Baryons 2002 Conference

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BARYONS

Photoexcitation of N* Resonances

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Baryonic resonances - N*

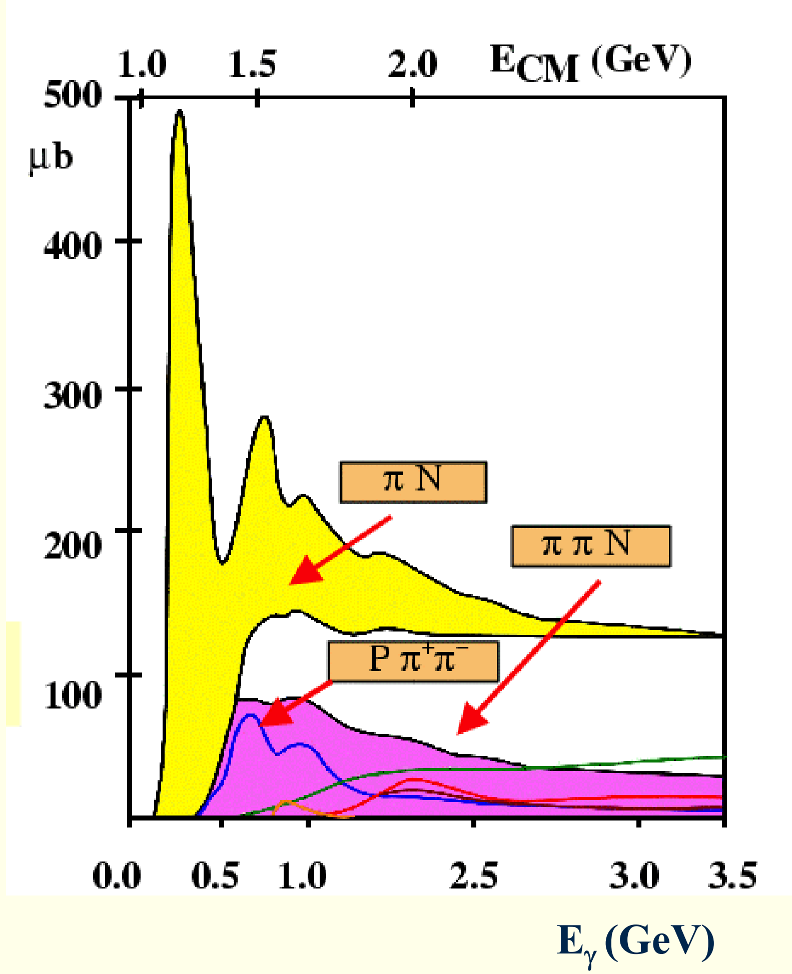
- The existence of N* resonances was observed for the first time in πN scattering, as clear peaks.

- Most of their properties have been extracted from πN data (see PDG).

- N* resonances are evident in photonuclear reactions as well.

- Complementary information on N* may be extracted from photoreaction data (e.g. photocouplings).

- Static and dynamical properties of N* are the testing ground for our "understanding" of the quark structure of the matter.



First Resonance Region

- Extraction of the E2/M1 ratio for the $\Delta(1232)$ excitation from very precise measurements of $p(\vec{\gamma},\pi^0)p$, $p(\vec{\gamma},\pi^+)n$ and $p(\vec{\gamma},\gamma)p$ (Mainz, Legs + BRAG analysis)
- New powerful measurements of double polarization observables (Mainz, Legs, Bonn)

2nd Resonance Region

- New precise measurements of beam asymmetries for single $p(\vec{\gamma},\pi^0 p)$, $p(\vec{\gamma},\pi^+ n)$ reactions (Graal). Input for SAID and MAID.
- Isospin selective η photoproduction measurements from Mainz, Graal and Class.

Determination of $S_{11}(1535)$, $D_{13}(1520)$ parameters. Extraction of $S_{11}(1650)$ and $F_{11}(1680)$ amplitudes and evidence for a third "missing" S_{11} resonance.

- Double π production at Mainz. Evidence of production of $D_{13}(1520)$ and subsequent decay in ρN and $\Delta^+ \pi^0$ channels

3nd Resonance Region

- $k^+\Lambda$ and ω photoproduction as a tool for the search of " missing resonances" (SAPHIR and Graal)

Overview

First Resonance

$\Delta(1232)$ P33 ****

2nd Resonance Region

$N(1440)$ P11 ****

$N(1520)$ D13 ****

$N(1535)$ S11 ****

3rd Resonance Region

$N(1650)$ S11 ****

$N(1675)$ D15 ****

$N(1680)$ F15 ****

$N(1700)$ D13 ***

$\Delta(1600)$ P33 ***

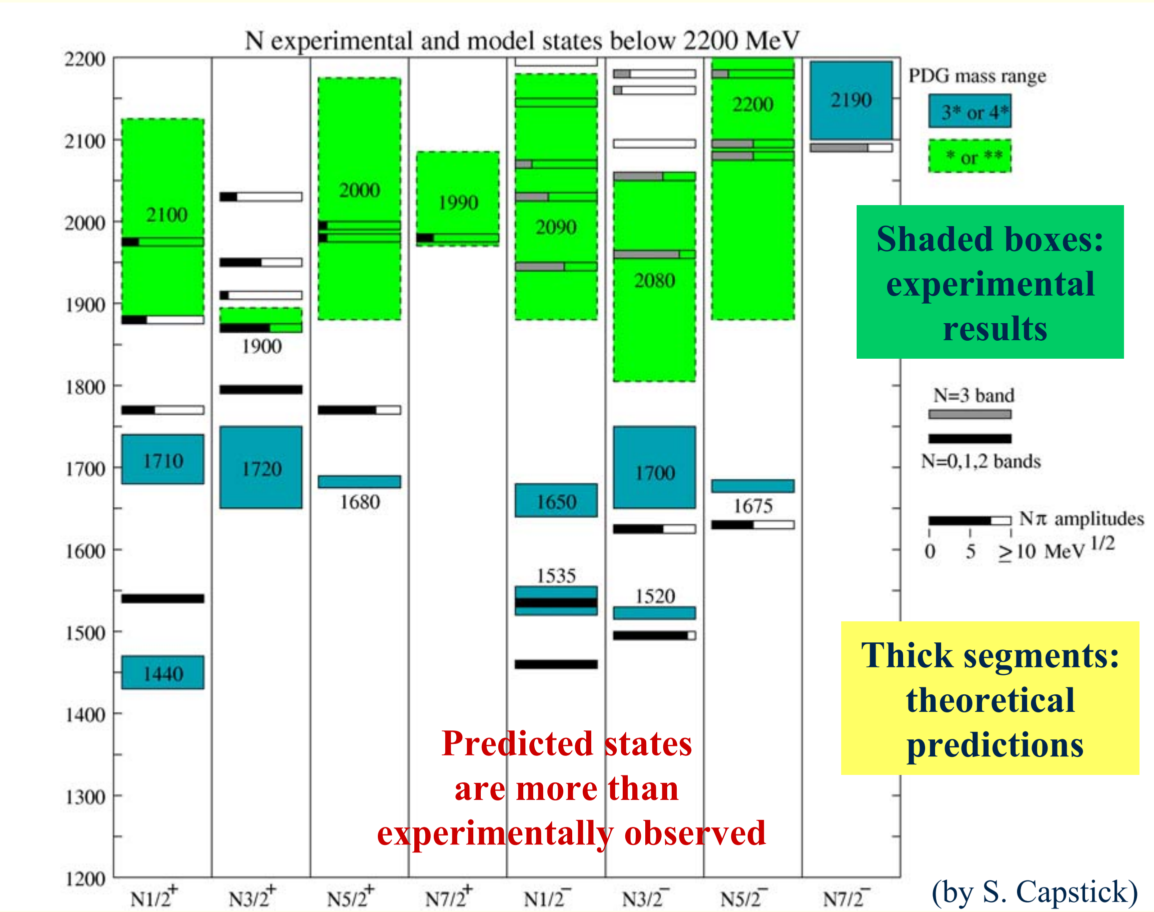
$\Delta(1620)$ S31 ****

$\Delta(1700)$ D33 ****

$\Delta(1750)$ P31 *

Goal - determination of static and dynamical properties N* resonances: mass M, width Γ, helicity amplitudes $A_{1/2}$ and $A_{3/2}$, partial decay widths in Nucleon-meson channels $\Gamma_{\eta N}$, $\Gamma_{\pi N}$, Γ_{YK}.

Different models produce changes in state position, ordering, splitting, etc,



Requirements:

- Precise measurements of cross sections and polarization observables to provide the most "complete" set of measurements.
- In the absence of direct QCD predictions → effective theories and models are necessary to analyze the experimental results and extract the N* properties.
- Resonance parameters are dependent from the procedure used to discriminate the resonant from the background contributions.

Stronger collaboration between experimental and theoretical physicists.

The extraction of the baryonic properties from data is difficult. A "model independent" analysis would require the measurement of a complete set of observables:

7 pseudoscalar meson photoproduction

23 vector meson photoproduction

Several overlapping resonance may contribute to the reaction mechanism.

The presence of intermediate resonances is detected by the multipole analysis of the available reaction observables.

Intermediate resonances having fixed quantum numbers may contribute to specific multipoles.

$\gamma + p \rightarrow N^*(\Delta) \rightarrow$ meson - p

$$(J_\gamma \pm \tfrac{1}{2})^{-(-1)^{L_\gamma}} \rightarrow J^\pi \rightarrow (L_m \pm \tfrac{1}{2})^{-(-1)^{Lm}}$$

$\boxed{N^*}$		$\boxed{\Delta}$	
$S_{11} : \frac{1}{2}^-$	$\rightarrow E_{0}^{+}$	$P_{33} : \frac{3}{2}^+$	$\rightarrow E_1^+ \quad M_1^+$
$P_{11} : \frac{1}{2}^+$	$\rightarrow M_1^-$	$S_{31} : \frac{1}{2}^-$	$\rightarrow E_0^+$
$P_{13} \ \frac{3}{2}^+$	$\rightarrow E_1^+ \quad M_1^+$	$D_{33} : \frac{3}{2}^-$	$\rightarrow E_2^- \quad M_2^-$
$D_{13} : \frac{3}{2}^-$	$\rightarrow E_2^- \quad M_2^-$	$P_{31} : \frac{1}{2}^+$	$\rightarrow M_1^-$
$D_{15} : \frac{5}{2}^-$	$\rightarrow E_2^+ \quad M_2^+$	$F_{35} : \frac{5}{2}^+$	$\rightarrow E_3^+ \quad M_3^+$
$F_{15} : \frac{5}{2}^+$	$\rightarrow E_3^+ \quad M_3^+$		

The Δ(1232) Resonance

• In the energy range corresponding to masses up to 1400 MeV, the excitation of the Δ(1232) resonance dominates the reaction mechanisms.

• It is therefore possible to extract its parameters with very high precision, not yet achieved at higher energies.

• The γ N $\rightarrow$ Δ transition mainly proceeds through an M1 multipole, due to a quark spin flip. The presence of a d-wave admixture in the nucleon wave-function, allows for the contribution of the E2 multipole.

