Generalized Distribution Amplitudes Studies with the Channel

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

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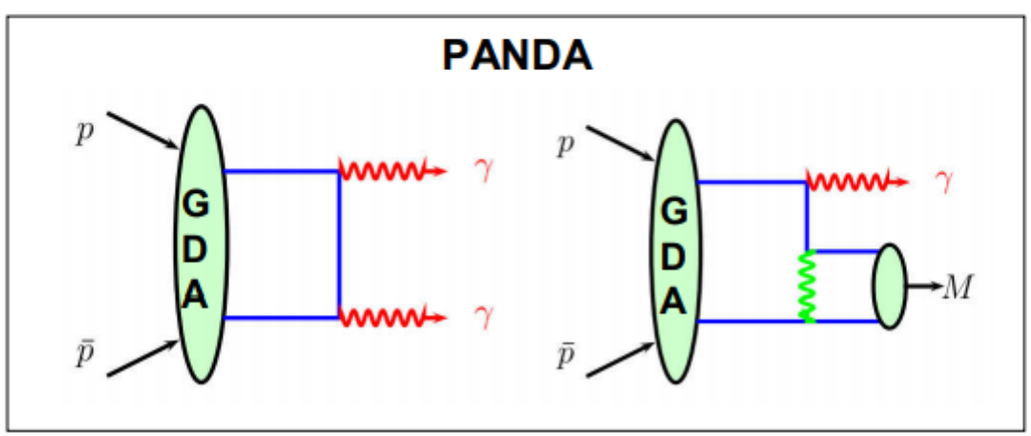
Introduction

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



Theoretical Predictions

- P.Kroll, A. Schafer, The process $p\bar{p} \to \gamma\pi^0$ 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:

$$p\bar{p} \to \gamma\,\gamma \qquad p\bar{p} \to \pi^0\,\gamma \qquad p\bar{p} \to \pi^0\,\pi^0$$

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

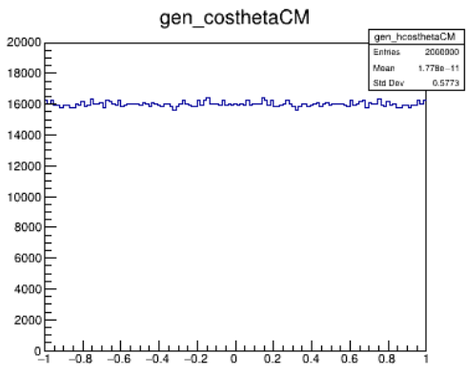
- Two gammas combined to form initial $\bar{p}p$ system

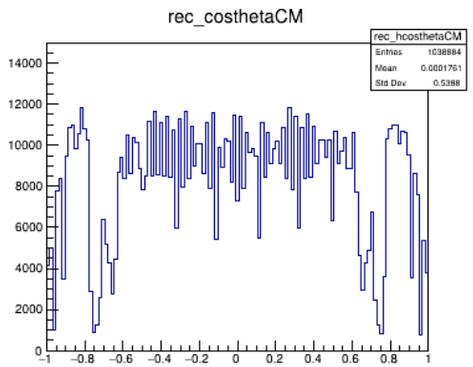
Events selection

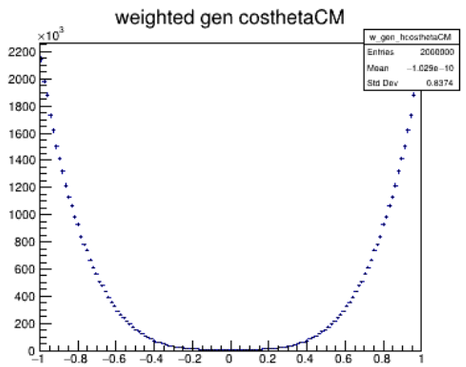
- Standard PID
- 4-Constraint fit applied to the reconstructed initial system
  - 4C Fit (RhoKinFitter) prob>0.01

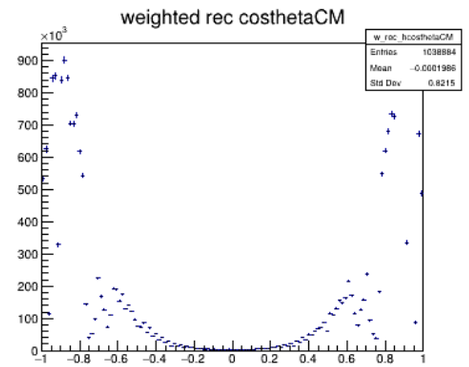
Acceptance Studies for $p\bar{p} \to \gamma\gamma$

2.5 GeV/c

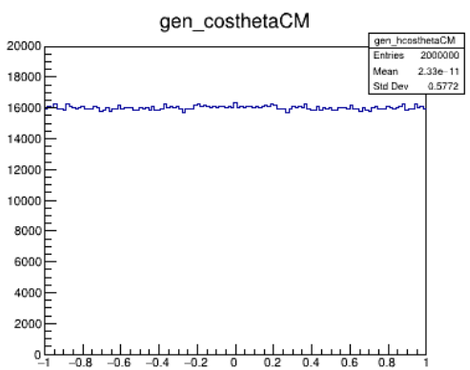


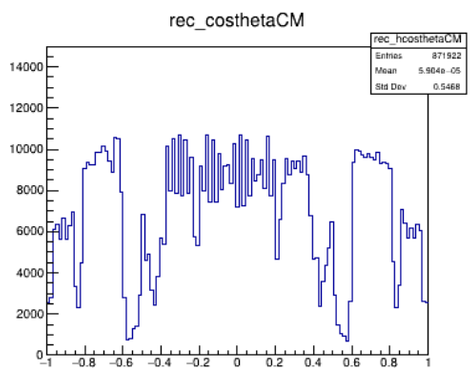


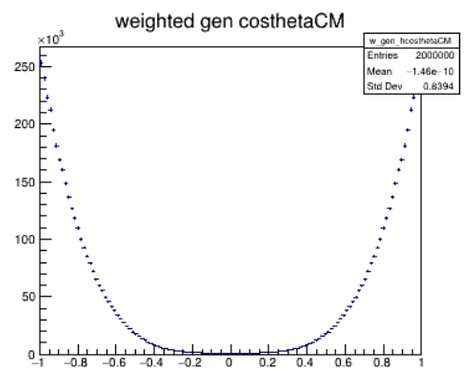


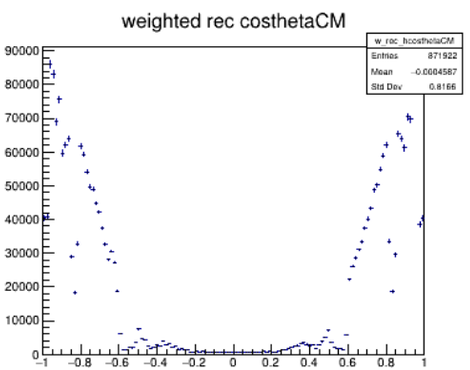


5 GeV/c

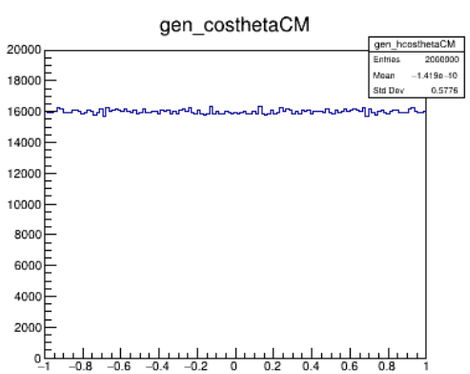


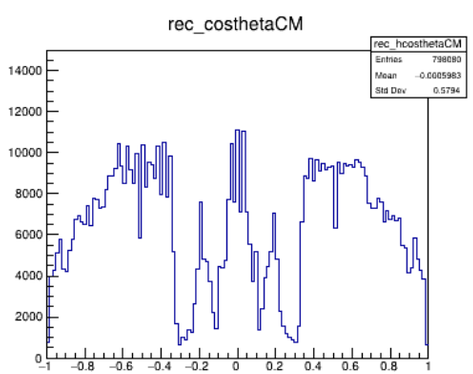


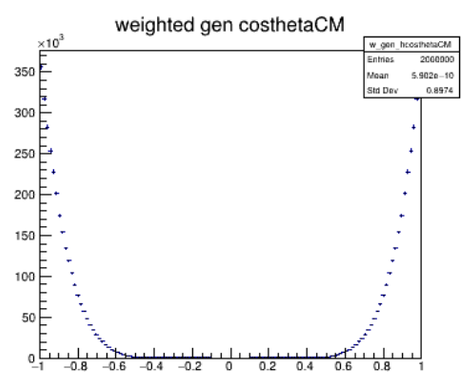


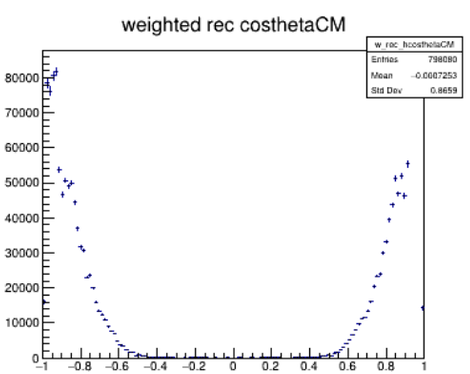


10 GeV/c







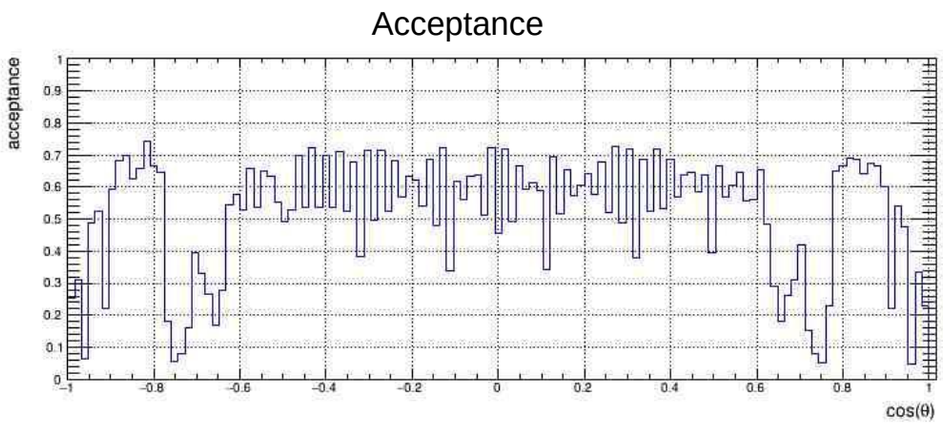


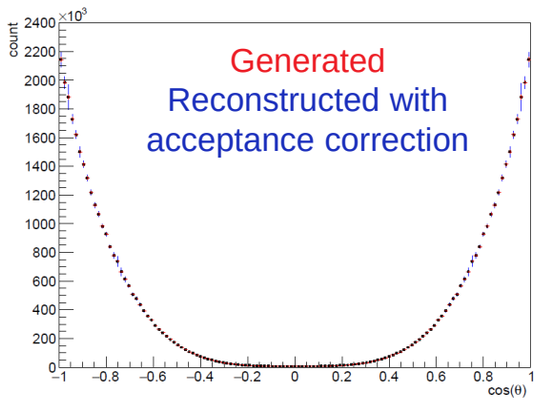
Acceptance for $p\bar{p} \rightarrow \gamma\gamma$

