Light Baryon Spectroscopy - Recent Results

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- Introduction

- Recent Results ELSA, JLAB and MAMI:

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

  $\vec{\gamma}\ \vec{p} \to p\, \eta$

- Narrow structure

  $\vec{\gamma}\ n \to n\, \eta$

- Summary and Outlook

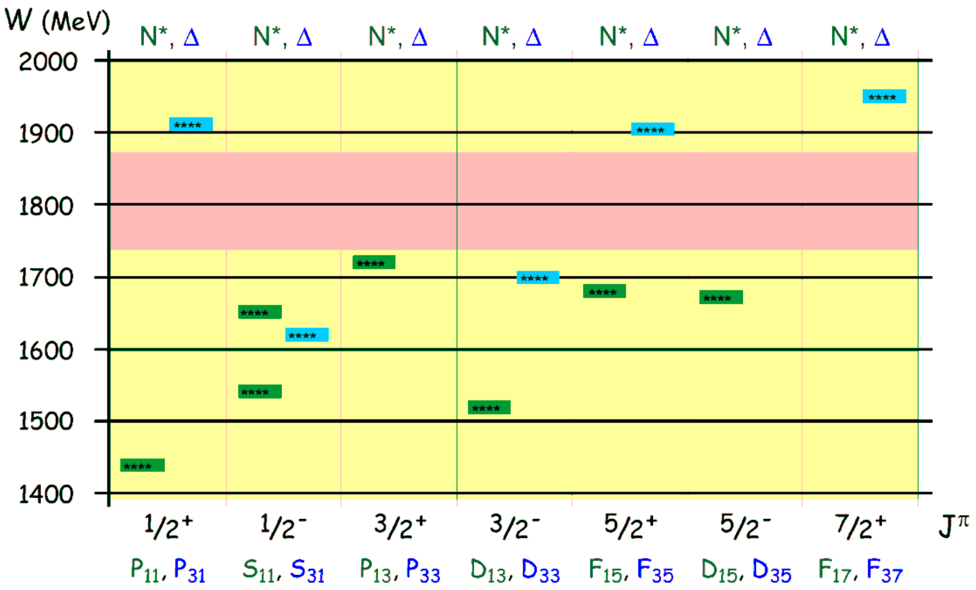
supported by the DFG within the SFB/TR16

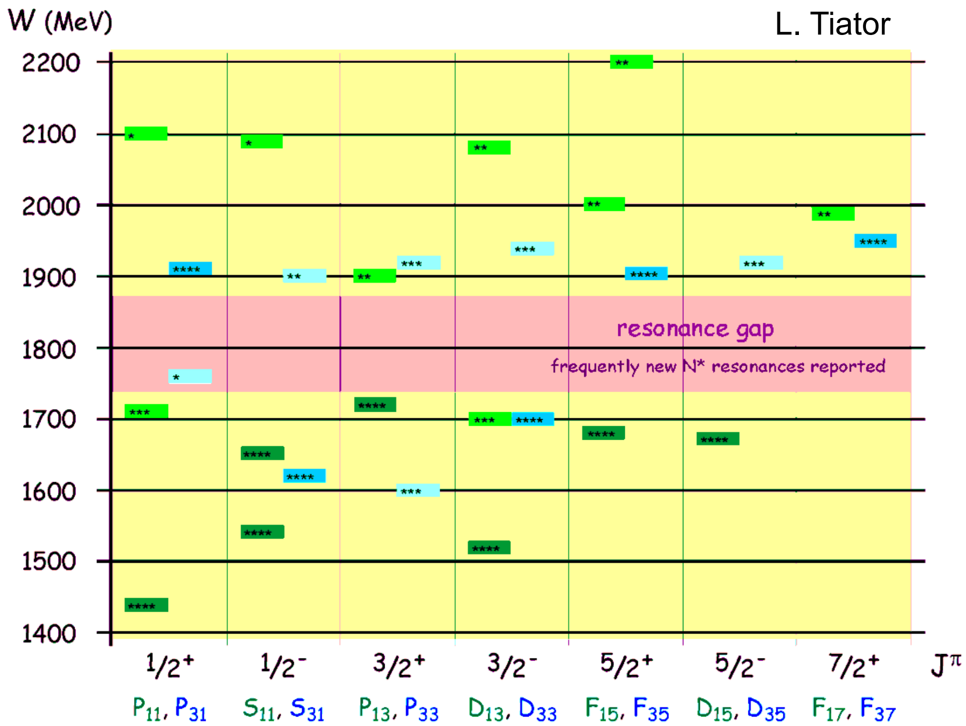
Introduction

PDG 2010: Status on nucleon resonances

only 7 N* and 5 Δ*

established in the region 1400 MeV < W < 2000 MeV





- Energy pattern for the dominant states

  Constituent Quark Models

  Dynamical Models

  Lattice QCD

- Various nucleon models predict many more states

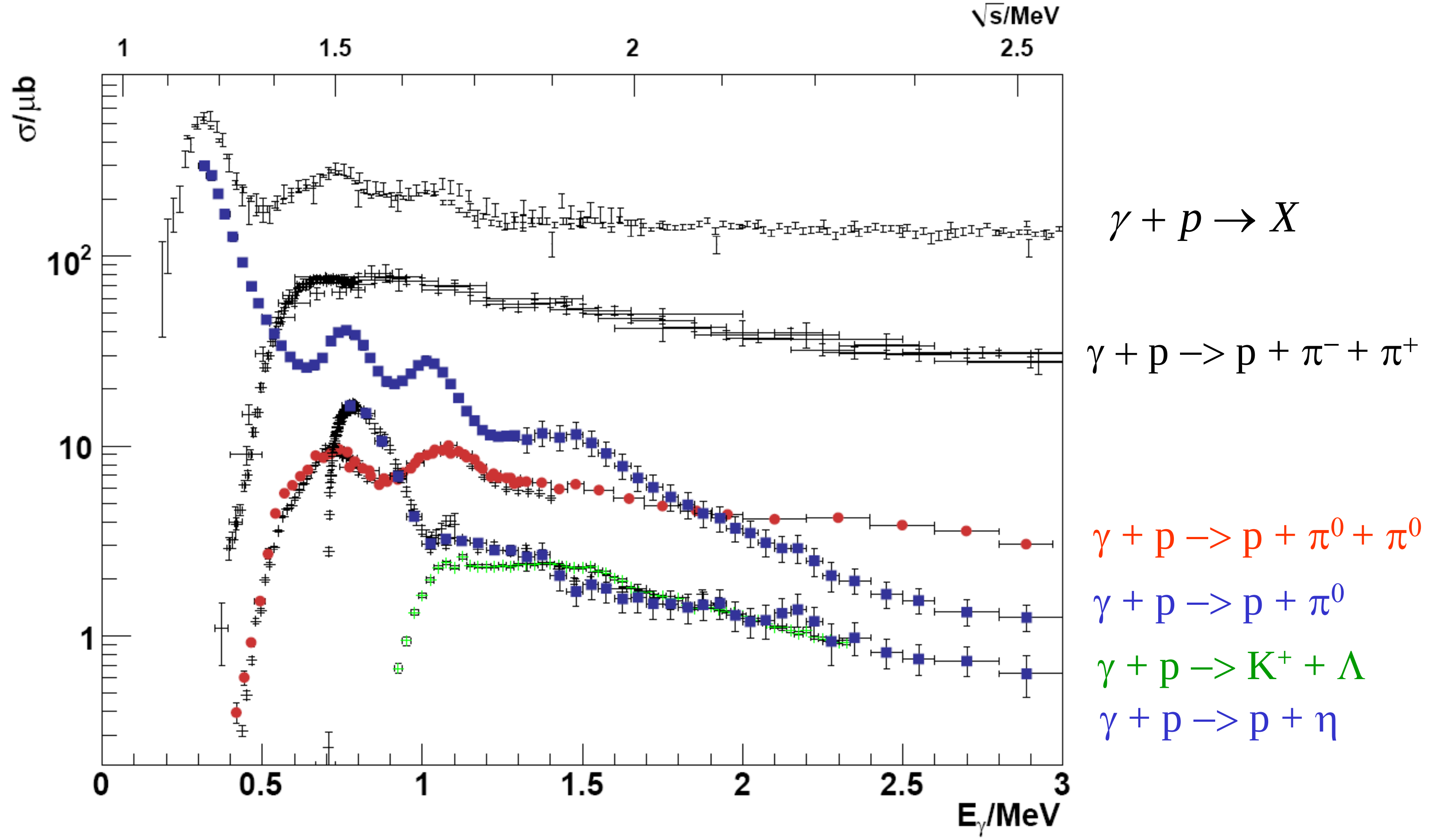
  weak coupling to πN final state

  insufficient data base

Experimental program for N*

Common effort at ELSA, JLab and MAMI,

- Precision data for different final states ($p\pi^0$, $n\pi^+$, $p\eta$, $K\Lambda$, $p\pi^0\pi^0$....)
- Polarization experiments (beam, target and recoil)
  "complete experiment"



Complete Experiment

$$\vec{\gamma} + \vec{N} \rightarrow N + \pi$$

8 well chosen observable have to be measured to determine the production amplitudes (F_1,F_2,F_3 and F_4)

- π- threshold until $\Delta^+(1232)$- region

  additional constraints:

  (a) s- and p- wave approximation

  (b) Fermi- Watson theorem

  $$\gamma + N \rightarrow N + \pi$$
  $$\pi + N \rightarrow N + \pi$$

  same I, J in the final state
  → same scattering phase δ_{IJ}

  two observable sufficient for "complete experiment"

  differential cross section : $d\sigma/d\Omega$

  beam asymmetry : Σ

- above $\pi\pi$- threshold

  Fermi- Watson theorem not valid any more

  More observable needed to find unique partial wave solution

Observables in Meson Photoproduction

Photon polarization		Target polarization			Recoil nucleon 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	-	-	-	-

data only for:

Differential cross section: σ

Beam asymmetry: Σ

Double polarization: **E**

Sensitive to: $\mathrm{Re}(P_1 \cdot P_2)$

data needed for:

Target asymmetry: **T**

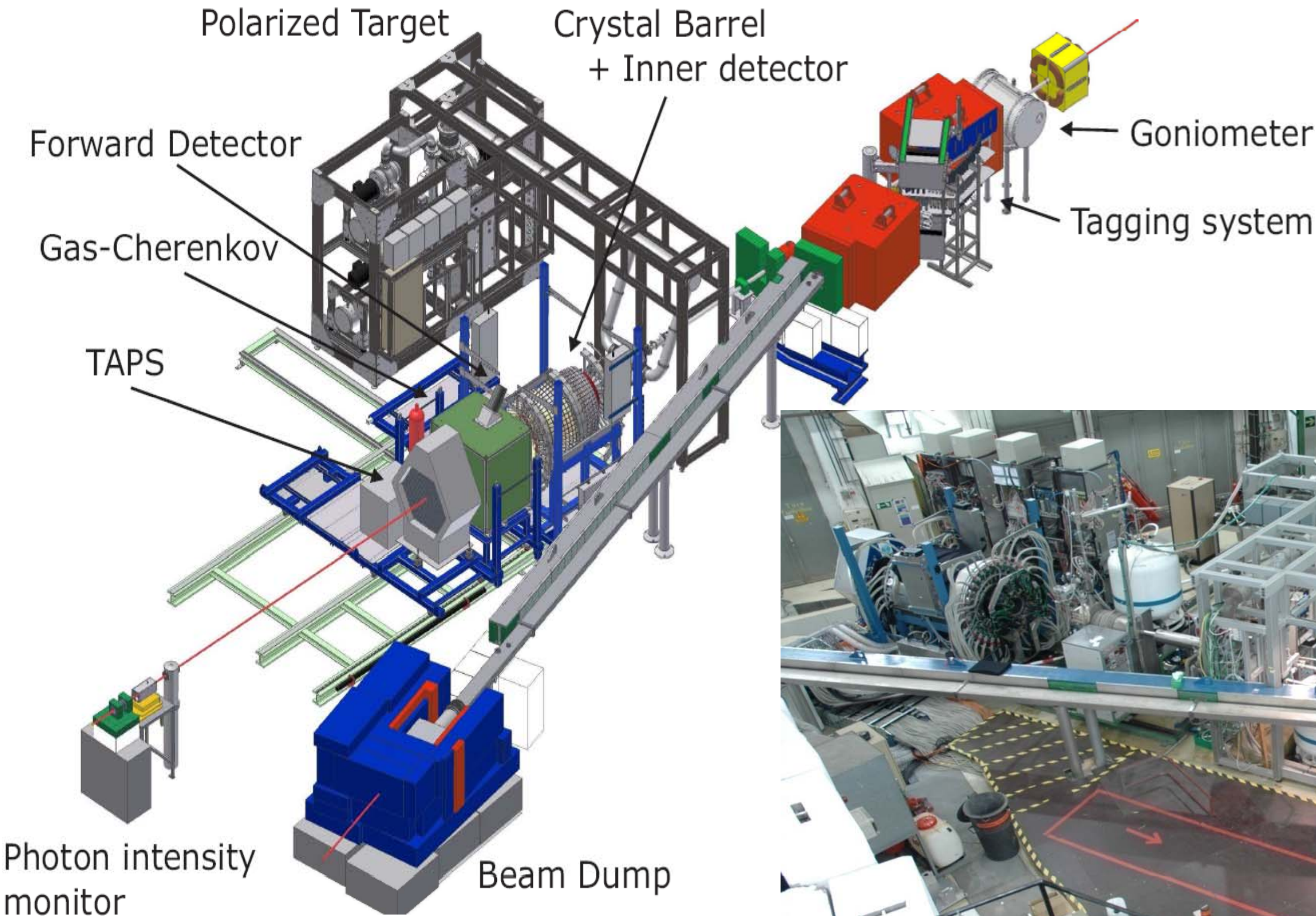
Recoil polarization: **P**

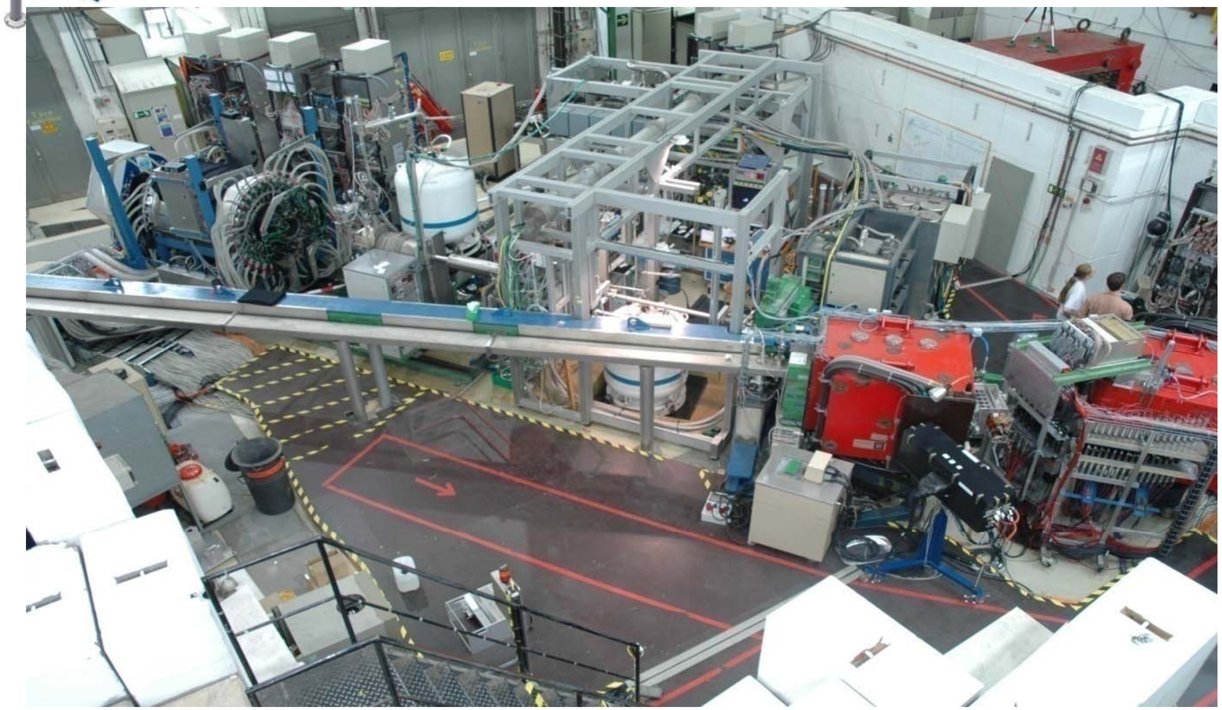
Double polarization: **G**

Sensitive to: $\mathrm{Im}(P_1 \cdot P_2)$

ELSA, JLAB, MAMI : polarized photons, polarized targets and 4π acceptance

Crystal Barrel Set Up at ELSA





Crystal Barrel Set Up at ELSA

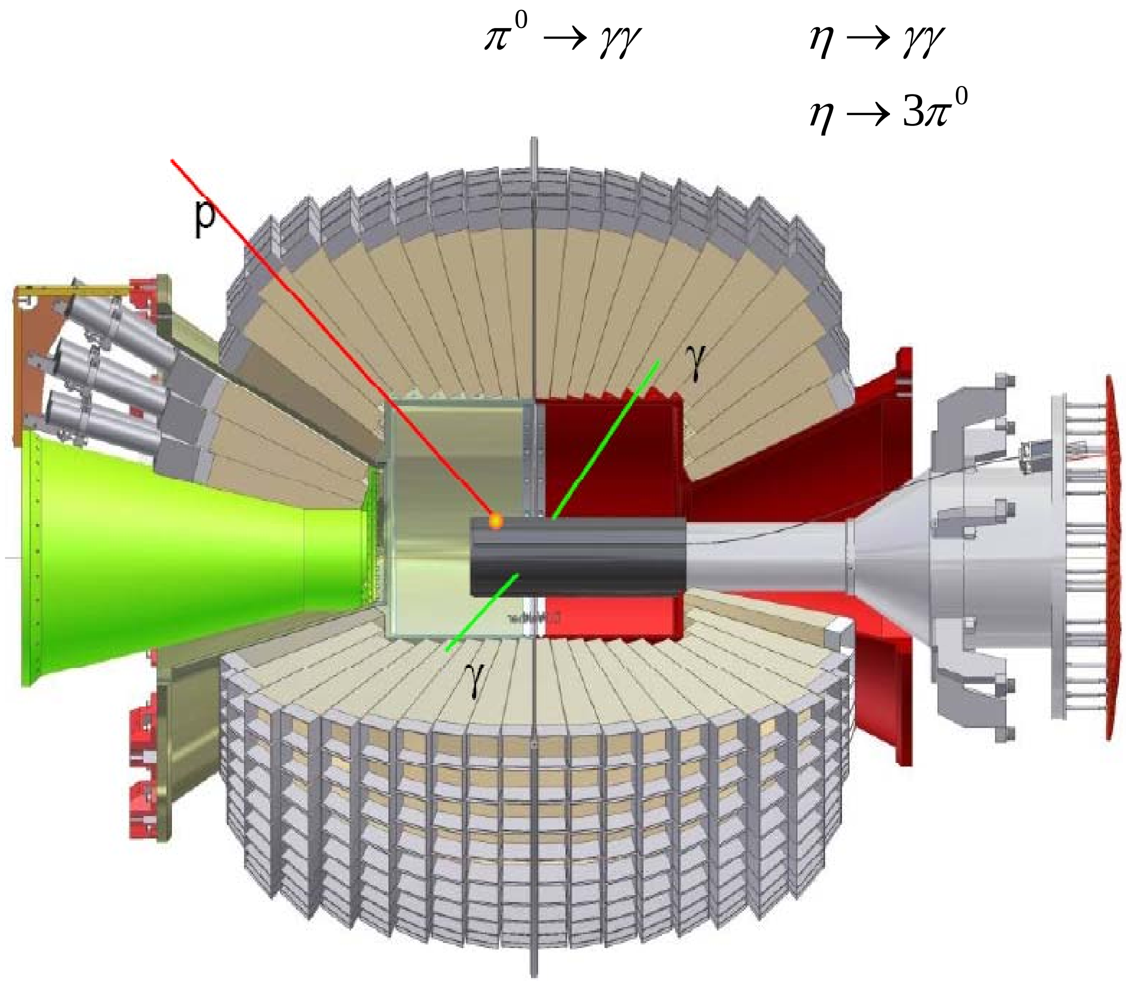
- Crystal Barrel detector
  1230 CsI crystals

- Inner-detector
  cylinder of 513 scintillating fibers

- forward detector (FWPlug)
  90 CsI crystals with PM's, 12^0-30^0

- forward detector (MiniTAPS)
  216 BaF_2 , 1^0-12^0

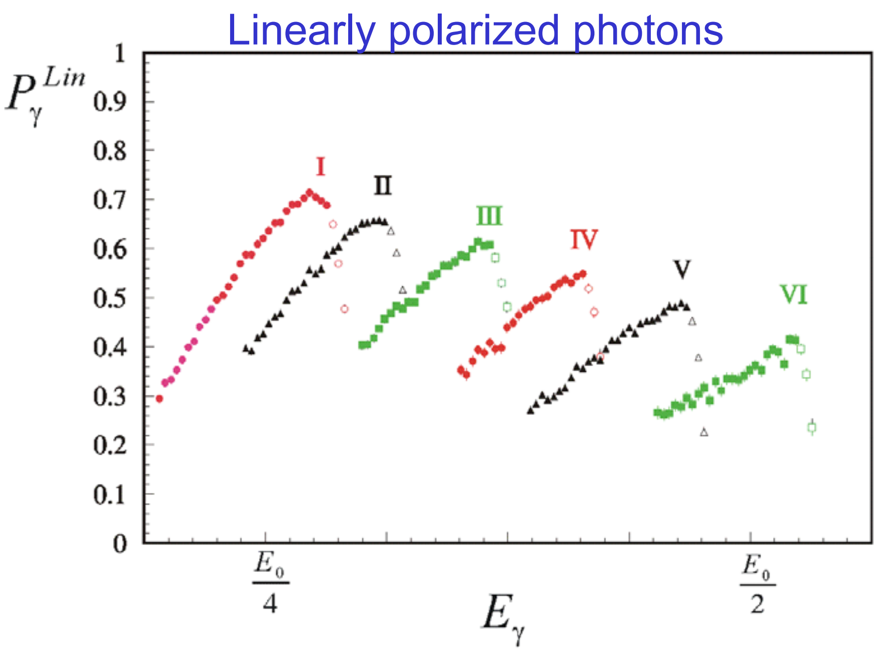
Close to 4π coverage



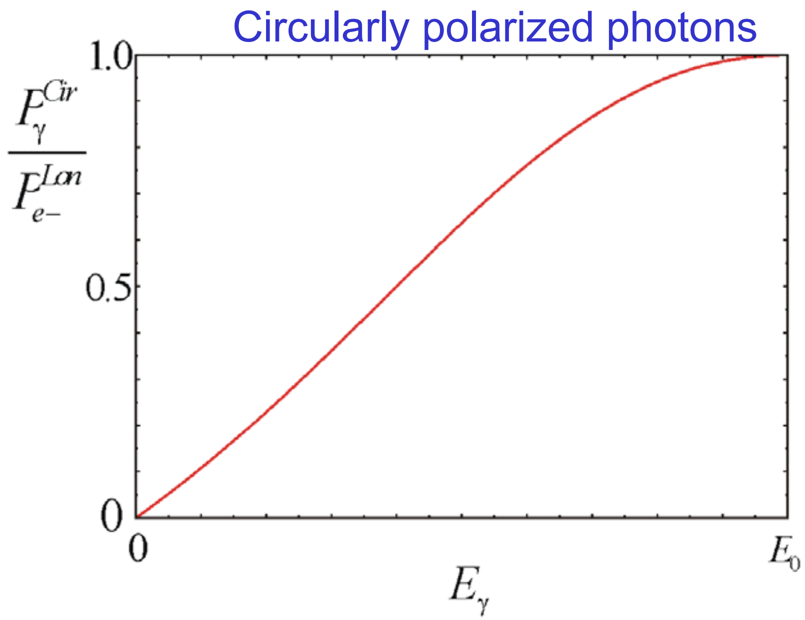
Polarized Photons

Linearly polarized photons:
- coherent bremsstrahlung
- diamond radiator

Circularly polarized photons:
- longitudinally polarized electrons
- helicity transfer to photon

