Photo-production of ω using CLAS at Jefferson Laboratory

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Outline

- Background and Motivation
- CLAS Detector at JLAB
- CLAS-g12 and CLAS-FROST Experiment
- Data Analysis
- Preliminary Result and Discussion
- Summary

Background & Motivation

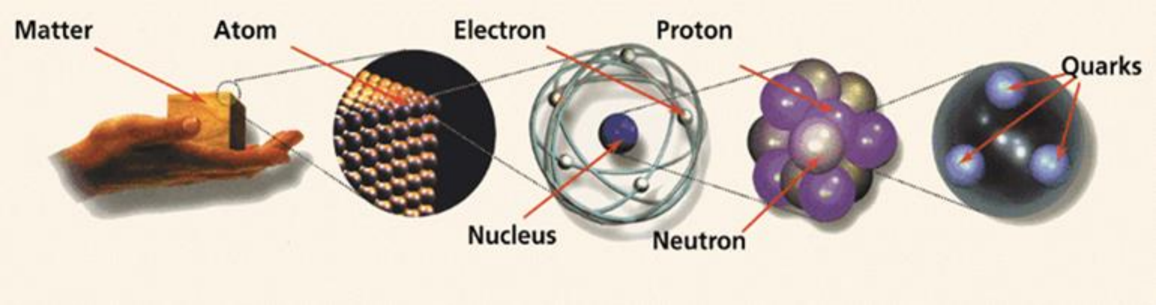
- The Principle Questions
- Baryon Resonances Spectrum
- Partial Wave Analysis (PWA)
- The Need of ω Photo-production
- Previous Study and Measurements

The principle questions

- The families of the fundamental Particles : Quark, Lepton, Gauge Boson.
- QCD governs the **Strong** interaction among quarks.
- Quarks/Antiquarks always form composite object called **Hadrons**.

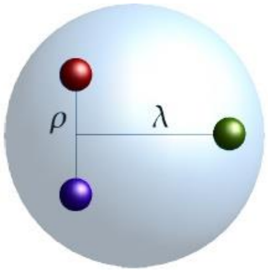
Principle questions :

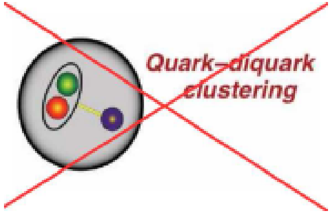
- How does the behaviors of quarks determine the properties of hadrons?
- How does the interactions among quarks give rise to the spectrum of hadrons?
- What are the fundamental degrees of freedom inside hadrons?

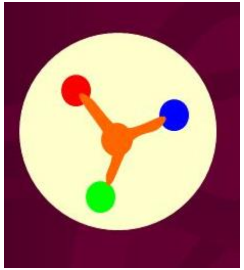


Baryon Resonances Spectrum

Some models :







Constituent Quark Model (CQM)

Hybrid Baryons

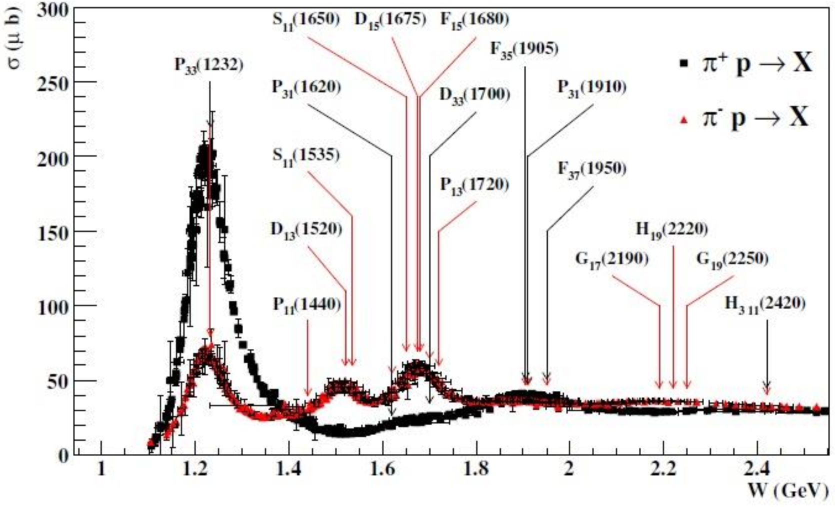
- Missing Baryon resonances from CQM (See Y16.0001 : Recent progress in understanding the baryon resonances spectrum)
- The discovery of N(1900)$3/2^+$ ruled out the static quark-diquark model.
- Mapping out the whole resonances spectrum is very important to test the models.

