Study of $\pi^+\pi^-$ and ω Photo- production using a circularly polarized beam at Jefferson Lab

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Outline

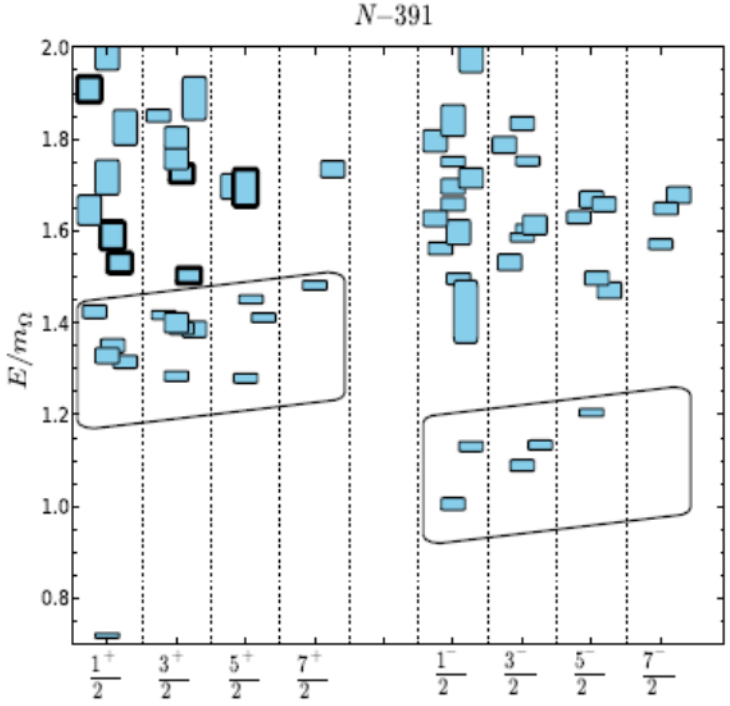
- Motivation
- Previous Measurement
- CLAS-g12 Experiment
- Data Analysis Technique
- Preliminary Result
- Summary and Outlook

MOTIVATION

- Missing Baryon Problem
- The need of Photo-production, Omega Channel and Polarization Observable

Missing Baryon Problem

- A lot of baryon resonances that is predicted by Constituent Quark Model (CQM) and Lattice QCD have not been observed vet.



Lattice calculation by R. G. Edwards *et al*

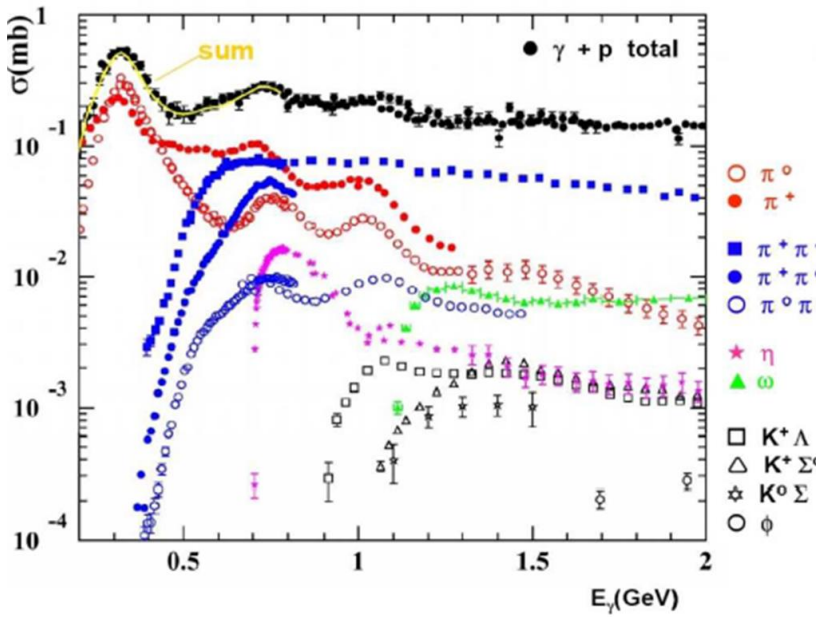
J^P	M_{CQM}	M_{PDG}	Rating	J^P	M_{CQM}	M_{PDG}	Rating
$1/2^-$	1460	1535	****	$1/2^+$	1540	1440	****
$1/2^-$	1535	1650	****	$1/2^+$	1770	1710	***
$1/2^-$	1945	2090	*	$1/2^+$	1880		
$1/2^-$	2030			$1/2^+$	1975		
$1/2^-$	2070			$1/2^+$	2065	2100	*
$1/2^-$	2145			$1/2^+$	2210		
$1/2^-$	2195						
$3/2^-$	1495	1520	****	$3/2^+$	1795	1720	****
$3/2^-$	1625	1700	***	$3/2^+$	1870		
$3/2^-$	1960	2080	**	$3/2^+$	1910		
$3/2^-$	2055			$3/2^+$	1950		
$3/2^-$	2095			$3/2^+$	2030		
$3/2^-$	2165						
$3/2^-$	2180						
$5/2^-$	1630	1675	****	$5/2^+$	1770	1680	****
$5/2^-$	2080			$5/2^+$	1980	2000	**
$5/2^-$	2095	2200	**	$5/2^+$	1995		
$5/2^-$	2180						
$5/2^-$	2235						
$5/2^-$	2260						
$5/2^-$	2295						
$5/2^-$	2305						
$7/2^-$	2090	2190	****	$7/2^+$	2000	1990	**
$7/2^-$	2205			$7/2^+$	2390		
$7/2^-$	2255			$7/2^+$	2410		
$7/2^-$	2305			$7/2^+$	2455		
$7/2^-$	2355						
$9/2^-$	2215	2250	****	$9/2^+$	2345	2220	****
$11/2^-$	2600	2600	***				
$11/2^-$	2670						
$11/2^-$	2700						
$11/2^-$	2770						
$13/2^-$	2715						

Resonance predicted by Capstick & Robert using CQM

• The need of Photo-production, Omega Channel and Polarization Observable

- **Why photoproduction?** A lot of experiment conducted using *N*π channel. Koniuk and Isgur suggested that missing resonances may not coupled strongly to *N*π system.
- Capstick also predicted that missing *N** coupled fairly strong to γp.
- **Why omega?** A lot of effort has been put to study *N** resonances through pseudoscalar meson channel. We need to complete those effort by studying *N** through vector meson production channel (pω, p*ρ*, pφ).
- Omega meson is still under explored. And it is Isospin filter, the resonances only comes from *N**.

