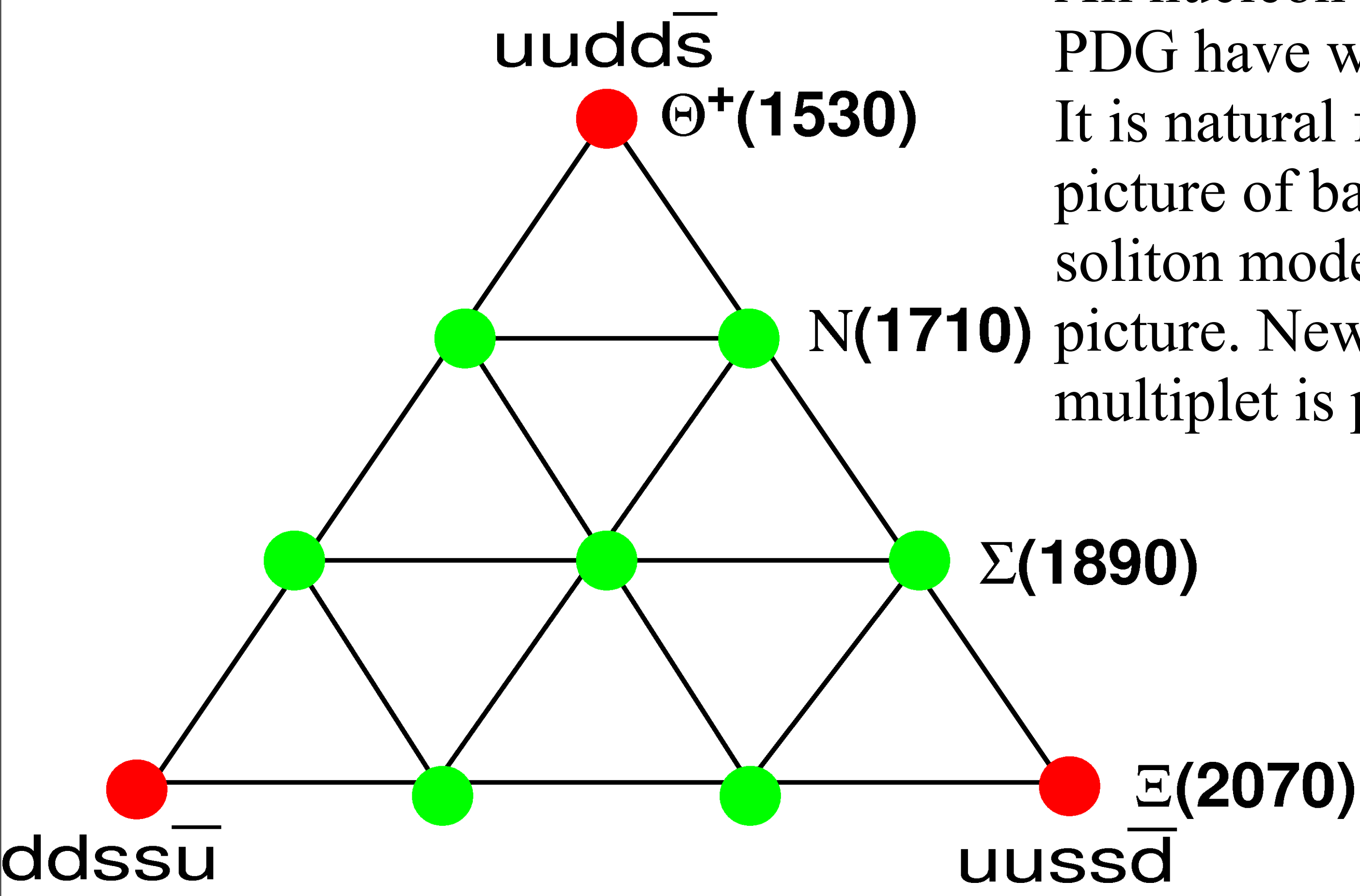
A Case for Narrow Nucleon Excitation N*(1685)

M. V. Polyakov (Ruhr University Bochum & Petersburg NPI)
http://www.tp2.rub.de/~maximp/

- Motivations for a narrow N*
- "Neutron anomaly" in eta photoproduction
- Evidence for narrow N* in the Compton scattering on the neutron
- PWA of MAMI data on eta photoproduction off free proton: an evidence for narrow N*
- Conclusions

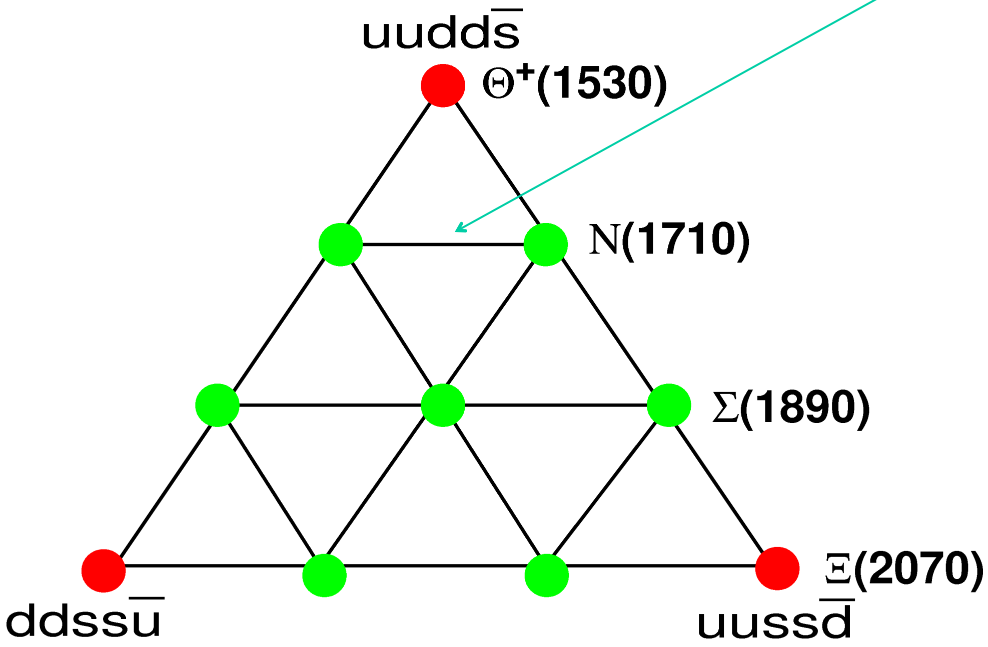
Anti-decuplet of baryons

D.Diakonov, V. Petrov, M.V.P., Z. Phys. A359 (1997) 302



All nucleon resonance listed in PDG have widths > 100 MeV. It is natural for quark model picture of baryons. Chiral soliton model challenges this picture. New narrow and light multiplet is predicted.

Nonstrange pentaquark



Initially was identified with P11(1710)

D.Diakonov, V. Petrov, M.V.P., Z. Phys. A359 (1997) 302

Predicted properties:
- P11 quantum numbers
- weakly couples to pi N state, narrow (< 40 MeV)
- significantly couples to eta N
- photopropuction on proton is suppressed by SU(3)

In 1997 very uncertain properties of P11(1710) were hardly but compatible with prediction of soliton picture of baryons, also at that time for us it was hard to believe that one could miss a narrow nucleon resonance around 1700 MeV after decades of baryon spectroscopy programme.

