Differential cross sections and photon beam asymmetries of η photoproduction on the proton in LEPS2/BGOegg experiment

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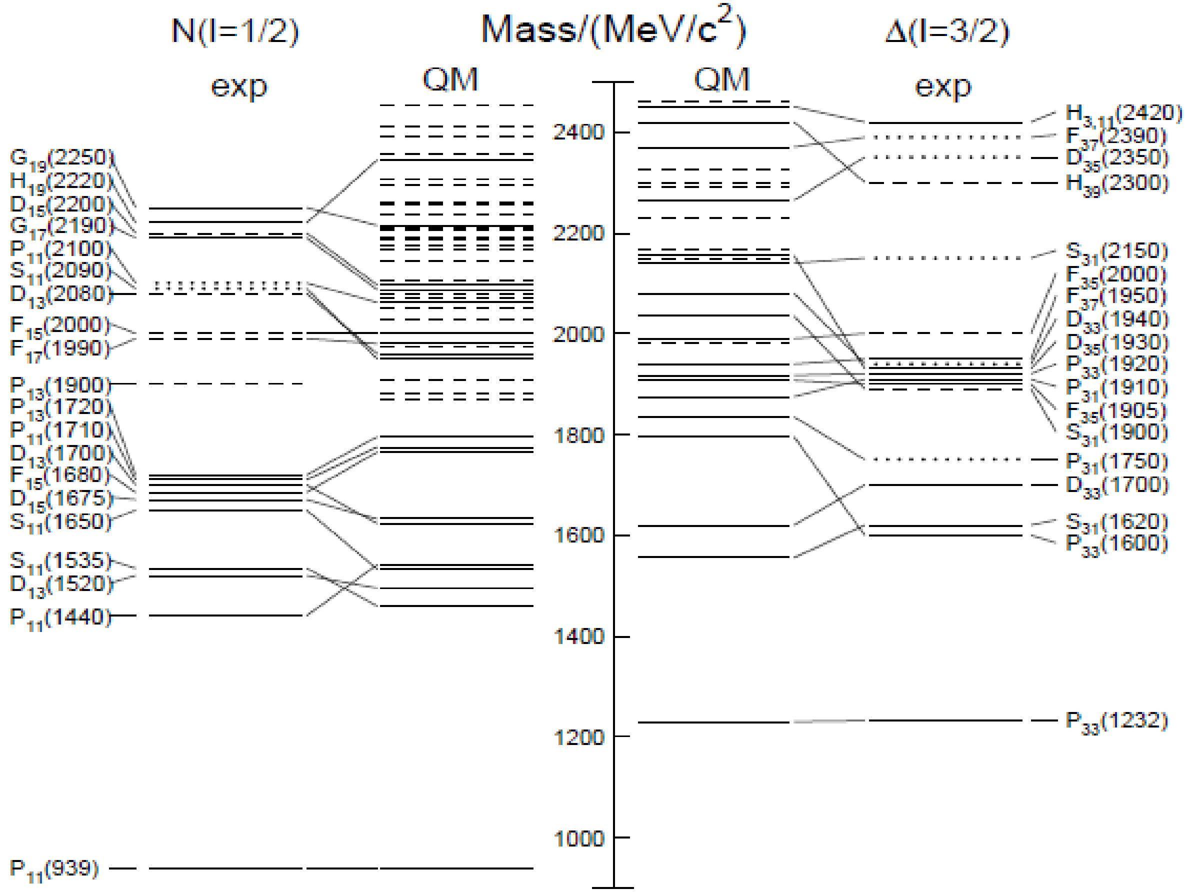
1. Introduction
2. LEPS2/BGOegg experiment
3. Differential cross section and beam asymmetry
4. Summary

Physics Motivation



The ground-states baryon resonances have been explained well by the constituent quark model, but the excited states differ from CQM in mass.

⇒ The study of these resonances is very important for understanding hadron structure.

Physics Motivation

Particle	J^P	overall	$N\gamma$	$N\pi$	$\Delta\pi$	$N\sigma$	$N\eta$	ΛK	ΣK	$N\rho$	$N\omega$	$N\eta\prime$
N	$1/2^+$	****										
$N(1440)$	$1/2^+$	****	****	****	****	***						
$N(1520)$	$3/2^-$	****	****	****	****	**	****					
$N(1535)$	$1/2^-$	****	****	****	***	*	****					
$N(1650)$	$1/2^-$	****	****	****	***	*	****	*				
$N(1675)$	$5/2^-$	****	****	****	****	***	*	*	*			
$N(1680)$	$5/2^+$	****	****	****	****	***	*	*	*			
$N(1700)$	$3/2^-$	***	**	***	***	*	*			*		
$N(1710)$	$1/2^+$	****	****	****	*		***	**	*	*	*	
$N(1720)$	$3/2^+$	****	****	****	***	*	*	****	*	*	*	
$N(1860)$	$5/2^+$	**	*	**		*	*					
$N(1875)$	$3/2^-$	***	**	**	*	**	*	*	*	*	*	
$N(1880)$	$1/2^+$	***	**	*	**	*	*	**	**		**	
$N(1895)$	$1/2^-$	****	****	*	*	*	****	**	**	*	*	****
$N(1900)$	$3/2^+$	****	****	**	**	*	*	**	**		*	**
$N(1990)$	$7/2^+$	**	**	**			*	*	*			
$N(2000)$	$5/2^+$	**	**	*	**	*	*				*	
$N(2040)$	$3/2^+$	*		*								
$N(2060)$	$5/2^-$	***	***	**	*	*	*	*	*	*	*	
$N(2100)$	$1/2^+$	***	**	***	**	**	*	*		*	*	**
$N(2120)$	$3/2^-$	***	***	**	**	**		**	*		*	*
$N(2190)$	$7/2^-$	****	****	****	****	**	*	**	*	*	*	
$N(2220)$	$9/2^+$	****	**	****			*	*	*			
$N(2250)$	$9/2^-$	****	**	****			*	*	*			
$N(2300)$	$1/2^+$	**		**								
$N(2570)$	$5/2^-$	**		**								
$N(2600)$	$11/2^-$	***		***								
$N(2700)$	$13/2^+$	**		**								

****	Existence is certain.
***	Existence is very likely.
**	Evidence of existence is fair.
*	Evidence of existence is poor.

