

Detector Challenges of the strong-field QED experiment LUXE at the European XFEL

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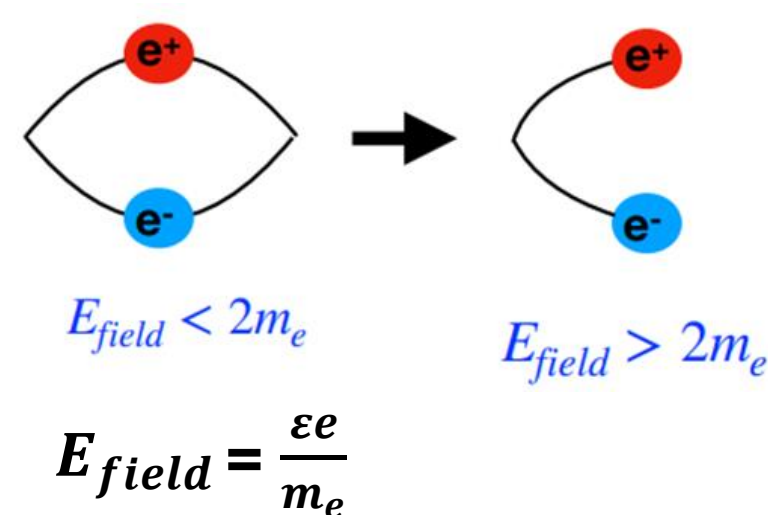
on behalf of the LUXE and FCAL Collaborations



Introduction

- Quantum electrodynamics (QED) is the world's most precisely known (and tested) theory.
- LUXE will study non-perturbative and non-linear QED phenomena in the strong-field regime.
- Vacuum boils if field large enough to create real pairs:
- "critical field"** = work by field over $\lambda_{Compton} > 2m_e$
- More details on LUXE physics:
LUXE CDR: [Eur.Phys.J.ST 230 \(2021\) 11, 2445-2560](#)
LUXE website: <https://luxe.desy.de>

QED becomes non-perturbative above Schwinger-Limit!



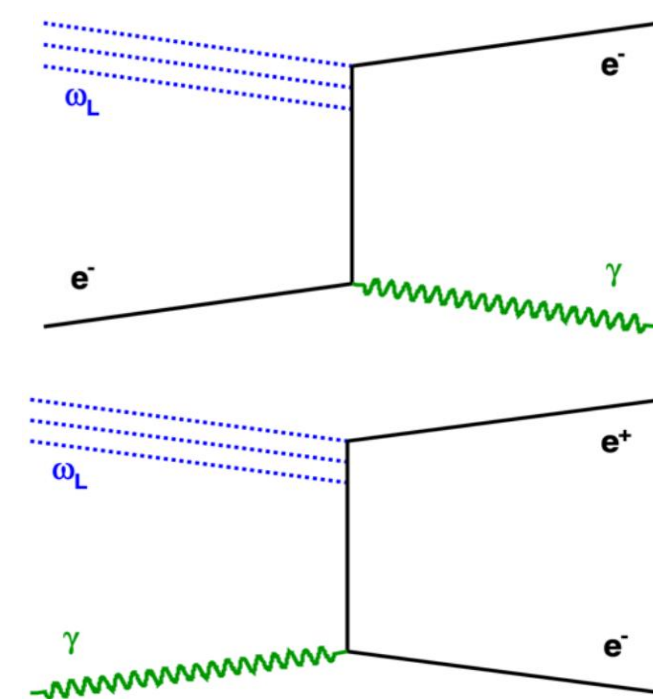
Schwinger-Limit:

$$\epsilon_{crit} = \frac{m_e^2 c^3}{\hbar e}$$

e.g. for electrical field:

