Systematic Studies for the π^0 Calibration of the Crystal-Ball Detector

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The Process

$$\gamma + p \rightarrow \pi^0 + p \rightarrow p + \gamma_1\gamma_2$$

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- How can it be checked whether there is a energy dependency in the CB or not?
  $\rightarrow |E_1 - E_2| < 25\,\text{MeV}$
- What are the reasons for the dependency?

Crystal-Ball-Function / Reduction of the Underground

- Gaussian Fit Function $\rightarrow$ Crystal-Ball Fit Function

Crystal-Ball-Function / Reduction of the Underground

- Gaussian Fit Function → Crystal-Ball Fit Function
- Check if the registered particles are charged
  → Reduction of the underground

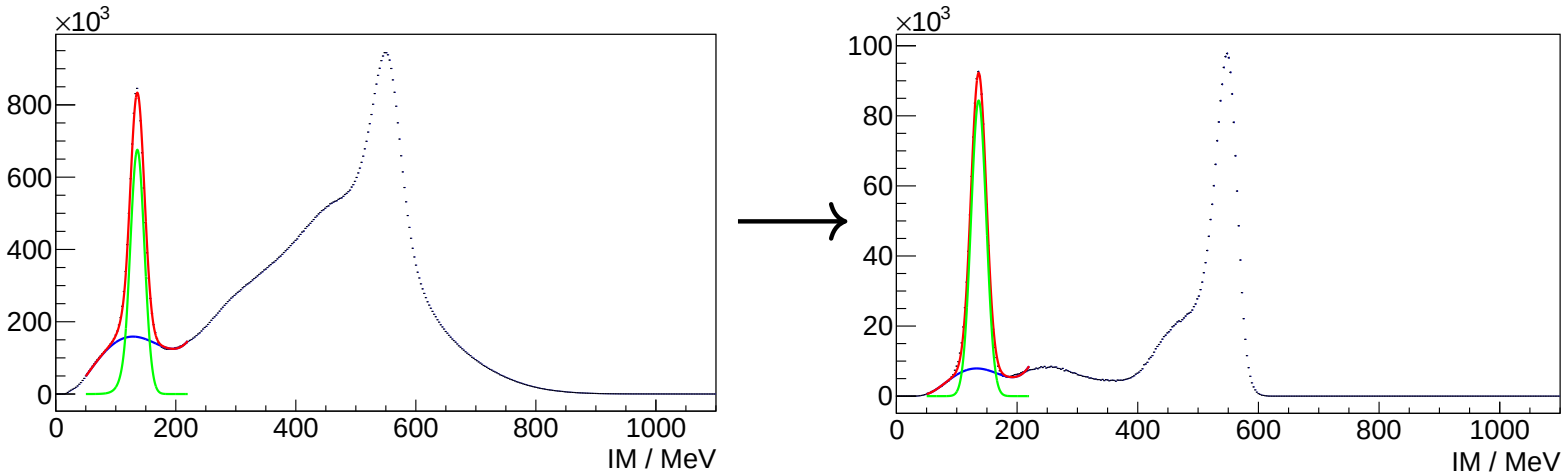

Figure: Beamtime: Example for not reduced and reduced underground

Event Generator

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- Creating a new package with enough events with an already existing event generator would take too much time (multiple days on blaster)
- It is better to use the same generator in all studies
  $\rightarrow$ The generator should be able to simulate MAMI-Beam and isotropic boost

Event Generator

```
auto cmd_Emin     = cmd.add<TCLAP::ValueArg<double>>     ("",  "Emin",     "Minimal incident energy [MeV]", false, 0.0, "double [MeV]");
auto cmd_Emax     = cmd.add<TCLAP::ValueArg<double>>     ("",  "Emax",     "Maximal incident energy [MeV]", false, 1.6*GeV, "double [MeV]");
auto cmd_events   = cmd.add<TCLAP::ValueArg<int>>        ("n", "",         "number of events", false, 10000, "n");
auto cmd_reqsym   = cmd.add<TCLAP::SwitchArg>            ("",  "sym",      "Require symmetric photon energies");
auto cmd_zboost   = cmd.add<TCLAP::SwitchArg>            ("",  "zboost",   "Boost the Pions in z-Direction; True or False");
auto cmd_Prod     = cmd.add<TCLAP::SwitchArg>            ("",  "Prod",     "Get the Product of the Pion; Change Beam Energy with E_min and E_max"  );
```

Figure: π^0-Event Generator: Commands

- Emin: Minimal energy of the beam/boost
- Emax: Maximal energy of the beam/boost
- Events: Number of events
- Sym: Require $|E_1 - E_2| < 25\,\mathrm{MeV}$
- ZBoost: Boost the π^0 in z-Direction, if false than isotropic boost
- Prod: Also takes the proton into account

