Helicity asymmetry in ω meson photoproduction from the proton

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Motivation

- ω mesons have isospin 0
  - One-step excited states of the proton can only be isospin ½.
  - Isospin filter
- These asymmetry measurements for the ω meson should further the understanding of the nucleon resonance spectrum.
- There is no published data for this asymmetry.
- Previous analyses of this channel relied on cross-sections and spin density matrix elements.
  - For example: M. Williams, *et al* (CLAS Collaboration), PRC 80, 065208, (2009)
    - PWA: M. Williams, *et al* (CLAS Collaboration), PRC 80, 065209, (2009)

Helicity Asymmetry

Theoretically: $$C_{zz}^{\gamma N} = \frac{\sigma_- - \sigma_+}{\sigma_- + \sigma_+}$$

Where σ_+ is the differential cross-section when the helicity of the photon and proton are aligned, while σ_- is the differential cross-section when anti-aligned.

Experimentally: $$C_{zz}^{\gamma N} = \frac{1}{P_z P_c} \frac{Y_- - Y_+}{Y_- + Y_+}$$

Where P_z is the polarization of the target, P_c is the polarization of the beam, Y_+ and Y_- are the yields when the polarization of the beam and target are aligned or anti-aligned, respectively.

Note: Bound nucleons in butonal have no polarization

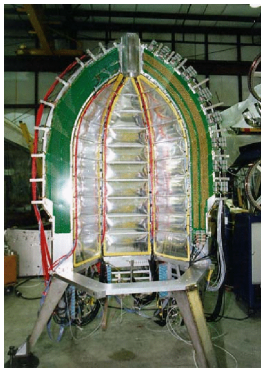
CLAS (CEBAF Large Acceptance Spectrometer) 1997 - 2012

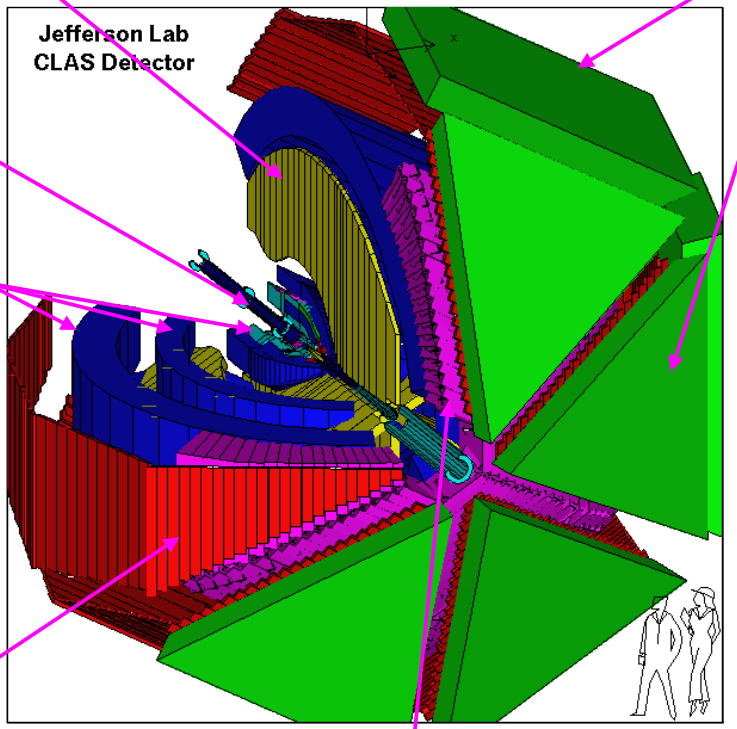
Torus magnet
6 superconducting coils

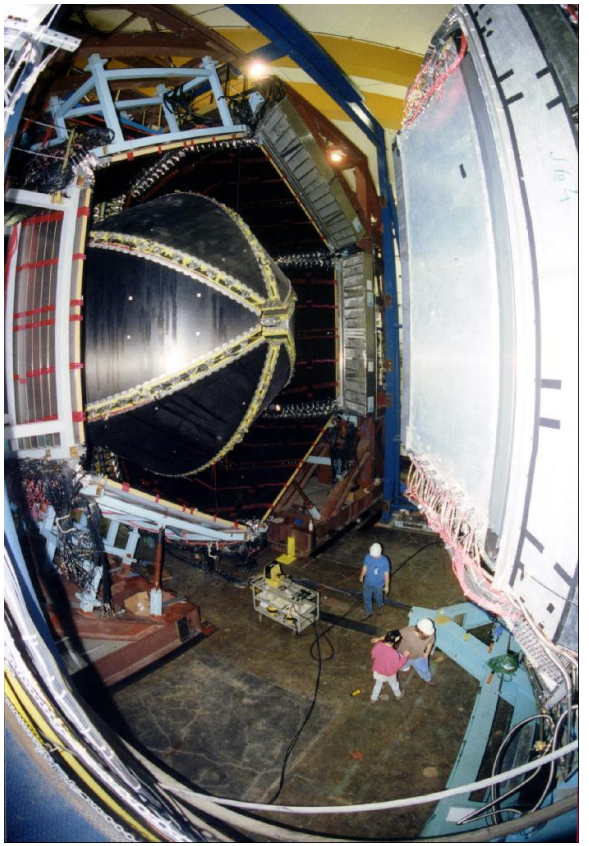
Electromagnetic calorimeters
Lead/scintillator, 1296 photomultipliers

polarized target + start counter

Drift chambers
argon/CO_2 gas, 35,000 cells







Time-of-flight counters
plastic scintillators, 684 photomultipliers

DAQ limit ~10kHz (~2.5TB/day)

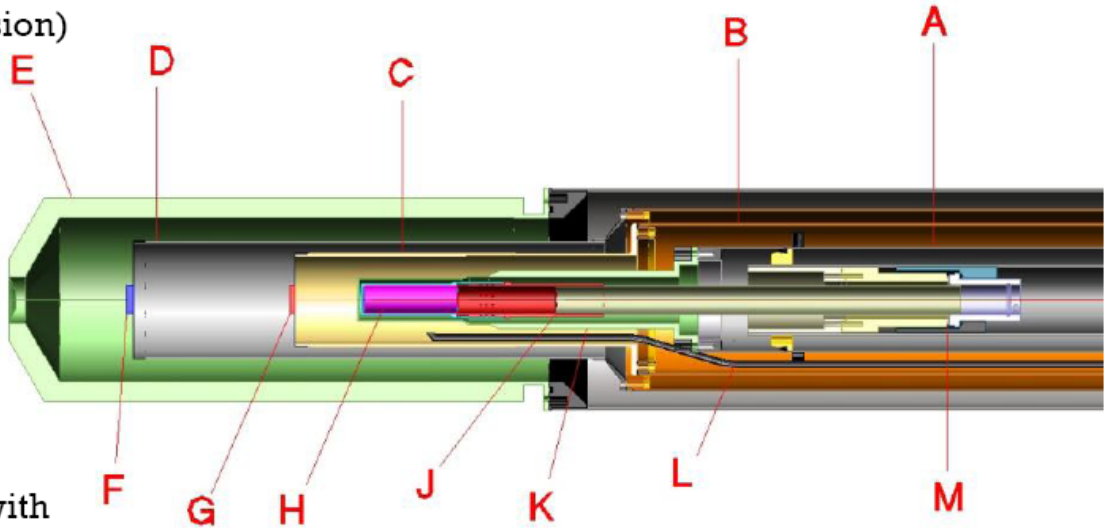
Gas Cherenkov counters
e/π separation, 256 PMTs

