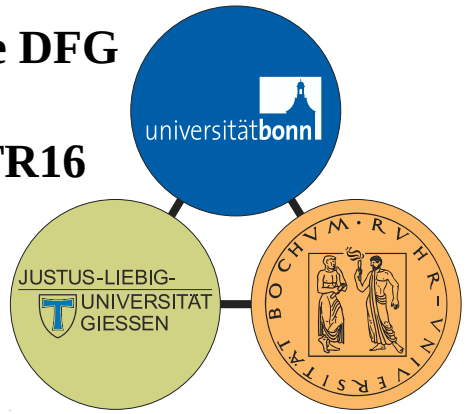
Baryon Spectroscopy: Recent Results from the Crystal Barrel/TAPS Experiment at ELSA

U.Thoma, Bonn University
for the CBELSA/TAPS collaboration

- Introduction
- η- photoproduction
- $2\pi^0$- photoproduction
- Double polarisation experiments at ELSA
- Summary

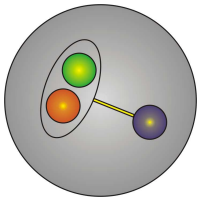
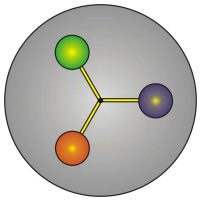
funded by the DFG
within the
SFB/TR16



Baryon spectroscopy

Aim: Good understanding of the spectrum and the properties of baryon resonances $\leftrightarrow$ bound states of strong QCD

- What are the relevant degrees of freedom ?
- Effective forces between them ?

e.g.:  or  ?

Symmetric quark models:

$\longrightarrow$ many more resonances expected than observed yet
- certain configurations completely missing !

- Certain configurations not realised by strong QCD ? Why ?
- Experimentally not found yet (resonances might decouple from πN)

$\leftrightarrow$ **Photoprod. experiments e.g.** $\gamma p \rightarrow N\eta,\ N\eta',\ N\omega,\ \Delta\pi,\ N\rho,\ \Delta\eta,\ \ldots$

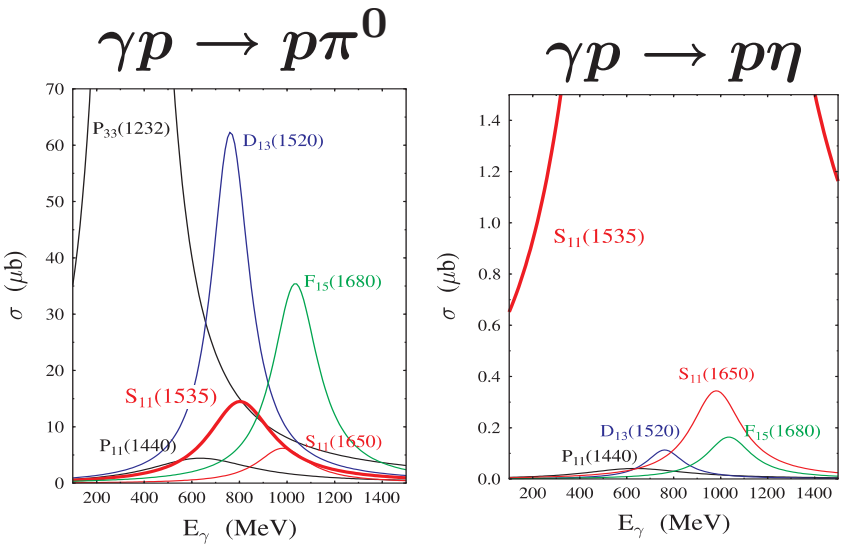
Experimentally:

Broad strongly overlapping resonances

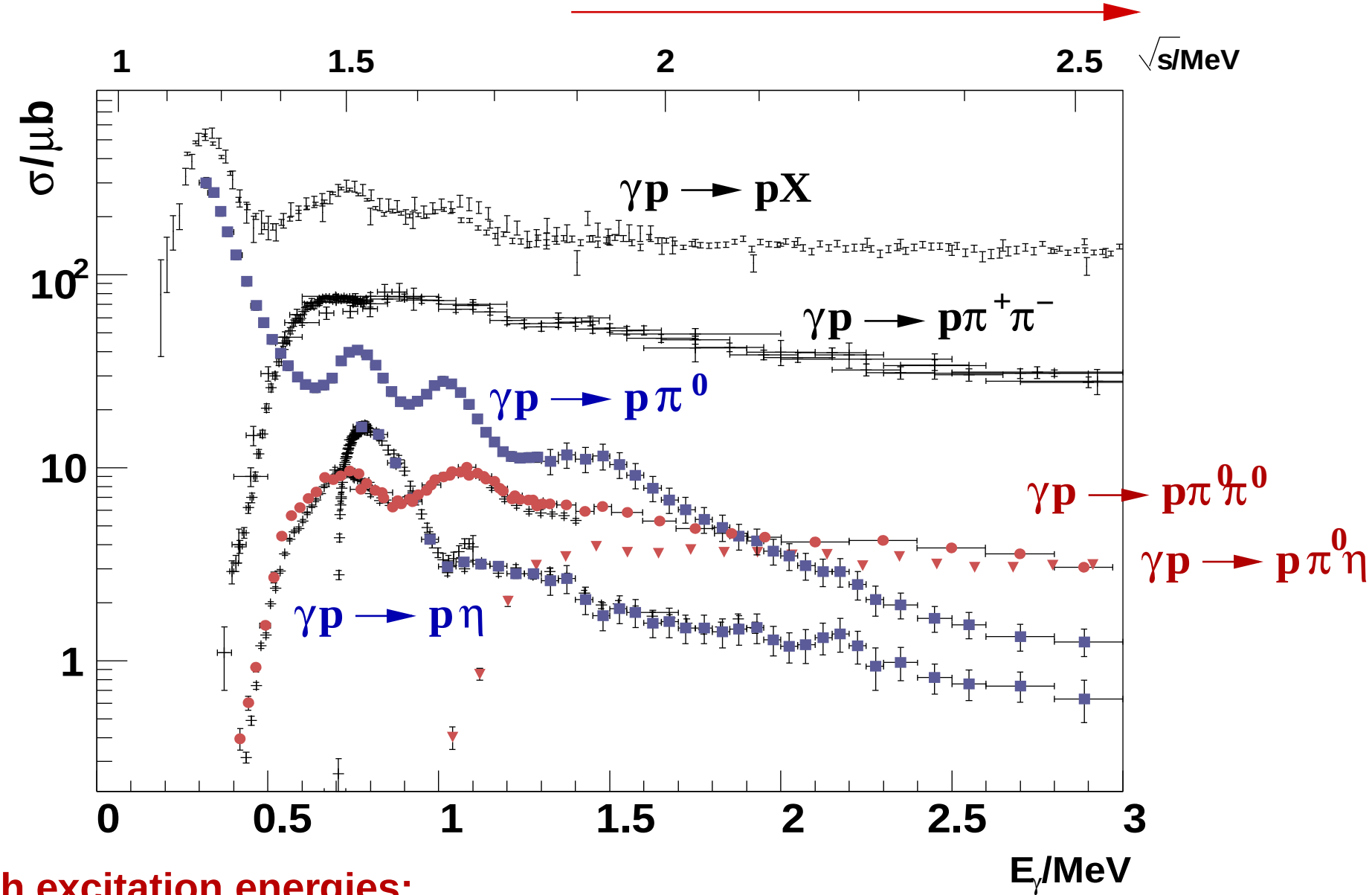
Important:

$\longrightarrow$ **Measurement of polarisation observables (unambigiuos PWA)**

$\longrightarrow$ **Investigation of different final states**



Photoproduction cross sections

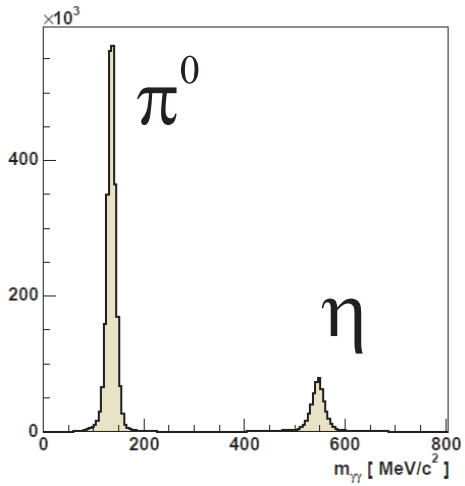


At high excitation energies:

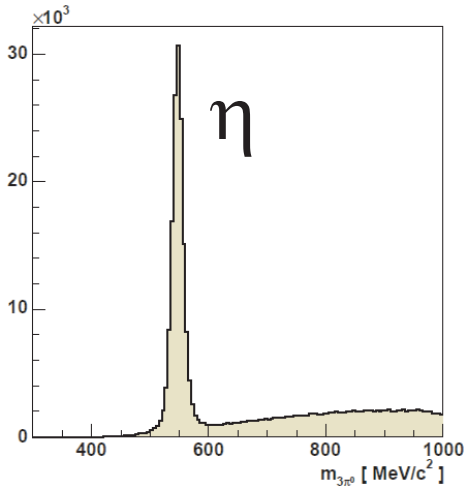
Multi-meson final states play a role of increasing importance

η - Photoproduction

$\eta \longrightarrow \gamma\gamma$



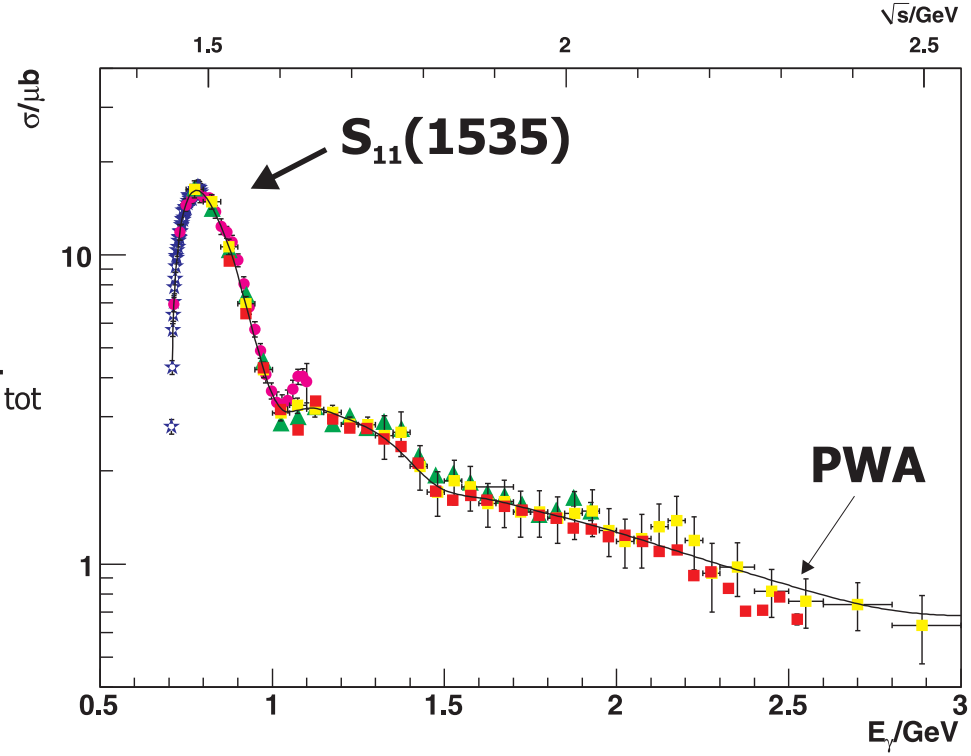
$\eta \longrightarrow 3\pi^0$



$d\sigma/d\Omega$

PWA

σ_{tot}



$S_{11}(1535)$, $D_{13}(1520)$, $S_{11}(1650)$, $F_{15}(1680)$, $P_{13}(1720)$, $D_{13}(2080)$ + ... + ρ -, ω -t-channel exchange

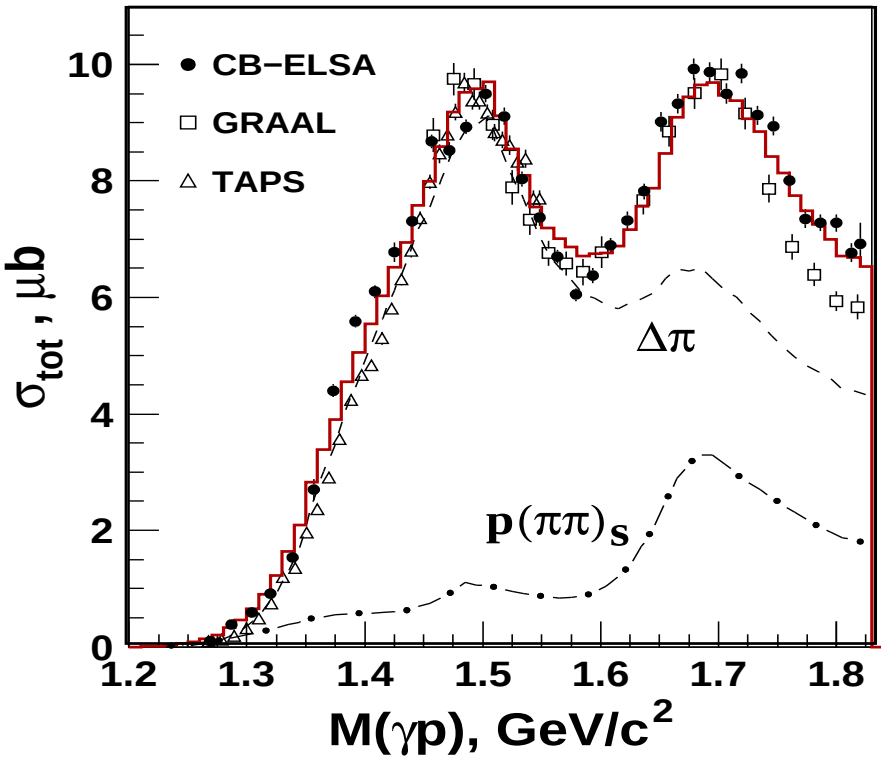
+ new D_{15}: m = 2068 $\pm$ 22 MeV,

Γ = 295 $\pm$ 40 MeV

(needed: confirmation in polarisation exp.)

