italy	17:20 - 17:30
Opportunities for radiobiology studies at EuPRAXIA	*Luca Umberto Labate*
Hotel Hermitage, La Biodola Bay, Isola d'Elba, Italy	17:30 - 17:40
High energy physics and detector testing applications at EuPRAXIA	*Arnd Specka*
Hotel Hermitage, La Biodola Bay, Isola d'Elba, Italy	17:40 - 17:50
General discussion	*Enrica Chiadroni et al.*
Hotel Hermitage, La Biodola Bay, Isola d'Elba, Italy	17:50 - 18:00

Update on XFEL beamlines

- Stability
- Repetition rate
- Tailoring of pulses
  - attosecond, polarization, seeding
- Combining multi-colour pulses in FELs

➔ Compact sources

Towards a High Quality Plasma-based FEL Facility

Funded by the European Union

- High quality beam

$$\varepsilon_n \ll 1mm\ mrad, I_{peak} \sim kA, \frac{\Delta\gamma}{\gamma} \ll 1\%$$

- Long term shot-to-shot stability

FEL requirement ⟷ **Driver-Witness separation**

$$\frac{\Delta\lambda}{\lambda} \propto \frac{\Delta E}{E} \propto \rho \approx 10^{-3} \quad \longleftrightarrow \quad \left.\frac{\Delta E}{E}\right|_{DW} = \frac{a\omega_p}{2\pi}\Delta t_{DW}$$

$$\left.\frac{\Delta E}{E}\right|_{p} = \frac{\Delta n_p}{n_p}$$

Plasma density
(Long Capillary – Diagnostics)

- High rep rate: from 10s Hz to 100s Hz

Spectral range among worldwide X-ray FEL facilities

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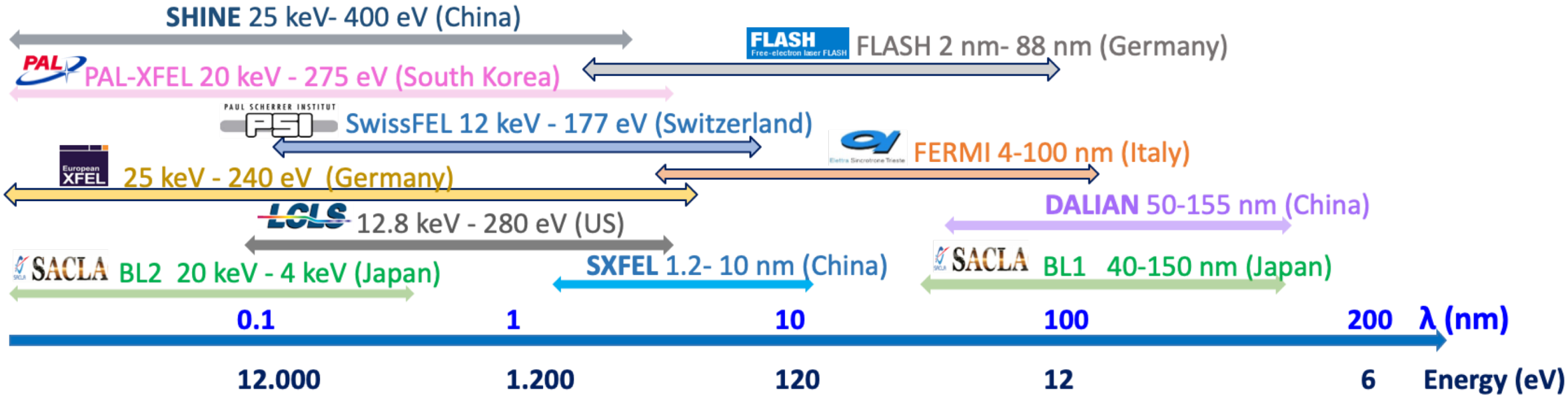
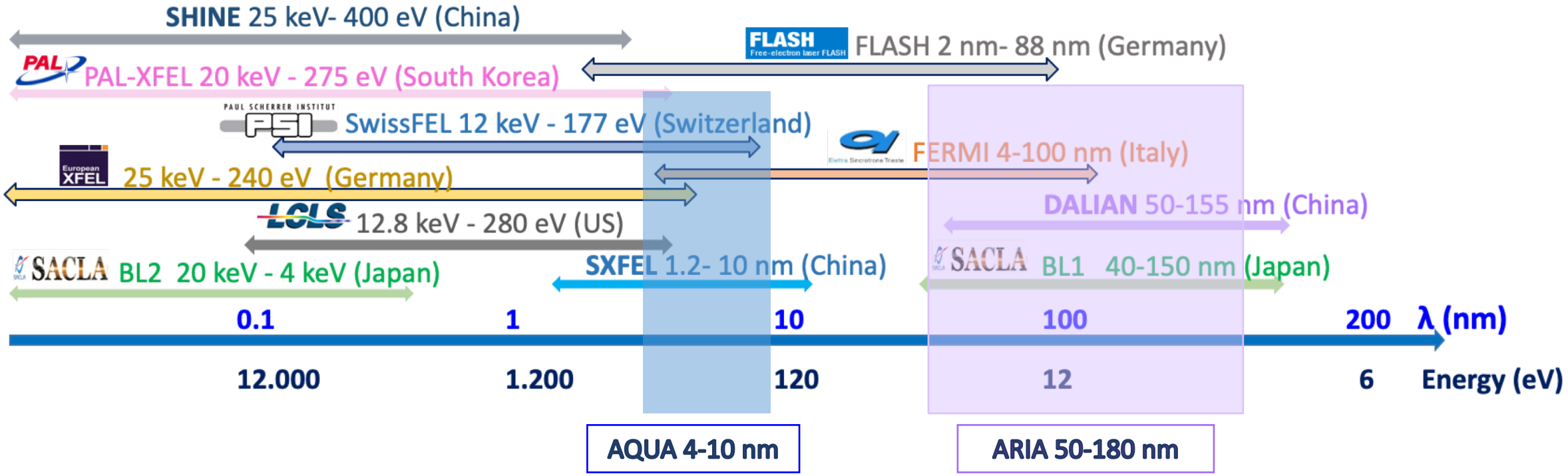


