Strong-field QED measurement tests at FACET-II using new electron detector concept

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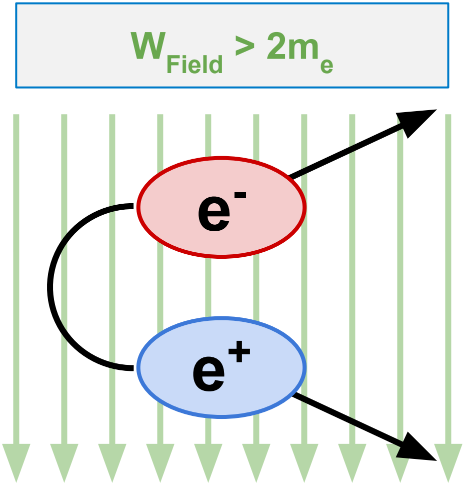
HELMHOLTZ

LUXE DESY.

Strong-Field QED

Theory

- QED tested to a very high precision
- In a **strong electromagnetic background field**:
    - The vacuum becomes a nonlinear medium
    - **Electron-Positron pairs can tunnel out of the vacuum!**
    - Perturbative approach to QED breaks down
- Key parameters:
    - **Schwinger Limit**, ε_{cr} = 1.32 * 10^{18} V/m
    - **Intensity Parameter** ($\xi \equiv a_0$) ⟶ Effective coupling to background field
        - $\xi \geq 1$ ⟶ Non perturbative
        - Quantifies how many photons interact with probe charge

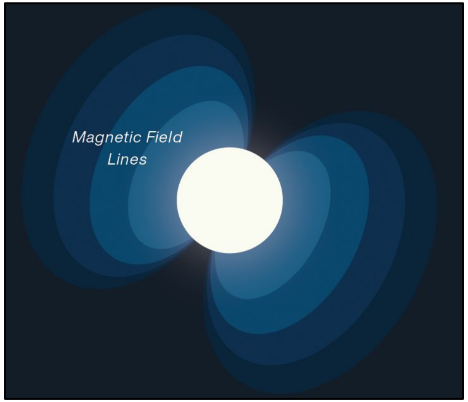


Strong-Field QED

In the Real World

Where are these strong fields achieved?

Magnetars (Neutron stars with B > 10^{10} T)



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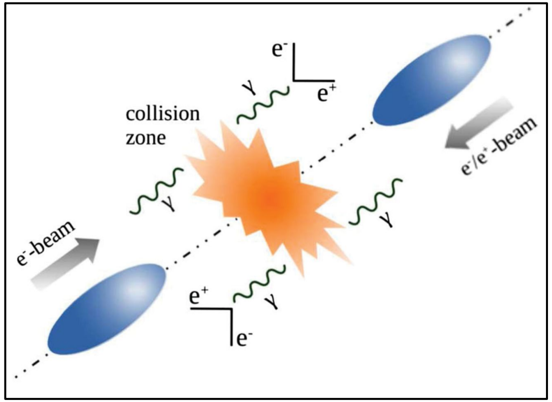
Future lepton colliders



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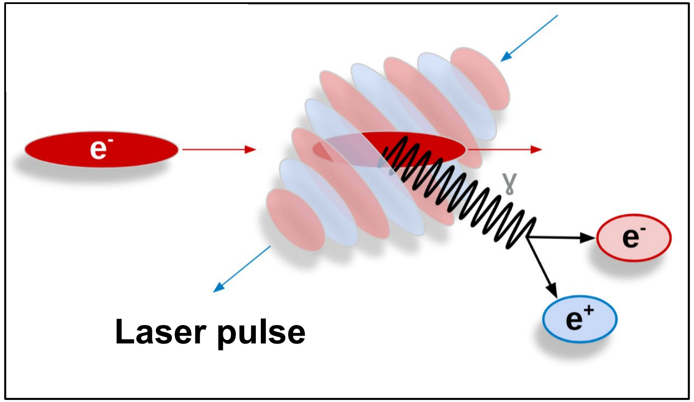
Beam-laser interactions

