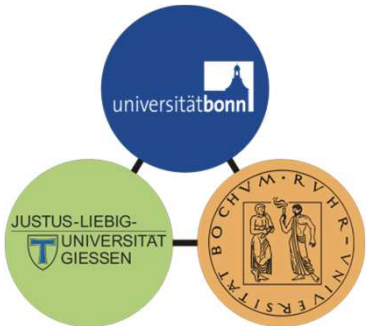


# CB-ELSA Contributions to Baryon Spectroscopy

R. Beck  
University Bonn

PWA/ Workshop, Camogli 2013

- Introduction
- Recent Results  
 $\vec{\gamma} \vec{p} \rightarrow p \pi^0$
- Impact of the new polarization data
- Summary and Outlook

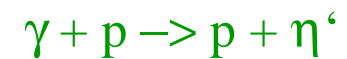
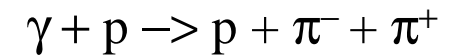
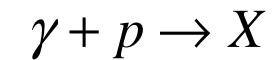
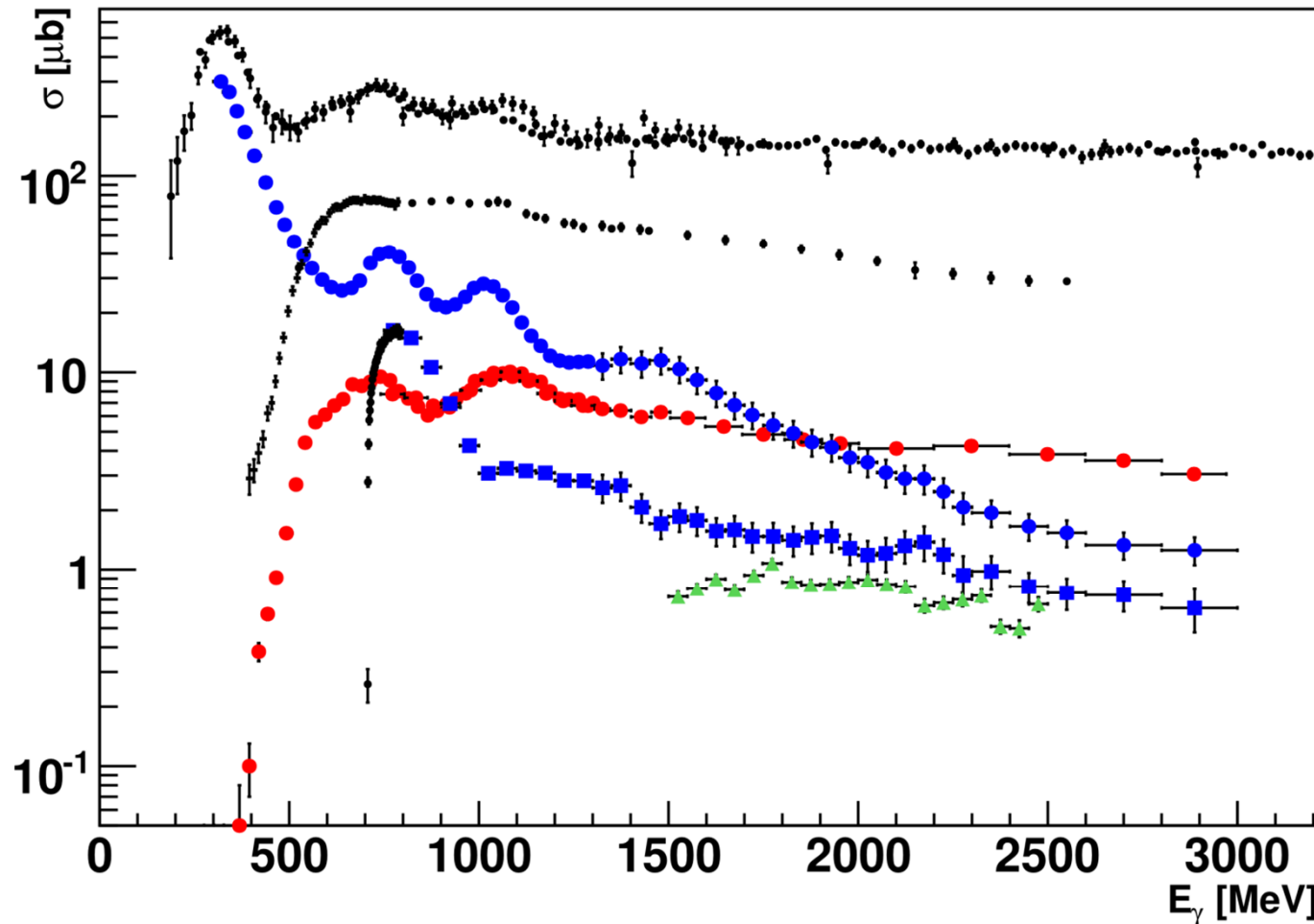


supported by the DFG within the SFB/TR16

# Introduction

Baryon spectroscopy with Crystal Barrel at ELSA

- Precision data for different final states ( $p\pi^0$ ,  $p\eta$ ,  $p\eta'$ ,  $p\pi^0\pi^0$ ....)
- Polarization experiments (beam, target and recoil)  
“complete data base”
- To constrain PWA  $\rightarrow$  unique PWA solution

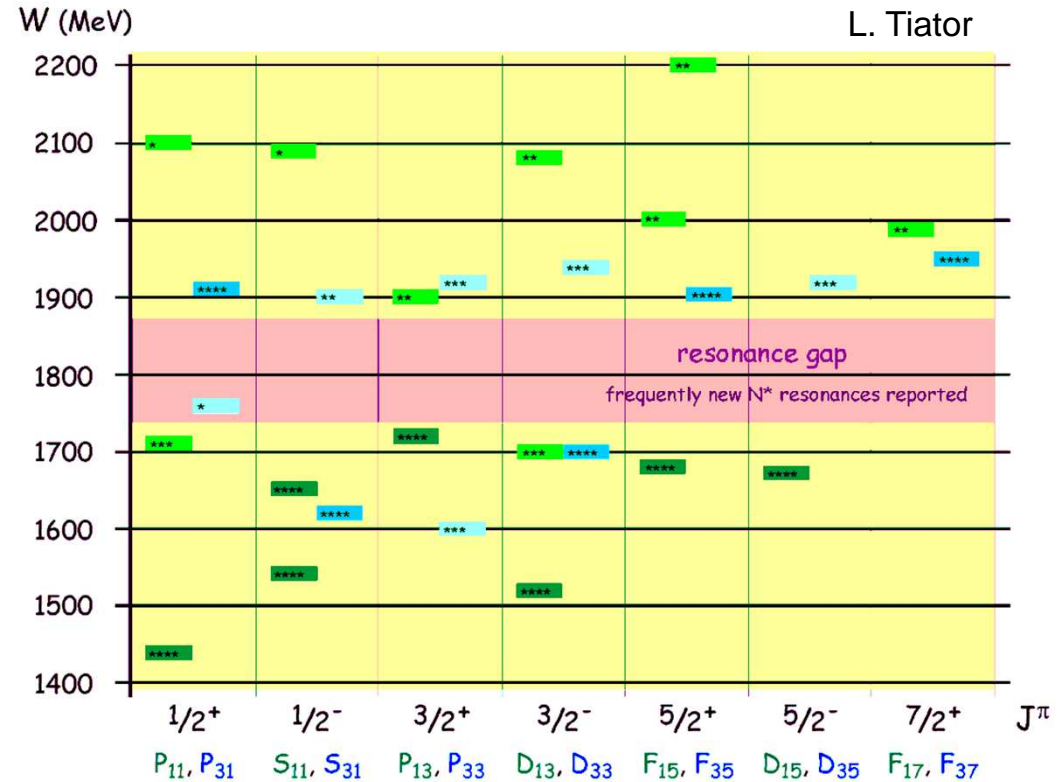
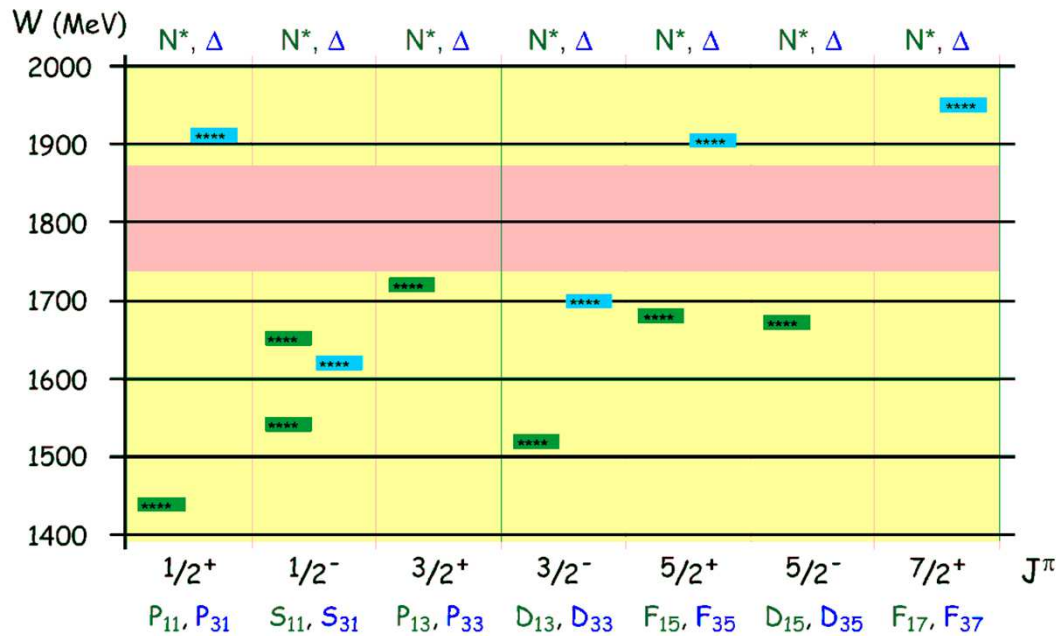


# Introduction

PDG: Status on nucleon resonances

only 7  $N^*$  and 5  $\Delta^*$

established in the region  $1400 \text{ MeV} < W < 2000 \text{ MeV}$



- Energy pattern for the dominant states

Constituent Quark Models

Dynamical Models

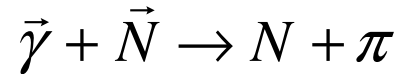
Lattice QCD

- Various nucleon models predict many more states

weak coupling to  $\pi N$  final state

insufficient data base

# Problem with a unique PWA solution



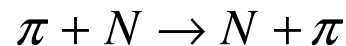
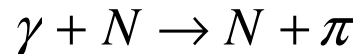
8 well chosen observable have to be measured to determine the production amplitudes ( $F_1, F_2, F_3$  and  $F_4$ )

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

additional constraints:

(a) s- and p- wave approximation

(b) Fermi- Watson theorem



same I, J in the final state

→ same scattering phase  $\delta_{IJ}$

two observable sufficient for “complete data base”

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

beam asymmetry :  $\Sigma$

- above  $\pi\pi$ - threshold

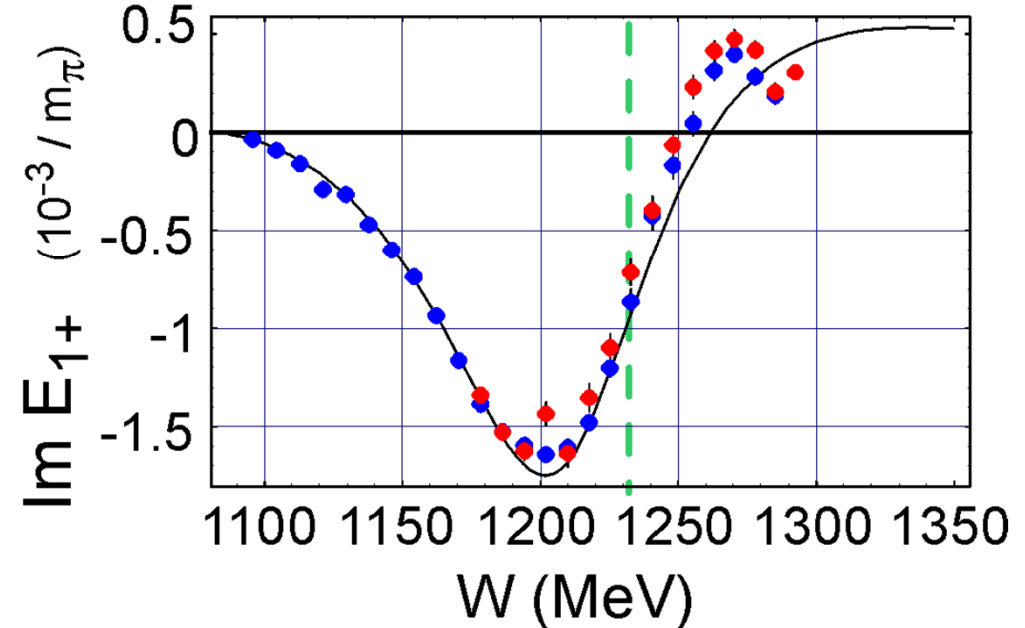
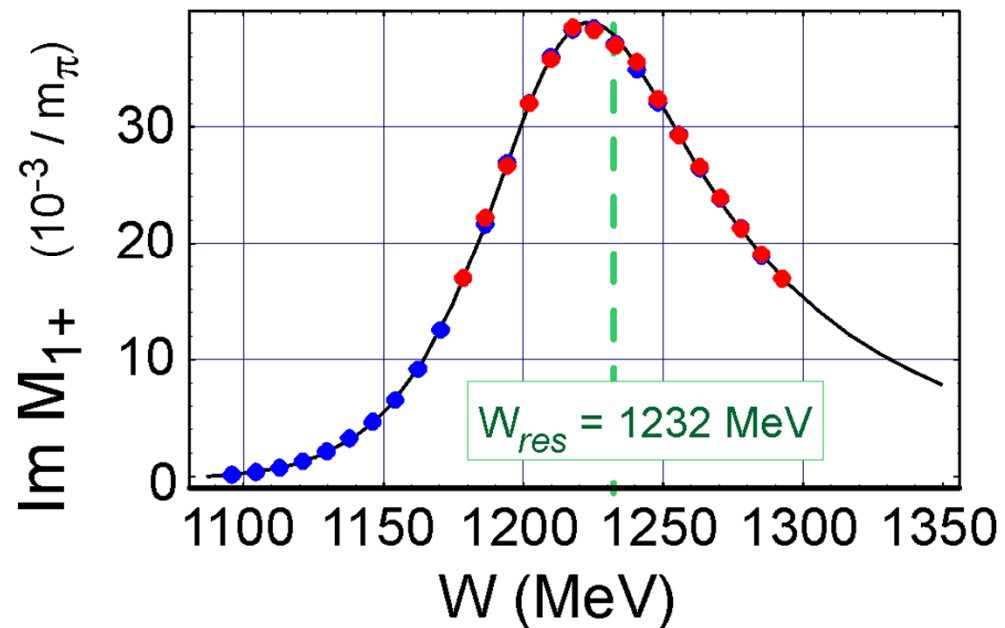
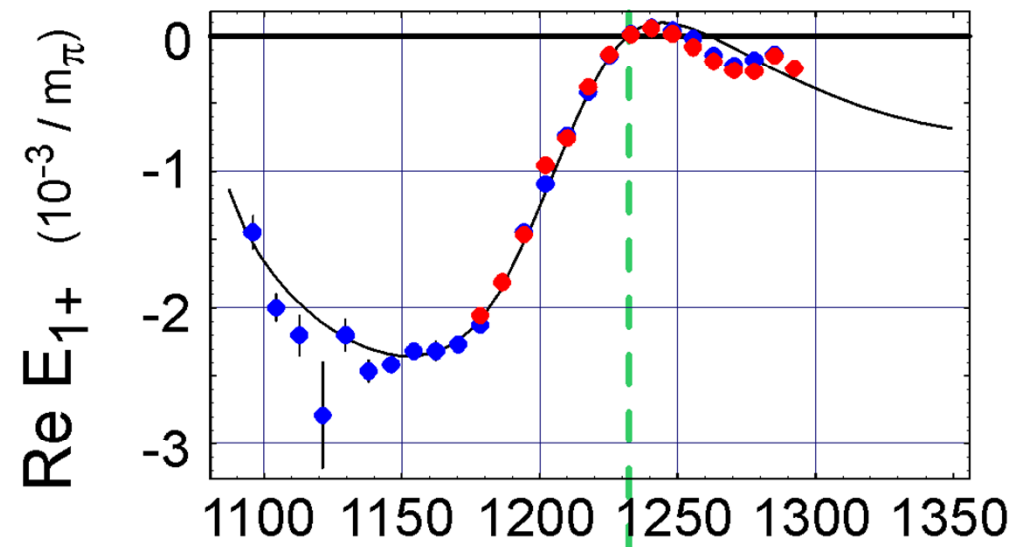
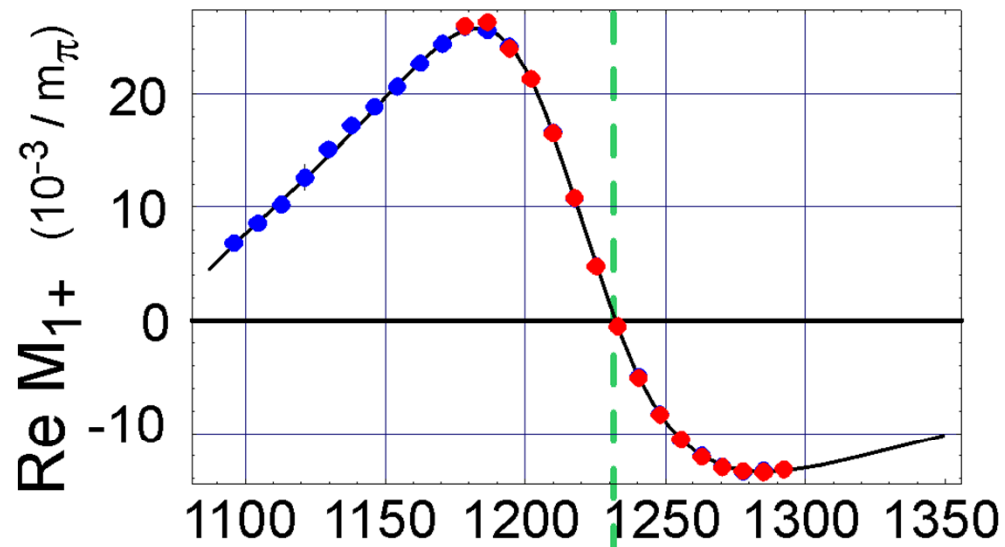
Fermi- Watson theorem not valid any more

More observable needed to get a unique partial wave solution

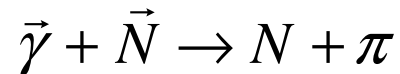


# Partial waves for the $P_{33}(1232)$

- energy dep. (global) fit, Hanstein et al
- energy indep. (local) fit, Hanstein et al
- ◆ exp. analysis, Krahn et al, Mainz 1997



# Problem with a unique PWA solution



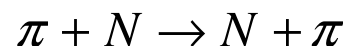
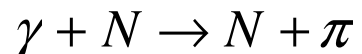
8 well chosen observable have to be measured to determine the production amplitudes ( $F_1, F_2, F_3$  and  $F_4$ )

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

additional constraints:

(a) s- and p- wave approximation:  $L_{\max} \leq 1$

(b) Fermi- Watson theorem



same I, J in the final state

→ same scattering phase  $\delta_{IJ}$

two observable sufficient for “complete data base”

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

beam asymmetry :  $\Sigma$

- above  $\pi\pi$ - threshold

Fermi- Watson theorem not valid any more

More observable needed to get a unique partial wave solution

# Observables in Meson Photoproduction

Photon polarization		Target polarization	Recoil nucleon polarization	Target and recoil polarizations
		X    Y    Z <sub>(beam)</sub>	X'    Y'    Z'	X'    X'    Z'    Z' X    Z    X    Z
unpolarized	$\sigma$	- <b>T</b> -	- <b>P</b> -	<b>T<sub>x</sub></b> <b>L<sub>x</sub></b> <b>T<sub>z</sub></b> <b>L<sub>z</sub></b>
linear	$\Sigma$	<b>H</b> (-P) <b>G</b>	<b>O<sub>x</sub></b> (-T) <b>O<sub>z</sub></b>	(-L <sub>z</sub> )    (T <sub>z</sub> )    (L <sub>x</sub> )    (-T <sub>x</sub> )
circular	-	<b>F</b> - <b>E</b>	<b>C<sub>x</sub></b> - <b>C<sub>z</sub></b>	-    -    -    -

Experiments at ELSA, JLAB, MAMI : polarized photons, polarized targets and  $4\pi$  detector acceptance

ELSA: Many new results on polarization observable for different final states are coming out

J. Müller talk on  $p \pi^0$ ,  $p \pi^0 \pi^0$ ,  $p \eta$  channel

H. Schmieden talk on  $K^+ \Sigma^0$  channel

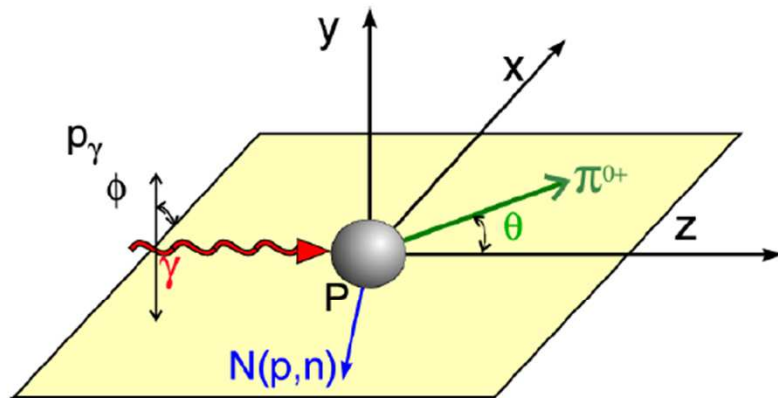
V. Vegna talk on  $p \omega$  channel

# Beam-Target Polarization Observables

photoproduction of pseudoscalar mesons with polarized beam and target :

- all three single polarization observables  $\Sigma$ ,  $P$ ,  $T$  and cross section  $\sigma$
- 4 double polarization observables  $G$ ,  $E$ ,  $F$  and  $H$

can be measured with the Crystal Barrel / TAPS Experiment

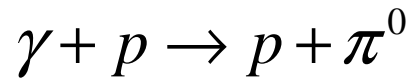


photon pol.		target pol. axis		
		$x$	$y$	$z$
unpolarized	$\sigma$		$T$	
linear	$-\Sigma$	$H$	$-P$	$-G$
circular		$F$		$-E$

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

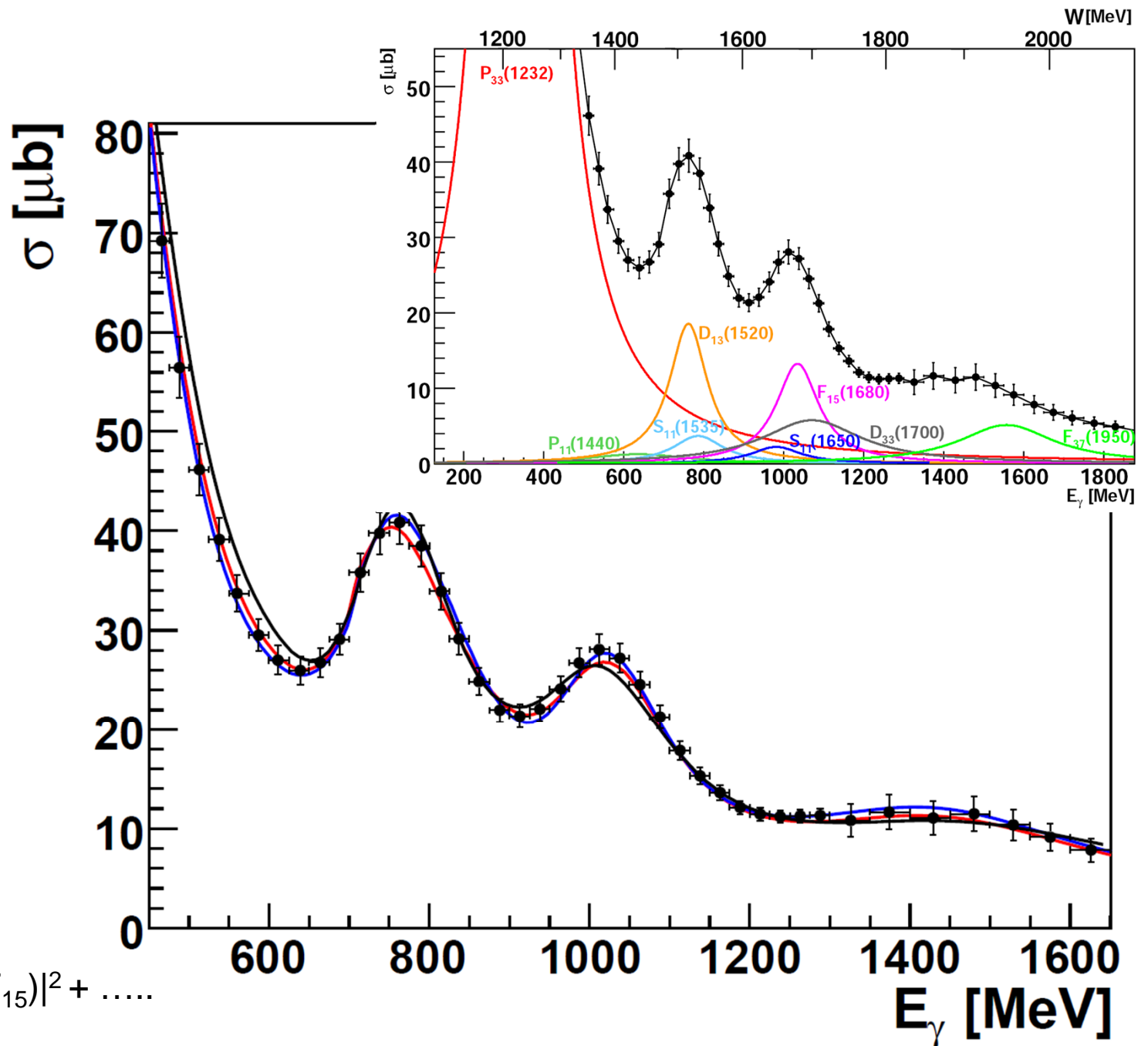
# Problem with a unique PWA solution

Total cross section:



Partial wave analysis

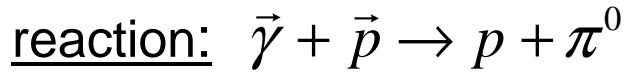
- BnGa
- SAID
- MAID



Total cross section:

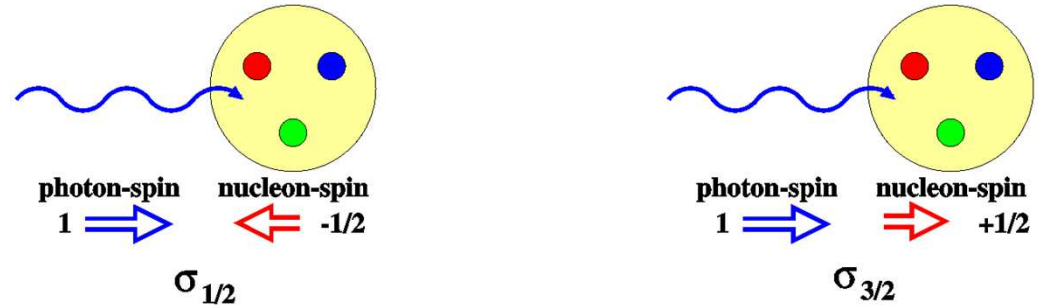
$$\sigma_{\text{tot}} \sim |A(P_{33})|^2 + |A(D_{13})|^2 + |A(F_{15})|^2 + \dots$$

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



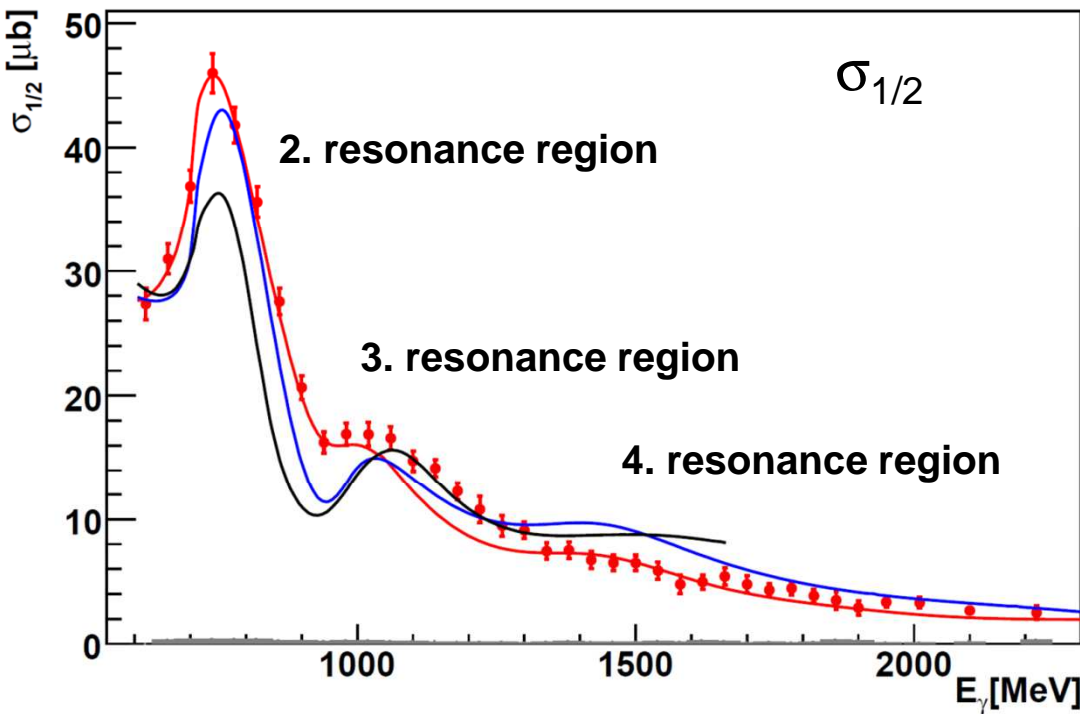
circularly polarized photons

longitudinally polarized proton

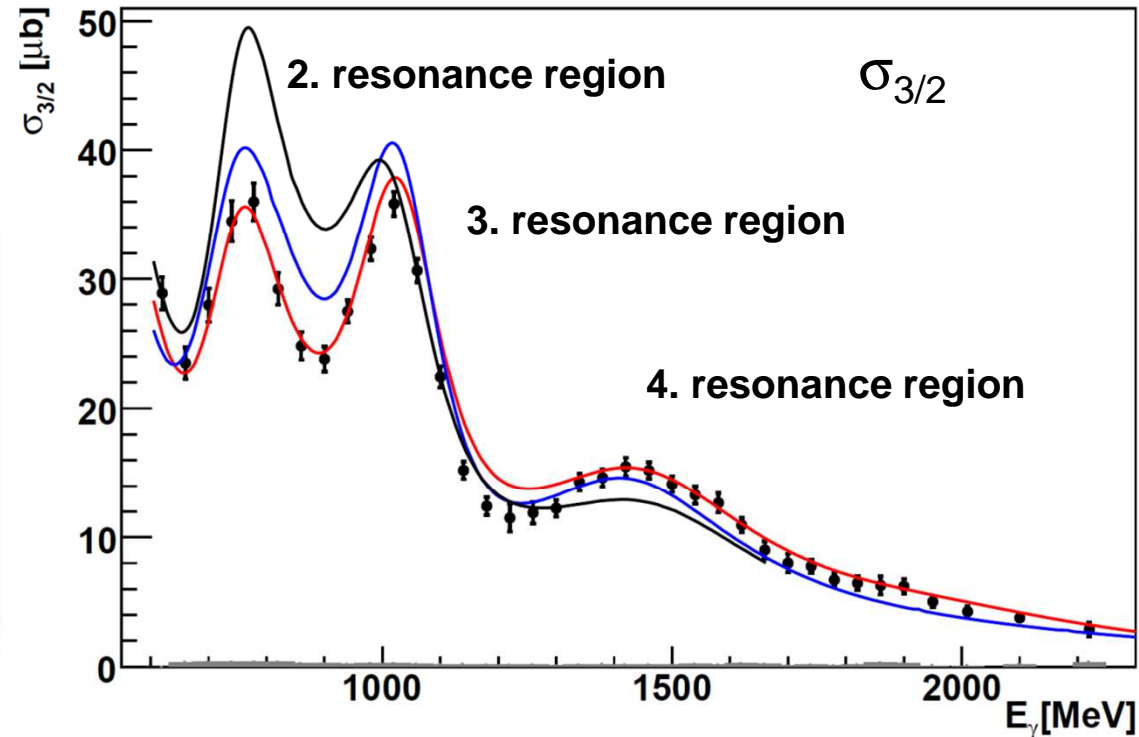


Crystal Barrel at ELSA (M. Gottschall submitted to PRL)

sensitive to interferences between resonances



partial wave analysis prediction — BnGa



— SAID (SN11) — MAID

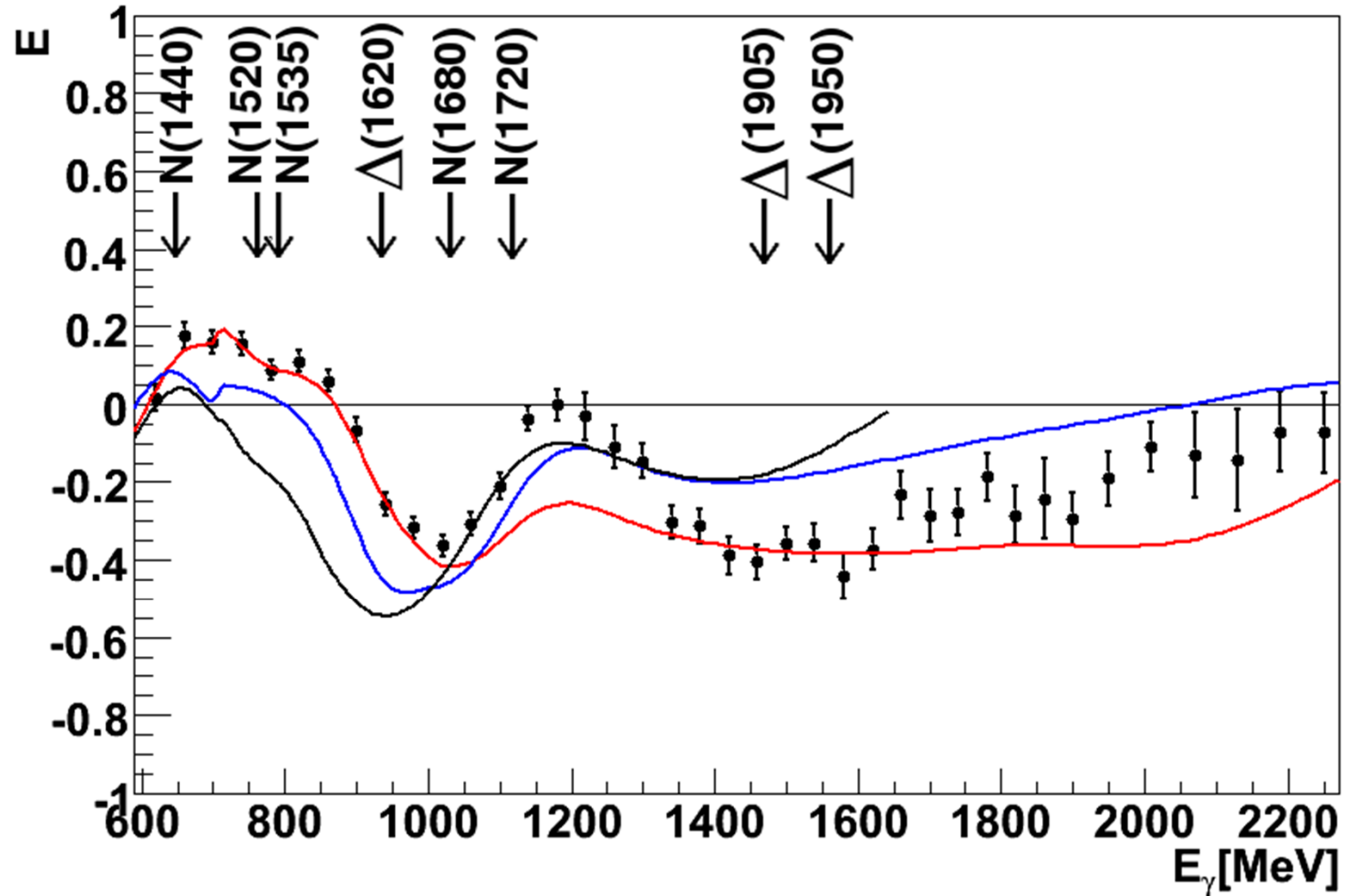
# Helicity Asymmetry E for $p\pi^0$

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

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

partial wave analysis  
prediction

— BnGa  
— SAID (SN11)  
— MAID



- PWA predictions fail already in 2. resonance region

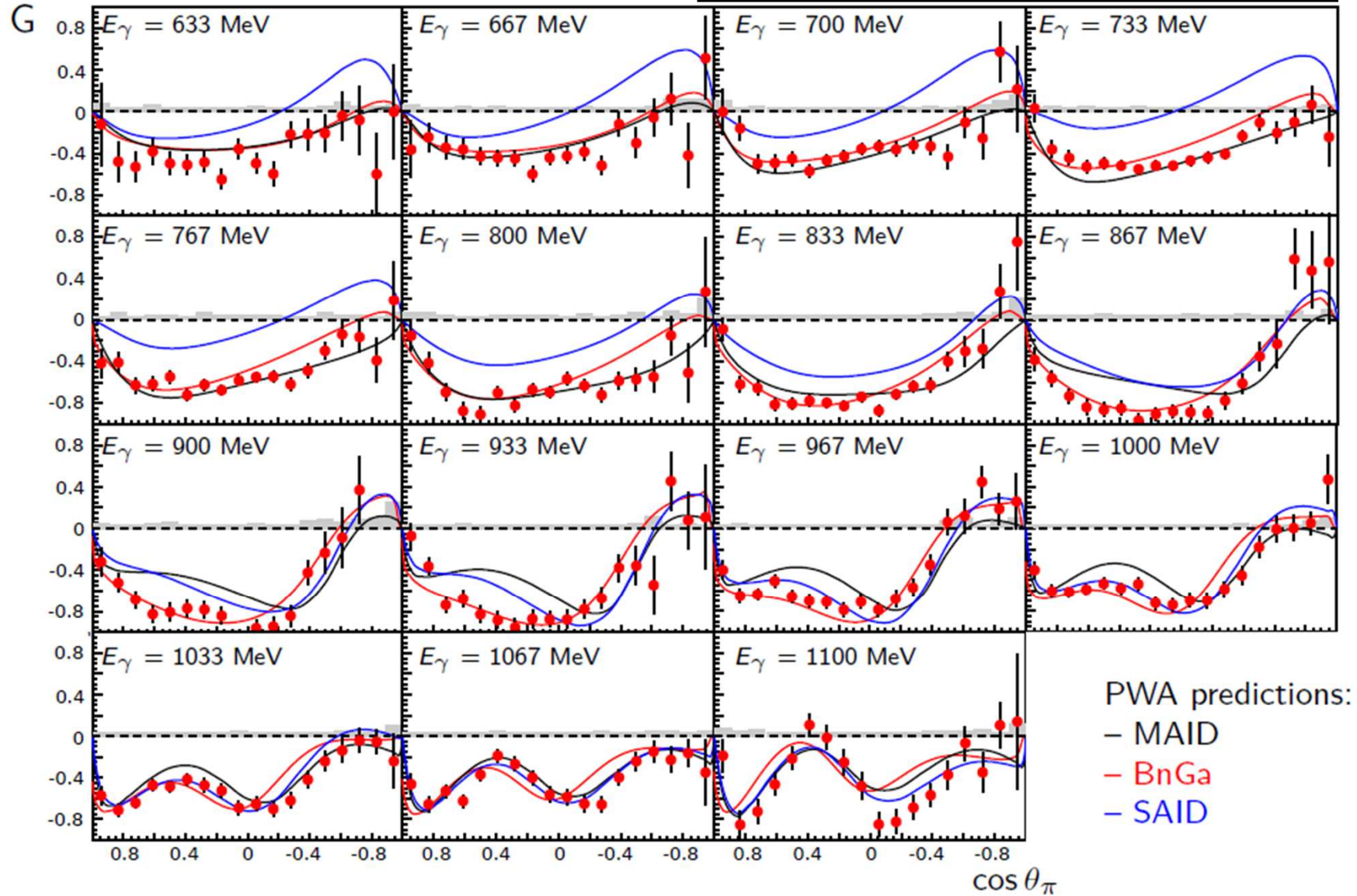


# G-Asymmetry for $p\pi^0$

linearly polarized beam, longitudinally polarized target:

