Meson photoproduction at SPring-8/LEPS

π^0, η, η', ω and ρ^0 photoproduction off proton

$\gamma p \rightarrow p X$

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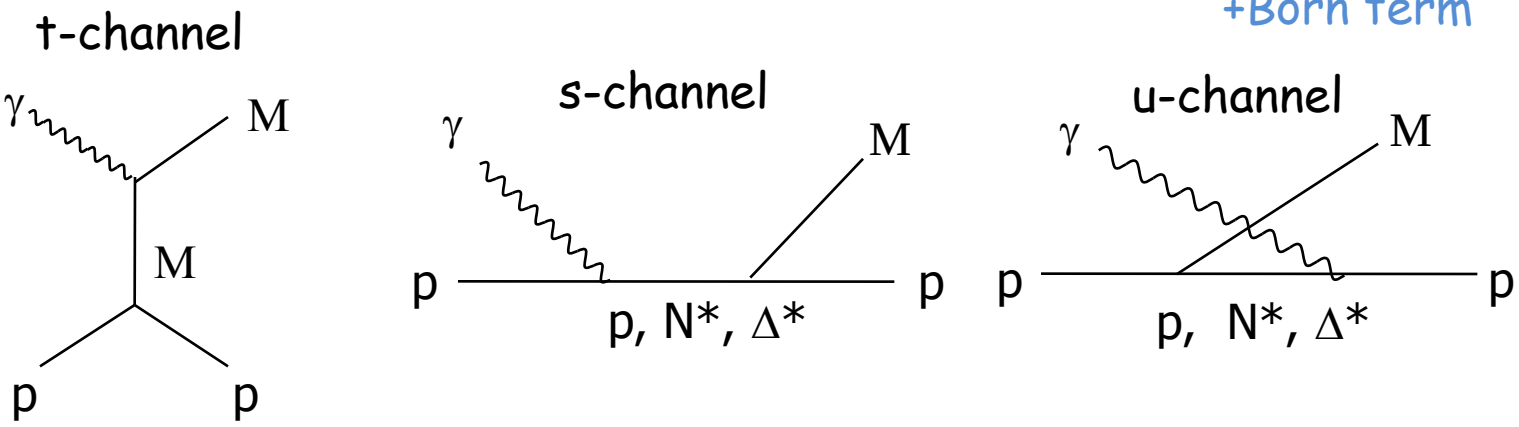
Dec. 24 2008

Physics motivation

Diagram in tree level

Resonance term
+Born term



Natural parity exchange Unnatural parity exchange	Missing resonances	Nucleon exchange Coupling constant, g_{NNM}

Forward ----- Backward

- ✓ W ($\sqrt{s}$) = 1.9 – 2.3 GeV
  resonance region ~ non-resonance region
- ✓ $\cos\Theta_{cm} = -1 \sim -0.6$
  backward angles

Missing baryon resonances

✓N* and Δ* resonances are well studied experimentally and theoretically. Test whether quark model calculation is valid or not.

Below M = ~1700 MeV → their properties are well known.
Above M = ~1700 MeV → many unknown or missing baryon resonances.
partly due to lack of experimental data.

✓Where are missing resonances?

- Not couple to πN, but couple to ρN, ηN, η'N, ωN.
  (KΛ, KΣ, discussion with D_{13} missing resonance.) .
  -ηN, η'N (ss-bar component)
  -Isospin filter :
  η, η', ω I=0, → N* only
  π, ρ I=1, → N* and Δ*
- High mass resonances, one-star, two-star, M > 1700 MeV

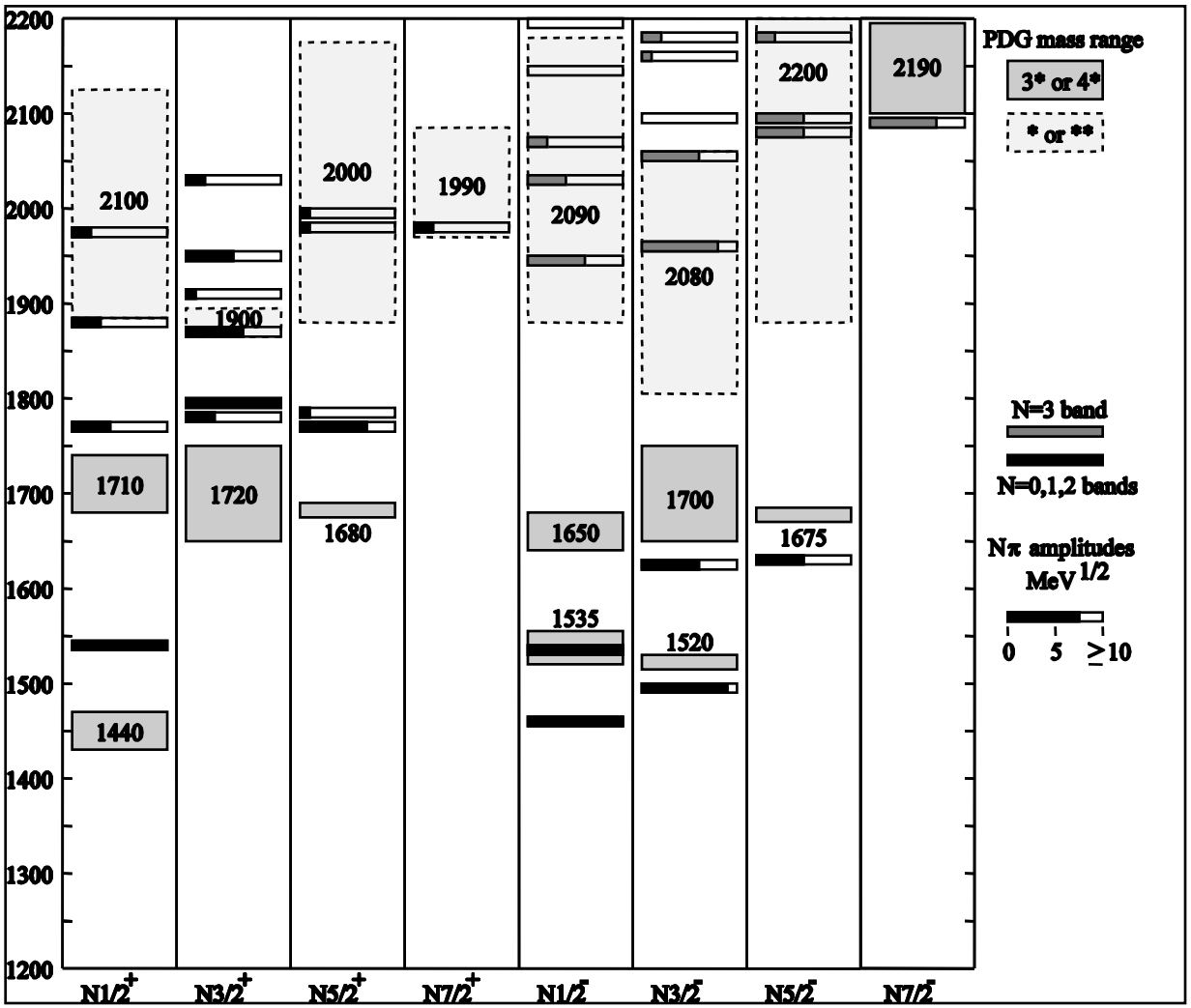
Table of Baryon excited states –PDG assessment

