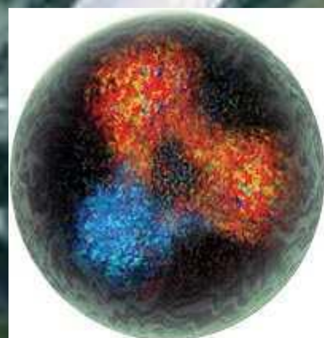
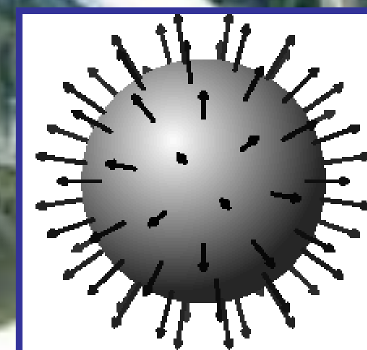
Spectroscopy of light baryons II: Experimental setups and methotds, and search for possible light-quark exotica.





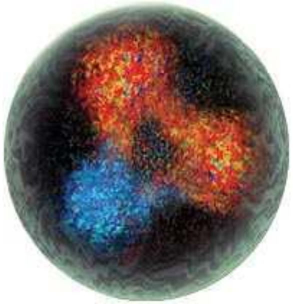
Viacheslav Kuznetsov,

In collaboration with Nuclear Physics Group of Catania University

(V. Bellini, F. Mammoliti et al.,) and

Maxim Polyakov@TPII@RUB-Bochum,

PNPI, January 29 2019.



Constituent Quark Model

Simon Capstick and Nathan Isgur
"Baryons in a Relativized Quark Model with Chromodynamics"
Phys. Rev. **D**34(1986) 2809

Prediction of Baryon resonances

3 Flavors: {u,d,s} → SU(3)
L+- quark spin 1/2 → SU(2)

Baryon multiplets: octet, dekuplet, 56-plet, 70-plet…

PDG2014: The N = 0 band, which contains the nucleon and Delta(1232), consists only of the (56,0+) supermultiplet. The N = 1 band consists only of the (70,1−1) multiplet and contains the negative-parity baryons with masses below about 1.9 GeV. The N = 2 band contains five supermultiplets: (56,0+), (70,0+2), (56,2+) ,(70,2+) and (20,1+).

In total hundreds of resonances composed of u, d, and s quarks.

PDG 1998: Total number of well established in experiment resonances is 49 (the so-called problem of missing resonances).
→ Need for more experimental data?

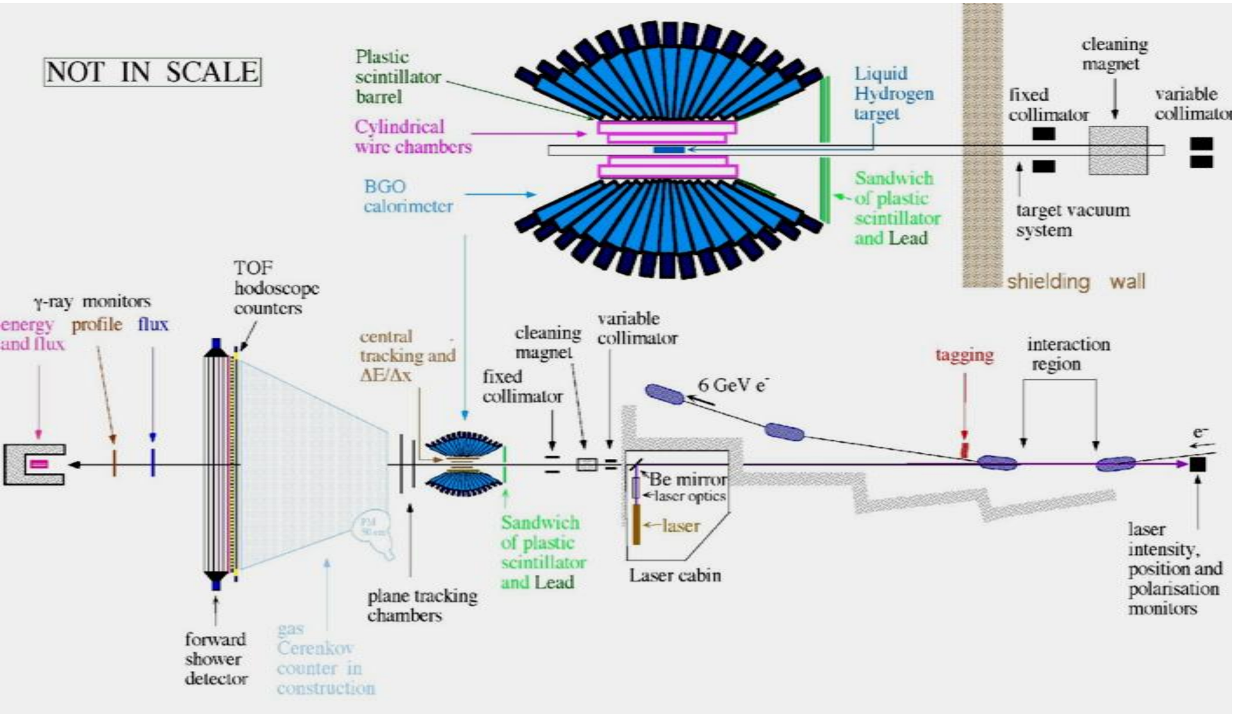
Photon factories

- GRAAL (Grenoble) (1996 -2007)
- CLAS/HallB@Jlab (1996 – ~2014)
- CBELSA/TAPS (Bonn) (~1998 - ?)
- A2@MaMiC (Mainz) (~2009)
- BGO-OD (Bonn) (~2014)

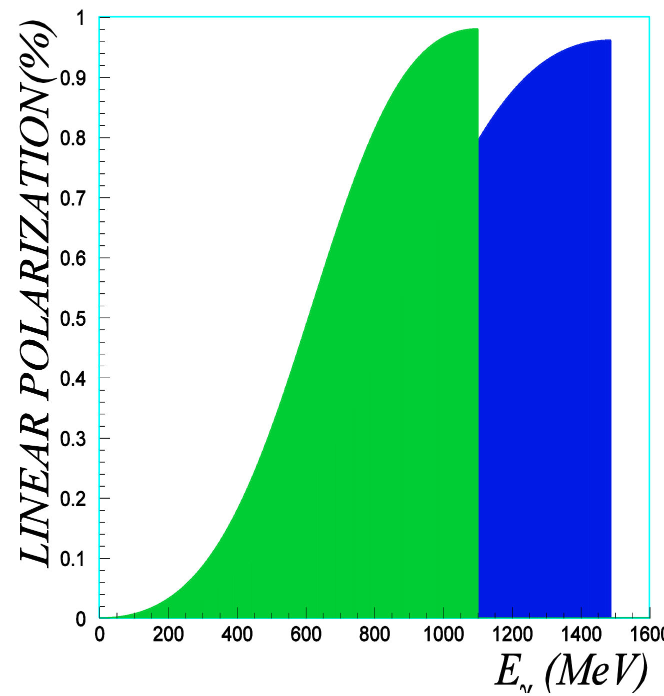
- LEPS (Tohoku) (~2000 - ~2010)
- LNS (Sendai) (?)

GRAAL Experiment at the European Synchrotron Radiation facility in Grenoble

GRAAL Setup



Linear beam polarization



Features :

-Excellent beam polarization up to 99%;

-High-resolution and high-efficiency detection of photons:

- Measurement of time-of-flight of recoil protons and **neutrons** (σ ~250 psec);

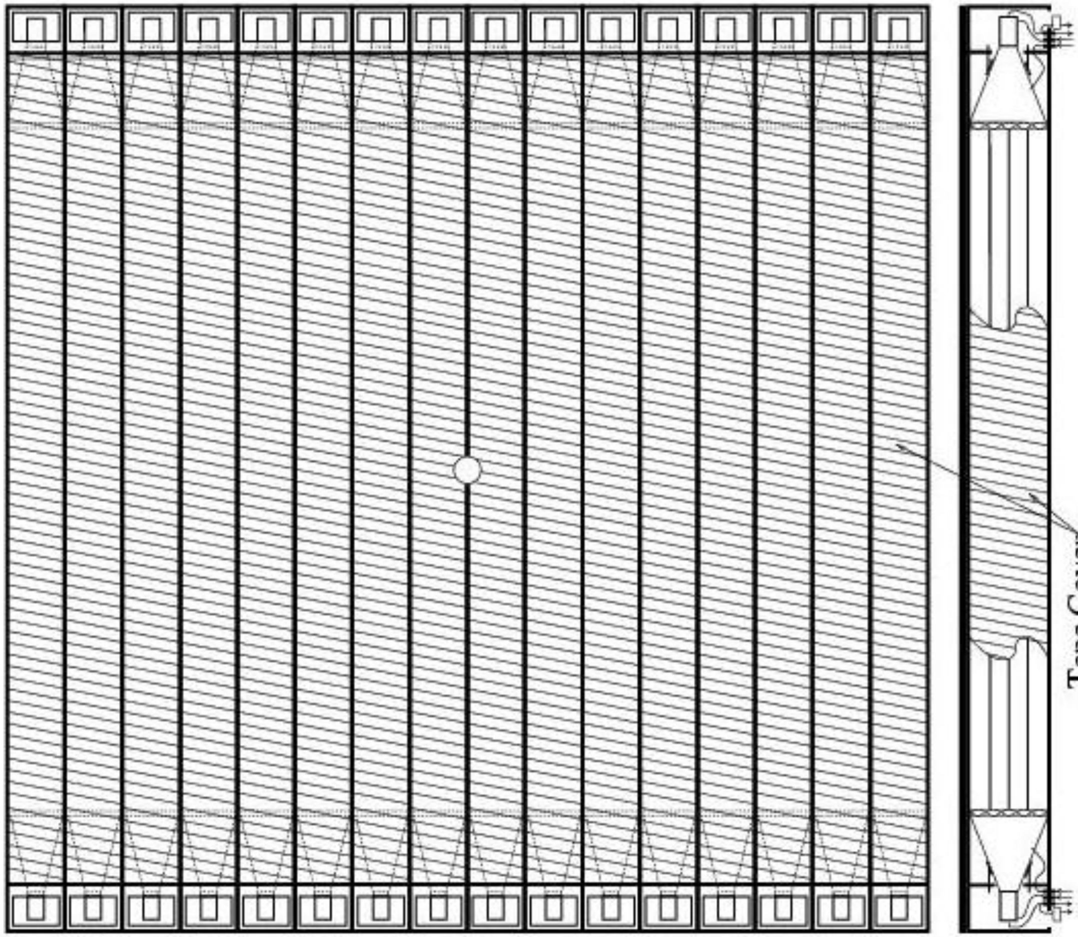
- Low ($2*10^6$ γ/sec) beam intensity (partly compensated by an all-time availability of beam);

- Poor measurement of the energy of final-state charged pions.

GRAAL forward lead-scintillator wall (``Russian Wall")

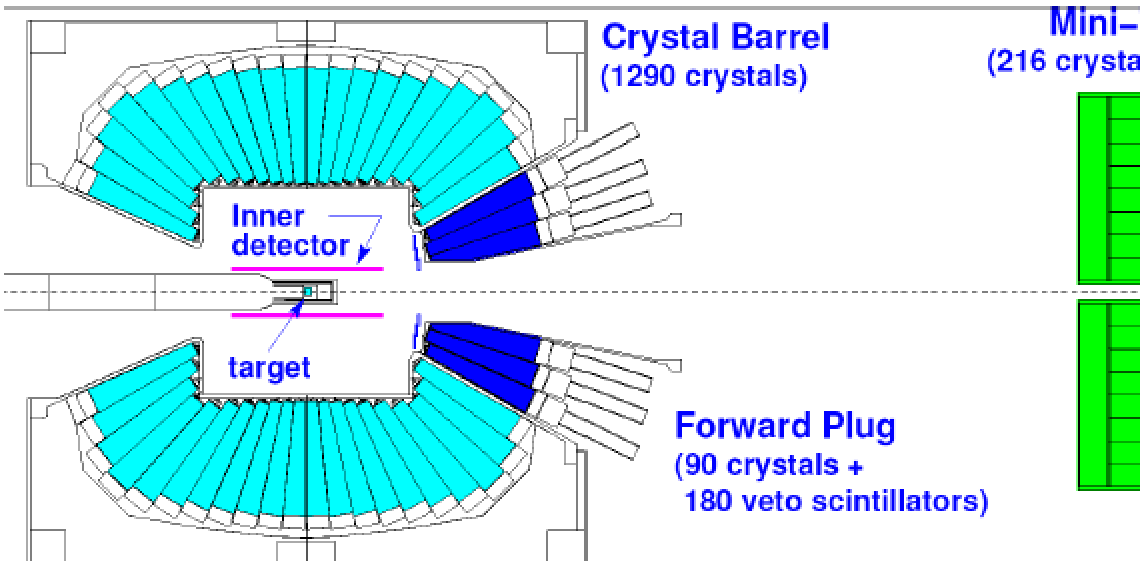
V.Kouznetsov et al., NIM A **487** (2002) 396.

An assembly of 16 modules. Each module is a sandwich of four 3000x40 mm2 bars with 3 mm thick lead plates between them. A 25 mm thick steel plate at the front of the module acts as a main converter and as a module support.

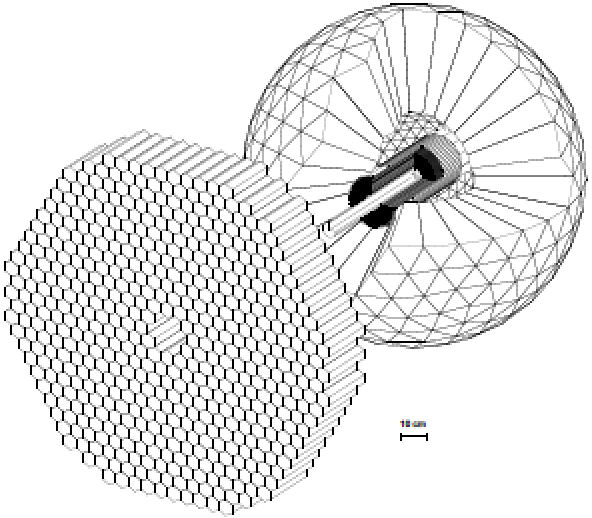


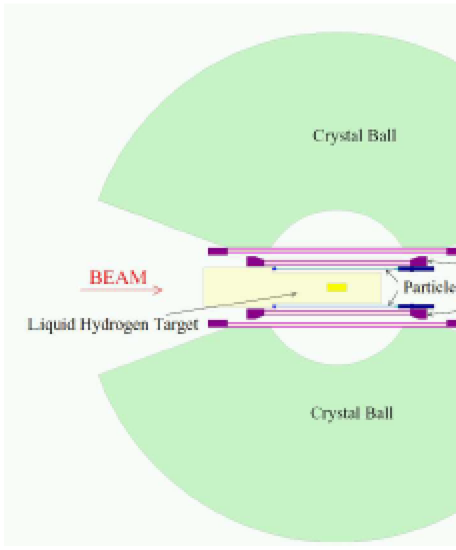
Experiments: Crystal Ball & Crystal Barrel with TAP

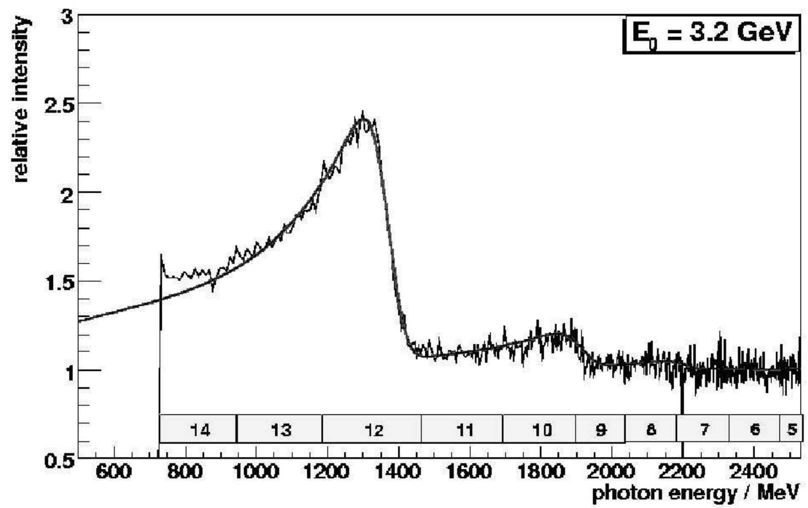
- **Bonn ELSA accelerator:**
  Crystal Barrel (CsI),
  TAPS (BaF_2) forward wall,
  inner detectors
  $E_\gamma \leq$ 3.5 GeV,
  lin. pol.: available,
  circ. pol.: available



- **Mainz MAMI accelerator:**
  Crystal Ball (NaJ),
  TAPS (BaF_2) forward wall,
  inner detectors
  $E_\gamma \leq$ 1.5 GeV,
  lin. pol.: available,
  circ. pol.: available







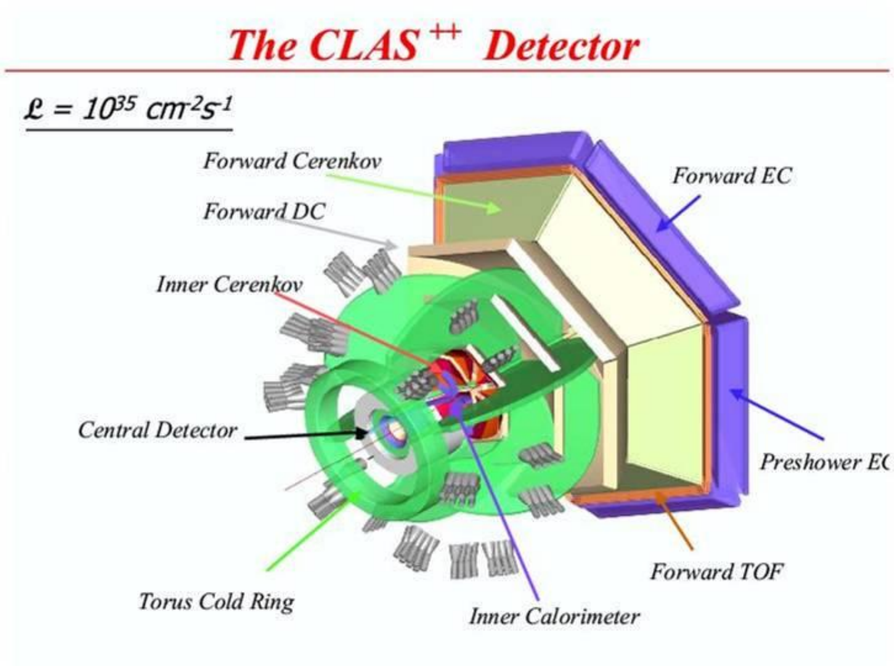
Features :

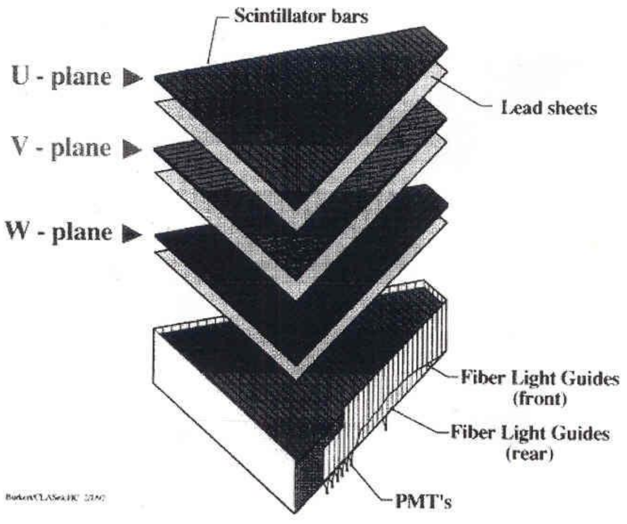
- beam polarization up to 30-60%;

-High-resolution and high-efficiency detection of photons:

  - Beam intensity ~10^8 γ/sec;
  - Poor measurement of the energy of final-state charged pions.

