Construction and Simulation of a Compton Scattering Experiment with a Xenon and a Germanium Detector

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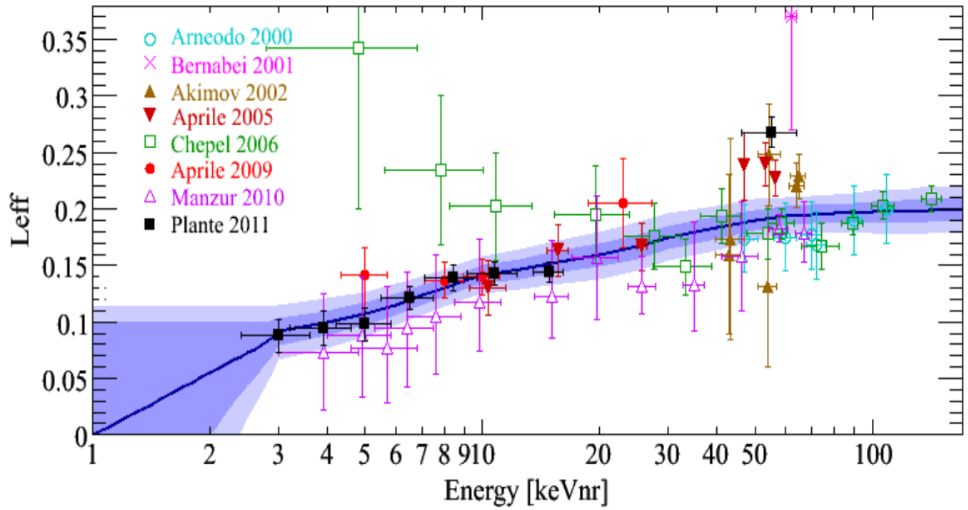
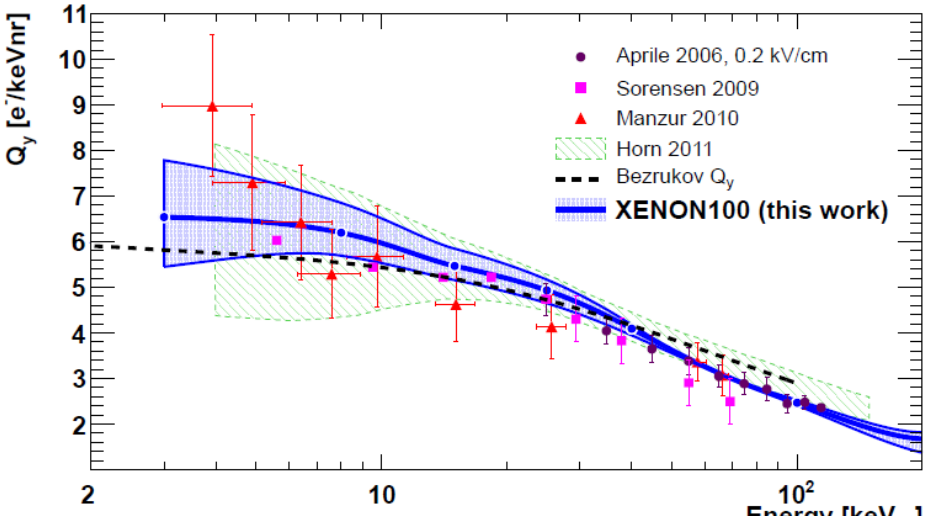
Motivation of the Experiment in Mainz

- Get more information about Xenon as detector medium
  - Electron recoils (Compton scatter experiment)
  - Nuclear recoils (Neutron scatter experiment)
- Study S1-pulseshape
- Discrimination of scintillation and ionization yield (low energy)



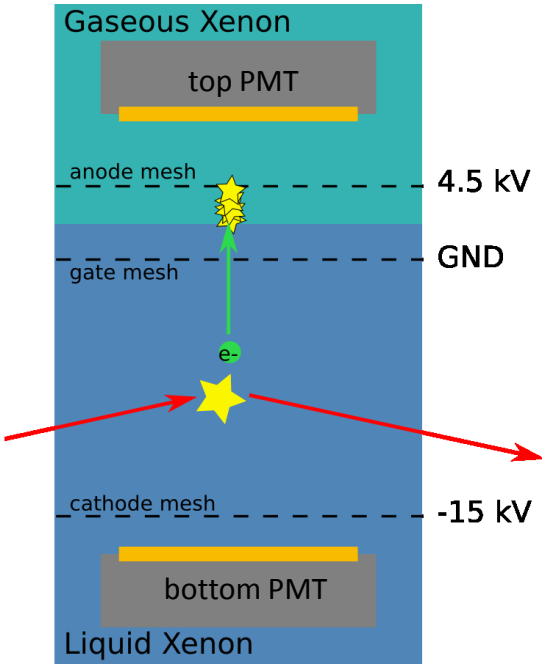
Ref: Phys. Rev. C84, 045805 (2011)

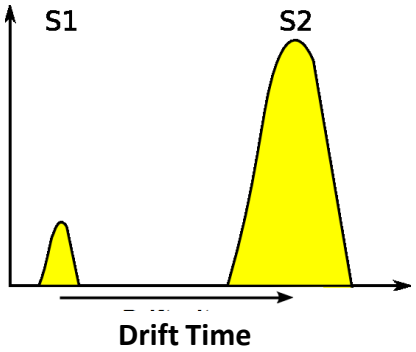


Ref: Phys.Rev D 88, 012006 (2013)

