

# Update on Feasibility of Measurement of Generalized Distribution Amplitudes with the Channels

$$p\bar{p} \rightarrow \gamma\gamma \text{ and } p\bar{p} \rightarrow \pi^0\gamma$$

---

**Faiza Khalid**

*Justus Liebig University Giessen*



# Introduction

$$p\bar{p} \rightarrow \gamma M$$

at large Mandelstamm variables

process amplitudes factorizes:

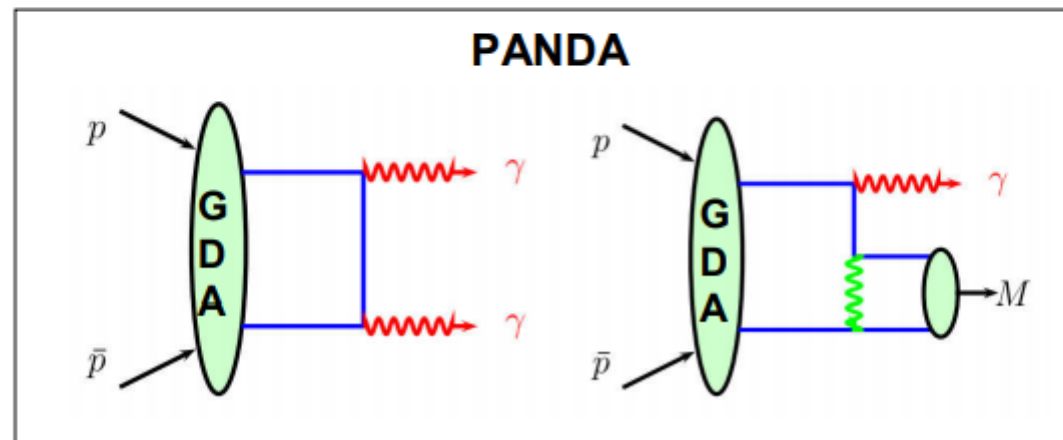
hard partonic subprocesses

+

annihilation form factors



represent moments of baryon-antibaryon  
**Generalized Distribution Amplitudes (GDAs)**



# Theoretical Predictions

- ❖ P.Kroll, A. Schafer, The process  $p\bar{p} \rightarrow \gamma\pi^0$  within the handbag approach, The European Physical Journal A 26, 89-98 (2005)
- ❖ Measurements of cross-section with the E760 experiment at Fermilab

Absolute cross-sections so far only available for:

$$p\bar{p} \rightarrow \gamma \gamma \quad p\bar{p} \rightarrow \pi^0 \gamma \quad p\bar{p} \rightarrow \pi^0 \pi^0$$

# Monte Carlo Simulation

## Analysis Framework

PANDARoot v-Oct19, FairSoft v-jun19p1, FairRoot v-18.2.0

## Event Generation

- Signal  $p\bar{p} \rightarrow \gamma \gamma$  and background  $p\bar{p} \rightarrow \pi^0 \pi^0$  and  $p\bar{p} \rightarrow \pi^0 \gamma$
- 1M signal and 1M background events simulated at beam momenta of 2.5, 5 and 10 GeV
- PHSP model was used for all event generations
- PHOTOS turned off for simplicity

# Event Selection

## Gamma gamma reconstruction

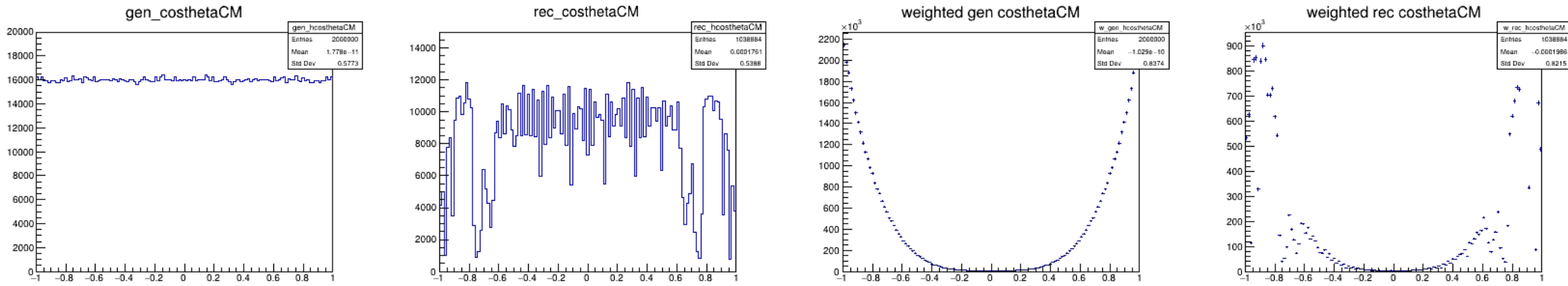
- Two gammas combined to form initial  $\bar{p}p$  system

## Events selection

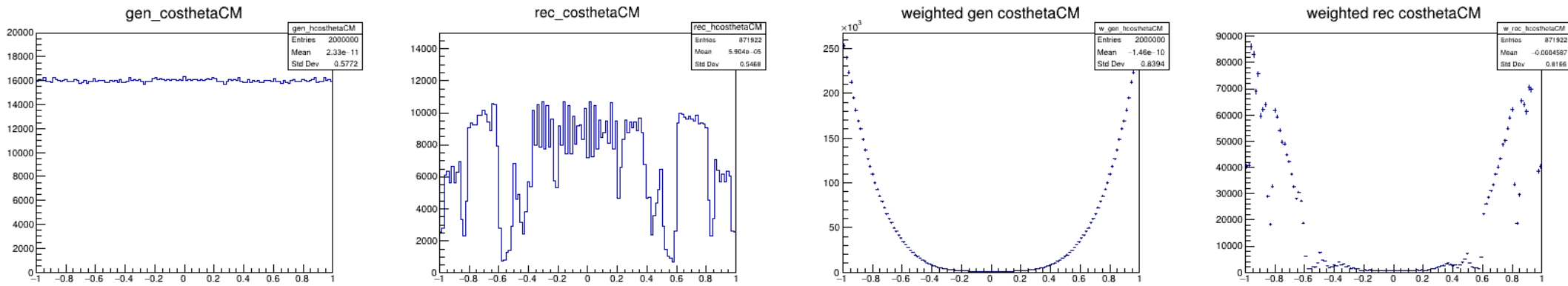
- Standard PID
- 4-Constraint fit applied to the reconstructed initial system
  - 4C Fit (RhoKinFitter) prob>0.01

