LUXE: a new experiment to study strong-field QED in a laser field

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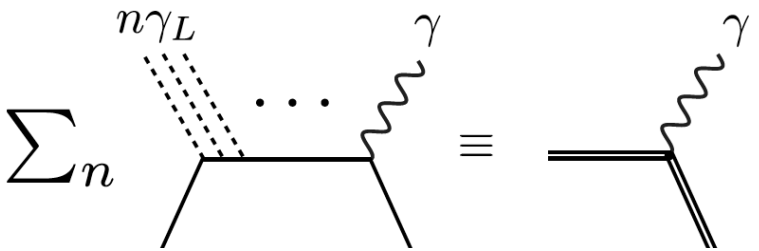
Introduction

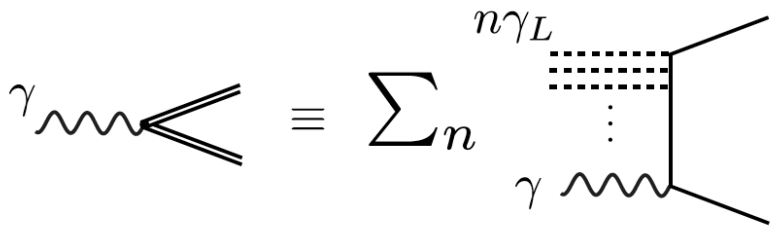
Strong-field QED

The main aim of laser-based experiments is to probe the high-field regime of quantum electrodynamics (QED):



Nonlinear Compton scattering

$$e^{\pm} + n\gamma_L \rightarrow e^{\pm} + \gamma$$



(Non-perturbative) Nonlinear Breit-Wheeler

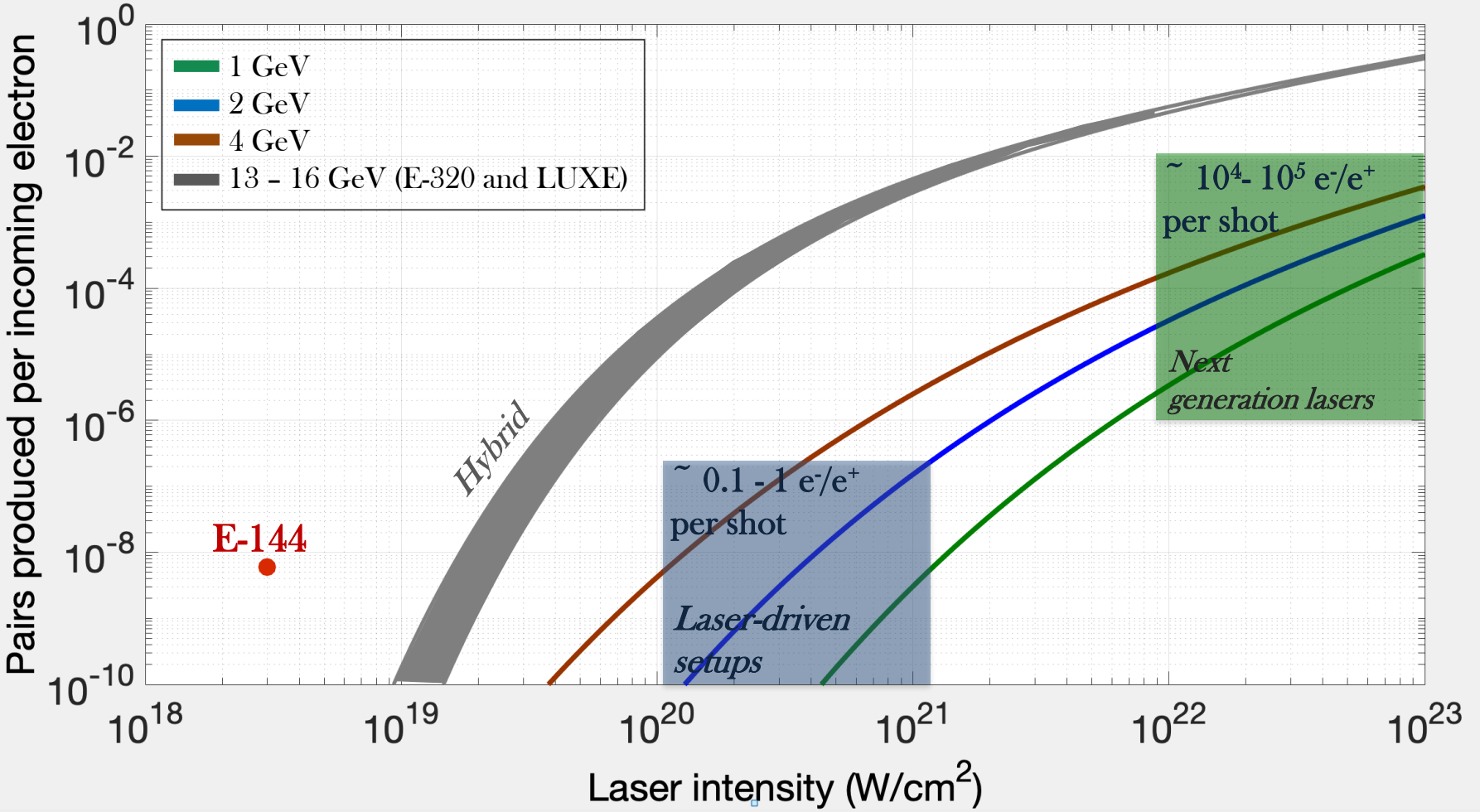
$$\gamma + n\gamma_L \rightarrow e^{+}e^{-}$$