LEPS: W = 1900 MeV ~ 2300 MeV.

Many *, or ** states

1700 MeV

, or * states



Coupling constant, nucleon pole

- The production mechanism will be investigated in a transition range from nucleon-meson degrees of freedom to quark-gluon degrees of freedom.

  quark counting rule → $d\sigma/d\Omega \sim s^{-(n-2)} = s^{-7}$

  large momentum transfer (middle angles)

- g_{NNM} coupling constant.

  $d\sigma/d\Omega$ of πN, ηN, $\eta' N$, ωN. ρN

  Ratios of these modes → $g_{\pi NN}$, $g_{\eta NN}$, $g_{\eta' NN}$, $g_{\omega NN}$

  But, not so simple…difficult to determine values.

  Can we extract a possible range?

  N*, Δ* exchange in u-channel?

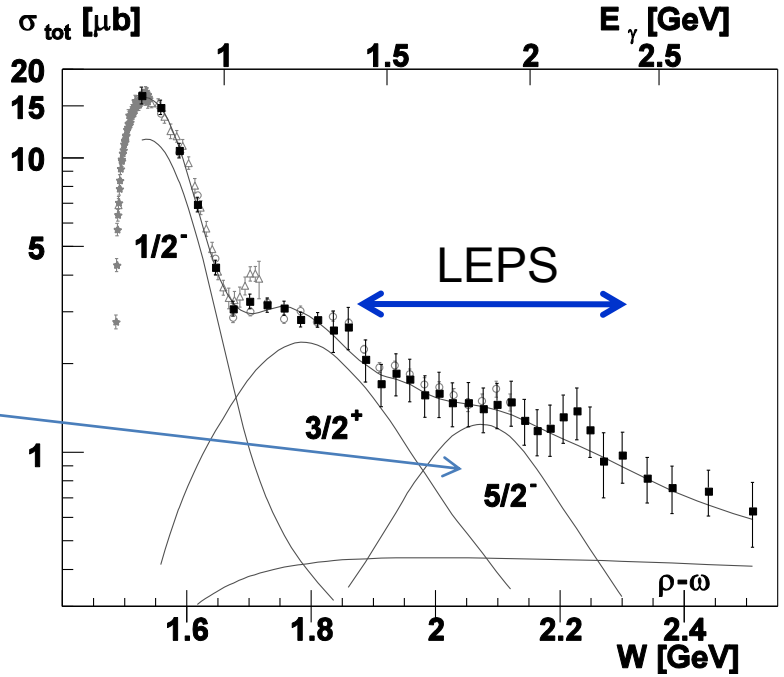
- Nucleon Regge pole, $d\sigma/du \sim s^{2\alpha(u)-2}$

  s^{-3} at u=0

Existing data at JLab and ELSA

η photoproduction

- JLab/CLAS data, PRL89,222002-1
  W < 2.1 GeV
  Crime evidence of S_{11} 1780/1846MeV
- Bonn/ELSA data, PRL94,012004
  W < 2.5 GeV
  No evidence of S_{11} 1780/1846MeV.
  Crime evidence of $N^*(2070)D_{15}$
  with $(M,\Gamma) = (2068\text{MeV}, 295\text{MeV})$.



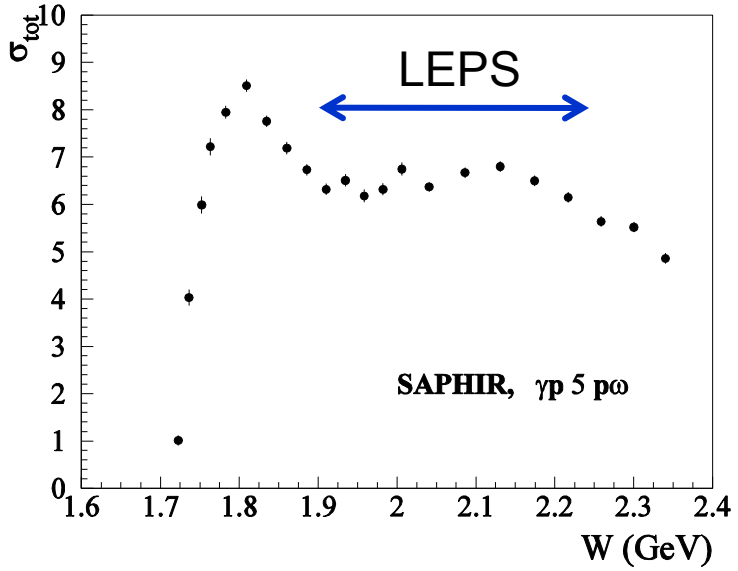
η' photoproduction

- Jlab/CLAS data, PRL96,062001
  W < 2.3 GeV
  $S_{11}(1535)$, $P_{11}(1710)$ and J=3/2.
  $g_{NN\eta'} \sim 1.33$.
- Bonn/ELSA data, PLB444,555
  W < 2.4 GeV, low statistics.
  evidence of $S_{11}(1897)$ / $P_{11}(1986)$

K. Nakayama and H. Haberzettl
PRC73,045211 (2006).
possible range → $g_{NN\eta'} < 2$
related to Flavor-singlet axial charge $G_A(0)$
Predict $D_{13}(2080)$, $P_{11}(2100)$
at W=2.09 GeV

ω photoproduction

- JLab/CLAS data, Phys.Rev.Lett.90:022002,2003
  $E\gamma$ > 3 GeV, $d\sigma/dt$, two-gluon exchange…
- Bonn/ELSA data, Eur.Phys.J.A18:117-127,2003
  $P_{11}(1710)$, small contribution of $P_{13}(1720)$ and $P_{13}(1900)$, W~2.15 GeV???



