

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

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The Process

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

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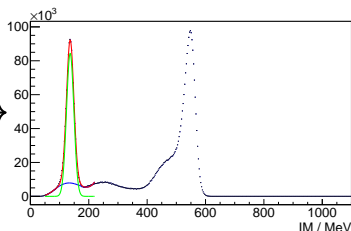
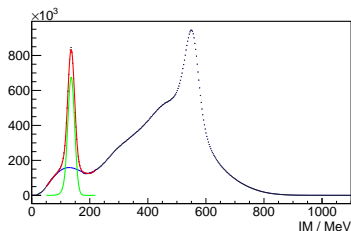
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- Is there an energy dependency in the CB?
- How can it be checked?
 $\rightarrow |E_1 - E_2| < 25 \text{ MeV}$
- What are the reasons for the dependency?

Reduction of the Underground / Crystal-Ball Function

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



Event-Generator

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→ 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
→ The generator should be able to simulate MAMI-Beam and isotropic boost

Event-Generator in ANT

New Event-Generator integrated in ANT

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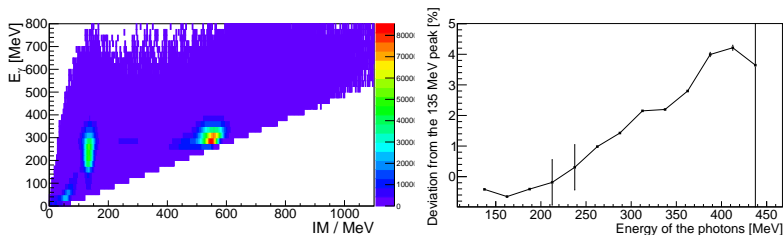
auto cmd_Emin      = cmd.add<TCLAP::ValueArg<double>>    ("", "Emin",      "Minimal incident energy [MeV]", false, 0.0, "double [MeV]");
auto cmd_Emax      = cmd.add<TCLAP::ValueArg<double>>    ("", "Emax",      "Maximal incident energy [MeV]", false, 1.6*GeV, "double [MeV]");
auto cmd_events     = cmd.add<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 $|E_1 - E_2| < 25$ 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

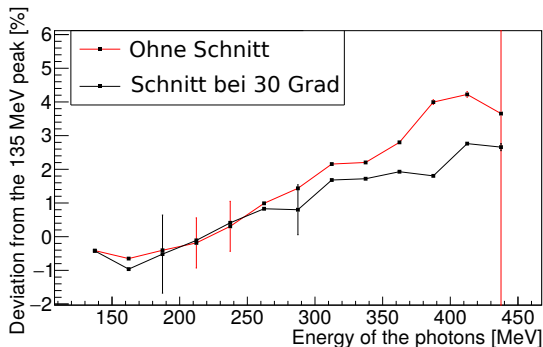
- Beamtime October 2014
- Well-calibrated



→ There is a energy dependency

Detectors on the Edge

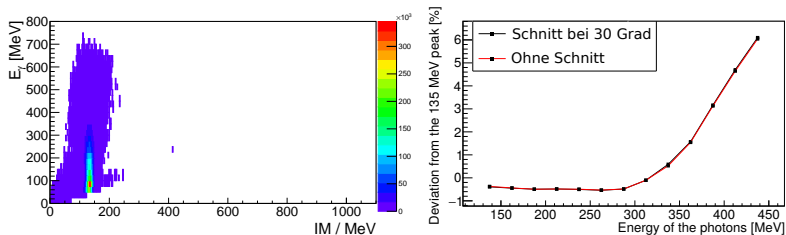
- Beamtime October 2014
- Neglect the detectors at the edge: They are difficult to calibrate because they have less neighbors



→ Slight improvement

How does MC look like?

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

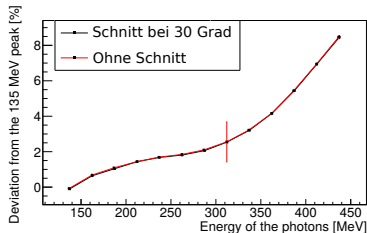
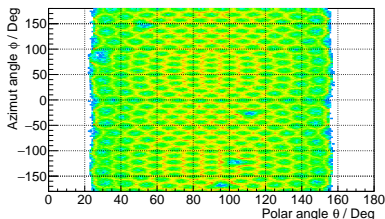


