EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA
Preparatory Phase

WP11: Update on schemes for secondary particle and photon sources at EuPRAXIA

Gianluca Sarri, Queen's University Belfast

EuPRAXIA_PP Annual Meeting 2024

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Pilot applications

Funded by the European Union

Flagship Science Goals:

Flagship Science Goal 1: free-electron laser (FEL) X-rays

10^9 - 10^{13} photons per pulse, 0.2 nm to 36 nm, 0.4 fs duration

Flagship Science Goal 2: betatron X-rays

10^{10} photons per pulse, energy of 5 –18 keV

Flagship Science Goal 3: low-energy positron beams

energies 0.5MeV - 10MeV, 10^6 positrons per pulse, 20–90 ps duration

Flagship Science Goal 4: electron and positron beams

energies 100MeV - 5 GeV for high-energy-physics-related R&D

Flagship Science Goal 5: Compton scattering (ICS) source

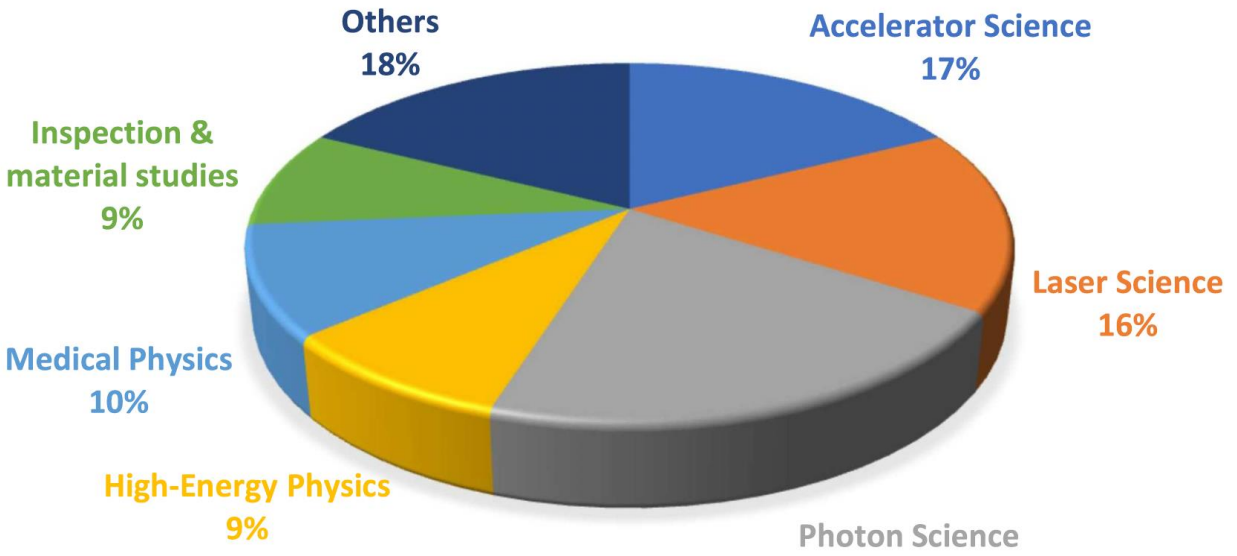
narrow-band spectrum for precision nuclear physics and highly penetrative radiography for users.

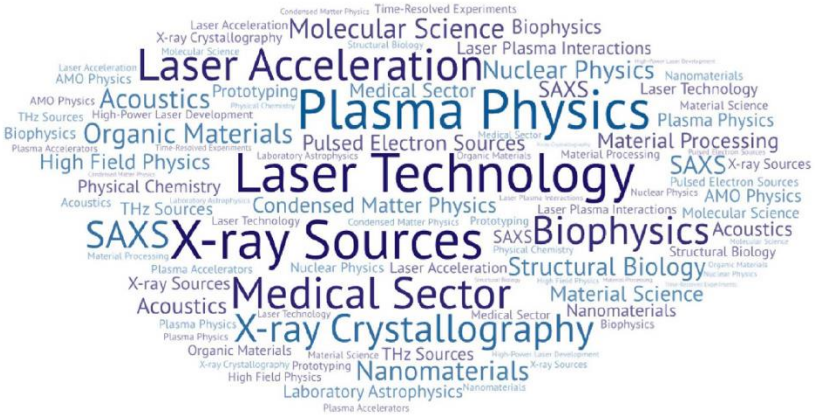
Flagship Science Goal 6: multi-stage high repetition-rate plasma accelerator

in the GeV range to users from accelerator science.