FEL Beamlines at EuPRAXIA@SPARC_LAB



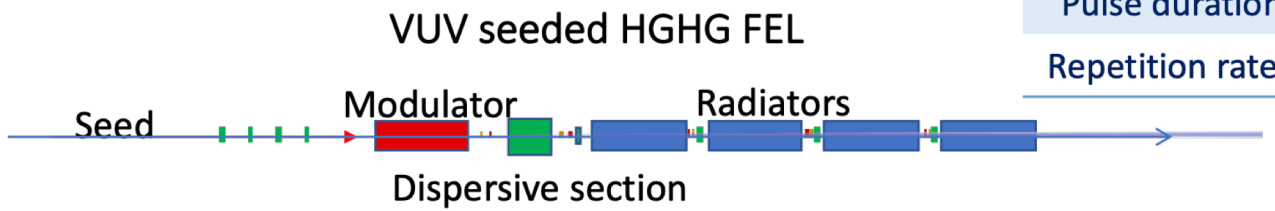
➔ Thursday sessions are dedicated to the first site status: EuPRAXIA@SPARC_LAB

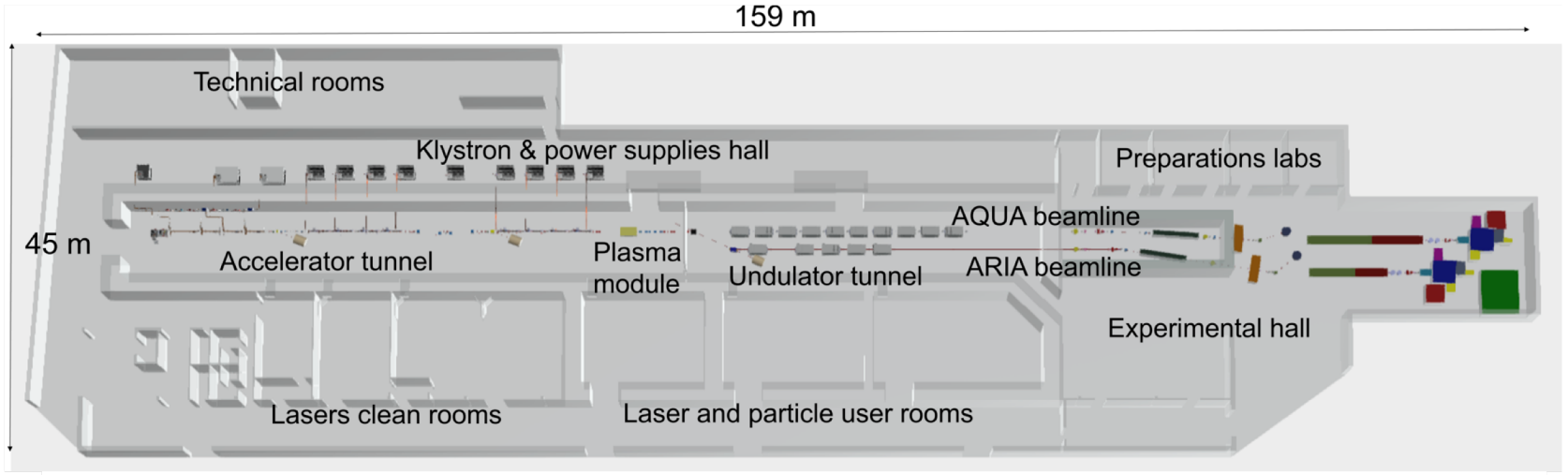
ARIA Beamline at EuPRAXIA@SPARC_LAB

- **ARIA** for gas phases
  - Apple II undulator: variable polar.
  - Seeded in the range 290 - 430 nm

ARIA[2] (~ 7-25 eV) — Seeded FEL

Parameter	Value
Wavelength	50-180 nm
Photons/pulse	10^{13} - 10^{14}
Pulse duration	20/200 fs
Repetition rate*	10 - 100 Hz





[1] F. Villa et al., (2020) *J. Phys. Conf. Ser.* **1596**
[2] F. Villa et al., (2022), *Condens. matter*, **7**

ARIA Parameters and Performances

Funded by the European Union

Electron beam parameters

Charge (pC)	30
rms Bunch length (μm)	2
Energy (GeV)	1
Peak current (kA)	1.8
Slice energy spread (%)	0.05
Slice emittance (mm mrad)	0.8

FEL radiation parameters

Radiation properties / HN	3	5	7	9
Wavelength (nm)	153	92	65	51
Seed energy (μJ)	6	15	18	30
Dispersion R56 (μm)	46	33	23	15
Pulse energy (μJ)	100	57	36	4
Photons/shot (10^{13})	7.6	2.6	1.16	0.1
FWHM Duration (fs)	21	24	20	10
