PANDA collaboration meeting

June 23, 2020

Accessing Generalized Distribution Amplitudes with PANDA

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Physics Motivation

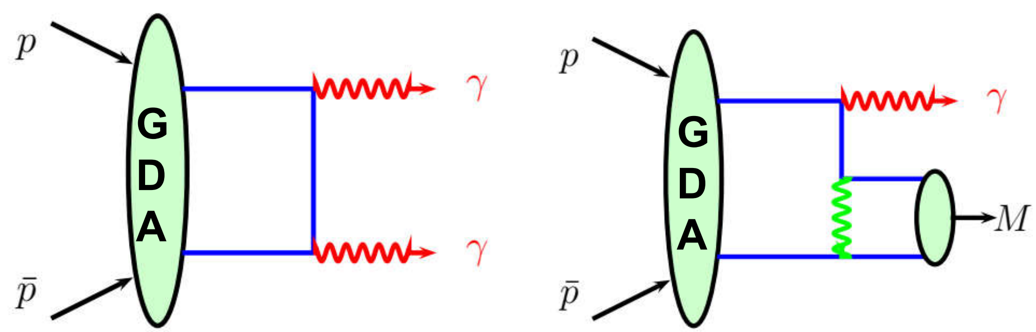
$p\bar{p} \rightarrow \gamma M$ at large Mandelstamm variables $s, -t, -u \gg \Lambda^2$

process amplitudes factorizes:

hard partonic subprocesses + annihilation form factor

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

PANDA



Theoretical work and possible channels

Theoretical work for baryon-antibaryon GDAs:

- P. Kroll, A. Schäfer, The process $p\,\bar{p} \rightarrow \gamma\,\pi^0$ within the handbag approach, The European Physical Journal A 26, 89-98 (2005)
- P. Kroll, A. Schäfer, Probing moments of baryon-antibaryon generalized parton distributions at BELLE and FAIR, The European Physical Journal A 50, 1 (2014)

possible channels: $p\;\bar{p} \rightarrow \gamma\;\gamma$ $\quad p\;\bar{p} \rightarrow \gamma\;\pi^0$

$p\;\bar{p} \rightarrow \gamma\;\eta$ $\quad p\;\bar{p} \rightarrow \gamma\;\rho$ $\quad p\;\bar{p} \rightarrow \gamma\;\omega$ $\quad p\;\bar{p} \rightarrow \gamma\;\eta`$

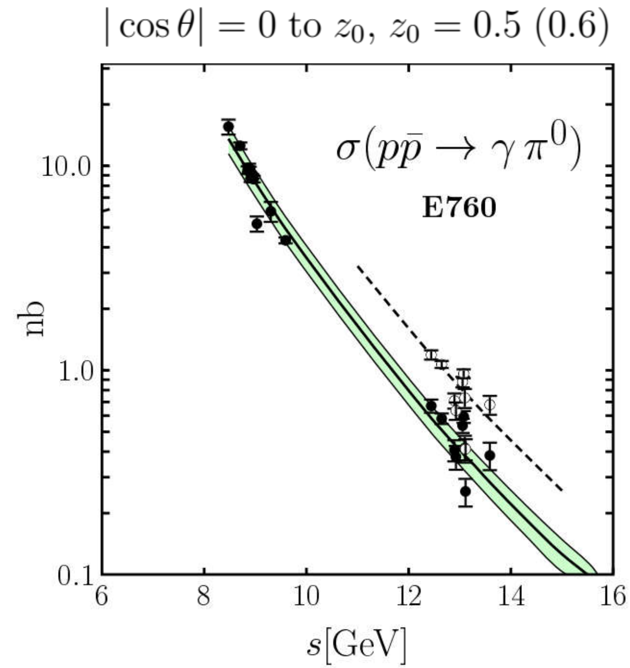
$p\;\bar{p} \rightarrow \gamma\;\phi$ $\quad p\;\bar{p} \rightarrow \gamma\;J/\psi$ + other charmonium states

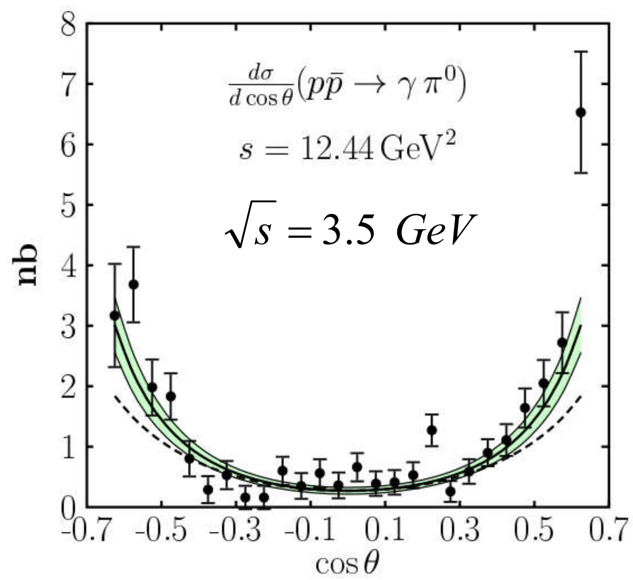
Phenomenology

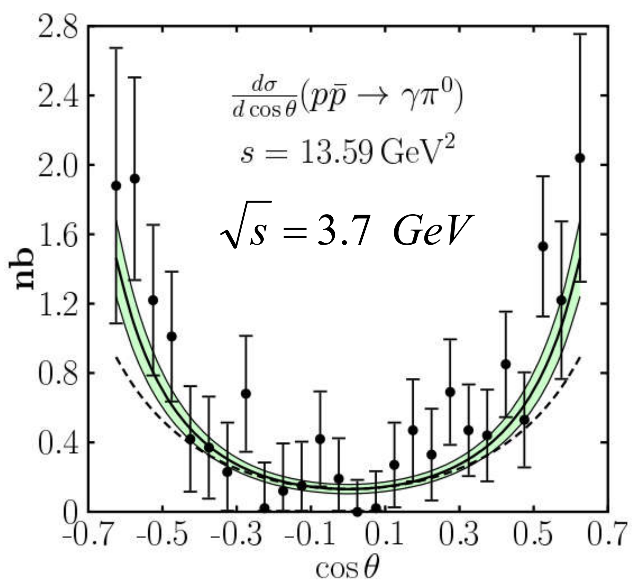
$$p\ \bar{p} \rightarrow \gamma\ \pi^0$$

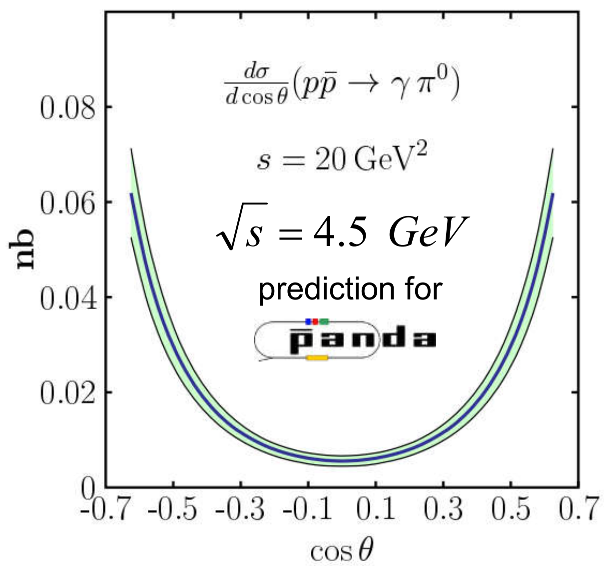
P. Kroll, A. Schäfer, The process p p → γ π^0 within the handbag approach, The European Physical Journal A 26, 89-98 (2005)

➔ Process at small s measured with the E760 experiment at Fermilab









Phenomenology

P. Kroll, A. Schäfer, The European Physical Journal A 50, 1 (2014)

$$\frac{d\sigma/dt(p\bar{p}\to\gamma\eta)}{d\sigma/dt(p\bar{p}\to\gamma\pi^0)} = \cos^2\Phi_P\Big[\frac{f_q\langle 1/\tau\rangle_{\eta_q}}{f_\pi\langle 1/\tau\rangle_\pi}\,\frac{e_u+e_d\rho_d}{e_u-e_d\rho_d}\Big]^2\,|1-\kappa_P\tan\Phi_P|^2$$

$$\frac{d\sigma/dt(p\bar{p}\to\gamma\eta')}{d\sigma/dt(p\bar{p}\to\gamma\eta)} = \tan^2\Phi_P\left|\frac{1+\kappa_P\cot\Phi_P}{1-\kappa_P\tan\Phi_P}\right|^2 \qquad \kappa_P = \sqrt{2}\,\frac{f_s\langle 1/\tau\rangle_{\eta_s}}{f_q\langle 1/\tau\rangle_{\eta_q}}\,\frac{e_s\rho_s}{e_u+e_d\rho_d}$$

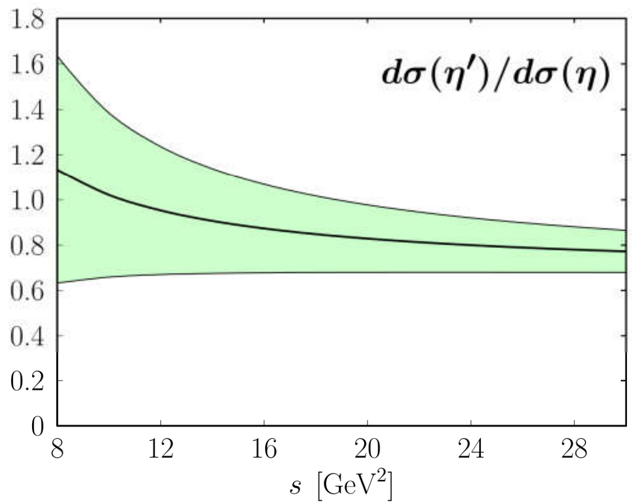
Annihilation form factor: $R_i^\gamma(p\bar{p}) = e_u^2F_i^u + e_d^2F_i^d + e_s^2F_i^s$

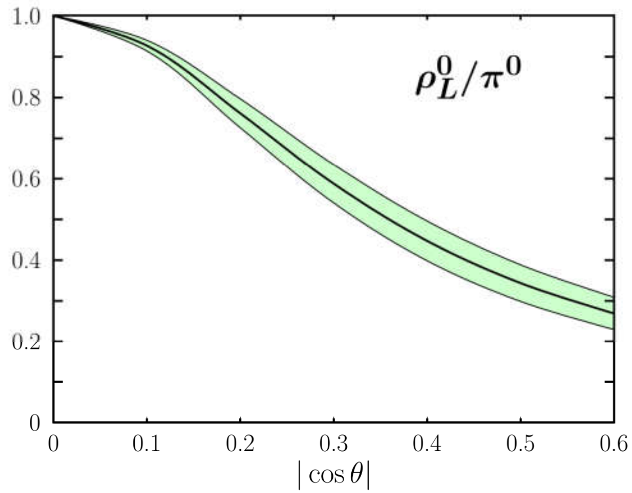
$$F_i^d = \rho_d\,F_i^u \qquad F_i^s = \rho_s\,F_i^u$$

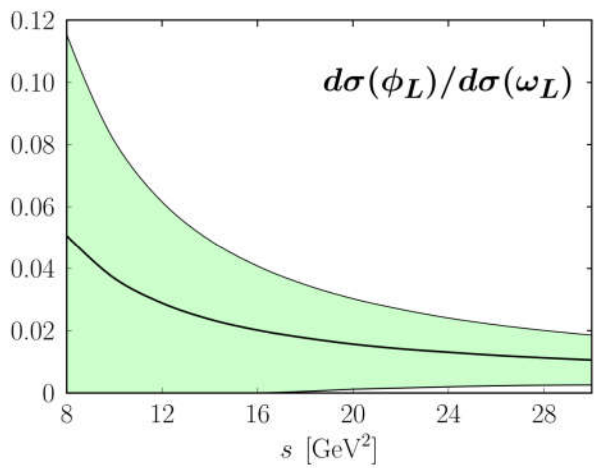
➔ Cross section ratios are independent on the scattering angle

➔ The annihilation form factors can be estimated by a fit to BELLE, L3 and CLEO data for the reactions $\gamma\gamma\to\Lambda\overline{\Lambda}$ and $\gamma\gamma\to\Sigma^0\overline{\Sigma}^0$

Phenomenology





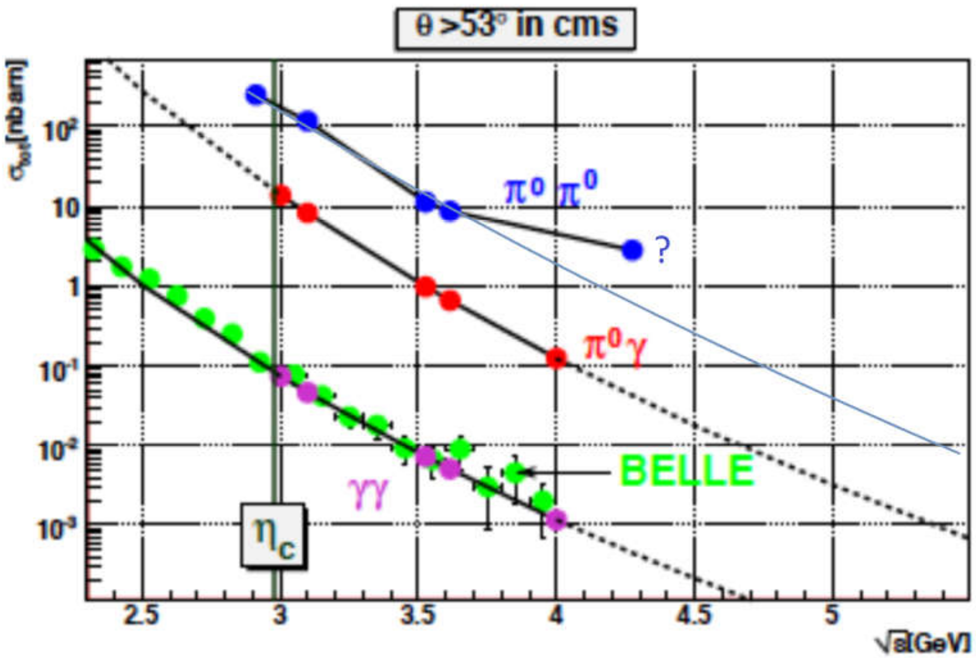


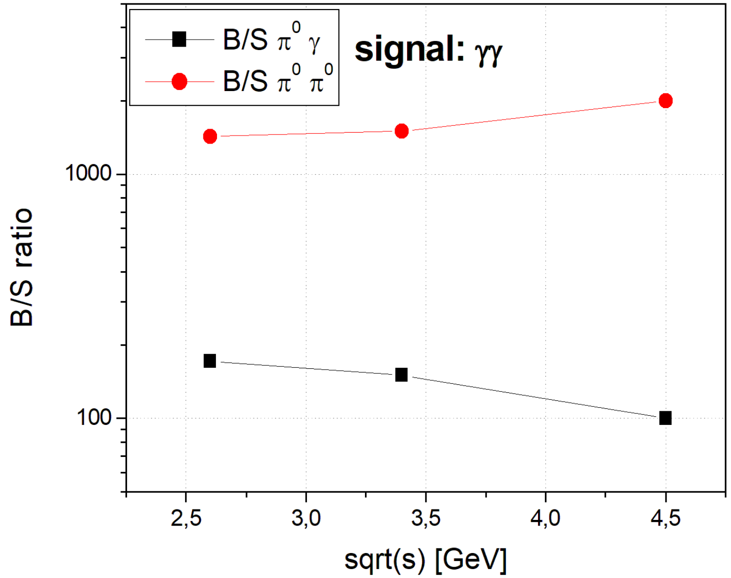
➔ Large error range due to the uncertainty of the available data from BELLE, L3 and CLEO + the included assumptions

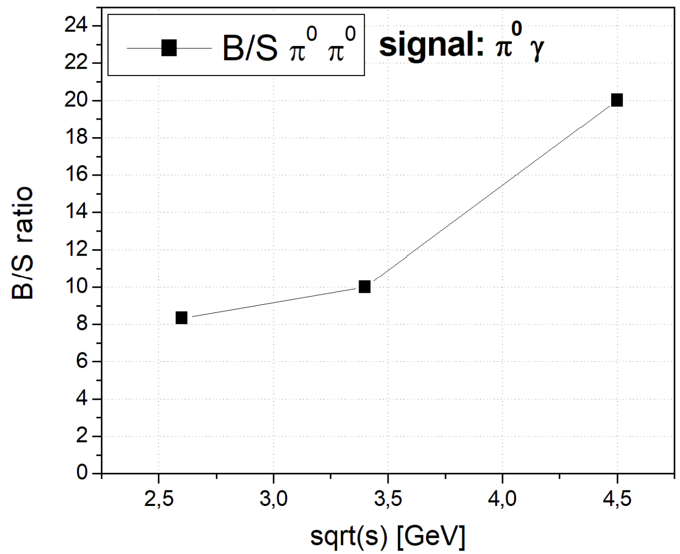
➔ For a reliable extraction of the annihilation form factors and the GDAs the cs for a set of mesons has to be measured and a global fit has to be performed

Cross sections and backgrounds

The process $\gamma\gamma \to B\overline{B}$ measured at BELLE can be used together with symmetry relations to predict the cross sections of $p\ \overline{p} \to \gamma\ \gamma$







Feasibility studies

➔ A phase space simulation has been perfromed for a set of mesons

➔ Exclusive events have been selected with a 5C kinematic fit and a cut on the invariant mass of the meson

➔ For each meson the background has been estimated (for equal cross section)

➔ The acceptance in cos(θ) has been checked

➔ The cos(θ) dependence of the cross section has been implemented and a reconstruction study has been performed

➔ Simulations have been perfomed at

$\sqrt{s} = 2.6\ GeV$	$\sqrt{s} = 3.4\ GeV$	$\sqrt{s} = 4.5\ GeV$
p_{beam} = 2.5 GeV	**p_{beam} = 5.0 GeV**	**p_{beam} = 10 GeV**

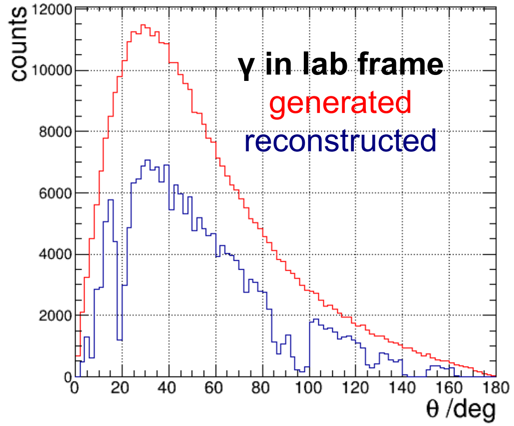
➔ The following reactions have been studied: $p\ \bar{p} \rightarrow \gamma\ \gamma$

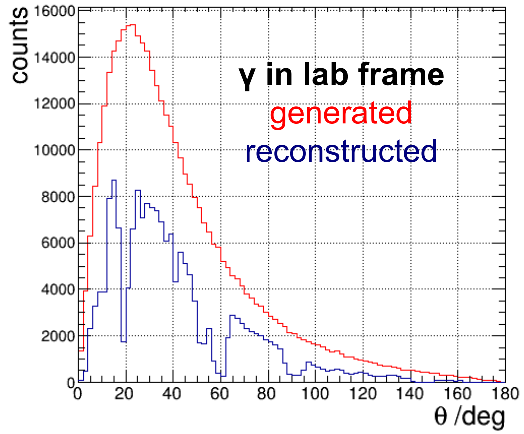
$p\ \bar{p} \rightarrow \gamma\ \pi^0$ $p\ \bar{p} \rightarrow \gamma\ \eta$ $p\ \bar{p} \rightarrow \rho\gamma$ $p\ \bar{p} \rightarrow \omega\gamma$

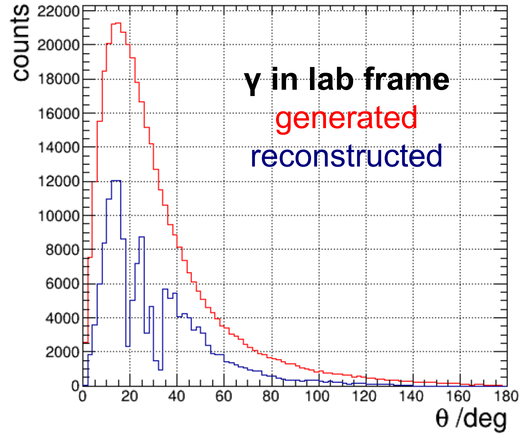
$p\ \bar{p} \rightarrow \gamma\ \phi$ $p\ \bar{p} \rightarrow \gamma\ J/\psi$