Flagship Science Goal 7: Novel schemes of pump probe configurations

and ultra-precise timing will be researched, feeding back into laser science

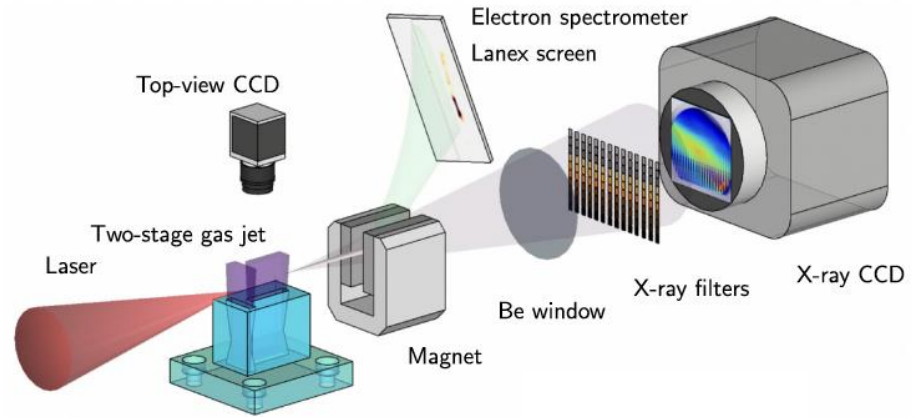


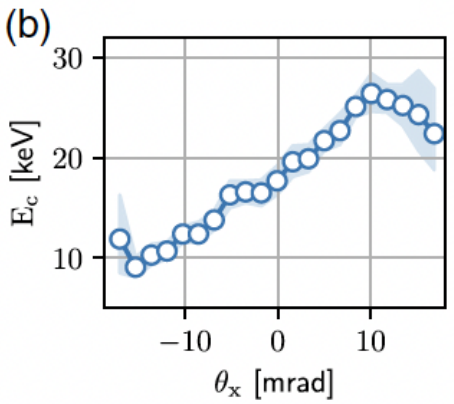


Funded by the European Union

Novel schemes for the generation and applications of betatron radiation

Streaked betatron x-rays, using a curved wakefield accelerator

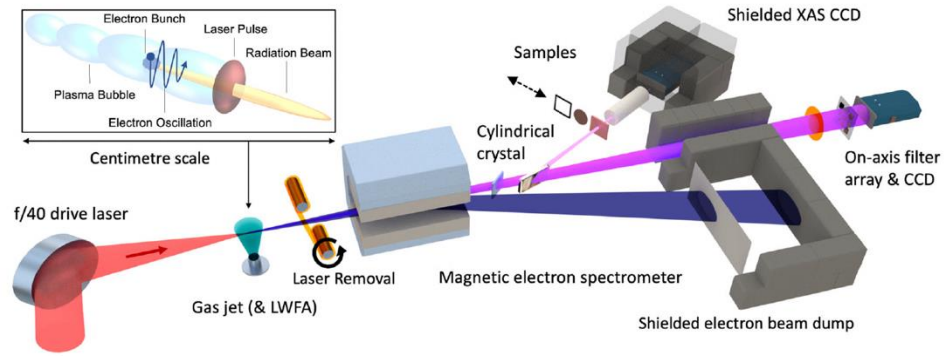


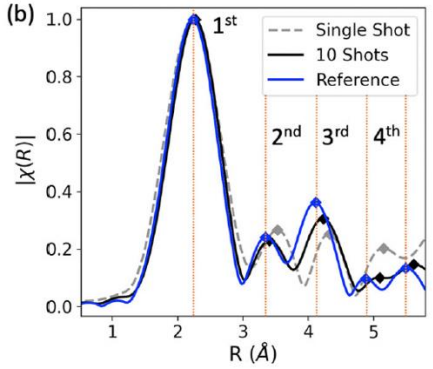


- Possibility of angularly streaking betatron x-rays
- On-shot diagnostic of electron acceleration through the plasma
- Intrinsic spatiotemporal correlation, which makes it a promising tool for single-shot pump-probe applications