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

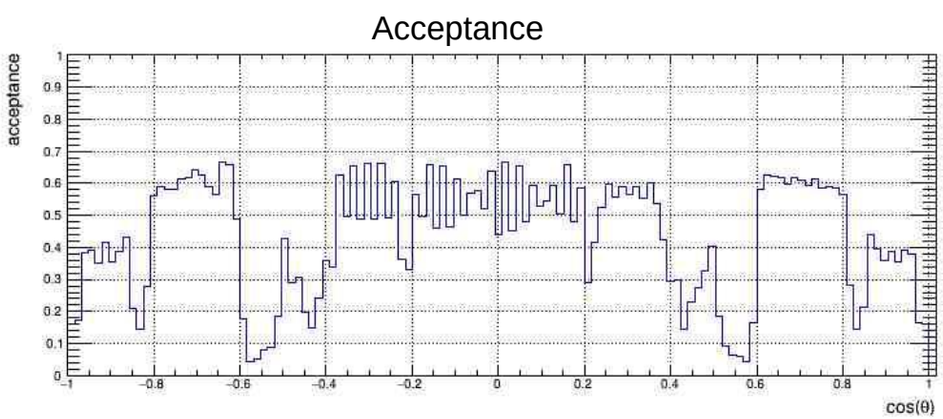
$$A_{corr} = \frac{N_{rec}}{A}$$

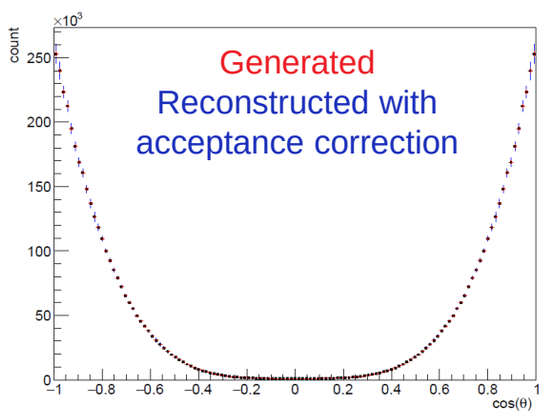
2.5 GeV/c



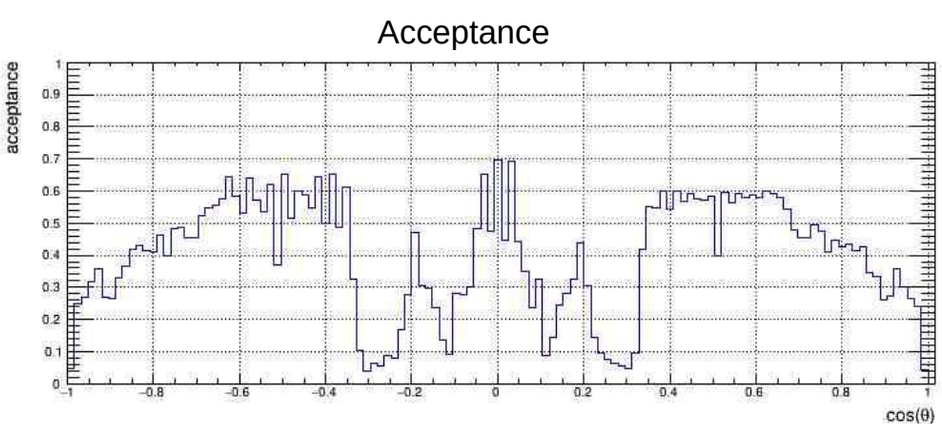


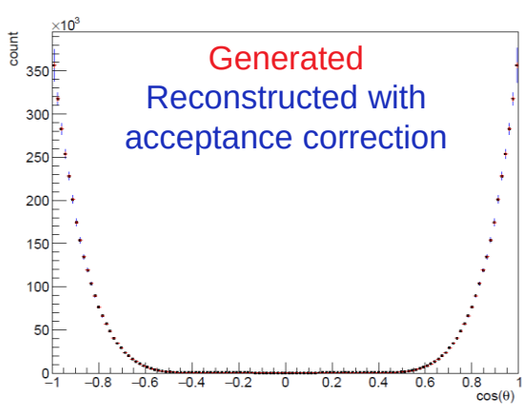
5 GeV/c





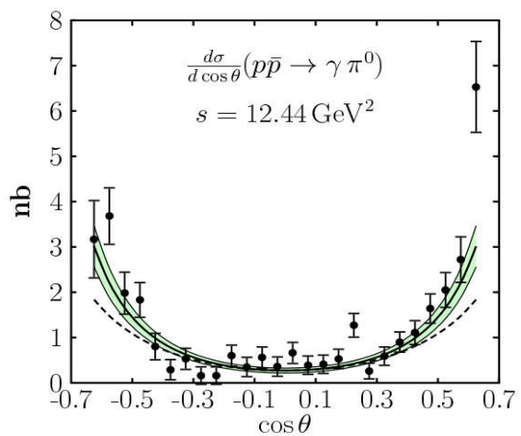
10 GeV/c

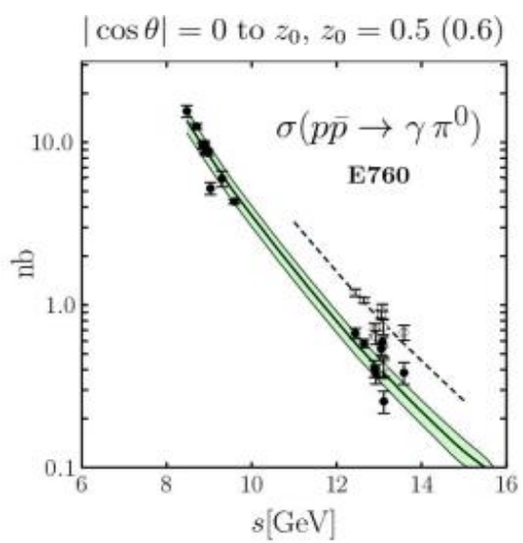




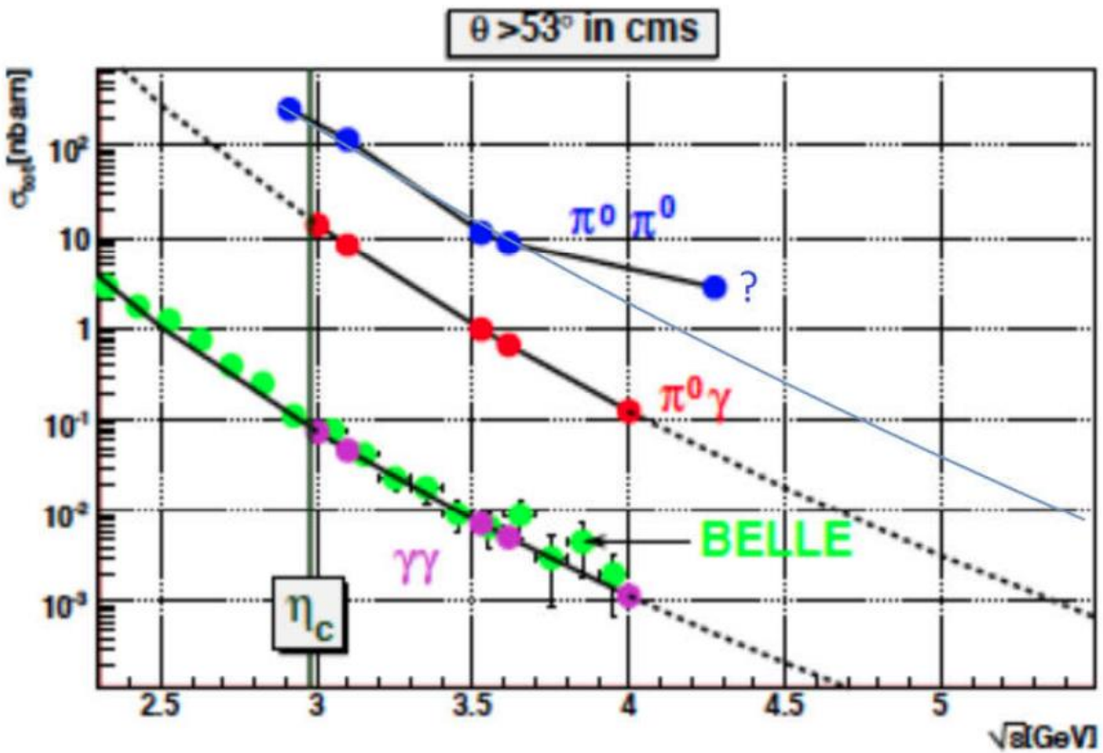
Determining Count Rate Estimate

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





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



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

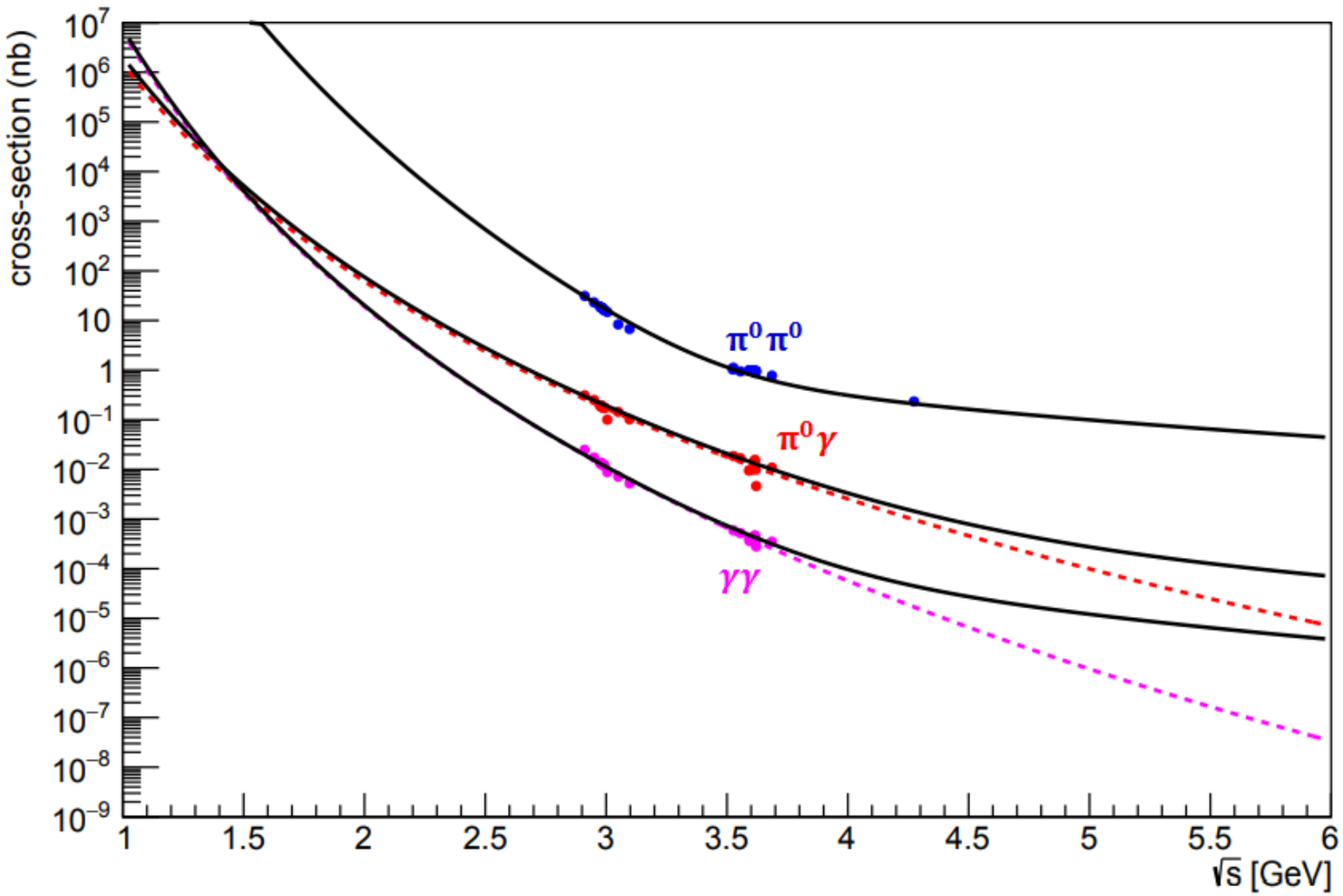
- Estimate the background correctly

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 $2.911 \leq \sqrt{s} \leq 3.686\ \mathrm{GeV}$
- 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.
- If only positive cos(θ) 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.

