The double polarization observable E in η'-photoproduction

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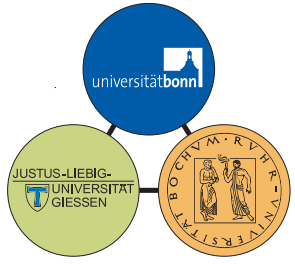
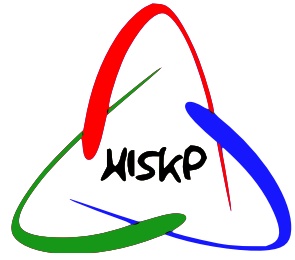


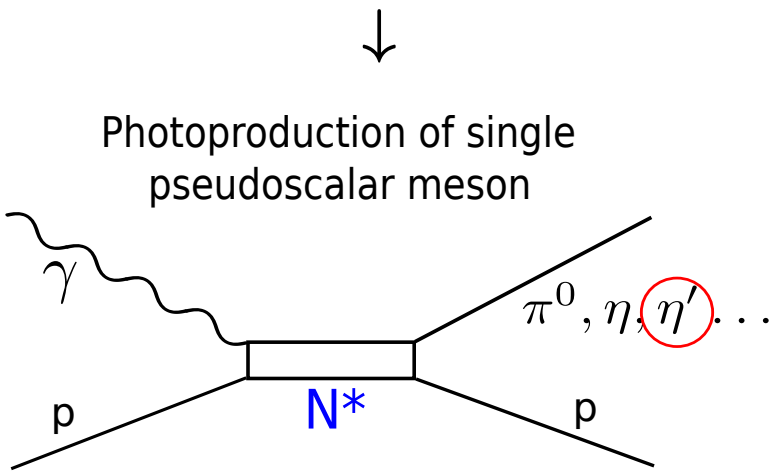


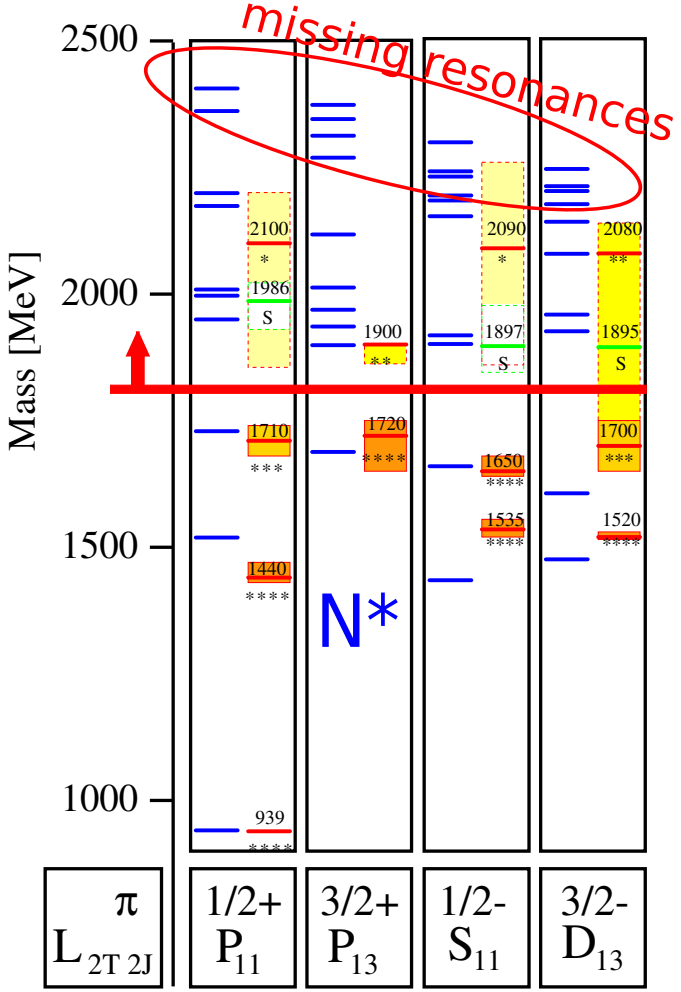
Outline

1. Motivation
2. Experimental Setup
3. Event Selection
4. Extraction of the observable E
5. Results

Baryon spectroscopy

- Goal: study dynamics of constituents inside the nucleon



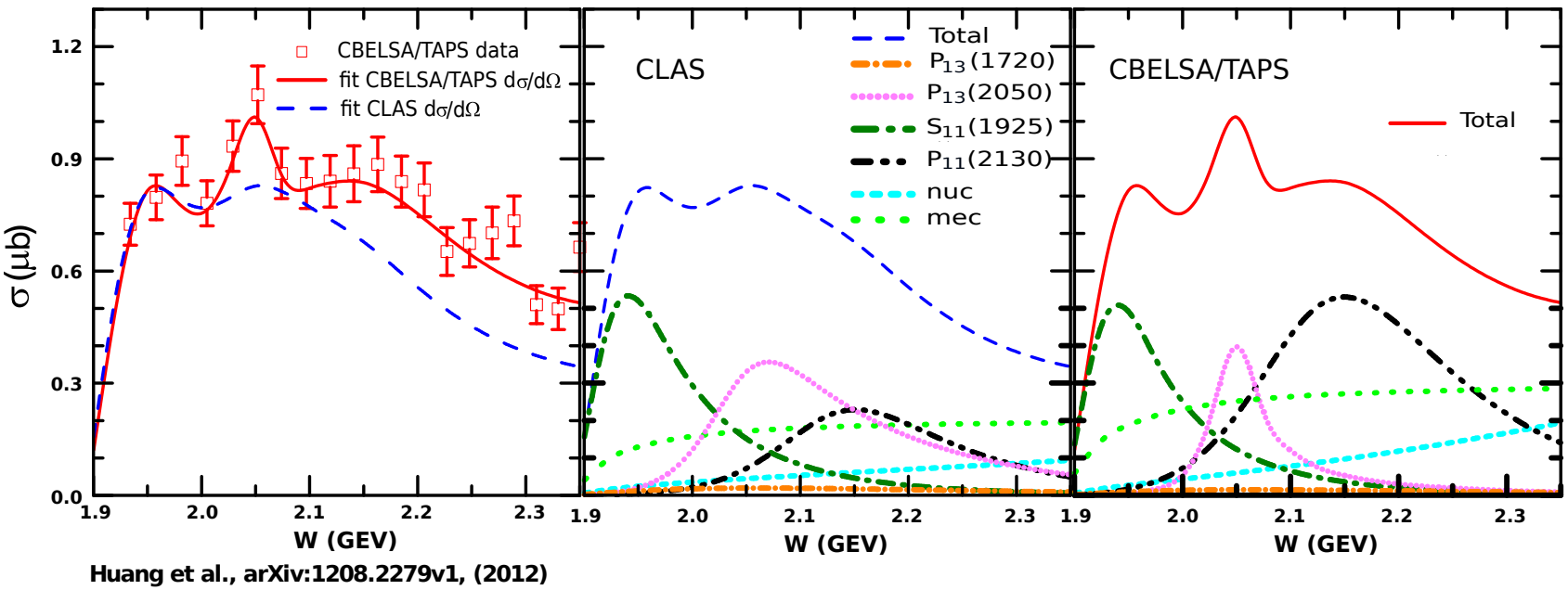


U. Loering et al., Eur.Phys.J. A, 10:395-446, 2001

- η' (T=0) $\rightarrow$ exclusive access to intermediate states N^* with T=1/2
- Probe mass range $W > 1896\,\mathrm{MeV}$

