Photoproduction of ω Mesons off the Free Proton at the CBELSA/TAPS Experiment

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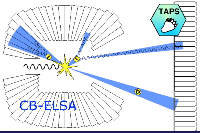
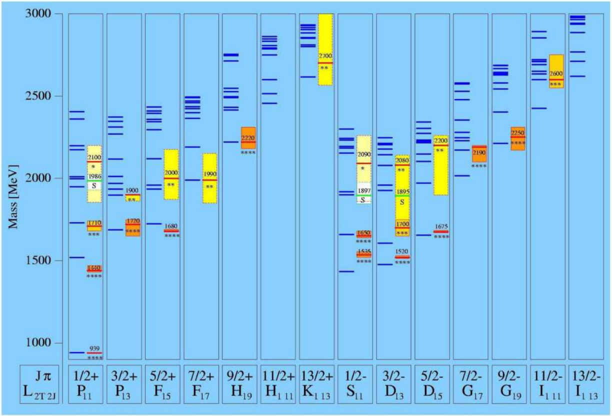


Where are the "Missing" Baryon Resonances?

Constituent Quark Model Prediction for
Isospin = 1/2, Strangeness = 0 Baryons

Constituent Quarks+ Confinement Potential+residual interaction



U. Loring, B. C. Metsch and H. R. Petry, Eur. Phys. J. A **10** (2001) 395.

- Seem to match low mass states.
- Where are the high mass states?

Models

All models predict high mass states.

Experimentally

haven't looked in the right places

Motivation for Studying ω Photoproduction

Find Missing Baryon Resonances

S. Capstick and W. Roberts, "Quasi two-body decays of nonstrange baryons," Phys.Rev., vol. D49, pp. 4570 - 4586, 1994.

Predicts 32 Baryon Resonances with significant couplings to $p\omega$ in the sensitivity range for this experiment (below 2.3 GeV/c^2 in mass)

PDG $\rightarrow$ 14 N^* Baryon Resonances with 3 or 4 star assignments below 2.3 GeV/c^2 in mass

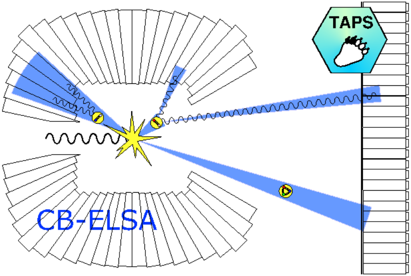
Why CBELSA/TAPS?

- No previous measurement measures the full kinematic range.
- Needed for separating dominant t-channel from resonance contributions

CBELSA/TAPS Experiment at ELSA (Bonn)

$\gamma p \rightarrow p\omega$ Measurements (2002-2003 Setup)

- Differential Cross Sections ($E_\gamma < 2.5$ GeV)
- Unpolarized Spin Density Matrix Elements ($E_\gamma < 2.5$ GeV)

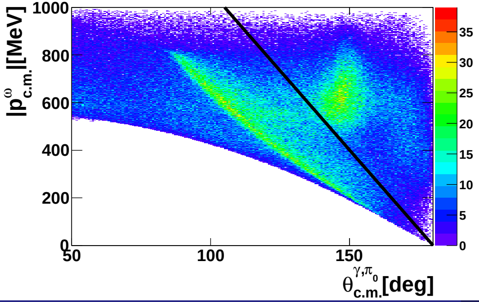


Beam: Unpolarized or linearly polarized tagged photons
Target: Liquid hydrogen

- Excellent photon energy and position reconstruction
- the presence of charged particles by scintillators

Unpolarized Measurement Reaction Selection

Decay channel selected for: $\gamma p \rightarrow p\omega \rightarrow p\pi^0\gamma \rightarrow p\gamma\gamma\gamma$
(Branching Ratios : $\omega \rightarrow \pi^0\gamma$ = 8.9% , $\pi^0 \rightarrow \gamma\gamma$ = 98%)
Data recorded: October - November 2002
Selected events with:
3 uncharged particles & charged particles < 2

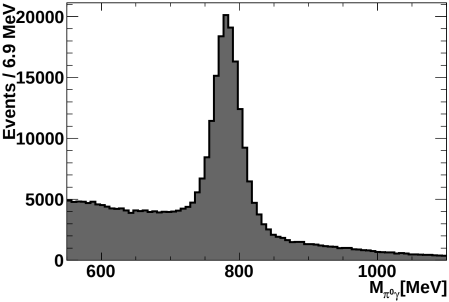


Kinematic Cuts

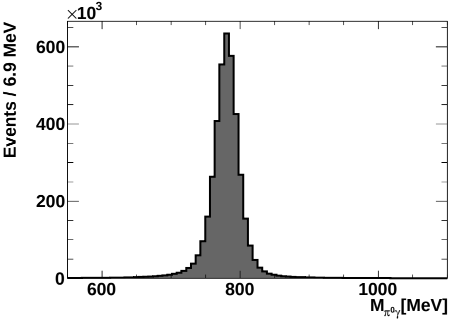
- **Timing Cut** - causality
- **Coplanarity Cut** - momentum conservation
- **Trigger Cut** - potential simulation issue
- **Kinematic Fitting Cut** - 0.5% CL cut on a $\gamma p \rightarrow p_{missing}\pi^0\gamma$ Fit
- **Opening Angle Cut**