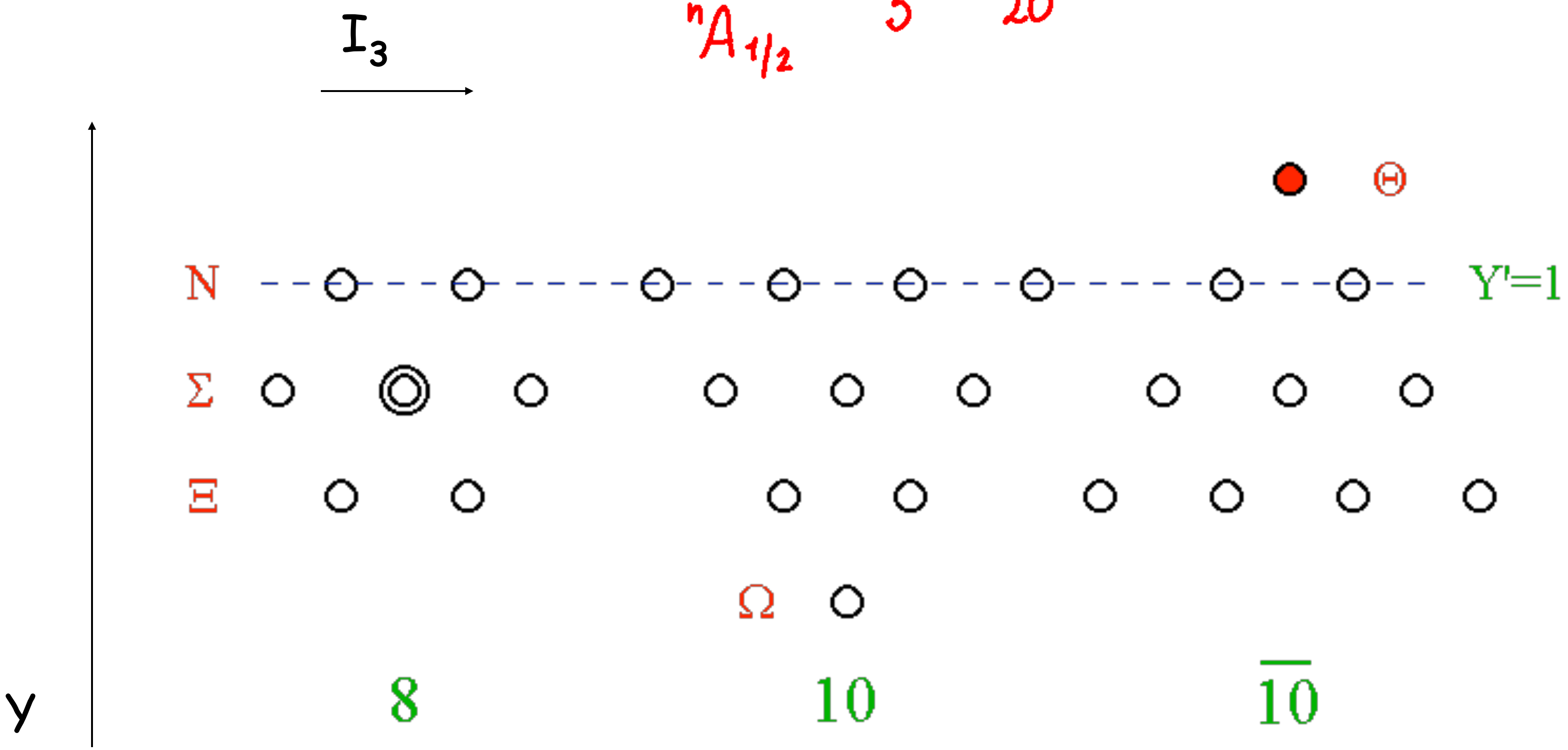
In 2003 it became clear that P11(1710) can not be member of anti-decouplet, therefore it was suggested in /R. Arndt, et al. PRC 69 (2004) 035208 / and /D.Diakonov, V. Petrov PRD69 (2004) 094011/ an existence of new P11 narrow nucleon resonance with the mass in 1700 MeV region.

Photon has U-spin = 0. Good filter for multiplets

Anti-decuplet N* in the SU(3) limit can be photoexcited only from the neutron target

A. Rathke, M.V.P. EPJ A18 (2003) 691

$$\frac{{}^{p}A_{1/2}}{{}^{n}A_{1/2}} \sim \frac{1}{5} \div \frac{1}{20}$$



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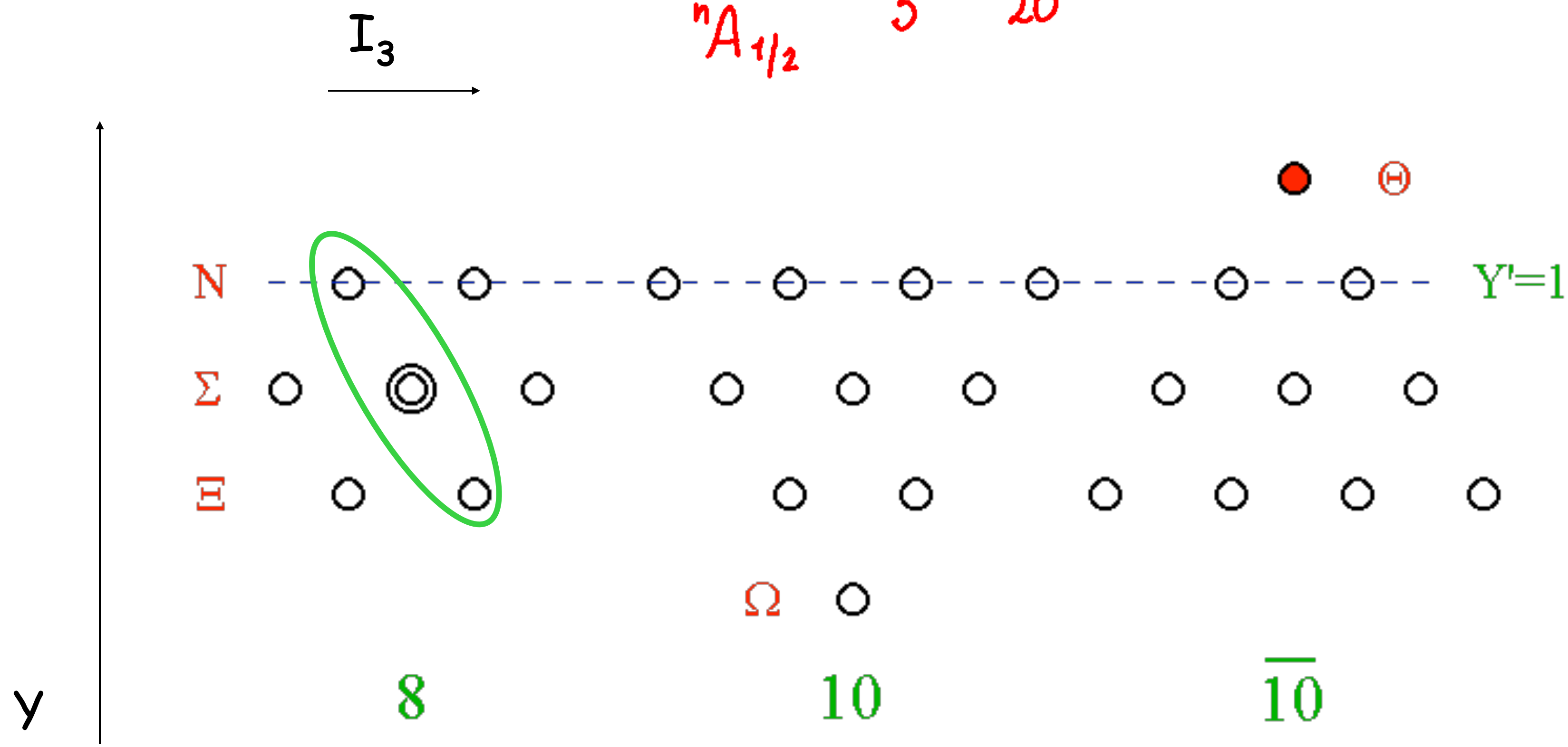

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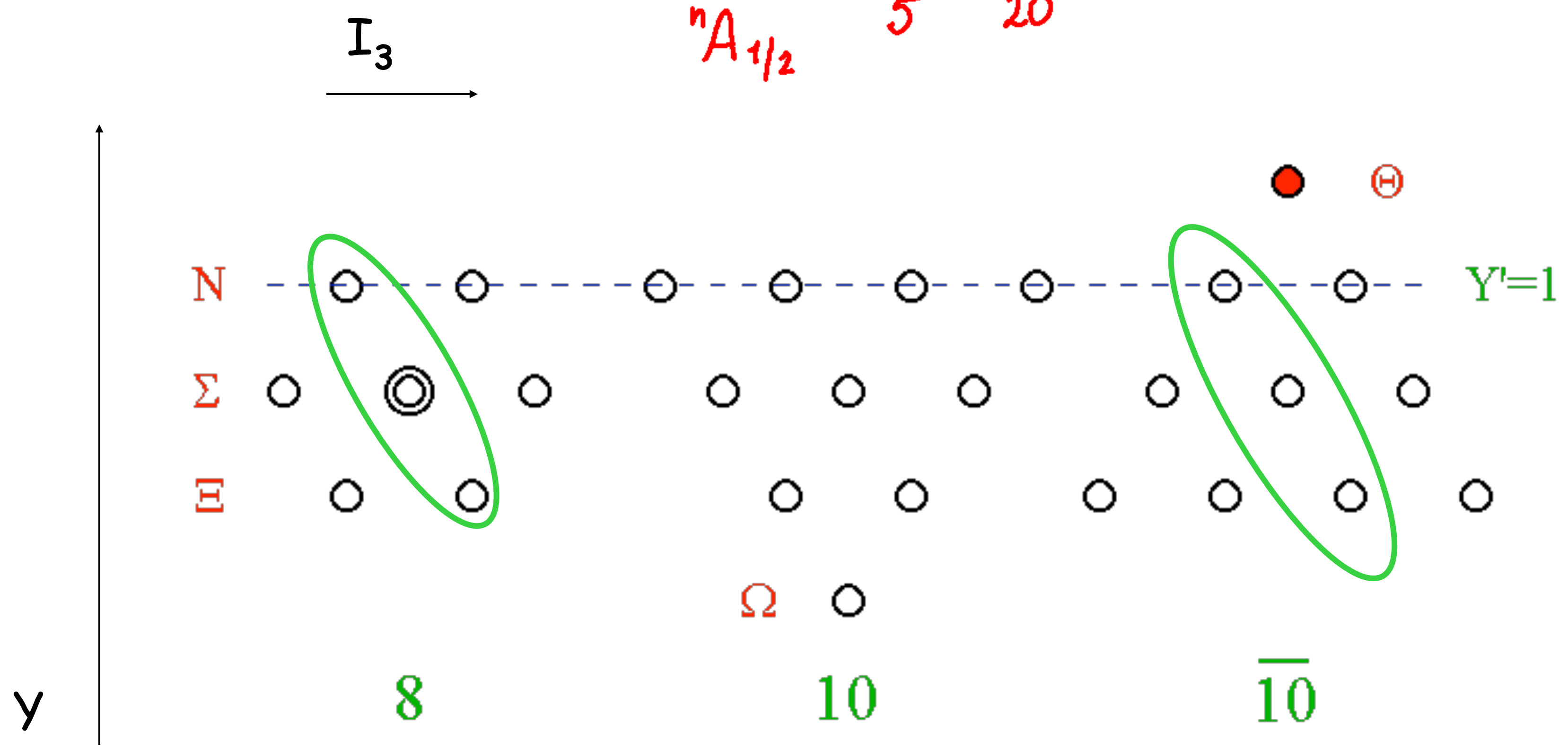