Cross section data in η'-photoproduction

- Discrepancies between measured cross section data of CLAS and CBELSA/TAPS



Huang et al., arXiv:1208.2279v1, (2012)

- The cross section alone is not sufficient to disentangle all resonance contributions unambiguously

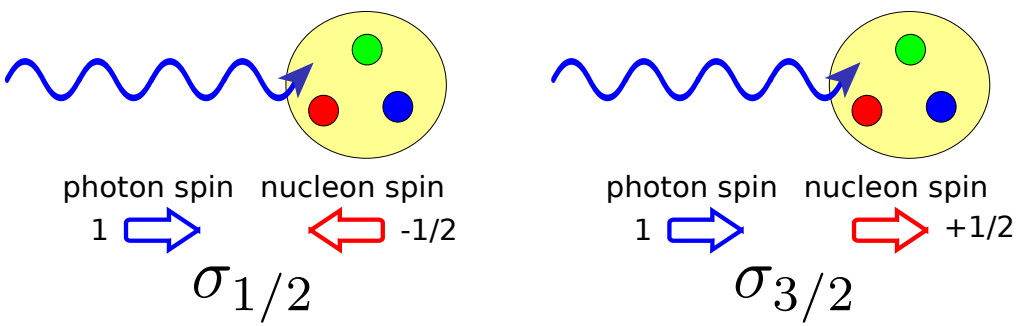
Polarization observables

- For unambiguous solution: ≥ 8 carefully chosen observables are required (Chiang and Tabakin, Phys.Rev.,C55:2054-2066, 1996)

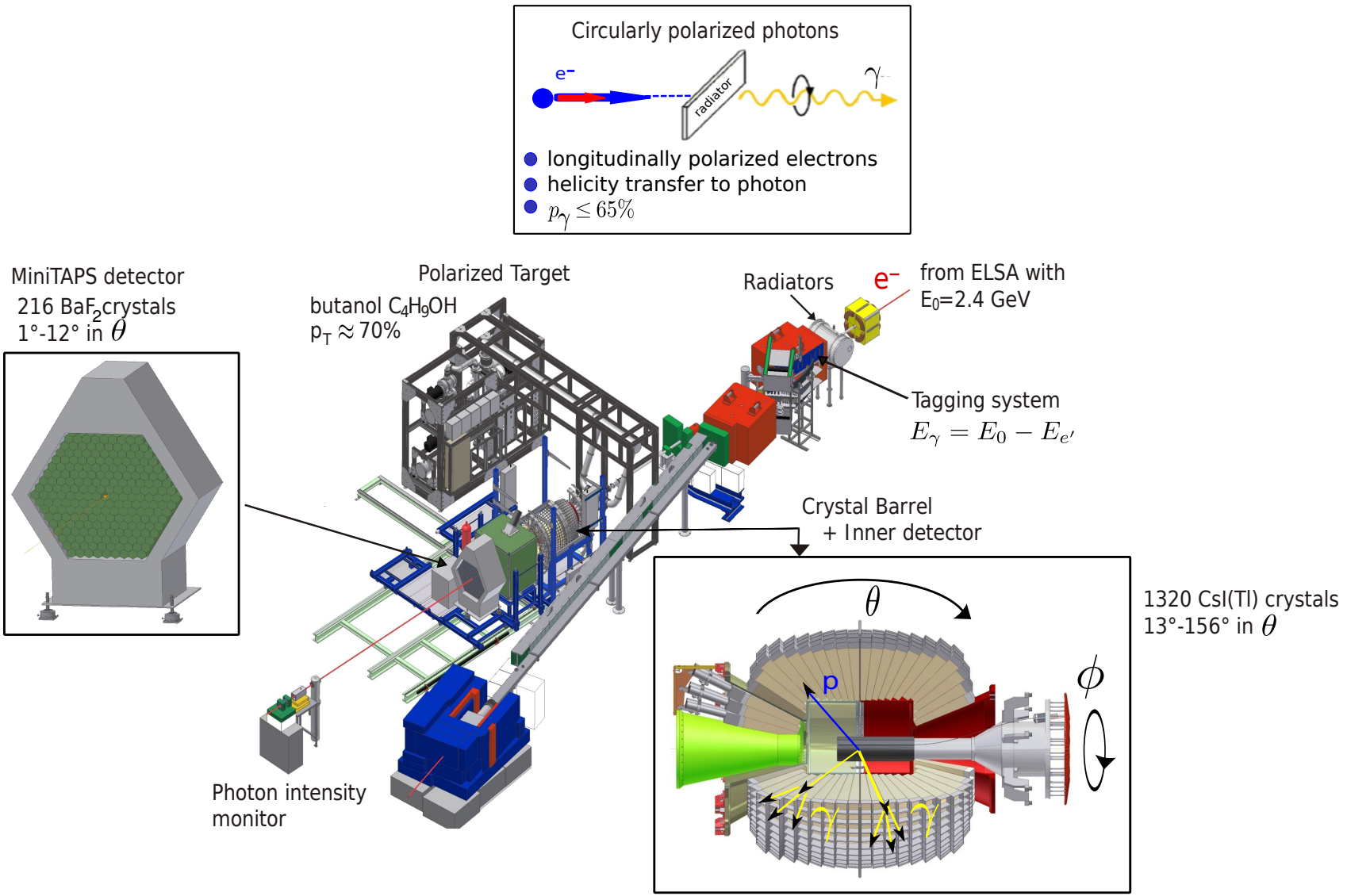
Photon polarization		Target polarization			Recoil nucleon polarization			Target and recoil polarizations			
		x	y	z	x'	y'	z'	x' x	x' z	z' x	z' z
unpolarized	σ	–	T	–	–	P	–	T_x	L_x	T_z	T_z
linearly	$\sum$	H	(-P)	-G	O_x	(-T)	O_z	$(-L_z)$	(T_z)	(L_x)	$(-T_x)$
circularly	–	F	–	-E	C_x	–	C_z	–	–	–	–

blue: measured with Crystal Barrel at ELSA in diff. reactions

- Helicity asymmetry E



The CBELSA/TAPS experiment



Decay modes of η'

The CBELSA/TAPS experiment is specialized in detecting photons in the final state

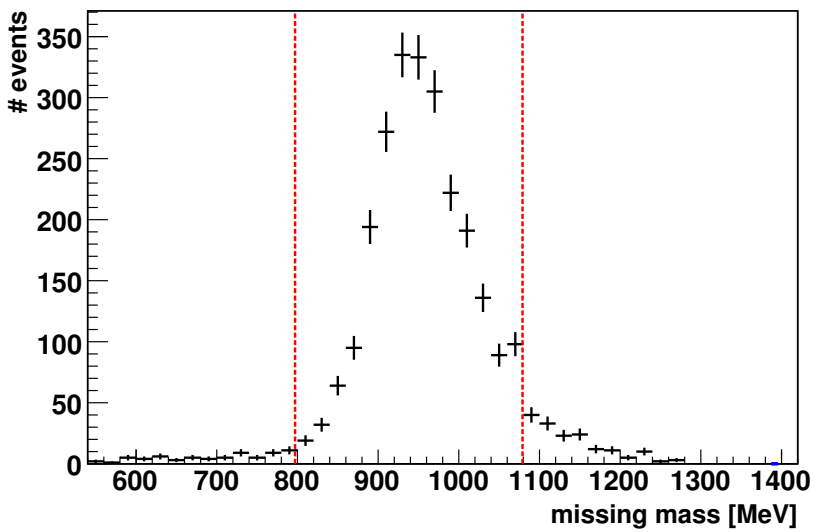
$\Rightarrow$ Choose decay modes III and V for analysis