- The choices of $p\pi^+\pi^-$ final states (detected) allow us to study vector meson (ω and *ρ).*
- **Why polarization observable?** Polarization observables are very important to isolate resonance duo to the overlapping nature among resonances.



PREVIOUS MEASUREMENT

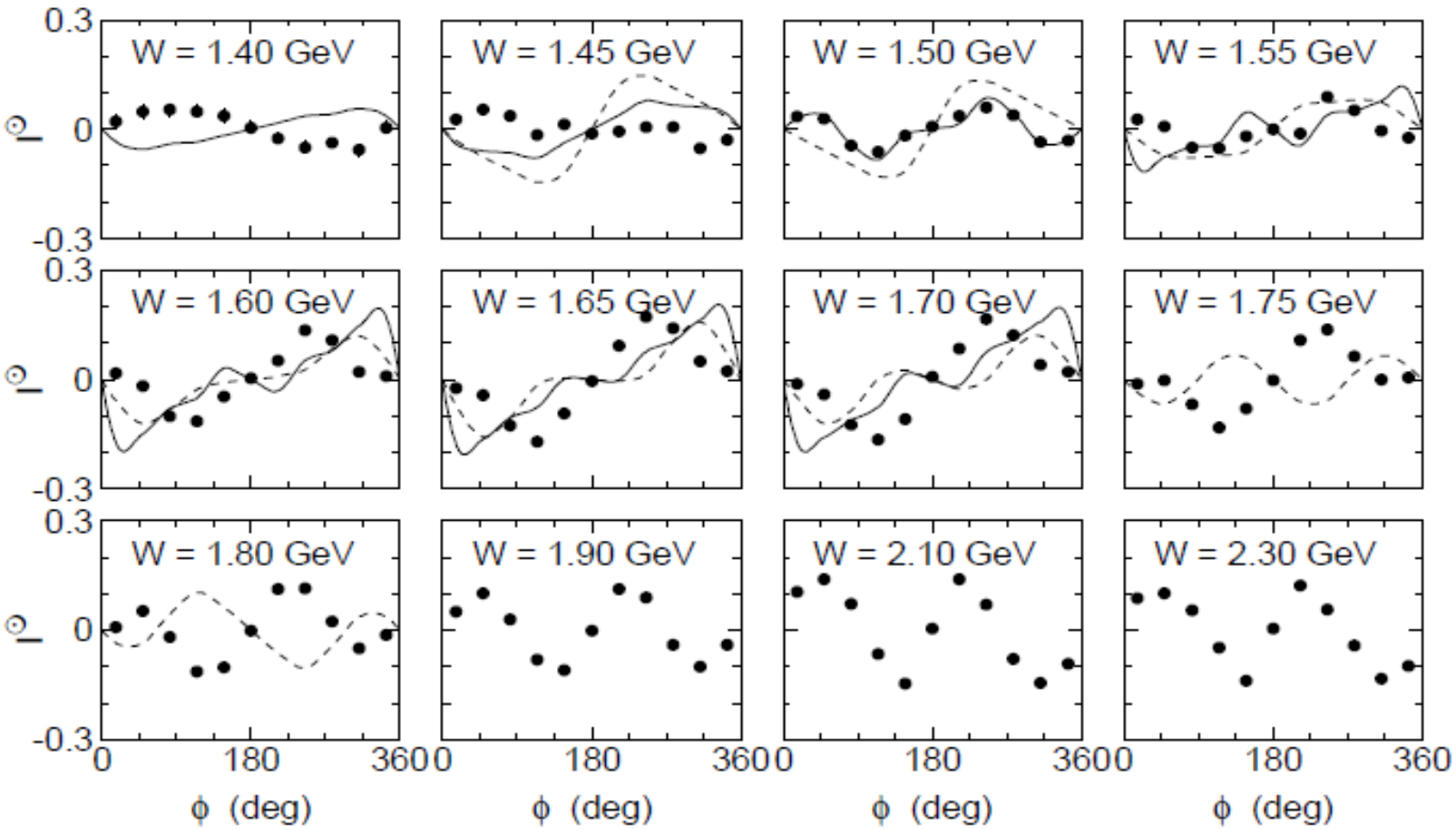
- Previous Measurement in $\gamma p \to p\omega$
- Previous Measurement in $\gamma p \to p\pi^+\pi^-$ from CLAS-g1c

Previous Measurement in γp -> pω

Experiment	Energy Range	Decay Channel	Observables
CLAS-g11 (M. Williams *et al*)	Threshold – 3.8 GeV	pω -> $p\pi^+\pi^-(\pi^0)$	• Differential Cross Section • Spin Density Matrix Element (SDME) : ρ^0_{00} , ρ^0_{1-1} , ρ^0_{10}
CBELSA/TAPS (A. Wilson *et al*)	Threshold-2.5 GeV	pω ->p $\pi^0\gamma$	• Differential Cross Section • SDME : ρ^0_{00} , ρ^0_{1-1} , ρ^0_{10}
MAMI (A2 collaboration) (I. I. Strakovsky *et al*)	Treshold-1.4 GeV	pω ->p $\pi^0\gamma$	• Differential Cross Section

NOTES : The ongoing analysis from g12 offer the first measurement of γp -> pω cross section in higher energy (up to 5.4 GeV) and also SDME from circularly polarized beam (ρ^3)