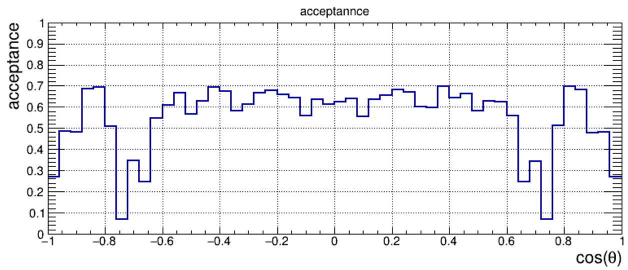
$p\ \bar{p} \rightarrow \gamma\ \gamma$

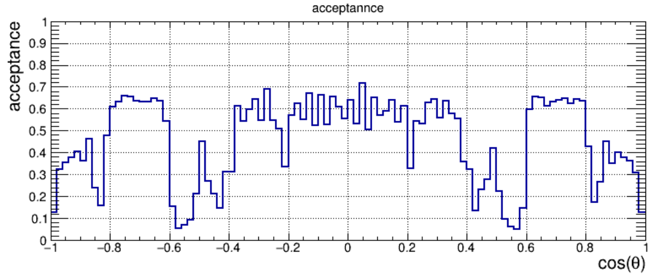
2.5 GeV | **5 GeV** | **10 GeV**

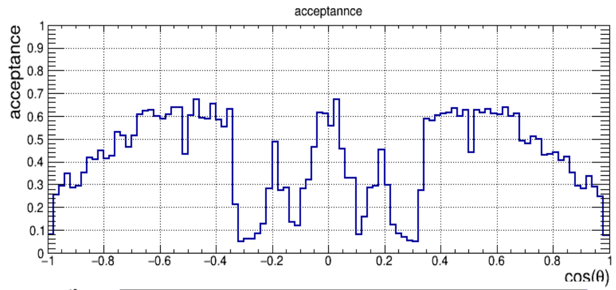


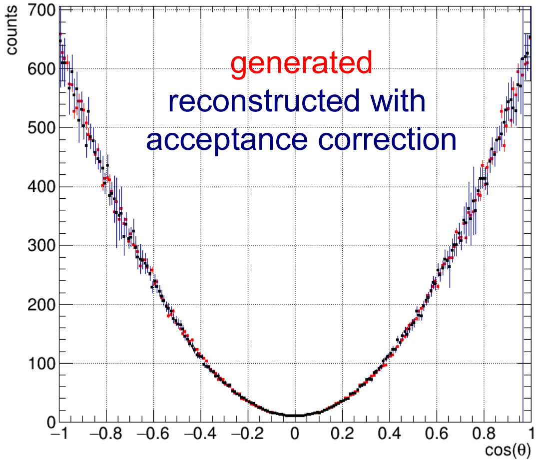


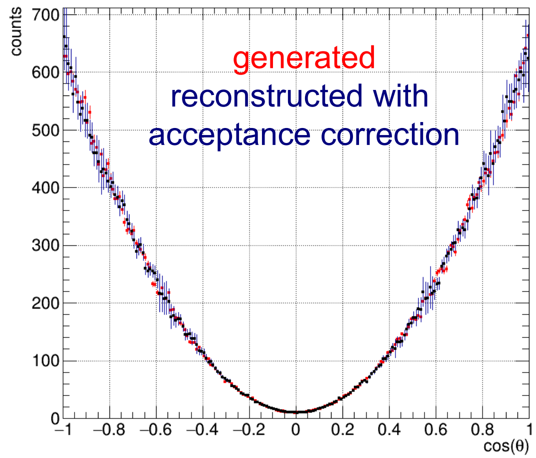


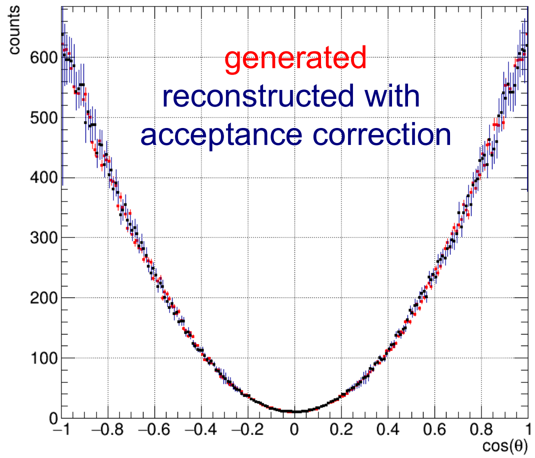






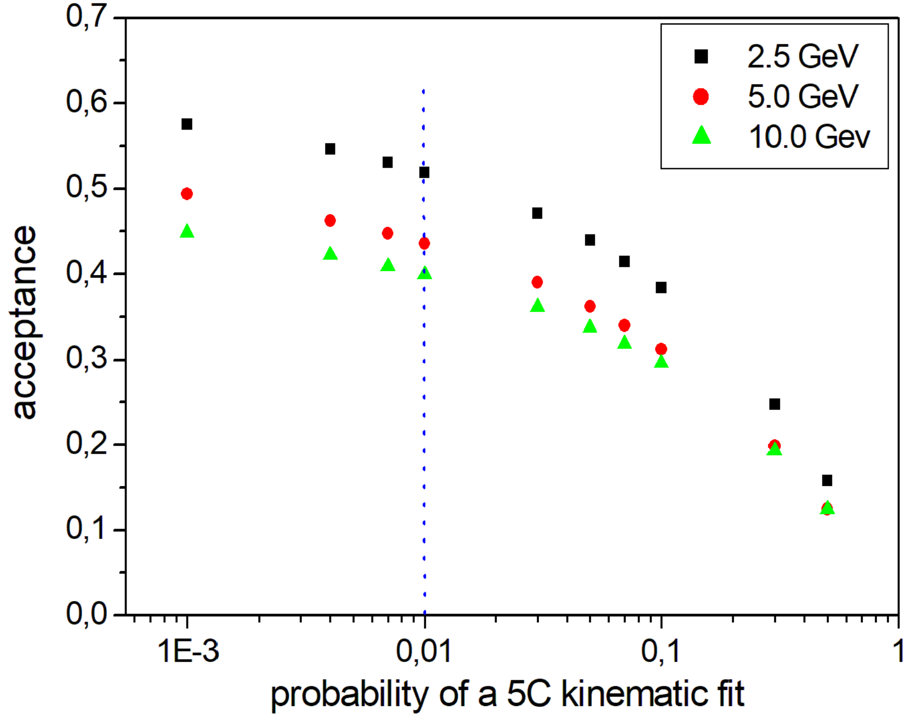


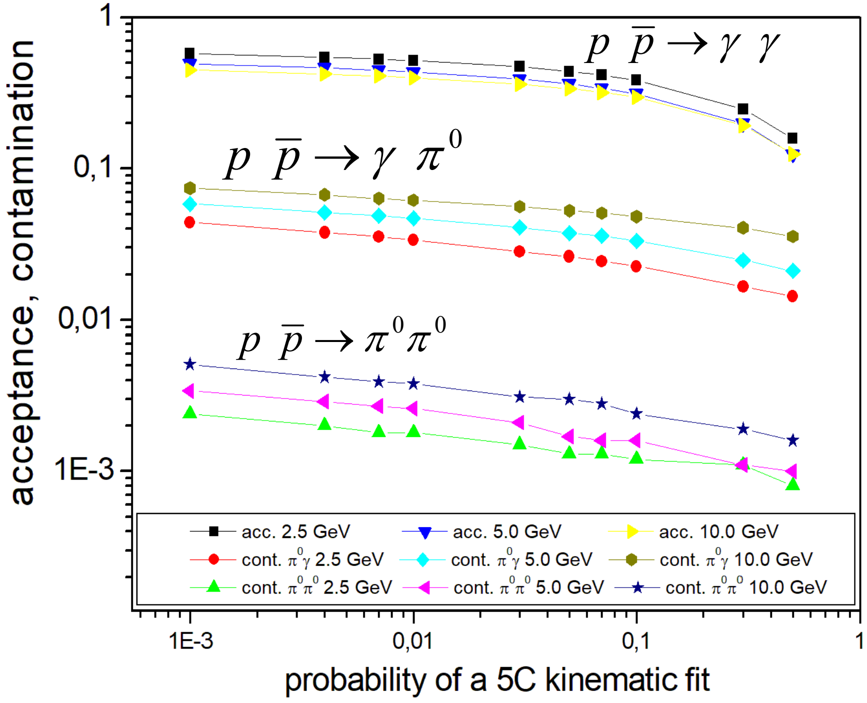




$p\ \bar{p} \rightarrow \gamma\ \gamma$

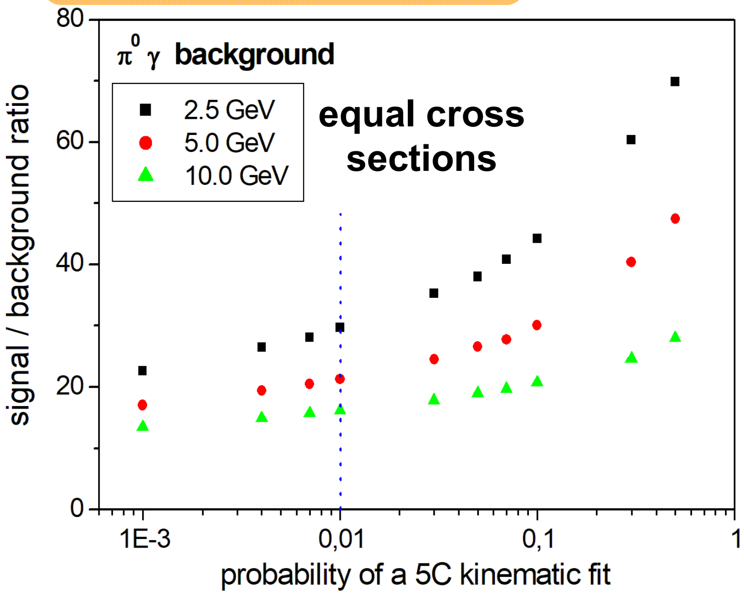
potential background: $p\ \bar{p} \rightarrow \gamma\ \pi^0$ $p\ \bar{p} \rightarrow \pi^0\pi^0$

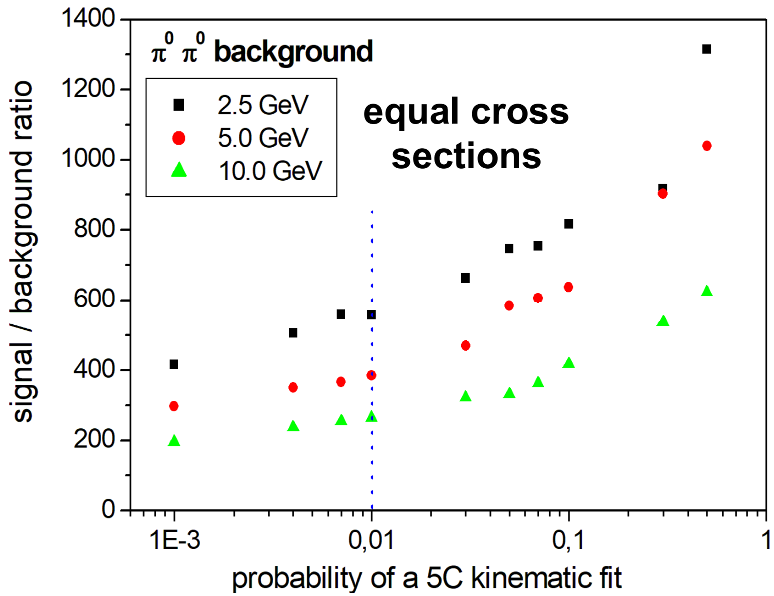


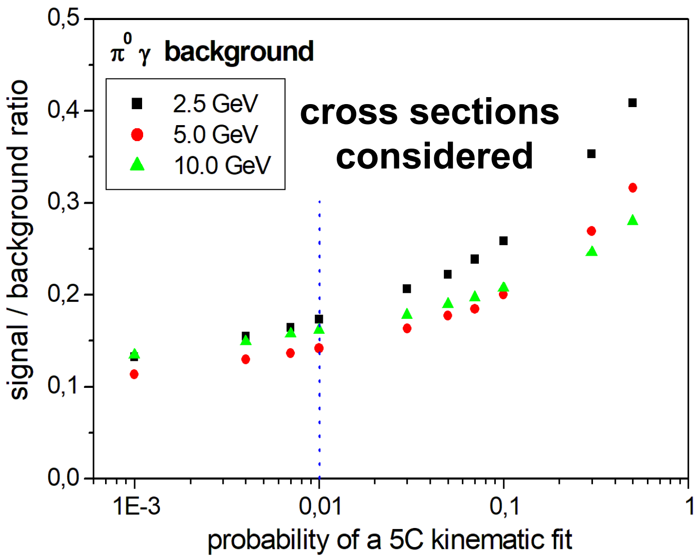


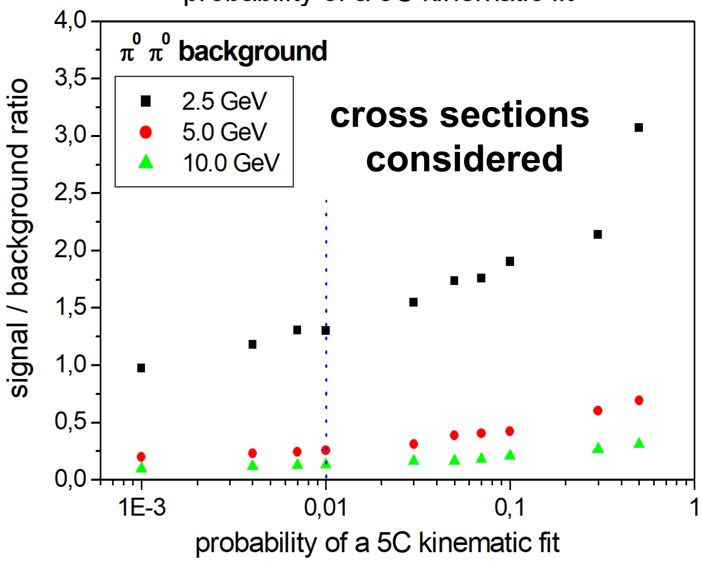
$p\,\bar{p} \to \gamma\,\gamma$

potential background: $p\,\bar{p} \to \gamma\,\pi^0$ $\quad p\,\bar{p} \to \pi^0\pi^0$





