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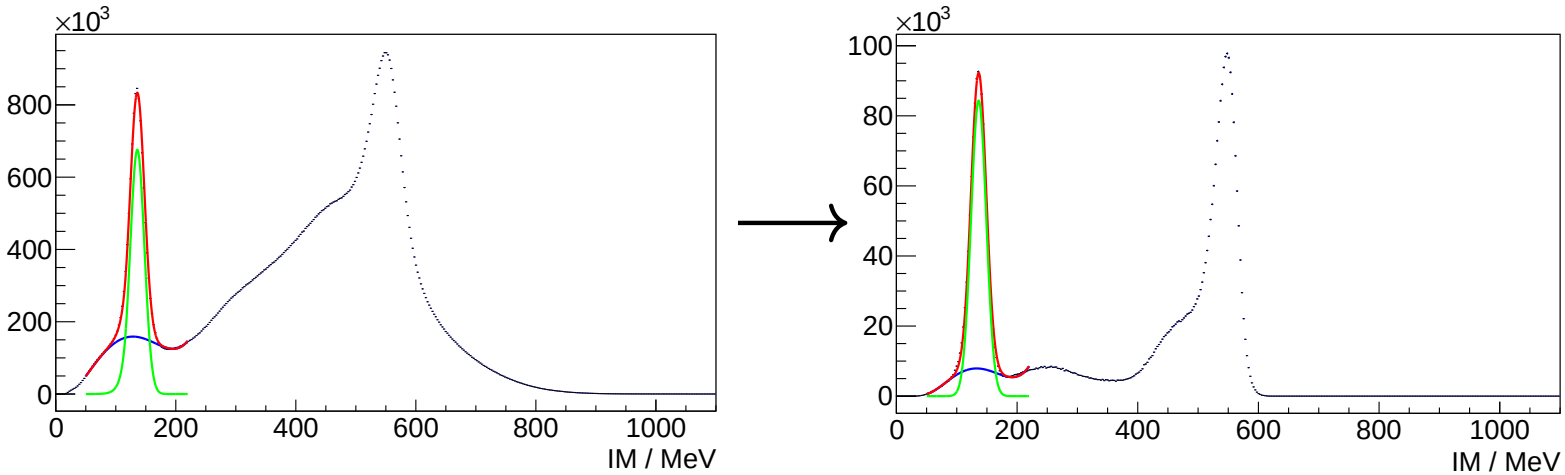
- How can it be checked?
  $\rightarrow |E_1 - E_2| < 25\,\text{MeV}$
- What are the reasons for the dependency?

Reduction of the Underground / Crystal-Ball Function

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



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- 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

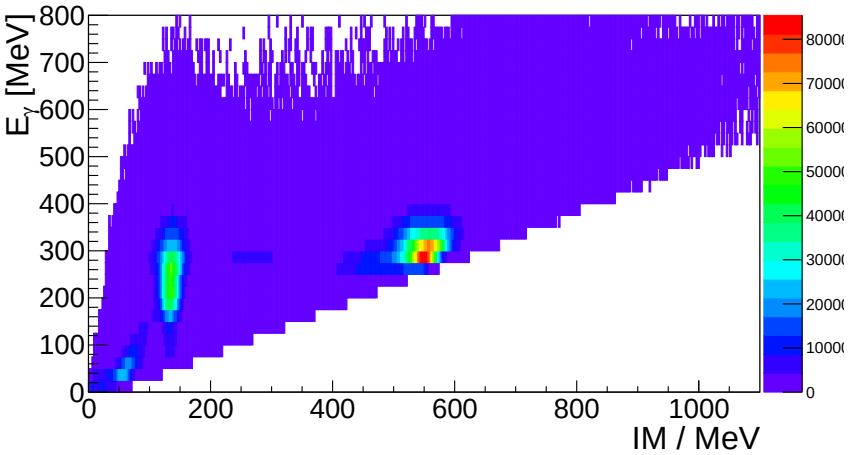
New Event-Generator integrated in ANT

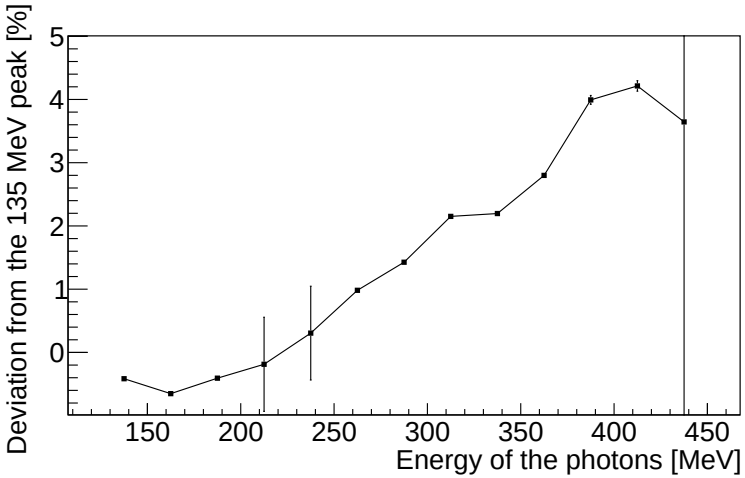
```
auto cmd_Emin     = cmd.add<TCLAP::ValueArg<double>>     ("",  "Emin",     "Minimal incident energy [MeV]", false, 0.0, "double [MeV]");
