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

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

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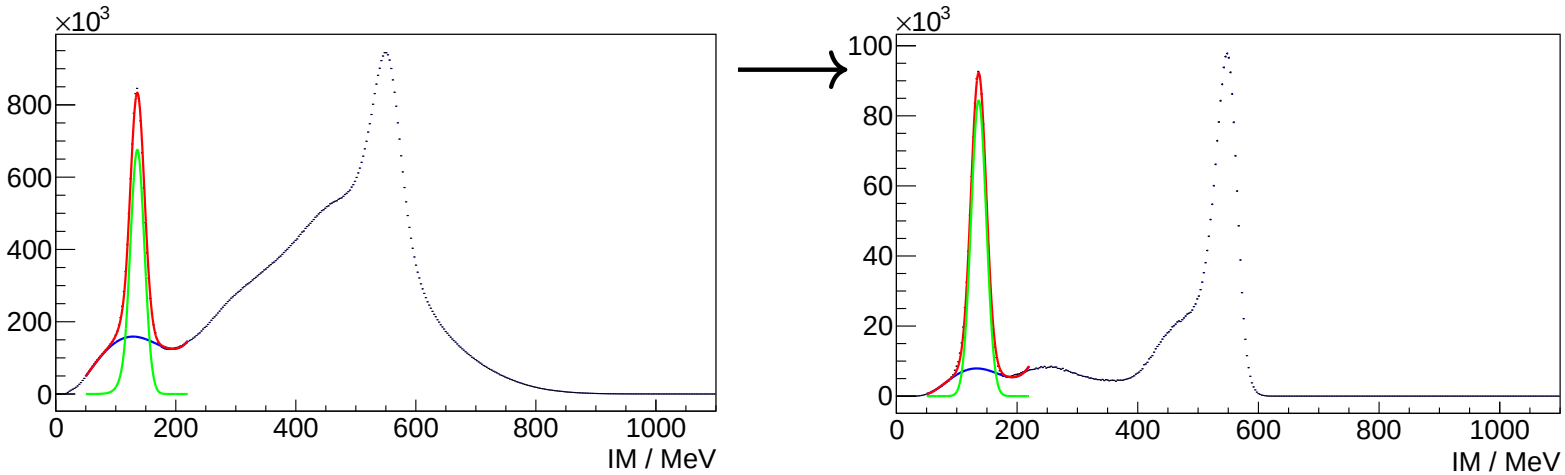
- Is there an energy dependency in the CB?
- How can it be checked?
  $\rightarrow |E_1 - E_2| < 25\,\text{MeV}$
- What are the reasons for the dependency?

Crystal-Ball-Function / Reduction of the Underground

- Check if the registered particles are uncharged
  $\rightarrow$ Reduction of the underground
- Used signal line shape: Crystal-Ball Function



Event-Generator

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  $\rightarrow$ There is no MC sample with enough events
- Creating a new sample with enough events with an already existing Event-Generator would take too much time (multiple days on blaster). Not Efficient!
- 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 in ANT

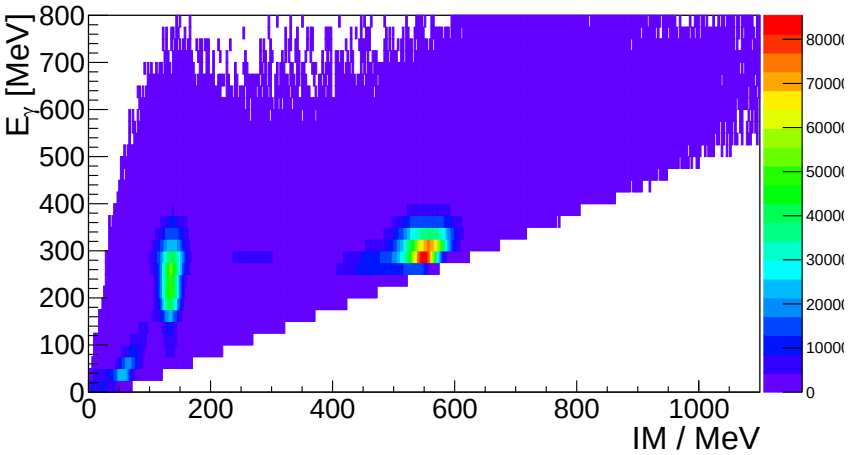
New Event-Generator integrated in ANT

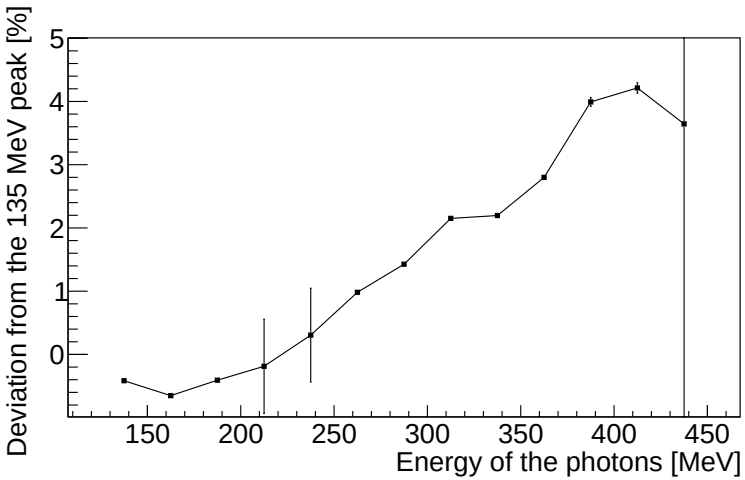
```
auto cmd_Emin     = cmd.add<TCLAP::ValueArg<double>>     ("",  "Emin",     "Minimal incident energy [MeV]", false, 0.0, "double [MeV]");
auto cmd_Emax     = cmd.add<TCLAP::ValueArg<double>>     ("",  "Emax",     "Maximal incident energy [MeV]", false, 1.6*GeV, "double [MeV]");
auto cmd_events   = 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"  );
```

