

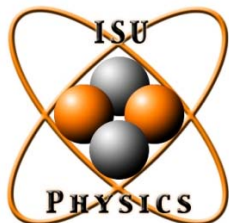
# *$\phi$ -meson Photoproduction by Using a Beam of Linearly-Polarized Photons*

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HADRON 2007

ROME, ITALY

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# Outline

## ☐ Motivation

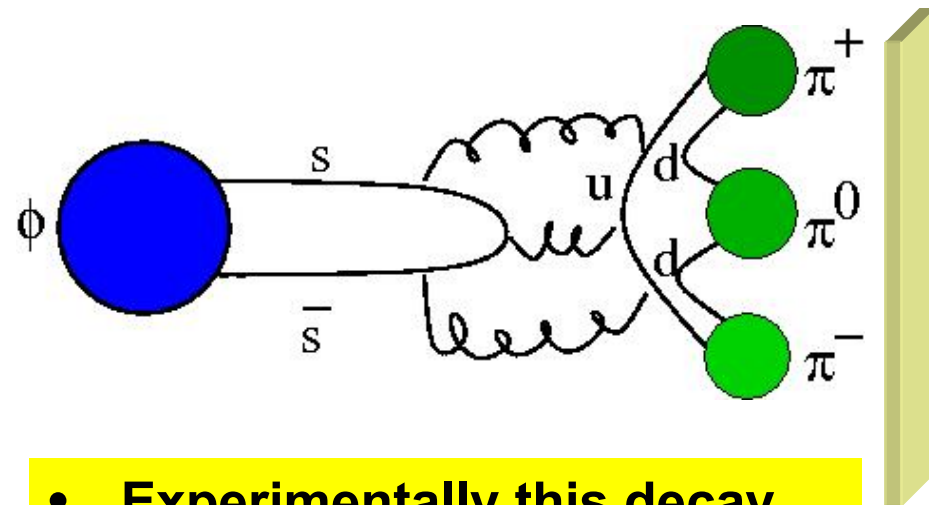
- ☐ OZI evading/respecting
- ☐ VMD (Vector Meson Dominance)
- ☐ Spin Density Matrix Elements

## ☐ $\phi$ -meson Photoproduction

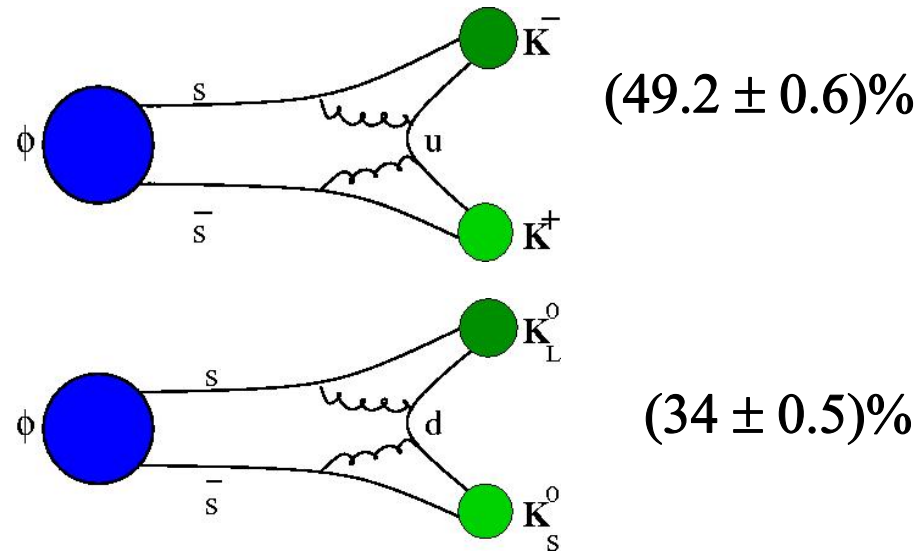
- ☐ CEBAF (Continuous Electron Beam Accelerator Facility )
- ☐ Coherent Bremsstrahlung Facility at CLAS (CEBAF Large Acceptance Spectrometer)
- ☐ Event Selection

# 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.

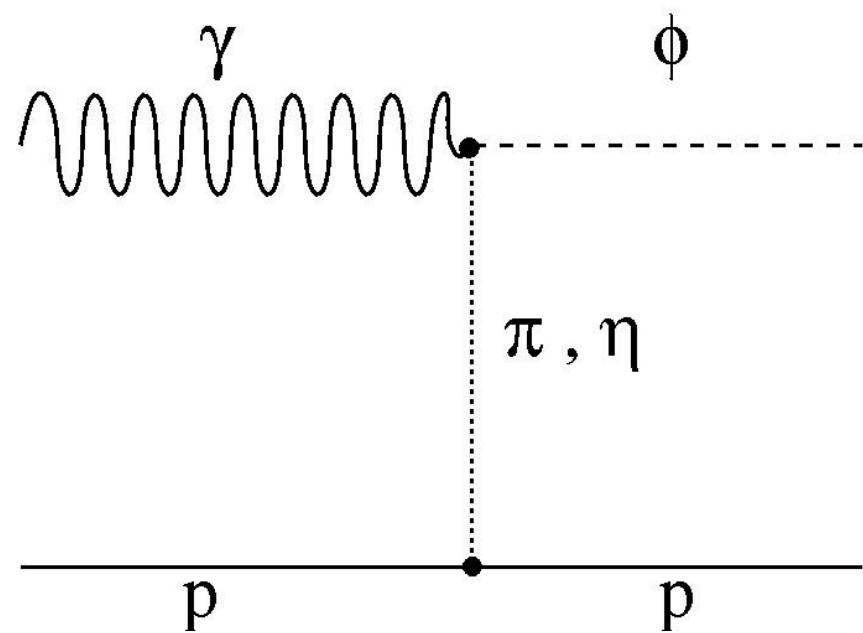
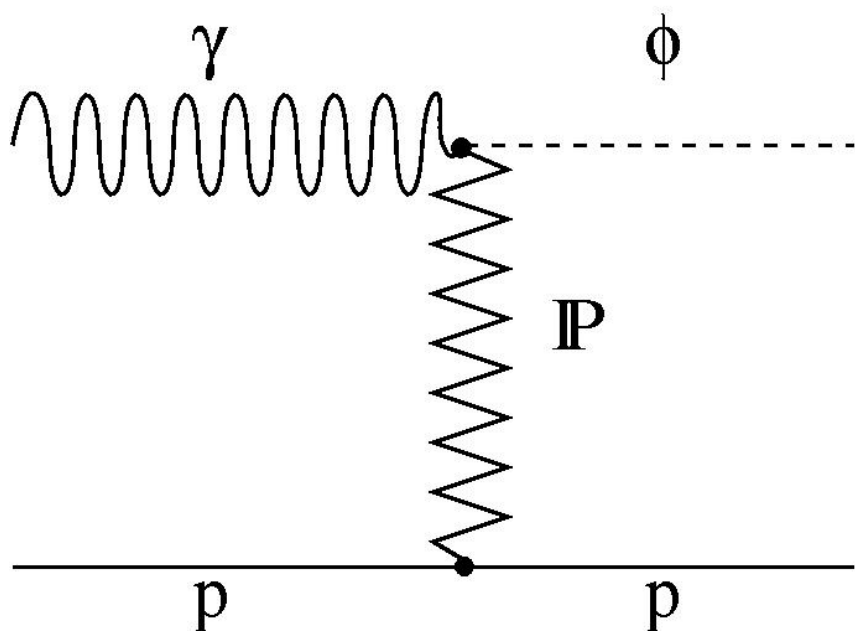


