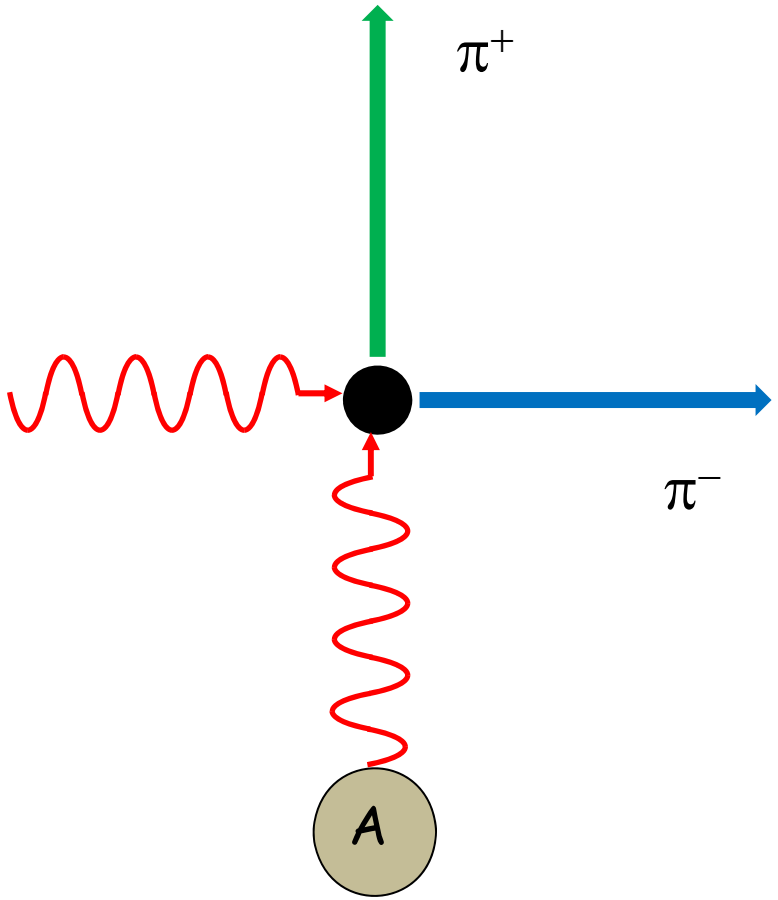
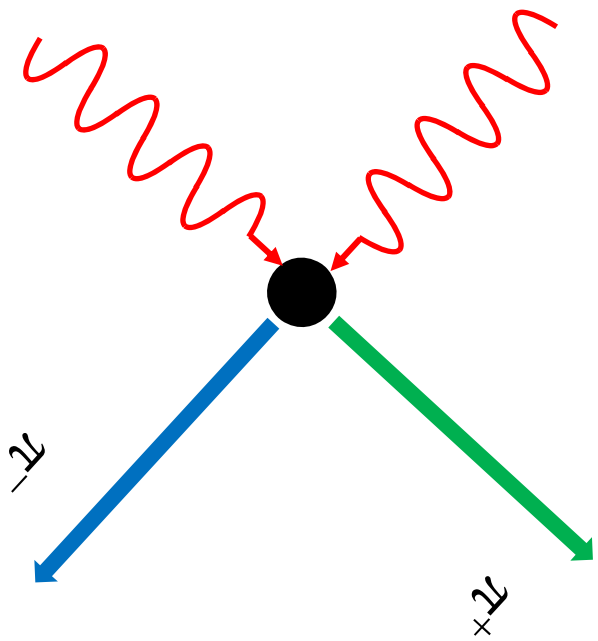
Charged Pion Polarizability Measured in $\gamma\,\gamma \rightarrow \pi^+\,\pi^-$
The Hall D CPP Experiment



Primakoff production

Charged Pion Polarizability Measured in $\gamma\gamma \rightarrow \pi^+\pi^-$
The Hall D CPP Experiment

Primakoff production: related through crossing-symmetry to Compton scattering



Theory for pion polarizability

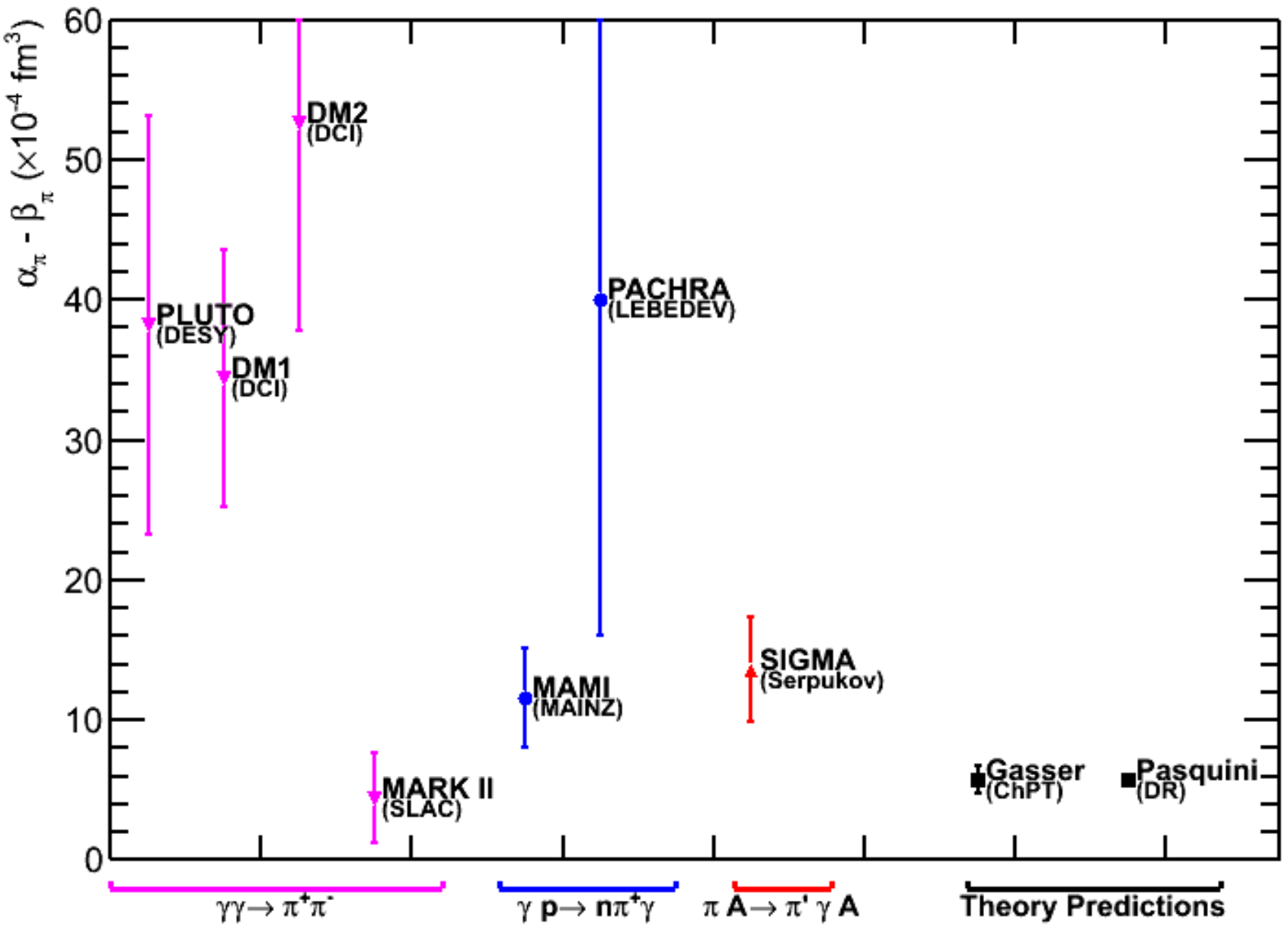
$$L_{QCD}(p^4) = L^{chiral-even}(p^4) + L^{chiral-odd}(p^4)$$