- 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

First look at real data

- Beamtime October 2014
- Well-calibrated

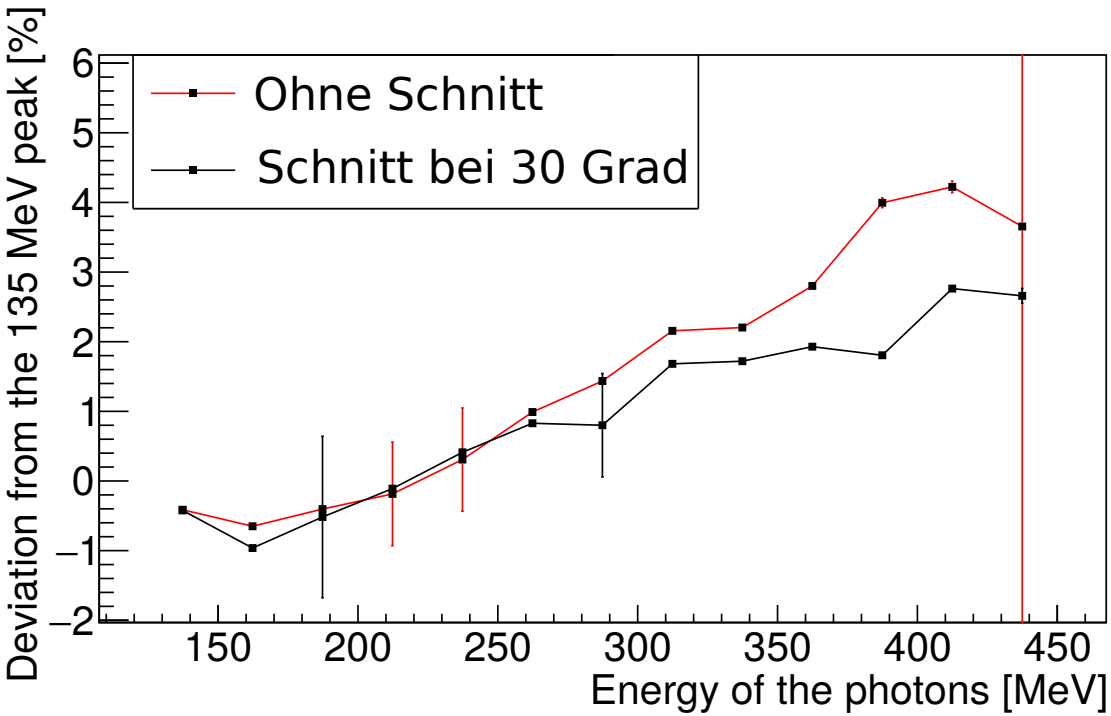




$\rightarrow$ There is a dependency

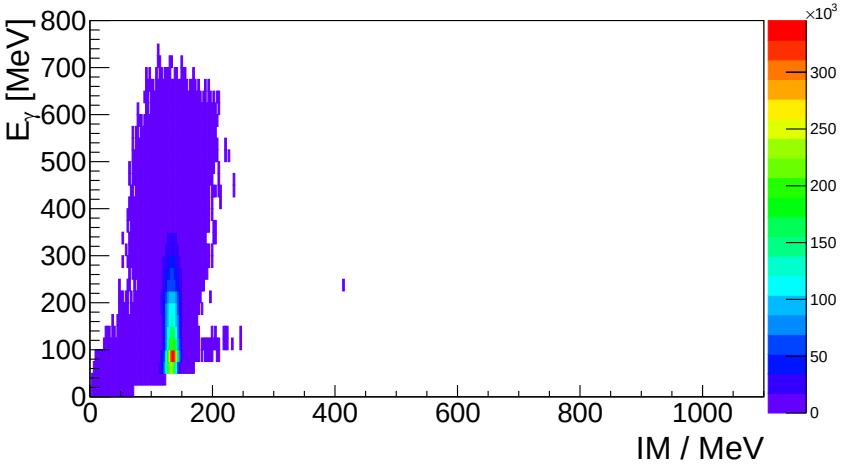
Detectors on the Edge

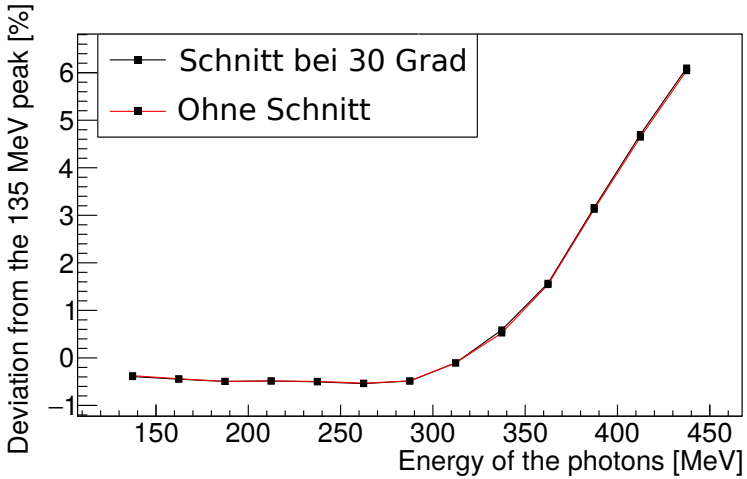
- Beamtime October 2014
- Neglect the detectors at the edge: They are difficult to calibrate because they have less neighbors



How does MC look like?

