Evidence for new Nucleon resonance N*(1685): Review of available results and forthcoming experiments

Citation: J. Beringer *et al.* (Particle Data Group), PR D86, 010001 (2012) (URL: http://pdg.lbl.gov)

N(1685) ?$^?$ $I(J^P) = \frac{1}{2}(?^?)$ Status: *

OMITTED FROM SUMMARY TABLE

There is a small literature (which we do not try to cover) on this possible narrow state. See KUZNETSOV 11A, MART 11, and the other papers for further references. This state does not gain status by being a sought-after member of a baryon anti-decuplet.

N(1685) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
~ 1670	JAEGLE	11	CBTP	$\gamma d \to \eta n (p)$
~ 1685	KUZNETSOV	11	GRAL	$\gamma d \to \gamma n (p)$
~ 1680	KUZNETSOV	07	GRAL	$\gamma d \to \eta n (p)$

N(1685) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
~ 25	JAEGLE	11	CBTP	$\gamma d \to \eta n (p)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<30	KUZNETSOV	11	GRAL	$\gamma d \to \gamma n (p)$
<30	KUZNETSOV	07	GRAL	$\gamma d \to \eta n (p)$

N(1685) REFERENCES

JAEGLE	11	EPJ A47 89	I. Jaegle *et al.*	(CBELSA/TAPS Collab.)
Also		PRL 100 252002	I. Jaegle *et al.*	(CBELSA/TAPS Collab.)
KUZNETSOV	11	PR C83 022201	V. Kuznetsov *et al.*	(GRAAL Collab.)
KUZNETSOV	11A	JETPL 94 503	V. Kuznetsov, M.V. Polyakov, M. Thurmann	(INRM+)
MART	11	PR D83 094015	T. Mart	(U. Indonesia)
KUZNETSOV	07	PL B647 23	V. Kuznetsov *et al.*	(GRAAL Collab.)

Viacheslav Kuznetsov

PNPI, April 2013

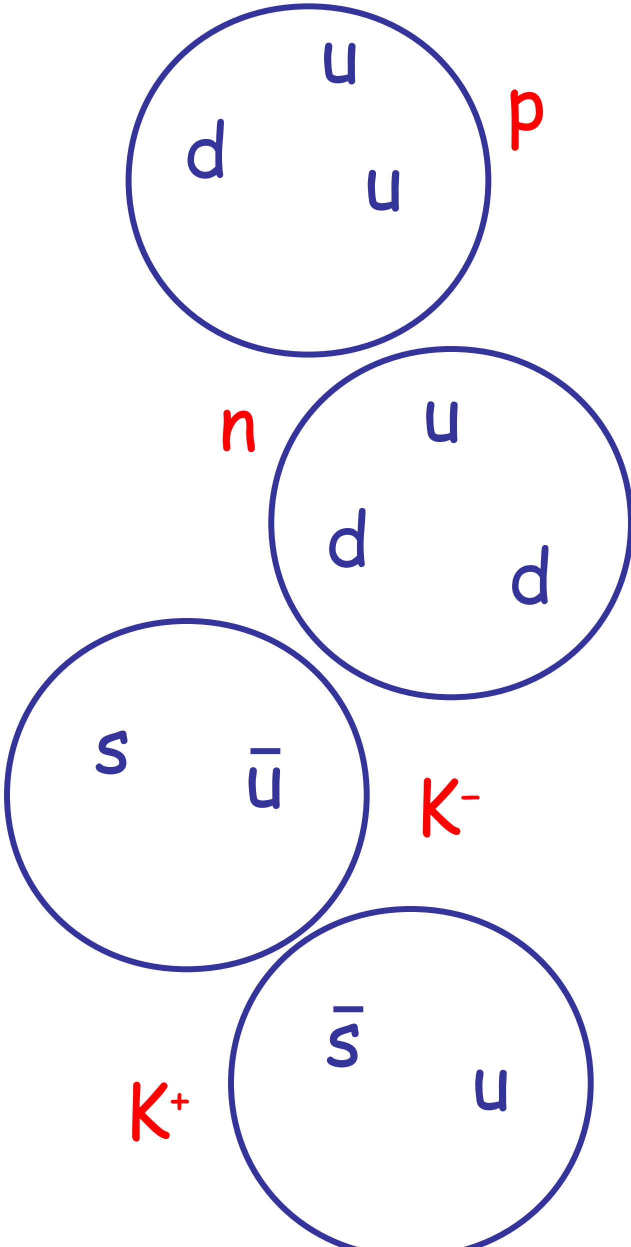
In memoriam of
Mitya Diakonov

Outline:

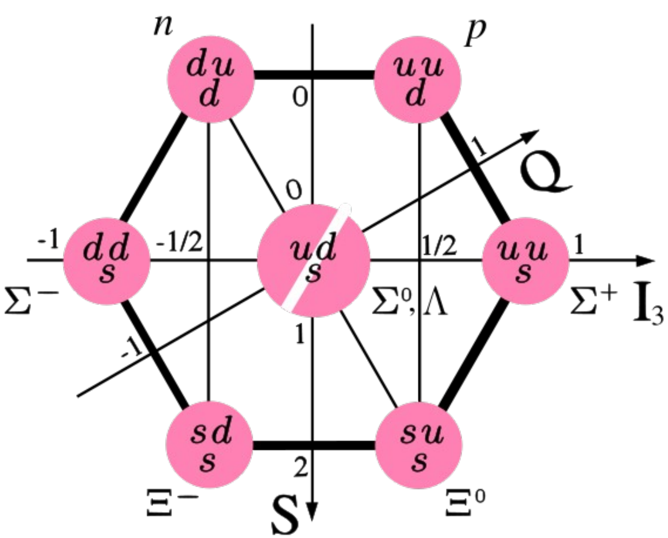
- Introduction. Two pictures of the nucleon;
- Some remark on the evidence/non-evidence for Θ^+
- ``Neutron anomaly" in η photoproduction on the neutron;
- Evidence for resonant structure at W~1.685 GeV in other reactions;
  - Partial Wave analyses;
- Alternative explanations: Discussion of validity;
- Properties of N*(1685) ;
- Current and future activities
  - i) Photon facilities (GRAAL, CBELSA/TAPS, MaM1iC, BGO-OD);
  - ii) High-resolution TOF detector for neutrons and charged particles;
  - iii) Possible measurements at PNPI and EPECUR;
- Conclusions.

Gell Mann (1955-1964) - baryons are (qqq) systems, mesons are (q~q)

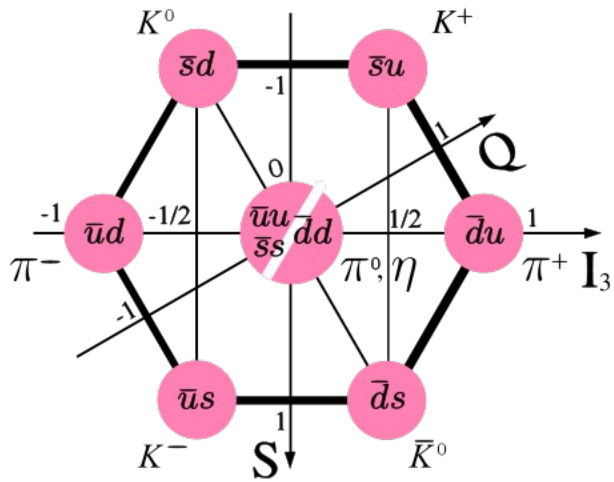
Quark Flavor	Charge (Q)	Baryon number	Strangeness (S)
u	+2/3	+1/3	0
d̄	−1/3	+1/3	0
s̄	−1/3	+1/3	+1
ū	− 2/3	−1/3	0
d	+1/3	−1/3	0
s	+1/3	−1/3	-1



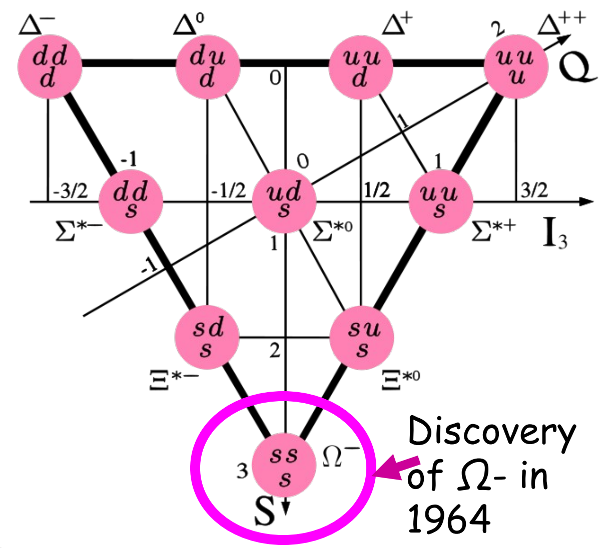
60th-80th – Remarkable success of Quark Model: *$SU(3)_f$ classification of light baryons and mesons*



Baryon octet [8,1/2+]



Meson octet



Baryon decuplet [10,3/2+]

Problem: *the mass of the nucleon (3 quarks) is ~940 MeV, the mass of π^0 (2 quarks) is ~135 MeV. Solution: the quark masses inside baryons are dynamical - three effective (constituent) quarks with the masses ~ 200 – 350 MeV →* ***Constituent Quark Model.***

Higher-lying multiplies ([10,1/2-],[8,1/2-],[10,1/2-] etc) describe the spectrum of baryon resonances. In 70-90th part of these resonances was found in experiment.

``...Quark model is the most successful tool for the classification and interpretation of hadrons spectrum."
(R.Jaffe)

Unresolved question: CQM also suggests the existence of

qqqq˜q (pentaquarks), qqqq˜q q˜q (septaquarks) etc. baryons.

Bag models [R.L. Jaffe '77, J. De Swart '80]

Jp =1/2- lightest pentaquark

Masses higher than 1700 MeV, width ~ hundreds MeV

Mass of the pentaquark is roughly 5 M +(strangeness) ~ 1800 MeV

An additional q –anti-q pair is added as constituent

For decades experimentalists were searching for such pentaquarks, with no results. Why?

Problem of "Missing" Resonances

CQM predicts rich spectrum of baryons resonances.

Baryon Summary Table

This short table gives the name, the quantum numbers (where known), and the status of baryons in the Review. Only the baryons with 3- or 4-star status are included in the main Baryon Summary Table. Due to insufficient data or uncertain interpretation, the other entries in the short table are not established as baryons. The names with masses are of baryons that decay strongly. For N, Δ, and Ξ resonances, the partial wave is indicated by the symbol $L_{2I,2J}$, where L is the orbital angular momuntum (S, P, D, ...), I is the isospin, and J is the total angular momentum. For Λ and Σ resonances, the symbol is $L_{I,2J}$.

p	P_{11}	****	$\Delta(1232)$	P_{33}	****	Λ	P_{01}	****	Σ^+	P_{11}	****	Ξ^0, Ξ^-	P_{11}	****
n	P_{11}	****	$\Delta(1600)$	P_{33}	***	$\Lambda(1405)$	S_{01}	****	Σ^0	P_{11}	****	$\Xi(1530)$	P_{13}	****
$N(1440)$	P_{11}	****	$\Delta(1620)$	S_{31}	****	$\Lambda(1520)$	D_{03}	****	Σ^-	P_{11}	****	$\Xi(1620)$		*
$N(1520)$	D_{13}	****	$\Delta(1700)$	D_{33}	****	$\Lambda(1600)$	P_{01}	***	$\Sigma(1385)$	P_{13}	****	$\Xi(1690)$		***
$N(1535)$	S_{11}	****	$\Delta(1750)$	P_{31}	*	$\Lambda(1670)$	S_{01}	****	$\Sigma(1480)$		*	$\Xi(1820)$	D_{13}	***
$N(1650)$	S_{11}	****	$\Delta(1900)$	S_{31}	**	$\Lambda(1690)$	D_{03}	****	$\Sigma(1560)$		**	$\Xi(1950)$		***
$N(1675)$	D_{15}	****	$\Delta(1905)$	F_{35}	****	$\Lambda(1800)$	S_{01}	***	$\Sigma(1580)$	D_{13}	**	$\Xi(2030)$		***
$N(1680)$	F_{15}	****	$\Delta(1910)$	P_{31}	****	$\Lambda(1810)$	P_{01}	***	$\Sigma(1620)$	S_{11}	**	$\Xi(2120)$		*
$N(1700)$	D_{13}	***	$\Delta(1920)$	P_{33}	***	$\Lambda(1820)$	F_{05}	****	$\Sigma(1660)$	P_{11}	***	$\Xi(2250)$		**
$N(1710)$	P_{11}	***	$\Delta(1930)$	D_{35}	***	$\Lambda(1830)$	D_{05}	****	$\Sigma(1670)$	D_{13}	****	$\Xi(2370)$		**
$N(1720)$	P_{13}	****	$\Delta(1940)$	D_{33}	*	$\Lambda(1890)$	P_{03}	****	$\Sigma(1690)$		**	$\Xi(2500)$		*
$N(1900)$	P_{13}	**	$\Delta(1950)$	F_{37}	****	$\Lambda(2000)$		*	$\Sigma(1750)$	S_{11}	***			
$N(1990)$	F_{17}	**	$\Delta(2000)$	F_{35}	**	$\Lambda(2020)$	F_{07}	*	$\Sigma(1770)$	P_{11}	*	Ω^-		****
$N(2000)$	F_{15}	**	$\Delta(2150)$	S_{31}	*	$\Lambda(2100)$	G_{07}	****	$\Sigma(1775)$	D_{15}	****	$\Omega(2250)^-$		***
$N(2080)$	D_{13}	**	$\Delta(2200)$	G_{37}	*	$\Lambda(2110)$	F_{05}	***	$\Sigma(1840)$	P_{13}	*	$\Omega(2380)^-$		**
$N(2090)$	S_{11}	*	$\Delta(2300)$	H_{39}	**	$\Lambda(2325)$	D_{03}	*	$\Sigma(1880)$	P_{11}	**	$\Omega(2470)^-$		**
$N(2100)$	P_{11}	*	$\Delta(2350)$	D_{35}	*	$\Lambda(2350)$	H_{09}	***	$\Sigma(1915)$	F_{15}	****			
$N(2190)$	G_{17}	****	$\Delta(2390)$	F_{37}	*	$\Lambda(2585)$		**	$\Sigma(1940)$	D_{13}	***	Λ_c^+		****
$N(2200)$	D_{15}	**	$\Delta(2400)$	G_{39}	**				$\Sigma(2000)$	S_{11}	*	$\Lambda_c(2593)^+$		***
$N(2220)$	H_{19}	****	$\Delta(2420)$	$H_{3,11}$	****				$\Sigma(2030)$	F_{17}	****	$\Lambda_c(2625)^+$		***
$N(2250)$	G_{19}	****	$\Delta(2750)$	$I_{3,13}$	**				$\Sigma(2070)$	F_{15}	*	$\Lambda_c(2765)^+$		*
$N(2600)$	$I_{1,11}$	***	$\Delta(2950)$	$K_{3,15}$	**				$\Sigma(2080)$	P_{13}	**	$\Lambda_c(2880)^+$		**
$N(2700)$	$K_{1,13}$	**							$\Sigma(2100)$	G_{17}	*	$\Sigma_c(2455)$		****
									$\Sigma(2250)$		***	$\Sigma_c(2520)$		***
									$\Sigma(2455)$		**	Ξ_c^+, Ξ_c^0		***
									$\Sigma(2620)$		**	$\Xi_c^{\prime +}, \Xi_c^{\prime 0}$		***
									$\Sigma(3000)$		*	$\Xi_c(2645)$		***
									$\Sigma(3170)$		*	$\Xi_c(2790)$		***
												$\Xi_c(2815)$		***
												Ω_c^0		***
												Λ_b^0		***
												Ξ_b^0, Ξ_b^-		*

**** Existence is certain, and properties are at least fairly well explored.

*** Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.

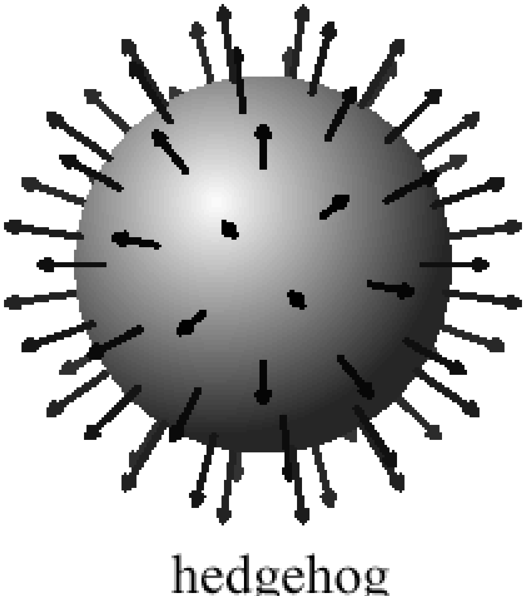
** Evidence of existence is only fair.

* Evidence of existence is poor.

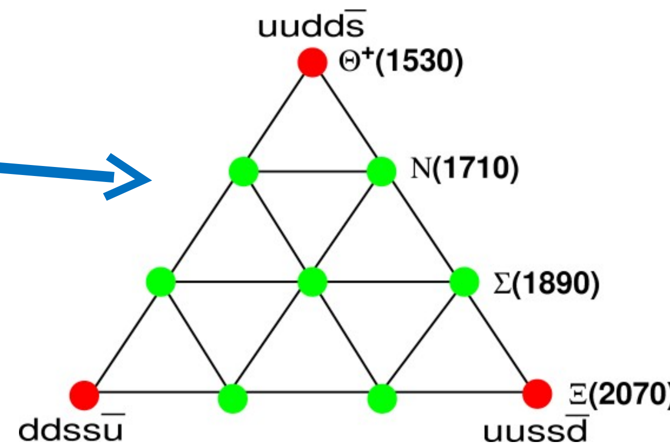
Despite of the availability of modern precise polarized data, only a half of CQM- predicted resonances is now established in experiment, especially above 1.8 GeV.

Furthermore, some well-known resonances seem to disappear!