$\varepsilon_{rest\ fr} = \gamma\ \varepsilon_{lab\ fr}$



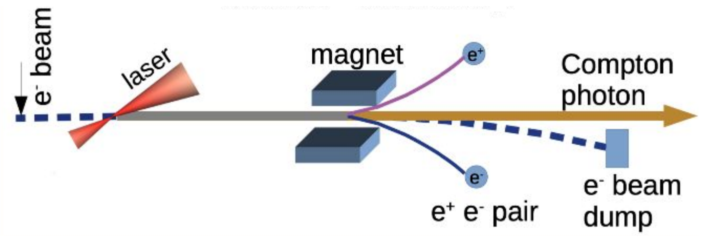
Strong-Field QED

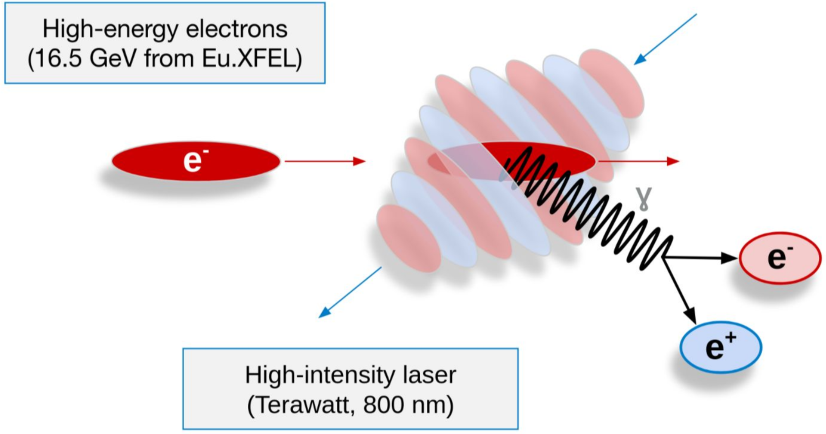
LUXE

- Laser Und XFEL Experiment (LUXE)
- Planned at European XFEL and DESY
- Study transition from QED to Strong Field QED
- High Energy electrons from European XFEL
  → ~10^9 electrons at 16.5 GeV
- Up to 350 TW Laser
- $\xi \leq 19$

LUXE

CDR & TDR available

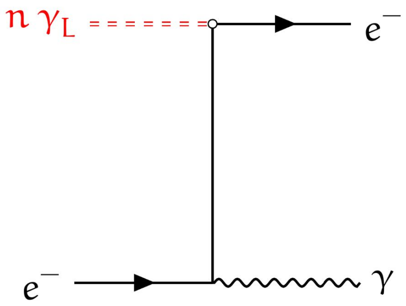




Strong Field QED

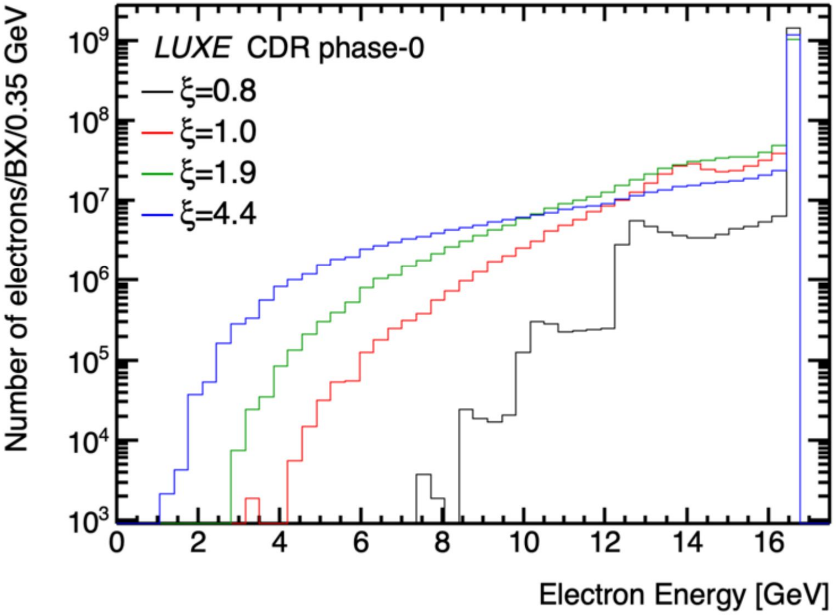
LUXE

Non-Linear Compton Scattering



- One of the processes to be studied by LUXE
- Multiple Compton edges
- Shifting Compton edge

