Study of $\bar{p}p \longrightarrow \pi^0\pi^0\eta \longrightarrow 6\gamma$ with the P̄ANDA-Detector

Observations in the photon reconstruction

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Photon Reconstruction

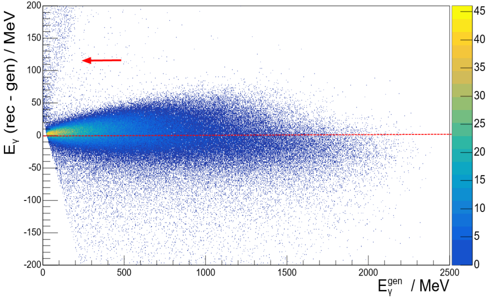
Photon Energy Reconstruction

- Test simulation:
  $\bar{p}p \longrightarrow \pi^0\pi^0\eta \longrightarrow 6\gamma$ at $1.94\,\mathrm{GeV}$ beam momentum

- Energy resolution:
  Photon energy residuals

  $\longrightarrow$ residual offset towards $E_{\text{rec}} > E_{\text{gen}}$

Energy residual vs. generated energy (wrong MC truth propagation)



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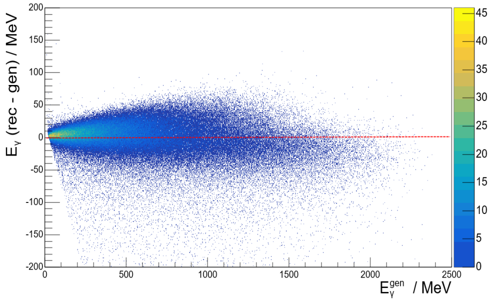


Possible causes

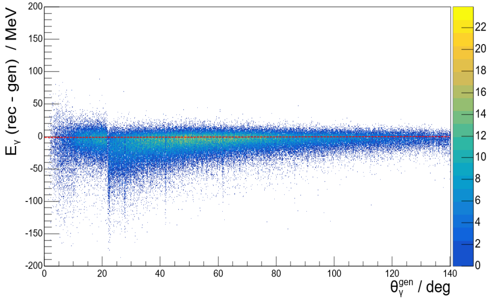
⟶ crystal non-uniformity

- non-uniform light yield across the scintillation crystals
- uniformity function shifts residual towards positive values

⟶ energy correction function

- leakage correction
- $E_{\gamma,\text{cor}} = E \cdot f(E, \theta)$
- shift towards larger reconstructed energies

Energy residual vs. generated position
(No data correction)



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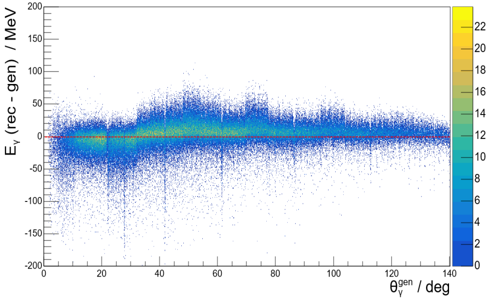
Energy residual vs. generated position
(Crystal Non-Uniformity)



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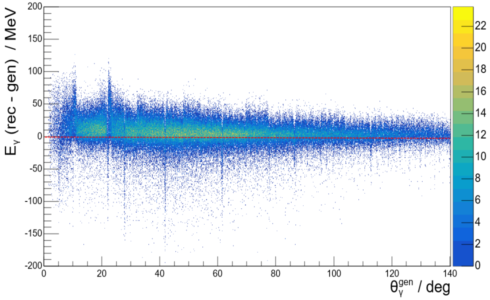
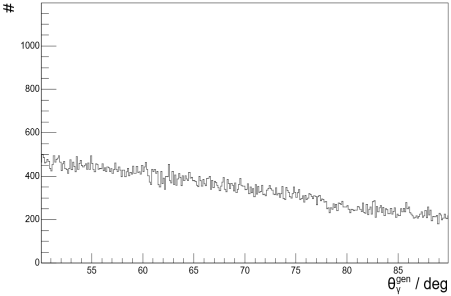
Energy residual vs. generated position (Crystal Non-Uniformity + ECF)



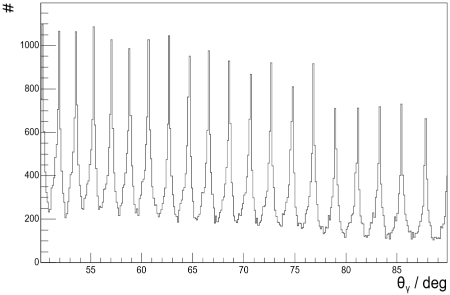
Photon Position Reconstruction

- issue: spikes in θ for reconstructed photon position

Generated photon position



Reconstructed photon position



$\longrightarrow$ nearly match θ positions of crystal centres

$\longrightarrow$ spikes not correlated to low-energy clusters or single-crystal clusters

