Calorimeter R&D for LPA Polarimetry

Felix Stehr[1, 2], Simon Bohlen[2], Oleksandr Borysov[3], Maryna Borysova[3], Jennifer Popp[1, 2], Jenny List[2], Gudrid Moortgat-Pick[1, 2], Jens Osterhoff[2] and Kristjan Põder[2]

DPG Spring Meeting, 22.03.2022

[1] Deutsches Elektronen-Synchrotron (DESY)
[2] Universität Hamburg
[3] Weizmann Institute of Science, Rehovot, Israel

HELMHOLTZ

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

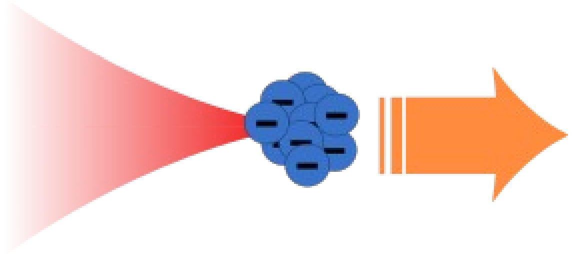
FTX

DESY.

Context

LEAP Project – Laser Electron Acceleration with Polarization

Aim: **Generation of relativistic polarized electron beams from a laser-plasma accelerator (LPA) for the first time**



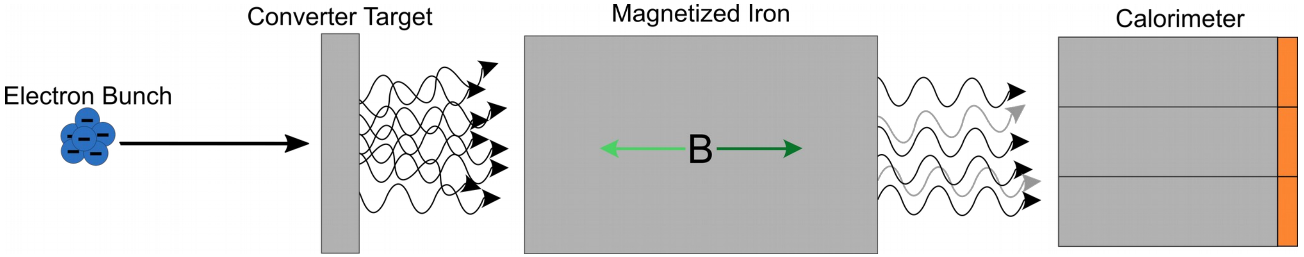
- Generation of a polarized electron beam with LPA

- Measuring the polarization of the generated beams

How to measure the polarization?

Transmission polarimeter for LEAP

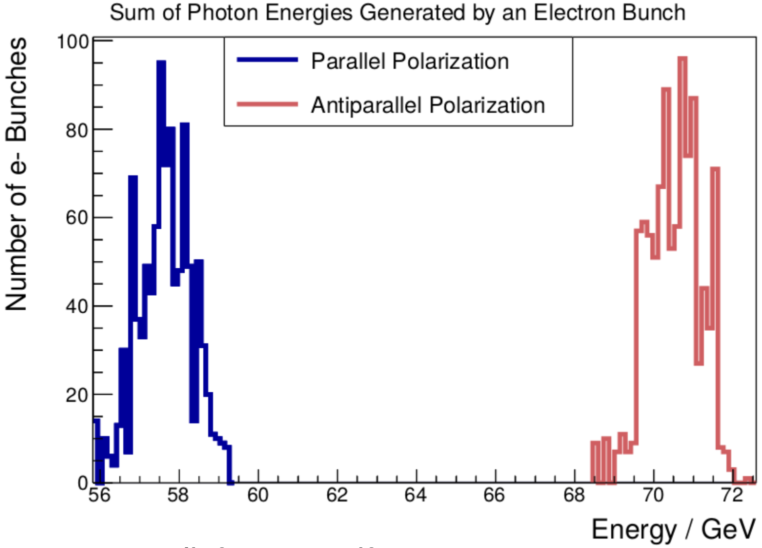
- The magnitude of the asymmetry with respect to the magnetization direction is proportional to the photon polarization.
- The value we have to measure in the experiment is the photon energy sum



