Photoproduction of ϕ-meson by Using Linearly-Polarized Photons at Threshold Energies

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CLAS Collaboration Meeting

Newport News, VA

June 12, 2009

IDAHO STATE UNIVERSITY

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Outline

- Motivation
  - OZI evading/respecting
  - VMD (Vector Meson Dominance)
  - Spin Density Matrix Elements

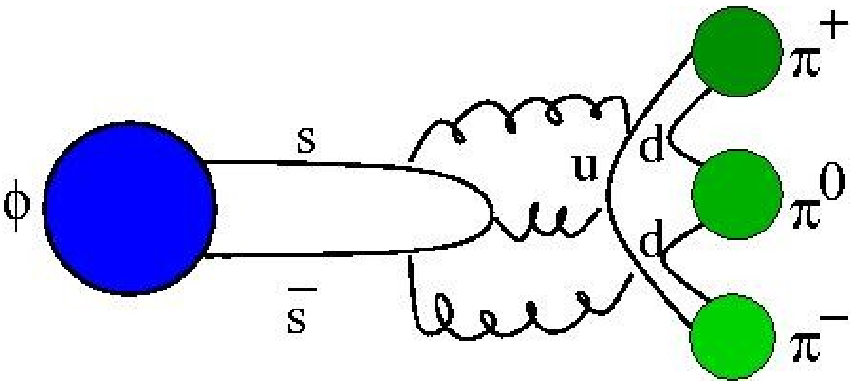
- ϕ-meson Photoproduction
  - CEBAF (Continuous Electron Beam Accelerator Facility)
  - Coherent Bremsstrahlung Facility at CLAS (CEBAF Large Acceptance Spectrometer)
    - Event Selection
    - Background Subtraction

➔ Results for the 1.9 GeV Coherent-Edge

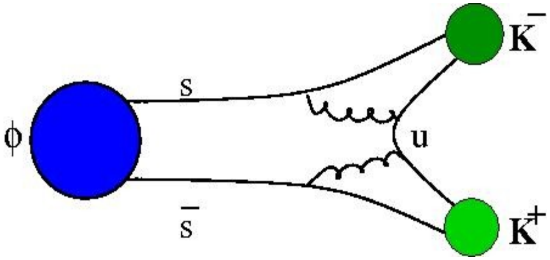
➔ Results for the 2.1 GeV Coherent-Edge

OZI evading/respecting process

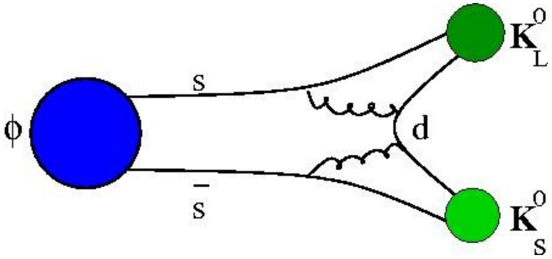
- Okubo Zweig Iizuka rule: In strong interaction processes where final states can only be reached via quark-antiquark annihilation are suppressed. You cannot cut gluon lines in the OZI picture.



- **Experimentally this decay mode is: (15.3 ± 0.4)%**



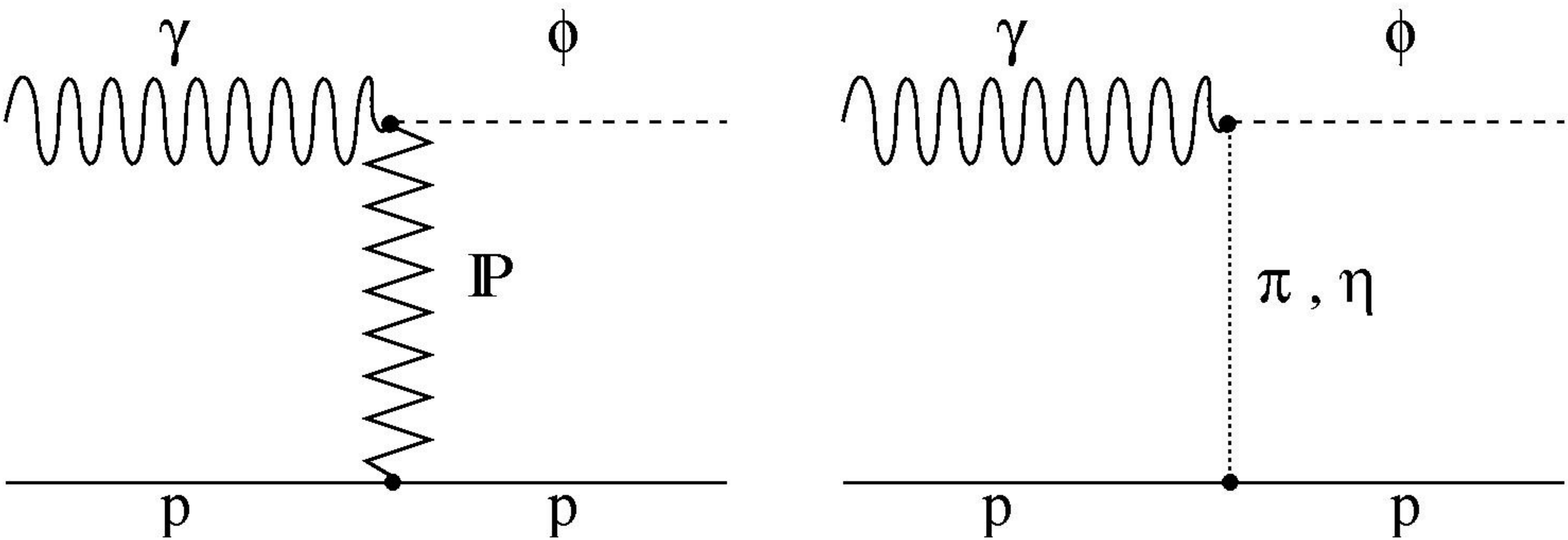
(49.2 ± 0.6) %



(34 ± 0.5)%

~84% of the Φ decay is OZI respecting.

VMD



Previous Measurements

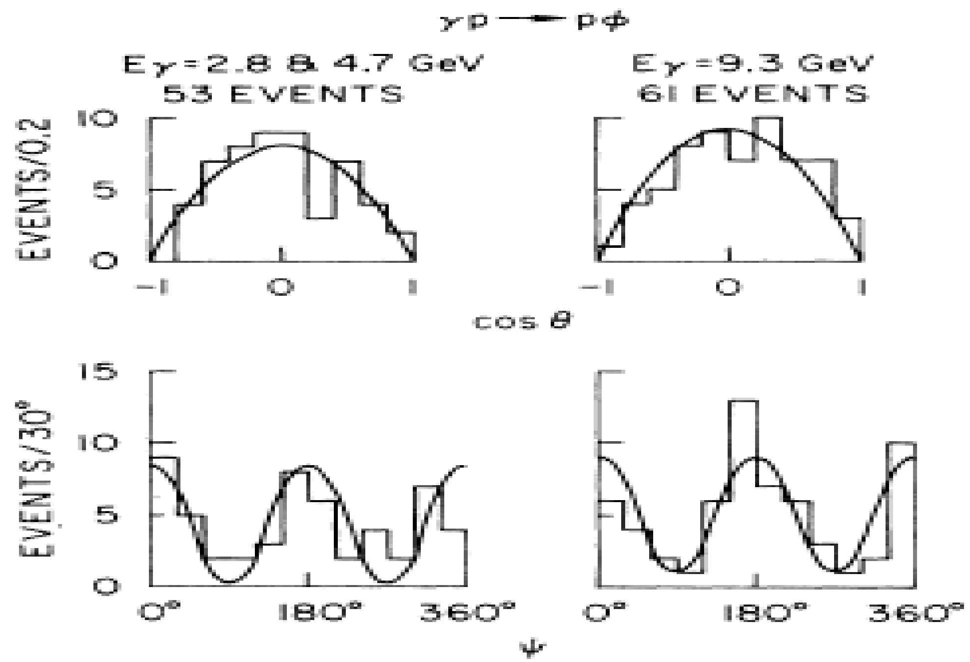


FIG. 29. Reaction $\gamma p \rightarrow p\phi$ at 2.8, 4.7, and 9.3 GeV. Decay angular distribution of $K\bar{K}$ pairs in the helicity system in the ϕ mass region $1.00 \le M_{K\bar{K}} \le 1.04$ GeV and in the momentum-transfer interval $0.02 \le |t| \le 0.8$ GeV^2. The curves are calculated for an s-channel helicity-conserving ϕ production amplitude.

J. Ballam, G. B. Chadwick *et al.*, Phys. Rev. D **7** 3150 (1972).

Previous Measurements

Spring-8 used a beam of linearly polarized photons (forward direction |t|<0.4 GeV ²)

- T. Mibe, “Measurement of ϕ meson photoproduction near production threshold with linearly polarized photons,” PhD Thesis, Osaka University, Japan (2004), unpublished.
- T. Mibe *et al.*, Phys. Rev. Lett. 95, 182001 (2005).

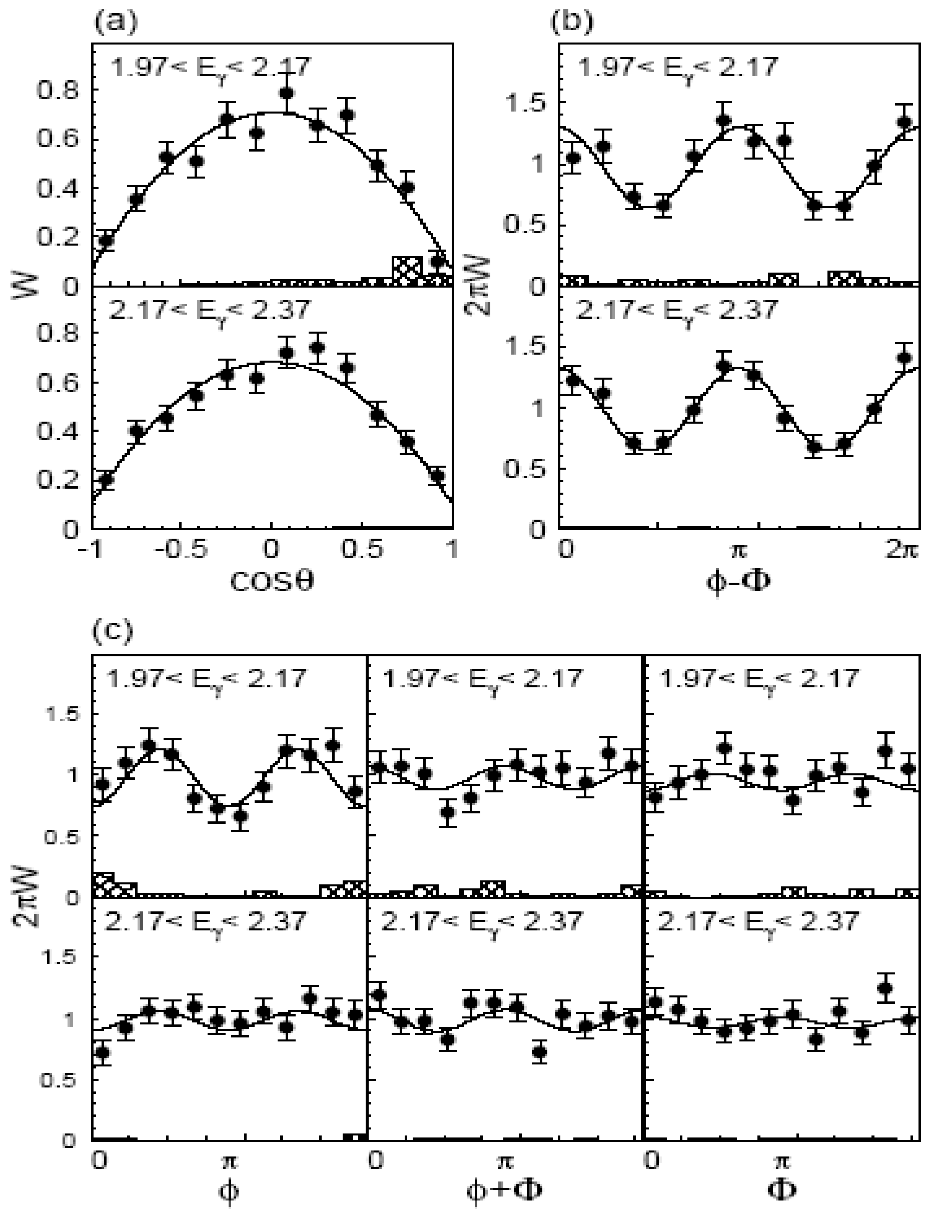


FIG. 4: Decay angular distributions for -0.2< $t+|t|_{min}$ in the Gottfried-Jackson frame. The solid curves are the fit to the data. The hatched histograms are systematic errors.