FROST target

- Butanol composition: C_4H_9OH
- Spin 0 bound nuclei

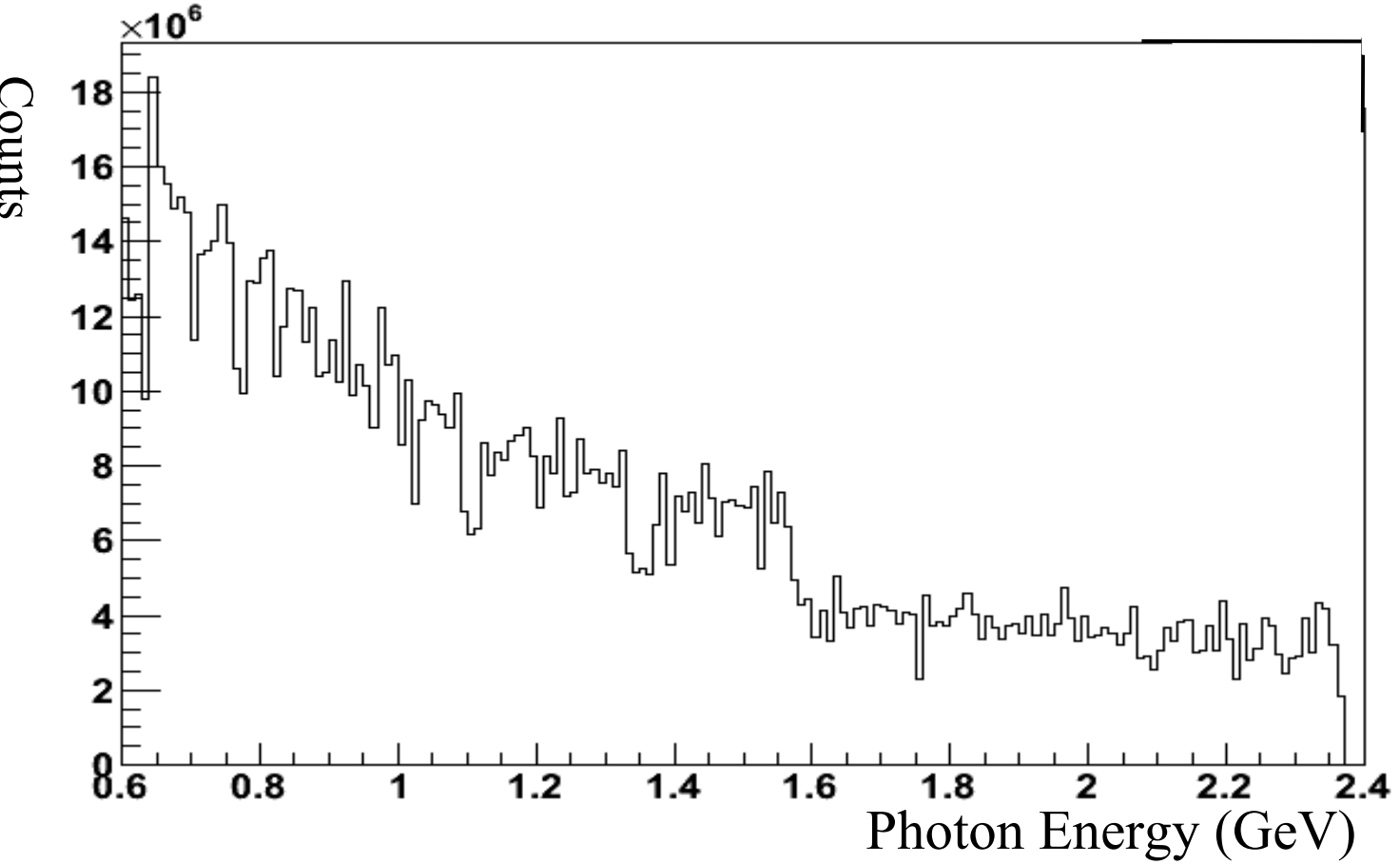
- Carbon target used to represent bound nucleon contribution of butanol

The FroST target and its components:
A: Primary heat exchanger
B: 1 K heat shield
C: Holding coil
D: 20 K heat shield
E: Outer vacuum can (Rohacell extension)
F: CH2 target
G: Carbon target
H: Butanol target
J: Target insert
K: Mixing chamber
L: Microwave waveguide
M: Kapton coldseal



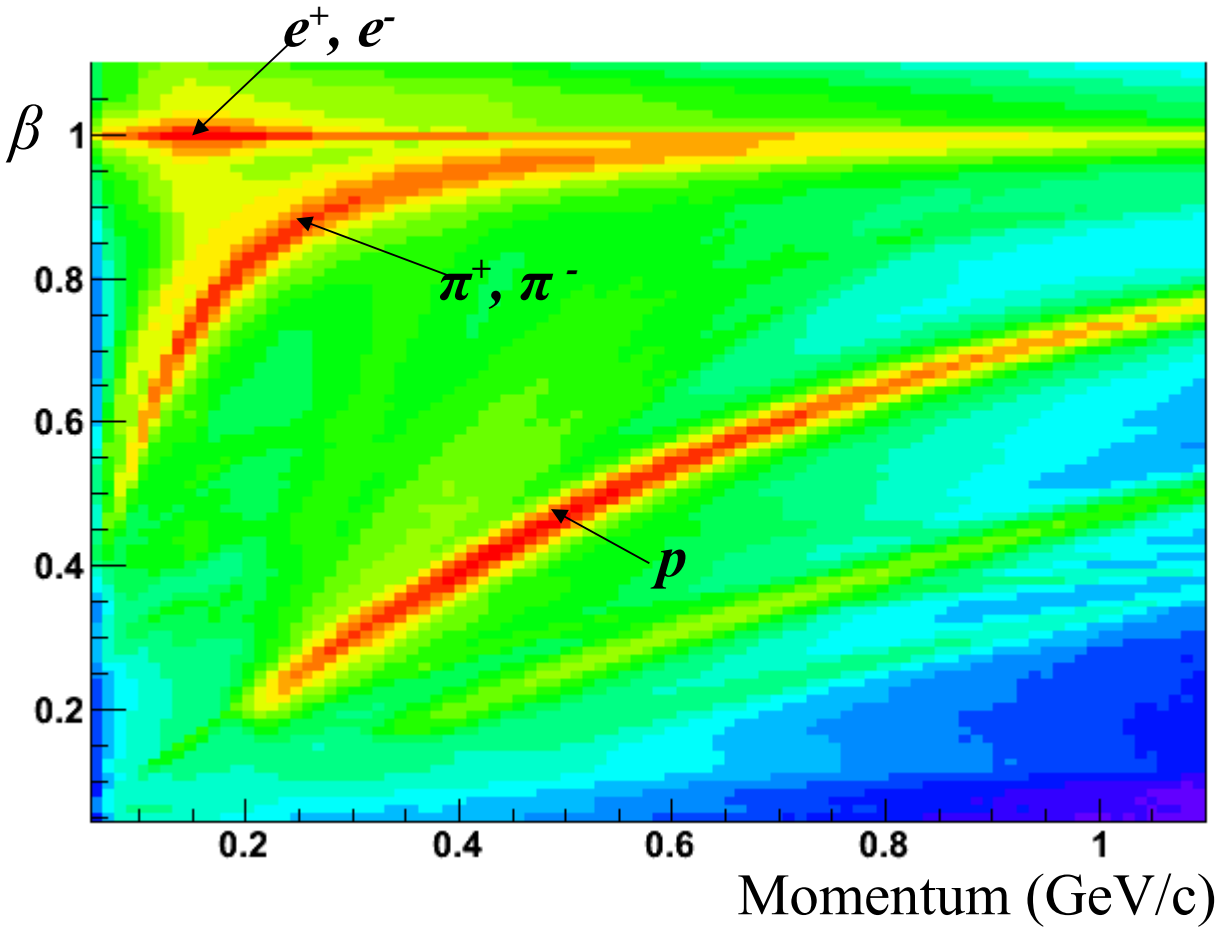
Performance Specs:
Base Temp: 28 mK w/o beam, 30 mK with
Cooling Power: 800 μW @ 50 mK, 10 mW @ 100 mK, and 60 mW @ 300 mK
Polarization: +82%, -90%
1/e Relaxation Time: 2800 hours (+Pol), 1600 hours (-Pol)
Roughly 1% polarization loss per day.