Electron-Photon-Conversion

Polarization Dependent Transmission

Photon Detection



➡Talk from Jennifer Popp

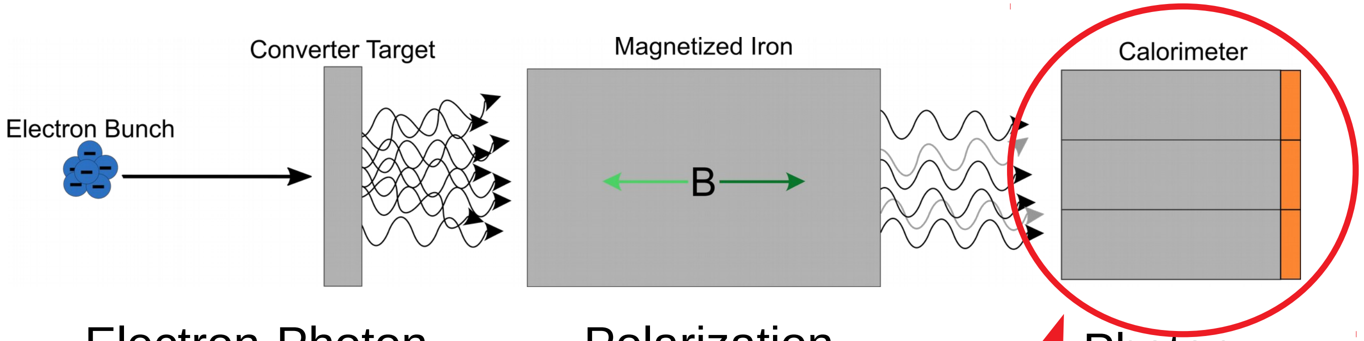
$$\delta = \frac{\bar{E}_{AP} - \bar{E}_P}{\bar{E}_{AP} + \bar{E}_P}$$

$$P = \frac{\delta}{\text{analyzing power}}$$

How to measure the polarization?

Transmission polarimeter for LEAP

- The magnitude of the asymmetry with respect to the magnetization direction is proportional to the photon polarization.
- The value we have to measure in the experiment is the photon energy sum

