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EUROPEAN NETWORK FOR NOVEL ACCELERATORS EuroNNAc4 | IFAST | INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati | TOR VERGATA | CLPU CENTRO DE LÁSERES PULSADOS

Preliminary Study of the X-ray Betatron Radiation Source in the EuAPS Project

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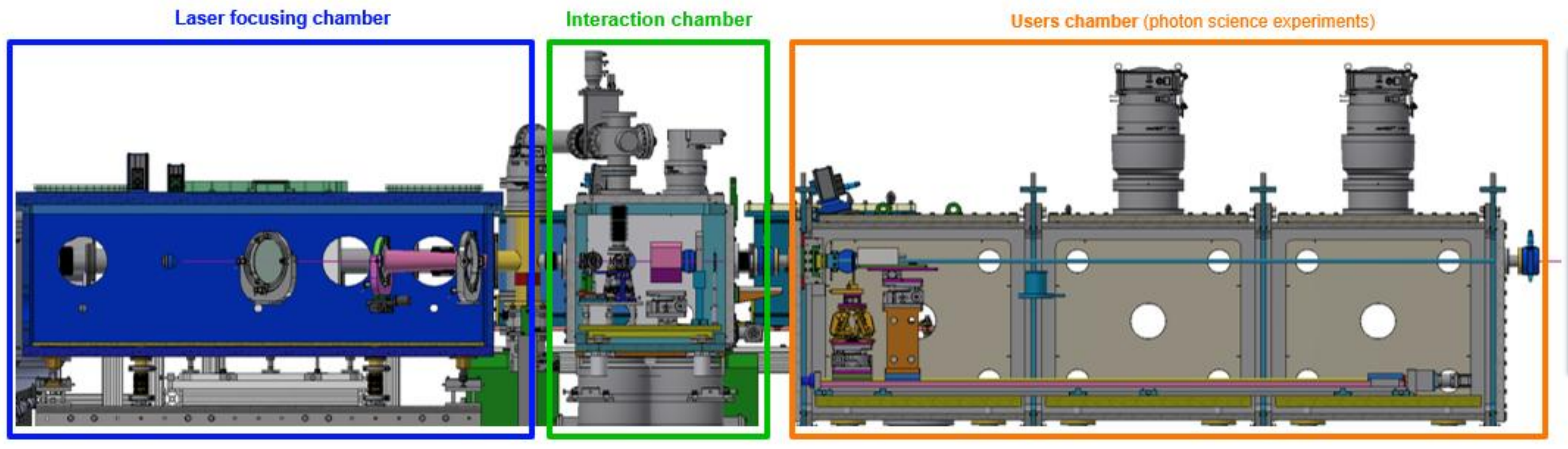
Introduction

X-ray radiation produced by electrons oscillating in a plasma during the Laser Wakefield Acceleration (LWFA) process is known as betatron radiation [1]. When an ultra-short, high-intensity laser pulse interacts with a supersonic gas jet, it simultaneously ionizes the ga, creating a plasma, and injects and accelerates electrons into the plasma wave. This acceleration process leads to the emission of betatron radiation. As part of the EuPRAXIA framework, the EuPRAXIA Advanced Photon Source (EuAPS) will be the first user-dedicated betatron radiation source, developed at INFN-LNF in Frascati. This contribution presents the expected parameters of the next user radiation source, along with the results of several experimental campaigns conducted within the EuAPS project for characterizing both the electron acceleration process and the resulting X-ray radiation.

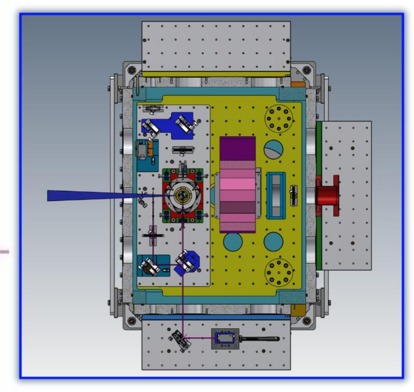
EuPRAXIA Advanced Photon Source at SPARC_LAB

The EuAPS main goal is the realization of the laser-driven **«betatron» X-ray user facility** at the SPARC_LAB laboratory [2].