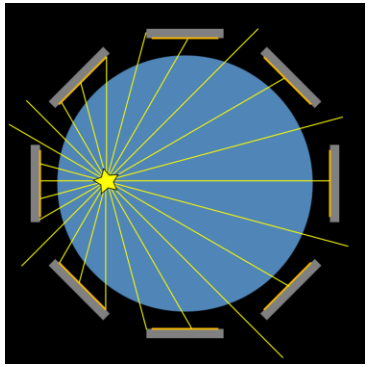
Nuclear Recoils

Principle of the MainzTPC

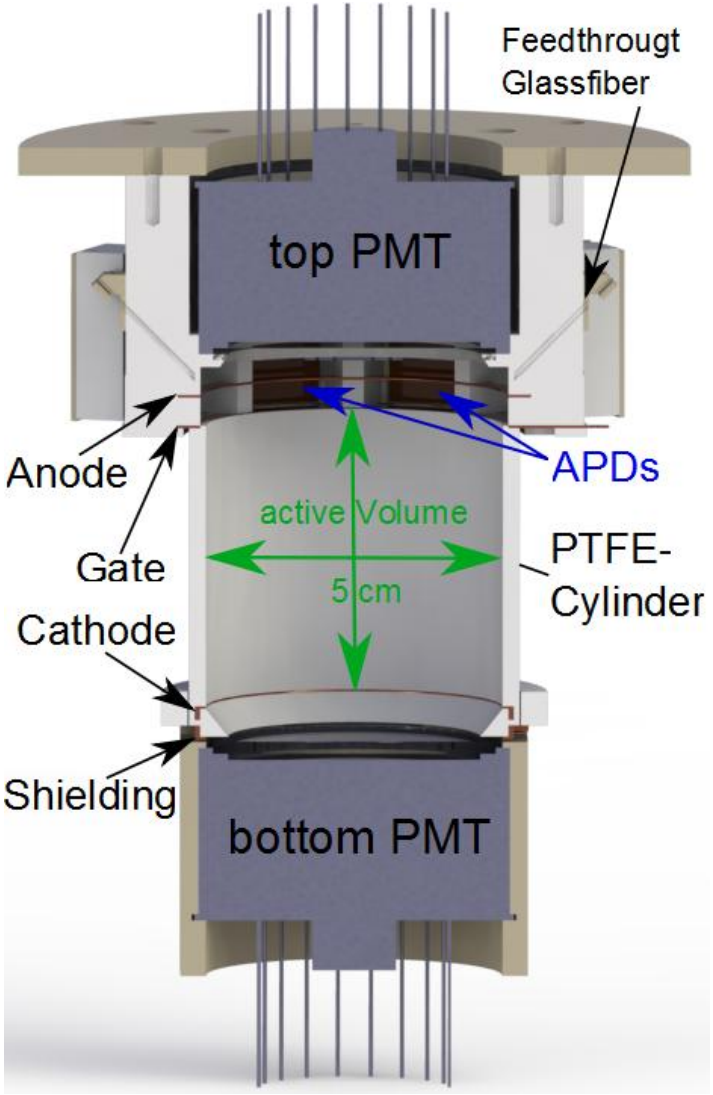




z-position
electron drift time

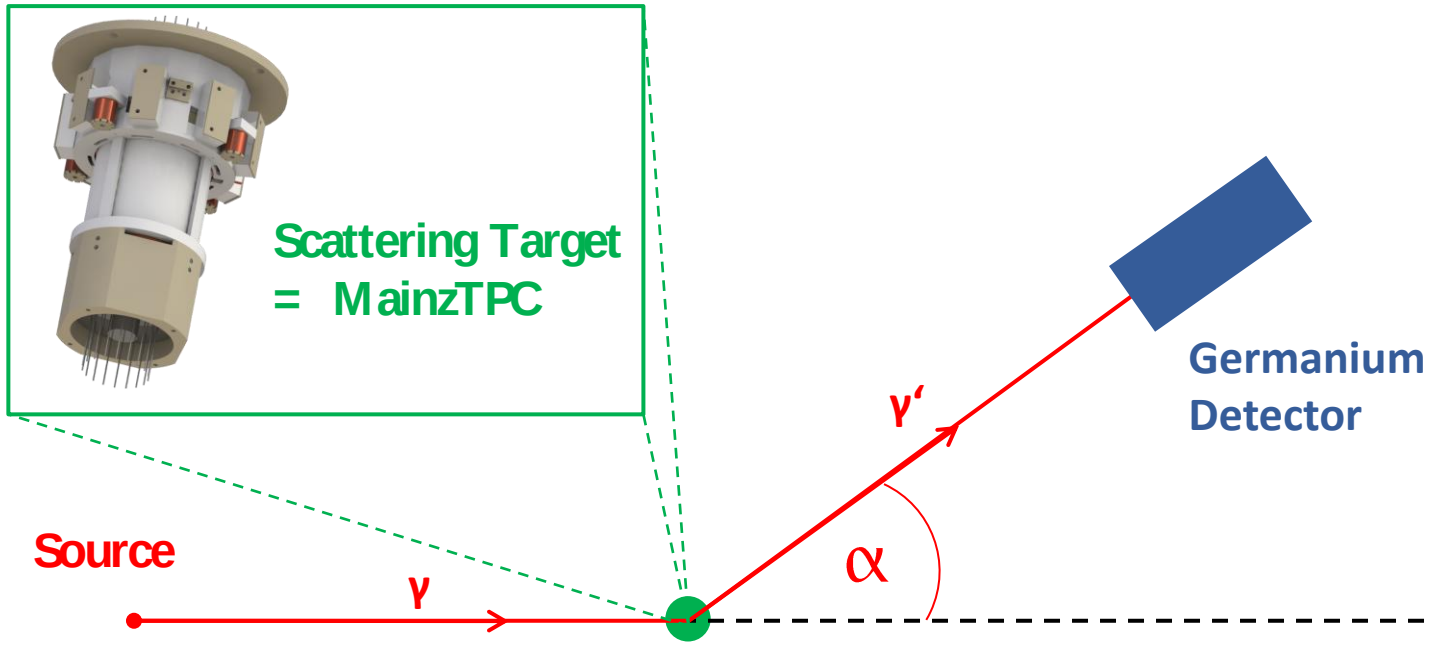


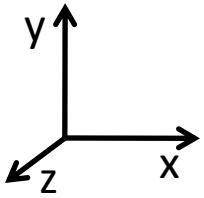
x/y-position
position of S2



