Prototype of a Cherenkov detector for the LUXE Experiment

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HELMHOLTZ LUXE FTX UHH Universität Hamburg DER FORSCHUNG | DER LEHRE | DER BILDUNG CLUSTER OF EXCELLENCE QUANTUM UNIVERSE DESY.

LUXE - Laser Und XFEL Experiment

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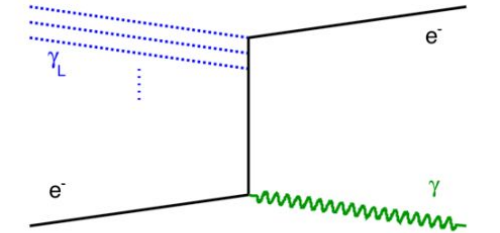
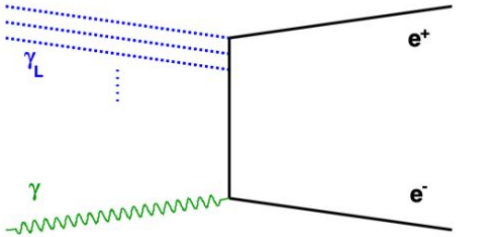
- To achieve field strength necessary for this non-linear regime (>Schwinger-Limit):
  - Relativistic electrons (16.5 GeV) from EU.XFEL will interact with a 40 - 350 TW laser[1]
  - Two effects have to be considered:



Non-linear Compton Scattering

$e^- + n\gamma_L \rightarrow e^- + \gamma_C$



Breit-Wheeler pair production

$\gamma_C + n\gamma_L \rightarrow e^+ + e^-$

[1] EPJST 230, 2445 - 2560 (2021)

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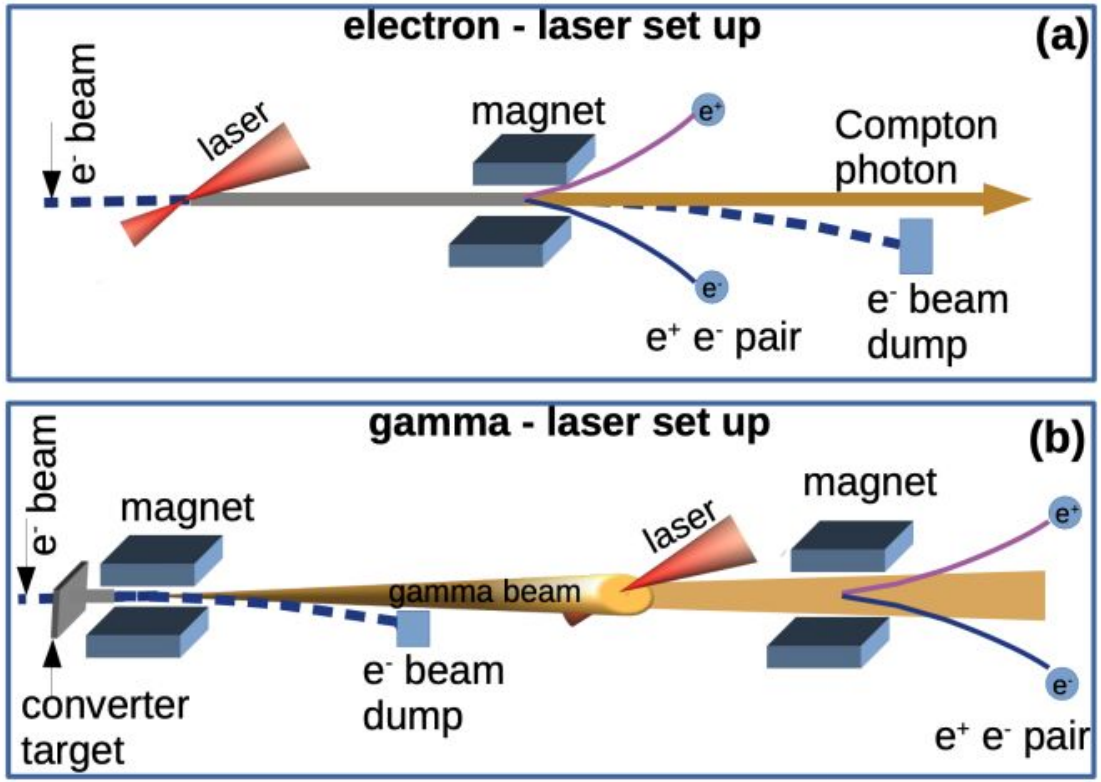

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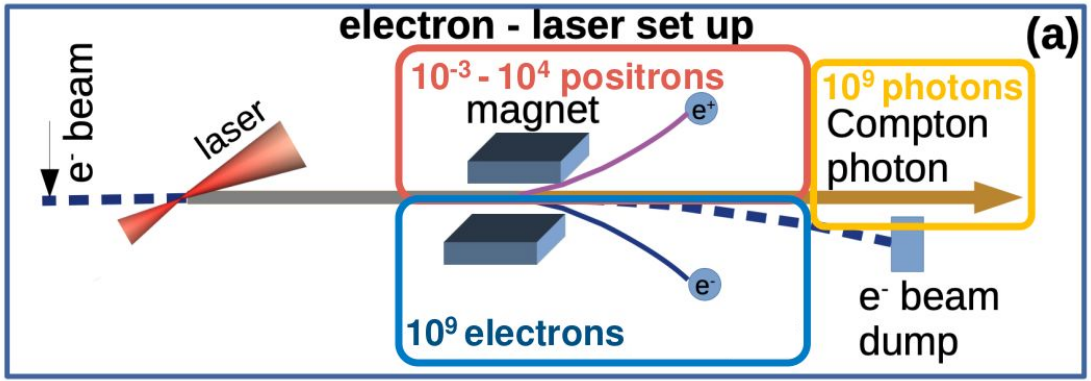