Y. Ma et al., Phys. Rev. Lett. 132, 225001 (2024)

Single-shot x-ray absorption spectroscopy





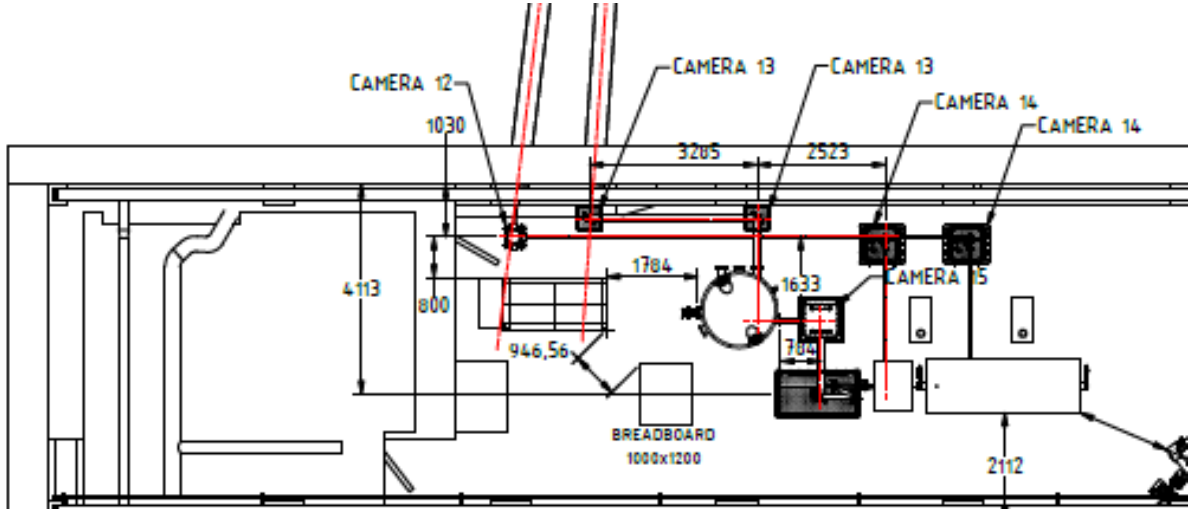
- Absorption profile around the copper K-edge over a 250 eV spectral window in a single shot
- Direct measurement of the local atomic structure and unique to the species of a sample.
- Information on the ion temperature, any sample compression or phase changes

B. Kettle et al., Communication Phys. 7, 247 (2024)

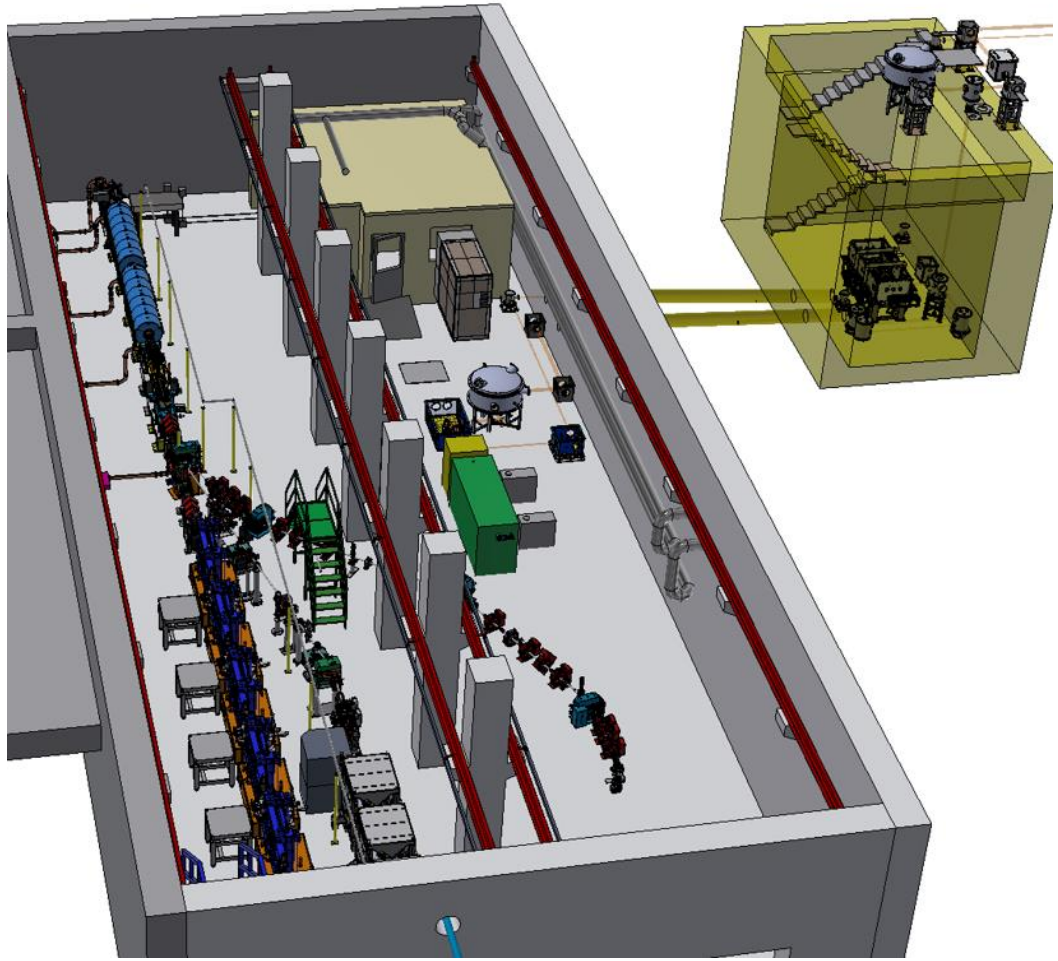
Betatron sources: EuAPS

Funded by the European Union

22 M€ investment for the EuPraxia Advance Photon Sources (EuAPS)



Parameter	Value	unit
Electron beam Energy	100-500	MeV
Plasma Density	10^{17}-10^{19}	cm^{-3}
Photon Critical Energy	1 -10	keV
Number of Photons/pulse	10^{6}-10^{9}	
Repetition rate	1-5	Hz
Beam divergence	3-20	mrad