EuAPS layout and interaction chamber's overview

(courtesy of S. Lauciani)



Expected parameters

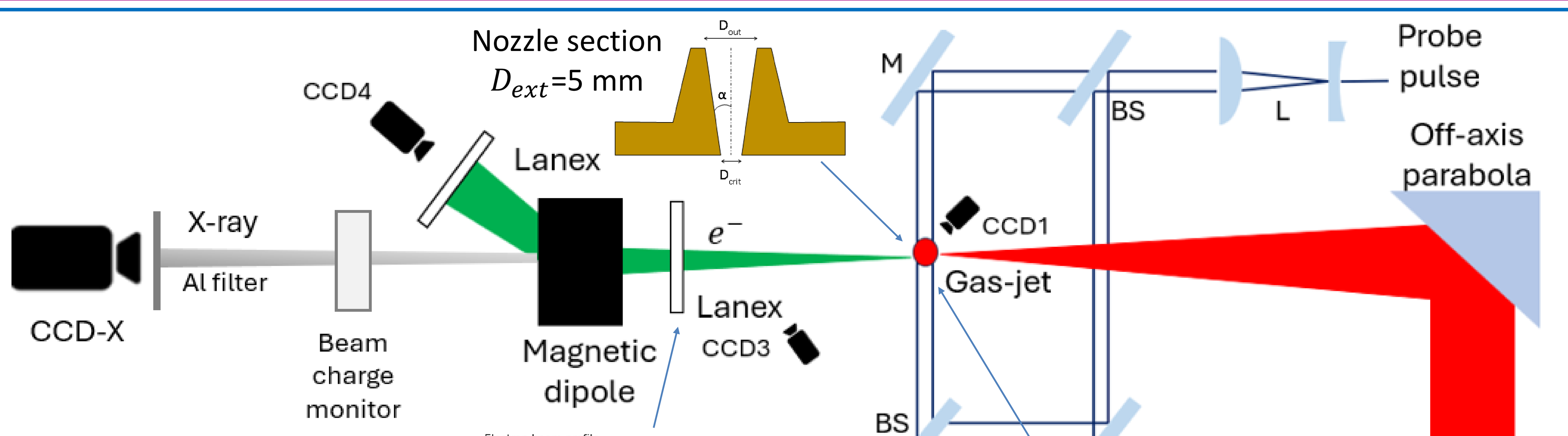
I $[W \cdot cm^{-2}]$	$\sim 2 \times 10^{19}$
n_e $[cm^{-3}]$	10^{18-19}
R.R [Hz]	1
E_e [MeV]	100 - 500
Photon E_c [keV]	1 - 10
N_γ per pulse	$10^6 - 10^9$
τ_γ	tens of fs

The high-power laser system FLAME will be the driver of the plasma-based acceleration process and betatron radiation emission.