Cross-sections from E760 Data



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

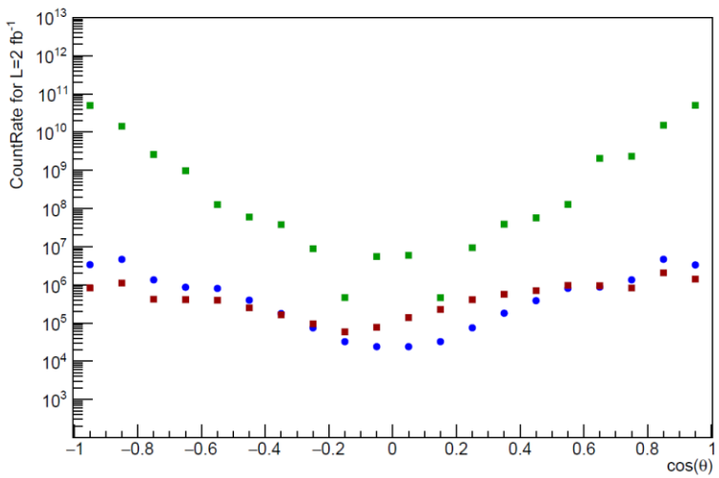
$$\mathbf{f}(x) = \frac{p_1}{x^{p_2}}$$

Count Rate

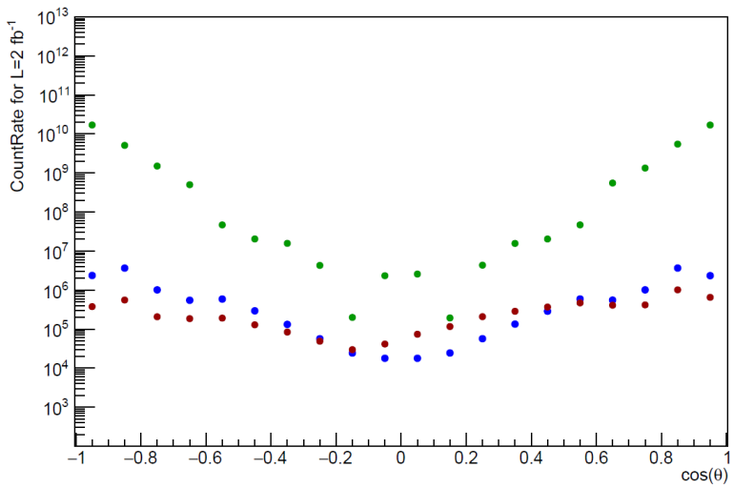
$p\,\bar{p} \rightarrow \gamma\,\gamma$
$p\,\bar{p} \rightarrow \pi^0\,\gamma$
$p\,\bar{p} \rightarrow \pi^0\,\pi^0$

