Pentaquarks

Status and recent results from A2 and other collaborations

Abstract

Some years ago, a lighter pentaquark was found in photoproduction, called Θ+ (1540) inspired by the beautiful theoretical speculation in a chiral soliton model predicting an (anti-) decuplet of narrow baryons , following, in turn, a number of earlier papers. The Θ+ (1540) was confirmed in a series of low-statistics experiments. The evidence for a pentaquark interpretation also came from of

observed in photoproduction of η-mesons off neutrons in a deuteron but the data are not really in conflict with standard properties of N1/2− (1535) and N1/2− (1650) and interference between them . The existance of a pentaquark or resonance in η -neutron system with mass 1680 MeV (R1680) and its nature is one of the most exiting problem of medium energy physics and resonance is still under the question. This problem initiated the reprocessing of experimental date (JLab,CLAS,MAINZ) for study of possible pentaquark or "neutron anomaly". The results

of such reprocessing and last results of MAINZ experiments are presented.
The new method of searching R1680 and preliminary results from processing of experimental data of A2collaboration(MAINZ) from deuteron target are presented

Content

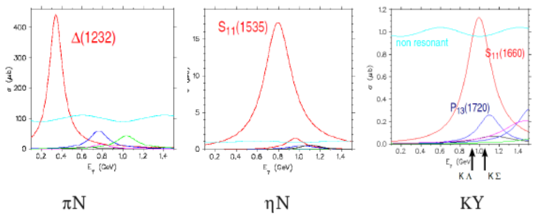
Introduction

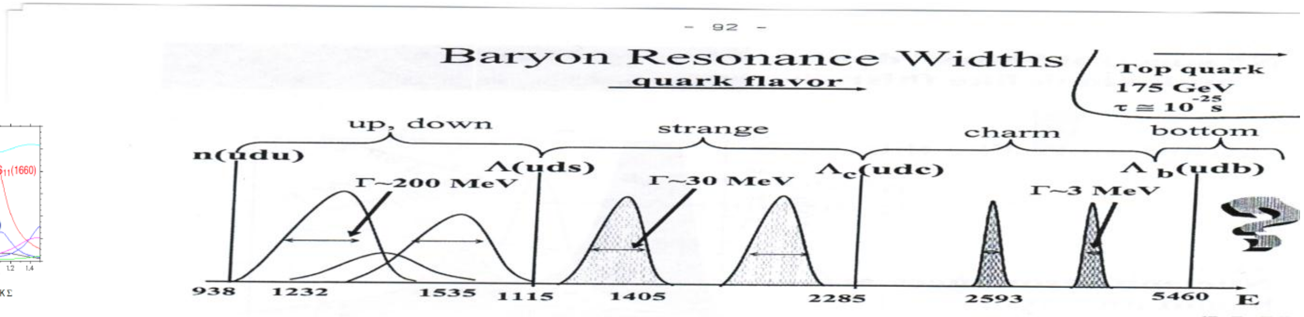
The first stage of experimental program of A2 collaboration on hydrogen, deutron and light nuclear is over. The second stage -- experiments on polarized trget is in progress now. The aim of program is a classic baryon spectroscopy. Especiallit is worse to point out Ƞ-Ƞ' physics with upgraded tagger. The obtained new precision experimental data initiated new problems wich was not included in experimental program One of such problem or, in common, exotic states in barions(myltiquarks, states. Quarks moleclas gluon component)). Pentaquarks problem exist from2007 and up to now attracts both – theoretical and experimental attention.

Now the experimental program of A2 collaboration(MAINZ) is aimed on spin observable experiments in framework of classic hadron spectroscopy — determination of resonance parameters. This program is closely related with programs of well-known world laboratory(JLab, BONN.COSY,ITEP) and include both — theoretical and experimental study.

Anothe program – the study of Ƞ' – physics. The tagger facility for high energy beam is in operation now and study of Ƞ'-meson (in comparison with Ƞ-meson) with high statistics and good beam energy resolution is very attractive experimental task.