auto cmd_Emax     = cmd.add<TCLAP::ValueArg<double>>     ("",  "Emax",     "Maximal incident energy [MeV]", false, 1.6*GeV, "double [MeV]");
auto cmd_events   =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

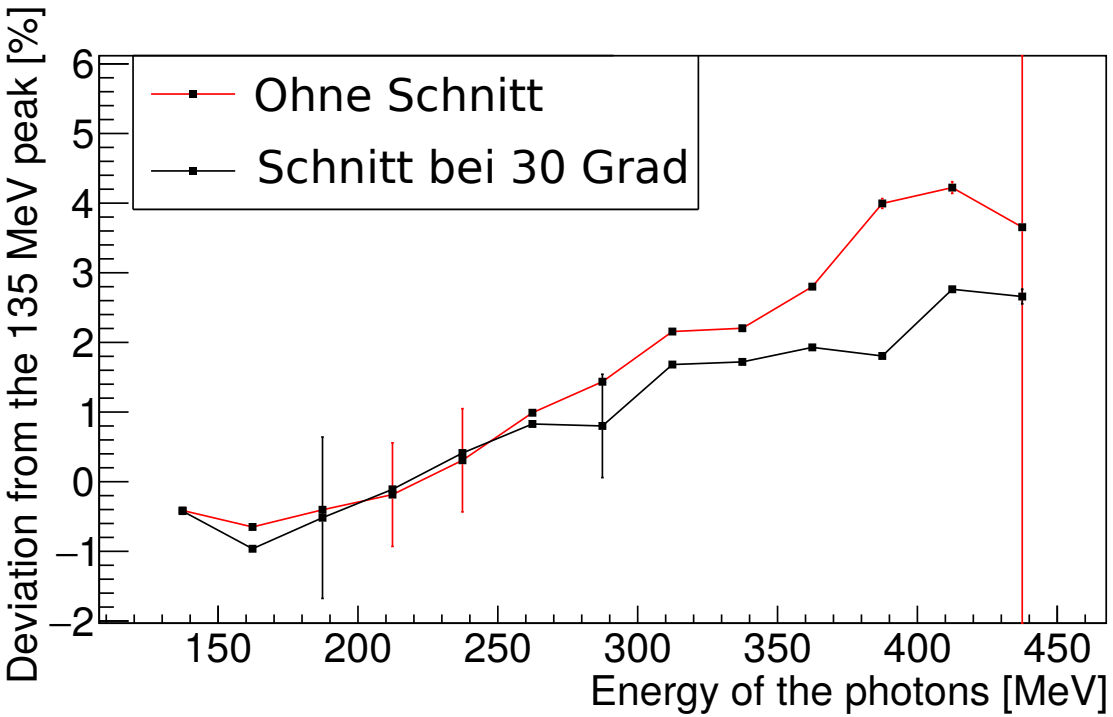




$\rightarrow$ There is a energy dependency

Detectors on the Edge

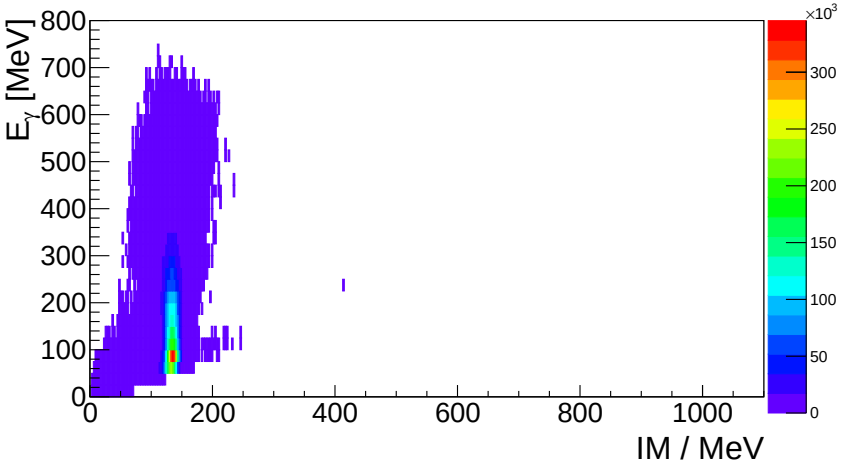
- Beamtime October 2014
- Neglect the detectors at the edge: They are difficult to calibrate because they have less neighbors

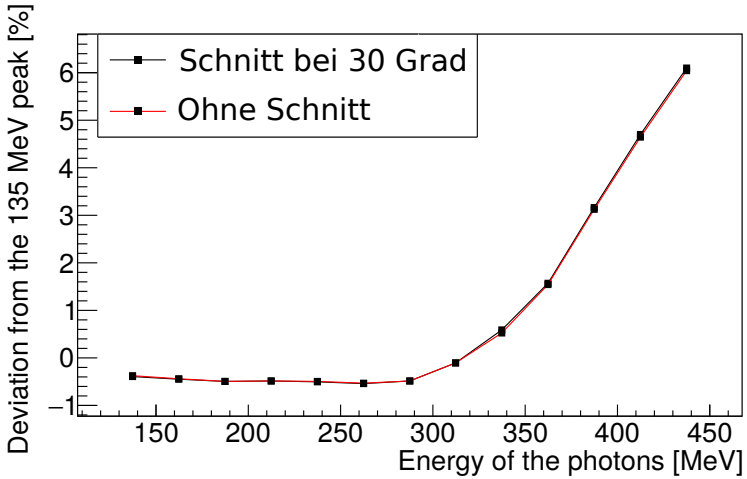


→ Slight improvement

How does MC look like?