To capture full Compton spectrum at LUXE, we need a detector able to detect a large dynamic range of electron flux



Electron Detection System (EDS)

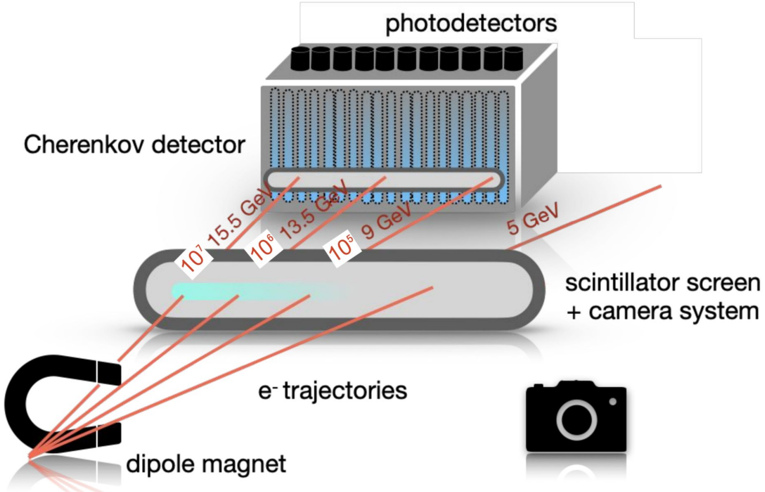
Detector Overview

Scintillating Screen and Camera

- Light yield proportional to no. of electrons
- 0.5 mm spatial resolution
- 2% energy resolution

Cherenkov Counter

- Segmented channels (‘straws’)
- Air-filled steel straws or glass rods
- < 2.1 mm spatial resolution
- More resistant to low-energy background particles



Electron Detection System (EDS)

Cherenkov Counter

Hollow tube filled with air

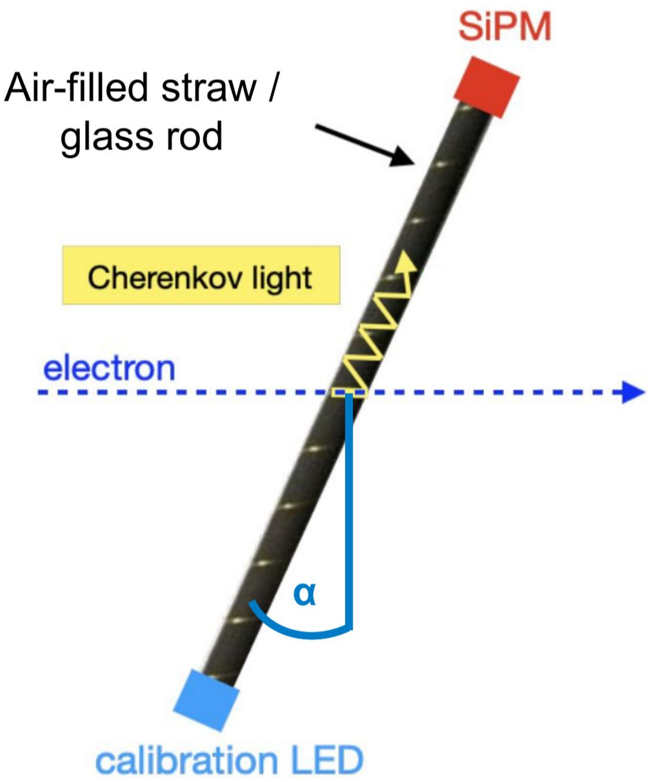
- Low Cherenkov production rate
- Energy threshold: 21 MeV

Solid glass rod

- Mainly SiO2
- Higher sensitivity to low e^- intensities
- Energy threshold: 0.73 MeV