Ref: Bastian Beskers

Compton Scatter Experiment

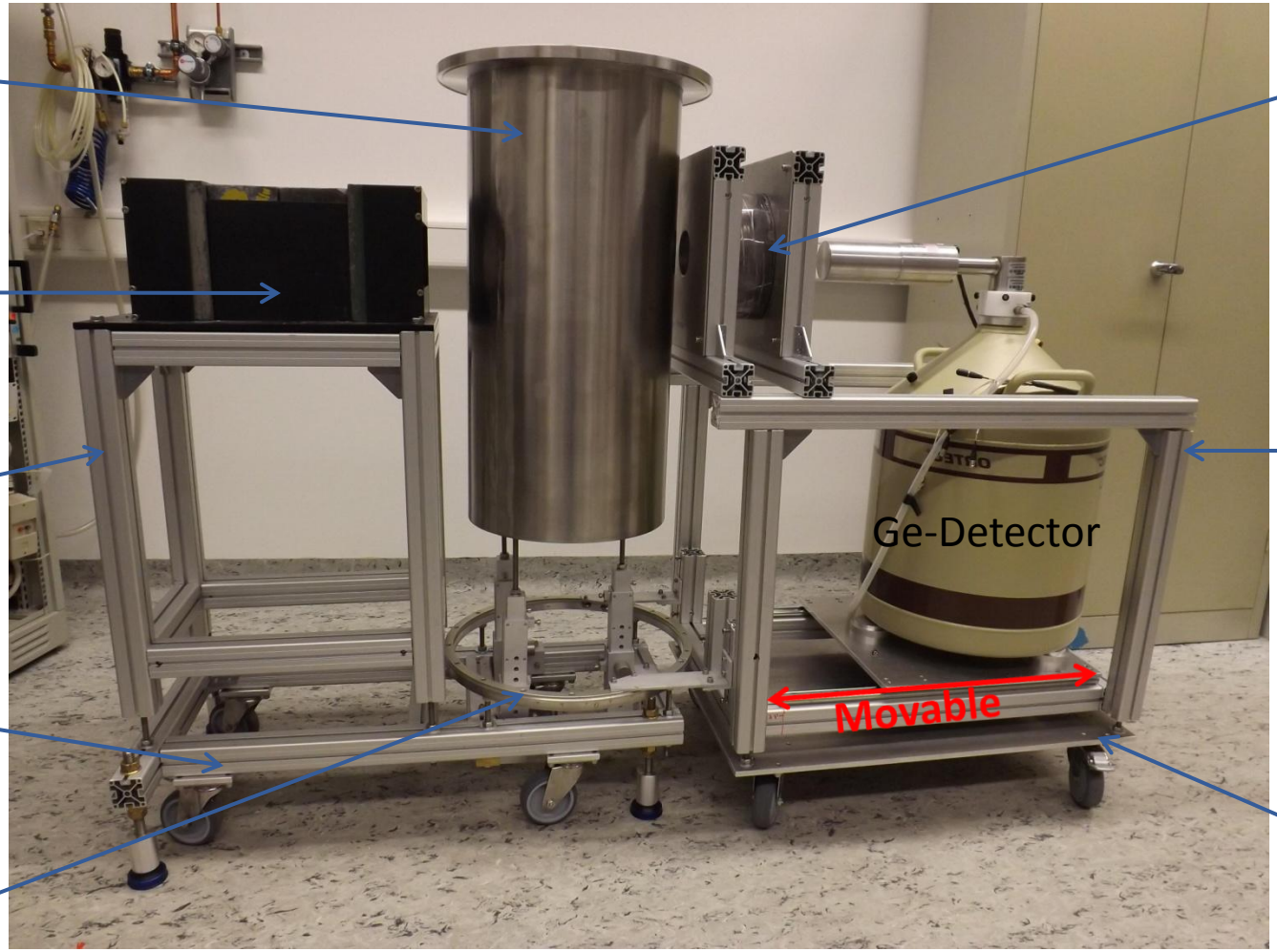




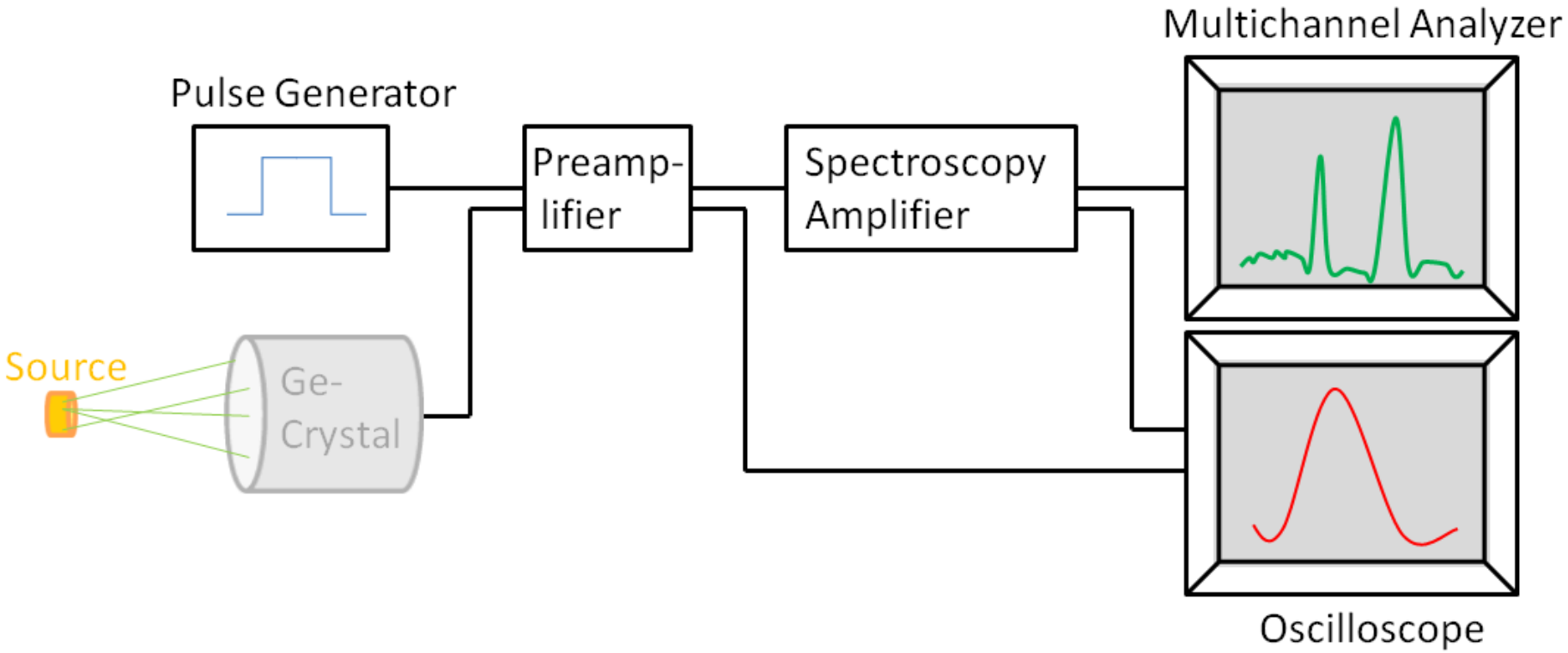
Energy of the scattered photon:

$$E_{\gamma'} = E_{\gamma} - E_{Ge} = \frac{h\nu}{1 + \frac{h\nu}{m_0 c^2} \cdot (1 - \cos\alpha)} = h\nu'$$