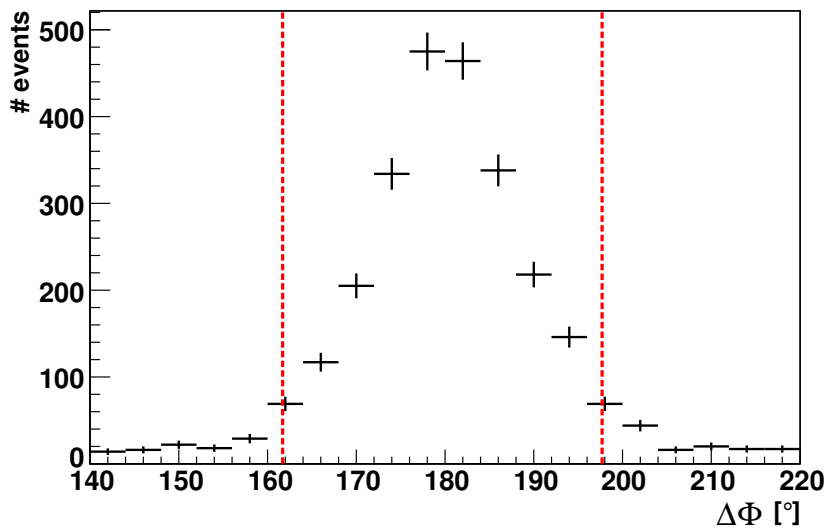
No.	decay mode	Branching ratio
I	$\pi^+\pi^-\eta$	43.2%
II	$\rho^0\gamma(\rightarrow \pi^+\pi^-\gamma)$	29.3% (29.3%)
III	$\pi^0\pi^0\eta(\rightarrow 6\gamma)$	21.7% (8.6%)
IV a)	$\omega\gamma(\rightarrow \pi^+\pi^-\pi^0\gamma)$	2.8% (2.5%)
b)	$\omega\gamma(\rightarrow \pi^0\gamma\gamma)$	2.8% (0.23%)
V	$\gamma\gamma$	2.2%

Selection process of $\eta' \to \gamma\gamma$ (BR: 2.2%)

Selected events had to fulfill kinematic constraints:

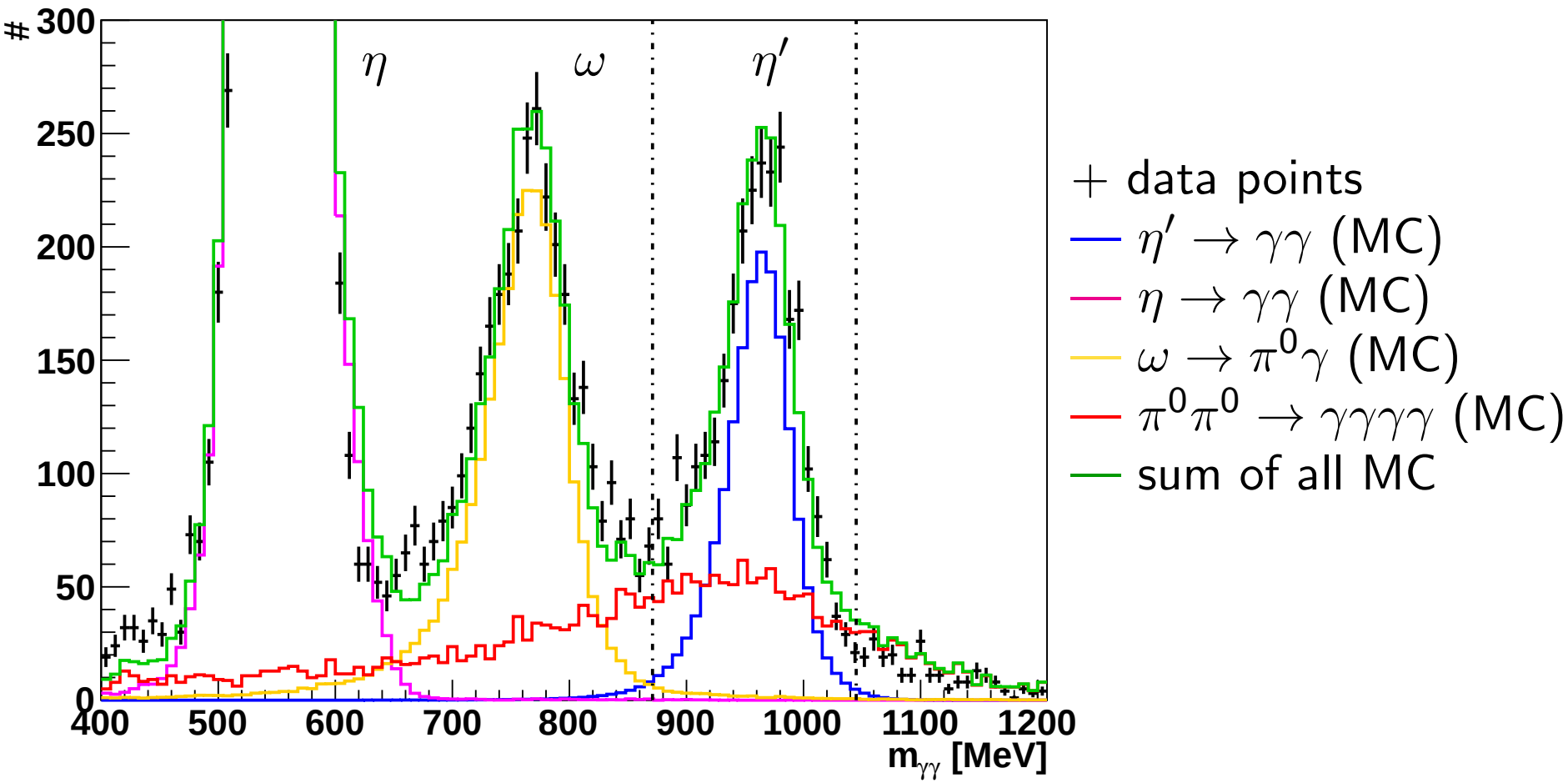
- 3 hits in calorimeters (p+2γ)
- Proton: calculated as missing mass of $\gamma p \to \eta' X$
- Angular-cuts:
  - Agreement of missing mass and measured charged particle in θ
  - Coplanarity-cut: $\Delta\Phi = |\Phi_{\eta'} - \Phi_p| = 180°$ within 3σ
- Beam photon: $E_\gamma > 1447\,\mathrm{MeV}$ and time coincidence with reaction products





