Outline

- Previous experiments. Evidence for a resonant structure at W=1.675 GeV in $\gamma n \to \eta p$ data at GRAAL;
- Theoretical assumptions: $D_{15}(1675)$ or the non-strange pentaquark?
- Comparison with MAID2000:
- Could it be a narrow state?
- Fermi motion correction: Some preliminaries
- Summary

Previous data

Region of the $S_{11}(1535)$ resonance

(from threshold to W=1.6 GeV)

- **Mainz:**

B.Krusche et al., Phys. Lett. **358** (1995) 40; V.Heiny et al. Eur. Phys. J. **A6** (1999) 83; V.Heiny, Eur. Phys. J. **A13** (2002) 493; J.Weiβ et al., Eur. Phys. J. A **16,** 275, 2003; Nucl-ex/0201003;

- **Bonn:**

P.Hoffman-Rothe, PRL **78** (1997) 4967;

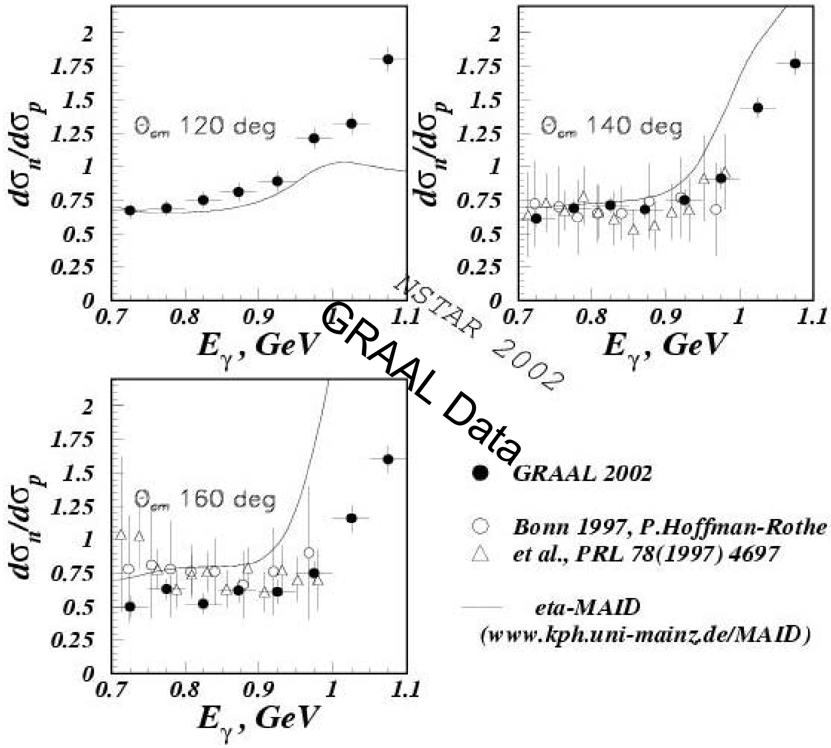
The ratio of quasi-free $\gamma n \rightarrow \eta n$ and $\gamma p \rightarrow \eta p$ cross sections is almost constant

$$d\sigma_n / d\sigma_p \approx 0.67$$

GRAAL 2002

V.Kuznetsov *et. al.,* (GRAAL) Proceedings of Workshop on the Physics of Excited Nucleons NSTAR2002, October 2002, Pittsburgh, USA, Ed. E.Swanson World Scientific, pg.267-270