Chiral Soliton Model (χQM) – complementary description of the nucleon (baryons)



Baryons are excitations of the same object – soliton in the chiral field



D.Diakonov, V. Petrov, M.V.P., ``Exotic Antidecuplet of bryons” Z. Phys. A359 (1997) 302

Further development

Mean-Field Approach (MFA)

Based on the papers

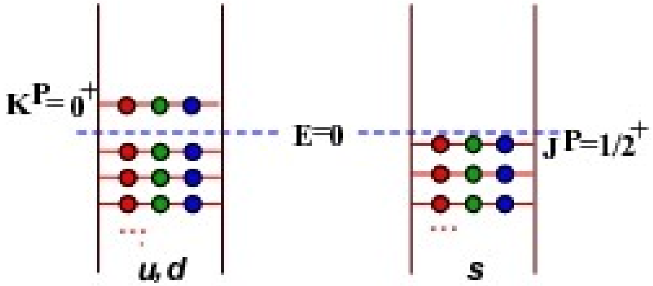
- D. Diakonov, `` Baryons resonances in the mean-field approach and the simple explanation of Θ+ pentaquark", Arxiv :0812.3418

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

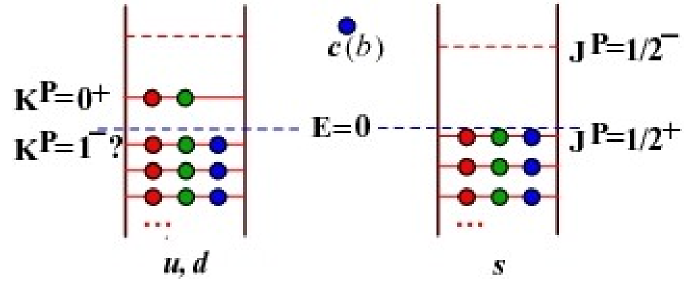
- D. Diakonov, V. Petrov, and A.Vladimirov, ``Baryon resonances at large N_c, or Quark Nuclear Physics", Arxiv:1207.3679

Baryons are multiquark systems stored in the mean field

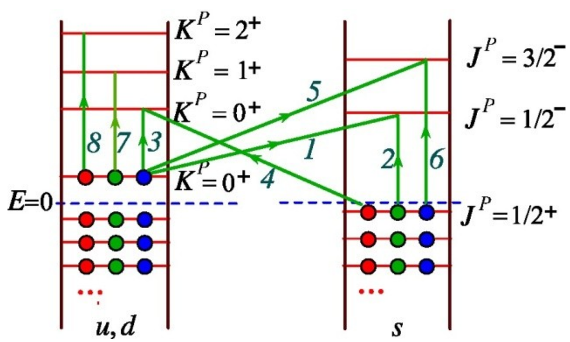
Proton and Neutron

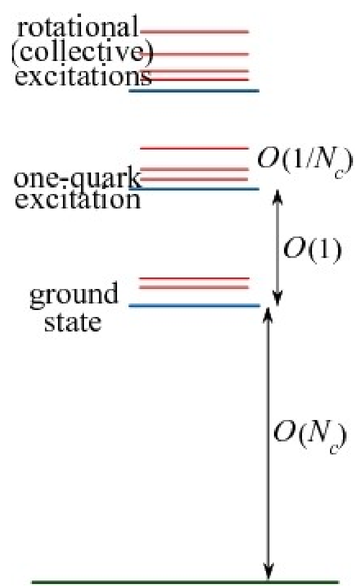


Charmed and Bottom baryons

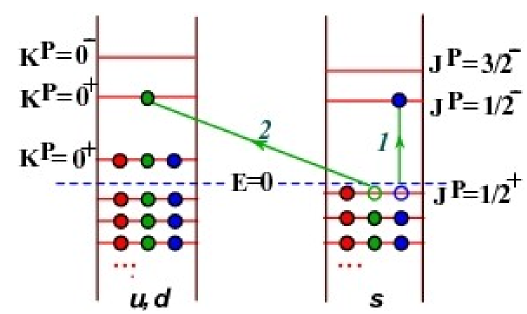


Baryon Resonances





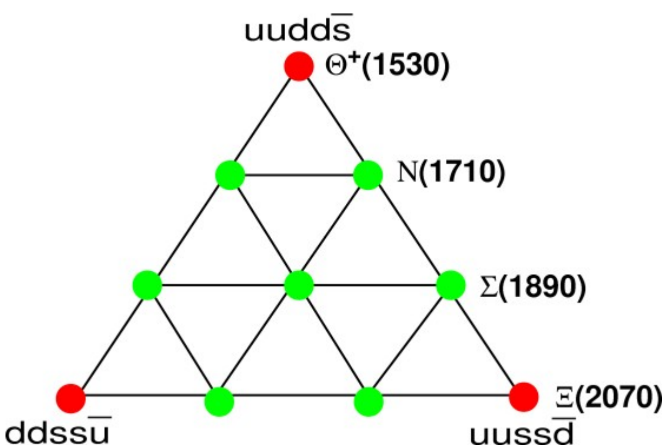
Pentaquarks – specific transitions

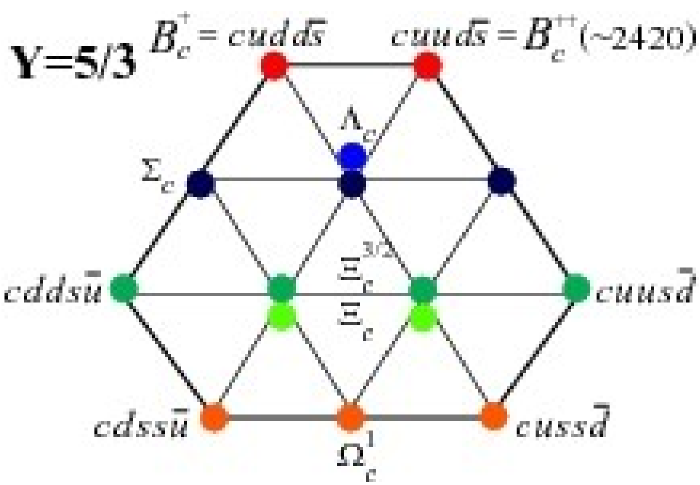


MFA predicts the same **octet and decuplet of known baryons**. It ``..also predicts baryons resonances from the PDG Tables. **Neither of resonances remain unaccounted for, and no additional resonances is predicted** except only one Δ(3/2+)" (citation from ***D. Diakonov, V. Petrov, and A.Vladimirov,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

⟶ *Solution of the problem of ``Missing Resonances"*

As byproduct, this approach predicts the existence of long-lived narrow exotic states (pentaquarks)



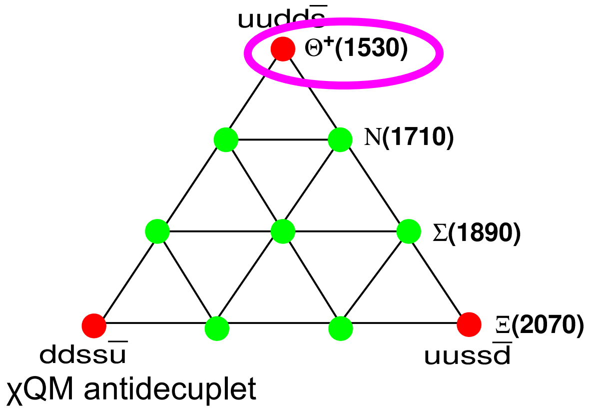


Search for exotic states might critical !

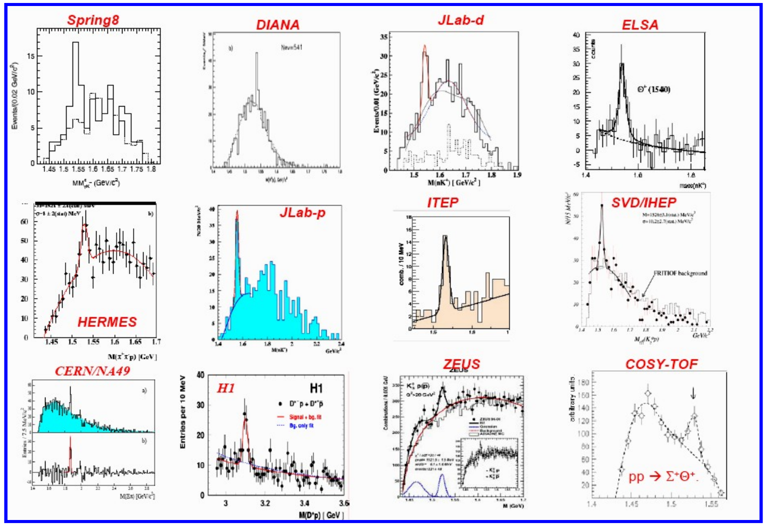
Some remarks

on the evidence / non-evidence for Θ^+

Some remarks on the recent (non)observation of $\Theta^+(1540)$



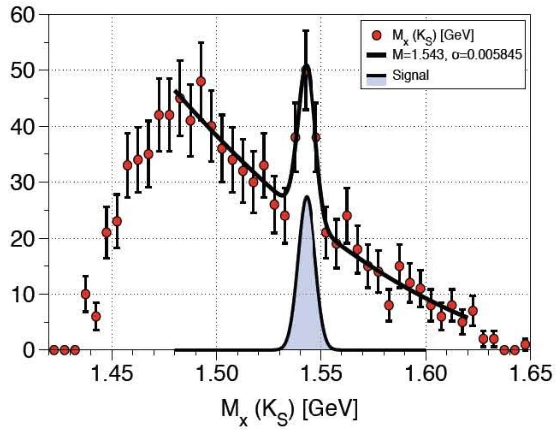
In 2002 – 2004 12 groups published the evidence for a narrow S=+1 baryon (plus ~12 preliminary results) which was attributed to the lightest member of the exotic antidecuplet Θ+(1540)



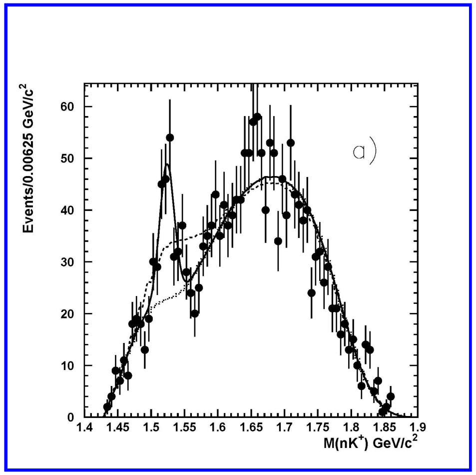
In 2005 – 2007 there were generous negative reports on the search for this particle. Some groups (CLAS, COSY) did not confirm their previous positive results in high-statistics experiments.

RECENT RESULTS

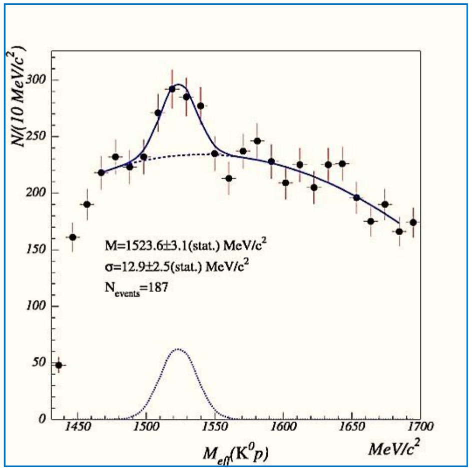
M.Amoryan et al., (part of CLAS), Phys.Rev. C 85,:035209 (2012)



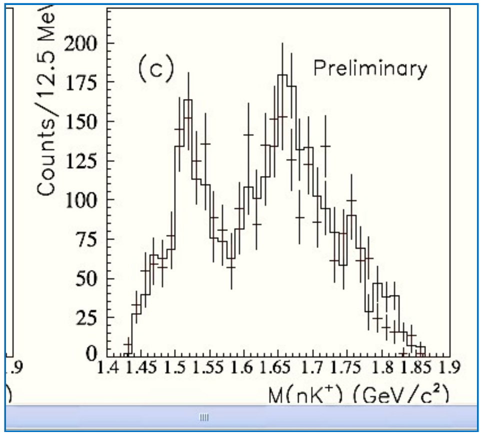
LEPS (T.Nakano et al, nucl-ex/0812.1035)



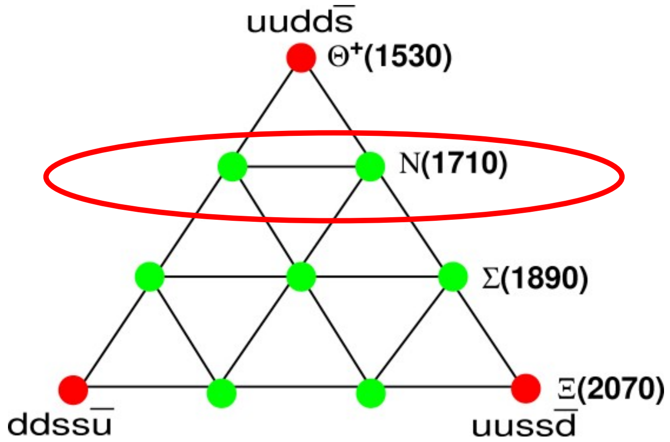
SVD-2 (A.Aleev et al., Nucl-ex/0803.3313)



LEPSII (M.Niiyama et al., Nucl. Phys. A (in press))



Observation of anomaly near W~1.685 Gev



M.Polyakov and A.Rathke
``On photoexcitation of baryon antidecuplet"
Hep-ph/0303138; Eur.Phys.J. A18, 691-695(2003)

``…qualitative feature (of the second member of the antidecuplet, the P11) … dominance of photoexcitation from the neutron target".

``…antidecuplet ``friendly" photoreactions…

$$\gamma n \to K^+ \Lambda, \quad \gamma n \to \eta n, \; \gamma n \to \gamma n$$

In these channels the antidecuplet part of the nucleon resonances should be especially enhanced, whereas in the analogous channels with the proton target the anti-10 component is relatively suppressed…."

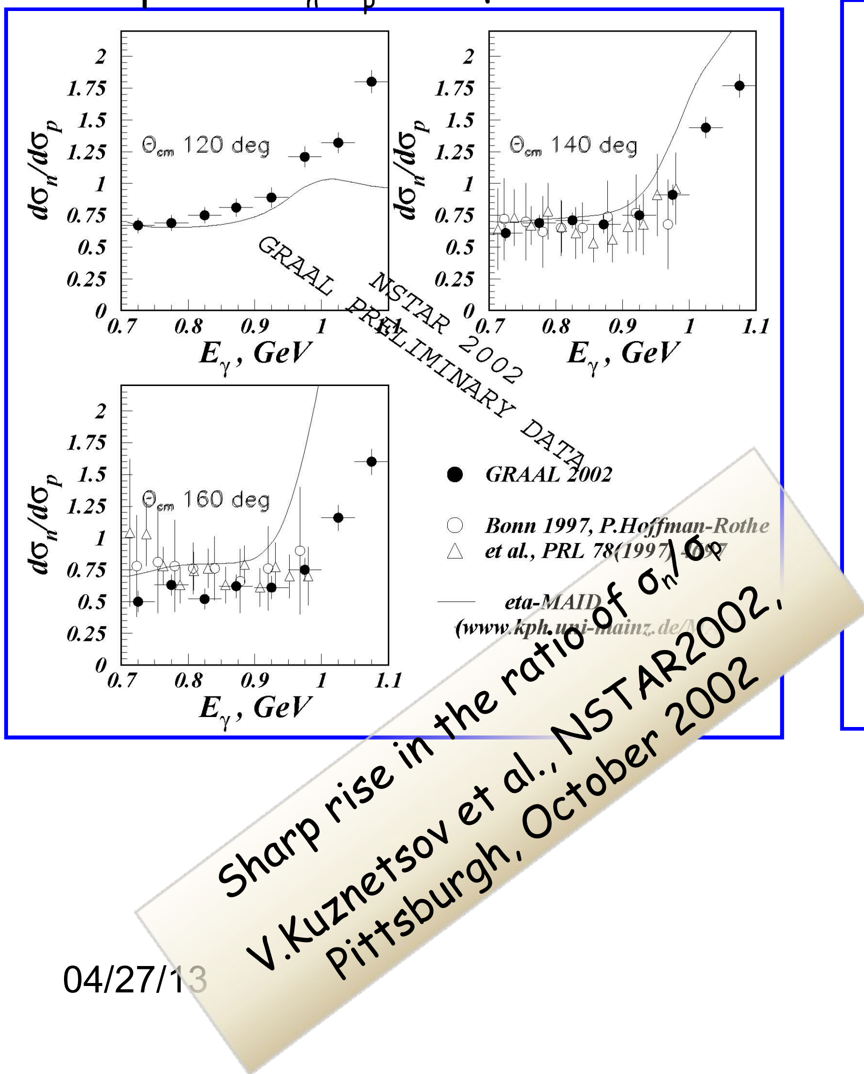
η Photoproduction off the neutron

$\gamma n \rightarrow \eta n$

History: First results on γn→ηn from GRAAL

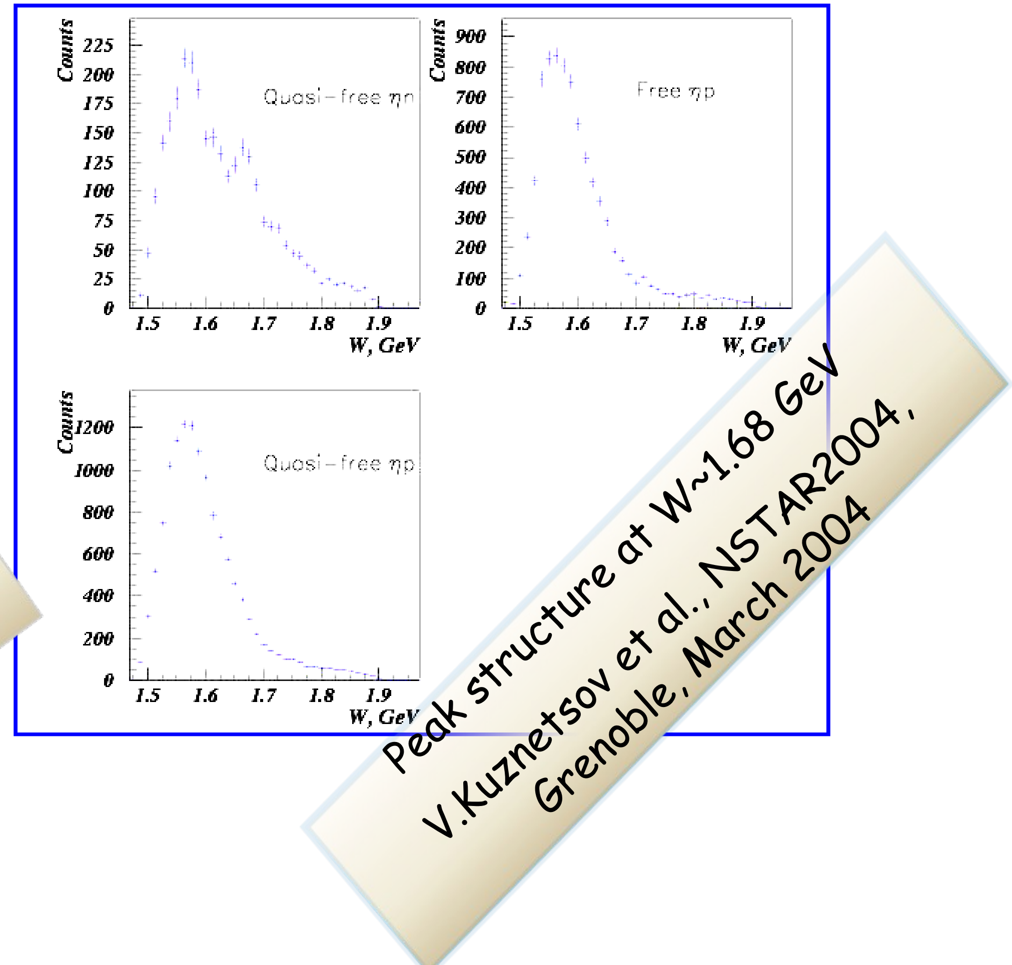
2002

Unexpected sharp rise of the ratio of the cross sections of the neutron and on the proton σ_n/σ_p at Eγ ≈ 1 GeV .