# Acceptance Studies for $p\bar{p} \rightarrow \gamma\gamma$

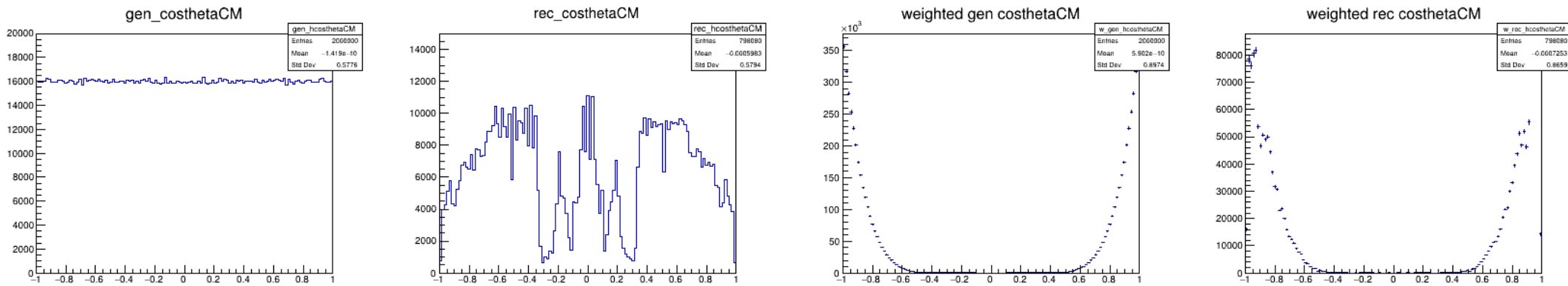
**2.5 GeV/c**



**5 GeV/c**



**10 GeV/c**

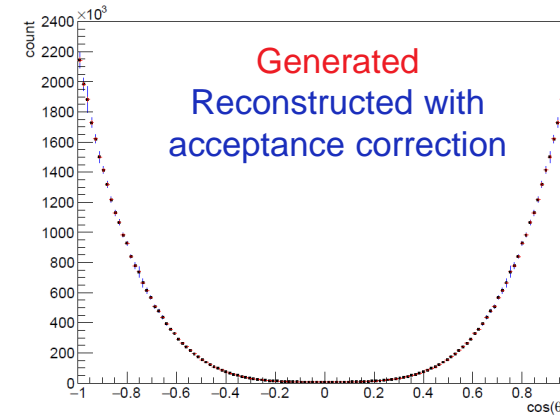
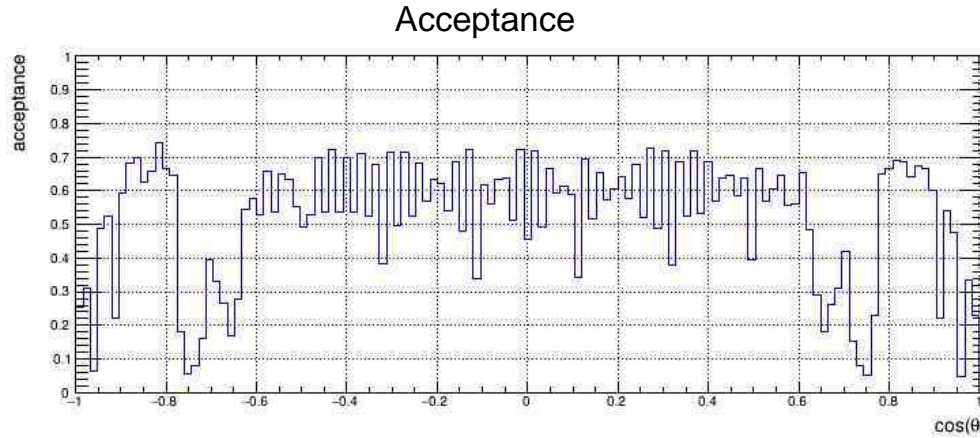


# Acceptance for $p\bar{p} \rightarrow \gamma\gamma$

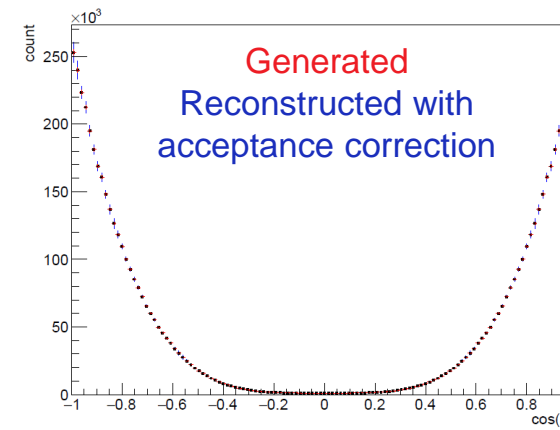
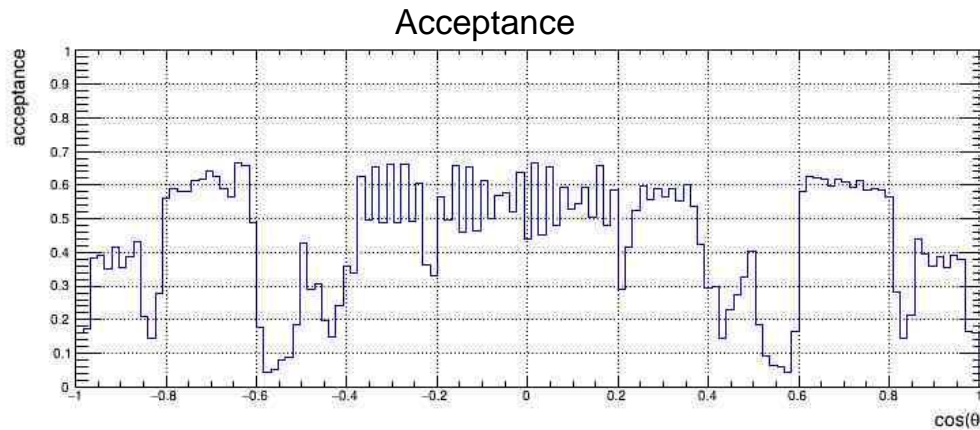
$$A = \frac{N_{rec}}{N_{gen}}$$