No Additional Cut

- Beamtime October 2014
- No additional cut

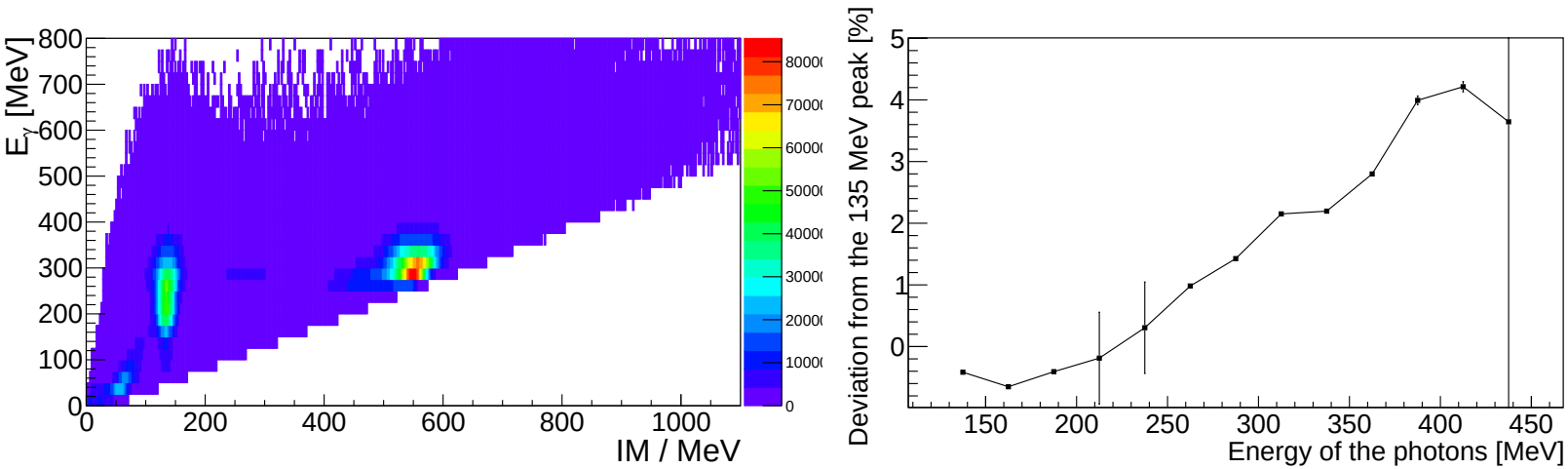


Figure: Beamtime: No additional cut

Detectors on the Edge

- Beamtime October 2014
- Neglect the detectors at the edge

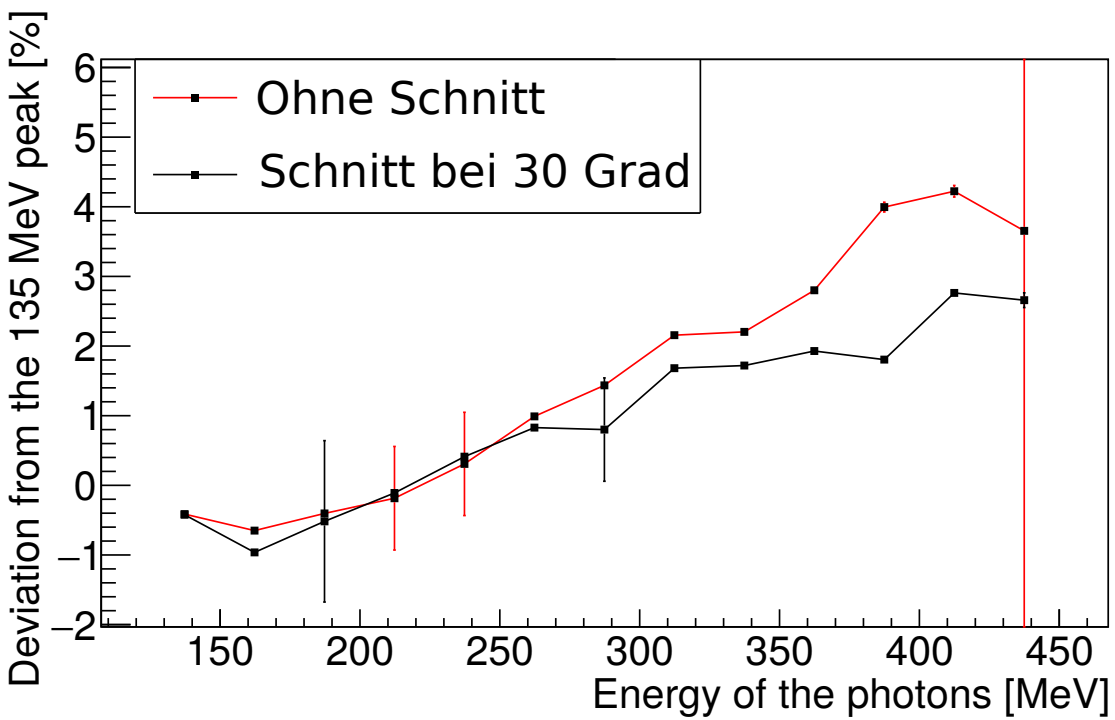


Figure: Beamtime: With and without considerations of the detectors on the edge of the beam entrance and exit