These phenomena will be studied at fields exceeding the Schwinger field and at a high photon density

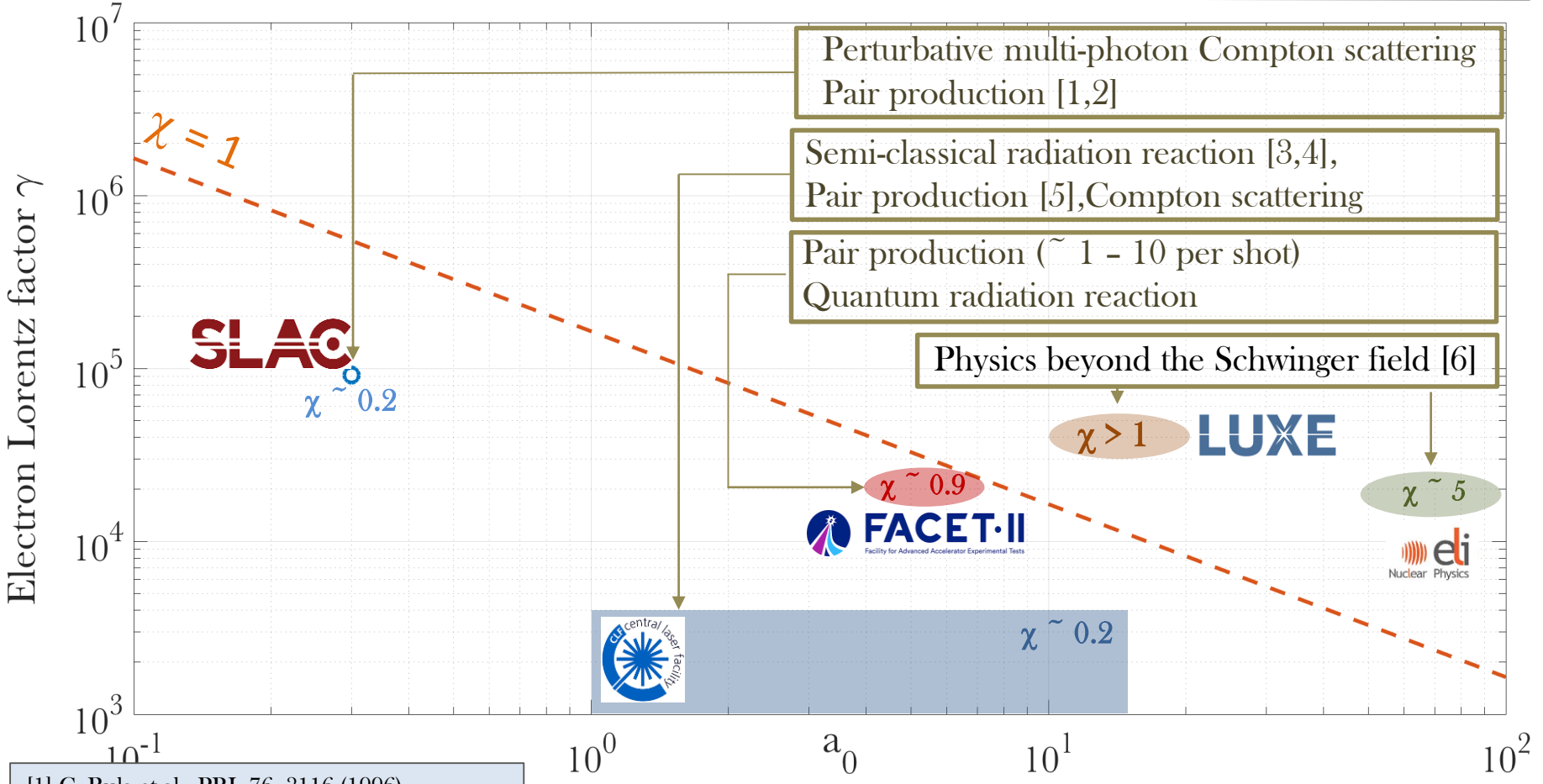
Laser intensity (ξ^2): $\xi = \frac{mc^2}{\hbar\omega}\frac{E}{E_{\mathrm{cr}}}$ $\xi = a_0 \propto \sqrt{I} > 1$ ⟹ non-linear (strong-field)