Sharp enhancement in the $d\sigma_n / d\sigma_p$ ratio above W=1.6 GeV



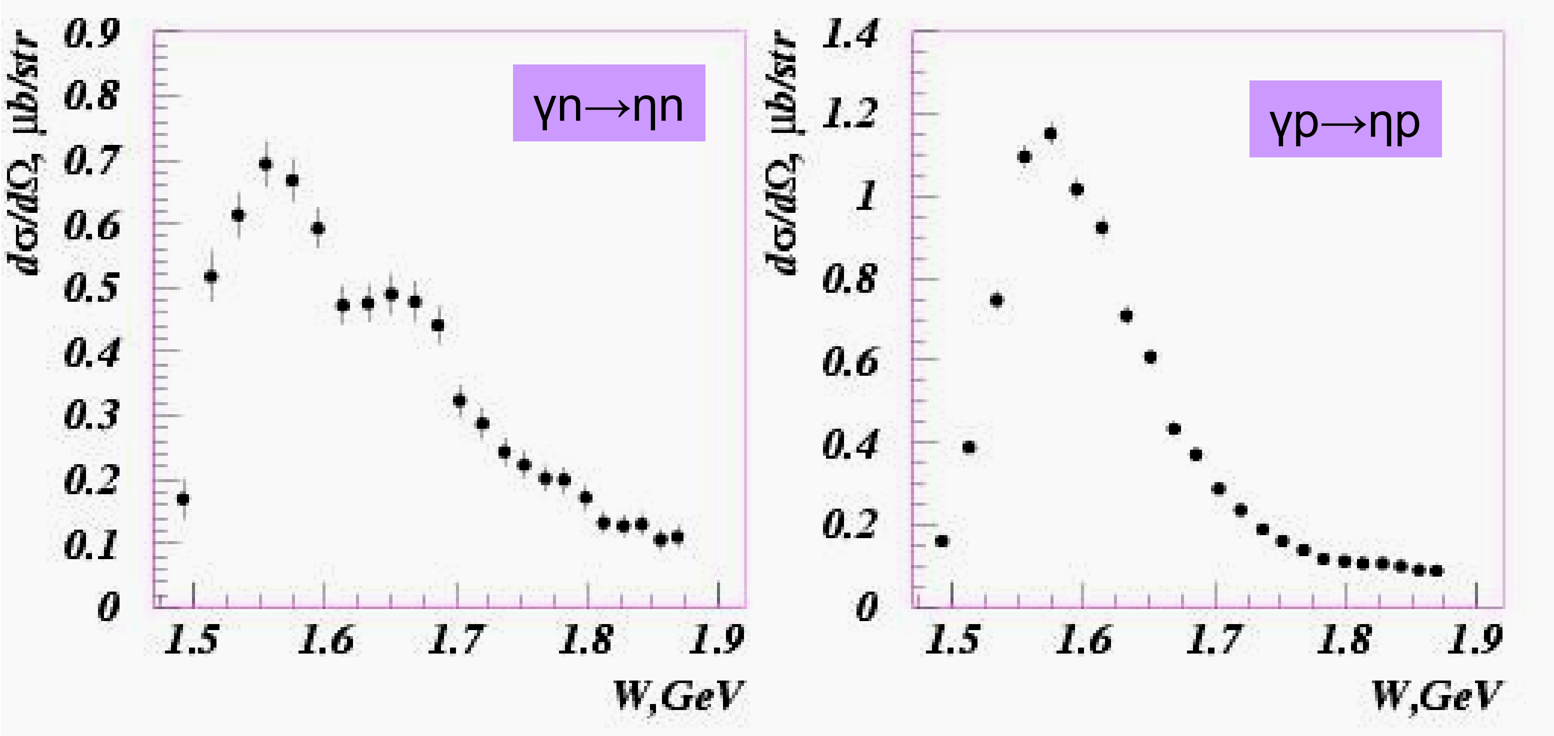
GRAAL 2004

V.Kuznetsov *et al.* , Proceedings of Workshop on the Physics of Excites Nucleons NSTAR2004, Grenoble, March 2004, Eds. J.-P.Bocquet, V.Kuznetsov, D.Rebreyend, World Scientific, pg.197; Hep-ex/0409032.

$\gamma n \to \eta n$ data clearly reveal a resonant structure near W≈1.675 GeV which is not seen on the proton.

Quasi-free differential cross sections at Θ_{cm}=137 deg

(soft cuts, normalization uncertainties 15%)



What is the nature of the observed structure?

Two main assumptions:

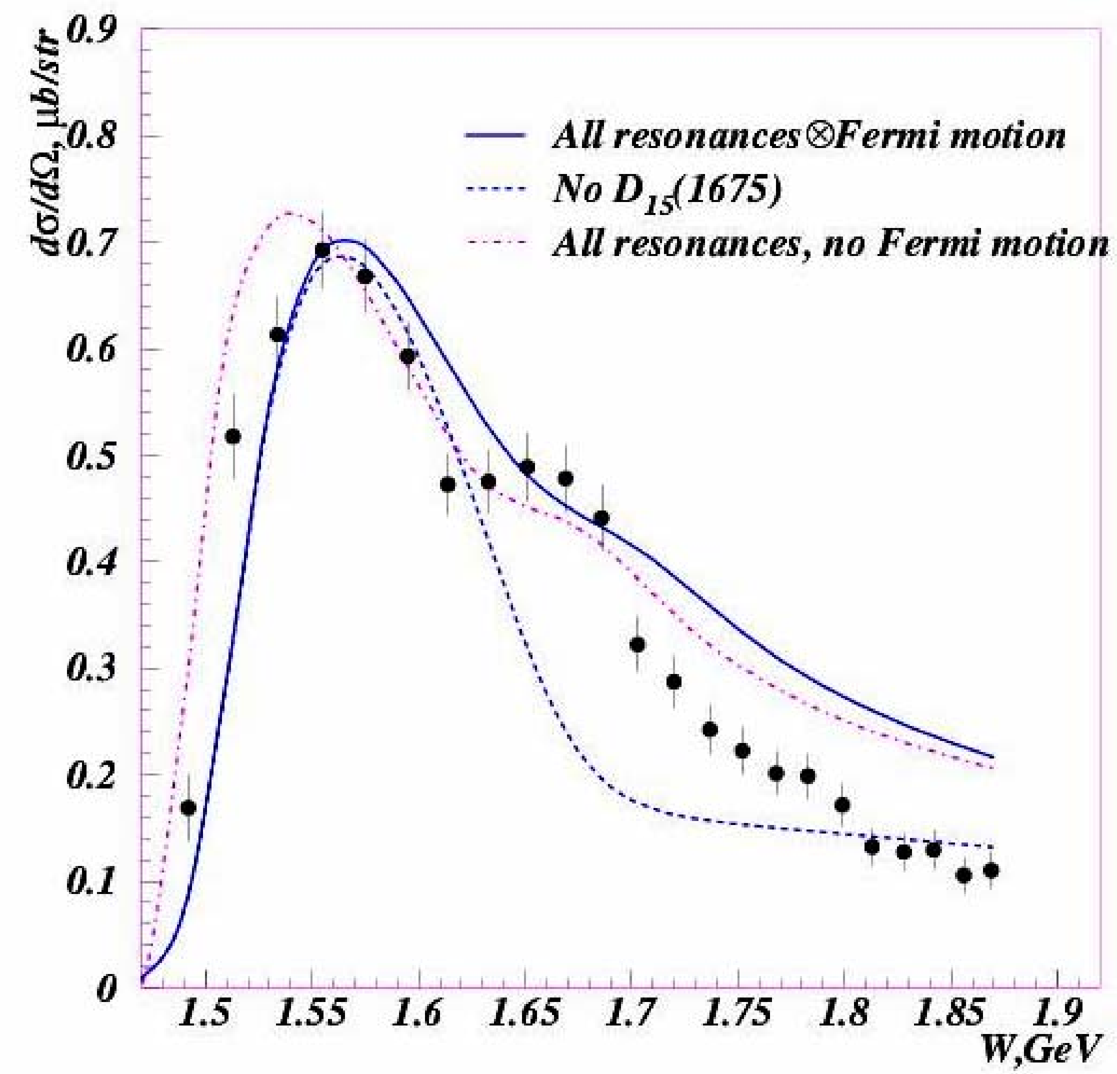
1. The $D_{15}(1675)$ resonance

- A single-quark transition model (V.Burkert *et al.,* PRC 67,035205(2003) Photocouplings of the $D_{15}(1675)$ resonance to the neutron are much larger that to the proton
- An isobar model for η photo- and electroproduction on the Nucleon MAID2000 (W.-T.Chiang, C.Benhold, and L.Tiator, Nucl. Phys. A 700, 429 – 453, 2002; Nucl-th/0110034): In addition to the $S_{11}(1535)$, the model suggests a strong contribution of the $D_{15}(1675)$.

2. The Non-strange pentaquark P_{11}

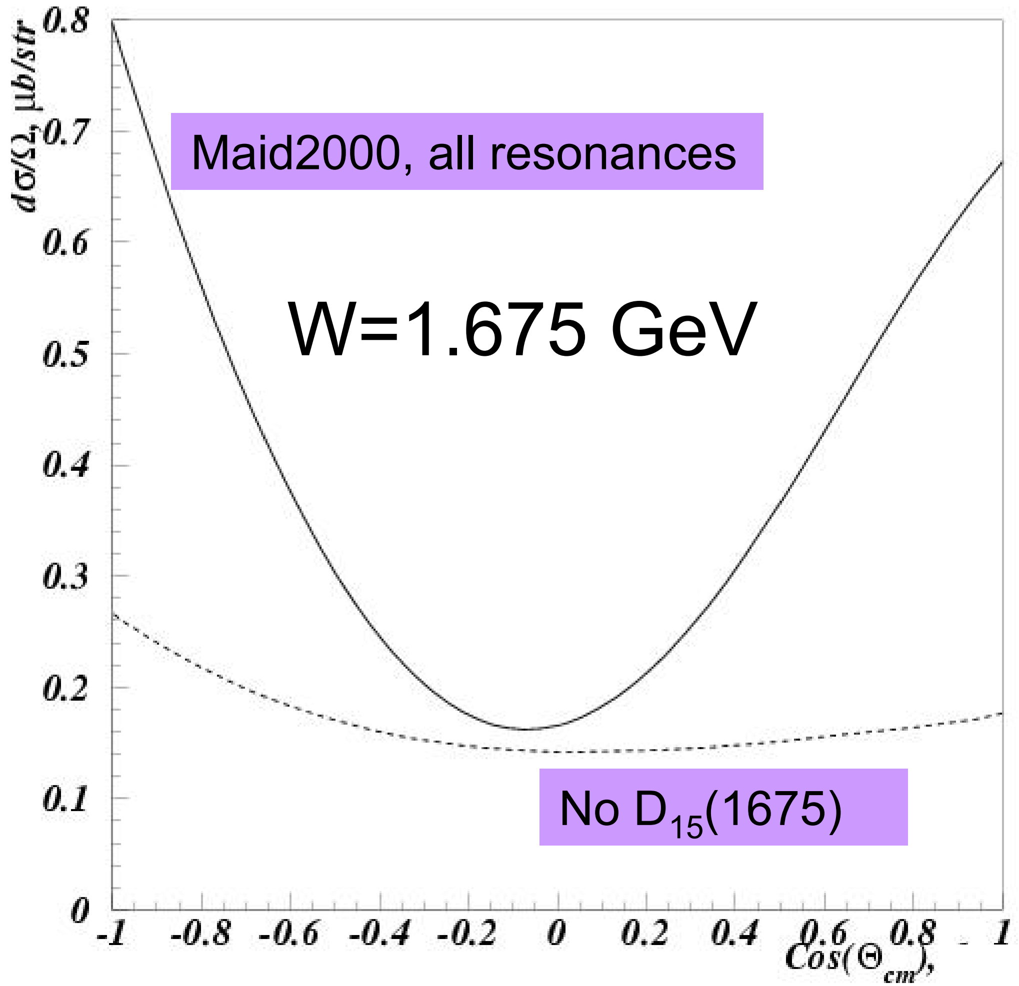
- Modified PWA of πN scattering suggests two candidates, with the masses of 1.68 and/or 1.73 GeV, and the total width ΔW≤10 MeV (R.Arndt *et al.,*PRC 69, 0352008,2004).
- The Chiral Soliton Model: **Photoexcitation of the non-strange pentaquark should be suppressed on the proton and should occur mainly on the neutron**. **Eta photoproduction is particularly sensitive to the manifestation of this particle** (M.Polyakov and A.Rathke, EPJA 18, 691, 2003.