2004

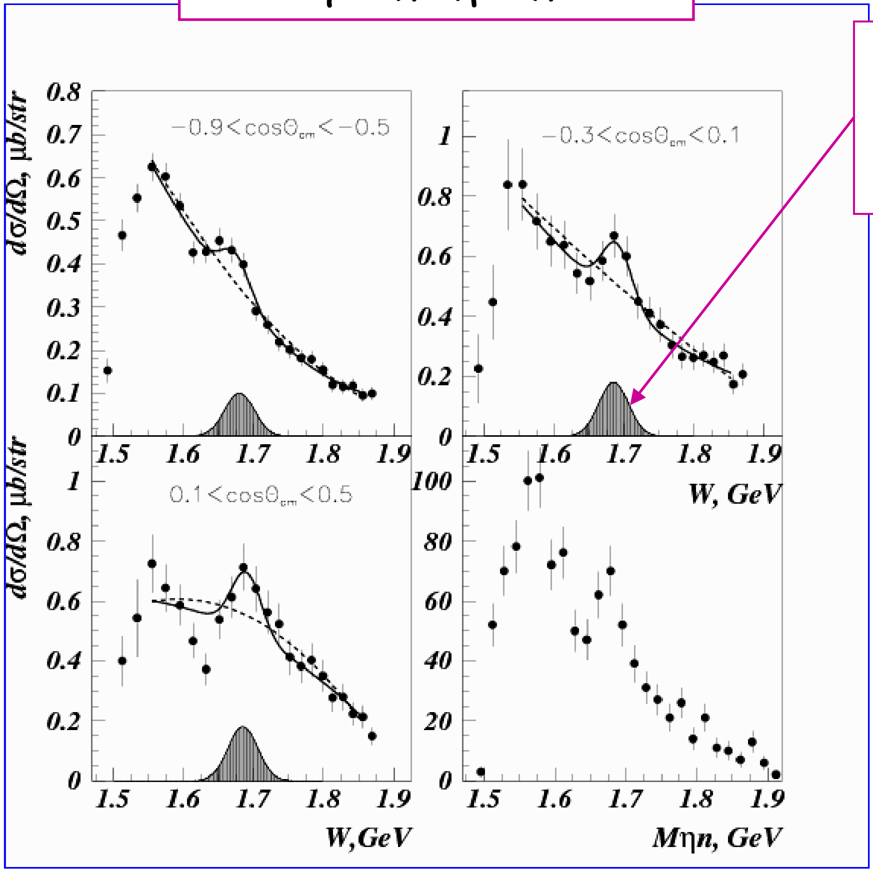
Narrow bump at W≈ 1.68 GeV γn→ηn which is not seen in γp→ηp



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

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

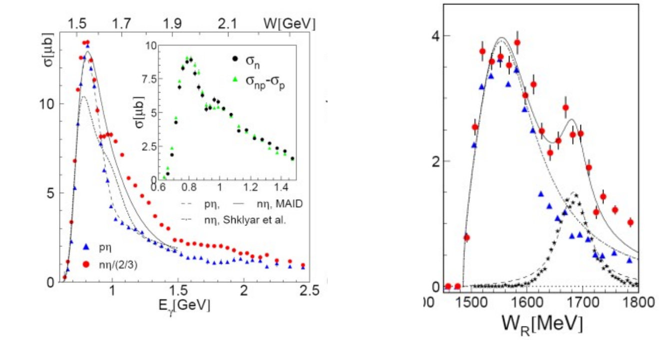
γ + n→η + n



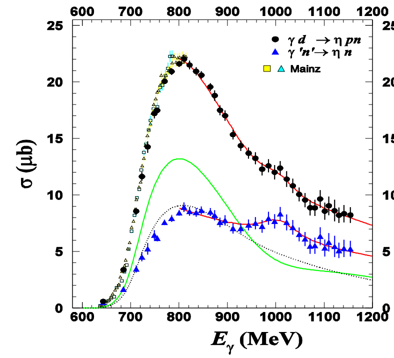
Simulated signal of a narrow (Γ=10 MeV) resonance

The width of the peak in the quasi-free cross section is close to that expected due to Fermi motion of the target neutron. The width of the peak in M(η,n) (40 MeV FWHM) is close to the instrumental resolution!

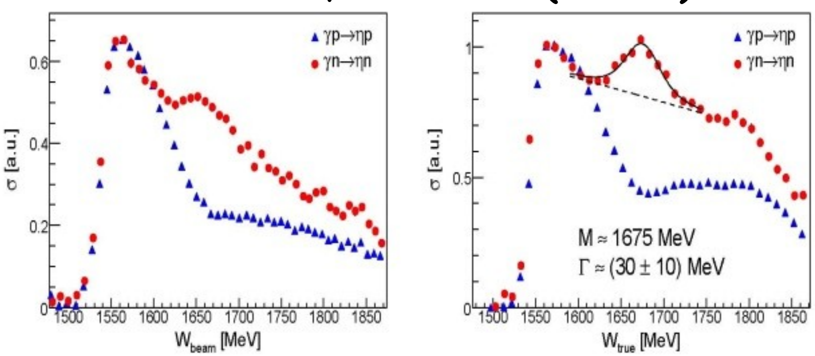
γn → ηn: Confirmation from other groups



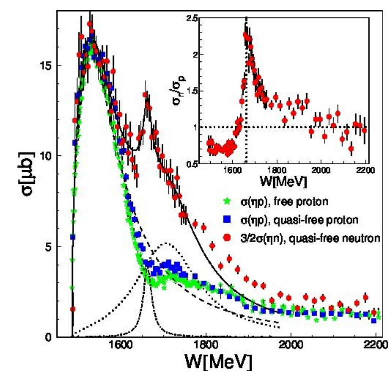
CBELSA/TAPS, J.Jeagle et al,
PRL **100**, 252002 (2008)



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



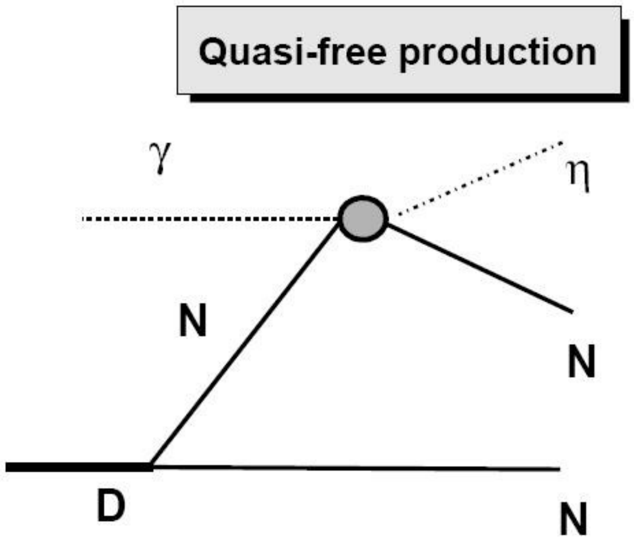
A2@Mainz, R.Wertmuller et al.,
Chin. Phys. C **33**, 1345

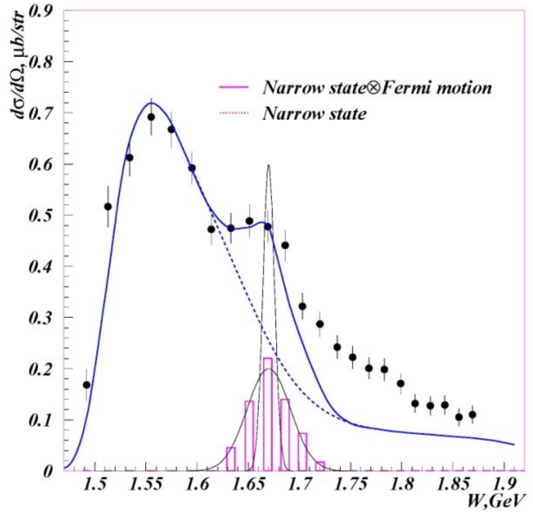


CBELSA/TAPS, J.Jeagle et al,
EPJA **47**, 89 (2011)

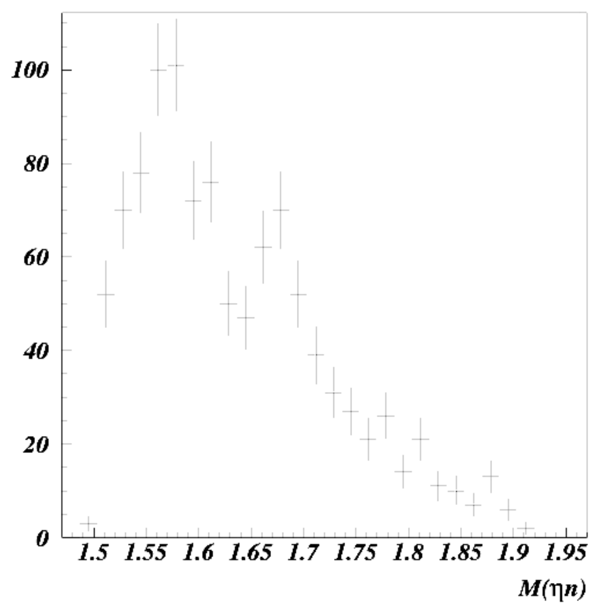
Pronounced structure at W~.168 GeV which is not (or poorly) seen in the eta photoproduction on the proton

Quasi-free reactions: The nucleon bound in a deuteron target, is not at rest → Experimental cross section is smeared by Fermi motion





The width of the bump in the quasi-free cross section is close to that expected for a narrow resonance smeared by Fermi motion.

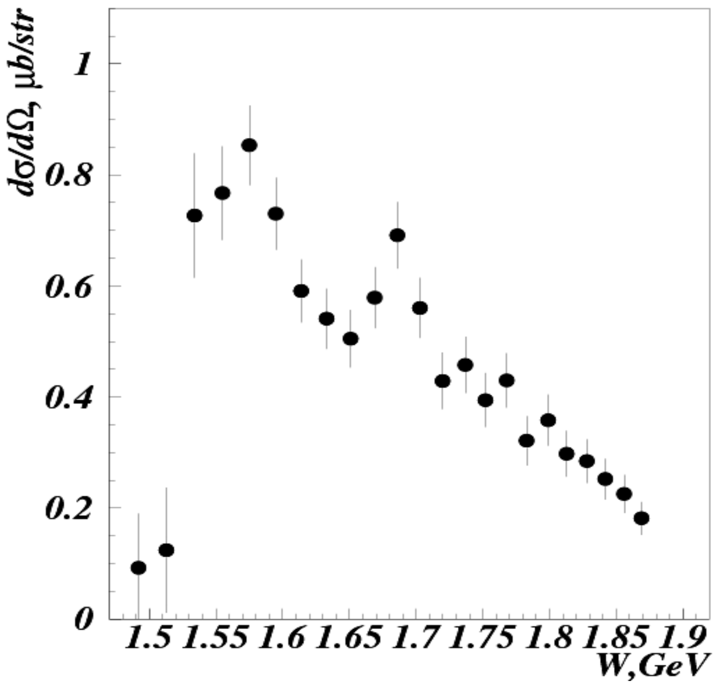


The invariant mass of the final-state η and the neutron is not affected by Fermi motion. The width of the peaks in the invariant-mass spectra are close to the instrumental resolution (40 MeV at GRAAL and 60 MeV at CBELSA/TAPS).

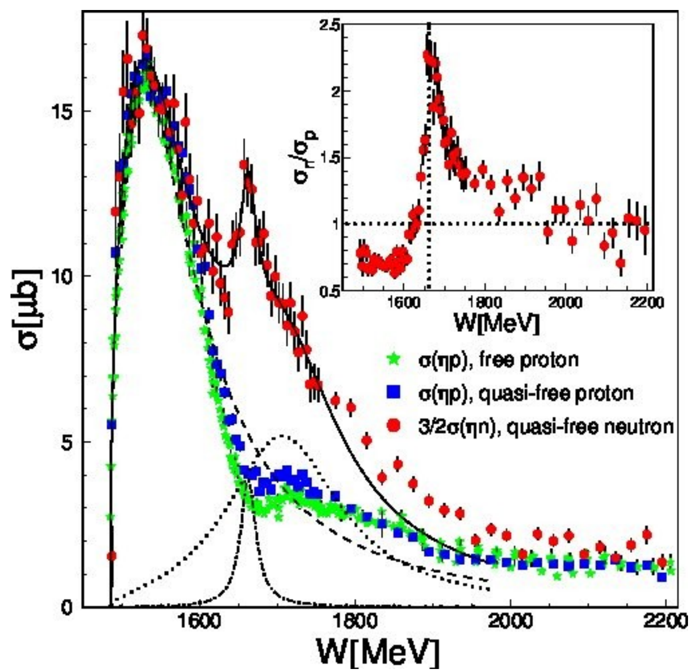
Really narrow structure!

The effect of Fermi motion of the target neutron is reduced

GRAAL



CBTAPS/ELSA



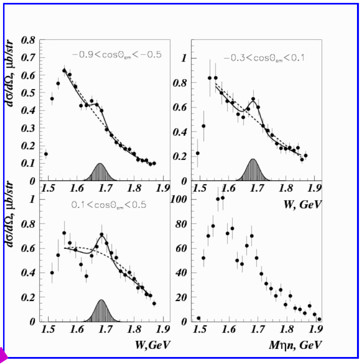
Γ≤ 30 MeV

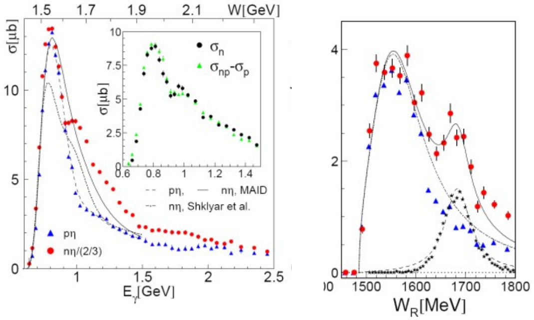
Γ~ 25 MeV

Do we see a new resonance?

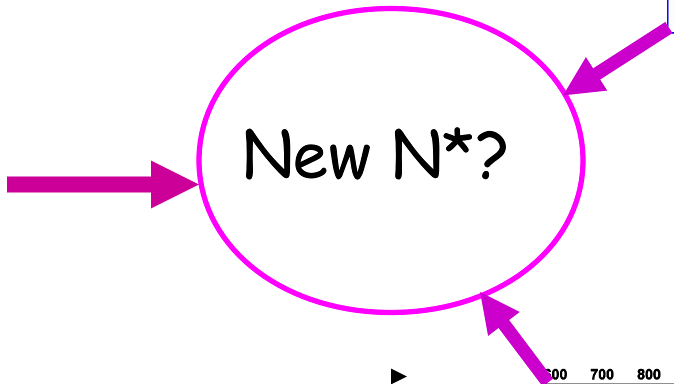
- Ya.Azimov, V.Kuznetsov, M.Polyakov, and I.Strakovsky, EPJA 25, 325(2005);
- Ki-Seok Choi, Seung-il Nam, Atsushi Hosaka, Hyun-Chul Kim, **Phys.Lett.B636:253-258,2006; hep-ph/0512136**
-A.Fix, M.Polyakov, and L.Tiator, EPJA 32,311(2007), hep-ph/0702034.
-and others….

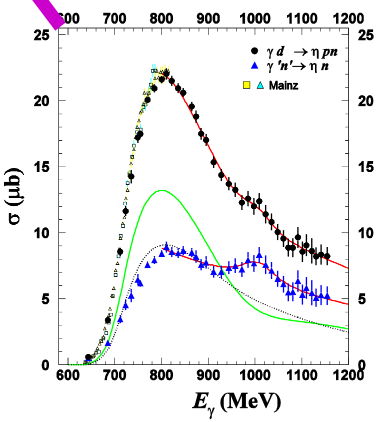
Graal γn→ηn





CBELSA/TAPS γn→ηn





LNS-Sendai γn→ηn

Intrepretations of this structure as new 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

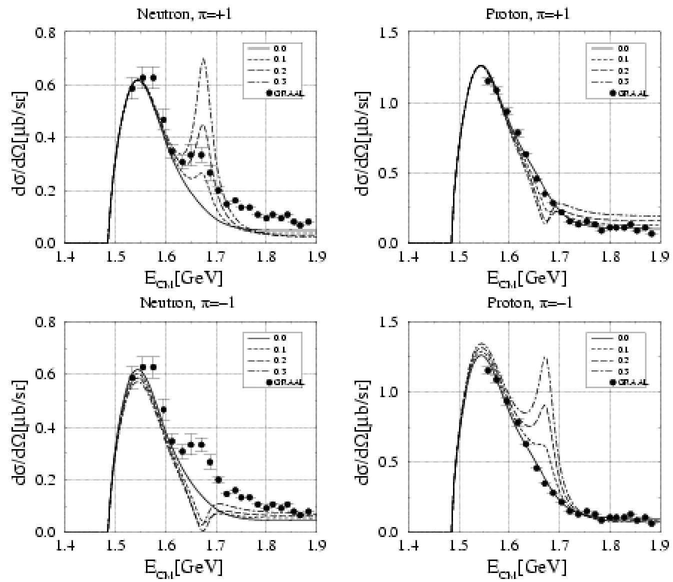


FIG. 2: The differential cross sections as functions of the total energy in the center of mass (CM) energy frame. We depict them in different targets (neutron at left column and proton at right one), parities of $N^*(1675)$ (positive at upper two panels and negative at lower two ones). The four curves in each panel indicate $\mu_{\gamma NN^*} = 0.0,\ 0.1,\ 0.2,\ 0.3\,\mu_N$. The experimental data are taken from Ref. [25].