The aim of this talk to review the exotic physics (pentaquarks, cusps, super nernarrow resonances) obtained from existing experimental data. Ths problems was not included in official program due to unpredictable results but new experimental progress allow to find unusial physics so the majority of me their experimental data.





Now the experimental program of A2 collaboration under a strong influence of EU Hadron Physics Project

June 17th to 19th , 2013, are presented — recent workshop MesonNet is a research network within EU Hadron-Physics3 project (1/2012 – 12/2014).

The obtained results from hydrogen target and EU Hadron Physics Project — two reason to revise the experimental program of A2 collaboration.

Classic pictures of resonances(baryon spectroscopy)

η and η' — mesons with hidden strangness change interaction

multyguarks states In hadrons(25%) and narrow resonances (glueballs, quarks moleculas) – the most exiting problem of modern medium energy physics.

The experimental program of A2 collaboration was aimed on classic Baryon Spectroscopy

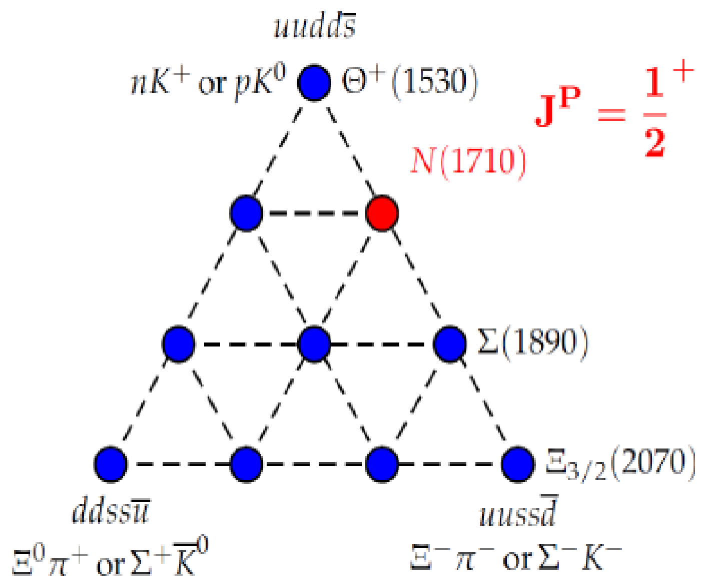
Pentaquark Θ^+(1540) Problem is still alive

The first observed multyquarks state ?

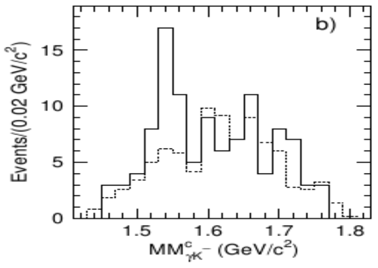
The pentaquarks problem exist from 1997(Theoretical speculation by Diakonov) and first experimental indication on existing narrow resonance Θ+(1540) up to now recent articles appeared in 2012)(

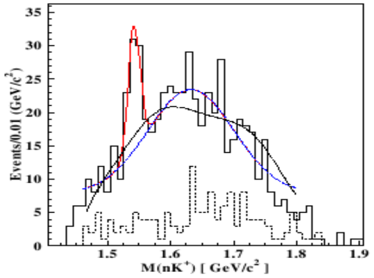
Some years ago, a lighter pentaquark was found in photoproduction, called Θ+ (1540) (Nakano et al., 2003), inspired by the beautiful theoretical speculation in a chiral soliton model predicting an (anti-) decuplet of narrow baryons (Diakonov et al., 1997), following, in turn, a number of earlier papers. The Θ+ (1540) was confirmed in a series of low-statistics experiments.