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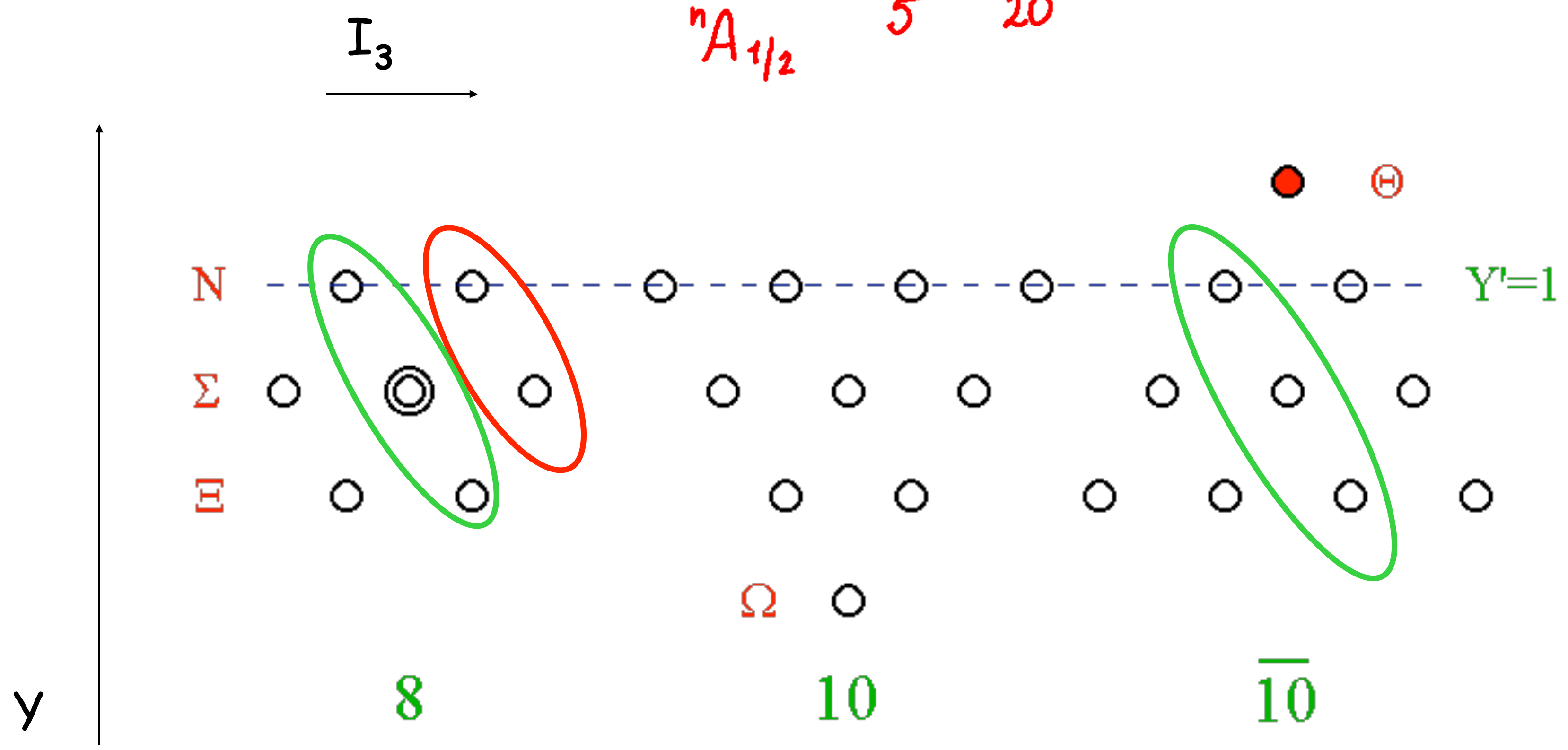

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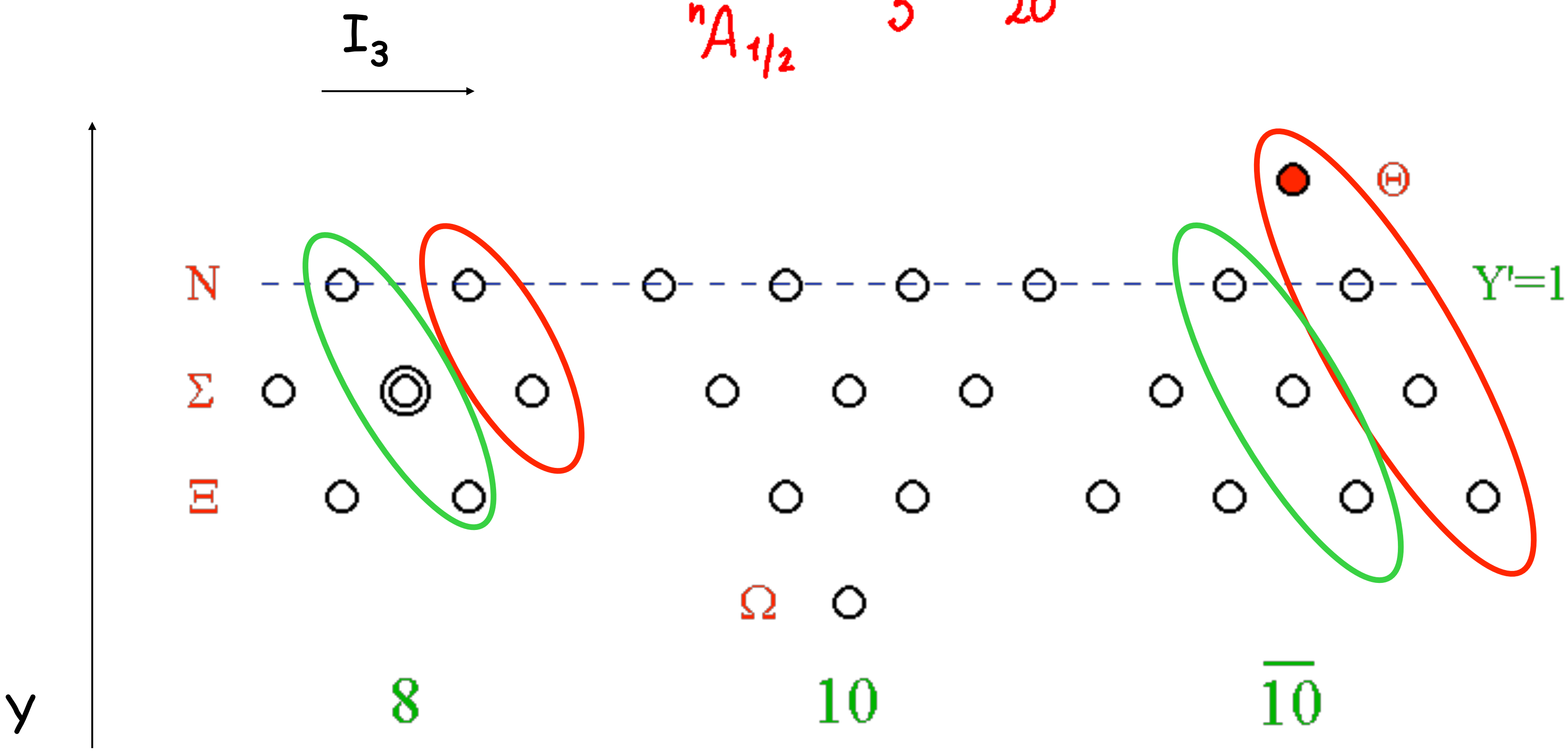
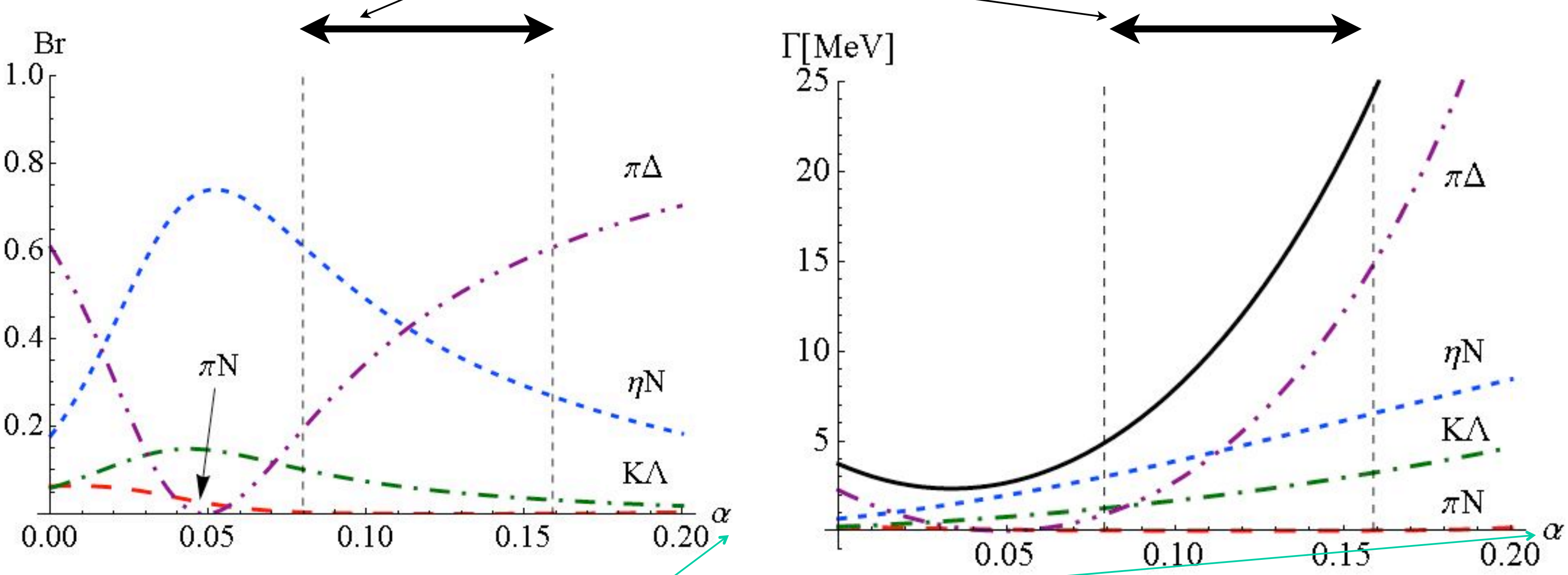