Measurements with the Germanium detector



Measurement Setup



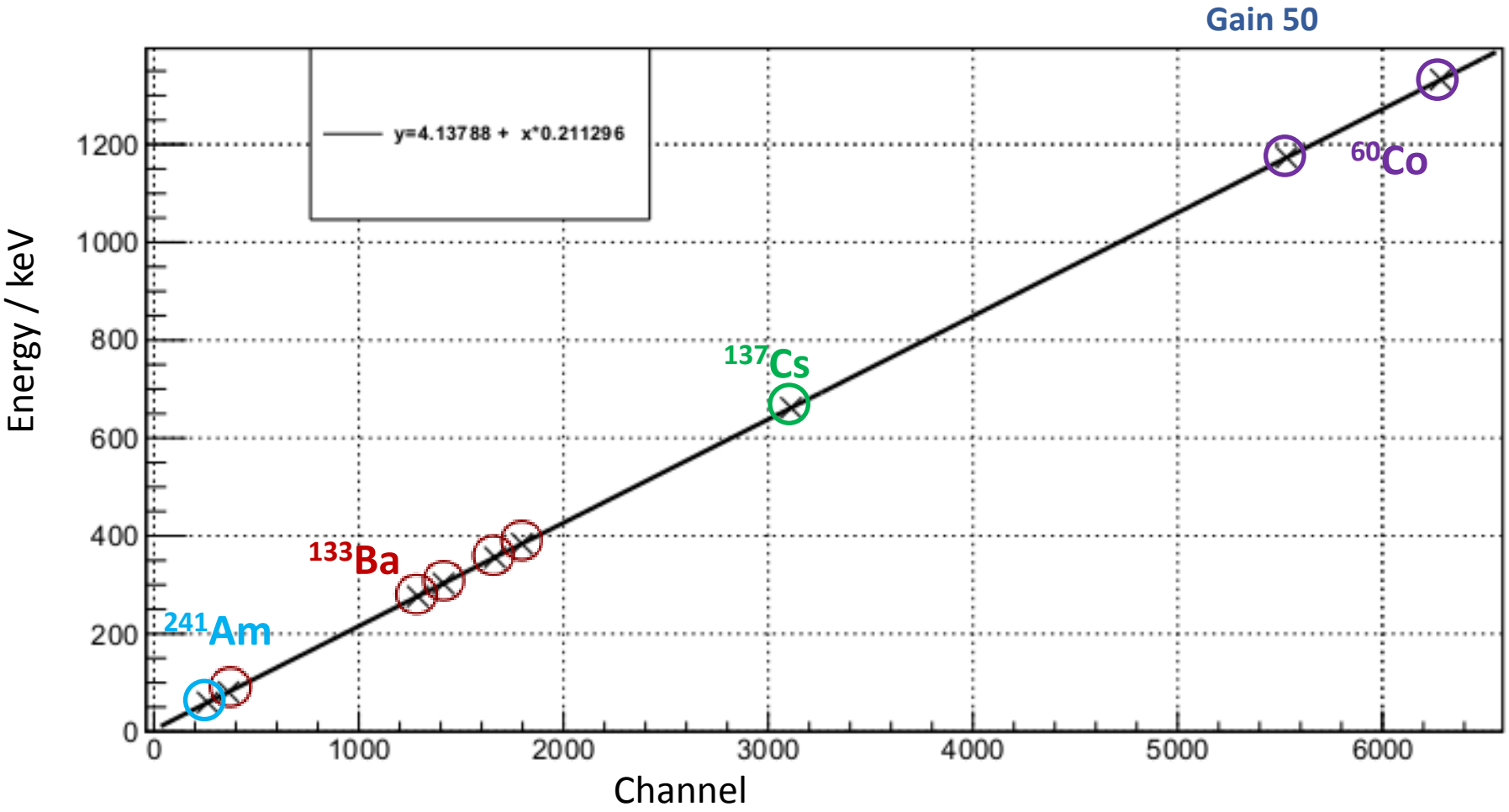
Characterization of the Germanium detector

- Energy calibration
  - Calibration sources
- Energy resolution
  - Calibration sources
  - Different test pulses
- Background measurement

Isotop	Energy /keV
^{214}Am	59,54
^{133}Ba	80,90
	276,39
	302,85
	356,00
	383,80
^{137}Cs	661,66
^{60}Co	1173,23
	1332,49

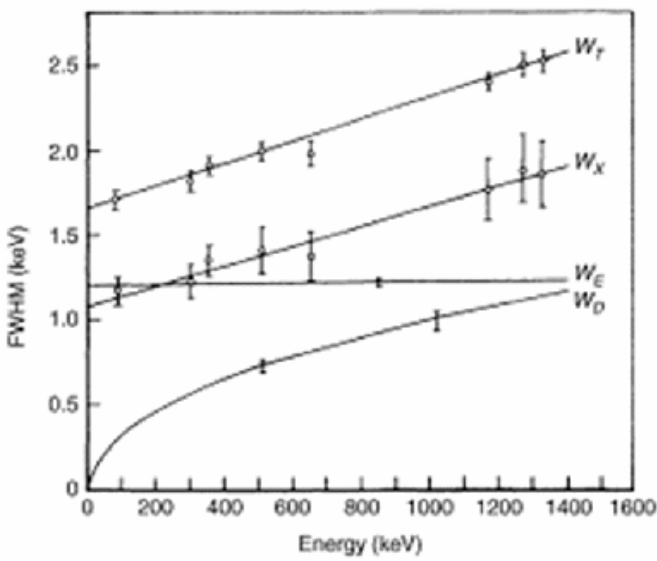
Ref: http://www.nndc.bnl.gov/

Energy Calibration



Energy Resolution

- FWHM: $W_T^2 = W_D^2 + W_X^2 + W_E^2$
  1. Statistical fluctuation in the number of charge carriers: $W_D^2 = (2.35)^2 \cdot F \cdot \varepsilon \cdot E$
  2. Incomplete charge collection: W_X^2
  3. Electric noise: W_E^2