Run Conditions



- Nov. 2007 – Feb 2008
- Electron beam energies:
  - 1.645 GeV
  - 2.478 GeV
- Electron beam polarization avg. 85%
- $E_\gamma = 20 - 95\ \% E_e$
- Longitudinally polarized target avg polarization 80%

Particle Identification



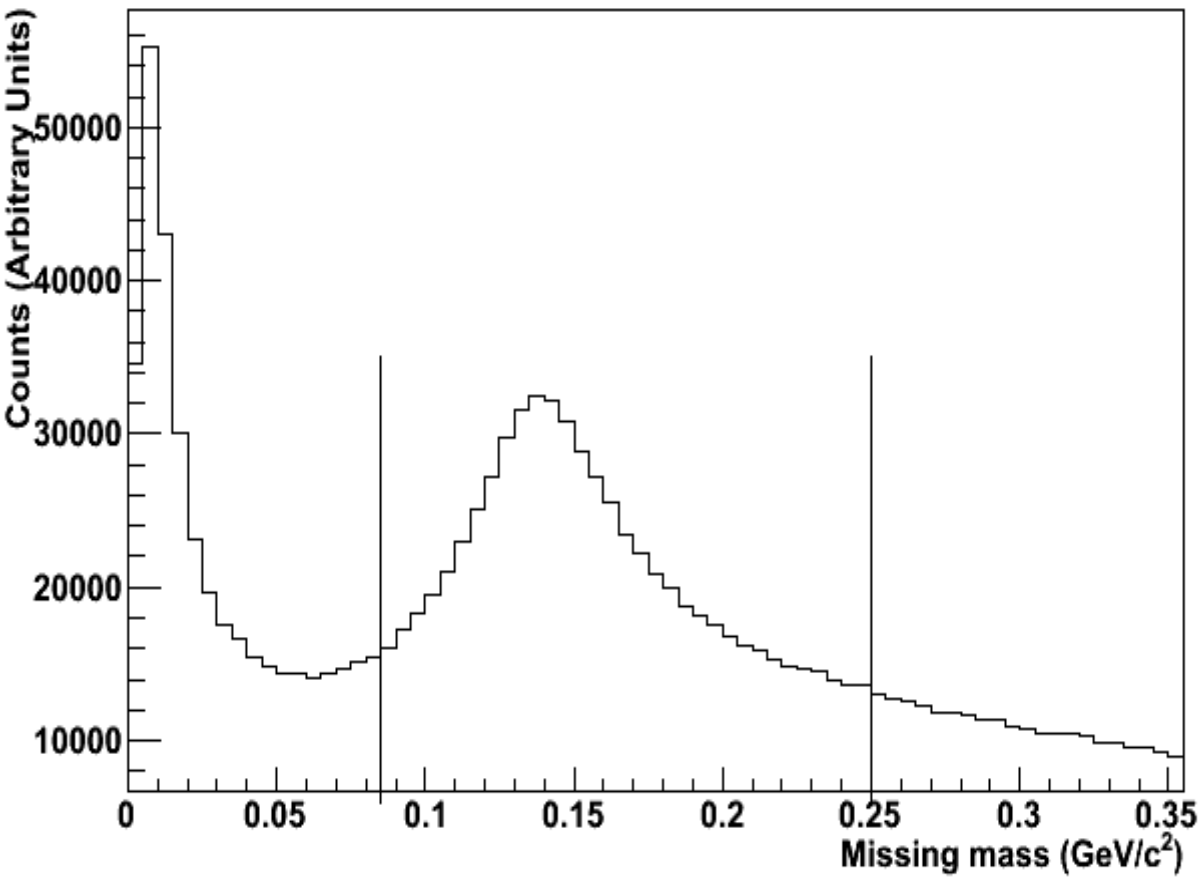
Particle Identification

$$\vec{\gamma}\,\vec{p} \rightarrow \omega\, p$$

$$\omega \rightarrow \pi^+ \pi^- \left(\pi^0\right)$$

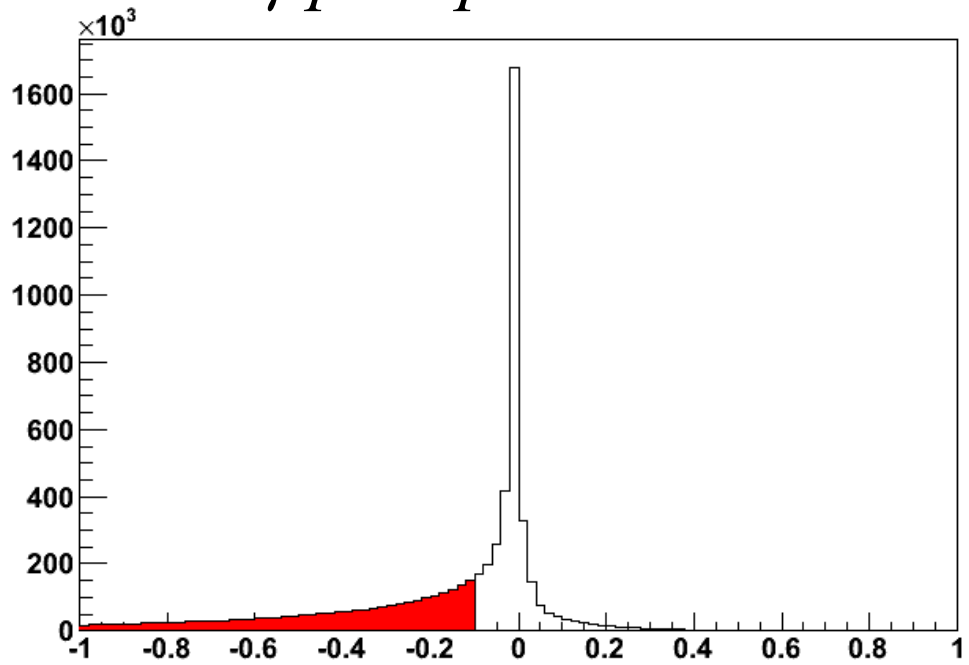
- Branching ratio: 89.2%
- Detected in final state: p, π^+, π^-
- Neutral pion identified in missing mass
- Lower mass cut is compromise between including π^0 events and excluding background events.