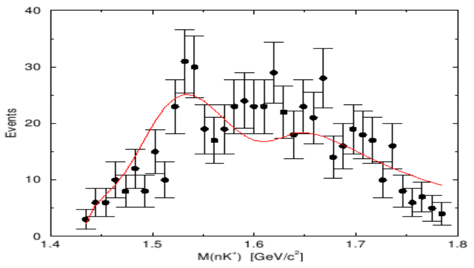
γD -> KP + KN -> KP + (us+udd) pentaquark 1540 MeV inclusive experiments
$\Theta^+ \rightarrow$ Kn K → ππππ (CLAS)
Pentaquark:
quark content uudds
mass around 1540 MeV
narrow width less then 15 MeV
decays into Kp or Kn
strangeness: S = +1
Isospin: probably 0 due to absence of q = 2
Spin 1/2, 3/2,5/2 ...
Parity: + or -



Mass (MeV)	Width (MeV)	N_{event}	Statist. signif.	Reaction	Experiment
$\Theta^+(1540)$					
$1540 \pm 10 \pm 5$	< 25	19 ± 2.8	$\sim 2.7\sigma$	$\gamma C \rightarrow C'K^+K^-$	LEPS
$1539 \pm 2 \pm 2$	< 9	29	$\sim 3.0\sigma$	$\gamma p \rightarrow nK^+K^0_s$	DIANA
$1542 \pm 2 \pm 5$	< 21	43	$\sim 3.5\sigma$	$\gamma d \rightarrow pnK^+K^-$	CLAS
$1540 \pm 4(\pm 3)$	< 25	63 ± 13	4.8σ	$\gamma p \rightarrow nK^+K^0_s$	SAPHIR
$1533 \pm 5(\pm 3)$	< 20	27	$\sim 4.0\sigma$	ν–induced	CERN, FNAL
$1555 \pm 1 \pm 10$	< 26	41	$\sim 4.0\sigma$	$\gamma p \rightarrow nK^+K^-\pi^+$	CLAS
1528 ± 4	< 19	~ 60	$\sim 4\sigma$	γ^*–induced	HERMES
$1526 \pm 3 \pm 3$	< 24	50	3.5σ	p-p reaction	SVD-2
1530 ± 5	< 18		3.7σ	p-p reaction	COSY
1545 ± 12	< 35	~ 100	$\sim 4\sigma$	p-A reaction	YEREVAN
$1521.5 \pm 1.5^{+2.8}_{-1.7}$	< 6	221	4.6σ	Fragmentation	ZEUS
$\Xi(1862)$					
1862	< 21		4.6σ	ν–induced	NA49
$\Theta_c(3099)$					
$3099 \pm 3 \pm 5$			5.4σ	γ^*–induced	HERA





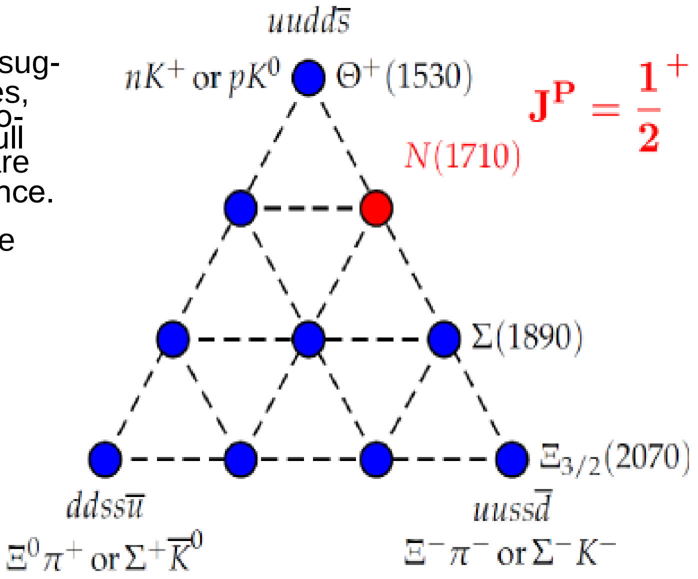


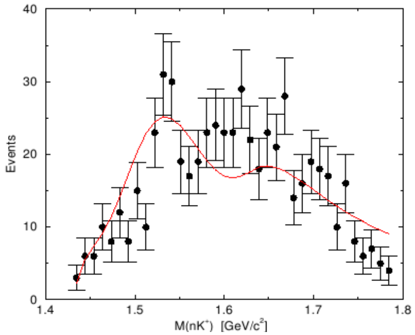
DIANA: The calculated (solid line) mKN distribution 182 , compared with the data 166 .

