Eta photoproduction on the neutron at GRAAL: Search for the non-strange pentaquark

Viacheslav Kuznetsov

Institute for Nuclear Research, 117312, Moscow

- Introduction
- GRAAL Facility
- ? photoproduction on the neutron: Evidence for a resonant structure at W=1.67 GeV
- Correction on Fermi motion of the target neutron: Is this a narrow state?
- Summary

What do we know about the second member of the antidecuplet?

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

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

``…antidecuplet ``friendly" photoreactions…

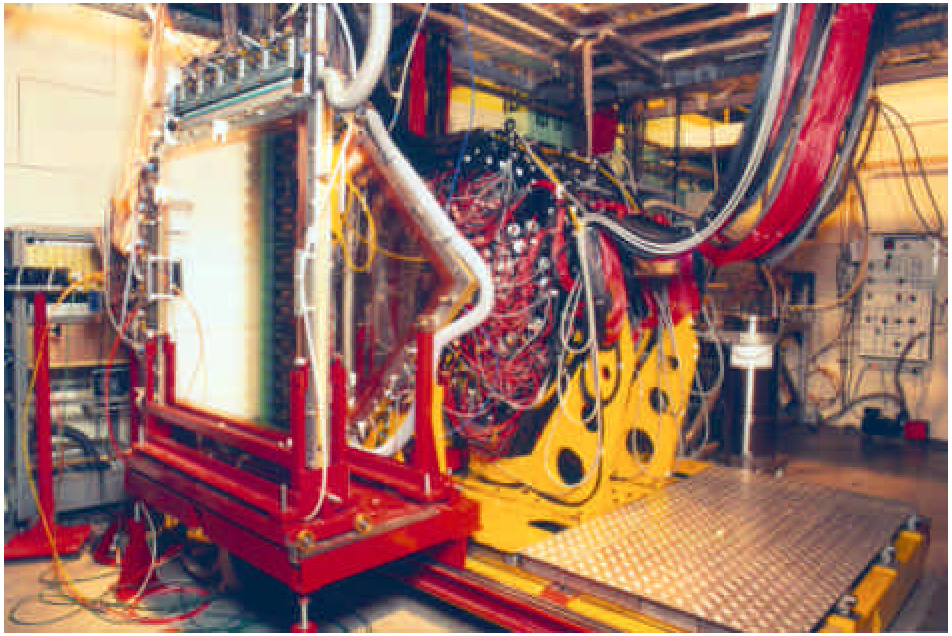
$$?n?\ K^{+}S^{-}\ ,\ \ ?n?\ \ ?n$$

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…."

R.Arndt, Ya.Azimov, M.Polyakov, I.Strakovsky, R.Workman
``Nonstrange and other flavor partners of the exotic ?$^+$ baryon"
Nucl-th/0312126, published in PRC.

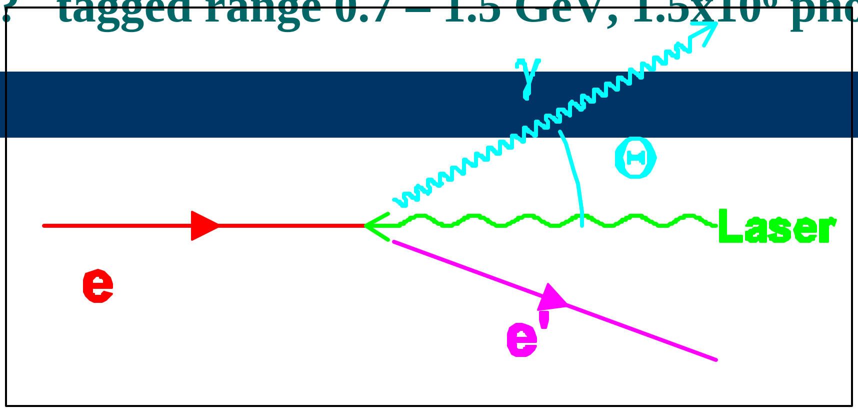
`` … given our present knowledge of the ?$^+$, the state commonly known as the N(1710) is not the appropriate candidate to be a member of the antidecuplet. Instead we suggest candidates with nearby masses, N(1680) (more promising) and/or N(1730) (less promising, but not excluded). Our analysis suggests that the appropriate state should be rather narrow (~10 MeV) and very inelastic…"

GRAAL Facility (ESRF, Grenoble)