P_{beam}= 2.5 GeV

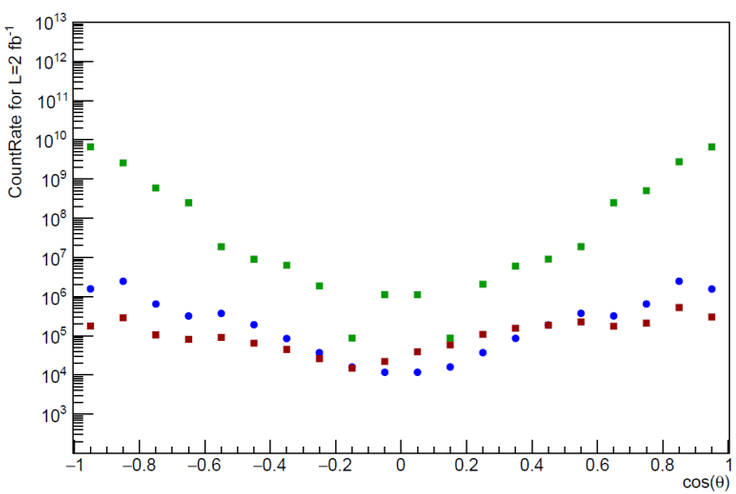
prob > 0.01



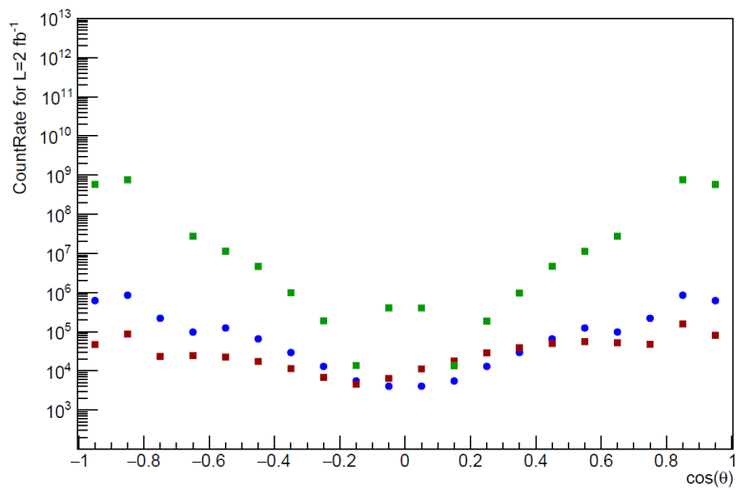
prob > 0.1



prob > 0.3

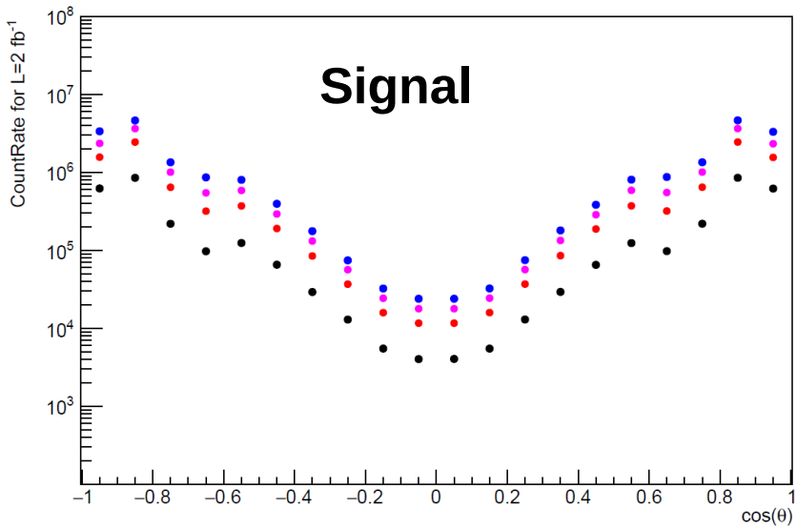


prob > 0.7

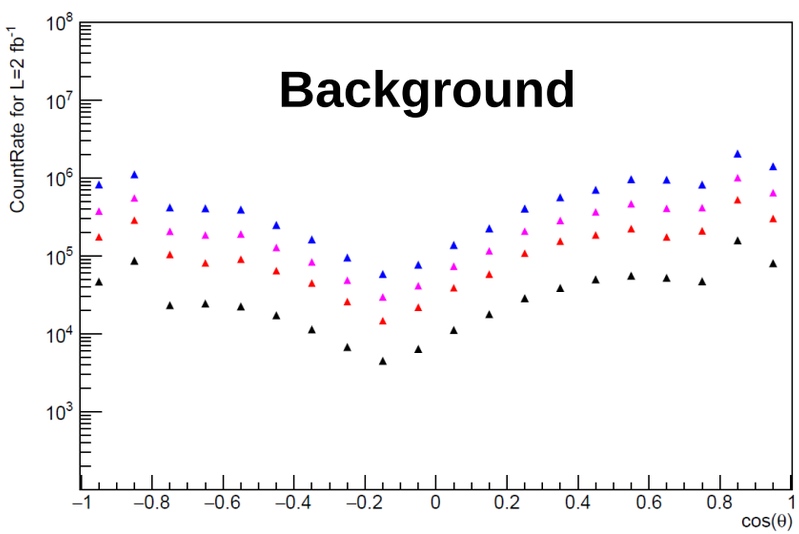


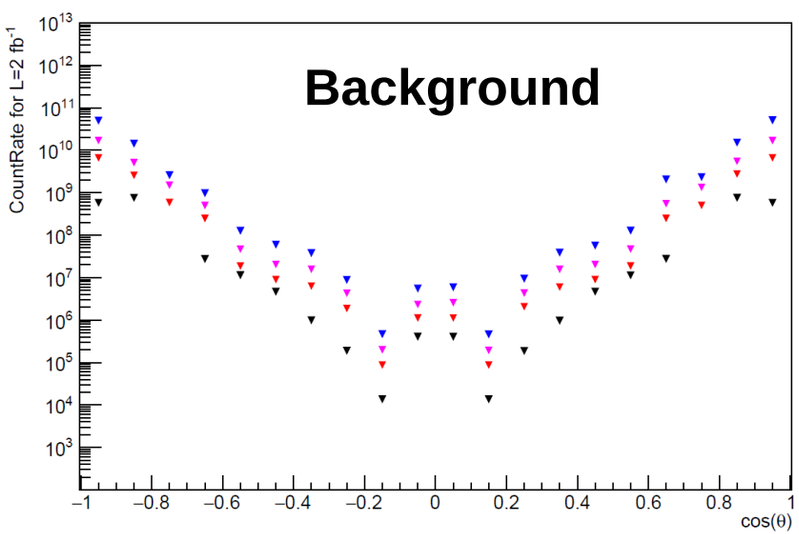
Count Rate

P_{beam}= 2.5 GeV



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



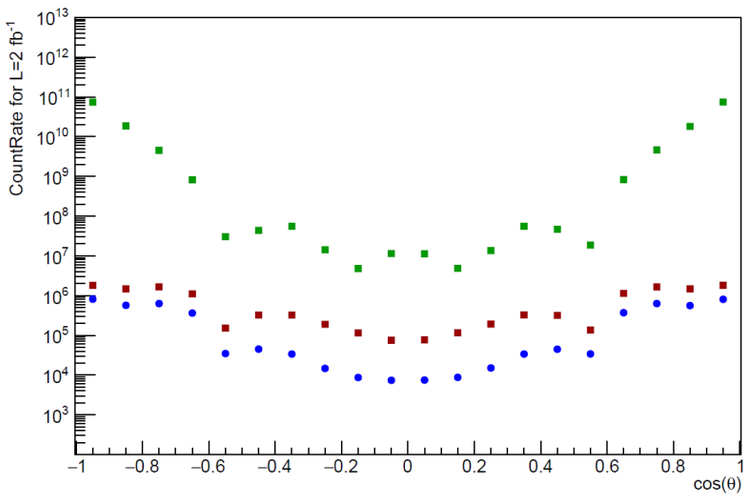


Count Rate

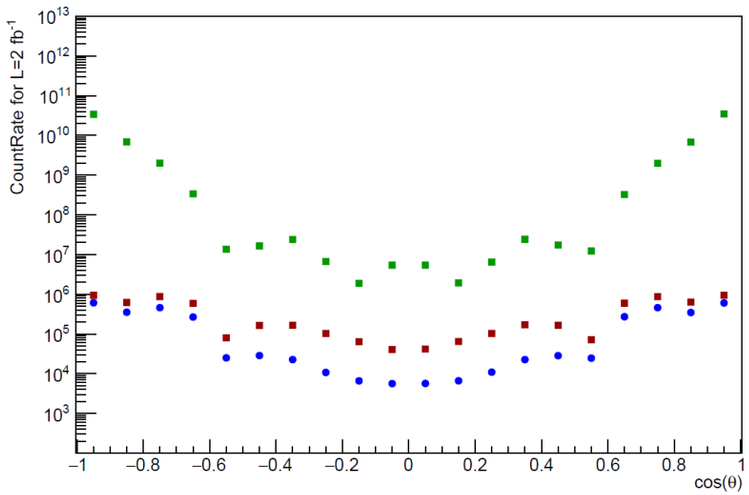
$p\,\bar{p} \rightarrow \gamma\,\gamma$
$p\,\bar{p} \rightarrow \pi^0\,\gamma$
$p\,\bar{p} \rightarrow \pi^0\,\pi^0$

P_{beam}= 5 GeV

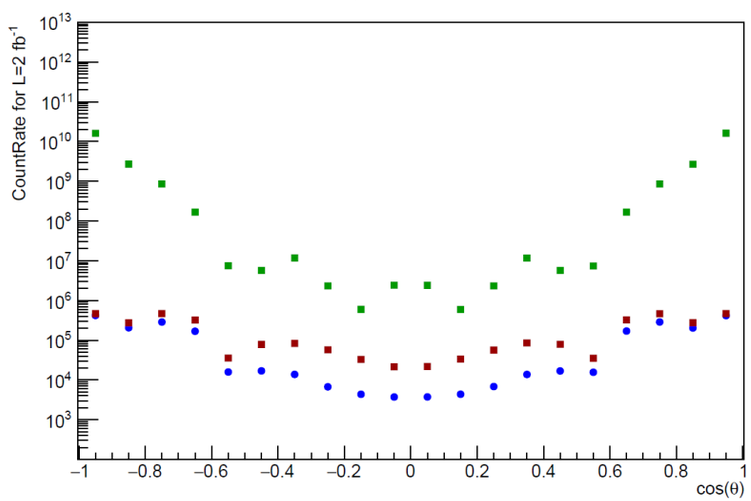
prob > 0.01



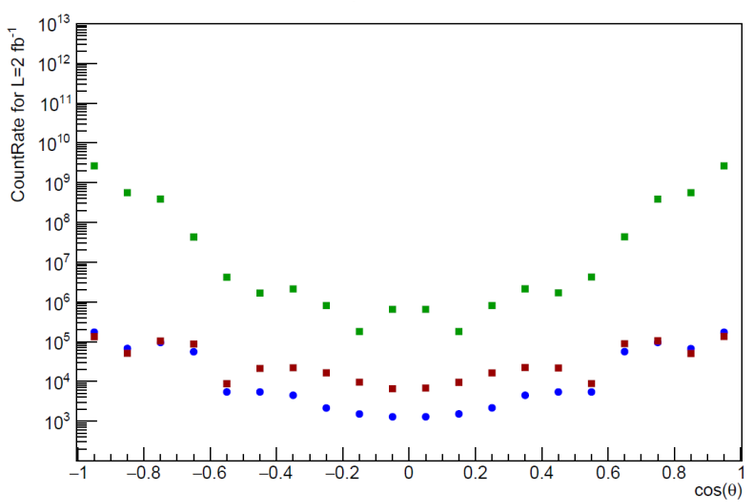
prob > 0.1



prob > 0.3

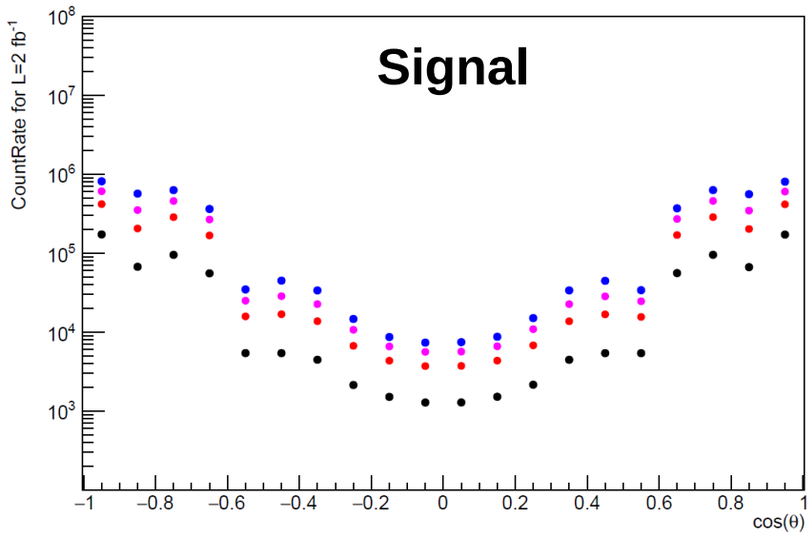


prob > 0.7

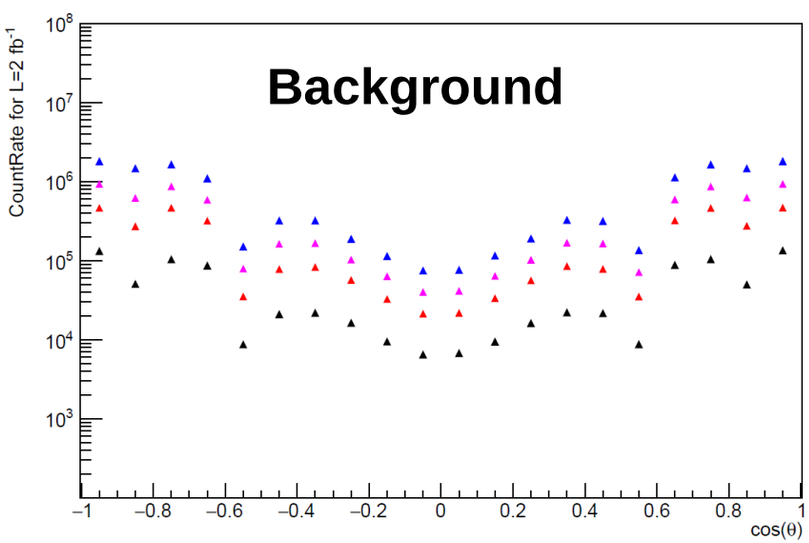


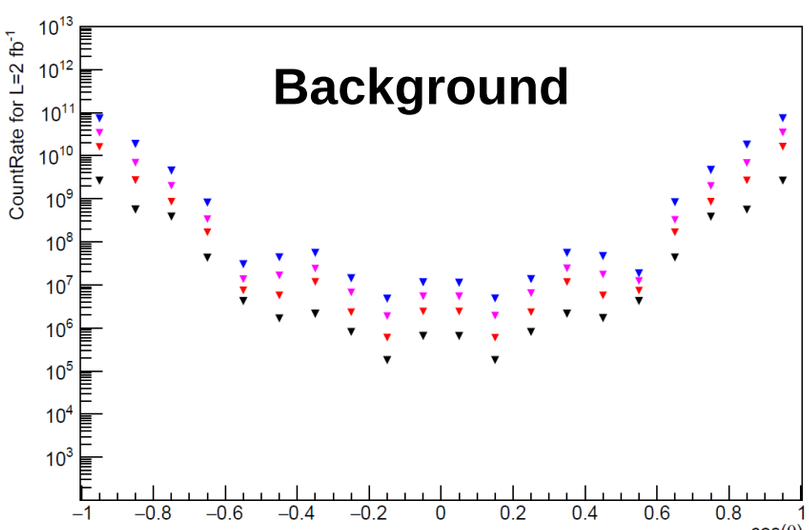
Count Rate

P_{beam}= 5 GeV



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



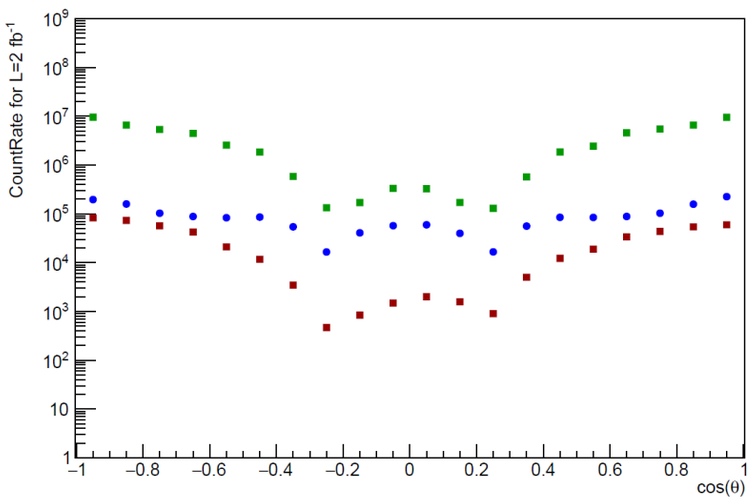


Count Rate

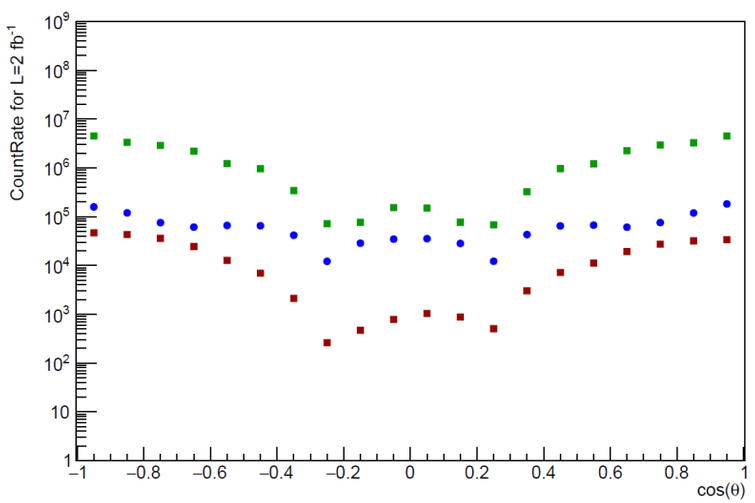
$p\,\bar{p} \rightarrow \gamma\,\gamma$
$p\,\bar{p} \rightarrow \pi^0\,\gamma$
$p\,\bar{p} \rightarrow \pi^0\,\pi^0$

