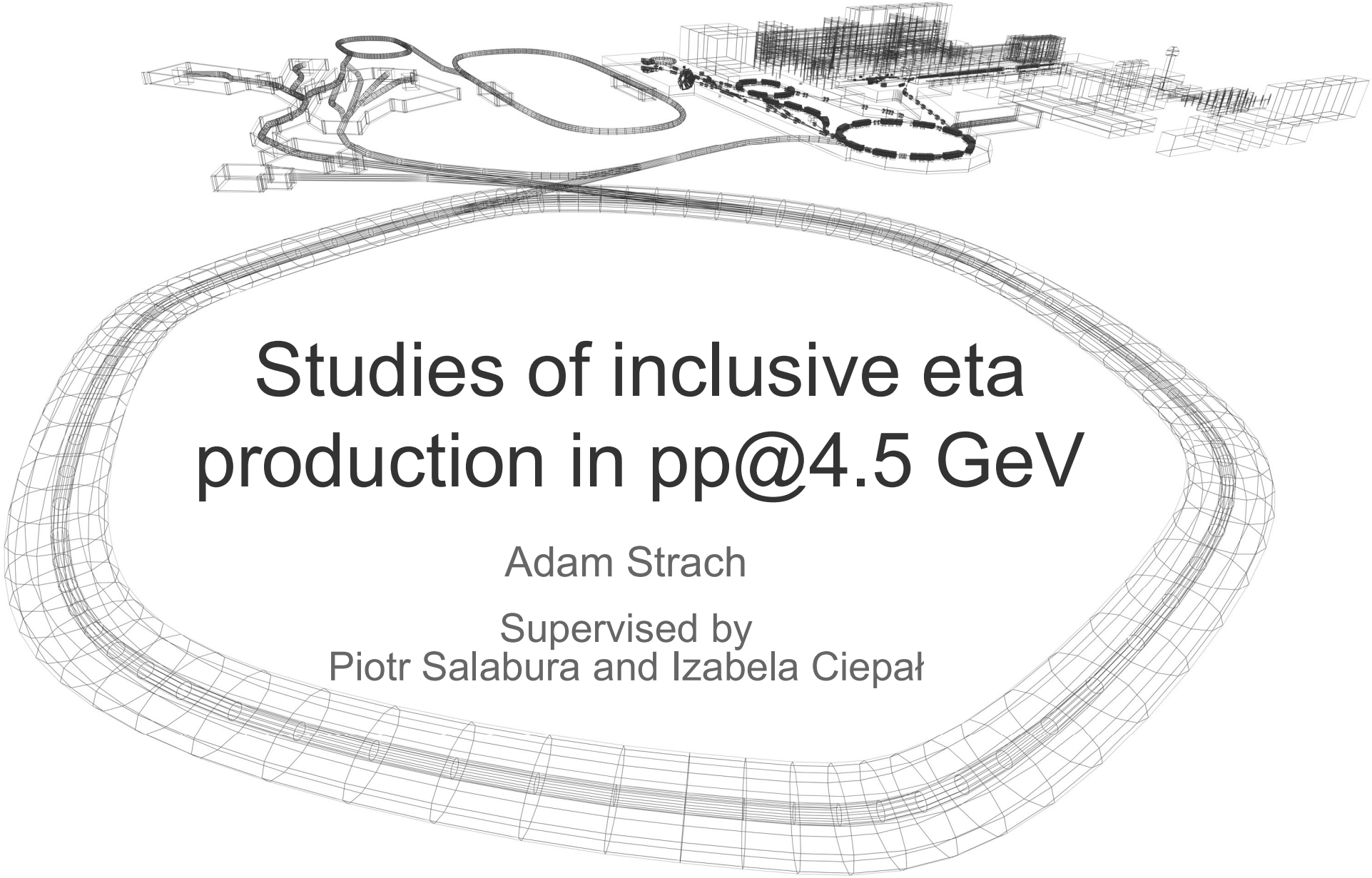


Studies of inclusive eta production in pp@4.5 GeV

Adam Strach

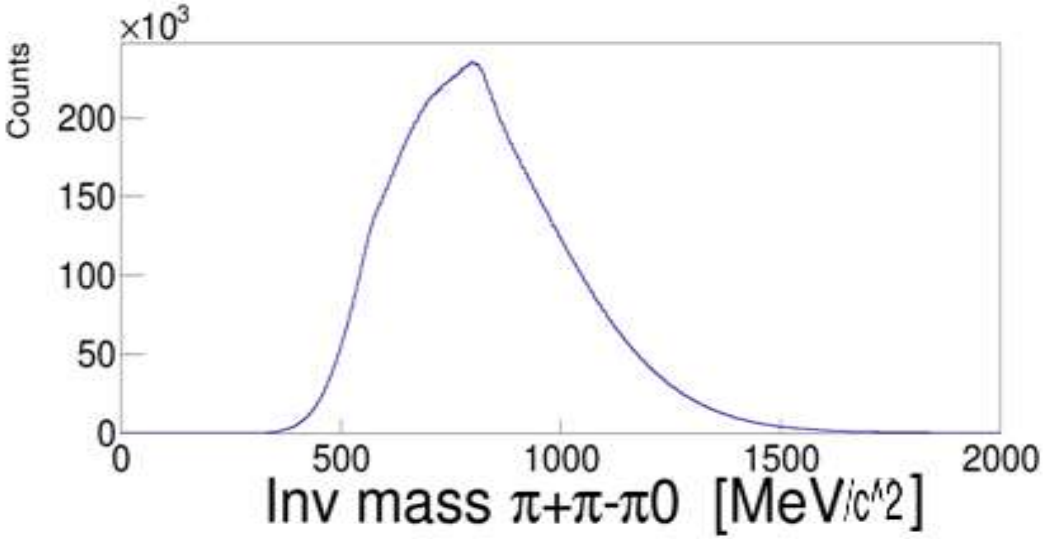
Supervised by
Piotr Salabura and Izabela Ciepał

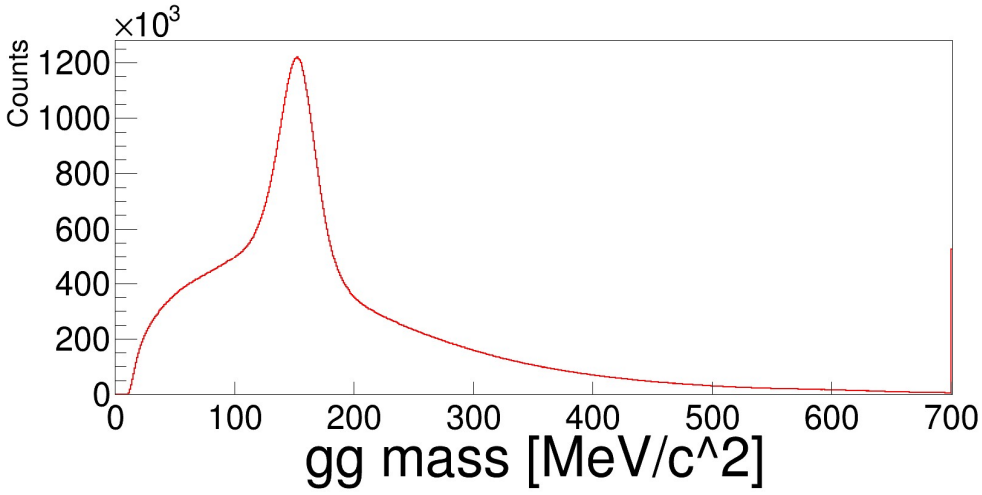
Plan of presentation

- Motivation of kinematic refit in $\pi^+\pi^-\pi^0$
- Error parametrization -studies of energy and angle resolutions in ECAL
- Results of $\pi^0 \rightarrow \gamma\gamma$ kinematic refit with mass constraint
- η mass reconstruction using kinematic refit
- Estimation of inclusive cross section for eta η production
- Outlook

Motivations

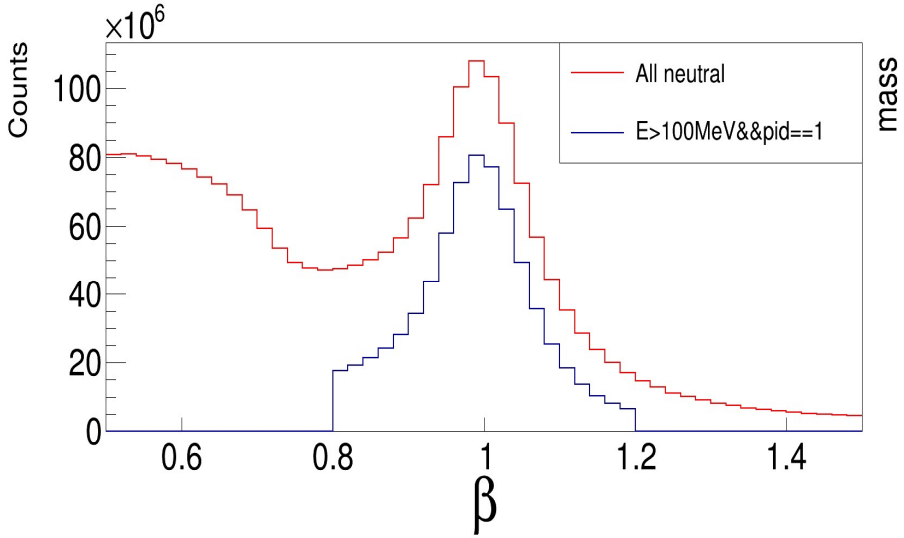
- Improvement of resolutions of channels with neutral mesons decays
- Ex. $\eta/\omega \rightarrow \pi^-\pi^+\pi^0[\rightarrow \gamma\gamma]$
  $\pi^0 \rightarrow \gamma\gamma$ improvement
- Kinematic refit cuts out large amount of background
- Kinematic fit for photons also important for studies of Sigma hyperon production
  (A. Władyszewska „Sigma production
  in Lambda gamma channel").

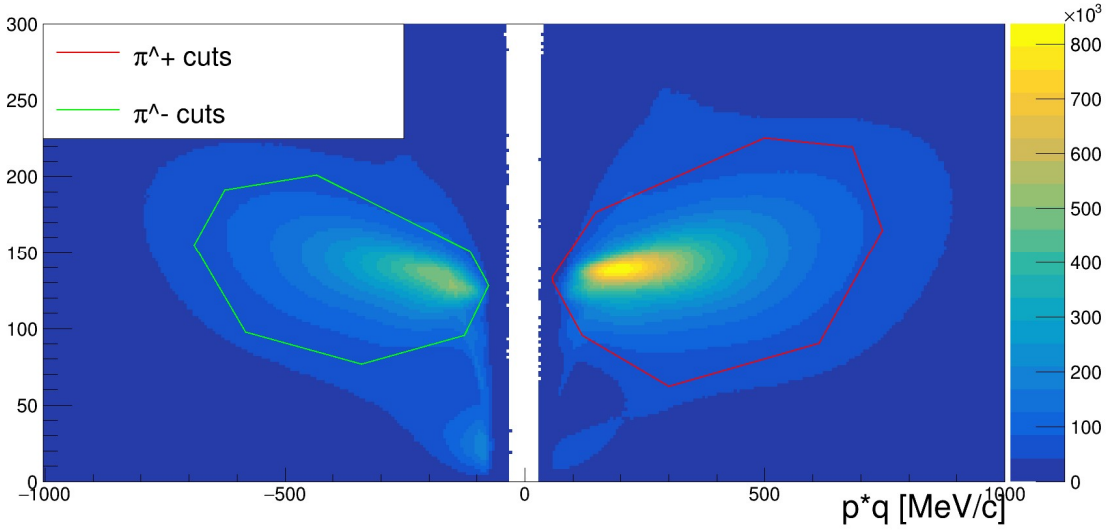




Event selection conditions

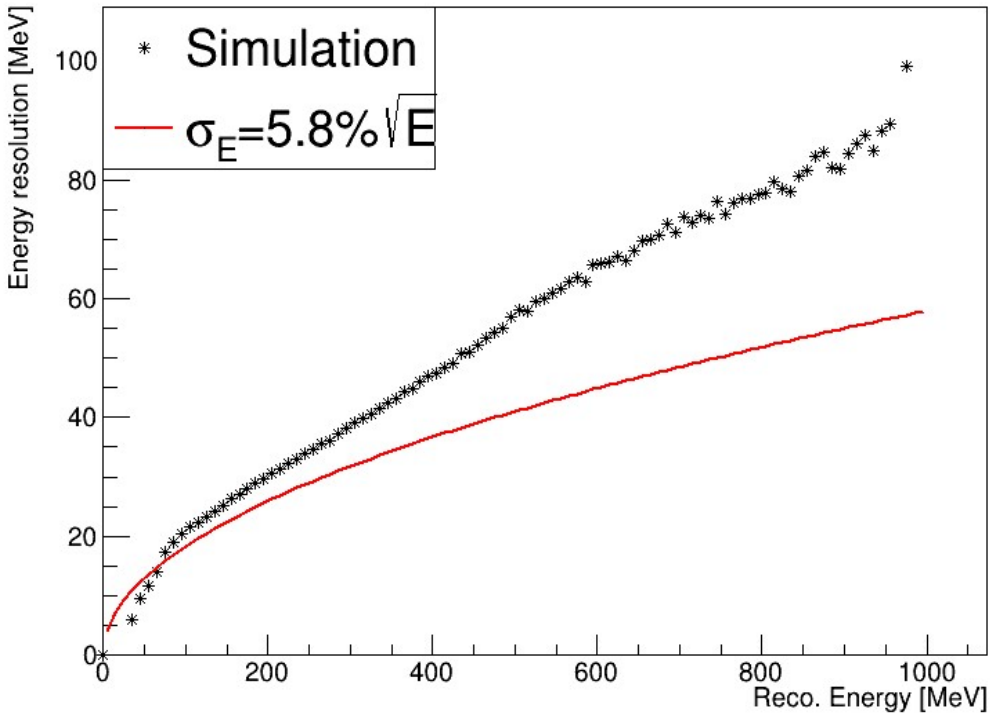
- Event selection:
- At least 2 photons with $E > 100$ MeV and 0.8<β<1.2
- At least one π^+ and at least one π^-. Chosen with graphical cuts on mass-charge*momentum spectrum
- Simulations: official channel 921 $\mathrm{pp} \rightarrow \mathrm{pp}\eta(\rightarrow \pi^+\pi^-\pi^0)$: 10^8 events
- Experimental data: days 34-53 and 59-66



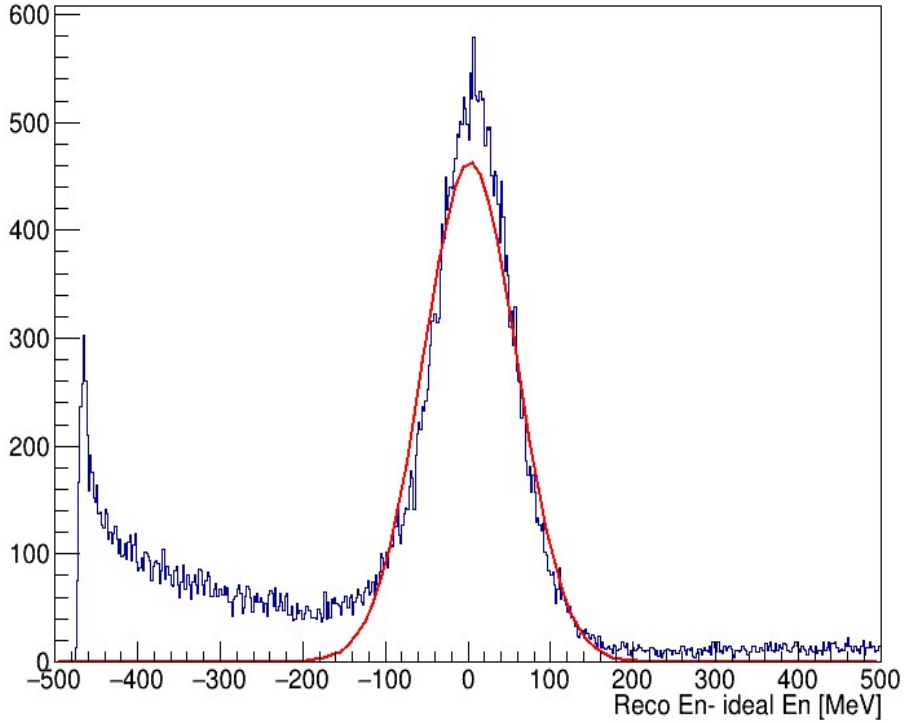


Energy resolution

- Parametrized in Energy bins of 10 MeV
- Standard deviation of fitted gaussian to residuals of energy.
- $5.8\%\sqrt{E}$-Energy resolution in HYDRA