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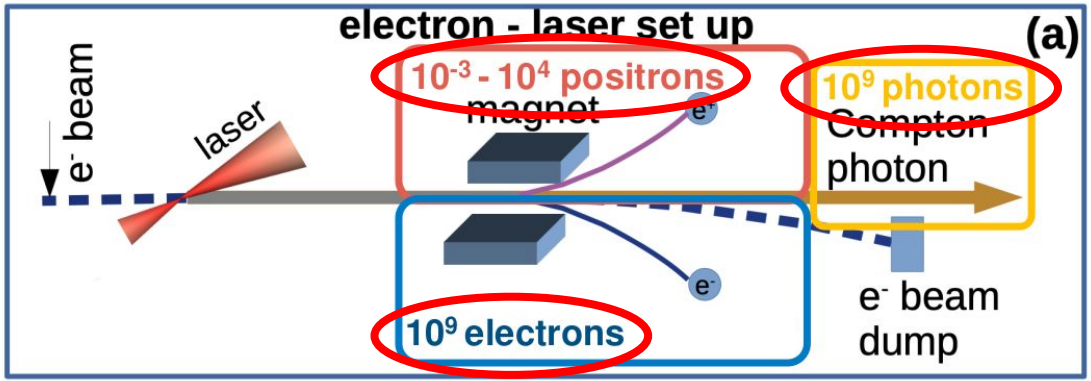

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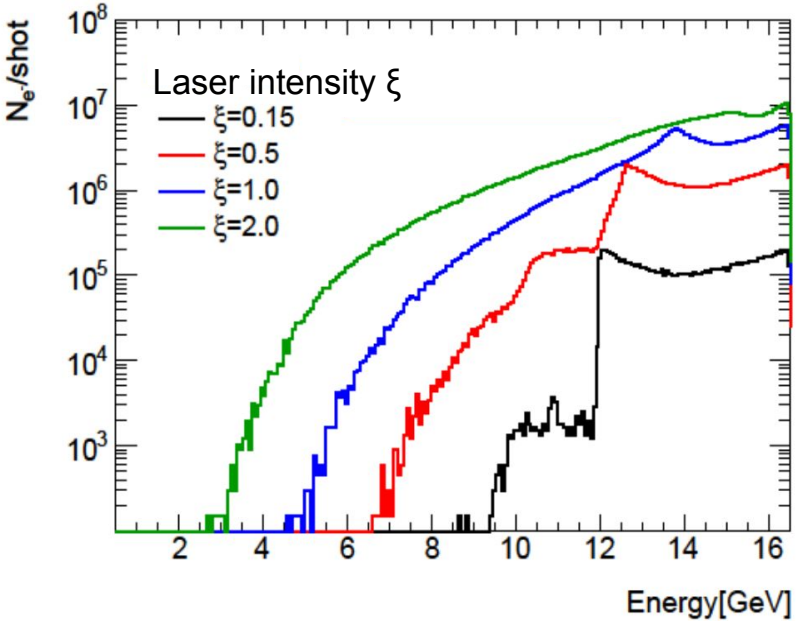
- Detector systems have to deal with high particle rates
  - Here: Focus on the Electron-Detection-System

LUXE - Laser Und XFEL Experiment

Preliminary simulation studies



- Compton edge is shifting non-linearly with laser intensity ξ
- Electron intensities: 10^4 to 10^9 particles
  - High dynamic range in energy spectra
  - **Flux tolerant electron detector needed**

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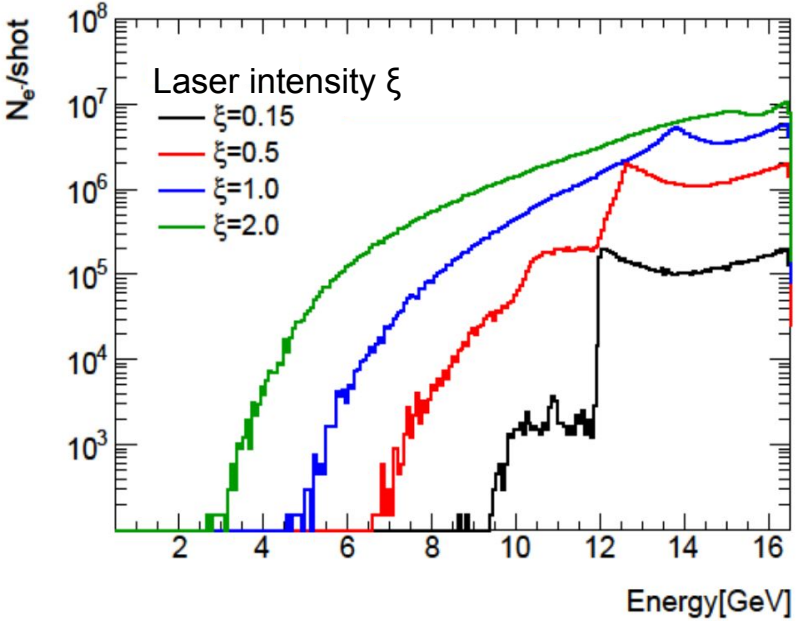