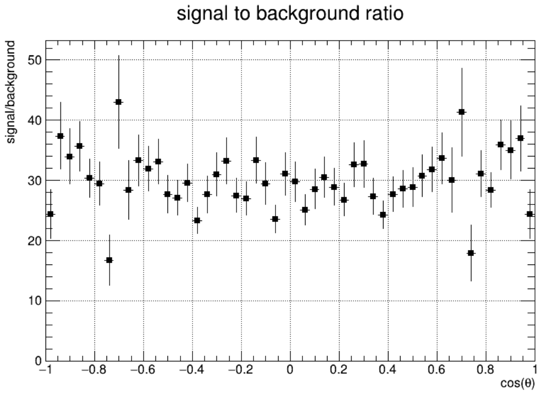




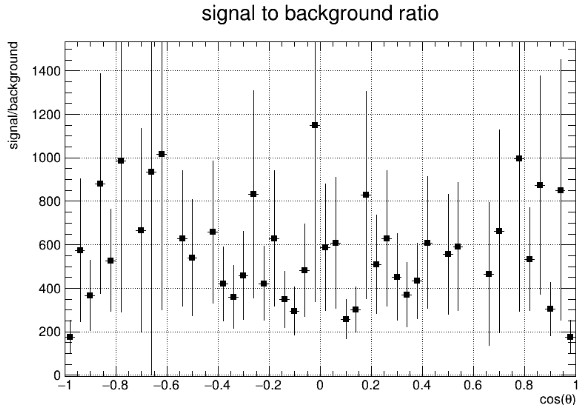
$p\ \bar{p} \to \gamma\ \gamma$

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

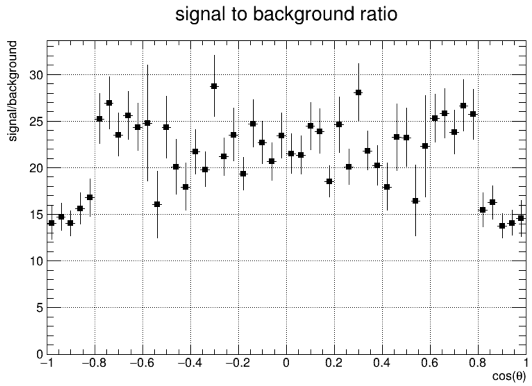
2.5 GeV

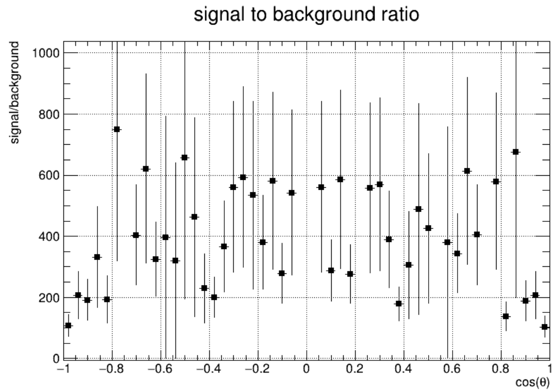


$p\ \bar{p} \to \pi^0 \pi^0$

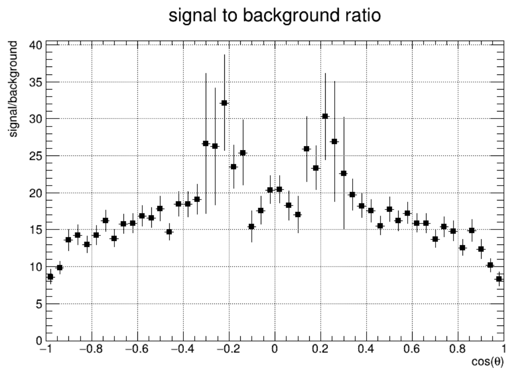


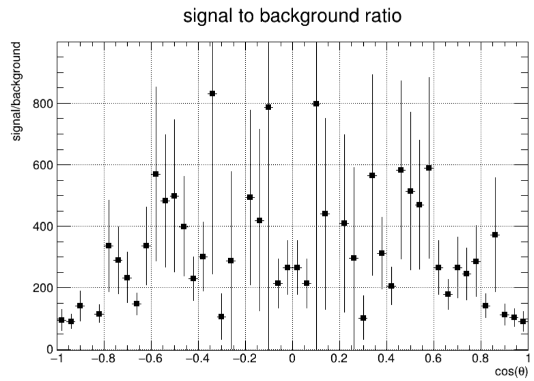
5 GeV



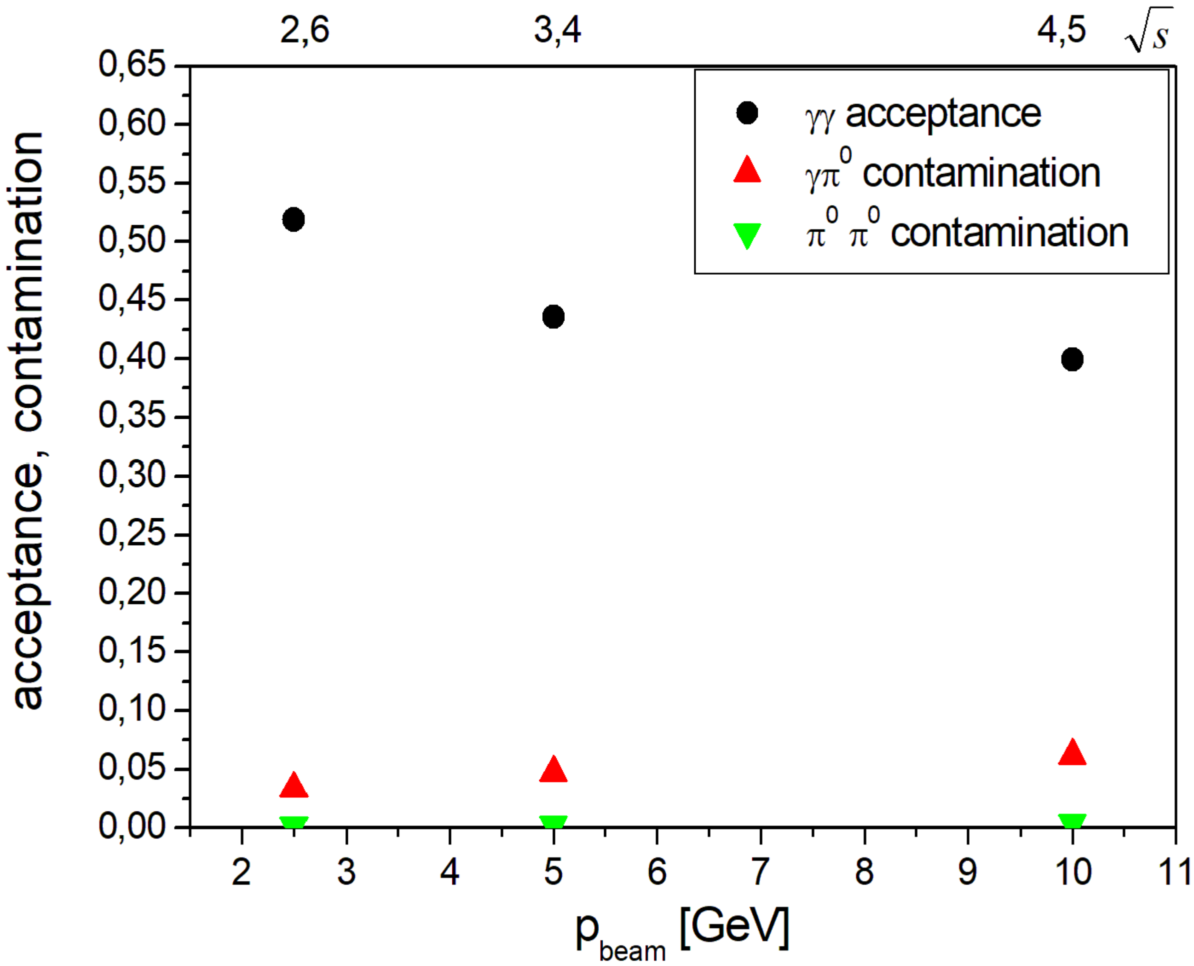


10 GeV



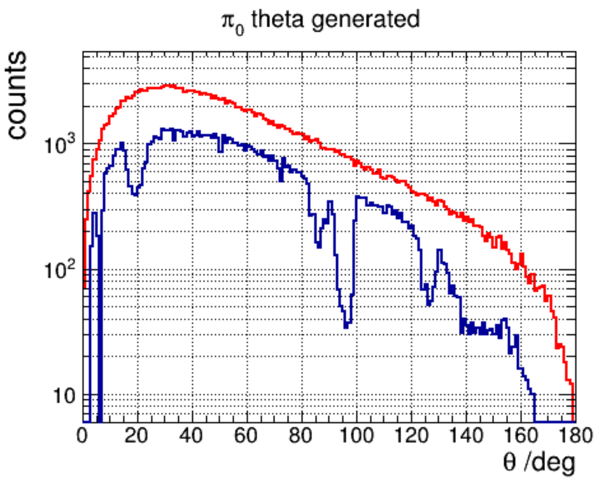


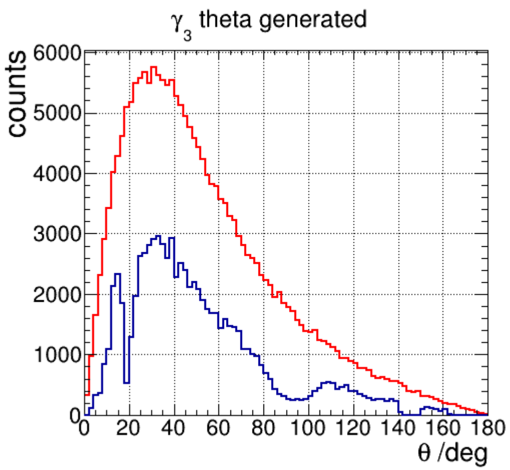
$p\,\bar{p} \rightarrow \gamma\,\gamma$

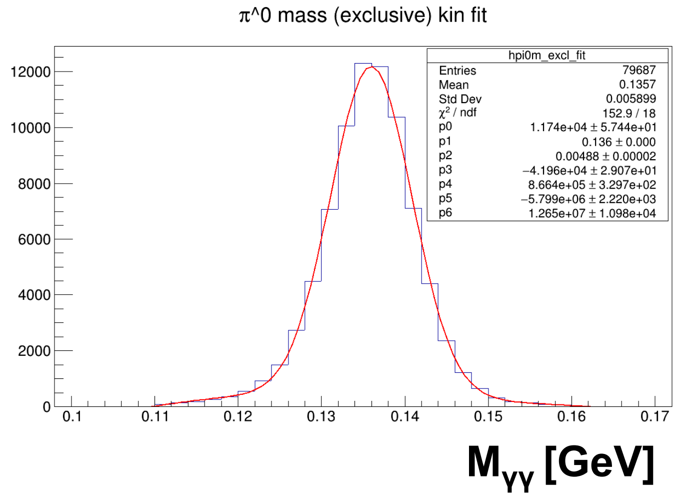


$p\,\bar{p} \rightarrow \gamma\,\pi^0 \rightarrow \gamma\,\gamma\,\gamma$ **BR ~ 99 %**

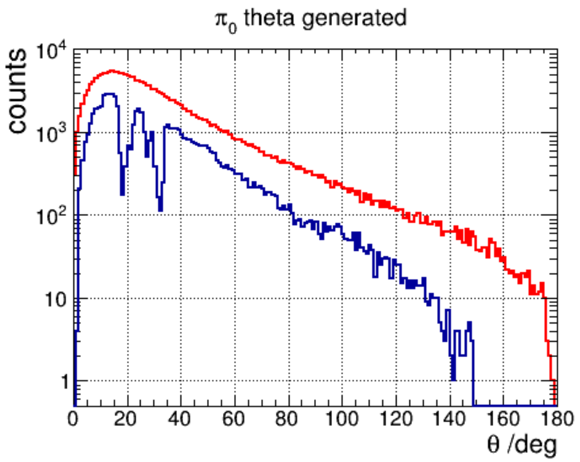
2.5 GeV

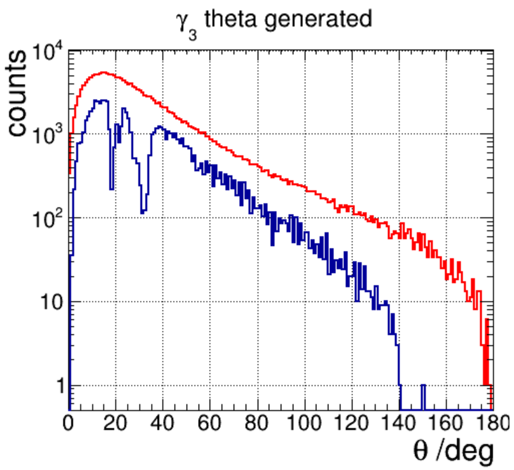


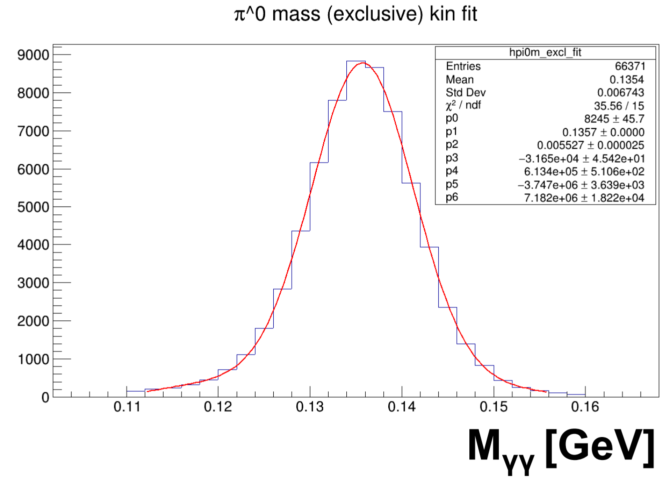




10 GeV

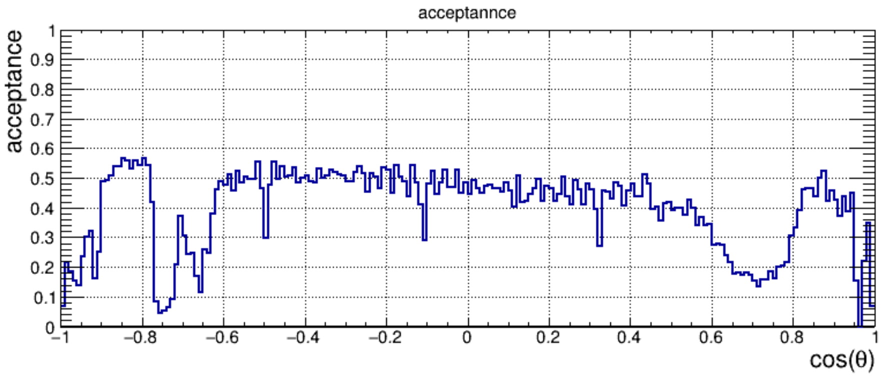


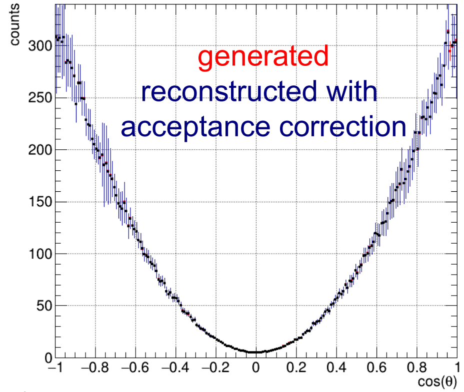




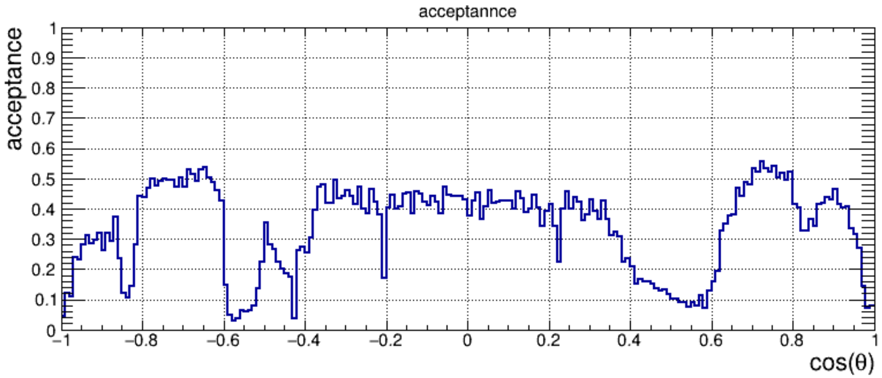
$p \bar{p} \rightarrow \gamma \pi^0 \rightarrow \gamma \gamma \gamma$

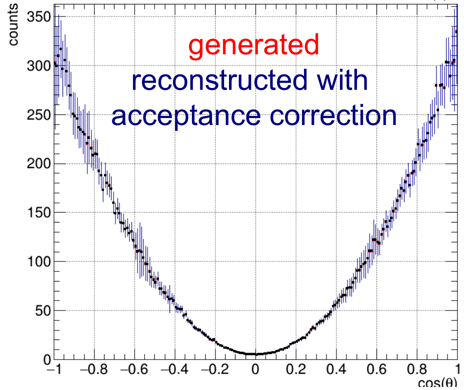
2.5 GeV



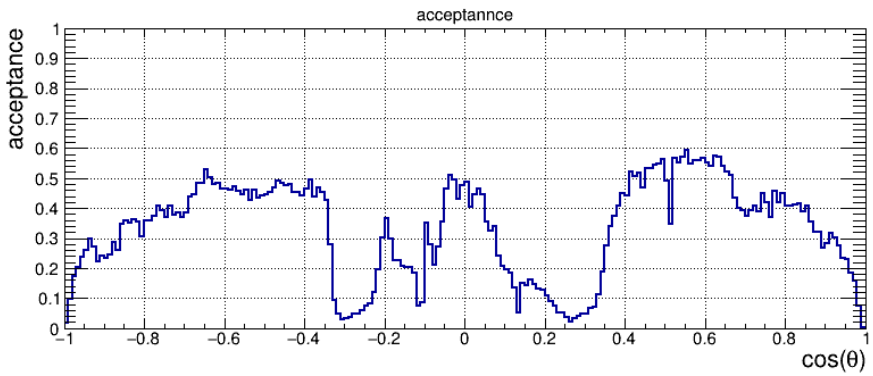


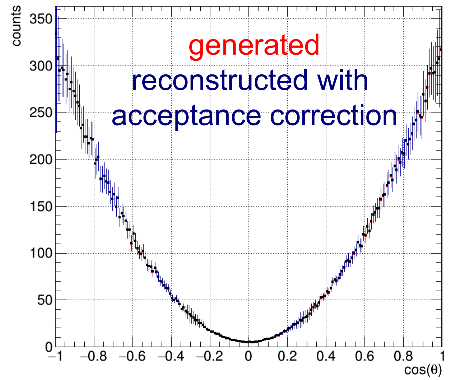
5 GeV





10 GeV

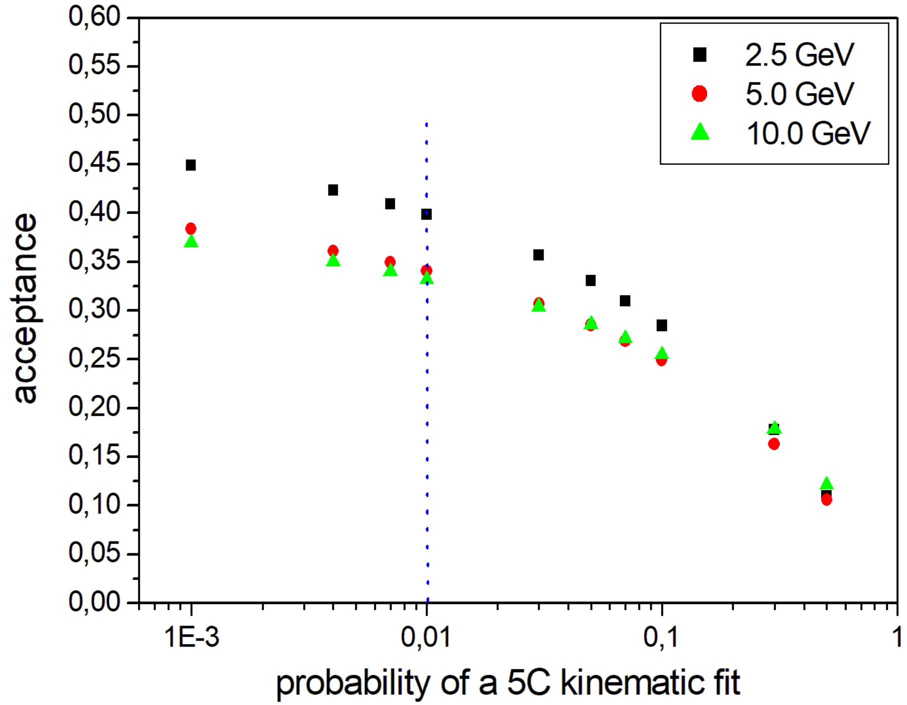


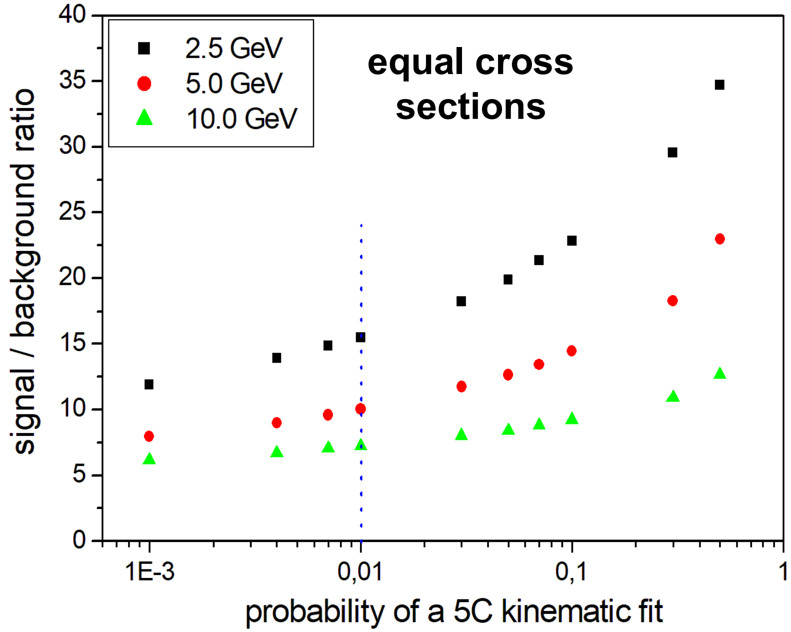


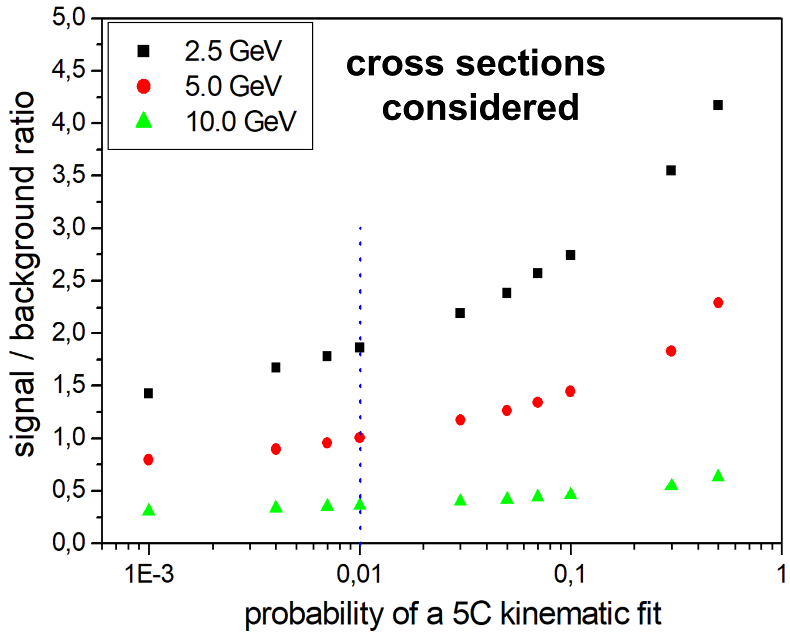
$$p\ \bar{p} \rightarrow \gamma\ \pi^0 \rightarrow \gamma\ \gamma\ \gamma$$

potential background:

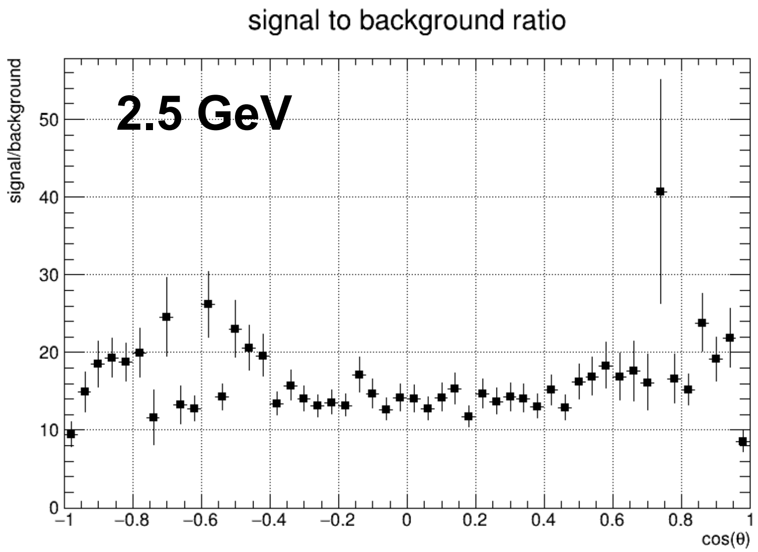
$$p\ \bar{p} \rightarrow \pi^0\ \pi^0$$

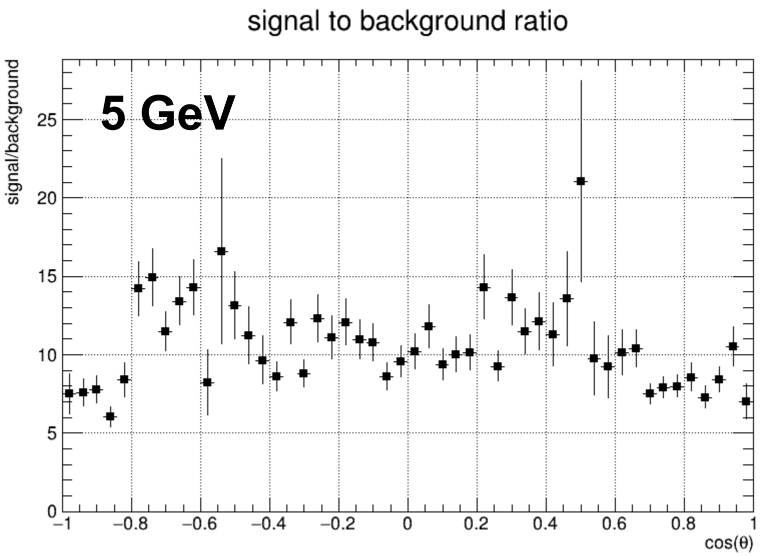


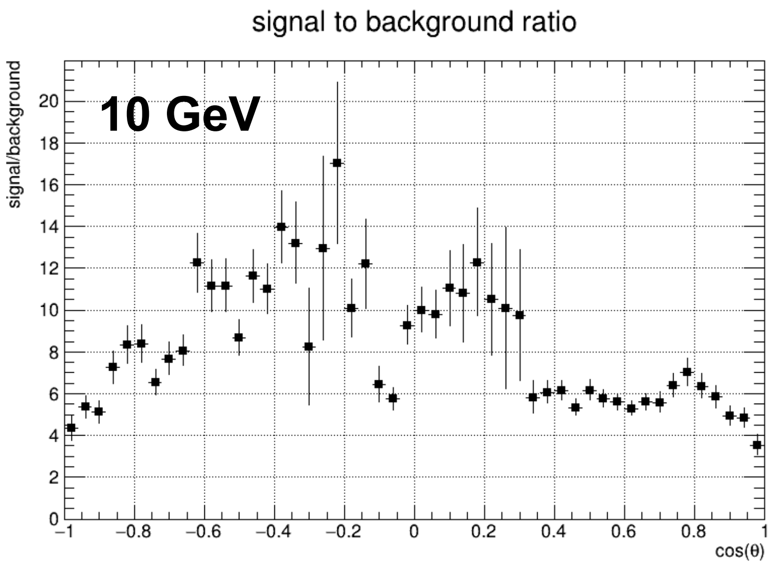




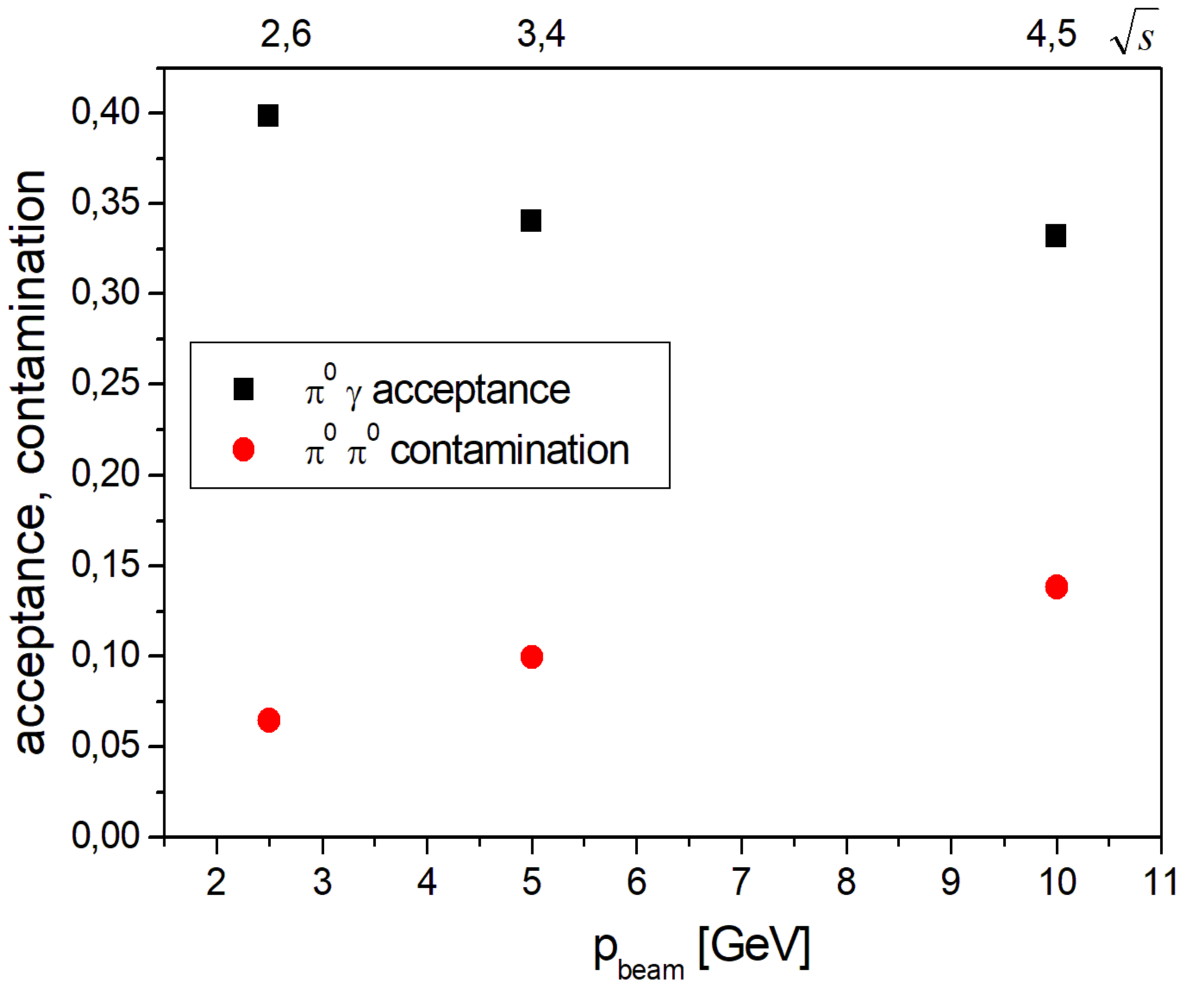
$p\ \bar{p} \rightarrow \gamma\ \pi^0 \rightarrow \gamma\ \gamma\ \gamma$





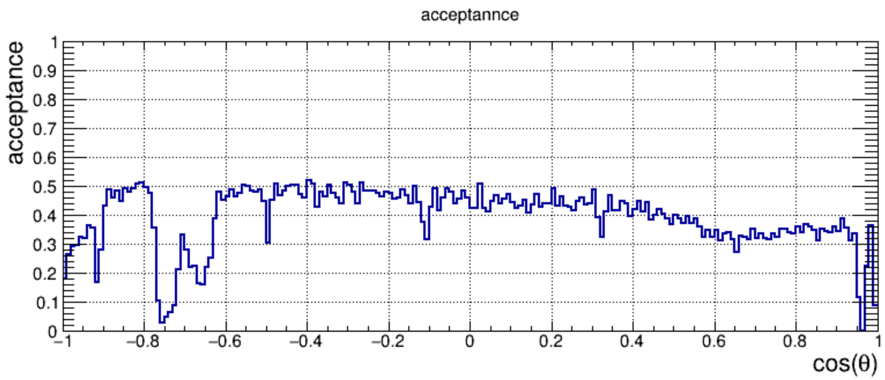


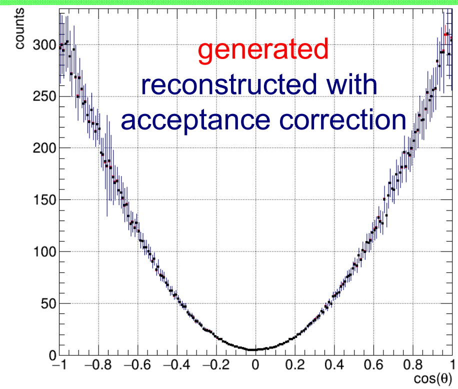
$p\ \bar{p} \rightarrow \gamma\ \pi^0 \rightarrow \gamma\ \gamma\ \gamma$



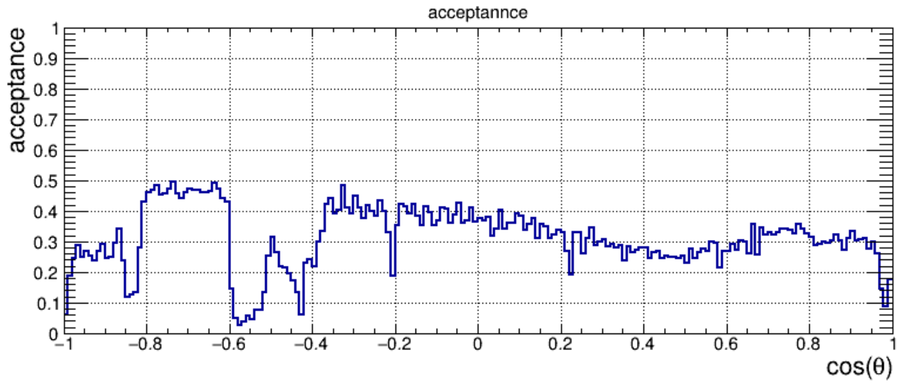
$p\,\bar{p} \rightarrow \gamma\,\eta \rightarrow \gamma\,\gamma\,\gamma$ **BR ~ 39 %**

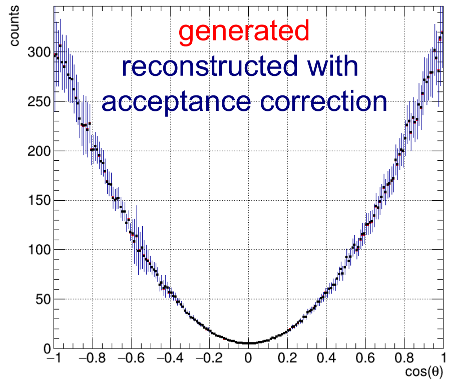
2.5 GeV



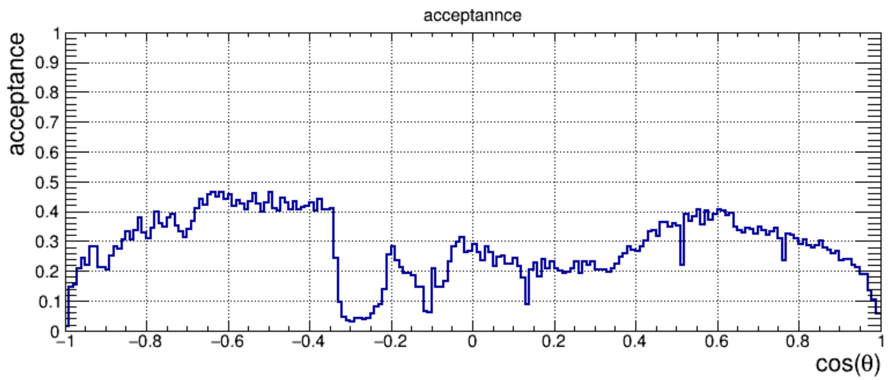


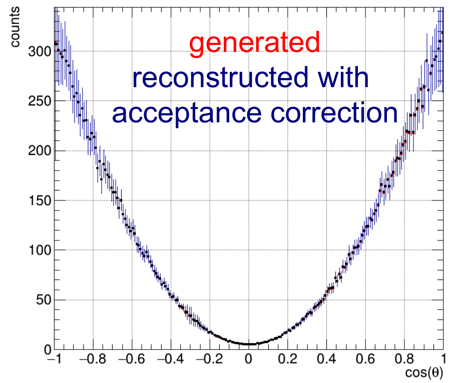
5 GeV





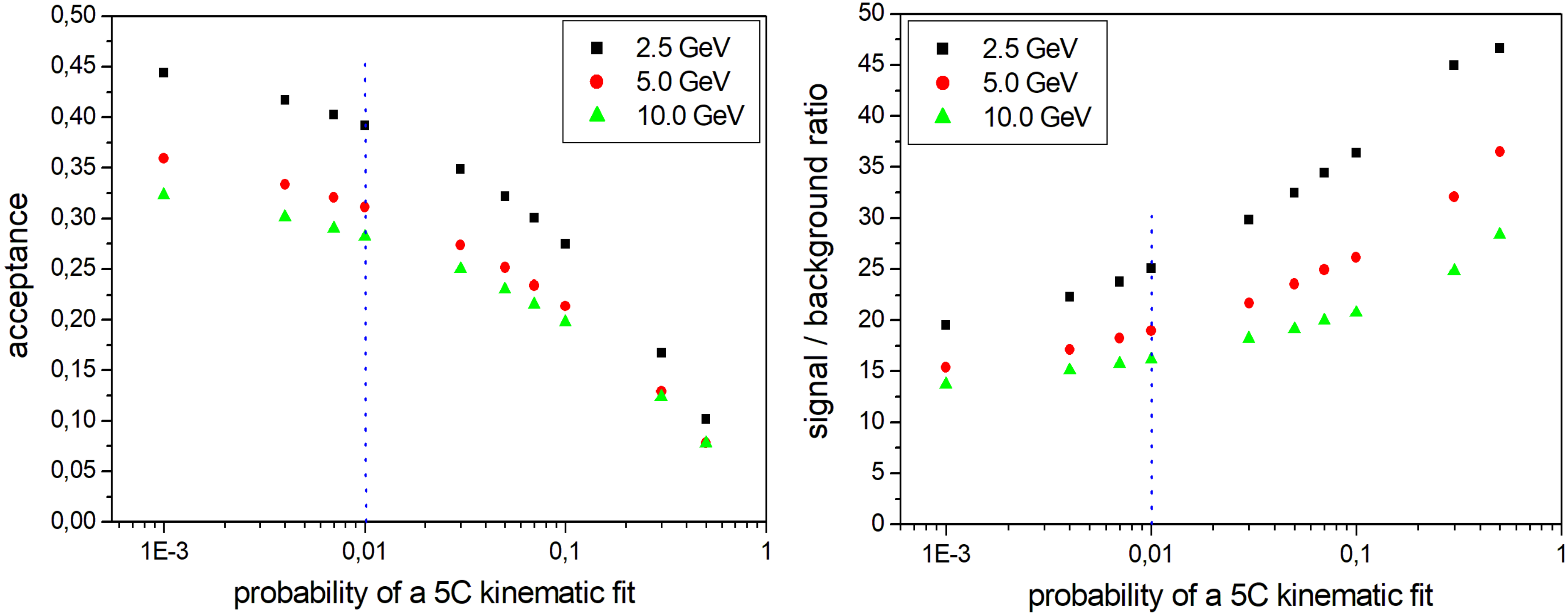
10 GeV



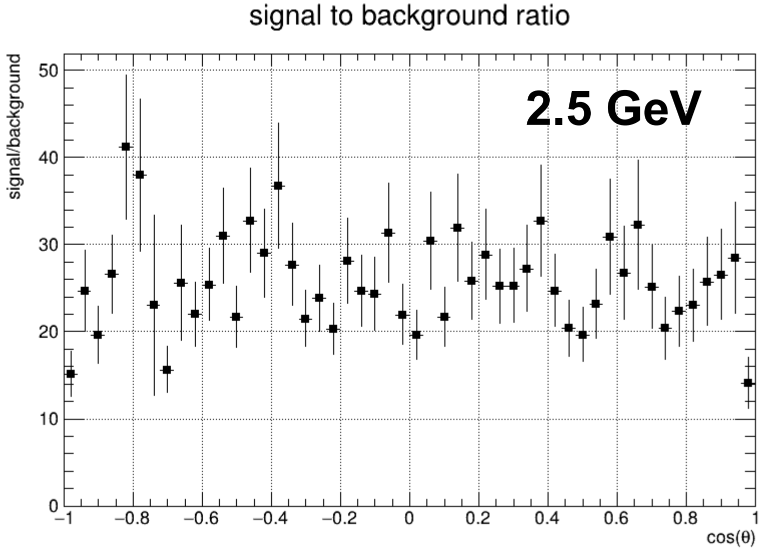


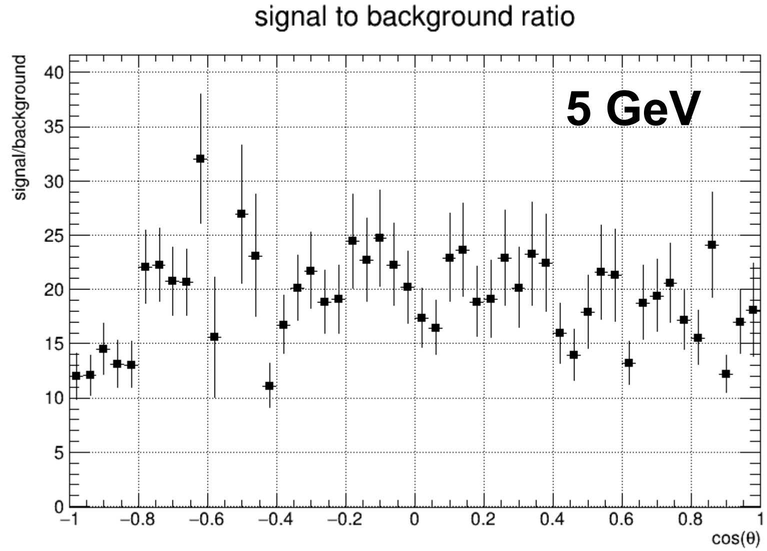
$p\ \bar{p} \rightarrow \gamma\ \eta \rightarrow \gamma\ \gamma\ \gamma$

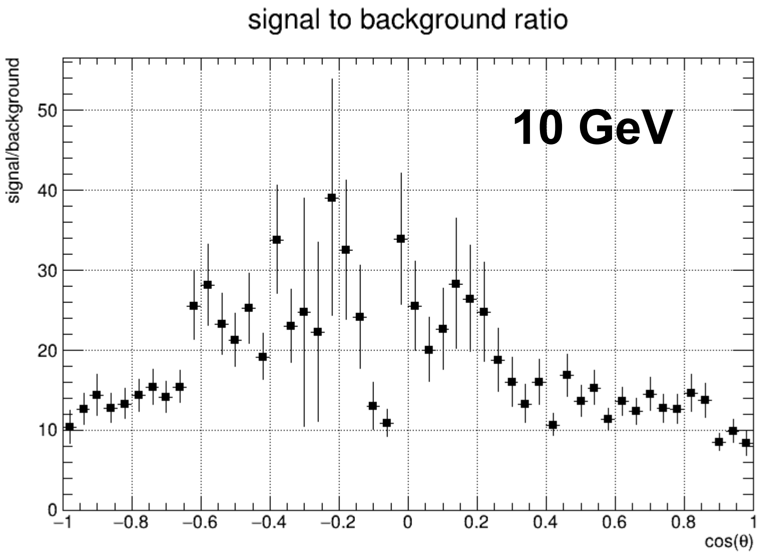
potential background: $p\ \bar{p} \rightarrow \pi^0\ \eta$



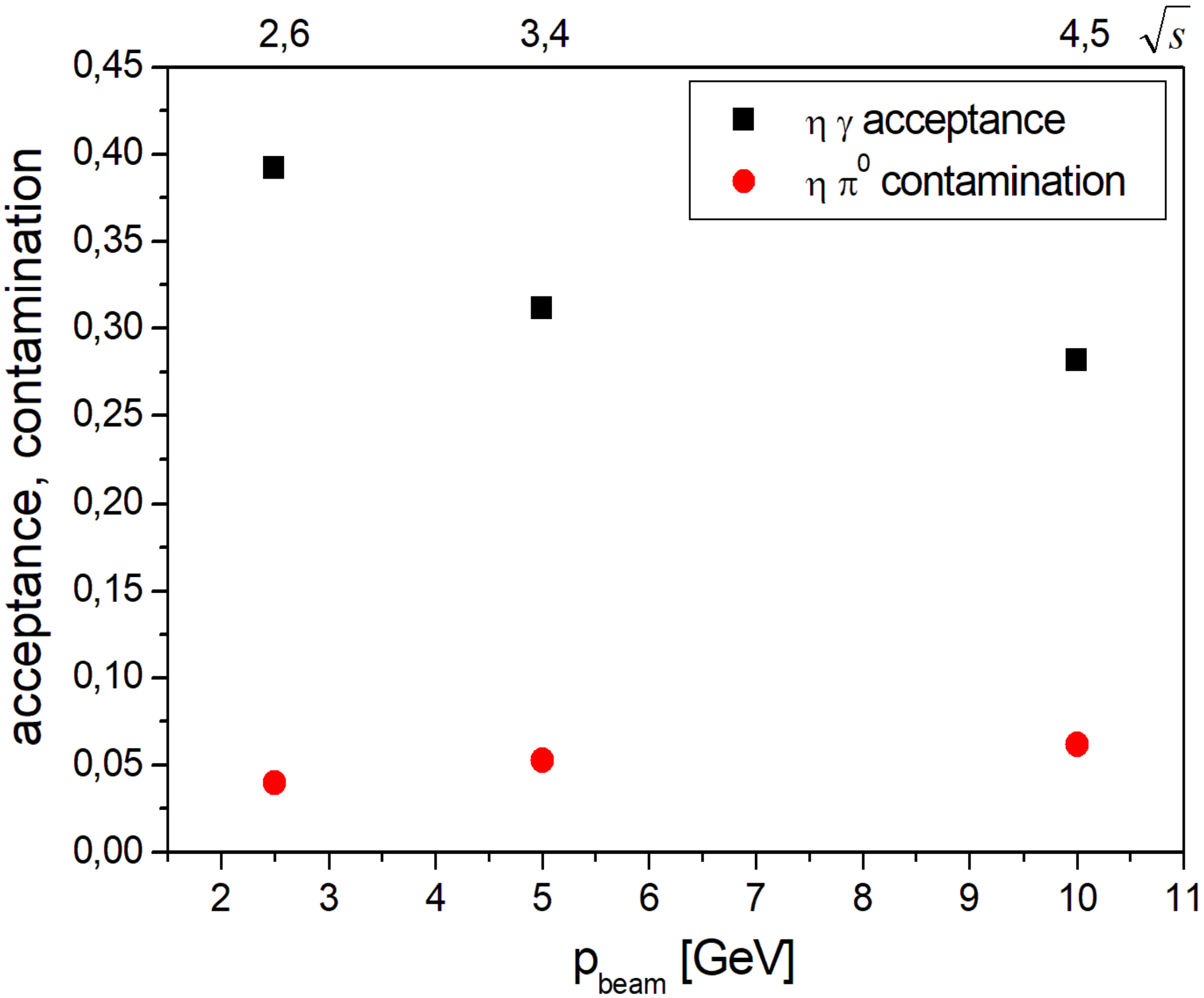
$$p\ \bar{p} \rightarrow \gamma\ \eta \rightarrow \gamma\ \gamma\ \gamma$$





