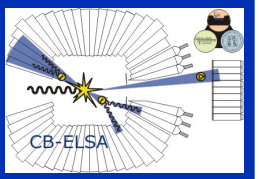
universitätbonn

Hadron Physics at ELSA

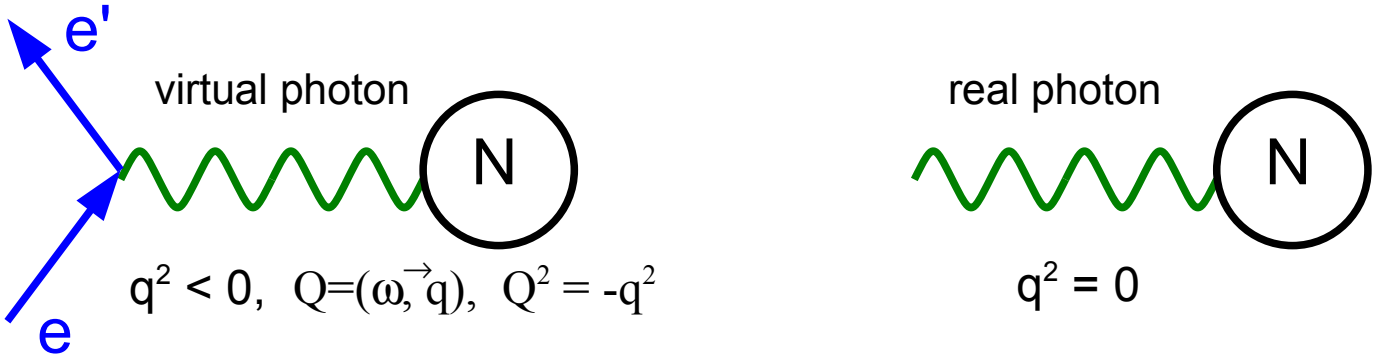
Michael Lang

for the

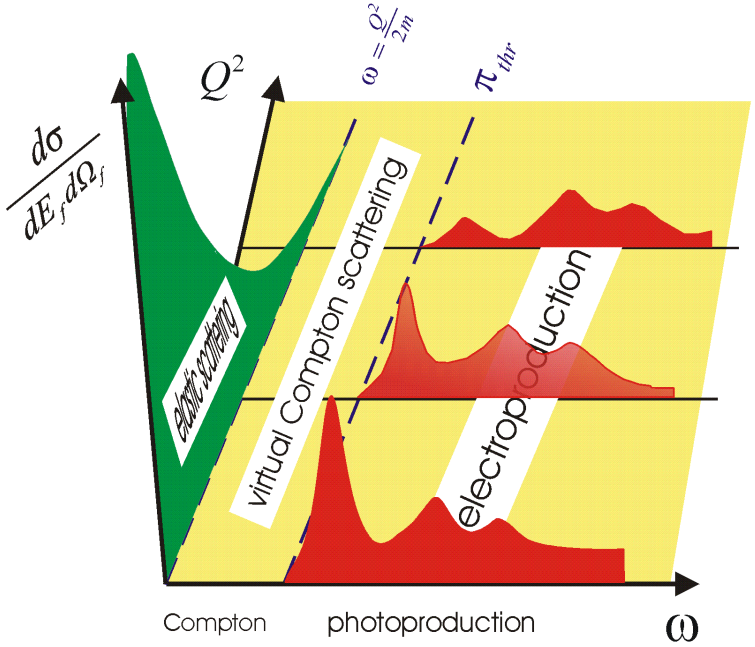
CBELSA-TAPS Collaboration



Nucleon Structure Experiments



(schematic view)



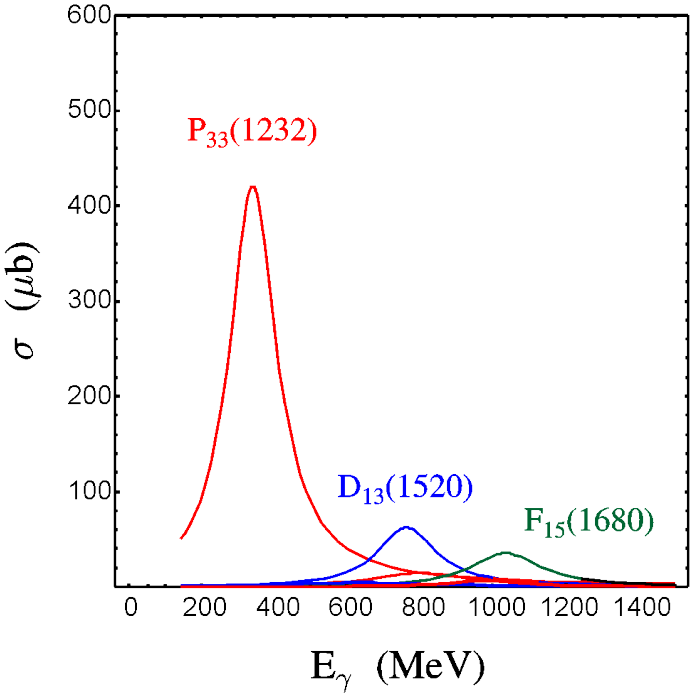
Nucleon properties to be measured

μ	magnetic moment
$\langle r^2 \rangle$	radius (elect. -, mag. -, axial)
	form factor
α, β, γ_i	polarizabilities + form factor
M^*	excitation spectrum
μ^*	transition moment + form factor
$A_{1/2}, A_{3/2}, S_{1/2}$	helicity amplitude

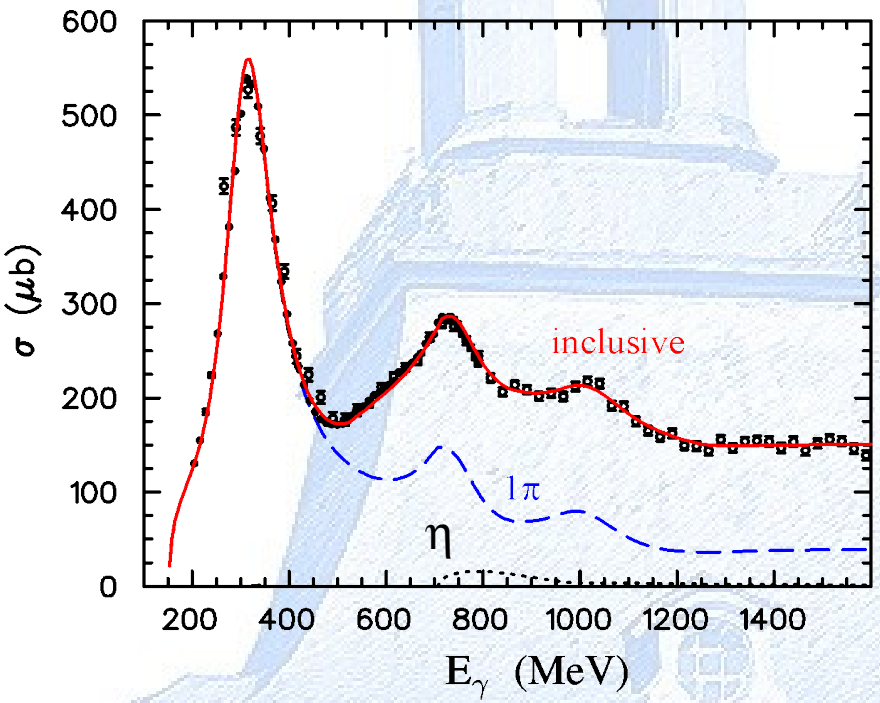
Resonance Structure of the Nucleon

Photoabsorption on the Proton

B-W Resonances in (γ,π)



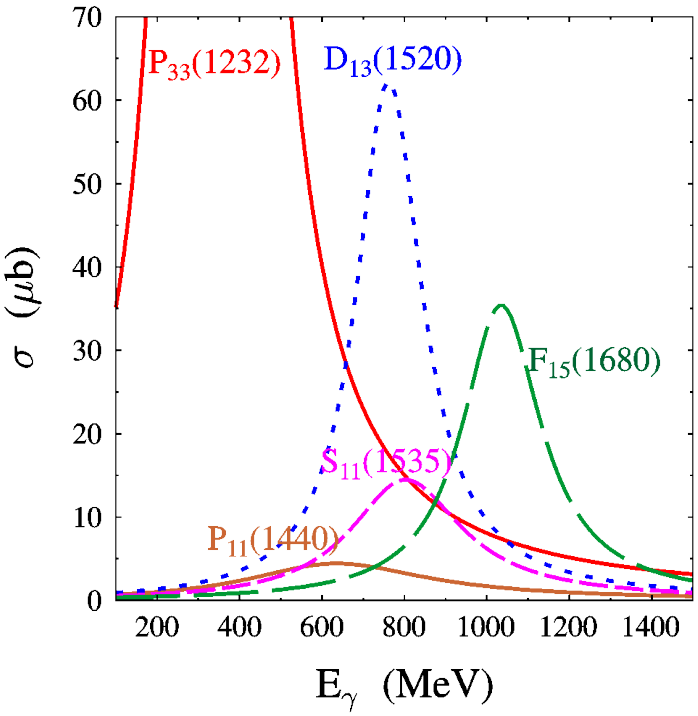
Experiments



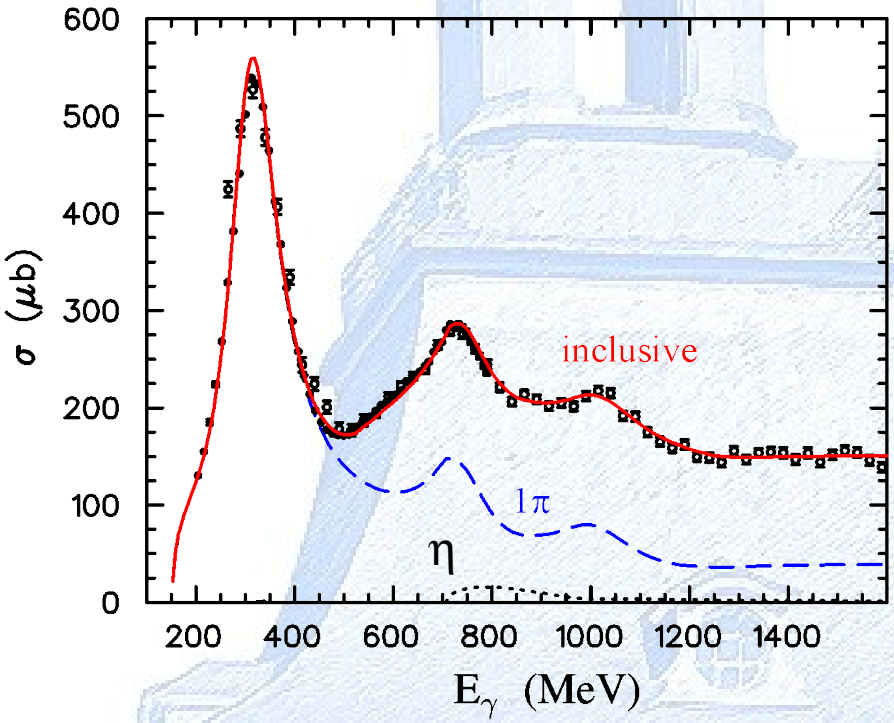
Resonance Structure of the Nucleon

Photoabsorption on the Proton

B-W Resonances in (γ,π)