• The origin of the d-wave component, and the corresponding deformation of the nucleon, differs in various models:

QCD inspired "constituent quark models" $\rightarrow$ effective color-magnetic tensor forces

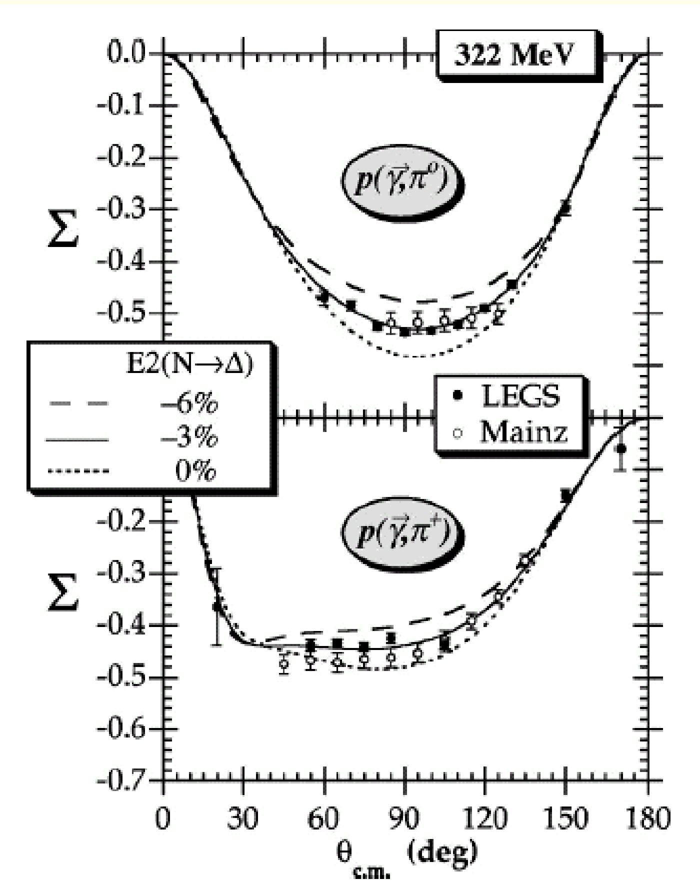
Chiral bag models $\rightarrow$ asymmetric coupling of the meson cloud to the spin of the nucleon

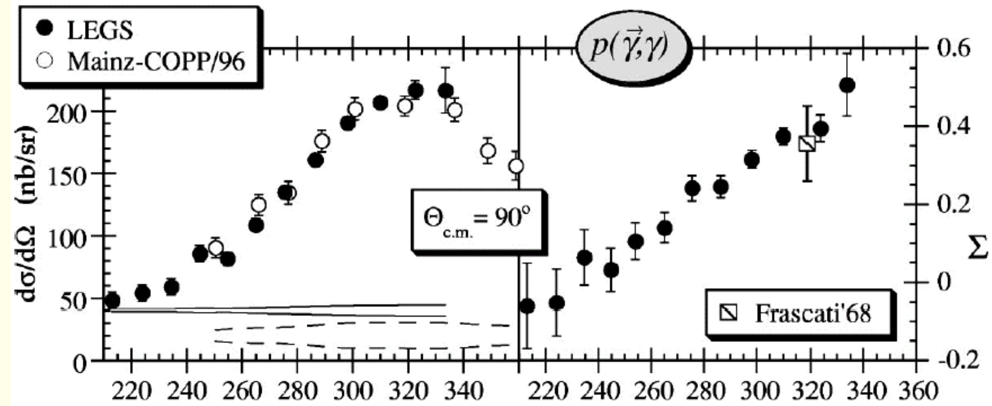
The ratio E2/M1 (REM) has been extracted from a large amount of available data, using different analysis procedures.

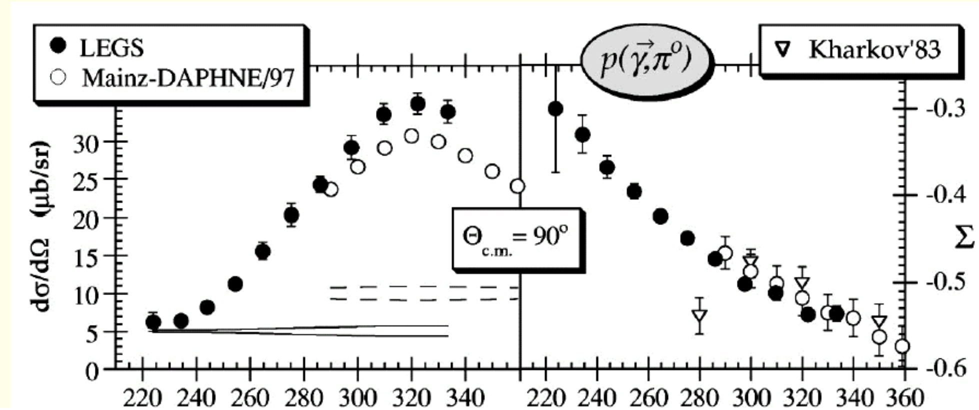
Dynamical approaches calculate explicit non-resonant mechanism: "bare" values of the REM are extracted, taking into account meson rescattering effects.

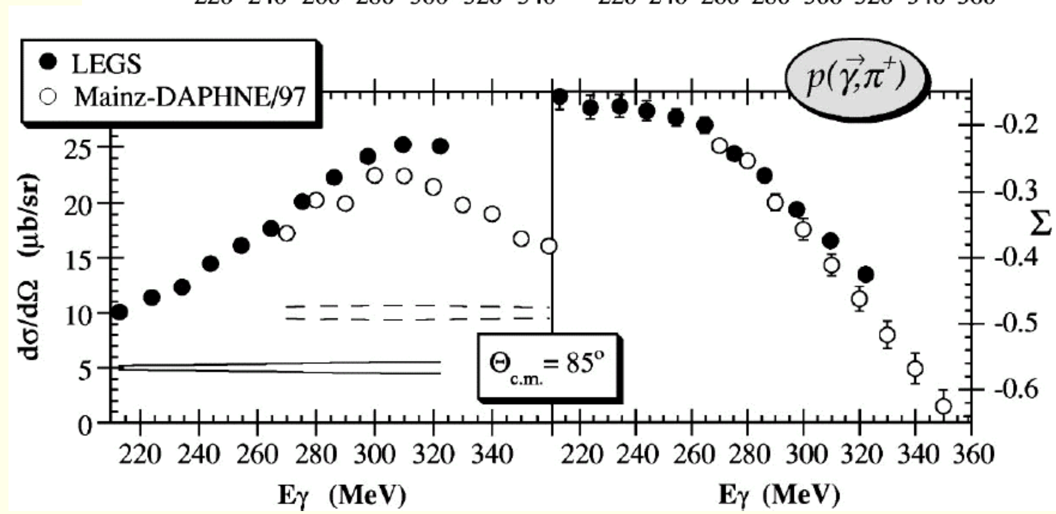
The Δ(1232) Resonance

G. Blampied et al PRC 64 (2001) 025203
R. Beck et al. PRC 61 (2000) 035204
G. Blampied et al PRL 79 (1997) 4337
R. Beck et al. PRL 78 (1997) 606









Extraction of “dressed” E2/M1 ratio in $\gamma N \to \Delta$

	REM(%)	$A_{1/2}$ $(10^{-3}/\sqrt{GeV})$	$A_{3/2}$ $(10^{-3}/\sqrt{GeV})$
Mainz multipole analysis PRC61,035204(2000)	-2.54 ±0.1 ±0.2	-(131±1)	-(251±1)
Legs multipole analysis PRC64,025203(2001)	-3.07 ±0.26 ±0.24	-(135.74 ±1.34 ±3.7)	-(266.74 ±1.6 ±7.8)

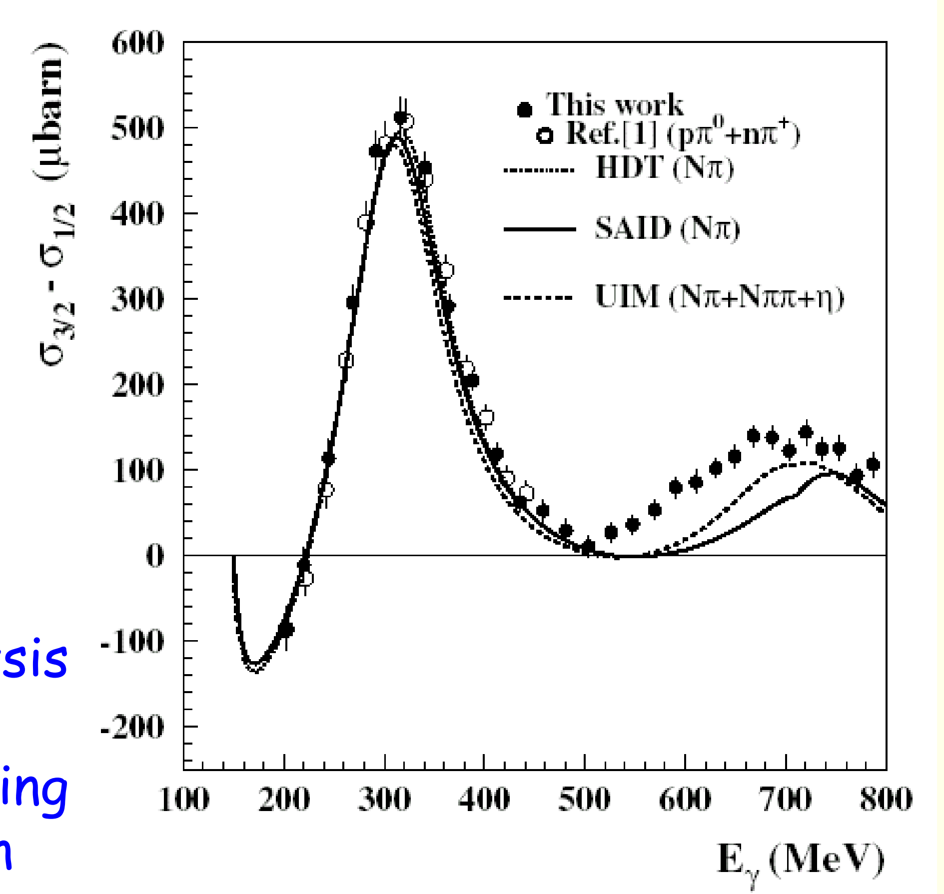
BRAG (Baryon Resonance Analysis Group)

same “bench-mark” data set of 1287 points	M1	E2	E2/M1(%)
Effective Lagrangian RPI	286	-7.2	-2.55
Partial wave analysis GWU - (SAID)	281	-7.2	-2.57
Multipole analysis fixed-t Disp. Relation HA	281	-6.6	-2.35
Multipole analysis with MAID Unitary Isobar Model	275	-5.3	-1.93
Dynamical model by Yang and Kamalov KY	280	-6.2	-2.24
Fixed-t Disp. Relation by Aznauryan AZ	278	-6.3	-2.28
Multipole analysis by Omelaenko OM	288	-7.8	-2.77
Average	281.3±4.5	-6.6 ±0.8	-2.38 ±0.27