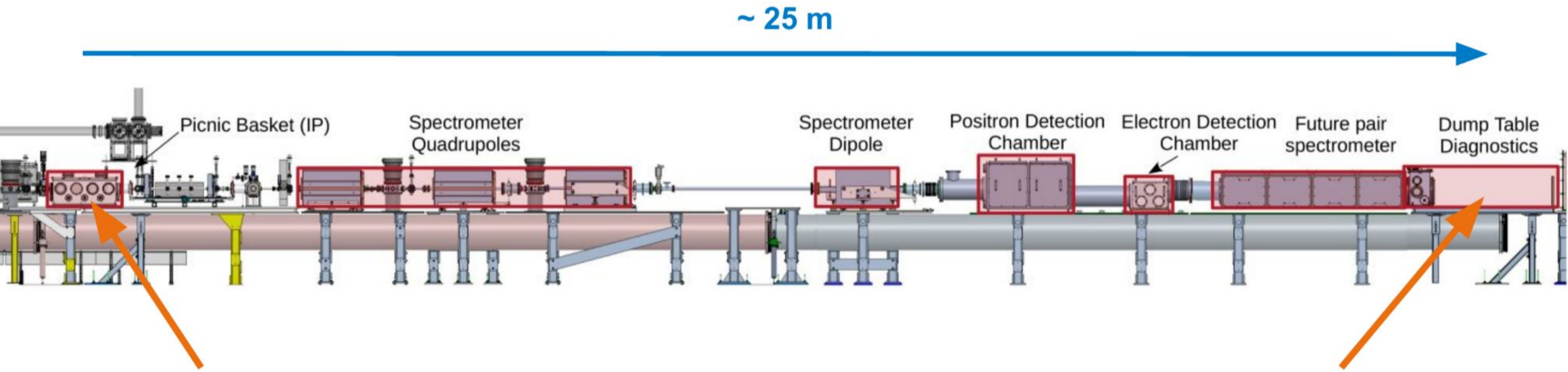
Silicon-Photomultipliers (SiPM)

- High dynamic range
- Low bias voltage



Detector Tests at E320

FACET-II Overview



Interaction Point for E320

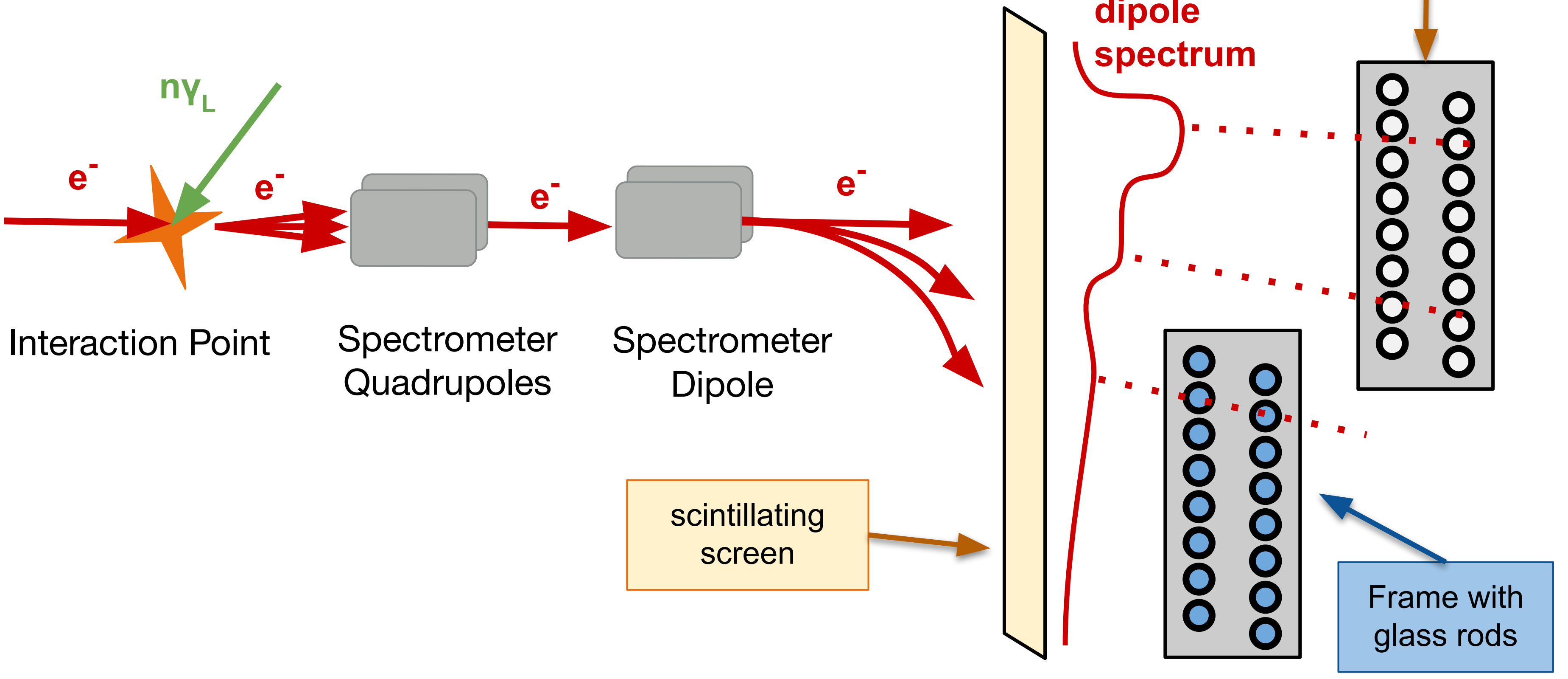
- 10 GeV electron beam, 1.6 nC
- 10 TW laser with ~0.3 J on target
- $\xi \leq 5$