The table includ data before 2007
Now the majority of data are reprocessing

Pentaquark θ^+(1540)

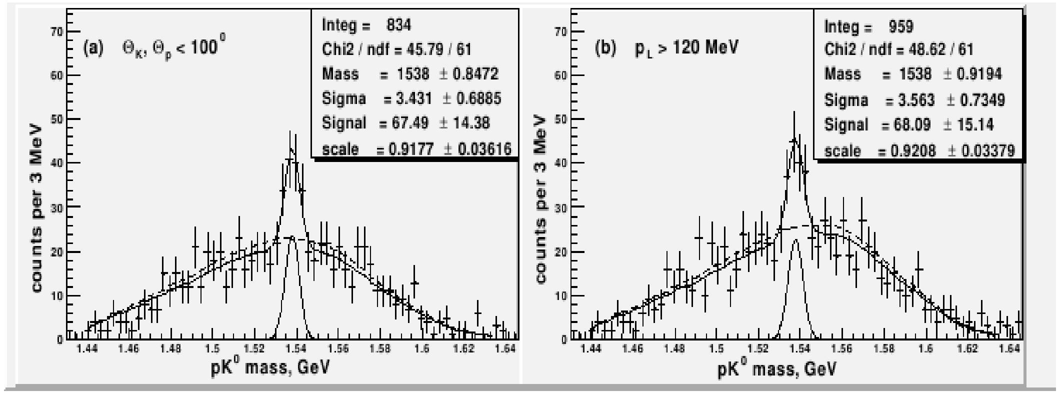
To understand the whole set of positive and null data on the Θ+ (1530)-production, we suggest the hypothesis that multiquark hadrons are mainly generated from many-quark states, which emerge either as short-term hadron fluctuations, or as hadron remnants in hard processes. This approach allows us to describe both non-observation of the Θ+ in current null experiments and peculiar features of its production in positive experiments. Further, we are able to propose new experiments that might be decisive for the problem of the Θ+ existence. Studies of properties and distributions of the Θ+ in such experiments can give important information on the structure of both conventional and multiquark hadrons. It would provide better insight into how QCD works.





DIANA: The calculated (solid line) mKN distribution 182 , compared with the data 166 .

DIANA Collaboration
ITEP ArXivJuly 2013



Reprocessing of CLAS data

Sammury:

The experimental confirmation of existance of Θ+(1540) pentaquark is still uder the quastion

Recently no special experiments devoted to seaching for Θ+(1540)

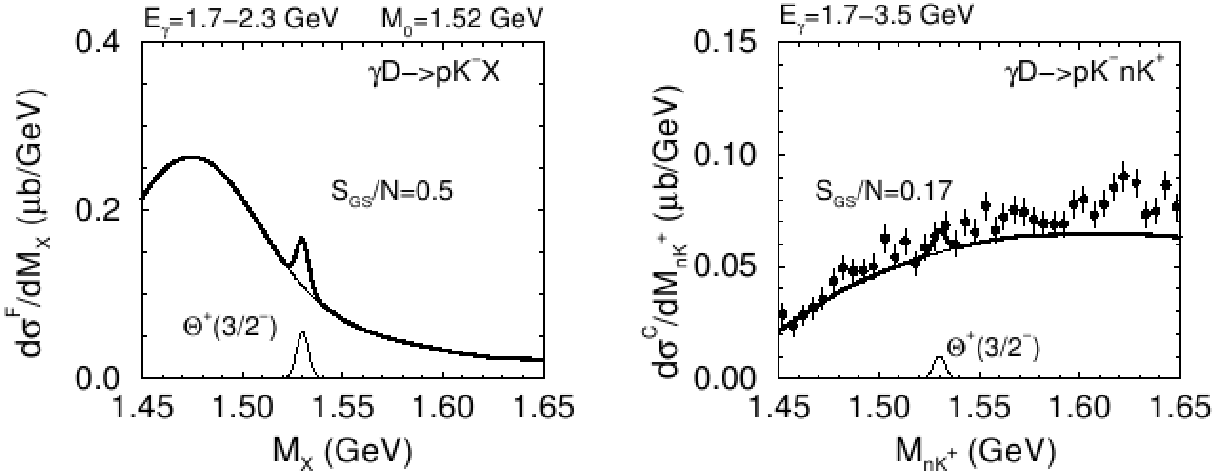
The results od different experiments have a positive and negative results and is out of stetistics