Selection process of $\eta' \to \gamma\gamma$

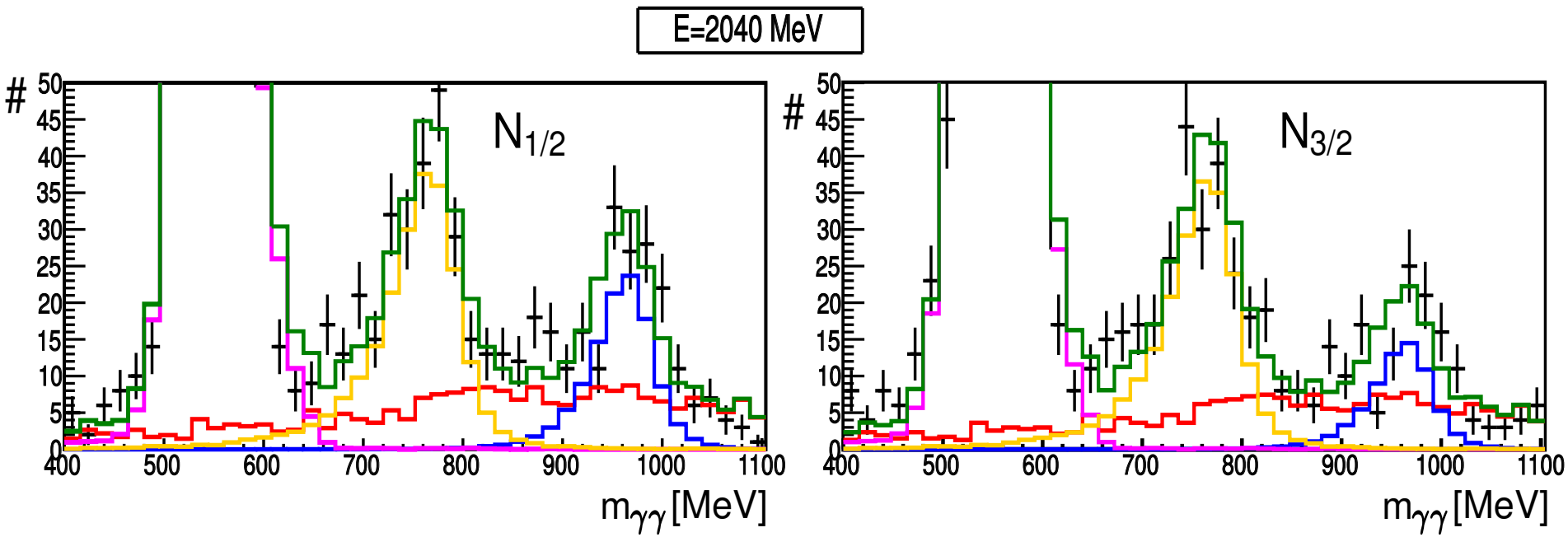
- The $\gamma\gamma$ invariant mass:



- Approximately 1800 η' events are selected

Background in $\eta' \to \gamma\gamma$

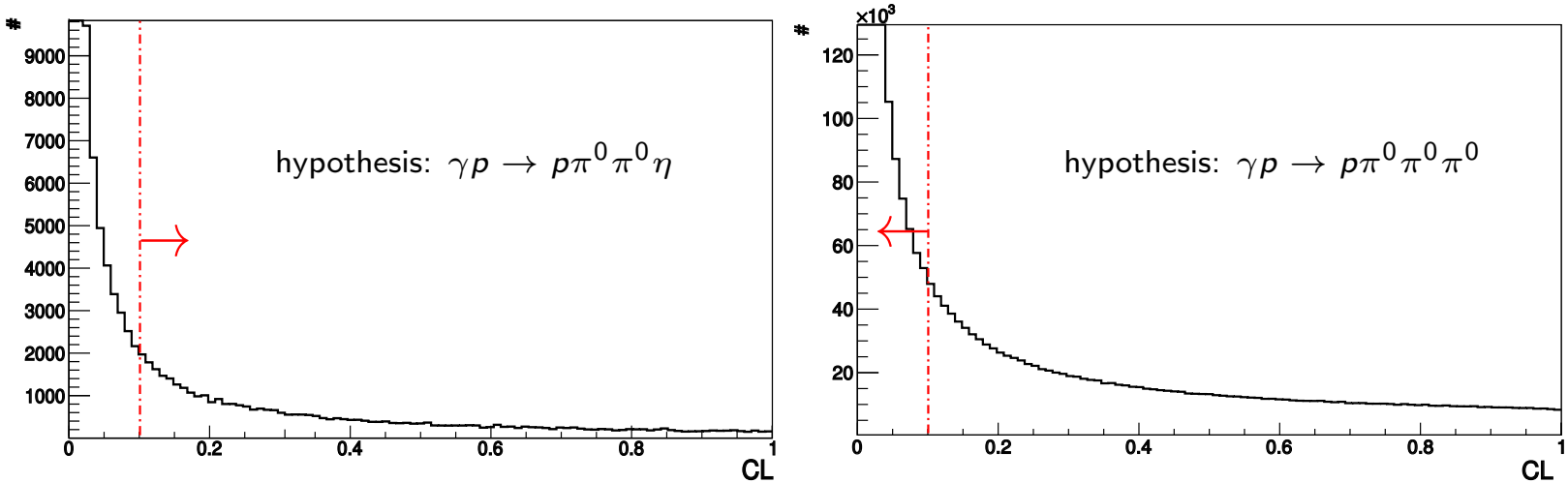
- Background estimated separately for $N_{1/2}$ and $N_{3/2}$:



+ data points
— $\eta' \to \gamma\gamma$ (MC)
— $\eta \to \gamma\gamma$ (MC)
— $\omega \to \pi^0\gamma$ (MC)
— $\pi^0\pi^0 \to \gamma\gamma\gamma\gamma$ (MC)
— sum of all MC

