Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

The EuAPS project: EuPRAXIA Advanced Photon Sources

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On behalf of the EuAPS collaboration

EuAPS: EuPRAXIA Advanced Photon Source

What?

- EuAPS project financed by Italian Ministry in the framework of PNRR
- Highest score among research and innovation infrastructures projects
- First brick of EuPRAXIA - The European Plasma Research Accelerator with eXcellence In Applications
- Realization of 3 facilities →

(WP2) INFN-LNF Frascati	(WP3) INFN-LNS Catania	(WP4) CNR-INO Pisa
Betatron Radiation X-ray source	High Power Laser	High Repetition Rate Laser

INFN TOR VERGATA UNIVERSITÀ DEGLI STUDI DI ROMA INFN

Why?

- **Innovative photon science applications**

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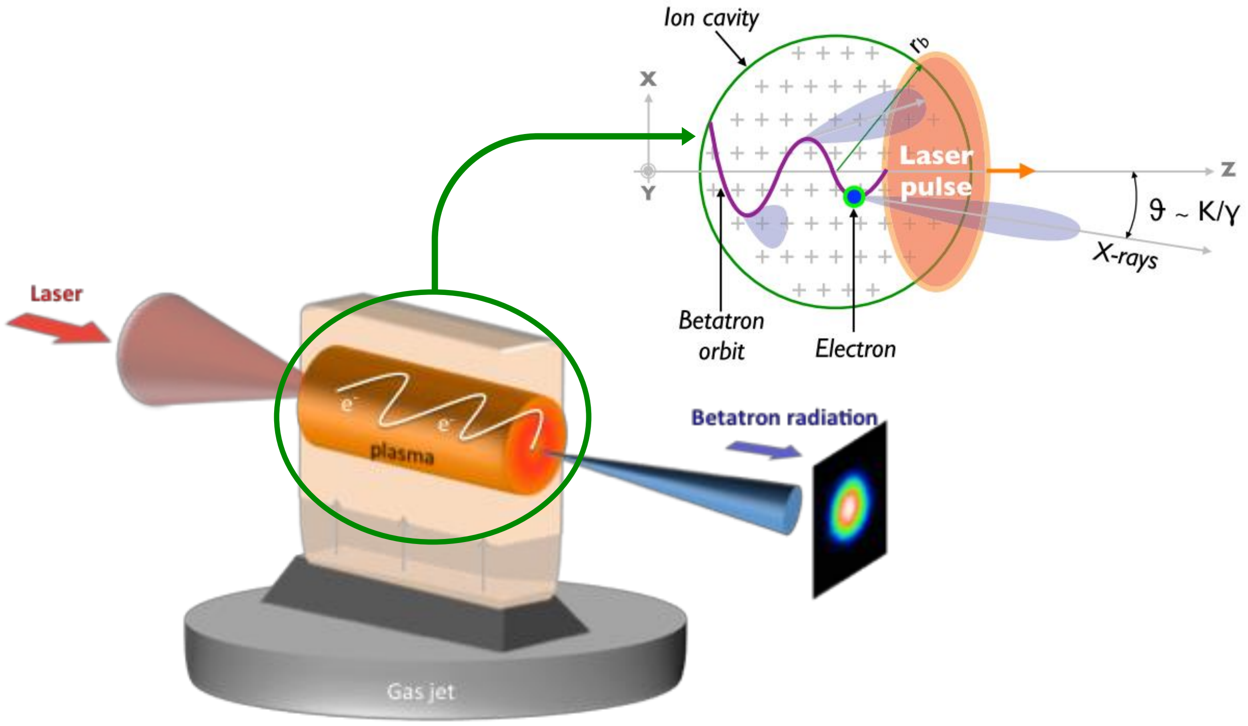
- **Innovative photon science applications**

EuAPS: EuPRAXIA Advanced Photon Source – WP2

EuAPS@LNF

(INFN-LNF, INFN-Mi, Tor Vergata, CNR-Montelibretti, CNR-Potenza)



Our goal:

User facility for advanced photon science applications

How?

FLAME high power laser focused on gas target in the **SPARC_LAB** bunker

⇩

LWFA: accelerated e^- production via self-injection

⇩

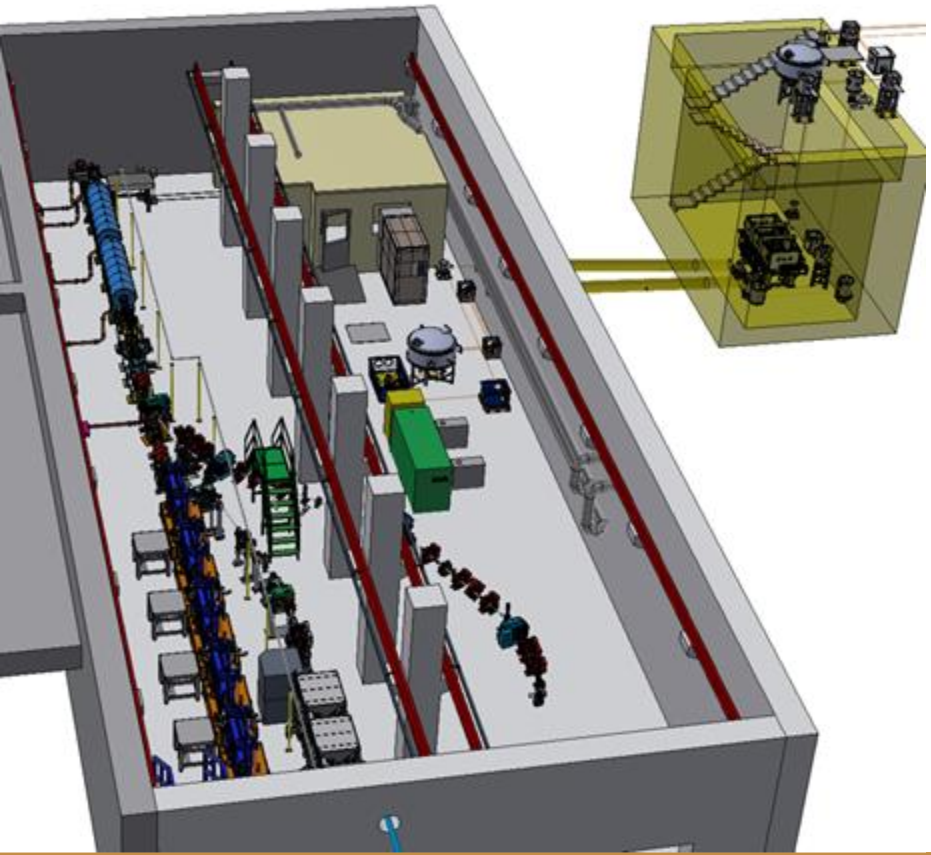
e^- oscillating in the plasma wakefild produce