- Experimentally this decay mode is:  $(15.3 \pm 0.4)\%$

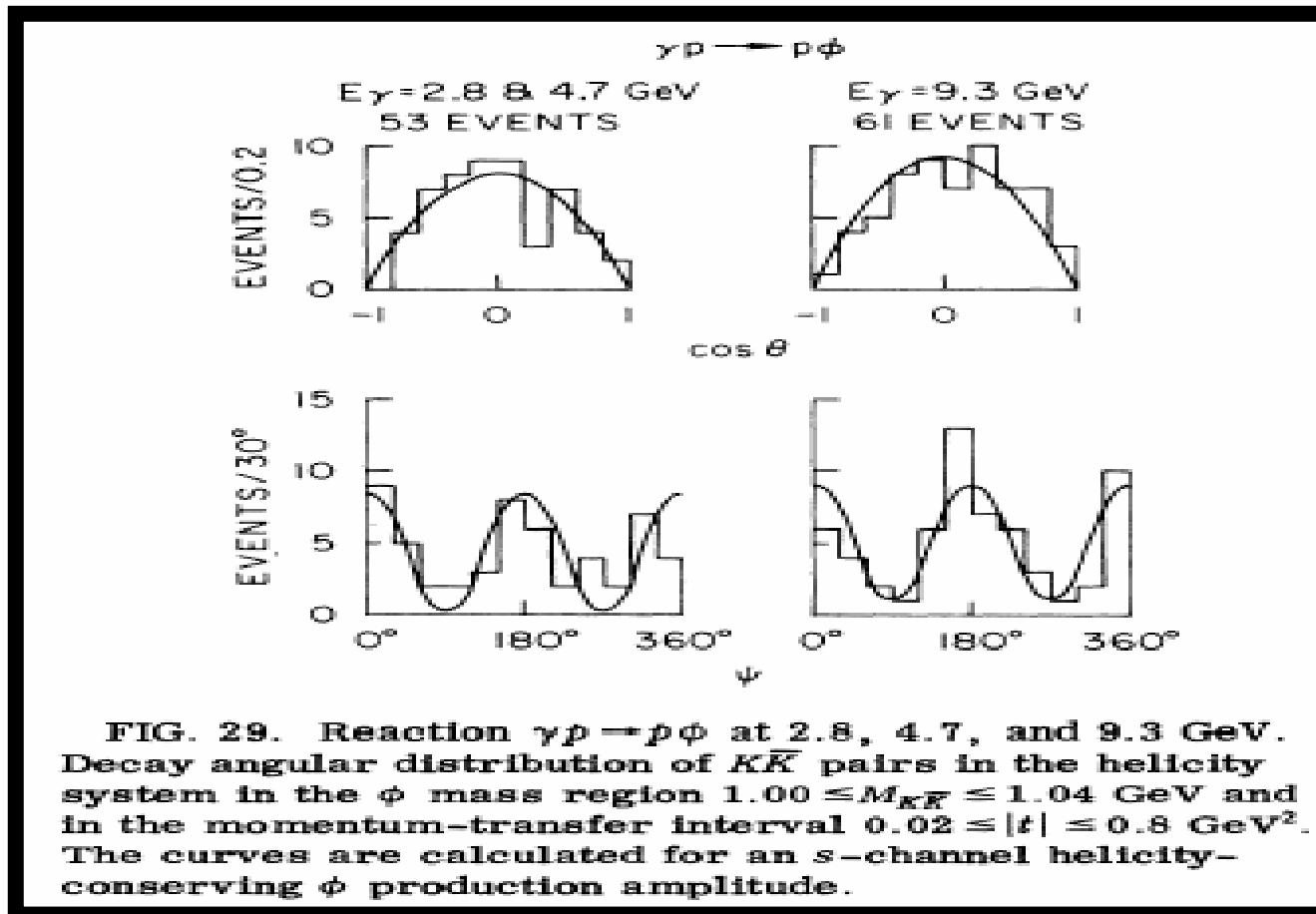


**~84% of the  $\phi$  decay is OZI respecting.**

# VMD



# Previous Measurements



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  $|t| < 0.4 \text{ GeV}^2$ )**