Previous Measurement in γp -> $p\pi^+\pi^-$ from CLAS-g1c



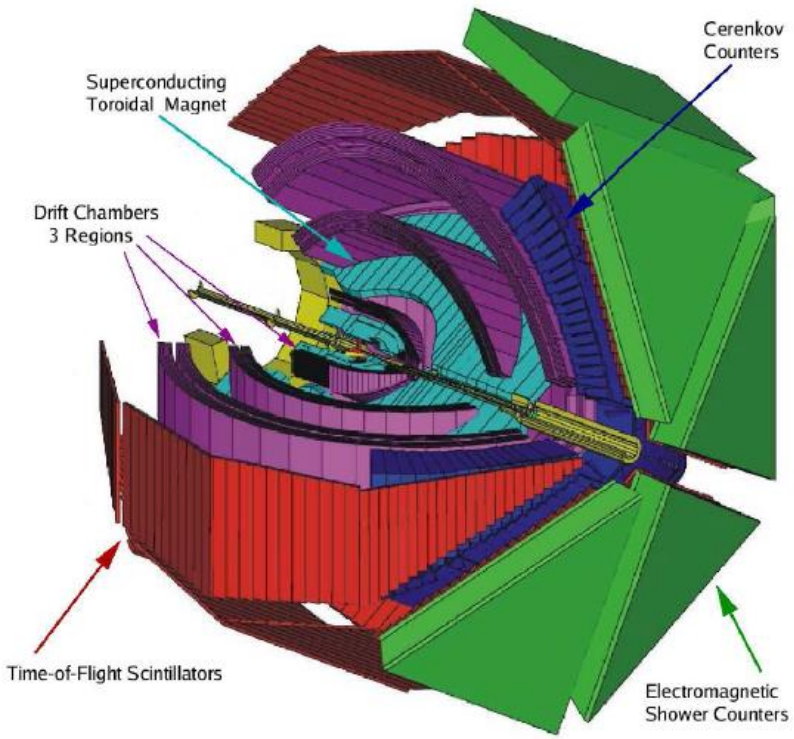
Beam Helicity Asymmetry
(S. Strauch *et al*)

NOTES : The CLAS-g1c measurement (Dot) in comparison with model by Mokeev *et al* (Dashed line) and by Fix & Arenhovel (Solid line)

CLAS-g12 Experiment

CLAS-g12 Experiment

CLAS Detector :



g12 Experiment :

Electron Energy	5.7 GeV
Electron Degree of Polarization	67.2 %
Tagged Photon Energy	1.1 – 5.45 GeV
Target Material	Liquid Hydrogen
Target Polarization	Unpolarized
Photon Polarization	Circular

Data Analysis Technique

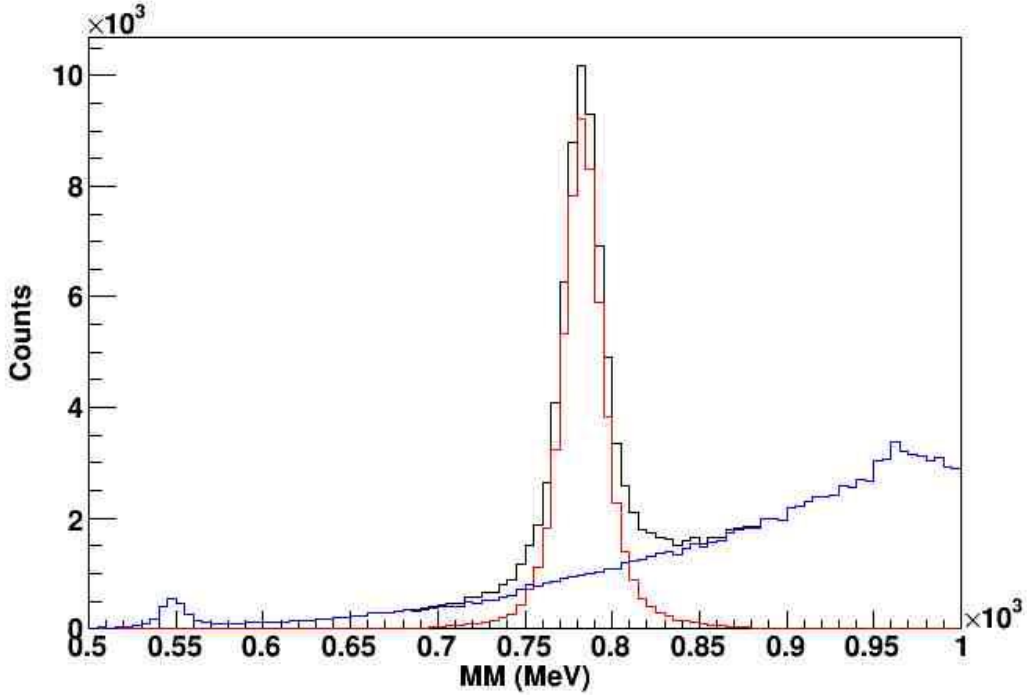
- Data Analysis for Differential Cross Section of $\gamma p \to p\omega$
- Data Analysis for Beam Helicity Asymmetry of $\gamma p \to p\pi^+\pi^-$

Data Analysis for Differential Cross Section of γp -> pω

- Final state particle detected : $p\pi^+\pi^-$
- Kinematically fit to missing π^0
- Use CL cut to select γp -> $p\pi^+\pi^-(\pi^0)$ events
- Apply event based method for signal (omega)-background subtraction
- Generate Monte Carlo events to find detector acceptance
- Calculate Differential Cross section :

$$\frac{d\sigma}{d\cos\theta^{\omega}_{CM}} = \left(\frac{A_{target}}{\rho_{target} \cdot l_{target} \cdot N_A \cdot \mathrm{Flux}}\right)\frac{\sum_i^n Q_i}{\Delta\cos\theta^{\omega}_{CM} \cdot \varepsilon_{MC} \cdot BR}$$

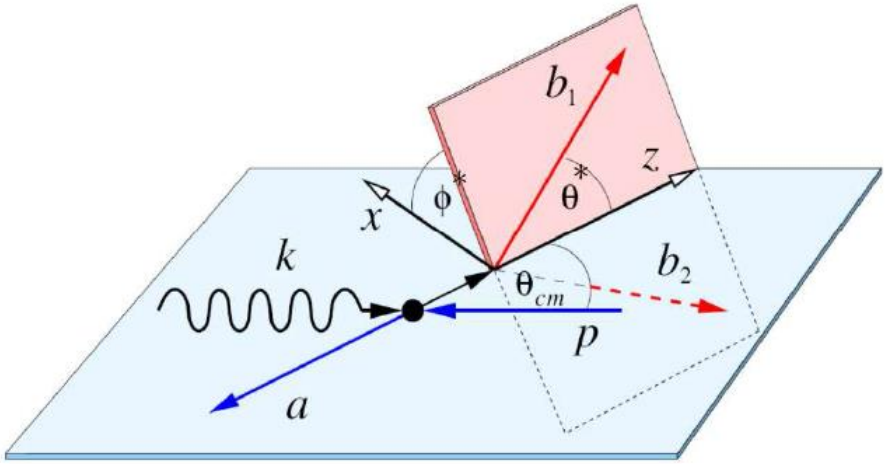
Q-value result for 2100-2200 MeV :