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	1895	**	$1/2^+$	1880	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	1900	***
$3/2^-$	1960	1875	***	$3/2^+$	1910		
$3/2^-$	2055			$3/2^+$	1950		
$3/2^-$	2095	2120	**	$3/2^+$	2030	2040	*
$3/2^-$	2165						
$3/2^-$	2180						
$5/2^-$	1630	1675	****	$5/2^+$	1770	1680	****
$5/2^-$	2080	2060	**	$5/2^+$		1860	**
$5/2^-$	2095			$5/2^+$	1980	2000	**
$5/2^-$	2180			$5/2^+$	1995	2000	**
$5/2^-$	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	2700	**				

Resonance predicted by Capstick & Robert using CQM

Partial Wave Analysis (PWA)

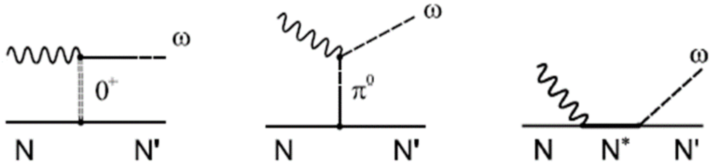
- The overlapping nature among resonances.



Nucleon resonances spectrum (courtesy of Mike Williams)

- PWA requires Differential cross section and Polarization observables as inputs

Set of Particles and Resonances :



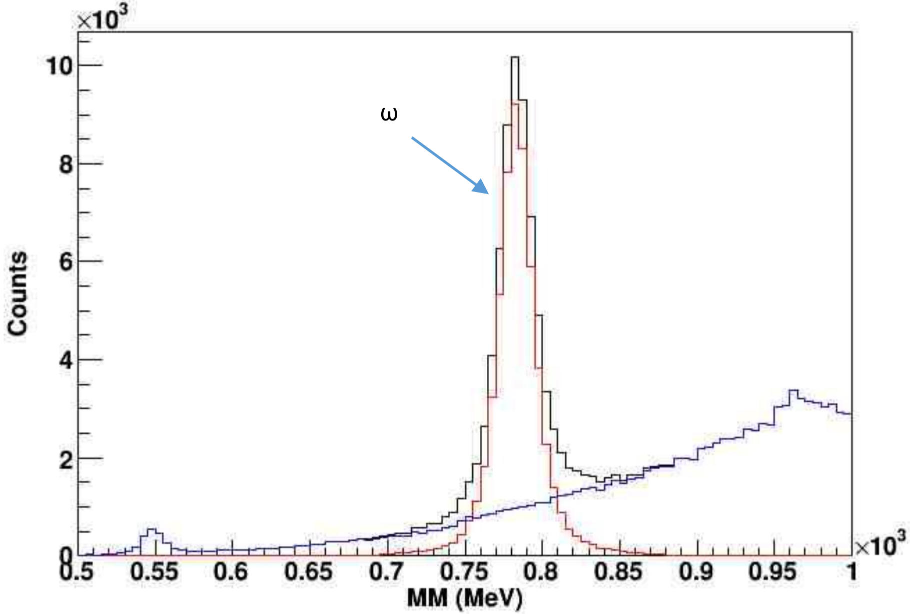
Amplitude Analysis

Fitting to Differential Cross Section or Polarization Observables data

The need of ω Photo-production

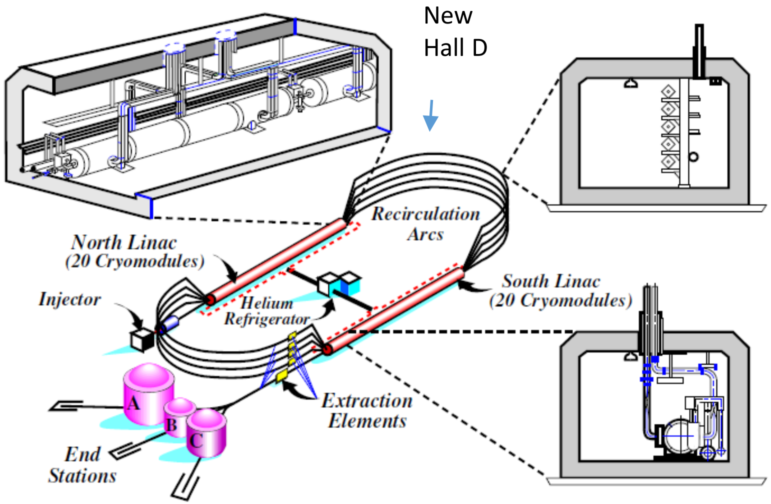
Why γp -> pω ?