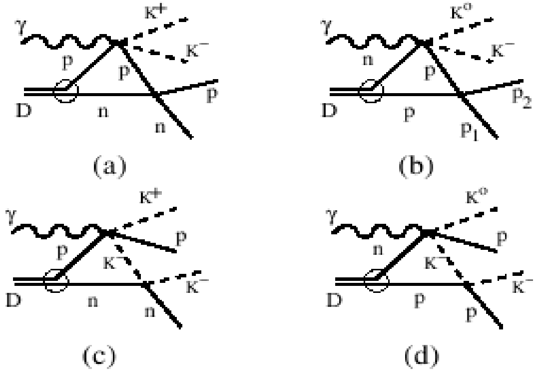
An explanation why the Θ+ is seen in some experiments and not in others Azimov arXiv 2007 - 2012

Θ+ formation in inclusive γD → pK − X arXiv:nucl-th/0607054v1 26 Jul 2006 Titov

Resanoble explanation of the peak absence

We analyze the possibility to produce an intermediate Θ+ via a KN → Θ+ formation process in γD → pK − X (X = nK + , pK 0) reactions at some specific kinematical conditions, in which a pK − pair is knocked out in the forward direction and its invariant mass is close to the mass of Λ∗ (Λ∗ ≡ Λ(1520)). The Θ+ signal may appear in the [γD, pK −] missing mass distribution. The ratio of the signal (cross section at the Θ+ peak position) to the smooth background processes varies from 0.7 to 2.5 depending on the spin and parity of Θ+ , and it decreases correspondingly if the pK − invariant mass is outside of the Λ∗ -resonance region. We analyze the recent CLAS search for
the Θ+ in the γD → pK − nK + reaction and show that the conditions of this experiment greatly reduce the Θ+ formation process making it difficult to extract a Θ+ peak from the data.

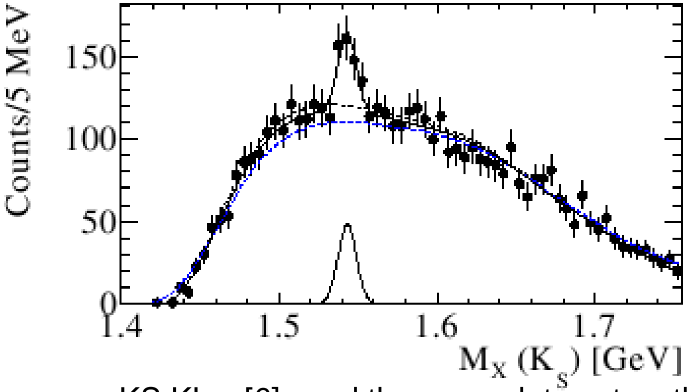




Left panel: Missing mass distribution in inclusive γD → pK − X at Eγ = 1.7 − 2.3 GeV and the pK − photoproduction angular cut (θpK − < 220 (c.m.s.)) and φ-meson cut. Right panel: nK + invariant mass distribution in exclusive γD → pK − nK + at Eγ = 1.7 − 3.5 GeV and for CLAS experimental conditions(i)-(v). Experimental data from Ref. [7]. In both cases, JΘ = 3/2− and the Θ+ signal is folded with a Gaussian resolution function with a width of 3 MeV.