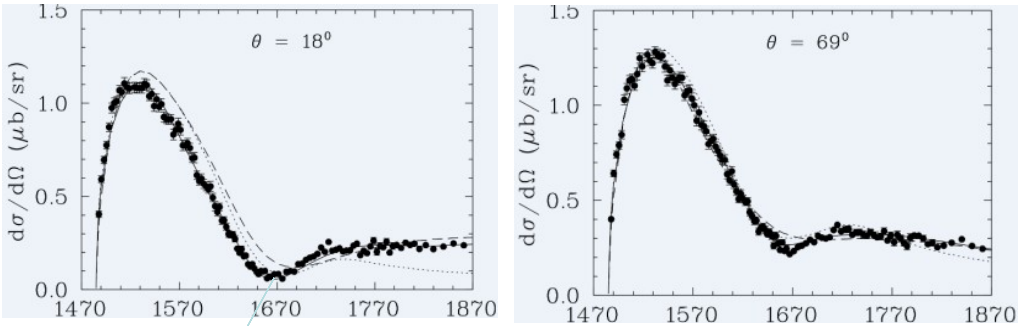
η Photoproduction off the free proton

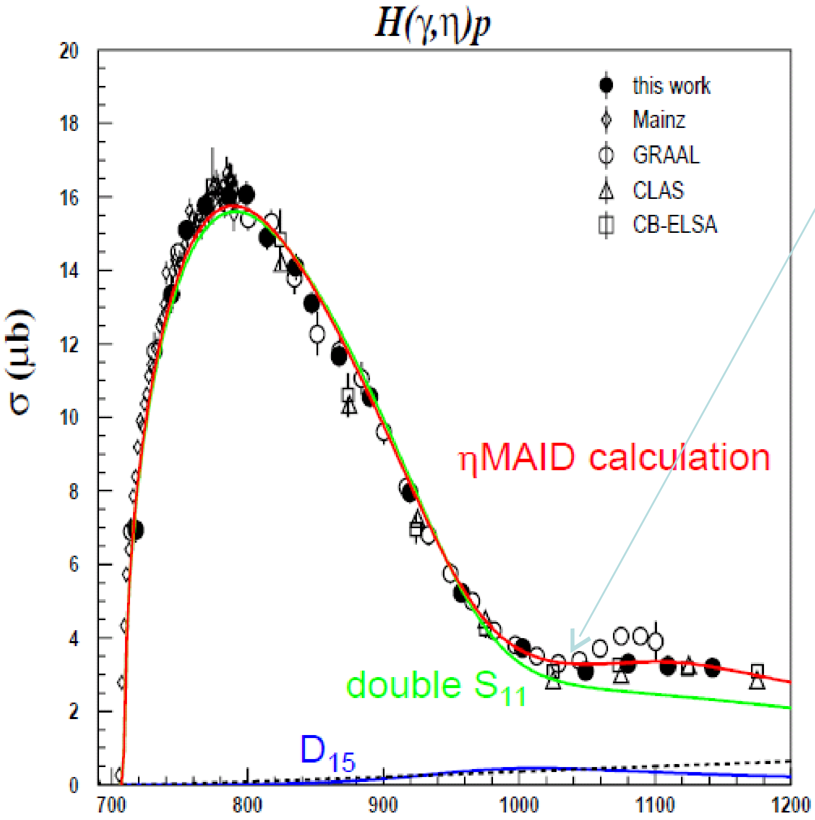
$$\gamma p \rightarrow \eta p$$

If photoexcitation of any resonance occurs on the neutron, its signal should also bee seen on the proton even if it suppressed by any reason.

$\gamma p \rightarrow \eta p$

cross section



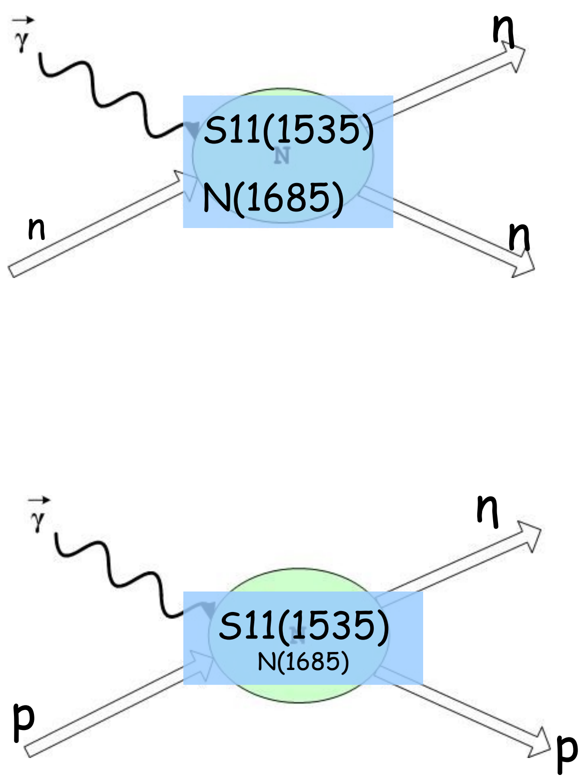


New high-resolution data from A2@MaMIC Phys.Rev.C82:035208,2010. arXiv:1007.0777 [nucl-ex] Small dip structure at W~1.67 GeV at forward angles

A structure near W=1.68 GeV is poorly seen in the eta photoproduction cross section on the free proton.

→ N(1685) photoexcitation on the proton (if exists) is suppressed

Do we really see a narrow N(1685)resonance? Test with beam asymmetry data



If photoexcitation of any resonance occurs on the neutron, it should also occur on the proton, even being suppressed by any reasons.

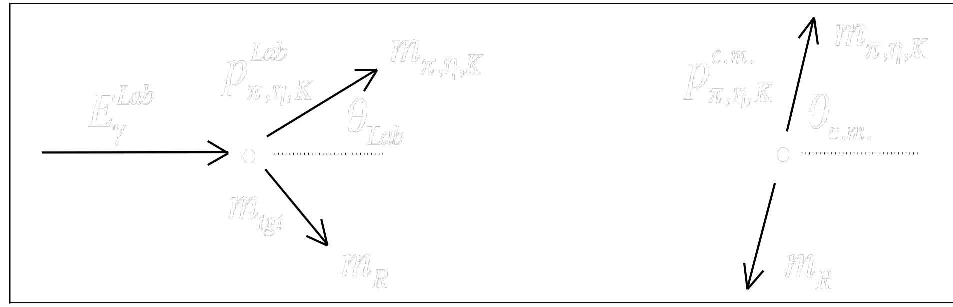
The signal of a weakly photoexcited resonance may not be seen in the cross section on the proton because of the S11(1535) dominance, but it should appear in polarization observables. On the contrary, interference of known resonances would not generate any structure on the proton.

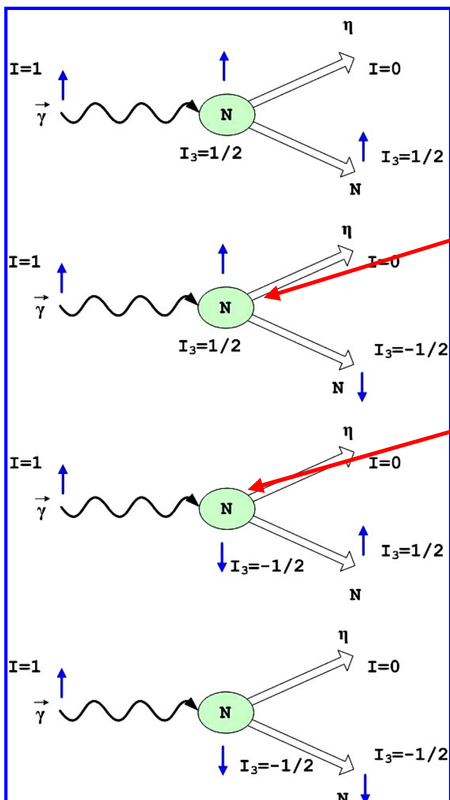
Helicity amplitudes for pseudoscalar meson photoproduction γN->MN and the role of polarization observables

Photon polarization: $\Sigma=(\sigma_{\parallel}-\sigma_{\perp})/(\sigma_{\parallel}+\sigma_{\perp})$;

Target polarization: $T=(\sigma_{\parallel}-\sigma_{\perp})/(\sigma_{\parallel}+\sigma_{\perp})$;

Reaction plane: $P=(\sigma_{\parallel}-\sigma_{\perp})/(\sigma_{\parallel}+\sigma_{\perp})$





H↑↑

N*

H↑↓

S11(1535)

H↓↑

H↓↓

Dominates in cross section

Helicity amplitudes :

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

S-P interference

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

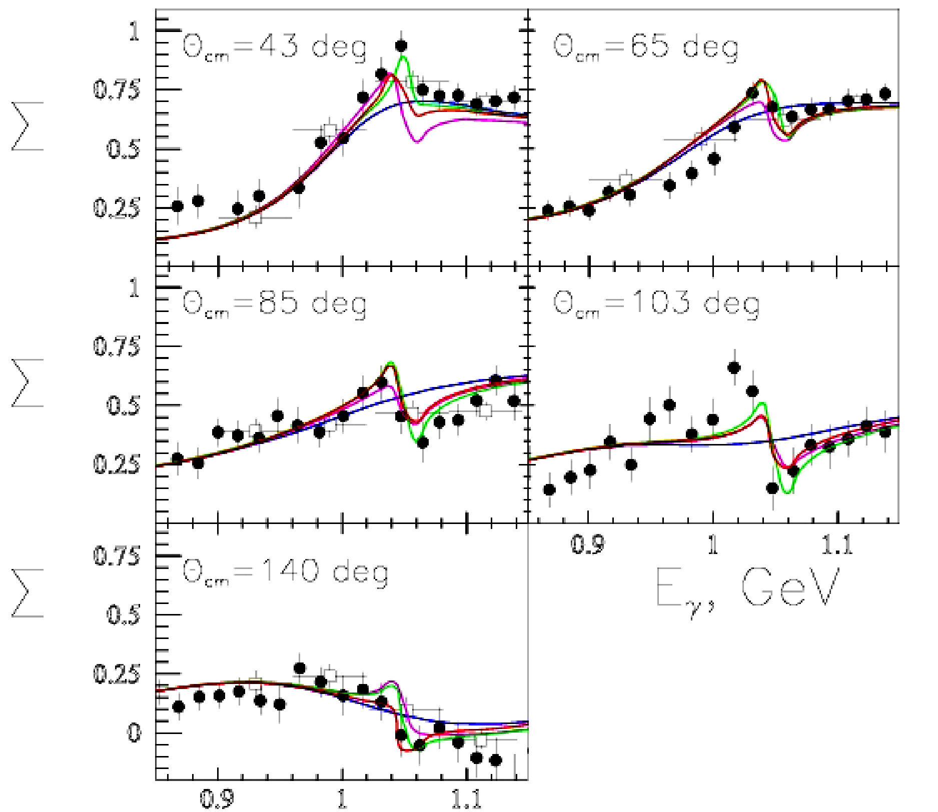
$T \sim Im\{H_{\uparrow\downarrow}H^*_{\uparrow\uparrow}+H_{\downarrow\downarrow}H^*_{\downarrow\uparrow}\}$

P ~ Im{H H* +H H* }

Any weakly photoexcited N* resonance may not be seen in the η cross section, but may appear in polarization observables through its interference with S11(1535)

GRAAL beam asymmetry for eta photoproduction on free proton with fine energy binning.

V. Kuznetsov, M.V.P, et al., hep-ex/0703003
V. Kuznetsov, M.V.P, et al., Acta Physica Polonica , 39 (2008) 1949
V. Kuznetsov, M.V.P., JETP Lett., 88 (2008) 347



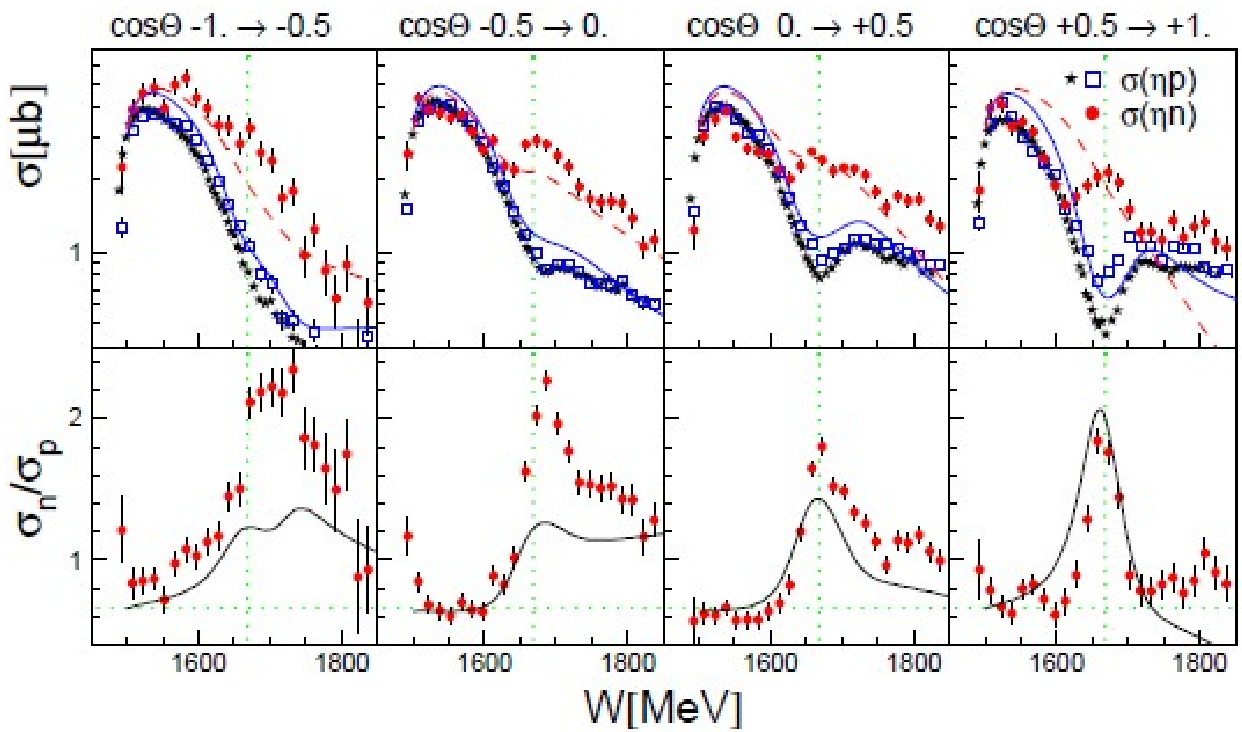
Well pronounced structure at W=1.685 GeV

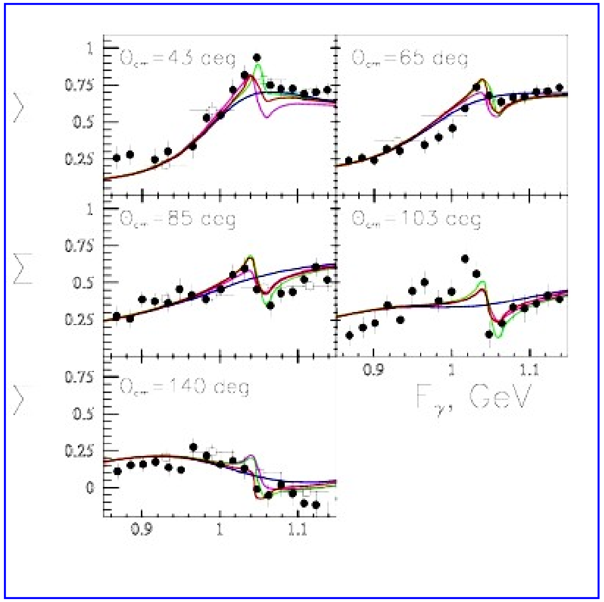
Fit: smooth SAID multipoles
+ a narrow resonance
Blue – SAID only
Magenta – SAID + narrow P11(1688)
Green – SAID +narrow P13(1688)
Red – SAID + narrow D13(1688)

M=1.685±10 GeV, Γ≤30 MeV

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

(Logarithmic scale)





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

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

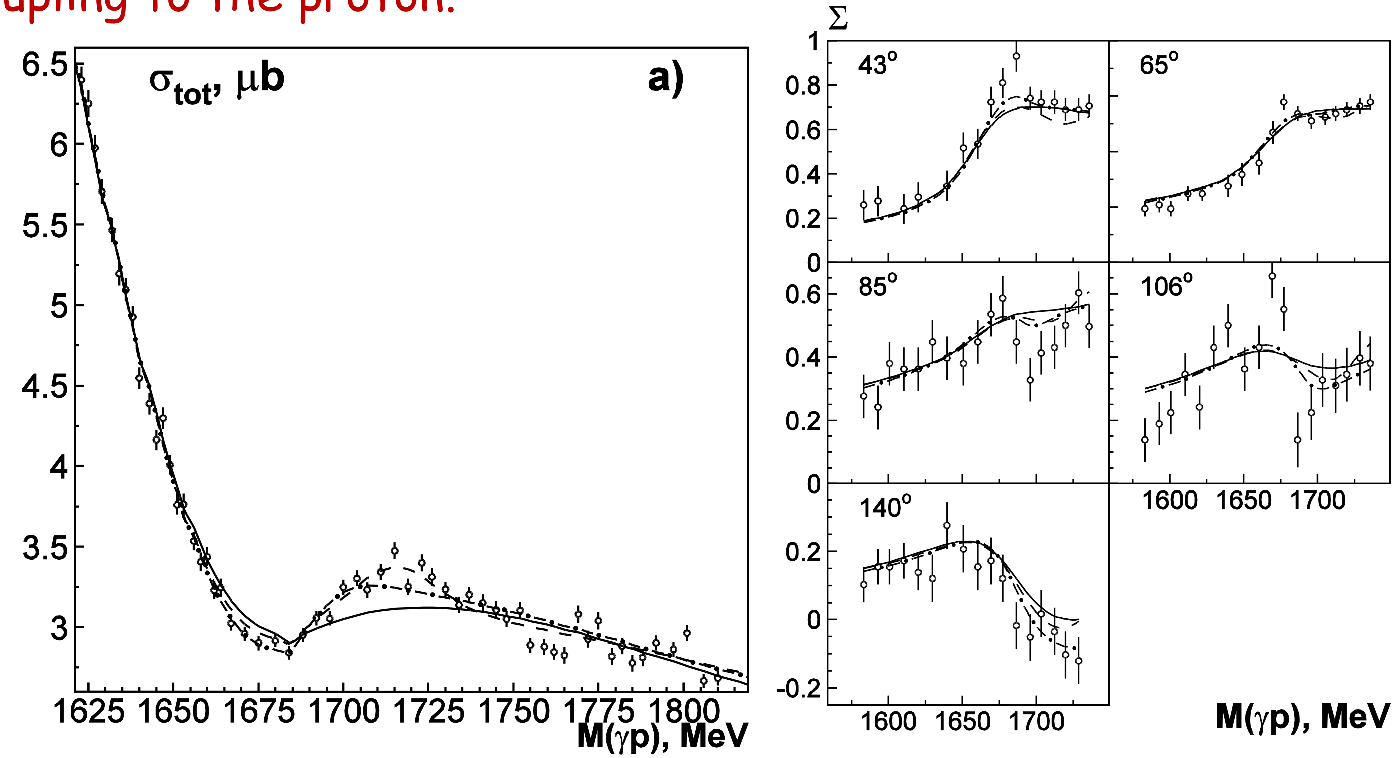
Bonn-Gatchina PWA of new MAMI data

``Search for Narrow Nucleon Resonance in γp-> ηp."

A. V. Anisovich, E. Klempt, V. Kuznetsov, V. A. Nikonov, M. V. Polyakov, A. V. Sarantsev, U. Thoma.,Arxiv 1108.3010.

Standard PWA shows a systematic deviation from the the data in the mass interval of 1650-1750 MeV.

