

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

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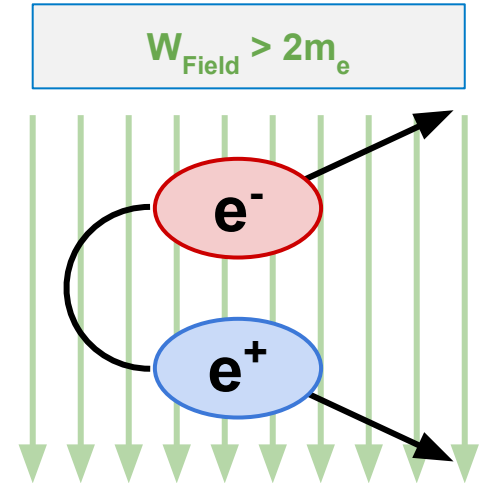
LUXE



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**, $\varepsilon_{cr} = 1.32 * 10^{18}$ V/m
 - **Intensity Parameter** ($\xi \equiv a_0$) \rightarrow Effective coupling to background field
 - $\xi \geq 1 \rightarrow$ Non perturbative
 - Quantifies how many photons interact with probe charge

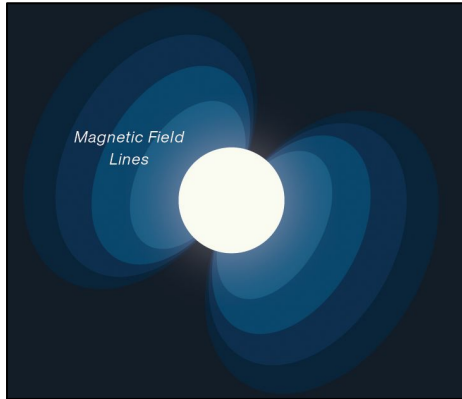


Strong-Field QED

In the Real World

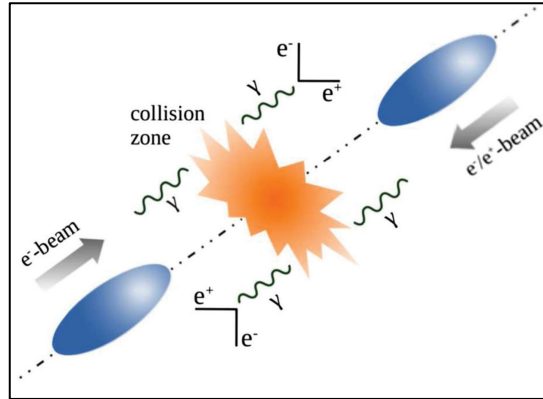
Where are these strong fields achieved?

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



<https://photojournal.jpl.nasa.gov/catalog/PIA23863>

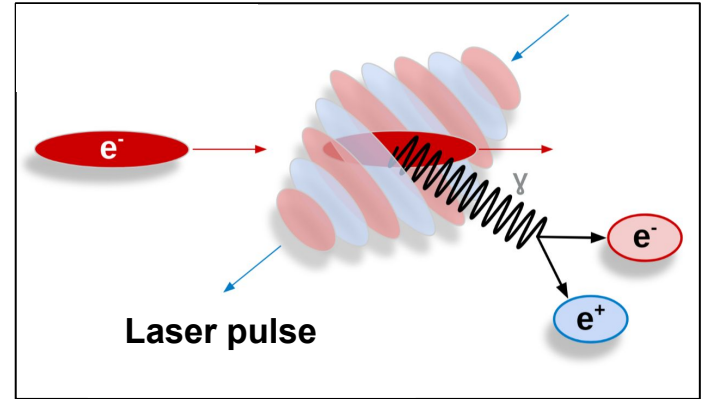
Future lepton colliders



DOI: 10.1103/PhysRevLett.122.190404

Beam-laser interactions

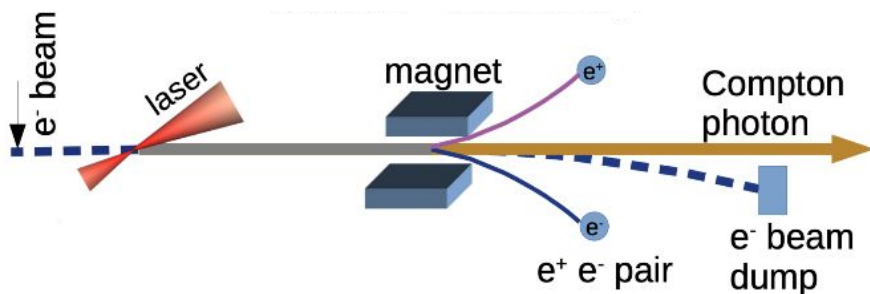
$$\epsilon_{rest\ fr} = \gamma \epsilon_{lab\ fr}$$