Nonstrange pentaquark: properties from ChQSM

Plots from Goeke, Praszalowicz, MVP (0912.0469)

Detailed studies:
R. Arndt, et al. PRC 69 (2004) 035208
J. Ellis, M. Karliner, M. Praszalowicz, (2004)JHEP 0405
M. Praszalowicz, Acta Phys.Polon. B35 (2004) 1625
T. Ledwig, Kim, K. Goeke, Phys.Rev.D78 (2008) 054005

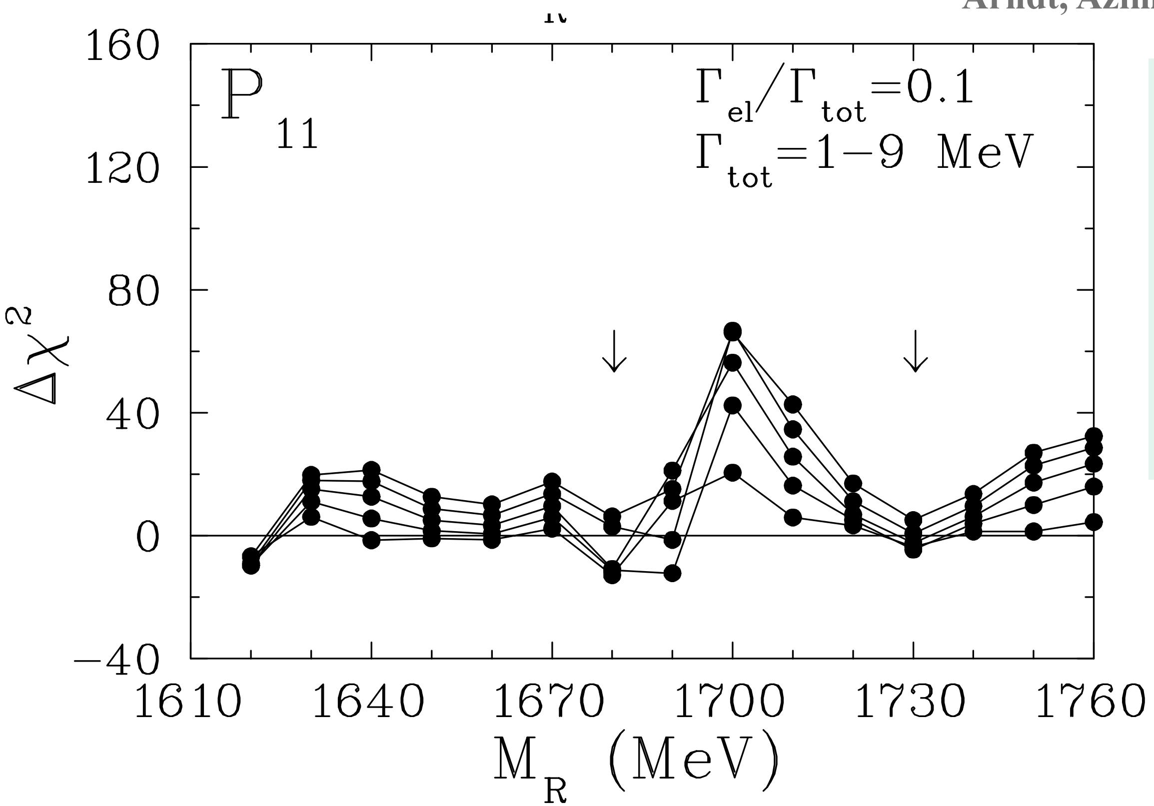
Range of the mixing angle predicted by solitons



Mixing angle with octet

Modified PWA of pi N scattering – new narrow N*(1680) can be tolerated by pi N scattering data if:

Arndt, Azimov, Strakovsky, Workman,MVP, PRC04



- mass ~1680 (or 1730)
- width< 30 MeV
- Br(piN) < 5%
- most probable quantum #'s P11

`` … 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…"

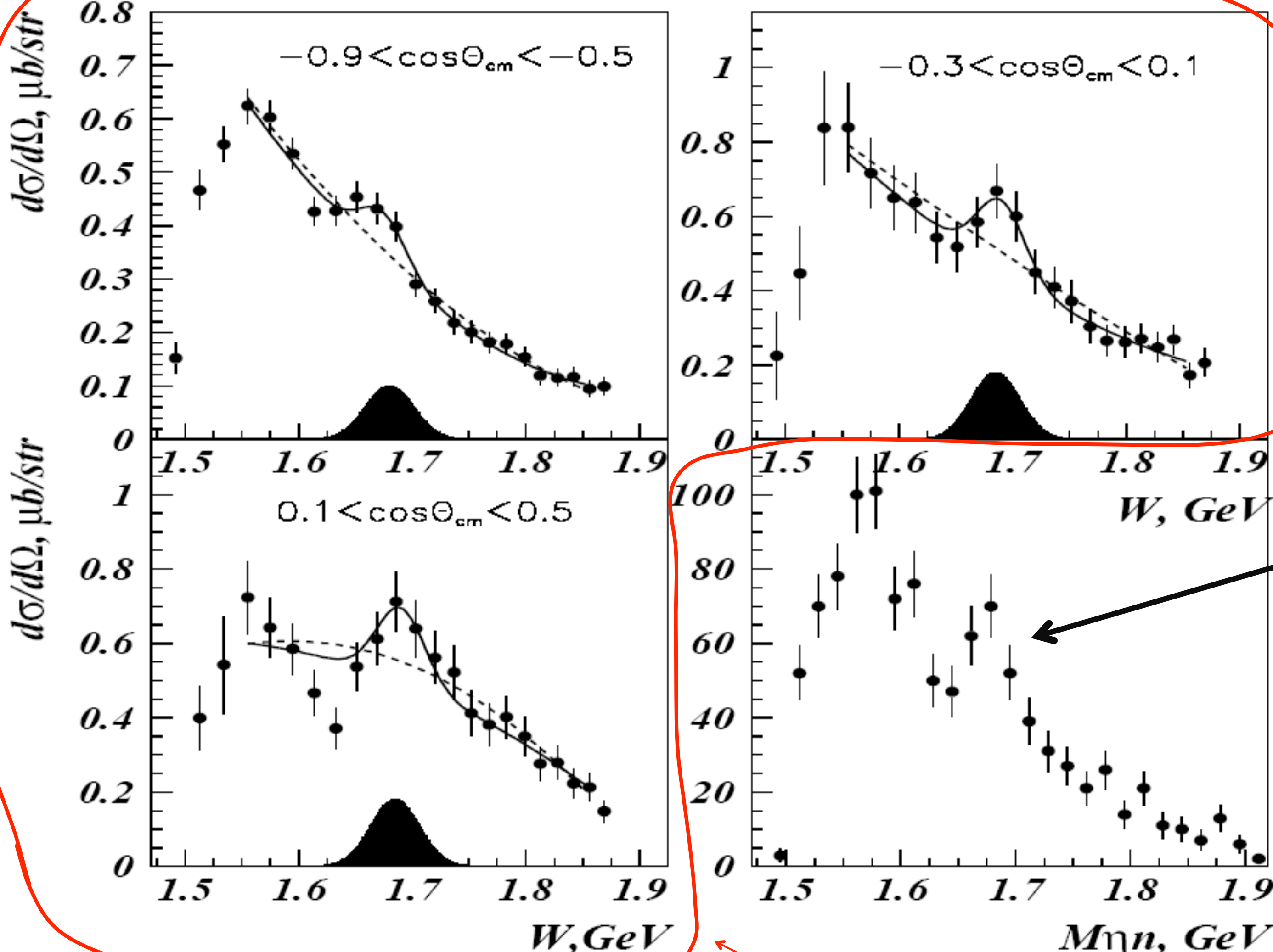
/**Arndt, Azimov, Strakovsky, Workman,MVP, PRC04**

/

Neutron Anomaly

Eta photoproduction on the neutron. First observation of „neutron anomaly" in GRAAL data.