$$A_{corr} = \frac{N_{rec}}{A}$$

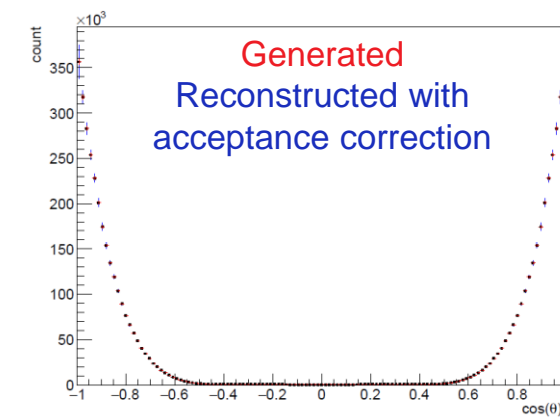
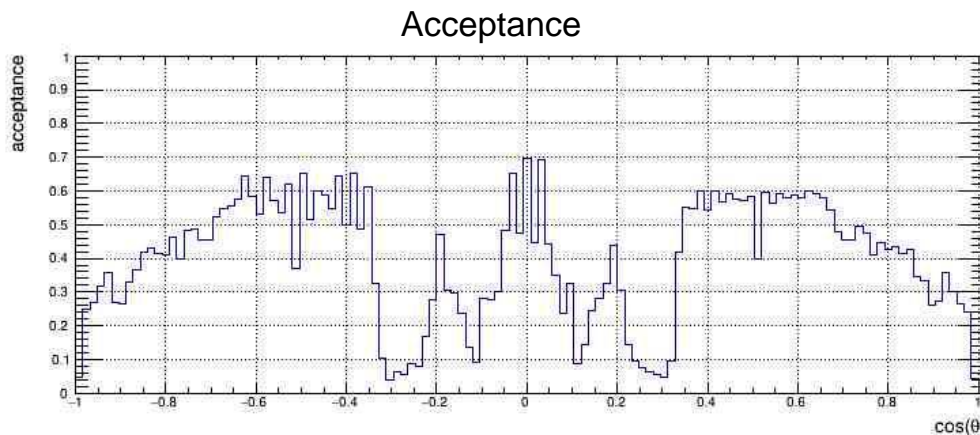
**2.5 GeV/c**

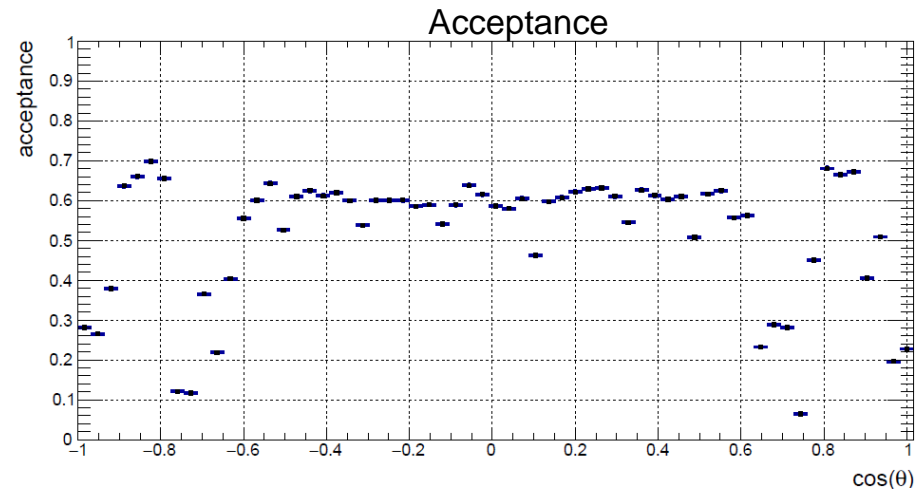


**5 GeV/c**



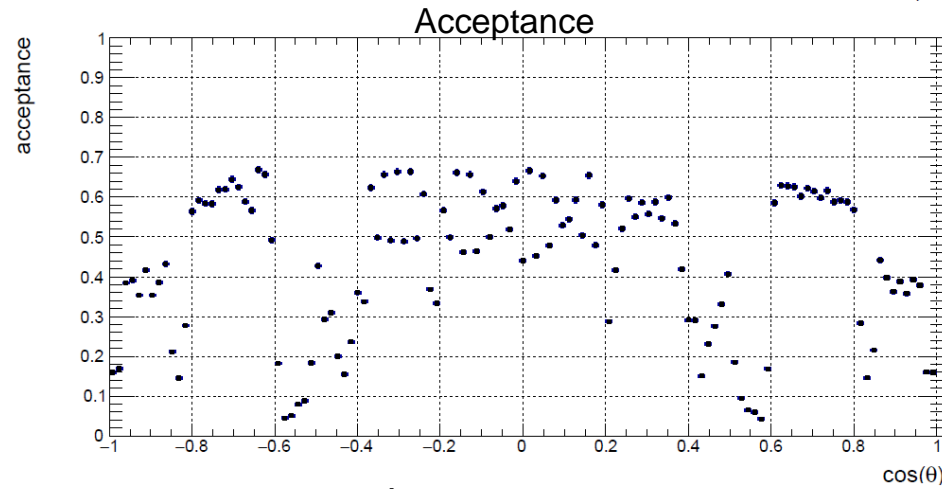
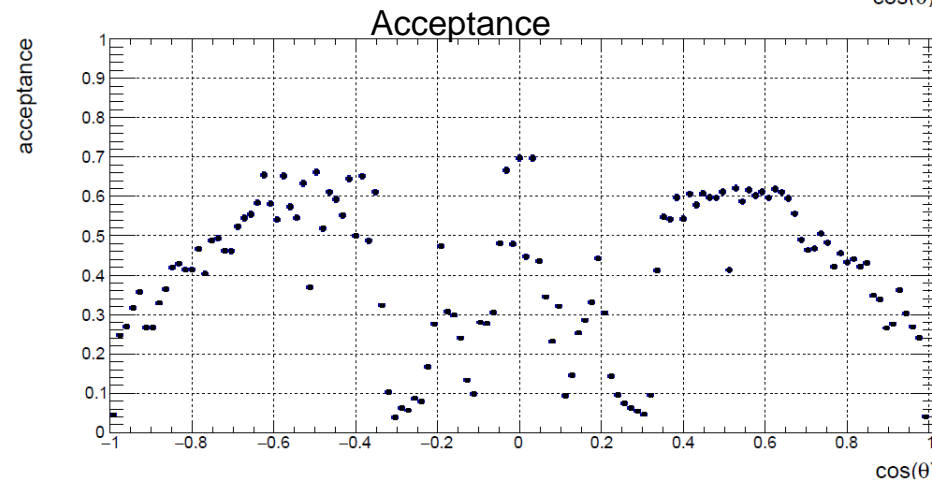
**10 GeV/c**