FINALLY!... Invariant Mass Distributions

Data Events



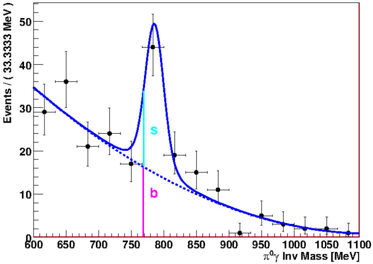
Reconstructed Simulated Events



Q-factor Background Subtraction

For each event left in the analysis.

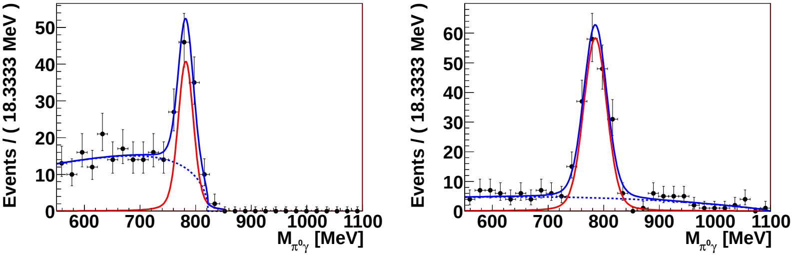
- Find the nearest neighbors in the final state's kinematic phase space.
- Fit the invariant mass spectrum of a particle in the desired final state. (background & signal functions)
- Define a Q-factor from the fit. (Probability the event is the desired final state)
- Weight each event with the Q-factor.

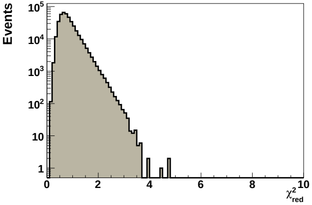


$$Q = \frac{s}{s+b}$$

M. Williams, M. Bellis, and C. Meyer, *JINST*, vol. 4, p. P10003, 2009.

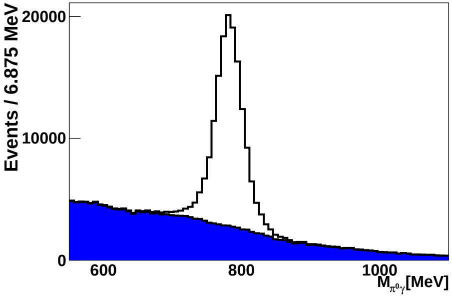
$\gamma p \to p\omega$ Experimental Data Fits





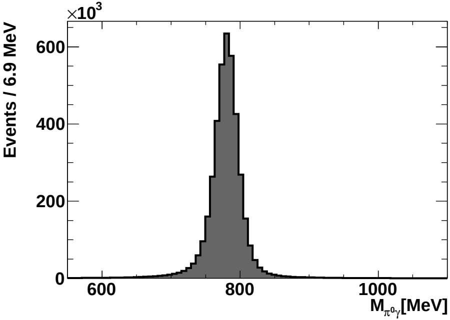
- 300 Nearest Neighbors
- Background function: Argus Function * first order Cheybchev polynomial
- Signal function: Voigt Function