P_{beam}= 10 GeV

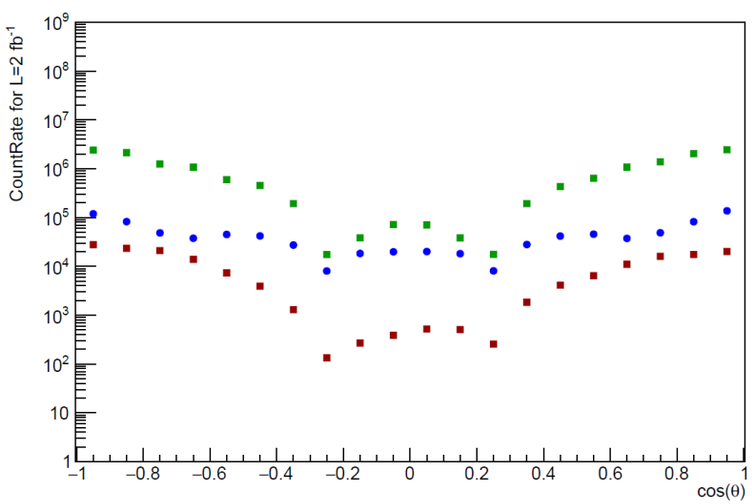
prob > 0.01



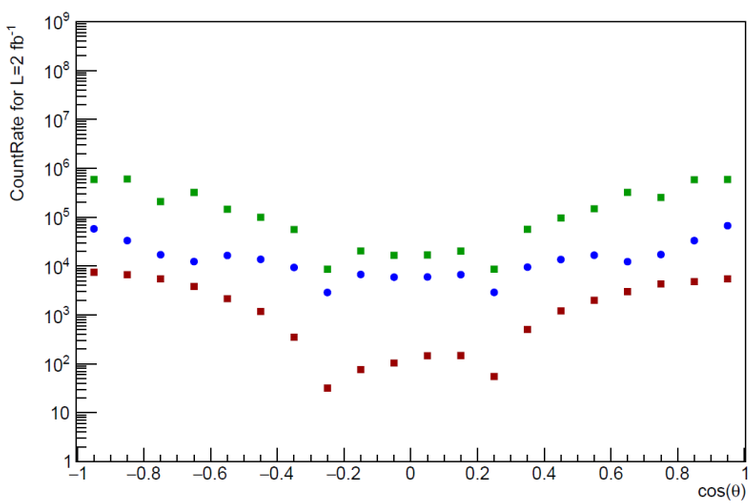
prob > 0.1



prob > 0.3

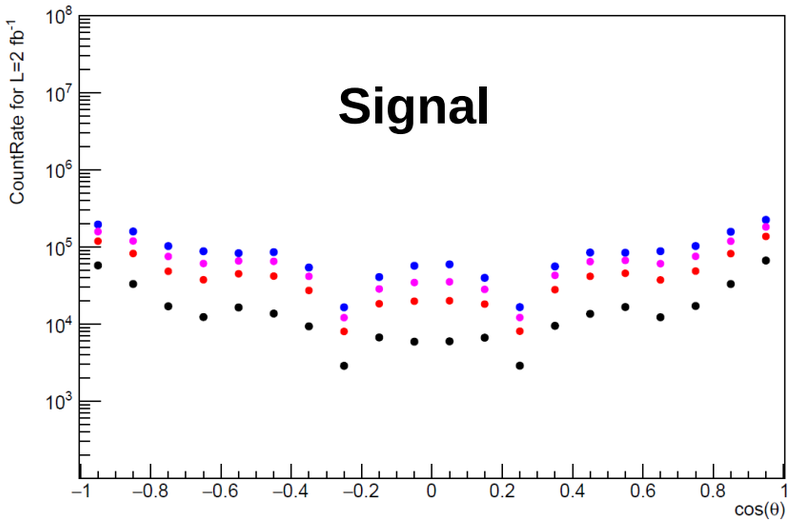


prob > 0.7

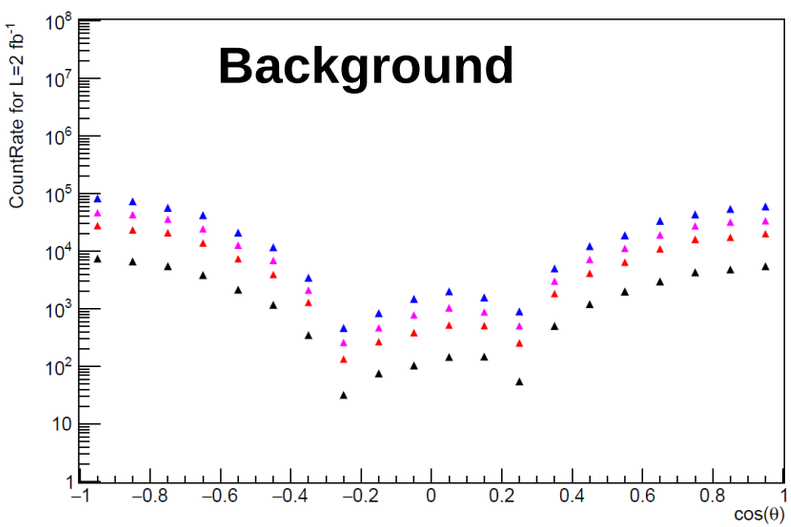


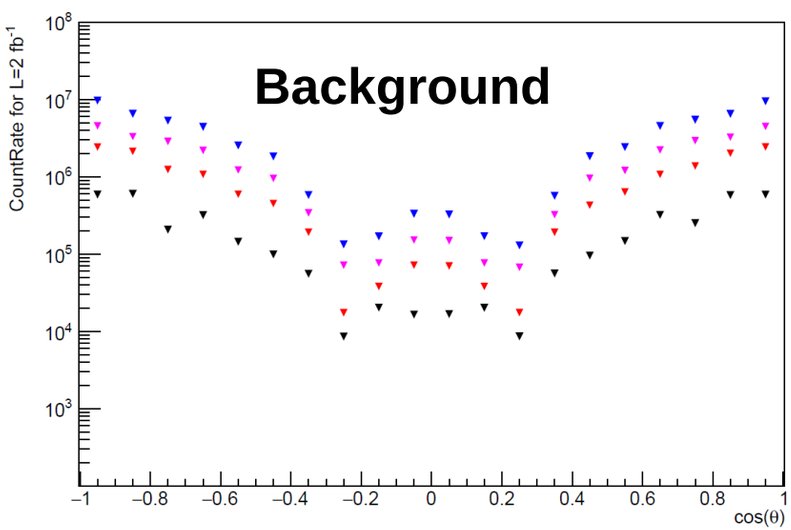
Count Rate

P_{beam}= 10 GeV



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

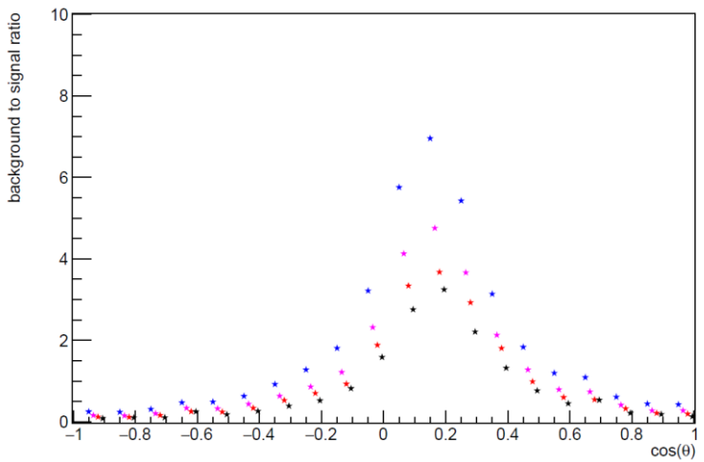


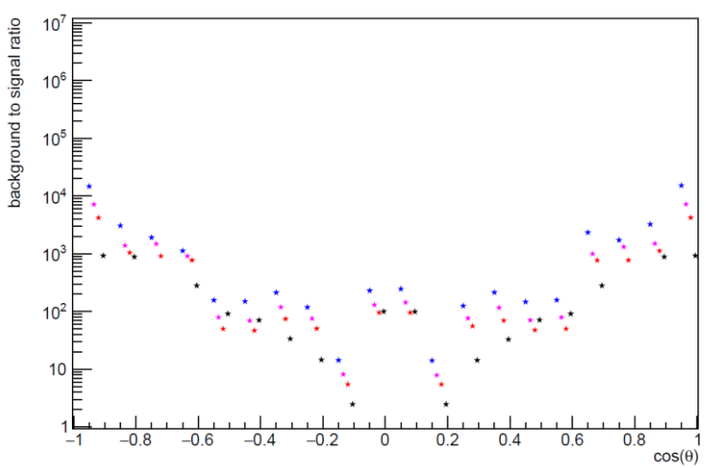


Background to Signal Ratio

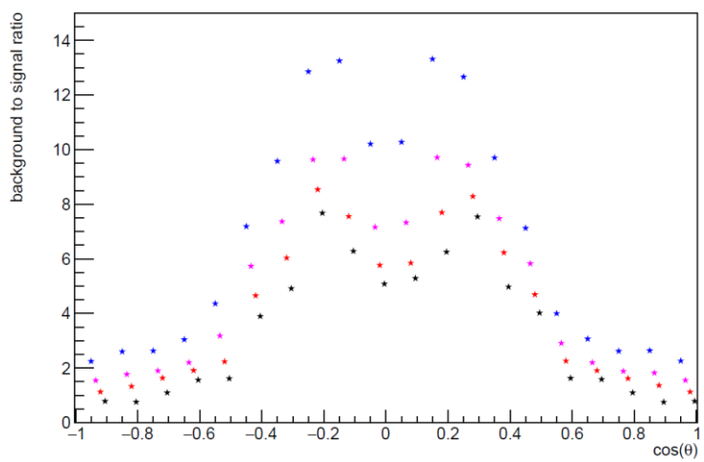
p>0.01
p>0.1
p>0.3
p>0.7

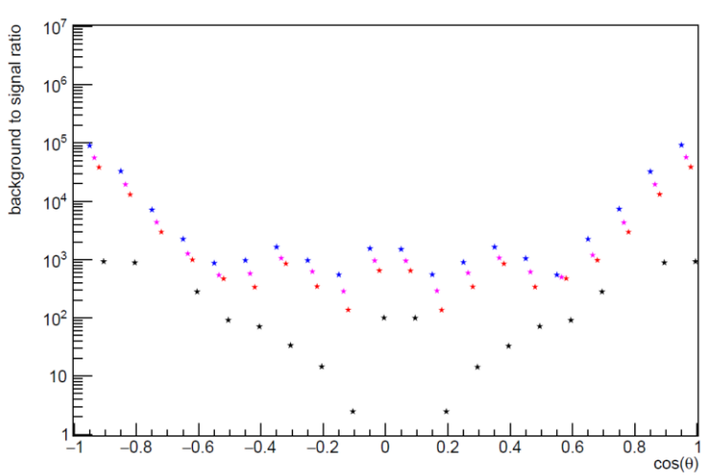
p_{beam}= 2.5 GeV



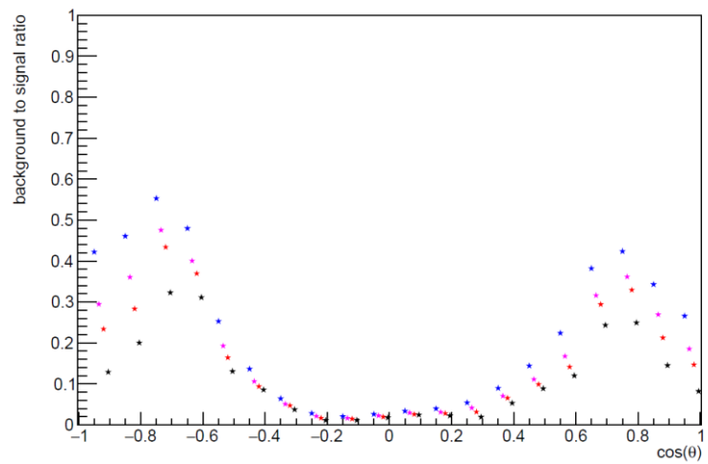


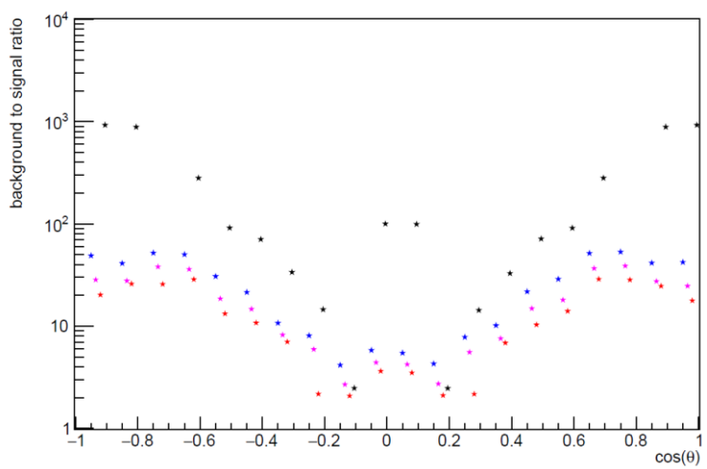
p_{beam}= 5 GeV





p_{beam}= 10 GeV





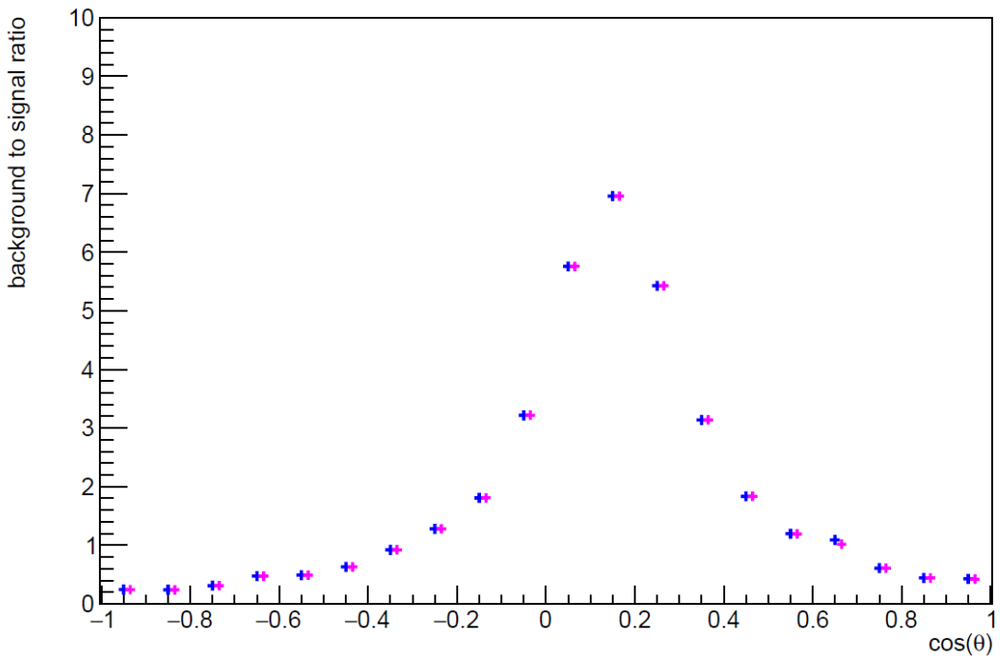
Suppressing the pion background in $p\bar{p} \rightarrow \gamma\,\gamma$ Channel

