

Facilities and Detectors for Baryon Physics

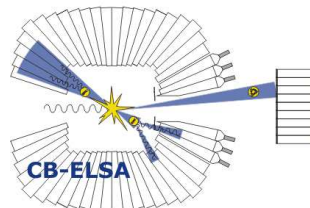
Volker Credé

Florida State University
Tallahassee, FL

APS-DNP Town Meeting
Rutgers University, 01/14/2007

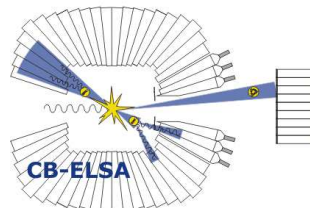
Outline

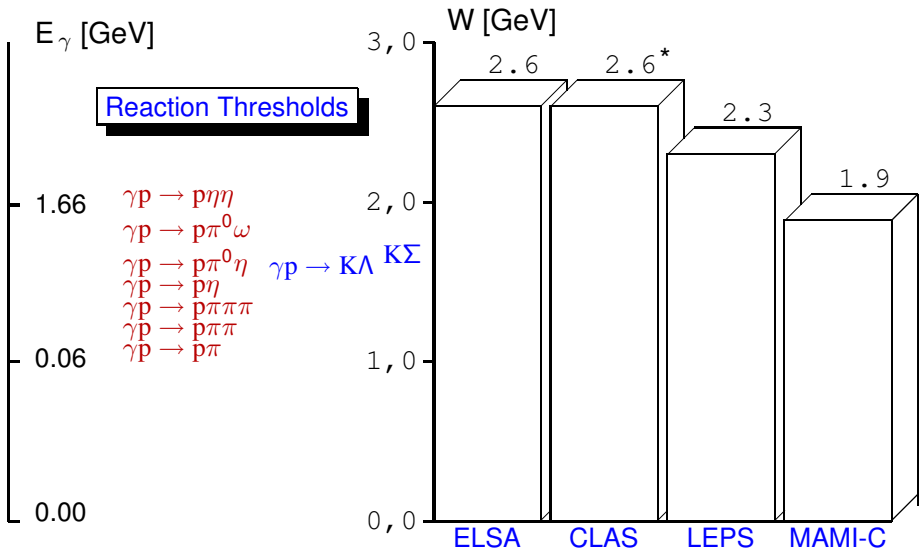
- 1 Introduction
- 2 (Photoproduction) Facilities
- 3 Advantages of Neutral Final States
- 4 Summary

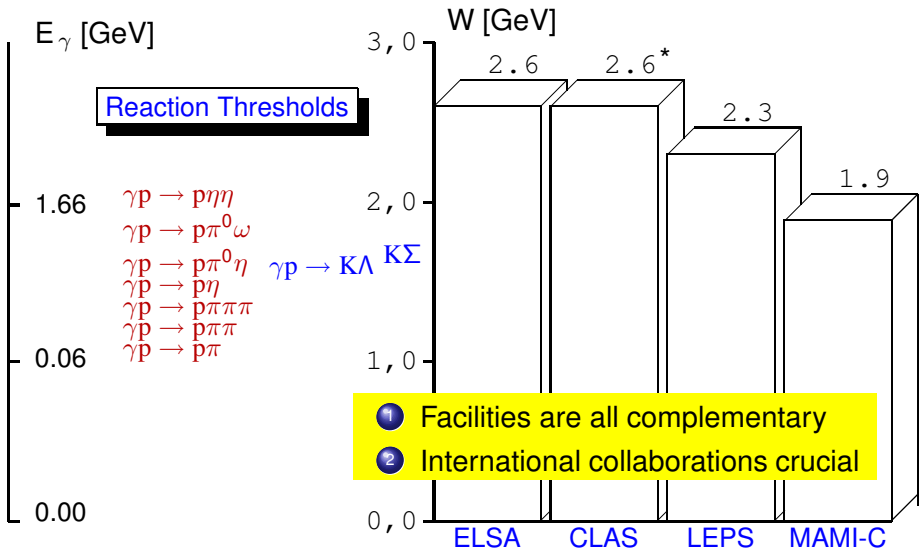


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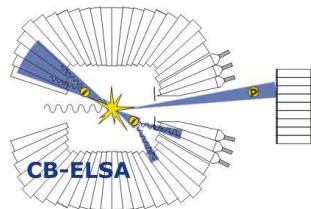