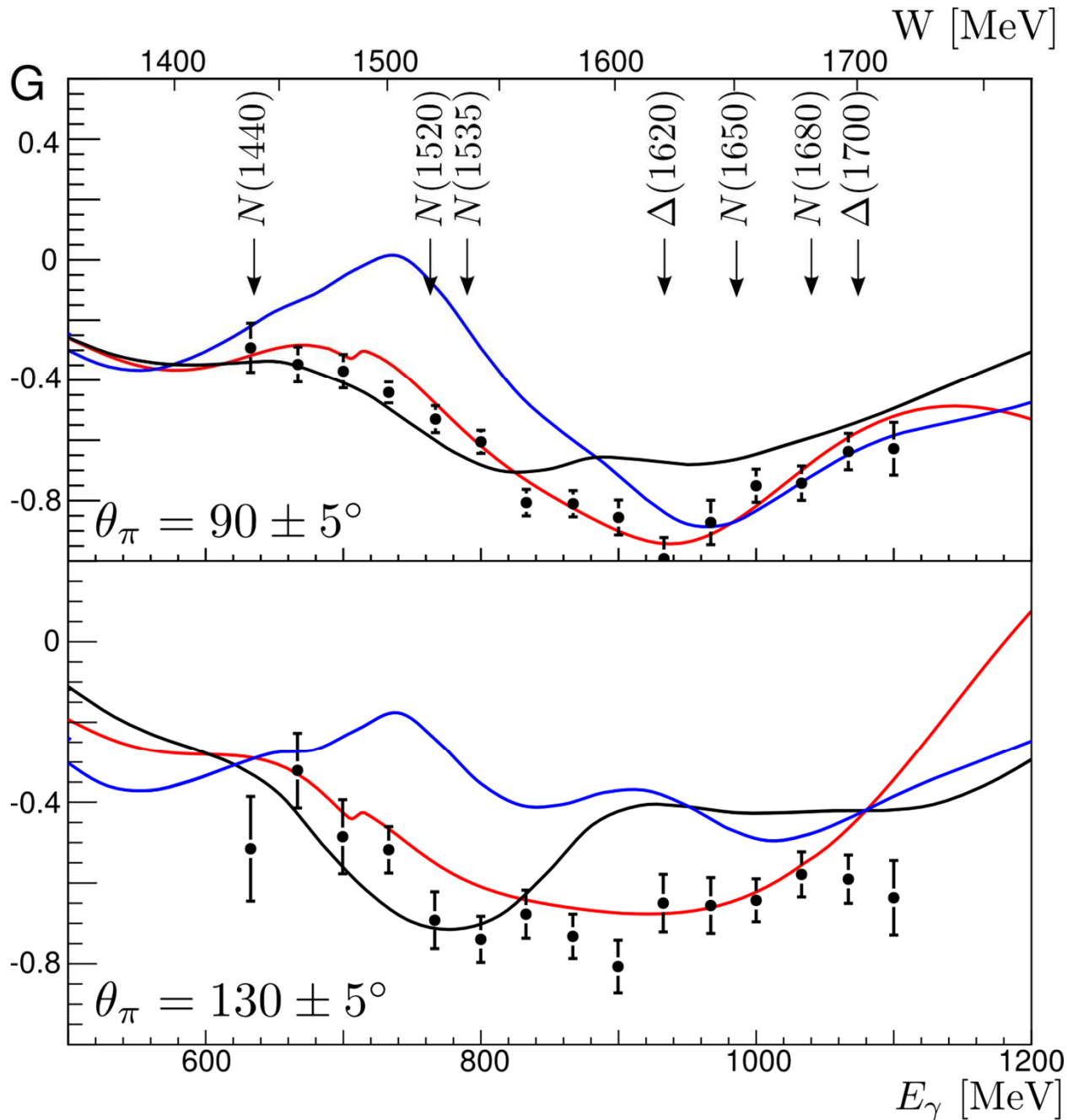
$$\frac{d\sigma}{d\Omega}(\phi) = \frac{d\sigma}{d\Omega_0} \cdot (1 - P_\gamma^{\text{lin}} \Sigma \cos(2\phi) + P_\gamma^{\text{lin}} P_z G \sin(2\phi))$$

Crystal Barrel at ELSA (A. Thiel published in PRL)





# G-Asymmetry for $p\pi^0$



- PWA predictions fail already in 2. resonance region

partial wave analysis prediction

— BnGa

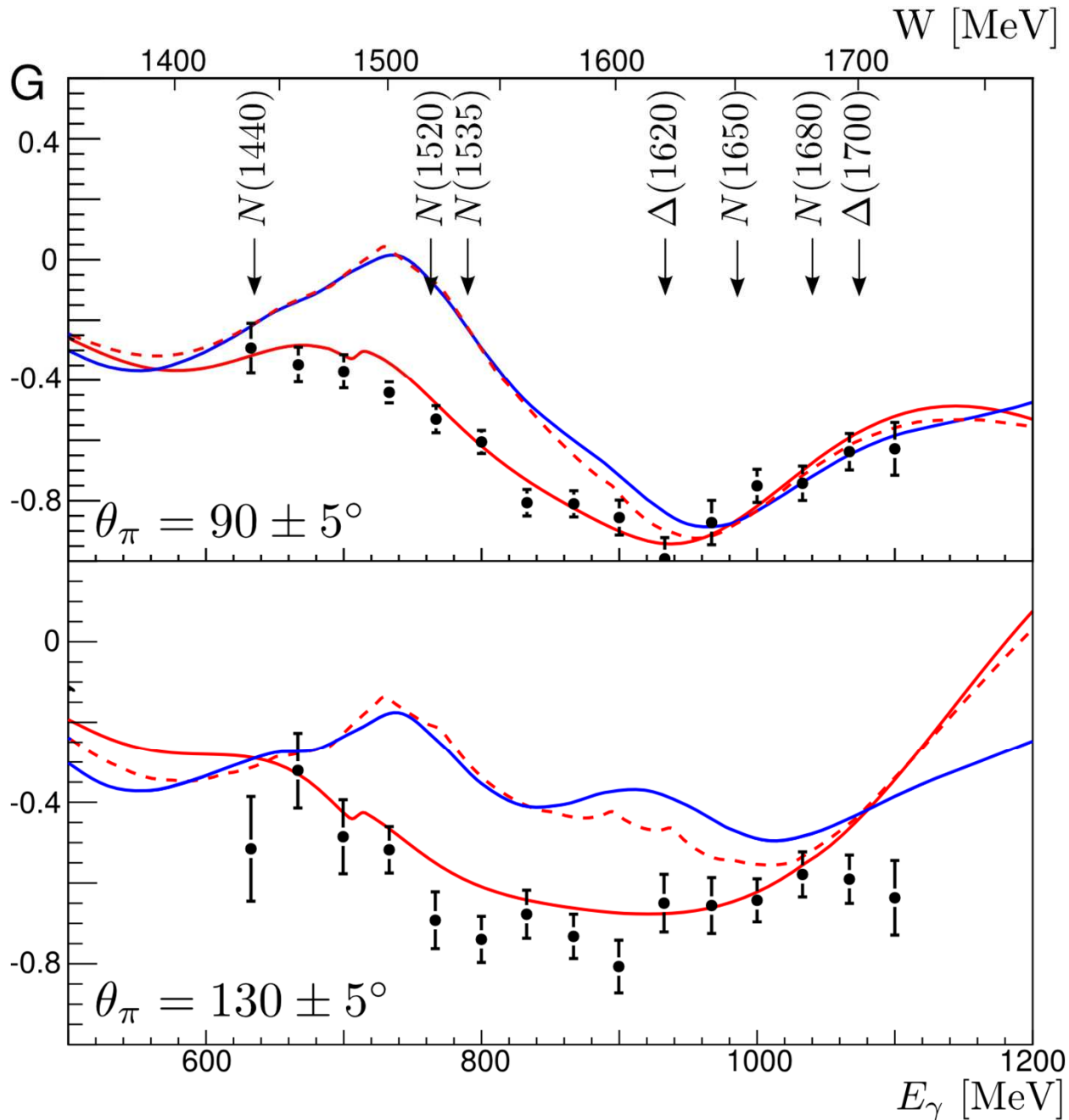
— SAID (SN11)

— MAID

- Below 1 GeV the discrepancies can be traced back to the  $E_{0+}$  and  $E_{2-}$  multipoles

s- and d-wave contributions

# G-Asymmetry for $p\pi^0$

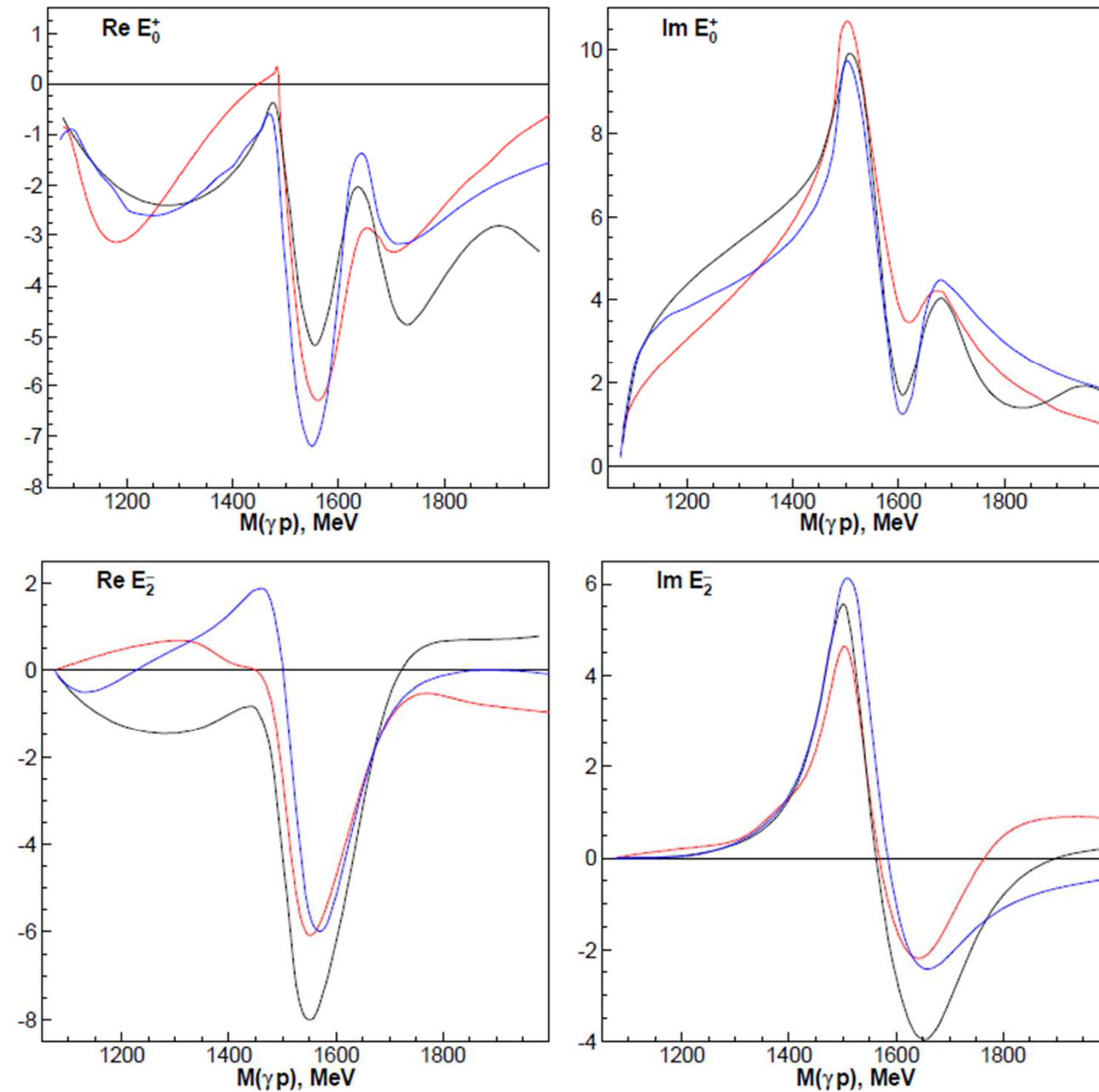


- Below 1 GeV the discrepancies can be traced back to the  $E_{0+}$  and  $E_{2-}$  multipoles
- $E_{0+}$  multipole  
 $S_{11}(1535)$ ,  $S_{11}(1650)$  and  $S_{31}(1620)$
- $E_{2-}$  multipole  
 $D_{13}(1520)$  and  $D_{33}(1700)$

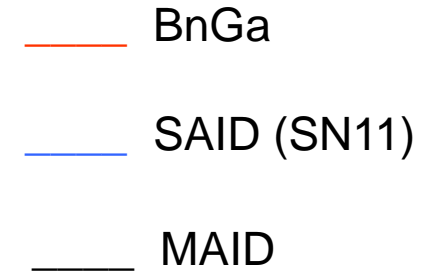
— BnGa  
— SAID (SN11)  
- - - BnGa (with  $E_{0+}$  and  $E_{2-}$  SAID)

- New SAID solution CM12

# $E_{0+}$ and $E_{2-}$ Multipoles



Partial wave analysis



- $E_{0+}$  multipole, s-wave  
 $S_{11}(1535)$ ,  $S_{11}(1650)$  and  $S_{31}(1620)$
- $E_{2-}$  multipole, d-wave  
 $D_{13}(1520)$  and  $D_{33}(1700)$

polarization observables necessary  
to constrain partial wave analysis  
(resonance + background contribution)

# Polarization Observables with trans. pol. Target

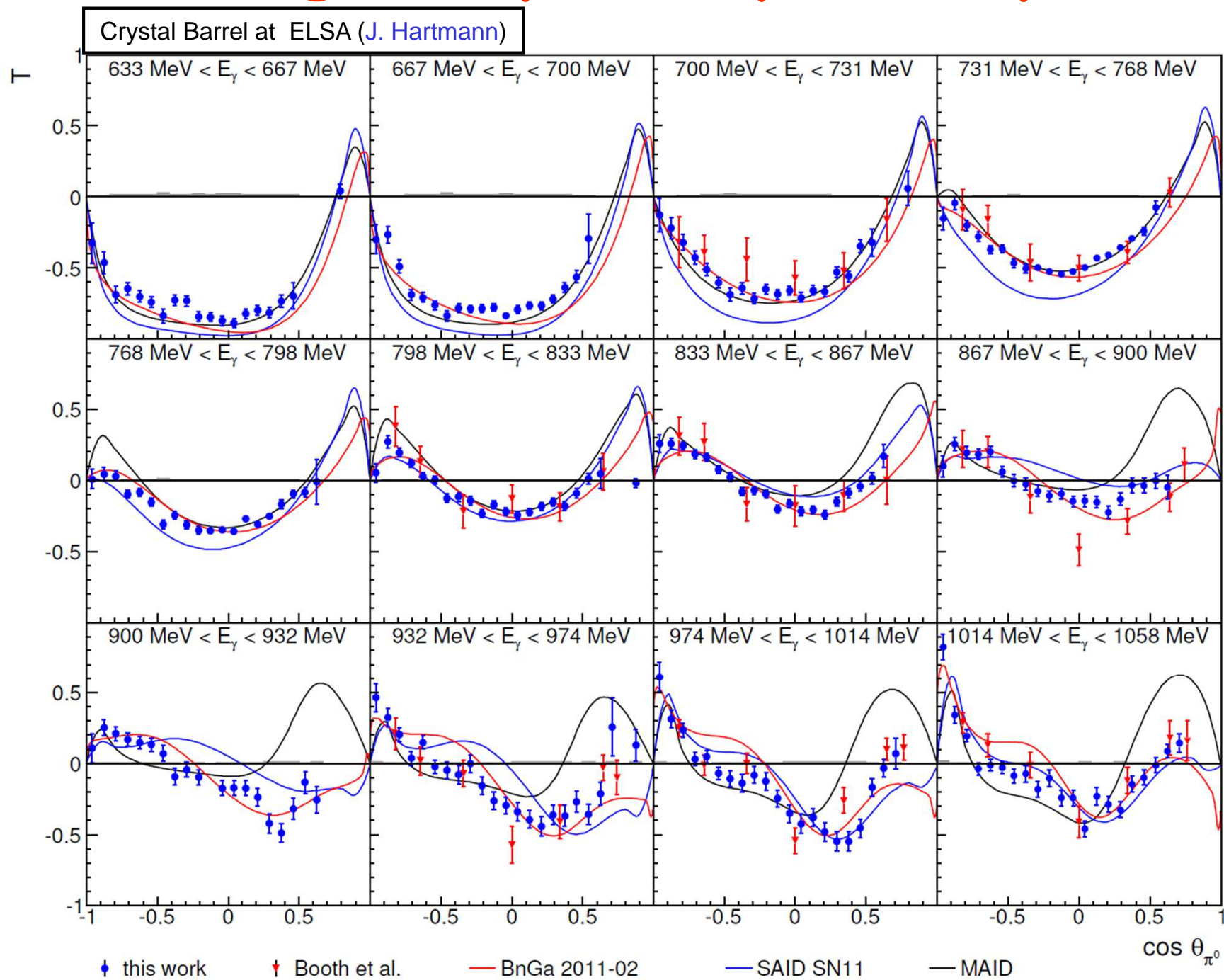
photon pol.		target pol. axis		
		$x$	$y$	$z$
unpolarized	$\sigma$		$T$	
linear	$-\Sigma$	$H$	$-P$	$-G$
circular		$F$		$-E$

Circularly polarized photons  
 Transversely polarized protons → double polarization asymmetry  $F$

Linearly polarized photons  
 Transversely polarized protons → double polarization asymmetry  $H$  and  $P$

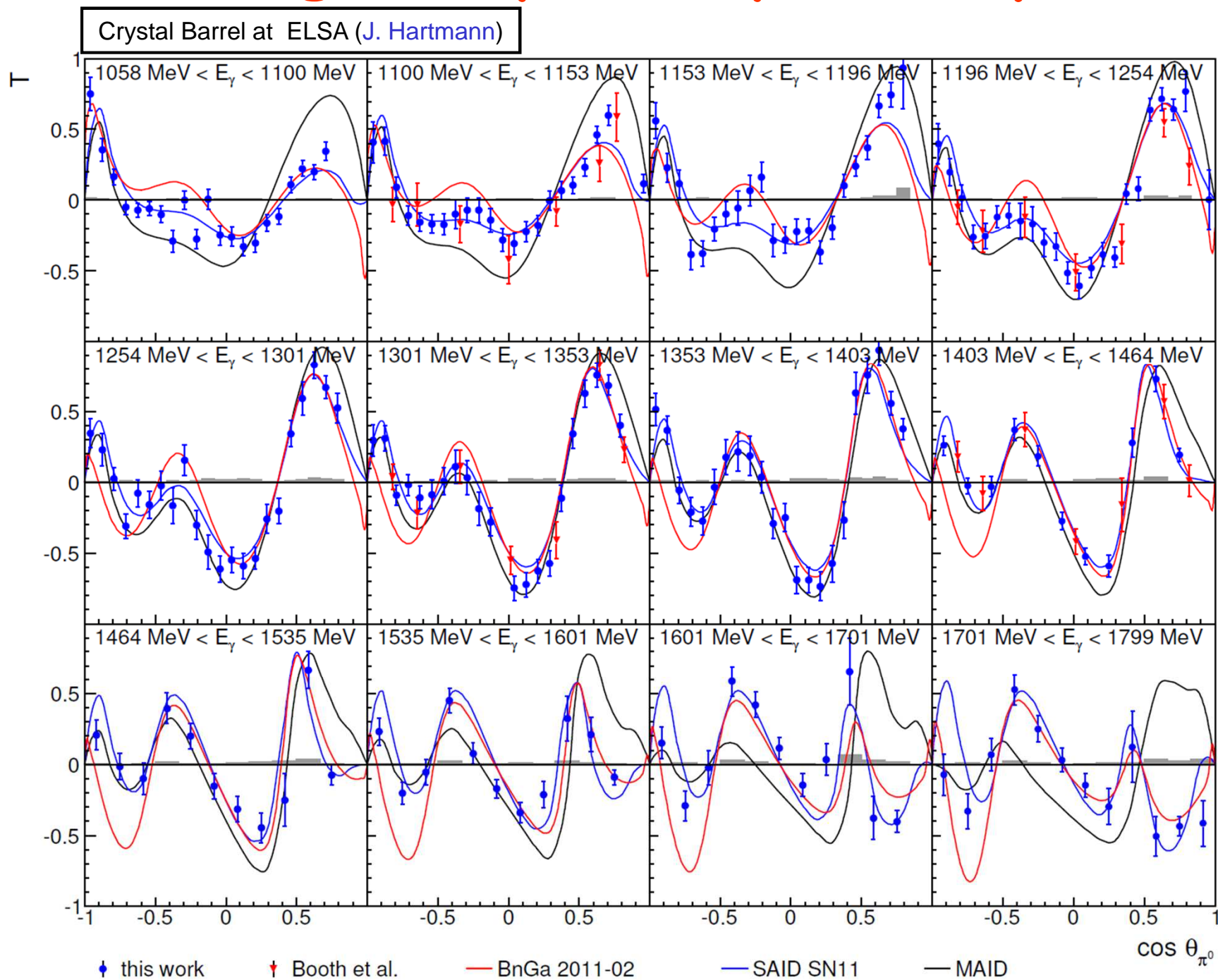
→ in addition Beam asymmetry  $\Sigma$  and  
 Target asymmetry  $T$

# Target Asymmetry $T$ for $p\pi^0$

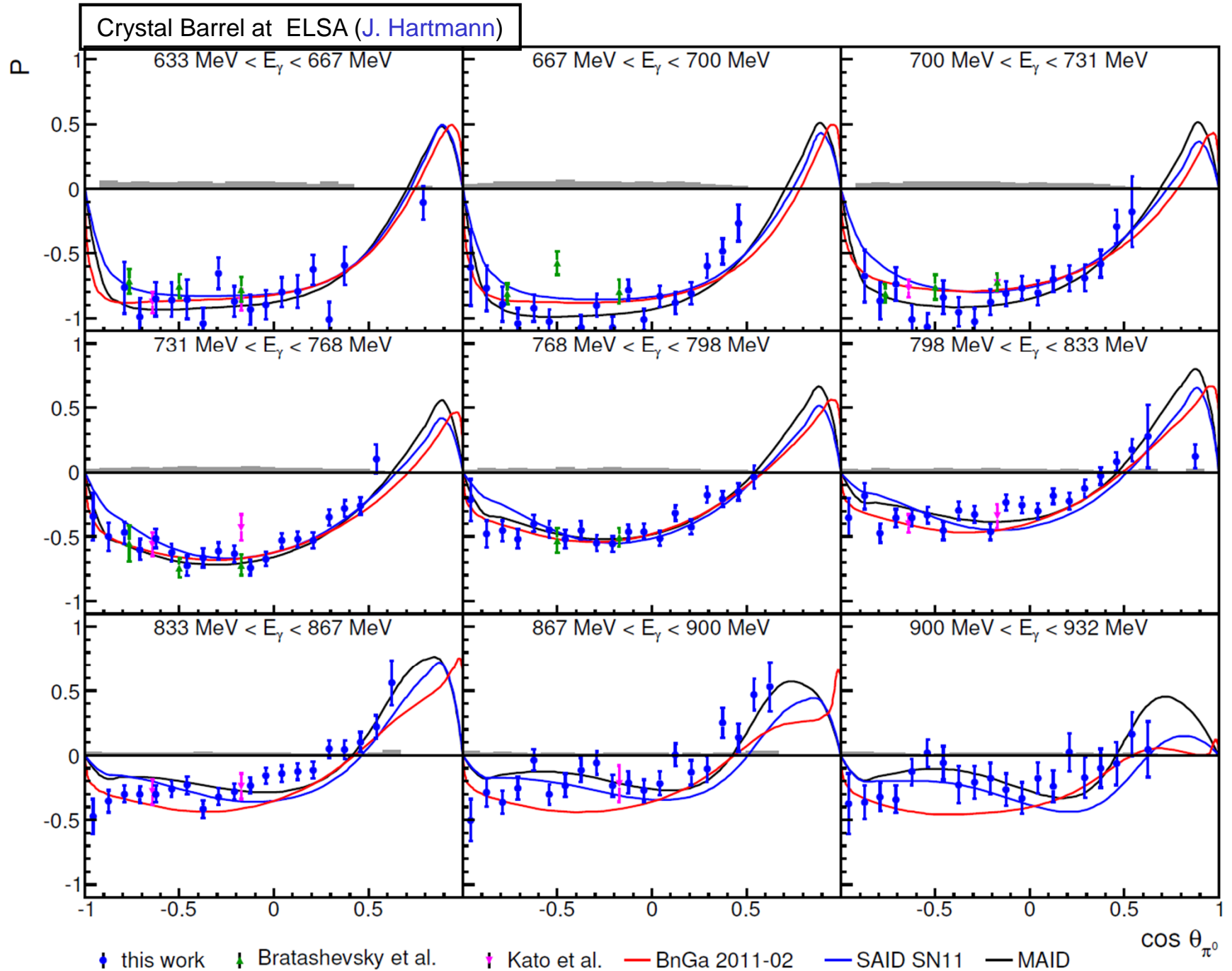




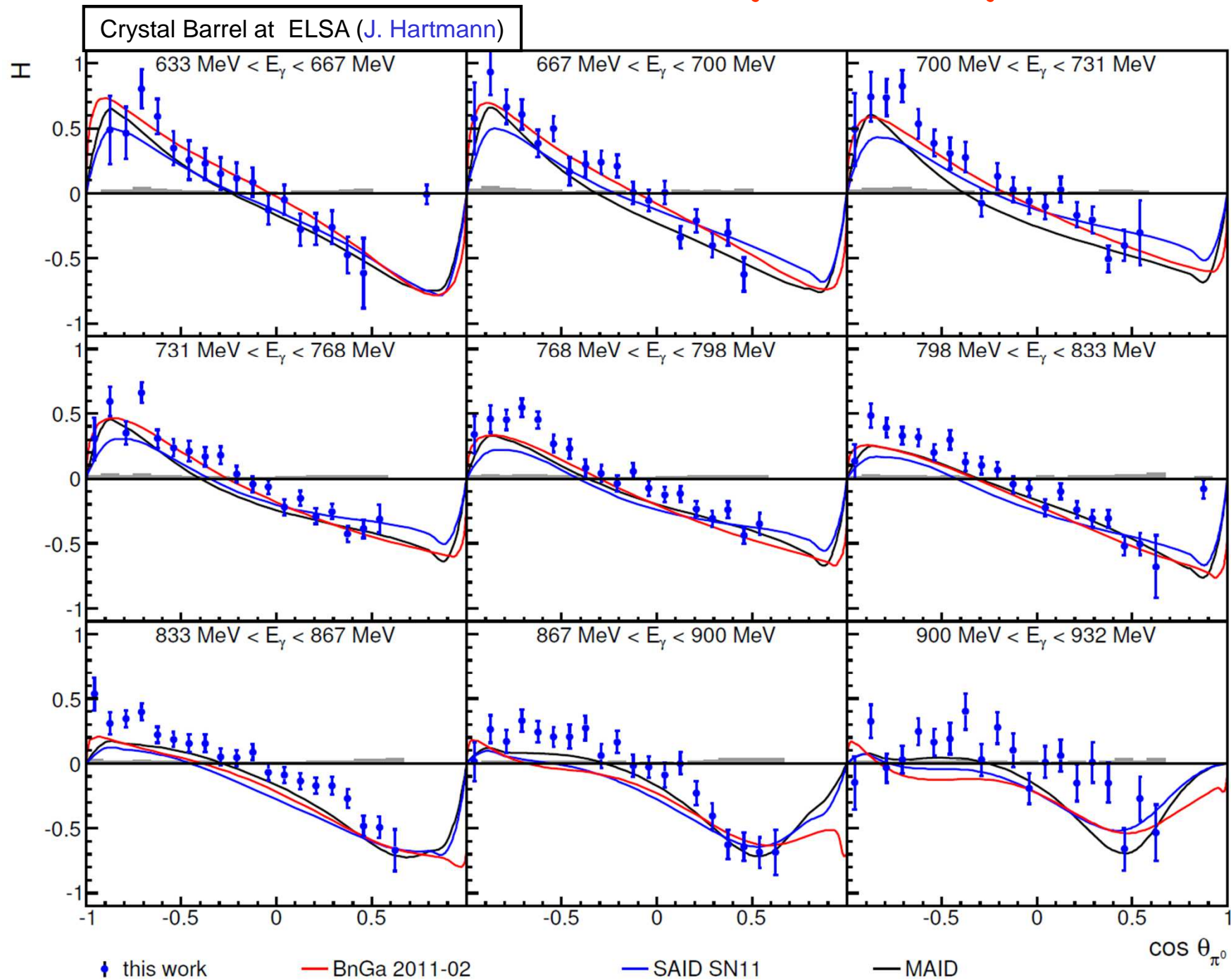
# Target Asymmetry $T$ for $p\pi^0$



# Recoil Polarization $P$ for $p\pi^0$

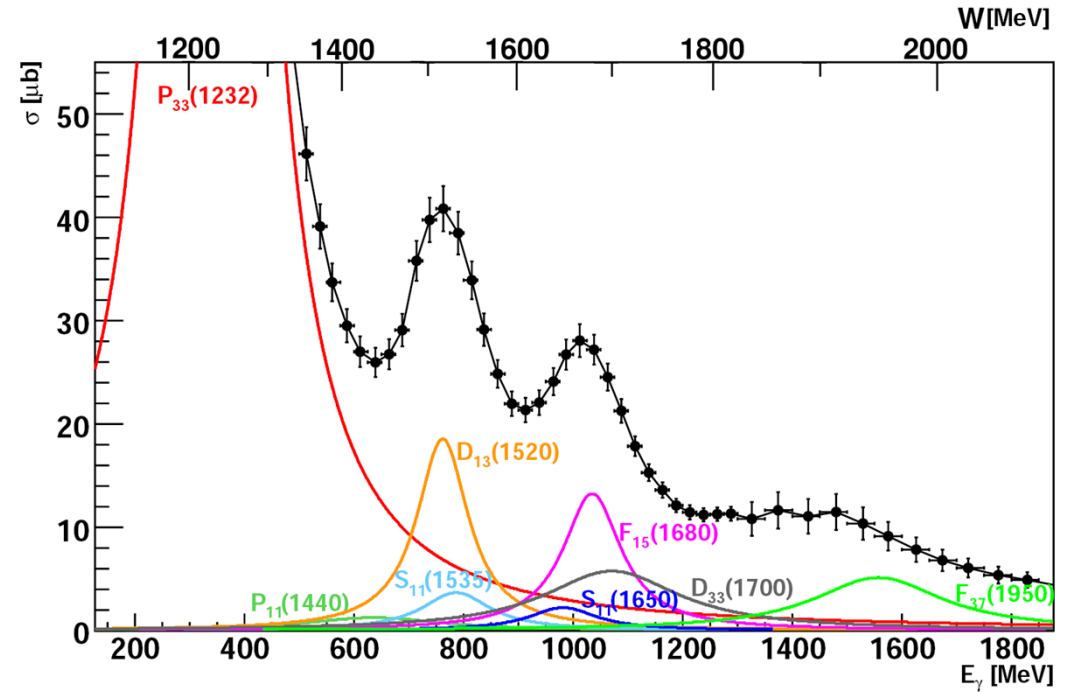
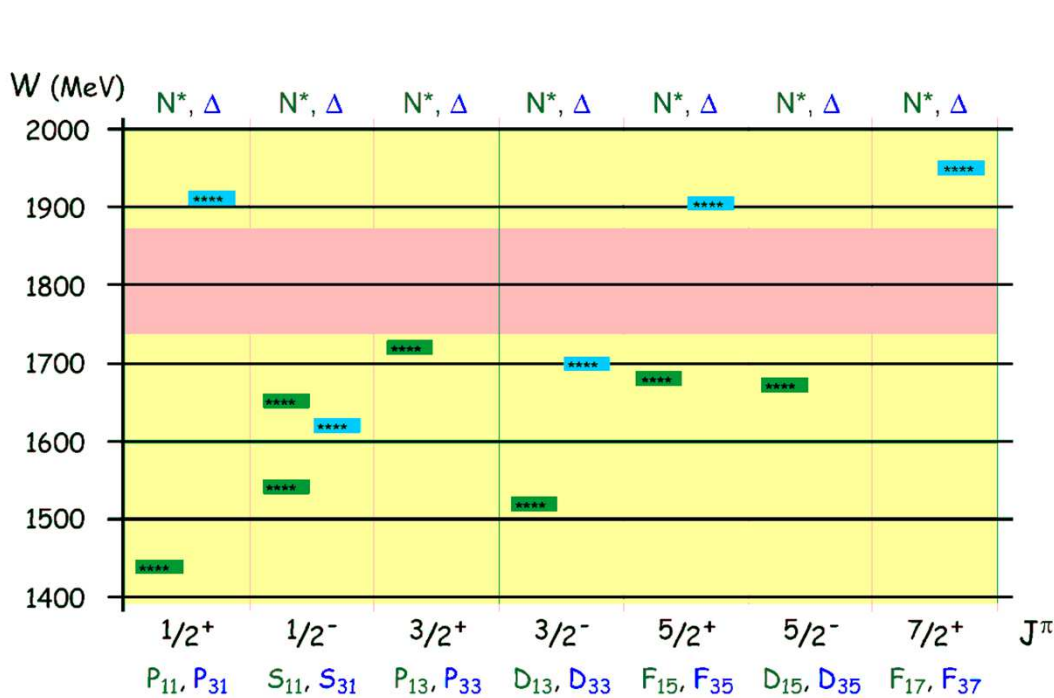


# Double Polarization Asymmetry $H$ for $p\pi^0$





# Impact of the new Data



Which  $L_{\max}$  is seen in the new data  $\rightarrow$  truncated partial wave analysis possible

$L_{\max} = 0$  , **S-wave** , resonances in S-wave:  $S_{11}(1535)$ ,  $S_{11}(1650)$ ,  $S_{31}(1620)$

$L_{\max} = 1$  , **P-wave** , resonances in P-wave:  $P_{11}(1440)$ ,  $P_{13}(1710)$ ,  $P_{33}(1232)$

$L_{\max} = 2$  , **D-wave** , resonances in D-wave:  $D_{13}(1520)$ ,  $D_{15}(1680)$ ,  $D_{33}(1700)$

$L_{\max} = 3$  , **F-wave** , resonances in F-wave:  $F_{15}(1680)$ ,  $F_{37}(1950)$

# $L_{\max}$ Interpretation of $G$ -Asymmetry

for  $L_{\max} \leq 1$  :

$$\hat{G} = \frac{G \cdot \frac{d\sigma}{d\Omega}}{\sin^2(\theta)} = A_0 = \text{constant}$$

for  $L_{\max} \leq 2$  :