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

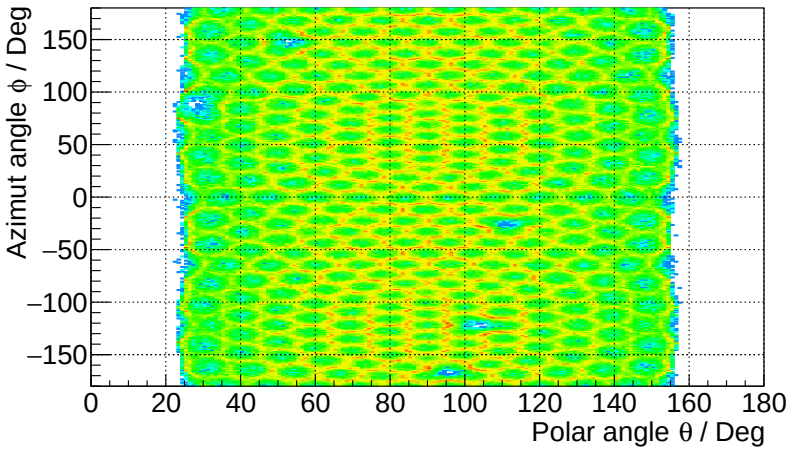


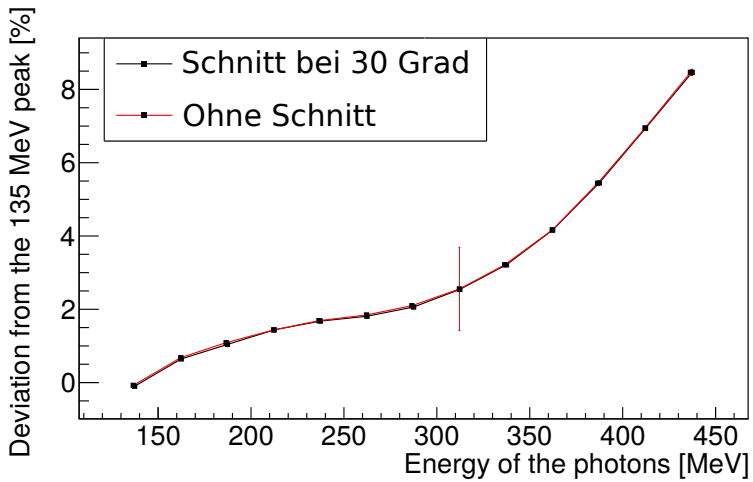


MC also shows this raise
$\rightarrow$ it can be used for further studies

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

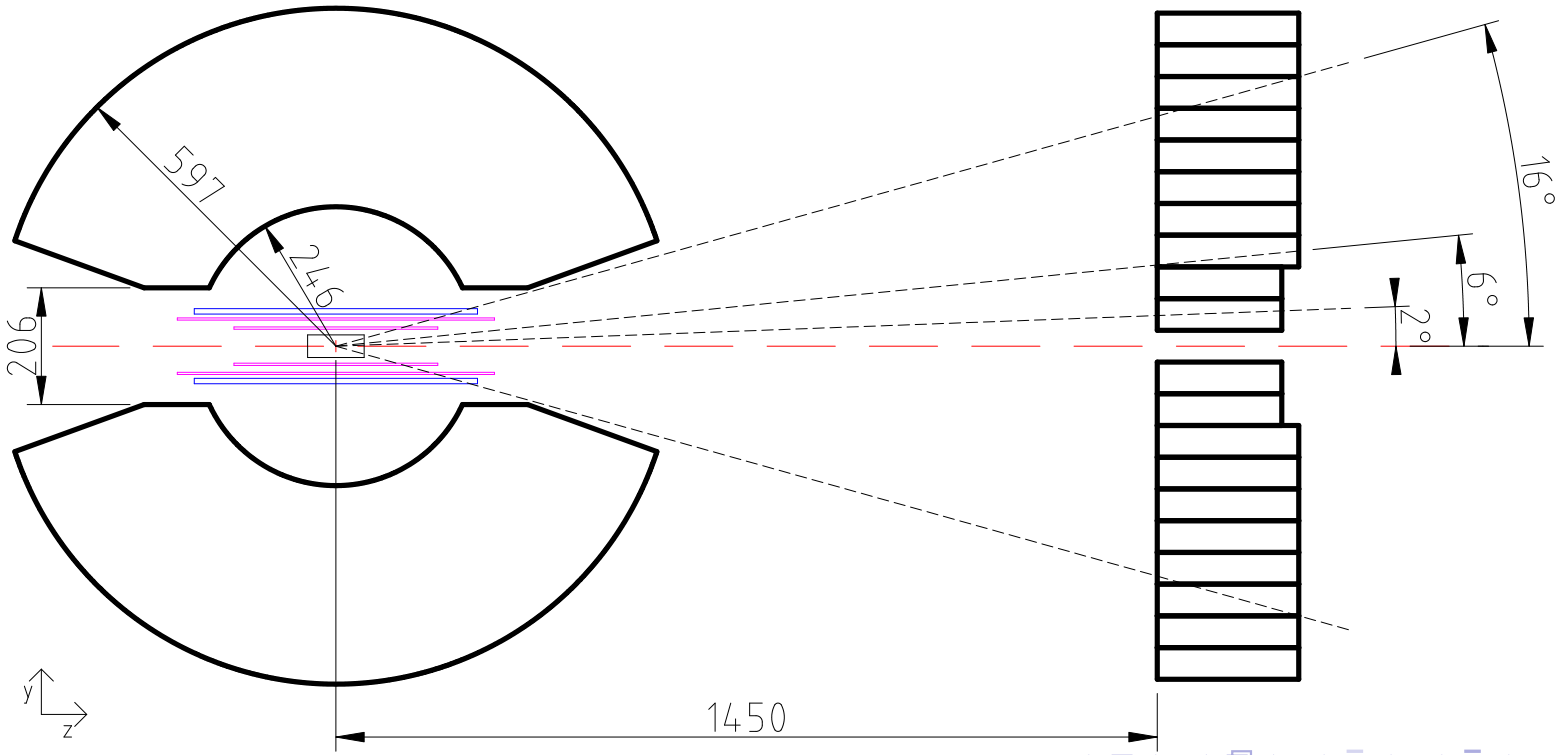




$\rightarrow$ Raise is not caused by specific detector elements

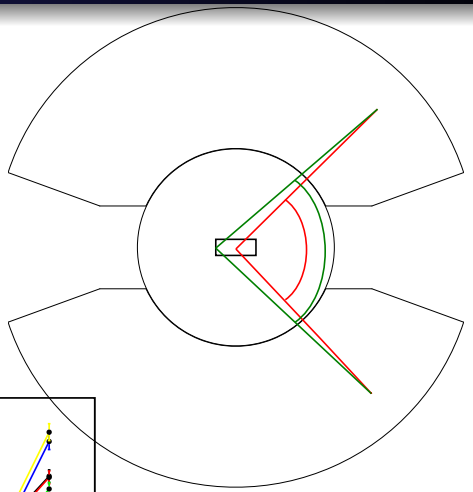
Dimension of the Target

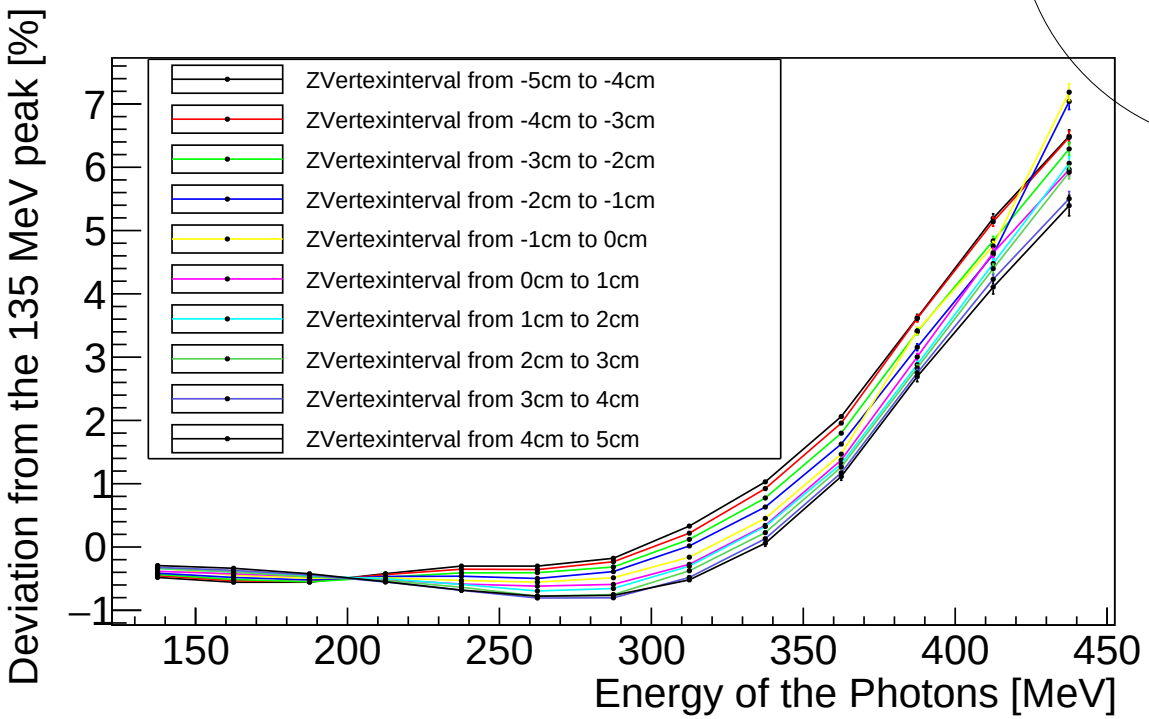
