FEASIBILITY STUDY OF GENERALIZED DISTRIBUTION AMPLITUDE OF THE CHANNEL $p\,\bar{p} \rightarrow\ \pi^0\,\gamma$ WITH PANDA

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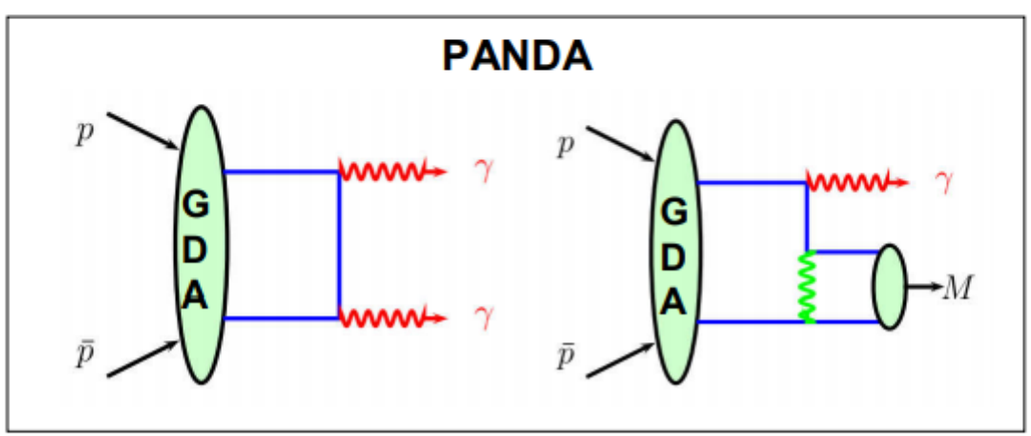
Introduction

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

process amplitudes factorizes:

hard partonic subprocesses + annihilation form factors

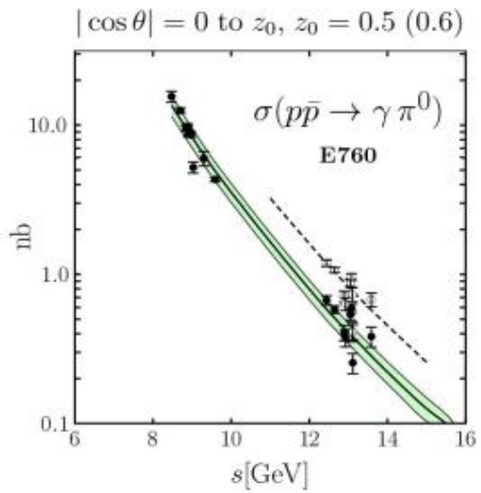
represent moments of baryon-antibaryon **G**eneralized **D**istribution **A**mplitudes (GDAs)

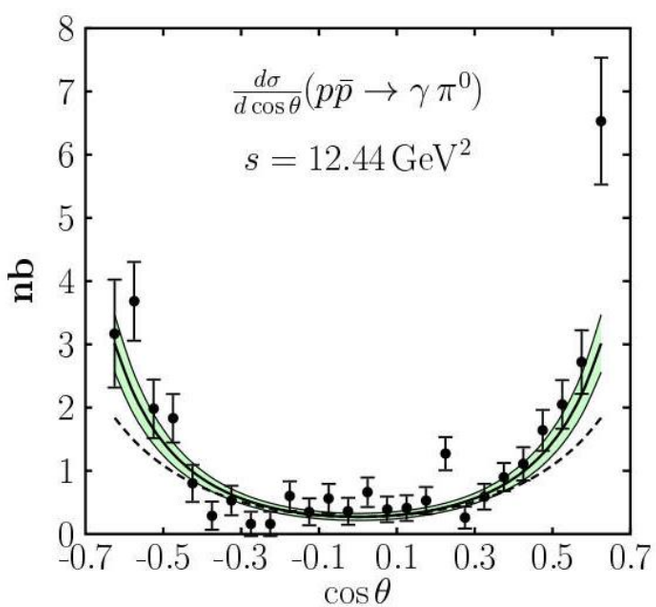


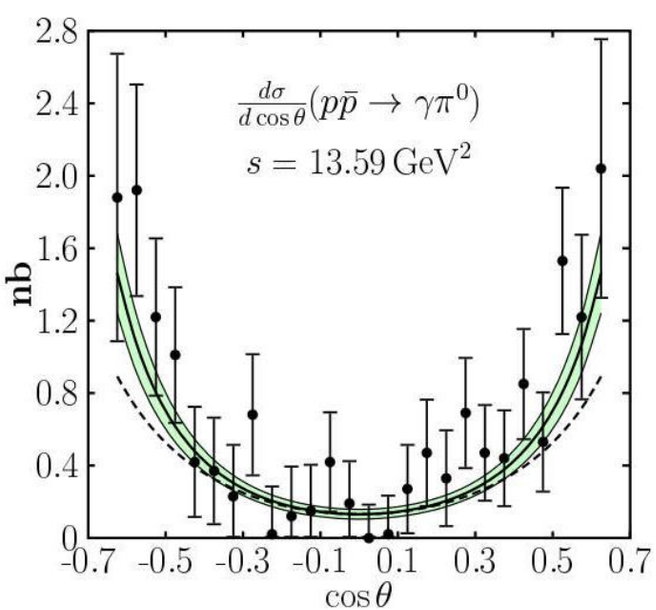
Theoretical Prediction $p\bar{p} \to \pi^0\gamma$

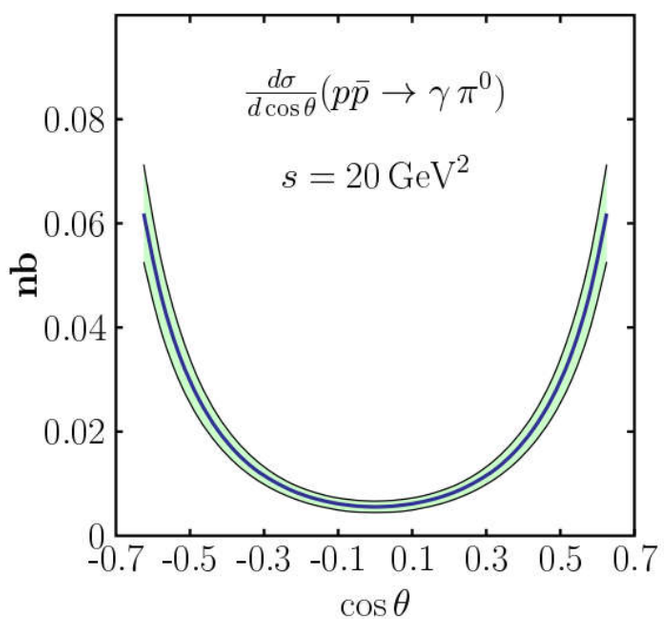
P.Kroll, A. Schafer, The process within the handbag approach, The European Physical Journal A 26, 89-98 (2005)

Measurements of cross-section with the E760 experiment at Fermilab









Monte Carlo Simulation

Analysis Framework

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

Event Generation

- Signal $p\bar{p} \rightarrow \pi^0\gamma$ and background $p\bar{p} \rightarrow \pi^0\pi^0$
- 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

Pion reconstruction

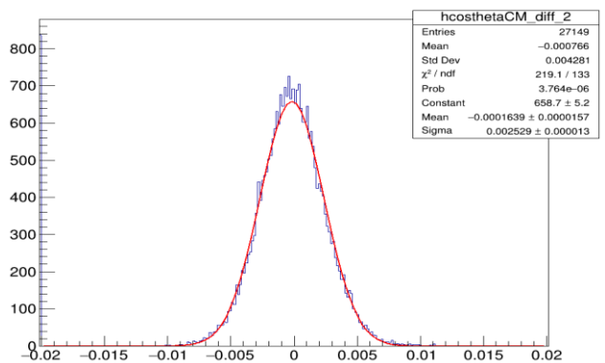
- At least two photons/event
- Pion mass cut: $0.125 < \mathrm{M}_{\pi^0} < 0.145\ (\mathrm{GeV}/c^2)$
- Two-photon system combined with gamma to form initial $\bar{p}p$ system

Events selection

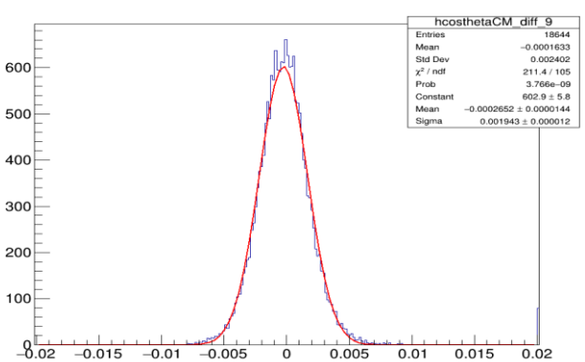
- Standard PID
- 4-Constraint fit applied to the reconstructed initial system
  - 4C Fit (RhoKinFitter) prob>0.01

Determining the Detector Resolution

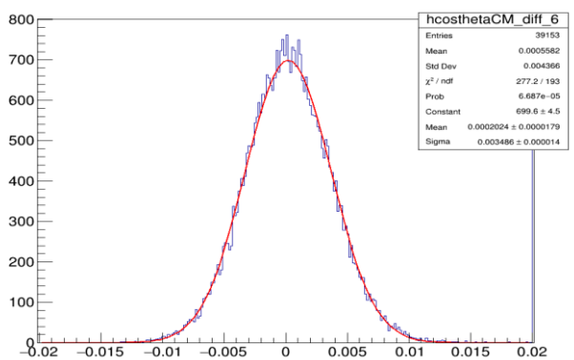
- Typically, choose bin width>resolution
  choose bin width=0.2
- For each of the ten bins,
  fill rec_costheta – gen_costheta
- Apply a Gaussian fit function
- Standard deviation from fit result gives estimate of the resolution for that bin