Bandwidth BW (%)	1.7	0.7	0.52	0.47
Time-BW Product (#)	1.88	1.5	1.3	0.69
Pulse size (mm)	0.74	0.63	0.51	0.35
Pulse divergence (mrad)	0.1	0.07	0.05	0.04

- ARIA operates in High Gain Harmonic Generation and may cover the VUV spectral range down to 50 nm with an undulator similar to the one of FERMI FEL-1.
  - Contrary to FERMI it uses a seed longer than the electron bunch and uses the electron bunch shaping and control capabilities of EuPRAXIA@SPARC_LAB for controlling light pulse properties

PHYSICAL REVIEW LETTERS **122,** 114801 (2019)

Editors' Suggestion

Longitudinal Phase-Space Manipulation with Beam-Driven Plasma Wakefields

V. Shpakov,[1,*] M. P. Anania,[1] M. Bellaveglia,[1] A. Biagioni,[1] F. Bisesto,[1] F. Cardelli,[1] M. Cesarini,[1] E. Chiadroni,[1] A. Cianchi,[2] G. Costa,[1] M. Croia,[1] A. Del Dotto,[1] D. Di Giovenale,[1] M. Diomede,[3] M. Ferrario,[1] F. Filippi,[1] A. Giribono,[1] V. Lollo,[1] M. Marongiu,[3] V. Martinelli,[1] A. Mostacci,[3] L. Piersanti,[1] G. Di Pirro,[1] R. Pompili,[1] S. Romeo,[1] J. Scifo,[1] C. Vaccarezza,[1] F. Villa,[1] and A. Zigler[1,4]