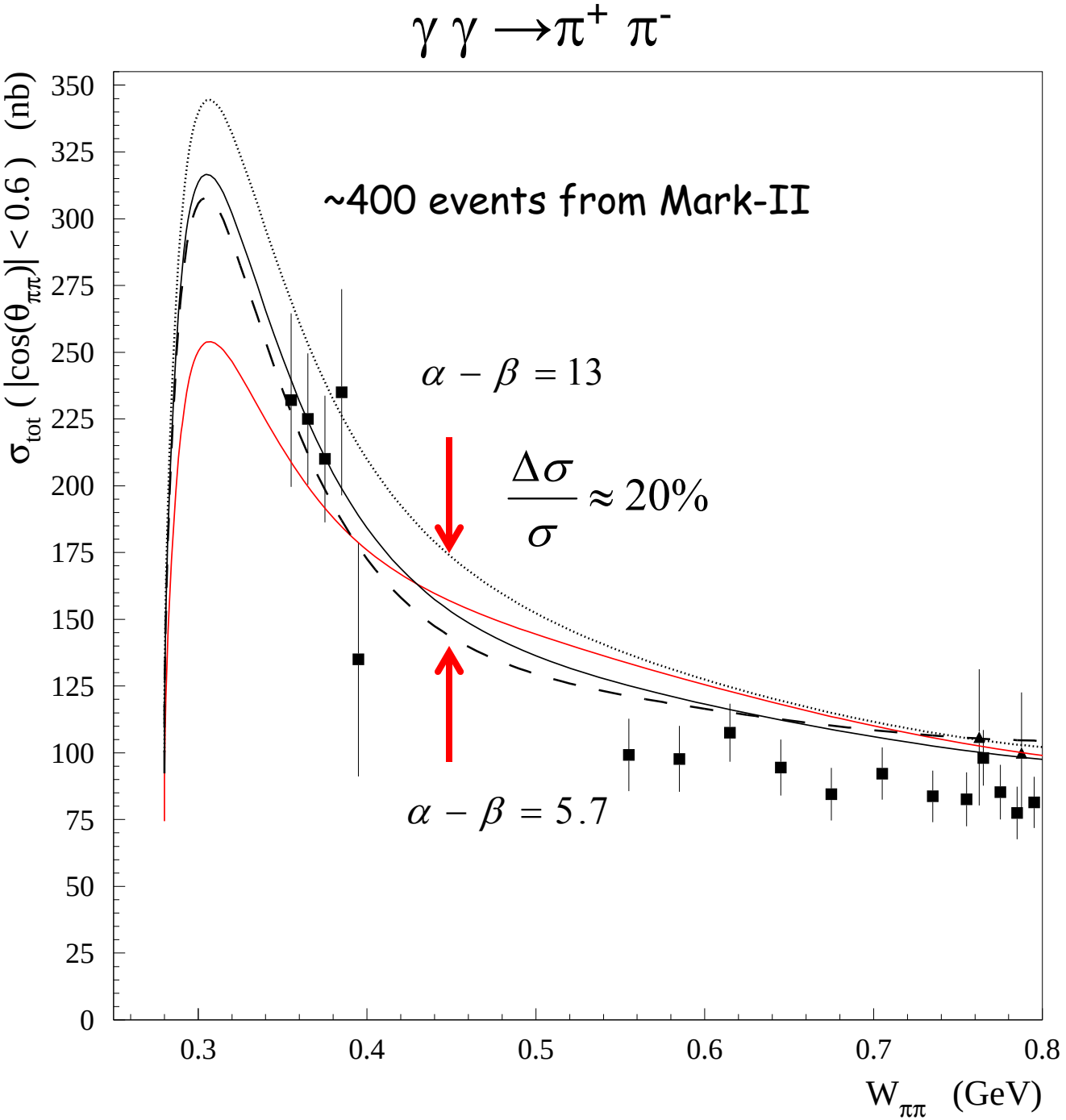
Charged pion polarizability

$$\alpha_{\pi^+} = -\beta_{\pi^+} = \frac{4\alpha}{m_\pi F_\pi^2}\left(L_9^r - L_{10}^r\right)$$

$$\pi^0 \longrightarrow \gamma\gamma$$

$$A_{\gamma\gamma} = \frac{\alpha N_c}{3\pi F_\pi}$$


$\alpha_\pi - \beta_\pi$ ($\times 10^{-4}$ fm^3)
60
50
40
30
20
10
0
DM2
(DCI)
PLUTO
(DESY)
DM1
(DCI)
PACHRA
(LEBEDEV)
MAMI
(MAINZ)
SIGMA
(Serpukov)
MARK II
(SLAC)
Gasser
(ChPT)
Pasquini
(DR)
$\gamma\gamma \rightarrow \pi^+\pi^-$
$\gamma\ p \rightarrow n\pi^+\gamma$
$\pi\ A \rightarrow \pi'\ \gamma\ A$
Theory Predictions


$\gamma\gamma \rightarrow \pi^+ \pi^-$
σ_{tot} ($|\cos(\theta_{\pi\pi})| < 0.6$) (nb)
~400 events from Mark-II
$\alpha - \beta = 13$
$\frac{\Delta\sigma}{\sigma} \approx 20\%$
$\alpha - \beta = 5.7$
$W_{\pi\pi}$ (GeV)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
0.3
0.4
0.5
0.6
0.7
0.8