Dump Table

In air area with scintillator screens, cameras and other user experiments

Detector Tests at E320

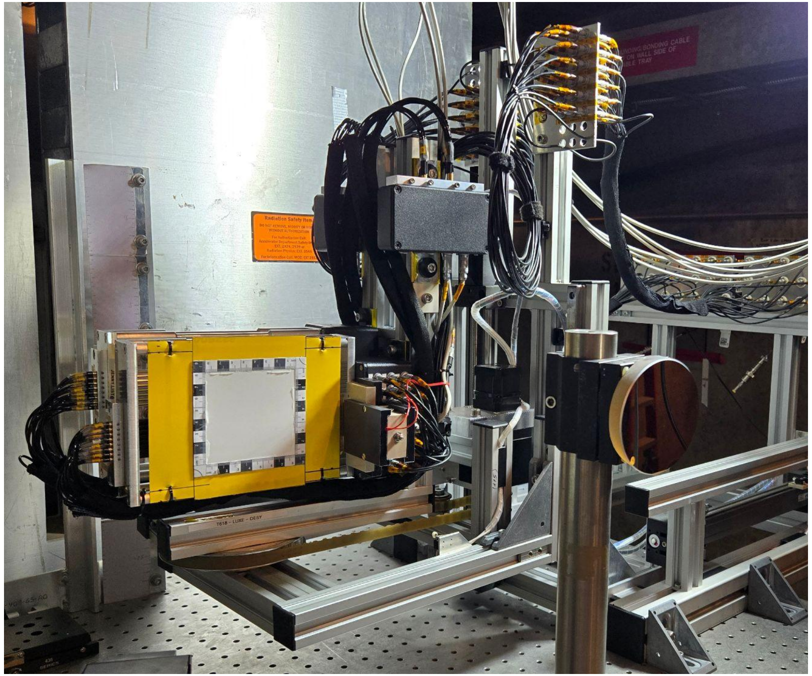
Experimental Setup Overview



Detector Tests at E320

Detector Prototype

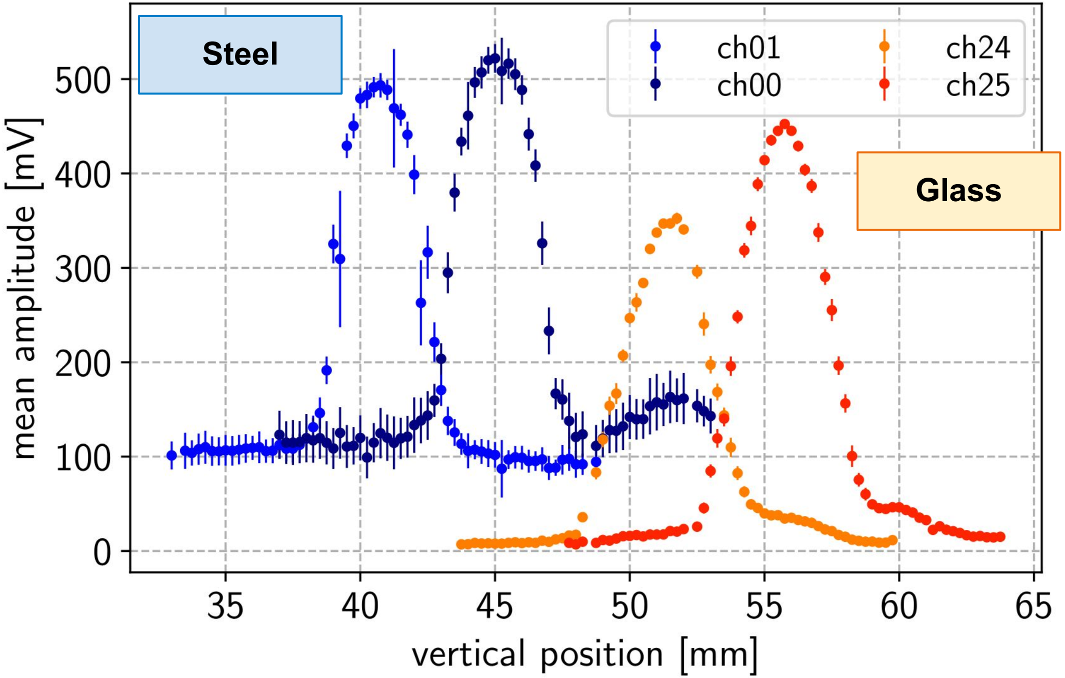
- 10x10cm scintillator screen
- 16 steel straws, 16 glass rods
- On a movable stage
  - Vertical, horizontal movement
  - Rotates around vertical axis
- Positioned just before beam dump