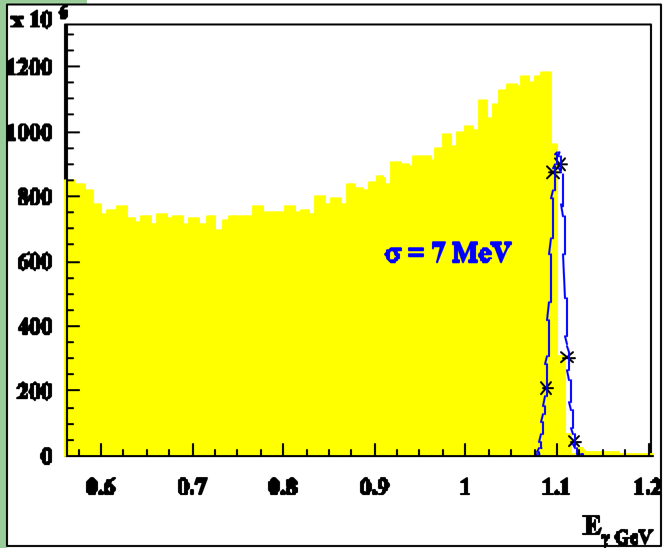


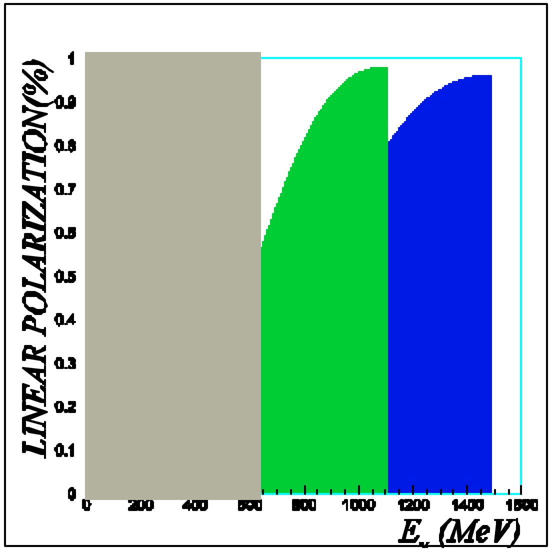
Compton Beam

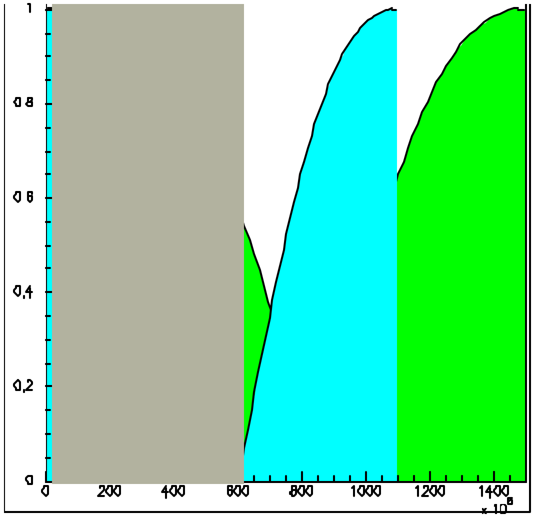
- Green laser line ? tagged range 0.65- 1.1 GeV, 3x10^6 photons/sec
- UV laser line ? tagged range 0.7 – 1.5 GeV, 1.5x10^6 photons/sec



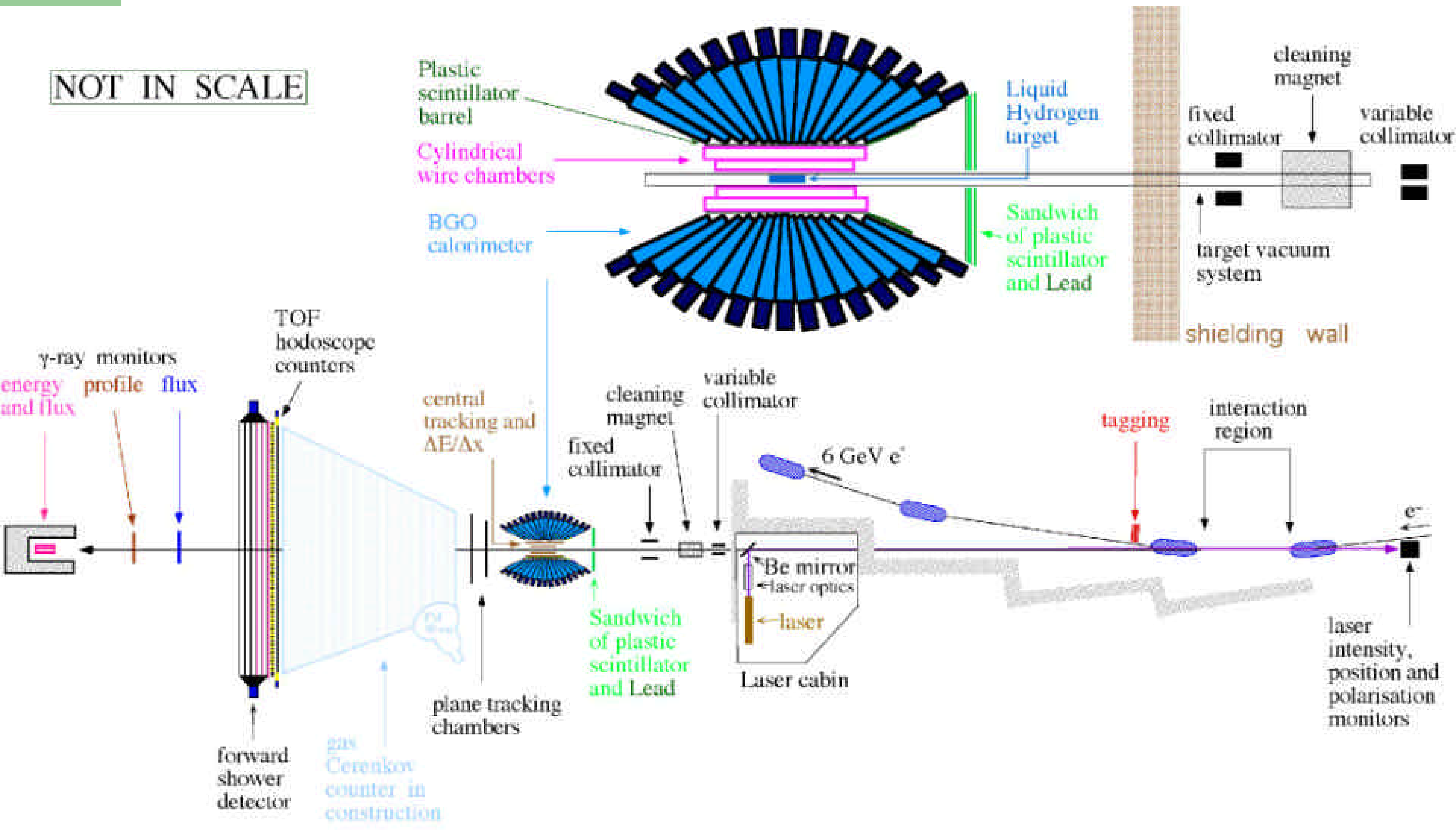
Beam Spectrum | Transverse Polarization | Circular polarization