Selection of $\eta' \to \pi^0\pi^0\eta \to 6\gamma$

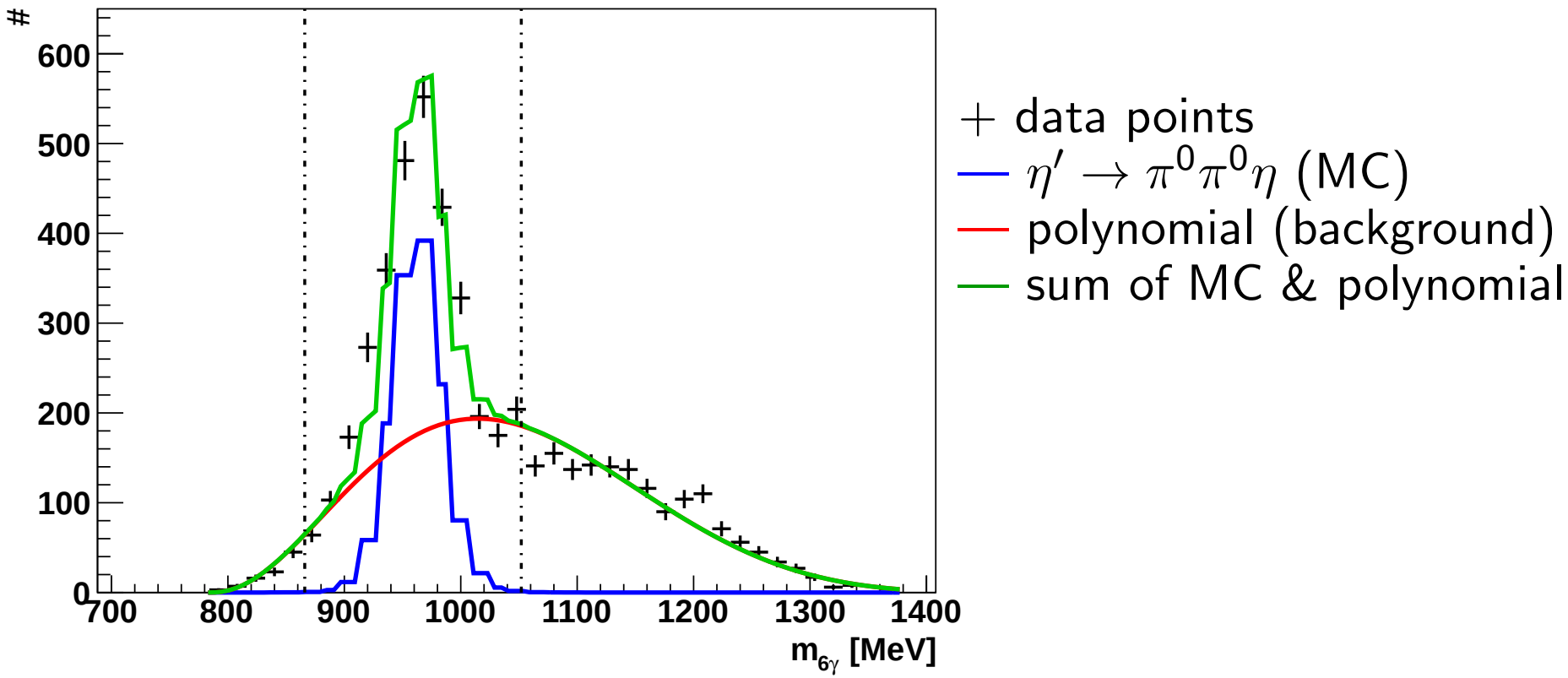
- 7 hits in the calorimeters (p+6γ)
- 3σ-cuts on meson masses $\pi^0\pi^0\eta$
- kinematic fit with hypothesis $\gamma p \to \pi^0\pi^0\eta p$ and $\gamma p \to \pi^0\pi^0\pi^0 p$
- Cuts on the confidence level of 0.1:



- time coincidence of reaction products, missing mass-cut, coplanarity-cut

Selection of $\eta' \to \pi^0\pi^0\eta \to 6\gamma$

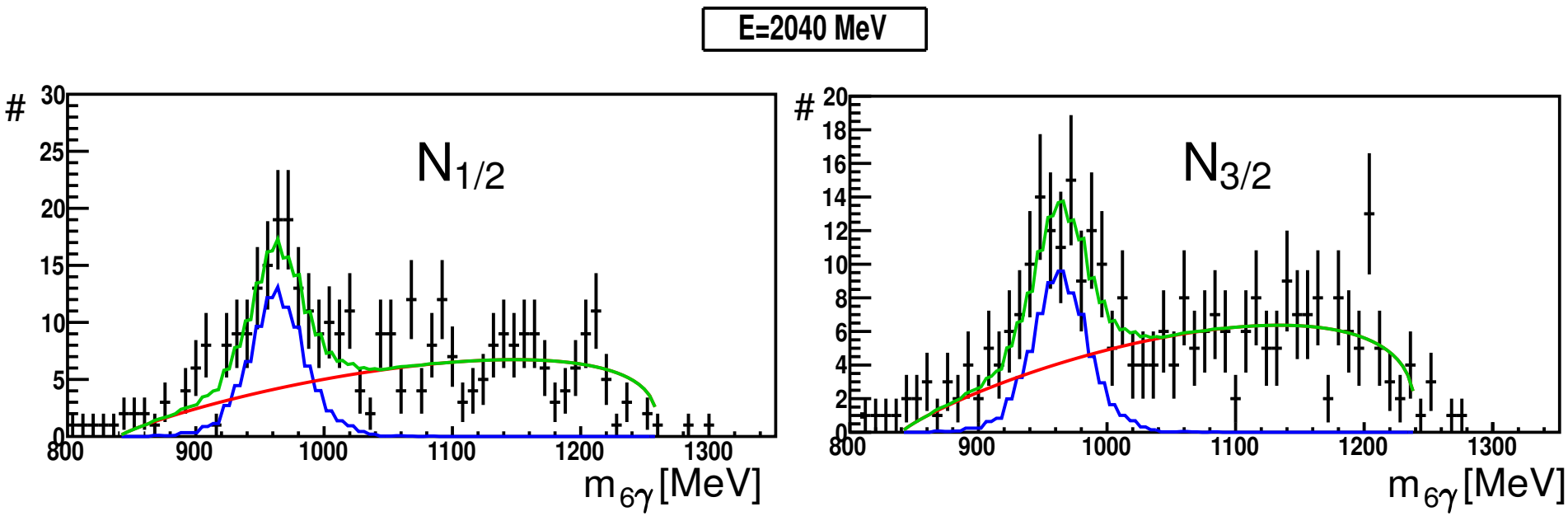
- The 6γ invariant mass:



- Approximately 2100 η' events are selected

Background in $\eta' \to \pi^0\pi^0\eta \to 6\gamma$

- Background estimated separately for $N_{1/2}$ and $N_{3/2}$:



+ data points

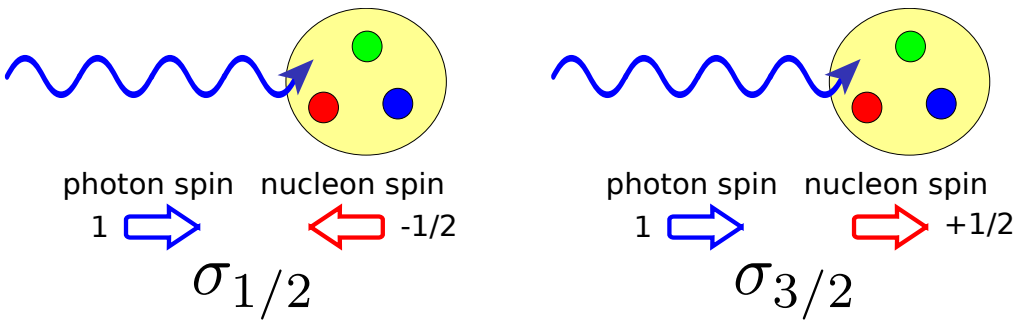
— $\eta' \to \pi^0\pi^0\eta$ (MC)

— polynomial (background)

— sum of MC & polynomial

The observable E

- Helicity asymmetry
- Two possible spin configurations



- Helicity dependent cross section:

$$\sigma^{1/2\ (3/2)} = \sigma_0 \cdot [1 \pm p_T p_\gamma \cdot E]$$

The observable E

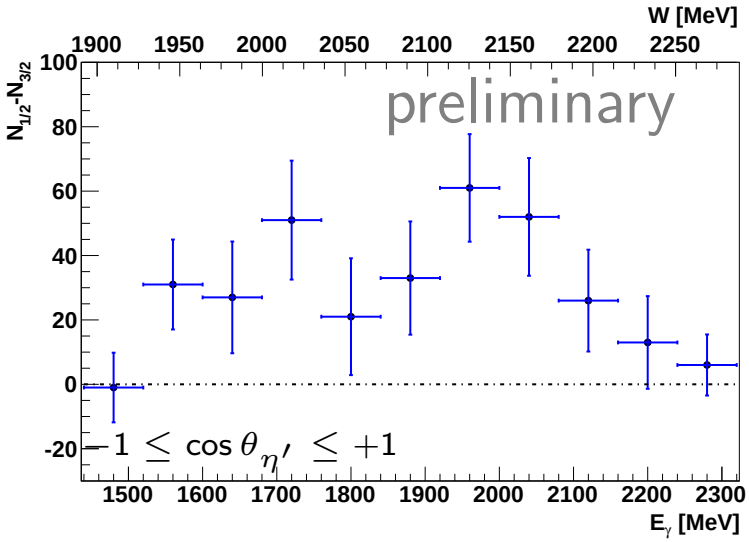
$$\sigma_B^{1/2\,(3/2)} = \sigma_f \cdot [1 \pm p_T p_\gamma \cdot E] + \sigma_b$$