CLAS at Hall B (Jlab, USA)



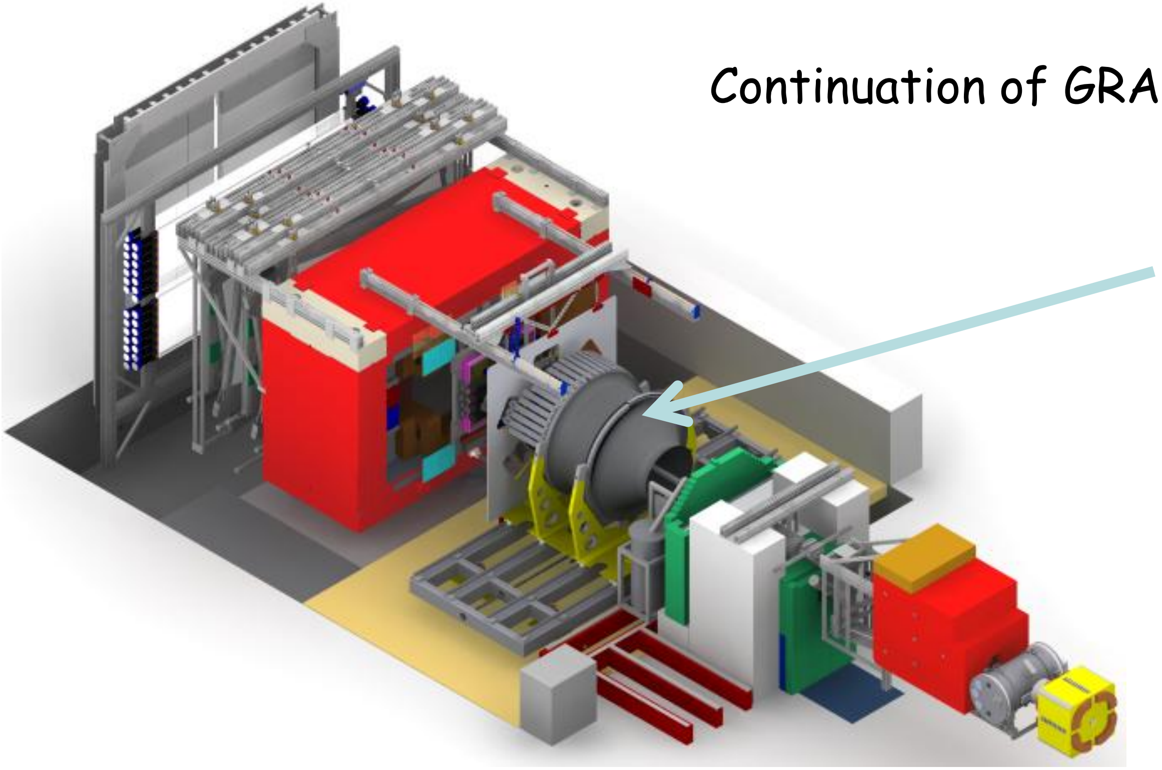


Features :

- beam polarization up to 30-60%;
- high-resoltion detection of charged particles;
- Resolution for photons ~10% :
  - Beam intensity up to 10^9 γ/sec;
  - Limited acceptance
  - No neutron detection.

BGO-OD (Bonn)

Continuation of GRAAL at new level of quality



BGO ball from GRAAL

Features :

- beam polarization up to 30-60%(?);

-High-resolution and high-efficiency detection of photons:

 - Beam intensity ~10^8 γ/sec;

 - High-resolution measurement of the energy of final-state charged particles.

 - TOF for neutrons.

Now these facilities which complement each the other, produce a lot of high-accuracy results for various reactions

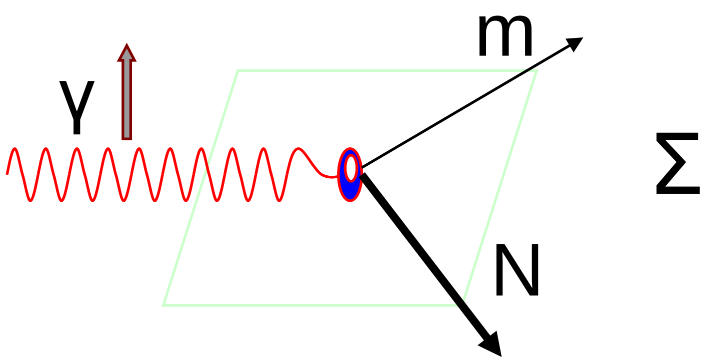
Observables in meson photoproduction

- **Unpolarised Cross section (*σ_0*)**

- **Single-polarization observables**
  - Recoil polarization (*P*)
  - Beam asymmetry (**Σ**)
  - Target asymmetry (**T**)

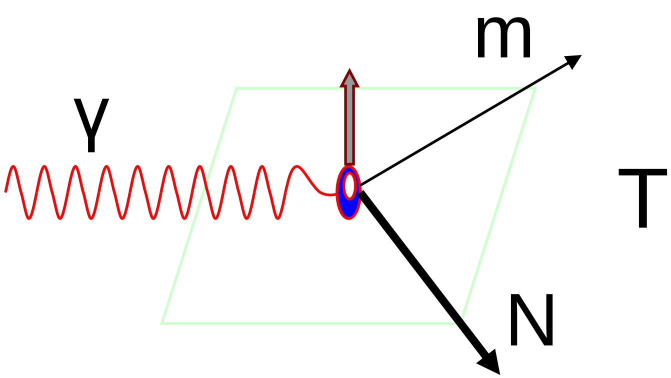
- **Double-polarization observables**
  - Beam + Recoil ($C_{x'}, C_{z'}, O_{x'}, O_{z'}$)
  - Beam + Target **(** E, F, G, H)
  - Recoil + Target ($T_{x'}, T_{z'}, L_{x'}, L_{z'}$)

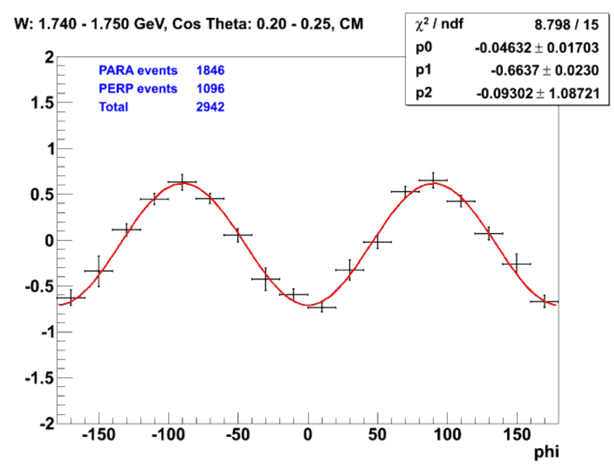
Single Polarization observables

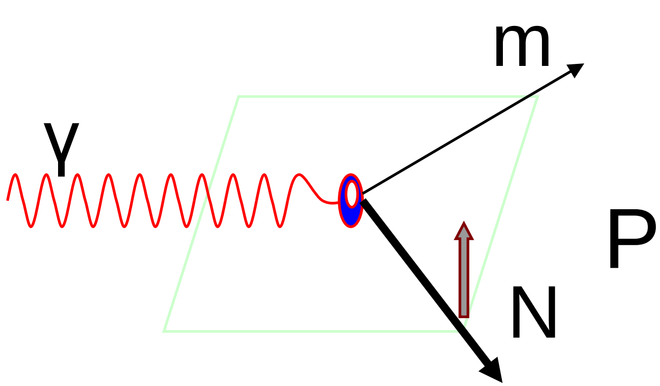


$$\frac{d\sigma}{d\Omega} = \sigma_0(1 + P\Sigma\cos(2\varphi))$$

$$\frac{n_V - n_H}{n_V + n_H} = P_\gamma\,\Sigma\cos(2\varphi)$$

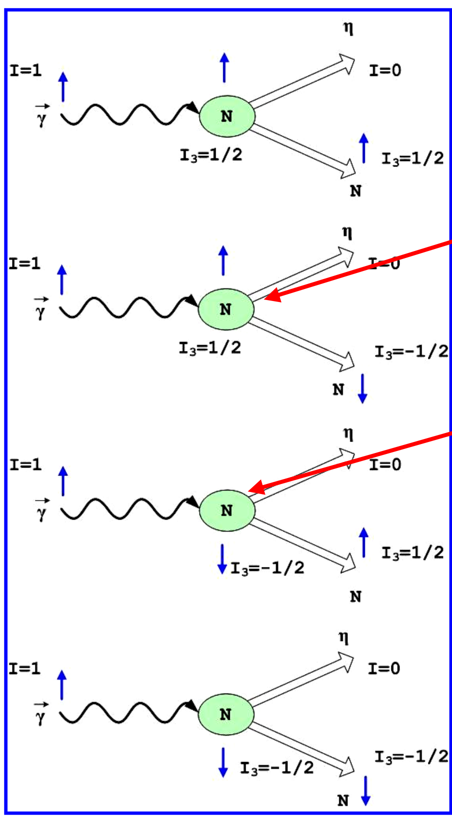






Role of polarization observables (illustration by using pseudoscalar meson photoproduction)

Helicity amplitudes $H_{\uparrow\uparrow}$ $H_{\downarrow\downarrow}$ $H_{\downarrow\uparrow}$ $H_{\uparrow\downarrow}$



H↑↑

P11

H↑↓

S11(1535)

H↓↑

H↓↓

Dominates in cross section

$$\sigma \sim |H_{\uparrow\uparrow}|^2+|H_{\downarrow\downarrow}|^2+|H_{\downarrow\uparrow}|^2+|H_{\uparrow\downarrow}|^2$$

S-P interference

$$\Sigma \sim Re\{H_{\uparrow\uparrow}H^*_{\downarrow\downarrow}-H_{\uparrow\downarrow}H^*_{\downarrow\uparrow}\}$$

$$T \sim -Im\{H_{\uparrow\downarrow}H^*_{\uparrow\uparrow}+H_{\downarrow\downarrow}H^*_{\downarrow\uparrow}\}$$

$$P \sim -Im\{H_{\uparrow\uparrow}H^*_{\downarrow\uparrow}+H_{\uparrow\downarrow}H^*_{\downarrow\downarrow}\}$$

The signal of a weakly photoexcited P11 resonance may not be seen in the cross section, but might be well seen in the ∑ beam asymmetry data through the interference with S11(1535)

Partial-wave analyses and fit to experimental data

Helicity amplitudes are linear combinations of multipoles – partial amplitudes which correspond to with certain parameters: incoming helicity, orbital momentum, outgoing helicity etc.

$$H_{xy} = \sum_{i=0}^{n} a_i M_{J\pm}$$

Multipole resonance-plus-background parameterization (oversimplified example)

$$M_{J\pm}(E) = \Sigma(A_{pc} Breight(M, E, \Gamma) Br_c C_T e^{i\varphi}) + Background$$

In total, 6 parameters per each resonance + 2 – 4 for background. Among them 2 (are common for all channels). All these parameters have to be determined from the fit of experimental data.

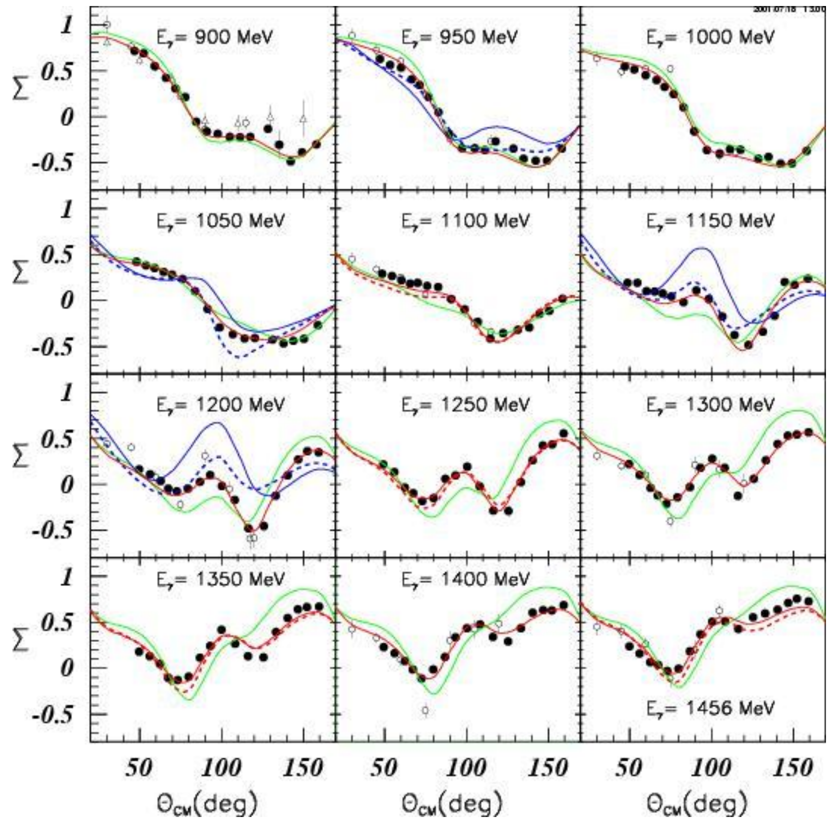
⇨ **Data base of experimental data used in the fit is critical!**

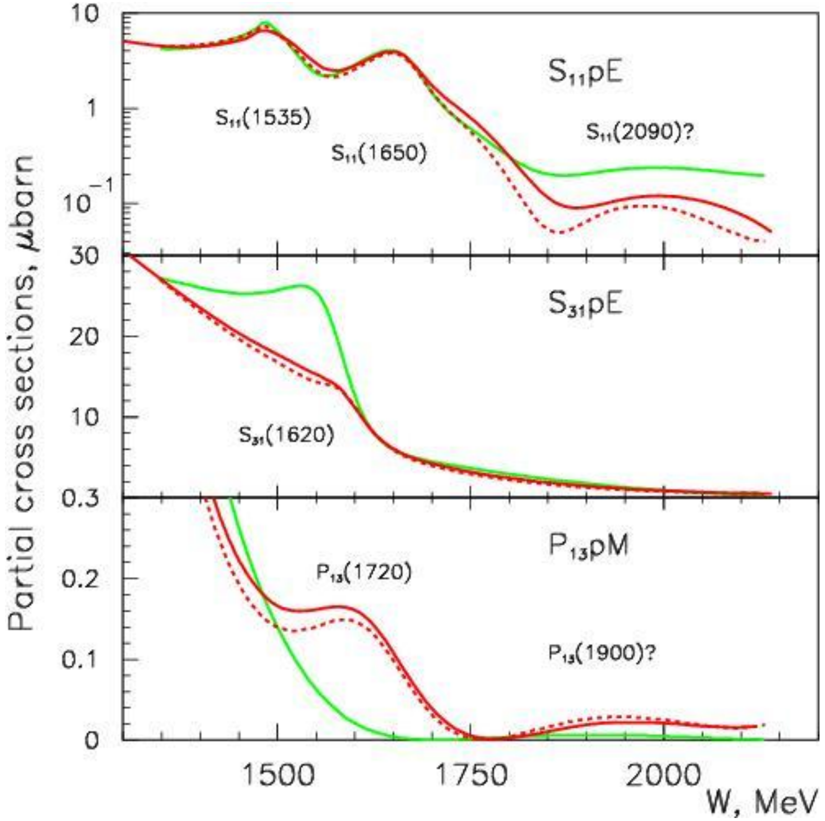
How does it work?

Illustration using GRAAL γp→π^+n beam asymmetry data

PLB **475**, 372(2000), PLB **544, 1**13,(2002) (corresponding author V.Kuznetsov)

By adding 340 beam asymmetry data points to the data base, we strongly constrained SAID multipoles





Development of Photoproduction Data Base

2002: Said data base comprised ~ 2000 data points, mostly unpolarised cross section for π photoproduction on the proton.

2019: 2553 data points only for π photoproduction on the proton (mostly polarised data…).
In total, likely more than 100 000 data points for various channels.

Problems of PW analyses

- Different approaches and different results
- Different data bases
- Quality of the data and their usage

Beam-target helicity asymmetry E in $K^0\Lambda$ and $K^0\Sigma^0$ photoproduction on the neutron

CLAS Collaboration (D.H. Ho (Carnegie Mellon U.) *et al.*). May 11, 2018. 11 pp.

Published in **Phys.Rev. C98 (2018) no.4, 045205**
JLAB-PHY-18-2741
DOI: 10.1103/PhysRevC.98.045205
e-Print: **arXiv:1805.04561 [nucl-ex] |**

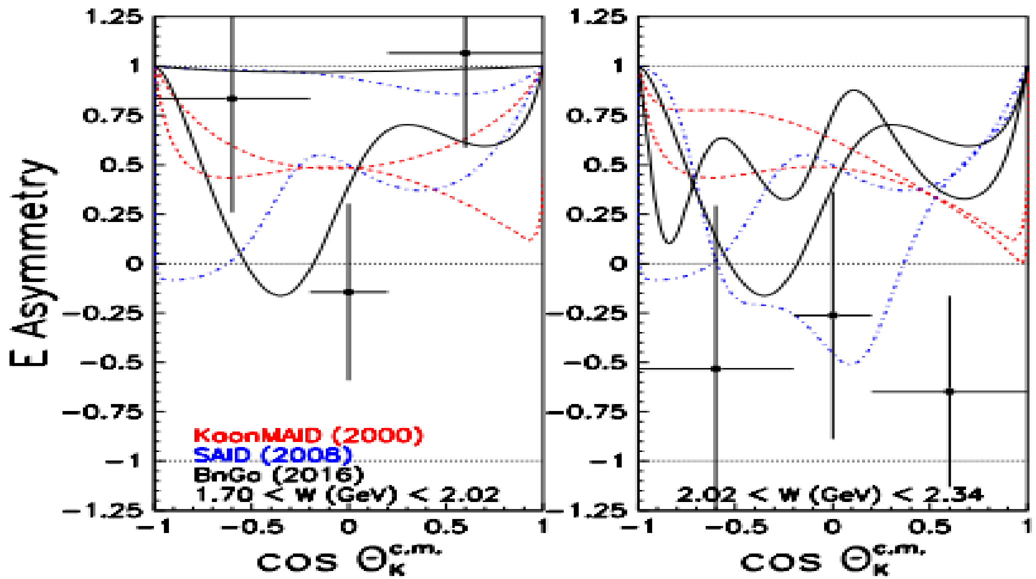


FIG. 7. Helicity asymmetry E for the $K^0\Lambda$ final state (with combined statistical and systematic uncertainties) vs. $\cos\theta_{K^0}$ The asymmetries are shown with the neutron-target theoretical models KaonMaid [36] (dashed red curve) and SAID [38] (dot-dashed blue curve) and Bonn-Gatchina [32, 41] (solid black curve). Because of the 0.32-GeV-wide W bins, each model is represented by two curves, computed at the bin end-point W values, as labeled.

The Impact of New Polarization Data from Bonn, Mainz and Jefferson Laboratory on $\gamma p \to \pi N$ Multipoles

A.V. Anisovich[1,2], R. Beck[1,a], M. Döring[3,4], M. Gottschall[1], J. Hartmann[1], V. Kashevarov[5], E. Klempt[1], Ulf-G. Meißner[1,6,7] V. Nikonov[1,2], M. Ostrick[5], D. Rönchen[1,6,b], A. Sarantsev[1,2], I. Strakovsky[3], A. Thiel[1], L. Tiator[5], U. Thoma[1], R. Workman[3], Y. Wunderlich[1]

[1]Helmholtz-Institut für Strahlen- und Kernphysik der Universität Bonn, Nußallee 14-16, 53115 Bonn, Germany
[2] NRS "Kurchatov Institute", PNPI, 188300, Gatchina, Russia
[3]Department of Physics, George Washington University, 725 21st Street, NW, Washington, DC 20052, USA
[4]Thomas Jefferson National Accelerator Facility, 12000 Jefferson Avenue, Newport News,VA, USA
[5]Institut für Kernphysik der Universität Mainz, Johann-Joachim-Becher-Weg 45, 55099 Mainz, Germany
[6]Bethe Center for Theoretical Physics, Universität Bonn, 53115 Bonn, Germany
[7]Institut für Kernphysik, Institute for Advanced Simulation, Jülich Center for Hadron Physics, JARA FAME and JARA HPC, Forschungszentrum Jülich, 52425 Jülich, Germany

Received: date / Revised version: date

Abstract. New data on pion-photoproduction off the proton have been included in the partial wave analyses Bonn-Gatchina and SAID and in the dynamical coupled-channel approach Jülich-Bonn. All reproduce the recent new data well: the double polarization data for E, G, H, P and T in $\gamma p \to \pi^0 p$ from ELSA, the beam asymmetry Σ for $\gamma p \to \pi^0 p$ and $\pi^+ n$ from Jefferson Laboratory, and the precise new differential cross section and beam asymmetry data Σ for $\gamma p \to \pi^0 p$ from MAMI. The new fit results for the multipoles are compared with predictions not taking into account the new data. The mutual agreement is improved considerably but still far from being perfect.