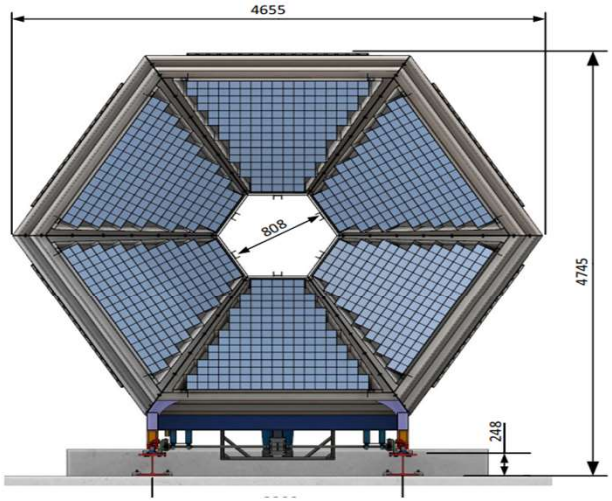


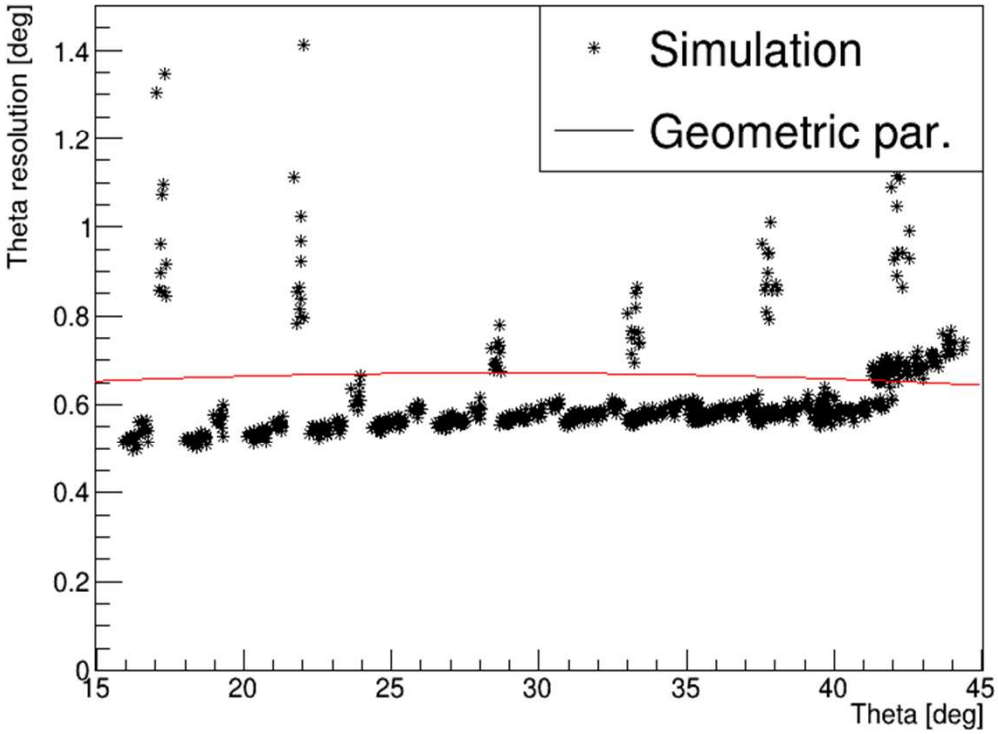
$E = 490$ MeV

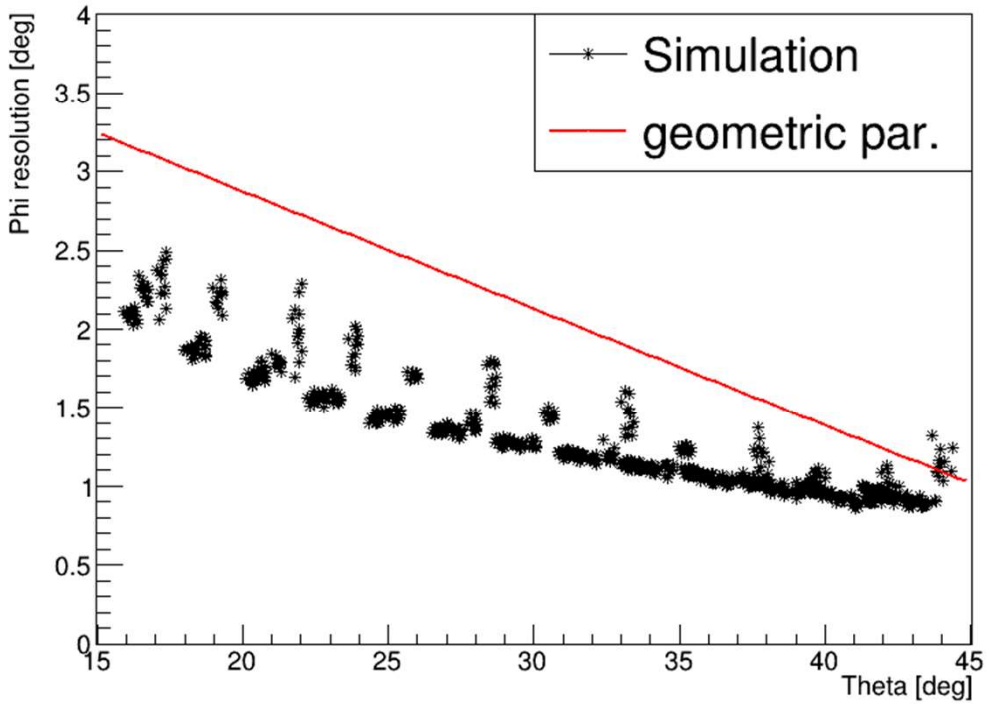


θ and ϕ resolution

- Cell-wise parametrization
- Cells at edges of each sector have lower a resolution
- Cells close to beamline are removed from analysis (θ<15)

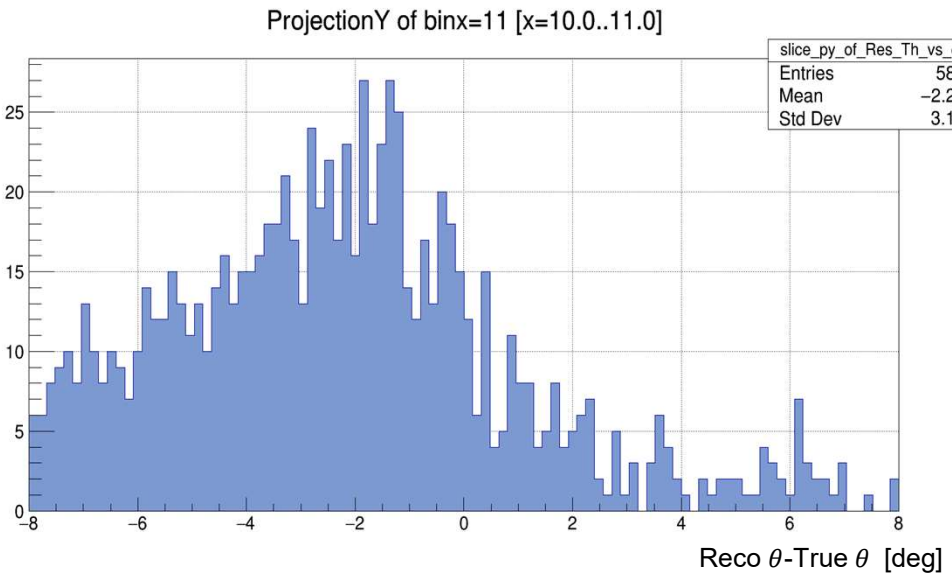


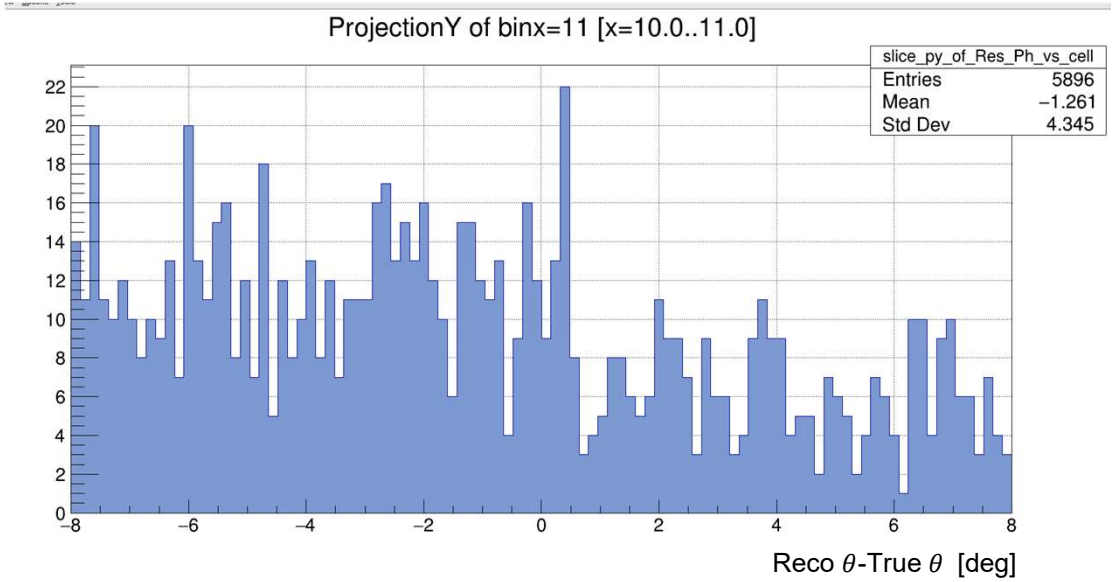




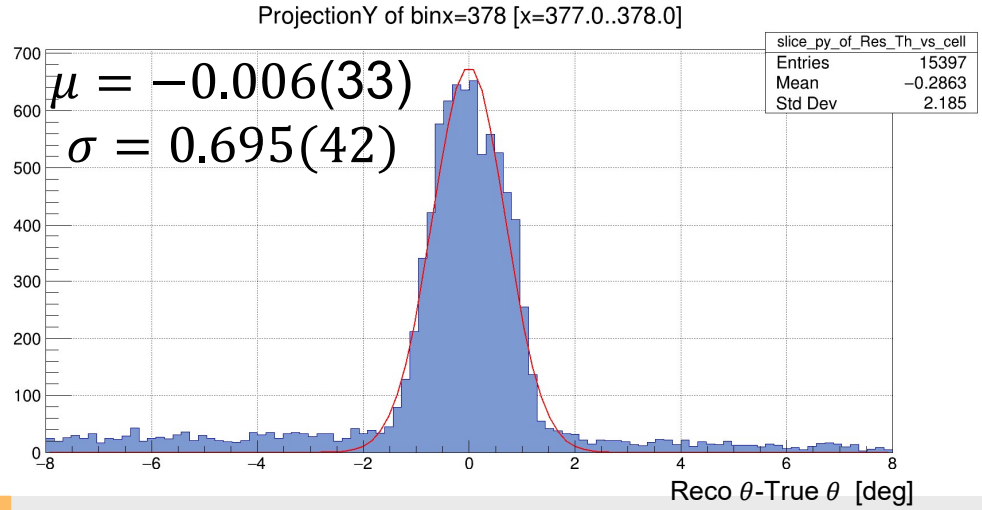
Outliers and θ<15

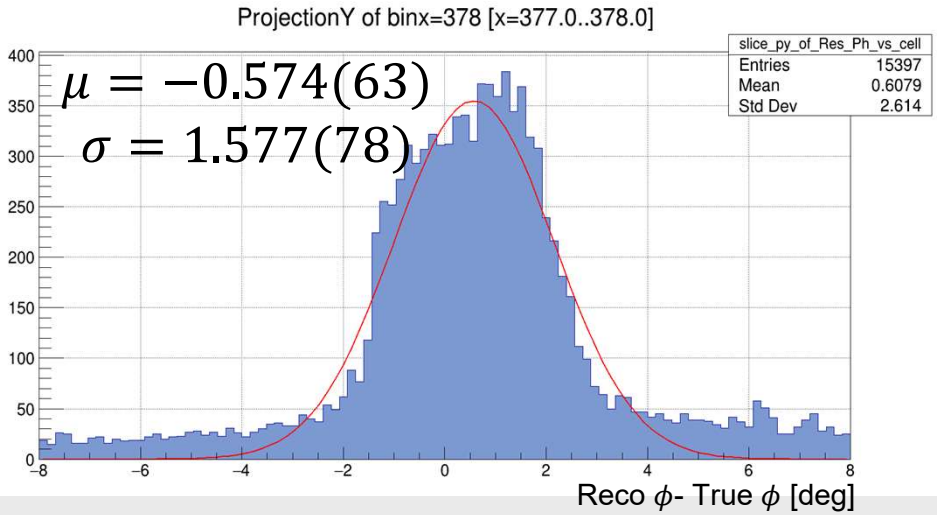
Cell 11: $\theta < 15$ deg



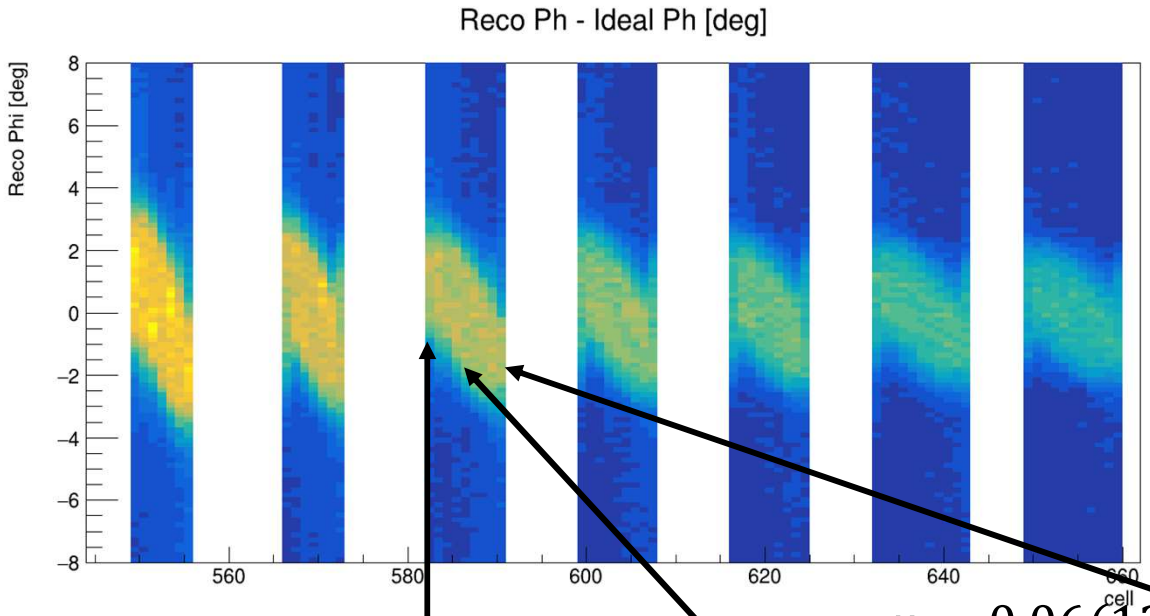


outlier





Correction for shift in ϕ residua

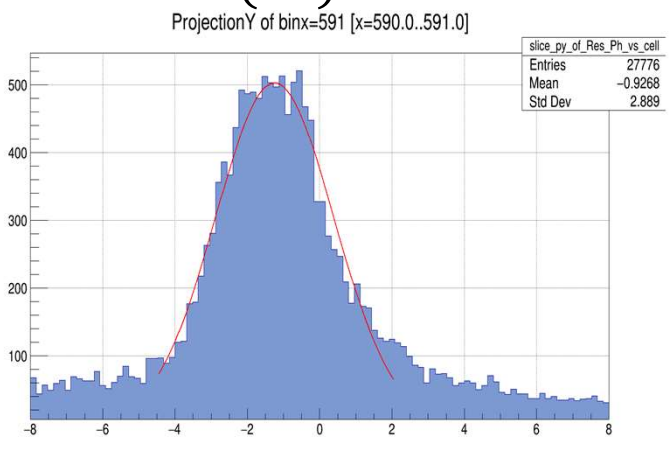


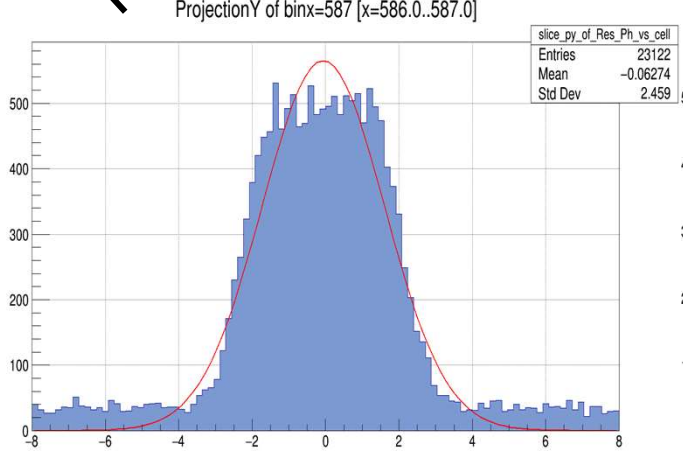
ϕ residuals are not centered at 0
Lookup table with shift equal to mean of residuals.