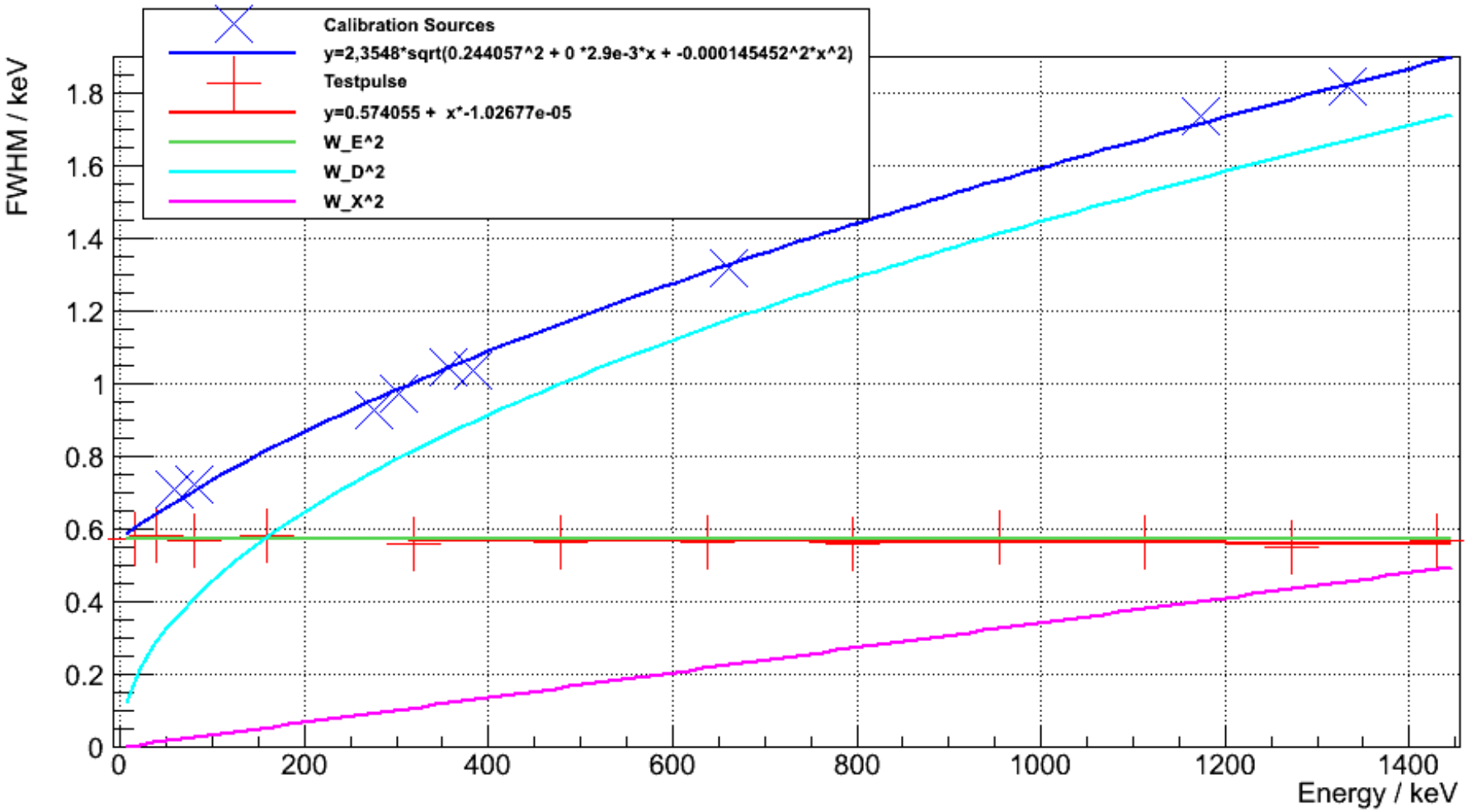
- Energy resolution:

$$\Delta E = \sqrt{W_T^2} = \sqrt{(2.35)^2 \cdot F_{Ge} \cdot \varepsilon_{Ge} \cdot E_{measured} + W_X^2 \cdot E_{measured}^2 + W_E^2}$$

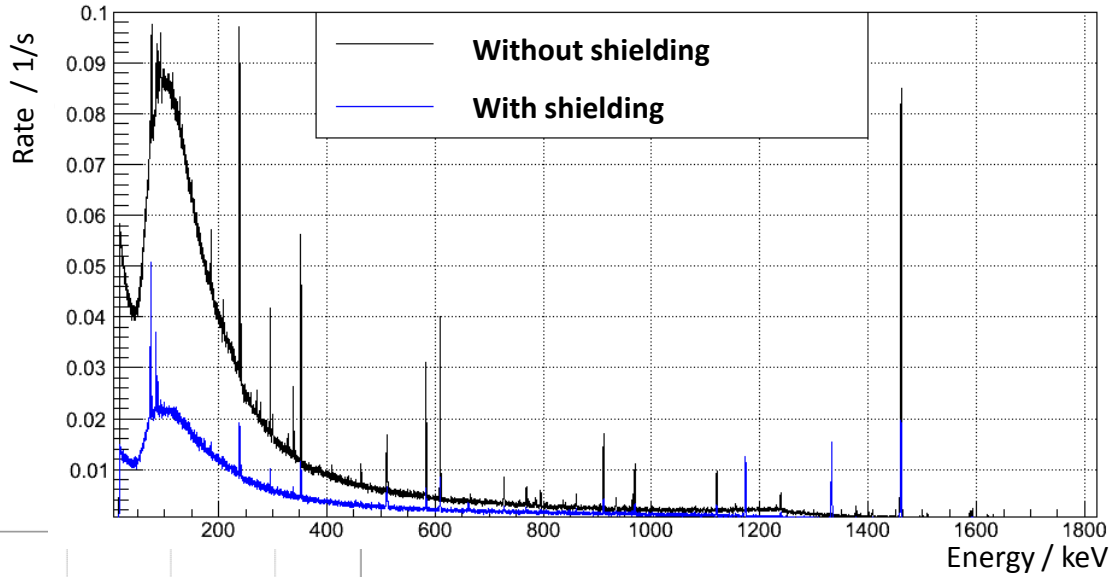
- Fanofactor: $F_{Ge} = 0.132 \pm 0.008$
- Electron-Hole-Pair production energy: $\varepsilon_{Ge} = 2.9\,\mathrm{eV}$