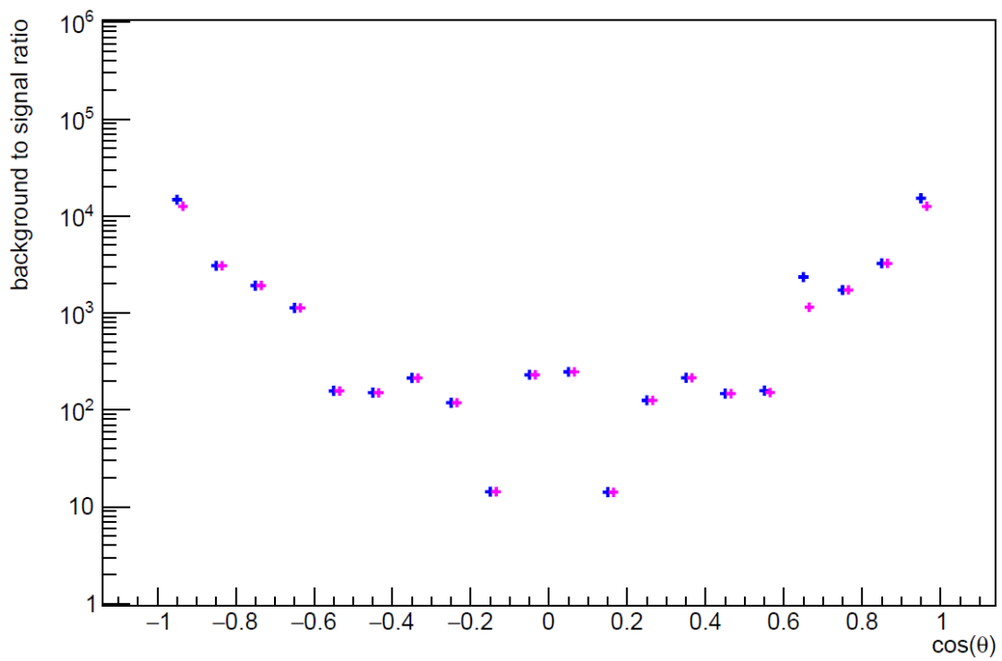
Background Suppression I: Background to Signal Ratio

cuts on angle>178° and $p\bar{p}$ invariant mass ± 3σ

p_{beam}= 2.5 GeV

Before cut
After cut



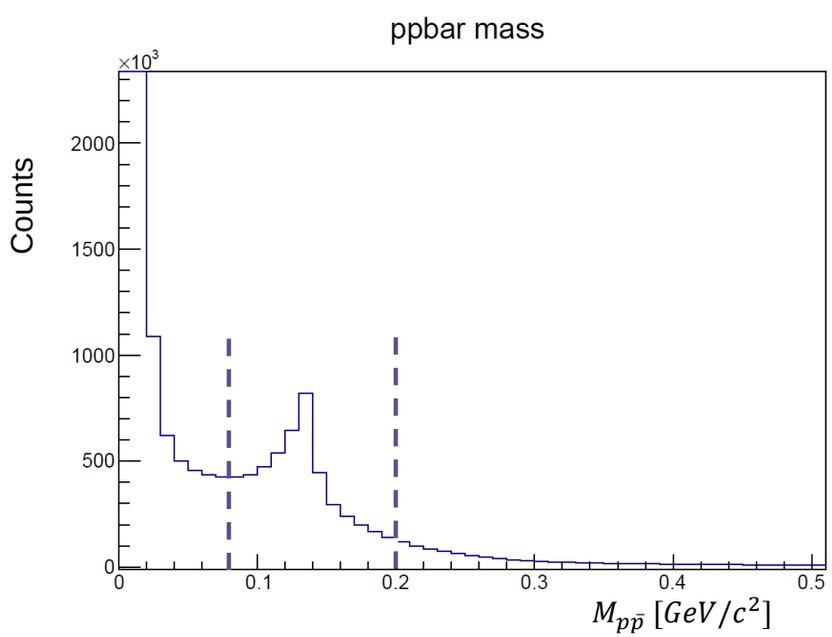


4C kinematic fit already includes this cut and hence, the cuts applied have no additional effect.

Background Suppression II

T. A. Armstrong, Two-body neutral final states produced in antiproton-proton annihilations at $2.911 \leq \sqrt{s} \leq 3.686$ GeV

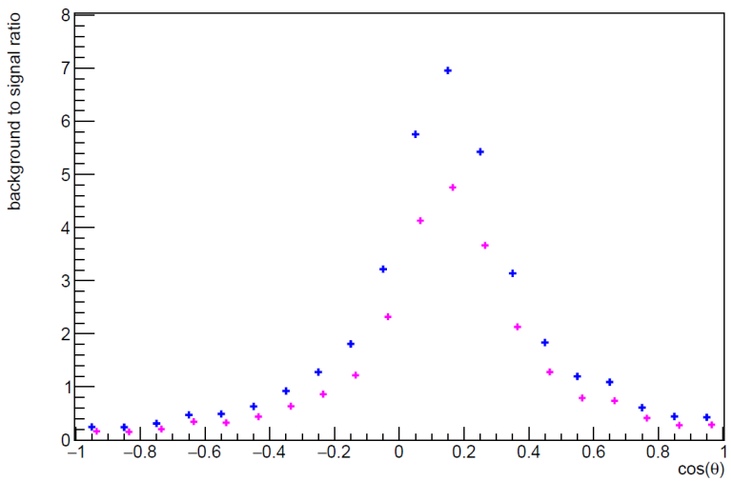
- All calorimeter clusters with energies greater than 50MeV
- Exactly two clusters required to have energies greater than 100MeV
- For cluster pairs, no invariant mass should fall between 80 and 200 MeV/c^2
- 4C kinematic fit is applied and events with confidence level less than 10% are rejected.