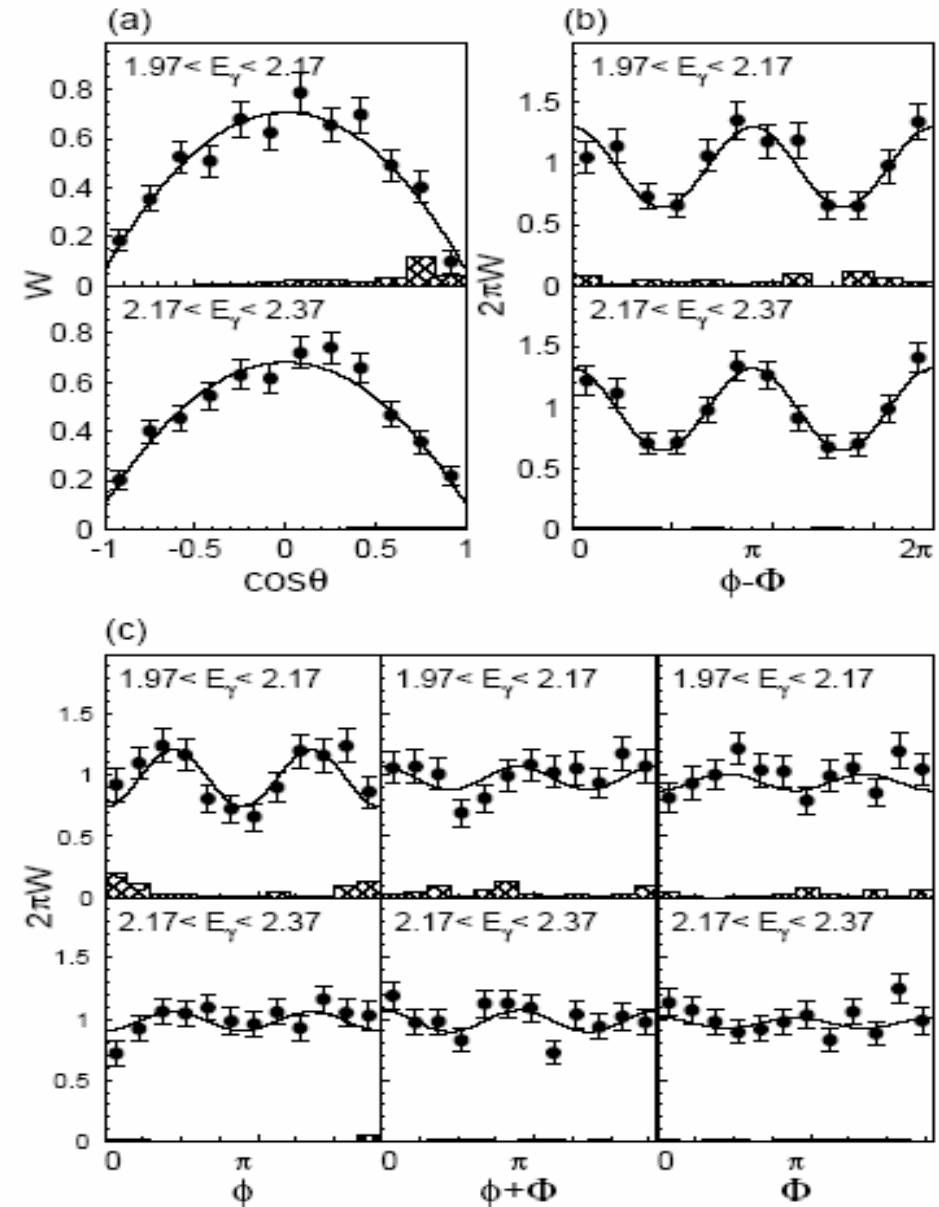
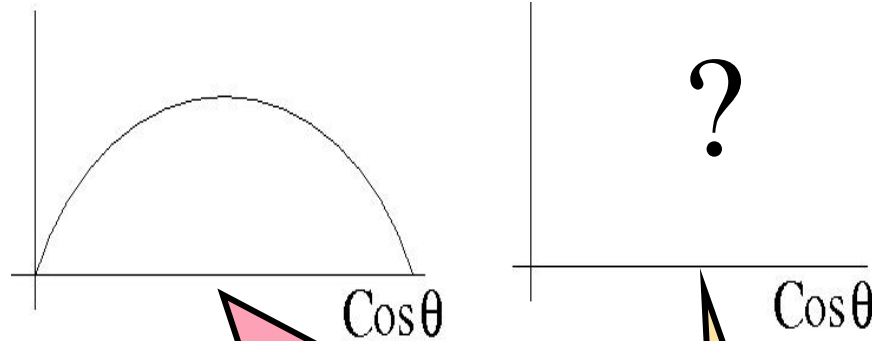
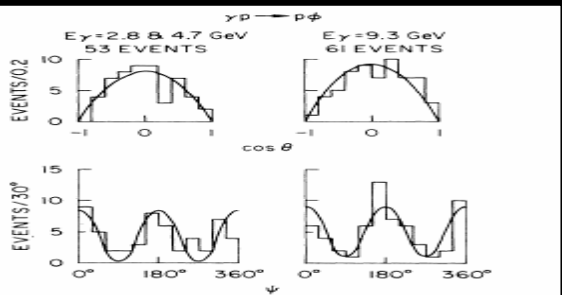


FIG. 4: Decay angular distributions for  $-0.2 < t + |t|_{min}$  in the Gottfried-Jackson frame. The solid curves are the fit to the data. The hatched histograms are systematic errors.

- T. Mibe, "Measurement of  $\phi$  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).

# VMD



VMD

**Low  $|t|$  regime (Spring-8 + SLAC)  
Forward Direction**

**Central region  
Non VMD ?**

**High  $|t|$  regime g8b  
Central Region**

g8b measuring region

$|t|$

# The Decay Angular Distribution Spin Density Matrix Elements

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

where

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

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

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

**Linearly polarization gives access to six more density matrix elements**

*\*Those are calculated in  $\phi$  rest frame (Helicity Frame)*



# Spin Density Matrix Elements

IF VMD:

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

If not:

- Knockout processes take place
- Interesting physics beyond VMD

# $\phi$ –Photoproduction: g8b experiment

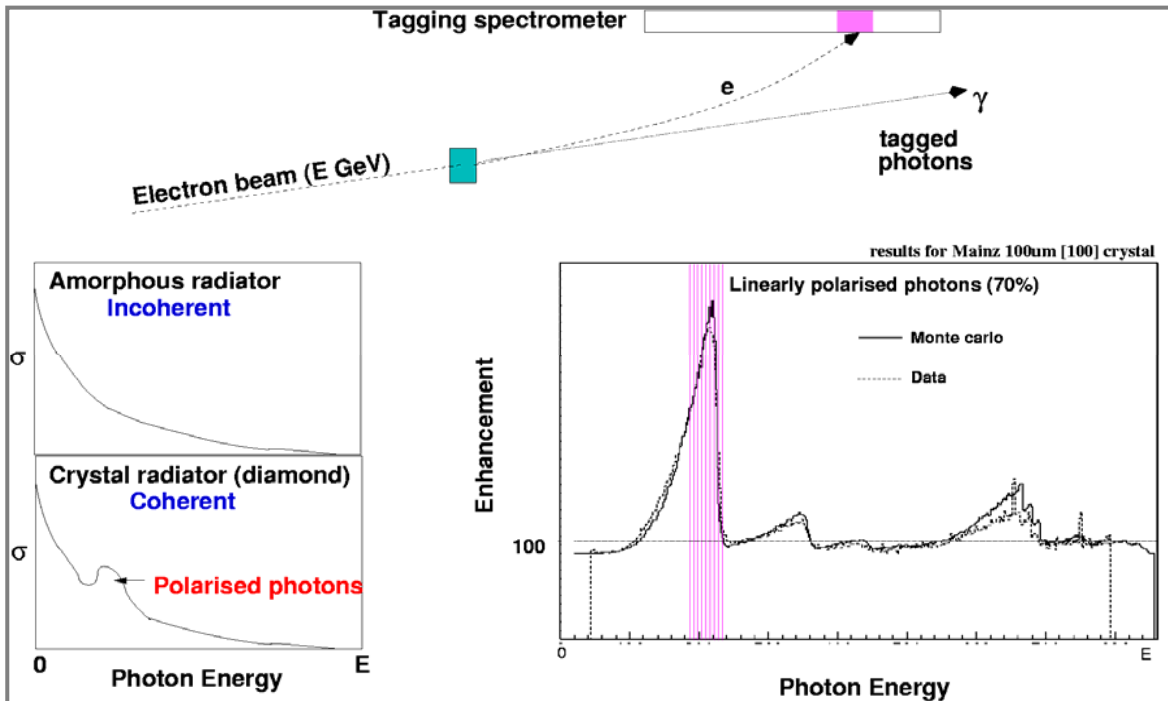
Linearly Polarized Photon Beam



Target: Hydrogen

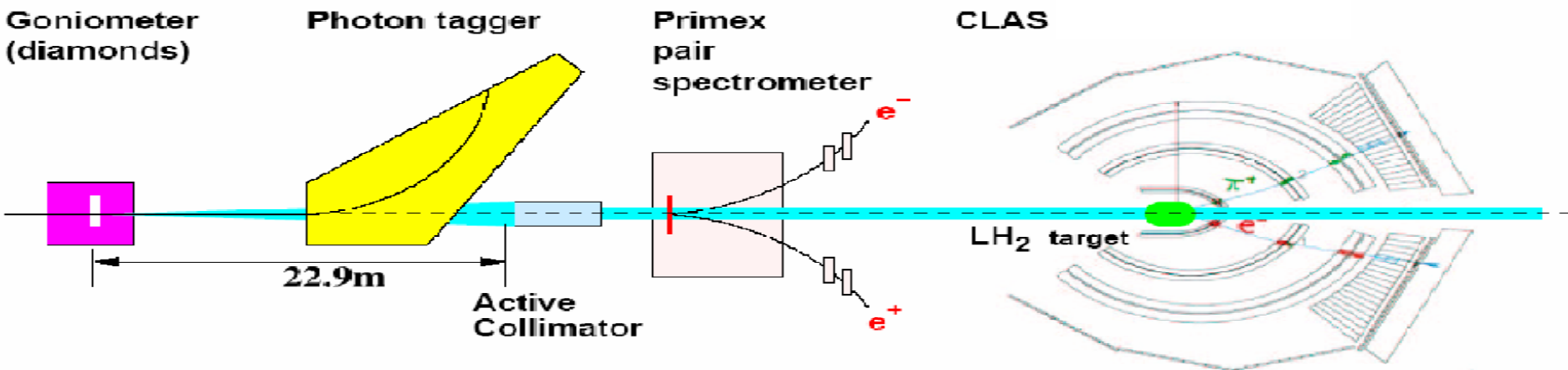
$p(\pi, \eta, \eta', \rho, \omega, \phi, K, \Lambda)$

# The Coherent Bremsstrahlung Facility at CLAS

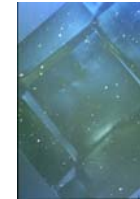
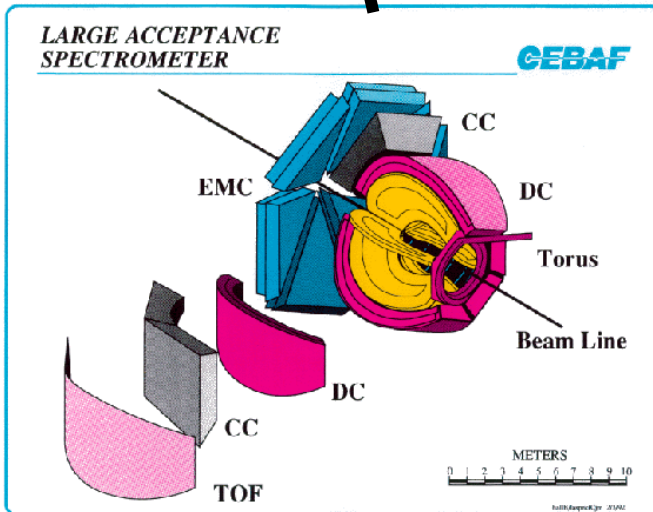
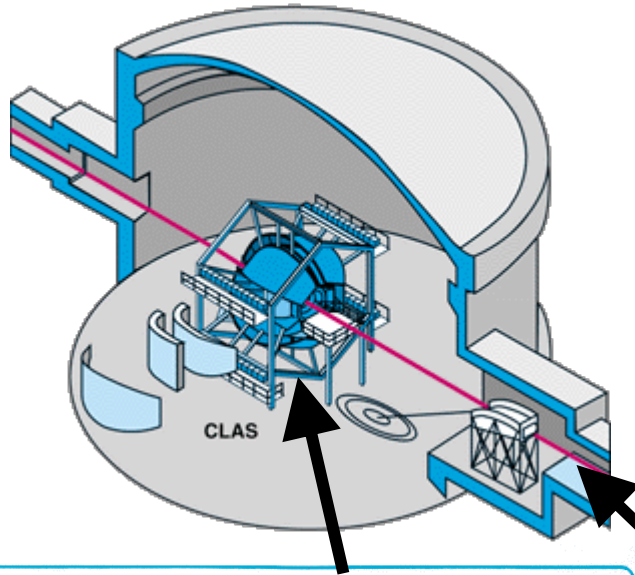