Detectors on the Edge

- Simulation
- Red: No additional cut
  Black: Neglect the detectors on the edge

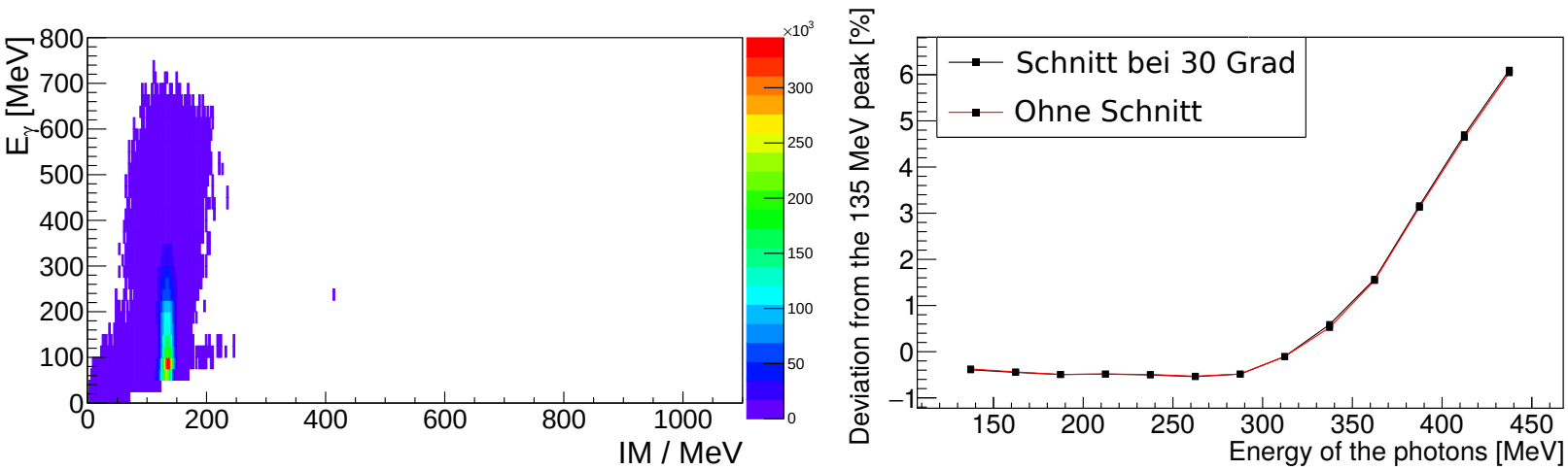


Figure: Simulation: Left: Example for the two dimensional histogram with simulated data. Right: Deviation with and without the detectors on the edge

Minimum Opening Angle

- Simulation
- Opening angle α has to be bigger than 30° degree
- $m_{\pi^0} = \sqrt{2E_1E_2(1-\cos(\alpha))}$ with $E_1 \approx E_2$
  $\rightarrow E_{max} \approx 250\,\text{MeV}$

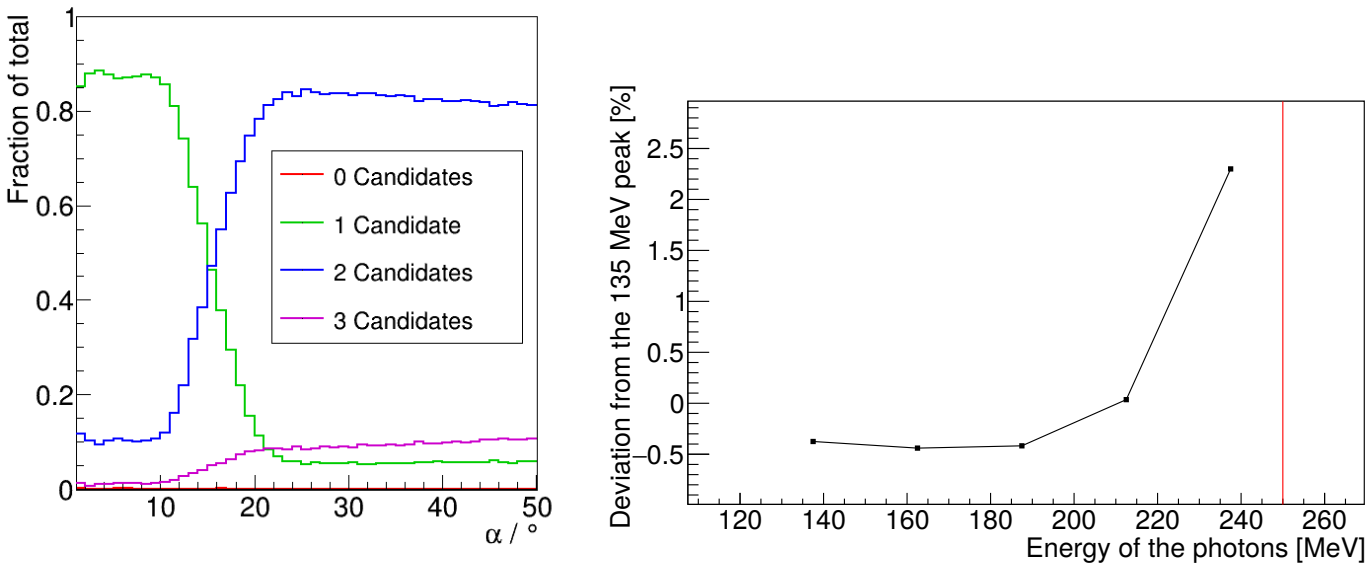


Figure: Left: Number of reconstructed candidates for different opening angles. Right: Deviation with $\alpha > 30^\circ$

Isotropic Boost

- Simulation
- π^0 decay in the origin of the target
- π^0 are boosted isotropically with an energy of $1420\,\text{MeV}$ to $1580\,\text{MeV}$

