
Recent results from baryon spectroscopy

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- **Introduction**
- **η - photoproduction at the proton**
- $\gamma p \rightarrow K^+ \Lambda, \gamma p \rightarrow K\Sigma$
- **η - photoproduction at the neutron**
- **$2\pi^0$ - photoproduction**
- **$\pi^0\eta$ - photoproduction**
- **Summary**

Baryon spectroscopy

Better understanding of strong QCD
and the structure of hadrons:

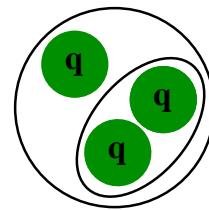
- What are the relevant degrees of freedom ?
- And the effective forces ?

Quark models:

Constituent quarks, confinement potential and residual interaction:

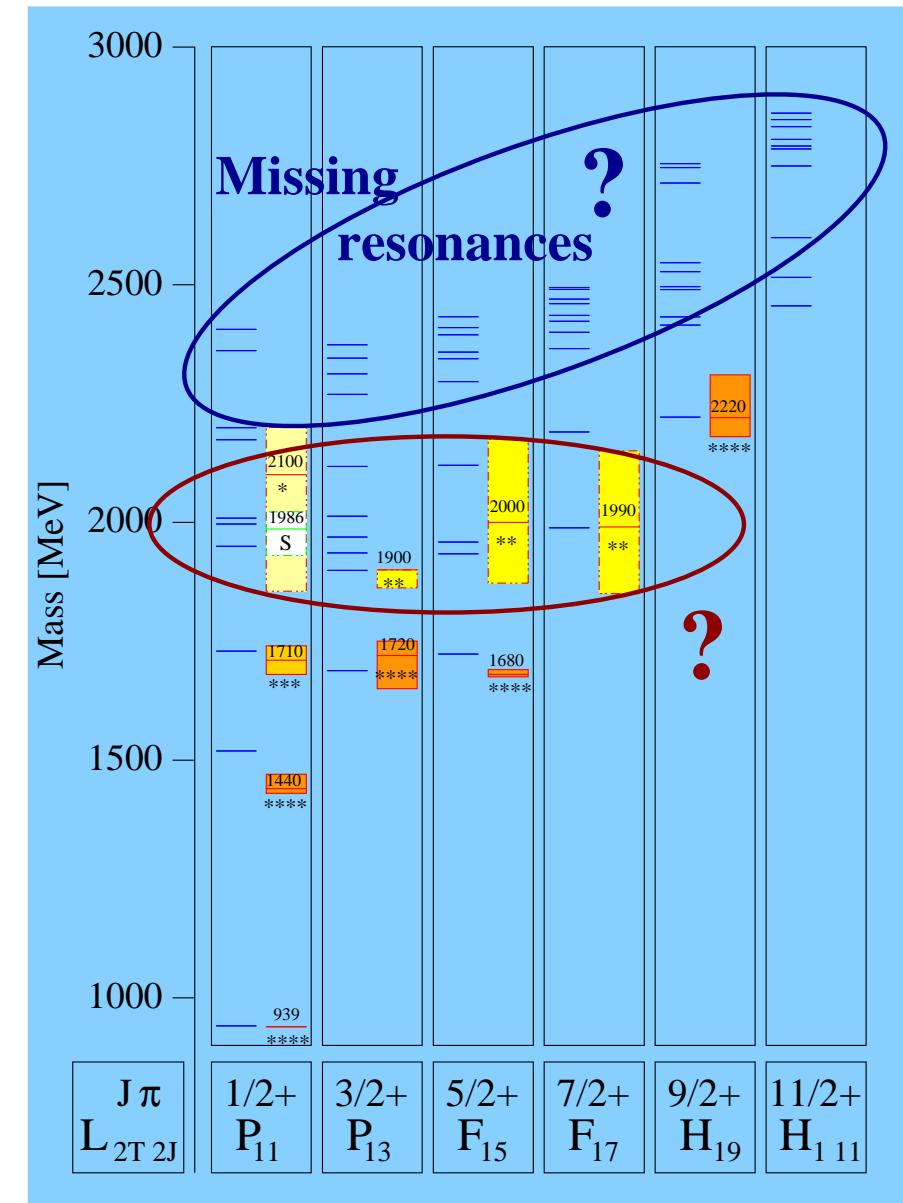
↔ quark models: More Baryons predicted \Rightarrow
than observed

\Leftrightarrow Do Baryons have a quark-diquark
structure ?



One of the internal
degrees of freedom
is frozen

\Leftrightarrow reduced number of states



U. Löring, B. Metsch, H. Petry et al.

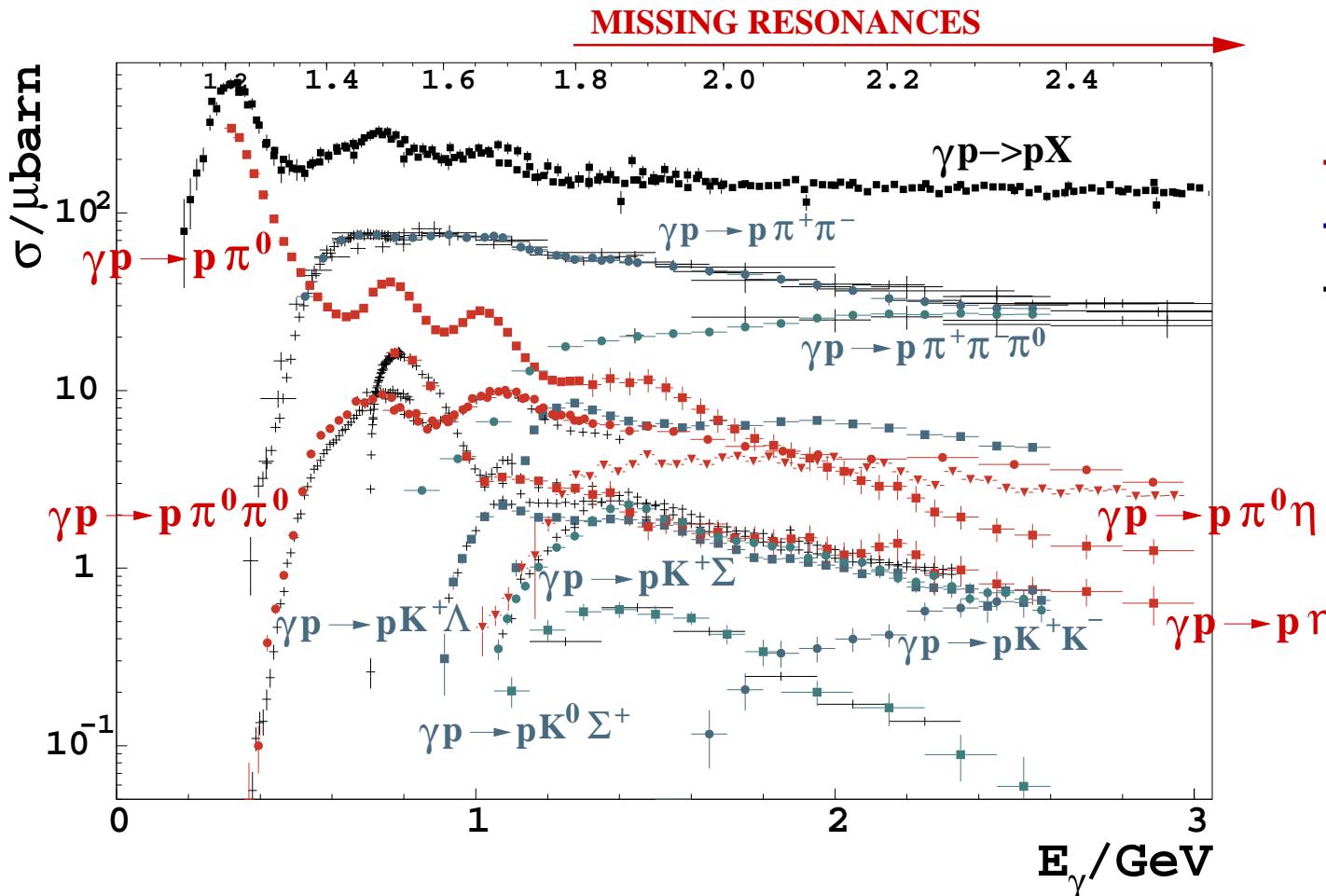
↔ Have the missing resonances just not been observed up to now ?

↔ Missing states might decouple from πN (supported by theory)

⇒ investigate initial and final states different from πN

e.g. Photoproduction of $N\eta$, $N\eta'$, $N\omega$, $\Delta\pi$, $N\rho$, $\Delta\eta$, $\Delta\omega$

Also important: Measurement of resonance properties: Photocouplings,
partial widths ...

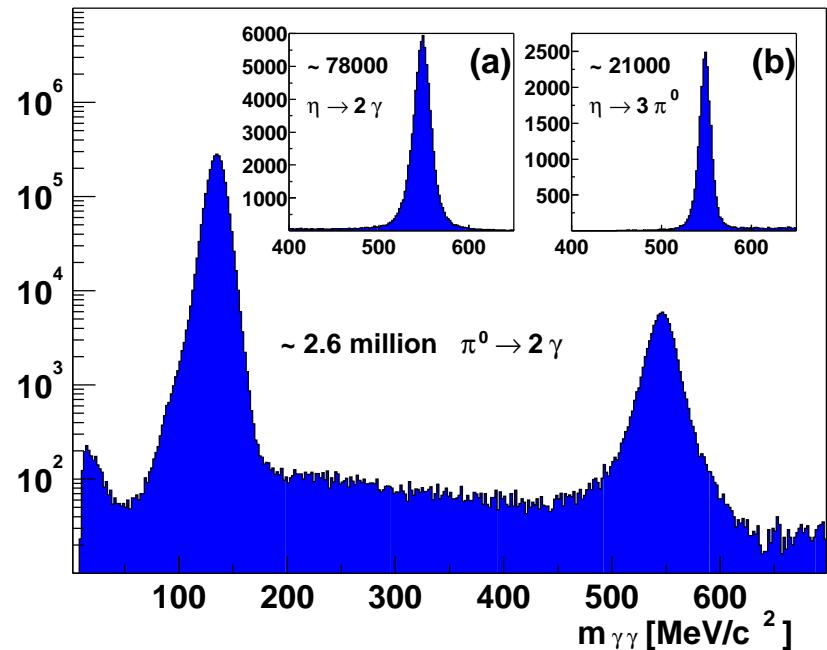


- CB-ELSA data ,
- SAPHIR data (ELSA) ,
- other experiments

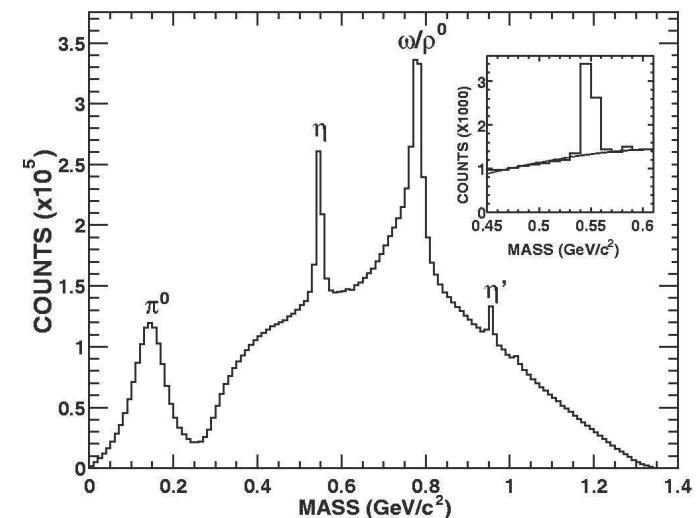
At high excitation energies:
Multi-meson final states play a role of increasing importance

η - Photoproduction

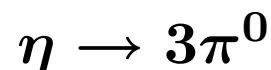
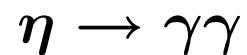
CB-ELSA:



CLAS:



$\gamma p \rightarrow p \eta :$

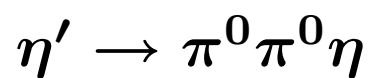
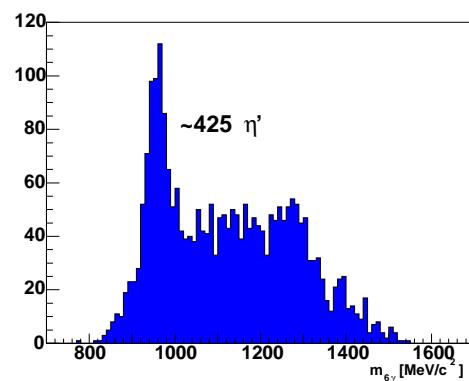


→ Proton detected

→ η from missing mass

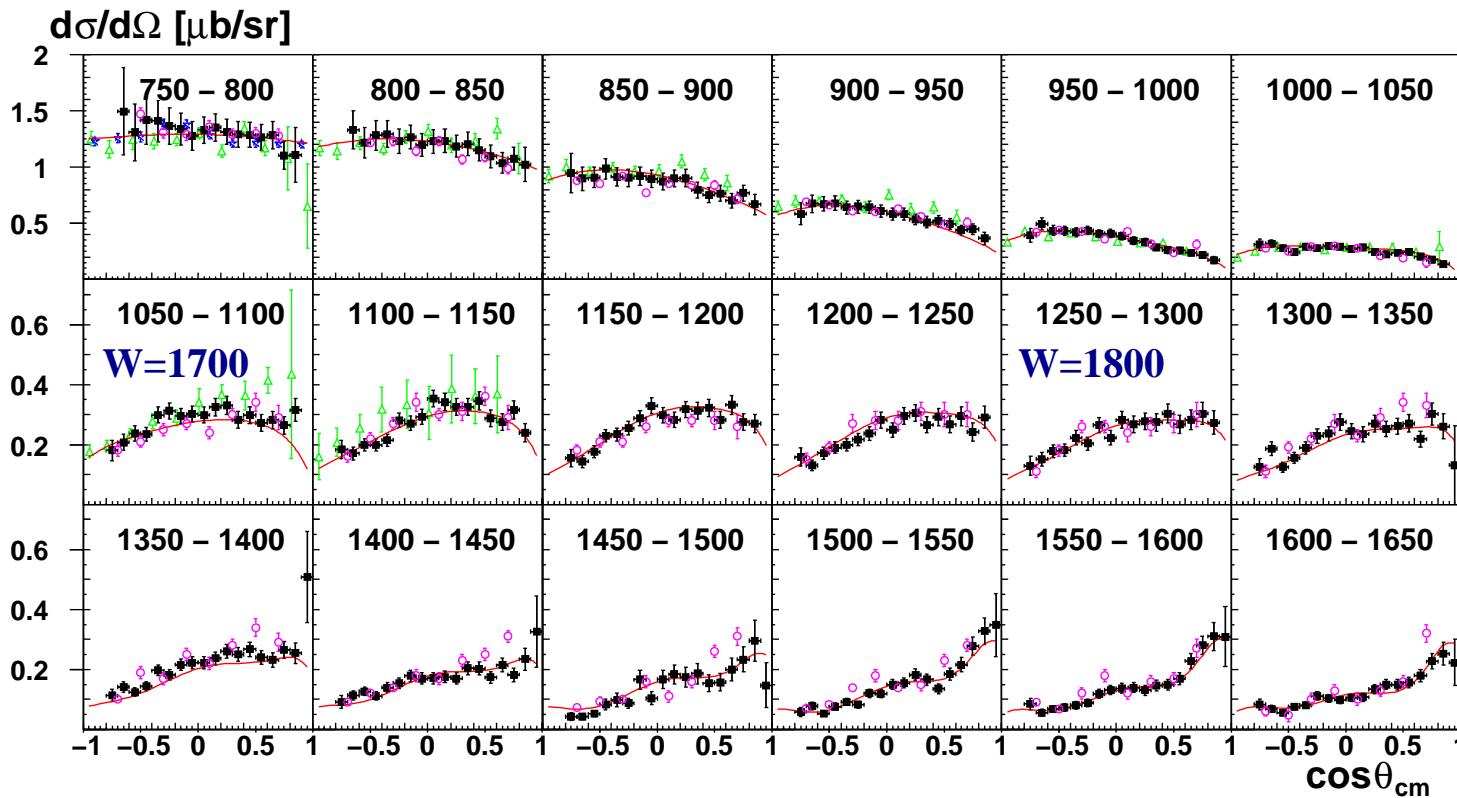
→ Photons are detected

→ Proton direction measured

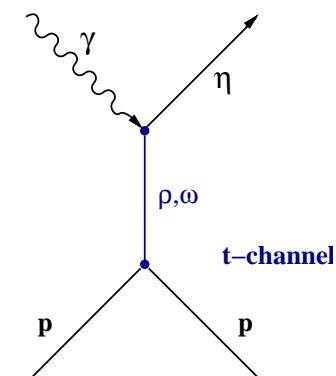
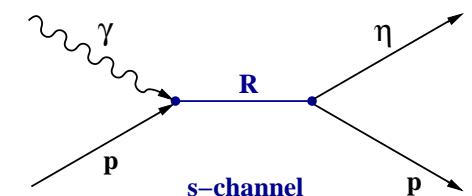
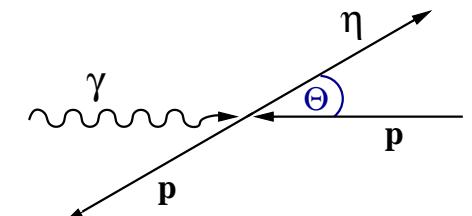
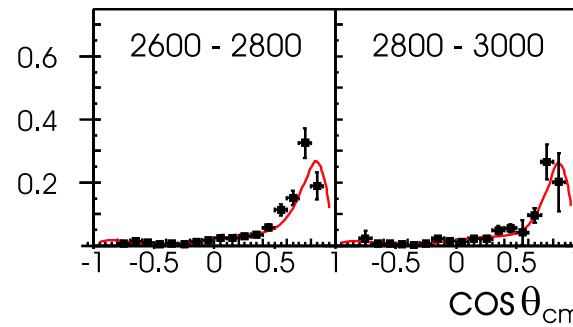


Differential cross section $\gamma p \rightarrow p\eta$

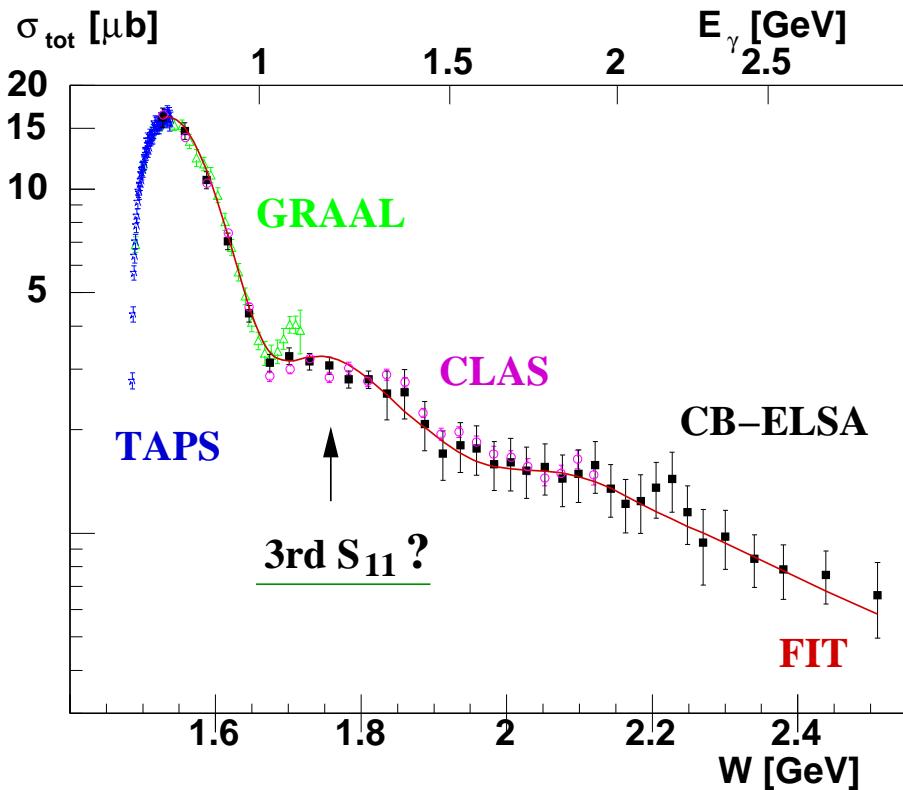
■ CB-ELSA ▲ GRAAL ○ CLAS ★ TAPS — CB-ELSA fit