Double polarization measurements

Polarized beams and targets:
first results

- MAINZ
- LEGS
- BONN

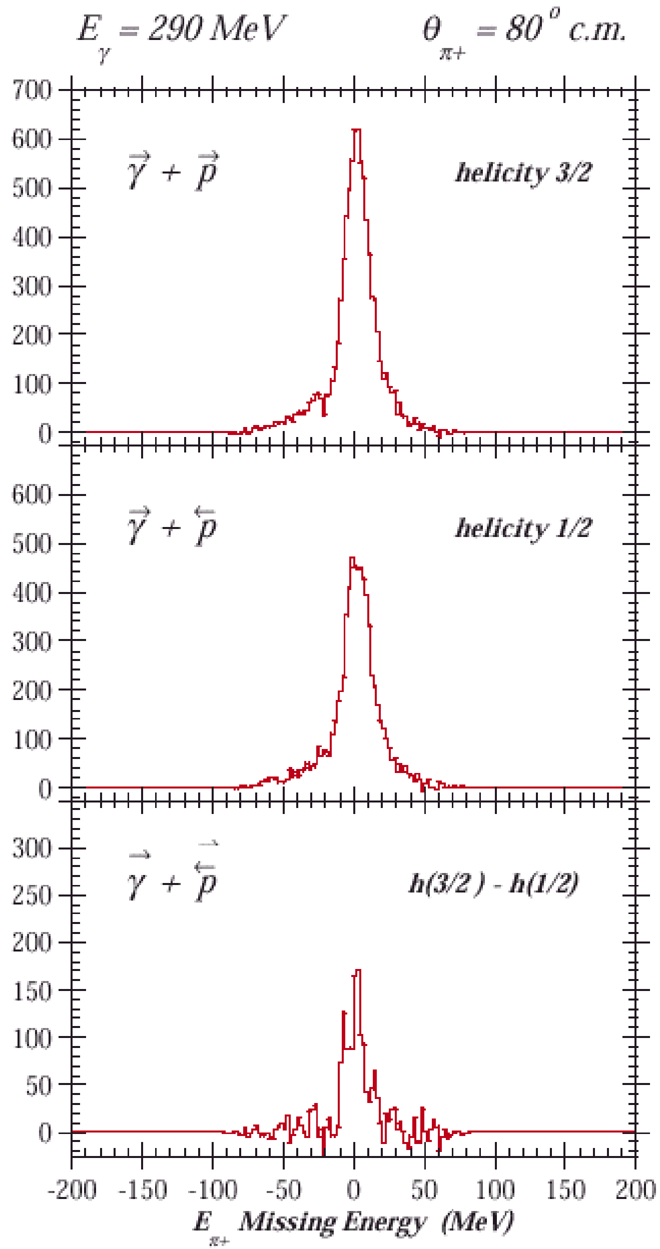


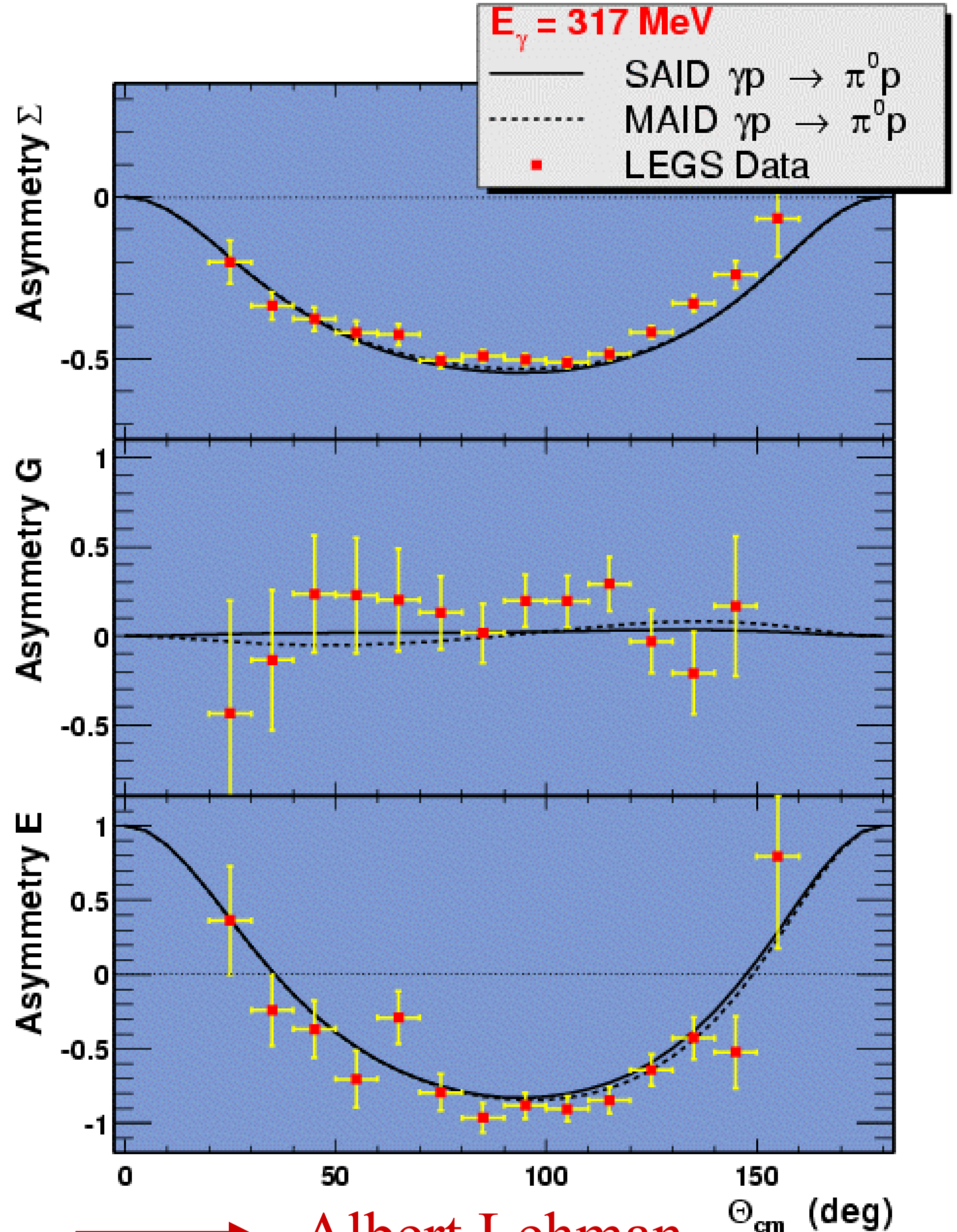
PRL 87(2001)022003

• Predictions based on multipole analysis do not include $N\pi\pi$ and η channels
• Unitary Isobar Model is missing strength in the second resonance region
• Contributions to GDH sum-rule and γ_0 spin polarizability are measured for the first time.

→ Braghieri, Michel

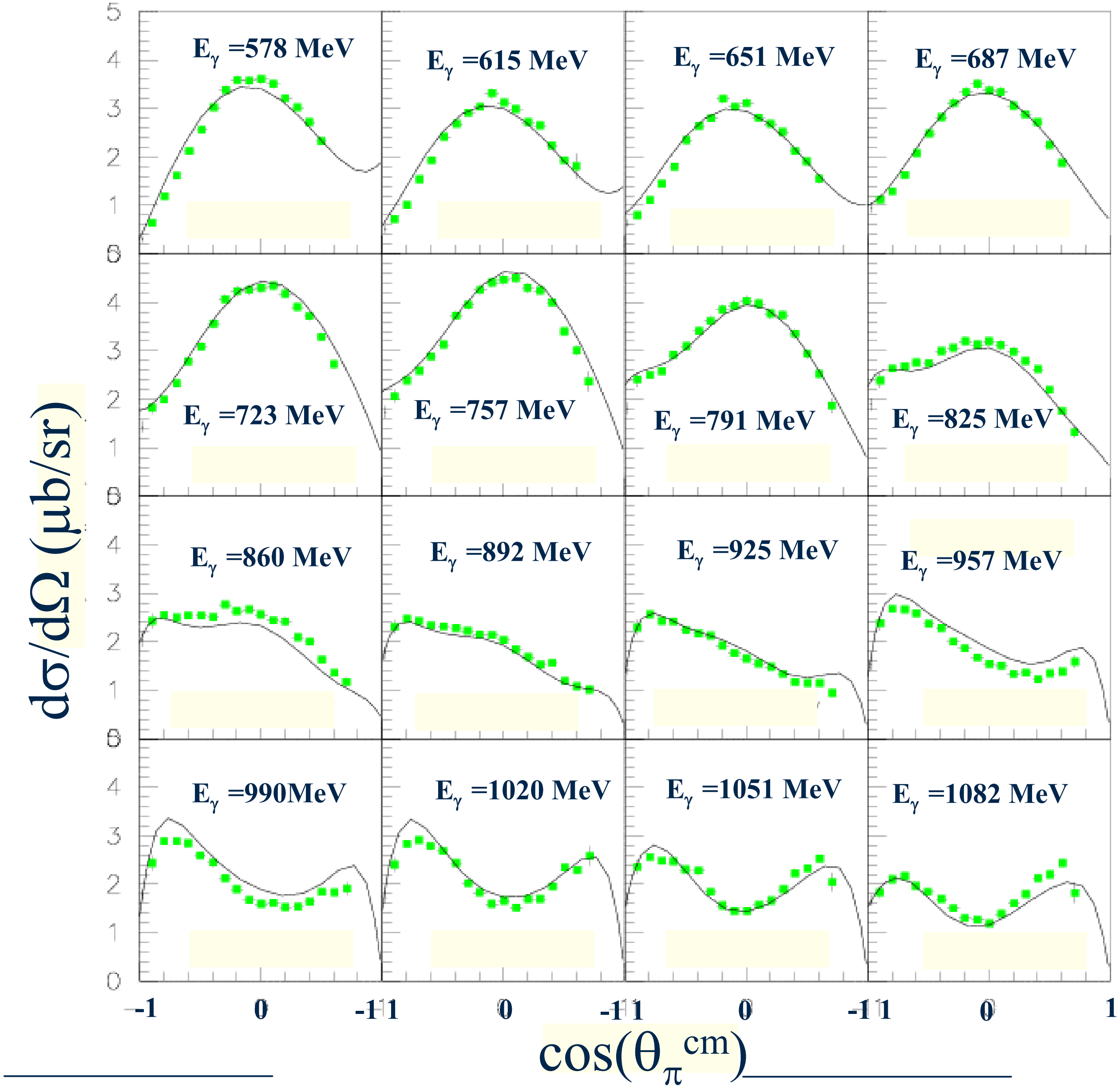
1st double polarization data with HD - LEGS / Nov 17 '01





Albert Lehman

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

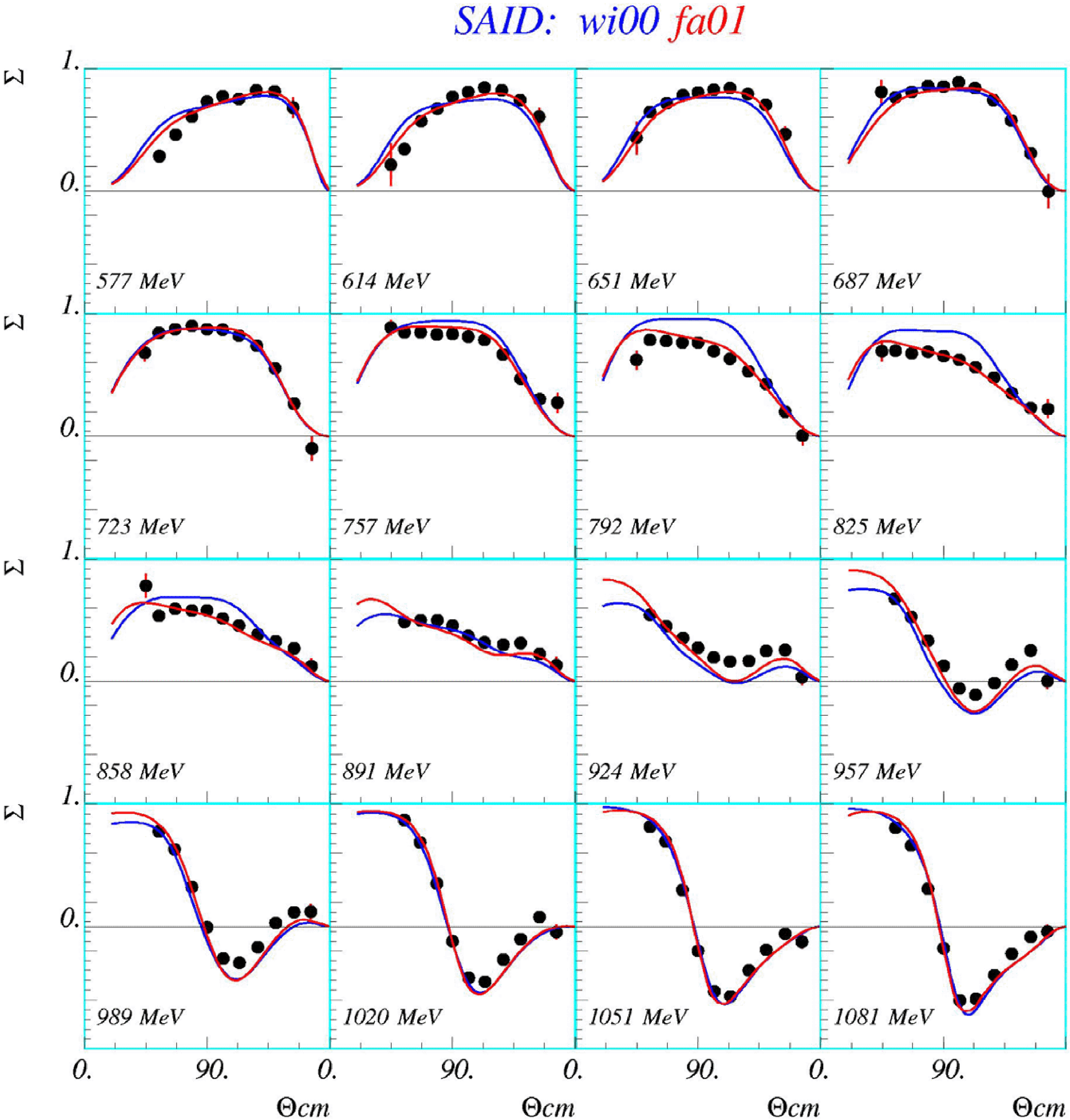


Very precise data from Graal on differential cross-section in the energy range

580 – 1100 MeV

are well reproduced by the SAID predictions

solid line - GWU-SAID WI00 solution



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

The same high quality results for the Σ asymmetry from Graal in the same energy range