Kommentar: Soll ich die Grafik auf einer extra Folie lassen (ggf. unnoetige Informationen entfernen) oder reicht die Grafik die ich auf der naechsten in die Ecke gequetscht habe? An sich brauche ich ja nur den CB und das Target.



z-Vertex Dependency

- Neglect the detectors on the edge
- Divide the target in sections of 1 cm

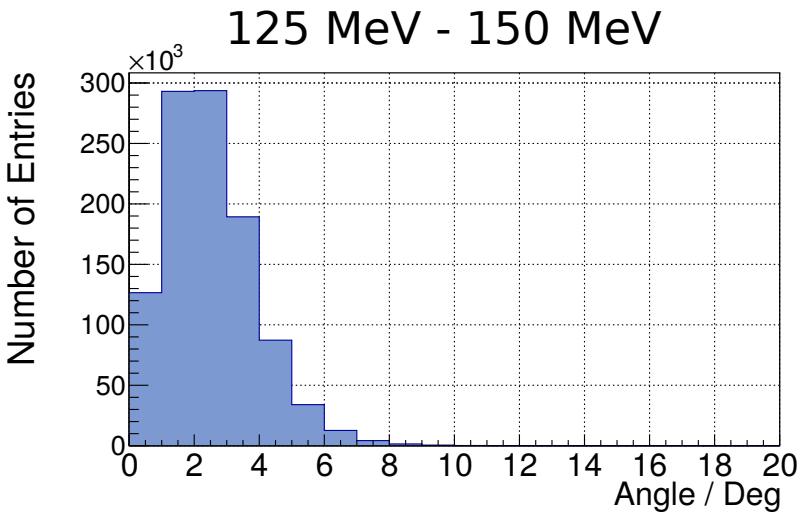


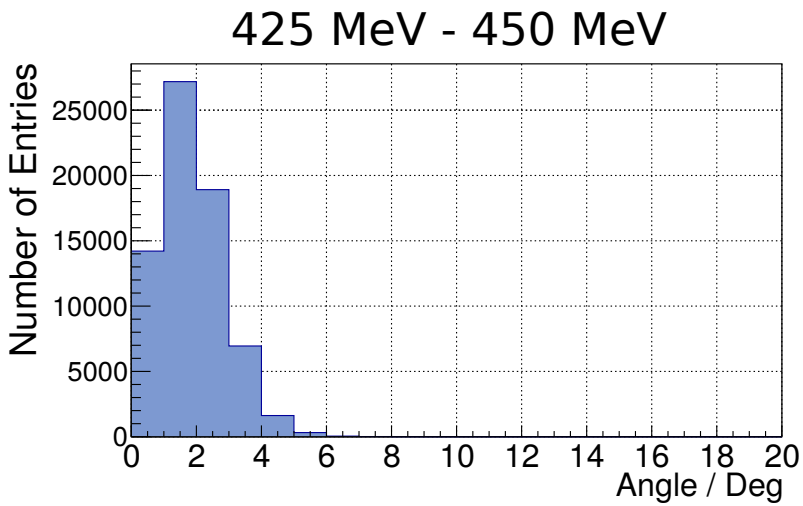


$\rightarrow$ Some dependence but small in compared to the main effect