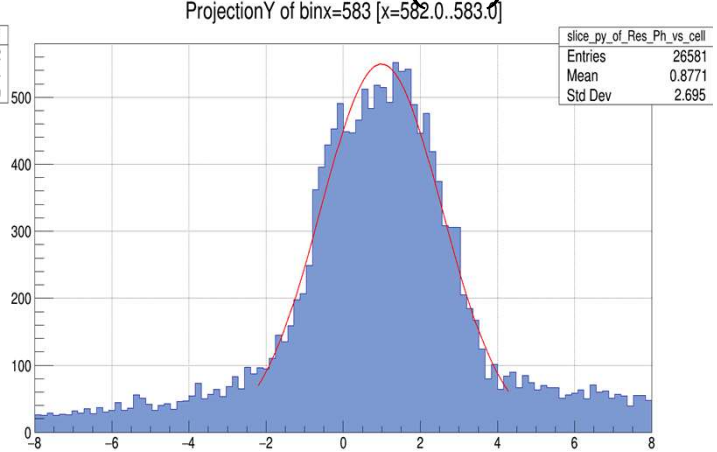
$\mu = 0.988(66)$
$\sigma = 1.573(85)$

$\mu = 0.06(12)$
$\sigma = 1.67(16)$

$\mu = -1.247(89)$
$\sigma = 1.63(10)$

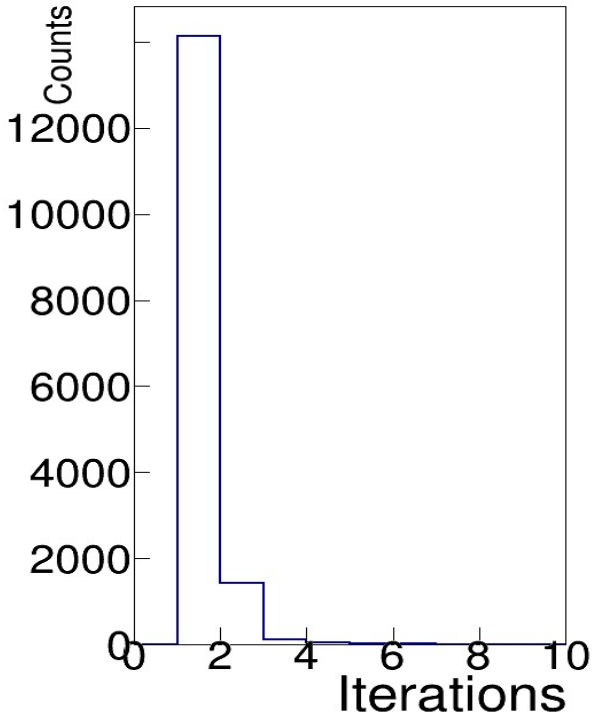


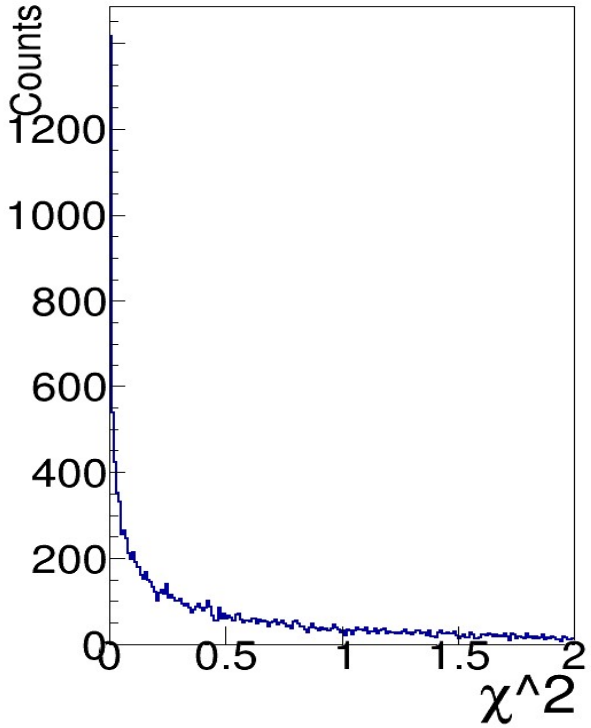


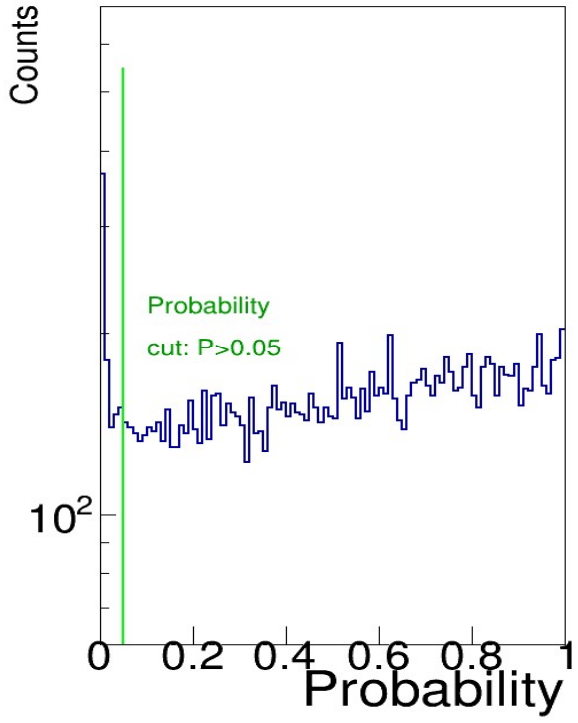


π_0 reconstruction-simulation

$$\eta \rightarrow \pi^+ + \pi^- + \pi^0 \, , \boldsymbol{\pi^0 \rightarrow \gamma\gamma}$$





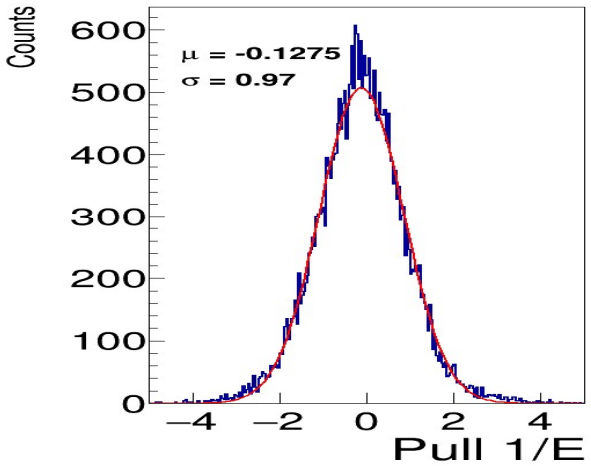


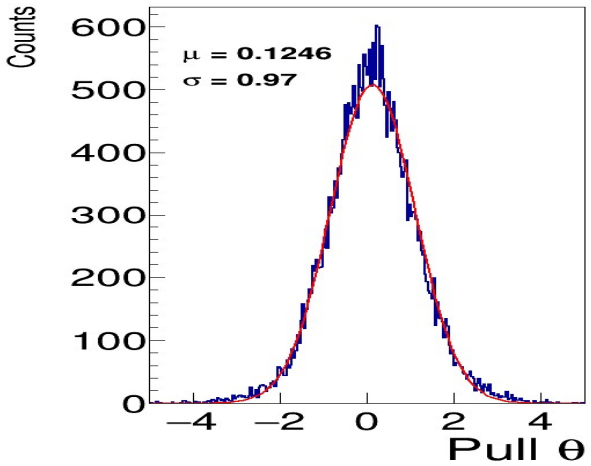
Fast convergance
Good χ^2 distribution
Probability distributions slighly rises

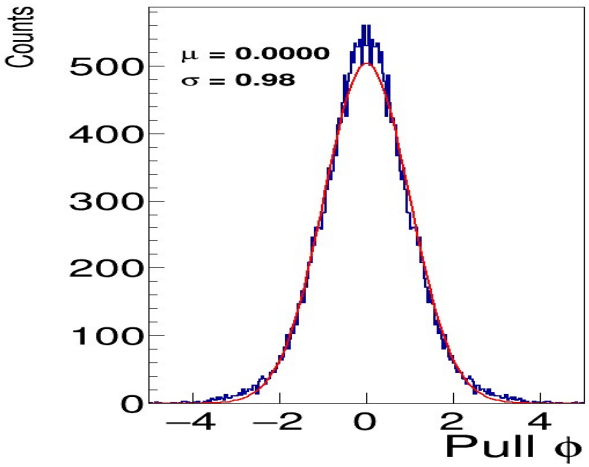
Reconstruction efficiency:

$$\epsilon = \frac{n_\eta^{reco}}{n_\eta^{tot}} = \frac{15000}{100\ mln} \approx 0.015\%$$

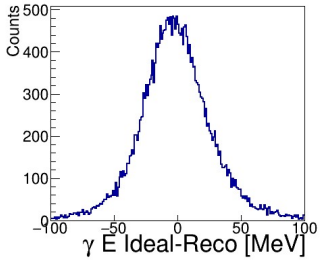
Pulls and Residuals

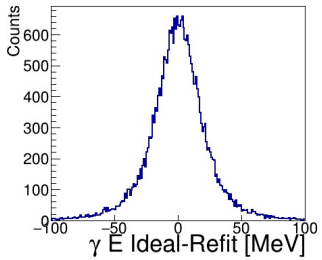


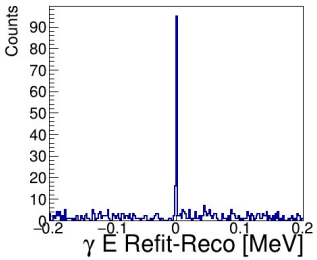


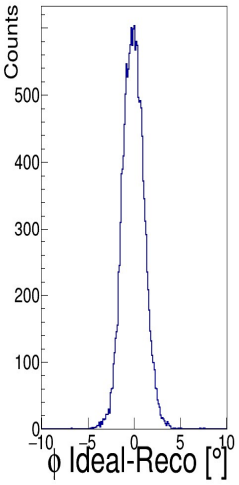


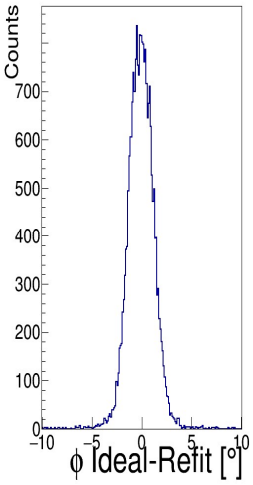
Pulls are **centred at zero**, with **normal distribution**.
Residuals are centred at zero and gaussian.

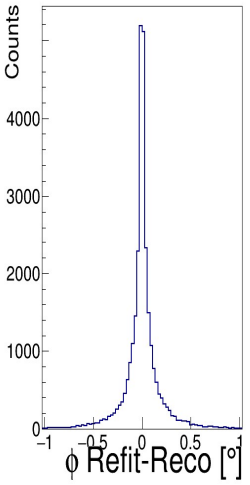


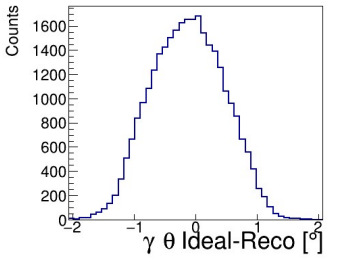


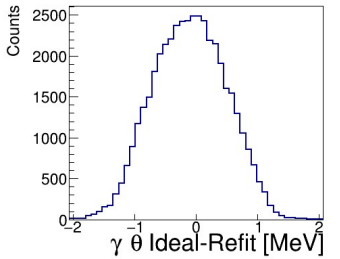


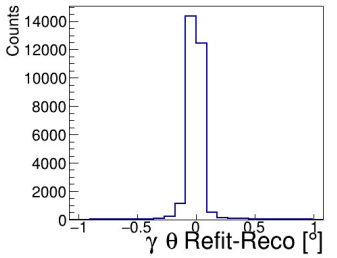






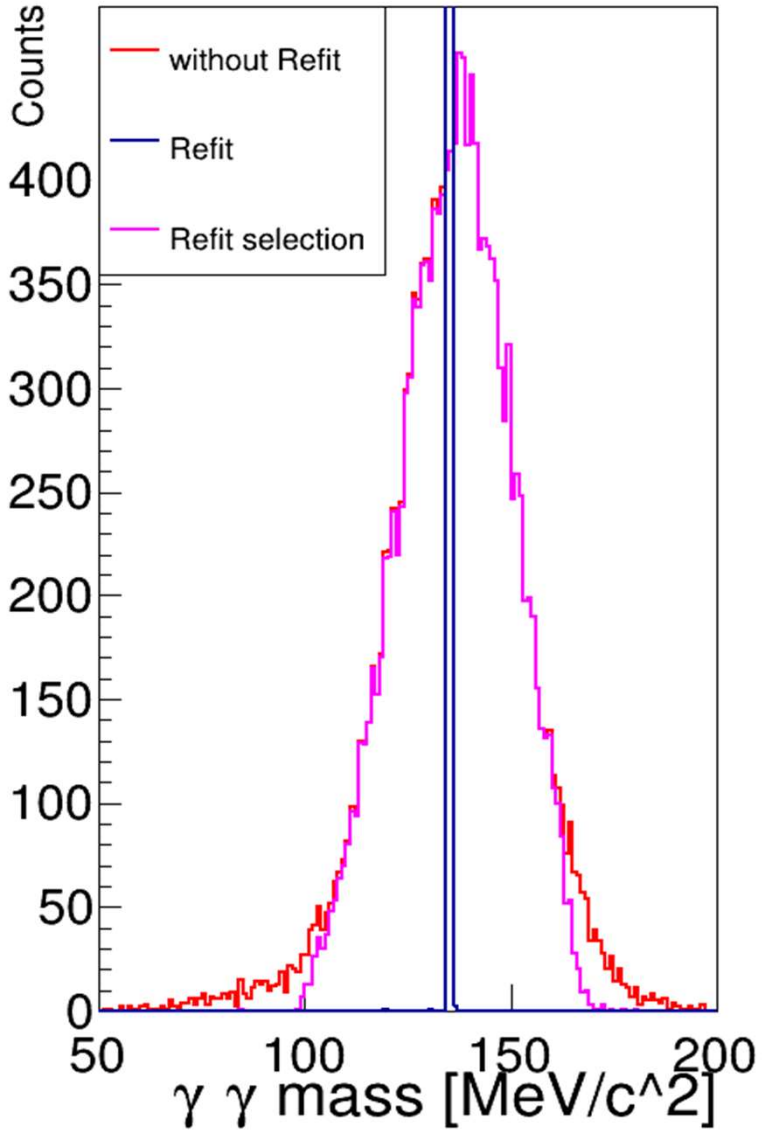




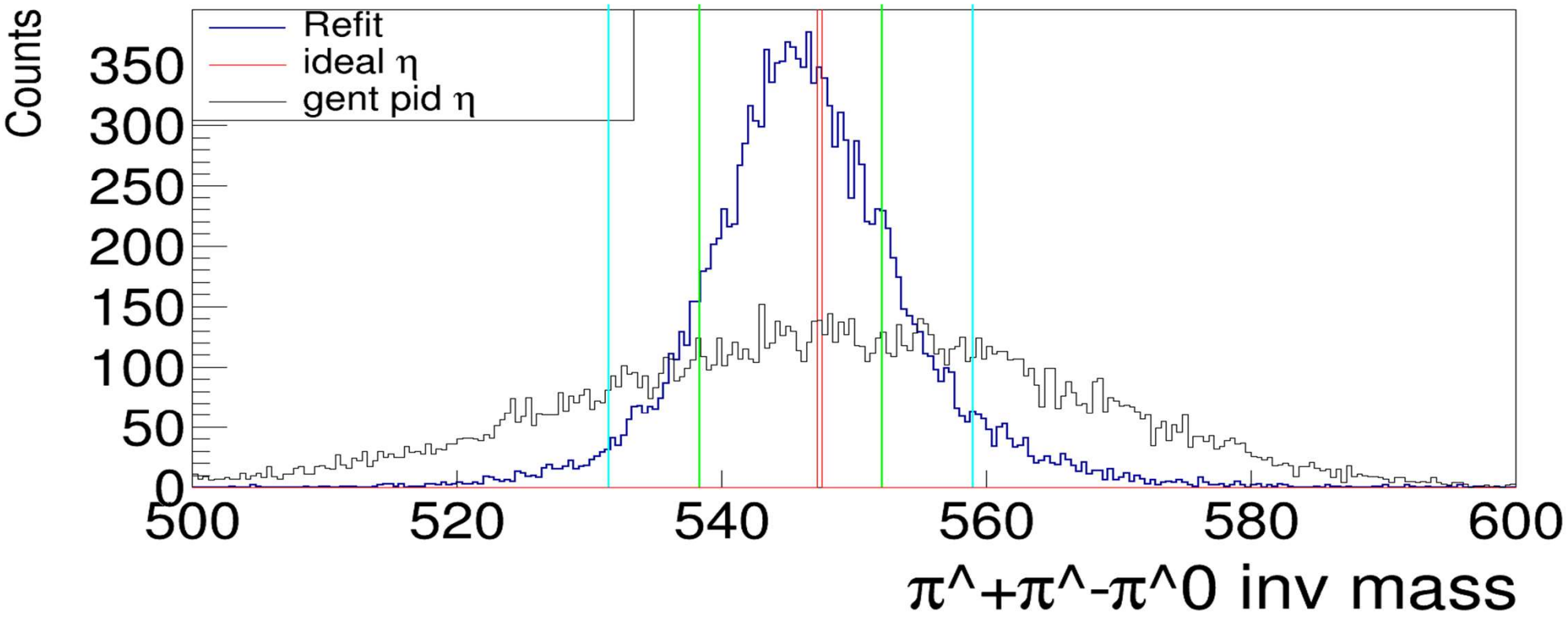


π^0 mass reconstruction

Reconstructed peak is at correct mass.
Refit selected mass distribution is gaussian.
Only primary γ from π^0 decay taken into account!