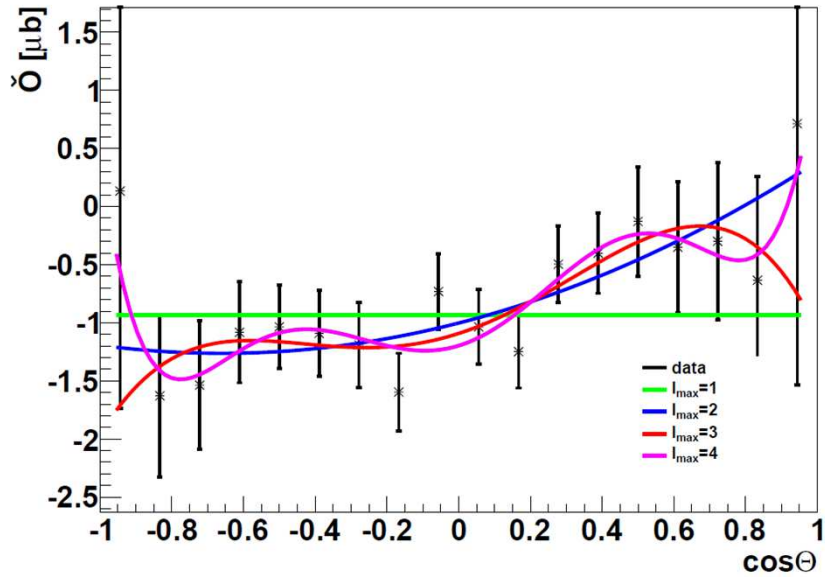
$$\hat{G} = \frac{G \cdot \frac{d\sigma}{d\Omega}}{\sin^2(\theta)} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta)$$

for  $L_{\max} \leq 3$  :

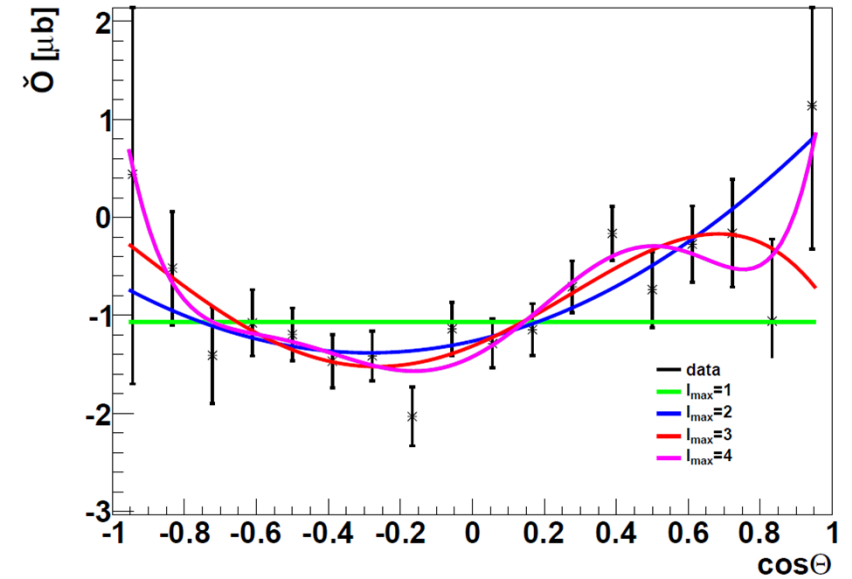
$$\hat{G} = \frac{G \cdot \frac{d\sigma}{d\Omega}}{\sin^2(\theta)} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta) + A_3 \cdot \cos^3(\theta) + A_4 \cdot \cos^4(\theta)$$

# Lmax Interpretation of G-Asymmetry

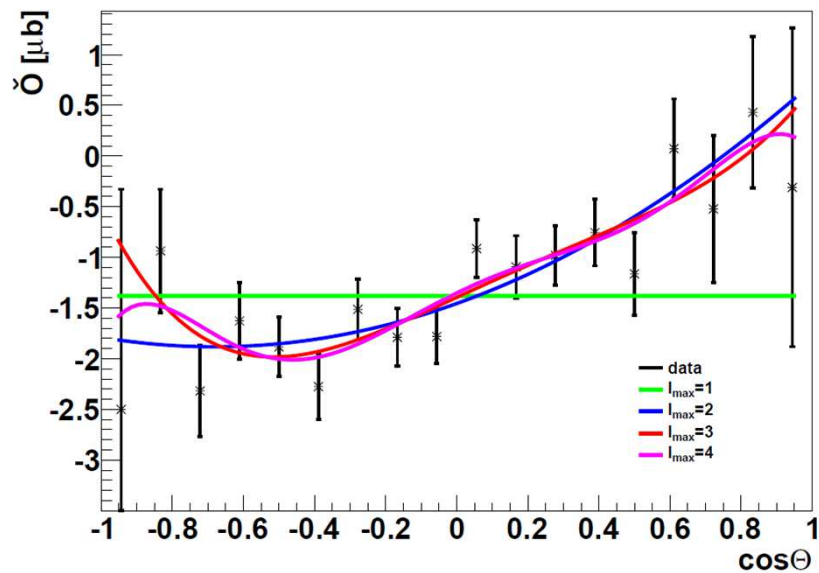
W=1438 MeV



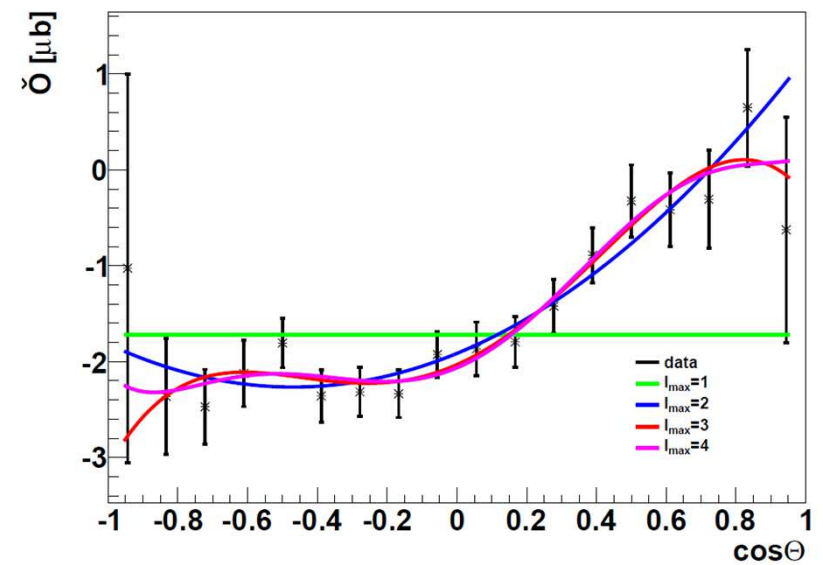
W=1460 MeV



W=1481 MeV

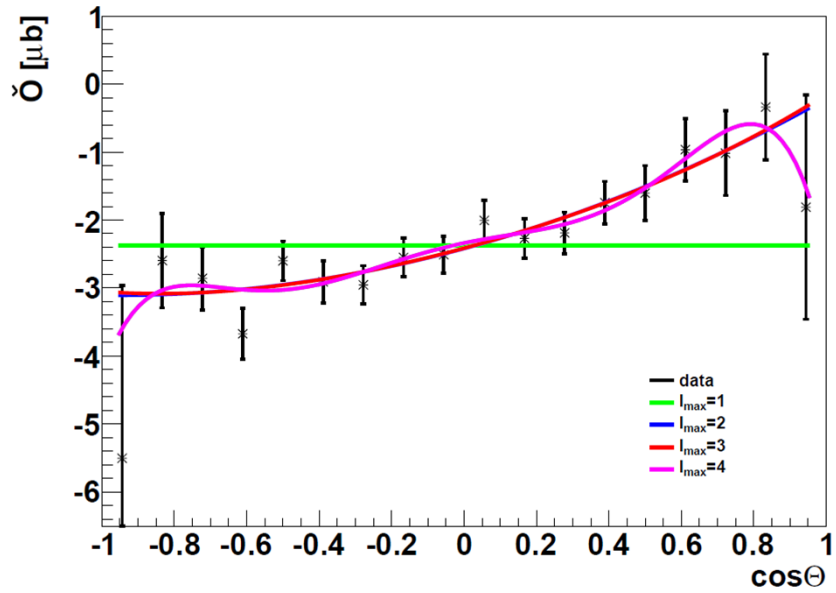


W=1502 MeV

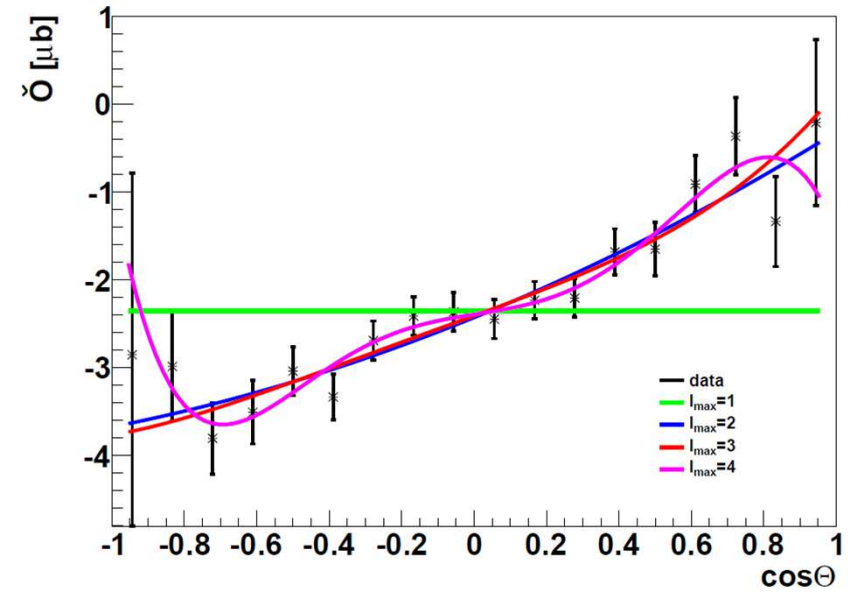


# Lmax Interpretation of G-Asymmetry

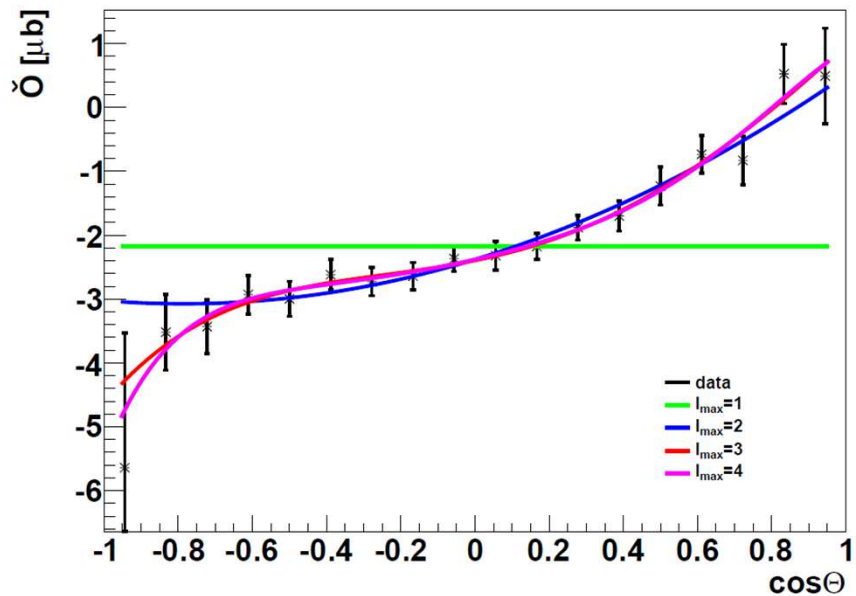
W=1523 MeV



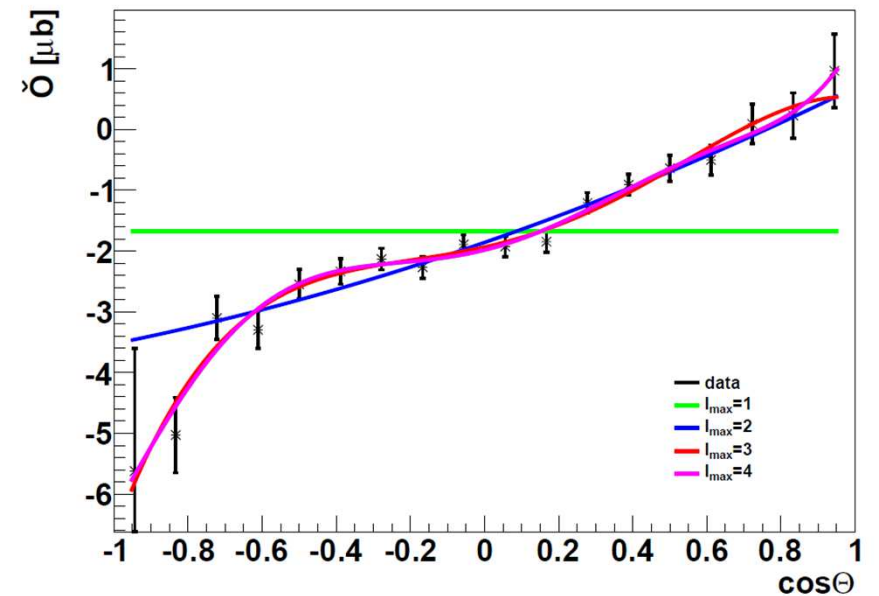
W=1543 MeV



W=1563 MeV

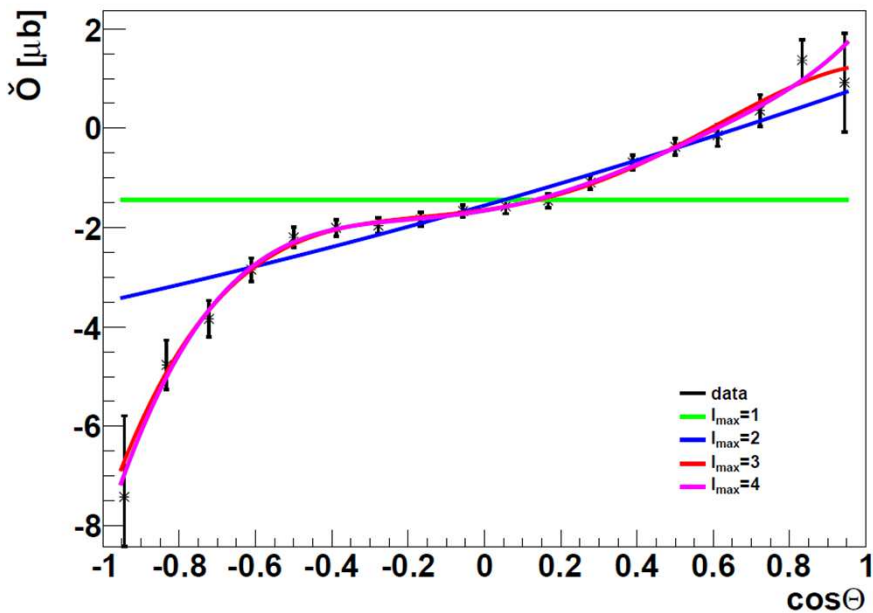


W=1584 MeV

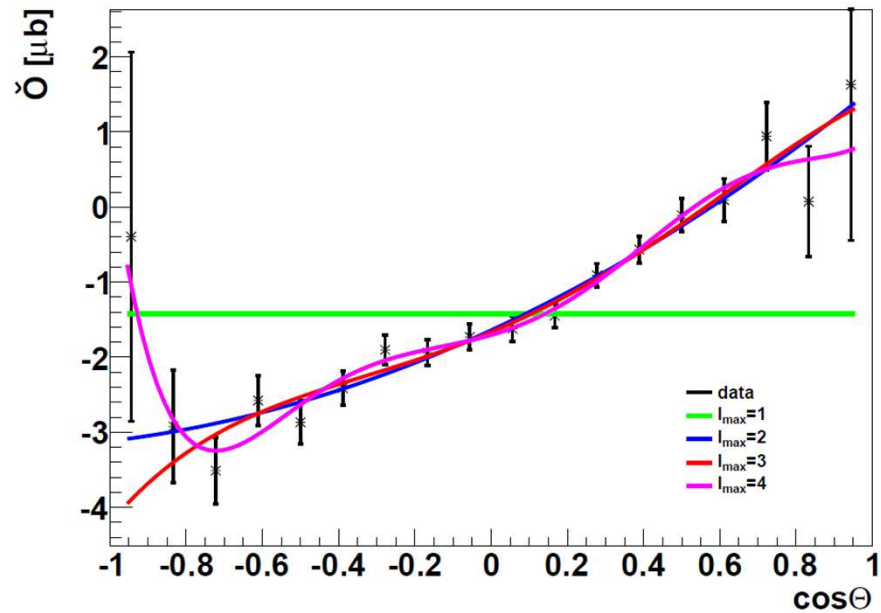


# Lmax Interpretation of G-Asymmetry

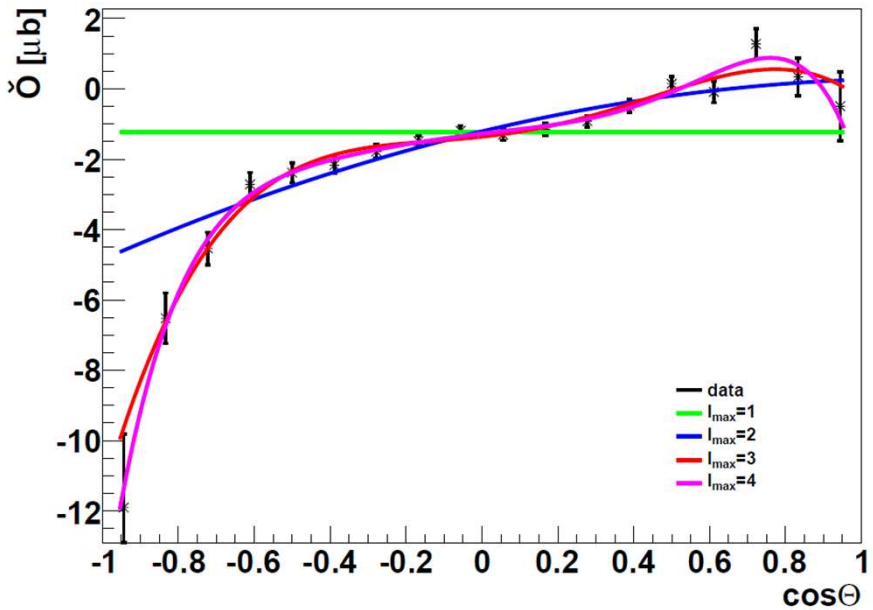
W=1603 MeV



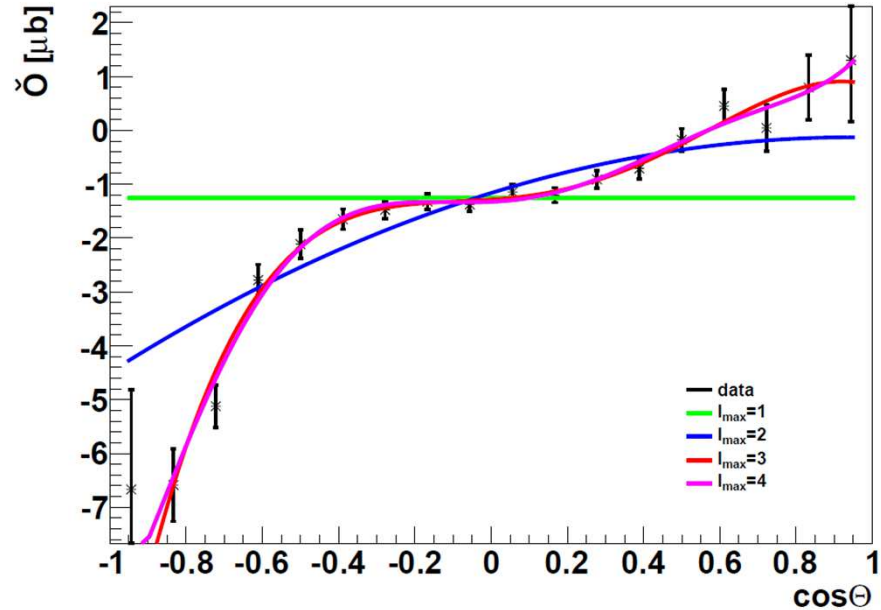
W=1622 MeV



W=1642 MeV

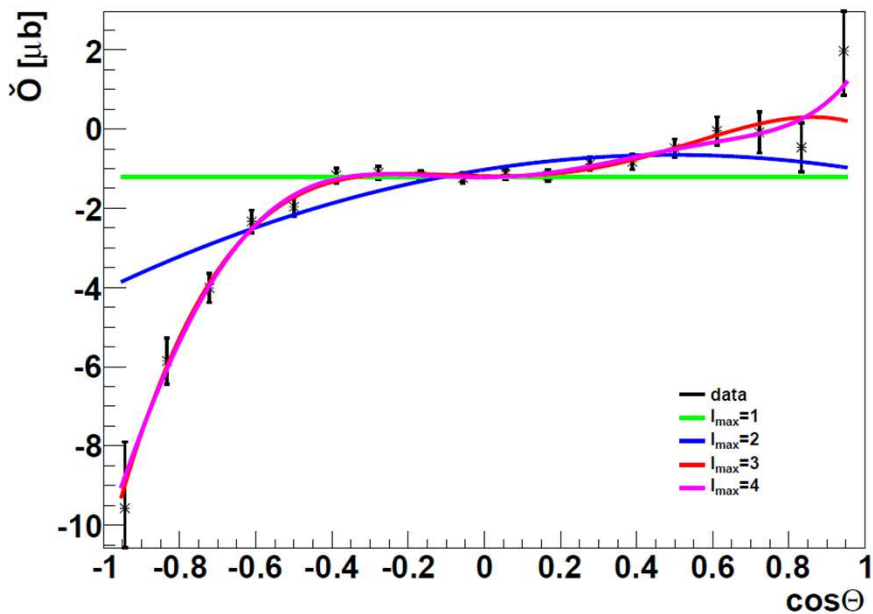


W=1660 MeV

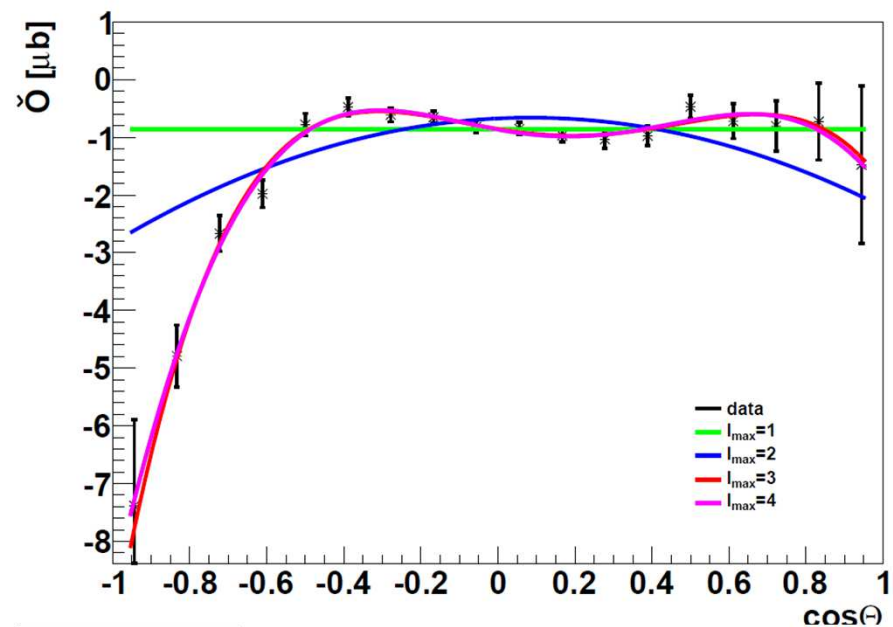


# Lmax Interpretation of G-Asymmetry

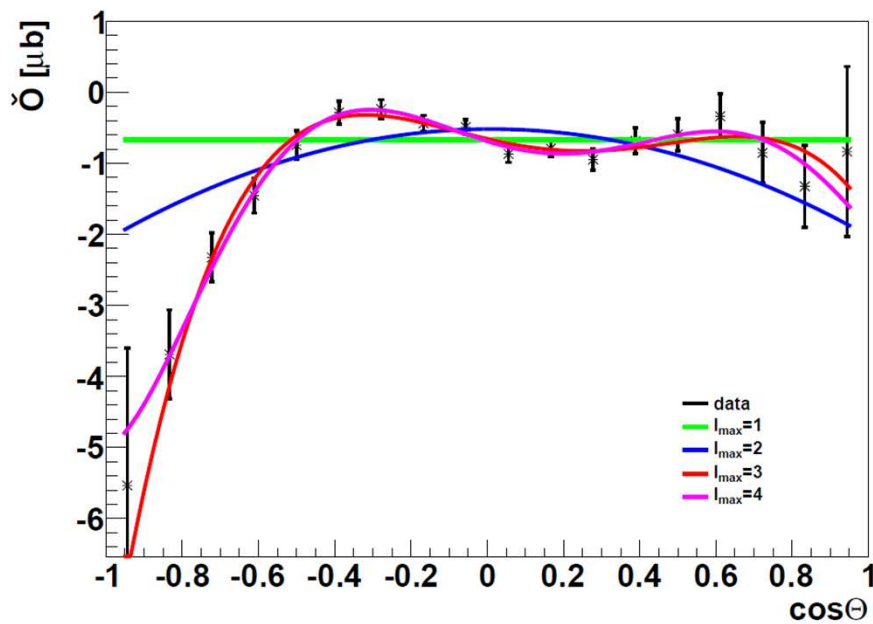
W=1679 MeV



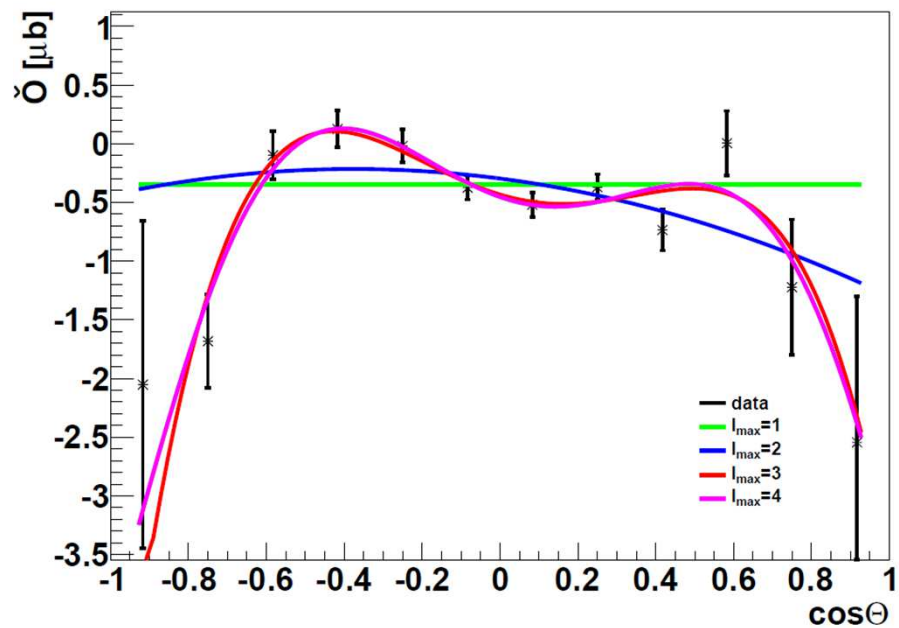
W=1698 MeV



W=1716 MeV



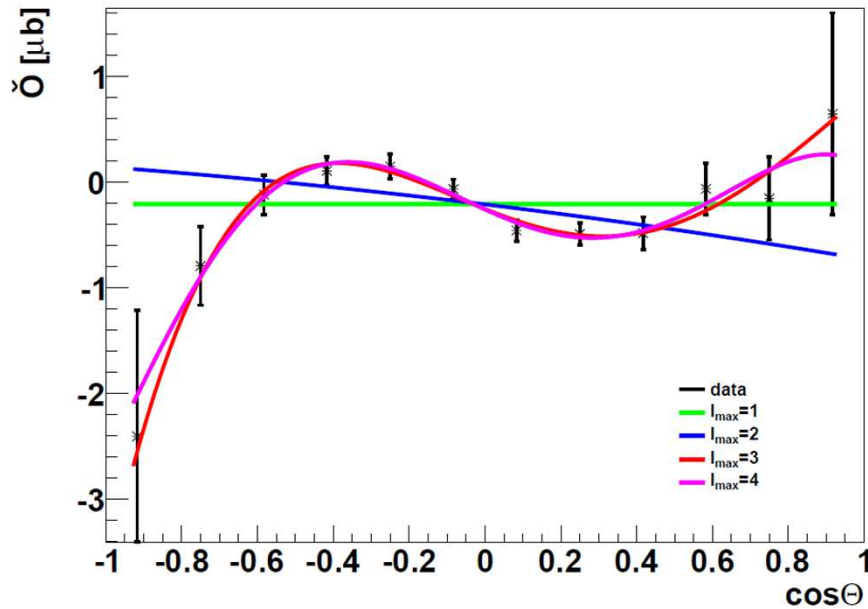
W=1743 MeV



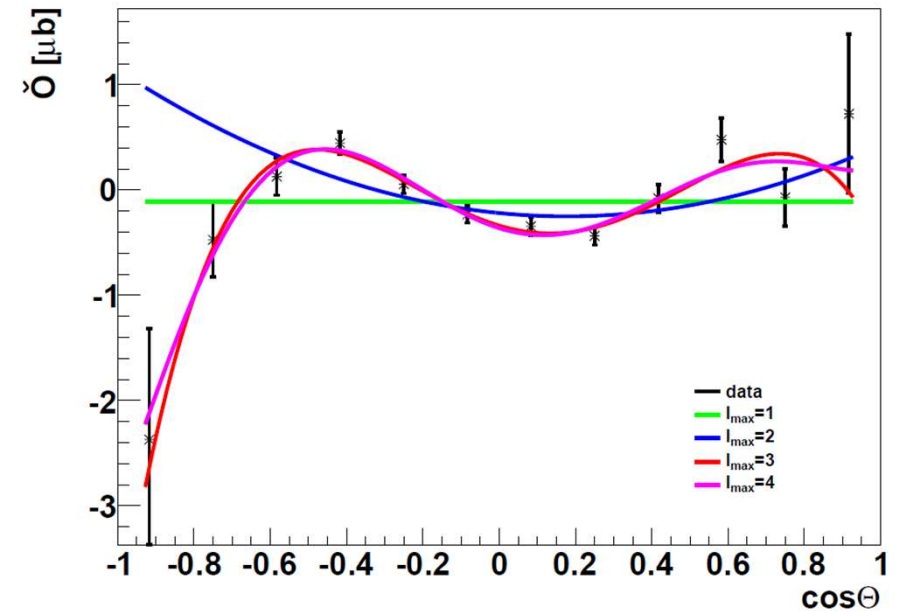


# Lmax Interpretation of G-Asymmetry

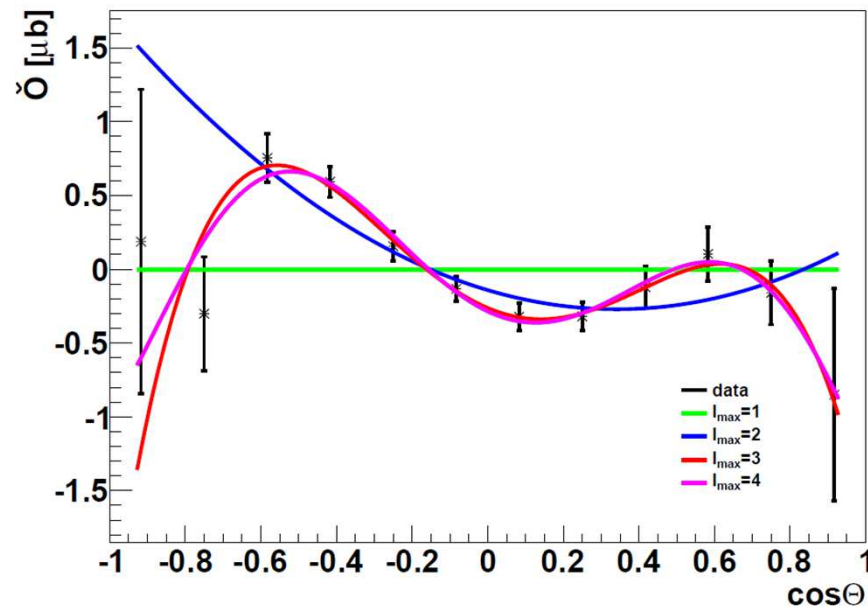
W=1770 MeV



W=1796 MeV

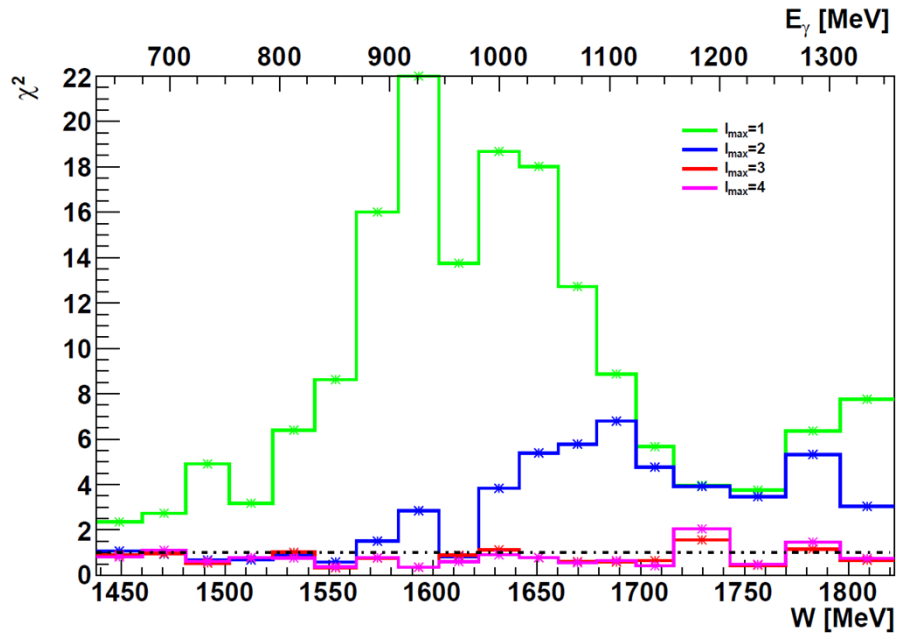


W=1822 MeV



- Full angular coverage important
- Precision is important

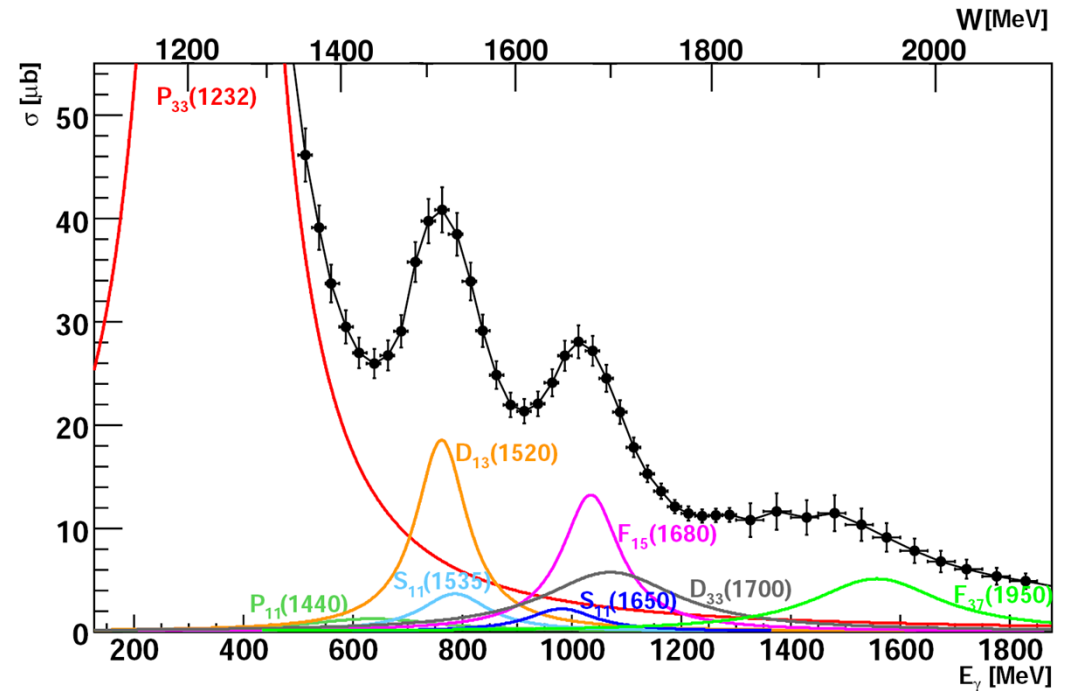
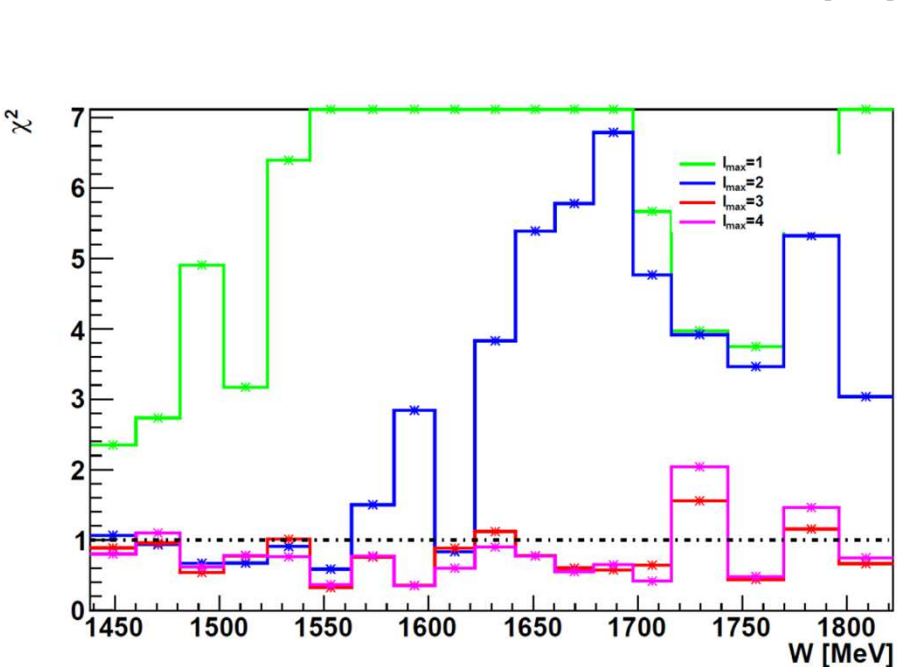
# Lmax Interpretation of G-Asymmetry