V. Kuznetsov, et al., NSTAR''04, hep-ex/0409032
V. Kuznetsov, et al., Phys. Lett. 647 (2007) 23



Peak in eta-neutron inv. (not affected by nuclear effects, only resolution)
Mass ~1680 MeV

Bump in quasi-free cross-section: „neutron anomaly" (affected by nuclear effects)

Assuming that peak is due to a narrow P11 resonance one can obtain its neutron photocoupling:

$$\sqrt{\mathrm{Br}_{\eta N}}A^n_{1/2} \sim 13 \cdot 10^{-3}\ \mathrm{GeV}^{-1/2}$$

YA. Azimov, V. Kuznetsov, I. Strakovsky, M.V.P.
EPJ A25 (2004) 325

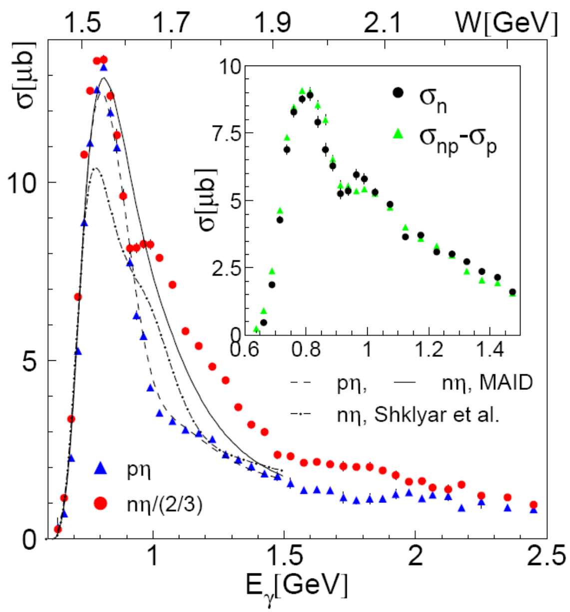
Eta photoproduction on the neutron. CB-ELSA/TAPS results.

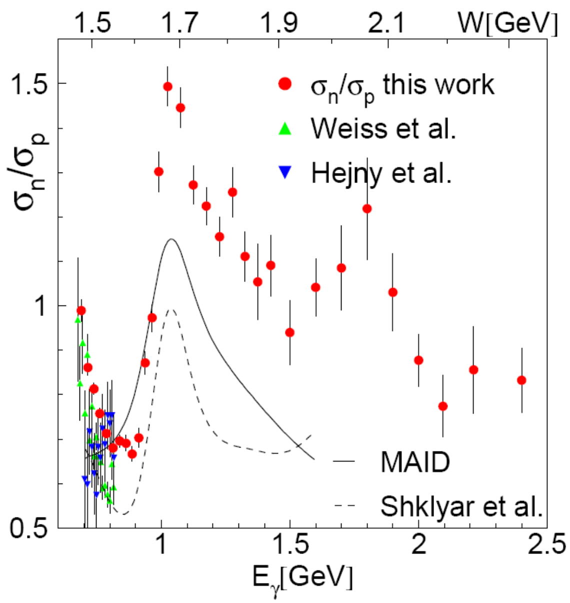
I. Jaegle, et al., Phys. Rev. Lett. 100 (2008) 252002

Note that the „neutron anomaly“ is affected by the Fermi motion, rescattering effects and the procedure of extraction quasi-free cross section

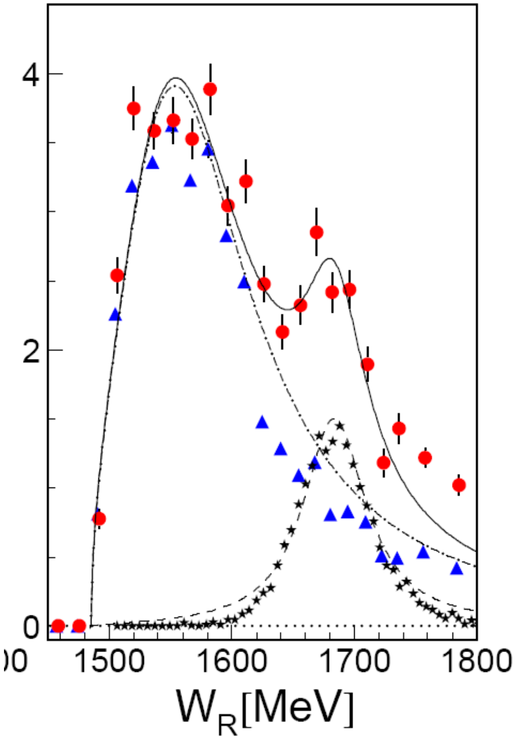
Peak in the inv. mass is Independent of these effects

Bump in quasi-free cross-section: „neutron anomaly“





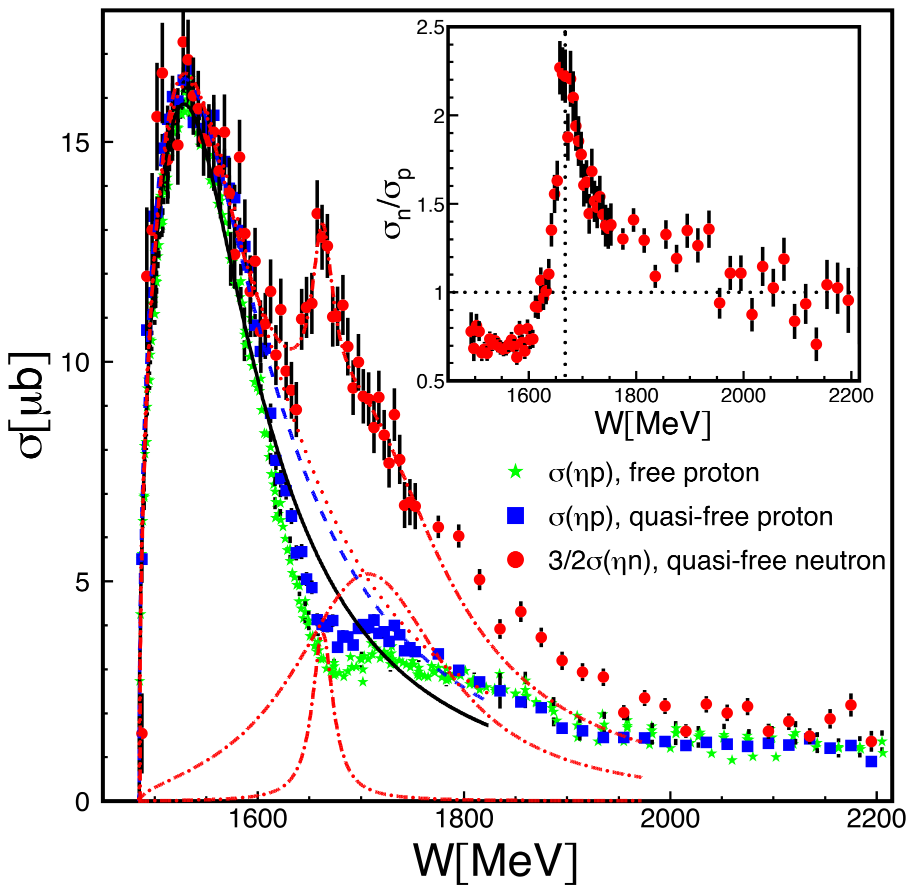
Peak in eta-neutron inv. Mass ~1683 MeV



De-folding Fermi motion in CB-ELSA/TAPS data.

- **structure in neutron excitation function width ≈(25±10) MeV (resolution dominated)**

B. Krusche, talk at RUB, January 2011



After defolding of the Fermi motion the peak became sharper, as one would expect for a resonance contribution.