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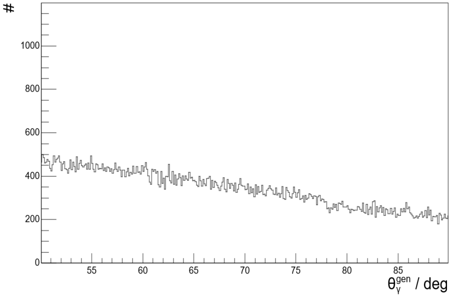
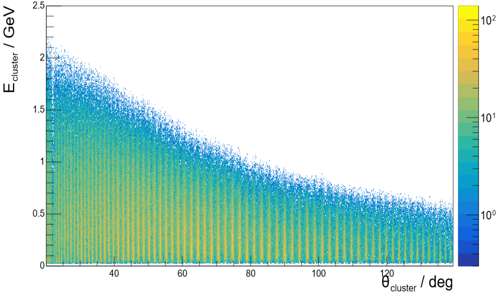


Cluster energy vs. reconstructed position



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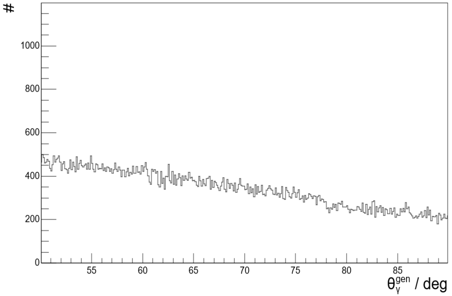
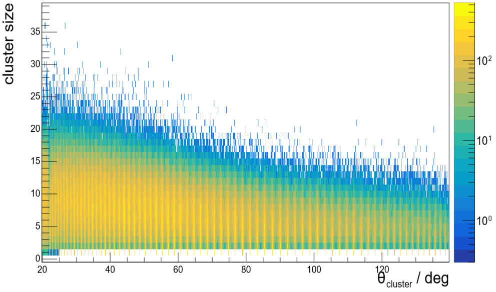


Cluster size vs. reconstructed position



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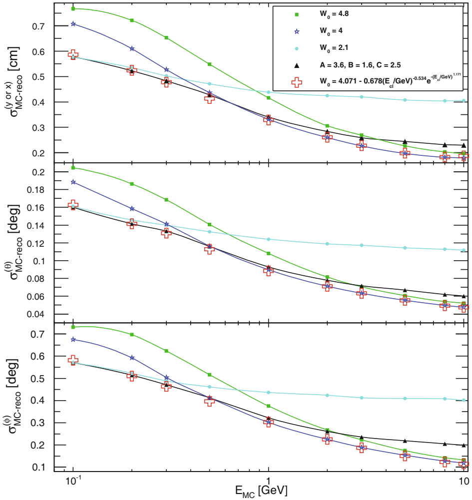
Linear-logarithmic (Lilo) Position Method

- method studied and optimised for FWEC
- (linear-)logarithmic weighting of the cluster position:
  $W_{\text{log}}^{\text{crystal}} = \log\left(\frac{E_{\text{crystal}}}{E_{\text{cluster}}}\right) + W_0$
- dynamic offset to ensure a positive weight:
  $W_0 = 4.071 - 0.678 \cdot E_{\text{cluster}}^{-0.534} \cdot e^{E_{\text{cluster}}^{1.171}}$
- optimised position resolution introduces additional bias



Moeini et al., Design studies of the PWO Forward End-cap calorimeter for PANDA

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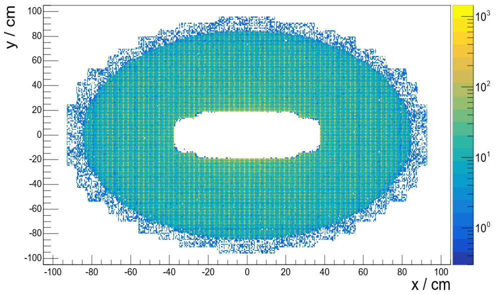
EMC Forward Endcap