Significant  $L = 3$  signal seen  
above  $W = 1550$  ( $E = 850$  MeV)

Below  $L \leq 2$  seems to be sufficient

No Significant  $L=4$  signal until  $W=1850$  ( $E = 1350$  MeV)





# Lmax Interpretation of E-Asymmetry

for  $L_{\max} \leq 1$  :

$$E = E \cdot \frac{d\sigma}{d\Omega} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta)$$

for  $L_{\max} \leq 2$  :

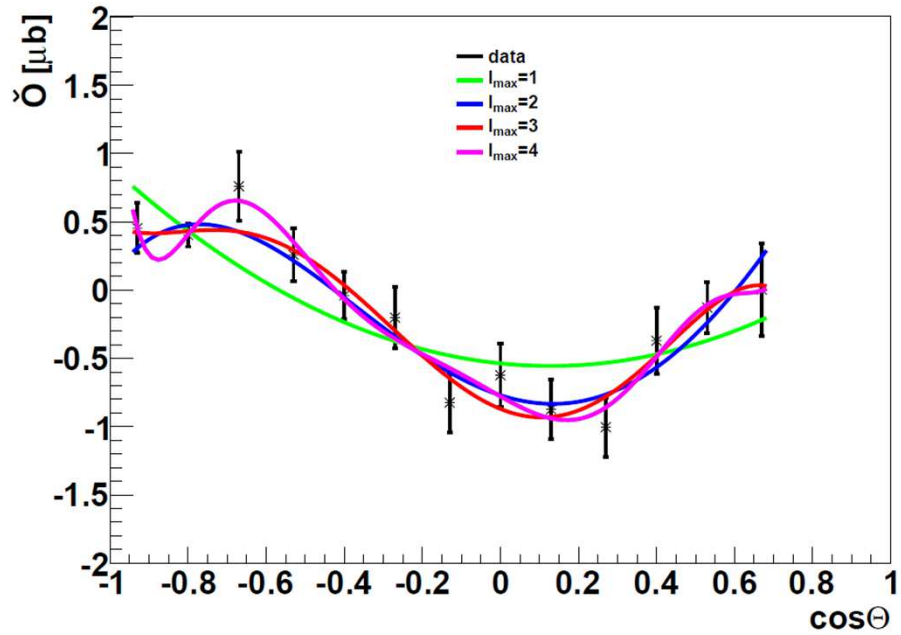
$$E = E \cdot \frac{d\sigma}{d\Omega} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta) + A_3 \cdot \cos^3(\theta) + A_4 \cdot \cos^4(\theta)$$

for  $L_{\max} \leq 3$  :

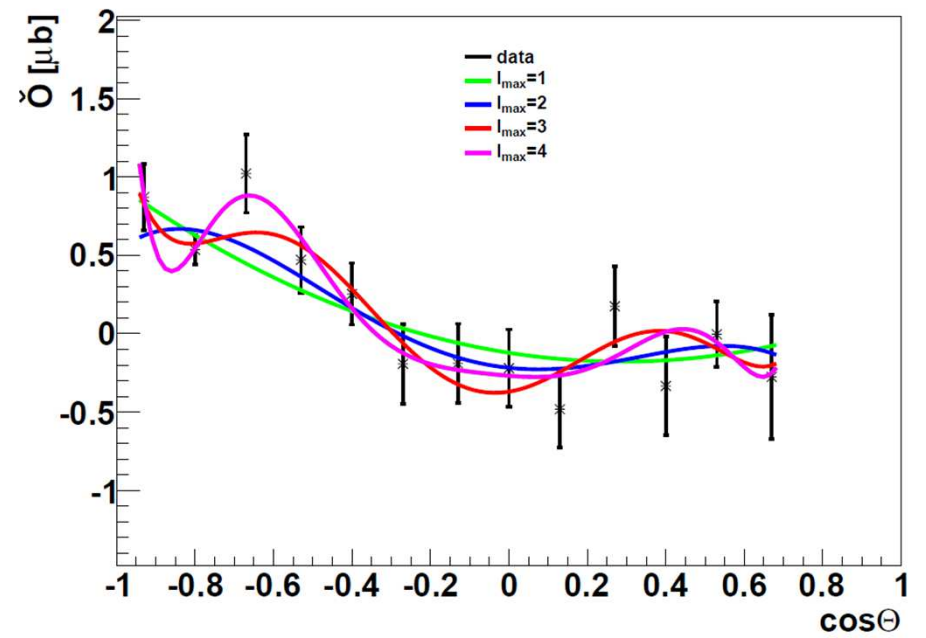
$$E = E \cdot \frac{d\sigma}{d\Omega} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta) + A_3 \cdot \cos^3(\theta) + A_4 \cdot \cos^4(\theta) \\ + A_5 \cdot \cos^5(\theta) + A_6 \cdot \cos^6(\theta)$$