Quantum parameter: $\chi = \frac{\gamma_e E_L}{E_{cr}} > 1$ ⟹ quantum

Pair production



A parameter space



[1] C. Bula et al., PRL 76, 3116 (1996).
[2] D. L. Burke et al., PRL 79, 1626 (1997).
[3] K. Poder et al., PRX 8, 031004 (2018).
[4] J. Cole et al., PRX 8, 011020 (2018).
[5] B. Kettle et al., NJP 23, 115006 (2021).
[6] J. Abramowicz et al., Eur. Phys. J. ST (2021)

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High-power lasers in the world

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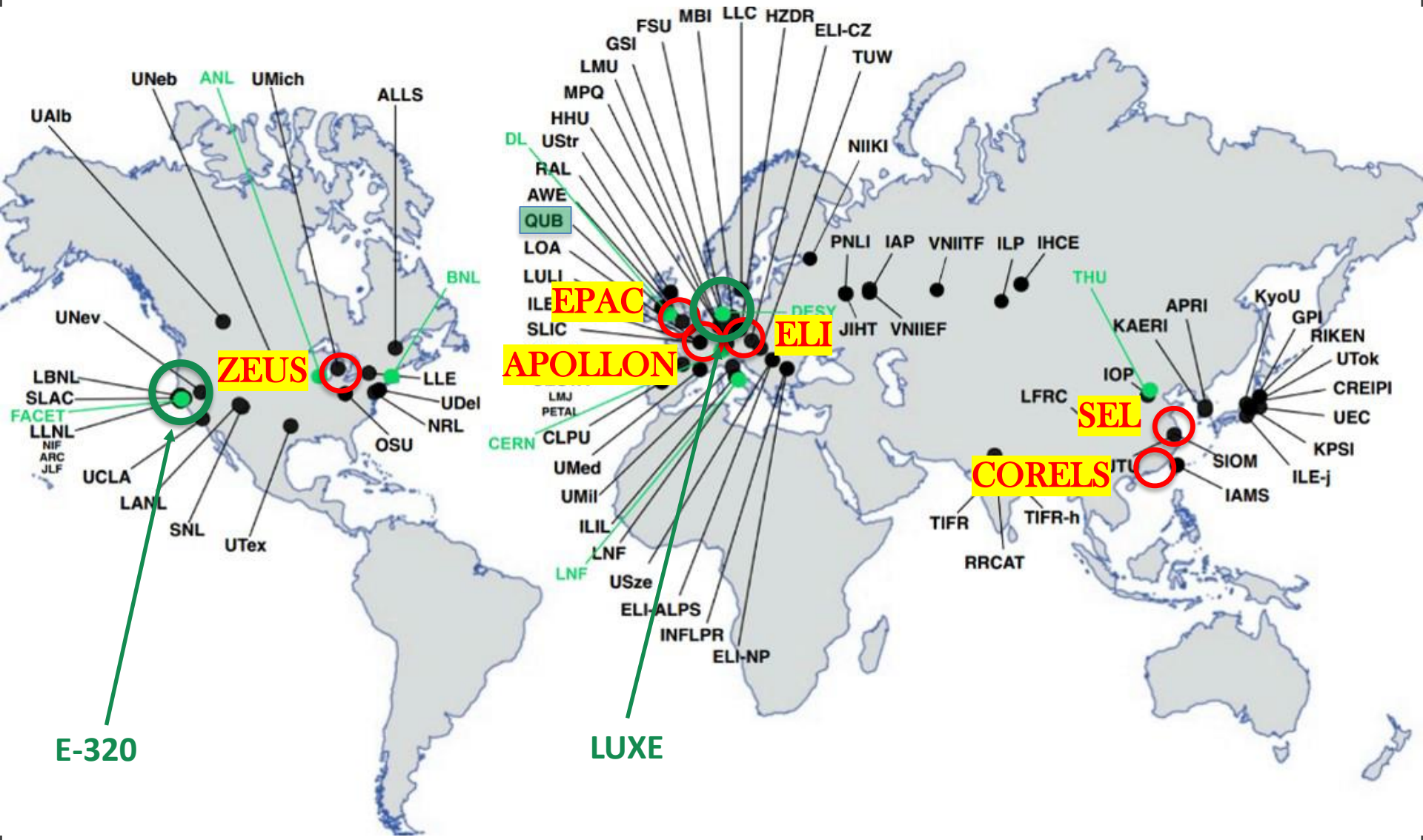