Strong-Field QED

LUXE

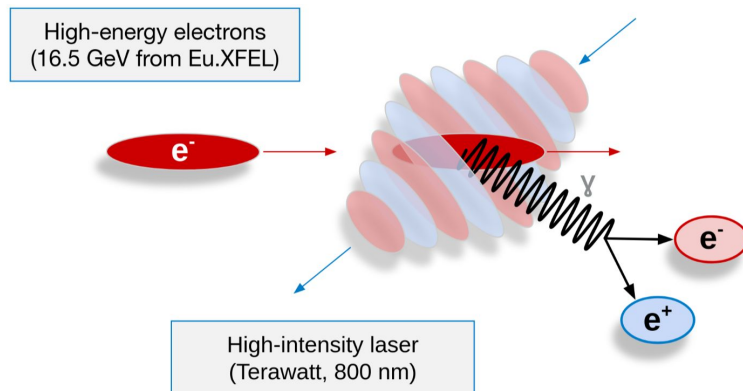
- Laser Und XFEL Experiment (LUXE)
- Planned at and DESY
- **Study transition from QED to Strong Field QED**
- High Energy electrons from European XFEL
→ $\sim 10^9$ electrons at 16.5 GeV
- Up to 350 TW Laser
- $\xi \leq 19$



LUXE

CDR: arXiv:2102.02032

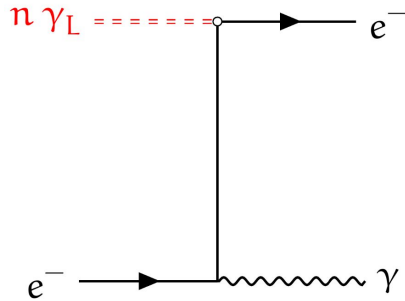
TDR: arXiv:2308.00515



Strong Field QED

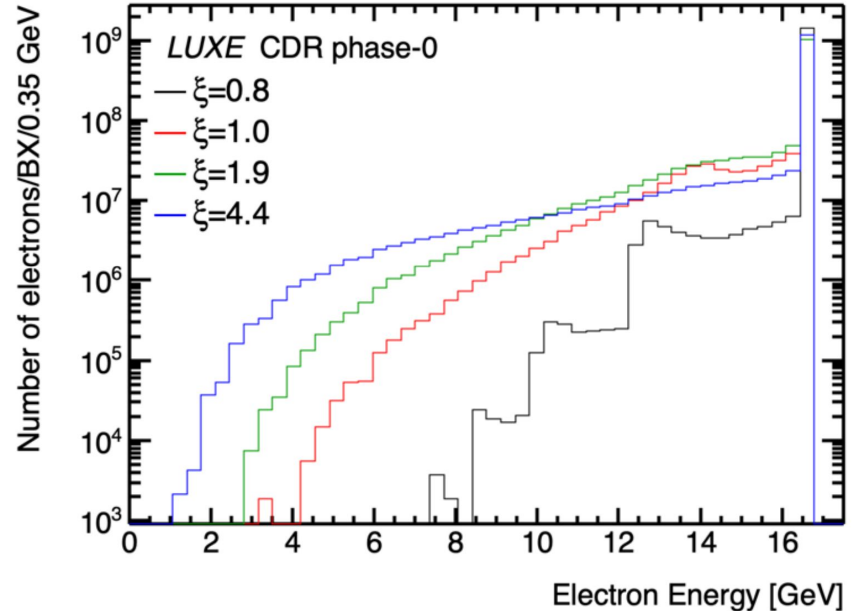
LUXE

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)