The Decay Angular Distribution
Spin Density Matrix Elements

$$W(\cos\theta,\phi,\Phi) = W^0(\cos\theta,\phi,\rho^0_{\alpha\beta}) - P_\gamma\cos 2\Phi\, W^1(\cos\theta,\phi,\rho^1_{\alpha\beta}) - P_\gamma\sin 2\Phi\, W^2(\cos\theta,\phi,\rho^2_{\alpha\beta})$$

where

$$W^0(\cos\theta,\phi,\rho^0_{\alpha\beta}) = \frac{3}{4\pi}[\frac{1}{2}\sin^2\theta + \frac{1}{2}(3\cos^2\theta - 1)\rho^0_{00} - \sqrt{2}\,\mathrm{Re}\,\rho^0_{10}\sin 2\theta\cos\phi - \rho^0_{1-1}\sin^2\theta\cos 2\phi]$$

$$W^1(\cos\theta,\phi,\rho^1_{\alpha\beta}) = \frac{3}{4\pi}[\rho^1_{11}\sin^2\theta + \rho^1_{00}\cos^2\theta - \sqrt{2}\,\mathrm{Re}\,\rho^1_{10}\sin 2\theta\cos\phi - \rho^1_{1-1}\sin^2\theta\cos 2\phi]$$

$$W^2(\cos\theta,\phi,\rho^2_{\alpha\beta}) = \frac{3}{4\pi}[\sqrt{2}\,\mathrm{Im}\,\rho^2_{10}\sin 2\theta\sin\phi + \mathrm{Im}\,\rho^2_{1-1}\sin^2\theta\sin 2\phi]$$

<u>Linearly polarization gives access to six more density matrix elements</u>

****Those are calculated in ϕ rest frame (Helicity Frame)***

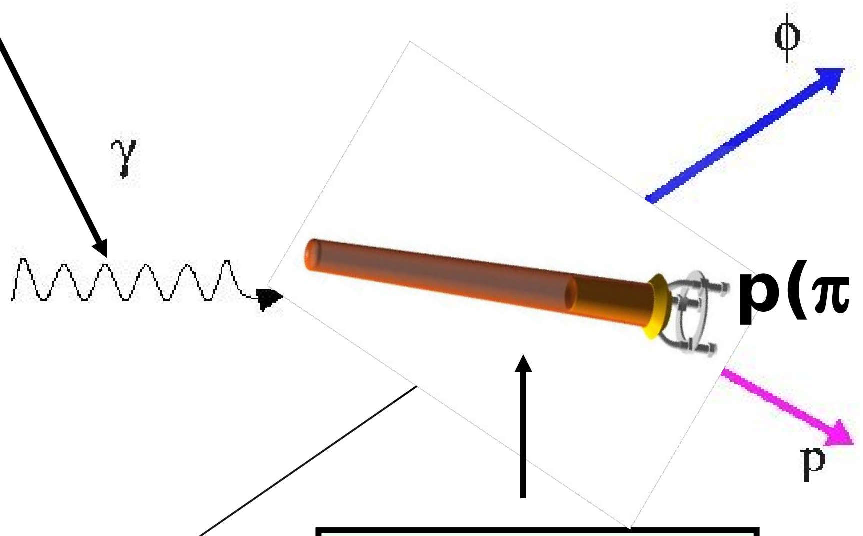
Spin Density Matrix Elements

IF VMD:

- **Density matrix elements should be equal to ZERO but ρ^1_{1-1} and $Im\{\rho^2_{1-1}\}$**
- **ρ^1_{1-1} , $Im\{\rho^2_{1-1}\}$ = (1/2, -1/2 : Pomeron)**
- **ρ^1_{1-1} , $Im\{\rho^2_{1-1}\}$ = (-1/2, 1/2 : Meson)**

ϕ–Photoproduction: g8b experiment

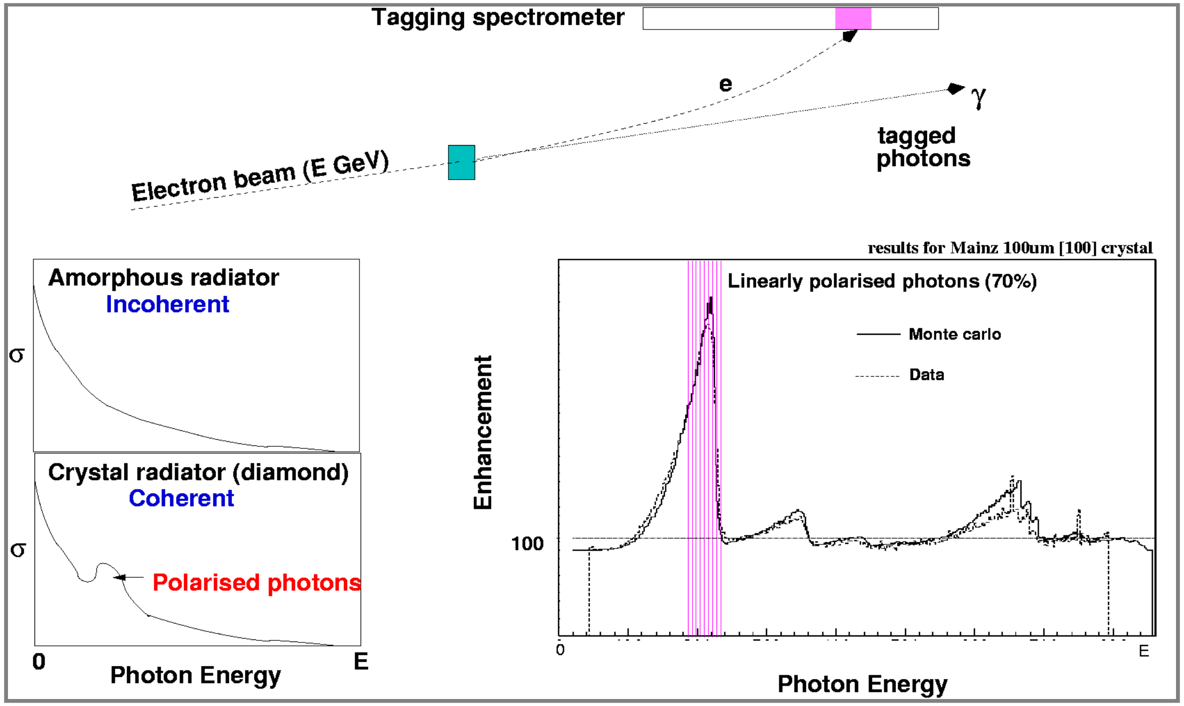
Linearly Polarized Photon Beam



p(π ,η ,η ’,ρ ,ω ,ϕ), KΛ

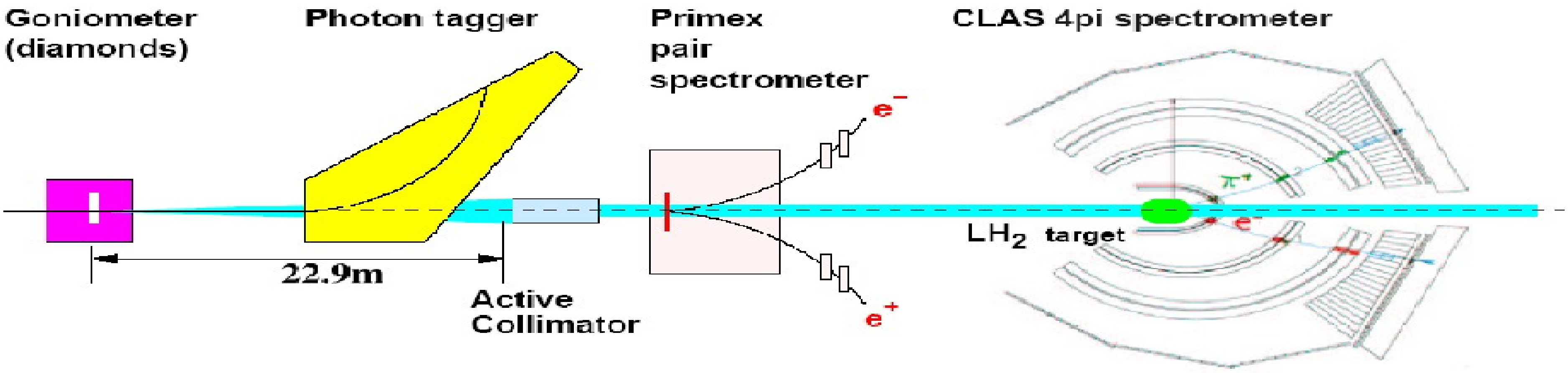
Target: Hydrogen

The Coherent Bremsstrahlung Facility at CLAS

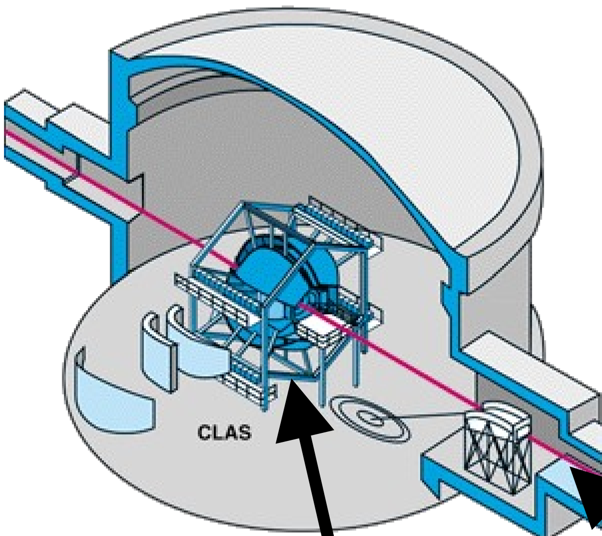


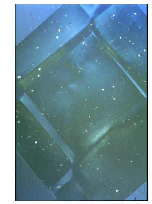
Requirements for Coherent Bremsstrahlung

- ❑ Low emittance, stable beam
- ❑ High quality thin crystal
- ❑ Collimation < 0.5 characteristic angle

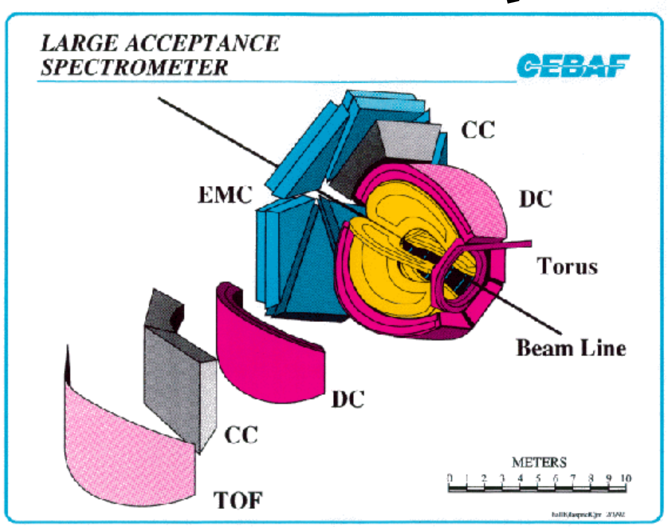


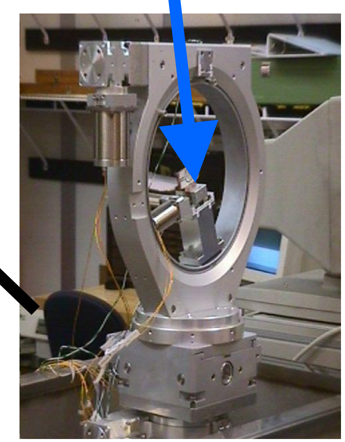
The Coherent Bremsstrahlung Facility at CLAS