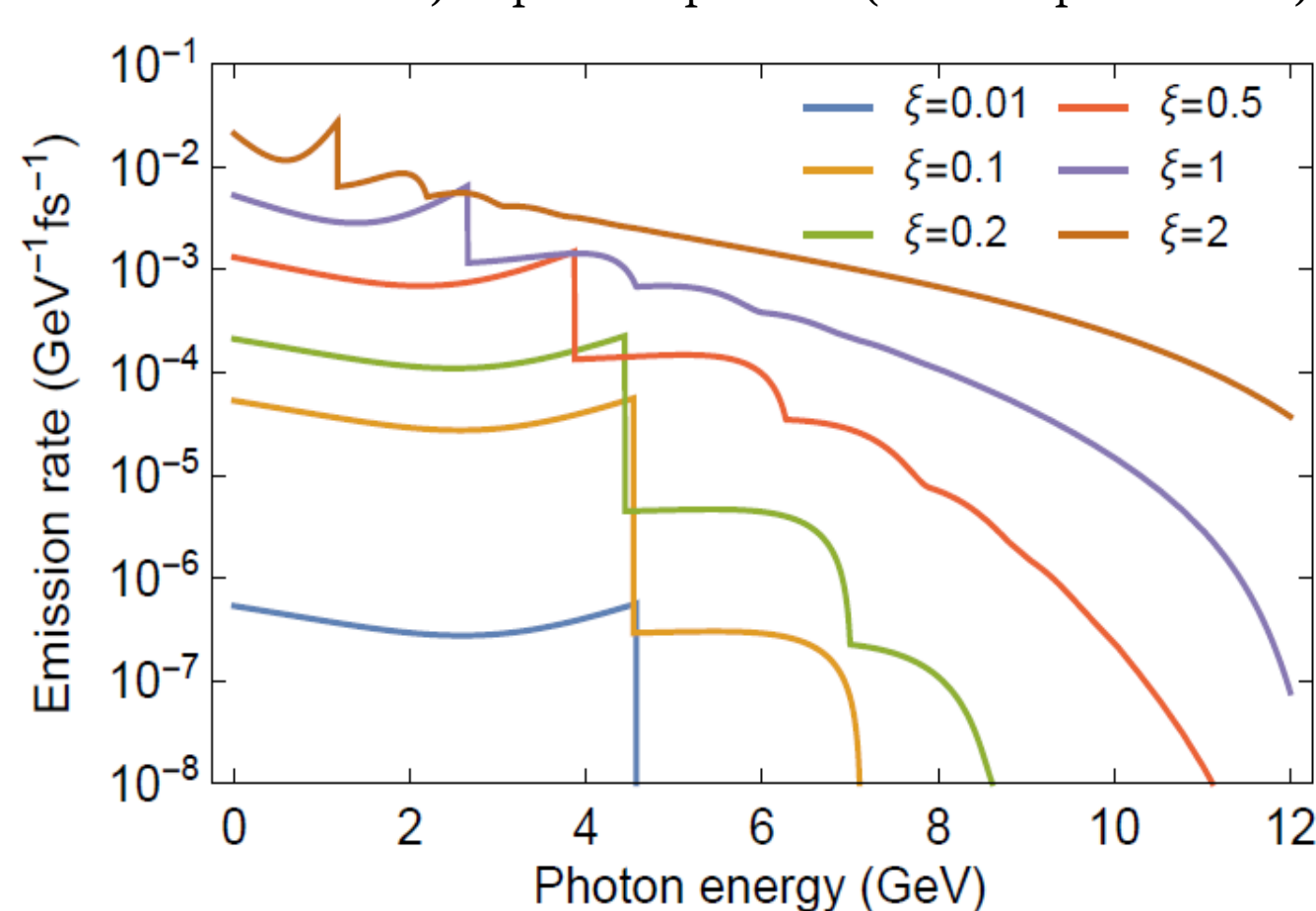
$$\epsilon_{crit} \approx 1.32 \cdot 10^{18} \text{ V/m}$$