Angle between Generated and Reconstructed Candidates

- The angle between generated and reconstructed candidate is calculated

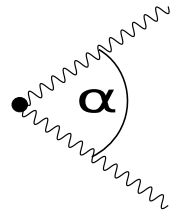


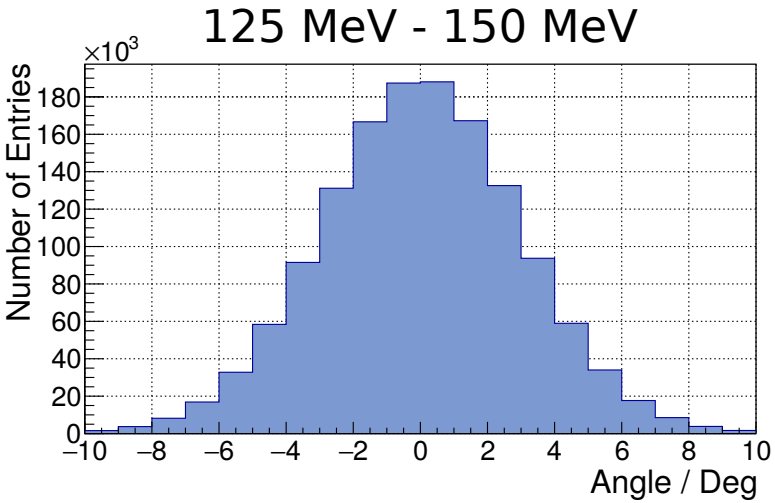


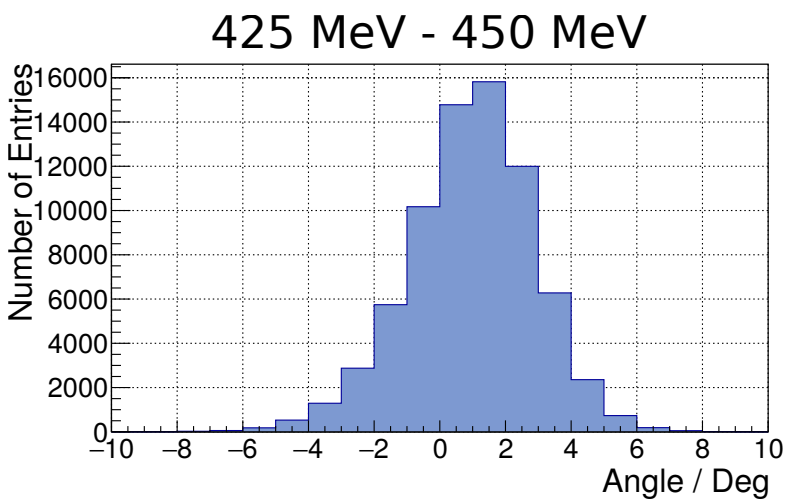
$\rightarrow$ Angular resolution $\sim 1^\circ$ to 2°

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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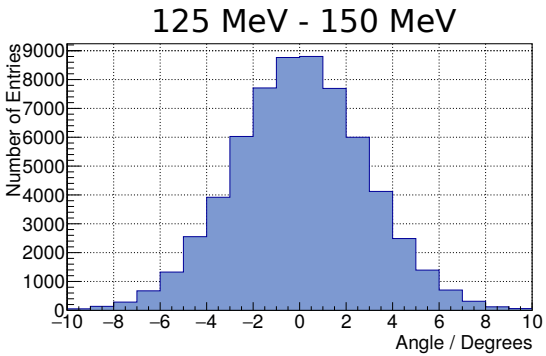
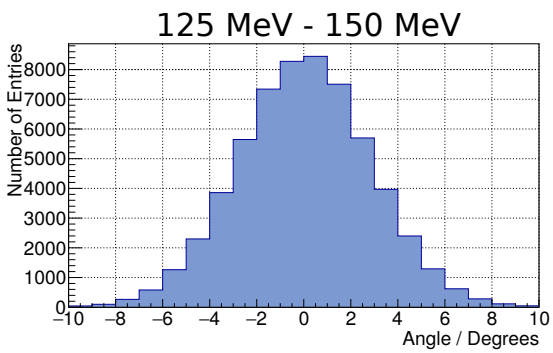