η mass reconstruction



Refit increased resolution of η mas.

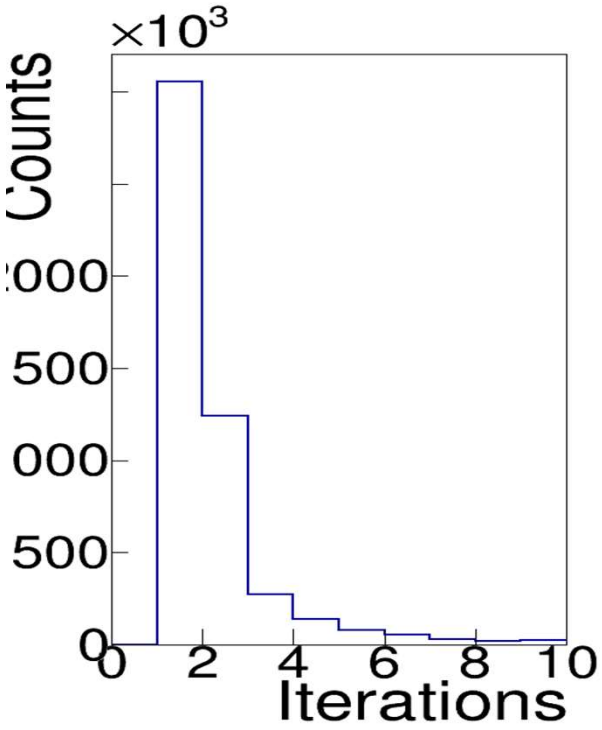
Refited η mas is slighly shifted to lower masses. PDG-

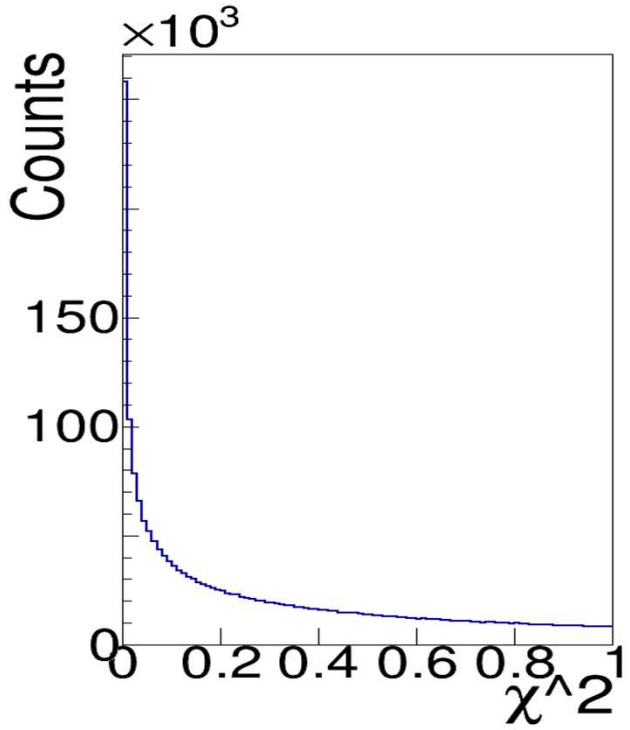
Refited η integrated in $\pm 1\sigma$ -10000 $\Rightarrow$ procedure efficiency=0.01%

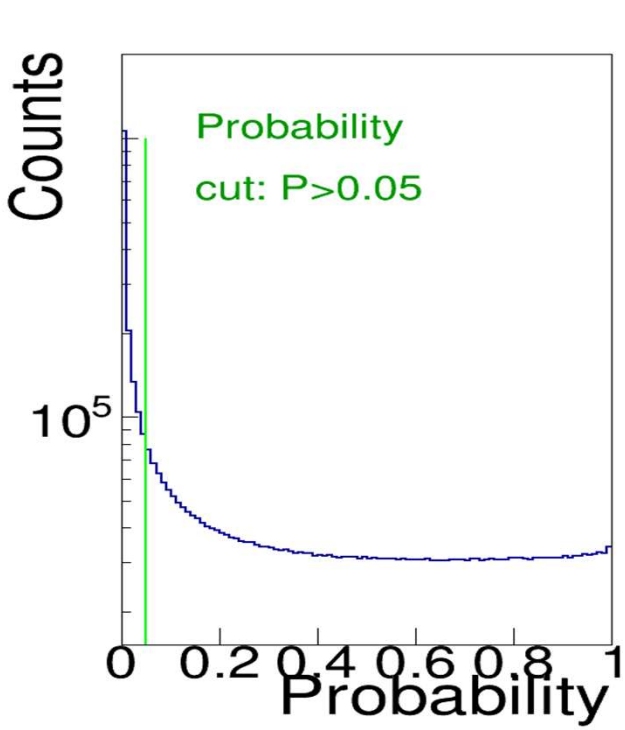
Refited η integrated in $\pm 2\sigma$ -14400 $\Rightarrow$ procedure efficiency=0.0144%

Experimental data

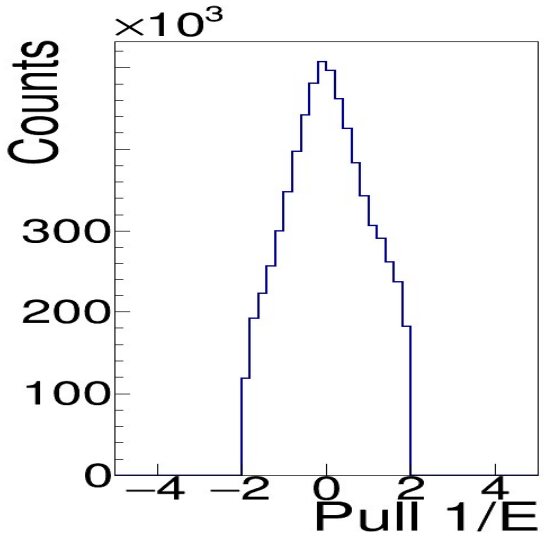
- At least 2 photons with $E > 100$ MeV and 0.8<β<1.2
- At least one π^+ and at least one π^-. Chosen with graphical cuts
- Experimental data: days 32-53 and 59-68





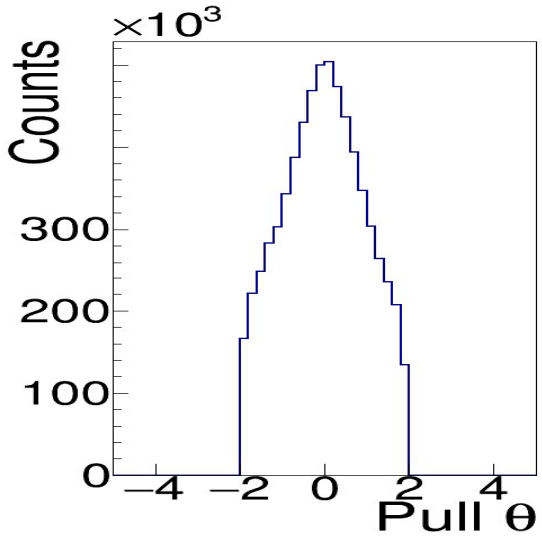


π^0 reconstruction



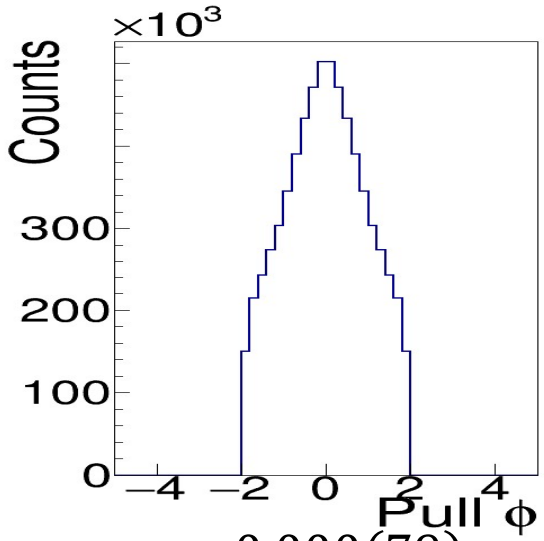
$\mu = 0.068(74)$

$\sigma = 1.269(84)$



$\mu = 0.029(85)$

$\sigma = 1.269(93)$

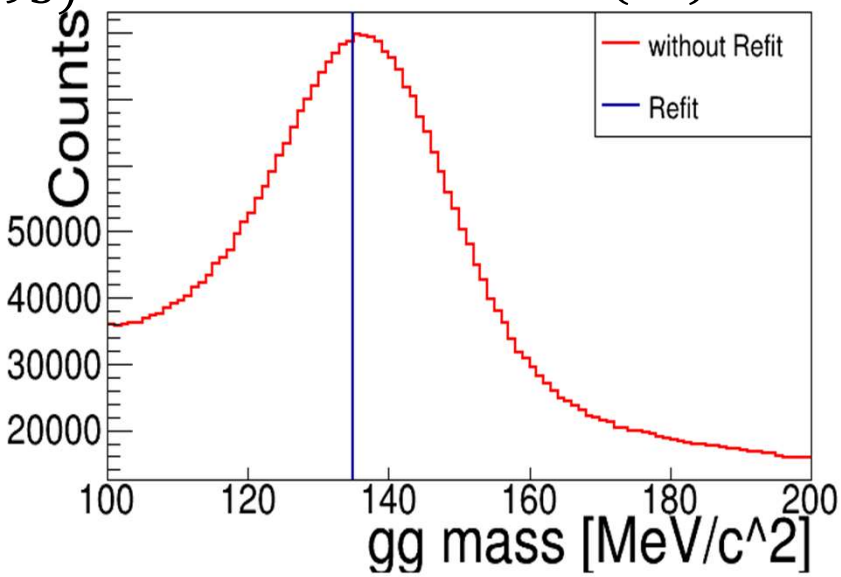


$\mu = 0.000(79)$

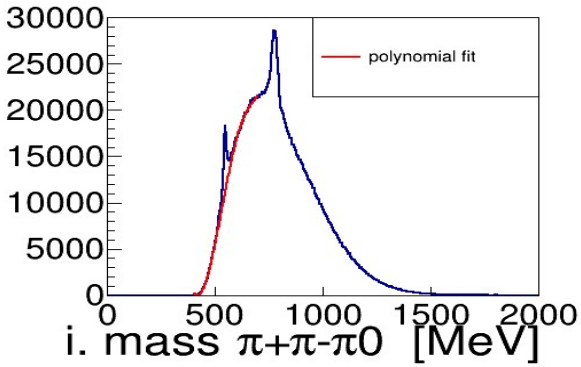
$\sigma = 1.27(11)$

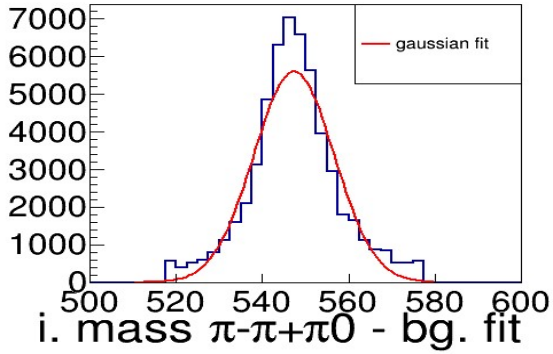
-Pulls are gaussian

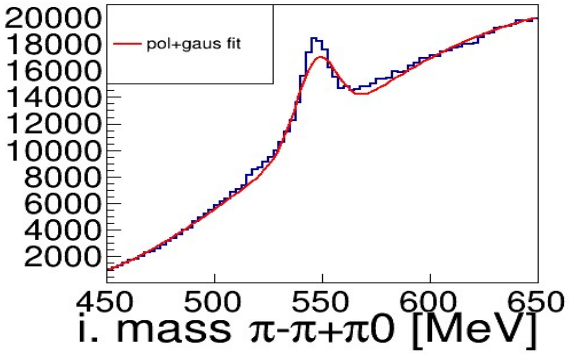
-Mass reconstructed corectly

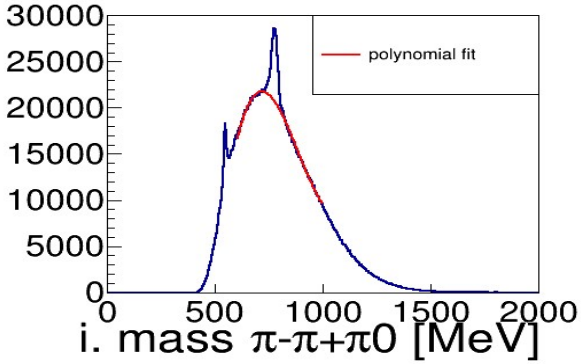


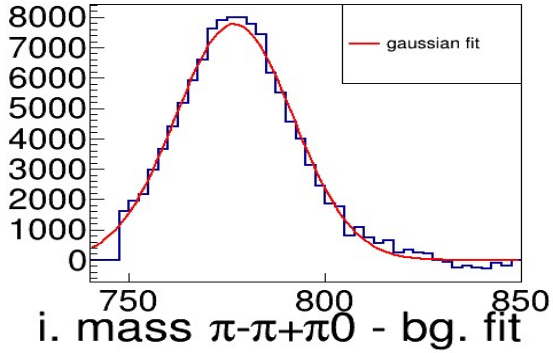
η reconstruction

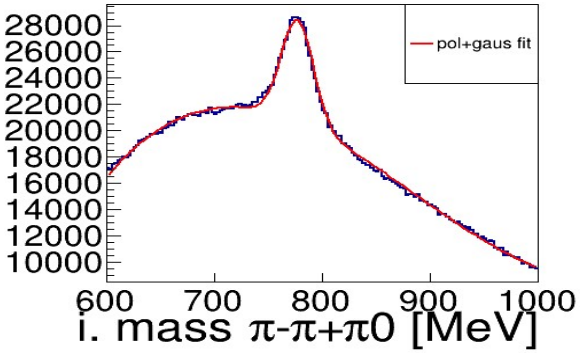












$\mu_\eta = 547.26(10)$ $\sigma_\eta = 9.30(10)$ $\mu_\omega = 776.77(14)$ $\sigma_\omega = 15.00(12)$

PDG: $\mu_\eta = 547.862(17)\frac{MeV}{c^2}$ PDG: $\mu_\omega = 782.65(12)\frac{MeV}{c^2}$

	$\pm 1\sigma$	$\pm 2\sigma$
η	40400	51400
ω	85100	108900

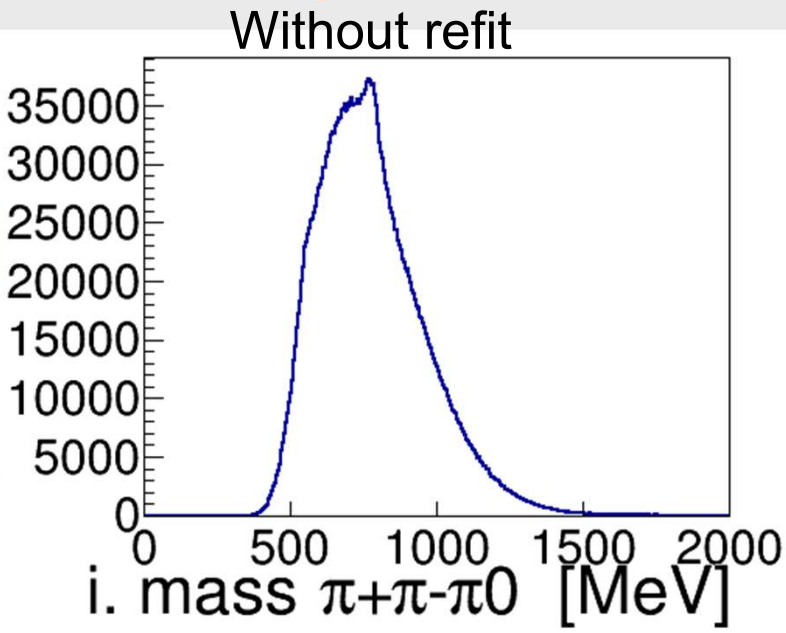
Preliminary cross section: $\sigma = 0.25$mb
In proposal (DISTO data) $\sigma = 1.5$mb