- The *N** may couple stronger to photon.
- Vector meson and photon share the same quantum number ($J^{PC} = 1^{--}$).
- Vector meson production channel (pω, p*ρ*, pφ) are under explored.
- The ω is an isospin filter.
- The ω has a lot of statistics.
- The ω threshold lies at the higher lying third resonance region.
- The relatively narrow width of the ω (8.5 MeV) enables a clean detection over background.

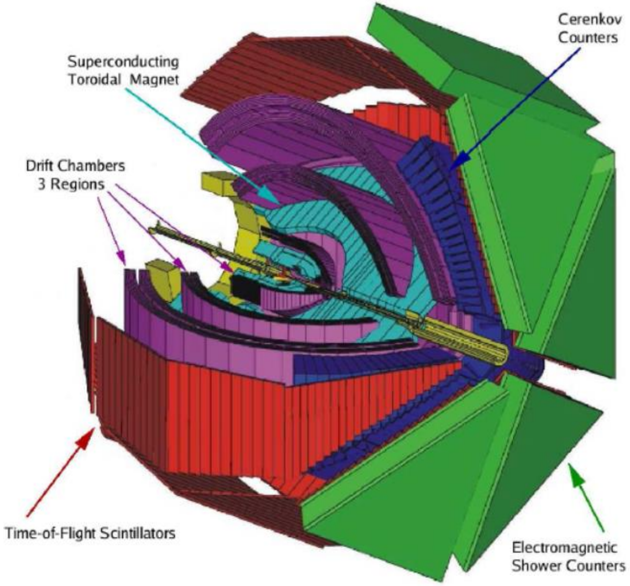


3π invariant mass

CLAS Detector at JLAB



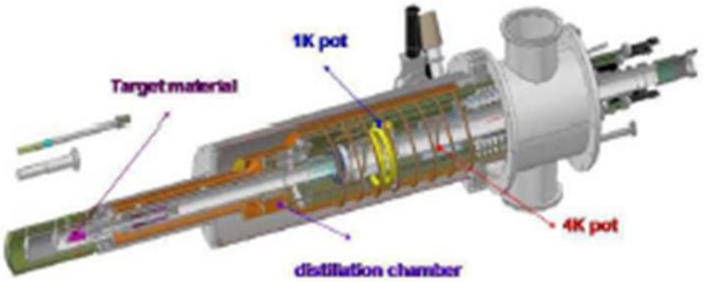
Continuous Electron Beam Accelerator Facility (CEBAF)



CEBAF Large Acceptance Spectrometer (CLAS)

CLAS-g12 and CLAS-FROST (g9a) Experiment

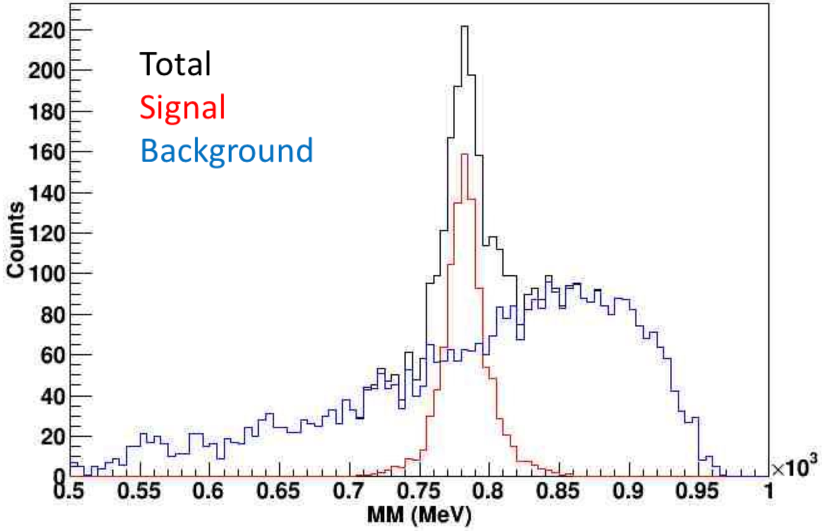
	FROST-g9a :	g12 :
Electron Energy	**Maximum at 2.4 GeV**	**5.7 GeV**
Electron Polarization	Maximum 84.8 %	67.2 %
Tagged Photon Energy	0.3 - 2.4 GeV	1.1 – 5.45 GeV
Target Material	Frozen Spin Butanol	Liquid Hydrogen
Target Polarization	Longitudinal	Unpolarized
Photon Polarization	Circular and Linear	Circular



FROST Target

Data Analysis

- We choose the decay mode $\omega \rightarrow \pi^+\pi^-\pi^0$.
- Hence, we are looking for all $\gamma p \rightarrow p\pi^+\pi^-(\pi^0)$ events.
- PID off γ, p, π^+ , π^- are reconstructed using the information from Start Counter, Drift Chamber, Time of flight and Tagger.
- π^0 is reconstructed using kinematic fitting.
- To isolate $\gamma p \rightarrow p\omega \rightarrow p\pi^+\pi^-(\pi^0)$ we apply event based Q-factor method.