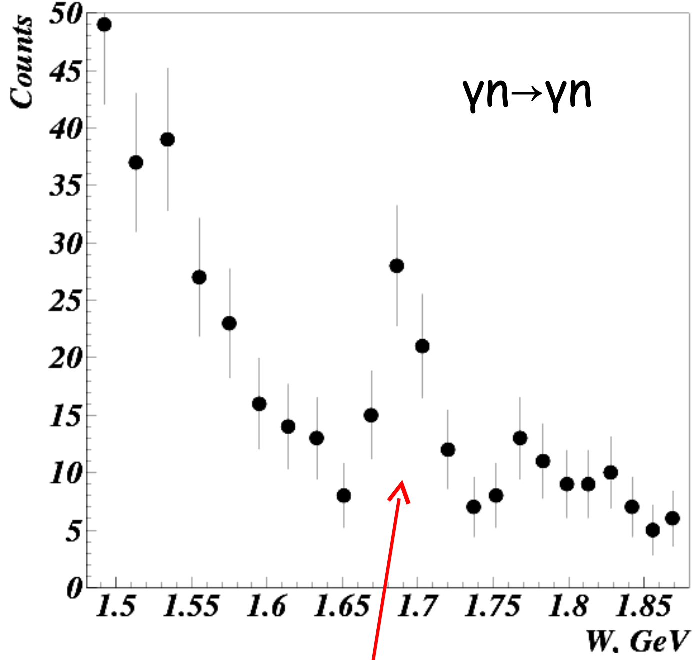
The description of the data can be improved significantly assuming the existence of a narrow resonance at about 1700 MeV, the width 30-40 MeV, and with small photo-coupling to the proton.

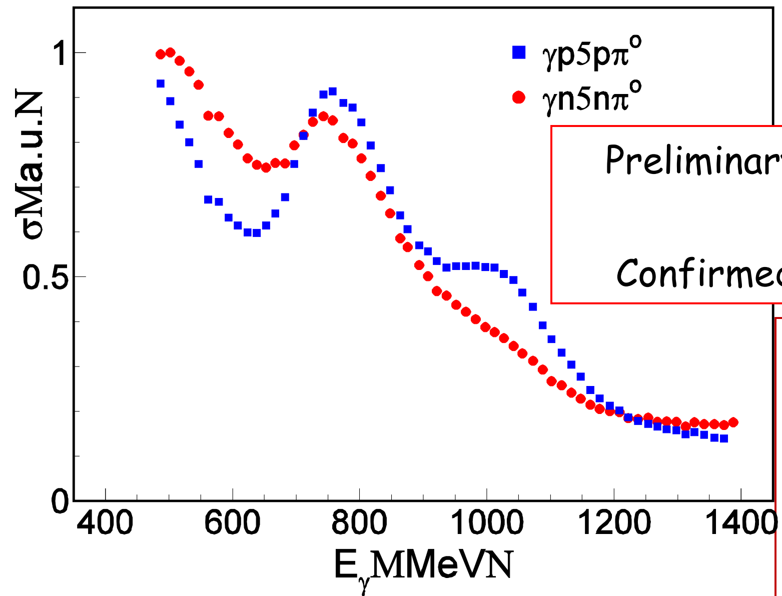


Compton scattering and π^0 photoproduction on the neutron (GRAAL)

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

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





Preliminary CBELSA/TAPS data

Confirmed by our analysis.

Compton scattering: Peak structure at 1.685 GeV

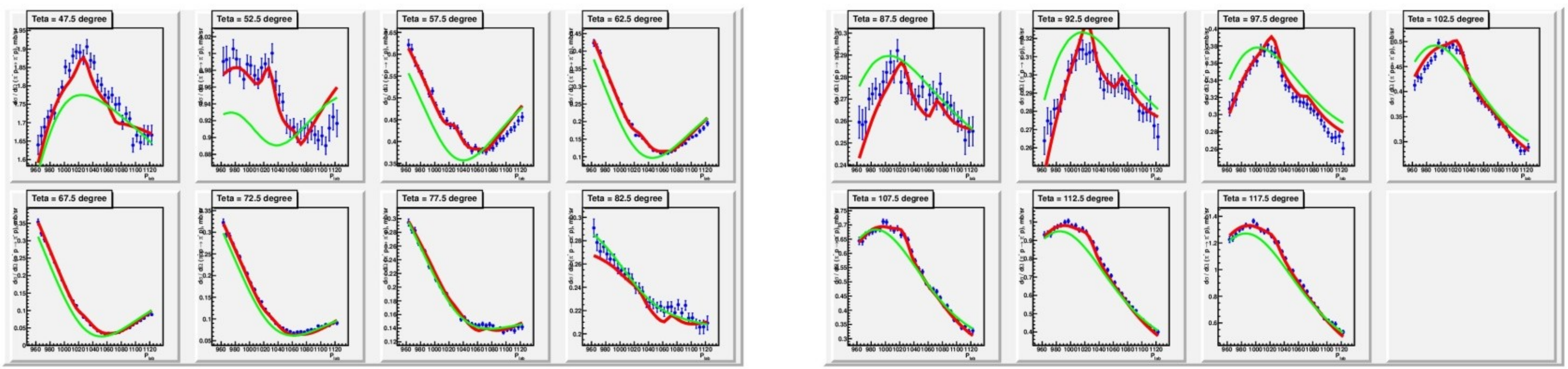
$\gamma n \rightarrow \pi^0 n$: Flat cross section at 800 -1300 MeV

Preliminary EPECUR data

$\pi^- p \rightarrow \pi^- p$

I.Alexeev et al., Arxiv 1204.6433

and Anatoly Gridnev, Private Communication



Green lines are from SAID. Red lines are calculations by A.Gridnev with two narrow resonances (M1=1.685 Gev and M2=1.72 GeV).

Well pronounced structure at W~1.685 GeV !
Additional stucture at W~1.72 GeV?

SAID PWA

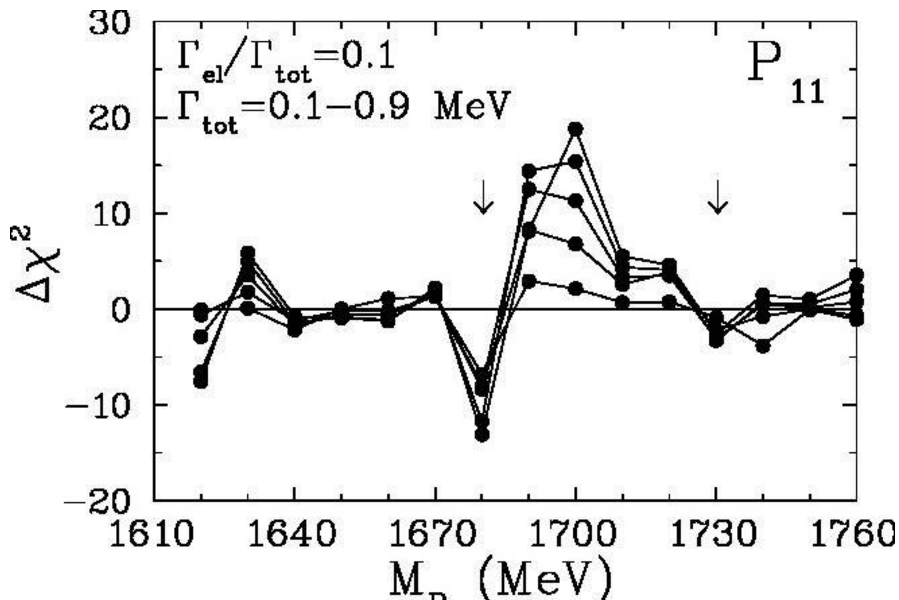
R.Arndt, Ya.Azimov, M.Polyakov, I.Strakovsky, R.Workman

``Nonstrange and other flavor partners of the exotic θ^+ baryon"

Phys.Rev. C69 (2004) 035208

Nucl-th/0312126;

`` … given our present knowledge of the θ^+, the state commonly known as the N(1710) is not the appropriate candidate to be a member of the antidecuplet. Instead we suggest candidates with nearby masses, N(1680) (more promising) and/or N(1730) (less promising, but not excluded). *Our analysis suggests that the appropriate state should be rather narrow and very inelastic…"*



Alternative intrepretations

Interference of S11(1650) and P11(1710) .

V. Shklyar, H. Lenske , U. Mosel , PLB650 (2007) 172 (Giessen group)

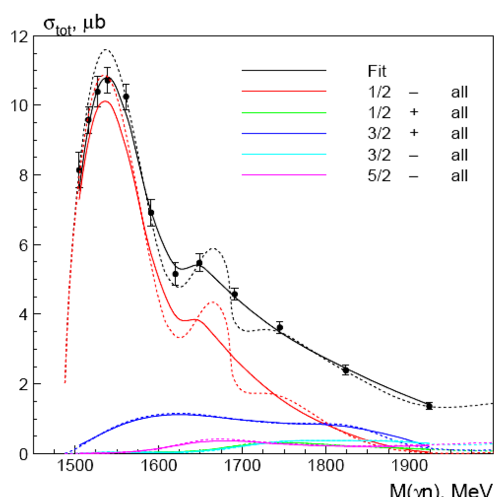
Interference effects of S11(1535) and S11(1650)

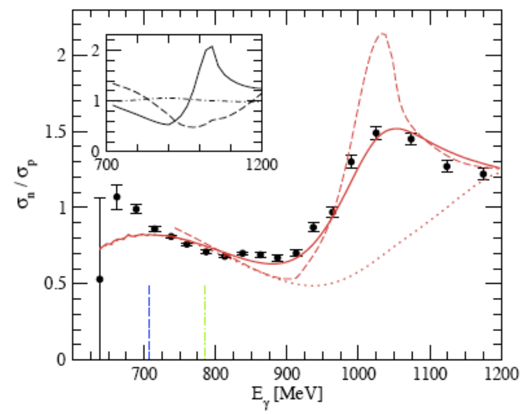
A. Anisovich et al. EPJA 41, 13 (2009), hep-ph/0809.3340 (Bonn-Gatchina group); X.-H. **Zong and Q.Zhao, Arxiv:1106.2892**

Intermediate sub-threshold meson-nucleon state

M.Doring, K. Nakayama, PLBB683:145 (2010), nucl-th/0909.3538.

Fits of CBTAPS/ELSA γn →ηn data ONLY!

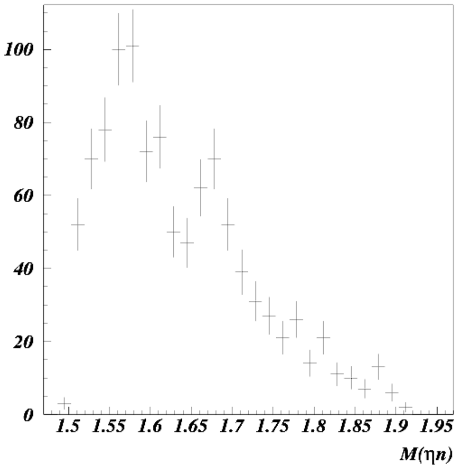




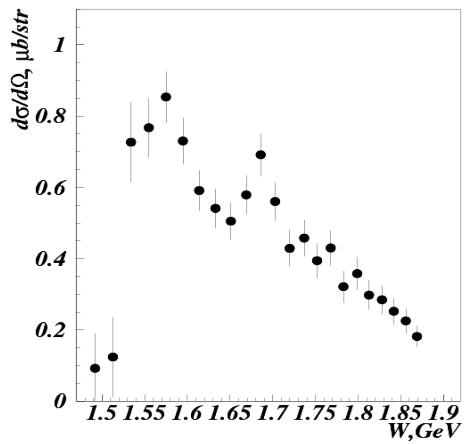
Data: I. Jaegle *et al.*, CBELSA & TAPS

→ To be discussed

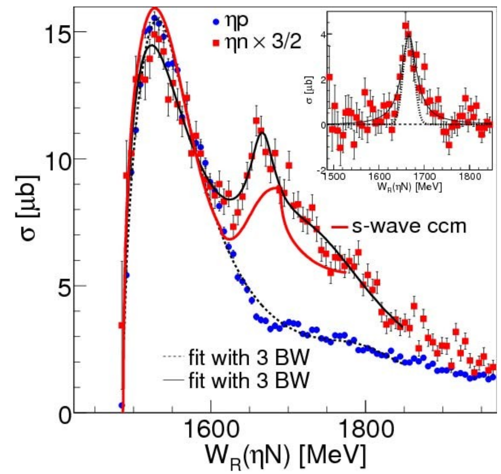
First Remark



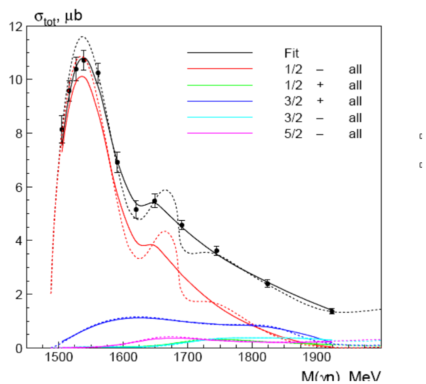
Graal M(η,n)

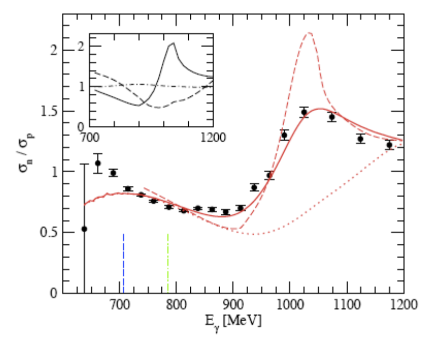


GRAAL cross section



CBELSA/TAPS cross section





Data: I. Jaegle *et al.*, CBELSA & TAPS

The structure in calculations seem to be wider than that experimental observations from GRAAL and CBTAPS-ELSA despite the latter are dominated by instrumental resolutions!

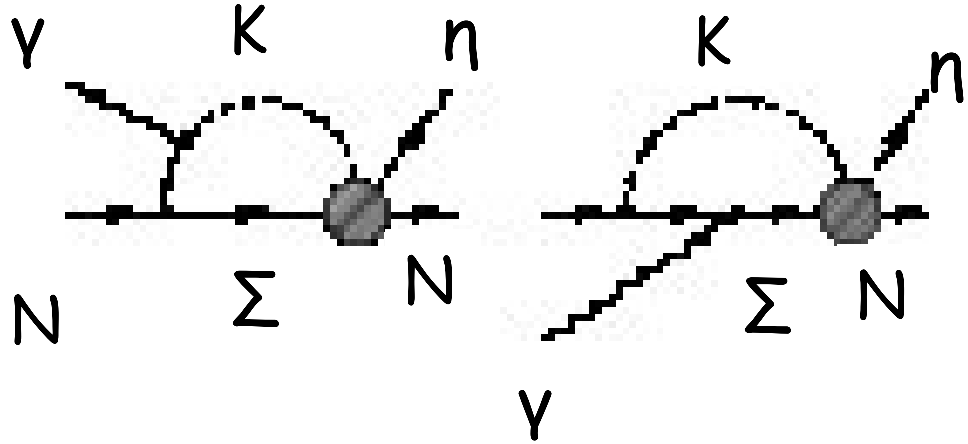
- The explanation of the bump in the $\gamma n \to \eta n$ cross section in terms of the interference of well-known resonances seem to be challenged
-by the narrow width of the structure,
-by the observation of the structures in the $\gamma p \to \eta p$ data;
- by the observation in Compton scattering on the neutron, elastic pion scattering, and no evidence in π^0 photoproduction,. These reactions

i) receive the contribution of resonances different from η photoproduction;

ii) If the structure is generated, it should be seen in all these reactions.

KΣ Cusp effect

M.Doring, K. Nakayama, PLBB683:145 (2010), nucl-th/0909.3538.



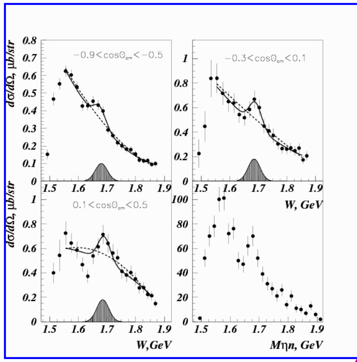
Question:
-Could the same effect occur in Compton scattering and do not occur in pion photoproduction?

Maxim Polyakov, Private Communication.

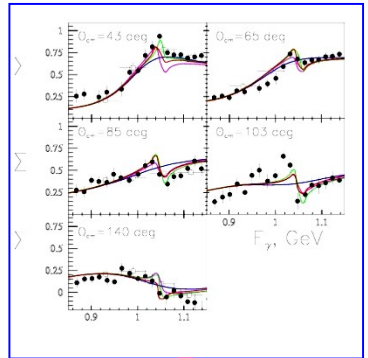
Explanation of the peak in gamma n --> eta n due to cusp effect (Doring, Nakayama) implies very strong violation of flavour SU(3) symmetry as well as very strong violation of chiral symmetry.

Publication in Preparation.

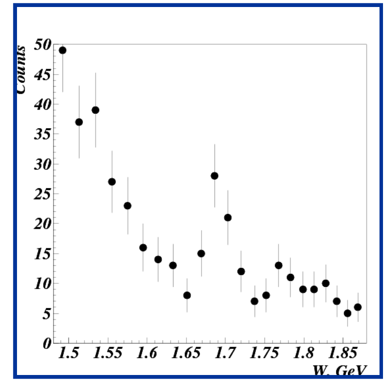
Graal γn→ηn



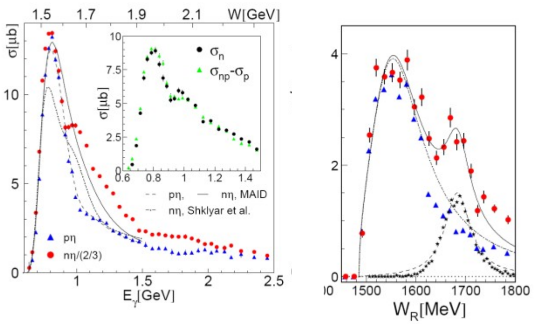
Graal γp→ηp



Graal γn→γn

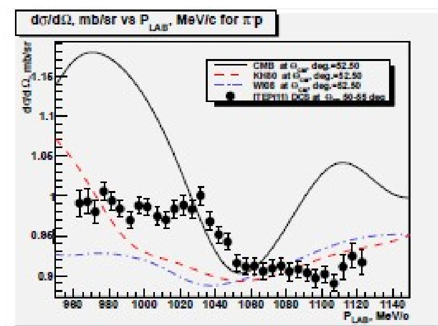


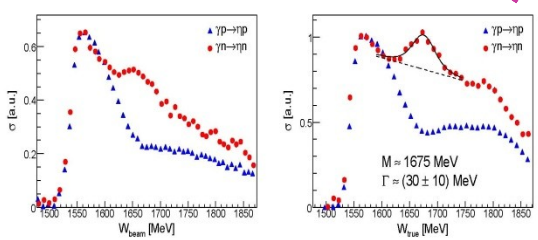
N*(1685)



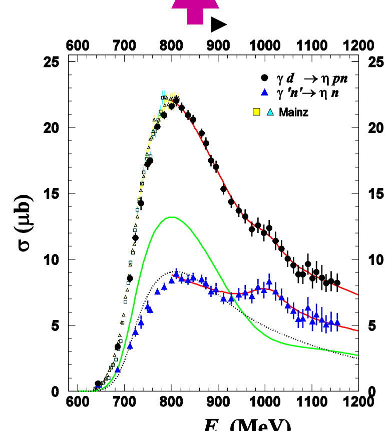
CBELSA/TAPS γn→ηn

EPECUR πp→πp





Mainz γn→ηn



LNS-Sendai γn→ηn

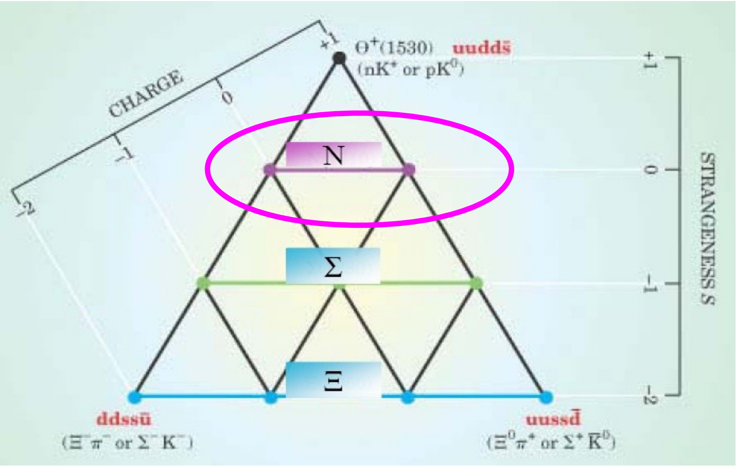
At present, the only explanation that accommodates all experimental findings is the existence of a narrow N(1685) resonance.