Courtesy of C. Vaccarezza/L. Giannessi/V. Petrillo

AQUA Beamline at EuPRAXIA@SPARC_LAB

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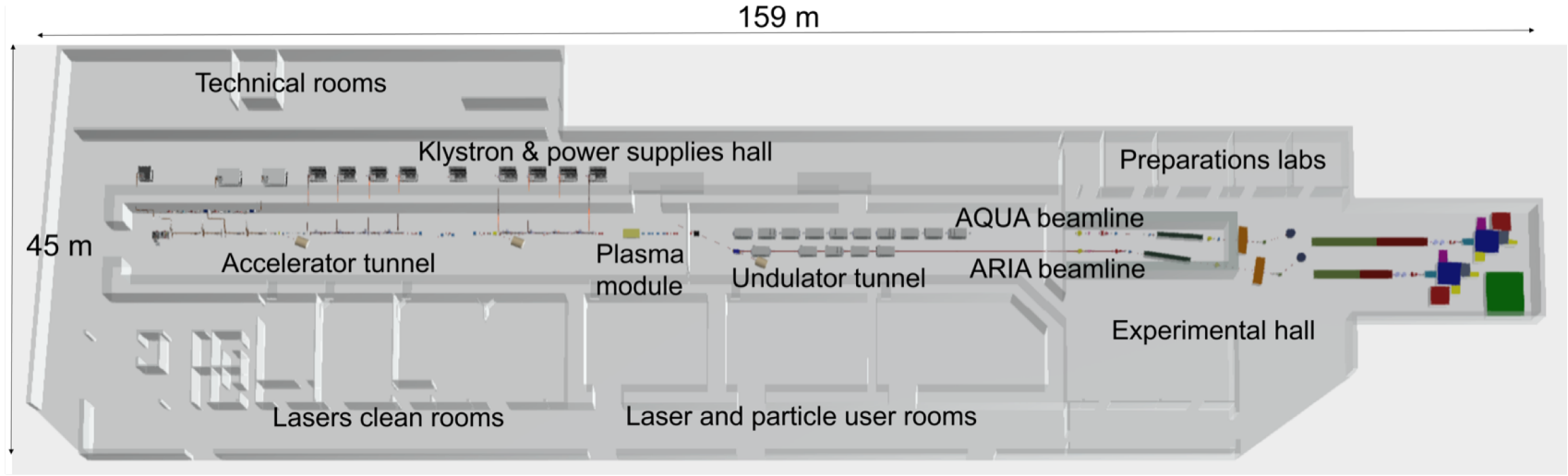


- **AQUA**
  - Water window optimised for the 4 nm (baseline)
  - Polarisation control => AppleX undulator
  - Generation of ultrashort radiation pulses

AQUA[1] (~ 125-310 eV) SASE FEL

Parameter	Value
Wavelength	~4-10 nm
Photons/pulse	10^{10} - 10^{11}
Pulse duration	< 50 fs
Repetition rate*	10 - 100 Hz

Soft-X ray SASE FEL – optimized for 4 nm

[1] F. Villa et al., (2020) *J. Phys. Conf. Ser.* **1596**
[2] F. Villa et al., (2022), *Condens. matter*, **7**

AQUA Parameters and Performances

Funded by the European Union

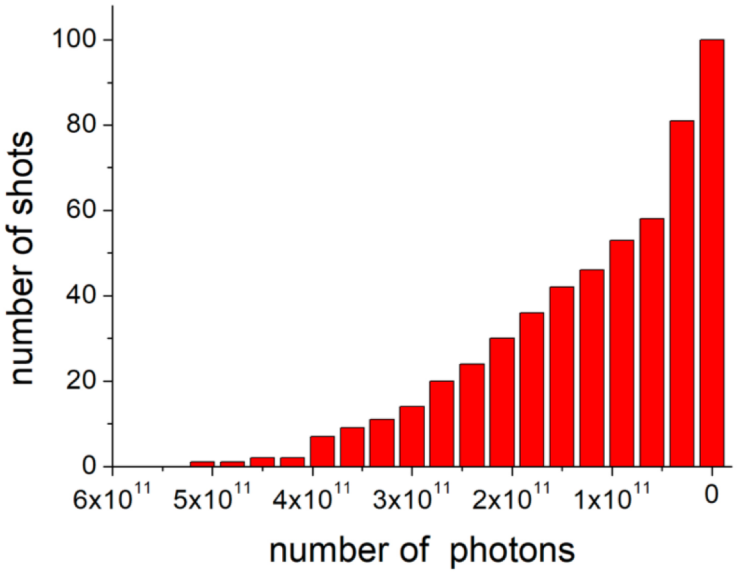
Electron beam parameters

	after plasma	after chic
Charge (pC)	30	30
E_e (MeV)	956	956
Emittance x,y (μm)	0.58, 0.69	0.63, 0.73
Energy spread	3.2e-3	1.7e-3
Peak Current (kA)	1.35	3.19
Current FWHM (μm)	4	1.5
Slice width (μm)	0.5	0.5