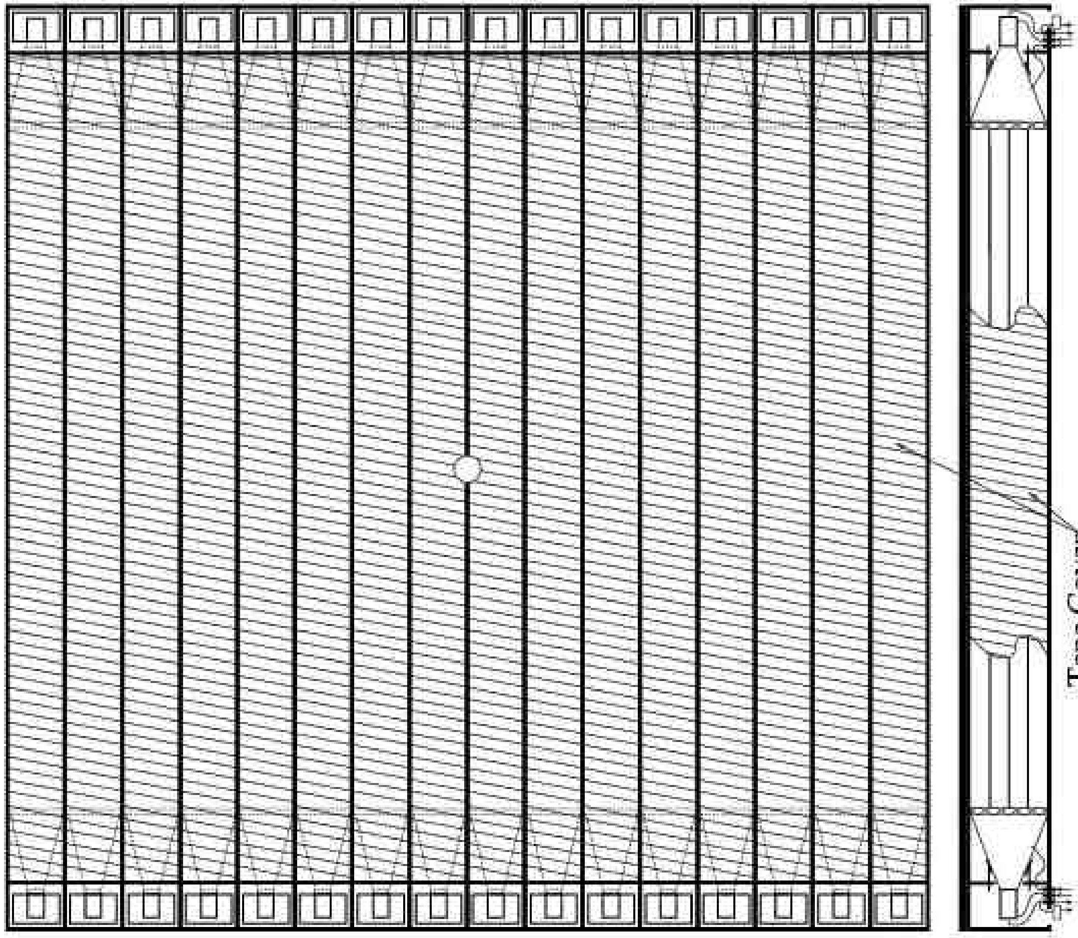


Graal Setup

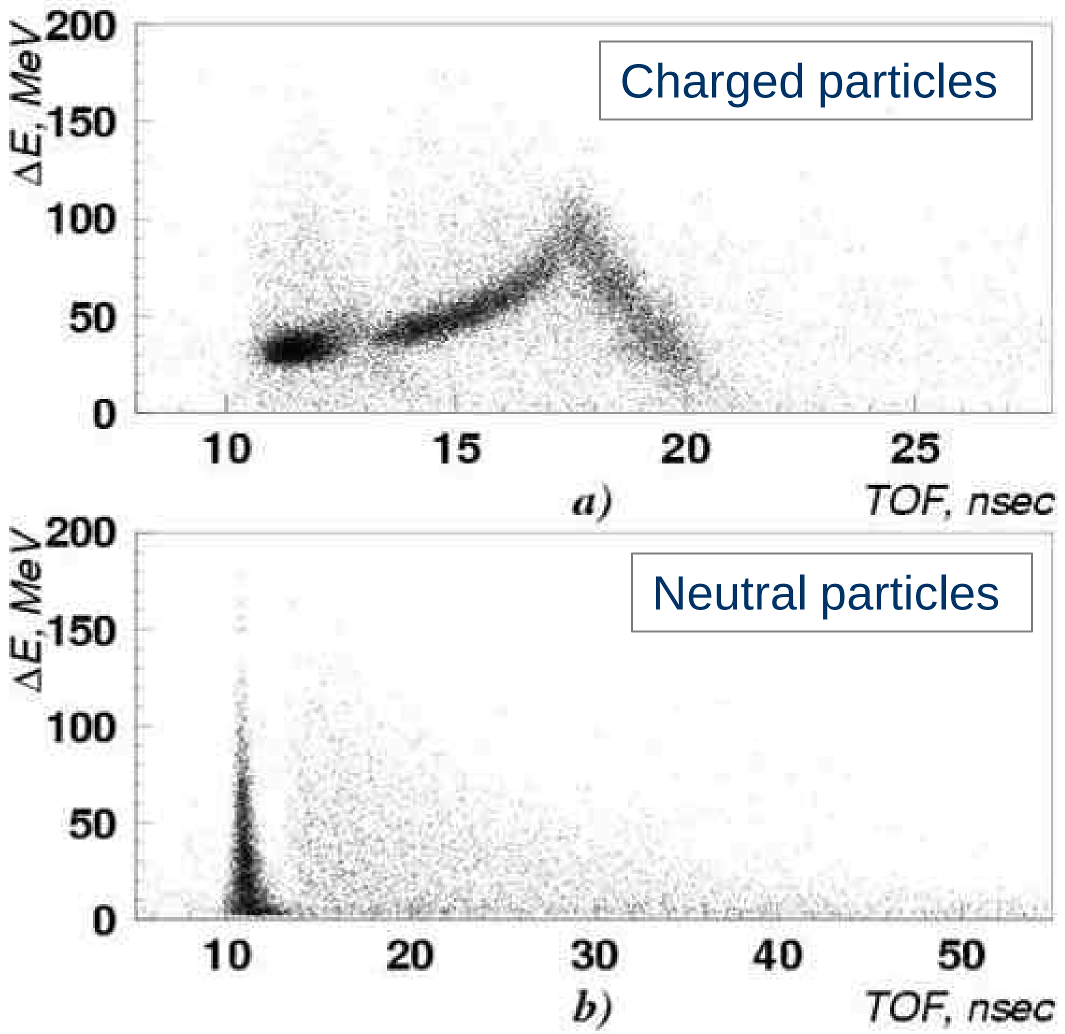

NOT IN SCALE
Plastic scintillator barrel
Cylindrical wire chambers
BGO calorimeter
Liquid Hydrogen target
Sandwich of plastic scintillator and Lead
cleaning magnet
fixed collimator
variable collimator
target vacuum system
shielding wall
γ-ray monitors
energy and flux
profile
flux
TOF hodoscope counters
central tracking and ΔE/Δx
cleaning magnet
variable collimator
fixed collimator
tagging
interaction region
6 GeV e-
e-
Be mirror
laser optics
laser
Laser cabin
Sandwich of plastic scintillator and Lead
plane tracking chambers
forward shower detector
gas Cerenkov counter in construction
laser intensity, position and polarisation monitors

Neutron detectors at 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.



