Accessing Generalized Distribution Amplitude with the channel $p\,\bar{p} \rightarrow \pi^0\gamma$ and investigation of the background channel $p\bar{p} \rightarrow \pi^0\pi^0$

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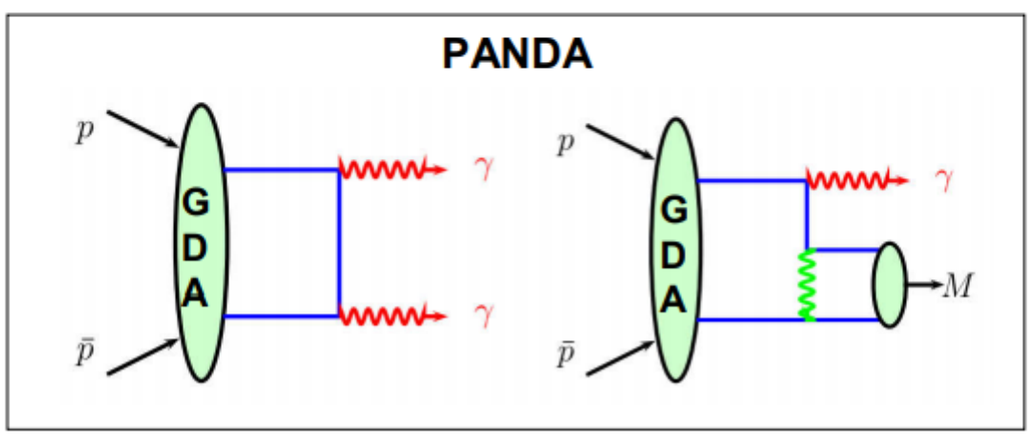
Introduction

$$p\bar{p} \rightarrow \gamma M$$ at large Mandelstam variables

process amplitudes factorizes:

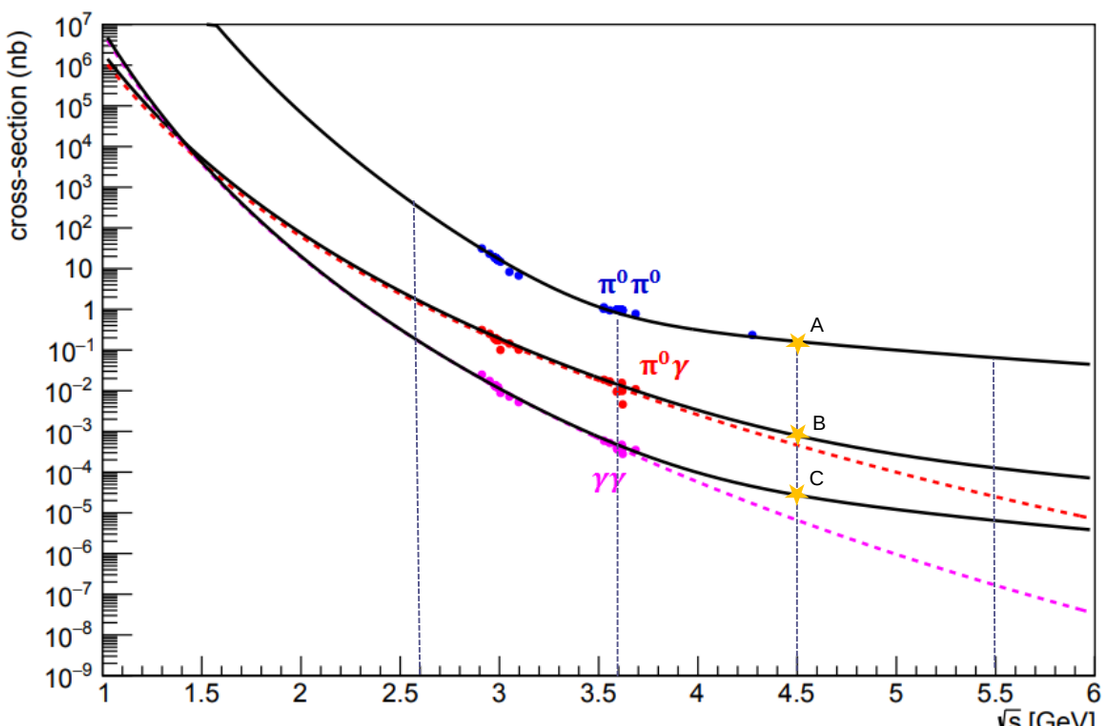
hard partonic subprocesses + annihilation form factors

represent moments of baryon-antibaryon **G**eneralized **D**istribution **A**mplitudes (GDAs)



Cross-sections from E760 Data

- T. A. Armstrong*, Two-body neutral final states produced in antiproton-proton annihilations at $2.911 \leq \sqrt{s} \leq 3.686\ \mathrm{GeV}$
- Integrated the angular range for a fixed $\sqrt{s}$ to get the partially integrated cross section in the cos(θ) range which is available for all energies.



$\sqrt{s}$	$\frac{\pi^0\pi^0}{\pi^0\gamma}$	$\frac{\pi^0\pi^0}{\gamma\gamma}$
2.6	226	1962
3.36	65.6	1502
4.5	385.9	27672
5.5	2484.8	361374

*https://doi.org/10.1103/PhysRevD.56.2509

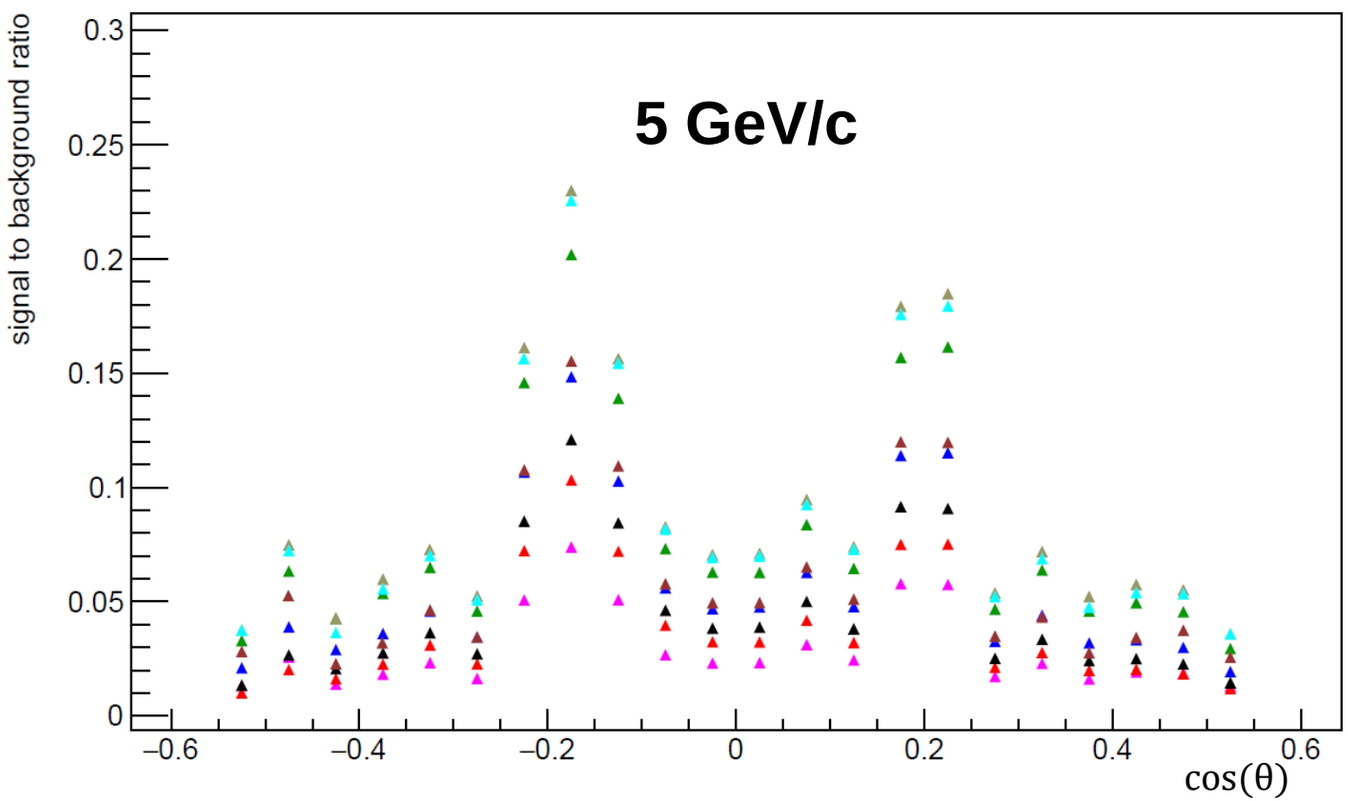
Background Suppression for $p\bar{p} \rightarrow \pi^0\gamma$:

Signal to Background Ratio at 5 GeV/c

Cuts applied:

- Calorimeter clusters each with threshold > X GeV
- Exactly one pion is detected in an event
- 4C kinematic fit is applied and events with confidence level less than 10% are rejected.

*signal to background ratio already contains the different cross sections.