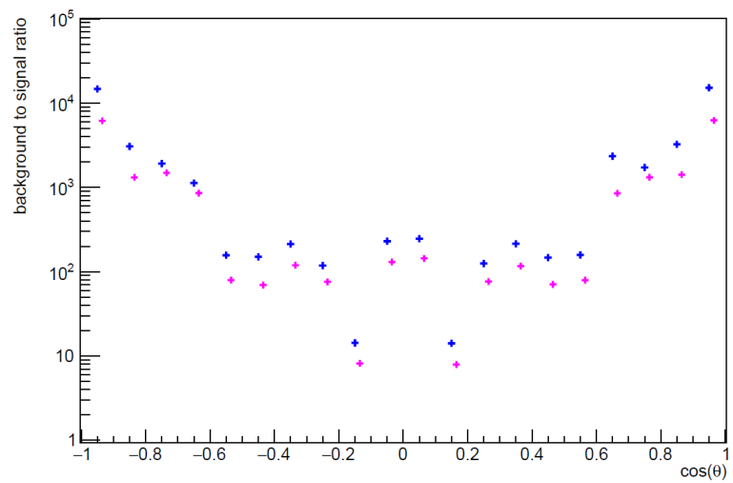


Background to Signal Ratio

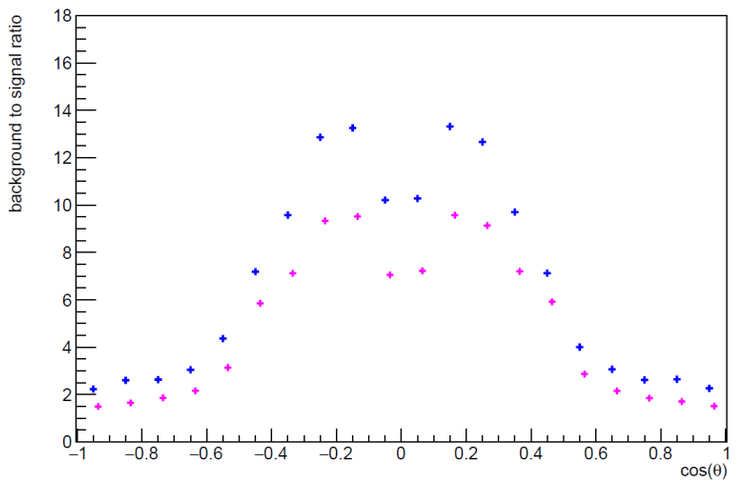
Before cut
After cut

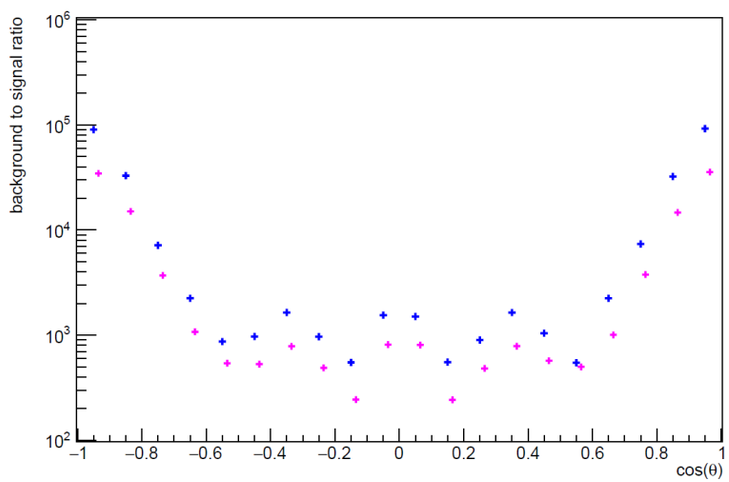
p_{beam}= 2.5 GeV



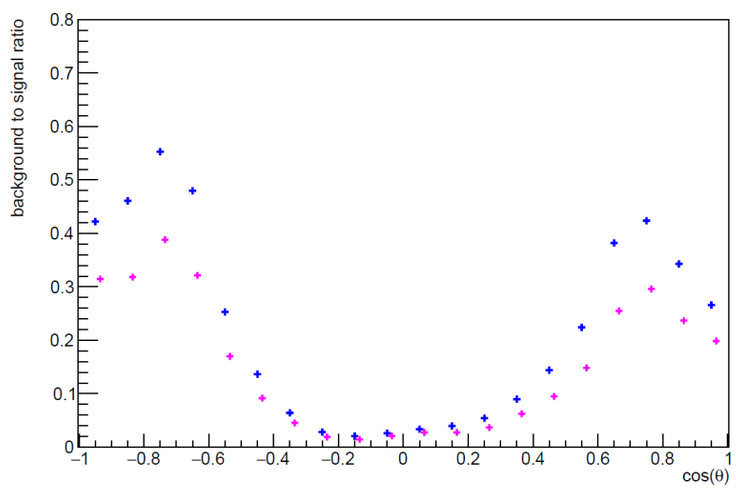


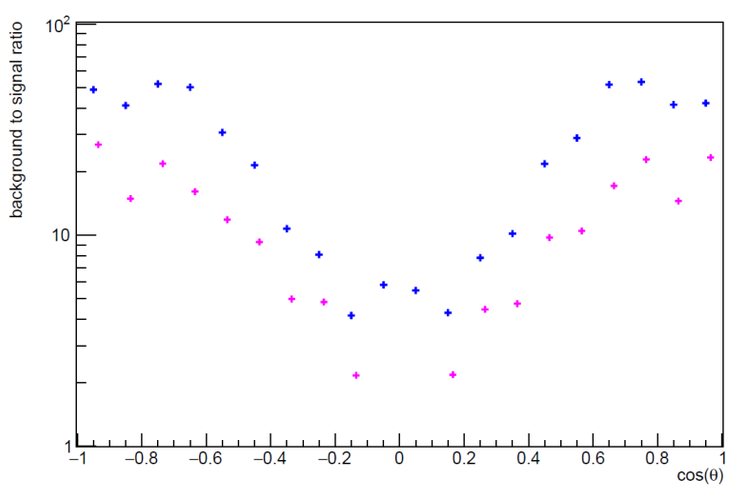
p_{beam}= 5 GeV





p_{beam}= 10 GeV



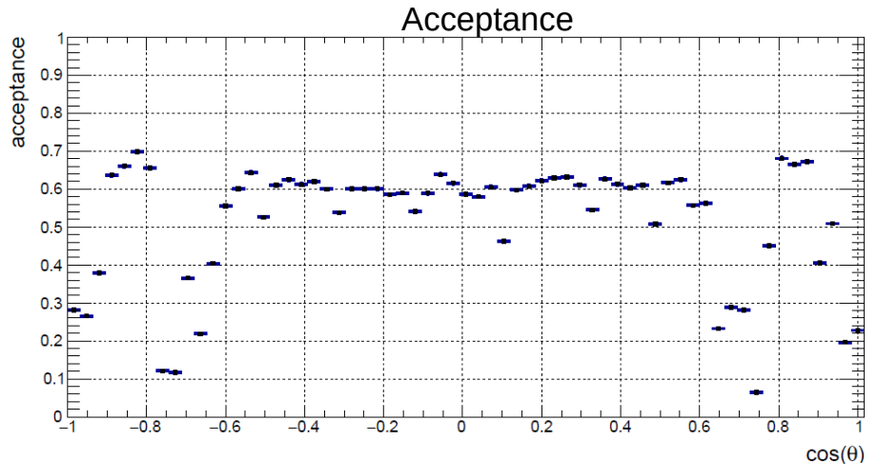


Summary

- Exclusive event selection with 4C kinematic fit was performed
- Acceptance in cos(θ) has been checked
- Acceptance corrections were done
- Simulations have been performed at $\sqrt{s} = 2.6\ GeV$ $p_{beam} = 2.5\ GeV/c$ $\sqrt{s} = 3.4\ GeV$ $p_{beam} = 5\ GeV/c$ $\sqrt{s} = 4.5\ GeV$ $p_{beam} = 10\ GeV/c$
- Integrated cross-sections from E760 data were re-evaluated to better estimate the extrapolation to higher momenta and its uncertainty.
- The cos(θ) dependence of the cross-section has been implemented and a reconstruction study has been performed
- Count rate estimates and background to signal ratio was determined for the decay channel $\bar{p}p \to \gamma\ \gamma$ for beam momentum of 2.5, 5 and 10 GeV/c
- Background to signal ratio was determined for the decay channel $\bar{p}p \to \gamma\gamma$ by suppressing background at different beam momenta.
- Refine cuts to further reduce background and increase signal efficiency in progress
- Continuation of study at 15 GeV/c beam momentum.

Thank You For Your Attention!