Betatron Radiation Emission

Expected parameters

Parameter	Value	Units
Electron Beam Energy	100 - 500	MeV
Plasma Density	10^{18} - 10^{19}	cm^{-3}
Photon Critical Energy	1 - 10	keV
Number of Photons/pulse	10^{6} - 10^{9}	-
Repetition Rate	1	Hz
Beam Divergence	3 - 20	mrad
Pulse Duration	tens	fs

EuAPS: EuPRAXIA Advanced Photon Source – WP2



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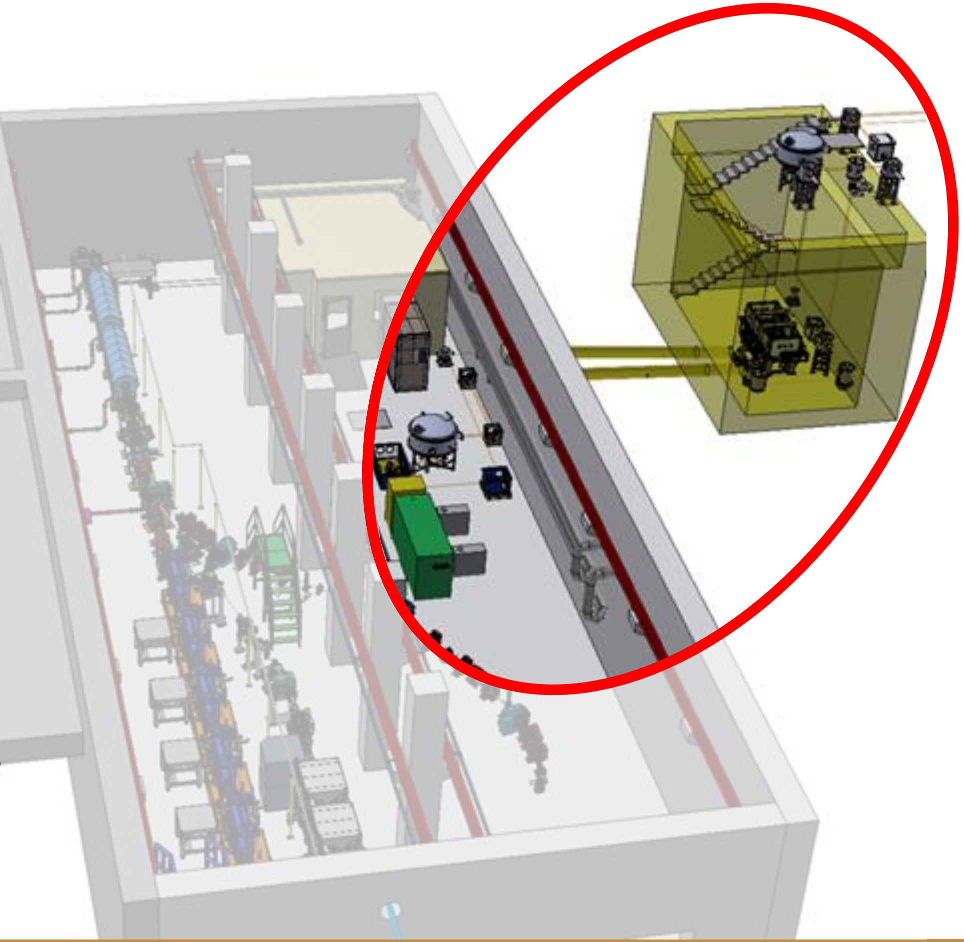
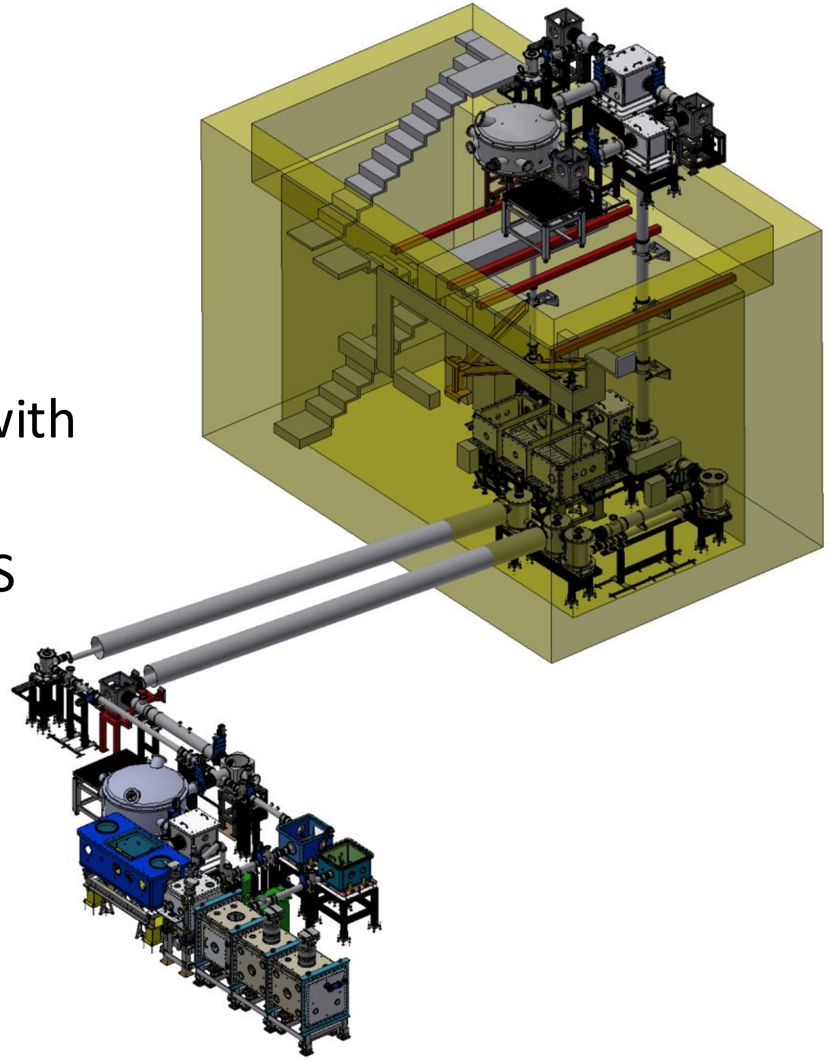


SPARC bunker connection with FLAME building for laser transportation to the EuAPS experimental area



