Study of Excited Baryons with the Crystal-Barrel Detector at ELSA

V. Credé

FSU, Tallahassee, Florida

NSF Review
Florida State University, 11/15/2007

Outline

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General Physical Motivation

Study of baryon properties and search for new resonances

	****	***	**	*
N Spectrum	11	3	6	2
Δ Spectrum	7	3	6	6

$\Rightarrow$ according to PDG
(J. Phys. **G33** (2006) 1)

$\Rightarrow$ little known
(many open questions left)

General Physical Motivation

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Quark models predict many more baryons than have been observed

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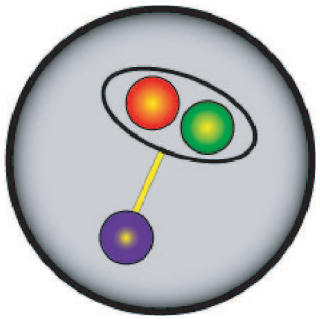
Possible solutions:

a) Quark-diquark structure



one of the internal degrees of freedom is frozen

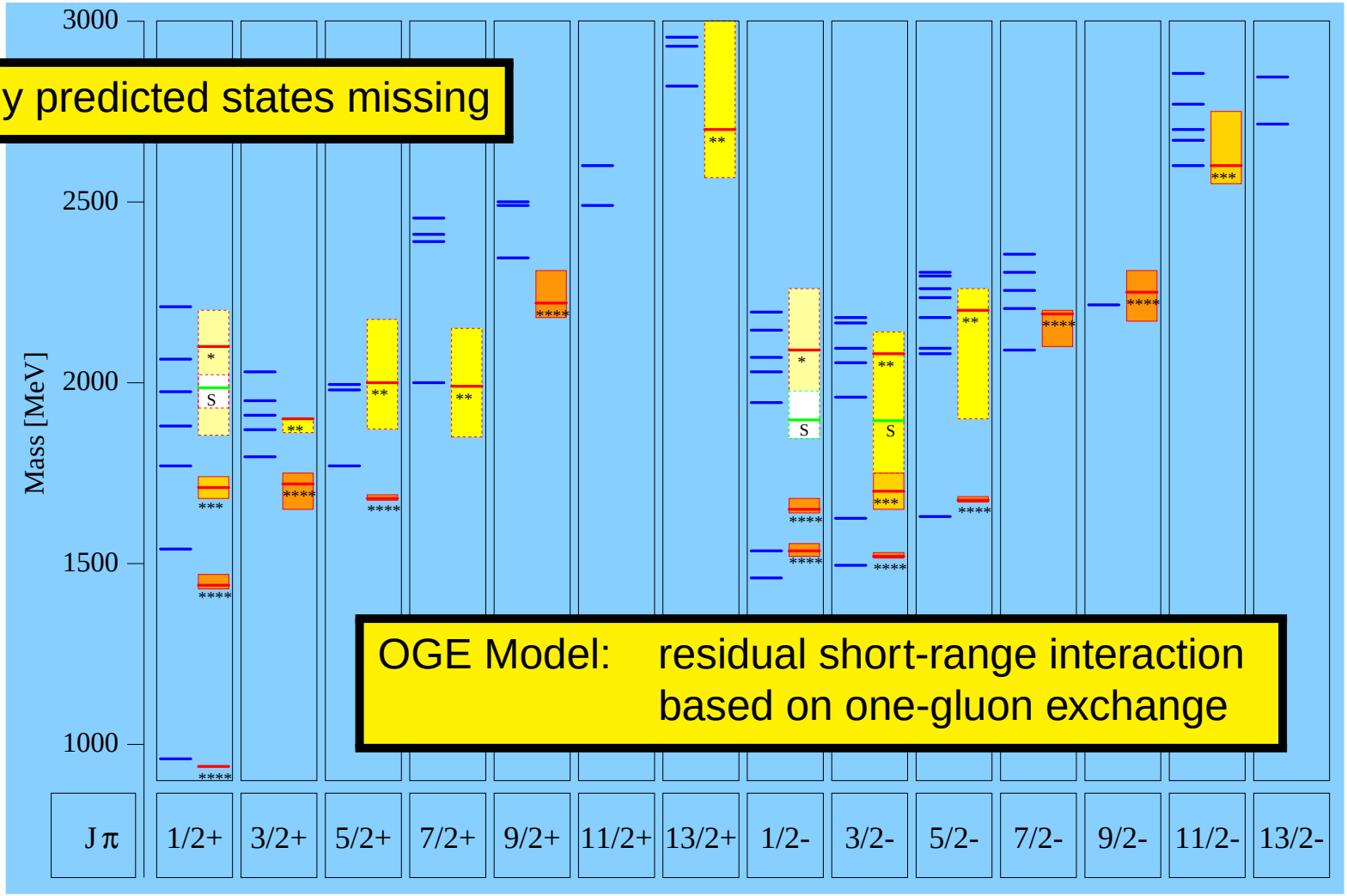
b) They have not been observed, yet

Nearly all existing data result from πN scattering experiments

$\Rightarrow$ If the missing resonances did not couple to Nπ, they would not have been discovered!!