$\longleftrightarrow$ **No need for a 3rd S_{11}!**

Multiparticle final states: $\gamma p \longrightarrow p\pi^0\pi^0$



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

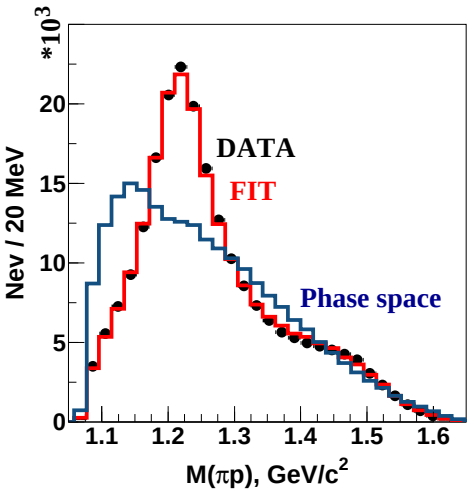
Results contradicting naive expectation:

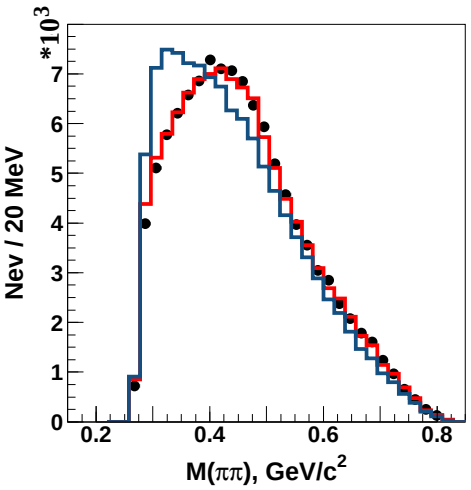
e.g.: $D_{13}(1520) \longrightarrow \Delta\pi$ decay with L=0 $\approx$ L=2

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

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

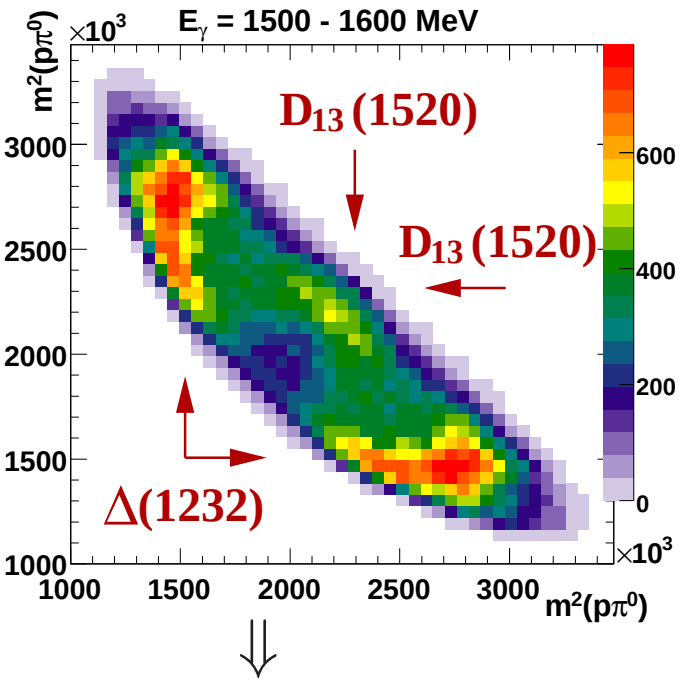
$\longrightarrow$ **Measurement of double polarisation observables necesarry**

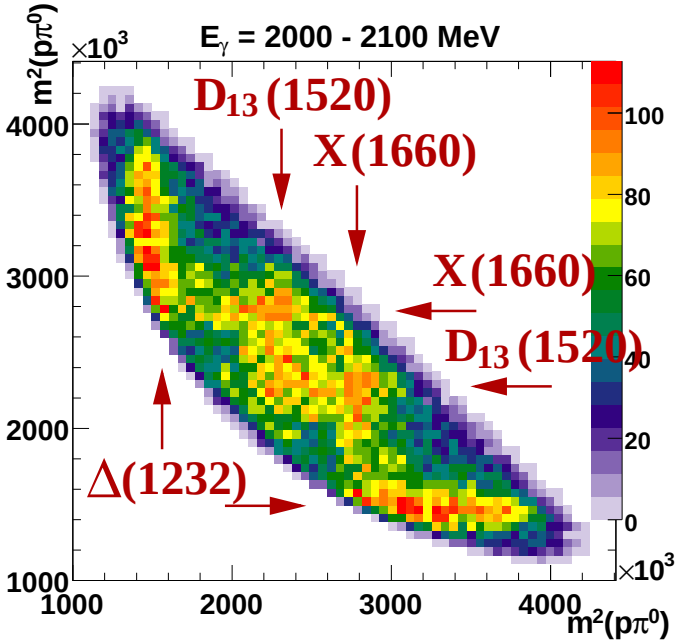


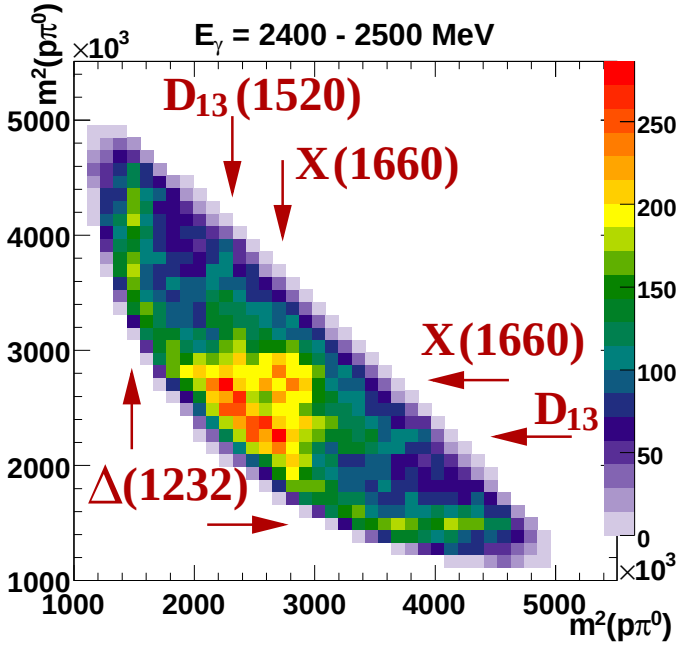


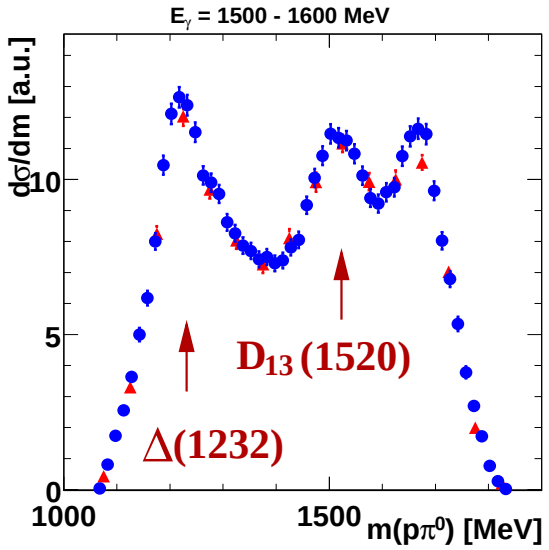
$\gamma p \rightarrow p\pi^0\pi^0$ - CBELSA/TAPS

(V. Sokhoyan, Bonn)



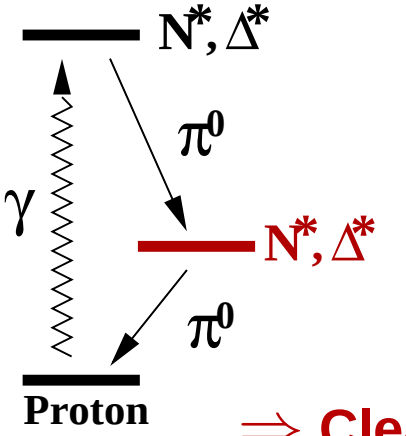






CB-ELSA data

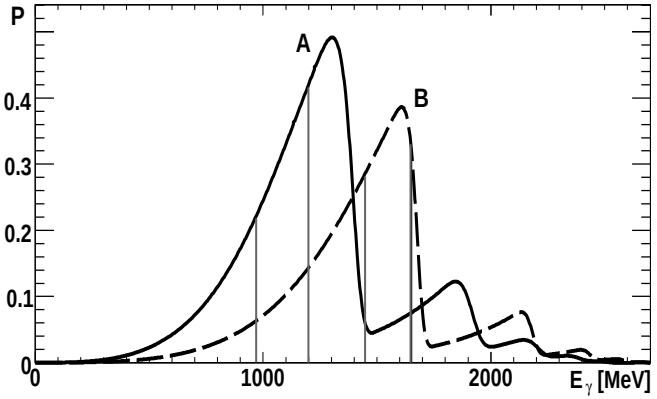
CBELSA/TAPS data



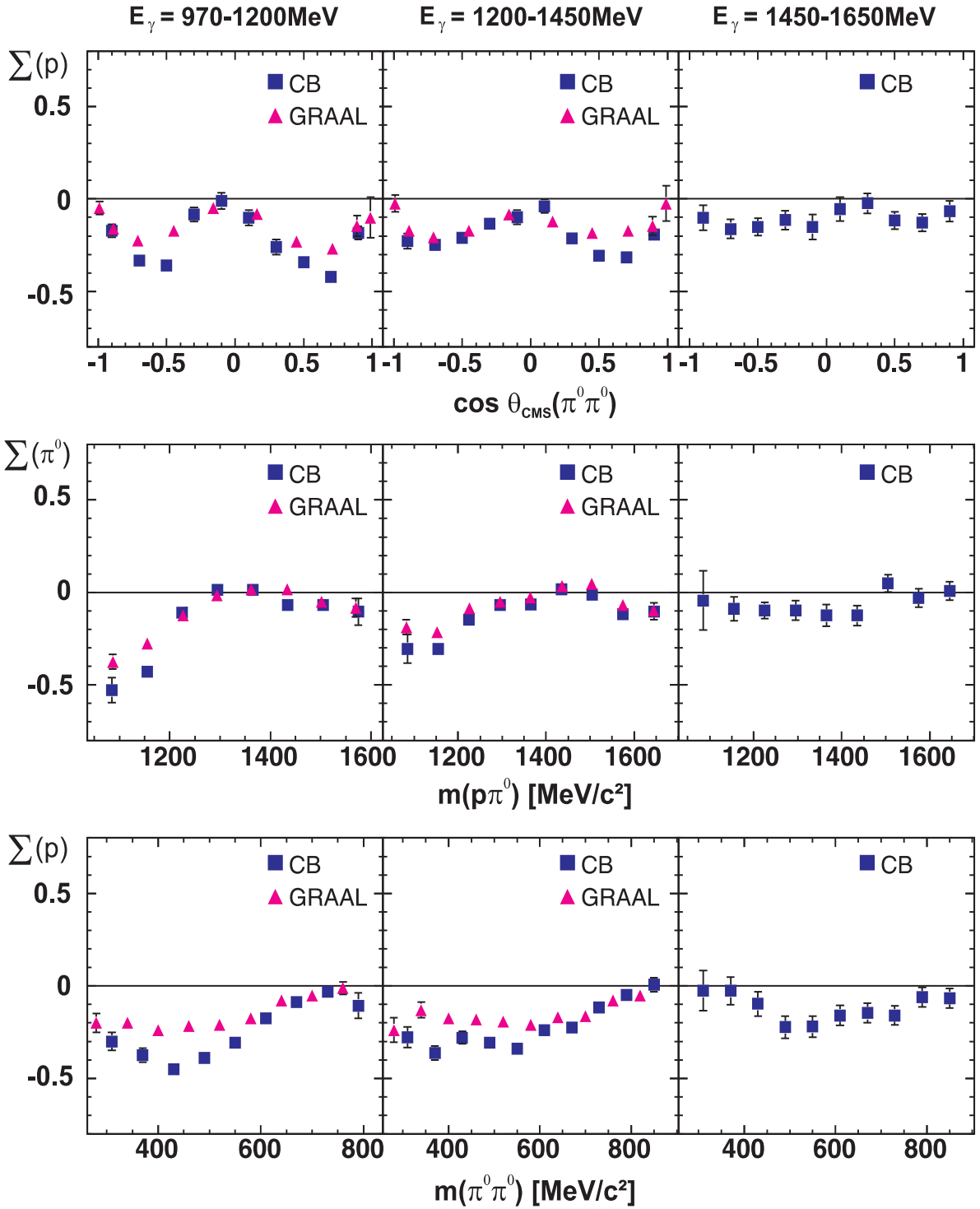
$\Rightarrow$ **Clear observation of baryon cascades !**