**2.5 GeV/c**

$$A = \frac{N_{rec}}{N_{gen}}$$

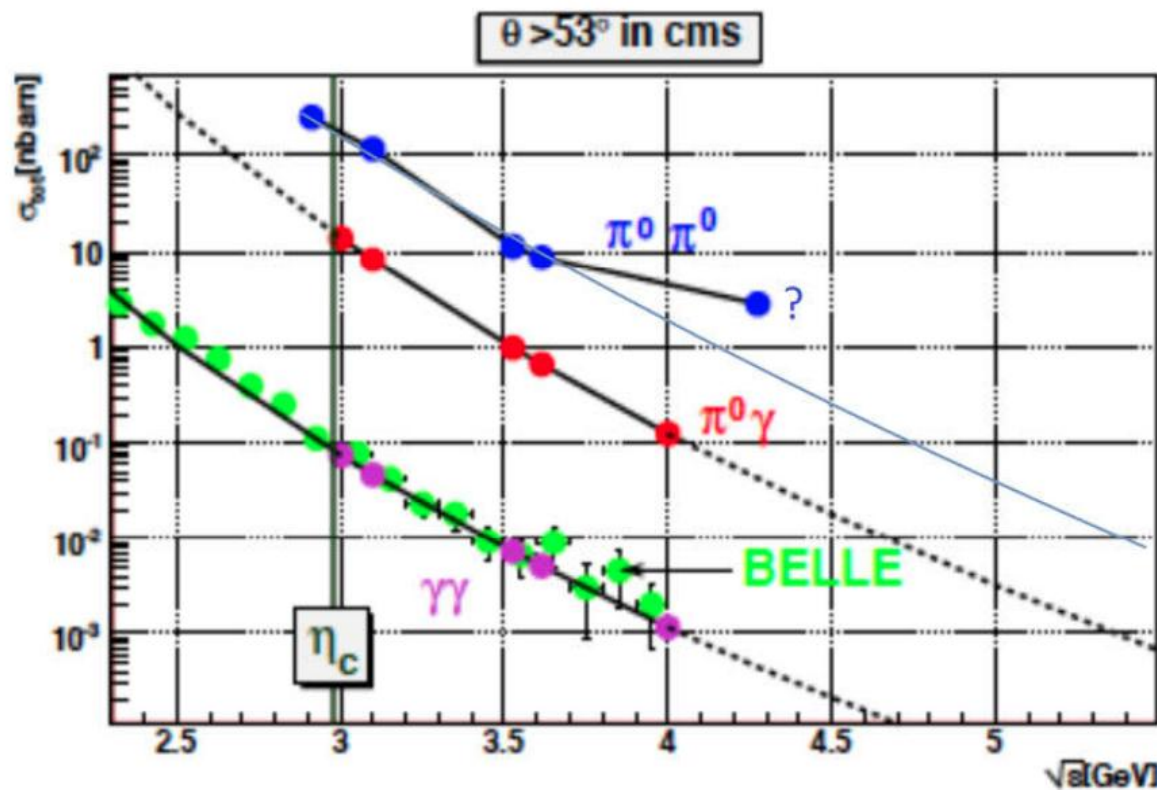
$$A_{corr} = \frac{N_{rec}}{A}$$

**5 GeV/c****10 GeV/c**



# Cross-sections for $p \bar{p} \rightarrow \gamma\gamma$

Use symmetry relations to predict the cross-sections of  $p \bar{p} \rightarrow \gamma\gamma$



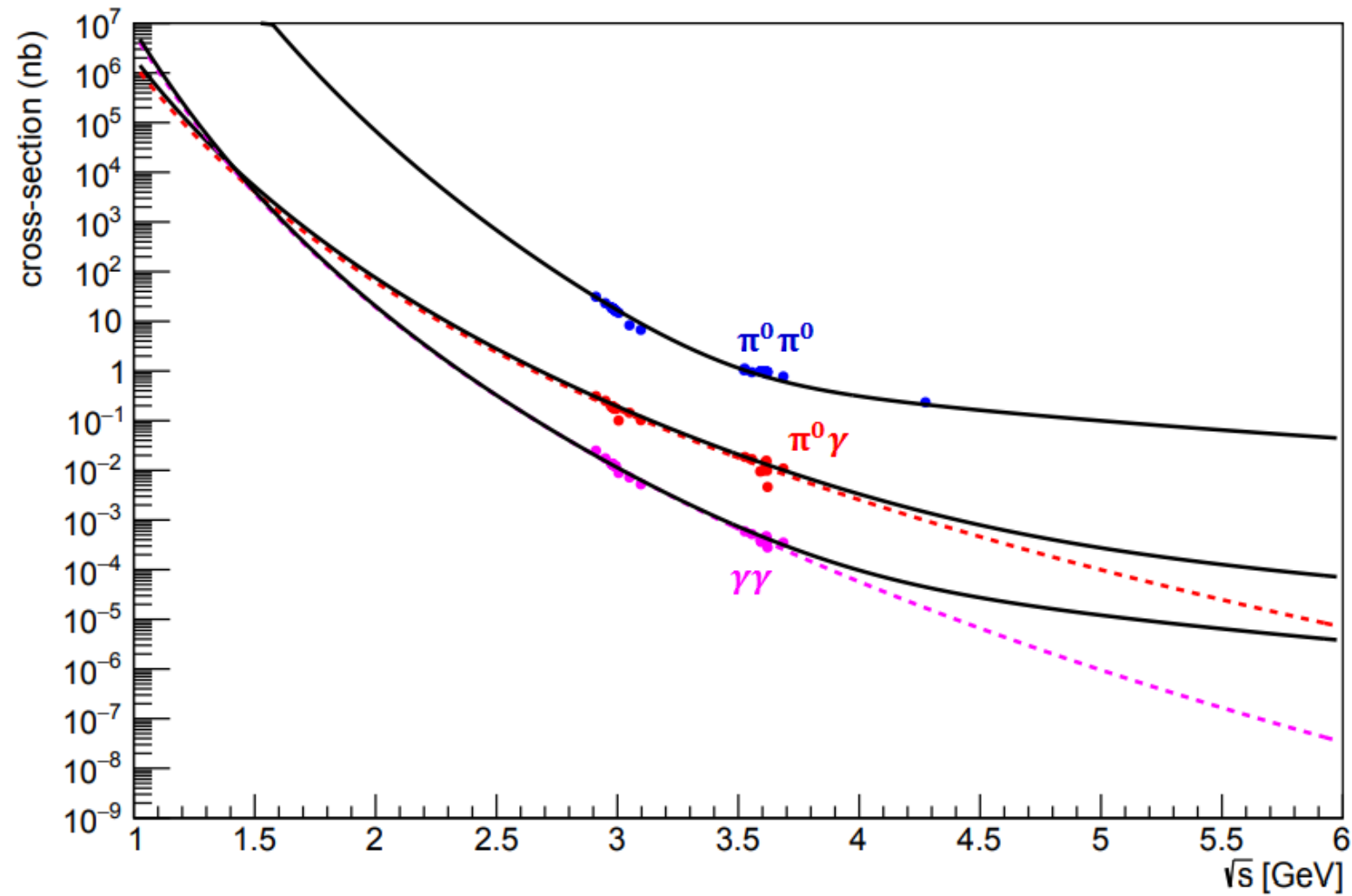
Cross-section for  $p \bar{p} \rightarrow \gamma\gamma$  is two order of magnitude larger than for  $p \bar{p} \rightarrow \pi^0 \gamma$