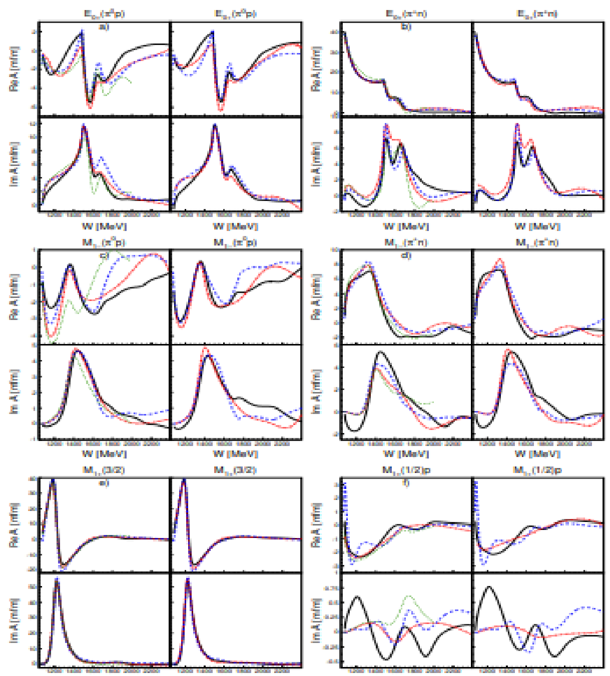
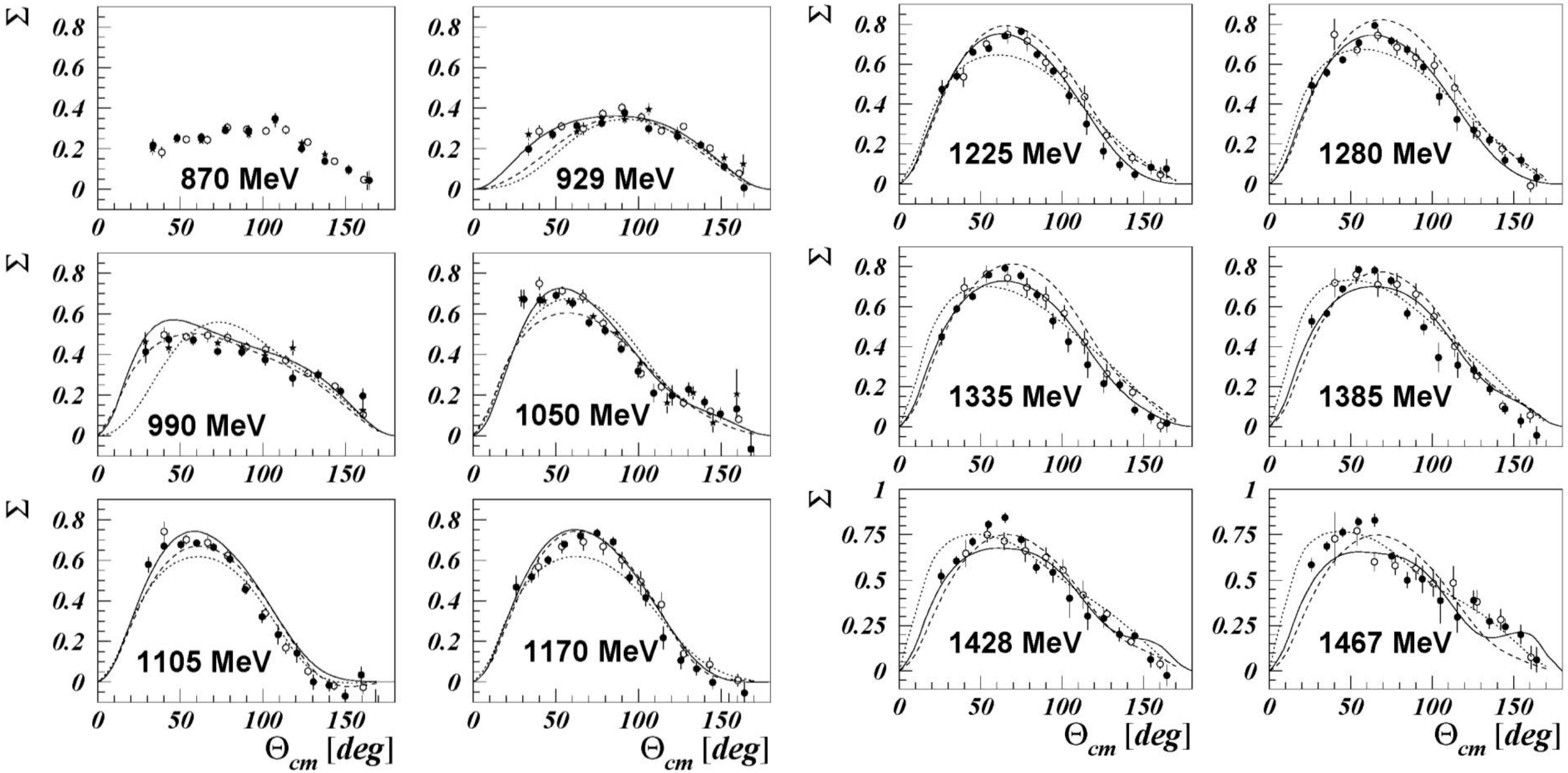
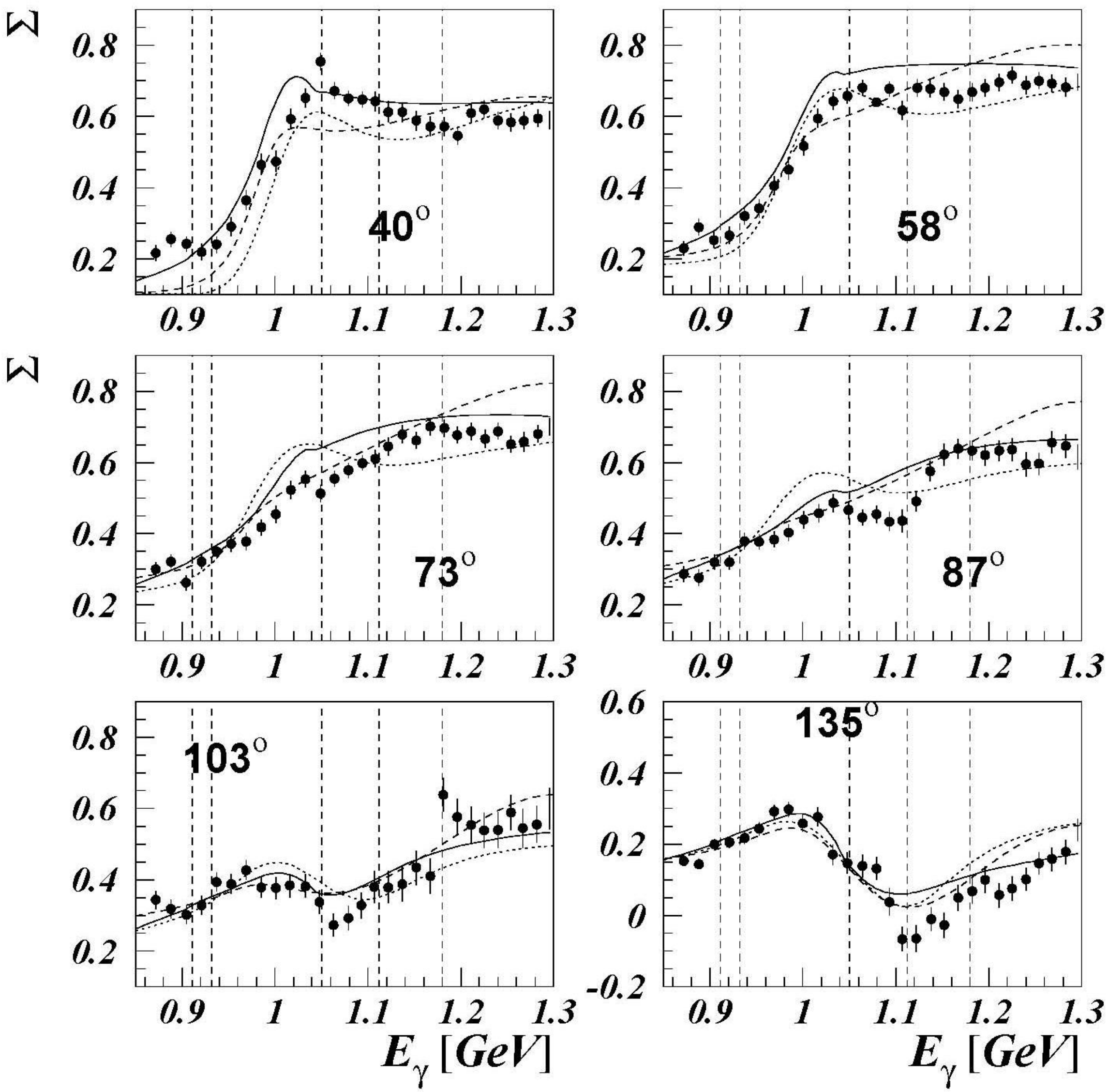


Fig. 3. Each block presents the real (top) and imaginary (bottom) part of multipoles for $\gamma p \to \pi N$, before (left) and after (right) including new data. Black solid line: BnGa, blue dashed: JüBo, red dashed-dotted: SAID, green dotted: MAID. Blocks a and c show the $\gamma p \to \pi^0 p$ multipoles, b and d those for $\gamma p \to \pi^+ n$. Block e (f) presents the $I = 3/2$ ($I = 1/2$) multipoles.

Impact of experimental data:
Published beam asymmetry Σ for γp→ηp from GRAAL



The same data obtained with the fine energy binning (unpublished)



PDG2004 vs **PDG**2018 (3-4* resonances)

	2004	2018
N	13	20(!)
Δ	9	11
Λ	13	13
Σ	9	9
Ξ	5	5
Ω	1	1

In total 9 resonances more.

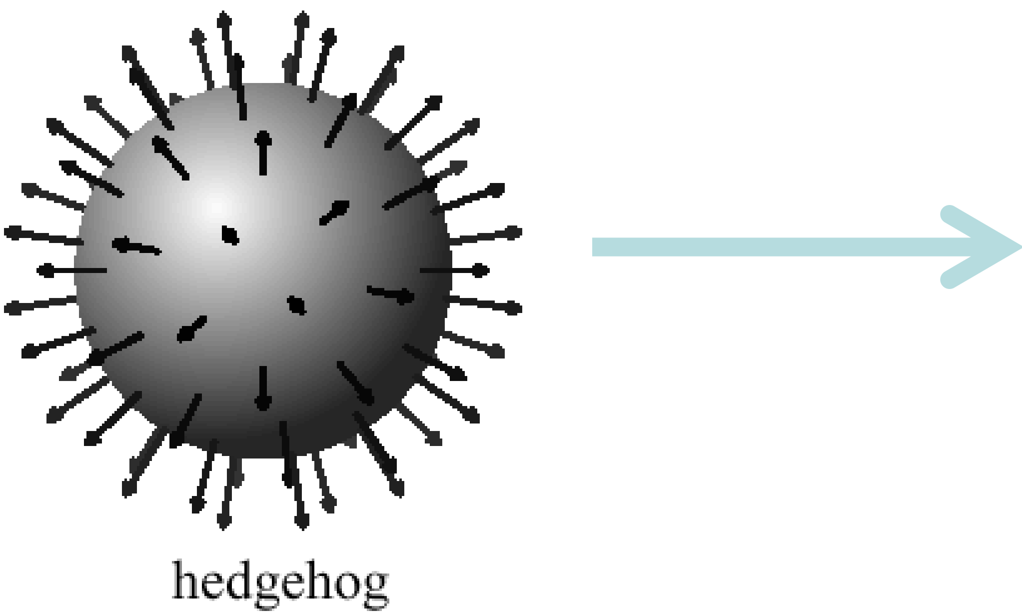
N(1875) 3/2- new!,
N(1875) ½+ new,
N(1895)1/2- new! (Bonn-Gatchina),
N(1900)3/2+ **->****,
N(2060) 5/2- new!,
N(2100) 1/2+ *->***,
N(2120) 3/2- new!,
Δ(1900) 1/2 - **-> ***,
Δ(2200)7/2- *->***,

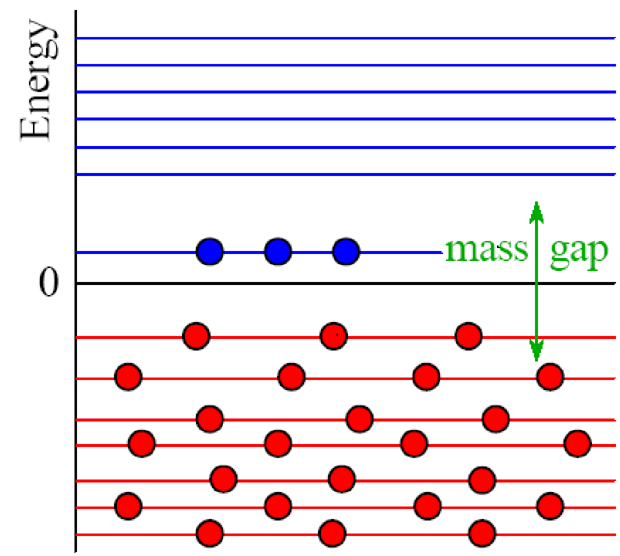
Do wee need an alternative model?

CQM Alternatives :

Chiral Soliton Model

Chiral Quark-Soliton Model





Mean-Field Approach (MFA)

Based on the papers

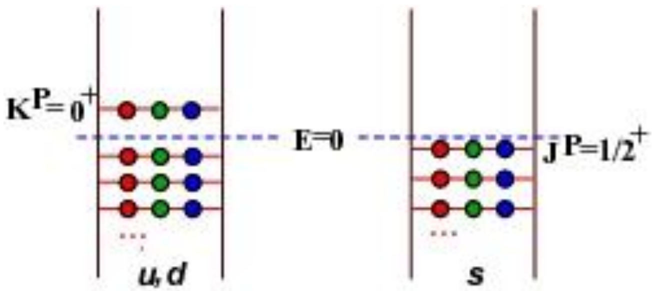
- D. Diakonov, `` Baryons resonances in the mean-field approach and the simple explanation of Θ+ pentaquark", Arxiv :0812.3418

- D.Diakonov, ``Prediction of New charmed and bottom exotics pentaquarks", Arxiv: 1003.2157

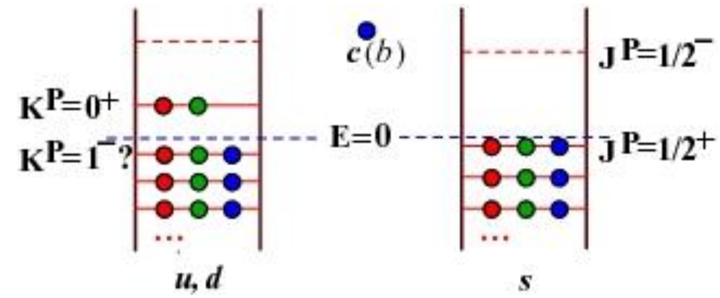
- D. Diakonov, V. Petrov, and A.Vladimirov, ``Baryon resonances at large N_c, or Quark Nuclear Physics", Arxiv:1207.3679

Baryons are multiquark systems stored in the mean field

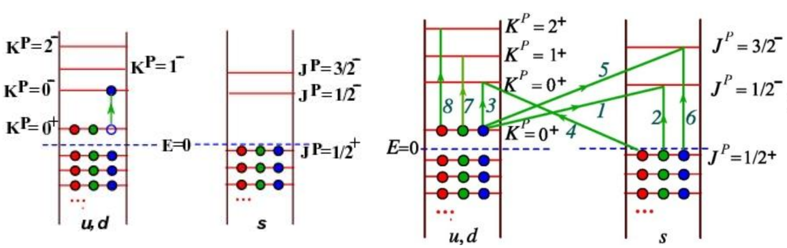
Proton and Neutron

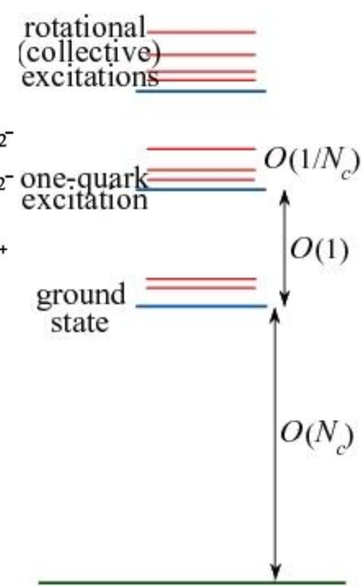


Charmed or bottom baryons

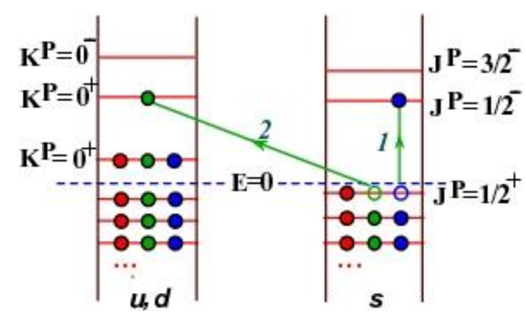


Baryon Resonances



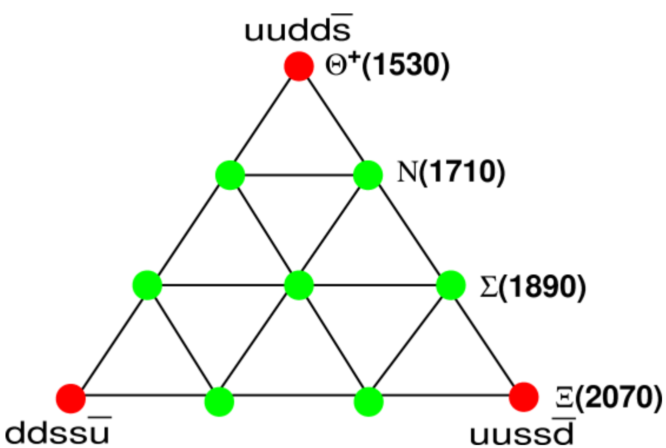


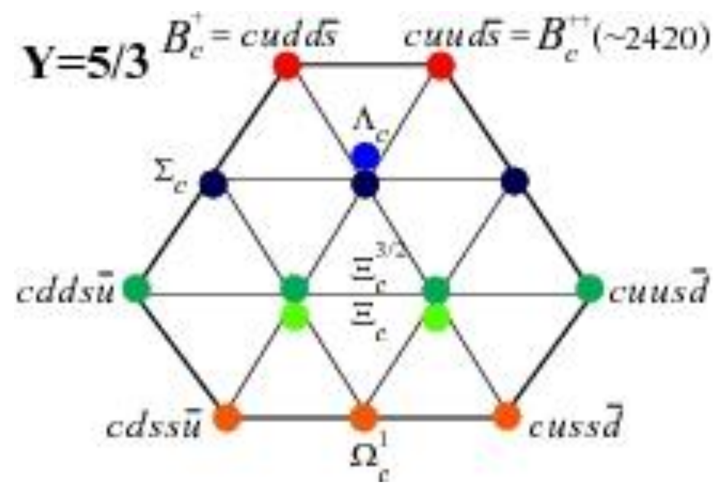
``Pentaquarks" – specific transitions



MFA predicts the same **octet and decuplet of known baryons**. It ``..also predicts baryons resonances from the PDG Tables. **Neither of resonances below 2 GeV remain unaccounted for, and no additional resonances is predicted** except only one Δ(3/2+)" (citation from ***D. Diakonov, V. Petrov, and A.Vladimirov, ``Baryon resonances at large N_c, or Quark Nuclear Physics", Arxiv:1207.3679***)

As byproduct, long-lived narrow exotic states (``pentaquarks") are predicted.





Search for exotics is critical to verify MFA!