Calibration Measurements

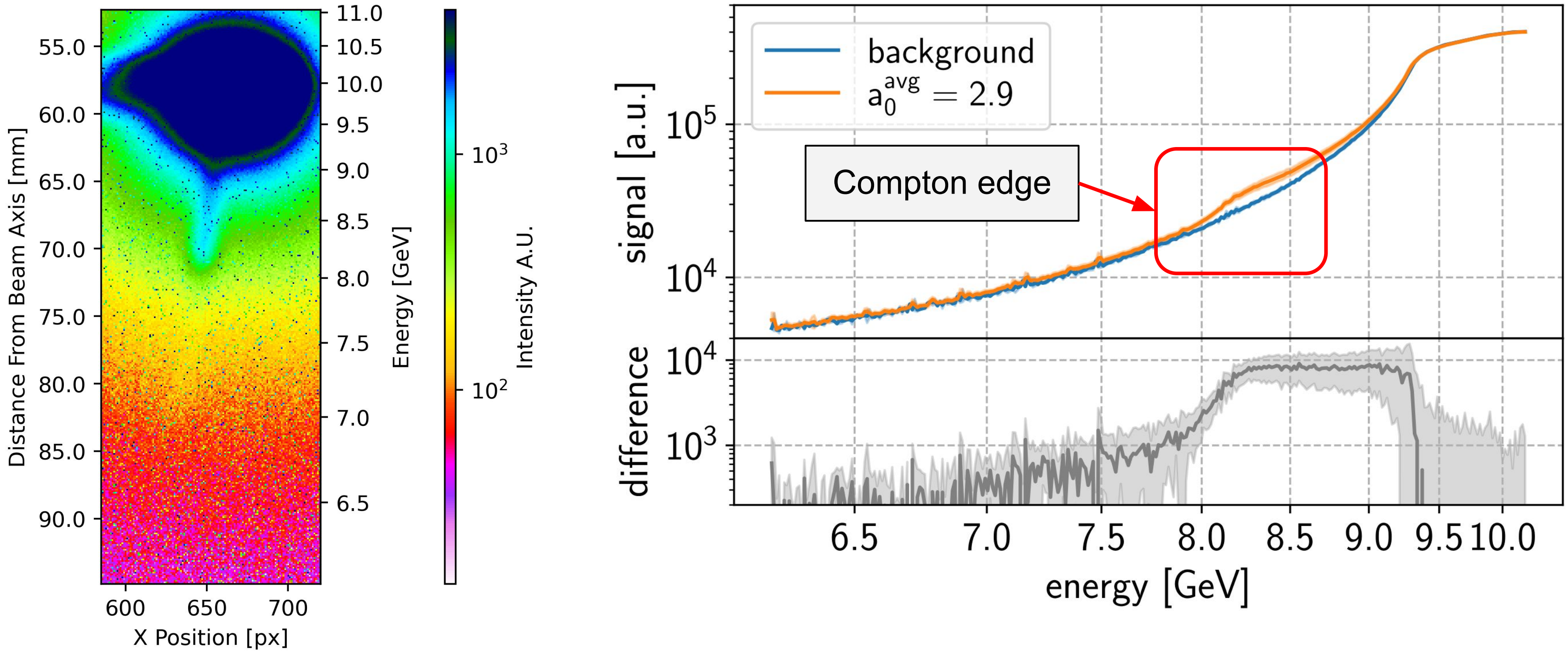
Cherenkov Data

- Measurements fully parasitic to E320
- Calibration measurements done without strong field QED interactions
- SiPM response (right)
- Main beam spot measurable
- Unstable beam conditions



Compton Spectrum Measurements

Scintillating Screen Data



Summary

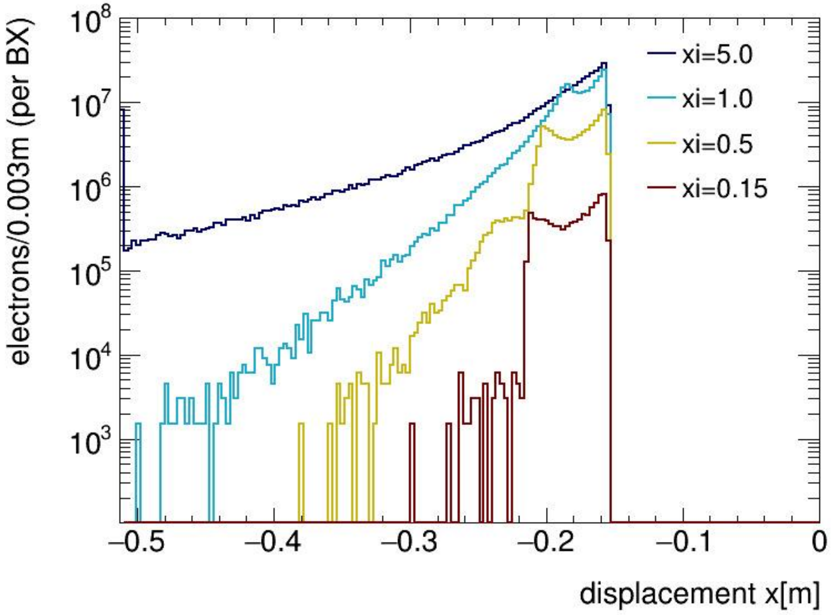
- Strong-Field QED presents a realistic opportunity to measure non-linearities in QED
- LUXE aims to study the transition into this regime
  ⟶ Needs robust detectors to measure large dynamic range of particle numbers
- Electron Detection System: Scintillating screen with segmented Cherenkov detector
- Prototype tested with E320 experiment at FACET-II
- Encouraging first results
  - Main beam measurable with Cherenkov detector
  - Compton spectrum visible on scintillating screen

Backup

Measurements

Simulations

LUXE



E320