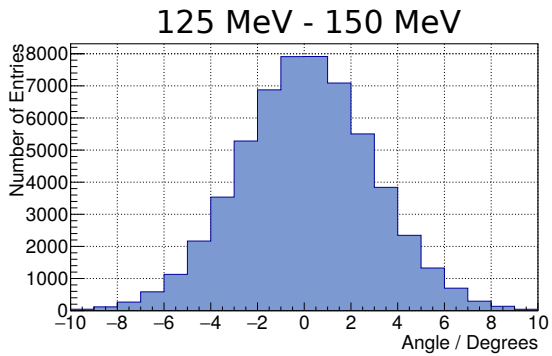
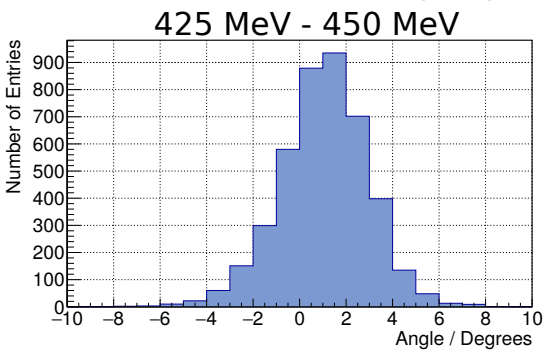
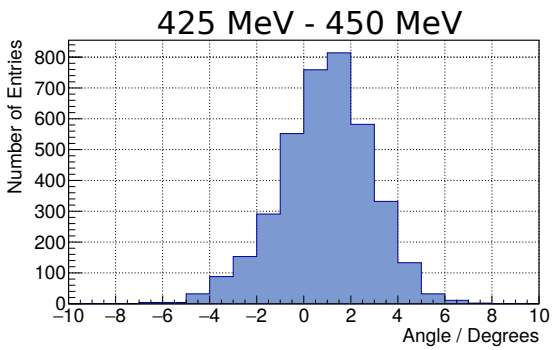
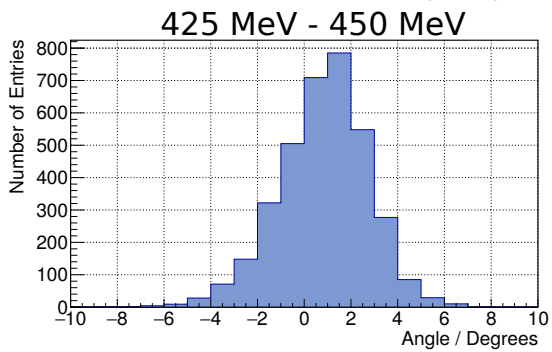






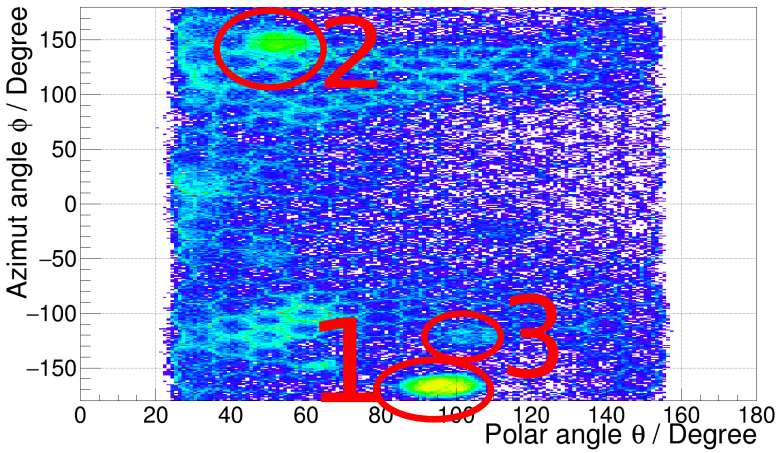


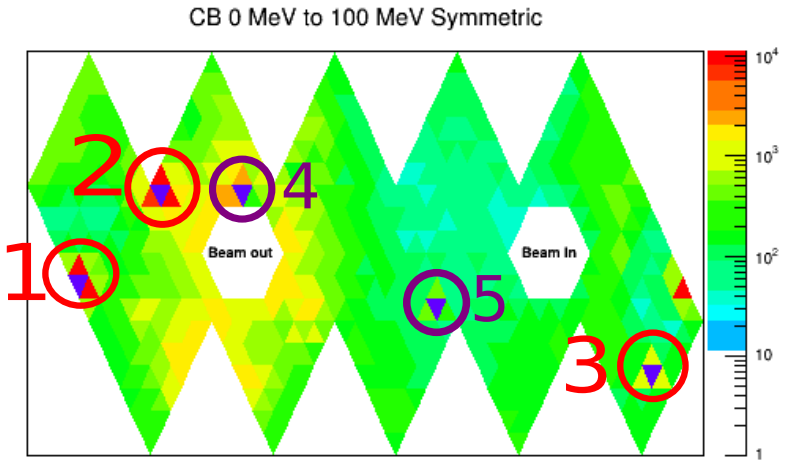




Hot Crystals

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

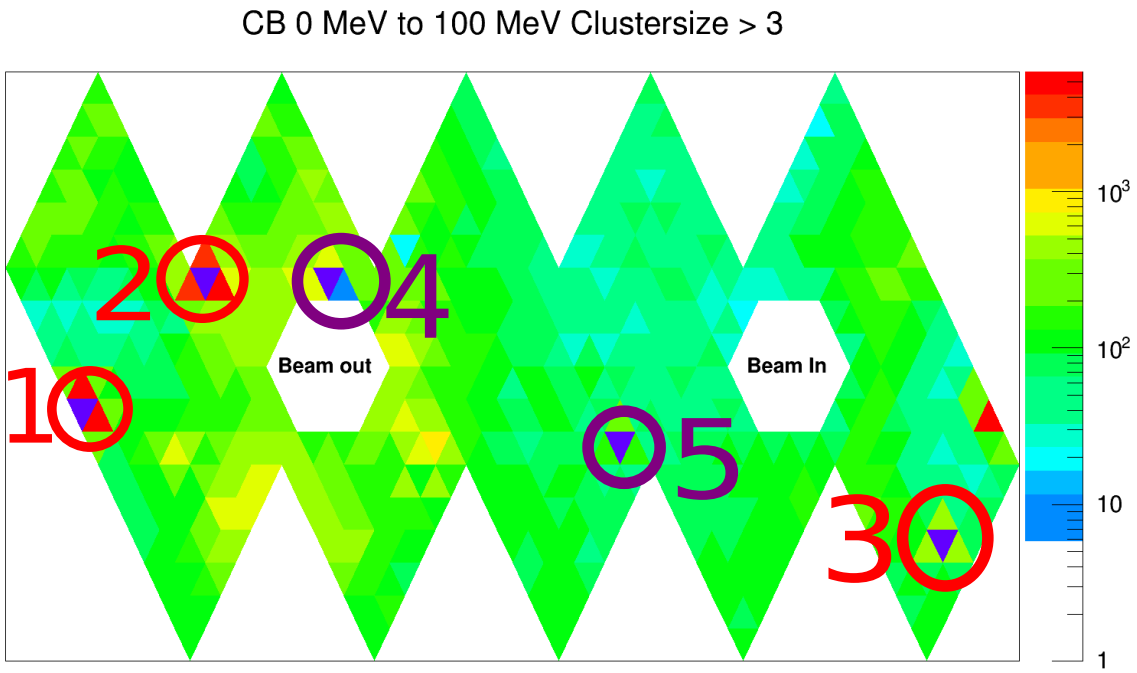




Number in the figures	1	2	3	4	5
Element Number	549	565	597	677	265

Hot Crystals and Clustersize > 3