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

V.Sokhoyan, Bonn



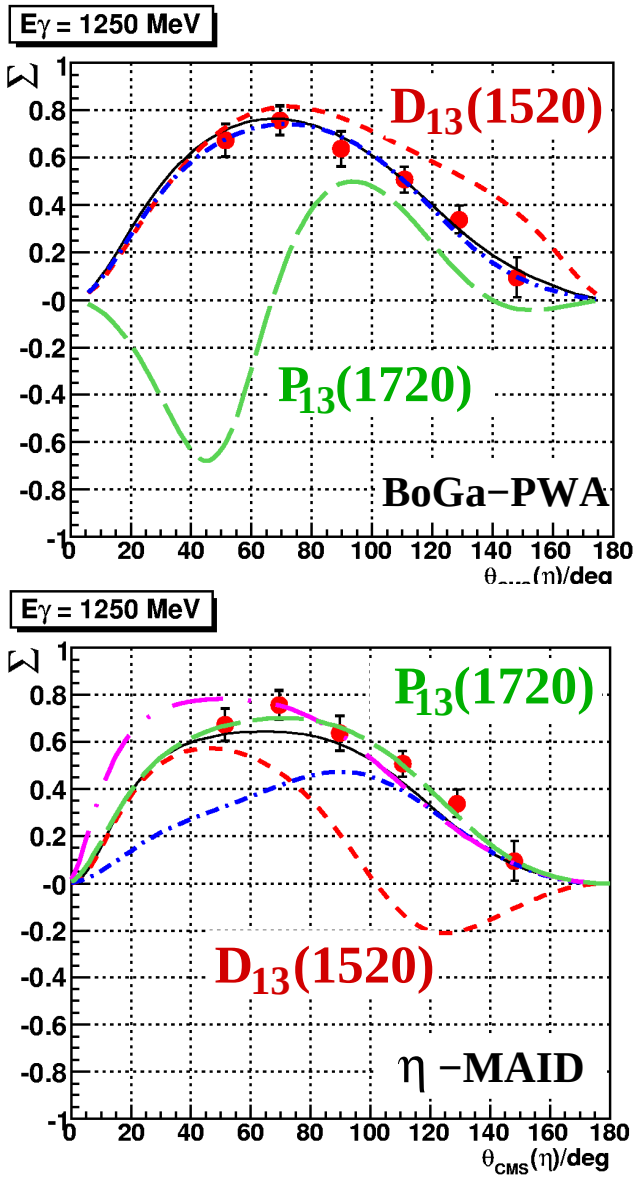
$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 (1 - \delta_l(\Sigma \cos 2\phi + I^s \sin 2\phi))$$



↔ **Data presently included in the PWA**

Polarisation observables, $\vec{\gamma}p \longrightarrow p\eta$

- **CB/TAPS beam-asymmetries $\Leftrightarrow$ provide additional information for the PWA**



D.Elsner et al.,EPJ. A33 (2), 147 (2007)

Single pseudoscalar meson photoproduction

Complete experiment

$\longrightarrow \geq$ 8 observables needed

Double pseudoscalar meson photoproduction

$\longrightarrow \geq$ 15 observables needed

(Roberts, Oed)

$\Rightarrow$ double polarisation experiments needed !

Crystal Barrel/TAPS at ELSA:

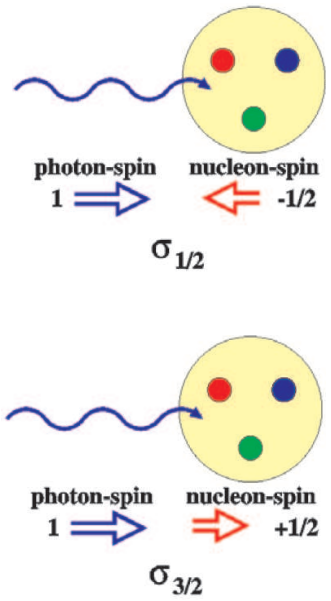
Experiments with longitudinally polarised target and circularly/linearly polarised beam

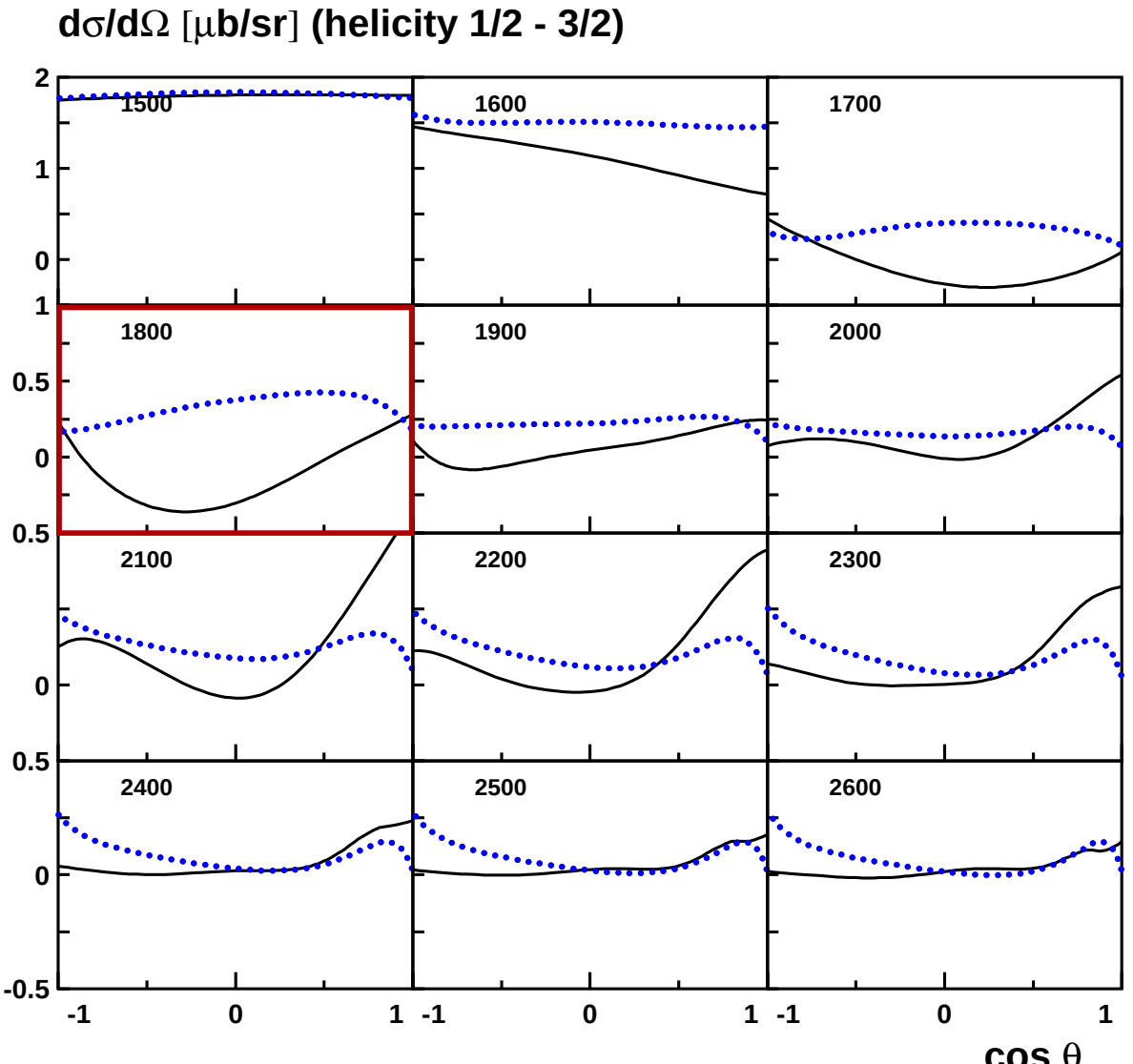
Circularly polarized beam + longitudinally polarized target η-photoproduction

Predictions:

η-MAID / BoGa-PWA

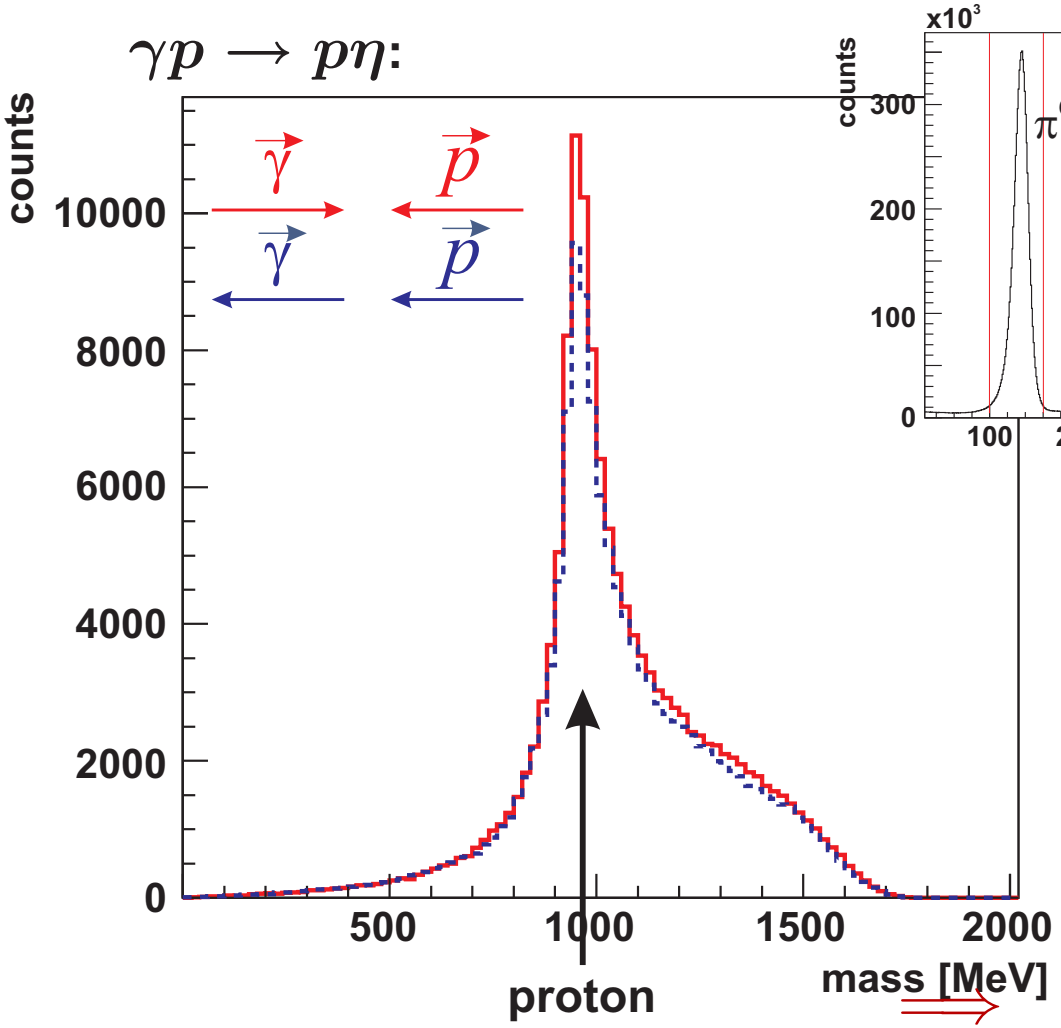
$$\frac{d\sigma_{(3/2-1/2)}}{d\Omega} = \frac{d\sigma_{3/2}}{d\Omega} - \frac{d\sigma_{1/2}}{d\Omega}$$