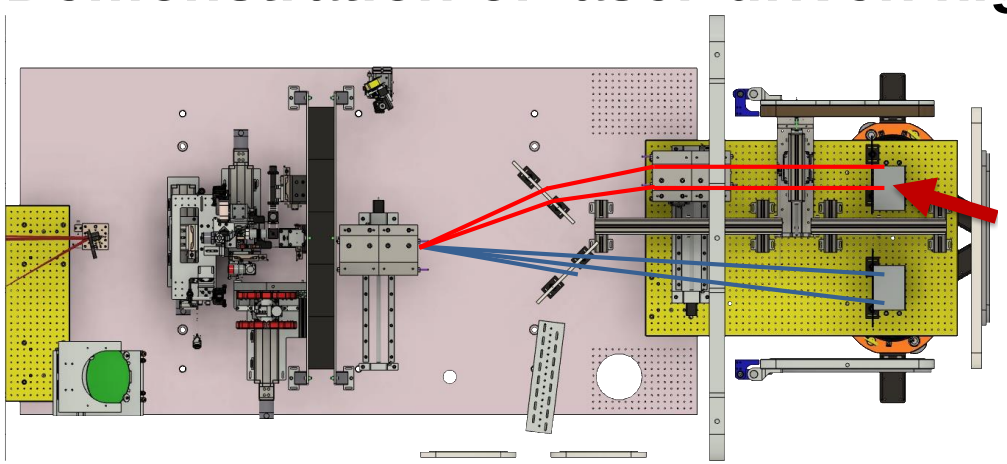


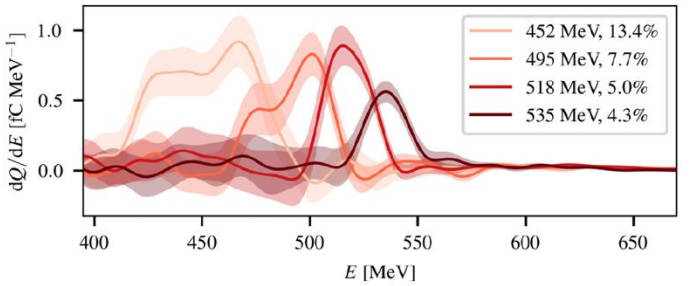
First photons summer 2025

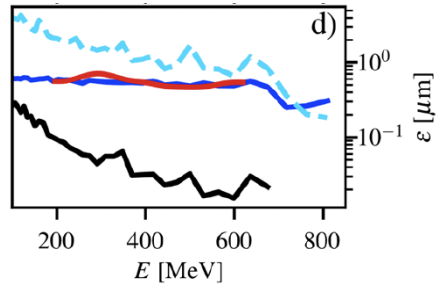
High-energy positron beams

Funded by the European Union

Demonstration of laser-driven high-quality narrow-band positron beams







M. Streeter et al., Scientific Reports 14, 6001 (2024)

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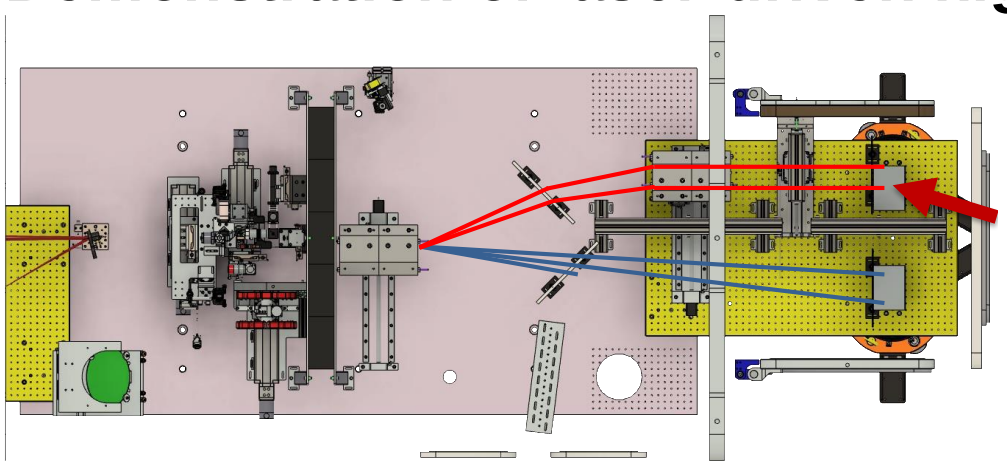