Cross sections with linearly polarized photons

$$\frac{d^3\sigma}{d\Omega_{\pi\pi}\,dW_{\pi\pi}\,d\Omega_{\pi}} =$$

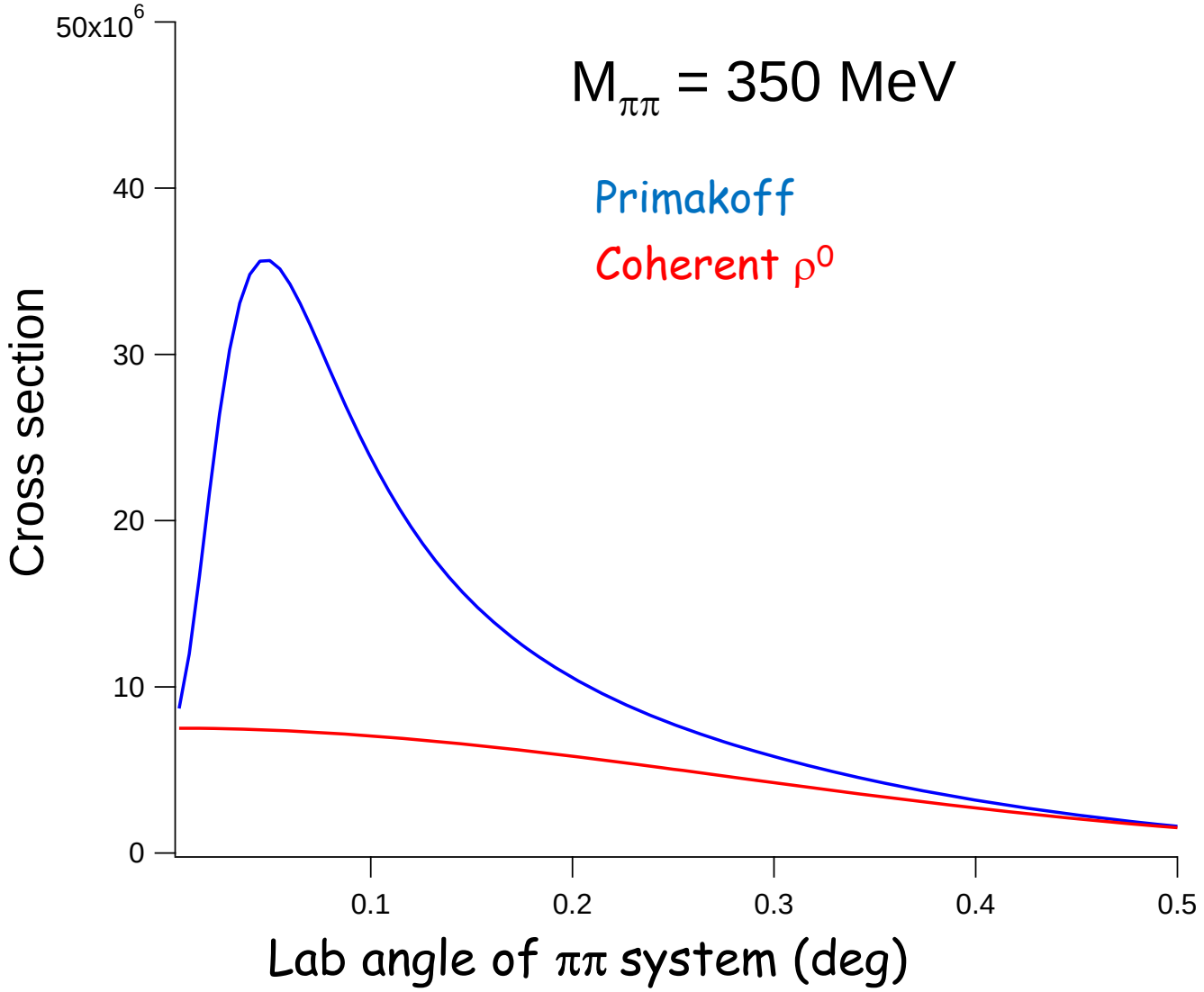
$$\frac{d\sigma_{Primakoff}}{d\Omega_{\pi\pi}}\frac{d^2\Gamma(\gamma\gamma\to\pi\pi)}{d\Omega_{\pi}\,dW_{\pi\pi}}\left(1+P_{\gamma}\cos 2\varphi_{\pi\pi}\right)+\frac{3}{8\pi}\sin^2\theta_{\pi}\left(1+P_{\gamma}\cos 2\Psi\right)\frac{d^2\sigma_{\rho}}{d\Omega_{\rho}\,dW_{\pi\pi}}$$

Primakoff

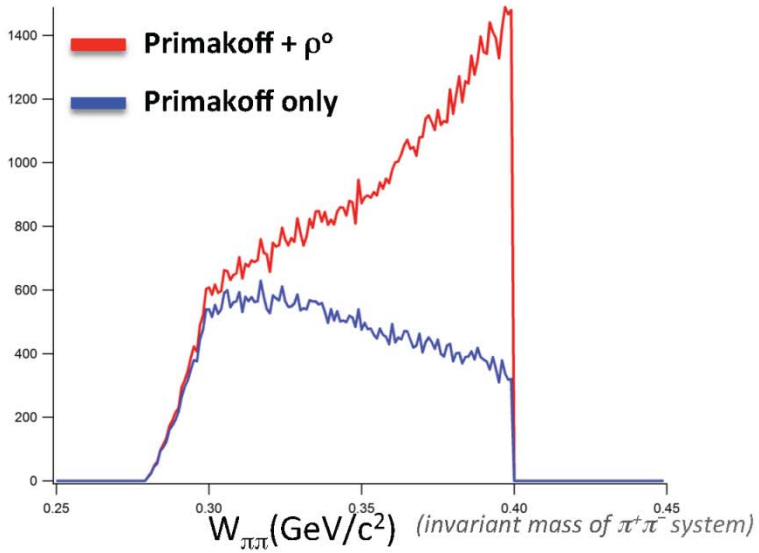
Coherent ρ^0 photoproduction

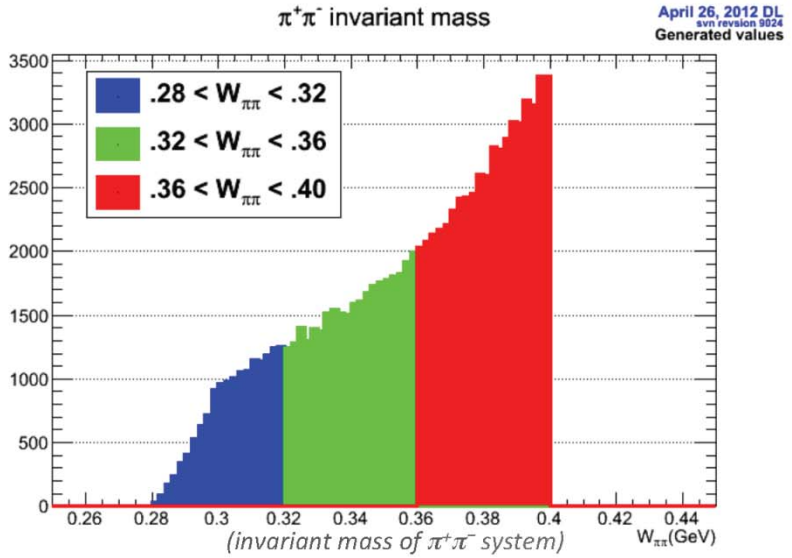
$\phi_{\pi\pi}$ = azimuthal angle of $\pi\pi$ system in the lab frame

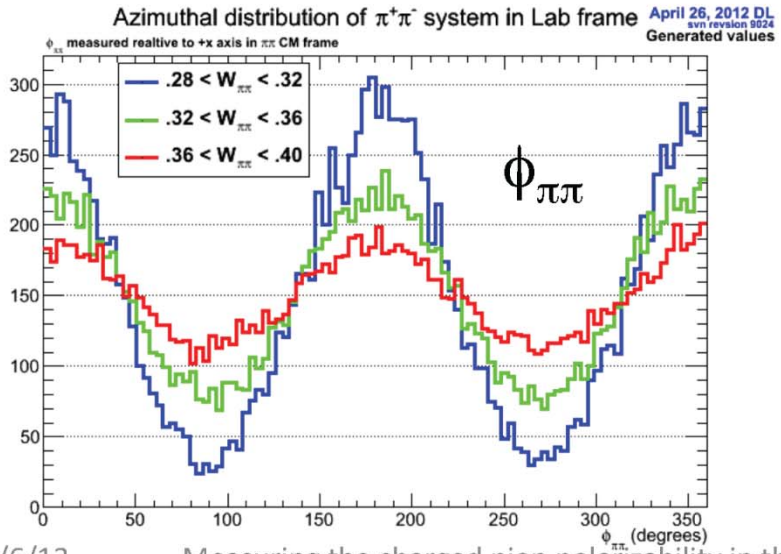
Ψ = azimuthal angle of π^+ in the helicity frame