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LEPS at SPring-8: Hyogo, Japan



LEPS (international) Collaboration

- Japan
- South Korea
- Taiwan
- Canada
- U. S. (Ohio University)

LEPS at SPring-8: Hyogo, Japan

Detector optimized for charged-particle final states

- Linear Polarization (Compton Backscattering)
- $E_\gamma < 2.4$ GeV (new laser will allow $E_\gamma < 3$ GeV)
- LEPS covers very forward angles ($\theta_{\text{lab}} > 1^\circ$)



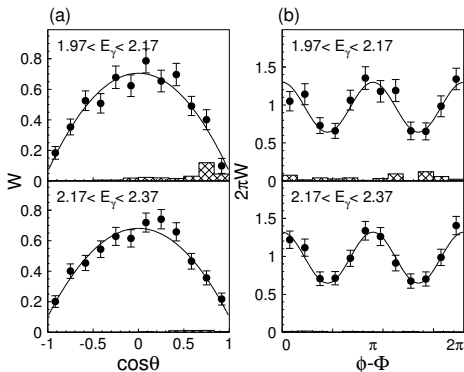
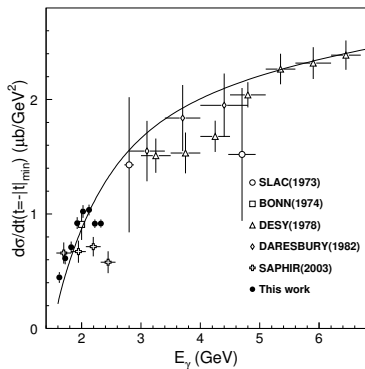
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LEPS at SPring-8: Hyogo, Japan

Original detector optimized for K detection

- Diffractive ϕ -Meson Photoproduction on the Proton near Threshold



LEPS at SPring-8: Hyogo, Japan

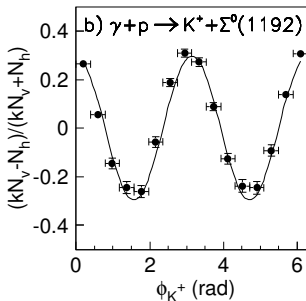
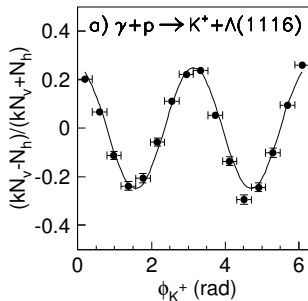
Original detector optimized for K detection

- Diffractive ϕ -Meson Photoproduction on the Proton near Threshold
- $\vec{\gamma}n \rightarrow K^+\Sigma^-$: Differential Cross Section/Photon Beam Asymmetry

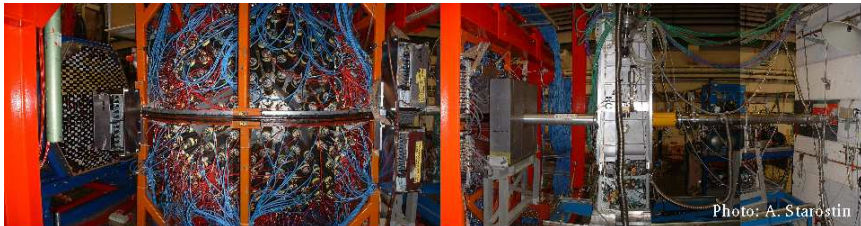
LEPS at SPring-8: Hyogo, Japan

Original detector optimized for K detection

- Diffractive ϕ -Meson Photoproduction on the Proton near Threshold
- $\vec{\gamma}n \rightarrow K^+\Sigma^-$: Differential Cross Section/Photon Beam Asymmetry
- **Beam Polarization Asymmetries for $\vec{\gamma}p \rightarrow K^+\Lambda$ and $\vec{\gamma}p \rightarrow K^+\Sigma^0$**