# Lmax Interpretation of E-Asymmetry

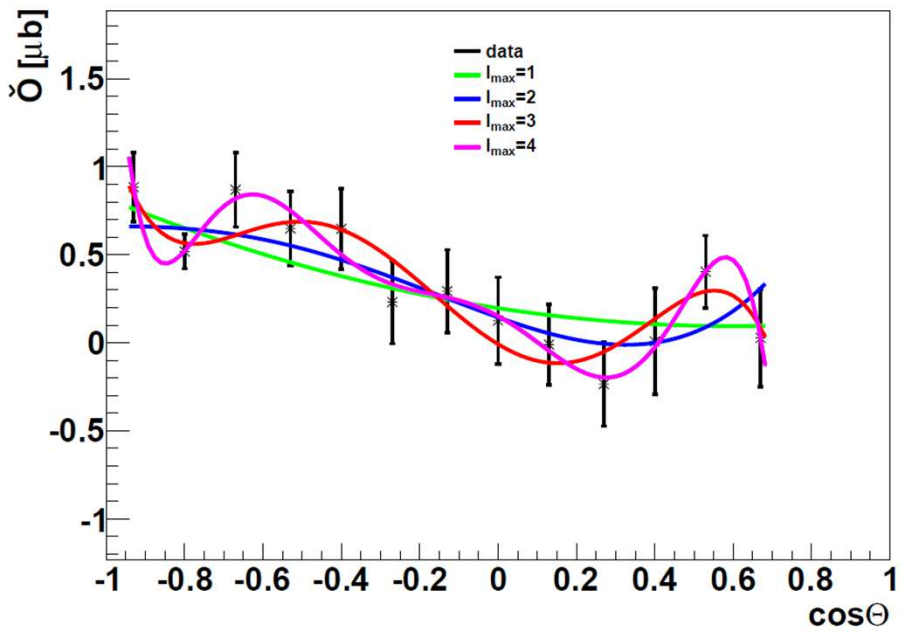
W=1426 MeV



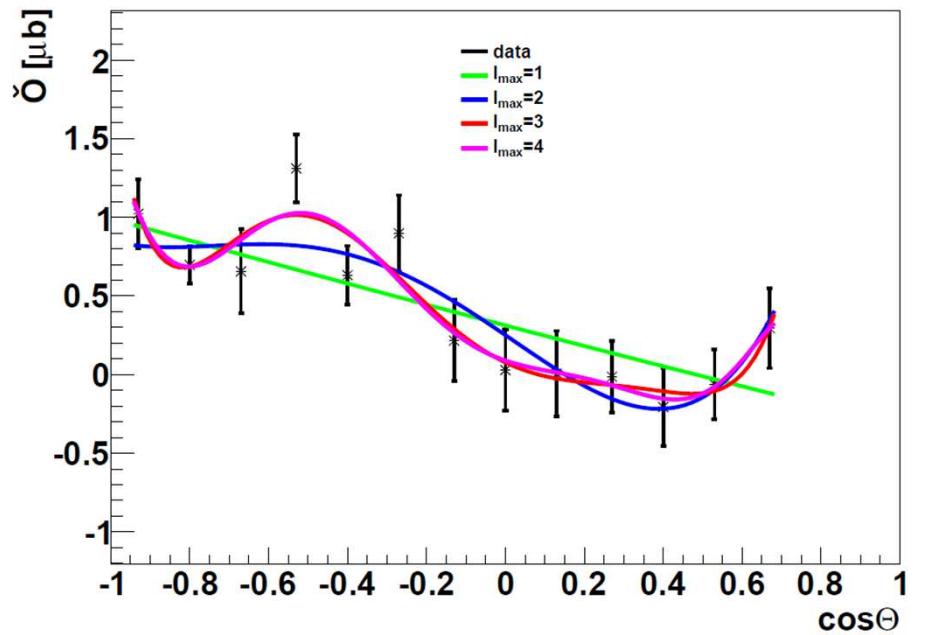
W=1446 MeV



W=1465 MeV

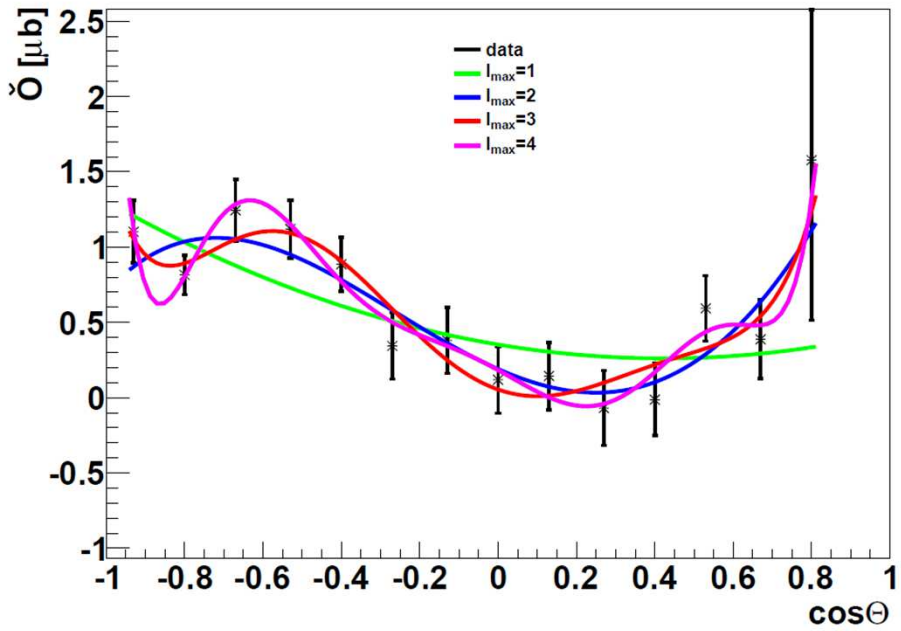


W=1484 MeV

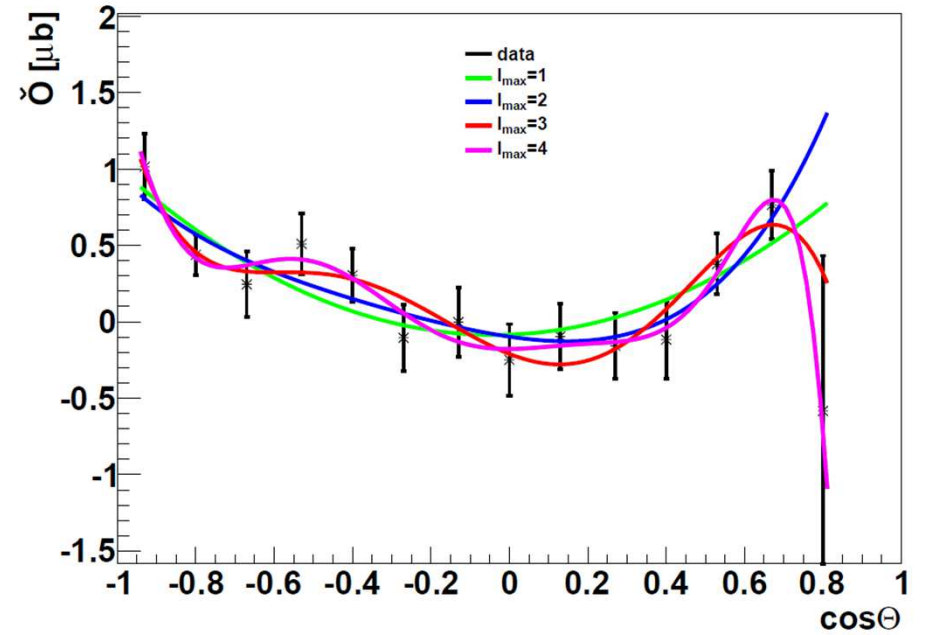


# Lmax Interpretation of E-Asymmetry

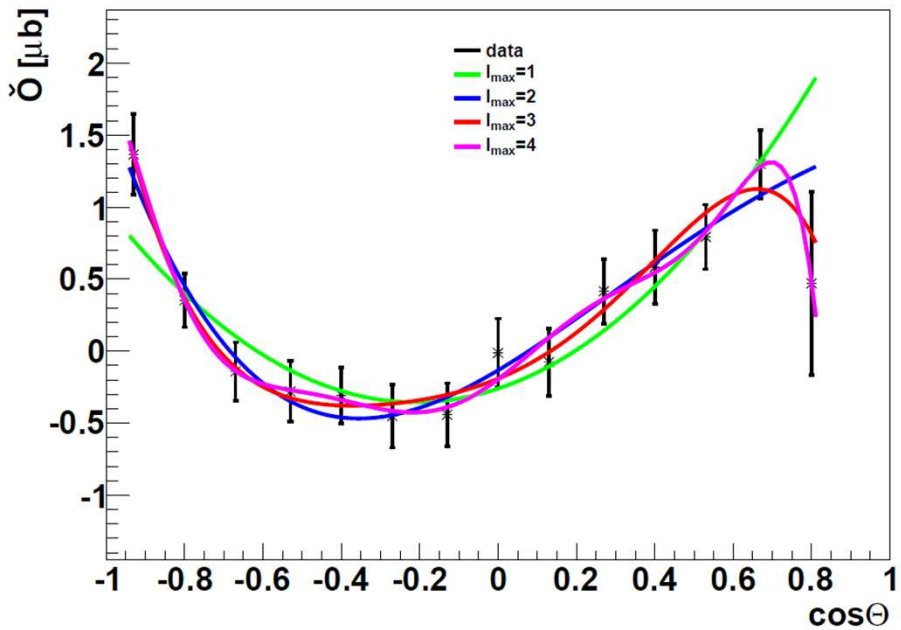
W=1503 MeV



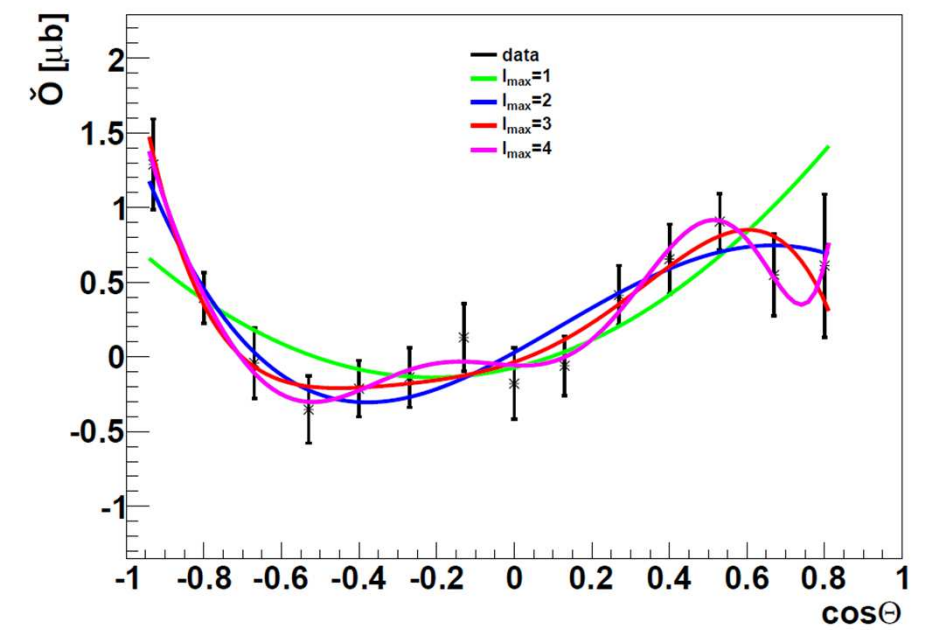
W=1522 MeV



W=1540 MeV

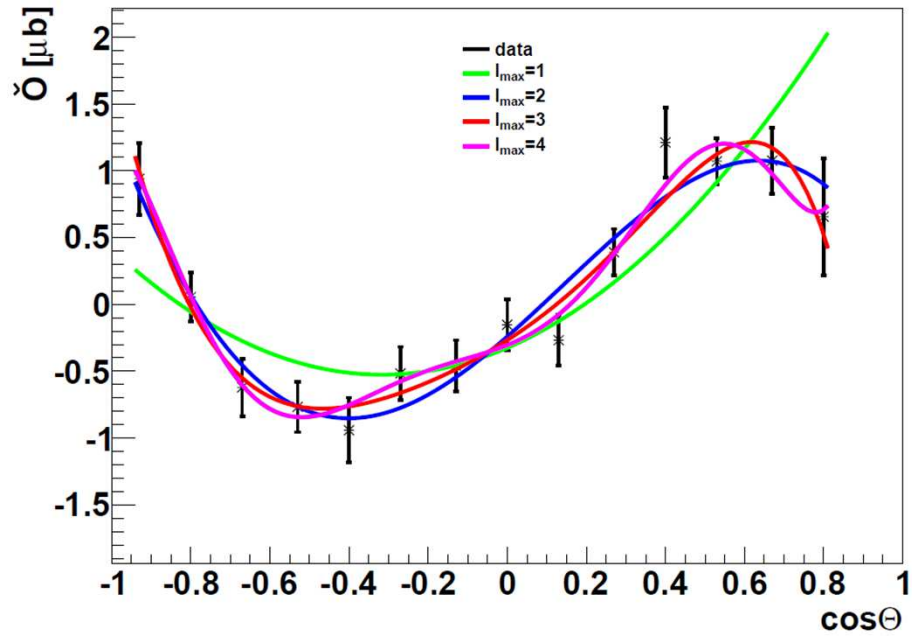


W=1558 MeV

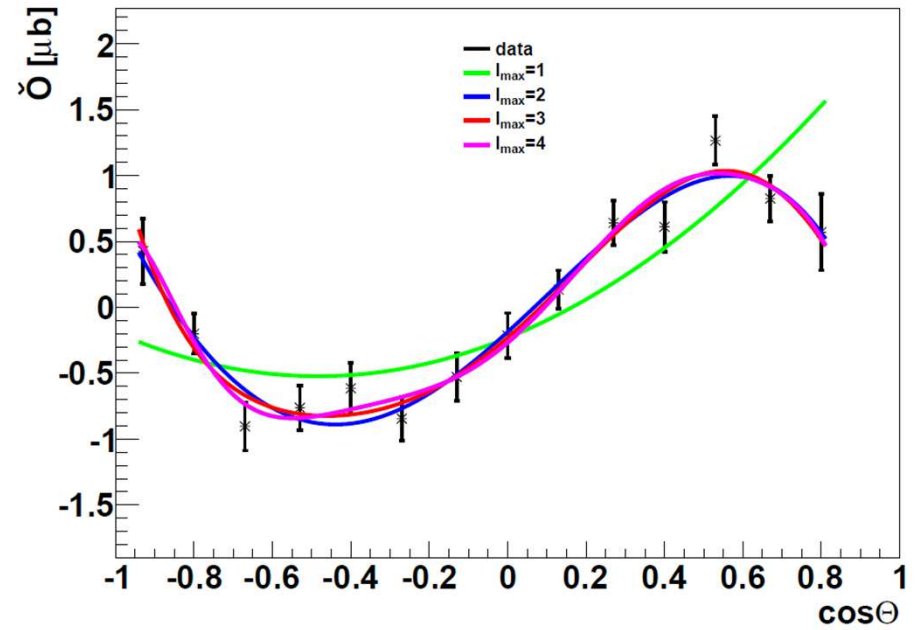


# Lmax Interpretation of E-Asymmetry

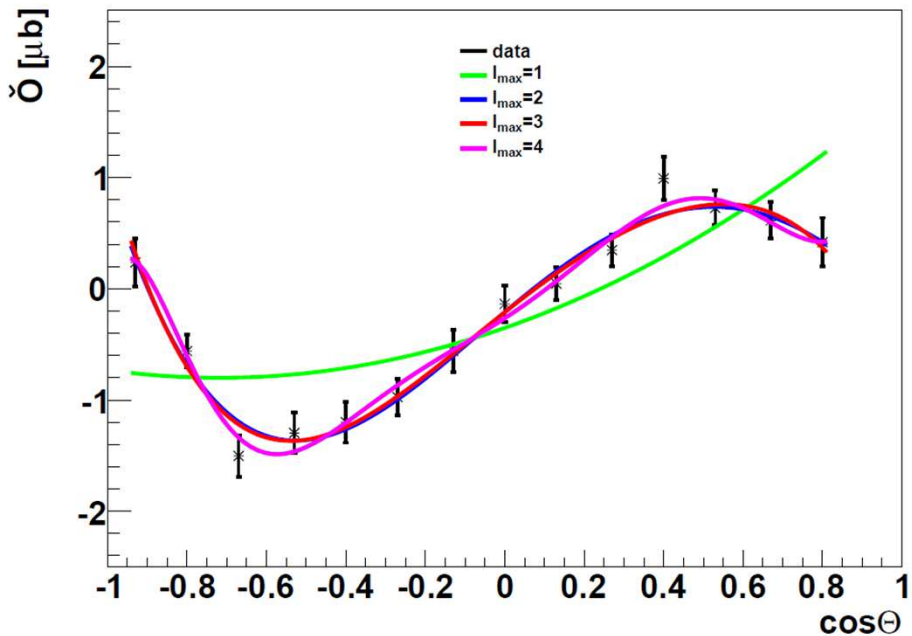
W=1576 MeV



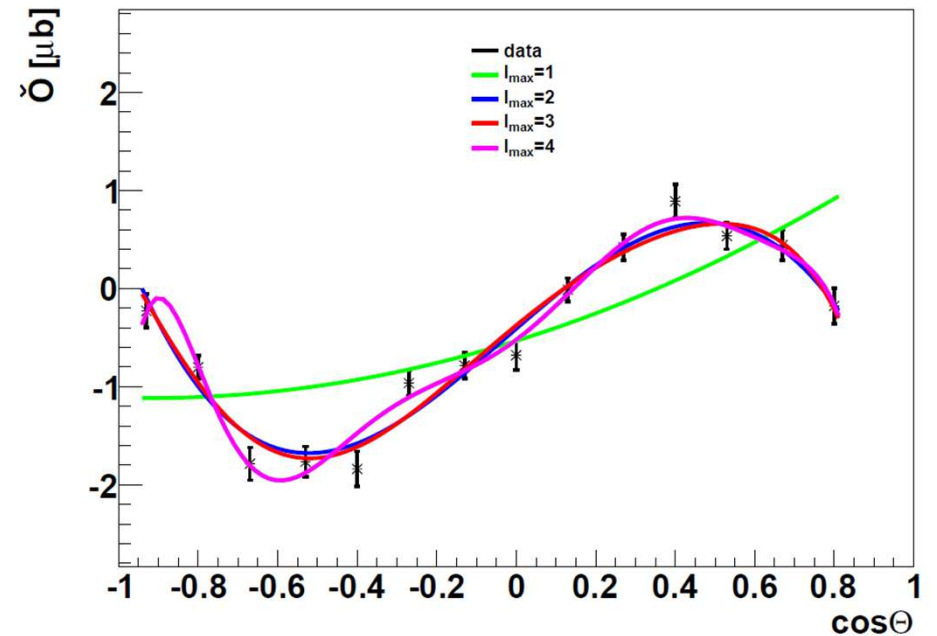
W=1594 MeV



W=1612 MeV

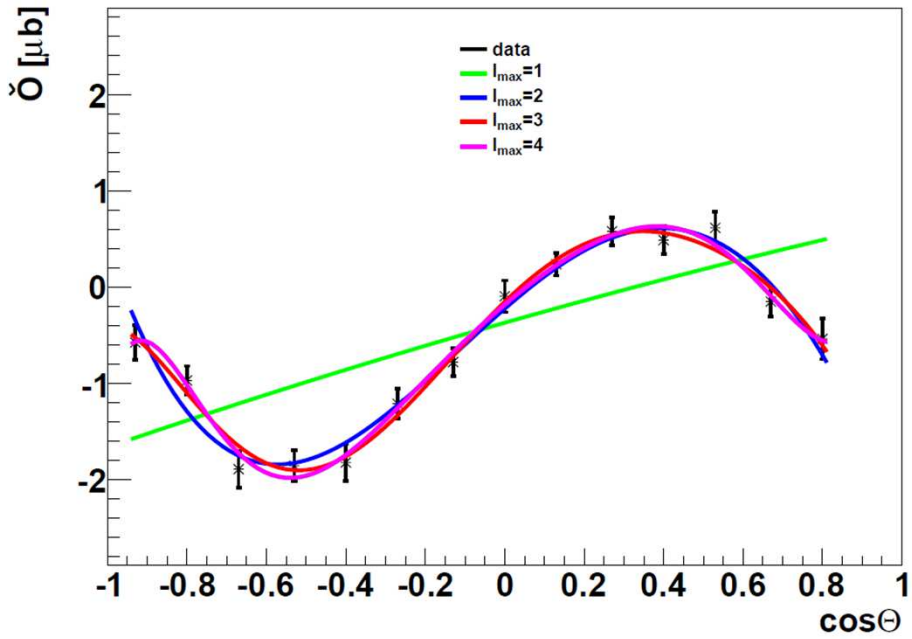


W=1629 MeV

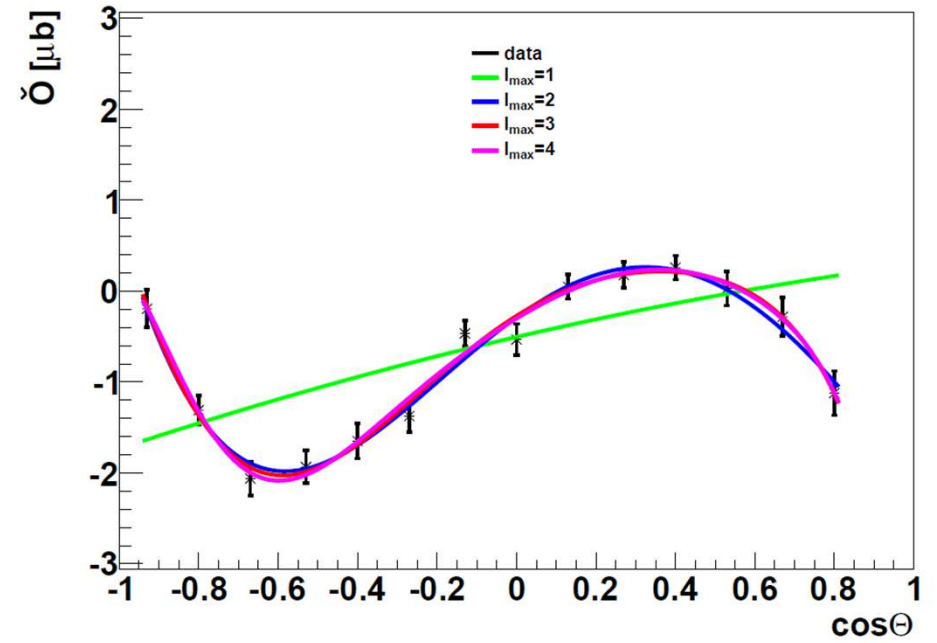


# Lmax Interpretation of E-Asymmetry

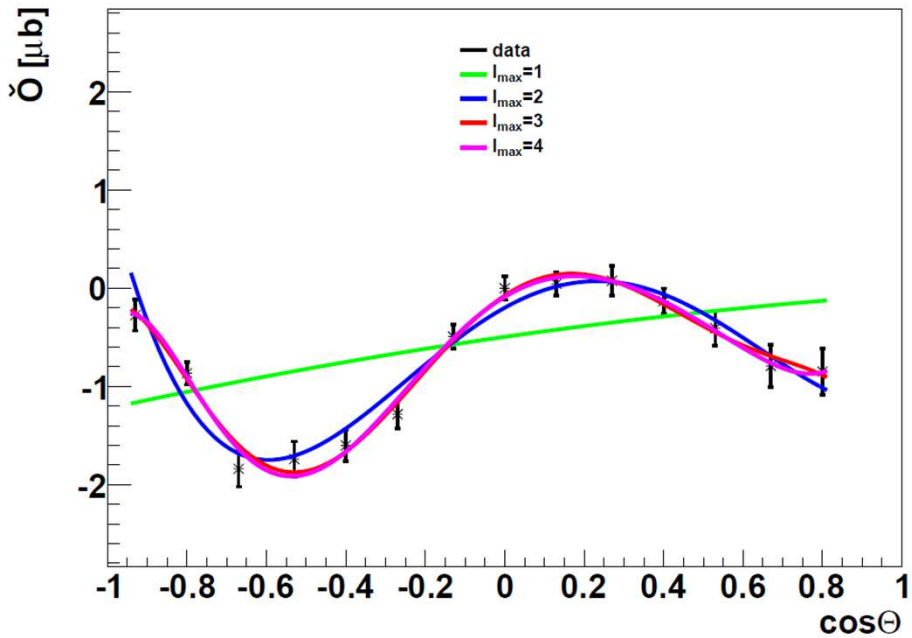
W=1646 MeV



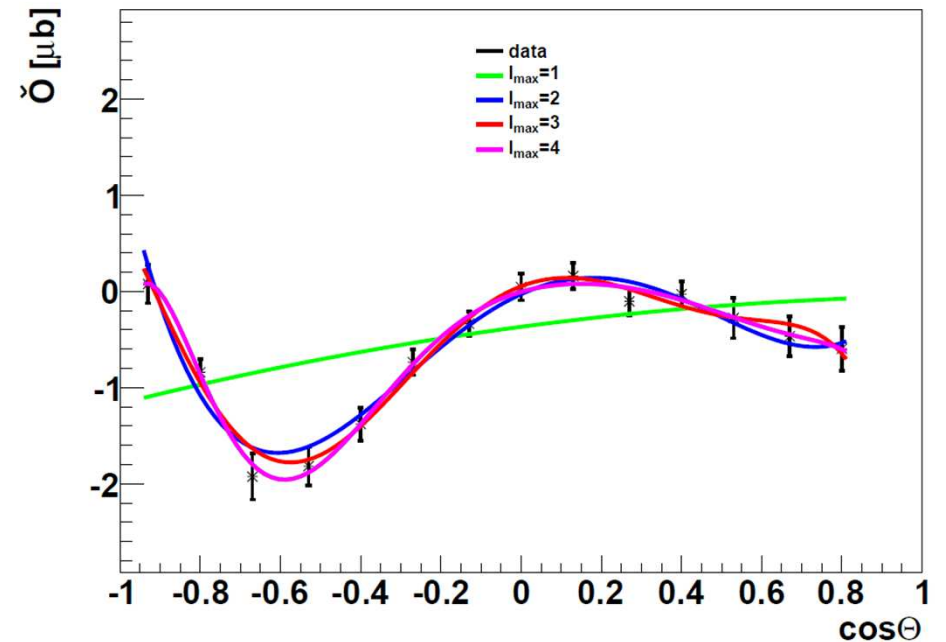
W=1663 MeV



W=1680 MeV



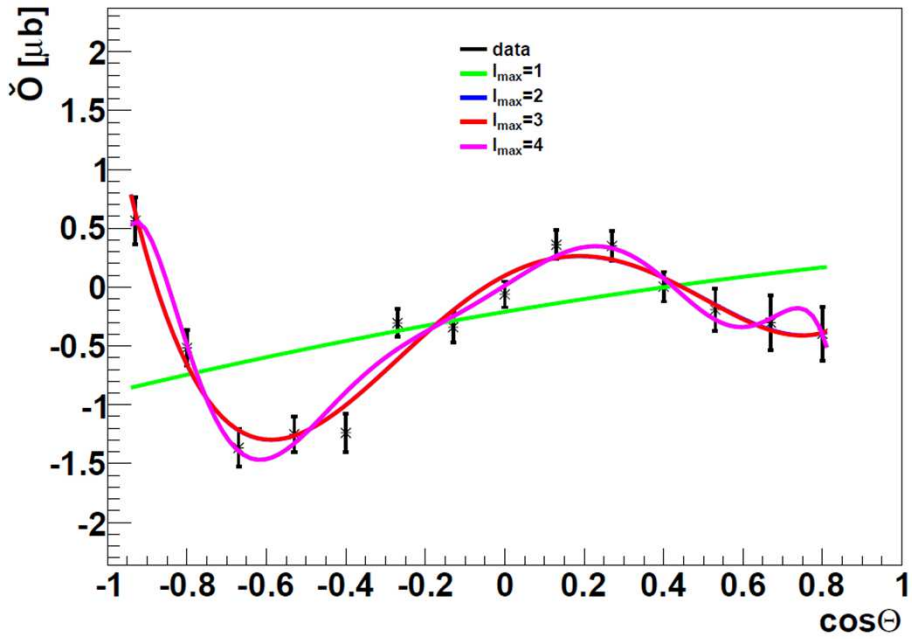
W=1697 MeV



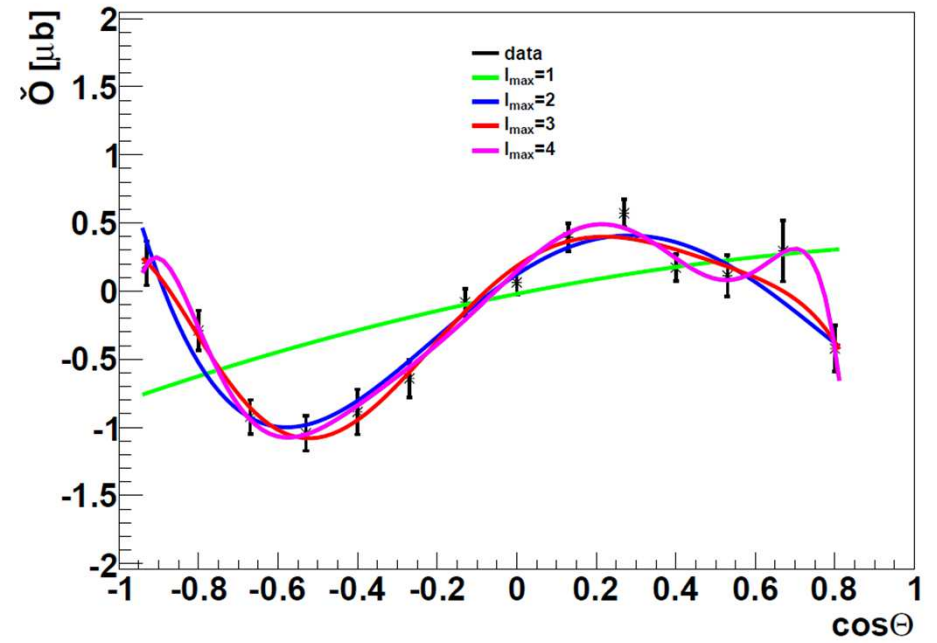


# Lmax Interpretation of E-Asymmetry

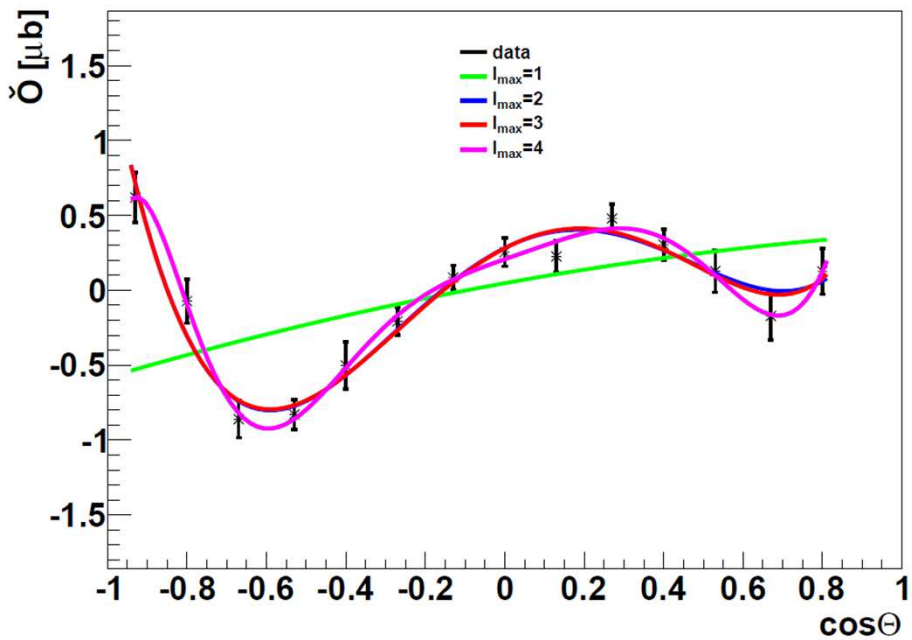
W=1713 MeV



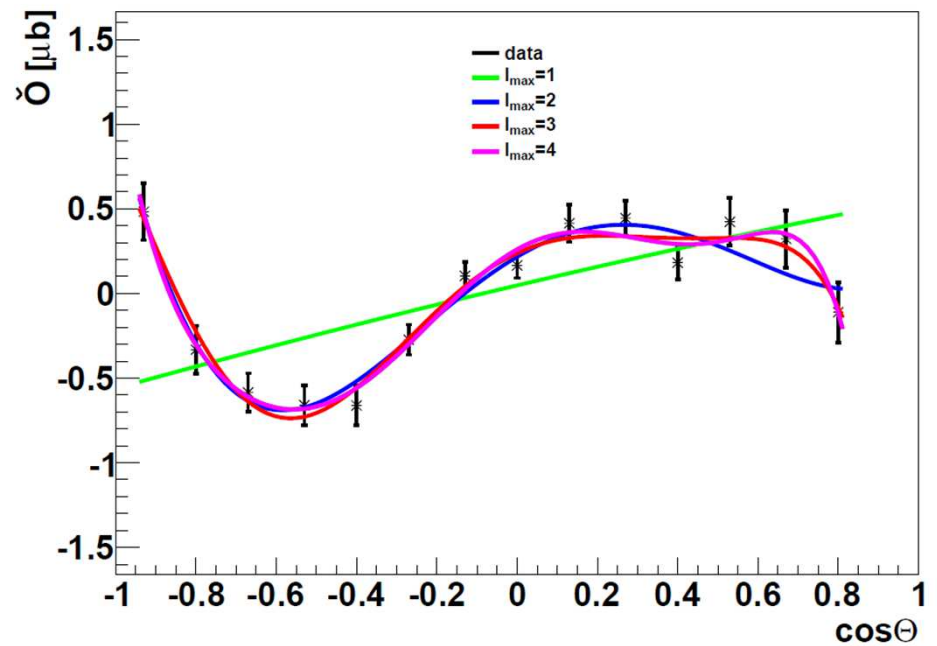
W=1730 MeV



W=1746 MeV

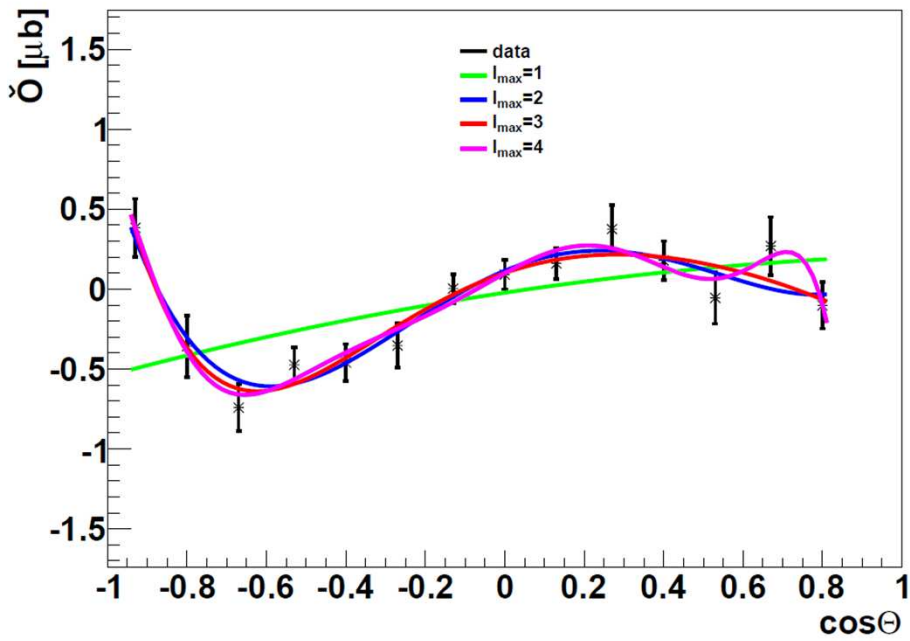


W=1762 MeV

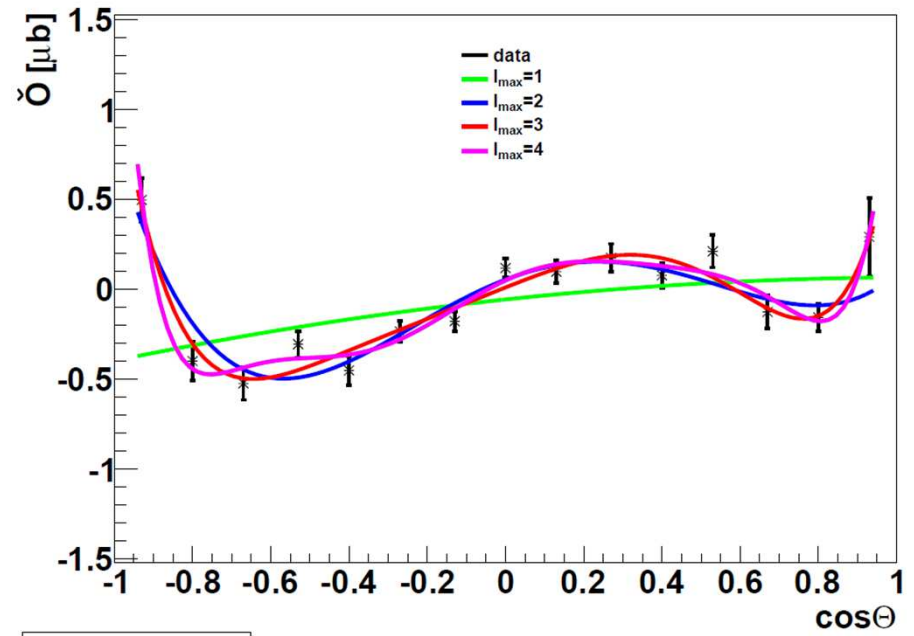


# Lmax Interpretation of E-Asymmetry

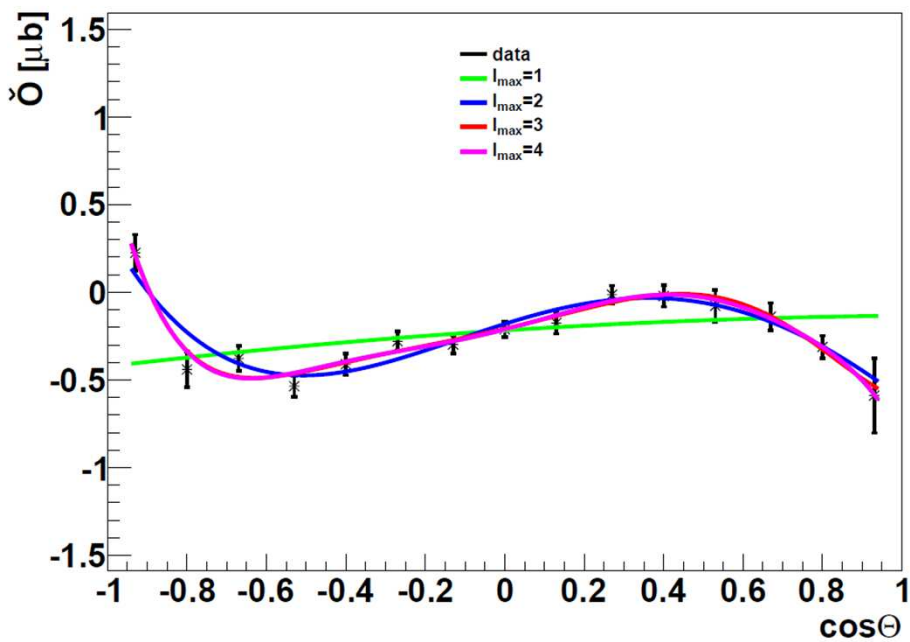
W=1778 MeV



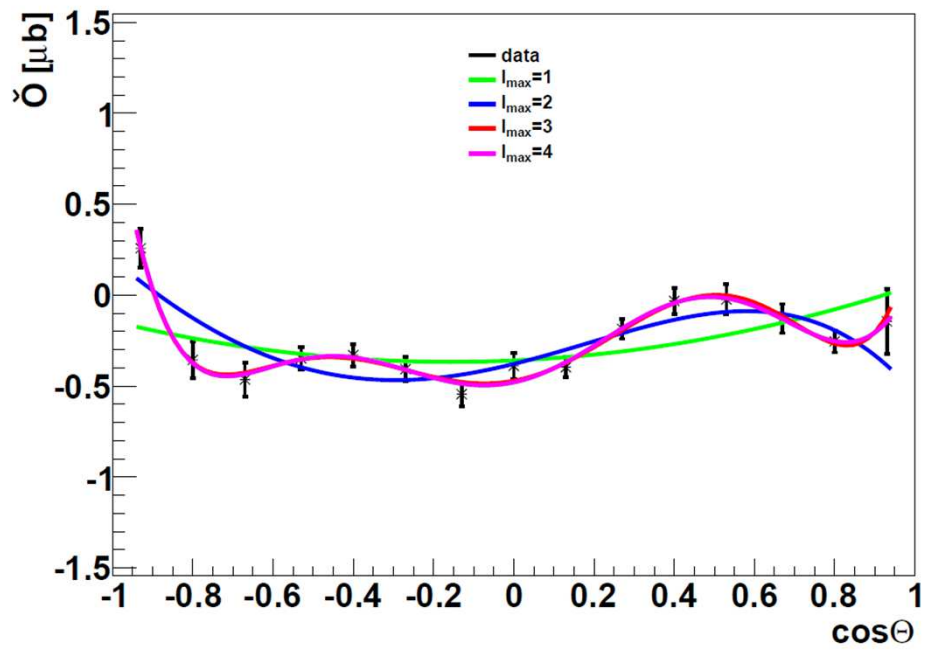
W=1801 MeV



W=1832 MeV

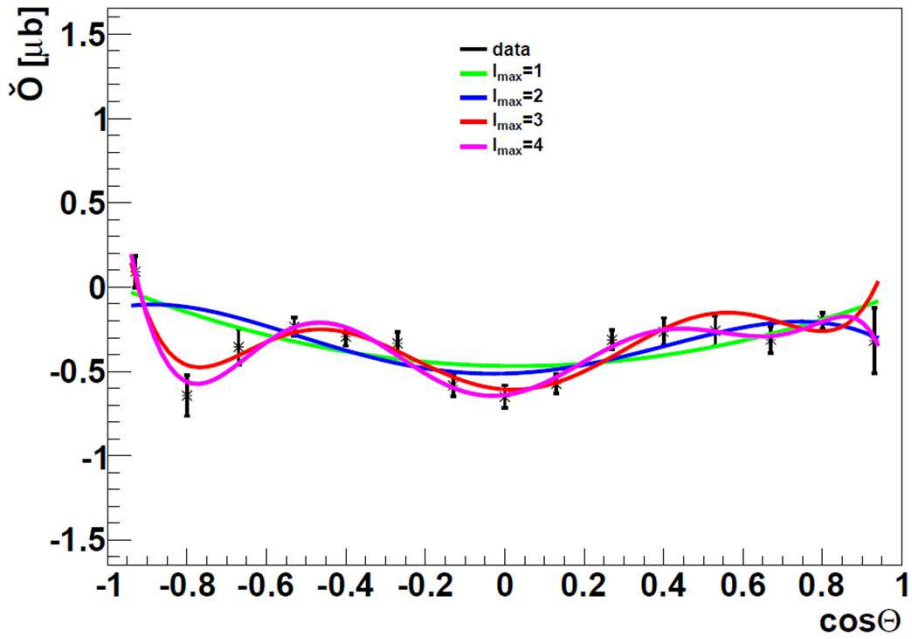


W=1863 MeV

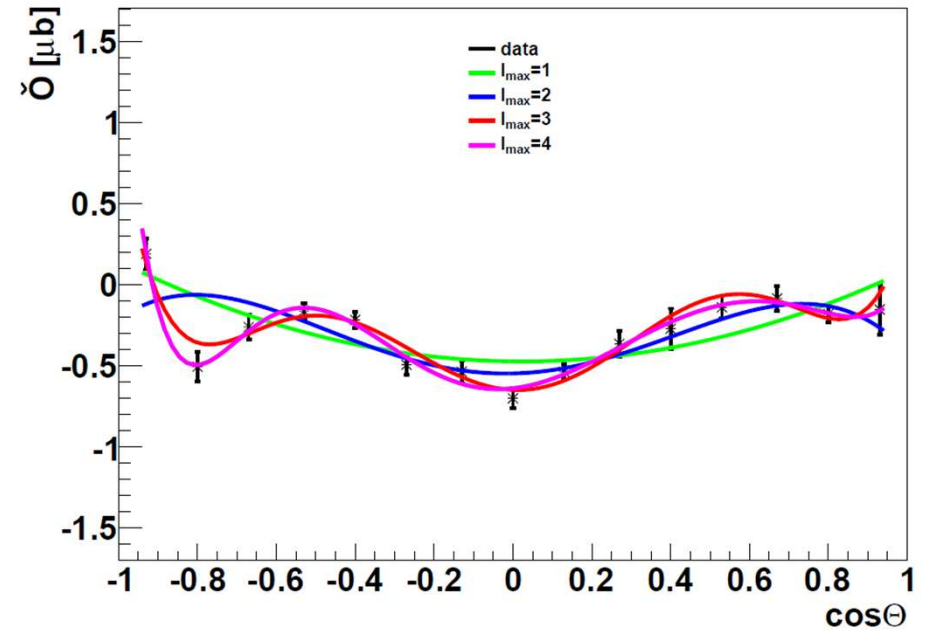


# Lmax Interpretation of E-Asymmetry

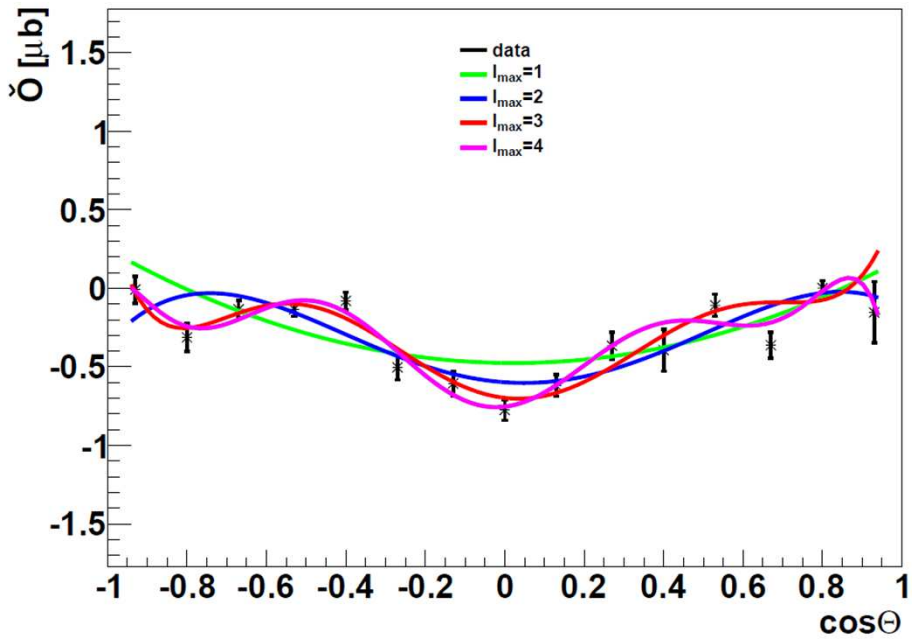
W=1893 MeV



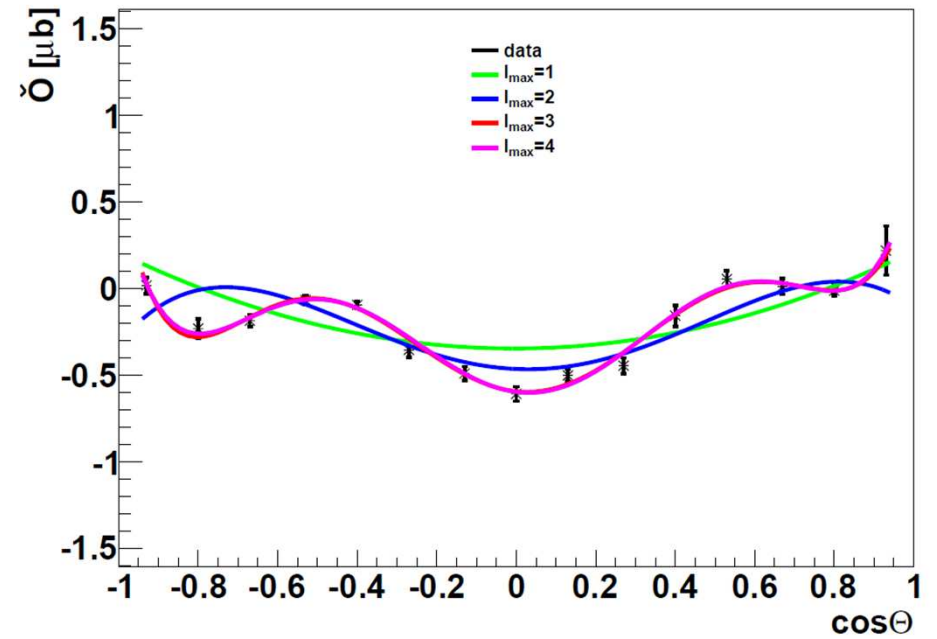
W=1922 MeV



W=1951 MeV



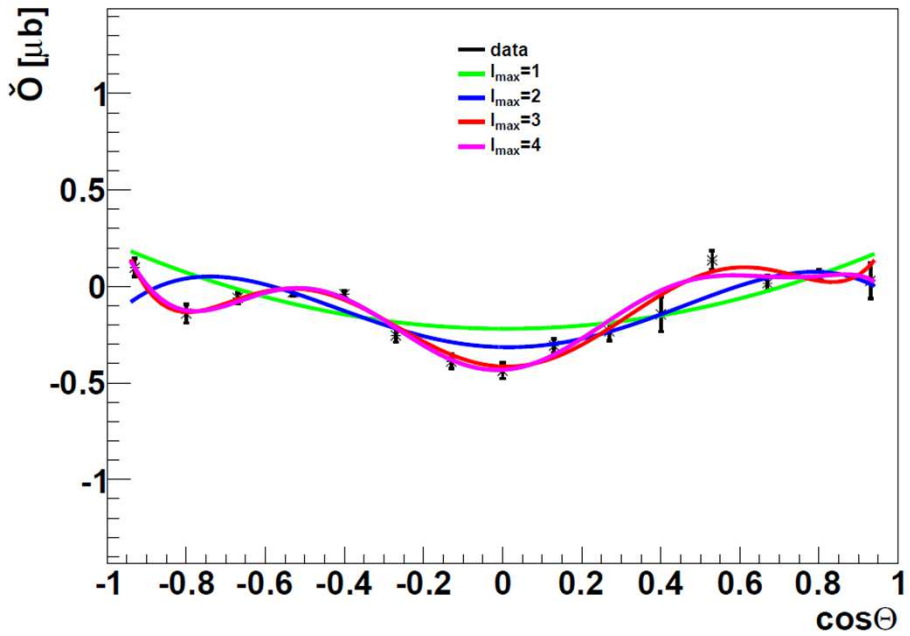
W=1994 MeV



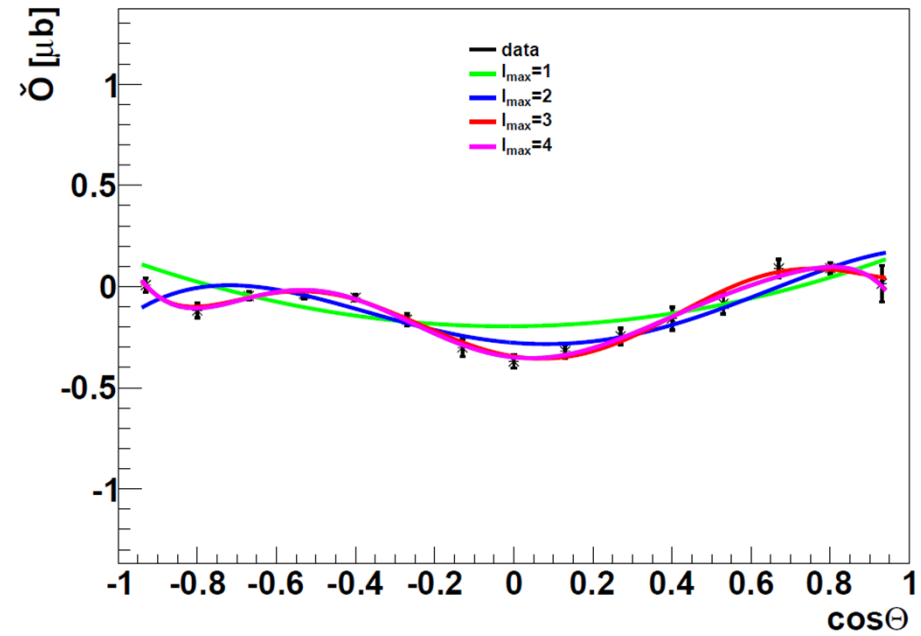


# Lmax Interpretation of E-Asymmetry

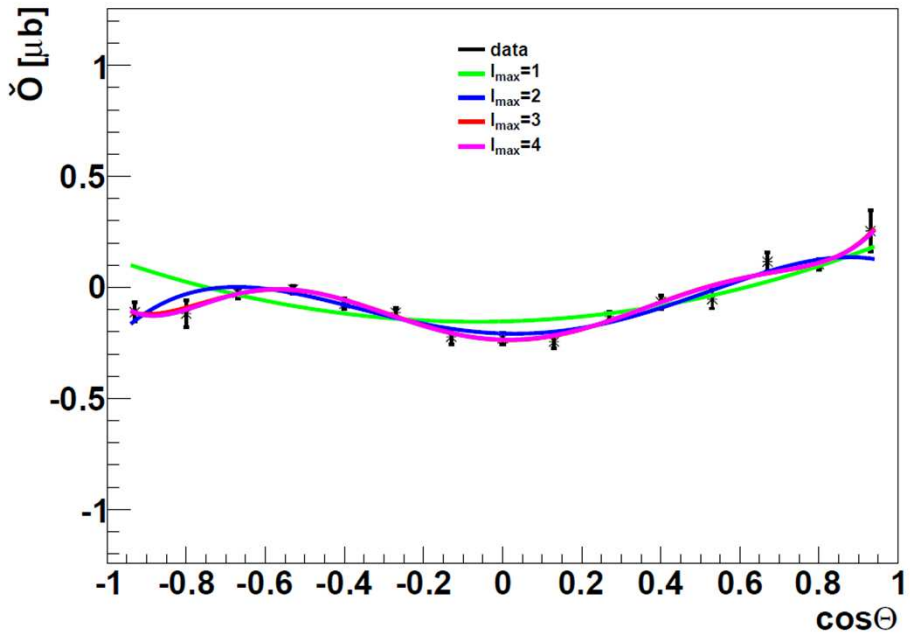
W=2050 MeV



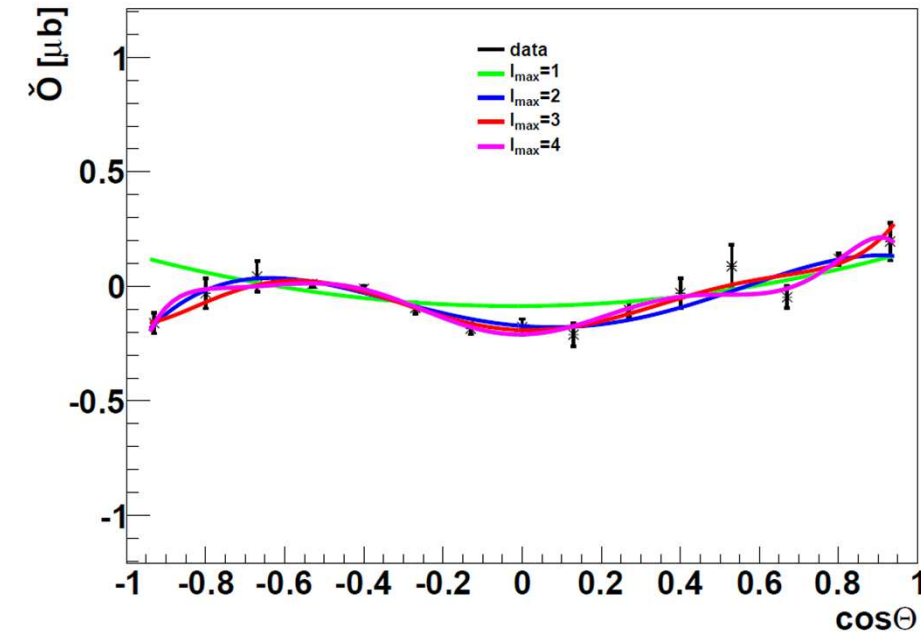
W=2104 MeV



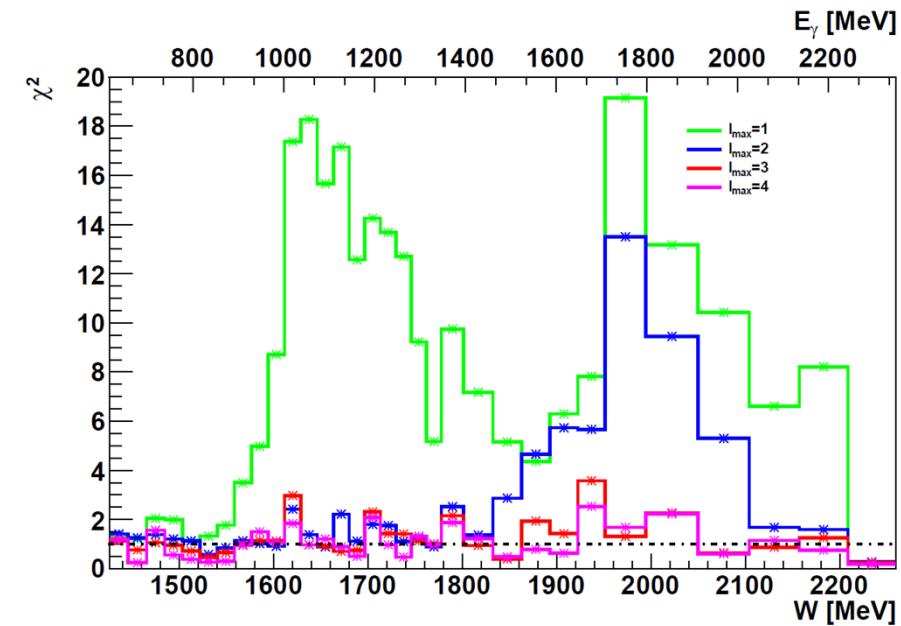
W=2157 MeV



W=2208 MeV



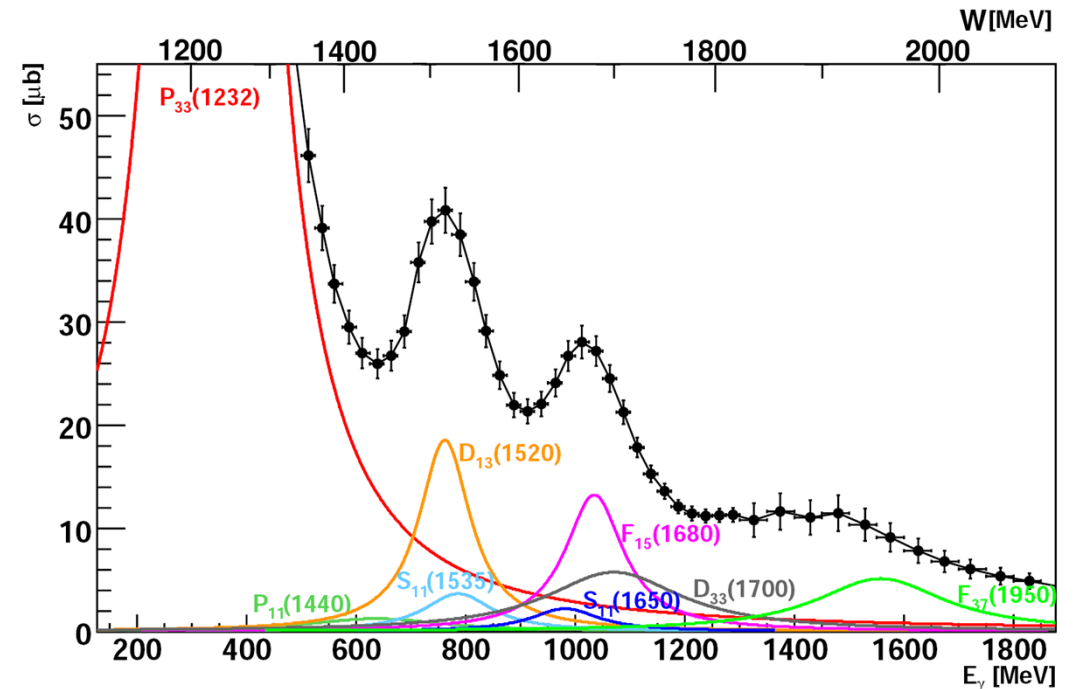
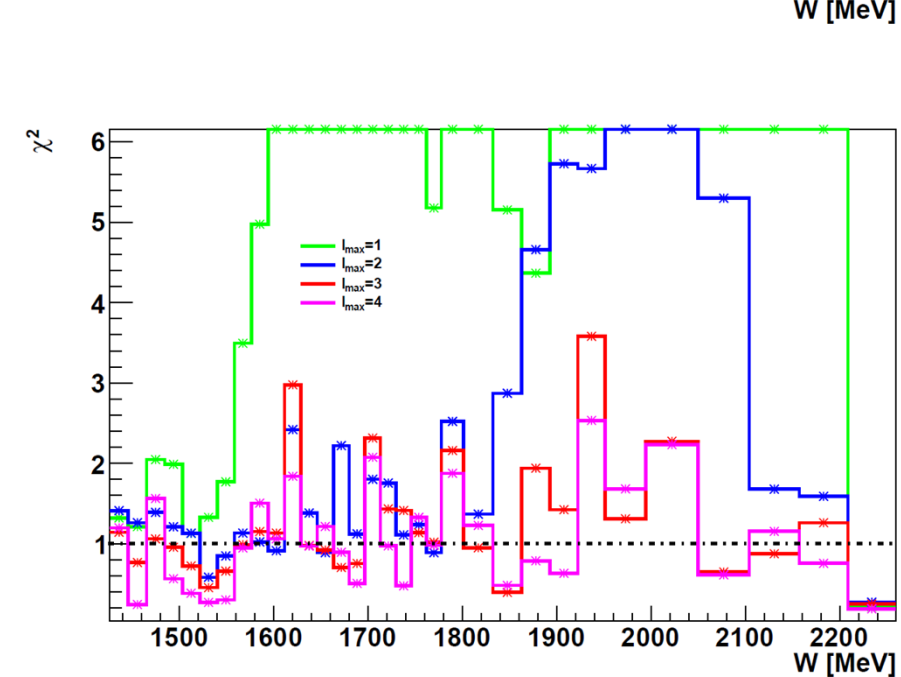
# Lmax Interpretation of E-Asymmetry



Significant  $L = 3$  signal seen  
above  $W = 1850$  ( $E = 1350$  MeV)

Below  $L \leq 2$  seems to be sufficient

No Significant  $L=4$  signal until  $W=2200$  ( $E = 2300$  MeV)



# Lmax Interpretation of T-Asymmetry

for  $L_{\max} \leq 1$  :

$$T = \frac{T \cdot \frac{d\sigma}{d\Omega}}{\sin^1(\theta)} = A_0 + A_1 \cdot \cos(\theta)$$

for  $L_{\max} \leq 2$  :

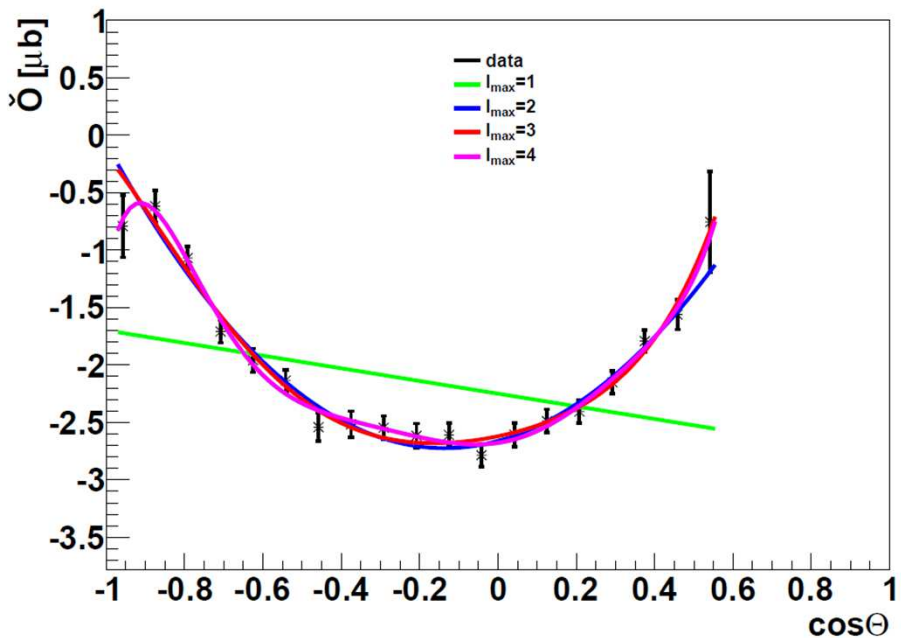
$$T = \frac{T \cdot \frac{d\sigma}{d\Omega}}{\sin^1(\theta)} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta) + A_3 \cdot \cos^3(\theta)$$

for  $L_{\max} \leq 3$  :

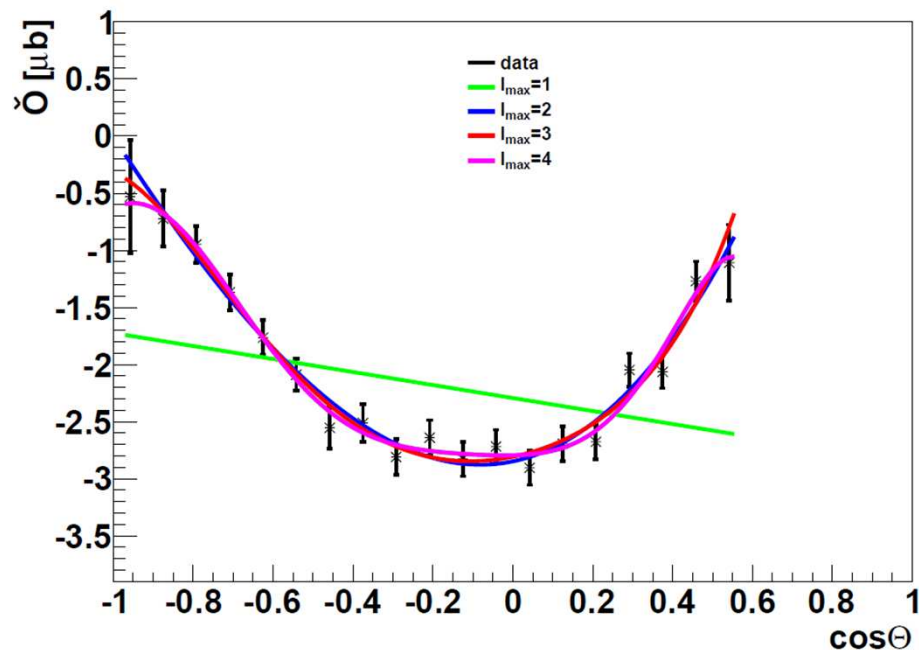
$$T = \frac{T \cdot \frac{d\sigma}{d\Omega}}{\sin^1(\theta)} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta) + A_3 \cdot \cos^3(\theta) + A_4 \cdot \cos^4(\theta) \\ + A_5 \cdot \cos^5(\theta)$$