• • • •



Total cross section $\gamma p \rightarrow p\eta$



CB-ELSA Isobar model fit:

Data included:

- $\gamma p \rightarrow p\eta, \gamma p \rightarrow p\pi^0$ (CB-ELSA)
- $\gamma p \rightarrow p\eta$ (TAPS)
- $\Sigma(\vec{\gamma}p \rightarrow p\eta), \Sigma(\vec{\gamma}p \rightarrow p\pi^0)$ (GRAAL)
- $\Sigma(\vec{\gamma}p \rightarrow p\pi^0), \sigma(\gamma p \rightarrow n\pi^+)$ (SAID)

⇒ **S₁₁(1535), D₁₃(1520), S₁₁(1650), F₁₅(1680), P₁₃(1720), D₁₃(2080)**
+ ... + ρ -, ω -t-channel exchange

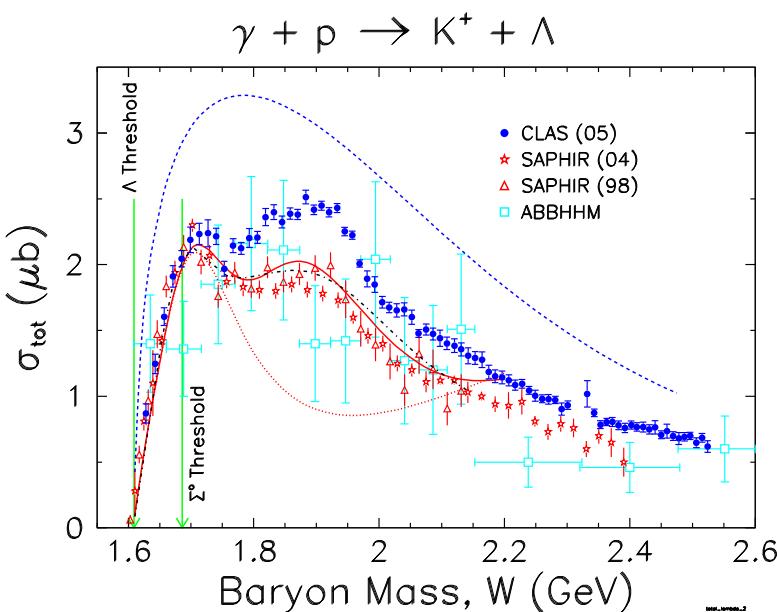
+ new D₁₅: $m = 2068 \pm 22 \text{ MeV}$,
 $\Gamma = 295 \pm 40 \text{ MeV}$

↔ No need for a 3rd S₁₁!

CBELSA/TAPS → talk by V.Crede

Strangeness photoproduction: $\gamma p \rightarrow K^+ \Lambda$, $\gamma p \rightarrow K \Sigma$

First indications for a new $D_{13}(1895)$ in the old $\gamma p \rightarrow K^+ \Lambda$ SAPHIR (98) data
but different models → different interpretations

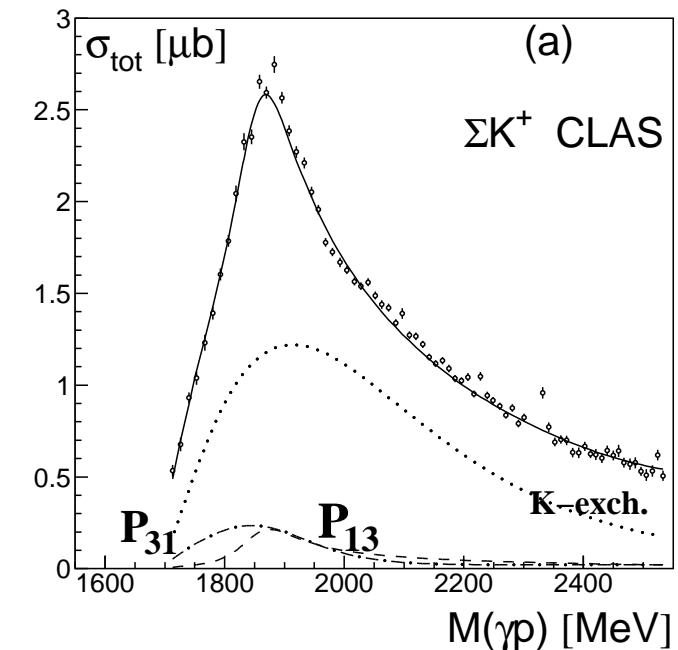
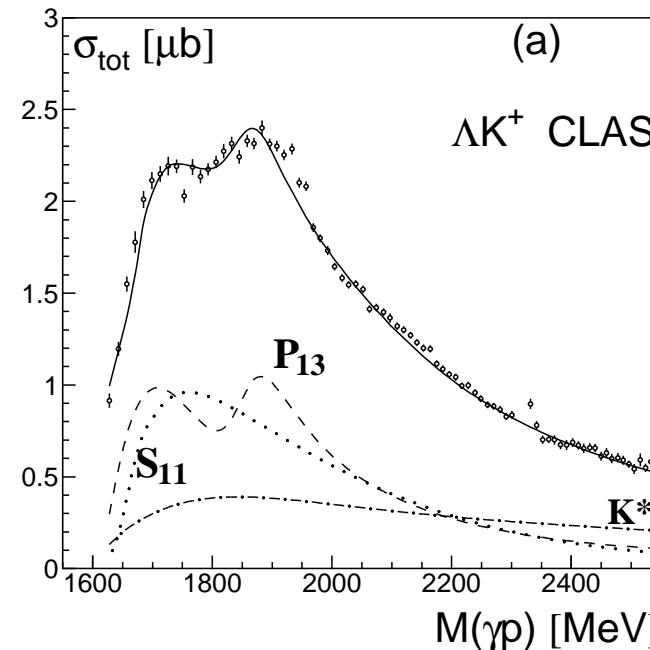


--- Regge model (M. Guidal et al.)

— Kaon Maid (T. Mart et al.)

... Kaon Maid no $D_{13}(1895)$

Bonn - Gatchina combined PWA:

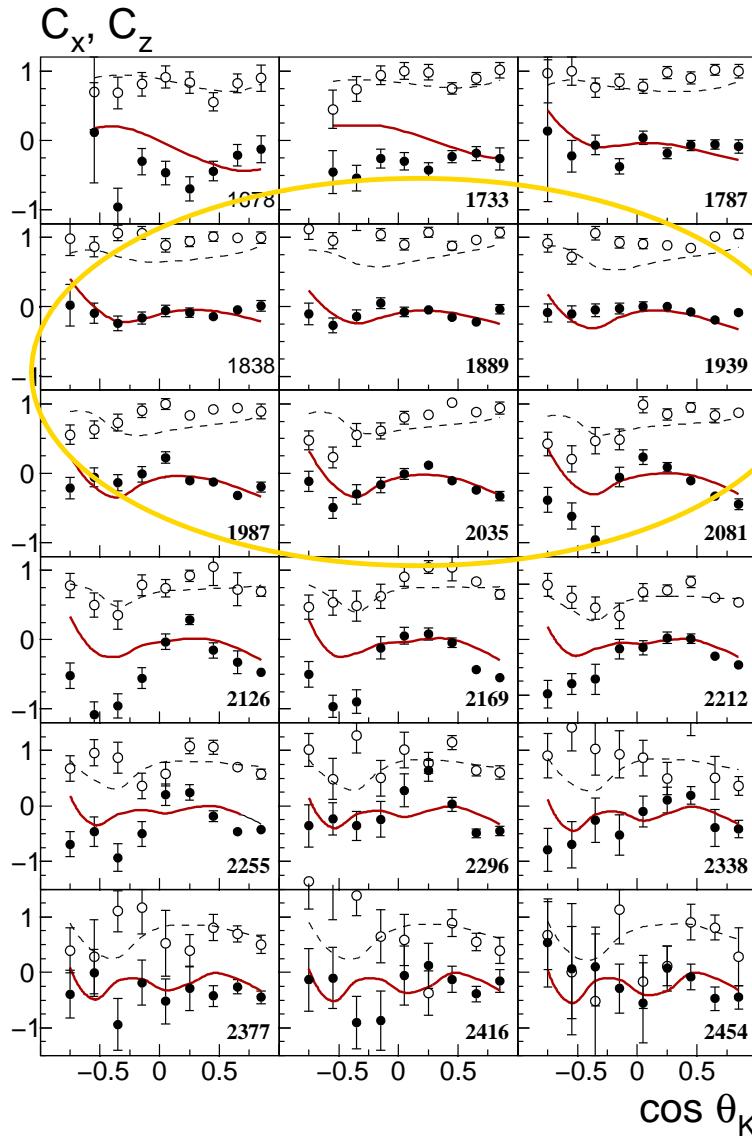


fit of: differential cross sections, recoil pol. (GRAAL, CLAS), beam asym. (LEPS, GRAAL), C_x, C_z (CLAS)

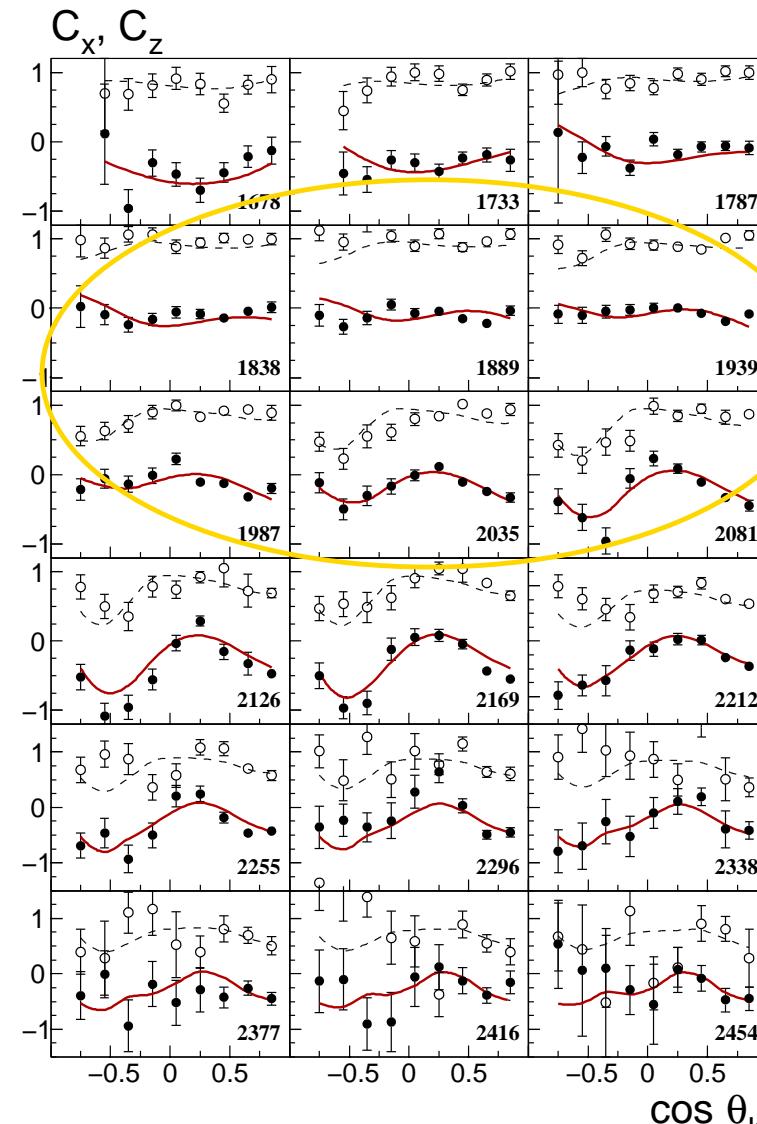
⇒ New $P_{11}(1840)$, $D_{13}(1875)$ + the $P_{13}(1900)$

CLAS: $\vec{\gamma}p \rightarrow K\bar{\Lambda}$ polarisation transfer

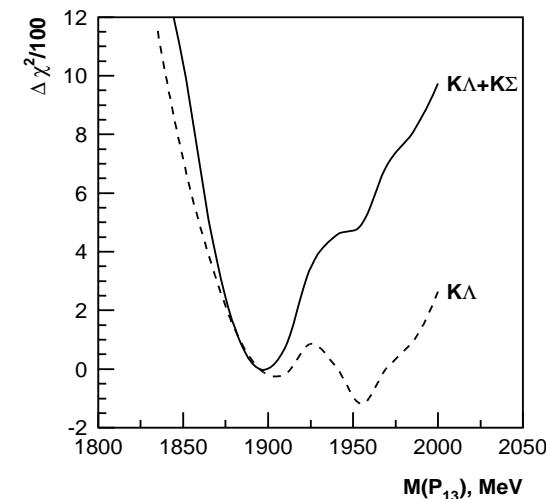
best fit without $P_{13}(1900)$



with $P_{13}(1900)$



↔ Bonn-Gatchina
PWA:
favours existence of
second P_{13} -state !



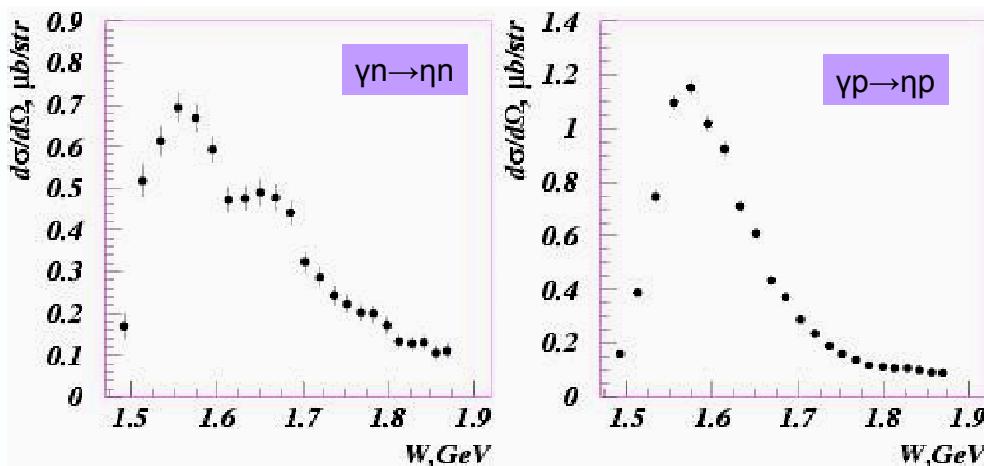
$P_{13}(1900)$: Evidence against the quark-diquark model

η -photoproduction at the neutron - GRAAL data -

V. Kuznetsov et al., NSTAR2004:

Quasi-free differential cross section at

$$\Theta_{cm} = 137^\circ:$$



What is the nature of the observed state?

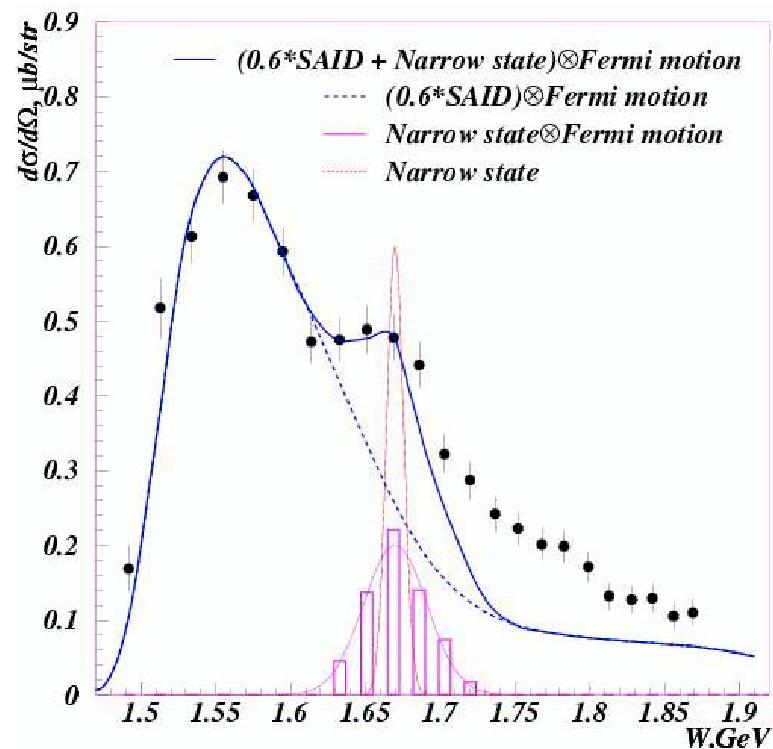
- $D_{15}(1675)$?
- non-strange Pentaquark P_{11} ?

↔ both should be suppressed at the proton and enhanced at the neutron

(Chiang et al., Polyakov et al.)

Is the $D_{15}(1675)$ too wide (150 MeV) for the observed structure ?

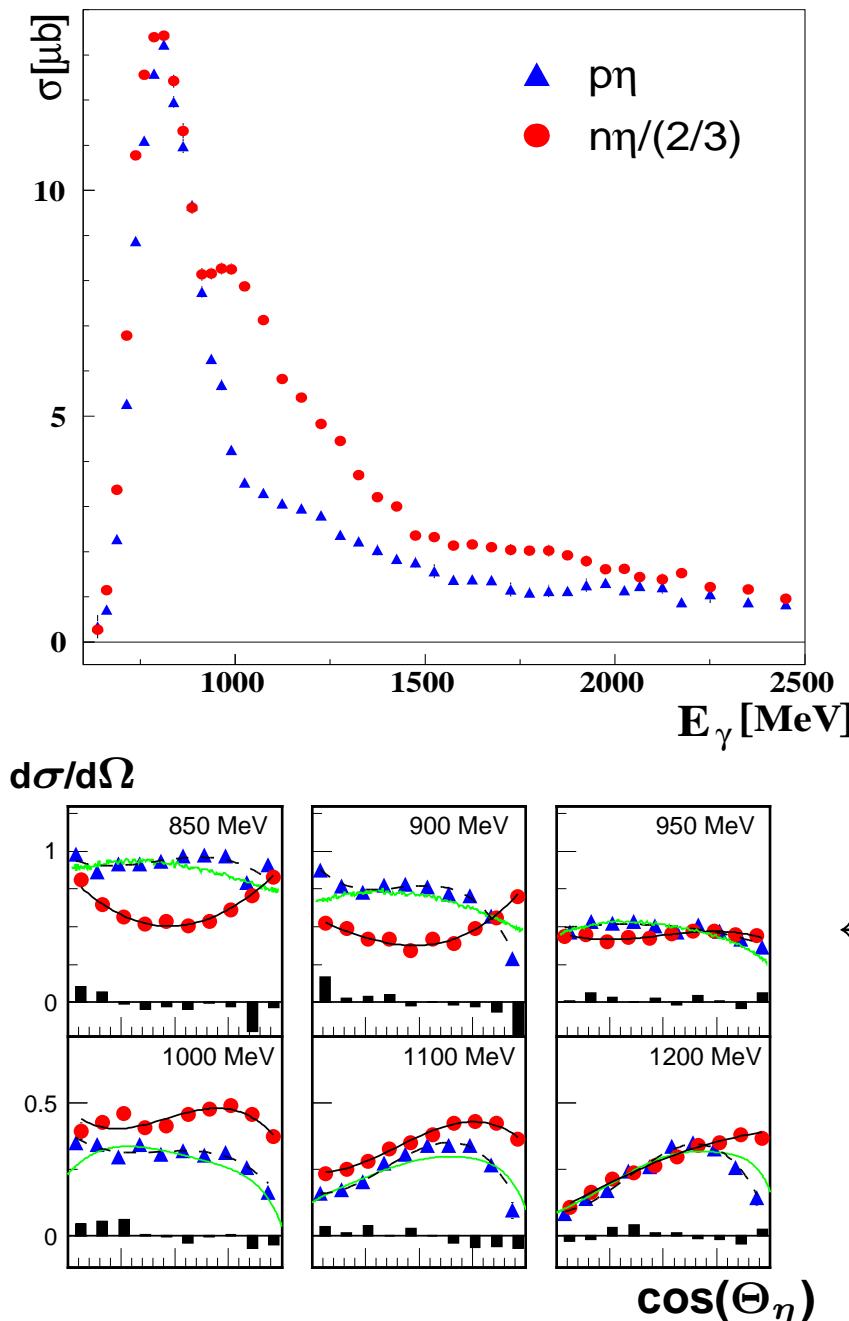
GRAAL (V. Kuznetsov, NSTAR'05/07): Yes !