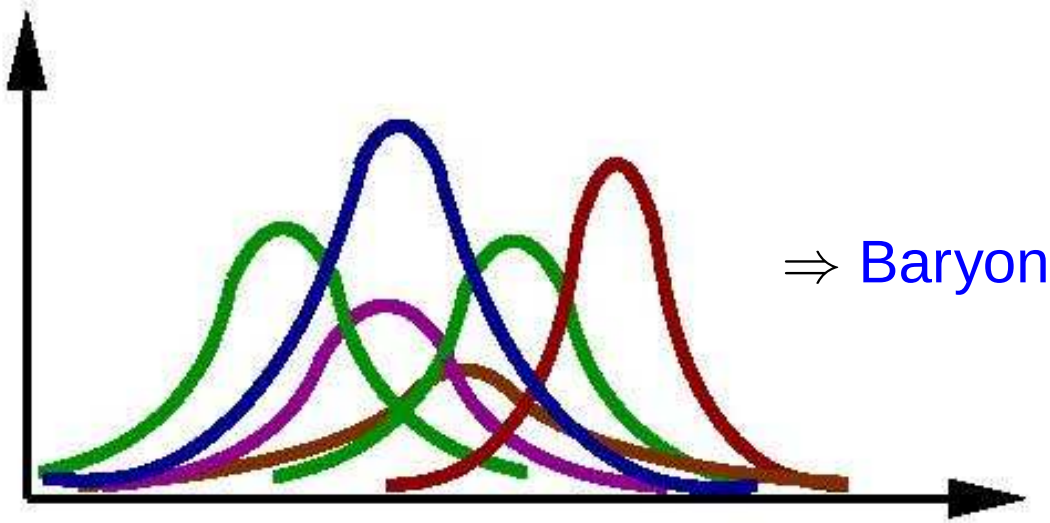
Nucleon Resonances

S. Capstick and N. Isgur, Phys. Rev. **D34** (1986) 2809



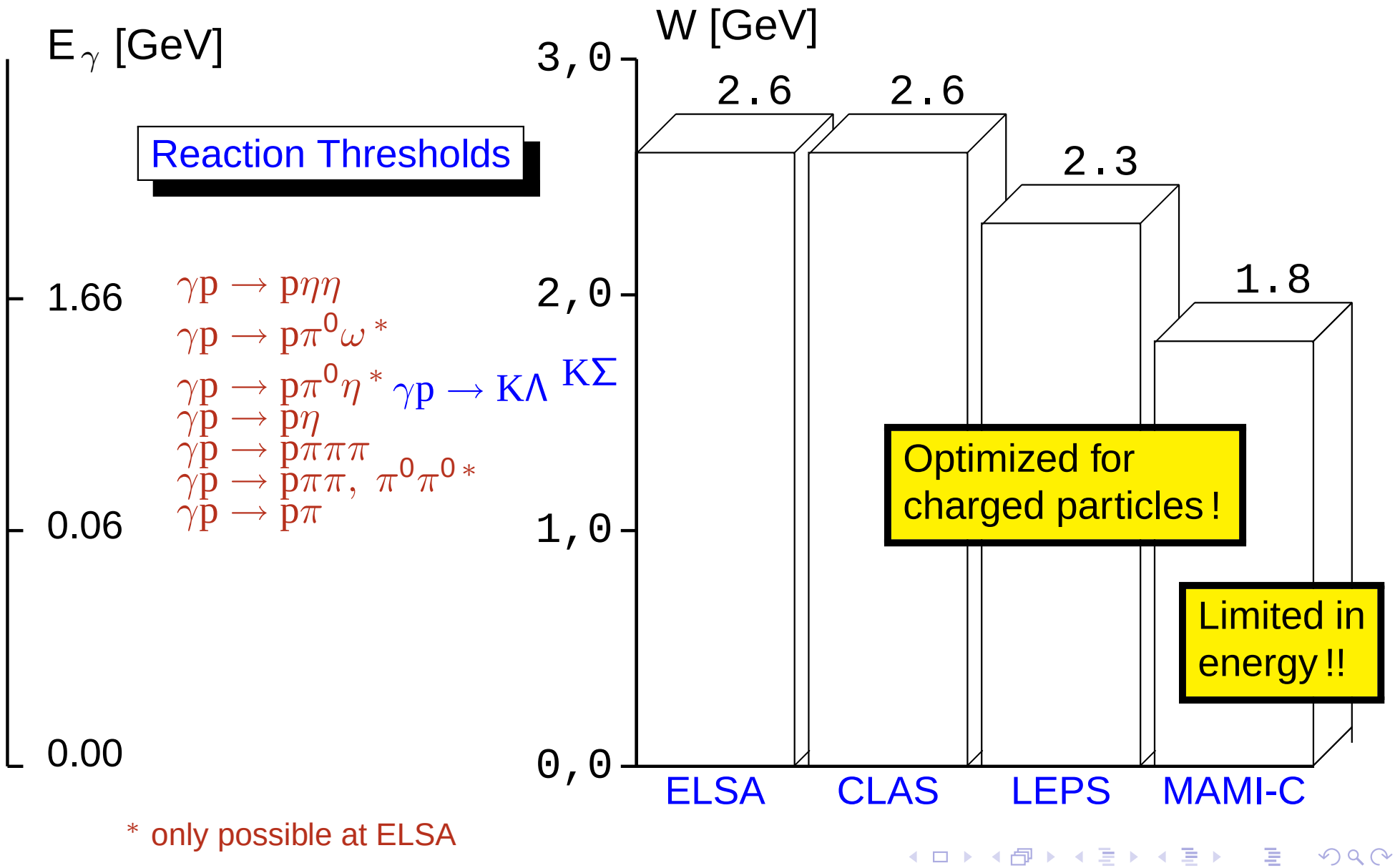
What is required experimentally to study baryons?

Unfortunately, N^* spectral lines look like



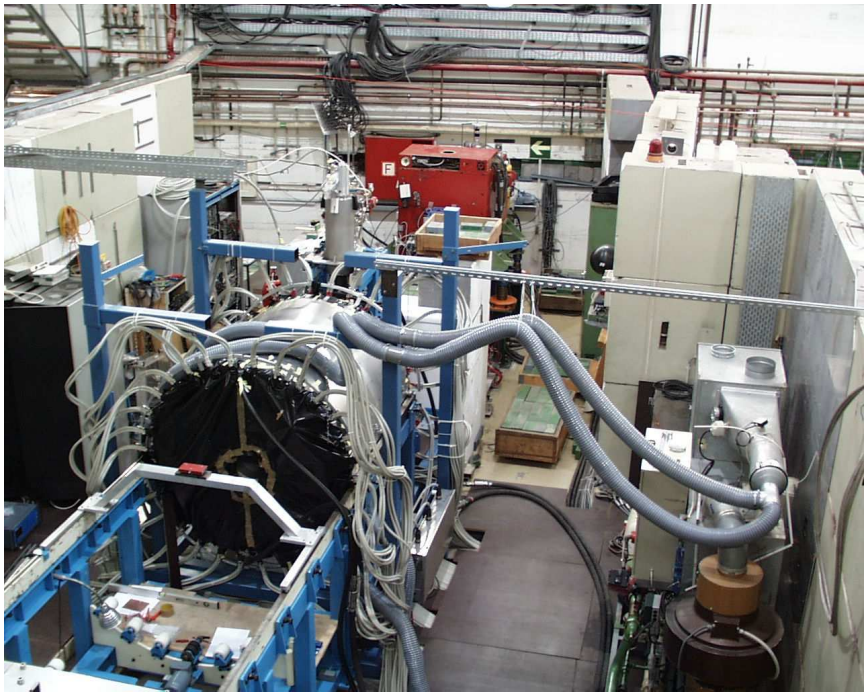
$\Rightarrow$ Baryons are broad and overlapping

- Rescattering Effects
  $\Rightarrow$ Require Coupled-Channel Analysis
  (need to measure as many final states as possible)
- Polarization (need complete experiments)



* only possible at ELSA

CLAS/CB-ELSA – Complementary Detectors



Photo/Electroproduction at CLAS

Great for charged particles:
p, $\pi^{\pm}$, etc. ➜

Photoproduction at ELSA with the Crystal-Barrel Detector

⇐ Great to measure neutral particles:
π^0, $\eta \to \gamma\gamma$, $\eta \to \pi^0\pi^0\pi^0$, etc.

All FSU Jefferson Lab efforts will be funded by DOE

- Collaboration with P. Eugenio (experiment, meson spectroscopy)
- My students involved with JLab N^* program:
  (Double-pion (FROST) proposal: "A−" rating)
  - C. Hanretty and S. Park (target construction, (FROST) chef)
  - Undergraduate student E. McClellan (Drift chamber calibration)

Funds requested here from NSF for N^* program at ELSA, Bonn

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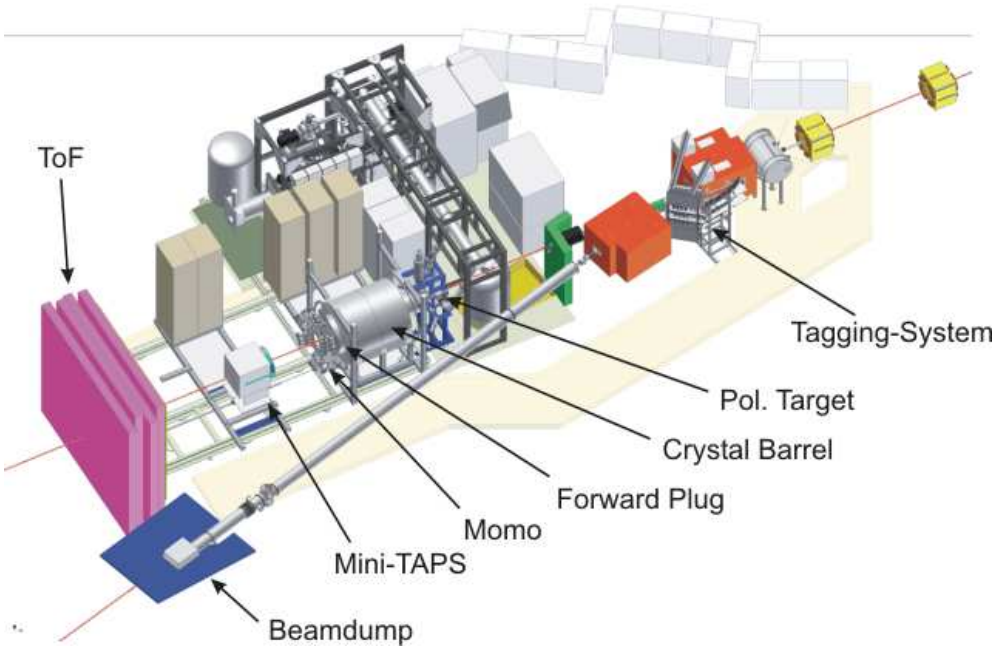
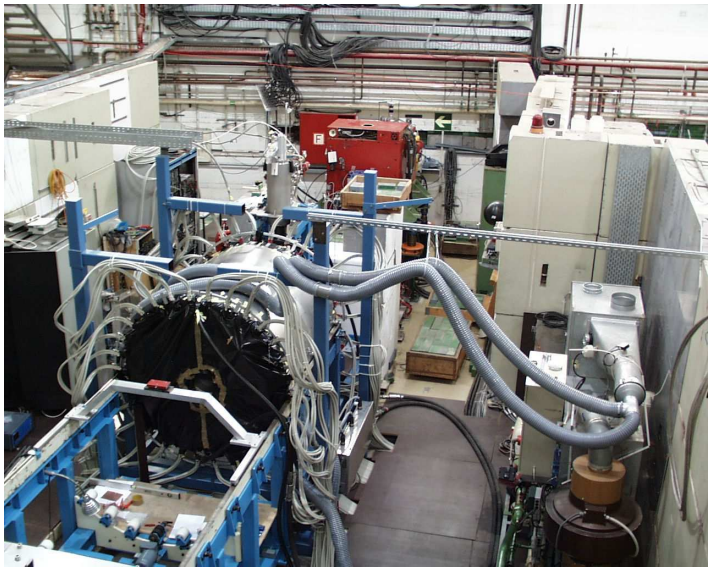
Crystal Barrel at ELSA: Bonn, Germany