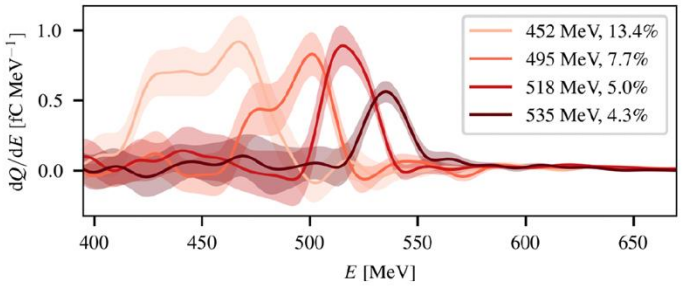

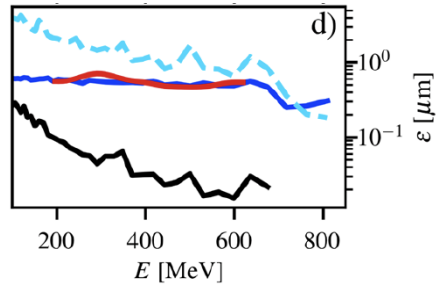

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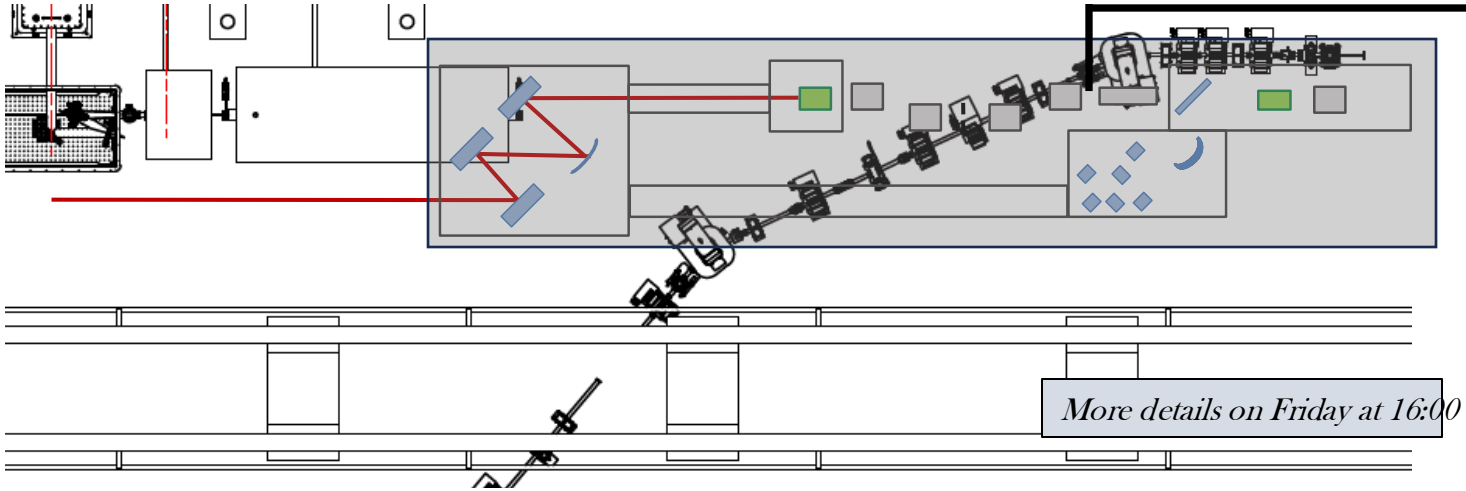
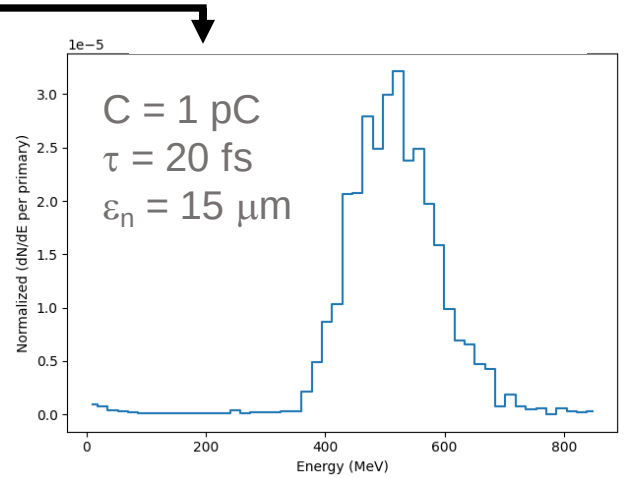
Proof-of-principle design @ LNF (QUB and LNF)