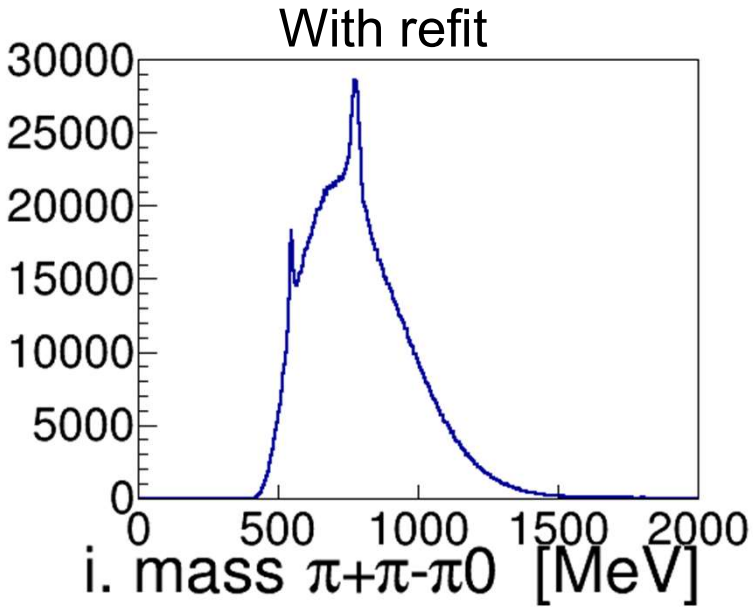
summary

- Important numbers:

Procedure efficiency	0.01%-0.0155%
Reconstruction eff	0.22%
Selection eff	0.044%
Refit efficiency	23%-35%

- Error parametrization: carefully prepared
- Significantly improved eta resolution





outlook

- Disagreement between Energy resolution in hydra and monte carlo resolution
- Too low resolution in simulation?
- Further analysis of η cross-section:
  -improvement of refit Monte Carlo efectivnes mesurment on data
  -analysis of „outliers” cells- which cel include in the analysis?
- Anlysis of systematic errors
- $\eta' \rightarrow \eta\pi^+\pi^-$ with $\eta \rightarrow \pi^+\pi^-\pi^0$ or $\eta \rightarrow \gamma\gamma$

BACKUP

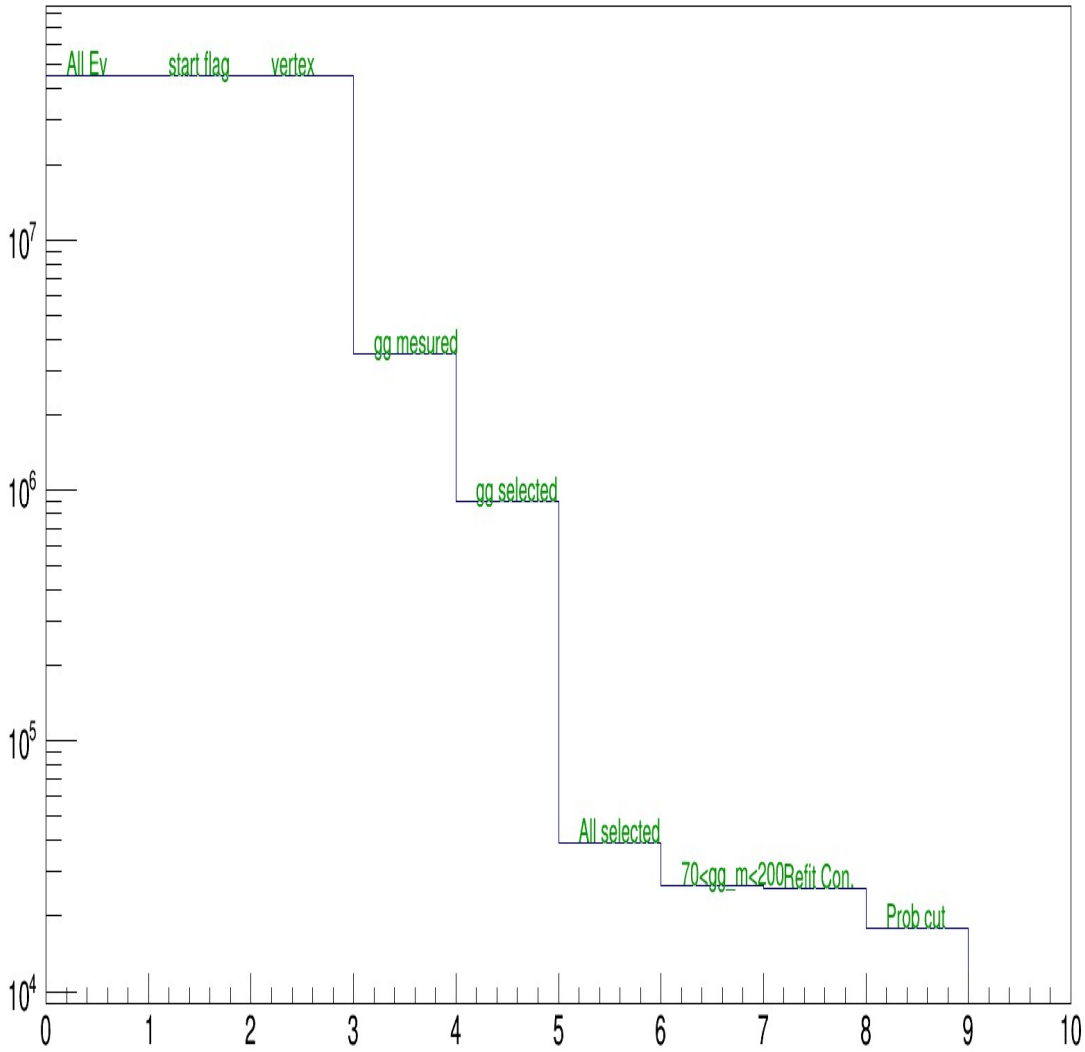
Error parametrization in Hydra

- facEnergSmear[0] = 1000.*TMath::Sqrt(sigmaEReal*sigmaEReal - sigmaEIntern*sigmaEIntern);
  facEnergSmear[1] = 1000.*TMath::Sqrt(sigmaEReal2*sigmaEReal2 - sigmaEIntern*sigmaEIntern);

  sigmaE = TMath::Sqrt(cdata->energy/1000.) * facEnergSmear[pmtType-1];

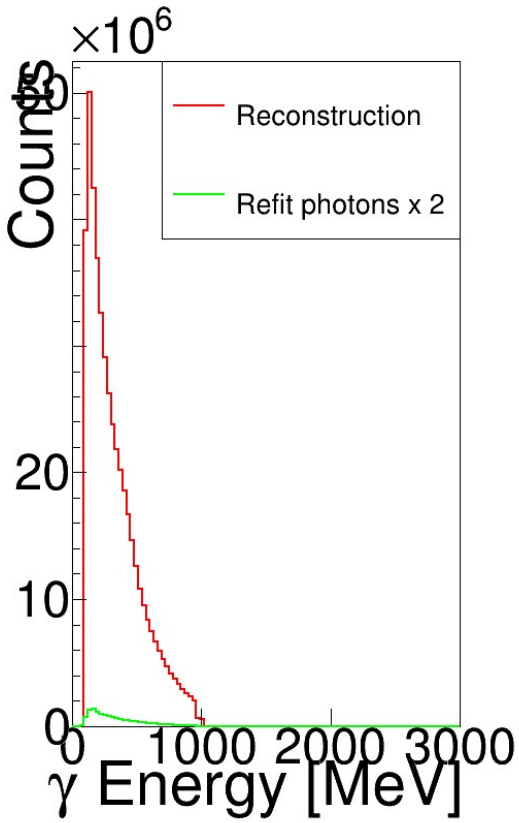
  sqrt(sigmaReal^2 -sigmaIntern^{2})

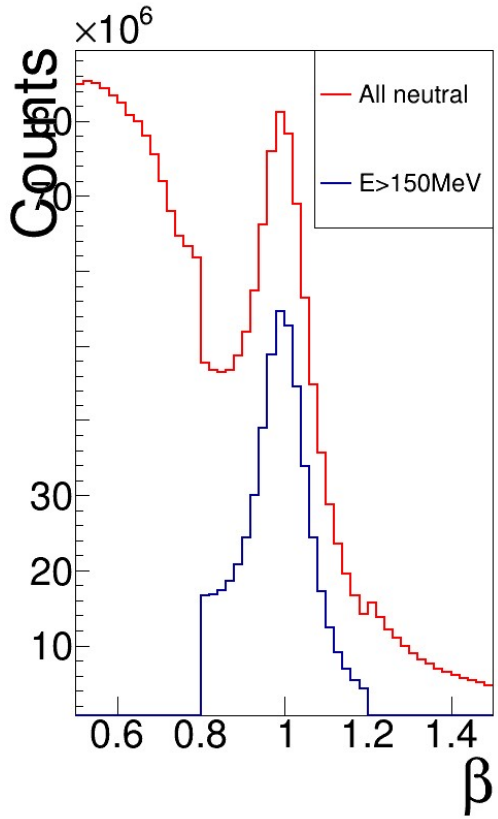
Statistic losses-backup

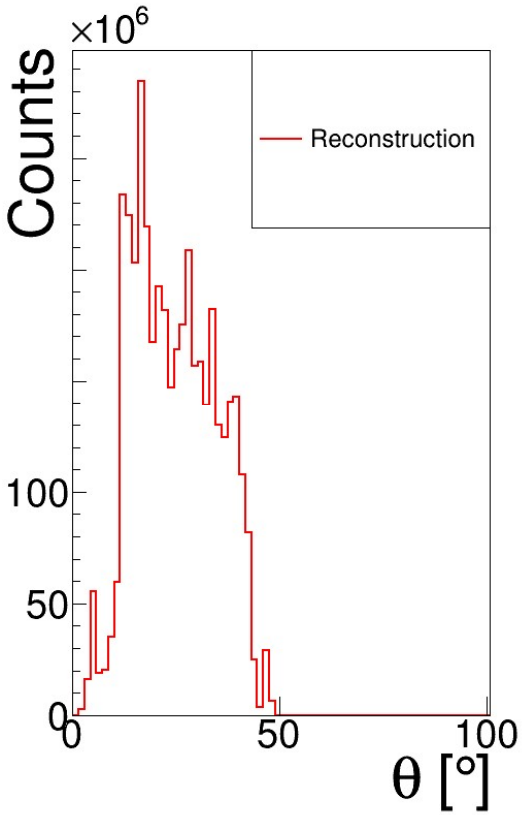


Gg-measured-at least 2 γ mesured
Gg-selected-at least 2 γ mesured with E>100 and $0.8 < \beta < 1.2$
All selected- at lest 2 γ selcted and at least 1 $\pi^+$and π^- inside graph cuts 70<gg_m<200- 70 MeV/c^2 <$\gamma\gamma$ inv mass<200 MeV/c^2
Reift con.- refit procedure converged
Prob cut-prob of refit>5%

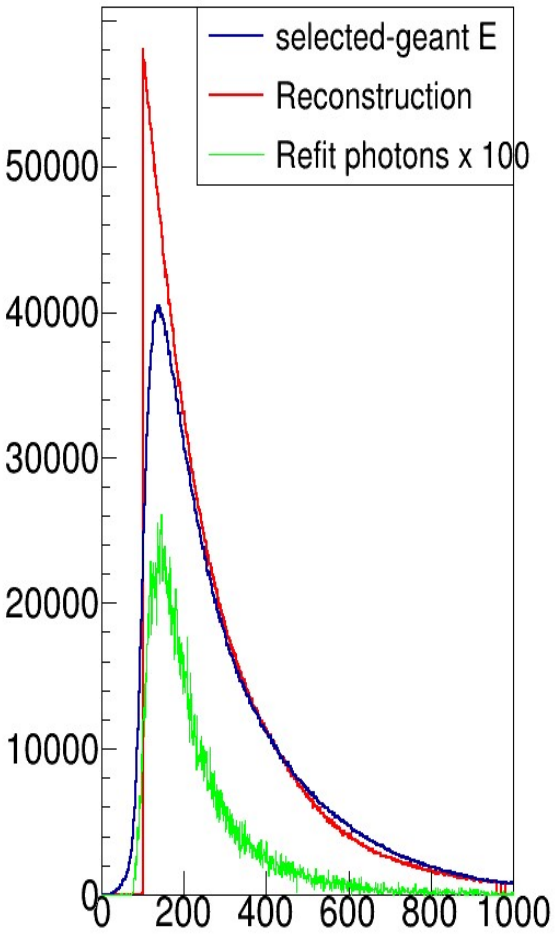
Photon distribtuons in data

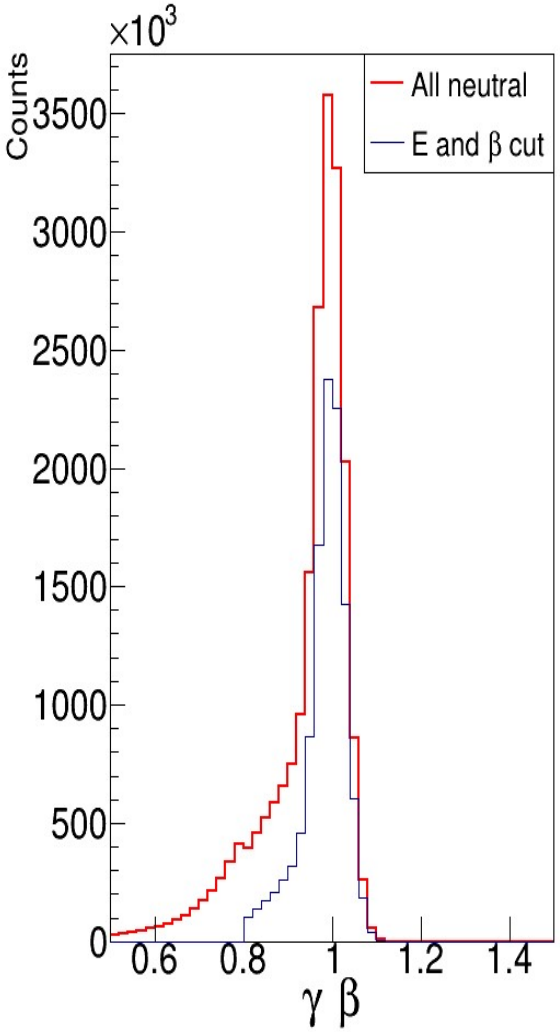


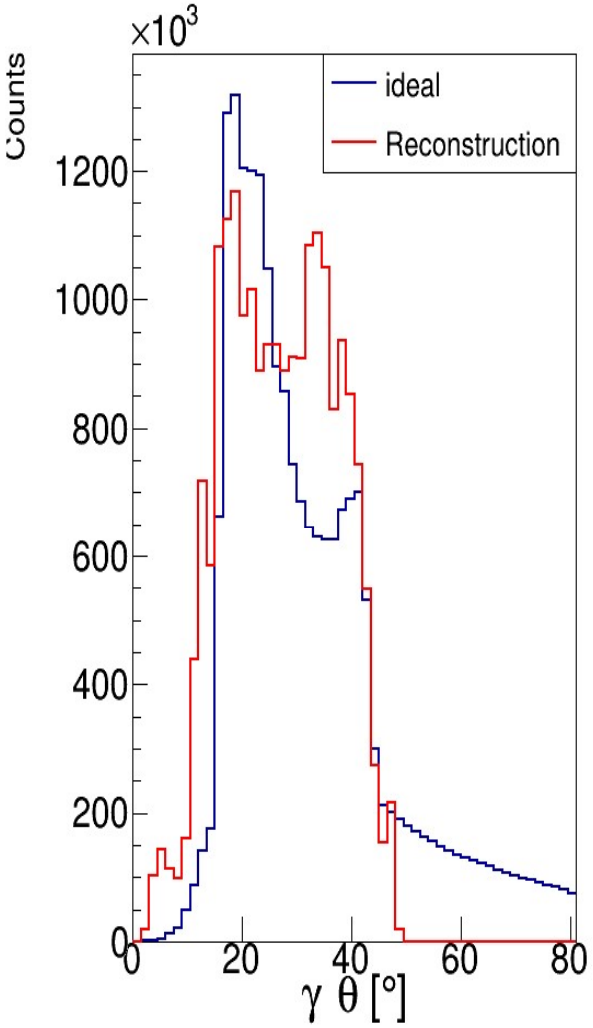




Photon distributions in simulations







Stokholm parametrization

- Error estimation for photon reconstruction and parametrization :

-photon energy resolution: $\frac{\sigma_E}{E} = \frac{5.8\%}{\sqrt{E[GeV]}}$ [A. Rost phd thesis]

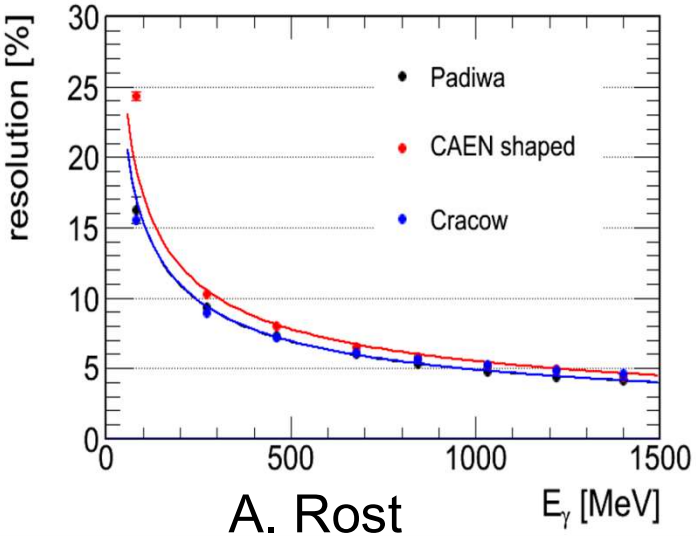
-photon θ and ϕ resoluton: $\sigma_\theta = \sigma_\phi = 2.5°$ [EMC geometry]

