Physics with η-mesons:

the last results from A2 collaboration and prospects

Аннотация

Представлены последние результаты А2 коллаборации. Новые данные по измерению с высокой точностью (увеличение статистики в 100 раз) дифференциальных сечений реакции $\gamma P \rightarrow \eta P$ позволили обнаружить новые особенности реакции. Впервые обнаружена аномалия в энергетической зависимости сечений при W =1700 MeV - энергии «нейтронной аномалии». Обсуждаются физические следствия полученных результатов. Рассмотрен статус «нейтронной аномалии»-одной из наиболее интересных проблем физики промежуточных энергии. Анализируются экспериментальные данные А2 коллаборации, полученные на дейтроне для использования нейтрона как мишени. Предложен новый метод изучения узких резонансов в "production" экспериментах на дейтронной мишени. Рассмотрены возможные эксперименты по изучении природы «нейтронной аномалии» на пионных и фотонных пучках.

Content:

Introduction:

New experiments on PT started. – classic program on base of old analysis

New high energy tagger in operation for η' - decay physics – experiments on H target will start soon.

Ricent results from A2

Study of reaction γp →ηp – experiment was performed in frame of clssic program to study broad resonances (150 MeV). Previous results – Mainz and BNL - increase energy range(s3) Results from Annand and ELSA .(s3 -4)

Mainz data — accuracy restricted by systematic, statistics is enough ..

Deeps in energy dependences of DCS (s5), sharpness in energy dependences of Legandre polynoms (s6-7).

Reasons: Compare with CLAS, cusp effects, pic of narrow cascade resonances (s8)

EPECUR – "cusp" or R(1680)(s9)

Conclusion: the first observation of deep at 1680 MeV – energy of "neutron anomaly", new narrow resonance with hidden strangeness(s10)?

Review of "neutron anomaly"

ηn – anomaly: the first narrow bump with small mass, assimetry in ηp, bump in in γn →γn hudge backgroung from pi0, ηp data from Mainz ηA-interaction bump (s11).

Two ways of W reconsteuction – beam energy and final state energy. Different interpritation (Bonn -Gatchina)(s12)

A2 data – data from P and N from D target are different(s13)

Conclusion: anomaly really exist but before all data came from deutron target.

Deuteron problem:

Standard way – reconstruction and cut on Dwf(s15);

Two conclusion(Sibirtzev and Saranzev). Experimental results of A2 coincide with Sib.

high beam energy resolution is needed (s16).

Bump interpritation – intrference or resonanse? (s17)

Methods of resonances study (s18)

TC method - the only way to improve the sensiviy of seaching

Method idea (s19), Experimental confirmation(s20)

TC for D(s21)? TC for tree-body reaction(s22).

TC for R(1680)(s23) Simulation of TC(s24) Influence of Fermi motion(s25)

Beam reconstruction from proton(s26)

Possible experiments(s27)

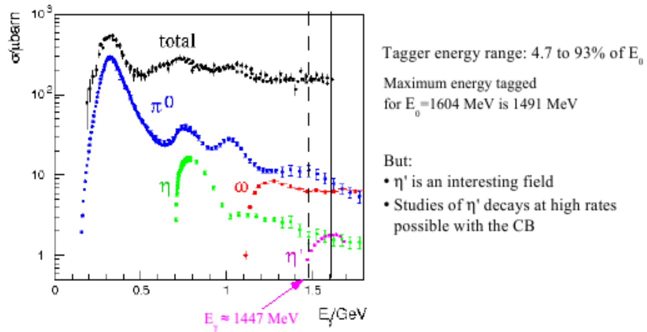
De folding of Fermi motion(s28) ??

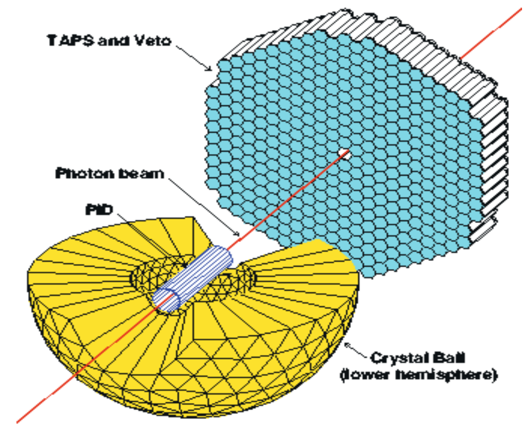
Experimental sets(s29)

Conclusion(s30)

Introduction — status of experiments

The experimental program was based on quality of existing experimental data and analysis The first group of experiments on hydrogen target was complited. Now the experiments on polarized target in progress- mainly data proceeding. Next step – experiments on hydrogen target with new tagger -energy range of etaprime production.The first run is expected in March.





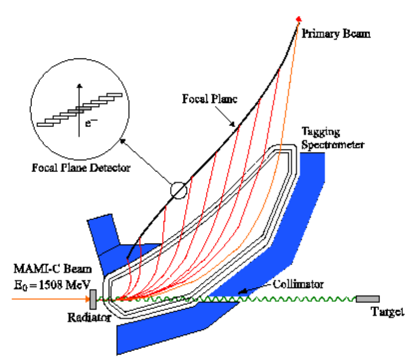
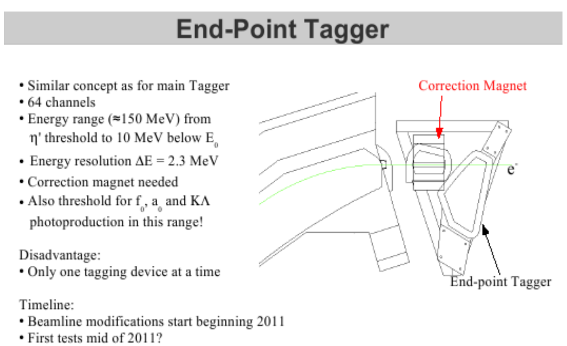


Figure 8: The Glasgow photon tagging spectrometer.



The first results from experiments on hydrogen target are published.
Now I want to present results of eta-production study and the influence of this high precision results on future program and experiments.
The first published article was eta-pi production but eta-productin is much more accurate experiment and much more carefull data handling is needed

The results of CB collaboration experiments on photon(Mainz) and pions(BNL) beams.

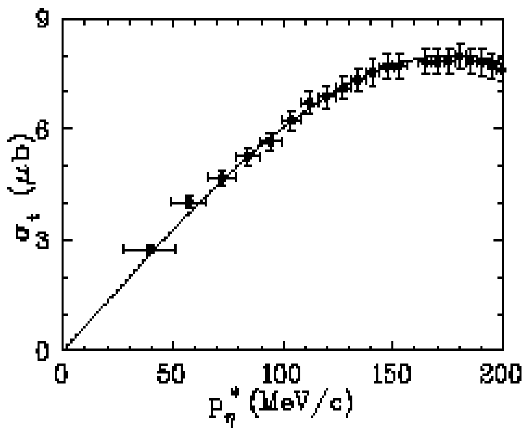
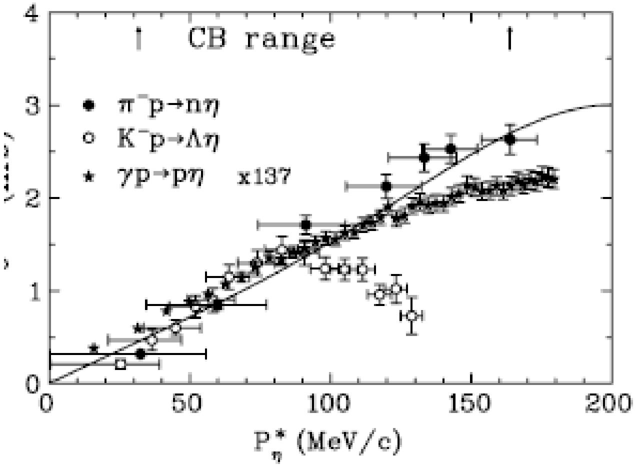


FIG. 12: Our total cross section (circles) for $\gamma p \to \eta p$ as a function of the η momentum in the c.m. frame. The solid line shows the results of fitting our data to a sum of linear and cubic terms.



The accuracy better than 10 % influence on study of reaction mechanizm

BNL dp/p 1% dpabs 2.5 Mev

Mainz dE 1 MeV

dM from Mainz(nik) ??

0.8 in dE --> 0.5 MeV in eta-mass

Conclusion:

The last results of DCS η-meson photoproduction really reach its limits in accuracy – unavoidable systematic errors

What is next step: Polarazed target,Neutron target, Other approaches

The good results from pion beam is only up to 747 MeV/c

At low energy CS = Pcm

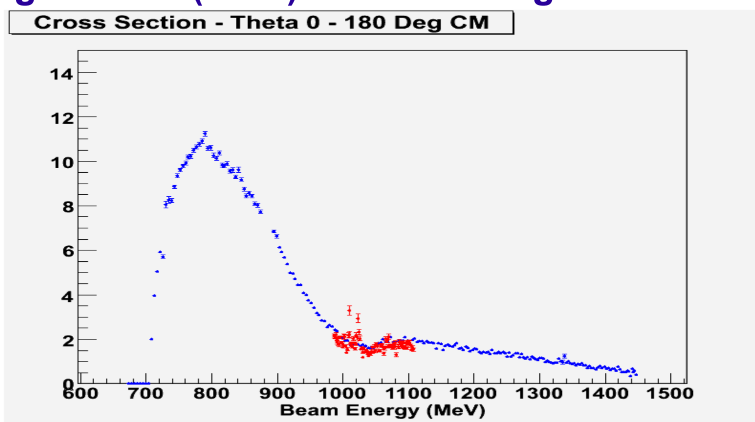
The program of eta-study was based on existingi experimental data and analysis, main goal — to enlage energy range of good experimental data in region of low energy resonances

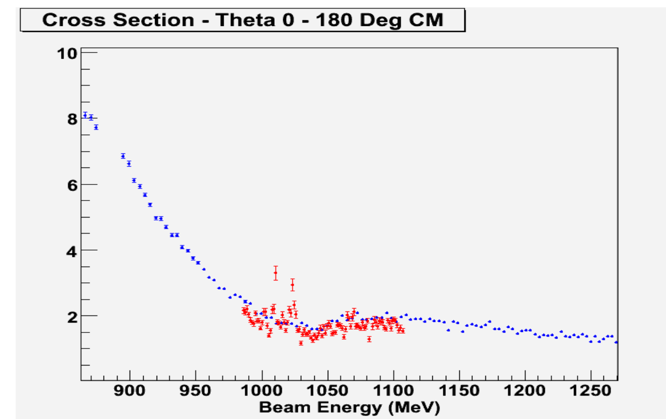
Study of the γp → ηp reaction with the Crystal Ball detector at the Mainz Microtron

One of the main reasons of experiment is a problem of R(1680) — bump or resonance?
Accumulated data about 4*10**6 events allows a detailed study of reaction dynamic.
The 120 energy bin in range 707-1400 MeV show dip in forward direction of η - mesons at energy W(1680 MeV) . Decay eta-> 6g was used as more relaible.

Total cross-sections from A2 experiments **Phys.Rev. C 82,035208(2010)**

No signal at W(1680) even from high beam energy resoution measurement





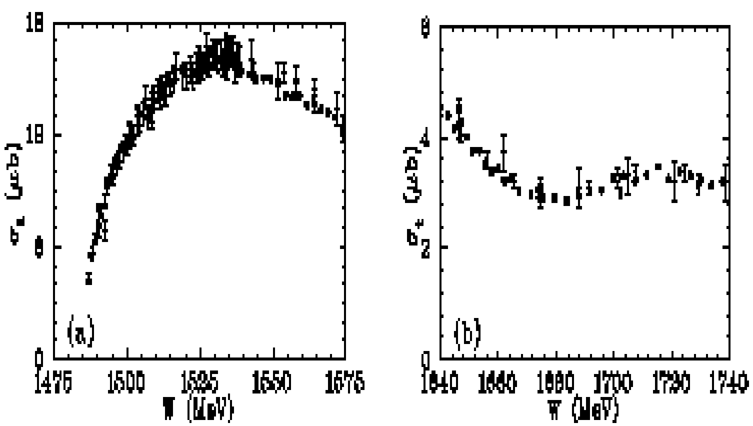
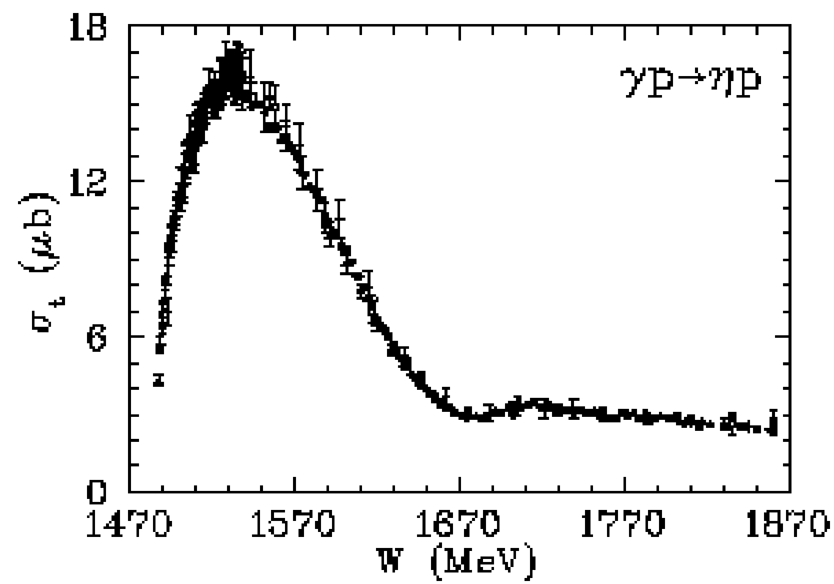


FIG. 7: Same as Fig. [?] but for narrower W ranges: (a) from the threshold to the maximum of the total cross section and (b) around a shallow dip, W = 1680 MeV.



Total CS concides for both A2 experiments

Changing of energy dependencies of DCS

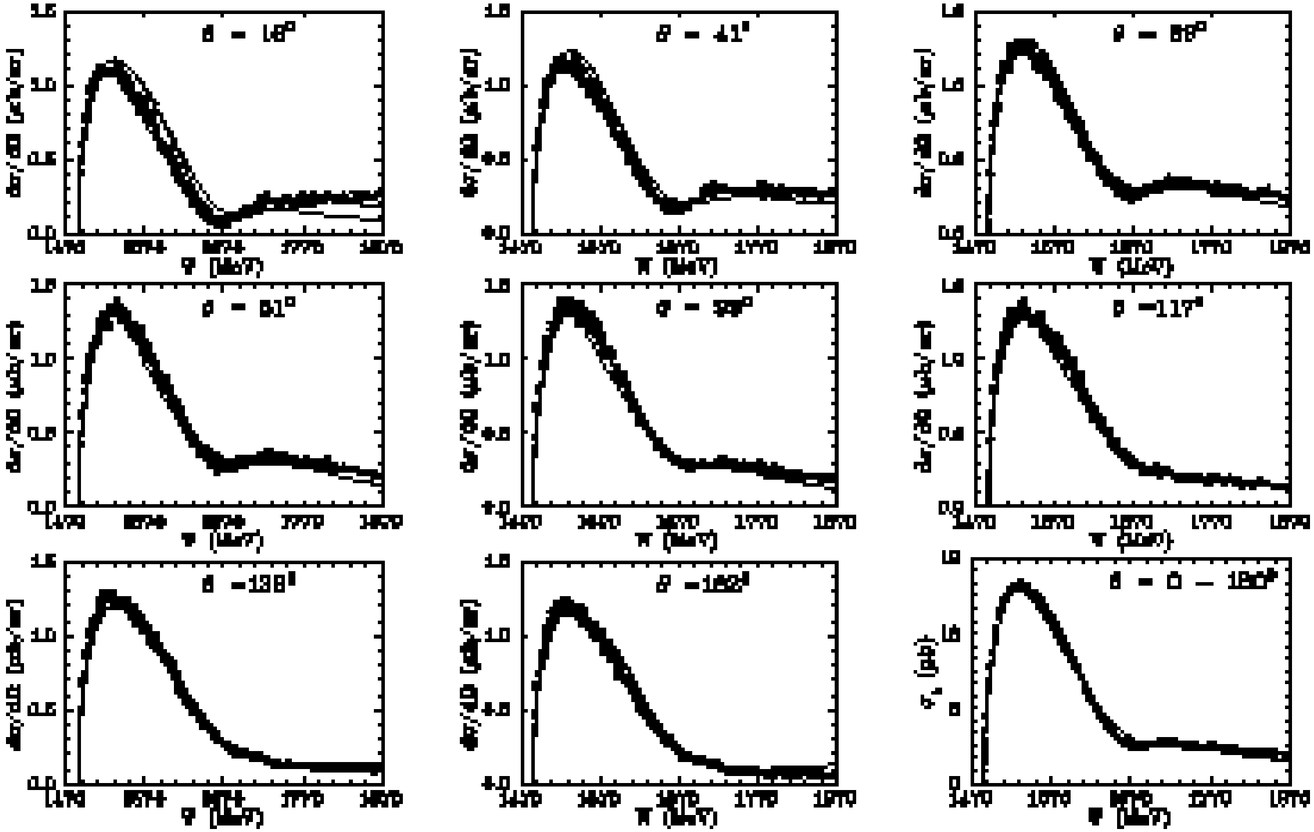


FIG. 10: Fixed-angle excitation functions for $\gamma p \to \eta p$ as a function of the c.m. energy W shown for eight values of the η production angle and for the full angular range. Our data are shown by solid circles. The plotted uncertainties are statistical only. The notation of the PWA solutions is the same as in Fig. [illegible]

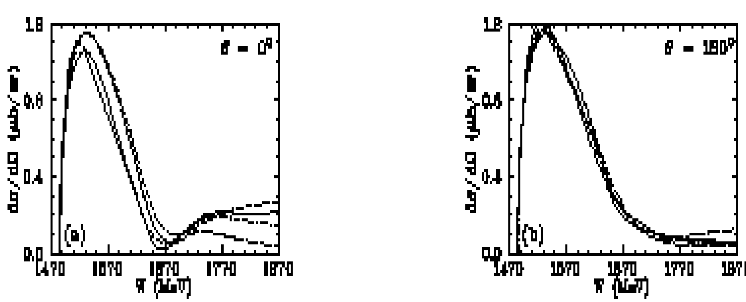


FIG. 11: PWA predictions for the $\gamma p \to \eta p$ excitation function at the extreme (forward and backward) production angles of η, shown as a function of the c.m. energy W. Notation of the PWA predictions is the same as in Fig. [illegible]

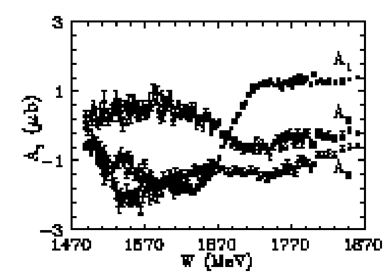
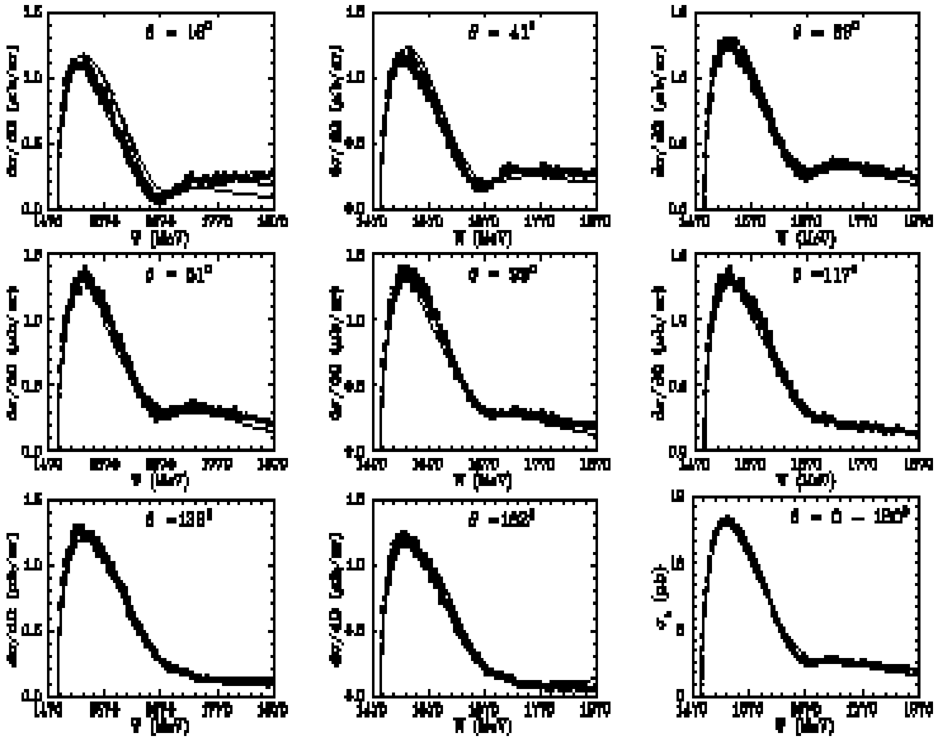


FIG. 8: Dominant Legendre coefficients from the fits to our differential cross sections. The coefficients are plotted as a function of the c.m. energy; A_1 is shown by solid circles, A_2 by open triangles, and A_3 by open circles.