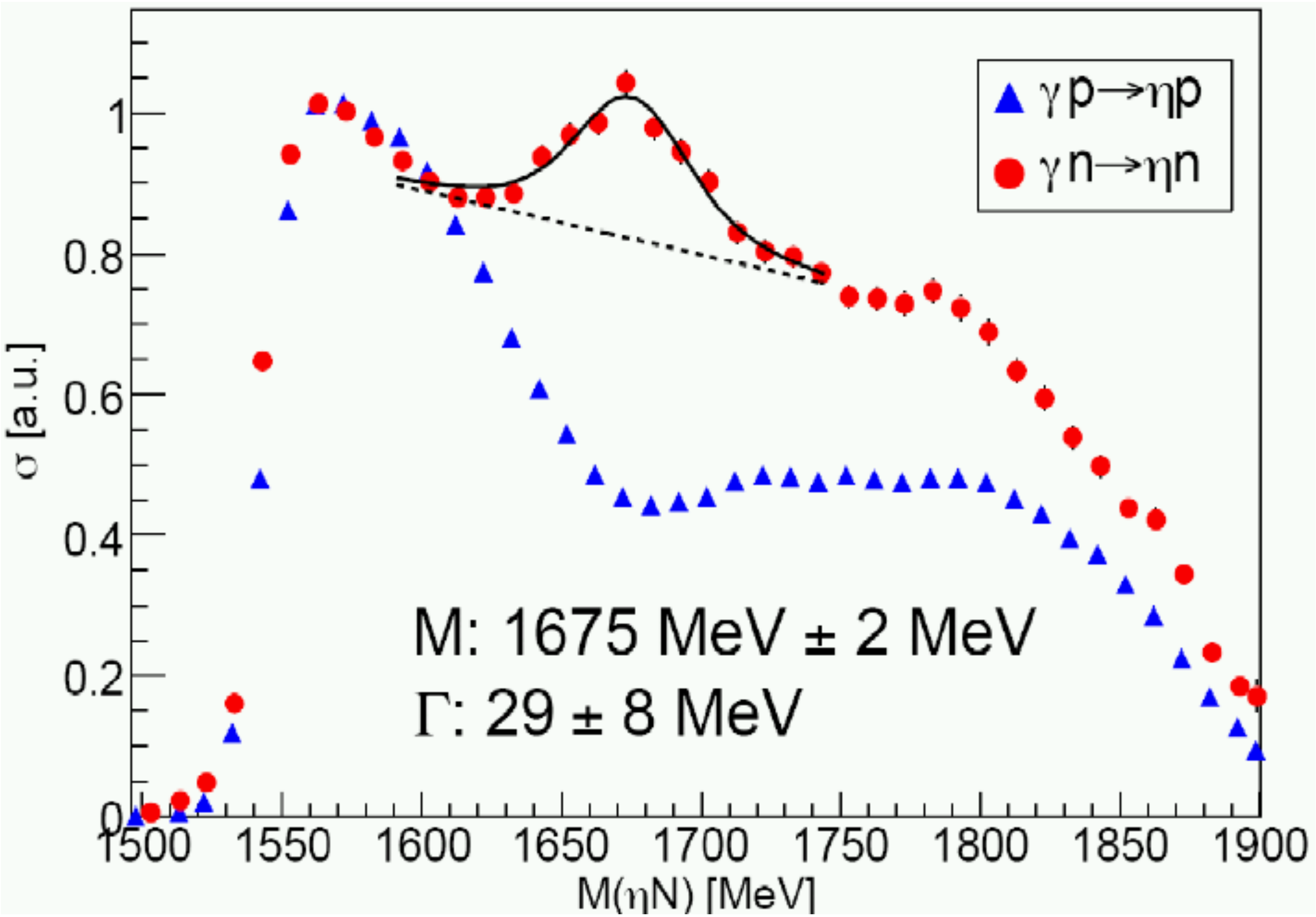
We extracted the photocoupling of putative n*(1685). The results is:

$$\sqrt{\mathrm{Br}_{\eta N}} A^n_{1/2} \sim 15 \cdot 10^{-3}\ \mathrm{GeV}^{-1/2} \quad (\mathrm{CBELSA/T}$$

in excellent agreement with the extraction of the photocoupling from the GRAAL data in
YA. Azimov, V. Kuznetsov, I. Strakovsky, M.V.P. EPJ A25 (2004) 325

Eta photoproduction on the neutron. Crystal-Ball @ MAMI-C result.

D. Werthmueller et al. Chin.Phys.C33:1345-1348,2009.



Neutron Anomaly is established! How to interpret it ?

Intrepretations of the neutron anomaly

✓**New narrow nucleon resonance with much stronger photocoupling to neutron. Was predicted before experiments as anti-decuplet member!**

A. Rathke, M.V.P. EPJ A18 (2003) 691
R. Arndt, et al. PRC 69 (2004) 035208
D.Diakonov, V. Petrov PRD69 (2004) 094011

These models require fine tuning to produce narrow structure. These models do NOT predict the neutron anomaly, it is used as an input to fit model parameters. No neutron anomaly in the Compton scattering.

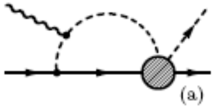
✓**Coupled channel effect of S11(1650) and P11(1710) .**

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

✓**Either interference effects of S11(1535) and S11(1650) OR new narrow resonance**

A. Anisovich et al. ArXiv: 0809.3340

✓**Effects of meson loops**



Döring, Nakayama ArXiv: 0909.3538

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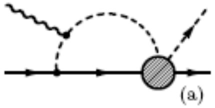


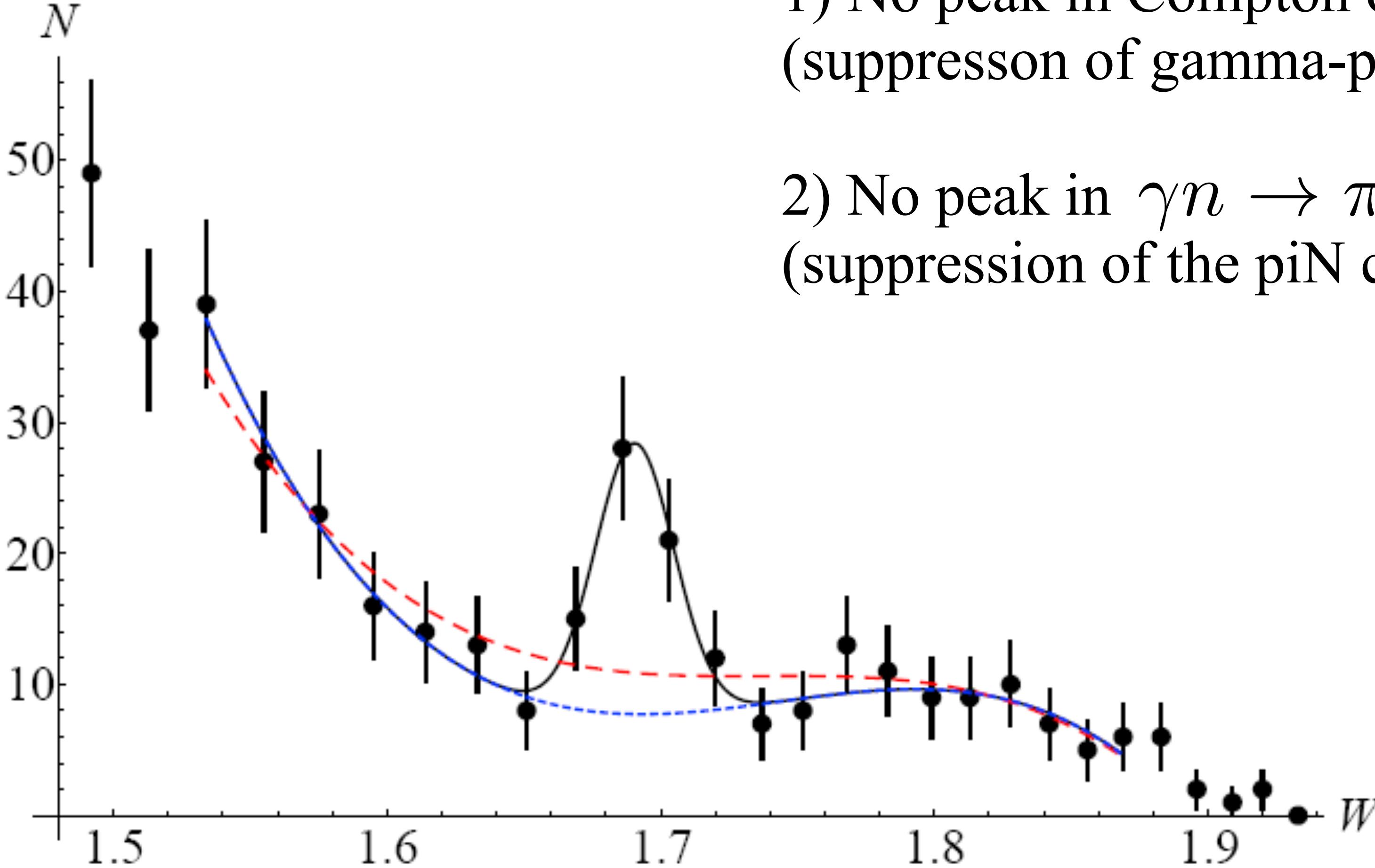
Döring, Nakayama ArXiv: 0909.3538

N*(1685) in Compton Scattering on Neutron

V. Kuznetsov et al.,
Phys.Rev.C83:022201,2011

1) No peak in Compton on proton
(suppresson of gamma-p coupling)

2) No peak in $\gamma n \to \pi^0 n$
(suppression of the piN coupling)



$M = 1686 \pm 5_{stat} \pm 5_{syst}$

FWHM $\sim$ 35 MeV

$\sqrt{2 \ln L_{B+S}/L_B}$ corresponds to 5.4σ

N*(1685) in eta photoproduction on free proton

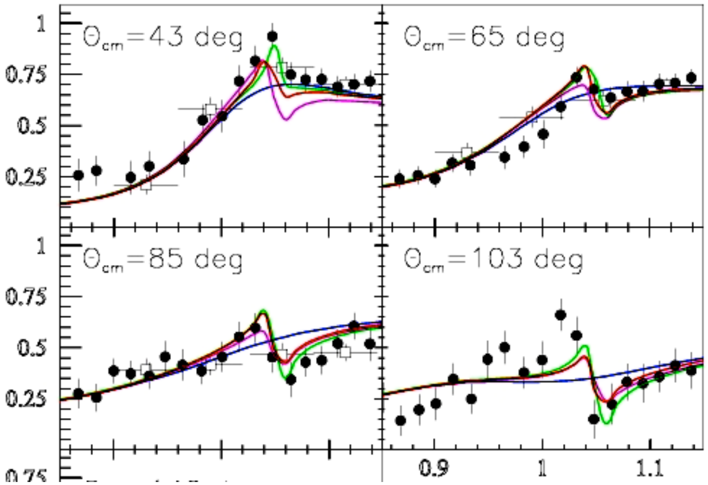
Anti-decuplet „proton" couples weakly to the photon (just flavour SU(3) symmetry, no dynamics)

A. Rathke, M.V.P. EPJ A18 (2003) 691

Therefore contribution of the putative nucleon resonance to the proton eta photo-production cross section is expected to be small.