FEL radiation parameters

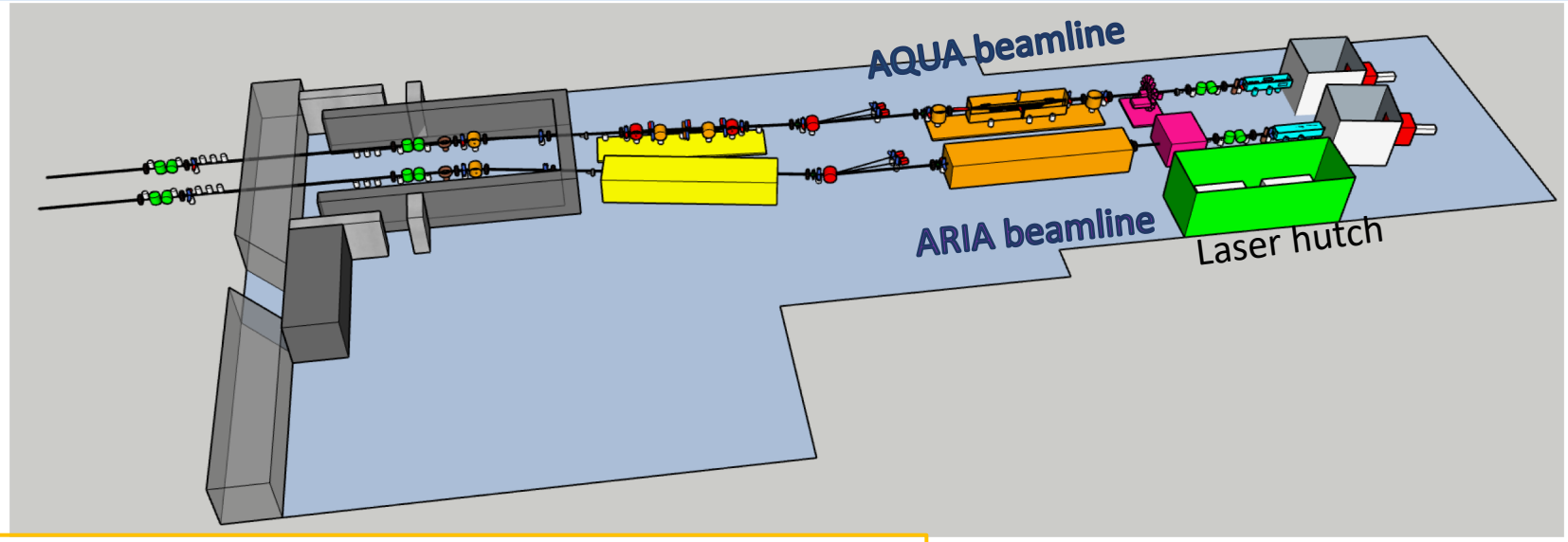
quantity	average value	error	average best 50	error on best 50
gamma	1886.7	26.74	1891.0	10.4
wavelenth(nm)	4.31	0.12	4.49	0.047
Energy (μJ)	5.67	5.75	10.3	4.58
Photon number(10^{11})	1.25	1.27	2.29	1.0
Bandwidth(%)	0.47	0.13	0.49	0.13
Size (μm)	180.6	69	163.9	64.8
Divergence (μrad)	41.27	5.66	38.8	4.54
FWHM length (μm)	1.56	1.91	1.86	2.1