The results of study reaction γP → ηP *in Mainz*
Energy step 7 MeV



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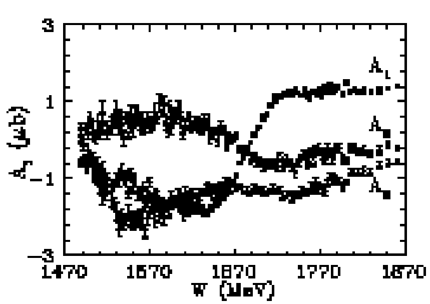

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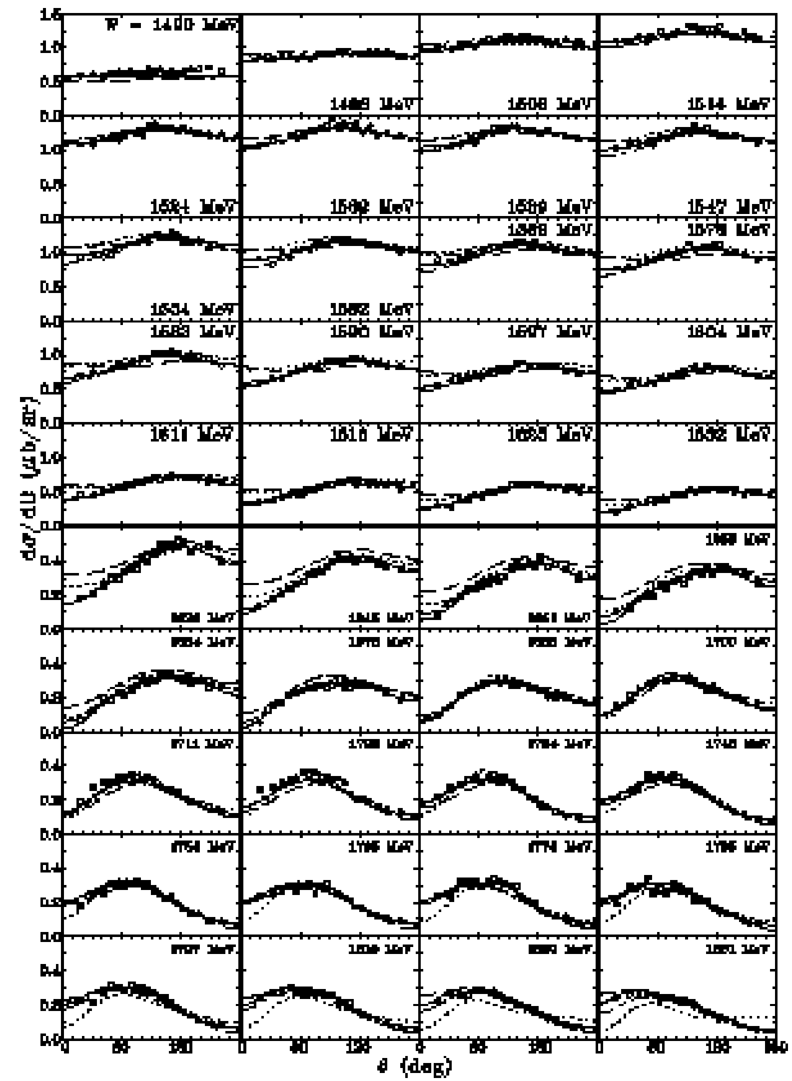


The shape of DCS is changing in energy range of 900 — 1100 MeV

Changing in shape of DCS results to sharp changing in expansion coefficient

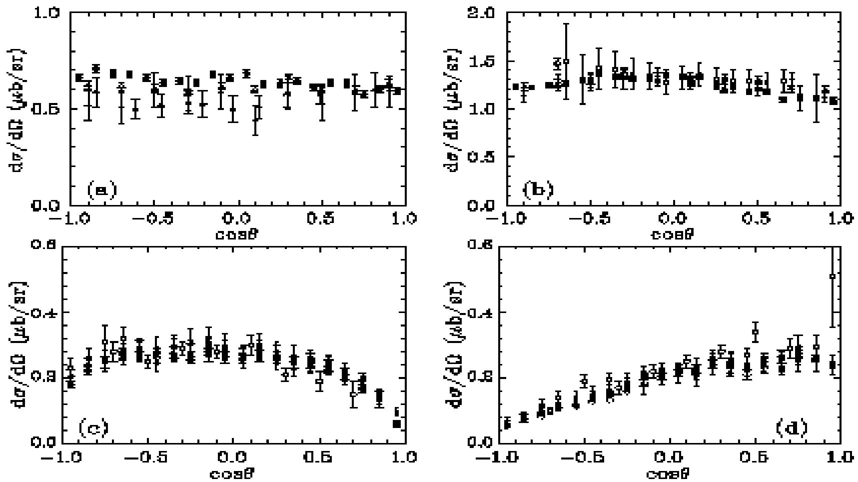
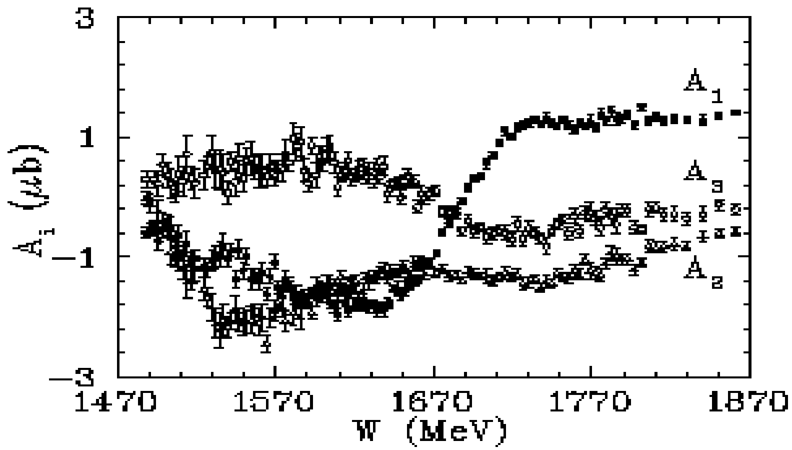


FIG. 5: Differential cross sections for $\gamma p \to \eta p$ as a function of $\cos\theta$, where θ is the production angle of η in the c.m. frame. The present data (solid circles) are shown for four energy bins: (a) $E_\gamma = 714.5 \pm 2.1$ MeV, (b) 772.9 ± 2.1 MeV, (c) 1026.8 ± 3.7 MeV, and (d) 1376.2 ± 9.7 MeV. Previous data are shown for experiments at MAMI-B [17] for 715.9 ± 5 MeV and 775.3 ± 5 MeV (open triangles); CLAS-g1c [18] for 775 ± 25 MeV, 1025 ± 25 MeV, and 1375 ± 25 MeV (open circles); CLAS-g11a [19] for 1384 ± 10 MeV (open diamonds); GRAAL [20] for 714 ± 9 MeV and 1024 ± 9 MeV (open diamonds with crosses); LNS [21] for 718.0 ± 10 MeV and 768.8 ± 10 MeV (horizontal bars); CB-ELSA [22] for 774 ± 25 MeV, 1025 ± 25 MeV, and 1374 ± 25 MeV (open squares); and CB-ELSA/TAPS [23] for 1025 ± 25 MeV and 1375 ± 25 MeV (crosses). Plotted uncertainties are statistical only.



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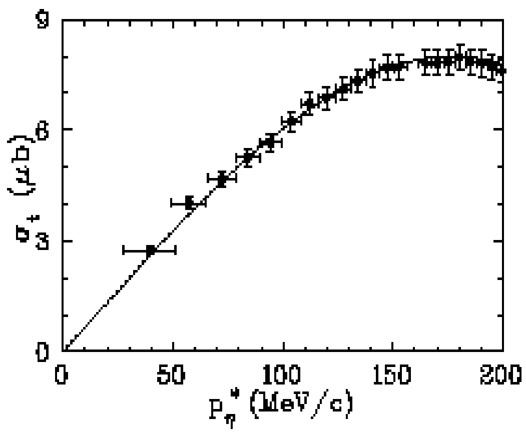

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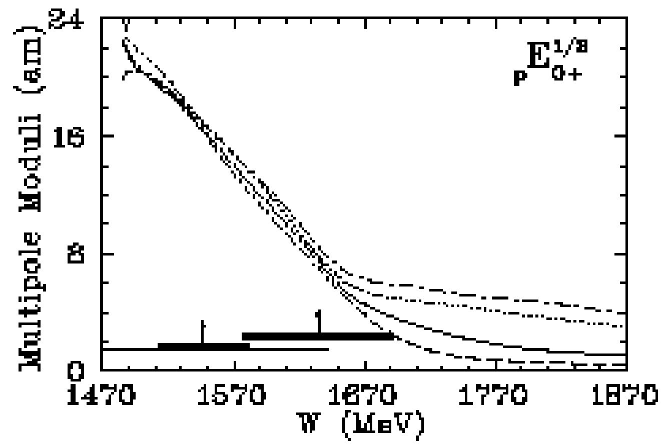


FIG. 13: Modulus of the multipole amplitude $S_{11}pE$ ($_pE^{1/2}_{0+}$) for $\gamma p \to \eta p$ from the reaction threshold to $E_\gamma = 1.4$ GeV. Notations for the amplitude curves are the same as in Fig. 9. The vertical arrows indicate W_R (Breit-Wigner mass) and the horizontal bars show the full and partial width Γ for $\Gamma_{\pi N}$ associated with the SAID solution SP06 for πN [2].

The possible reason s of sharp structures in DCS

Effects of narrow strange resonance

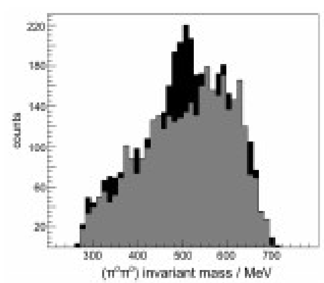


Figure 3: $\pi^0\pi^0$ invariant mass distribution for the bin 1350 – 1450 MeV in photon energy and 0 – 0.33 in $\cos\Theta^K_{CMS}$ after a cut on the Σ^+ mass in Figure 2: 1170 MeV $\leq M_{p\pi^0} \leq$ 1210 MeV. The grey area represents the simulated background from uncorrelated $3\pi^0$ photoproduction, scaled to the experimental yield outside the signal area (cf. text).

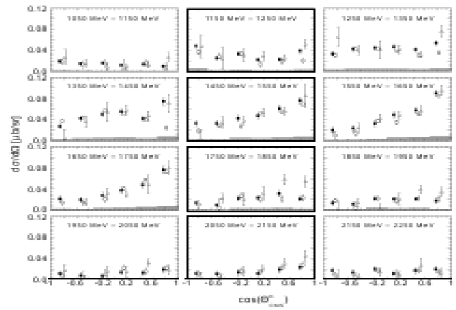


Figure 5: Measured differential cross sections for $K^0\Sigma^+$ photoproduction as a function of the kaon center-of-mass angle in ±50 MeV wide bins of photon energy from 1100 to 2200 MeV. The present results (full squares) are compared to previous measurements of Crystal Barrel (open squares) [21] and SAPHIR (triangles) [22]. The error bars are purely statistical. An estimate of the systematic uncertainty is given by the bars on the abscissa (cf. text).

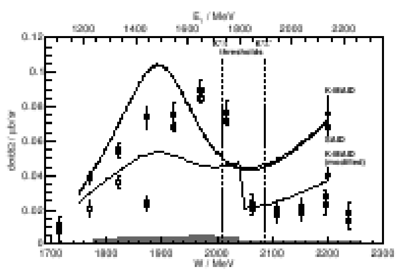
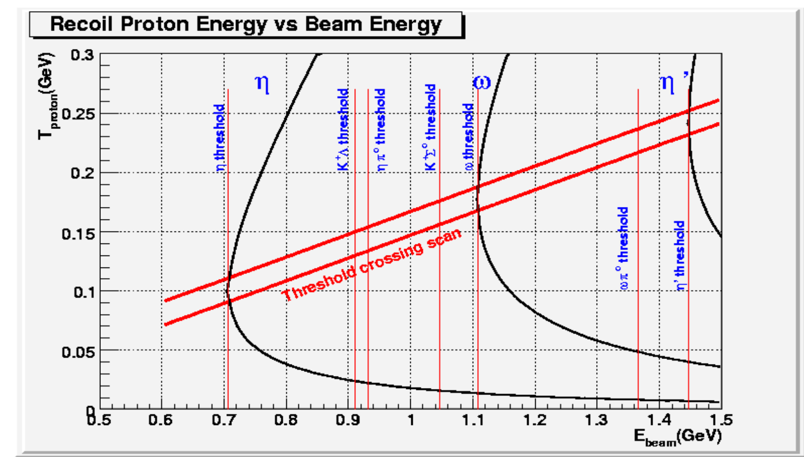
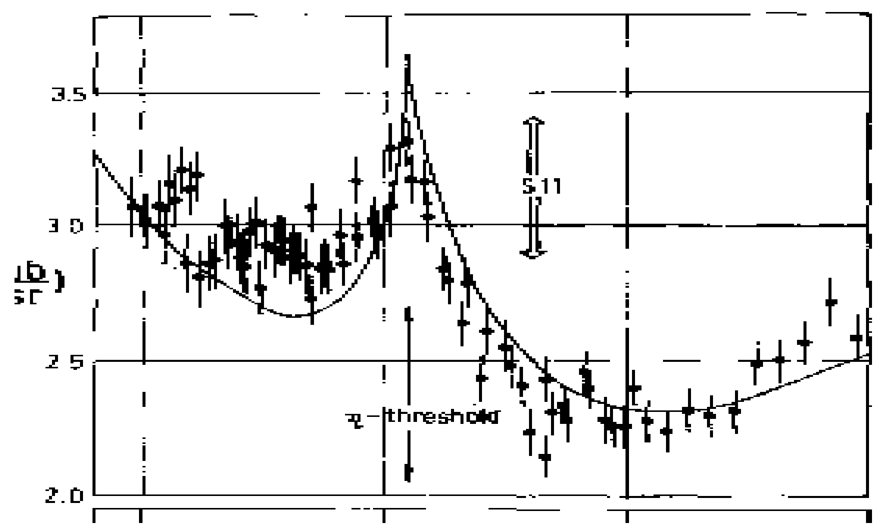


Figure 7: Cross section for $K^0\Sigma^+$ photoproduction as a function of the centre-of-mass energy from the present (full squares) and a previous (open squares) [21] Crystal Barrel experiment in the most forward angular bin of Figure 5. Plotted errors and curves represent the same as in Figure 6, the vertical lines as well.

Anomaly in the $K^0_S\Sigma^+$ photoproduction cross section off the proton at the K^* threshold

CUSP effects





To understand the reason of bump the extra experimental data are needed

Classic way --PT and neutron target experiments are in progress

eta-p bump in A1

eta-n bump in A0

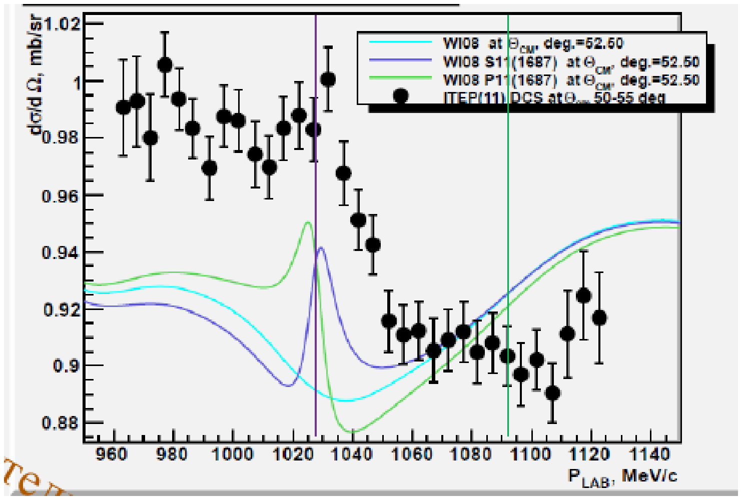
Example of «cusp» effect in PiPlus Photoproduction at eta-meson threhold

The FWHM of effect is about 20 MeV.

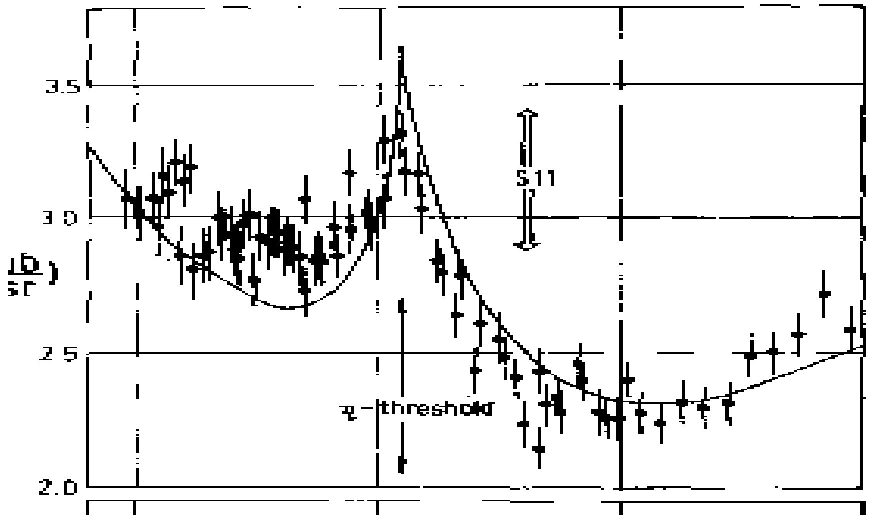
Cusp exists in any reaction.

Examples of «cusp» effects

EPECUR- what it means?



ELSA-cusp from eta



$\pi^- p \to K^0 \Sigma^0$ – M_{inv}=1690.2 МэВ P_{beam} = 1033 МэВ/с

$\pi^- p \to K^+ \Sigma^-$ – M_{inv}=1691.1 МэВ P_{beam} = 1035 МэВ/с

$\pi^- p \to \omega n$ – M_{inv}=1722.3 МэВ P_{beam} = 1092 МэВ/с

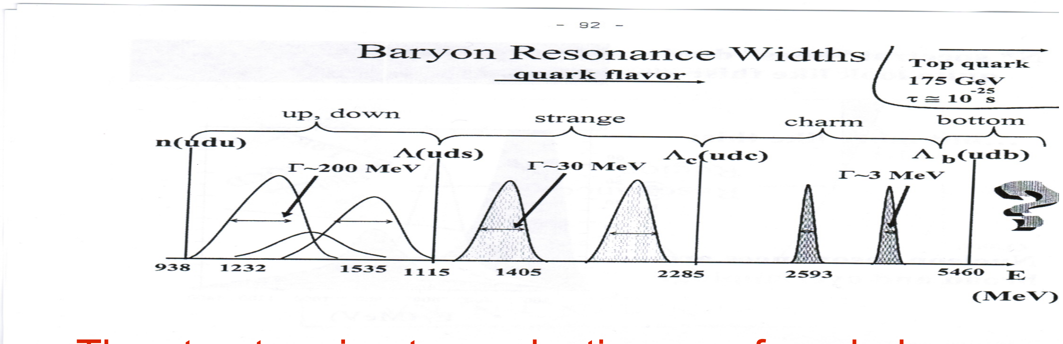
The «cusp» effect is clearly seen :
Rutherford Lab pi- p at eta-production threshold clean cusp no other channels
EPECUR — pi- p at R(1680)
ELSA gp->pi p at eta-production threshold
MAMI gp->eta p at R(1680) production threshold

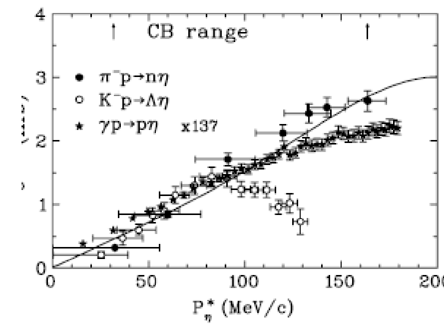
«Cusp» should be in S-state but gp->etap A1

Other A0

EPECUR -cusp or R(1680)?

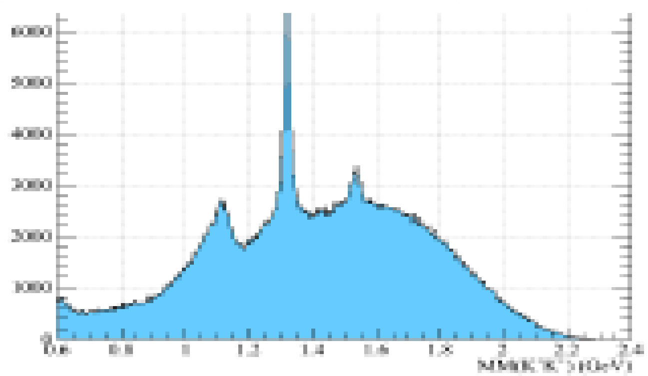
New narrow resonance with hidden strangeness?

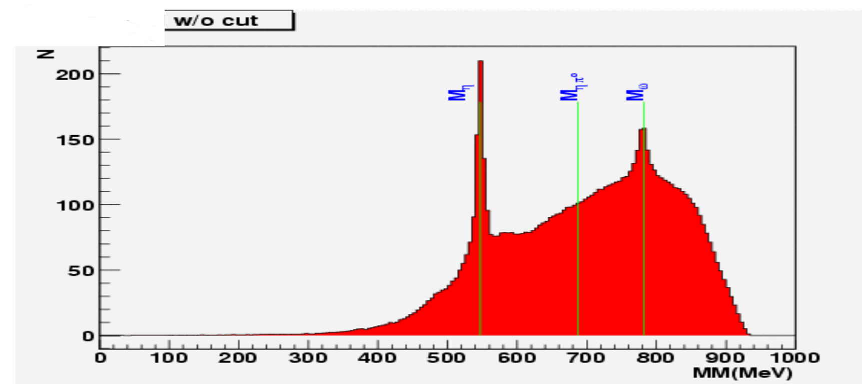


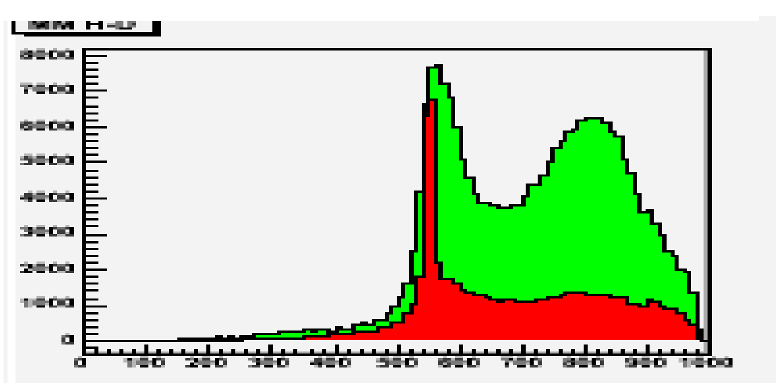


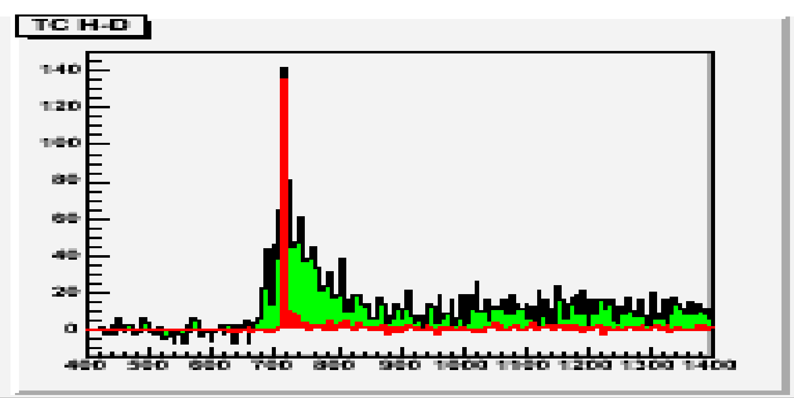
The structure in eta production was founded .
R(1680) -cusp or narrow resonance?
Eta-meson – hidden strangness, attractive interaction
The TC technique for reaction study of narrow resonances (cascade hyperons, charm and beauty

The narrow strange resonances came mainly from CLAS data
New narrow resonances wih hidden strangeness and neutral decay mode?