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The LUXE experiment

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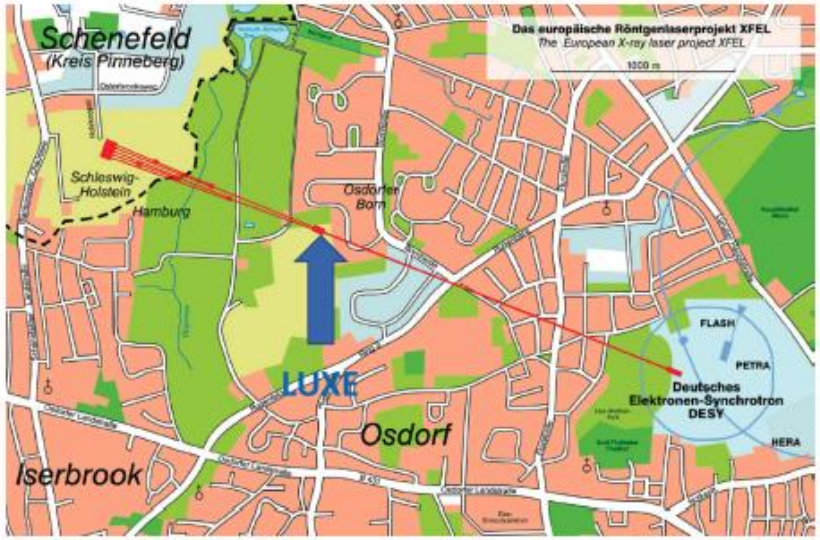
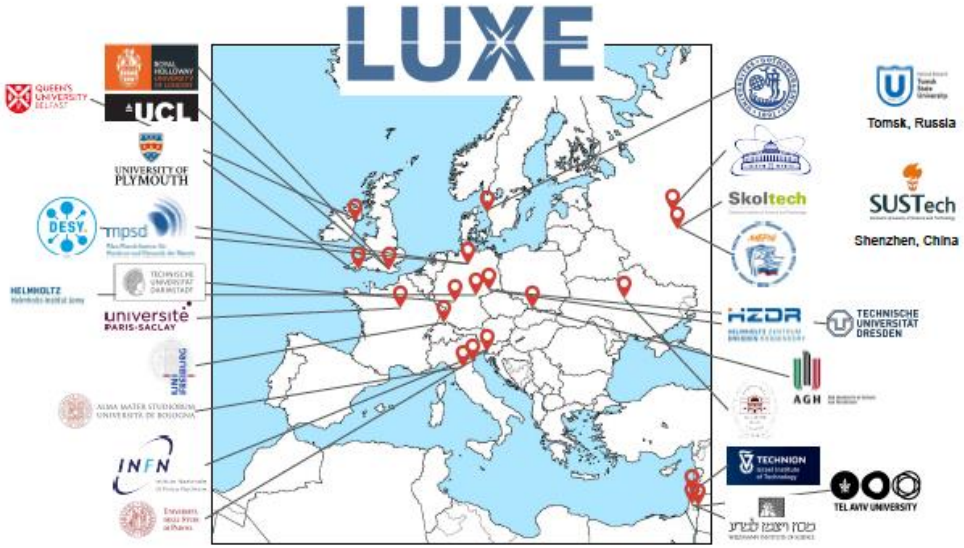
The LUXE experiment

LUXE is a proposed experiment at DESY and EuXFEL to study the interaction of the XFEL electron beam with the focus of a high-power laser





Conceptual Design Report: H. Abramowicz et al., Eur. Phys. J. Special Topics 230, 2445 (2021)
arXiv: 2012.02032

Technical Design Report: to be published (expected January 2023)