We get the omega signal (Red) by weighted each event with a quality factor (Q) and the background (blue) by weighted each event with 1 -Q

Data Analysis for Beam Helicity Asymmetry of γp-> pπ⁺π⁻

- Final state particle detected : $p\pi^+\pi^-$
- Kinematically fit to No missing particle
- Use CL cut to select $\gamma p \to p\pi^+\pi^-$ events
- Define kinematics for 2 pion Final states :



- The beam Helicity Asymmetry is defined by :

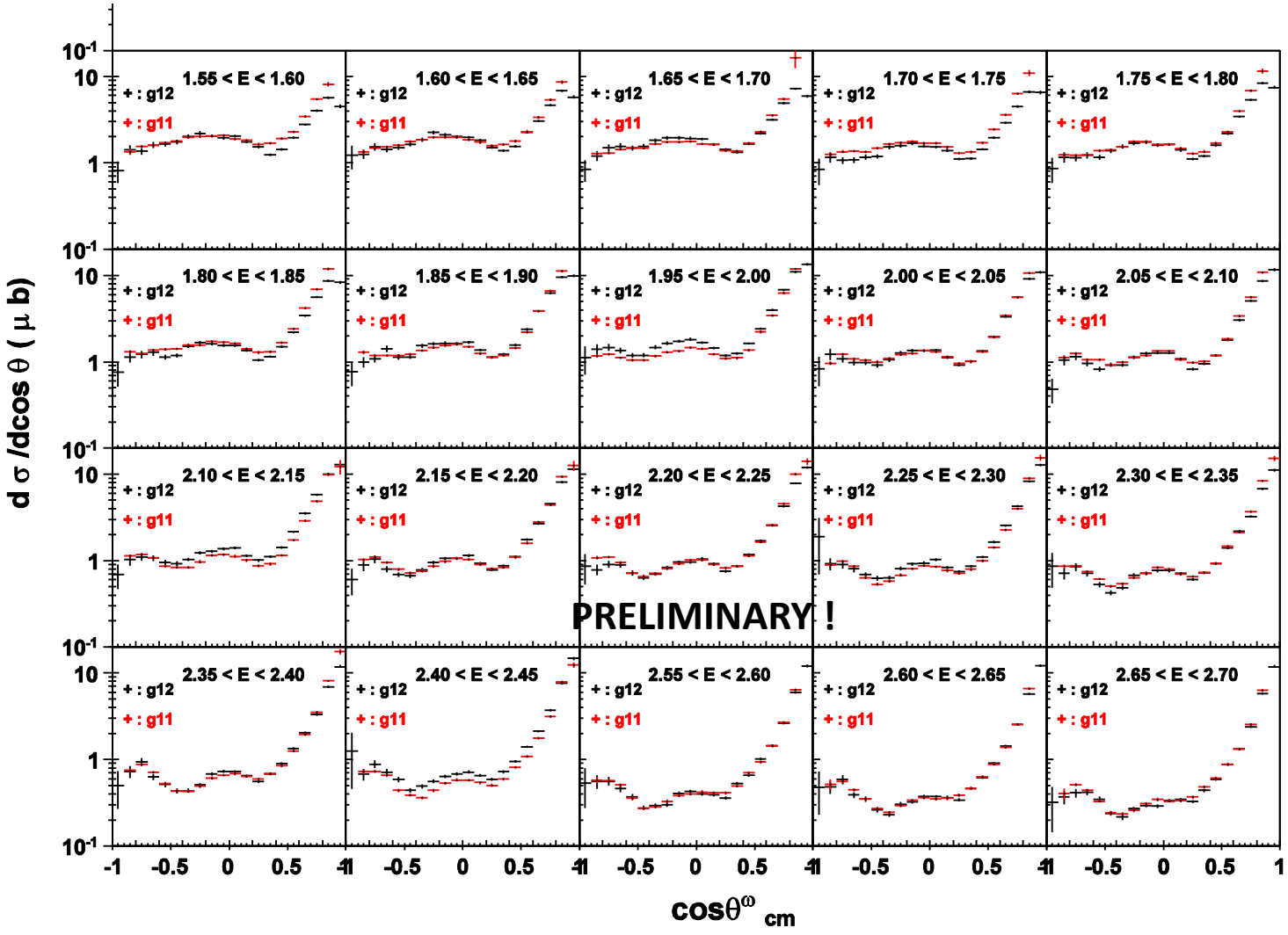
$$\frac{N(\phi^*, \sigma(\rightarrow)) - N(\phi^*, \sigma(\leftarrow))}{N(\phi^*, \sigma(\rightarrow)) + N(\phi^*, \sigma(\leftarrow))} = \bar{\delta}_{\odot} \mathbf{I}^{\odot}$$

- Fit with sine series $\sum_{k=1}^{4} a_k \sin k\varphi$ to extract the Fourier coefficient a_k