$M = 1675$ MeV, $\Gamma = 10$ MeV fits the cross section well up to $W=1.7$ GeV

↔ ?

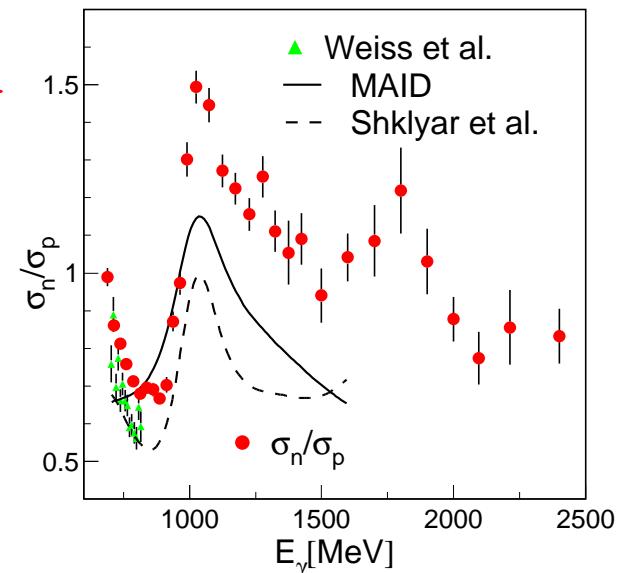
η -photoproduction at the neutron - CB-ELSA/TAPS data -



Investigation of $\gamma d \rightarrow n\eta(p); \eta \rightarrow 3\pi^0$

↔ also CB-ELSA/TAPS data shows an enhancement around 1670 MeV (preliminary)

σ_n/σ_p data in comparison to MAID (—) prediction
↔ effect of the $D_{15}(1675)$



↔ something quite interesting going on

- role of the $D_{15}(1675)$?
- narrow $P_{11}(1670)$?
- explainable by S_{11} -states + $P_{11}(1710)$?
- interference of $S_{11}(1535)/S_{11}(1650)$?

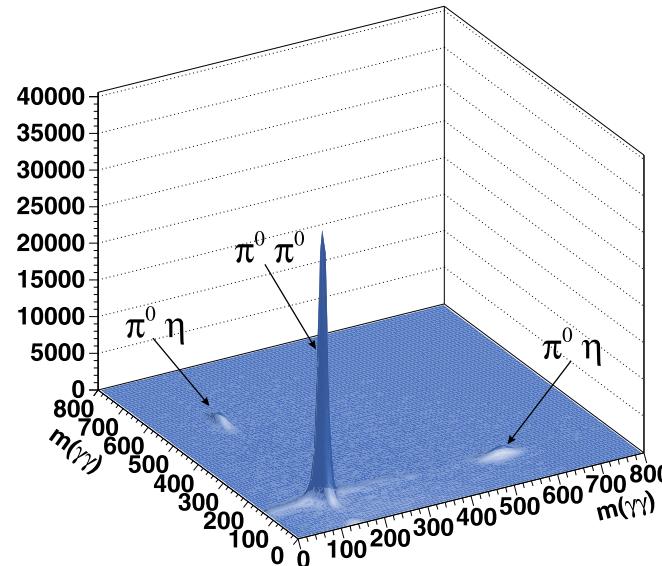
↔ additional observables needed

Multiparticle final states: $\gamma p \rightarrow p\pi^0\pi^0$, $\gamma p \rightarrow p\pi^0\eta$

Search for $N^*/\Delta^* \rightarrow \Delta\pi$, $\Delta^* \rightarrow \Delta\eta$:

CB-ELSA

$\gamma p \rightarrow p4\gamma$:

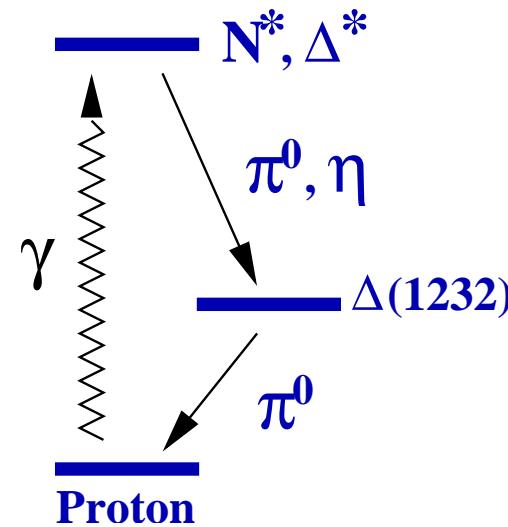


$\Rightarrow \gamma p \rightarrow p\pi^0\pi^0$
and $\gamma p \rightarrow p\pi^0\eta$
clearly observed

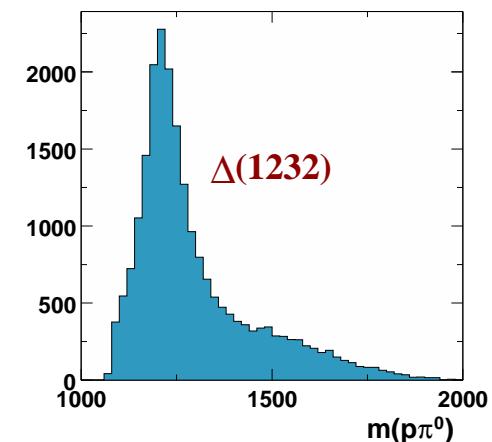
$\gamma p \rightarrow N^*/\Delta^* \rightarrow \Delta\pi^0 \rightarrow p\pi^0\pi^0$

$\gamma p \rightarrow \Delta^* \rightarrow \Delta\eta \rightarrow p\pi^0\eta$

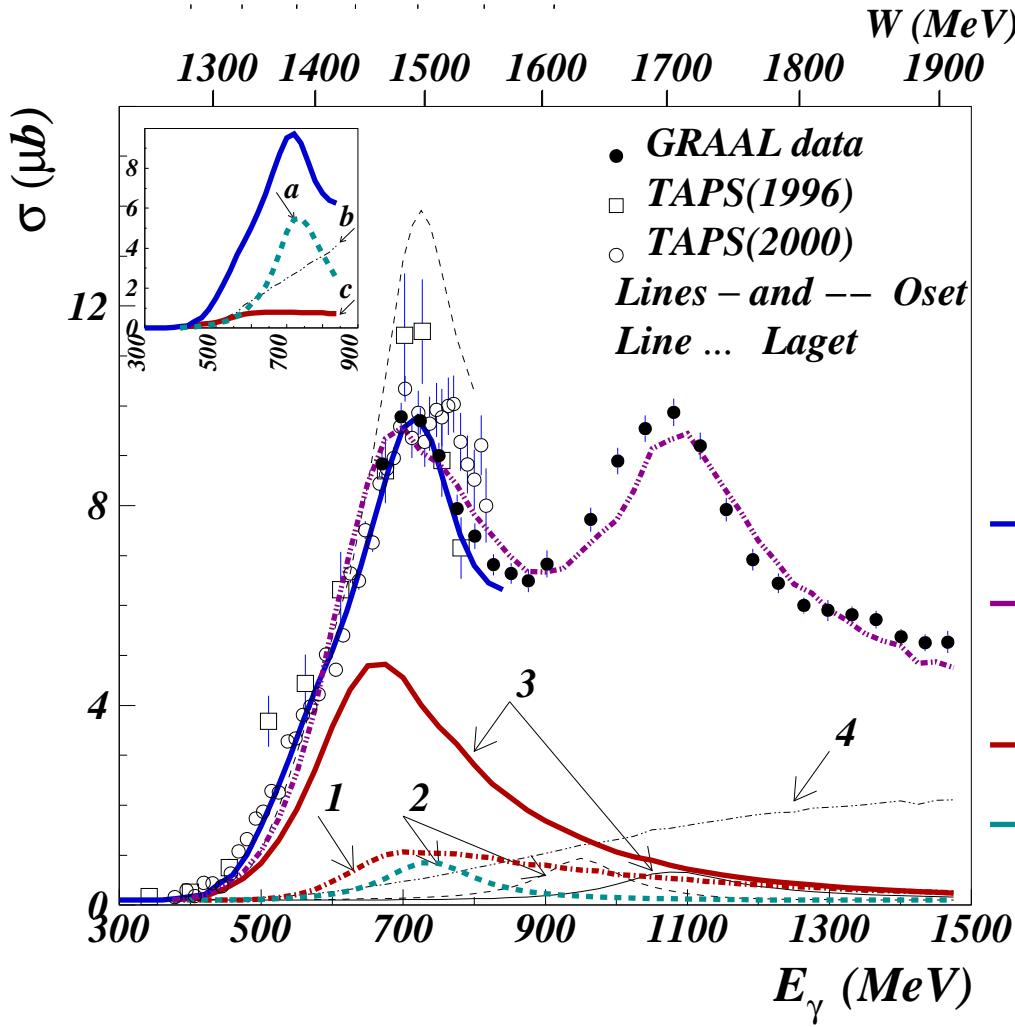
isospin selective \Rightarrow investigation of
the Δ^* -spectrum



$\gamma p \rightarrow p\pi^0\eta$



$\gamma p \rightarrow p\pi^0\pi^0$ from TAPS and GRAAL



↔ Total cross section

Data analysed by:

- Oset et al.:

⇒ $P_{11}(1440)$, $D_{13}(1520)$,
 $D_{33}(1700)$

(limited to low energy)

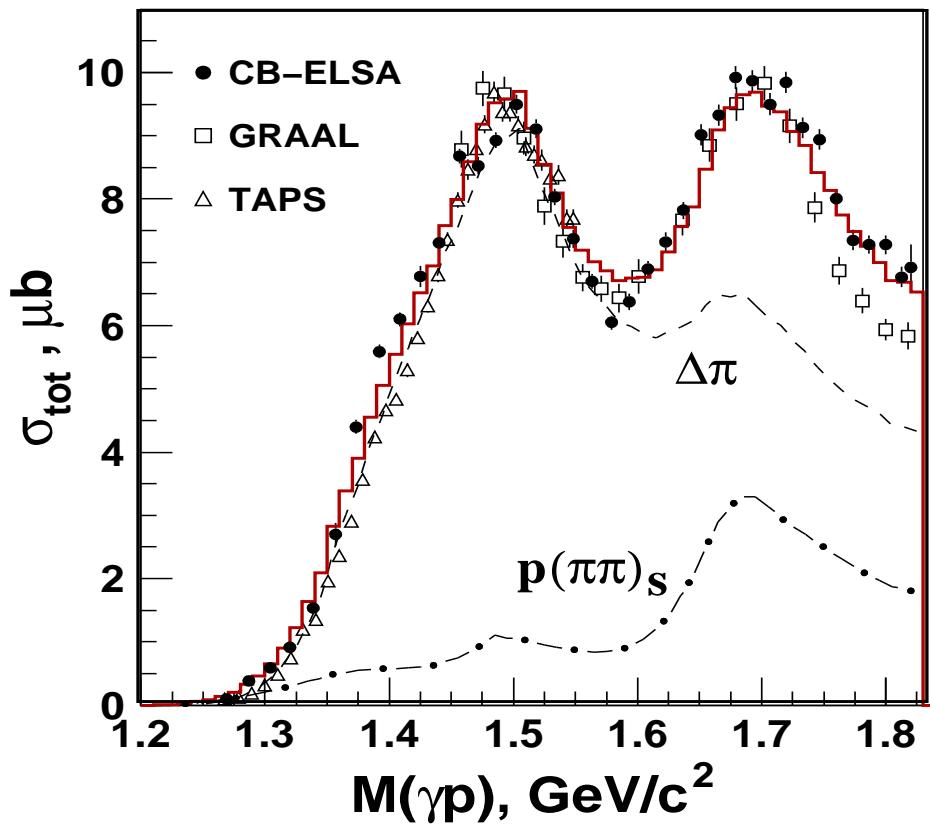
- Laget et al.:

⇒ $P_{11}(1440)$, $D_{13}(1520)$,
 $D_{13}(1700)$, $D_{33}(1700)$,
 $P_{11}(1710)$

↔ Big discrepancy:

Oset: $D_{13}(1520) \rightarrow \Delta\pi$ dominant, Laget: $P_{11}(1440) \rightarrow p\sigma$ dominant

$\gamma p \rightarrow p\pi^0\pi^0$



Results contradicting naive expectation:

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

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

high E, beam asym. → talk by R.Beck

PWA → talk by A.Anisovich

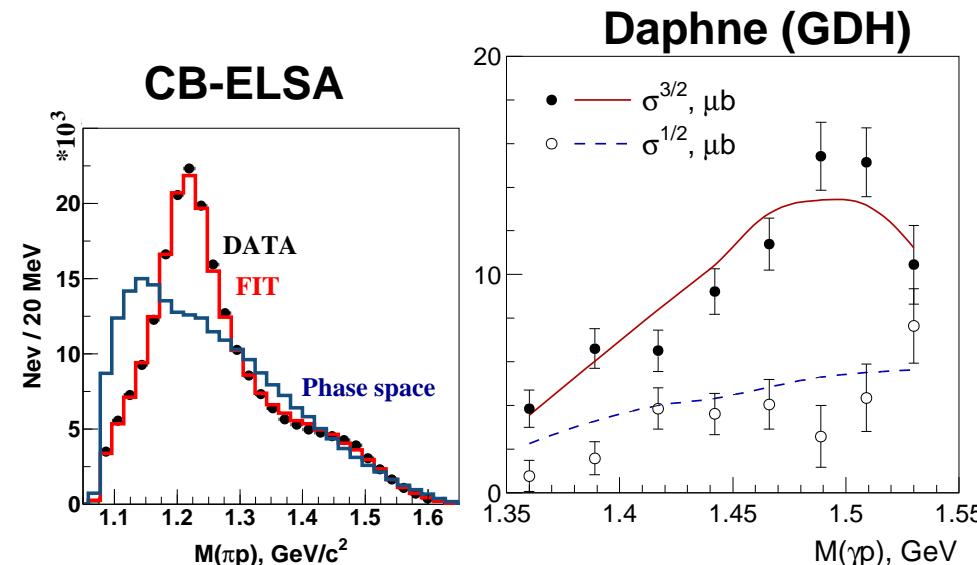
CB-ELSA Fit including additional data from:

- single meson photoproduction,
- $\pi^- p \rightarrow n 2\pi^0$ (CBall),
- $P_{11}, S_{11}, P_{33}, D_{33}$ - πN -partial waves

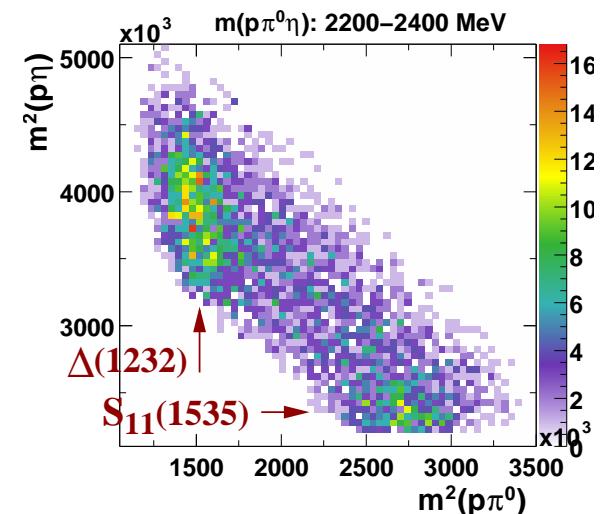
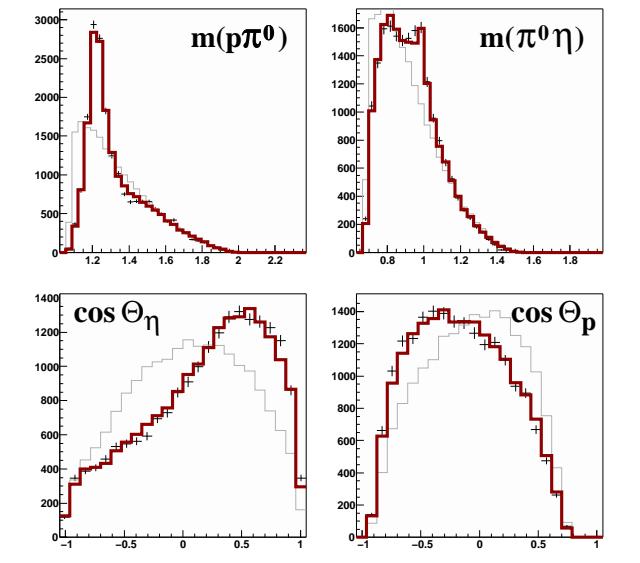
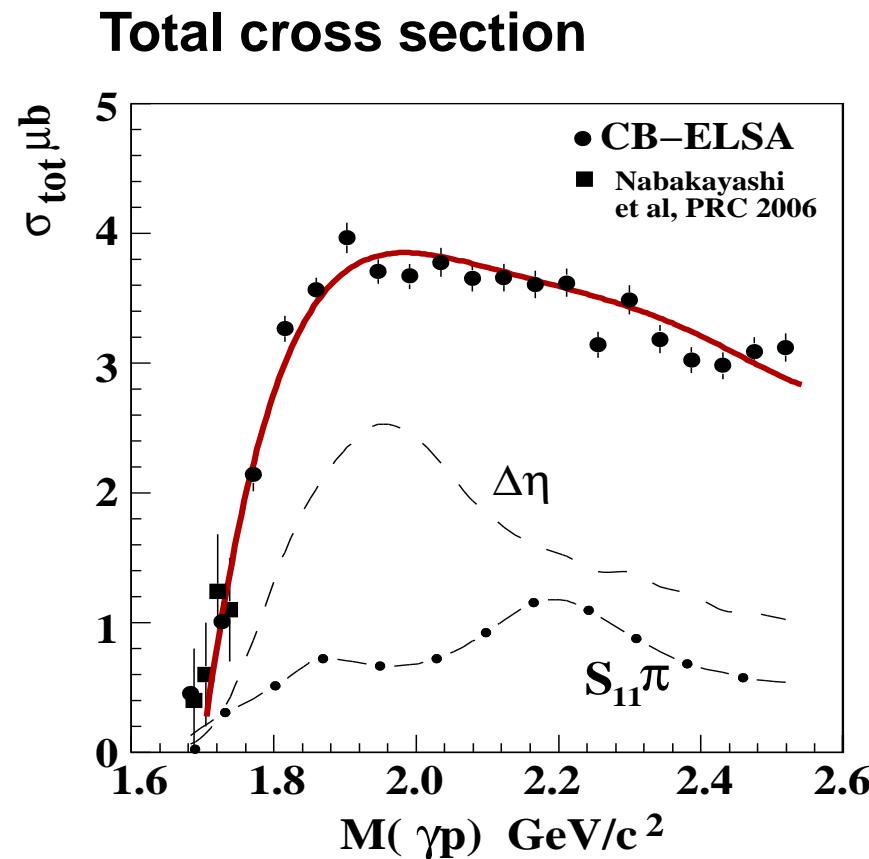
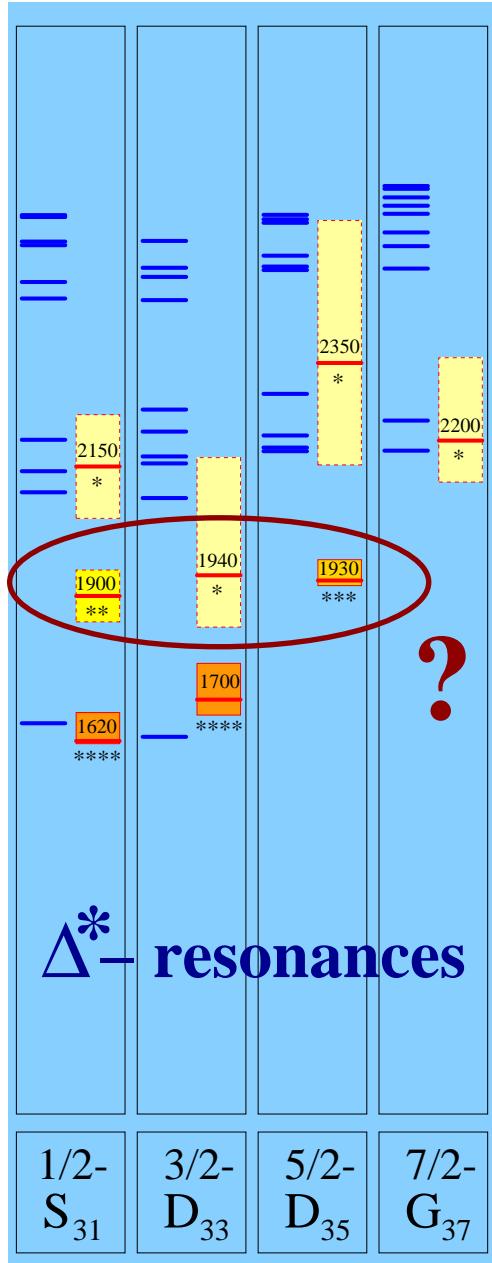
↔ Event based maximum likelihood fit