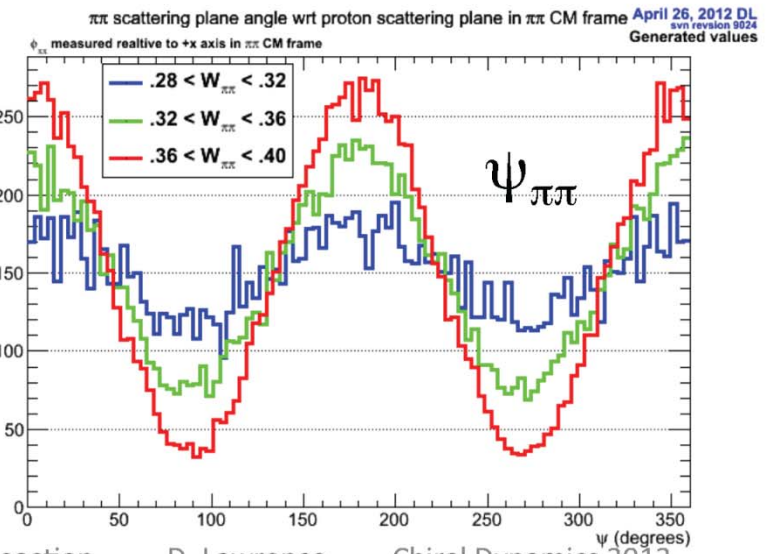

$M_{\pi\pi}$ = 350 MeV
Primakoff
Coherent ρ^0
Cross section
50x10^6
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
Lab angle of ππ system (deg)

Linear Polarization of incident photon beam helps distinguish Primakoff from coherent ρ^o production