$E_\gamma > 0$
$E_\gamma > 0.005$
$E_\gamma > 0.01$
$E_\gamma > 0.02$
$E_\gamma > 0.03$
$E_\gamma > 0.05$
$E_\gamma > 0.1$
$E_\gamma > 0.15$
$E_\gamma > 0.2$

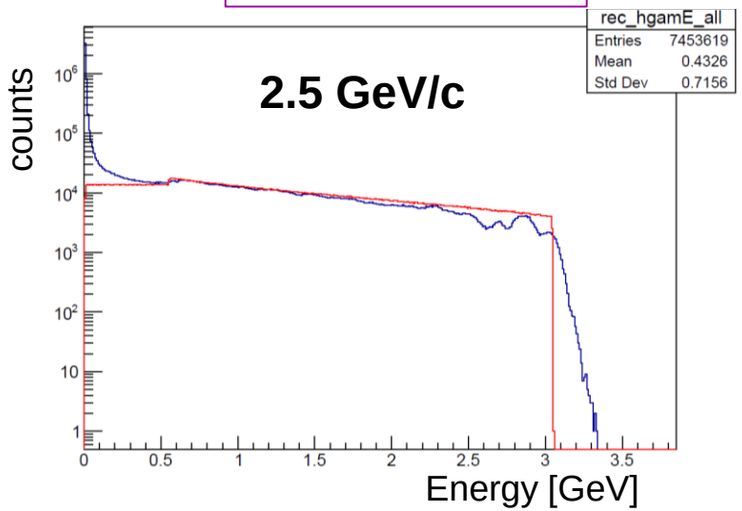
signal $p\,\bar{p} \rightarrow \pi^0\gamma$
background $p\bar{p} \rightarrow \pi^0\pi^0$

Energy of generated and reconstructed gammas

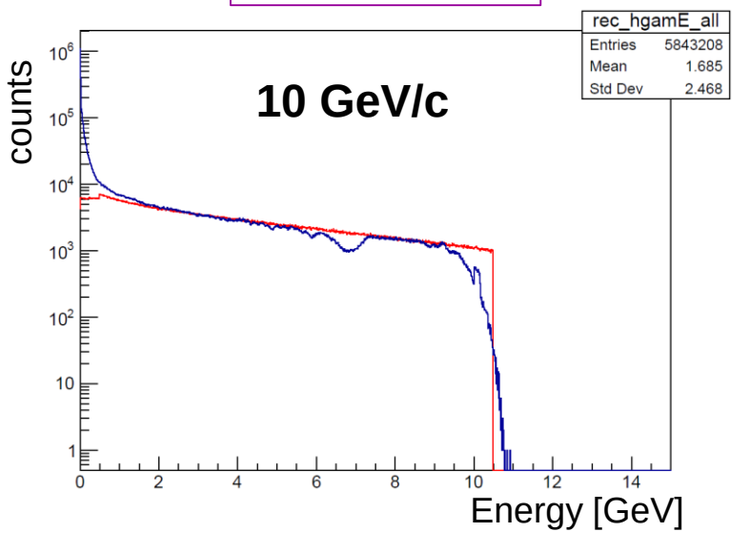
Reconstructed
Generated

$E_\gamma > 0.015$ GeV

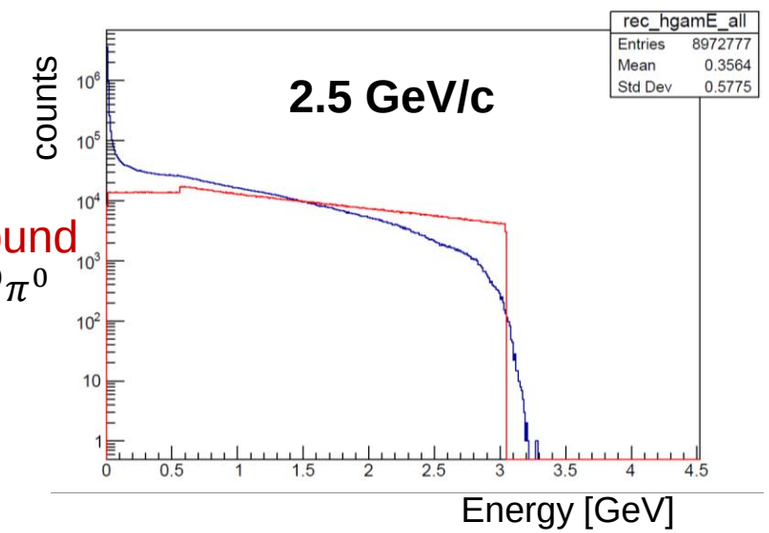
signal
$p\,\bar{p} \rightarrow \pi^0\gamma$

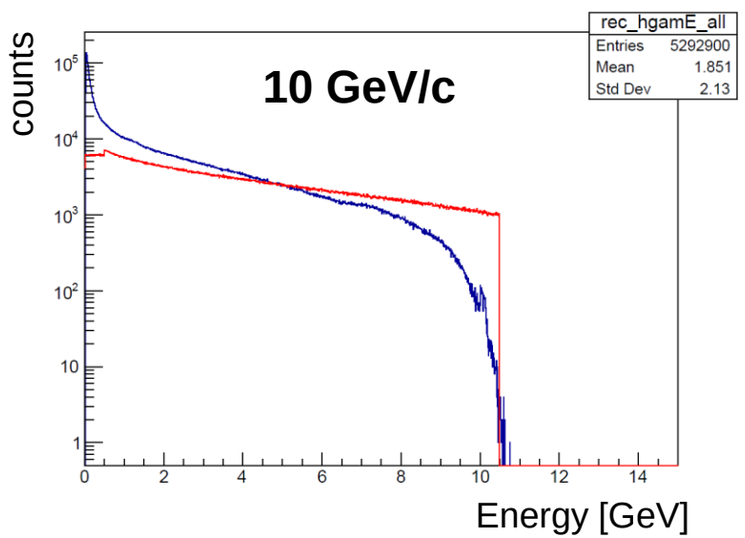


$E_\gamma > 0.5$ GeV



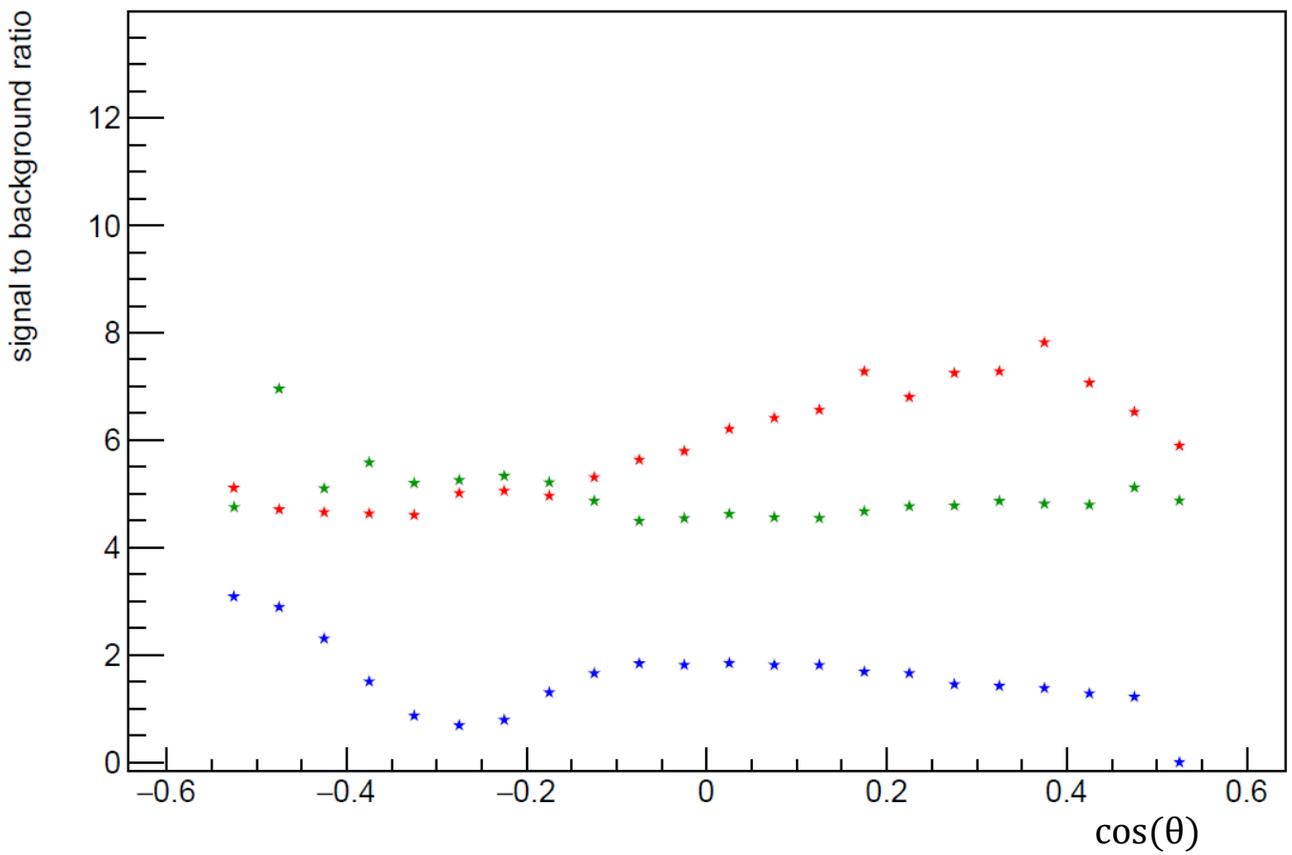
background
$p\bar{p} \rightarrow \pi^0\pi^0$





Signal to background ratio at different beam momenta

$N_{\pi^0} = 1 \ + \ E_\gamma > X + OA$



$\mathbf{p_{beam} = 2.5\ GeV/c}$
$\mathbf{p_{beam} = 5\ GeV/c}$
$\mathbf{p_{beam} = 10\ GeV/c}$