⇒ Determination of resonance properties:

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



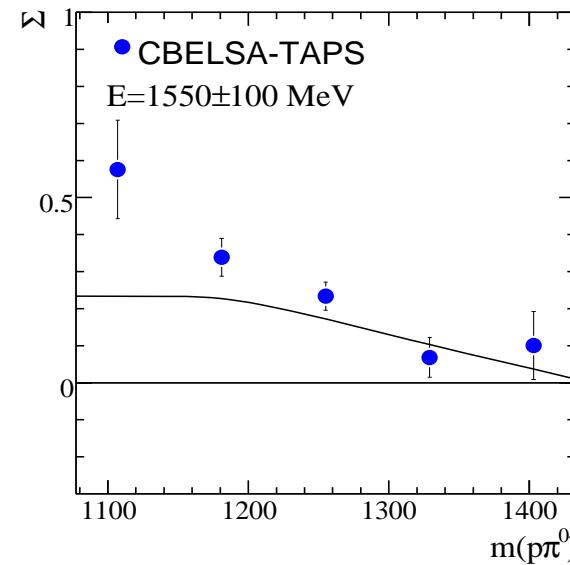
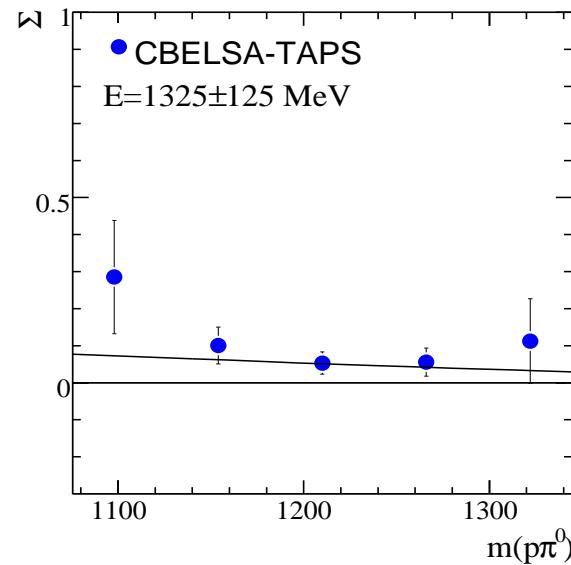
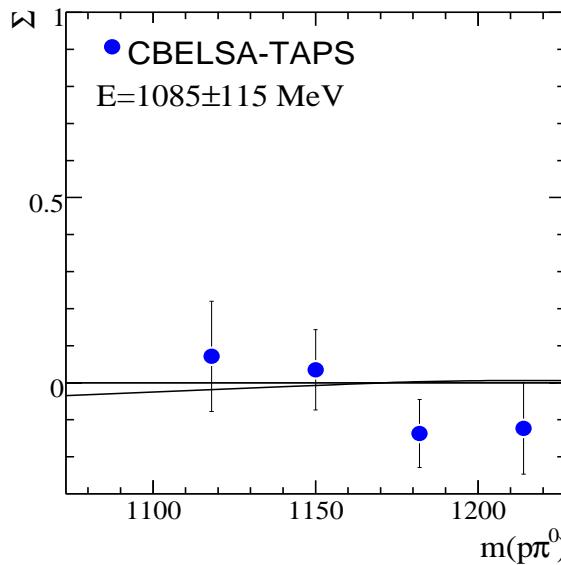
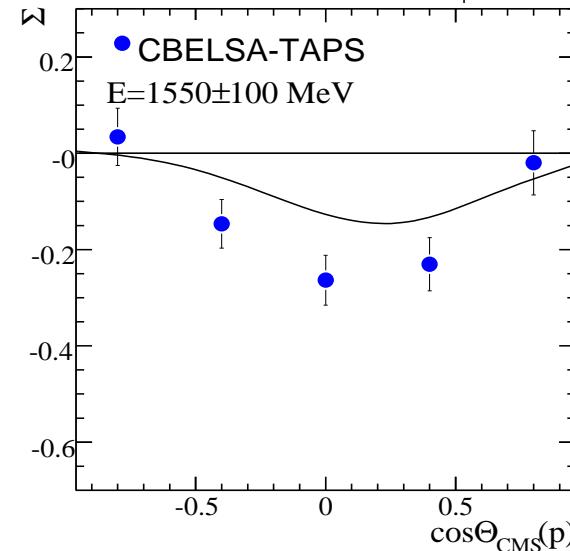
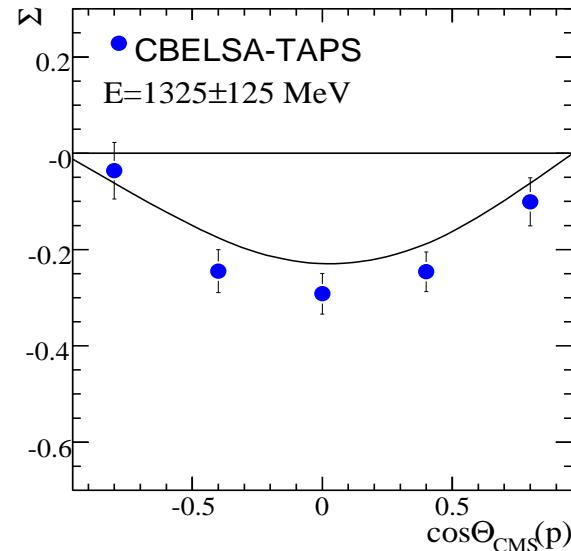
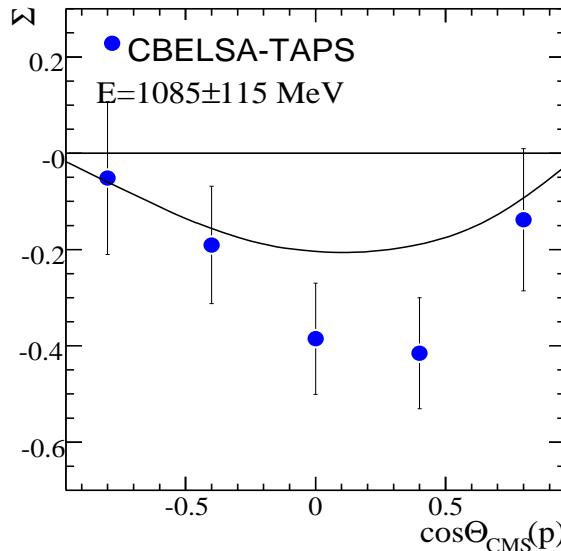
$\gamma p \rightarrow p\pi^0\eta$ CB-ELSA



Event based maximum likelihood fit:
 $\Rightarrow D_{33}(1940)$ clearly contributes

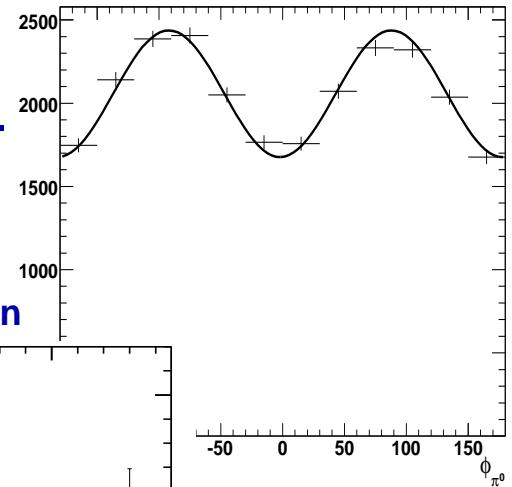
$\vec{\gamma}p \rightarrow p\pi^0\eta$ - CBELSA/TAPS -

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



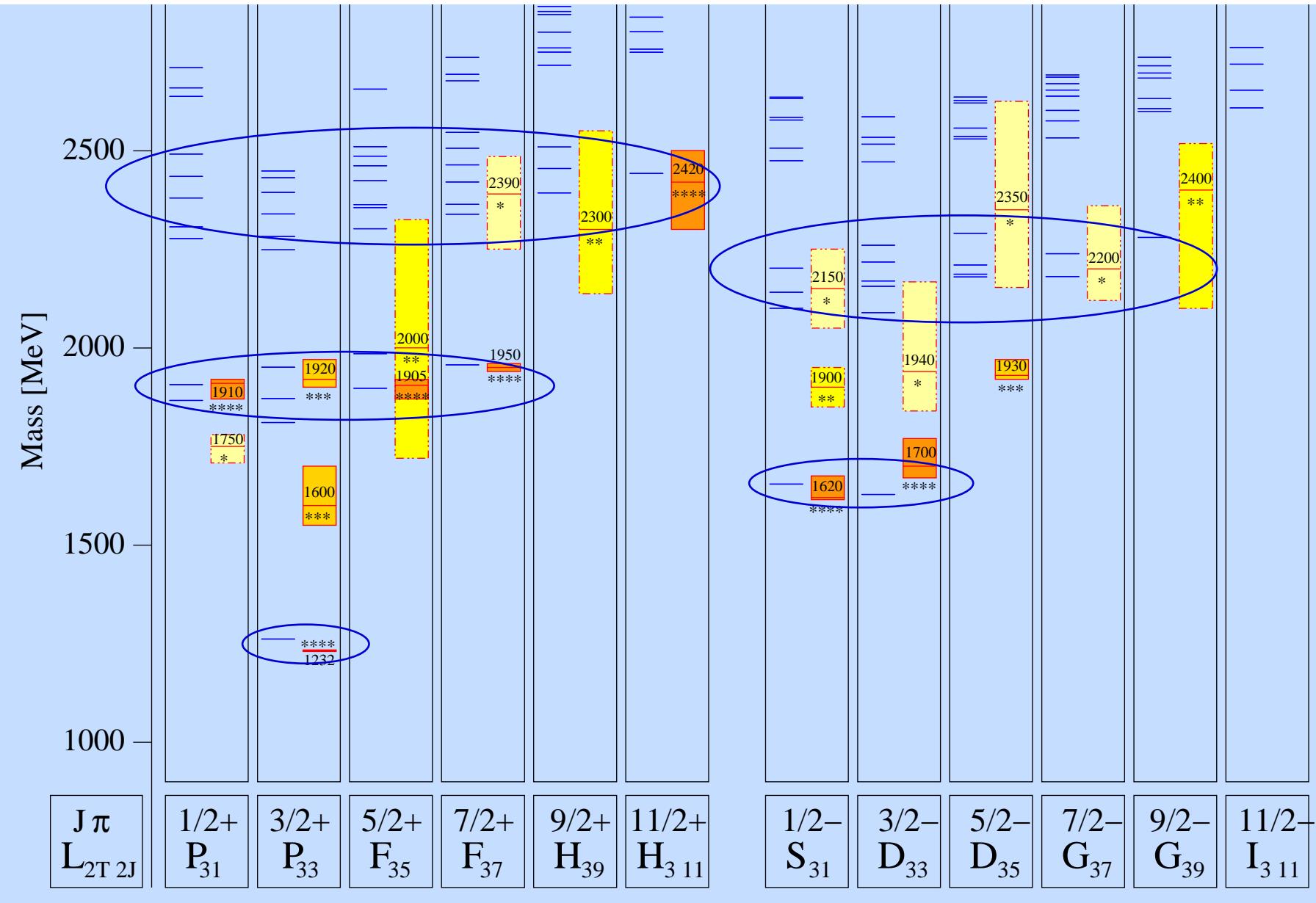
PRELIMINARY

- PWA
prediction



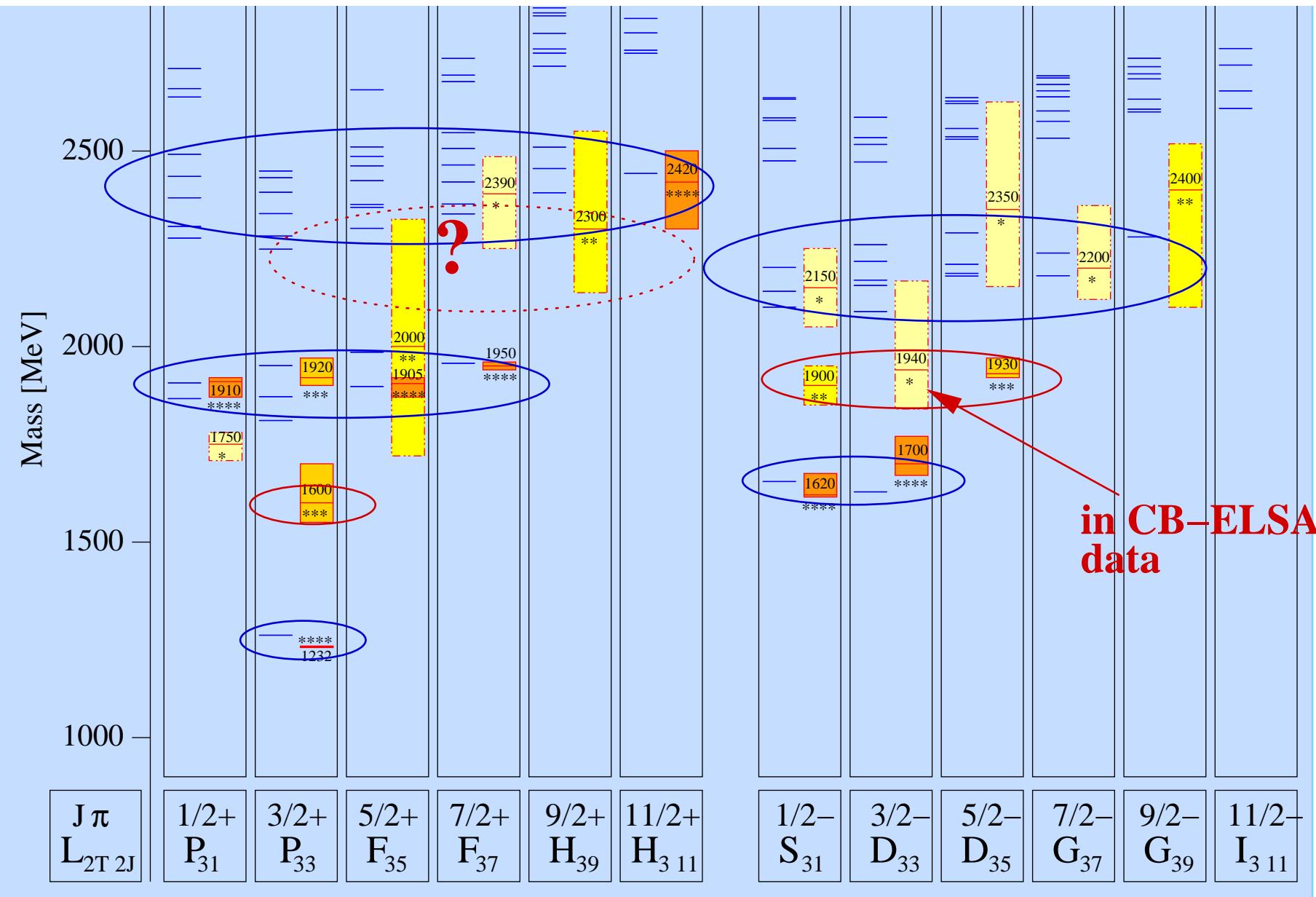
The Δ^* - states

Quark model
U. Löring, B. Metsch,
H. Petry et al.