-vertex constrait (R,Z) not used

- $\gamma\gamma \rightarrow \pi^0$ refit using π^0 mass constraint:

-Convergence: max 10 iterations $\Delta\chi^2 < 1$

-Probabilty cut P>0.25



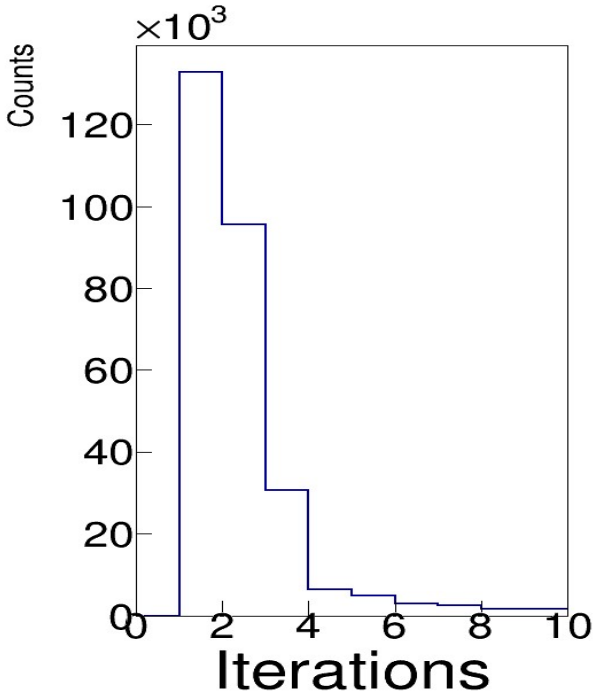
A. Rost

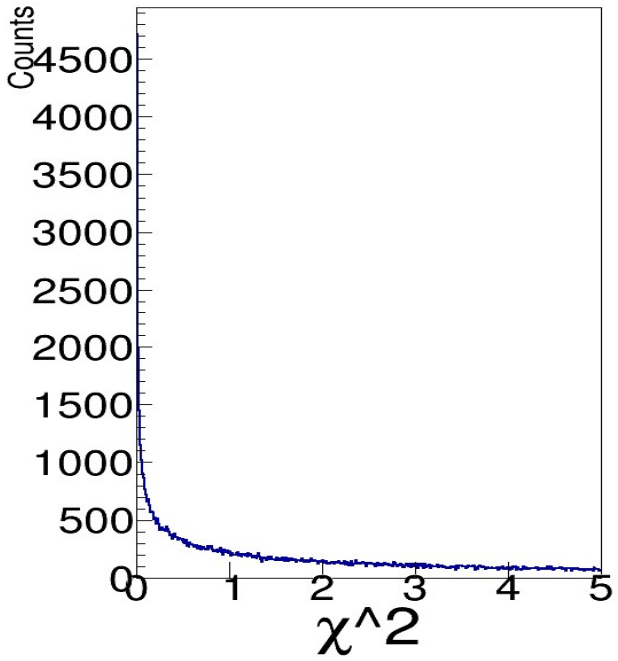
Stokholm Results-Simulations-QA plots

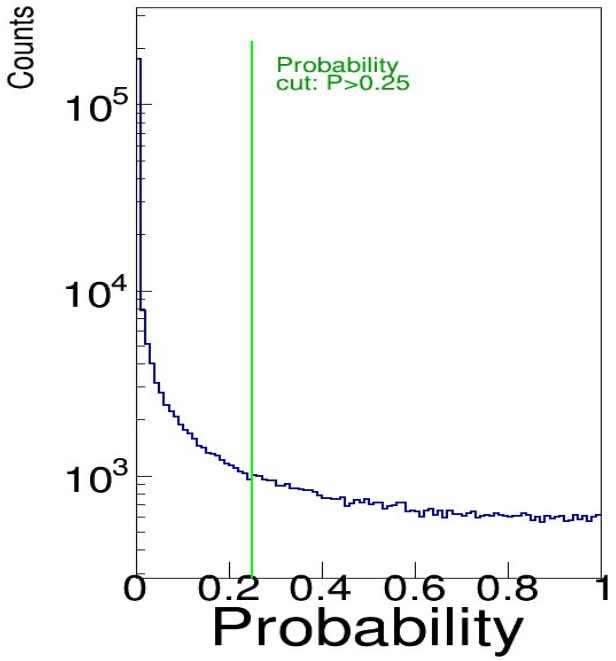
- π^0 procedure efficiency after cut on probability

$$\epsilon_{\pi_0} = Acc.* rec.eff. = \frac{true\ \pi_0\ events\ returned}{Total\ events} = \frac{149202}{100000000} \approx 1.5\%$$

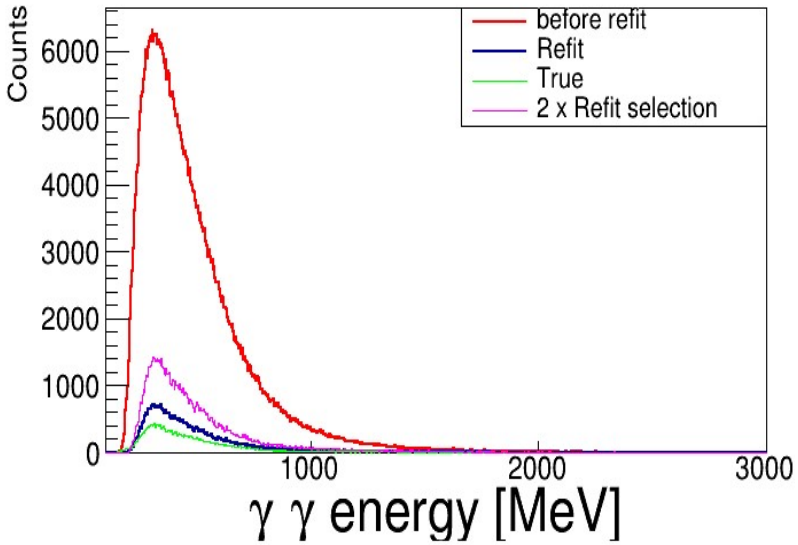
- η procedure efficiency:
- $\epsilon_\eta = \text{Acc.}* \text{ rec. eff.} = \frac{\text{true } \eta \textit{ events } \text{ returned}}{\text{Total events}} = \frac{25629}{100000000} \approx 0.026\%$
- Refit efectivnes: $\epsilon_{refit} = \frac{\gamma\gamma\ refited}{total\ \gamma\ \gamma\ number} = \frac{52057}{200998} \approx 26\%$