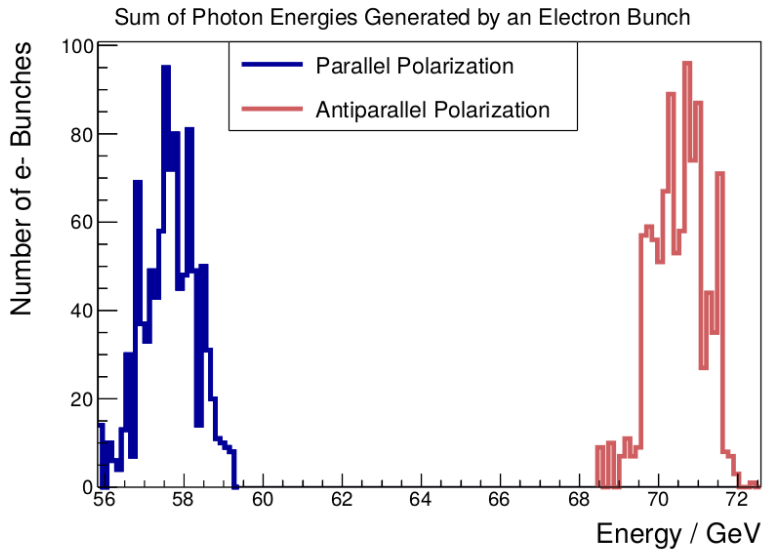


Electron-Photon-Conversion

Polarization Dependent Transmission

Photon Detection

Starting off with a
lead glass calorimeter



$$\delta = \frac{\bar{E}_{AP} - \bar{E}_P}{\bar{E}_{AP} + \bar{E}_P}$$

$$P = \frac{\delta}{\text{analyzing power}}$$

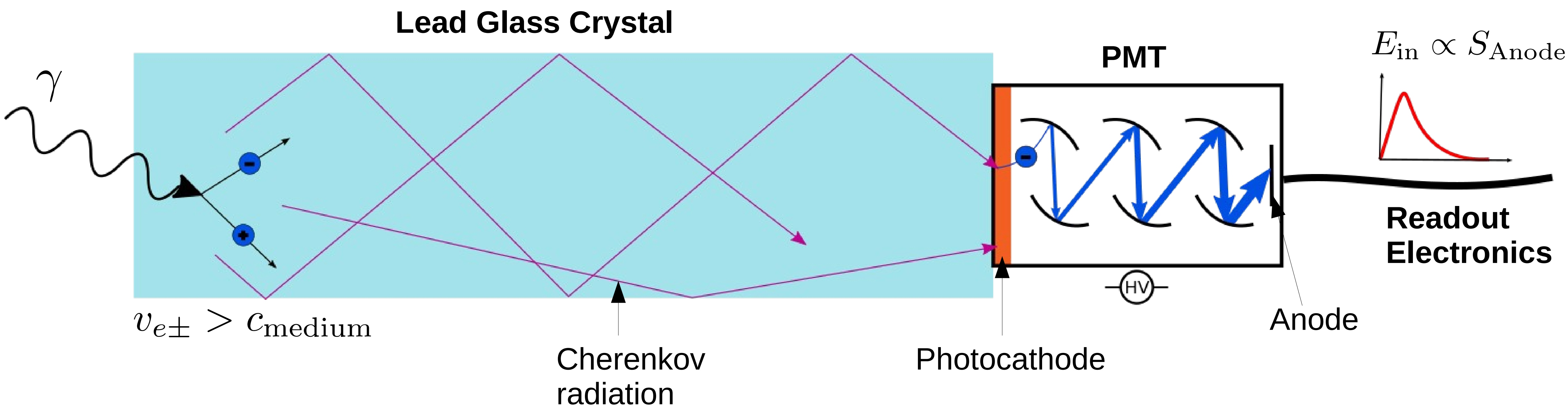
➡ Talk from Jennifer Popp

Lead glass calorimeter

Basic concept

Lead glass calorimeter

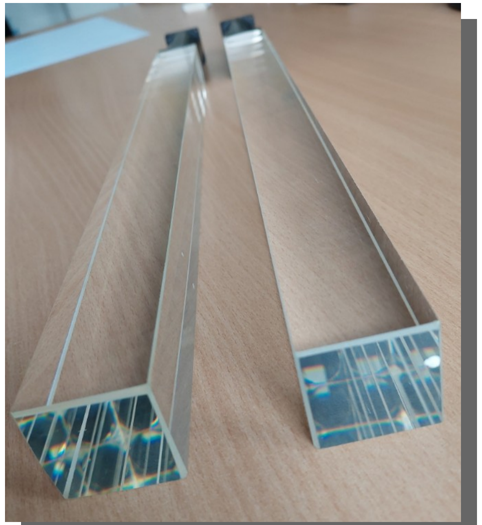
Basic concept



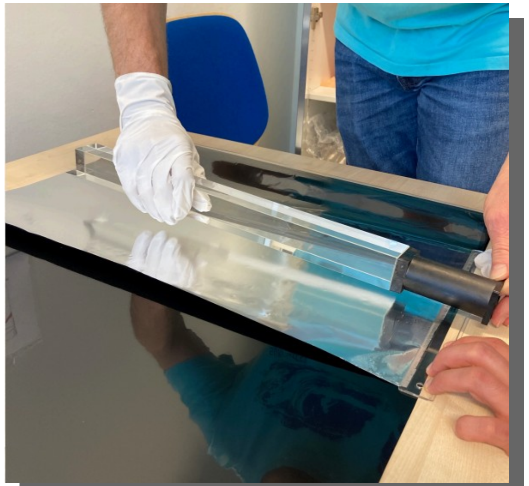
First prototype

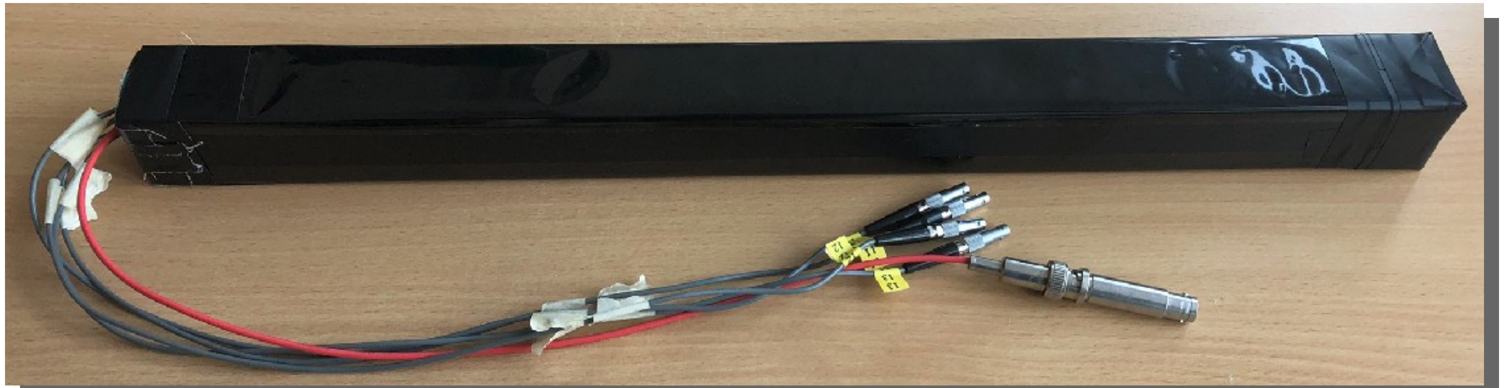
Assembly of the calorimeter prototype

- TF1 lead glass crystal (38x38x450)mm^3
- PMT attached to the crystal with a 3D-printed mount
- Crystal wrapped in aluminum and light tight vinyl foil
- Planning to use 9 crystals in a 3x3 array for the LEAP calorimeter



Hamamatsu R7600U-M4



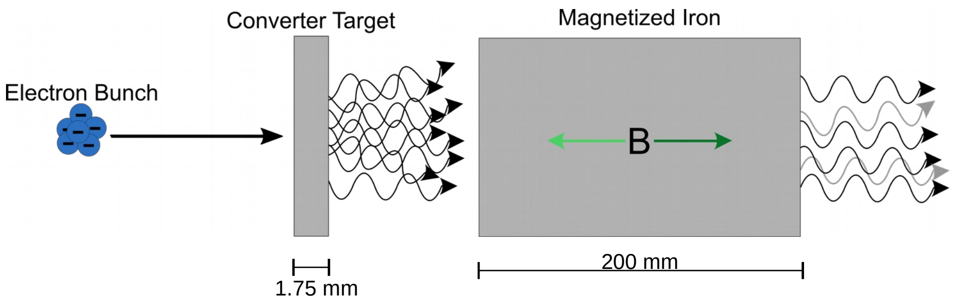


Necessary energy resolution

Expected parameters

Electron bunch

Energy	25 MeV
Bunch charge	1 pC
Polarization	~ 25 %



Polarimeter

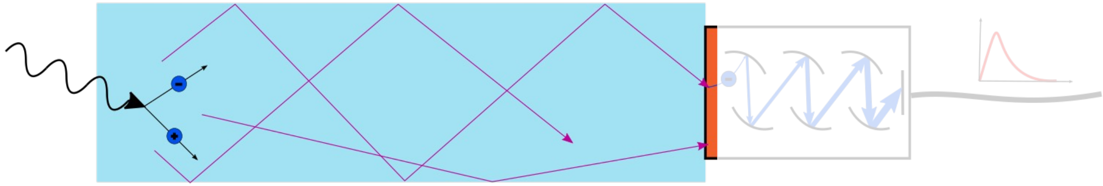
Analyzing Power	~ 30 %
Transmitted energy	~ TeV