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

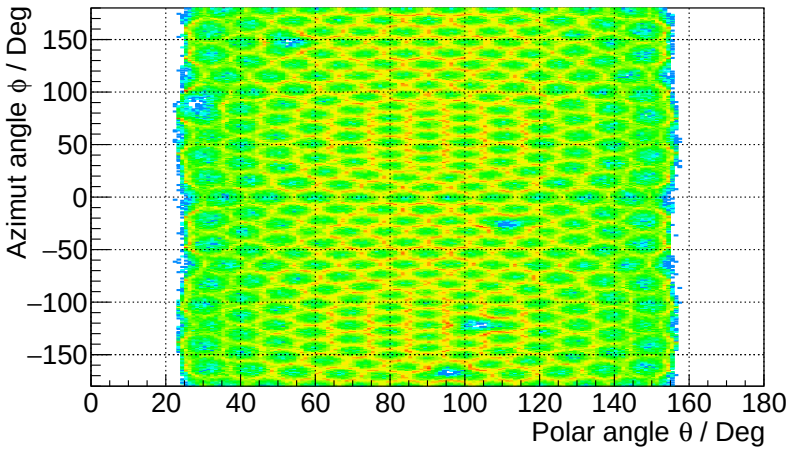


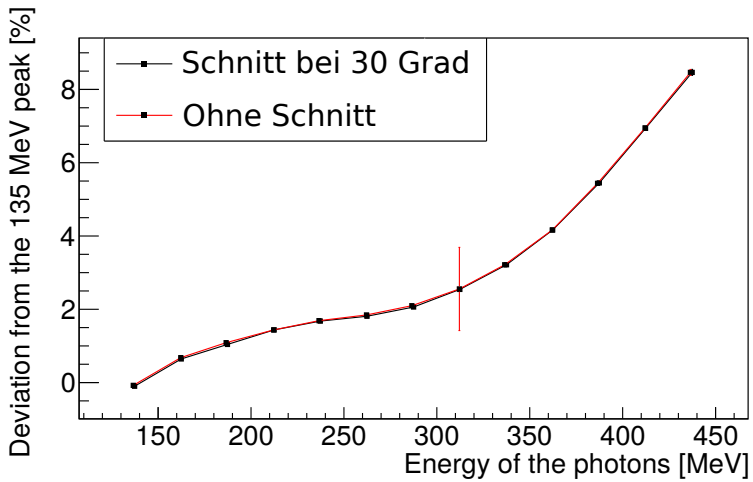


MC also shows this raise
$\rightarrow$ it can be used for further studies

Isotropic Boost

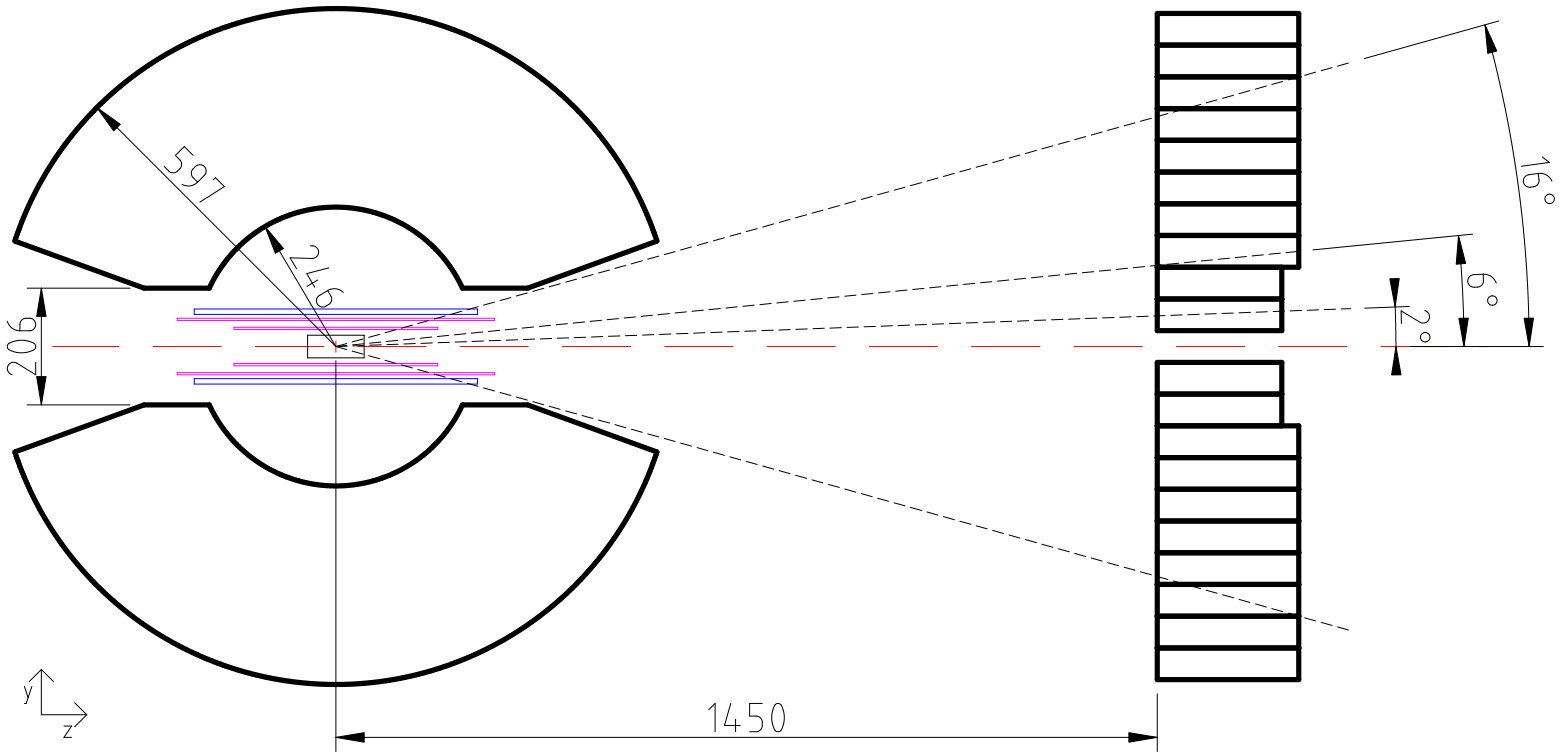
- π^0 decay in the origin of the target
- π^0 are boosted with an energy of $1420\,\text{MeV}$ to $1580\,\text{MeV}$ isotropically
  $\rightarrow$ all detector elements are hit roughly equally