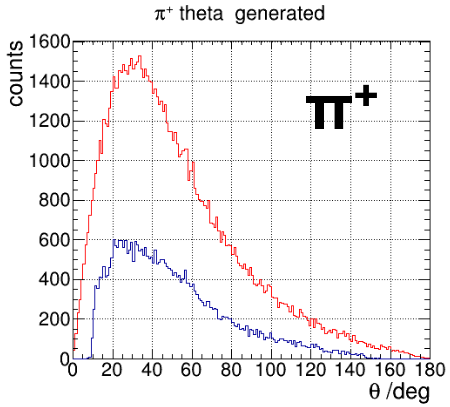


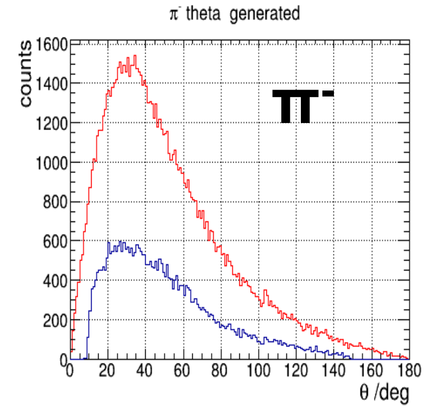
$p\ \bar{p} \rightarrow \gamma\ \eta \rightarrow \gamma\ \gamma\ \gamma$

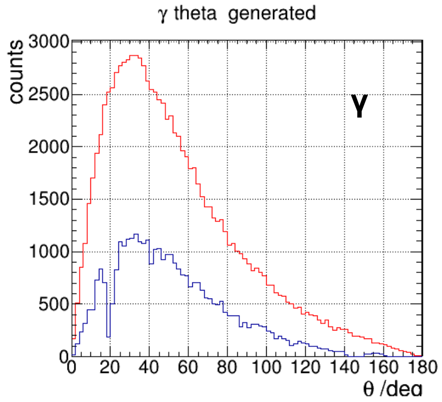


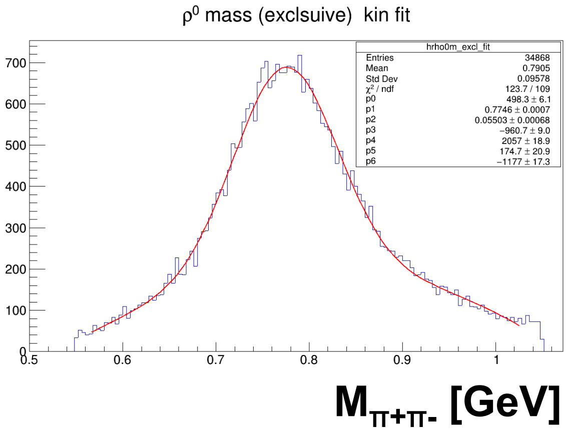
$p\ \bar{p} \rightarrow \rho\gamma \rightarrow \pi^{+}\pi^{-}\gamma$ BR ~ 100 %

2.5 GeV

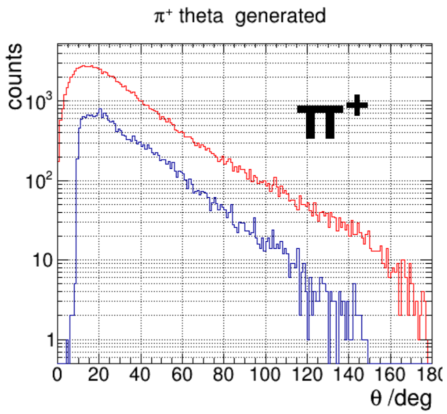


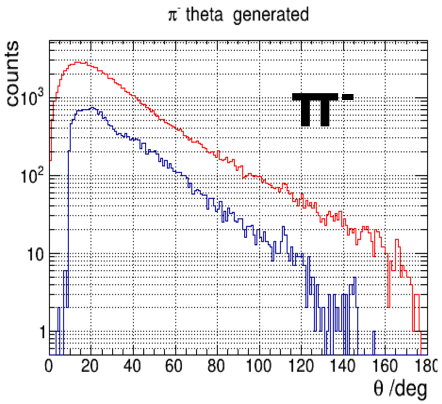


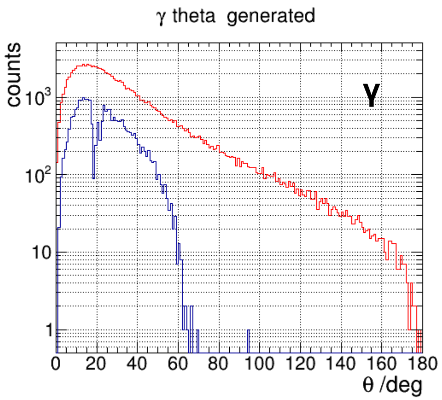


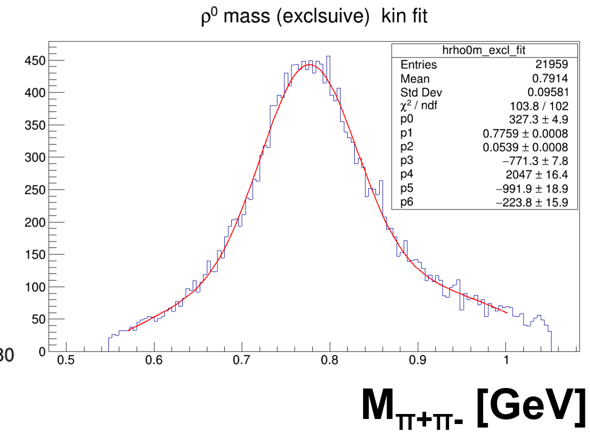


10 GeV



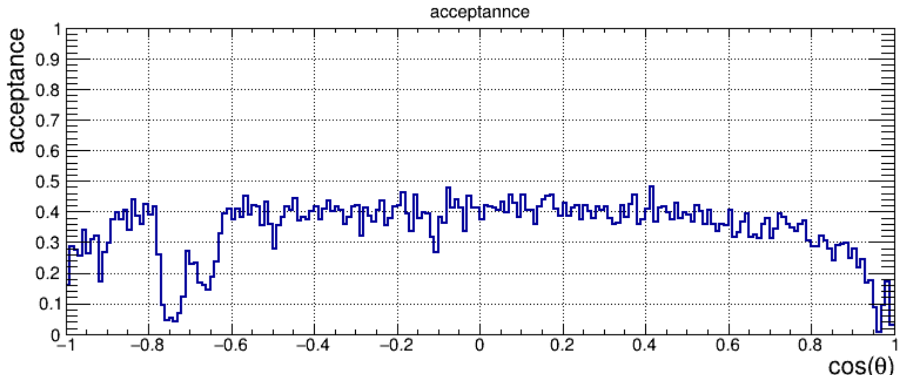


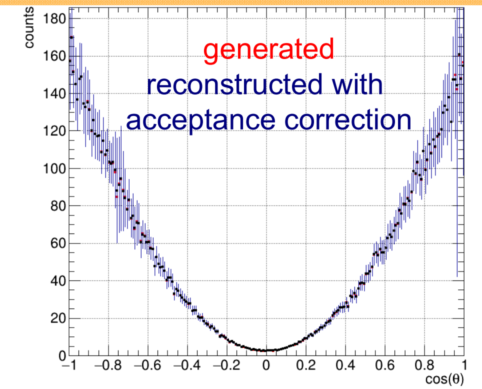




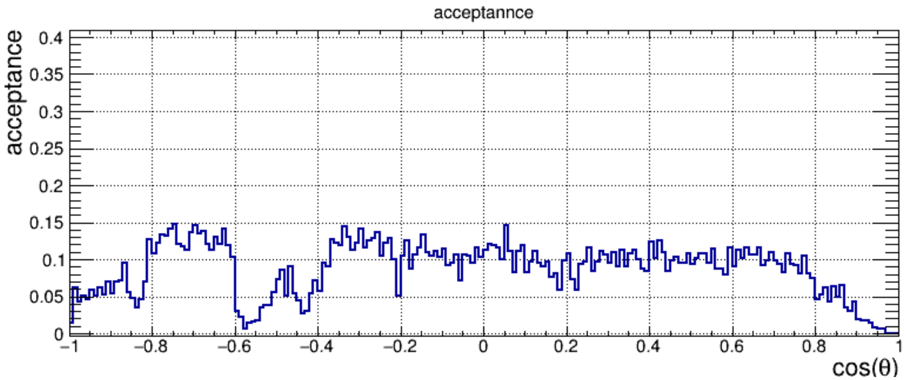
$p\ \bar{p} \rightarrow \rho\gamma \rightarrow \pi^{+}\pi^{-}\gamma$

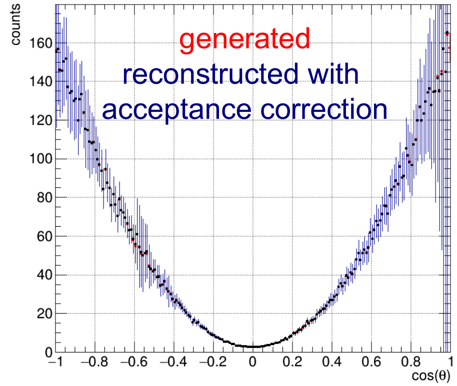
2.5 GeV



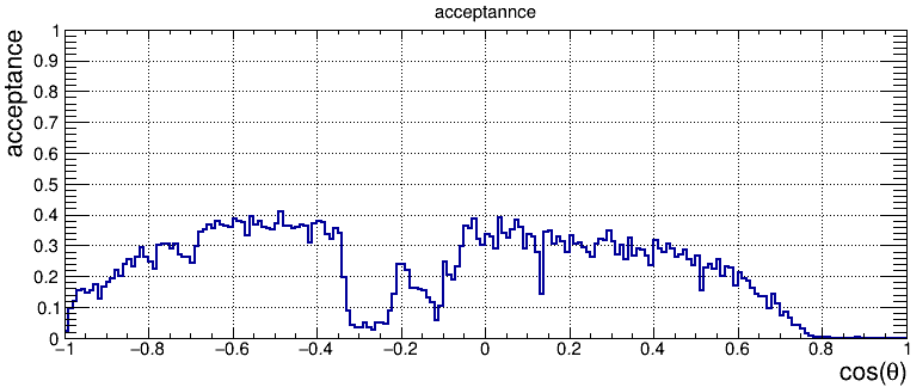


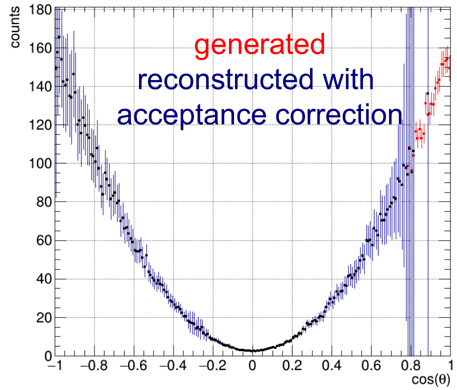
5 GeV





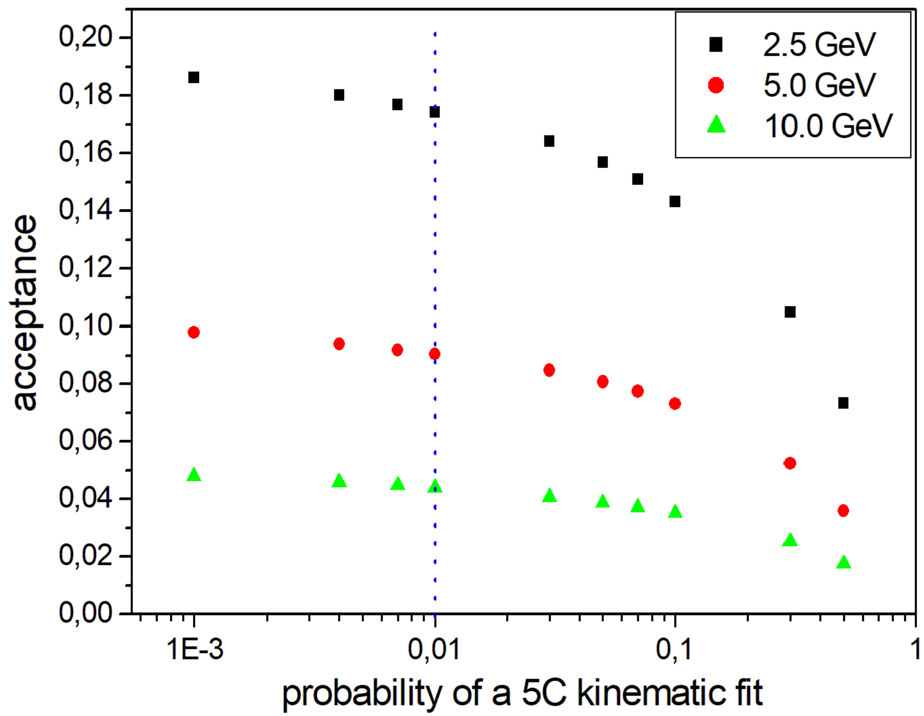
10 GeV

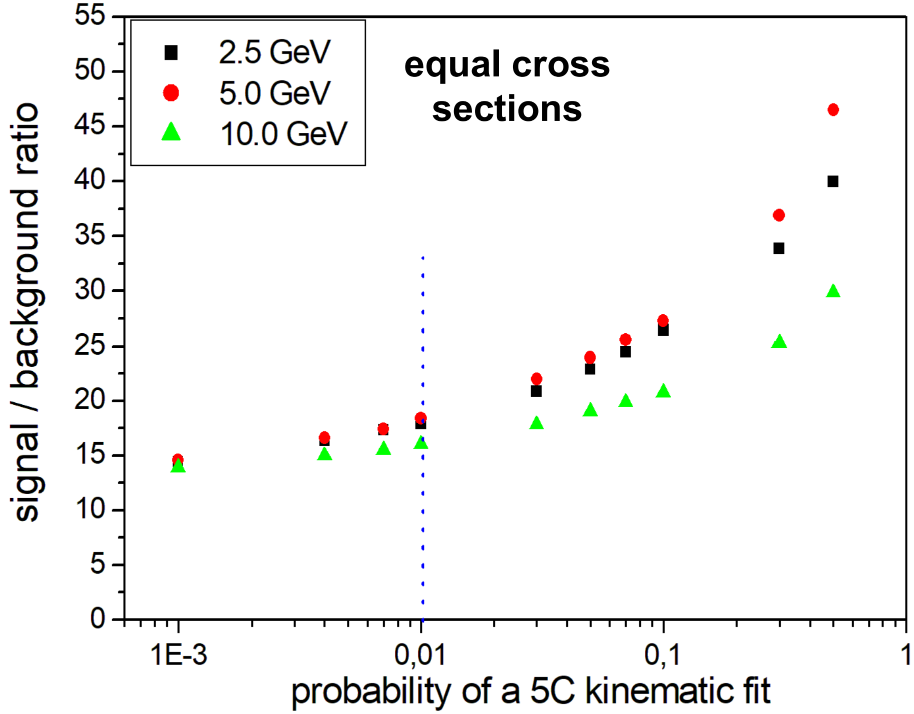




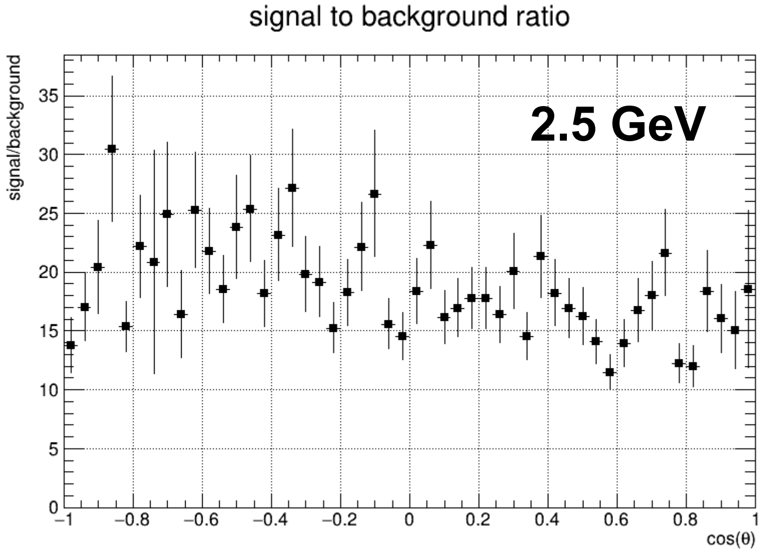
$p\,\bar{p} \rightarrow \rho\gamma \rightarrow \pi^+\pi^-\gamma$

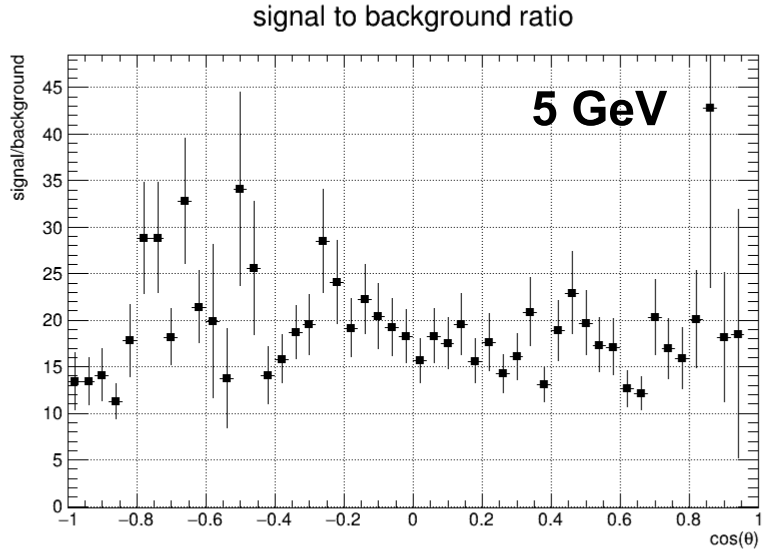
potential background: $p\,\bar{p} \rightarrow \rho\pi^0$

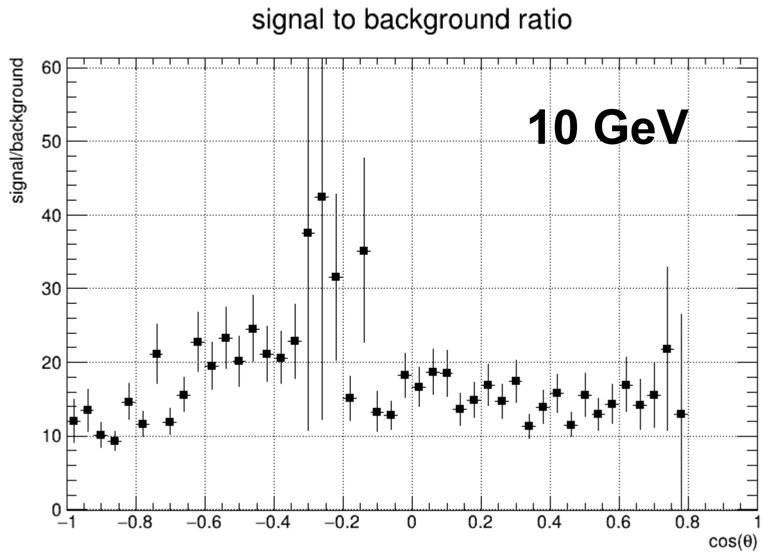




$p\,\bar{p} \rightarrow \rho\gamma \rightarrow \pi^+\pi^-\gamma$

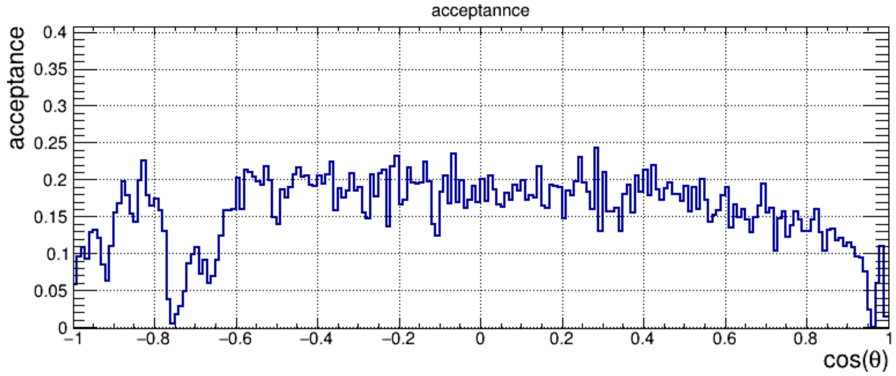


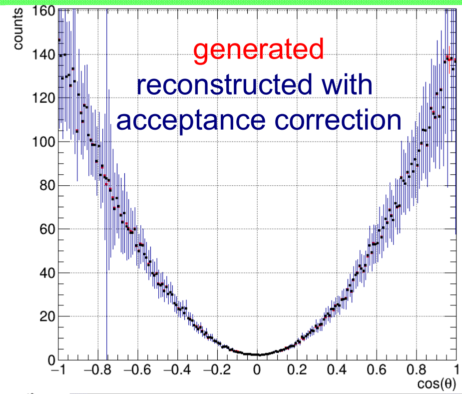




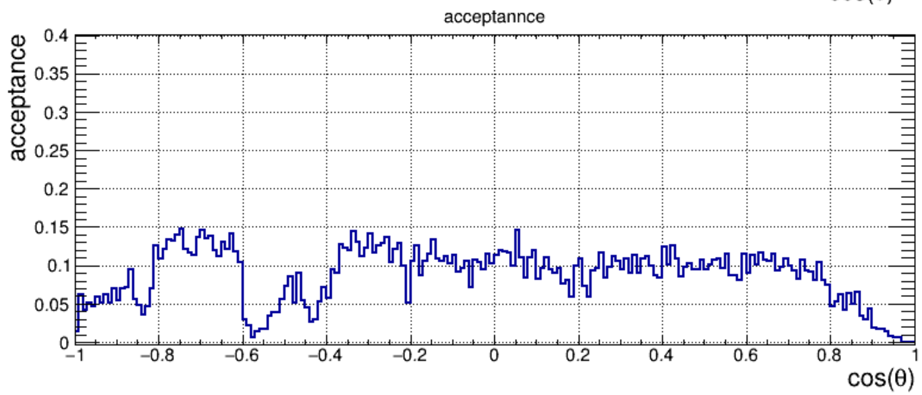
$p\,\bar{p} \rightarrow \omega\gamma \rightarrow \pi^{+}\pi^{-}\pi^{0}\gamma$ **BR ~ 89 %**