$$\left.\begin{aligned} \sigma_B^{1/2} - \sigma_B^{3/2} &= \sigma_f \cdot 2 p_T p_\gamma \cdot E \\ \sigma_B^{1/2} + \sigma_B^{3/2} &= 2 \cdot (\sigma_f + \sigma_b) \end{aligned}\right\} \Rightarrow E = \frac{\sigma_B^{1/2} - \sigma_B^{3/2}}{\sigma_B^{1/2} + \sigma_B^{3/2}} \cdot \frac{1}{d} \cdot \frac{1}{p_T p_\gamma}$$

$$\boxed{E(E_\gamma) = \frac{N_B^{1/2} - N_B^{3/2}}{N_B^{1/2} + N_B^{3/2}} \cdot \frac{1}{d} \cdot \frac{1}{p_T p_\gamma}}$$

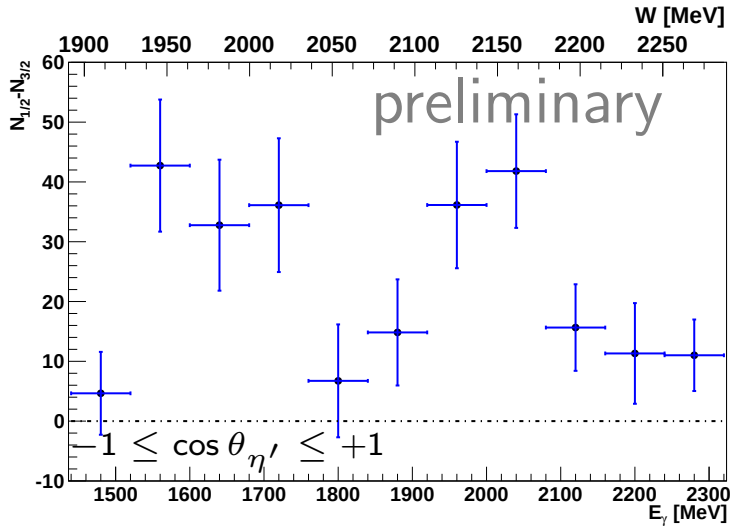
- Dilution factor d: fraction of polarizable protons
- $d(E_\gamma) = \frac{\sigma_f}{\sigma_f + \sigma_b} = 1 - \frac{\sigma_b}{\sigma_f + \sigma_b} = 1 - s_C \cdot \frac{N_C}{N_B}$

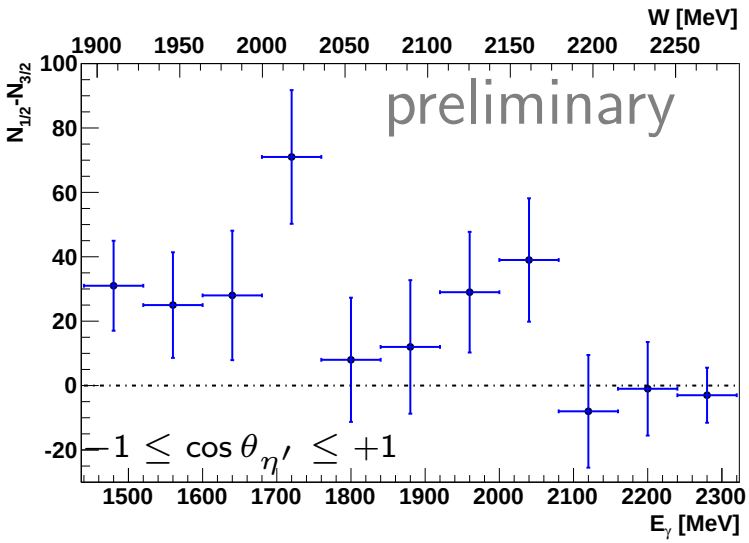
Count rate difference in η'-photoproduction



$\eta' \rightarrow 2\gamma$

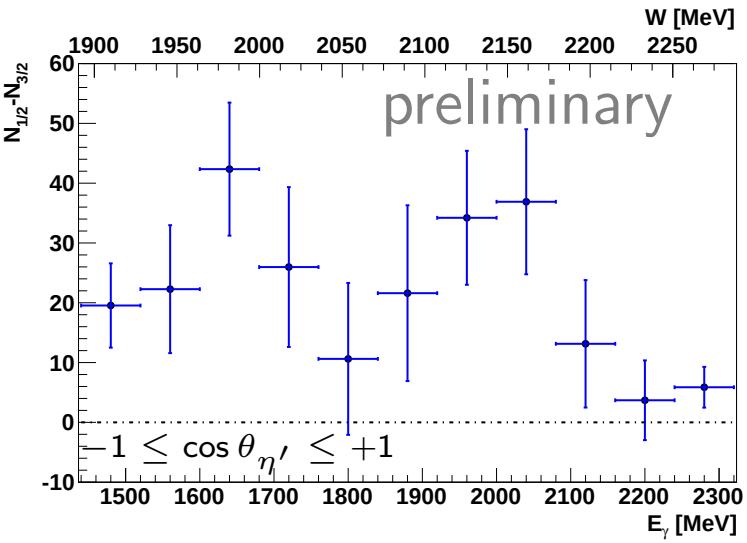
background corr.