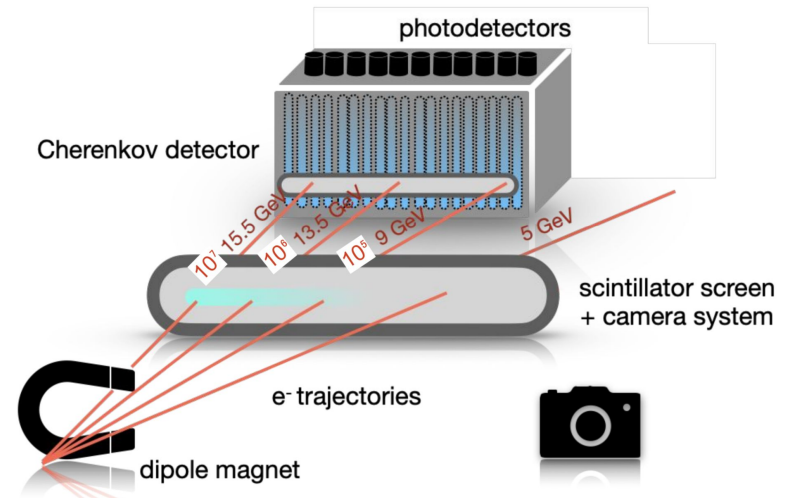
Detector Overview

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

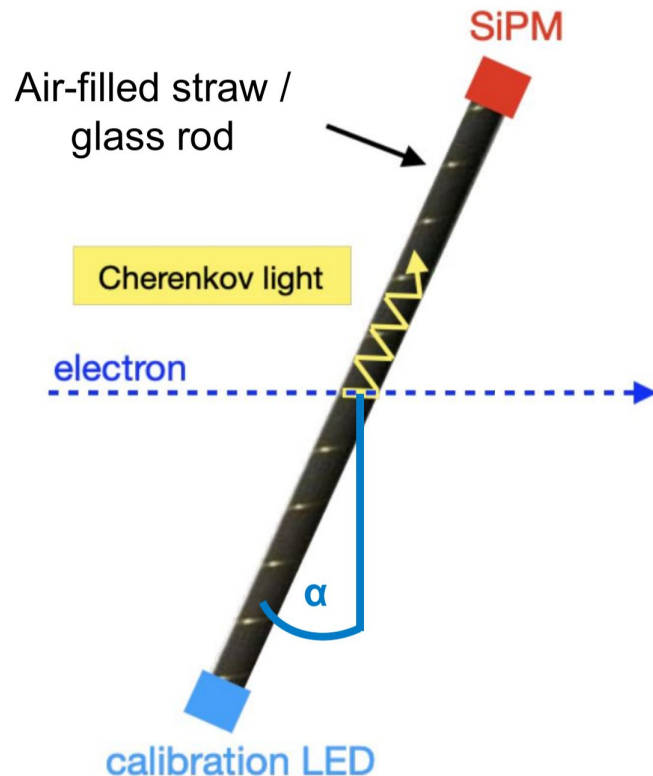
- Low Cherenkov production rate
→ Useful for high electron flux
- Energy threshold: 21 MeV

Solid glass rod

- Mainly SiO_2
- Higher sensitivity to low e^- intensities
- Energy threshold: 0.73 MeV

Silicon-Photomultipliers (SiPM)