Ref: Knoll, Radiation Detection and Measurement

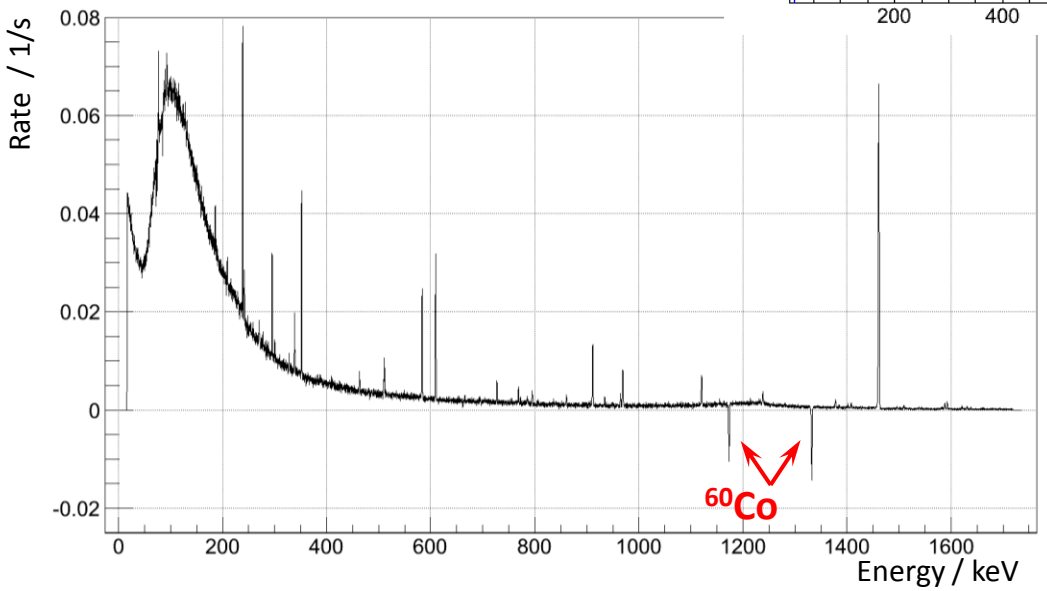
Energy Resolution

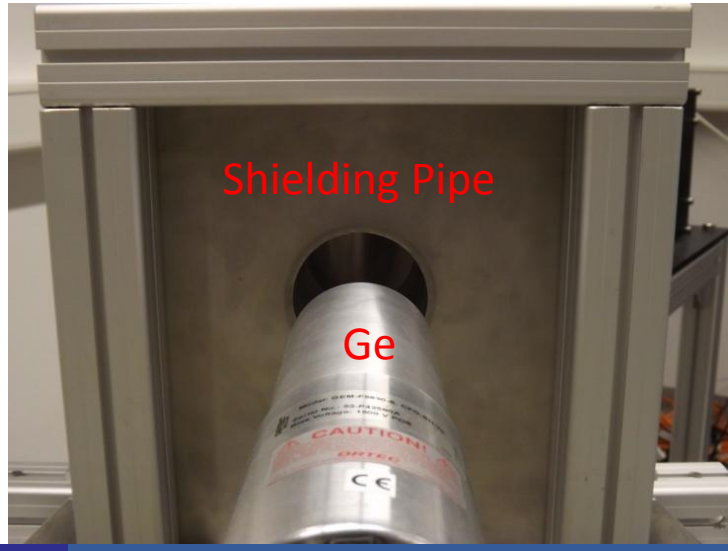


Background Measurements



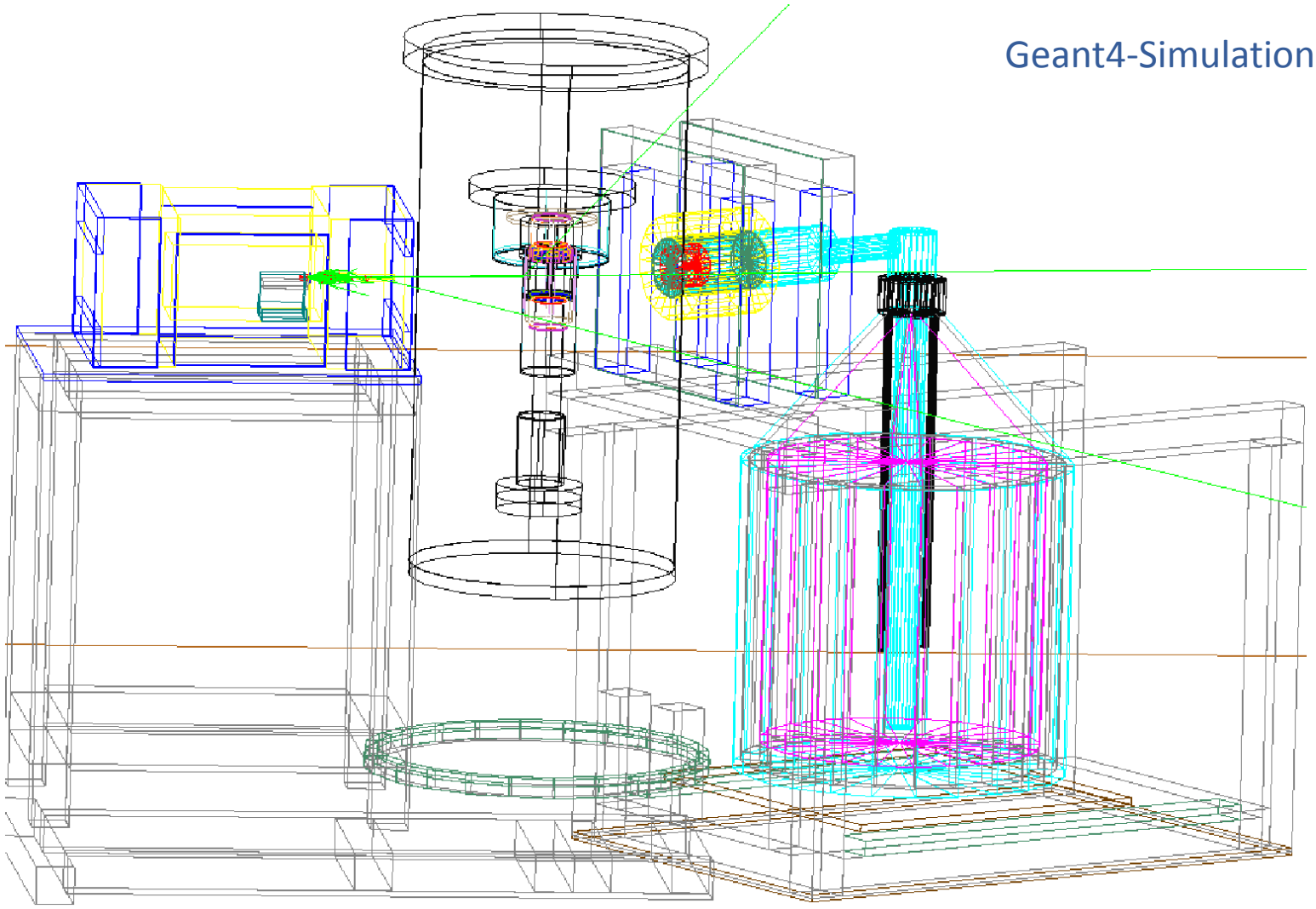
Background without Shield
- Background with Shield
= Background Reduction





Simulations of the whole Setup

Geant4-Simulation

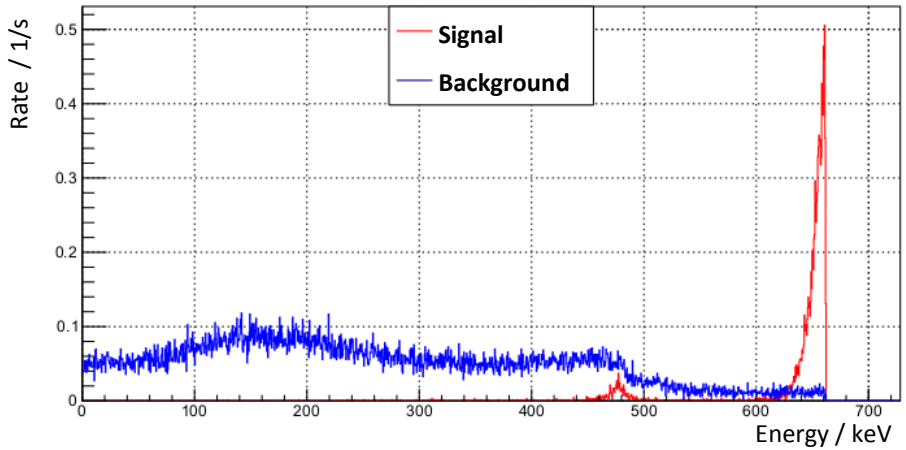


Signals

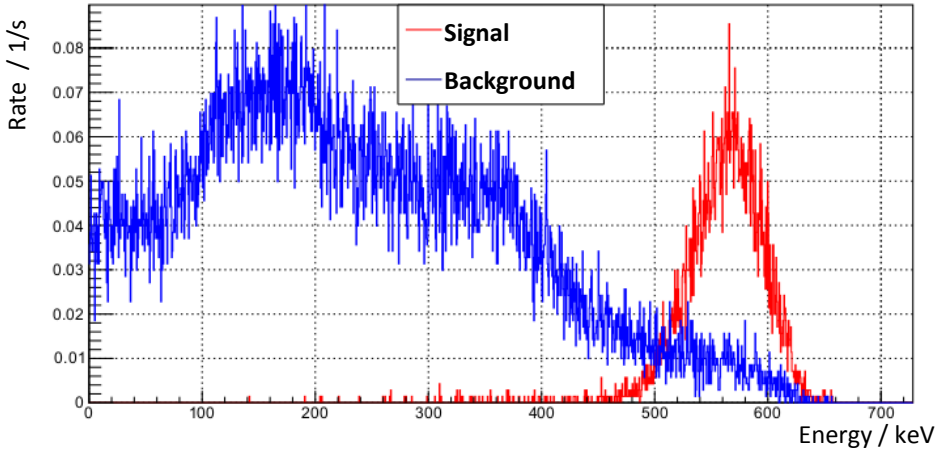