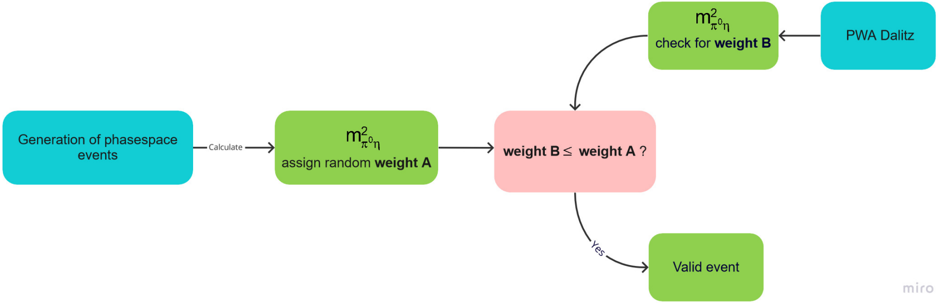
Analysis of $\bar{p}p \longrightarrow \pi^0\pi^0\eta \longrightarrow 6\gamma$

About RHEA[1]

- RHEA: mini-analysis framework for neutral final states
- easy access to important variables
- combinatorics, particle selection, energy/momentum conservation
- includes tests and documentation

[1] RHo-Edition AG-Thoma

PANDA Analysis Chain



- simulation: $\bar{p}p \longrightarrow \pi^0\pi^0\eta \longrightarrow 6\gamma$ (phasespace)
- Bonn-Gatchina PWA Group: PWA weighted Dalitz Plot as input
- 2.5 million events at $1.94\,\mathrm{GeV}$ beam momentum

Event selection

- Preselection

  $\longrightarrow$ require 6 neutral photon candidates and 0 charged

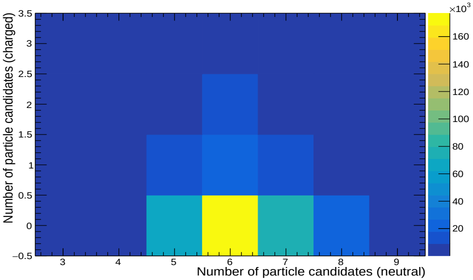
  $\longrightarrow$ Mass selector (for η and π^0 mass)

- Final selection

  $\longrightarrow$ Energy and momentum conservation for reconstructed $\bar{p}p$ system

  $\longrightarrow$ require 6 distinct primary photon candidates (including preshower events)

Event multiplicity



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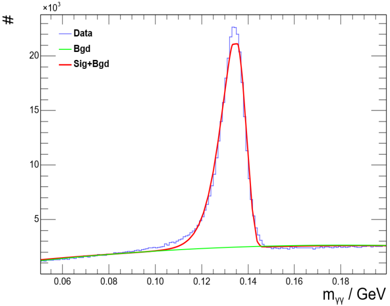

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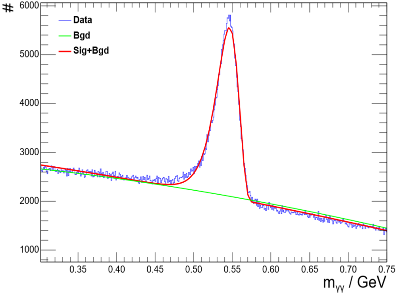
Mass fit η



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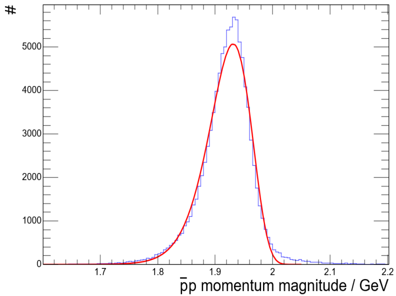
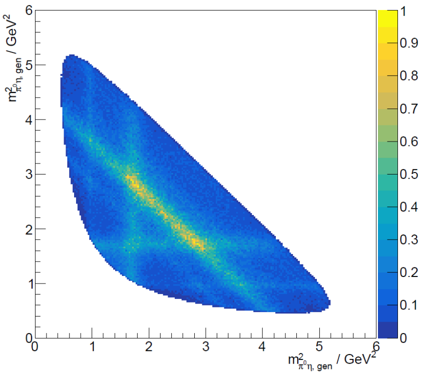
Momentum $\bar{p}p$