Comparison with MAID2000

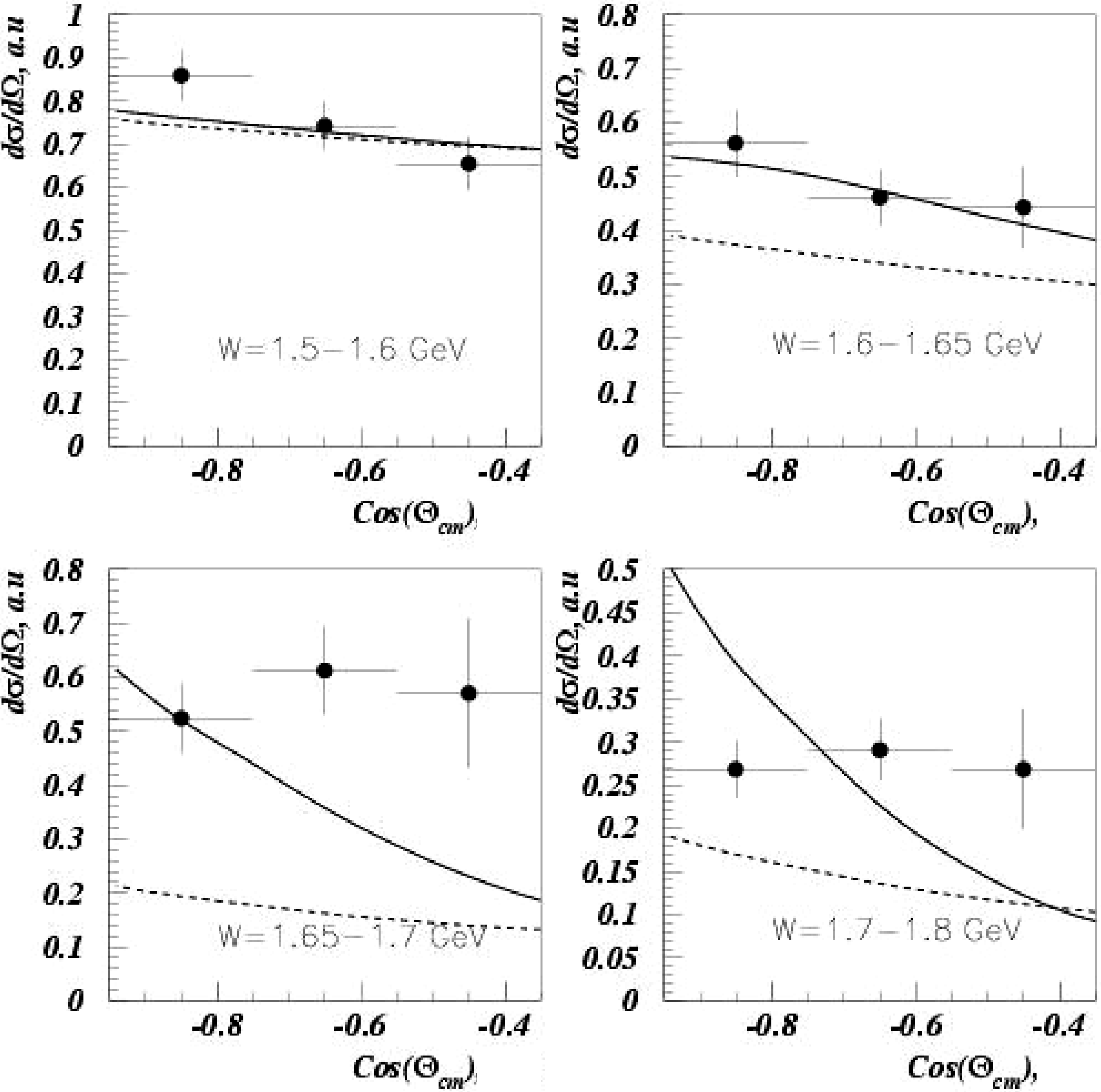


- MAID2000 **predicts a similar bump-like structure.** This structure is due to the $D_{15}(1675)$ resonance.
- MAID2000 reproduces the rise in the ratio of the neutron/proton cross sections
- **However, the structure in the experimental data looks more narrow .**

Main signature of the $D_{15}(1675)$ is the strong angular dependence of the cross section