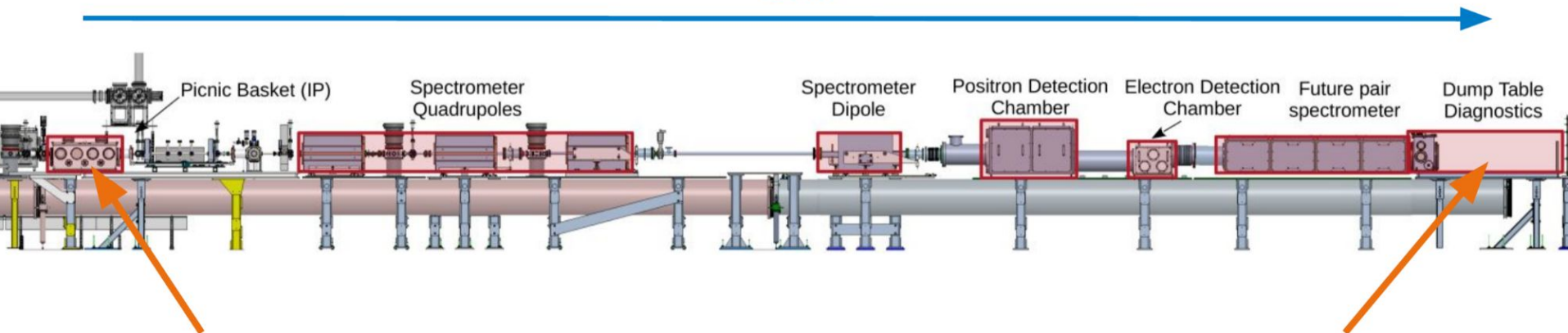
- High dynamic range
- Low bias voltage



Detector Tests at E320

FACET-II Overview

~ 25 m



Interaction Point for E320

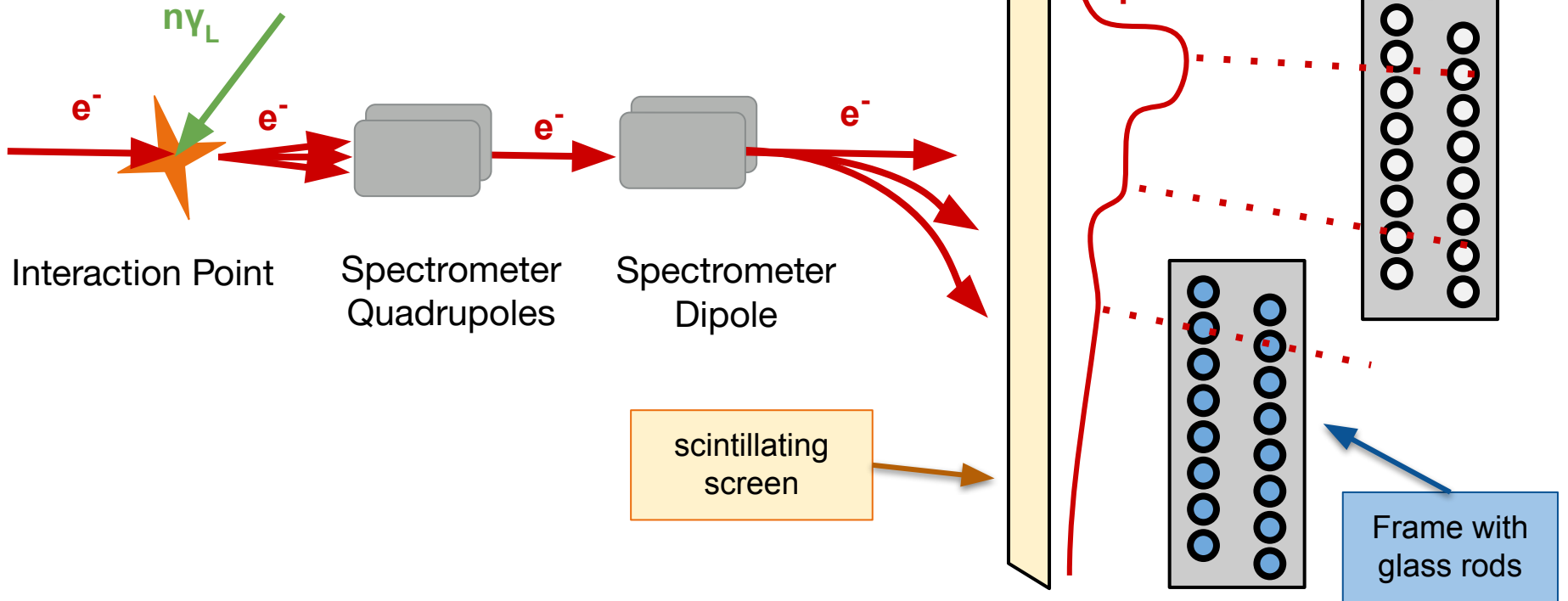
- 10 GeV electron beam, 1.6 nC
- 10 TW laser with ~ 0.3 J on target
- $\xi \leq 5$