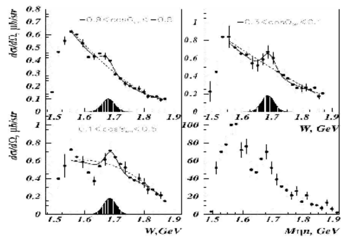


Status of «neutron anomaly» ηN in different reactions

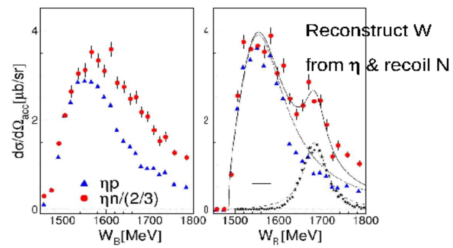
Problem of Fermi motion -two approaches

What is seen for $d(\gamma,n\eta)$?

V.Kuznetsov et al., arXiv:0807.2316 [hep-ex]



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



Kuznetsov background subtracted "peak" has width σ ~ 20 MeV

Integrated Strength of background subtracted structure ~ 10 µb/sr away from backward angles.

S_{11} background ~ 0.5 µb/sr in bump region.

If the bump is intrinsically narrow σ ~ 1 MeV then with suitably high E_γ resolution, then one should "easily see" a structure with a factor 20 lower cross section.

MAMI has much higher intensity than GRAAL or ELSA...aim to determine p(γ,pη) upper limit < 0.1 µb/sr (still needs to be quantified)

H(γ,ηp) @MAMI-C, J.R.M. Annand, Mainz, March 2009

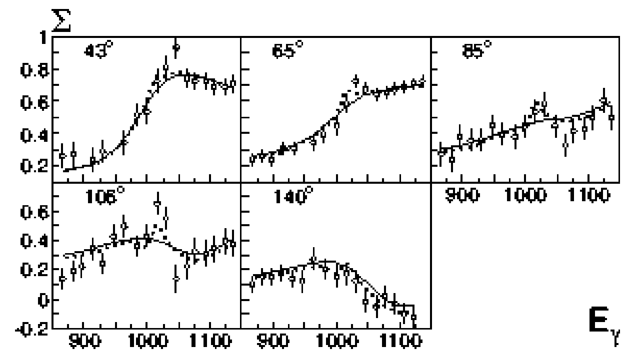
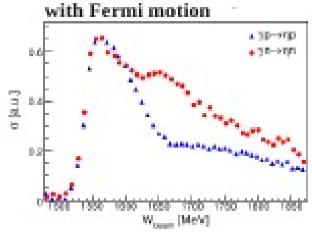


Fig. 12. Beam asymmetry for the reaction $\gamma p \to \eta p$ [17]. The PWA description is shown as solid line (solution 1) and dotted line (solution 3).

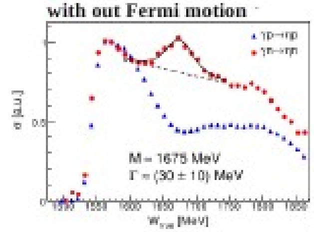
New high statistics measurement at MAMI-C

PhD of L. Witthauer — Preliminary — PhD of D. Werthmueller

with Fermi motion

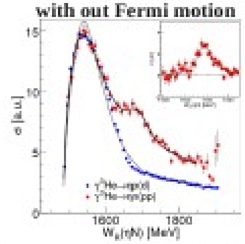


with out Fermi motion



A2

with out Fermi motion

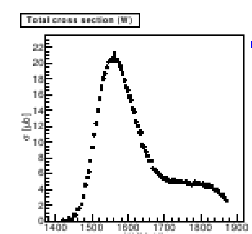


- very preliminary analysis on
- LD_2 (no efficiency corrections)
  W ~ 1675 MeV, Γ ~ 30 MeV
- L^3He
  W ~ 1690 MeV, Γ ~ 83 MeV ± 18 MeV
- structure not due to a nucleus effect

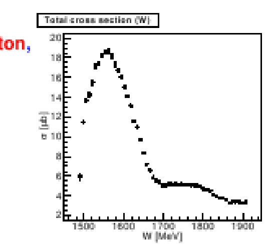
similar results for ^{3}He target

L. Witthauer et al.

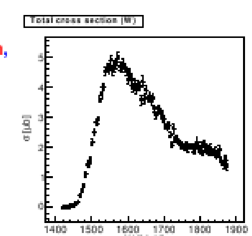
- quasi-free proton, W from incident photon energy



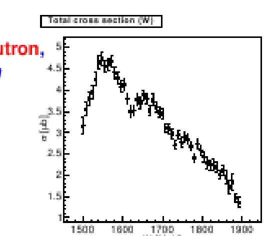
- quasi-free proton, W from $p-\eta$ final state



- quasi-free neutron, W from incident photon energy



- quasi-free neutron, W from $n-\eta$ final state



The last experimental results on «neutron anomaly» ηN

The most serious anaysis is performed by Gatchina-Bonn team

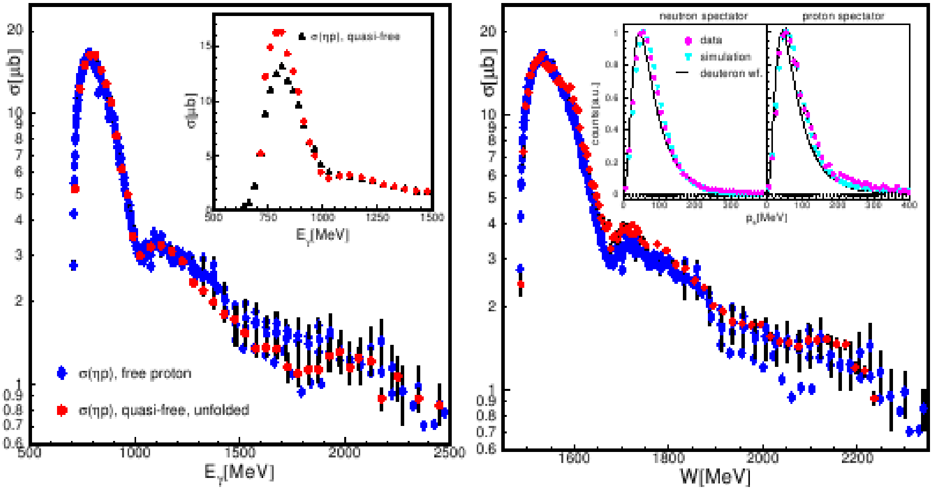


Fig. 13. Comparison of free and quasi-free photoproduction of η-mesons off the proton (see text). Left hand side: (Blue) diamonds world data base for $\gamma p \to p\eta$ versus incident photon energy. (Red) dots: quasi-free $\gamma' p' \to' p'\eta$ reaction after applying correction factors for Fermi smearing. Insert: quasi-free data with (red dots) and without (black triangles) correction for Fermi motion. Right hand side: Free proton data (blue diamonds) versus W. (Red) dots: quasi-free data from kinematical reconstruction of W. Insert: reconstructed momenta of spectator nucleons compared to momentum distributions from deuteron wave function (neutron spectator corresponds to detection of recoil proton and vice versa).

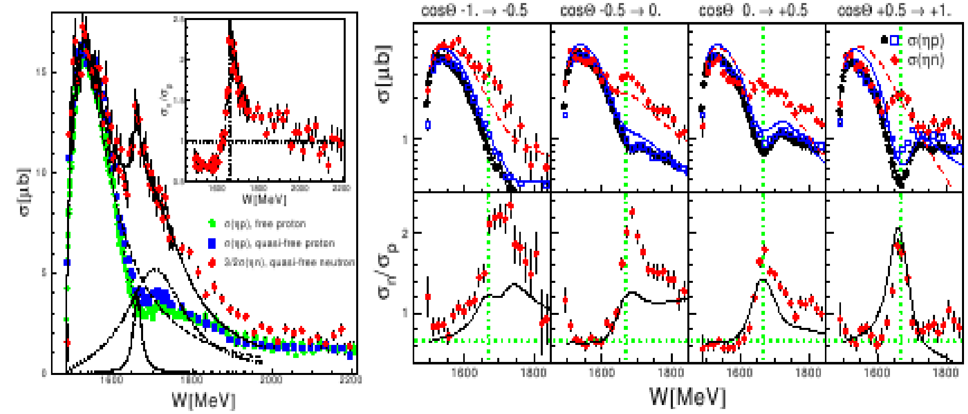


Fig. 16. Quasi-free photoproduction of η-mesons off the proton and neutron [127]. Left hand side: Total cross sections as function of final state invariant mass W (Red) dots: quasi-free neutron, (blue) squares: quasi-free proton, (green) stars: free proton data. Insert: ratio of quasi-free neutron - proton data. All curves for neutron data; dashed: fitted S_{11} line shape, dotted: broad Breit-Wigner resonance, dash-dotted: narrow Breit-Wigner, solid: sum of all. Right hand side: First row: excitation functions for different bins of η cm polar angle. (Blue) open squares: quasi-free proton data, (black) stars: free proton data from [147], (red) dots: quasi-free neutron data scaled up by 3/2. (Blue) solid lines: η-MAID [151] for the proton target, (red) dashed lines: η-MAID for the neutron target. Second row: ratio of neutron and proton cross section for data and η-MAID. Vertical dotted lines: position of narrow peak in neutron data, horizontal dotted lines: σ_n/σ_p=2/3.

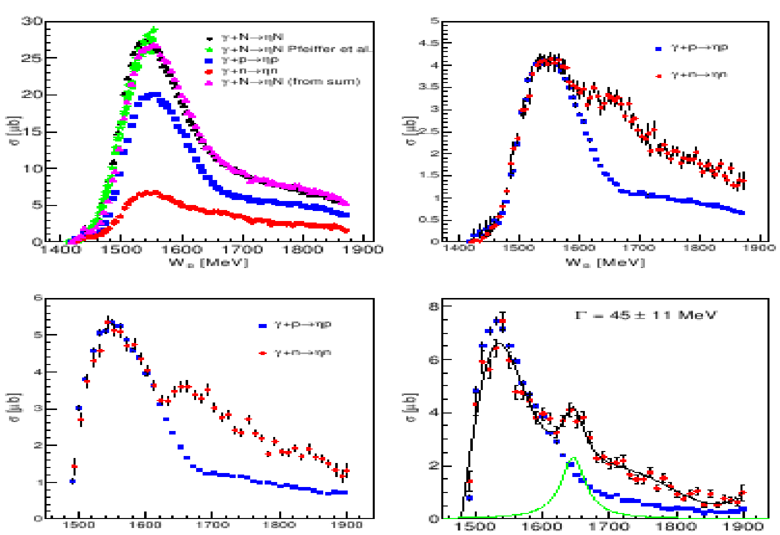
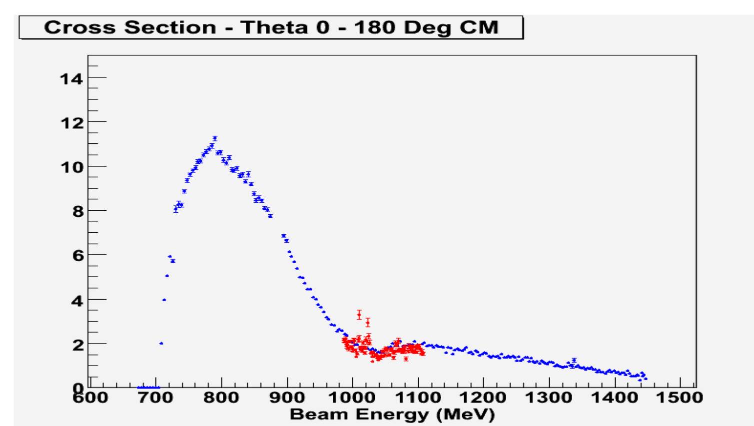


Fig. 17. Preliminary results for quasi-free η-photoproduction off ^{3}He [150]. Upper left:



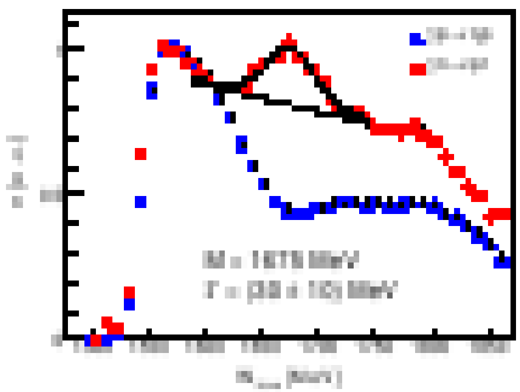
ELSA — two methods of W reconstruction

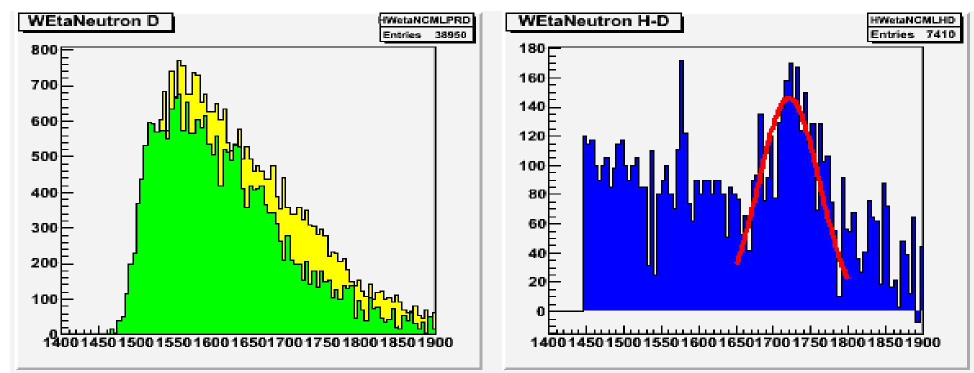
Does the "neutron anomaly" really exist?

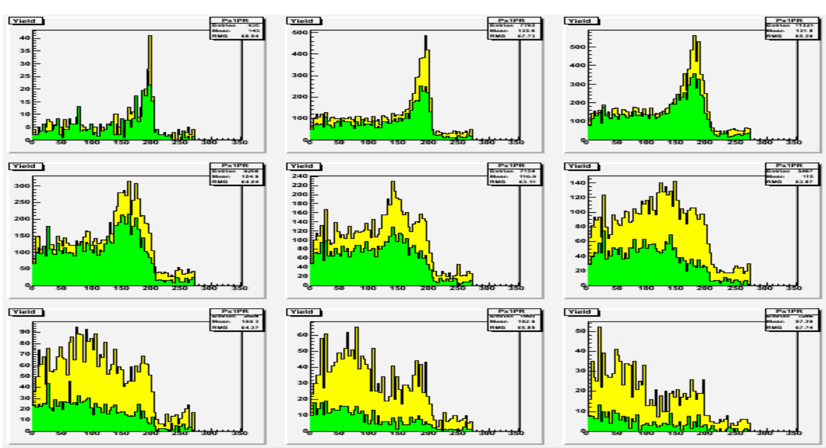
Green – H target
Yellow – D target

Top left – published result in Arhiv right – one of preliminary result
Bottom left -- Energy yield for different W (Peta+ PprotonCalc)
right – W spectra for different Ebeam
The spectra from recoil N and P are different and it is posible to obtaine extra peaks except R(1680)
We need and extra independed ways to confirm the existences of R(1680)

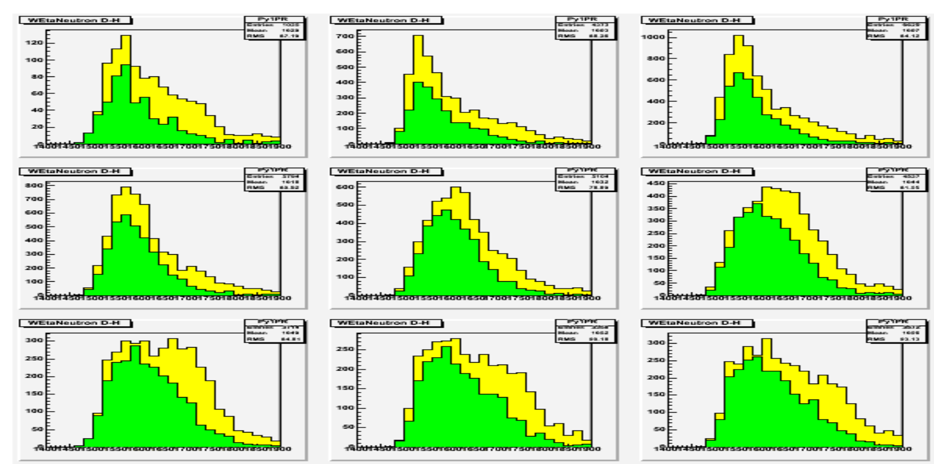
The problem – ELSA data are published but MAMI are still published only in Archiv
MAMI experiment on D target was not aimed on serch for narrow resonances
-- the distance between CB and TAPS was not enought for TOF measurment(Neutron energy)



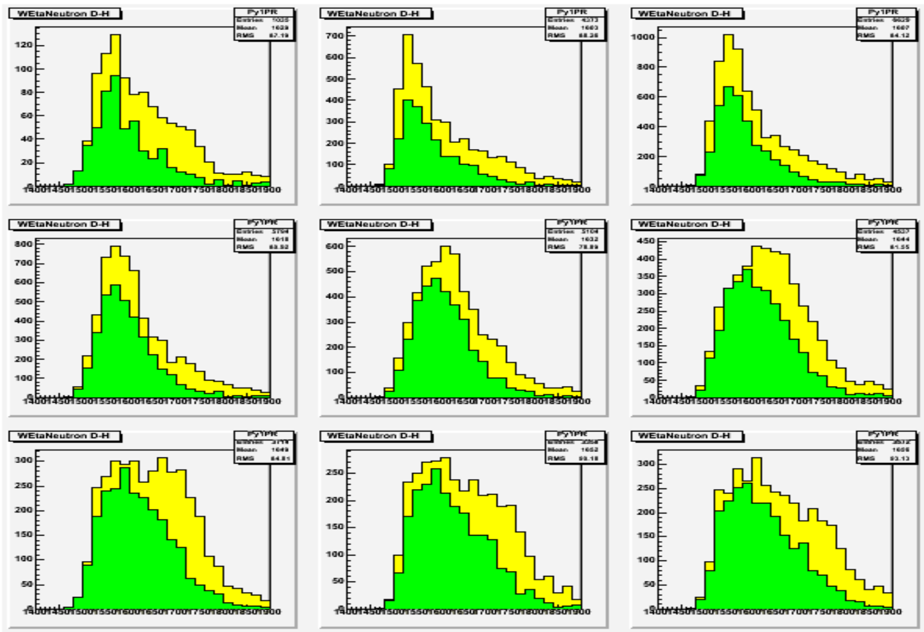


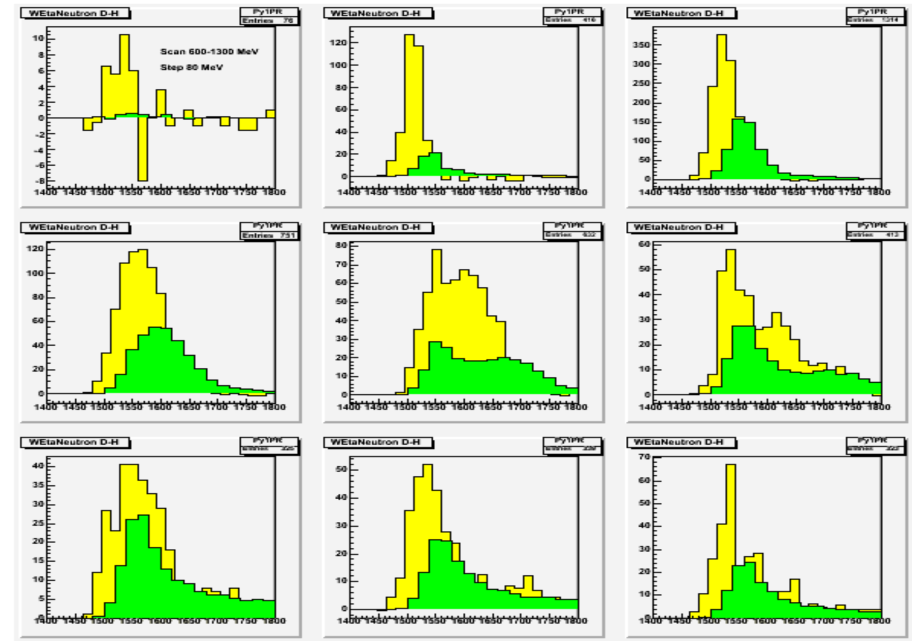


Yield Ebeam with W cut



Yield W with E cut





A2 experimental set: the distance between CB and TAPS do not allow to resonstruct final state W for eta-n with good resolution, so we must use the kinematics overdeterming wor reconstruction of neutron energy