June 5, 2018 20:07

Traditionally π-nucleon scattering has been studied well.

These resonances which don't couple to π are confirmed via meson photoproduction.

The feature of η mesons

These isospin is 0, so only N* contribute.
(π's isospin is 1 ⇒
π couples to both N* and Δ*)
η strongly couples to N* including $s\bar{s}$.

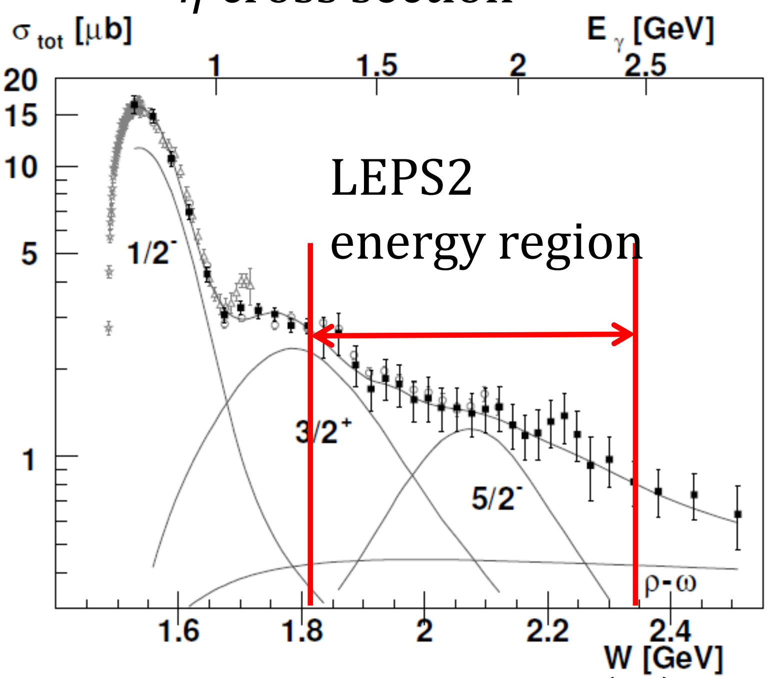
Physics Motivation

- The N*s with broad widths have overlapped each other at W>2 GeV. The photon beam asymmetry measurement is necessary in addition to the differential cross section to decompose the N*s using the interference of helicity amplitudes.

$$\sigma \propto |H_1|^2 + |H_2|^2 + |H_3|^2 + |H_4|^2$$
$$\Sigma \propto Re(H_1 H_4^* + H_2 H_3^*)$$

H_i:helicity amplitude

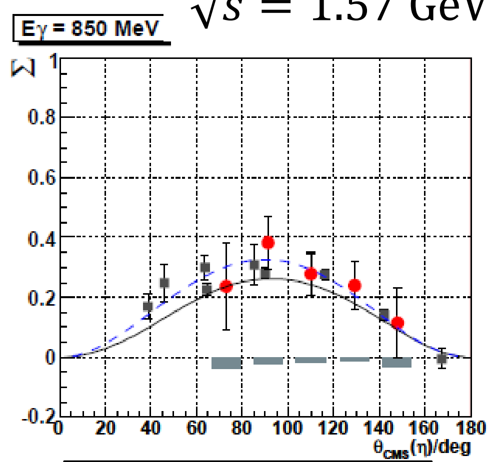
η cross section



A. Sarantev , CPC2009, 33(12)

η beam asymmetry

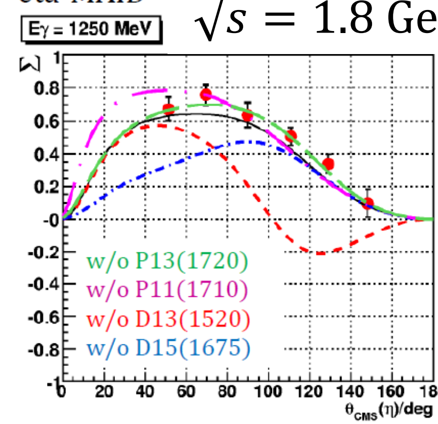
$\sqrt{s} = 1.57$ GeV



S_{11} is dominant.

eta-MAID

$\sqrt{s} = 1.8$ GeV

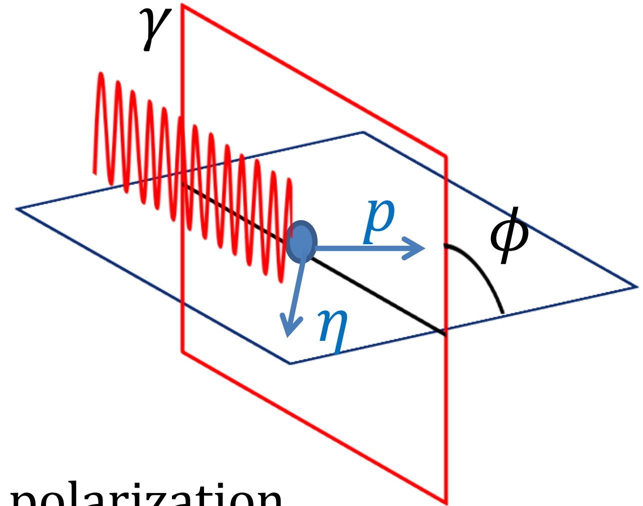


D.Elsner et al. EPJA 2007 33 2 147

D_{13} and D_{15} is necessary

Beam asymmetry is sensitive to contributed resonances.