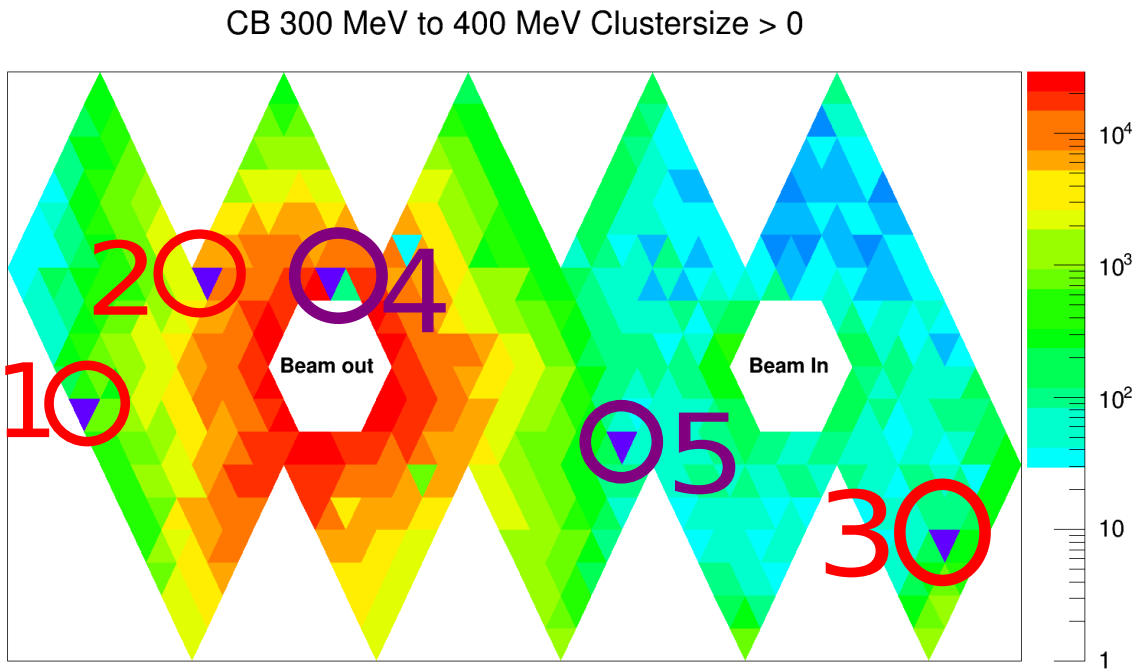
- Beamtime October 2014
- Photon energy between $0\,\text{MeV}$ and $100\,\text{MeV}$
- Clustersize > 3



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

Hot Crystals for Higher Energies

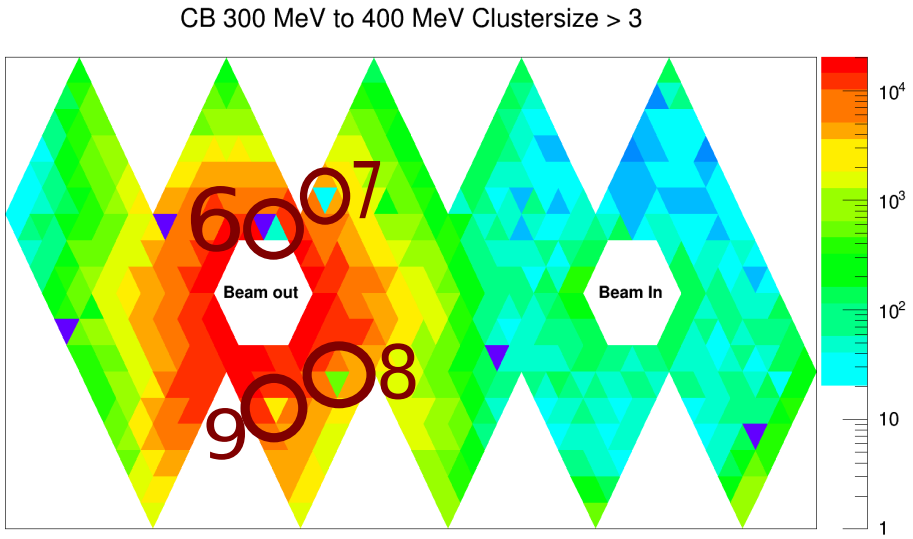
- Beamtime October 2014
- Photon energy between $300\,\text{MeV}$ and $400\,\text{MeV}$



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

Additional Dead Crystals

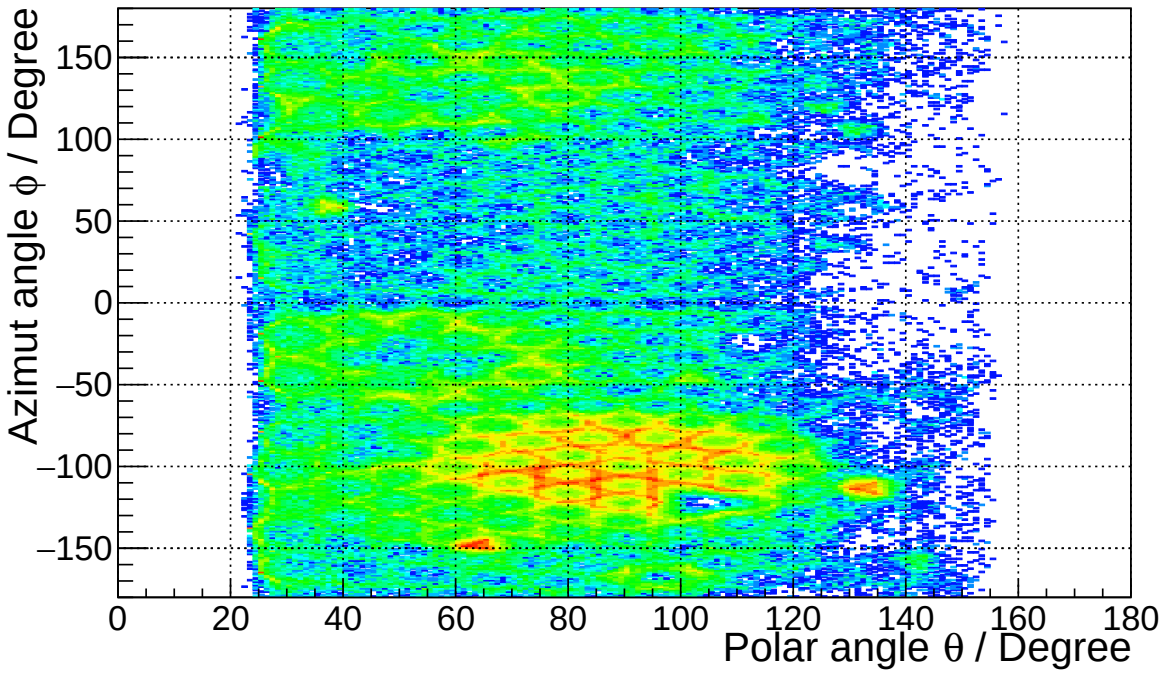
- Beamtime October 2014