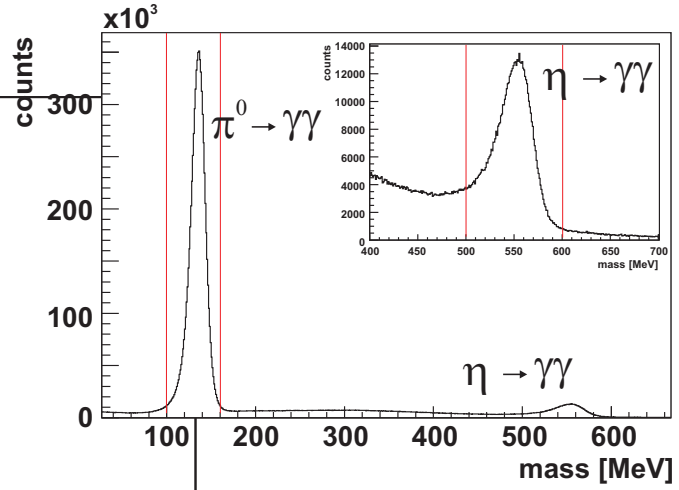




Double Polarisation Experiments at ELSA

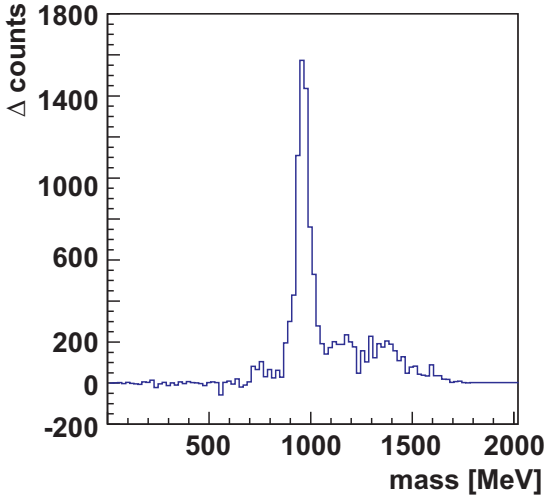
Online spectra: circularly polarised beam, longitudinally polarised target



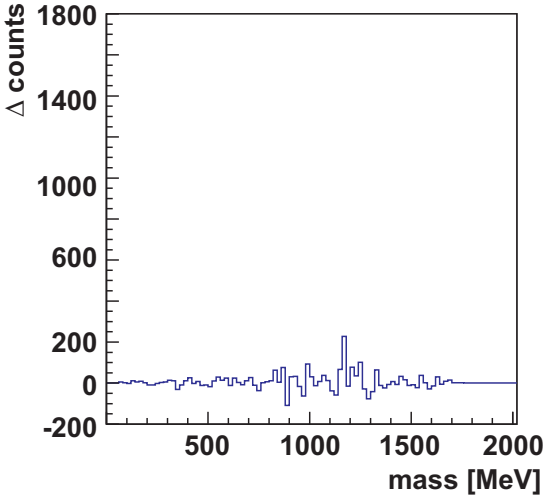


$\gamma p \longrightarrow p\gamma\gamma$

difference



unpolarised difference

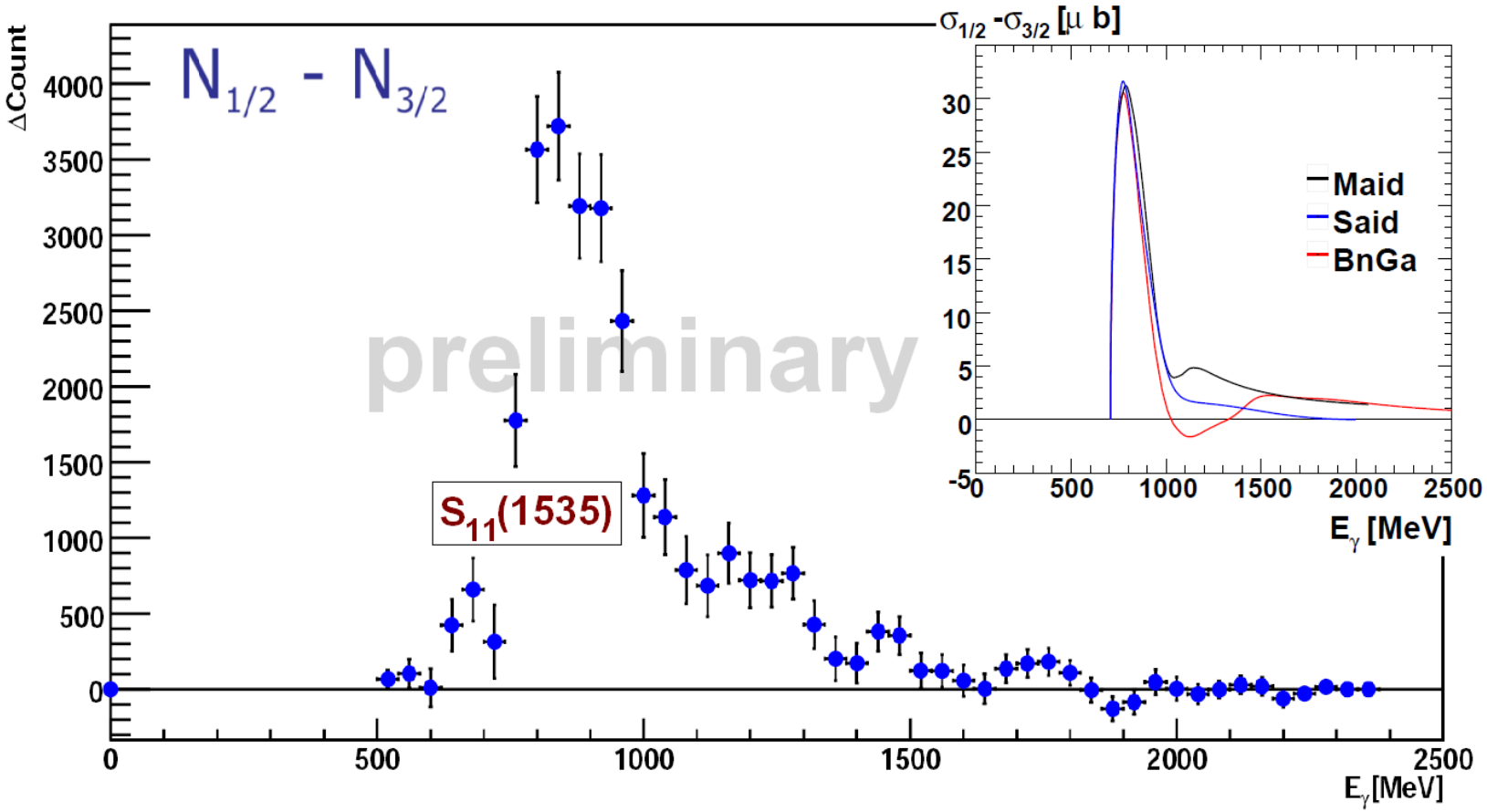


$\Rightarrow$ **First asymmetries observed**

The new CBELSA/TAPS data $\vec{\gamma}\vec{p} \longrightarrow p\eta$

M. Gottschall, Bonn

Count rate differences plotted:

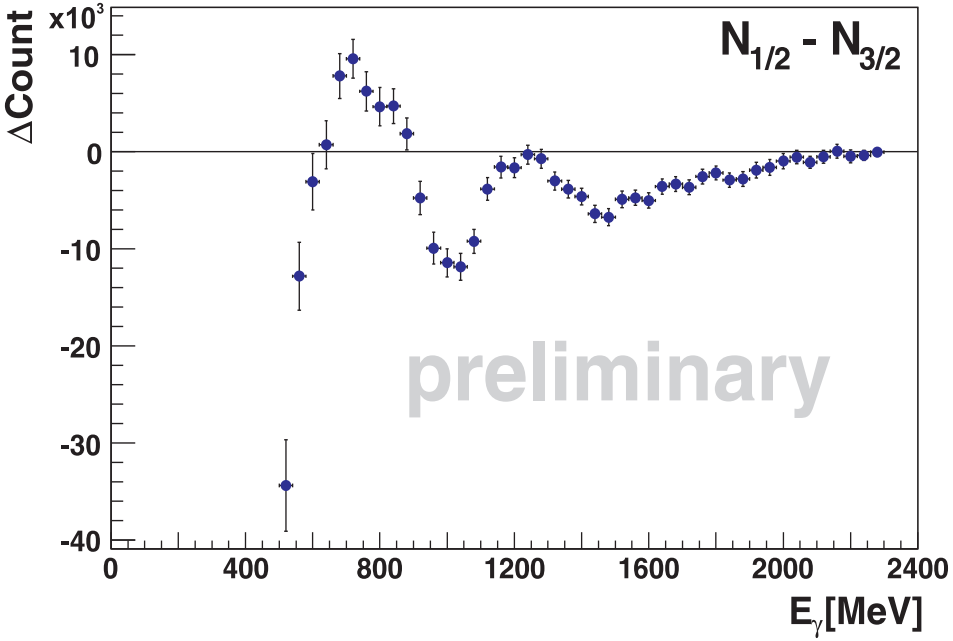


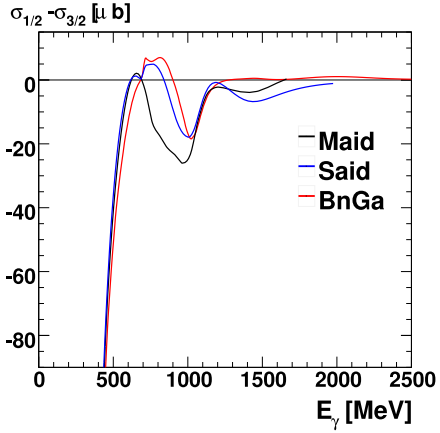
Clear asymmetries observed !

$\sim$ complete angular coverage

$\Rightarrow$ New and important information for the PWA

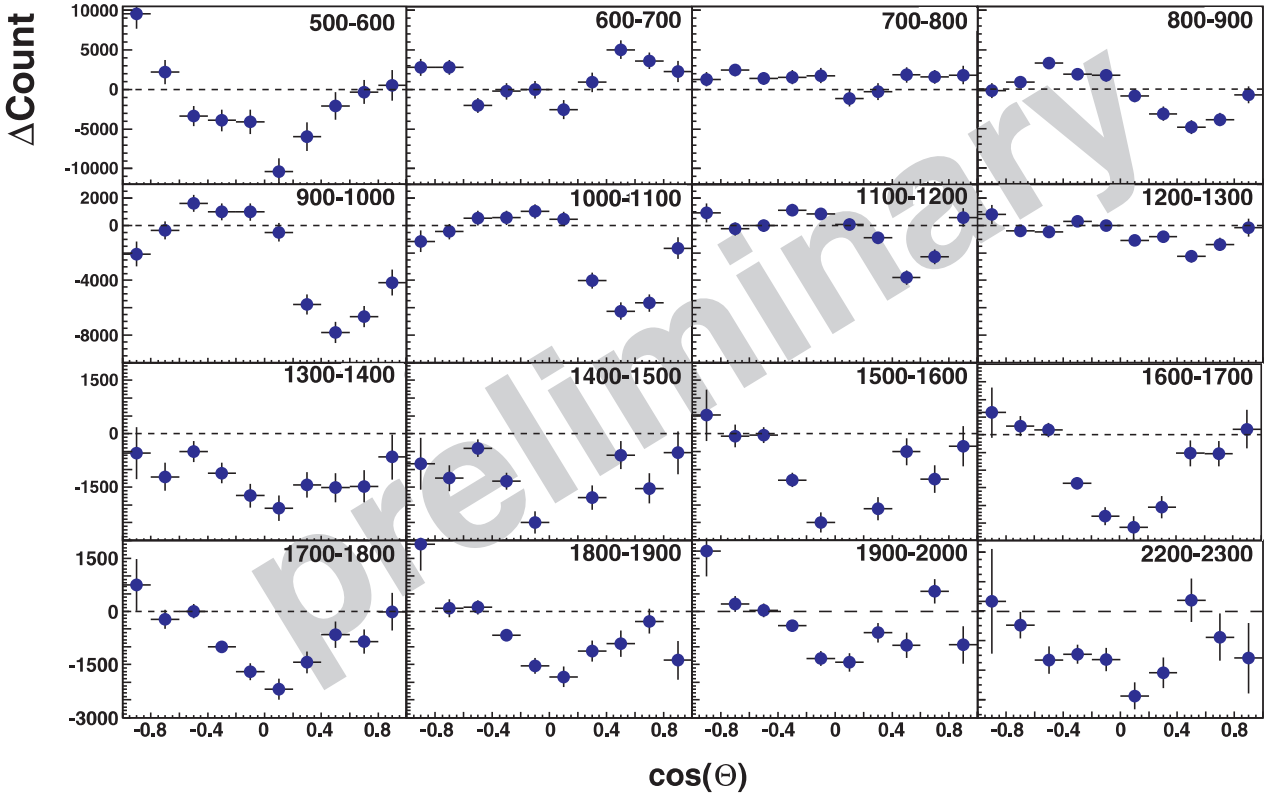
CBELSA/TAPS data $\vec{\gamma}\vec{p} \rightarrow p\pi^0$ (M.Gottschall,Bonn)





– $p2\gamma$-events shown

Count rate differences (prelim. acceptance correction)