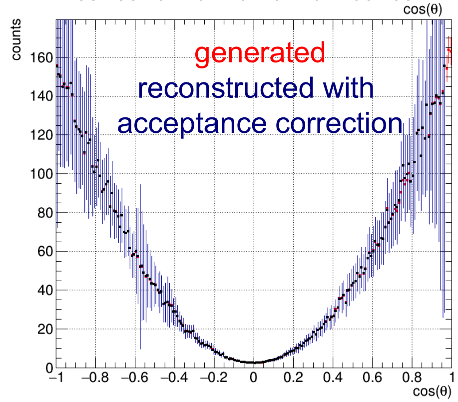
2.5 GeV



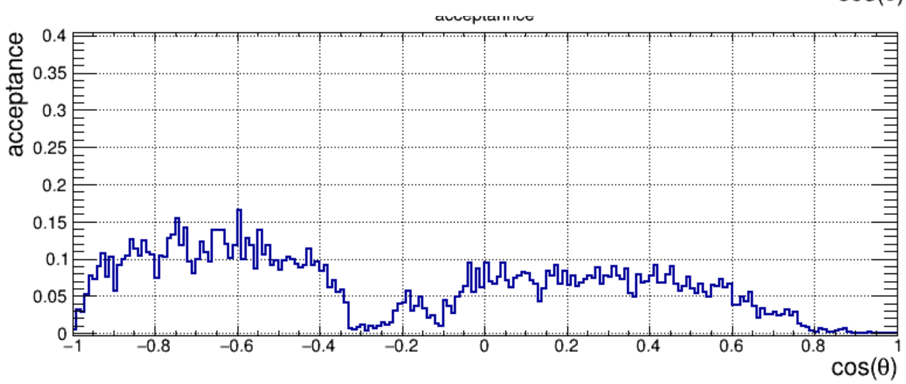


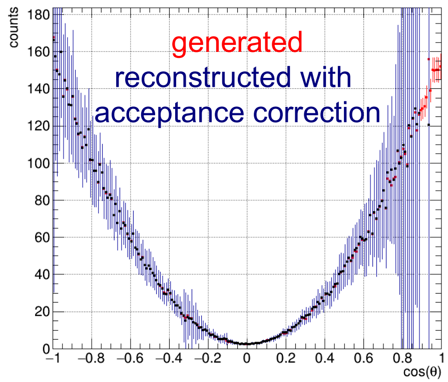
5 GeV





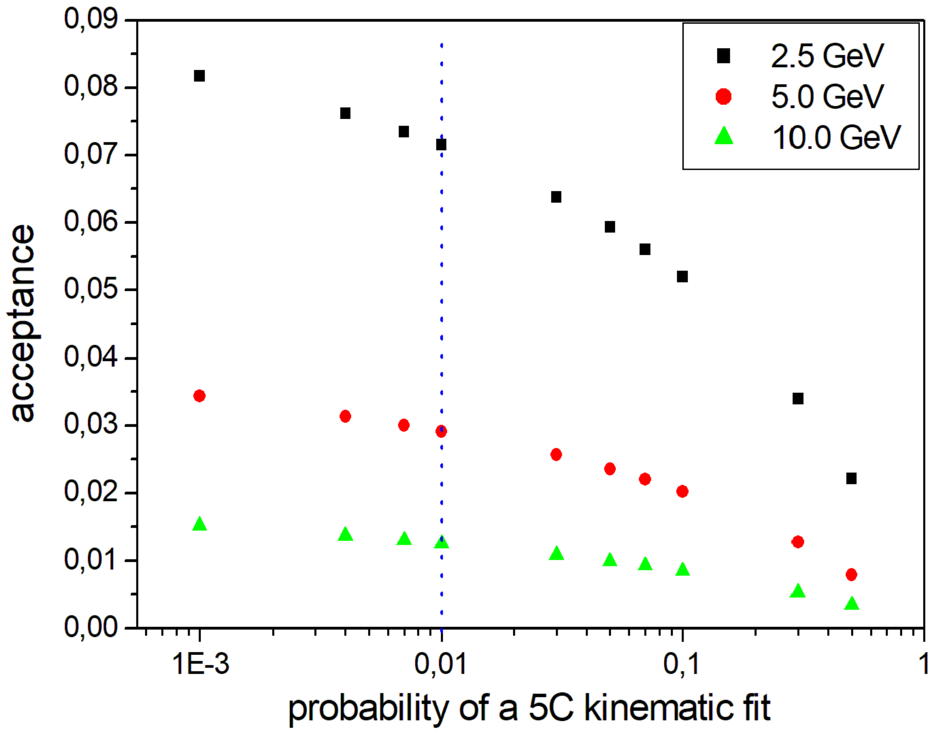
10 GeV

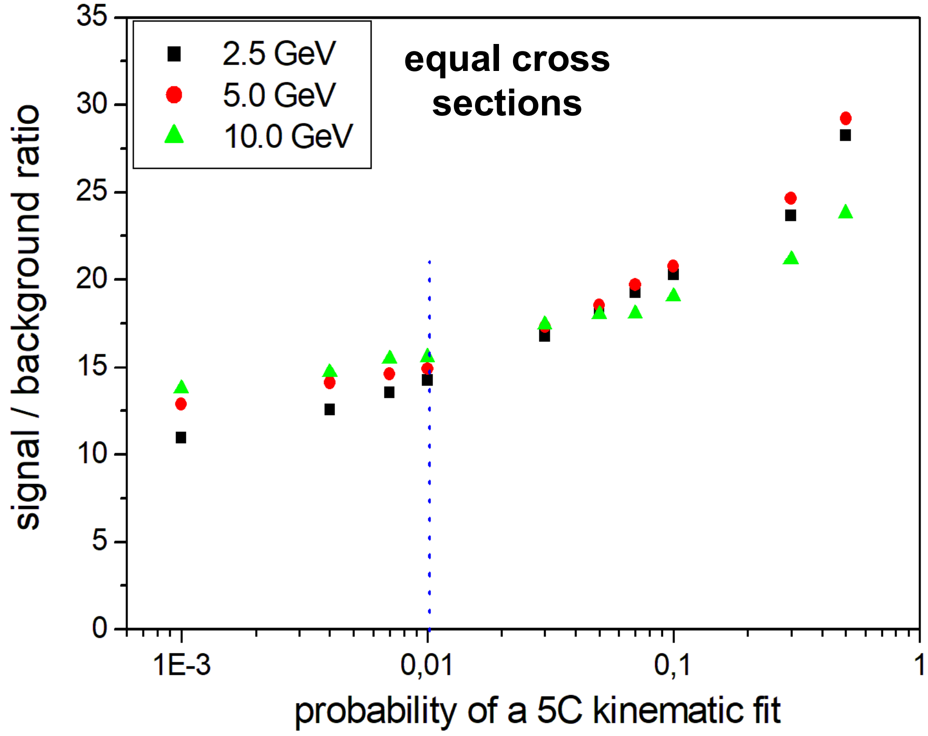




$$p\ \bar{p} \to \omega\gamma \to \pi^+\pi^-\pi^0\gamma$$

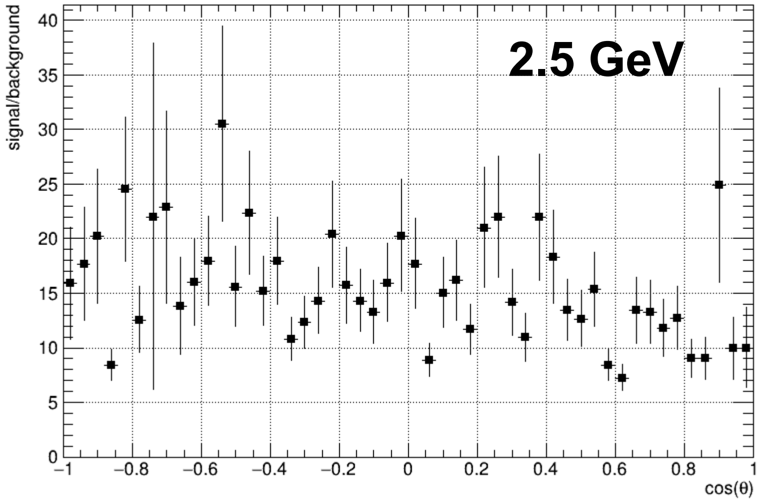
potential background: $p\ \bar{p} \to \omega\pi^0$



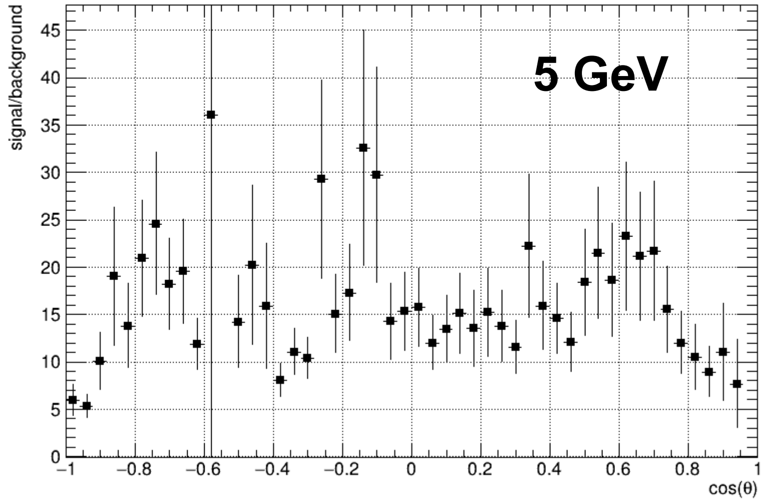


$p\,\bar{p} \rightarrow \omega\gamma \rightarrow \pi^+\pi^-\pi^0\gamma$

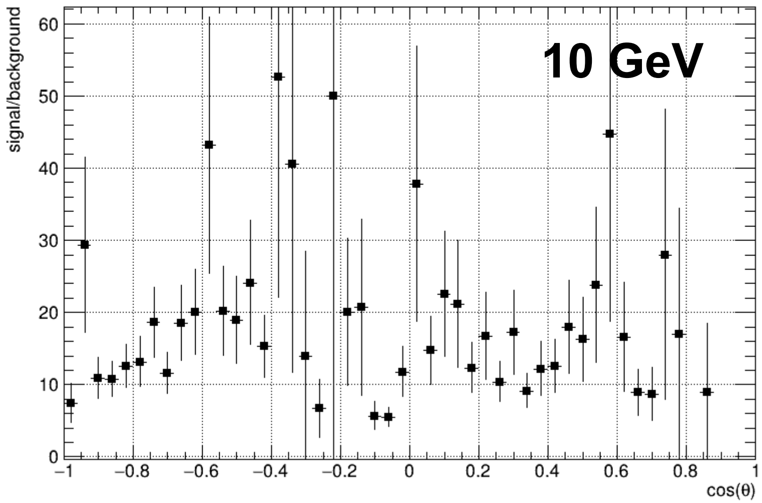
signal to background ratio



signal to background ratio



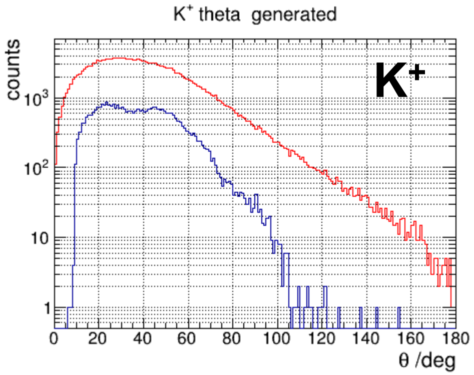
signal to background ratio

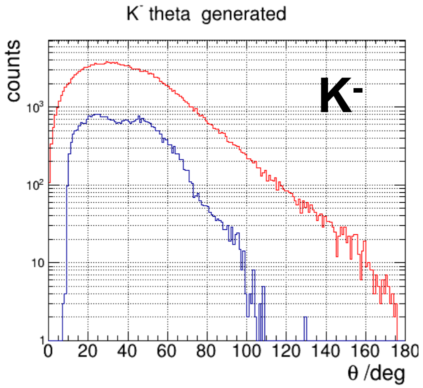


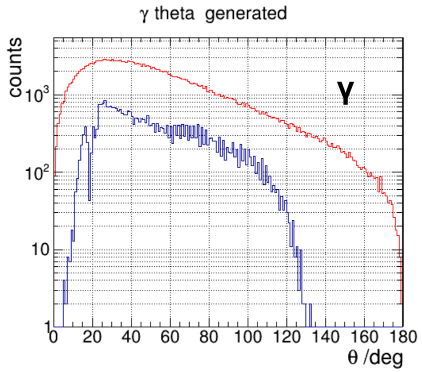
$$p\ \bar{p} \rightarrow \gamma\ \phi \rightarrow \gamma\ K^{+}\ K^{-}$$

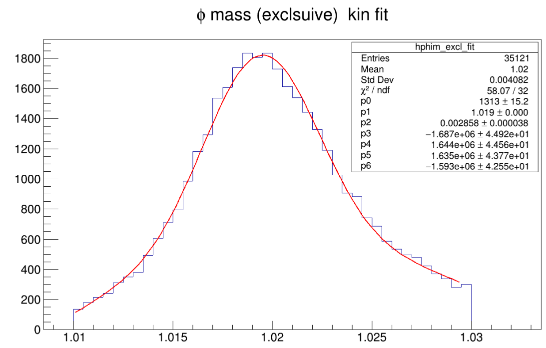
BR ~ 49 %

2.5 GeV



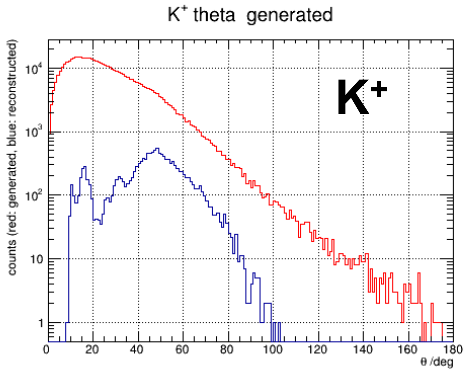


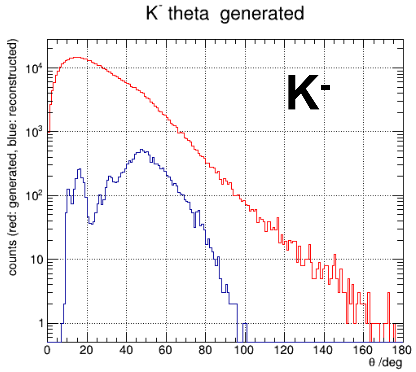


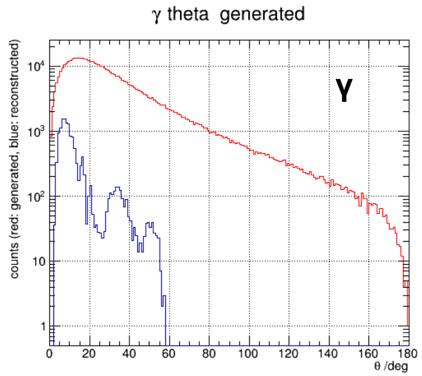


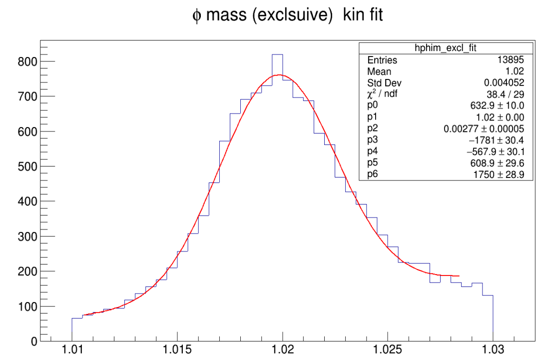
M_{K+K-} [GeV]

10 GeV





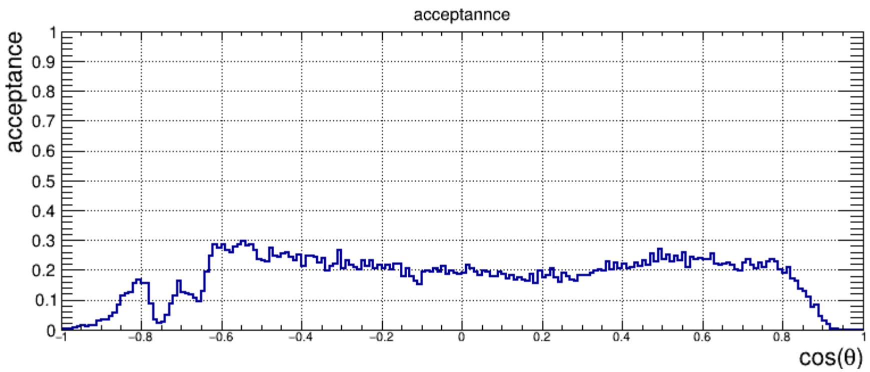


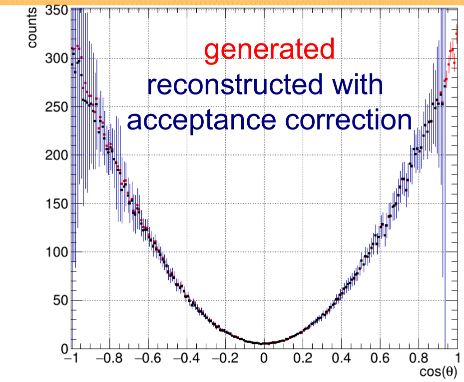


M_{K+K-} [GeV]

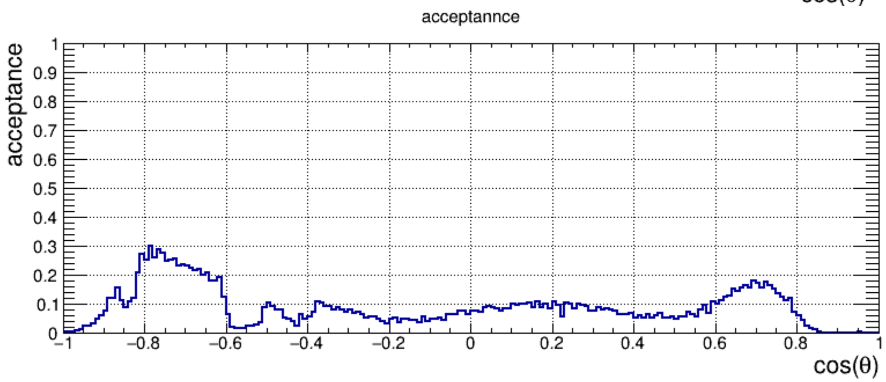
$p\ \bar{p} \rightarrow \gamma\ \phi \rightarrow \gamma\ K^{+}\ K^{-}$