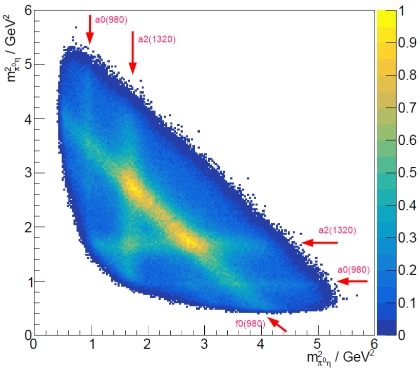


PWA weighted Dalitz plot

Generated PWA weighted Dalitz plot



Reconstructed PWA weighted Dalitz plot



- input: Crystal Barrel Lear Data by Bonn-Gatchina Partial Wave Analysis Group

Photon Efficiency

Photon Efficiency

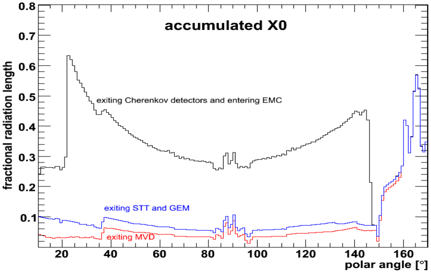
- analysis: left with 16.3% of reconstructed $\bar{p}p \longrightarrow \pi^0\pi^0\eta \longrightarrow 6\gamma$ events
- 1γ Efficiency for EMC $\epsilon = \frac{N_{\text{MC}}}{N_{\text{rec}}}$:

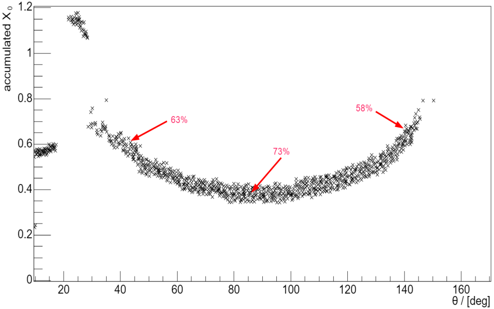
  $\longrightarrow$ 59.5%

  $\longrightarrow$ 73.8% (including preshower events)
- photon beam intensity reduced to $e^{-\frac{7}{9}} = 0.46$ after passing one X_0

Photon Efficiency – Radiation Length

- How many radiation lengths before reaching the EMC ?





P̄ANDA Collaboration, Physics Performance Report for PANDA

Summary

- new issues to be solved in photon reconstruction
- investigating detector material budget

  $\longrightarrow$ photon efficiency optimisation
- results on $\bar{p}p \longrightarrow \pi^0\pi^0\eta \longrightarrow 6\gamma$ (Dalitz Plot) promising

  $\longrightarrow$ extended analysis, with e.g. kinematic fitting

Questions?

References

References

[Moe+13] H. Moeini et al. “Design studies of the PWO Forward End-cap calorimeter for $\bar{\text{P}}$ANDA”. In: *The European Physical Journal A* 49.11 (Nov. 2013). ISSN: 1434-601X. DOI: *10.1140/epja/i2013-13138-0*. URL: *http://dx.doi.org/10.1140/epja/i2013-13138-0*.

[$\bar{\text{P}}$AN09] $\bar{\text{P}}$ANDA Collaboration. *Physics Performance Report for $\bar{\text{P}}$ANDA: Strong Interaction Studies with Antiprotons*. 2009. DOI: *10.48550/ARXIV.0903.3905*. URL: *https://arxiv.org/abs/0903.3905*.

Appendix

Kinematics i

- fixed-target experiment:

$$\longrightarrow P_1 = (E_{\text{LAB}}, 0, 0, p_{\text{LAB}}),\ P_2 = (m_2, 0, 0, 0)$$

- Energy (LAB-system)

$$\longrightarrow p_{\text{beam}} = 1.94\,\text{GeV},\ m_1 = m_2 = 0.938\,\text{GeV}$$

$$\longrightarrow E_{\text{LAB}} = \sqrt{p_{beam}^2 + m_1^2} = 2.15\,\text{GeV}$$

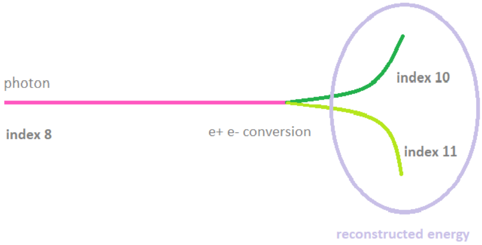
- $p\bar{p}$ system properties

$$\longrightarrow E_{\text{reaction}} = 2.15\,\text{GeV} + 0.938\,\text{GeV} = 3.09\,\text{GeV}$$

$$\longrightarrow p_{\text{reaction}} = 1.94\,\text{GeV}$$

Photon Preshower Events i

- Expectation:
  event generator consequently assigns Mc indices 1 - 3 to mesons and 4 - 9 to gammas



- Special case: Preshower Events
- Mc truth is reduced to the lowest Mc index
- Mc truth sees just a fraction of the photon's energy
- reconstructed energy is determined by whole digi entry
- Solution:
  recursively check for primary particle