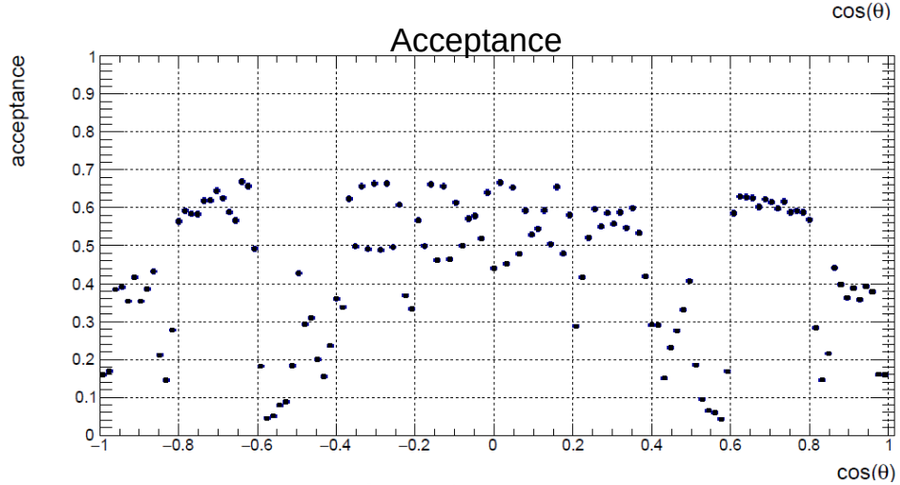
2.5 GeV/c



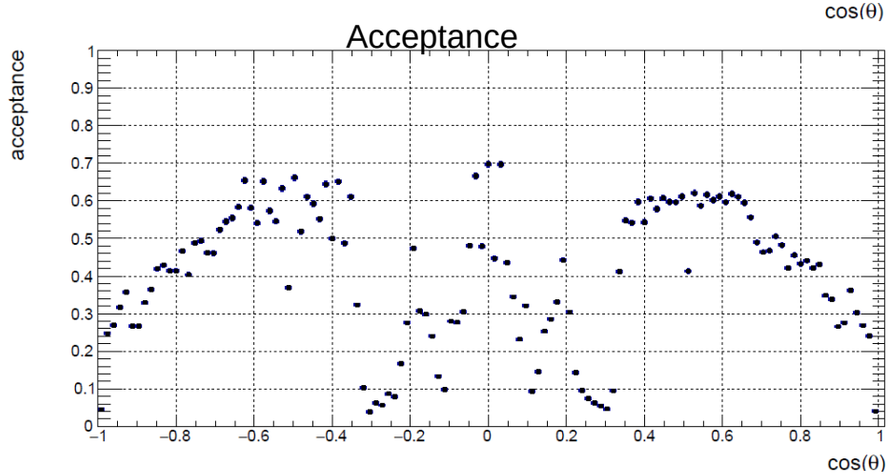
$$A = \frac{N_{rec}}{N_{gen}}$$

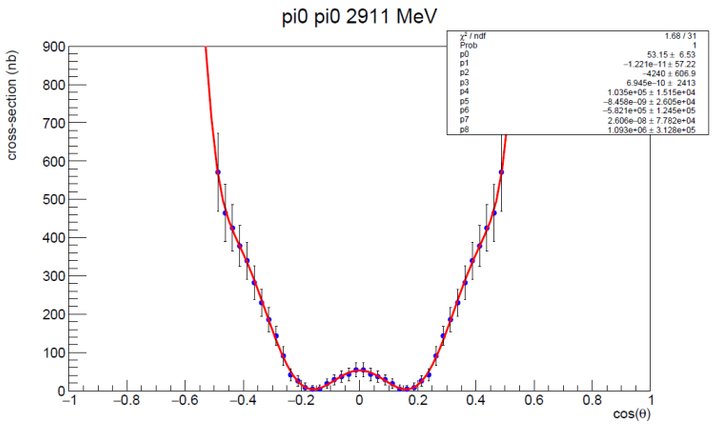
$$A_{corr} = \frac{N_{rec}}{A}$$

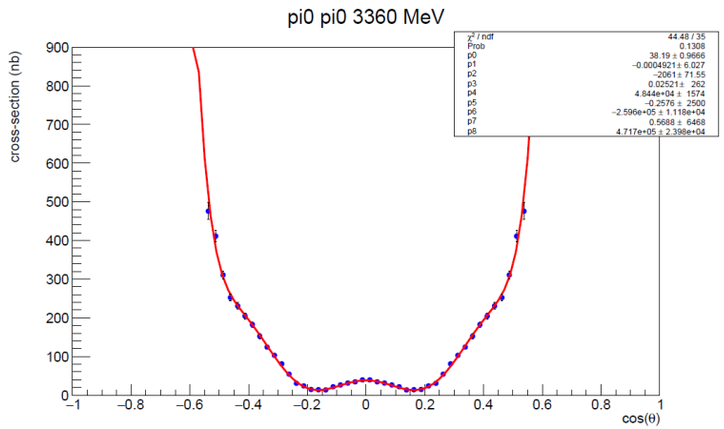
5 GeV/c

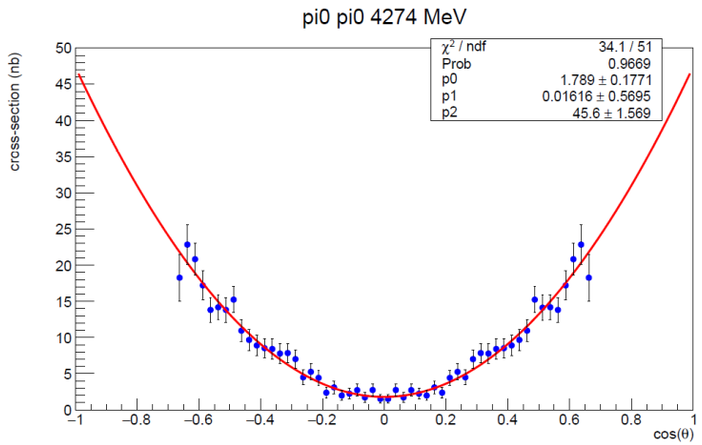


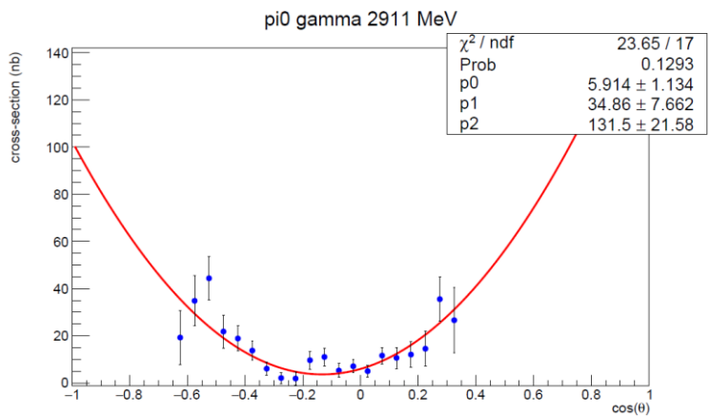
10 GeV/c

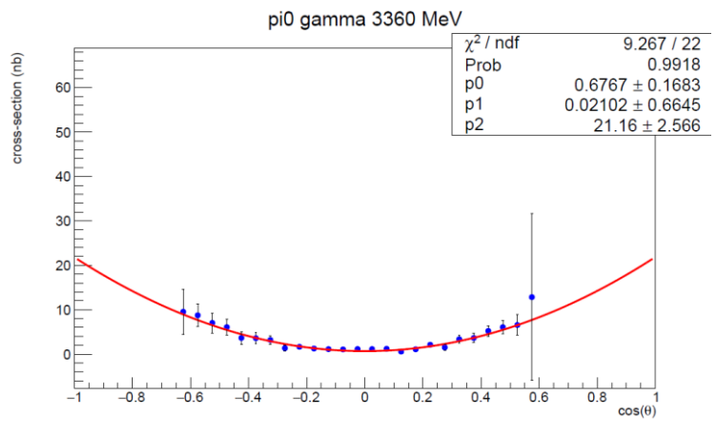


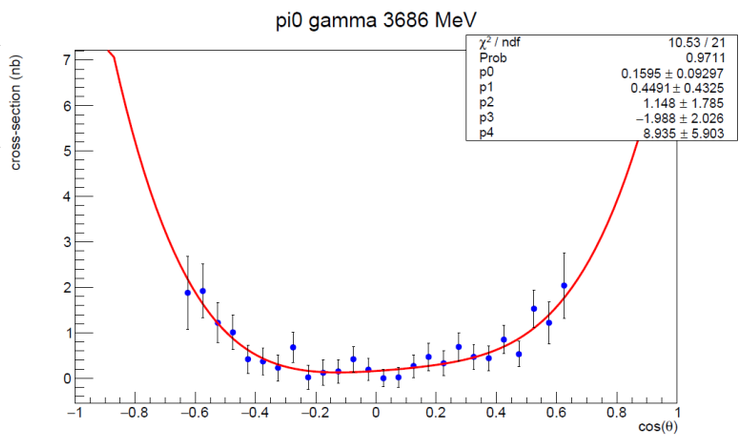

pi0 pi0 2911 MeV
cross-section (nb)
cos(θ)

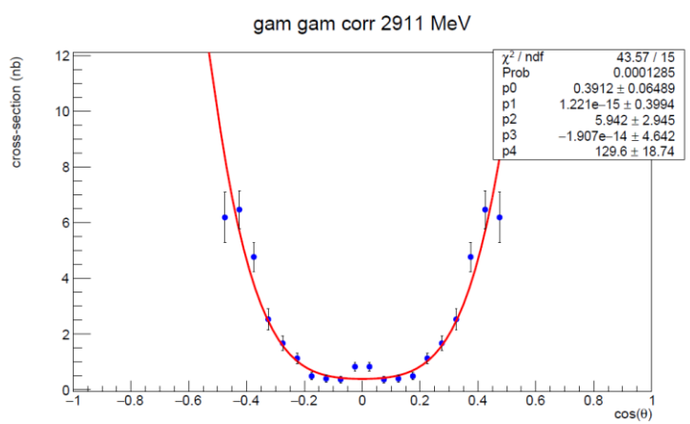

pi0 pi0 3360 MeV
cross-section (nb)
cos(θ)

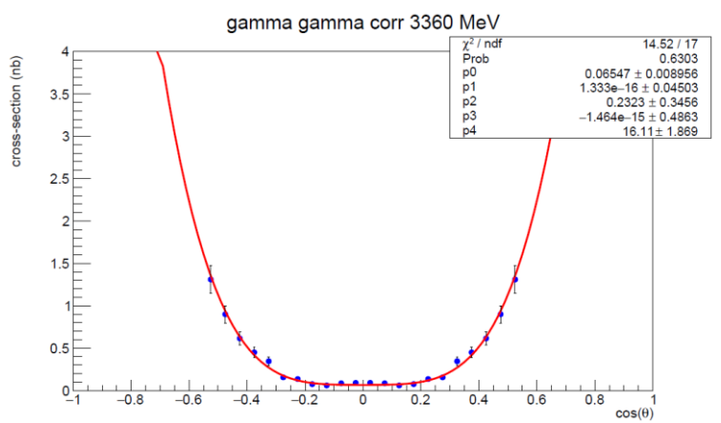

pi0 pi0 4274 MeV
χ² / ndf 34.1 / 51
Prob 0.9669
p0 1.789 ± 0.1771
p1 0.01616 ± 0.5695
p2 45.6 ± 1.569
cross-section (nb)
cos(θ)

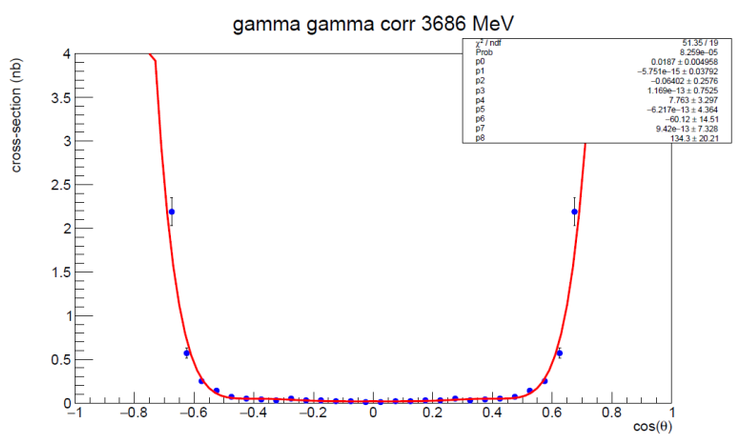

pi0 gamma 2911 MeV
χ² / ndf 23.65 / 17
Prob 0.1293
p0 5.914 ± 1.134
p1 34.86 ± 7.662
p2 131.5 ± 21.58
cross-section (nb)
cos(θ)


pi0 gamma 3360 MeV
χ² / ndf 9.267 / 22
Prob 0.9918
p0 0.6767 ± 0.1683
p1 0.02102 ± 0.6645
p2 21.16 ± 2.566
cross-section (nb)
cos(θ)


pi0 gamma 3686 MeV
χ² / ndf 10.53 / 21
Prob 0.9711
p0 0.1595 ± 0.09297
p1 0.4491 ± 0.4325
p2 1.148 ± 1.785
p3 −1.988 ± 2.026
p4 8.935 ± 5.903
cross-section (nb)
cos(θ)


gam gam corr 2911 MeV
χ² / ndf 43.57 / 15
Prob 0.0001285
p0 0.3912 ± 0.06489
p1 1.221e−15 ± 0.3994
p2 5.942 ± 2.945
p3 −1.907e−14 ± 4.642
p4 129.6 ± 18.74
cross-section (nb)
cos(θ)


gamma gamma corr 3360 MeV
χ² / ndf 14.52 / 17
Prob 0.6303
p0 0.06547 ± 0.008956
p1 1.333e−16 ± 0.04503
p2 0.2323 ± 0.3456
p3 −1.464e−15 ± 0.4863
p4 16.11 ± 1.869
cross-section (nb)
cos(θ)


gamma gamma corr 3686 MeV
cross-section (nb)
cos(θ)