Website: luxe.desy.de

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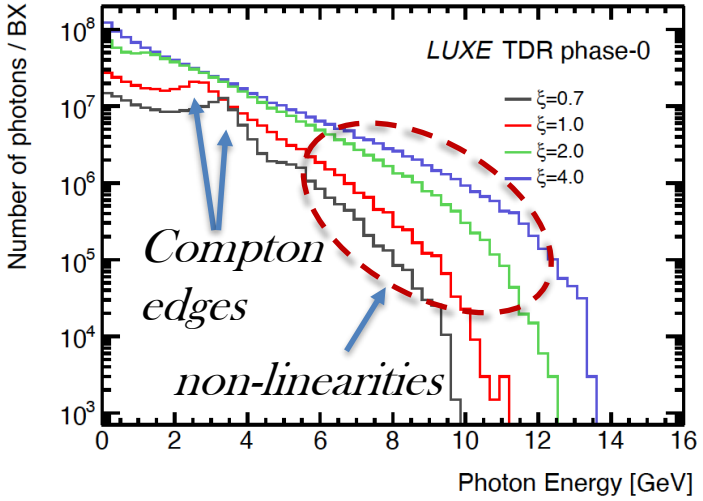
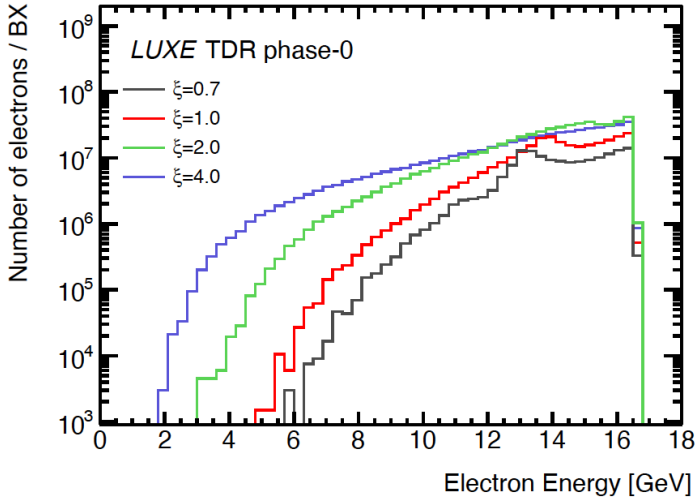
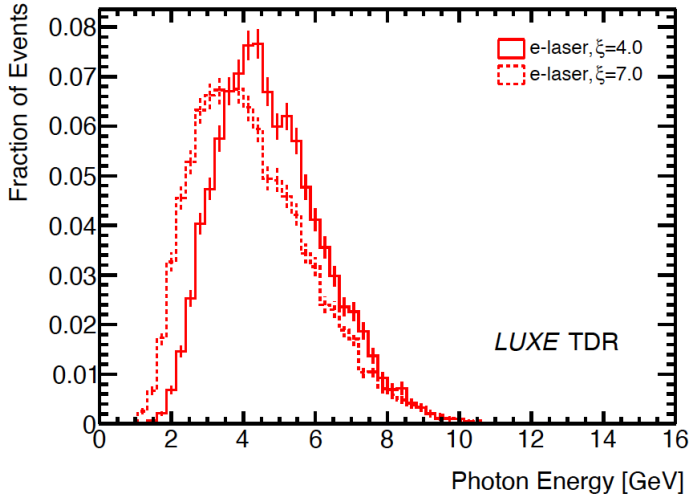
Measurables