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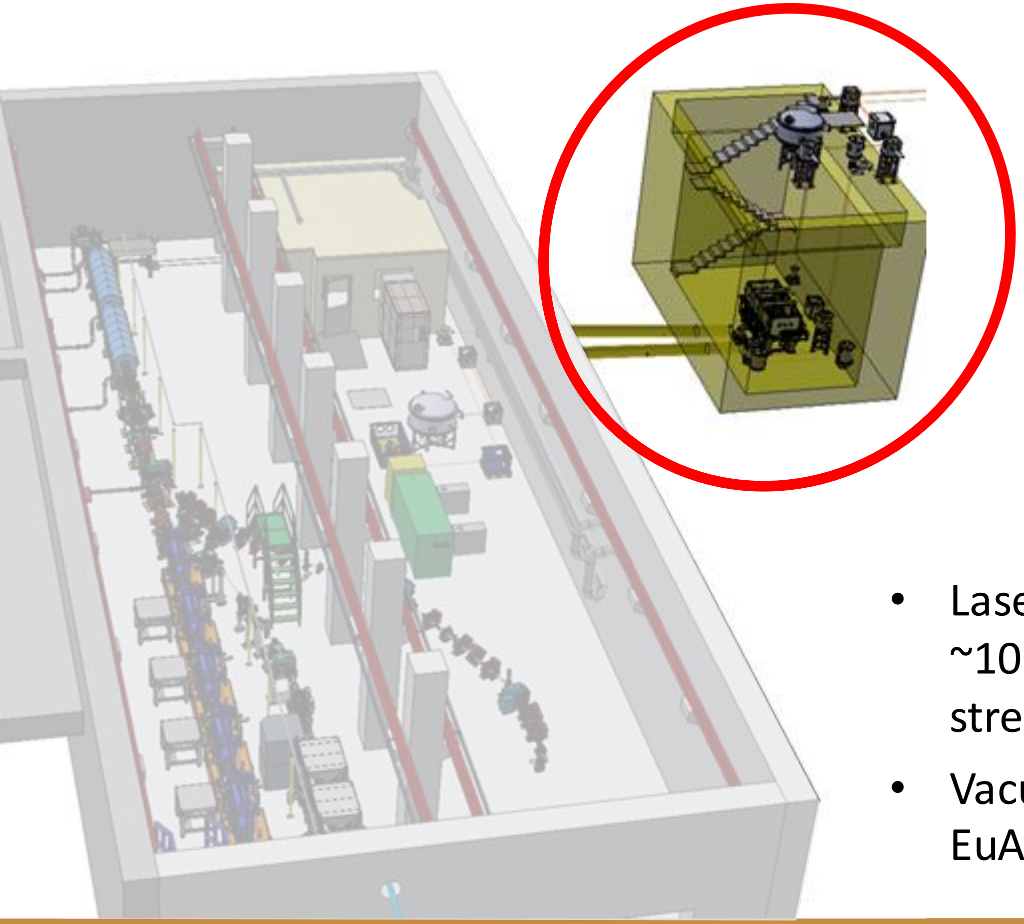
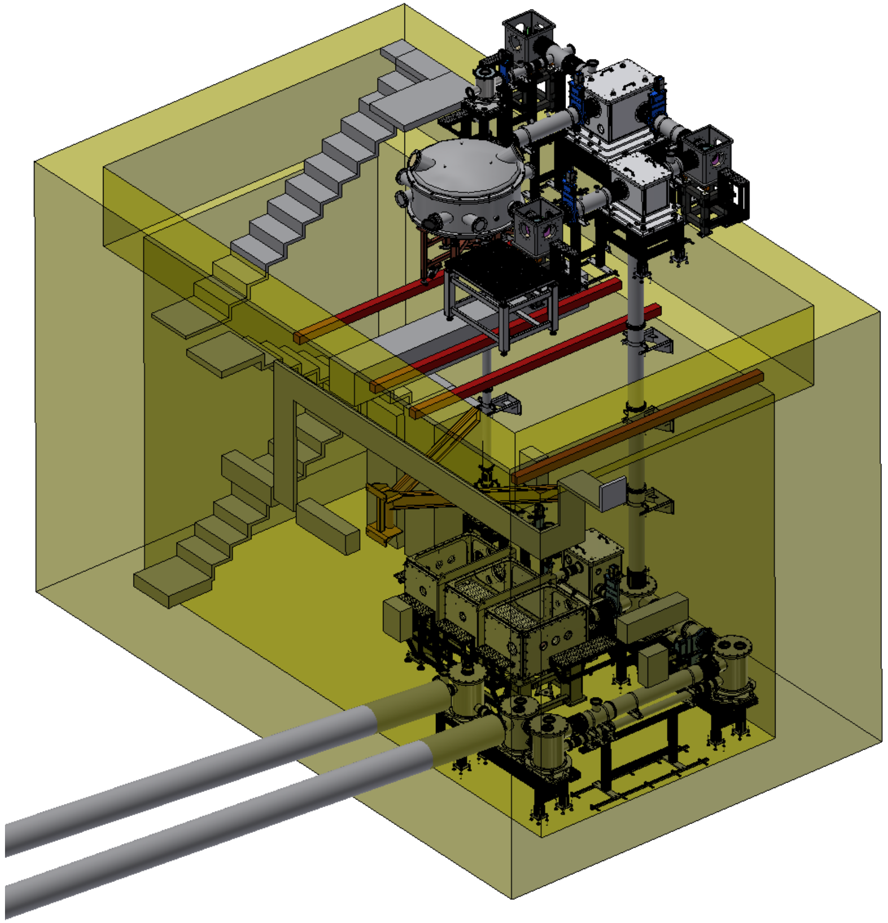
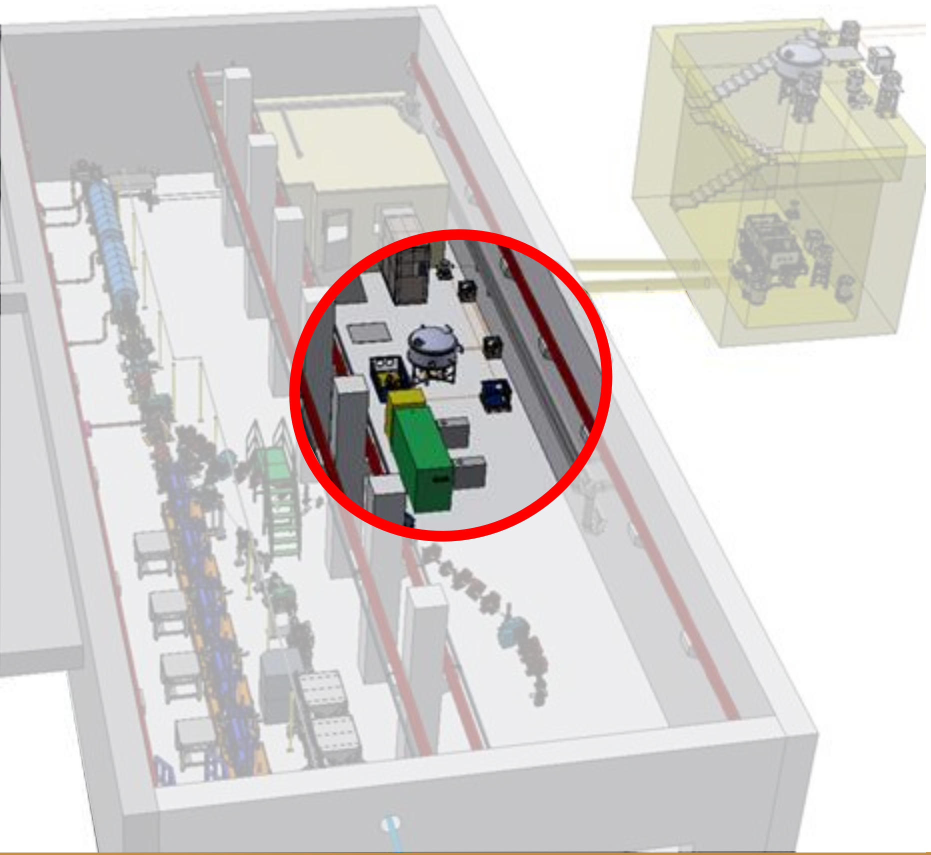