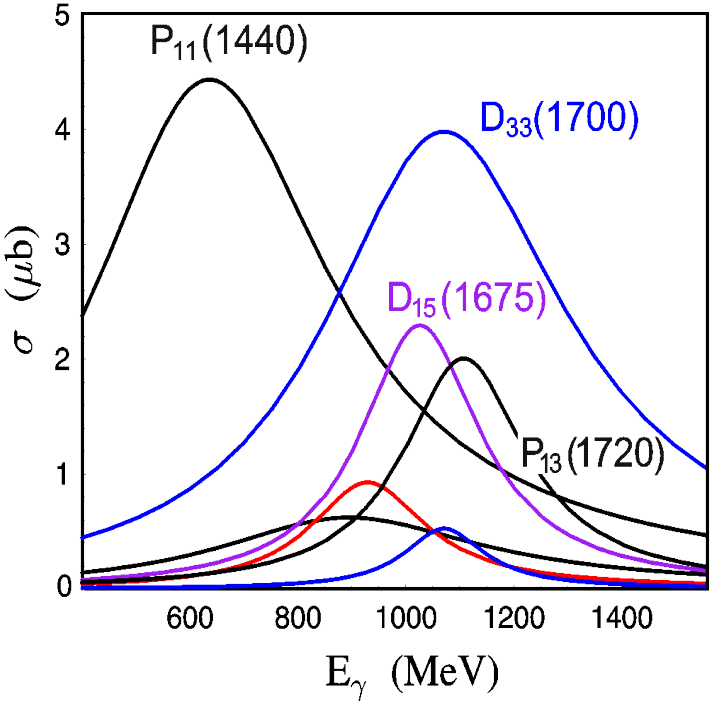
Experiments



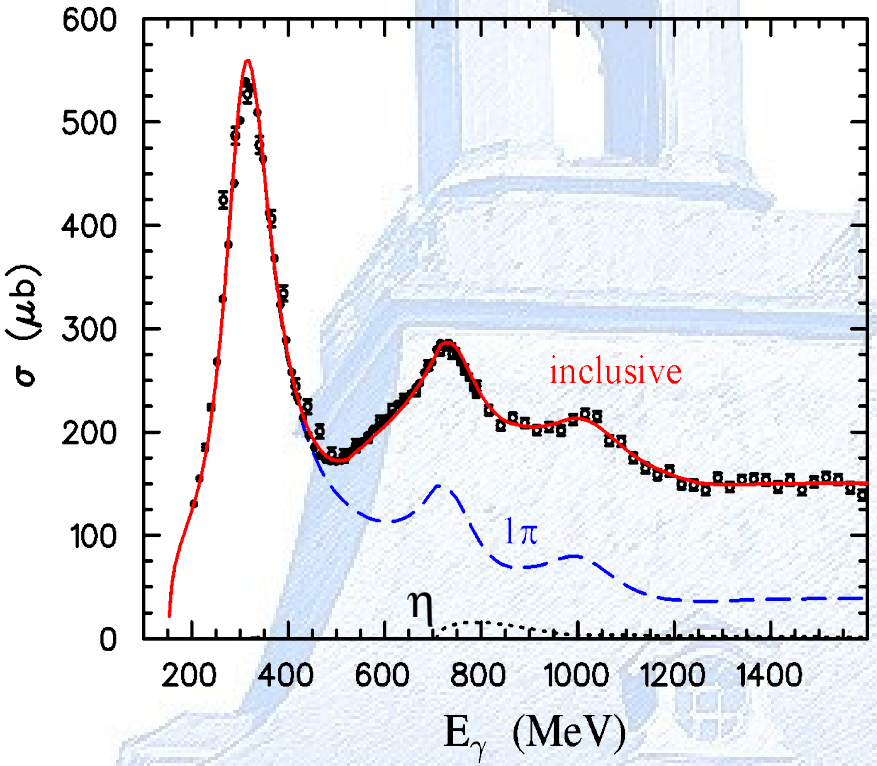
Resonance Structure of the Nucleon

Photoabsorption on the Proton

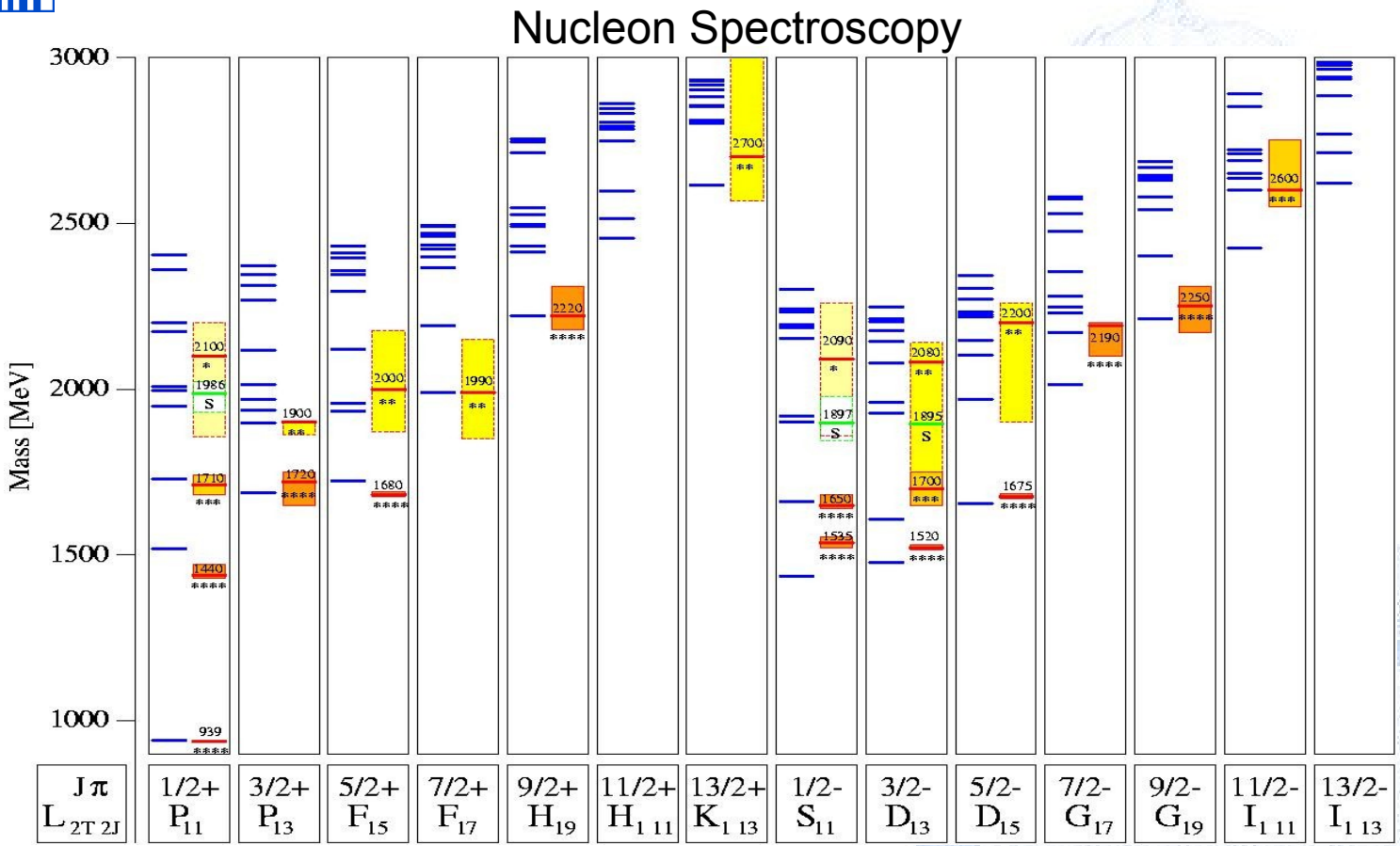
B-W Resonances in (γ,π)