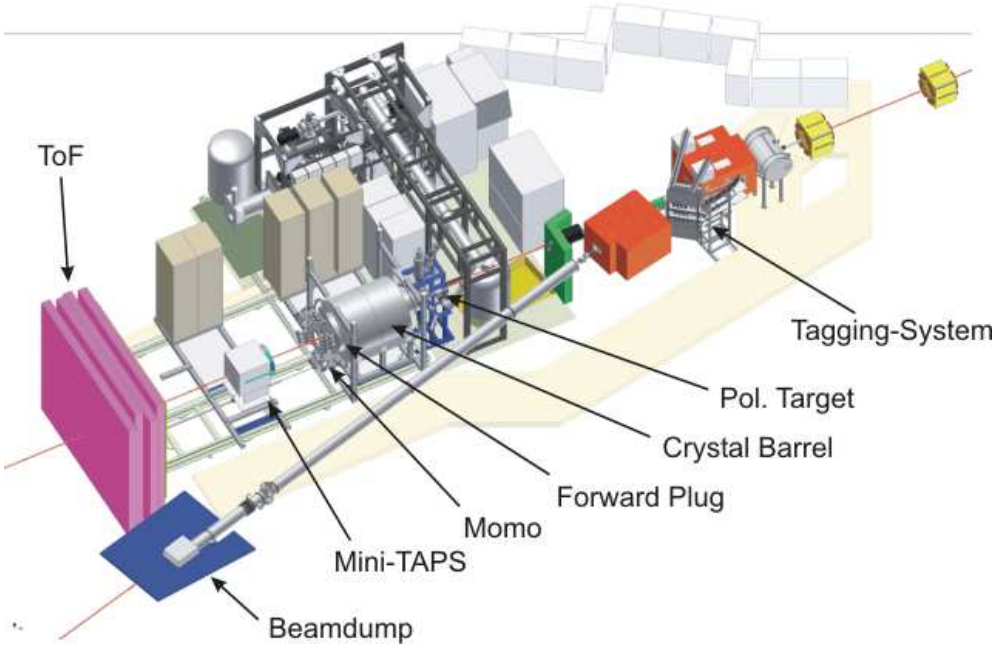
Collaboration

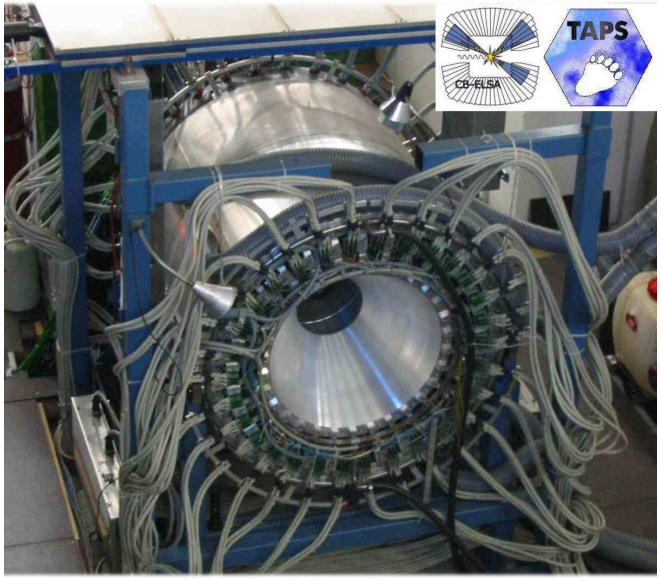
- Germany
- Russia
- Switzerland
- U. S. (Florida State)

Crystal Barrel at ELSA: Bonn, Germany

Optimized for neutral-particle final states

- 4π Calorimeter (Crystal Barrel + TAPS)
- Linear/Circular Beam Polarization
- Frozen-Spin (Butanol) Target
- $E_\gamma < 3$ GeV ($W < 2.6$ GeV)





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Photoproduction of Neutral Mesons: e.g. $\gamma p \rightarrow p\pi^0\pi^0$

General Advantage: γ does not couple to π^0

- Fewer Born-terms, t-channel exchanges

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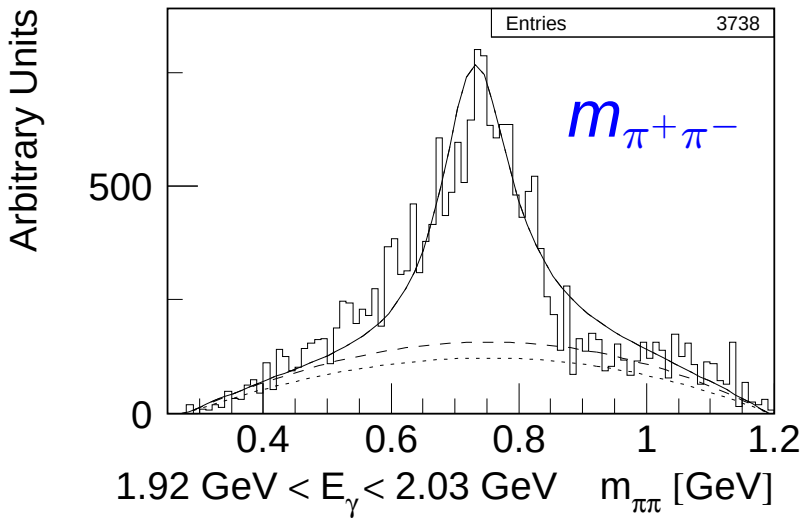
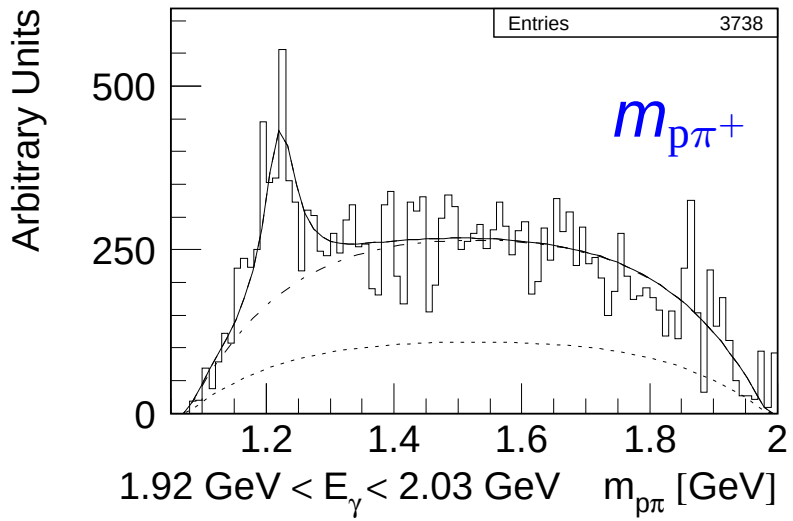
General Advantage: γ does not couple to π^0

- Fewer Born-terms, t-channel exchanges
- No diffractive $\rho(770)$ production: $\rho^0 \nrightarrow \pi^0\pi^0$
- No direct $\Delta^{++}\pi^-$ production (Kroll-Ruderman term)

➜ Bigger contribution of resonant amplitudes!