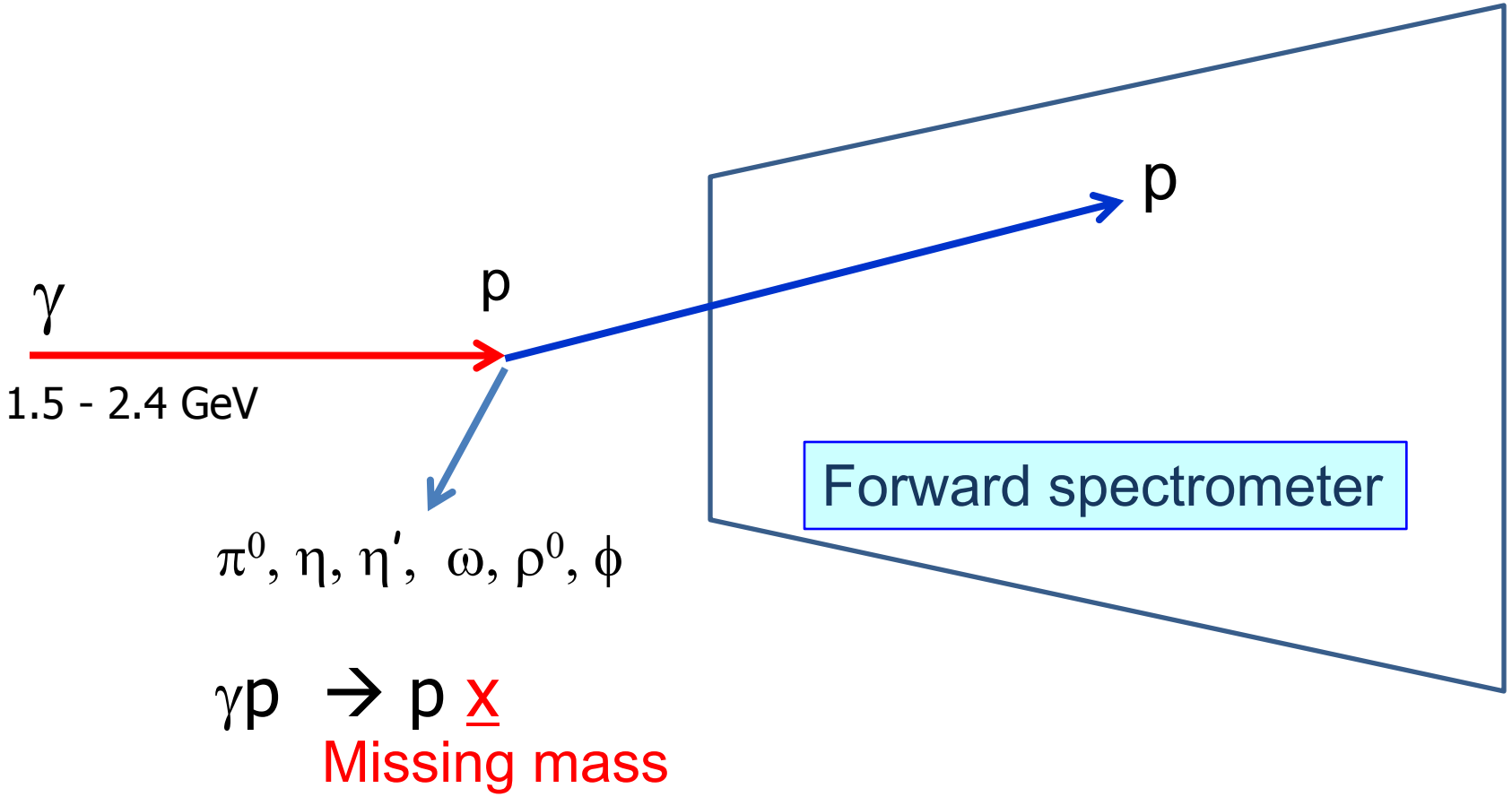
ρ^0 photoproduction

- JLab/CLAS data, Phys.Rev.Lett.87:172002,2001.
  $E\gamma$ > 3 GeV, $d\sigma/dt$, two-gluon exchange…
- Bonn/ELSA data, Eur.Phys.J.A23:317-344,2005
  forward angles, t-channel

Experiment at LEPS

Experiment

Detect protons and identify mesons in missing mass.



