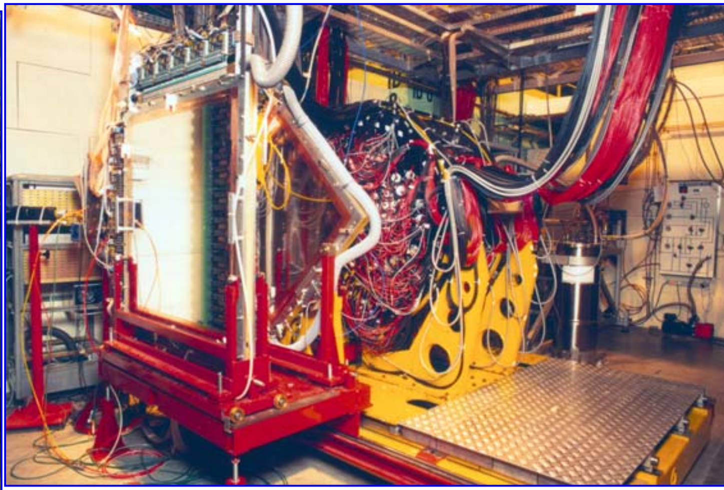
Evidence for Narrow N*(1685) Resonance: Open questions and New results from GRAAL



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and

Institute for Nuclear Research, 177312,Moscow

Outline

- Experimental Review on eta photoproduction on the neutron: Evidence for N*(1685) or interference of known resonances?;

- Cut-dependence of the quasi-free cross section;

- ηn Invariant mass spectrum and its dependece of time-of-filght resolution;

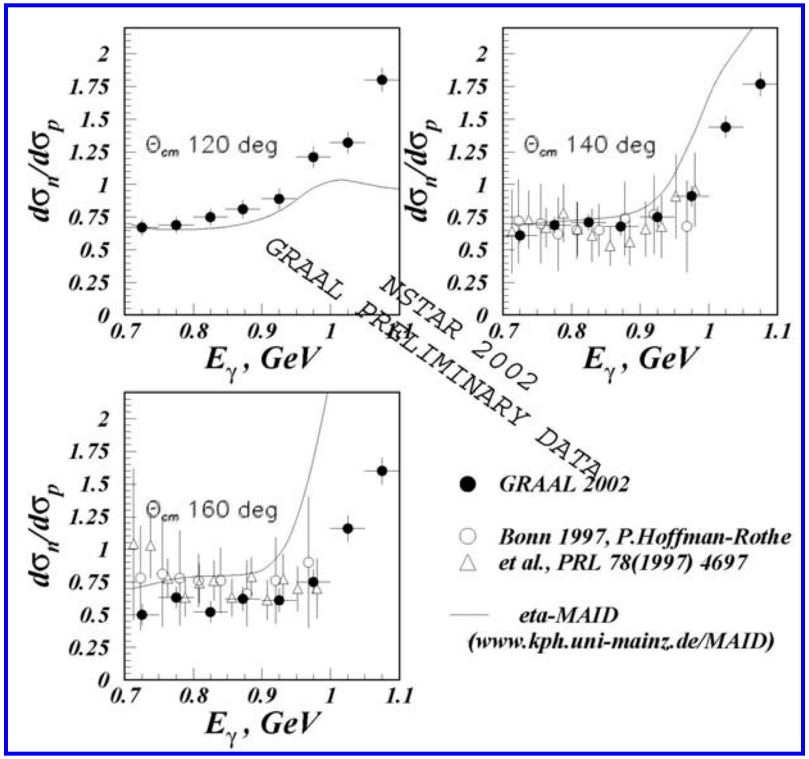
- Search for N*(1685) in other reactions;

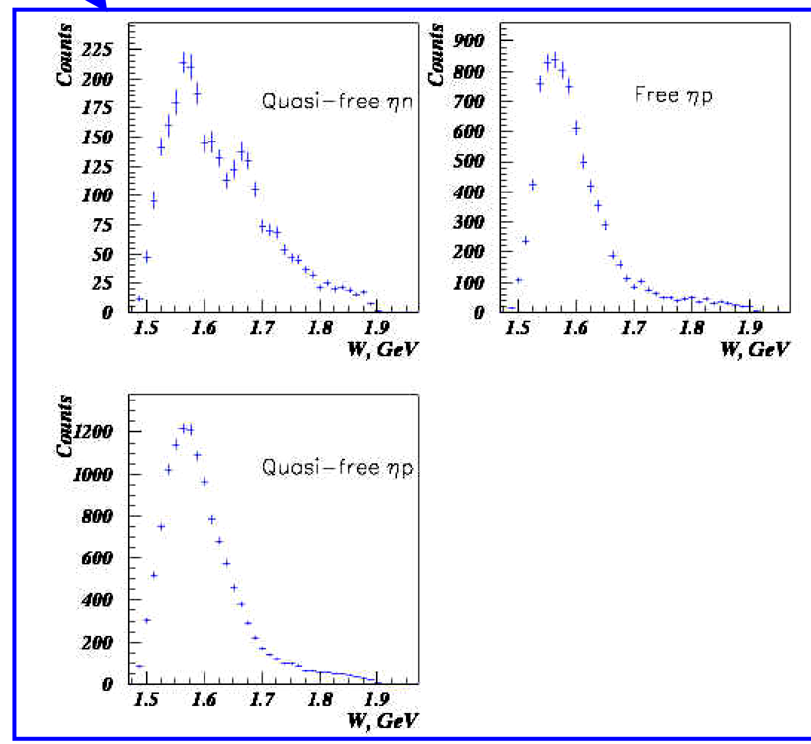
- Summary slides.

History of Experiments: First results on $\gamma n \to \eta n$

(Complete historical review in Talk of Ya. Azimov by Tuesday)

``On Photoexcitation of exotic Antidecuplet",
M.Polyakov, A.Rathke, EPJA 18, 691, 2003, Hep-ph/0303138





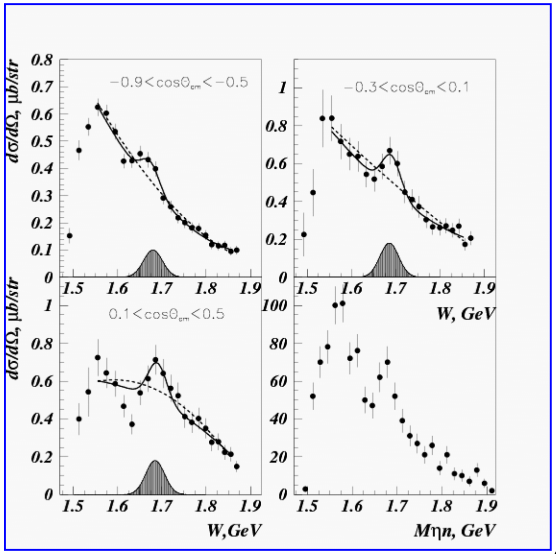
Sharp rise in the ratio of σ_n/σ_p

NSTAR2002, Pittsburgh, October 2002

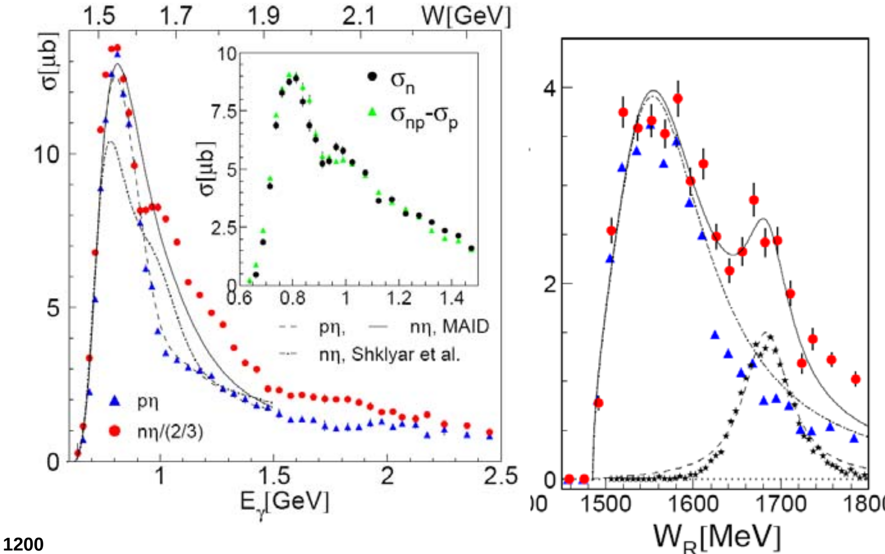
Peak structure at W~1.675 GeV

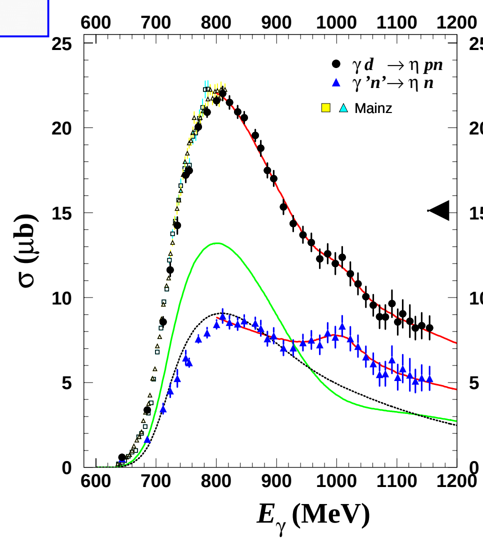
NSTAR2004, Grenoble, March 2004

Graal γn→ηn, V.Kuznetsov et al., Phys Lett. B647, 22,(2007); hep-ex/0606065.