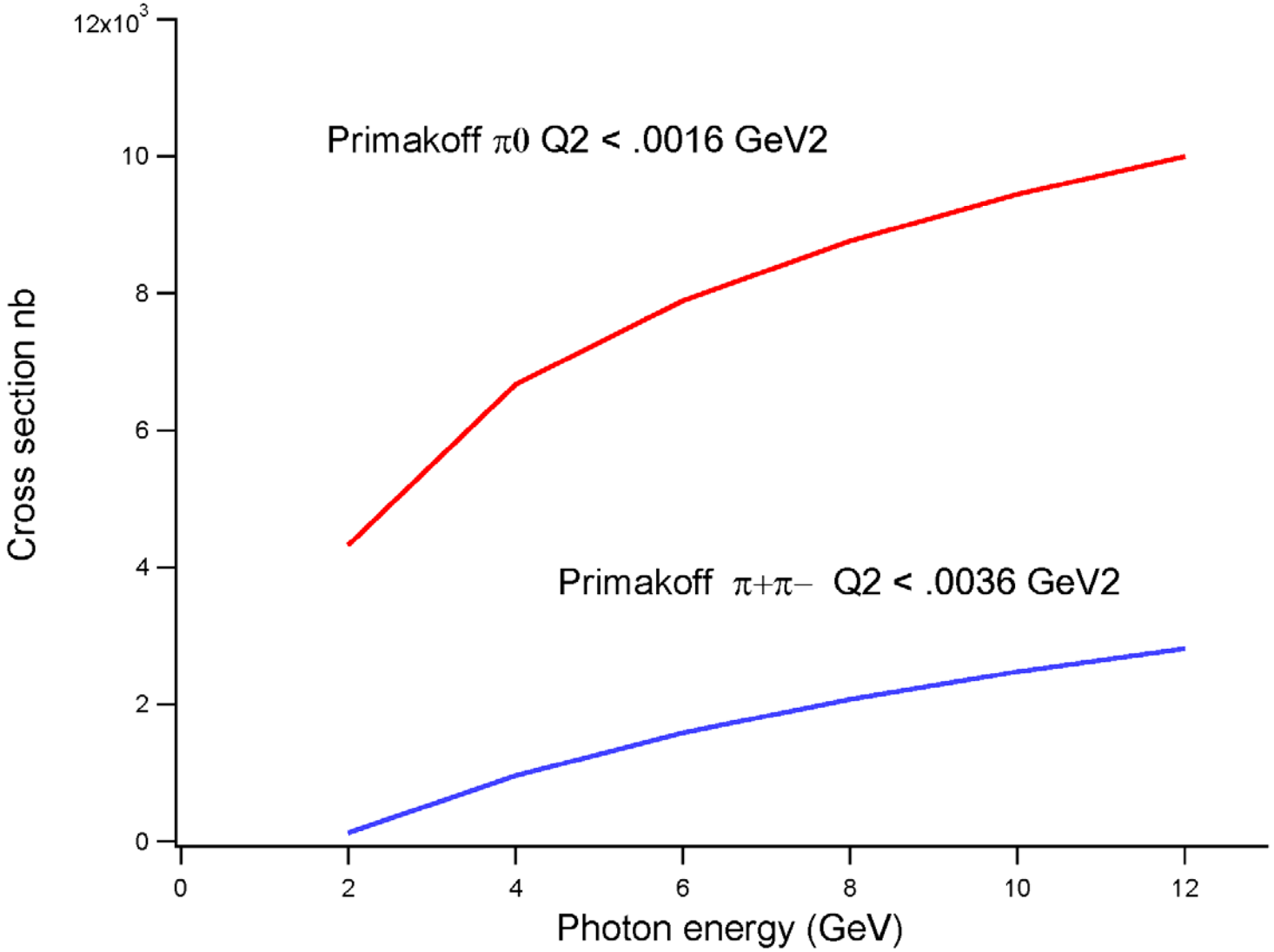






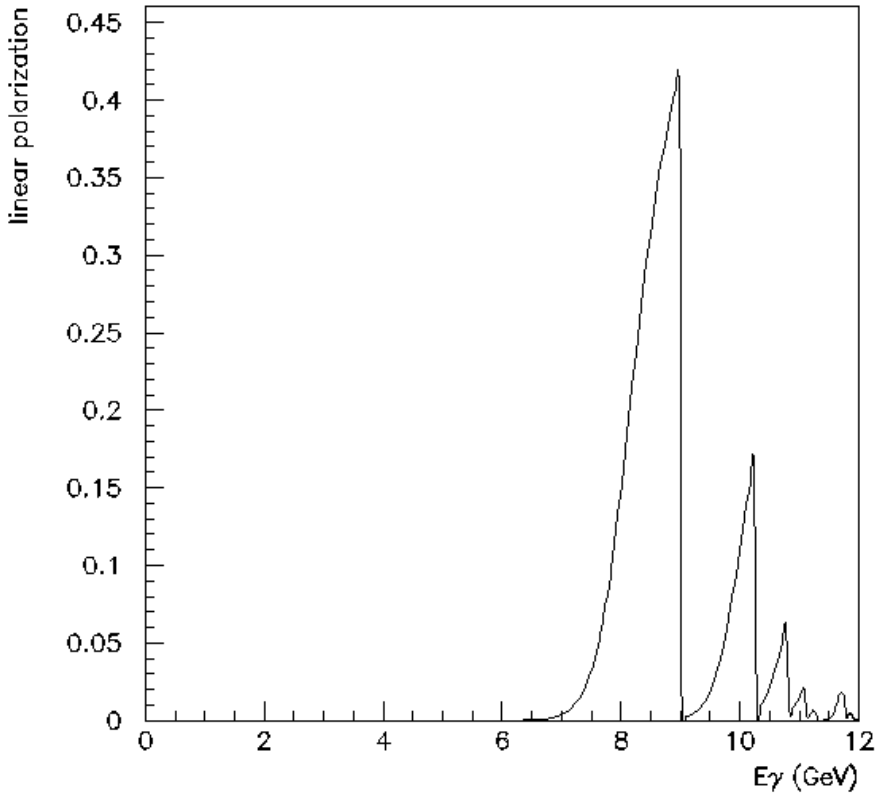


Optimizing the beam energy for the experiment

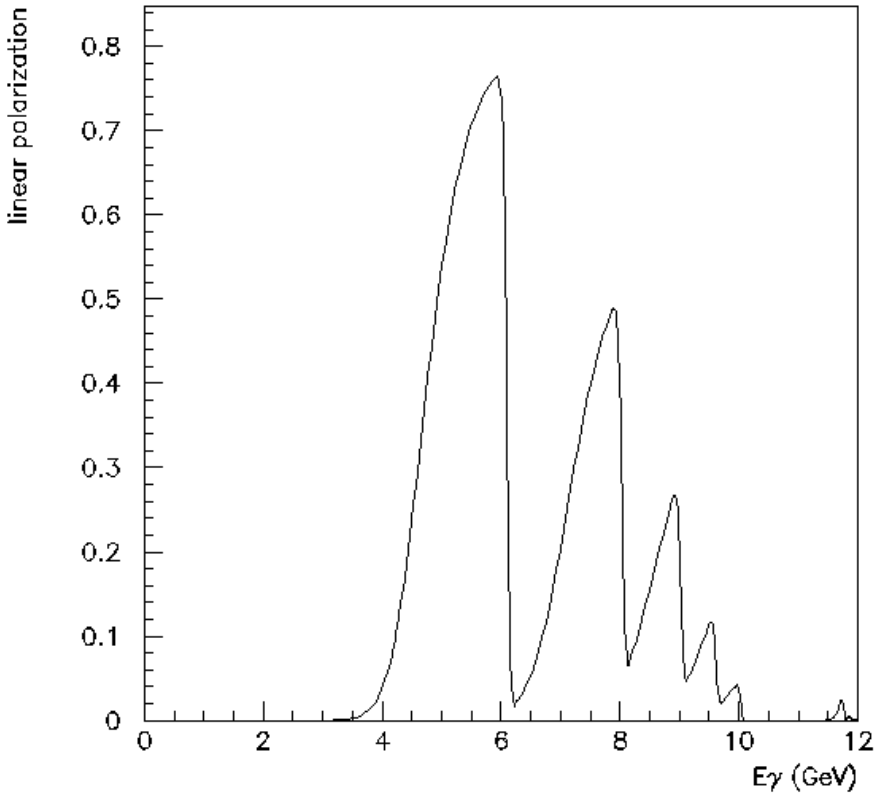

12x10^3
10
8
6
4
2
0
Cross section nb
Primakoff π0 Q2 < .0016 GeV2
Primakoff π+π− Q2 < .0036 GeV2
0
2
4
6
8
10
12
Photon energy (GeV)