Photon beam asymmetry



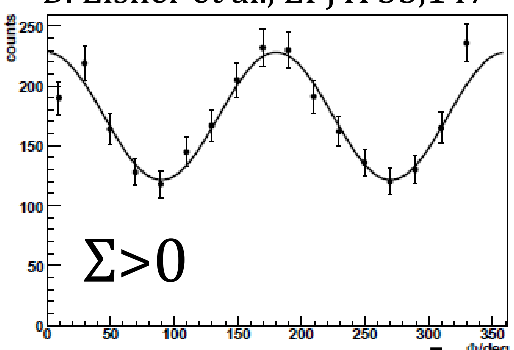
$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 \{1 - P_\gamma \Sigma \cos(2\phi)\}$$

P_γ : incident photon polarization

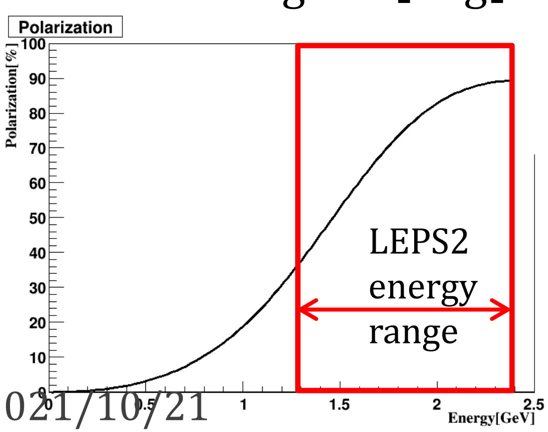
Σ : Beam Asymmetry

ϕ : azimuthal orientation of reaction plane to beam polarization

D. Elsner et al., EPJ A 33,147



η azimuthal angle Φ[deg]



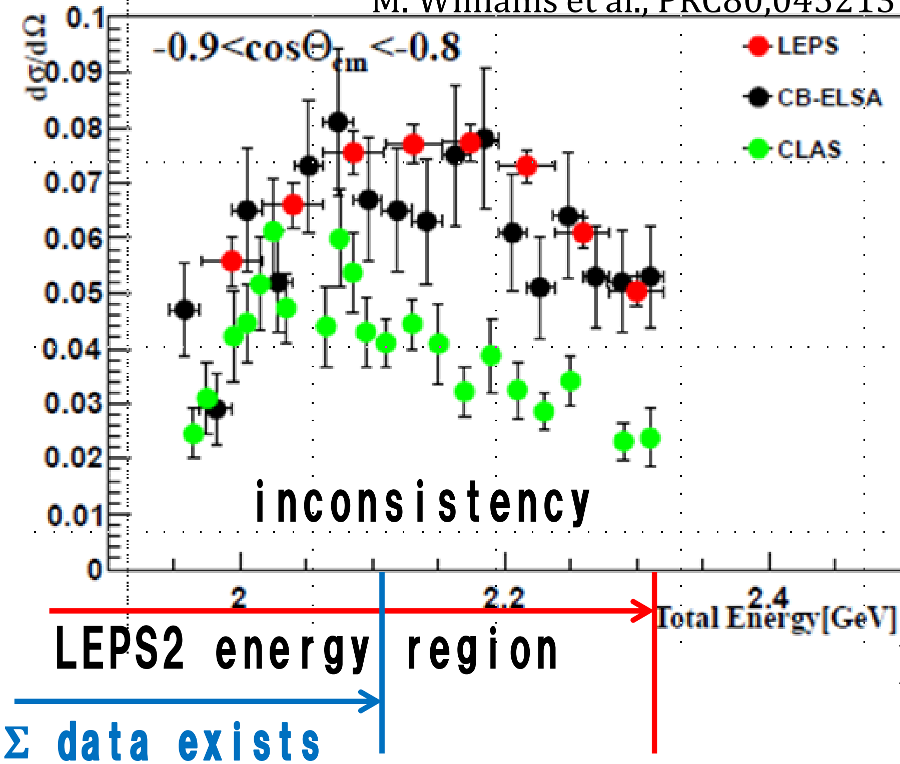
- The differential cross section oscillates.
- This amplitude is P_γ Σ.
- A spin-dependent amplitude can be measured.
- **High P_γ** is necessary for precise study of Σ.

⇒ LEPS2 can provide highly polarized beam in high energy using the Backward Compton Scattering. This polarization degree is 40~90 %.