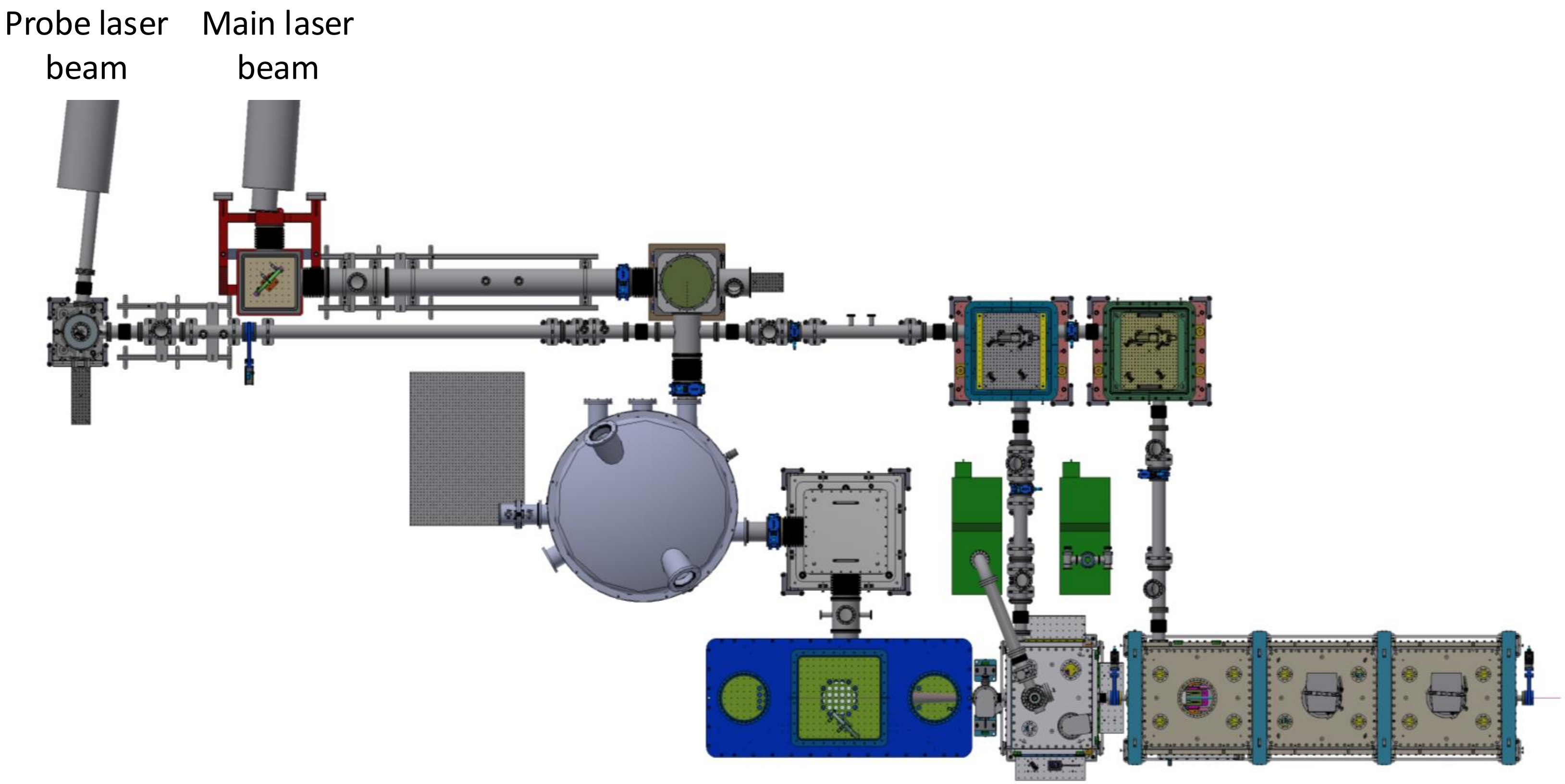
FLAME laser infrastructure



- Laser from FLAME clean room: ~10 cm diameter and temporally stretched
- Vacuum transportation lines to EuAPS@SPARC (probe and main beams)