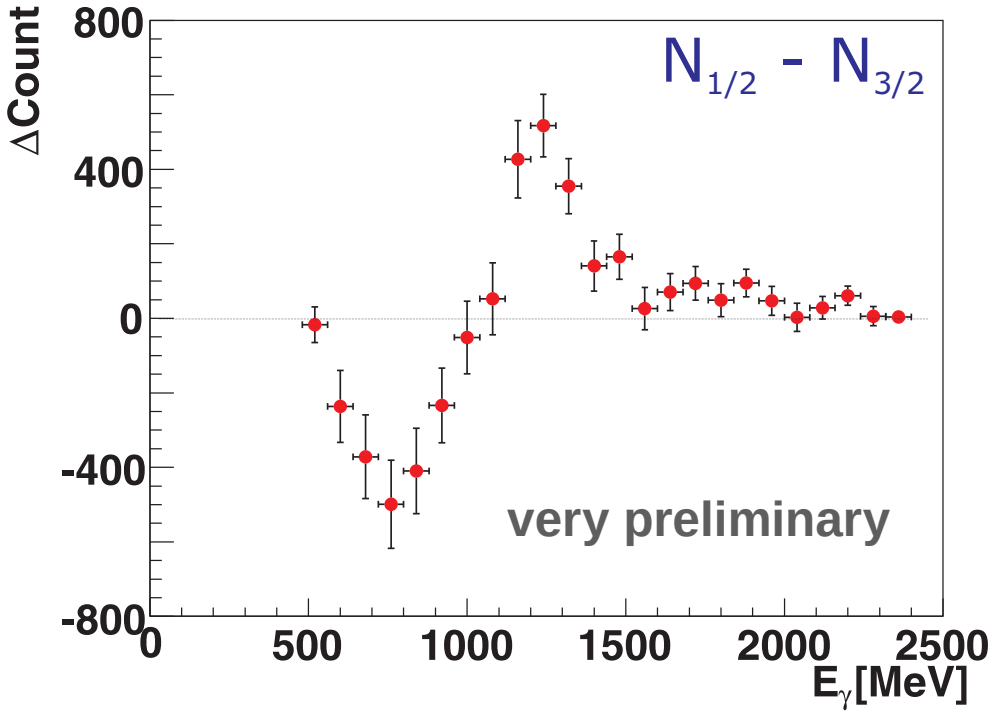


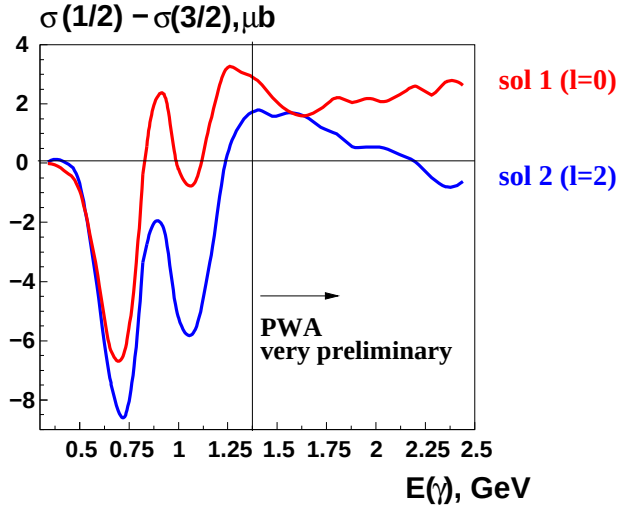
Clear asymmetries observed !

$\sim$ complete angular coverage

$\Rightarrow$ New and important information for the PWA

CBELSA/TAPS data $\vec{\gamma}\vec{p} \rightarrow p\pi^0\pi^0$ (D.Piontek, Bonn)

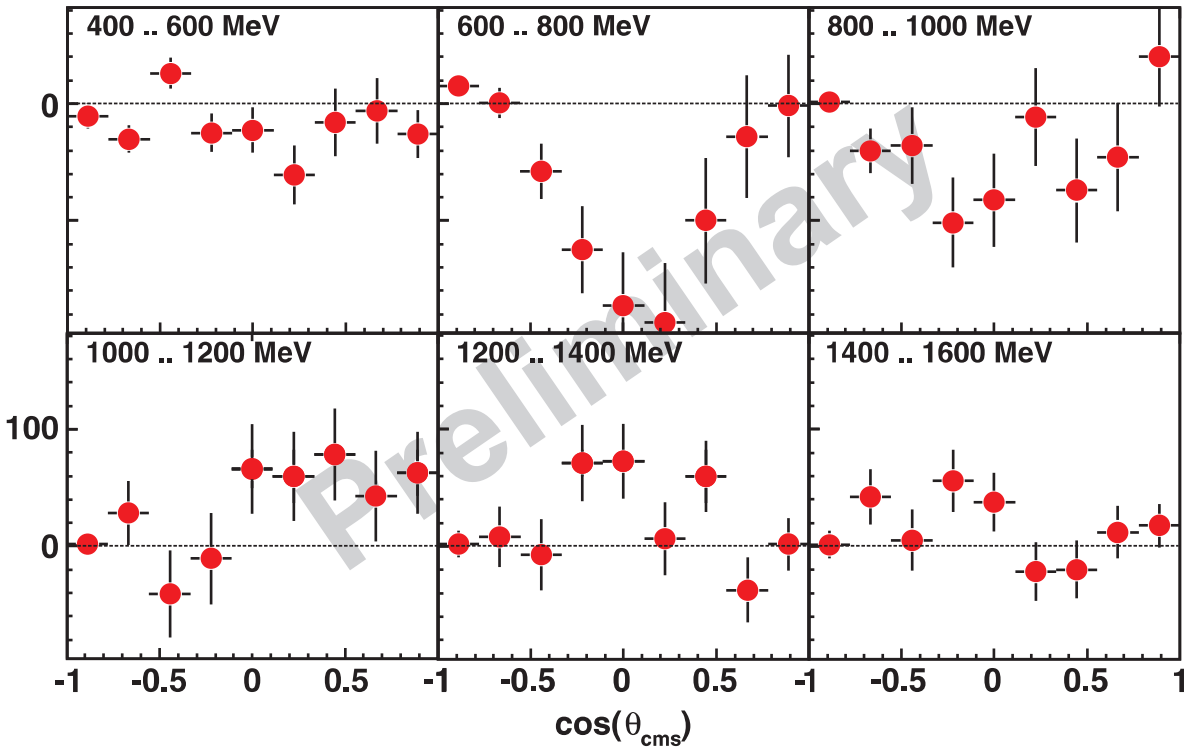




Count rate differences plotted

first look into differential distributions (very preliminary)

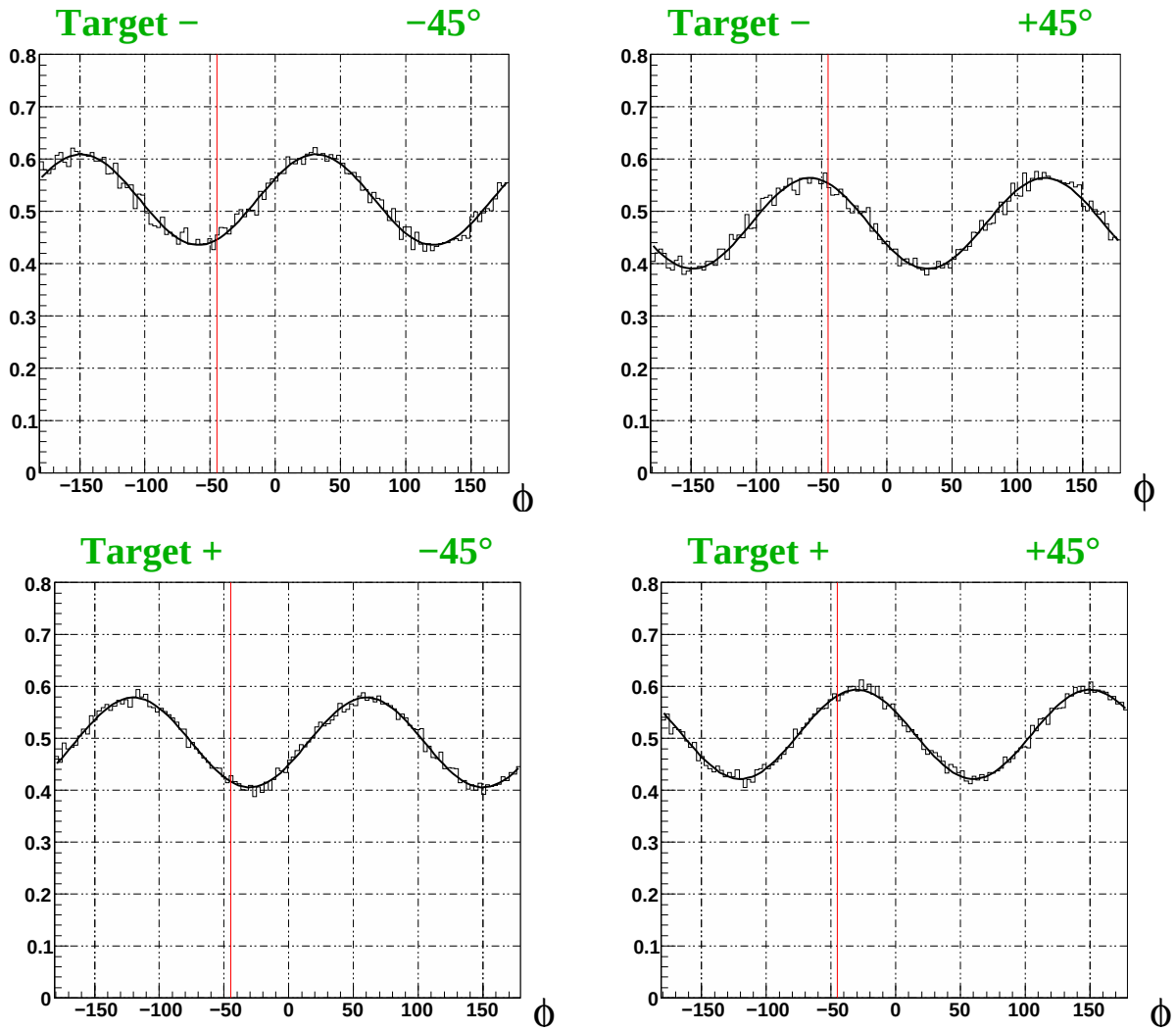
$\cos\theta_p$-distributions:



Double Polarisation Experiments $\leftrightarrow$ G

First online spectra: linearly polarised beam, longitudinally polarised target

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 (1 - \delta_l(\Sigma \cos 2\phi - \Lambda_z G \sin 2\phi))$$

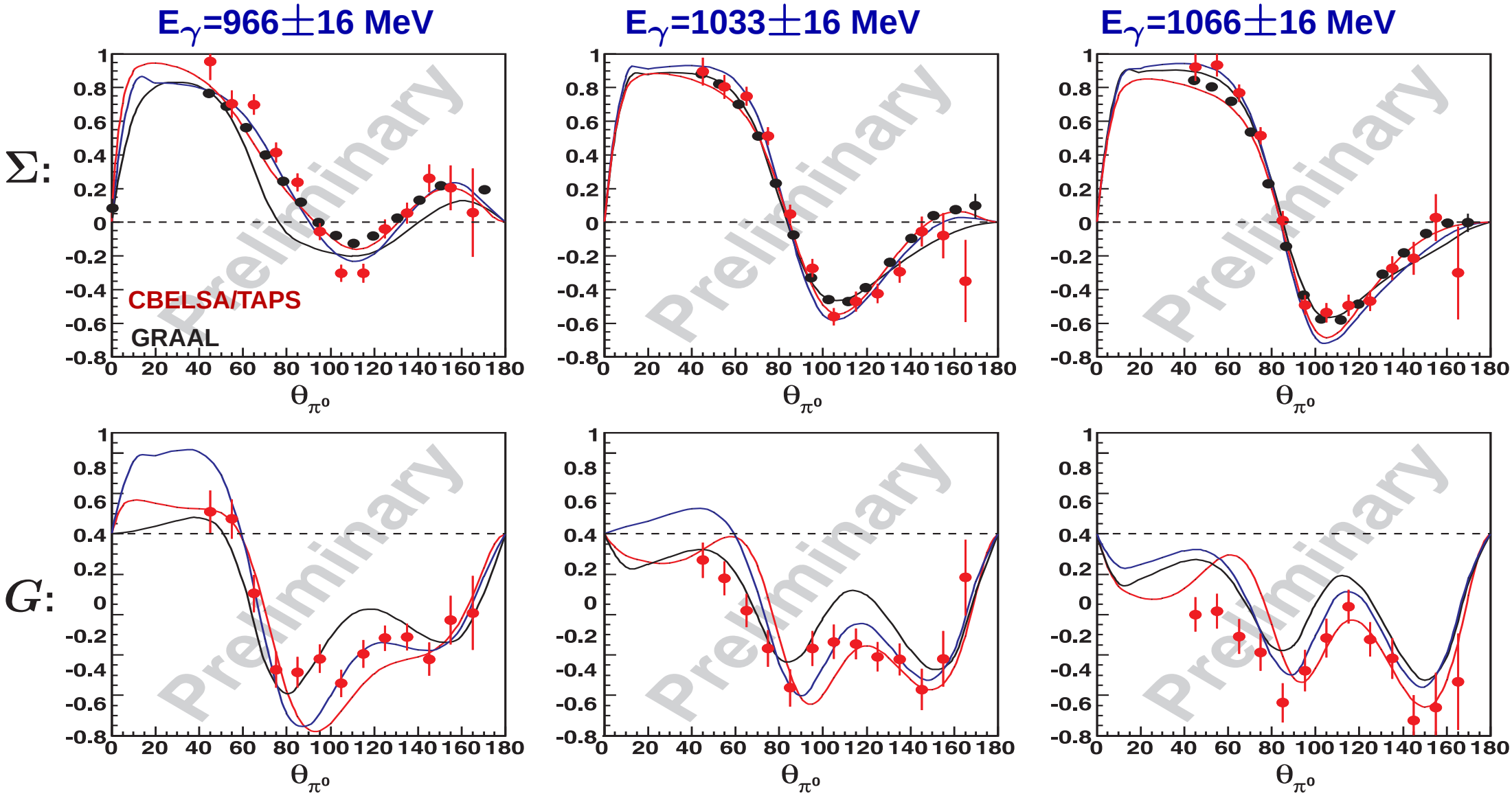


$\vec{\gamma}\vec{p} \rightarrow p\pi^0$

(E_γ=750-1200 MeV)