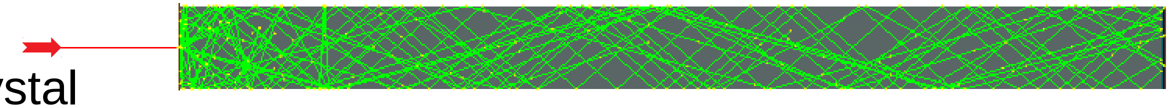
➡ Talk from Jennifer Popp

- Expected asymmetries ~ 7.5 %
- Energy resolution around **2 %** required
- Is the energy resolution of the calorimeter a limiting factor?
- Next step: Check the energy resolution of the prototype using GEANT4 simulations

Calorimeter simulations

Using GEANT4

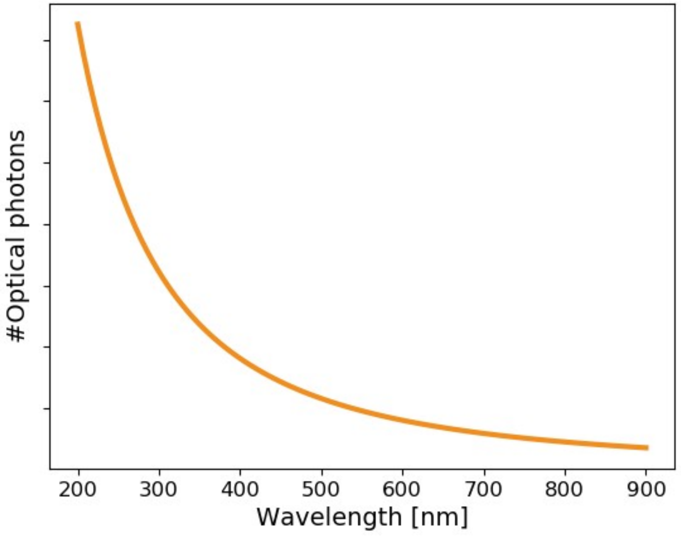




- Geometry of the calorimeter
  - Lead glass crystal (38x38x450)mm^3
  - Aluminum and vinyl foil wrapping
  - Sensitive detector volume at the back of the crystal (counts optical photons)
- Simplified idealistic gamma beam
- GEANT4 optical PhysicList including:
  - Cherenkov process
  - Absorption
  - Boundary process

