Strong-Field Quantum Electrodynamics

Physics processes at LUXE

non-linear Breit-Wheeler
$\gamma \rightarrow e^+ + e^-$

non-linear Compton
$e^\pm \rightarrow e^\pm + \gamma$

non-linear trident
$e^\pm \rightarrow e^\pm + e^+e^-$
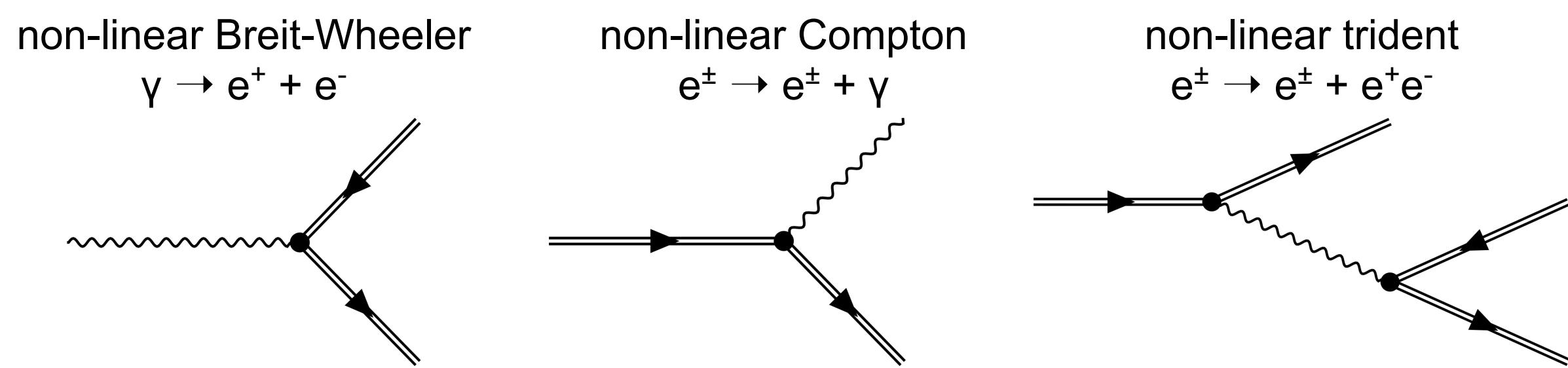
Physical quantities and parameter space
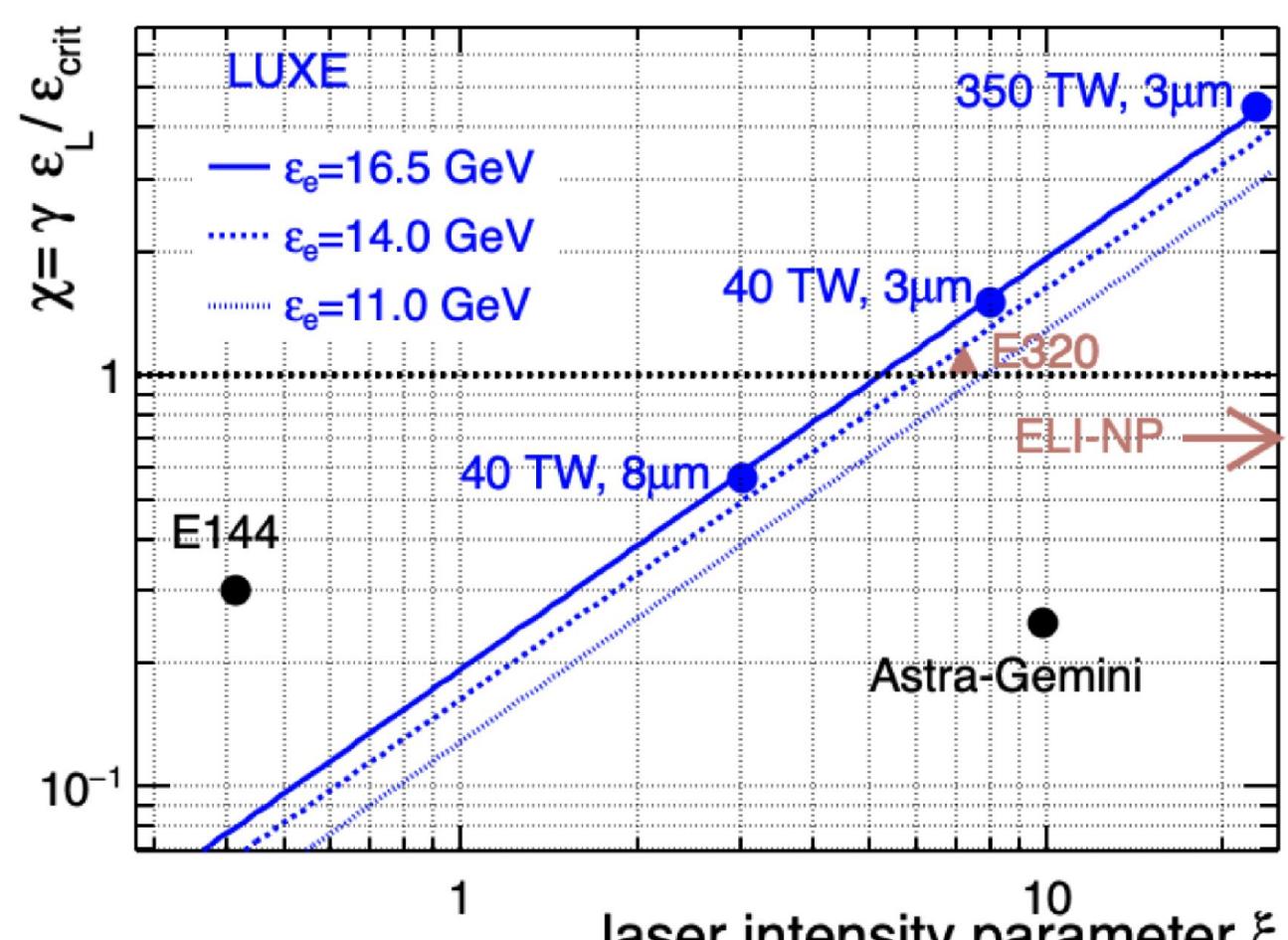
field intensity parameter
$$\xi = \sqrt{4\pi\alpha}\left(\frac{\epsilon_L}{\omega_L m_e}\right) = \frac{m_e \epsilon_L}{\omega_L \epsilon_c}$$