➤ Estimate the background correctly

This is what we used so far from the PANDA physics book.

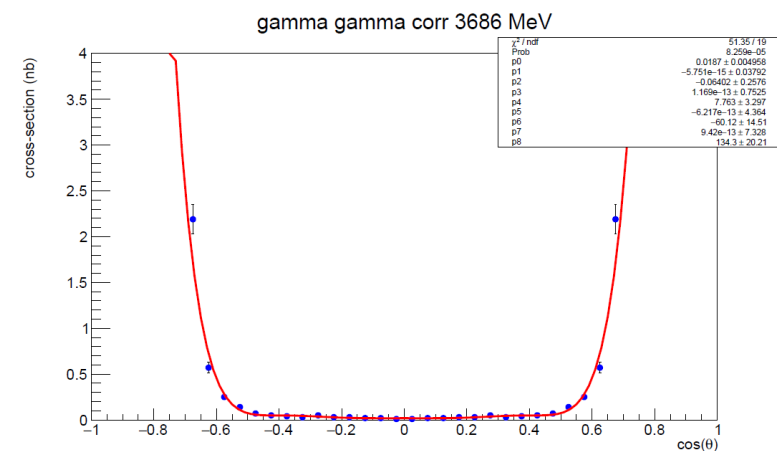
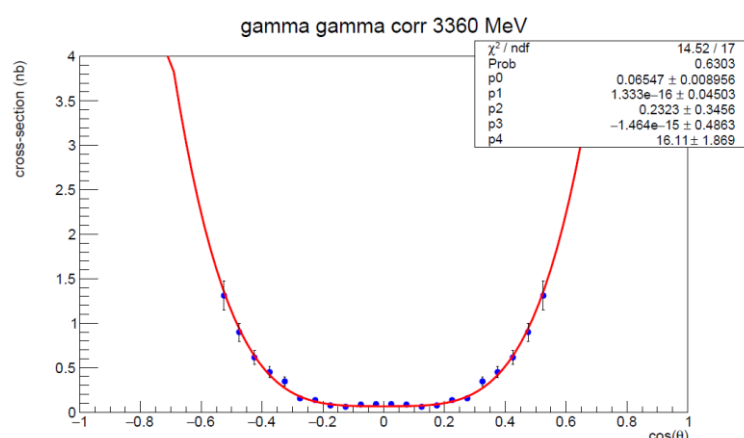
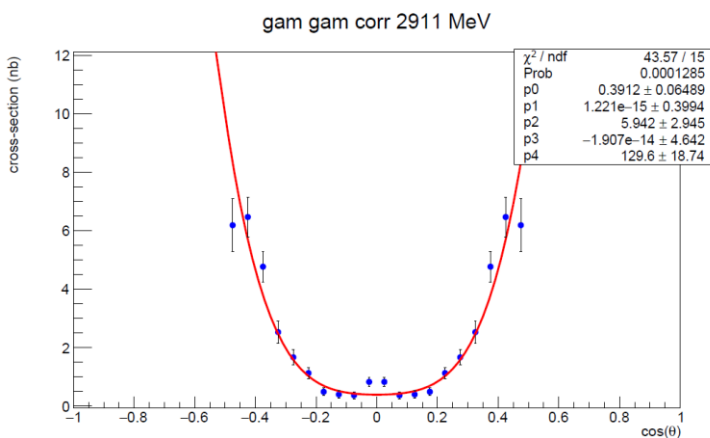
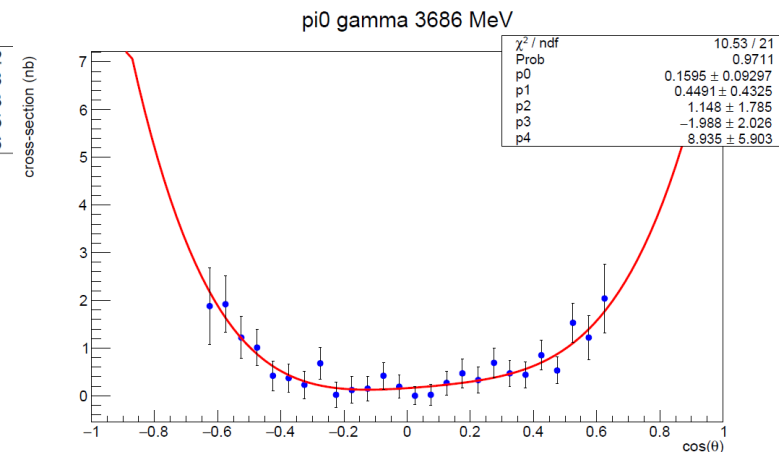
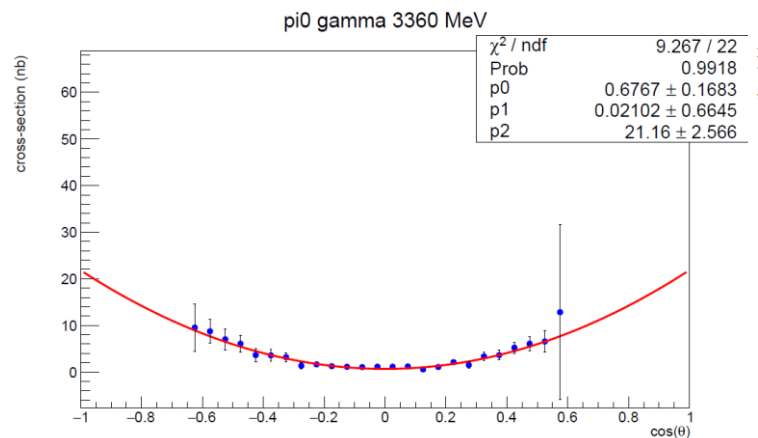
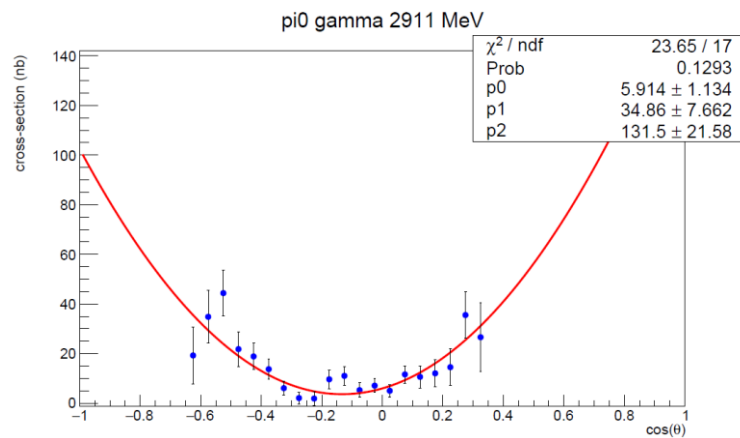
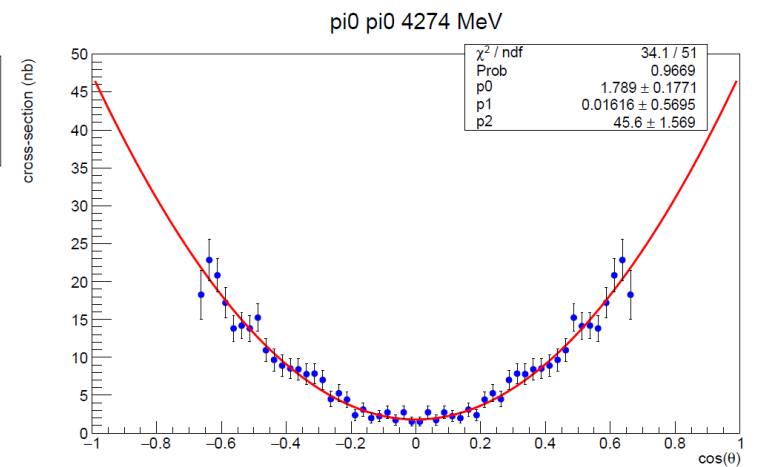
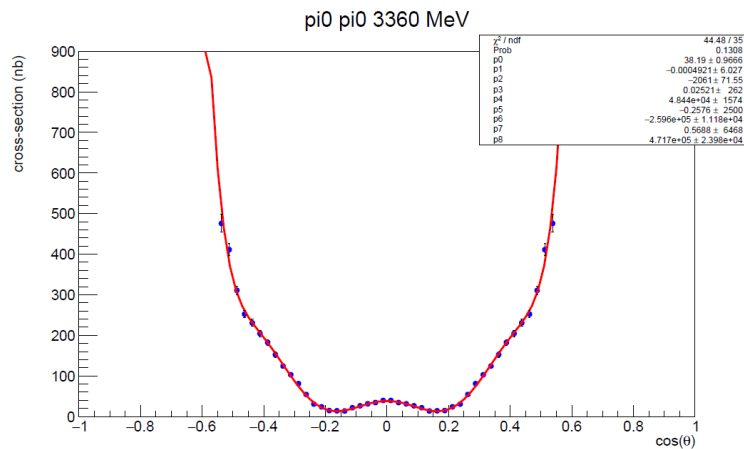
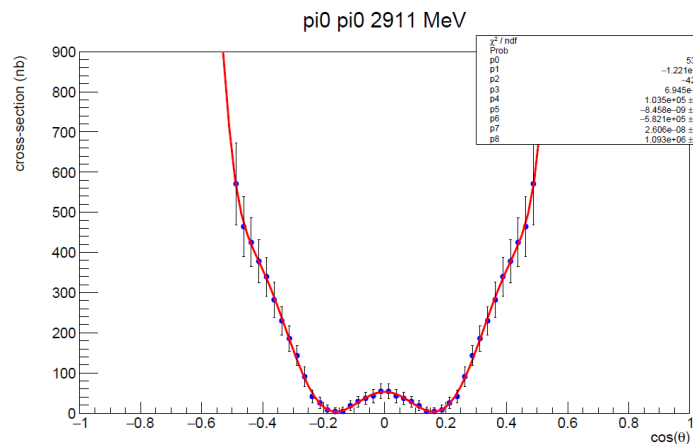
# Cross-sections from E760 Data

- T. A. Armstrong, Two-body neutral final states produced in antiproton-proton annihilations at  $2.911 \leq \sqrt{s} \leq 3.686$  GeV
- Integrated the angular range for a fixed  $\sqrt{s}$  to get the partially integrated cross section in the  $\cos(\theta)$  range which is available for all energies.
- If only positive  $\cos(\theta)$  are available, symmetry is assumed in the negative side.
- Partially integrated cross section was plotted vs  $\sqrt{s}$  and fits were applied.
- Error estimate was also determined.