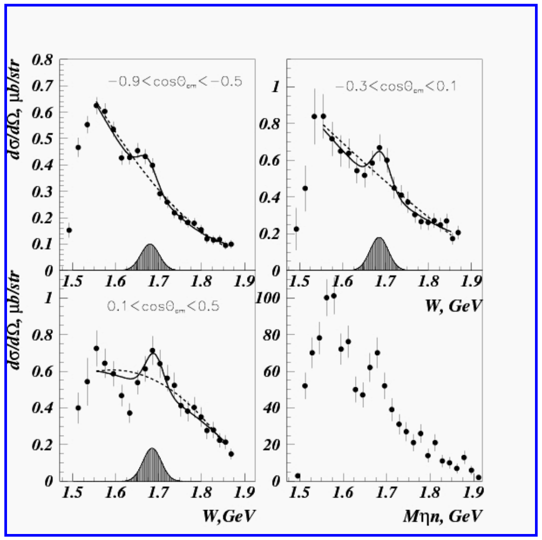
Search for exotics might be critical

Narrow bump-like structure at W=1.68 GeV in quasi-free η photoproduction on the neutron

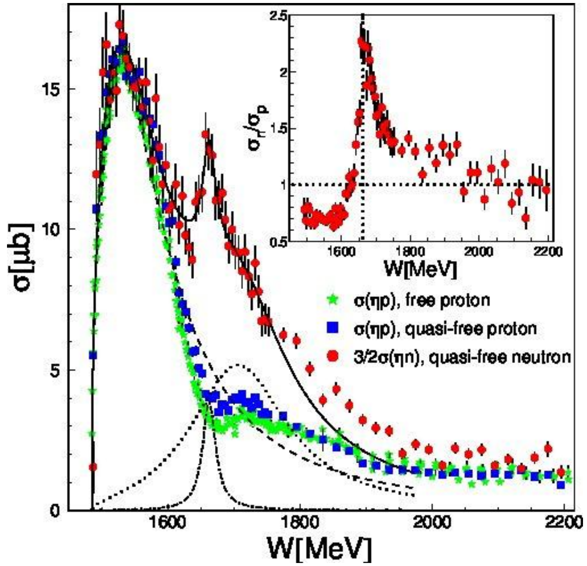
$\gamma + n \rightarrow \eta + n$

V.Kuznetsov et al.,

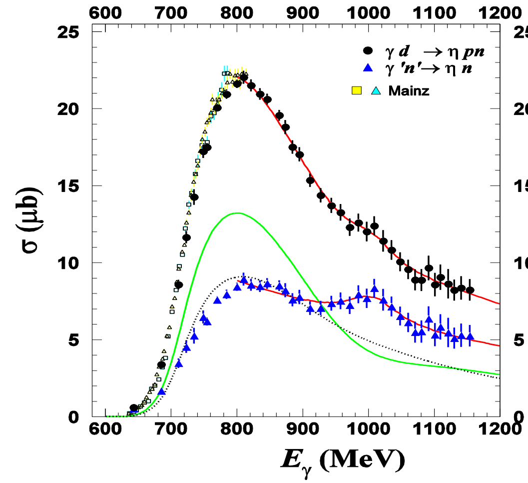
Phys. Lett. B**647**, 23, 2007(hep-ex/0606065)



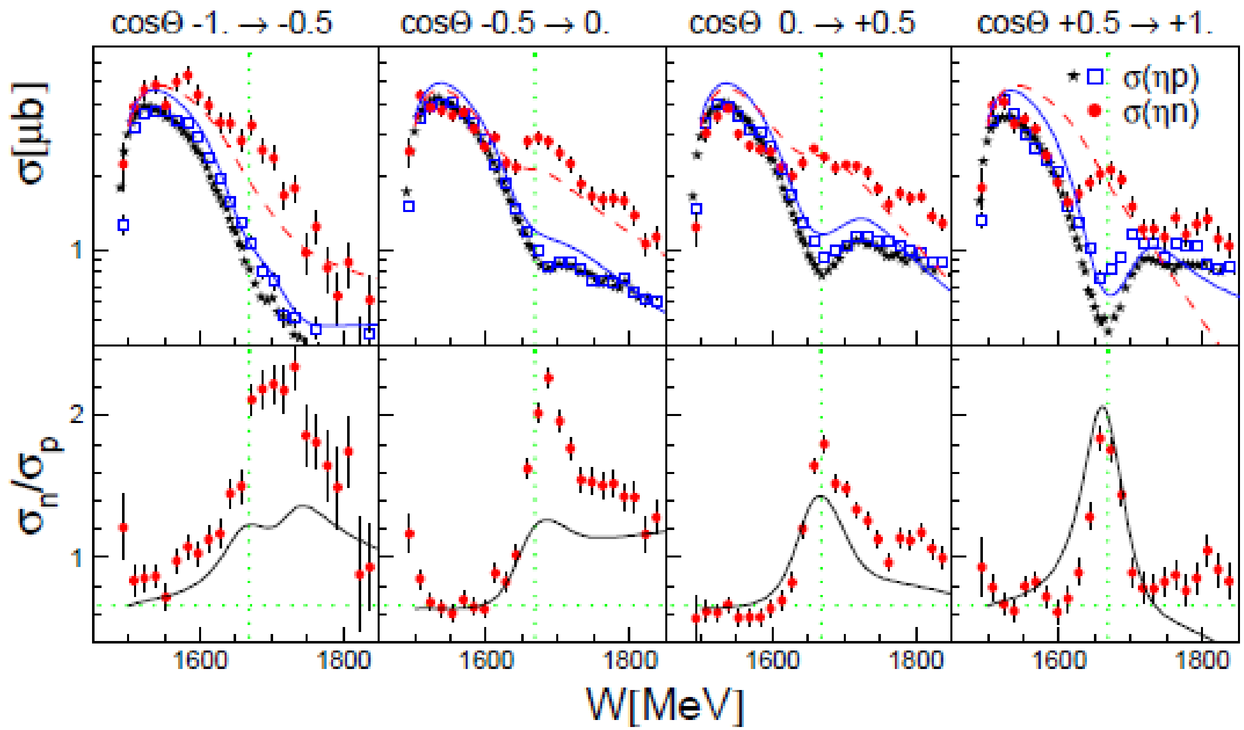
CBELSA/TAPS, J.Jeagle et al,
EPJA **47**, 89 (2011)

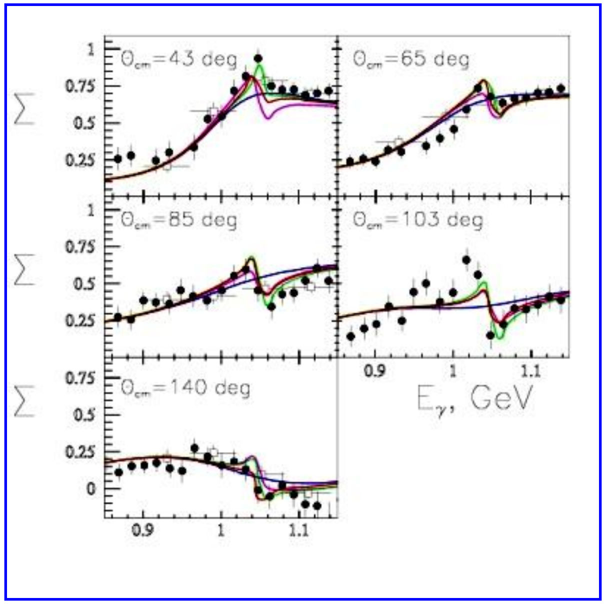


F.Miyahara et al., Prog. Theor. Phys. Suppl. **168**, 90, 2007



Compilation of recent CBTAPS/ELSA (γn->ηn) and A2@MaMiC (γp->ηp) data and γp->ηp beam asymmetries from GRAAL





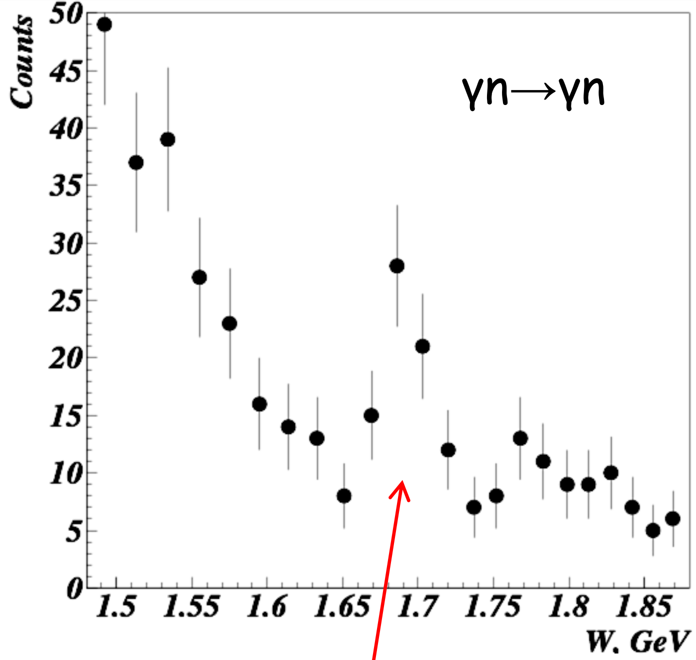
- 'peak' in neutron cross section related to 'dip' in proton cross sections (?) only 'dip' reproduced by MAID!

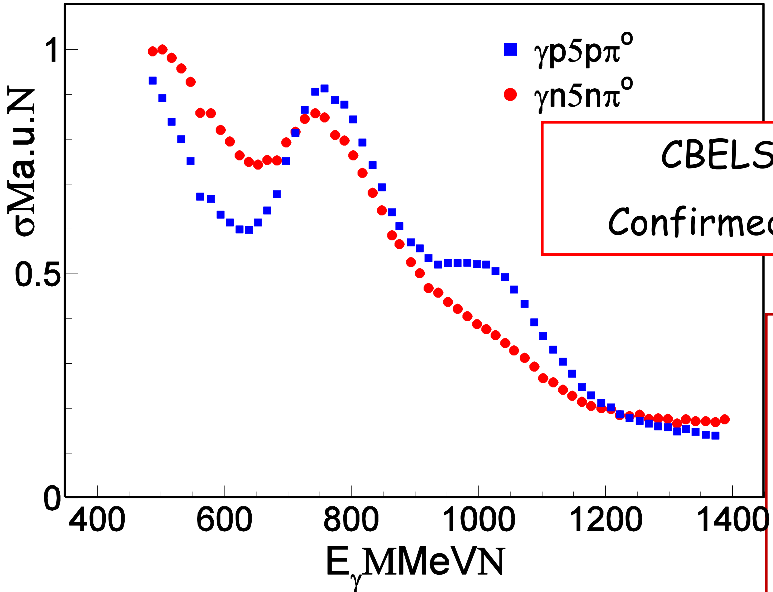
Beam asymmetry from GRAAL on the free proton: the structure at the same position as in the cross section.

Compton scattering and π^0 photoproduction on the neutron (GRAAL)

$\gamma n \rightarrow \gamma n$ $\gamma n \rightarrow \pi^0 n$

V.Kuznetsov et al., PRC 83, 022201,2011





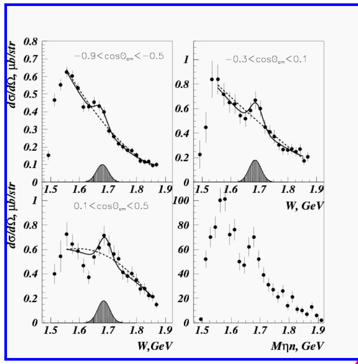
CBELSA/TAPS data

Confirmed by our analysis.

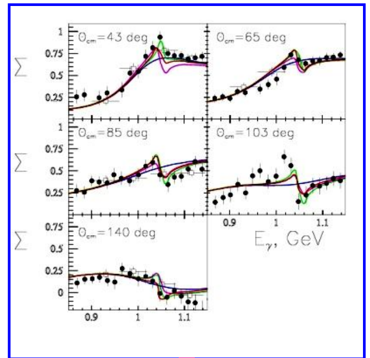
Compton scattering: Peak structure at 1.685 GeV

$\gamma n \rightarrow \pi^0 n$: Flat cross section at 800 -1300 MeV

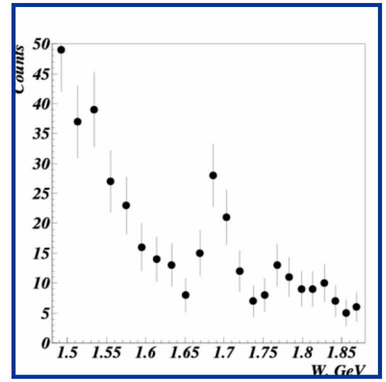
Graal γn→ηn



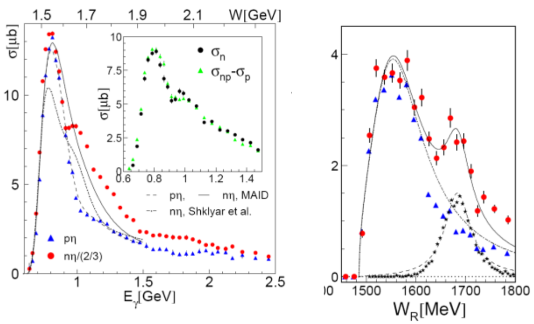
Graal γp→ηp



Graal γn→γn

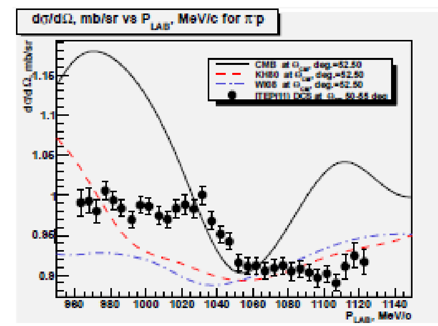


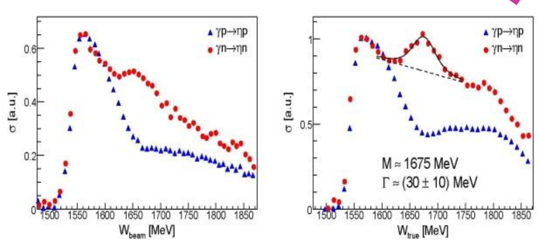
N*(1685)?



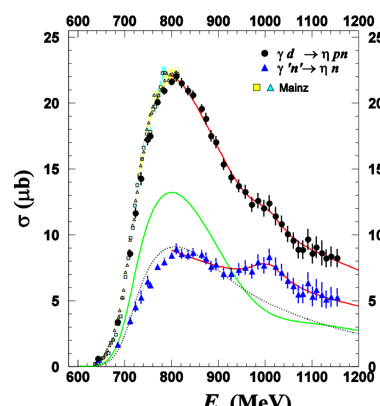
CBELSA/TAPS γn→ηn

EPECUR πp→πp





Mainz γn→ηn

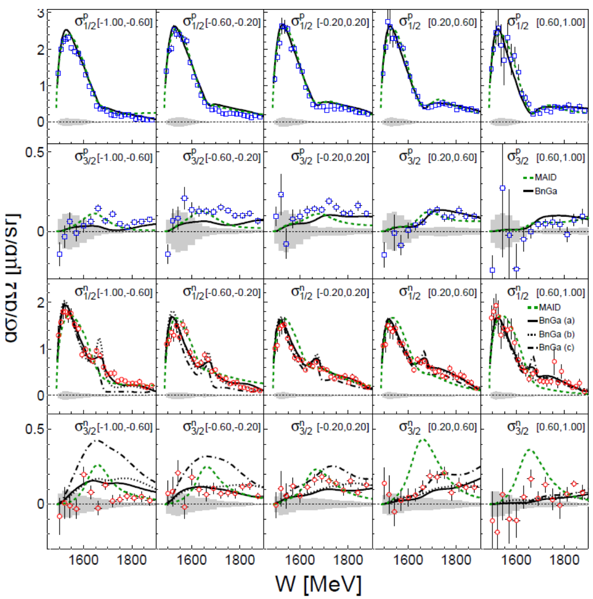


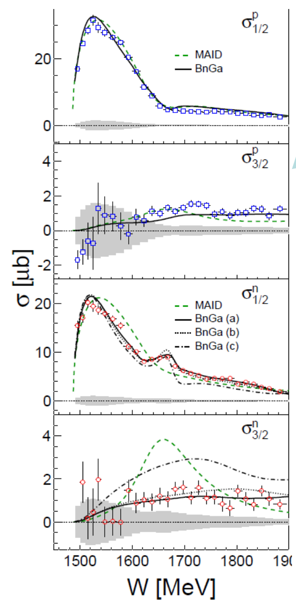
LNS-Sendai γn→ηn

Updates from 2017

L. Witthauer et al., Phys. Rev. Lett. **117**, 132502 (2016)
[A2@MAMI C Collaboration]
Measurement of Helicity-dependent γn→ηn cross sections

``…The extracted Legendre coefficients of the angular distributions for 1/2 are in good agreement with recent reaction model predictions assuming a narrow resonance in the P11 wave as the origin of this structure...”



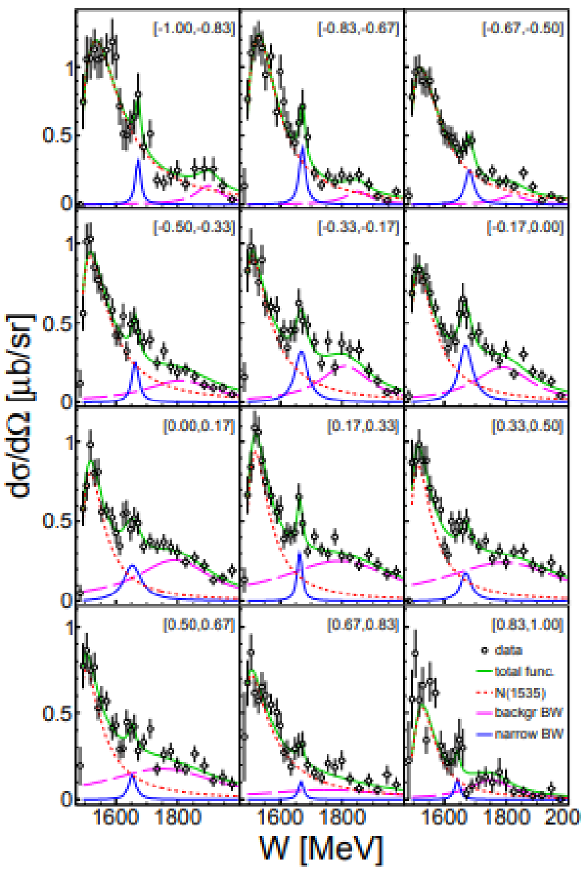


``Scrutinizing the evidence for N(1685)”
A.V. Anisovich, V. Burkert, E. Klempt, V.A. Nikonov, A.V. Sarantsev, U. Thoma
Phys.Rev. C**95** (2017), 035211
arXiv:1701.06387
`` …There is hence the suspicion that the dip might be a statistical fluctuation…a partial wave analysis without a narrow $J^P = 1/2^+$ resonance is excellent…”

Comments

Comments on Comments

``New Narrow N(1685) and N(1722)? Remarks on the interpretation of the neutron anomaly as an interference phenomenon”
V. Kuznetsov et al., JEPT Letters **105** (2017) no.10, 625-630



Photoproduction of η mesons from the neutron: cross sections and double polarization observable E

L. Witthauer[1], M. Dieterle[1], F. Afzal[2], A.V. Anisovich[2,4], B. Bantes[3], D. Bayadilov[2,4], R. Beck[2], M. Bichow[5], K.-T. Brinkmann[2,7], S. Böse[2], Th. Challand[1], V. Crede[6], H. Dutz[3], H. Eberhardt[3], D. Elsner[3], R. Ewald[3], K. Fornet-Ponse[3], St. Friedrich[7], F. Frommberger[3], Ch. Funke[2], St. Goertz[3], M. Gottschall[2], A. Gridnev[4], M. Grüner[2], E. Gutz[2,7], D. Hammann[3], Ch. Hammann[2], J. Hannappel[3], J. Hartmann[2], W. Hillert[3], Ph. Hoffmeister[2], Ch. Honisch[2], T. Jude[3], D. Kaiser[2], H. Kalinowsky[2], F. Kalischewski[2], S. Kammer[3], A. Käser[1], I. Keshelashvili[1], P. Klassen[2], V. Kleber[3], F. Klein[3], K. Koop[2], B. Krusche[1], M. Lang[2], I. Lopatin[4], Ph. Mahlberg[2], K. Makonyi[7], V. Metag[7], W. Meyer[5], J. Müller[2], J. Müllers[2], M. Nanova[7], V. Nikonov[2,4], D. Piontek[2], G. Reicherz[5], T. Rostomyan[1], A. Sarantsev[2,4], Ch. Schmidt[2], H. Schmieden[3], T. Seifen[2], V. Sokhoyan[2], K. Spieker[2], A. Thiel[2], U. Thoma[2], M. Urban[2], H. van Pee[2], N.K. Walford[1], D. Walther[2], Ch. Wendel[2], D. Werthmüller[1], A. Wilson[2,6], and A. Winnebeck[2]
(The CBELSA/TAPS collaboration)