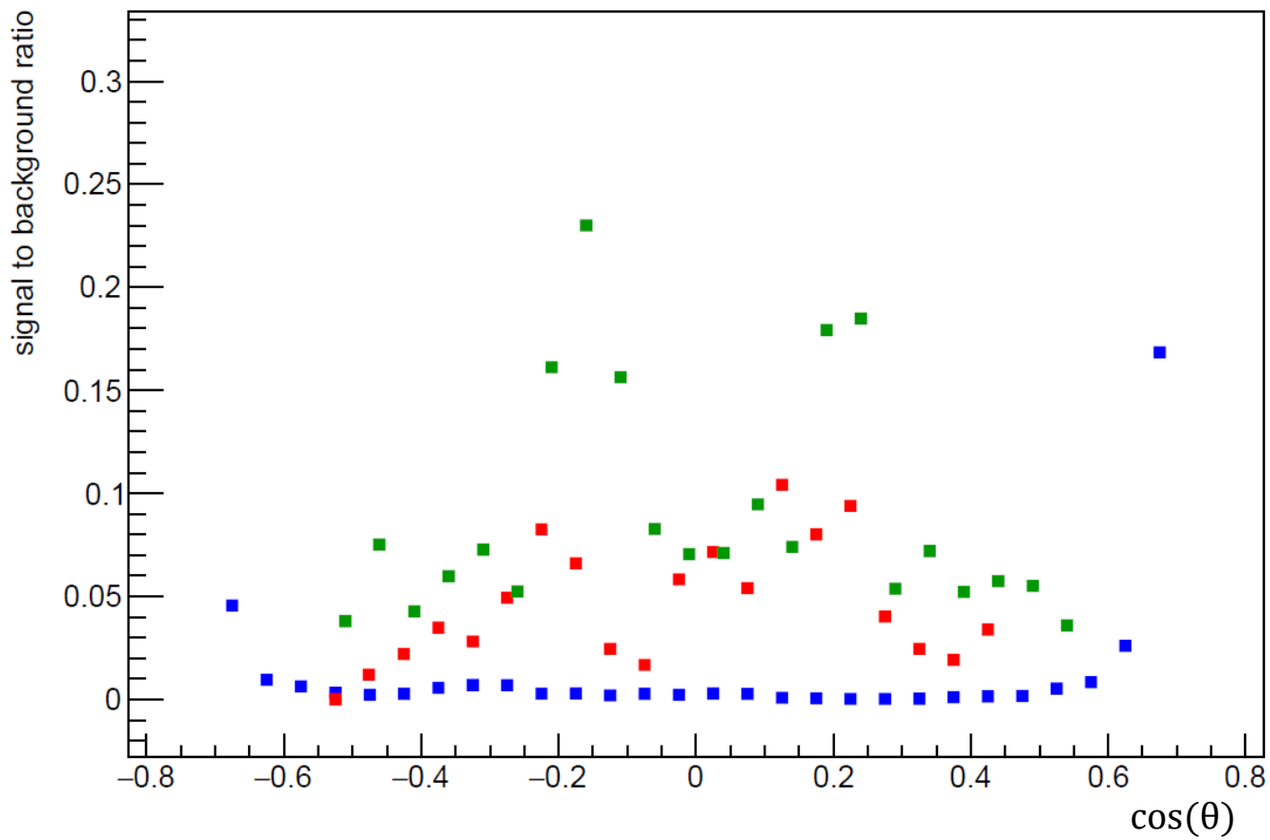
plot assumes equal cross-sections to see the rejection power of the applied cuts.

Ratio of the acceptances

signal $p\,\bar{p} \rightarrow \pi^0\gamma$
background $p\bar{p} \ \rightarrow \ \pi^0\pi^0$

Signal to background ratio at different beam momenta

$N_{\pi^0} = 1 + E_\gamma > X + OA$



$\mathbf{p_{beam} = 2.5\ GeV/c}$
$\mathbf{p_{beam} = 5\ GeV/c}$
$\mathbf{p_{beam} = 10\ GeV/c}$

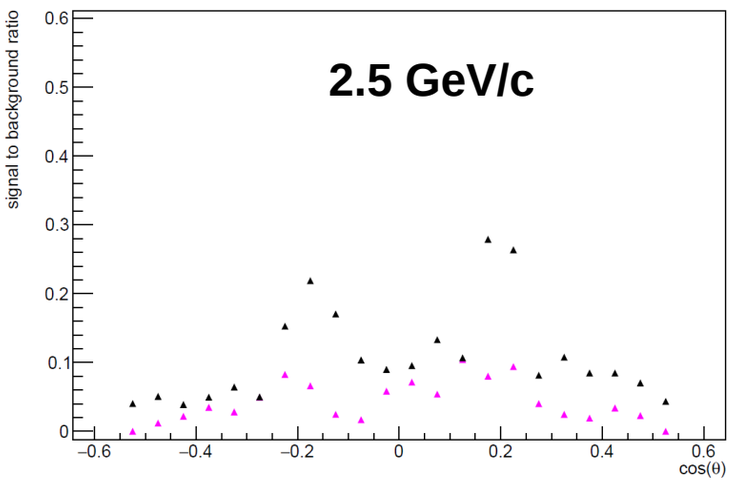
Signal to background ratio at various beam momenta

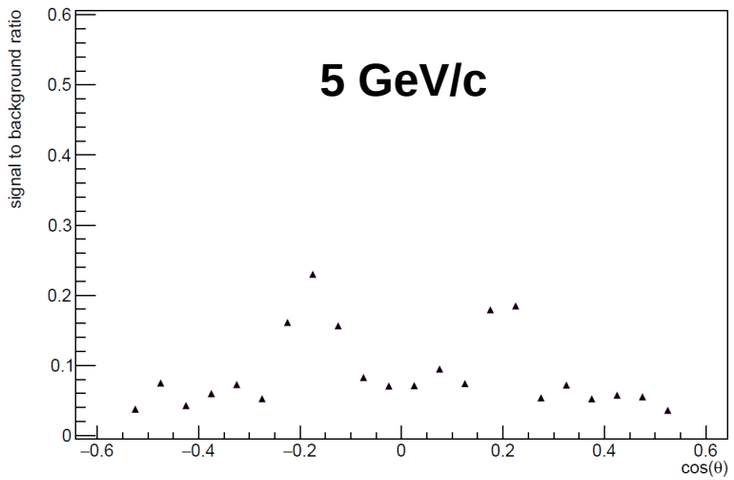
signal $p\,\bar{p} \rightarrow \pi^0\gamma$
background $p\bar{p} \rightarrow \pi^0\pi^0$

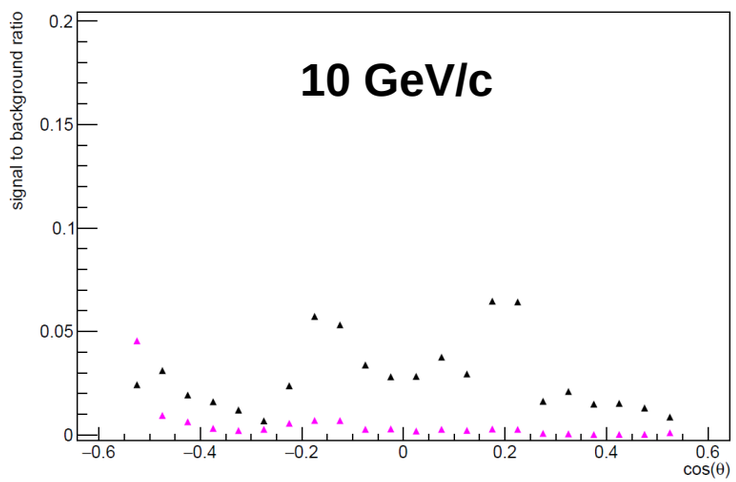
Signal to background ratio

▲ $\frac{Acceptance_{sig}}{Acceptance_{bkg}}$* cross-section ratio from 5GeV

▲ $\frac{Acceptance_{sig}}{Acceptance_{bkg}}$ * cross-section ratio at respective energies







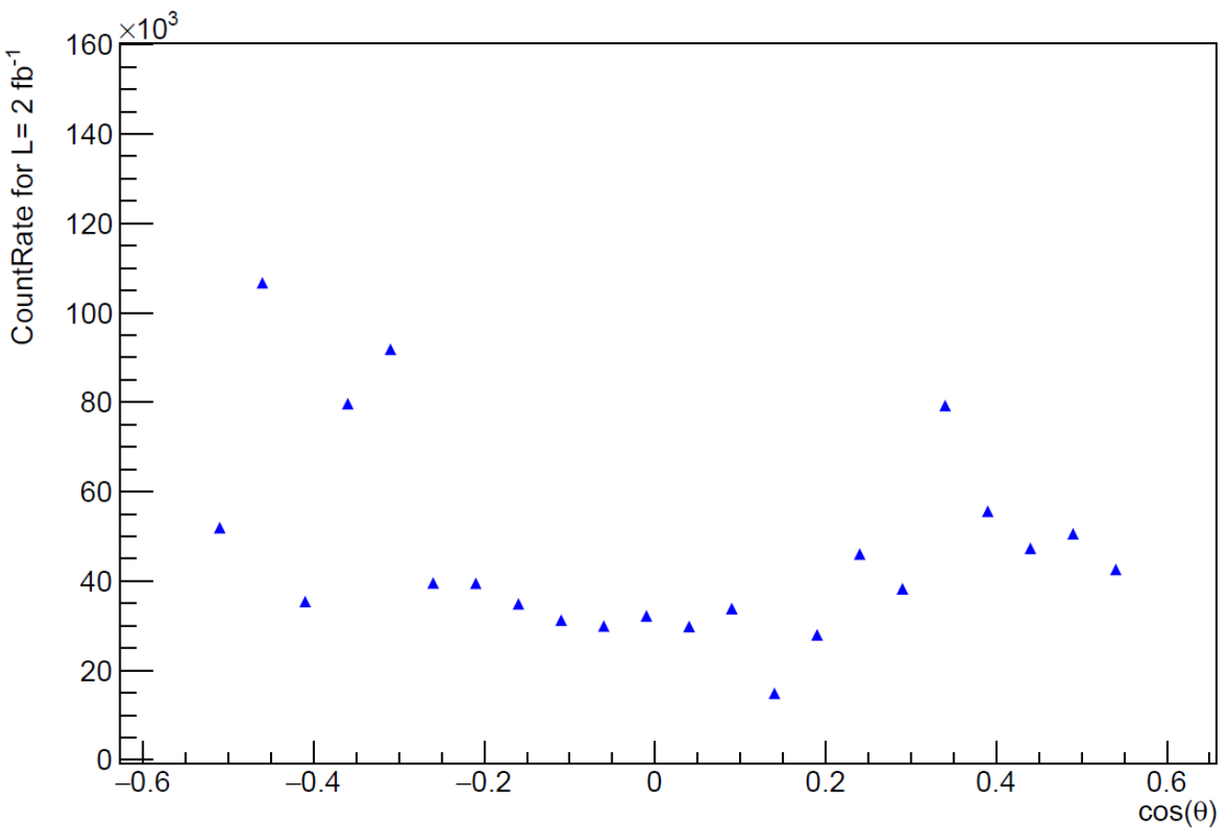
Signal to background ratio at different beam momenta. Black markers show ratio of acceptances with the ratio of cross-sections from 5GeV. Magenta markers correspond to ratio of cross-sections at their corresponding energies.