$$f(x) = \frac{p_1}{x^{p_2}} + \frac{p_3}{x^{p_4}}$$

$$f(x) = \frac{p_1}{x^{p_2}}$$



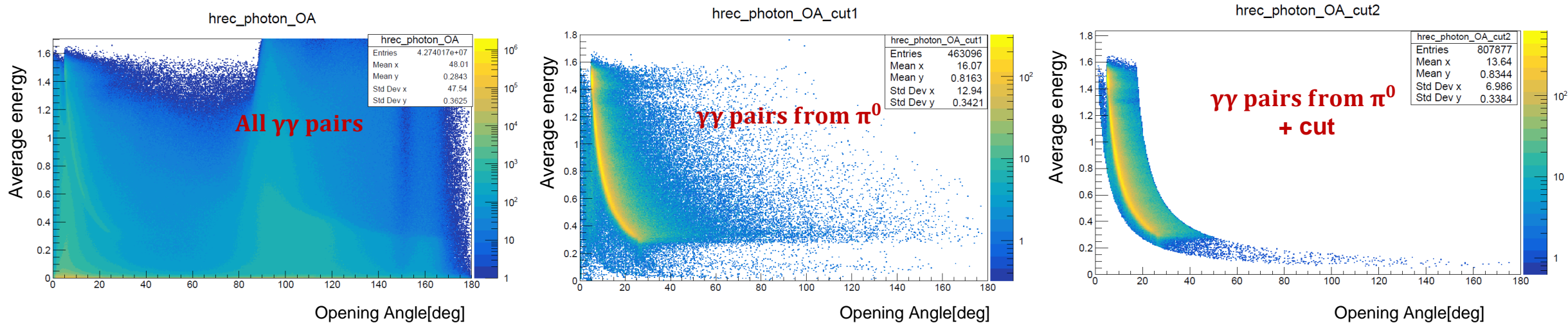
# Short Update on the $p\bar{p} \rightarrow \pi^0\gamma$ Channel

---

# Background Suppression with improved pions

- Neutral pions are reconstructed through their two photon decay channel
- Invariant mass spectrum is formed by combining all photons within an event into  $\gamma\gamma$  pairs
- Invariant mass spectra has contribution from combinatorial  $\gamma\gamma$  pairs which can be reduced by relying on the kinematics correlation of pion decay photons that the combinatorial  $\gamma\gamma$  pairs do not display.
- Feasibility study for the measurement of  $\pi N$  TDAs at PANDA in  $\bar{p}p \rightarrow J/\Psi\pi^0$

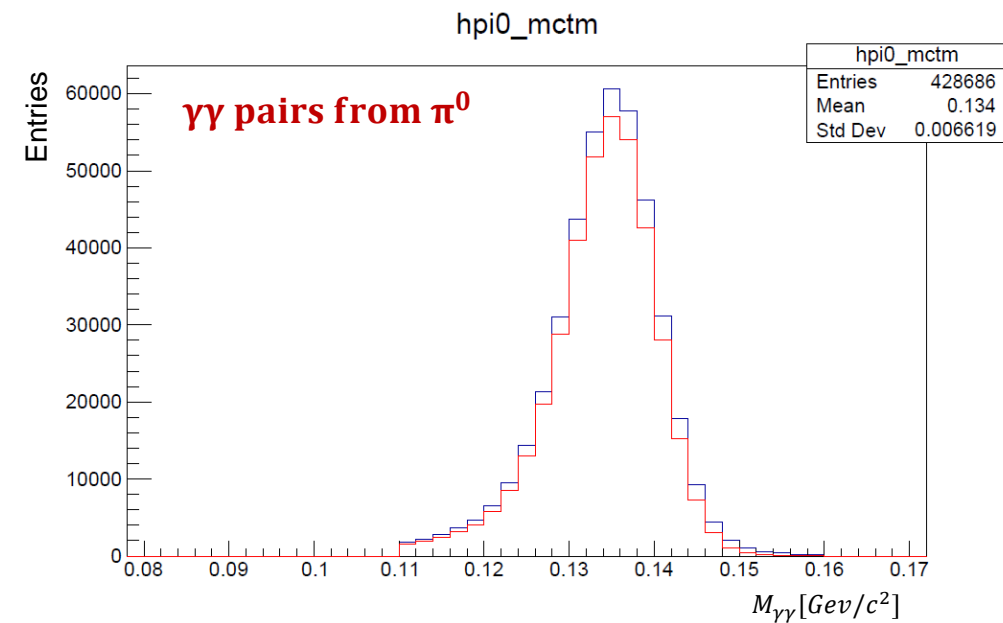
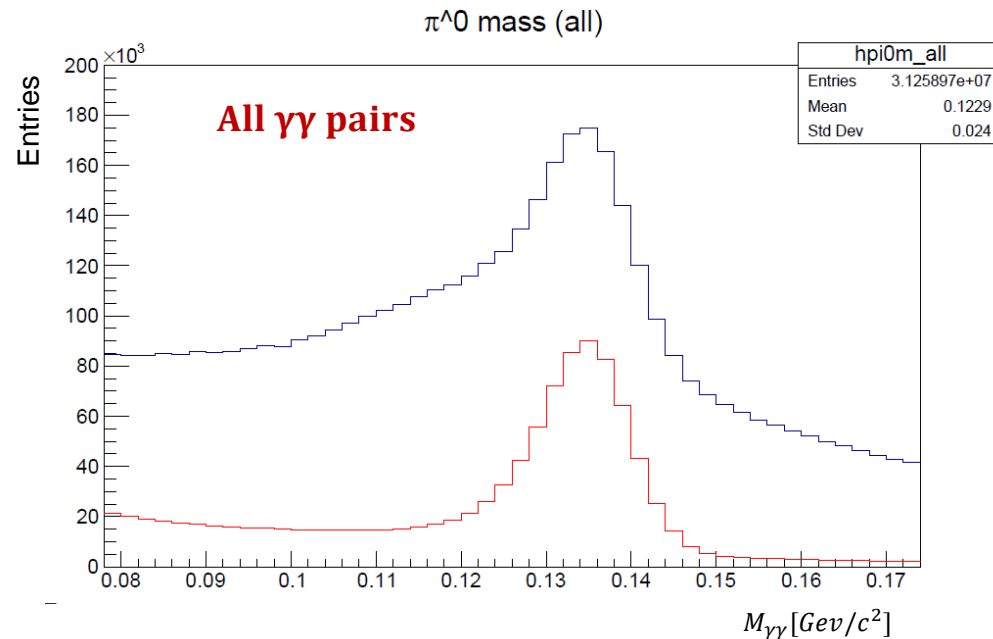
$$f_L(OA) < \frac{E_{\gamma_1} + E_{\gamma_2}}{2} < \begin{cases} \infty, & \text{if } OA \leq a_2^U \\ f_L(OA), & \text{if } OA > a_2^U \end{cases} \quad \begin{aligned} f_L(x) &= a_0^L + \frac{a_1^L}{x - a_2^L} \\ f_U(x) &= a_0^U + \frac{a_1^U}{x - a_2^U} \end{aligned}$$



Average reconstructed energy of a photon pair versus its opening angle for all  $\gamma\gamma$  pairs within an event (extreme left panel) compared to  $\gamma\gamma$  pairs stemming from  $\pi^0$  decay before (middle panel) and after the cut (extreme right panel), in a simulation of  $\bar{p}p \rightarrow \pi^0\gamma$  at beam momentum of 2.5 GeV/c.