3π invariant mass

Differential Cross Section & Polarization Observable E

The differential cross section

$$\frac{d\sigma}{dcos\theta_{CM}^{\omega}} = \left(\frac{A_{target}}{\rho_{target} \, . \, l_{target} \, . N_A . \, \text{Flux}}\right) \frac{\sum_i^n Q_i}{\Delta cos\theta_{CM}^{\omega} \, . \, \varepsilon_{MC} \, . BR}$$

- The number of ω yields is the sum of Q-value.
- The detector acceptance is modelled using montecarlo simulation

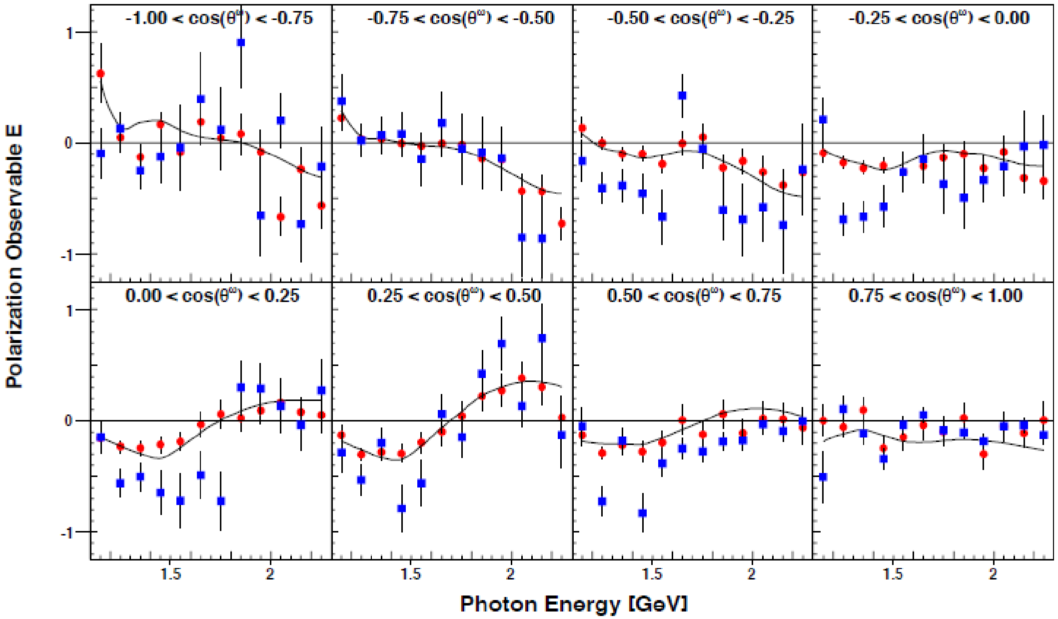
The Polarization observable E

$$E = -\frac{1}{\Lambda_z \delta_o}\left(\frac{N_+ - N_-}{N_+ + N_-}\right)$$

- Polarization observable E is the asymmetry between the ω produced when the polarization of the beam and target are parallel and antiparallel).
- Measured asymmetry is normalized by the product of beam and target polarizations,

Preliminary Results & Discussion

1. Polarization Observable E along with Bonn-Gatchina PWA Fit :



PRELIMINARY !

- The figure shows the polarization observable E from CLAS-FROST at 1.1 – 2.3 GeV (red point) along with the Bonn-Gatchina PWA fit result (**solid line**), in comparison with the previous measurement from CBELSA/TAPS (blue point)
- The dominant contribution from N(1720) $3/2^+$ is found.
- The background is dominated by the t-channel contributions (pomeron-exchange and a smaller π-exchange).
- The full description of the data need the contribution from:
  - N(1680) $5/2^+$
  - N(2000) $5/2^+$
  - N(1895) $1/2^-$
  - N(2100) $3/2^-$