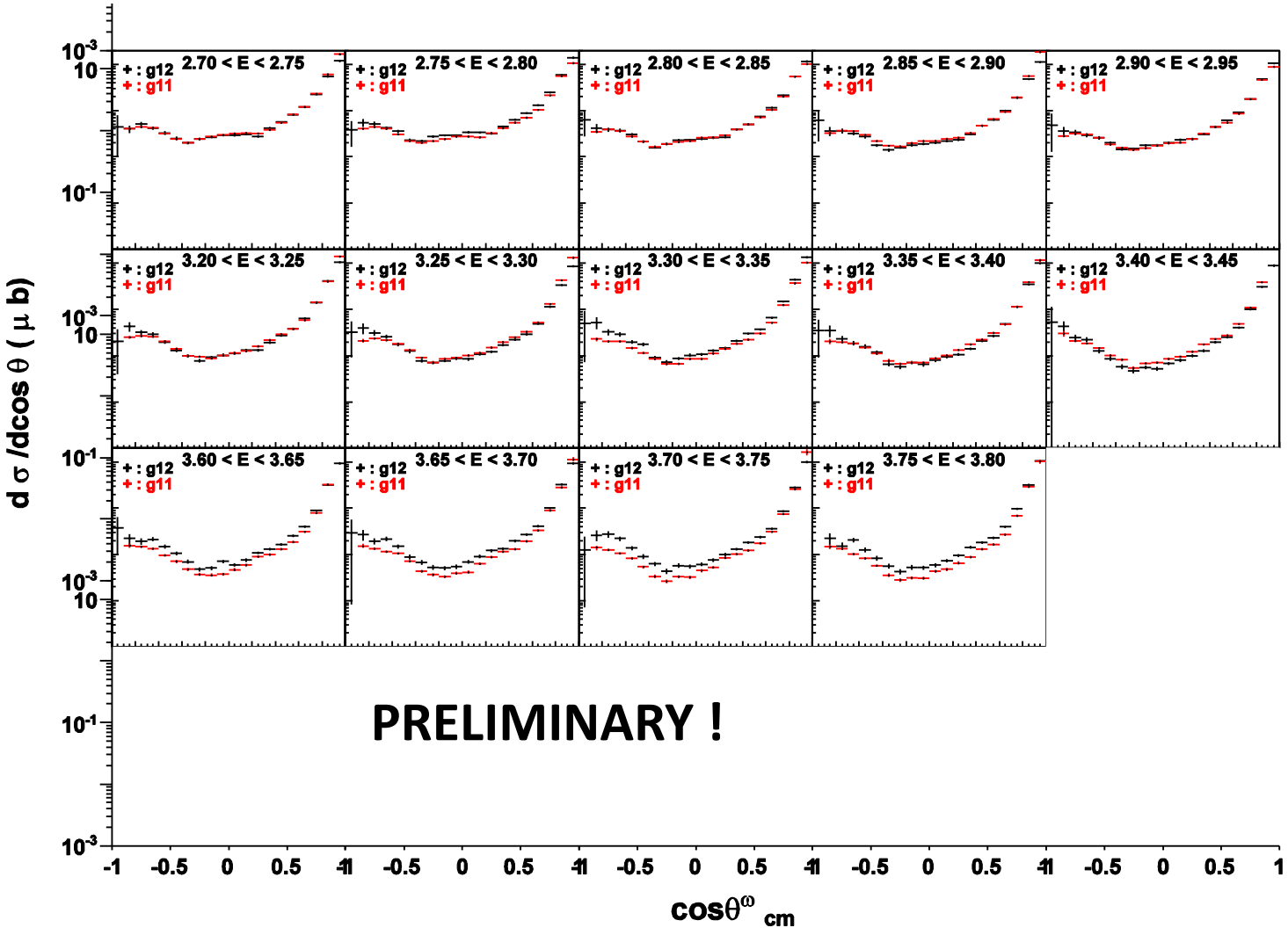
Preliminary Result

- Differential Cross Section of $\gamma p \to p\omega$ from 1.55 – 2.65 GeV
- Differential Cross Section of $\gamma p \to p\omega$ from 2.65 – 3.80 GeV
- Differential Cross Section of $\gamma p \to p\omega$ from 3.80 – 4.80 GeV
- 2-Dimensional plot of Beam Helicity Asymmetry of $\gamma p \to p\pi^+\pi^-$
- Fourier Coefficient for 2D plot of Beam Helicity Asymmetry
- Fourier Coefficient as a function of Invariant Mass
- Comparison of Beam Helicity Asymmetry with CLAS-g1c

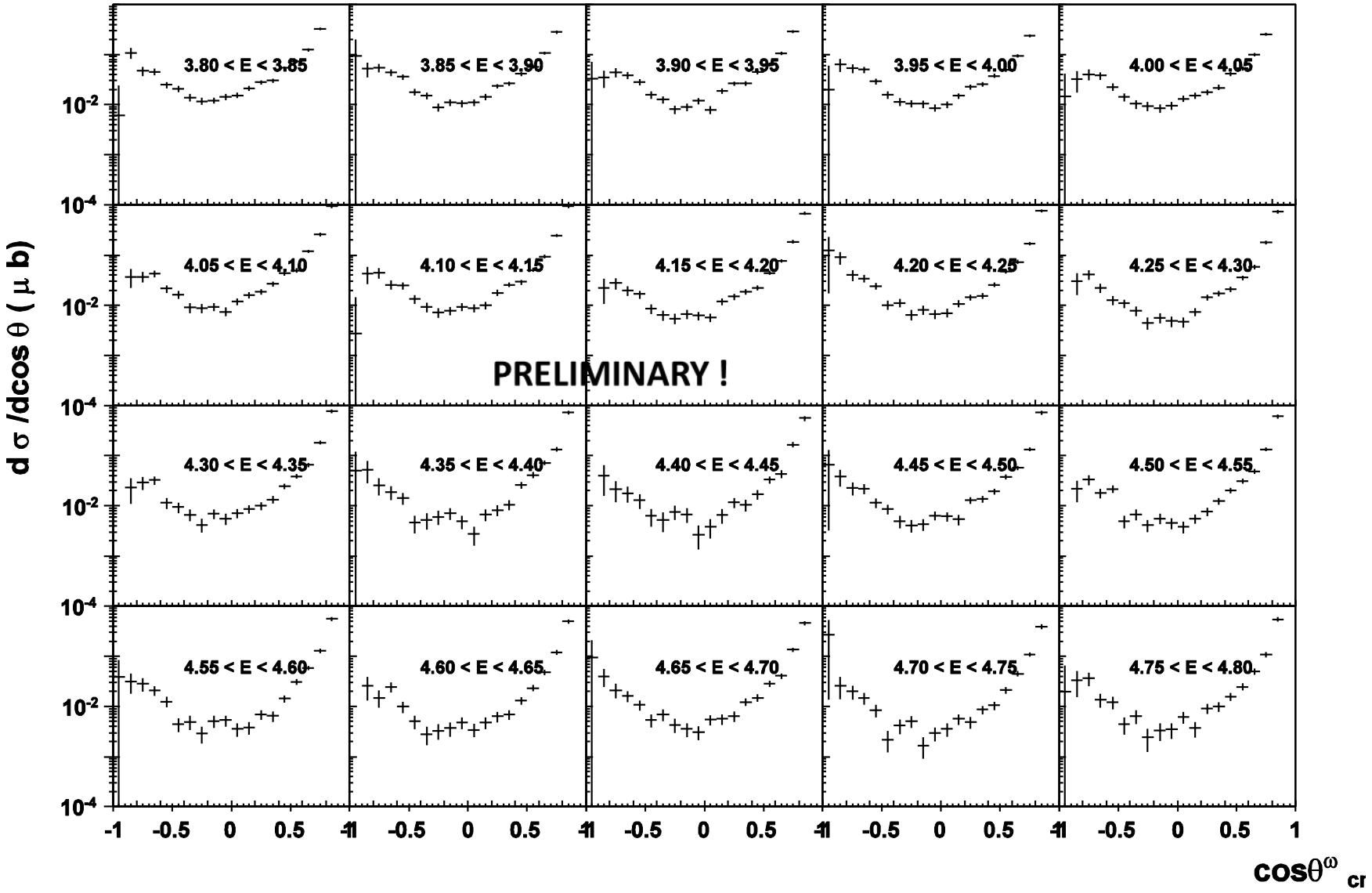
Differential Cross Section of γp -> pω from 1.55 – 2.65 GeV