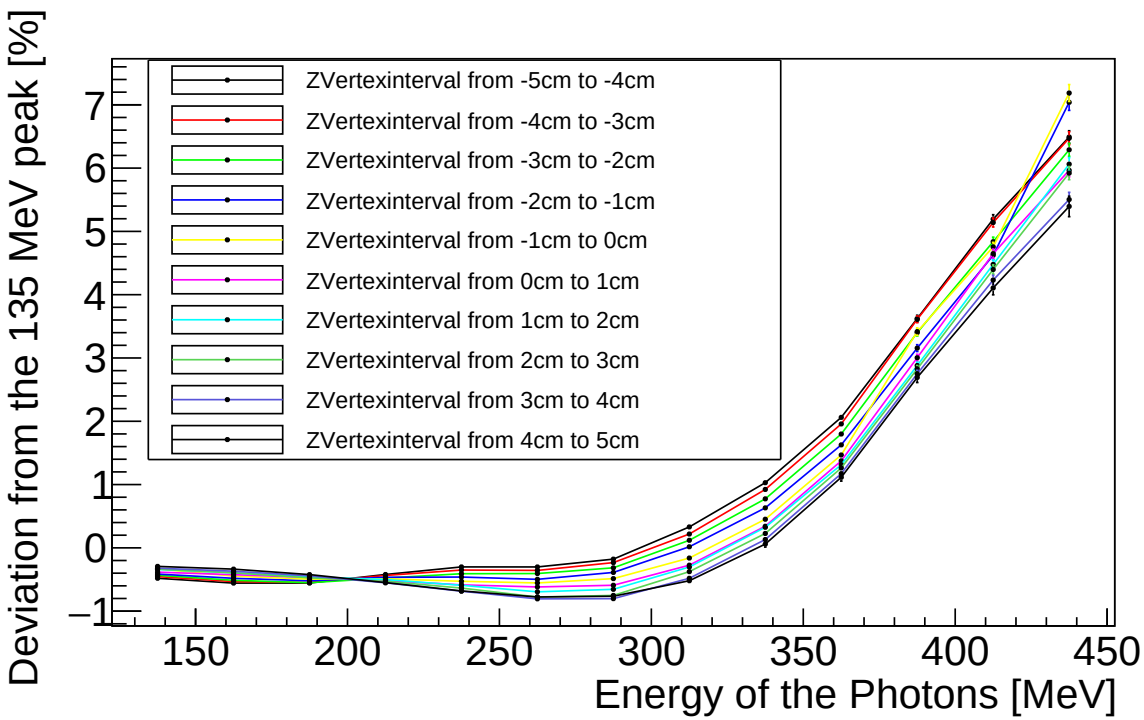
$\rightarrow$ Raise is not caused by specific detector elements

Dimension of the Target



z-Vertex Dependency

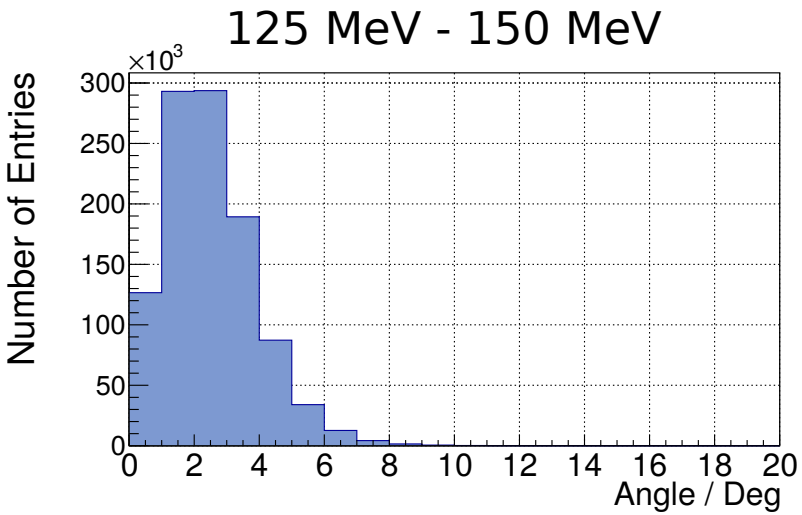
- Neglect the detectors on the edge
- Divide the target in sections of $1\,\mathrm{cm}$