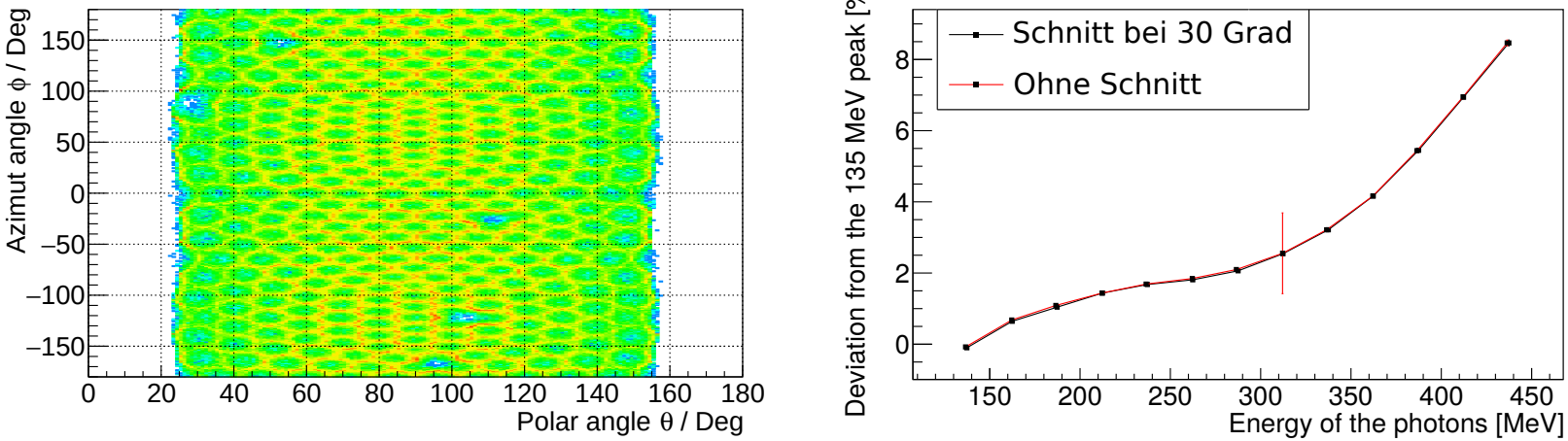


Figure: Simulation: Isotropic decay in the origin of the target

z-Vertex Dependency

- Simulation
- Neglect the detectors on the edge
- Devide the target in sections of $1\,\mathrm{cm}$

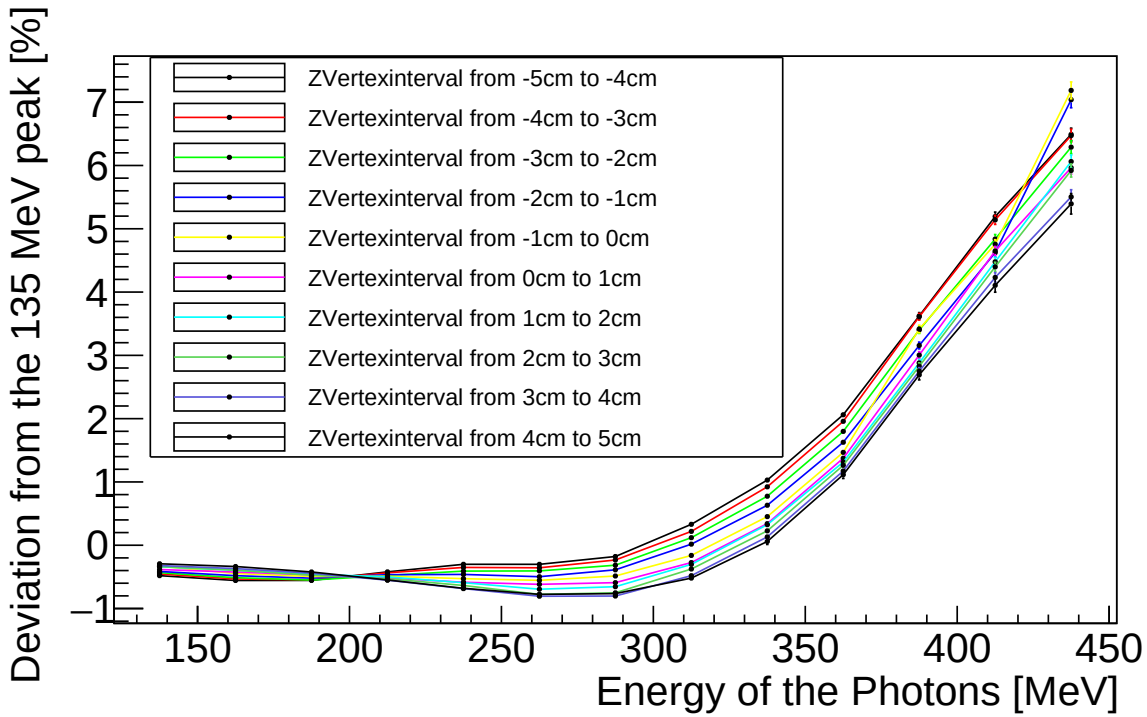


Figure: Simulation: Deviations for different z-Vertices

Angle between Generated and Reconstructed Candidates

- Simulation
- The angle between generated and reconstructed candidate is calculated

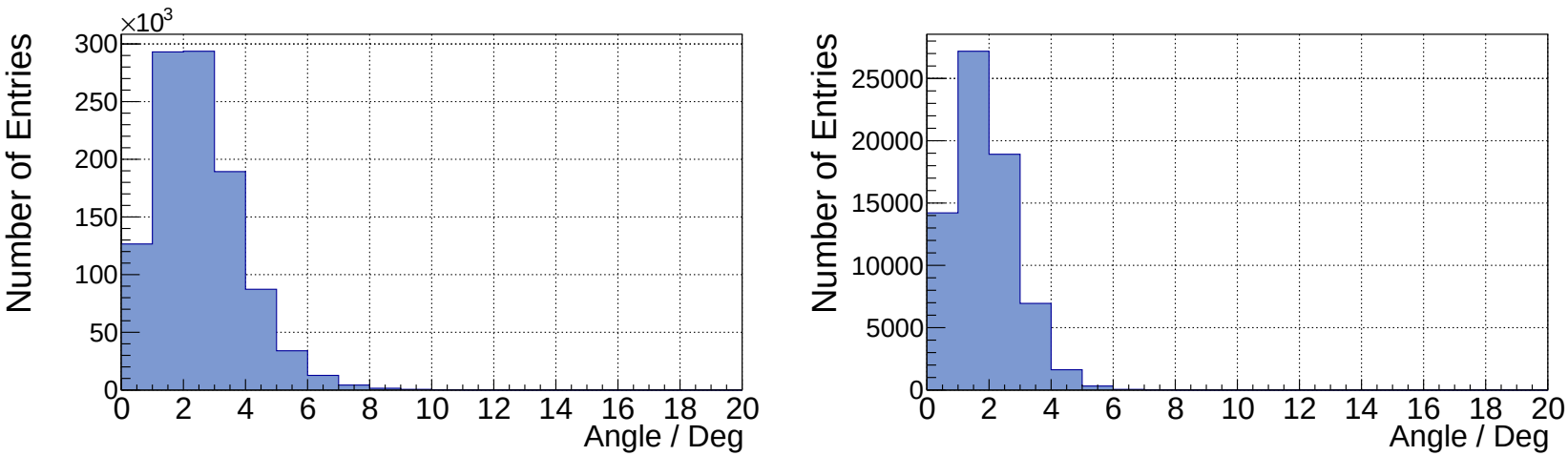


Figure: Simulation: Angle between gen. and rec. candidates. Left: Photon energy between $125\,\text{MeV}$ and $150\,\text{MeV}$. Right: Photon energy between $425\,\text{MeV}$ and $450\,\text{MeV}$