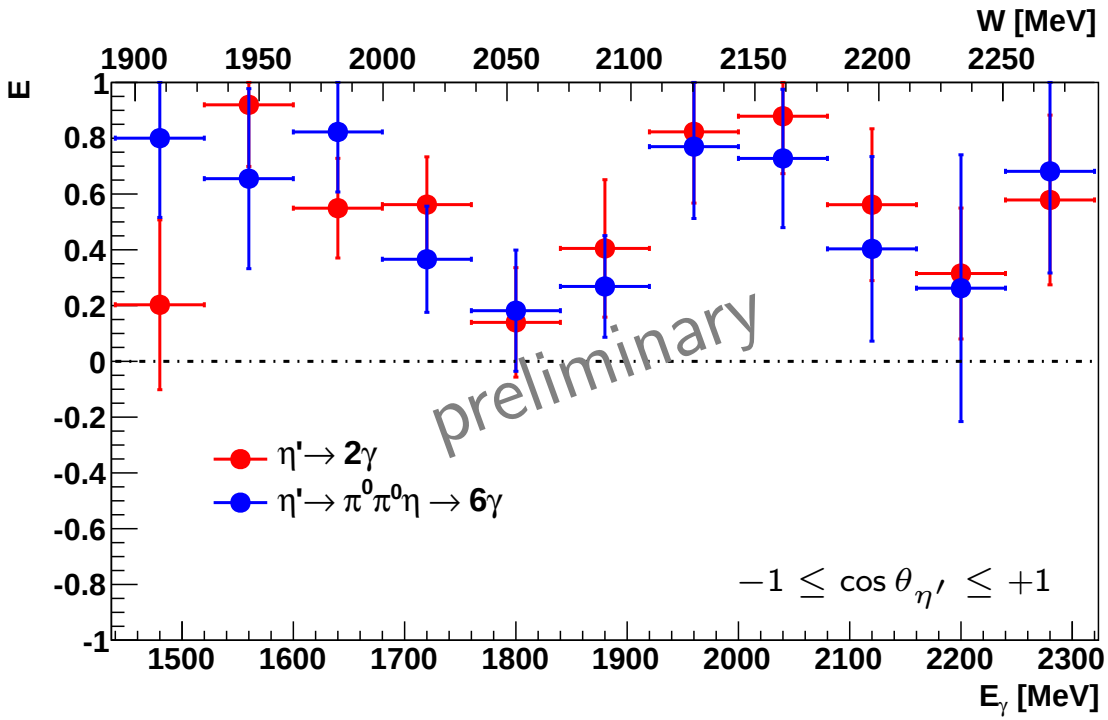


$\eta' \rightarrow \pi^0\pi^0\eta \rightarrow 6\gamma$

background corr.

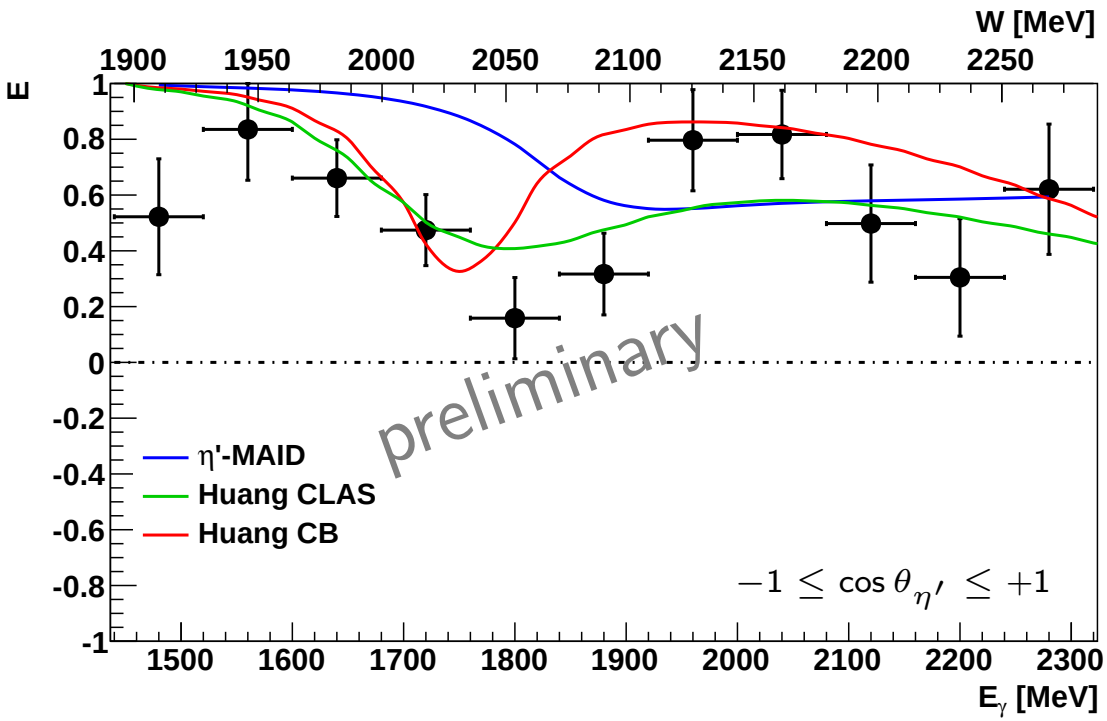


Comparison of results for the observable E



$\Rightarrow$ Results of both decay channels are in agreement

Results of $E(E_\gamma)$ in η'-photoproduction



Predictions:

- η'-MAID model:
(L. Tiator, Int.J.Mod.Phys. A22, 2007)

— η'-MAID
$S_{11}(1904)$
$P_{11}(2083)$
$P_{13}(1926)$
$D_{13}(2100)$

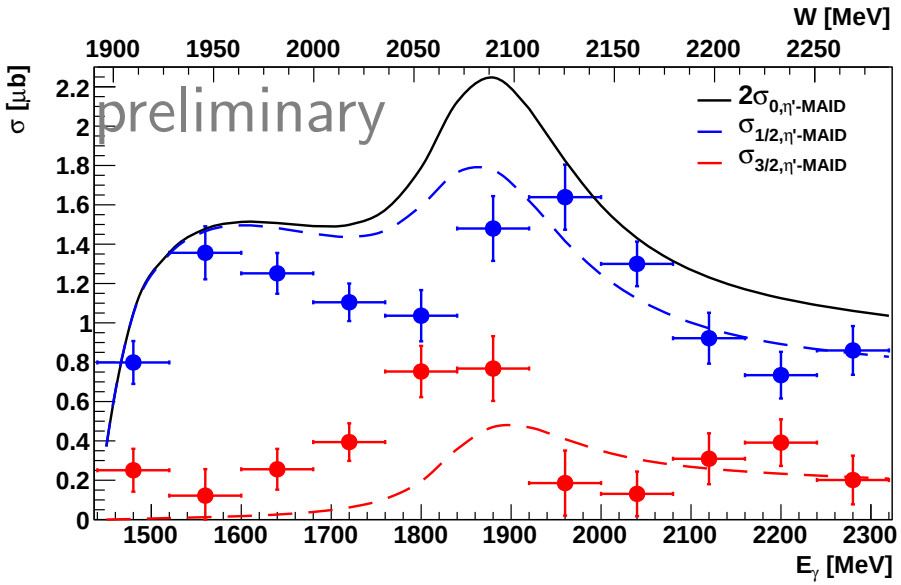
- Huang et al. model:
(Huang et al., arXiv:1208.2279v1, 2012)

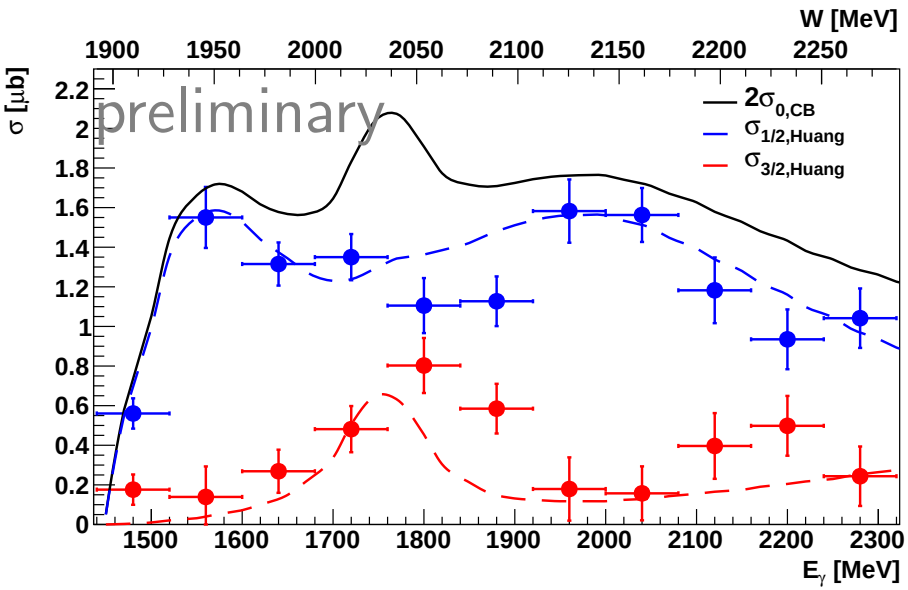
— CBELSA/TAPS — CLAS
$S_{11}(1925)$
$P_{11}(2130)$
$P_{13}(2050)$
$P_{13}(1720)^{****}$