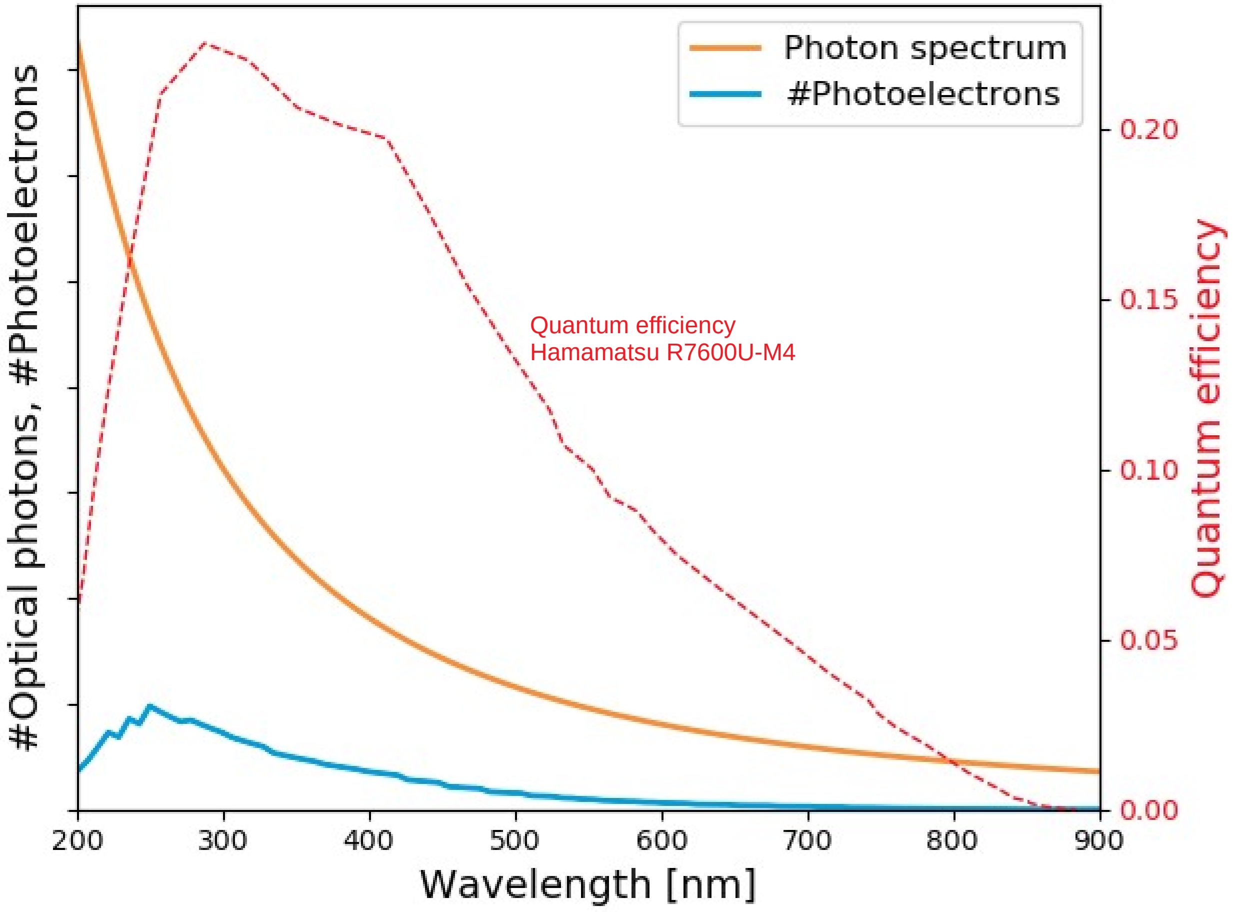
<u>Frank-Tamm formula</u>

$$\frac{d^2N}{dx d\lambda} = \frac{2\pi\alpha Z^2}{\lambda^2}\left(1 - \frac{1}{\beta^2 n^2(\lambda)}\right)$$



Calorimeter simulations

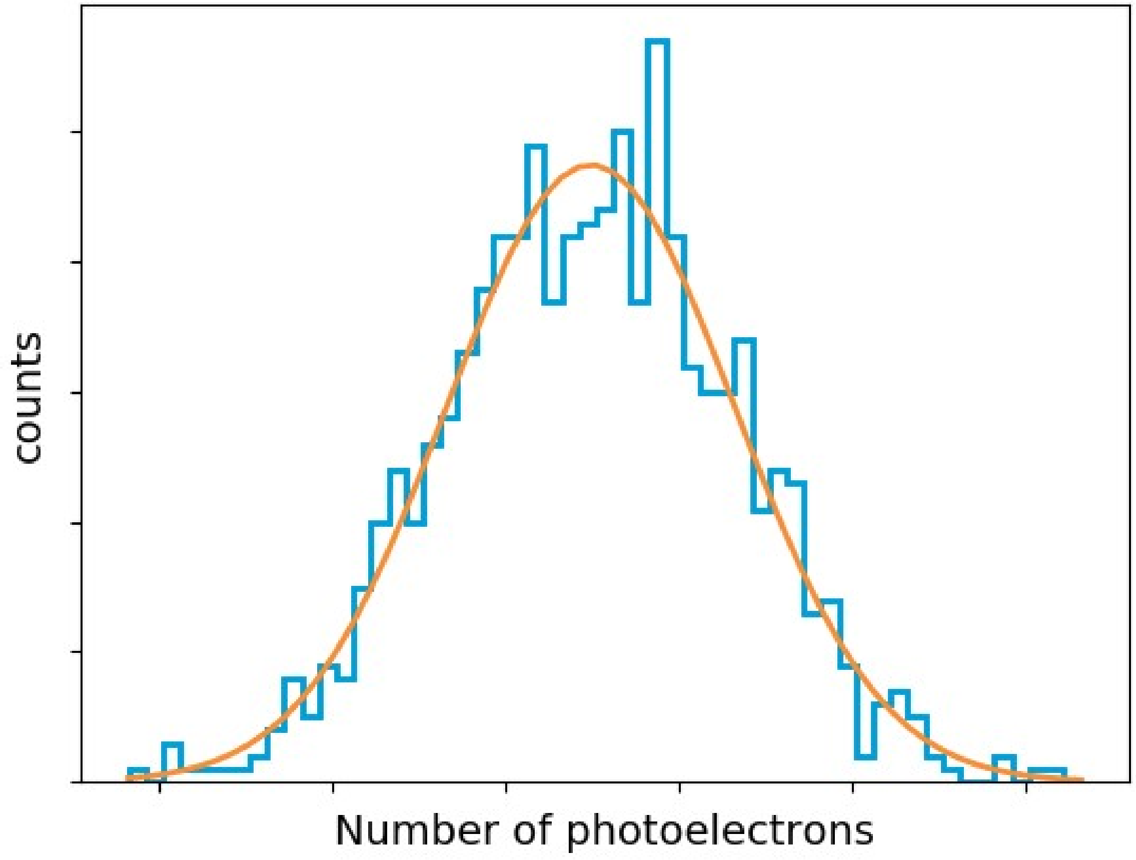
Basic approach to get the energy resolution



- Simulate the optical photon spectrum for a specific total incoming energy (eg. 1TeV)
- Apply quantum efficiency of the PMT to get number of photoelectrons