- Photon energy between $300\,\text{MeV}$ and $400\,\text{MeV}$



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

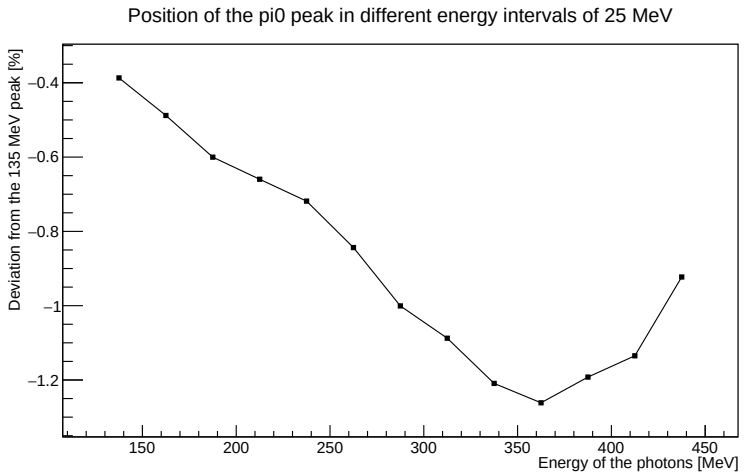
- Beamtime October 2014
- Photon energy between $200\,\text{MeV}$ and $225\,\text{MeV}$
- Weird bump



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



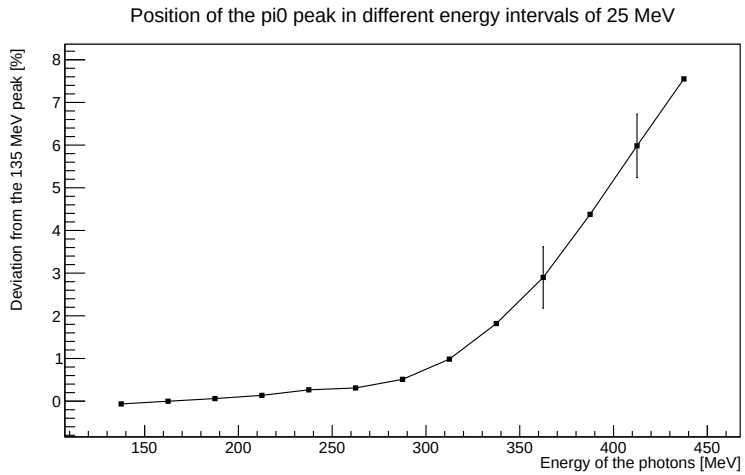


Figure: Simulation:Left: Reconstructed energy and true opening angle. Right: True energy and reconstructed opening angle