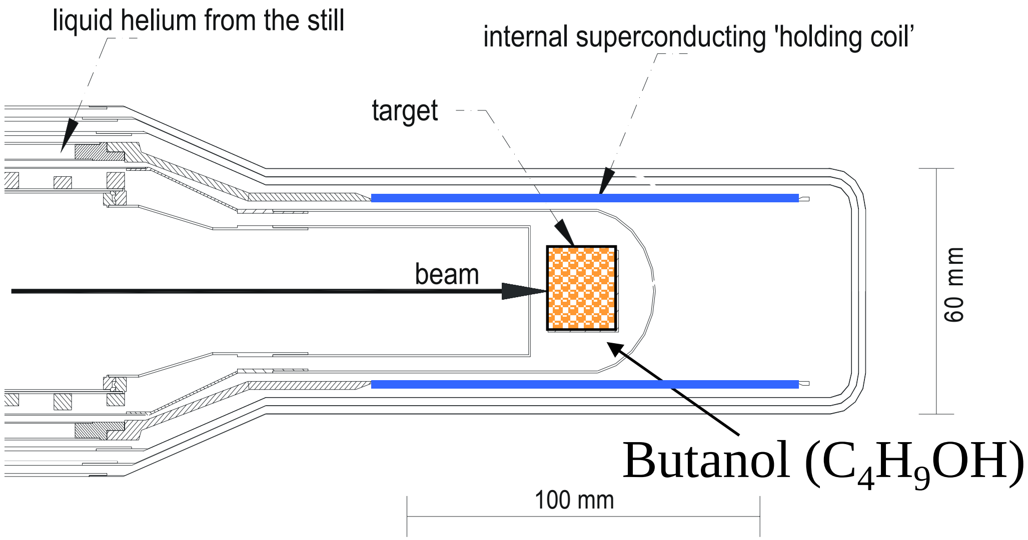


high polarization at low photon energies



high polarization at high photon energies

Polarized Target

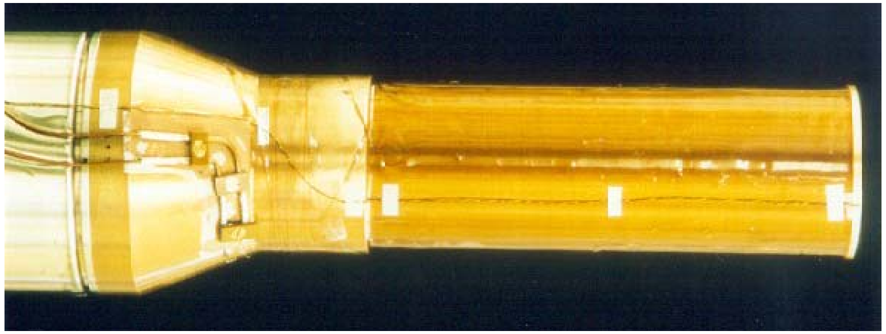


„Frozen Spin Target"

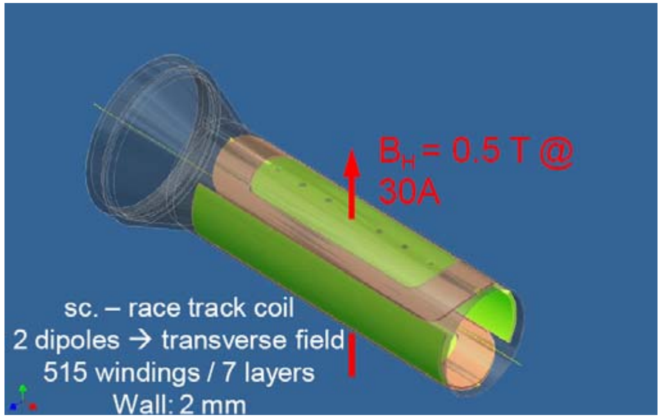
Horizontal cryostat with integrated solenoid to freeze up the spin

Target: Butanol (C_4H_9OH)

Polarization: DNP at high B-field (2.5 T)
„freeze" up the spin (0.4 T)
relaxation time T~500h



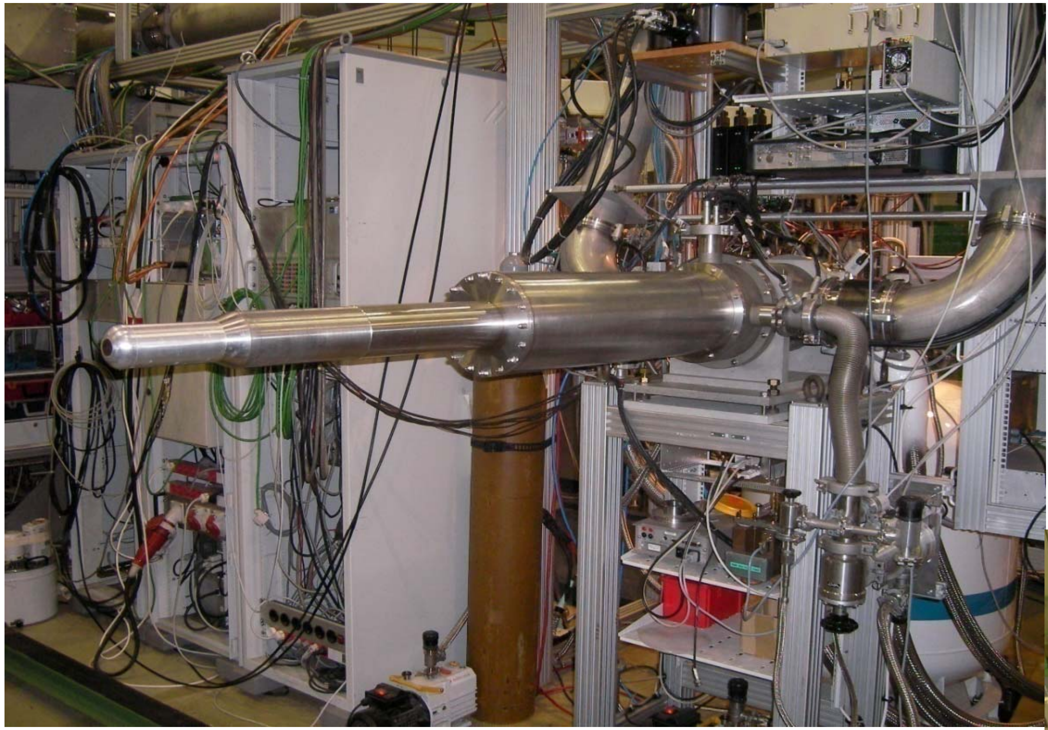
„longitudinally polarized Target"



„transversely polarized Target"

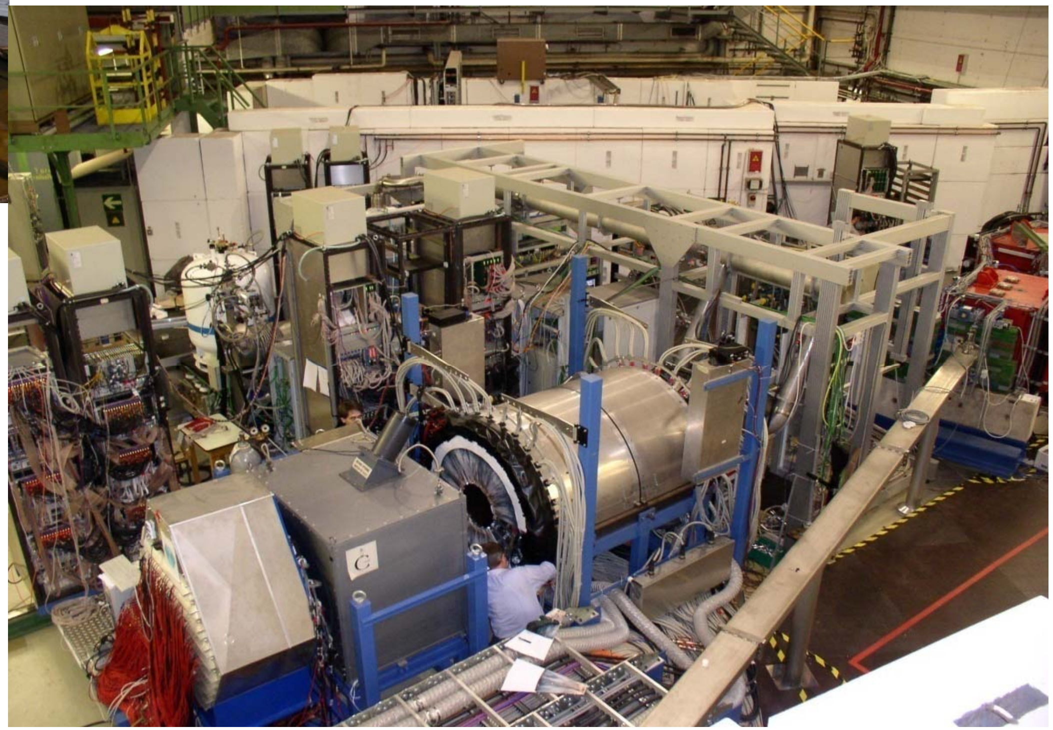
ELSA, JLAB and MAMI

Polarized Target at ELSA



Running time over 2500 hours in year 2008
over 2200 hours in year 2009
over 1500 hours in year 2010

High. polarization	$P_+ =$ 83.4 %
	$P_- = -$ 80.9 %
fast build-up	05h04min (May/June)
	05h39min (August)
Pol.-time	06h10min

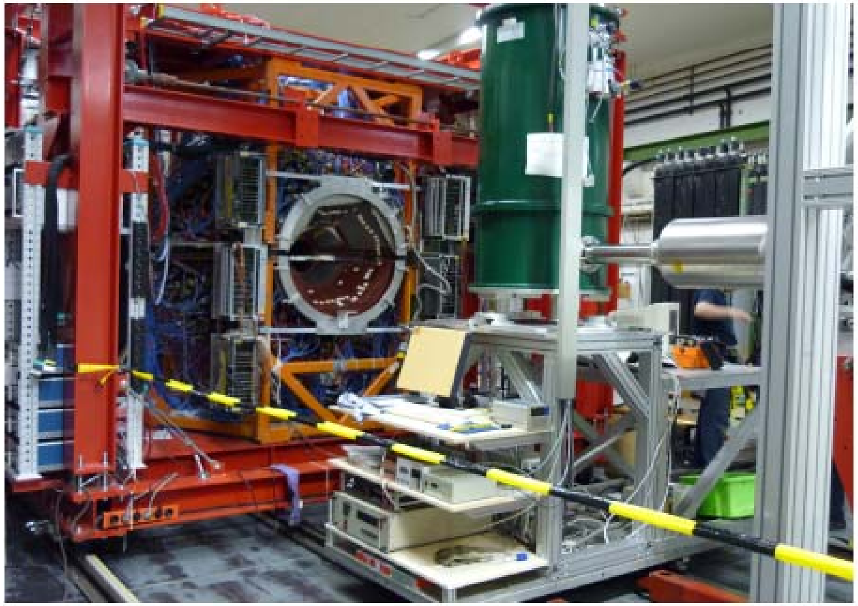


horizontal cryostat
in experimental area

data taking

Polarized Target at MAMI

Polarized Target running since beginning 2010

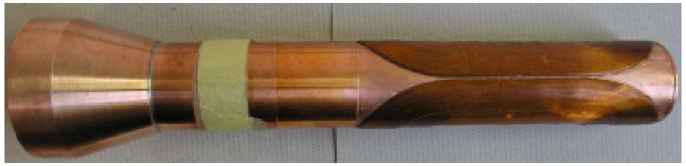


$^3He^4He$-Dilution refrigerator (Mainz/JINR Dubna)

Material: Butanol, Polarization > 90%

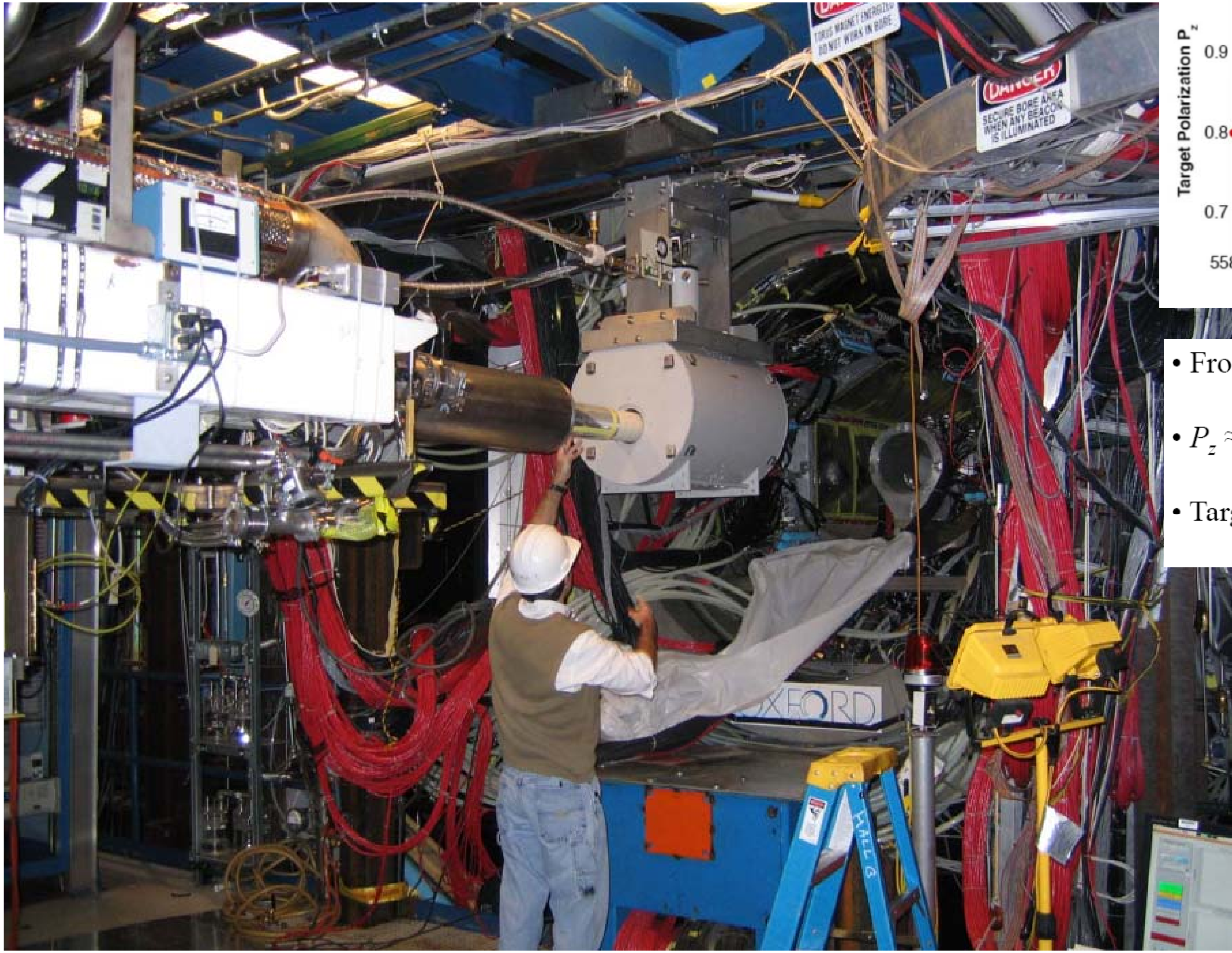
~1000 hours relaxation time & low He consumption

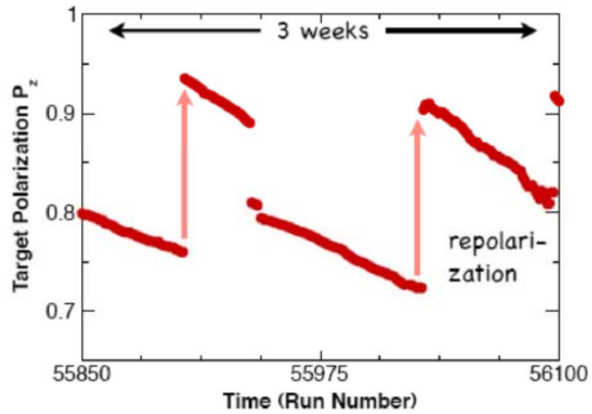
Running with transverse polarized target!



Polarized Target at JLAB

Polarized Target running since beginning 2007





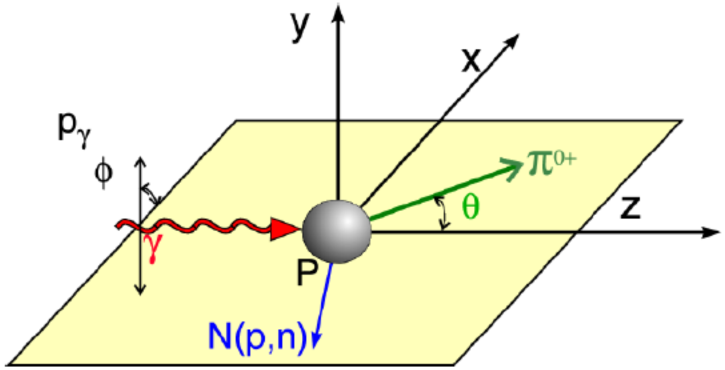
- Frozen spin butanol (C_4H_9OH)
- $P_z \approx 80\%$
- Target depolarization: $\tau \approx 100$ days

Beam-Target Polarization Observables

photoproduction of pseudoscalar mesons:

- all 3 single polarization observables
- 4 double polarization observables

can be measured with the Crystal Barrel/TAPS experiment



photon pol.		target pol. axis		
		x	y	z
unpolarized	σ		T	
linear	$-\Sigma$	H	$-P$	$-G$
circular		F		$-E$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}(\theta,\phi) = \frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}(\theta) \cdot \Big[1 - P_\gamma^{\text{lin}}\,\Sigma(\theta)\cos(2\phi)$$
$$+P_x \cdot \left(-P_\gamma^{\text{lin}}\,H(\theta)\,\sin(2\phi) + P_\gamma^{\text{circ}}\,F(\theta)\right)$$
$$+P_y \cdot \left(+P_\gamma^{\text{lin}}\,P(\theta)\,\cos(2\phi) - T(\theta)\right)$$
$$-P_z \cdot \left(-P_\gamma^{\text{lin}}\,G(\theta)\,\sin(2\phi) + P_\gamma^{\text{circ}}\,E(\theta)\right)\Big]$$

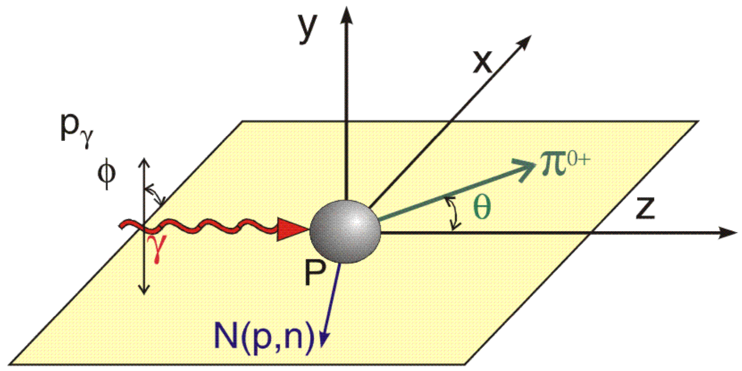
Polarization Observables with long. pol. Target

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

Linearly polarized photons: p_γ^{Lin}

Circularly polarized photons: p_γ^{Cir}

Longitudionally polarized protons: p_z



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

Linearly polarized photons –> beam asymmetry Σ

Circularly polarized photons
Longitud. polarized protons –> double polarization asymmetry *E*

Linearly polarized photons
Longitud. polarized protons –> double polarization asymmetry *G*

Crystal Barrel experiment at ELSA: Preliminary results for *G* and *E* for $p\pi^0$ and $p\eta$

Parallel Session: M. Grüner, J. Müller

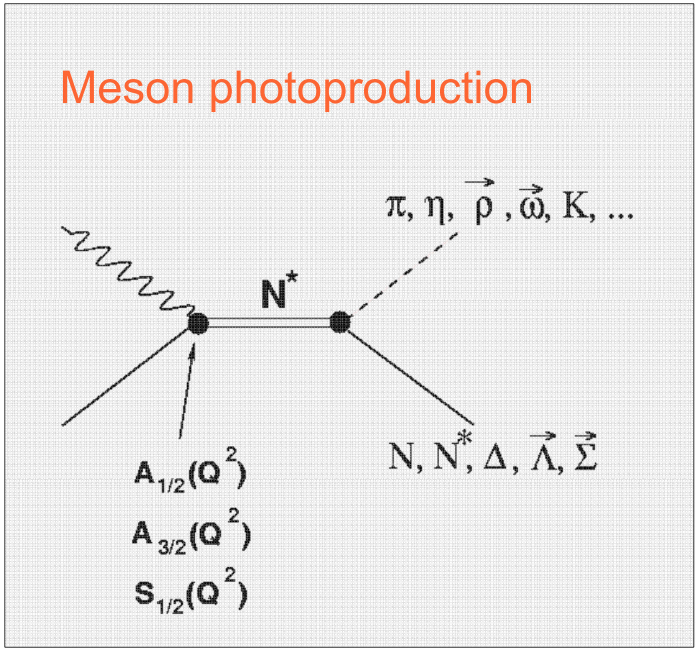
CLAS experiment at JLAB: Preliminary results for *G* and *E* for $n\pi^+$ and $p\eta$

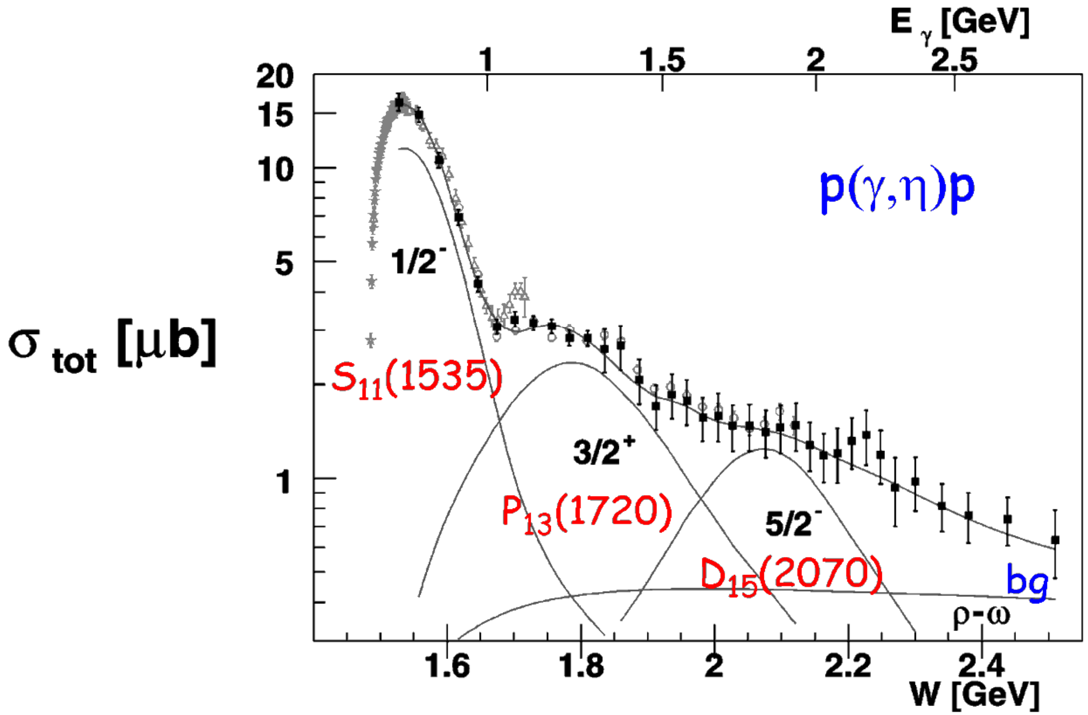
Parallel Session: V. Crede

Results for pη

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

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





Photon helicity couplings: $A_{1/2}$ und $A_{3/2}$

$S_{11}(1535)$: $A_{1/2}(S_{11}(1535))$ only

$D_{13}(1520)$: $A_{1/2}(D_{13}(1520))$ and $A_{3/2}(D_{13}(1520))$

$P_{13}(1720)$: $A_{1/2}(P_{13}(1720))$ and $A_{3/2}(P_{13}(1720))$

Total cross section:

$$\sigma_{tot} \sim |A_{1/2}(S_{11})|^2 + |A_{1/2}(P_{13})|^2 + |A_{3/2}(P_{13})|^2 + \ldots..$$