CBELSA/TAPS γn→ηn, J.Jeagle, Phys. Rev. Lett. 100:252002 (2008); nucl-ex/0804.4841 (Talk of B.Krusche)

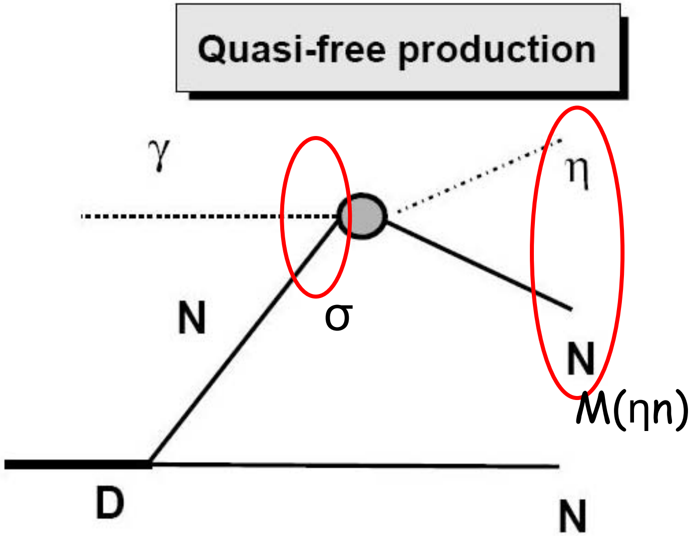


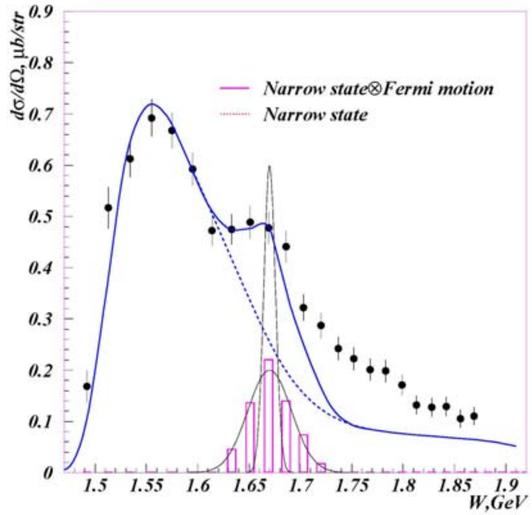


LNS-Sendai γn→ηn, Talk of H.Shimizu

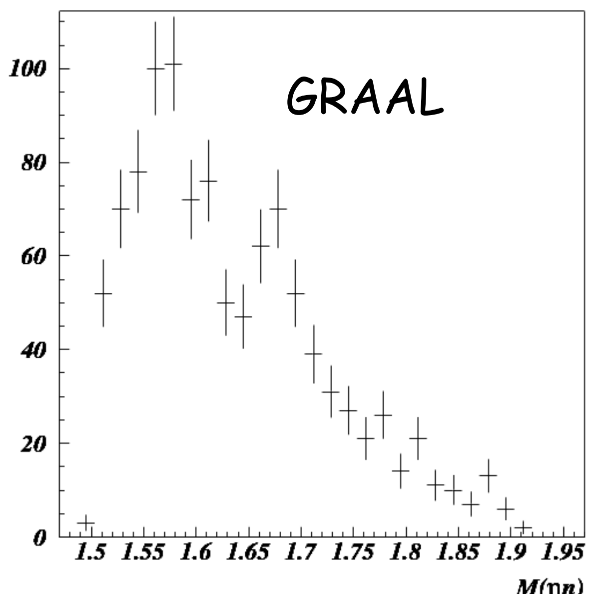
Narrow peak structure in the γn→ηn quasi-free cross section and in M(ηn) spectrum at W~1.67-1.685 GeV

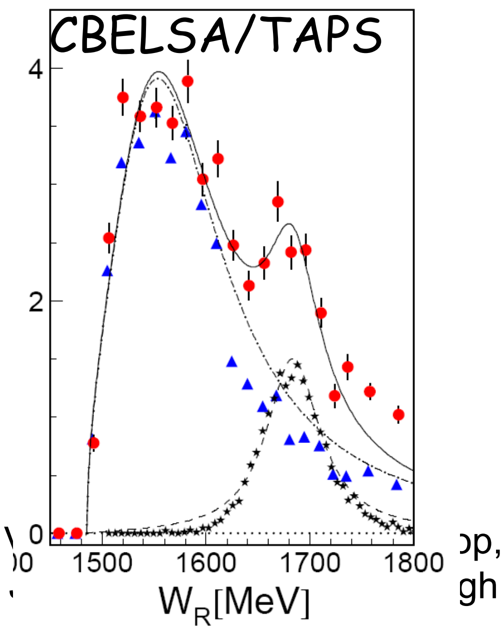
Quasi-free cross section is obtained assuming the target neutron to be at rest.. In reality the neutron bound in a deuteron target is not at rest → Experimental cross section is smeared by Fermi motion





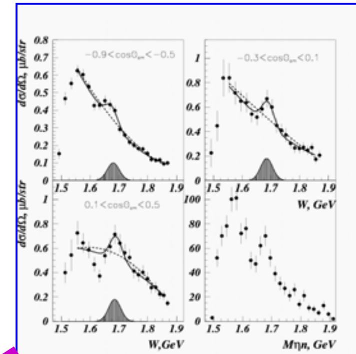
The width of the bump in the quasi-free cross section is close to that expected for a narrow resonance smeared by Fermi motion.



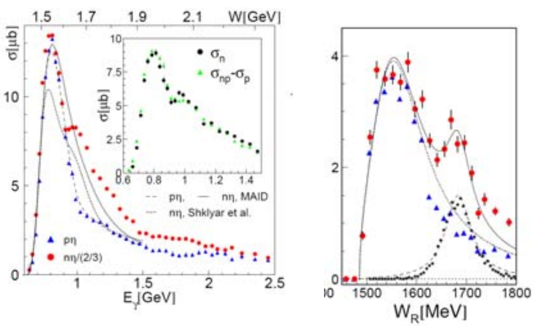


The invariant mass of the final-state η and the neutron is not affected by Fermi motion. The width of the peaks in the invariant-mass spectra are close to the instrumental resolution (40 MeV at GRAAL and 60 MeV at CBELSA/TAPS).

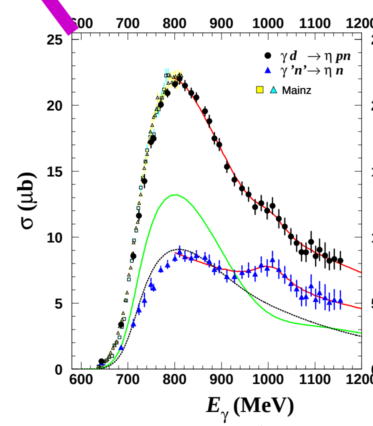
Graal $\gamma n \rightarrow \eta n$



New N*?



CBELSA/TAPS $\gamma n \rightarrow \eta n$



LNS-Sendai $\gamma n \rightarrow \eta n$

Available Intrepretations

New narrow nucleon resonance: Ya.Azimov, V.Kuznetsov, M.Polyakov, and I.Strakovsky, EPJA 25, 325(2005); A.Fix, M.Polyakov, and L.Tiator, EPJA 32,311(2007), hep-ph/0702034.

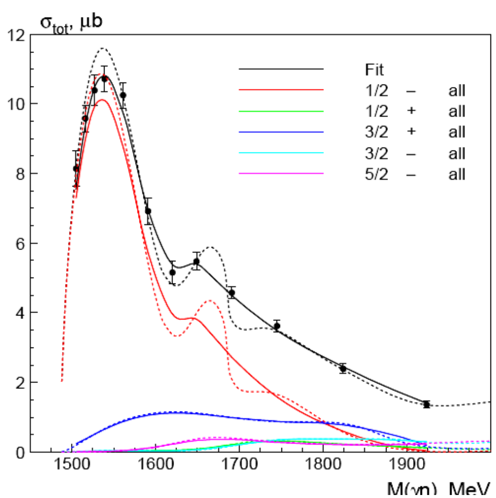
Interference of S11(1650) and P11(1710) .

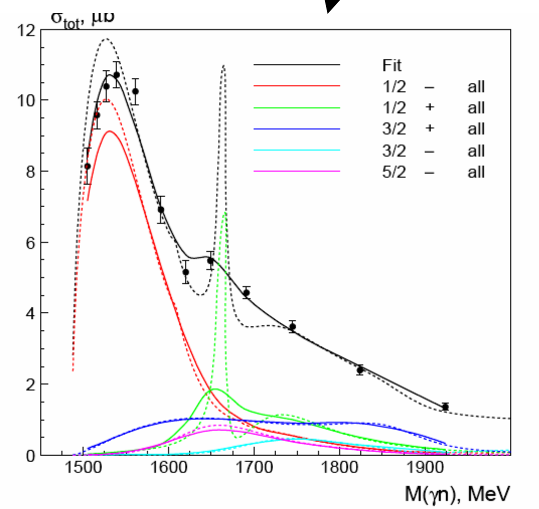
V. Shklyar, H. Lenske , U. Mosel , PLB650 (2007) 172 (Giessen group)

Interference effects of S11(1535) and S11(1650) or narrow P11(1670) resonance

A. Anisovich et al. ArXiv: hep-ph/0809.3340 (Bonn-Gatchina group)

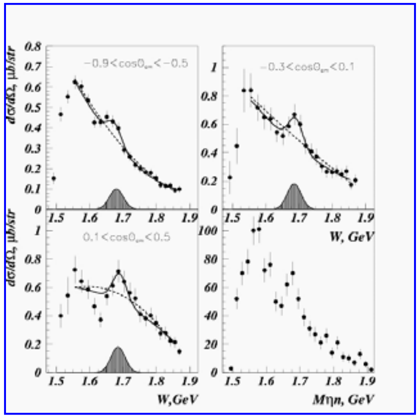
Fit of CBTAPS/ELSA data

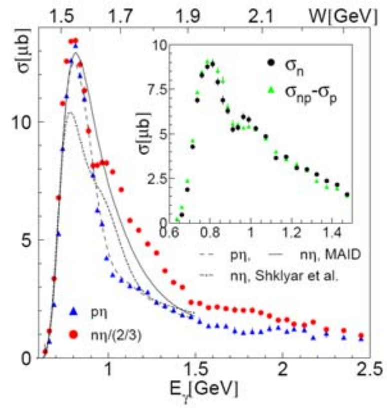


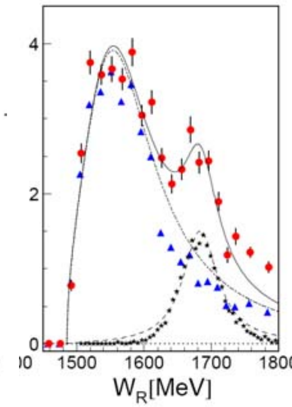


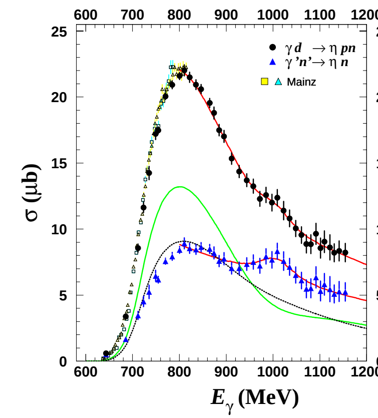
→ Situation to be understand

Is there the discrepancy between experimental data?