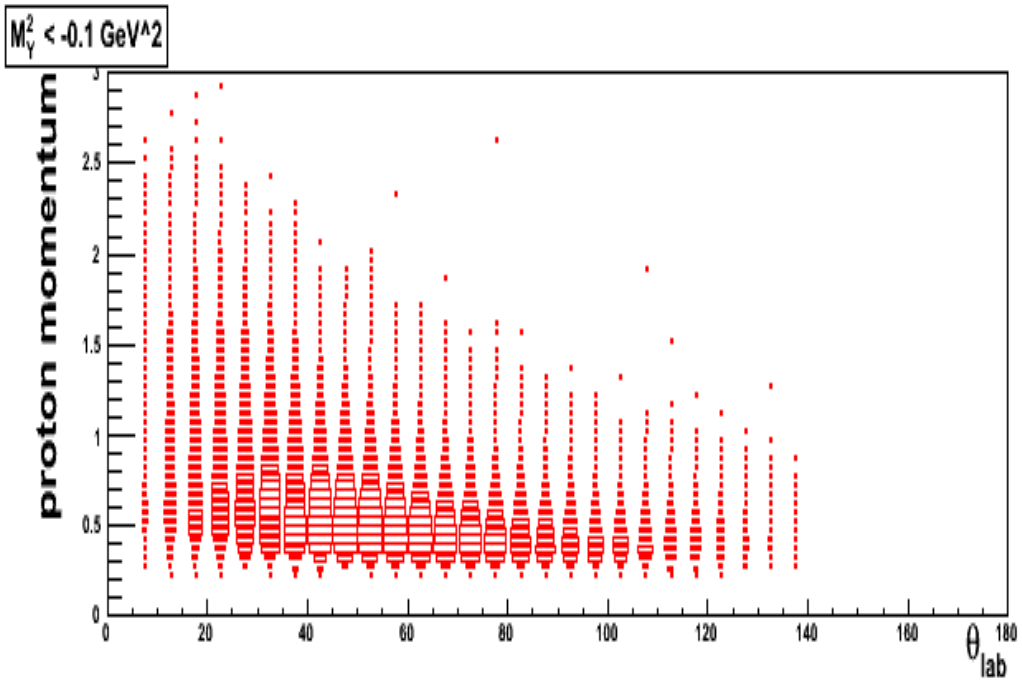
Missing mass for: $\gamma\, p \rightarrow p\, \pi^+ \pi^-\, X$

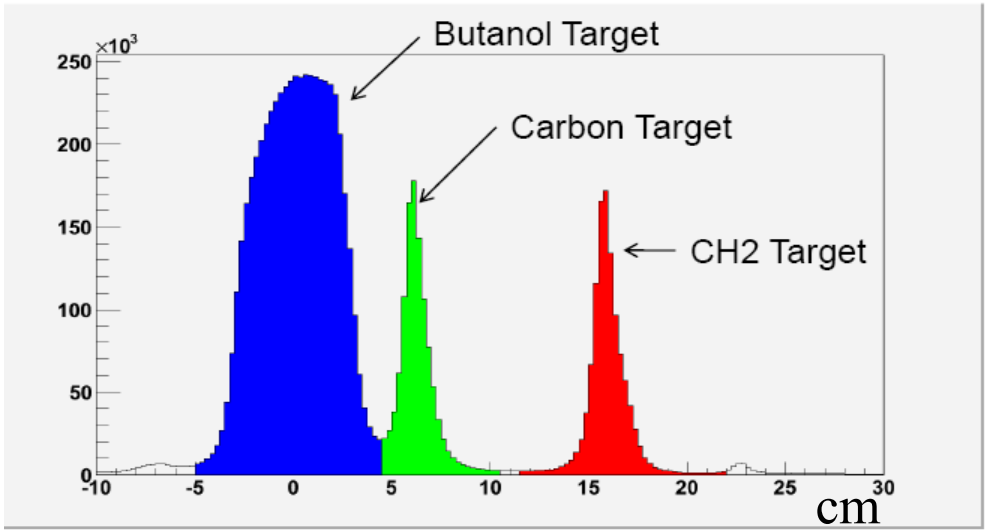


Bound Nucleon Events

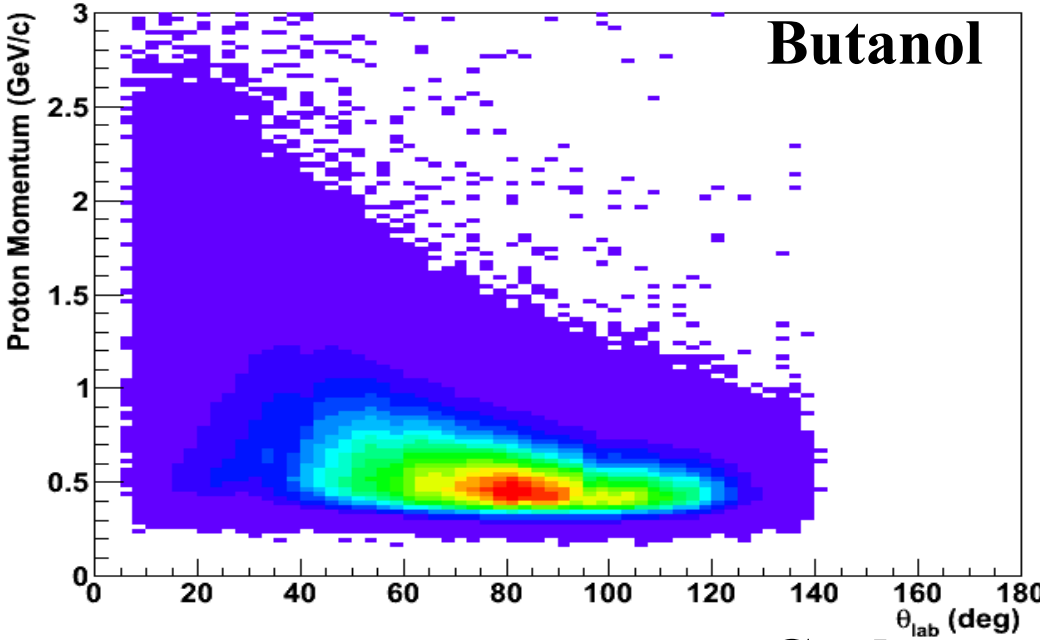
$$\gamma\, p \rightarrow p\, \pi^{+}\, \pi\, X$$