Experiments



Resonance Structure of the Nucleon

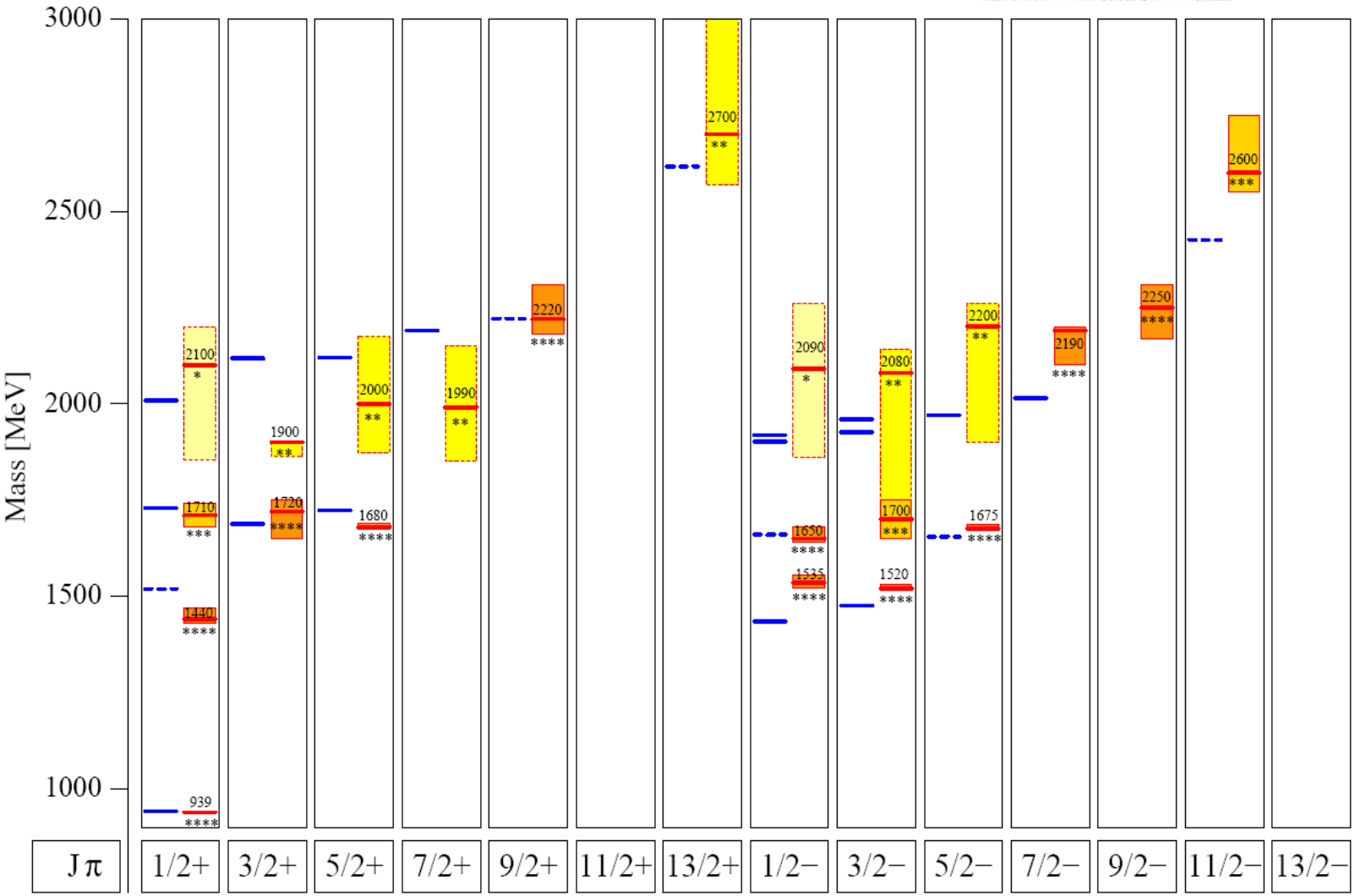


Löhring, Metsch, Petry, EPJ A10, 395(2001)

- Quark models predict many more resonance states than observed by experiments. Why have they not been observed yet? Do they decouple from πN states?
- Investigate inital and final states different from πN, such as ηN, $\eta\pi^0$N, $\pi^0\pi^0$N.

Resonance Structure of the Nucleon

Only strong πN couplings



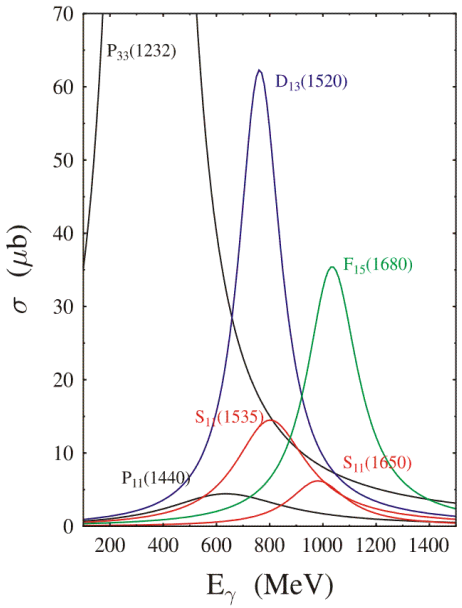
Metsch, pers. comm. 2008

Resonance Structure of the Nucleon

Photo Production in Partial Channels

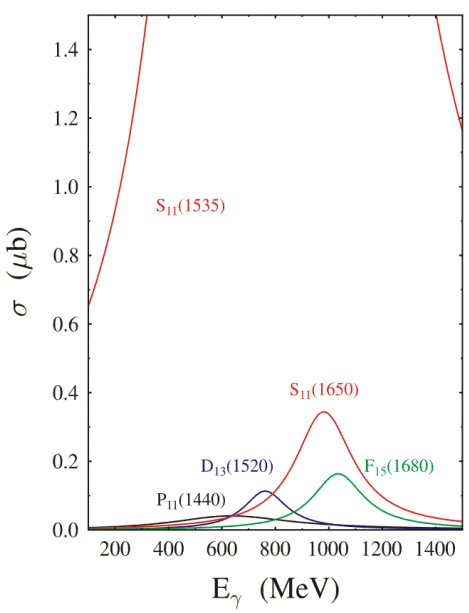
Pion-Production

$\gamma + N \rightarrow N^* \rightarrow N + \pi$



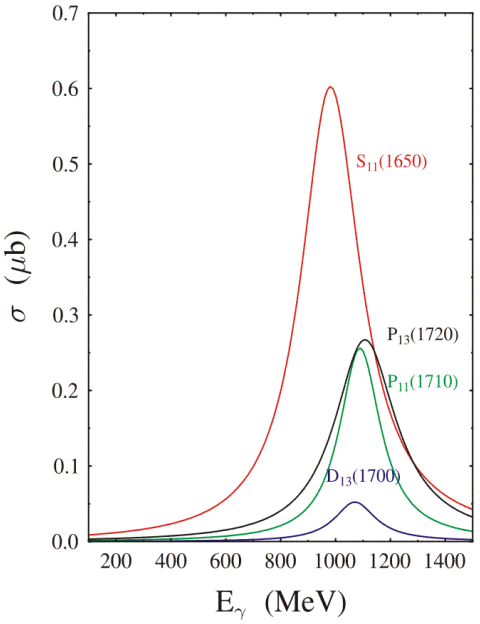
Eta-Production

$\gamma + N \rightarrow N^* \rightarrow N + \eta$



Kaon-Production

$\gamma + N \rightarrow N^* \rightarrow K^+ + \Lambda$



Problem: Overlapping resonances that can not be determined even by observing partial channels.

→ observation of polarization observables

ELSA: Polarized photons and polarized targets available.

Polarized Experiments

Polarization Observables for Photoproduction on the Nucleon

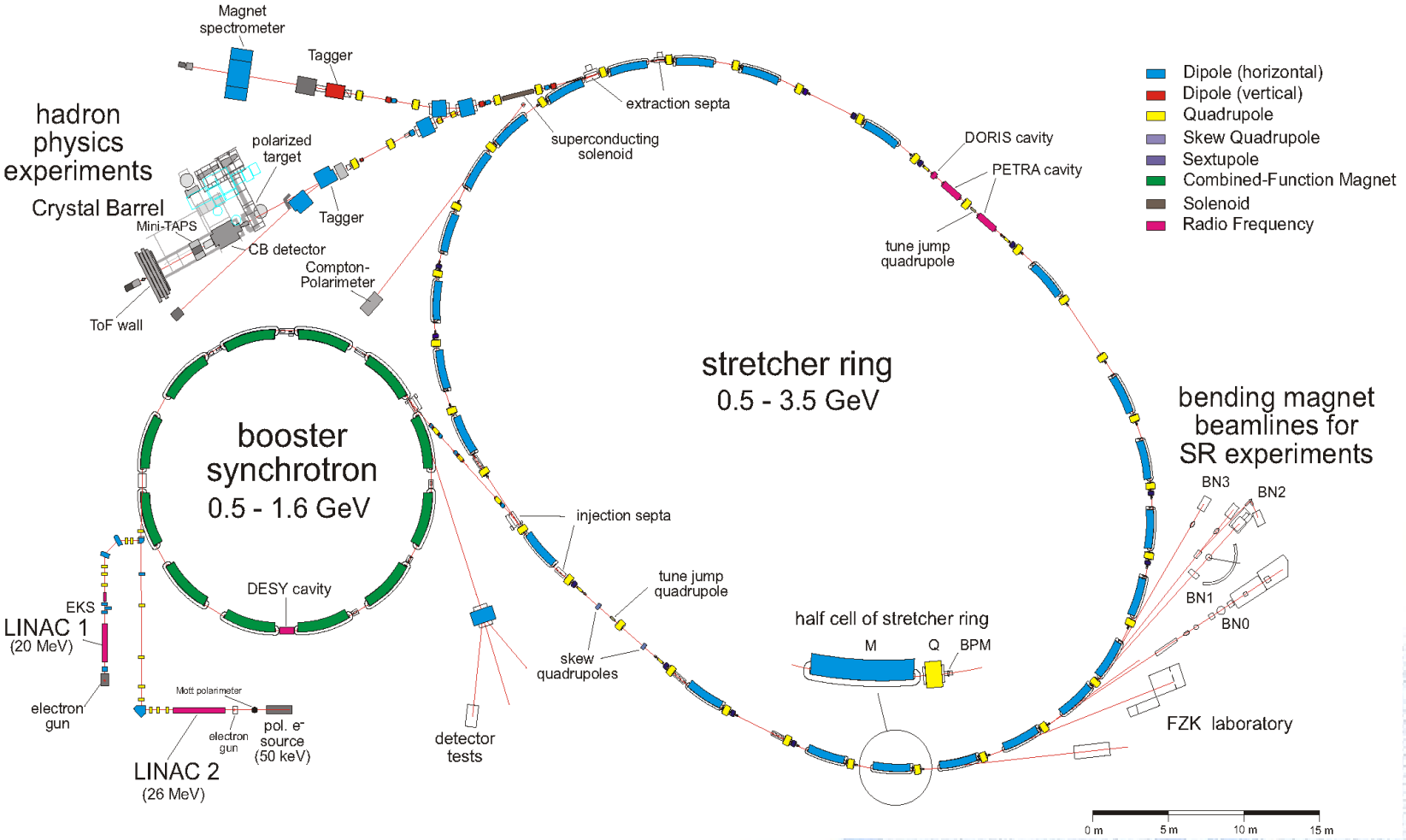
Photon polarization		Target polarization			Recoil Nucl. polarization			Target and Recoil polarizations			
		X	Y	$Z_{(beam)}$	X′	Y′	Z′	X′ X	X′ Z	Z′ X	Z′ Z
unpolarized	σ	-	T	-	-	P	-	T_x	L_x	T_z	L_z
linear	Σ	H	(-P)	G	O_x	(-T)	O_z	$(-L_z)$	(T_z)	(L_x)	$(-T_x)$
circular		F	-	E	C_x	-	C_z	-	-	-	-

1 unpolarized measurement

3 single polarization measurements

12 double polarization measurements

Electron Stretcher Accelerator (ELSA)