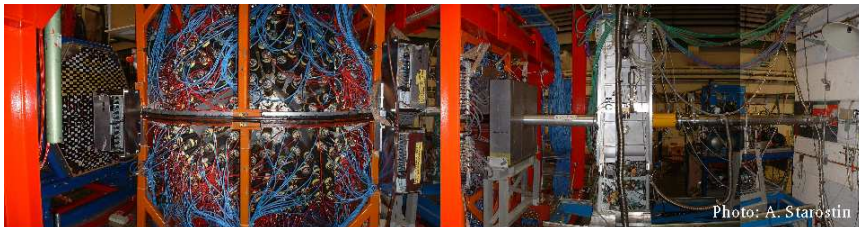
Crystal Ball at MAMI-C: Mainz, Germany



A2 (international) Collaboration

- Germany
- U. S. (GWU, UCLA, Kent State)
- Great Britain
- Belgium
- Italy
- Sweden
- Russia
- Croatia
- Switzerland
- Canada

Crystal Ball at MAMI-C: Mainz, Germany



Optimized for neutral-particle final states

- 4π Calorimeter (Crystal Ball + TAPS)
⇒ First-Level Trigger



Crystal Ball at MAMI-C: Mainz, Germany

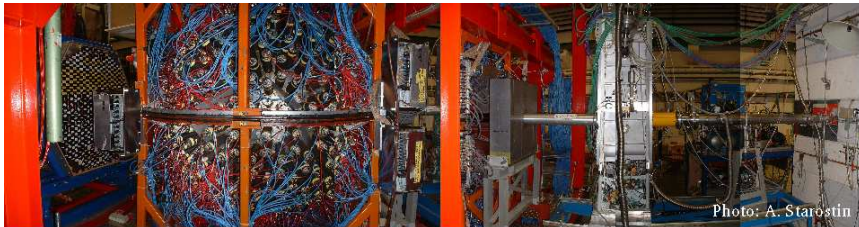
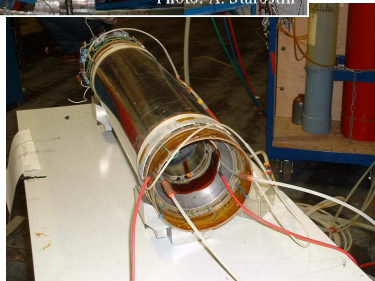


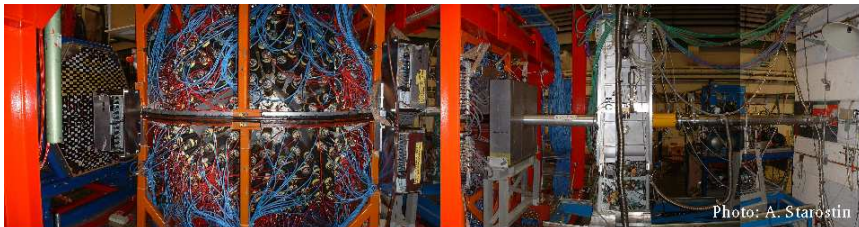
Photo: A. Starostin

Optimized for neutral-particle final states

- 4π Calorimeter (Crystal Ball + TAPS)
⇒ First-Level Trigger
- Charged-Particle Detection (MWPC)

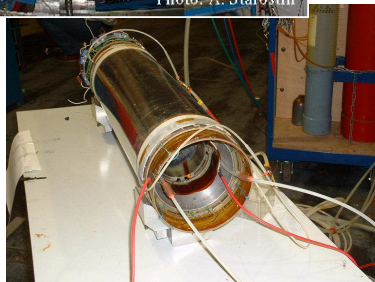


Crystal Ball at MAMI-C: Mainz, Germany



Optimized for neutral-particle final states

- 4π Calorimeter (Crystal Ball + TAPS)
⇒ First-Level Trigger
- Charged-Particle Detection (MWPC)
- Polarized Beam and Target
- $E_\gamma < 1.5 \text{ GeV}$ ($W < 1.9 \text{ GeV}$)

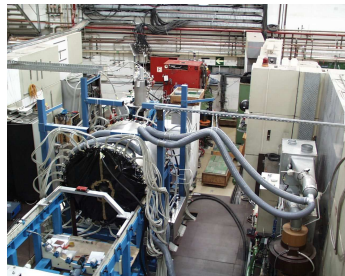
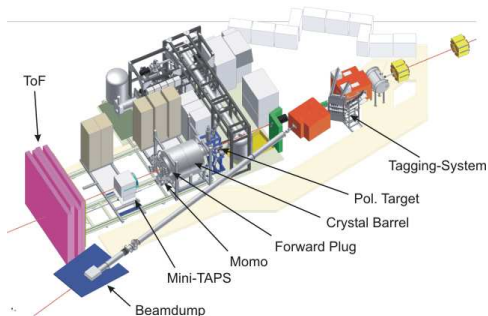