# Lmax Interpretation of T-Asymmetry

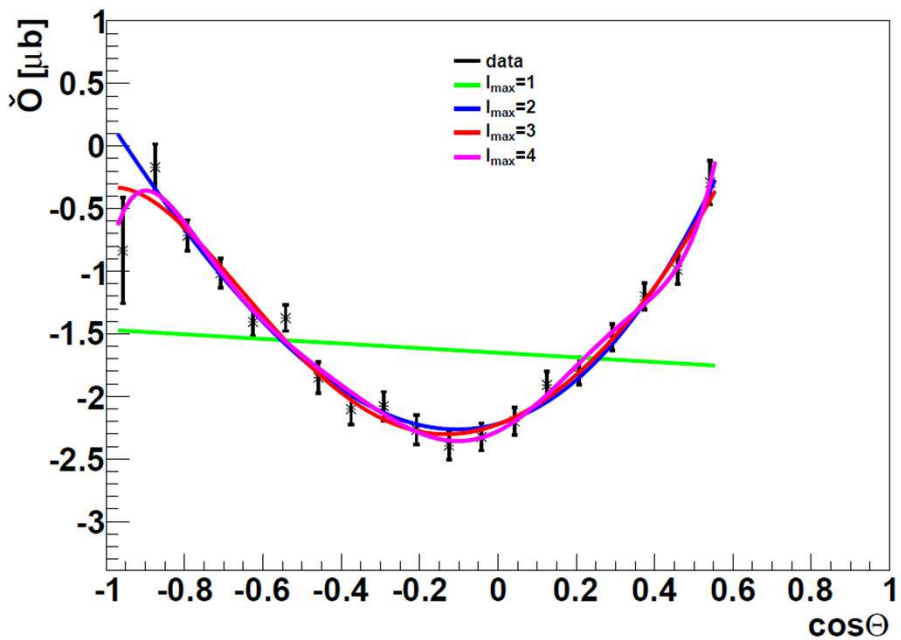
W=1470 MeV



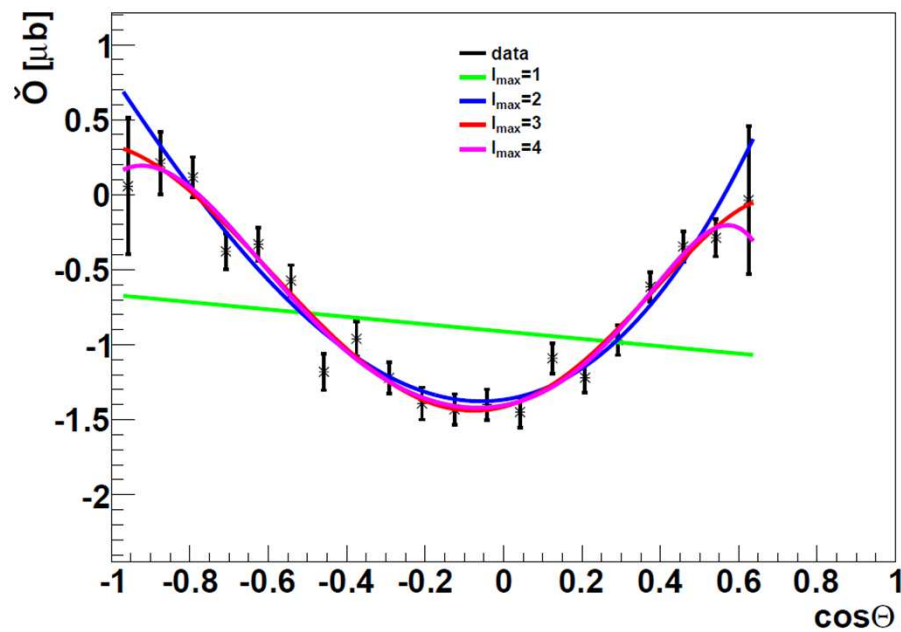
W=1491 MeV



W=1512 MeV

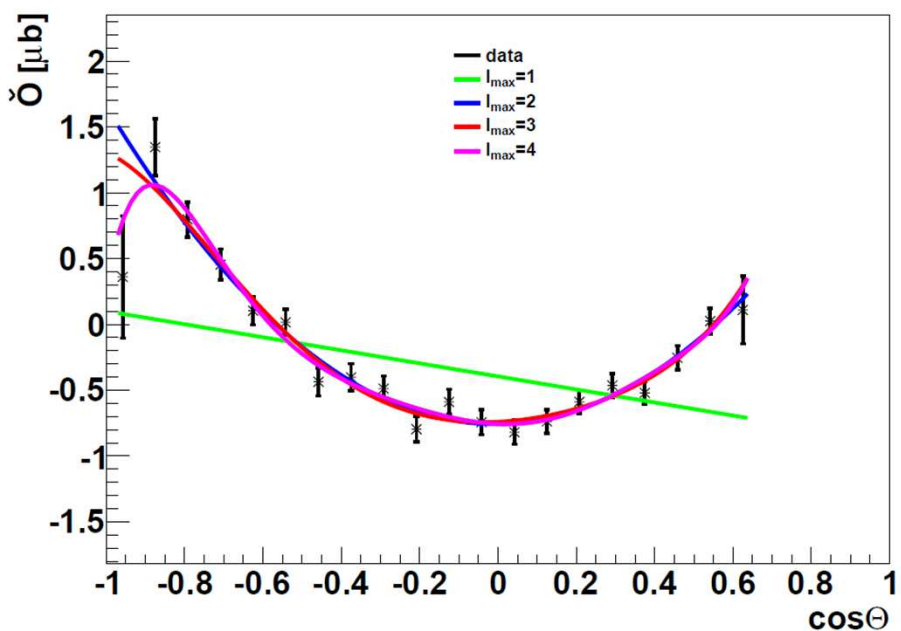


W=1533 MeV

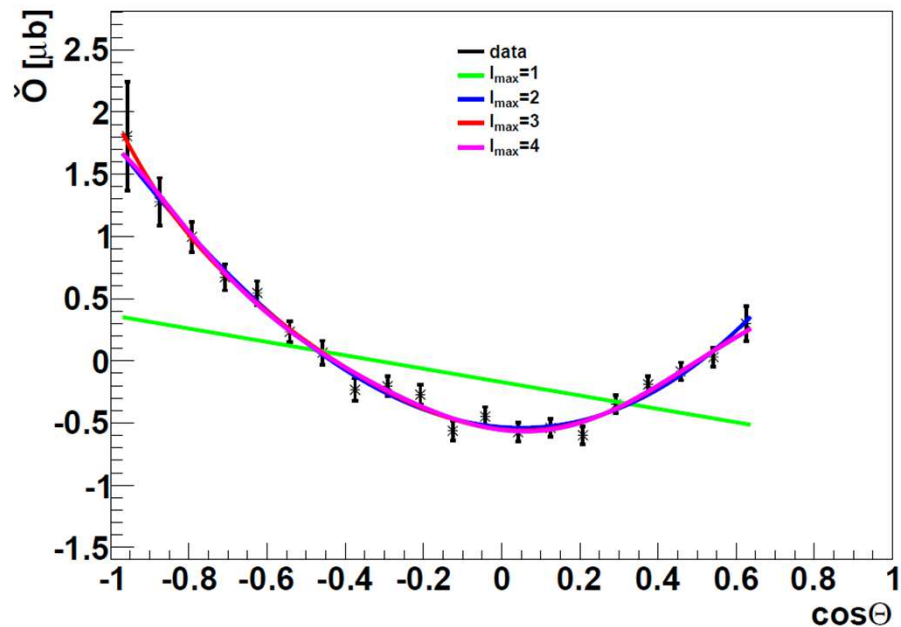


# Lmax Interpretation of T-Asymmetry

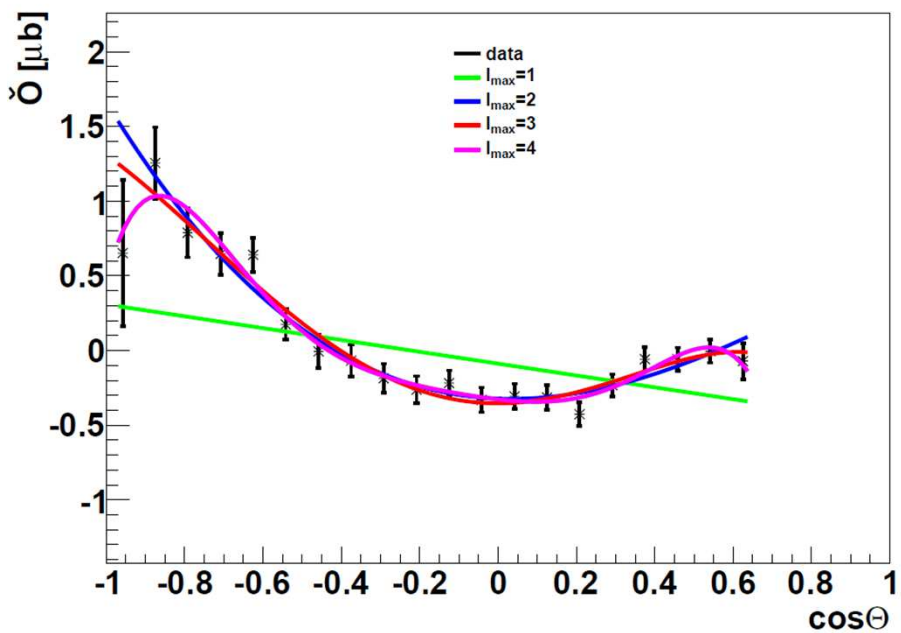
W=1553 MeV



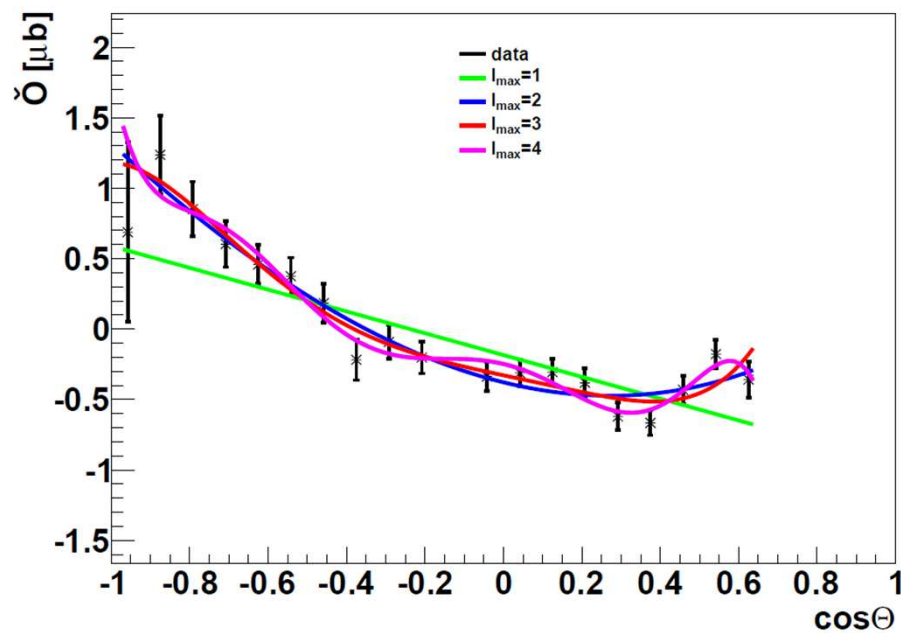
W=1574 MeV



W=1593 MeV

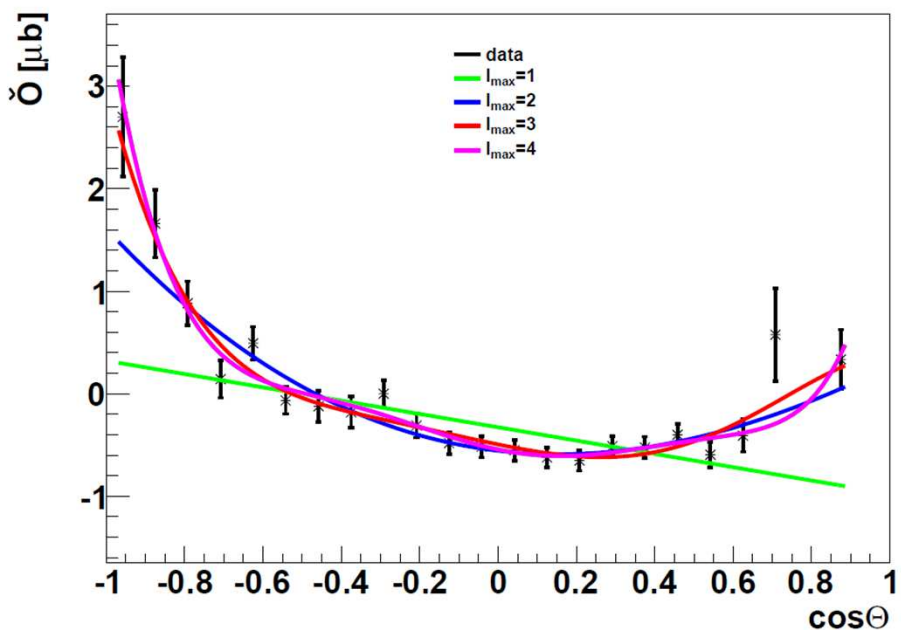


W=1612 MeV

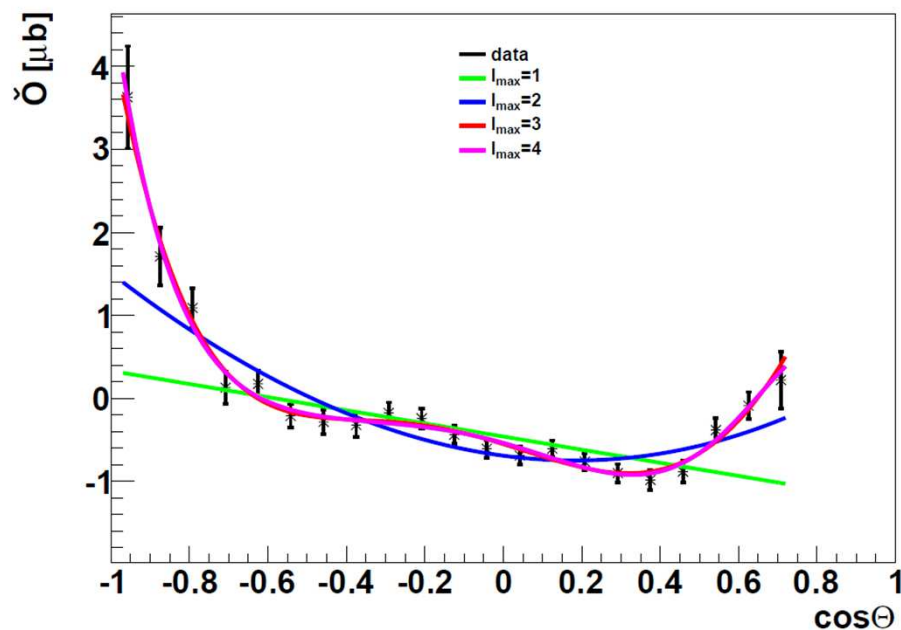


# Lmax Interpretation of T-Asymmetry

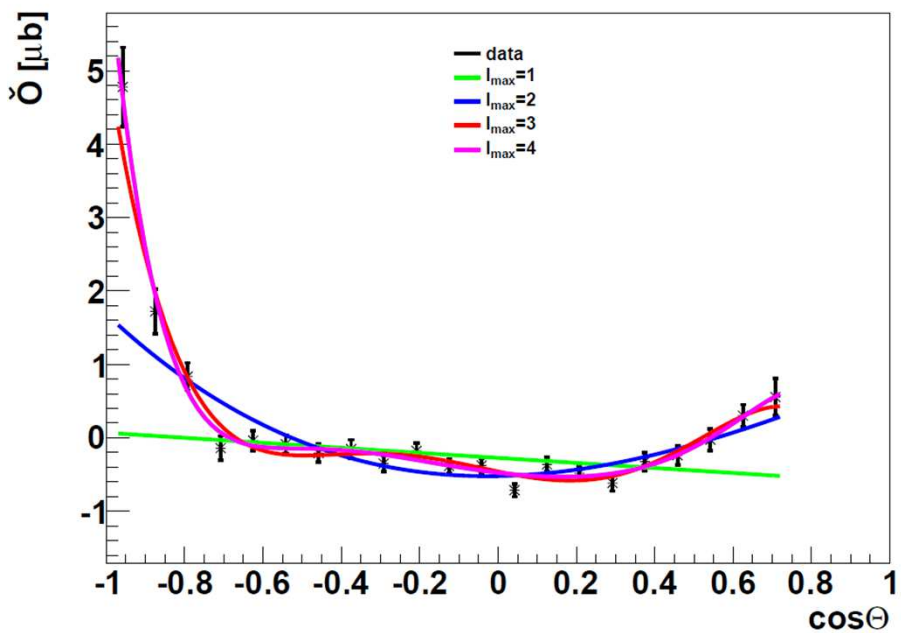
W=1634 MeV



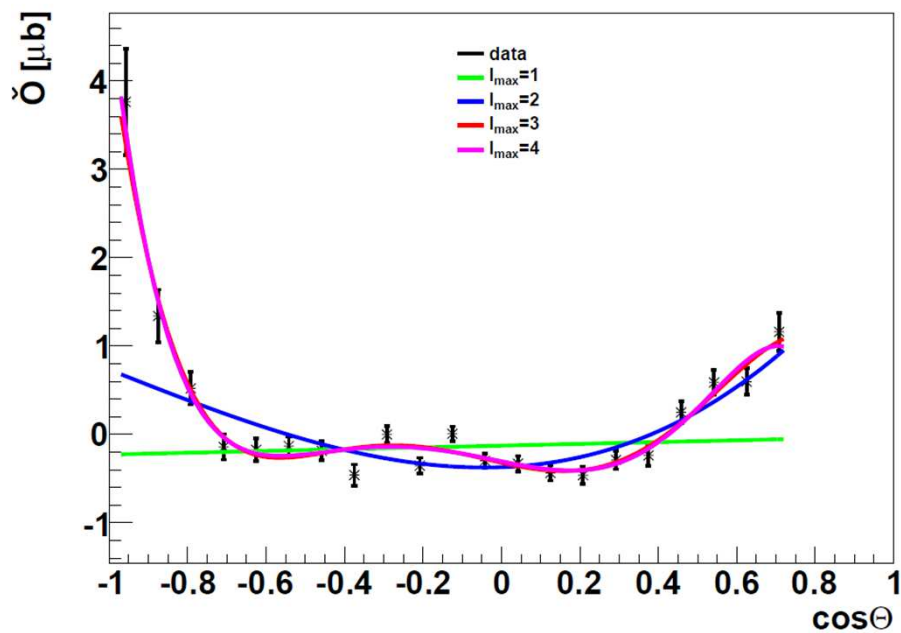
W=1657 MeV



W=1681 MeV



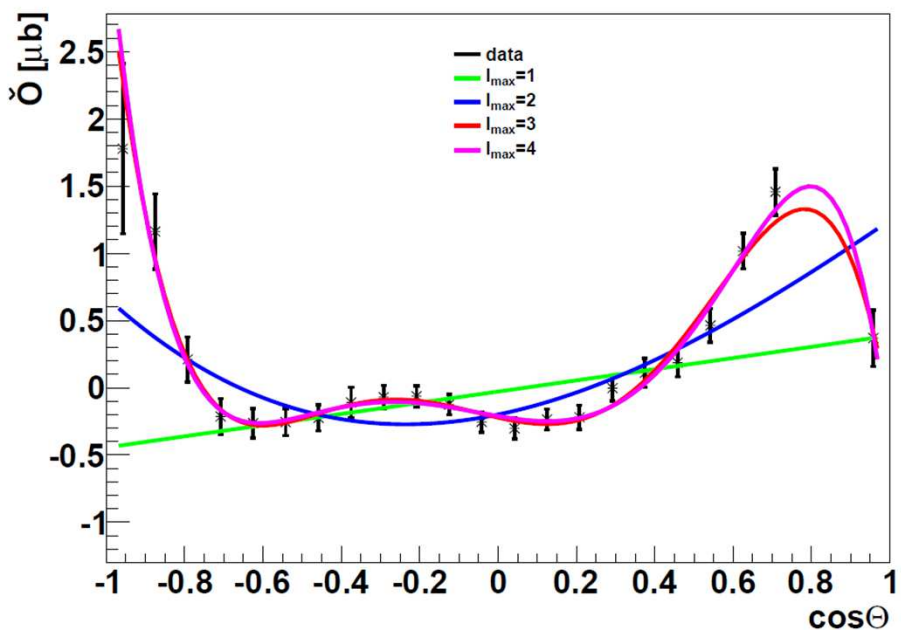
W=1704 MeV



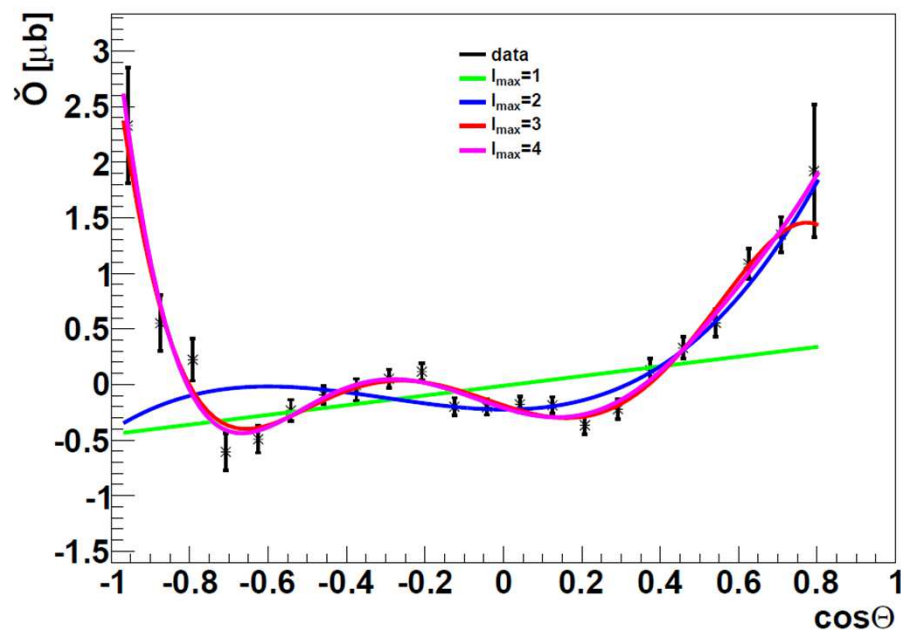


# Lmax Interpretation of T-Asymmetry

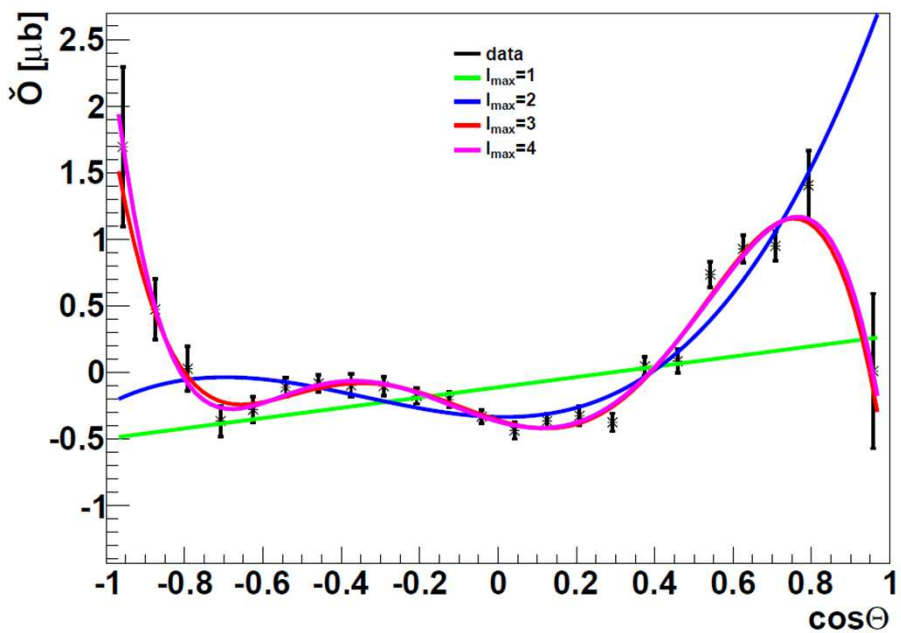
W=1730 MeV



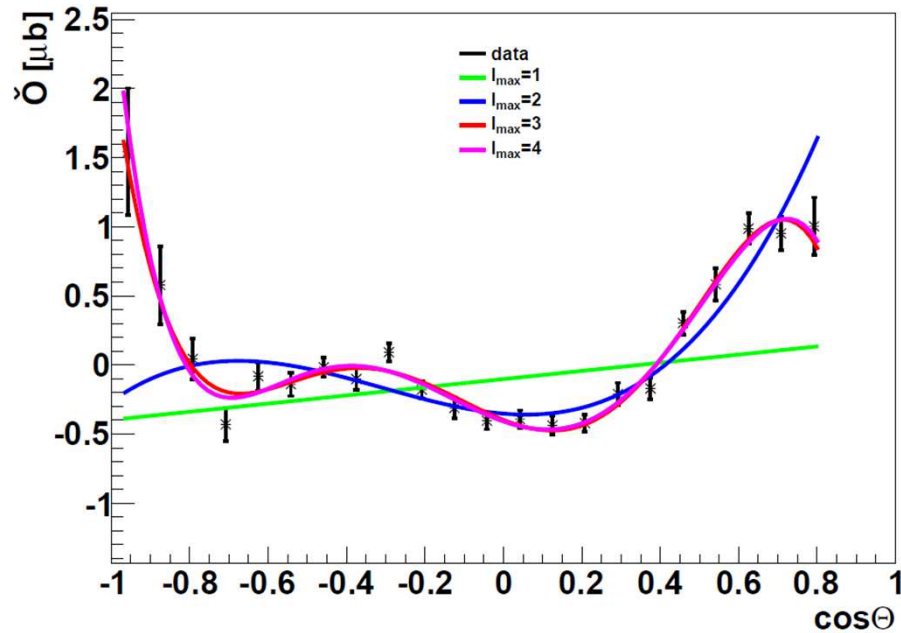
W=1756 MeV



W=1783 MeV



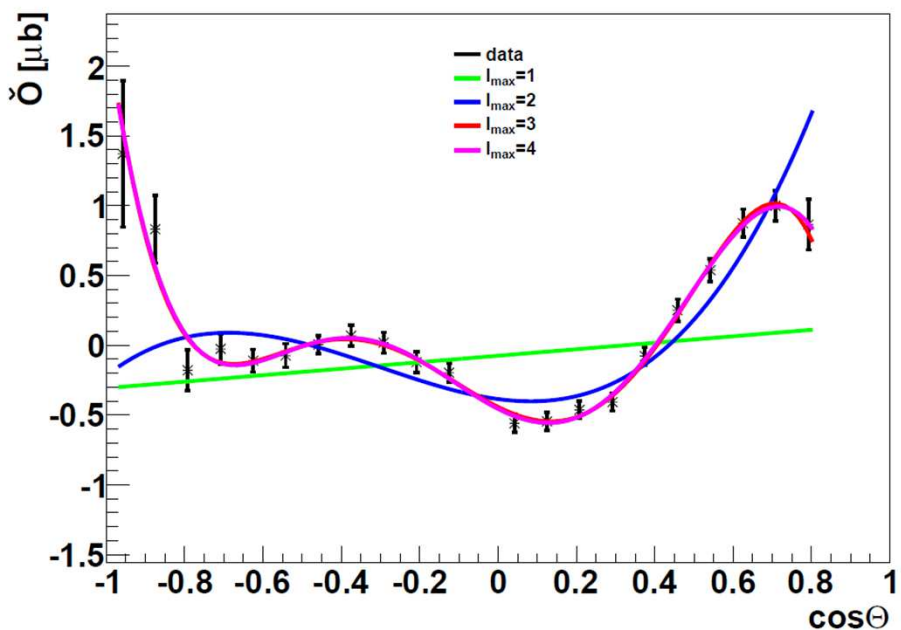
W=1810 MeV



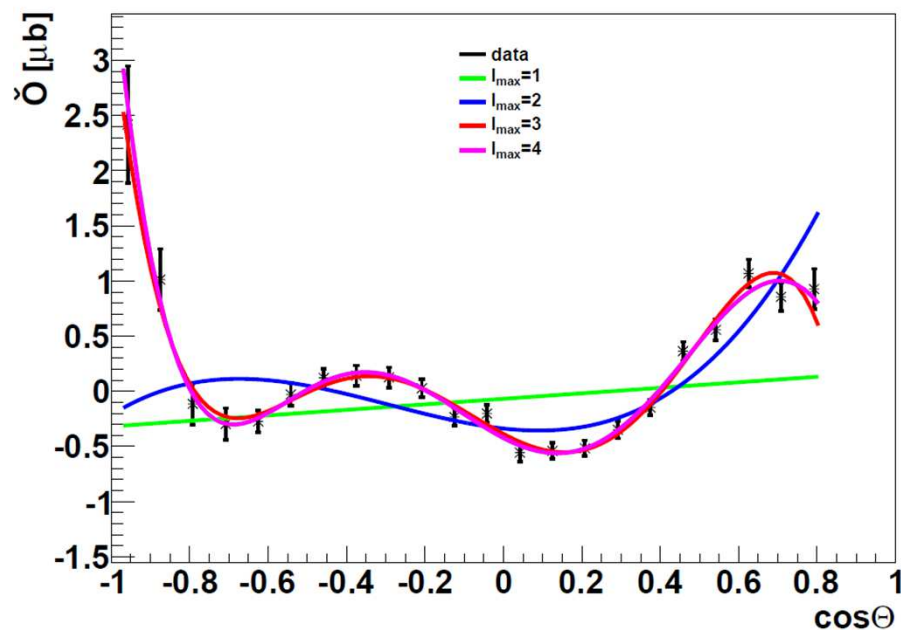


# Lmax Interpretation of T-Asymmetry

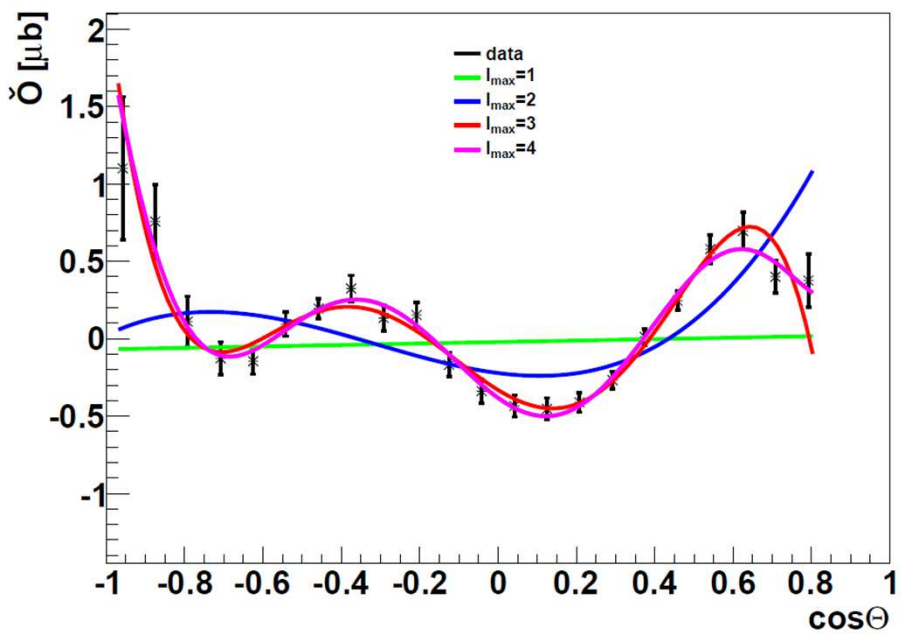
W=1836 MeV



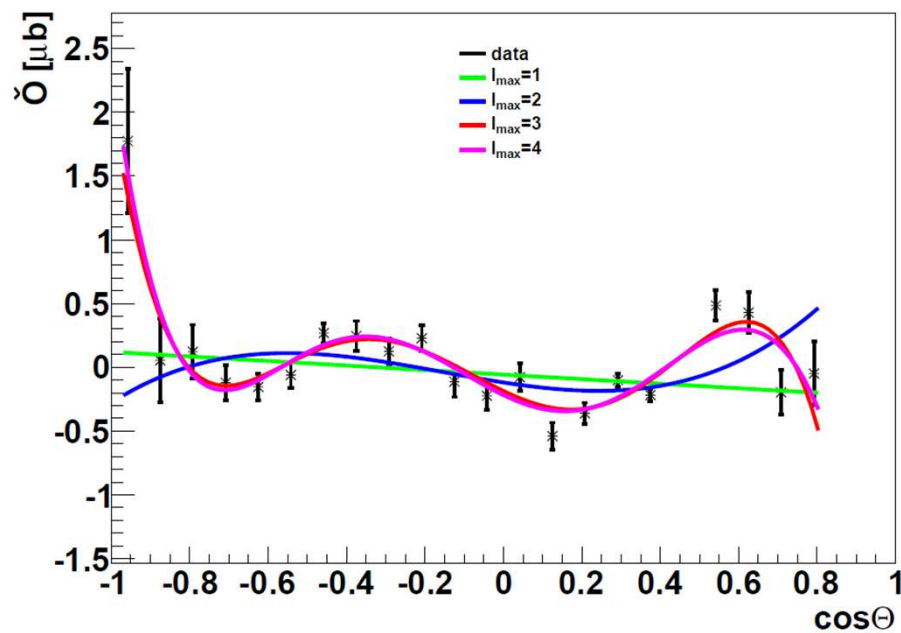
W=1862 MeV



W=1890 MeV

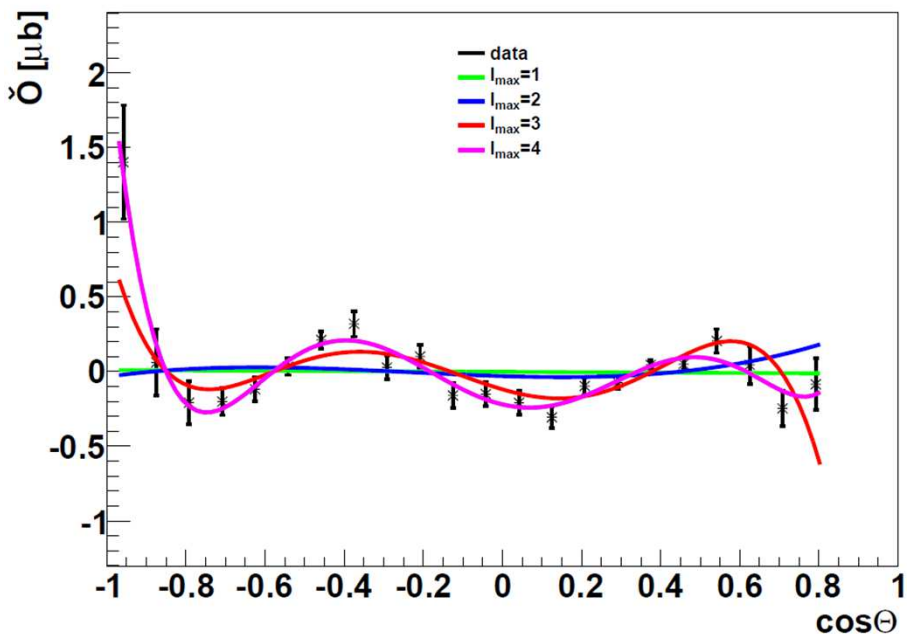


W=1922 MeV

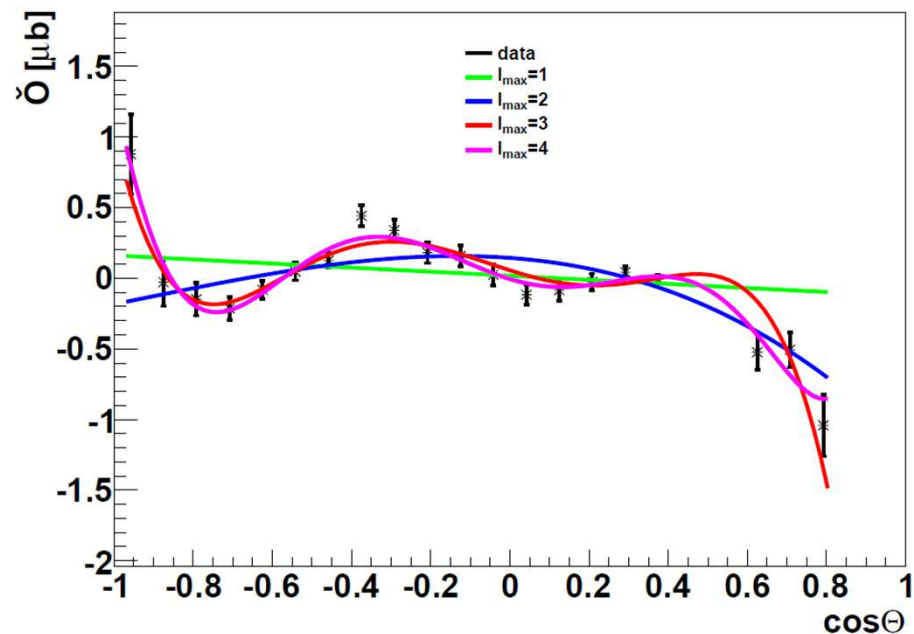


# Lmax Interpretation of T-Asymmetry

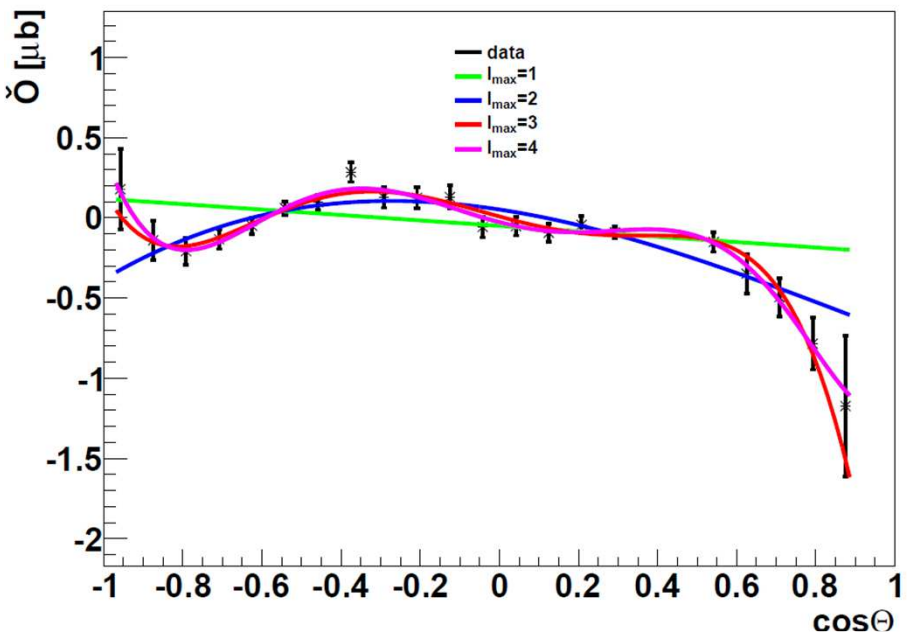
W=1955 MeV



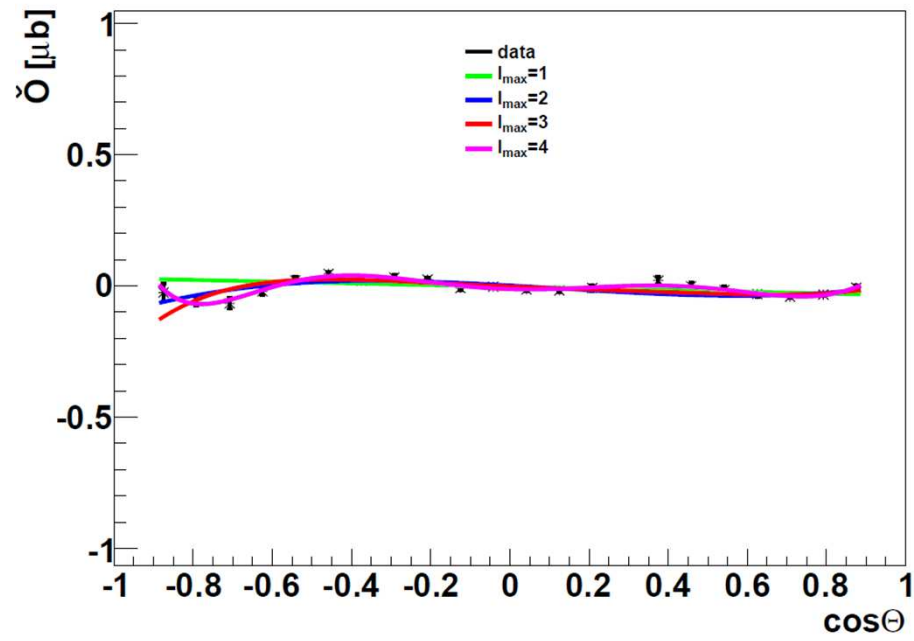
W=1994 MeV



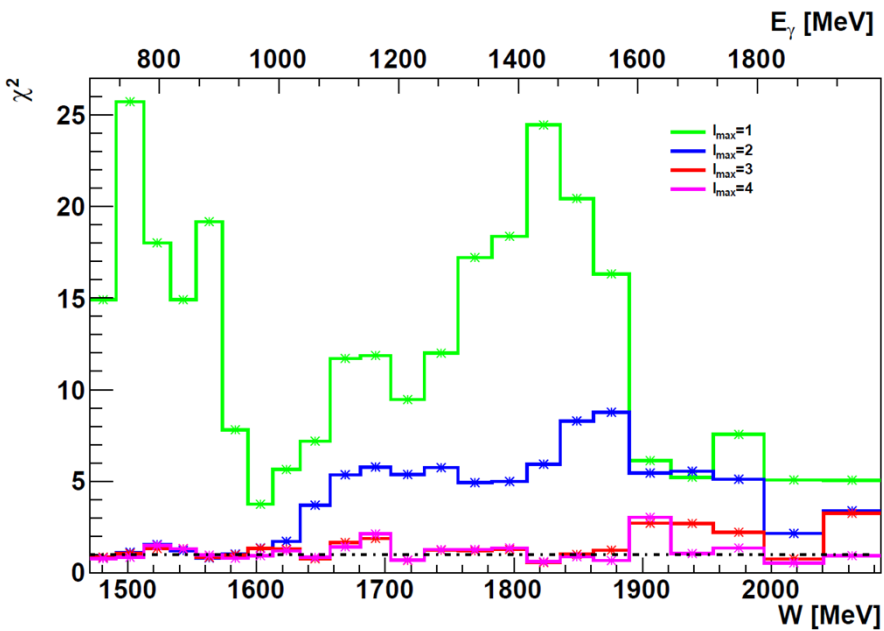
W=2041 MeV



W=2085 MeV



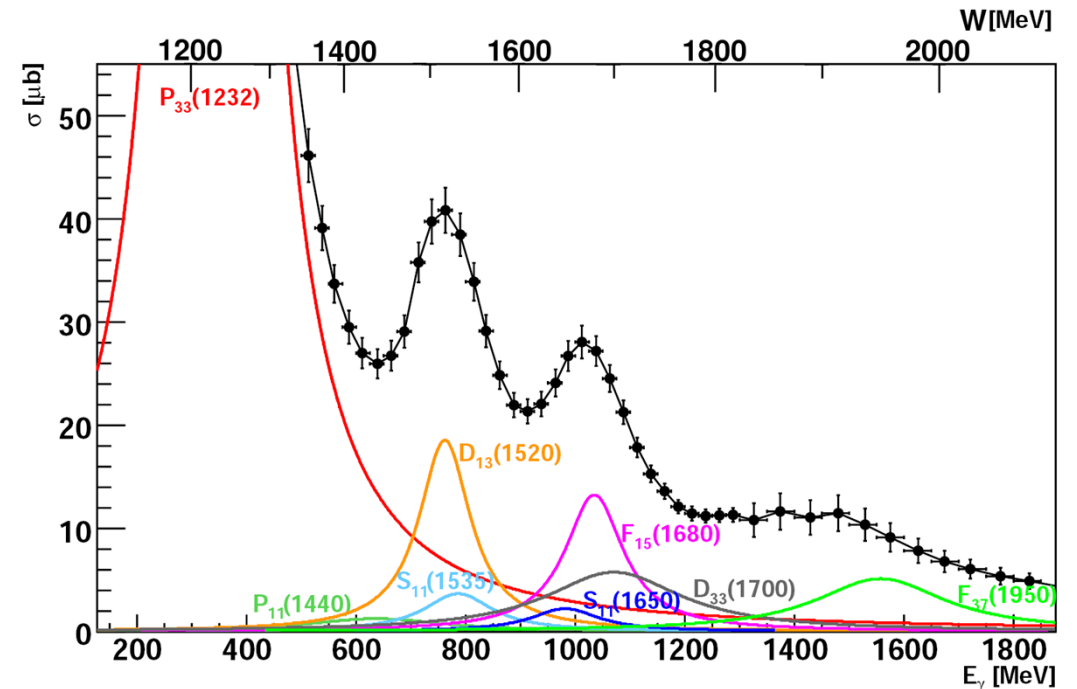
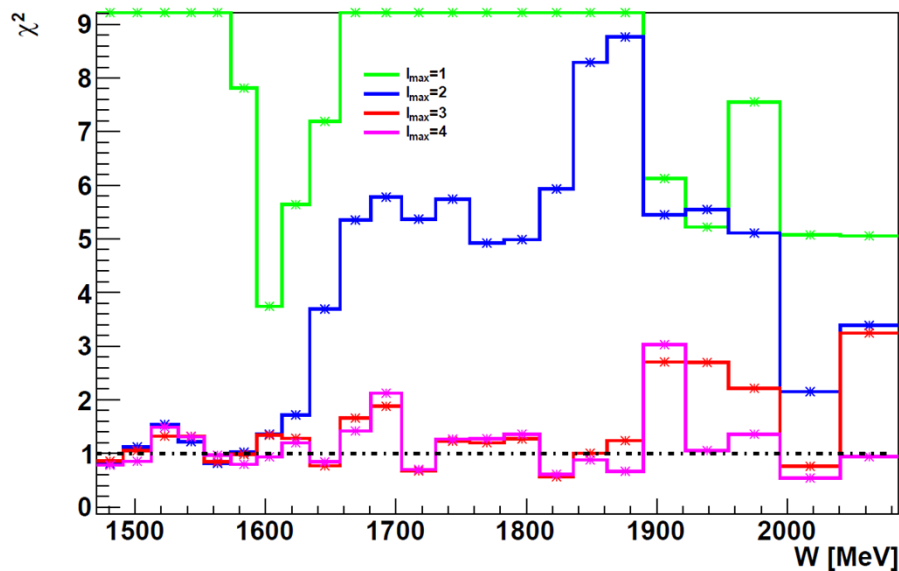
# Lmax Interpretation of T-Asymmetry



Significant  $L = 3$  signal seen  
above  $W = 1600$  ( $E = 1000$  MeV)

Below  $L \leq 2$  seems to be sufficient

No Significant  $L=4$  signal until  $W=2100$  ( $E = 2000$  MeV)



# Lmax Interpretation of H-Asymmetry

for  $L_{\max} \leq 1$  :