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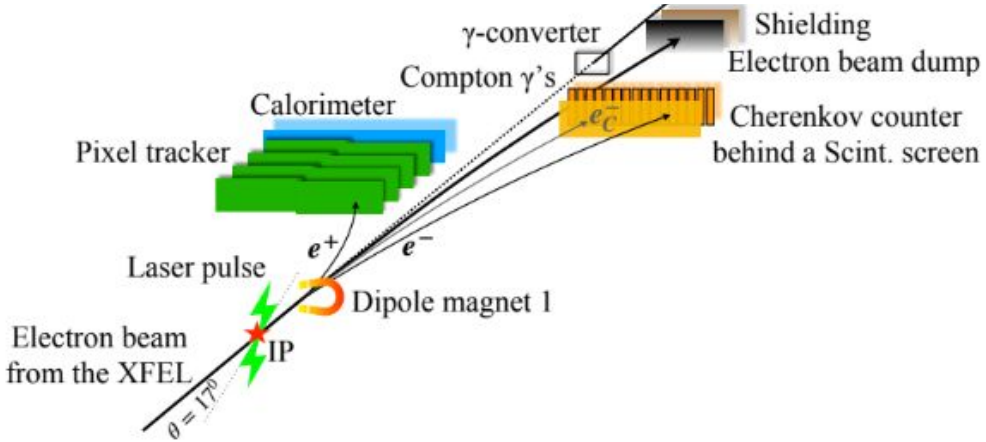

Cherenkov detector system

Requirements

- Requirements strongly linked to dipole properties
  - Area of 15 cm x 1 mm has to be covered

- Aiming for an energy resolution below 2%
  - spatial segmentation of **Δx = 3 mm**

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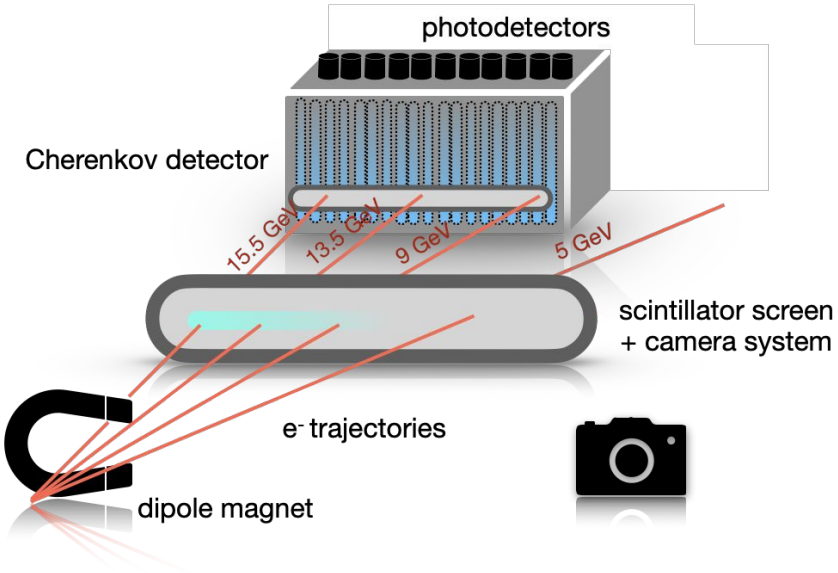
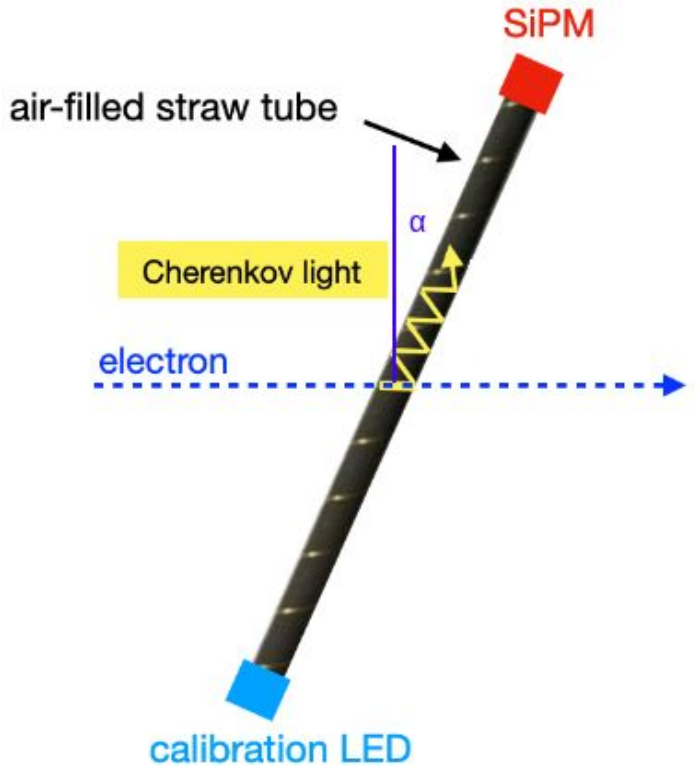
- Cherenkov detector will consist of reflective straws (or tubes) aligned in a grid