Neutron detectors at GRAAL



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

- Performance of the BGO ball for neutrons:
- Neutron detection efficiency – 35%
- Partial discrimination of neutrons from photons
- No energy/momentum determination, only angular information

? photoproduction on the quasi-free neutron and on the quasi-free proton

- Detection of two photons from ?? 2? decay in the BGO ball; ? identification through the invariant mass of two photons;
- Detection of recoil neutrons and protons in the forward direction;

? **Fully exclusive simultaneous measurements on the quasi-free neutron and on the quasi-free proton in the same experimental run, at the same conditions and in the same solid angle.**

Available data for eta photoproduction on the neutron

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.Weiß et al., Nucl-ex/0201003;

Bonn:

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

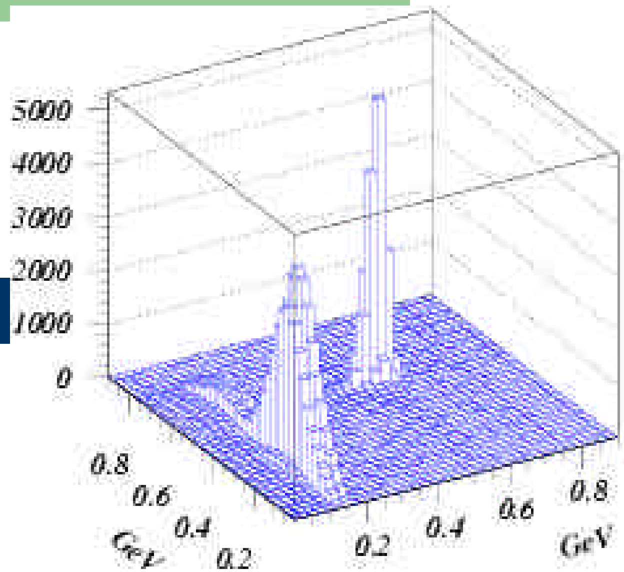
Main outcome

$d s_n / d s_p = 0.67$

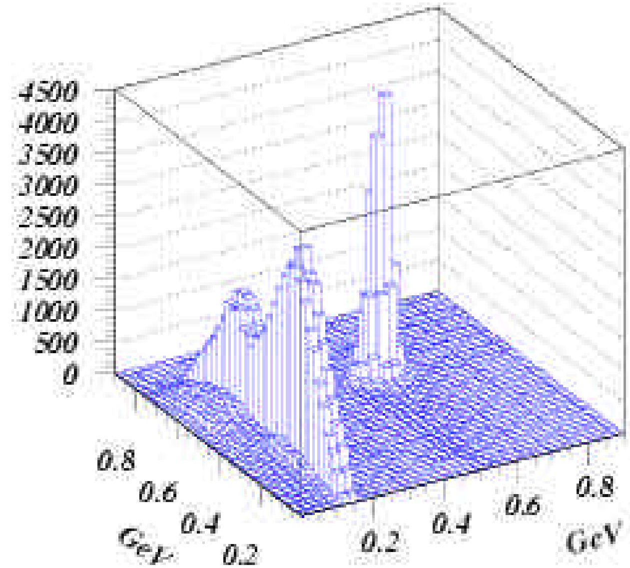
in the energy range from threshold to 0.95 GeV.

New data from GRAAL: V.Kuznetsov et al, Hep-ex/0409032

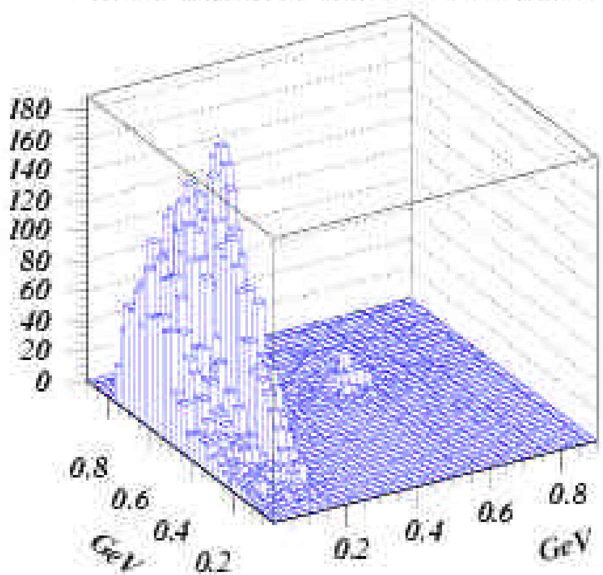
InvMass(2?) vs MissMass(?,N)



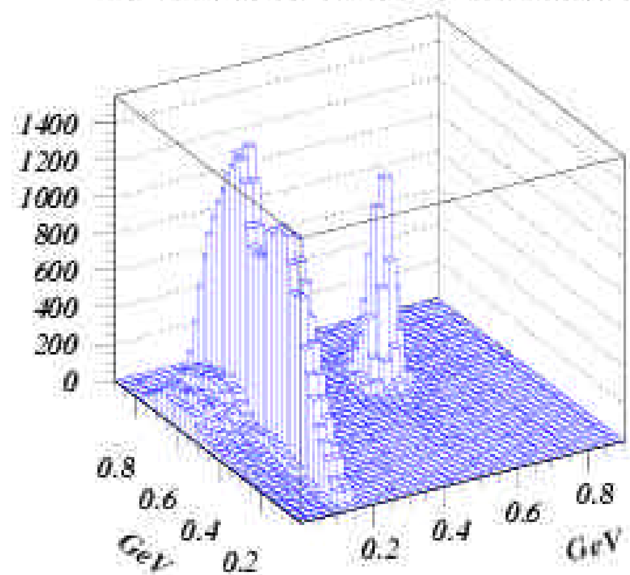
Recoil proton, proton target



Recoil proton, deuteron target



Recoil neutron, proton target



Recoil neutron, deuteron target

Analysis strategy: to study evolution of spectra making cuts tighter, to reduce those events which originate from re-scattering and of which kinematics is strongly distorted by Fermi motion.