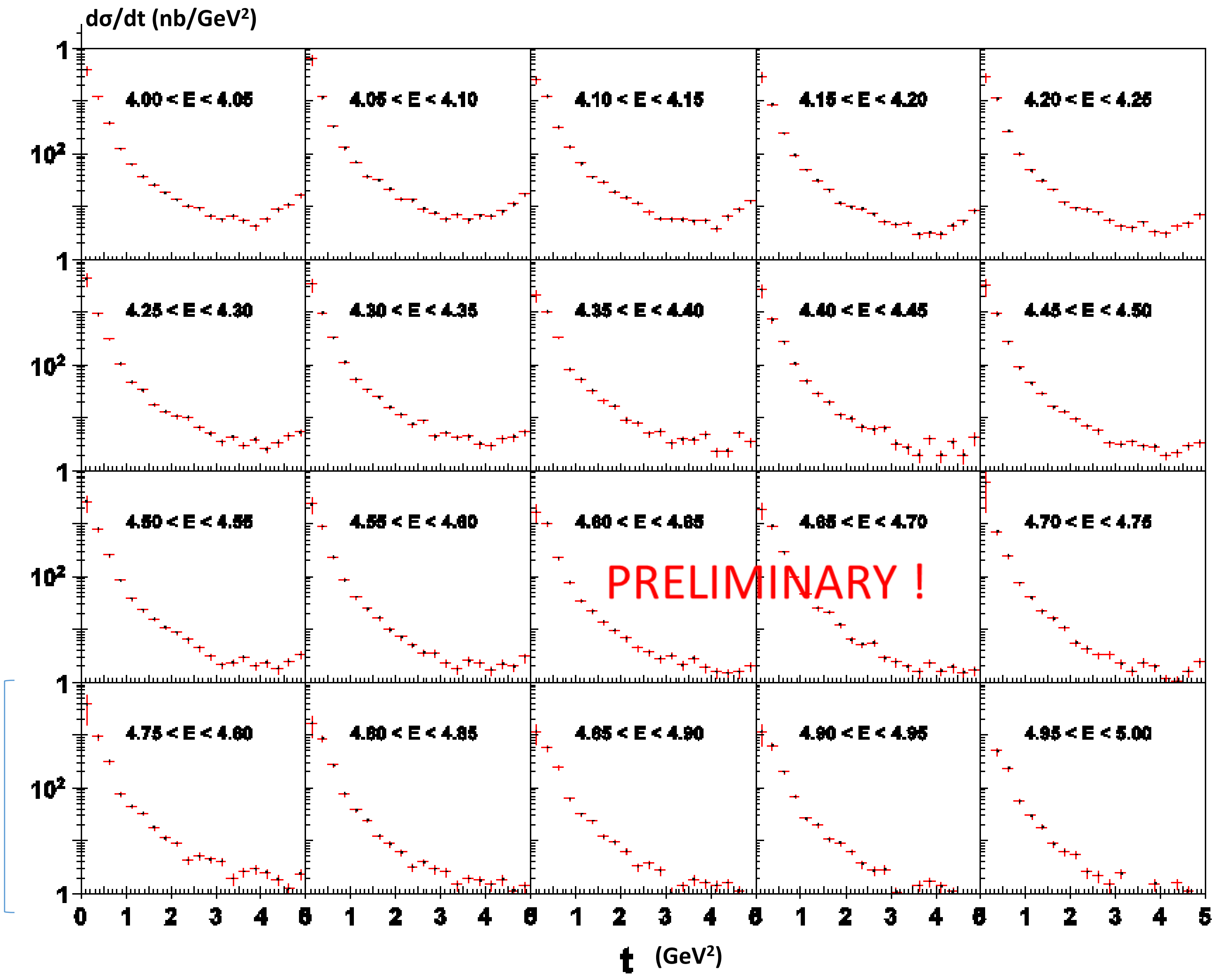
2. differential cross section of γp ->pω from 1.5 – 5.4 GeV (from CLAS-g12)

Here we only show the result from 4.0 – 5.0 GeV.

The cross section behavior due to the t channel pomeron exchange is expected to falling off exponentially at low t.

We see that the pomeron exchange contribution is more dominant when the energy is increasing.

But there are still significant contributions from non Pomeron exchange at the region 4.0 – 4.5 GeV).



Summary

- $\gamma p \rightarrow p\omega$ is a great channel for Baryon resonances study.
- The high statistic of the differential cross section and the polarization observable E have been measured at JLAB using CLAS-g12 and CLAS-FROST dataset.
- The Bonn-Gatchina PWA fit found some resonance contributions as well as the t-channel contributions from pomeron-exchange and a smaller π-exchange.

THANK YOU