$\gamma p \rightarrow p\ \underline{x}$

Missing mass

Backward meson photoproduction

Missing mass spectrum

$\gamma p \rightarrow p\,\pi\,\pi$

$\gamma p \rightarrow p\,\pi\,\pi\,\pi$

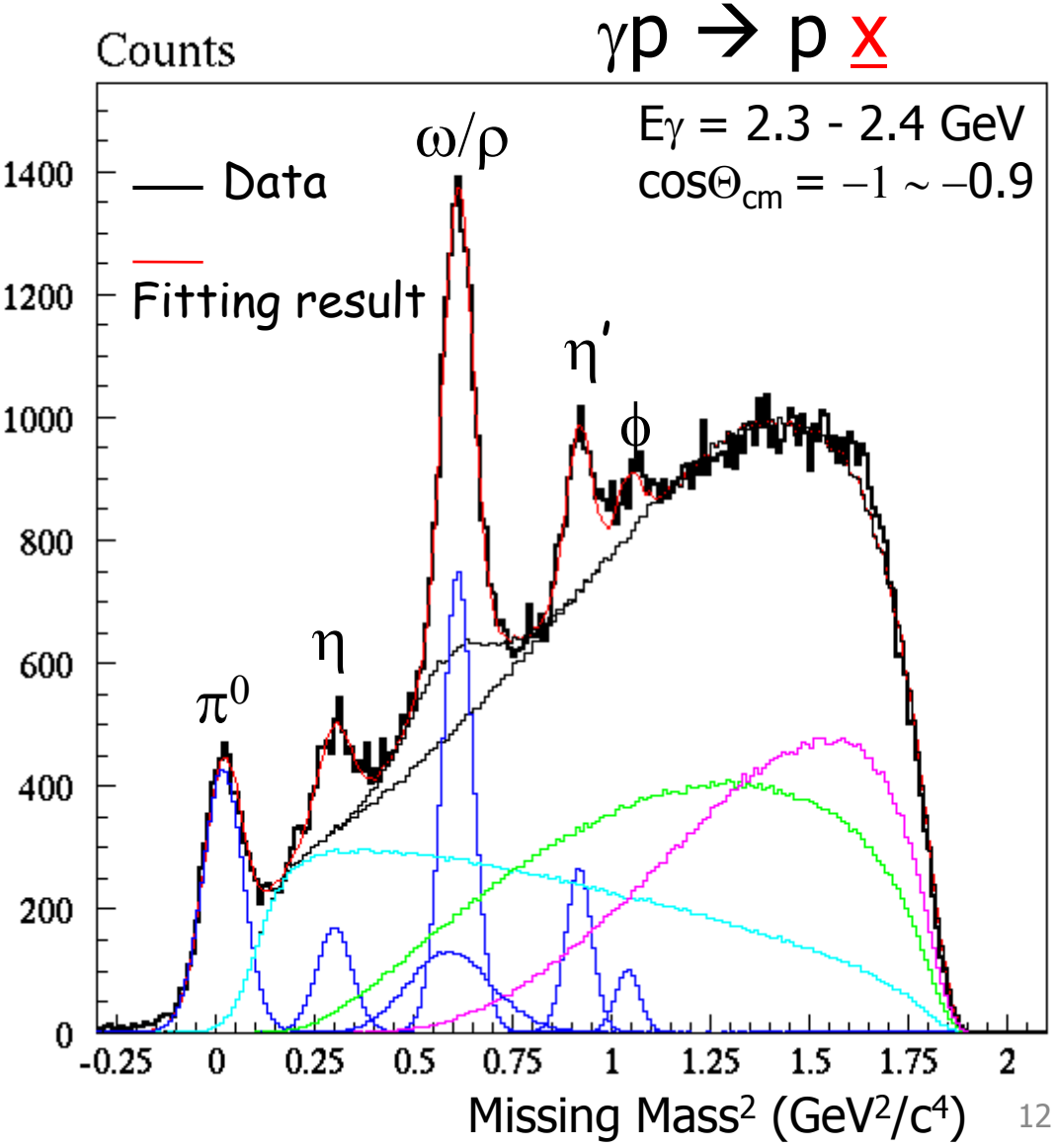
$\gamma p \rightarrow p\,\pi\,\pi\,\pi\,\pi$

$\gamma p \rightarrow p\,\underline{\pi^0, \eta, \eta'}, \underline{\omega, \rho}, \phi$

Distributions of single meson production and multi-pion production are generated by MC simulation, and are fitted to data by a template fit determining a relative height.

$\underline{\chi^2 = 1\sim3.}$

Systematic error 5%



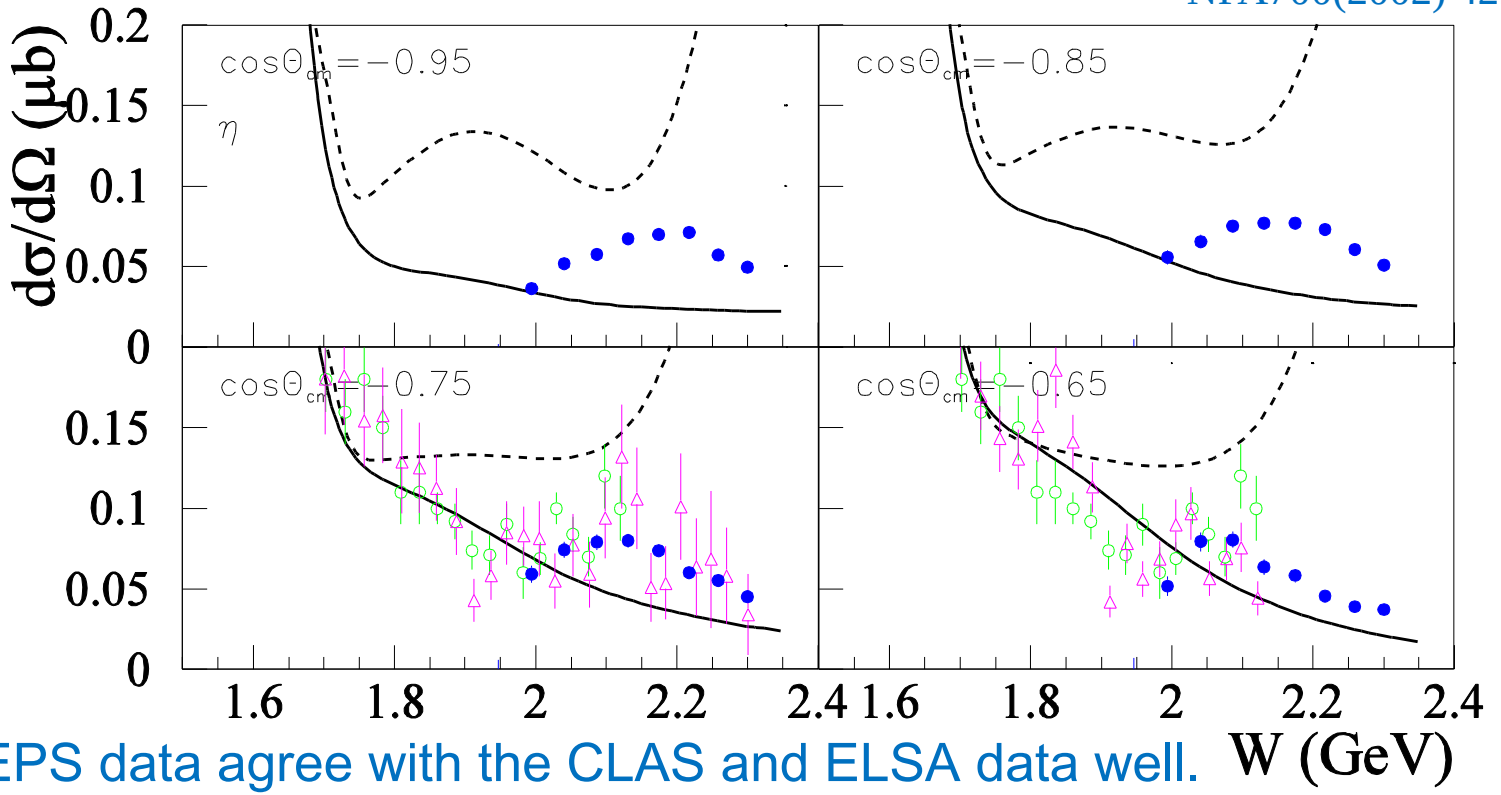
η, η', ω and ρ^0 photoproduction

η : Differential cross sections

- ● LEPS data
- ○ Jlab/CLAS data
- △ Bonn/ELSA data

—— SAID -partial-wave analysis
PRC66,055213(2002)