Results for pη

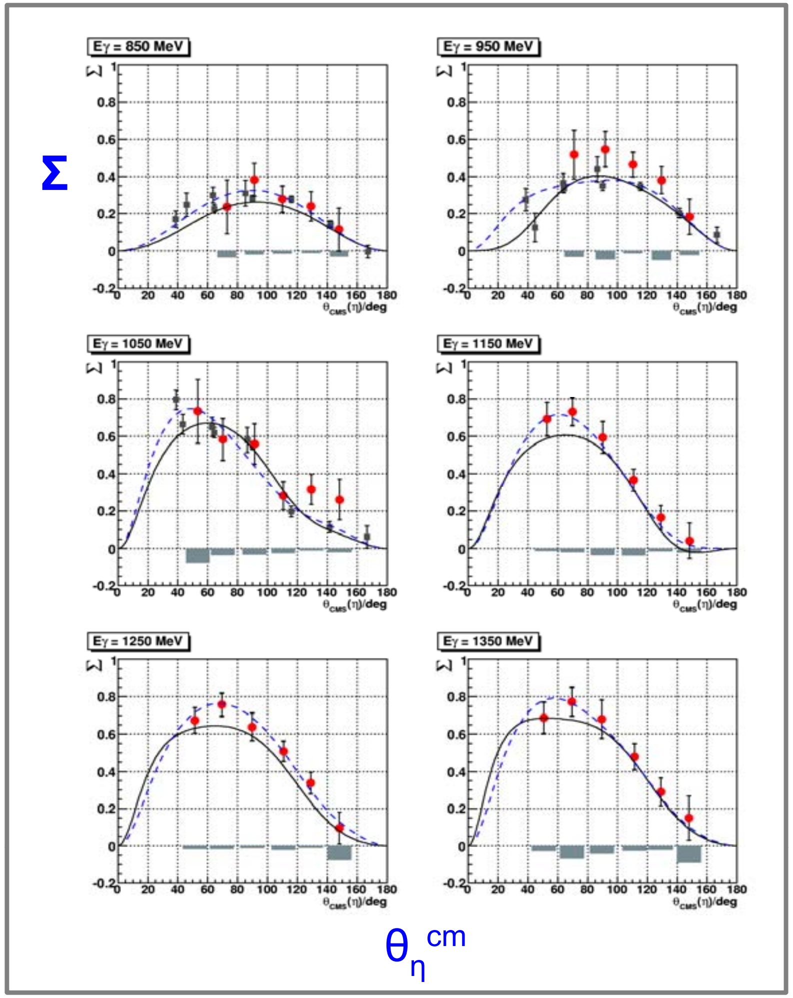
Beam asymmetry: Σ

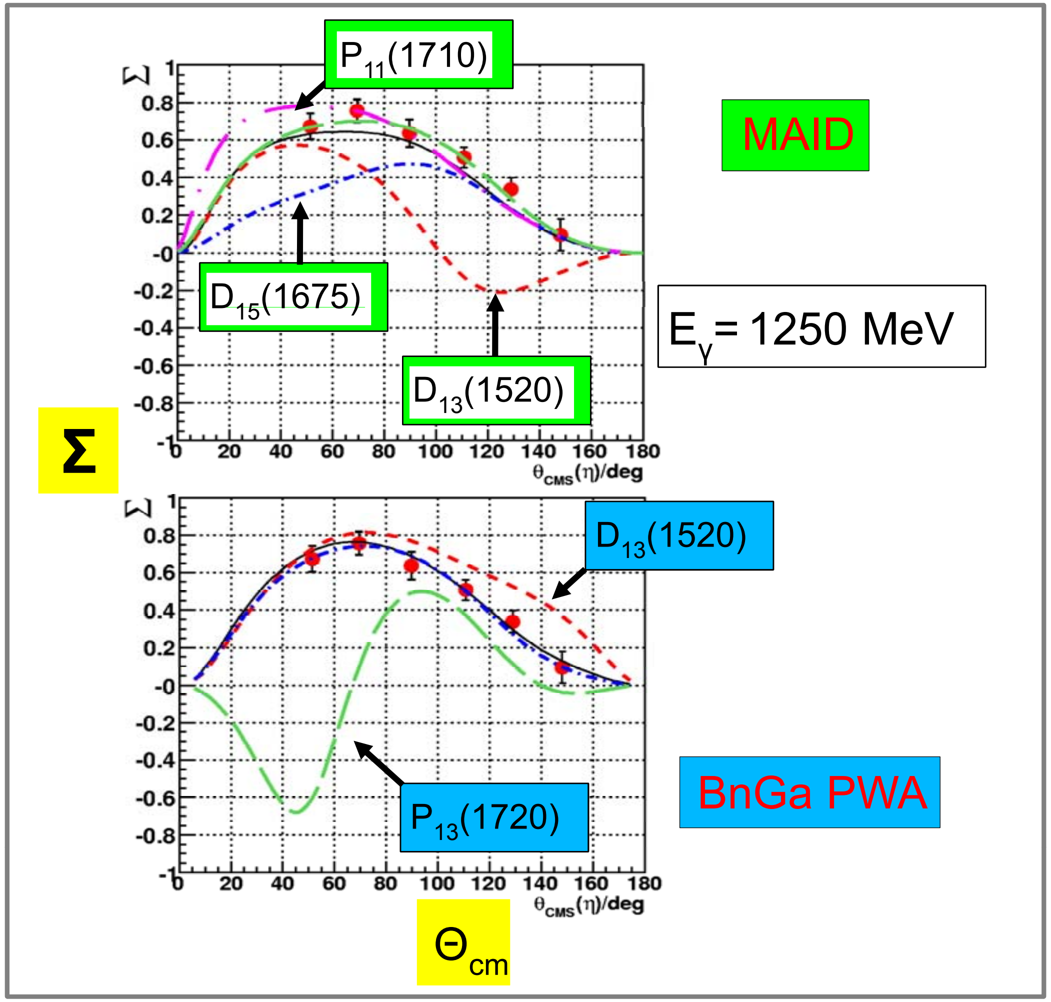
$\vec{\gamma} + p \rightarrow p + \eta$

Higher sensitivity because of interference between different resonance contributions

$\Sigma \sim A_{1/2}(S_{11}) * A_{1/2}(P_{13}) + \ldots$

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



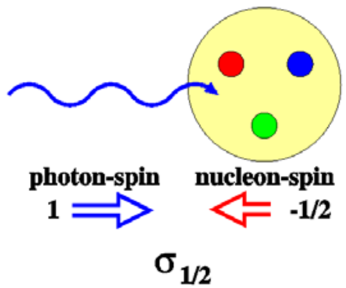


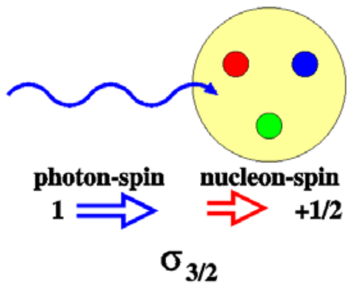
Helicity dependent cross section for pη

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

circularly polarized photons

longitudinally polarized proton

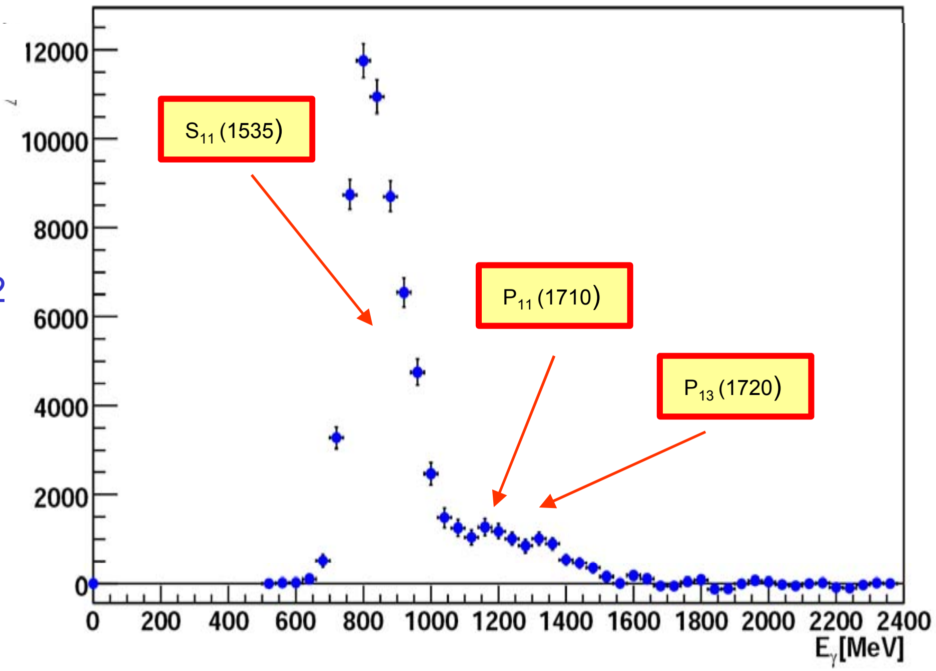


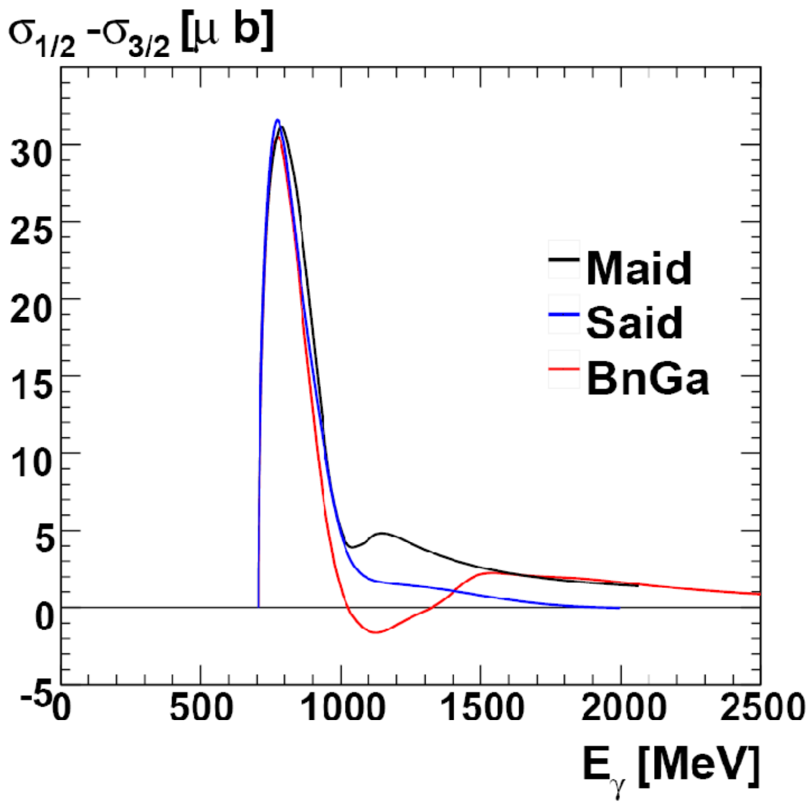


Preliminary results Crystal Barrel at ELSA (J. Müller)

$N_{1/2}$ - $N_{3/2}$

no acceptance correction



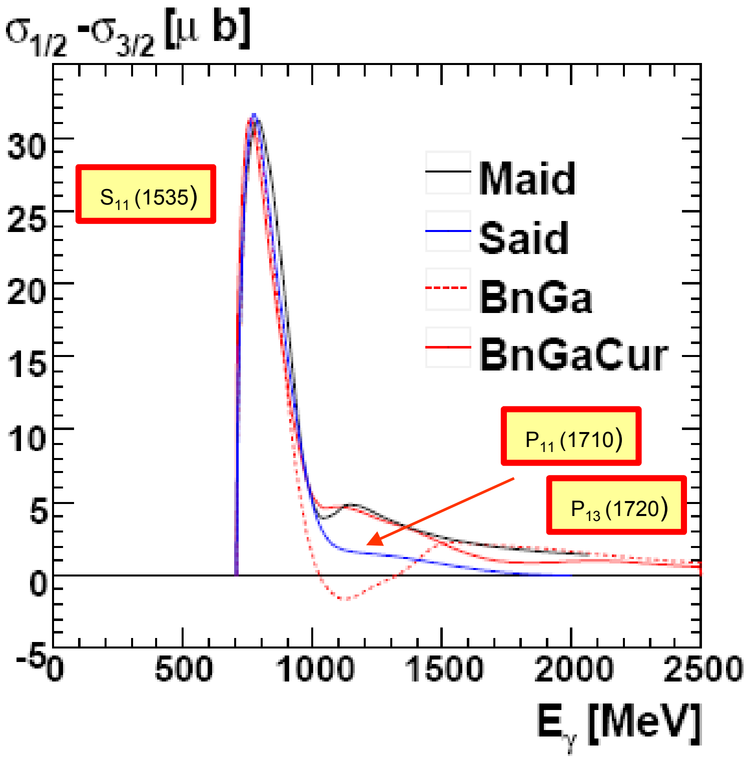


Helicity dependent cross section for pη

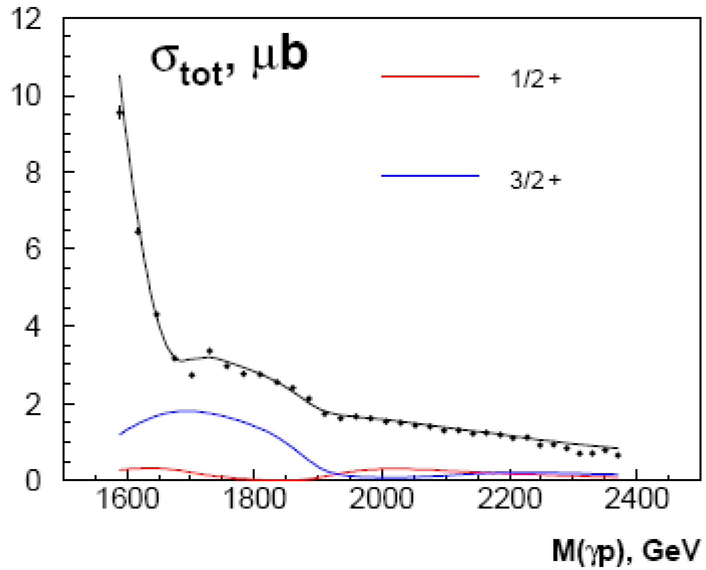
<u>reaction:</u> $\vec{\gamma} + \vec{p} \rightarrow p + \eta$

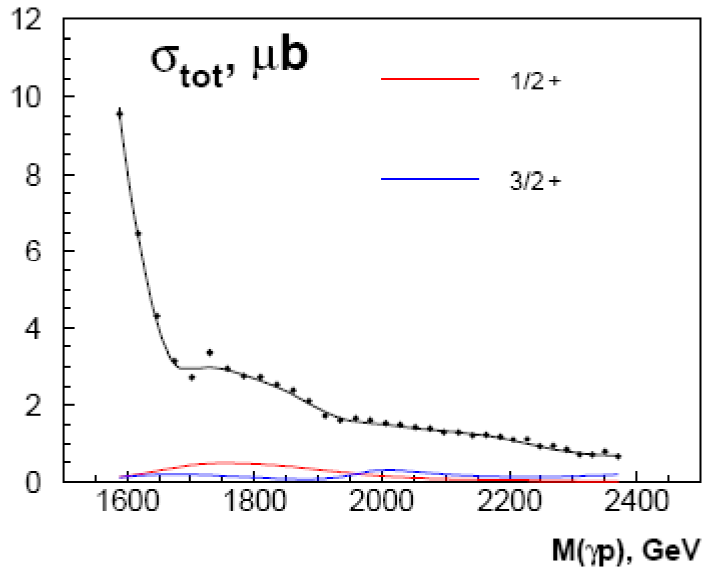
circularly polarized photons

longitudinally polarized proton



$\gamma p \rightarrow \eta p$





Helicity dependent cross section for pη

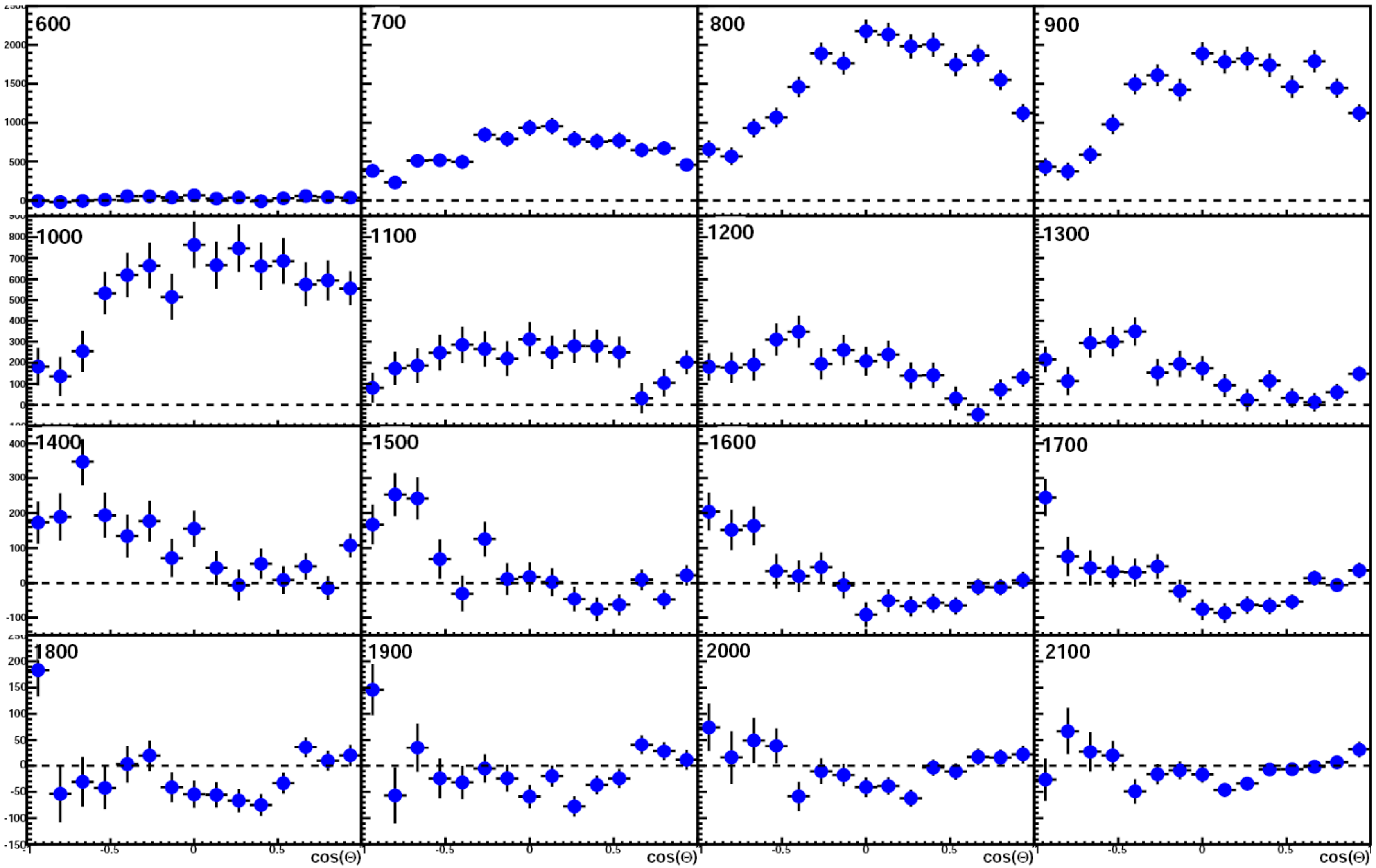
reaction: $\vec{\gamma} + \vec{p} \rightarrow p + \eta$

Angular distribution

Preliminary results Crystal Barrel at ELSA (M. Gottschall, J. Müller)

$N_{1/2} - N_{3/2}$

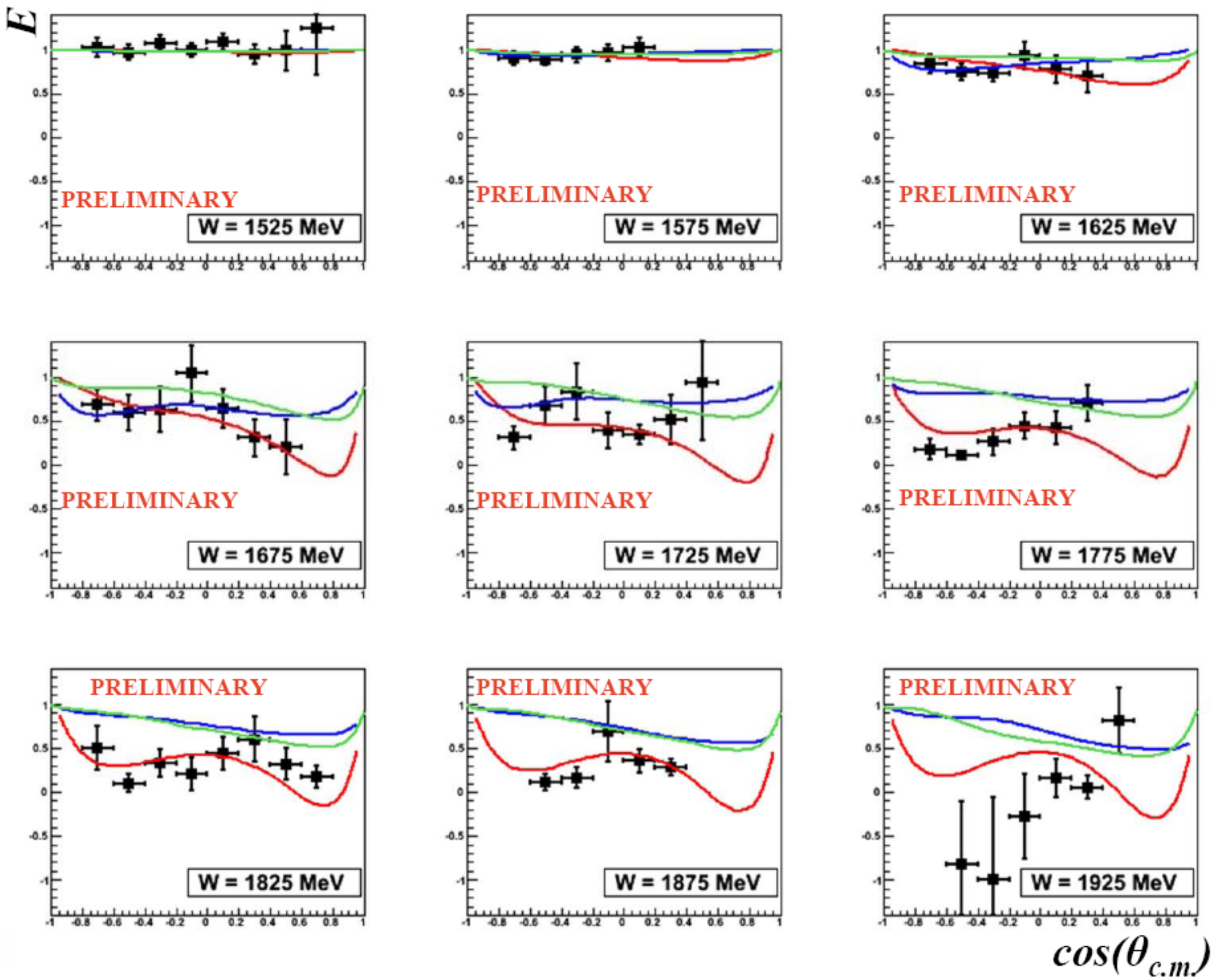
count rate difference
no acceptance correction



Helicity dependent cross section for pη

$$E = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$$

Preliminary results CLAS at JLAB (V. Crede, M. Dugger)



SAID
MAID
Bonn-Gatchina

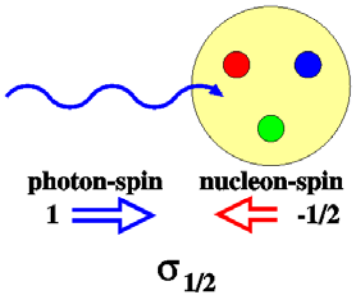
Helicity dependent cross section for $p\pi^0$