Crystal Ball at MAMI-C: Physics Goals

Focus on

- Measurements of total (σ) and differential cross sections ($\frac{d\sigma}{d\Omega}$) using unpolarized neutrons (LD_2):
 - $\gamma n \rightarrow n \pi^0$
 - $\gamma n \rightarrow n \eta$,
 - $\gamma n \rightarrow n \eta'$
 - $\gamma n \rightarrow K\Lambda$
- Single- and double-polarization measurements with polarized deuterium target

Crystal Barrel at ELSA: Bonn, Germany



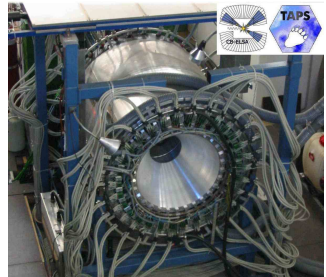
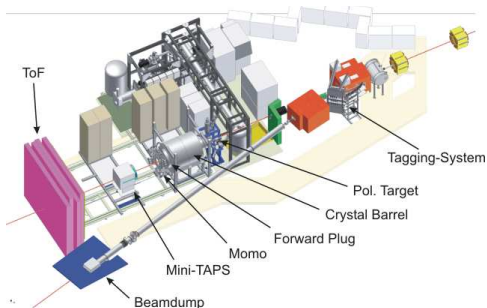
CB-ELSA Collaboration

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

Crystal Barrel at ELSA: Bonn, Germany

Optimized for neutral-particle final states

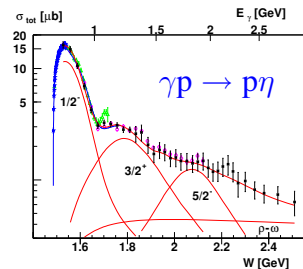
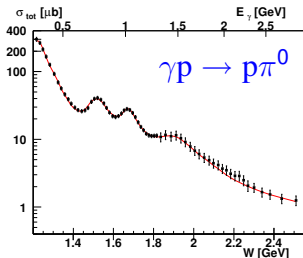
- 4π Calorimeter (Crystal Barrel + TAPS)
- Linear/Circular Beam Polarization
- Frozen-Spin (Butanol) Target
- $E_\gamma < 3 \text{ GeV}$ ($W < 2.6 \text{ GeV}$)



CB-ELSA Collaboration

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

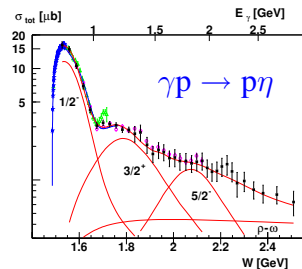
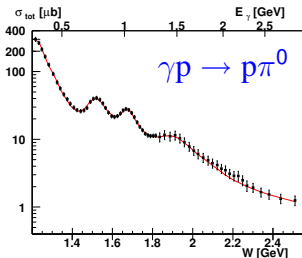
Neutral-Meson Final States: Available Data from ELSA



• Crystal Barrel @ ELSA (2000/2001)

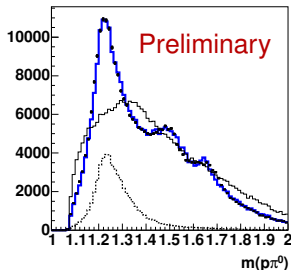
- $\gamma p \rightarrow p\pi^0$ (PRL **D94**, 012003 (2005))
- $\gamma p \rightarrow p\eta$ (PRL **D94**, 012004 (2005))

Neutral-Meson Final States: Available Data from ELSA



Crystal Barrel @ ELSA (2000/2001)

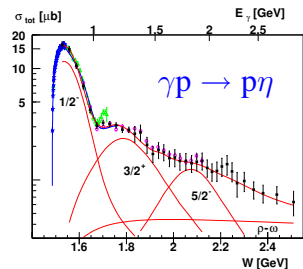
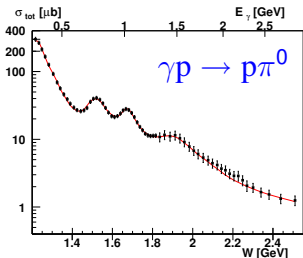
- $\gamma p \rightarrow p\pi^0$ (PRL **D94**, 012003 (2005))
 - $\gamma p \rightarrow p\eta$ (PRL **D94**, 012004 (2005))
 - $\gamma p \rightarrow p\pi^0\eta$ ($\pi^0\pi^0$)
- Strong indication for new states