Saphir

Outline

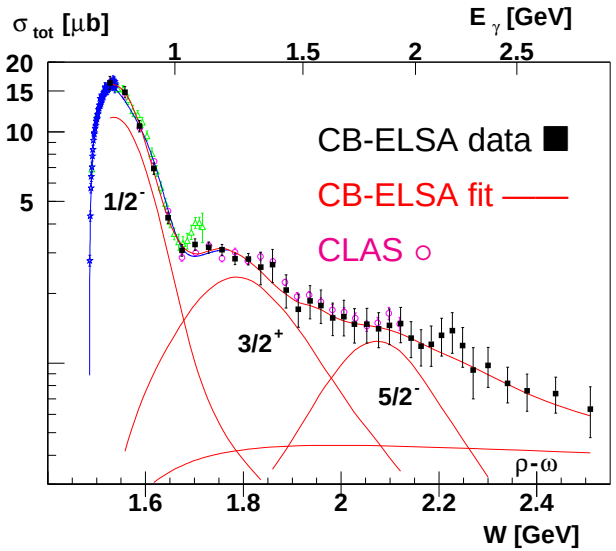
1 CB-ELSA Collaboration

- ## Photoproduction of π^0 Mesons

  O. Bartholomy, V. C., H. van Pee et al., Phys. Rev. Lett. 94 (2005) 012003

- ## Photoproduction of η Mesons

  V. C., O. Bartholomy et al., Phys. Rev. Lett. 94 (2005) 012004



Hint for new N* resonance N(2070)D_{15}

1. Needs confirmation!
2. No need for third S_{11}

Three resonances are dominantly contributing!

N(1535)S_{11}, N(1720)P_{13}, N(2070)D_{15}

1 CB-ELSA Collaboration

- Photoproduction of π^0 Mesons

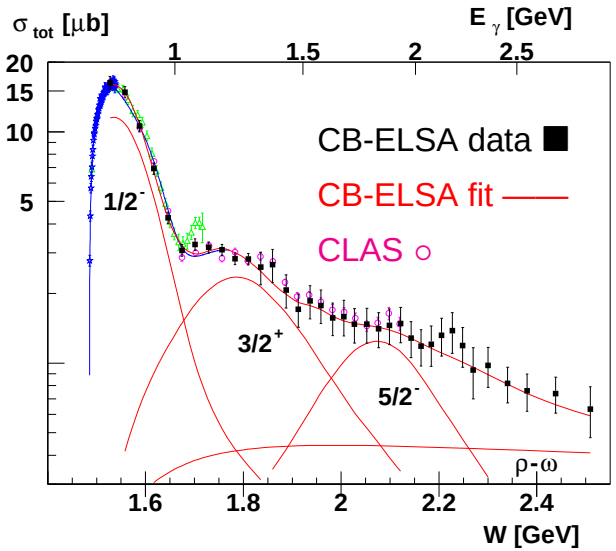
  O. Bartholomy, V. C., H. van Pee et al., Phys. Rev. Lett. 94 (2005) 012003

  H. van Pee, O. Bartholomy, V. C. et al., Eur. Phys. J. A 31 (2007) 61

- Photoproduction of η Mesons

  V. C., O. Bartholomy et al., Phys. Rev. Lett. 94 (2005) 012004

  O. Bartholomy, R. Bogendörfer, V. C., I. Fabry, Eur. Phys. J. A 33 (2007) 133



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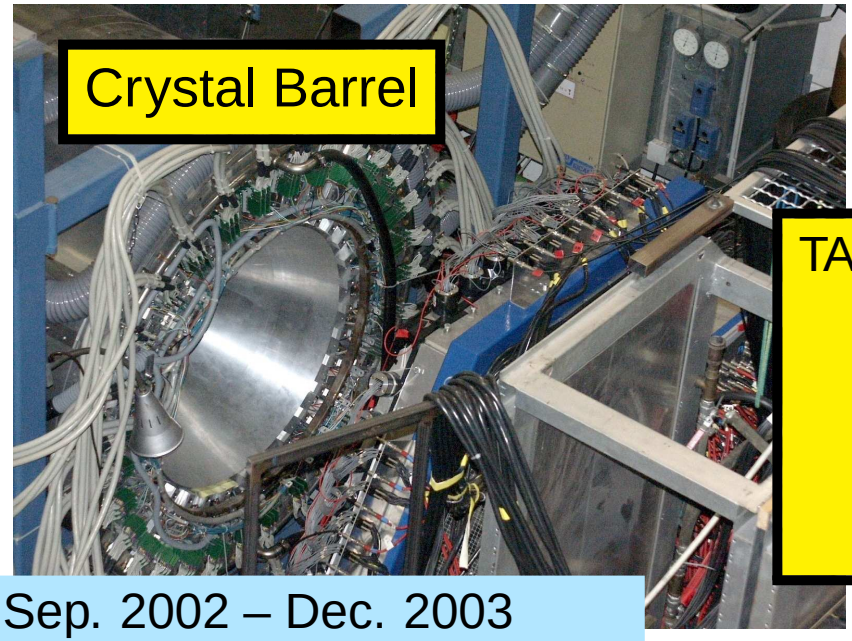
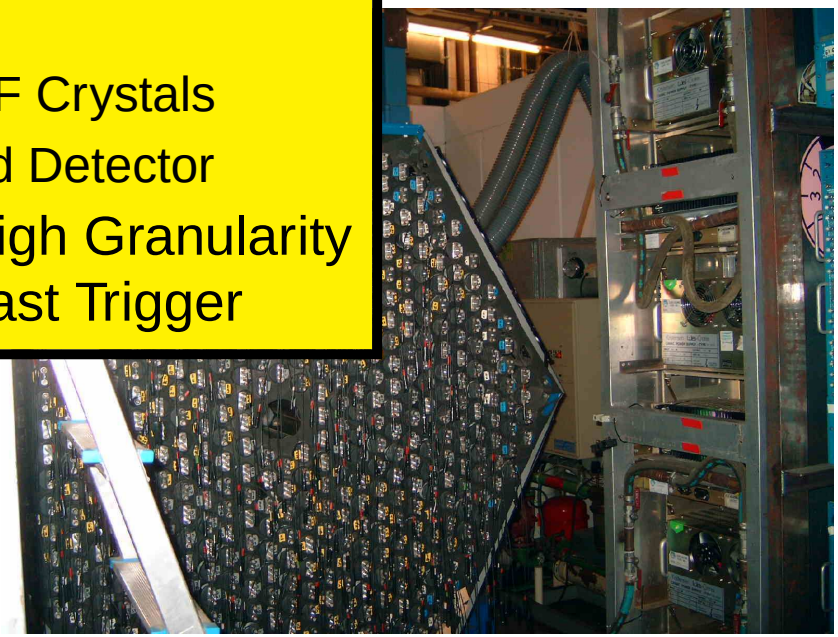
   - Photoproduction of π^0 Mesons
   - Photoproduction of η Mesons
2. CBELSA/TAPS Collaboration



Sep. 2002 – Dec. 2003
- (Un)polarized beam
- Liquid H_2, deuterium
- Solid targets