signal $p\,\bar{p} \rightarrow \pi^0\gamma$

background $p\bar{p} \rightarrow \pi^0\pi^0$

Feasibility Study for the channel $p\,\bar{p} \rightarrow \pi^0\pi^0$:

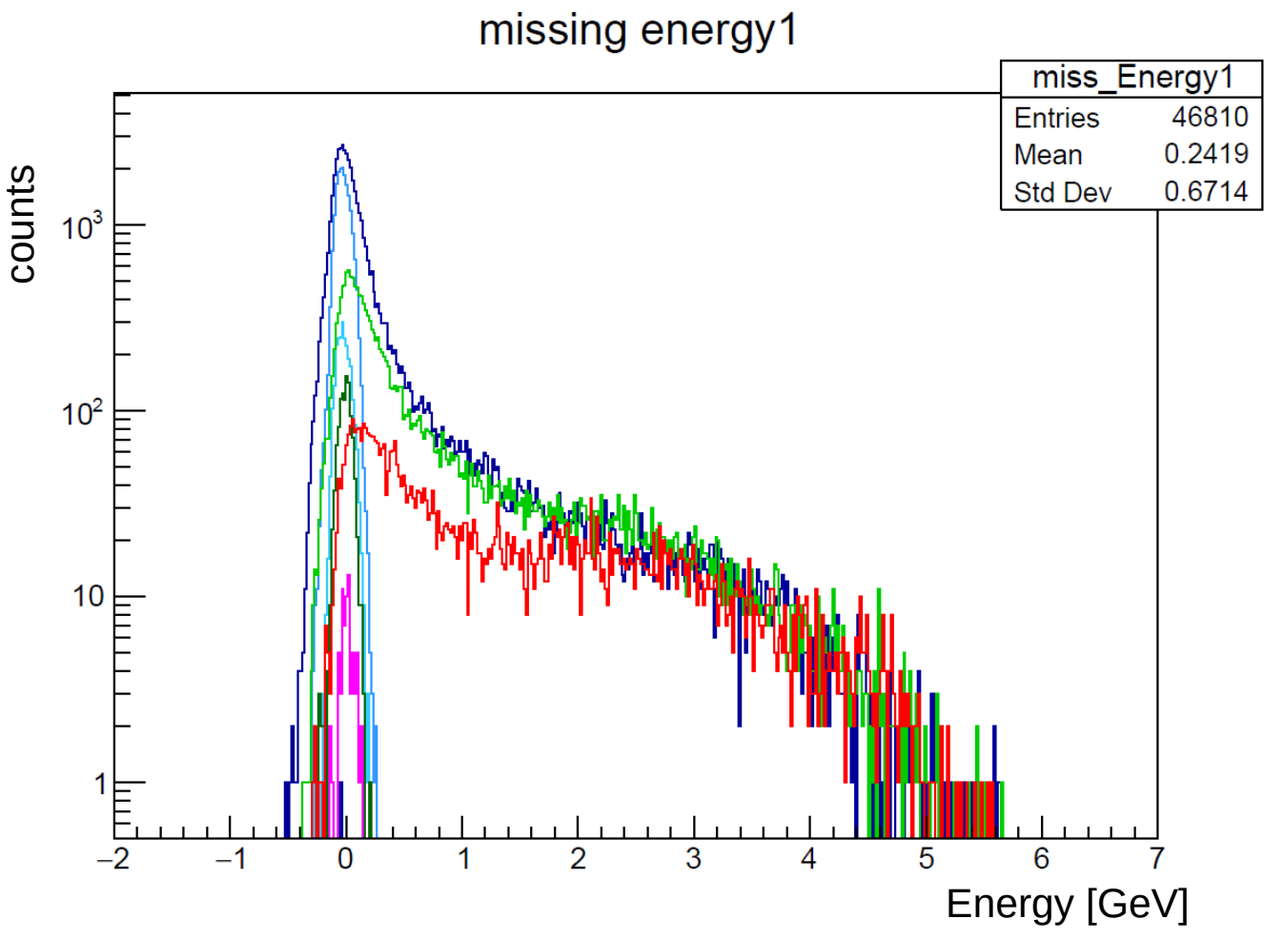
Count Rate Estimate at 5 GeV/c



Can measure this channel very well

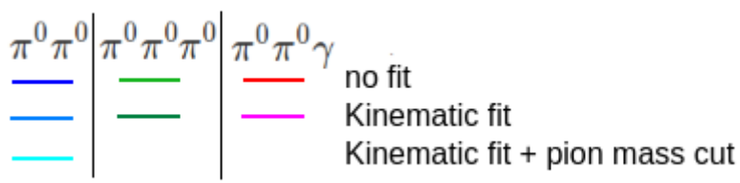
Feasibility Study for the channel $p\,\bar{p} \rightarrow \pi^0\pi^0$:

Missing Energy Plot at 5 GeV/c for Various Cuts



Background:

- $p\bar{p} \rightarrow \pi^0\pi^0\pi^0$
- $p\bar{p} \rightarrow \pi^0\pi^0\,\gamma$



We can well suppress the BG channels and therefore well measure $\pi^0\pi^0$

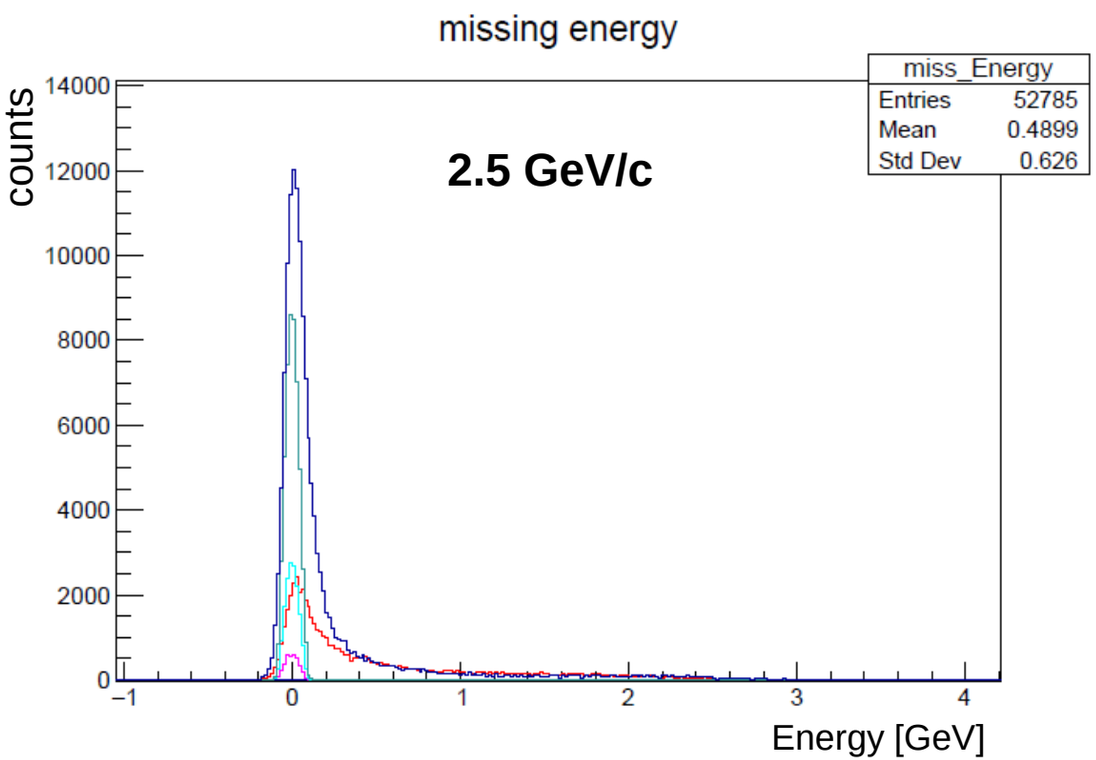
Missing Energy Plot at 2.5 GeV/c and 10 GeV/c for Various Cuts