Cherenkov detector system

Technical details

- Straws filled with air as optical medium
- Cherenkov light produced by electrons will be captured
- Optical photons guided towards Silicon-Photomultipliers (SiPMs)



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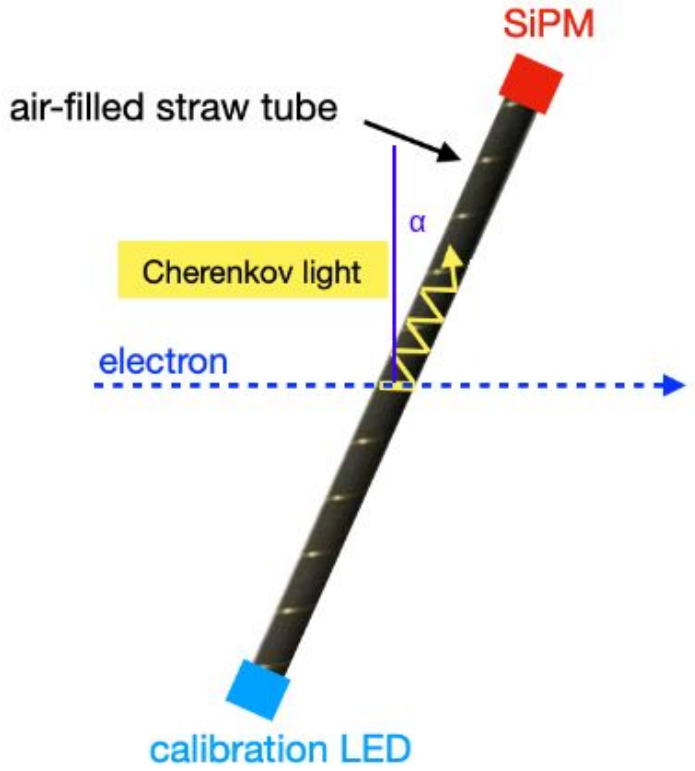
- Many parameters have to be optimized:
  - Straw dimensions, material, reflectivity and position
  - SiPM dimensions and characteristics



Monte-Carlo simulations on the Cherenkov detector

GEANT4 - Geometry And Tracking 4

- Study of electron interactions via Monte-Carlo techniques

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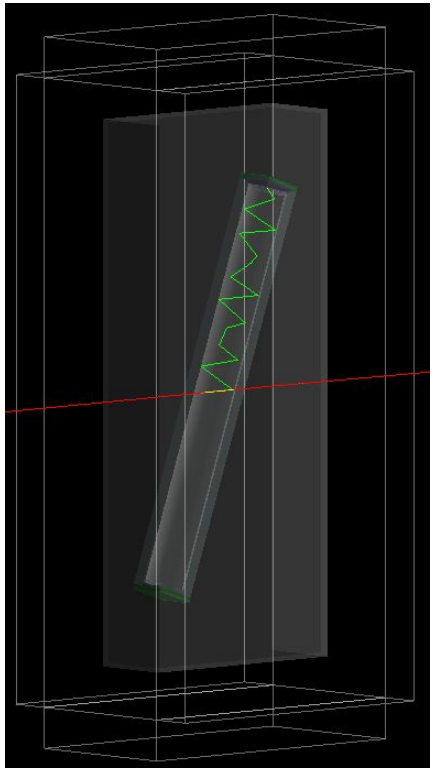