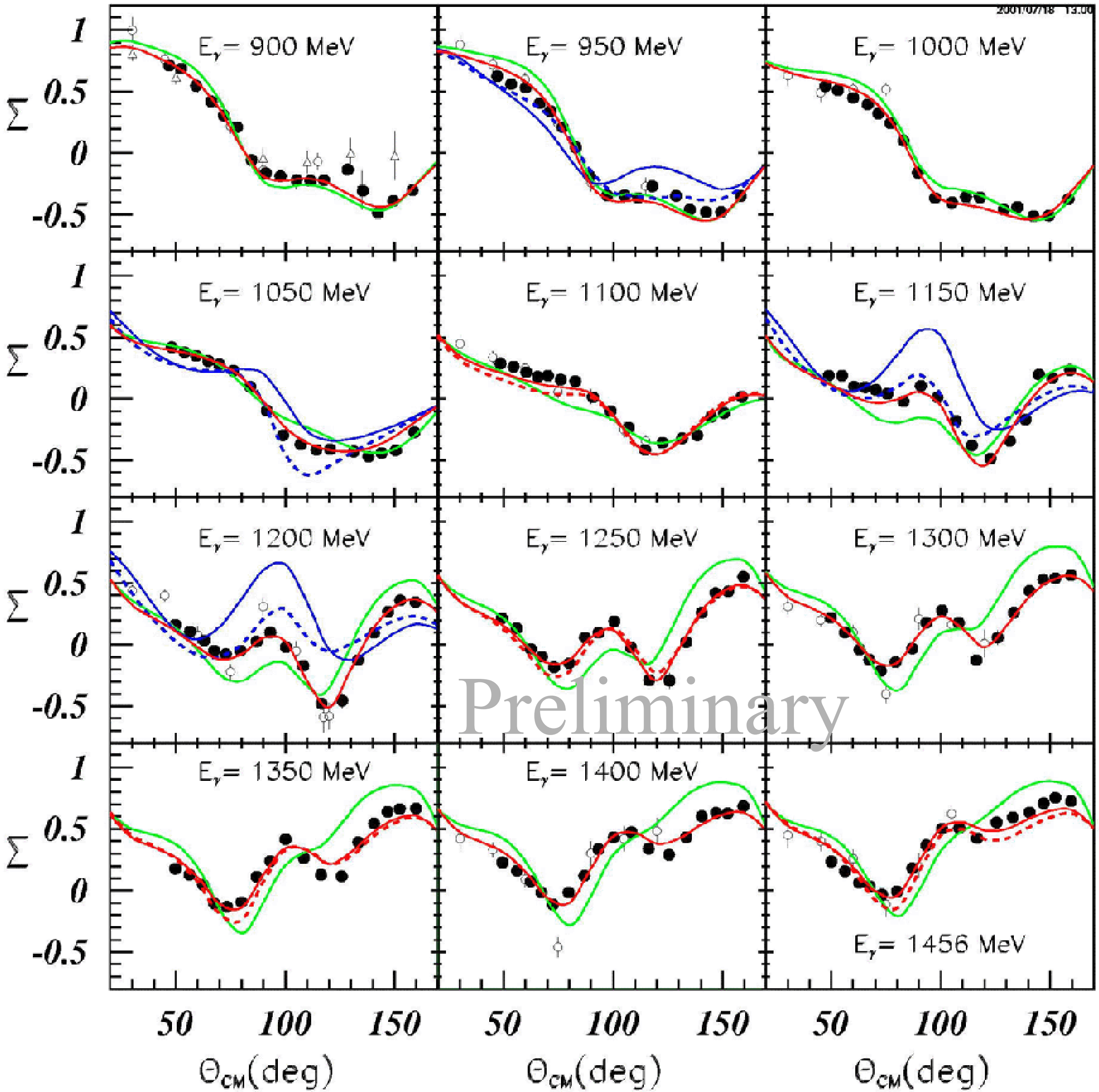
580 – 1100 MeV

required an update of the analysis

SAID analysis

solid blue line – WI00 solution

solid red line – FA01 solution



$\vec{\gamma} + p \rightarrow \pi^+ + n$

data

black circles – new Graal data

open circles – Daresbury (1979)

open triangles –SLAC (1974)

curves

green solid – SAID WI00

red dashed – SAID SP01

red solid –SAID FA01

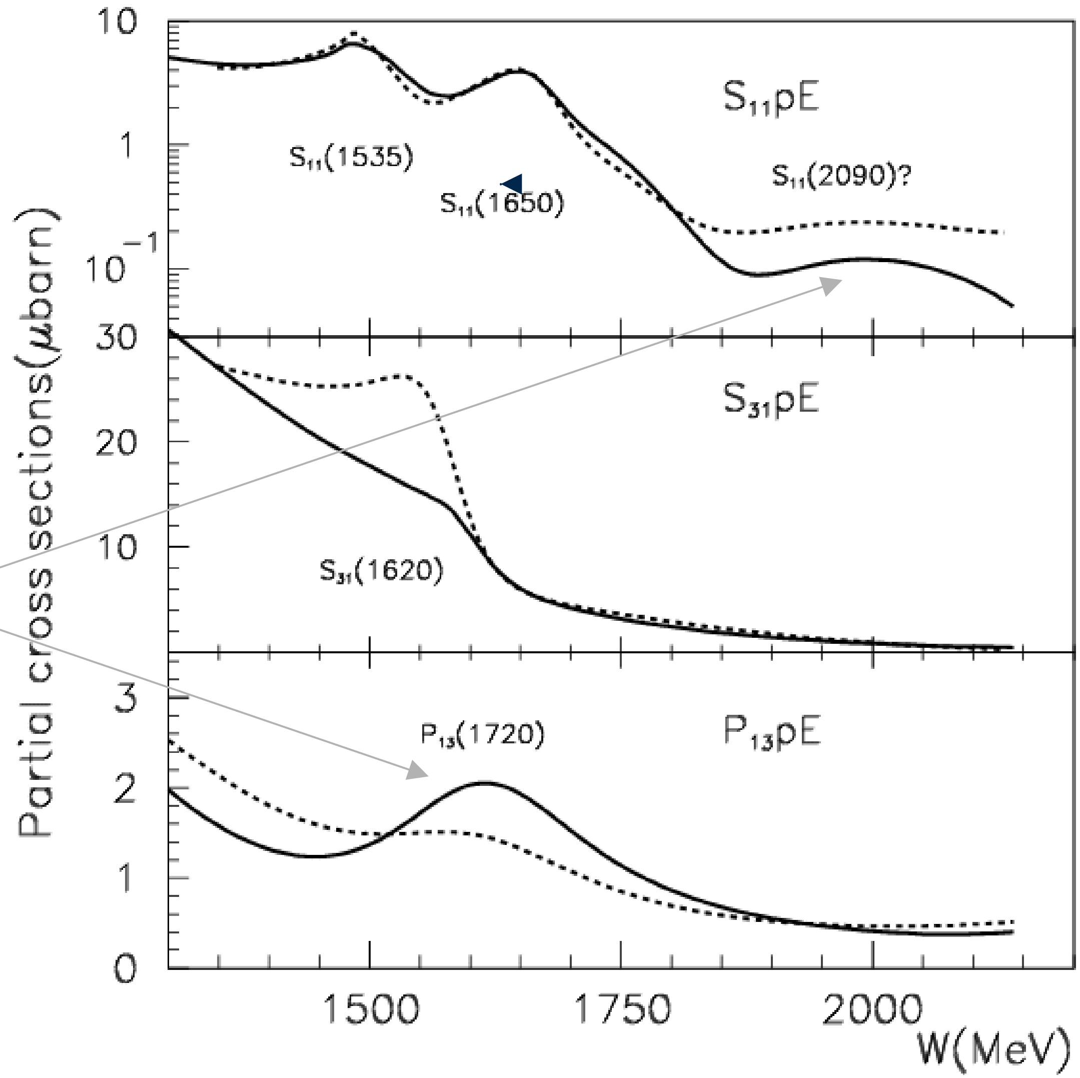
blue dashed – MAID (benchmark database)

blue solid – MAID 2000

Born, vector meson exchange, $P_{33}(1232)$, $P_{11}(1440)$, $D_{13}(1520)$, $S_{11}(1535)$, $S_{31}(1620)$, $S_{11}(1650)$, $F_{15}(1680)$, $D_{13}(1700)$

Extracted SAID multipoles

Solution	$\chi^2\ \pi^+n(\Sigma)$	overall χ^2
Wi00	2704/237	35144/17047
SP00 (dashed line)	1047/237	33928/17047
FA01 solid line	555/23	34664/17374



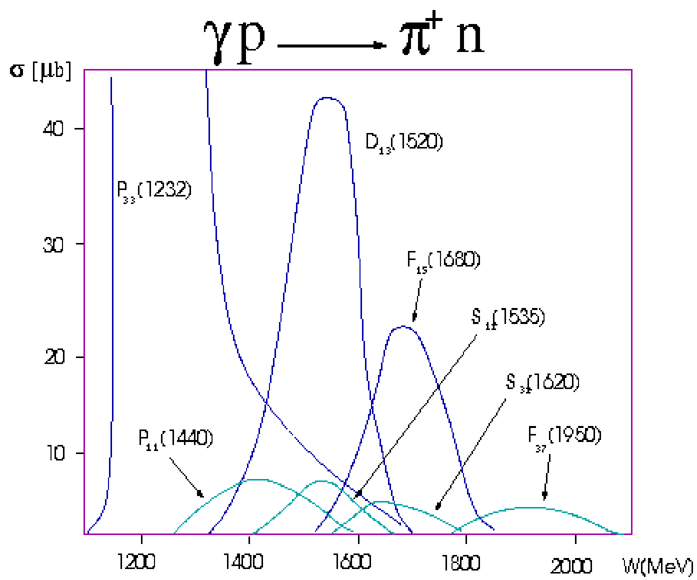
The new data analysis shows

- suppression of $S_{31}(1620)$
- presence of the P13(1720) (confirmed by Ron Crawford analysis in fixed-t disp. Rel)
- possible evidence of a third S_{11} resonance