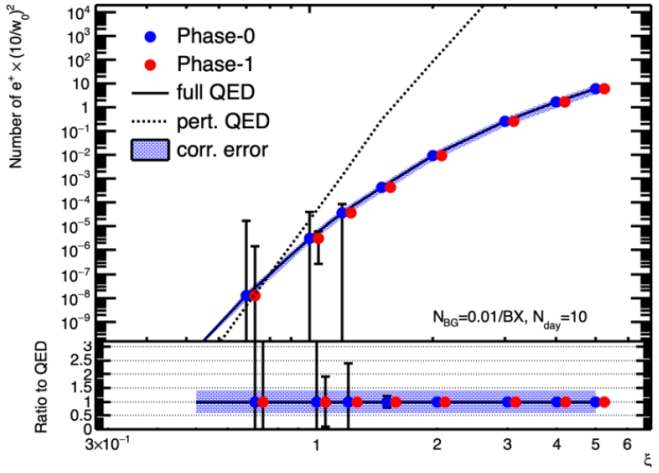
Inverse Compton scattering





Breit Wheeler pair production





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The laser system at LUXE

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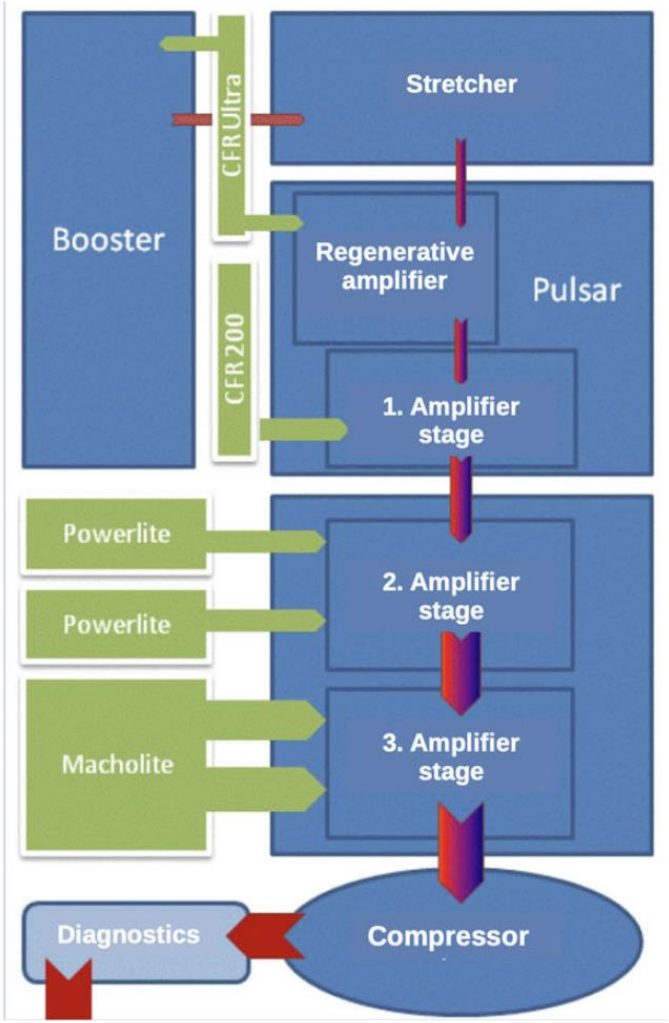
Laser characteristics