---- Eta-MAID - isobar model
NPA700(2002) 429

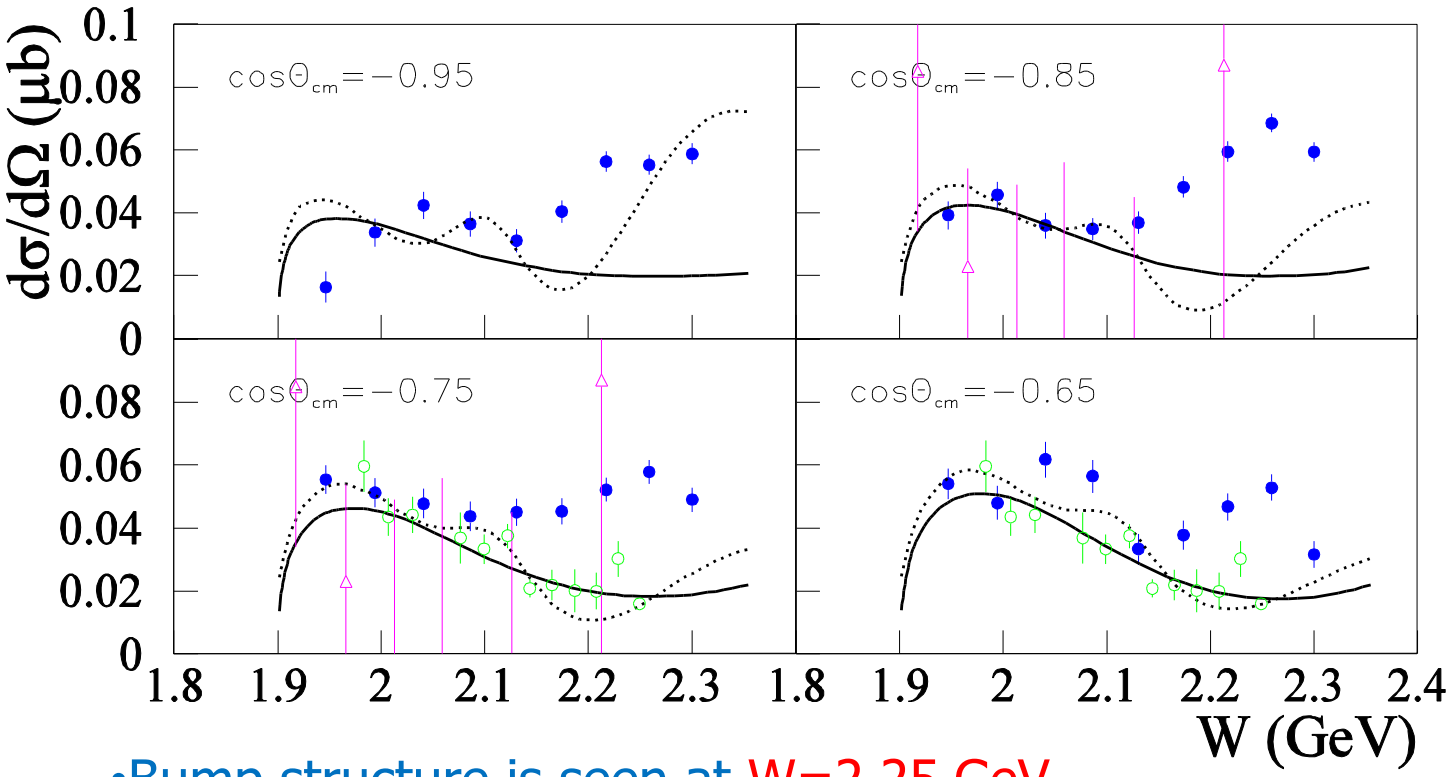


- LEPS data agree with the CLAS and ELSA data well.
- wide structure is seen around W=2.15 GeV.
- SAID/MAID do not reproduce the structure.

η′ : Differential cross sections

- ● LEPS data
- ○ Jlab/CLAS data, PRL96,062001
- △ Bonn/ELSA data, PLB444,555

—— SAID -partial-wave analysis
preliminary fit
- - - - Eta-Prime MAID - Regge pole
PRC68, 045202 (2003), New fit