Possible to reduce the combinatorial background to a few percent while keeping an efficiency larger than 90% for pairs where both photons originate from  $\pi^0$  decays.

Invariant mass cut:  $110 < M_{\gamma\gamma} < 160 \text{ MeV}/c^2$

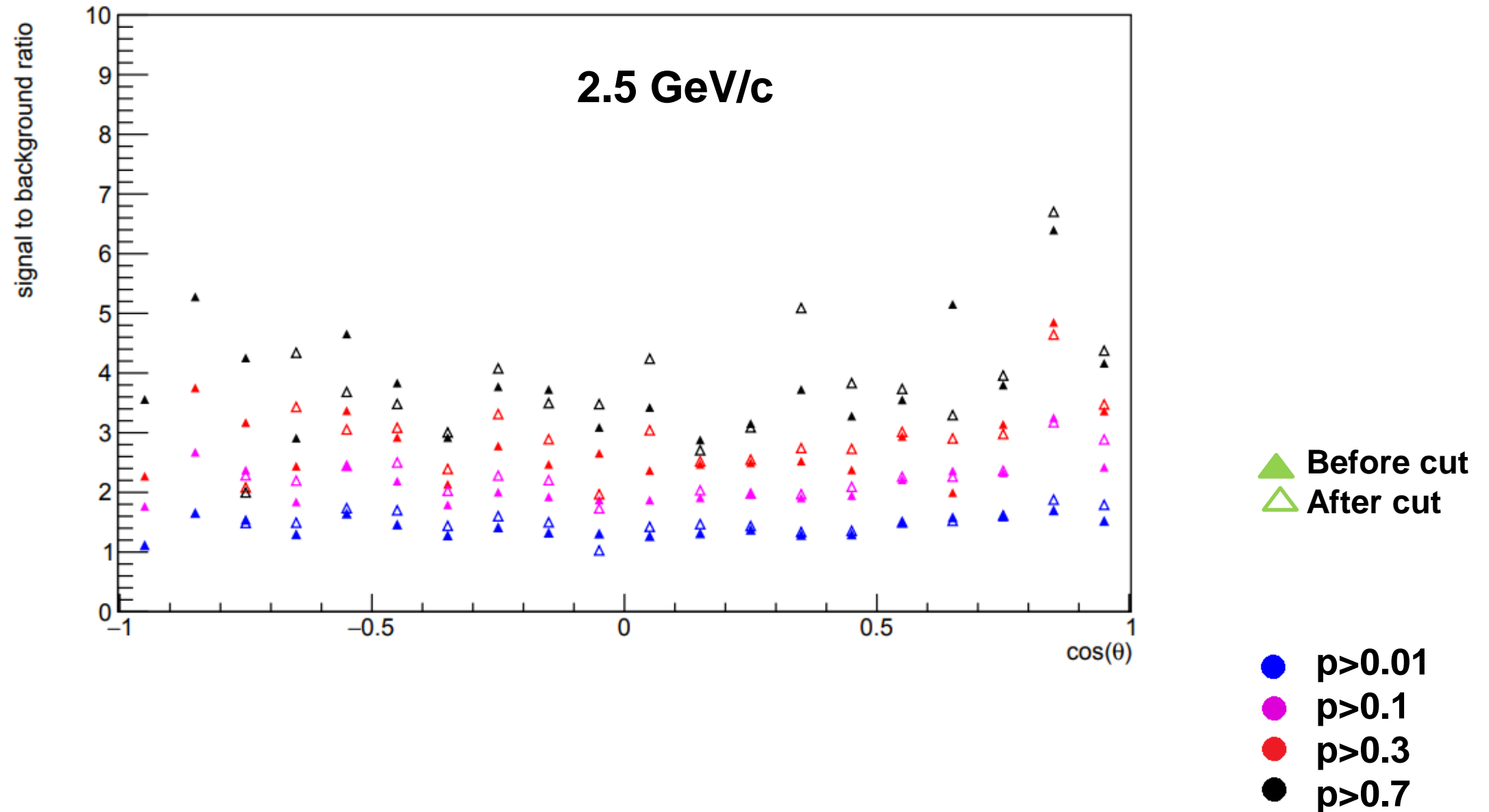


Two photon invariant mass spectra for all  $\gamma\gamma$  pairs in the event (left panel) and for reconstructed photon pairs from  $\pi^0$  decay (right panel), in the signal reaction of  $\bar{p}p \rightarrow \pi^0\gamma$  at incident beam momentum of 2.5 GeV/c.

— Before cut  
— After cut



# Signal to background ratio using improved pions



# Summary

- Exclusive event selection with 4C kinematic fit was performed
- Acceptance in  $\cos(\theta)$  has been checked
- Acceptance corrections were done
- Simulations have been performed at  $\sqrt{s} = 2.6 \text{ GeV}$   $\sqrt{s} = 3.4 \text{ GeV}$   $\sqrt{s} = 4.5 \text{ GeV}$   
 $p_{beam} = 2.5 \text{ GeV}/c$   $p_{beam} = 5 \text{ GeV}/c$   $p_{beam} = 10 \text{ GeV}/c$
- More detailed studies, including count rate estimates and Signal to background are in progress
- Continuation of study at 15 GeV/c beam momentum
- Integrated cross-sections from E760 data were plotted and fitted.
- Differential cross-sections from E760 data were plotted and fitted to give estimate at  $p_{beam} = 2.5 \text{ GeV}, 5 \text{ GeV}$  and  $10 \text{ GeV}$ .
- Count rate estimates and signal to background ratio was determined for the decay channel  $\bar{p}p \rightarrow \pi^0 \gamma$  using improved pions for beam momentum of 2.5 GeV/c
- Study in progress for beam momentum of 5, 10 and 15 GeV/c

**Thank You For Your Attention!**