-0.8<costheta< -0.6

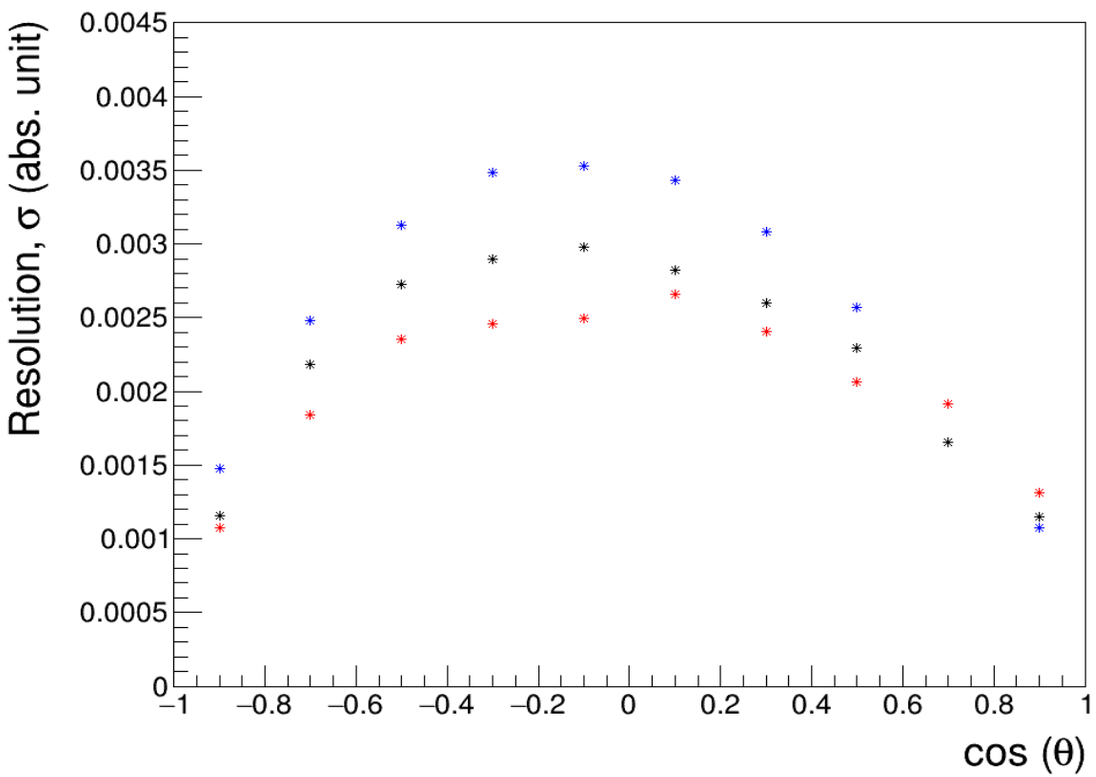


0.6<costheta< 0.8



0.0 <costheta< 0.2

Detector Resolution



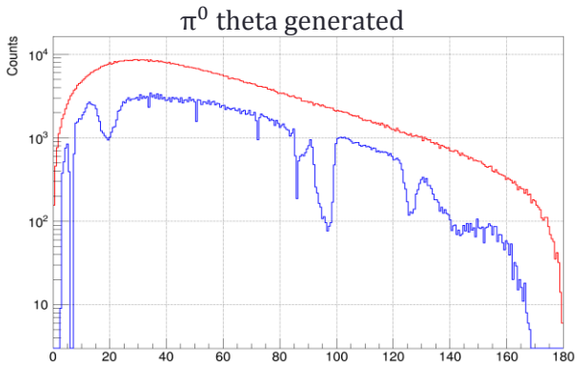
$\mathbf{p_{beam} = 2.5\ GeV/c}$

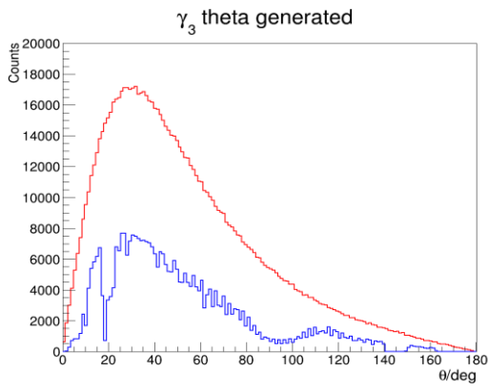
$\mathbf{p_{beam} = 5\ GeV/c}$

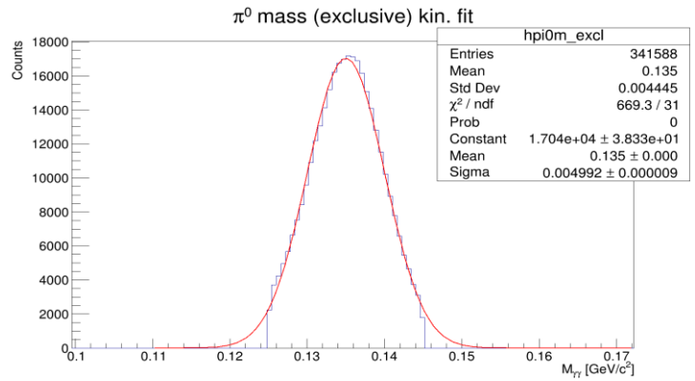
$\mathbf{p_{beam} = 10\ GeV/c}$

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

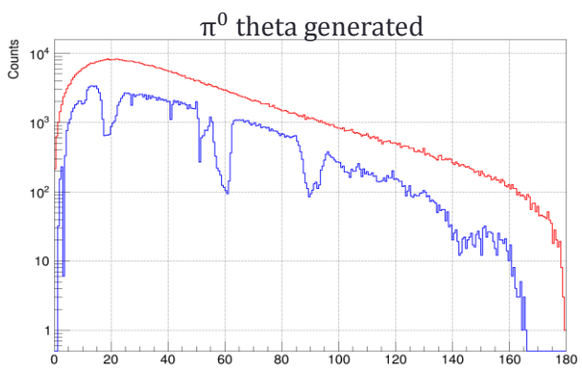
2.5 GeV/c

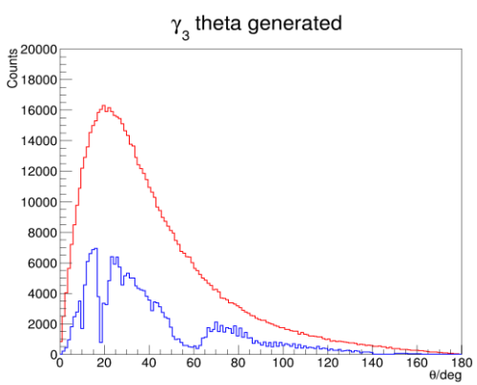


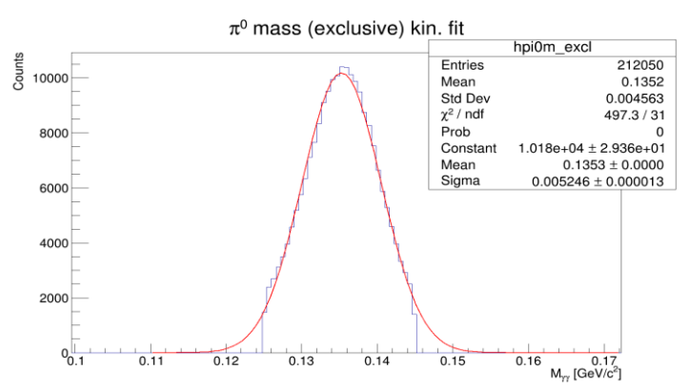




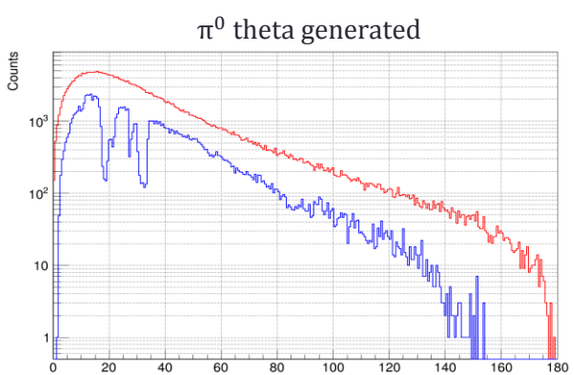
5 GeV/c

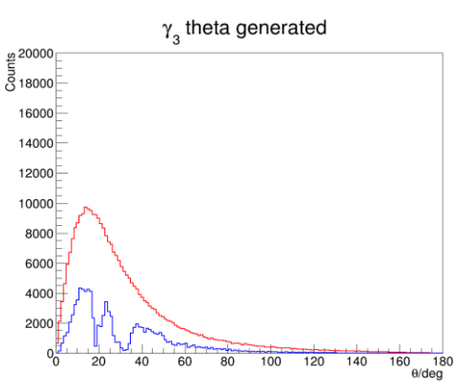


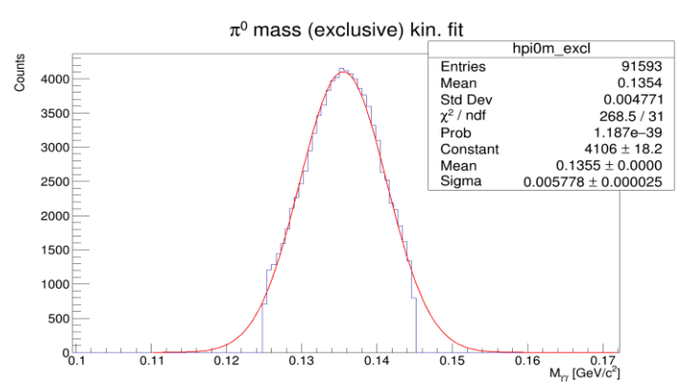




10 GeV/c



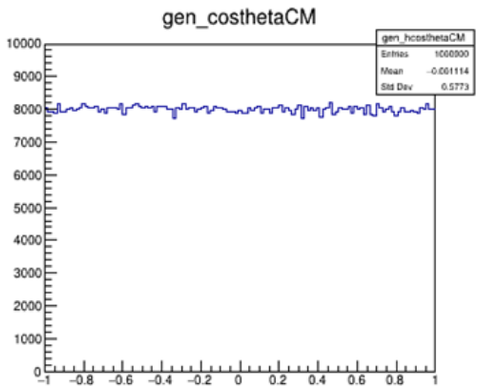


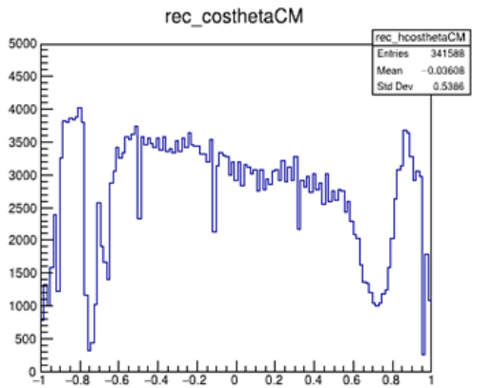


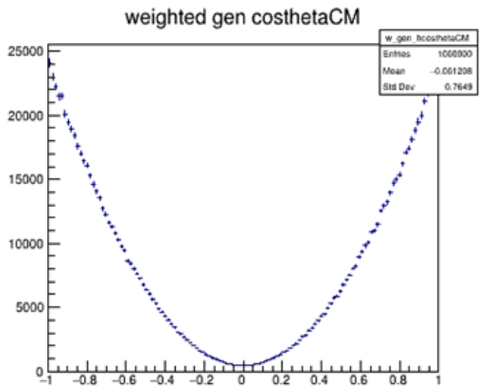
Generated

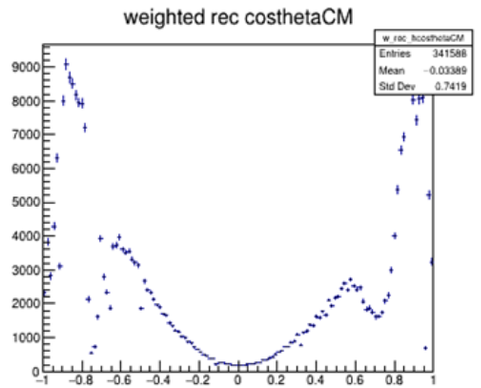
Kinematic Fit

2.5 GeV/c

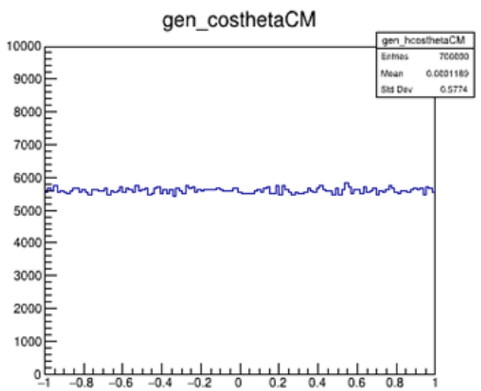


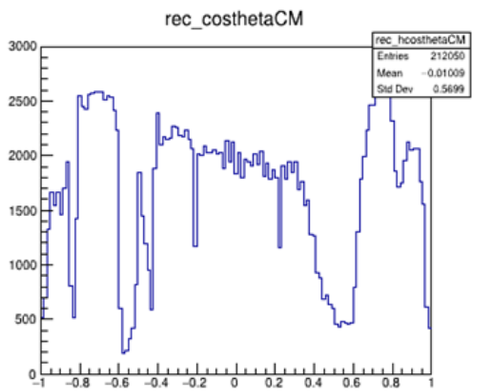


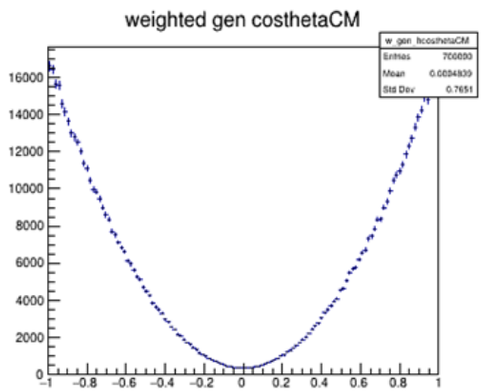


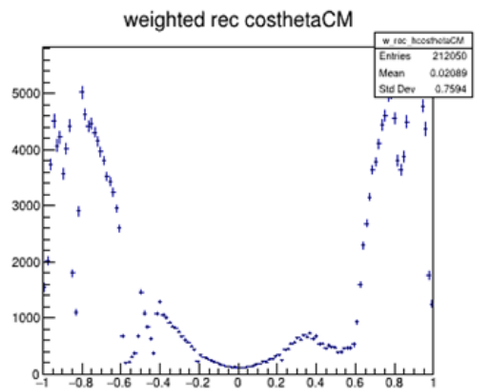


5 GeV/c

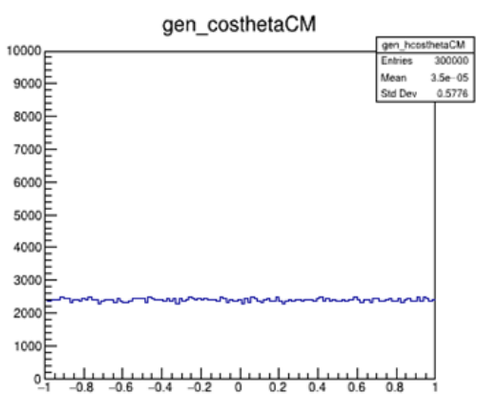