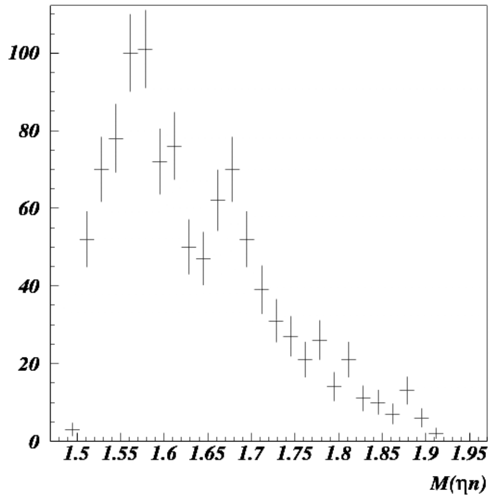
Graal: peak position in quasi-free cross section and M(ηn) spectrum is ~1.684 GeV;

CBTAPS-ELSA: peak position in quasi-free cross section ~1.67 GeV, peak position in M(ηn) spectrum is ~1.684 GeV;

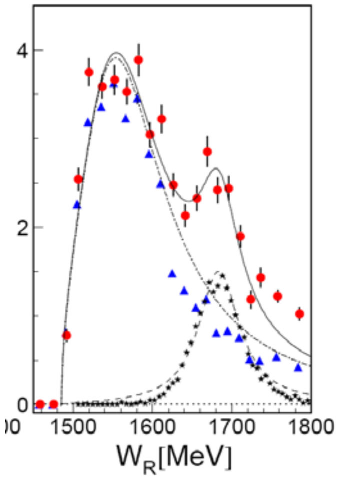
LNS: peak position is ~1.67 GeV;

Shape of the cross sections look different.

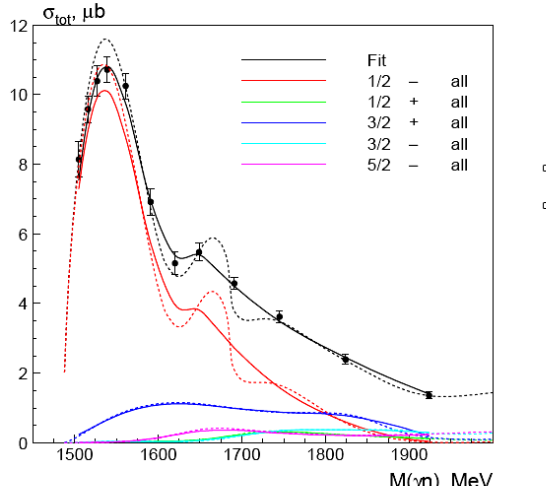
Fisrt Comments



Could Bonn-Gatchina and Geissen groups reproduce M(ηn) spectra?



Graal: Instrumental resolution ~40 MeV. The width of the peak is similar.



CBTAPS-ELSA: Instrumental resolution ~60 MeV. The width of the peak is again similar.

Assumptions on the interference of known resonances seem to contradict to the observed narrow peaks in the M(ηn) invariant-mass spectra from GRAAL and CBTAPS-ELSA. The structure in the calculated cross section is essentially wider. More is coming….

Cut-dependence of the quasi-free cross section

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

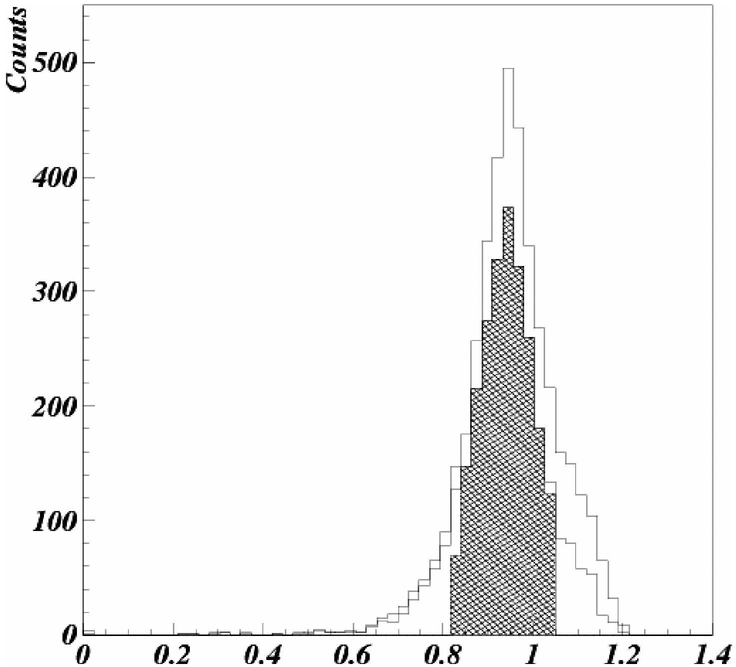
Cut-dependent FSI effects(not discussed here)

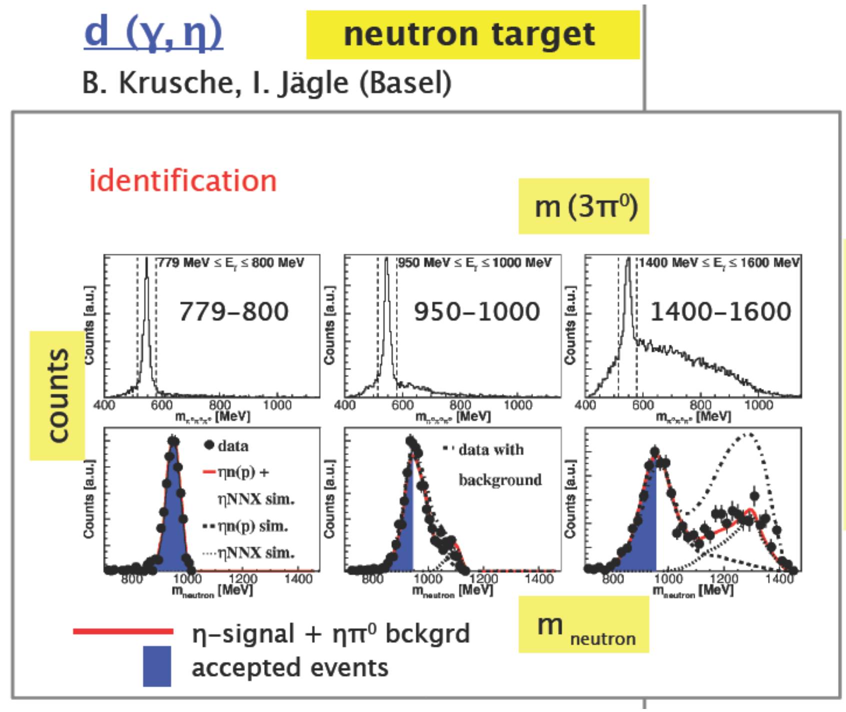
Is this formula applicable for experimental data?

Dependence on the cut on the neutron missing mass $MM(\gamma n,\eta)=sqrt((E_\gamma+m_n)_2-\mathbf{p}^2{}_n)$

As well as the qf cross section. MM is calculated assuming the target neutron to be at rest.

GRAAL and CBTAPS-ELSA groups used different cuts on the neutron missing mass.





GRAAL: Symmetric cut around the neutron mass

CBELSA-TAPS: Asymmetric cut $MM(\gamma n,\eta)<0.94$

Could this cut affect the experimental cross sections?

Simple Calculations by M.Polyakov

Smearing of the qf cross section is

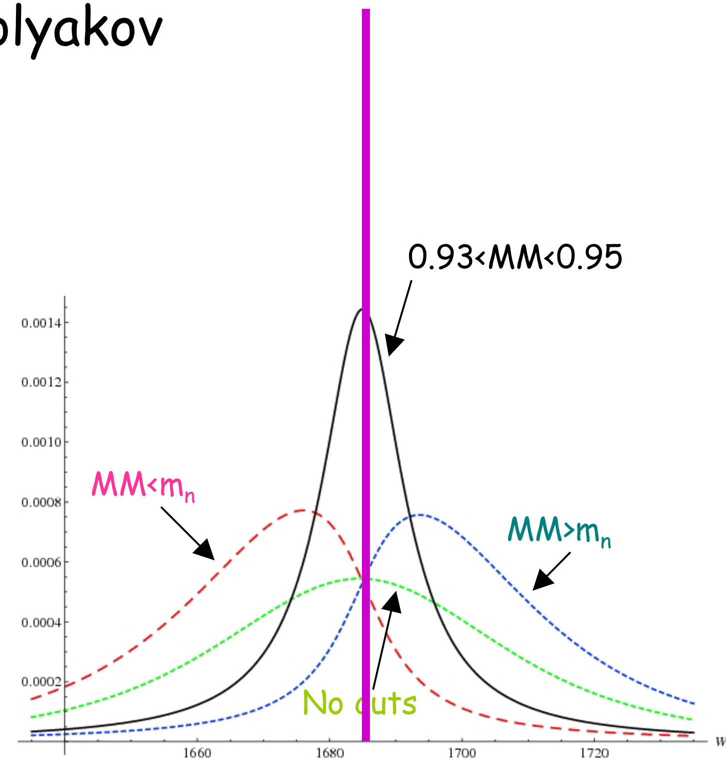
$$W^* - W \approx p_z E_\gamma / W$$

W* is the real center-of-mass energy, W is deduced from the photon energy assuming the target neutron to be at rest (the quantity really used in experiment). The smearing is mostly defined by the Z-projection of the momentum of the target neutron on the beam axis.

$$MM = m_n + p_z \alpha\left(W, \cos\theta_{\rm cm}\right) + \frac{|\vec{p}_\perp||p^*_\eta|}{m_n} \sin\theta_{\rm cm} \cos\Phi$$

Neutron missing mass is also smeared by Fermi motion! Any cut on the neutron missing mass MM means the selection of events with certain values of the Z-component, and, therefore, affects the smearing of the cross section!