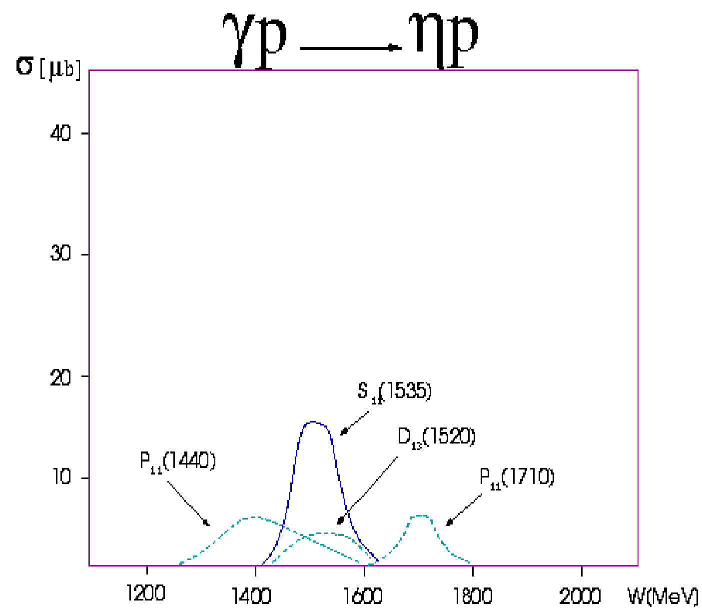
$$\vec{\gamma} + p \rightarrow \eta + p$$

Motivations:

Isospin selection



Both N* and Δ resonances may contribute to the reaction mechanism



Only N* resonances may contribute to the reaction mechanism

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

N*	Status	SU(6) ⊗ O(3)	Parity	Δ*	Status	SU(6) ⊗ O(3)
P11(938)	****	$\boxed{(56,0^+)}$	$+$	P33(1232)	****	$\boxed{(56,0^+)}$
S11(1535)	****	$\boxed{(70,1^-)}$				
S11(1650)	****	$\boxed{(70,1^-)}$		S31(1620)	****	$\boxed{(70,1^-)}$
D13(1520)	****	$\boxed{(70,1^-)}$	$-$	D33(1700)	****	$\boxed{(70,1^-)}$
D13(1700)	***	$\boxed{(70,1^-)}$				
D15(1675)	****	$\boxed{(70,1^-)}$				
P11(1520)	****	$\boxed{(56,0^+)}$		P31(1875)	****	$\boxed{(56,2^+)}$
P11(1710)	***	$(70,0^+)$		P31(1835)		$(70,0^+)$
P11(1880)		$(70,2^+)$				
P11(1975)		$(20,1^+)$				
P13(1720)	****	$\boxed{(56,2^+)}$		P33(1600)	***	$\boxed{(56,0^+)}$
P13(1870)	*	$(70,0^+)$		P33(1920)	***	$\boxed{(56,2^+)}$
P13(1910)		$(70,2^+)$	$+$	P33(1985)		$(70,2^+)$
P13(1950)		$(70,2^+)$				
P13(2030)		$(20,1^+)$				
F15(1680)	****	$\boxed{(56,2^+)}$		F35(1905)	****	$\boxed{(56,2^+)}$
F15(2000)	**	$(70,2^+)$		F35(2000)	**	$(70,2^+)$
F15(1995)		$(70,2^+)$				
F17(1990)	**	$(70,2^+)$		F37(1950)	****	$\boxed{(56,2^+)}$

Motivations: searching for missing resonances

Symmetric CQM models predict more states than the observed ones.

1) The "missing" states do not exist (di-quark models)
2) The "missing" states have not been observed in reactions where Resonances couple to the πN channel.

They may be observed in other channels such as ηN ρN ωN

SU(6)⊗O(3) Super-multiplets assignments – Cutkosky model

Boxes are consistent with di-quark model

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

First data are from Mainz (open circles)

Krusche et al PRL 74(1995) 3736

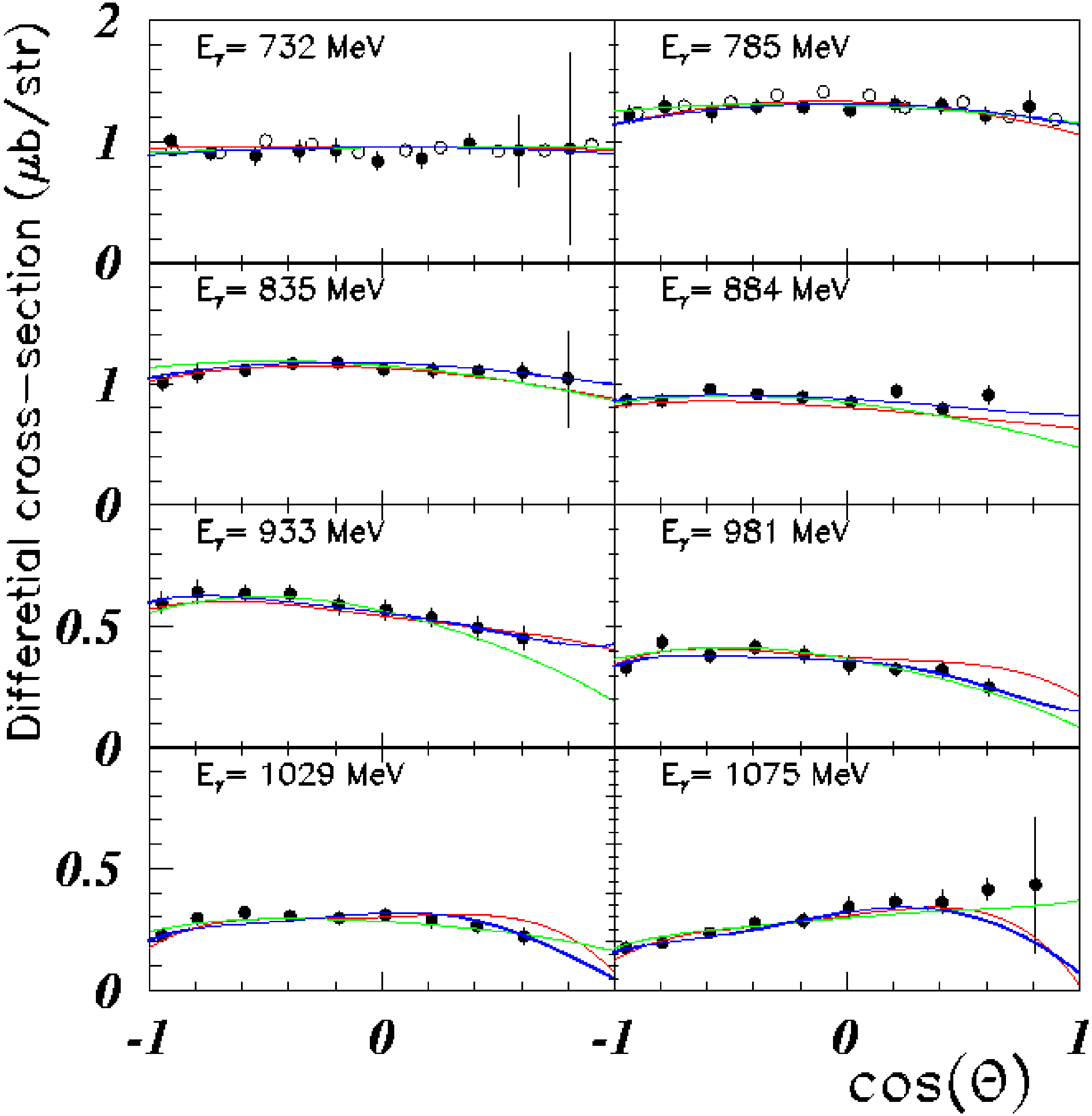
Nearly isotropic shape of the low energy angular distribution $\rightarrow$ $S_{11}(1535)$ dominance.

Data up to 1100 MeV are from GRAAL.

Red curve: SAID BO12

Blue curve : eta MAID

Green curve: B. Saghai and Z. Li



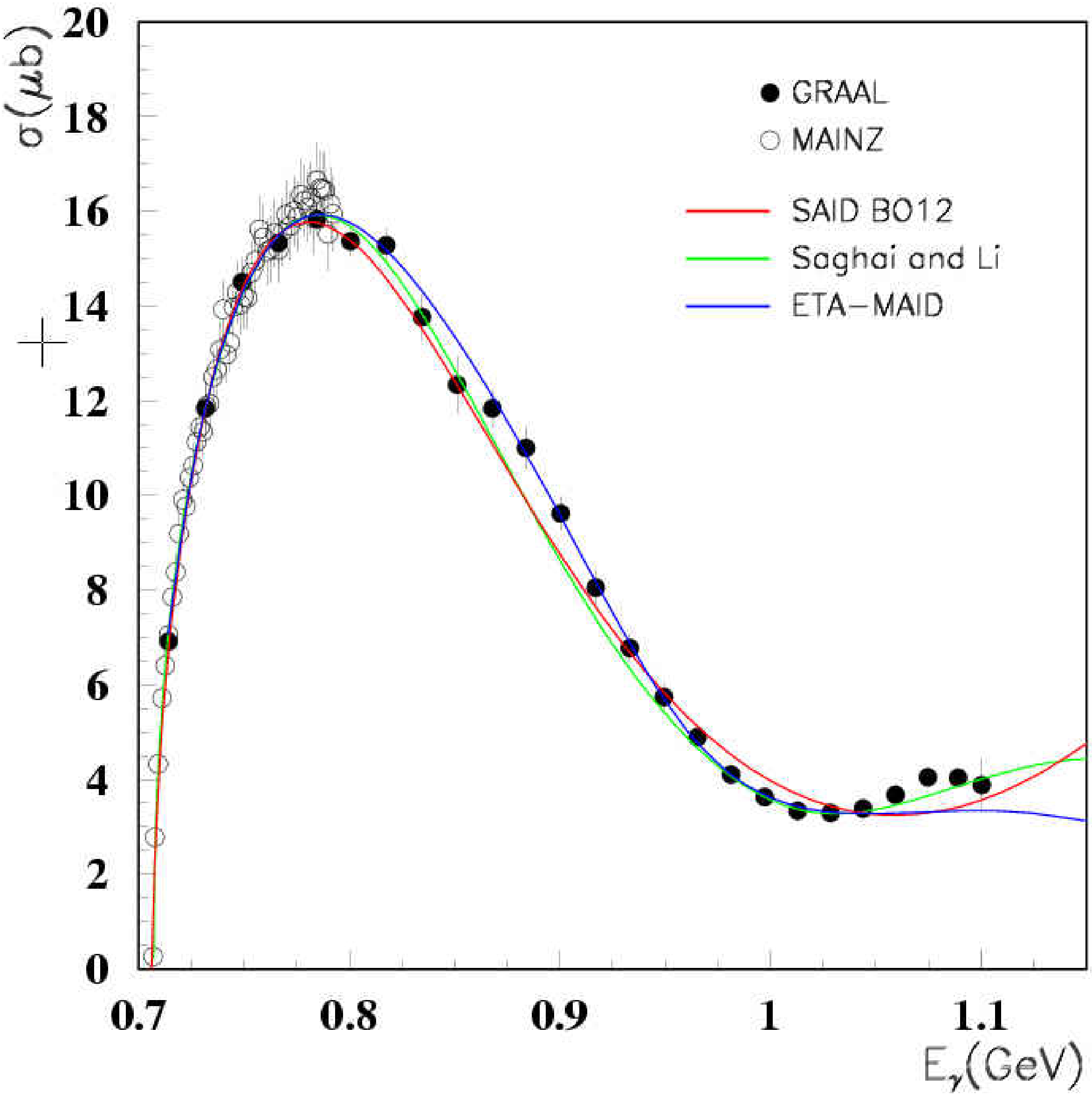
Most recent analyses: $\vec{\gamma} + p \rightarrow \eta + p$

1. PWA from SAID: BO12 solution. All GRAAL data are included in the database. Data are well reproduced only up to 1056 MeV. Discrepancy remains in the differential cross section at very forward angles.