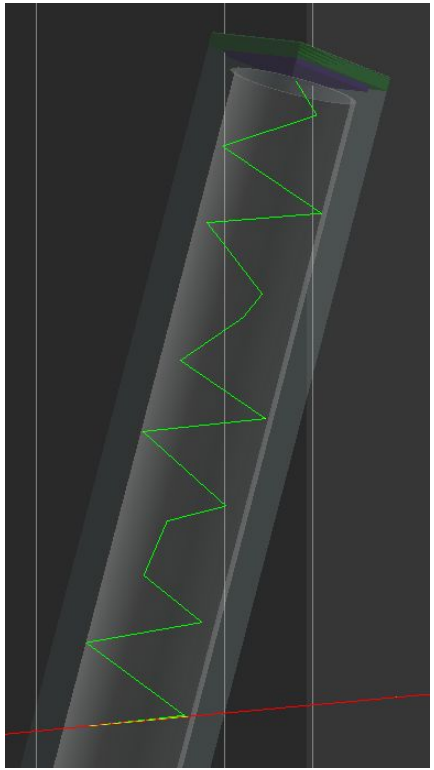

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- Study of electron interactions via Monte-Carlo techniques
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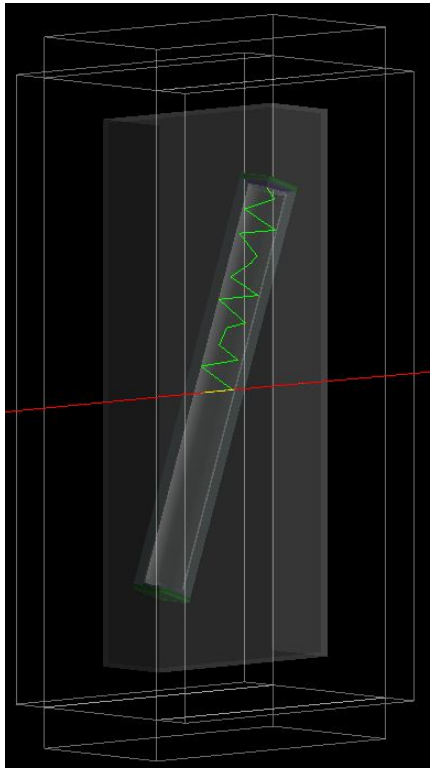
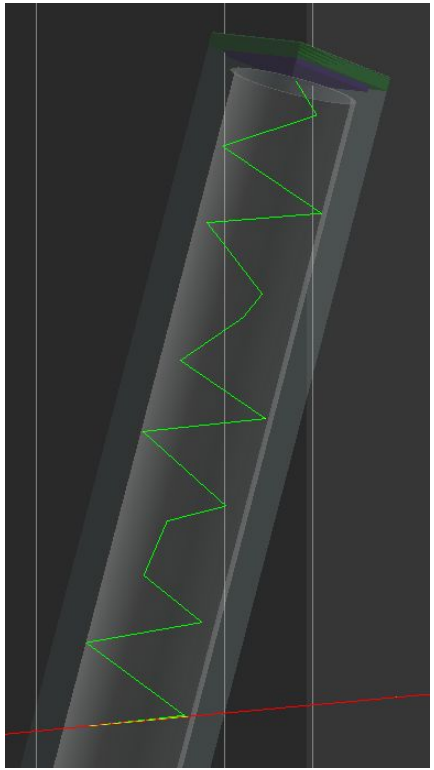
- Cherenkov light and optical properties simulated
- Straw parameters e.g. **dimensions**, **reflectivity** or the **angle** are considered





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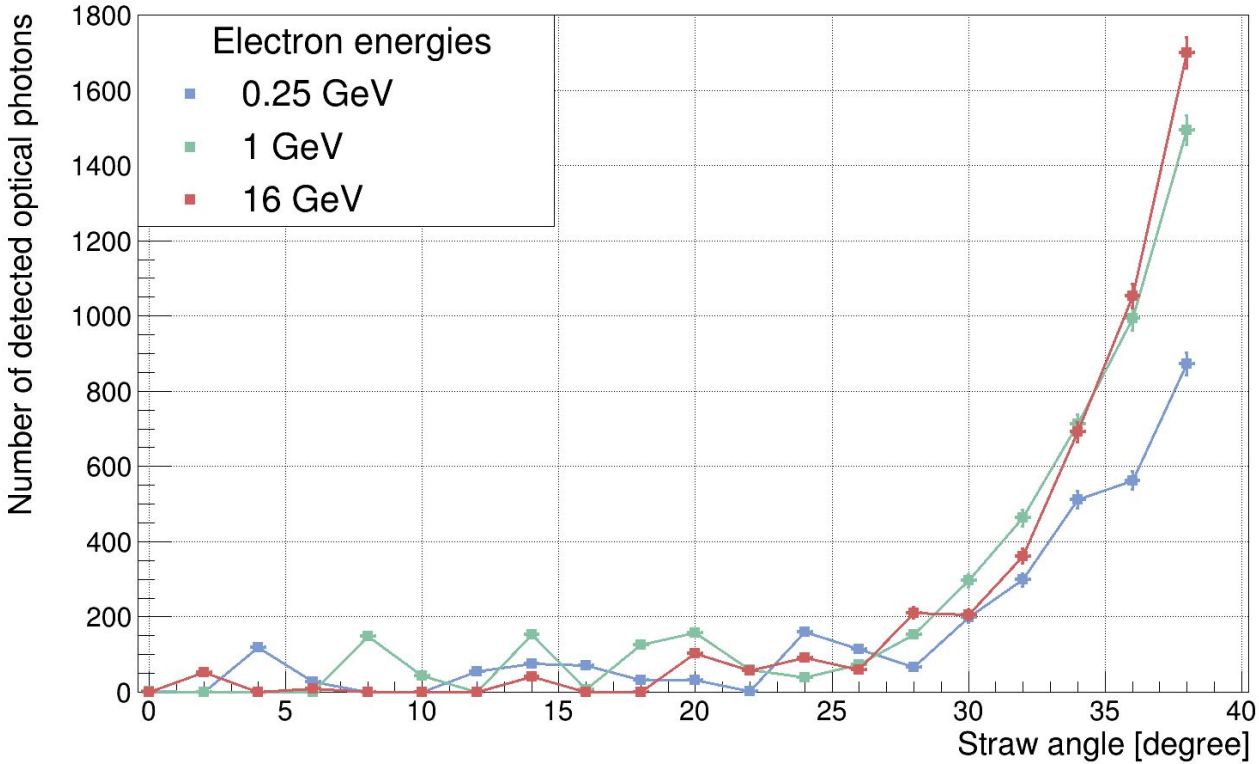
Analysis of efficiency studies