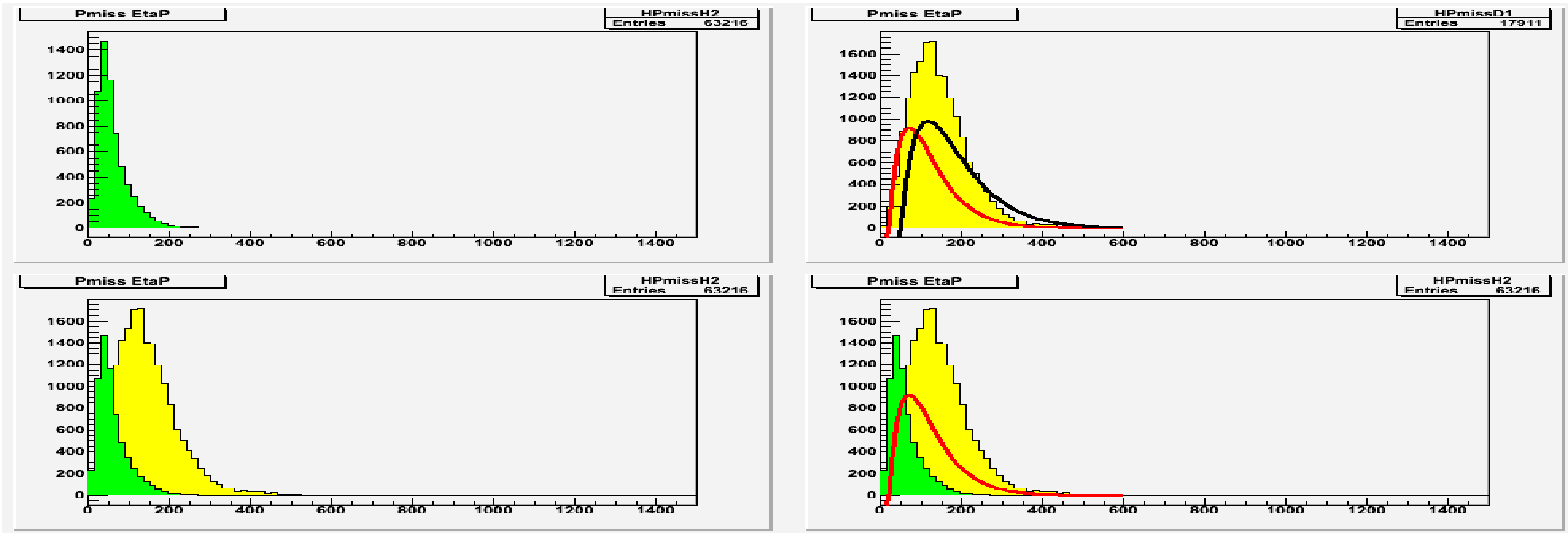
Two ways of reconstruction of W
Energy scan 600-1300 MeV, step 80 Mev
Left –reconstruction from Ebeam
Right Ebeam from P4eta

W frombeam enrergy include the
rong influence of Fermi motion
Two methods of defolding of Fermi motion:
W from measured energy of fina state – ELSA
W from beam energy ELSA
W reconstruction -- MAMI

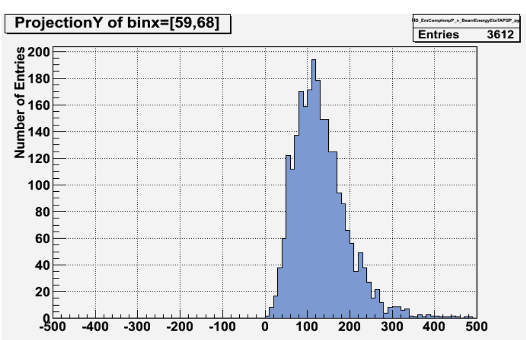
The differences between N and P in D really exist and depend on beam energy. The extra peaks is real?

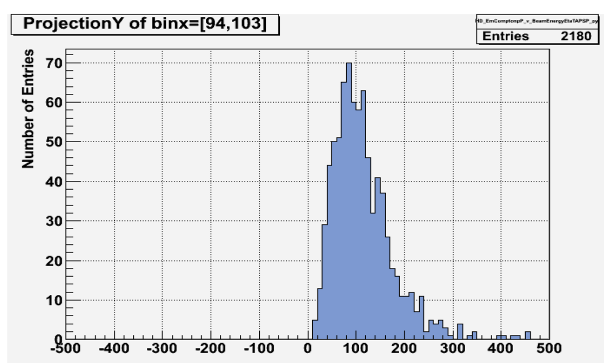
Deutron wave function

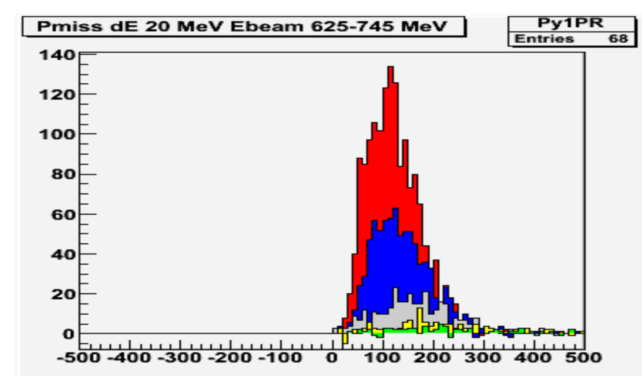
Reconstruction of deutron wave function from experimental data
Green — H target Yellow – D target. The accuracy mainly determined by energy resolution of gamma-detector. Standard way -cut about 100 MeV



Small dependences of wave function on beam energy



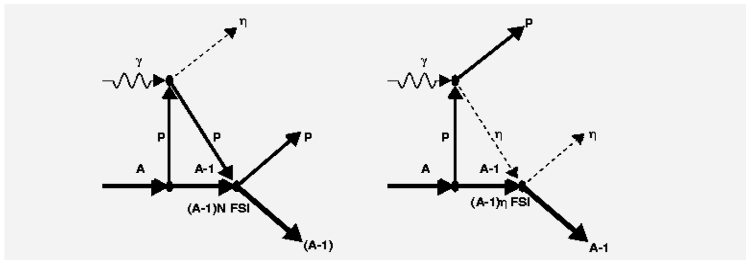


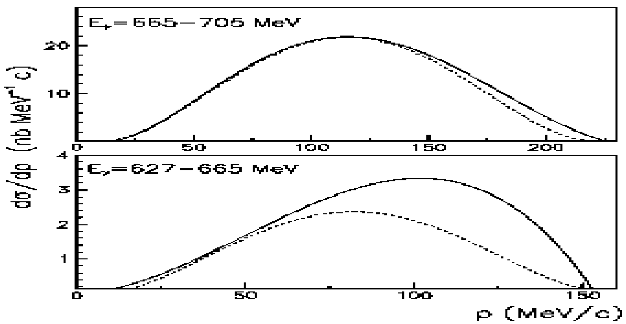


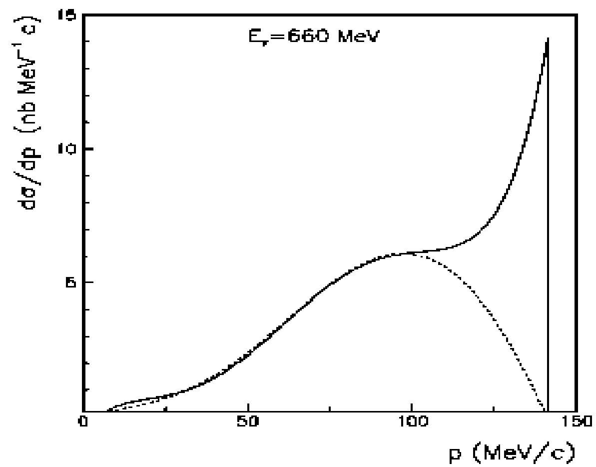
Deuteron wave function
left – beam energy 720-740 MeV
right -beam energy 900-920 MeV

Deuteron wave function
for 5 beam energy in
threshold region

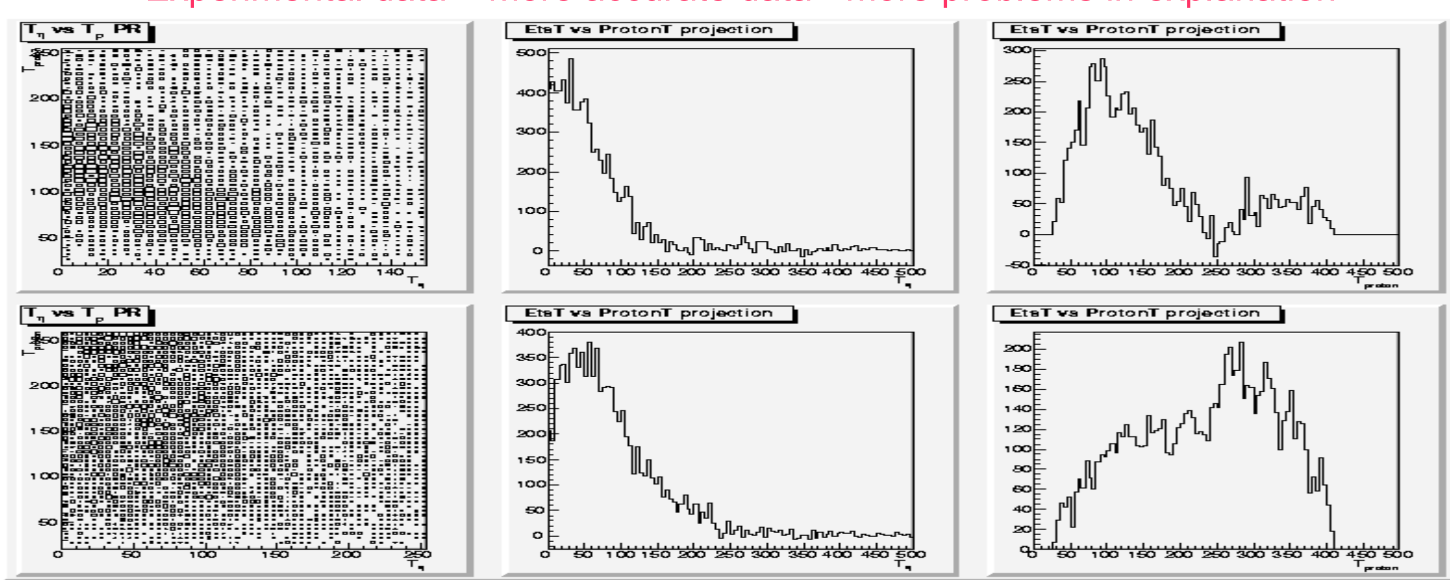
Now the most sophisticate anlysis of experimental data is performed by Gatchina group(PNPI-BONN)
Deuteron problems – we still need the experimental data with hihg beam energy resolution for direct measurements of effets of η-meson rescattering and FSL
The high beam energy resolution permits to see the sharp changes in shapes of energy spectra predicted by calculations



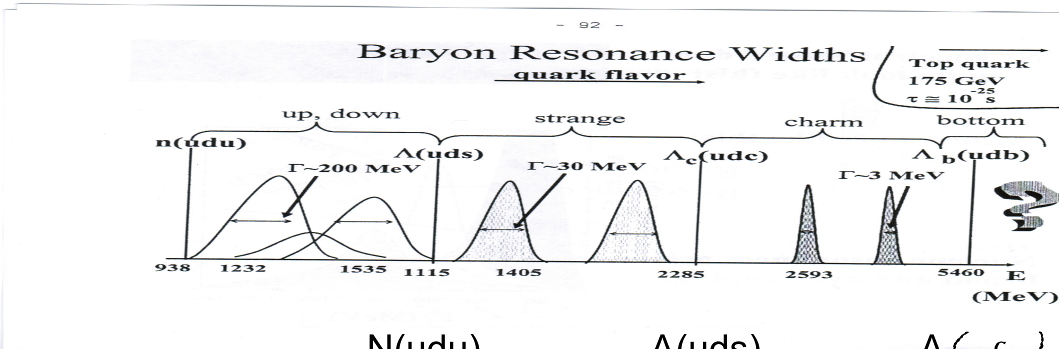


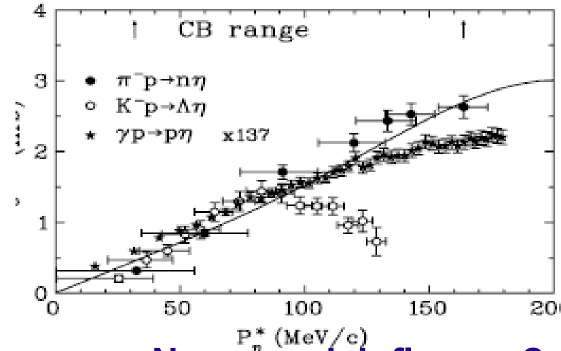


Experimental data – more accurate data - more problems in explanation



Baryon Resonance Widths





No s-quark influence?

N(udu) up,down — Λ(uds) strange — Λ(udc) charm — bottom?

R(1680) – hidden strangeness(ƞN)

γD -> KP + KN -> KP + (us+udd) pentaquark 1540 MeV inclusive experiments
$\Theta^+ \rightarrow$ Kn K → ππππ (CLAS)
Pentaquark:

quark content uudds
mass around 1540 MeV
narrow width less then 15 MeV
decays into Kp or Kn
strangeness: S = +1
Isospin: probably 0 due to absence of q = 2
Spin 1/2, 3/2,5/2 ...
Parity: + or -

R(1680) existances,, mass and width -are very important

R(1680) the first low mass narrow resonance with hidden strangeness
η-meson -meson with hidden strangeness and its interaction with
nucleon is attractive. Before we know only strange narrow resonances

The problem of existances of such resonances are very interesting.

What is really going on at W(1680)MeV ?

The new independend methods are needed for study of bump nture.

Experimental methods of resonances study

A + B -> R -> C + D formation experiments (EPECUR)
Main features: reaction identification, good beam energy resolution for measurment of resonances width good ratio signal/background

A + B -> R + D production experiments (PENTAQUARC)

Main fetures: good energy resolution for resonances decay particles.
Really resolution is limited by30-40 MeV — energy resolution of η-mesons

A + B -> R + D Threshold — crossing technique
Main features: good beam energy resolution, good energy and angle resolution for recoil particle.

The results of R(1680) study

The neutron “bump” width is limited by energy resolution of experimental set - mainly by shower detector
Problem with neuteron target . Gatchina-Bonn analysis, Teoretical calculation and presision experimental data
Interpritation of “neuteron anomaly”. Interference , resonance or cusp?
gn->gn – hudge background from pi0
Standard way: DCS and polarization

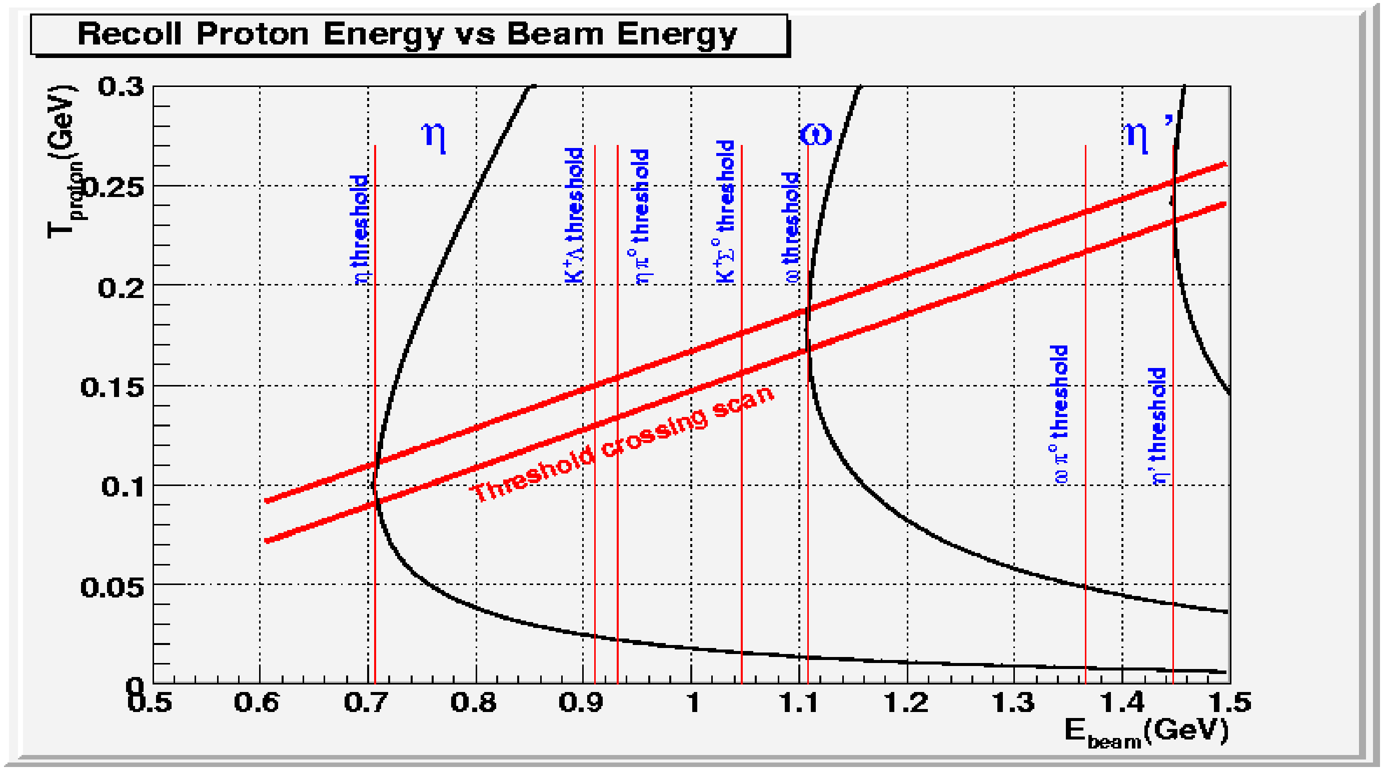
The increasing of experimental accuracy open a new problems
The problem of “neutron anomaly” is one of the most interesting problem in medium energy physycs from theoretical and experimental point of view.

The independing methods for study of nature of “neutron anomaly” are very important.

«Neutron anomaly» is published only by ELSA group, A2 published only in **arXiv**

The TC technique – is a independent way to study of nrrow resonances.

Threshold-crossing technique(TC) is other way of resonances study

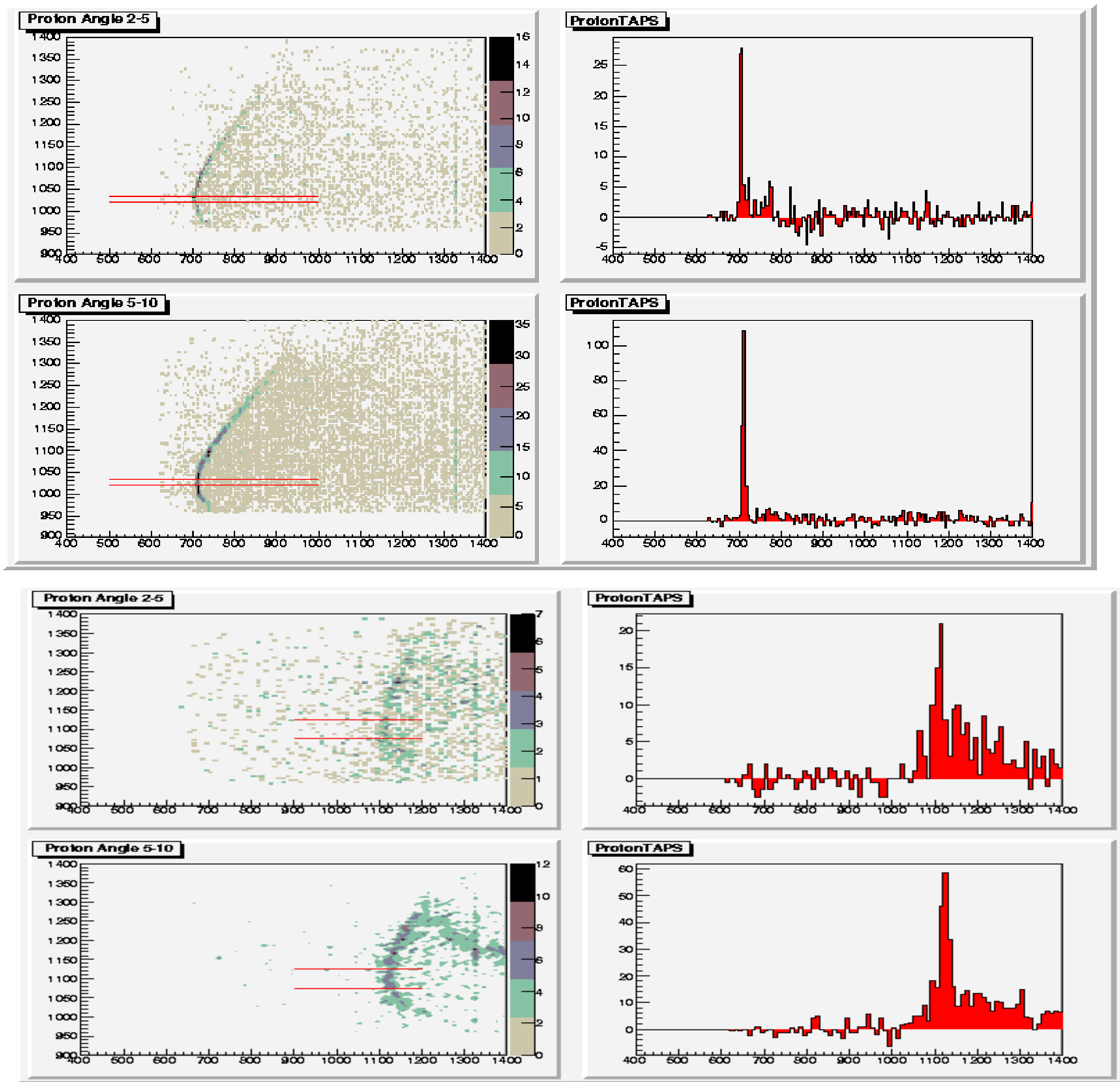


Idea and advantages

1. The resolution is mainly determined by beam energy resolution
2.The MAX Jacobian peak is a best ratio signal/backgroung
3. The method permits to study narrow resonances
4. The “low” branch is sutable for resonances search for at high energy like ELSA or CLAS xperiments(poor beam energy and good recoil proton resolution

The TC technique for reaction γP → ηP and γP → ωP

Test of TC technique for measurements of resonances width



The TC method really work and obtained width of ω-meson coincides with PDG

The experimental test ofTC technique confirmed the prospects of its using for study of narrow resonances. The accuracy of method depends on beam energy resolution.