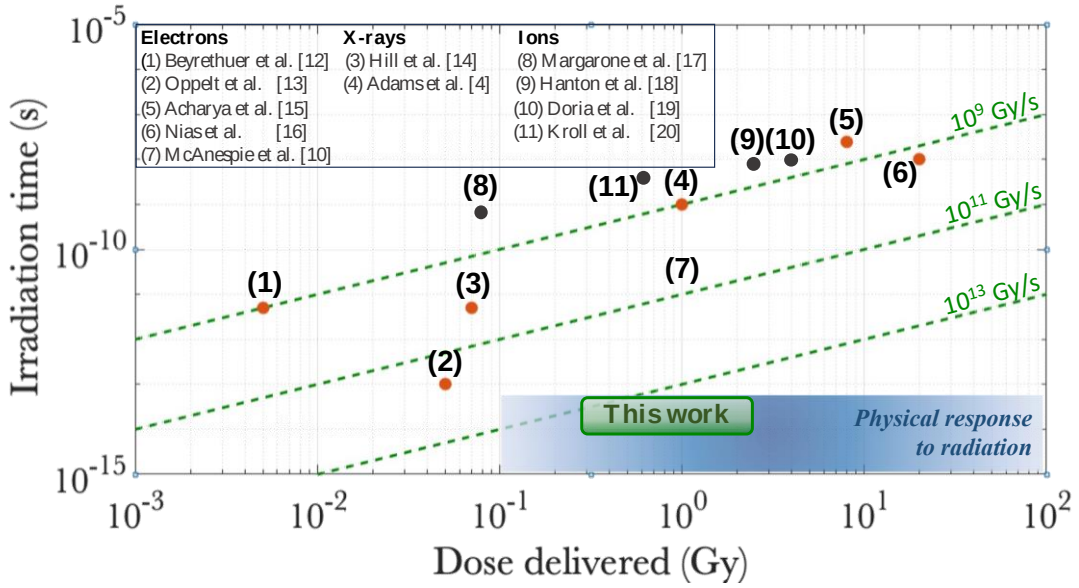
More details on Friday at 16:00

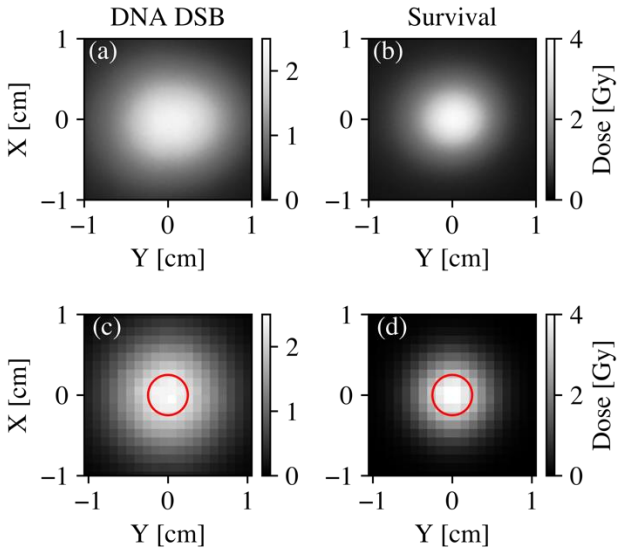


Radiobiological applications

Funded by the European Union

Femtosecond-scale electron beams allow accessing a novel regime of radiobiology





- Broadband nC electron beams can deliver multi-Gy doses in a single shot.
- Dose-rates >10^{13} Gy/s
- Cm-scale irradiation areas
- High degree of spatial uniformity

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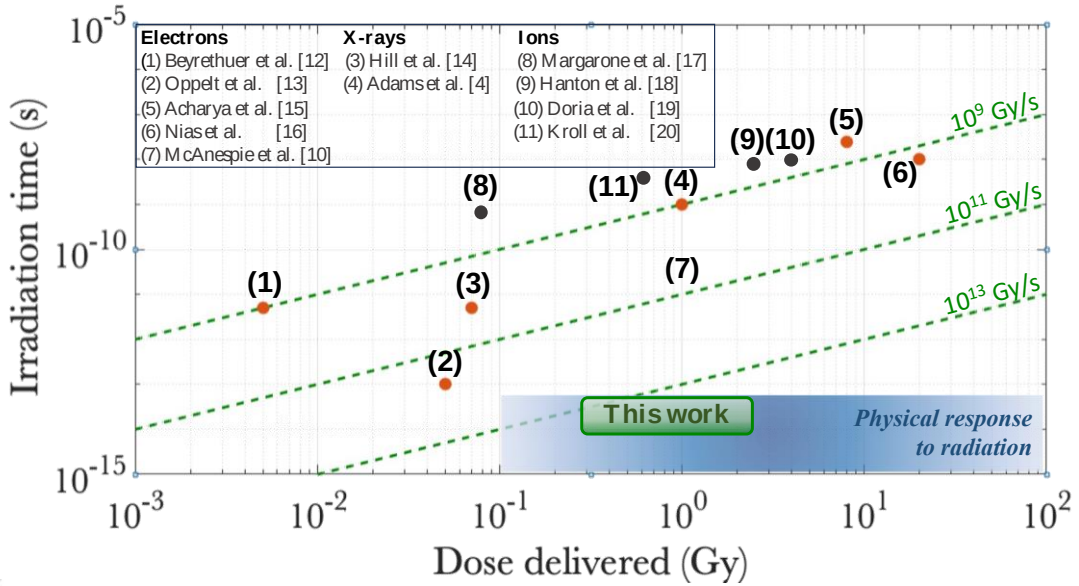