Angular dependence of the γn→ηp cross section

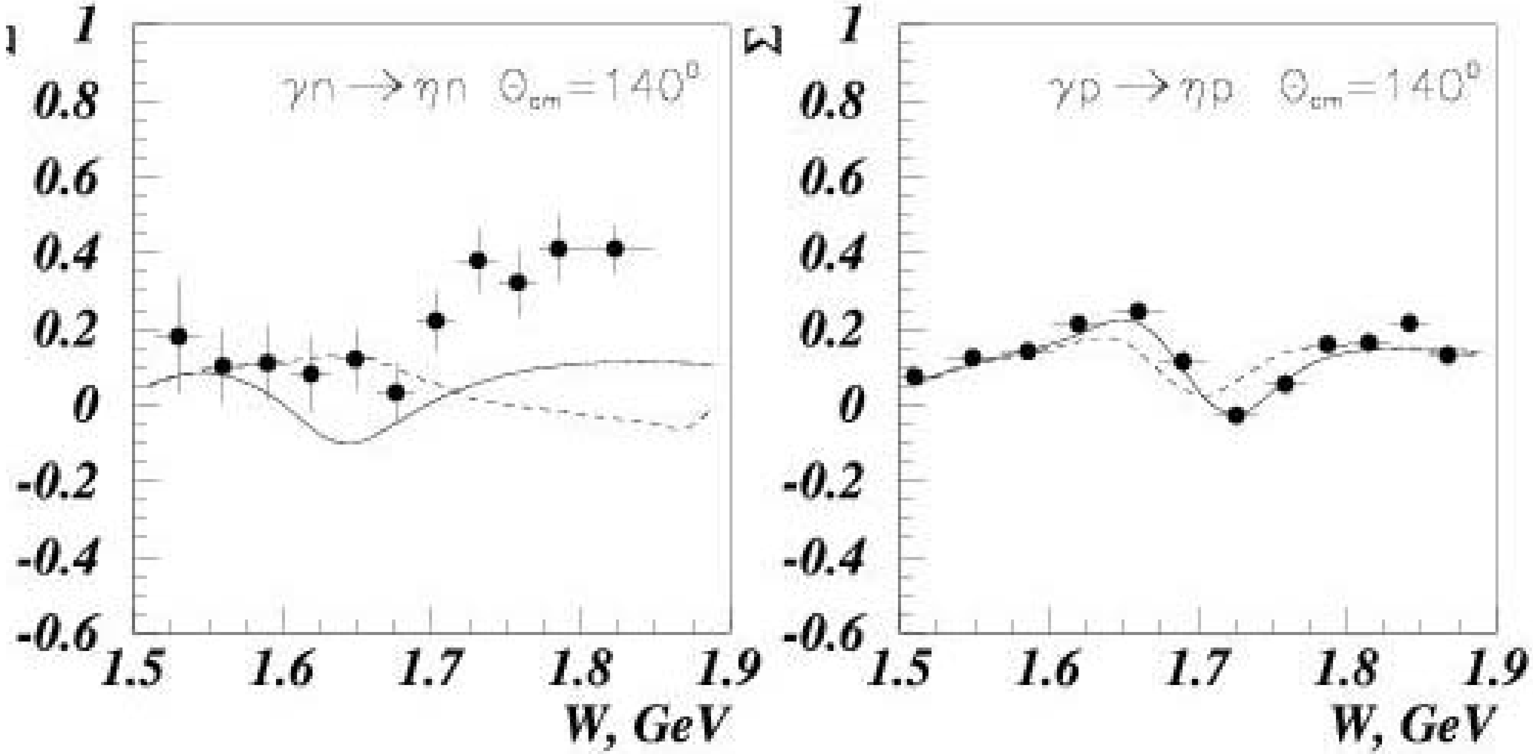


Solid lines are MAID2000(all resonances);

Dashed lines are MAID2000 (no D_{15}(1675)).

Measured angular dependences above W≈1.65 GeV are different from MAID2000 predictions