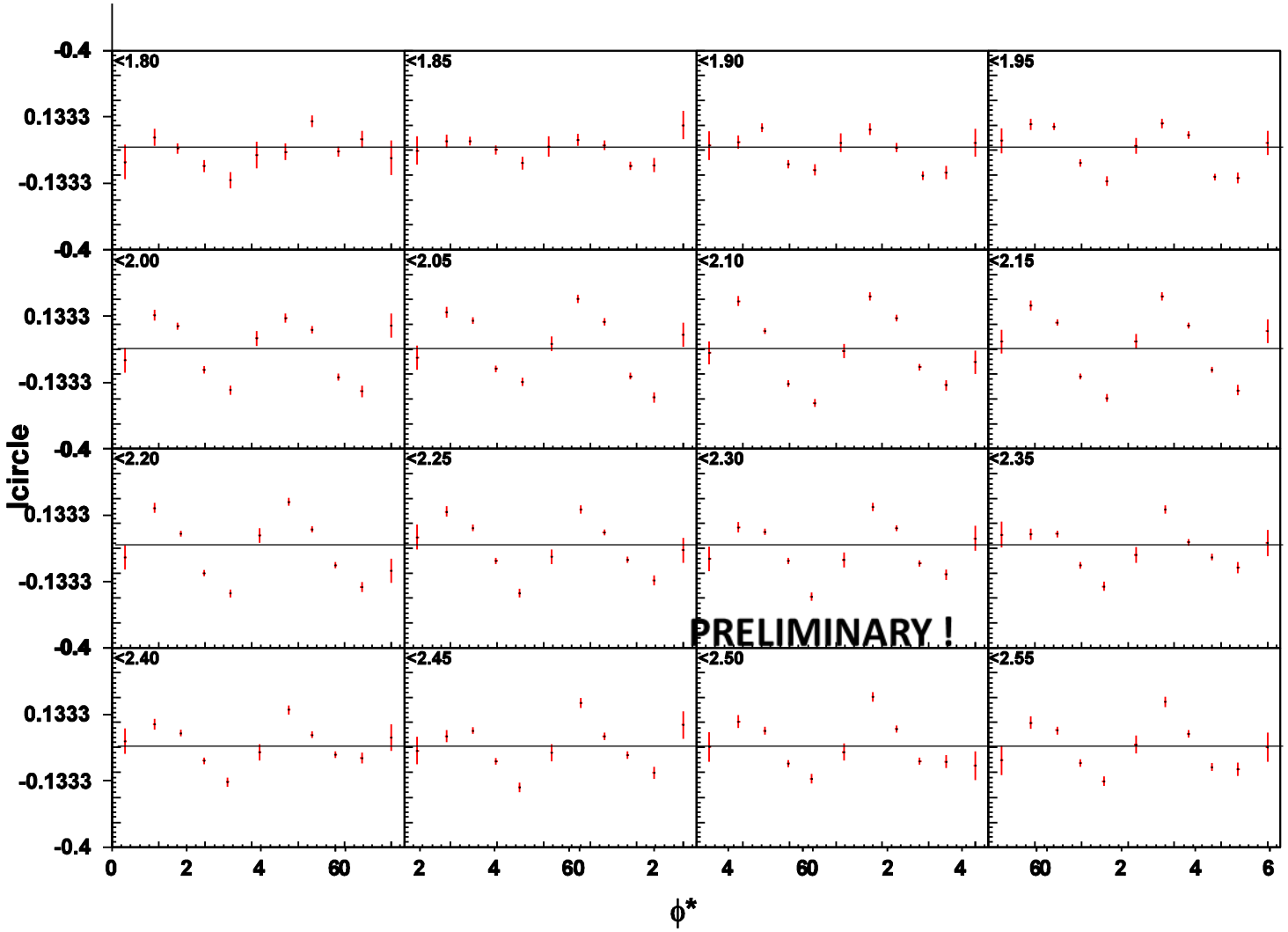
Differential Cross Section of γp -> pω from 2.65 – 3.80 GeV