EuAPS: EuPRAXIA Advanced Photon Source





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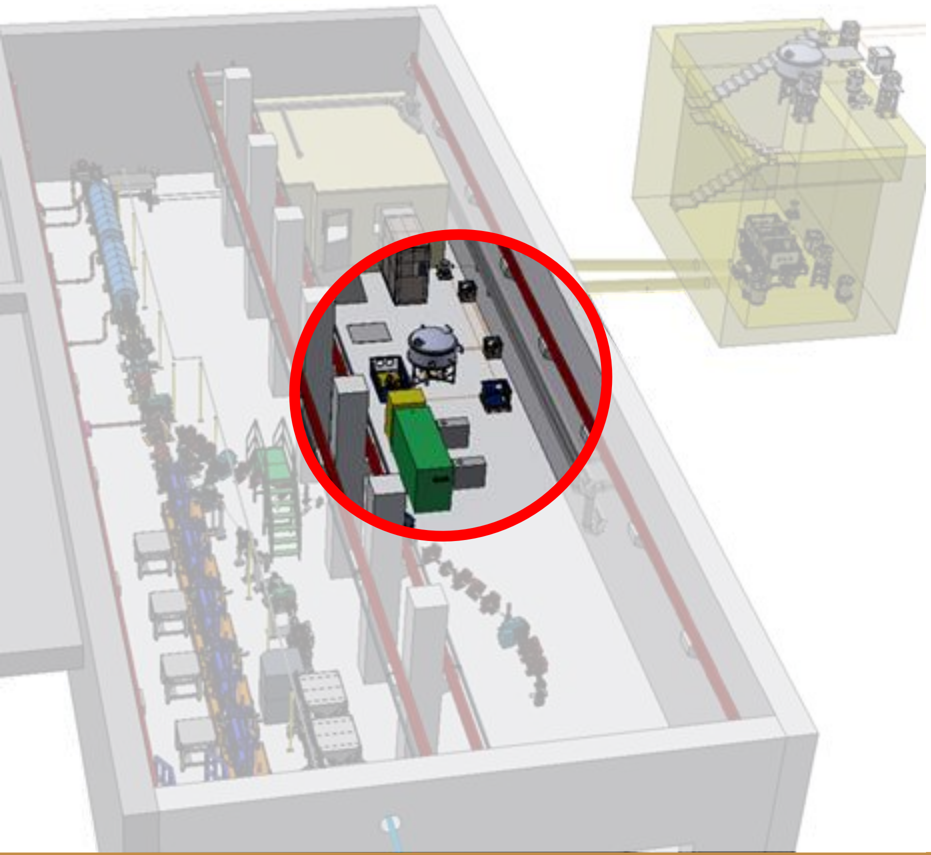
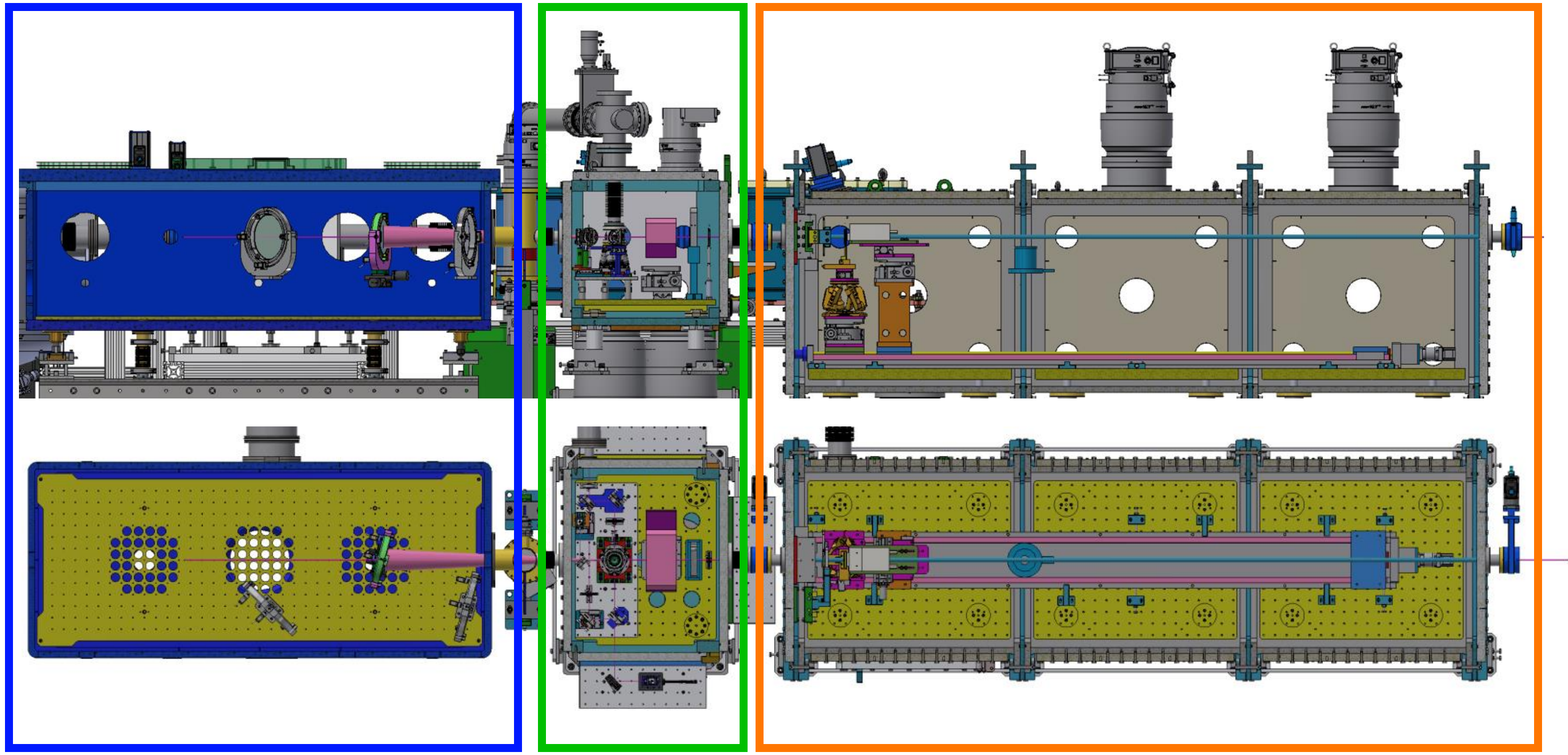


Parabola chamber (laser focusing)

Interaction point (betatron rad. generation)

Users chamber (photon science experiments)