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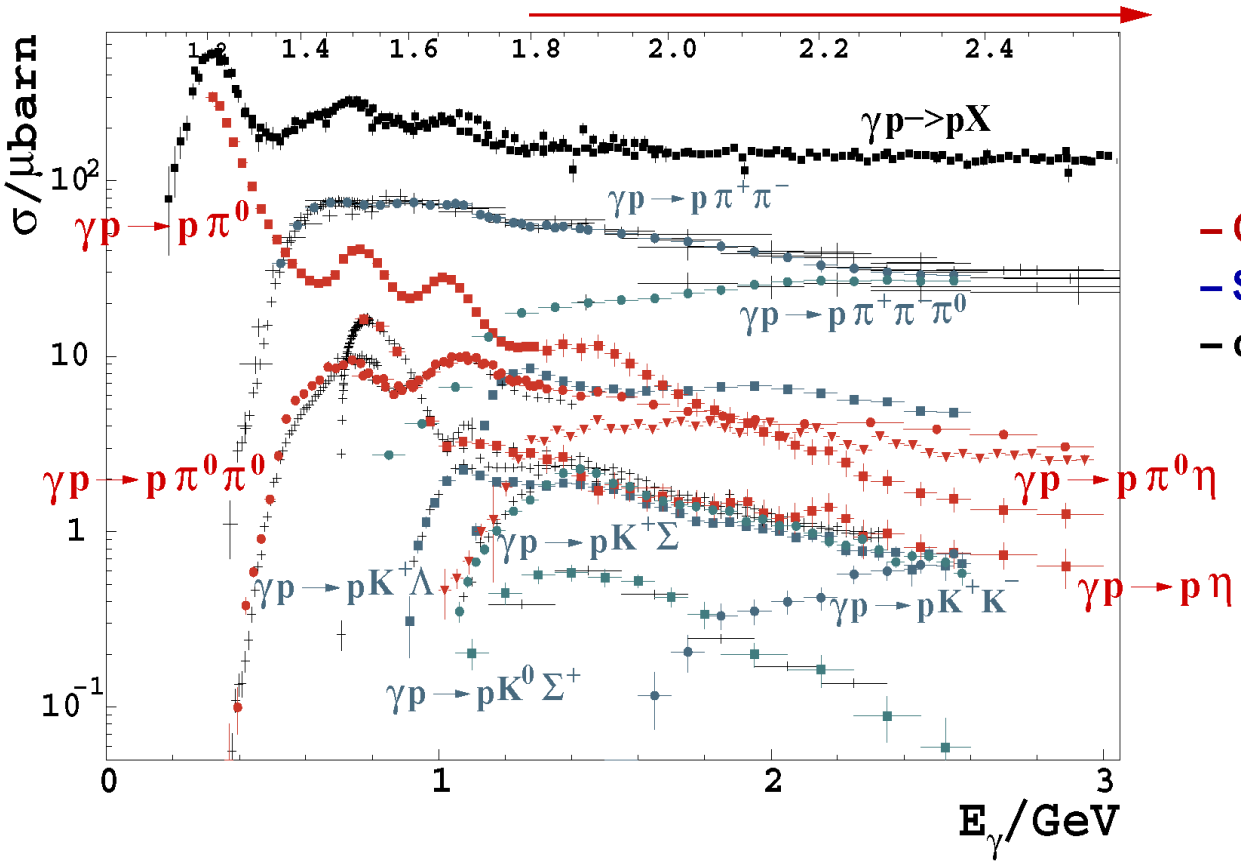
Results

Photo-Production Cross-Sections

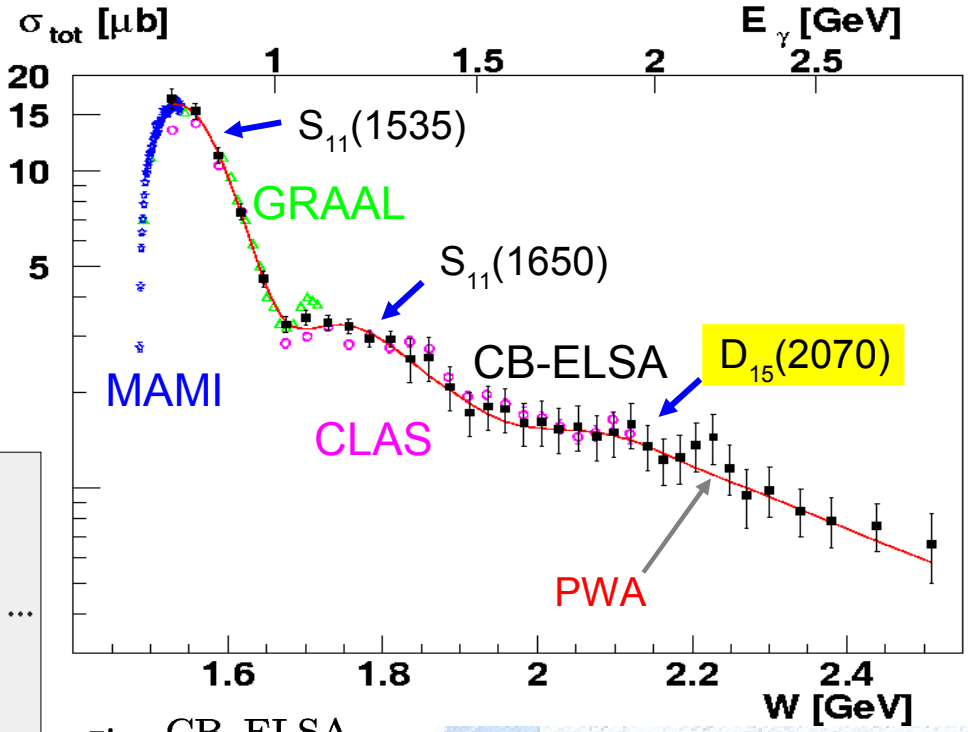


– CB-ELSA data ,
– SAPHIR data (ELSA) ,
– other experiments

Results

$\gamma + p \rightarrow p + \eta$

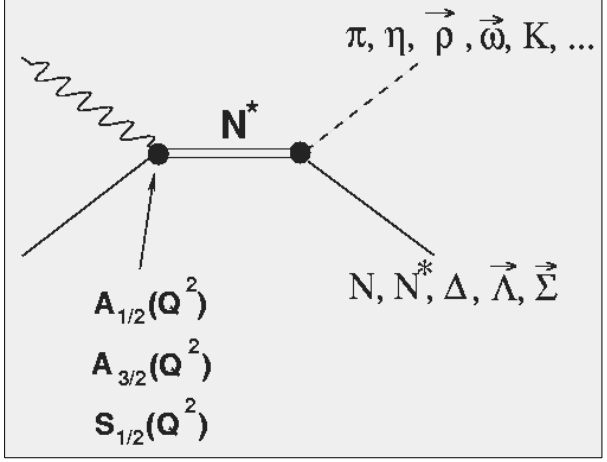
Nucleon Spectroscopy



■: CB–ELSA
☆: TAPS
△: GRAAL
○: CLAS

V. Crede, O. Bartolomy et al.,
PRL 94 (2005) 012004,
new: EPJ A33 (2007) 133

Meson photoproduction

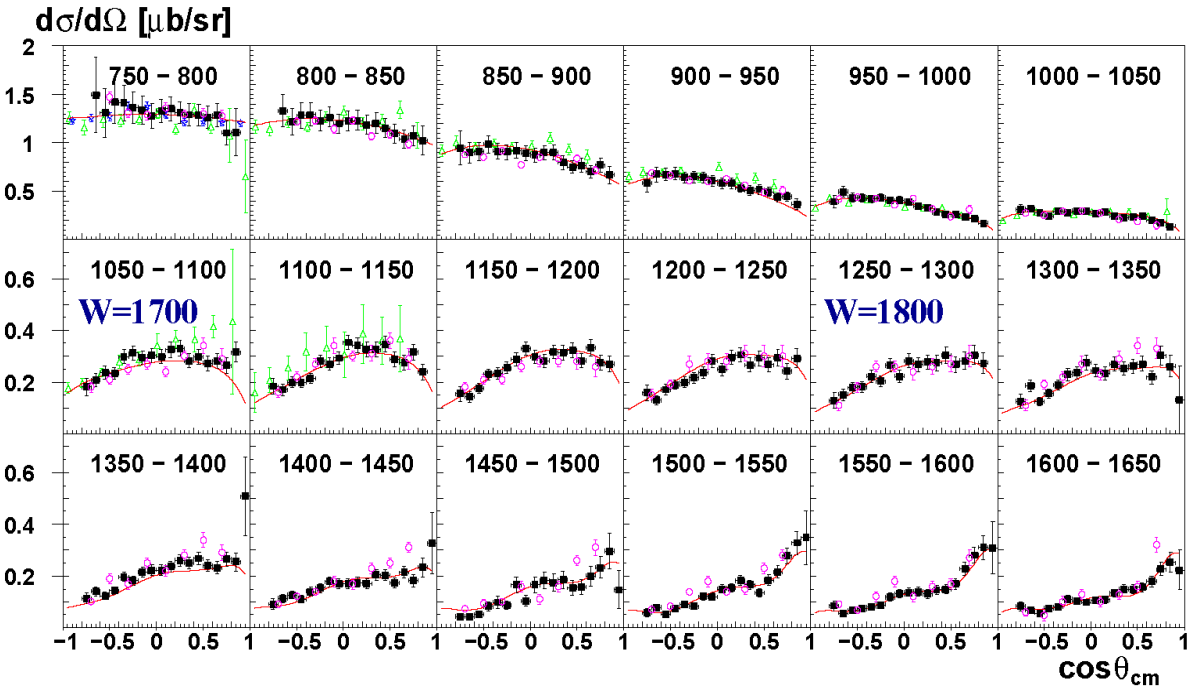


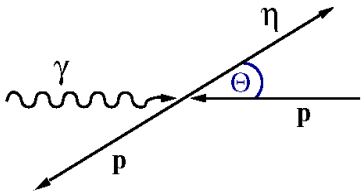
Results

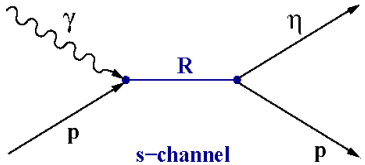
$\gamma + p \rightarrow p + \eta$

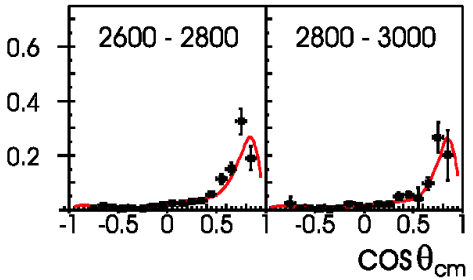
■ CB-ELSA △ GRAAL ○ CLAS ★ TAPS — CB-ELSA fit

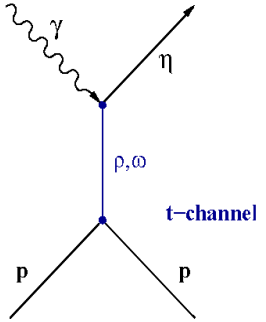
V.Crede, O.Bartholomy et al., PRL 94, 012004 (2005)