2. Isobar Model. ETA - MAID Wen-Tai Chiang, L. Tiator et al. It includes $S_{11}(1535)$, $D_{13}(1520)$, $S_{11}(1650)$, $D_{15}(1675)$, $F_{15}(1680)$, $D_{13}(1700)$, $P_{11}(1710)$, $P_{13}(1720)$. Includes vector meson (ρ,ω) exchange in the t-channel. It extracts a sizable branching ratio $\Gamma_{\eta N}/\ \Gamma$ for the $S_{11}(1650)$ .It is not able to reproduce the target asymmetry data.

3. Coupled-channel analysis by Agung Waluyo, C. Bennhold et a.et al. (Giessen group) Effective Lagrangian model and coupled-channel analysis in the K-matrix approximation. Vector meson (ρ,ω) exchange in the t-channel. No P-wave resonances. Only $S_{11}(1535)$, $D_{13}(1520)$, $S_{11}(1650)$, $D_{13}(1700)$ play a role.

4. Chiral constituent quark model - Chiral effective Lagrangian B. Saghai and Z. Li It includes all resonances up to 2 GeV in the s and u channel.No t-exchange contributions (duality hypothesis.) It extracts the mixing angle between the two $S_{11}$and D_{13} resonances. It requires the inclusion of a third S_{11} (1730) *($K\Lambda$ quasibound state)* to reproduce the peak at forward angles in the cross section. The role of the $F_{15}(1680)$ is sizable. It is confirmed in the analysis of Class data.



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

Graal and Mainz data

Graal data cover the full resonance.

They show a "structure" at 1050 MeV, confirmed by new CLAS data

→ Pasyuk

Red curve: SAID BO12

Blue curve : eta MAID

Green curve: B. Saghai and Z. Li

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

Red curve: SAID BO12

Blue curve : eta MAID

Green curve: B. Saghai and Z. Li

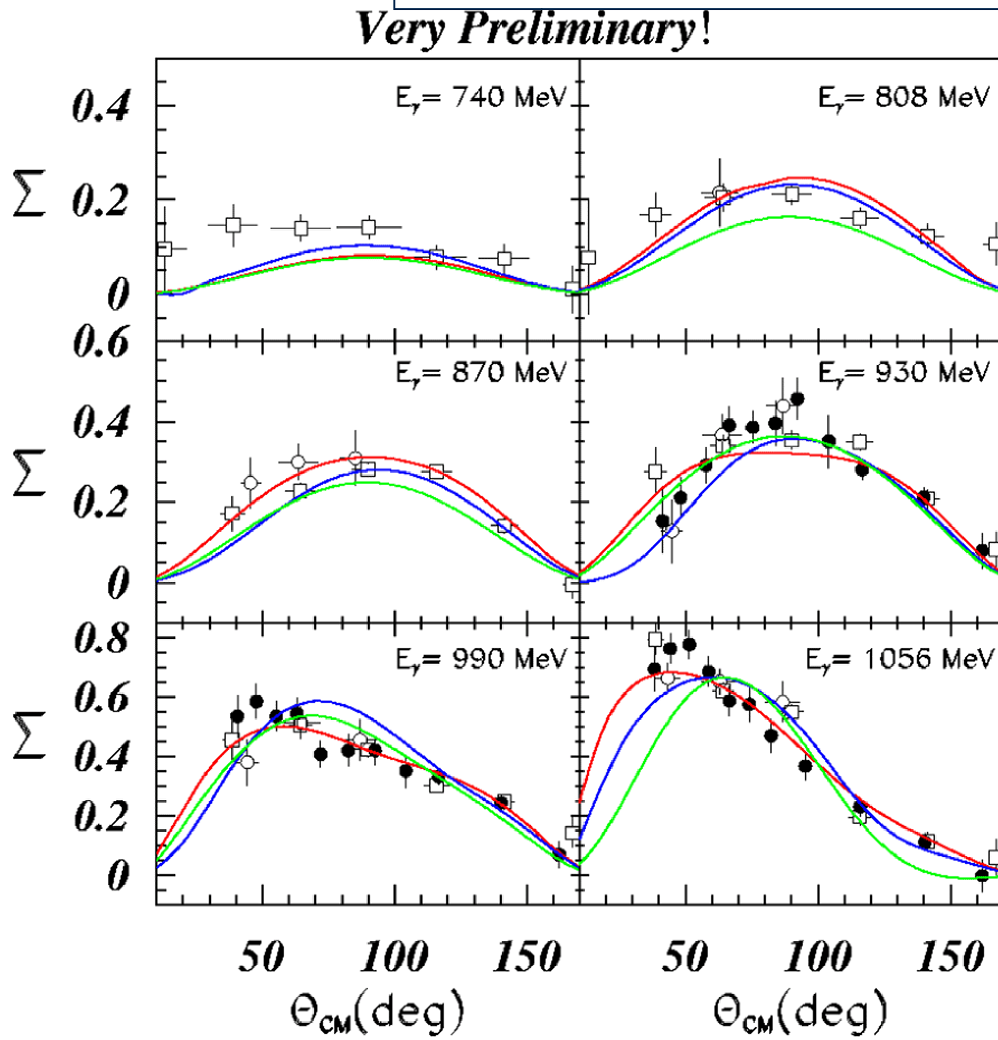
Graal data are the first results for the beam asymmetry Σ.

open squares and circles : old Graal data (740 – 1056 MeV)

full circles: new preliminary Graal data (930-1445 MeV)

The sizable non-zero asymmetry is due to the interference of $S_{11}(1535)$ with $D_{13}(1520)$

It is possible to extract $D_{13}(1520)$ helicity amplitudes



The forward peak at higher energies is due to higher resonances e.g..$F_{15}(1680)$

L. Tiator et al. PRC 60 (1999) 035210

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

The peak is confirmed by the latest GRAAL results.

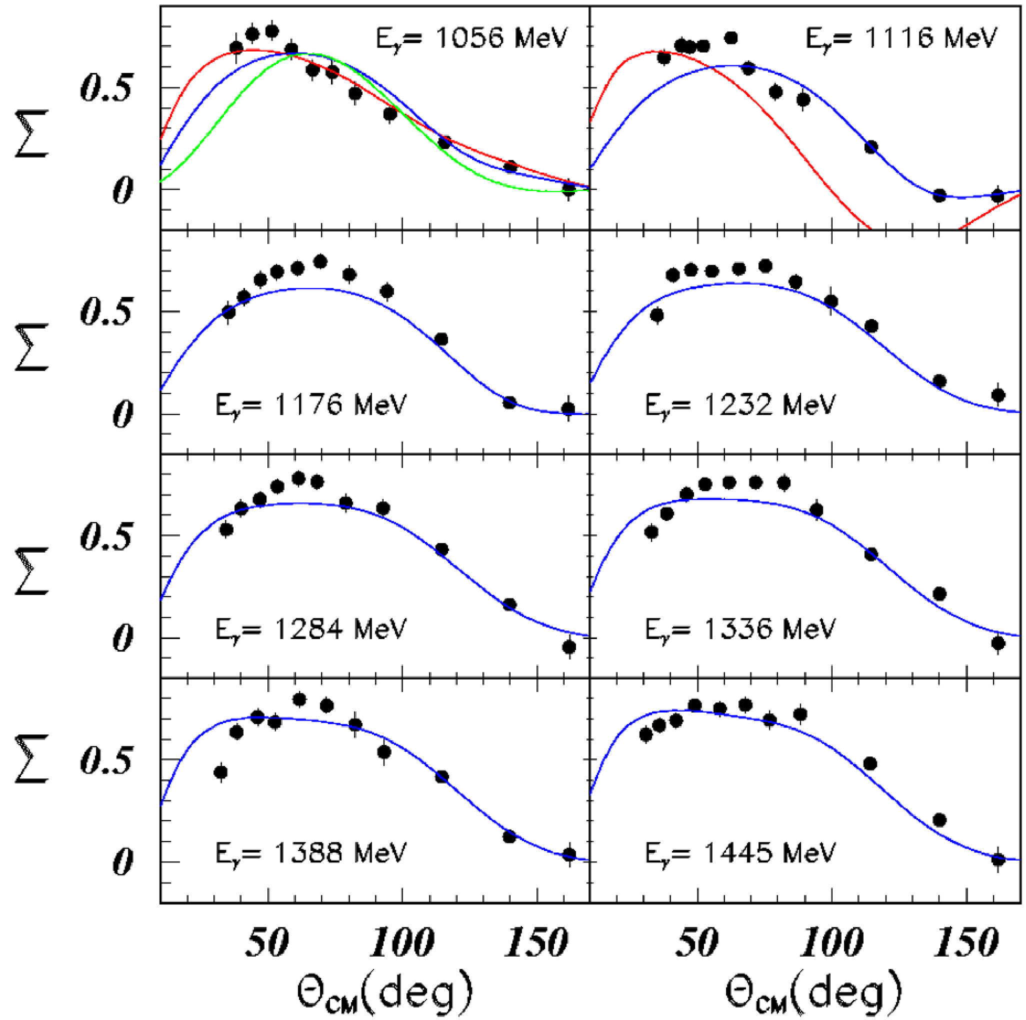
MAID predictions agree quite well up to the highest energies

Red curve: SAID BO12

Blue curve : eta MAID

Green curve: B. Saghai and Z. Li

Very Preliminary!



Extraction of resonance parameters

$\gamma + p \rightarrow S_{11}(1535) \rightarrow \eta N$

	Ib	CC	Chiral	PDG
Mass(MeV)	1541	1556	1542	1535
Γ(MeV)	191	252	162	150
$A_{\frac{1}{2}}(10^{-3}\sqrt{GeV})$	118	-	64	90 +/- 30
$\Gamma_{\eta N}/\Gamma$	-	0.5	0.62	0.3-0.55

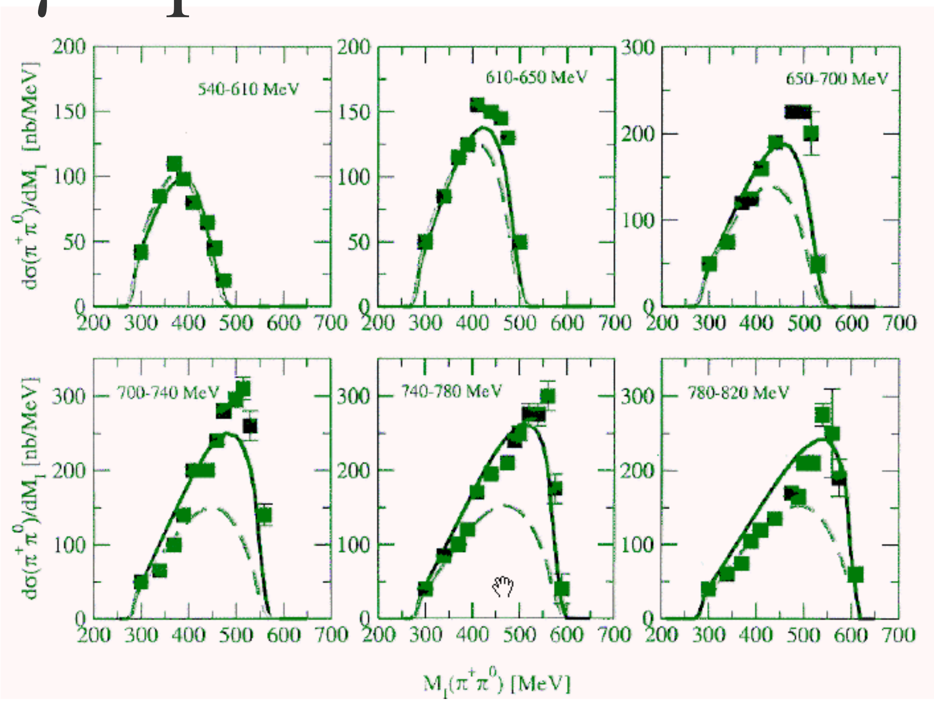
$\gamma + p \rightarrow D_{13}(1520) \rightarrow \eta N$