Diamond



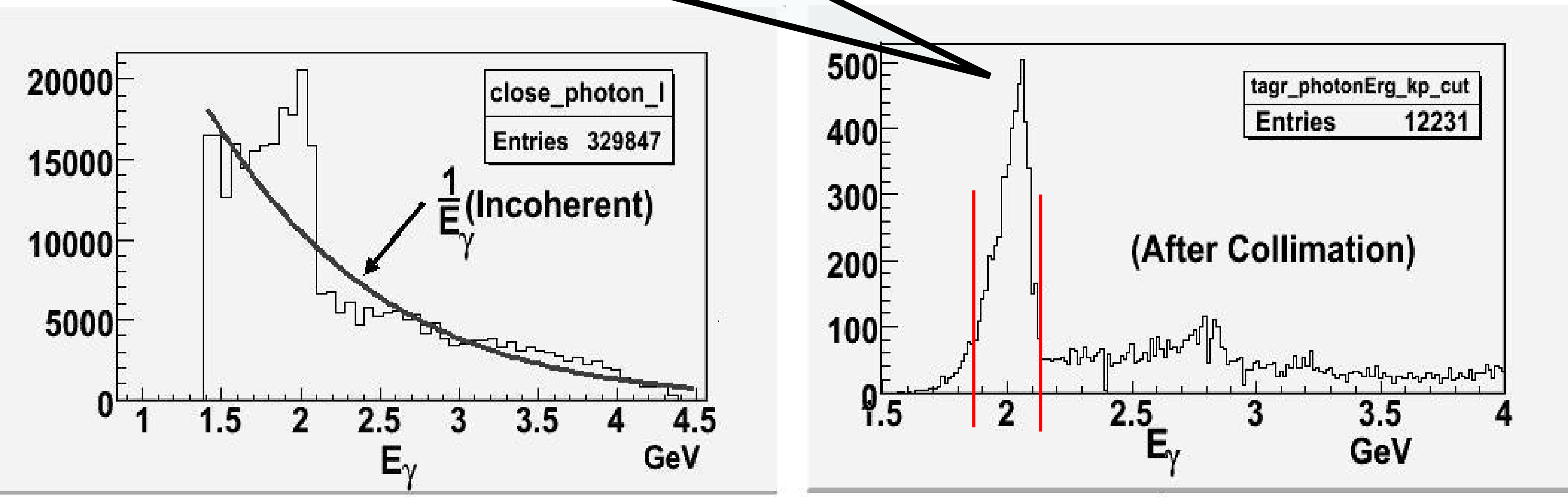


Goniometer,

George Washington University

Linearly Polarized Photons

i. e. Coherent Peak at 2.1 GeV



a

b

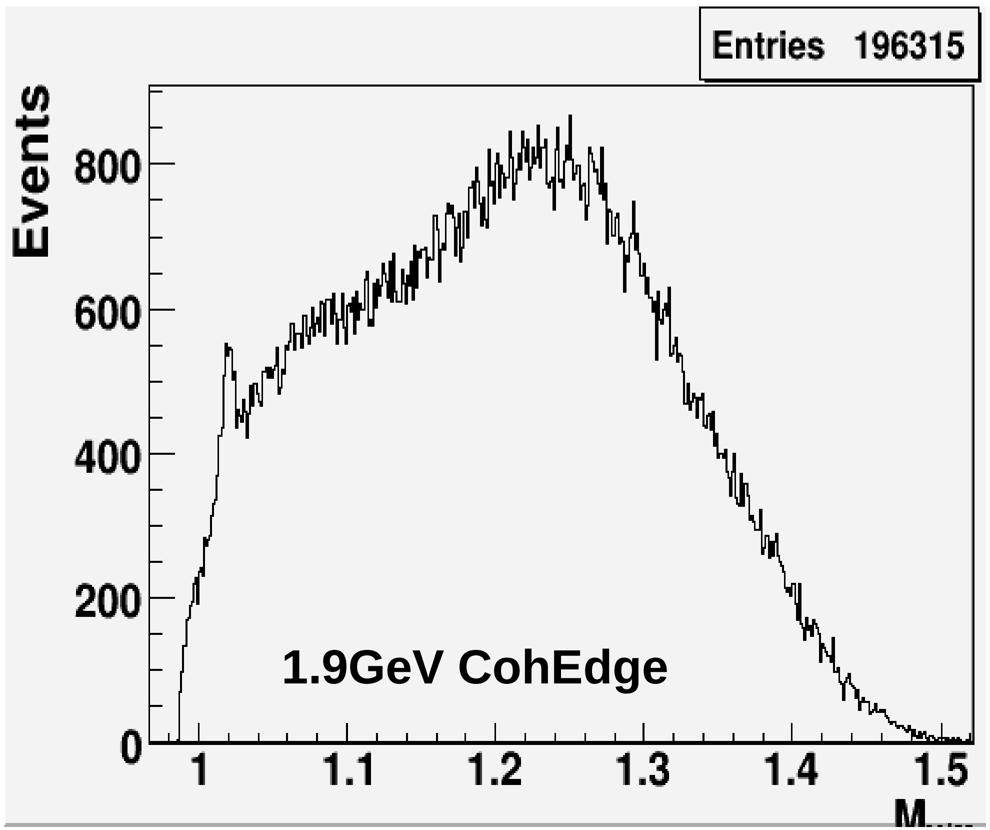
- **Mean polarization estimated to be ~70% from comparison with the coherent bremsstrahlung calculation***

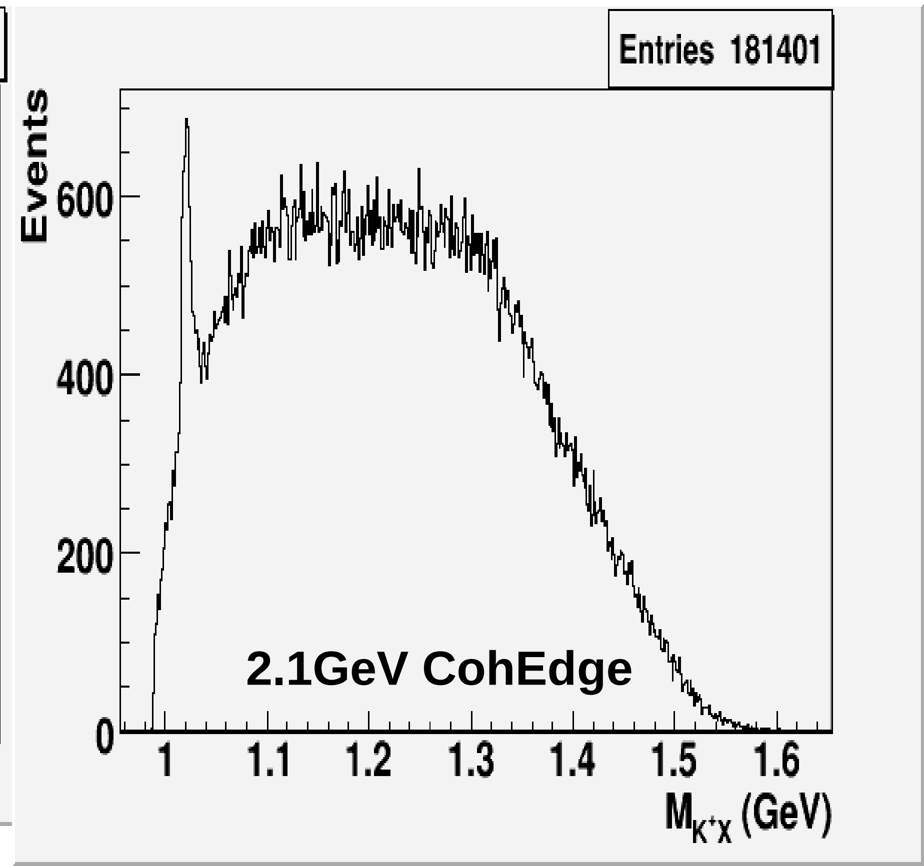
* A. Natter. http://www.pit.physik.uni-tuebingen.de/grabmayr/software/brems/brems-analytic.html