Calorimeter simulations

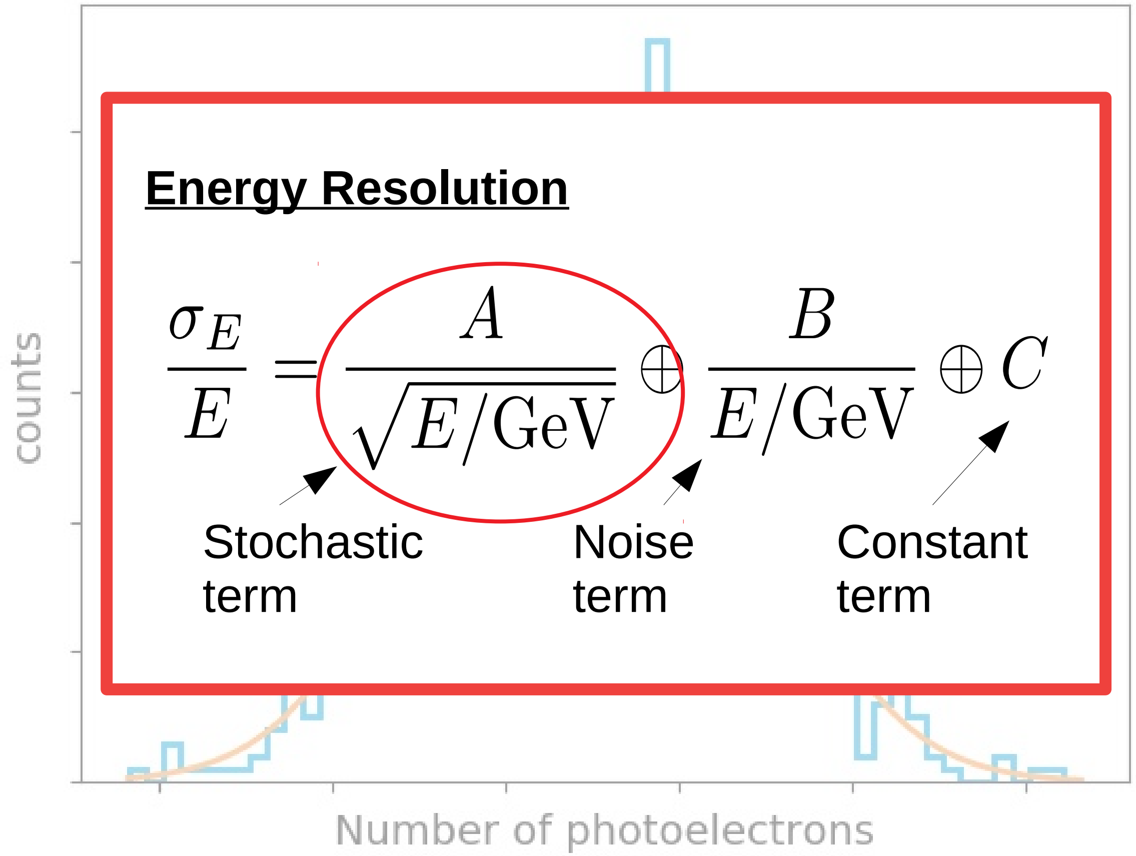
Basic approach to get the energy resolution



- Simulate the optical photon spectrum for a specific total incoming energy (eg. 1TeV)
- Apply quantum efficiency of the PMT to get number of photoelectrons
- Repeat for statistics
- $\frac{\sigma_N}{\bar{N}}$