TAPS
- 512 BaF Crystals
- Forward Detector
  - High Granularity
  - Fast Trigger



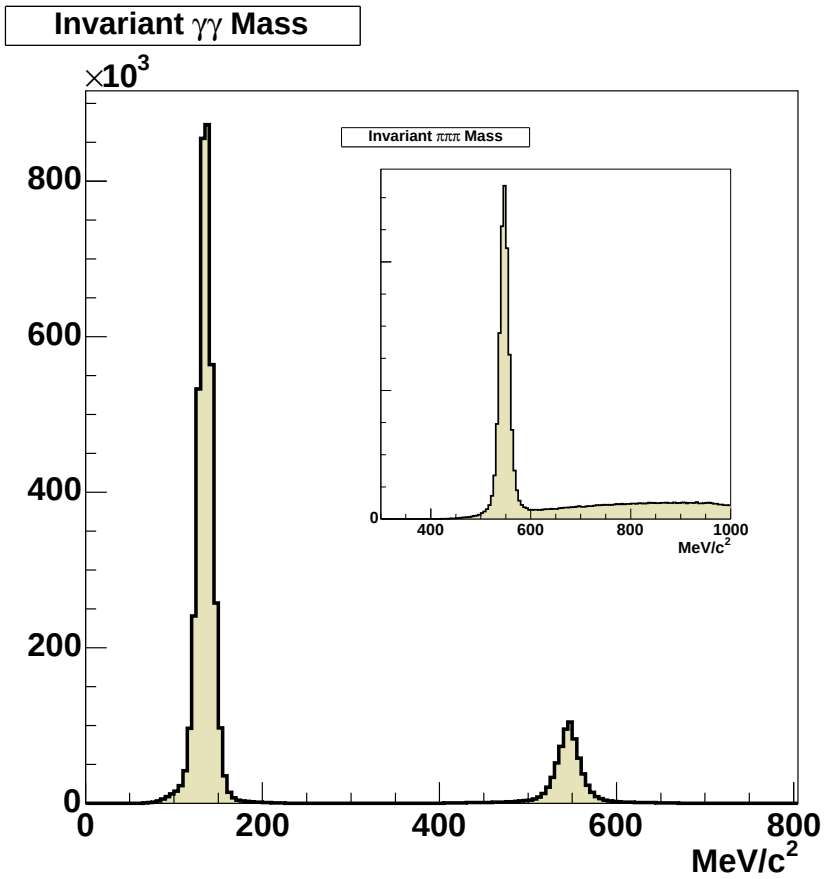
Data Analysis at Florida State

(A. McVeigh, A. Woodard)

$\gamma p \rightarrow p\pi^0,\ \eta,\ \eta'$ $(p\pi^0\pi^0,\ p\pi^0\eta)$

$\vec{\gamma} p \rightarrow p\eta'$ (Topic of Ph.D. thesis)

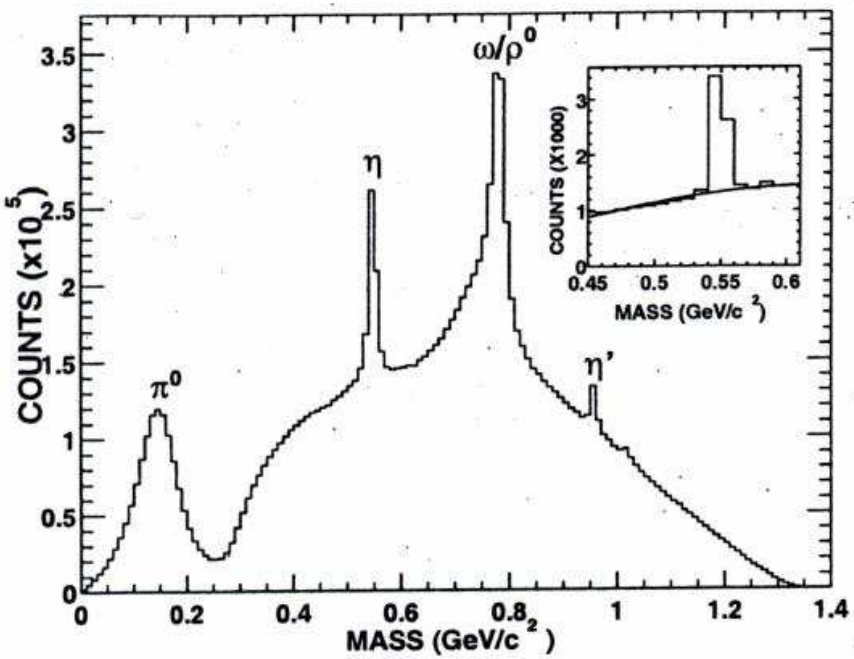
Study of $\gamma p \rightarrow p\eta$ with CBELSA/TAPS



$\eta \rightarrow \gamma\gamma,\ 3\pi^0$ (inset)
(CBELSA/TAPS)

$\gamma p \rightarrow p X$ (missing mass)
(CLAS)

M. Dugger et al., PRL **89**, 222002 (2002)



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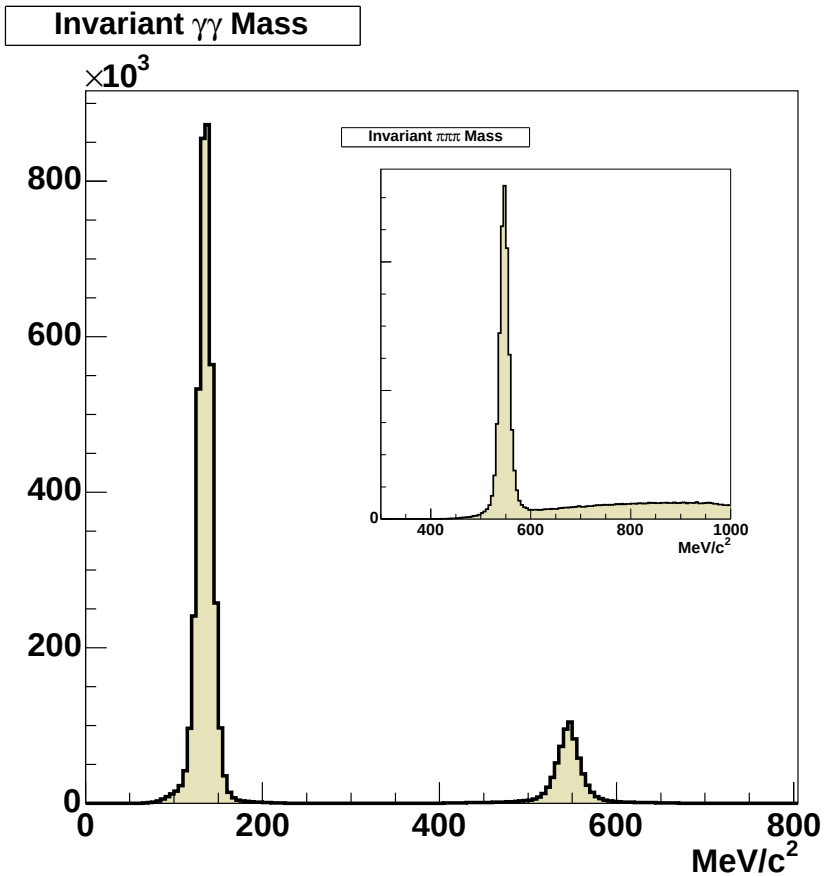
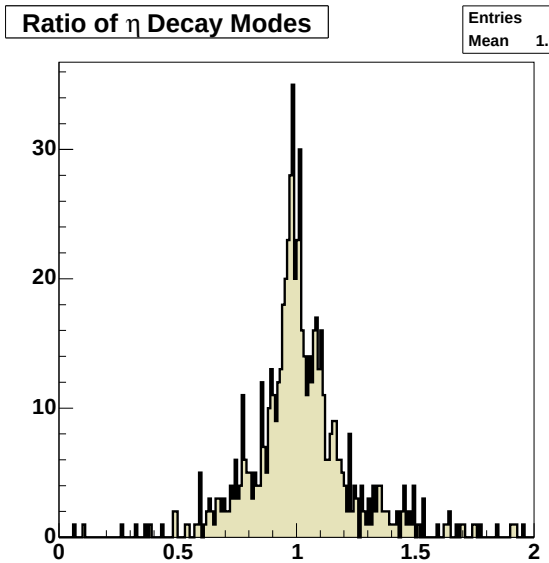


$\eta \rightarrow \gamma\gamma,\ 3\pi^0$ (inset)
(CBELSA/TAPS)

Why is η (π^0) production important?



$$\frac{d\sigma^{(\eta\rightarrow 3\pi^0)}}{d\Omega} \Big/ \frac{d\sigma^{(\eta\rightarrow\gamma\gamma)}}{d\Omega}$$

Acceptance studies:

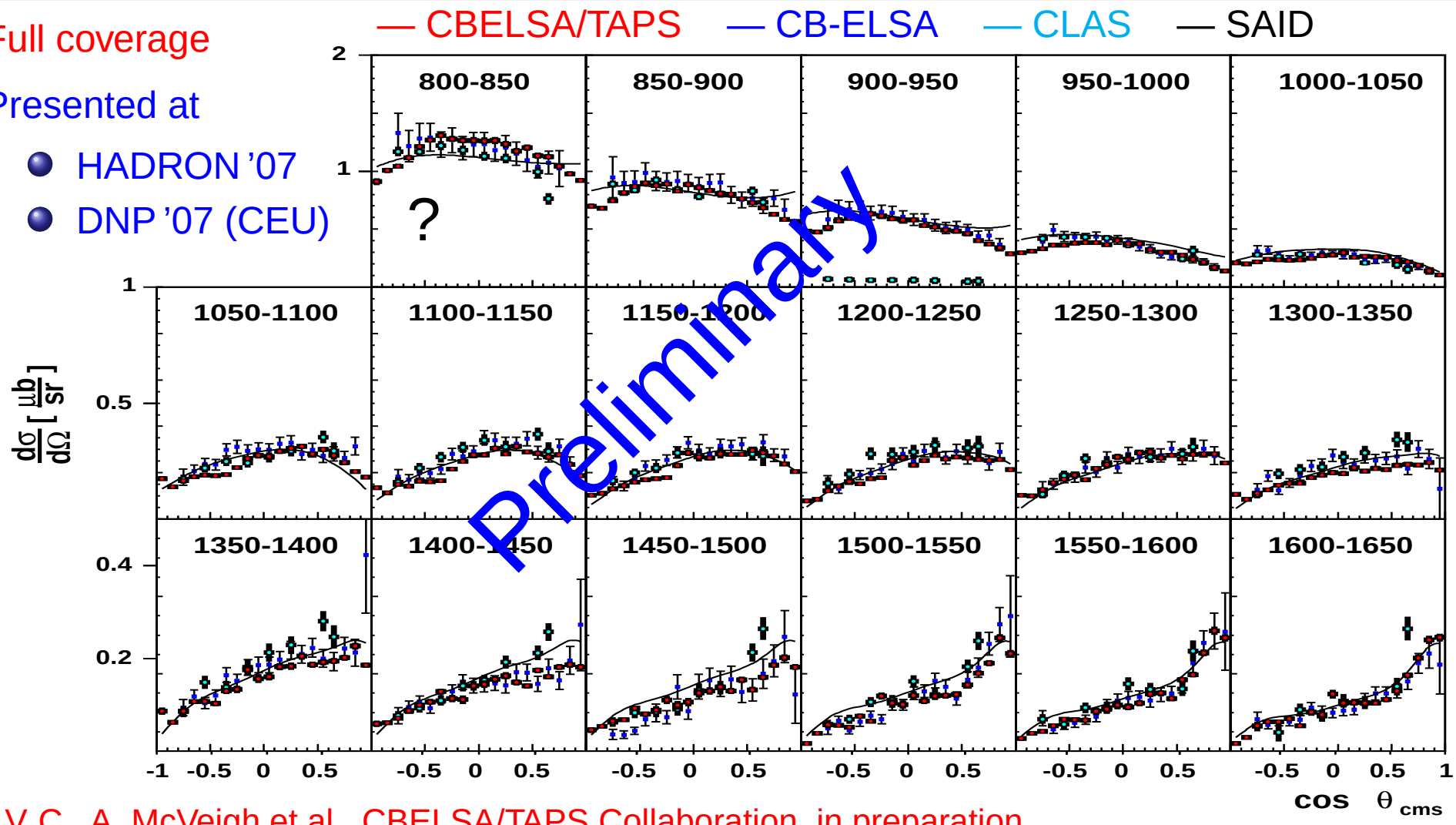
- $\eta \rightarrow 2\gamma$
- $\pi^0\eta,\ \pi^0\pi^0 \rightarrow 4\gamma$
- $\eta \rightarrow 6\gamma$

Differential Cross Sections for $\gamma p \rightarrow p\eta$

Full coverage

Presented at

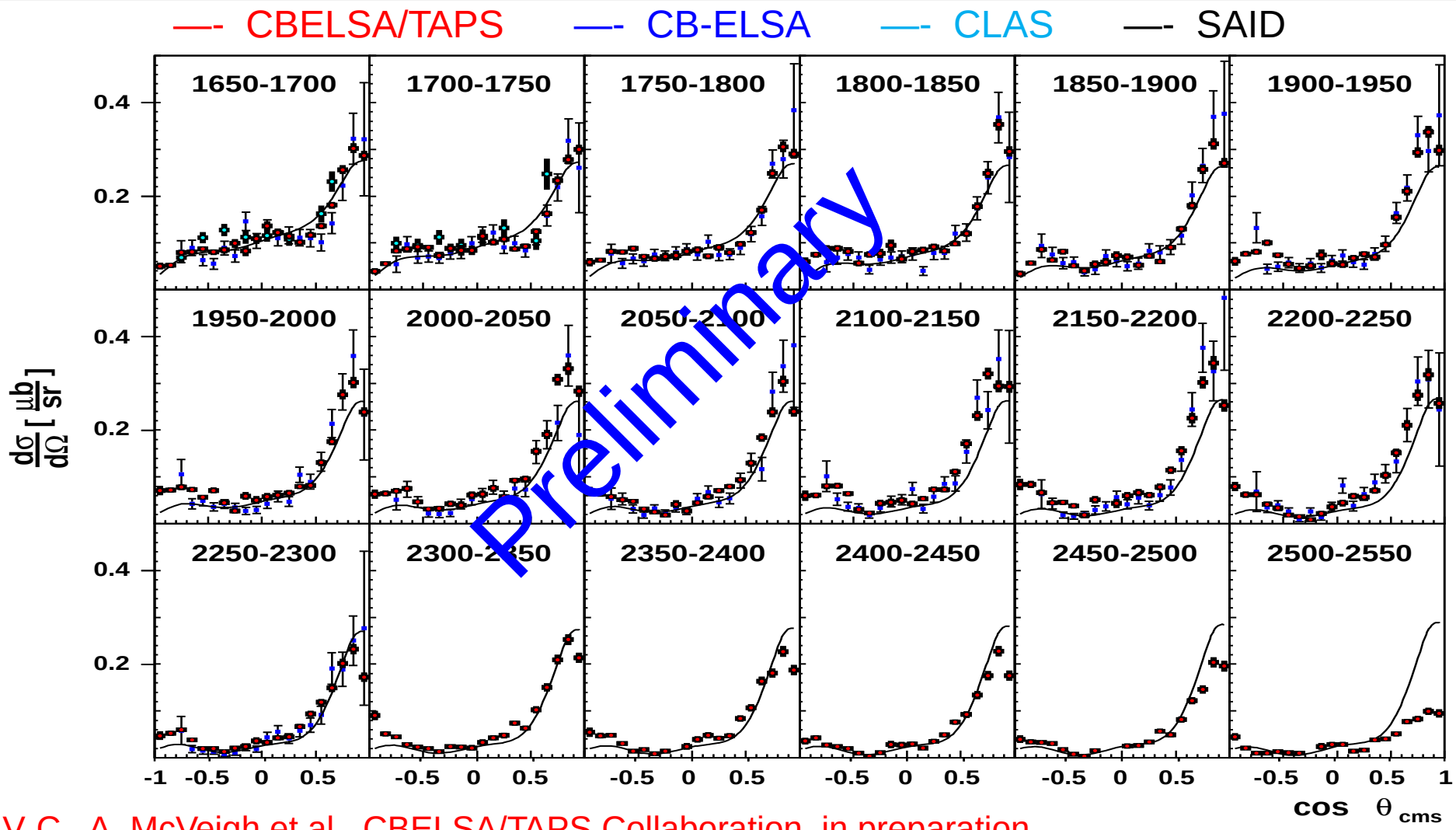
- HADRON '07
- DNP '07 (CEU)



V. C., A. McVeigh et al., CBELSA/TAPS Collaboration, in preparation

V. C., O. Bartholomy et al., CB-ELSA Collaboration, PRL **D94**, 012004 (2005)

Differential Cross Sections for $\gamma p \rightarrow p\eta$



V. C., A. McVeigh et al., CBELSA/TAPS Collaboration, in preparation

V. C., O. Bartholomy et al., CB-ELSA Collaboration, PRL **D94**, 012004 (2005)

Proposal: Study of $\vec{\gamma}\mathbf{p} \rightarrow \mathbf{p}\eta'$ with CBELSA/TAPS