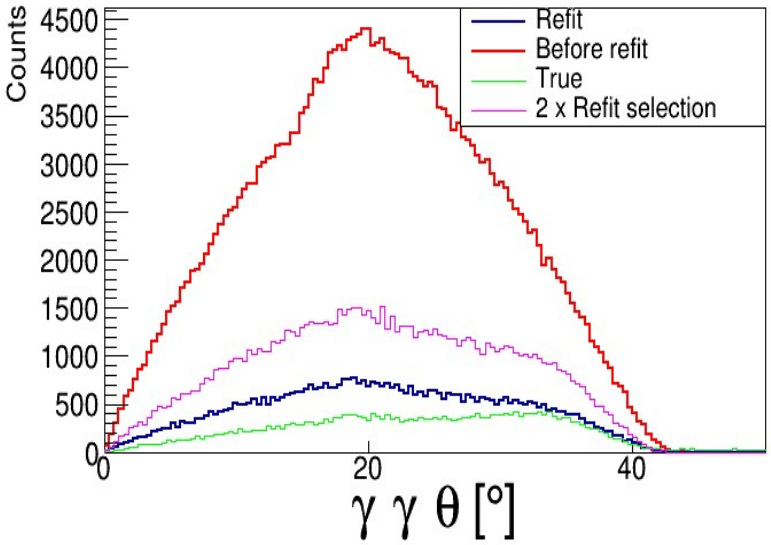


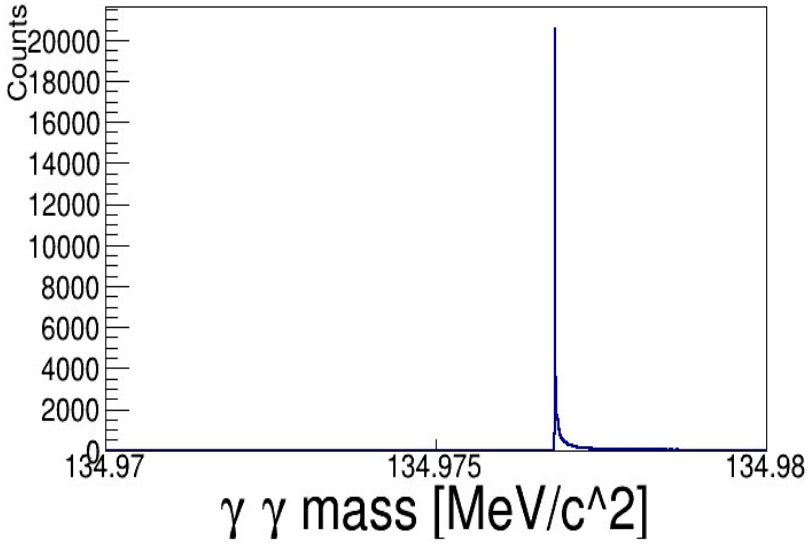


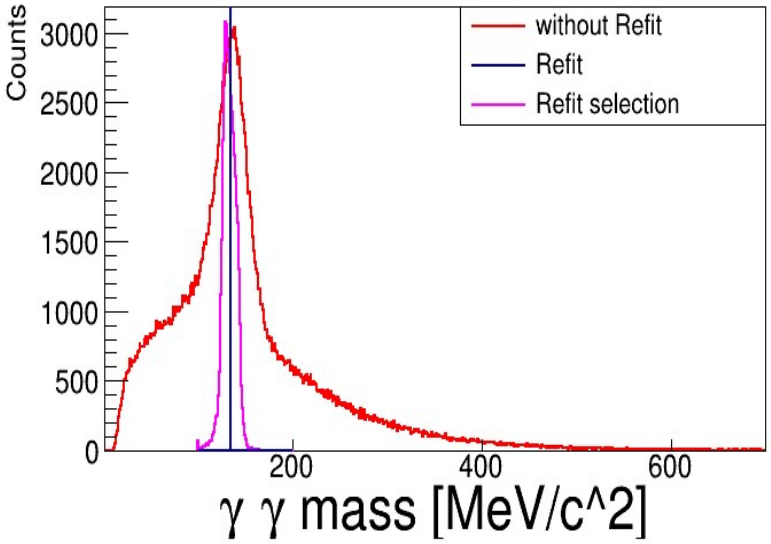


Stokholm$\pi^0 \rightarrow \gamma\gamma$ refit results- simulations



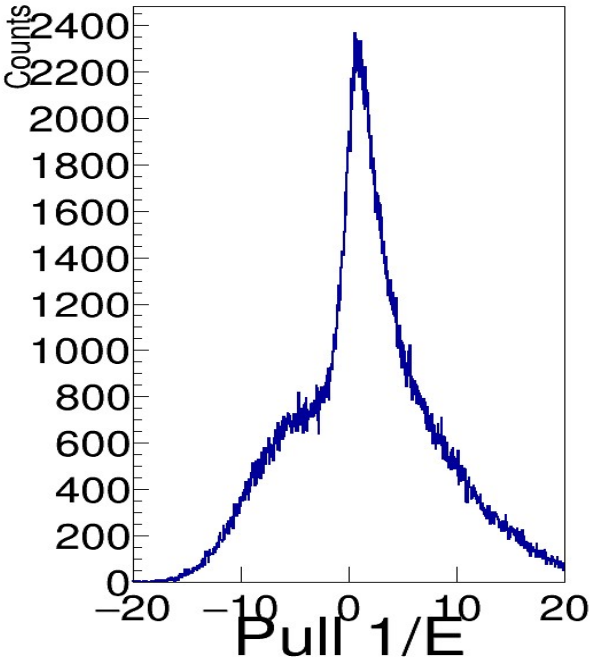


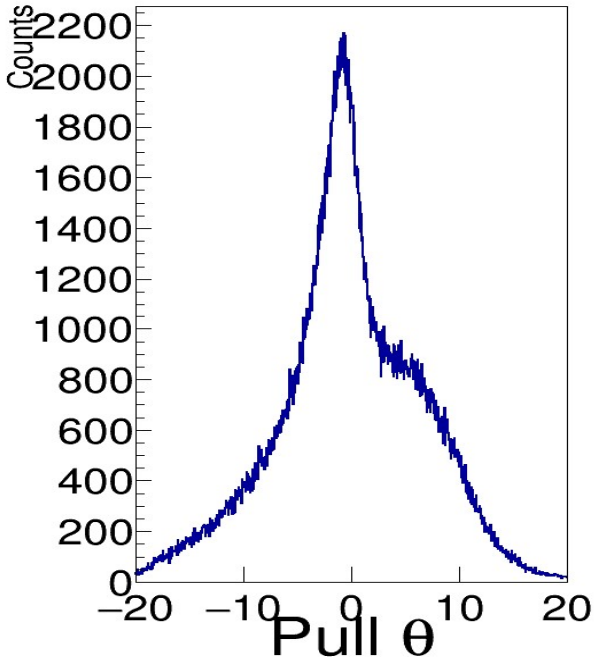


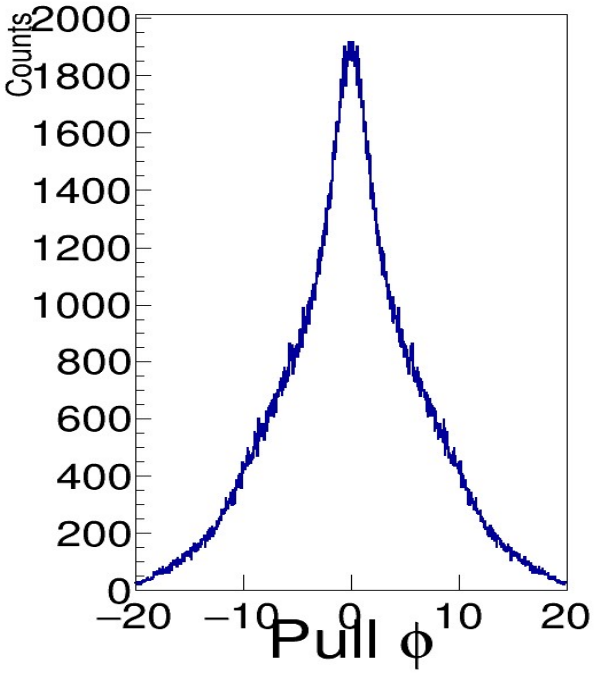


Stokholm Pulls-Simulations

- $Pull = \frac{y_{fit} - y_{con}}{\sqrt{\sigma_{con}^2 - \sigma_{fit}^2}}$

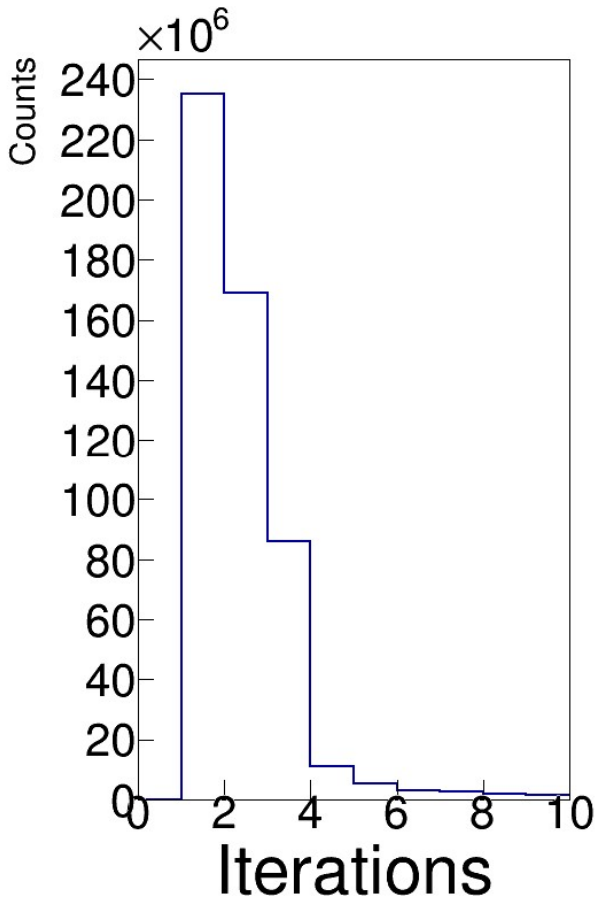


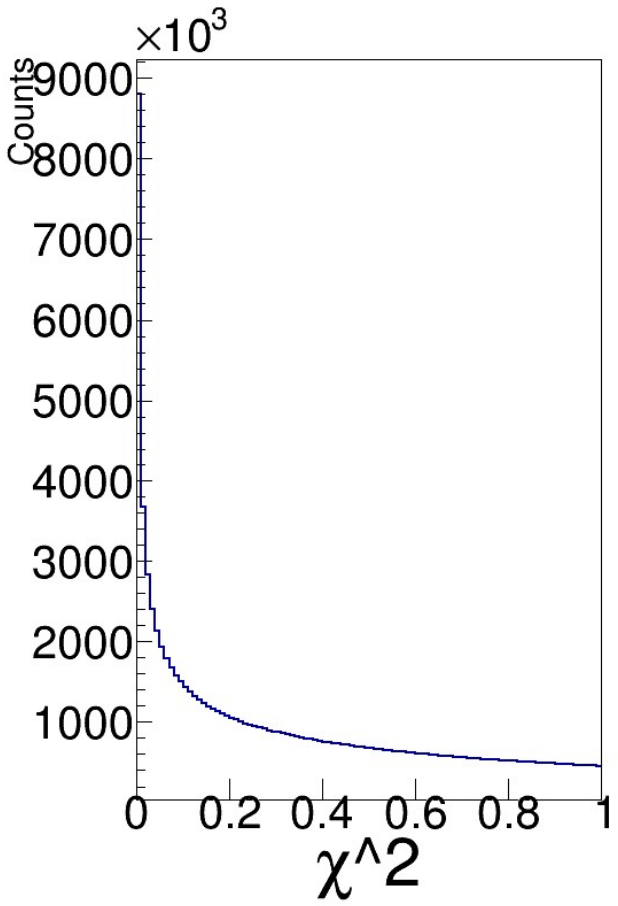


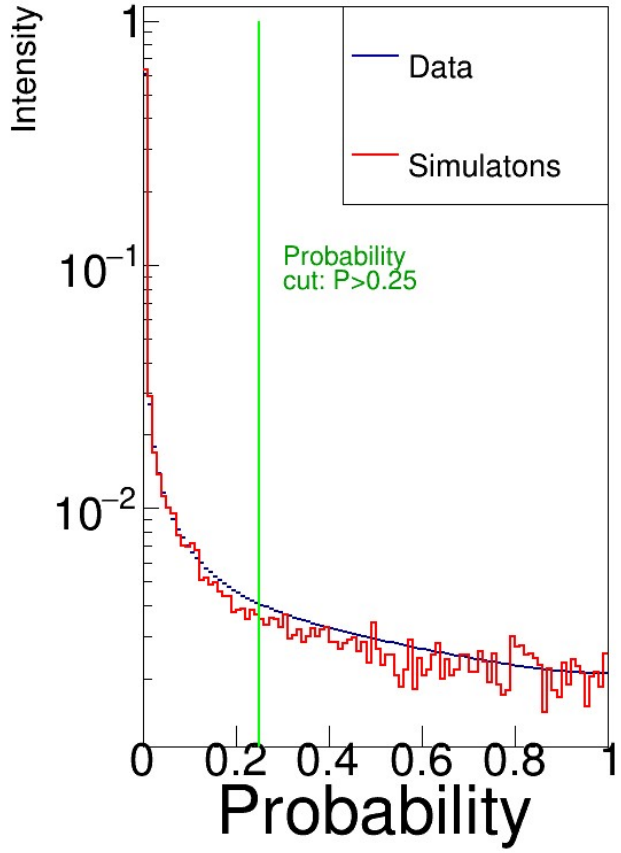


- Visible background tails are cut off by probability conditions.

Stokholm Results-data

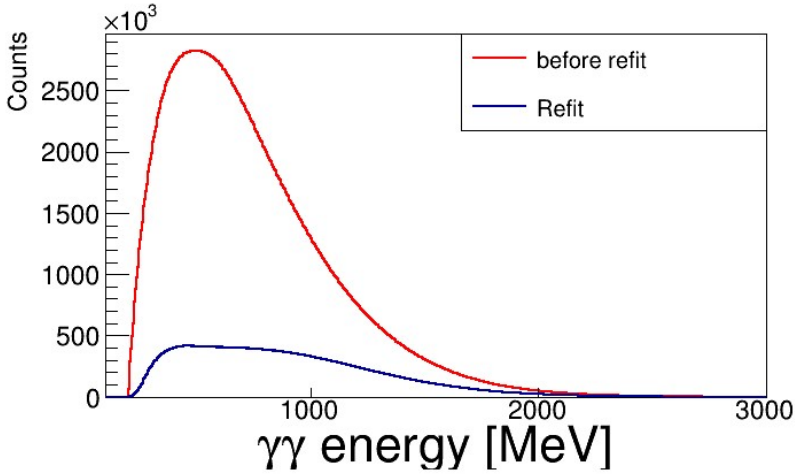


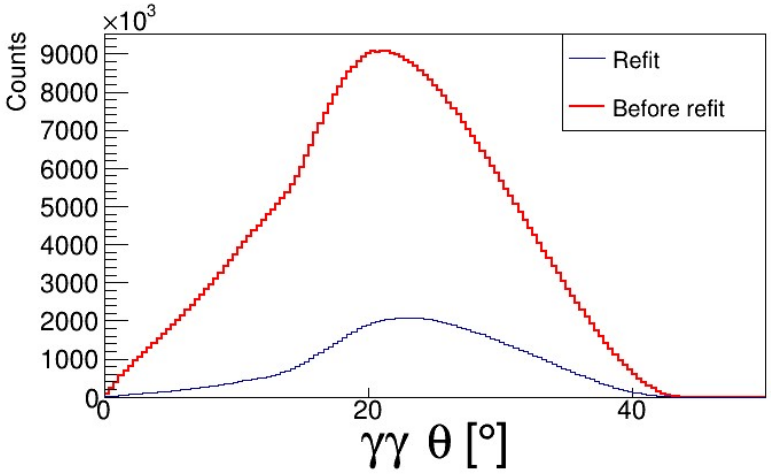


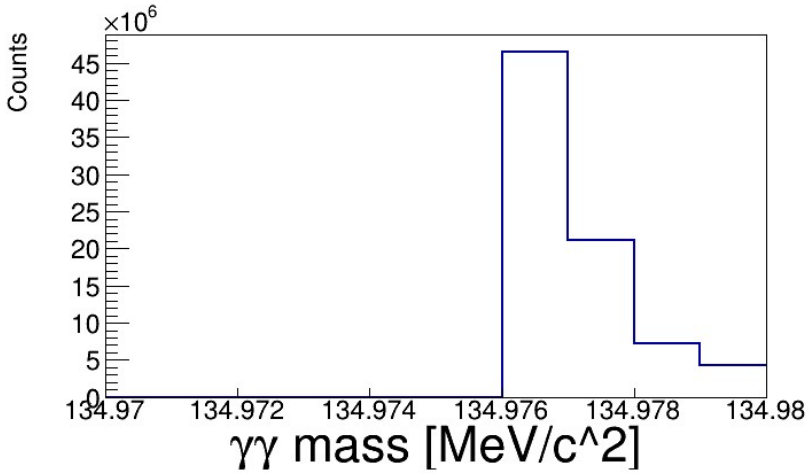


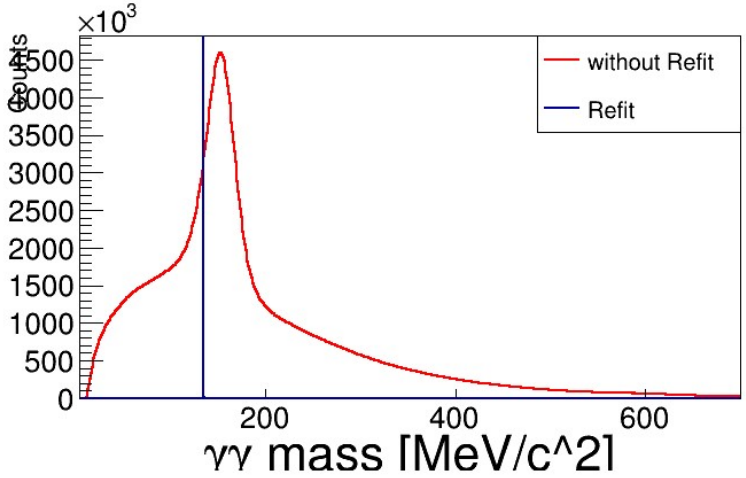
- Simulations agrees with the data

Stokholm $\pi^0 \rightarrow \gamma\gamma$ refit results−data



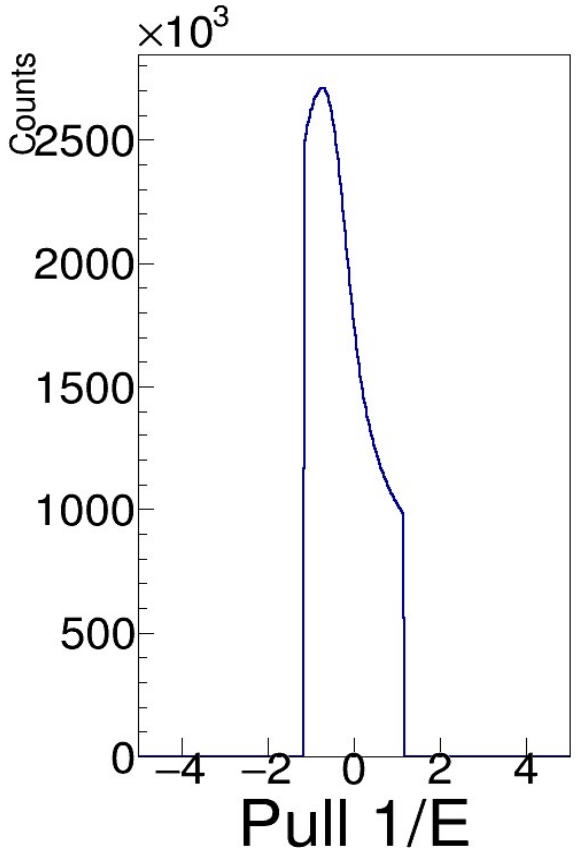


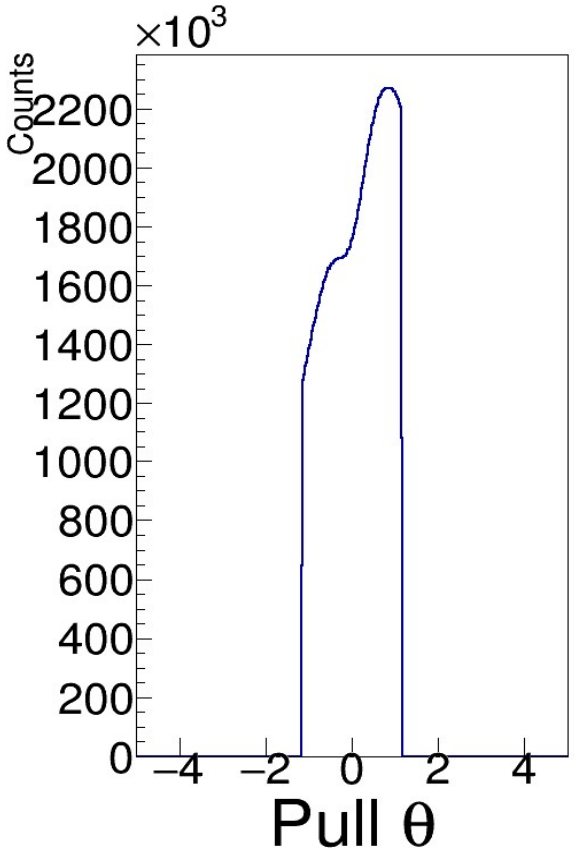


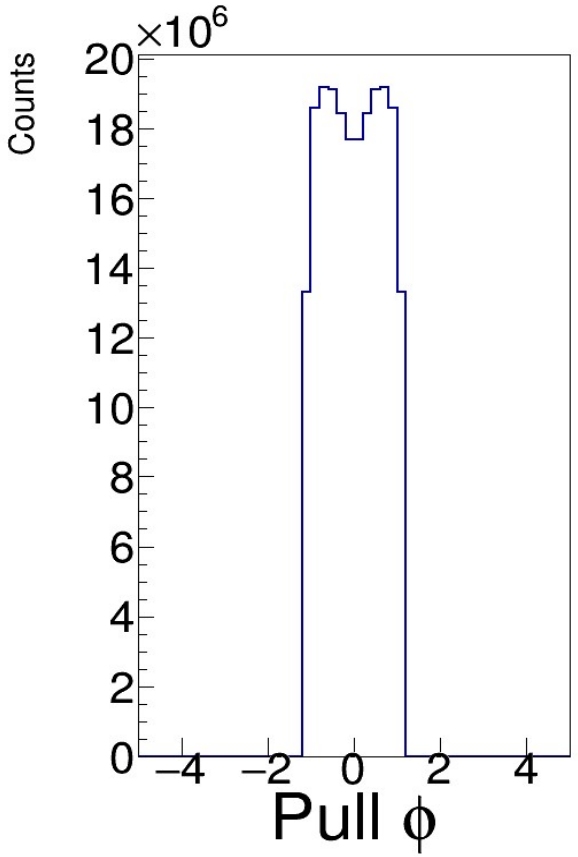


- The π^0 mass peak shift will be fixed by the new ECAL calibration (GEN3).This shift influences pull distributions and decreases efficiency of the refit procedure.

Stokholm Pull distributions-data

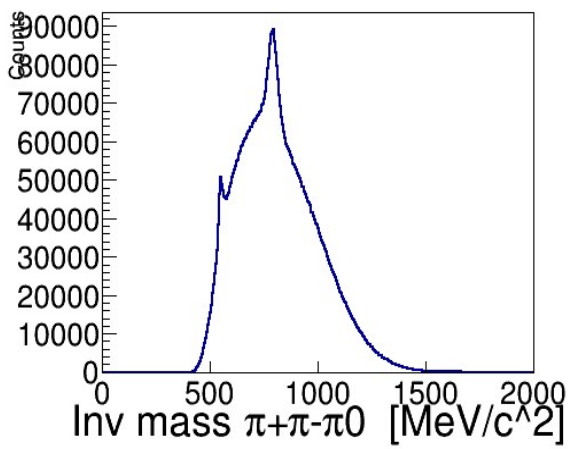


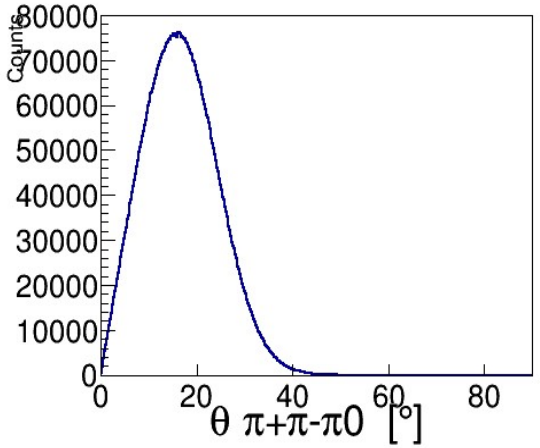


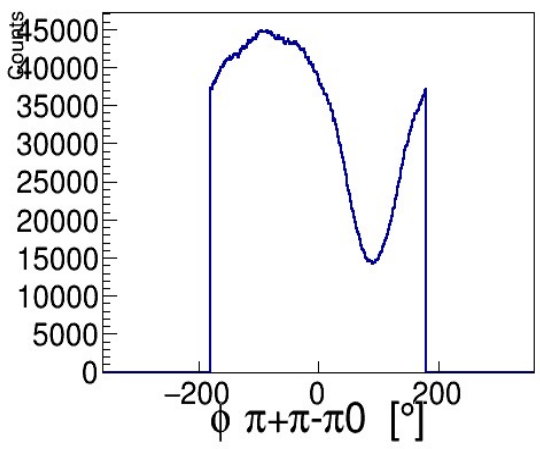


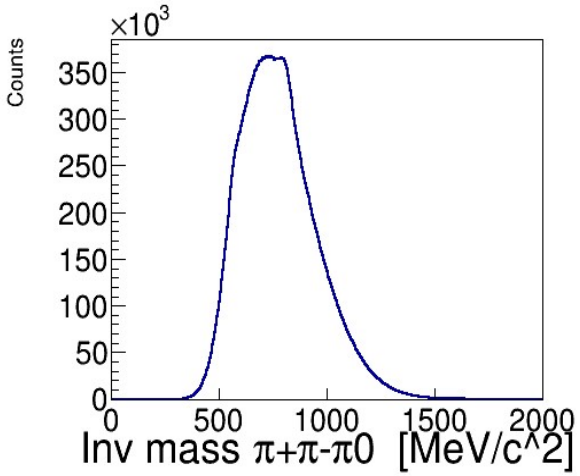
- Pull distribution deformation is caused by not correct ECAL energy calibration.
- Sharp edges of distributions are caused by probability cut.