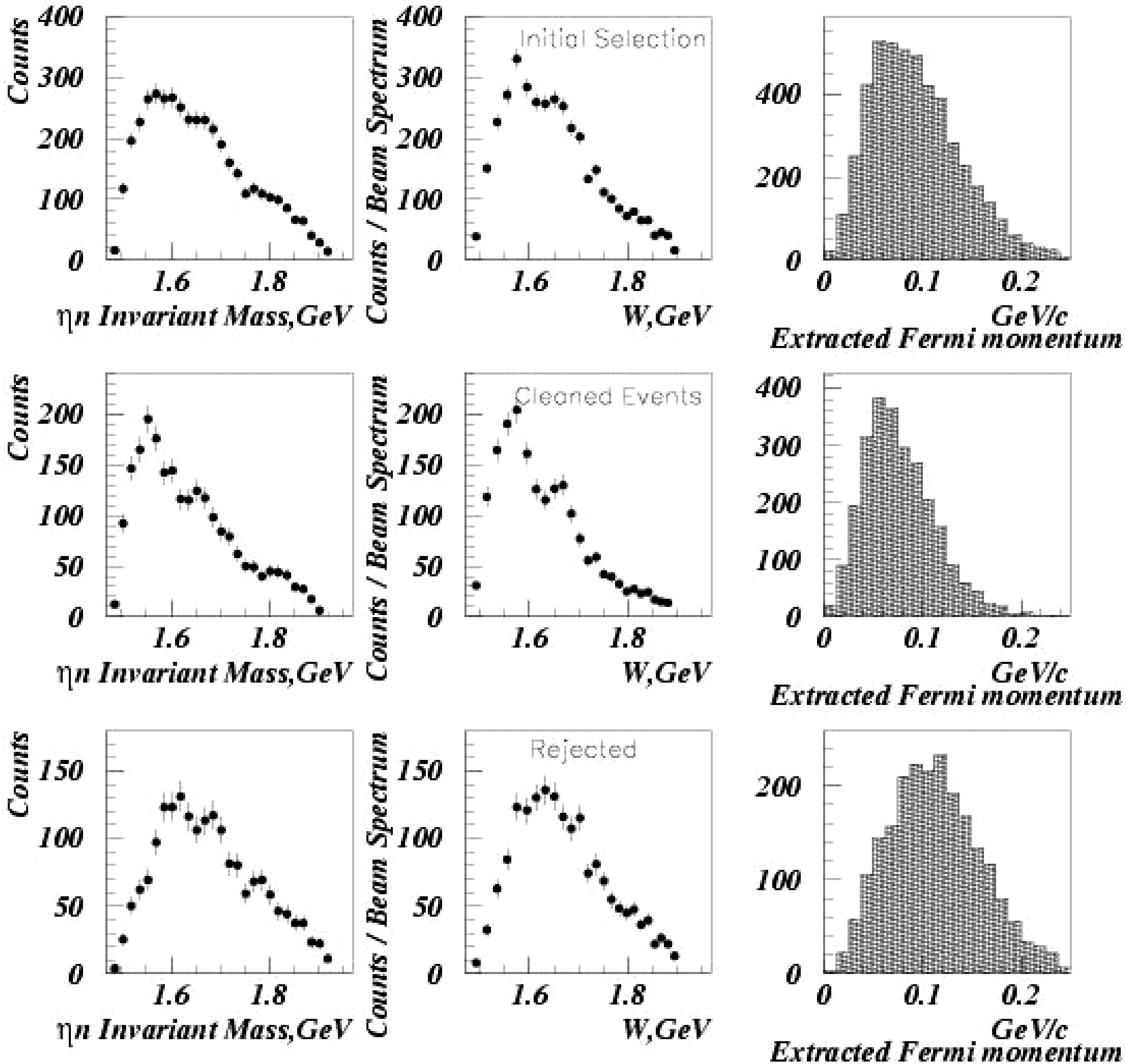
Used quantities at this step:

Center-of-mass energy calculated from energy of the incoming photon

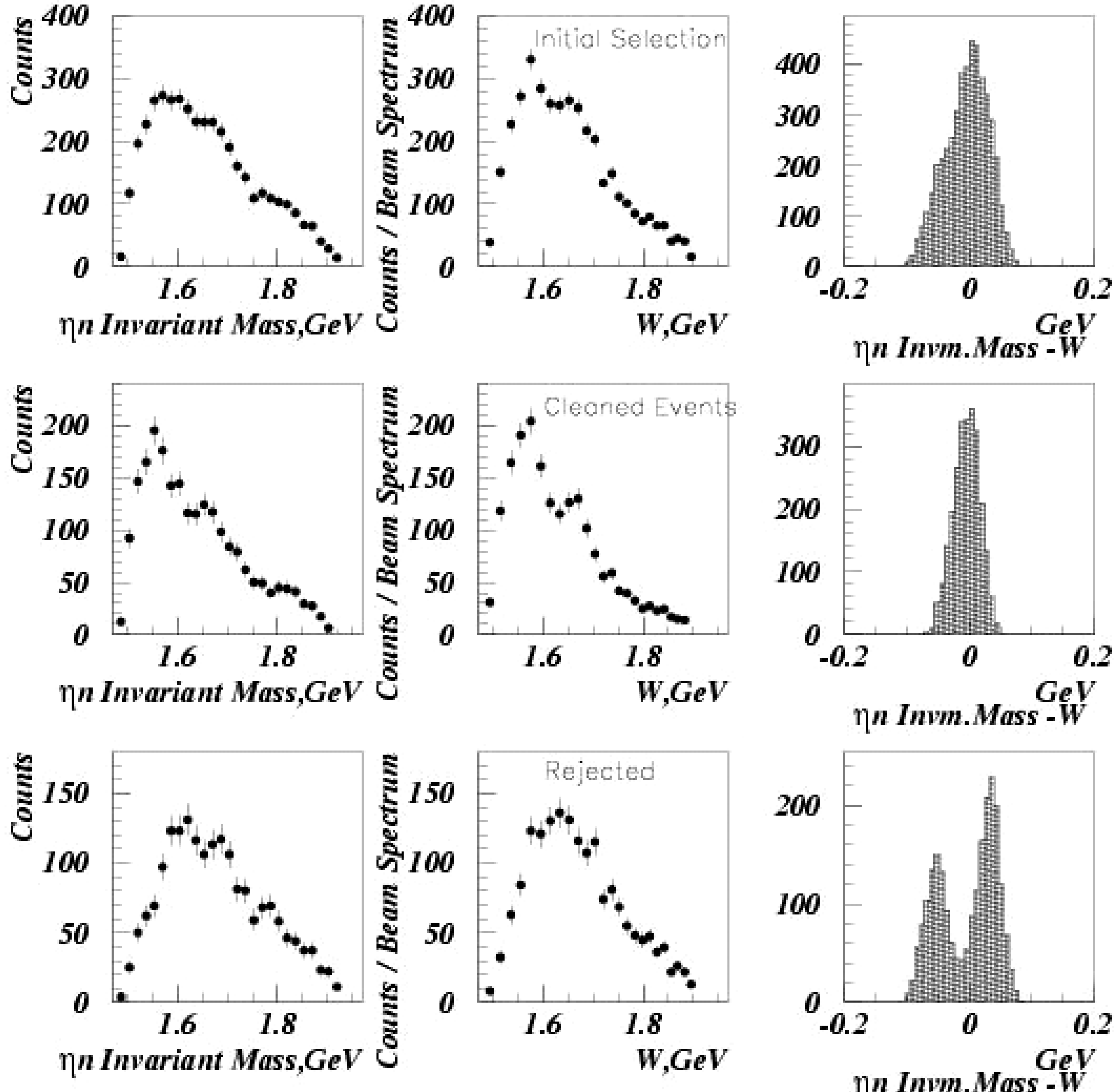
$W=sqrt((E_?+M_n)^2 – E_?^{2)}$

of the target nucleon. W is ``folded” with Fermi motion and is ``peaked” around real center-of-mass energy W*;