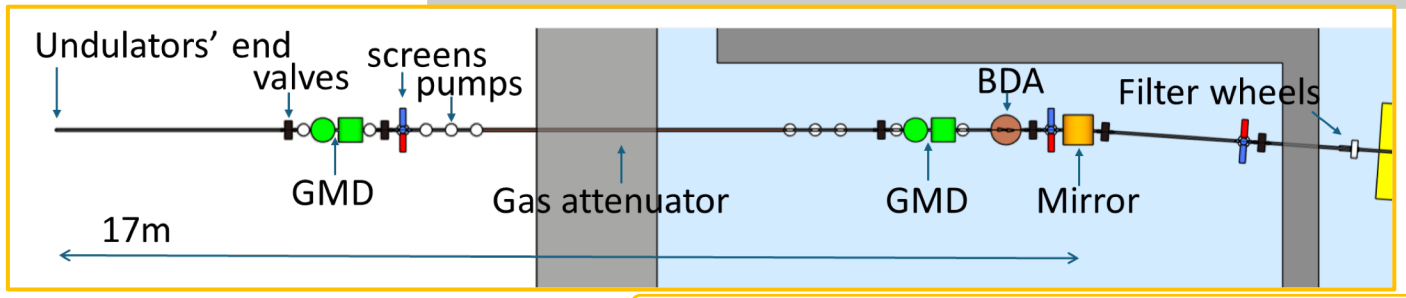
Table 3: Average FEL photon



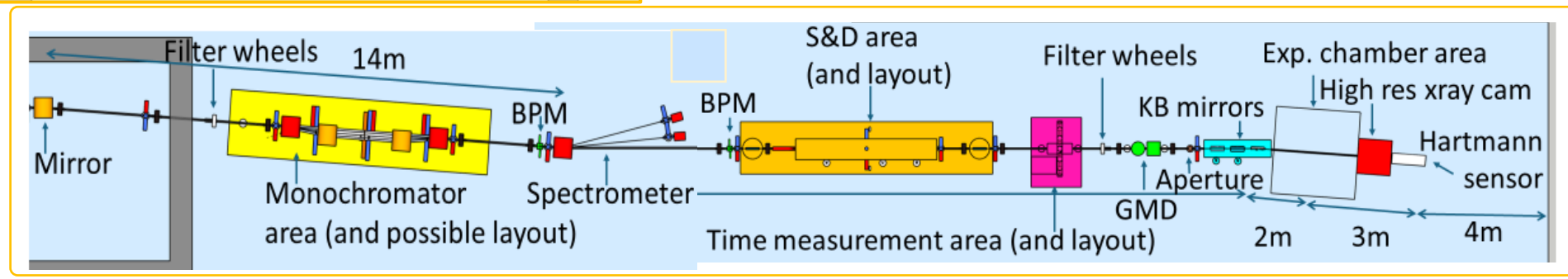
Courtesy of V. Petrillo/C. Vaccarezza/L. Giannessi

Beamline Layout





Courtesy of Fabio Villa



Conclusions

Thank you for filling out the survey

SCAN ME

WP5: EuPRAXIA-PP survey for the potential user community

https://surveys.infn.it/index.php/718177

Longitudinal Photon and Virtual Diagnostics Workshops 2024

November 6 - 8, 2024, INFN - Laboratori Nazionali di Frascati, Italy

We are excited to announce two consecutive workshops, bringing together experts from both the laser and FEL communities to foster an exchange of ideas on photon beam diagnostics:

Longitudinal Diagnostics for Photon Beams – November 6-7, 2024
Virtual Diagnostics Workshop – November 7-8, 2024

Longitudinal Photon and Virtual Diagnostics Workshops will gather experts in photon beam diagnostics, discussing advancements in various methods, techniques, and instruments. Topics will include nonlinear optics techniques, betatron sources, FEL, synchrotron, and others, with an emphasis on improving photon diagnostics and data analysis across the EUV to hard X-ray range.

Topics for the Longitudinal Photon Workshop
- Nonlinear optics techniques: transient reflectivity, cross-correlation methods
- Gas ionization streaking: longitudinal or transverse streaking using visible or THz pulses
- Indirect source reconstruction: analyzing spent electrons from FELs using deflecting cavities, THz generation
- Advanced longitudinal diagnostic techniques: wavefront reconstruction, interferometry, speckle-based methods
- Characterization of large bandwidth or partially coherent photon beams: synchrotron pink beams, plasma accelerator betatron sources, inverse Compton scattering

Topics for the Virtual Diagnostic Workshop:
- Fidelity augmentation of photon diagnostics using AI
- Full FEL AI model as a basis for virtual diagnostics
- Integration of online virtual diagnostic data into machine operation

Abstract & Registration open: 10.09.2024
Abstract submission deadline: 01.11.2024
Registration deadline: 01.11.2024
Website: https://agenda.infn.it/event/41662/

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Christopher Arrell (PSI)
Jan Gruenert (European XFEL)
Jia Liu (European XFEL)

LOCAL ORGANISING TEAM
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Funded by the European Union

Thank You for the Attention

EuPRAXIA-PP Consortium

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Coordinator

INFN Istituto Nazionale di Fisica Nucleare

Consiglio Nazionale delle Ricerche

Elettra Sincrotrone Trieste

ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

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Università di Roma Tor Vergata