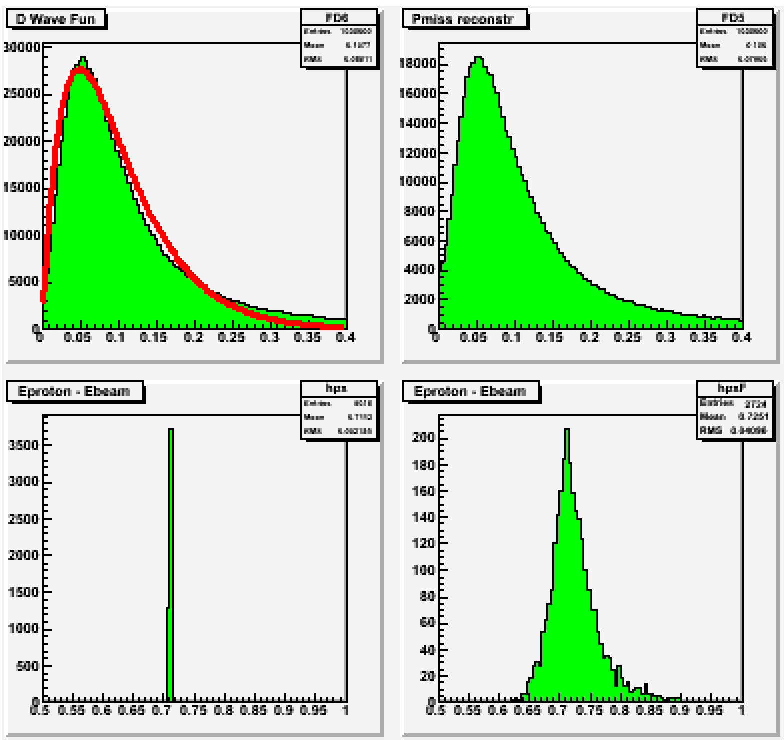
The TC technique for reaction γP → ηP on deuteron

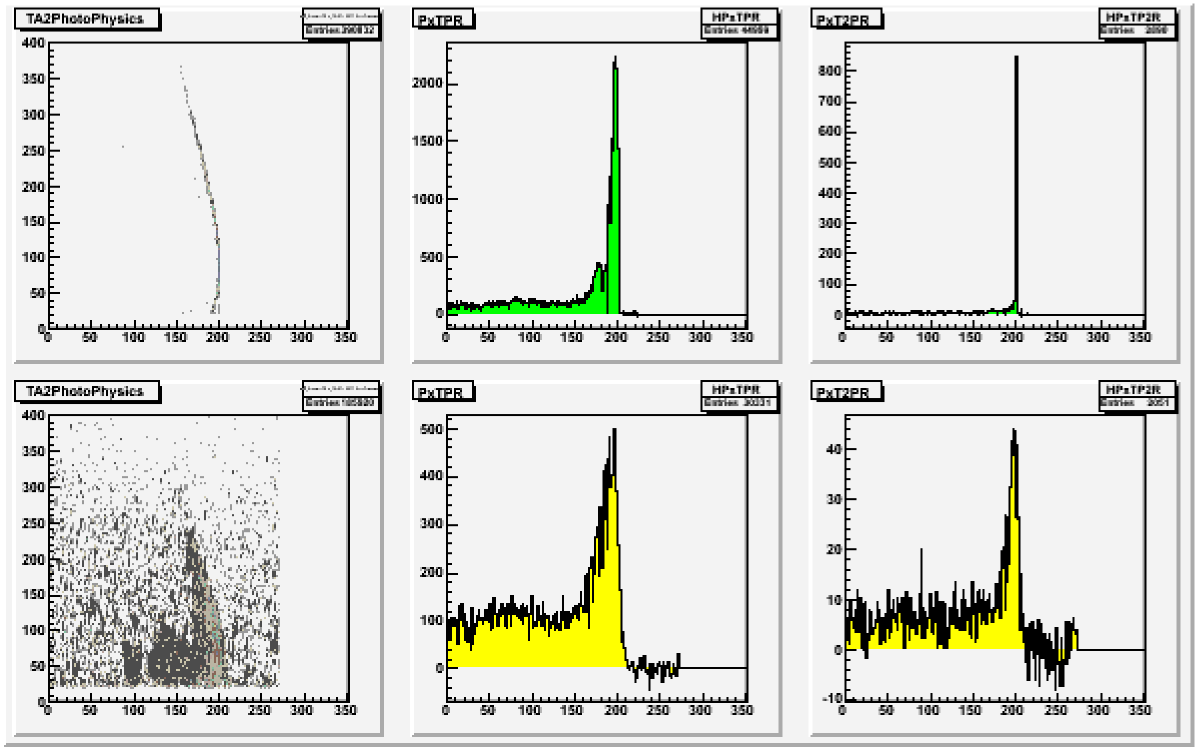
Application for measurements of deuteron wave function

T

Simulation

Experimental data

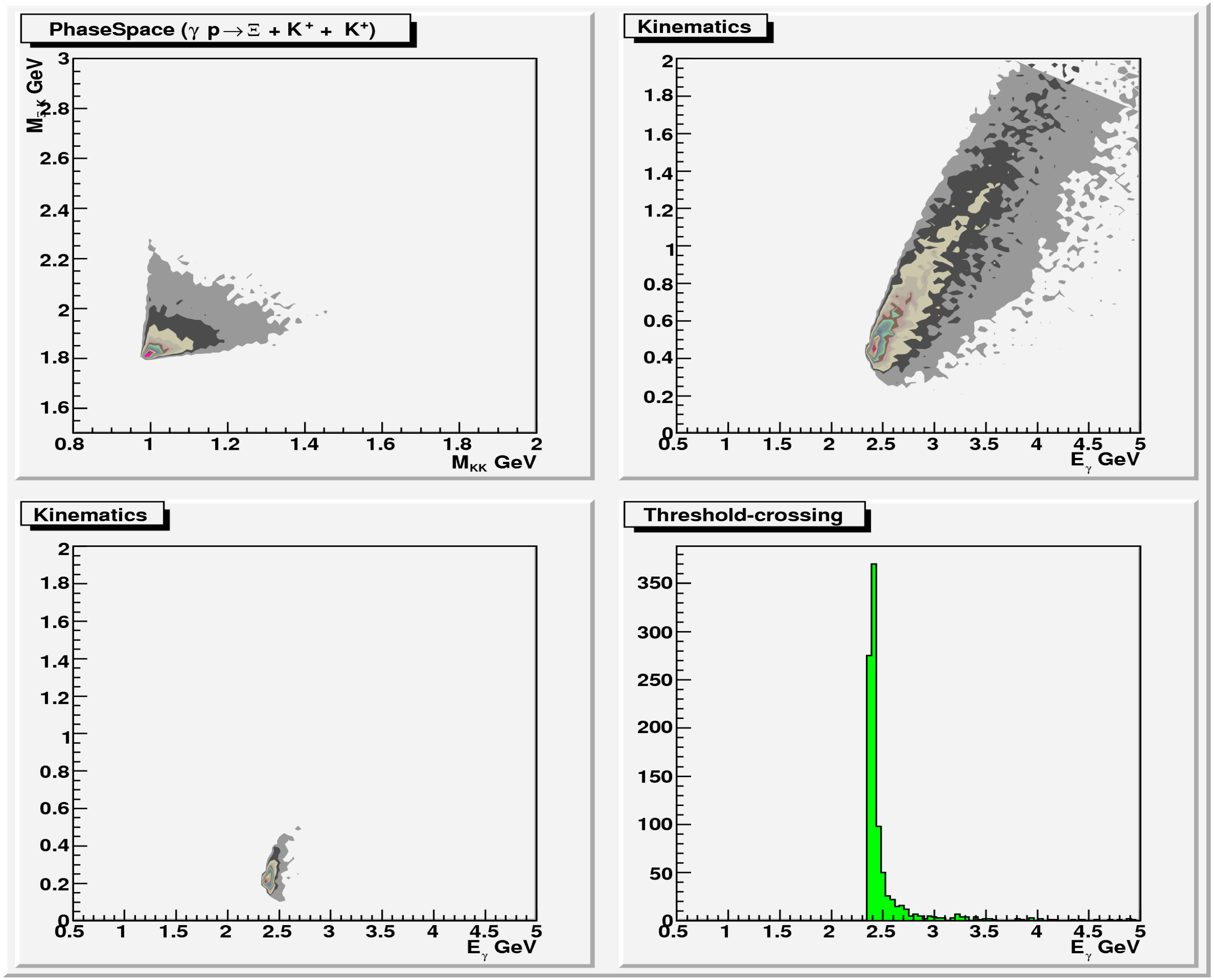




The study of deutron wf by TC technique 3 times more sensitive in comparizonwith conventional method

The TC technique for reaction $\gamma P \rightarrow$ K K X
Application for measurements of cascade hyperons
The previous CLAS experiments indicate on existances of number of narrow resonances. The TC technique may be applied not only for for two-body final states

Simulation

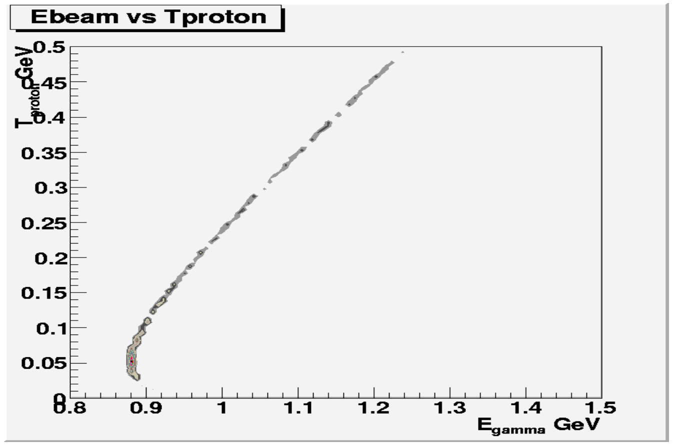


Pentaquark problem still exist. Experiments are planned in MAINZ and PNPI-IHEP. The TC method may be applied for looking for R(1680)(eta-neuteron system) on deuteron target in reaction:

The problems: independent method
to avoid influence of Fermi motion
two-body final state

Reaction of interest:

$$\gamma + D \rightarrow \gamma + N + (P) \rightarrow \eta + N + (P) \rightarrow R(1680) + P$$



Kinematics of R(1680) production

Reaction $\gamma + D \to R + P$

Kinematics of recoil proton

Experiment EPECUR in ITEP(ITEP-PNPI collaboration on pion beam):
1. two charged states
2. deuteron target

The TC method may be applied for pentaquark search for on D-target.
The experimental set must be added by proton detectors.

Simulation of TC technique for reaction g + D → R + P

The CS of R(1680) production is normalized on experimental data of GRAL

The TC technique displays the much more clear signal of R(1680)

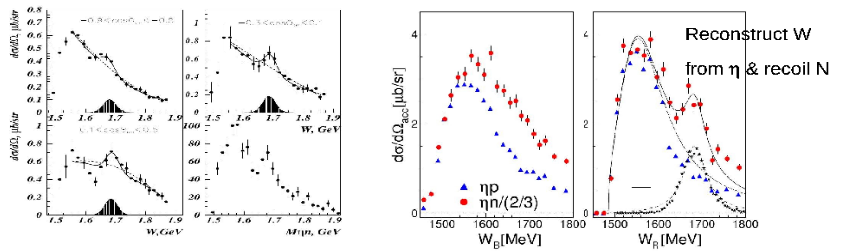
Results of GRAAL experiment

TC method for seching for R(1680)

What is seen for $d(\gamma,n\eta)$?

V.Kuznetsov et al., arXiv:0807.2316 [hep-ex]

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



Kuznetsov background subtracted “peak” has width σ ~ 20 MeV

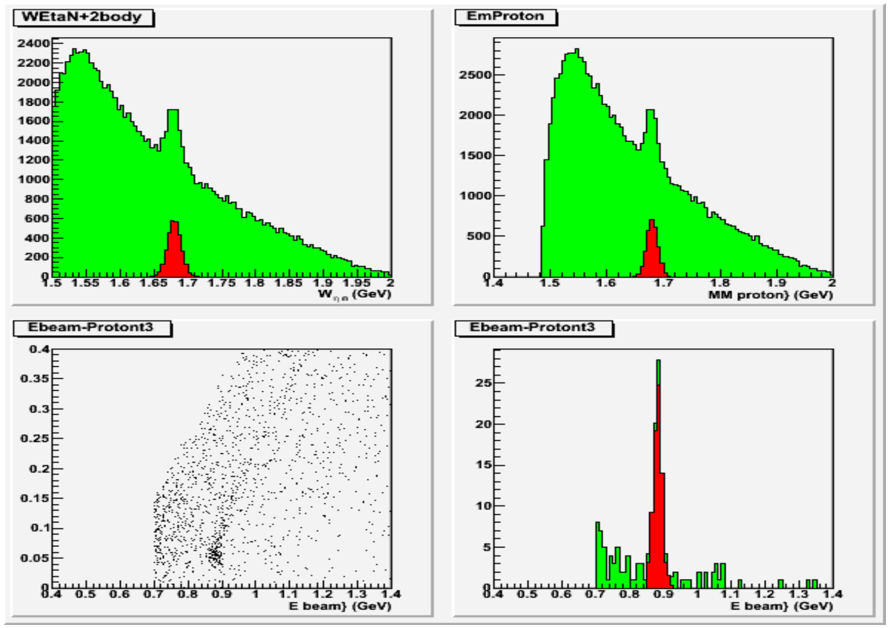
Integrated Strength of background subtracted structure ~ 10 μb/sr away from backward angles.

S_{11} background ~ 0.5 μb/sr in bump region.

If the bump is intrinsically narrow σ ~ 1 MeV then with suitably high E_γ resolution, then one should “easily see” a structure with a factor 20 lower cross section.

MAMI has much higher intensity than GRAAL or ELSA...aim to determine p(γ,pη) upper limit < 0.1 μb/sr (still needs to be quantified)

H(γ,ηp) @MAMI-C, J.R.M. Annand, Mainz, March 2009

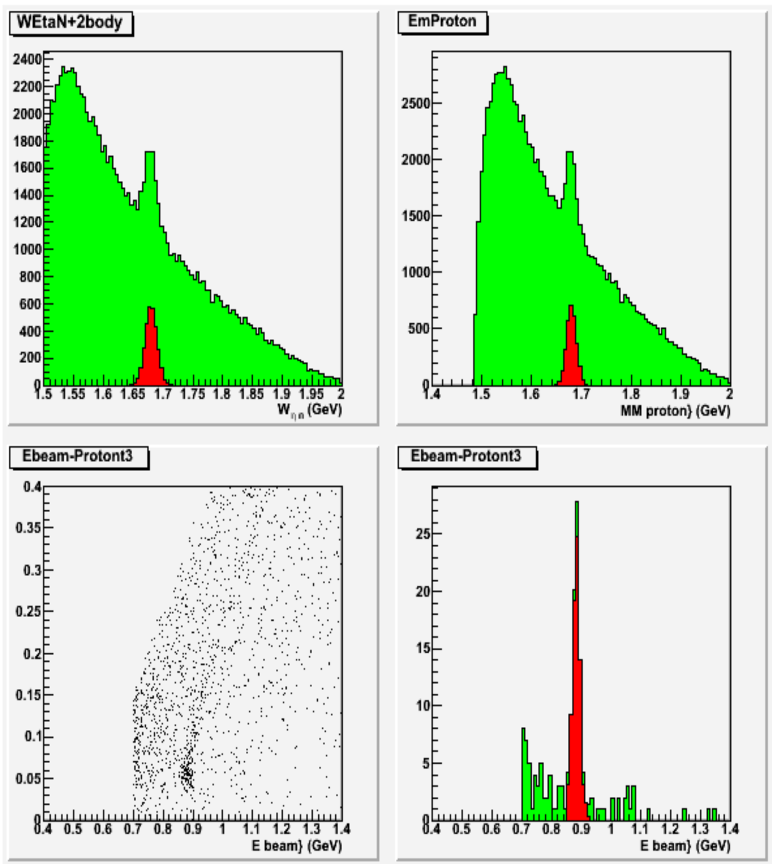


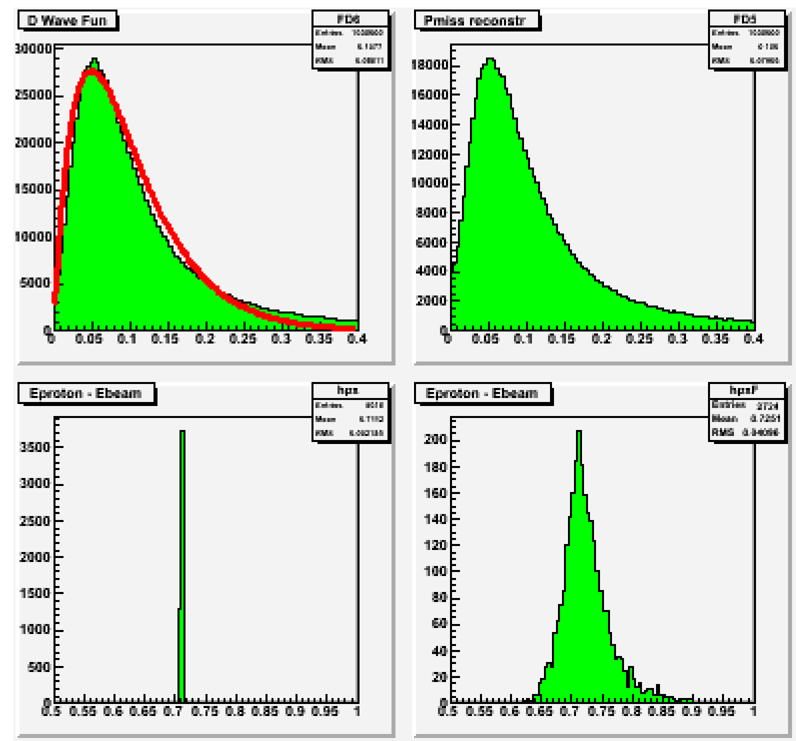
The TC technique produces the much better ratio effect/background

The simulation of TC technique for reaction

γD → R(1680)P on deuteron

Application for study of deutron wave function





The infuence of Fermi motion on W

The effect of Fermi motion is eqvivalent the Beam energy resolution 100 MeV(FWHM)

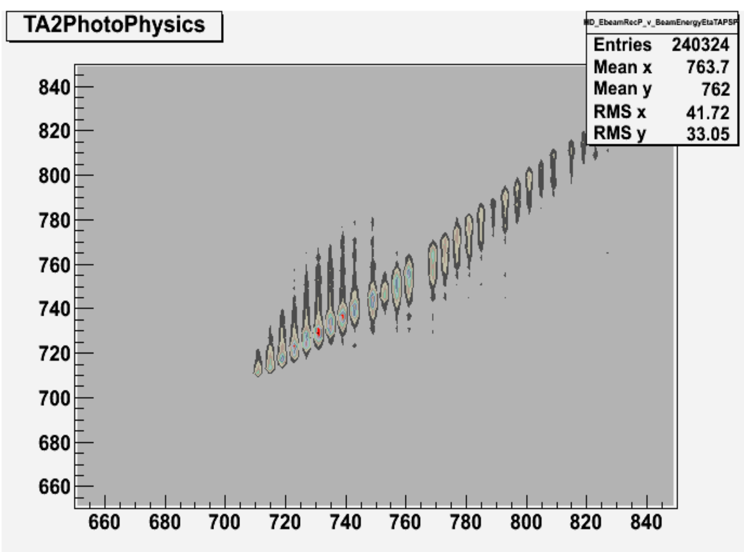
De folding of Fermi motion – the main problem of using neutron from D as target

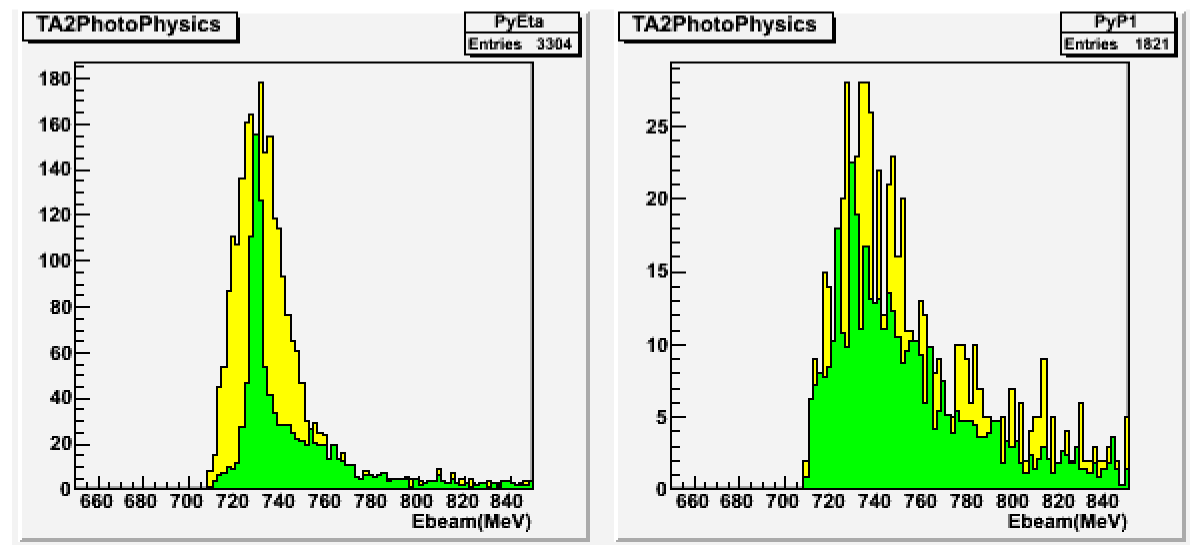
Standard way – measurement of final state energy
The high beam energy resolution(4 MeV) and overdeterming of kinematics permits to measure the accuracy of beam energy reconstruction