Dump Table

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

Detector Tests at E320

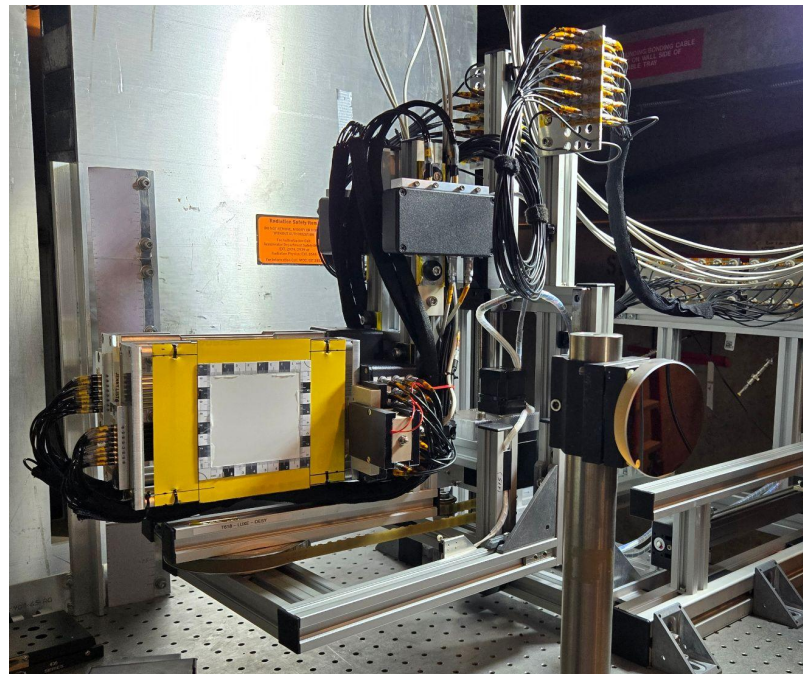
Experimental Setup Overview



Detector Tests at E320

Detector Prototype

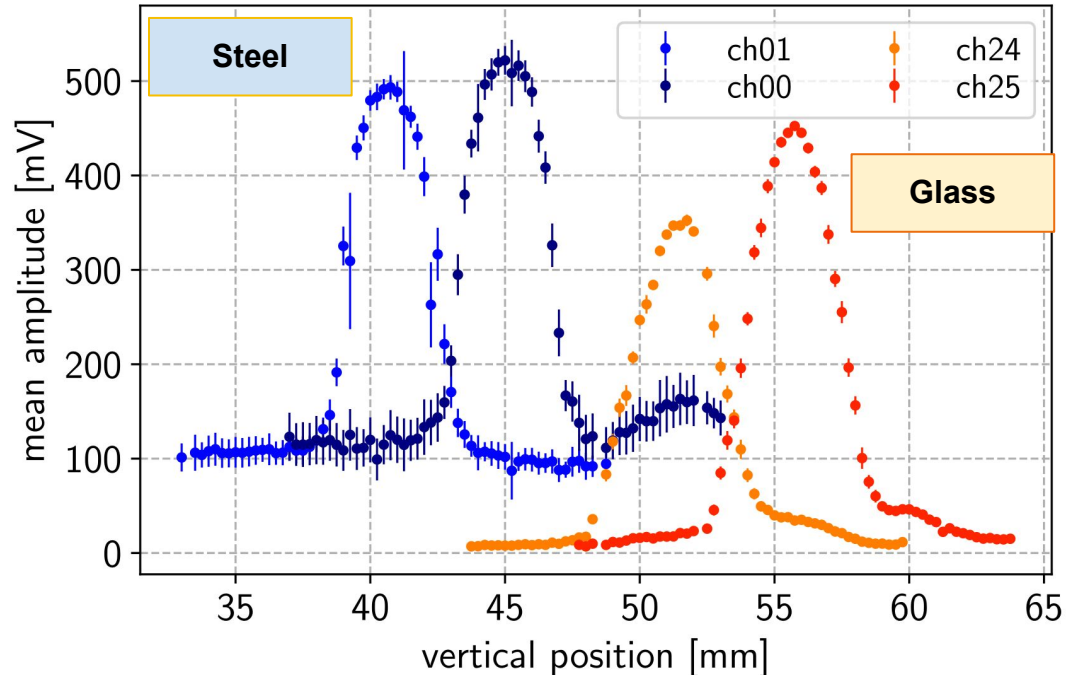
- 10x10cm scintillator screen
- 16 steel straws, 16 glass rods
- On a movable stage
 - Vertical, horizontal movement
 - Rotates around vertical axis
- Positioned just before beam dump



Calibration Measurements

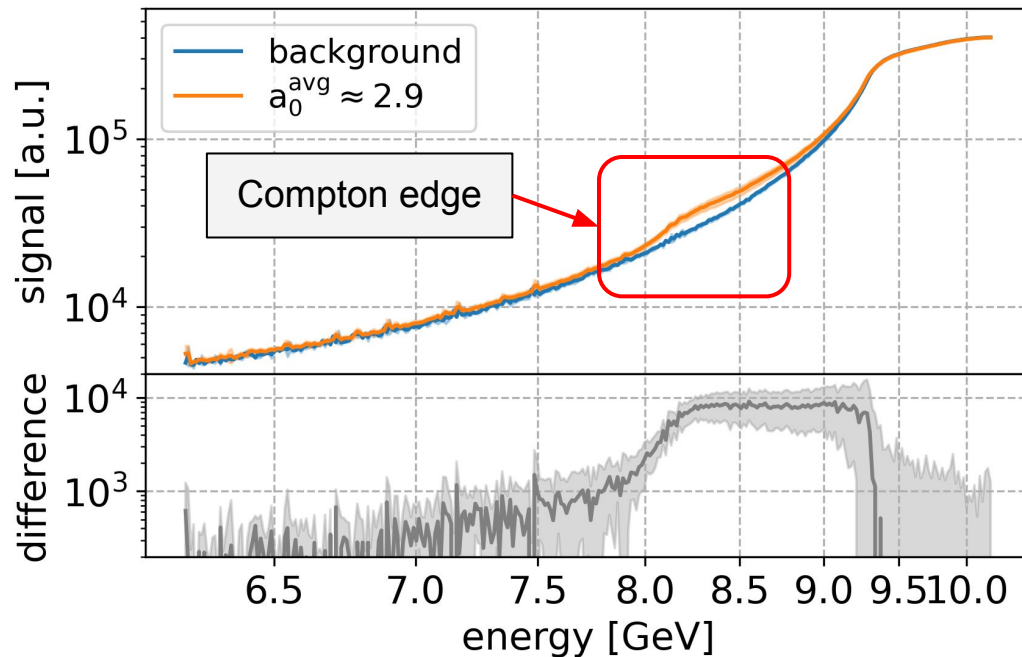
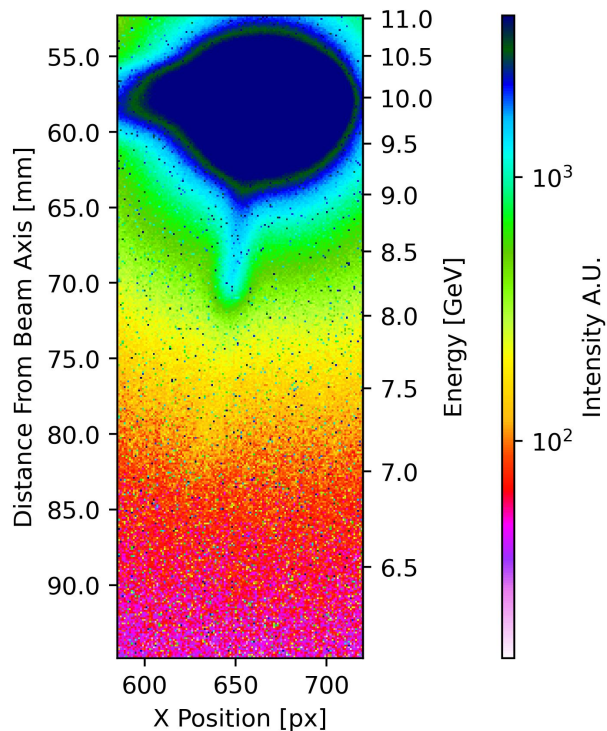
Cherenkov Data