Main processes of interest in LUXE



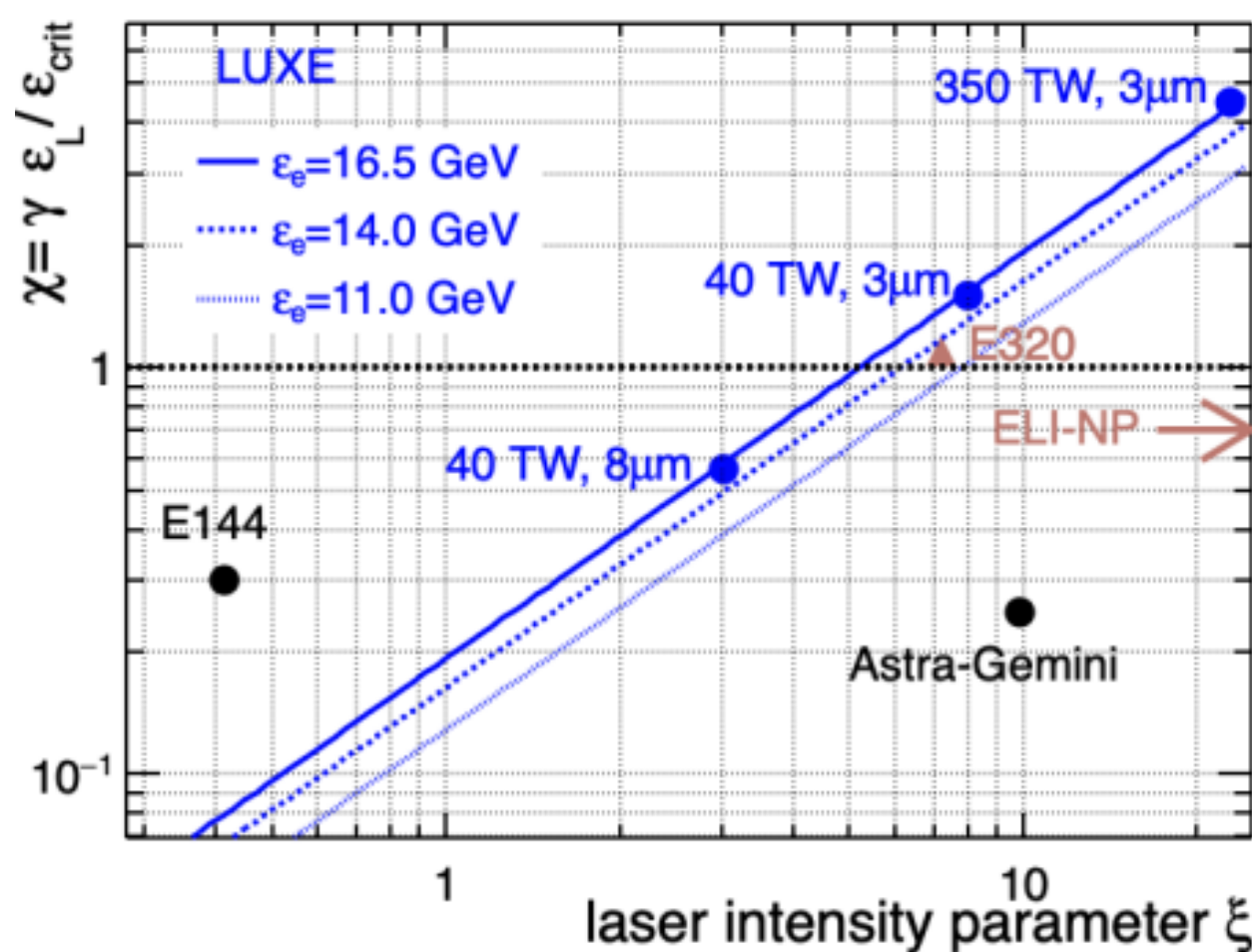
Goals

- Non-linear Compton scattering:**
Reconstruct Compton edge in electron (Scintillator or Cherenkov detector) or photon spectrum (Photon spectrometer)