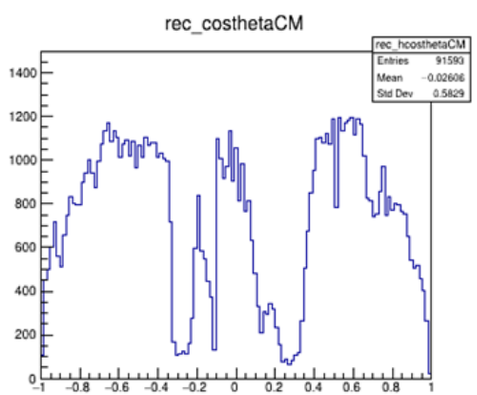


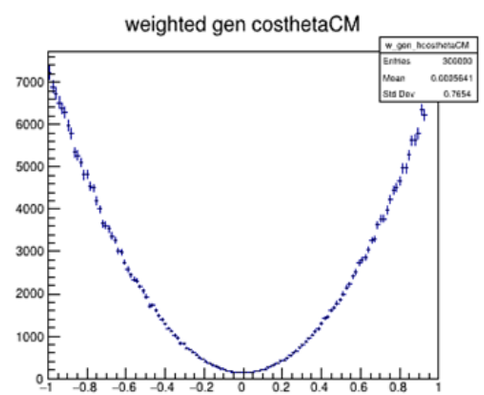


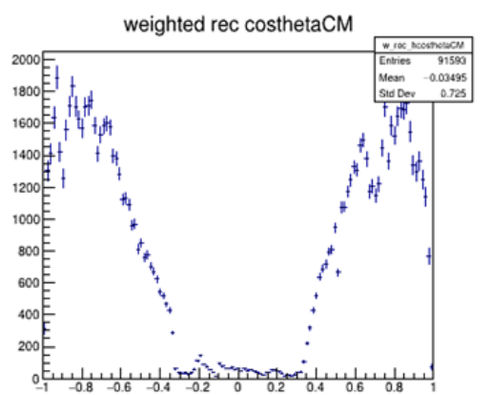


10 GeV/c

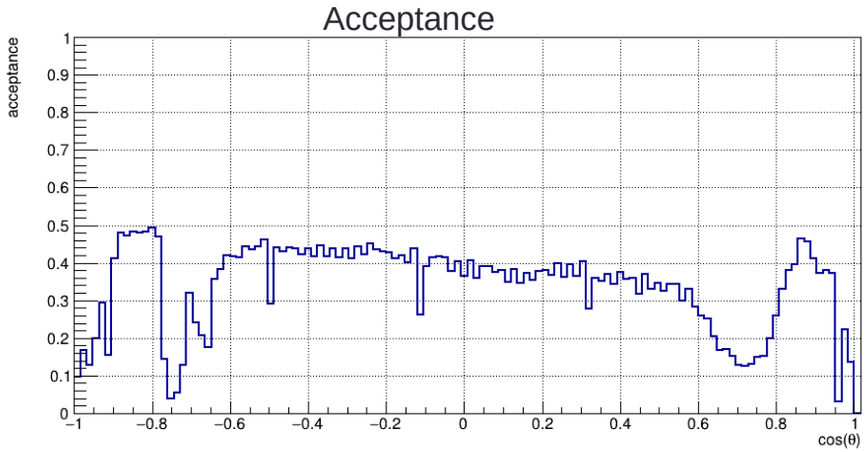


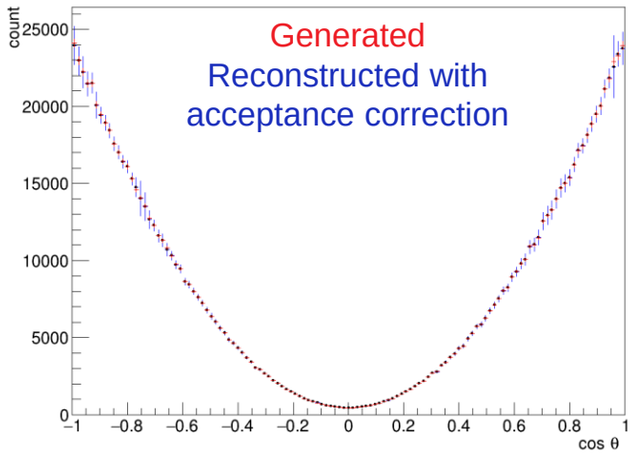






2.5 GeV/c

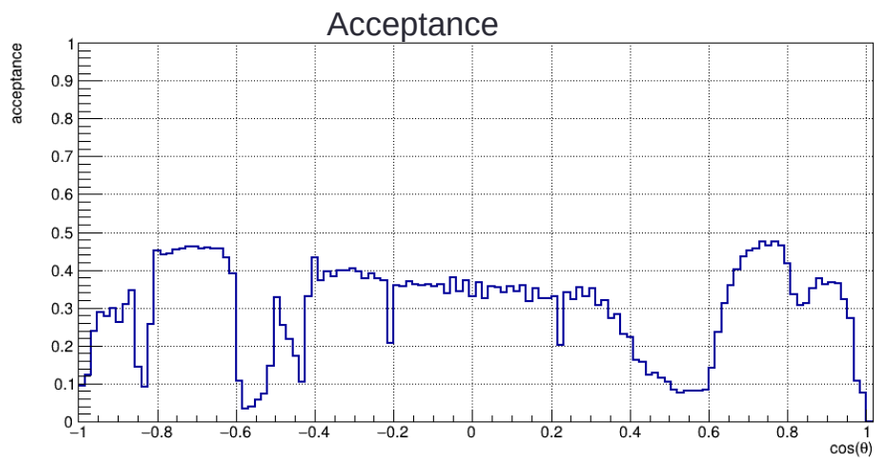


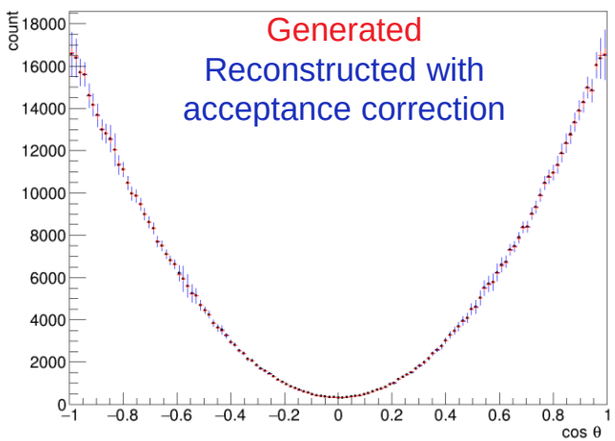


$$A = \frac{N_{rec}}{N_{gen}}$$

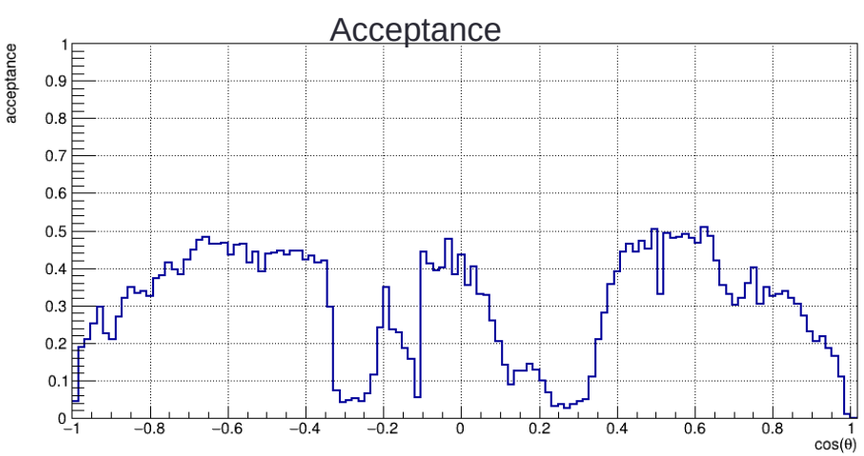
$$A_{corr} = \frac{N_{rec}}{A}$$

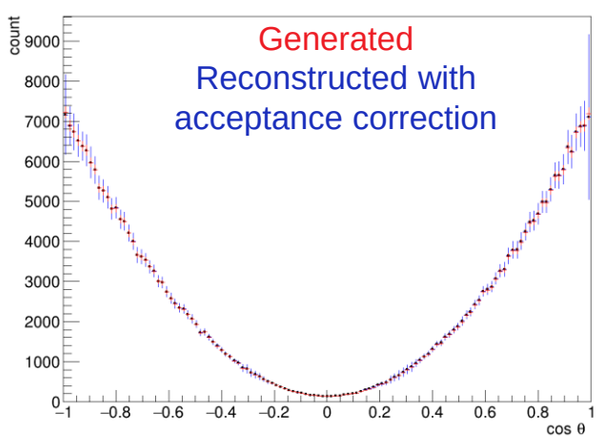
5 GeV/c



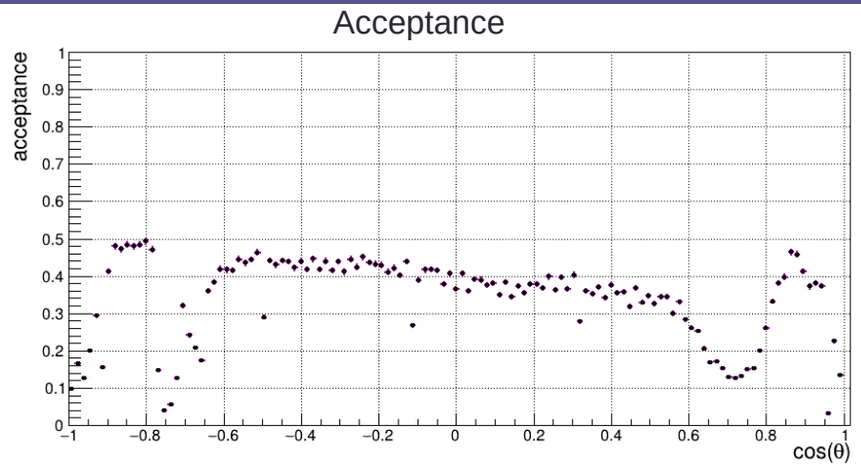


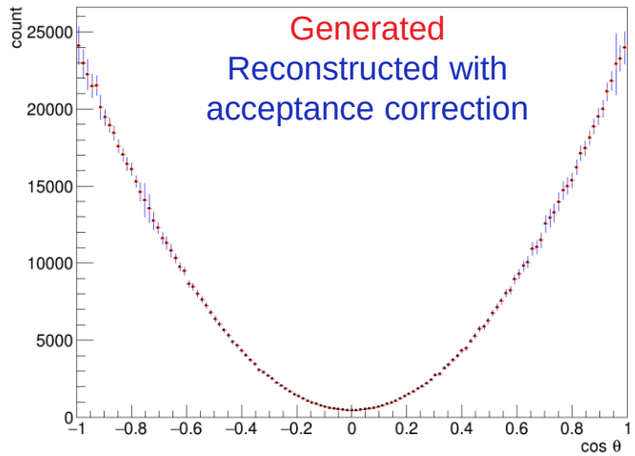
10 GeV/c



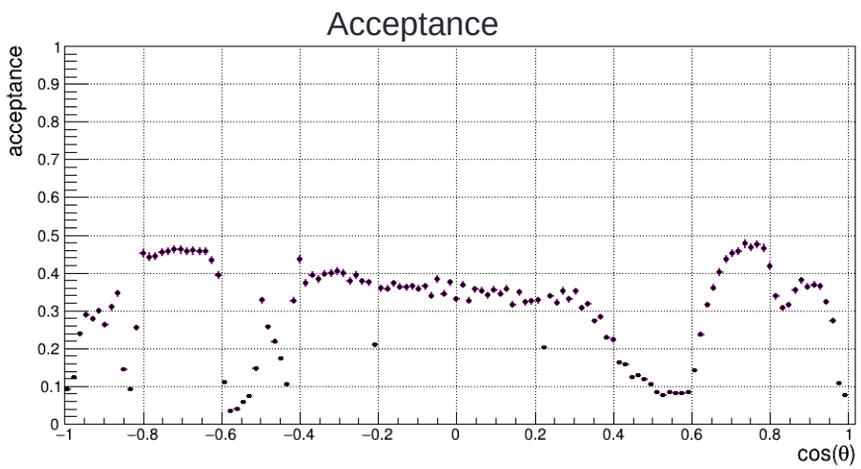


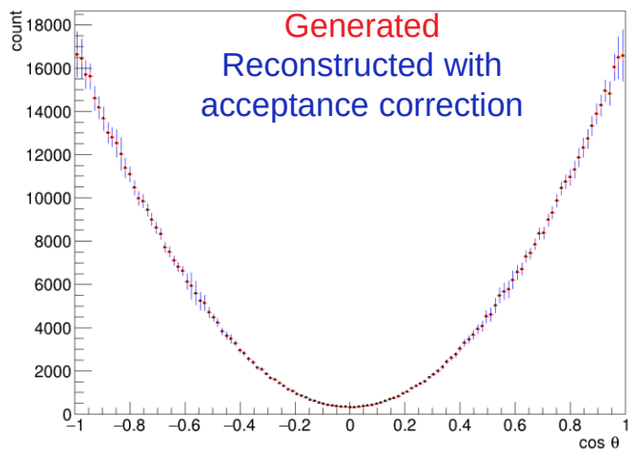
2.5 GeV/c



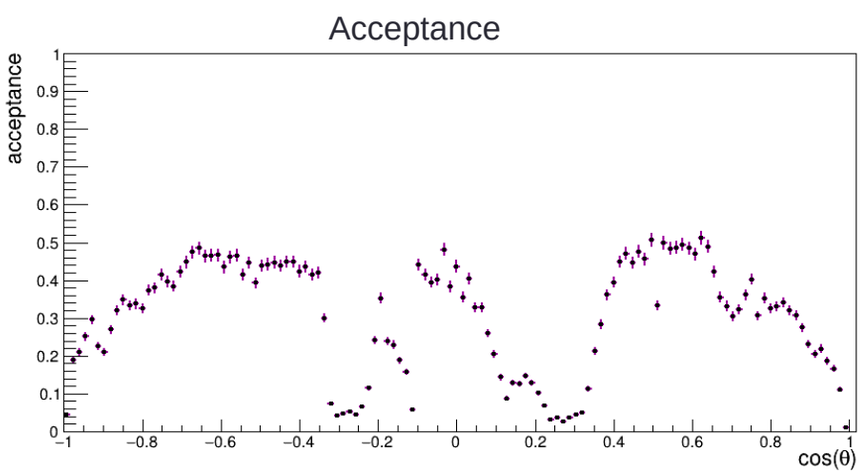


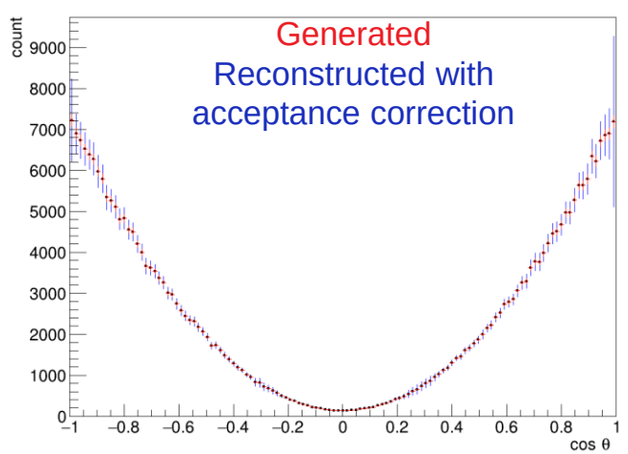
5 GeV/c





10 GeV/c





Bin Migration

- Use 20 bins, bin size= 0.5

- Reconstructed events in a given bin: y_i^{rec}
- Generated MC in a given bin: x_i^{gen}
- Number of events which are both generated and reconstructed in the same bin: $y_i^{rec\ \&\ gen}$

- Acceptance: $\frac{y_i^{rec}}{x_i^{gen}}$

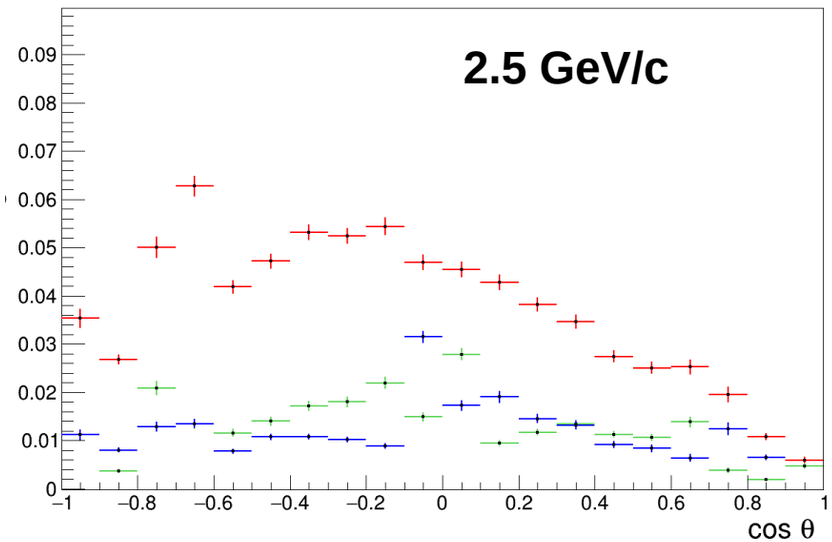
- Bin purity: $\frac{y_i^{rec\ \&\ gen}}{y_i^{rec}}$