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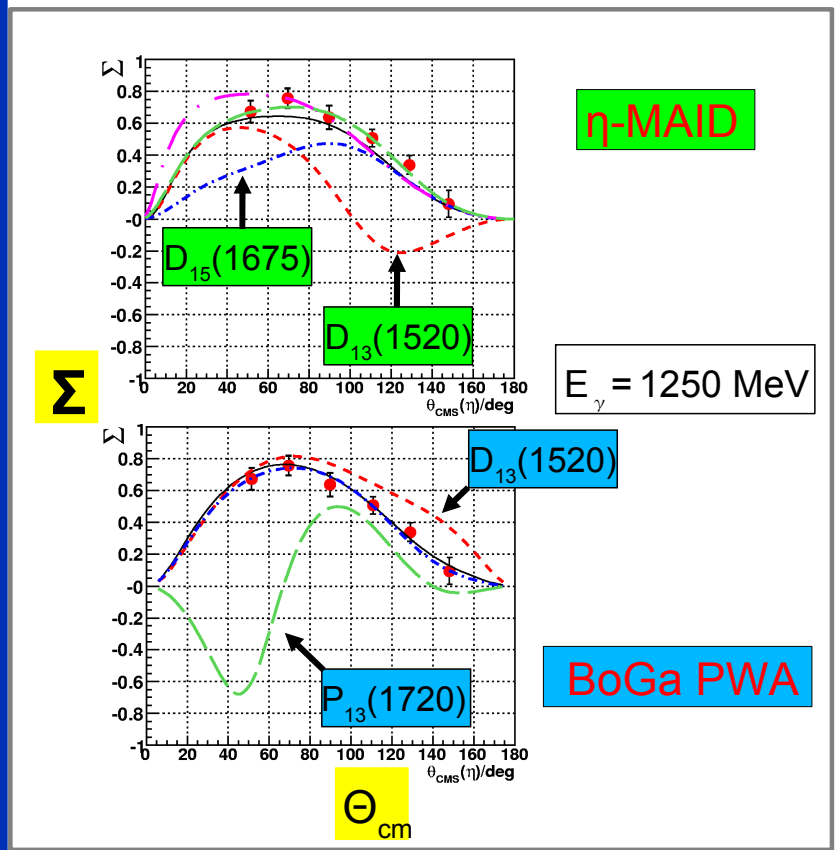
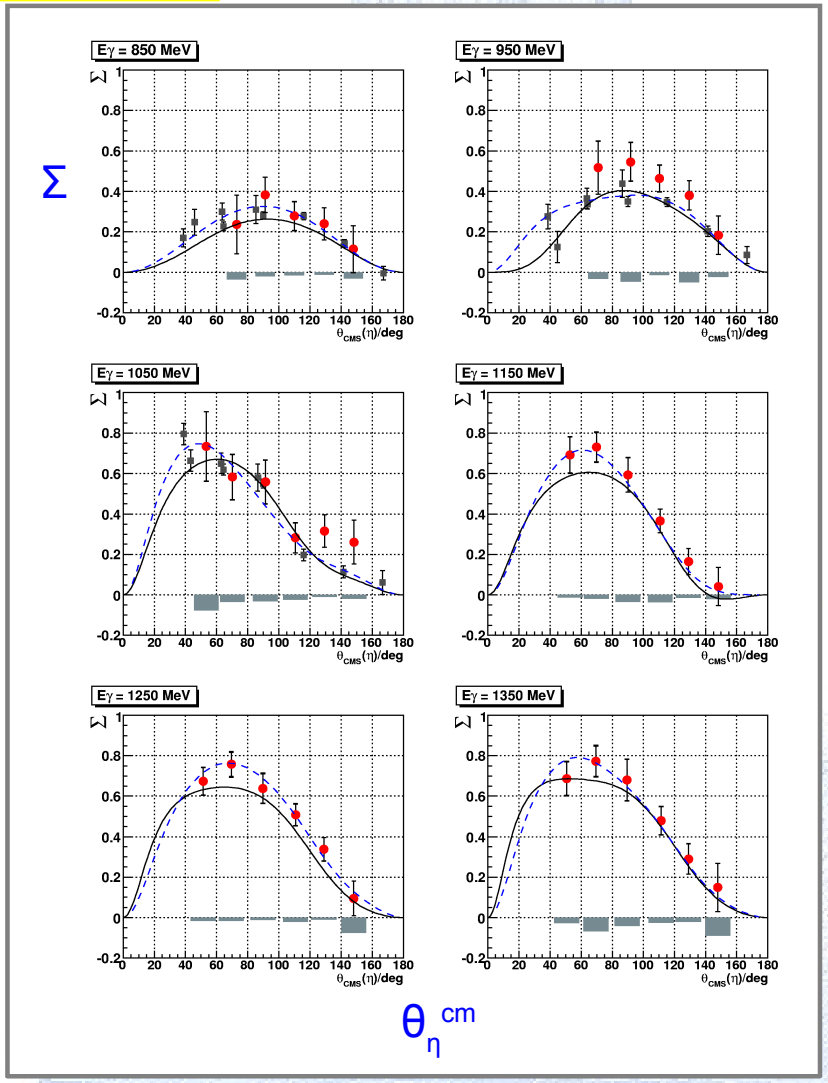
Results

$\vec{p}\,(\gamma,\eta)\,p$ linear polarisation

D. Elsner et al., EPJ A33 (2007) 147



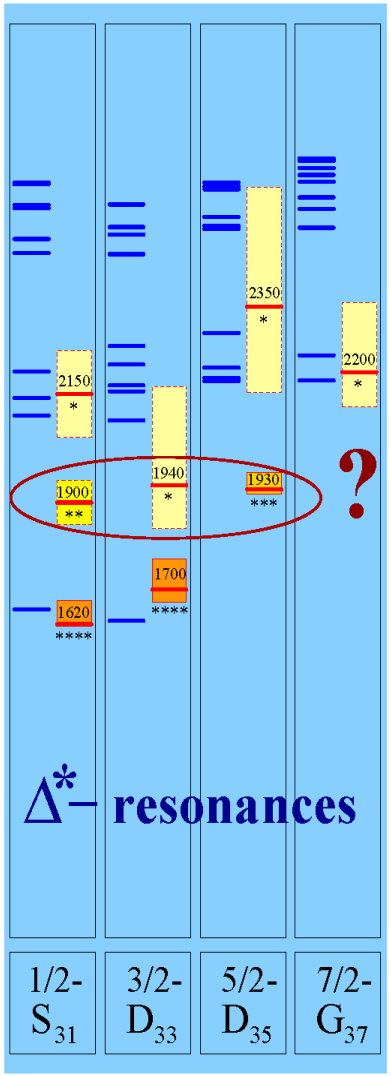


GRAAL: J. Ajaka et al., PRL 81
new: O. Bartalini et al., arXiv:0707.1385

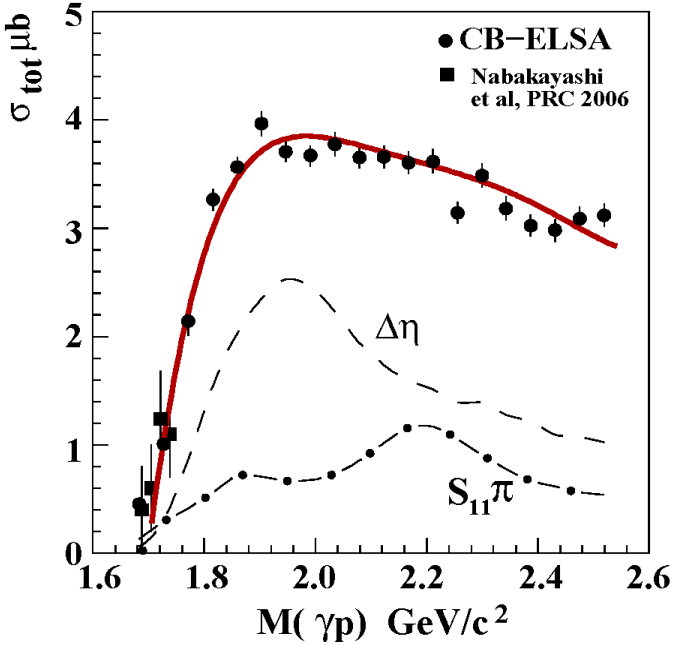
Results

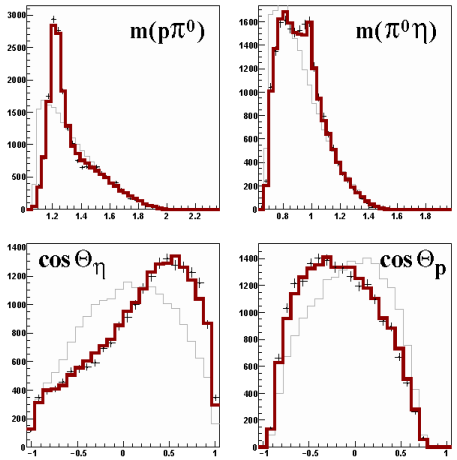
$\gamma p \to p\pi^0\eta$ CB-ELSA

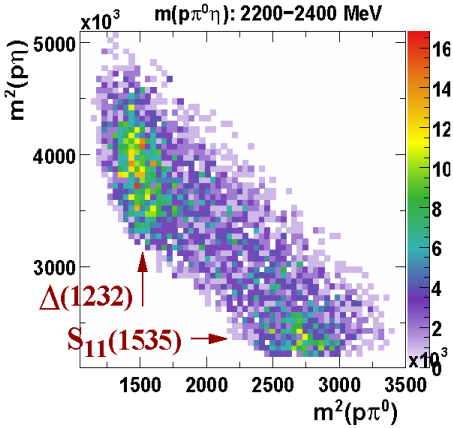
I.Horn, Bonn



Total cross section







Event based maximum likelihood fit:

$\Rightarrow D_{33}(1940)$ **clearly contributes**

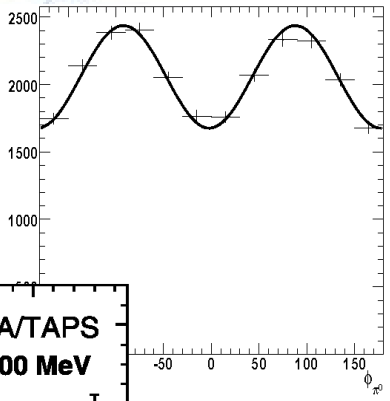
U. Loering et al.