	MA	Ib	CC	Chiral	PDG
Mass(MeV)	-	-	1506	-	1520
Γ(MeV)	-	-	84	-	120
$A_{\frac{1}{2}}(10^{-3}\sqrt{GeV})$	-79 ± 9	-52	-	- 9	-24 ± 9
$A_{3/2}/A_{1/2}$	-2.1 ± 0.2	-	-	-16.5	-6.91

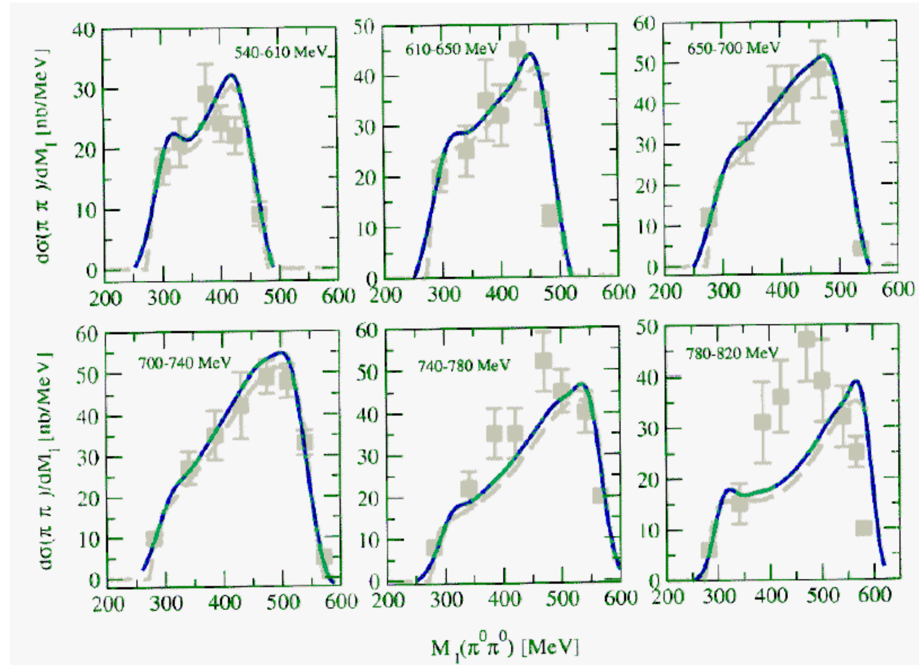
Isgur	-5.56		Capstick	-8.93
Li-Close	-2.49	-4.86	Bijker	-2.5

double pion production on the proton

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



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



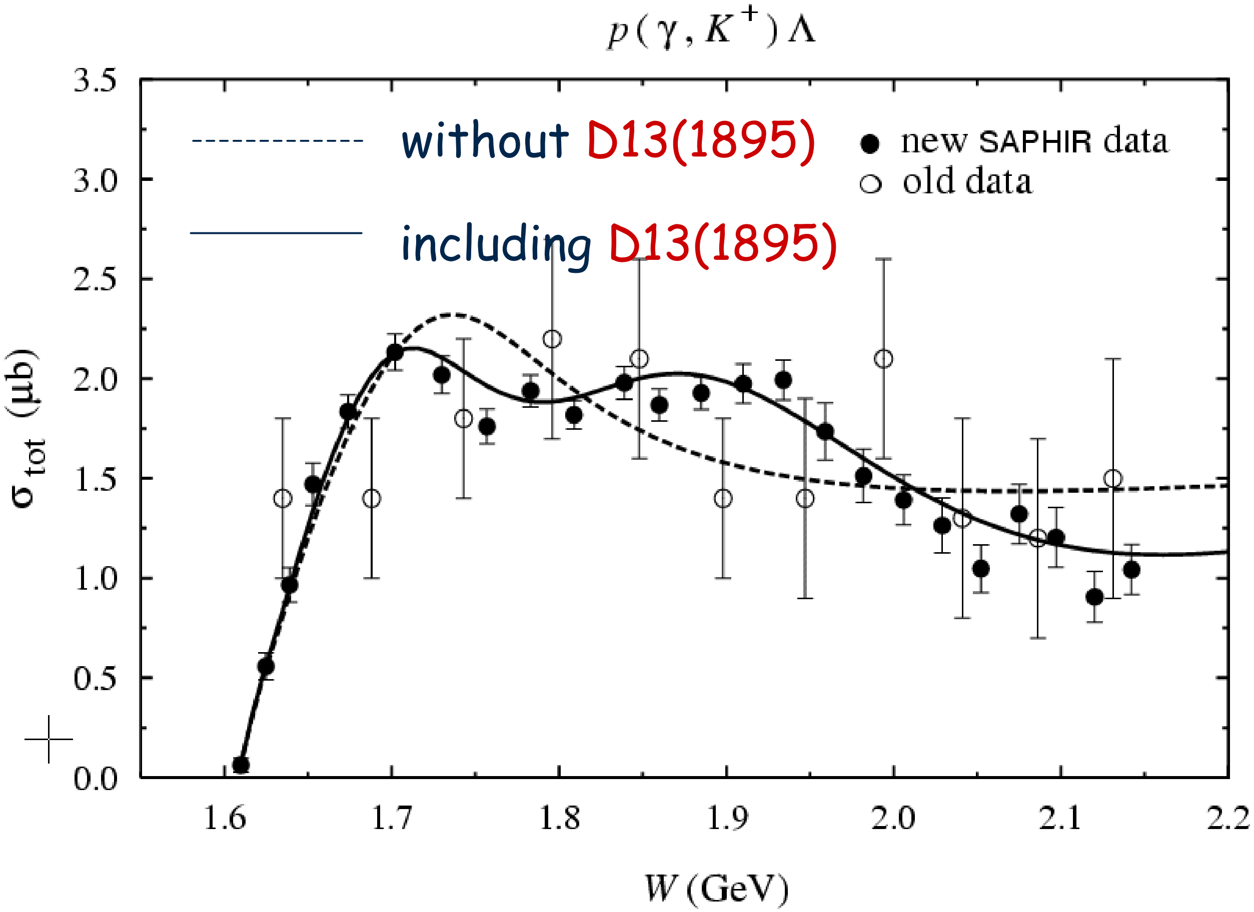
The dominant resonant excitation mechanism have been understood (Oset et al.) to be :

$\gamma + p \rightarrow D_{13}(1520) \rightarrow \Delta^0\ \pi^+ \rightarrow n\ \ \pi^0\ \pi^+$ $\qquad$ $\gamma + p \rightarrow D_{13}(1520) \rightarrow \Delta^0\ \pi^0 \rightarrow p\ \ \pi^0\ \pi^0$

However the model (dashed curve) could not reproduce the full strength of the $\pi^+\ \pi^0$ channel. The measure of the invariant mass spectra of the $\pi\pi$ systems was the key measure to reveal the direct decay $D_{13}(1520) \rightarrow \rho N$ in the $\pi^+\ \pi^0$ channel

$\gamma + p \rightarrow D_{13}(1520) \rightarrow N\rho \rightarrow n\ \ \pi^+\ \pi^0$ (solid curve)

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



Extracted mass and width are M=1895 MeV and Γ = 372 MeV

SAPHIR data show a structure at W=1900 MeV

M.Q.Tran PLB 445(1998)20

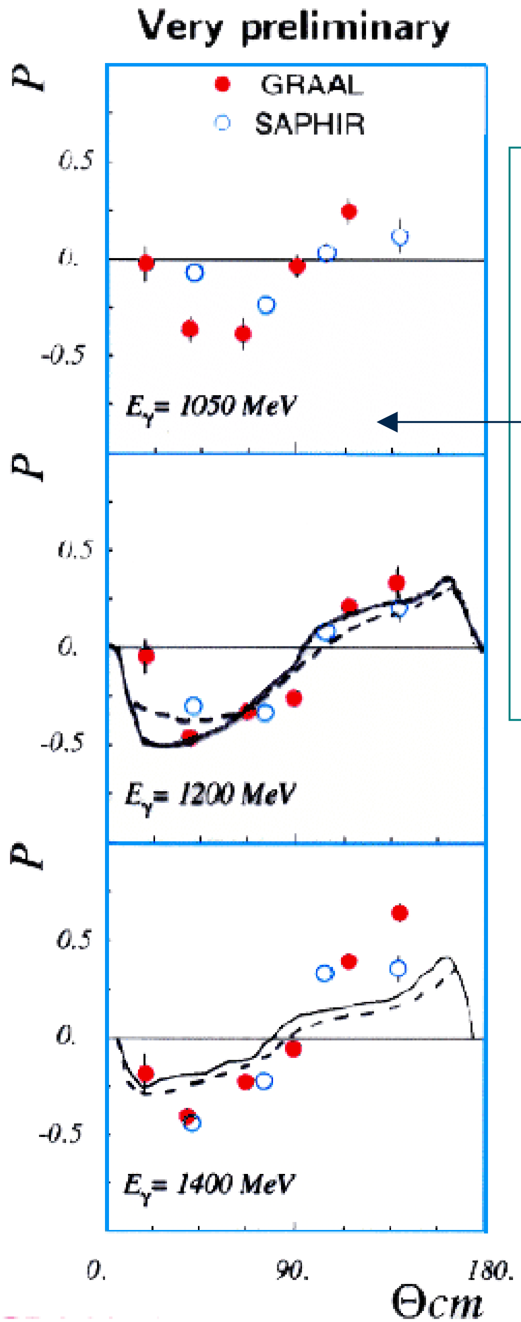
Coupled -channel analysis finds that $S_{11}(1650)$, $P_{11}(1710)$ and $P_{13}(1720)$ have the most significant decay widths in the $k^+\Lambda$ channel

T. Feuster and U. Mosel PRC58 (1998),457

Isobar model by C. Bennhold and collaborators, requires the inclusion of a "missing" $D_{13}(1960)$ resonance to reproduce the cross section data.

more data from SAPHIR and SPRING8 $\rightarrow$ R.G.T. Zegers

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

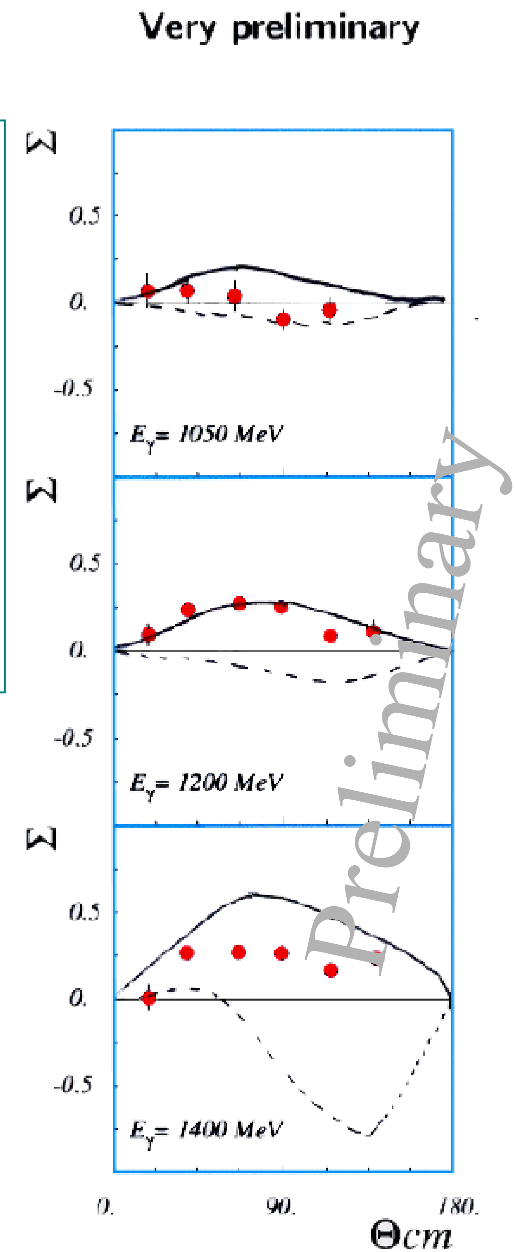


The recoil polarization asymmetry P may be measured from the angular distribution of the $\Lambda \rightarrow p\pi^-$ weak-decay.