- iRec=iGen
MC events generated and reconstructed in bin i

- iRec=iGen±1
MC events generated in a neighbor bin i-1 or i+1

- iRec!=iGen
MC events generated in a neighbor bin

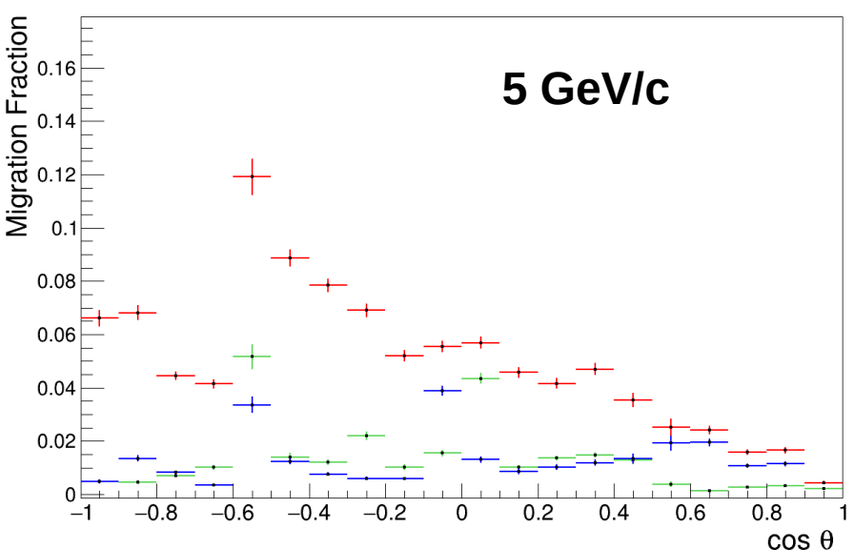
Migration Fraction

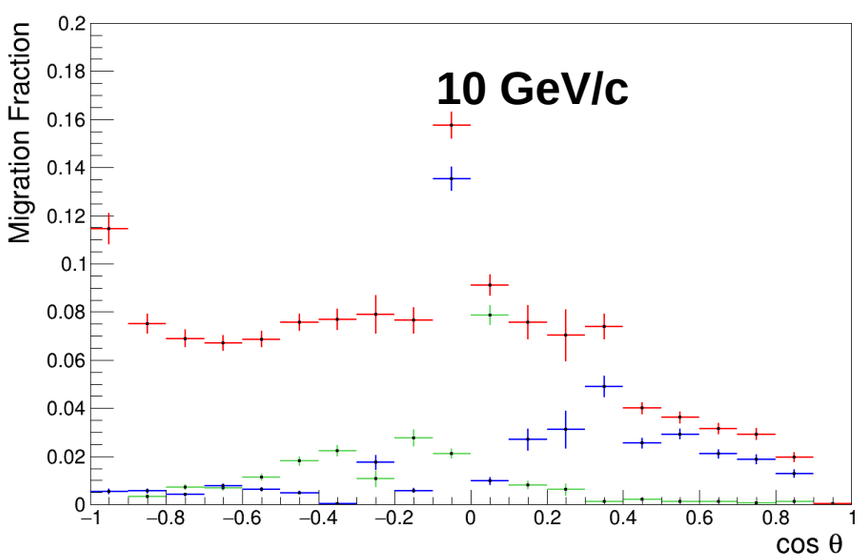


Migrated bins

rec=gen-1

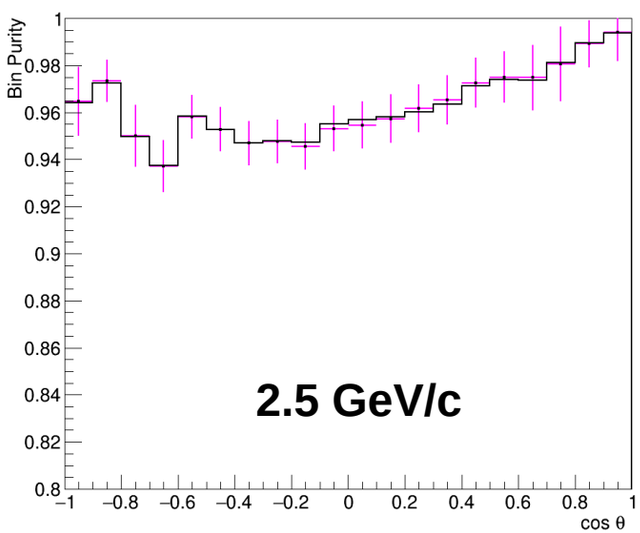
rec=gen+1

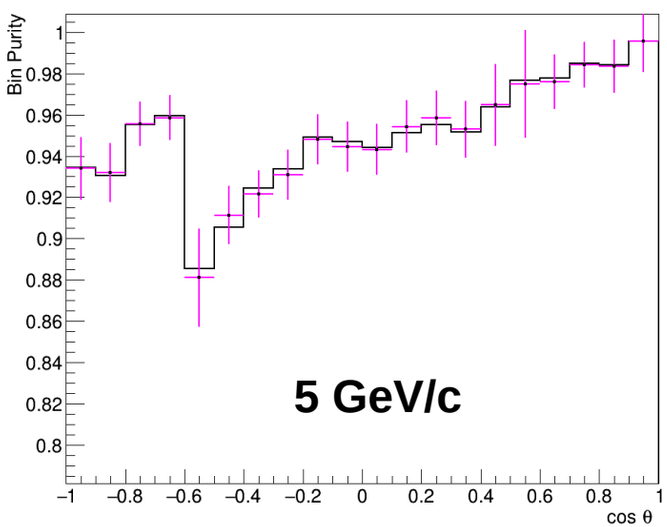


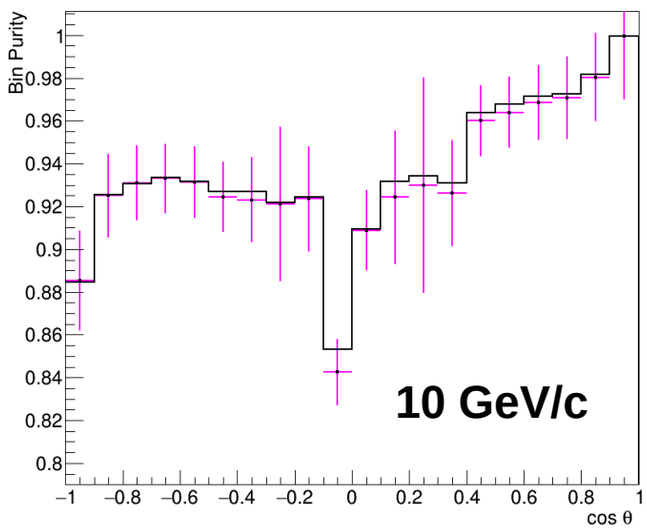


Bin Purity

Weighted
Flat



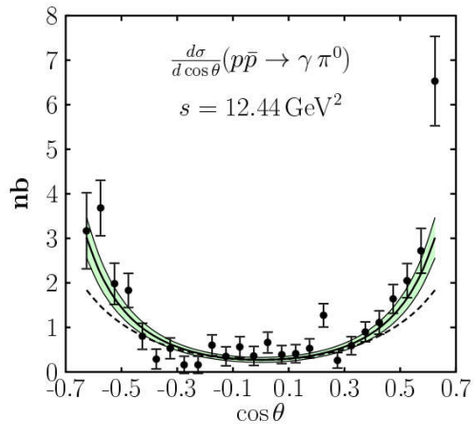


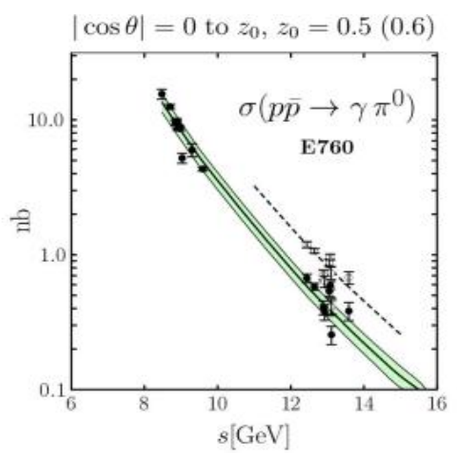


Determining Count Rate Estimate

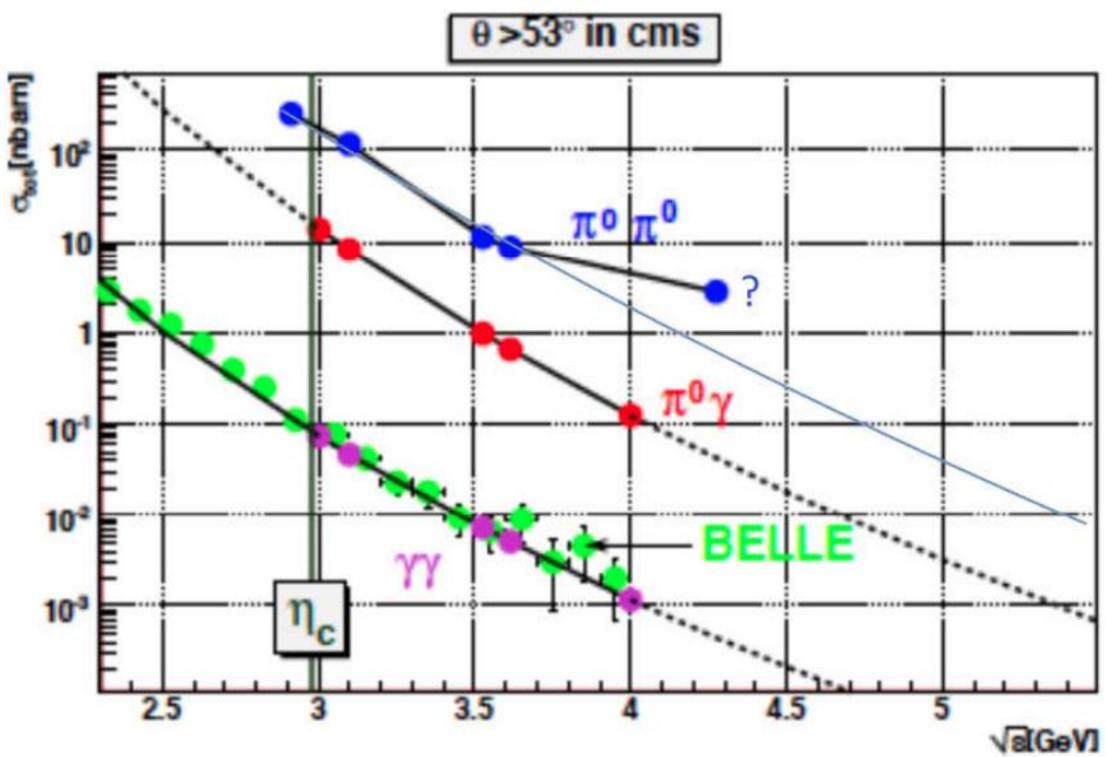
- Obtain cross-section and scaling factor from theoretical prediction
- $\text{Acceptance} = \frac{N^{rec}}{N^{gen}}$
- $\text{Cross section}_{scaled} = \text{cross section}_{theor.} * \text{scaling factor}$
- Count rate

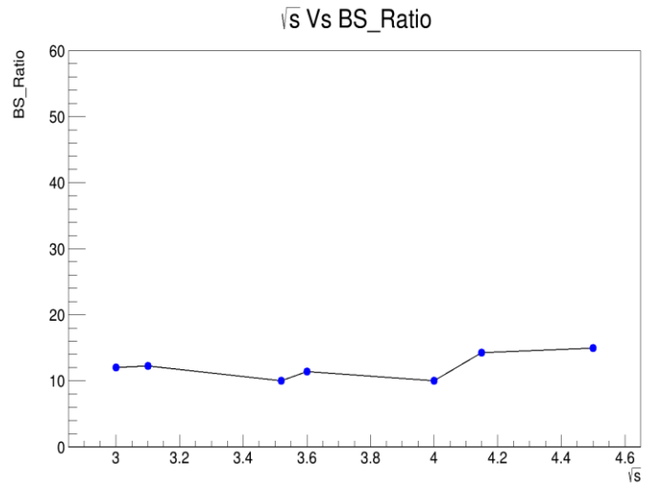
  $= \text{Cross section}_{scaled} * \text{Acceptance} * \text{Bin Size} * \text{Integrated Luminosity}$





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





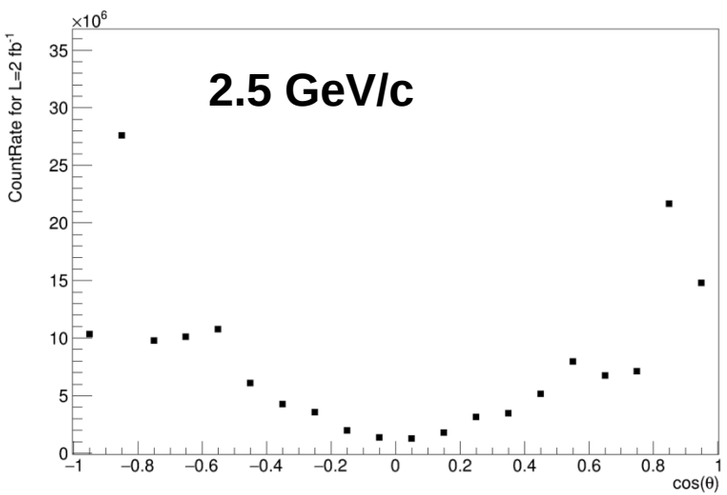
Cross-section for $p\overline{p} \rightarrow \pi^0\,\pi^0$ is one order of magnitude larger than for $p\overline{p} \rightarrow \pi^0\gamma$