Properties of tentative N(1685)

- M=1685±10 MeV
- Γ≤30 MeV
- Isospin ½
- S=0
- Strong photoexcitation on the neutron and suppressed (~100 times) photoexcitation on the proton

The existence of a resonance with such properties was not predicted by the conventional CQM !

Expected properties of the second member of the χQM antidecuplet [10,1/2-]



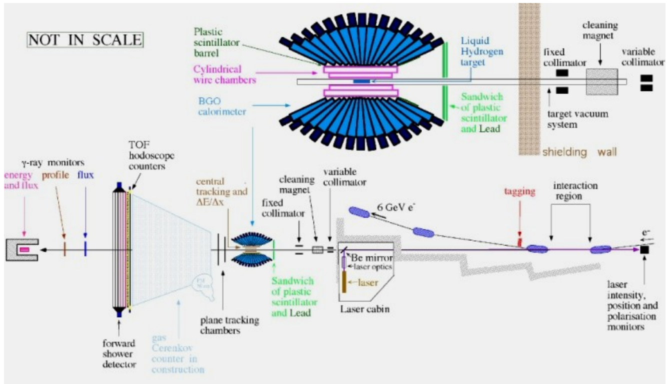
- M= 1650 – 1690 MeV
- Γ≤30 MeV
- Isospin ½
- S=0
- Strong photoexcitation on the neutron and suppressed (~100 times) photoexcitation on the proton
- Quantum numbers P11

Further tasks:

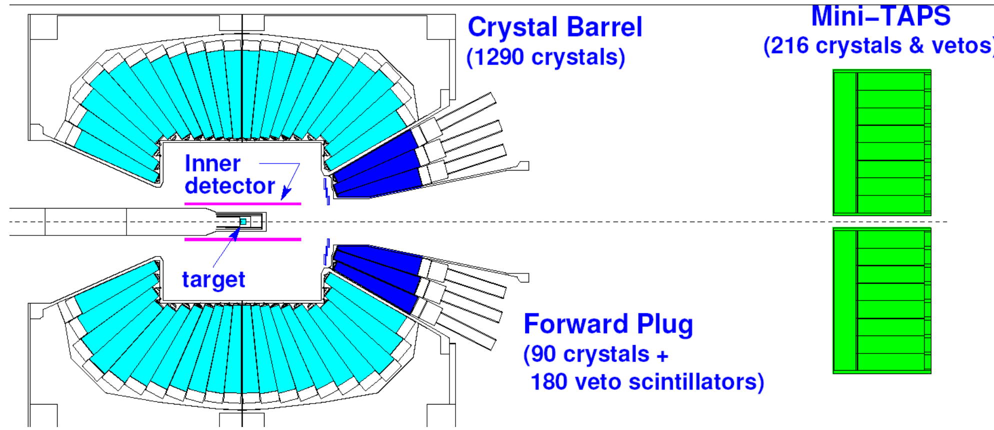
- To determine quantum numbers;
- To determine the width.

New measurements at photon facilities (GRAAL, CBTAPS/ELSA, MaMiC, BGO-OD);

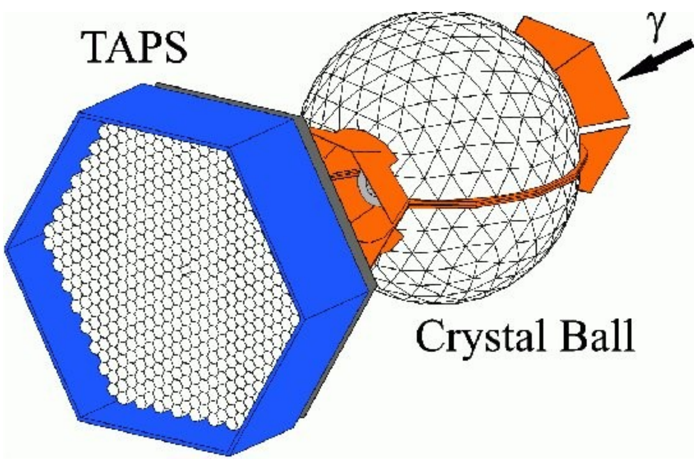
Detectors



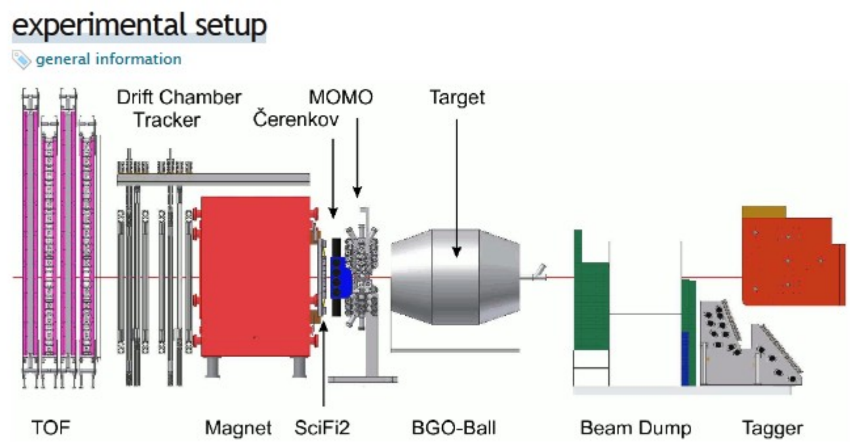
GRAAL



CBELSA/TAPS



MaMiC



BGO-OD

The detectors are similar.
Specific features:

GRAAL – highly polarized (up to 98%) beam up to 1.5 GeV, detection of neutrons :

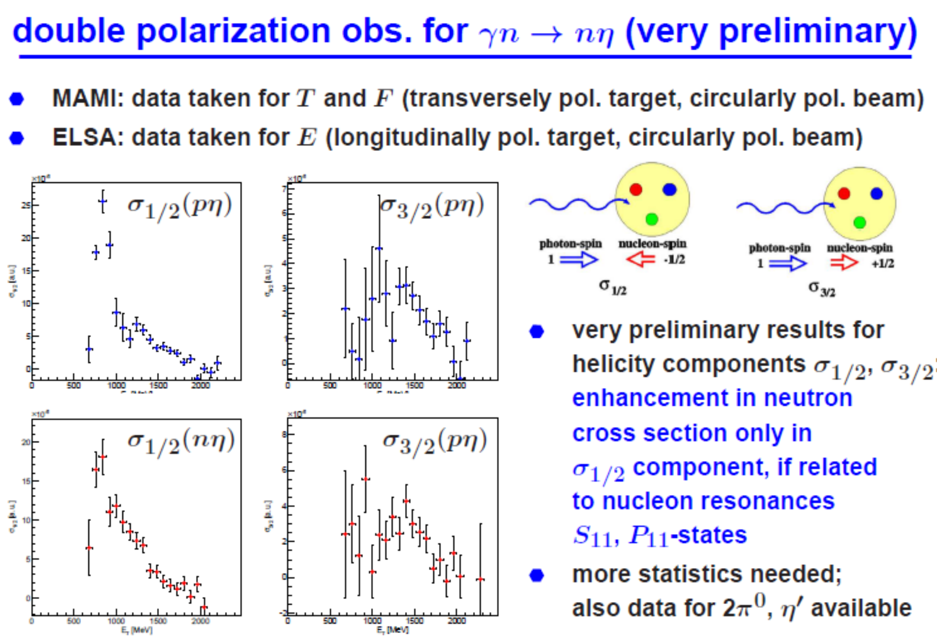
CBELSA/TAPS – bremstrahlung beam up to 3 GeV, polarized target;

MaMiC - bremstrahlung beam up to 1.5 GeV, polarized target, high-resolution tagger;

BGO-OD (not yet in operation) - bremstrahlung beam up to 3 GeV, high-resolution detection of charged particles due to magnetic spectrometer;

Expected results:

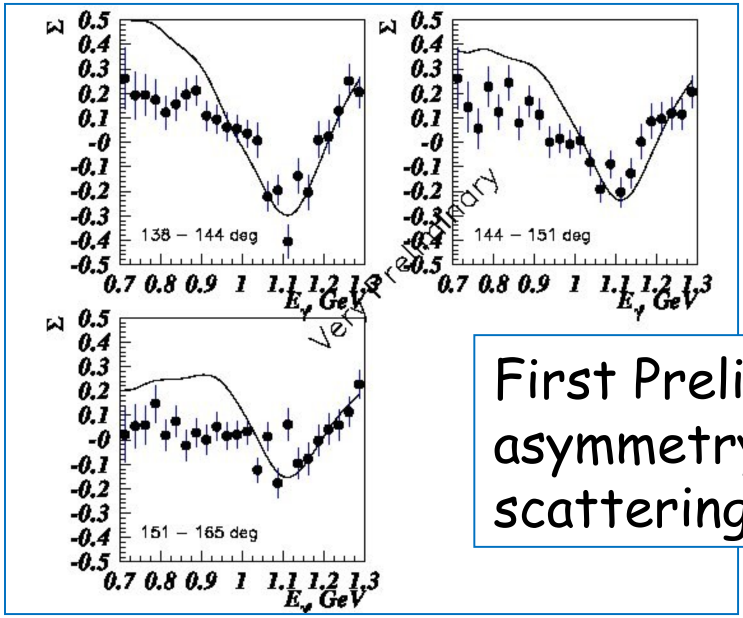
- High-precision single-polarization data;
- Search for N*(1685) in ``production" reactions like γN→πN*(1685)→πηN;
- **Double-polarization data**



GRAAL – unique facility to measure beam asymmetry Σ

A lot of data have been collected, checked, calibrated and …. not yet analyzed. These data are now available at PNPI.

Their analysis is set in progress in collaboration with the former GRAAL collaborators (University of Catania, Rome, Torino) and Ruhr University of Bochum (Maxim Polyakov).



First Preliminary results on beam asymmetry for Compton scattering on the proton

Personal remark on BGO-OD

Possibility to measure

$$\gamma n \rightarrow K^- \Theta^+ \rightarrow K^- K^+ n$$

A relevant proposal could be discussed…

New Time-of-Flight detector for neutrons and charged particles

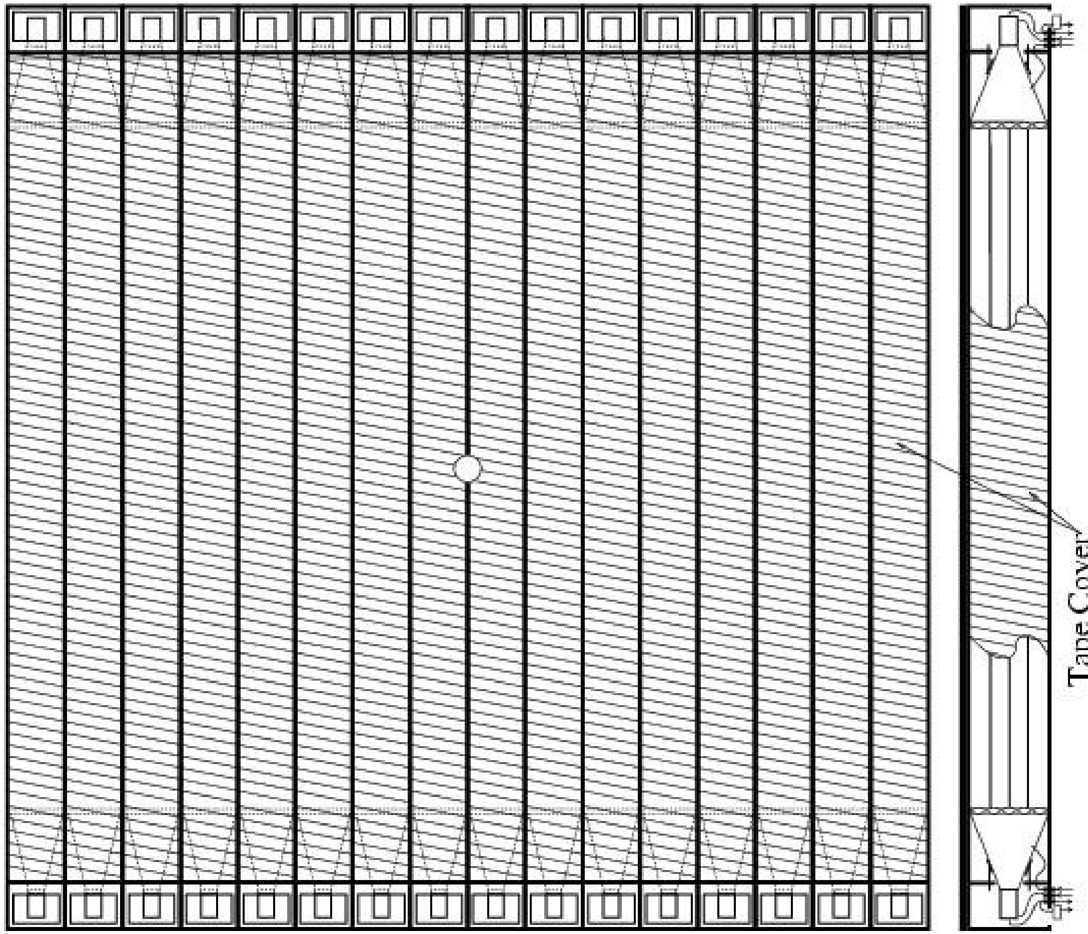
One problem for all the mentioned detectors is poor resolution for neutrons. The only detectors that provides the reconstruction of neutron momentum is the ``Russian Wall" at GRAAL (TOF resolution ~ 300 ps).

Possibly the forward walls at BGO-OD will provide the same option.

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.



Time-of-Flight Resolution of scintillator counters

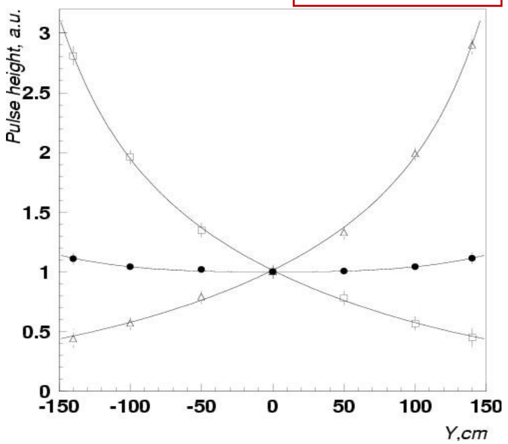
$$\sigma_t = \sqrt{\frac{\sigma_{sci}^2 + \sigma_{pmt}^2 + \sigma_{pl}^2}{N_{pe}} + \sigma_{elec}^2}$$

2.1 ns

PM TTS ~ 0.4 ns Depends on the PM size

Strongly depends on the length of scintillator bars and light guides

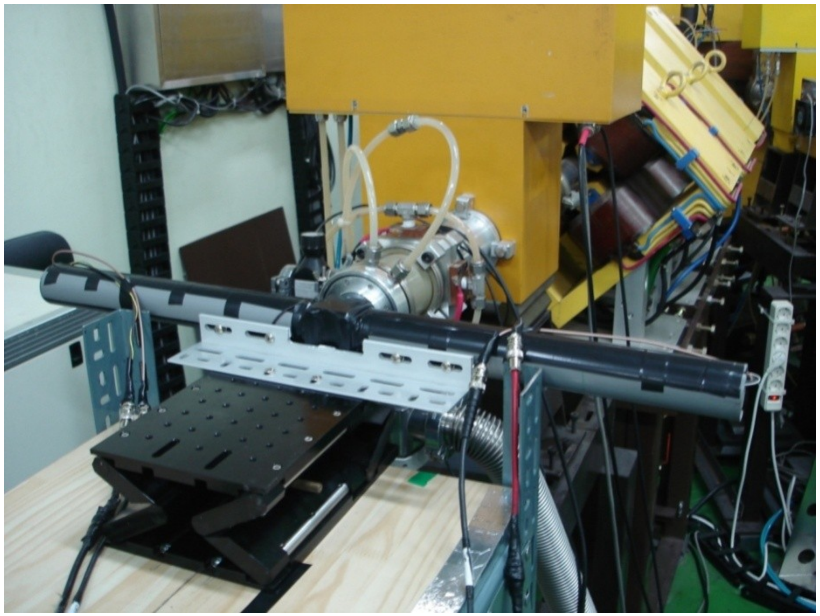
Depends on the light attenuation and the light collections

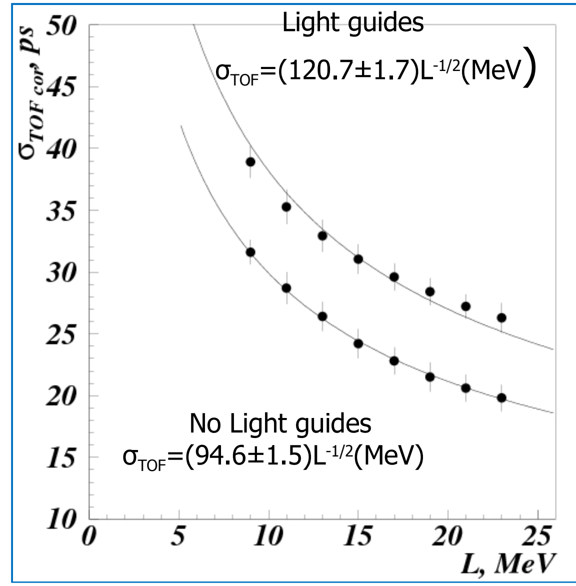


Light attenuation in a long scintillator bar

The shorter and smaller scintillator bars, the better is the TOF resolution!