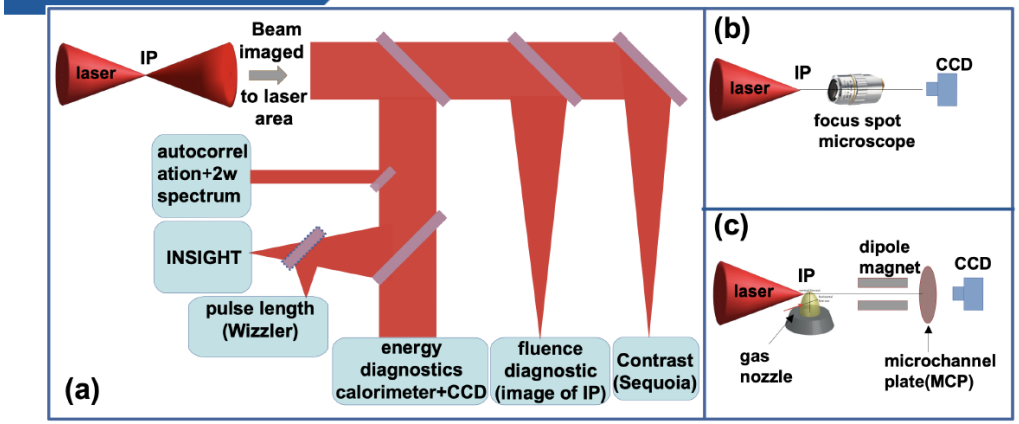
Laser layout



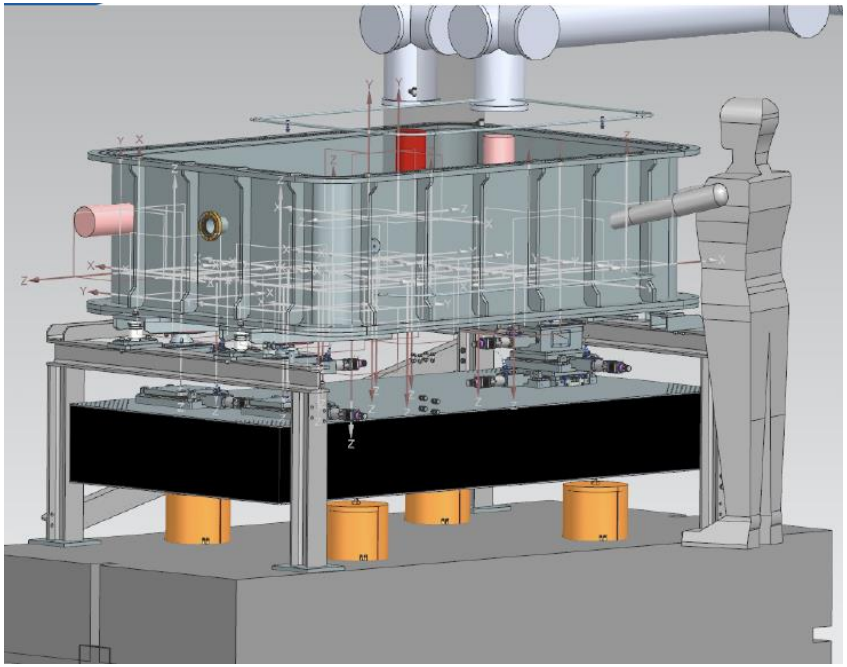
Laser parameters

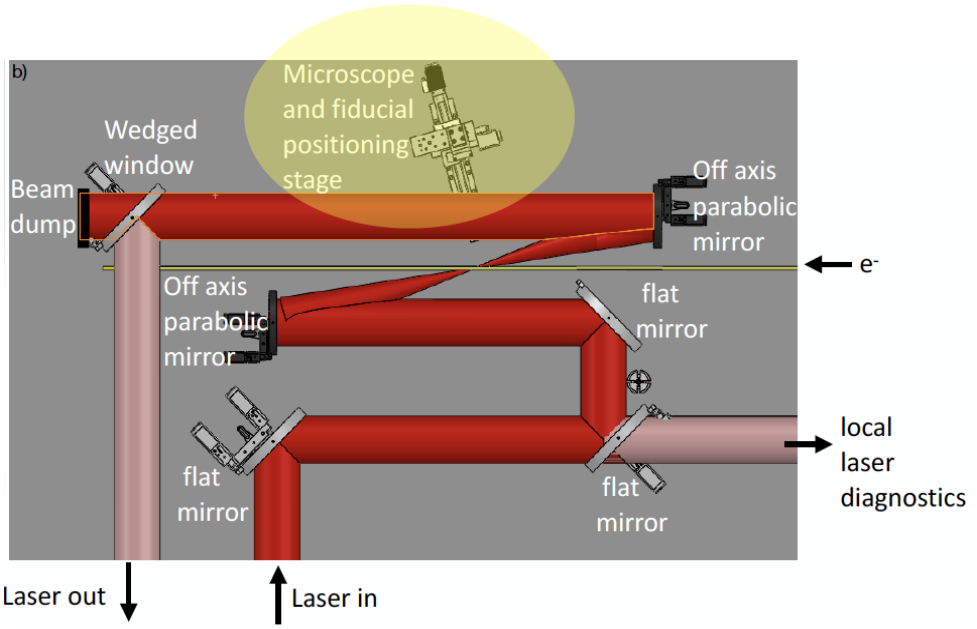
	Phase 0		Phase I
	40 TW, 8μm	40 TW, 3μm	350 TW, 3μm
Laser energy after compression (J)	1.2	1.2	10
Laser pulse duration (fs)		30	
Laser focal spot waist w_0 (μm)	8	3	3
Fraction of ideal Gaussian intensity in focus (%)		0.5	
Peak intensity in focus ($\times 10^{20}$ Wcm^{-2})	0.19	1.33	12
Dimensionless peak intensity, ξ	3.0	7.9	23.6
Laser repetition rate (Hz) - full power, on target		1	
Electron-laser crossing angle (rad)		0.35	
Quantum parameter			
χ_e for $E_e = 14.0$ GeV	0.48	1.28	3.77
χ_e for $E_e = 16.5$ GeV	0.56	1.50	4.45
χ_e for $E_e = 17.5$ GeV	0.6	1.6	4.72

Laser diagnostics



Interaction chamber





- Low-aberration imaging with off-axis mirrors
- Precision mirror mount designs (high angular precision, low backlash)
- Neural network for jitter stabilization
- Micron-scale precision in electron-laser overlap
- Femtosecond-scale synchronization with electro-optic sampling

in collaboration with Helmoltz Institute Jena (Germany) and Weizmann Institute (Israel)