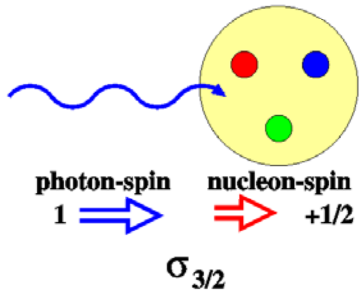
reaction: $\vec{\gamma} + \vec{p} \rightarrow p + \pi^0$

circularly polarized photons

longitudinally polarized proton

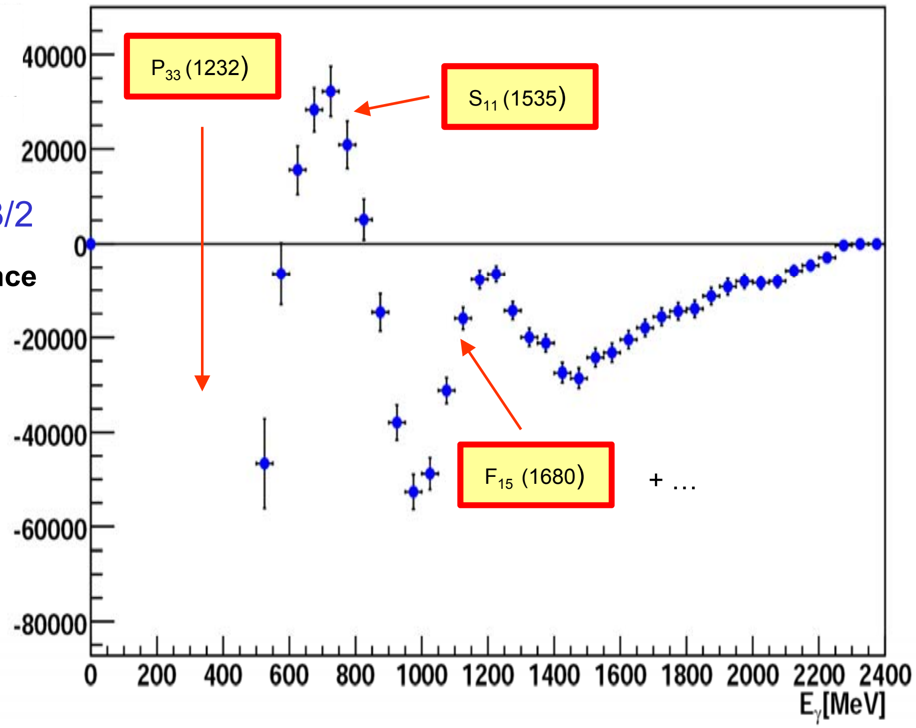
count rate difference
acceptance correction

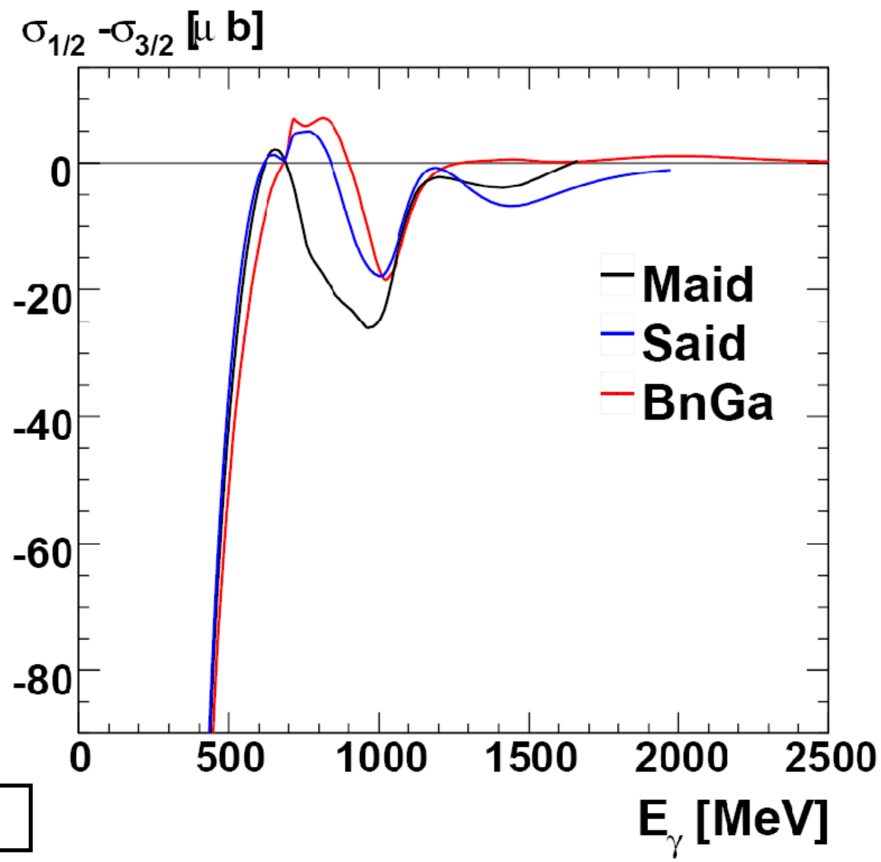




$N_{1/2} - N_{3/2}$

with acceptance correction





Preliminary results Crystal Barrel at ELSA (M. Gottschall, J. Müller)

Helicity dependent cross section for $p\pi^0$

reaction: $\vec{\gamma} + \vec{p} \rightarrow p + \pi^0$ Angular distributions sensitive to interference between resonances

Preliminary results Crystal Barrel at ELSA (M. Gottschall, J. Müller)

$$E \sim \frac{N_{1/2} - N_{3/2}}{N_{1/2} + N_{3/2}}$$

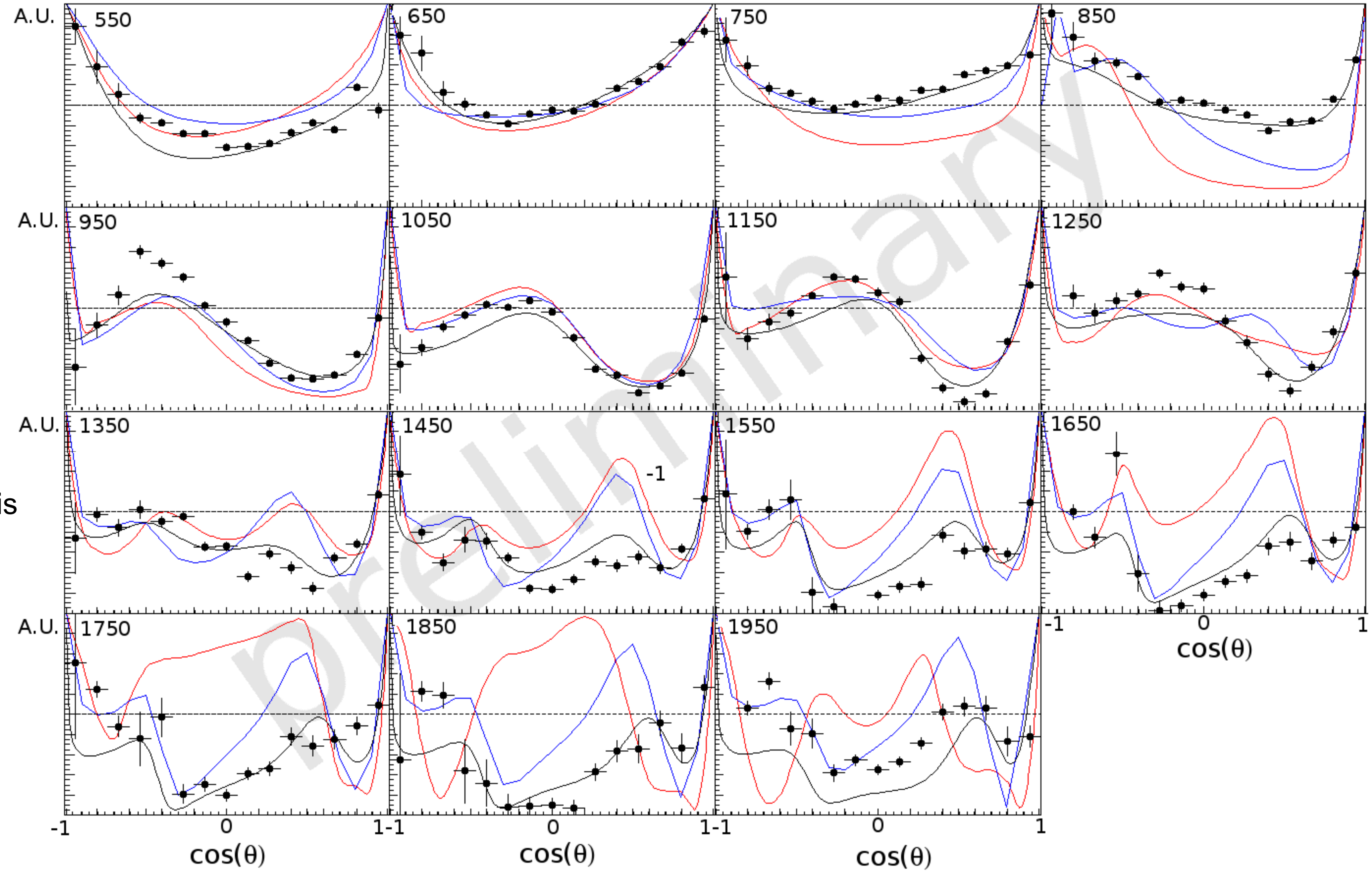
with acceptance correction

prediction
partial wave analysis

MAID

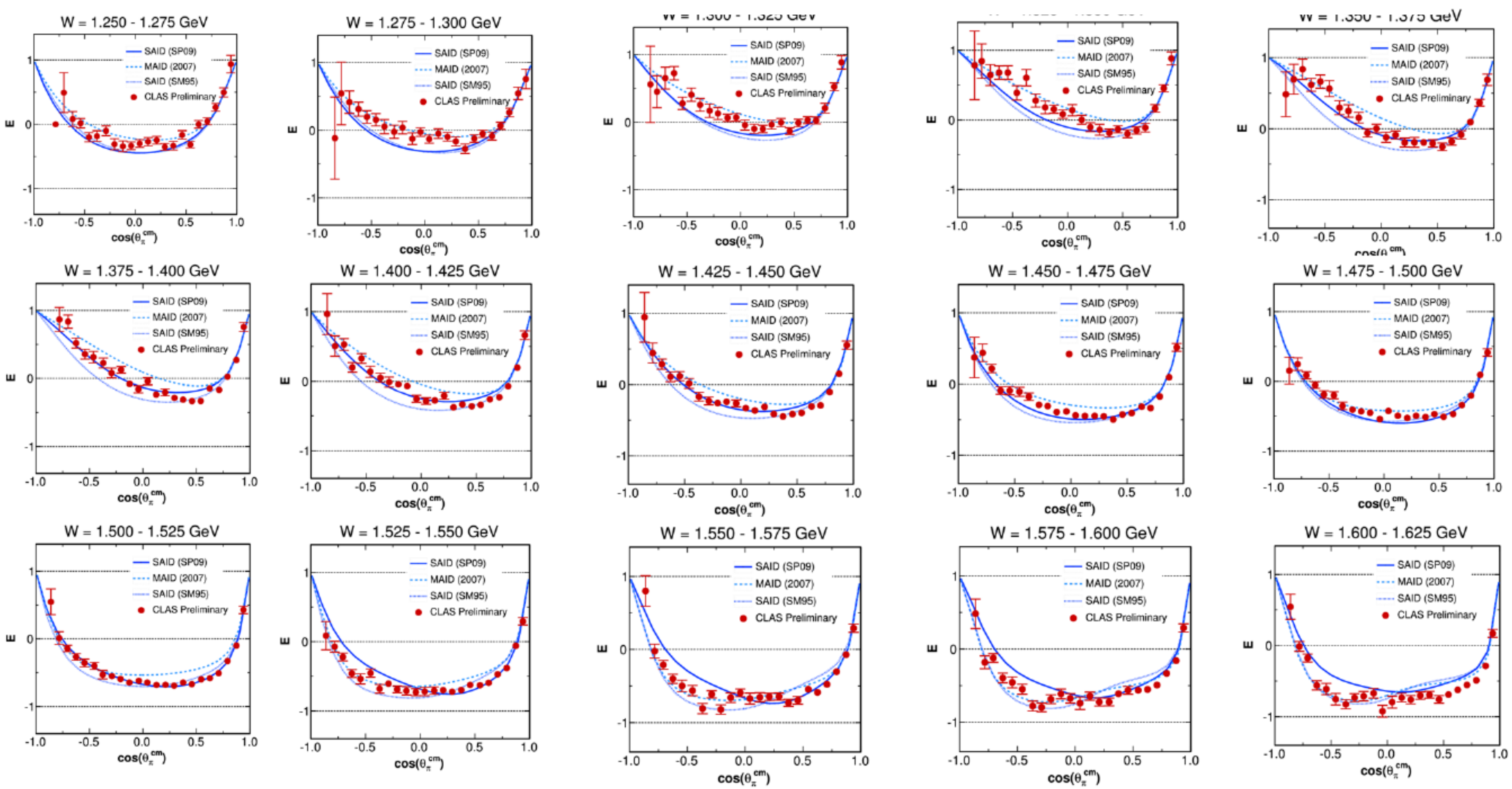
SAID

BoGa



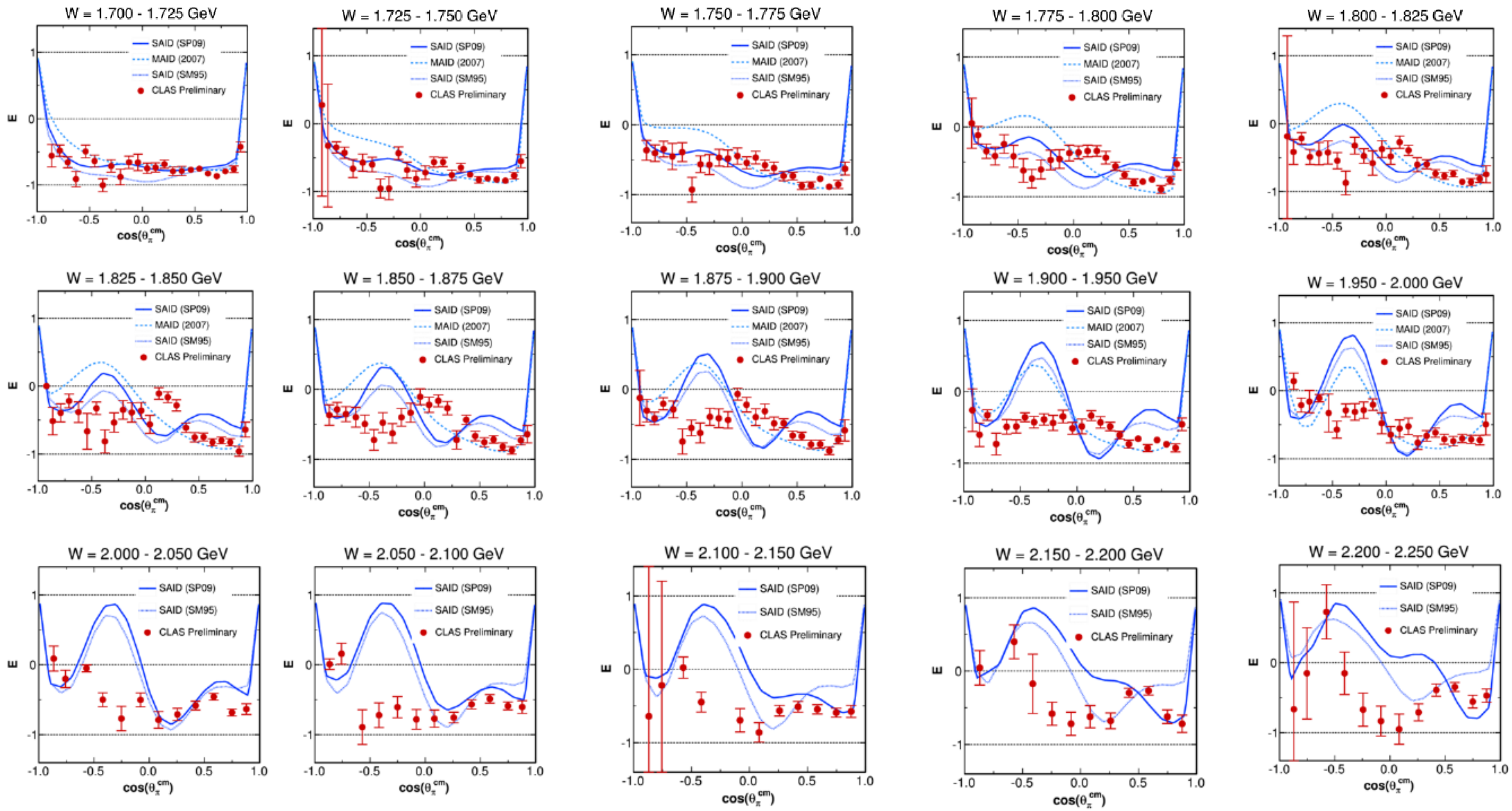
Double Polarization observable E for $n\pi^+$

Preliminary results CLAS at JLAB (V. Crede, M. Dugger)



Double Polarization observable E for $n\pi^+$

Preliminary results CLAS at JLAB (V. Crede, M. Dugger)



Σ– and G- Asymmetry for pη

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

linearly polarized photons

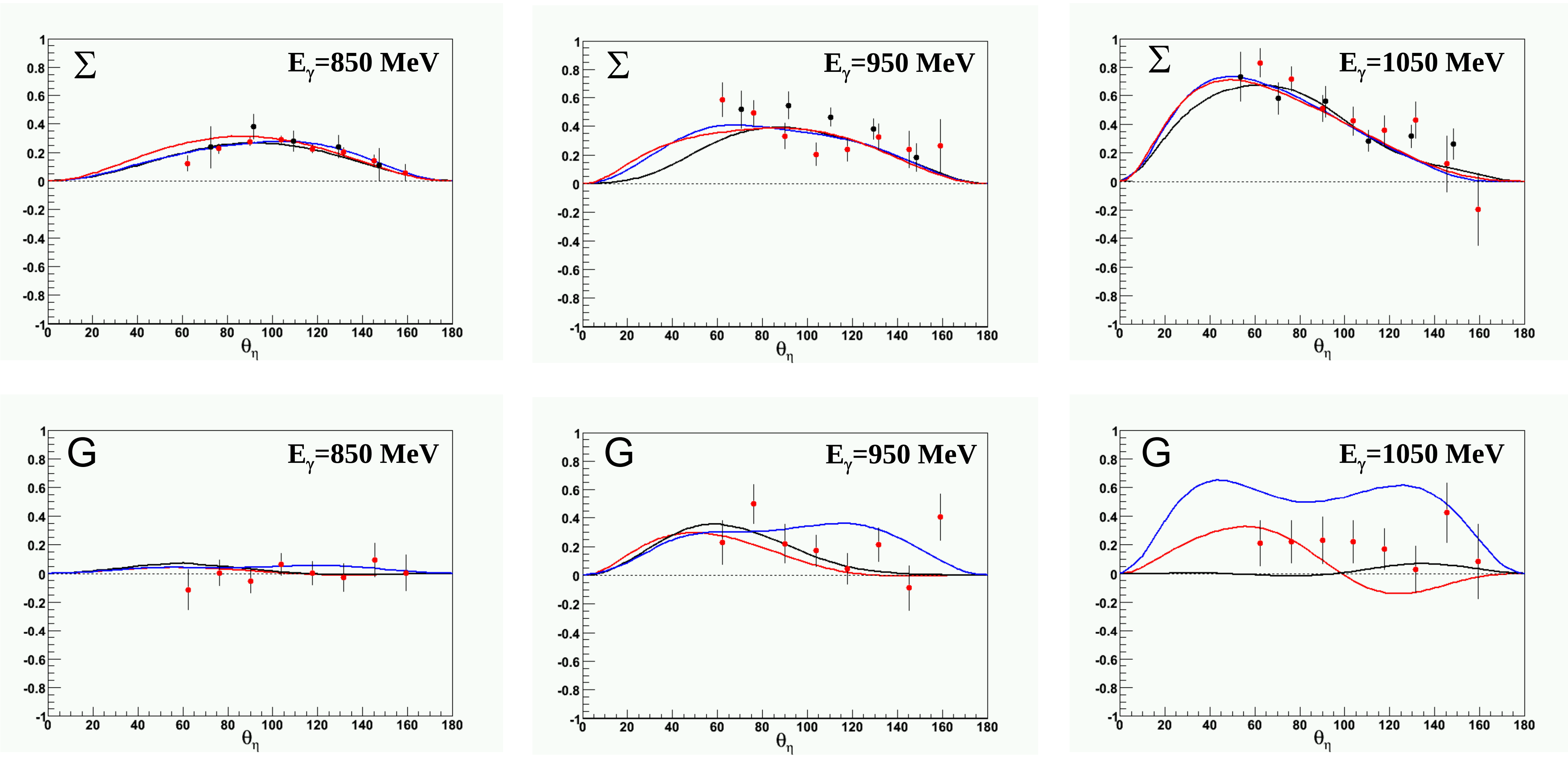
longitudinally polarized proton

__ BoGa

__ SAID

__ MAID

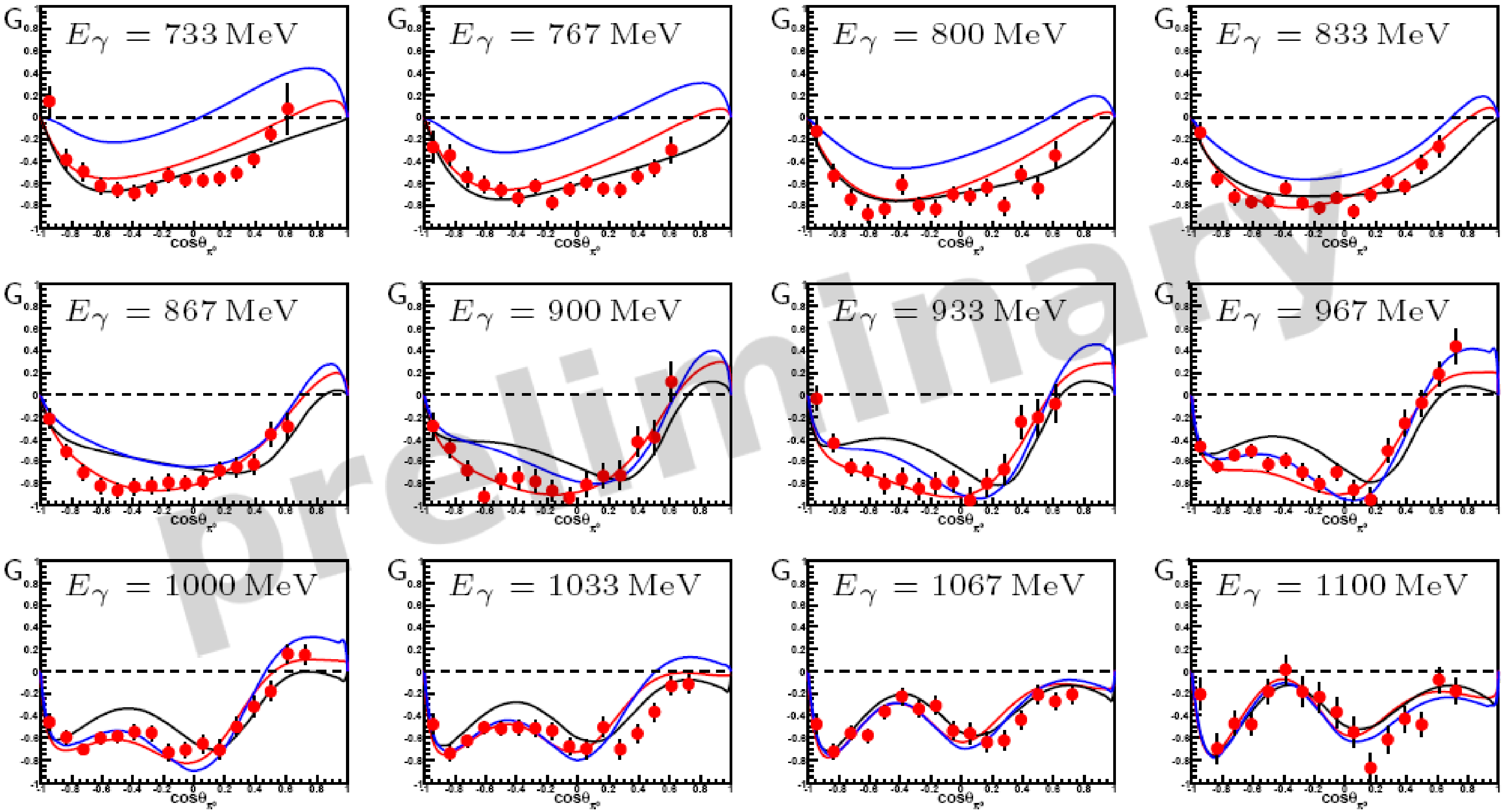
Preliminary results Crystal Barrel at ELSA (A. Thiel, M. Grüner)