Previous study

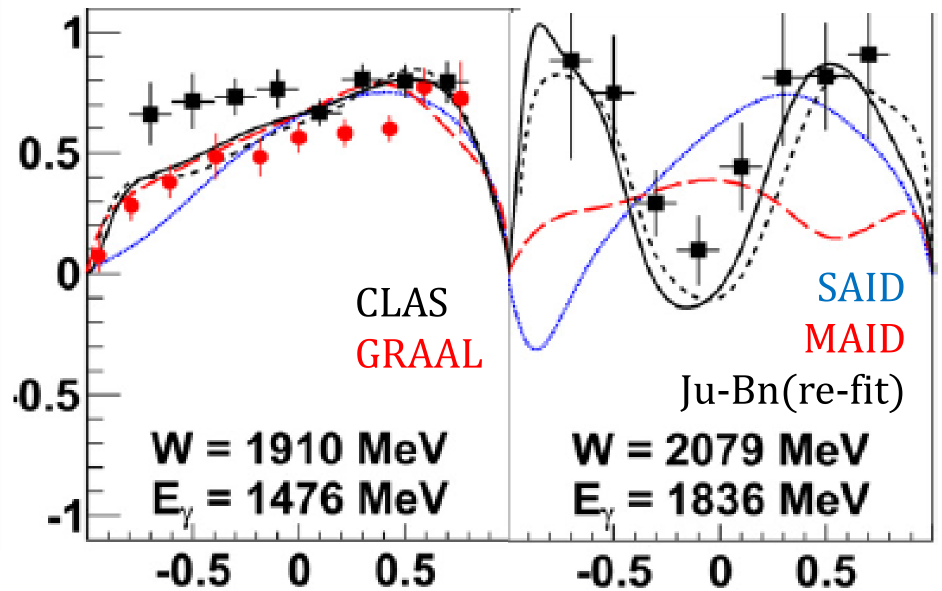
η differential cross section

M. Sumihama et al., PRC80,052201
V. Crede et al., PRC80,055202
M. Williams et al., PRC80,045213



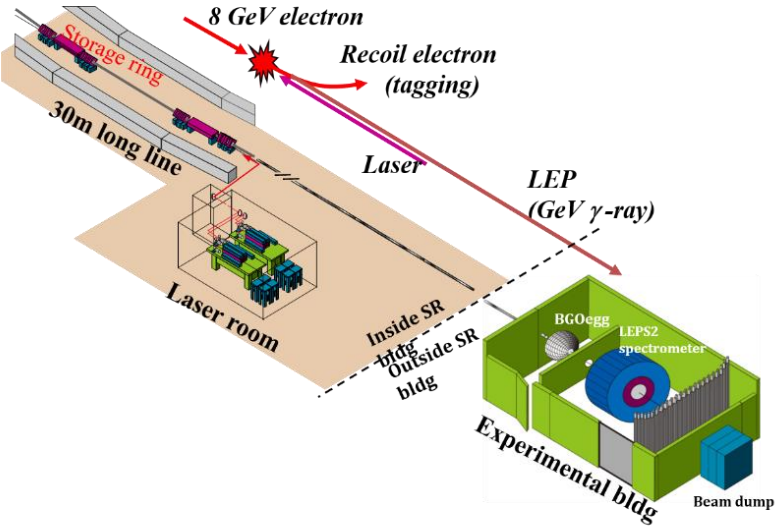
η beam asymmetry

P. Collins et al.,PLB 771(2017) 213
O. Bartlini et al, EPJA33(2007)



In high energy region,
the experimental data are scarce and
the theoretical uncertainty is large.

SPring-8/LEPS2 beamline



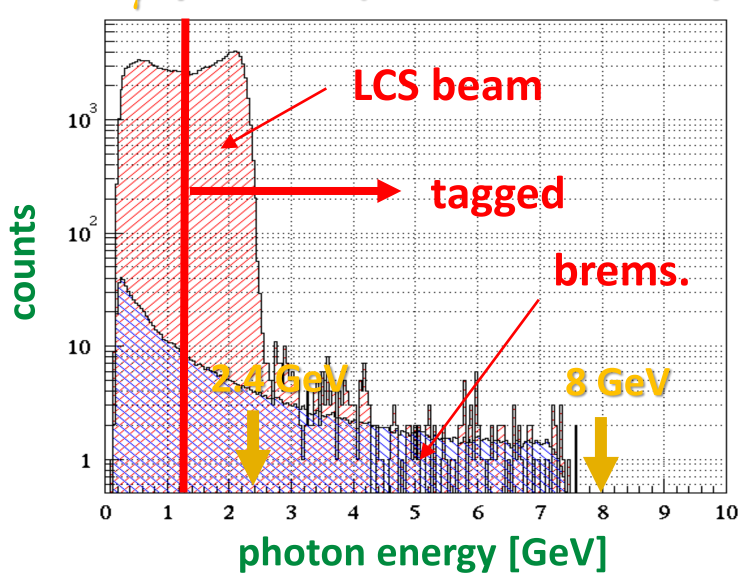
Backward compton scattering with 355nm UV laser and 8 GeV electron