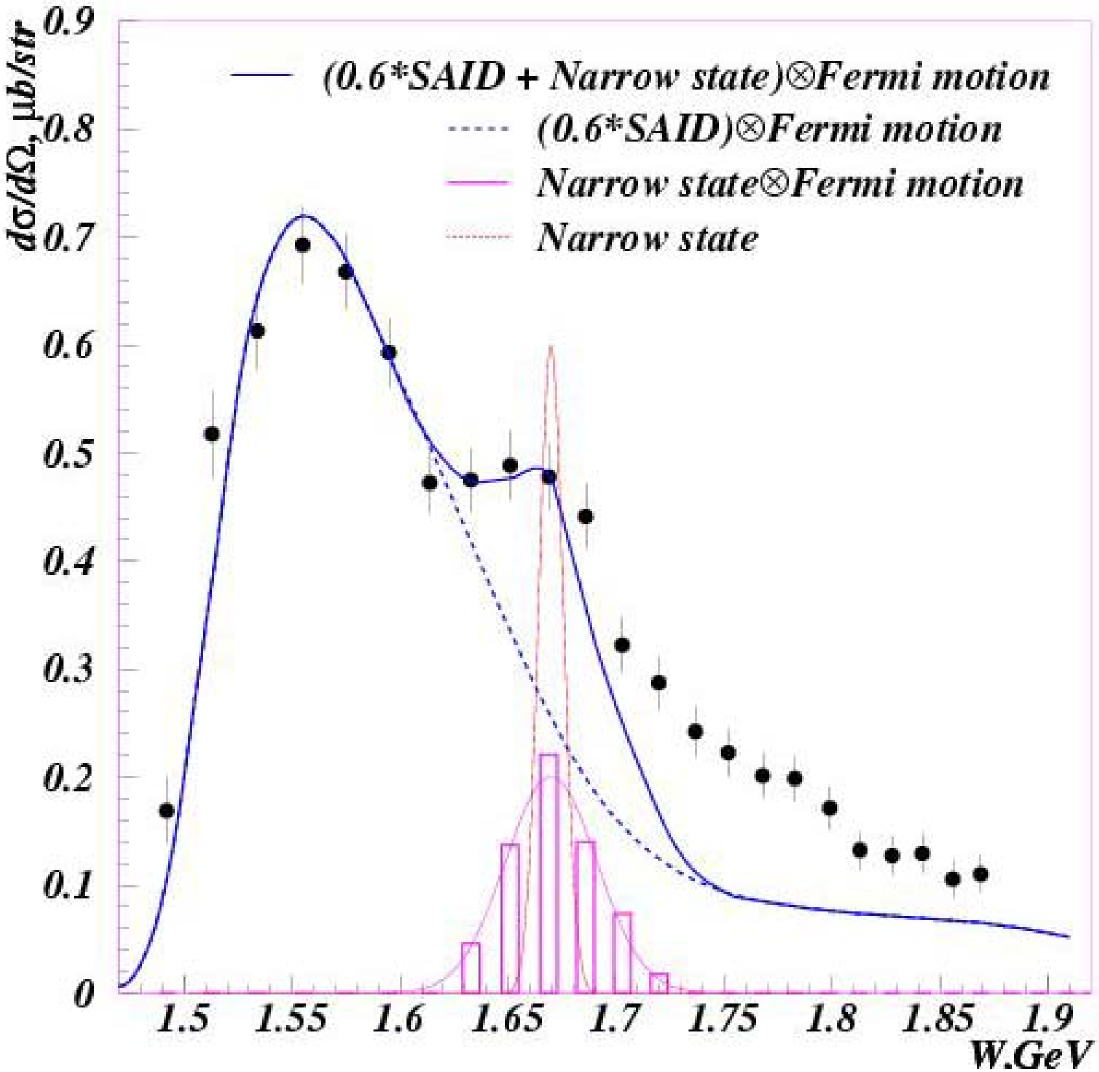
Beam Asymmetry Σ



Solid lines are MAID2000, all resonances

Dashed lines are MAID2000, no D_{15}(1675)

Could it be a narrow state?



The SAID E429 solution for the proton scaled by factor 0.6, as is suggested by previous experiments, well fits the cross section on the neutron in the region of the $S_{11}(1535)$ below W≈1.62 GeV.

The sum of the SAID solution scaled by 0.6, and the simulated contribution of a narrow state (M=1.675 GeV, ΔW=10 MeV), fits well the cross section on the neutron up to W≈1.7 GeV!

This state appears as a bump in the cross section due to Fermi motion.

Some remarks

In terms of L≤2 multipoles, the cross section is

$$\sigma(\theta) \sim \mathrm{Re}\{|E_0^+|^2+(9/2)\,|E_1^+|^2+|M_1^-|^2+(5/2)\,|M_1^+|^2+M_1^{-*}(3E_1^{+}+M_1^+)+ 3E_1^{+*}\,M_1^+ + \cos(\theta)[2E_0^{+*}(3E_1^{+}+M_1^+)-2E_0^{+}\,M_1^-] + \cos^2(\theta)[(9/2)\,|E_1^+|^2-(5/2)\,|M_1^+|^2-3M_1^{-*}(3E_1^{+}+M_1^+)+9\,E_1^{+*}\,M_1^+]\}$$

(C.G.Fasano, F.Tabakin, and B.Saghai, PRC **46**, 6, 1992).

If to assume that the $\gamma n \to \eta n$ reaction near W=1.675GeV is dominated by the $S_{11}(1535)$ resonance (E_0^+) and by a narrow P_{11} state (M_1^-),

$$\sigma(\theta) \sim \mathrm{Re}\{|E_0^+|^2+|M_1^-|^2-2\cos(\theta)\,E_0^{+*}\,M_1^-\}$$

Near W=1.675 GeV Re(E_0^+) and Im(E_0^+) are flat. The P_{11} state would appear as a narrow peak in the ``free" cross section, and as a bump in the quasi-free cross section.

$\gamma n \to \eta n$ data are not in contradiction with the expectation of the χSM and the SAID PWA for the non-strange pentaquark.

The main source of ambiguity is Fermi motion.

Quasi-free cross section is ``folded” with Fermi motion

$$\sigma_{quasi\text{-}free}(w) = \int \sigma_{free}(w^*) A(w,w^*) dw^*$$

where $W=\mathrm{sqrt}((E_\gamma+M_n)^2 - E_\gamma^2)$ is a usually used quantity (ignores Fermi motion), $W^* = \mathrm{sqrt}\{(E_\gamma+E_F)^2-(E_\gamma+P_{Fz})^2-P_{Fx}^2-P_{Fy}^2\}$(+ small correction on binding energy) is the real center-of-mass energy which accounts for Fermi motion, A(W,W*) depends on the deuteron wave function and on cuts used in the analysis.