## Requirements for Coherent Bremsstrahlung

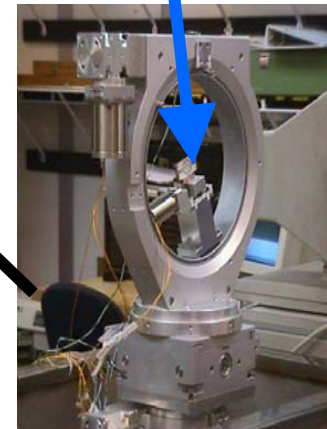
- ☐ Low emittance, stable beam
- ☐ High quality thin crystal
- ☐ Collimation  $< 0.5$  characteristic angle



# The Coherent Bremsstrahlung Facility at CLAS



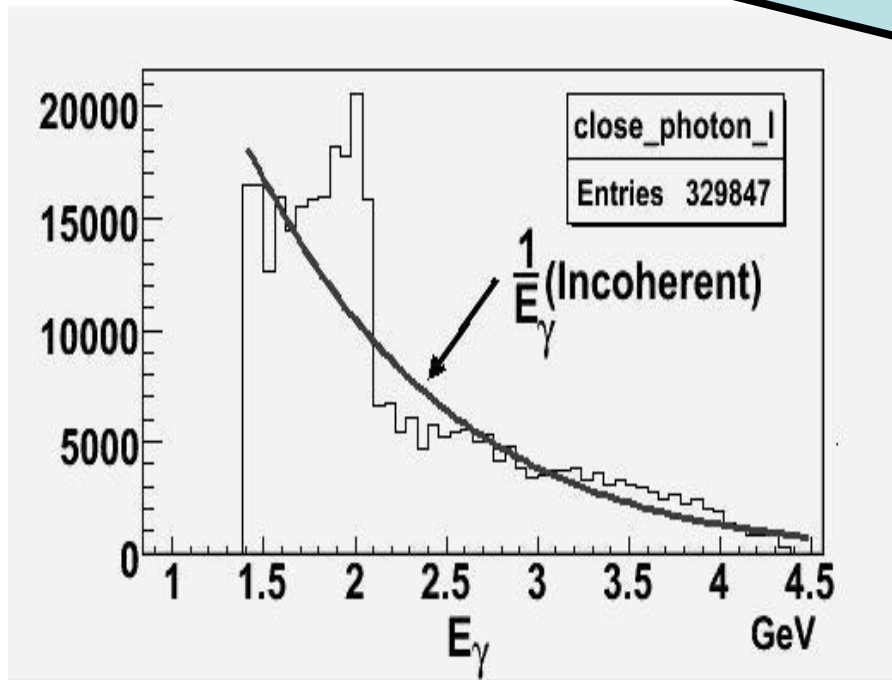
*Diamond*



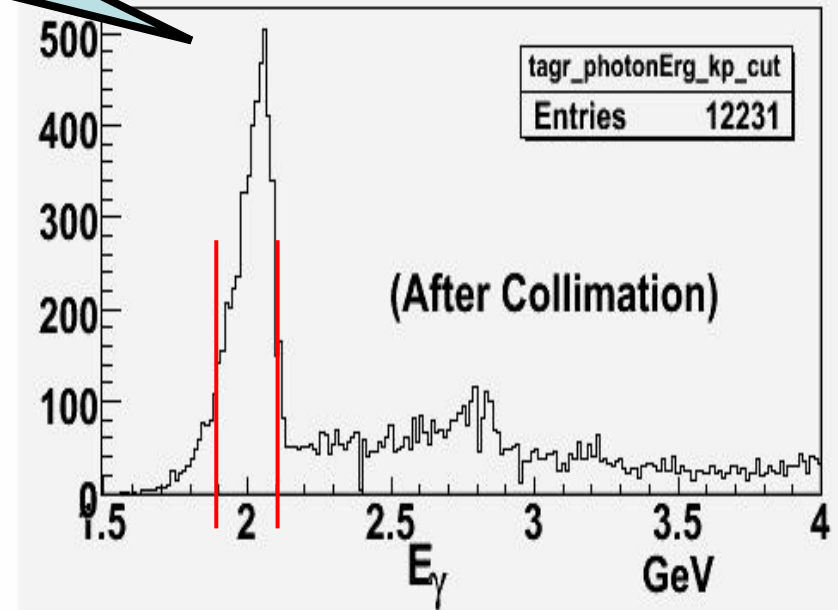
**Goniometer,  
G.W. University**

# Linearly Polarized Photons

i. e. Coherent Peak at 2.1 GeV



a