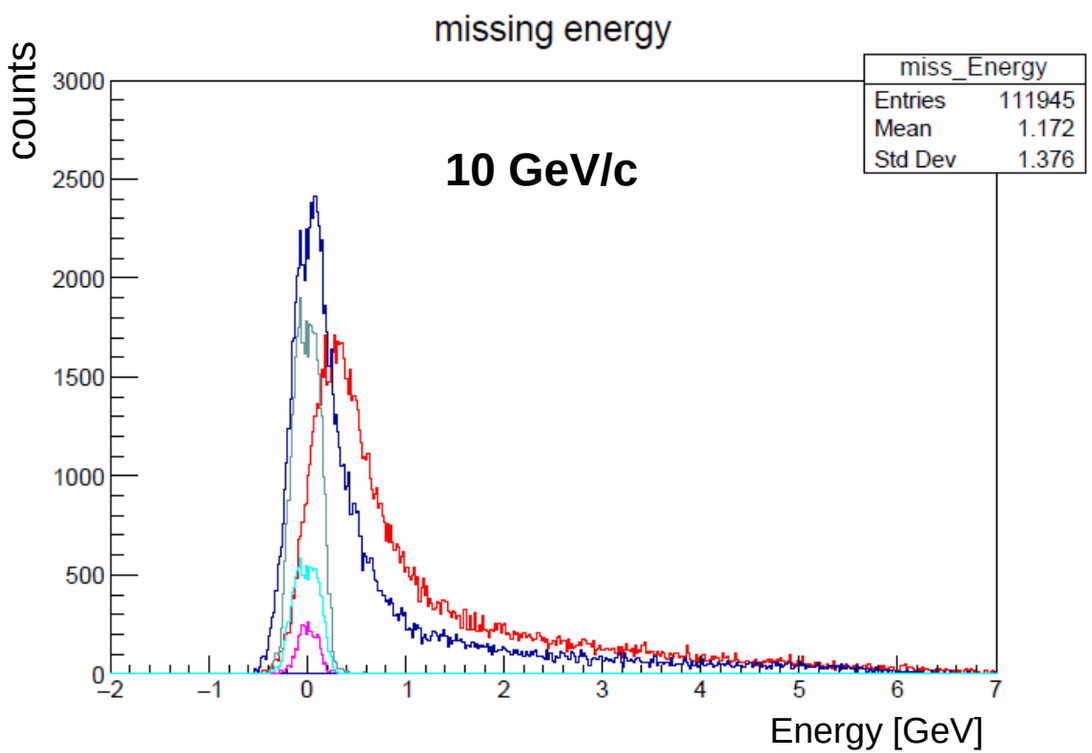
$\pi^0\pi^0$ | $\pi^0\pi^0\pi^0$ | $\pi^0\pi^0\gamma$

no fit
Kinematic fit
Kinematic fit + pion mass cut

Background:

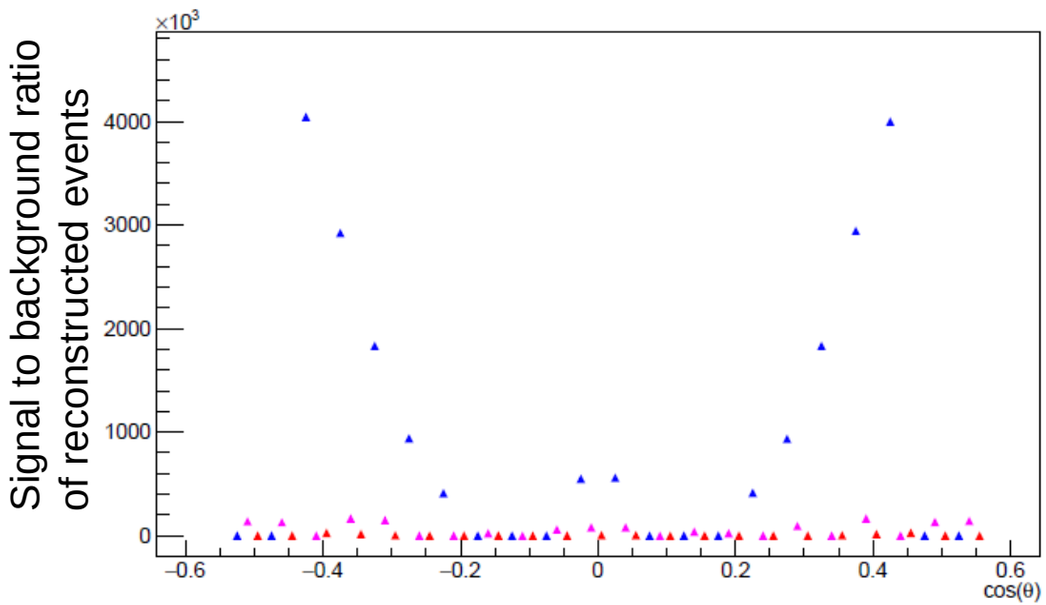
- $p\bar{p} \rightarrow \pi^0\pi^0\pi^0$
- $p\bar{p} \rightarrow \pi^0\pi^0\,\gamma$

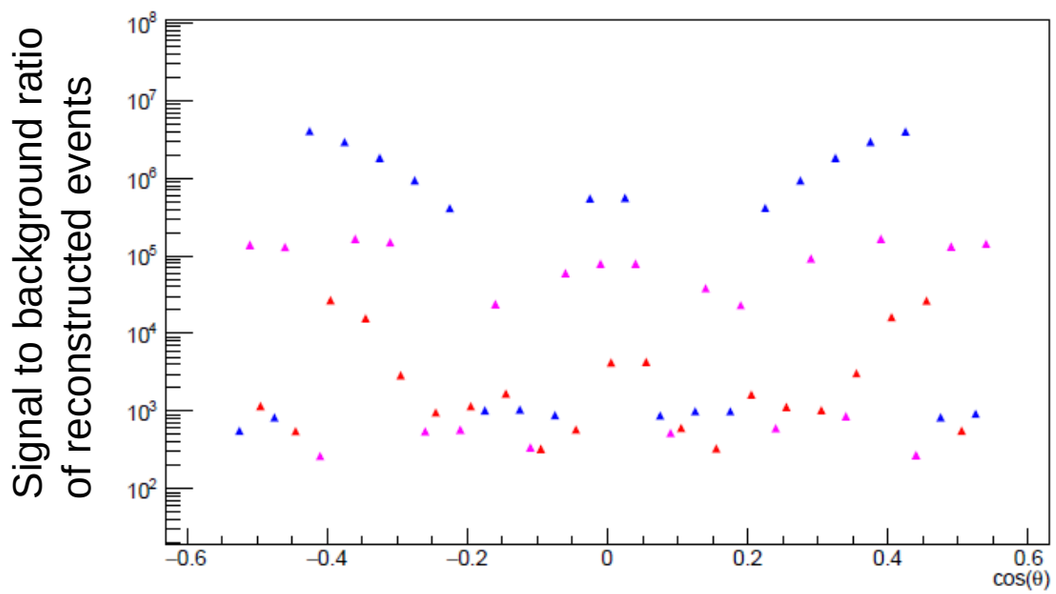




Signal to background ratio of reconstructed events

▲ 2.5 GeV/c ▲ 5 GeV/c ▲ 10 GeV/c



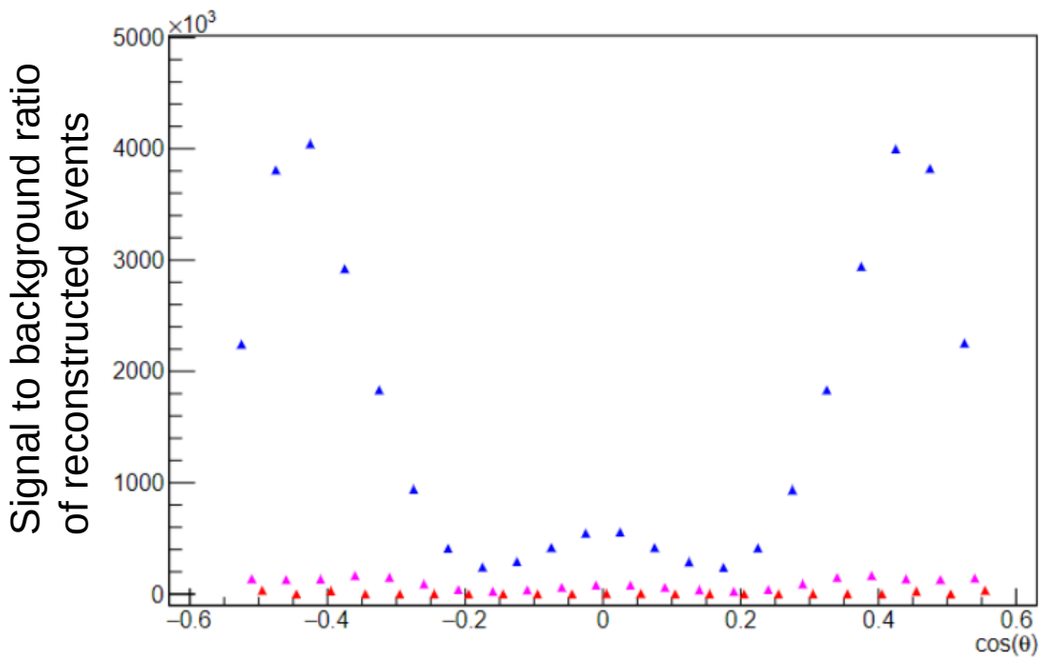


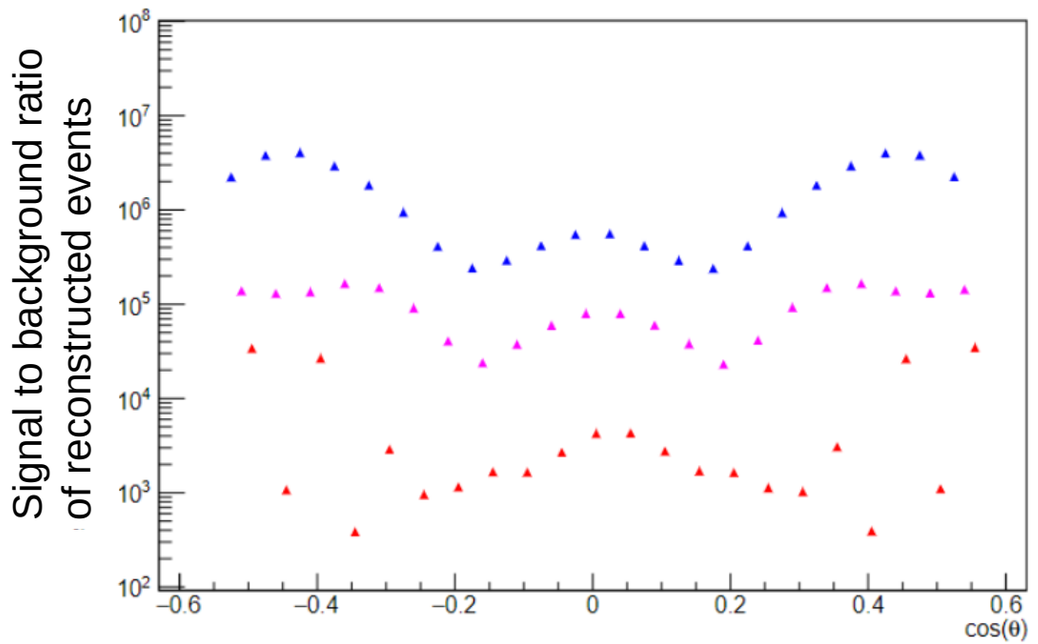
signal $p\,\bar{p} \rightarrow \pi^0\pi^0$