quantum parameter
$$\chi_\gamma = (1 + \cos\theta)\frac{E_\gamma}{m_e}\frac{\epsilon_L}{\epsilon_c}$$

first experiment:
- E144 @ SLAC in 1990s

todays experiments:
- SLAC-E320 (US)
- Astra Gemini (UK)
- ELI-NP (RO, planned)

16.5 GeV electron, 800 nm laser, 17.2° crossing angle

Experimental Setup
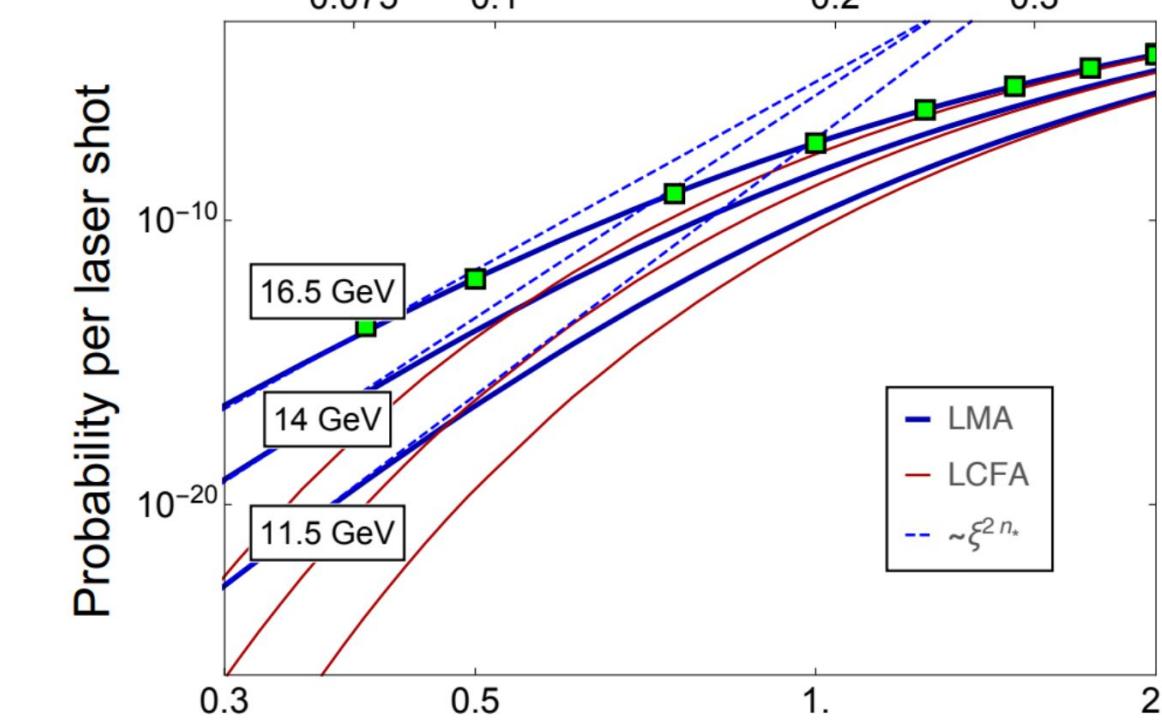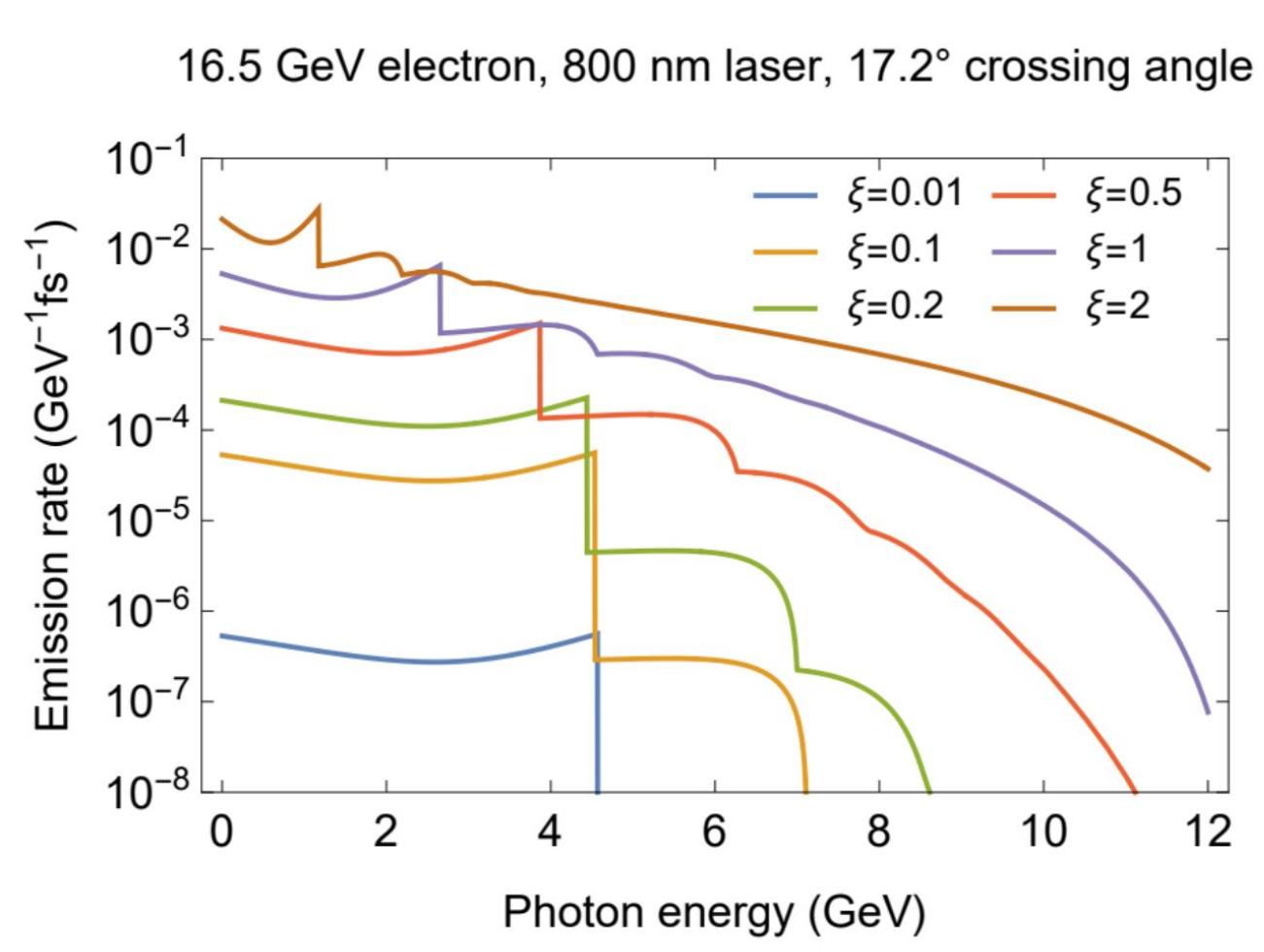
Location at the European XFEL at DESY in Hamburg (DE)
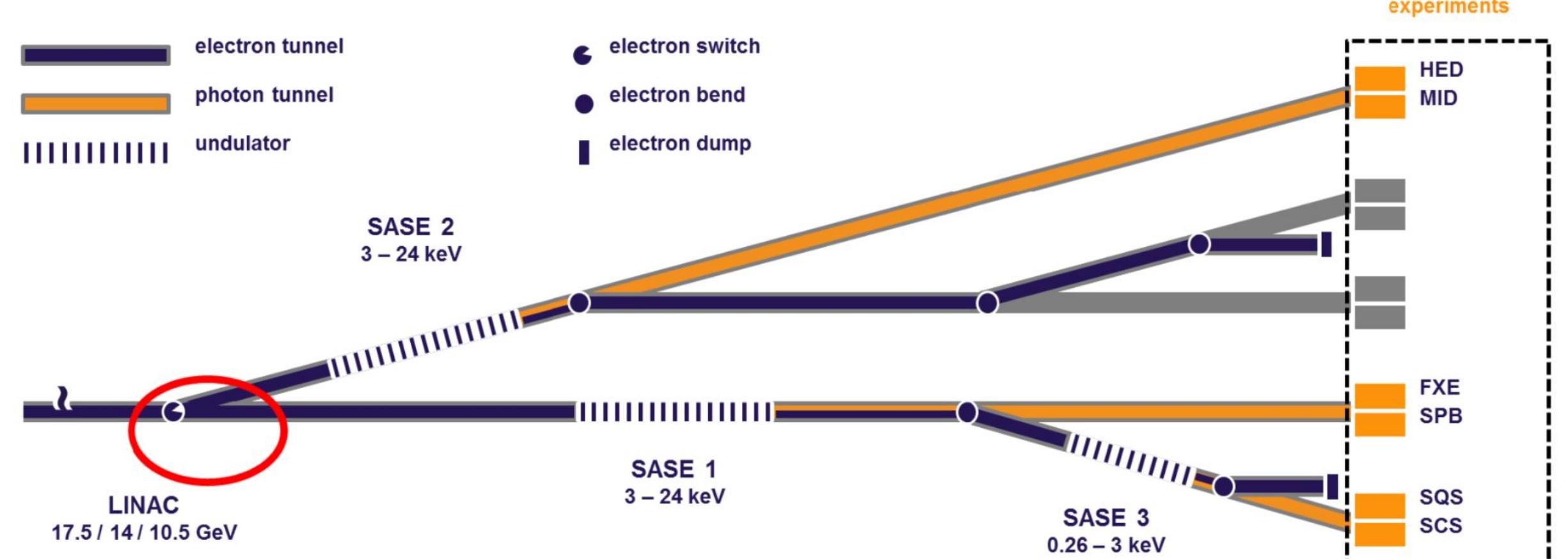