- Number of photons represents signal intensity



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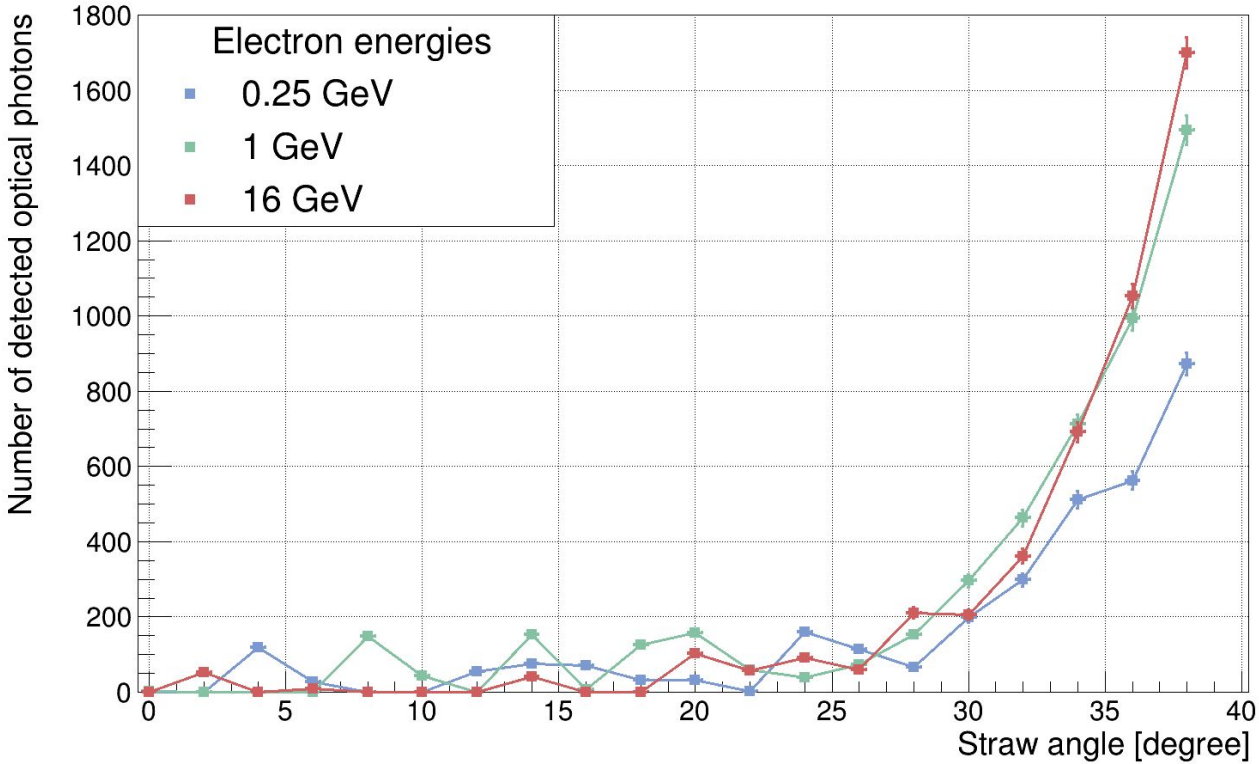
➤ Strong dependence on angle



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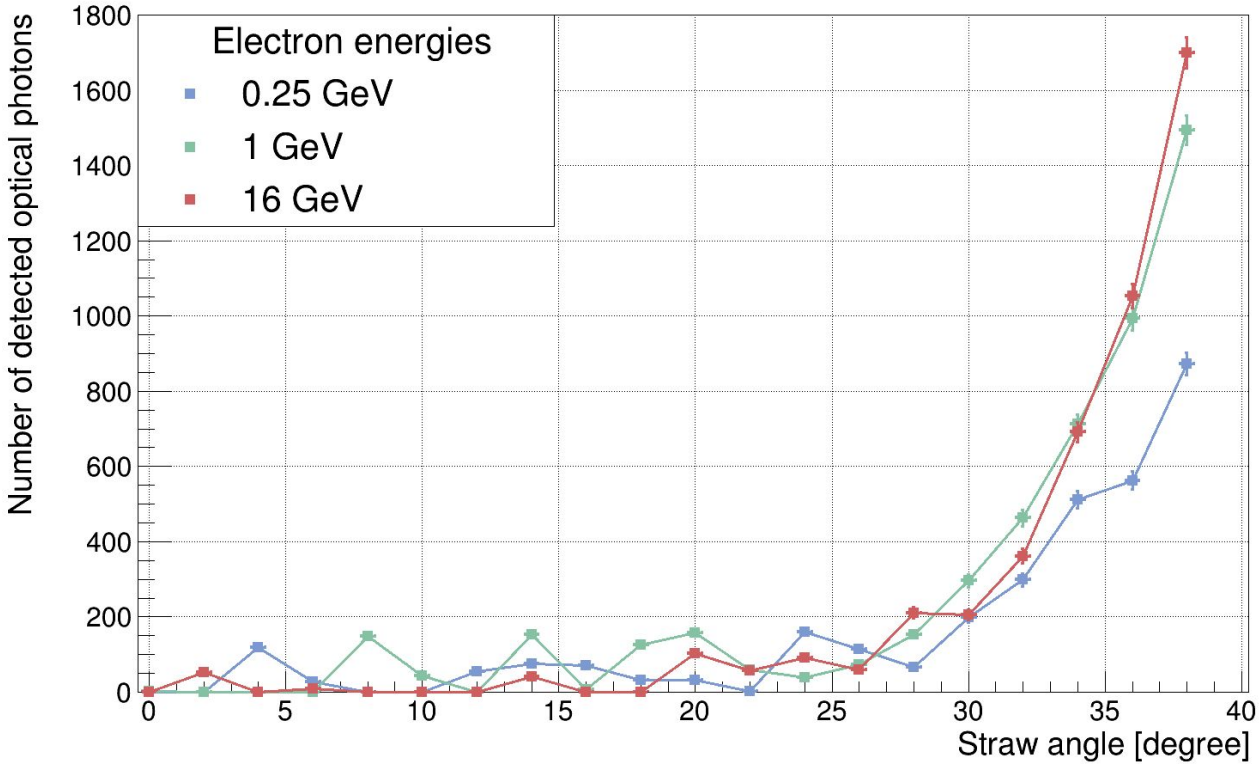
➤ Strong dependence on angle