Data Events



128,135 $p\omega$'s

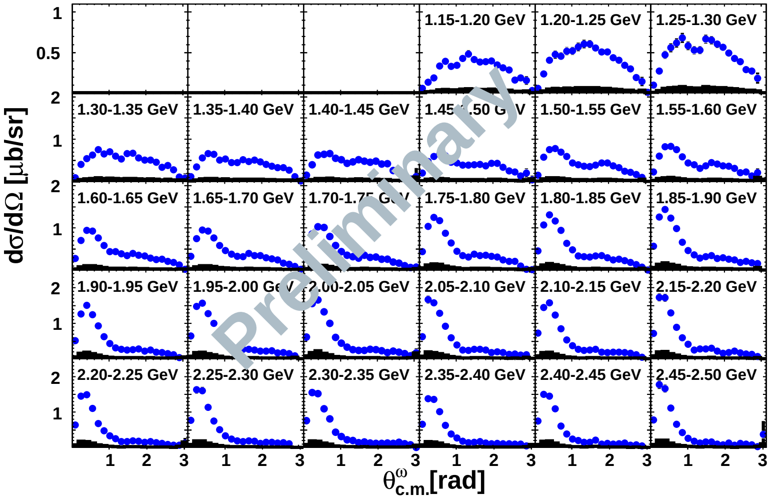
Reconstructed Simulated Events



4,036,361 $p\omega$'s

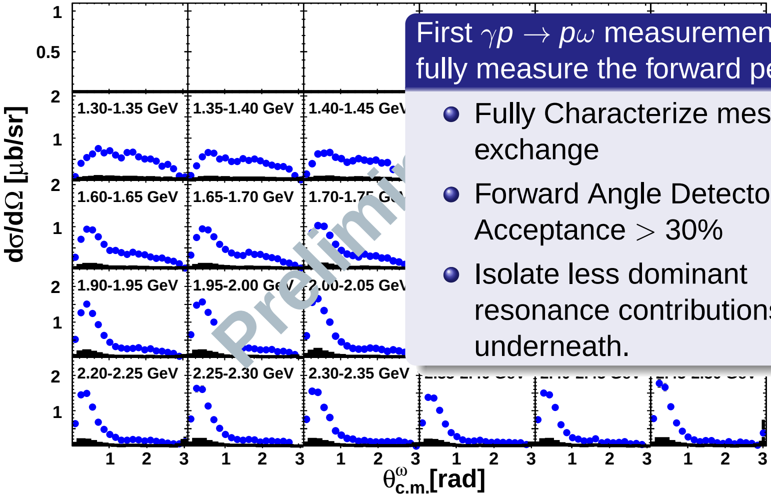
Total generated $p\omega$ events = 27,000,000

$\gamma p \to p\omega$ Differential Cross Sections



Labeled with incoming photon energy.

$\gamma p \rightarrow p\omega$ Differential Cross Sections



First $\gamma p \rightarrow p\omega$ measurement to fully measure the forward peak.

- Fully Characterize meson exchange
- Forward Angle Detector Acceptance $> 30\%$
- Isolate less dominant resonance contributions underneath.

Unpolarized Spin Density Matrix Elements

$$\rho_{ij} \sim M_i M_j^*$$

i and j is the spin polarization (ω rest frame) of the ω (-1,0,1)

θ_d and ϕ_d angles of the γ in $\omega \to \pi^0\gamma$ in ω rest frame.

Extraction Method

- Angular Distributions : 6 $\cos\theta_d$ bins and 8 ϕ_d bins
- Angular Distribution Fit Functions taken from:

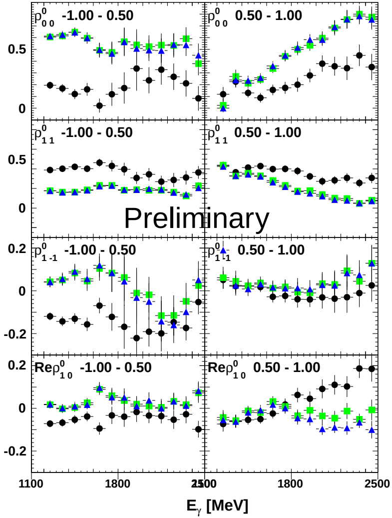
Q. Zhao, J. Al-Khalili, and P. Cole, Phys.Rev., vol. C71, p. 054004, 2005.

$$W^0(\theta_d, \phi_d, \rho^0) = \frac{3}{8\pi}(\sin^2\theta_d \rho^0_{00} + \left(1+\cos^2\theta_d\right)\rho^0_{11} + \sin^2\theta_d \cos 2\phi_d \rho^0_{1-1} + \sqrt{2}\sin 2\theta_d \cos\phi_d Re\rho^0_{10})$$

Reference Systems

- Helicity system - z-axis $||$ $\vec{q}_\omega^{\,c.m.}$
- Adair system - z-axis $||$ $\vec{k}_{c.m.}$
- Gottfreid-Jackson system - z-axis $||$ $\vec{k}_{\omega\ frame}$.

Unpolarized $\gamma p \rightarrow p\omega$ Spin Density Matrix Elements



Labeled with SDME and cos $\theta^{\omega}_{c.m.}$

- Same Data used in differential cross sections

First $\gamma p \rightarrow p\omega$ Unpolarized SDMEs measured over the full kinematic range

• Helicity System ■ Gottfried-Jackson system ▲ Adair system

Future

Improvements to be made

- Effects of binning in low statistics data are significant
- Develop an un-binned, unbiased fitting method to extract Spin-density Matrix Elements.
- Develop an interpretation of $\gamma p \to p\pi^0\omega$ data.
  - Include ω decay.
  - Take into account all dimensionality.

Future Plans

- Publish data soon (under Collaboration Review)
- Measure Polarized Spin-density Matrix Elements for ω photoproduction.