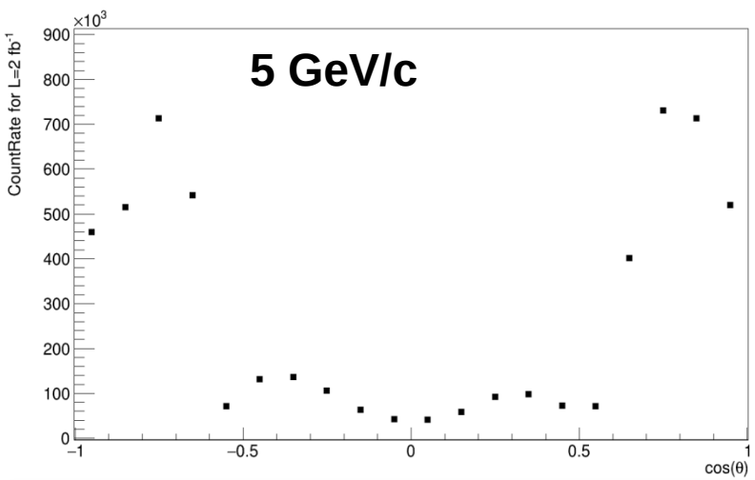
- Estimate the background correctly

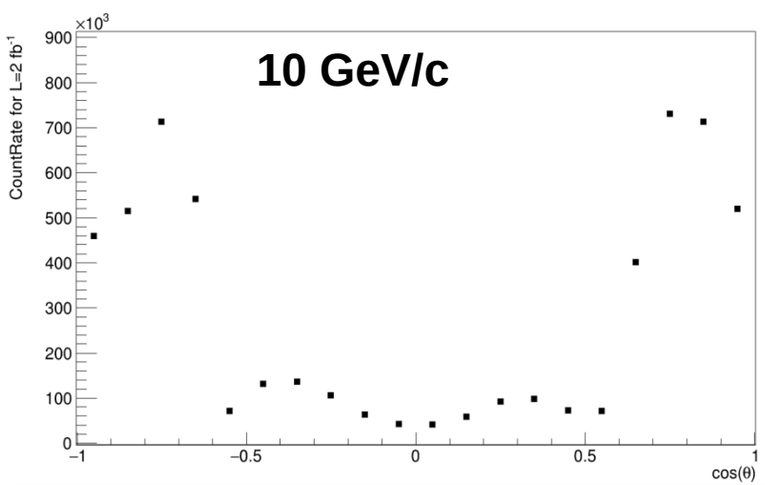
Count rate estimate

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

Set the bin size to $\Delta\cos(\theta) = 0.1$

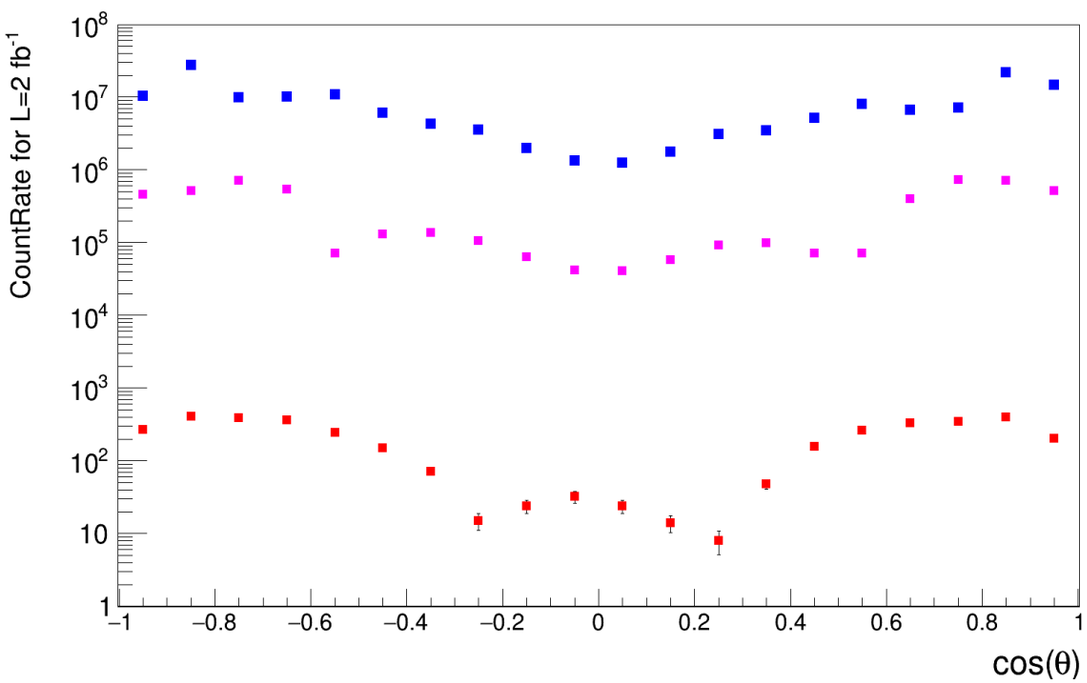


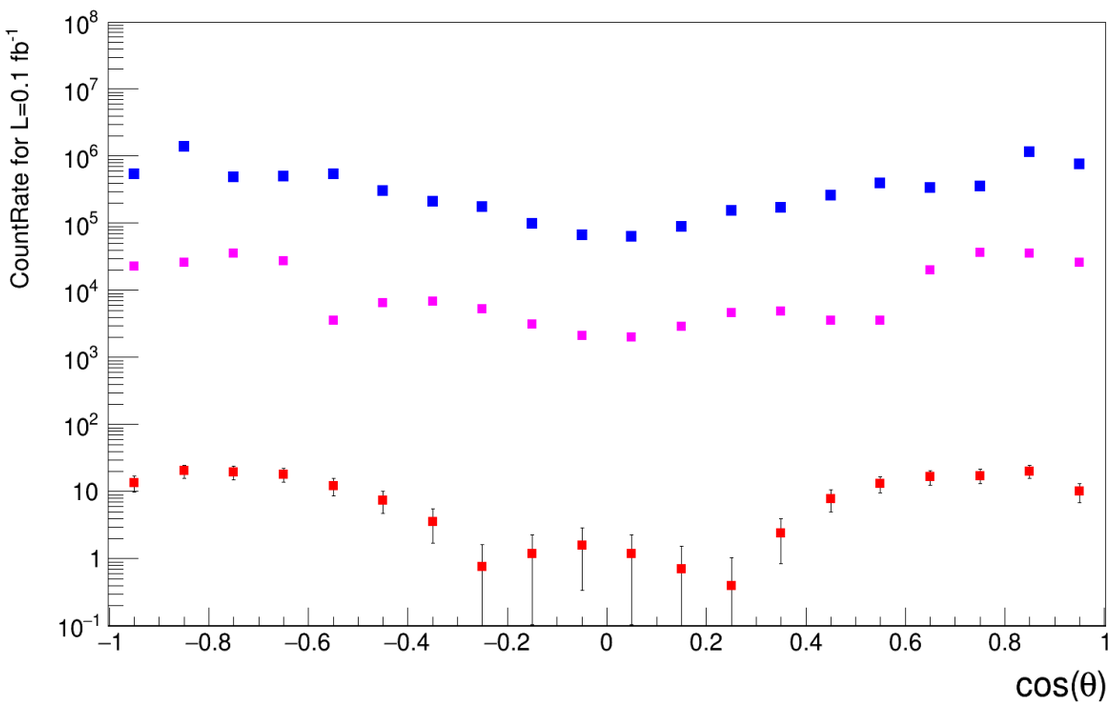




Count Rate for $\mathcal{L} = 2\ \mathrm{fb}^{-1}$ and $\mathcal{L} = 0.1\ \mathrm{fb}^{-1}$