Comparing beam figure-of-merit at 9 GeV with 6 GeV

Polarization edge at 9 GeV

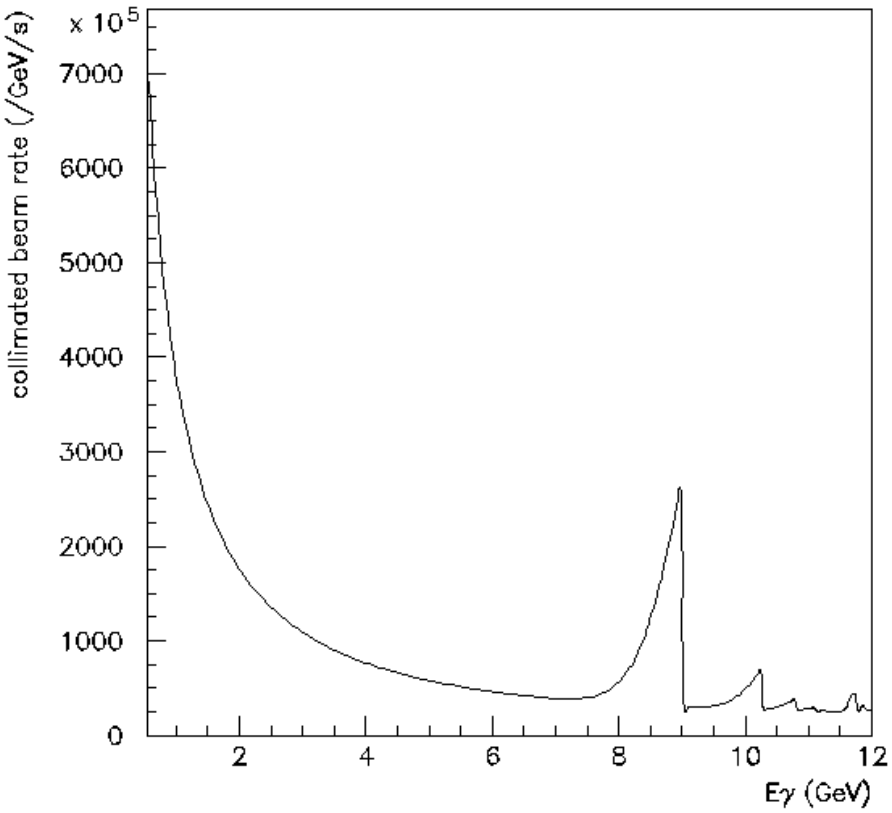


Polarization edge at 6 GeV



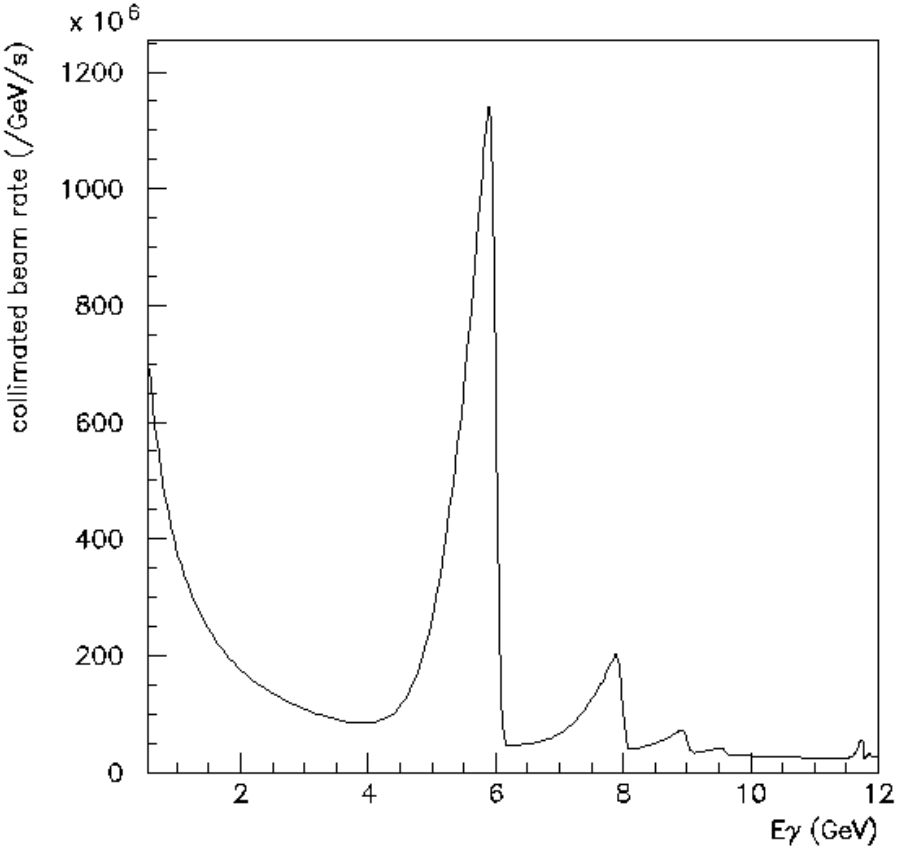
Increase in peak polarization = × 1.7

Polarization edge at 9 GeV



Events 0.1 to 8 GeV = 1.8×10^9
Events 8 to 9 GeV = 1.3×10^8
Events 9 to 12 GeV = 9.9×10^7
Events in peak/Events outside of peak = .068

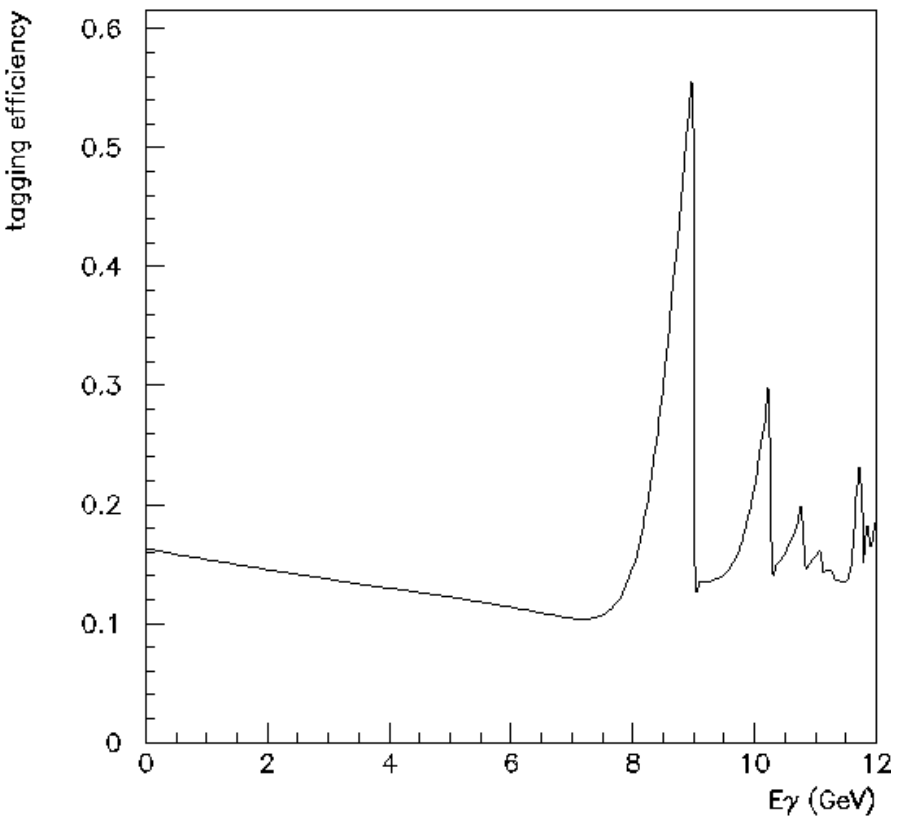
Polarization edge at 6 GeV



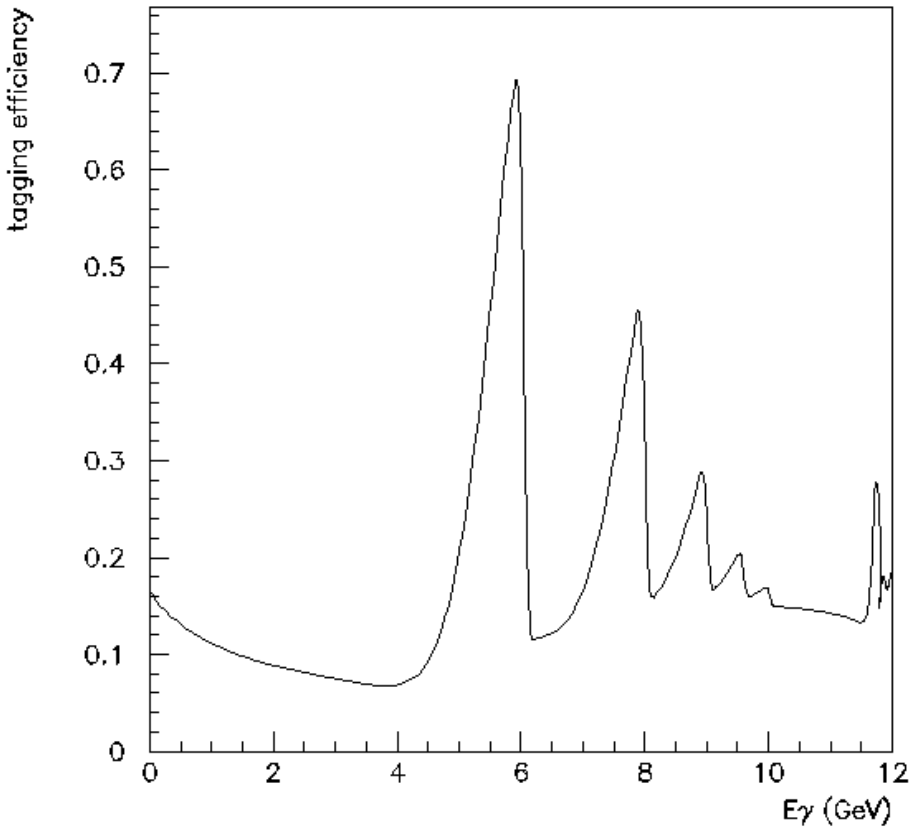
Events 0.1 to 5 GeV = 1.7×10^9
Events 5 to 6 GeV = 6.6×10^8
Events 6 to 12 GeV = 3.5×10^8
Events in peak/Events outside of peak = .32