$\Rightarrow$ Clear effect from G observed

$\vec{\gamma}\vec{p} \longrightarrow p\pi^0$ (A.Thiel, Bonn)



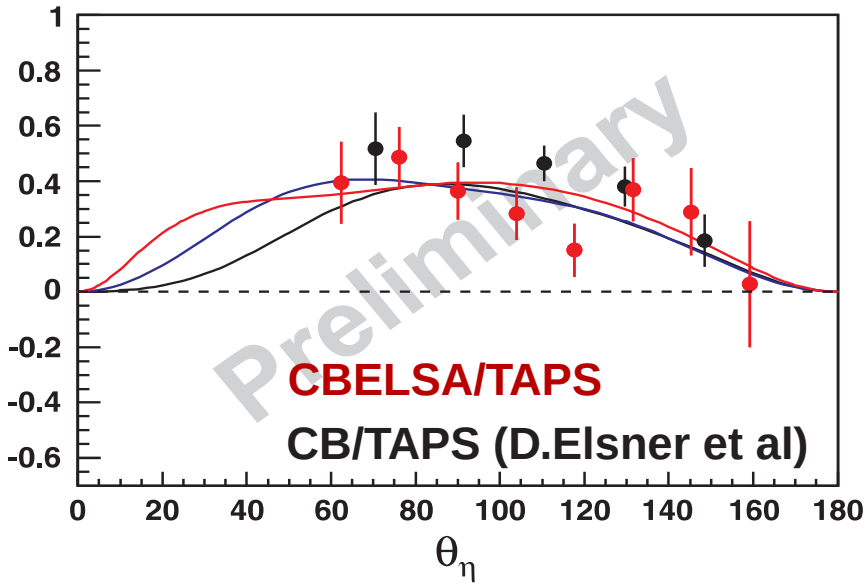
– MAID – BnGa – SAID ⟷ preliminary dilution factor included

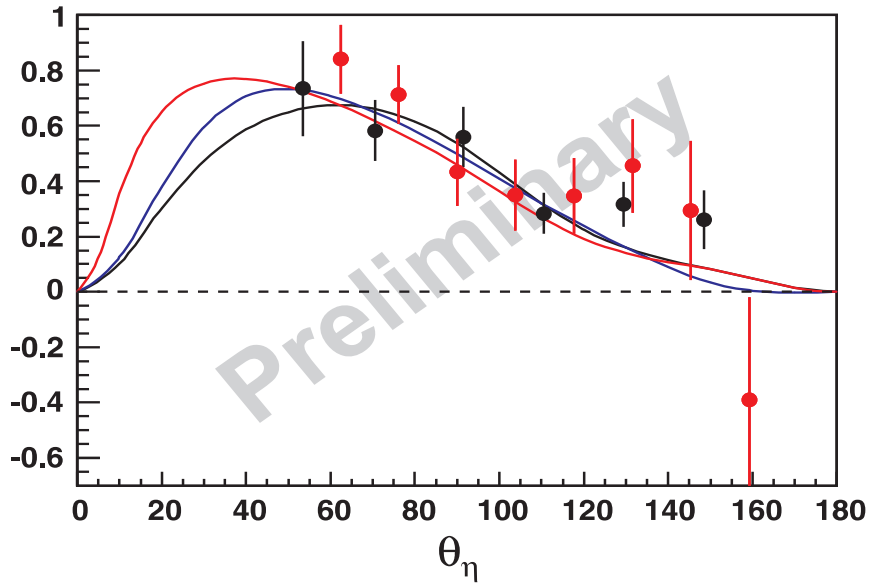
$\vec{\gamma}\vec{p} \rightarrow p\eta$:

E_γ=950±50 MeV

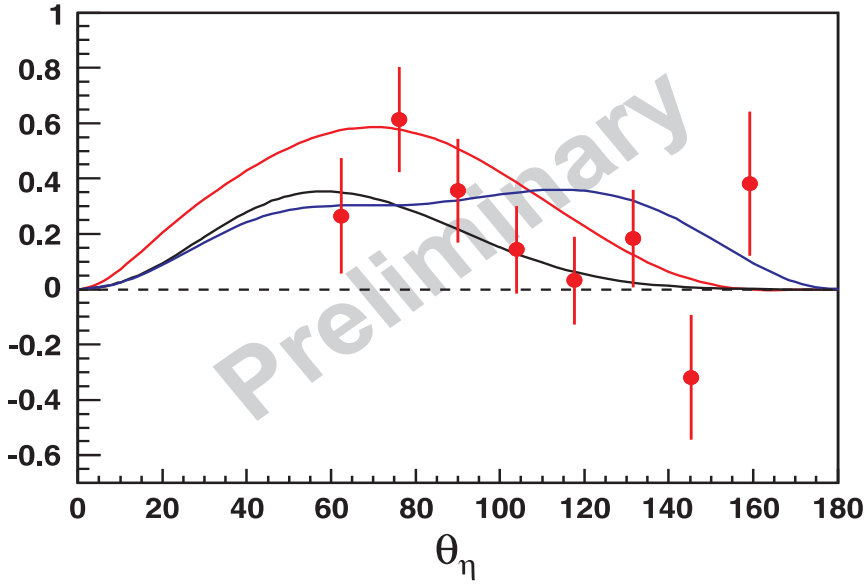
E_γ=1050±50 MeV

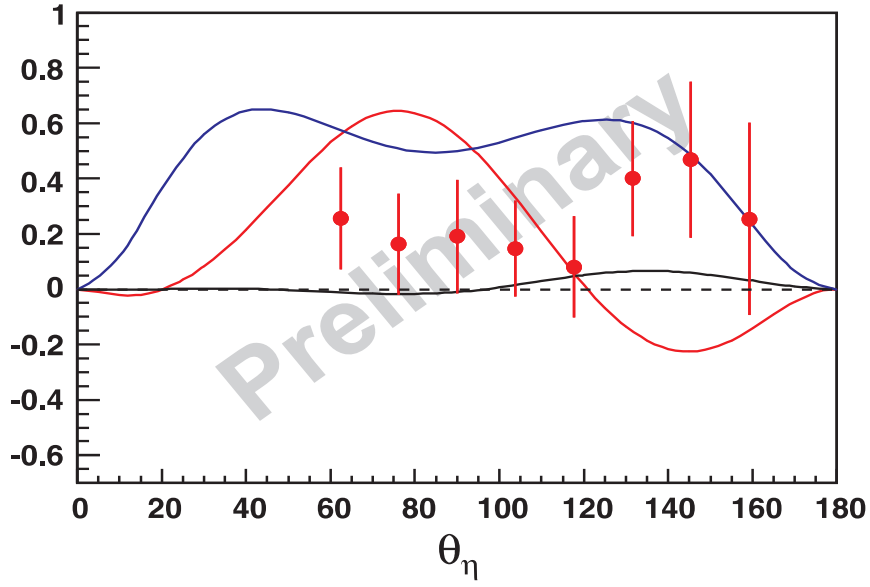
Σ:





G:





– MAID – BnGa – SAID

↔ preliminary dilution factor included

Summary

- **High quality data has been taken**
  ($\gamma p, \vec{\gamma} p \rightarrow p\pi^0, p\eta,\ p\pi^0\pi^0,\ p\pi^0\eta,\ \vec{\gamma} p \rightarrow p\omega, \gamma p \rightarrow p\eta', p\pi^0\omega,\ K^0\Sigma^+,\ \ldots$)

  – Extends the covered angular and energy range,
  $\rightarrow$ determination of resonance properties

  – Decays via higher mass resonances observed,
  baryon cascades e.g. via $\Delta(1232)\pi^0$, $D_{13}(1520)\pi^0$, $S_{11}(1535)\pi^0$, X(1660)π^0

- **First double polarisation data has been taken**
  (longitudinally polarised target, circulary and linearly pol. beam)

  $\Rightarrow$ A step closer towards a complete experiment

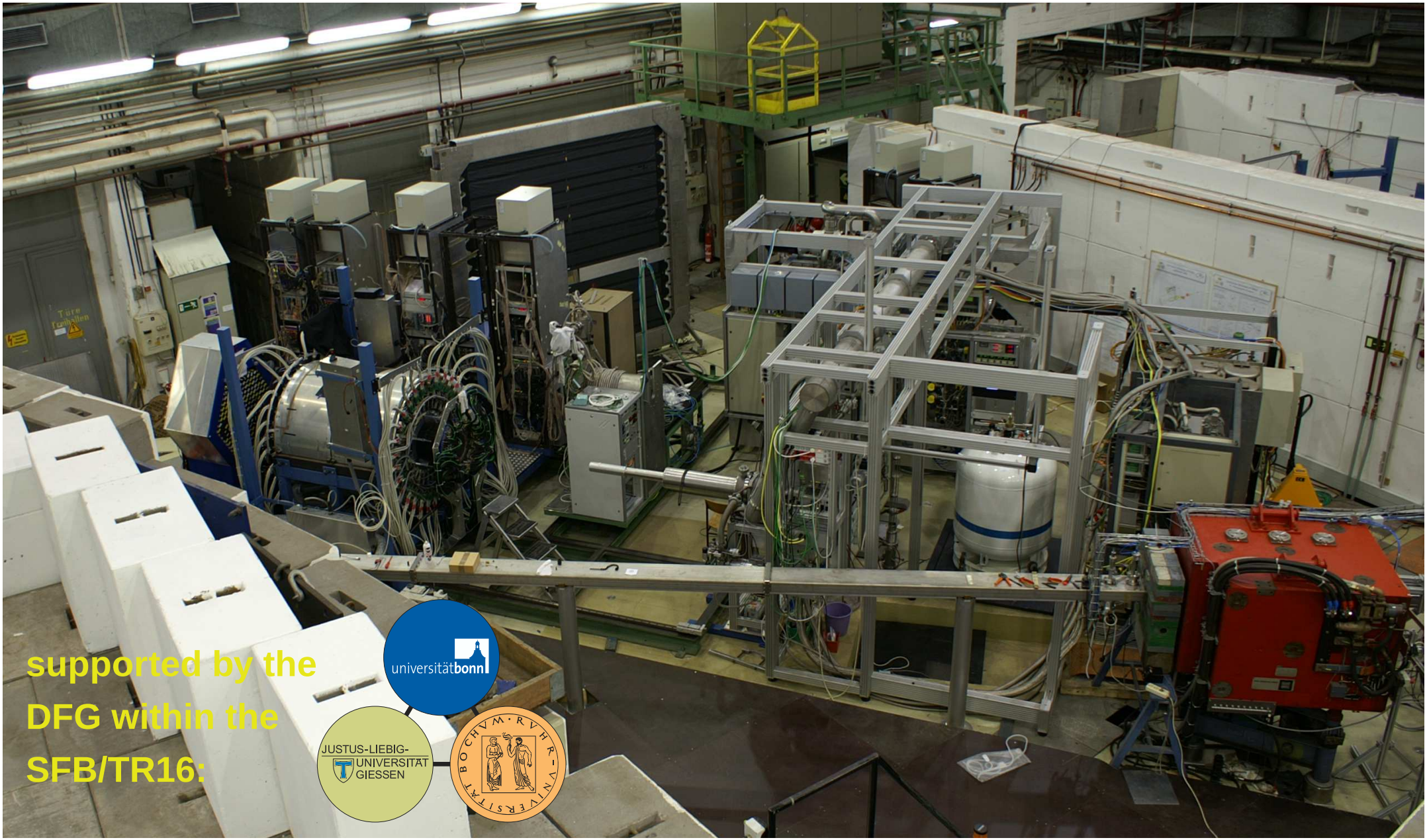
  $\leftrightarrow$ transversally polarised target in preparation