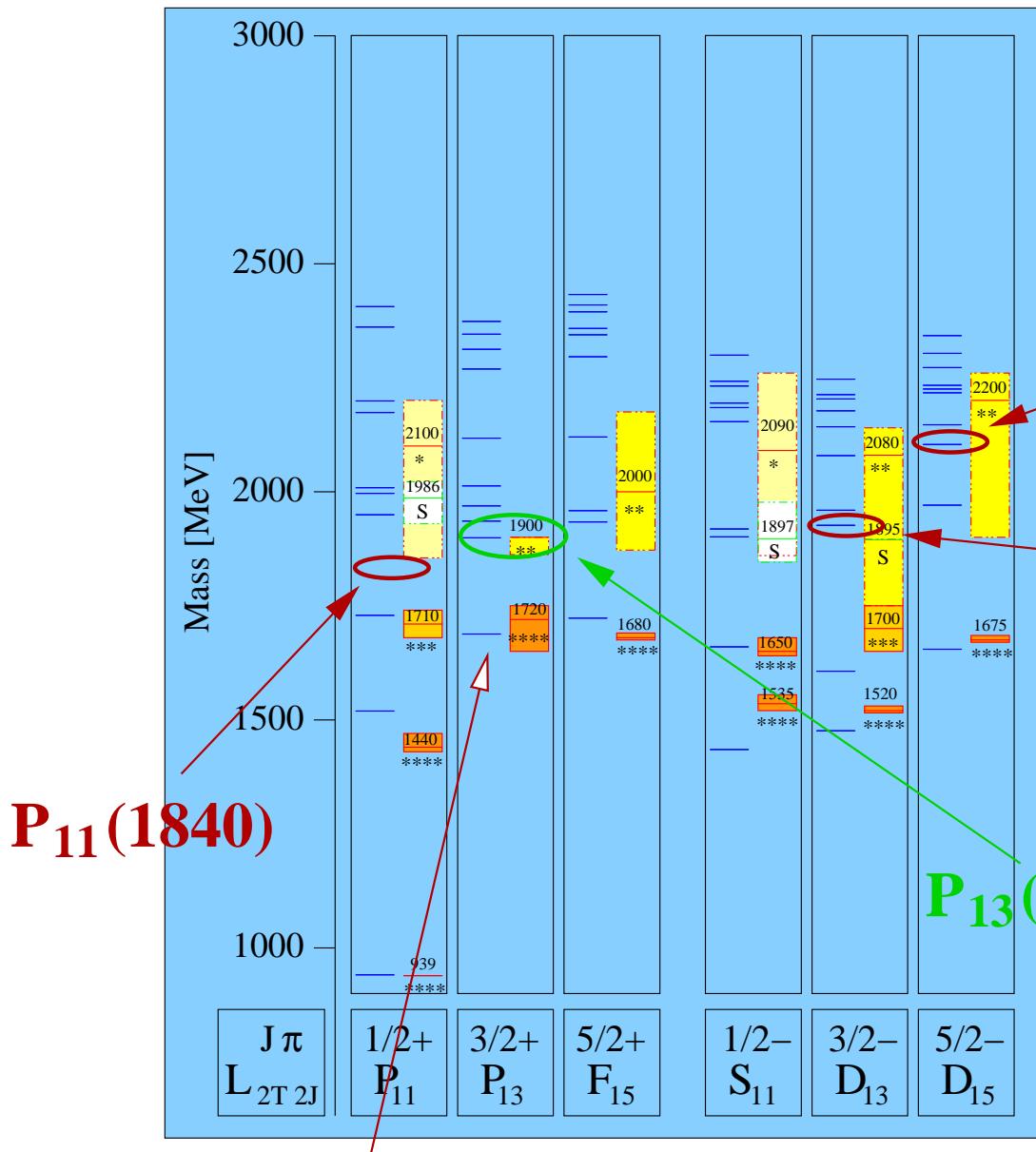
The Δ^* - states

Quark model
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H. Petry et al.



↔ Additional experimental information needed !!

The " new " states - a comparison with the quark model -



2 states ? $p\pi^+\pi^-$ electroproduction (CLAS)

Quark model calculations by:
U. Löring, B. Metsch, H. Petry et al.

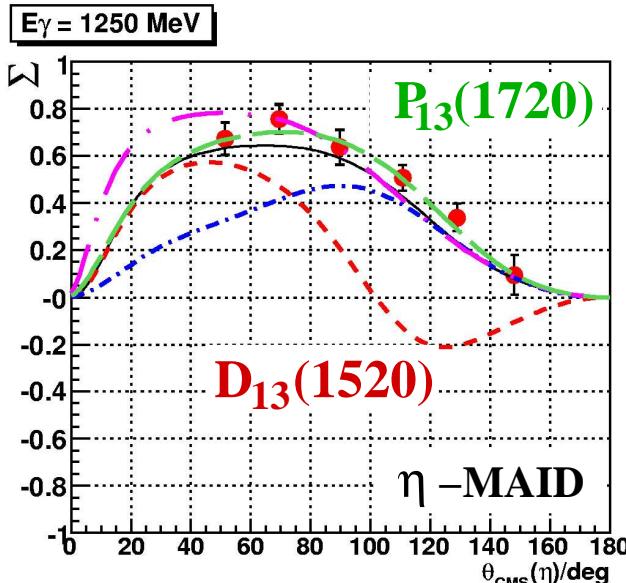
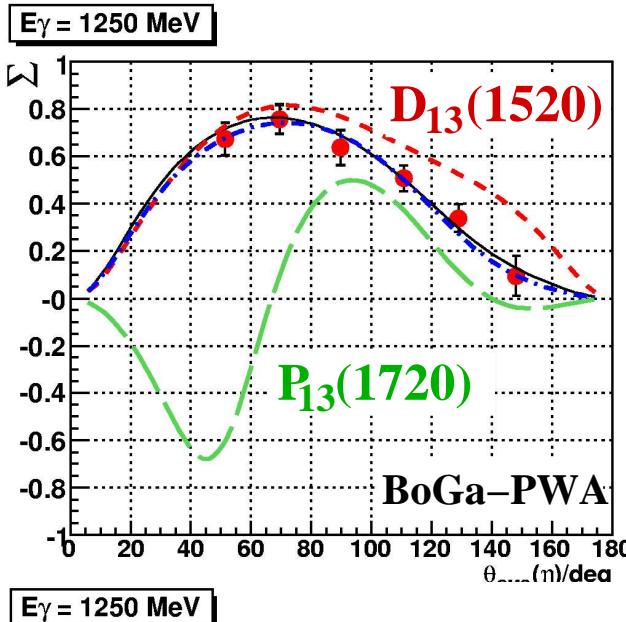
$D_{15}(2070)$

$D_{13}(1875)$

... important : further polarisation experiments!

- confirmation of new resonances
- ↔ higher sensitivity on resonance contributions !

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



Single pseudoscalar meson photoproduction

Complete experiment

→ ≥ 8 observables needed

Double pseudoscalar meson photoproduction

→ ≥ 15 observables needed

(Roberts, Oed)

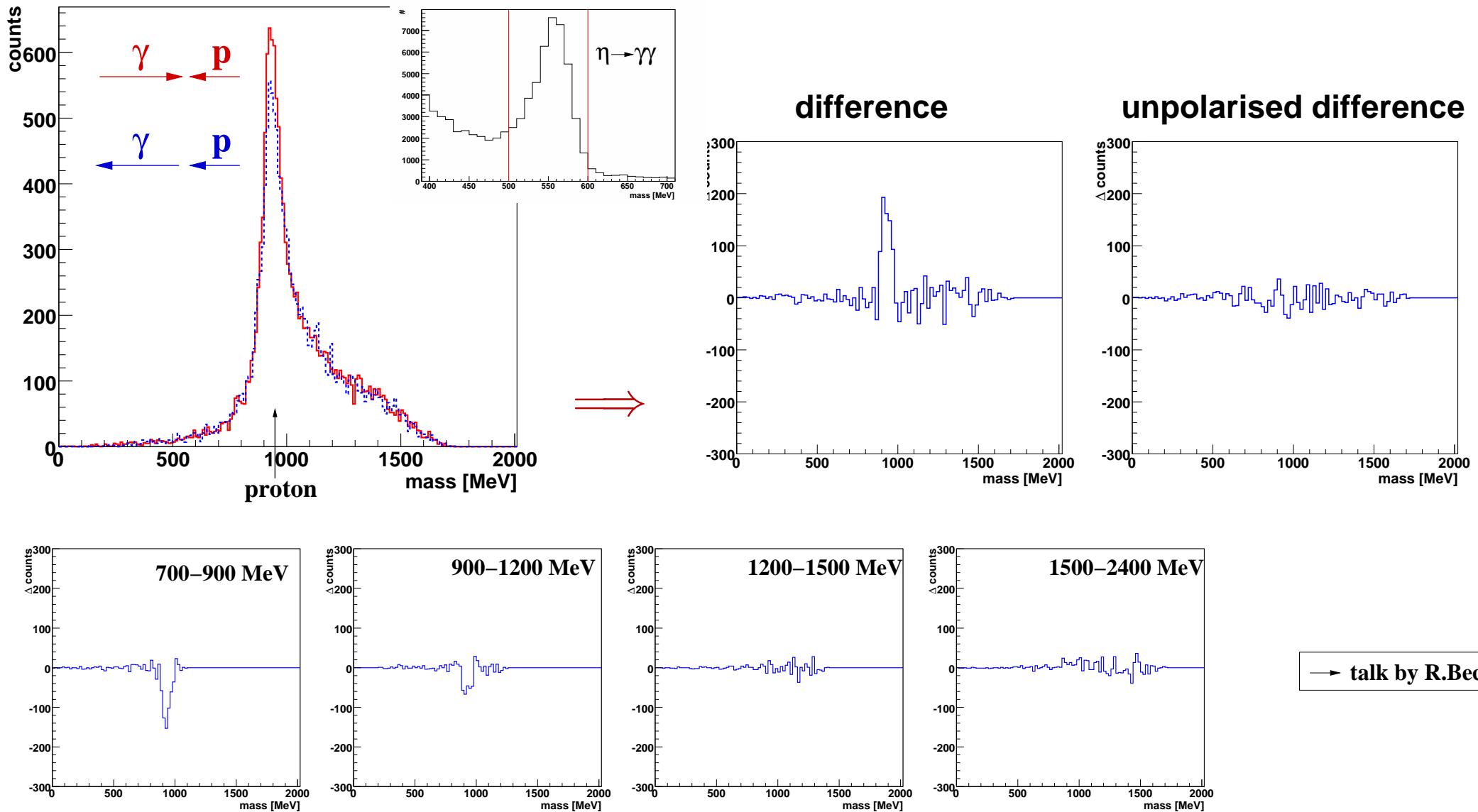
⇒ double polarisation experiments needed !

**Experiments with polarised target
and polarised beam:**

- planned at Crystal Ball (MAMI), CLAS (JLab)
- started at Crystal Barrel (ELSA)

Presently: Double polarisation experiments at ELSA

First online spectra: circularly polarised beam, longitudinal polarised target



⇒ First asymmetries observed !

Summary

- High quality data has been taken
 - Extends the covered angular and energy range, new final states, first polarisation observables
 - First evidence for new resonances
 - Decays via higher mass resonances observed
(e.g. $D_{13}(1520)\pi^0$, $S_{11}(1535)\pi^0$)
- New data on transition formfactors
 - ↔ Already very interesting !

But there is a lot more to be discovered
+ cross check new states

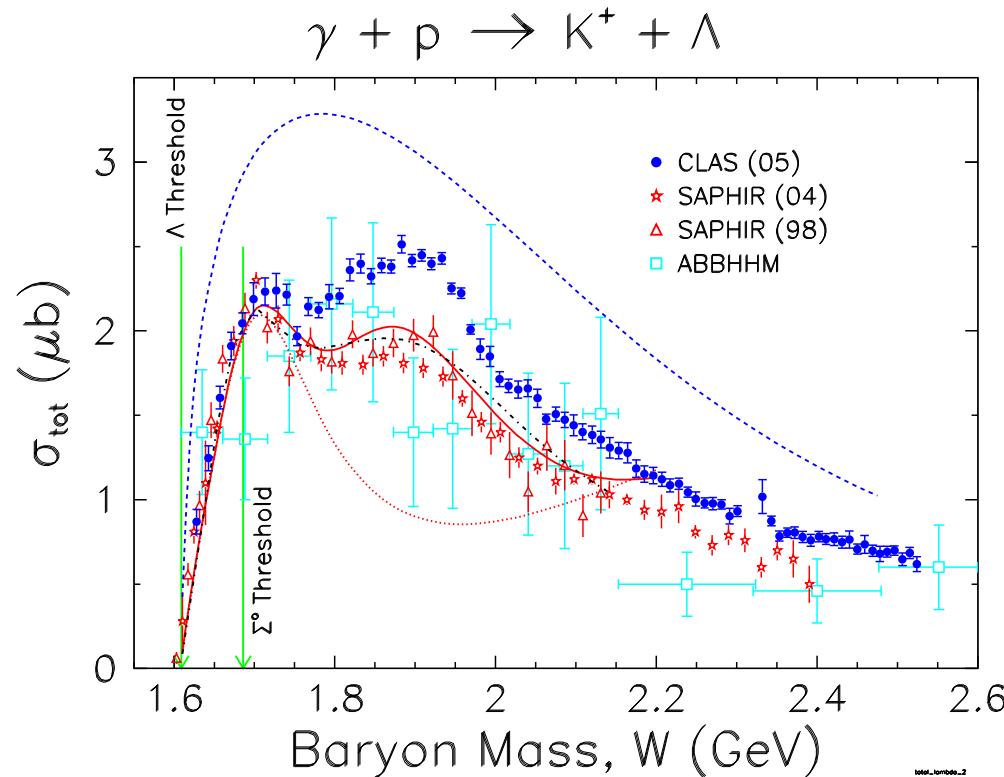
↔ Polarisation experiments !

⇒ Detailed testing ground for quark models, lattice QCD calculations ...

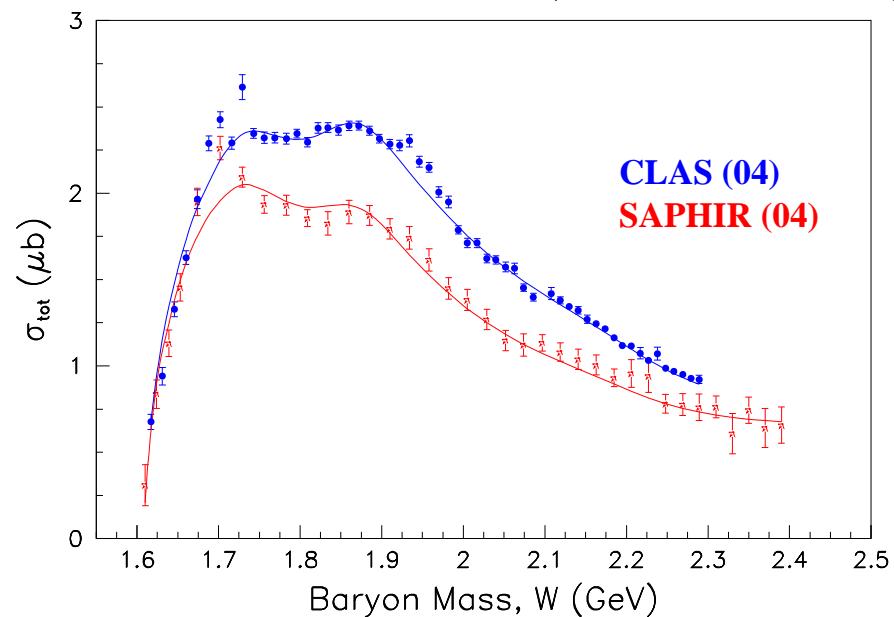
Thank you !

$\gamma p \rightarrow K^+ \Lambda$

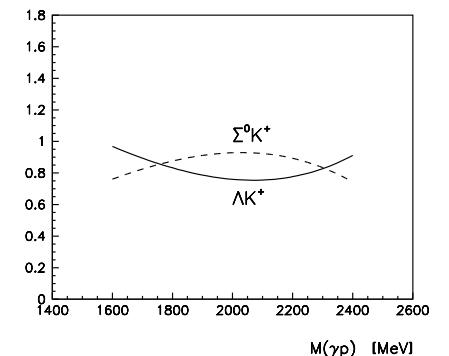
**First indications for a new $D_{13}(1895)$ in the old SAPHIR (98) data
but different models → different interpretations**



**Bonn - Gatchina PWA:
(combined analysis with $\gamma p \rightarrow p\pi^0, p\eta, K\Sigma$)**

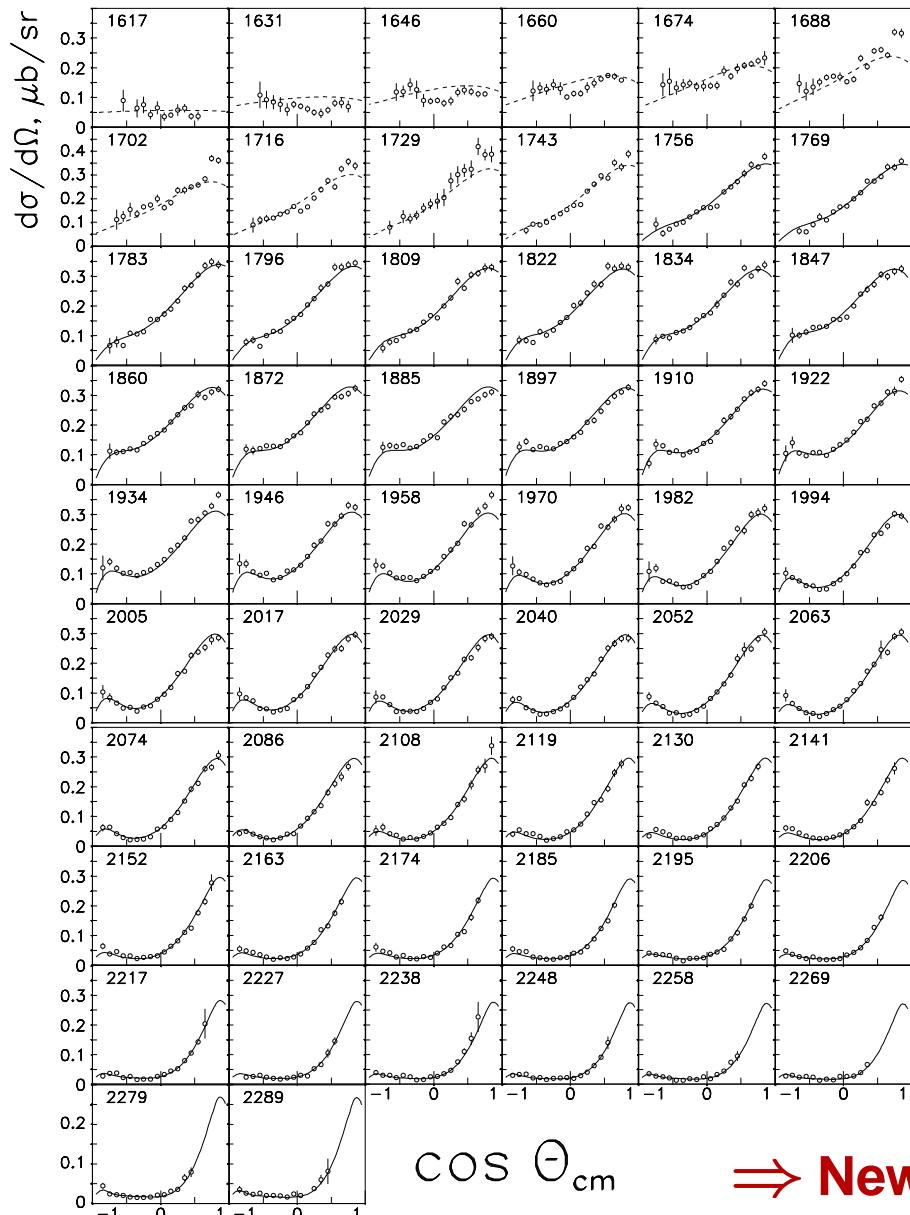


scale factor used in
PWA for SAPHIR data:
↔ renormalisation

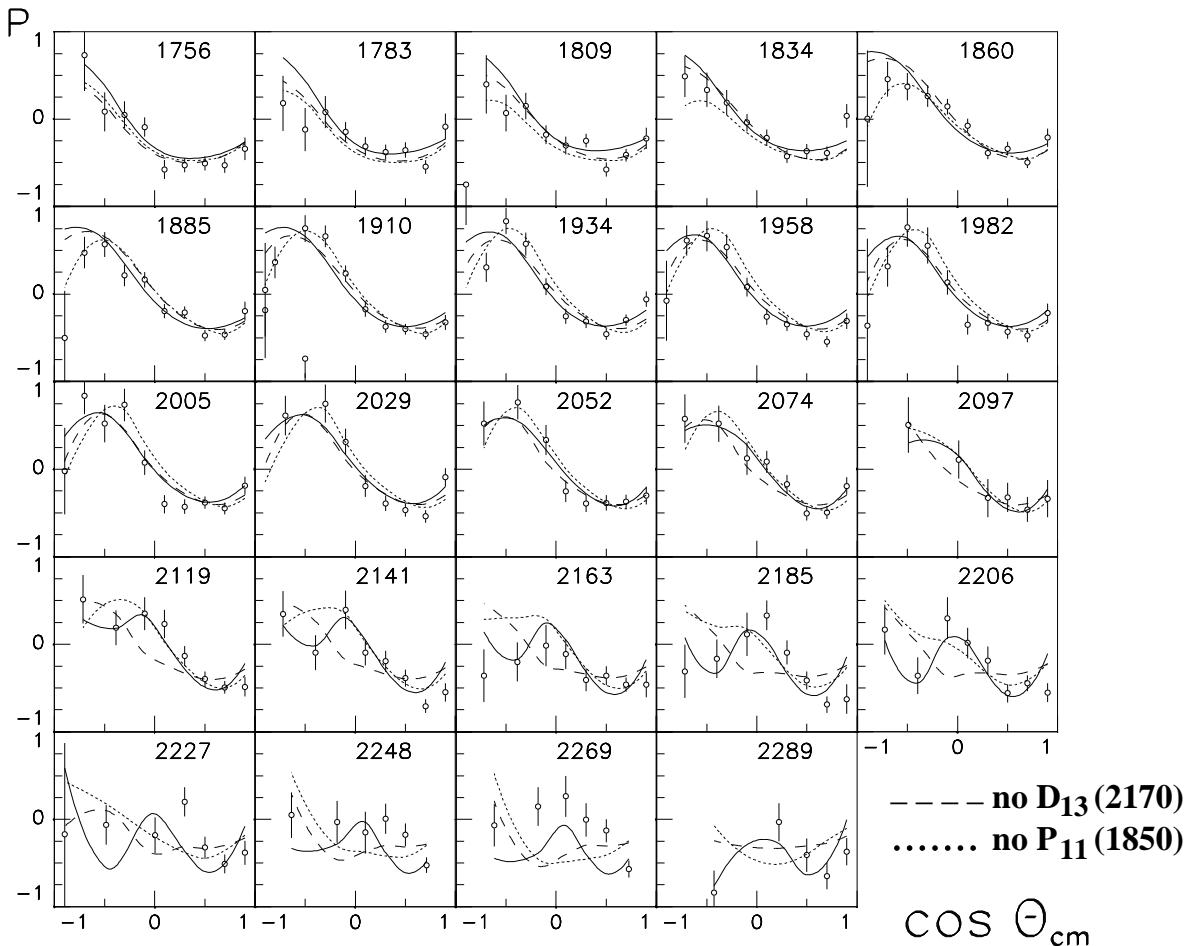


Bonn-Gatchina combined PWA including $\gamma p \rightarrow K\Lambda, K\Sigma$

CLAS: $\gamma p \rightarrow K\Lambda$ diff. cross section:



CLAS: $\gamma p \rightarrow K\Lambda$ recoil polarisation:

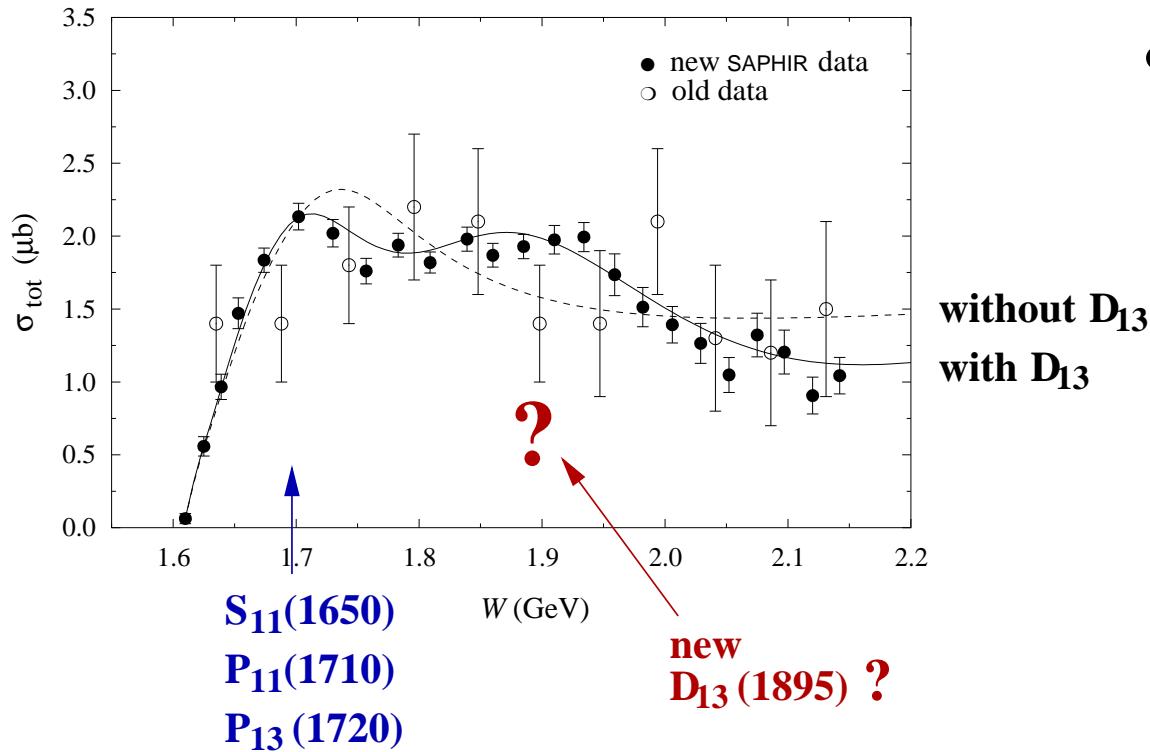


also included in the fit: beam asymmetry data
from LEPS (Spring-8)

⇒ New $P_{11}(1840)$, $D_{13}(1875)$, possible new $D_{13}(2170)$

$\gamma p \rightarrow K^+ \Lambda$ - different interpretations -

SAPHIR(98) (7591 events):



- Tree level isobar model

(T.Mart, C.Bennhold)
→ new resonance needed
~1900 MeV

Constituent quark-model:

$S_{11}(1945)$, $P_{11}(1975)$, $P_{13}(1950)$,
 $D_{13}(1960)$: significant $K\Lambda$ - width
→ all can reproduce the data

Only D_{13} predicted to have
a significant γp -coupling
⇒ $D_{13}(1895)$

Fits to the latest SAPHIR(04) data: suggest that a larger number of new resonances could contribute (Mart, Sulaksono, Bennhold)

- Chiral quark model (B.Saghai)

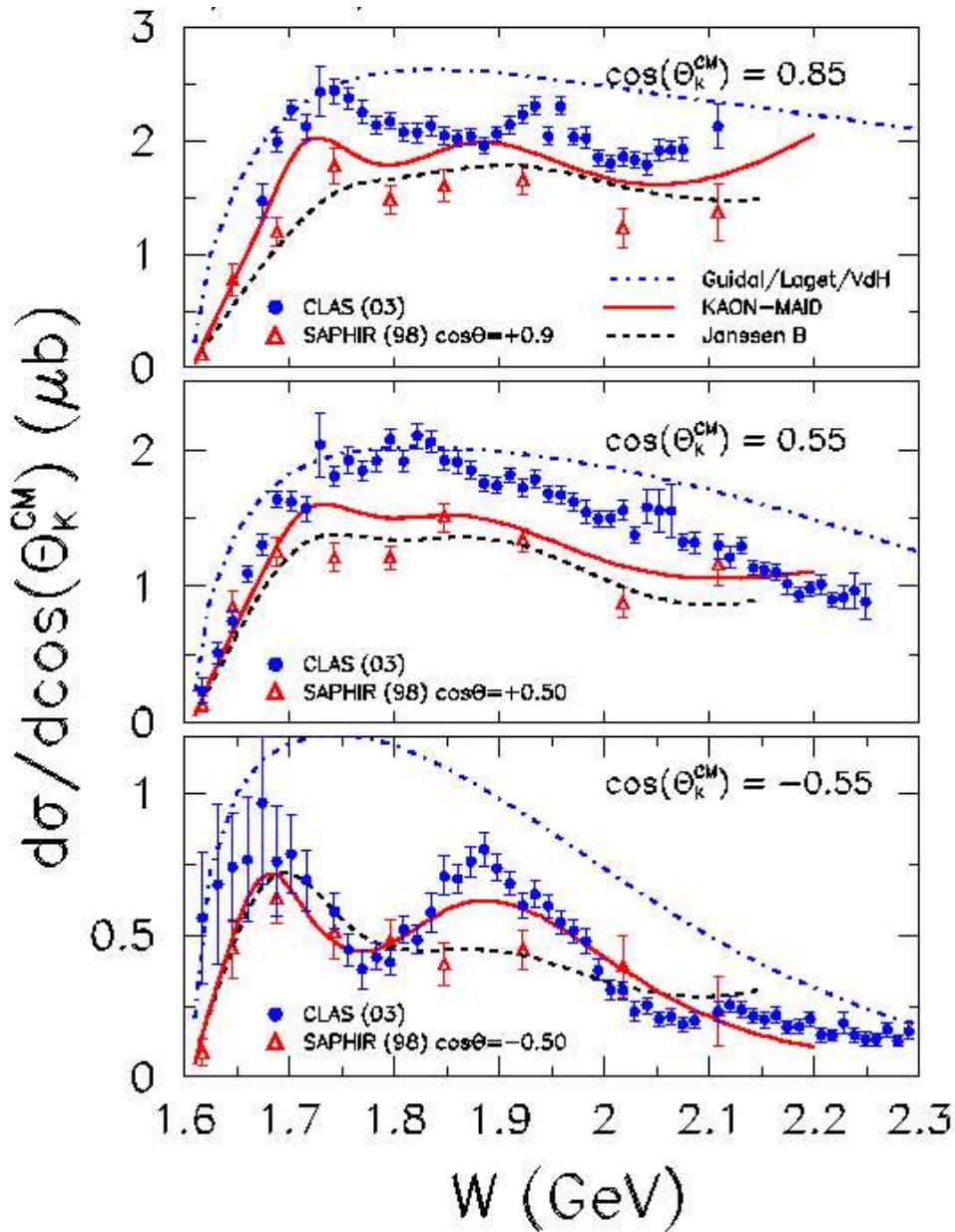
- no $D_{13}(1895)$ needed, exchange of $\Lambda(1810)$, $\Lambda(1890)$ in u-channel
→ explains the enhancement ~1900 MeV

$\gamma p \rightarrow K^+ \Lambda$ - different interpretations -

- Coupled channel approach - chiral constituent quark model
(Julia-Diaz, Saghai, Chiang et al.)
Third $S_{11}(1900)$ needed to describe CLAS(04) data
- Effective Lagrangian approach with hadronic degrees of freedom
(Ireland, Janssen, Ryckebusch)
 - also includes hyperon exchange in the u-channel
 - additional S_{11} , P_{11} , P_{13} , $D_{13} \sim 1900$ MeV improves the fit
 $P_{11}(1900)$ most favorable
- Giessen-model: unitarity coupled channel effective Lagrangian model
(Penner, Mosel, Shklyar, Lenske)
 $D_{13}(1950)$ included in the calculation but $\gamma p \rightarrow K^+ \Lambda$ negligible
no significant effect from $P_{11}(1710)$
main contributions from: $S_{11}(1650)$, $P_{13}(1720)$, $P_{13}(1900)$

Different interpretations \Leftrightarrow very controversial

$\gamma p \rightarrow K^+ \Lambda$ - CLAS(04) data -



— . — . — . — . Regge-model, no s-channel resonances

-----, —— hadrodynamic models:
effective Lagrangian approach

⇒ Resonance structure looks different at different $\cos \Theta$

⇒ Hints for more than one resonance !

$\gamma p \rightarrow p\eta$ - results of different analyses

↔ CB-ELSA data not included

- Isobar model, ETA-MAID (Chiang et al.)

⇒ $S_{11}(1535)$, $D_{13}(1520)$, $S_{11}(1650)$, $D_{15}(1675)$, $F_{15}(1680)$,
 $D_{13}(1700)$, $P_{11}(1710)$, $P_{13}(1720)$, ρ -, ω -t-channel exchange

- Giessen coupled channel analysis (Penner, Mosel)

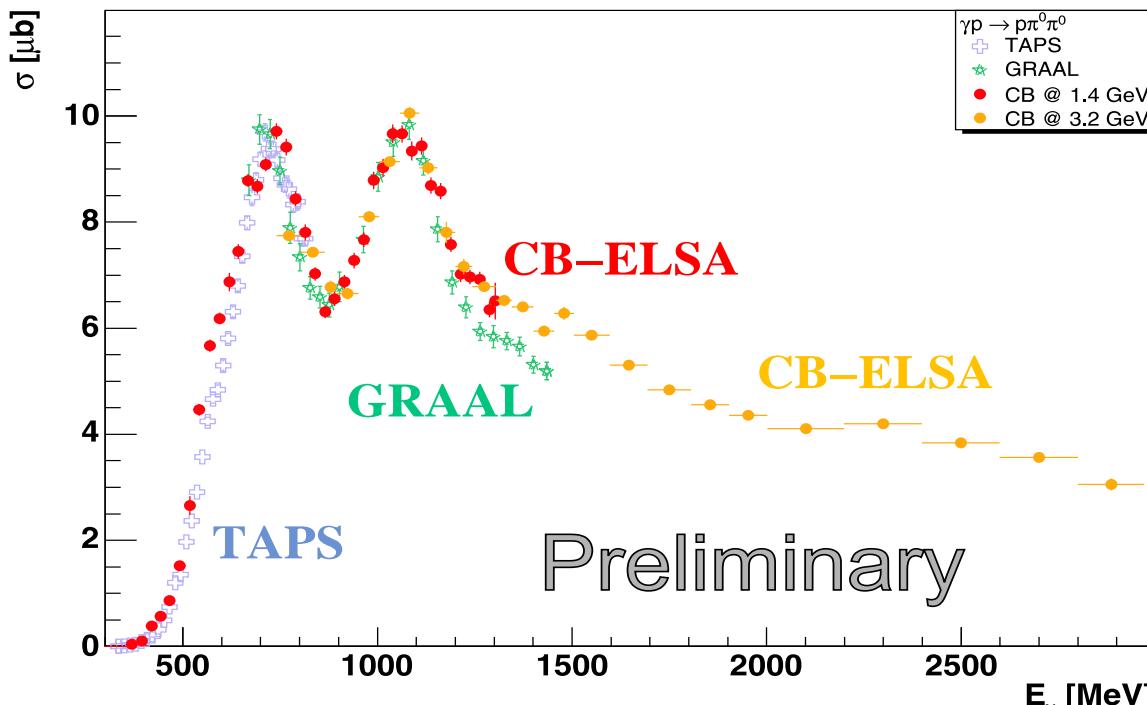
⇒ $S_{11}(1535)$, $D_{13}(1520)$, $S_{11}(1650)$, $D_{15}(1675)$, $F_{15}(1680)$,
 $P_{11}(1710)$ (small), ρ -, ω -t-channel exchange

- Chiral constituent quark model (Saghai,Li)

⇒ all known *** and **** -resonances, no t-channel exchange

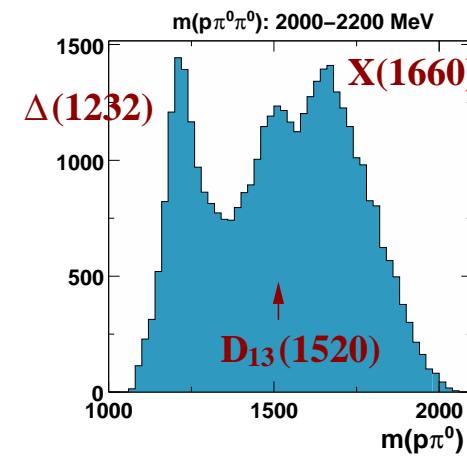
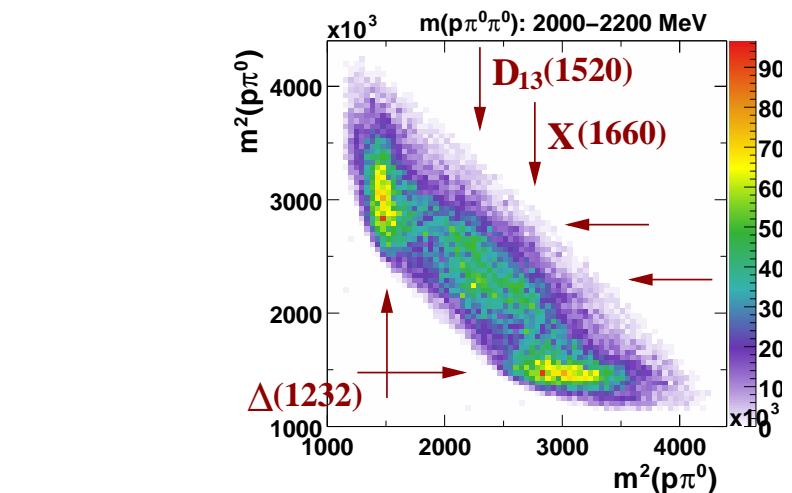
↔ 3rd S_{11} resonance needed $M = 1780$ MeV, $\Gamma = 280$ MeV

Total cross section $\gamma p \rightarrow p\pi^0\pi^0$



M. Fuchs, Bonn

Partial wave analysis of high energy data in progress



Clear observation of baryon cascades:

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

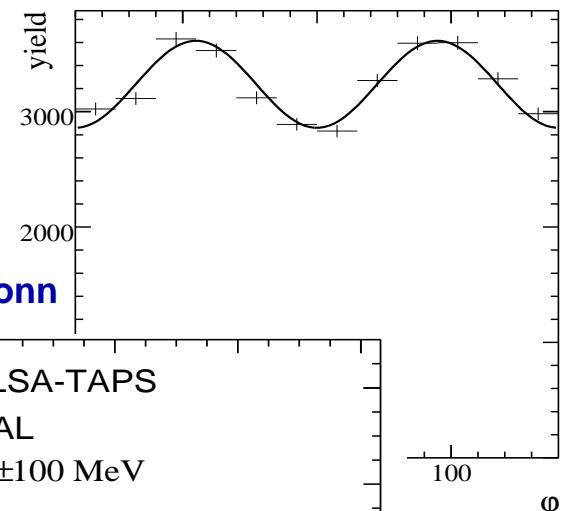
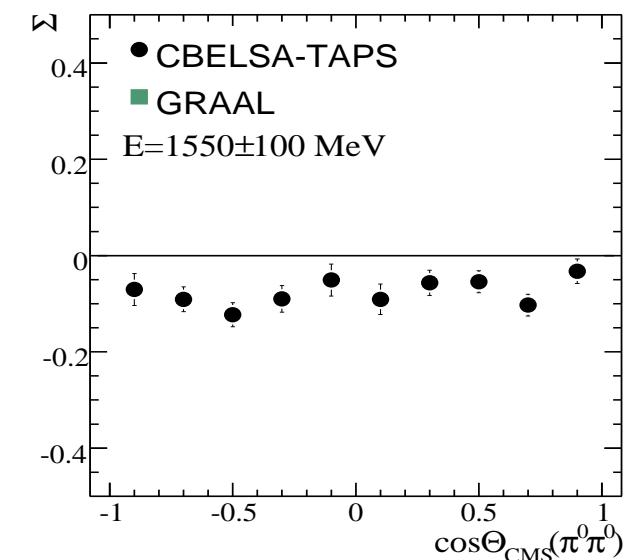
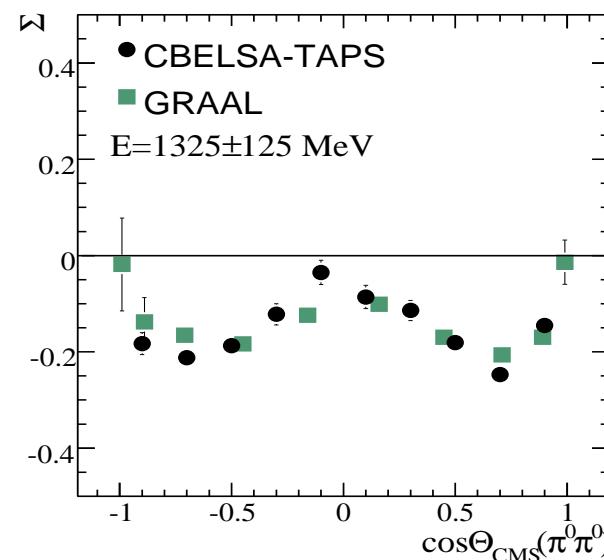
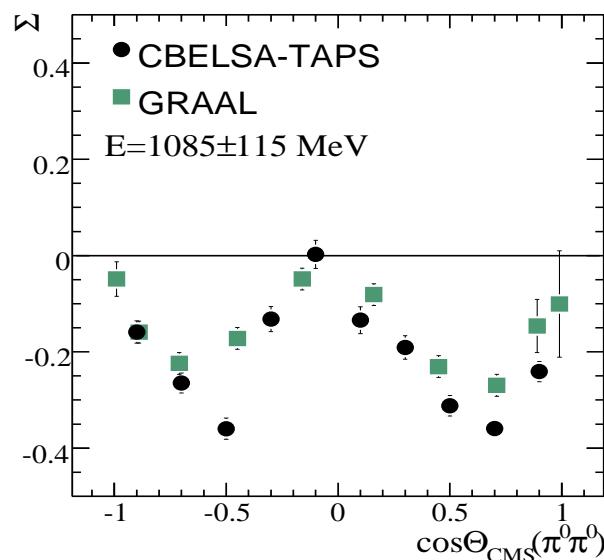
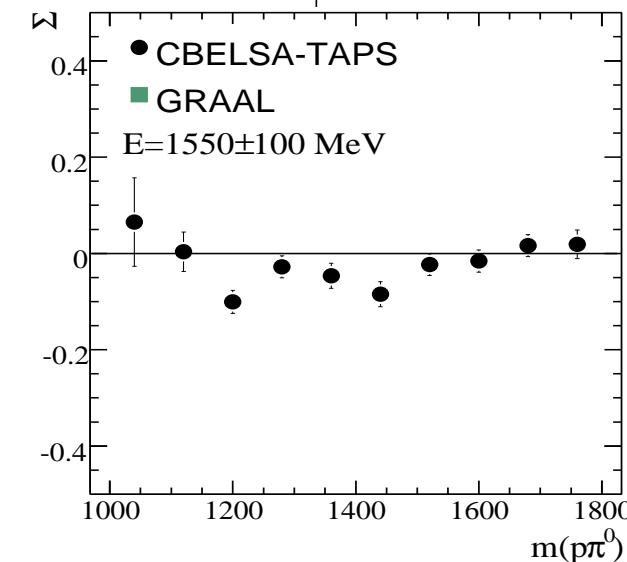
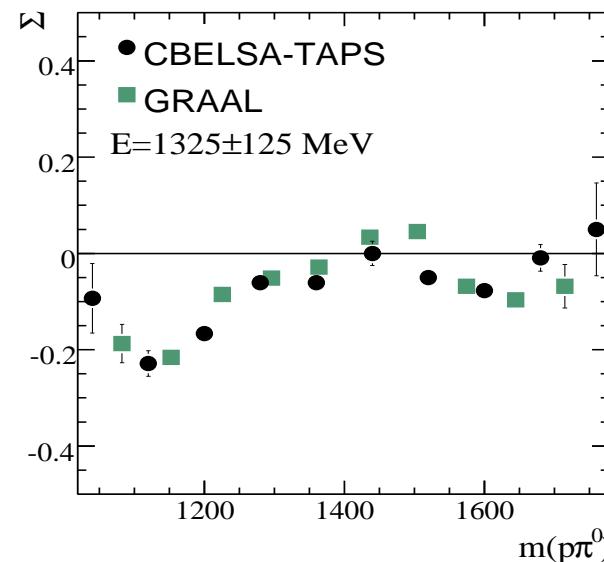
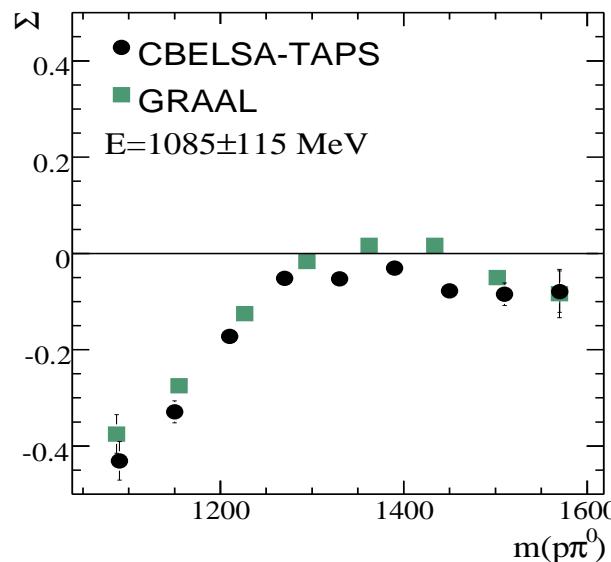
$$\gamma p \rightarrow N^*/\Delta^* \rightarrow D_{13}(1520) \pi$$

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

→ Observed for the first time in this data

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

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



V. Sokhoyan, Bonn

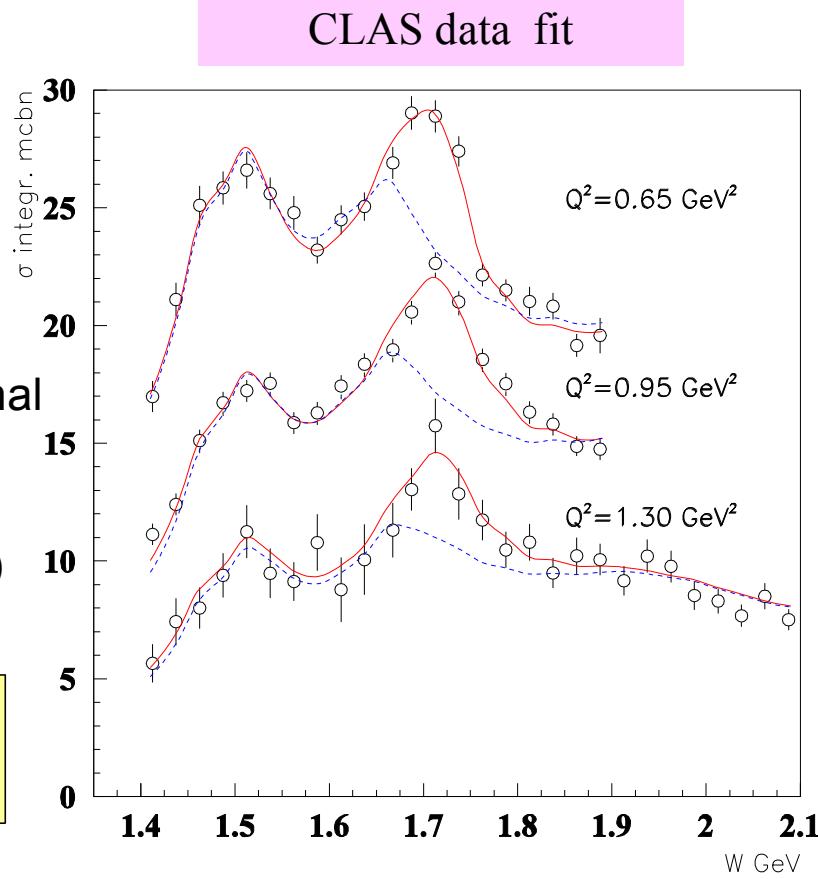
PRELIMINARY

Electroproduction data fit. A candidate $3/2^+(1720)$ baryon state.

N* photocouplings were varied within 30% σ around values obtained from world meson photo and electroproduction data analysis in SQT M approach: V.D.Burkert et. al., Phys. Rev. C67, 035204 (2003)

- Contributions from conventional states only
- Fit with candidate $3/2^+(1720)$ state

M.Ripani et. al.
Phys. Rev. Lett.91, 022002
(2003)



Difference between curves due to signal from candidate $3/2^+(1720)$ state



Description of 1.7 GeV mass region.

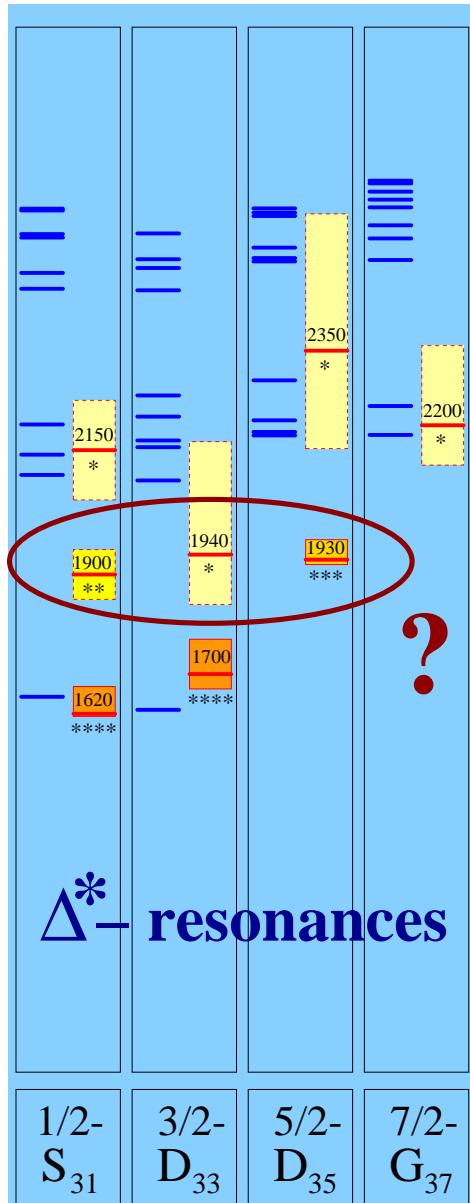
Two alternative ways to describe the structure at 1.7 GeV:

- Modification of hadronic couplings for P13(1720) PDG state with respect to established values
- Implementation of candidate baryon state with $J^\pi = 3/2^+$.

	M, MeV	Γ , MeV	$\Gamma_{\pi\Delta}/\Gamma$, %	$\Gamma_{\rho p}/\Gamma$, %
modified P13(1720)	1725±20	114±19	60±12	19±9
PDG P13(1720)	1650-1750	100-200	absent	70-85
candidate $3/2^+(1720)$	1720±20	88±17	41±13	17±10

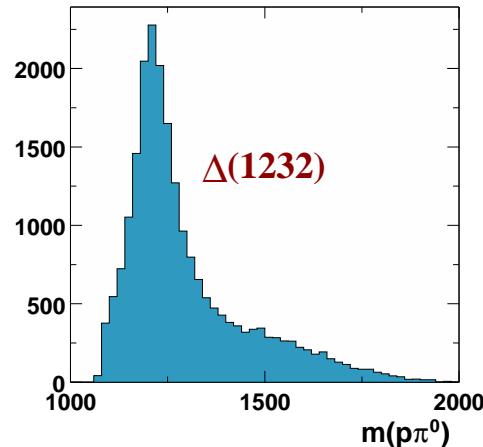


$\gamma p \rightarrow p\pi^0\eta$



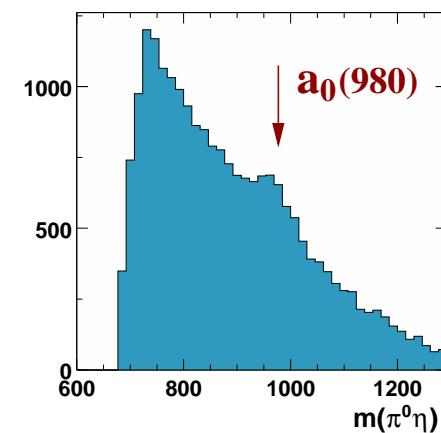
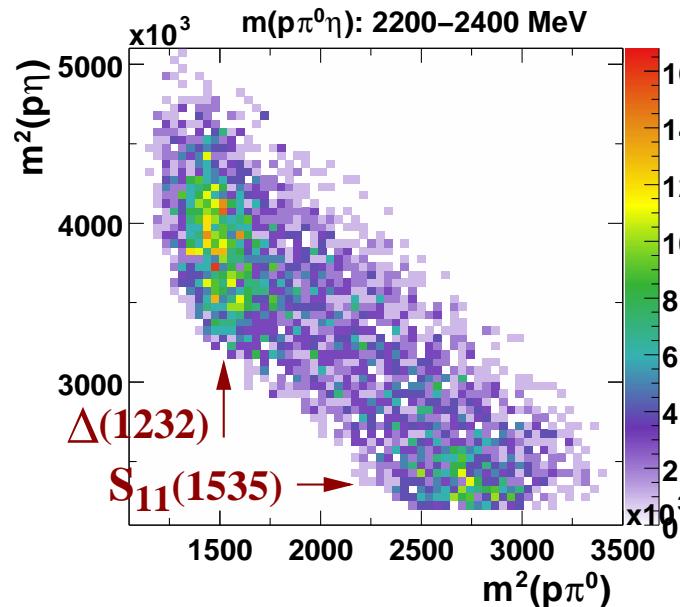
U. Loering et al.

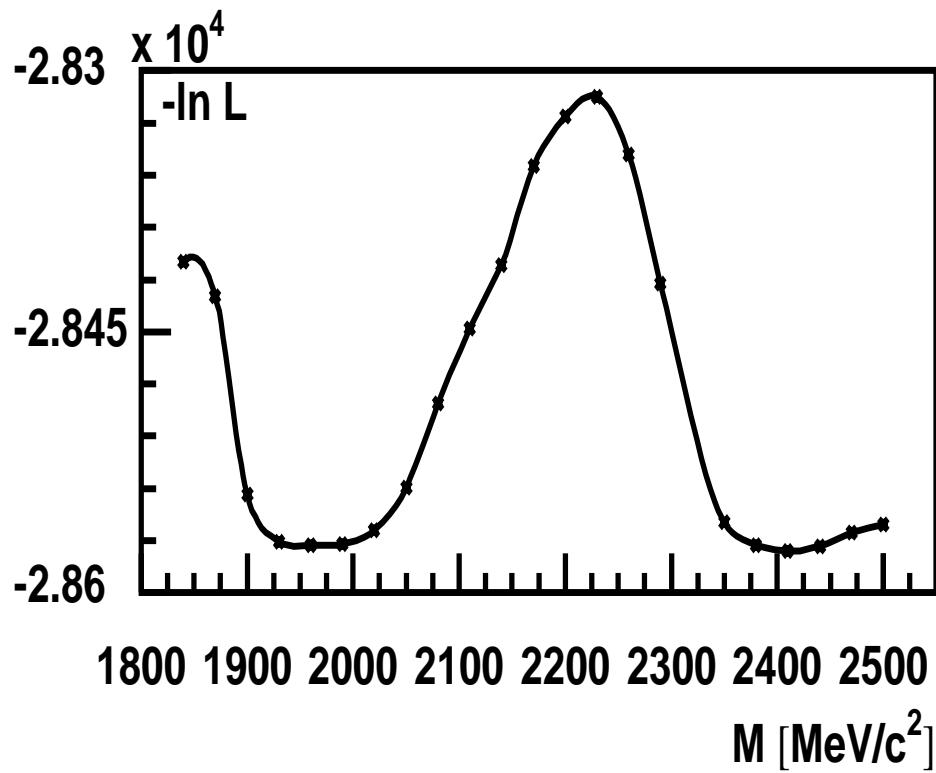
- $\gamma p \rightarrow \Delta^* \rightarrow \Delta(1232)\eta \rightarrow p\pi^0\eta$



$\Rightarrow \Delta(1232)$ clearly observed !

but there are also additional interesting structures :

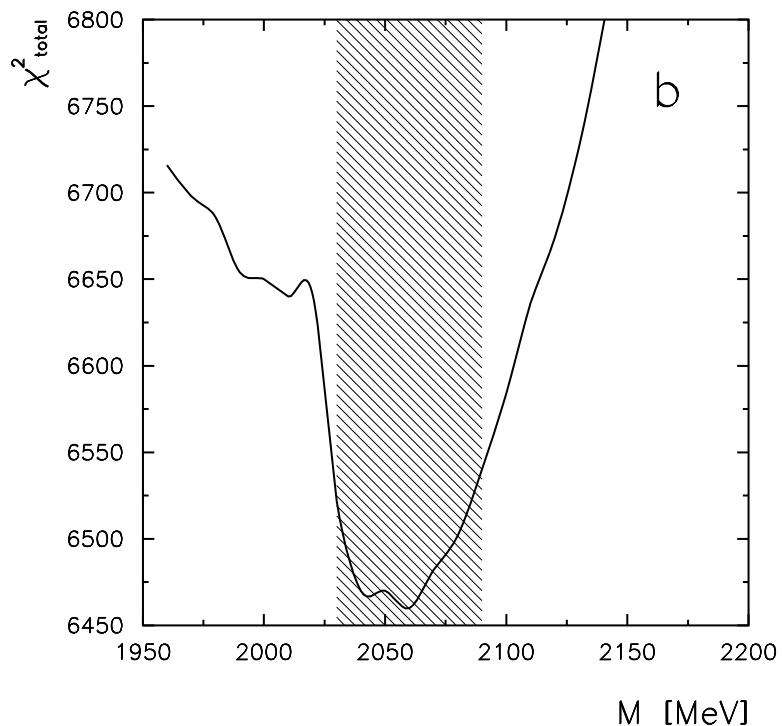




The change of $\ln \mathcal{L}_{tot}$ as a function of the mass pole position in the fits with Breit-Wigner parametrization of the second ΔD_{33} resonance

New D₁₅ -state

- D₁₅(2060 ± 30, 340 ± 50):



N(2200) D₁₅

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

OMMITTED FROM SUMMARY TABLE

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

N(2200) BREIT-WIGNER MASS

VALUE (MeV)
≈ 2200 OUR ESTIMATE

1900

2180 ± 80

1920

2228 ± 30

2240 ± 65

• • • We do not use the following data for averages, fits, limits, etc. • • •

DOCUMENT ID

TECN

COMMENT

BELL

83

DPWA $\pi^- p \rightarrow \Lambda K^0$

CUTKOSKY

80

IPWA $\pi N \rightarrow \pi N$

SAXON

80

DPWA $\pi^- p \rightarrow \Lambda K^0$

HOEHLER

79

IPWA $\pi N \rightarrow \pi N$

BATINIC

95

DPWA $\pi N \rightarrow N\pi, N\eta$

varies strongly !