E_γ 1.3～2.4GeV

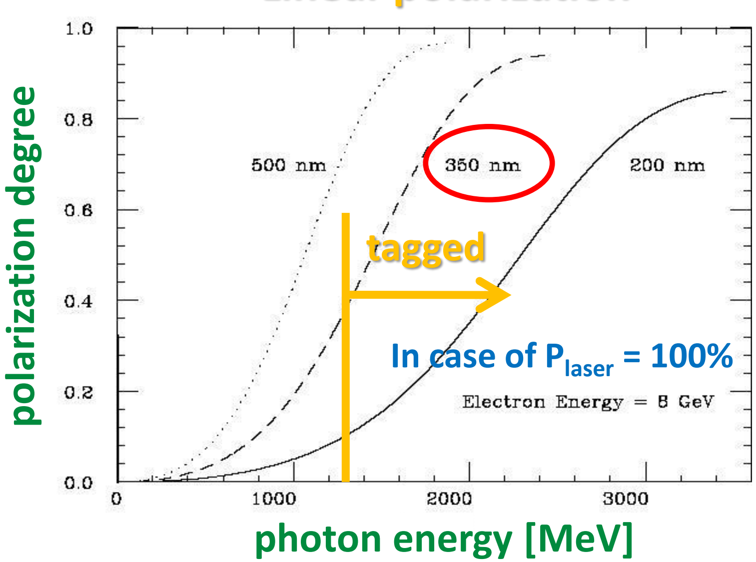
beam intensity ～2Mcps

beam polarization ~90% at maximum energy

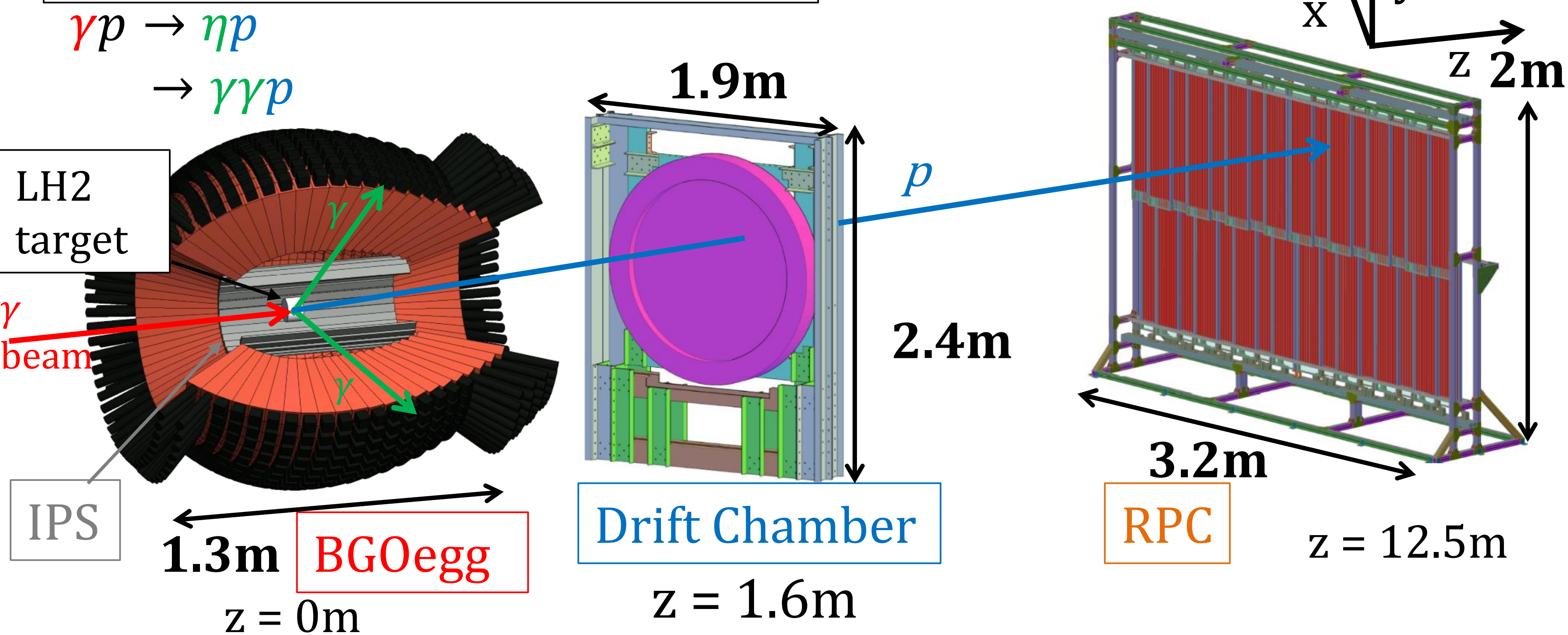
E_γ spectrum (PWO calorimeter)



Linear polarization



LEPS2/BGOegg experiment



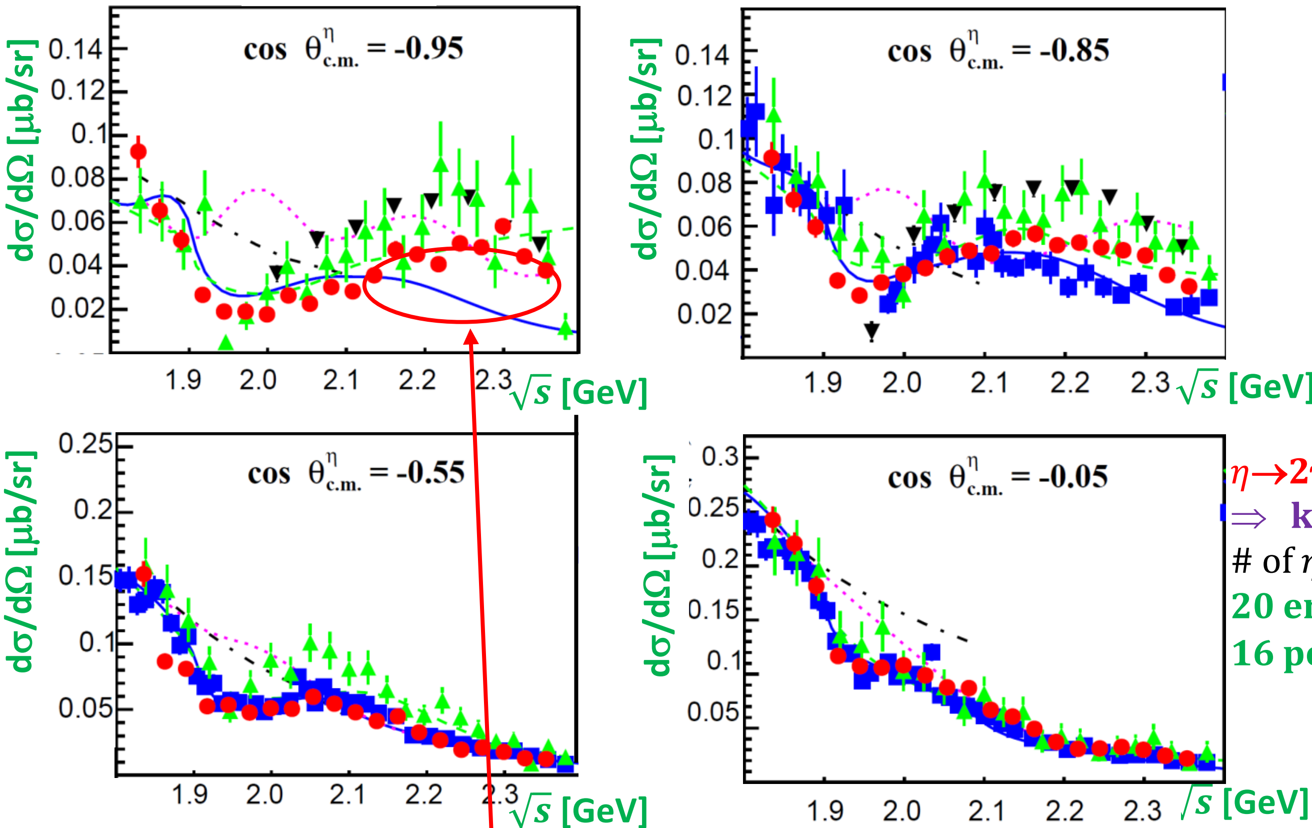
We measure all particles in final state and use a kinematic fit.