Difference between Generated and Reconstructed Opening Angle

- Simulation
- $\Delta\alpha = \alpha_{rec} - \alpha_{gen}$

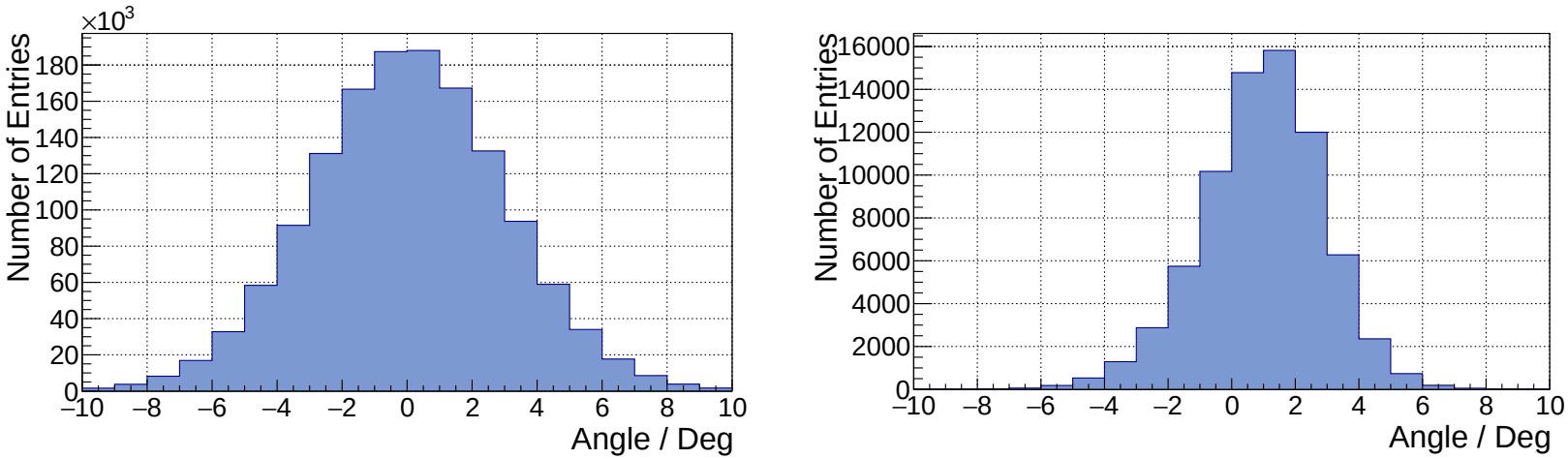


Figure: Simulation: $\Delta\alpha$ for different photon energies. Left $125\,\text{MeV}$ to $150\,\text{MeV}$. Right from $425\,\text{MeV}$ to $450\,\text{MeV}$