- 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
- On the right path to make LUXE a reality by the end of the decade

The logo for the LUXE experiment, featuring the word "LUXE" in a bold, blue, sans-serif font. The letter 'X' is stylized with a white starburst or spark effect at its center.

CDR: arXiv:2102.02032

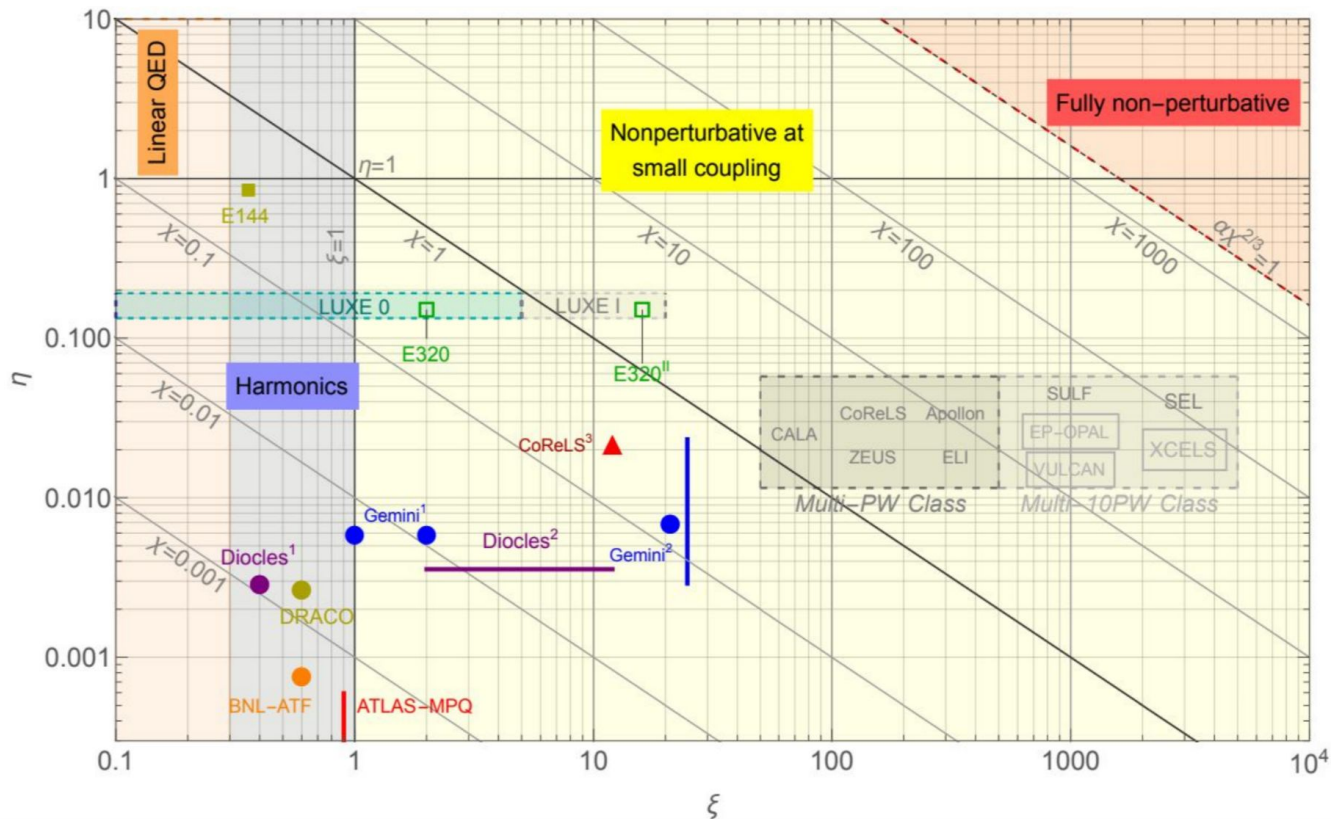
TDR: arXiv:2308.00515

*Special thanks to the E320
collaboration and the people
working on FACET-II for making
this possible*