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





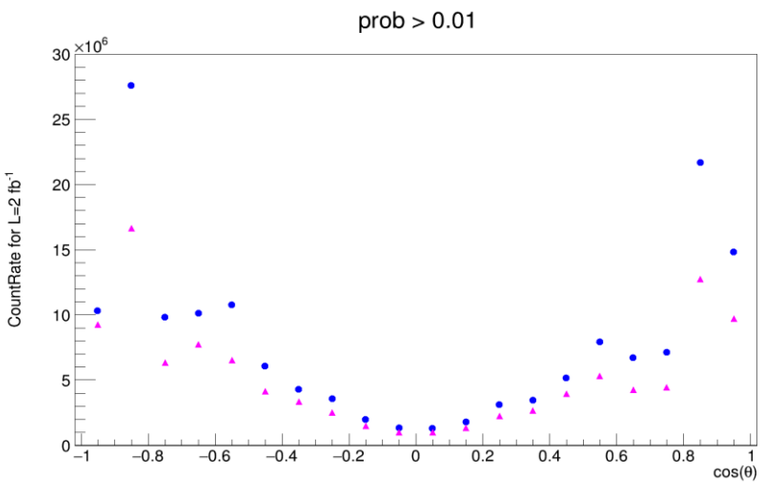
Count Rate

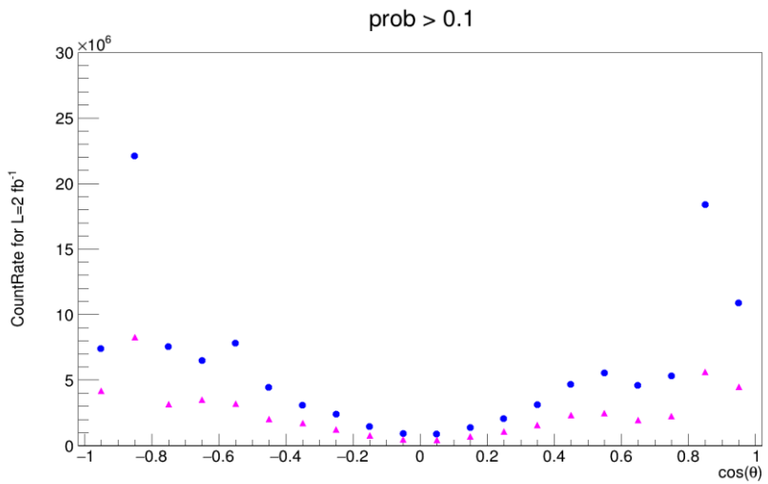
$p\,\bar{p} \rightarrow \pi^0\,\pi^0$

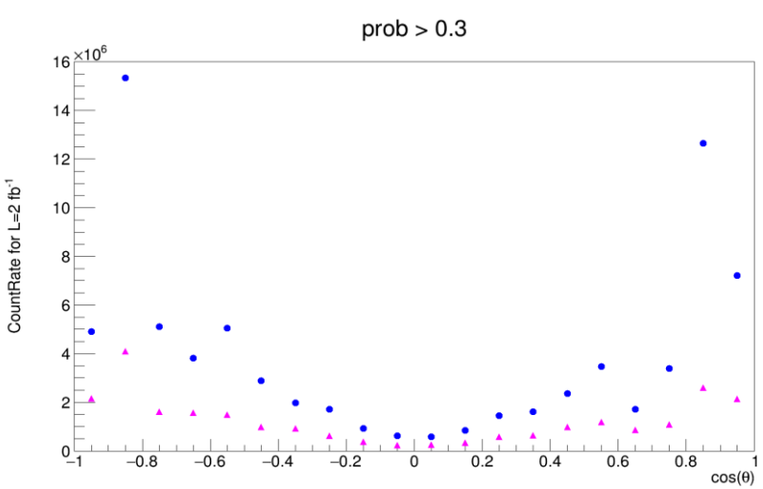
$p\,\bar{p} \rightarrow \pi^0\,\gamma$

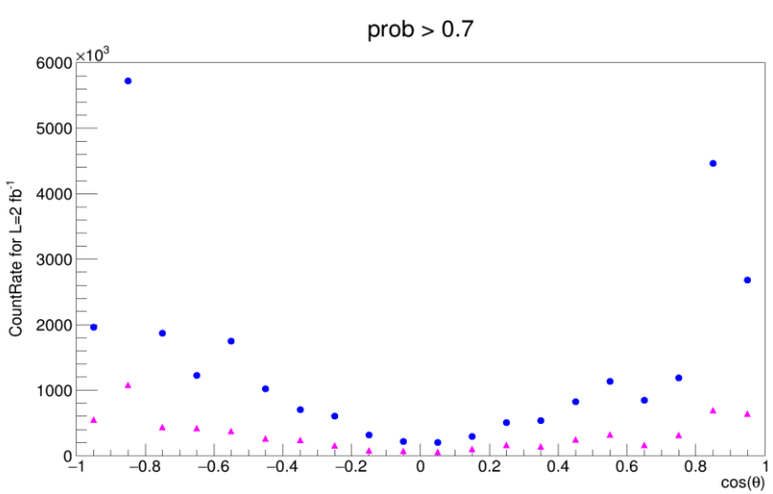
P_{beam}= 2.5 GeV

Signal
Bkg

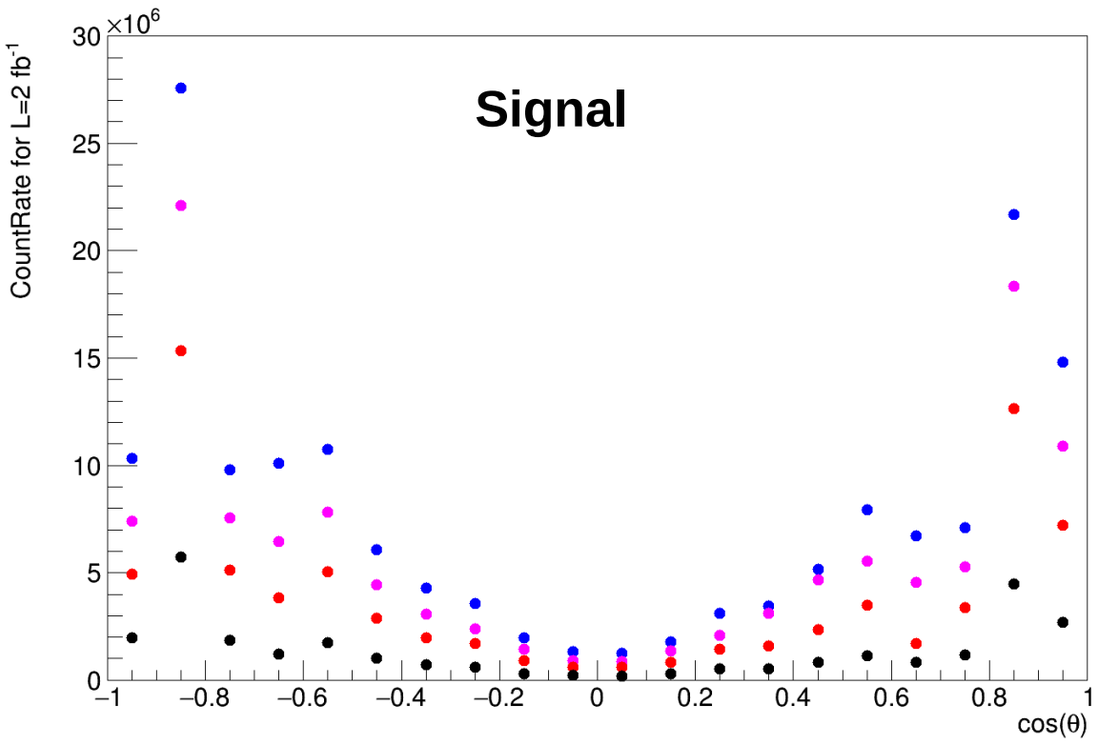


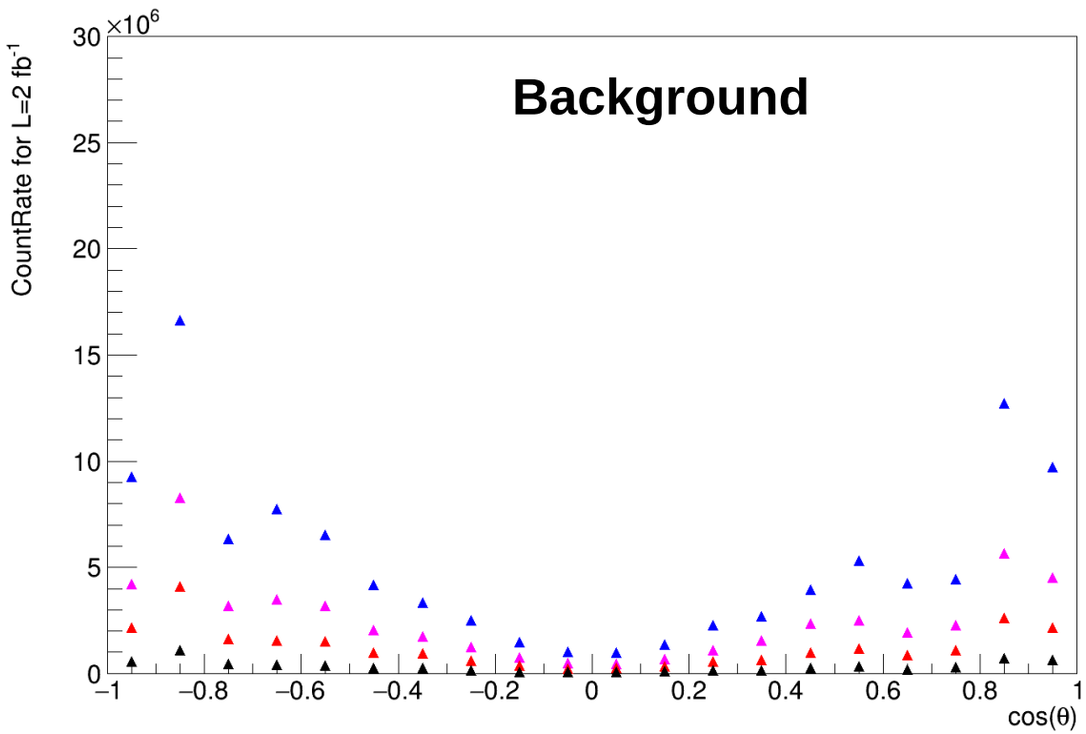






P_{beam}= 2.5 GeV





With an increase in probability of kinematic fit,
background count rate decreases more than signal count rate

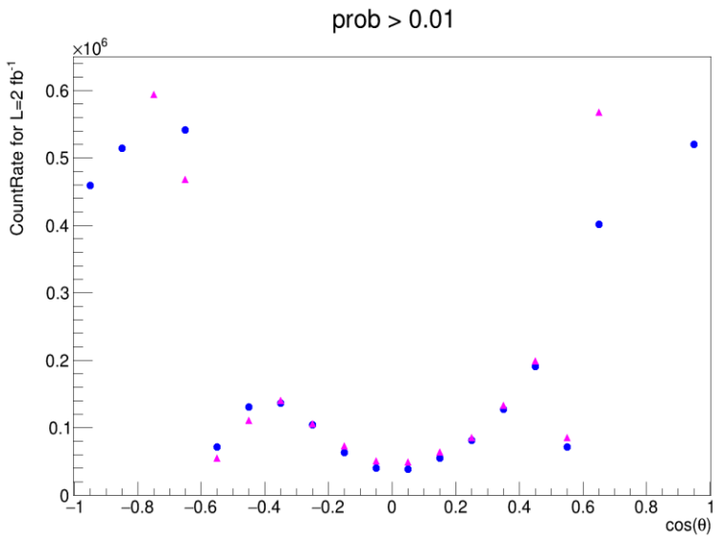
- **p>0.01**
- **p>0.1**
- **p>0.3**
- **p>0.7**