Event Selection

$$\vec{\gamma}\, p \rightarrow p\phi \rightarrow pK^+K^-$$

Mode: $pK^+(X) \rightarrow pK^+(K^-)$

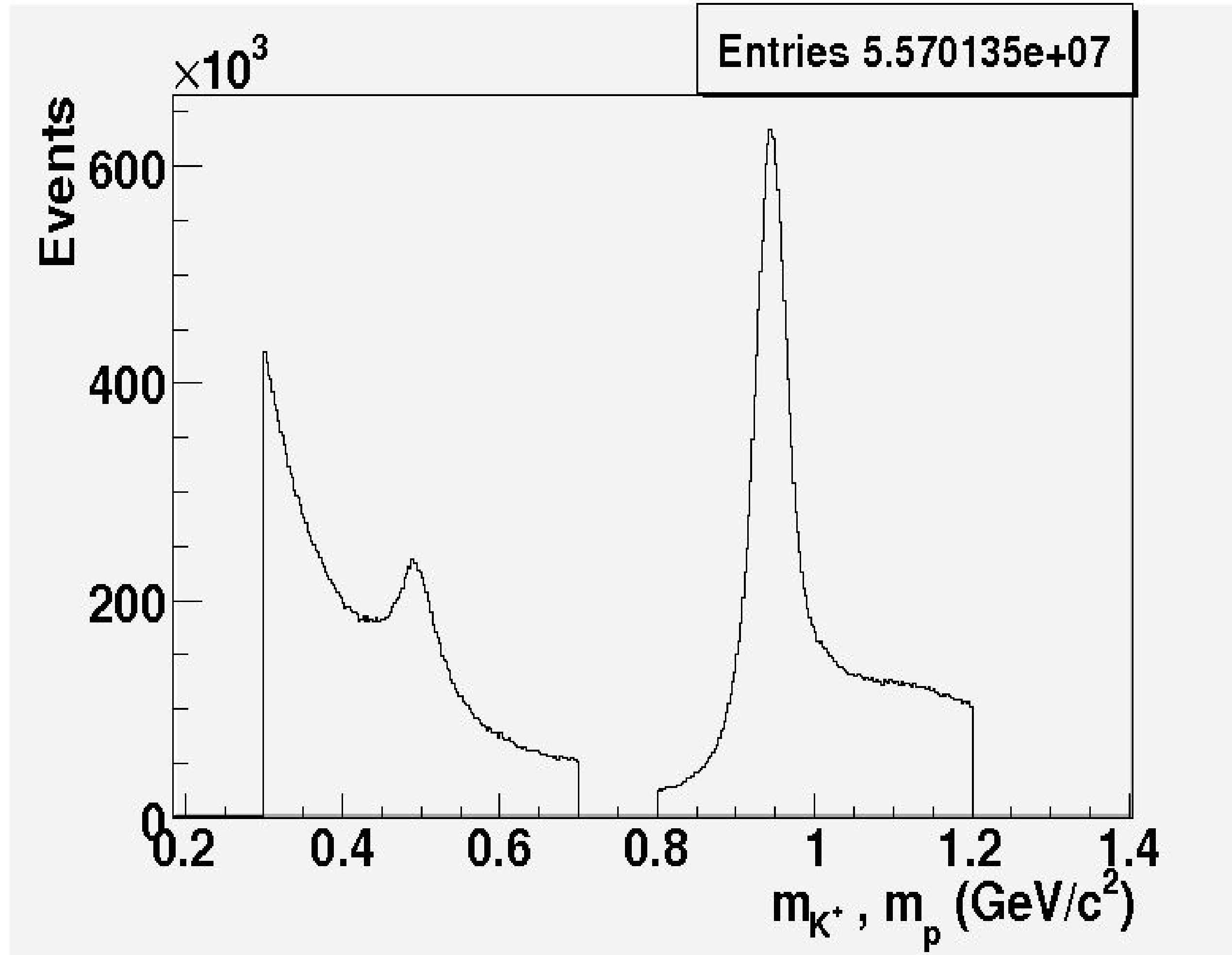




Event Selection

Quality flags:
TAGR status = 7 or 15
EVNT
DC status > 0
EC status > 0
Status > 0

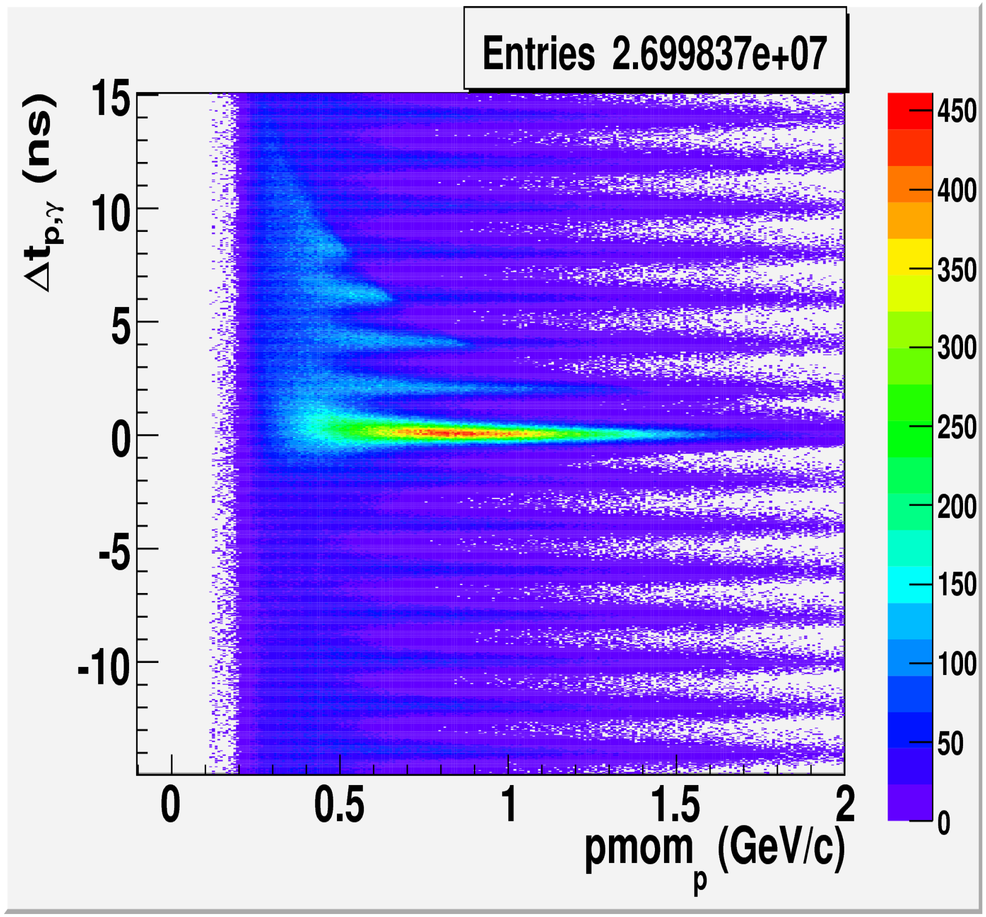
i.e. 2.1GeV CohEdge

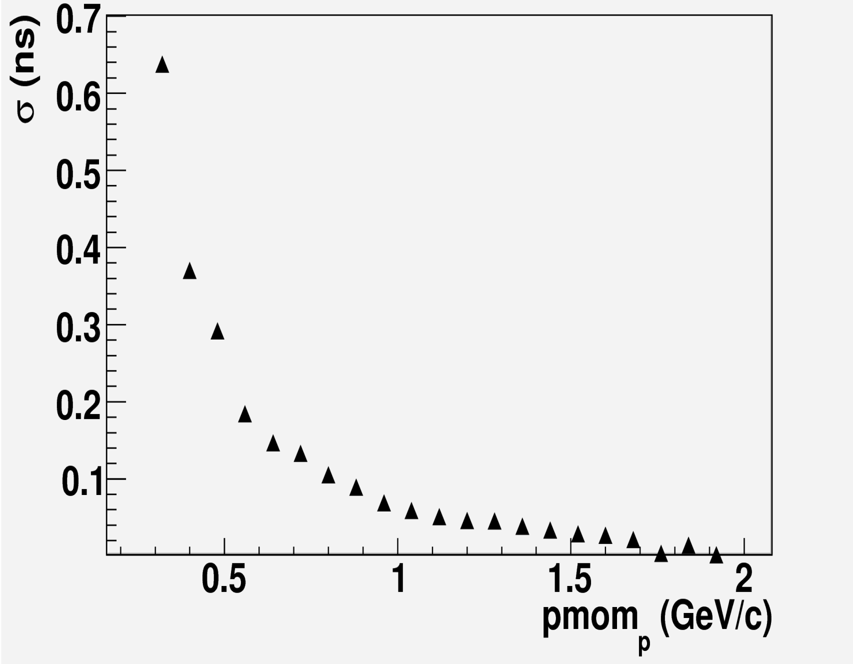


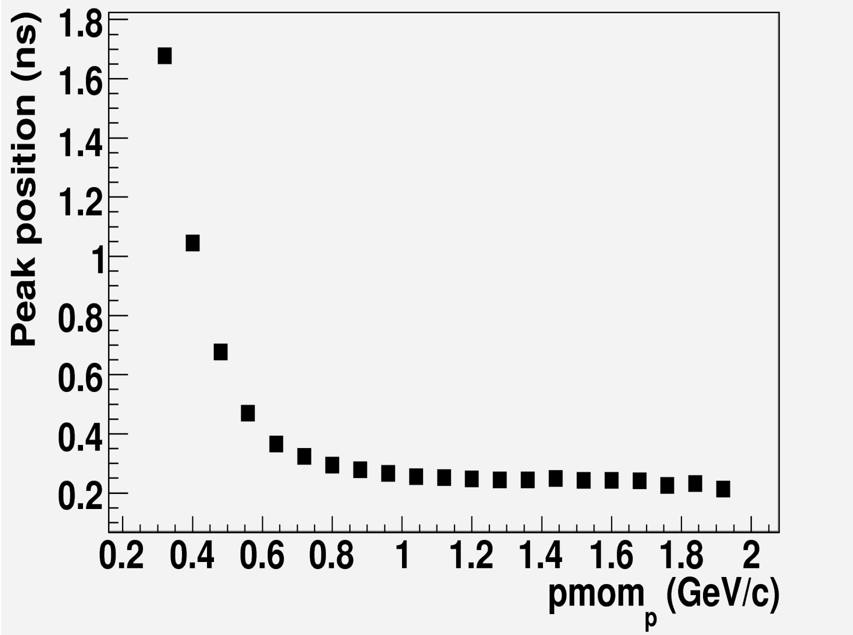
Loose cuts on p and K + masses. Applied cuts were $0.8 < m_p < 1.2$ GeV and $0.3 < m_{K+} < 0.7$ GeV.

Event Selection

Timing cuts base on proton vertex time





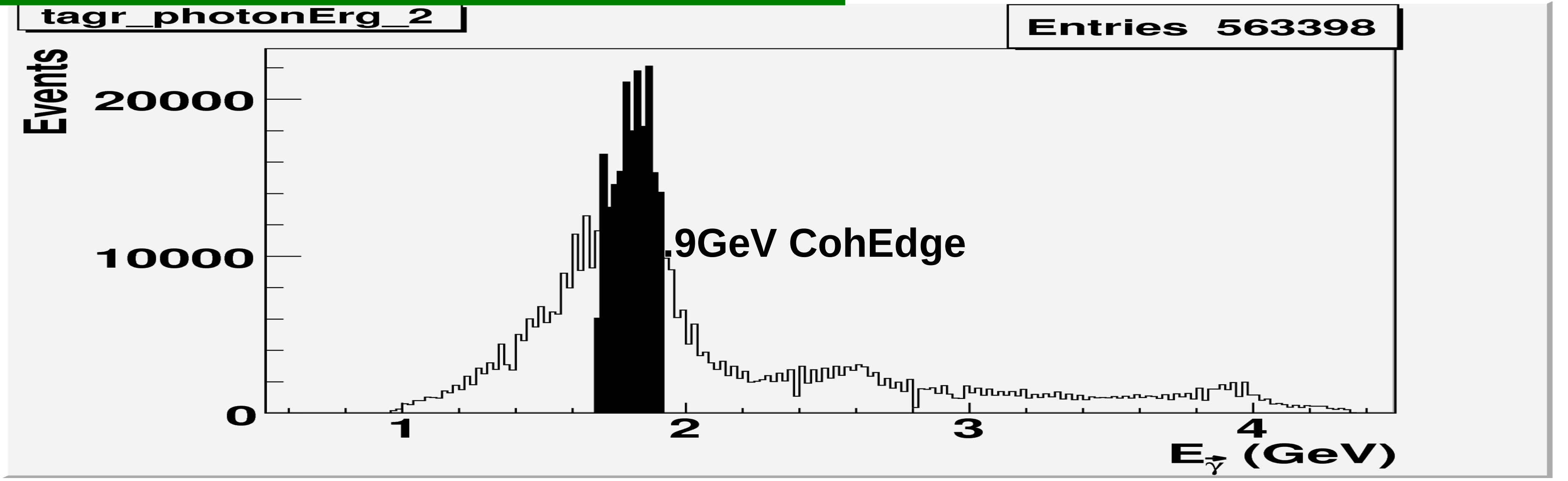


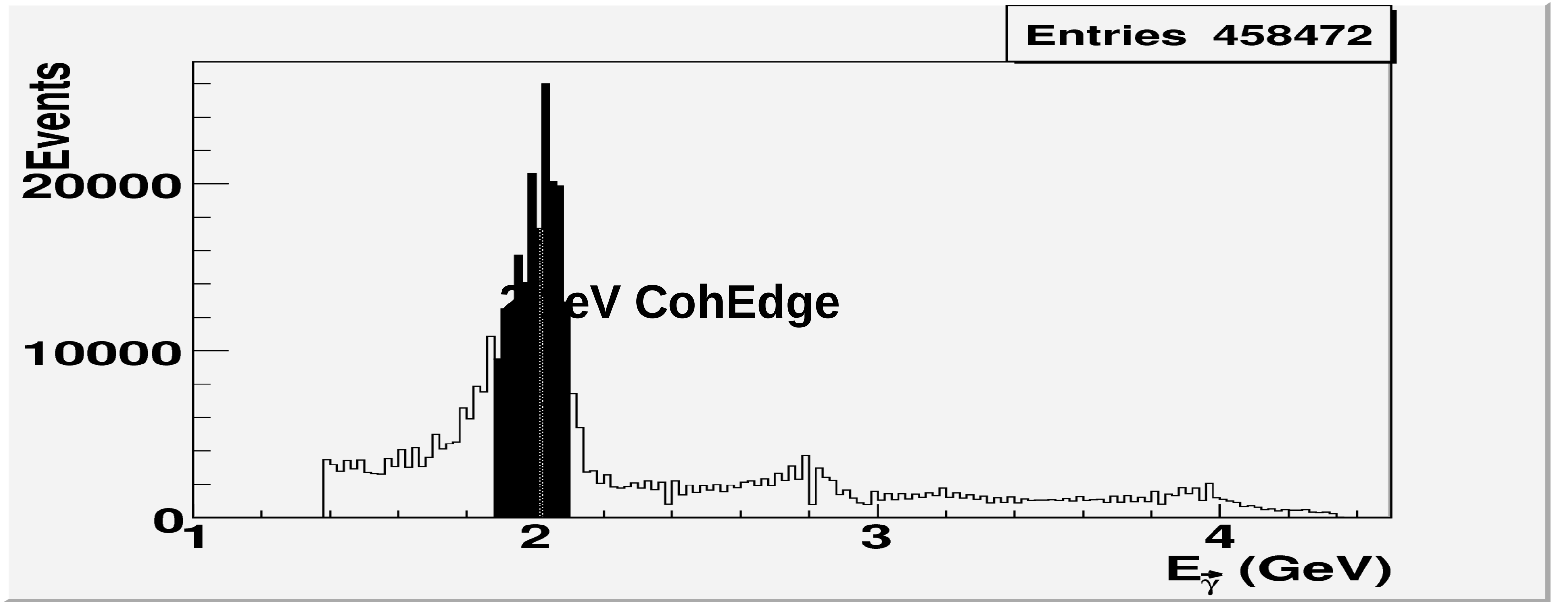
Event Selection

Energy cut:

1 .68 to 1 .92 GeV

1 .88 to 2 .102 GeV

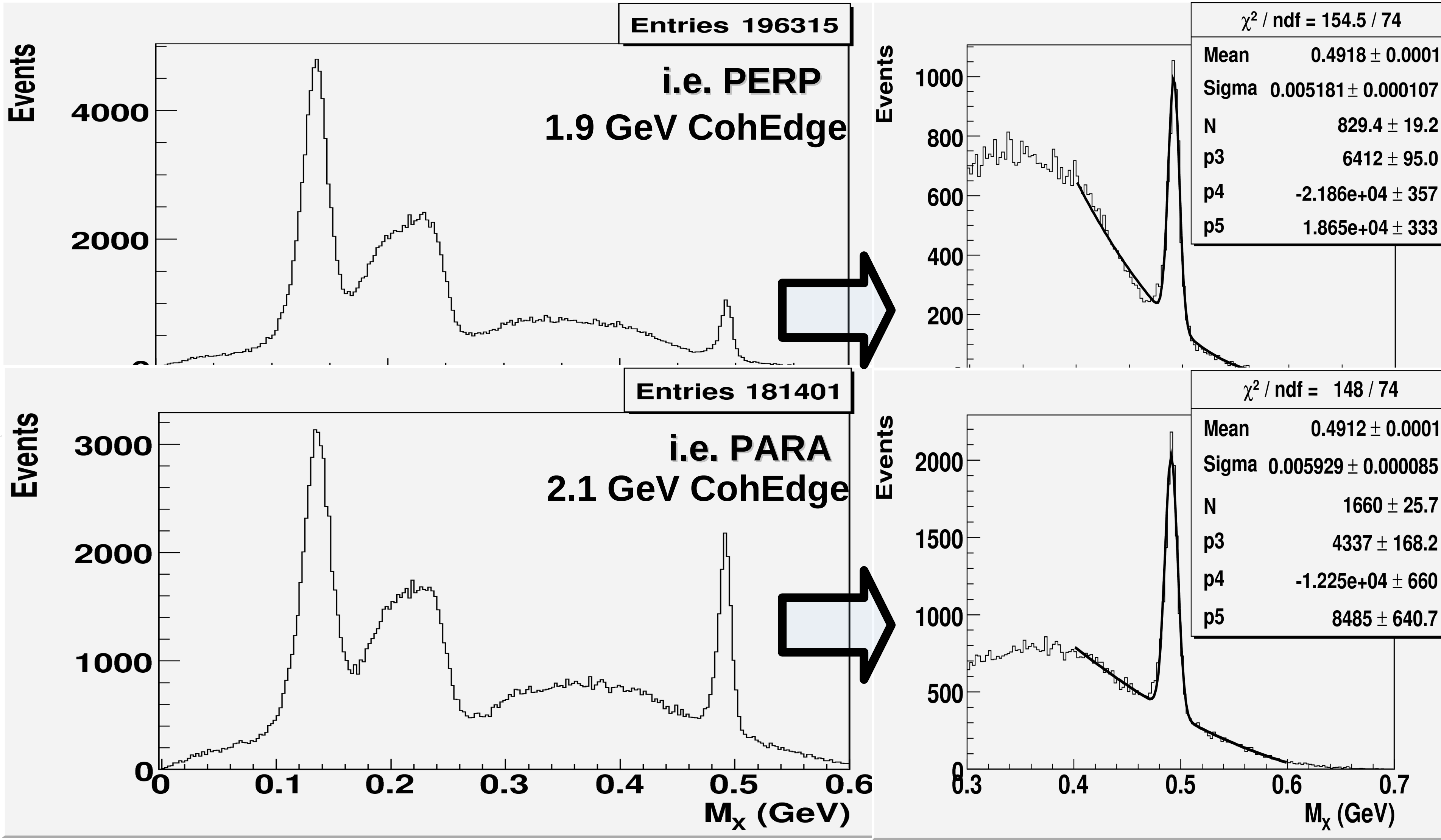




Event Selection

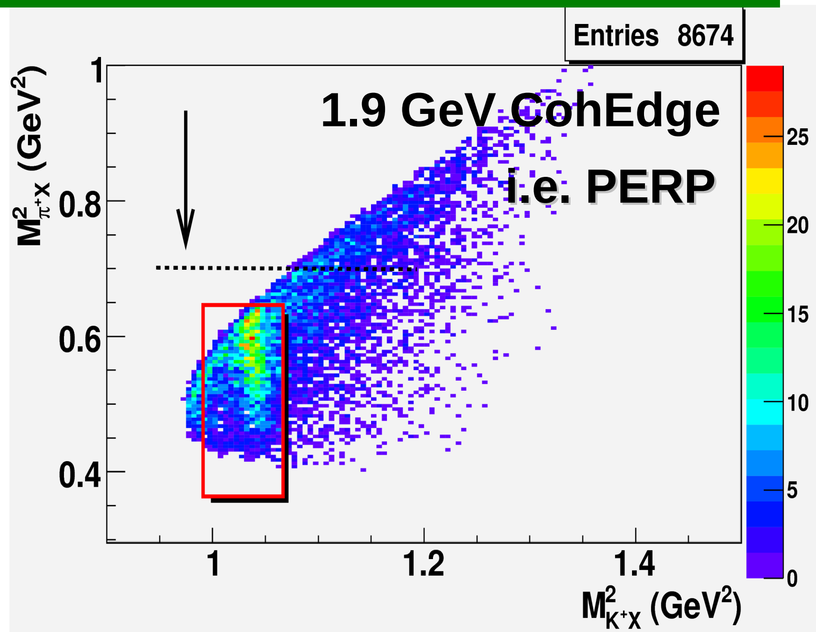
K^- missing mass cut

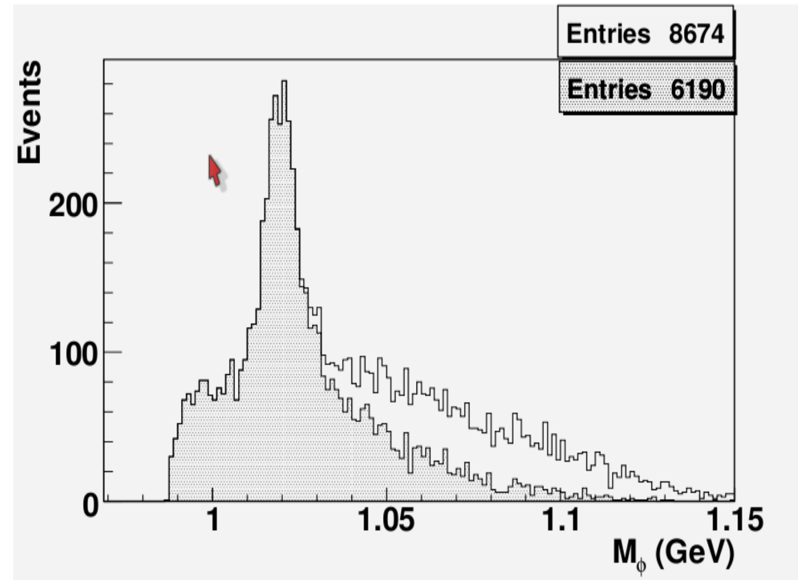
A 5-sigma cut on the K^- missing mass was applied by using a Gaussian function + 2nd polynomial.

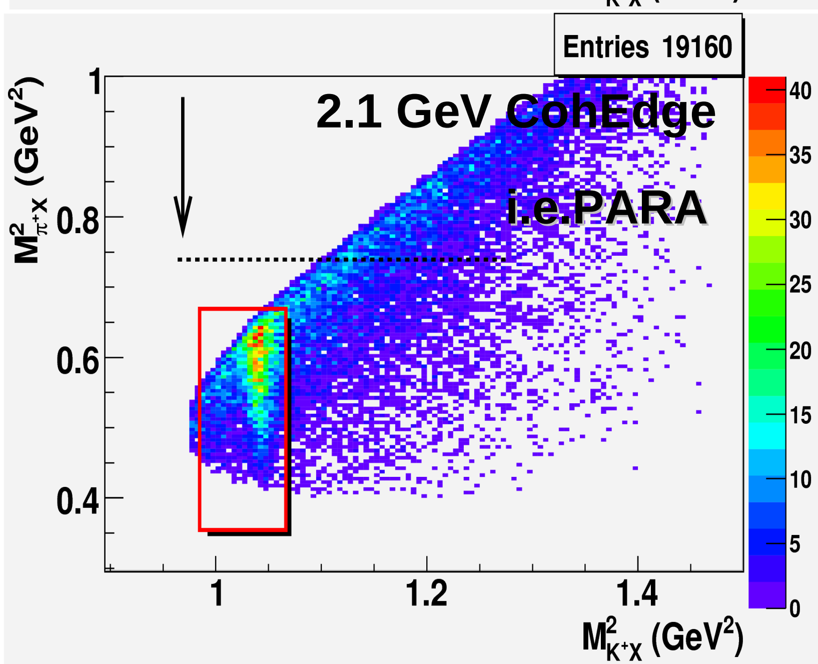


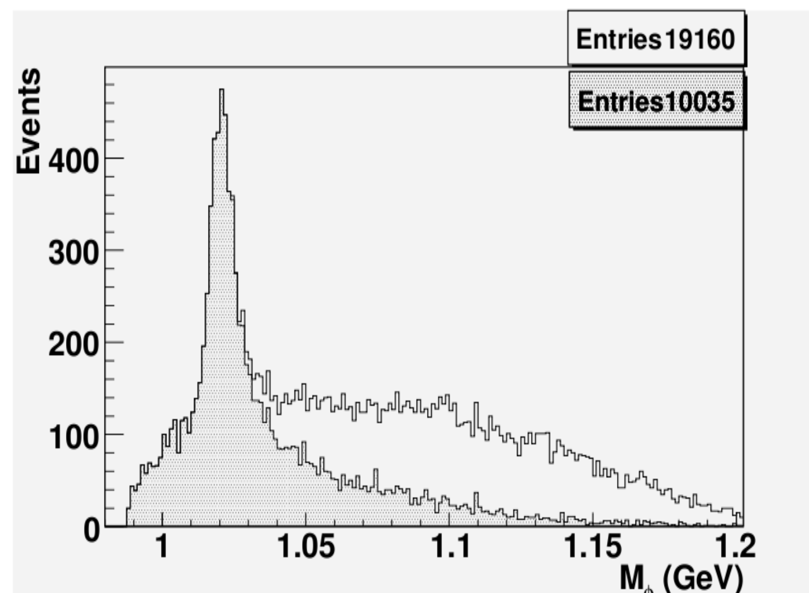
Event Selection

π^+ background subtraction





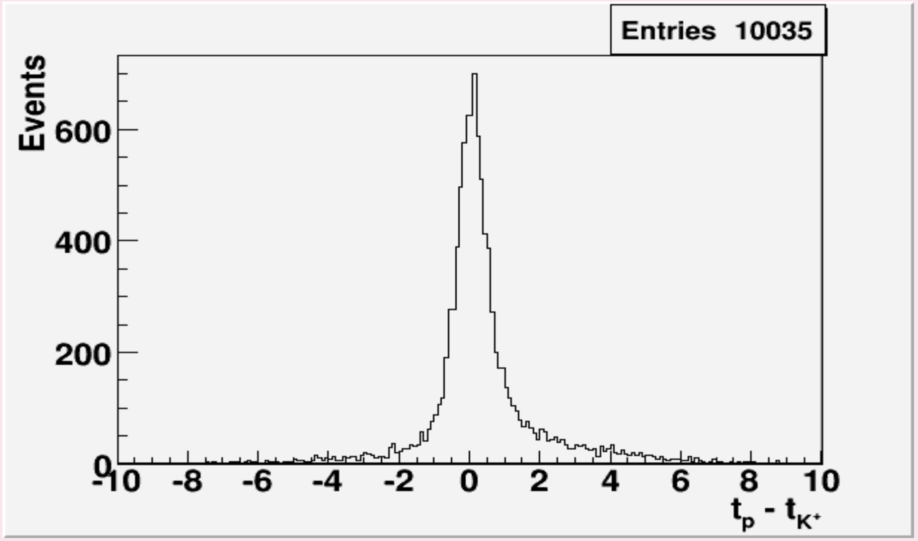




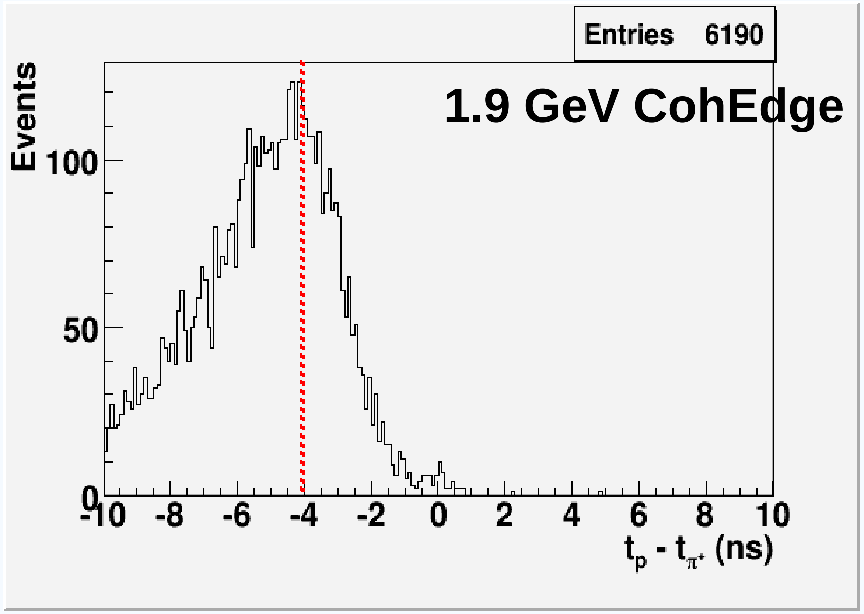
Event Selection

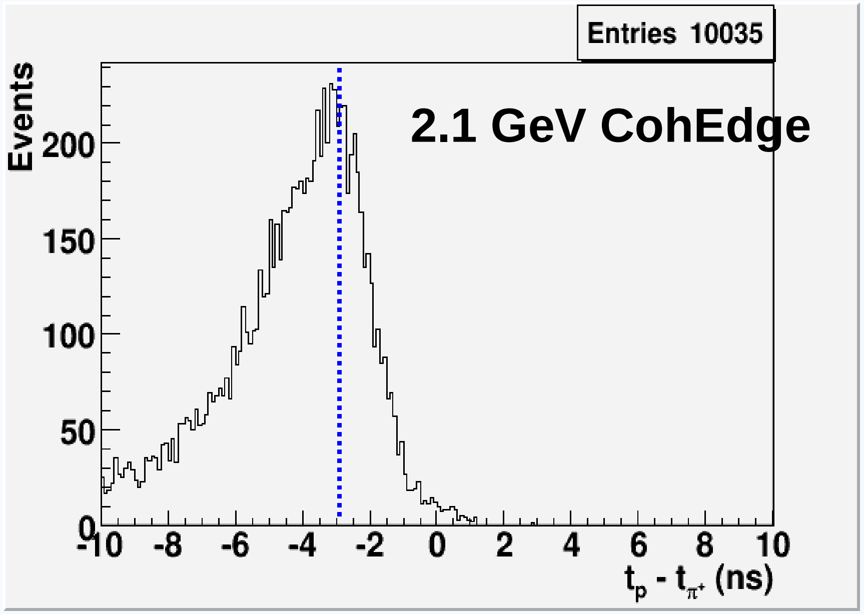
It seems the event selection we made was not enough to get rid of the π^+ background. The tails coming down from a maximum located around -4ns (1.9 GeV CohEdge) and -3ns (2.1 GeV CohEdge data) seem to be fully misidentified kaons. Applying the $t_p - t_{\pi^+}$ < -4 ns (-3 ns) condition improves our results.

Time difference between p and K⁺ vertex times.



Time difference between p and π^+ vertex times.