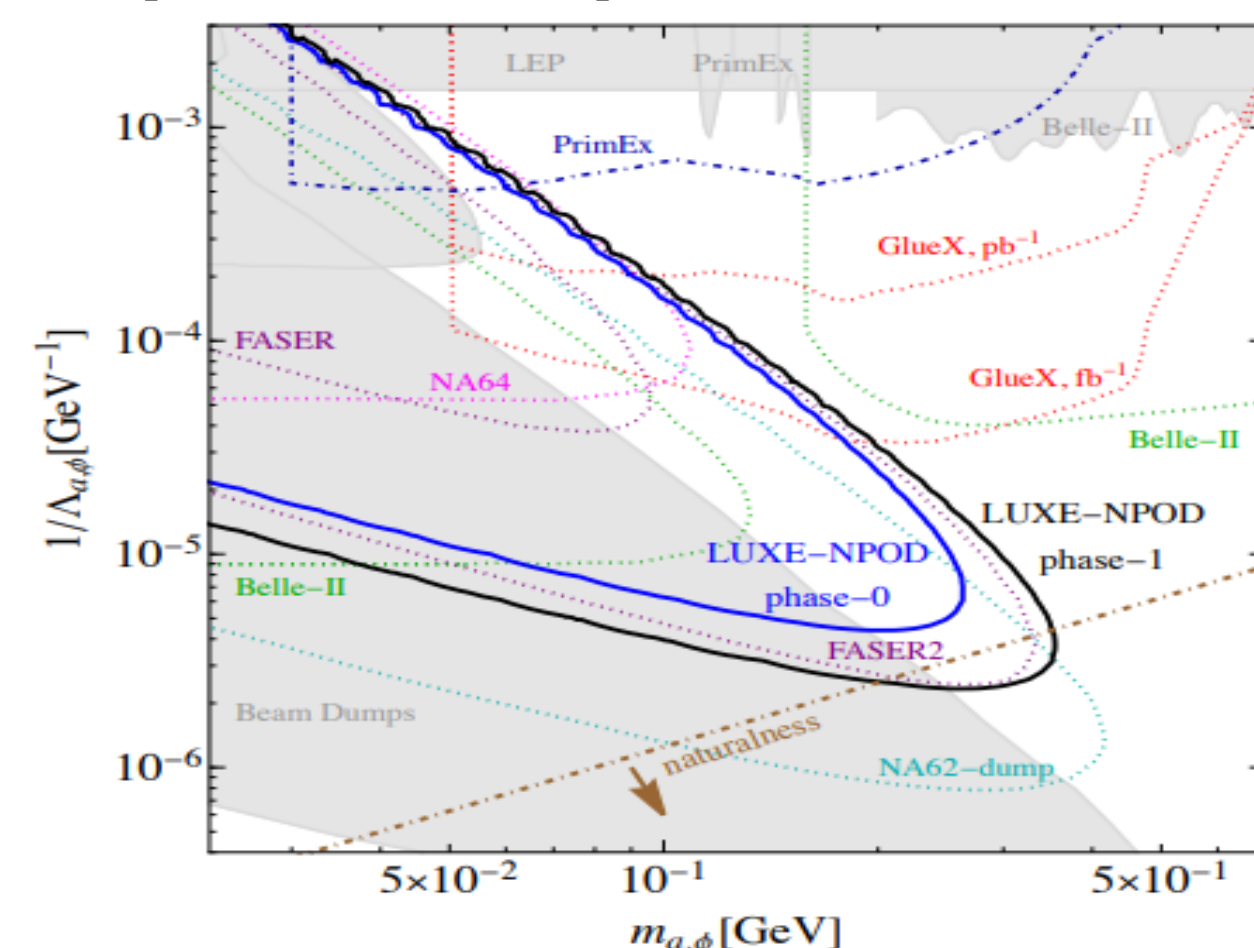
- Non-linear Breit-Wheeler:**

Measure positron rate with combined pixel tracking detector and EM calorimeter



- Search for BSM physics:**

The high-intensity photon beam can be used to search for (pseudo-) scalars or milli-charged particles in beam-dump.