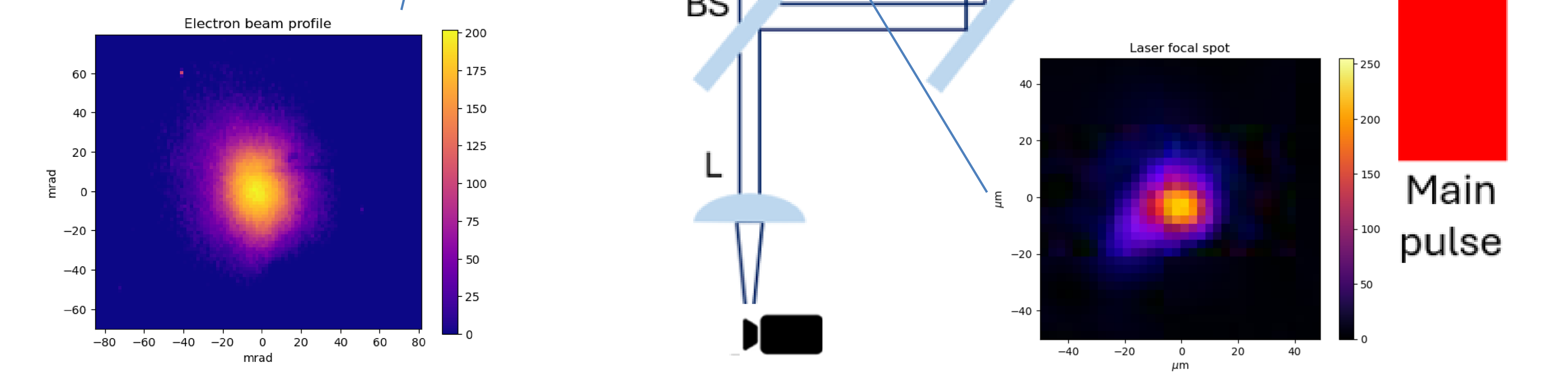
Experimental setup and diagnostics

The 200 TW **Ti:Sa FLAME laser system [3]** delivers 30 fs (FWHM) pulses with a maximum energy of 6 J, at 800 nm and 10 Hz repetition rate. The pulse is focused on the gas jet.

I $[W/cm^2]$	$\sim 10^{19}$
w (FWHM) $[\mu m]$	18
Gas	90% He + 10% N_2
Pressure (bar)	30