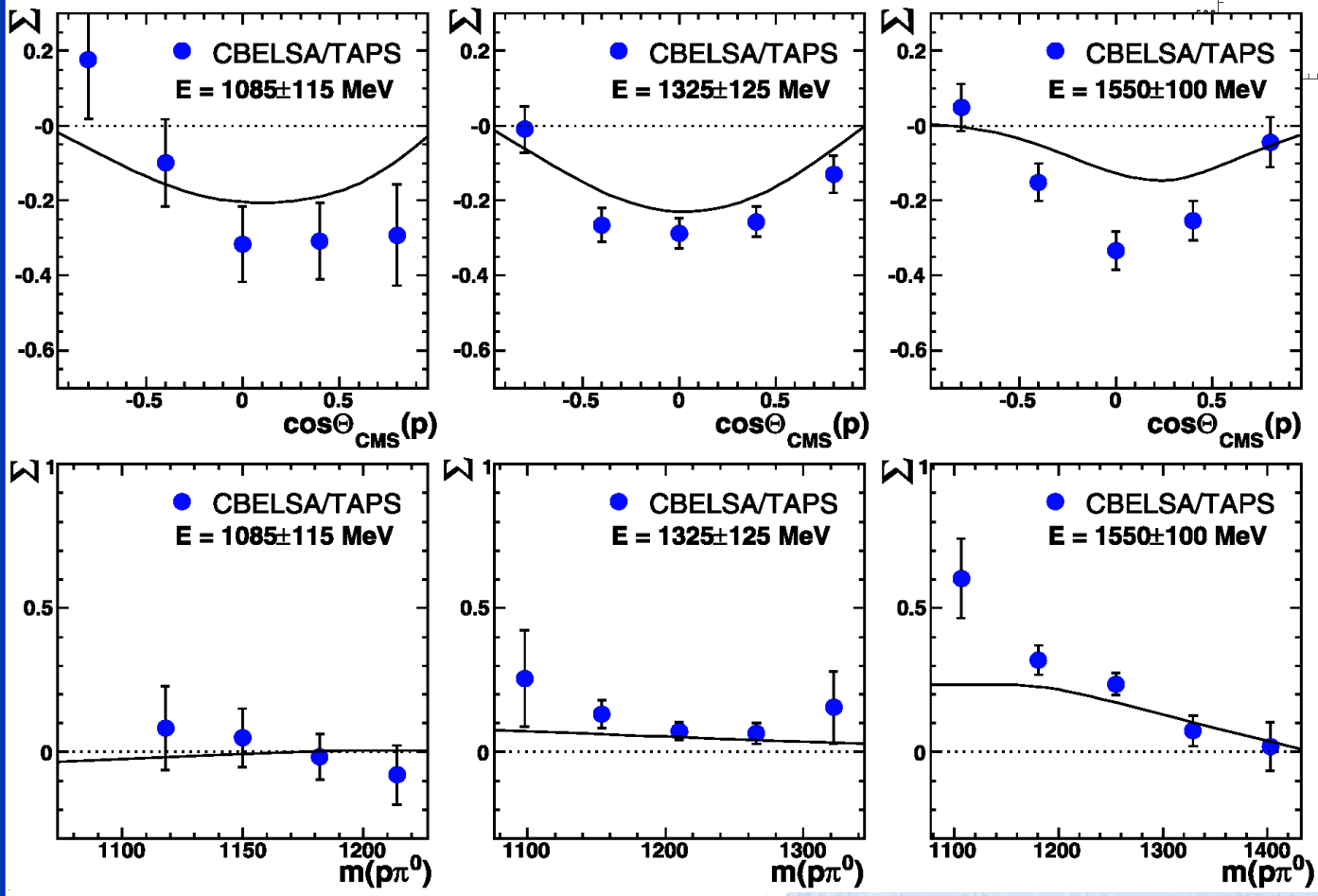
Results

$\vec{\gamma}p \rightarrow p\pi^0\eta$ - CBELSA/TAPS -

linear polarization

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 (1 - \delta_l(\Sigma \cos 2\phi + I^s \sin 2\phi))$$



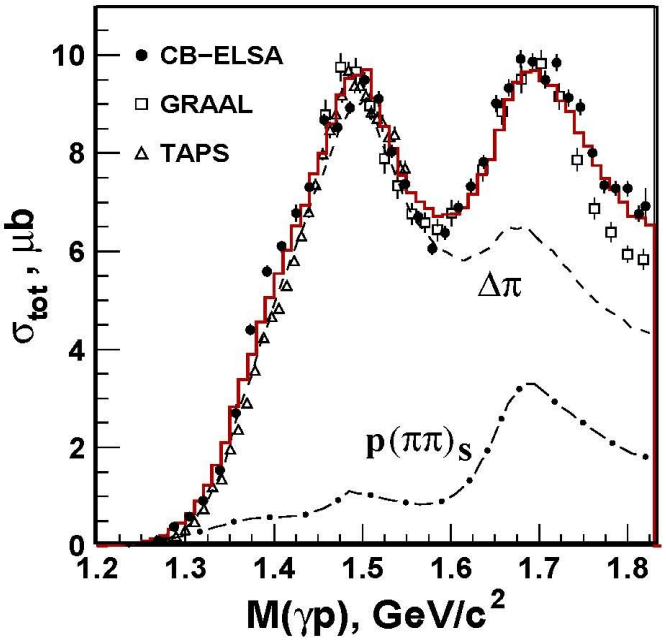


— PWA prediction

E.Gutz et al., EPJ A 35, 291 (2008)

Results

$p(\gamma,\pi^0\pi^0)p$



U. Thoma et al., PLB 659 (2008) 87

CB-ELSA Fit including additional data from:

- single meson photoproduction,
- $\pi^- p \longrightarrow n2\pi^0$ (CBall),
- $P_{11}, S_{11}, P_{33}, D_{33}$ - πN-partial waves

$\leftrightarrow$ Event based maximum likelihood fit

$\Rightarrow$ Determination of resonance properties:

$m\,,\,\Gamma_i\ (\Delta\pi^0, N\sigma, P_{11}\pi, D_{13}\pi, +...)$

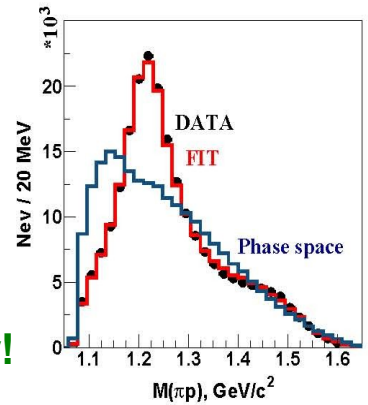
Results contradicting naive expectation:

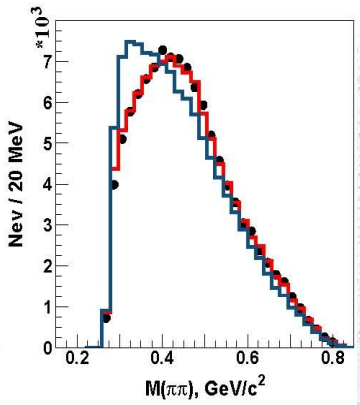
e.g.: $D_{13}(1520) \longrightarrow \Delta\pi$ decay with L=0 $\approx$ L=2

$D_{13}(1700) \longrightarrow \Delta\pi$ decay with L=0 $<$ L=2

$D_{33}(1700) \longrightarrow \Delta\pi$ decay with L=0 or L=2

Measurement of pol. observables necessary!





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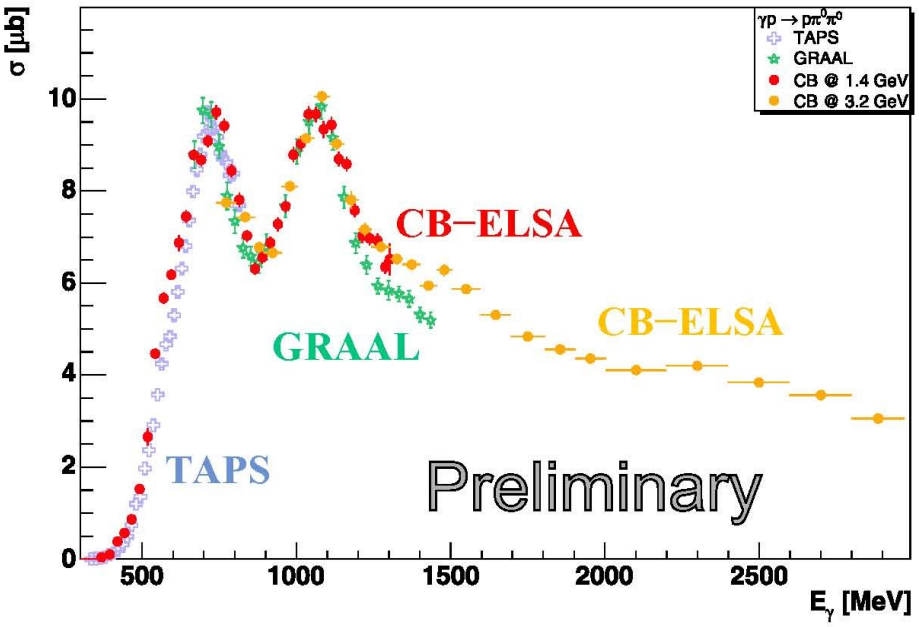
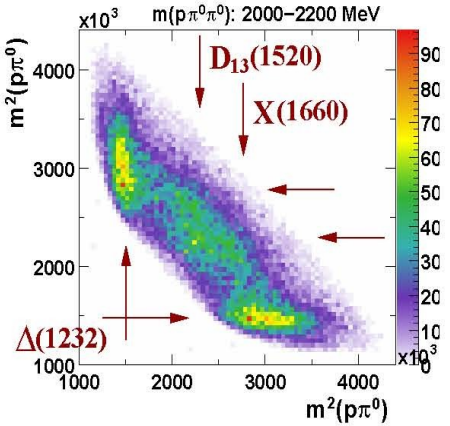
Results

$p(\gamma,\pi^0\pi^0)p$



M. Fuchs, Bonn

Partial wave analysis of high energy data in progress



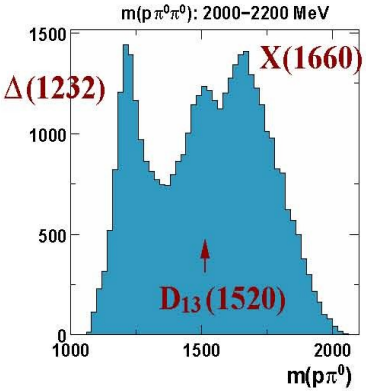
Clear observation of baryon cascades:

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

$$\gamma p \rightarrow N^*/\Delta^* \rightarrow D_{13}(1520)\,\pi$$

$$\gamma p \rightarrow N^*/\Delta^* \rightarrow N^*/\Delta^*\,(\sim 1660)\,\pi$$

→ **Observed for the first time in this data**



Polarized Experiments

Polarization Observables for Photoproduction on the Nucleon

Photon polarization		Target polarization			Recoil Nucl. polarization			Target and Recoil polarizations			
		X	Y	$Z_{(beam)}$	X'	Y'	Z'	X' X	X' Z	Z' X	Z' Z
unpolarized	σ	-	T	-	-	P	-	T_x	L_x	T_z	L_z
linear	Σ	H	(-P)	G	O_x	(-T)	O_z	$(-L_z)$	(T_z)	(L_x)	$(-T_x)$
circular		F	-	E	C_x	-	C_z	-	-	-	-

currently investigated

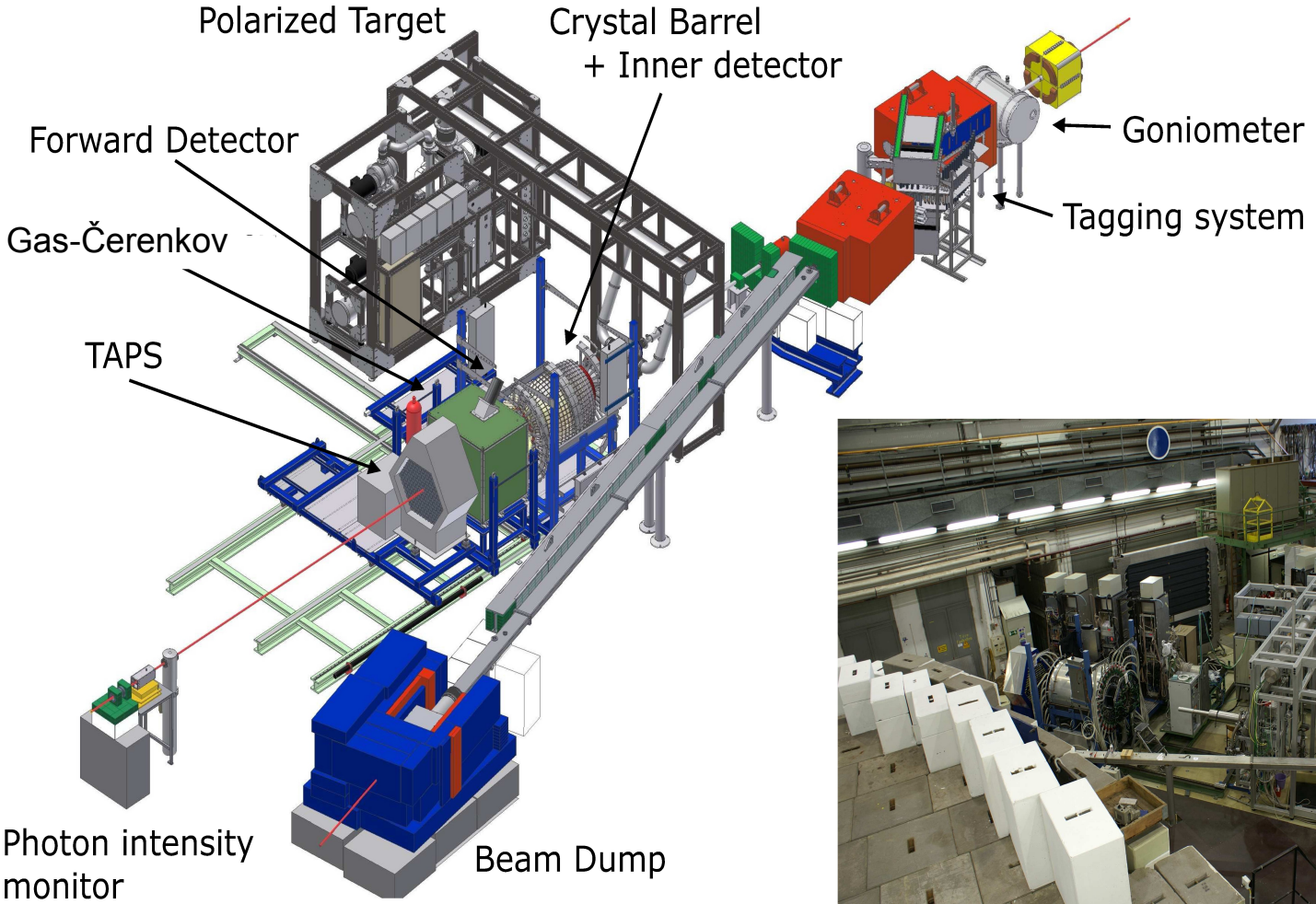
1 unpolarized measurement

3 single polarization measurements

12 double polarization measurements

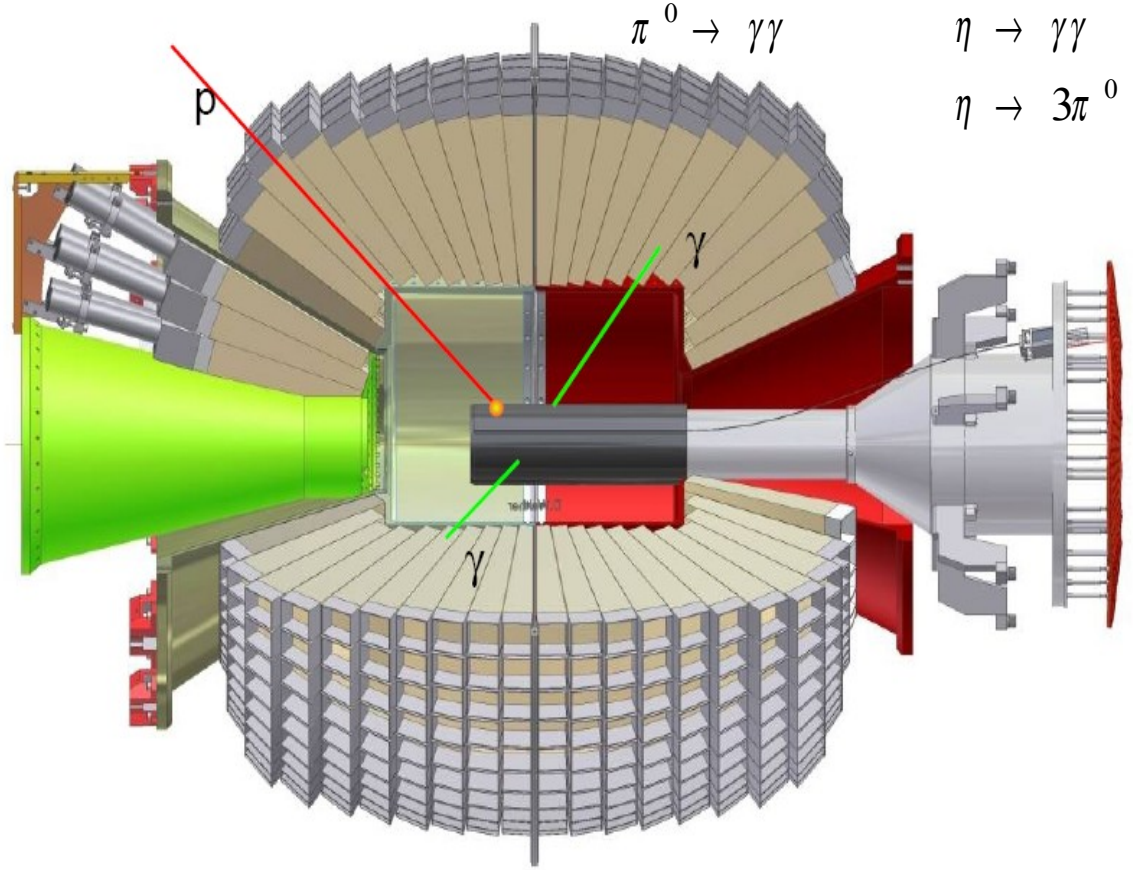
The CB-ELSA / TAPS Experiment

Experiments with: - linearly or circularly polarized photon beam
- longitudinally polarized frozen spin butanol target



The Crystal Barrel Detector

- CB detector: 1230 CsI(Tl) detectors.
- Inner detector: cylinder of 513 scintillating fibers.
- Forward detector: 90 CsI(Tl) with PMs for 12° - 30°.
- Forward detector MiniTAPS: 216 BaF_2 , 1° - 12°.
- CO_2 gas Čerenkov detector.



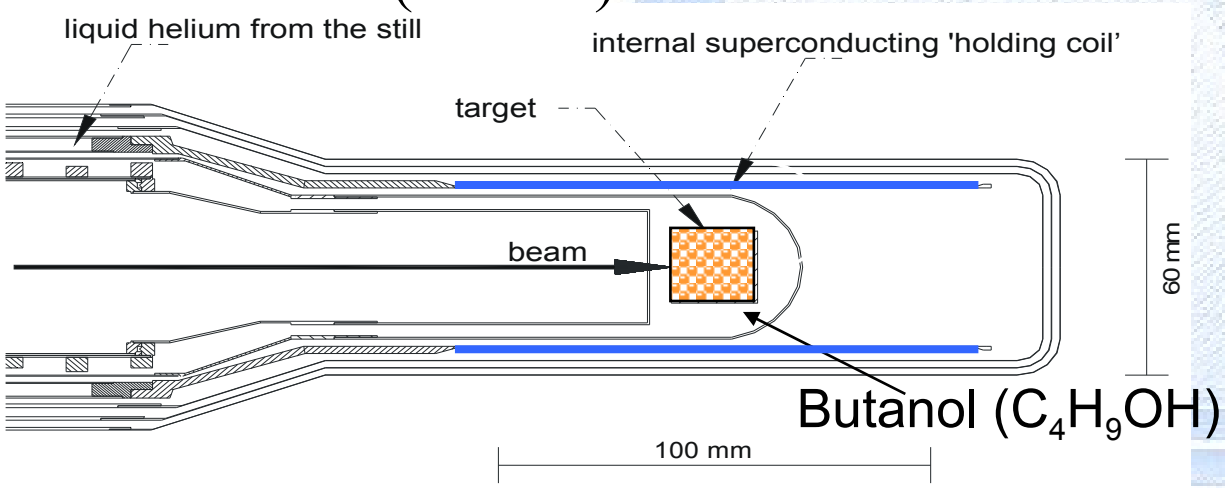
The Bonn Polarized Target

„Frozen Spin Mode“

- Polarization : DNP at high B-Field (2.5 T)
- Measurement : very low T ($\lesssim 50\,mK$)
  relaxation time > 400h (in 2008)
  ´freeze´ the spin (0.4 Tesla)

New Technology: horizontal cryostate with integrated solenoid (holding field)
1.2 Kelvin
0.42 Tesla