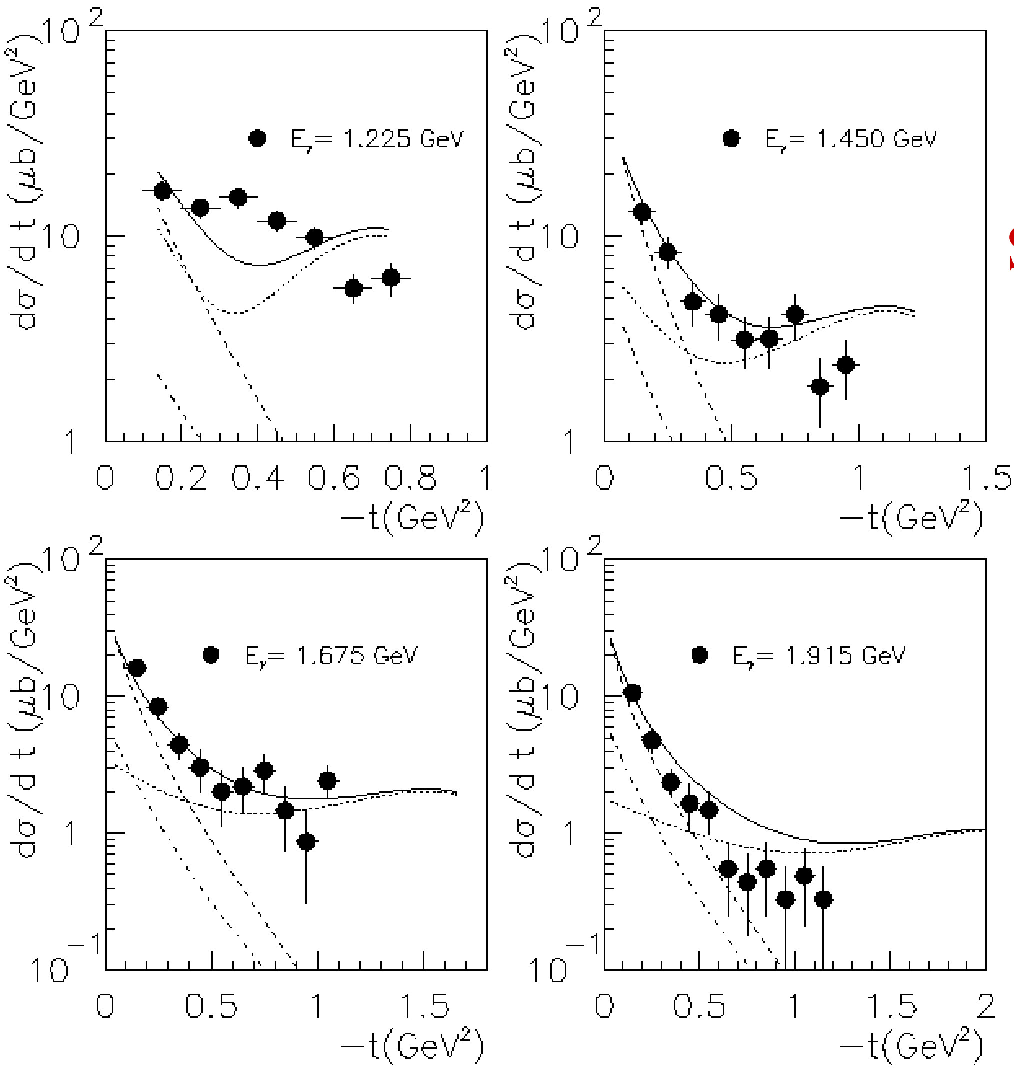
Results are available from SAPHIR and GRAAL . They are in agreement, but the observable is not quite sensitive to the inclusion of the "missing" D_{13}(1960)

The beam polarization asymmetry Σ is on the contrary very sensitive to the inclusion of the "missing" resonance. The model predict a change of sign in the observable.

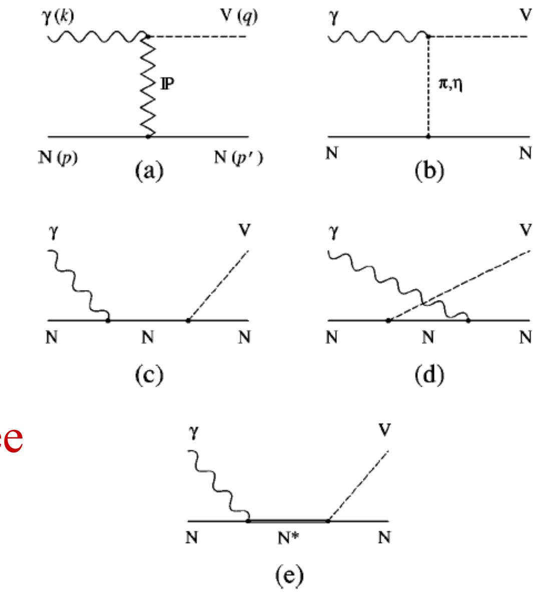
First preliminary data on Σ from GRAAL confirm the presence of the resonance



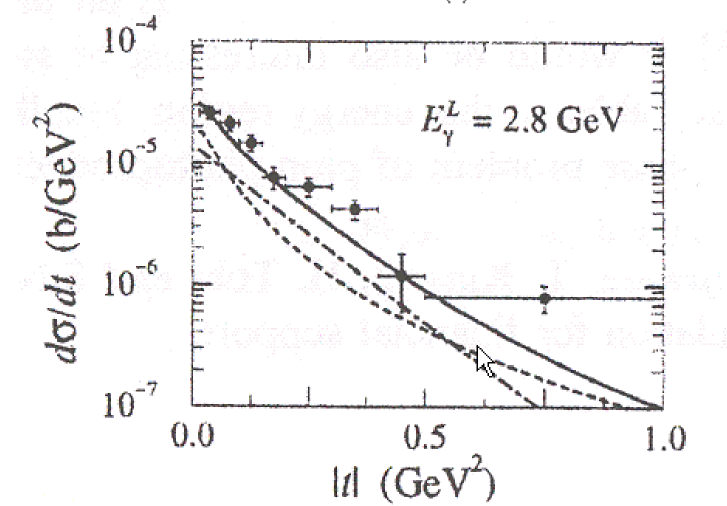
$\gamma + p \rightarrow \omega + p$



Saphir data



Predictions by
Oh,Titov, H.Lee
and
Qiang Zhao

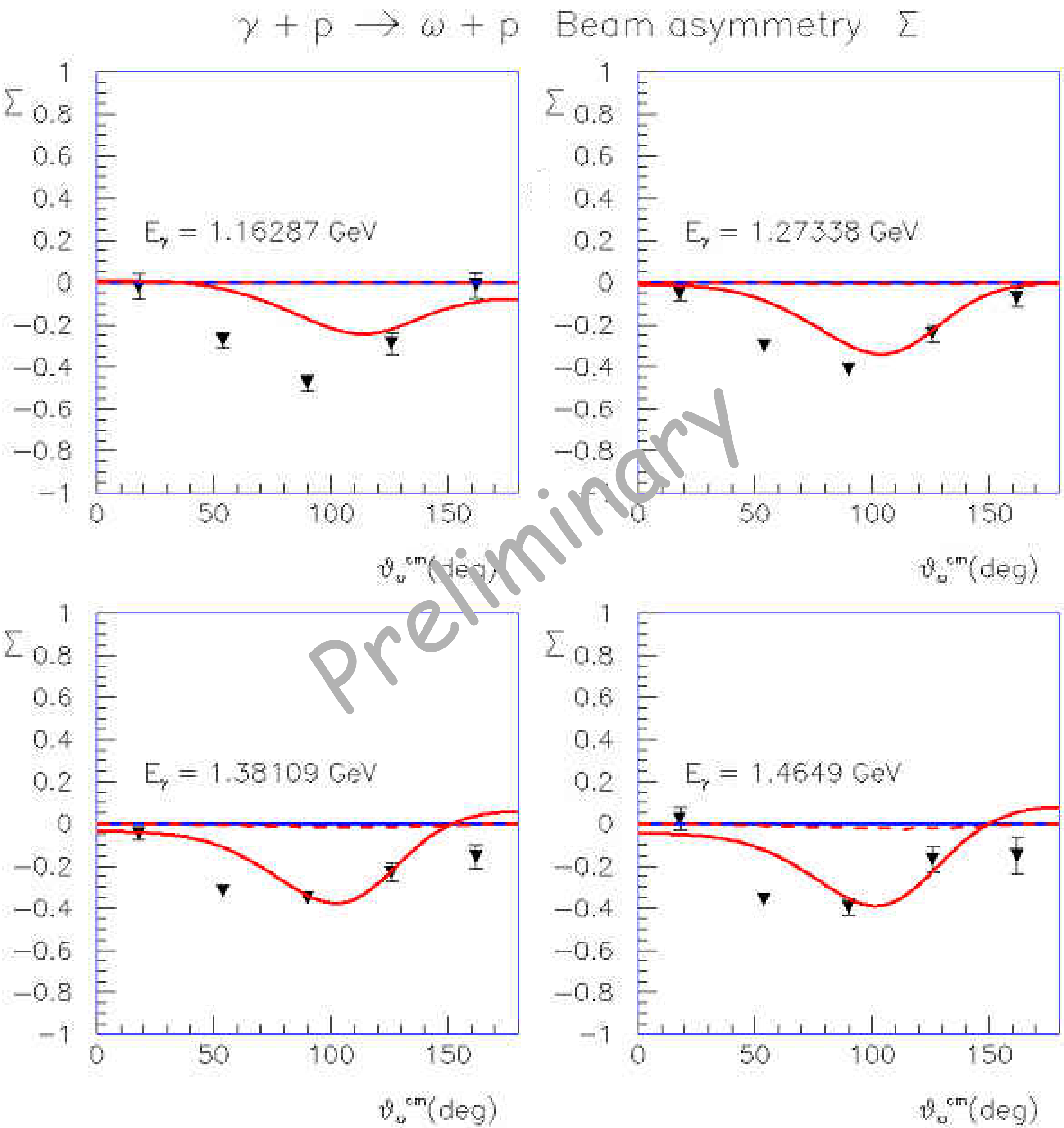


t-channel Pomeron exchange

t-channel π^0 exchange

u-s –channels and N* resonances

full calculation



$\vec{\gamma} + p \rightarrow \omega + p$

The beam asymmetry Σ is very sensitive to the inclusion of the N* resonances.

The inclusion of the diffractive t-exchange terms alone produces no asymmetry.

First preliminary results from GRAAL.
Sizable contribution from N* resonances.

Model from Zhao includes $P_{11}(1440)$, $S_{11}(1535)$, $D_{13}(1520)$, $P_{13}(1720)$, $F_{15}(1680)$, $P_{13}(1900)$, $F_{15}(2000)$

Conclusions

- New precise results involving also double polarization measurements are available from many Laboratories:

-MAINZ
-BONN
-LEGS
-GRAAL
-SPRING-8
-JLAB

- The experimental determination of the $\Delta(1232)$ EMR is very precise (0.3 % absolute errors – 10% relative error)
- The helicity amplitudes of the $D_{13}(1520)$ and $S_{11}(1535)$ have been extracted from η photoproduction showing important discrepancies with respect to the PDG (π data)
- Reaction mechanisms involving higher resonances in $\pi\pi$, $k^+\Lambda$, and ω photoproduction are becoming clear.

PER ASPERA AD ASTRA