Reconstruction of beam energy from measured proton(green) or eta-meson(yellow)
Left – hydrogen target
Right – deuteron target

The reconstructed beam energy resolution is about 15 MeV from proton and about 30 MeV from eta-meson(FWHM)

The deuteron effect is about 100 MeV -so we can improve deuteron effect 4 times





Two types of experiments:
High beam energy resolution – formation experiments on H target(EPECUR,MAMI)
Production experiments on D target
Reconstruction W from final state particle – neutron from D as target.
The high beam energy resolution of A2 experimental set permits to study De-folding of fermi-motion on deuteron target

E Experiments on π-beam(ITEP)

1. **beam energy resolution 1-2 MeV**
2. **clean η-signal**

Epecur update

$\pi^{\times}p \rightarrow R(1680) \rightarrow \pi^{\times}p$ formation experiment (EPECUR)
$\pi^{\times}D \rightarrow \pi^{\times}p(n) \rightarrow R(1680)(n) \rightarrow \pi^{\times}p + (n)$ production experiment
$\pi^{\times}D \rightarrow \pi^{\times}n(p) \rightarrow R(1680)(p) \rightarrow \pi^{\times}p + (p)$ (EPECUR + forwrd p,n detector)
$\pi_{+}D \rightarrow \pi{+}n(p) \rightarrow R(1680)(p) \rightarrow \pi{+}p + (p)$
$\pi_{+}D \rightarrow \pi{+}p(n) \rightarrow R(1680)(n) \rightarrow \pi{+}p + (n)$

η-meson detector + forward wall

$\pi^{+}D \rightarrow \pi^{+}n(p) \rightarrow \eta p(p) \rightarrow R(1680)p$ production
$\pi^{\times}D \rightarrow \pi^{\times}p(n) \rightarrow \eta n(n) \rightarrow R(1680)n$

- Experiments on γ-beam(MAMI)

$\gamma D \mathcal{N} \rightarrow \gamma pn \rightarrow \eta pn \rightarrow R(1680)N$ $\mathcal{N}$(p or n)
$\gamma D \rightarrow \gamma p(n) \rightarrow \eta p(n) \rightarrow R(1680)n$
$\gamma D \rightarrow \gamma n(p) \rightarrow \eta n(p) \rightarrow R(1680)p$

$\gamma D R \rightarrow \gamma pn \rightarrow \eta pn \rightarrow$ R(1680) + (p)

Experiments on π-beam(PNPI)

$\pi\mathcal{D} \rightarrow \eta p(n)$ – study of neutron as target and test of W reconstruction

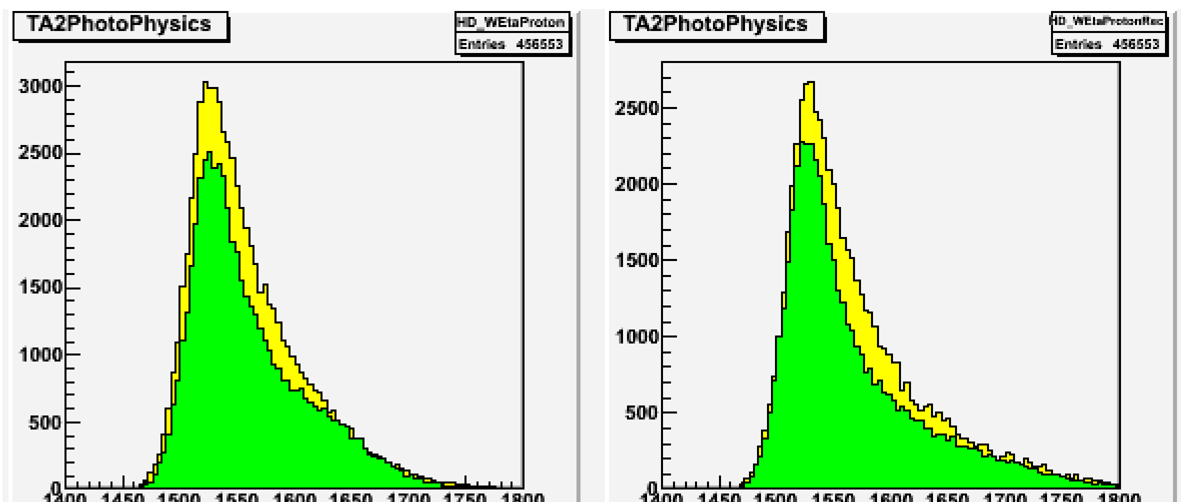
No experimental data on neutron

De folding of Fermi motion

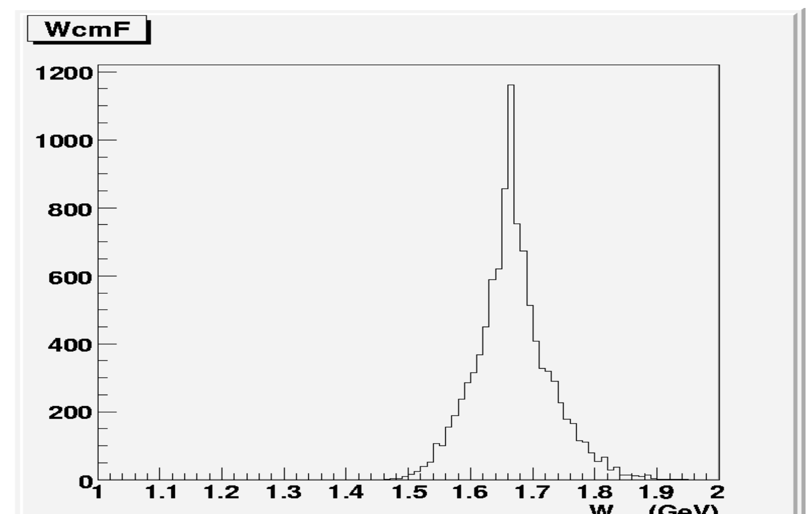
Comprison of W measured – reconstructed of final state

Yellow - W reconstucted
Green - W measured

Left – H target
Right D target
The spectra almost the same for measuted and reconstructed W
The shape of spectra mainly determined by poor energy resolution of eta-meson

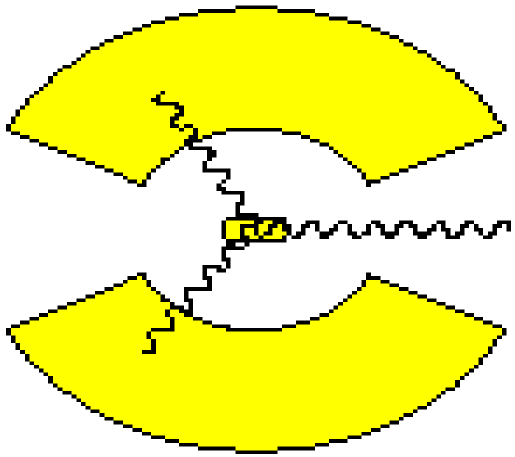


Measured and reconstructed W



W with Fermi motion

Reconstraction of W final state and de-folding of Fermi motion aloow to perform a new type of experiments on beam with poor energy resolution(PNPI) and obtane data from neutron target with accuracy compatable with world data.
The experimental set in this case are relativly simlpe and cheep



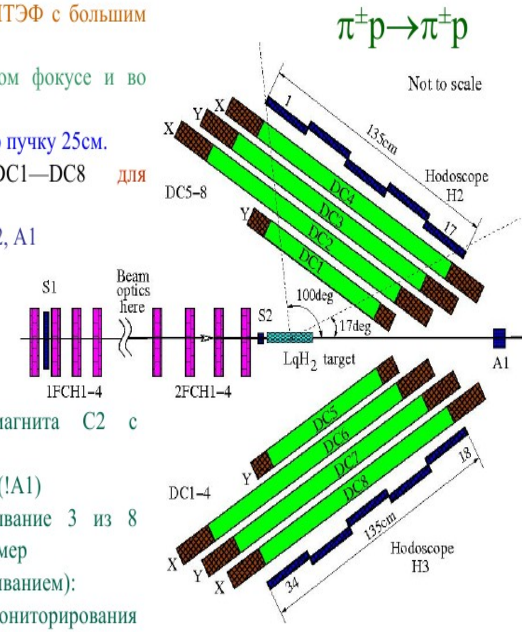
⊙ Пионный пучок ускорителя У-10 ИТЭФ с большим углом поворота (322).

⊙ Пропорциональные камеры в первом фокусе и во втором перед мишенью.

⊙ Жидководородная мишень длиной по пучку 25см.

⊙ Система дрейфовых камер DC1—DC8 для регистрации рассеянных частиц.

⊙ Система триггерных счетчиков S1, S2, A1



✓ Измерение поля поворотного магнита C2 с точностью лучше 0.1% (ЯМР).

✓ Основной триггер: $S1 \cdot S2 \cdot ПК_{1Ф} \cdot ПК_{2Ф} \cdot (!A1)$

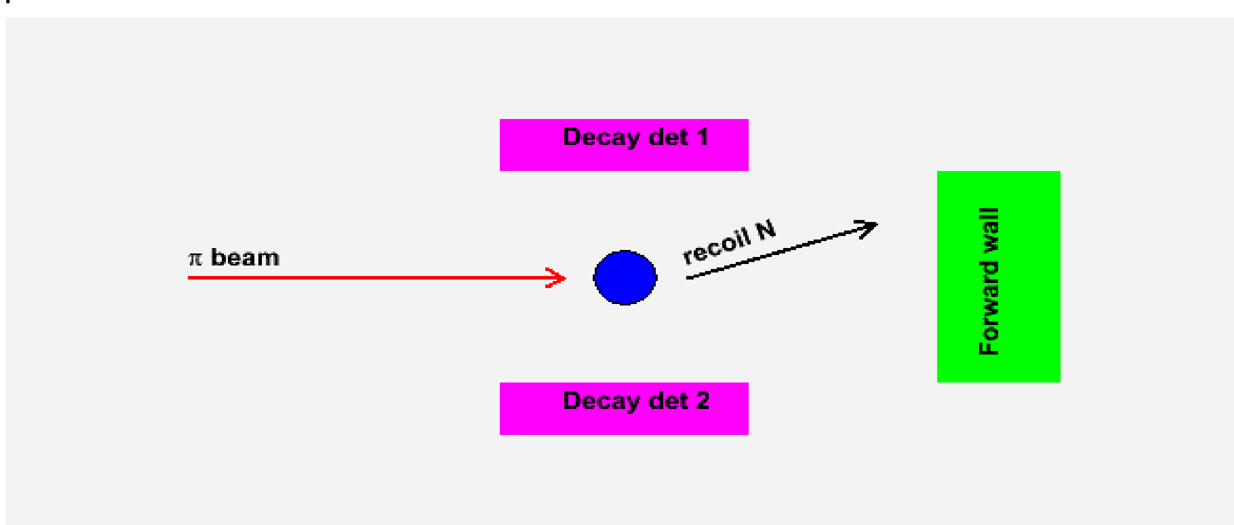
$ПК_{1Ф}, ПК_{2Ф}$ – мажоритарное срабатывание 3 из 8 плоскостей соответствующего блока камер

✓ Дополнительные триггера (с прореживанием):

- $S1 \cdot S2 \cdot ПК_{1Ф} \cdot ПК_{2Ф}$ – для мониторирования

The draw of experimental set for study of narrow resonances

Forward detector – something like SHANS
Two types of experiments are possible :
high beam energy resolution – MAMI, ITEP
low beam energy resolution,deuteron target and W reconstruction
from recoil particle in forward detector.



Conclusion:

1. The “neutron anomaly” is a real problem of medium energy physics both from theoretical and experimental point of view.
2 The hydrogen data of A2 collaboration on η-meson photoproduction is determined now by systematics errors. The quality of data allowed to display unsmoothness(singularity) in energy dependences of DCS. The neutron data are in progress. PT data also in progress.
3. The problem of “neutron anomaly“ still exist. The nature of anomaly should be investigated in sophisticate experiments- it is the first narrow law mass bump.
4. The phenomenology problems: bump in A0 for neutron and A1 for proton production. Bump in A1 strange for cusp – cusp effect usually in S-state as we see in existing experiments on gamma and pion beams.
5. The "neutron anomaly" mainly came from deuteron target. The problem of “neutron target“ needs a new experimental data with good beam energy resolution.
6. The TC technique may be applied for R(1680) study. The TC technique is an only way to study narrow resonances width.
7. The pion7beam with energy resolution about 1 MeV(ITEP) is very effective for R(1680) study. The good data on DCS exist only up to 747 MeV/c so the only ITEP may produce the new high quality experimental data.
8. The TC technique use the recoil nucleon in a small solid angle so the detector for recoil nucleons not so big as in conventional experiments.
9. The obtained data on D target permitted to measure the accuracy of W reconstruction (de-folding of Fermi motion).
10. New detector for recoil nucleon(TOF-detector, SHANS).
11. The neutron data are needed for complete analysis of eta production. The experiments on deuteron target in PNPI are very promising as we do not need good beam energy resolution, eta-production by pion produces much more clear signal of eta-production and two isotopic channel exist. Today the experimental data on neutron do not exist.
12. Tte more good experimental data – more problem.

The problem of «bump» at W(1680) is confirmed now in different experiments

The existing experimental data sometimes contradict each other in phenomenology interpretation

Now we expect the new experimental data and it is difficult to predict its influence on

future program of experimental program

Cusp or new effects from strange quarks?

Dear Colleague, I am very happy to announce that yesterday the proposal to establish a new Collaborative Research Center ("The low energy frontier of the standard model") at the Institu Kernphysik has been approved by the Deutsche Forschungsgemeinschaft. The funding will sta January 2012. The maximal funding period will be 12 years with reviews each 4 years. You wi soon find details about the scientific program and new opportunities for PhD or Postdoc positi on our webpages. Best regards, Michael

Thank you

- $\gamma d \rightarrow \pi^0 \eta d$ good candidate to study the η-d interaction
- $\gamma ^3He \rightarrow \eta ^3He$ good candidate to study the η-^3He interaction
- $\gamma ^3He \rightarrow \pi^+ \eta ^3H$ good candidate to study the η-^3H interaction
- $\gamma ^4He \rightarrow \pi^0 \eta ^4He$ good candidate to study the η-^4He interaction

cb16-jaegle

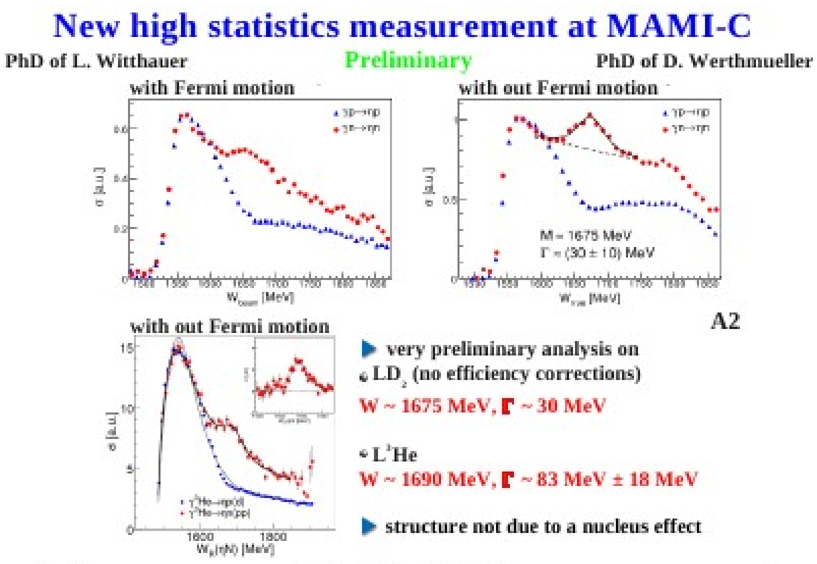
γd →π oηd good candidate to study the η-d interaction

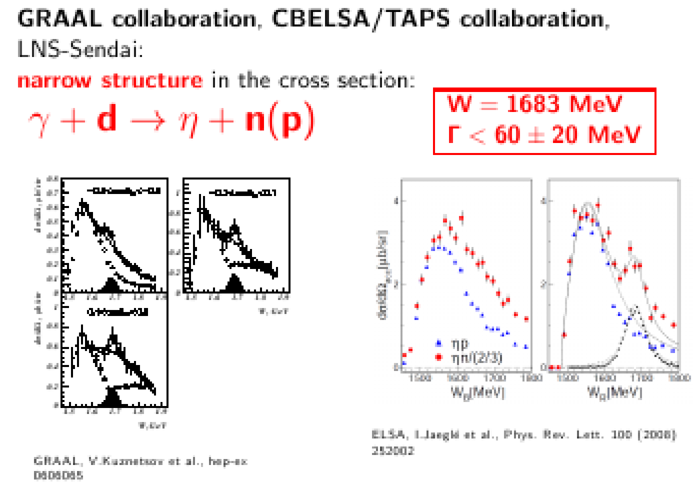
γ 3 He→η 3 He good candidate to study the η-3He interaction

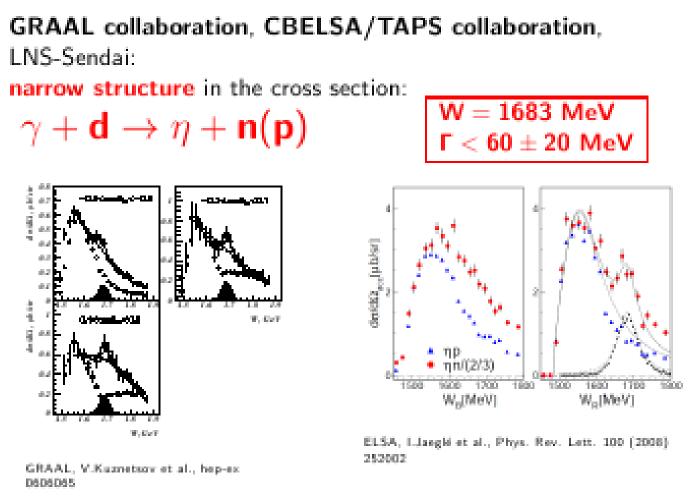
γ 3 He→π +η 3 H good candidate to study the η-3H interaction

γ 4He→π oη 4He good candidate to study the η-4He interactio

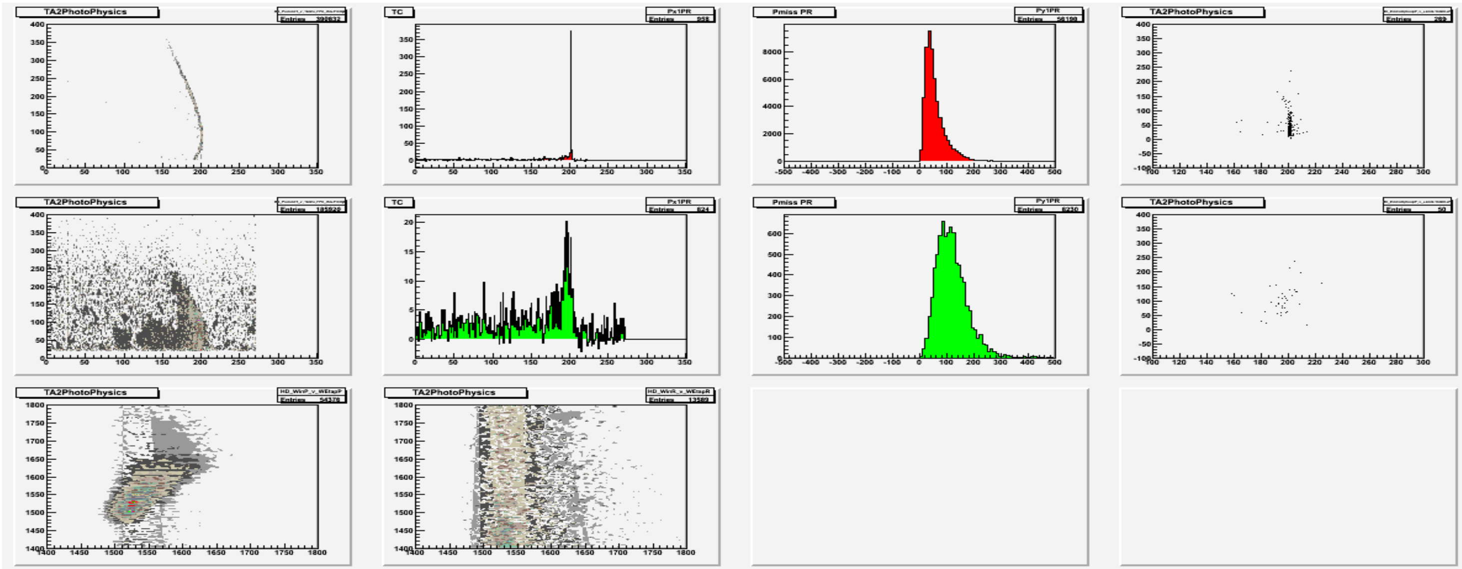
n

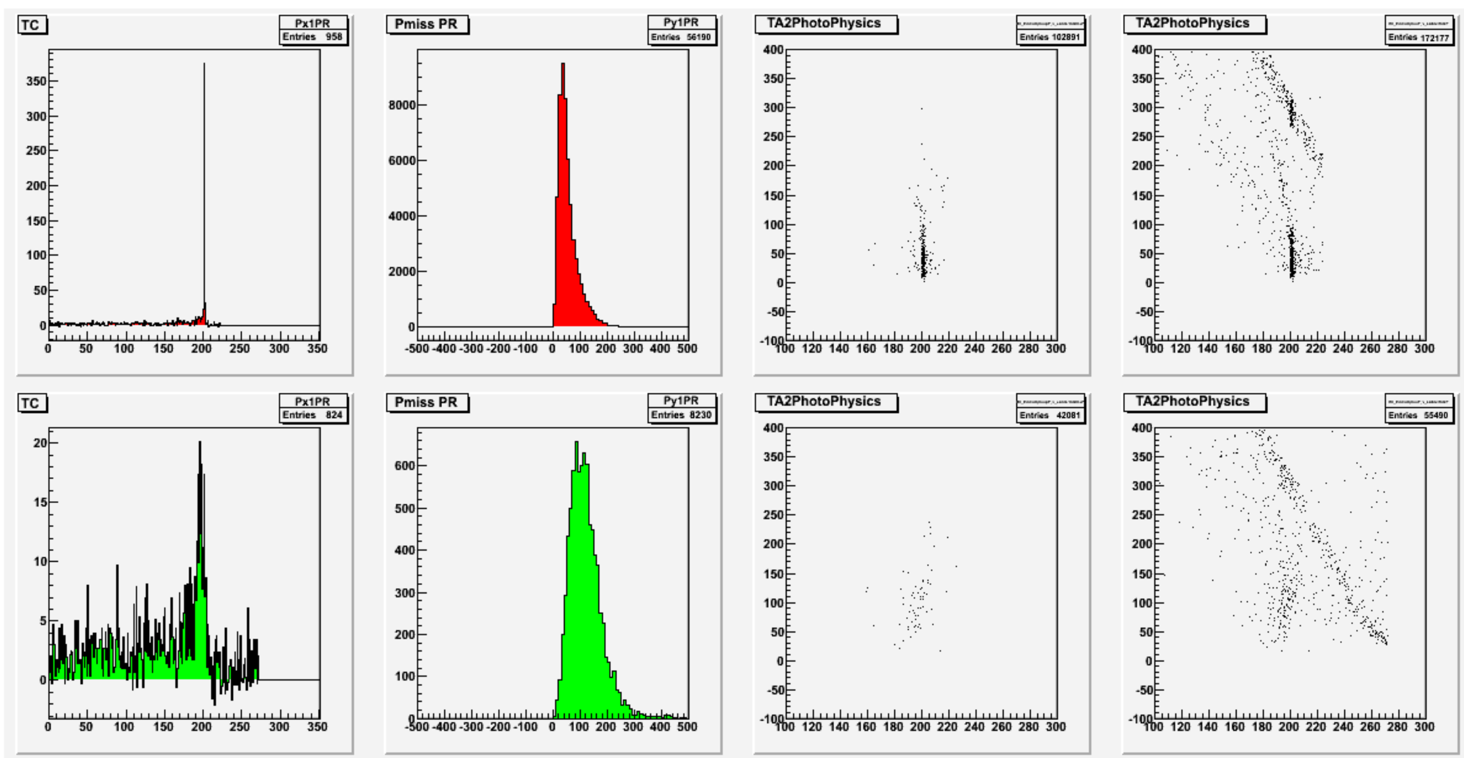






CLAS Data
Y. Ilieva et al. (arXiv:nucl-ex/0703006)