G- Asymmetry for $p\pi^0$

linearly polarized beam, longitudinally polarized target:

$$\frac{d\sigma}{d\Omega}(\phi) = \frac{d\sigma}{d\Omega}_0 \cdot \left(1 - P_\gamma^{\text{lin}}\, \Sigma \cos(2\phi) + P_\gamma^{\text{lin}} P_z\, G \sin(2\phi)\right)$$



$\vec{\gamma}\vec{p} \to p\pi^0$ — Maid — Said — BnGa

A. Thiel (Bonn)

Polarization Observables with trans. pol. Target

photon pol.		target pol. axis x	y	z
unpolarized	σ		T	
linear	$-\Sigma$	H	$-P$	$-G$
circular		F		$-E$

Circularly polarized photons
Transversely polarized protons –> double polarization asymmetry *F*

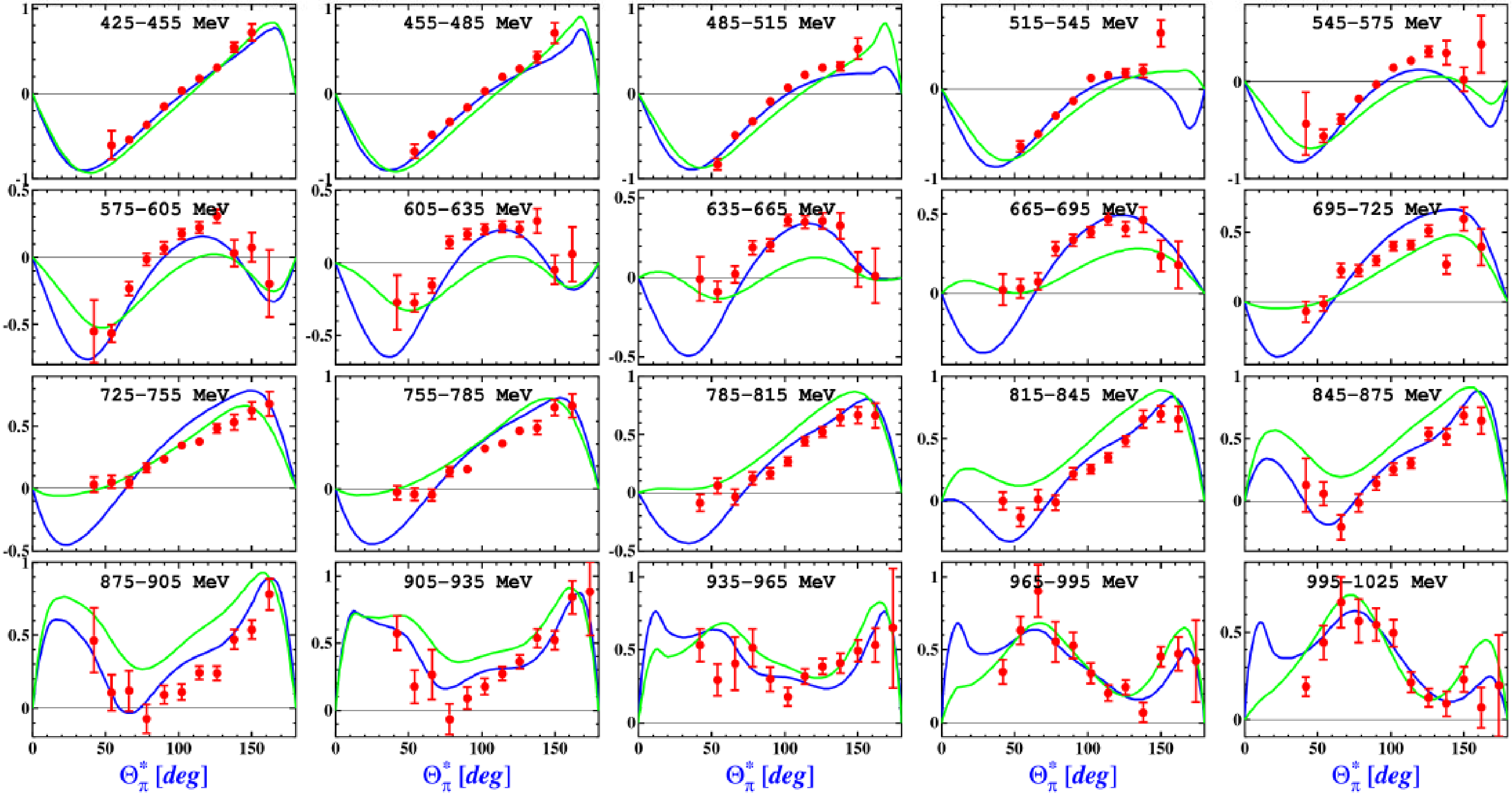
Linearly polarized photons
Transversely polarized protons –> double polarization asymmetry *H* and *P*

–> in addition Beam asymmetry Σ and
Target asymmetry *T*

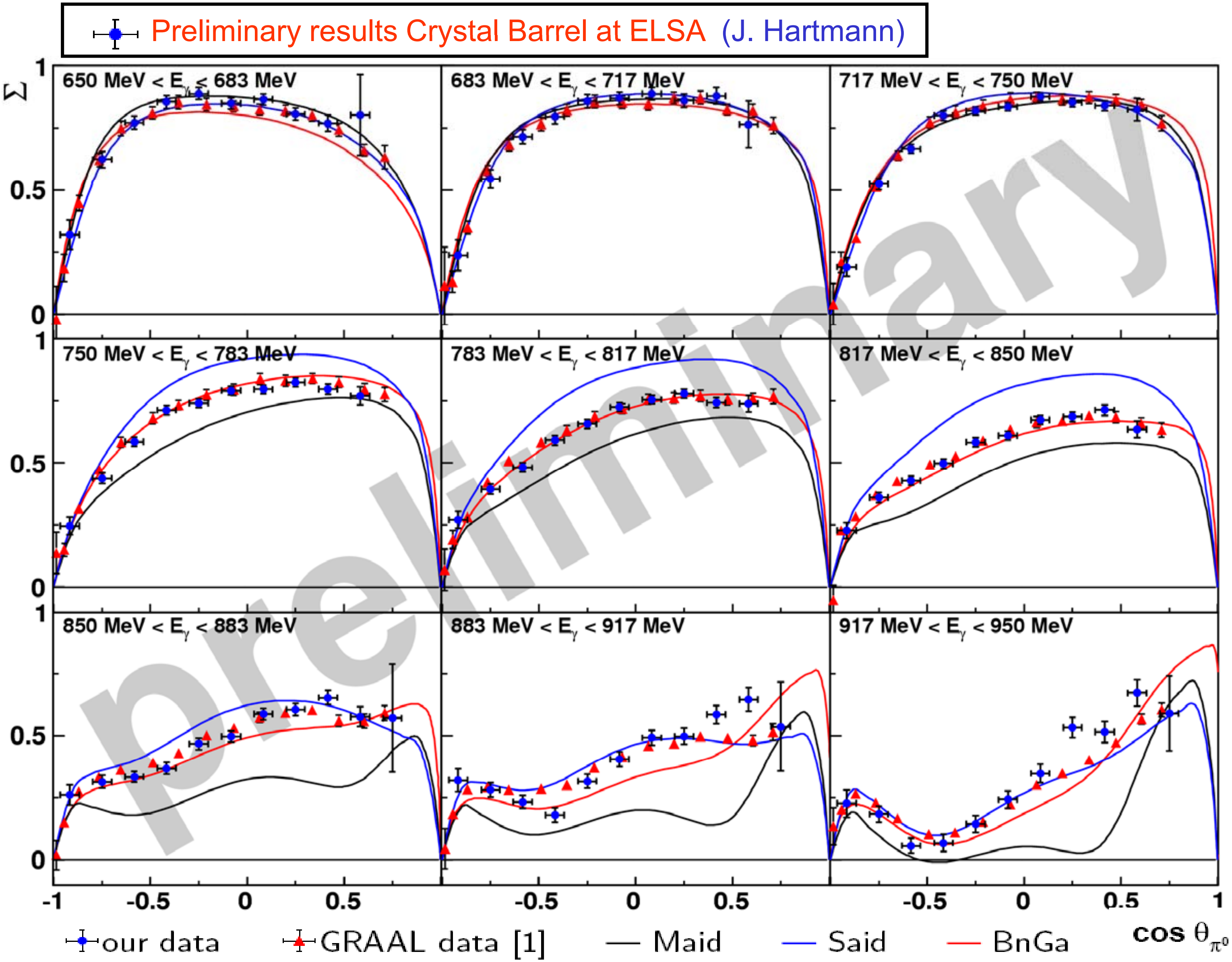
Double Polarization Asymmetry F for $p\pi^0$

Preliminary results Crystal Ball at MAMI (H.J. Arends, M. Ostrick)

blue line – MAID-2007
green line – SAID



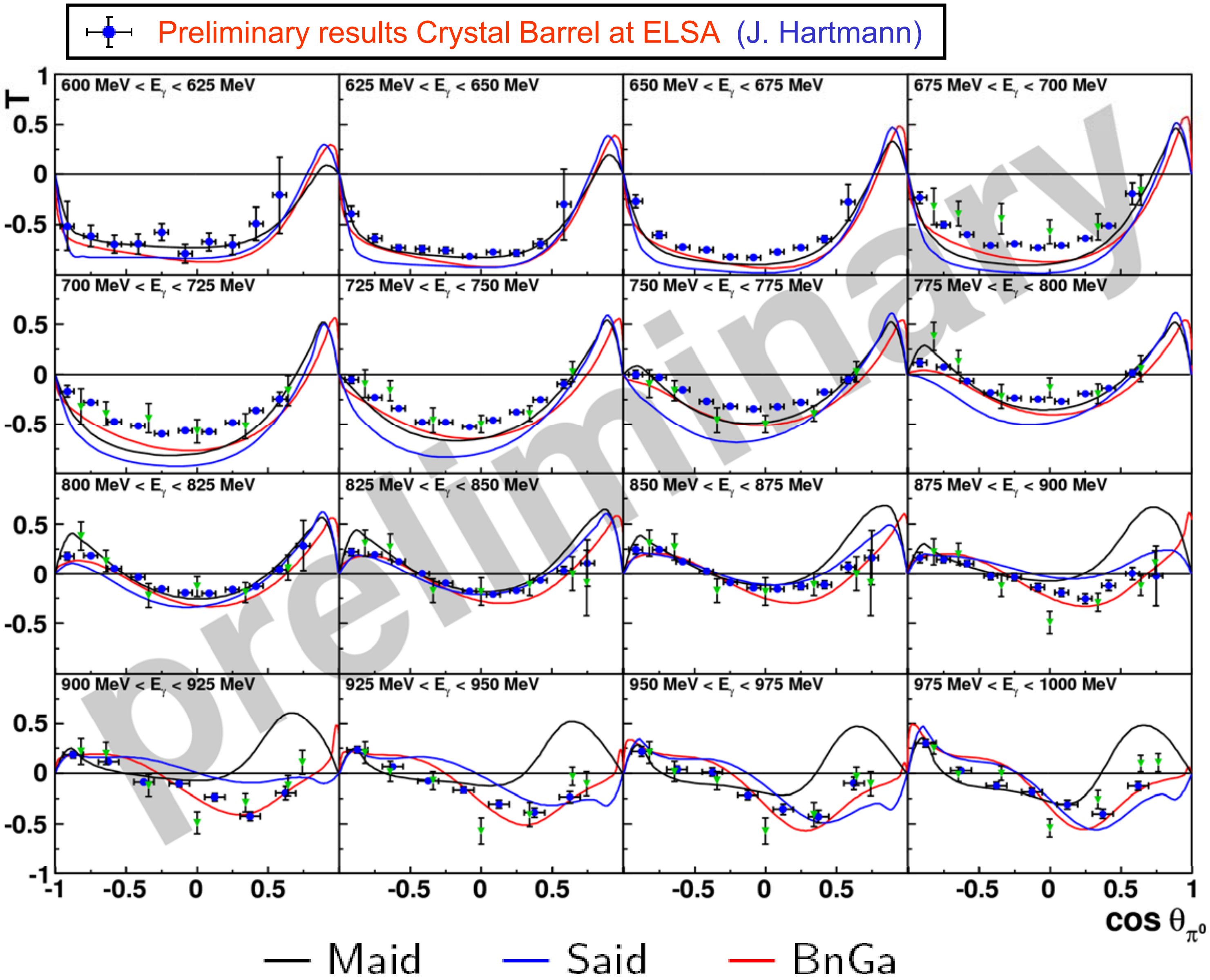
Beam Asymmetry Σ for $p\pi^0$



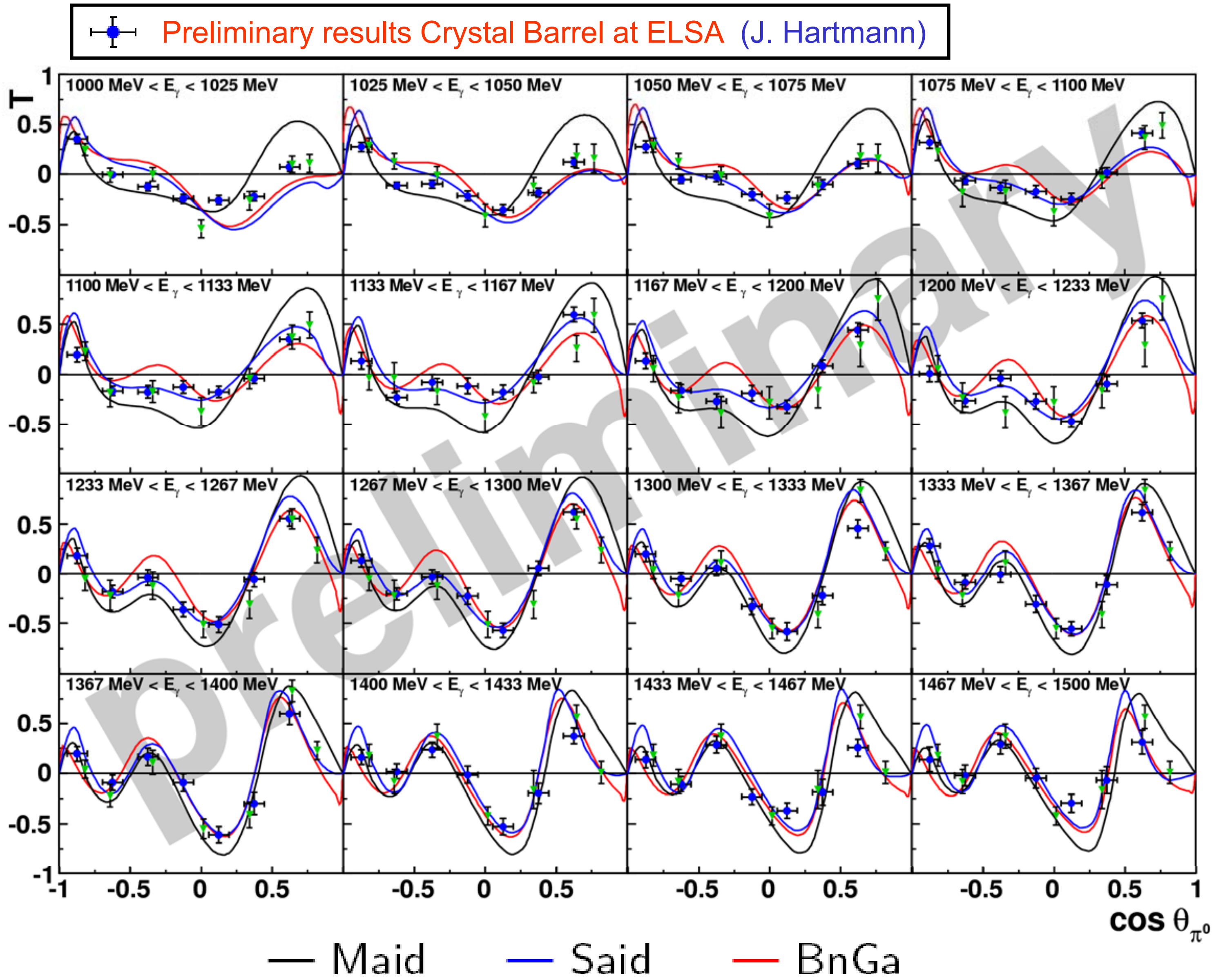
Note: target material butanol ⇝ also small contribution from C

[1] O. Bartalini *et al*, Eur. Phys. J. A 26, 399-419 (2005)

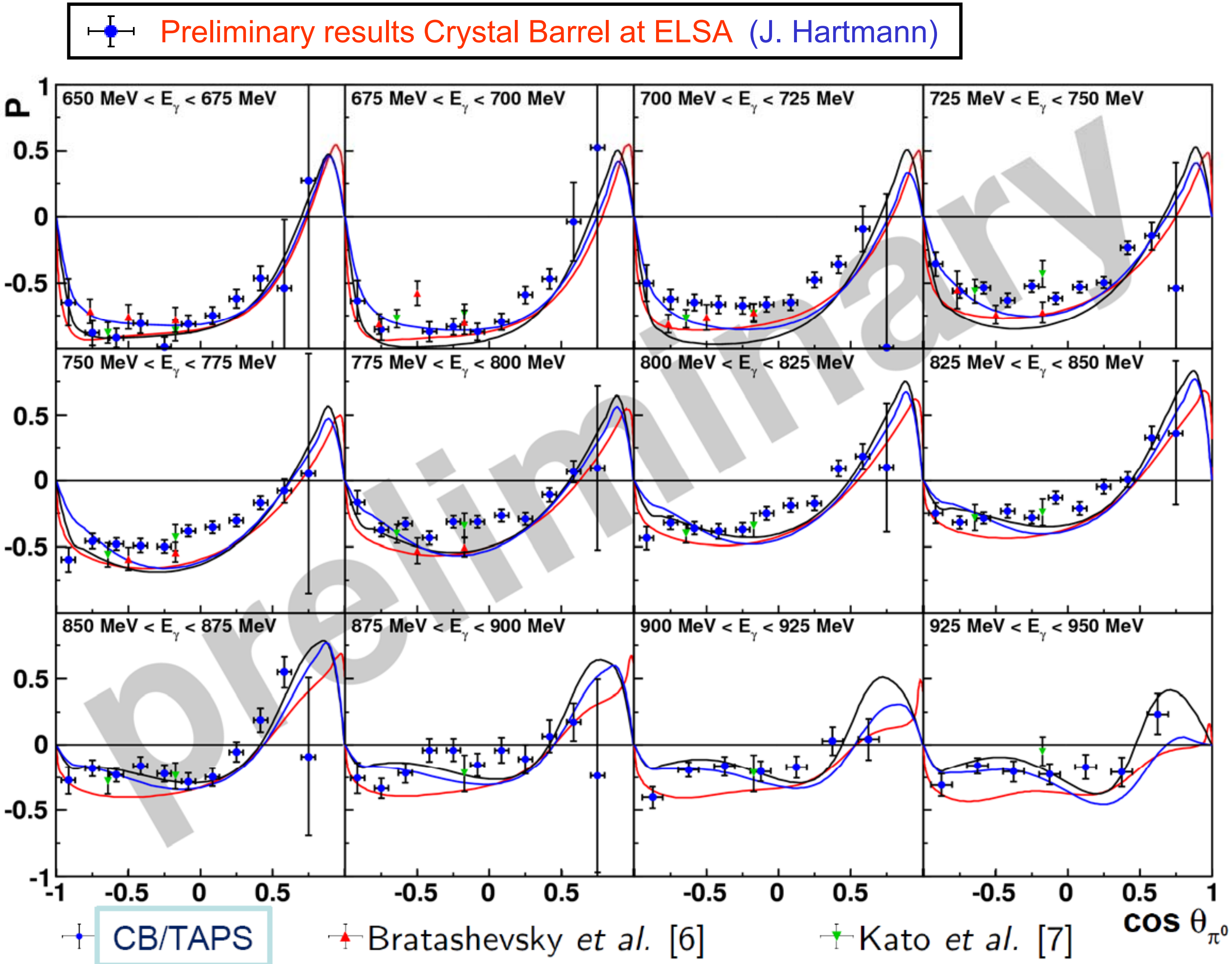
Target Asymmetry T for $p\pi^0$



Target Asymmetry T for $p\pi^0$



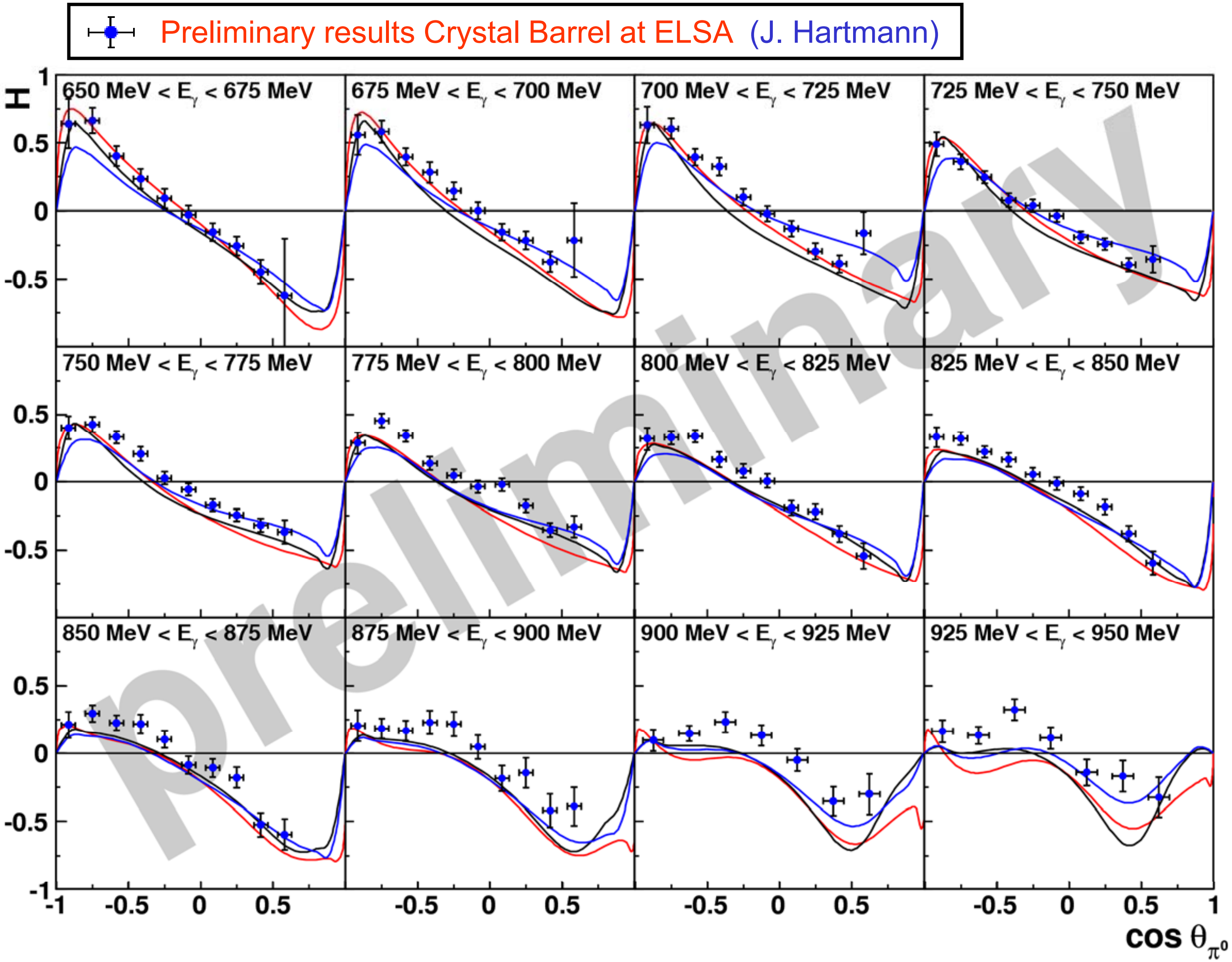
Recoil Polarization P for $p\pi^0$



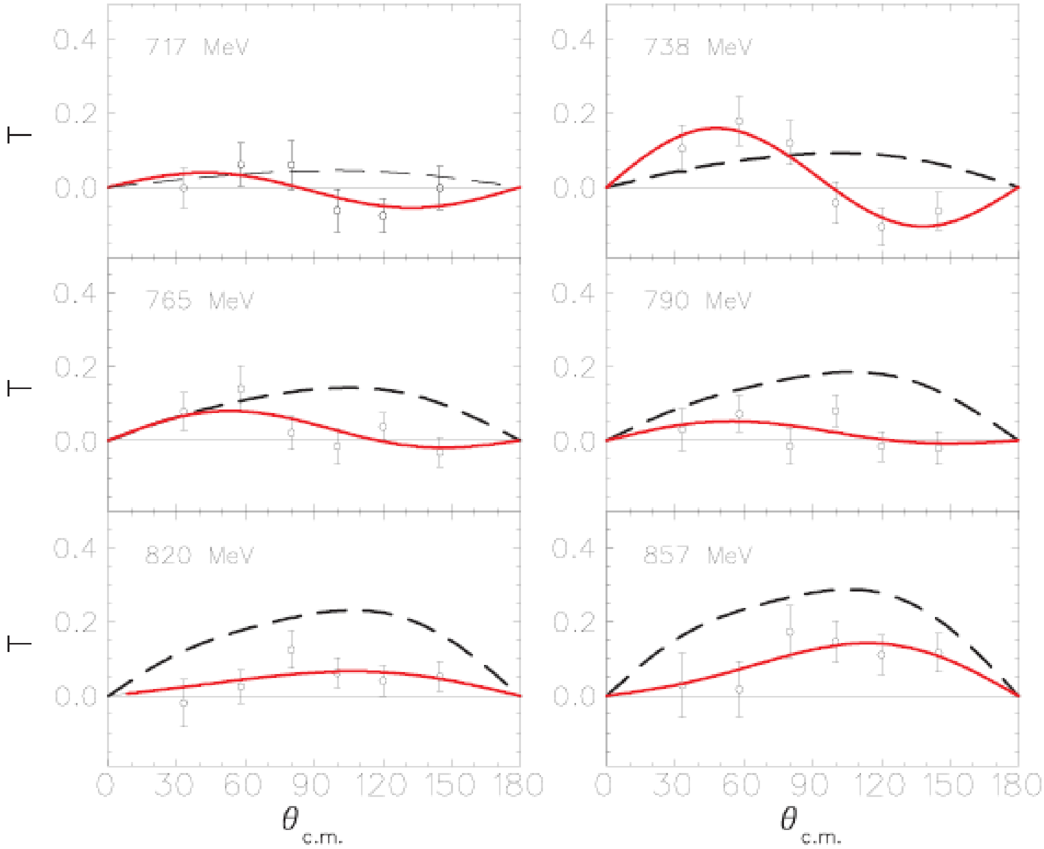
[6] A.S. Bratashevsky *et al.*, Nucl. Phys. **B166** (1980)