Calorimeter simulations

Basic approach to get the energy resolution



Energy Resolution

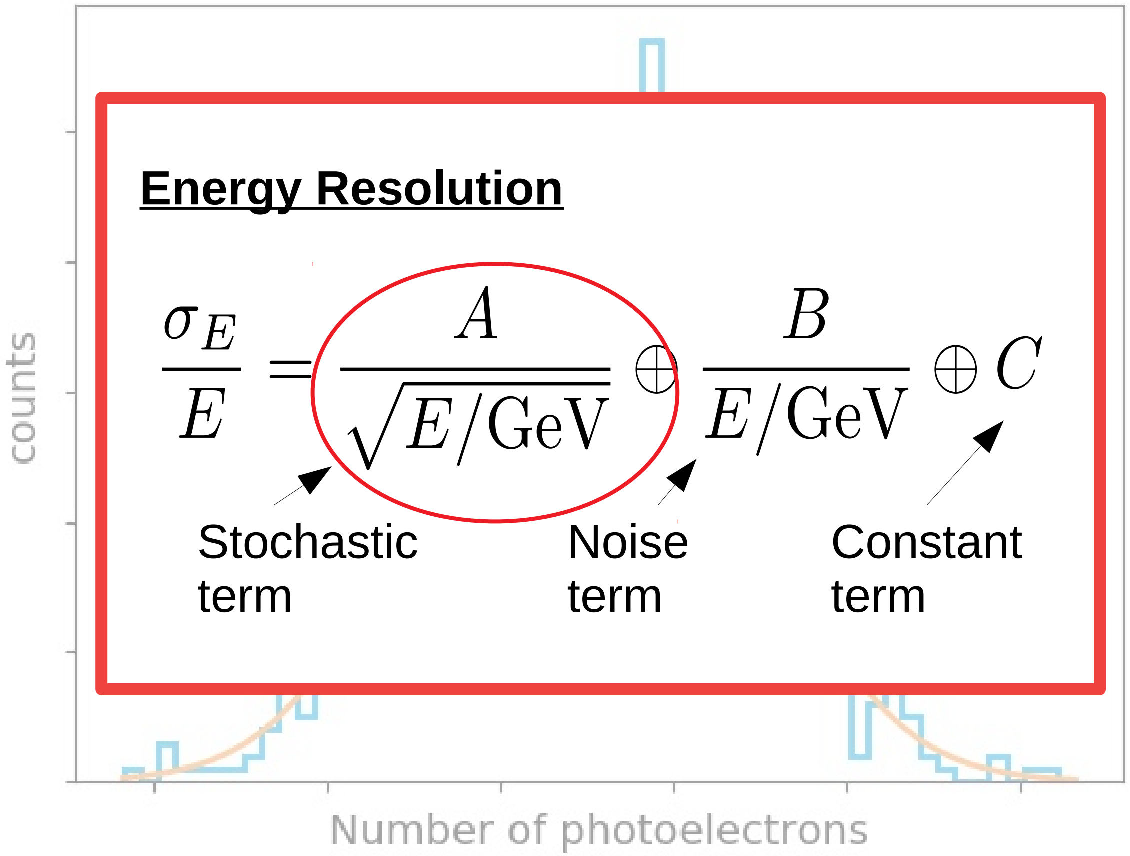
$$\frac{\sigma_E}{E} = \frac{A}{\sqrt{E/\mathrm{GeV}}} \oplus \frac{B}{E/\mathrm{GeV}} \oplus C$$

Stochastic term — Noise term — Constant term

- Simulate the optical photon spectrum for a specific total incoming energy (eg. 1TeV)
- Apply quantum efficiency of the PMT to get number of photoelectrons
- Repeat for statistics
- $\frac{\sigma_N}{\bar{N}}$ (stochastic term)

Calorimeter simulations

Basic approach to get the energy resolution



Energy Resolution

$$\frac{\sigma_E}{E} = \frac{A}{\sqrt{E/\mathrm{GeV}}} \oplus \frac{B}{E/\mathrm{GeV}} \oplus C$$

Stochastic term — Noise term — Constant term

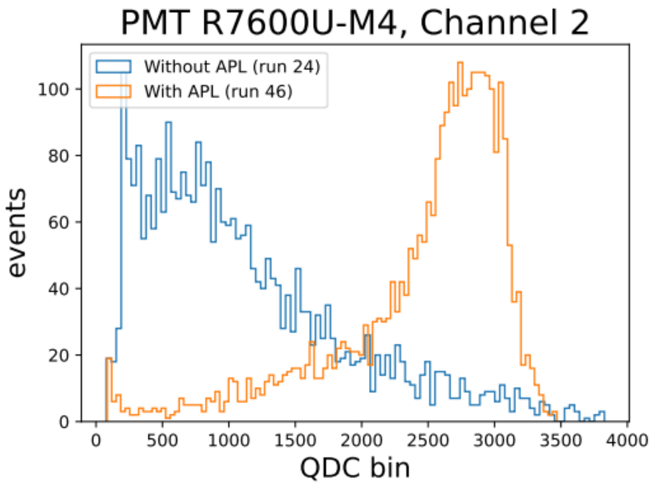
- Simulate the optical photon spectrum for a specific total incoming energy (eg. 1TeV)
- Apply quantum efficiency of the PMT to get number of photo electrons
- Repeat for statistics
- $\frac{\sigma_N}{\bar{N}}$ (stochastic term)