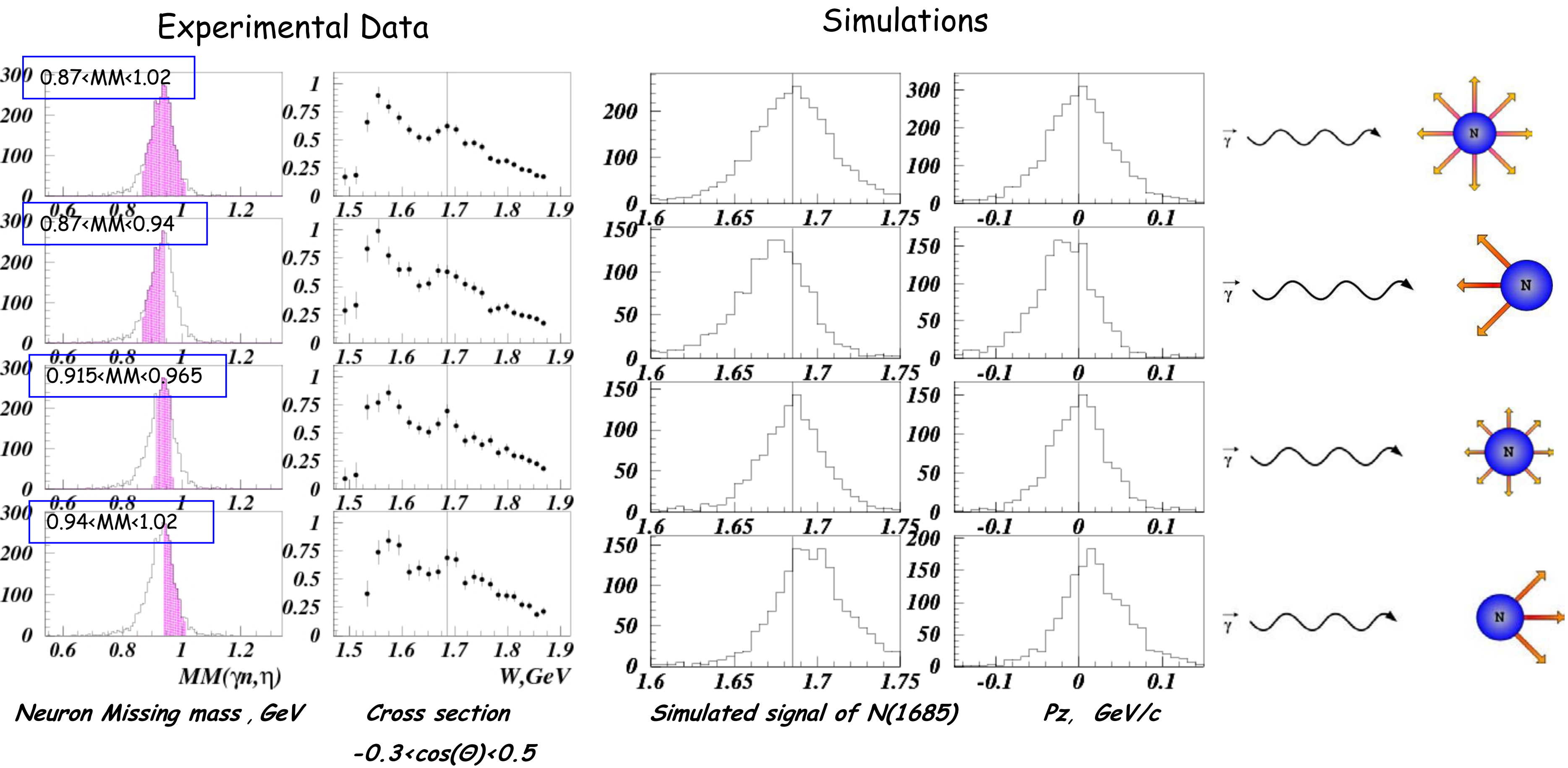
$$\alpha\left(W, \cos\theta_{\rm cm}\right) \equiv \frac{E_\gamma}{m_n}\left[1 - \frac{E^*_\eta}{W} - \frac{W^2 + m_n^2}{W^2 - m_n^2}\frac{|p^*_\eta|}{W}\cos\theta_{\rm cm}\right] \geq 0$$



Smearing of a narrow N(1685) resonance with different cuts on the neutron missing mass.

These cuts shift the peak position!

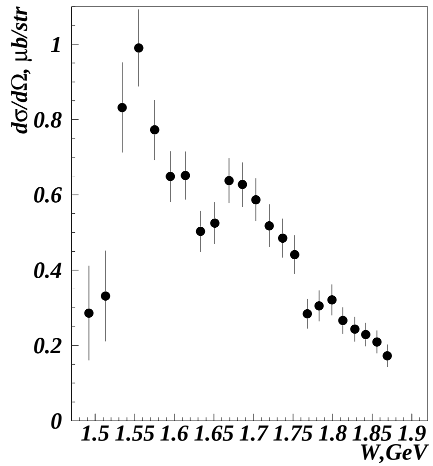
γn→ηn cross section with different cuts on the neutron missing mass



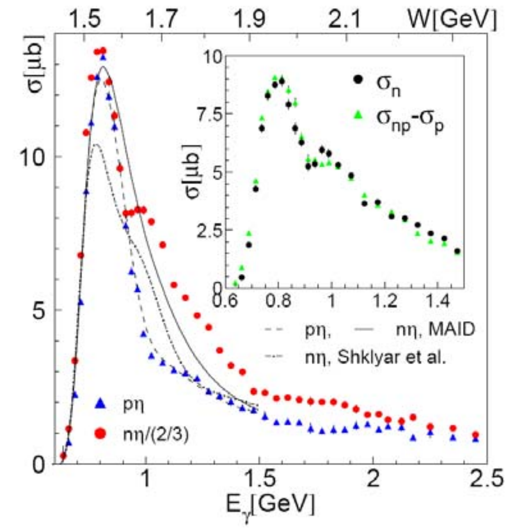
The width and the position of the peak in the γn→ηn cross section are affected by the cut on the neutron missing mass!

Cross sections with the asymmetric cut MM(γn,η)<0.94

GRAAL



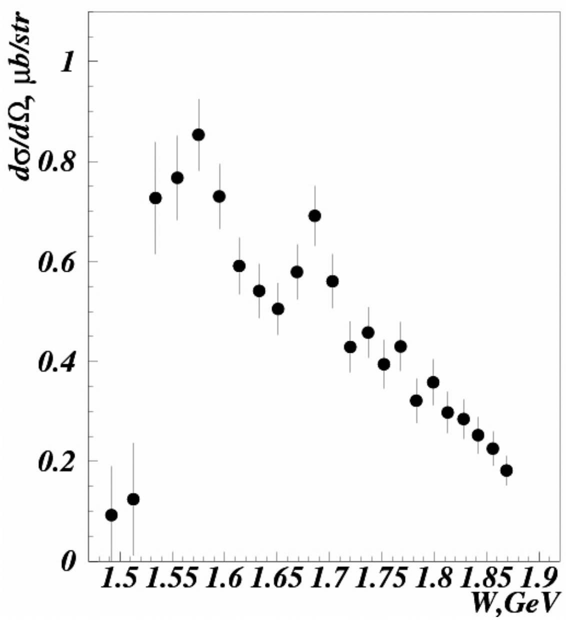
CBELSA-TAPS



With the asymmetric cut on the neutron missing mass GRAAL and CBTAPS-ELSA cross sections look similar. Peak is wide and is located at 1.67 GeV.

Has the effect bee taken into account in the fitting procedure by Bonn-Catchina and Giessen groups?

Cross section with the tight symmetric cut on MM(γn,η)



Cross section

M(ηn) spectrum

Tight symmetric cut on MM(γn,η) reduces the influence of Fermi motion. The peak is narrow (Γ≈30 MeV) and is located at W~1.685 GeV.

So narrow peak in the qf cross section seem not to be reproduced in terms of photoexcitation of known resonances.

Quasi-free Cross section is cut-, analysis-, and facility-dependent.

The procedure of its fitting still has to be established!