TA2PhotoPhysics
TC
Pmiss PR
Px1PR
Py1PR


TC
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Pmiss PR
Py1PR
Entries 56190
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Entries 102891
TA2PhotoPhysics
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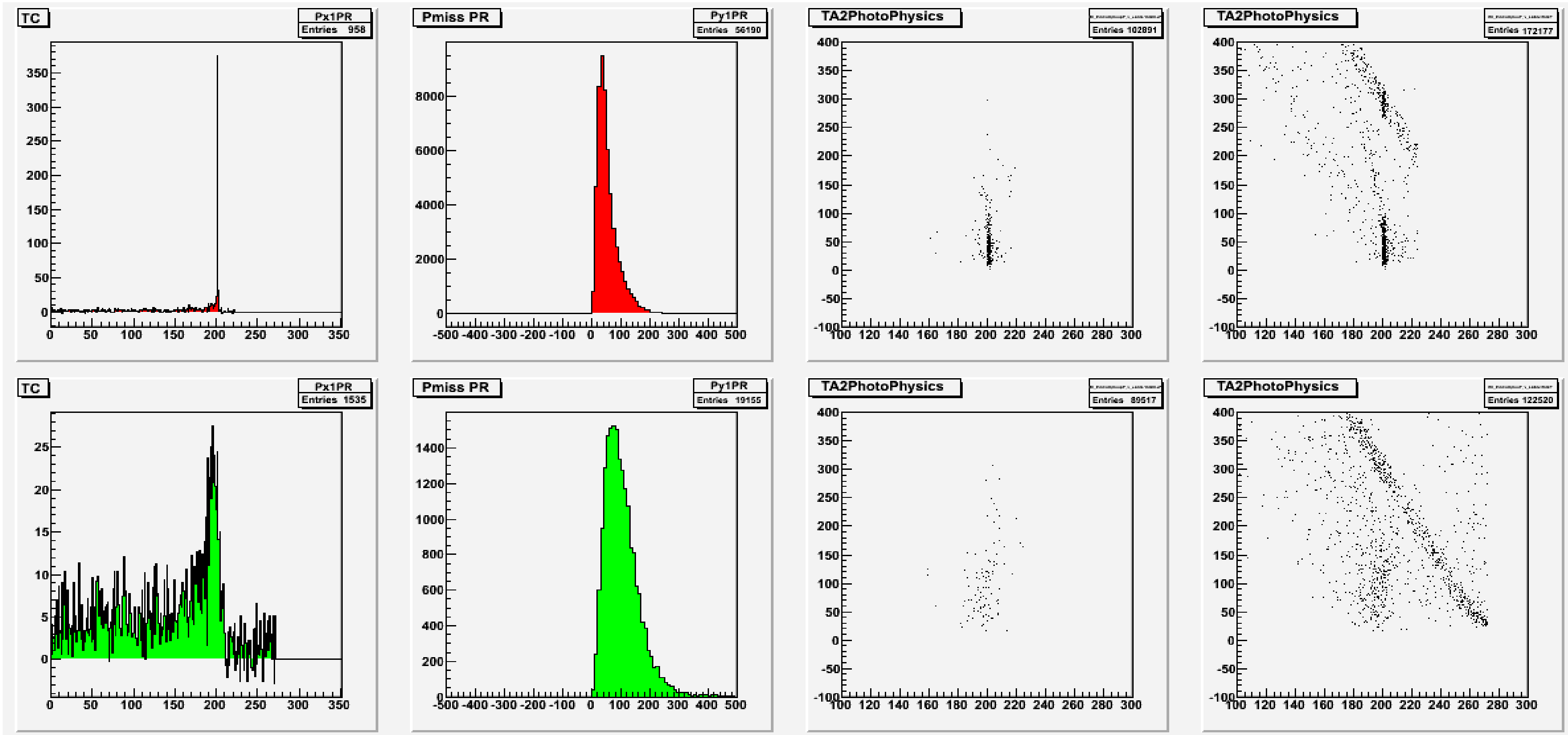
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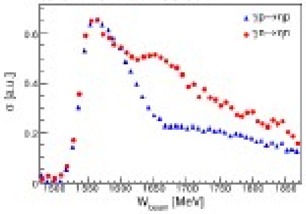
Entries 1535
Pmiss PR
Py1PR
Entries 19155
TA2PhotoPhysics
Entries 89517
TA2PhotoPhysics
Entries 122520

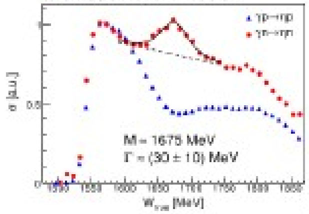
New high statistics measurement at MAMI-C

PhD of L. Witthauer — Preliminary — PhD of D. Werthmueller

with Fermi motion

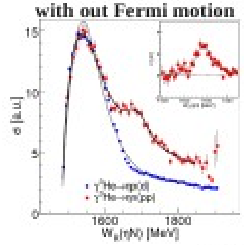


with out Fermi motion



A2

with out Fermi motion



- very preliminary analysis on
  - LD_2 (no efficiency corrections)
    W ~ 1675 MeV, Γ ~ 30 MeV
  - L^3He
    W ~ 1690 MeV, Γ ~ 83 MeV ± 18 MeV
- structure not due to a nucleus effect

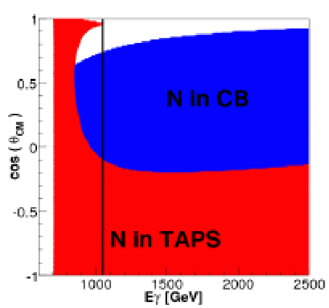
De-folding the fermi motion

CBELSA/TAPS

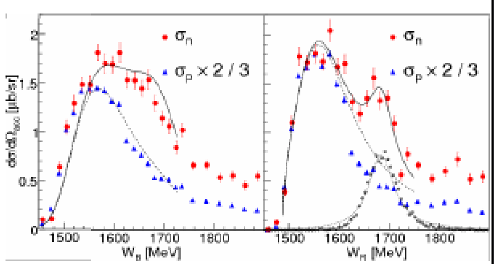
- Find the true cm energy from

$$s = (E_\eta + E_N)^2 - (p_\eta + p_N)^2$$

- Possible when the recoil nucleon is going into the forward wall, use of the time-of-flight ($\cos(\theta_{cm}) < -0.1$)

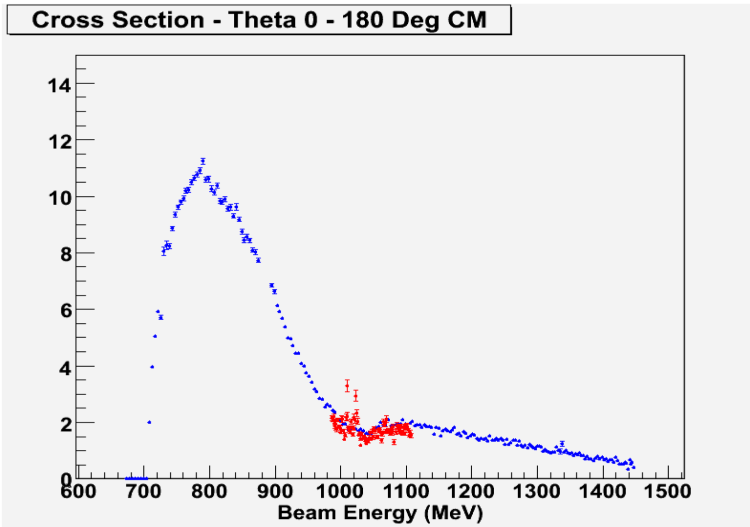


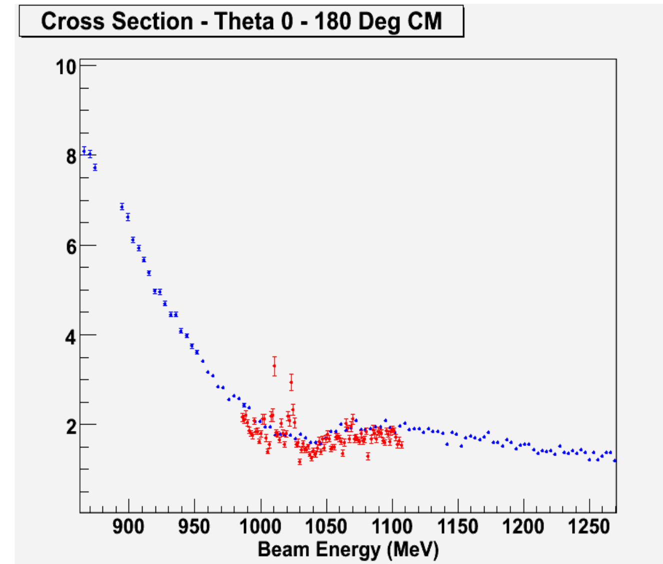
- Result
  - de-folded proton cross section similar to free proton
  - de-folded neutron cross section shows narrow structure around 1 GeV

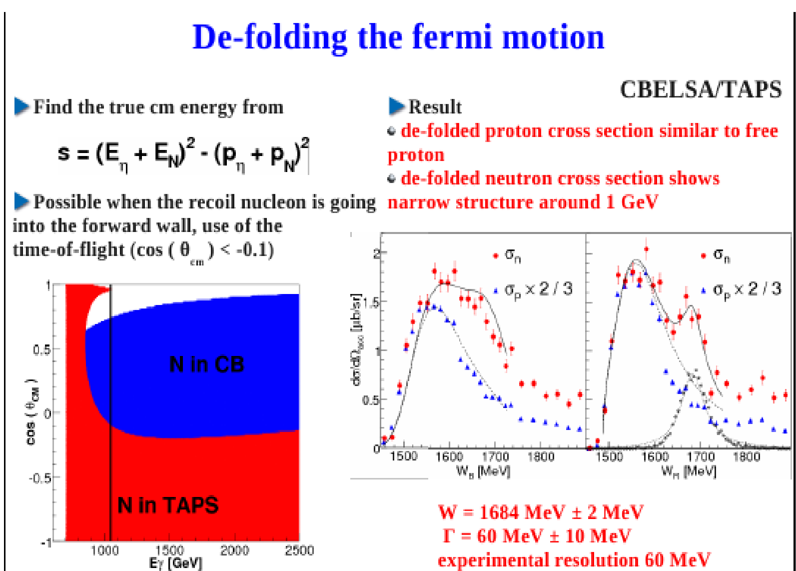


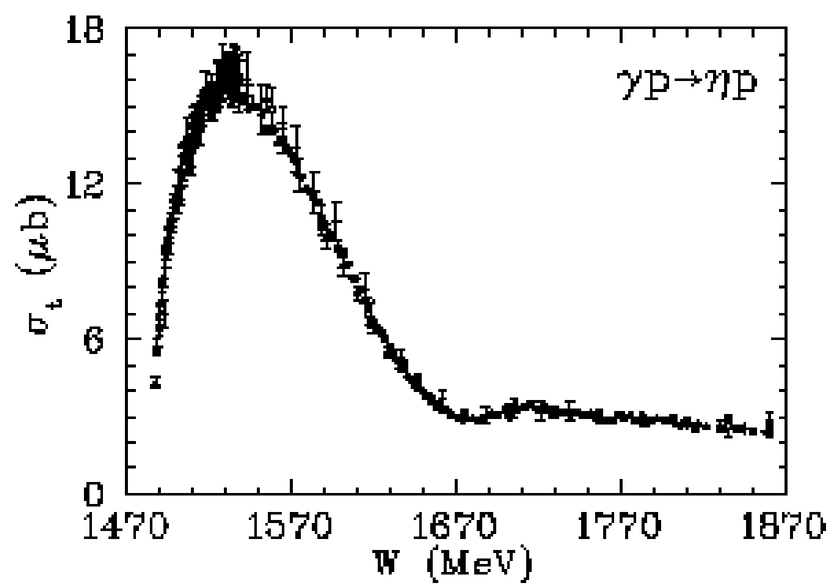
W = 1684 MeV ± 2 MeV
Γ = 60 MeV ± 10 MeV
experimental resolution 60 MeV

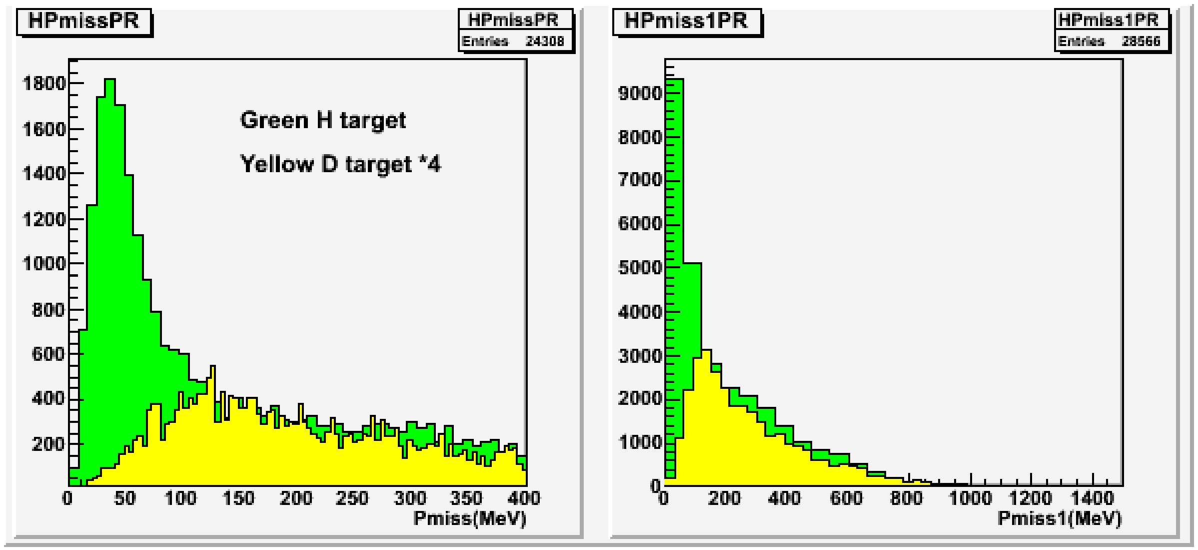
The energy dependences of total cross-section of reaction $\gamma P \rightarrow \eta P$











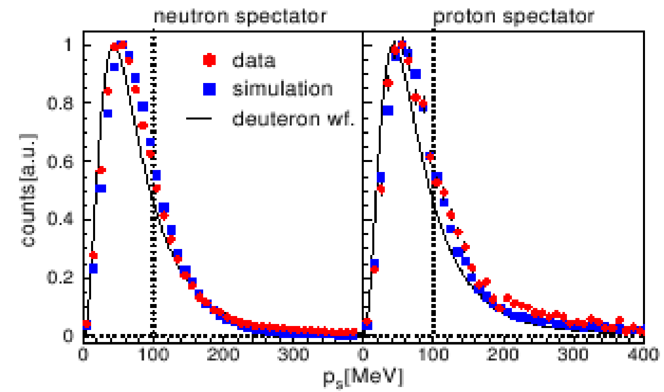
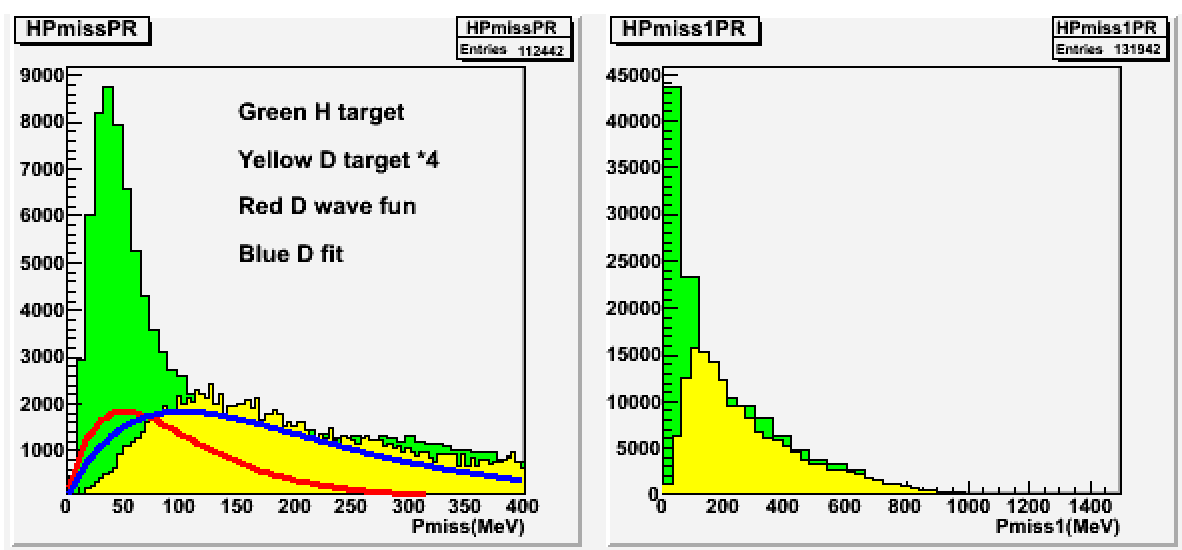


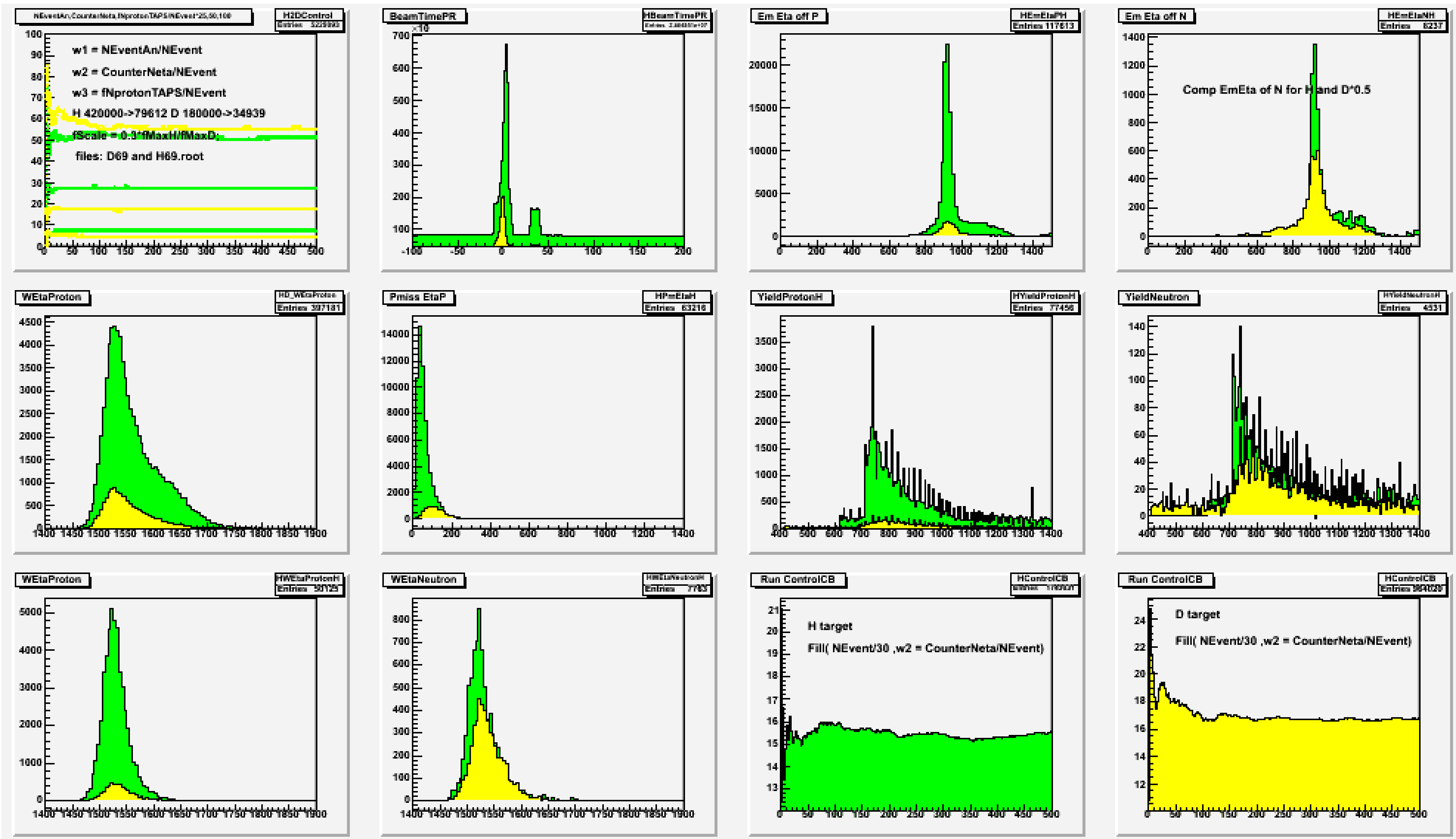
Fig. 22. Momentum distributions of spectator nucleons. (Red) dots: reconstructed from data, (black) lines: expected from deuteron wave function [68], (blue) squares: Monte Carlo simulation including detector response. Left hand side: neutron spectator (i.e. recoil proton detected), right hand side: proton spectator (i.e. recoil neutron detected).