$\Rightarrow$ Better understanding of the hadron spectrum

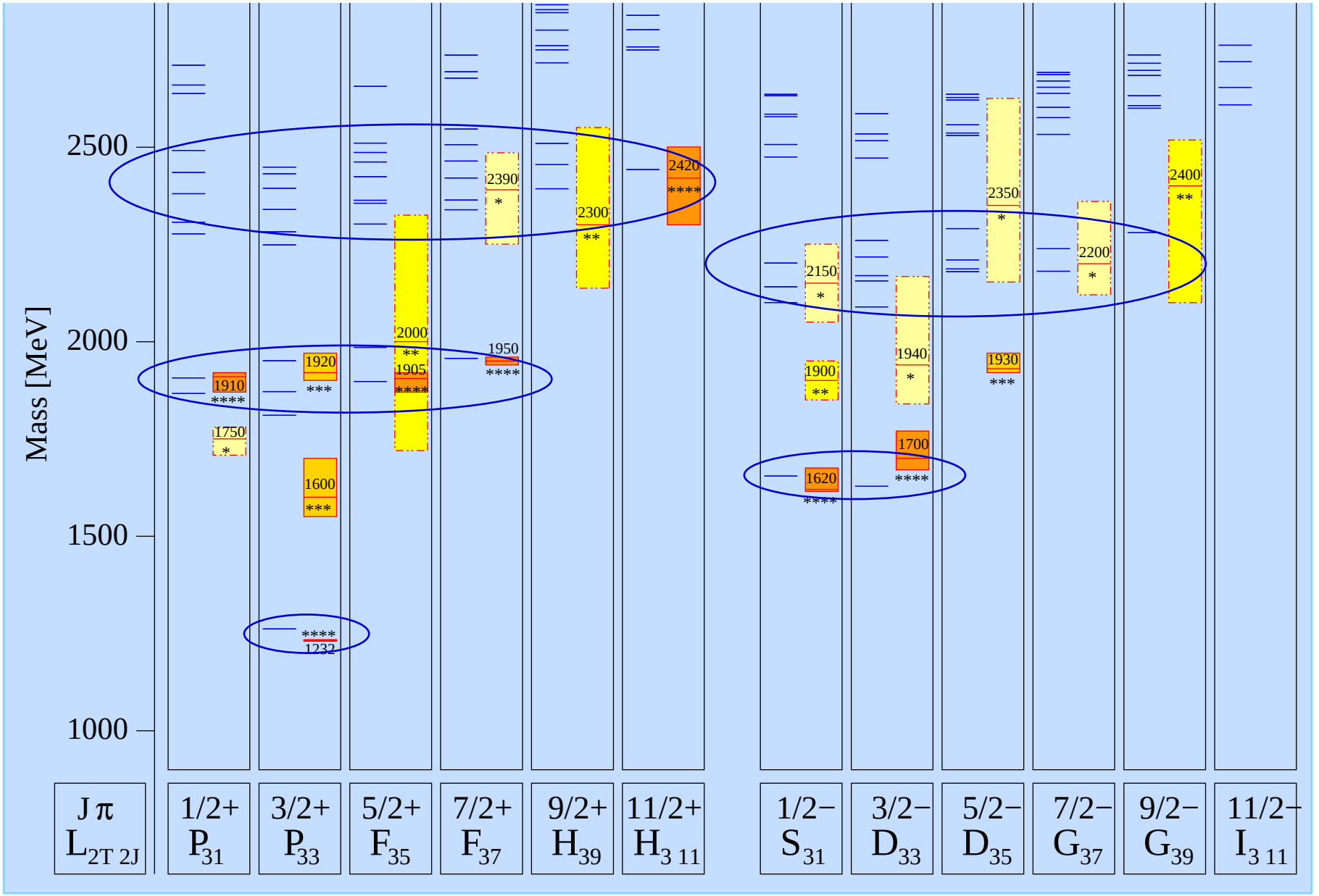
$\Rightarrow$ Detailed testing ground for quark models,
models of dynamically generated resonances,
lattice QCD calculations ...

funded by the DFG
within the
SFB/TR16

Thank you for your attention !