Detectors

European XFEL electron beam:

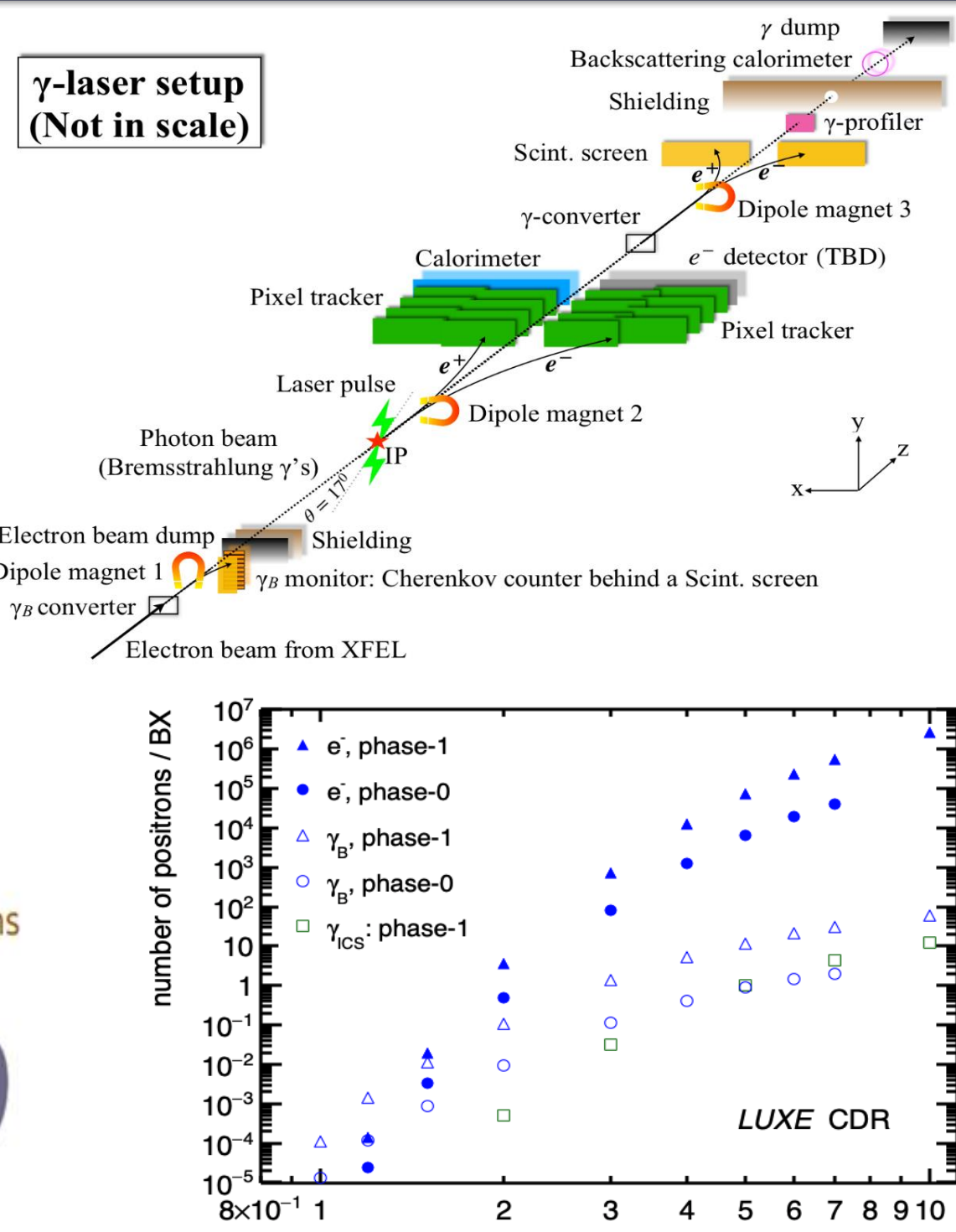
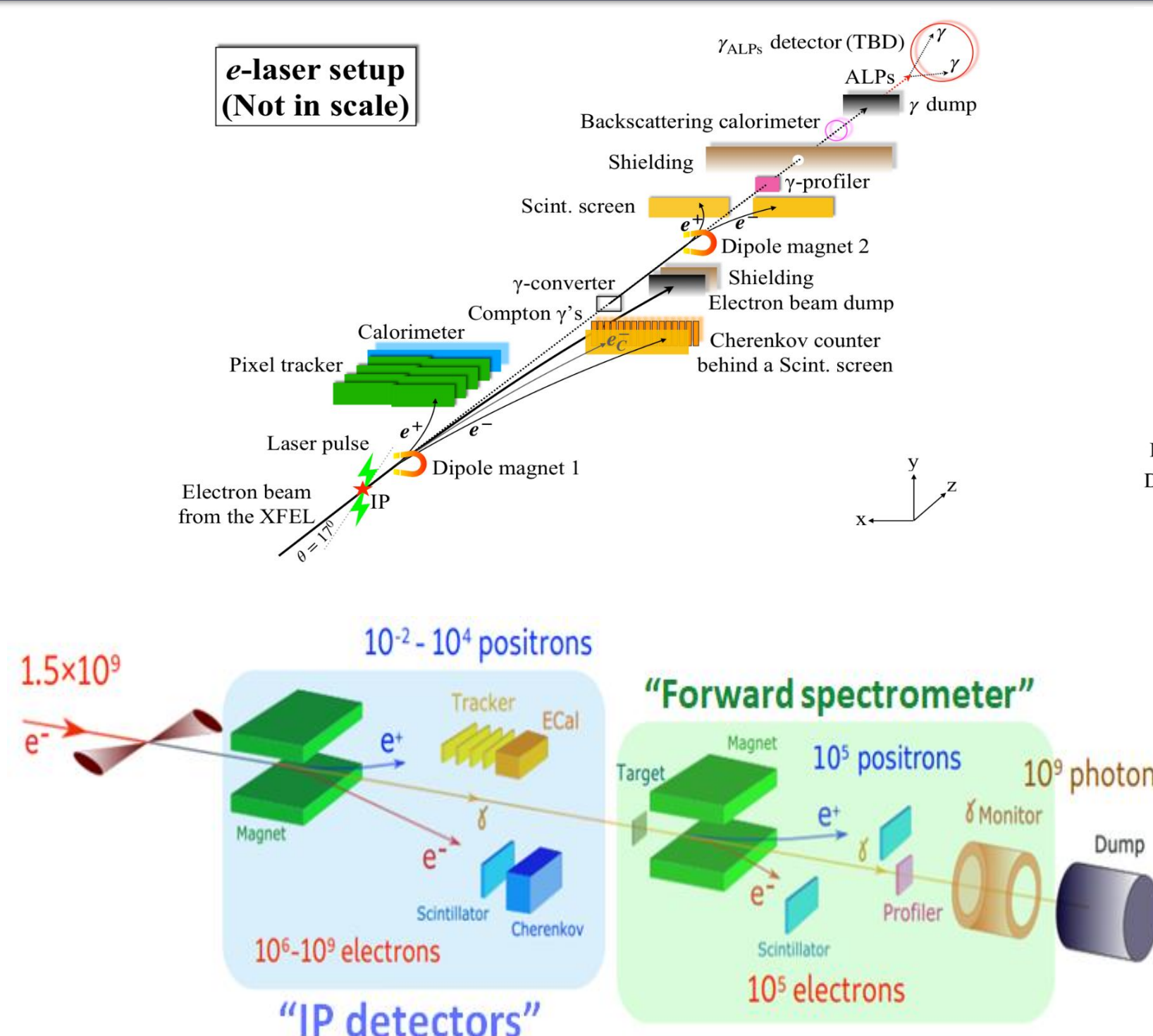
- Energy 16.5 GeV (possible 10 GeV and 14 GeV);
- LUXE uses one out of 2700 bunches per train;
- Repetition rate 10 Hz;
- Normalized emittance 1.4 mm mrad;