INTERFERENCE OF RESONANCES AND OBSERVATION OF THE Θ+ -PENTAQUARK Azimov another idea

Experimentally, smallness of the Θ+ -production (if it exists at all) was demonstrated by the CLAS analysis of the reaction γp → K Kp [8]. The Θ+ was not observed, and strict bound was provided for its production cross section. This stimulated both the suggestion [4] and searches for an enhanced signal in rearrangement interference, which resulted in the paper [6].

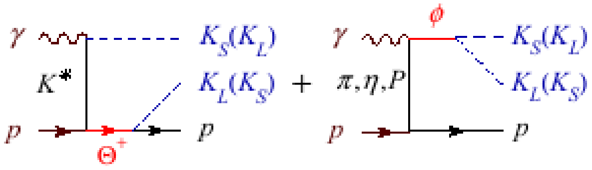


The new analysis of reaction γp → KS KL p [6] used the same data set as the earlier analysis [8] and was, to some extent, similar to it. In both analyses one kaon was reconstructed by the peak in the mass of π + π − pairs, the other by the peak in the missing mass MX (pπ + π −). But the analysis [6], in difference with Ref. [8], applied some additional requirements to improve identification of the KS . In both analyses the KS KL spectrum shows a very pronounced φ-peak. In Ref. [8] it was traditionally cut out, by applying the condition MX (p) > 1.04 GeV. Analysis of Ref. [6], just opposite, used events under the φ-peak, with MX (p) = 1.02 ± 0.01 GeV, where interference is most efficient.

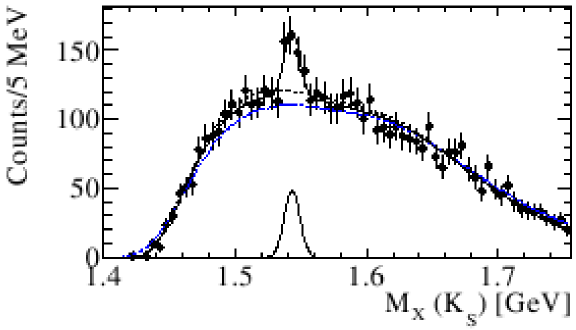
Observation of a narrow structure in 1 H(γ, KS)X via interference with φ-meson production

arXiv:1110.3325v3 [hep-ex] 21 Mar 2012

i We report observation of a narrow peak structure at ~1.54 GeV with a Gaussian width σ = 6 MeV h the missing mass of KS in the reaction γ + p → pKS KL . The observed structure may be due to the interference between a strange (or anti-strange) baryon resonance in the pKL system and the φ(KS KL) photoproduction leading to the same final state. The statistical significance of the observed excess of events estimated as the log likelihood ratio of the resonant signal+background hypothesis and the φ-production based background-only hypothesis corresponds to 5.3σ.



(Color online). Two different subprocesses in the reaction γp → pKS KL that can lead to the same final state: Θ+ (pK 0) production (left) and φ-meson production (right).



Missing mass of KS with a cut −tΘ < 0.45GeV2 . The dashed line is a result of φ MC simulation, the dashed-dotted line is a modified MC distribution, and the solid line is a result of the fit with modified MC distribution plus Gaussian function.

In our analysis we looked for a possible resonance structure that interferes with φ-production in the final state KS KL p. We looked for deviation of the missing mass spectra of KS in the experimental data from the missing mass of KS for pure φ-production.

Our φ photoproduction Monte-Carlo simulation is based on the Titov-Lee model [28]. The angular de-

The looking for pentaquarks is based on producing of strange final states so the high bean energy is needed but in this case we have a multy particle final state and as wos showned in numerous analysis the FSI of known resonances may produce an additional irregulatity in IM distribution.