Invariant mass of final-state ? and recoil nucleon. It is not affected by Fermi motion but includes large instrumental uncertainties (40 - 80 MeV FWHM);



Initial Selection
Cleaned Events
Rejected
Counts
Counts / Beam Spectrum
ηn Invariant Mass,GeV
W,GeV
GeV/c
Extracted Fermi momentum



Initial Selection
Cleaned Events
Rejected
Counts
Counts / Beam Spectrum
ηn Invariant Mass,GeV
W,GeV
GeV
ηn Invm.Mass - W

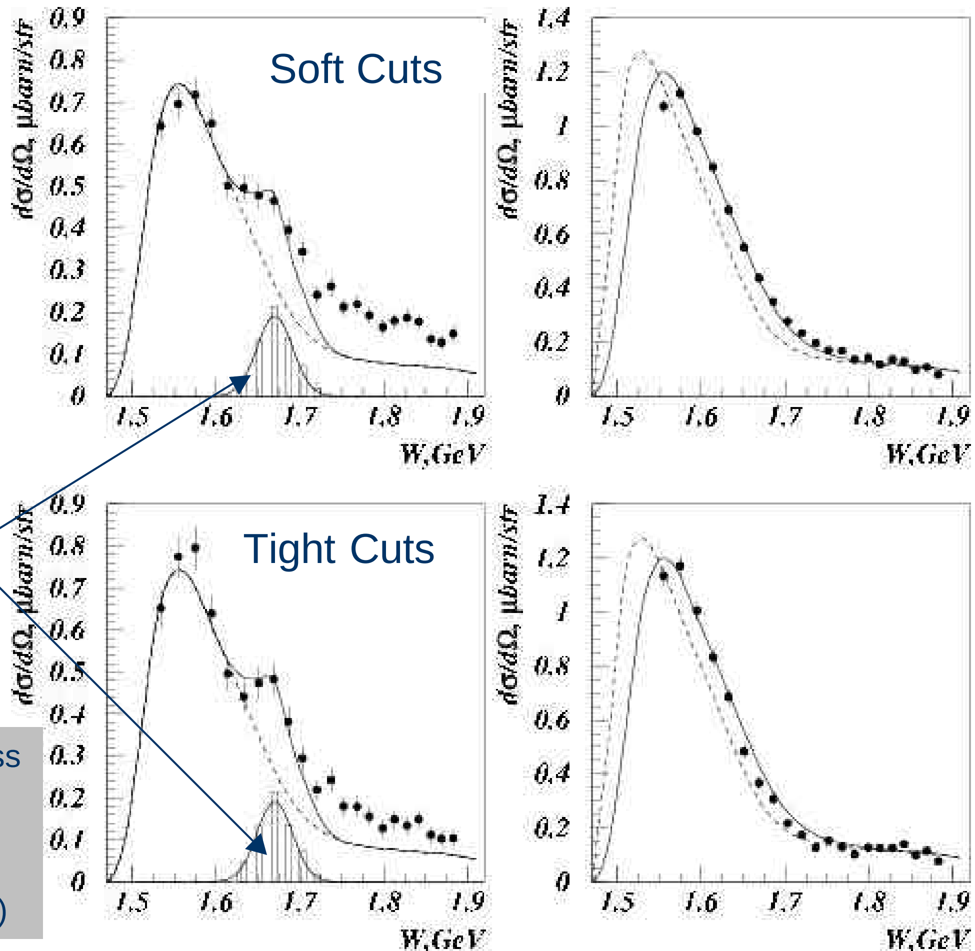
Quasi-free cross sections at T=137 deg

?n? ?n   ?p? ?p

Solid line is the sum of the SAID solution scaled by 0.62 and the contribution of a narrow state

Simulated contribution of a state M=1.675 GeV

?W=10 MeV



Dashed line is E429 solution of the SAID PWA for ?p? ?p;

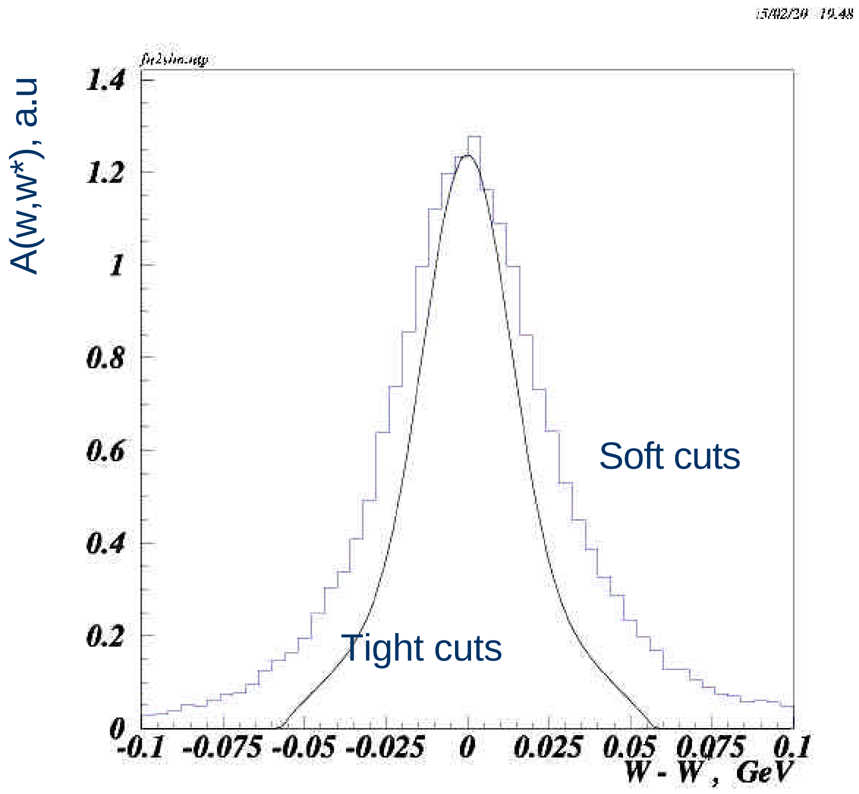
Solid line is the same solution folded with Fermi motion.