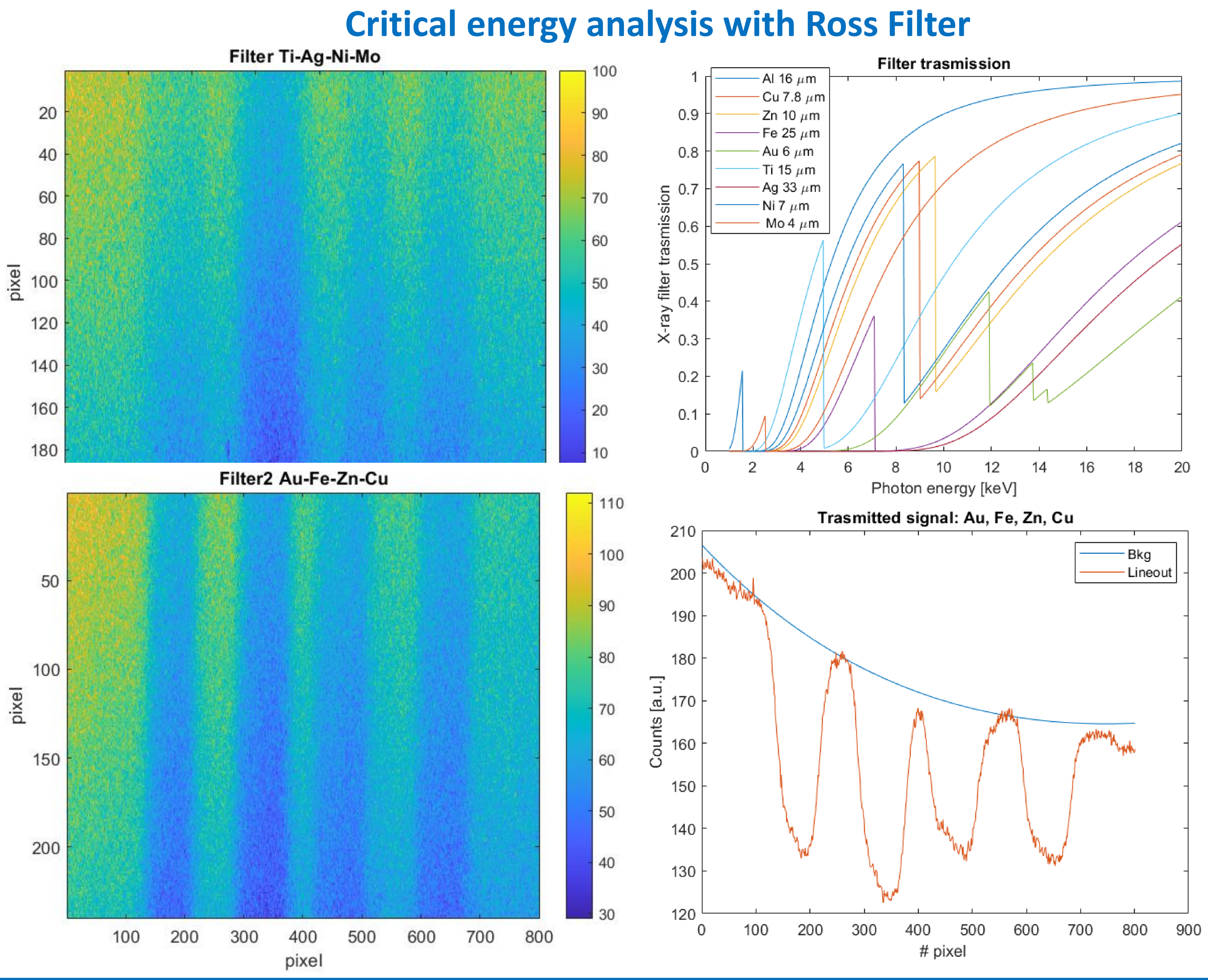


Sketch of the experimental setup set at FLAME laser facility (INFN-LNF).



Experimental results @FLAME

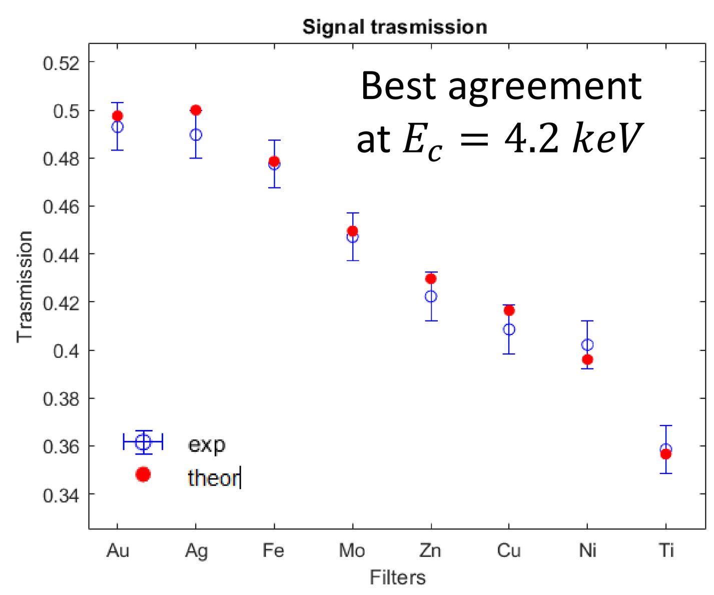
Critical energy analysis with Ross Filter



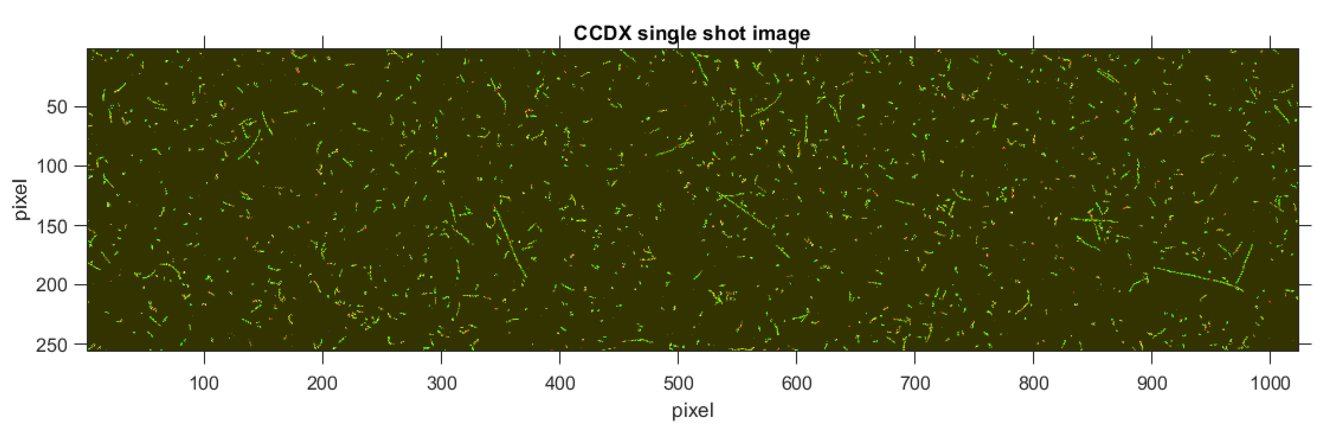
On-axis synchrotron-like spectrum [1] and theoretical signal counts