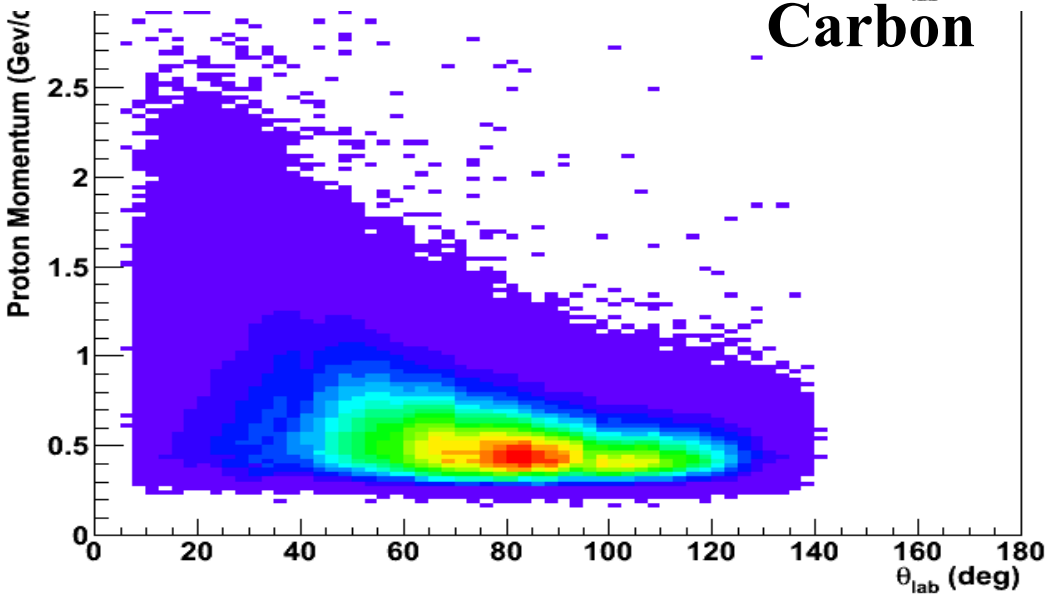


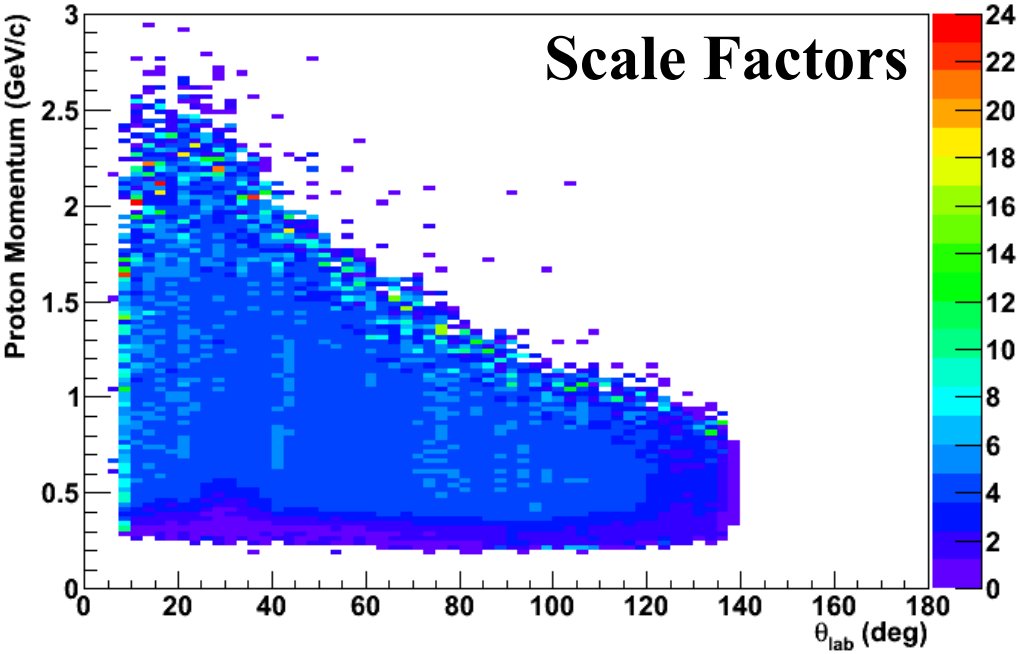




Butanol Scale Factors



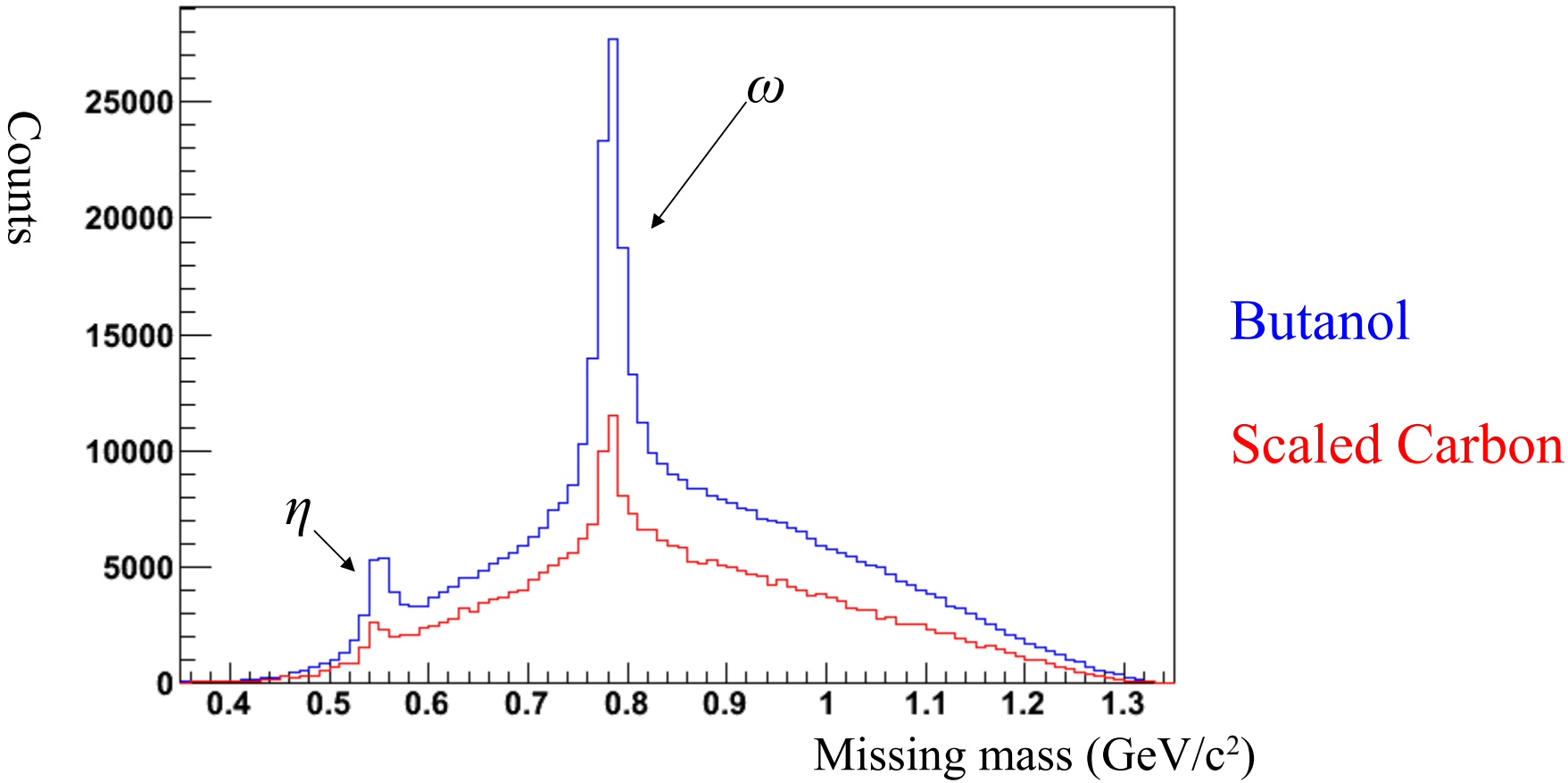




Scaled Carbon Spectrum

$$\vec{\gamma}\,\vec{p} \rightarrow p\,X$$

For events where π^+, π^- are detected, and π^0 is identified



Butanol

Scaled Carbon

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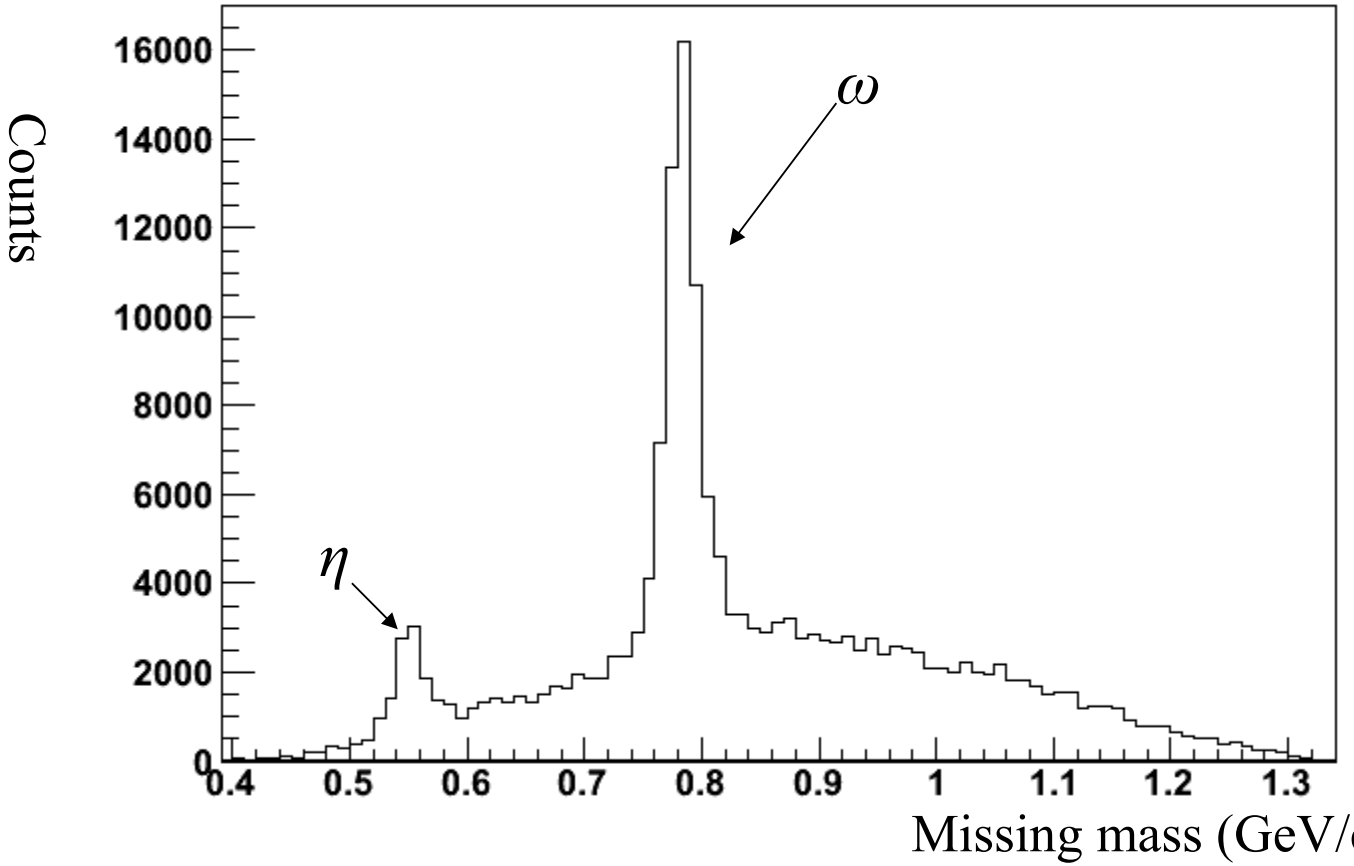
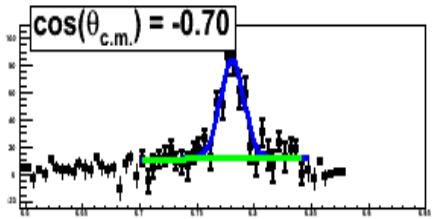
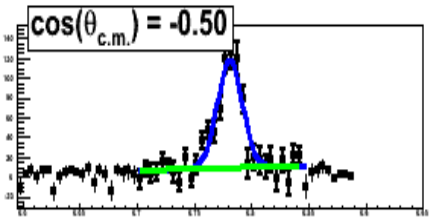


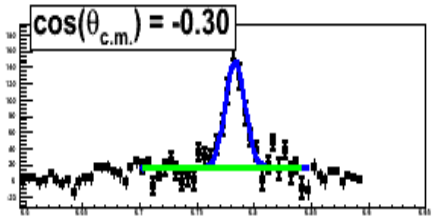