Approximate fit of the partial cross section

ds=0.19µbarn/str x

exp((W-1.675GeV)^2/(0.03GeV)^2)

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



Simulated function A(w,w*)

where W=sqrt((E?+Mn)^2 – E?^{2}) is usually used quantity;

W* is the real center-of-mass energy which accounts for Fermi motion.

Two ways:

1) to solve the above equation;

2) to derive Fermi momentum and to reconstruct W*.

Correction on Fermi motion

- Simplest way: Fermi momentum of the target nucleon can be obtained from measured momenta of outgoing particles and the momentum of the incoming photon

$$\mathbf{P}_F = \mathbf{P}_{?} + \mathbf{P}_n - \mathbf{P}_{?}$$

(+small correction on binding energy)

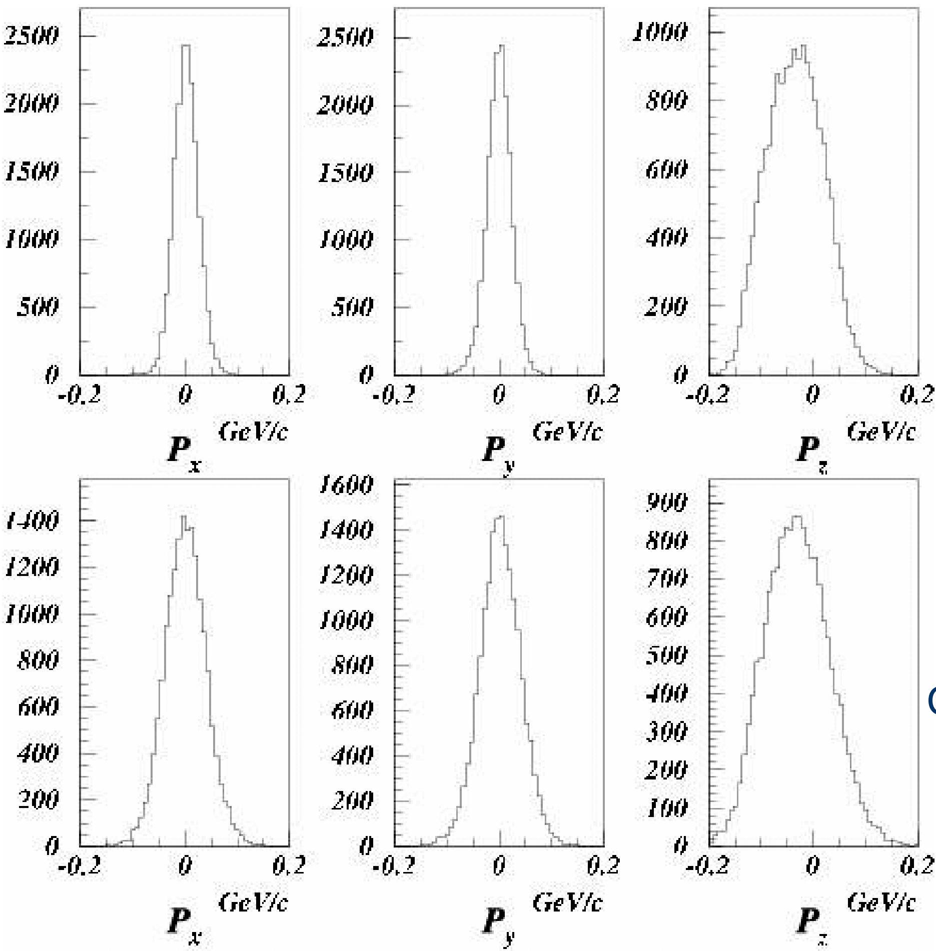
? Reasonable determination of transverse components P_x and P_Y: $P_y \sim P_? \sin(?_?)\cos(f_?) + P_n \sin(?_n)\cos(f_?)$

$$P_x \sim P_? \sin(?_?)\sin(f_?) + P_n \sin(?_n)\sin(f_?)$$

? Large uncertainties in determination of the longitudinal component P_z

$$P_z \sim P_? \cos(?_?) + P_n \cos(?_n) - P_?$$

Components of Fermi momentum extracted in the analyses of eta photoproduction on the free (no Fermi motion, only detector resolution) and quasi-free proton (Fermi motion+resolution)



Free Proton

Quasi-free proton

Different widths for Px and Py,

The same width for Pz

? bad resolution for Pz.

How to solve the problem?

Kinematical fit

Basic idea: Minimization of ?^{2}=S($P_{meas\ i}$ – $P_{calc\ i}$)^2/s^2_i

where $P_{meas\ i}$ denotes measures quantities (i.e. polar and azimuthal angles, TOF, energies etc; $P_{calc\ i}$ are the same quantities defined by the set of independent variables ?$_{cm}$, f , ?$^*_{?,}$f * (? scattering angle, azimuthal angle of (?n) plane, polar and azimuthal angles of ?? 2? decay in the ? rest frame respectively).

Usual application: The value of ?^{2} is used for the selection of events

Modification for quasi-free eta photoproduction

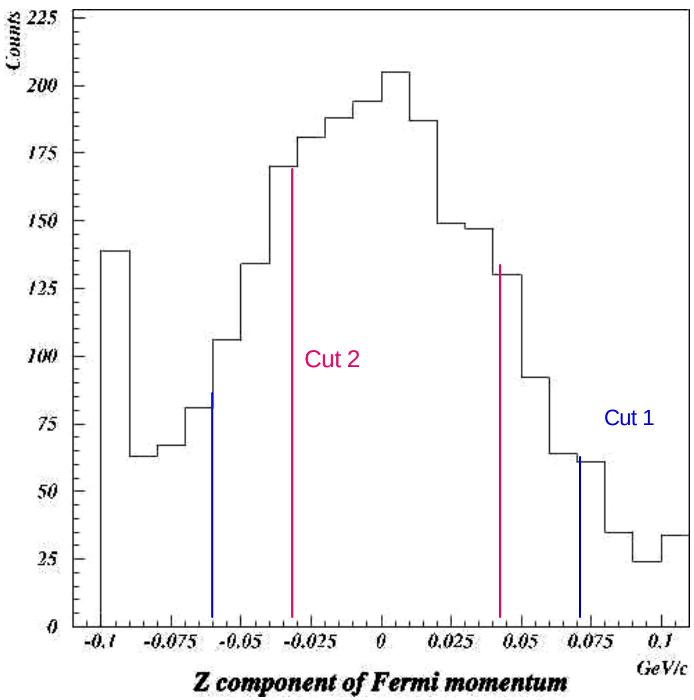
Longitudinal component of Fermi momentum P_z is added to the set of independent variables $?_{cm}$, f , $?^*_{?,}$f .