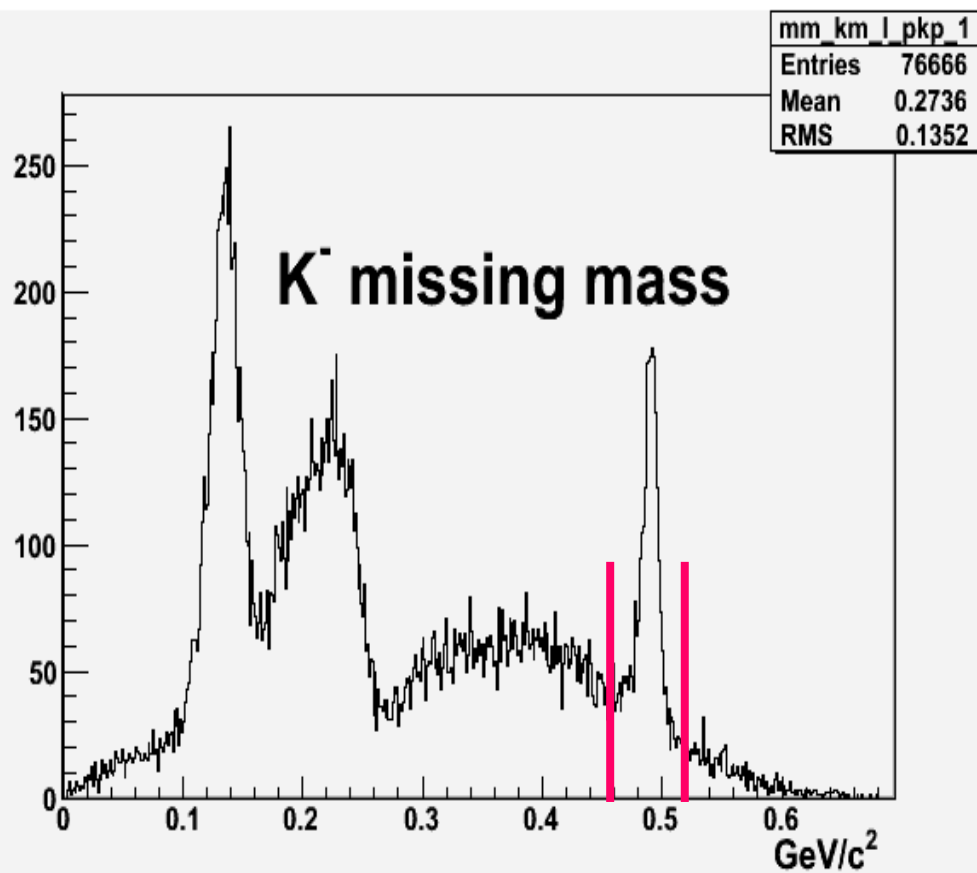
b

□ Mean polarization estimated to be ~70%, from comparison with the coherent bremsstrahlung calculation.

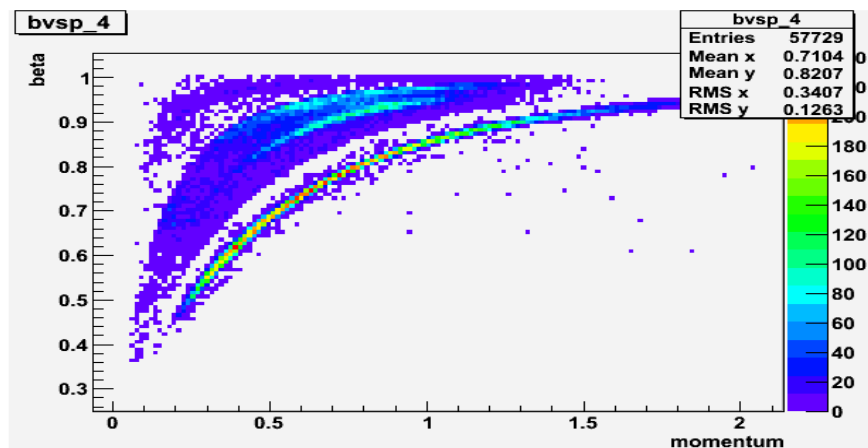
# Event Selection

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

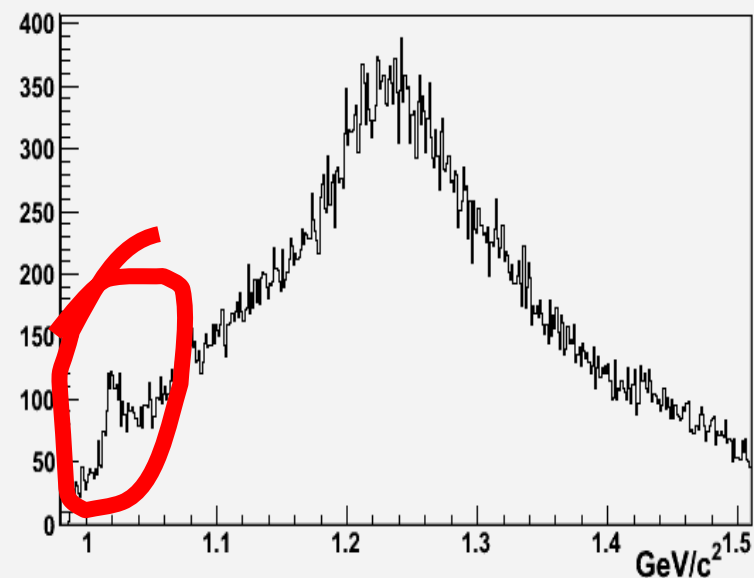
Mode:  $(pK^+)K^-$



Before K<sup>-</sup> missing mass cut



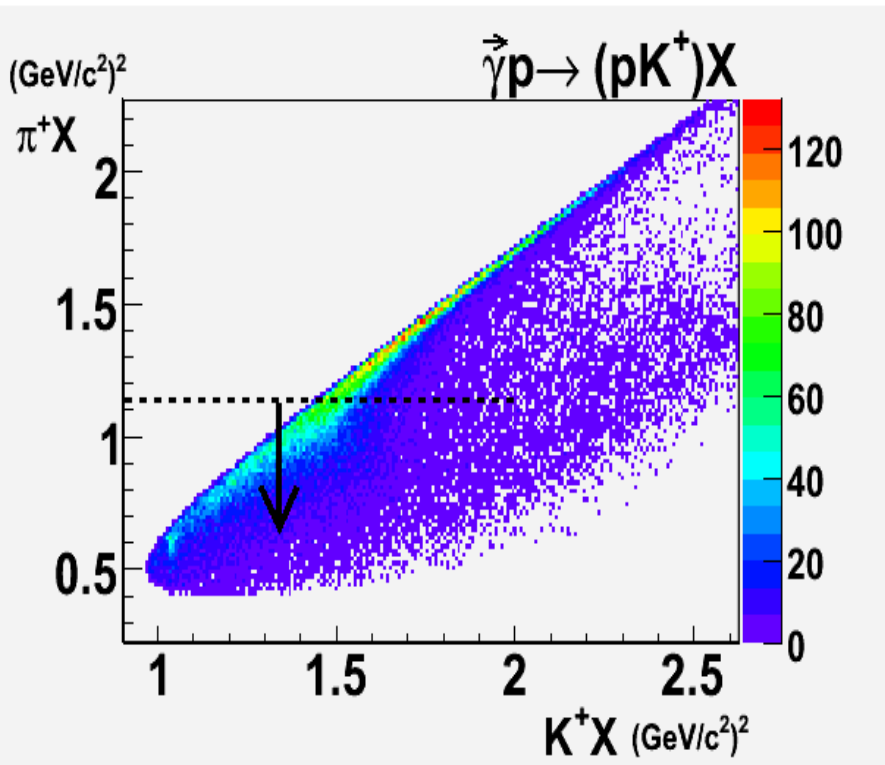
*$\phi \rightarrow K^+K^-$  Invariant mass (before)*