Carbon subtracted spectrum

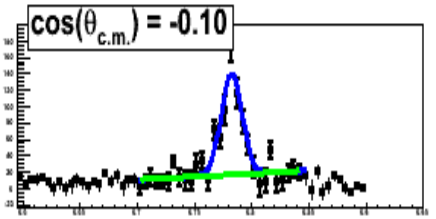
Missing mass plots
W = 1825 MeV

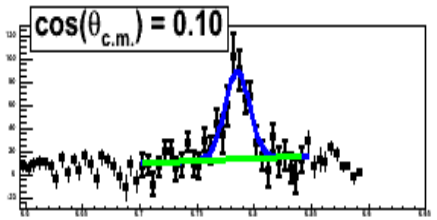
$(Y_- + Y_+)$ Carbon subtracted

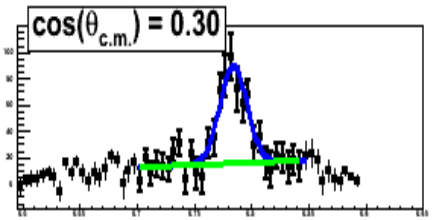


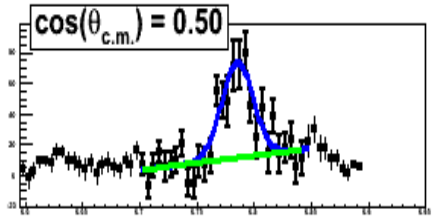


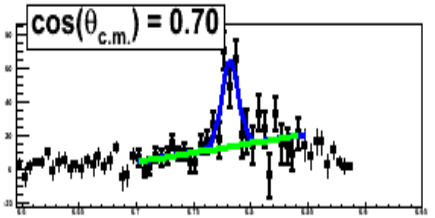






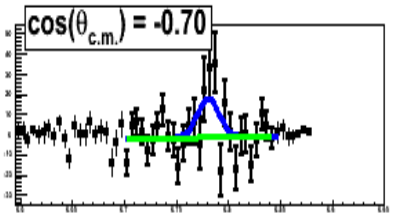


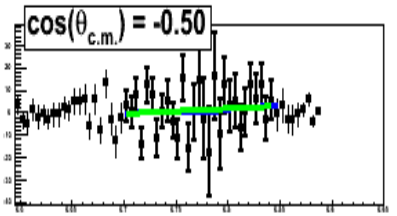


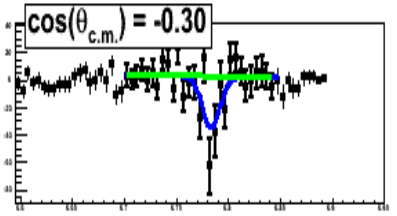


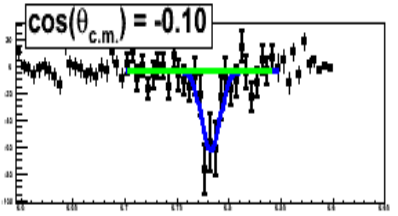
Missing mass (GeV/c²)