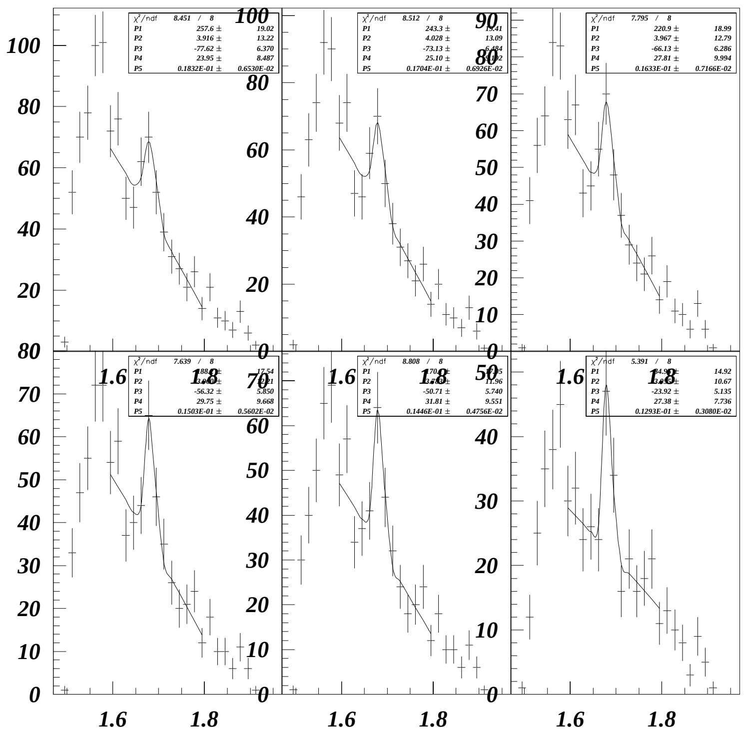
Invariant mass spectrum M(ηn) is not affected by Fermi motion. More on this spectrum in the next slide…

Dependence of M(ηn) spectrum on TOF resolution

(different cuts on the neutron light output in the Russian Wall at GRAAL"

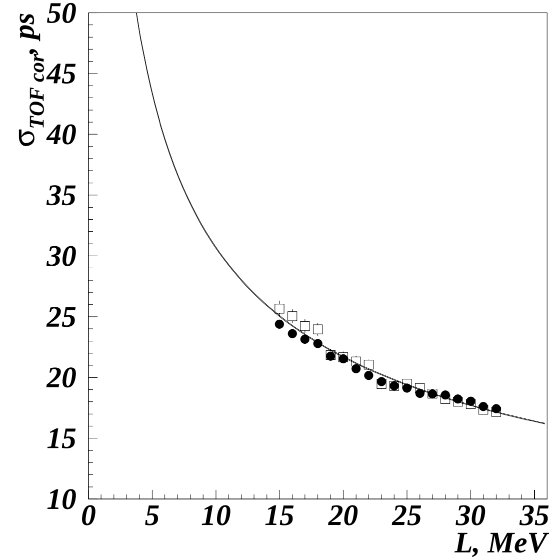
$\sigma(M(\eta n)) \sim \sigma_{TOF}$

$\sigma_{TOF} \sim 1/\mathrm{sqrt}(\text{Light output})$



Narrow peak

Γ≤30 MeV

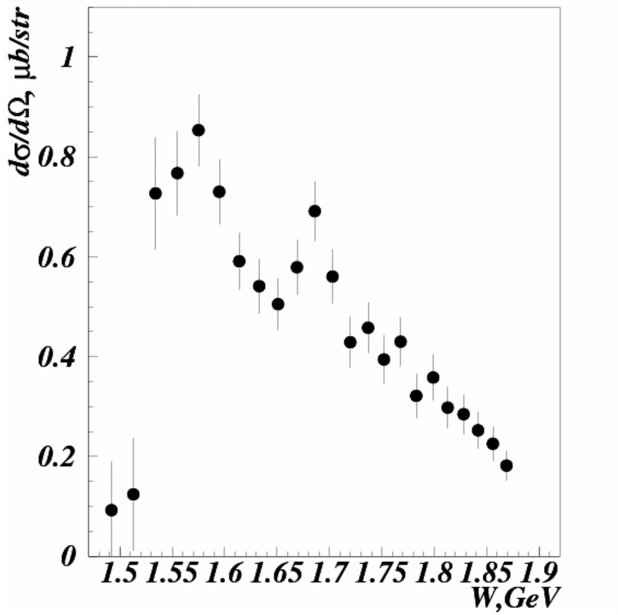


``Test Measurements of prototype counters for CLAS12 Central Time-of-Flight System using 45-MeV protons",

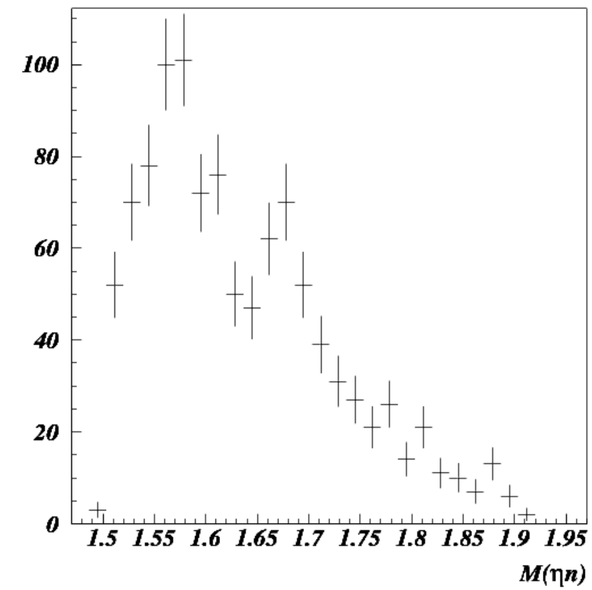
V.Kuznetsov et al, CLAS-Note 2009-016, Arxiv 0905.4109 [Phys-Det].

Russian Wall at GRAAL,

γn→ηn Cross section with the tight symmetric cut and M(nη)



Cross section



M(ηn) spectrum

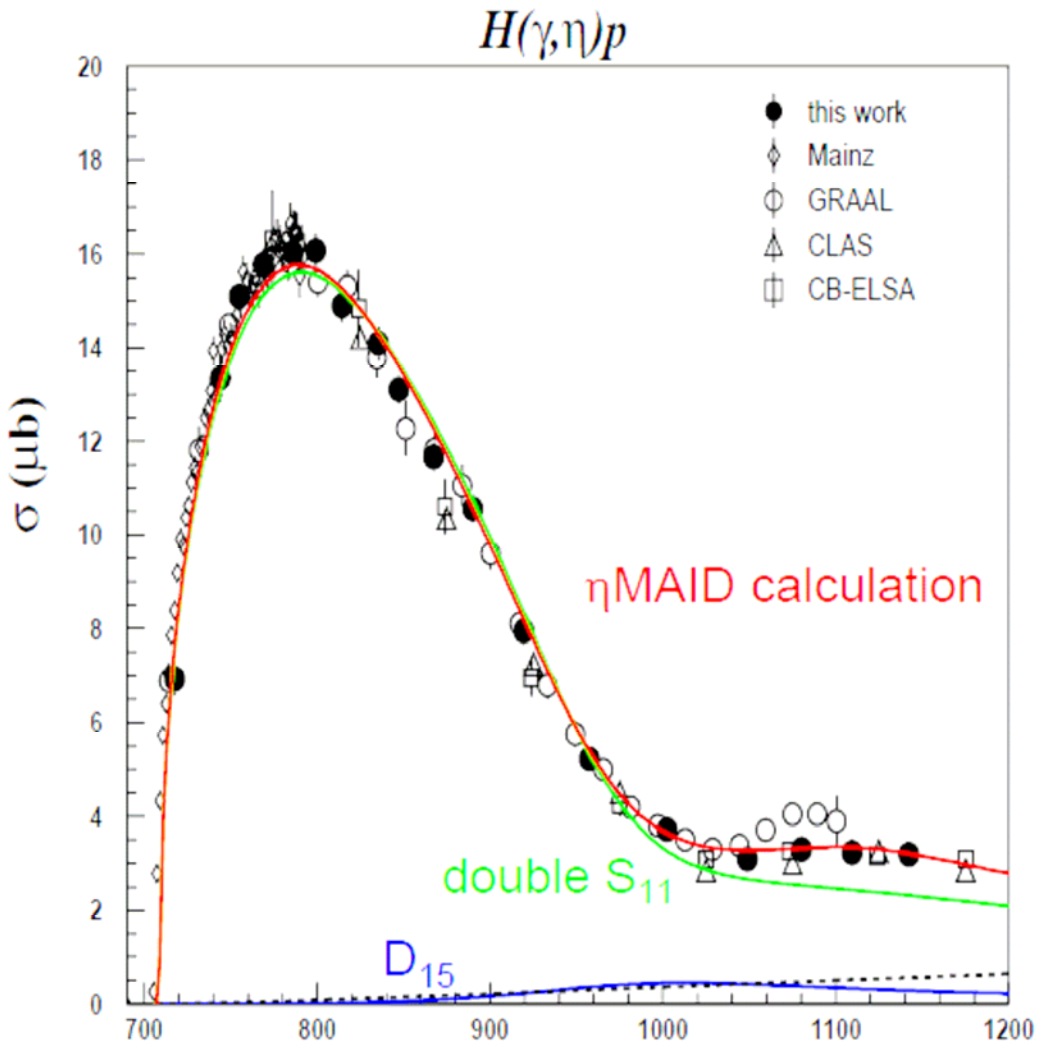
Both cross-section and M(nη) reveal the narrowpeak (Γ<30 MeV) located at W~1.685 GeV.

So narrow peaks in the cross section and in the M(η,n) spectrum seem not to be reproduced in terms of photoexcitation of known resonances. The only available explanation is the existence of a narrow resonance N*(1685).

→ **Obvious test is to search for this resonance in other reactions.**

Search for N(1685) in other reactions

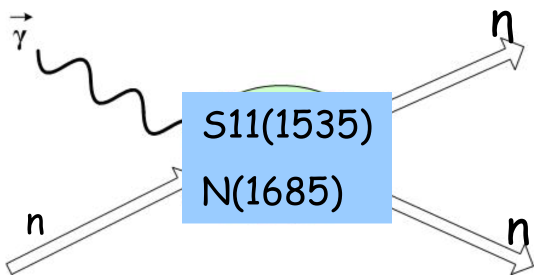
Total cross section
for the $\gamma p \rightarrow \eta p$ reaction

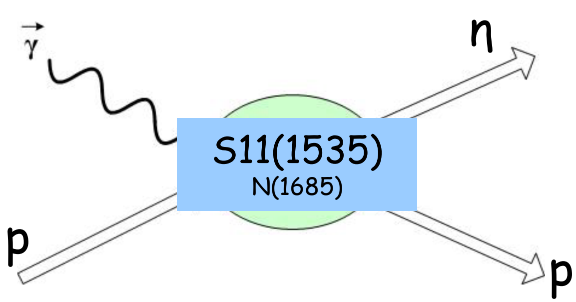


A narrow structure near W=1.68 GeV (Eγ≈1.05 GeV) is not (or poorly) seen in the eta photoproduction cross section on the free proton.