[1] Department of Physics, University of Basel, CH-4056 Basel, Switzerland
[2] Helmholtz-Institut für Strahlen- und Kernphysik der Universität Bonn, Germany
[3] Physikalisches Institut, Universität Bonn, Germany
[4] National Research Centre "Kurchatov Institute", Petersburg Nuclear Physics Institute, Gatchina, Russia
[5] Institut für Experimentalphysik I, Ruhr-Universität Bochum, Germany
[6] Department of Physics, Florida State University, Tallahassee, USA
[7] II. Physikalisches Institut, Universität Giessen, Germany

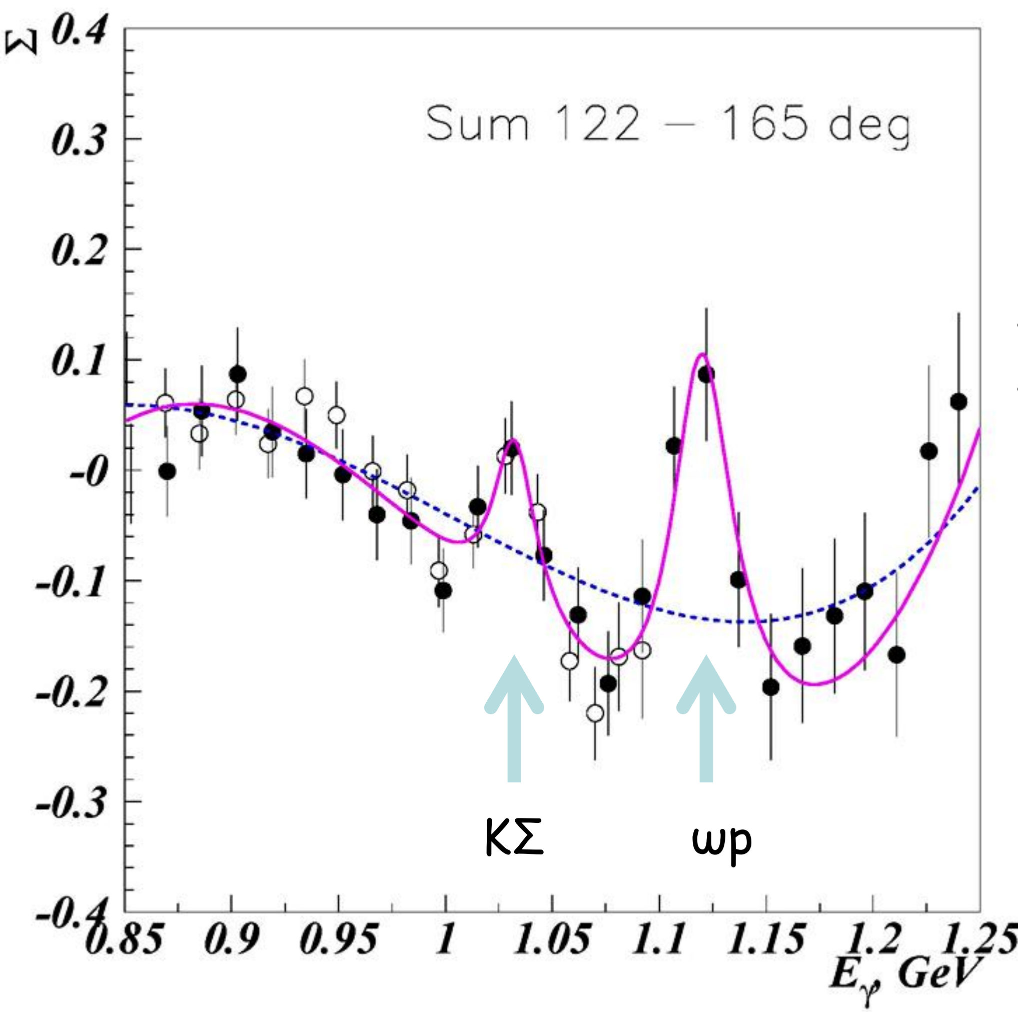
Received: date / Revised version: date

structure seen in previous measurements of the $\gamma n \rightarrow n\eta$ reaction was also confirmed. Angular distributions have shown that the structure is more distinct for backward angles in the cm of the η meson and the neutron and less pronounced in the forward direction. This is a behavior which would agree with an interference between a P_{11} and the strongly dominant S_{11} partial wave. However, the angular dependence is more complicated with a pronounced maximum around 90°. Nevertheless, as a calculation of the χ^2 values showed, the data seem to be in better agreement with the BnGa model solution [51] including an additional narrow P_{11} state than without. This question needs further investigation.

10. B. Krusche *et al.*, Phys. Rev.
11. B. Krusche *et al.*, Phys. Lett.
12. J. Ajaka *et al.*, Phys. Rev. Le
13. D. Elsner *et al.*, Eur. Phys. J.
14. O. Bartalini *et al.*, Eur. Phys.
15. M. Dugger *et al.*, Phys. Rev.
16. M. Williams *et al.*, Phys. Rev
17. V. Crede *et al.*, Phys. Rev. Le
18. O. Bartholomy *et al.*, Eur. Ph
19. V. Crede *et al.*, Phys. Rev. C
20. F. Renard *et al.*, Phys. Lett.
21. T. Nakabayashi *et al.*, Phys.
22. E.F. McNicoll *et al.*, Phys. Re
23. C.S. Akondi *et al.*, Phys. Rev

Two narrow (Γ~20 MeV) structures at W~1.68 and W~1.72 GeV in the beam asymmetry data for Compton scattering off the proton at GRAAL

V.Kuznetsov et al., Phys.Rev. C91 (2015) no.4, 042201



W_1 = 1681 ±1 MeV

W_2 = 1726 ±1 MeV

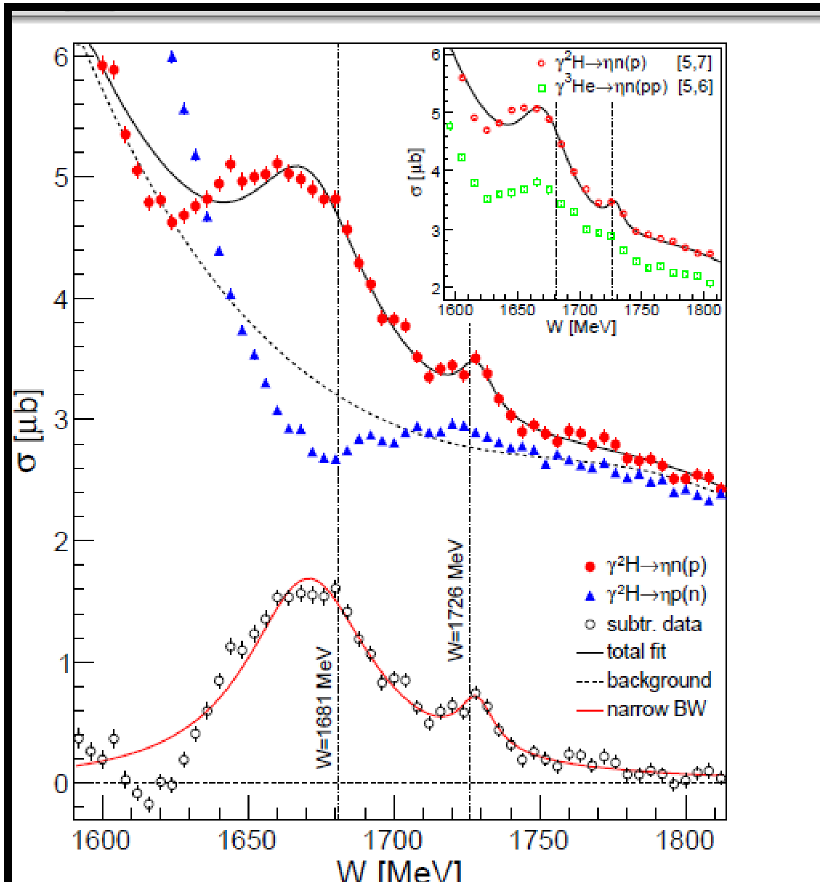
PHYSICAL REVIEW C **92**, 069801 (2015)

Comment on "Evidence for narrow resonant structures at $W \approx 1.68$ GeV and $W \approx 1.72$ GeV in real Compton scattering off the proton"

D. Werthmüller,[1,2] L. Witthauer,[2] D. I. Glazier,[1] and B. Krusche[2]
[1]School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, Scotland, United Kingdom
[2]Departement Physik, Universität Basel, CH-4056 Basel, Switzerland
(Received 8 July 2015; published 11 December 2015)

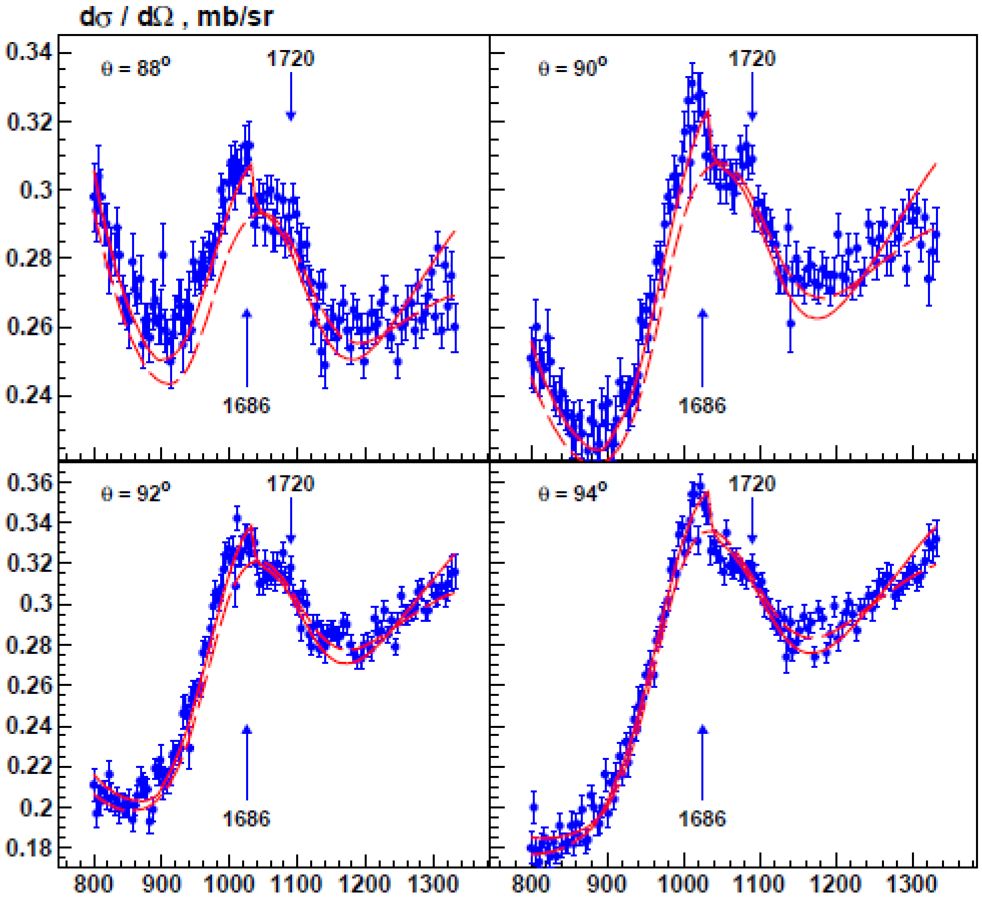
We comment on the statement by Kuznetsov *et al.* that the structure around $W = 1.72$ GeV seen in the beam asymmetry in Compton scattering off the proton is not observed in the total cross section of η photoproduction on the neutron.

Observation of two narrow structure at W~1.68 and W~1.72 GeV in γn→ηn at A2@MaMiC and CBELSA/TAPS



``Search for narrow resonances in πp elastic scattering from the EPECUR experiments"

A. Gridnev et al, Phys.Rev. C93 (2016) no.6, 062201



Do we see one (N(1685)) or two (N(1685) and N(1726)) narrow resonances?

Interpretations of the narrow structure at W~1.68 GeV:

Interference of Known resonances V. Shklyar, H. Lenske , U. Mosel , PLB650 (2007) 172 (Giessen group): A. Anisovich et al. EPJA 41, 13 (2009), hep-ph/0809.3340 (Bonn-Gatchina group); X.-H. Zong and Q.Zhao, Arxiv:1106.2892 and several other publications…

- **Intermediate sub-threshold meson-nucleon state**

M.Doring, K. Nakayama, PLB683, 145 (2010), nucl-th/0909.3538

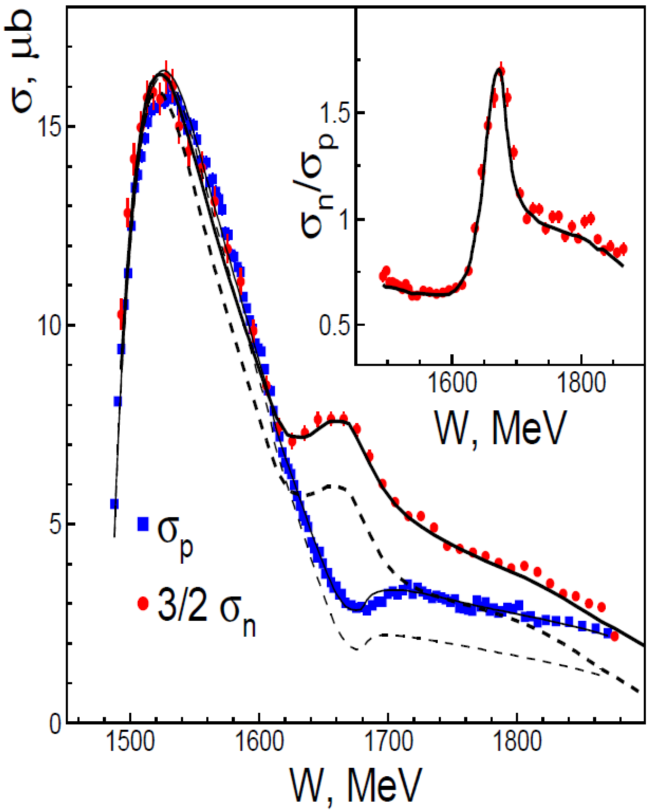
Narrow resonance

- Y.Azimov, V.Kuznetsov, M.Polaykov, and I.Strakovsky, Eur. Phys. J. A **25**, 325, 2005.
- A.Fix, L.Tiator, and M.Polyakov, Eur. Phys. J. A **32**, 311, 2007.
- K.S.Choi, S.I. Nam, A.Hosaka, and H-C.Kim, Phys. Lett. B **636**, 253, 2006.
- K.S.Choi, S.I. Nam, A.Hosaka, and H-C.Kim, Prog. Theor. Phys. Suppl. **168**, 97, 2008.
- G.S.Yang, H.S.Kim, Arxiv:1204.5644
- Etc…

Interference of know resonances:

Latest example
A. Sarantsev, *Proc. 10th Int. Workshop on the Physics of Excited Nucleons (NSTAR2015),*
JPS Conf. Proc. , 010005 (2016)

http://doi.org/10.7566/JPSCP.10.010005



``...the analysis of new data (from A2@MaMiC) showed a preferable solution with the interference inside the S11 partial waves. The solution with the narrow P11 state were collapsed to the solutions with the interference inside the S-wave showing the strong decreasing of the P11 signal.... Therefore the new data do not support the existence of a narrow state with the quantum numbers $\frac{1}{2}$+ in the 1.68 GeV mass region.

BnGa solutions are limited to only γn→ηn cross section while the data base is much larger!

Comments on the Interference of Known resonances

by A. Anisovch, V. Burkert, A. Sarantsev et al.

- Explains only the enhancement in the enhancement at W~ 1.68 GeV in **$\gamma n \to \eta n$ excitation function** but not the whole complex of experimental observations;
- Doesn't reproduce the second stucture at W ~ 1.72 GeV;
- Bugs in fitting of the quasifree $\gamma n \to \eta n$ cross.

Quite questionable!

ISSN 0021-3640, JETP Letters, 2017, Vol. 105, No. 10, pp. 625–630. © Pleiades Publishing, Inc., 2017.

arXiv:1703.07425

FIELDS, PARTICLES, AND NUCLEI

New Narrow N(1685) and N(1726)? Remarks on the Interpretation of the Neutron Anomaly as an Interference Phenomenon[1]

V. Kuznetsov[a, b, *], V. Bellini[b, c], V. Brio[b, c], A. Gridnev[a], N. Kozlenko[a], F. Mammoliti[b, c], F. Tortorici[b, c], M. V. Polyakov[a, d], G. Russo[b, c], M. L. Sperduto[b, c], V. Sumachev[a], and C. M. Sutera[b]

[a] *Petersburg Nuclear Physics Institute, Gatchina, 188300 Russia*

[b] *NFN—Sezione di Catania, Catania, I-95123 Italy*

[c] *Dipartimento di Fisica ed Astronomia, Università di Catania, Catania, I-95123 Italy*

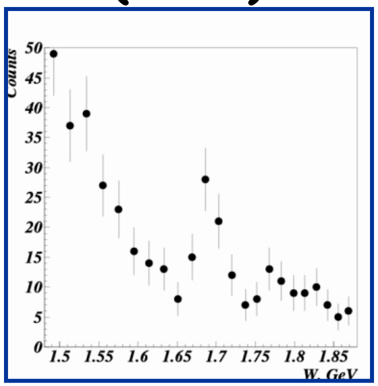
[d] *Institute für Theoretische Physik II, Ruhr-Universität Bochum, Bochum, D-44780 Germany*

**e-mail: kuznetsov_va@pnpi.nrcki.ru*

Received March 22, 2017

Why only γn→ηn cross section is fit while the other results are ignored?????

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



One major challenge for this interpretation is the observation of a narrow enhancement at W~1.68 GeV in Compton scattering on the neutron (γn→γn),

Comments on "Interference phenomena in the $J^p = 1/2^-$ - wave in η photoproduction" by A.V. Anisovich, E. Klempt, B. Krusche, V.A. Nikonov, A.V. Sarantsev, U. Thoma, D. Werthmuller, arXiv:1501.02093v1 [nucl-ex].

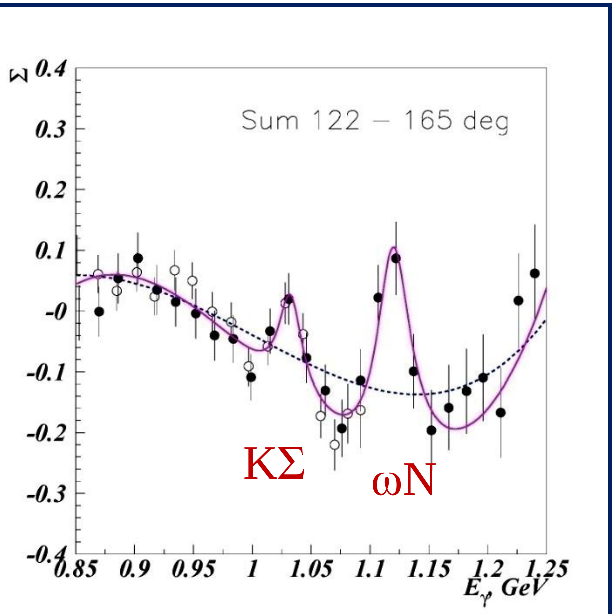
Viacheslav Kuznetsov
[1] *Petersburg Nuclear Physics Institute, Gatchina, 188300, St. Petersburg, Russia*

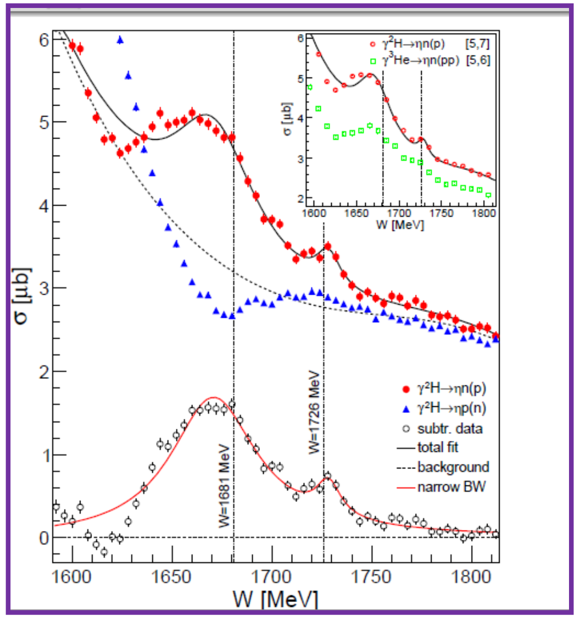
The authors of Ref. [1] claimed that " ... narrow structure observed in the excitation function of $\gamma n \to \eta n$ can be reproduced fully with a particular interference pattern in the $J^p = 1/2^-$ partial wave..." while a narrow structure in Compton scattering off the neutron is "...a stand-alone observation unrelated to the structure observed in $\gamma n \to \eta n$...". The source for the second statement may be a simple numerical error. If so, the interpretation of the narrow structure in $\gamma n \to \eta n$ as interference effects in the $J^p = 1/2^-$-wave and some conclusions from Ref. [1] are questionable.