Increase in signal/background= × 4.7

Polarization edge at 9 GeV



Polarization edge at 6 GeV



Increase in peak tag eff. = × 1.3

Beam figure of merit =

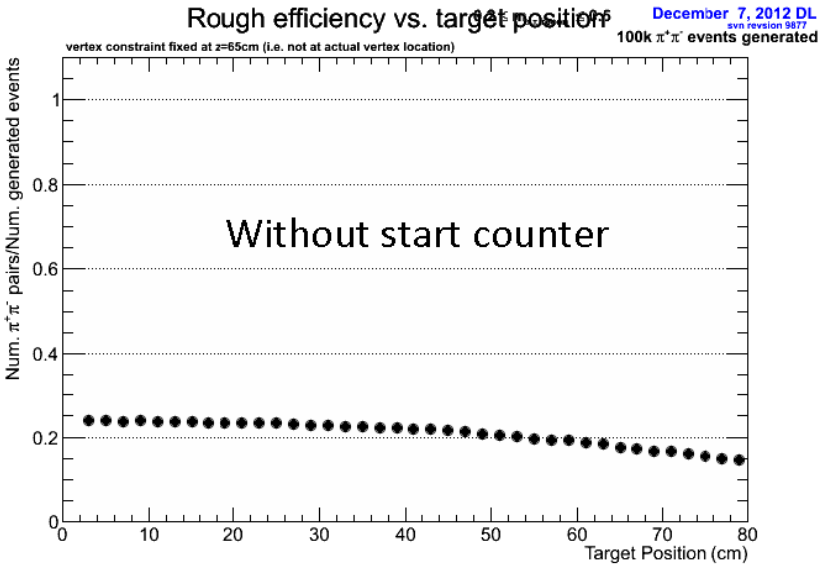
P^2 × (Photons in peak/Photons out of peak) × (Tagging eff.)

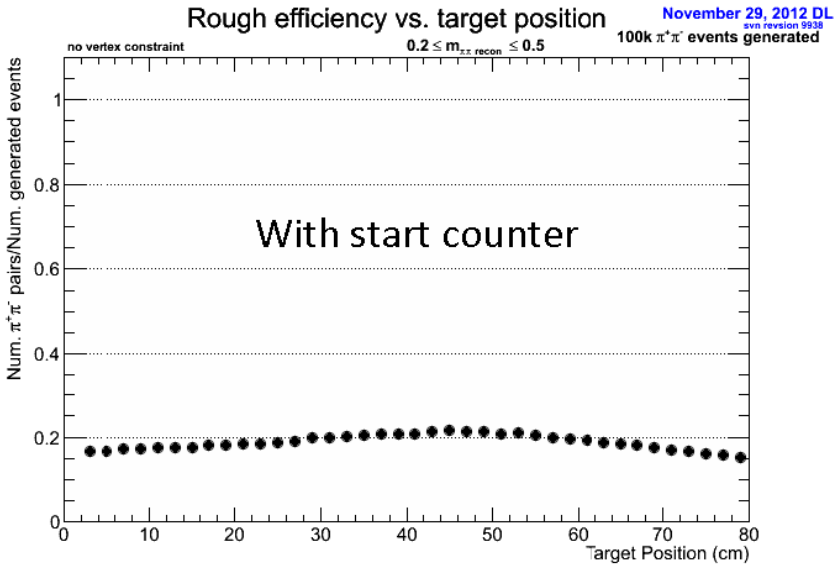
The F.O.M. increase in moving the polarization edger from 9 GeV to 6 GeV is

$$1.7^2 \times 4.7 \times 1.3 = 18$$

Moving the target position

$\pi^+ \pi^-$ reconstruction efficiency

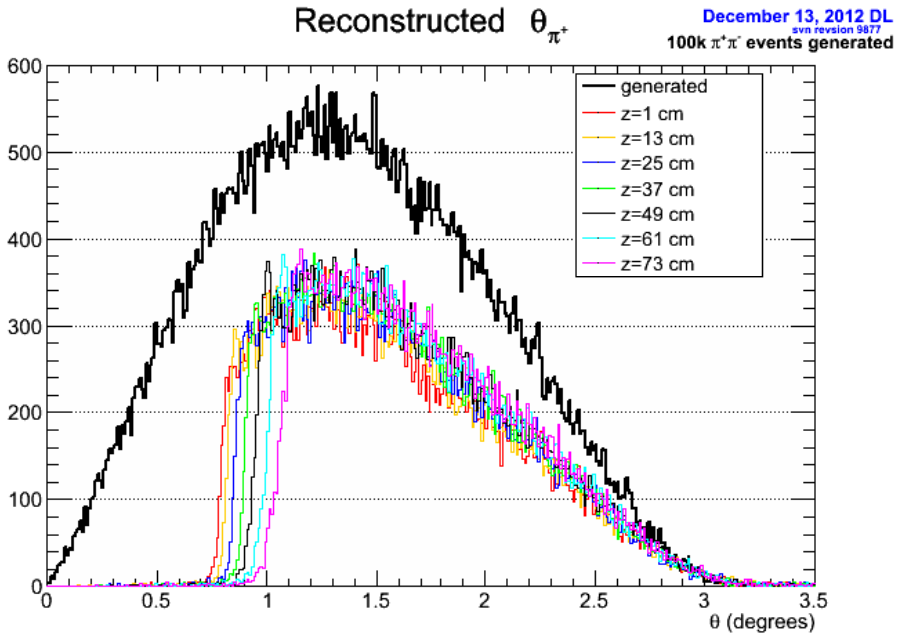




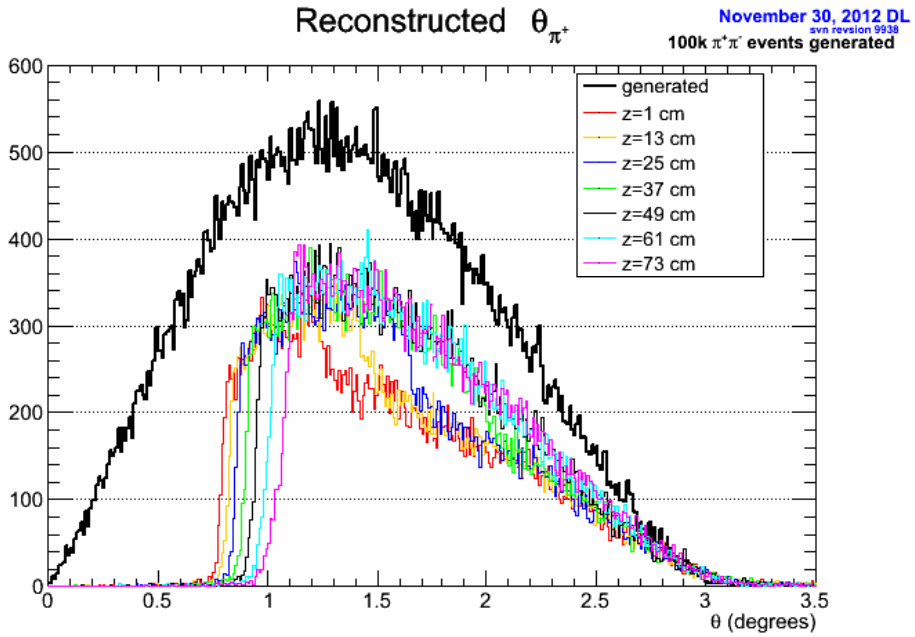
Need to investigate the acceptance as a function of Mππ