Differential Cross Section of γp -> pω from 3.80 – 4.80 GeV



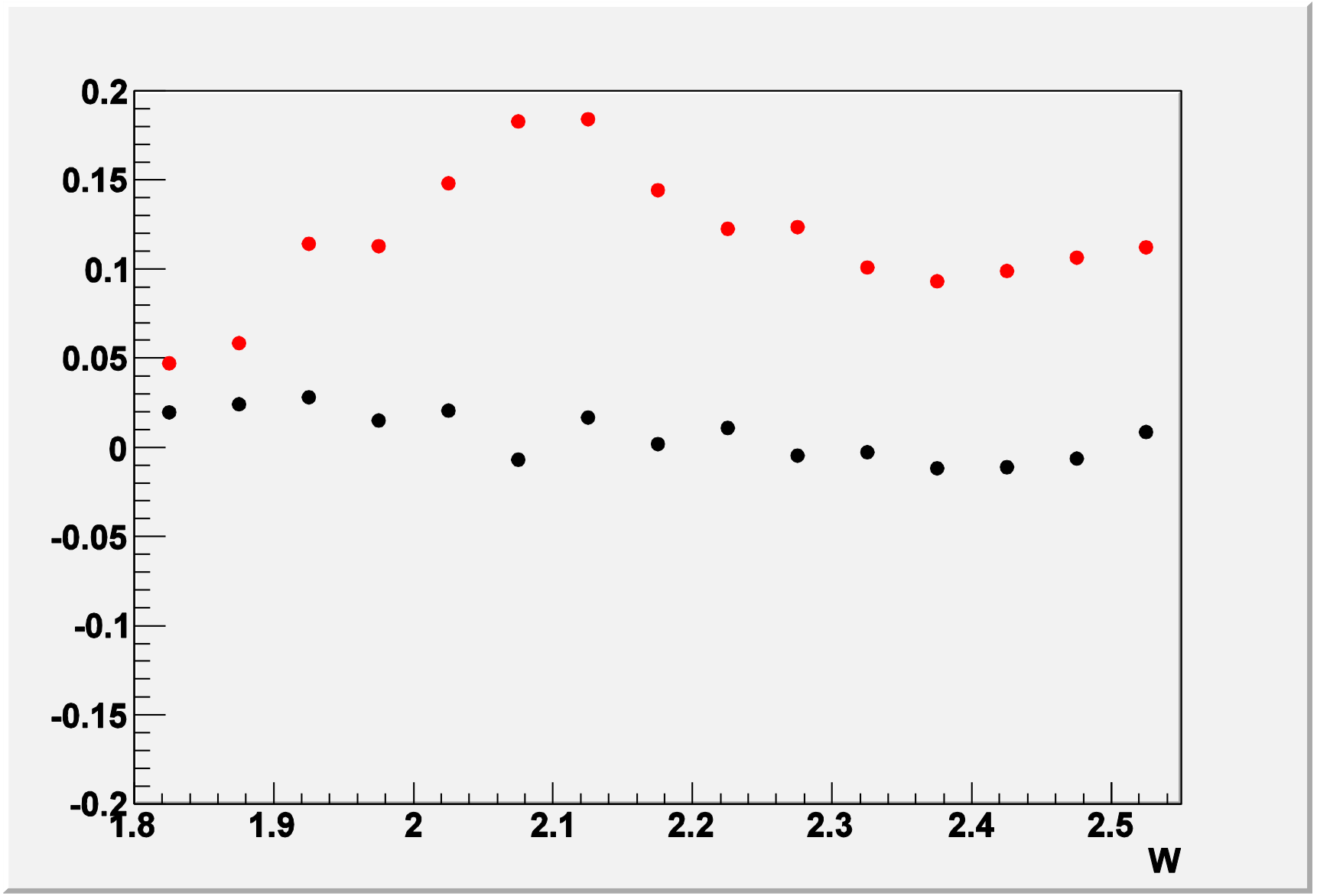
2-Dimensional plot of Beam Helicity Asymmetry of $\gamma p \rightarrow p\pi^+\pi^-$



This preliminary result only use small subset of CLAS-g12 data (7 M events)

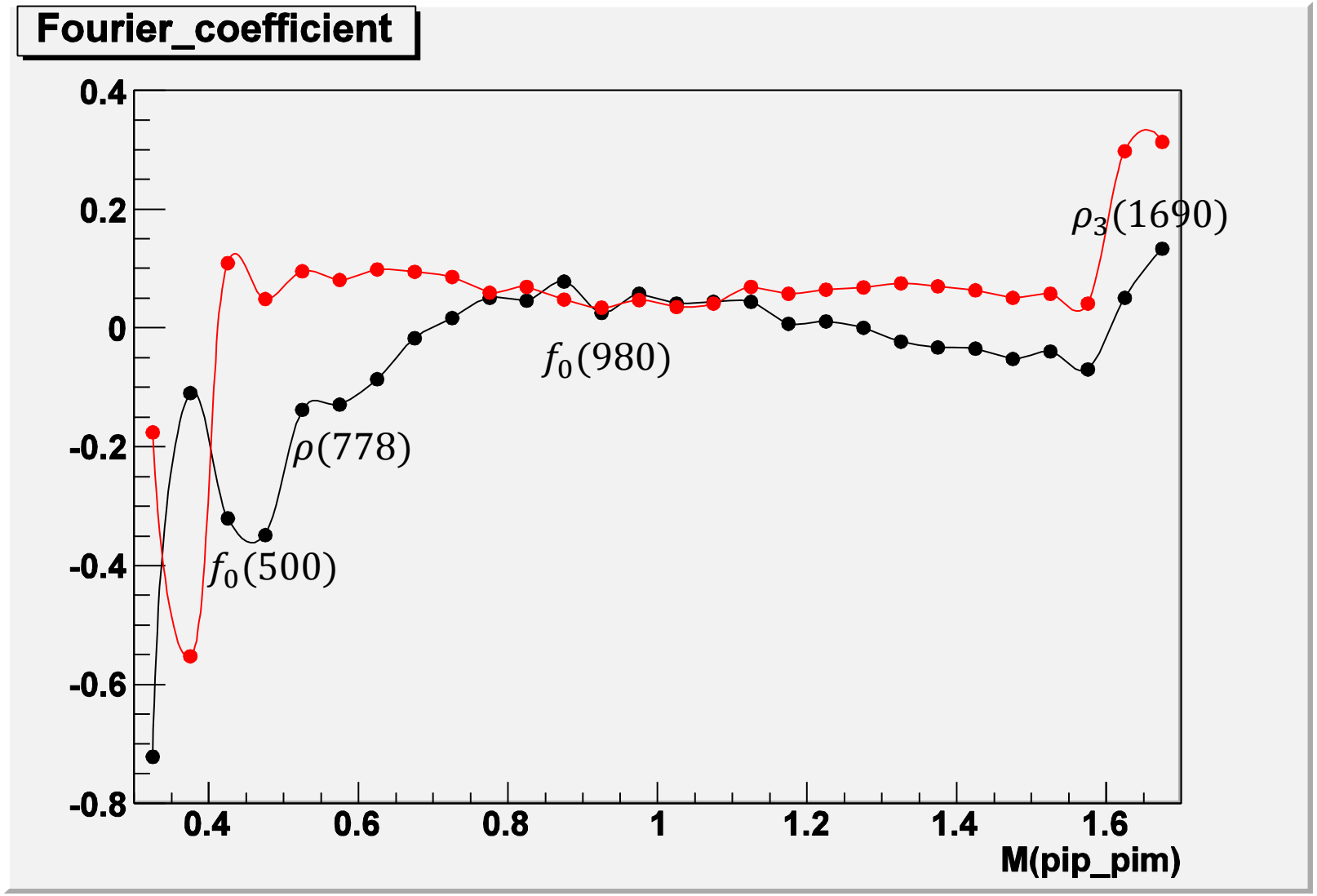
Fourier Coefficient for 2D plot of Beam Helicity Asymmetry