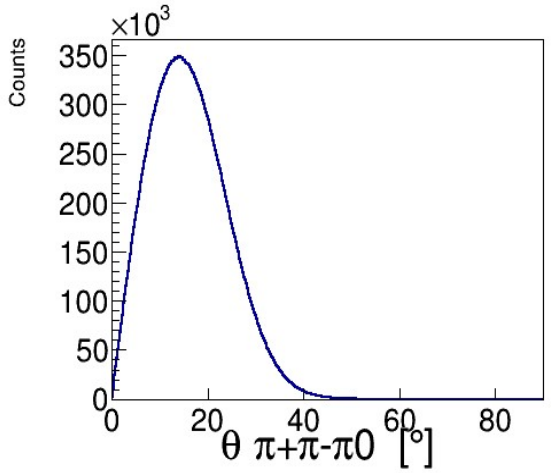
Stokholm $\pi^+\pi^-\pi^0$ with $\pi^0 \rightarrow \gamma\gamma$ refit

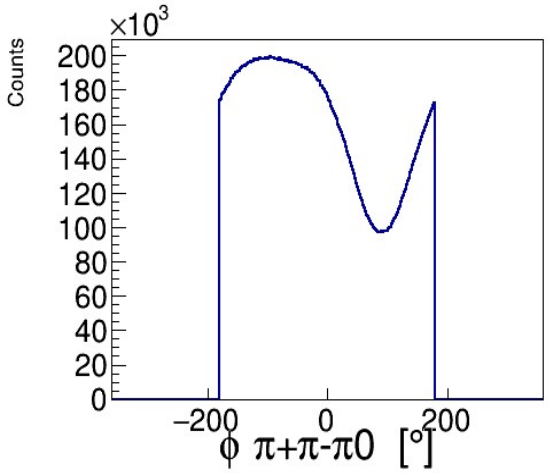






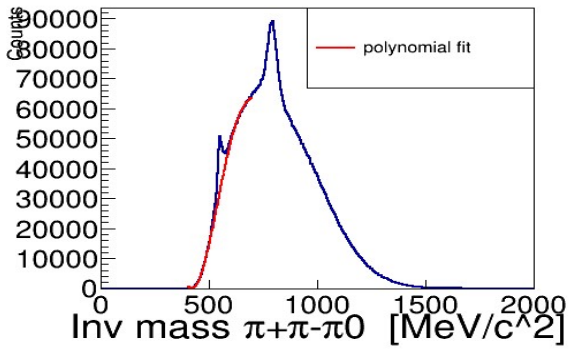


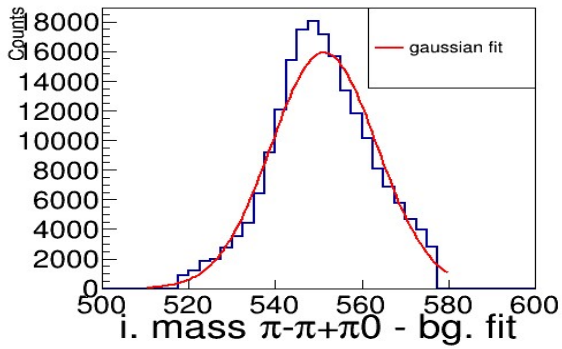


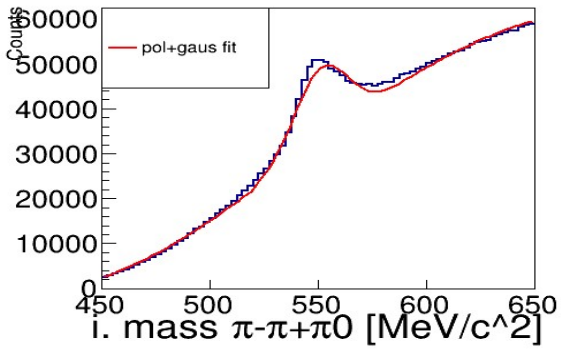


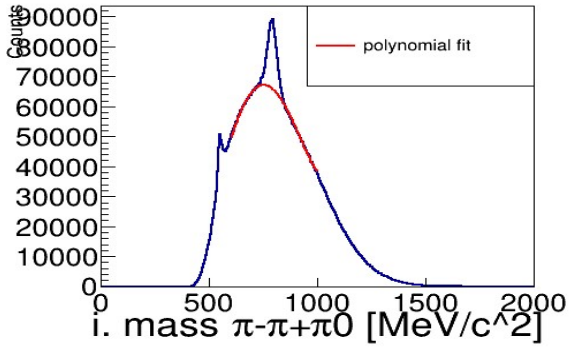
- $\pi^0 \rightarrow \gamma\gamma$ refit greatly makes η and ω peaks visible!

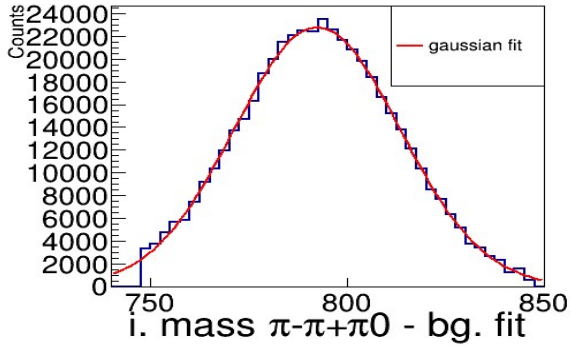
Stokholm η and ω peak positions and widths

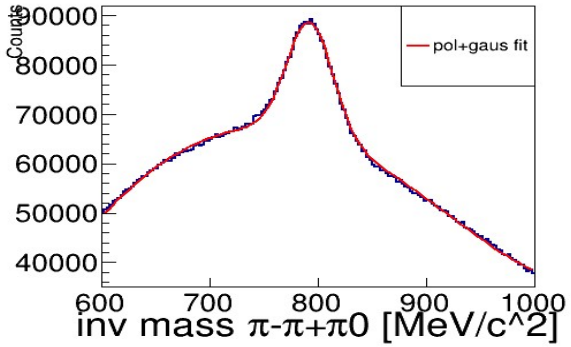










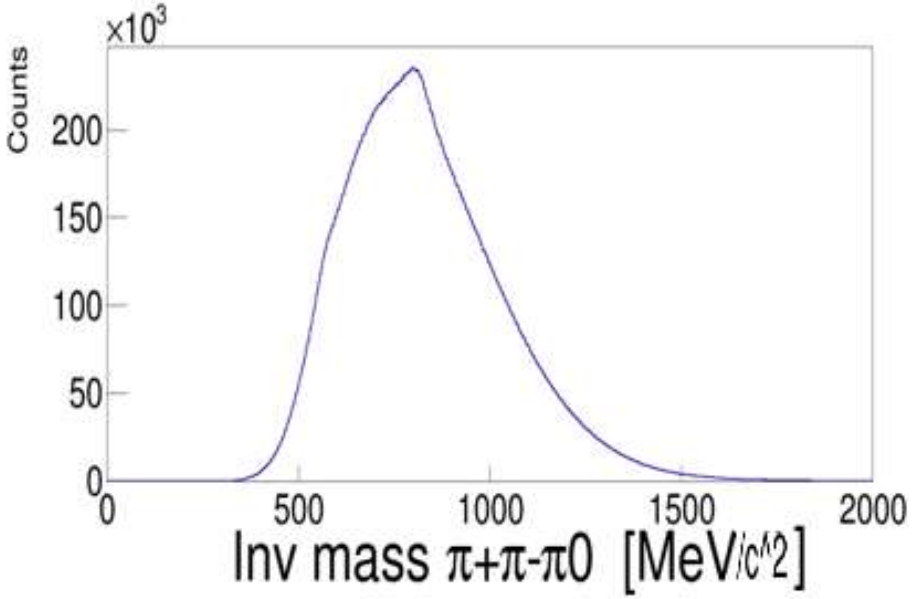


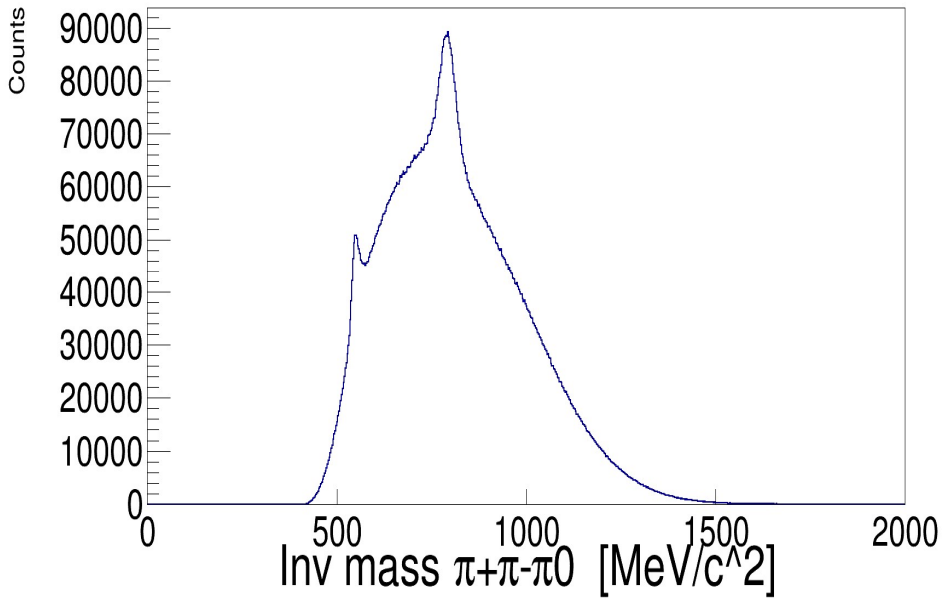
- $\mu_\eta = 550.81(41)\ \frac{MeV}{c^2},\ \sigma_\eta = 11.81(39)\frac{MeV}{c^2}$ PDG: $\mu_\eta = 547.862(17)\frac{MeV}{c^2}$
  $\mu_\omega = 792.260(34)\ \frac{MeV}{c^2},\ \sigma_\omega = 21.075(28)\frac{MeV}{c^2}$ PDG: $\mu_\omega = 782.65(12)\frac{MeV}{c^2}$

$230\ 259\ \eta$ messons in peak, background 784 799. Signal to bg. ratio 0.29.
536 903 ω in peak, background 2 594 890. Signal to bg. ratio 0.19.
Results: incosistency with PDG needs further investigation.

Stokholm Summary

- Estimation of total reconstruction efficiency (including refit)=$\frac{25\,629}{100\,000\,000}$ ≈0.026% and 0.1 % without refit.
- Kinematic refit of $\pi_0 \rightarrow \gamma\gamma$ greatly increases signal to background ratio of η and ω.

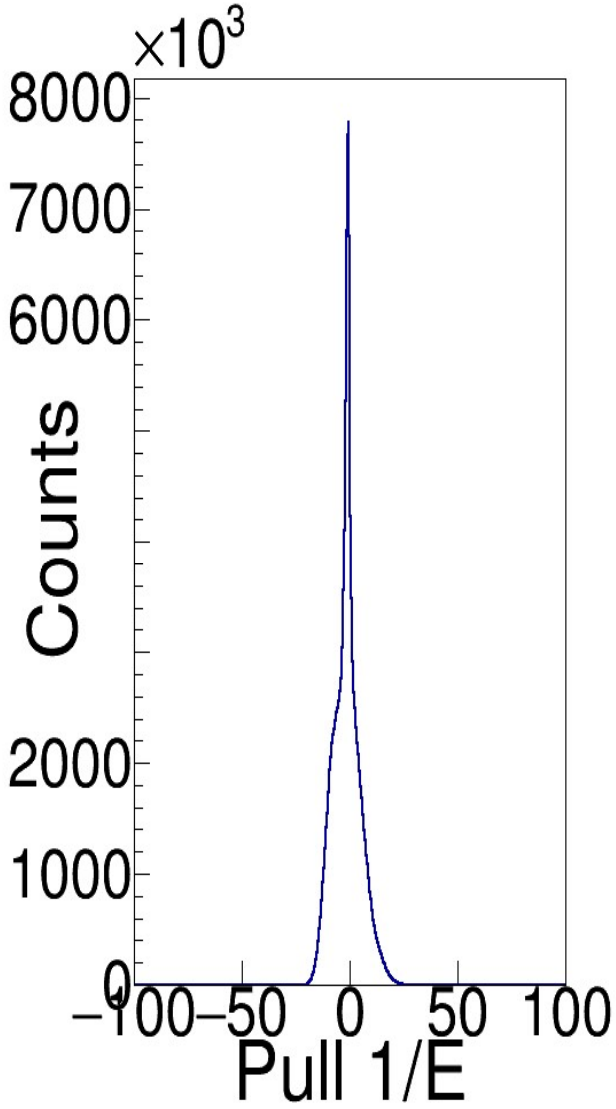


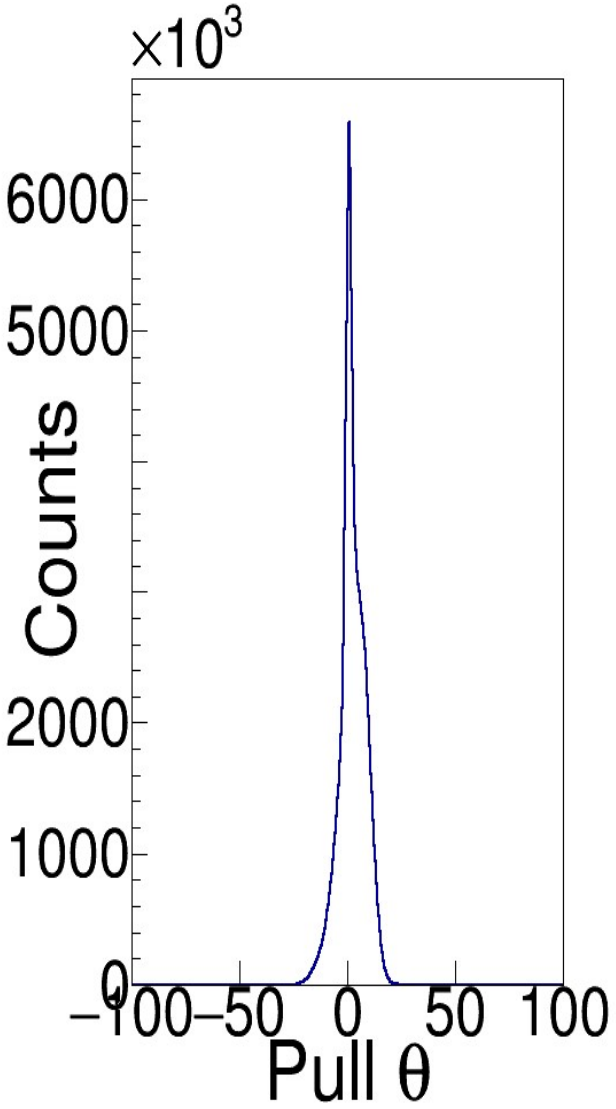


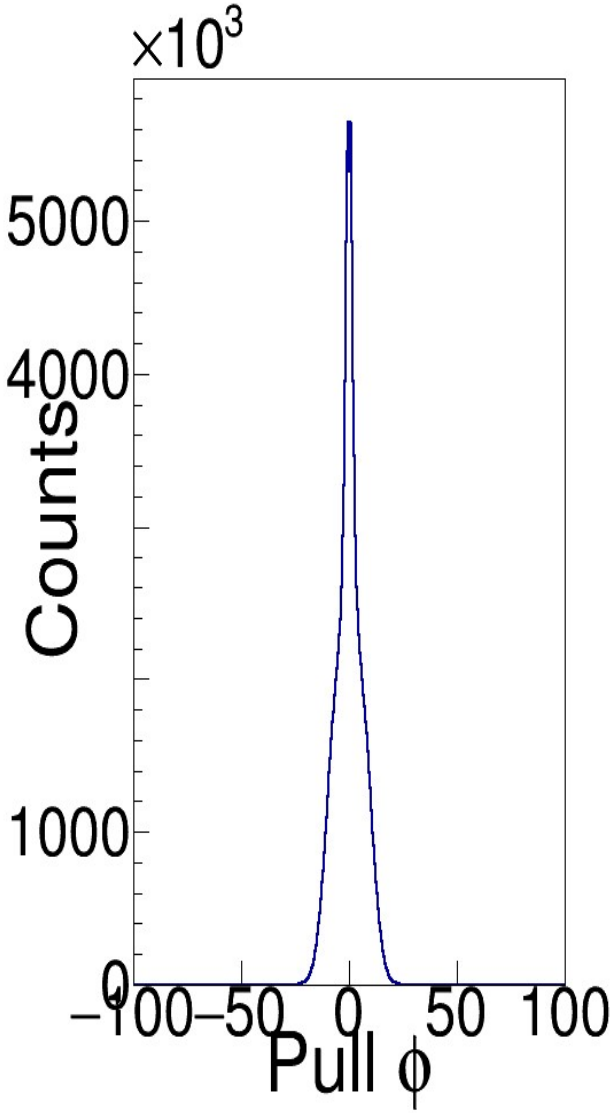
Stokholm Outlook

- Data analysis with gen3 ECAL calibration.
- Subtraction of combinatorial background (event mixing) in η and ω mass distributions.
- Kinematic refit for $\eta \to \gamma\gamma$ channel.
- Reconstruction of $\eta' \to \eta\ \pi^+\pi^-$ channel using $\eta \to \pi^+\pi^-\pi^0$ or $\eta \to \gamma\gamma$.
- Extraction of inclusive production cross sections for η, ω and η'.

Stokholm Data- pulls no prob cut







Stokholm η events-simulations

- Total η events 10 000 000
- Only 544637 events where all η daughters have been detected in HADES
- 134925 events with true η daughters after pion and photon cuts (2414666 true+background)
- 25614 events with η after refit (31338 true+background)

Stokholmη' studies