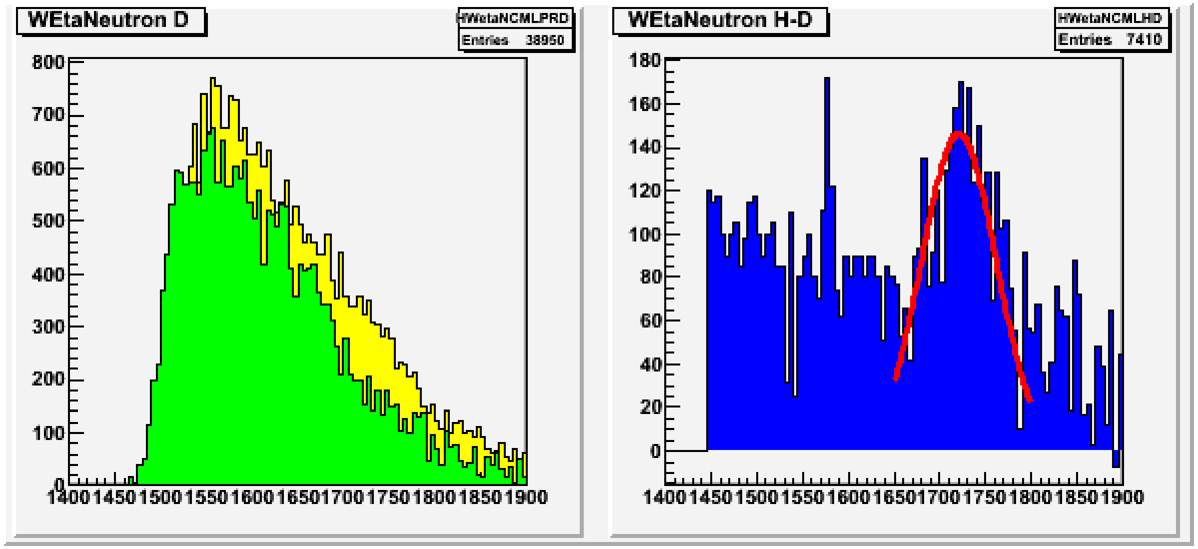


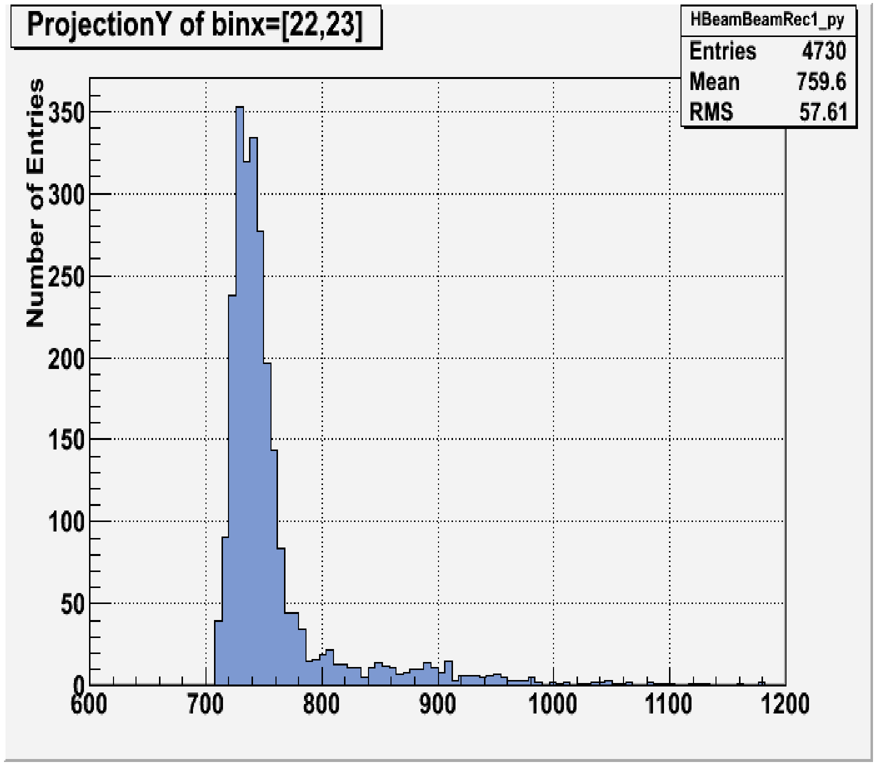
Reconstruction of deuteron vawe function

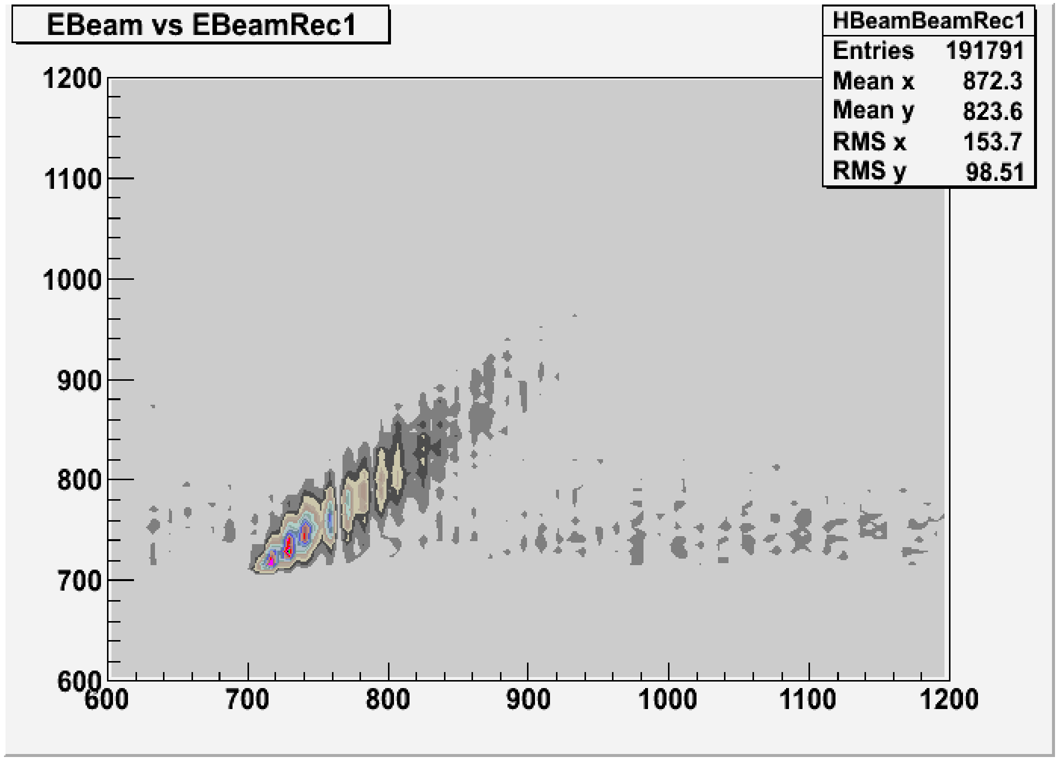
Green – H target

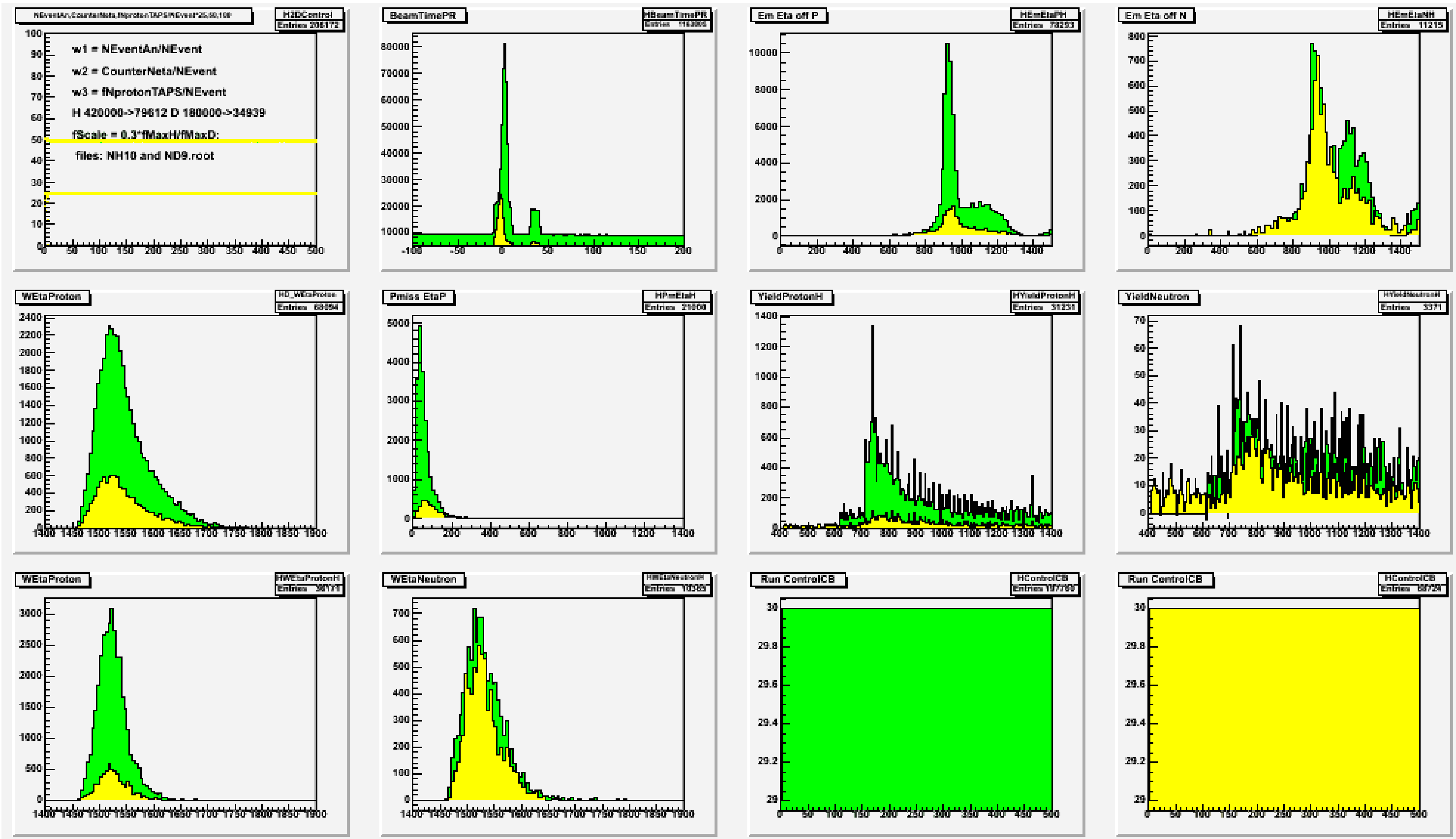
Yellow – D target


H2DControl
w1 = NEventAn/NEvent
w2 = CounterNeta/NEvent
w3 = fNprotonTAPS/NEvent
H 420000->79612 D 180000->34939
fScale = 0.3*fMaxH/fMaxD;
files: D69 and H69.root
BeamTimePR
HBeamTimePR
Em Eta off P
HEmEtaPH
Entries 117613
Em Eta off N
HEmEtaNH
Entries 6237
Comp EmEta of N for H and D*0.5
WEtaProton
Entries 397181
Pmiss EtaP
HPmEtaH
Entries 63216
YieldProtonH
HYieldProtonH
Entries 77456
YieldNeutron
Entries 4531
WEtaProton
HWEtaProtonH
Entries 30125
WEtaNeutron
Entries 7763
Run ControlCB
HControlCB
H target
Fill(NEvent/30 ,w2 = CounterNeta/NEvent)
Run ControlCB
HControlCB
Entries 984020
D target
Fill(NEvent/30 ,w2 = CounterNeta/NEvent)


WEtaNeutron D
HWetaNCMLPRD
Entries 38950
WEtaNeutron H-D
HWetaNCMLHD
Entries 7410

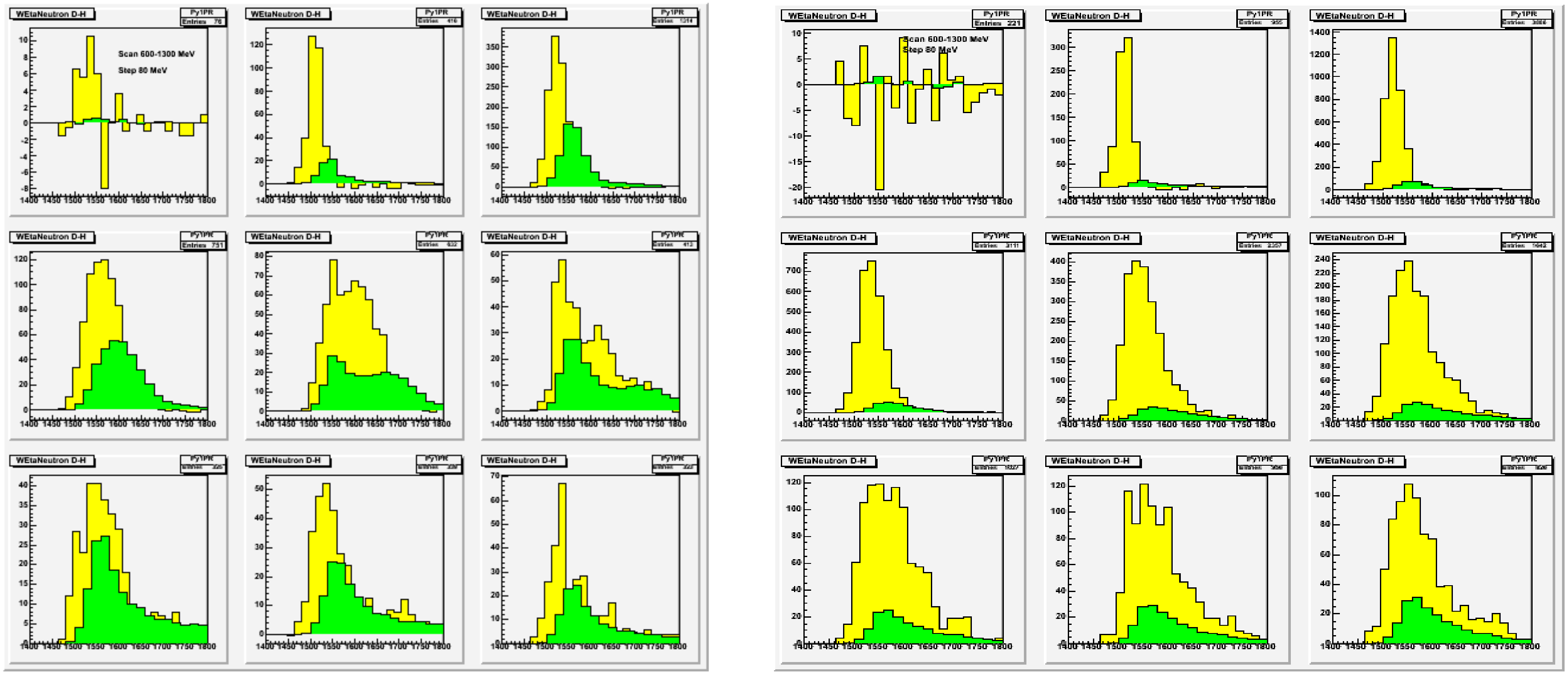

ProjectionY of binx=[22,23]
HBeamBeamRec1_py
Entries 4730
Mean 759.6
RMS 57.61
Number of Entries
0
50
100
150
200
250
300
350
600
700
800
900
1000
1100
1200

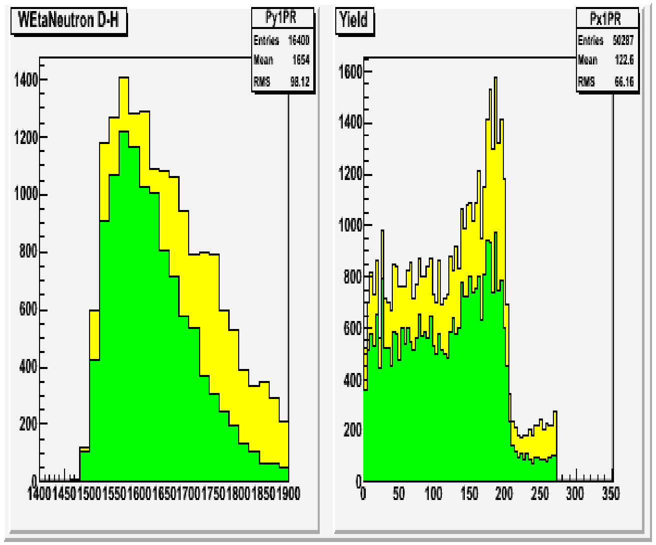

EBeam vs EBeamRec1
HBeamBeamRec1
Entries 191791
Mean x 872.3
Mean y 823.6
RMS x 153.7
RMS y 98.51
600
700
800
900
1000
1100
1200
600
700
800
900
1000
1100
1200


H2DControl
Entries 206172
w1 = NEventAn/NEvent
w2 = CounterNeta/NEvent
w3 = fNprotonTAPS/NEvent
H 420000->79612 D 180000->34939
fScale = 0.3*fMaxH/fMaxD:
files: NH10 and ND9.root
BeamTimePR
HBeamTimePR
Em Eta off P
HEmEtaPH
Entries 78293
Em Eta off N
HEmEtaNH
Entries 11215
WEtaProton
Entries 68094
Pmiss EtaP
HPmEtaH
Entries 21000
YieldProtonH
HYieldProtonH
Entries 31231
YieldNeutron
Entries 3371
WEtaProton
HWEtaProtonH
WEtaNeutron
Entries 10385
Run ControlCB
HControlCB
Run ControlCB
HControlCB

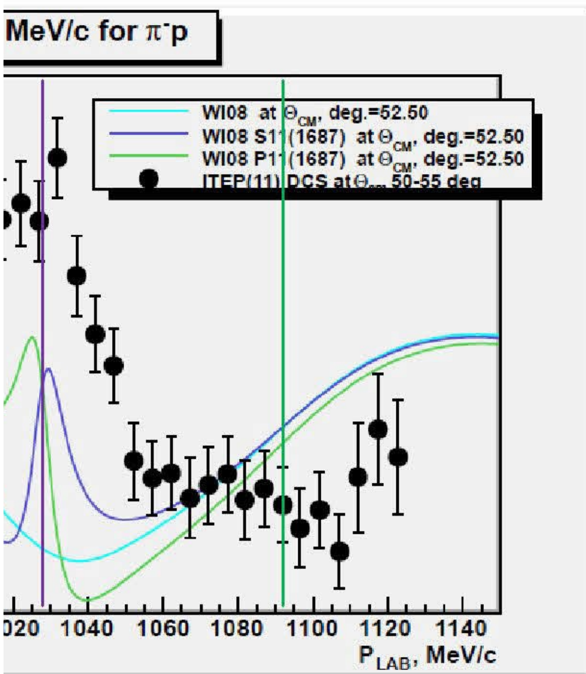
Comparison of H(left) and D(right) targets

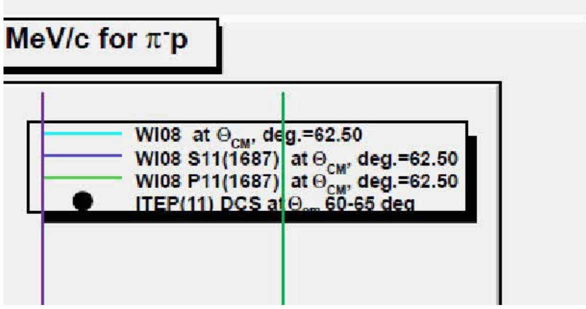
W(P4eta + P4ProtonCalc).M() for different beam energy bins





WEtaNeutron D-H
Py1PR
Entries 16400
Mean 1654
RMS 98.12
Yield
Px1PR
Entries 50287
Mean 122.6
RMS 66.16


MeV/c for π⁻p
WI08 at Θ_CM, deg.=52.50
WI08 S11(1687) at Θ_CM, deg.=52.50
WI08 P11(1687) at Θ_CM, deg.=52.50
ITEP(11) DCS at Θ_cm 50-55 deg
020 1040 1060 1080 1100 1120 1140
P_LAB, MeV/c


MeV/c for π⁻p
WI08 at Θ_CM, deg.=62.50
WI08 S11(1687) at Θ_CM, deg.=62.50
WI08 P11(1687) at Θ_CM, deg.=62.50
ITEP(11) DCS at Θ_cm 60-65 deg