The Δ^*- states



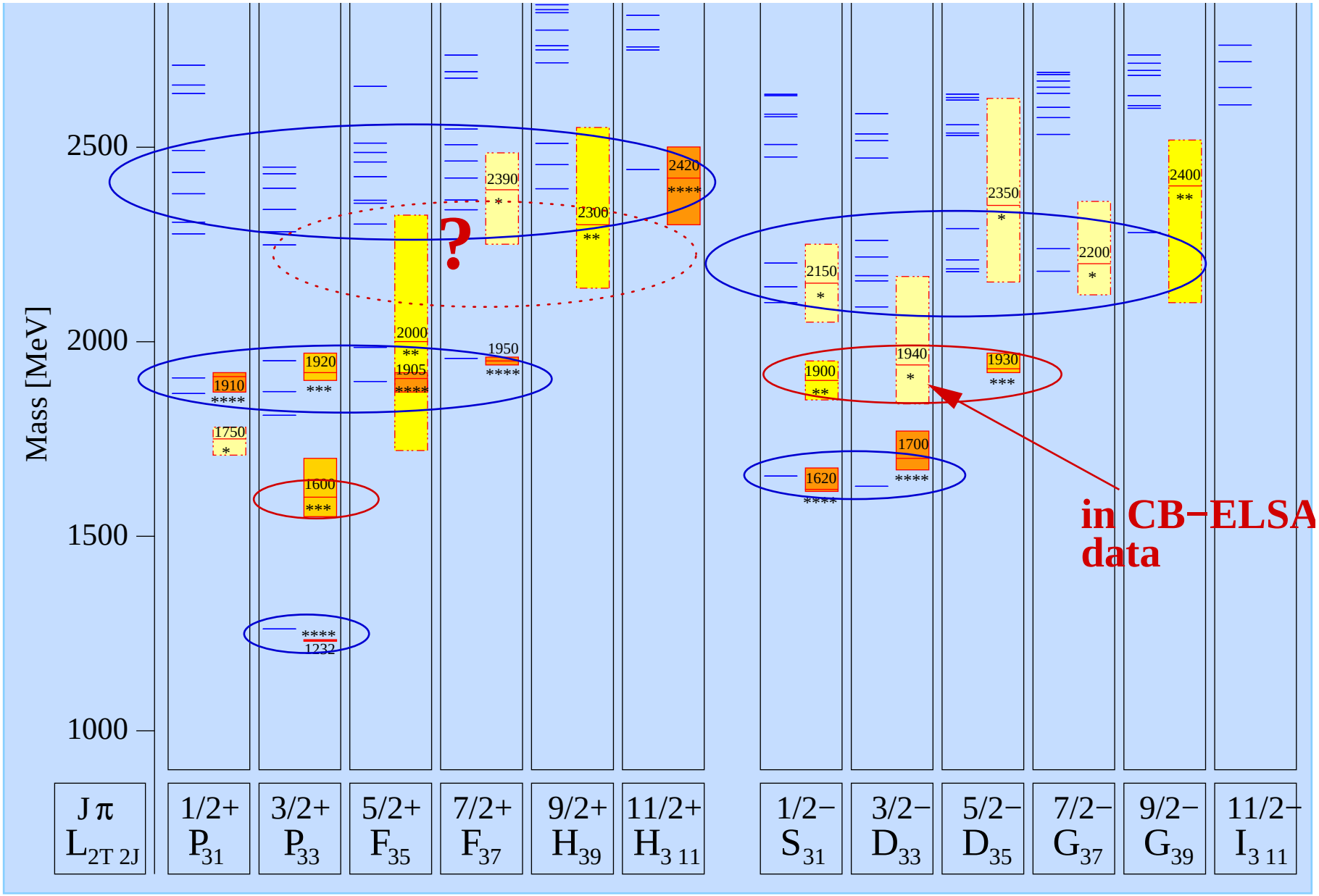
Quark model

U. Löring, B. Metsch, H. Petry et al.

model

$\sim 2n + \ell$

The Δ^*- states



Quark model

U. Löring, B. Metsch, H. Petry et al.

model

$\sim 2n + \ell$

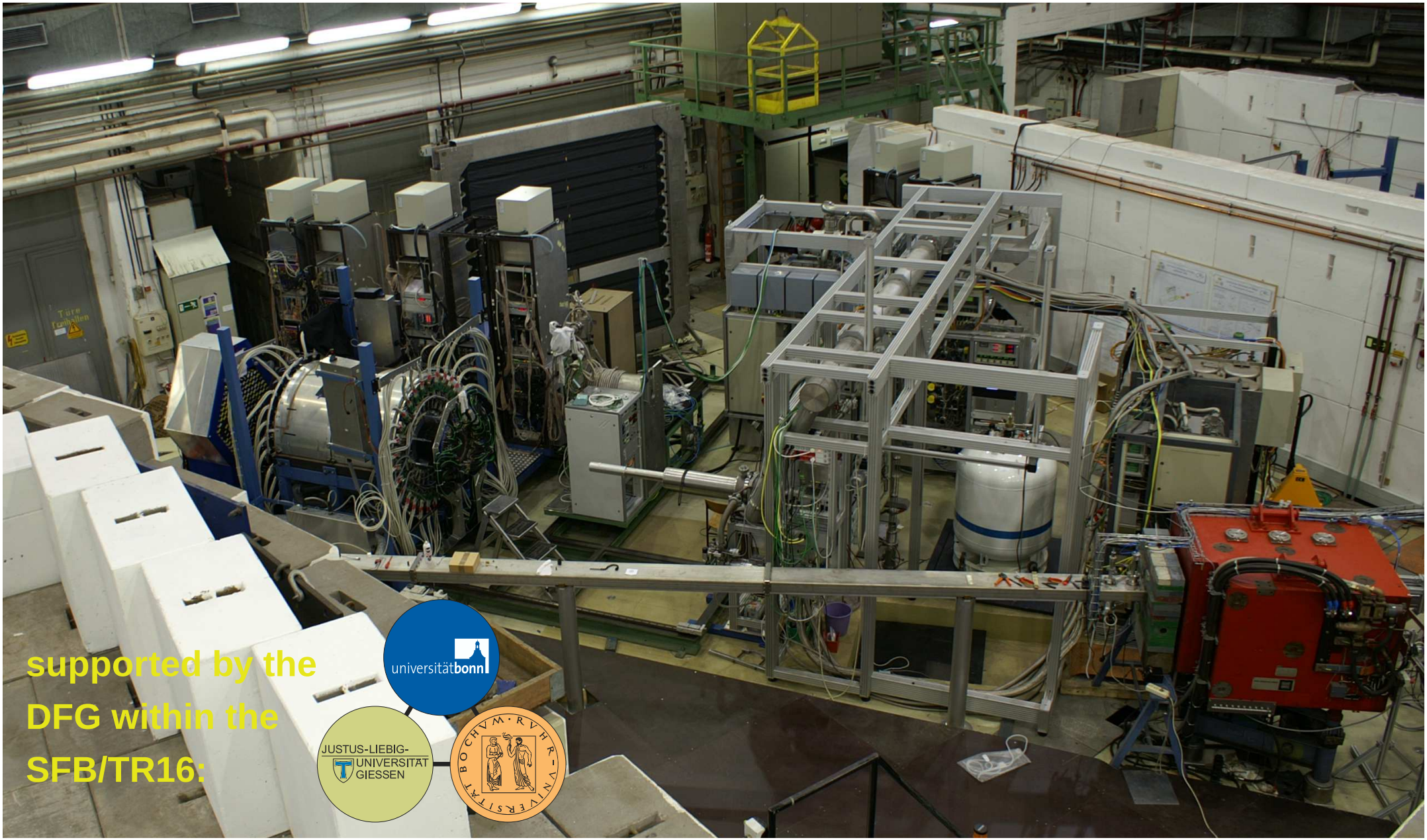
data

$\sim n + \ell$ **?**

$\leftrightarrow$ **Parity doublets ?**

$\Leftrightarrow$ **Additional experimental information needed !!**

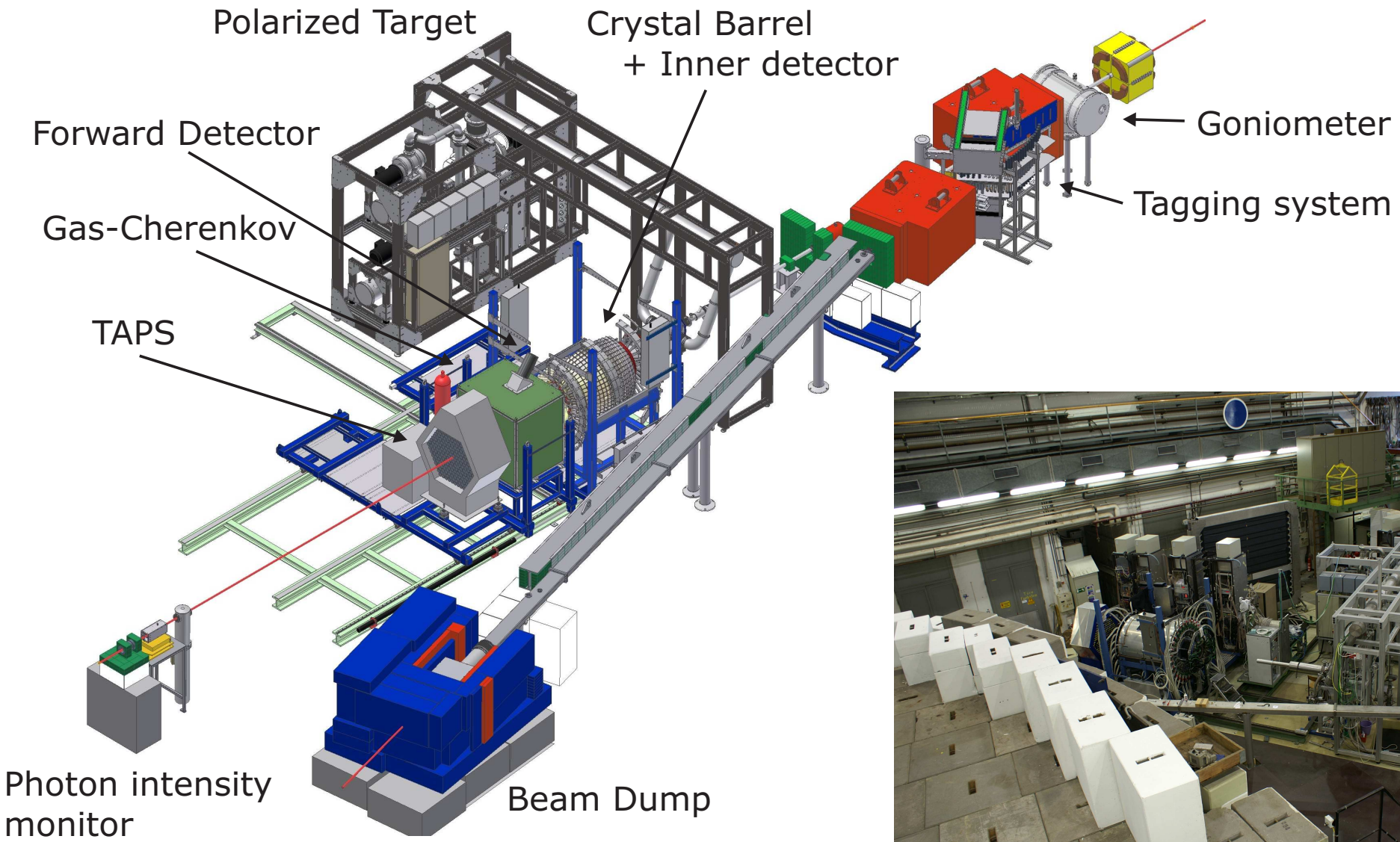
Thank you for your attention !



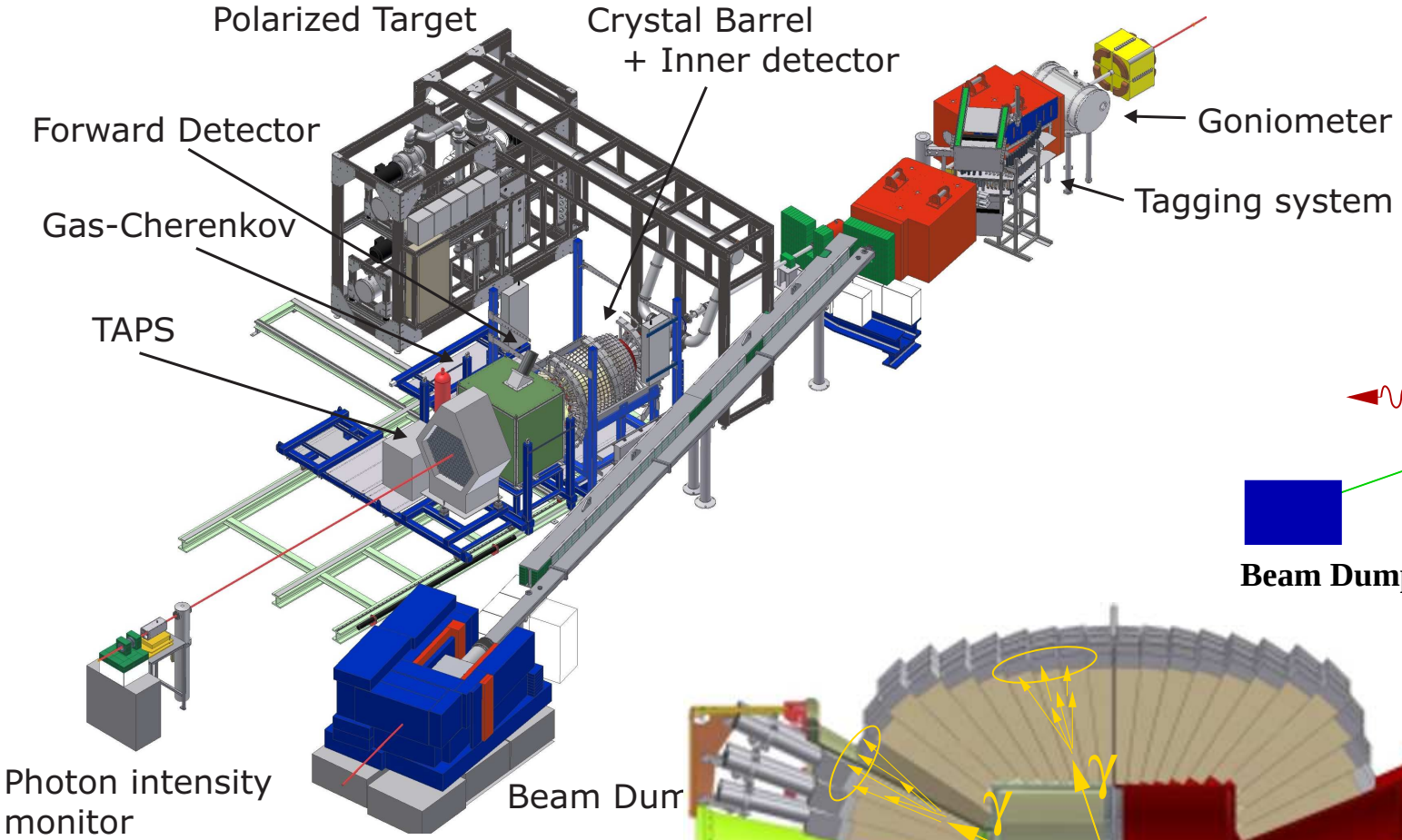
Double Polarisation Experiments at ELSA

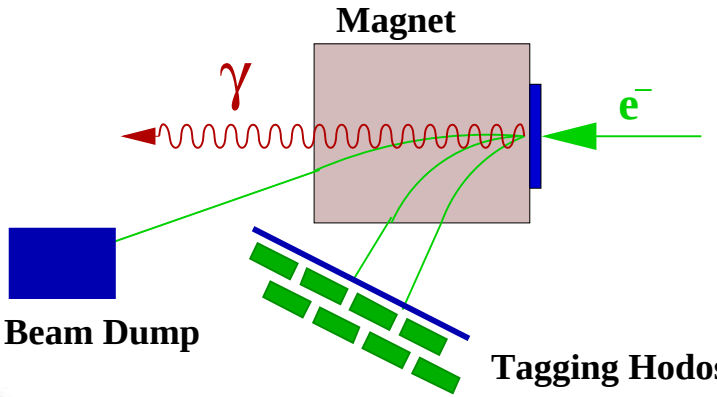
Experiments with: - linear or circular polarised beam

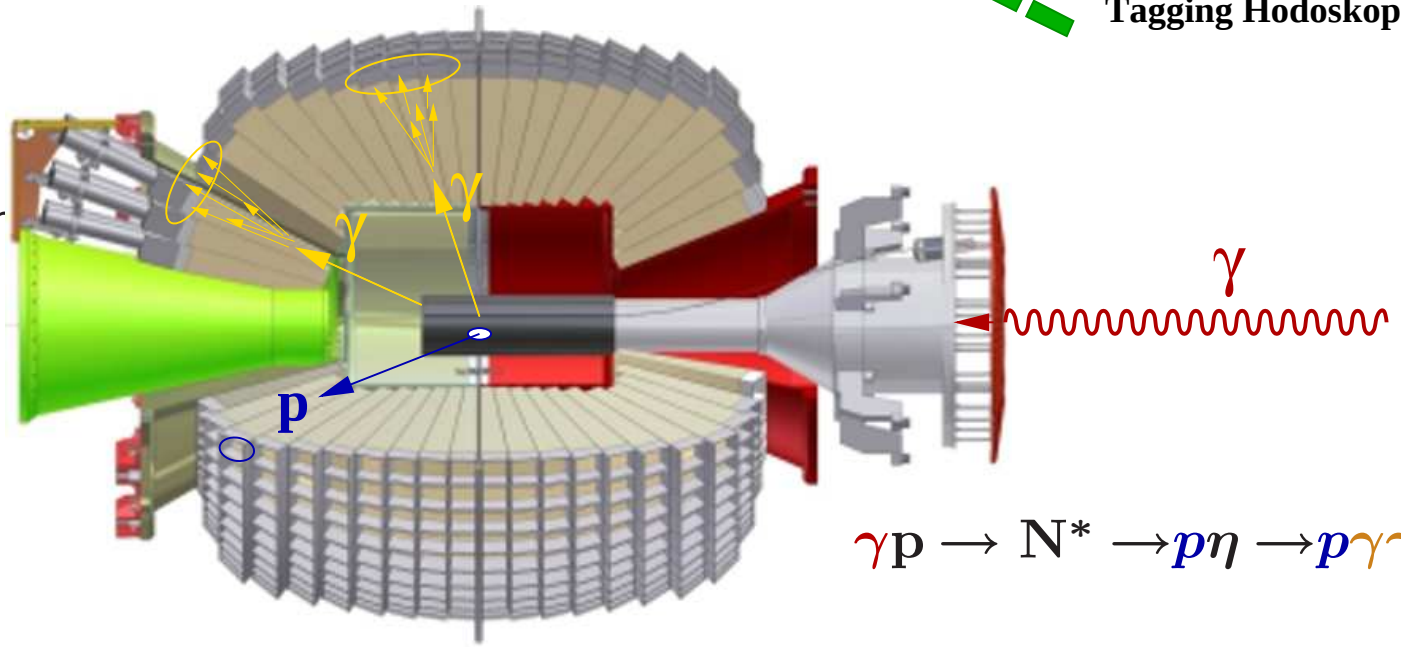
- longitudinal polarised target (frozen spin butanol)



The Crystal Barrel Experiment at ELSA



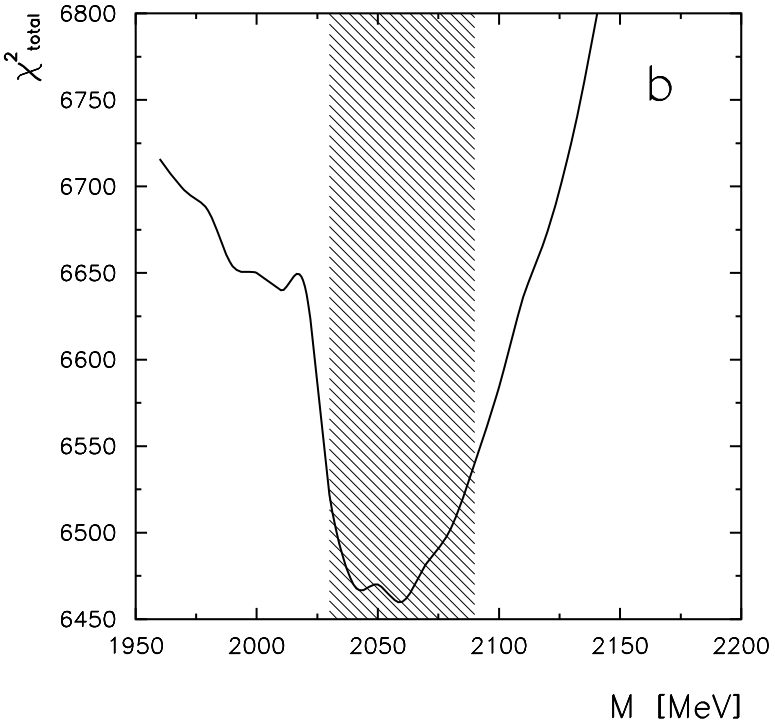




$\gamma p \rightarrow N^* \rightarrow p\eta \rightarrow p\gamma\gamma$

New D_{15} -state

- $D_{15}(2060 \pm 30, 340 \pm 50)$:



$N(2200)$ D_{15} $I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$ Status: **

OMITTED FROM SUMMARY TABLE

The mass is not well determined. A few early results have been omitted.

$N(2200)$ BREIT-WIGNER MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
≈ 2200 OUR ESTIMATE				
1900	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$
2180±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1920	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
2228±30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2240±65	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$

varies strongly !

$N(2200)$ BREIT-WIGNER WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
130	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$
400±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
220	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
310± 50	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
761±139	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$

$\Leftrightarrow$ Results vary strongly!