# Event Selection

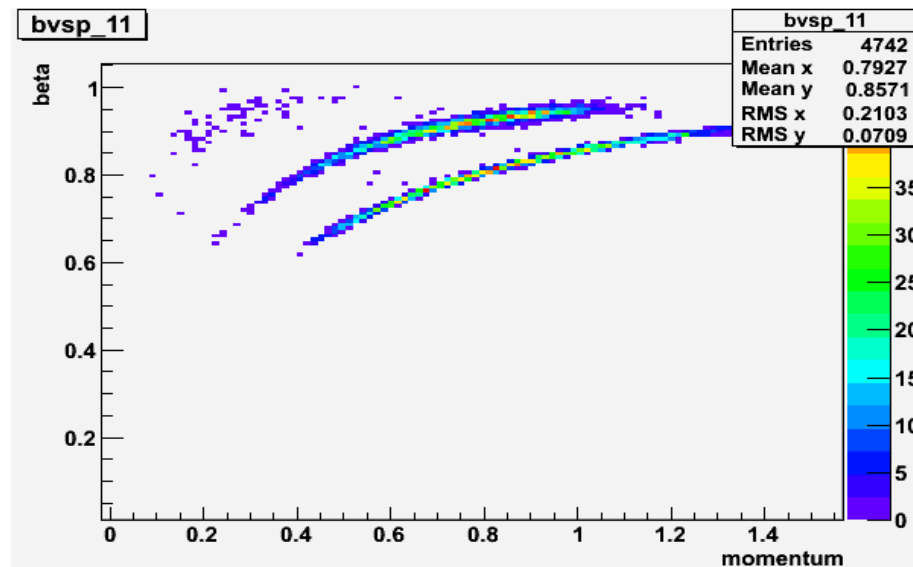
$$\gamma \vec{p} \rightarrow p \phi \rightarrow p K^+ K^-$$

Mode:  $(pK^+)K^-$

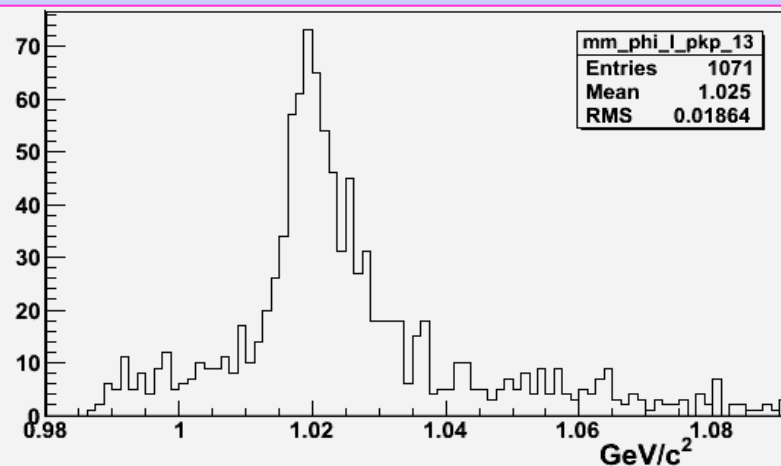


*All this is just for 5 runs.  
We have 400 runs in total.*

*After  $\pi^+X$  vs  $K^+X$  cut, timing cuts and  $K^-$  missing mass cut*



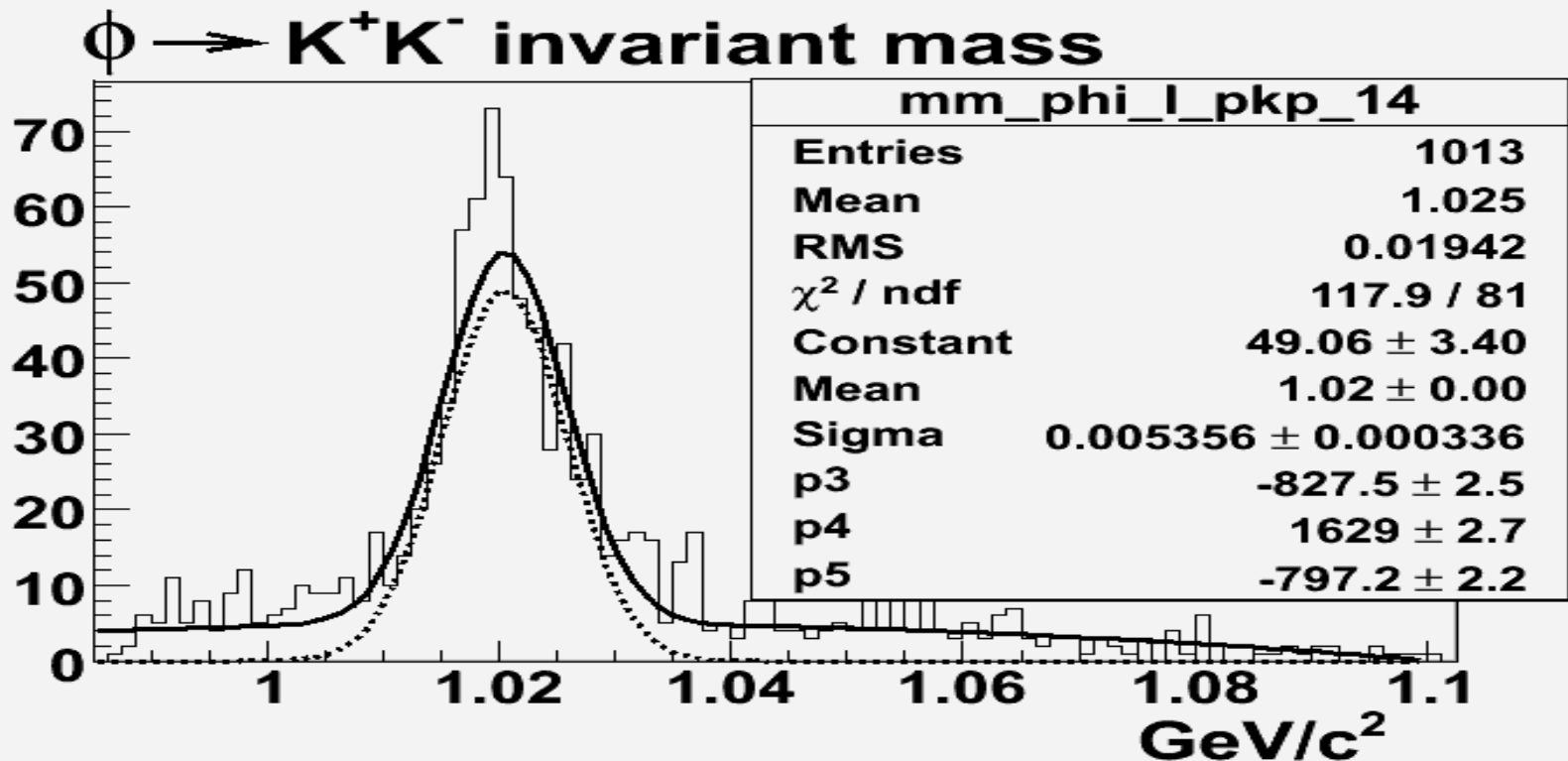
*$\phi \rightarrow K^+K^-$  invariant mass  
(after cuts)*