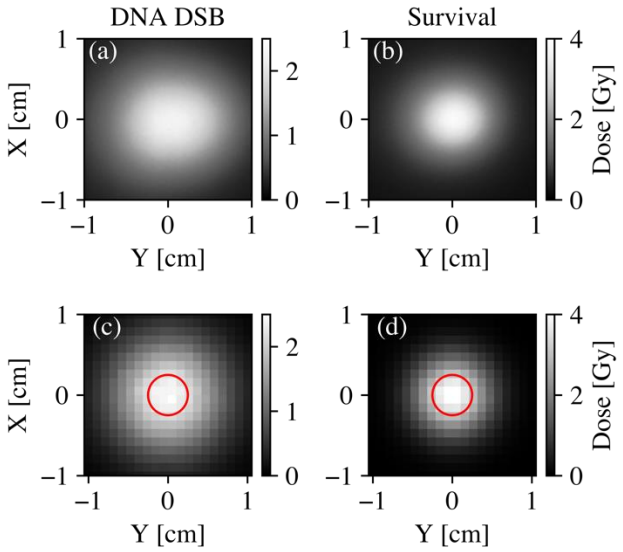

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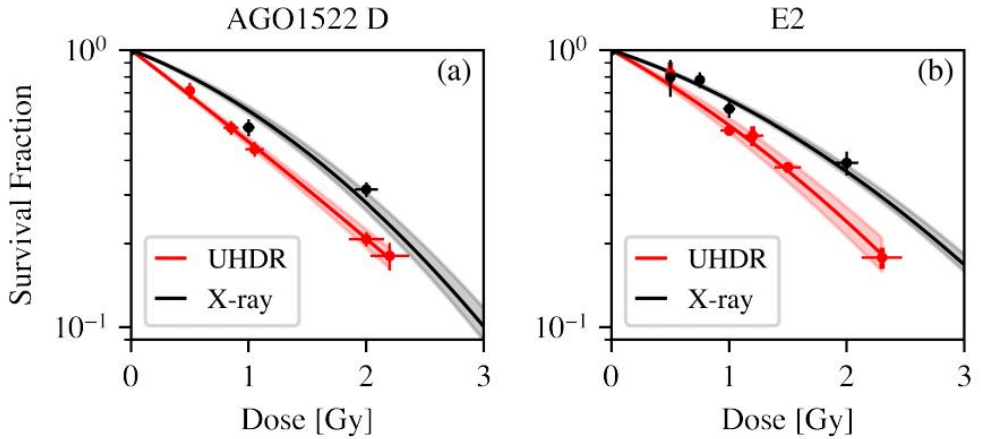
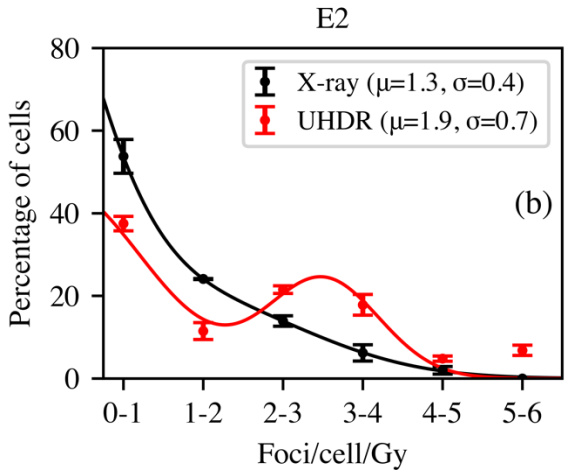




- Novel cell response in pilot experiments.
- High RBE
- Reduced tumor resistance
- Higher complexity of damages