Second Location: Mainz (MAMI)



Polarized Experiments

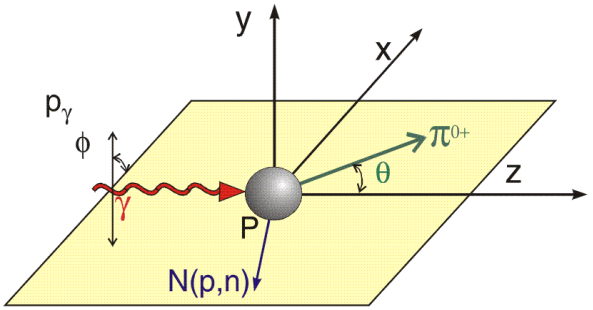
Polarization Observables

$$\vec{\gamma}\ \vec{p} \rightarrow p\ \pi^0$$

Linearly polarized photons: p_γ^{Lin}

Circularly polarized photons: p_γ^{Cir}

Longitudionally polarized protons: p_z

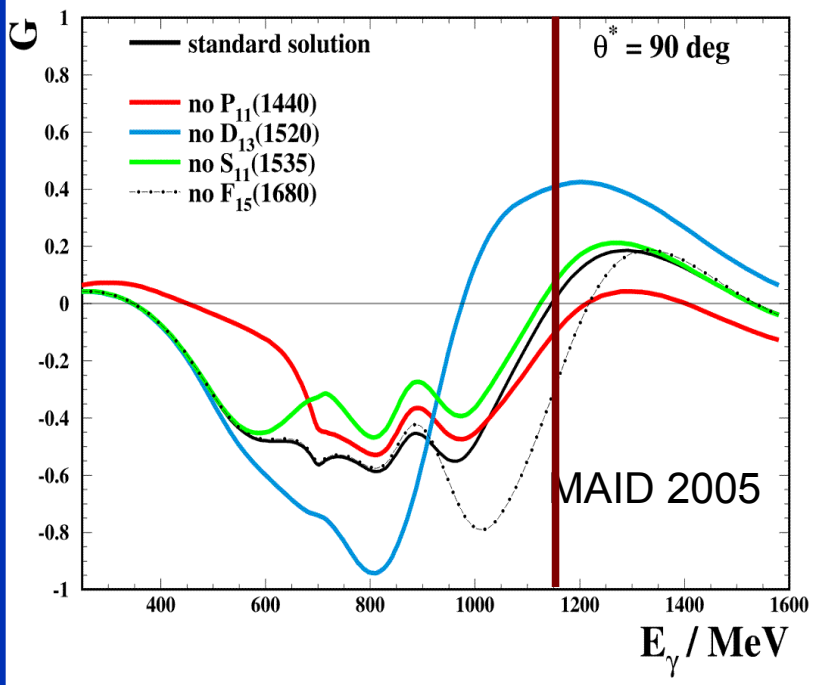


$$\frac{d\sigma}{d\Omega}(\theta,\phi) = \frac{d\sigma}{d\Omega}(\theta)\left(1 - p_\gamma^{Lin}\Sigma\cdot\cos(2\phi) - p_\gamma^{Lin}\,p_z G\cdot\sin(2\phi) + p_\gamma^{Cir}\,p_z E\right)$$

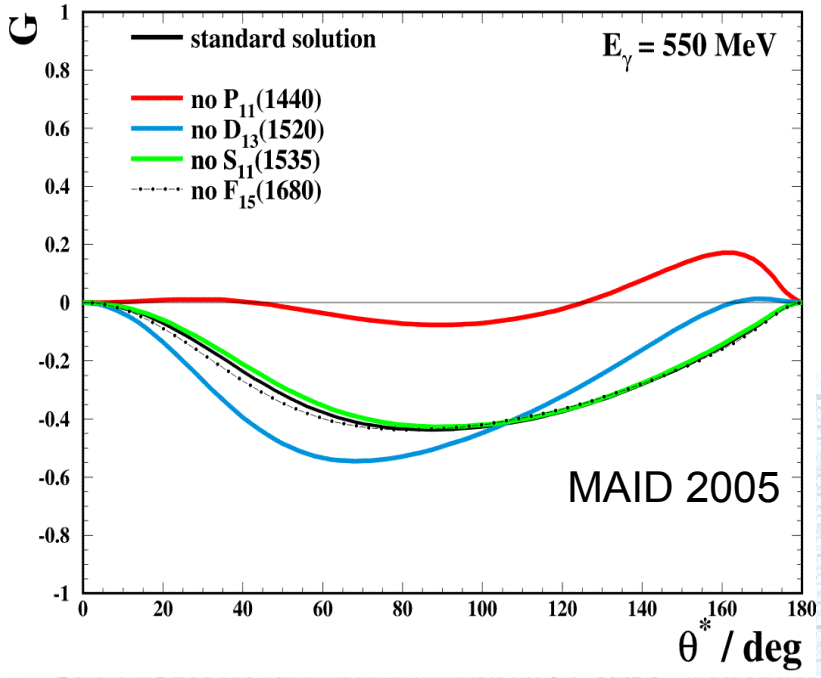
Observable G in π Photo-Production

$$\vec{\gamma}\ \vec{p} \rightarrow p\ \pi^0$$

Energy dependence

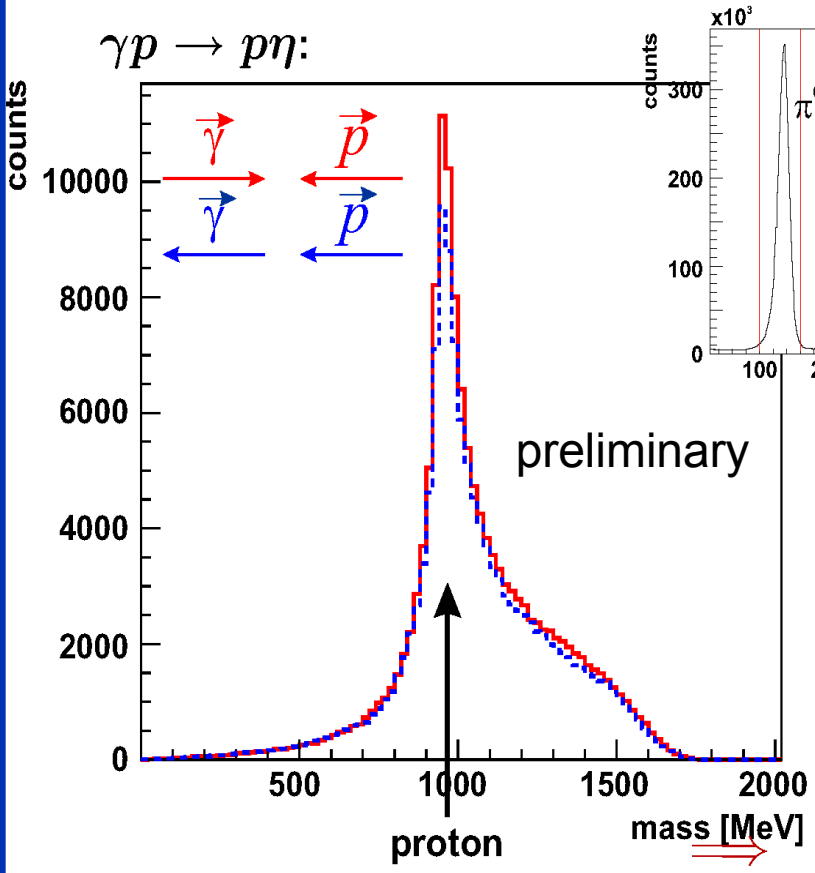


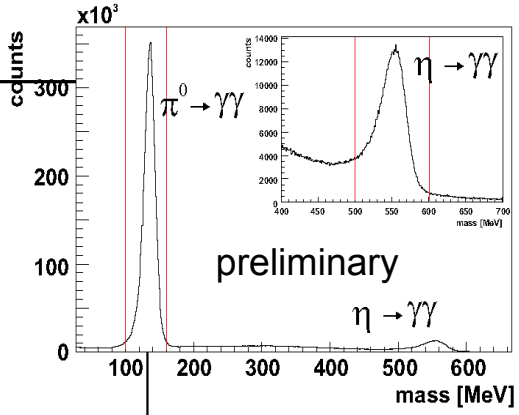
Angular dependence



Preliminary Results

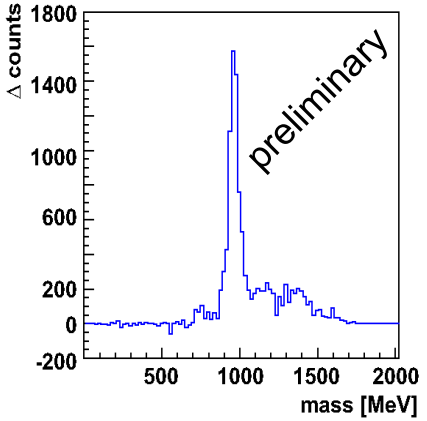
Online spectra: circularly polarised beam, longitudinally polarised target



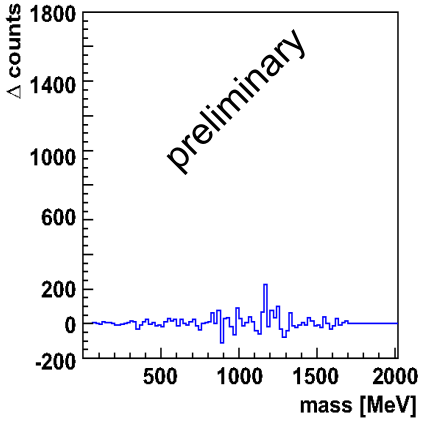


$\gamma p \rightarrow p\gamma\gamma$

difference



unpolarised difference



⇒ **First asymmetries observed**

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Summary and Outlook

- Photo-production can be used to explore the resonance structure of nucleons.
- The Breit-Wigner parametrization shows many overlapping resonances.
- Quark models show many more resonances than observed, yet.
- If these resonances decouple from πN states, they could probably be observed in ηN, $\eta\pi^0$N, $\pi^0\pi^0$N.
- Experiments to measure the unpolarized cross section of photo-production reactions and the single polarization observable Σ have been carried out at ELSA (SAPHIR, CB, CB-ELSA, ...).
- Polarization observables open up new degrees of freedom to better understand resonance contributions in photo-production on the nucleon.
- The CBELSA-TAPS experiment is a new experiment carried out at ELSA to measure double polarization values.
- The first topics on schedule are the measurement of the observables E and G.
- The measurement has been started in Summer 2007 and first preliminary results were shown from runs with circularly polarized photons (E) and linearly polarized photons (G).