Backup

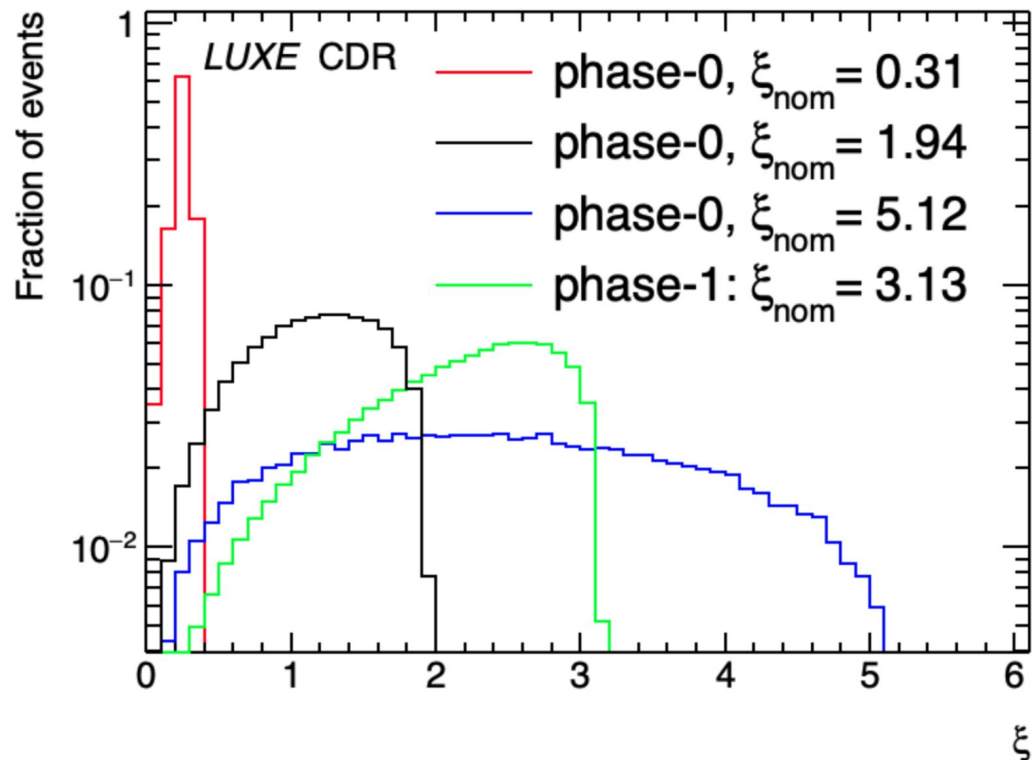
Strong Field QED Experiment Landscape

Non-Linear



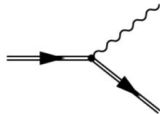
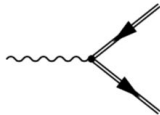
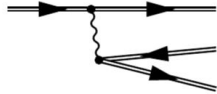
Strong Field QED