# Event Selection

Signal to background  
ratio: 4.18  
Events Signal: 502  
Events Background: 120

$\vec{\gamma} p \rightarrow p \phi \rightarrow p K^+ K^-$   
**Mode:  $(p K^+) K^-$**



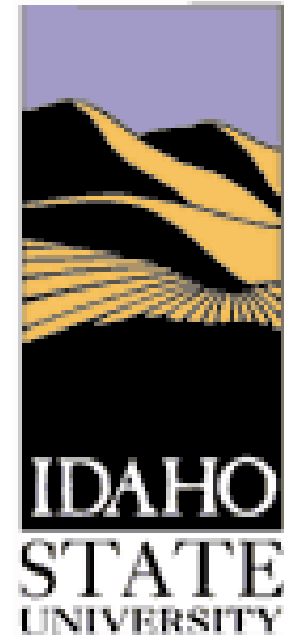
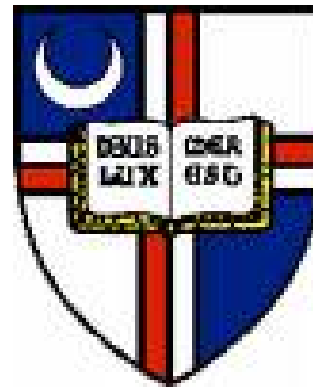


# Conclusions

- ❑ Polarization 70%
- ❑ Over 500  $\phi$ -meson were found for 5 runs\* in g8b data.
- ❑ We predict over 7500 events from 1.9 to 2.1 GeV.
- ❑ We are working on optimizing the  $\phi$ -meson signal through direct  $pK^+K^-$  measurement and missing mass  $(p,K^-)K^+$

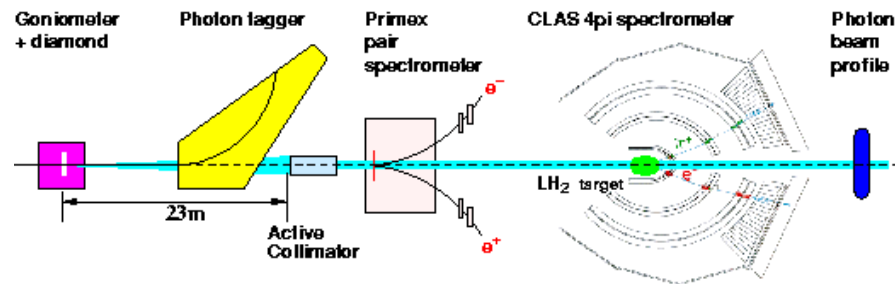
*\* This represents ~5% of data*

# g8 history so far...





g8b (6/20 - 9/01/05)

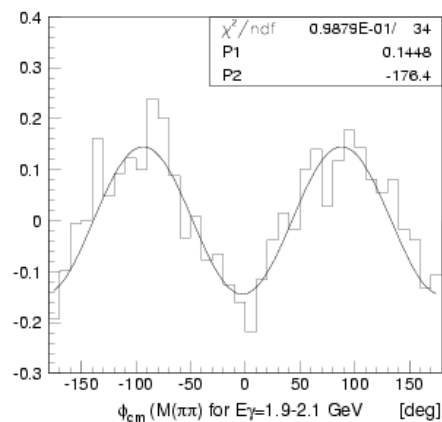


Tagged and Collimated  $\vec{\gamma}$  beam in Hall B  
for beam-asymmetry studies for the reactions:

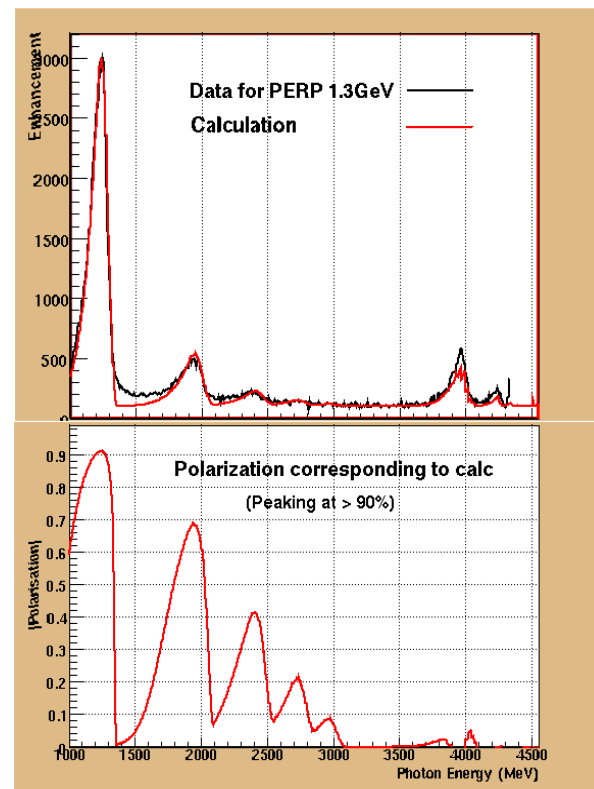
$$\gamma p \rightarrow p(\pi, \eta, \rho, \omega, \phi), K\Lambda$$

<u>Coh. Peak</u>	<u>good evts</u>
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  $\gamma p \rightarrow p p^0$



$p^0$  at low  $|t|$  ( $< 0.30 \text{ GeV}^2$ )



Photon Polarization  
exceeds 90% in the peak

**Thanks!!!**