- use 3-momentum for 2γs and a proton, a beam energy and a z-vertex
- require 4-momentum conservation and meson mass
- magnitude of proton momentum is unmeasured

  * If a proton goes most forward, a proton momentum is measured by RPC.

The typical background is 5 % after the kinematic fit with a 99 % CL cut.

η differential cross section



● : BGOegg
▼ : LEPS ,PRC80,052201
▲ : CBELSA ,PRC80,055202
■ : CLAS,PRC80,045213

— ANL-Osaka
— Bonn-Gatchina2019
— GWU SAID2009
— EtaMAID2018

$\eta \to 2\gamma$ **@BGOegg** (Br=39.31±0.20%)

$\Rightarrow$ **kinematical fit** (CL cut @1%)

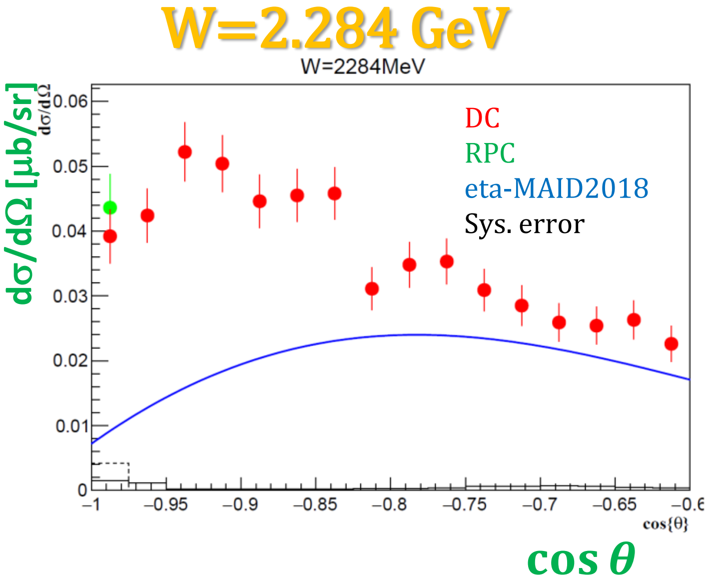
of η : **56304 $\pm$ 237 events**

20 energy bins for 1820<$\sqrt{s}$<2320 MeV

16 polar angle bins for -1.0<cos $\theta^{\eta}_{c.m}$<0.6

The bump structure in backward angle region above 2 GeV is observed.
BGOegg results are
consistent with CLAS and ELSA in middle region,
NOT consistent with ELSA and **LEPS** in backward region.
There are **inconsistency with PWA results** in high energy and backward region.

η differential cross section



At high energies and backward narrow angles, there is enhance of differential cross section.

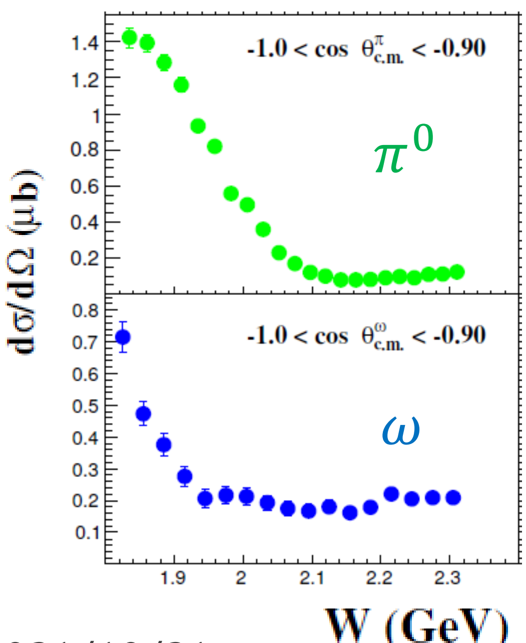
$\Rightarrow$ interference between **u-channels** and **s-channels**?

high spin resonance($J \geq \frac{5}{2}$)?

*Helicity is limited $|h| \leq \frac{3}{2}$ in photon-proton reaction.

$\Rightarrow$ Resonance helicity state is $|h| \leq \frac{3}{2}$

$\Rightarrow$ If a resonance with $J \geq \frac{5}{2}$ decays, η goes most **forward or backward**.



We obtained also the differential cross section π^0 of ω and using the same data set.