Analysis of the GRAAL beam asymmetry gives an estimate of the „proton" photo-coupling:

V. Kuznetsov, M.V.Polyakov, et al., Acta Physica Polonica , 39 (2008) 1949
V. Kuznetsov, M.V.Polyakov., JETP Lett., 88 (2008) 347



$$\sqrt{\mathrm{Br}_{\eta N}} A^p_{1/2} \sim (1 \div 2) \cdot 10^{-3}\ \mathrm{GeV}^{-1/2}$$

Corresponding resonance cross section at the maximum is:

$$\sigma_{\mathrm{res}}(\gamma p \to \eta p)|_{W=M_R} \sim 0.038\ \left(\frac{10\ \mathrm{MeV}}{\Gamma_{\mathrm{tot}}}\right)\ \mu\mathrm{b}.$$

No chance to see resonance PEAK. The only way is to use interference with strong background. The putative resonance will show up as peak, dip or oscillating structure. The maximally possible magnitude of the structure:

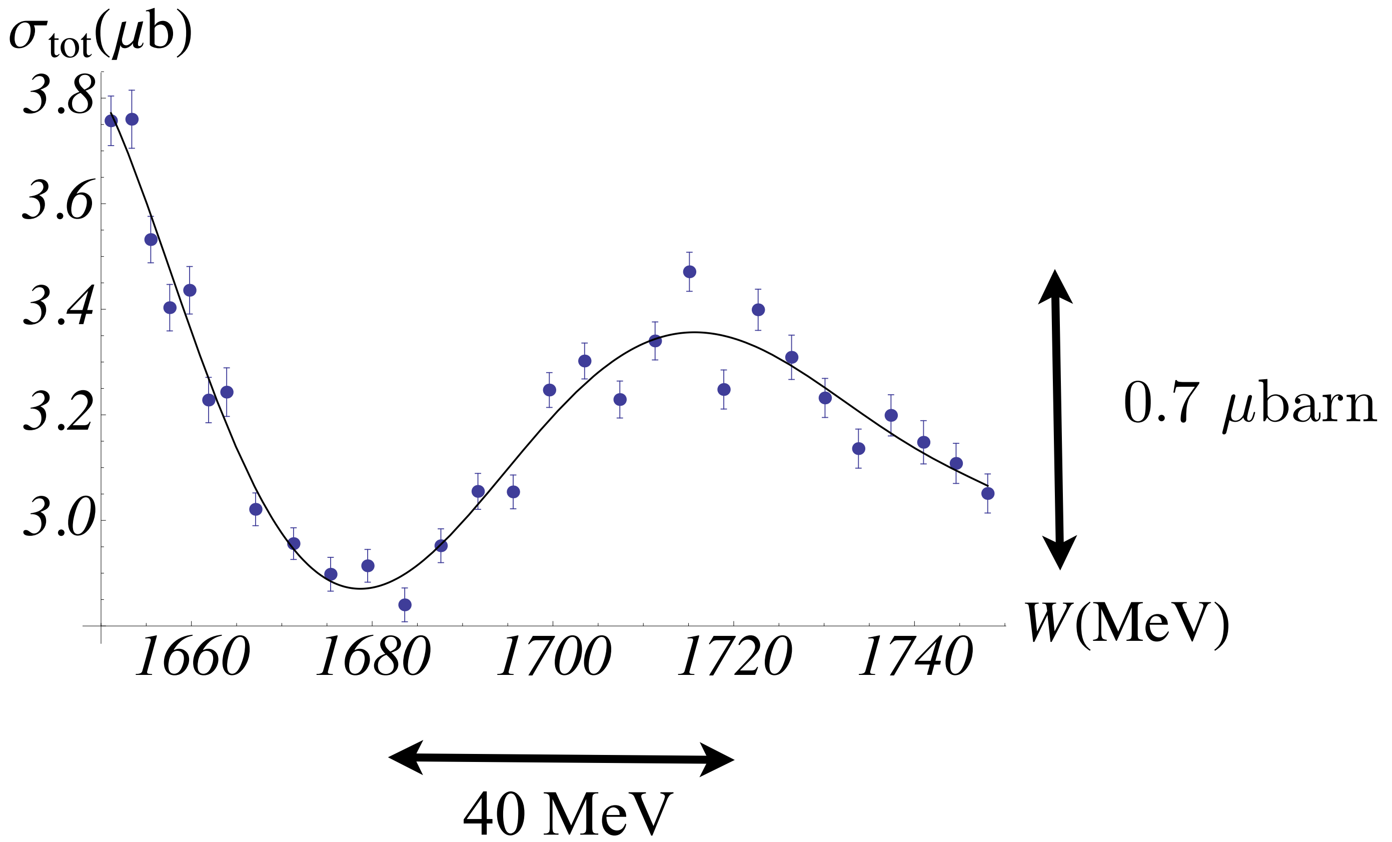
$$\Delta\sigma_{\mathrm{tot}} = 2\sqrt{\sigma_p\ \sigma_{\mathrm{res}}(\gamma p \to \eta p)|_{W=M_R}} \sim 0.7\ \mu\mathrm{b},$$

The structure is expected to be wider than the underlying resonance.

New high precision MAMI data on eta photoproduction off free proton

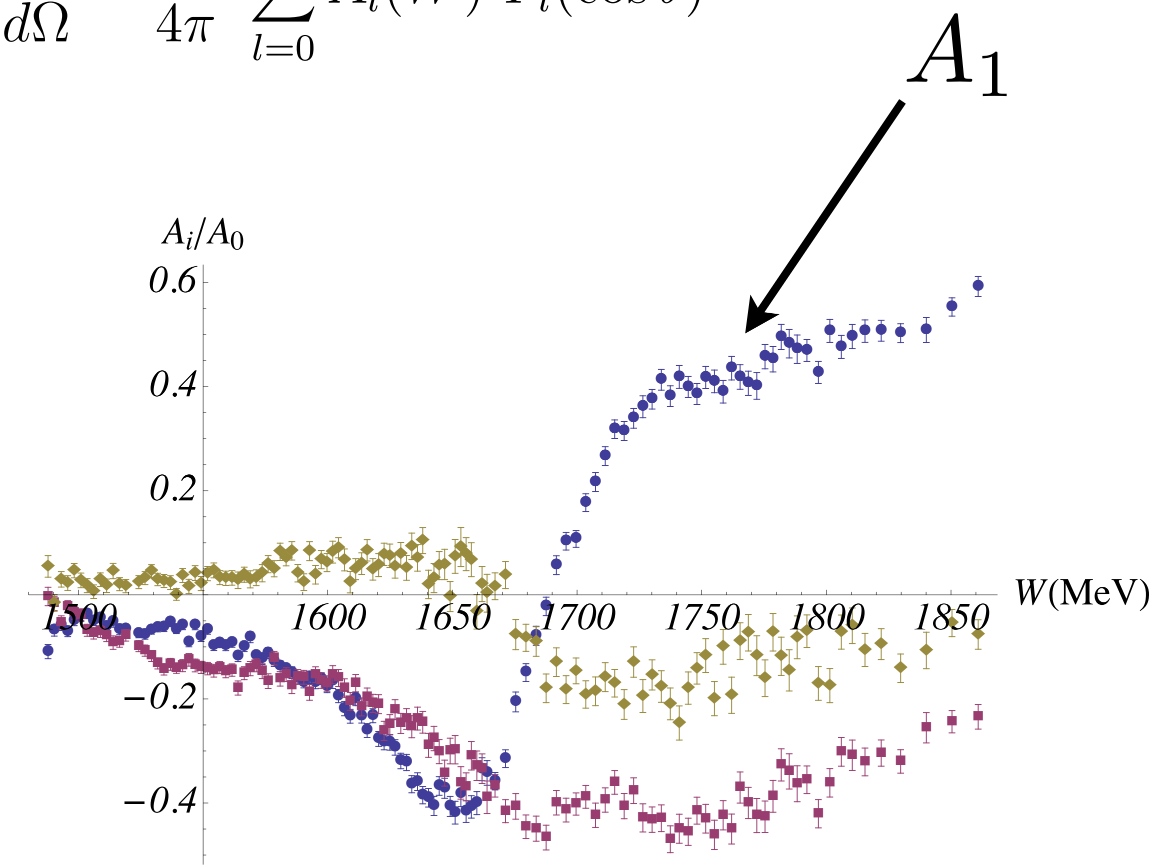
E.F. McNicoll et al., Phys.Rev.C82:035208,2010