$\Delta\alpha$ for Different z-Vertices

- Simulation
- $\Delta\alpha$ for different z-Vertices

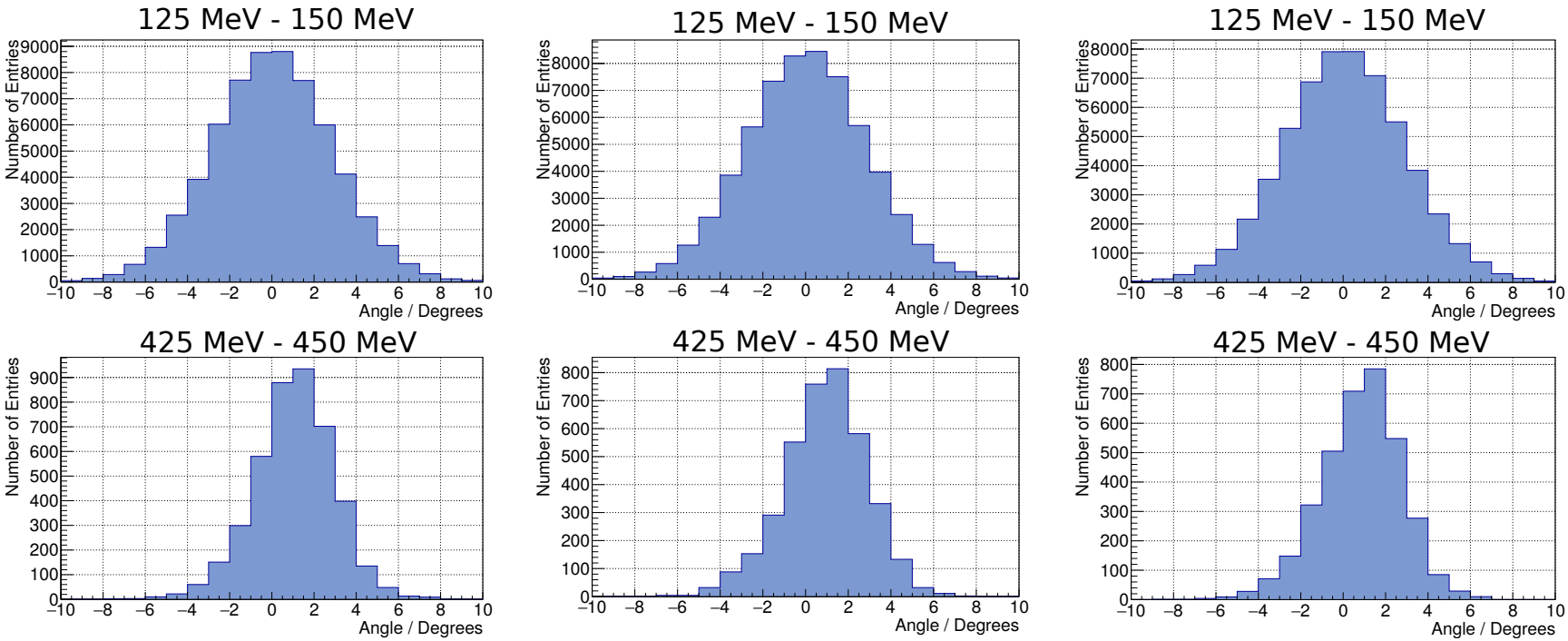
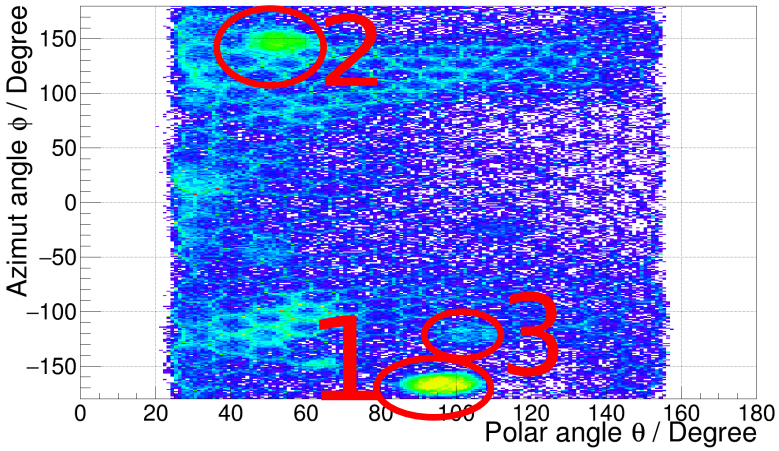


Figure: Simulation: $\Delta\alpha$ for different photon energies. Decay at different z-Vertices (Beginning, Center and End)

Hot Crystals

- Beamtime October 2014
- Photon energy between 0 MeV and 100 MeV



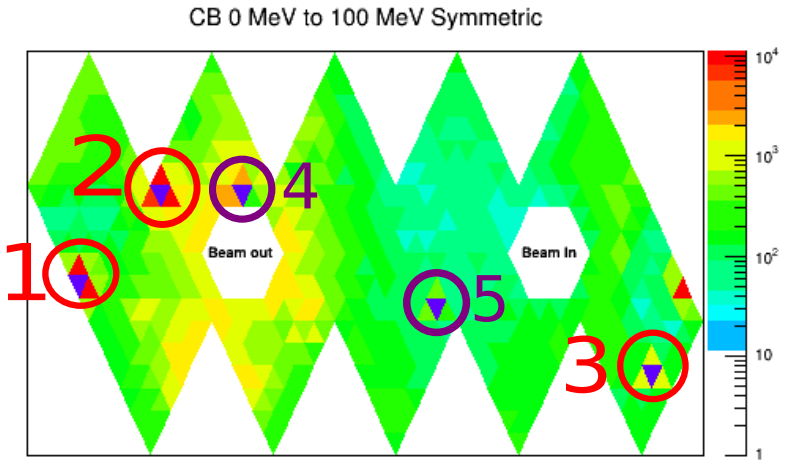


Figure: Beamtime: Marked are Hot and known Dead Crystals

Table: Beamtime: Element No. and No. in figure

Number in the figures	1	2	3	4	5
Element Number	549	565	597	677	265

Hot Crystals and Clustersize > 3

- Beamtime October 2014
- Photon energy between $0\,\text{MeV}$ and $100\,\text{MeV}$
- Clustersize > 3