- Signal: events that have hits in both detectors. At least one in the Ge-detector and one hit in the LXe after summing up hits within a radius of 3 mm and a height of 1 mm.
- Background: all other events that have hits in both detectors.

Simulated Spectra in Ge Detector

^{137}Cs for 3.92° (Energy Range: 600-662 keV)



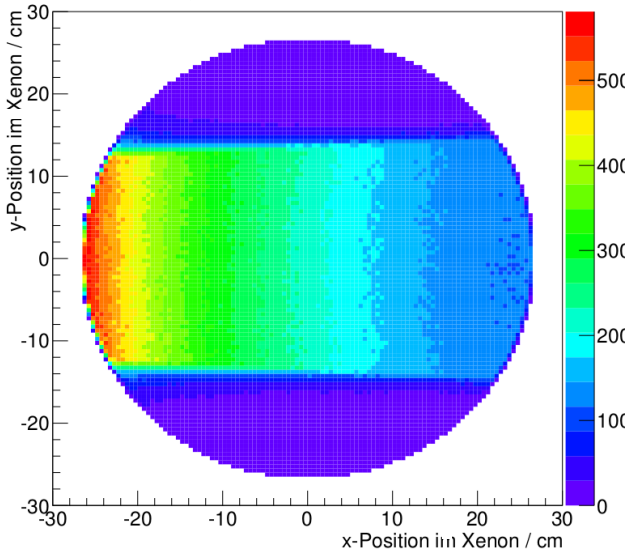
^{137}Cs for 30.40° (Energy Range: 450-662 keV)