Fourier Coefficient
Black = a1
Red = a2

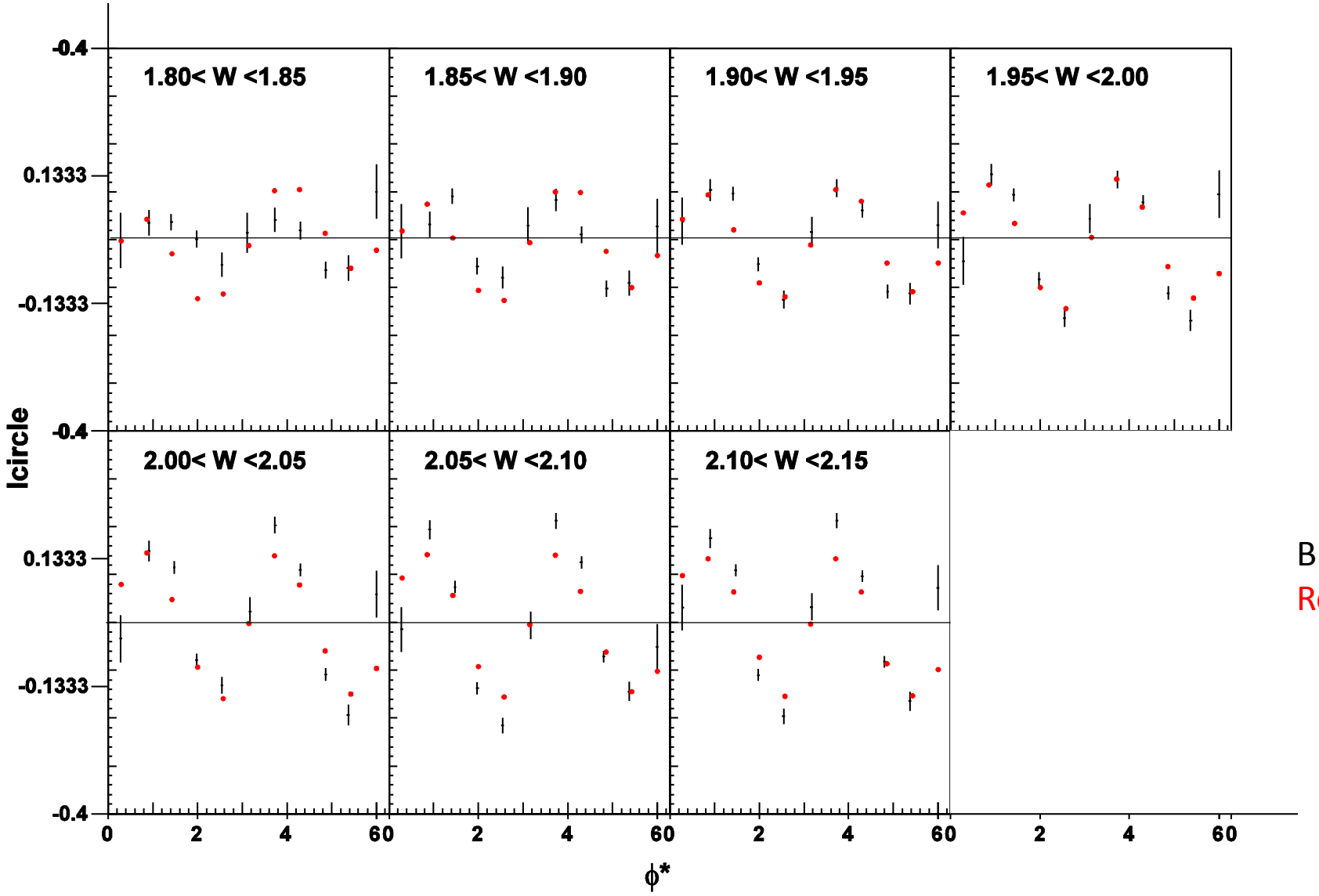


Fourier Coefficient as a function of Invariant Mass

Fourier Coefficient
Black = a1
Red = a2
(1.15<E<1.8 GeV)



Comparison of Beam Helicity Asymmetry with CLAS-g1c



Black = g12

Red = g1c (No Error bar)

Summary & Outlook

- We have been measured $\gamma p \to p\omega$ cross section from $\gamma p \to p\pi^+\pi^-(\pi^0)$ final states. Our results are in fair agreement with previous measurement from CLAS-g11. We also provide the extension of the cross section to higher energy.
- The data (in higher energy) provide access to study production mechanism of ω -> Need input from theorist.
- The highest energy of g12 will overlap with the lowest energy of Glue-X -> Provide future comparison with Glue-X.
- We will also determine the SDME.
- We have been measured Beam-Helicity Asymmetry of $\gamma p \to p\pi^+\pi^-$. Our results are also in fair agreement with measurement from CLAS-g1c. We also provide the higher energy up to W = 2.55 GeV (Beam Helicity Asymmetry for more higher energy is being studied by FIU group).
- We will provide a lot of more statistics.
- The of $\gamma p \to p\pi^+\pi^-$ data recently is being studied by Bonn-Gatcina PWA group using event based analysis.

Thank You