background $p\bar{p} \rightarrow \pi^0\pi^0\,\gamma$

Signal to background ratio of reconstructed events

▲ 2.5 GeV/c ▲ 5 GeV/c ▲ 10 GeV/c





signal $p\,\bar{p} \rightarrow \pi^0\pi^0$

background $p\bar{p} \rightarrow \pi^0\,\pi^0\,\pi^0$

Determining Count Rate Estimate and Error

- No. of counts of signal, N_{sig}
- No. of counts of background, N_{bkg}

- Count rate $=$ Diff. Cross section $*$ Acceptance $*$ Bin Size $*$ Integrated Luminosity $*$ Counts

- Acceptance $= \frac{\mathrm{N^{rec}}}{\mathrm{N^{gen}}}$

- $\mathrm{CR_{Measured}} = \mathrm{CR_{sig}} + \mathrm{CR_{bkg}}$

- Pure signal, $\mathrm{CR_{sig\,pure}} = \mathrm{CR_{measured}} - \mathrm{CR_{bkg}}$

- Error of Signal, $\Delta\mathrm{CR_{sig}} = \sqrt{\Delta\mathrm{CR_{measured}}^2 + \Delta\mathrm{CR_{bkg}}^2}$

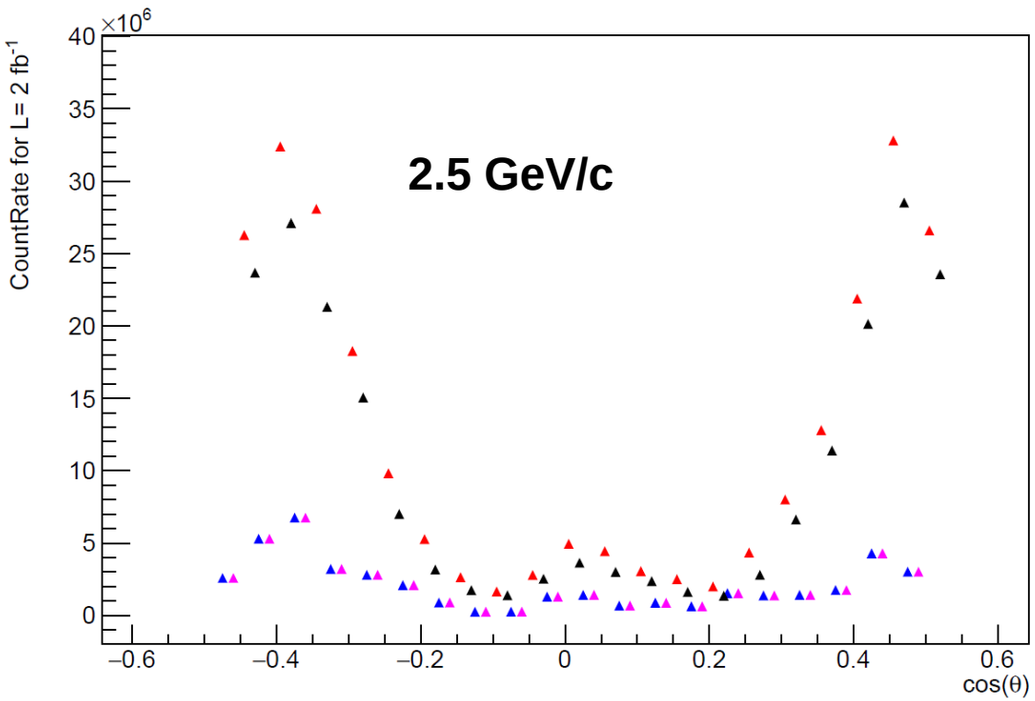
- $\Delta\mathrm{CR_{measured}} = \sqrt{\mathrm{CR_{measured}}}$ and $\Delta\mathrm{CR_{bkg}} = \sqrt{\mathrm{CR_{bkg}}}$

Count rate estimate at 2.5 GeV/c

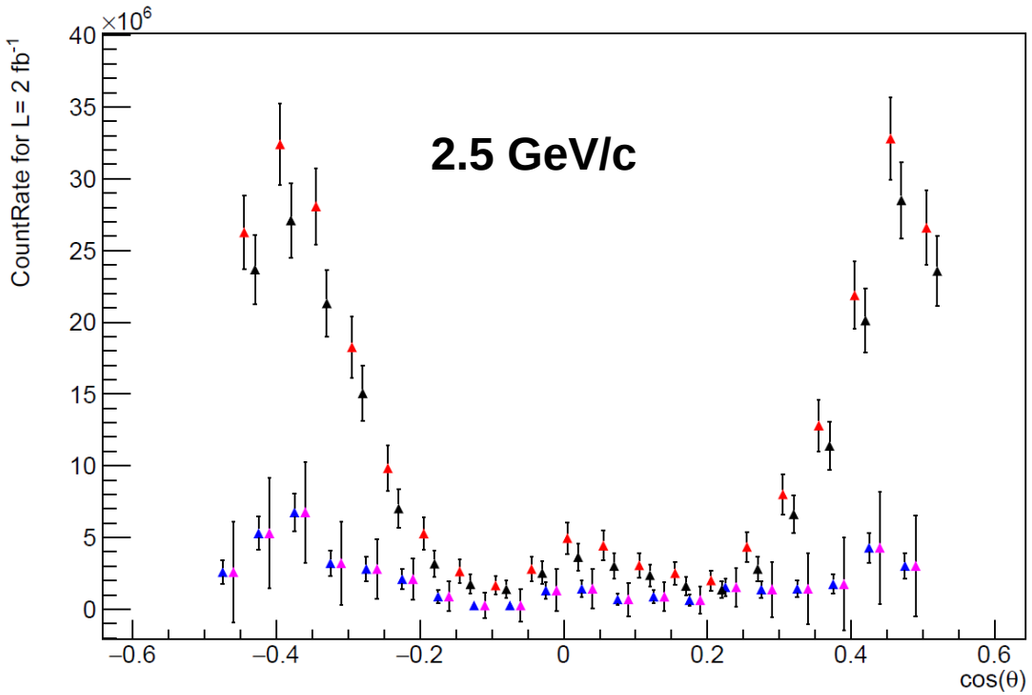
L = 2 fb^{-1}

CR_{sig} $CR_{sig\,pure}$ $CR_{measured}$ CR_{bkg}

Error * 1



Error * 500



- Propagated error after BG subtraction (in red) is less than the errors obtained from measurement
- BG subtraction can be nicely performed and obtain much better results than measurements

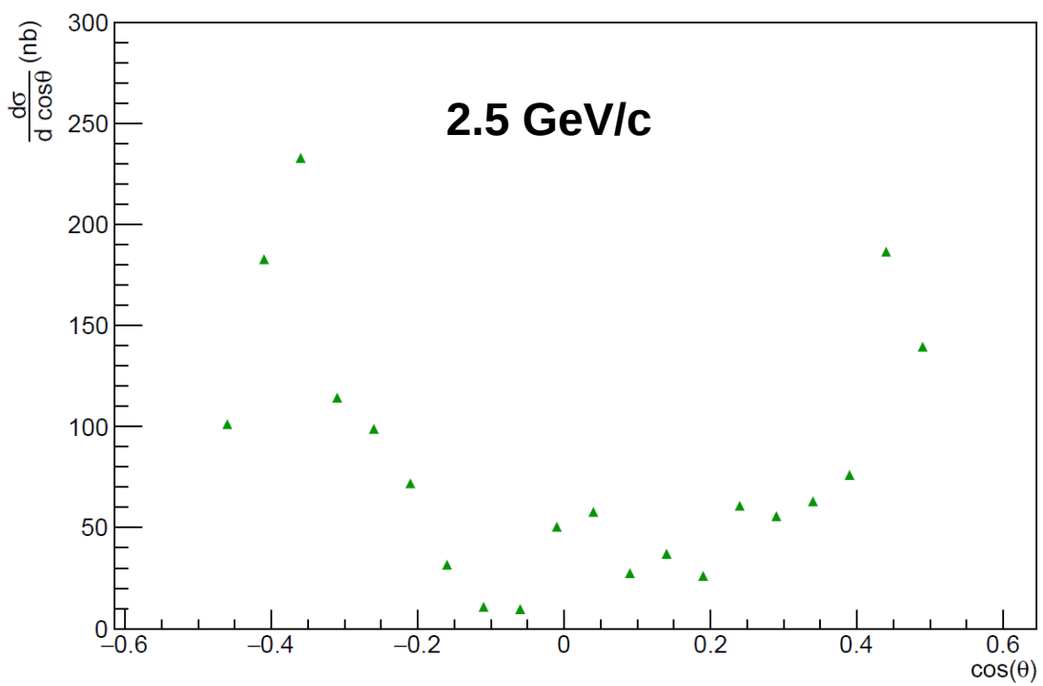
signal $p\,\bar{p} \rightarrow \pi^0\gamma$