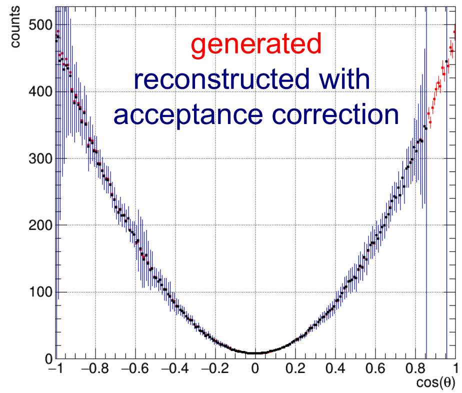
2.5 GeV



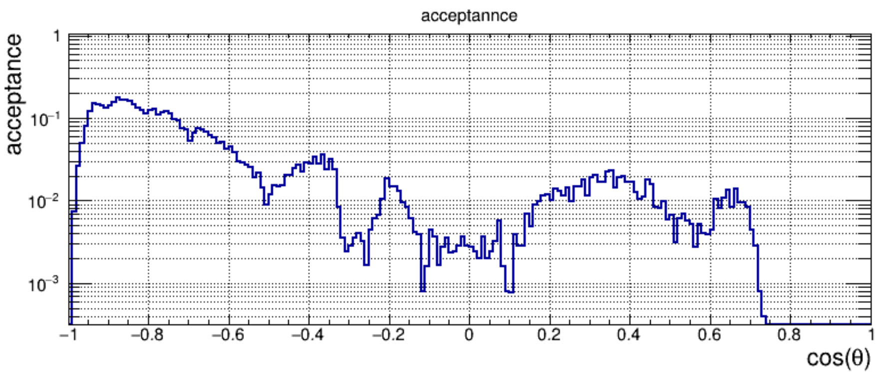


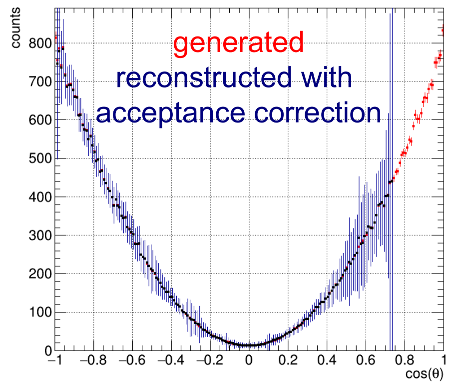
5 GeV





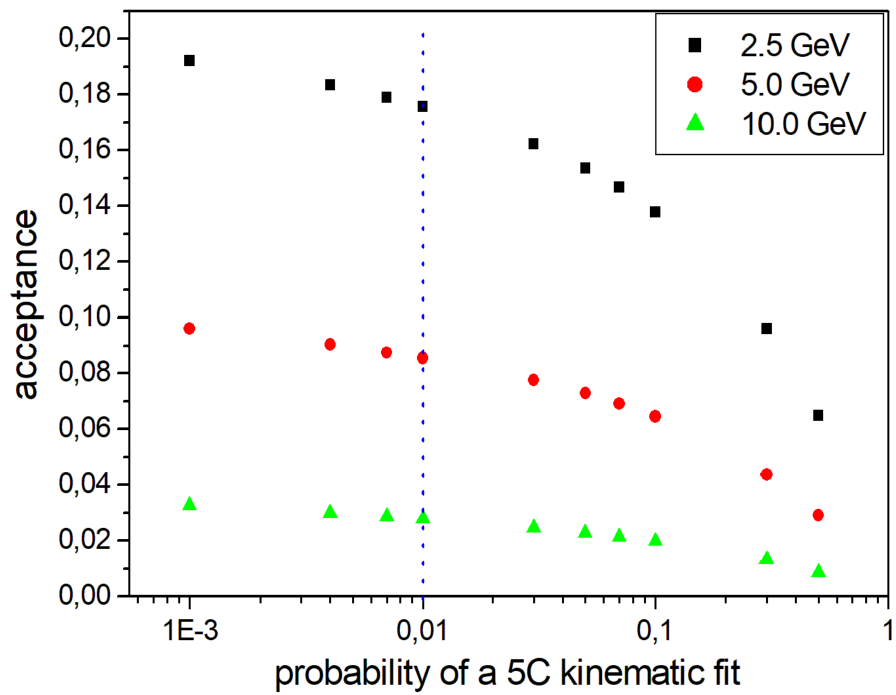
10 GeV

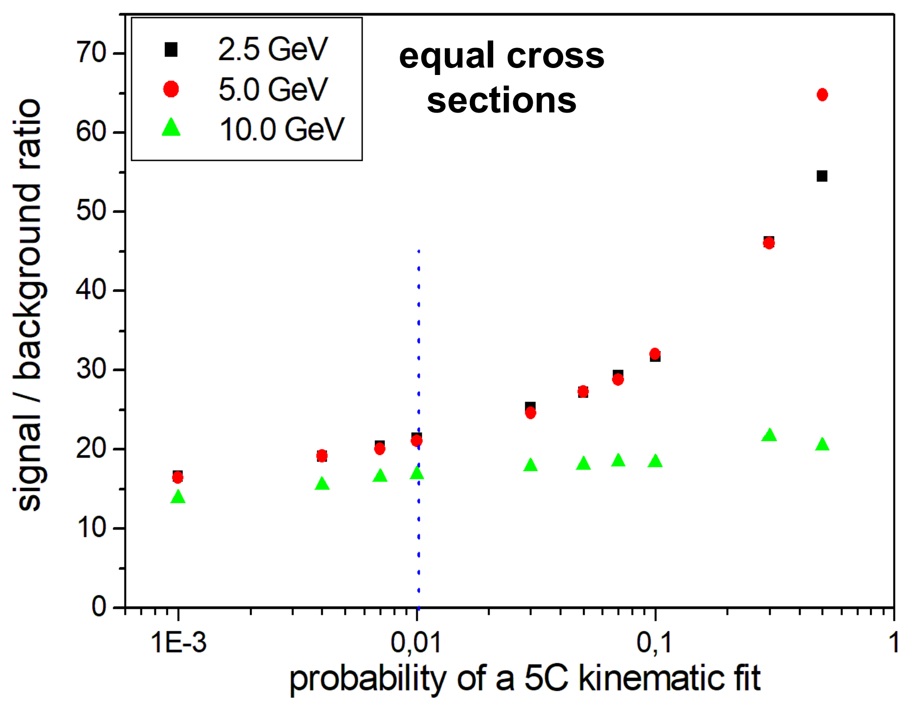




$p\ \bar{p} \rightarrow \gamma\ \phi \rightarrow \gamma\ K^+\ K^-$

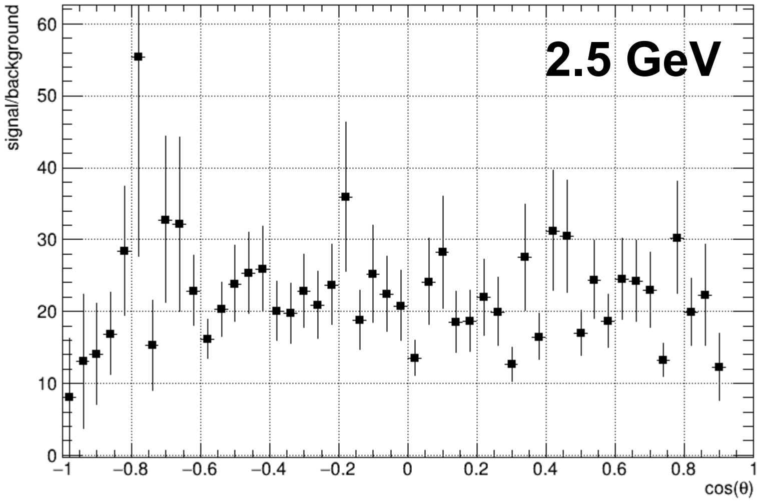
potential background: $p\ \bar{p} \rightarrow \pi^0\ \phi$ + hadronic background



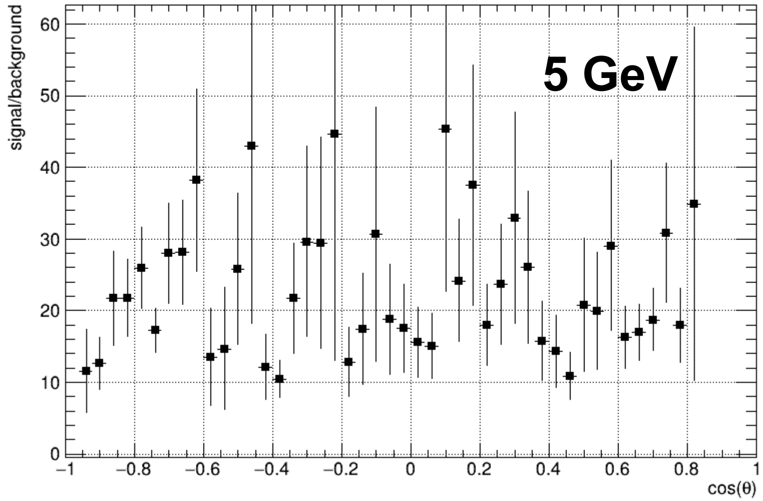


$p\ \bar{p} \to \gamma\ \phi \to \gamma\ K^+\ K^-$

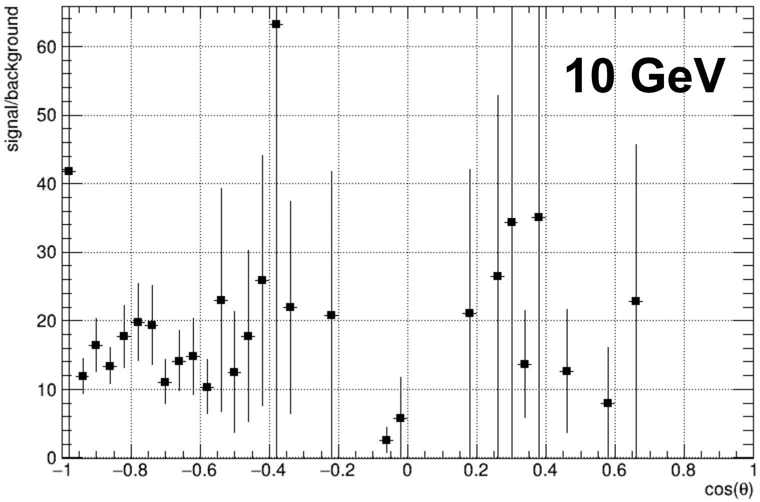
signal to background ratio



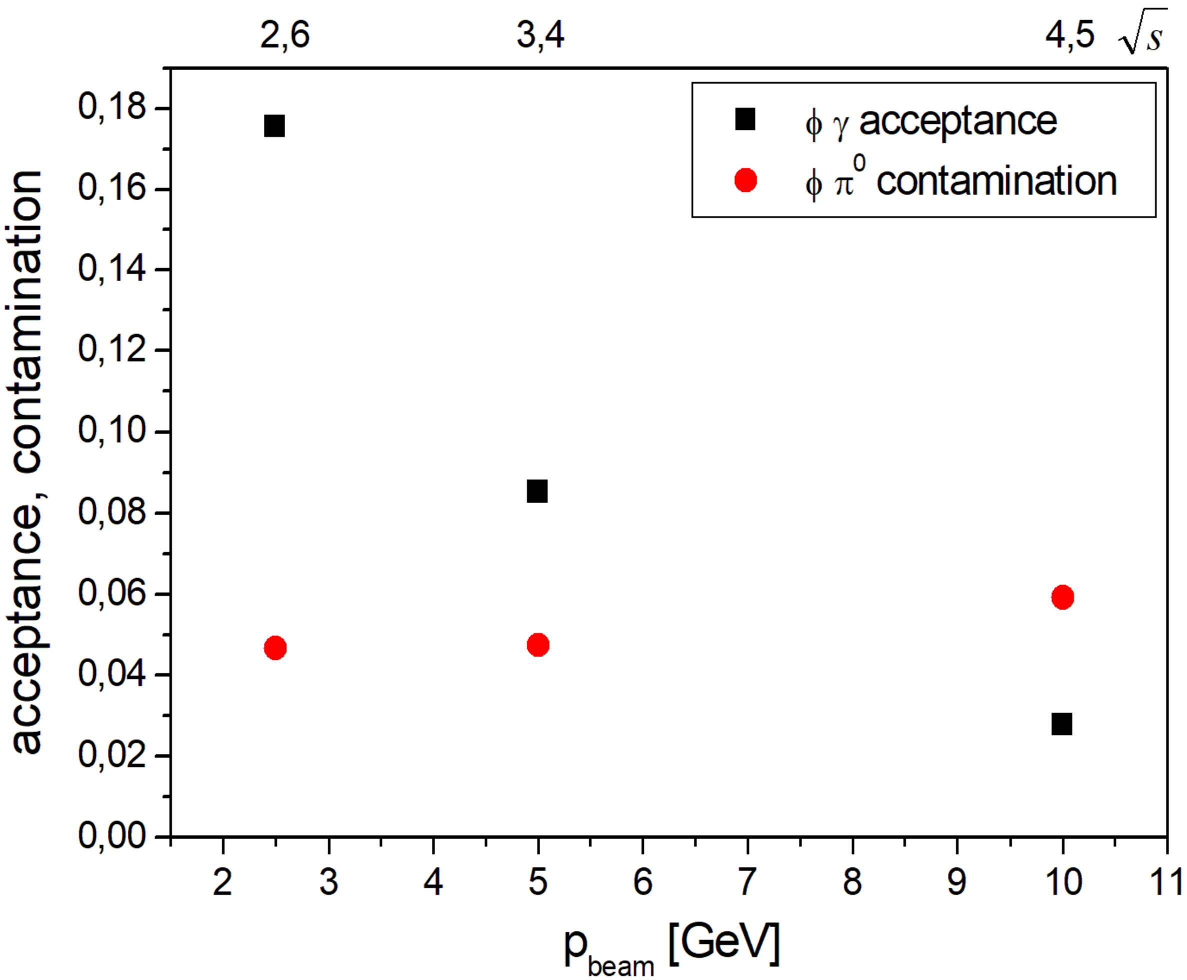
signal to background ratio



signal to background ratio

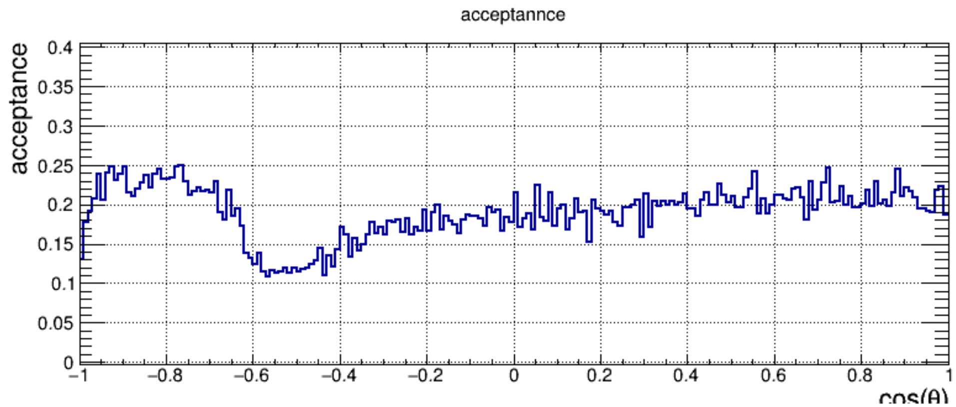


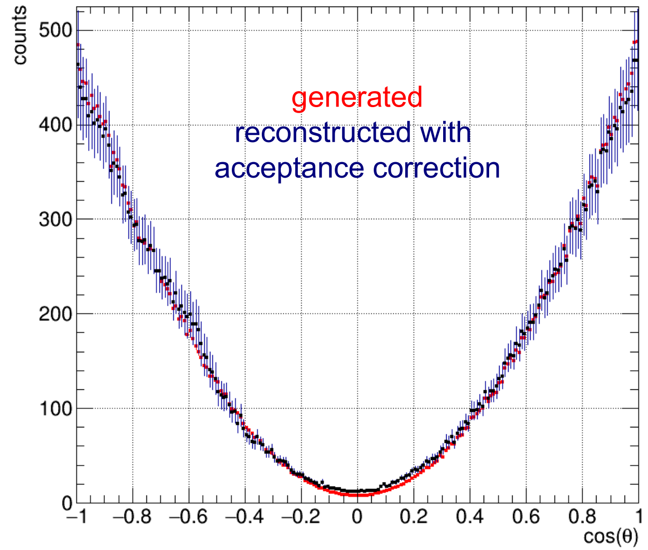
$p\ \bar{p} \rightarrow \gamma\ \phi \rightarrow \gamma\ K^+\ K^-$



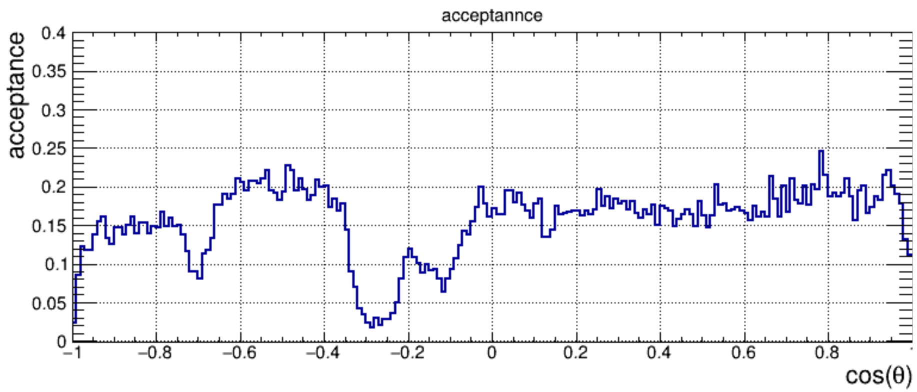
$$p\ \bar{p} \rightarrow \gamma\ J/\psi \rightarrow \gamma\ e^{+}\ e^{-}$$ **BR ~ 6 %**

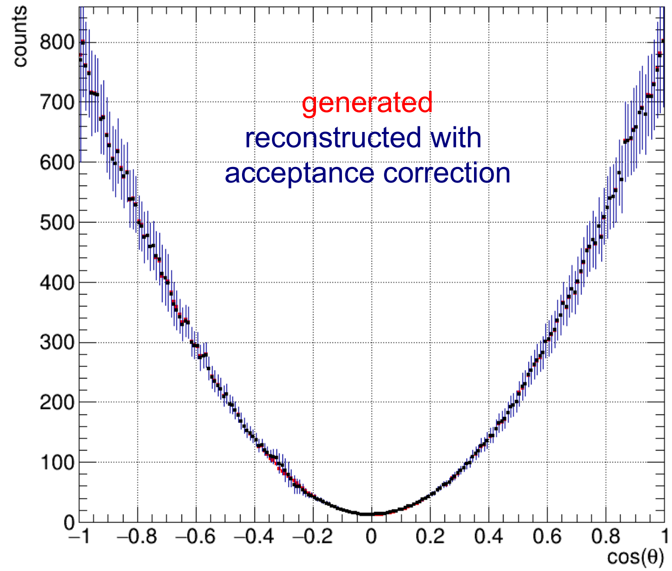
5 GeV





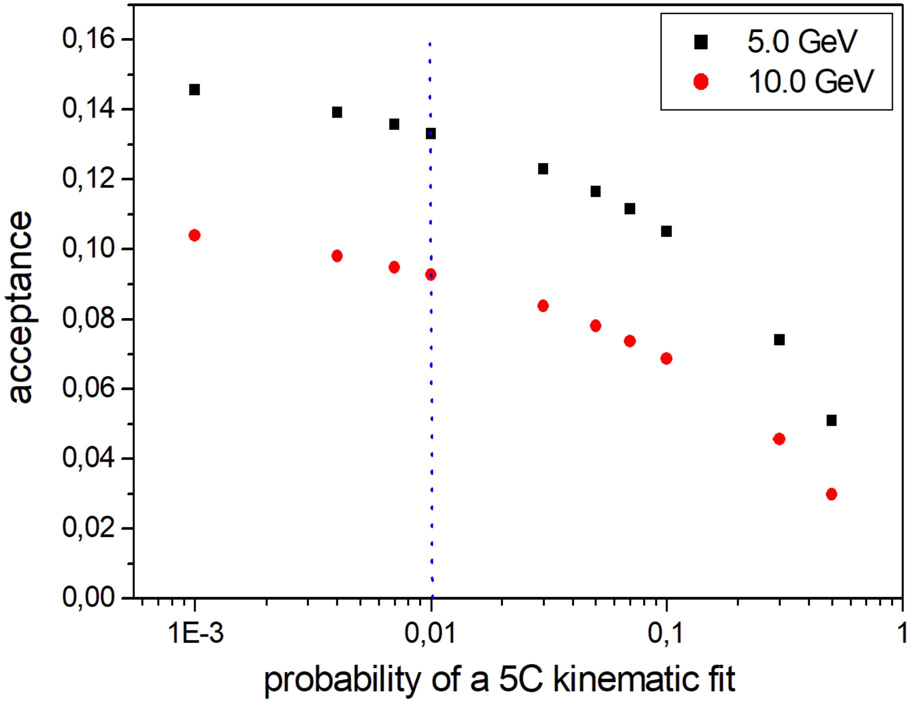
10 GeV

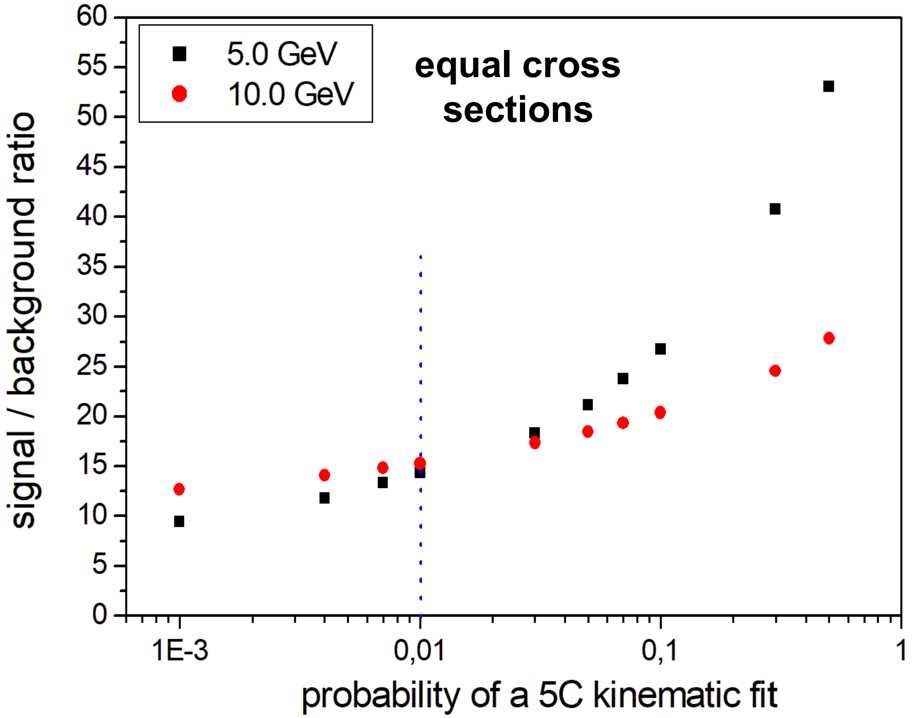




$p\,\bar{p} \rightarrow \gamma\, J/\psi \rightarrow \gamma\, e^+ e^-$

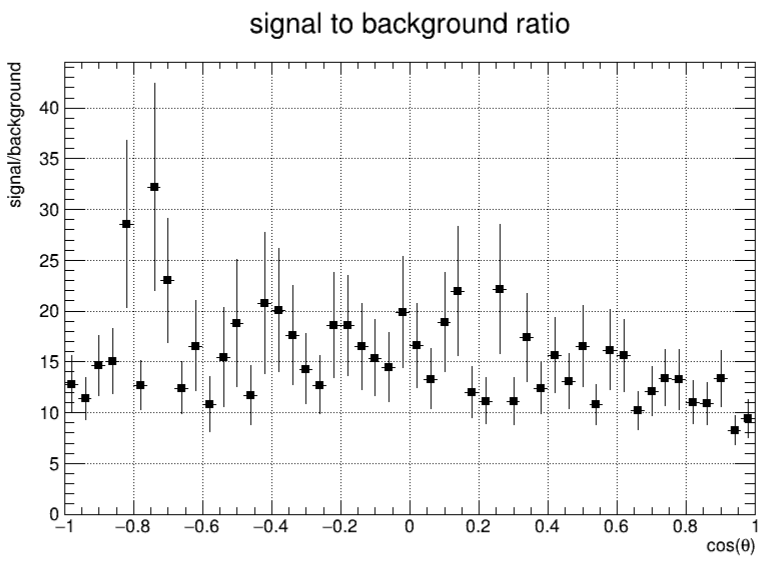
potential background: $p\,\bar{p} \rightarrow \pi^0\, J/\psi$ + leptonic background