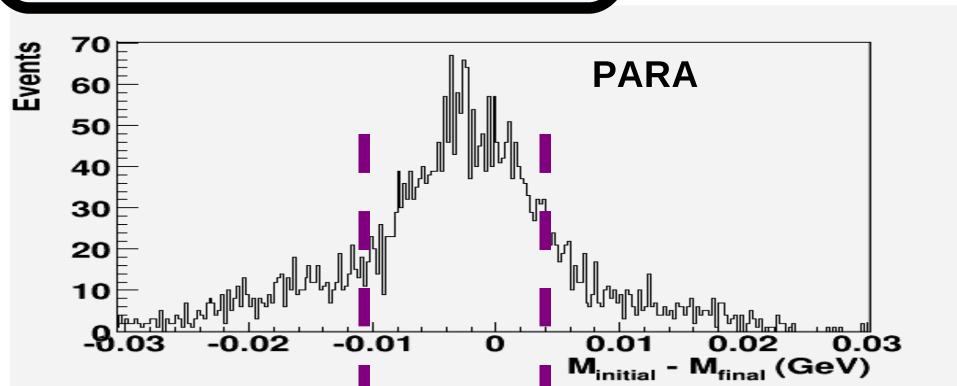


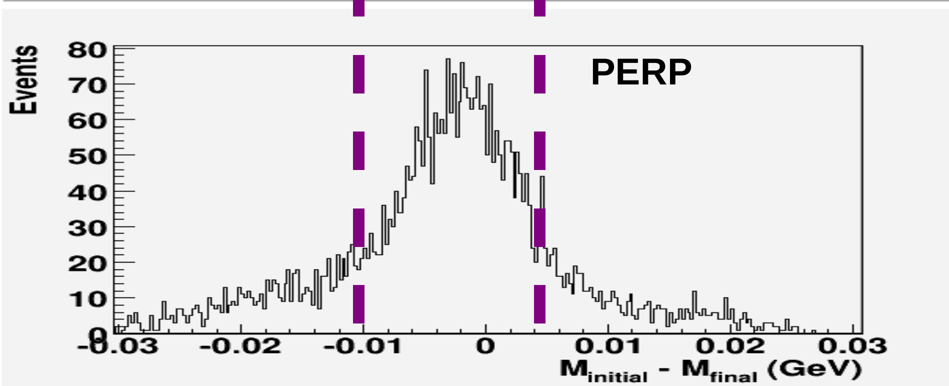


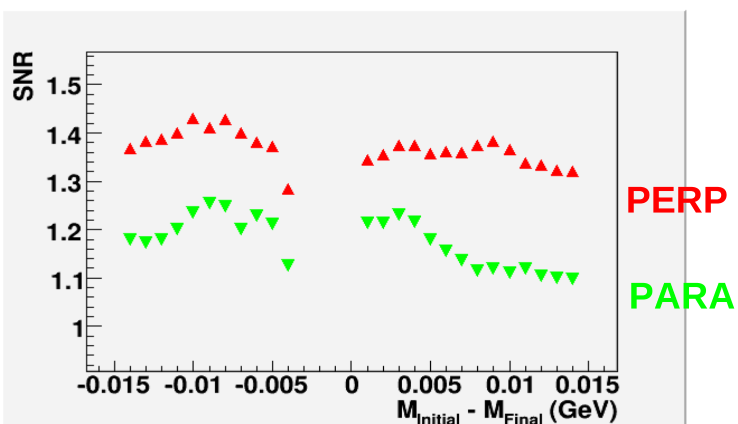
Event Selection

Energy-Balance check : $M_{initial} - M_{final} \sim 0$

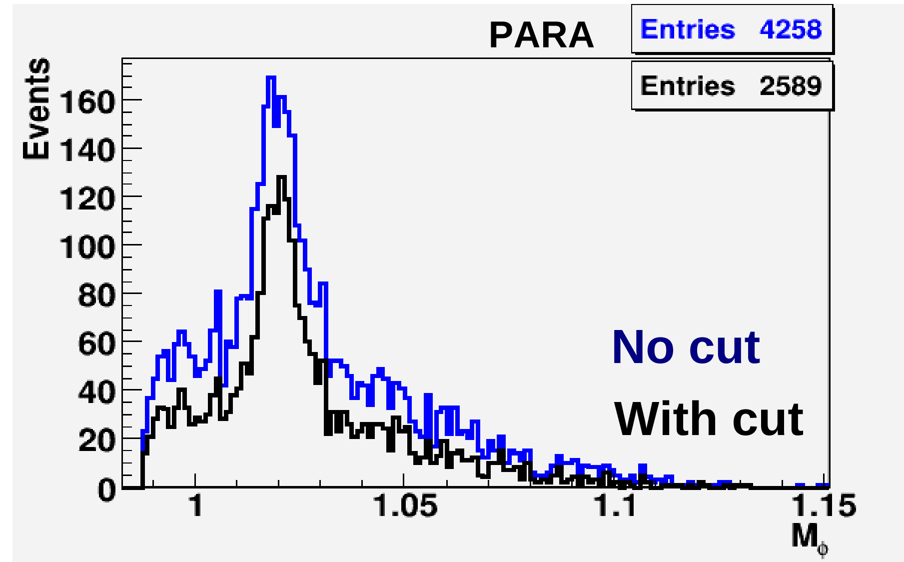
i.e. 1.9 GeV CohEdge

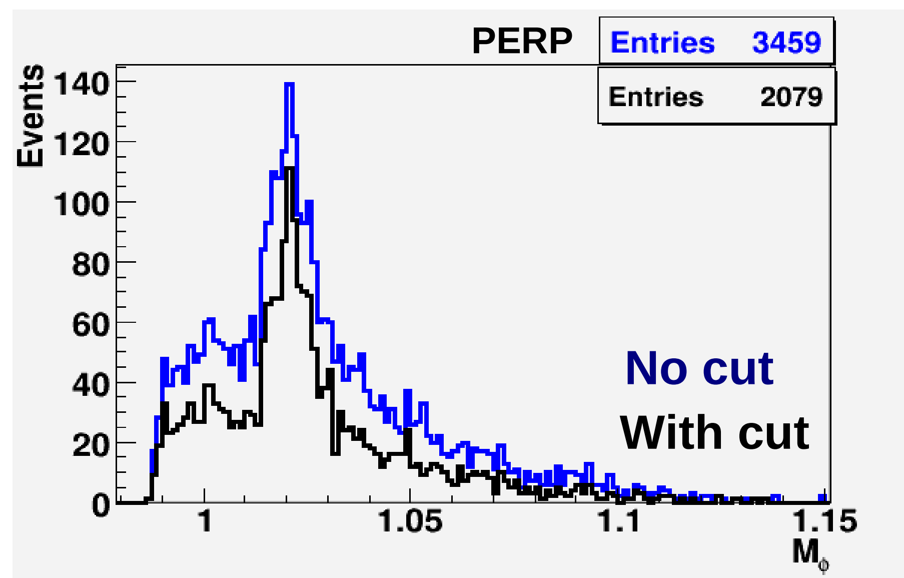






$-0.01 < M_{initial} - M_{final} < 0.003$ GeV

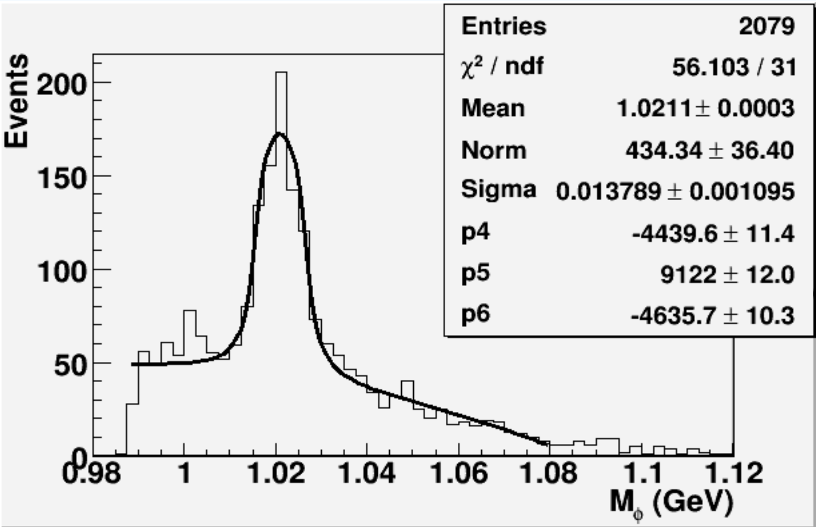




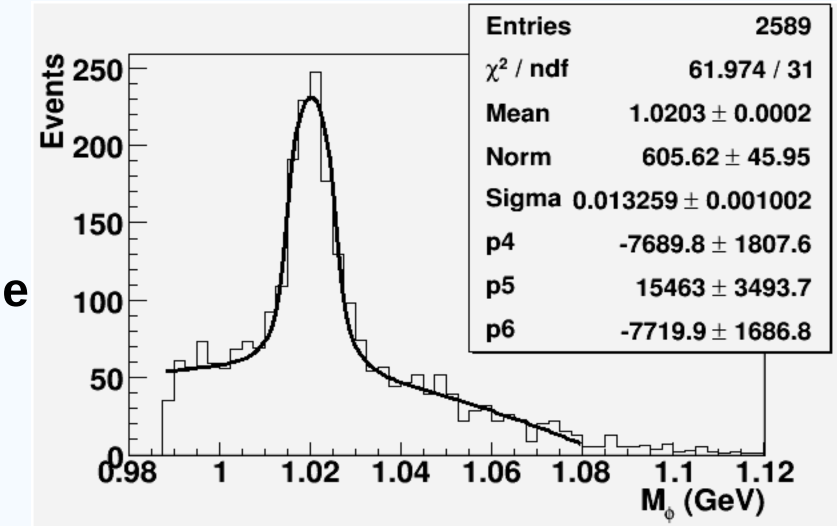
Φ-meson reconstruction was fitted by a Breit-Wigner convoluted with a Gaussian + 2nd order polynomial (We fix Γ_ϕ = 4.26 MeV from PDG)