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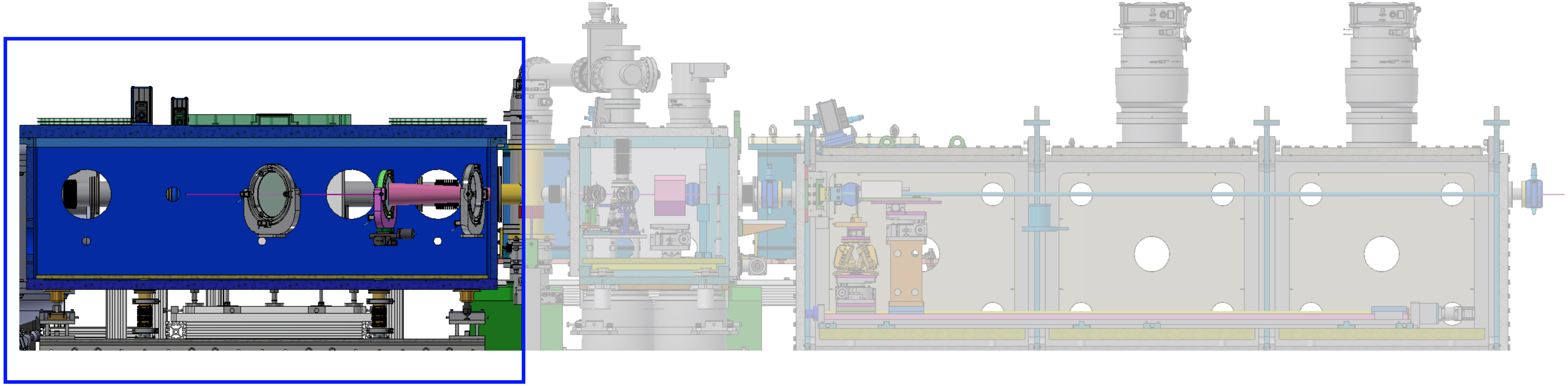

Parabola chamber

- Hosting the laser focusing parabola: from 10 cm to ~10 µm $1/e^2$ spot
- Vacuum level down to 10^{-4} mbar at least

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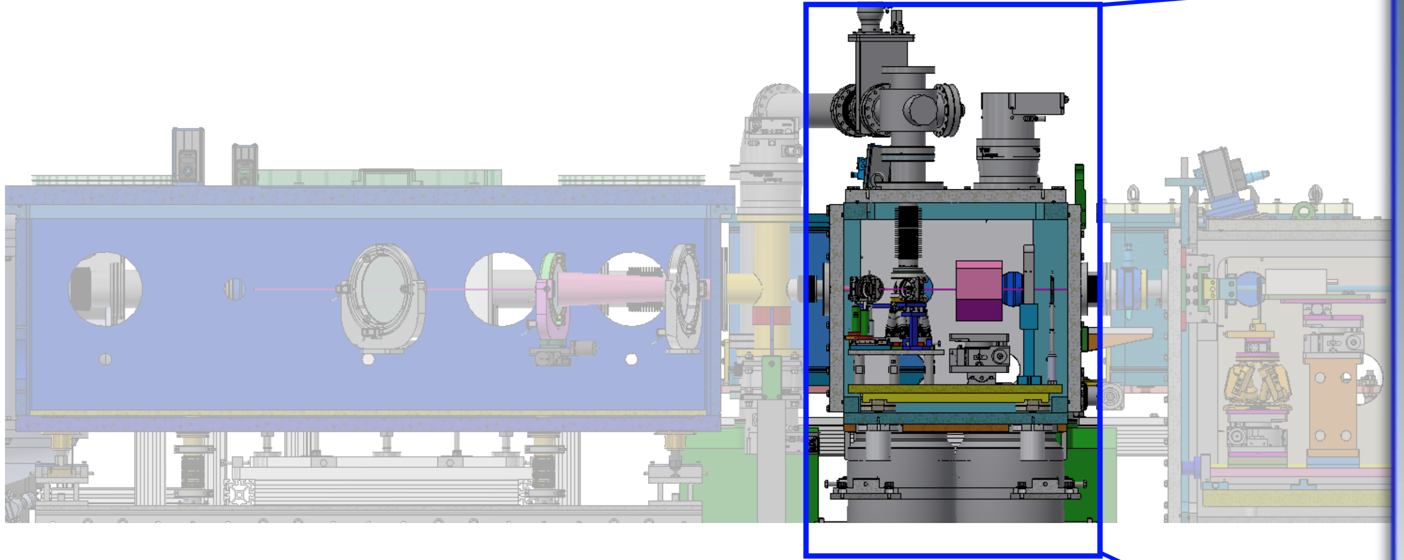

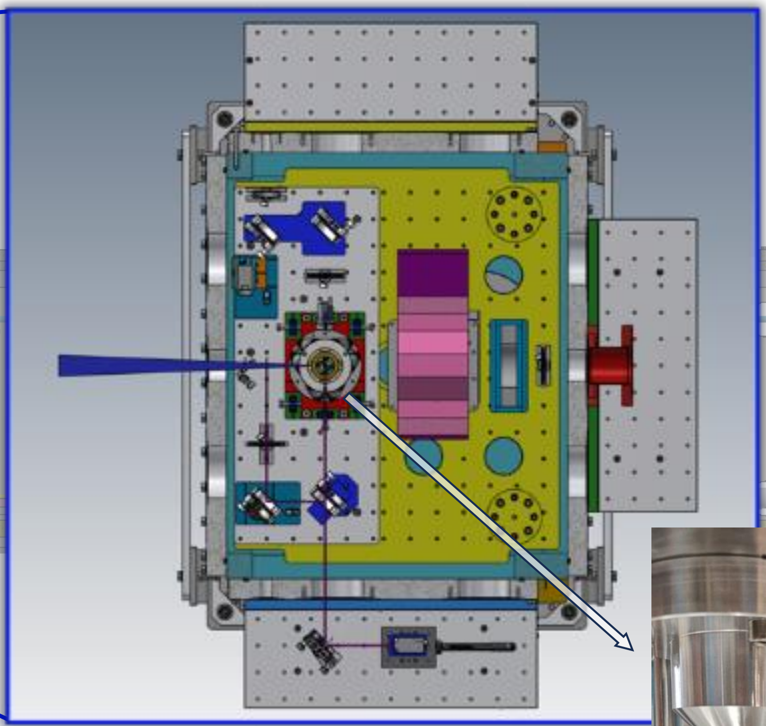

Interaction chamber

- Here the betatron radiation is generated: LWFA through laser interaction with the gas (He, N_2 , Ar)
- 1.2 T magnetic dipole and scintillator lanex screen for e^- deviation and energy measuring
- Interferometer for plasma density measurement