Test of prototype counters for the CLAS12 Central Time-of-Flight System using minimum-ionizing cosmic-ray muons

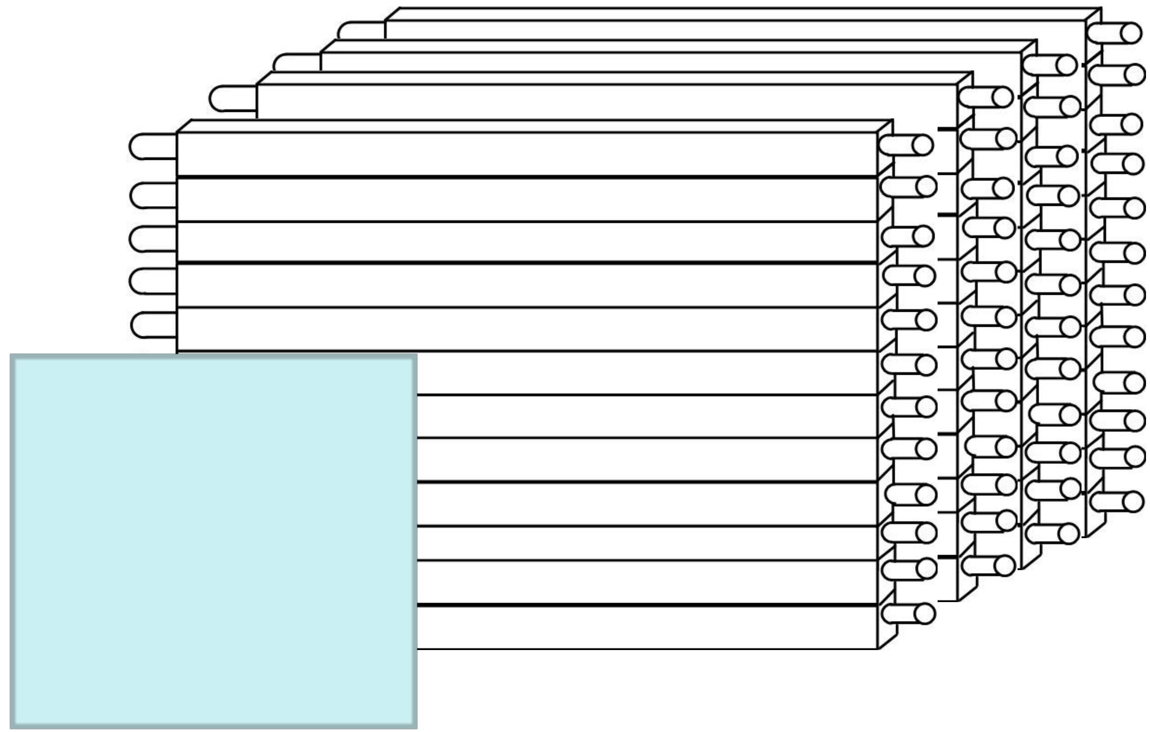




TOF resolution of a counter made of BC-408 66x3x3 cm^3 scintillator bar and fine-mesh Hammamatsu R7761-70 PM for minimum-ionizing particles

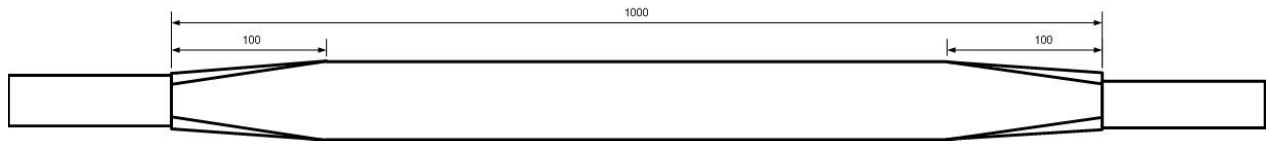
$\sigma_{TOF} \approx 33$ -37 ps (!)

Detector Design



Four separate layers each made of 16 counters covering altogether an active area of 80x80 cm.
Veto counter at the front.

Single counter will be a a 45x45x1000 mm3 scintillator bar viewed by two FEU-36 PMs

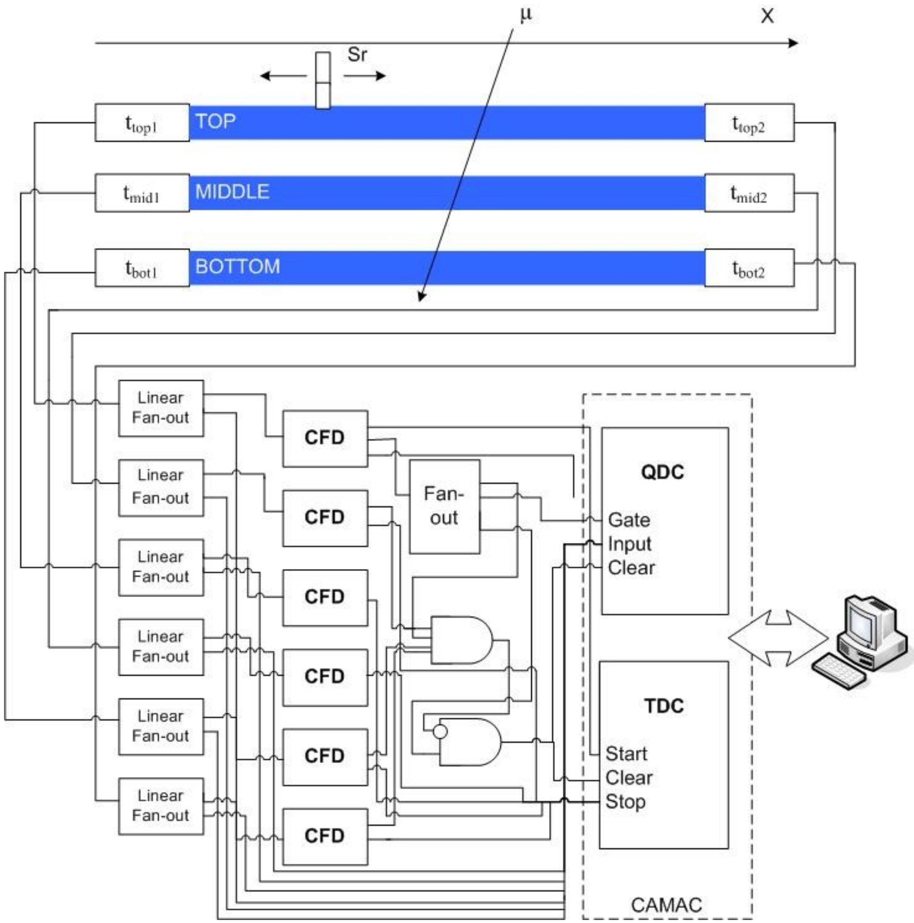


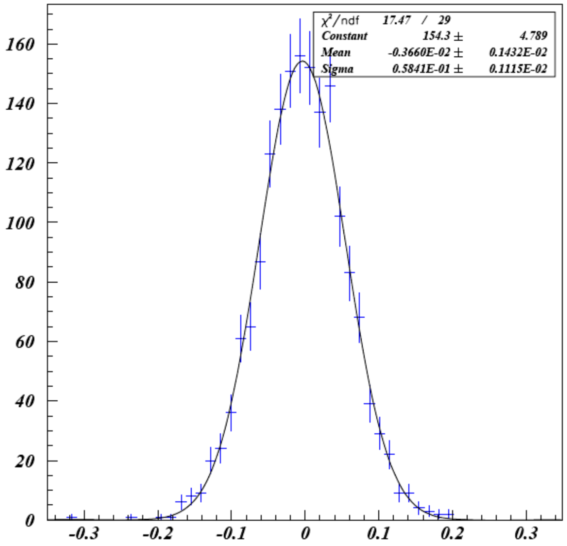
Anode pulse rise time ~ 3ns

Expected TOF resolutions:
~50 ps for MIP paricles,
50 – 150 ps for neutron
(depending on the threshold)

All components for one layer are available in LMP.

Measurement of TOF resolution
Cosmic-ray tracking





Basic Idea.

Cosmic ray tracking

- We make use of three counters equipped with six identical PMTs. The counters are aligned horizontally and are stacked parallel at equal distance each from the other. The times of scintillations caused by a cosmic-ray muon crossing all three counters (top, middle, and bottom respectively), are defined as:

$$t_{top} = (t_{top1} + t_{top2})/2 + C_1$$
$$t_{middle} = (t_{mid1} + t_{mid2})/2 + C_2$$
$$t_{bottom} = (t_{bot1} + t_{bot2})/2 + C_3$$

- Where t_{top1} **…** t_{bot2} are the corresponding TDCs readout values, C_1**…** C_6 are the calibration constants. The muon looses a small part of its energy/momentum inside the counters. Its velocity remains nearly constant. Therefore

$$t_{middle} = (t_{top} + t_{bottom})/2 + C$$

  or

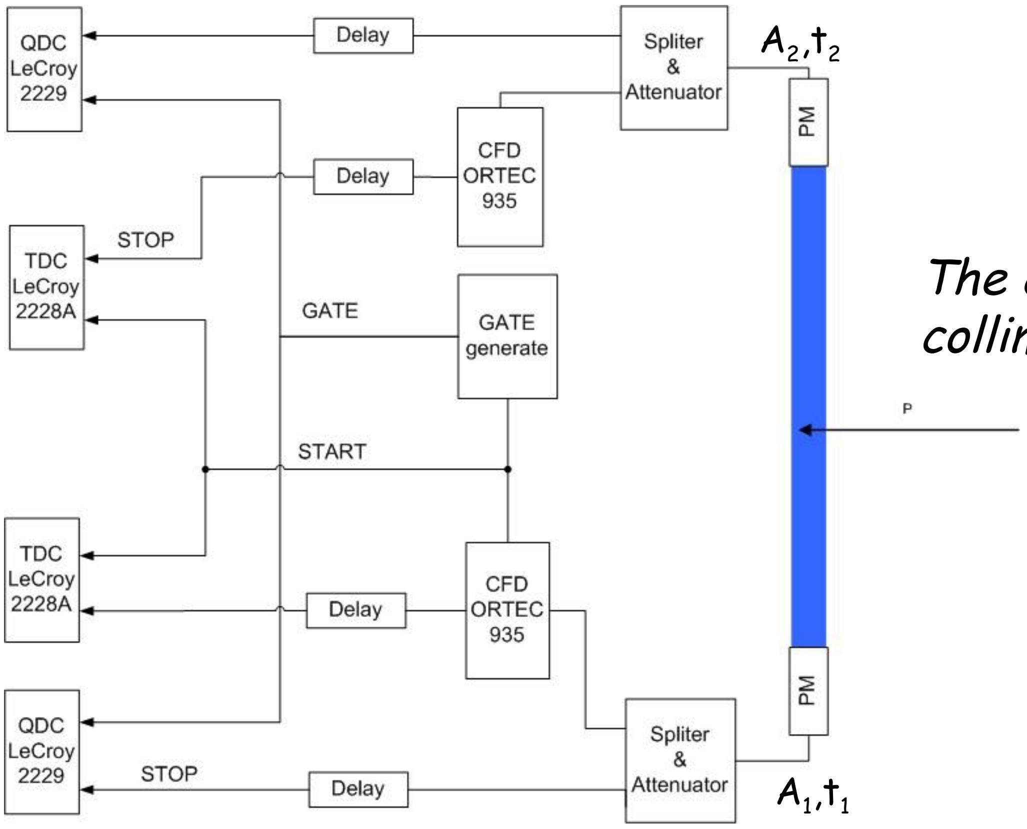
$$\tau = t_{middle} - (t_{top} + t_{bottom})/2 = (t_3 + t_4)/2 - (t_1 + t_2)/4 - (t_5 + t_6)/4 = C$$

- However, since t_1 **…** t_6 are smeared by the PMT resolutions, τ is distributed around some constant value ***C***. Using the variance of τ , one may deduce the average PMT resolution

$$\sigma_{PMT} = \frac{2}{\sqrt{3}}\sqrt{\mathrm{var}(\tau)} = \frac{2}{\sqrt{3}}\sigma_{\tau}$$

- In practice, the PMT resolution is derived from the Gaussian fit of the peak in the measured spectrum of τ.

Beam Test at PNPI: Basic Idea and Experimental Setup (developed previously in Korea)

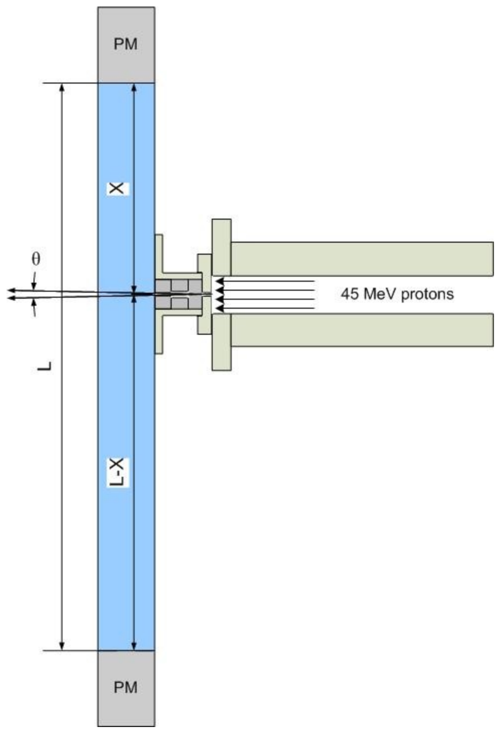


The counter is irradiated by well-collimated (point-like) beam.

Measured PM times are defined by the following relations

$t1=TOF+x/v+Const$; $t2=TOF+(L-x)/v+Const$;

Where TOF is time-of-flight of protons from a certain point (target), x is a hit position along the counter axis, L is the counter length, v is the efficient speed of light propagation inside the counter, Constants originate from cable and electronic delays.



$TOF=(t1+t2)/2+Const$; $x/v=(t1-t2)/2+Const$;

TOF resolution $\sigma_{TOF} = \sigma((t1+t2)/2)=$

$sqrt(\sigma^2_{t1}+\sigma^2_{t2})/2$;

Variation of $(t1-t2)/2$

$\sigma((t1-t2)/2) \approx \sigma_{TOF}+\Delta x/v$

where Δx is the size of the beam spot.

For a point-like beam ($\Delta x \sim 0$)

$\sigma((t1-t2)/2) \approx \sigma_{TOF}$

TOF resolution of a scintillator counter can be directly extracted from measured spectra of $(t1-t2)/2$

Possible experiments at LMP beam line

- Simultaneous measurements of pion scattering on the proton and on the neutron bound in a deuteron target

$$\pi^- p \to \pi^- p \qquad \pi^- n \to \pi^- n$$

- Study of $\pi^- p \to \pi^- X$ at low energies ~200 MeV/c
The goal is to verify the observation of narrow resonances with masses below Delta (1.004, 1044, and 1.094 GeV)
B.Tatischev et al., Phys. Rev. Lett. 79, 601(1997).

EPECUR (if repaired)

- **π^-p -> ηn** at the energies around ~1020 MeV/c
  Signal and properties of N*(1685)

- **π^-p -> K^-K^+n** (to be investigated in detail)
  Search for Θ^+

Byproducts

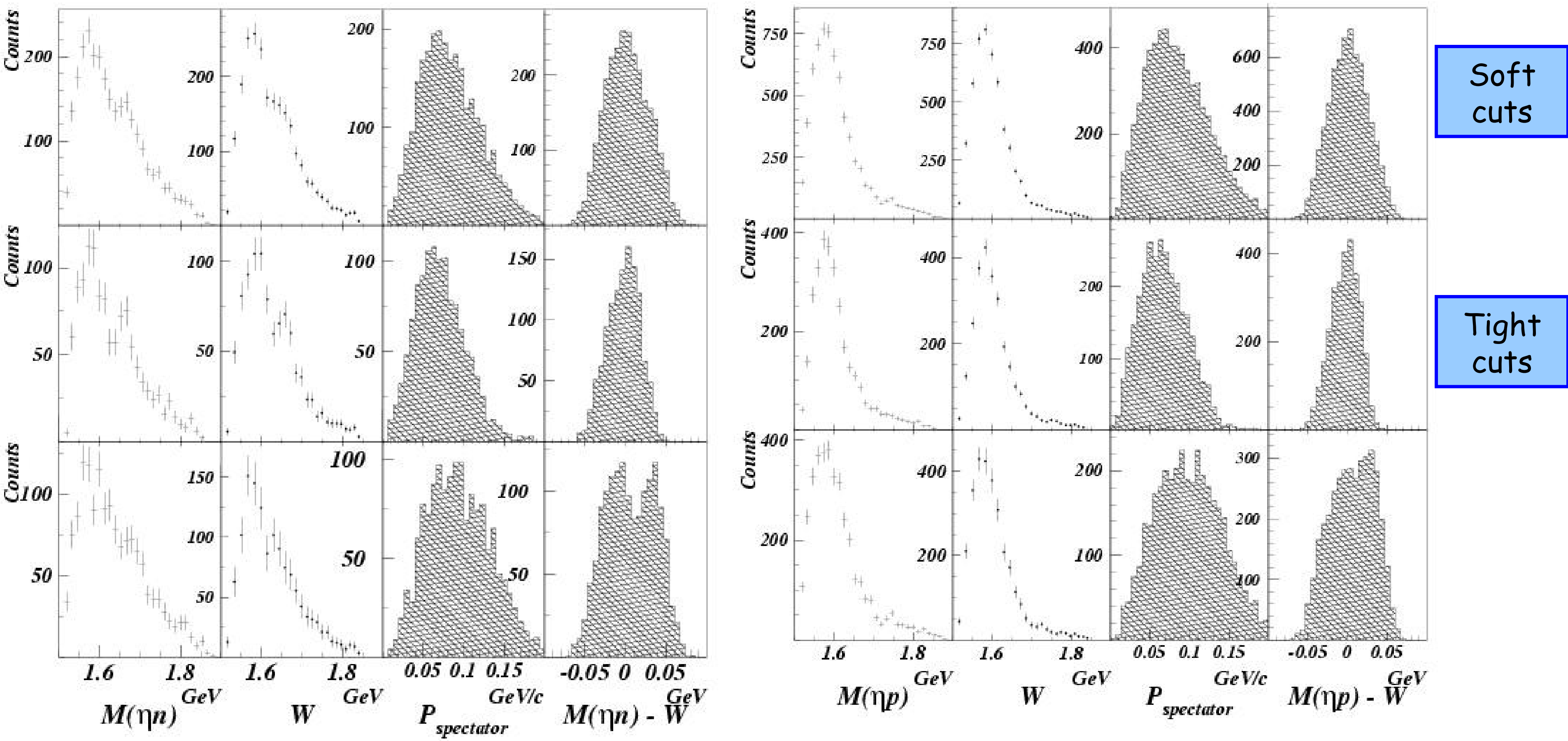
Potential participation in development/construction of new neutron detectors.

High-resolution neutron polarimeter for HallA@JLAB is now under discussion

-> possible collaboration with University of Catania and INFN Sezione di Catania.

Thank you for your attention!