Baryon Decays into $p\pi^0\pi^0$

- N^*/Δ^* resonances not coupling to $N\pi$ or γN could be produced in such decay cascades

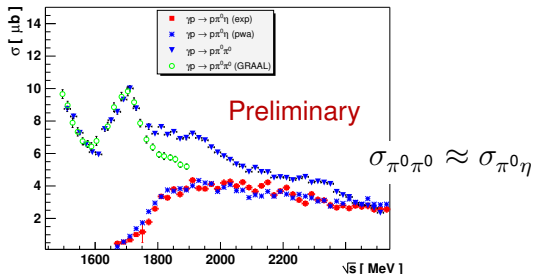
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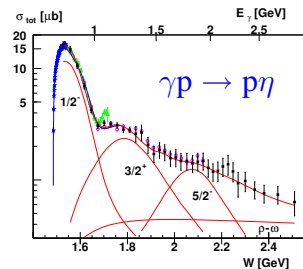
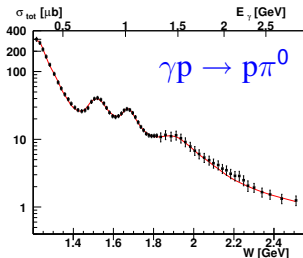
• Crystal Barrel @ ELSA (2000/2001)

- $\gamma p \rightarrow p\pi^0$ (PRL **D94**, 012003 (2005))
 - $\gamma p \rightarrow p\eta$ (PRL **D94**, 012004 (2005))
 - $\gamma p \rightarrow p\pi^0\eta$ ($\pi^0\pi^0$)
- Strong indication for new states

Total cross sections with 20 MeV bin size



Neutral-Meson Final States: Available Data from ELSA



● Crystal Barrel @ ELSA (2000/2001)

- $\gamma p \rightarrow p\pi^0$ (PRL **D94**, 012003 (2005))
- $\gamma p \rightarrow p\eta$ (PRL **D94**, 012004 (2005))
- $\gamma p \rightarrow p\pi^0\eta$ ($\pi^0\pi^0$)
→ Strong indication for new states

● CB/TAPS @ ELSA (2002/2003)

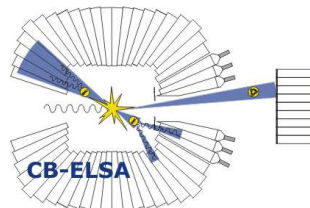
- Factor of 10 more unpolarized data and (almost) full angular coverage
- Linear photon polarization
- Cross sections, asymmetries, PWA

● Double-Polarization (2007 –)

- Longitudinal Target Polarization

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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

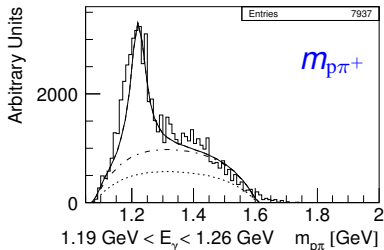
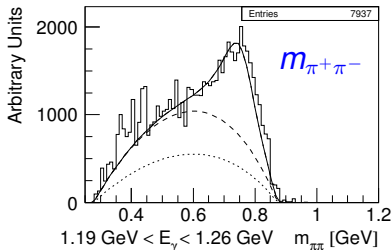
- Fewer Born-terms, t-channel exchanges

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
- No diffractive $\rho(770)$ production: $\rho^0 \rightarrow \pi^0\pi^0$
- No direct $\Delta^{++}\pi^-$ production (Kroll-Ruderman term)

$1.19 \text{ GeV} < E_\gamma < 1.26 \text{ GeV}$



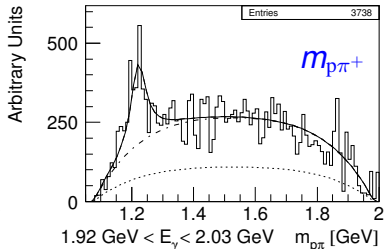
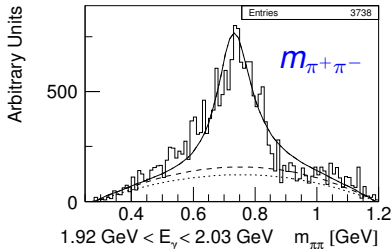
Saphir