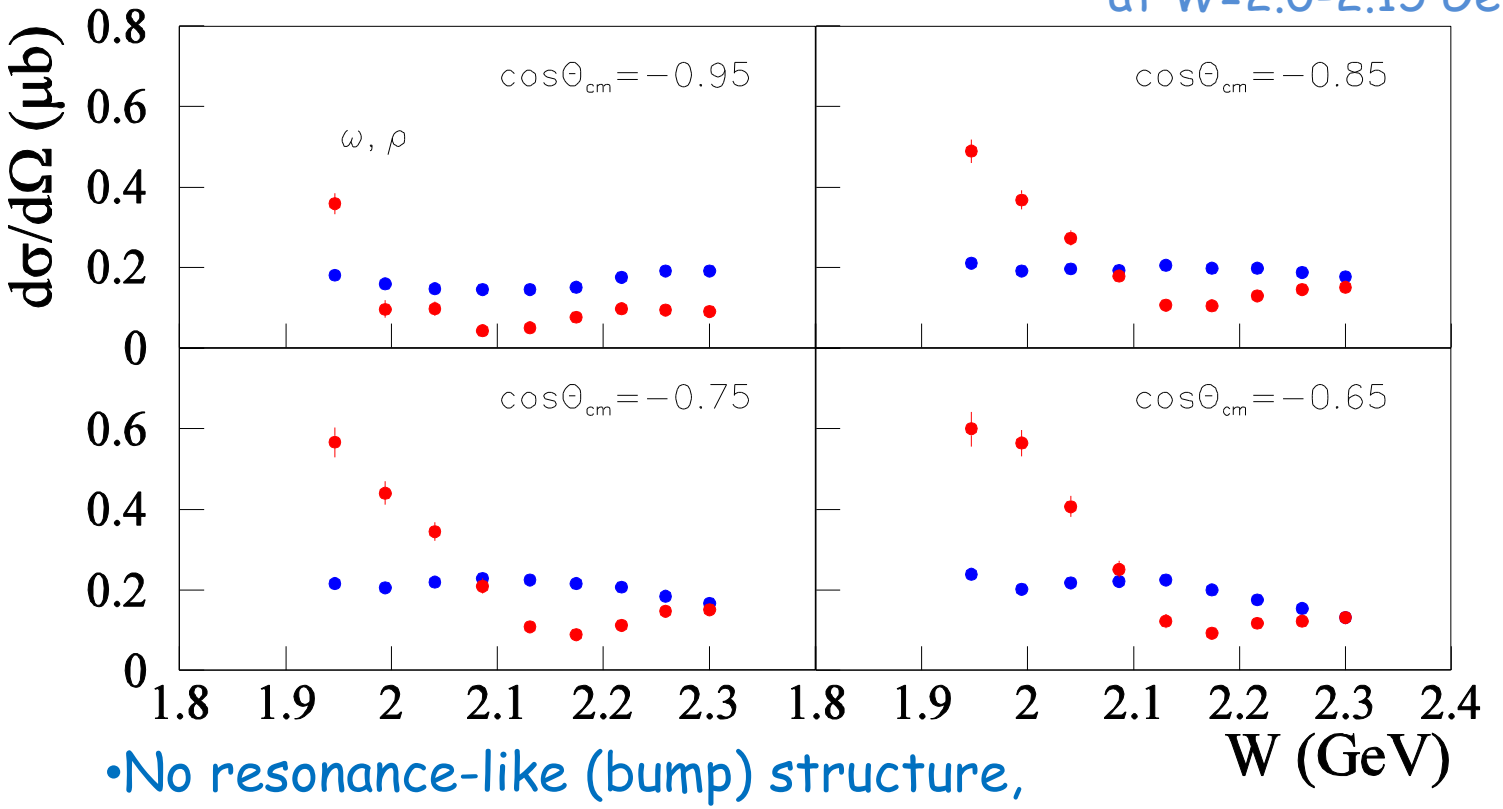


•Bump structure is seen at W=2.25 GeV,
but the enhancement is larger than CLAS data.

ω, ρ^0 : Differential cross sections

● ω, ● ρ LEPS data

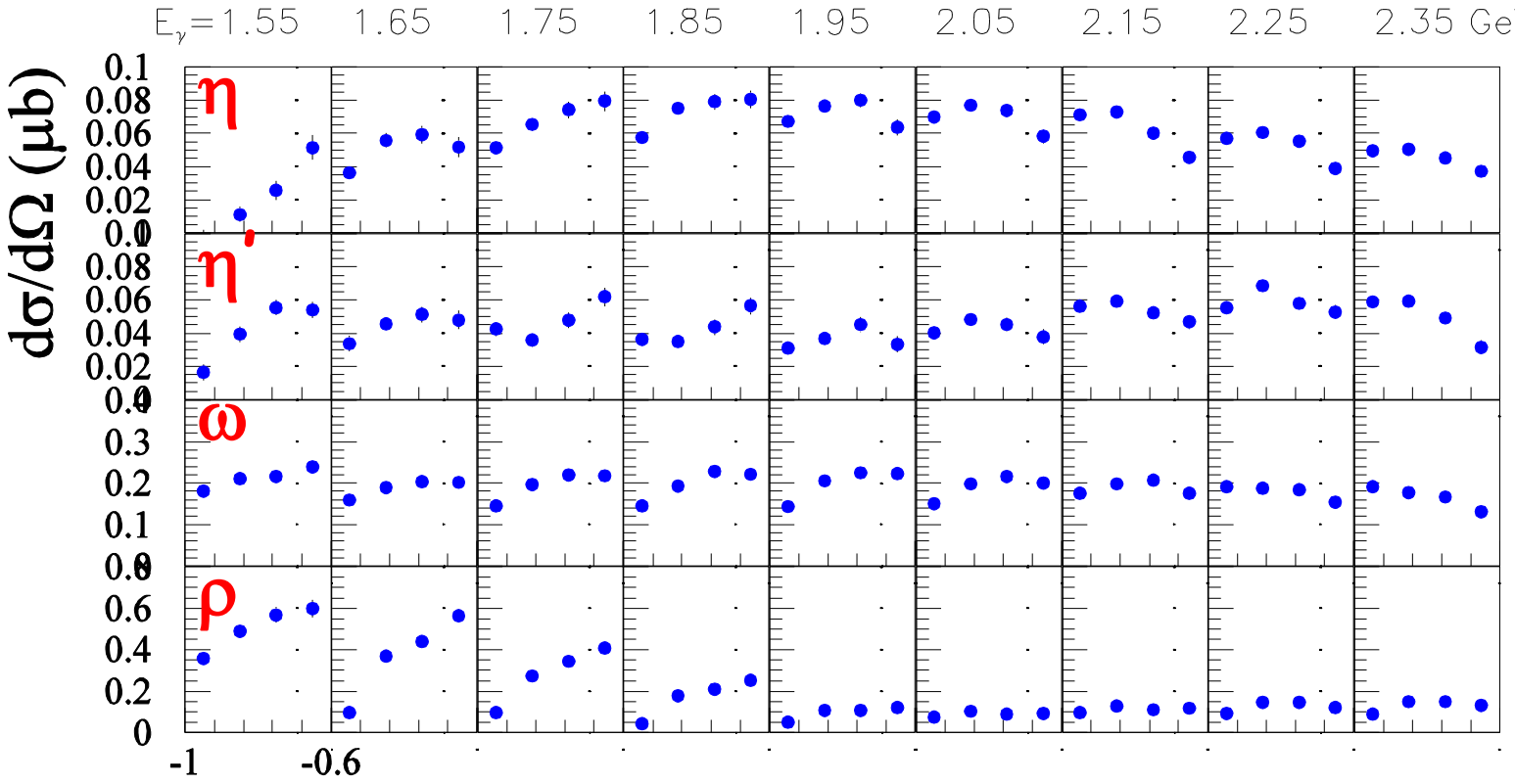
CLAS , ω and ρ^0 at Eγ > 3.2 GeV.
$d\sigma/d\Omega$ ~ 0.03 for ρ
$d\sigma/d\Omega$ ~ 0.015 for ω
ELSA $d\sigma/d\Omega$ ~ 0.2 for ω
at W=2.0-2.15 GeV



- No resonance-like (bump) structure,
- Mostly flat distribution for ω photoproduction.