Laser:

- Laser wavelength = 800.00 nm (1.5498 eV);
- Repetition rate ~1 Hz;
- Power:
 - Phase 0: 40 TW, focal spot size: 3 or 8 mm ($\xi = 7.9$);
 - Phase 1: 350 TW, focal spot size: 3 mm ($\xi = 23.6$);

Use different detector technologies!!!

- Measure fluxes and energy spectra of e^+ , e^- and γ .
- Particles fluxes vary between $\sim 10^{-2}$ (e^+) and 10^9 (e^- , γ) per laser shot



FLAME - LumiCal new readout:

- FLAME is a **System on Chip (SoC)** solution;
- 130 nm CMOS** technology;
- 32 mix-mode channels per ASIC;
- Each channel contains FE+10 bit ADC;
- Followed by high speed data link.
- Online data processing:
 - pedestal, CM subtraction;
 - Pulse detection;
 - Deconvolution;
 - ToA and amplitude reconstruction.

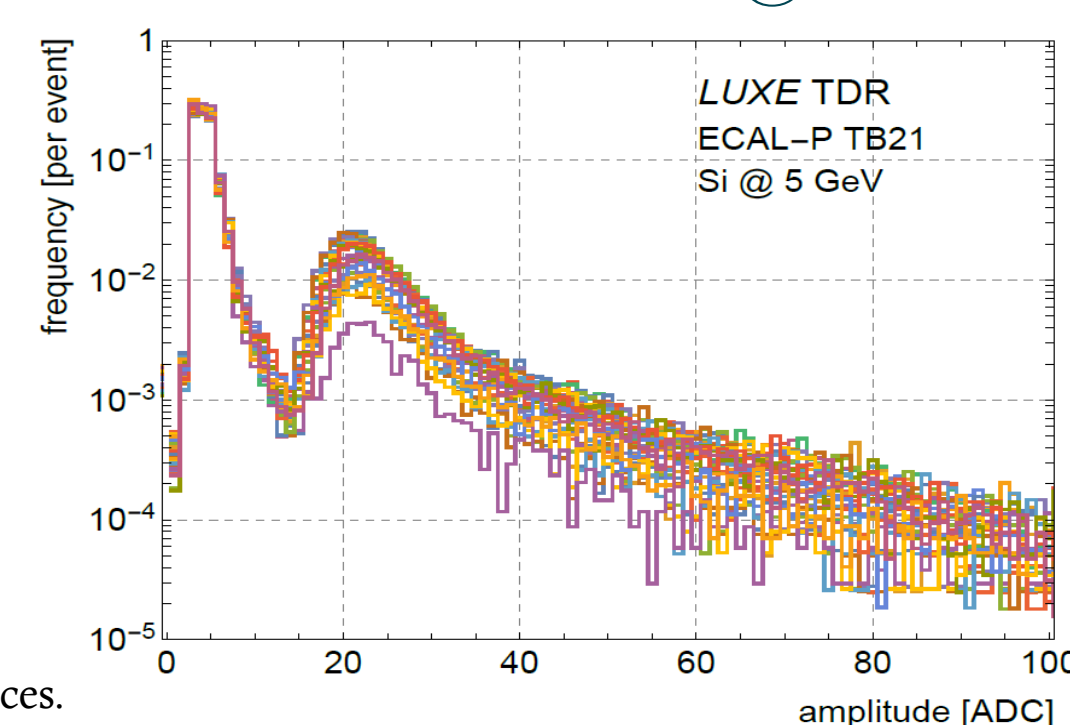
LUXE ECAL design:

- High granularity EM calorimeter;
- Sampling calorimeter with 20 W absorber plates;
- Si or GaAs sensors (5x5 cm² pads) installed in 1 mm gap between absorber plates;
- Small Molière radius, high spatial resolution of local energy deposits;
- The fiducial volume: 53 x 5.2 x 9 cm³.

Test beam infrastructure @ DESY-II:

- Electron beam 1 - 5 GeV energy;
- 6 ALPIDE telescope planes;
- DUT (ECAL calorimeter):
 - FLAME ASIC;
 - Si (320µm) sensor or GaAs (500µm) sensor with traces.

ECAL Calorimeter – 1st beamtest @ DESY



Conclusions & Future Work

- The LUXE experiment will explore strong-field QED using European XFEL and high power laser.
- The calorimeter is designed to measure the number of positrons per bunch crossing in a wide range.
- ECAL will be a compact EM calorimeter with high granularity.
- LUXE is a new experiment designed to test strong field QED predictions in a region never explored before in clean environments.
- Parasitically: search for BSM physics (axion-like particles (ALPs) or millicharged particles (mCPs) produced in dump).
- Installation is foreseen in 2024 during the extended shutdown of the European XFEL.
- The experiment received a stage 0 critical approval (CD0) from the DESY management.
- Data taking phase 0 from 2024 and 2025, phase 1 will start in 2026.

Acknowledgements:

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