Electron-laser setup
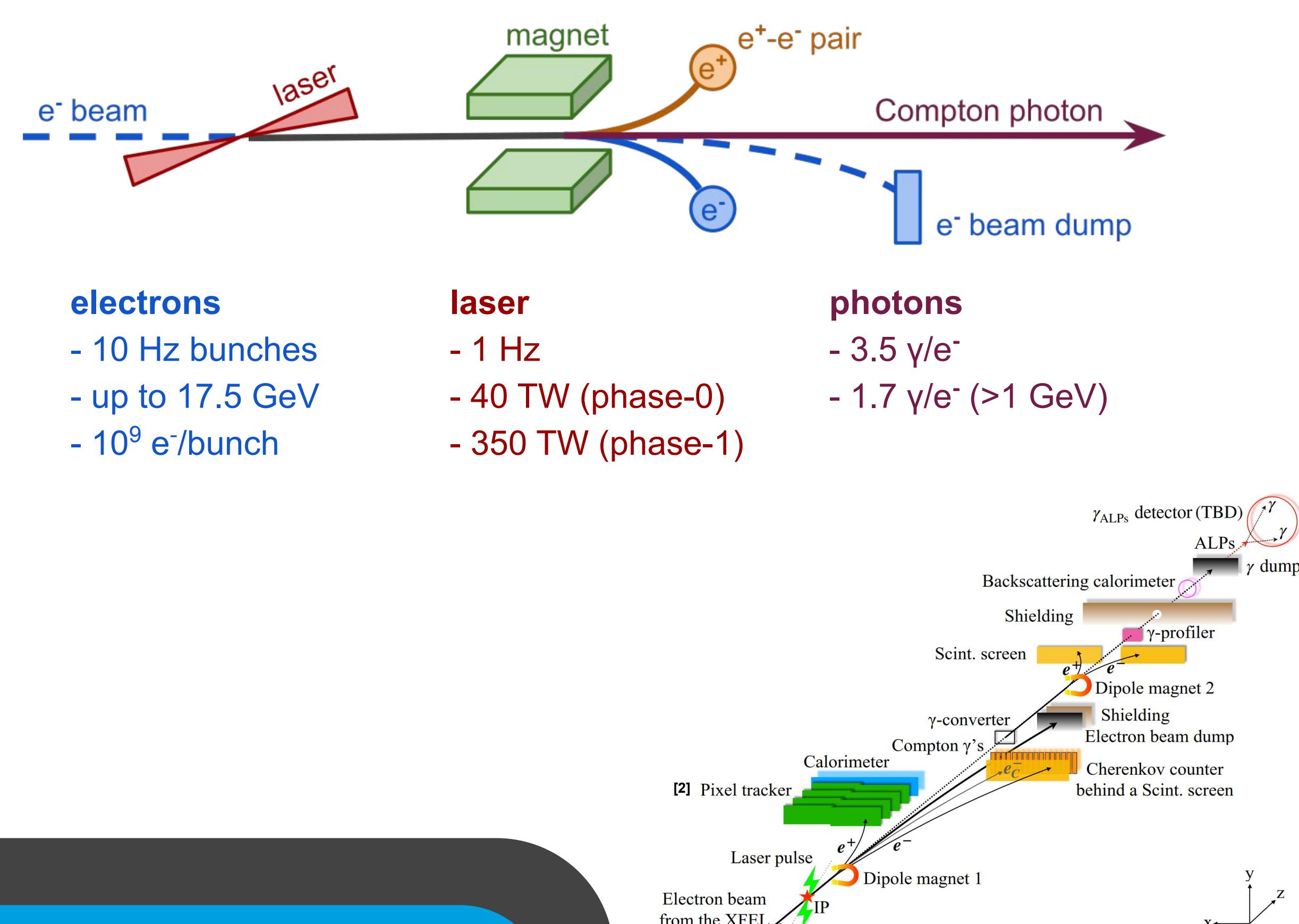
electrons
- 10 Hz bunches
- up to 17.5 GeV
- 10^9 e⁻/bunch

laser
- 1 Hz
- 40 TW (phase-0)
- 350 TW (phase-1)

photons
- 3.5 γ/e⁻
- 1.7 γ/e⁻ (>1 GeV)

The LUXE experiment and the new physics search with optical dump NPOD

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Optical Dump

laser oscillation
$1/\omega_L \approx 0.4$ fs

Compton scattering
$\tau_\gamma \approx \mathcal{O}(10)$ fs

laser pulse
$t_L \approx \mathcal{O}(10 - 200)$ fs

pair production
$\tau_{ee} \approx \mathcal{O}\left(10^4 - 10^6\right)$ fs

$$1/\omega_L \ll \tau_\gamma \lesssim t_L \ll \tau_{ee}$$

Beam electron

Laser pulse "Optical Dump"