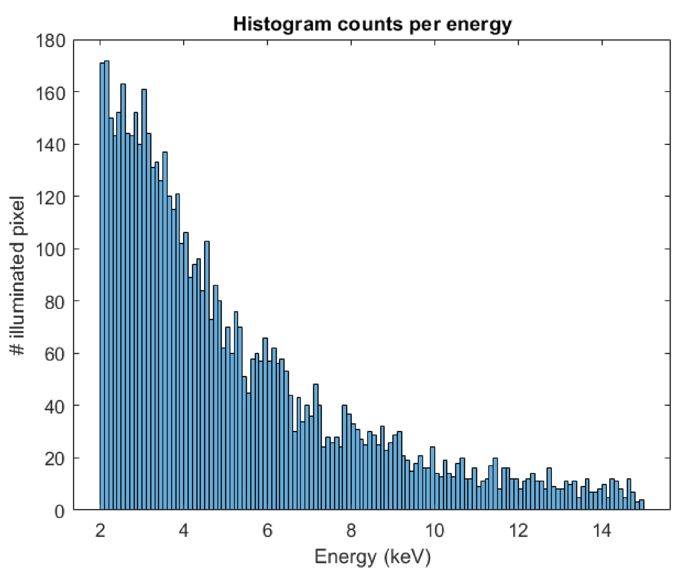
$$S(E) = \frac{d^2 I}{dE d\Omega}\Big|_{\theta=0} \propto \left(\frac{E}{E_c}\right)^2 K_{\frac{2}{3}}^2\left(\frac{E}{E_c}\right)$$

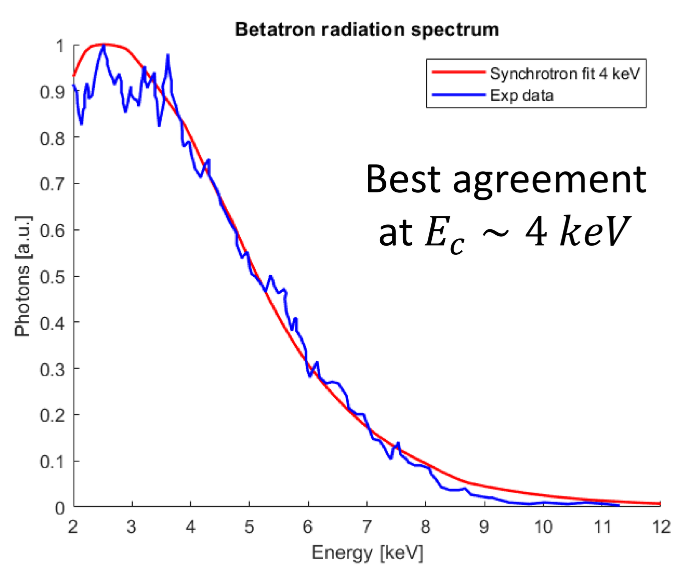
$$T_{th} = A \int_{E_{min}}^{E_{max}} S(E) Q(E) T_{f_i}(E) dE$$



Critical energy analysis in single photon counting [3]