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Queen's University Belfast

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Wigner

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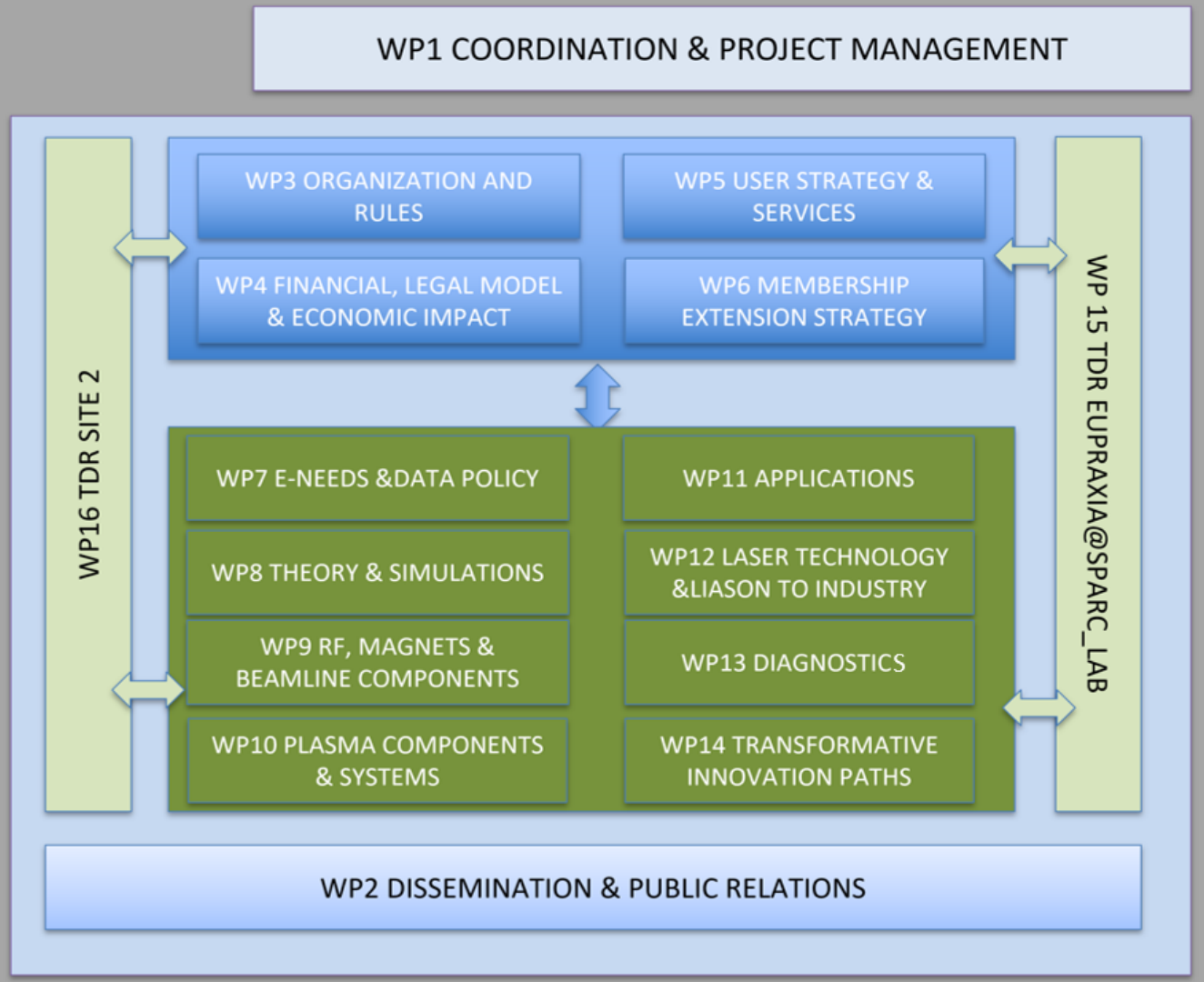
EuPRAXIA-PP Structure



Selected Committees and Boards

GOVERNING BOARD
(decision-making body, 1 representative per institute)

Steering Committee
(coordinator plus WP leaders plus experts)

Scientific/Technical Advisory Board
(external experts in user services, RI implement-tation, ESFRI aspects and technical themes)

Board of Financial Sponsors
(connection to decision makers and funding authorities)

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- EuAPS

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