$$H = \frac{H \cdot \frac{d\sigma}{d\Omega}}{\sin^1(\theta)} = A_0 + A_1 \cdot \cos(\theta)$$

for  $L_{\max} \leq 2$  :

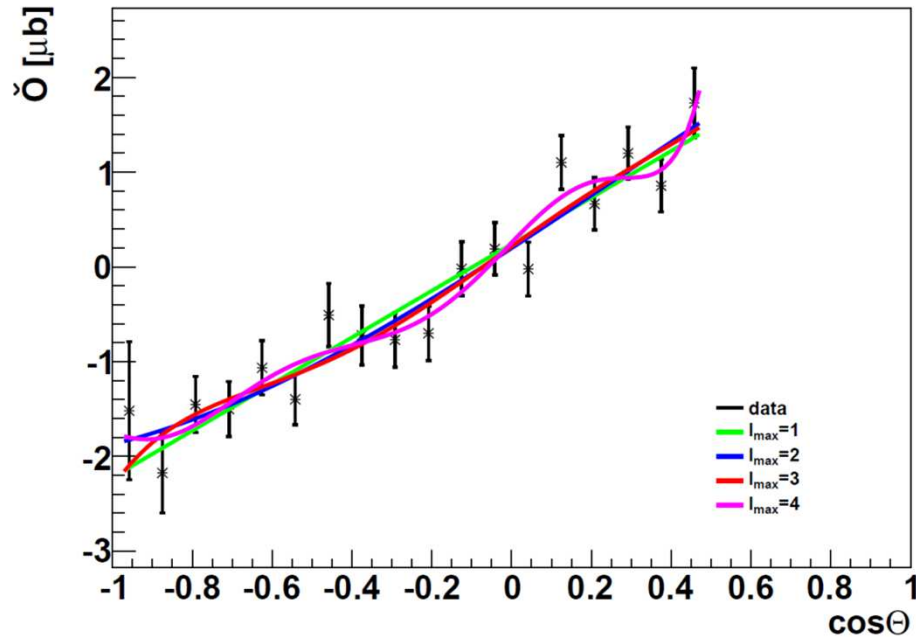
$$H = \frac{H \cdot \frac{d\sigma}{d\Omega}}{\sin^1(\theta)} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta) + A_3 \cdot \cos^3(\theta)$$

for  $L_{\max} \leq 3$  :

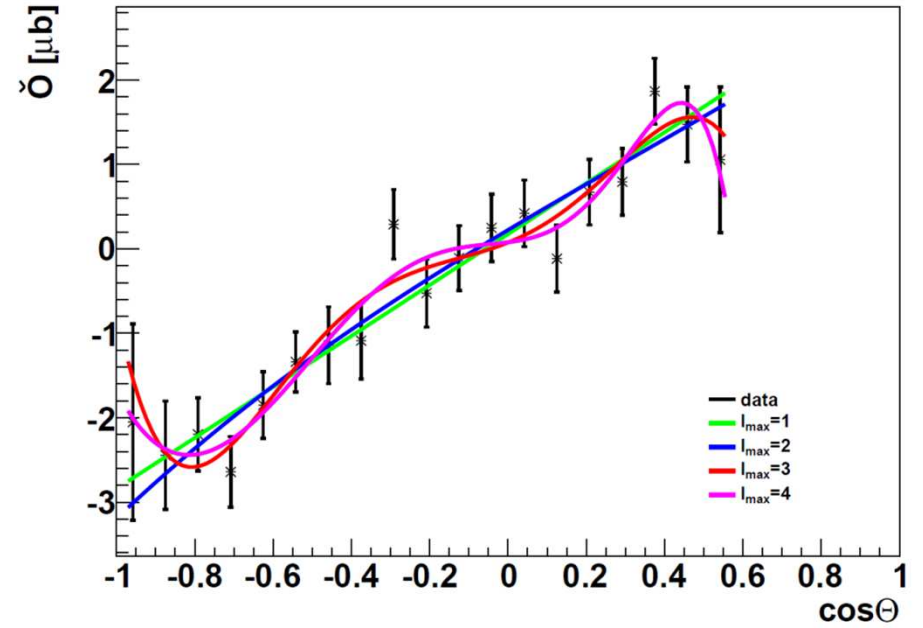
$$H = \frac{H \cdot \frac{d\sigma}{d\Omega}}{\sin^1(\theta)} = A_0 + A_1 \cdot \cos(\theta) + A_2 \cdot \cos^2(\theta) + A_3 \cdot \cos^3(\theta) + A_4 \cdot \cos^4(\theta) \\ + A_5 \cdot \cos^5(\theta)$$

# Lmax Interpretation of H-Asymmetry

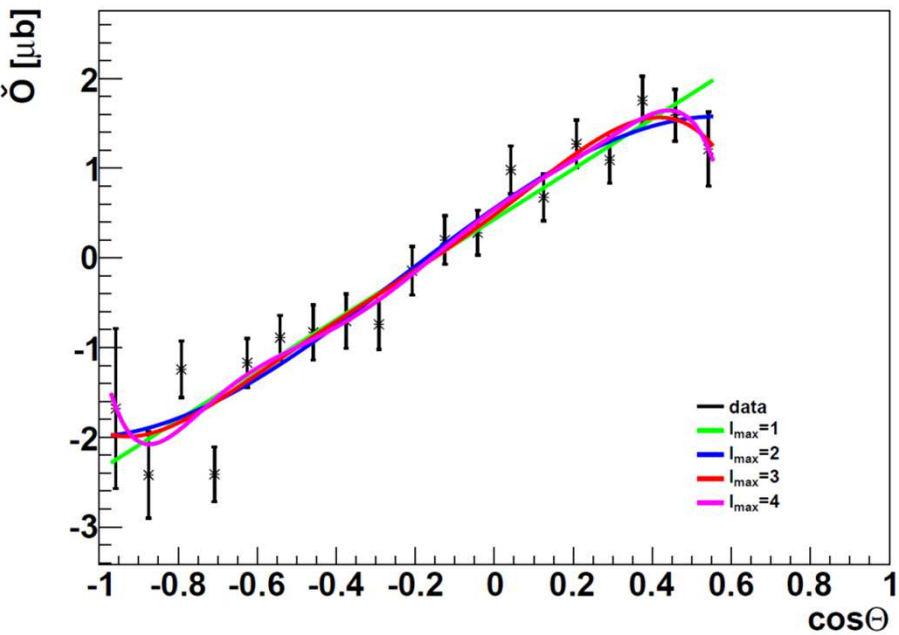
W=1470 MeV



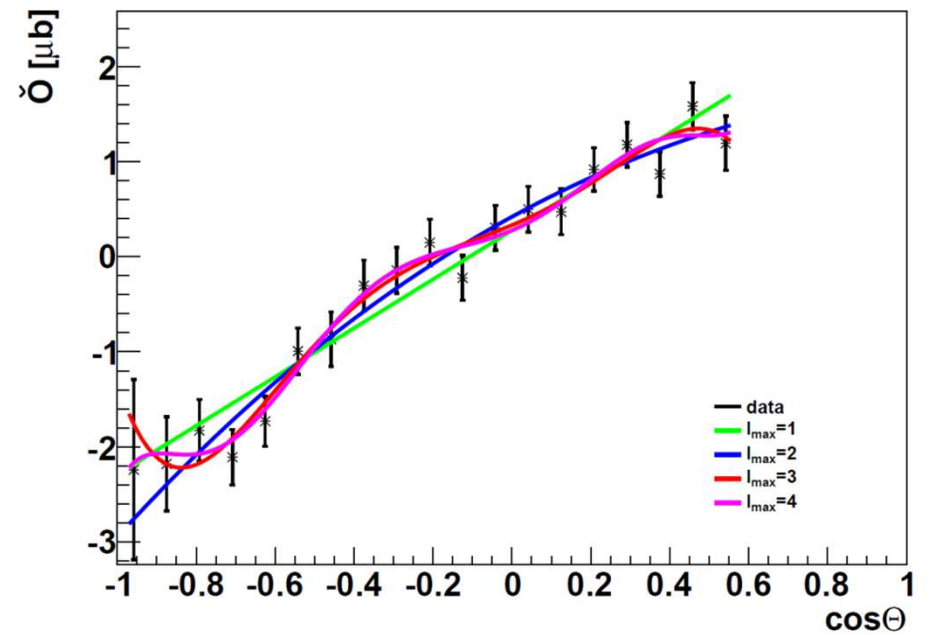
W=1491 MeV



W=1512 MeV

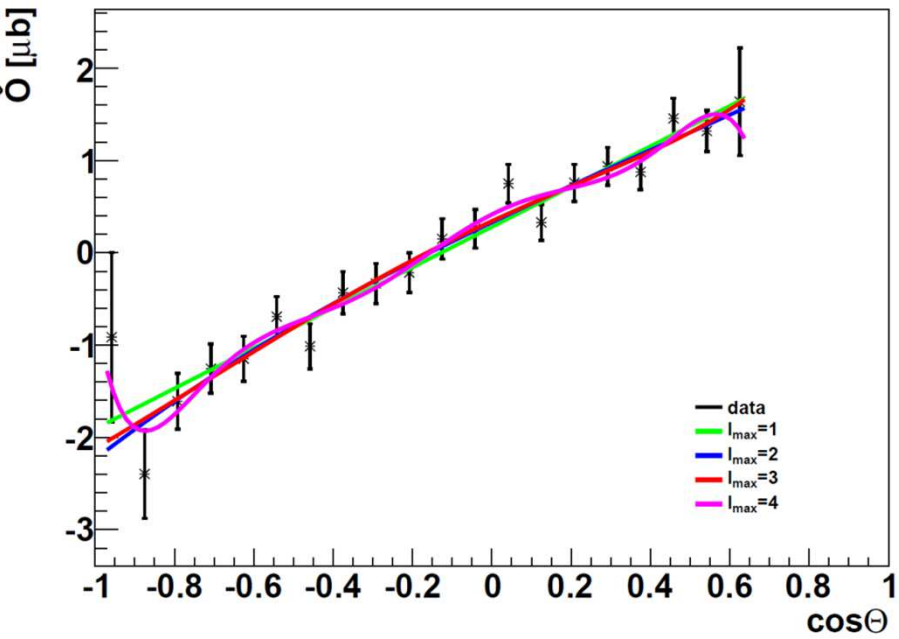


W=1533 MeV

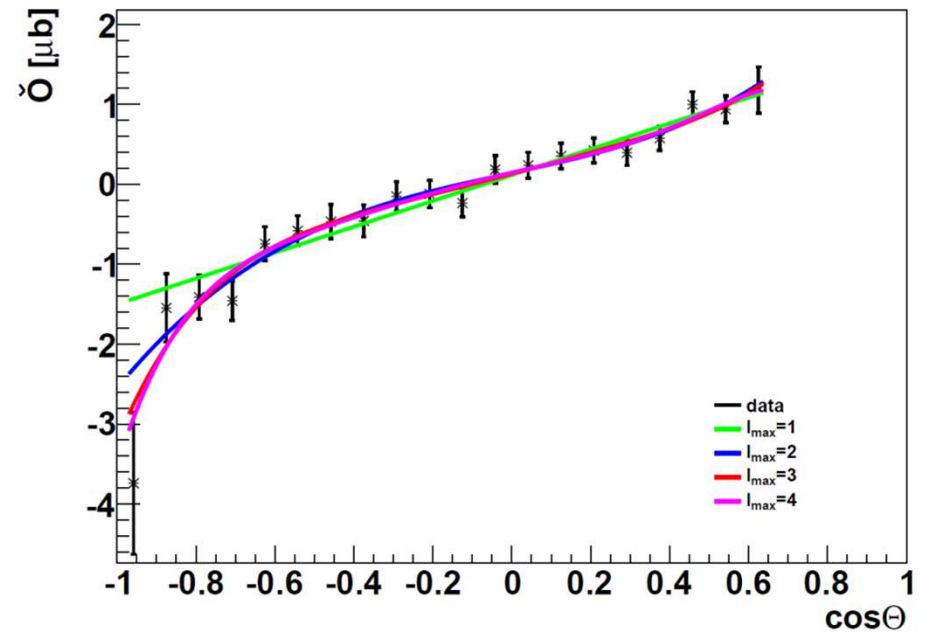


# Lmax Interpretation of H-Asymmetry

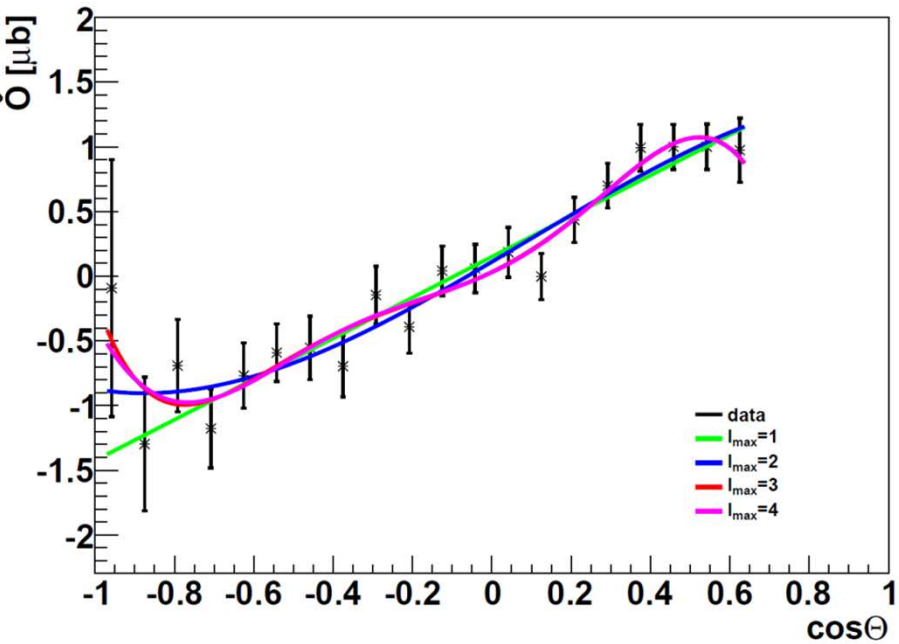
W=1553 MeV



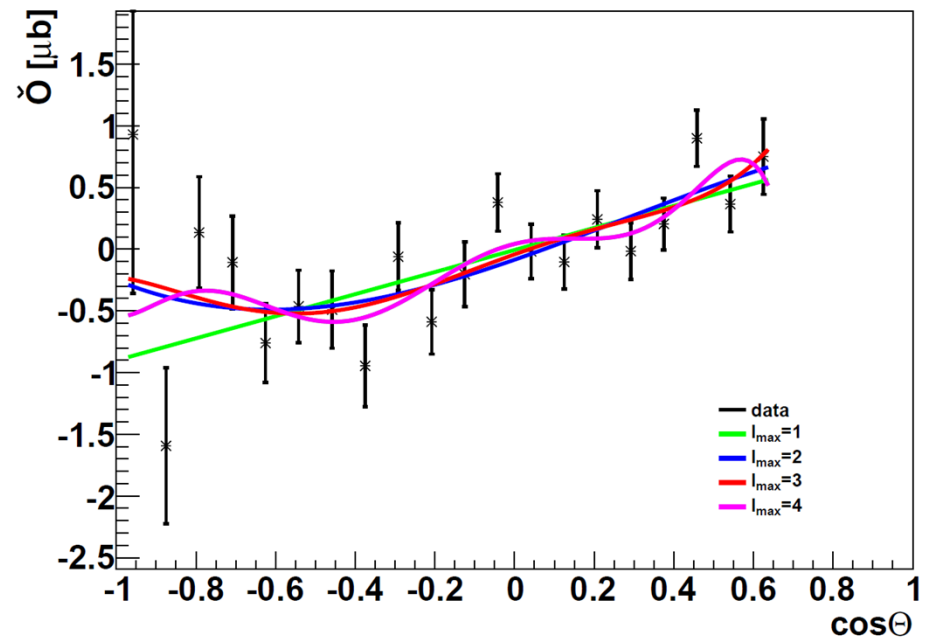
W=1574 MeV



W=1593 MeV

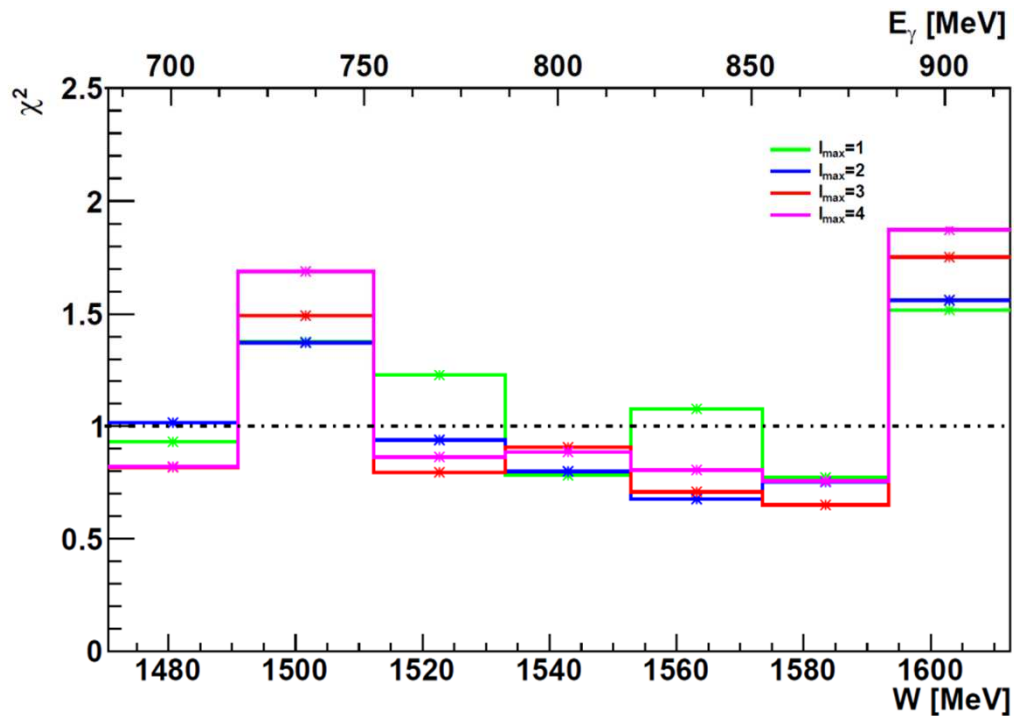


W=1612 MeV





# Lmax Interpretation of H-Asymmetry

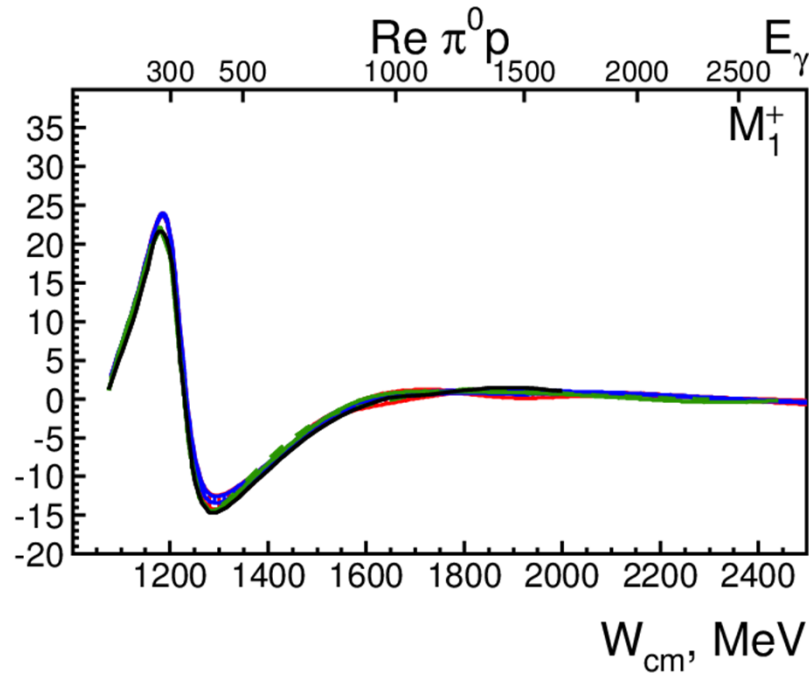


$L_{\max} \leq 1$  seems to be sufficient in the whole energy range  $W = 1480$  to  $1620$  MeV ( $E = 650$  to  $950$  MeV)

This is the reason for the good predictions of the different PWA's only s-wave and p-waves needed

Even no significant L=2 signal seen,  $D_{13}(1520)$

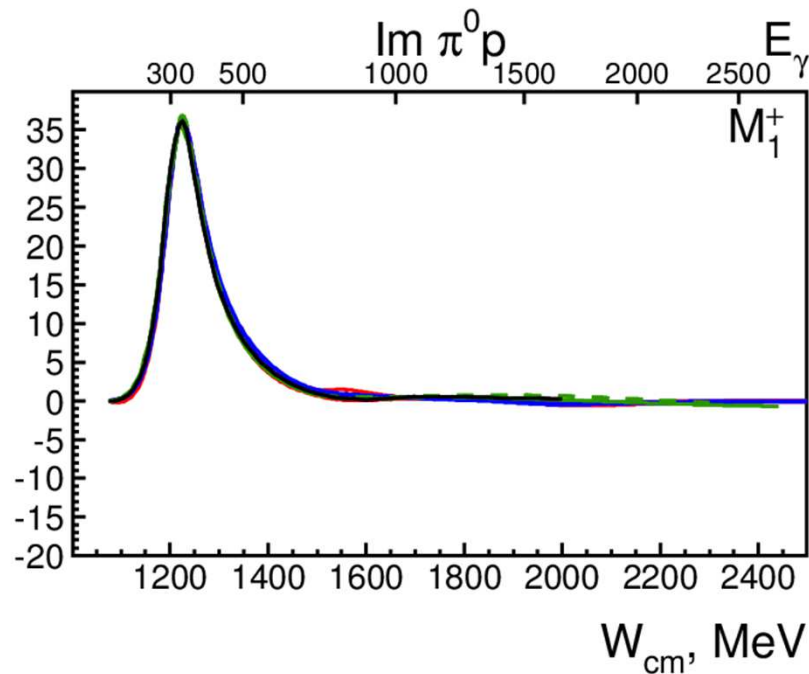
# $\rho\pi^0$ : Impact of the new G,E,T,P and H data



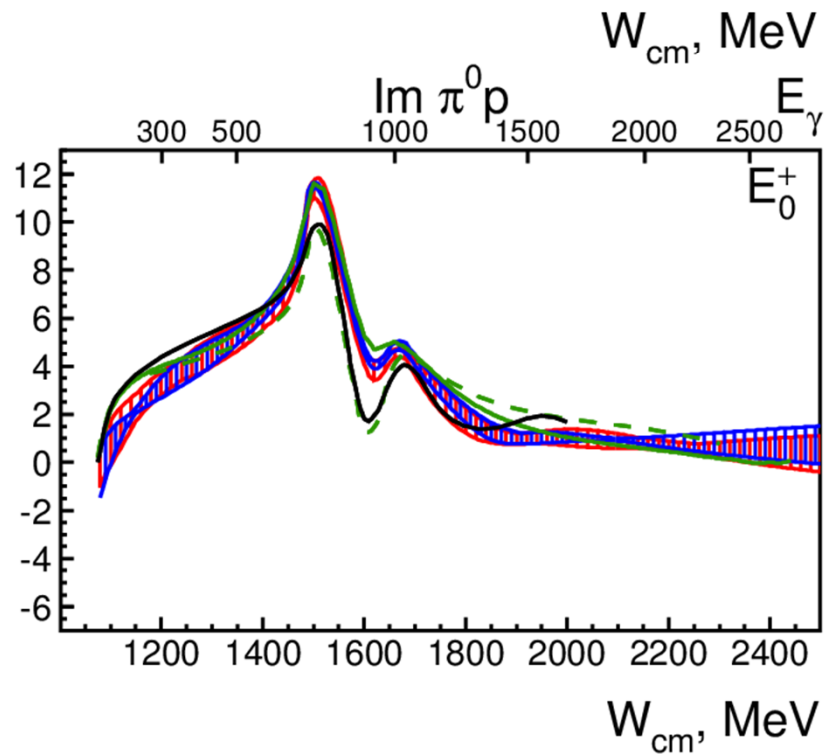
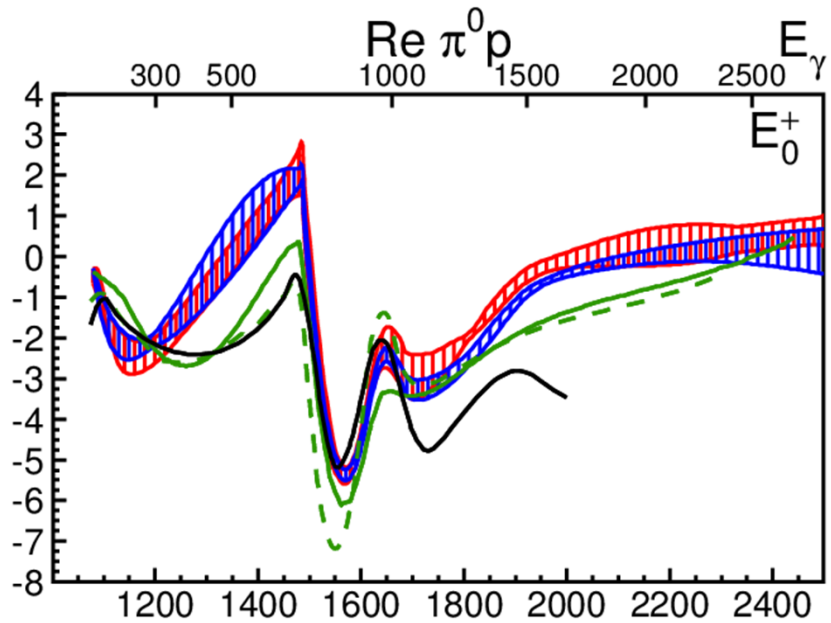
Very preliminary: new BnGa multipole solution including the new polarization data G,E,T,P and H (A. Sarantsev talk)

M1+ Multipole

- $M_{1+}$  multipole  
 $P_{33}(1232)$ ,  $P_{33}(1620)$  and  $P_{13}(1720)$



# $\rho\pi^0$ : Impact of the new $G, E, T, P$ and $H$ data

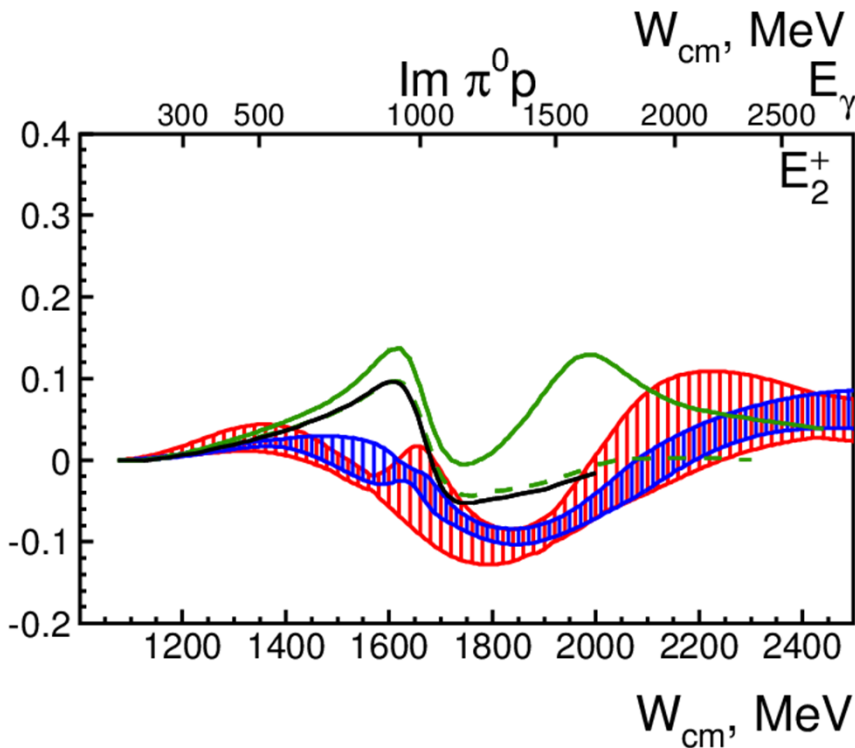
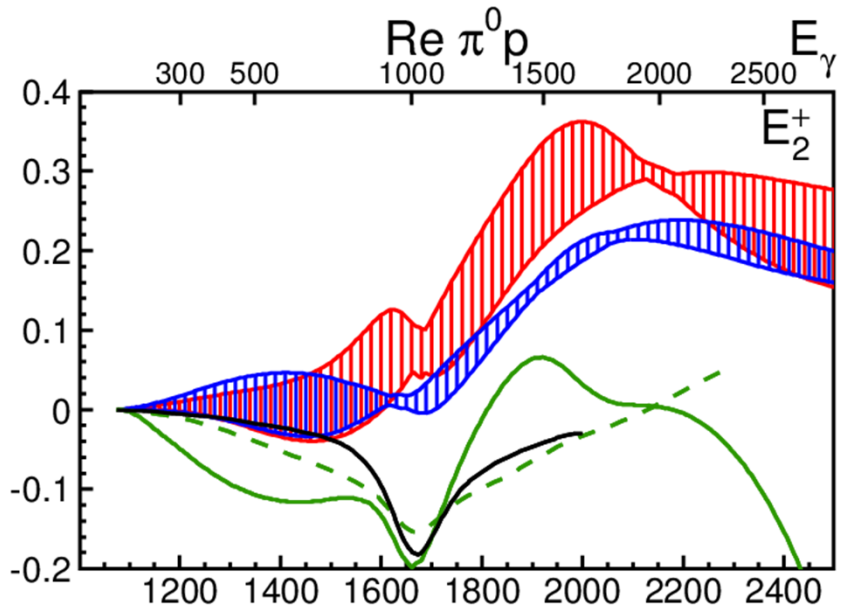