[7] S. Kato *et al.*, Nucl. Phys. **B168** (1980)

Double Polarization Asymmetry H for $p\pi^0$

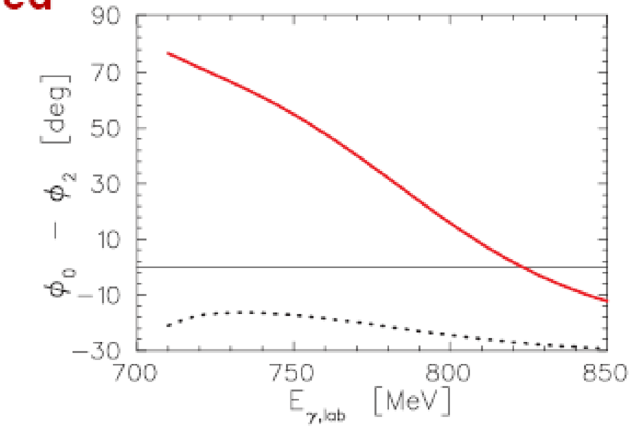


Target Asymmetry in pη



— Tiator et al.:
Model independent fit, assuming S-wave multipoles and their interference with p- and d-waves sufficient ($E_\gamma \leq$900 MeV)

$\Rightarrow$ Energy dependent phase between S_{11}(1535) and D_{13}(1530) needed



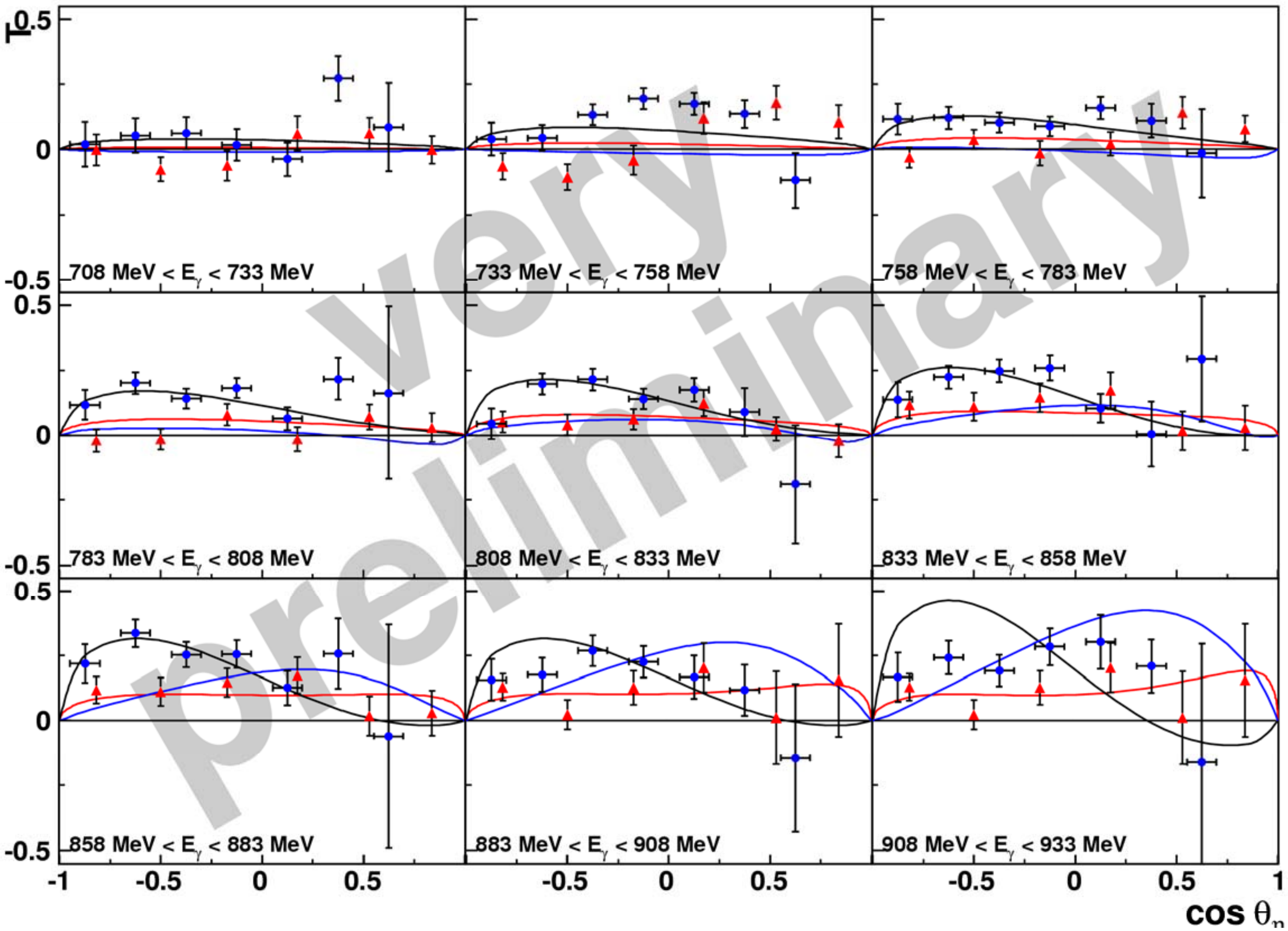
$\Rightarrow$ Energy dependent phase $\leftrightarrow$ origin presently not understood

- nature of the S_{11}(1535) ?
- interpretation of the data ?

$\Rightarrow$ Cross check and improve the precision of the existing data !

Target Asymmetry T for pη

Preliminary results Crystal Barrel at ELSA (J. Hartmann)

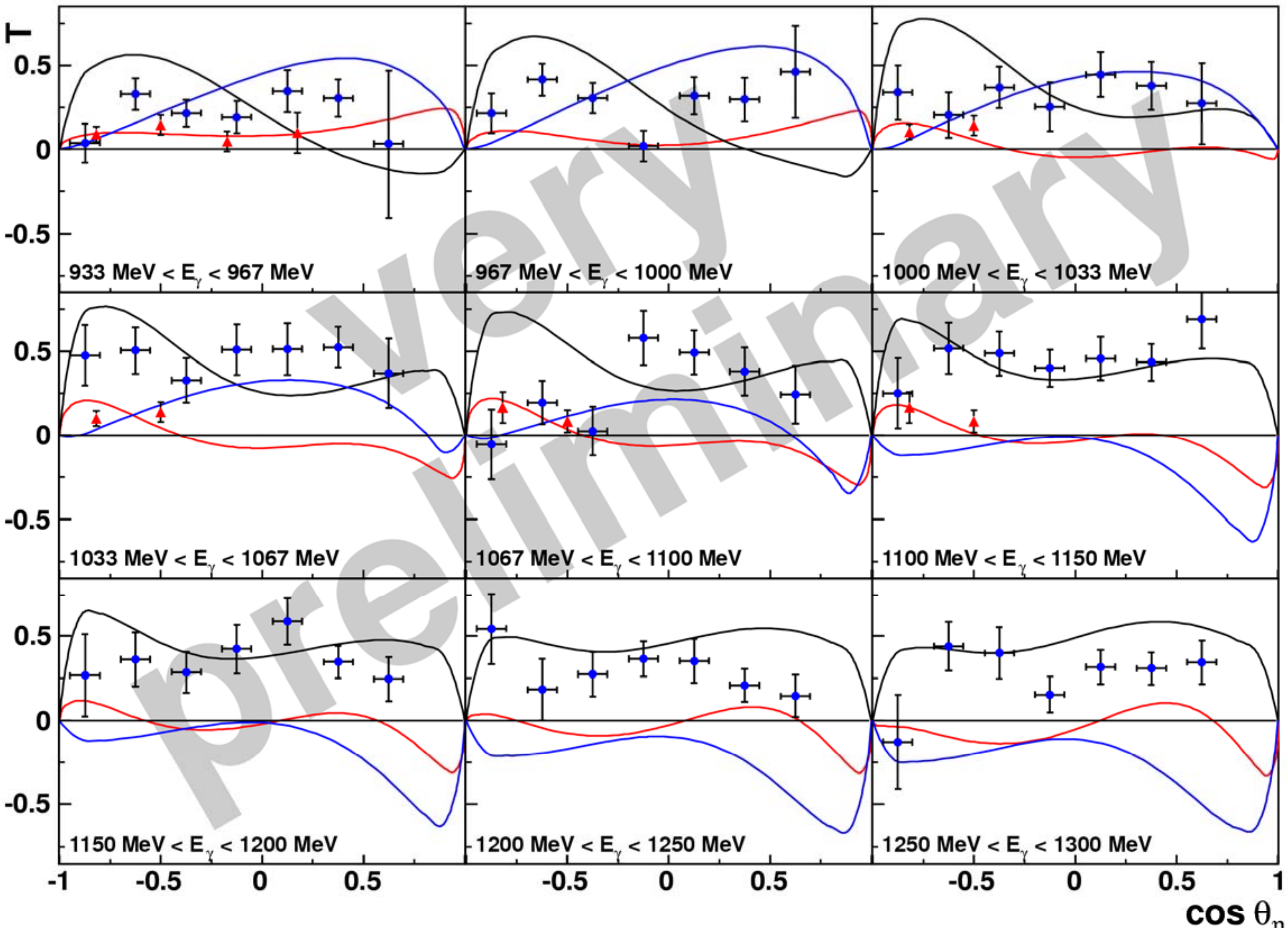


CB/TAPS PHOENICS data [5] — Maid — Said — BnGa

Note: preliminary dilution factor

[5] A. Bock *et al.*, Phys. Rev. Lett **81** (1998) 534

Target Asymmetry T for pη



CB/TAPS PHOENICS data [5] Maid Said BnGa

Note: preliminary dilution factor

[5] A. Bock *et al.*, Phys. Rev. Lett **81** (1998) 534

Status on Meson Photoproduction

Crystal Barrel at ELSA

CLAS at JLAB

Crystal Ball at MAMI

	σ	Σ	T	P	E	F	G	H	T_x	T_z	L_x	L_z	O_x	O_z	C_x	C_z
Proton target																
$p\pi^0$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{gray}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$								
$n\pi^+$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{gray}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$								
$p\eta$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{gray}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$								
$p\eta'$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{gray}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$								
$p\omega$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{gray}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$								
$K^+\Lambda$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{red}{\checkmark}$	$\color{red}{\checkmark}$
$K^+\Sigma^0$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{red}{\checkmark}$	$\color{red}{\checkmark}$
$K^{0*}\Sigma^+$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$									$\color{green}{\checkmark}$	$\color{green}{\checkmark}$				
Neutron target																
$p\pi^-$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{blue}{\checkmark}$		$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$								
$p\rho^-$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{blue}{\checkmark}$		$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$								
$K^-\Sigma^+$	$\color{red}{\checkmark}$	$\color{green}{\checkmark}$	$\color{blue}{\checkmark}$		$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$								
$K^0\Lambda$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$
$K^0\Sigma^0$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$	$\color{blue}{\checkmark}$
$K^{0*}\Sigma^0$	$\color{green}{\checkmark}$	$\color{green}{\checkmark}$														

$\color{red}{\checkmark}$ - published, $\color{green}{\checkmark}$ - acquired, $\color{blue}{\checkmark}$ - planned

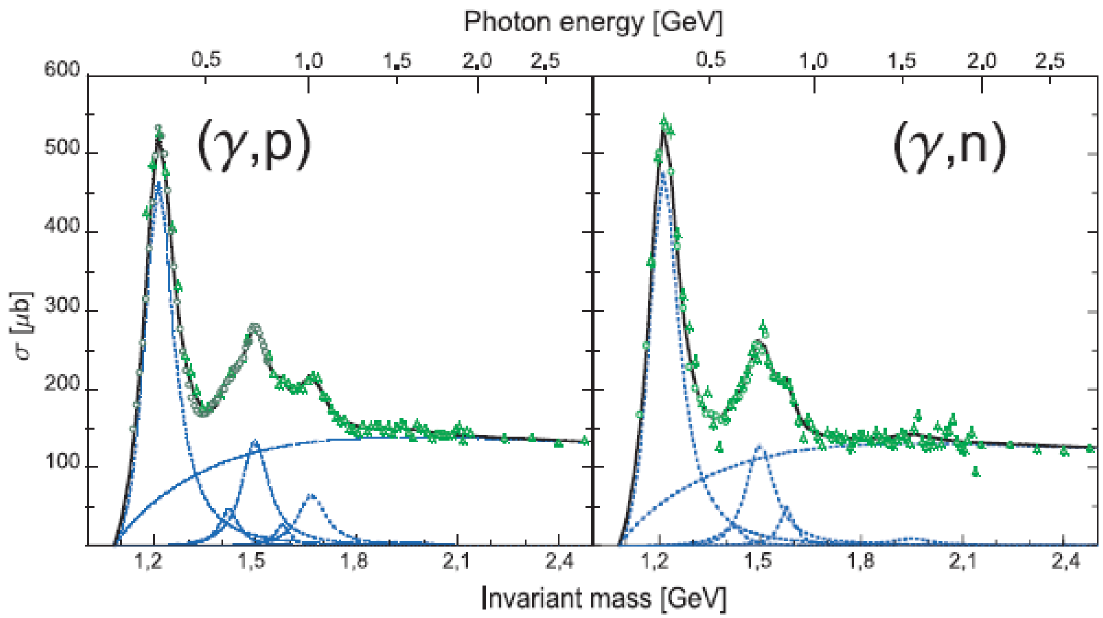
Nearly complete data base

Complete data base

Only a few experiments

Electromagnetic excitation off the neutron

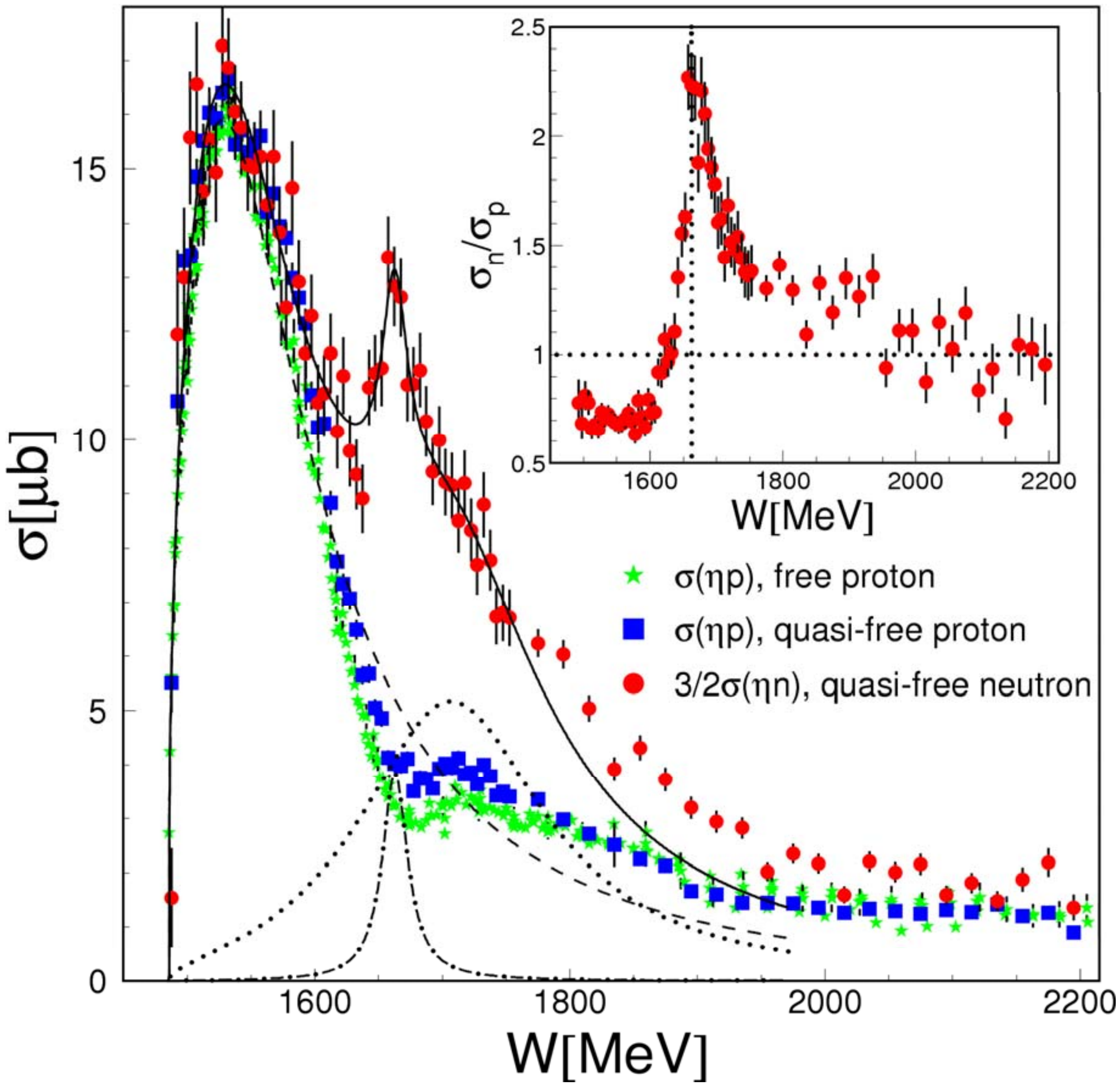
- **importance of measurements off the neutron:**
  - different resonance contributions
  - needed for extraction of iso-spin composition of elm. couplings



- **complications due to use of nuclear targets (deuteron):**
  - Fermi motion
  - nuclear effects like FSI, re-scattering, coherent contributions

Electromagnetic excitation off the neutron

Crystal Barrel at ELSA result



quasifree η photoproduction:

$$\gamma + d \rightarrow n + p + \eta$$

Narrow structure in nη - final state

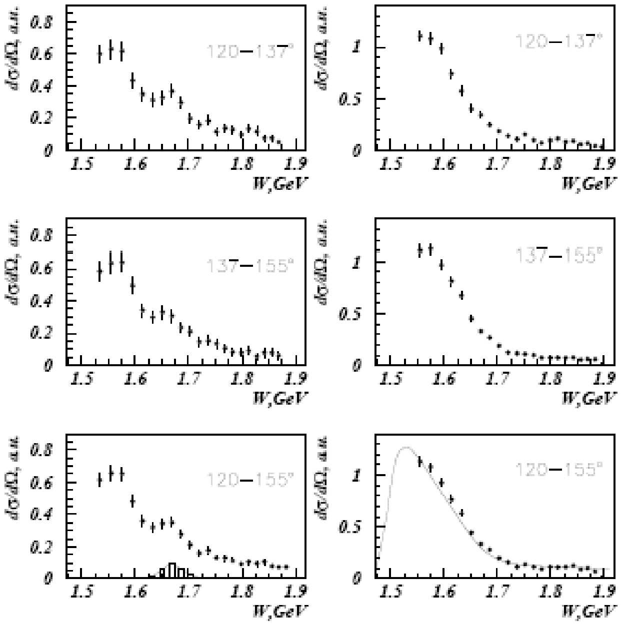
$$W \approx 1670 MeV$$

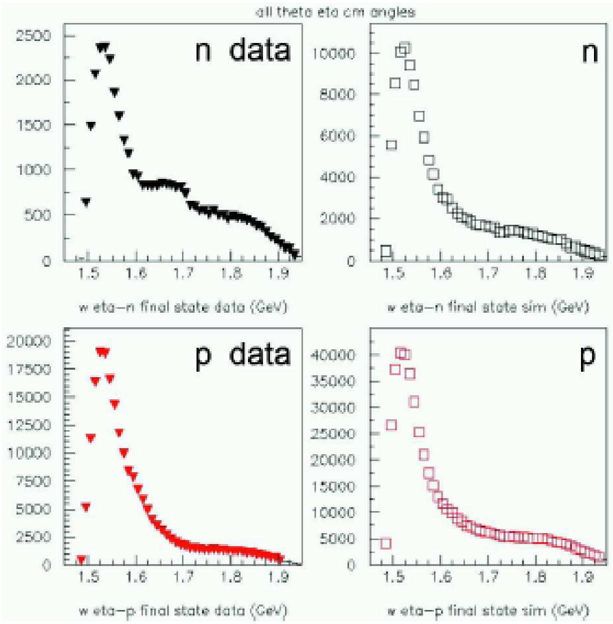
$$\sigma \approx 25 MeW \ (FWHM)$$

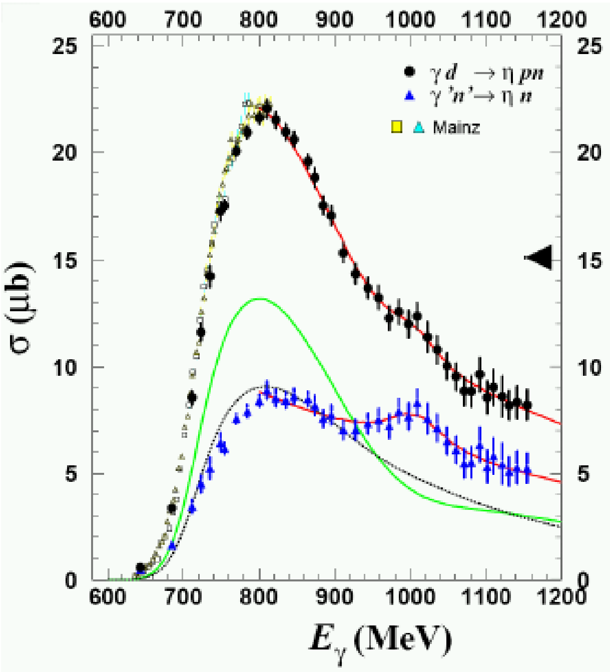
Publication:
I. Jaegle, B. Krusche, …
accepted by EPJA

Experimental evidence from other Labs

- GRAAL (Kuznetsov 04)
- GRAAL (Schaerf 09)
- Sendai 07







Comparison Narrow Structure

- narrow structure in excitation function of $\gamma n \rightarrow n\eta$:

- GRAAL: $W \approx$ 1680 MeV, $\Gamma <$30 MeV
- Tohoku-LNS: $W \approx$ 1666 MeV, $\Gamma <$40 MeV
- ELSA: $W \approx$ 1685 MeV, $\Gamma <$60 MeV
- MAMI-C: $W \approx$ 1675 MeV, $\Gamma <$40 MeV

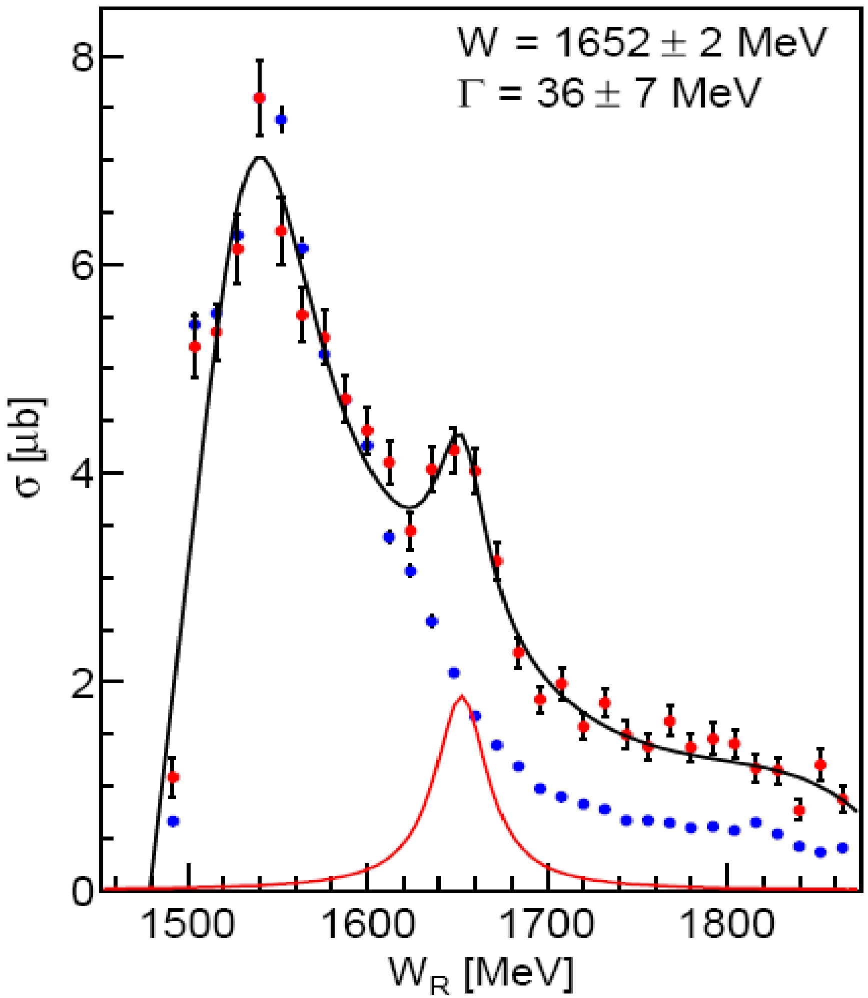
Parallel session on monday
M. Polyakov

- Effect of photo-excitation of D15(1675) ?
- Coupled channel effect of S11(1535) and P11(1710) ?
- Interference effect of S11(1535) and S11(1650) ?
- New narrow state with stronger photo-coupling to the neutron ?