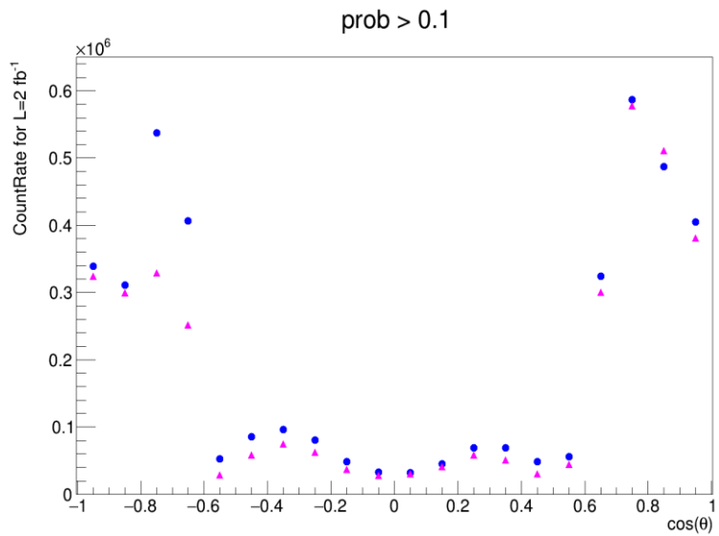
Count Rate

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

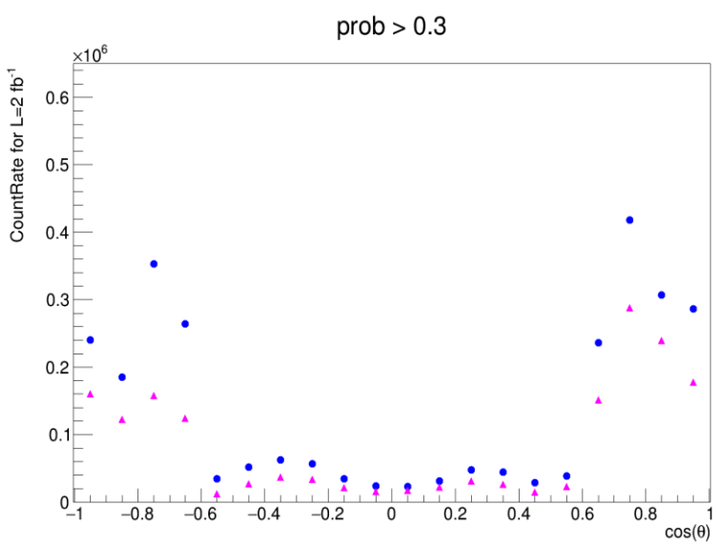
$p\,\bar{p} \rightarrow \pi^0\,\gamma$

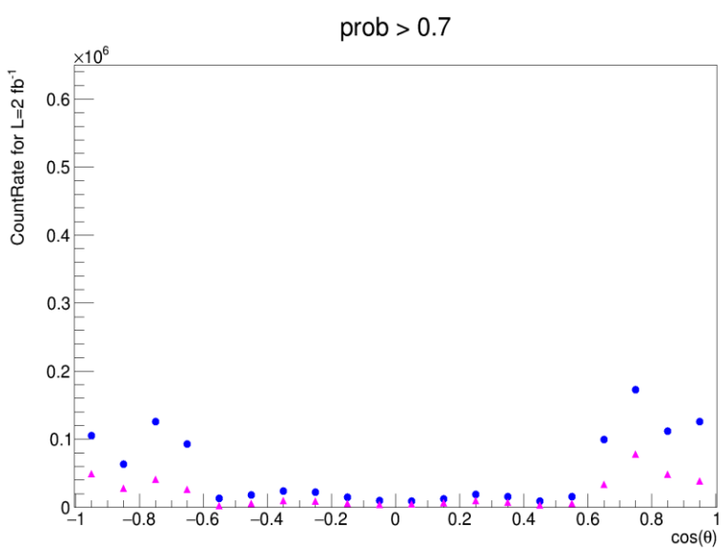
P_{beam}= 5 GeV



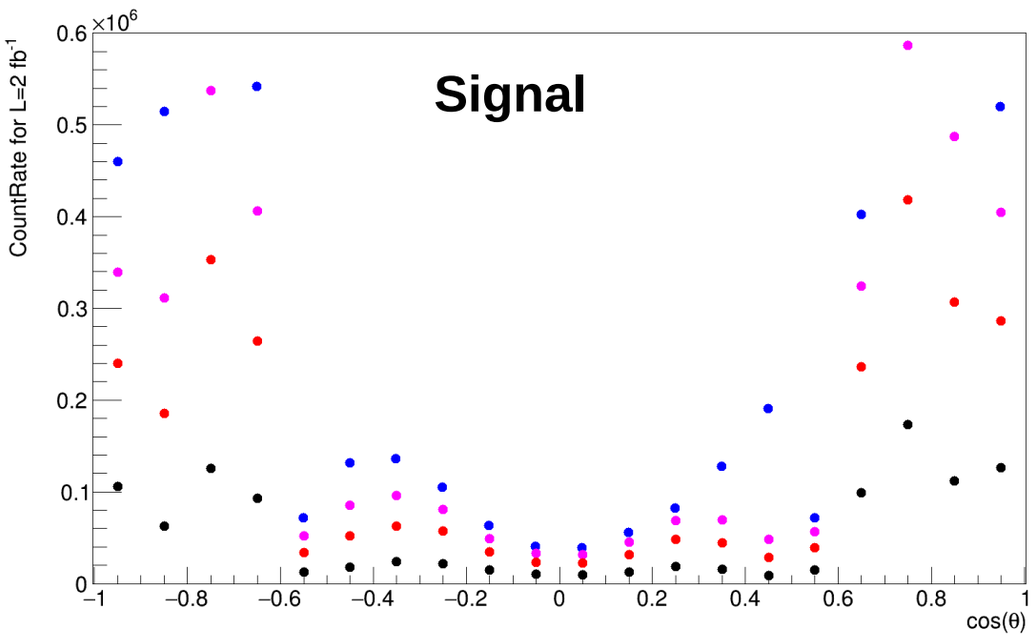


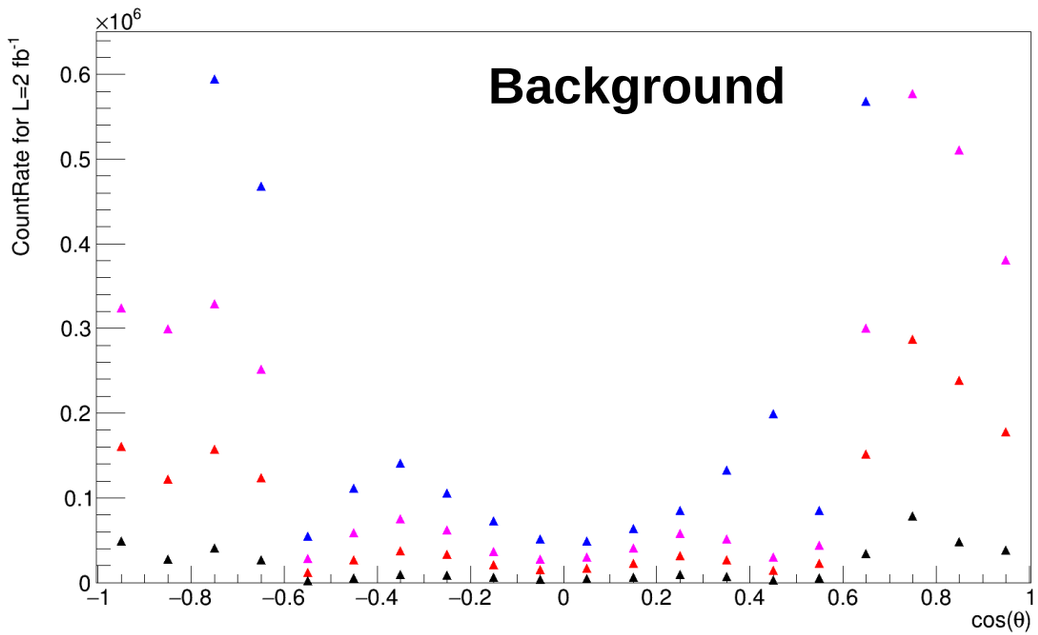
Signal
Bkg





P_{beam}= 5 GeV





p>0.01
p>0.1
p>0.3
p>0.7

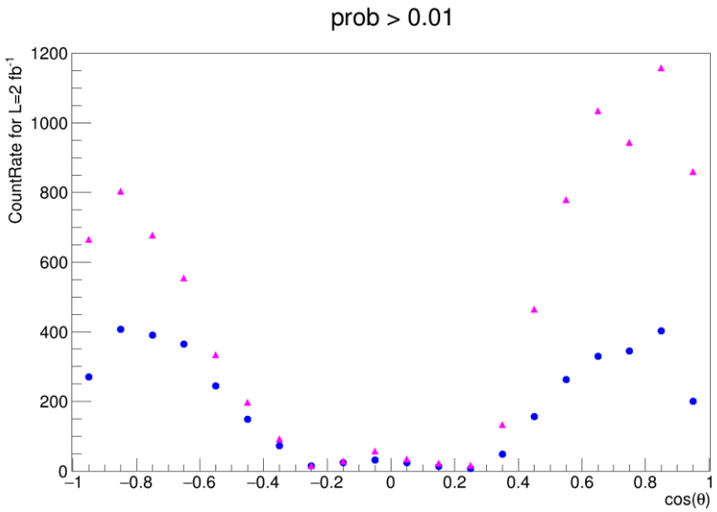
Count Rate

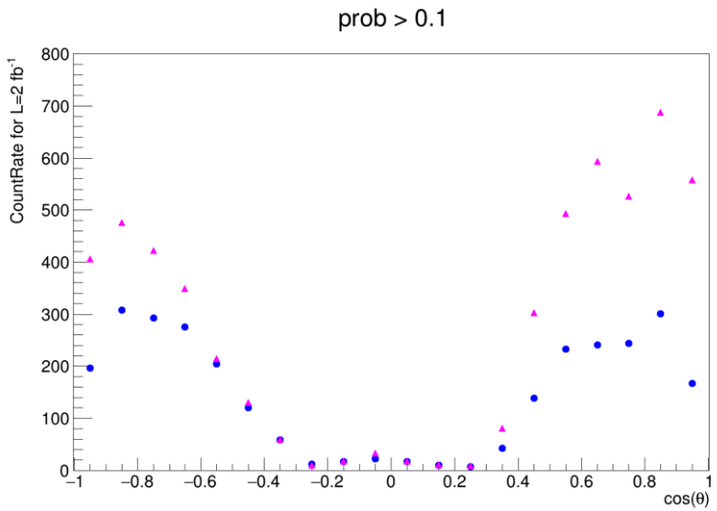
$p\,\bar{p} \rightarrow \pi^0\,\pi^0$

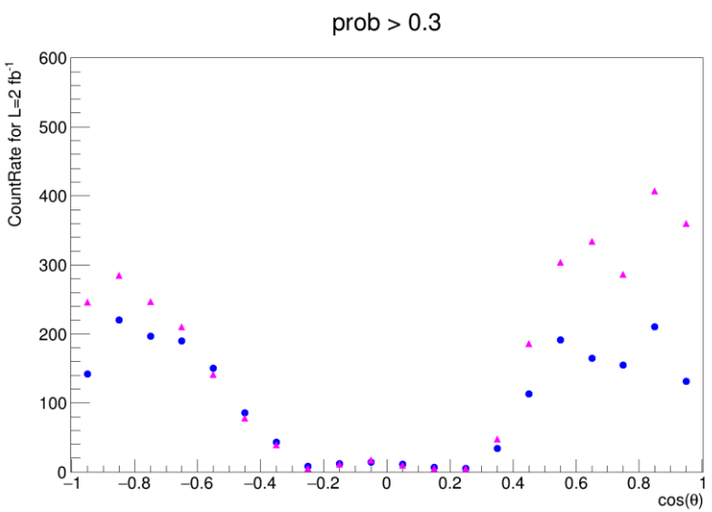
$p\,\bar{p} \rightarrow \pi^0\,\gamma$

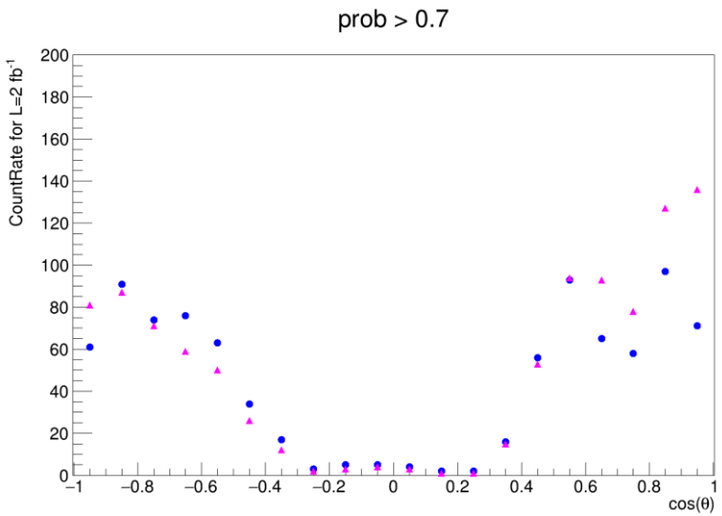
P_{beam}= 10 GeV

Signal
Bkg

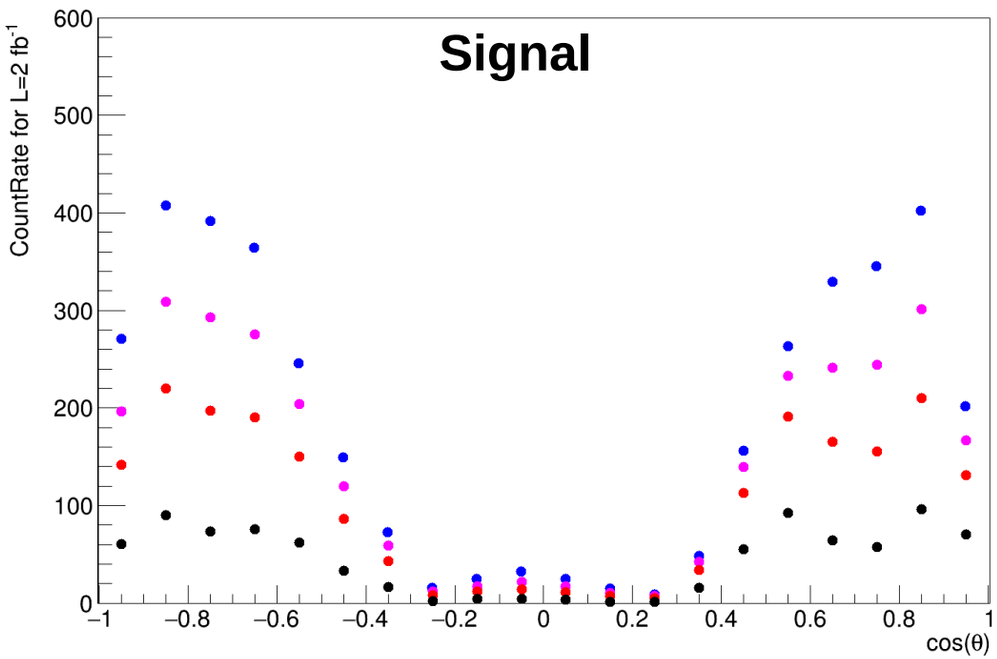


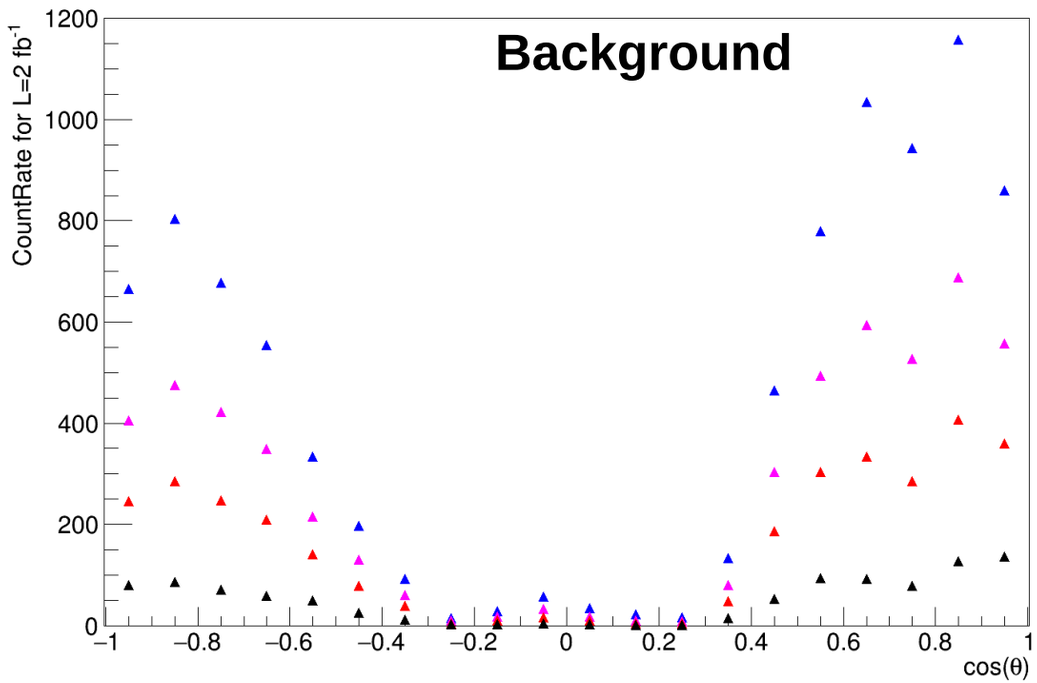






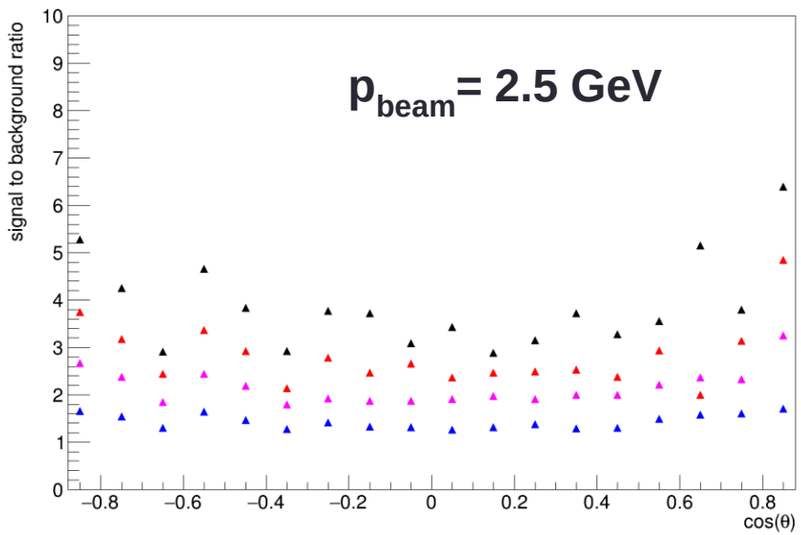
P_{beam}= 10 GeV

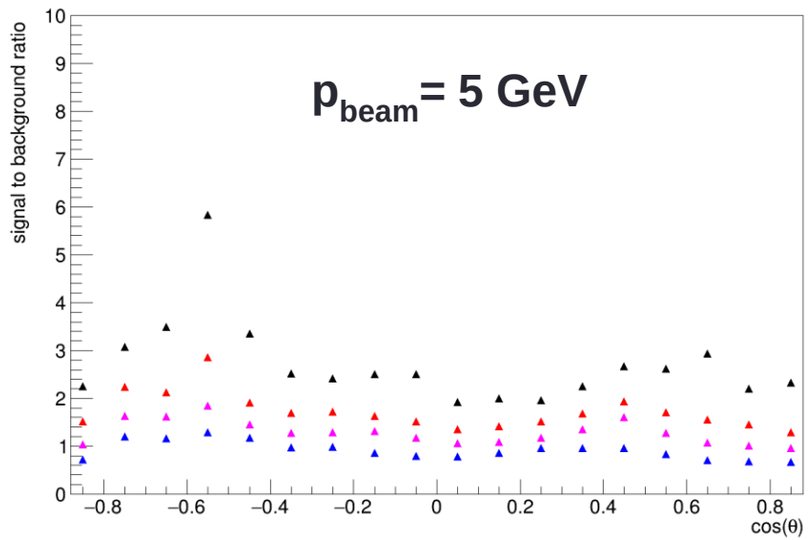


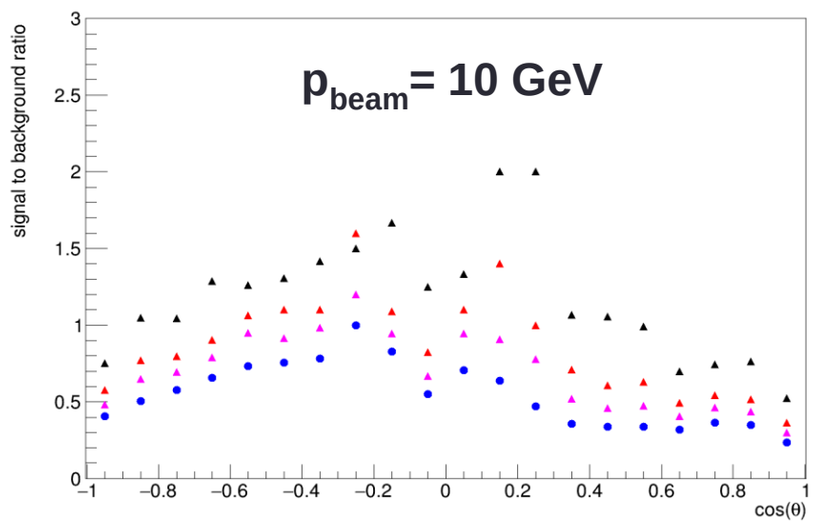


p>0.01
p>0.1
p>0.3
p>0.7

Signal to Background Ratio

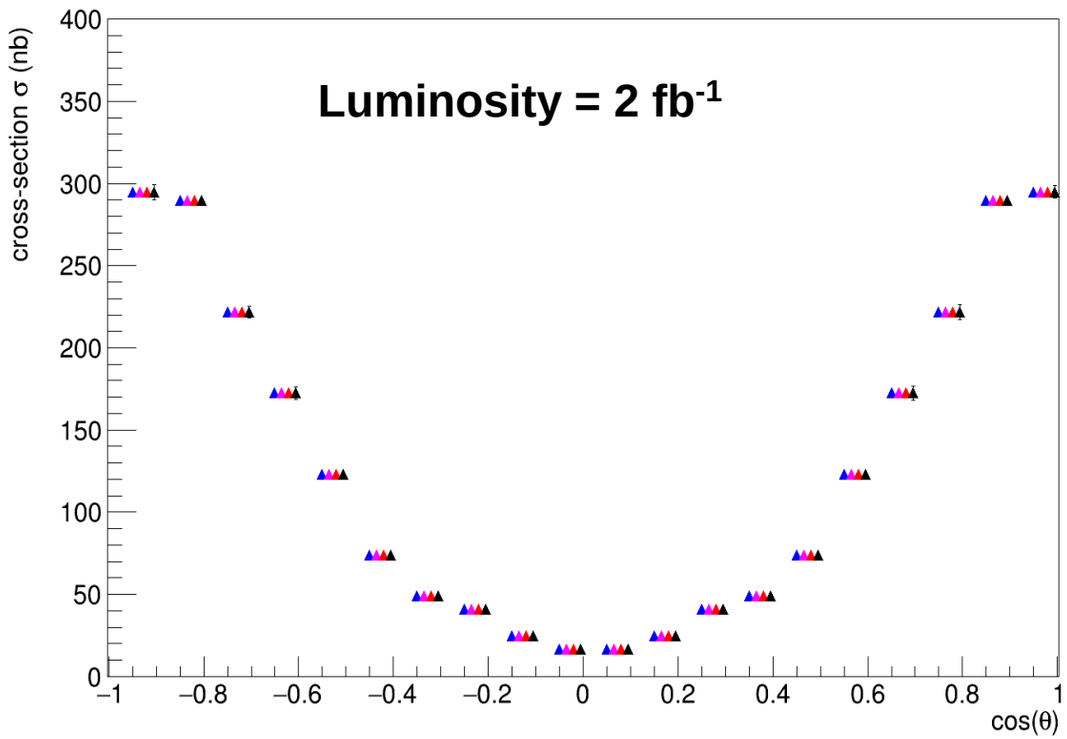


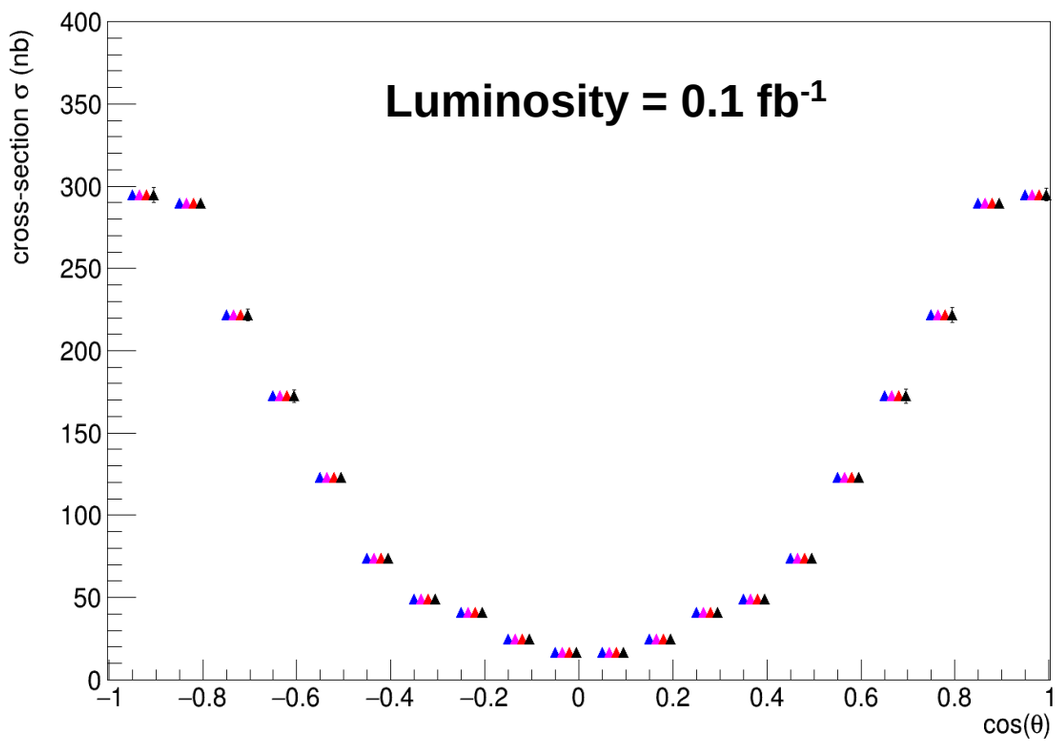




p>0.01
p>0.1
p>0.3
p>0.7

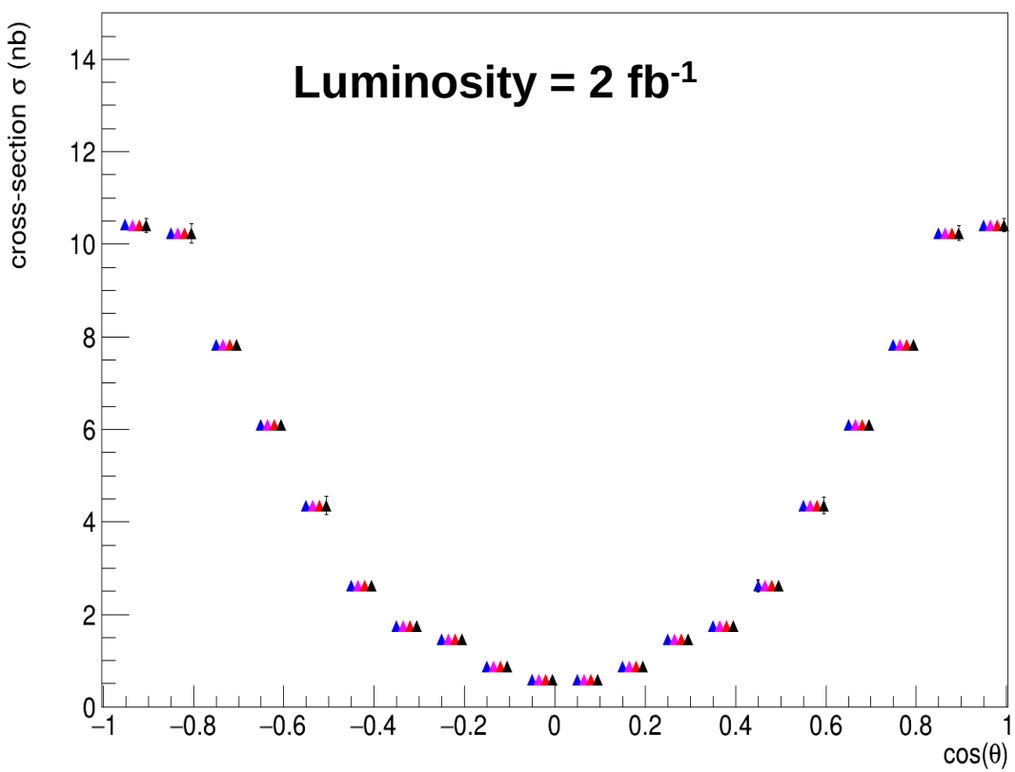
Background Subtraction: Cross-section at p=2.5 GeV/c