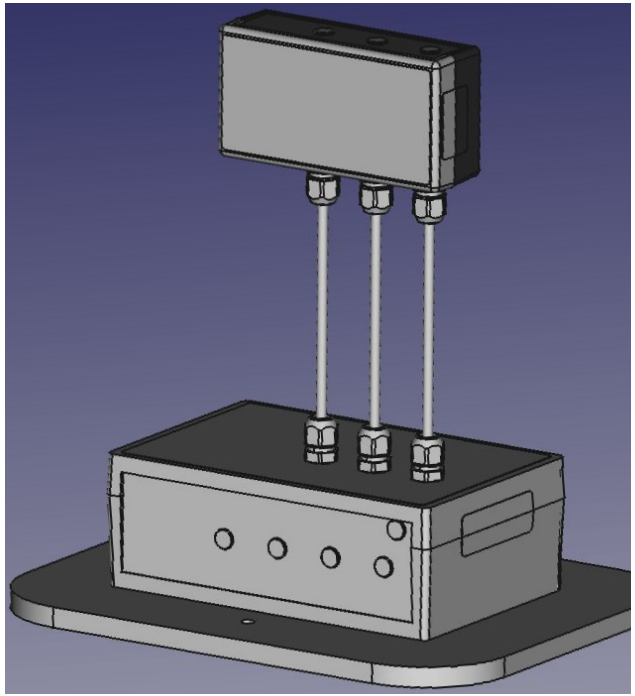
➤ Control of high dynamic range via straw angle variations



Experimental work

Prototype

- Designed prototype was built by the technical team for studies on a high-rate electron testbeam



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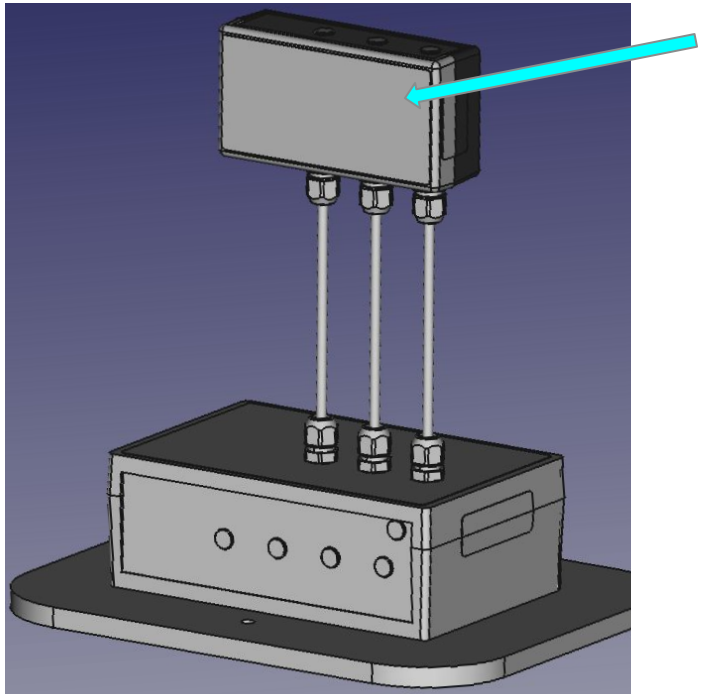

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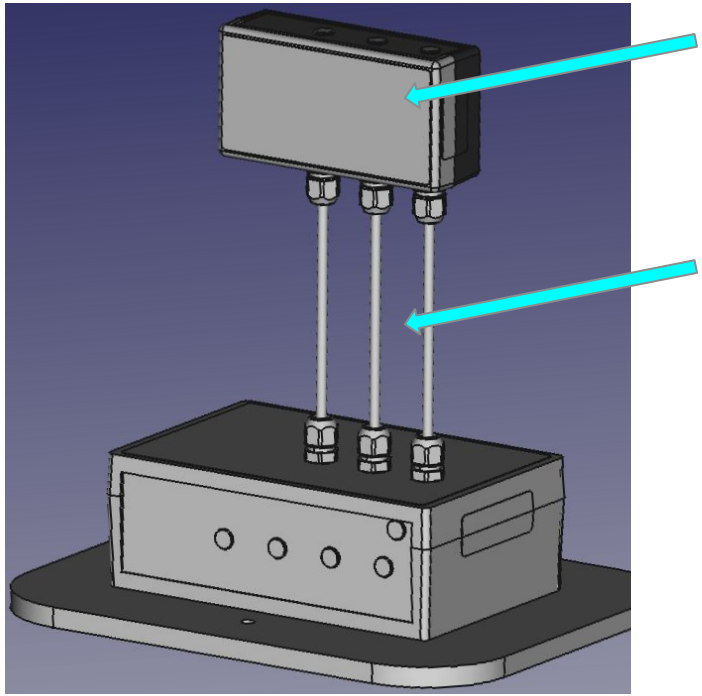