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

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



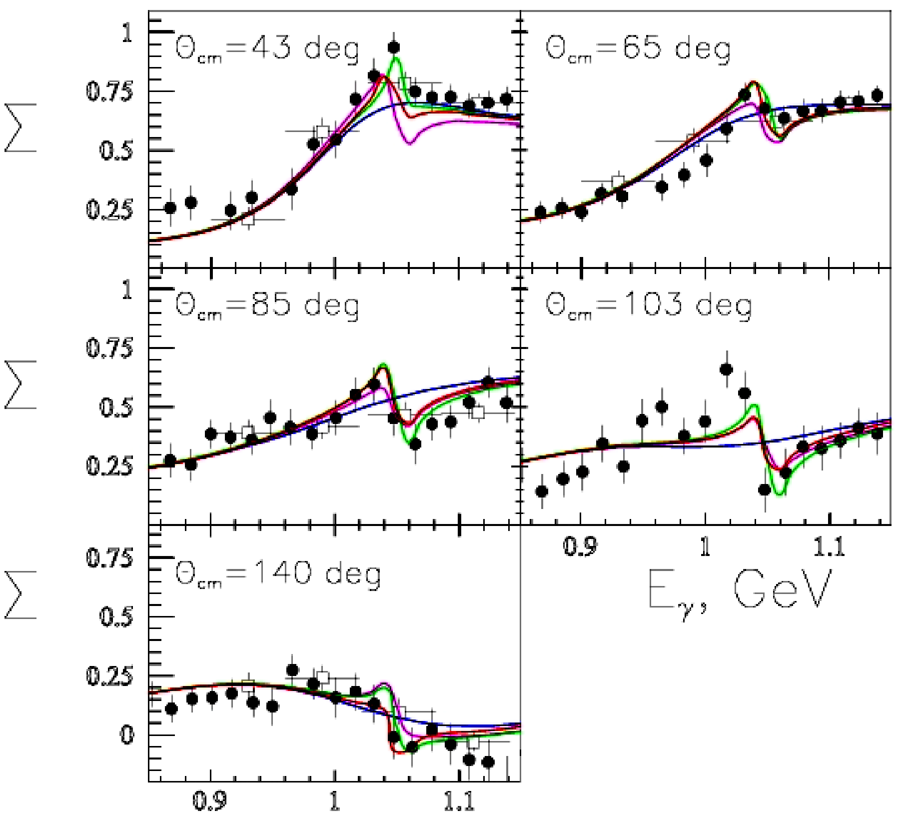


If photoexcitation of any resonance occurs on the neutron, it should also occur on the proton, even being suppressed by any reasons.

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.

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

V. Kuznetsov, M.V.Polyakov, et al., hep-ex/0703003
V. Kuznetsov, M.V.Polyakov, et al., Acta Physica Polonica , 39 (2008) 1949
V. Kuznetsov, M.V.Polyakov., 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, $\Gamma \leq 30$ MeV

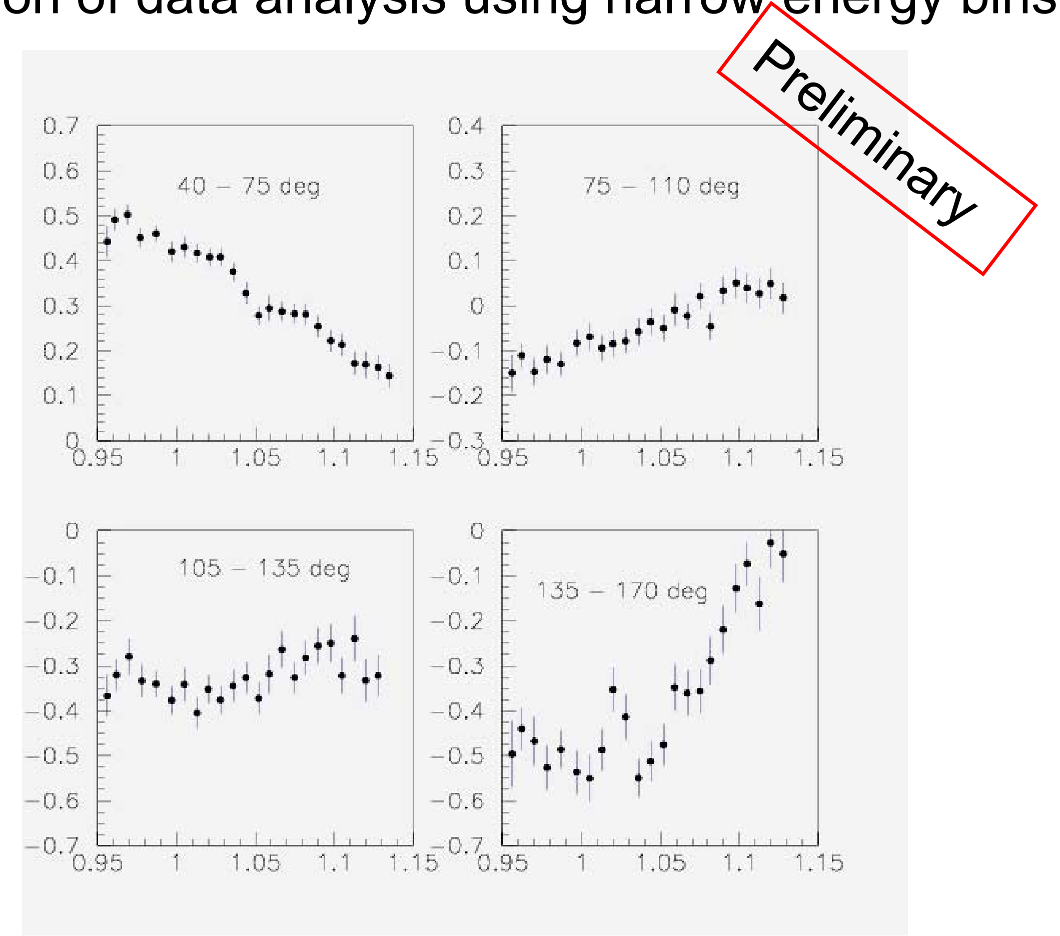
Comments on publication of O.Bartalini et.al . nucl-ex/07071385 are in backup slides.

$\gamma p \to \pi^+ n$ beam asymmetry Σ at GRAAL:

Phys. Lett. B**544**, 113 (2002),

Nucl-ex/0207010, (joint GRAAL-SAID publication).

Revision of data analysis using narrow energy bins

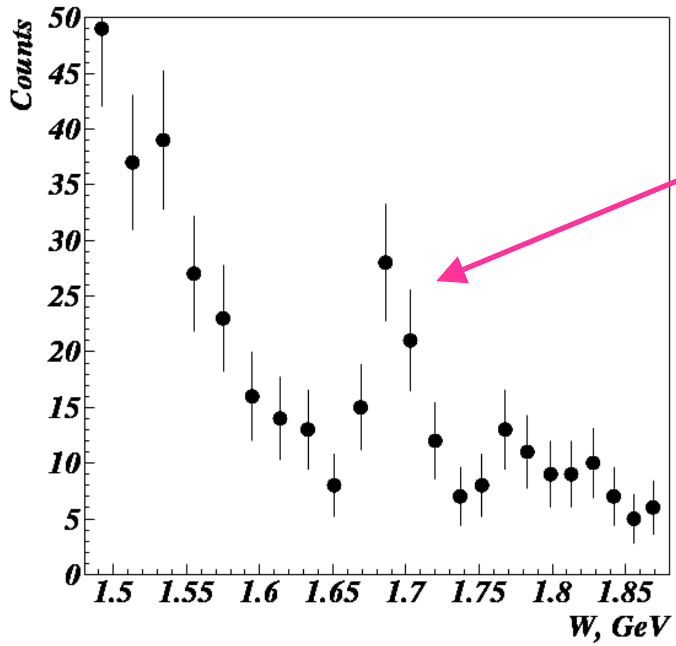


Backward-angles Compton scattering on the neutron at GRAAL

$\gamma n \rightarrow \gamma n$

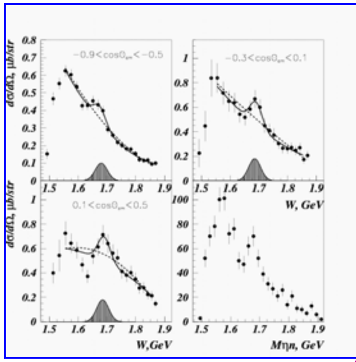
*First **Preliminary** Results*

(Details will be given in my Talk by Tuesday)

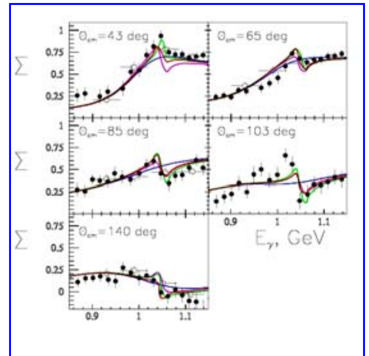


Narrow peak at W=1.685 GeV in Compton scattering on the neutron which is not seen in Compton scattering on the proton.