MC also shows this raise

→ it can be used for further studies

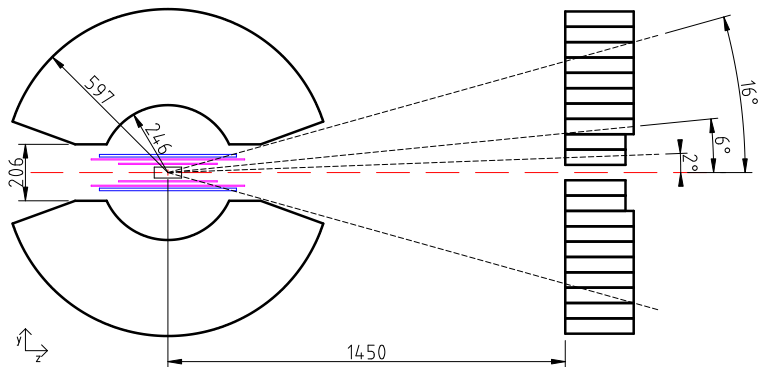
Isotropic Boost

- π^0 decay in the origin of the target
- π^0 are boosted with an energy of 1420 MeV to 1580 MeV isotropically
→ all detector elements are hit roughly equally



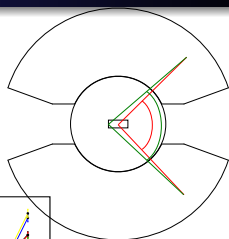
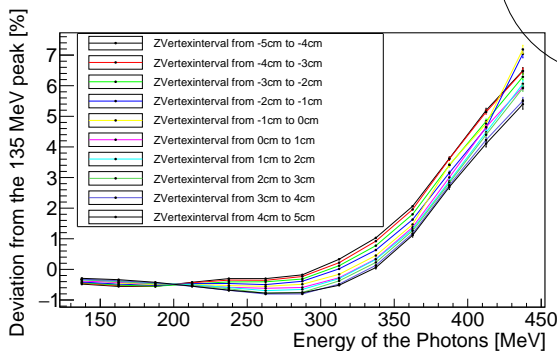
→ Raise is not caused by specific detector elements

Dimension of the Target



z -Vertex Dependency

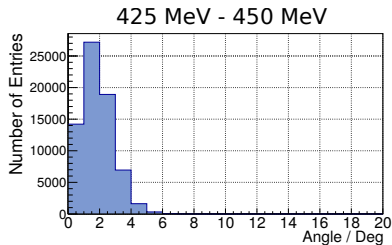
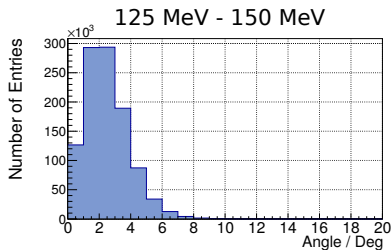
- Neglect the detectors on the edge
- Divide the target in sections of 1 cm



→ Some dependence but small in compared to the main effect

Angle between Generated and Reconstructed Candidates

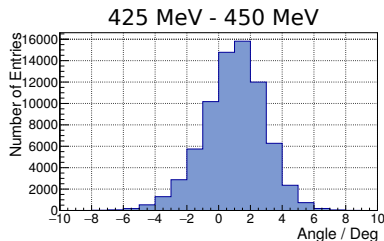
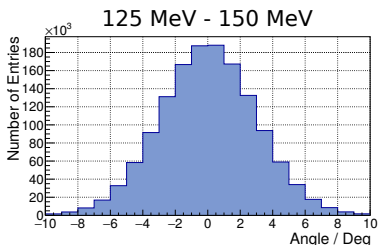
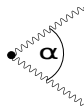
- The angle between generated and reconstructed candidate is calculated



→ 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?

$$m_{\pi^0} = \sqrt{2E_1 E_2 (1 - \cos(\alpha))}$$

$$\rightarrow \Delta m_{\pi^0} = \sqrt{E_1 E_2} \cdot \cos\left(\frac{\alpha}{2}\right) \cdot \Delta\alpha$$

with $E_1 = E_2 = 450 \text{ MeV} \rightarrow \alpha \approx 17.3^\circ$

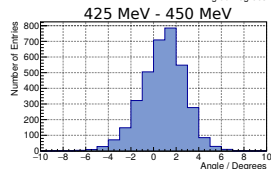
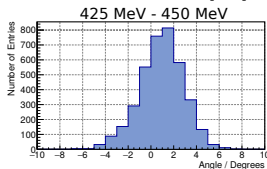
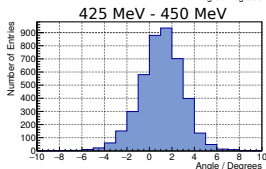
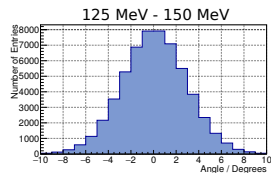
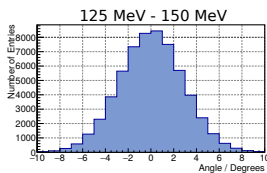
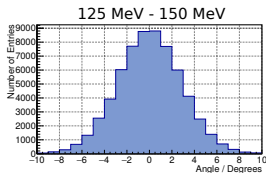
Lets assume: $\Delta\alpha = 1.0^\circ$