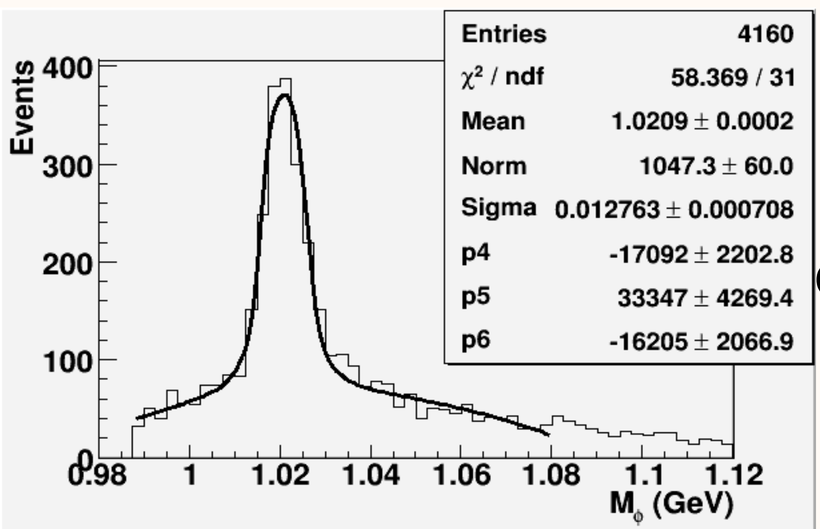
Event Selection

PARA **PERP**

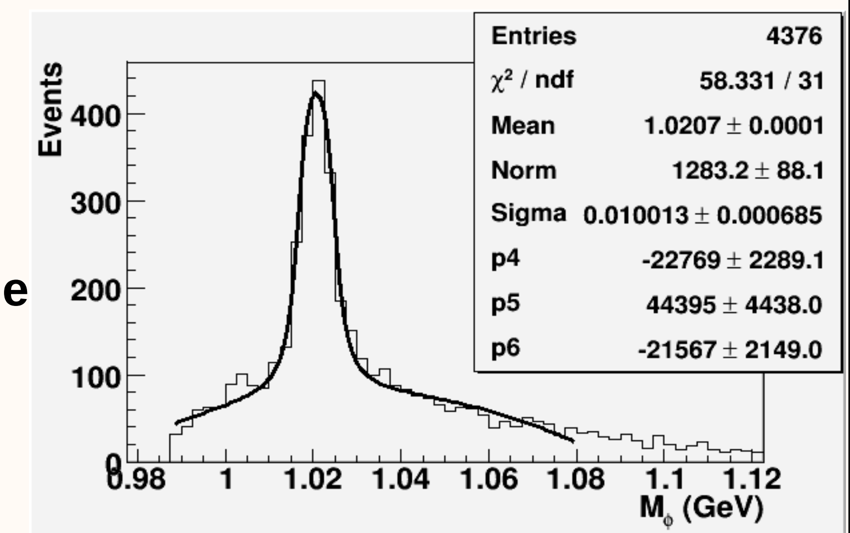


1.9 GeV Coh Edge



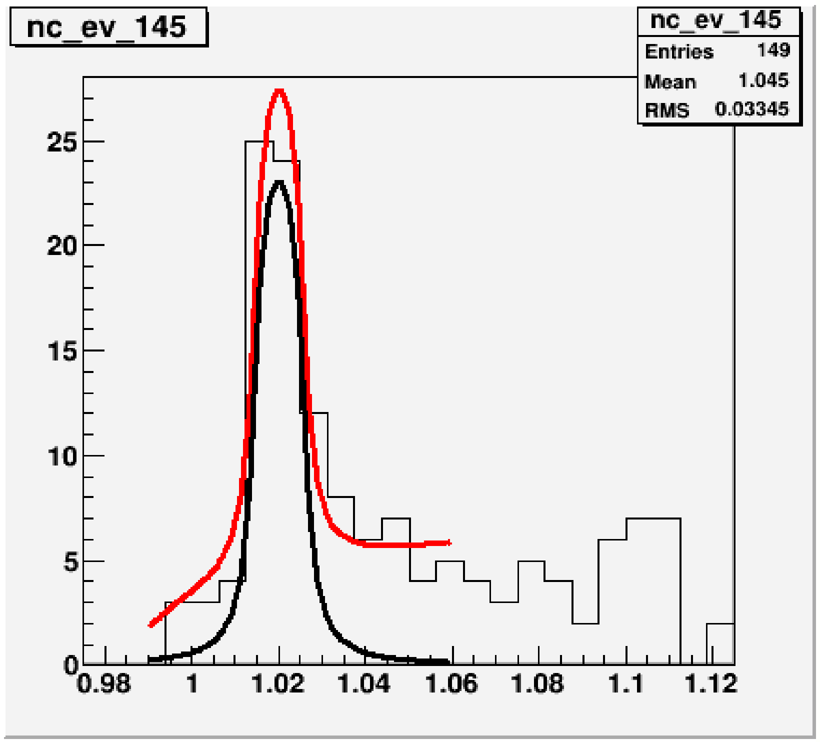


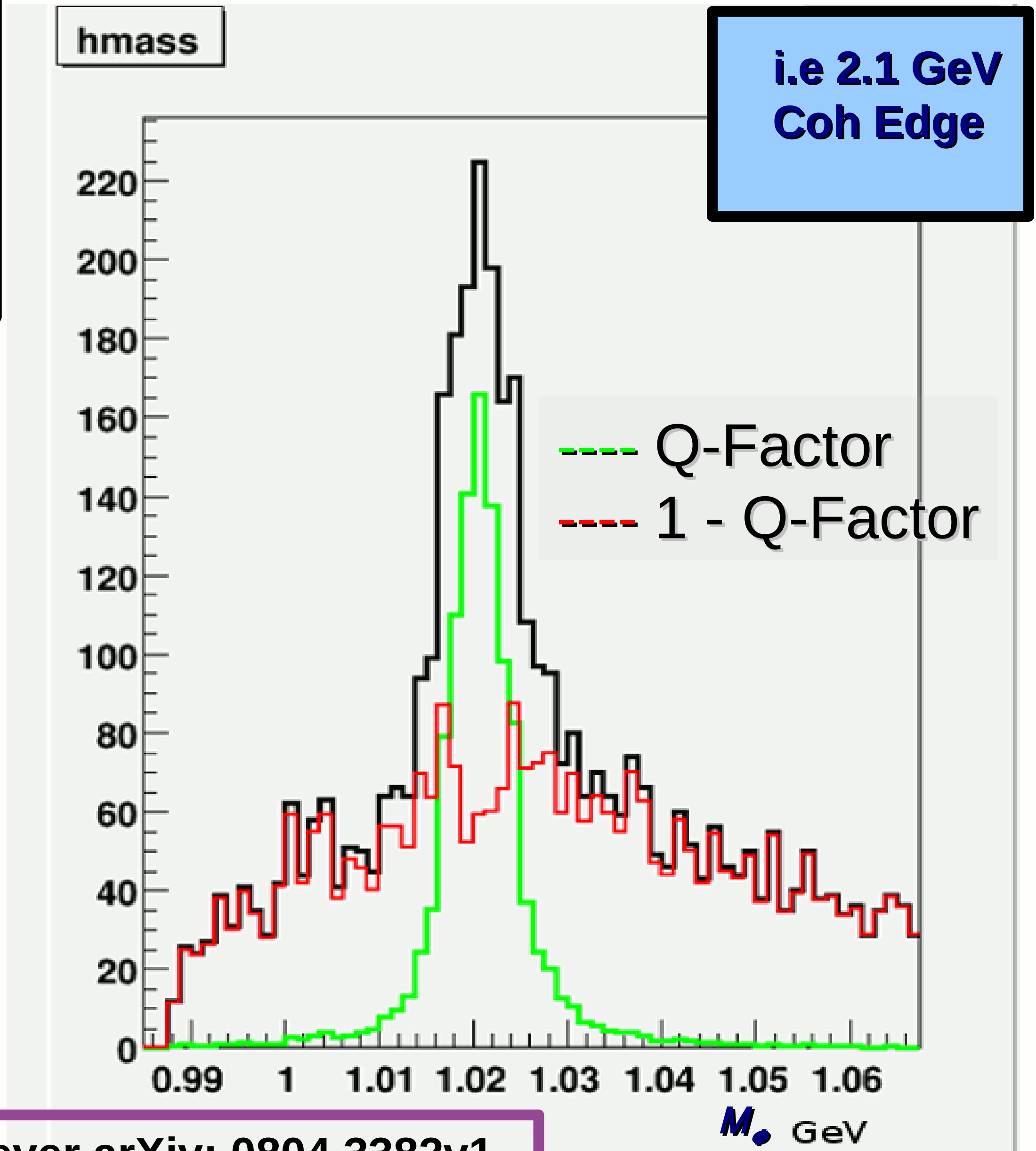
2.1 GeV Coh Edge



Background Subtraction

- Probabilistic Event Weighting*
  - Q-factor = Fs/(Fs+Fb)
    - Fs (Signal): Voigtian
    - Fb (Background): 2nd order polynomial





* M. Williams, M. Bellis and C.A. Meyer arXiv: 0804.3382v1

SDME parametrization.

$$W(\cos\theta) = N[\tfrac{1}{2}(1 - \rho^0_{00})\sin^2\theta + \rho^0_{00}\cos^2\theta]$$ $\rho^0_{00} = \rho^1$

$$W(\phi) = N[1 - 2\rho^0_{1-1}\cos2\phi]$$ $\rho^0_{1-1} = \rho^2$

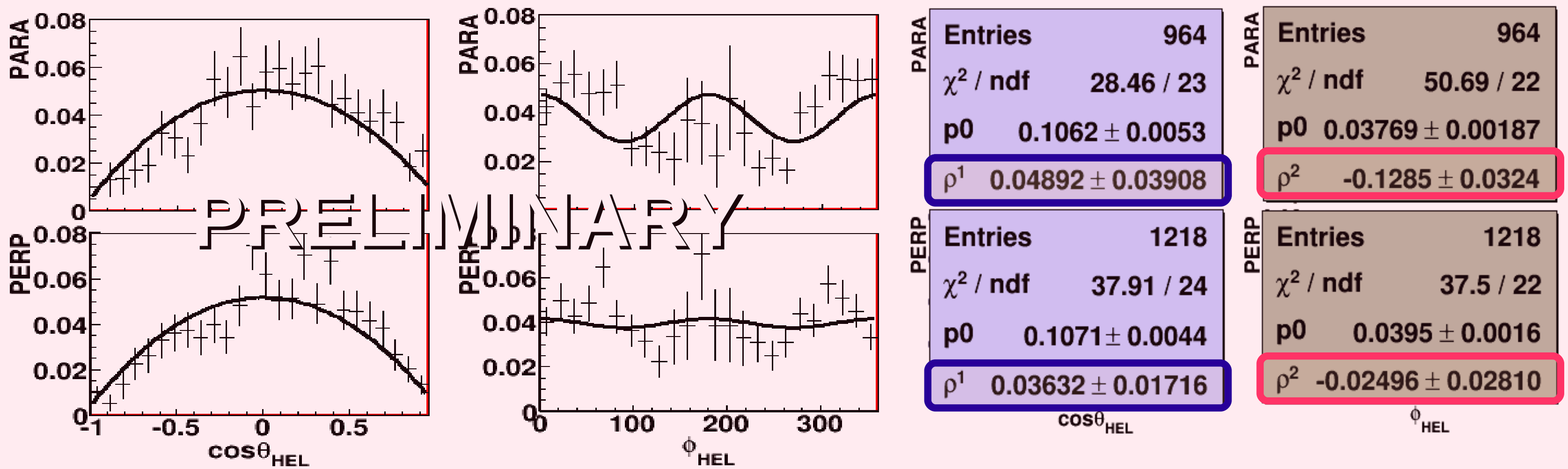
$$W(\phi - \Phi) = N[1 + 2P_\gamma(\rho^1_{1-1} - \mathrm{Im}\rho^2_{1-1})\cos2(\phi - \Phi)]$$ $\frac{1}{2}(\rho^1_{1-1} - \mathrm{Im}\rho^2_{1-1}) = \rho^3$

$$W(\phi + \Phi) = N[1 + 2P_\gamma(\rho^1_{1-1} + \mathrm{Im}\rho^2_{1-1})\cos2(\phi + \Phi)]$$ $\frac{1}{2}(\rho^1_{1-1} + \mathrm{Im}\rho^2_{1-1}) = \rho^4$

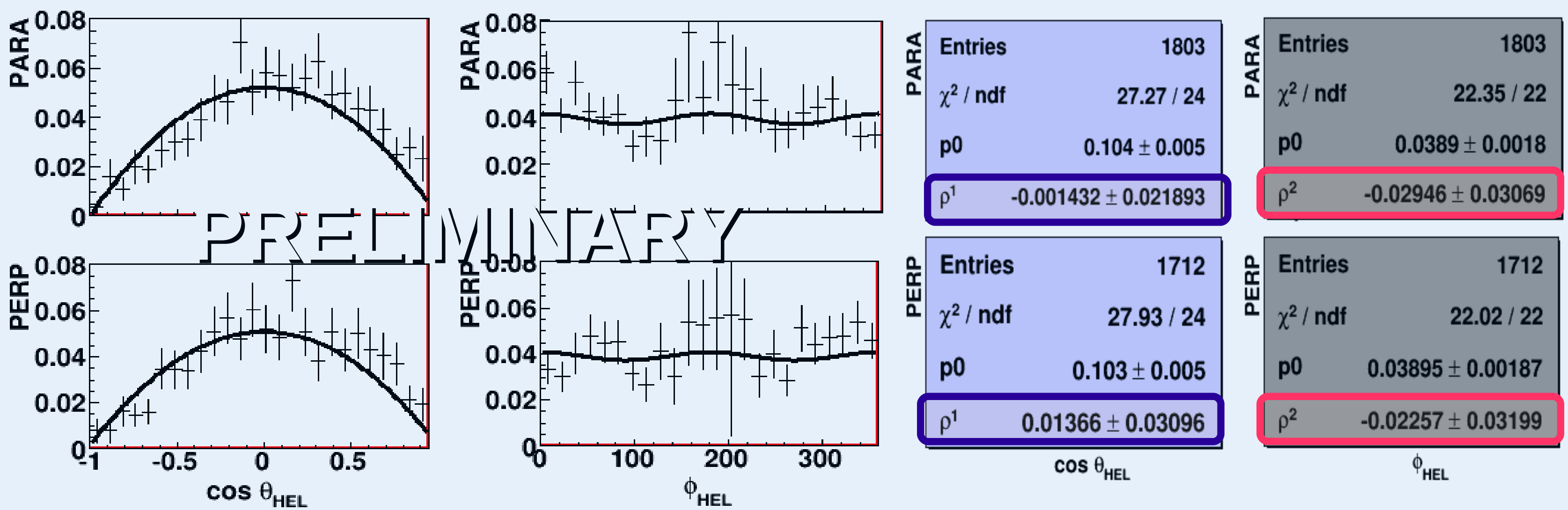
$$W(\Phi) = N[1 - P_\gamma(2\rho^0_{1-1} + \rho^1_{00})\cos2\Phi]$$ $2\rho^1_{11} + \rho^1_{00} = \rho^5$