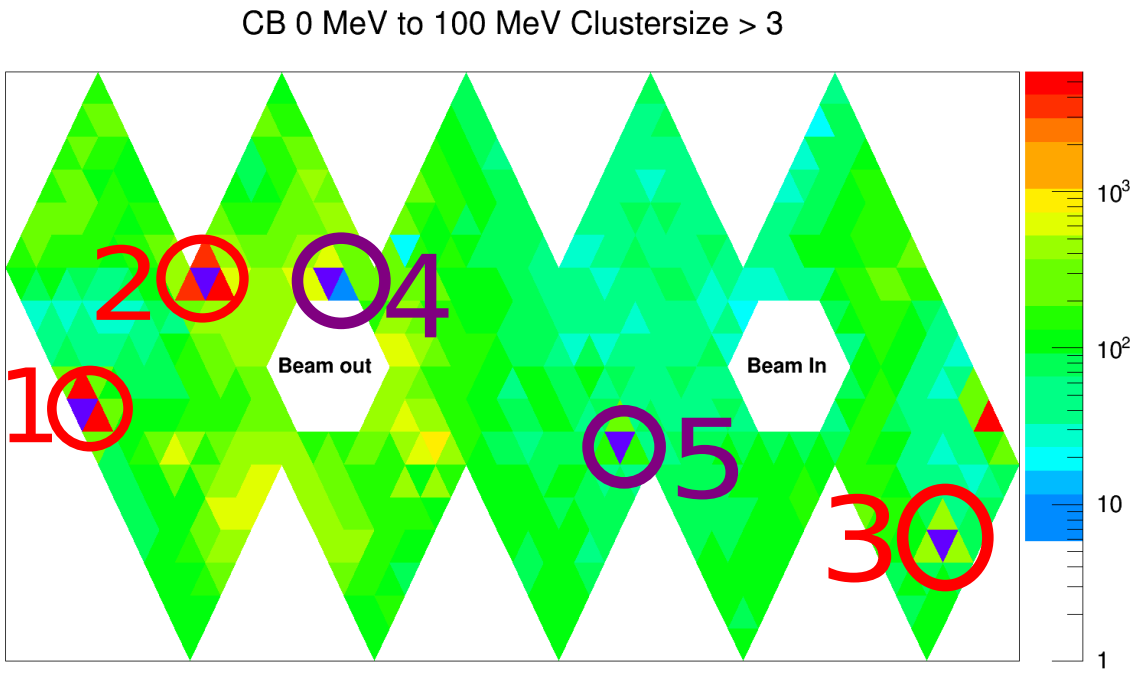


Figure: Beamtime: Marked are Dead and Hot Crystals. The Clustersize must be bigger than 3

Hot Crystals for Higher Energies

- Beamtime October 2014
- Photon energy between $300\,\text{MeV}$ and $400\,\text{MeV}$

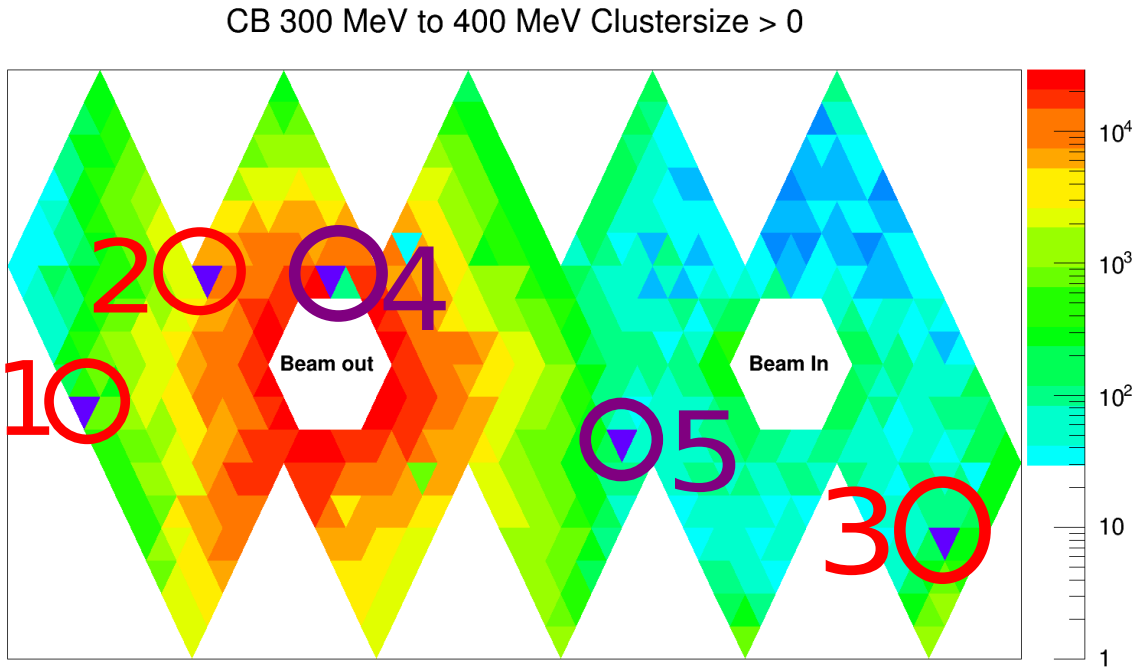


Figure: Beamtime: Marked are Dead and Hot Crystals for high energies

Dead Crystals

- Beamtime October 2014
- Photon energy between $300\,\text{MeV}$ and $400\,\text{MeV}$

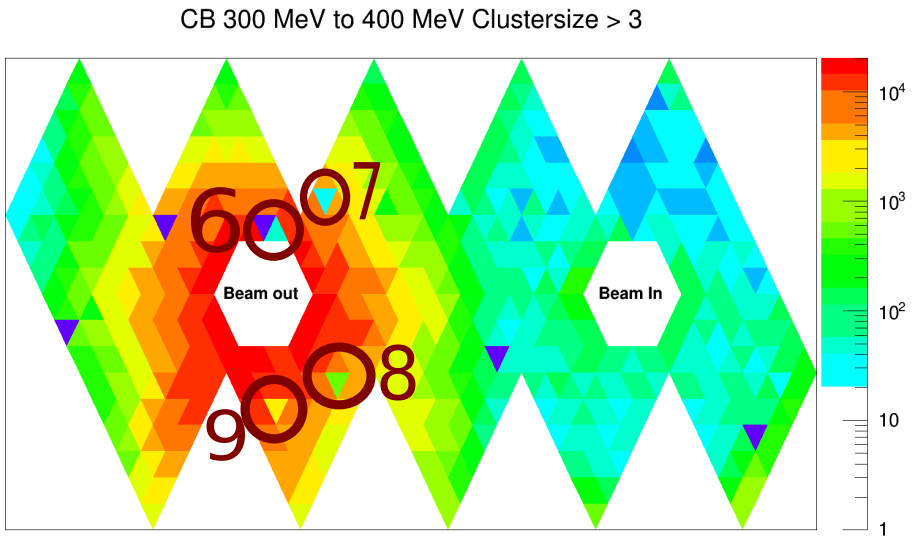


Figure: Beamtime: Marked are probably Dead Crystals

Table: Beamtime: No. of events for the Dead Crystals and their neighbors

No. in Fig.	Element Number	No. of Hits
6	678	48
	677	0
	676	11808
7	17	21
	16	3311
	18	7175
	19	3439
8	125	513
	122	6613
	128	5307
	126	4103
9	89	2500
	88	8591
	90	7975
	91	4652