Goal: to get the more reliable estimate of P_z from the minimization of $?^2$. No cut on $?^2$ is applied.

X and Y components are calculated as before.

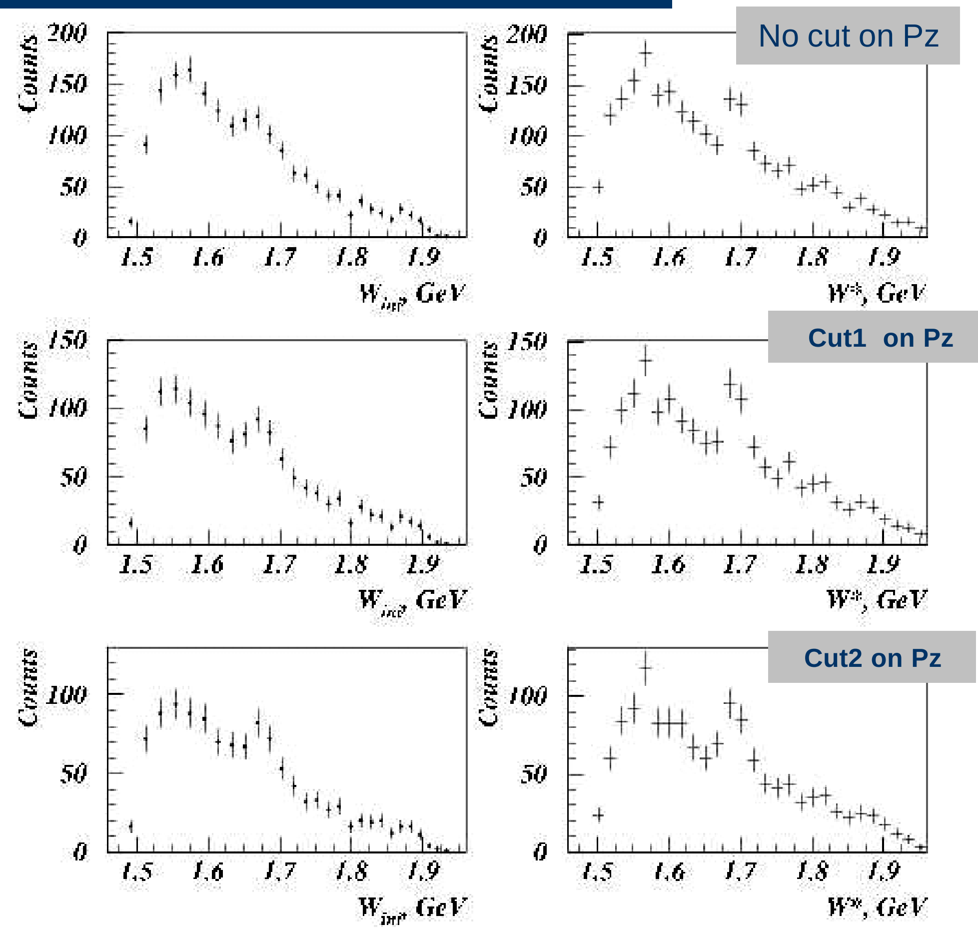
The real cm energy W* is calculated using the energy E? of the incoming photon and the deduced components of the Fermi momentum Px,Py,Pz.

Preliminary data

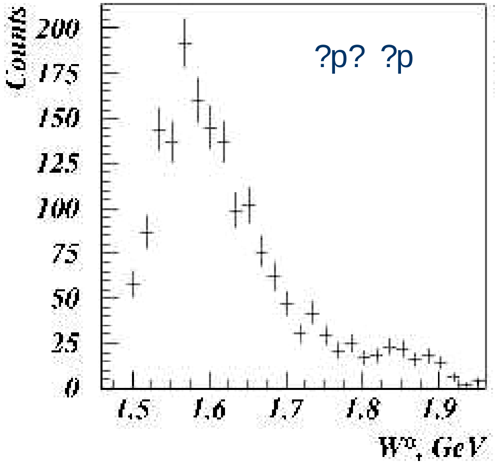


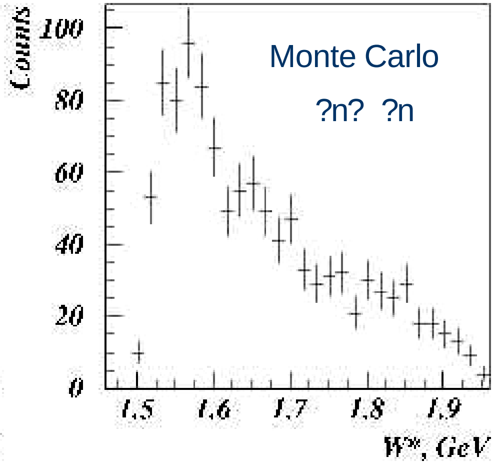
Initial Spectra

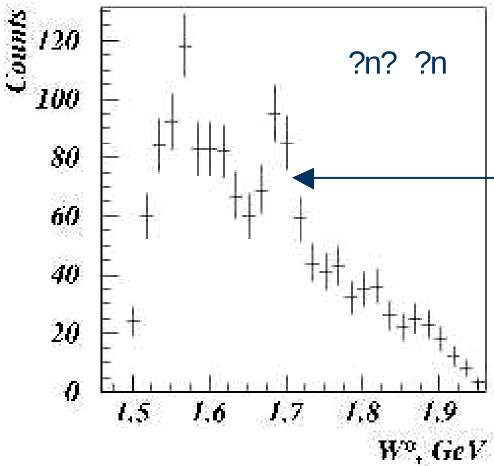
Spectra after correction on Fermi motion



Preliminary







Narrow state?

Summary

- Resonant structure has been observed in ?n? ?n cross section. This structure is not (or poor) seen in ?p? ?p.
- Preliminary, this structure may correspond to a narrow state M=1.675±15 GeV, ?W<15 MeV; analysis to be continued;
- There is a need for confirmation from other facilities (MamiC, Clas/Jlab, Bonn).

Thank you for your attention!