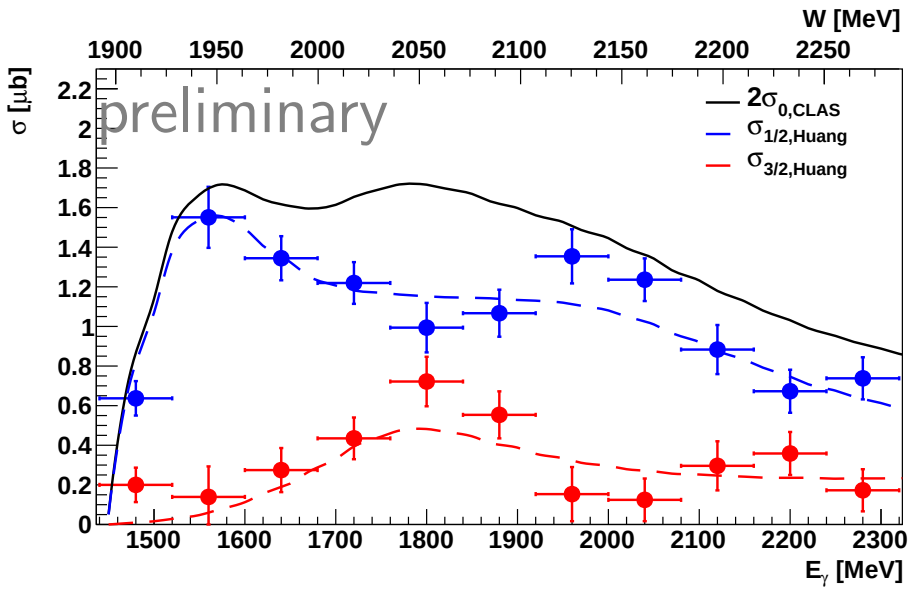
Helicity dependent cross sections $\sigma_{1/2}$ and $\sigma_{3/2}$

$$\sigma_{1/2} = \sigma_0(1 + E p_\gamma p_T)$$
$$\sigma_{3/2} = \sigma_0(1 - E p_\gamma p_T)$$

$\sigma_{0,\eta' - MAID}$: (Dugger et al., Phys.Rev.Lett.96,062001(2006))
$\sigma_{0,CLAS}$: (Williams et al., Phys.Rev.C80,045213(2009))
$\sigma_{0,CB}$: (Crede et al., Phys.Rev.C80,055202(2009))





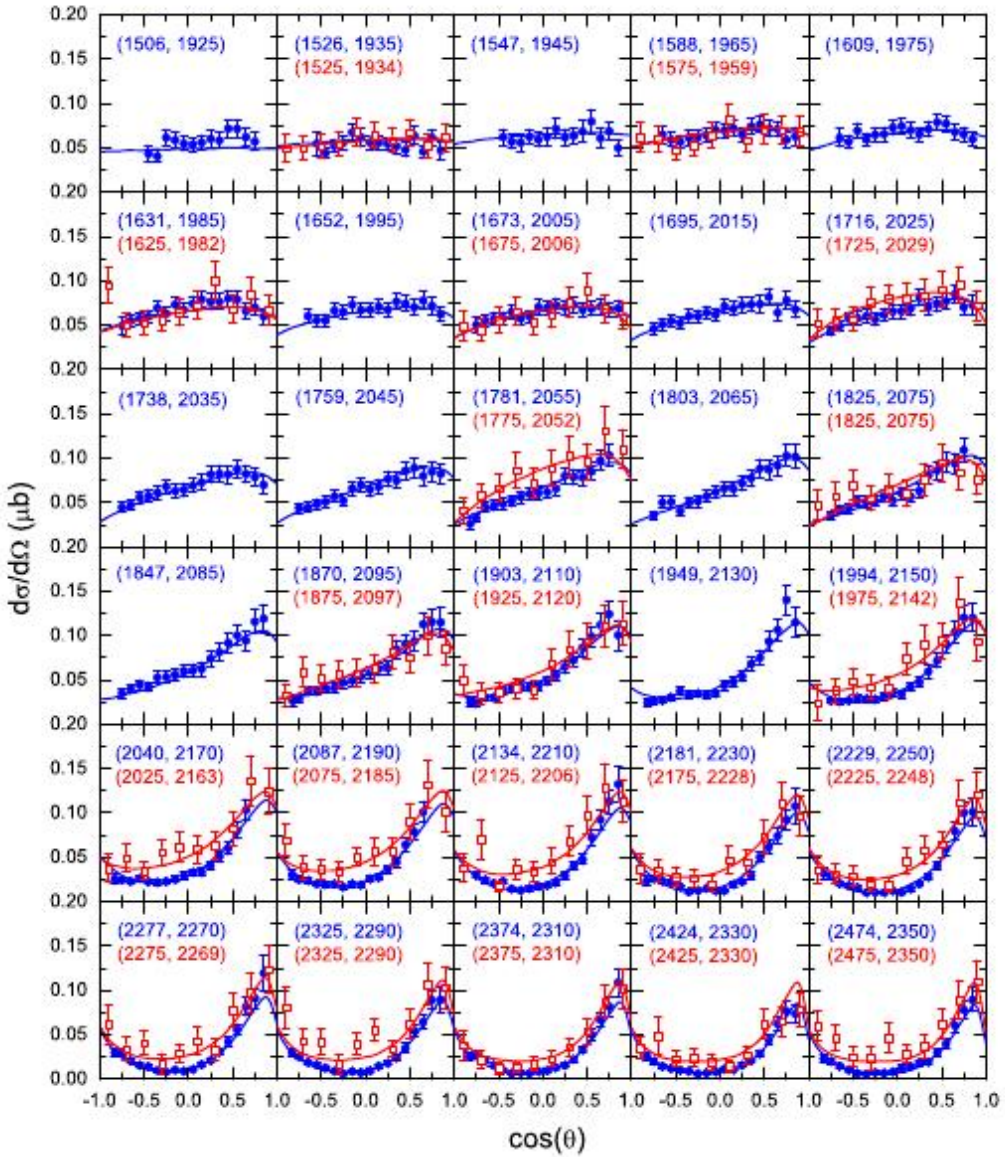


Summary and Outlook

- The observable E was determined in $\vec{\gamma}\vec{p} \rightarrow \eta' p$
- The results of both decay modes are in agreement
- Results:
  - Resonances contribute mainly to $\sigma_{1/2}$
  - Deviations to models observed
  - New information for model calculations
- Outlook:
  - Taking data with linearly polarized photons and hydrogen target
    $\rightarrow$ Access beam asymmetry Σ for $E_\gamma = 1450\,\mathrm{MeV}$ - $1700\,\mathrm{MeV}$

Thank you!

Measured η' cross section data



Huang et al., arXiv:1208.2279v1, 2012

Acceptance of both decay modes