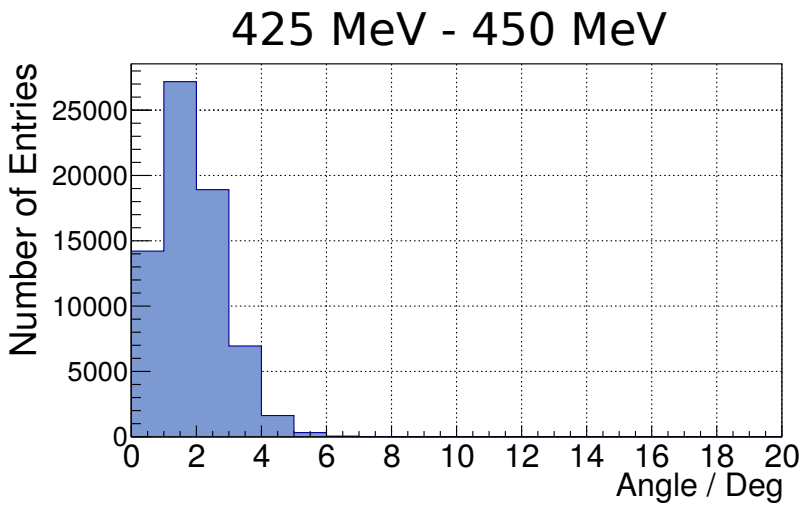


$\rightarrow$ Some dependence but small in compared to the main effect

Angle between Generated and Reconstructed Candidates

- The angle between generated and reconstructed candidate is calculated

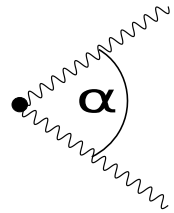


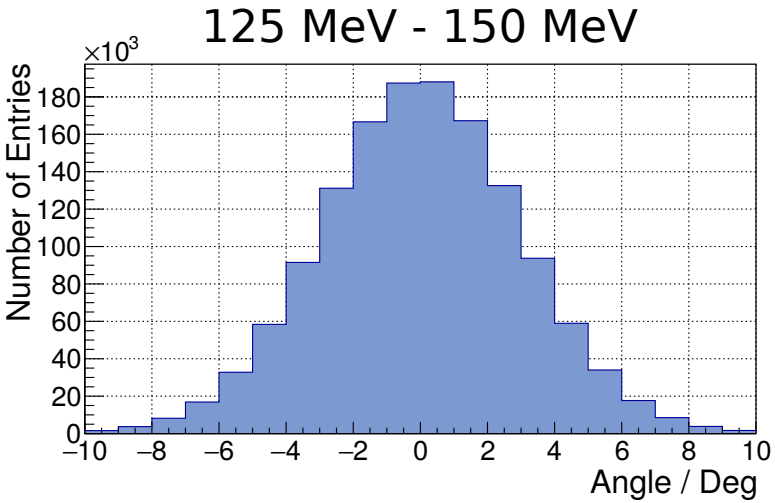


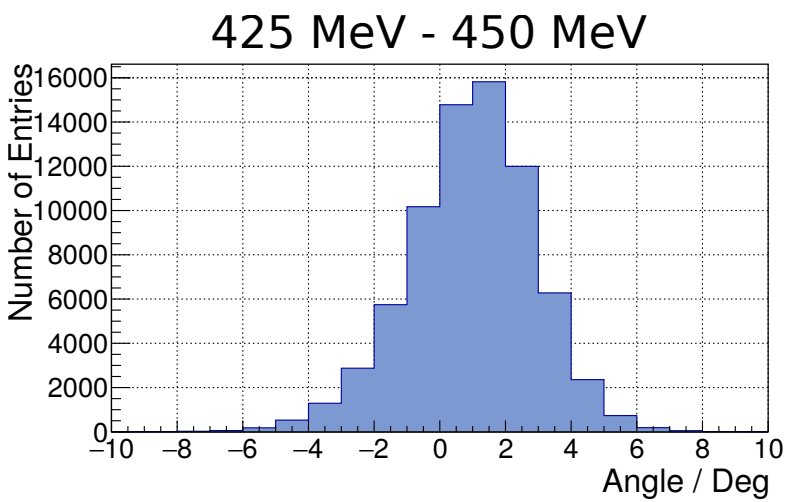
$\rightarrow$ Angular resolution $\sim 1^\circ$ to 2°

Difference between Generated and Reconstructed Opening Angle

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







→ Systematic bias for high photon energies

Reason for the Deviation?

$$m_{\pi^0} = \sqrt{2E_1E_2(1-\cos(\alpha))}$$
$$\rightarrow \Delta m_{\pi^0} = \sqrt{E_1E_2} \cdot \cos(\tfrac{\alpha}{2}) \cdot \Delta\alpha$$

with $E_1 = E_2 = 450\,\text{MeV} \rightarrow \alpha \approx 17.3°$

Lets assume: $\Delta\alpha = 1.0°$
$\rightarrow \Delta m_{\pi^0} = 7.8\,\text{MeV}$
Which is a deviation of about 6% to the true m_{π^0} mass