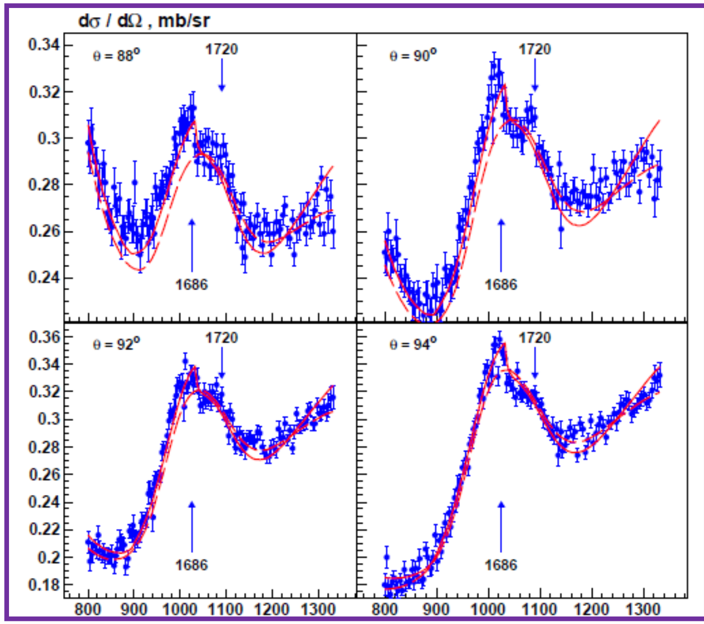
In accordance with (corrected) calculations by A. Anisovich et al., the total cross-section of N*(1685) should be 10-25 nb. Therefore, if N*(1685) does exist, its peak should be clearly seen in the Compton cross-section on the neutron.

The observation of the peak in Compton scattering on the neutron is in fact refutes the explanation of the neutrons anomaly in terms of interference phenomena. This interference cannot generate a peak in eta photoproduction, which is governed by isospin-1/2 resonances, simultaneously genenerate the same peak in Compton scattering, which is governed by isospin-1/2 and isospin-3/2 resonances, and generate neither of peak in pion photoproduction on the neutron, which is governed by the same resonances as Compton scattering.

Two narrow structures at W ~ 1.68 and W ~ 1.72 GeV







γp→γp (GRAAL)

γn→ηn (CBELSA/TAPS)

$\pi^- p \to \pi^- p$ (EPECUR)

Does not explain the second structure at 1.72 GeV.

Two hypotheses under discussion:

- One (N*(1685)) or two (N(1685) and N(1726)) narrow resonances;

- Threshold effects (cusps) . Favored by the fact that the structures are observed at $K\Lambda$ and ωN thresholds.

→ Need for more data.

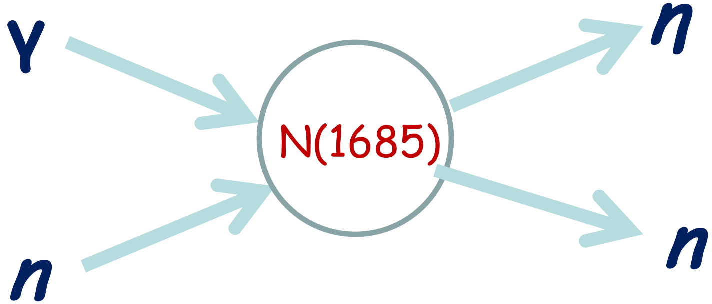
Search for N*(1685) resonances in

$$\gamma p \rightarrow \pi^0 \eta p$$
$$\gamma p \rightarrow \pi^+ \eta n$$
$$\gamma d \rightarrow \pi^+ \eta n(n)$$
$$\gamma d \rightarrow \pi^0 \eta p(n)$$
$$\gamma d \rightarrow \pi^- \eta p(p)$$
$$\gamma d \rightarrow \pi^0 \eta n(p)$$

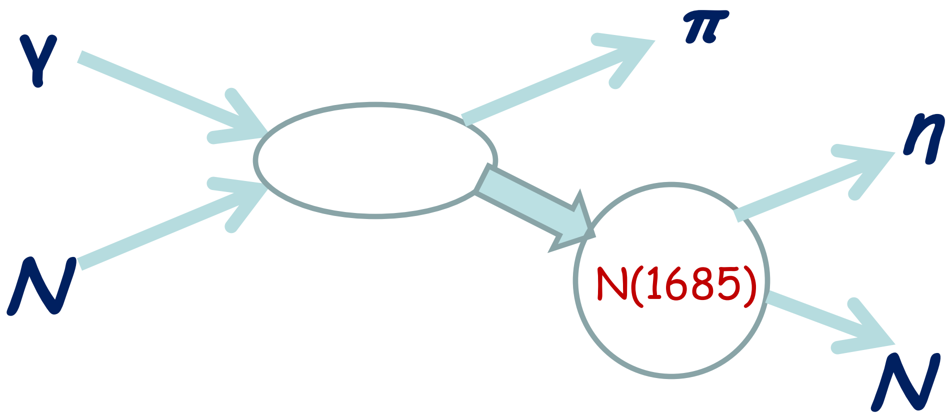
New analysis of the GRAAL data

Published in ***JEPT Letters, arXiv:*** 1705.05177

If N(1685) does really exist, its signal should also be seen in multiparticle "production" reactions in which it would manifest itself as a peak in the invariant mass spectra of the final-state products. Possible reactions could be ***γN→πηN.***



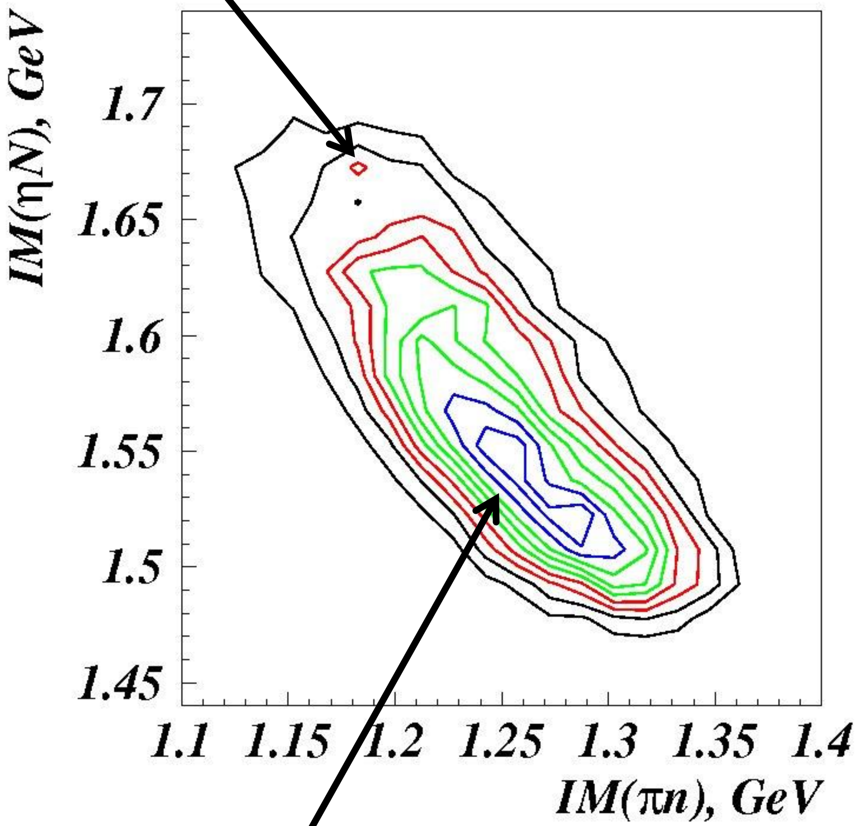
Formation of N(1685)

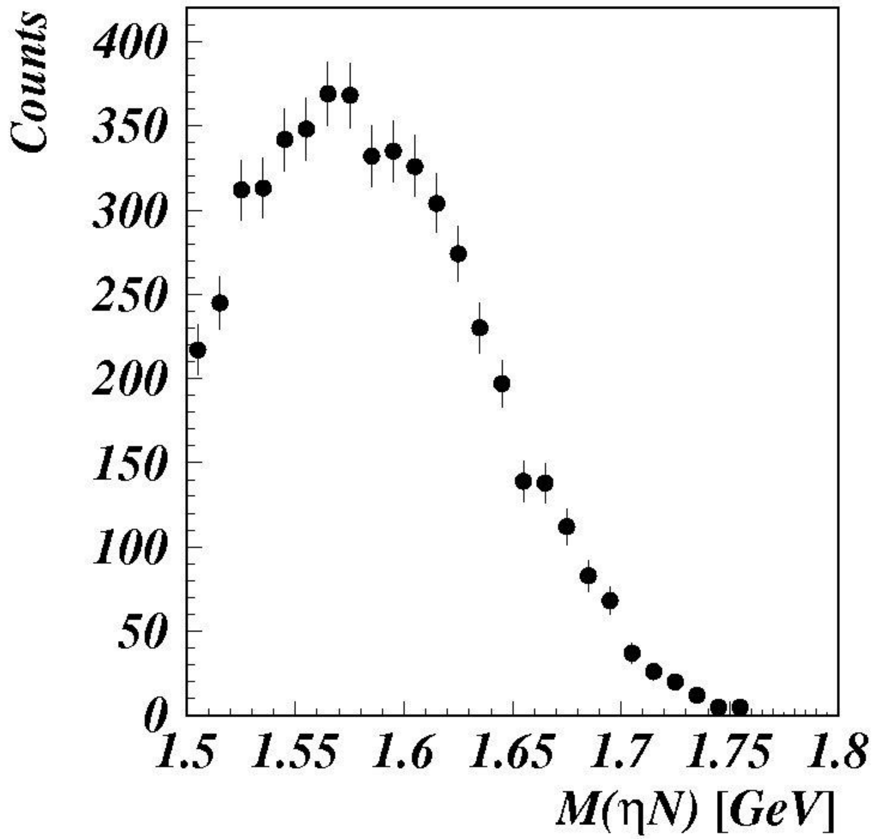


Production of N(1685)

The results

Small enhancement at
IM(ηN) ~ 1.68 GeV



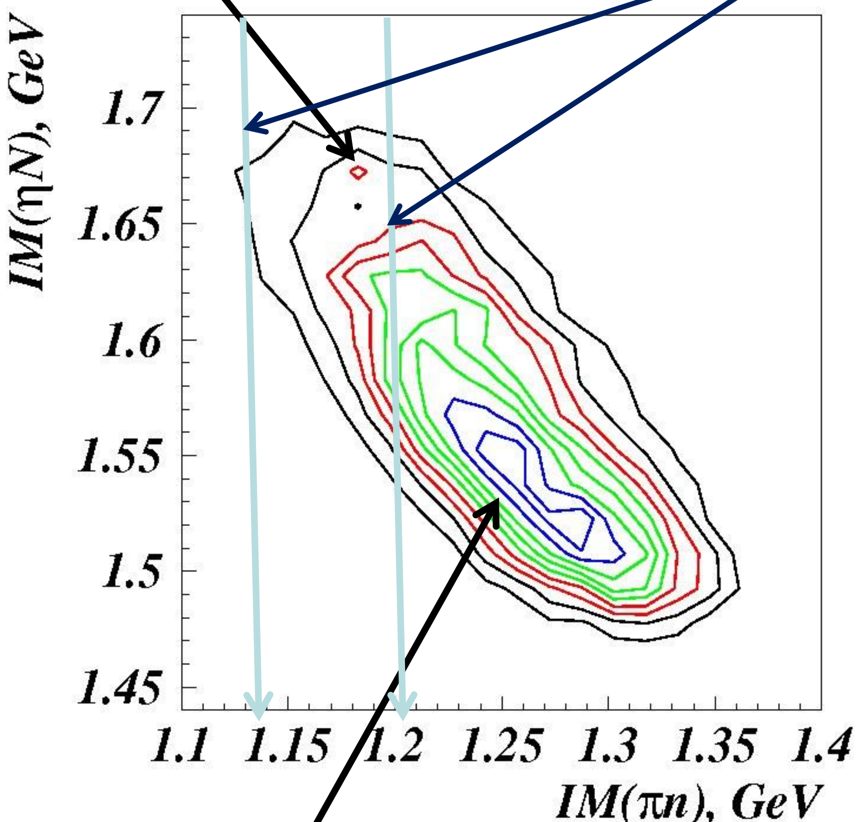


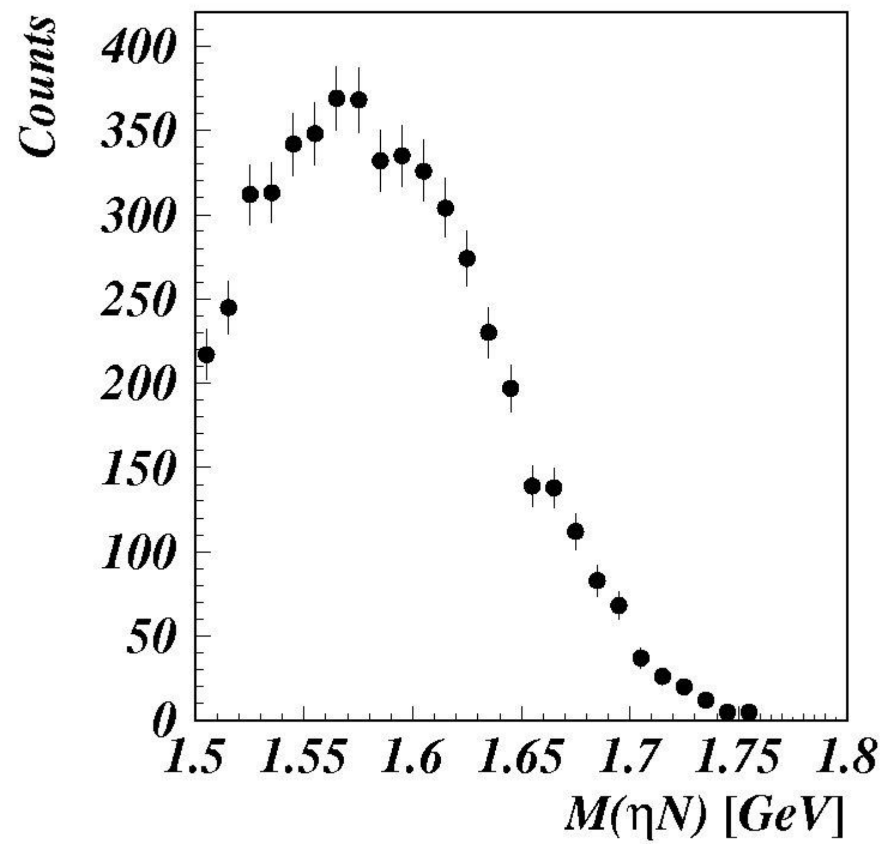
Dominating contribution of
γN→ηΔ events

The results

Small enhancement at
IM(ηN) ~ 1.68 GeV

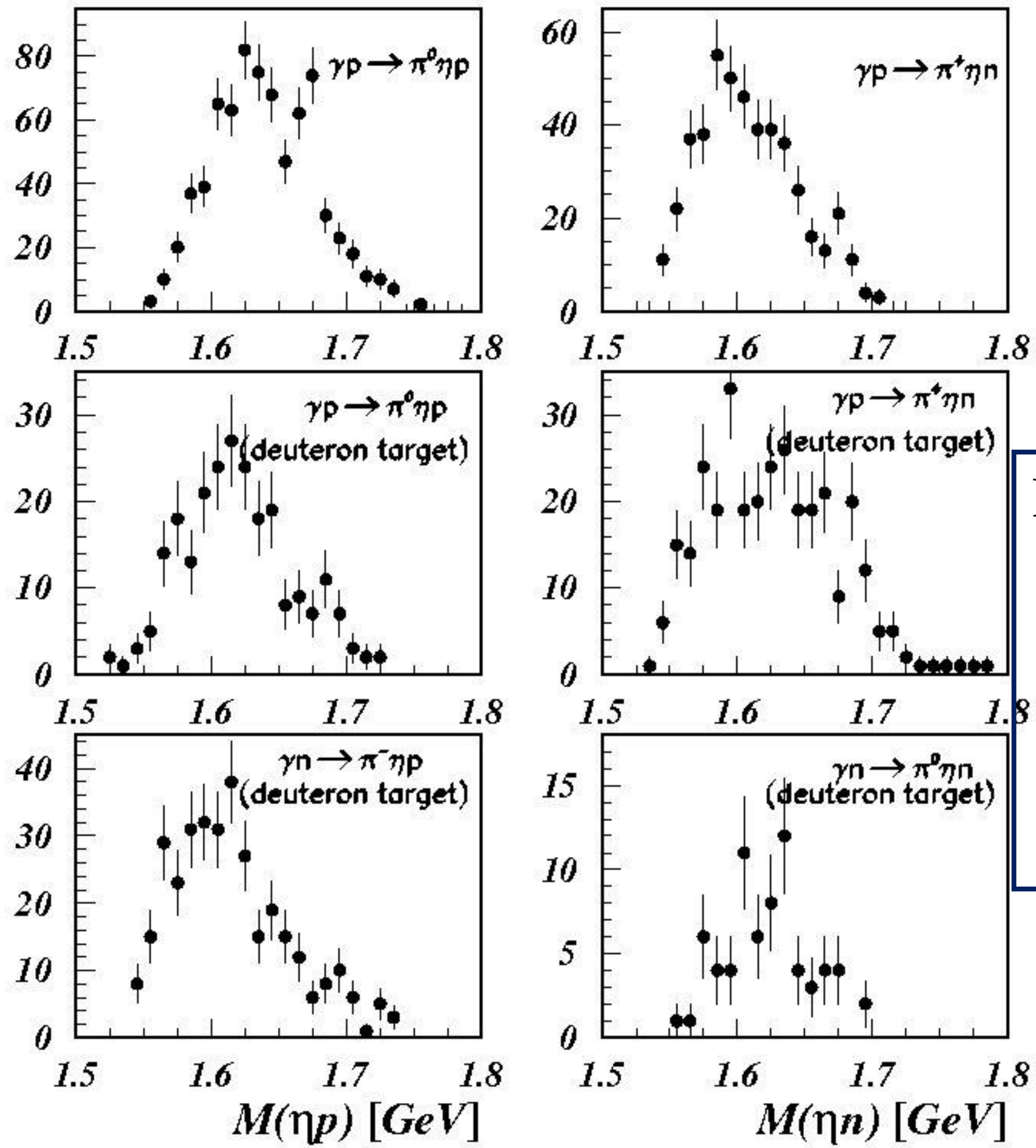
Cuts on the IM(πN)