background $p\bar{p} \rightarrow \pi^0\pi^0$

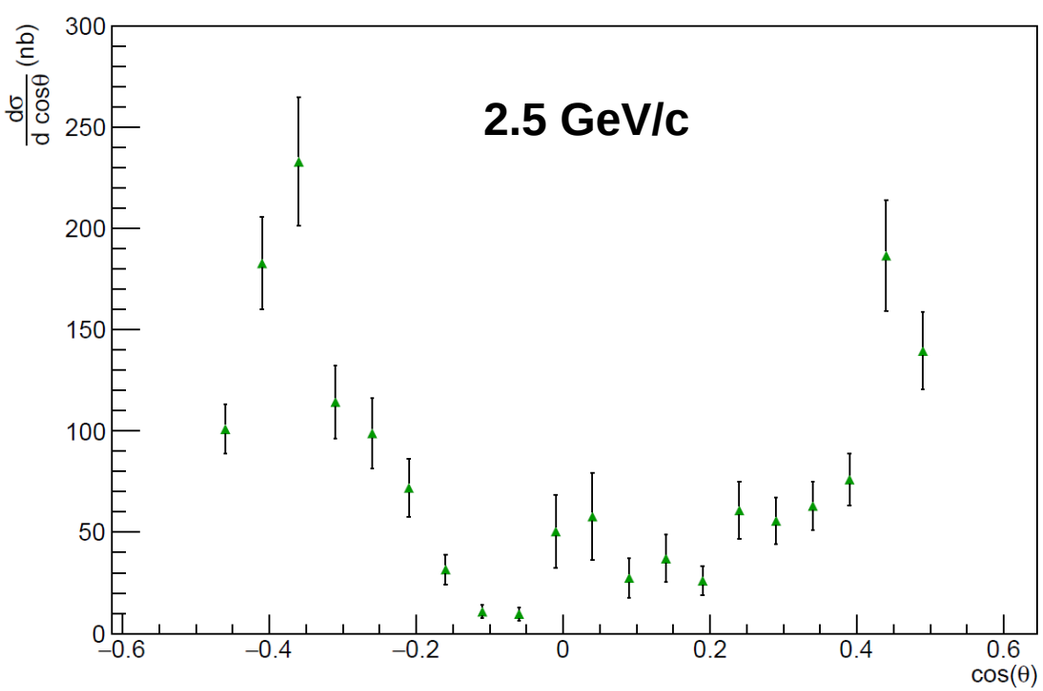
Expected Cross-section with Statistical Uncertainties at 2.5 GeV/c

$CS_{sig\_propagated}$

Error * 1



Error * 50



signal $p\,\bar{p} \rightarrow \pi^0\gamma$

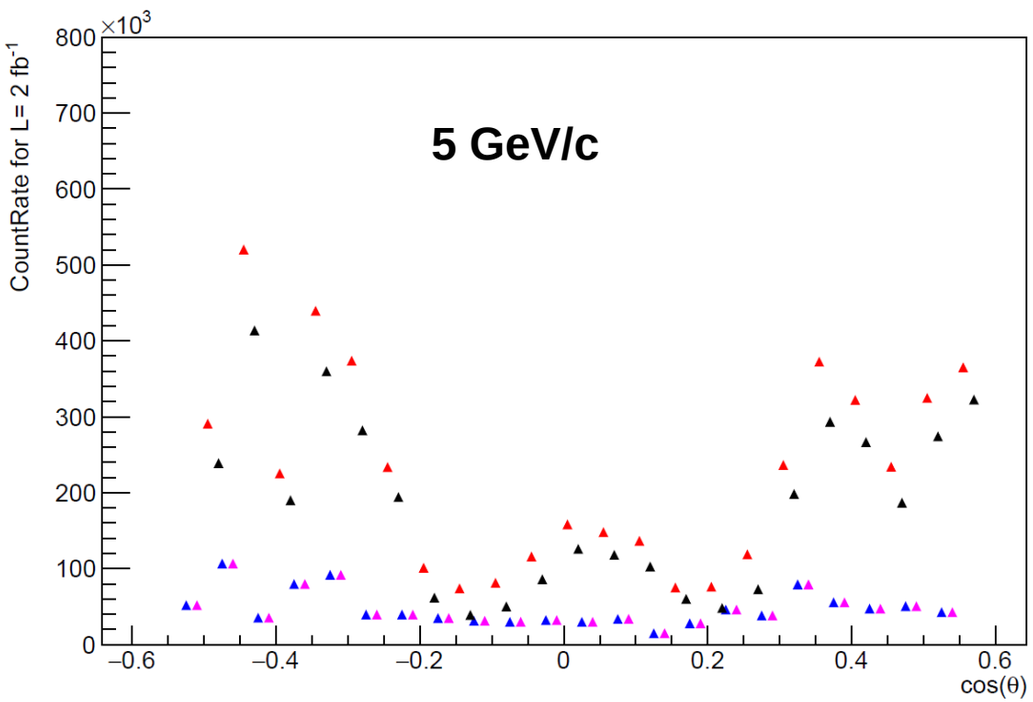
background $p\bar{p} \rightarrow \pi^0\pi^0$

Count rate estimate at 5 GeV/c

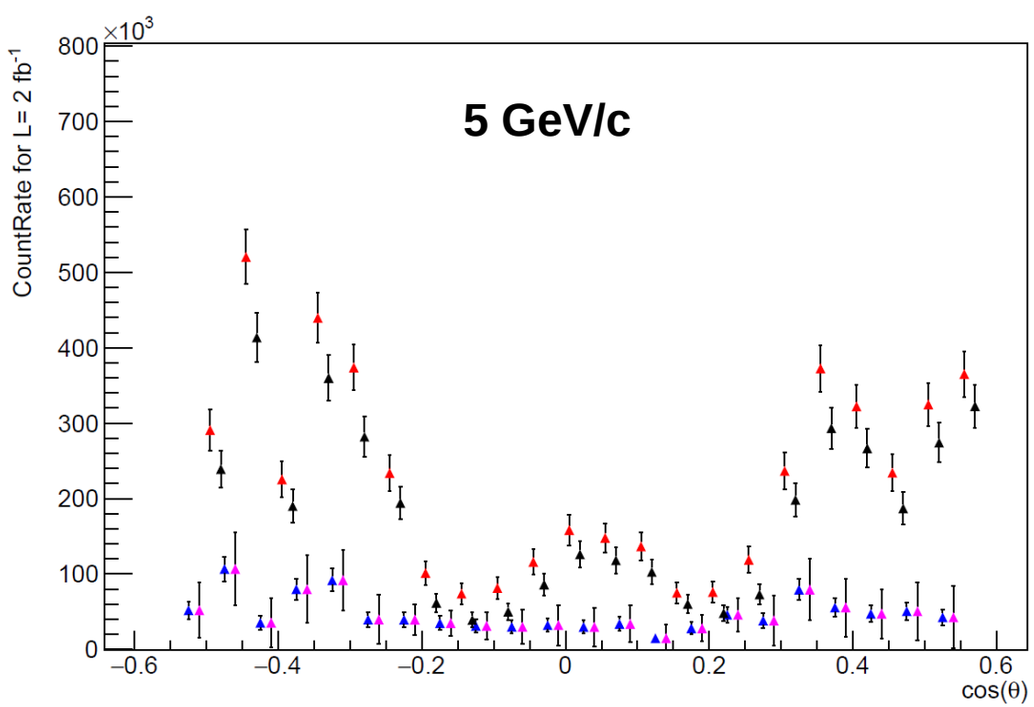
$L = 2\ fb^{-1}$

CR_{sig} $CR_{sig\ pure}$ $CR_{measured}$ CR_{bkg}

Error * 1



Error * 50



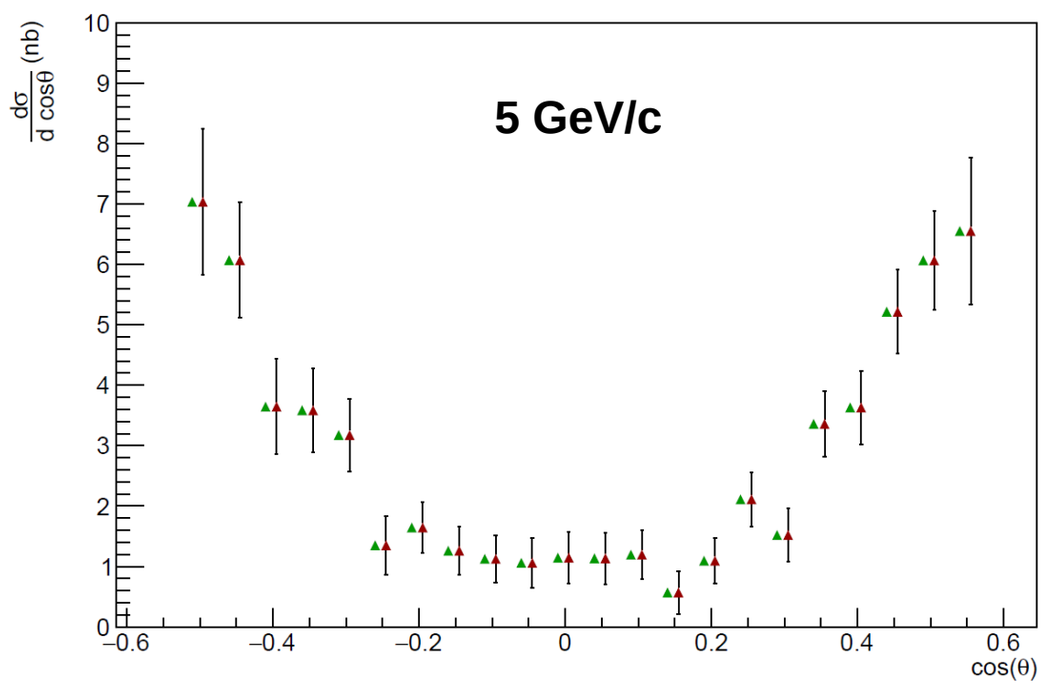
signal $p\,\bar{p} \rightarrow \pi^0\gamma$