C. McAnespie et al., arXiv:2309.06870v1 (2024)

New laser systems within the collaboration

Funded by the European Union

Significant national investment on laser systems at high repetition rate

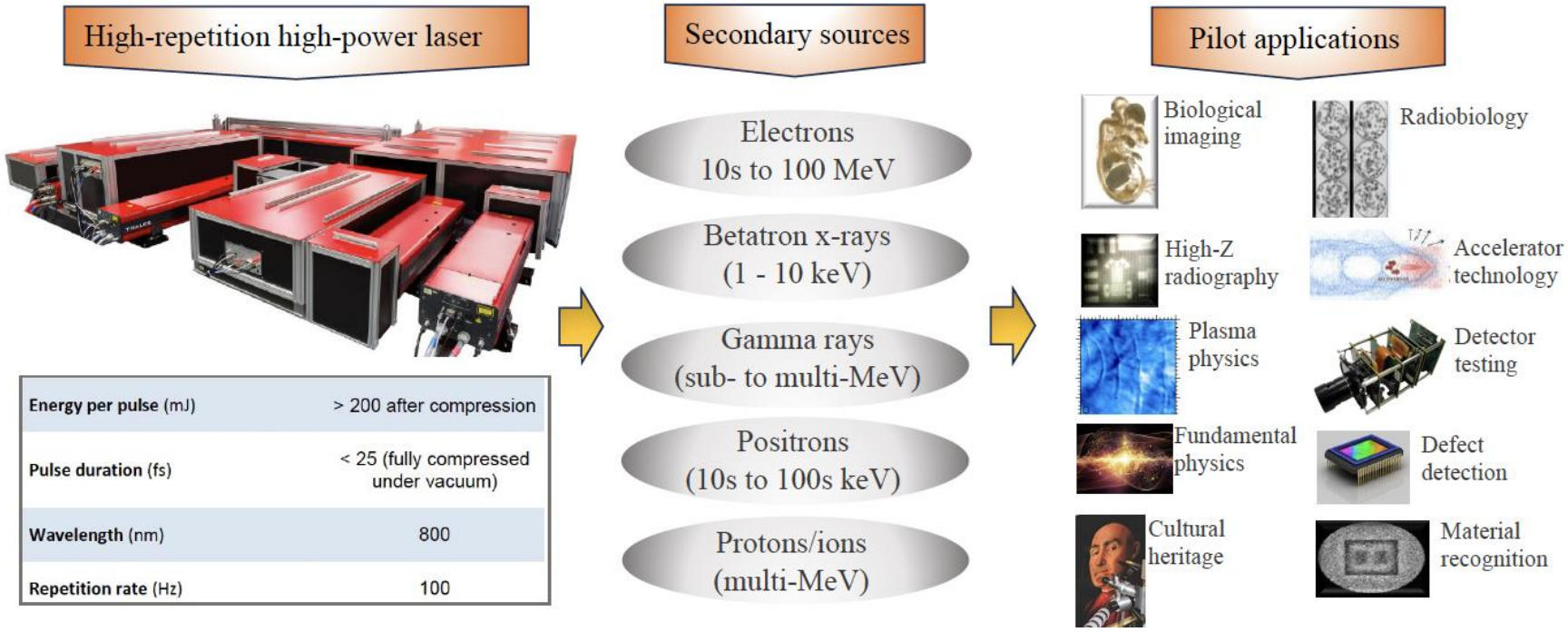
Queen's University Belfast (UK)

EPSRC

100 Hz, 200 mJ, 20 fs laser system to operate as a user facility
Operational at the start of 2027

Istituto Nazionale di Ottica (Italy)

PNRR funding for a 100 Hz, 1 J, 20 fs system



Energy per pulse (mJ)	> 200 after compression
Pulse duration (fs)	< 25 (fully compressed under vacuum)
Wavelength (nm)	800
Repetition rate (Hz)	100

Excellent opportunities for R&D systematic studies for high repetition rate operations

Possible baseline parameters

Funded by the European Union

Additionally to FEL, EuPRAXIA can provide a wide range of particle and photon beam parameters:

	E	ΔE/E	t	σ_x	θ_x	N
X-rays (Betatron)	few - 10s keV	100%	~ 20 fs	μm	10 mrad	> 10^9
Gamma-rays (Compton)	few – 10s MeV	~5 – 10%	~ 20 fs	10 μm	2 – 5 mrad	10^7 - 10^8
High-energy positrons	500 MeV	5-10%	~ 30 fs	10 μm	5 mrad	10^7
Low-energy positrons	0.5 - 3 MeV	10%	~ 10 ps	100 μm	10 mrad	10^3
Electrons (narrowband)	5 GeV	<1%	~ 20 fs	μm	mrad	2x10^8
Electrons (broadband)	up to 5 GeV	~ 100%	~ 50 fs	2-5 μm	3 -5 mrad	10^{10}

Open questions (for everybody to get involved!):

1. Design beamlines for the delivery of these parameters (e.g., Eu_COLL, Eu_APS)
2. Are there any specific parameters (or others…?) that would be particularly interesting?
3. Design suites of diagnostics and experimental capabilities for user end-stations

PLEASE FILL AND SPREAD THE USER SURVEY!

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

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EuPRAXIA
Preparatory Phase

Thank you for your attention!

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