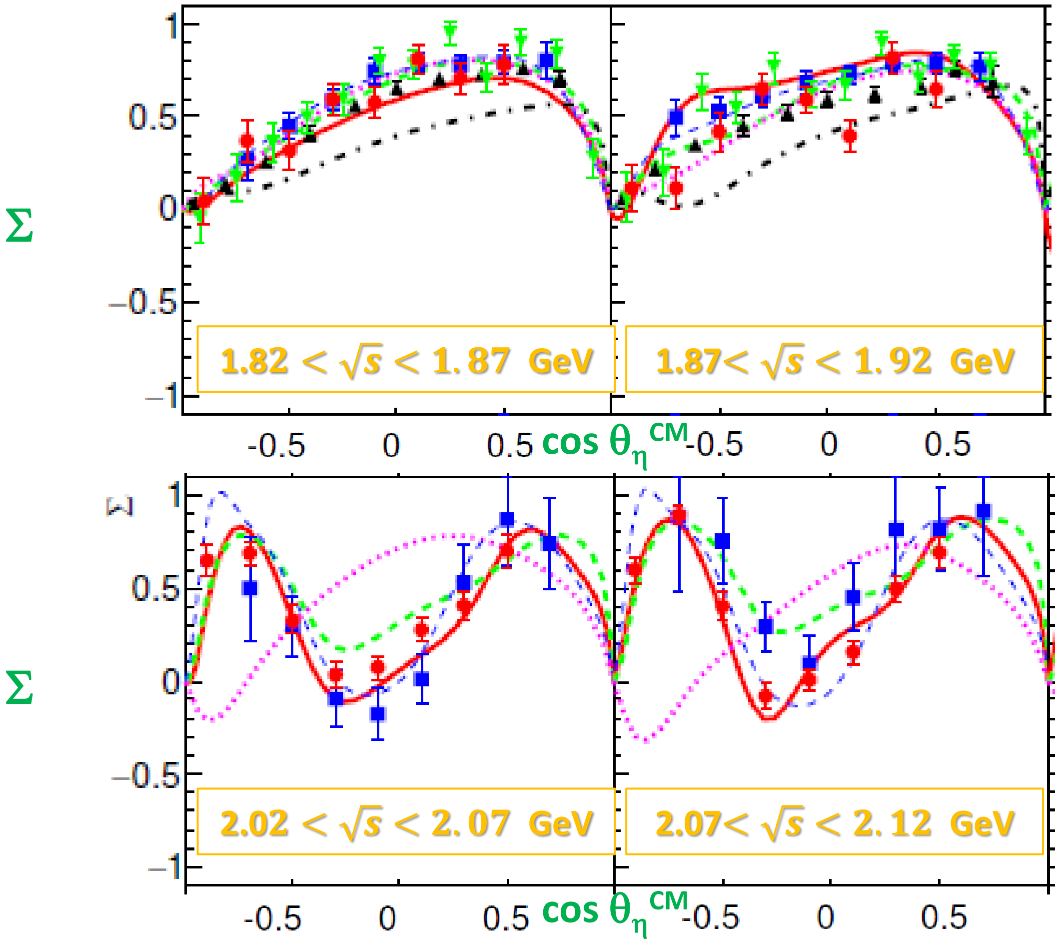
$\Rightarrow$ The bump structure in backward angle region is not observed.

$\Rightarrow$ The structure of η may relate to resonances with large $s\bar{s}$ components.

η beam asymmetry

Lower energy region

Data exist.



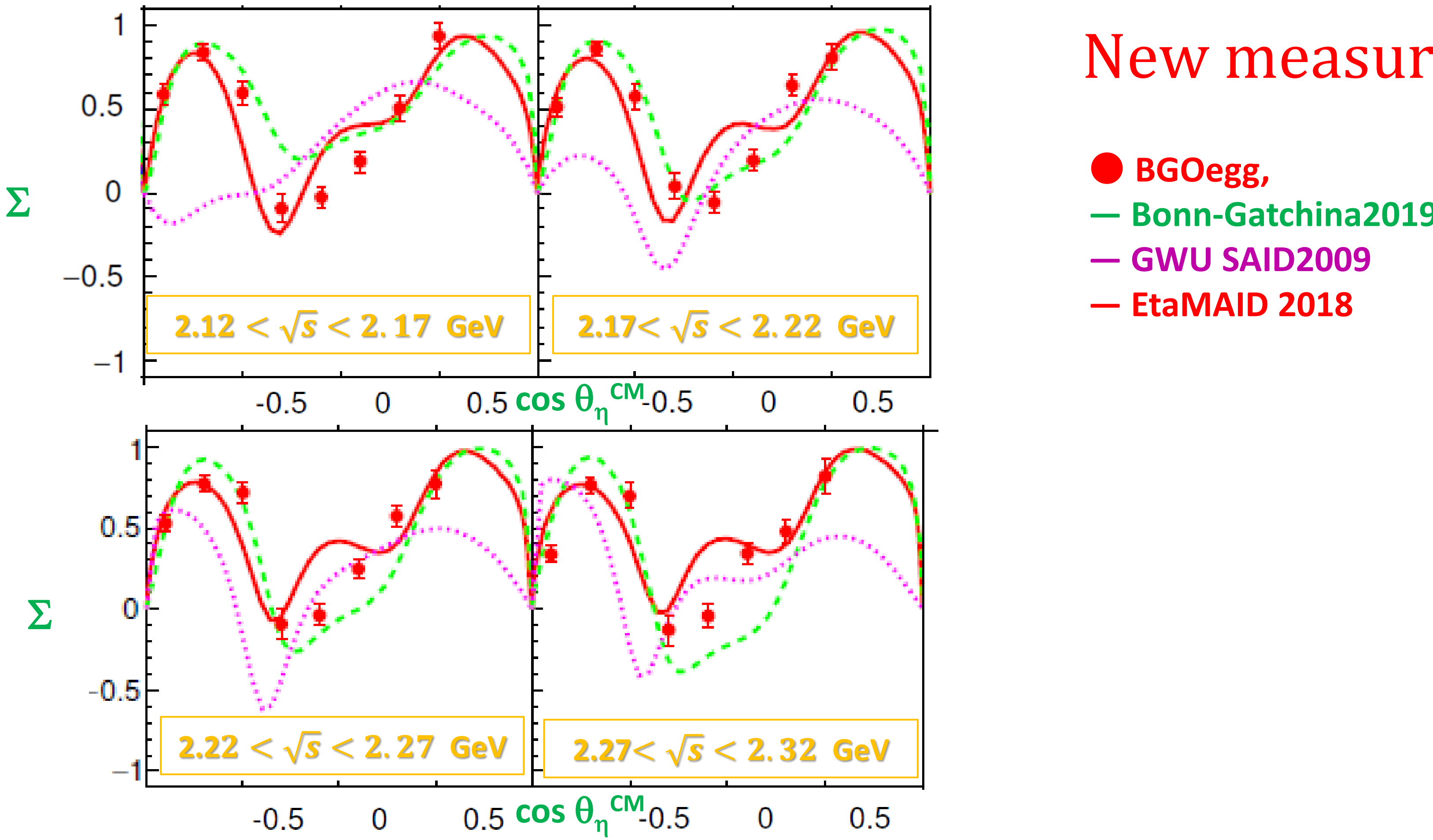
● BGOegg,
■ CLAS [PLB 771 (2017) 213]
▲ GRAAL [PLB 803 (2020) 135323]
▼ CBELSA [PLB 771 (2017) 213]
— ANL-Osaka,
— Bonn-Gatchina2019
— GWU SAID2009
— EtaMAID 2018
— Julich-Bonn