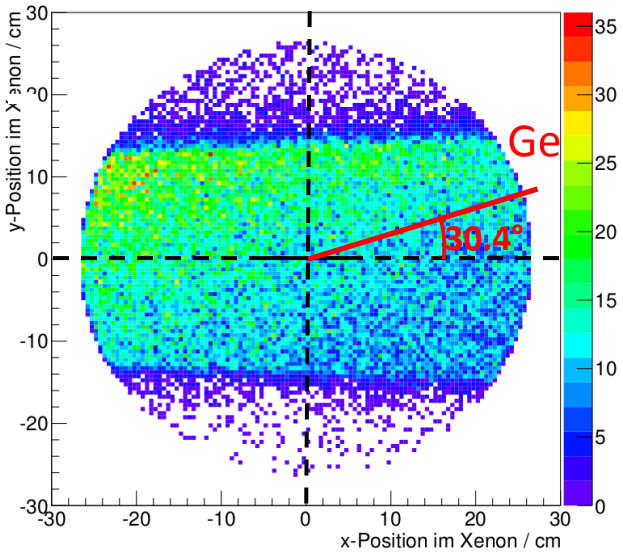
Spatial Distribution

- Cuts through the LXe-Volume
  - 5 mm high
  - Around the middle
- ^{137}Cs source is located at the left side
- Ge-Detector at 30.4° to the MainzTPC

First signal events in LXe



Coincident events



Summary and Outlook

- Development and construction of the geometry for the Compton scatter experiment
- Characterization of the Ge-detector
- Implementation of the setup into the simulations $\longrightarrow$ detailed simulations
- Commissioning and measurements with the Compton scatter experiment

Any Questions?

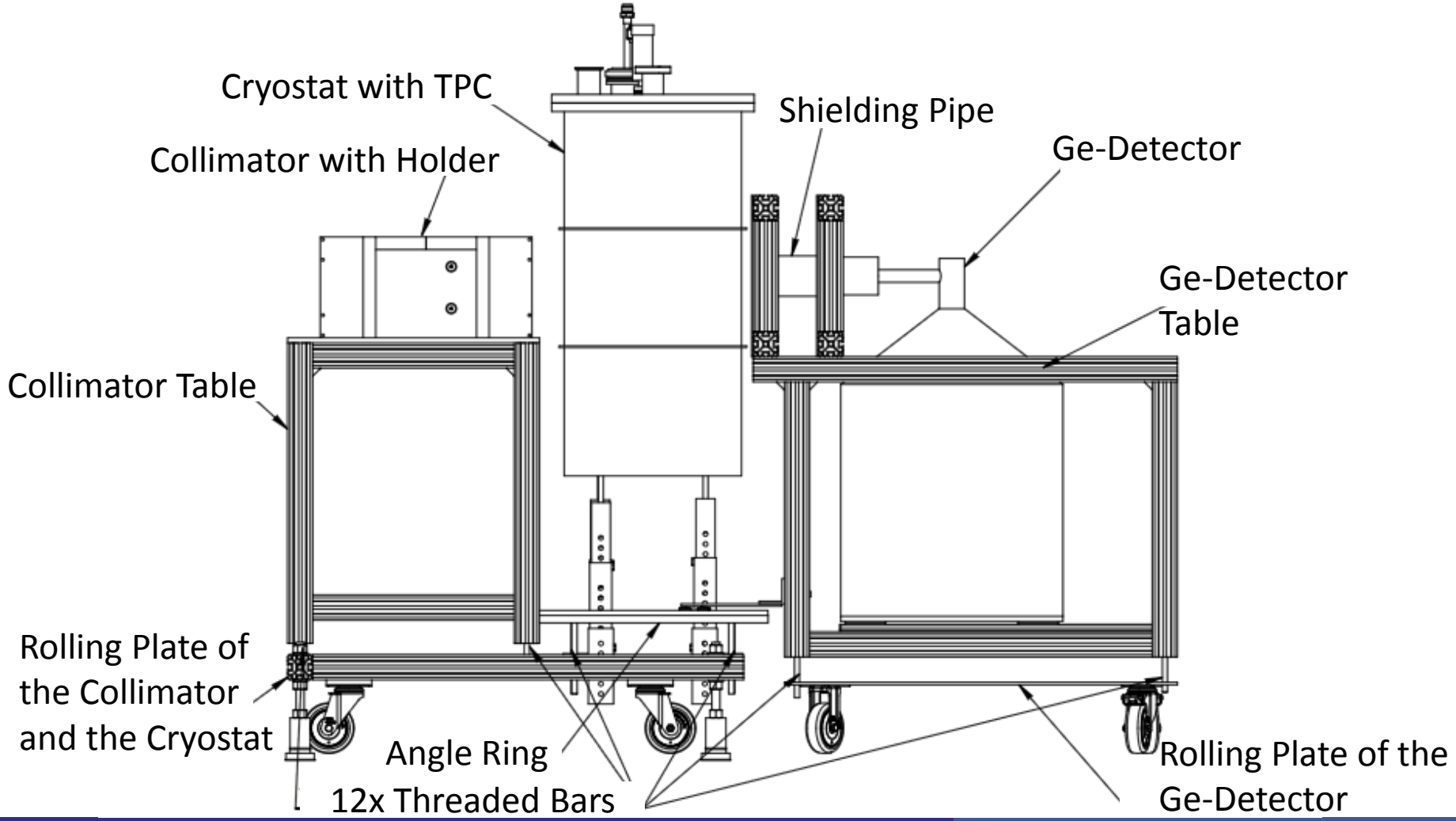
Thanks to the Mainz XENON Group

Cluster of Excellence
PRISMA

HELMHOLTZ
ASSOCIATION
Alliance for Astroparticle Physics

Back up Slides

Geometry of the Compton Scatter Experiment



Peak Identification of the Background