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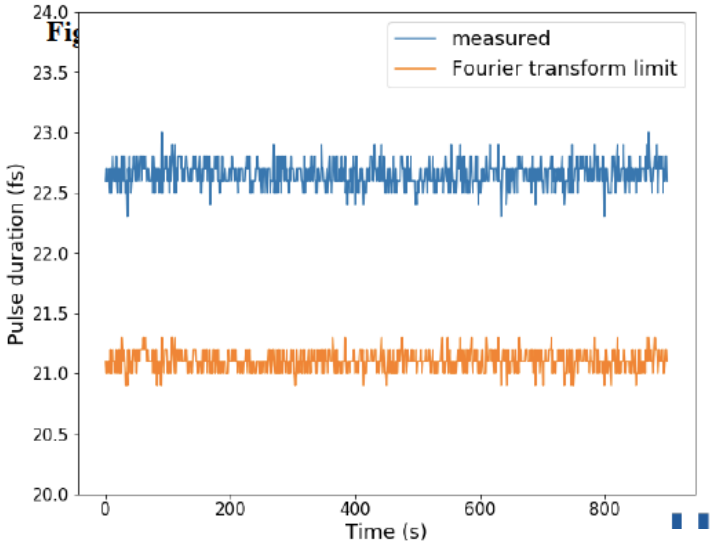
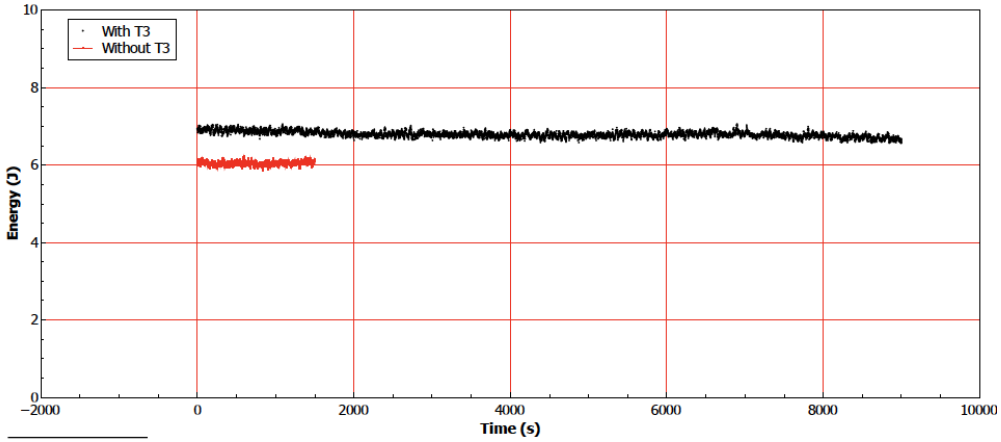
Preliminary tests

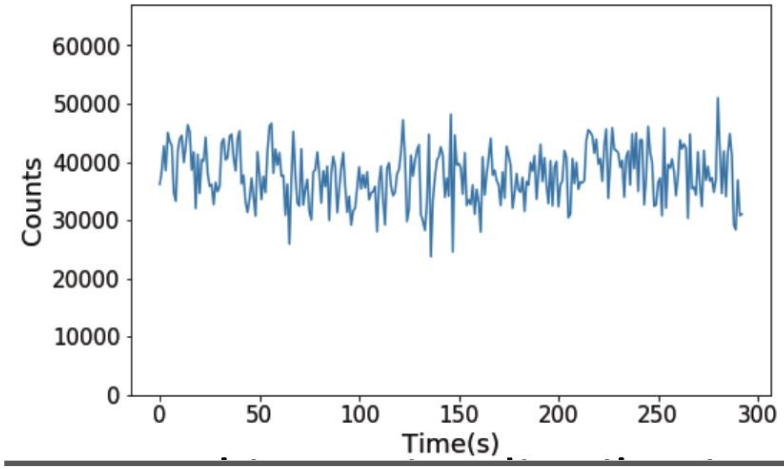
Laser pulse duration

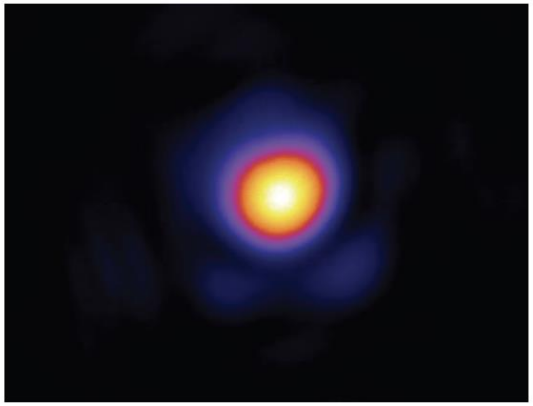


Laser energy stability (1.1% RMS)



Laser intensity stability (<10% RMS)





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Thanks for your attention

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