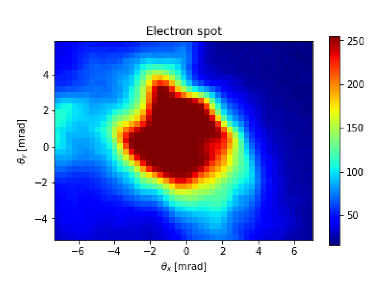


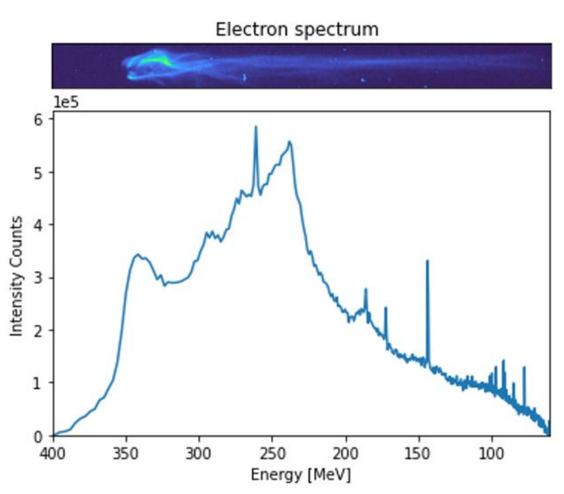


Experimental results @VEGA2

Same laser system parameters [4,5]