A crucial task is to retrieve the ``free” cross section

$$\sigma_{free}(w^*)$$

There are two ways:

1) to solve the above equation;

2) to derive Fermi momentum components P_{Fx} P_{Fy} P_{Fz} from data and to reconstruct W* event by event.

Extraction of Fermi momentum from data

Momentum conservation:

$\mathbf{P}_F = \mathbf{P}_\eta + \mathbf{P}_n - \mathbf{P}_\gamma$ (+small correction on binding energy)

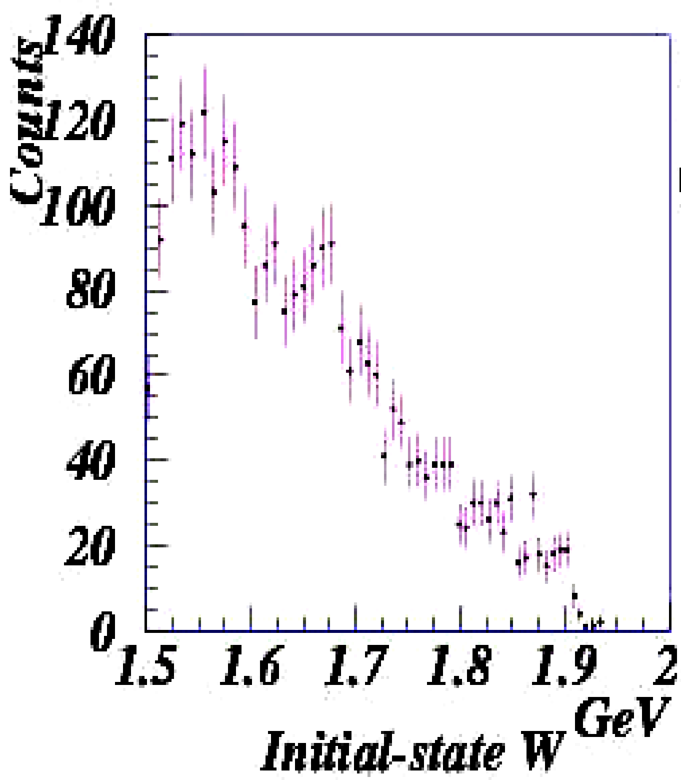
$P_{Fy} \sim P_\eta \sin(\theta_\eta)\cos(\varphi_\eta) + P_n \sin(\theta_n)\cos(\varphi_\eta)$ | Reasonable extraction of
$P_{Fx} \sim P_\eta \sin(\theta_\eta)\sin(\varphi_\eta) + P_n \sin(\theta_n)\sin(\varphi_\eta)$ | transverse components

$\mathbf{P_{Fz} \sim P_\eta \cos(\theta_\eta) + P_n \cos(\theta_n) - P_\gamma}$ | Longitudinal component is a small difference of large values → Large uncertainties due to experimental resolution.

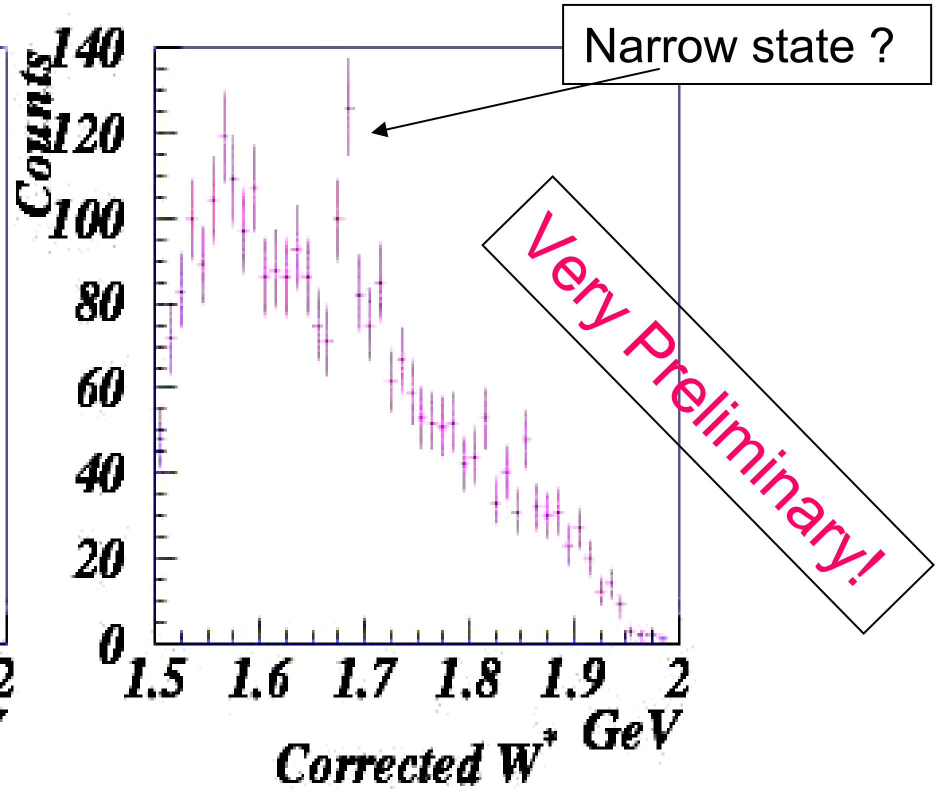
Alternative way: the longitudinal component P_{Fz} is derived from the χ^2 fit (kinematical fit) using the measured η and n parameters and the energy of the incoming photon (details are not presented).