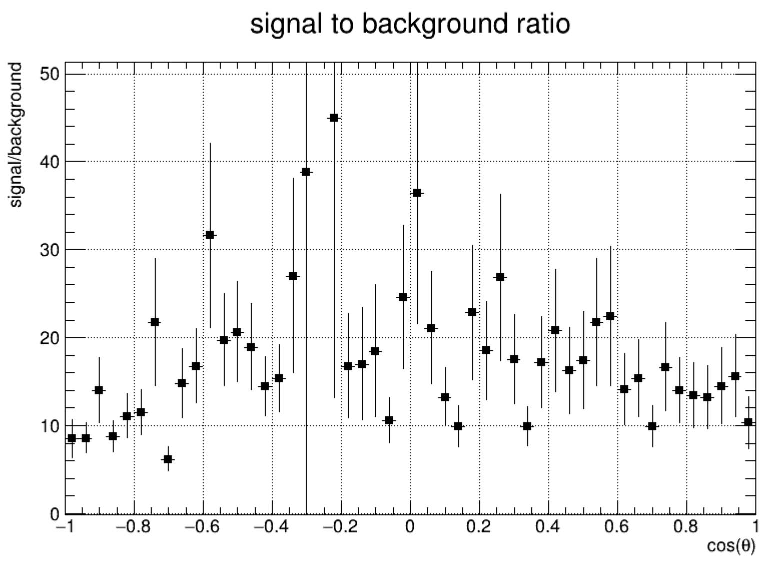


$p\,\bar{p} \rightarrow \gamma\, J/\psi \rightarrow \gamma\, e^{+}\, e^{-}$

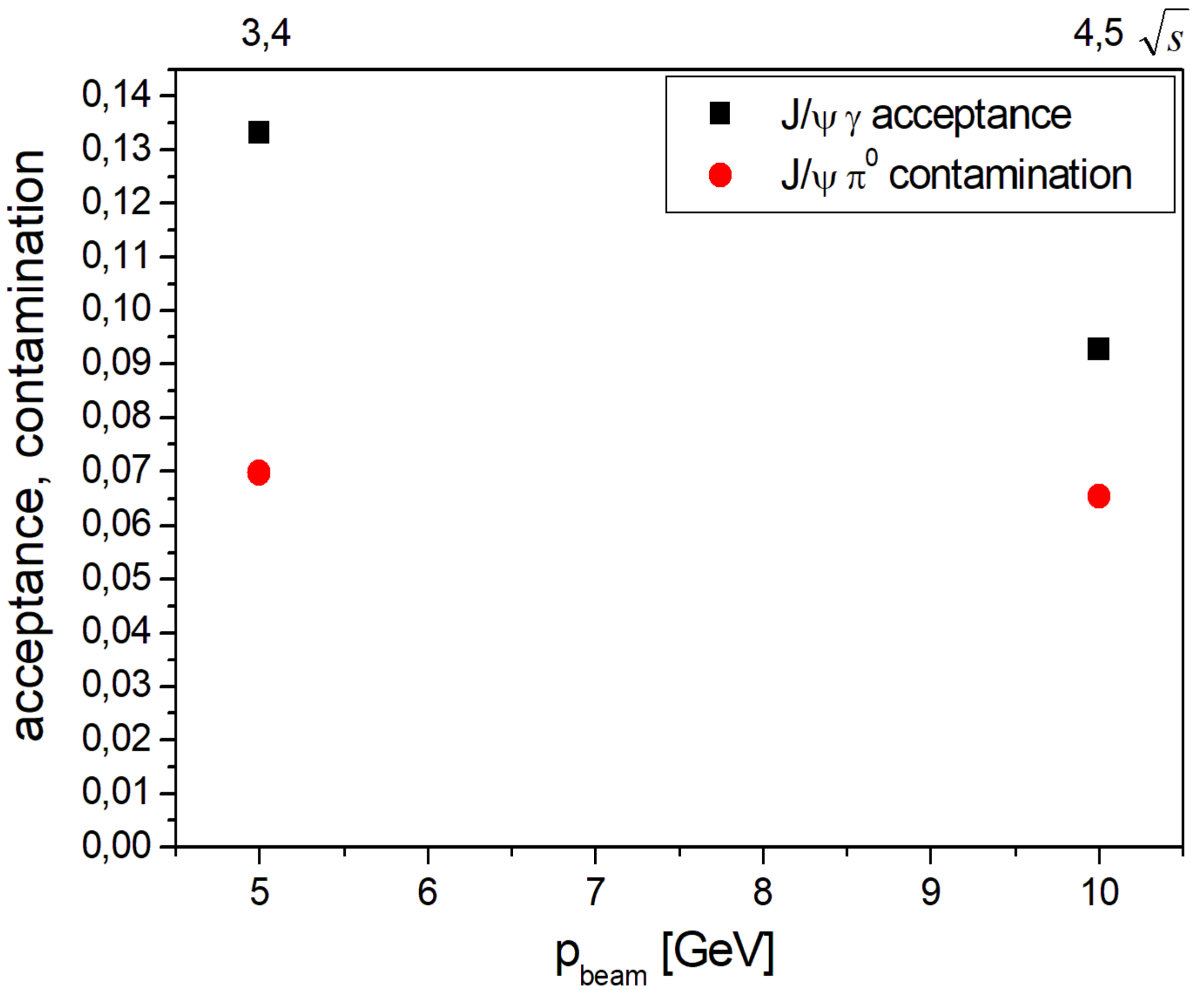
5 GeV



10 GeV



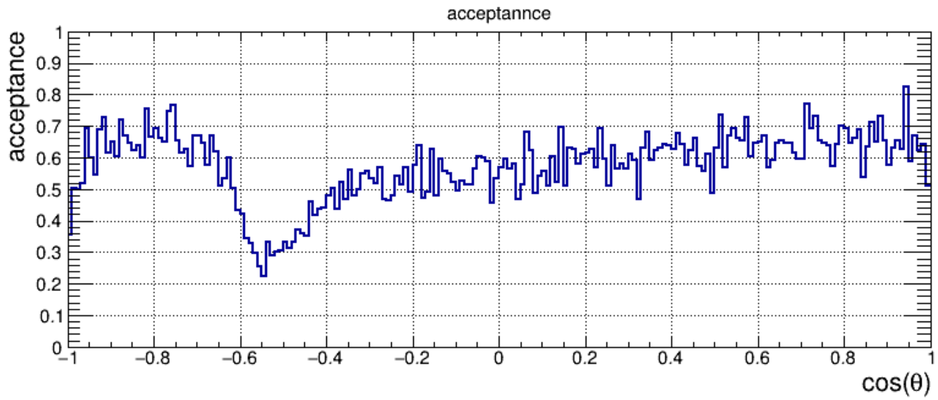
$p \bar{p} \rightarrow \gamma J/\psi \rightarrow \gamma e^+ e^-$

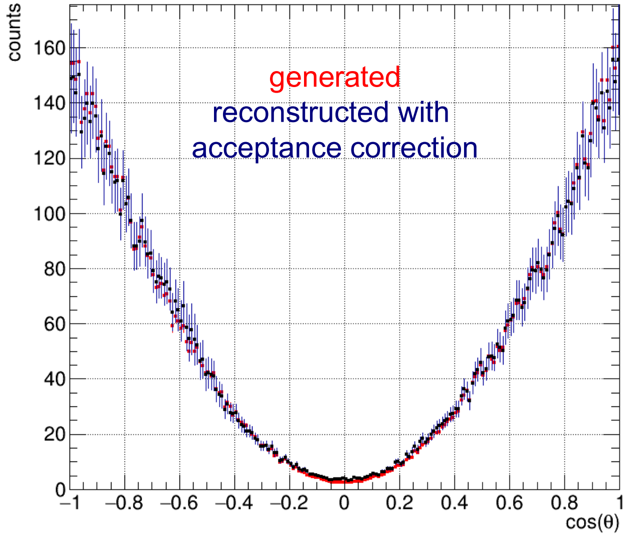


$$p\ \bar{p} \rightarrow \gamma\ J/\psi \rightarrow \gamma\ \mu^{+}\ \mu^{-}$$

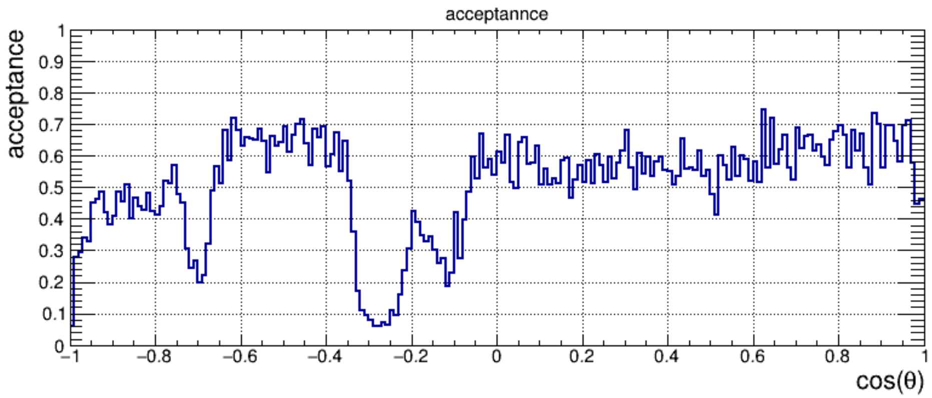
BR ~ 6 %

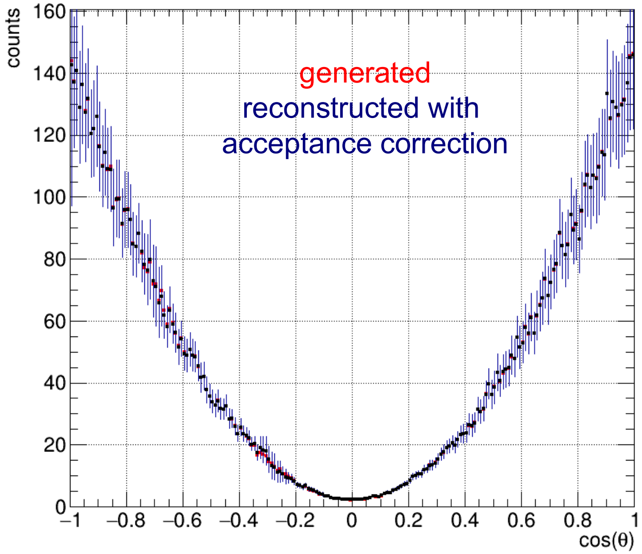
5 GeV





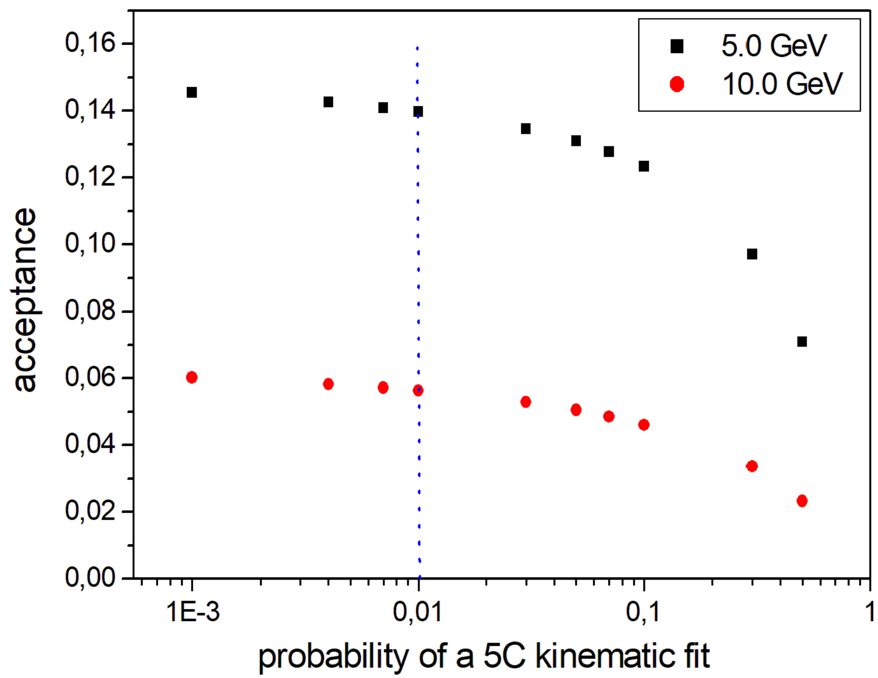
10 GeV

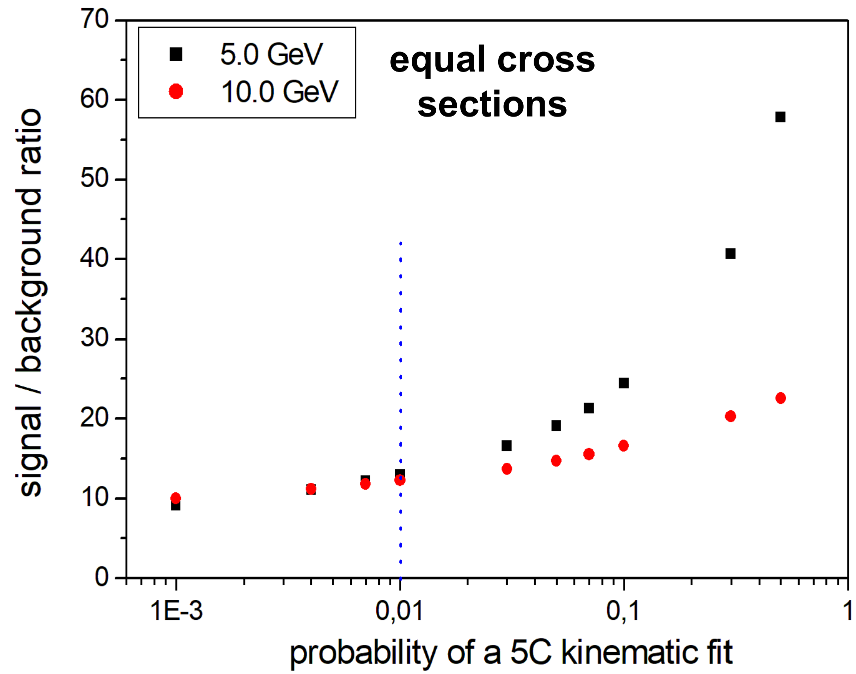




$p\,\bar{p} \rightarrow \gamma\, J/\psi \rightarrow \gamma\, \mu^+\, \mu^-$

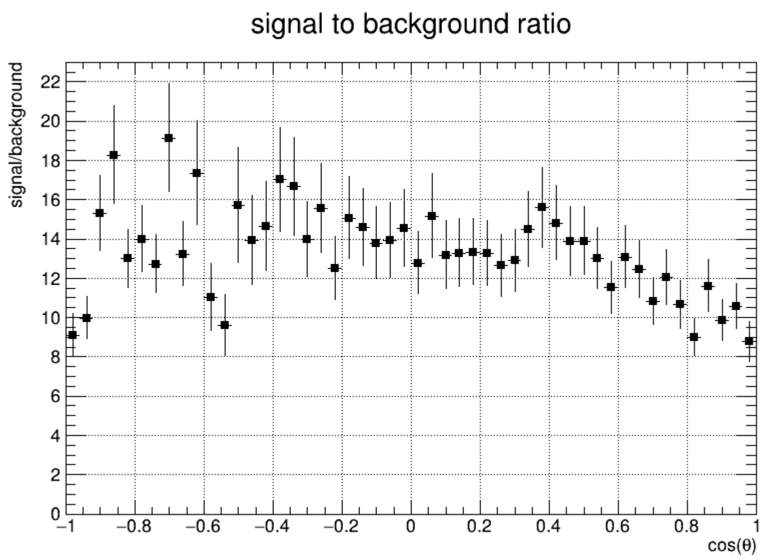
potential background: $p\,\bar{p} \rightarrow \pi^0\, J/\psi$ + leptonic background



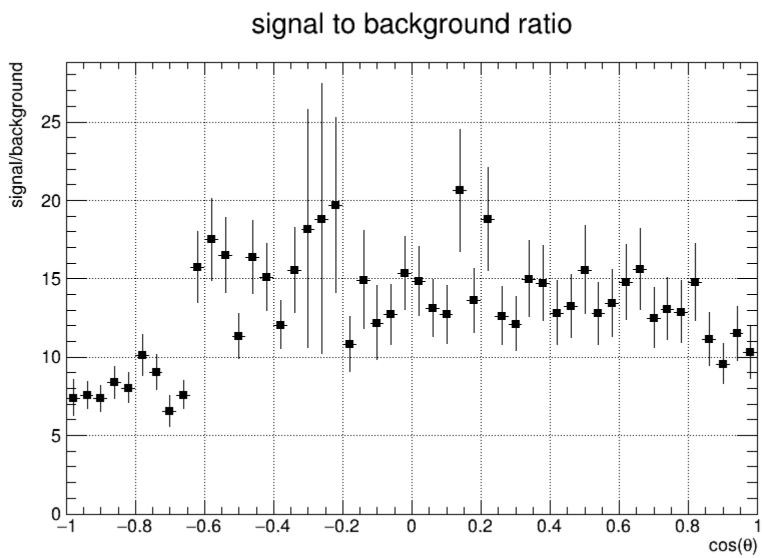


$p\ \bar{p} \rightarrow \gamma\ J/\psi \rightarrow \gamma\ \mu^{+}\ \mu^{-}$

5 GeV



10 GeV



Summary and Outlook

- GPDs in the space like region are currently extensively studied at experiments like CLAS12.
- The study of GDAs / time-like GPDs with PANDA can help us to get more detailed / additional insights into the 3D nucleon structure.
- First theoretical modells and predictions exist by Kroll and Schäfer.
- An initial feasability study has been done for a set of mesons.
- The results show, that GDAs can be extracted with PANDA.
- More cuts have to be added to reduce the background.
- More detailed studies, including count rate / beamtime estimates are in progress.

The GDA program can be extended to charmonium resonances and measurements can probably be done together with the spectroscopy program.