Energy distribution of differential cross sections

- LEPS data



- Smaller at backward angles at lower Eγ.
- Larger at backward angles at higher Eγ.
  → contribution of u-channel?

π^0 photoproduction

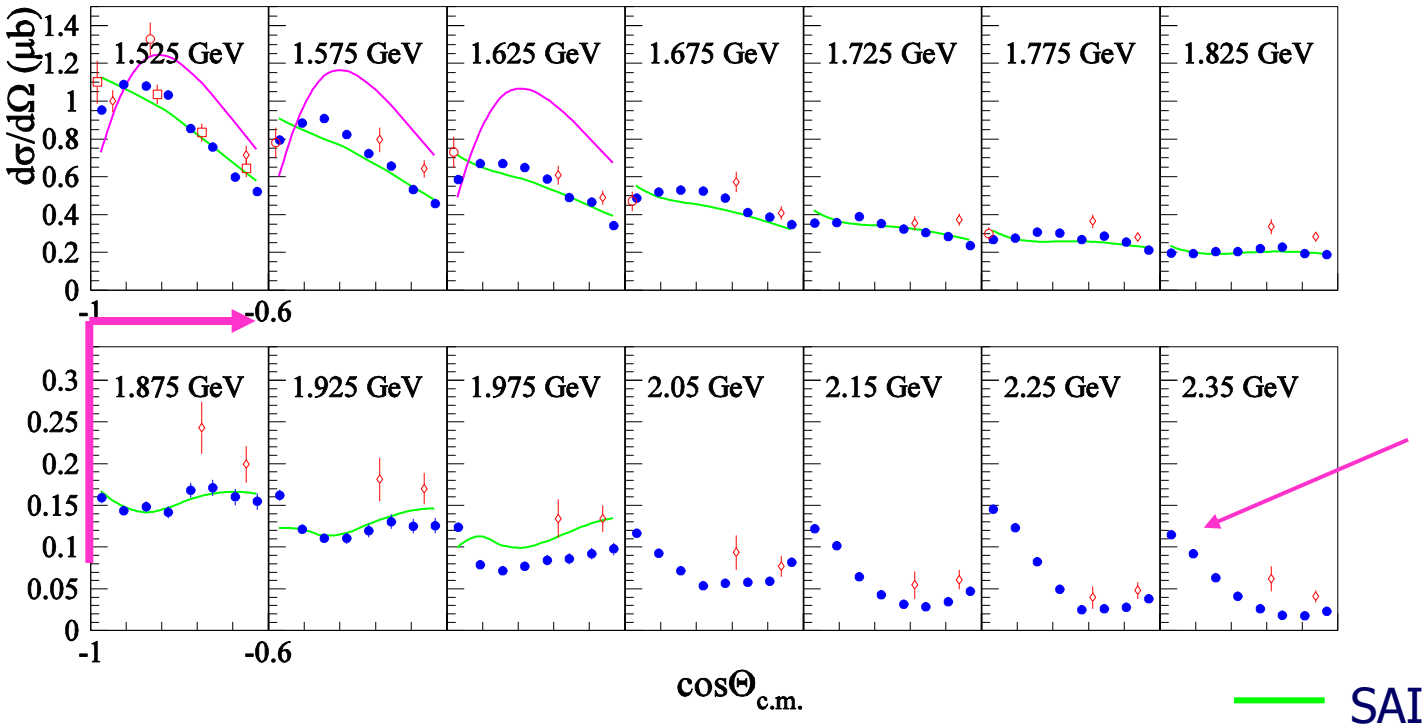
π^0 photoproduction data

- GRAAL below W=1.9 GeV, CLAS/ELSA ~ 2.5 GeV.
  Not cover backward angles.
- Enhancement in cross sections at ~2.2 GeV for charged pion photoproduction at CLAS. → new resonance?
  L.Y.Zhu, et. al, PRL 91 022003(2003)/PRC,71 044603(2005)
- Angular dependence in induced polarization for neutral pion photoproduction around 2.5 ~ 3.1 GeV at CLAS.
  K. Wijesooriya, et al., Phys. Rev. C 66 (2002) 034614.

LEPS : Backward angles
- Differential cross sections
- Photon beam asymmetries (single polarization)
  strong restriction.

Differential cross section in $\cos\theta_{cm}$

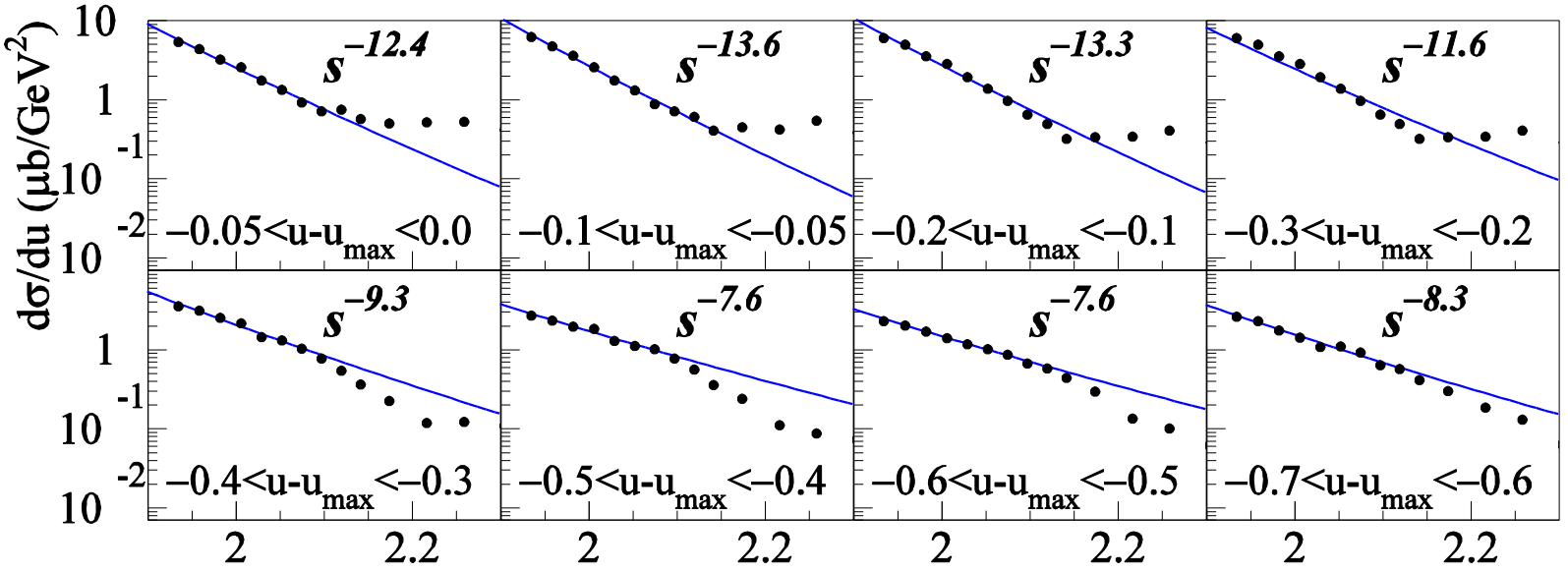
- LEPS data ○ Existing data (GRAAL, ELSA, old Bonn).