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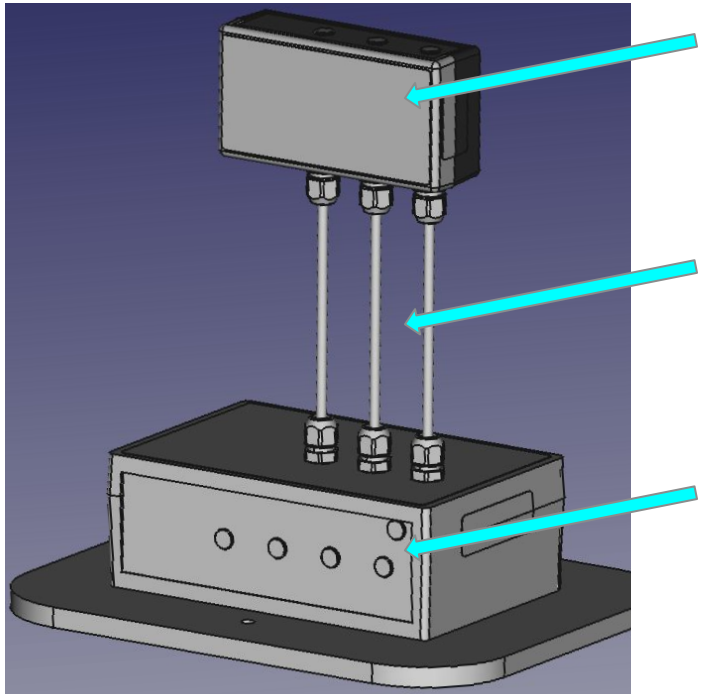

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The lower box contains a readout board for the SiPMs

Experimental work

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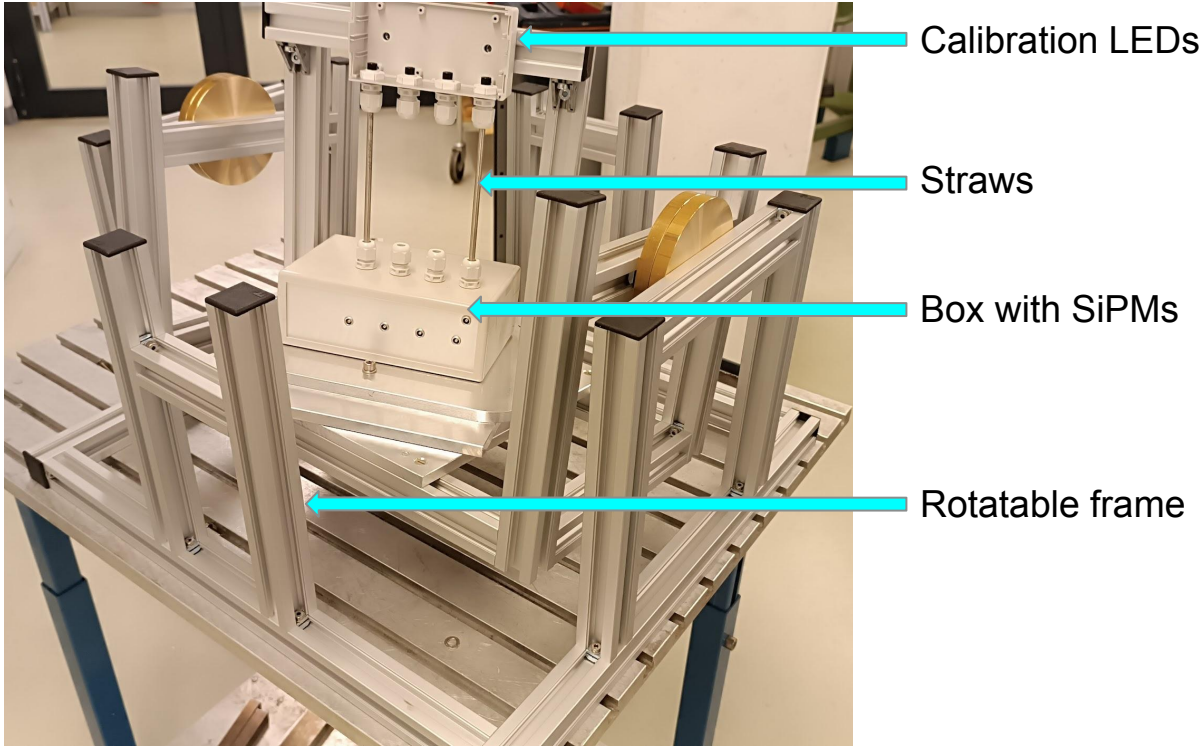
- Dimensions of 50x50x40 cm³
- Straws / SiPMs exchangeable
- Straws rotatable
  - Along / Parallel to beam
  - Angle of max. ±30°



Future plans

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- Further simulation studies will underline measurements

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- First simulation studies show that signal intensities can be adjusted by straw angle variations

- To validate simulation data, further measurements have to be taken

Thank you

Contact

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