ξ -distributions

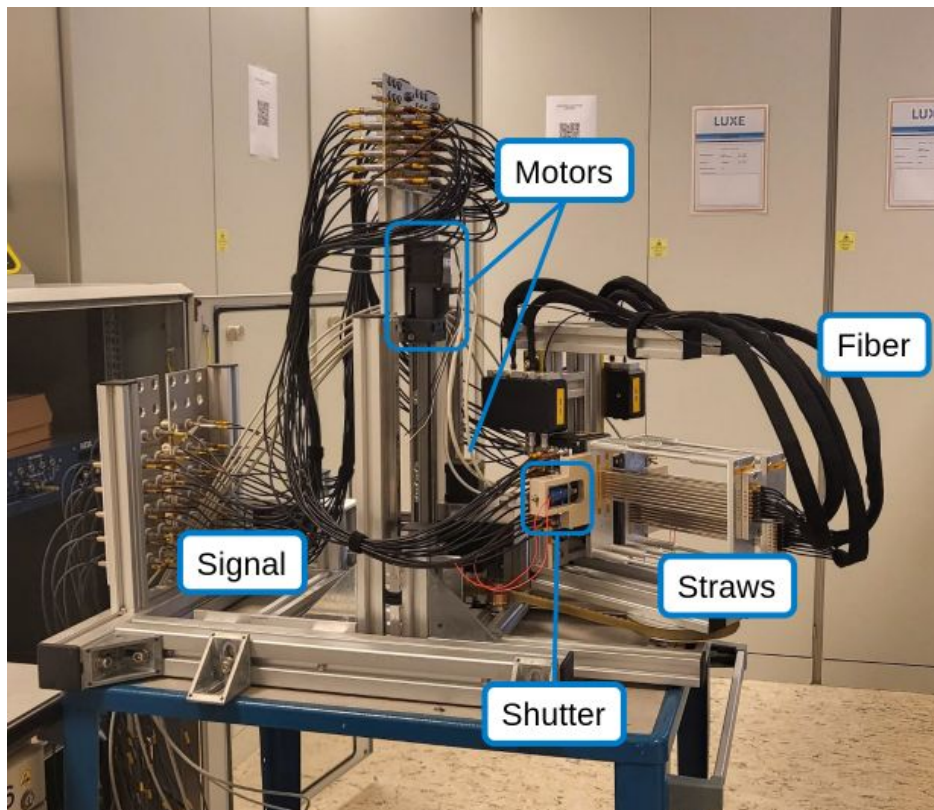


LUXE

Candidate Processes

LUXE Candidate Processes		
	Non-linear Compton	$e^{\pm} \rightarrow e^{\pm} + \gamma$
	Non-linear Breit-Wheeler	$\gamma \rightarrow e^{-} e^{+}$
	Non-linear trident	$e^{\pm} \rightarrow e^{\pm} + e^{-} e^{+}$

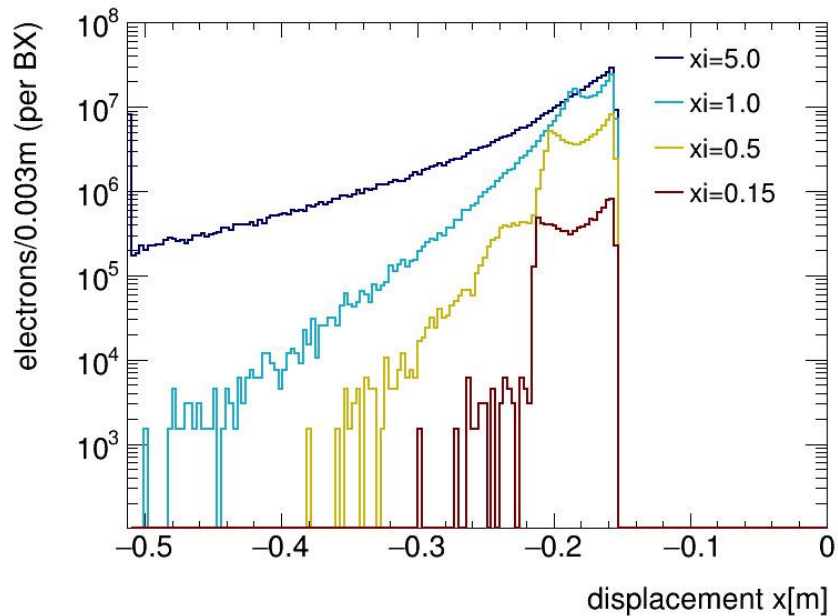
Overview EDS Prototype



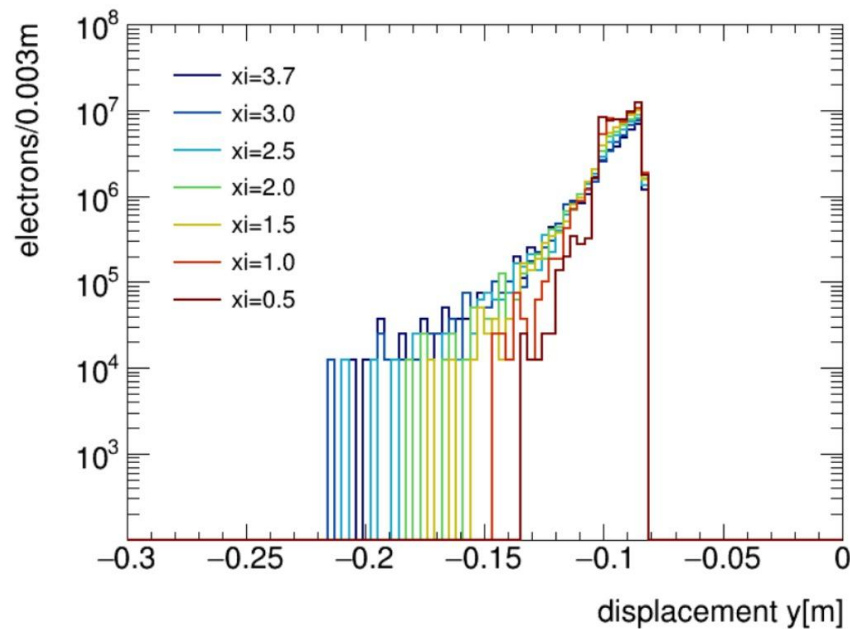
Measurements

Simulations

LUXE



E320



Compton Spectrum Measurements

- Find main beam spot using algorithm
- From there get Compton spectrum area
- For each horizontal slice:
 - 1) Apply median filter to filter out noise and dead pixels
 - 2) Take integral of this slice