$$P_\gamma\rho^5\cos2\Phi = \frac{W_{PARA} - W_{PERP}}{W_{PARA} + W_{PERP}}$$

Results

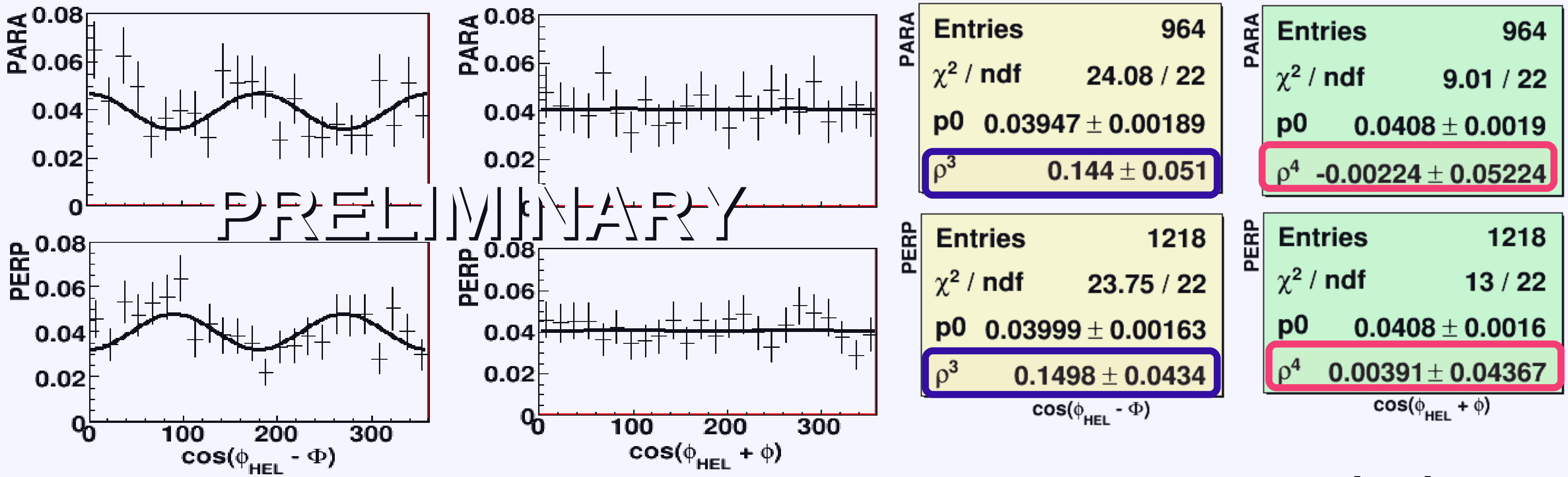


1.9 GeV CohEdge

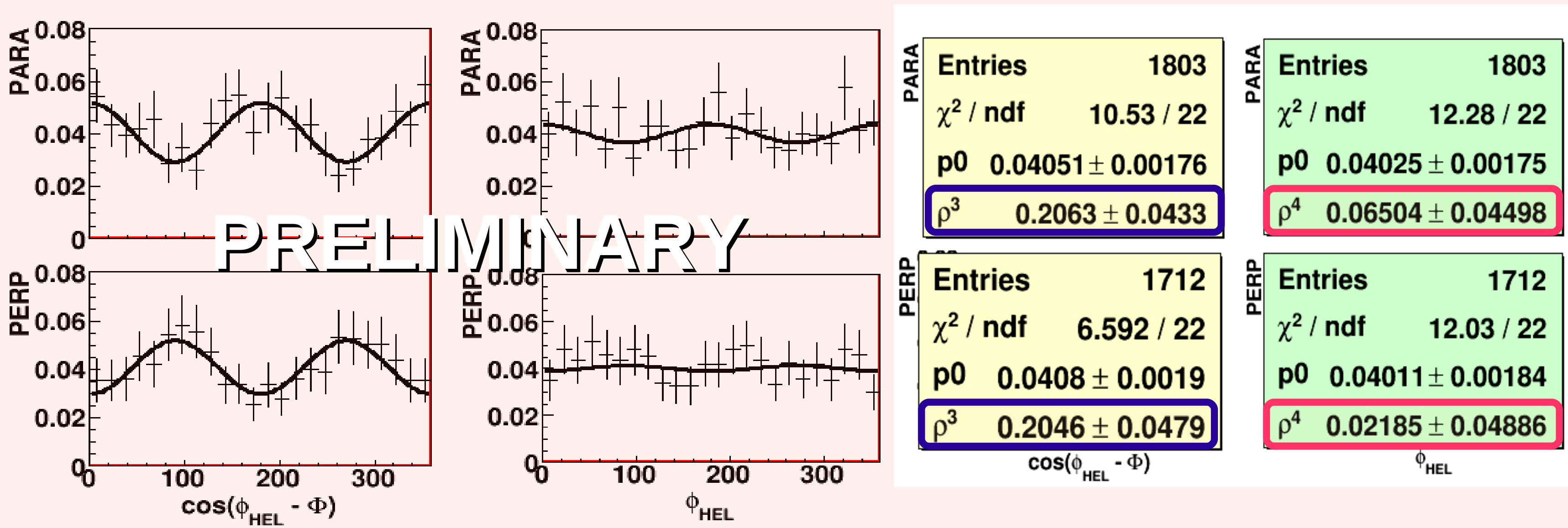


2.1 GeV CohEdge

Results



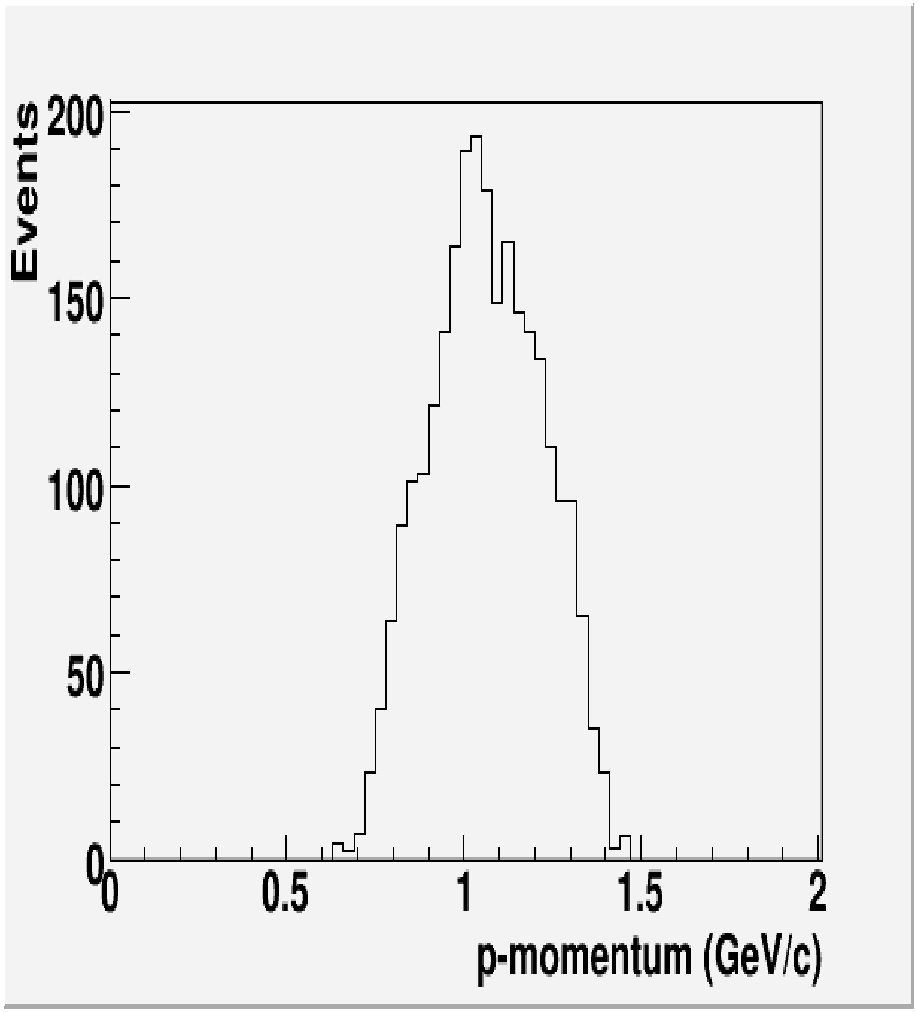
1.9 GeV CohEdge



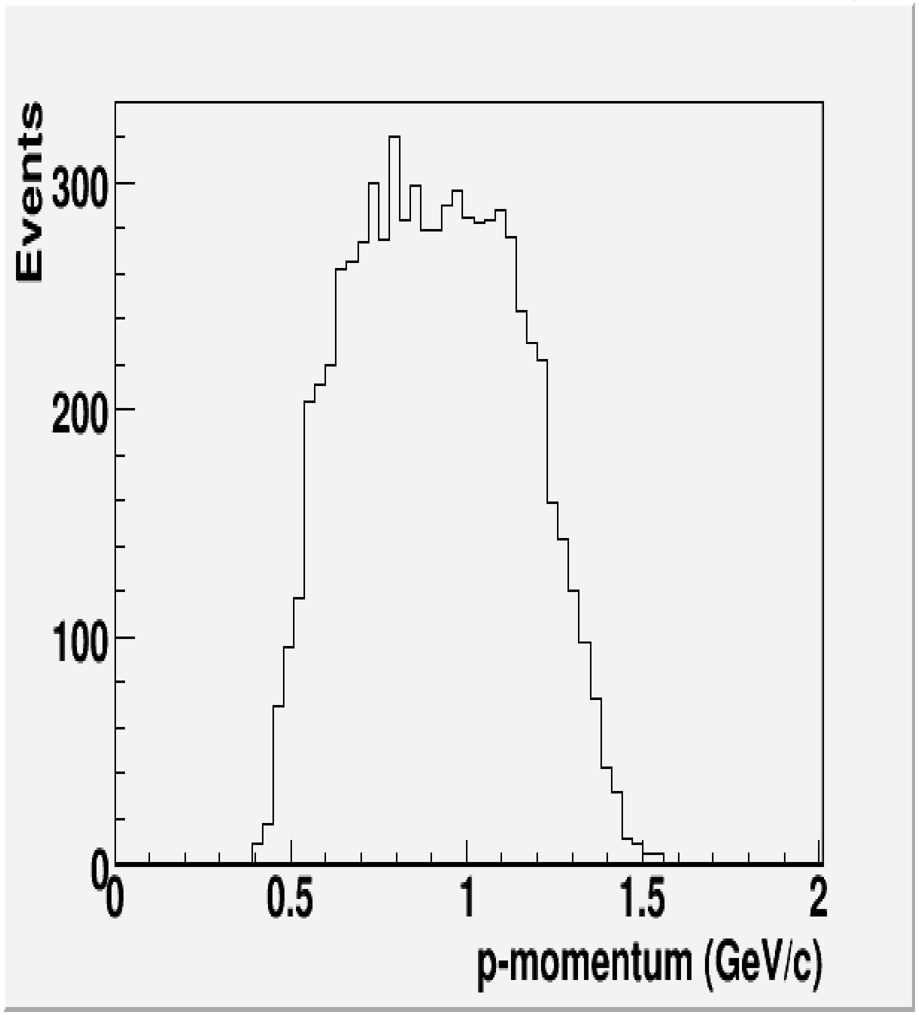
2.1 GeV CohEdge

Momentum Corrections ?

i.e. 1.9 GeV CohEdge



i.e. 2.1 GeV CohEdge



Conclusions

- Polarization ~70%
- Over 14000 ϕ-meson events were analyzed.
- Extract Spin Density Matrix Elements (SDMEs)
- Double check on Polarization calculation
- Study of systematic errors
- Compare to Spring-8[1] data as well as J. Ballam *et al*.
- Write up !!!

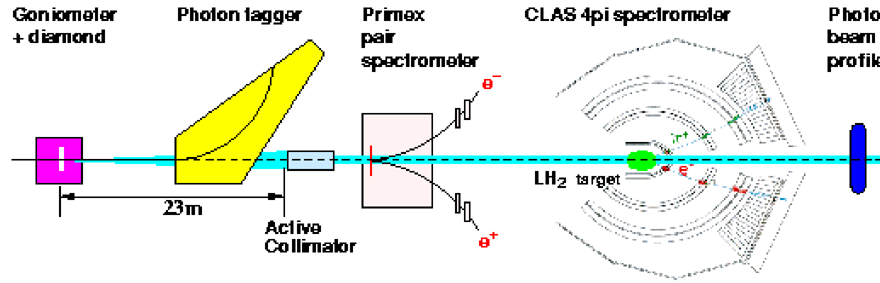
– [1] T. Mibe *et al*., Phys. Rev. Lett. 95, 182001 (2005).
– [2] J. Ballam, G. B. Chadwick, *et al*., Phys. Rev. D 7 3150 (1972).

g8 history so far…

Jefferson Lab

Thomas Jefferson National Accelerator Facility

g8b (6/20 – 9/01/05)

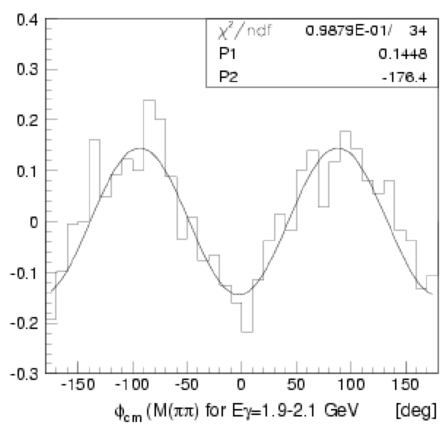


Tagged and Collimated $\vec{\gamma}$ beam in Hall B for beam-asymmetry studies for the reactions:

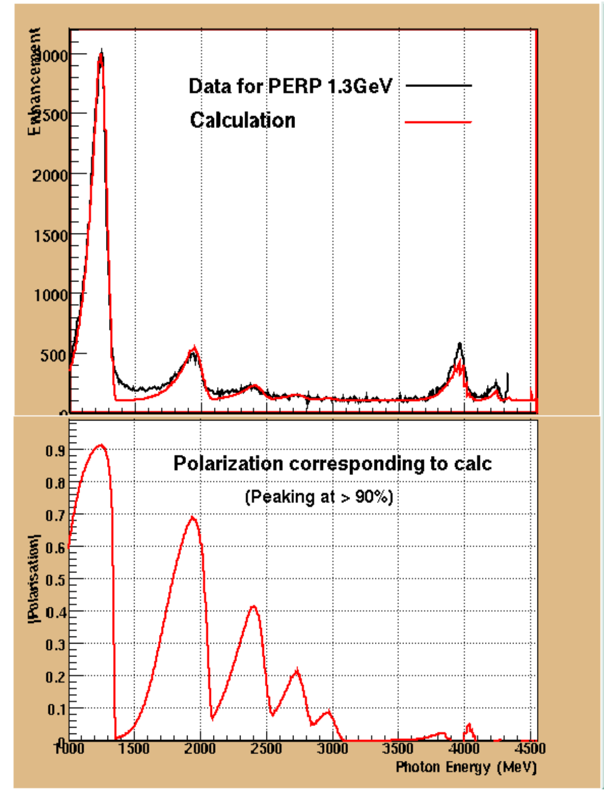
$$\vec{\gamma} p \Rightarrow p(\pi,\eta,\rho,\omega,\varphi),K\Lambda$$

Coh. Peak	good evts
1.3 GeV	(1.4 Billion)
1.5 GeV	(2.0 Billion)
1.7 GeV	(1.8 Billion)
1.9 GeV	(1.2 Billion)
2.1 GeV	(0.9 Billion)
Amorphous	(1.8 Billion)

asymmetry for $\gamma p \to p\rho^0$



ρ^0 at low $|t|$ (< 0.30 GeV^2)



Photon Polarization exceeds 90% in the peak

ARIZONA STATE UNIVERSITY

Idaho Accelerator Center

UNIVERSITY of GLASGOW

ISU

Thanks!!!