N(2200) BREIT-WIGNER WIDTH

VALUE (MeV)

DOCUMENT ID

TECN

COMMENT

BELL

83

DPWA $\pi^- p \rightarrow \Lambda K^0$

CUTKOSKY

80

IPWA $\pi N \rightarrow \pi N$

SAXON

80

DPWA $\pi^- p \rightarrow \Lambda K^0$

HOEHLER

79

IPWA $\pi N \rightarrow \pi N$

• • • We do not use the following data for averages, fits, limits, etc. • • •

BATINIC

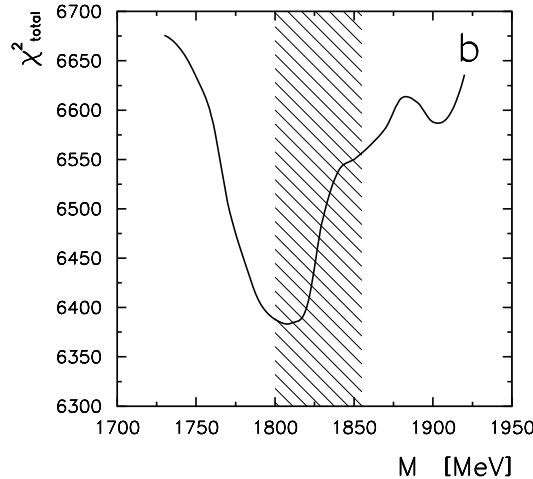
95

DPWA $\pi N \rightarrow N\pi, N\eta$

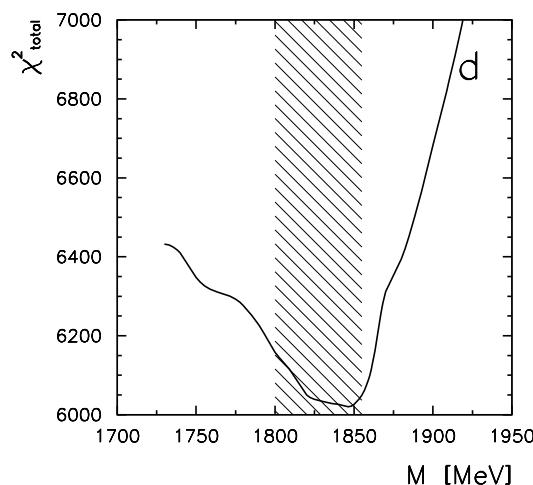
↔ Results vary strongly!

New P₁₁

- P₁₁(1840₋₄₀⁺¹⁵, 140₋₅₀⁺³⁰):



p π^0 , p η - data



K Λ , K Σ - data

N(2100) P₁₁

I(J^P) = $\frac{1}{2}(\frac{1}{2}^+)$ Status: *

OMMITTED FROM SUMMARY TABLE

N(2100) BREIT-WIGNER MASS

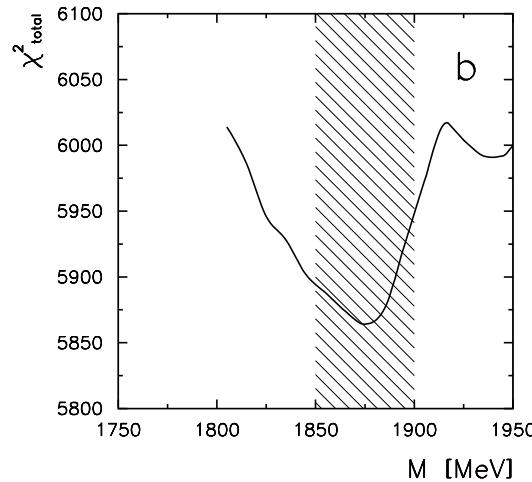
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
≈ 2100 OUR ESTIMATE			
1885 ± 30	MANLEY	92	IPWA $\pi N \rightarrow \pi N & N\pi\pi$
2125 ± 75	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
2050 ± 20	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
2084 ± 93	VRANA	00	DPWA Multichannel
1986 ± 26 ⁺¹⁰ ₋₃₀	PLOETZKE	98	SPEC $\gamma p \rightarrow p\eta'(958)$
2203 ± 70	BATINIC	95	DPWA $\pi N \rightarrow N\pi, N\eta$

N(2100) BREIT-WIGNER WIDTH

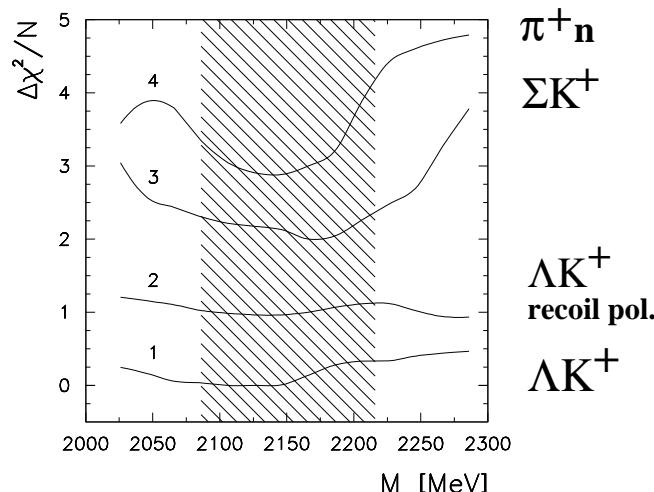
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
≈ 2100 OUR ESTIMATE			
113 ± 44	MANLEY	92	IPWA $\pi N \rightarrow \pi N & N\pi\pi$
260 ± 100	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
200 ± 30	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1077 ± 643	VRANA	00	DPWA Multichannel
296 ± 100 ⁺⁶⁰ ₋₁₀	PLOETZKE	98	SPEC $\gamma p \rightarrow p\eta'(958)$
418 ± 171	BATINIC	95	DPWA $\pi N \rightarrow N\pi, N\eta$

New D₁₃ -states

- D₁₃(1875 ± 25, 80 ± 20):



- D₁₃(2166⁺⁵⁰₋₈₀, 300 ± 65):



N(2080) D₁₃

$I(J^P) = \frac{1}{2}(\frac{3}{2}-)$ Status: **

OMMITTED FROM SUMMARY TABLE

There is some evidence for two resonances in this wave between 1800 and 2200 MeV (see CUTKOSKY 80). However, the solution of HOEHLER 79 is quite different.

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

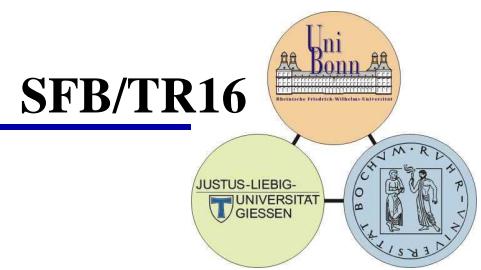
N(2080) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
≈ 2080 OUR ESTIMATE			
1804 ± 55	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
1920	BELL	83	DPWA $\pi^- p \rightarrow \Lambda K^0$
1880 ± 100	¹ CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
2060 ± 80	¹ CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
1900	SAXON	80	DPWA $\pi^- p \rightarrow \Lambda K^0$
2081 ± 20	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1946 ± 1	PENNER	02C	DPWA Multichannel
1895	MART	00	DPWA $\gamma p \rightarrow \Lambda K^+$
2003 ± 18	VRANA	00	DPWA Multichannel
1986 ± 75	BATINIC	95	DPWA $\pi N \rightarrow N\pi, N\eta$
1880	BAKER	79	DPWA $\pi^- p \rightarrow n\eta$

N(2080) BREIT-WIGNER WIDTH

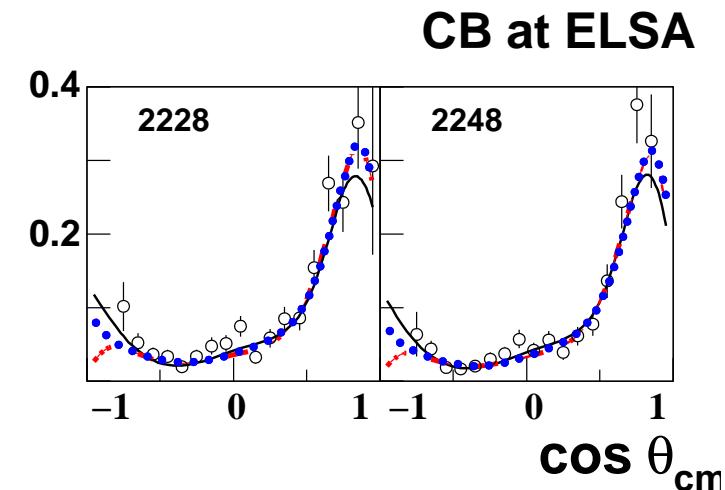
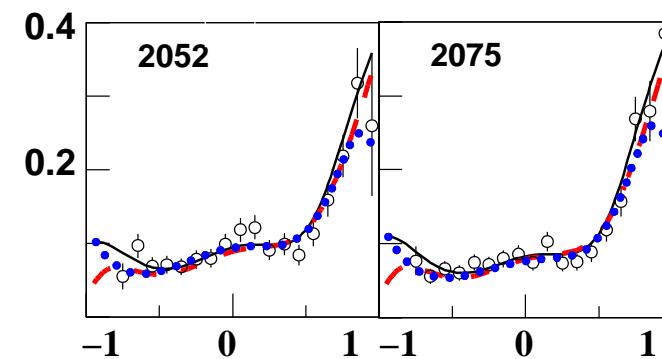
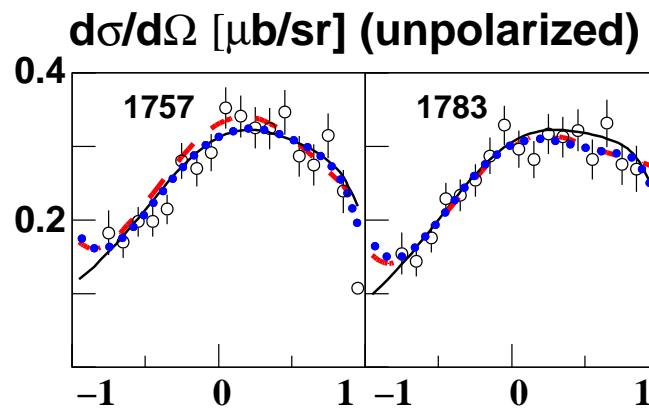
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
≈ 2080 OUR ESTIMATE			
450 ± 185	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
320	BELL	83	DPWA $\pi^- p \rightarrow \Lambda K^0$
180 ± 60	¹ CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$ (lower m)
300 ± 100	¹ CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$ (higher m)
240	SAXON	80	DPWA $\pi^- p \rightarrow \Lambda K^0$
265 ± 40	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
859 ± 7	PENNER	02C	DPWA Multichannel
372	MART	00	DPWA $\gamma p \rightarrow \Lambda K^+$
1070 ± 858	VRANA	00	DPWA Multichannel
1050 ± 225	BATINIC	95	DPWA $\pi N \rightarrow N\pi, N\eta$
87	BAKER	79	DPWA $\pi^- p \rightarrow n\eta$

Double polarisation experiments $\vec{\gamma}\vec{p} \rightarrow p\eta$

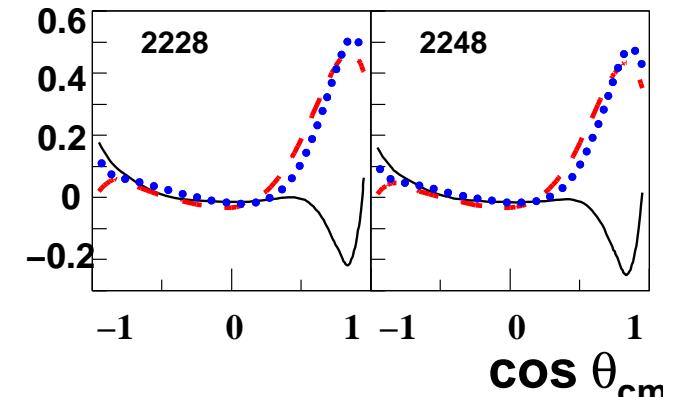
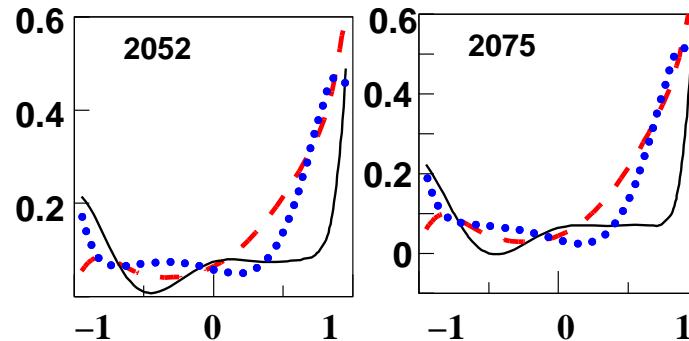
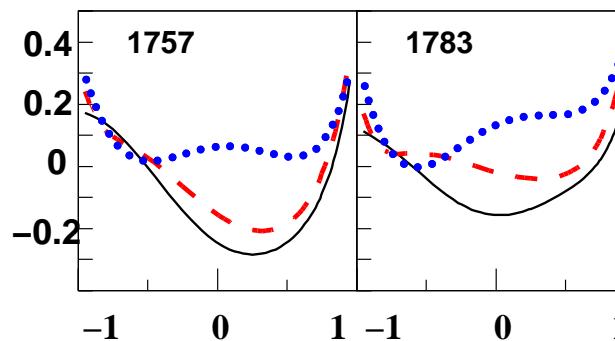


Sensitivity on the quantum numbers of the new $D_{15}(2070)$

— : best solution: $D_{15}(2070)$
 — : $1/2^-$ state substitutes $D_{15}(2070)$ — : $1/2^+$ state substitutes $D_{15}(2070)$



$d\sigma/d\Omega [\mu\text{b}/\text{sr}]$ (helicity $1/2$ – helicity $3/2$)

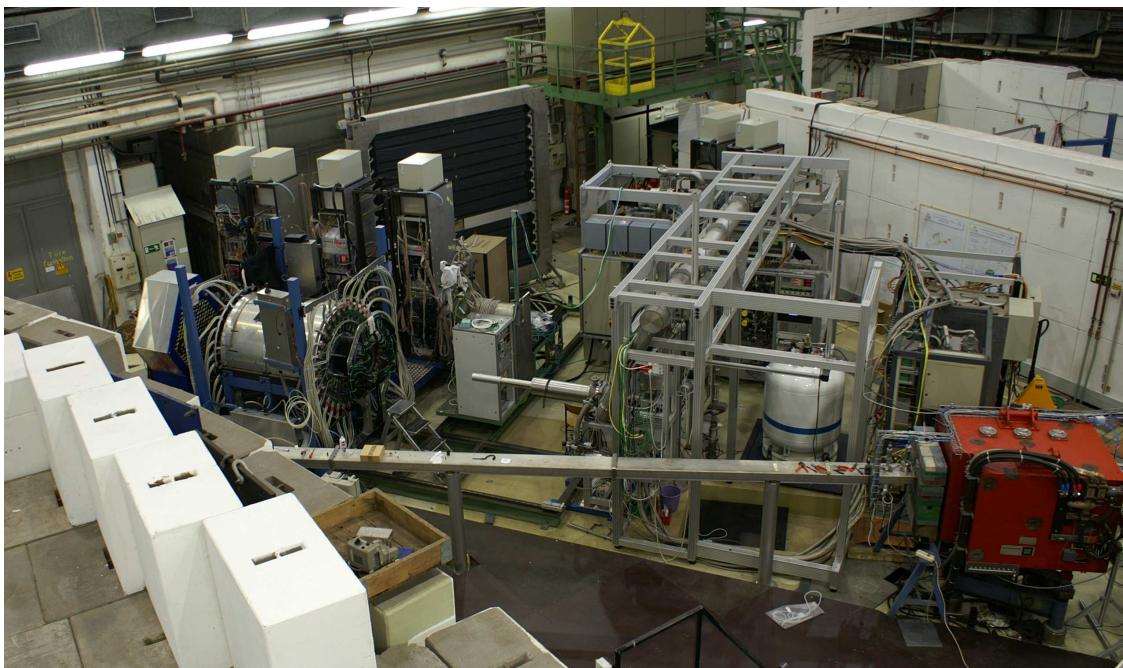
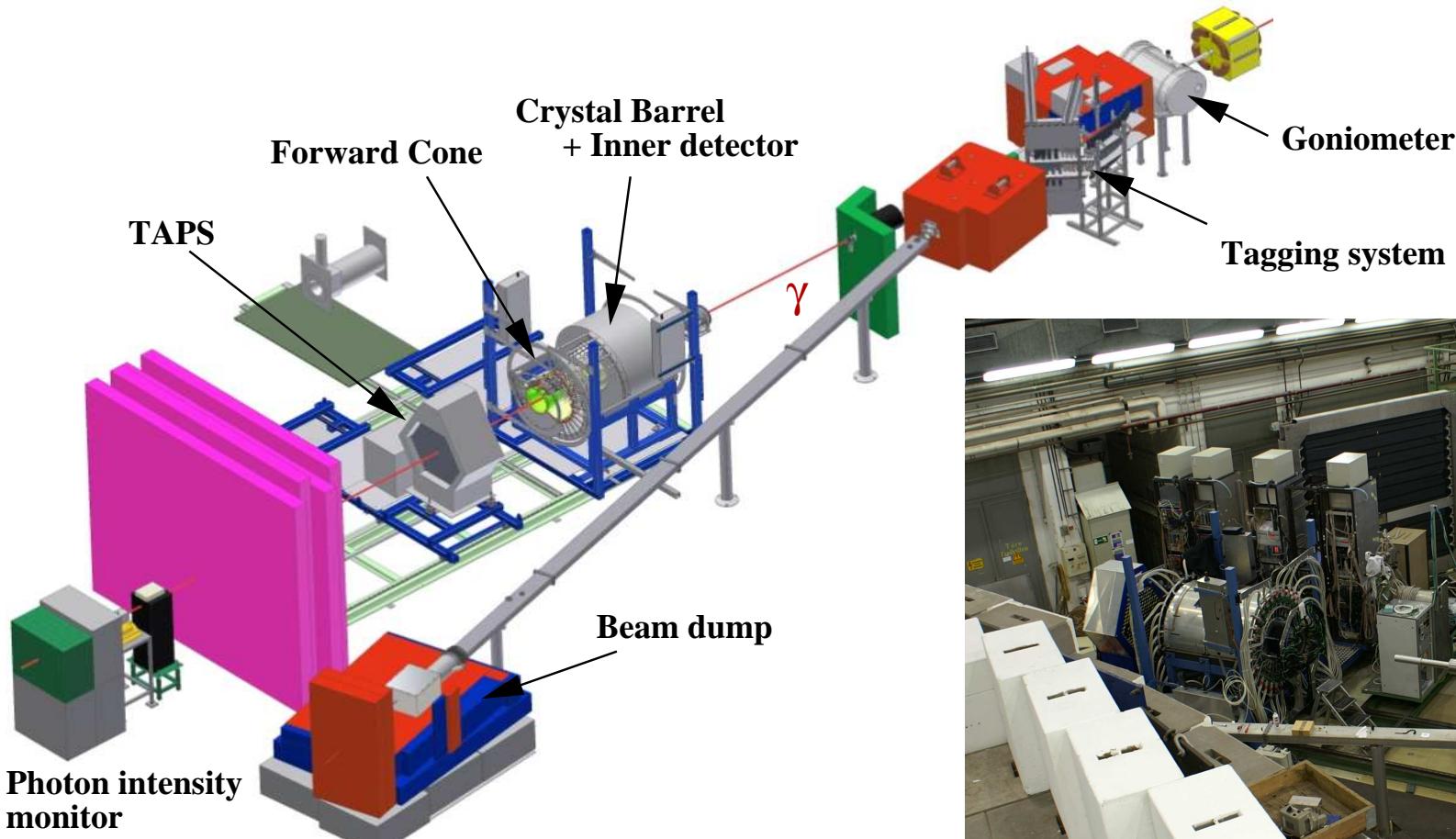


⇒ High sensitivity of polarisation variables !!

Double polarisation experiments at ELSA

Experiments with:

- linear or circular polarised beam
- longitudinal polarised target (frozen spin butanol)



= presently a unique possibility to perform
double polarisation experiments up to $E_\gamma = 3 \text{ GeV}$