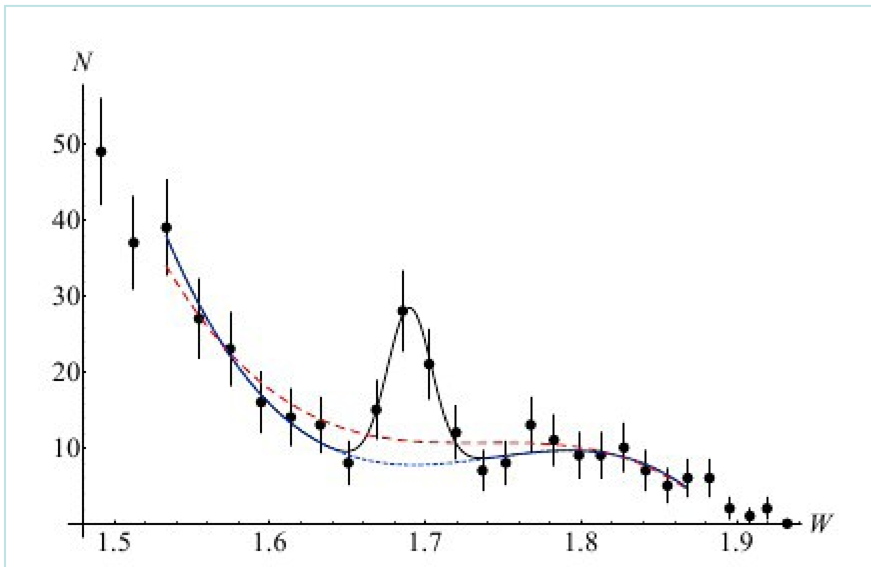
Yield of γN→ηN: Data and MC



Quasi-free neutron

Quasi-free proton

~4.6 σ

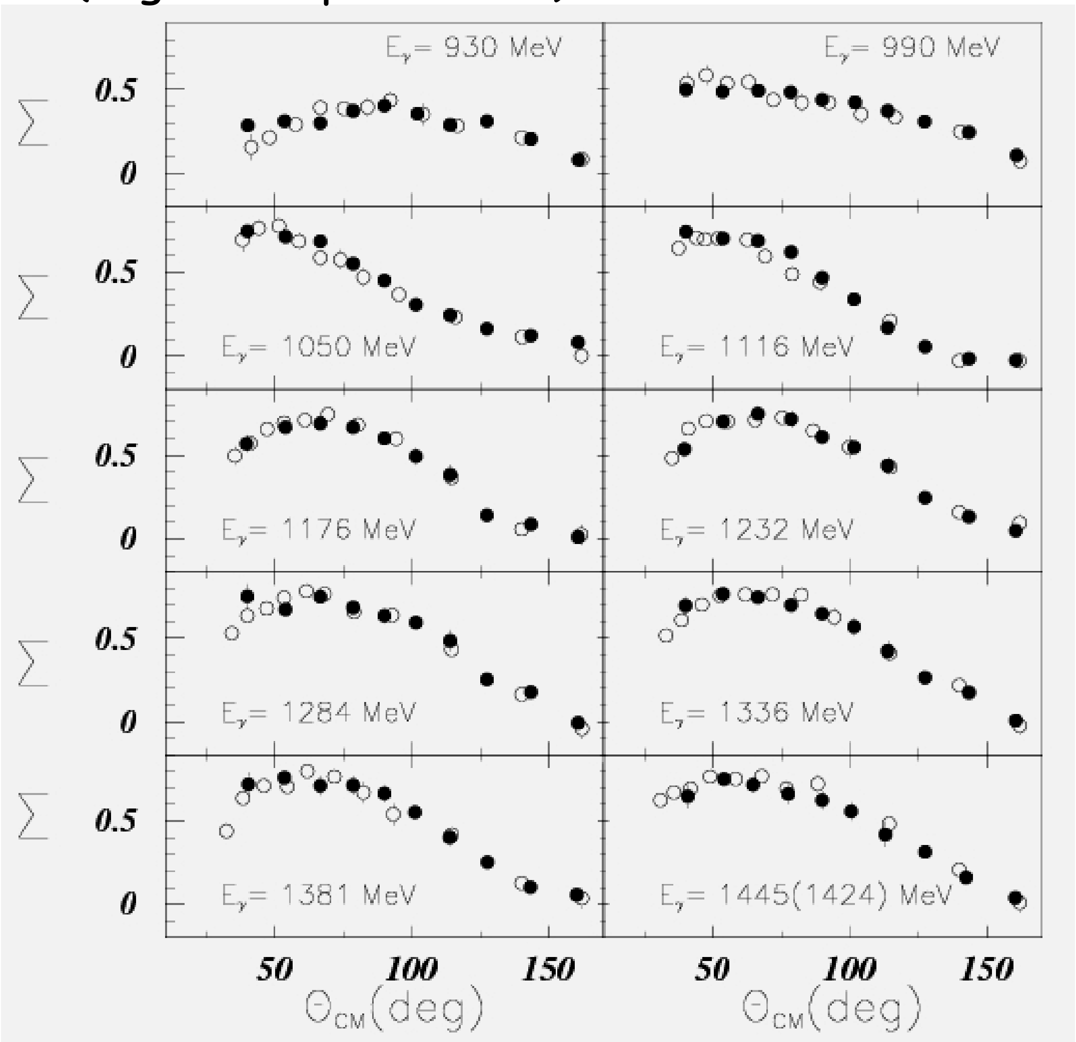


Comments on O.Bartalini *et al.* (by the GRAAL Collaboration (?)) ``Measurement of eta photoproduction on the proton from threshold to 1500 MeV", Nucl-ex:0707.1385.

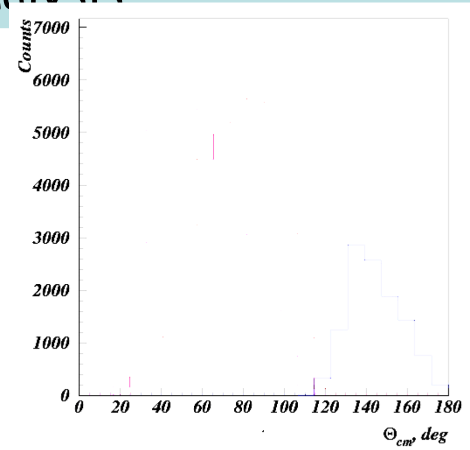
Data analysis has been performed by A.Lleres, LPSC Grenoble.

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)

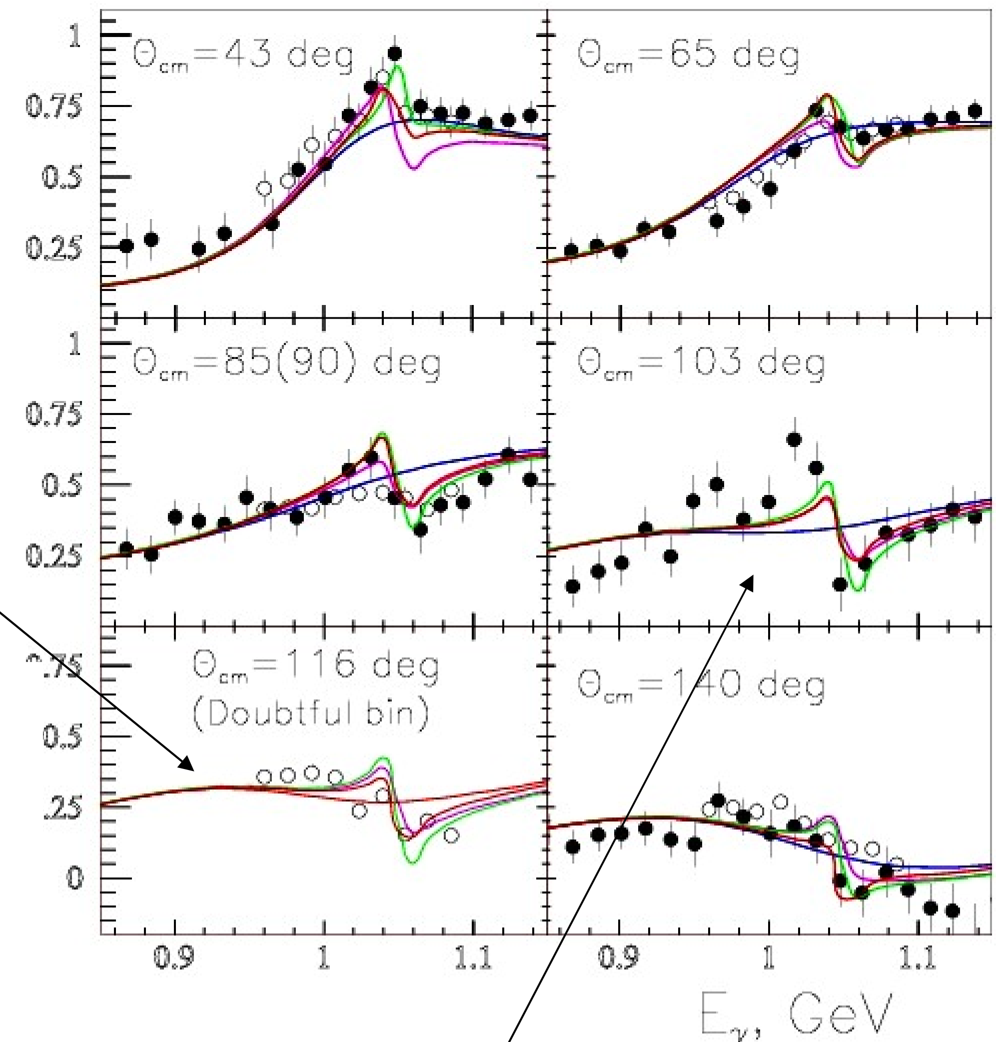


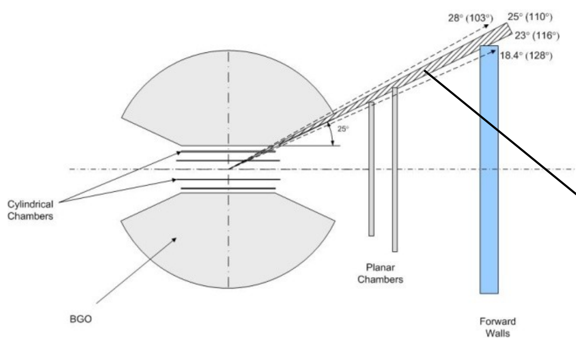
Despite the triple increase of statistics, new data are less accurate at forward angles! The reason is that events in which one of the photons from η→2γ decay is detected in the forward wall, are excluded from data analysis

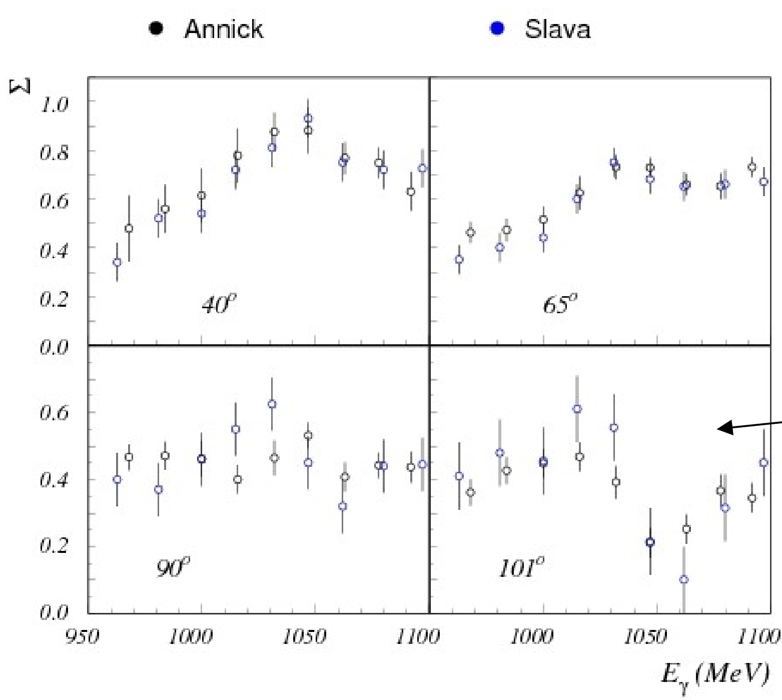


γp→ηp Yield for different types of events

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 with 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

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

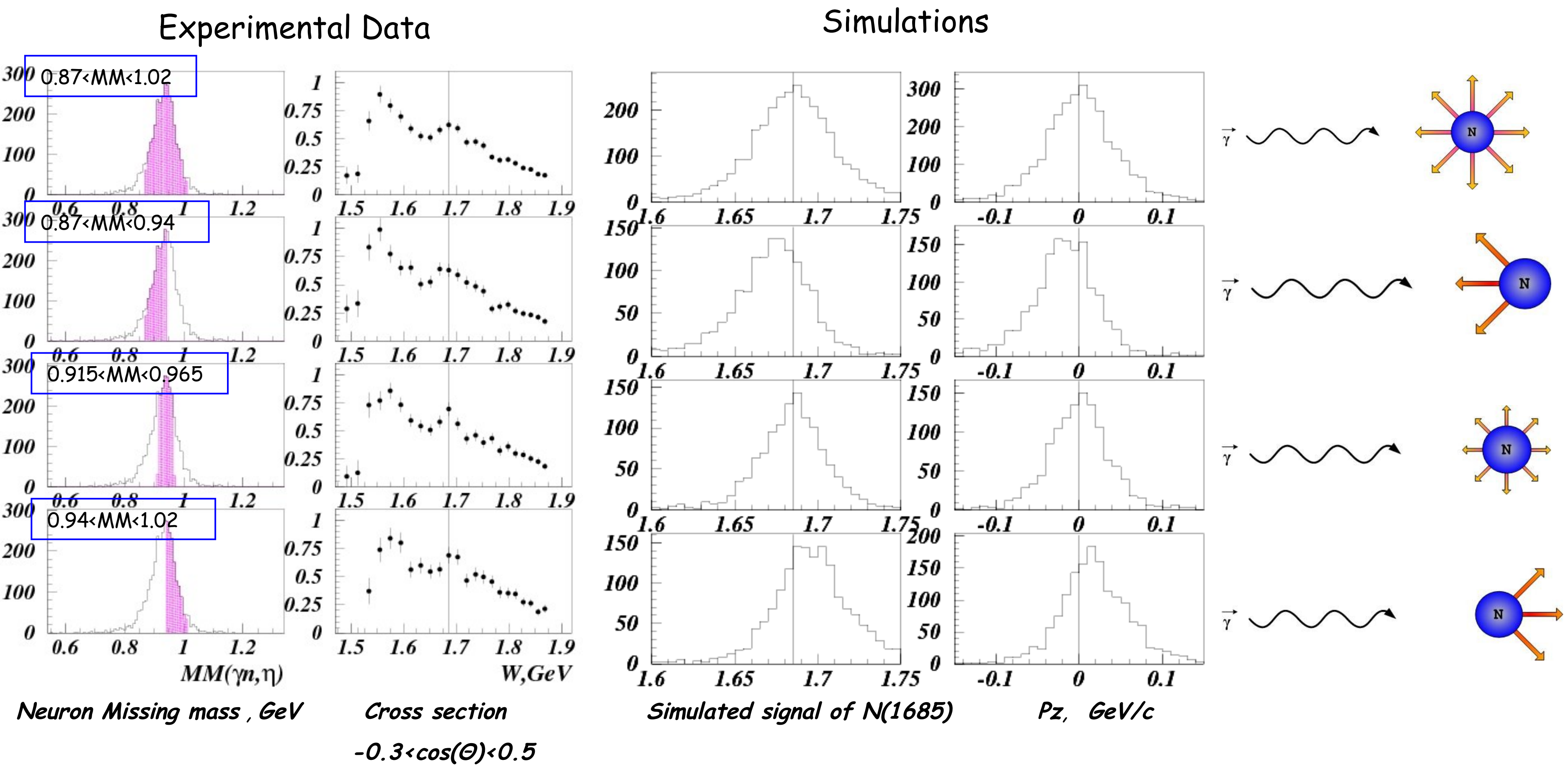
Cut-dependent Integral

Cut-dependent function

Cut-dependent FSI effects(not discussed here)

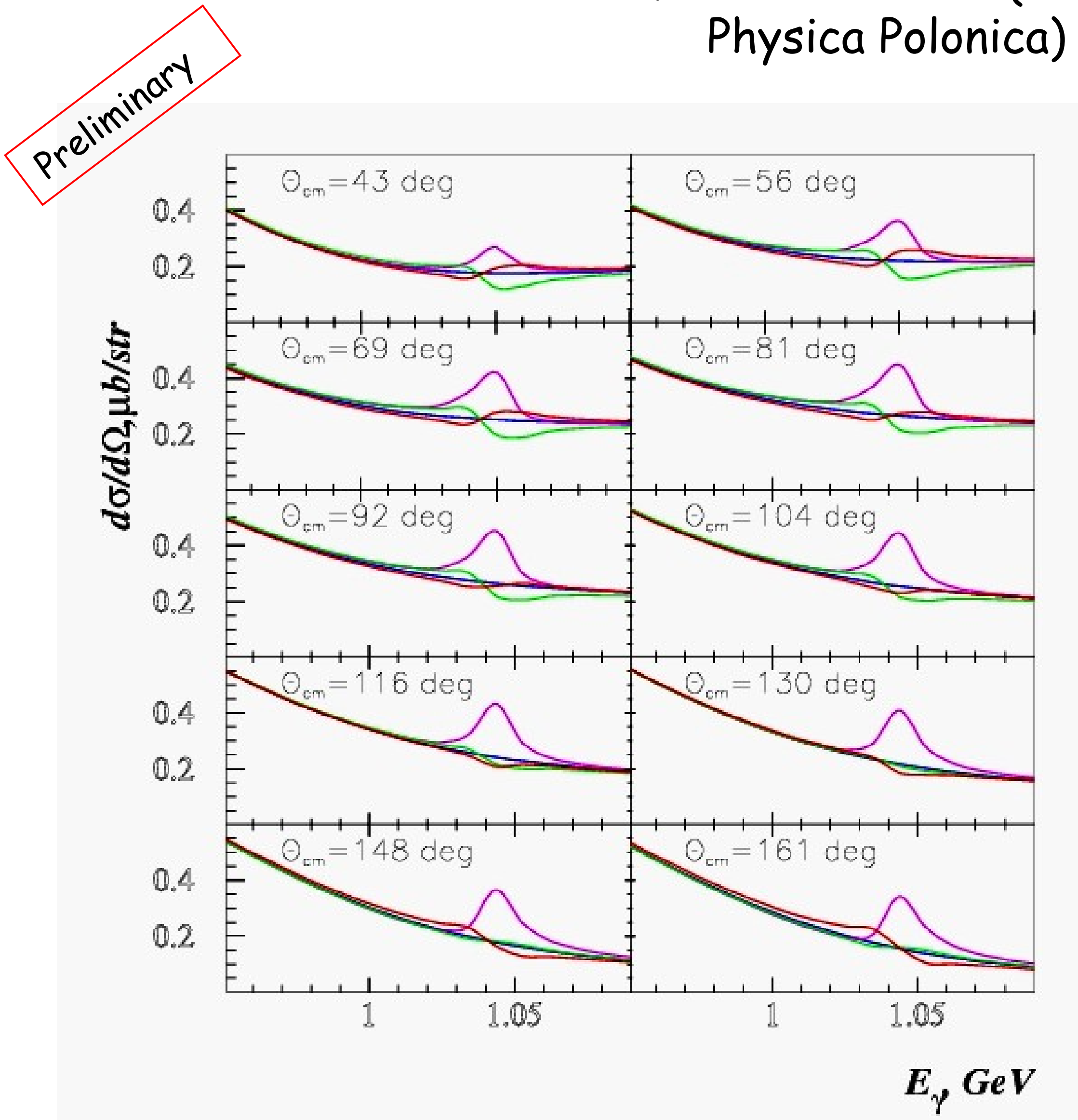
Is this formula applicable for experimental data?

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



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)



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

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