ϕ-Distribution in the CB

- Beamtime October 2014
- Photon energy between $200\,\text{MeV}$ and $225\,\text{MeV}$

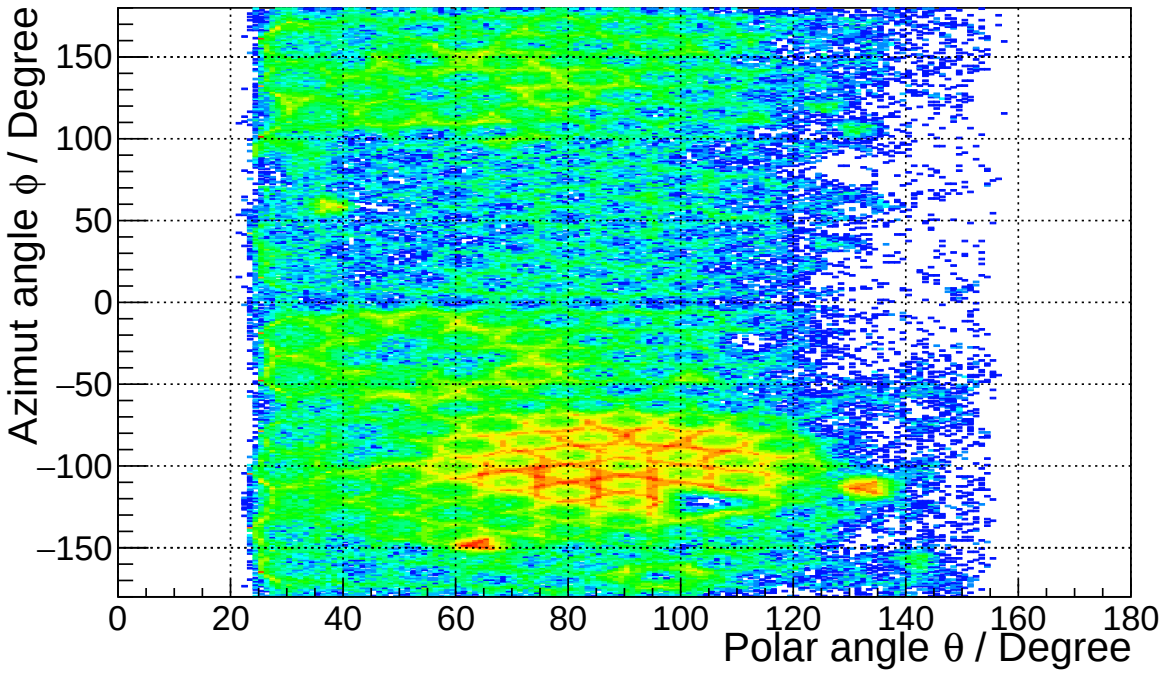
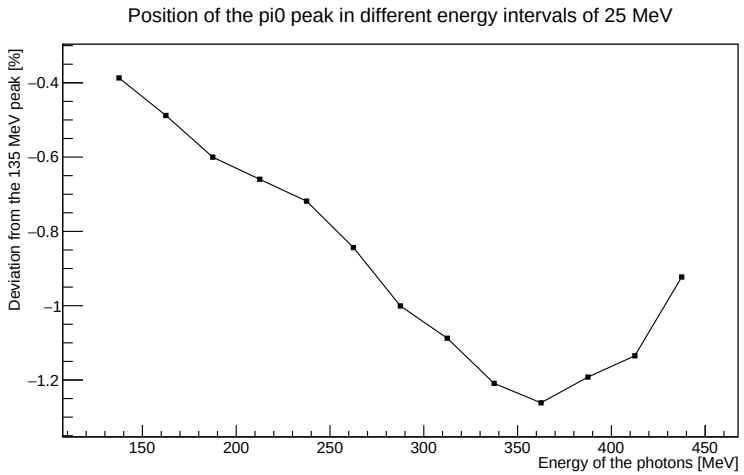


Figure: Beamtime: Distribution in the CB

Conclusion

- There is a energy dependency in the detector
- The reconstructed opening angle is too big for high energies
  $\rightarrow$ wrong reconstruction of the photon impact position is probably the reason for the dependency (Clustering Algorithm)
- The hardware of some PIDs has to be checked (too few or to many events)
- There is a strange ϕ-distribution in the detector
  $\rightarrow$ reason for this has also to be determined

Appendix



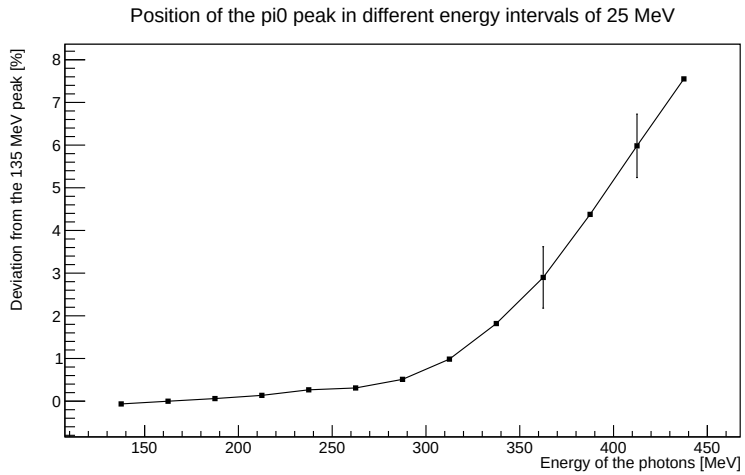


Figure: Simulation:Left: Reconstructed energy and true opening angle. Right: True energy and reconstructed opening angle