- Change angular distribution at E_γ~1.8 GeV
- **Backward peaking** W ~ 2.1 GeV
  - u-channel contribution

Energy dependence of slope in differential cross sections

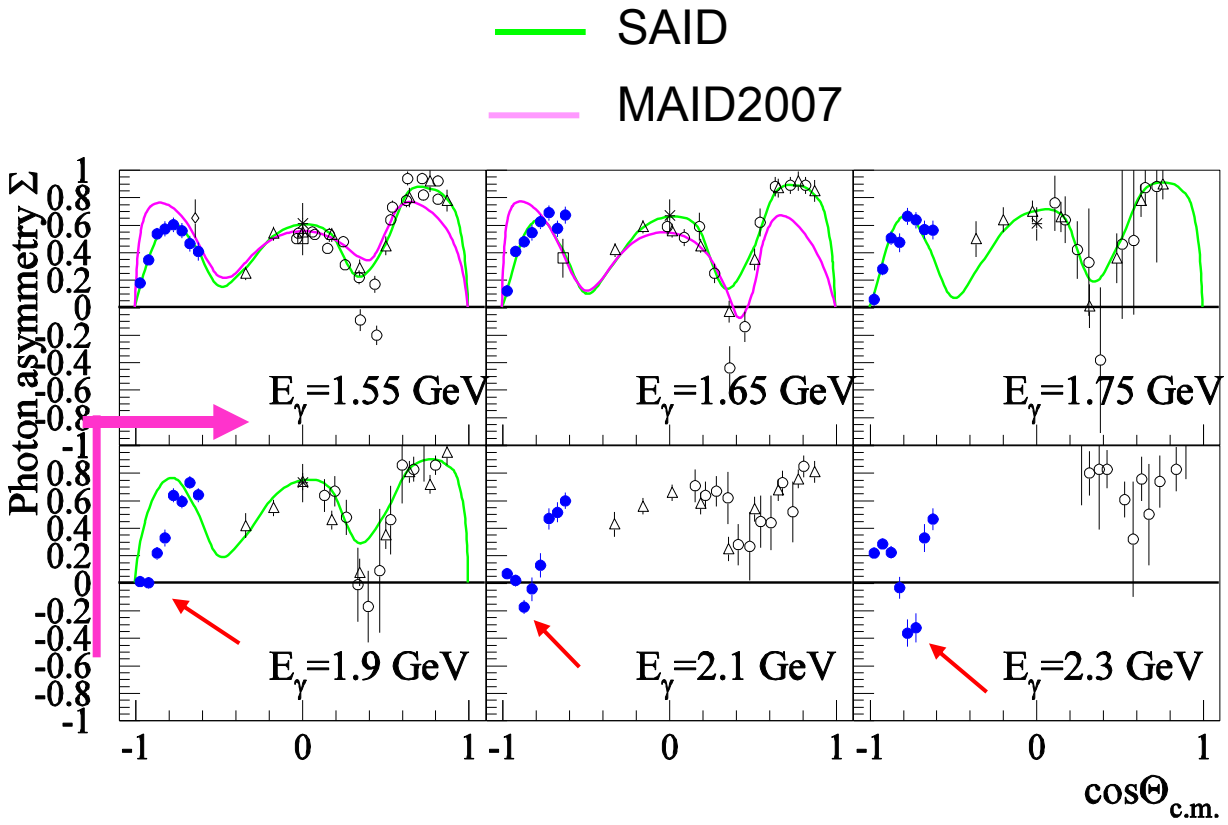
Strong s dependence (large slope)



s^{-7} : quark counting rule

s^{-3}: nucleon Regge pole

Photon beam asymmetry Σ



- LEPS data
- Existing data.

PLB544(2002)113
NPB104(1976)253…

Positive sign:
$\sigma_{//} < \sigma_{\perp}$
Negative sign:
$\sigma_{//} > \sigma_{\perp}$

- Strong angular dependence above 1.9 GeV.
- Higher mass resonances need to be included.

Summary

η photoproduction at backward angles with W=1.9 – 2.3GeV.

- Wide bump structure is seen around W=2.15 GeV.

  $D_{15}(2070)$ with (M,Γ) = (2068MeV, 295MeV).

η' photoproduction

- Small bump structure is seen around W=2.25 GeV.
- Prediction of $D_{13}(2080)$, and $P_{11}(2100)$ at W=2.09 GeV.

ω photoproduction

- Energy distributions of differential cross sections are mostly flat. No structure.

ρ^0 photoproduction

- Decrease up to W=2.0 GeV and flat distribution above 2.0 GeV. Similar with π^0.

Summary

Angular distribution

- Enhancement at backward angles is seen at large energy regions for η, η' and ω. Not for ρ^0.
- Is u-channel contribution significant?
- Is it possible to extract the coupling constant?

π^0 photoproduction

- Differential cross sections show a backward peak at W>2.0 GeV due to a u-channel contribution.
- Large slope of $d\sigma/du$ is not explained by nucleon Regge pole nor scaling rule. Slope changes at W=2.0 GeV.
- Angular dependence of beam asymmetries changes at W = 2.0 GeV. A strong angular dependence is seen and may be due to resonances.

Next step of experiment is to extend to 3 GeV.

LEPS collaboration

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