Free GeV photons

Primakoff production

photon decay channel

new physics search
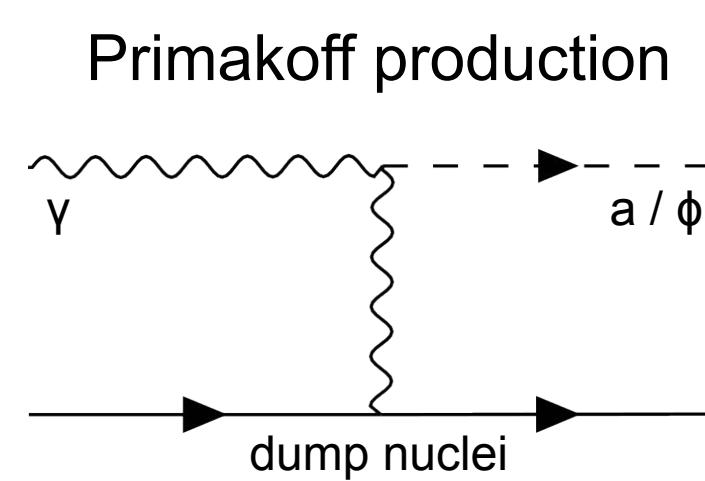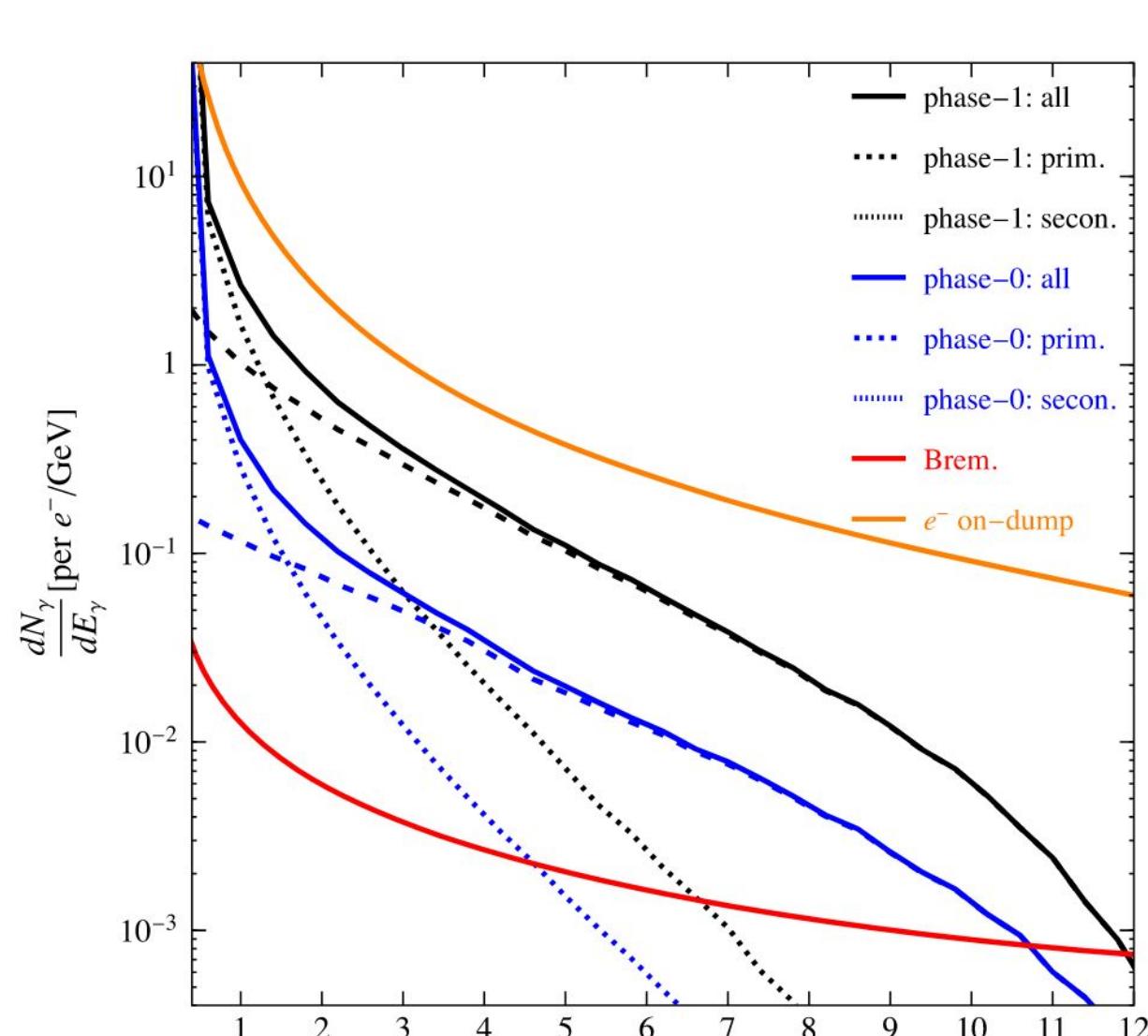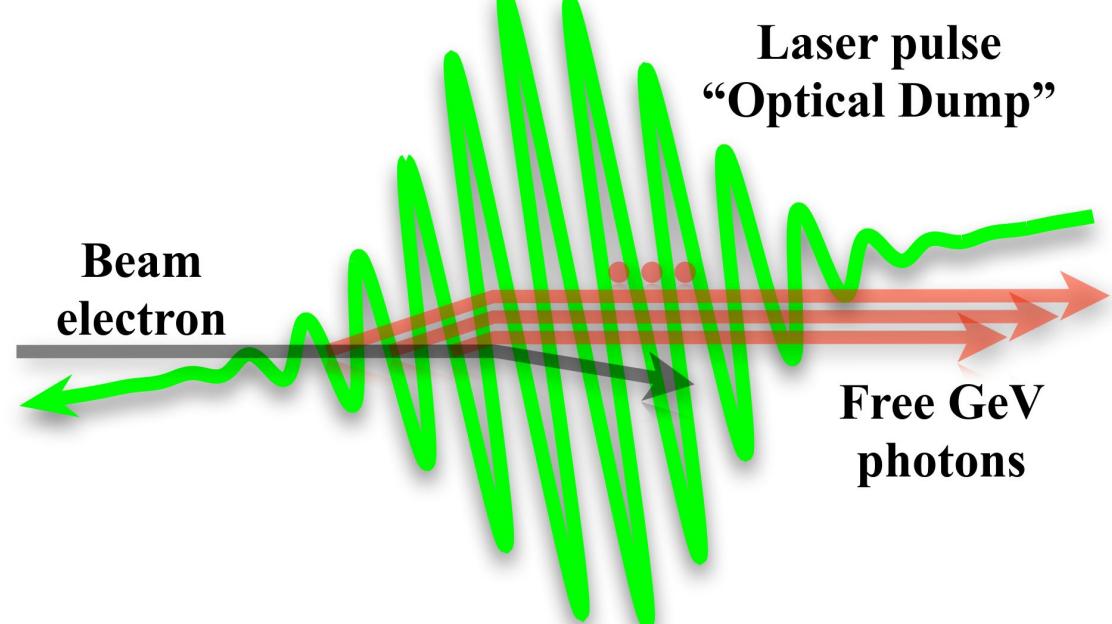
$$\mathcal{L}_a = \frac{a}{4\Lambda_a}F_{\mu\nu}\tilde{F}^{\mu\nu}$$