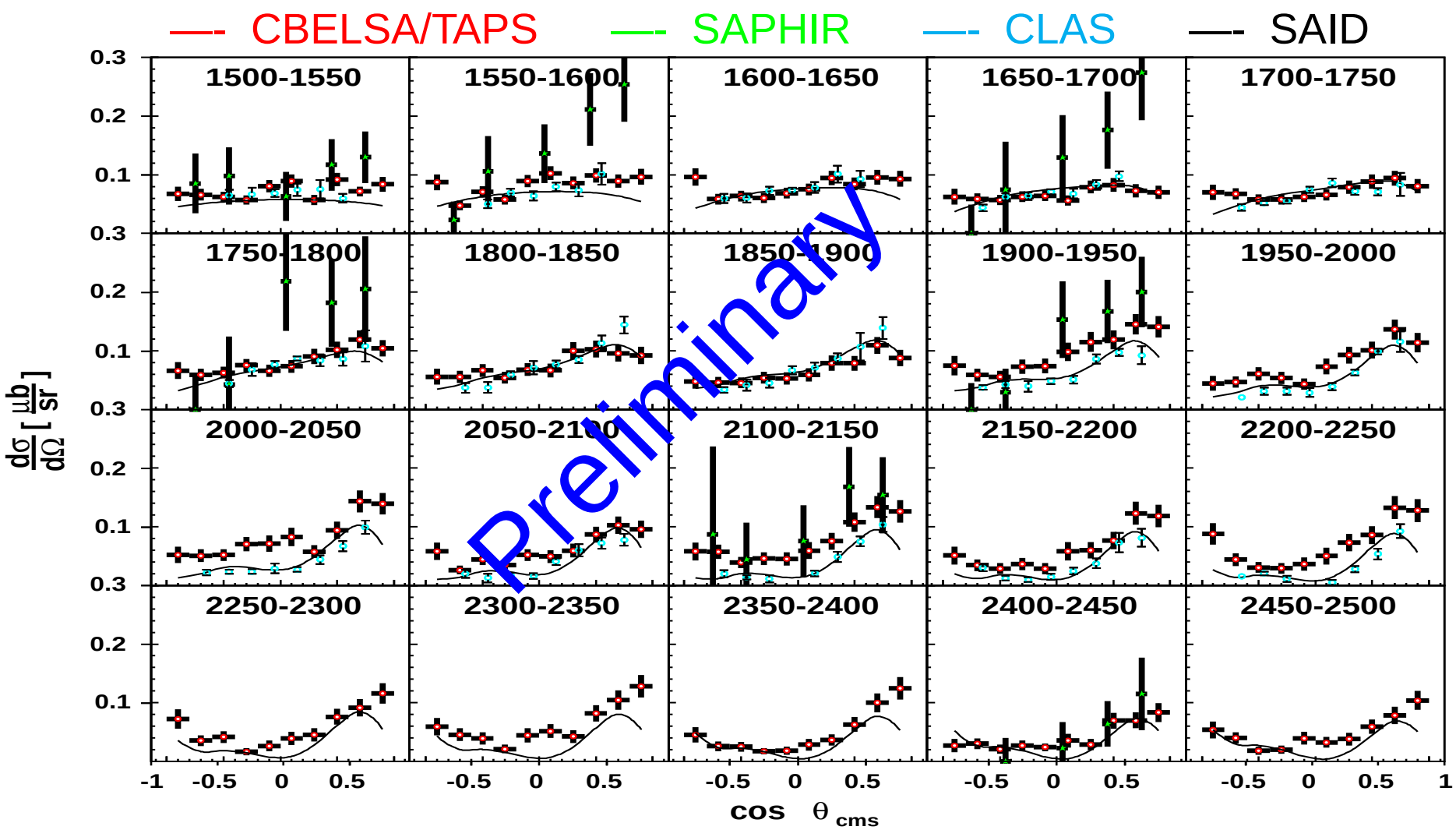
Isospin Filter: only N* resonances can contribute

- 1968: 11 events from the ABBHHM bubble chamber experiment
- 1976: 7 events from the AHHM streamer chamber experiment
- 1998: 250 events from SAPHIR collaboration
  ➜ First differential cross sections
- 2006: over $2 \cdot 10^5$ events from CLAS (limited in angular coverage)
  (Contributions from N(1535)S_{11}, N(1710)P_{11}, $J = 3/2$ states)
- 2007: New data from CBELSA/TAPS over the full angular range
  HADRON'07, DNP/CEU Program (undergraduate student A. Woodard)

No published beam-asymmetry data yet for η' (linearly-polarized beam)

- Data available from ELSA ($\eta' \rightarrow \pi^0\pi^0\eta$)
  ➜ Ph.D. thesis of A. McVeigh

Differential Cross Sections for $\gamma p \rightarrow p\eta'$

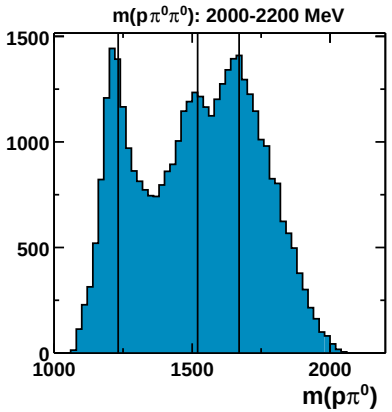


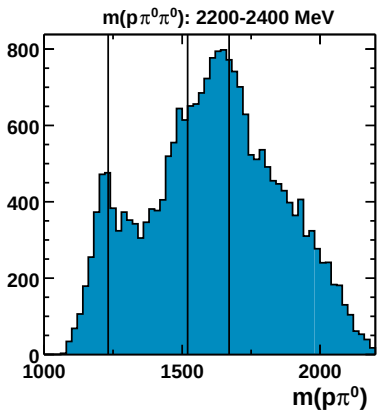
FSU et al., CBELSA/TAPS Collaboration, in preparation

Proposal: Combined PWA of CLAS and CB Data

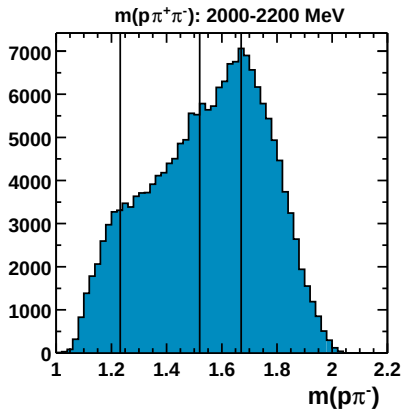
$\gamma p \to p\pi^0\pi^0$ and $\gamma p \to p\pi^+\pi^-$ from CB-ELSA and CLAS

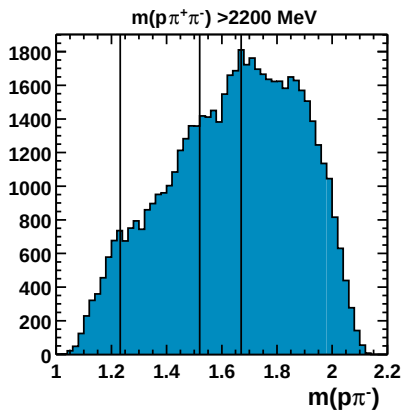
- CB-ELSA:





- CLAS:





$$\gamma p \to N^*/\Delta^* \to X\pi$$

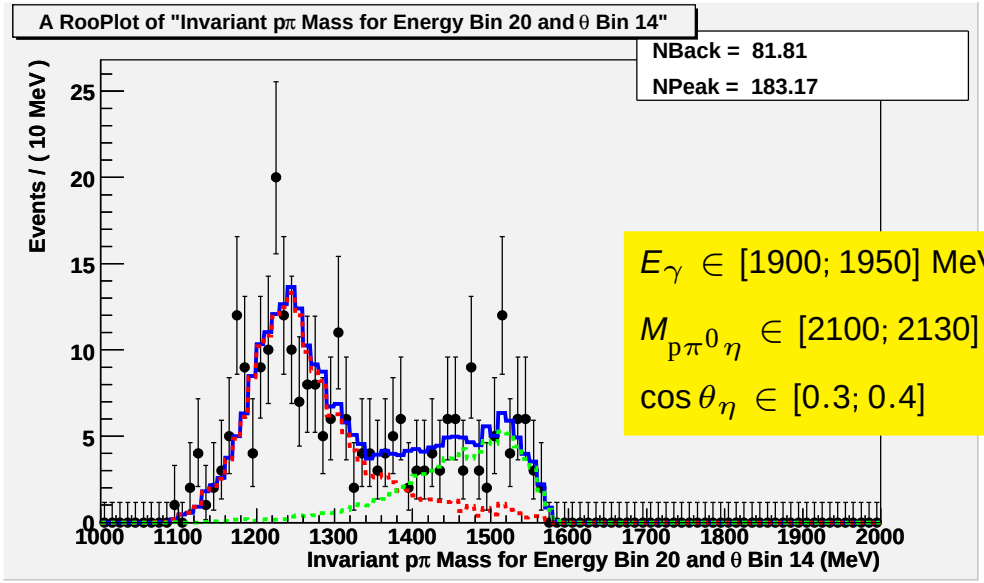
$$X = \Delta(1232)$$
$$X = D_{13}(1520)$$
$$X = X(1660)$$

$\Rightarrow$ **Similar resonance structures in both data sets !**

Collaboration with CLAS group at CMU

- Use existing (CMU) code
- Add polarization data (CLAS/ELSA)

Proposal: Study of $\Delta\,\eta\,(\longrightarrow \mathrm{p}\,\pi^0\,\eta)$ Events



$E_\gamma \in [1900; 1950]$ MeV

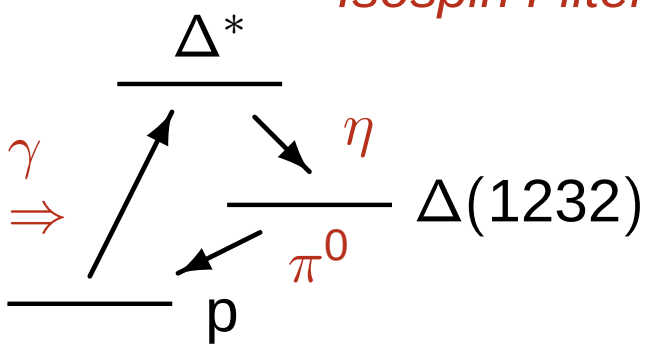
$M_{\mathrm{p}\pi^0\eta} \in [2100; 2130]$ MeV/c^2

$\cos\theta_\eta \in [0.3; 0.4]$

— $\Delta\eta\ (\eta \to \gamma\gamma)$ MC Distribution
(Breit-Wigner Distribution)

— $S_{11}\pi^0$ MC Distribution
(Breit-Wigner Distribution)

Isospin Filter for Δ^*



Study of $\gamma\mathrm{p} \to \mathrm{p}\pi^0\eta$
($\approx$ 500,000 events, full angular range)

- Determination of prel. cross sections
  (➜ Honors thesis A. Woodard)
- Collaboration with FSU theorists
  S. Capstick and his graduate student
  A. Kiswandhi

Outline

1. CB-ELSA Collaboration
   - Photoproduction of π^0 Mesons
   - Photoproduction of η Mesons
2. CBELSA/TAPS Collaboration
3. The Double-Polarization Program at ELSA

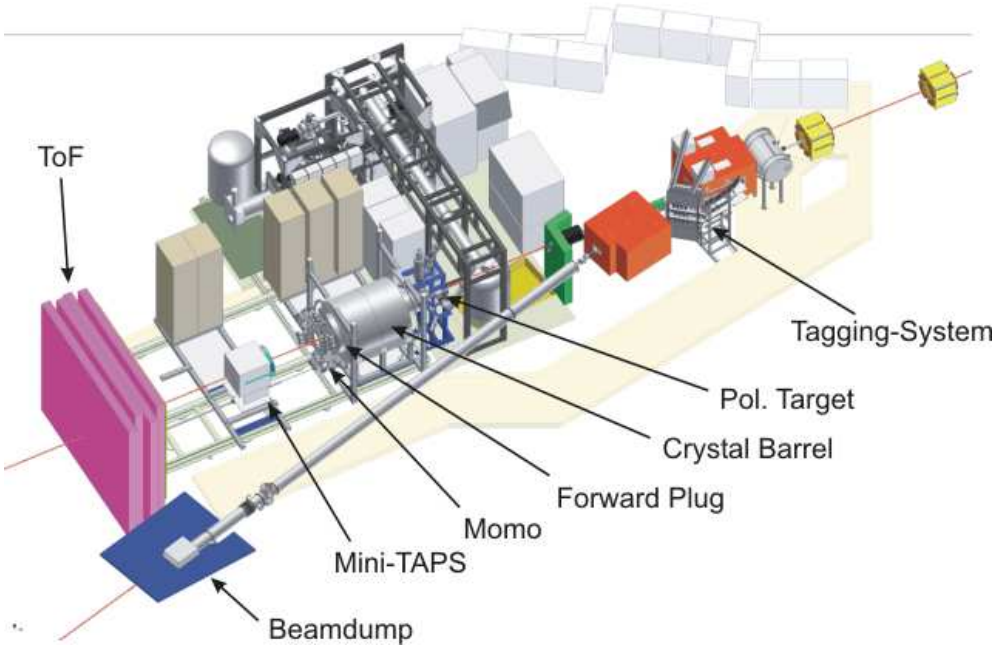
Proposals to MAMI/ELSA PAC in September 2005

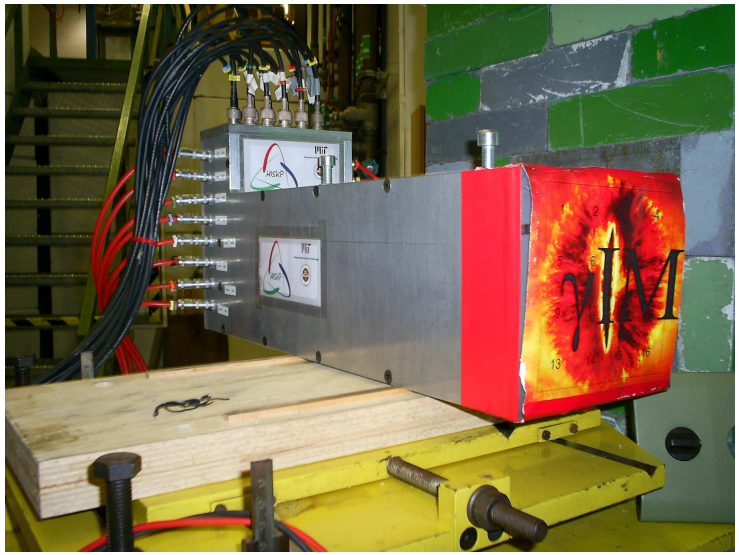
- ELSA/1-2005 $\Rightarrow$ **G** in single π^0 and η production
- ELSA/2-2005 $\Rightarrow$ Helicity dependence in π^0 and η production
- ELSA/3-2005 $\Rightarrow$ **Σ** and **G** in η photoproduction off neutron
- ELSA/4-2005 $\Rightarrow$ Beam-target asymmetry in ω production
- ELSA/5-2005 $\Rightarrow$ Meson-nucleus bound state
- ELSA/6-2005 $\Rightarrow$ Double polarisation in $\pi^0\pi^0$ production
  ($\approx$ 4000 h to measure **E, G** with $\Delta\mathbf{E} \approx 0.05$)
- ELSA/7-2005 $\Rightarrow$ Helicity difference in $\pi^0\eta$ production (FSU "A$-$" proposal)
  ($\approx$ 2000 h to measure **E** with $\Delta\mathbf{E} \approx 0.06$)

The Double-Polarization Program at ELSA

Data taking has started in September 2007

- Several weeks of circularly-polarized beam on longitudinally-polarized target
- Collaboration on polarization observables with FSU theorist Winston Roberts
- FSU students: A. McVeigh, A. Wilson





γ-Intensity Monitor (γIM)

- 4x4 array of lead glass crystals
  ➜ Determination of photon flux
- FSU student A. McVeigh redesigned/assembled detector

Summary