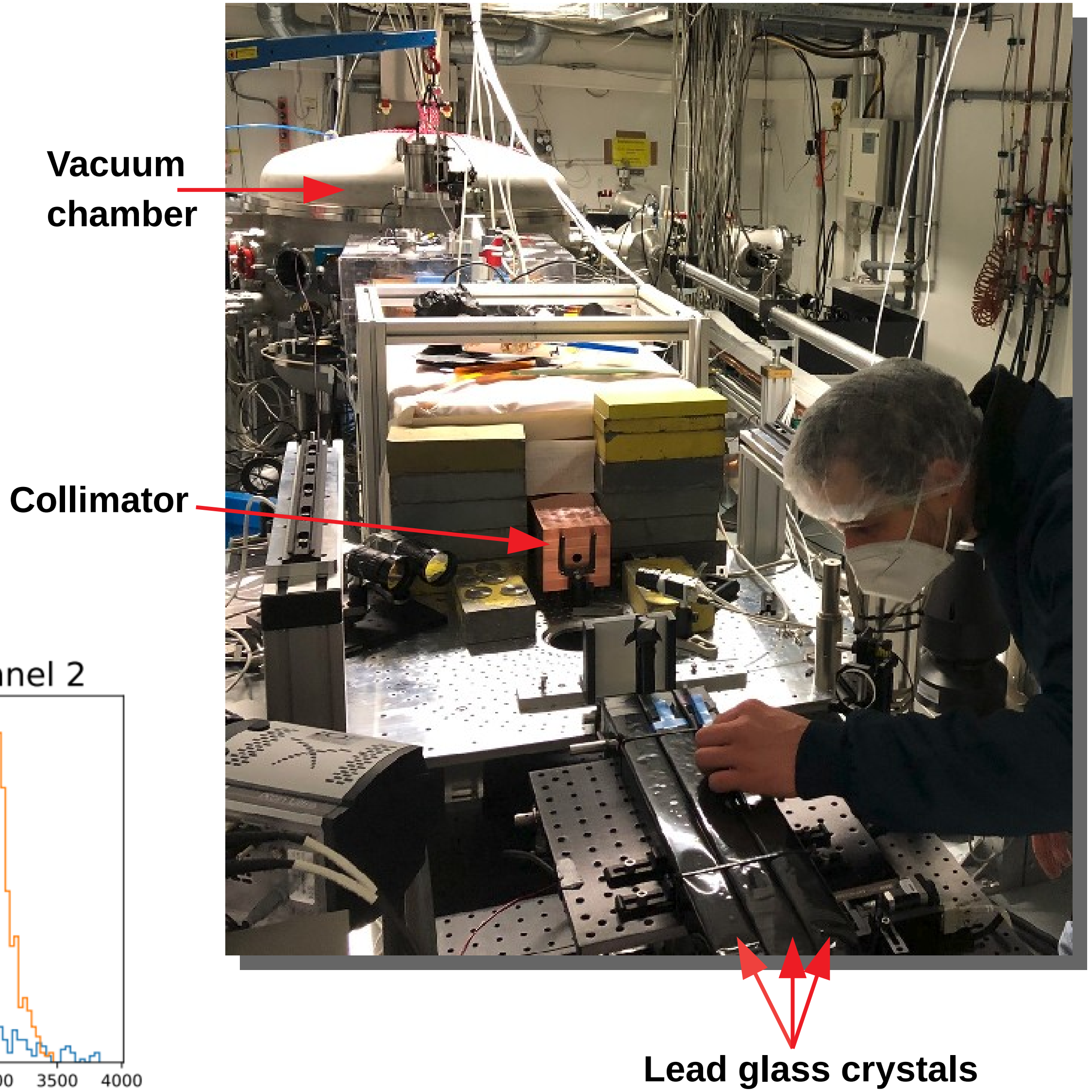
➡ **The intrinsic energy resolution of the calorimeter is expected to be small due to high energies**

Taking the calorimeter prototype to the lab

Recent calorimeter test with a LPA electron beam

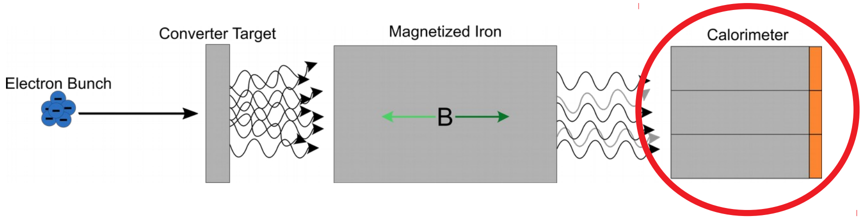
- Laser-Plasma-Accelerator @ DESY
- Energy ~ 60 MeV
- ~ 10^8 electrons / bunch
- ~ 3 Hz repetition rate
- Three lead glass crystals in the beam
- Testing the DAQ-System
- Data analysis still ongoing

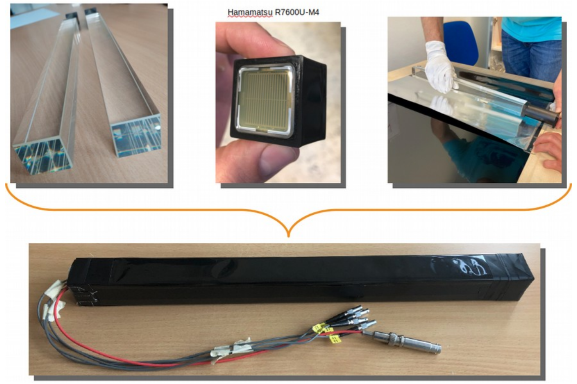


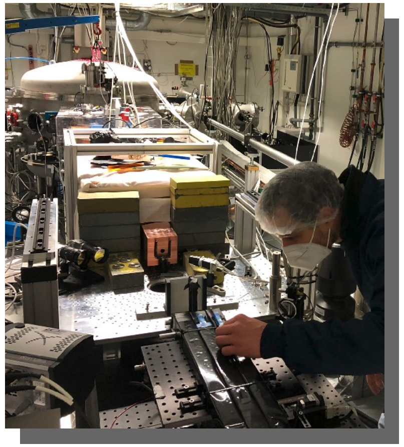


Summary

- LEAP is planning a crystal calorimeter for the LPA Polarimetry
- Lead glass calorimeter prototype
- GEANT4 calorimeter simulations are ongoing
- Calorimeter test in a LPA electron beam has been performed
- Data analysis ongoing







Thank you

Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

Felix Stehr
FTX
Felix.paul.georg.stehr@desy.de
+49 40 8998 5343