$$\Gamma_{a\rightarrow 2\gamma} = \frac{m_a^3}{64\pi\Lambda_a^2}$$

New Physics Search

$e, \mu, \pi, K, p, \ldots$
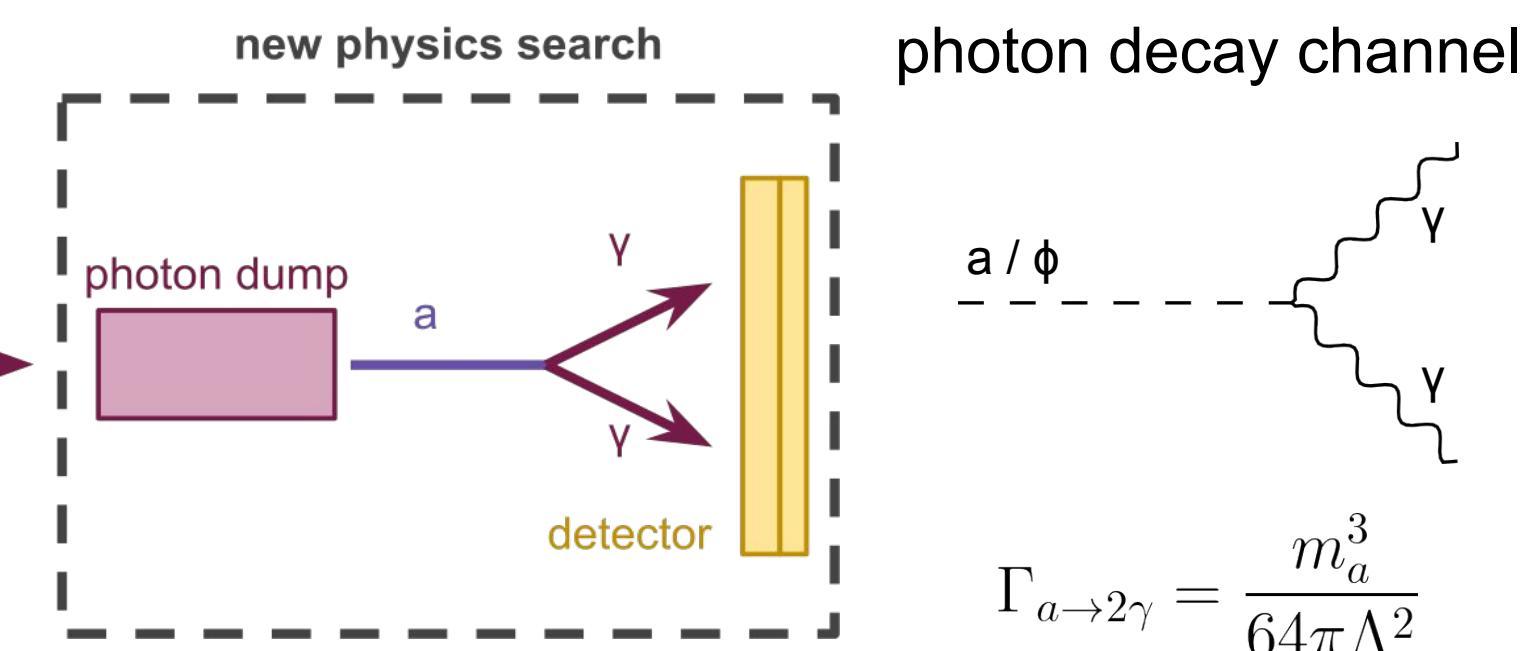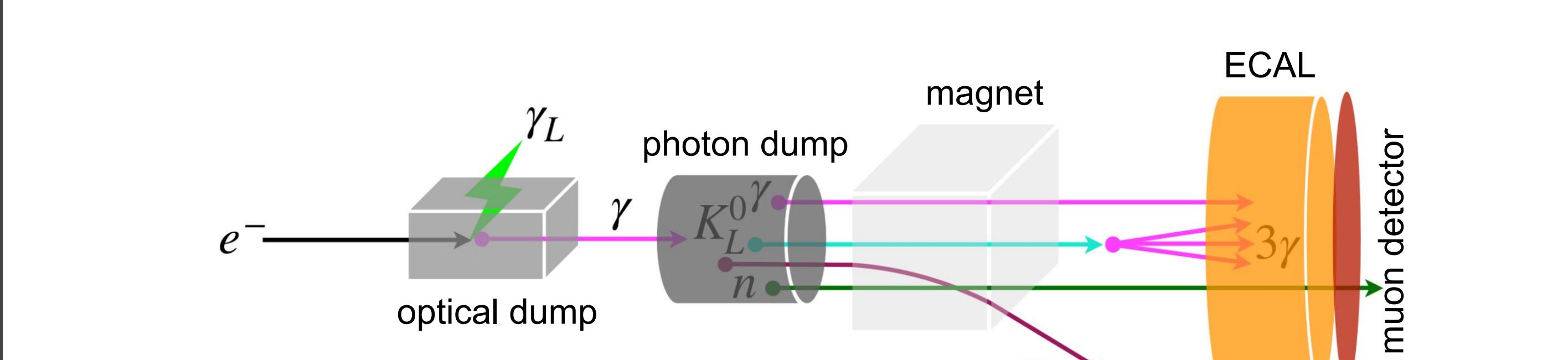
remaining background sources:
- neutrons (10 / BX)
- photons (0.01 / BX)
  ➔ detector optimization