background $p\bar{p} \rightarrow \pi^0\pi^0$

Expected Cross-section with Statistical Uncertainties at 5 GeV/c

$CS_{sig\_propagated}$ CS_{E760}

Error * 1



signal $p\,\bar{p} \rightarrow \pi^0\gamma$

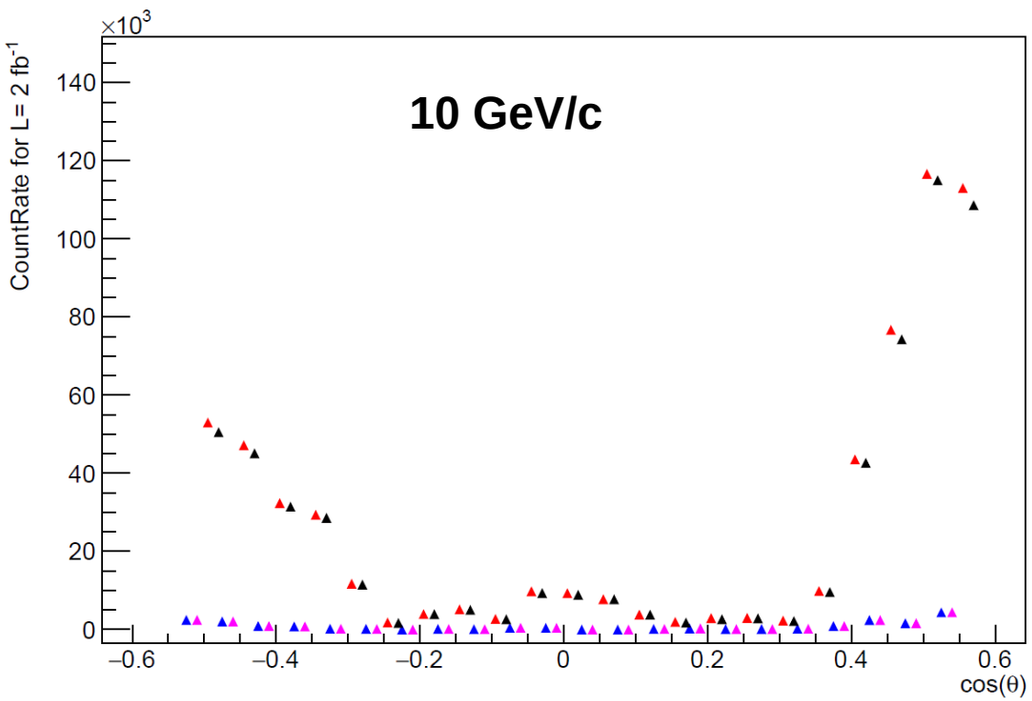
background $p\bar{p} \rightarrow \pi^0\pi^0$

Count rate estimate at 10 GeV/c

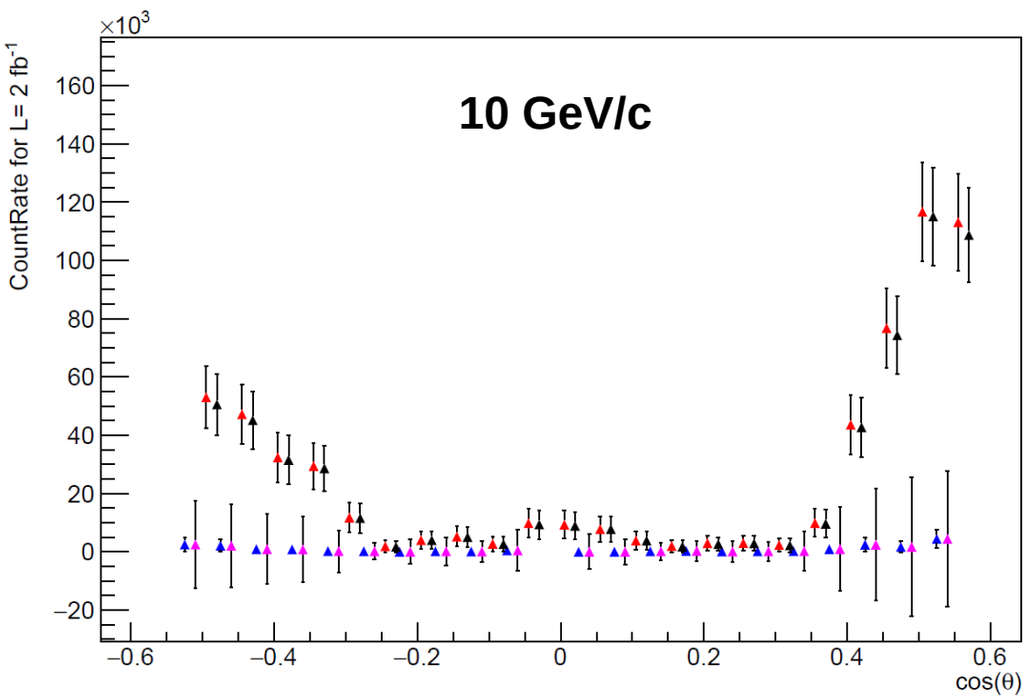
L = 2 fb^{-1}

CR_{sig} $CR_{sig\,pure}$ $CR_{measured}$ CR_{bkg}

Error * 1



Error * 50



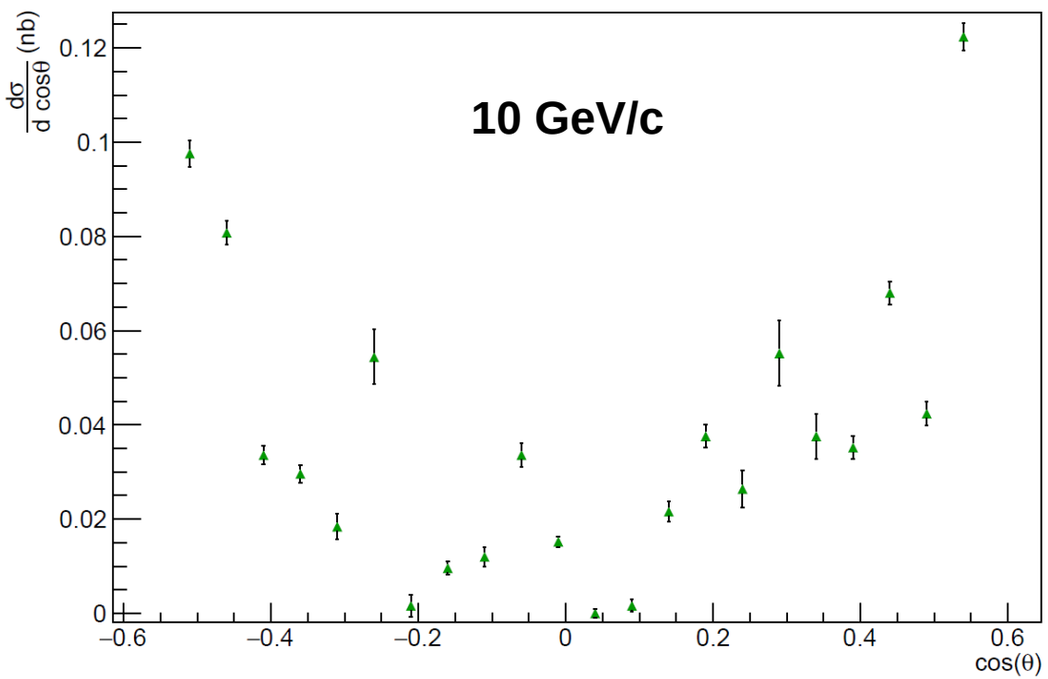
signal $p\,\bar{p} \rightarrow \pi^0\gamma$

background $p\bar{p} \rightarrow \pi^0\pi^0$

Expected Cross-section with Statistical Uncertainties at 10GeV/c

$CS_{sig\_propagated}$

Error * 1



Error gets large, but still we can measure the cross-section nicely

signal $p\,\bar{p} \rightarrow \pi^0\gamma$

background $p\bar{p} \rightarrow \pi^0\pi^0$

Summary

- The cos(θ) dependence of the cross-section has been implemented and a reconstruction study has been performed at $\sqrt{s} = 2.6\ GeV$, $\sqrt{s} = 3.4\ GeV$ and $\sqrt{s} = 4.5\ GeV$
- Count rate estimates and estimates of the expected statistical uncertainty was performed.
- Signal to background ratio was determined.
- Different selection cuts were investigated to optimize the signal to background ratio while keeping a reasonable reconstruction efficiency.
- The channel $\mathrm{p\bar{p}} \rightarrow \pi^0\gamma$ can be well measured with $\overline{\mathrm{P}}\mathrm{ANDA}$ but background has to be considered as it was done in the E760 experiment.
- A feasibility study for $\pi^0\pi^0$ was done in order to subtract background in other channels and improve signal to background ratio

Outlook:

- For the feasibility study for $p\overline{p} \rightarrow \pi^0\ \pi^0$:
  - Determine the signal to background ratio of reconstructed events for the background $p\overline{p} \rightarrow \pi^0\pi^0\pi^0$
  - Perform the feasibility study with higher statistics.

- Continuation of feasibility studies of all channels at 15 GeV/c beam momentum
- Prepare release note and do thesis write-up.
- For consistency, prepare plots with data simulated on cluster with the newest PANDAroot version.

Thank You For Your Attention!