Our results are consistent with CLAS and EtaMAID at these energies.
The angle dependence drastically changed at W>1.9 GeV
⇒The contributions of $N(1720)\frac{3}{2}^{+}$, $N(1900)\frac{3}{2}^{+}$, $N(2070)\frac{5}{2}^{-}$ etc are expected.

η beam asymmetry

Higher energy region

New measurement

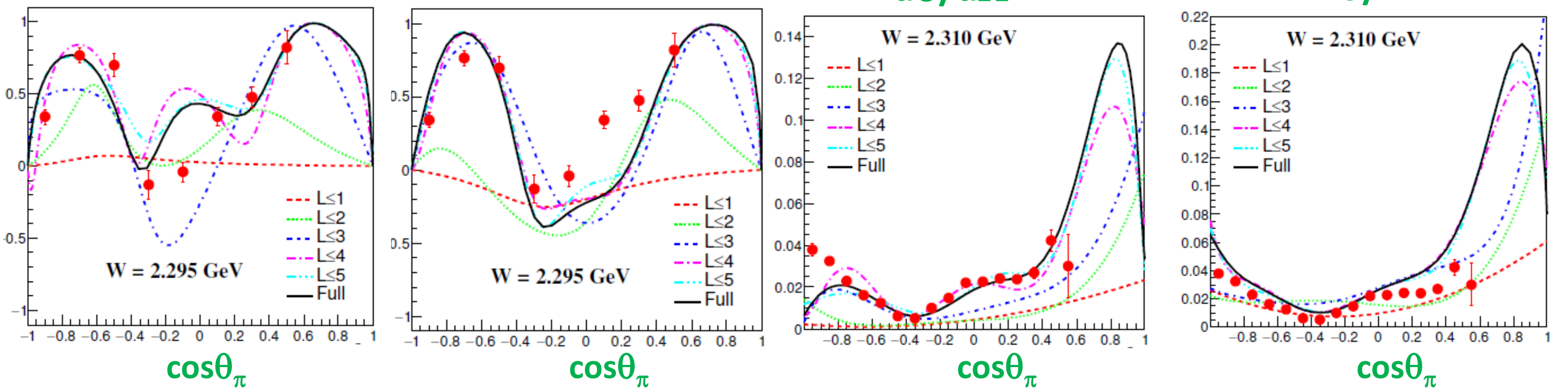


Our results are NOT consistent with etaMAID at these energies around middle angle.

η multipole analysis

Photon Beam Asymmetry (Σ) — **Differential Cross Section ($d\sigma/d\Omega$ nb/sr)**

EtaMAID 2018 Σ | **Bonn-Gatchina 2019** Σ | **EtaMAID 2018** $d\sigma/d\Omega$ | **Bonn-Gatchina 2019** $d\sigma/d\Omega$



Both EtaMAID2018 and Bonn-Gatchina don't reproduce our results in high energy region.

At beam asymmetries, the difference between L≤3 and L≤4 is large.

⇒ L=4 resonances(N(2190)$\frac{7}{2}^{-}$ and N(2250) $\frac{9}{2}^{-}$) may affect.

It is difficult to distinguish resonances from the interference b/w s- and u-channel.

Summary

- We measured **the differential cross section and photon beam asymmetry of η** photoproduction using a kinematic fit.

Differential cross section

- η differential cross section differs from other experimental data and PWA model calculations.

⇒ High spin states' contribution is expected.

- The bump structure in backward angle region above 2 GeV can be seen.

⇒ The same kind of structure can **not** be seen in $\boldsymbol{\pi^0}$ **and** $\boldsymbol{\omega}$ photoproduction.

Photon beam asymmetry

- We measured beam asymmetries of η **above 2.1 GeV for the first time**.
- At the highest energy region, beam asymmetries of η differs from PWA model calculations.

⇒ There is room to update PWA model parameters.

We plan to submit our results in a paper soon.