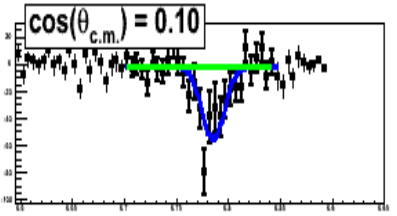
$Y_- - Y_+$

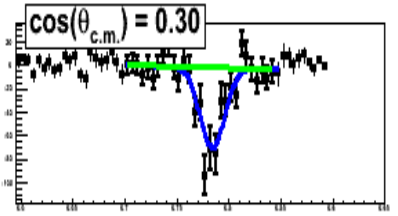


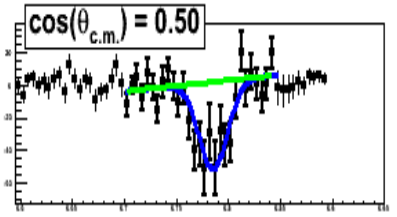


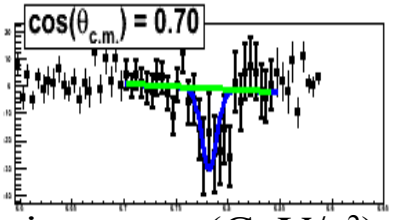








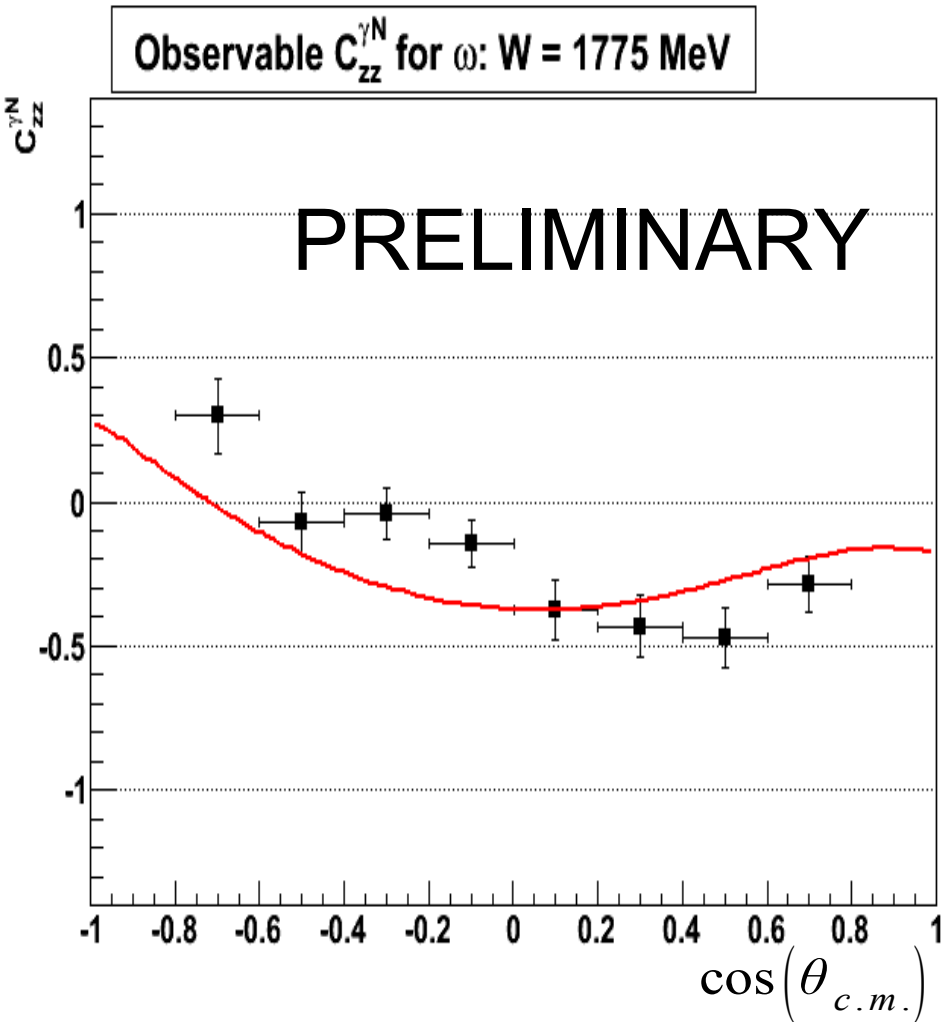


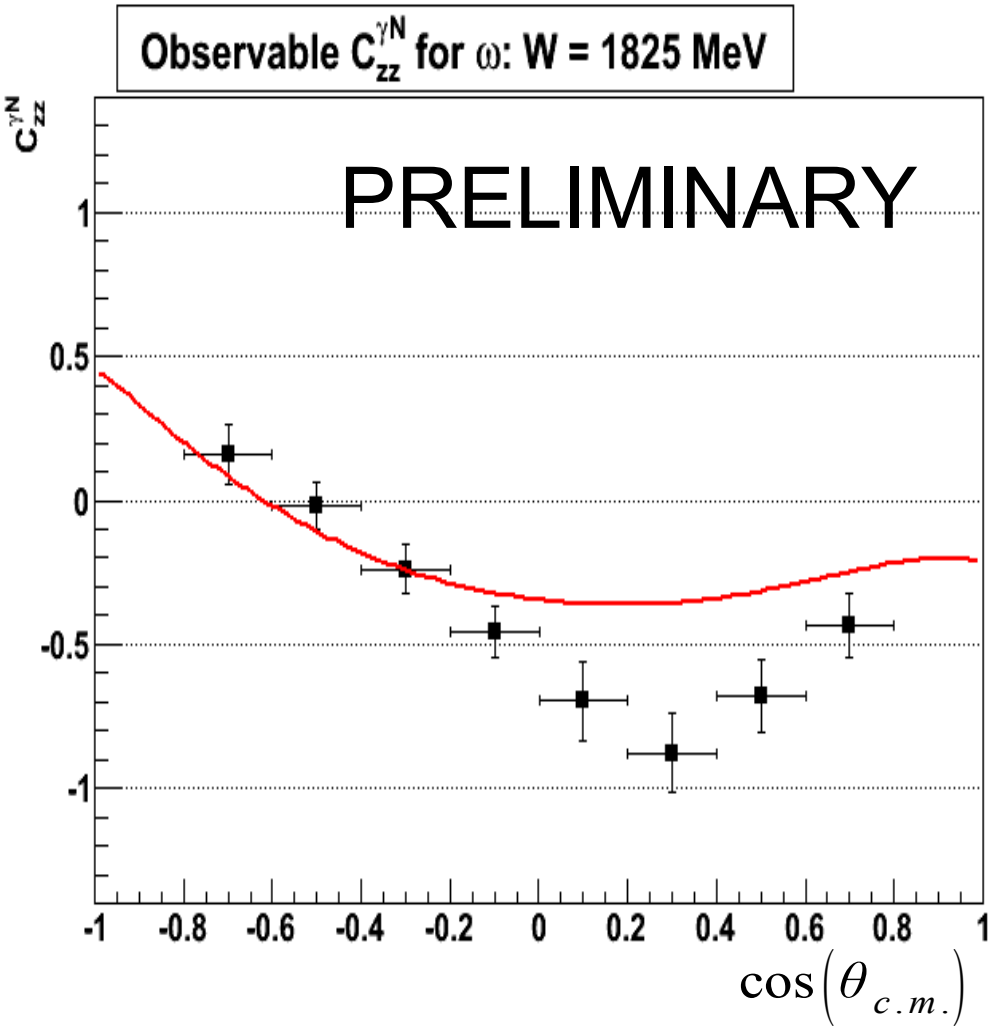


Missing mass (GeV/c²)