	LUXE NPOD	LUXE: e⁻ on dump
N_a	4	16.5
N_{BG}	0.8	156.1
SNR	5	0.1
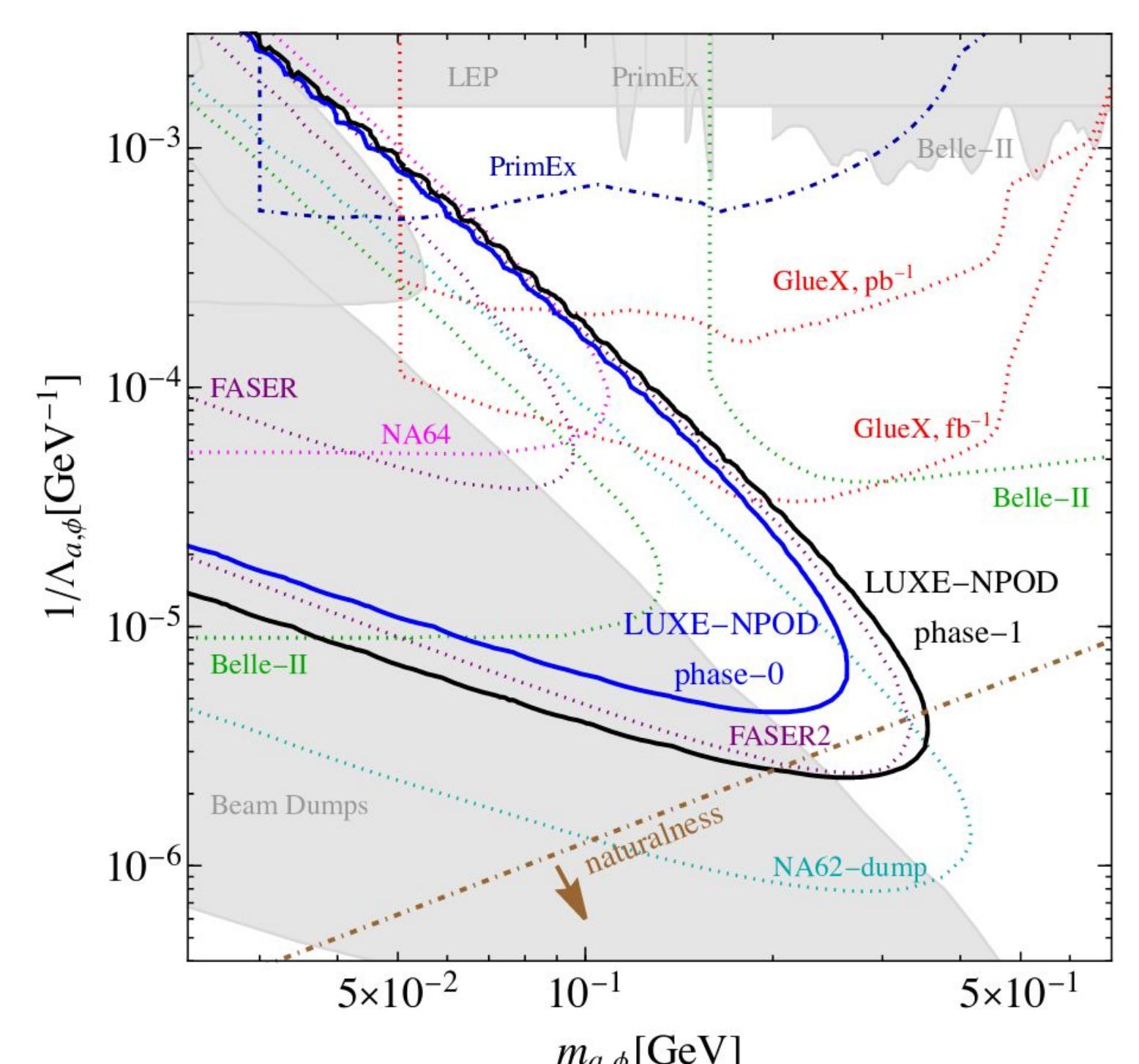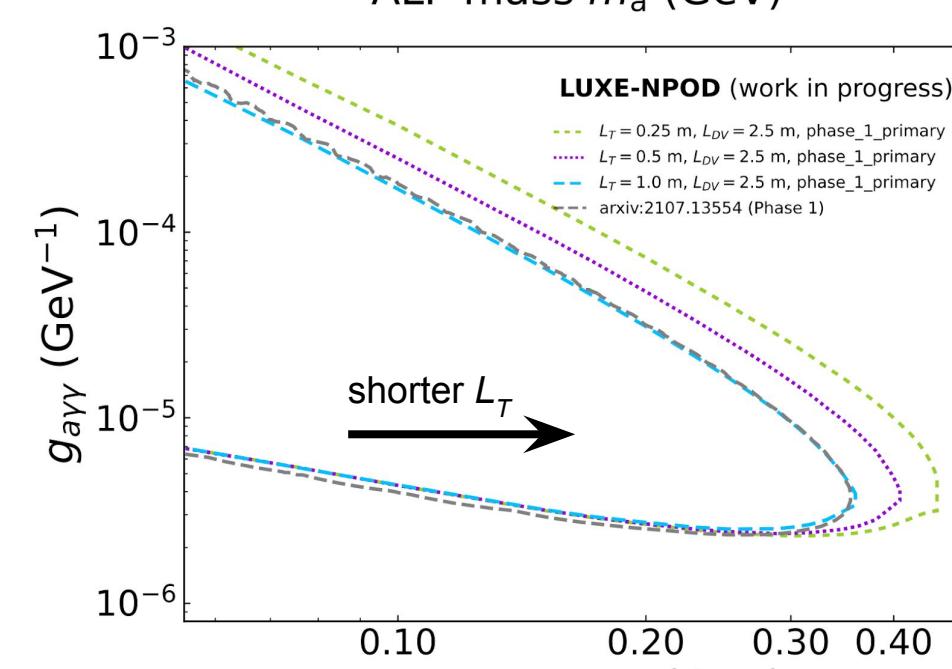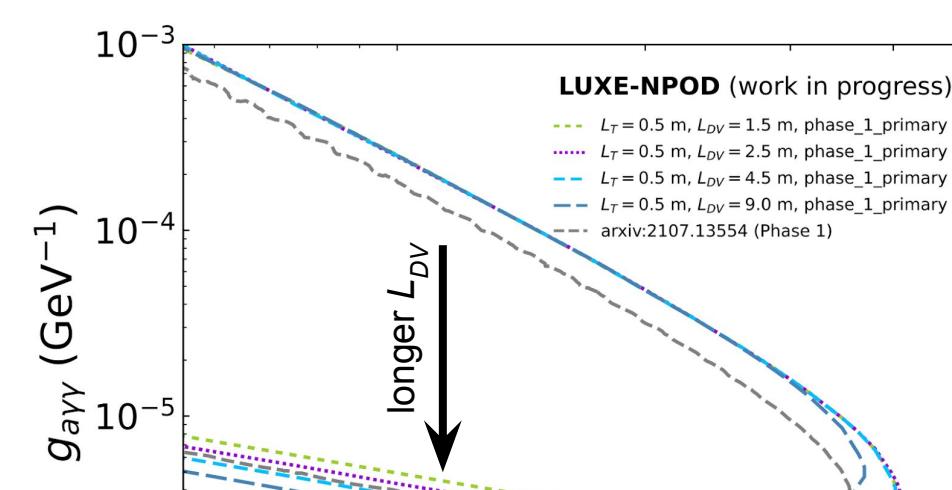
[1] Abramowicz, H. et al. *Conceptual Design Report for the LUXE Experiment.*
Eur. Phys. J. Spec. Top. **230**, 2445–2560 (2021).
DOI: 10.1140/epjs/s11734-021-00249-z

[2] Crippa, A. et al. *Quantum algorithms for charged particle track reconstruction in the LUXE experiment.*
DOI: 10.48550/arXiv.2304.01690

[3] Bai, Z. et al. *New physics searches with an optical dump at LUXE.*
Phys. Rev. D **106**, 115034 (2022).
DOI: 10.1103/PhysRevD.106.115034