Very preliminary: new BnGa multipole solution including the new polarization data  $G, E, T, P$  and  $H$  (A. Sarantsev talk)

$E_{0+}$  Multipole

- $E_{0+}$  multipole  
 $S_{11}(1535)$ ,  $S_{11}(1650)$  and  $S_{31}(1620)$

# $\rho\pi^0$ : Impact of the new G,E,T,P and H data



Very preliminary: new BnGa multipole solution including the new polarization data G,E,T,P and H (A. Sarantsev talk)

E<sub>2+</sub> Multipole

- E<sub>2+</sub> multipole D<sub>15</sub>(1675)

# Summary

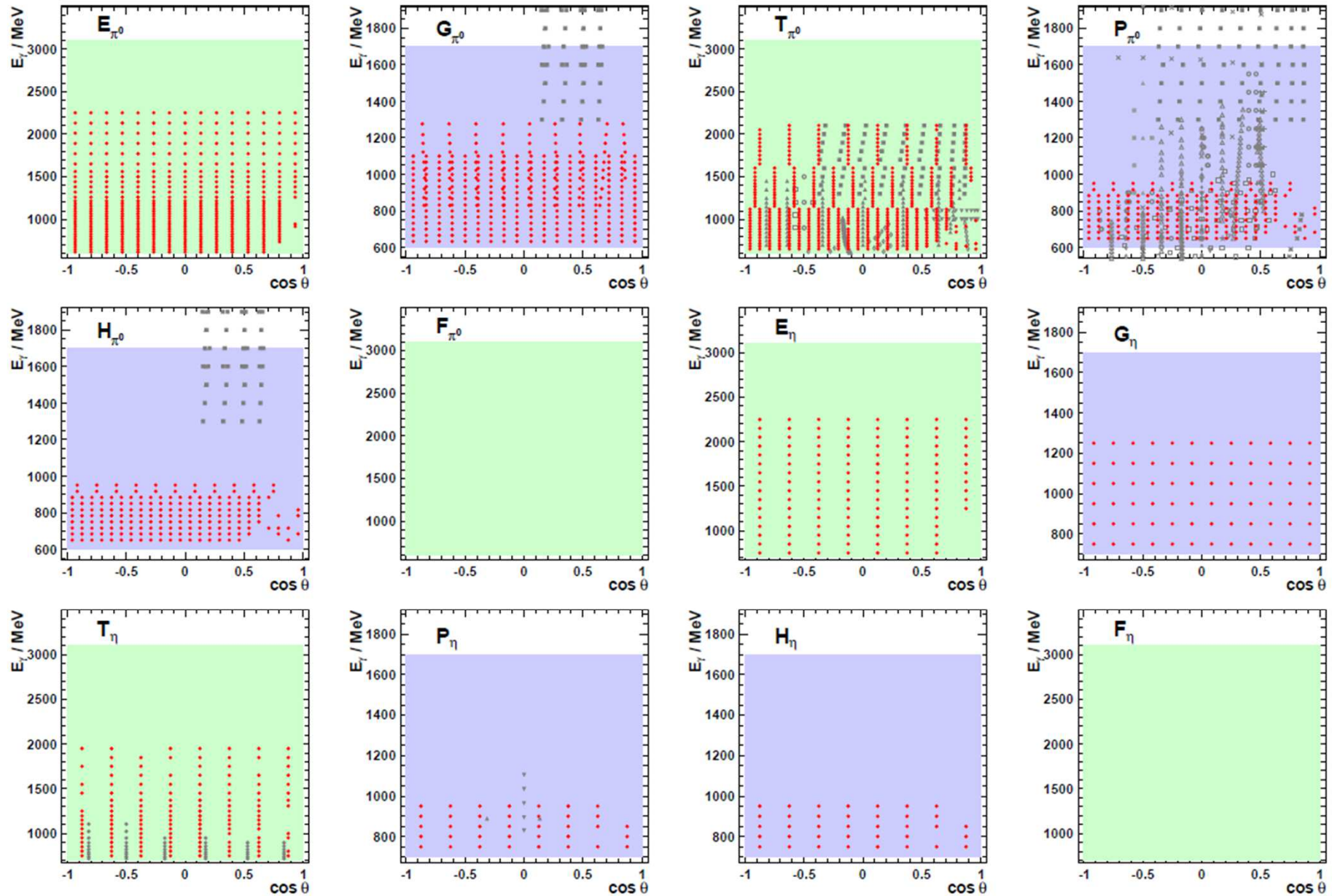
- First round of double polarization experiments at ELSA finished
- Final results for the polarization observable **T**, **P**, **G**, **E** and **H** in  $\vec{\gamma} \vec{p} \rightarrow p \pi^0$ 
  - **G** results is published in PRL (A. Thiel et al.)
  - **E** results ready for publication, is submitted to PRL (M. Gottschall et al.)
  - **T**, **P** and **H** results publication in preparation (J. Hartmann et al.)
- Close to final results for the polarization observable **T**, **P**, **G**, **E** and **H** in  $\vec{\gamma} \vec{p} \rightarrow p \eta$ 
  - Results based on the PhD thesis of M. Grüner, J. Hartmann and J. Müller
- Our new polarization data for  $\vec{\gamma} \vec{p} \rightarrow p \pi^0$  are included in the BnGa PWA
  - polarization observables are essential
  - the new data constrain the possible multipole solutions
  - a truncated partial wave analysis seems possible
- New polarization data will determine nucleon excitation spectrum

**Thank You**

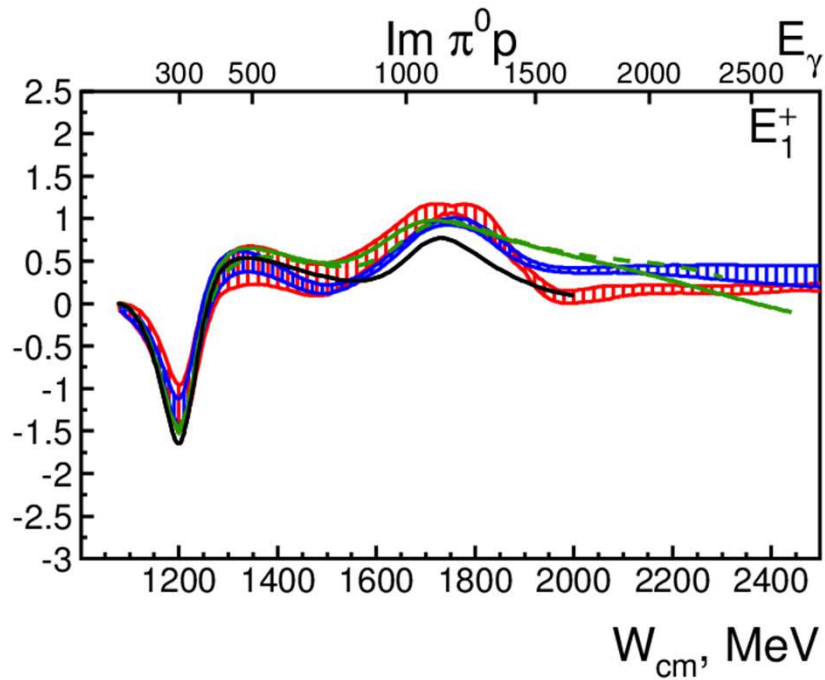
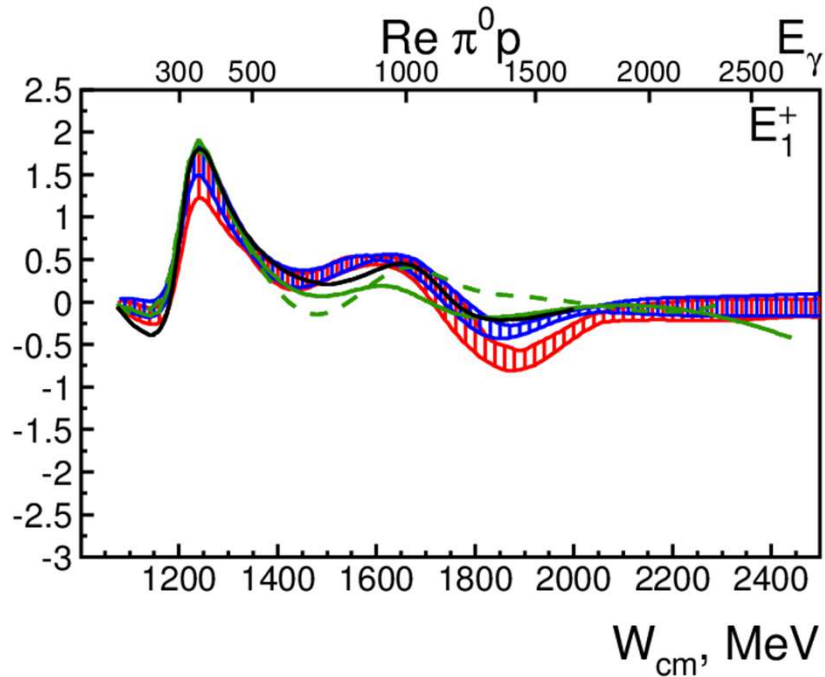


# Polarization observable off the proton

Data from first round of double polarization experiments with Crystal Barrel / Taps experiment



# $\rho\pi^0$ : Impact of the new $G,E,T,P$ and $H$ data

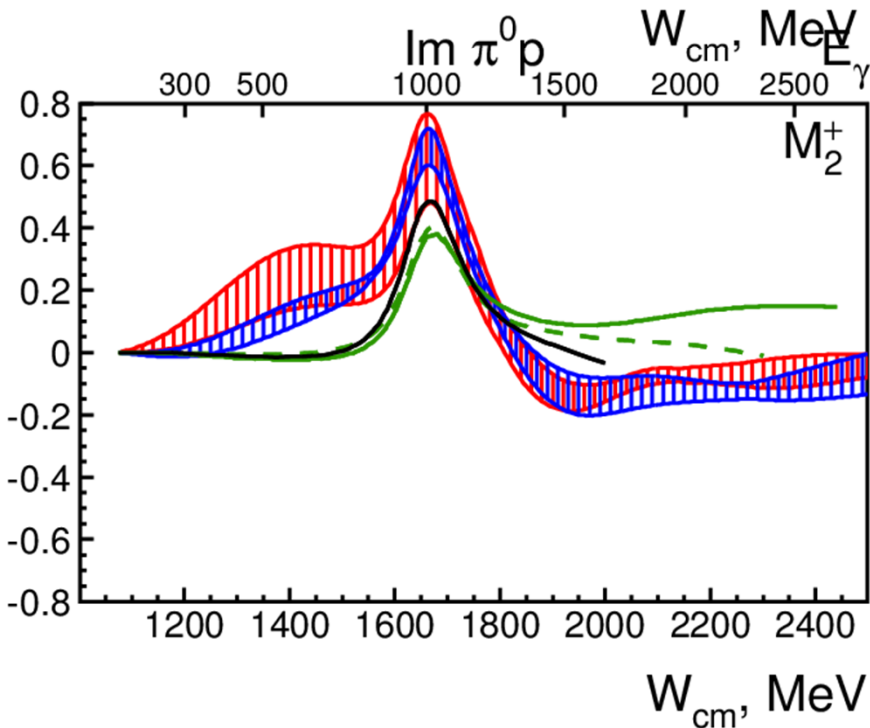
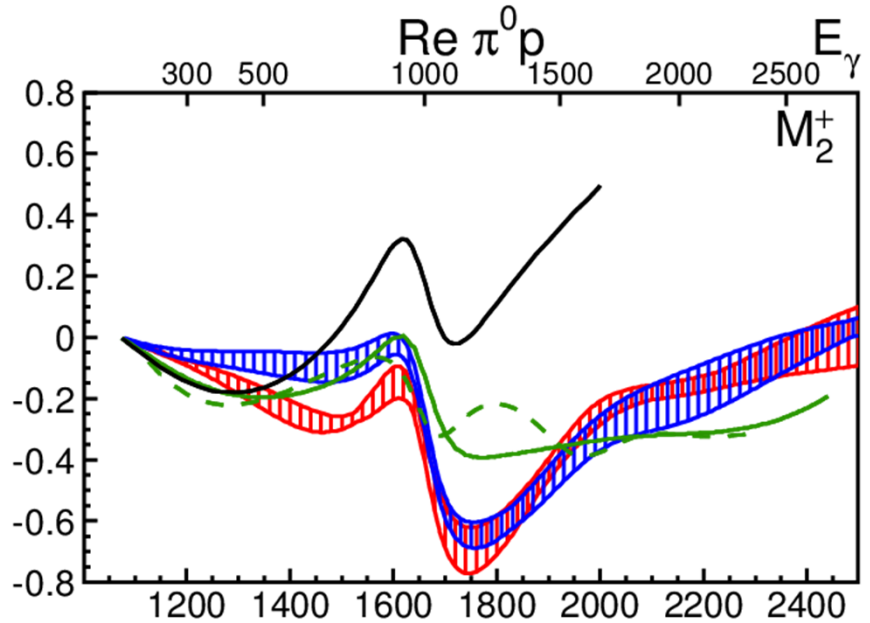


Very preliminary: new BnGa multipole solution

M1+ Multipole

- $E_{1+}$  multipole  
 $P_{33}(1232)$ ,  $P_{33}(1620)$  and  $P_{13}(1720)$

# $\rho\pi^0$ : Impact of the new G,E,T,P and H data



Very preliminary: new BnGa multipole solution including the new polarization data G,E,T,P and H (A. Sarantsev talk)

M2+ Multipole

- $M_{2+}$  multipole  $D_{15}(1675)$

# Status on Baryon Resonances

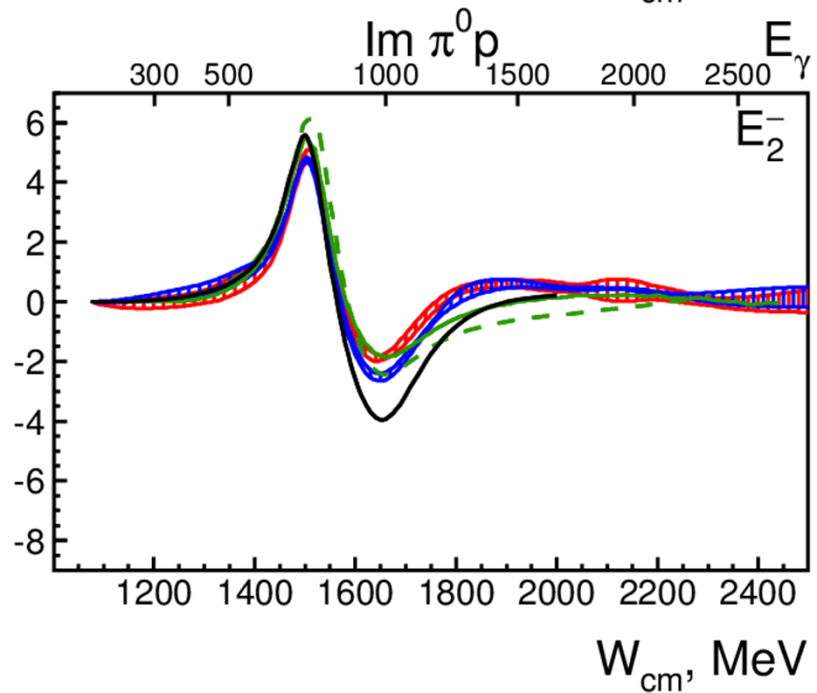
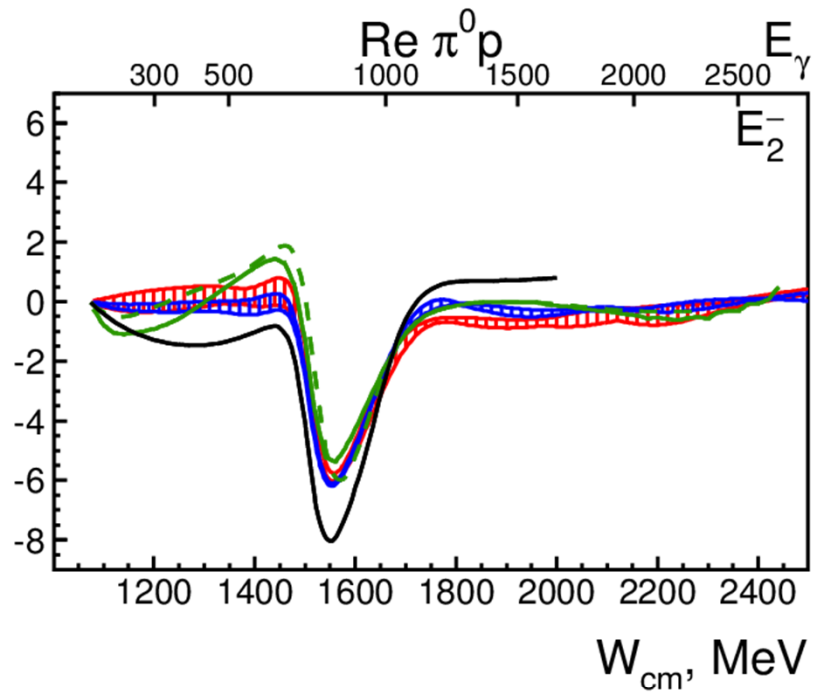
Multi-channel BnGa partial wave analysis, including data from Crystal Barrel/TAPS at ELSA and other labs

confirmation of known resonances  
search for new resonances

	PDG 2010	BnGa-PWA	PDG 2012	GWU'06
<b>N(1860)5/2<sup>+</sup></b>		*	**	
<b>N(1875)3/2<sup>-</sup></b>		***	***	
<b>N(1880)1/2<sup>+</sup></b>		**	**	
<b>N(1895)1/2<sup>-</sup></b>		**	**	
<b>N(1900)3/2<sup>+</sup></b>	**	***	***	no evidence
<b>N(2060)5/2<sup>-</sup></b>		***	**	
<b>N(2150)3/2<sup>-</sup></b>		**	**	
<b>Δ(1940)3/2<sup>-</sup></b>	*	*	**	no evidence

Results from meson-photoproduction do now enter the PDG and determine the properties of baryon resonances

# $\rho\pi^0$ : Impact of the new $G, E, T, P$ and $H$ data



Very preliminary : new BnGa multipole solution

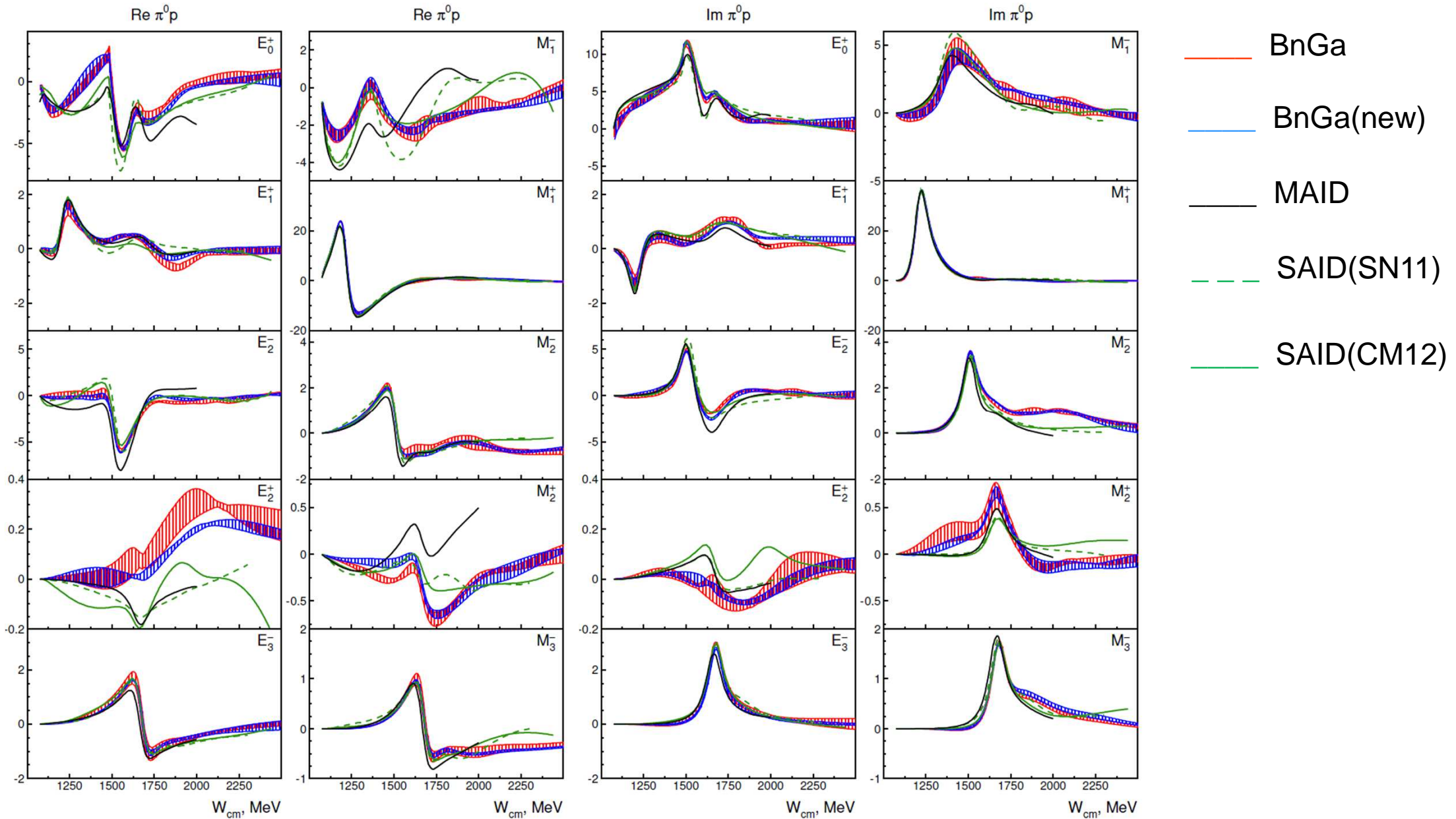
E2- Multipole

- $E_{2-}$  multipole  
 $D_{13}(1520)$ ,  $D_{13}(1700)$  and  $D_{33}(1700)$



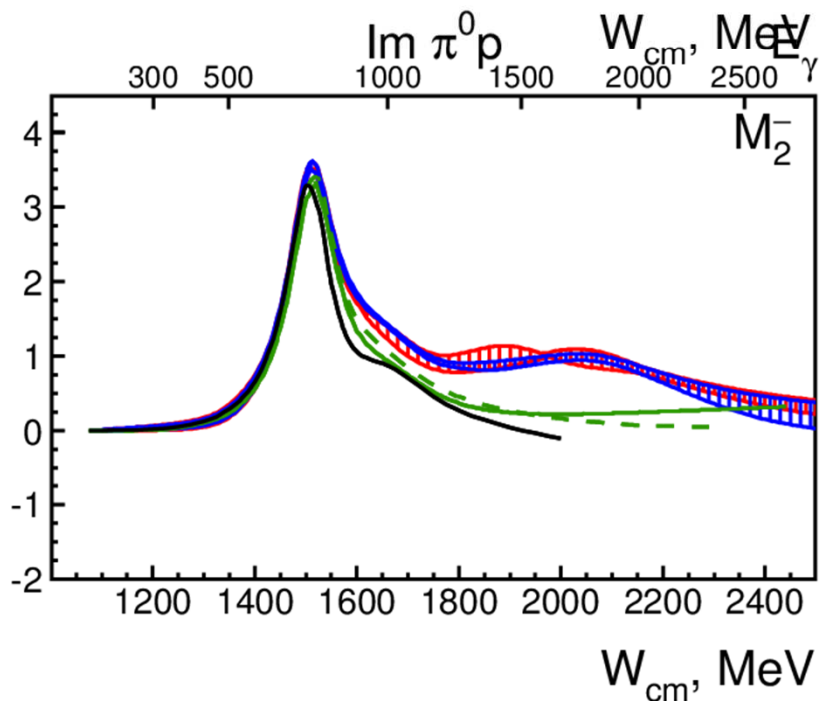
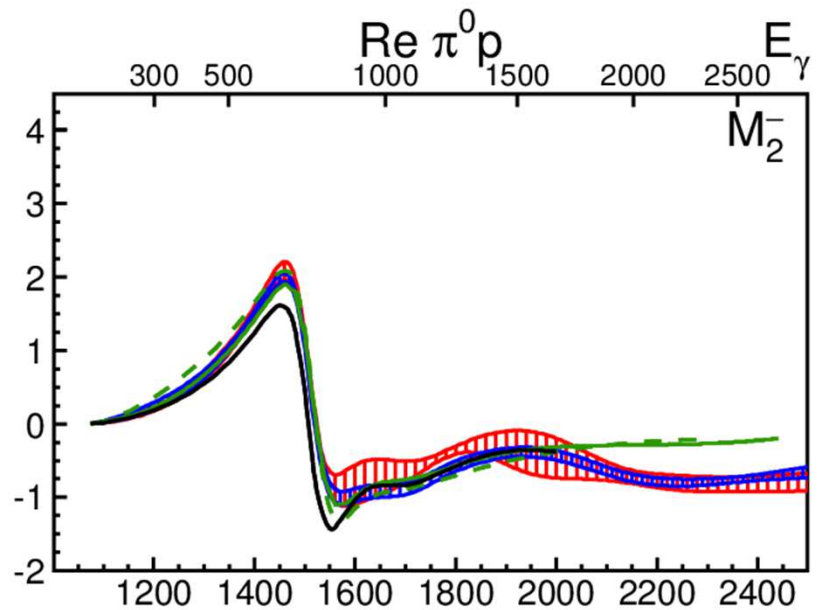
# $\rho\pi^0$ : Impact of the new $G, E, T, P$ and $H$ data

Very preliminary : new BnGa multipole solution, impact of our new data in the full data base





# $\rho\pi^0$ : Impact of the new $G, E, T, P$ and $H$ data

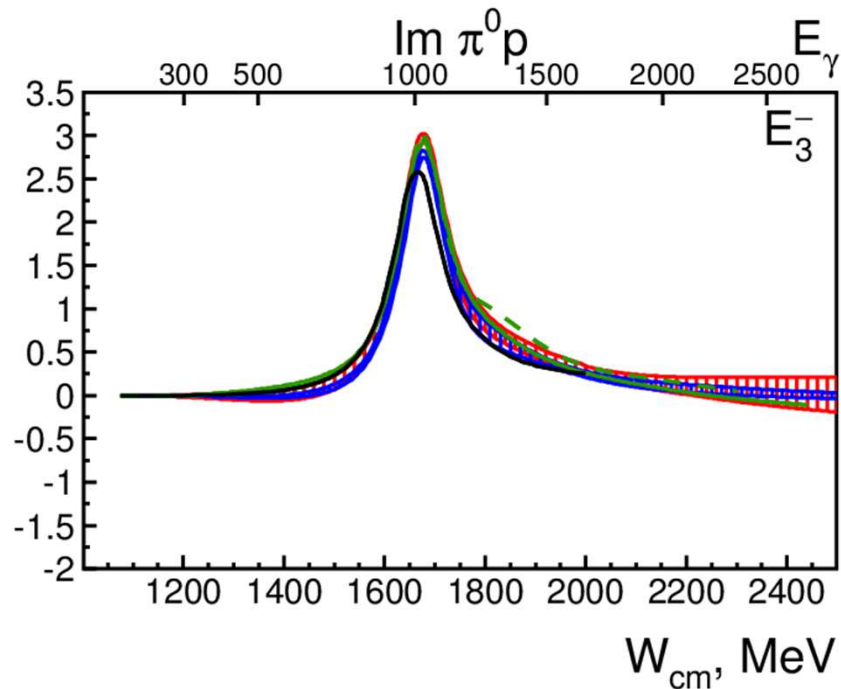
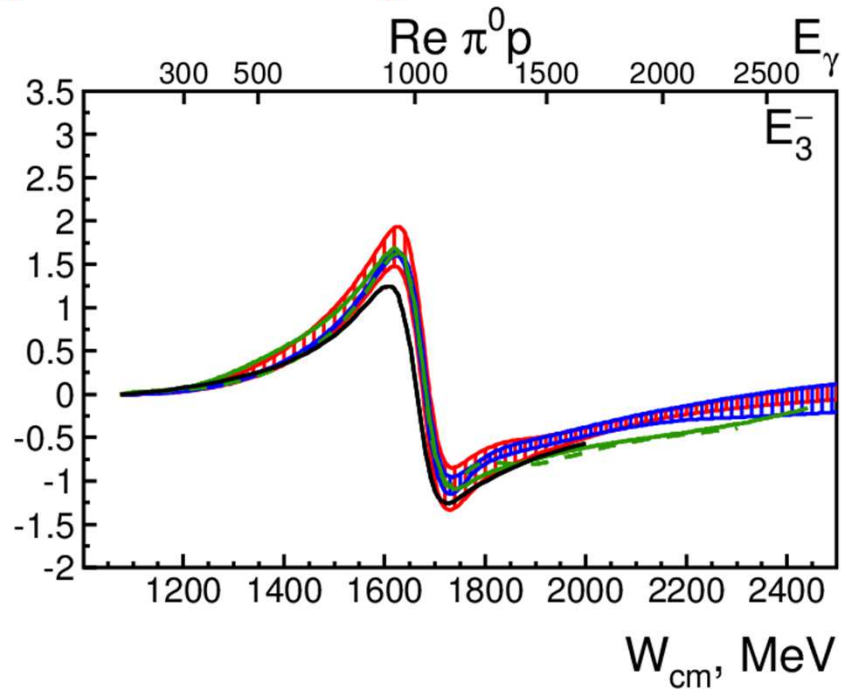


Very preliminary : new BnGa multipole solution

$M_2$ - Multipole

- $M_2$ - multipole  
 $D_{13}(1520)$ ,  $D_{13}(1700)$  and  $D_{33}(1700)$

# $\rho\pi^0$ : Impact of the new $G, E, T, P$ and $H$ data

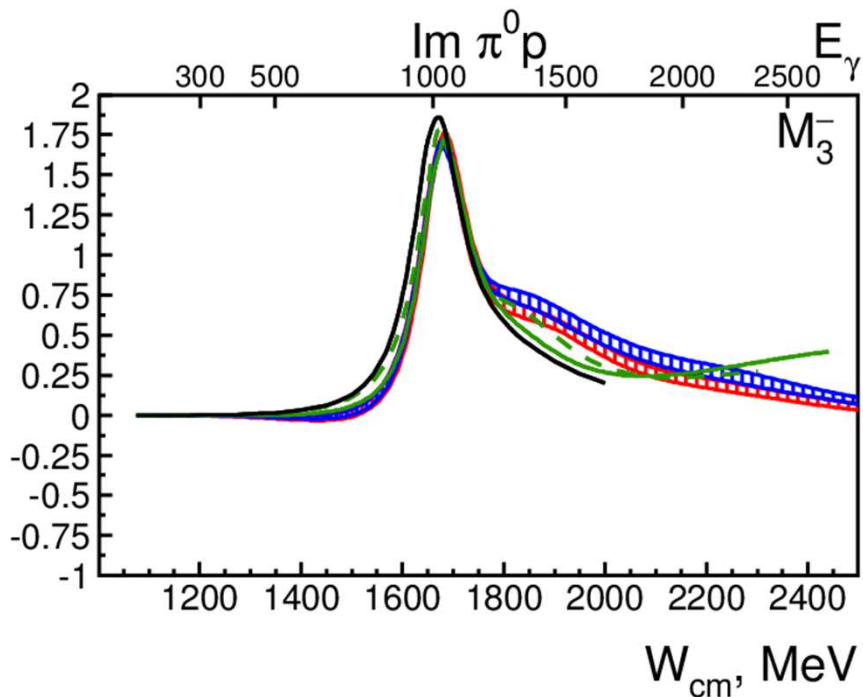
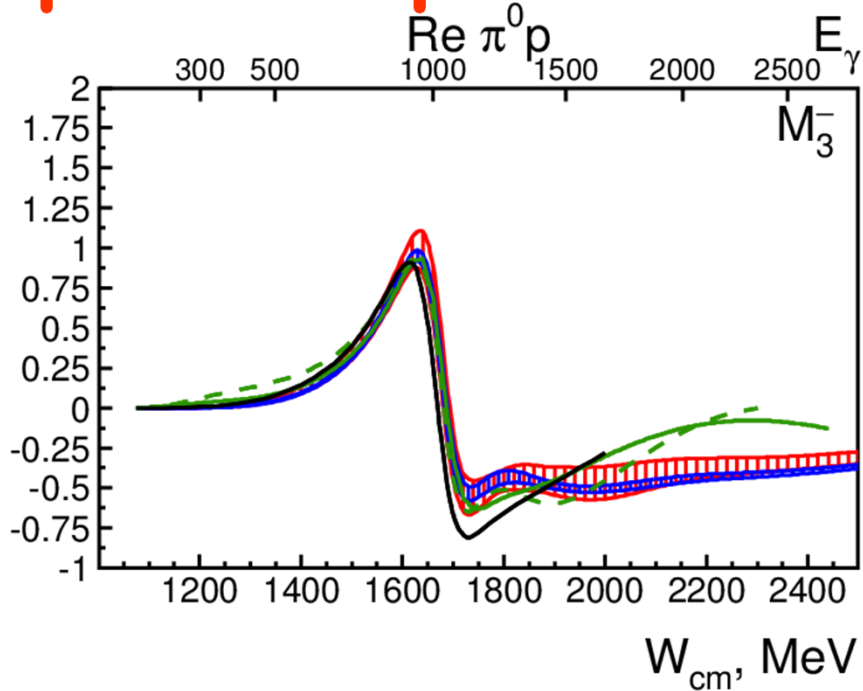


Very preliminary : new BnGa multipole solution

E3- Multipole

- $E_{3-}$  multipole  
 $F_{15}(1680), F_{35}(1905)$

# $\rho\pi^0$ : Impact of the new $G, E, T, P$ and $H$ data

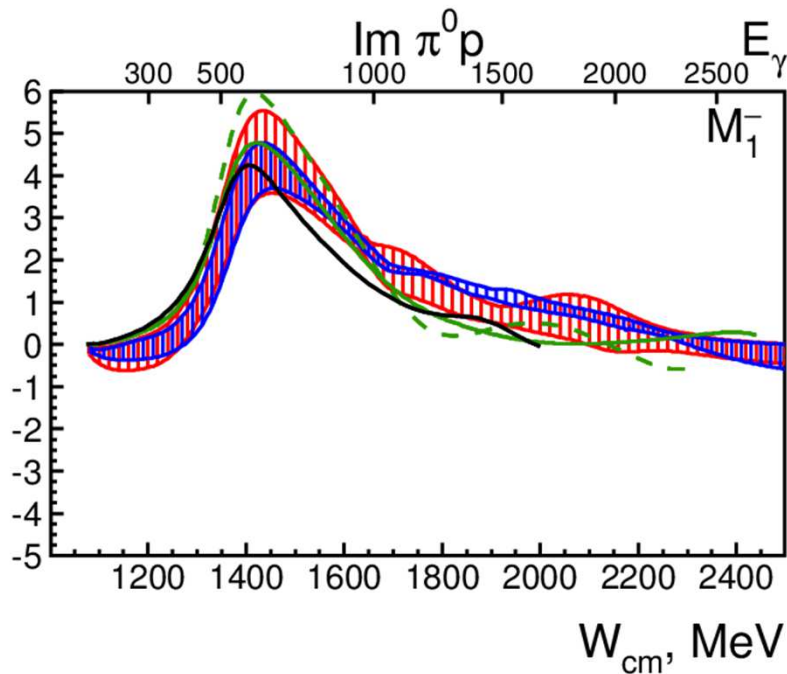
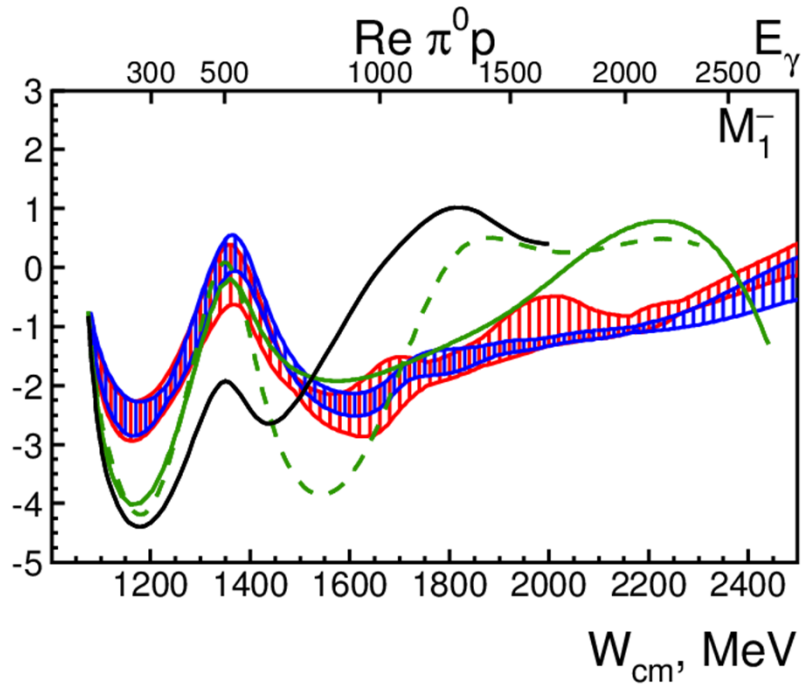


Very preliminary : new BnGa multipole solution

M3- Multipole

- $M_{3-}$  multipole  
 $F_{15}(1680)$ ,  $F_{35}(1905)$

# $\rho\pi^0$ : Impact of the new G,E,T,P and H data



Very preliminary: new BnGa multipole solution including the new polarization data G,E,T,P and H (A2- Projekt)

M1- Multipole

- $M_{1-}$  multipole  
 $P_{11}(1440)$ ,  $P_{11}(1710)$ ,  $P_{31}(1910)$