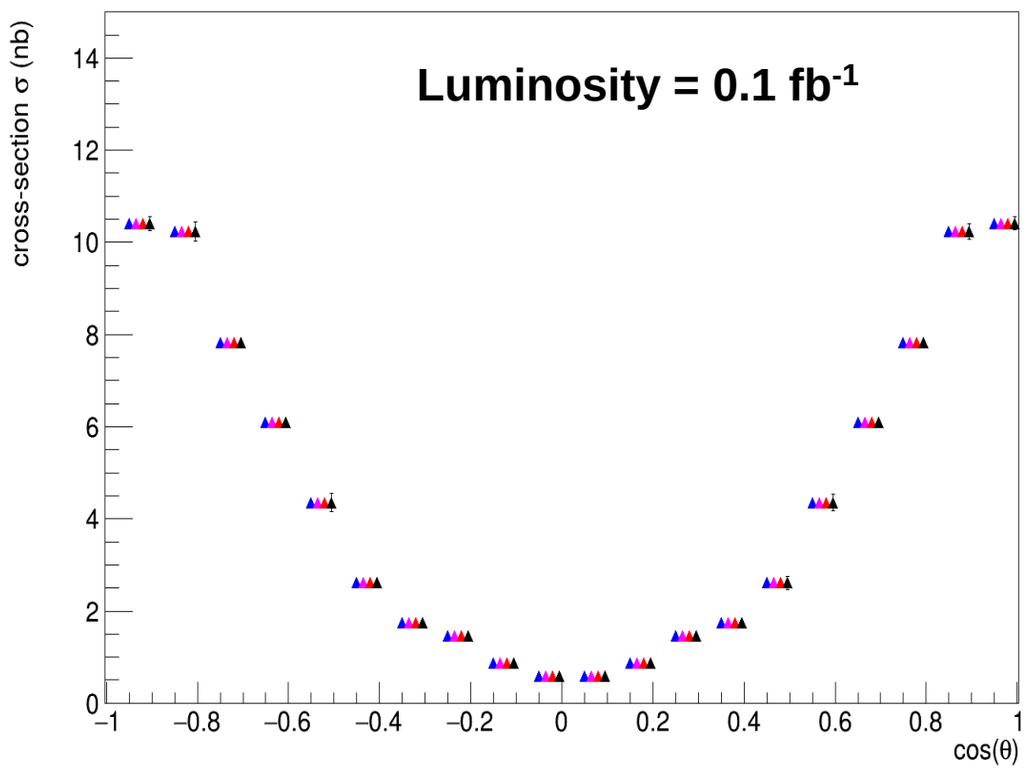




p>0.01
p>0.1
p>0.3
p>0.7

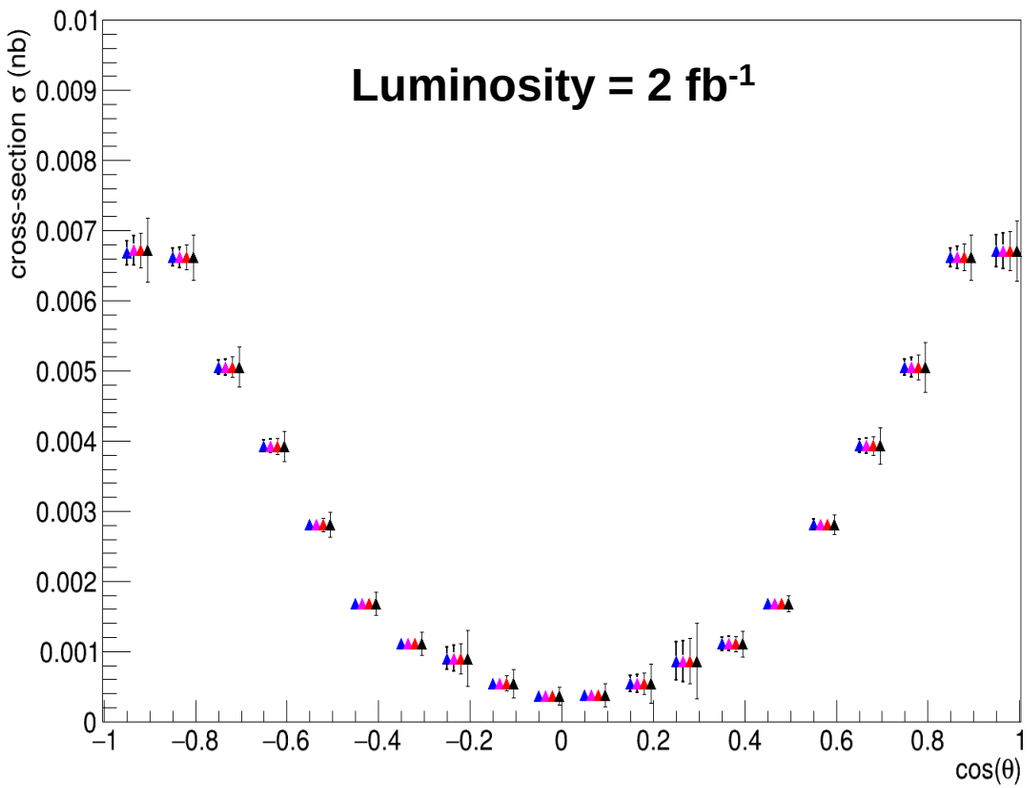
Background Subtraction: Cross-section at p=5 GeV/c

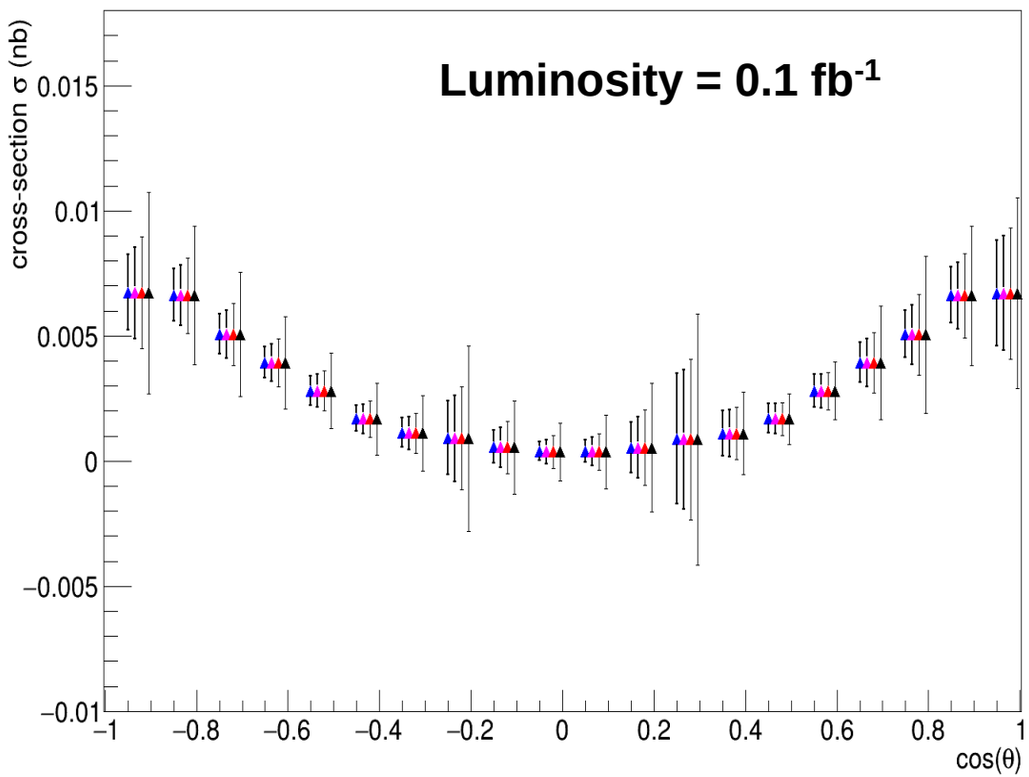




p>0.01
p>0.1
p>0.3
p>0.7

Background Subtraction: Cross-section at p=10 GeV/c





p>0.01
p>0.1
p>0.3
p>0.7

Summary

- Exclusive event selection with 4C kinematic fit and cut on the invariant mass of the two-photon system was performed
- Acceptance in cos(θ) has been checked
- Acceptance corrections including signal reconstruction efficiency and bin migrations have been determined
- Reconstruction capability for theoretical model predictions have been investigated by looking into detector resolution.
- The cos(θ) dependence of the cross-section has been implemented and reconstruction study has been performed
- Simulations have been performed at $\sqrt{s} = 2.6\ GeV$ ($p_{beam} = 2.5\ GeV$) $\sqrt{s} = 3.4\ GeV$ ($p_{beam} = 5\ GeV$) $\sqrt{s} = 4.5\ GeV$ ($p_{beam} = 10\ GeV$)
- Count rate estimates and estimates of the expected statistical uncertainty for different integrated luminosities has been performed.
- Signal to background ratio was determined

Thank You For Your Attention!