- 100 % He
- 35 bar
- 5 mm nozzle
- ~ 3 J on target

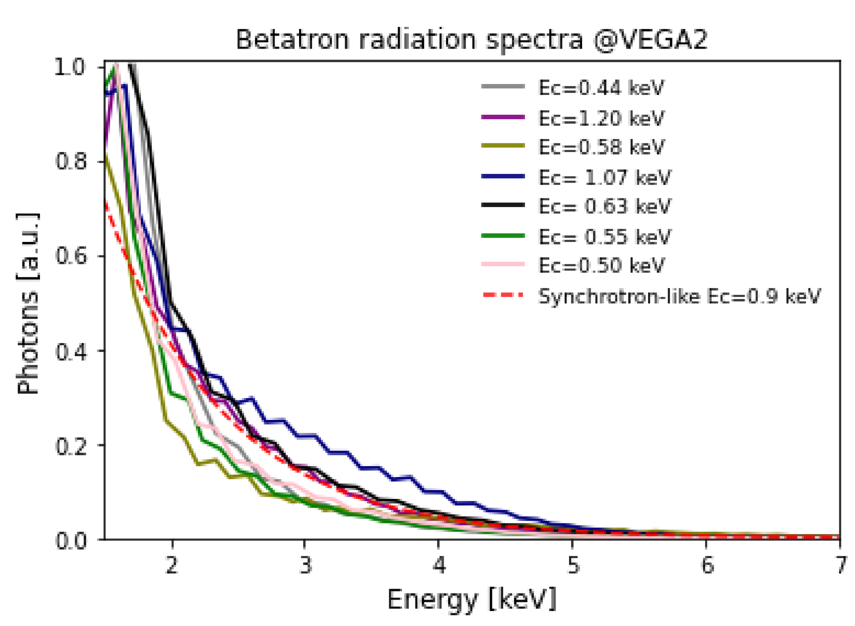




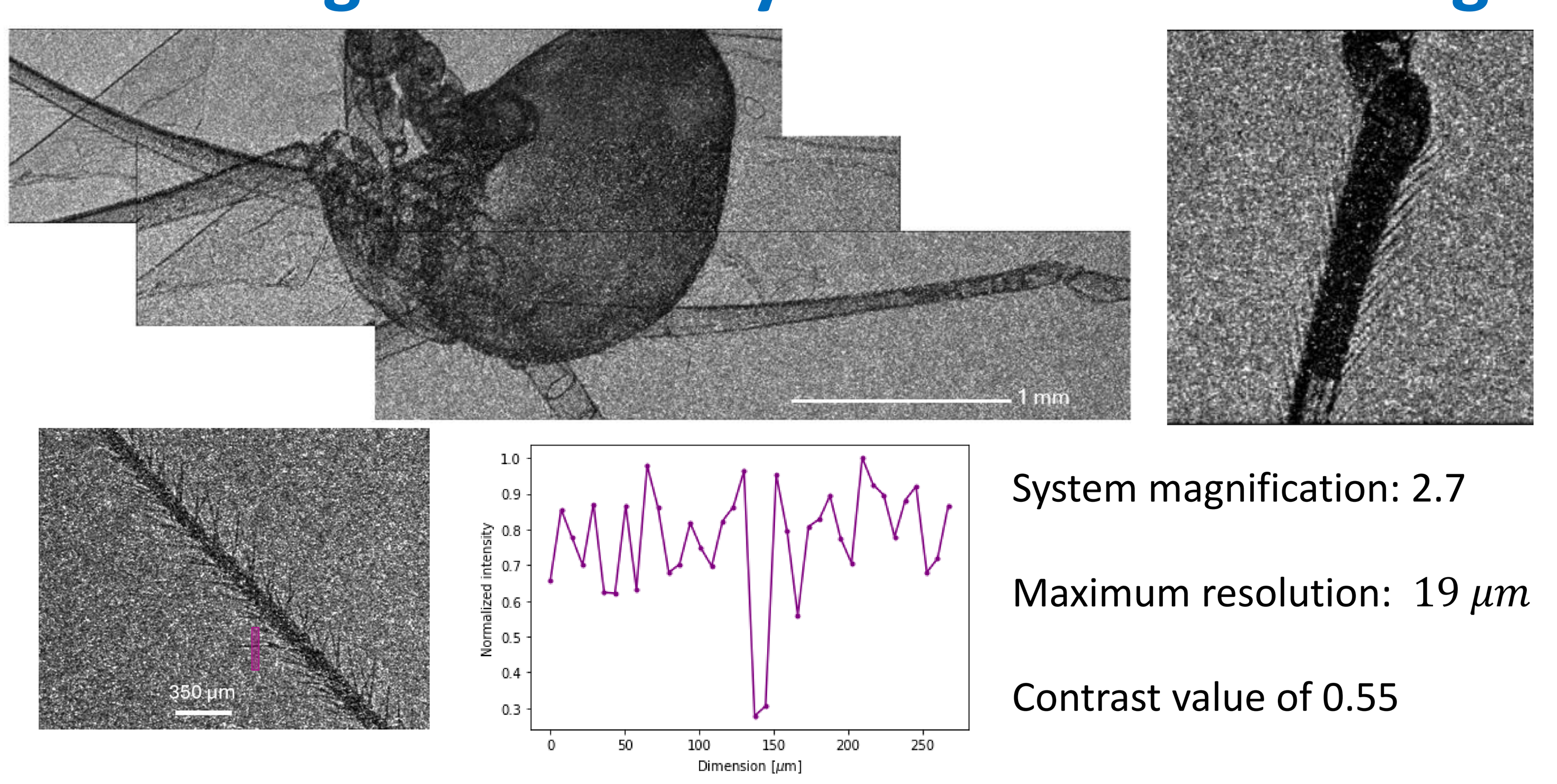
Electron bunch parameters

θ [mrad]	~ 4
Q [pC]	~ 250-300
Mean/Max En [MeV]	250 / 400
Relative energy spread	28 %

n_e $[cm^{-3}]$	$\sim 4 \cdot 10^{18}$
N_γ per pulse	$(3.5 \pm 2) \times 10^5$
$\bar{E}_c$ [keV]	(0.7 ± 0.3)
$\bar{E}_{e^-}$ [MeV]	~ 280



Single-shot X-ray Phase Contrast Image



System magnification: 2.7

Maximum resolution: 19 μm

Contrast value of 0.55

(a) Single-shot XPCI of a spider, **(b-c)** details of the biological sample and **(d)** intensity lineout of the purple box.

References

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[2]] M. Ferrario, et al., *NIMB*, 309, 183 (2013).

[3] M. Galletti, F. Stocchi, et al., *Appl. Sci.*, *14*, 8619 (2024).

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