π^+ polar angle

Without start counter

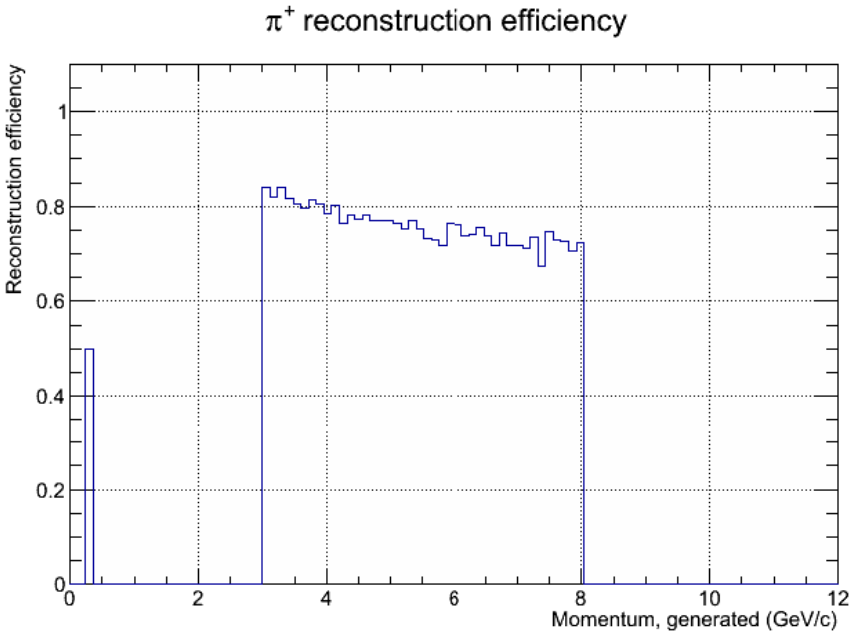


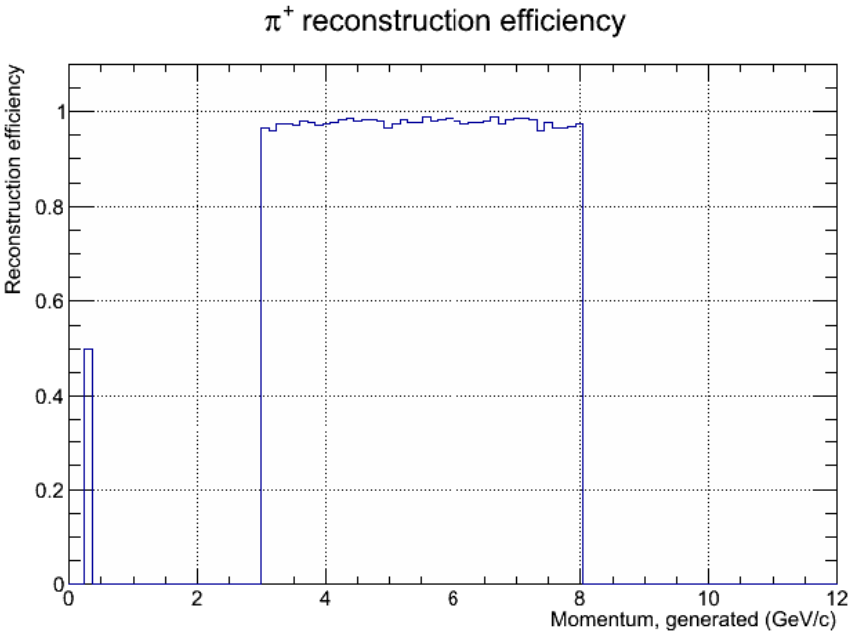
With start counter



Target Vertex point for Candidates

- Forward going track finder set to use target vertex, but only if all hits are within 10cm of beamline.
- Made this value into a configuration parameter that can be set from command line: TRKFIND:MAX_R_VERTEX_LIMIT
- Set value very high so target vertex is always used





Calibration reaction: π^0 Primakoff photo-production

$$\frac{d\sigma}{d\Omega_\pi} = \Gamma\left(\pi^0 \to \gamma\gamma\right)\frac{8\alpha Z^2}{m_\pi^3}\frac{\beta^3 E_\gamma^4}{Q^4}\left|F(Q)\right|^2 \sin^2\theta_\pi\left(1 - P_\gamma \cos 2\varphi_\pi\right)$$

Polarized coherent photo-production has the same azimuthal distribution as Primakoff

Possible to calibrate photon flux and polarization

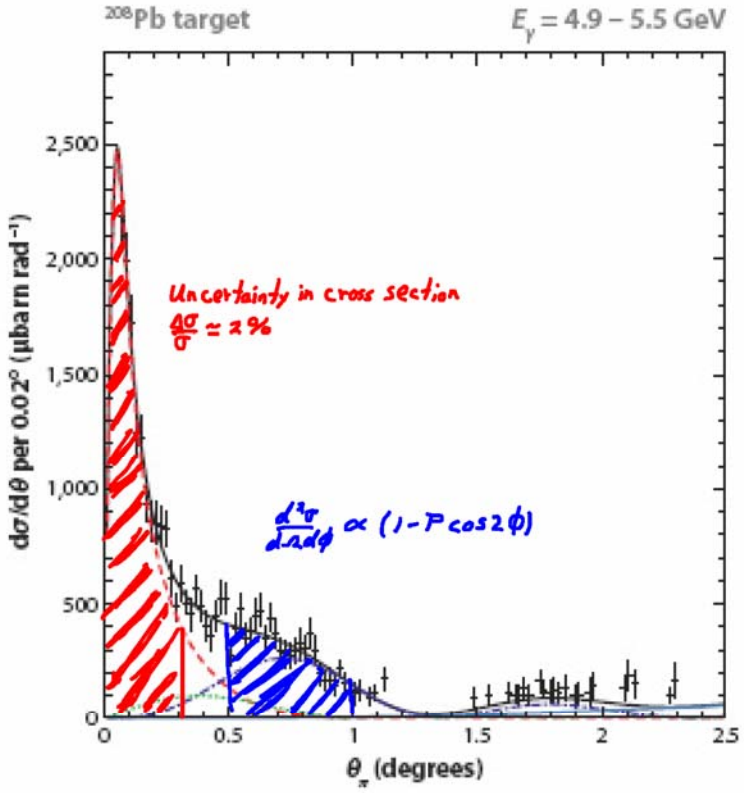


Figure 3

Differential cross section as a function of π^0 production angle for ^{208}Pb. The curves have the same meaning as those in Figure 2.

Trigger:

(2 charged tracks in the FCAL with E_{sum} > E ?) OR

(2 neutral tracks in the FCAL with E_{sum} > 5 GeV)

PID:

- $\gamma A \rightarrow \phi \rightarrow K^+ K^-$ most problematic hadronic background
- No START counter: Time of flight from Tagger - TOF counter time difference. Can we identify the beam bucket?
- dE/dX from TOF counter and FDC 's ?