$$\rightarrow \Delta m_{\pi^0} = 7.8 \text{ MeV}$$

Which is a deviation of about 6% to the true m_{π^0} mass

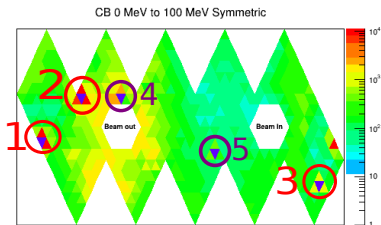
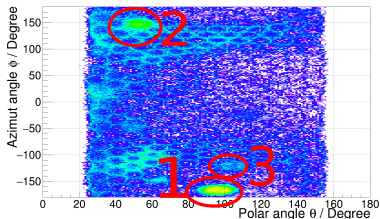
$\Delta\alpha$ for Different z -Vertices

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



Hot Crystals

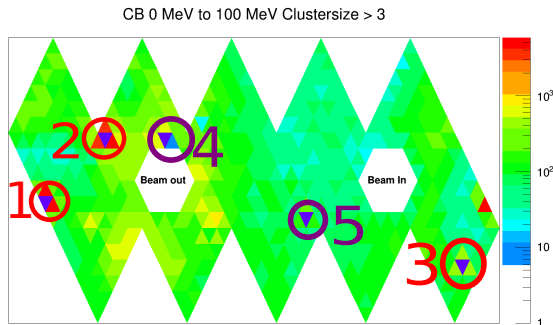
- Beamtime October 2014
- Photon energy between 0 MeV and 100 MeV



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

Hot Crystals and Clustersize > 3

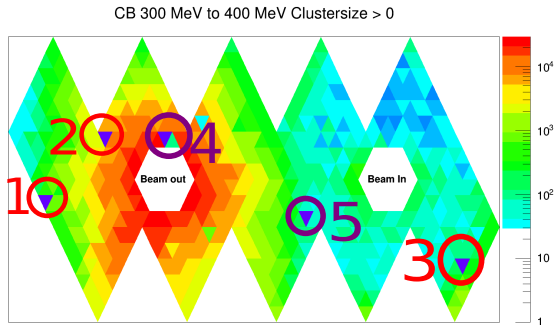
- Beamtime October 2014
- Photon energy between 0 MeV and 100 MeV
- Clustersize > 3



→ Neighbors of some dead crystals appear hot for low energies

Hot Crystals for Higher Energies

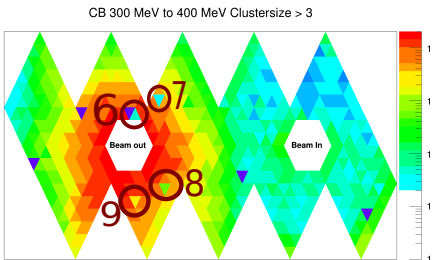
- Beamtime October 2014
- Photon energy between 300 MeV and 400 MeV



→ *Hot Neighbors* disappear at larger energies

Additional Dead Crystals

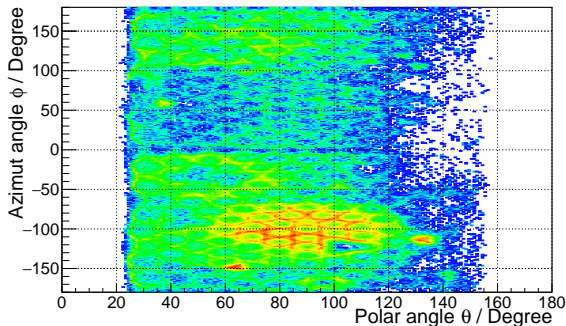
- Beamtime October 2014
- Photon energy between 300 MeV and 400 MeV



| 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 MeV and 225 MeV
- Weird bump



Conclusion

- There is a energy dependency in the detector
- The reconstructed opening angle is too big for high energies
→ 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 too many events)
- There is a strange ϕ -distribution in the detector
→ reason for this has also to be determined

Appendix

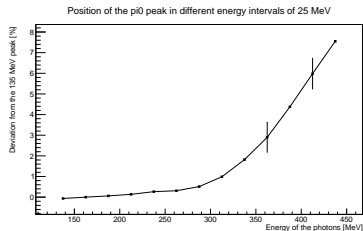
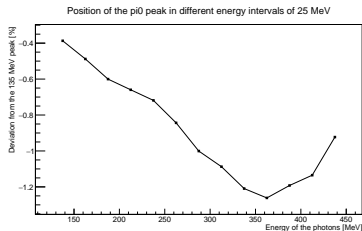


Figure: Simulation: Left: Reconstructed energy and true opening angle.
Right: True energy and reconstructed opening angle