Dominating contribution of
γN→ηΔ events

Spectra of extracted ηN masses

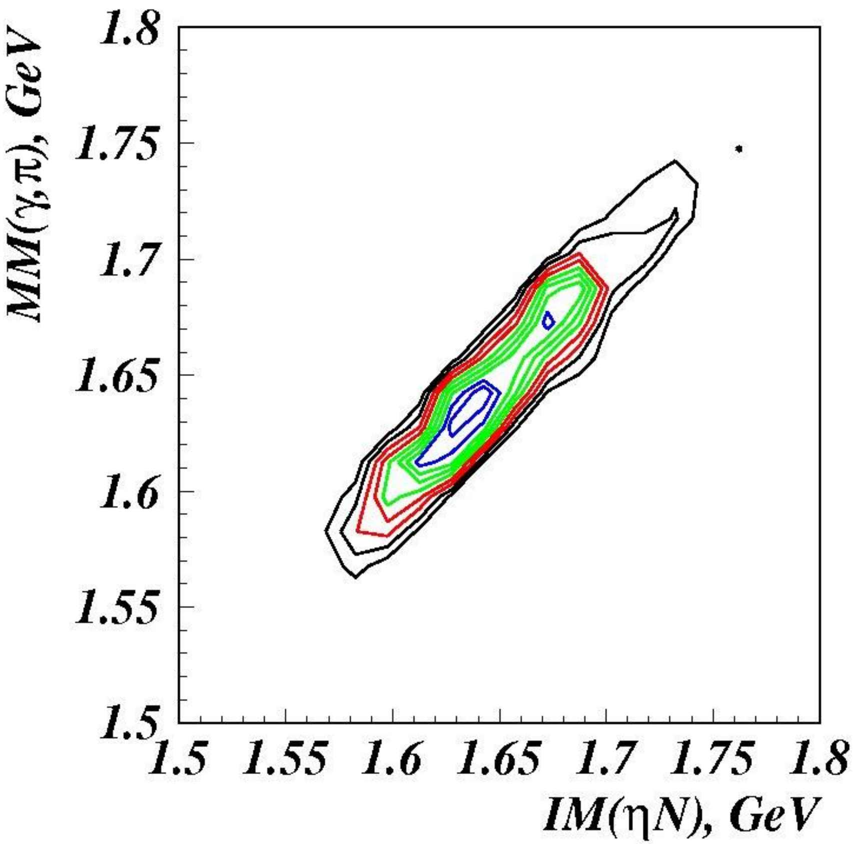


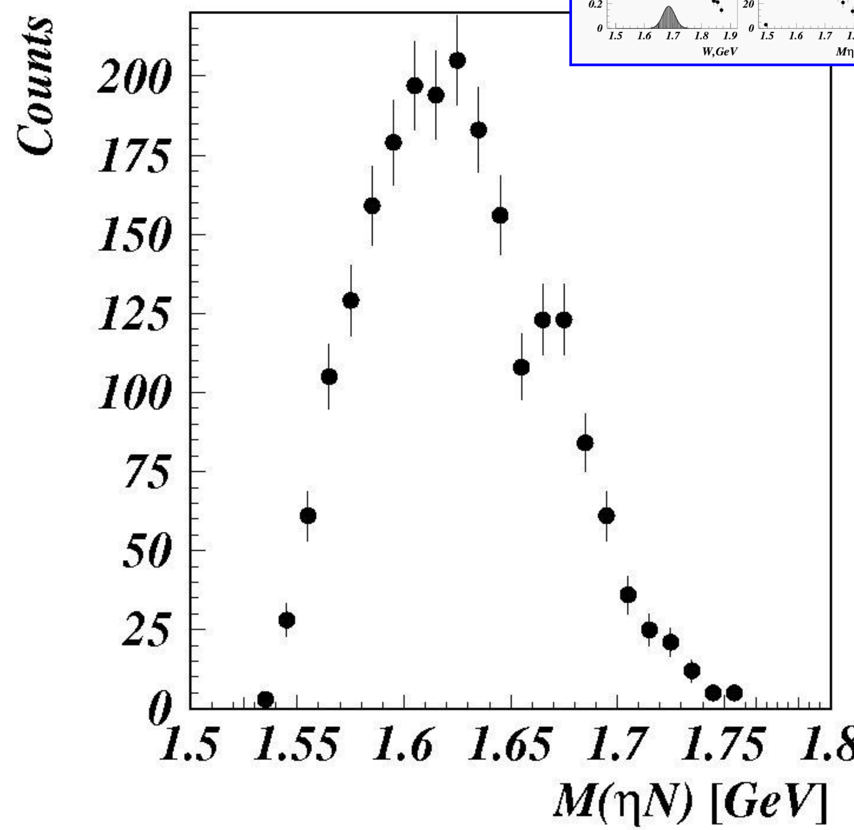
Peaks near ~ 1.68 GeV in the M(ηp) and M(ηn) spectra .

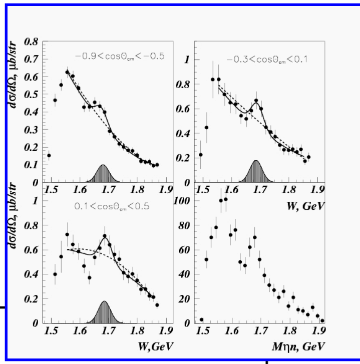
$N^+(1685)$ and $N^0(1685)$ resonances?

Sum of all reactions under study

Enhancement at the same energy as in formation reactions (γn→ηn, Compton, πp→πp)







Need for high-statistics confirmation!

Revision of $\gamma p \rightarrow \pi^0 \eta p$

8. **Experimental study of the $\gamma p \rightarrow \pi^0 \eta p$ reaction with the A2 setup at the Mainz Microtron**
A2 Collaboration (V. Sokhoyan (Mainz U., Inst. Kernphys.) *et al.*). Mar 2, 2018. 15 pp.
Published in **Phys.Rev. C97 (2018) no.5, 055212**
DOI: 10.1103/PhysRevC.97.055212
e-Print: **arXiv:1803.00727 [nucl-ex]** | PDF

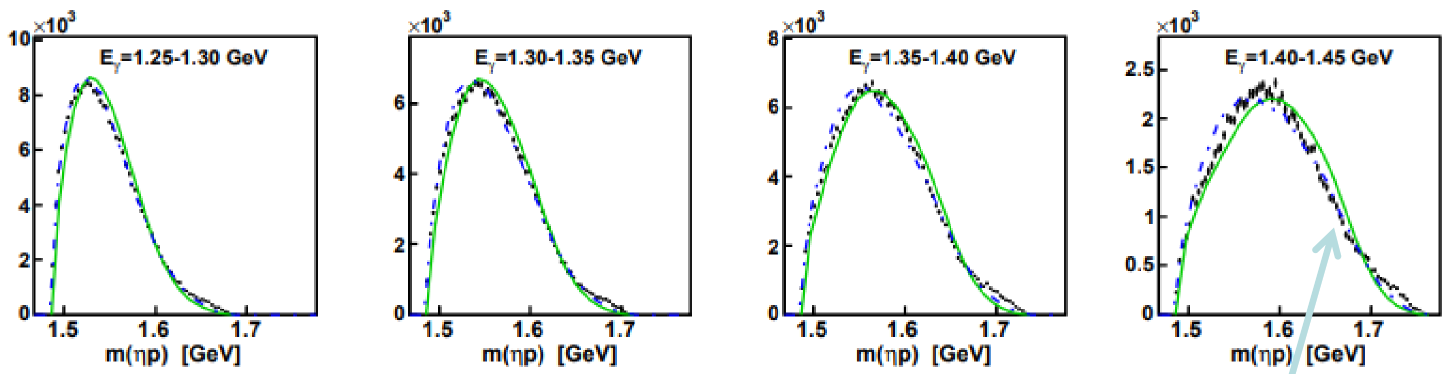


FIG. 7: Same as Fig. 6, but for the invariant mass $m(\eta p)$.

No peak?

GRAAL: Energy of recoil protons is derived from measured TOFs -> better resolution, many independent cuts which are used in the analysis.

Mainz: Energy of recoil protons is derived from the momentum conservation -> just few cuts are used for the selection of events. No cut on M(πp) –critical !

Repetition of the A2 analysis using GRAAL data

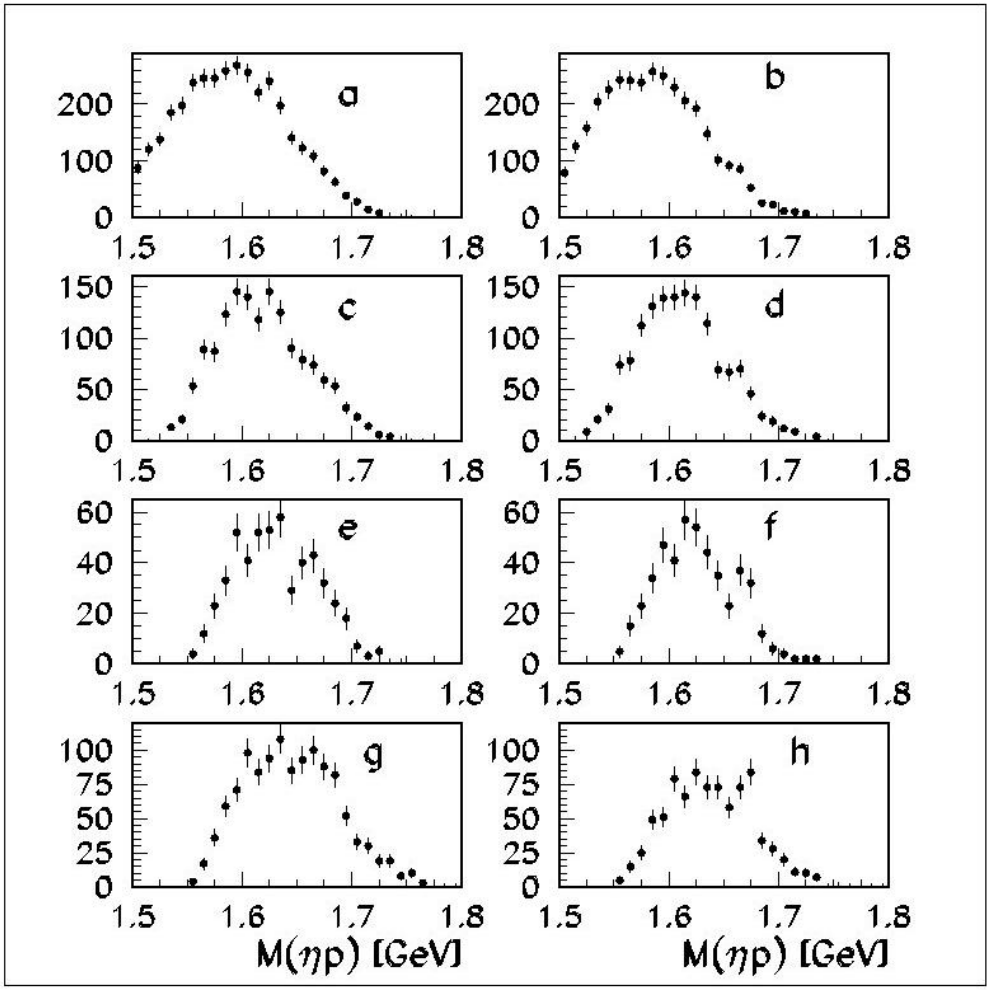
No TOF | TOF

Cuts like in Mainz

Cut on MM(γ,η) added

All cuts E=1.4 -1.43 GeV

All cuts E=1.4 -1.5 GeV



Need for dedicated experiments!

BGO-OD?

Summary&Conclusions

-Interference of known resonances cannot explain the whole complex of experimetal findings;

- There might be one (N(1685) or two (N(1685) and N(1726) narrow resonances ;
- The properties of N(1685), namely

Mass 1680±10 MeV

Narrow width Γ<25 MeV

S=0

I=1/2

Strong photoexcitation on the neutron

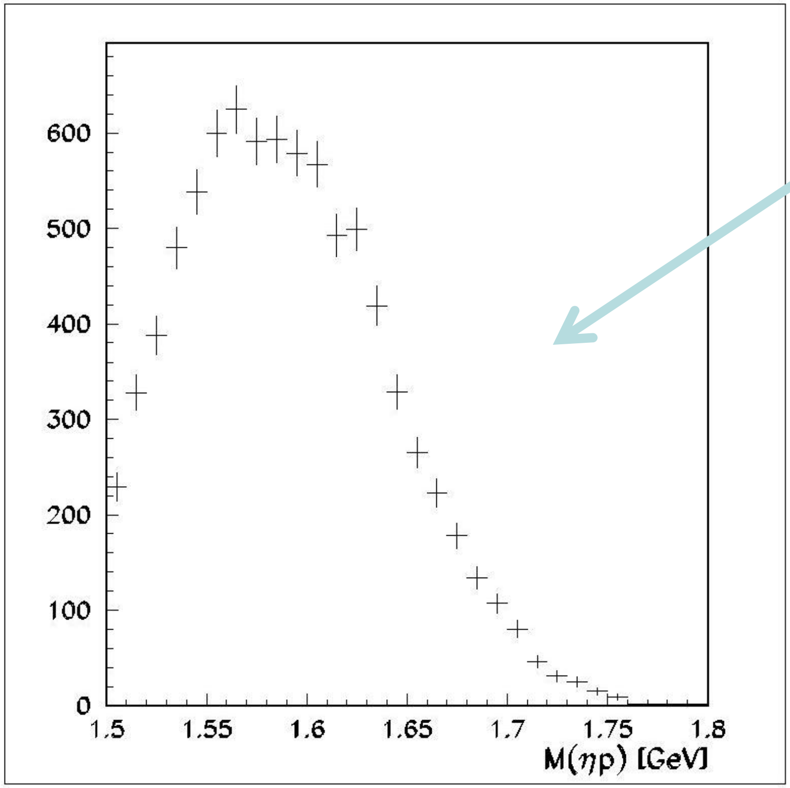
-> Need for theoretical contribution!

Thanks for your attention!

Comments on "Study of the $\gamma p \to \pi^0 \eta p$ reaction with the A2 setup at MAMI"

Time-of-flights of recoil protons are not measured! Consequently

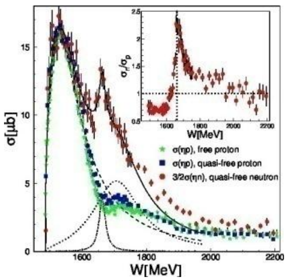
- Only part of information from the detector is used;
- Missing Mass MM(γ,π) is not used;
- M(ηp) is extracted just as IM(ηp); Poor mass resolution;
- No cuts on M(πp) are applied.



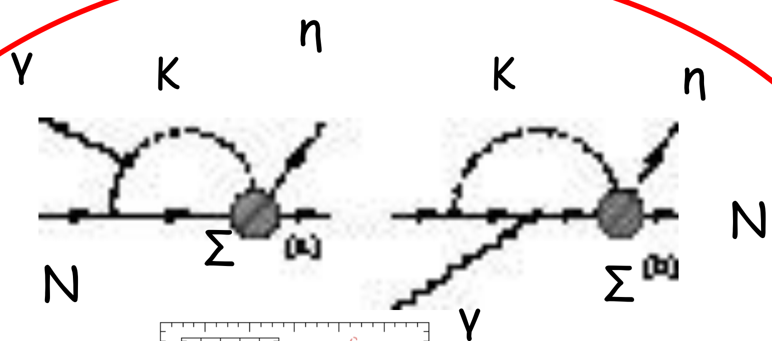
Repetition of the A2 analysis using GRAAL data – No peak structure is seen.

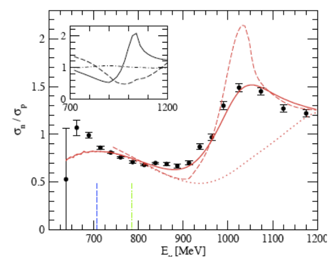
Corresponding comment is now being prepared for publication.

Cusp effect: open questions

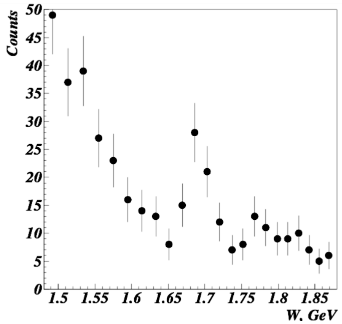


Real width is essentially more narrow



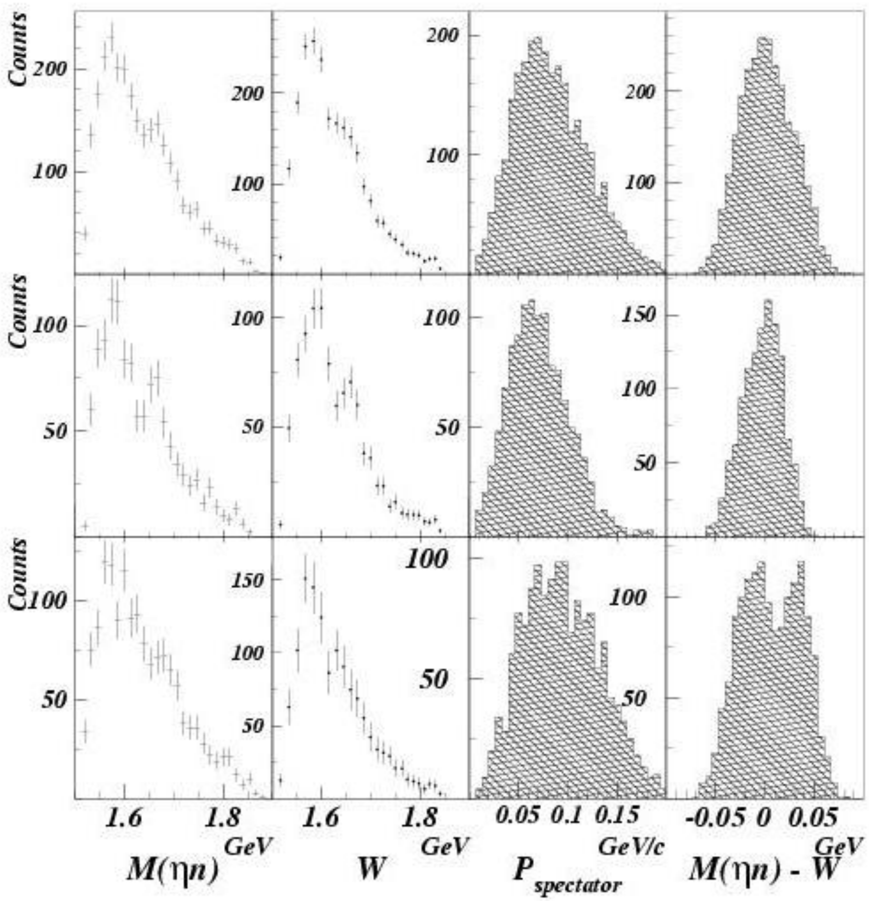


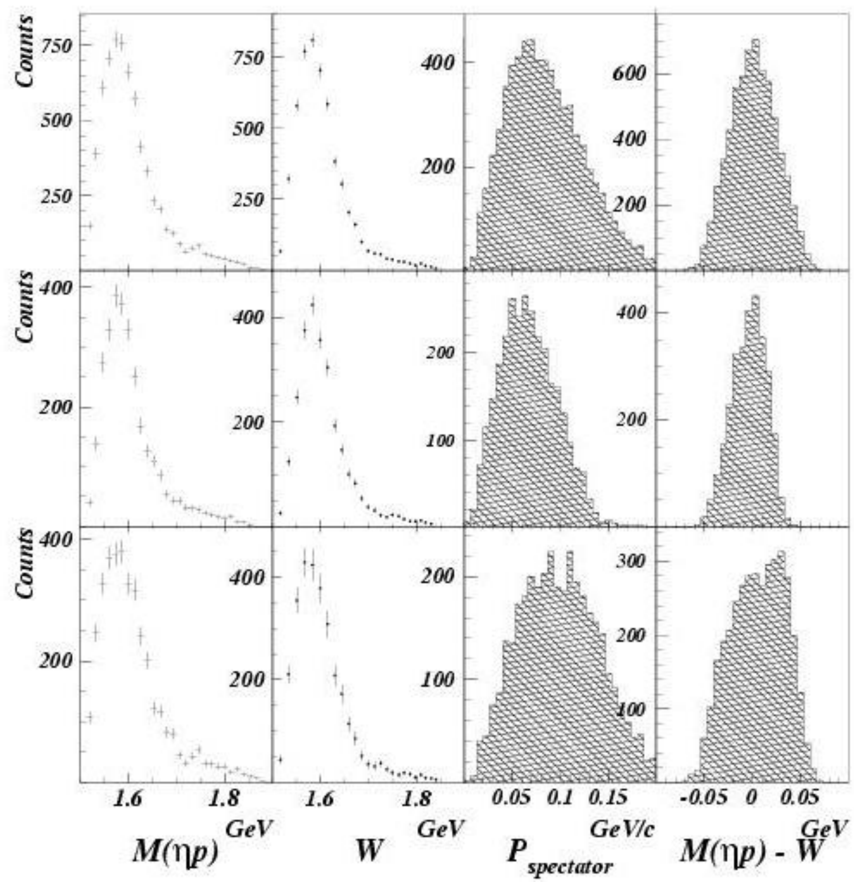
Unlikely can be seen in Compton scattering



Why it is not seen in π^0 photoproduction on the neutron and on the proton while it is seen in $\pi^- p \rightarrow \pi^- p$?
Why there is no similar peak corresponding to the virtual KΛ?