$\Delta\alpha$ for Different z-Vertices

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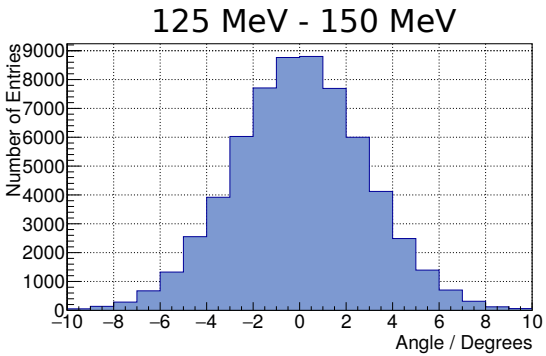
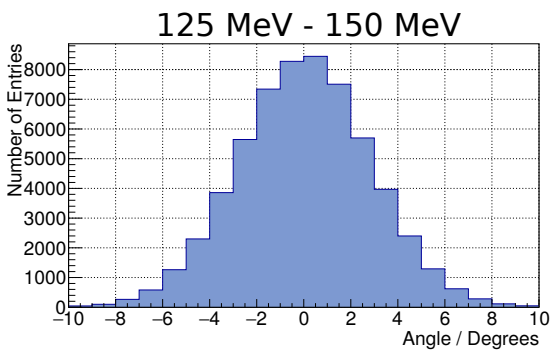
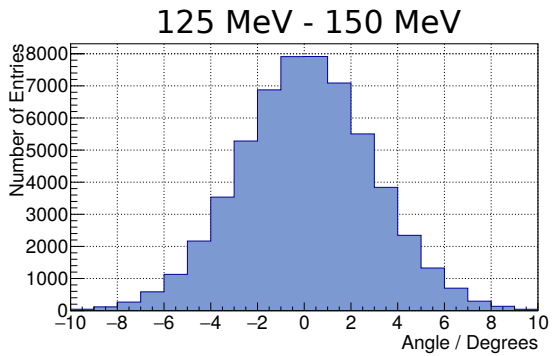
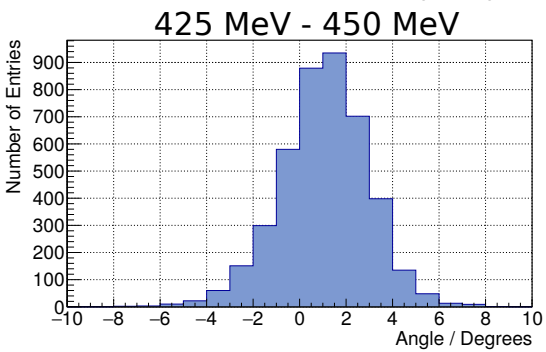
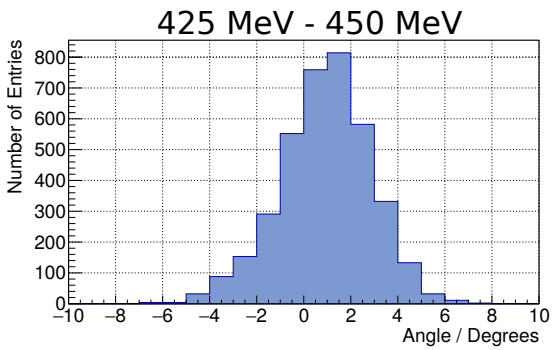
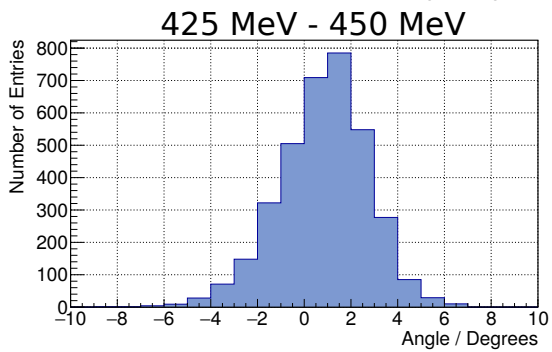