Yield of γn→ηn

No correction



Correction on Fermi motion



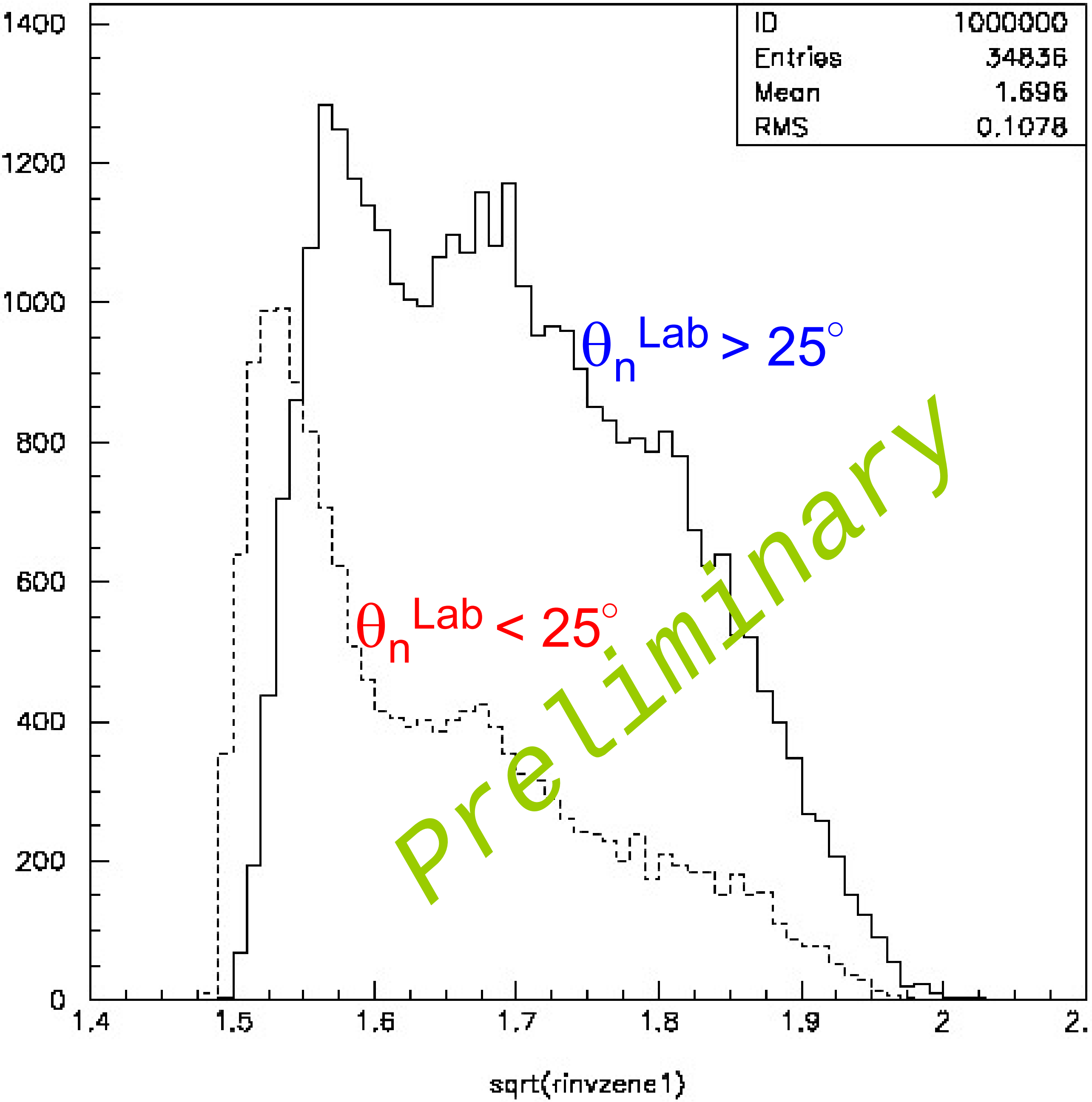
Conclusions

- Quasi-free $\gamma n \rightarrow \eta n$ cross section clearly reveal a resonant structure at $W \approx 1.675$ GeV. This structure may be a manifestation of one of the nucleon resonances. *A priori* its properties, namely the strong photocoupling to the neutron and the possibly narrow width, look surprising. Present experimental data seem not to support the assumption that this is the $D_{15}(1675)$ resonance.
- The observed structure may signal the existence of a relatively narrow ($\Delta W < 20$ MeV) state. If confirmed, this state could be considered as a candidate for the non-strange pentaquark.
- More experimental data are needed to establish the nature of the observed resonance. New data are coming from Bonn (talk of J.Jeagle at NSTAR2005). A new program to study $\gamma n \rightarrow \eta n$ is now launched at the upgraded MamiC facility using the Crystal Ball/Taps setup.

Thank you for your attention!

Invariant η–n mass

(FD vs BGO)



Dashed Line Neutron in the Forward Detector $\theta_n^{Lab} < 25^\circ$

Solid Line Neutron in the BGO $\theta_n^{Lab} > 25^\circ$