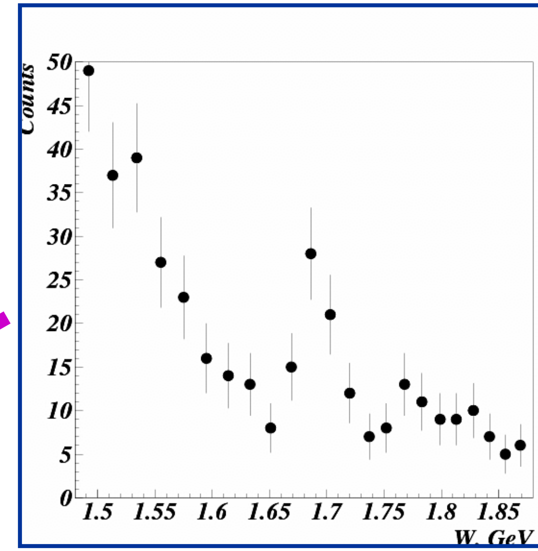
Graal γn→ηn



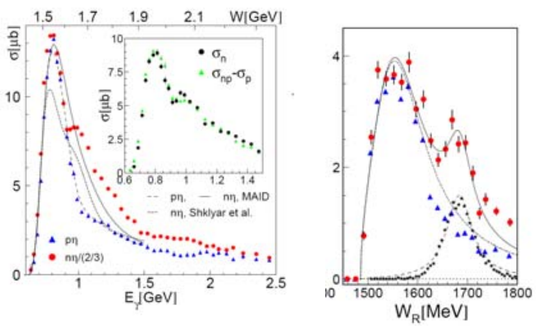
Graal γp→ηp



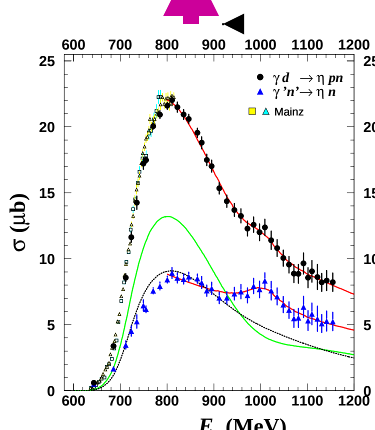
Graal γn→γn



N*(1685)



CBELSA/TAPS γn→ηn



LNS-Sendai γn→ηn

The only explanation that accommodates all experimental findings is the existence of a narrow N(1685) resonance (V.Kuznetsov, M.Polyakov, JEPT Lett. 88,347(2008)).

Properties of N*(1685)

- M=1685±10 MeV

- Γ≤30 MeV

- Isospin ½

- S=0

- Strong photoexcitation on the neutron and suppressed photoexcitation on the proton

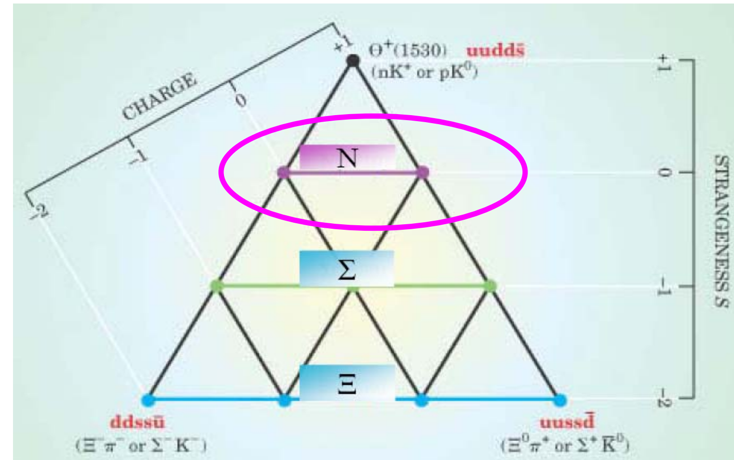
- Quantum numbers

P11, or P13, or D13

Reactions: γn→ηn; γn→γn

The properties of N*(1685) are similar to those predicted for the second member of the exotic antidecuplet.

Expected properties of the second member of the χQM antidecuplet (D.Diakonov, V.Petrov, M.Polyakov)



- 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
-Reactions: γn→ηn; γn→γn; γn→ KΛ

Thank you for your attention!

Polarization Observables in pseudo-scalar meson photoproduction

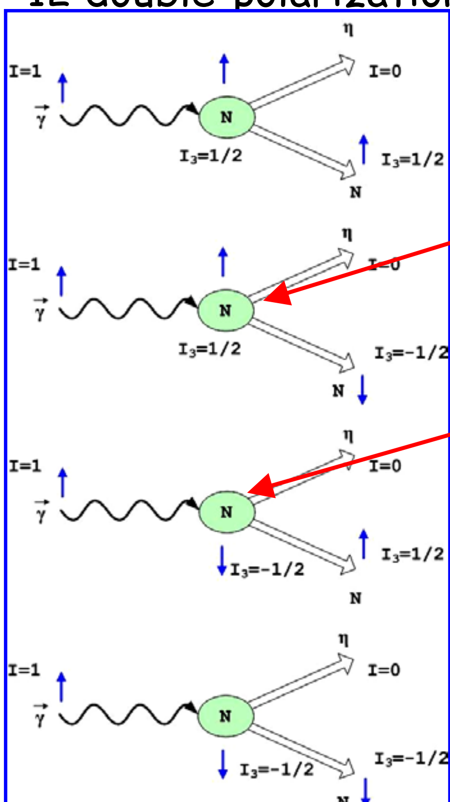
Unpolarized cross section σ

Beam asymmetry – Azimuthally asymmetry of the reaction yield relatively the linear polarization of the photon $\Sigma=(\sigma_{\parallel}-\sigma_{\perp})/(\sigma_{\parallel}+\sigma_{\perp})$:

Target asymmetry – Azimutal asymmetry of the reaction yield relatively the transverse polarization of the target nucleon $T=(\sigma_{\parallel}-\sigma_{\perp})/(\sigma_{\parallel}+\sigma_{\perp})$;

Recoil polarization – azimuthal asymmetry of the polarization of the recoil nucleon relatively reaction plane $P=(\sigma_{\parallel}-\sigma_{\perp})/(\sigma_{\parallel}+\sigma_{\perp})$

12 double-polarization observables



$H_{\uparrow\uparrow}$

$H_{\uparrow\downarrow}$

$H_{\downarrow\uparrow}$

$H_{\downarrow\downarrow}$

P11

S11(1535)

Dominates in cross section

S-P interference

Helicity amplitudes :

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

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

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

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

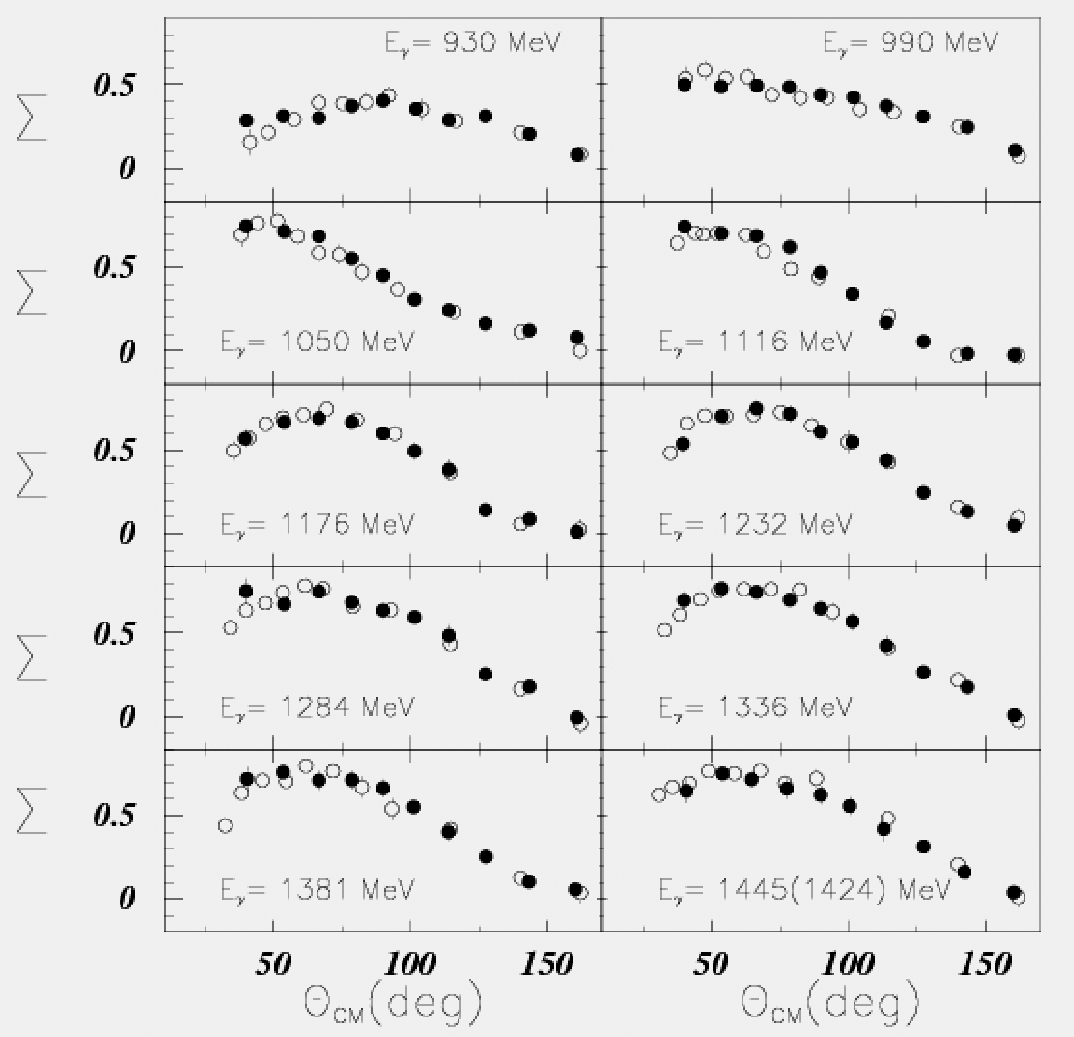
The signal of a weakly photoexcited P11 resonance may not be seen in the cross section, but might be well seen in the Σ beam asymmetry data through the interference with S11(1535)

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.

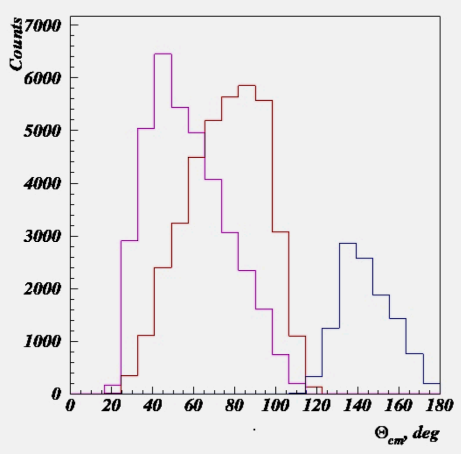
Data analysis has been performed by A.Lleres, LPSC Grenoble.