Gas injection and extraction system

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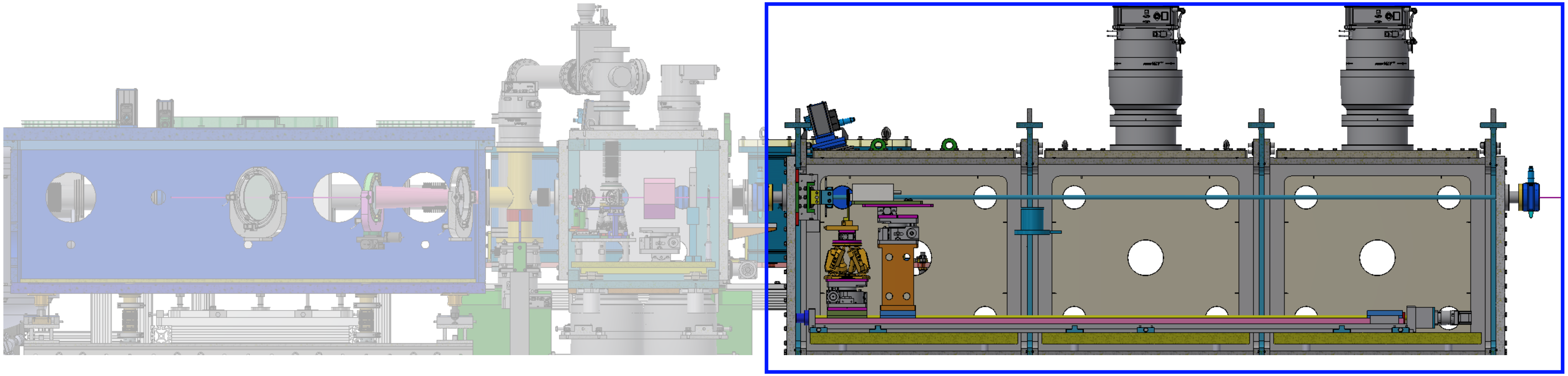

User experimental chamber

- Complete modularity of the structure, with 3 units of 100 cm lenght
- Each unit has/can be slotted with:
  - 5 flanges (4x 100 CF and 1x 150 CF), left and right side
  - 5 flanges (4x 100 CF and 1x 200 CF) tops side
  - 3 flanges (3 x 100 CF) front and back side
- Vacuum level down to 10^{-6} mbar

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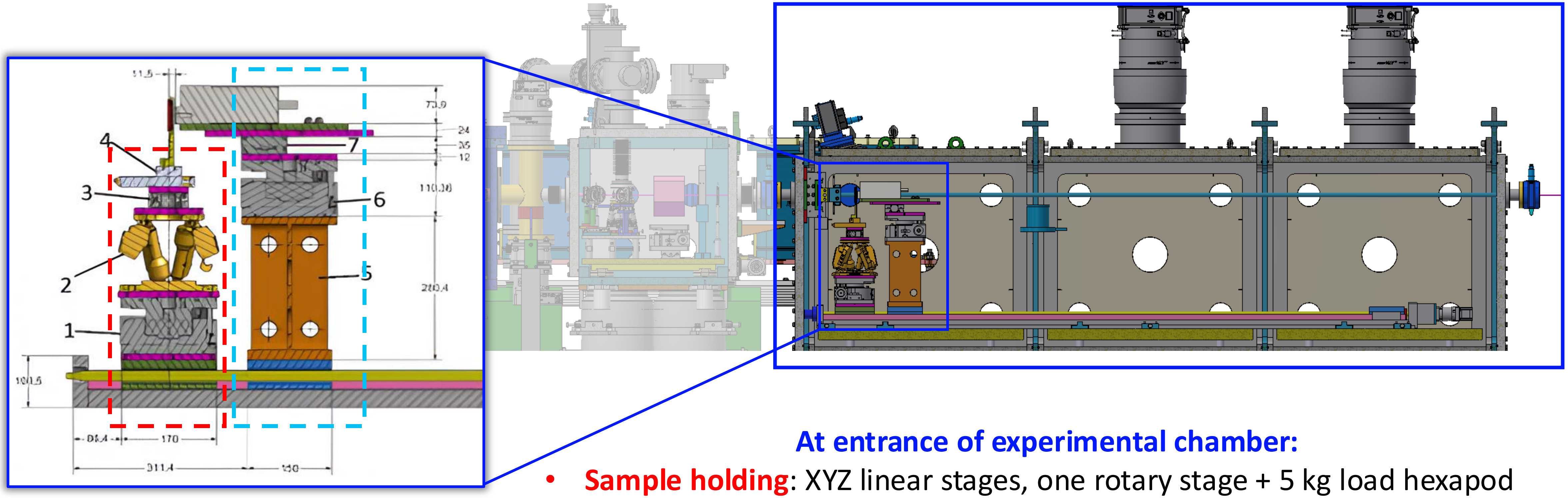


At entrance of experimental chamber:

- **Sample holding**: XYZ linear stages, one rotary stage + 5 kg load hexapod for a sample **placement precision around ±0.05 µm and ±20 mdeg**
- **X-ray CCD Camera**: imaging array 2048 x 2048, 15 x 15 µm^2 pixel size, positionable in a 10 x 10 x 4 cm^3 range

Possible applications

Plasma-Generated X-ray Pulses: Betatron Radiation Opportunities at EuPRAXIA@SPARC_LAB

Francesco Stellato [1,2,*], Maria Pia Anania [3], Antonella Balerna [3], Simone Botticelli [2], Marcello Coreno [3,4], Gemma Costa [3], Mario Galletti [1,2], Massimo Ferrario [3], Augusto Marcelli [3,5,6], Velia Minicozzi [1,2], Silvia Morante [1,2], Riccardo Pompili [3], Giancarlo Rossi [1,2,7], Vladimir Shpakov [3], Fabio Villa [3] and Alessandro Cianchi [1,2]

Condensed Matter 7.1 (2022): 23.

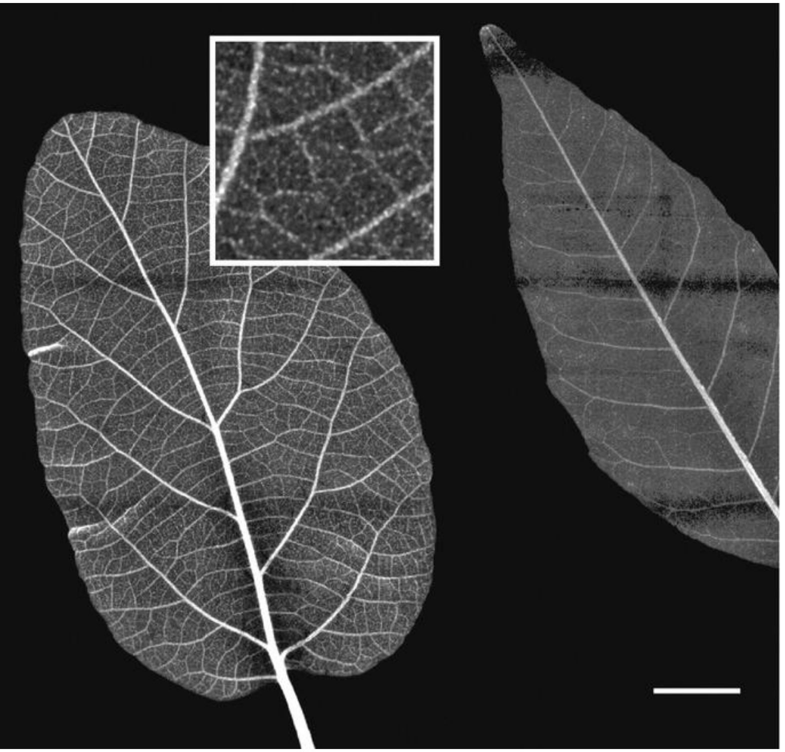
- **Imaging of biological (and cultural heritage) samples**
  Exploits the brilliance and coherence of betatron radiation, requires small divergence and good focusing
- **Static X-ray Spectroscopy**
  Relatively easy, but does not exploit the radiation time structure
- **Ultra-fast X-ray spectroscopies exploiting ultra-short betatron pulses**
  More complicated, requires timing between pump and probe pulses, but fully exploits the fs pulse duration
- **Time-resolved imaging (ultrafast dynamics)**
- **Wide angle scattering, diffraction**
  Depending on the samples, requires monochromatic beams with high flux