Yield of γN→ηN: Data and MC





Soft cuts

Tight cuts

Quasi-free neutron

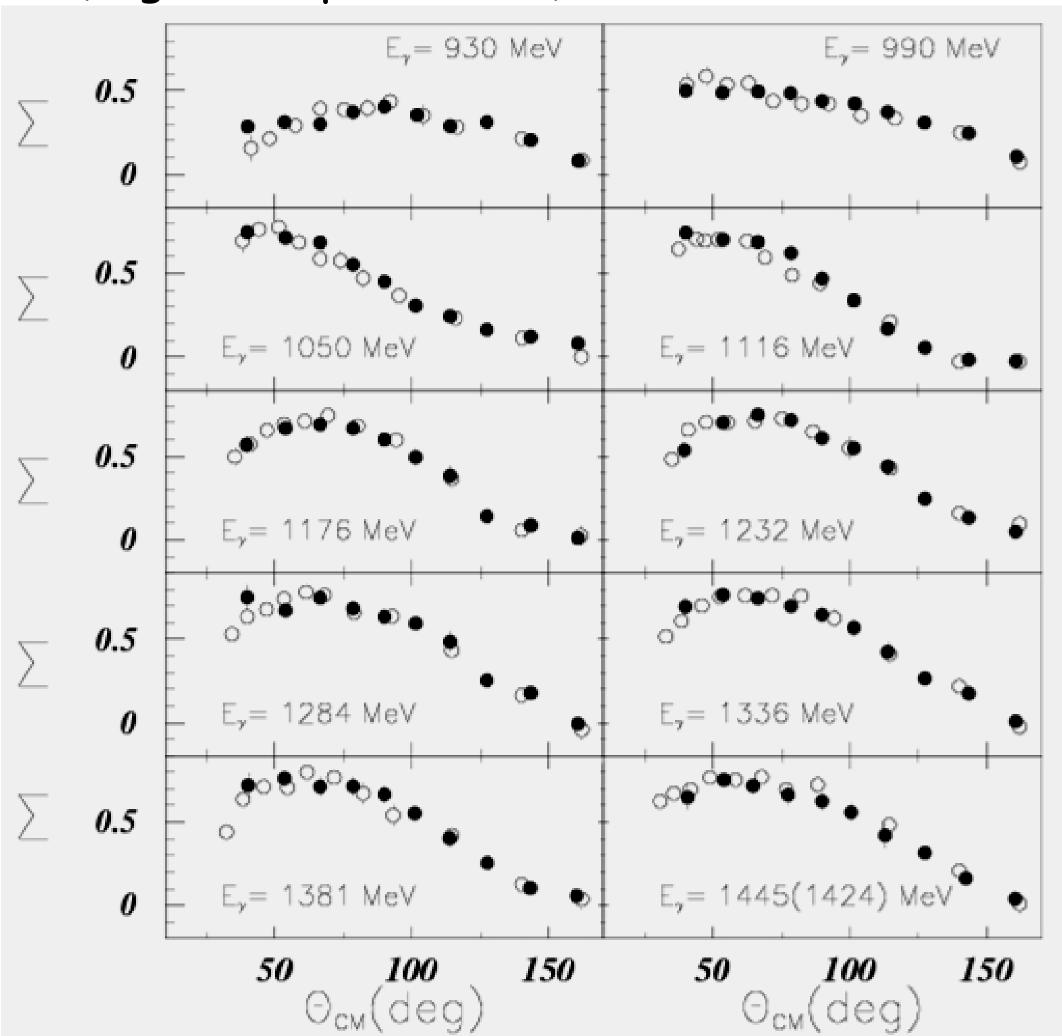
Quasi-free proton

Comments on O.Bartalini *et al.* (by the GRAAL Collaboration (?)) ``Measurement of eta photoproduction on the proton from threshold to 1500 MeV", Nucl-ex:0707.1385.

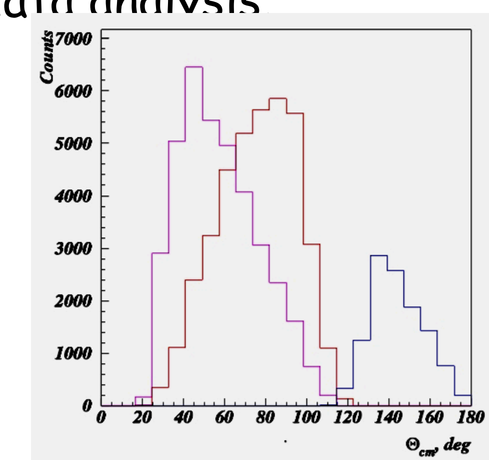
Data analysis has been performed by A.Lleres, LPSC Grenoble.

Authors claimed no evidence for a narrow N(1670) state in beam asymmetry and cross section data for eta photoproduction on the proton.

Comparison of O.Bartalini et al.(black circles) with the old GRAAL publication V.Kuznetsov, πN News Letters, **16**, 160(2002) (open circles) (angular dependences)

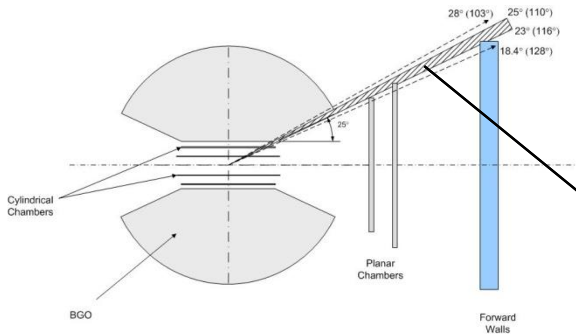


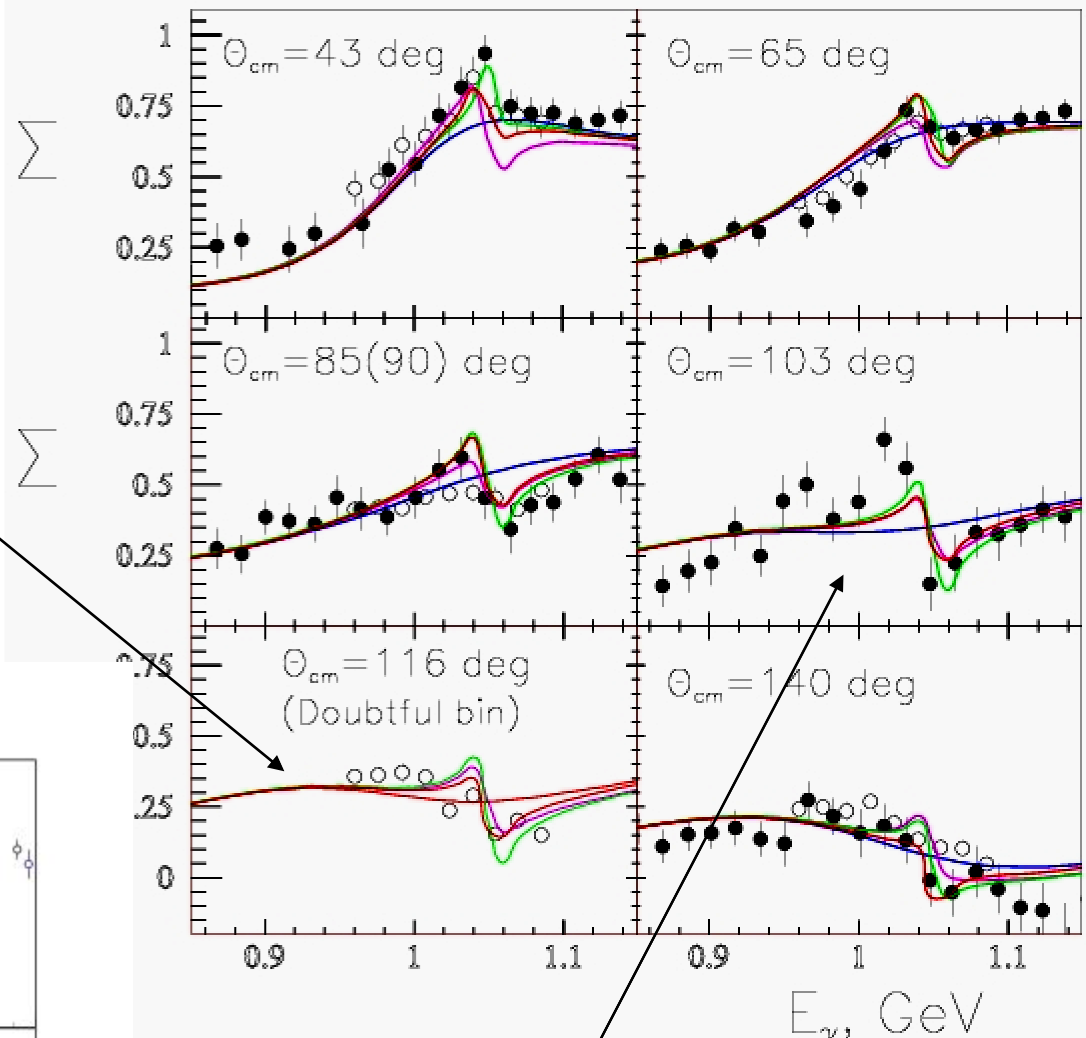
Despite the triple increase of statistics, new data are less accurate at forward angles! The reason is that events in which one of the photons from η→2γ decay is detected in the forward wall, are excluded from data analysis

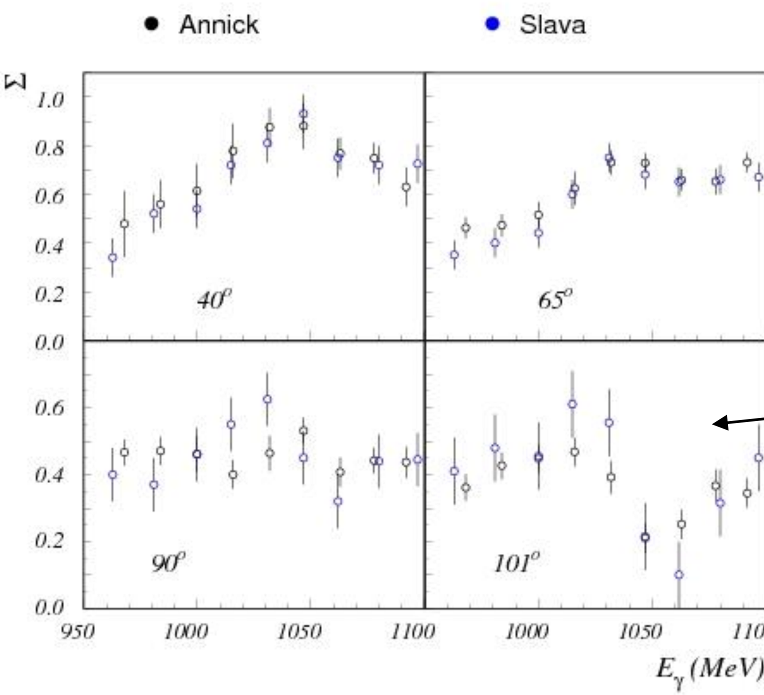


γp→ηp Yield for different types of events

Comparison of O.Bartalini et al. (open circles) and our results (black circles). Main difference is at 103/116 deg.







The same dip structure at 103 deg!

Comparison wilh preliminary results done by A.Lleres (A.Lleres, private communication (E-mail from Feb 5, 2007)).

What does mean quasi-free cross section?

To fit experimental data , the cross section calculated for the free neutron, is then smeared by Fermi motion using the deuteron wave function

This formula is from A.Anisovich et al., Hep-ph/0809.3340

$$\frac{d^2\sigma_{\rm qf}}{d\Theta}(W,\theta_{cm}) \propto \int d|\vec{p}_N||\vec{p}_N|^2 f^2(\vec{p}_N)\frac{d\cos(\theta_N)d\phi_N}{4\pi}\frac{d\sigma_{\rm free}}{d\Theta}(W^*,\theta^*_{cm})d\Phi$$

Cut-dependent Integral

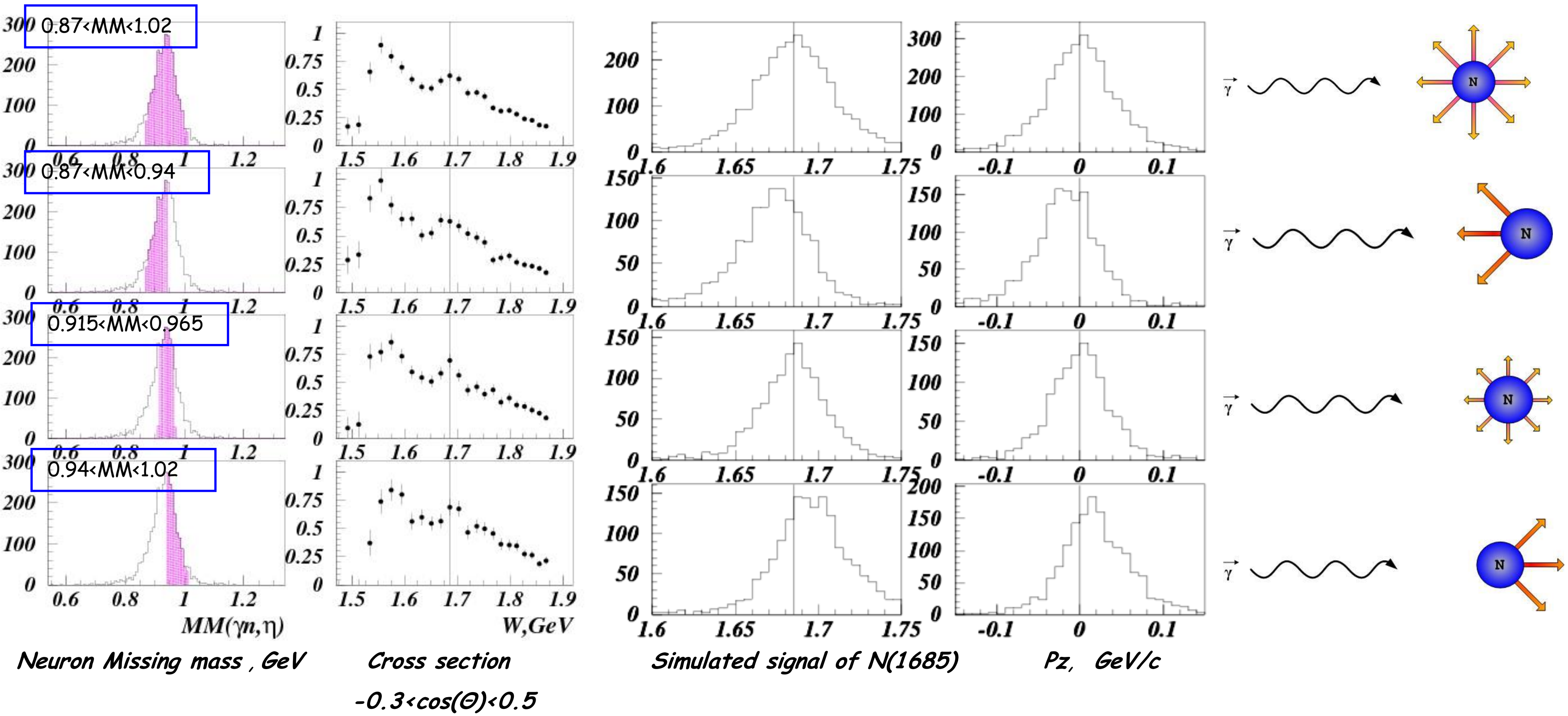
Cut-dependent function

Cut-dependent FSI effects(not discussed here)

Is this formula applicable for experimental data?

γn→ηn cross section with different cuts on the neutron missing mass

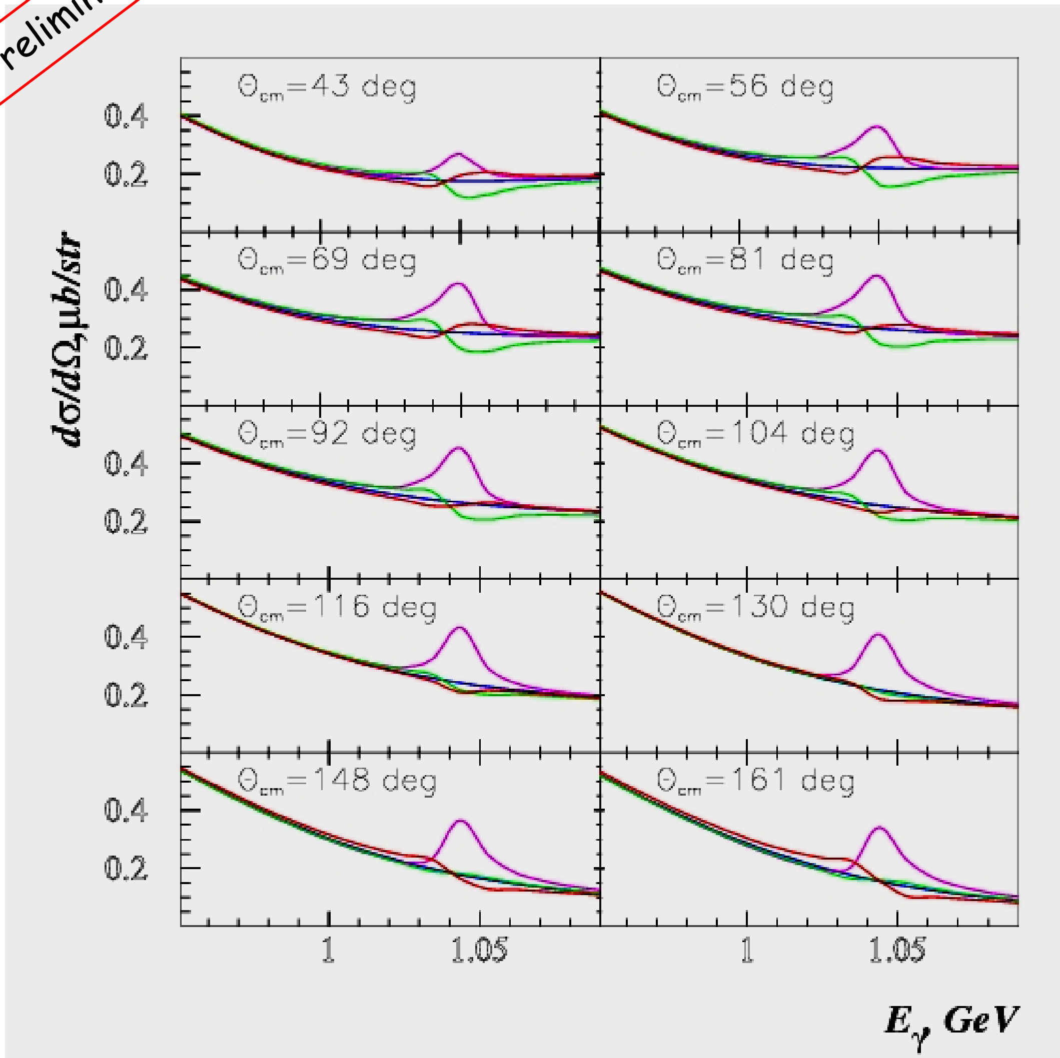
Experimental Data   Simulations



The width and the position of the peak in the γn→ηn cross section are affected by the cut on the neutron missing mass!

Calculation of cross sections (Published in Acta Physica Polonica)

Preliminary



Blue – SAID only
Magenta – SAID + P11
Green – SAID +P13
Red – SAID + D13

P13 would generate a small .dip structure st forward angles.

Particle identification and performance

- Performance of the Russian Wall at GRAAL:
- TOF resolution – 0.6 ns(FWHM)
- Angular resolution – 2-3 deg(FWHM)
- Photon efficiency – 95%
- Neutron efficiency – 22%