$$C_{zz}^{\gamma N} = \frac{1}{P_z P_c} \frac{Y_- - Y_+}{Y_- + Y_+}$$

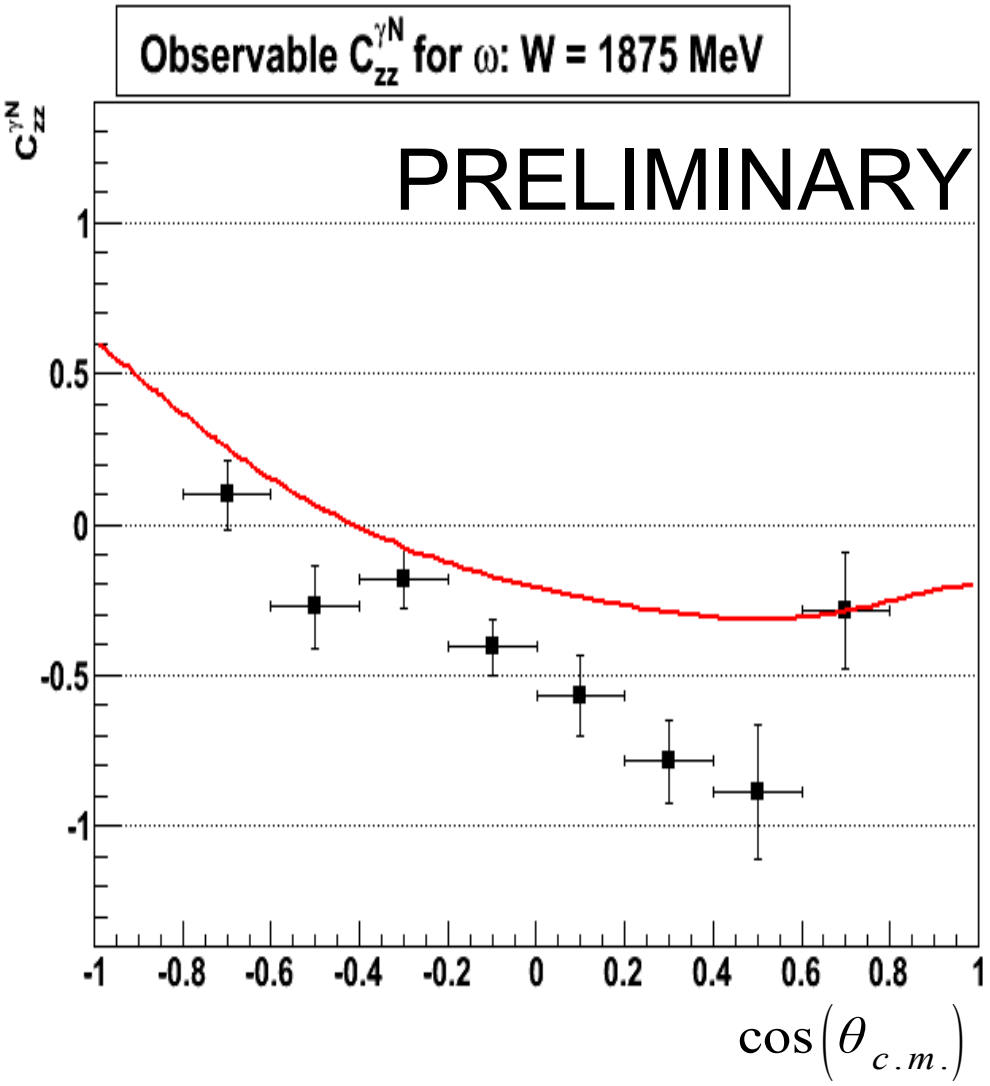
$C_{zz}^{\gamma N}$

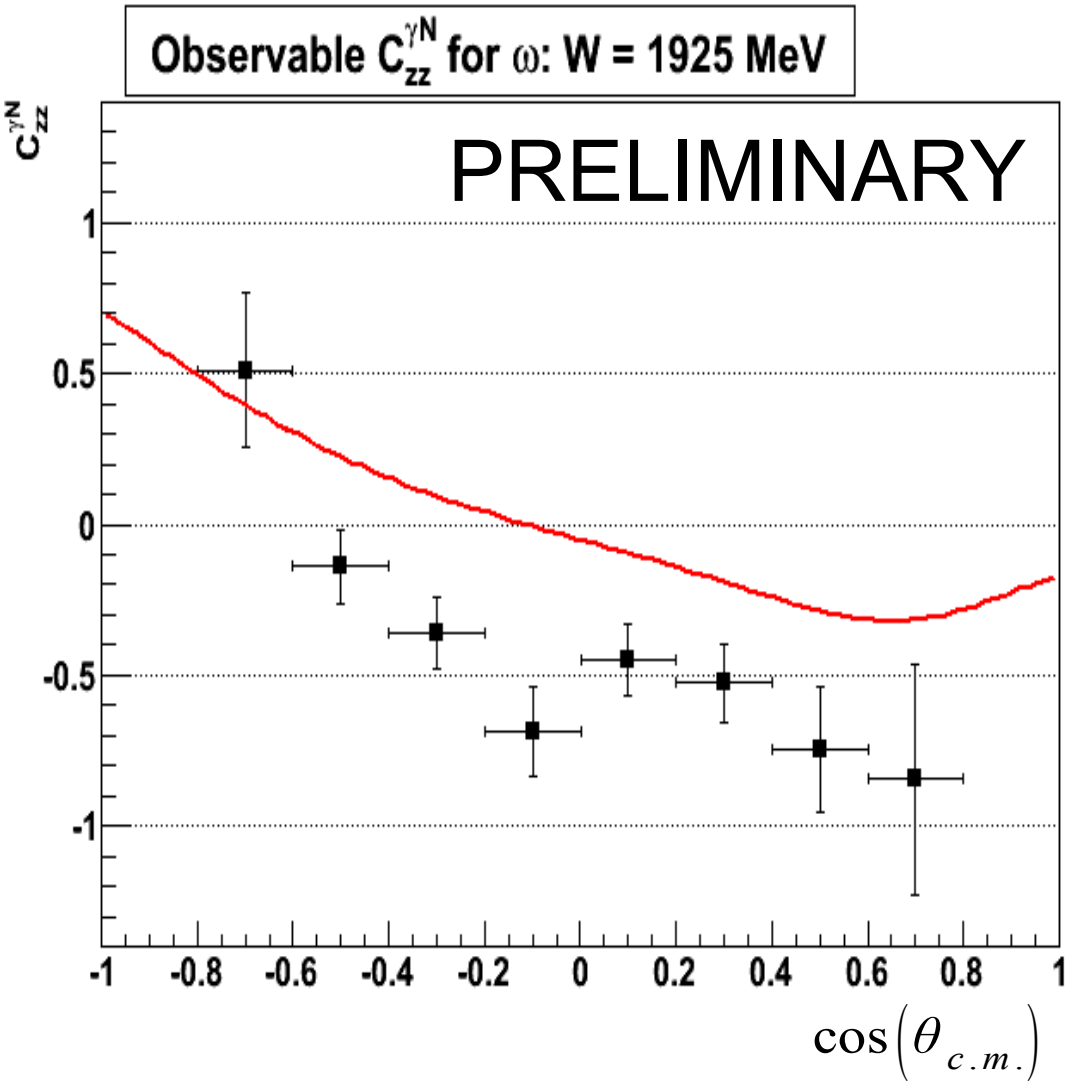




Red curves: M. Paris, Phys. Rev. C 79, 025208 (2009), extension of EBAC model

$C_{zz}^{\gamma N}$





Red curves: M. Paris, Phys. Rev. C 79, 025208 (2009)

Conclusions

- Preliminary results for double polarization observable for ω photoproduction from the proton.
- There is no published data for this observable.
- The FROST running period took data with other target polarization and beam polarization combinations, allowing for extraction of other polarization observables.
- These data should further the study of hadron spectroscopy.