  –> polarization observables needed !!

Narrow structure in other reaction channels

Preliminary results Crystal Ball at MAMI



$\gamma\ ^3He \rightarrow \eta p\ (np)$

$\gamma\ ^3He \rightarrow \eta n\ (pp)$

nucleons via TOF
in TAPS only,

η at backward angles

Parallel session on monday
L. Witthauer

Summary

- First round of double polarization experiments
  at ELSA, JLAB and MAMI

- Preliminary results for the polarization observable
  T, P,G,E,F and H

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

- Model independent partial wave analysis
  polarization observables are essential
  different final states are essential

- Will shed new light on the nucleon excitation spectrum

Σ and G-Asymmetry for $p\pi^0$

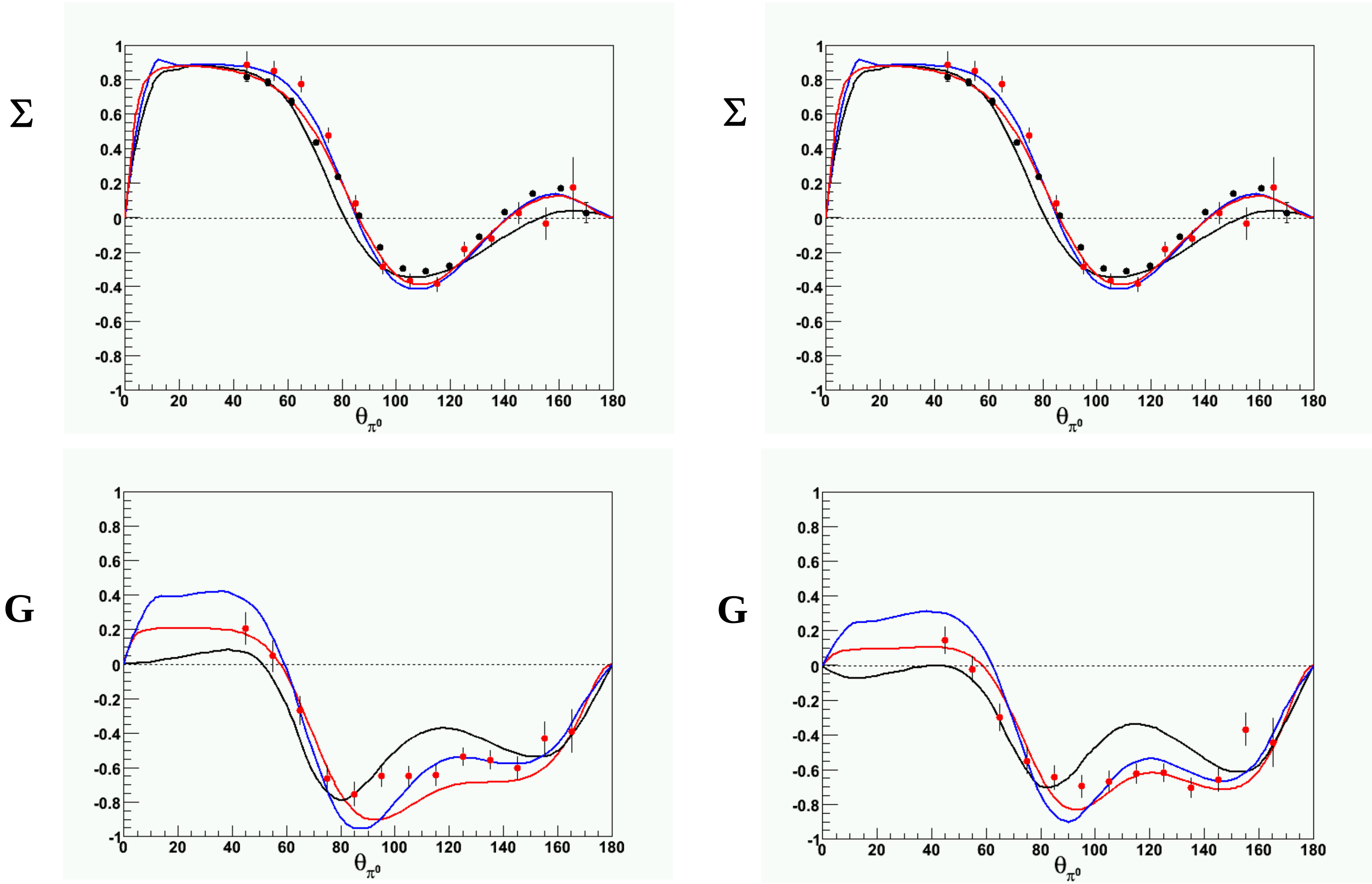
reaction: $\vec{\gamma} + \vec{p} \rightarrow p + \pi^0$

linearly polarized photons

longitudinally polarized proton

E_γ=966 MeV

E_γ=1000 MeV



● Preliminary results (A. Thiel)

● GRAAL data

prediction partial wave analysis

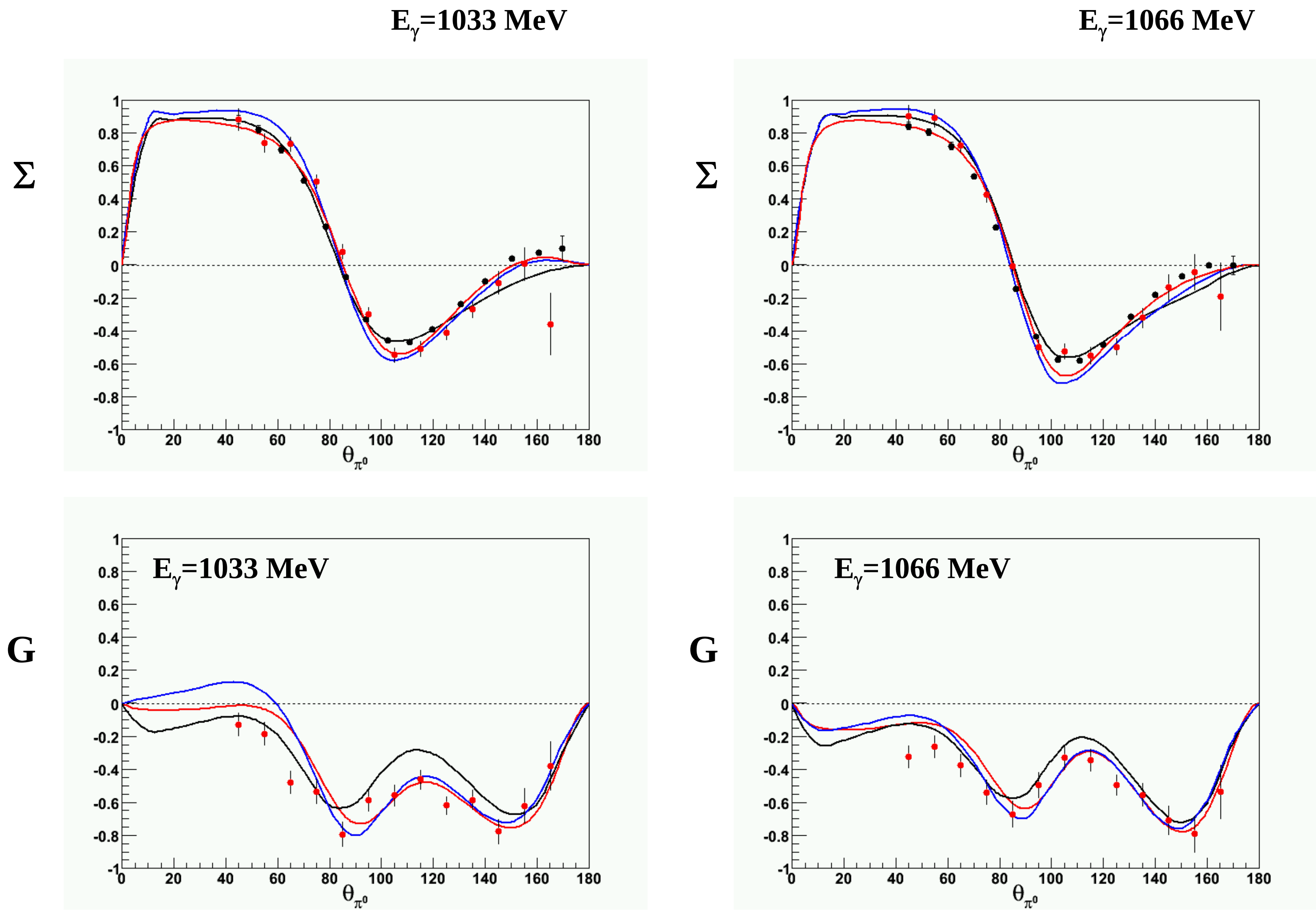
BoGa

SAID

MAID

Σ and G-Asymmetry for $p\pi^0$

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



● Preliminary results (A. Thiel)

● GRAAL data

prediction partial wave analysis

BoGa

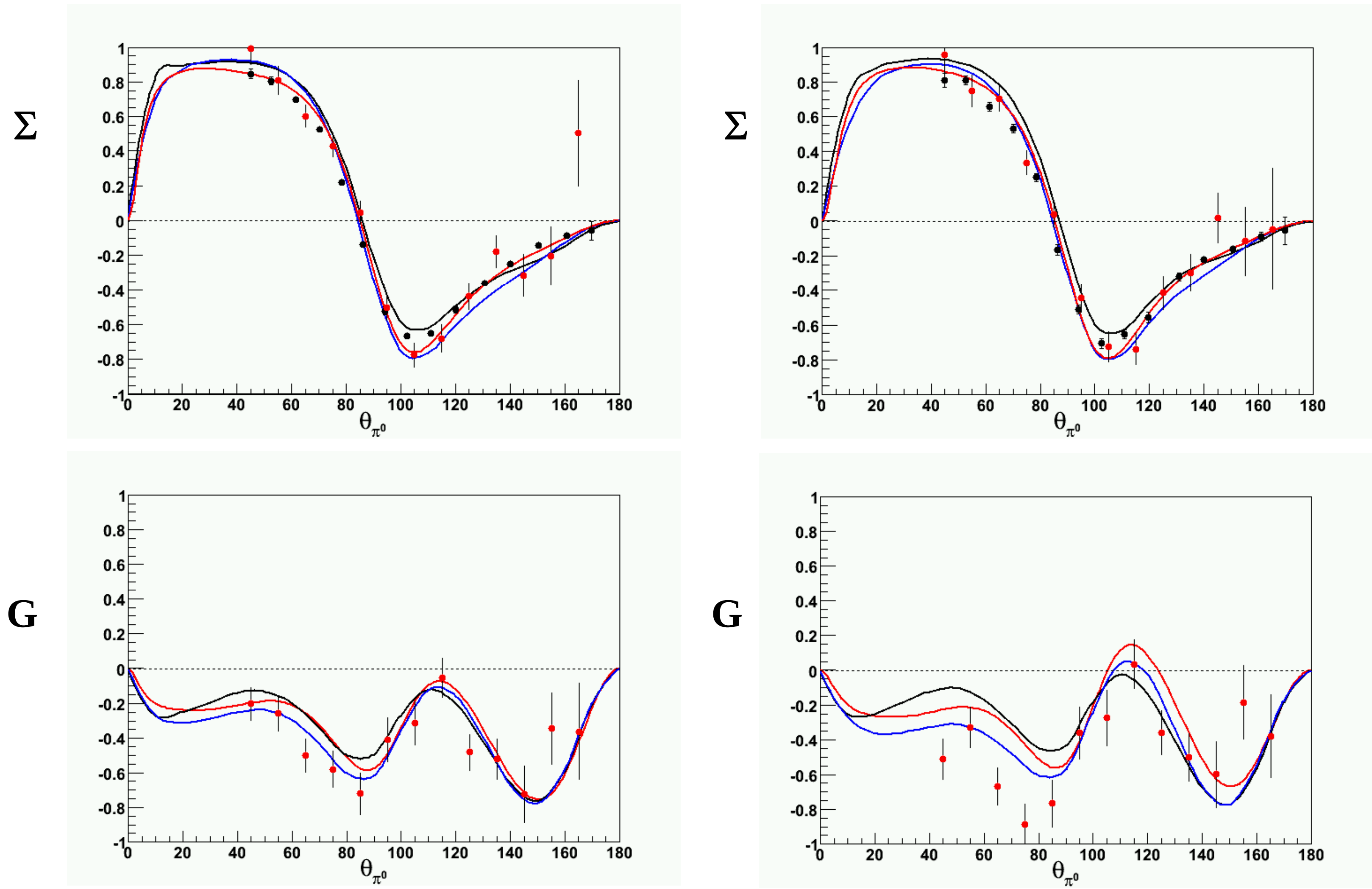
SAID

MAID

Σ and G-Asymmetry for $p\pi^0$

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

E_γ=1100 MeV E_γ=1133 MeV



● Preliminary results (A. Thiel, M. Grüner)

● GRAAL data

prediction partial wave analysis

BoGa

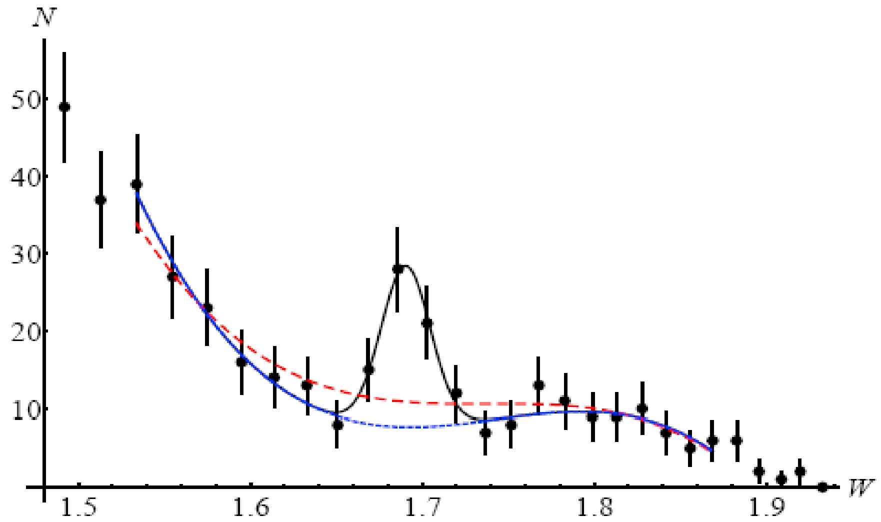
SAID

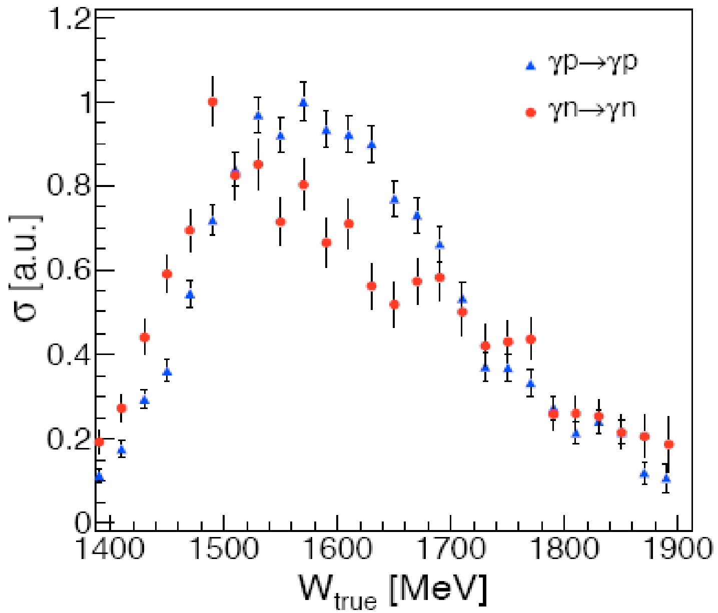
MAID

Compton Scattering

- a resonance with strong electromagnetic coupling to the neutron could (should) show up in $\gamma n \rightarrow n\gamma$
- experimentally extremely challenging!
- positive result reported in:

V. Kuznetsov et al. Phys. Rev. C83 (2011) 022201(R)





- MAMI data under analysis
  first very preliminary results
  (less than 50 % statistics,
  still contaminated with
  π^o decay photons)
  $\Rightarrow$ not yet conclusive

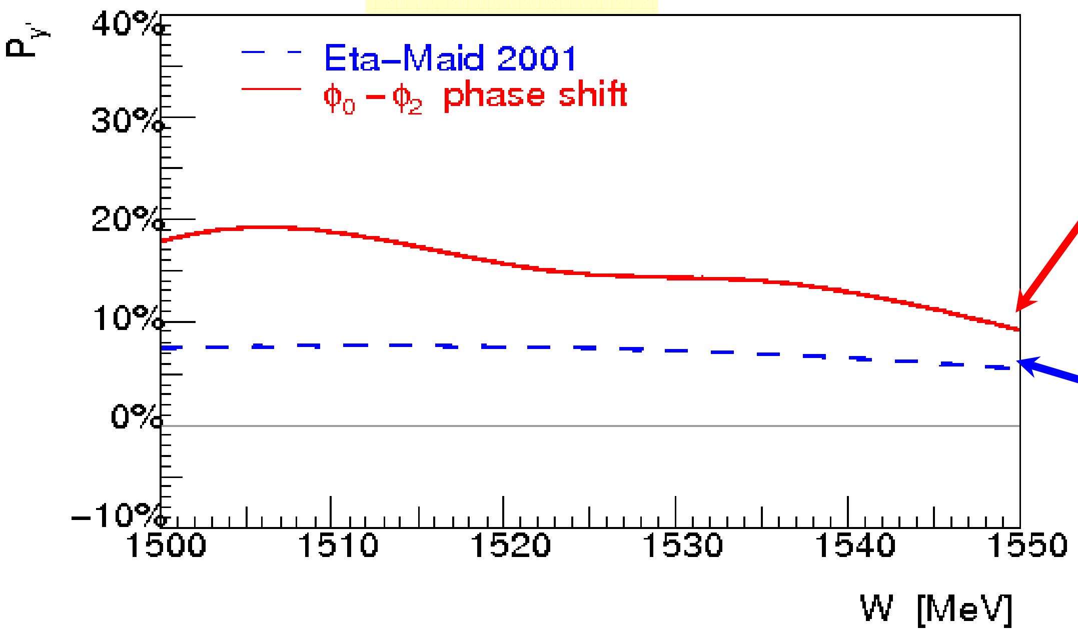
Recoil proton polarisation: $p(e, e' \vec{p}) \eta$

First experiment with MAMI C and the 3-spectrometer setup

Merkel et al., PRL 99:132301 (2007)

$P_y \sim \mathrm{Im}\,(E_{0+}^* (E_{2-} + M_{2-}))$ $\sim T$

$\Theta = 120^o$

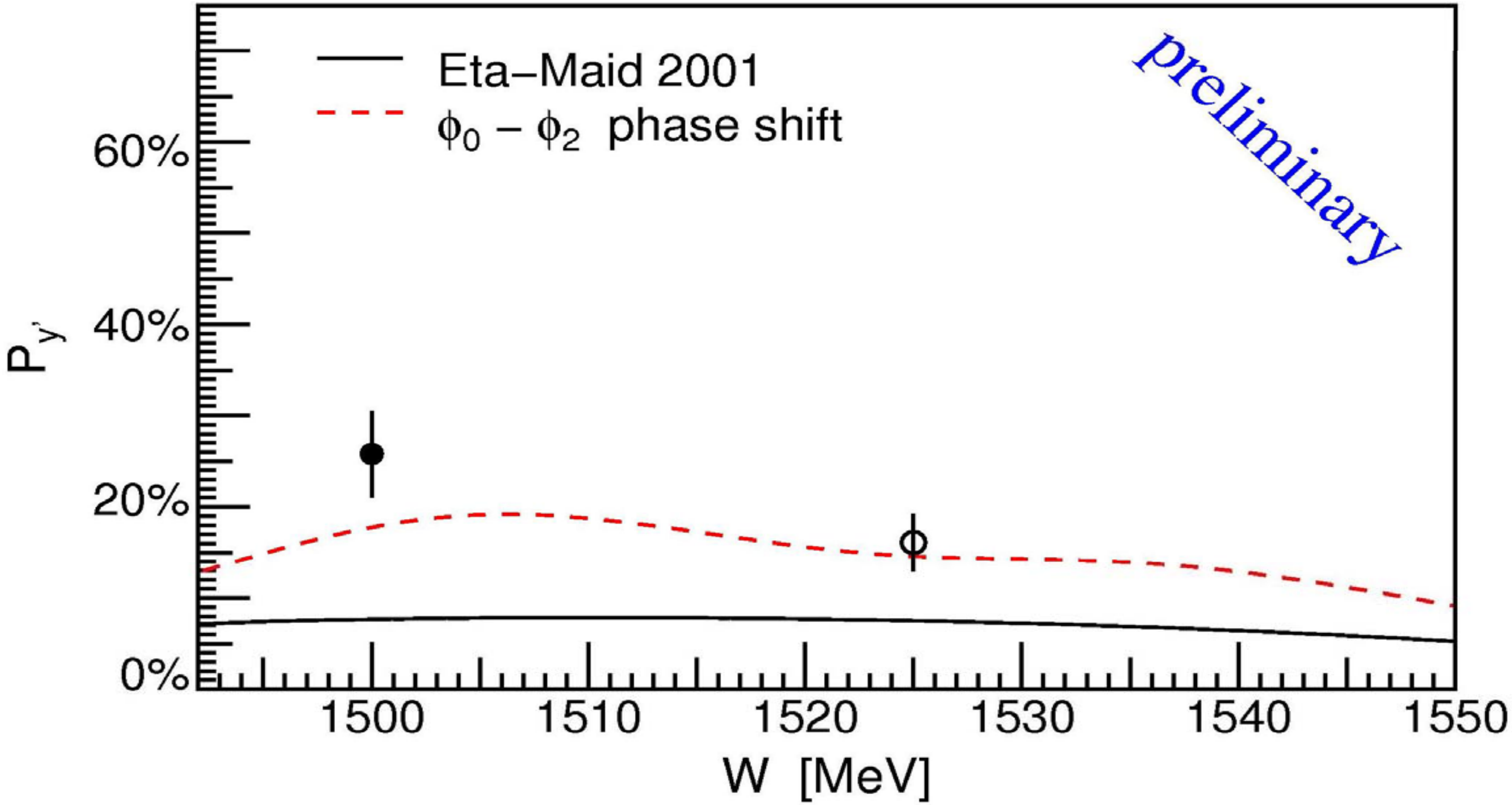


energy dependent phase shift between $J^P = 1/2^-$ and $3/2^+$ partial wave amplitudes