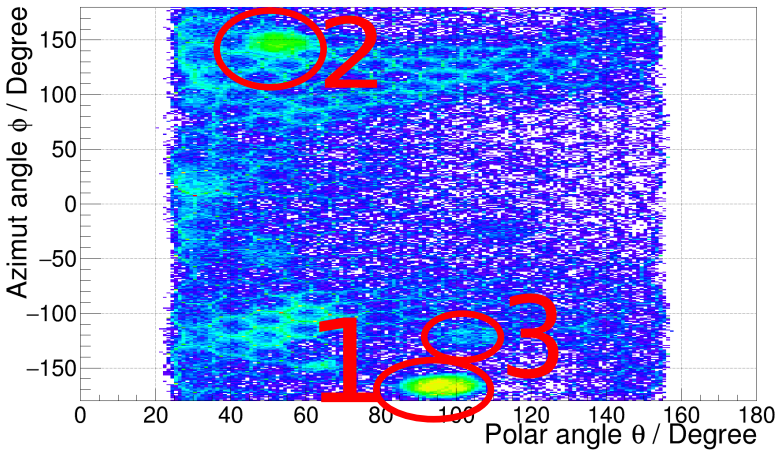


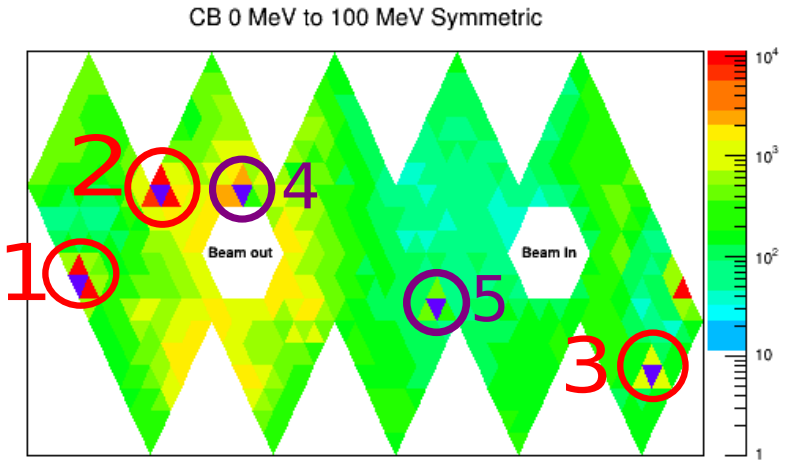




Hot Crystals

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

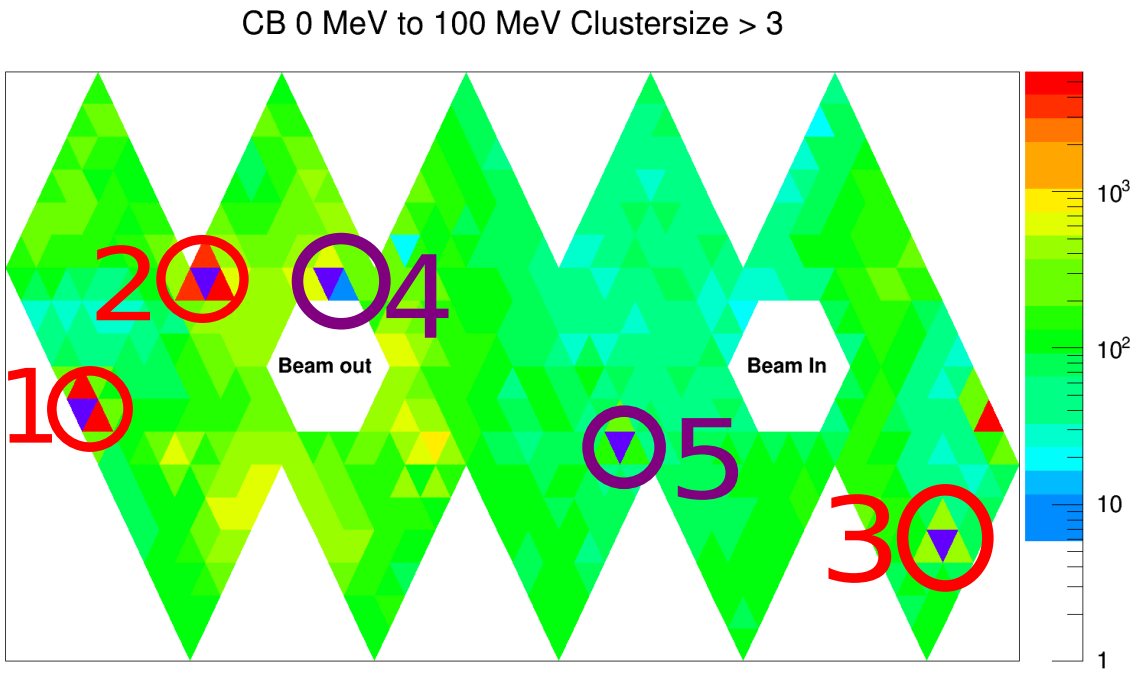




Number in the figures	1	2	3	4	5
Element Number	549	565	597	677	265

Hot Crystals and Clustersize > 3

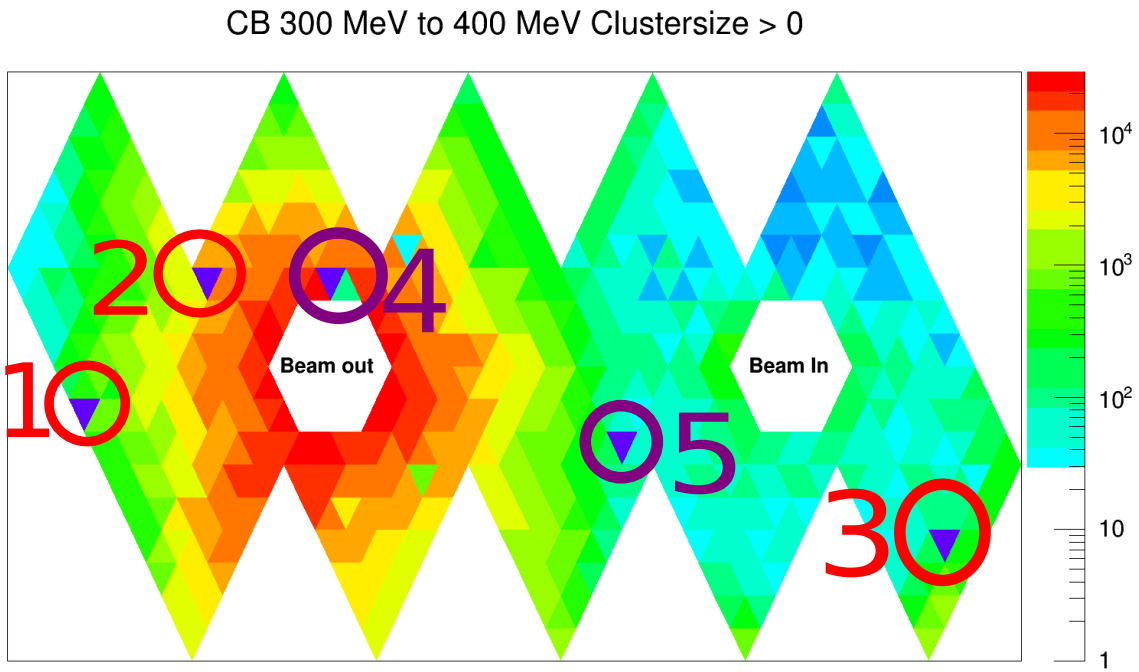
- Beamtime October 2014
- Photon energy between $0\,\text{MeV}$ and $100\,\text{MeV}$
- Clustersize > 3



$\rightarrow$ Neighbors of some dead crystals appear hot for low energies

Hot Crystals for Higher Energies

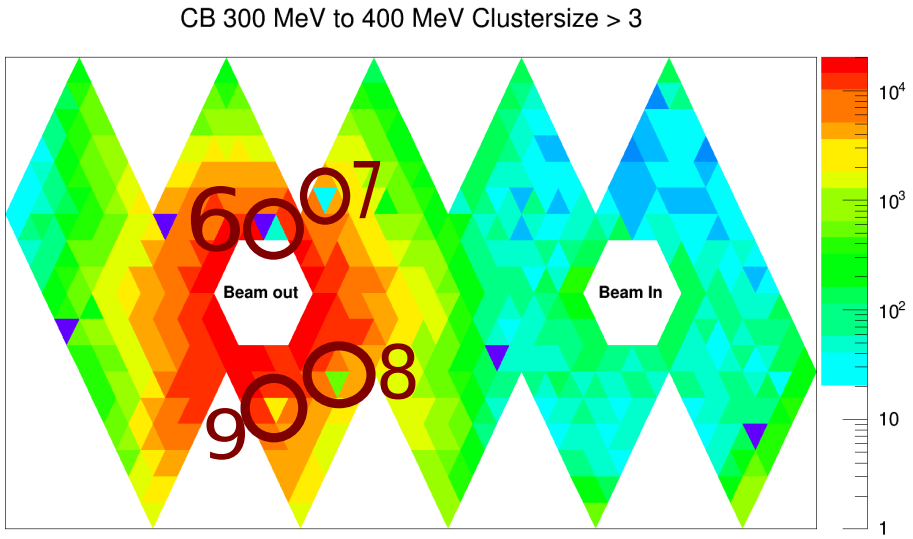
- Beamtime October 2014
- Photon energy between $300\,\text{MeV}$ and $400\,\text{MeV}$