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
- No diffractive $\rho(770)$ production: $\rho^0 \nrightarrow \pi^0\pi^0$
- No direct $\Delta^{++}\pi^-$ production (Kroll-Ruderman term)

$1.92 \text{ GeV} < E_\gamma < 2.03 \text{ GeV}$

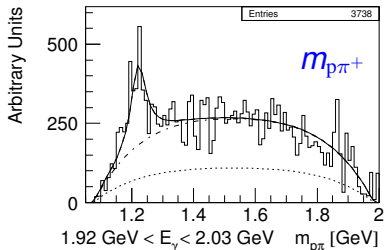
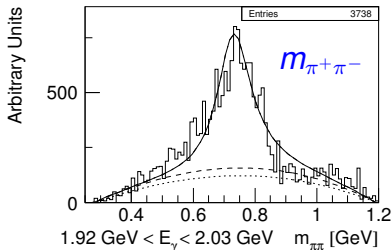


Saphir

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

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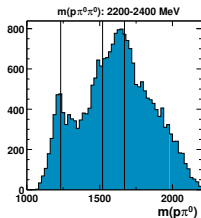
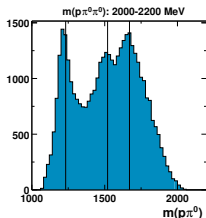
- Fewer Born-terms, t-channel exchanges
 - No diffractive $\rho(770)$ production: $\rho^0 \not\rightarrow \pi^0\pi^0$
 - No direct $\Delta^{++}\pi^-$ production (Kroll-Ruderman term)
- Bigger contribution of resonant amplitudes!



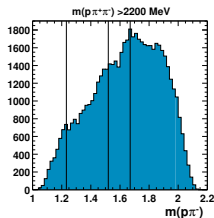
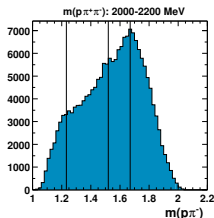
Saphir

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

- CB-ELSA:



- CLAS:



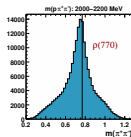
$$\gamma p \rightarrow N^*/\Delta^* \rightarrow X\pi$$

$$X = \Delta(1232)$$

$$X = D_{13}(1520)$$

$$X = X(1660)$$

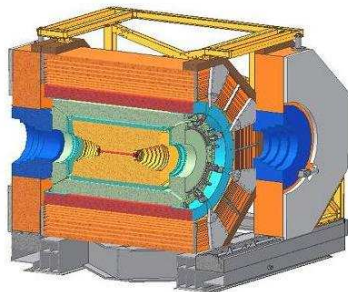
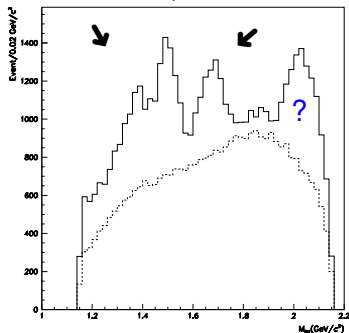
⇒ Similar resonance structures in both data sets !



$$\gamma p \rightarrow p\rho$$

Baryon Spectroscopy at BES: $J/\psi \rightarrow p\pi^- \bar{n}$ ($\bar{p}\pi^+ n$)

$N^*(1440)?$
 $N^*(1520)$
 $N^*(1535)$
 $N^*(1650)$
 $N^*(1675)$
 $N^*(1680)$



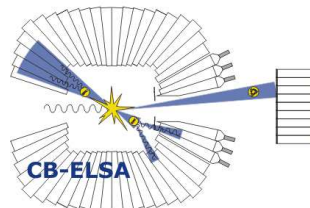
Possible new state

- $M = 2065 \pm 3_{-30}^{+15} \text{ MeV}/c^2$
- $\Gamma = 175 \pm 12 \pm 40 \text{ MeV}/c^2$

⇒ Prel. PWA favors $\frac{3}{2}^+$ (hep-ex/0405030)

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Summary

European and Asian facilities/detectors important (complementary to CLAS)

- Crystal Ball (A2 Collaboration)
- Crystal Barrel (CB-ELSA Collaboration)
 - 1 Neutral final states
 - 2 Beam/target polarization
- SPring-8 (LEPS Collaboration)
 - Charged-particle final states (very forward direction)
 - Polarized photon beam (Compton Backscattering)