Breit-Wigner resonances in $J^P = 1/2^-$ and $3/2^+$ partial waves

Recoil proton polarisation: p(e, e' p) η

Θ = 120 °



PRL 99, 132301 (2007), and K. Grießinger et al., to be published

target asymmetry measurement with real photons under analysis in A2 (MAMI); also F, $C_{x'}$, P

Target Asymmetry in pη

only few partial−
waves contribute

threshold

increasing number of partial waves

E γ

Δ (1232)−region

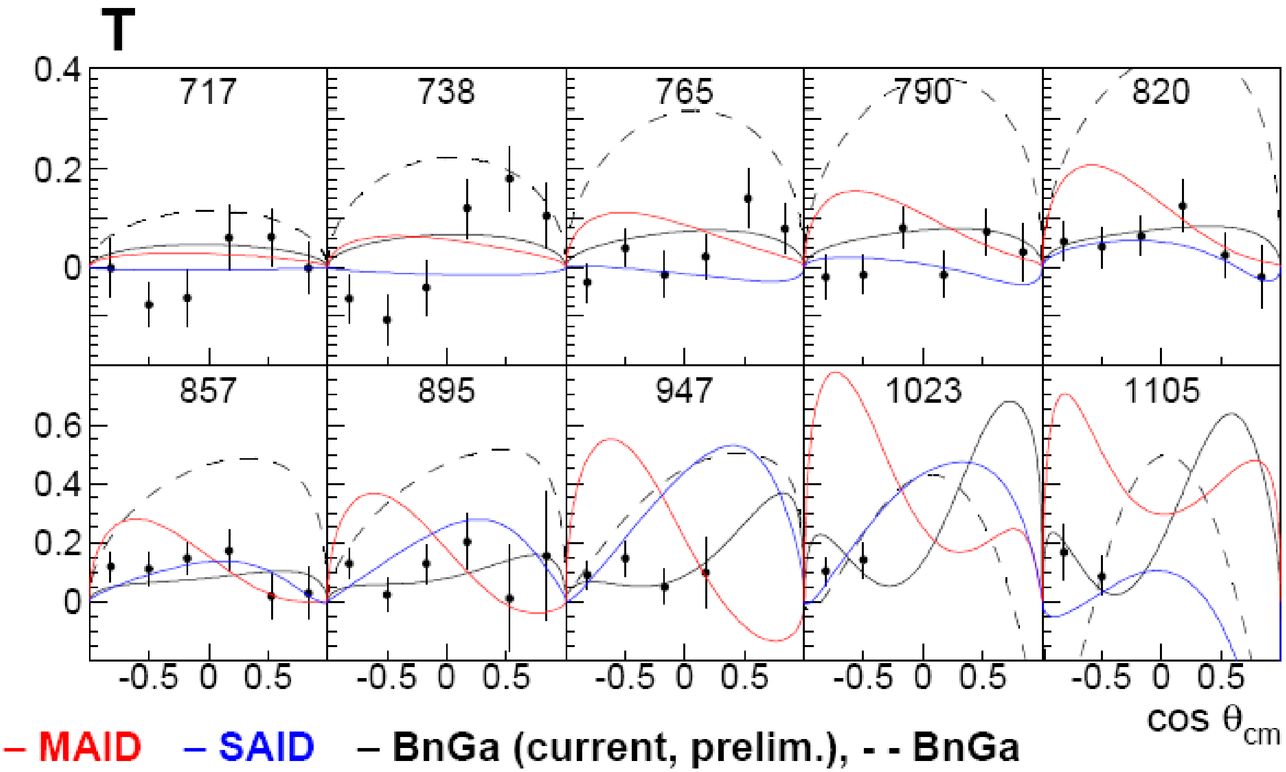
Low energy regime:

$\gamma p \longrightarrow p\eta$:

PHOENICS data on T

⇒ isobar models fail to describe the data

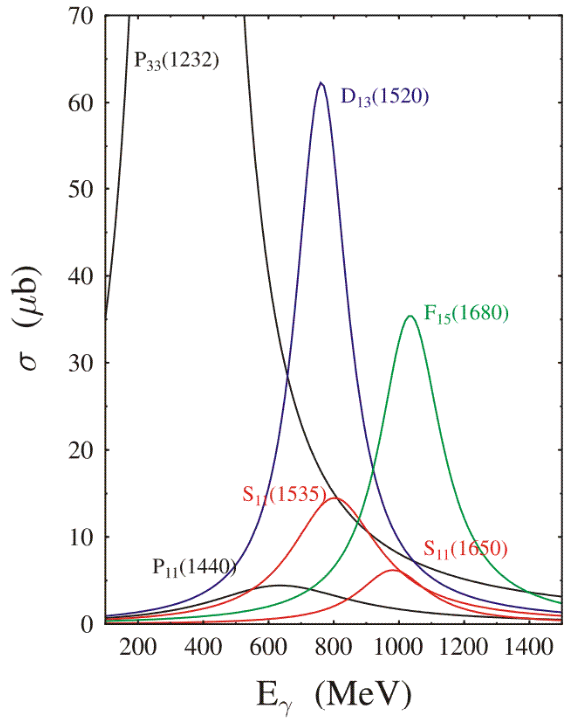
⇒ big differences between the different solutions



Nucleon Resonances

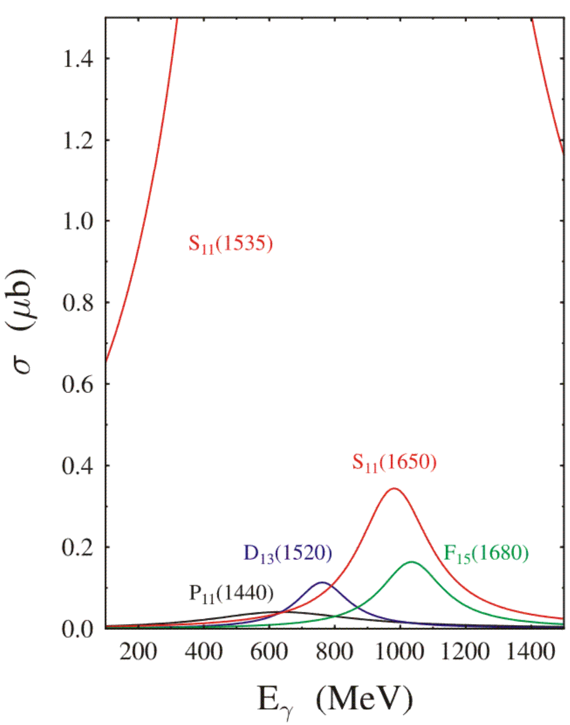
Pion-Production

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



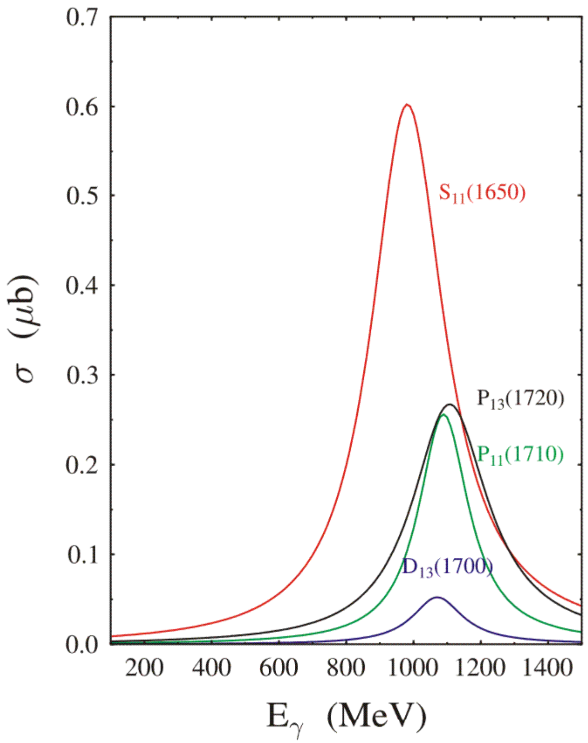
Eta-Production

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



Kaon-Production

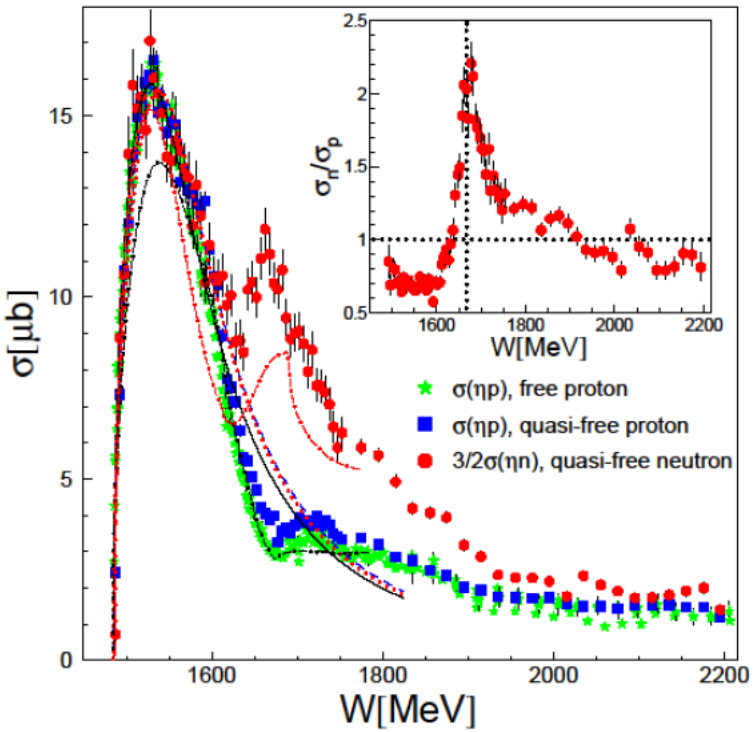
$$\gamma + N \rightarrow N^* \rightarrow K^+ + \Lambda$$

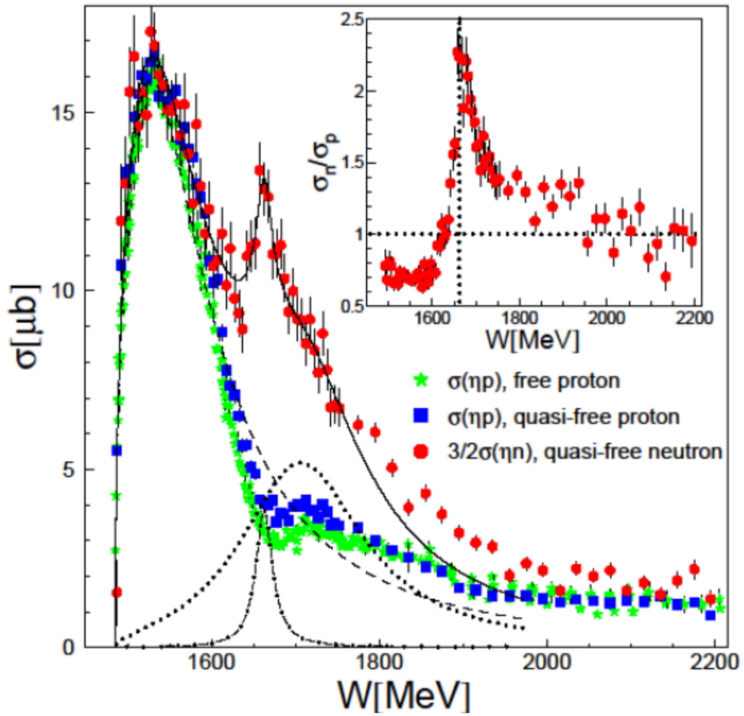


Problem : overlapping resonances
Polarization observable

ELSA and MAMI : polarized photons and polarized targets

Electromagnetic excitation off the neutron



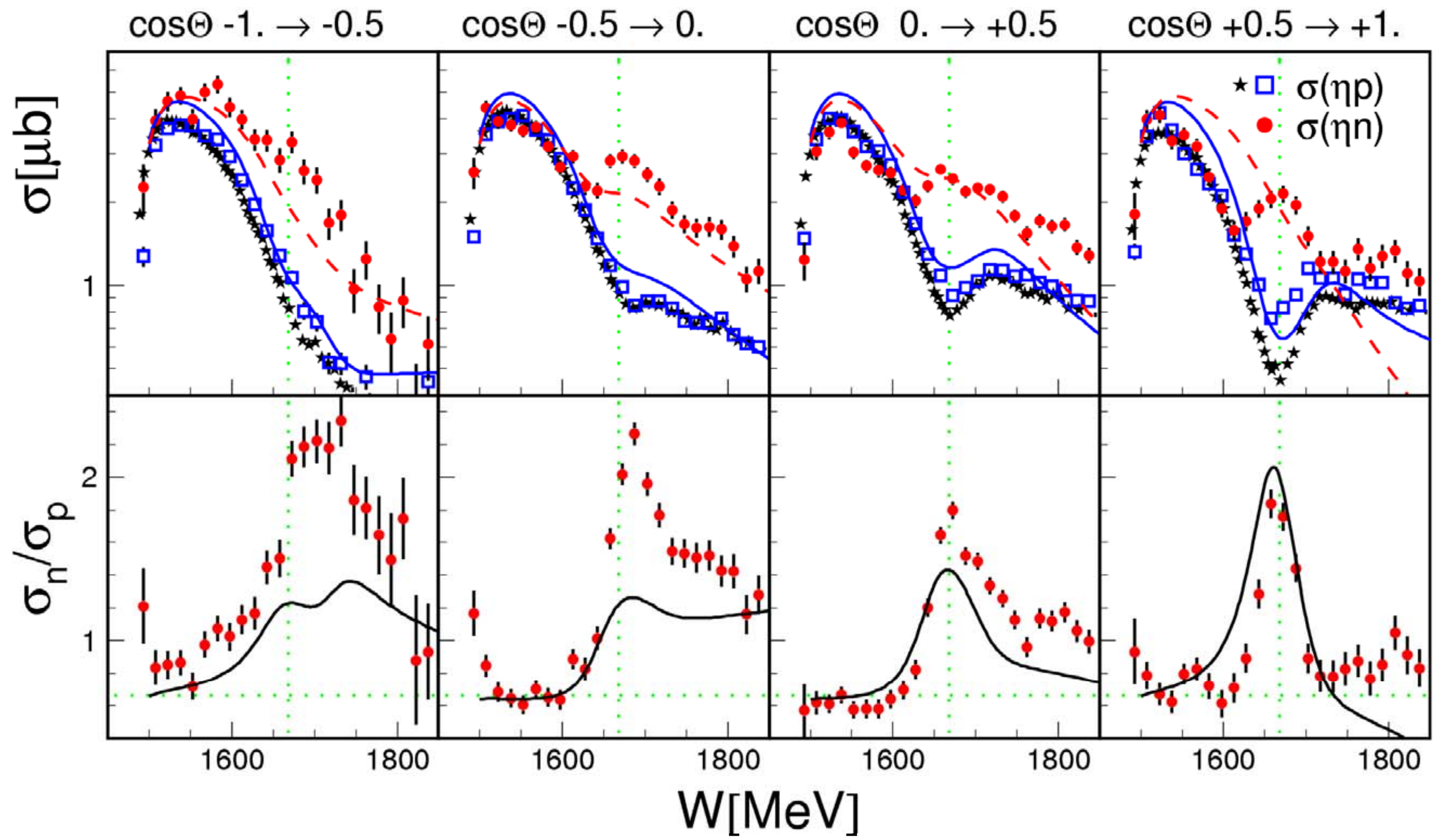


position: W≈1.67 GeV
width: σ≈25 MeV (FWHM)

<u>narrow structure in excitation fct. of $\gamma\, n \rightarrow n\, \eta$:</u>

GRAAL:	W ≈ 1680 MeV, Γ <30 MeV
Tohoku-LNS:	W ≈ 1666 MeV, Γ <40 MeV
ELSA:	W ≈ 1685 MeV, Γ <50 MeV
MAMI-C:	W ≈ 1675 MeV, Γ <40 MeV

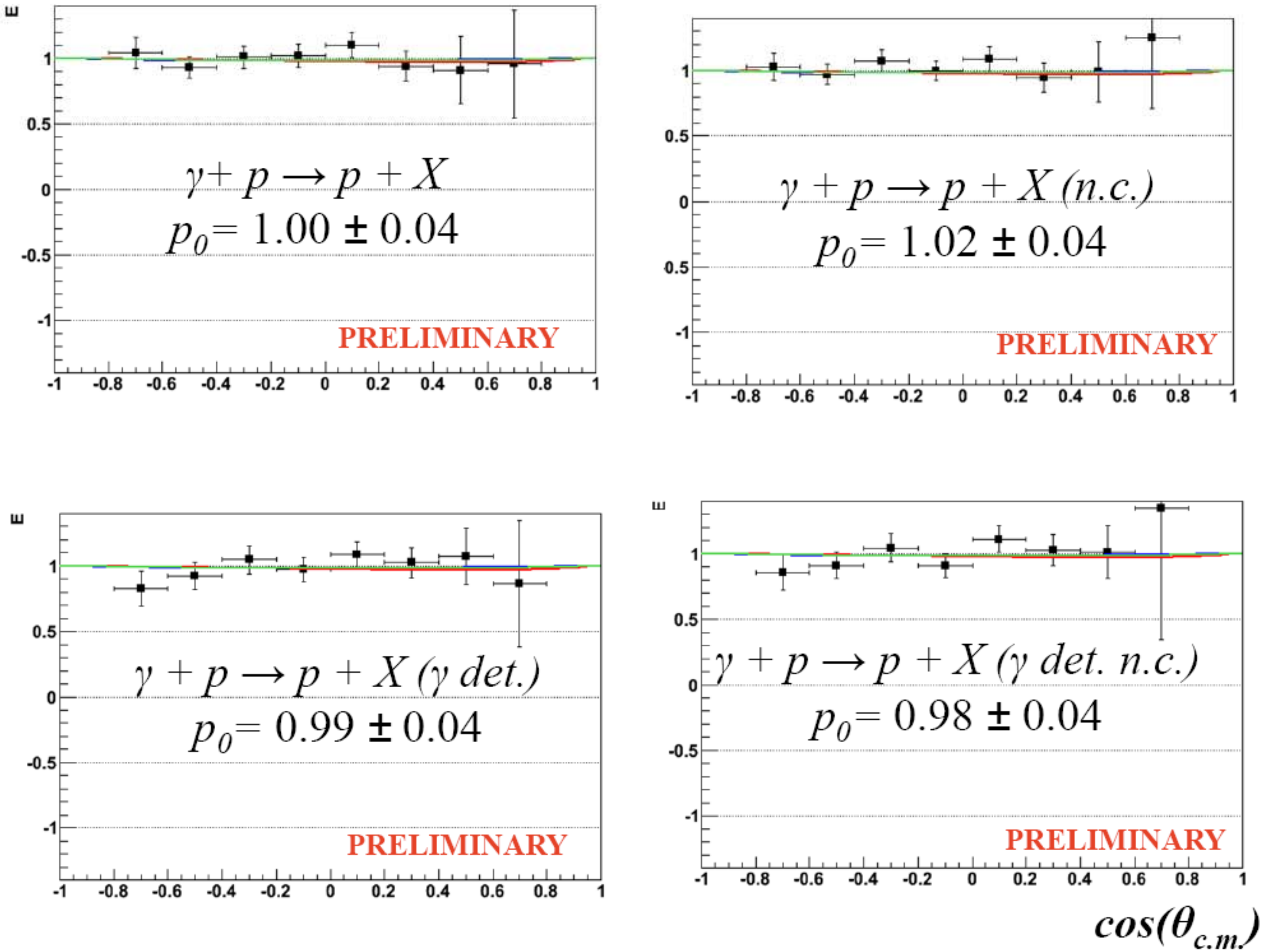
Electromagnetic excitation off the neutron



Helicity dependent cross section for pη

$$E = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$$

Preliminary results CLAS at JLAB (V. Crede, M. Dugger)

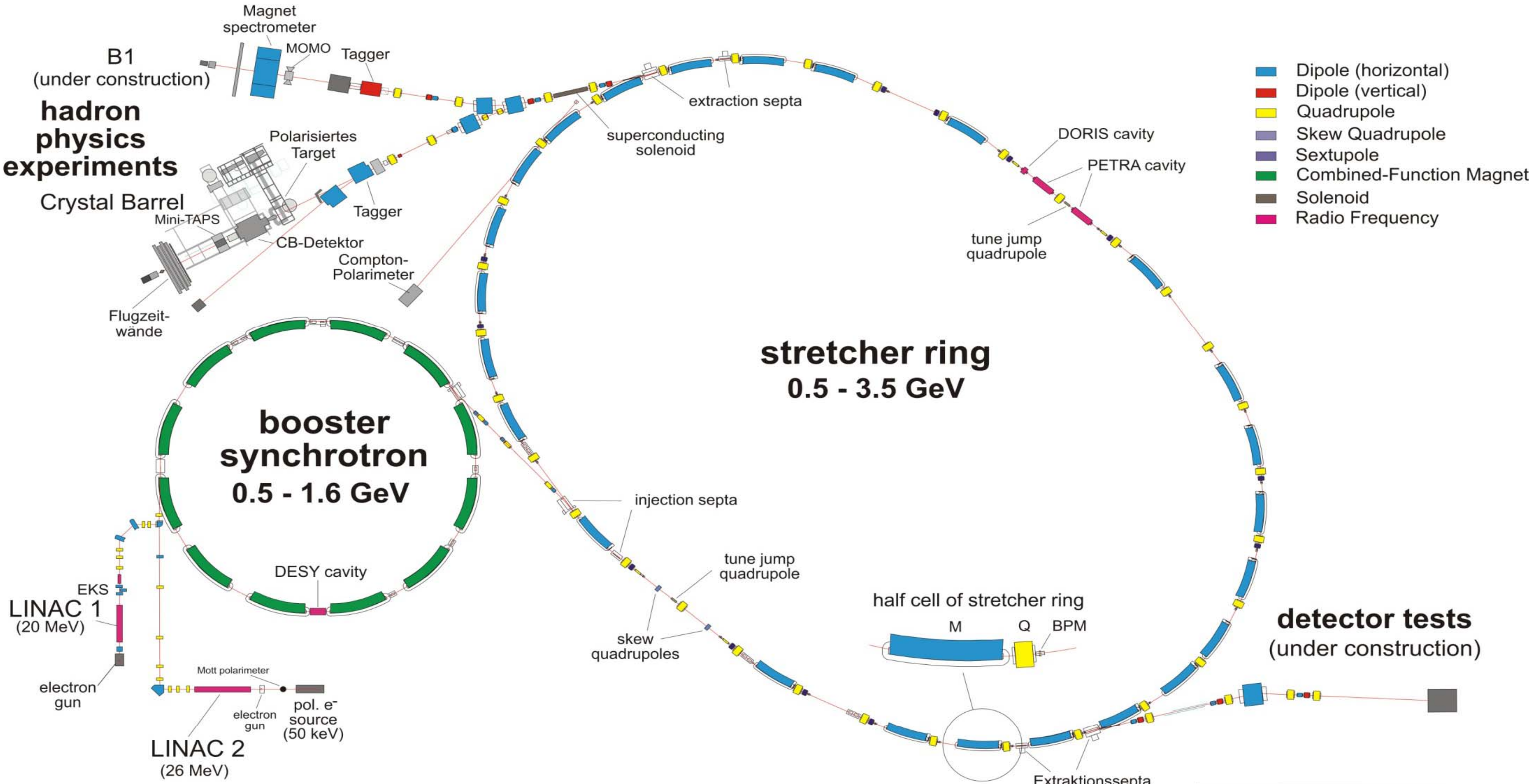


SAID
MAID
Bonn-Gatchina

- $W = 1525$ MeV
- All have E=1, within statistical uncertainties

☺

Electron Stretcher Accelerator (ELSA)



(W. Hillert, F. Klein)