$\rightarrow$ *Hot Neighbors* disappear at larger energies

Additional Dead Crystals

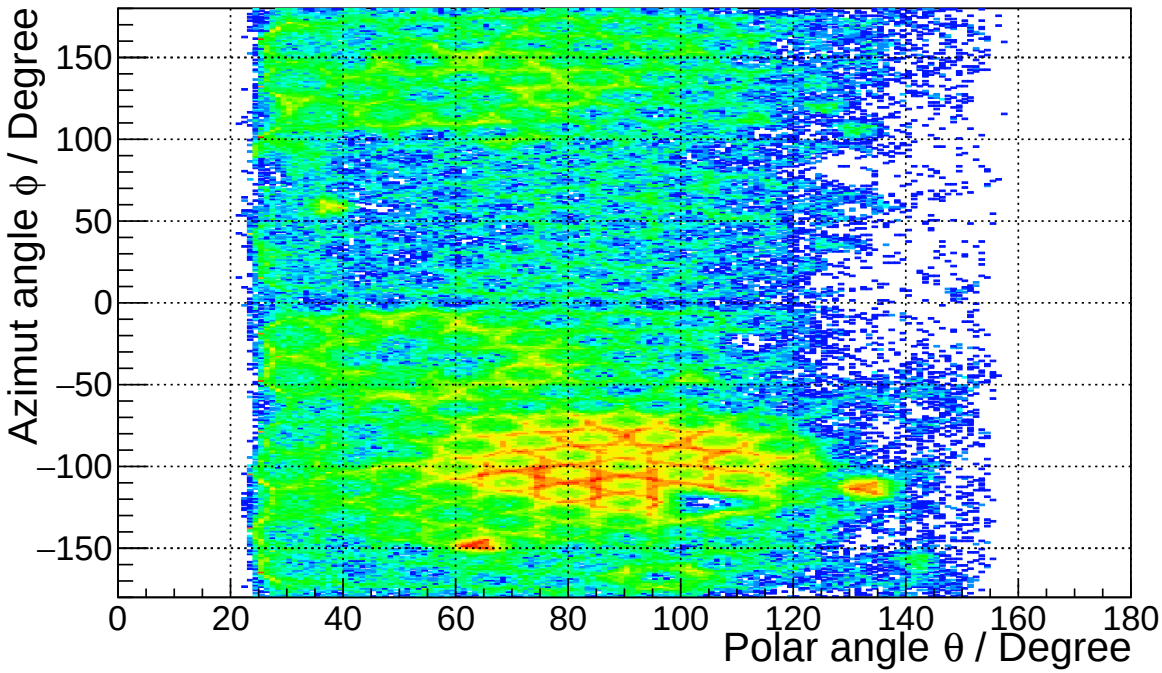
- Beamtime October 2014
- Photon energy between $300\,\text{MeV}$ and $400\,\text{MeV}$



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

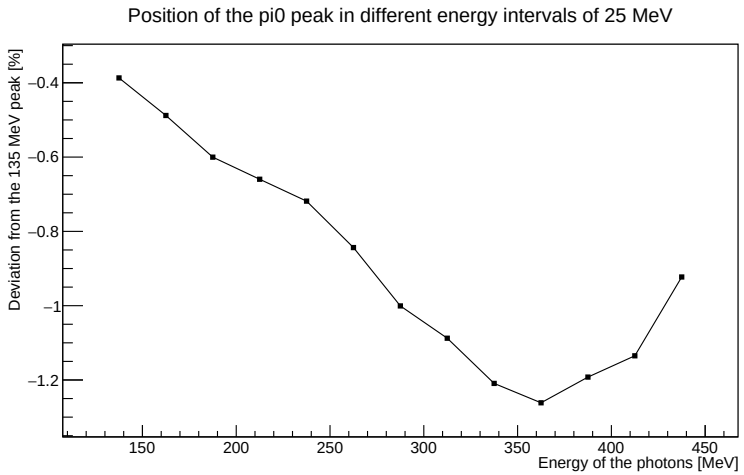
- Beamtime October 2014
- Photon energy between $200\,\text{MeV}$ and $225\,\text{MeV}$
- Weird bump



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



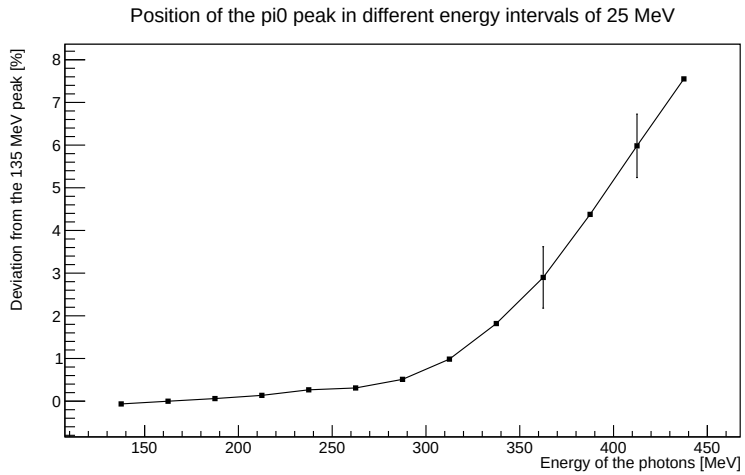


Figure: Simulation:Left: Reconstructed energy and true opening angle. Right: True energy and reconstructed opening angle