Courtesy F. Stellato

Possible applications: e.g. Imaging

E.g. biological, cultural heritage samples

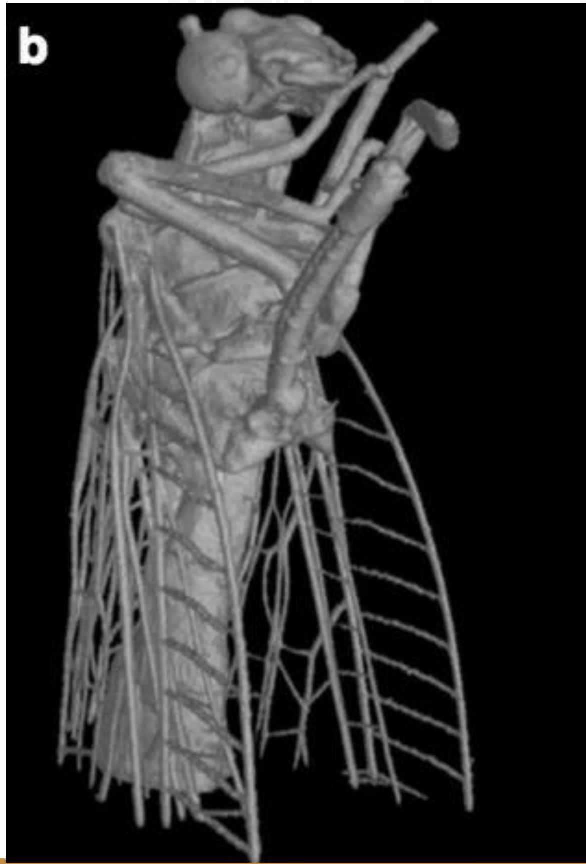
Wenz *et al.* Nature communications 2015



Reale et al. - MIDIX Soft X-rays microradiography

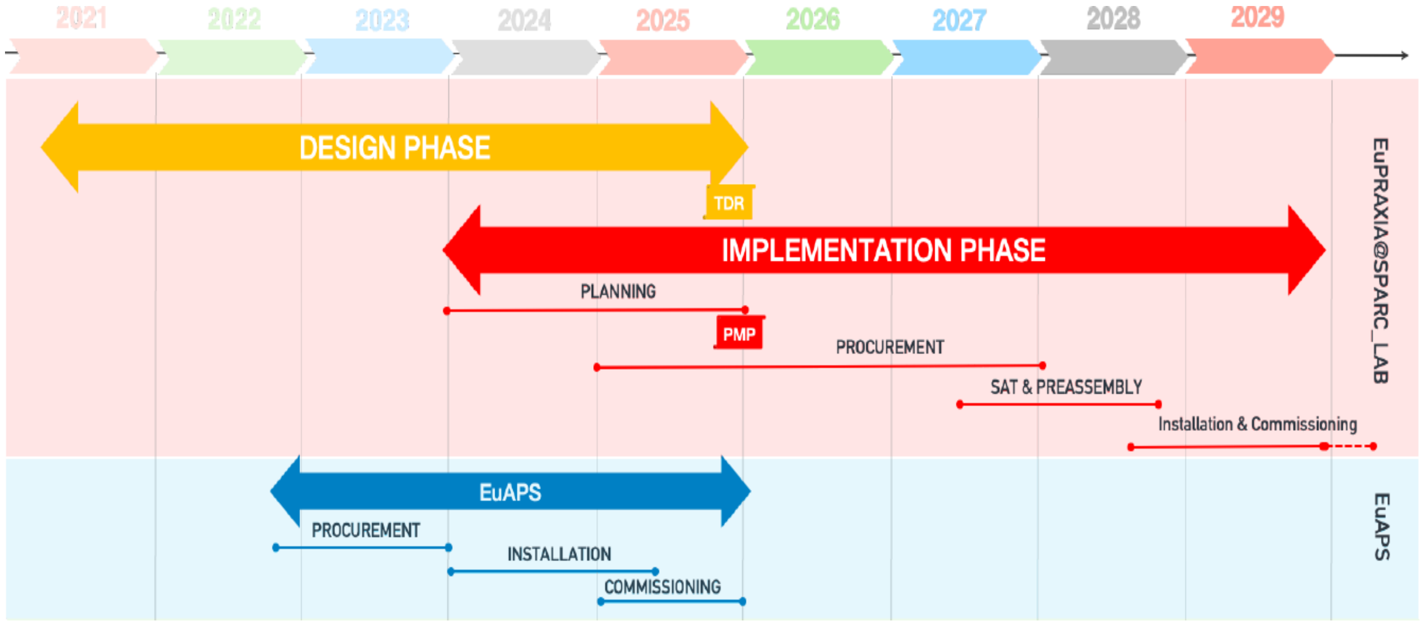
X-ray imaging: exploiting the broad spectrum
Aiming at ~10s μm resolution, different materials have different absorption coefficients and filter the radiation giving rise to **difference maps** emphasizing the presence of heavy metal contaminants (e.g. **pollution control)**

Phase Contrast Imaging: exploits spatial coherence
measure of the difference in wavefront providing better contrast



EuAPS current status and timeline

- Installation in FLAME in progress until mid Feb 2025
- Upgrade laser FLAME up to Mar 2025
- Installation in SPARC up to May 2025
- Setup and startup May/Jul 2025
- Beam to users Sep/Nov 2025



Conclusions

- EuAPS will be the first betatron radiation source operating as users facility
- FLAME laser upgrade and components installation in the SPARC bunker are currently ongoing
- Betatron radiation beam will be ready for users in fall 2025
- Innovative radiation source to realize completely new experiments

Thank you!