Oscillating structure in the cross section



Legendre expansion of the diff. cross section:

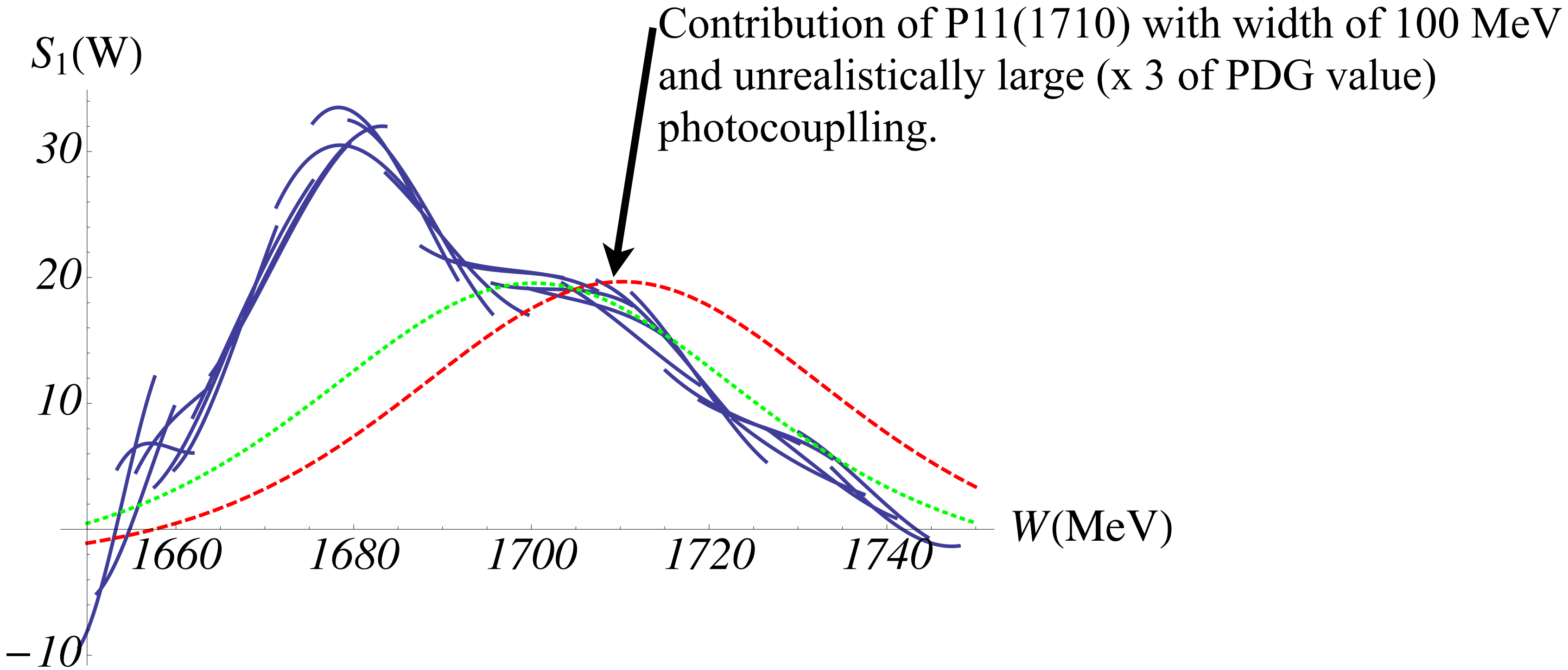
$$\frac{d\sigma}{d\Omega} = \frac{1}{4\pi} \sum_{l=0}^{\infty} A_l(W)\ P_l(\cos\theta)$$



Rapid change of A_1 coefficient around 1690 MeV. There are rapid "oscillations" in the cross section in mass interval of 1650-1750 MeV.

Speed characteristic: $S_1(W) \equiv W \frac{d}{dW} \left(\frac{A_1(W)}{A_0(W)} \right)$

V.Kuznetsov, M. Thurmann, MVP, ArXiV **1102.5209**

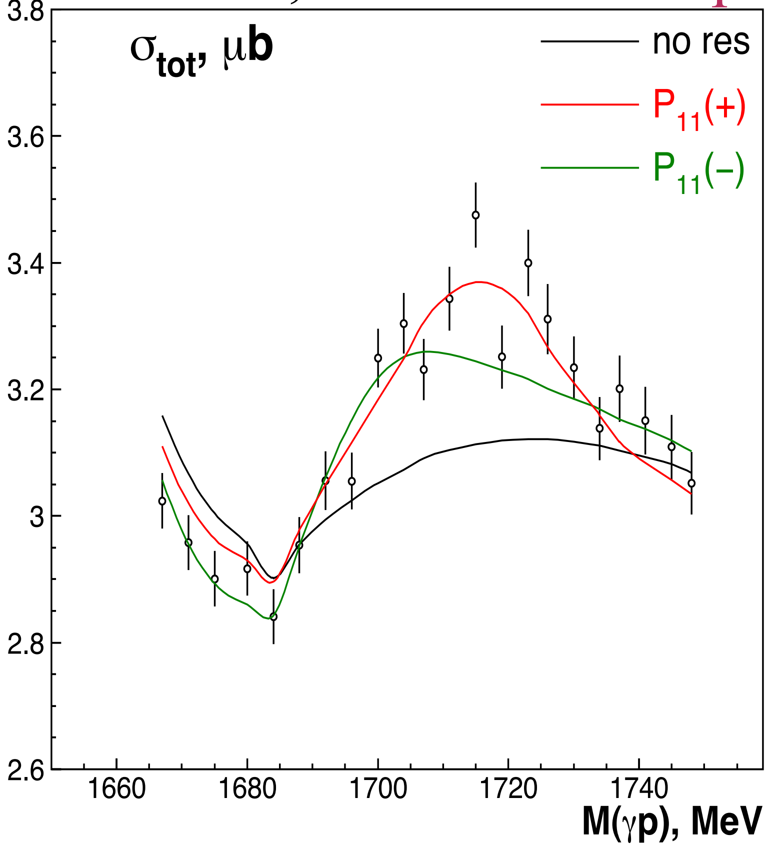


Narrow and weak resonance can explain large speed characteristic!
What a PWA gives?

Bonn-Gatchina PWA of new MAMI data

A.V. Anisovich et al. to appear soon

A fit using known broad resonances with standard background assumptions can not describe the narrow structure in the mass region 1660-1750 MeV. The description of the data can be improved significantly assuming the existence of a narrow resonance at about 1700 MeV, and with small photo-coupling.



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

Resonance	Mass (MeV)	$\Gamma_{\rm tot}$ (MeV)	$\sqrt{{\rm Br}_{\eta N}}A^p_{1/2}$	$\sqrt{{\rm Br}_{\eta N}}A^p_{3/2}$	$\chi^2_{\rm tot}/N_{\rm dat}$	$\chi^2_{\rm sel}/N_{\rm dat}$	$\chi^2_{\Sigma}/N_{\rm dat}$
no res.	-	-	-	-	1.21	1.48	1.46
$P_{11}(+)$	1719	41	3.1	-	1.07	0.93	1.51
$P_{11}(-)$	1694	35	2.9	-	1.11	0.91	1.11
P_{13}	1728	72	2.6	4.7	1.02	0.93	1.47
S_{11}	1685	30	0.8	-	1.12	1.12	1.47
$S_{11}(\omega p)$	-	-	-	-	1.12	0.93	1.41

Inclusion of a narrow resonance improves significantly description of MAMI data, especially in narrow energy interval of 1660-1750 MeV (see change of $\chi^2_{\rm sel}/N_{\rm dat}$).

The data on the photon beam asymmetry prefer the solution with a narrow P11 resonance. The mass and width of the resonance is consistent with parameters of the neutron anomaly. Its proton photocoupling is considerably smaller than the neutron one (3 vs 15). that makes the anti-decuplet interpretation plausible

$\frac{{}^pA_{1/2}}{{}^nA_{1/2}} \sim \frac{1}{5} \div \frac{1}{20}$ Prediction from solitons A. Rathke, M.V.P. EPJ A18 (2003) 691

Conclusions

The observation of the strong narrow peak in eta photoproduction on the neutron and PWA of new high precision data on eta photoproduction off free proton, considered together, provide a strong case for new narrow nucleon resonance.

It seems that for many years we have been overlooking a narrow nucleon resonance with mass around 1685 MeV and with stronger photocoupling to the neutron.

Such nucleon excitation is a very good candidate for non-strange member of the anti-decouplet of exotic baryons → provides support for existence of Theta+

New narrow nucleon state – a challenge for standard PWA technique, which for last 40 years has been guided by the predictions of variants of quark models.