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)

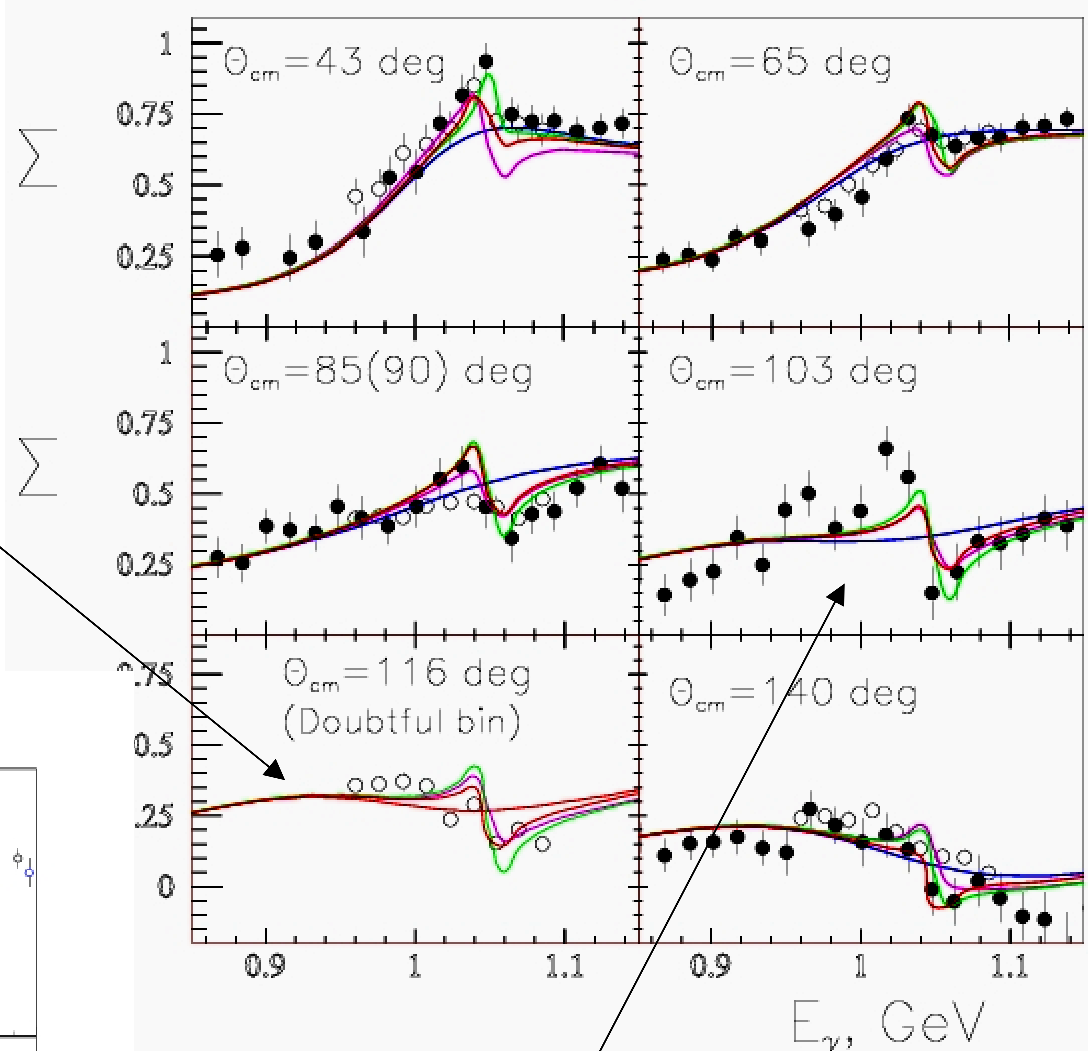


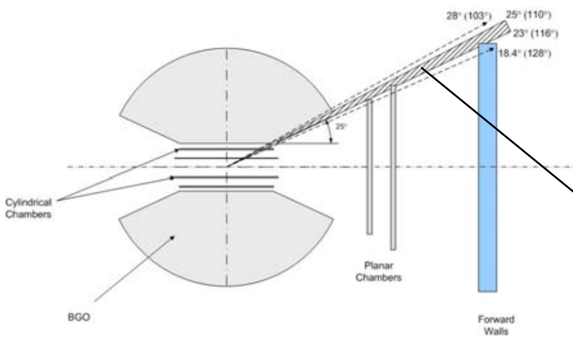
Despite the triple increase of statistics, new data are less accurate at forward angles! The reason is that events in which one of the photons from η→2γ decay is detected in the forward wall, are excluded from data analysis.

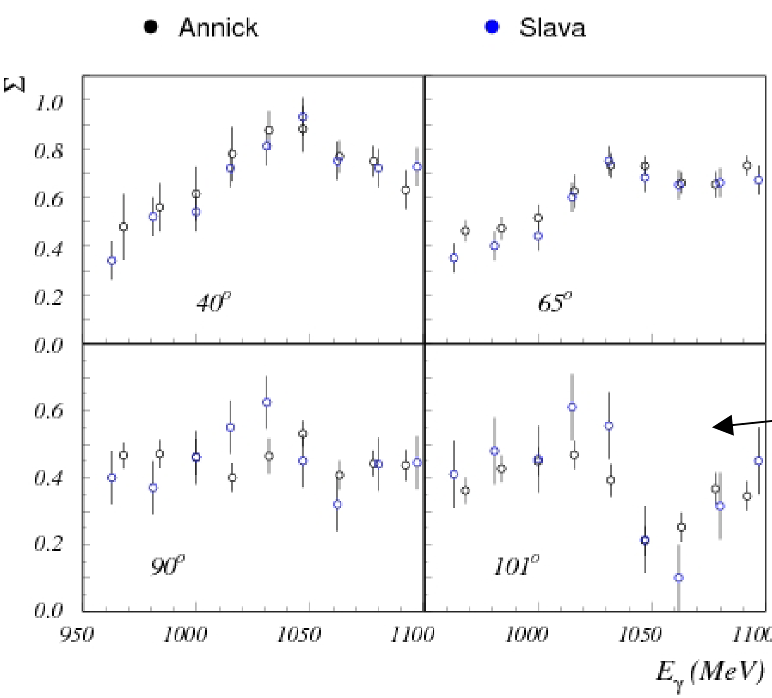


γp→ηp Yield for different types of events

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)).

The question to be addressed to authors of O.Bartalini et al.,

Nucl-ex:0707.1385 (A.Lleres):

- Why one type of events has been excluded from data analysis and how does it affect the quality of data at forward angles?

- What is the reason to choose the angular bin around 116 deg?

- Whether there is ``… a marked dip structure at 101 deg "(citation from A.Lleres, PC Feb 5, 2007) in the beam asymmetry data?

The beam asymmetry data reveal a sharp narrow structure at forward angles and near 103 deg. This structure might signal a narrow nucleon resonance.

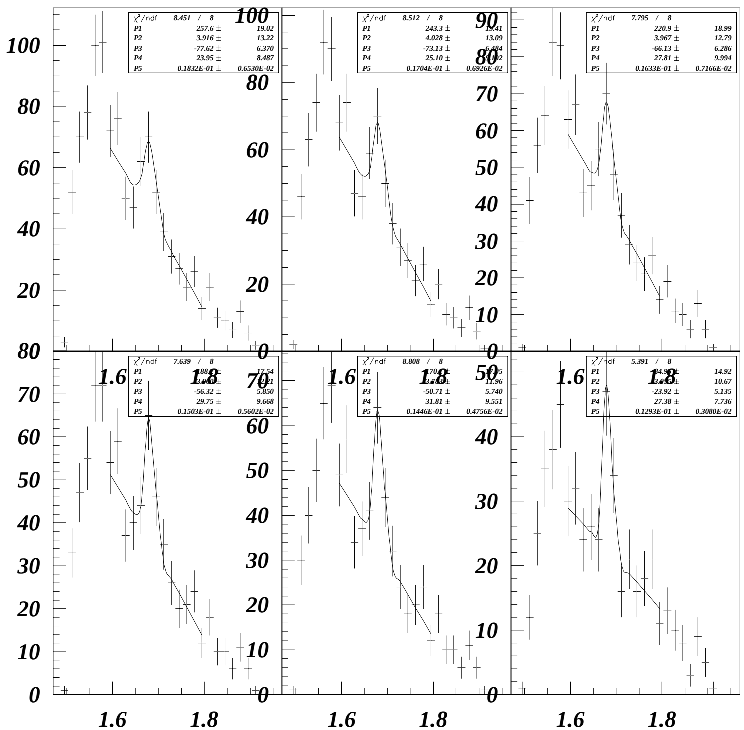
Dependence of M(ηn) spectrum of TOF resolution

(diferent cuts on the neutron light output in the Russian Wall at GRAAL"

$\sigma(M(\eta n)) \sim \sigma_{TOF}$

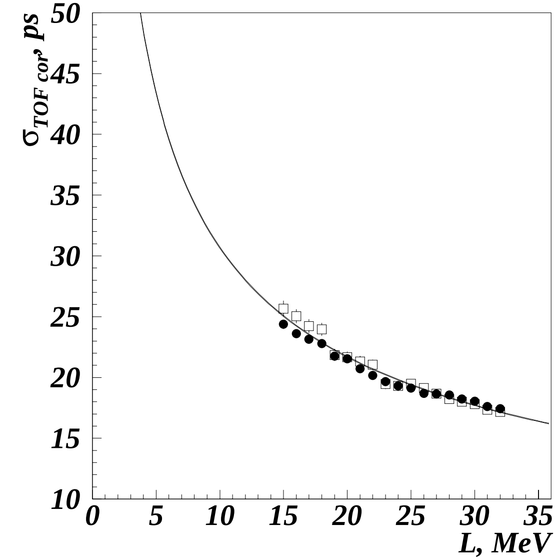
$\sigma_{TOF} \sim 1/\mathrm{sqrt}(\text{Light output})$

L>5MeV L>10 MeV L>15 MeV



L>20MeV L>30 MeV L>40 MeV

Γ≤30 MeV



``Test Measurements of prototype counters for CLAS12 Central Time-of-Flight System using 45-MeV protons",

V.Kuznetsov et al, CLAS-Note 2009-016, Arxiv 0905.4109 [Phys-Det].

Russian Wall at GRAAL,