An explanation why the Θ+ is seen in some experiments and not in others Azimov arXiv 2007 – 2012

Thre are several groups (ITEP, PNPI, Jlab, JINR) devoted to explanation of experiments results

Exotic - quark dynamic(like eta in intermadiate states) quarks moleculas

eta -> uu + dd + ss -> (uu + dd + s) + s virtual pentaguark + s

pi + D -> etaN(1540) + p (threshold 680 MeV/c, Trecoil proton 30 MeV)

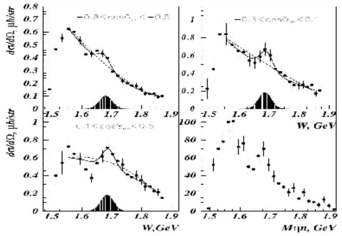
Status of «neutron anomaly» ηN in different reactions

Problem of Fermi motion -two approaches

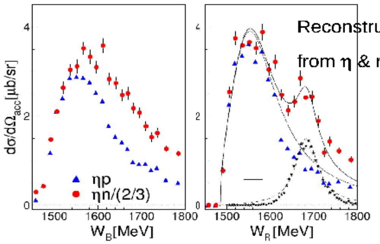
Neutron anomaly came from pionereng work by Kuznetsov and initiated both -- theoretical and experimental efforts to study this effect and its origin.

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.

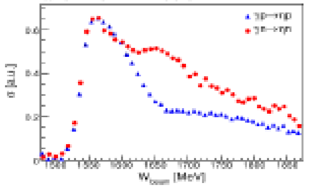
MAMI has much higher intensity than GRAAL or ELSA...aim to determine p(γ,pη) upper limit < 0.1 μb/sr (still needs to be quantified)

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

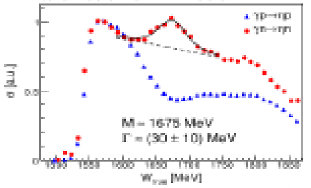
New high statistics measurement at MAMI-C

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

with Fermi motion

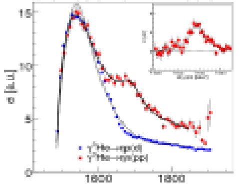


with out Fermi motion



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**

Problem — defolding of Fermi motion(W reconstruction from final-state)

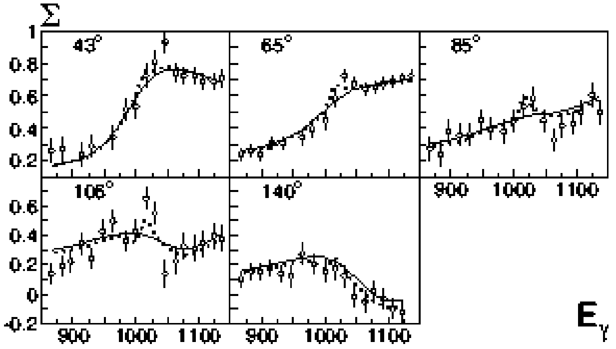
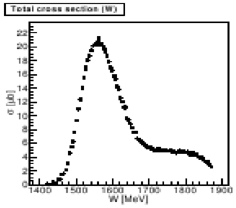


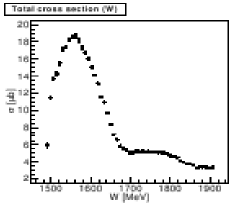
Fig. 12. Beam asymmetry for the reaction $\gamma p \to \eta p$ [17]. The PWA description is shown as solid line (solution 1) and dotted line (solution 3).

I.

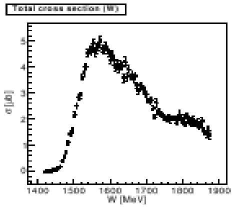
- quasi-free proton, W from incident photon energy



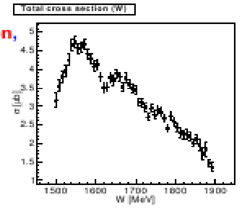
- quasi-free proton, W from $p-\eta$ final state



- quasi-free neutron, W from incident photon energy



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



Status of R(1680)

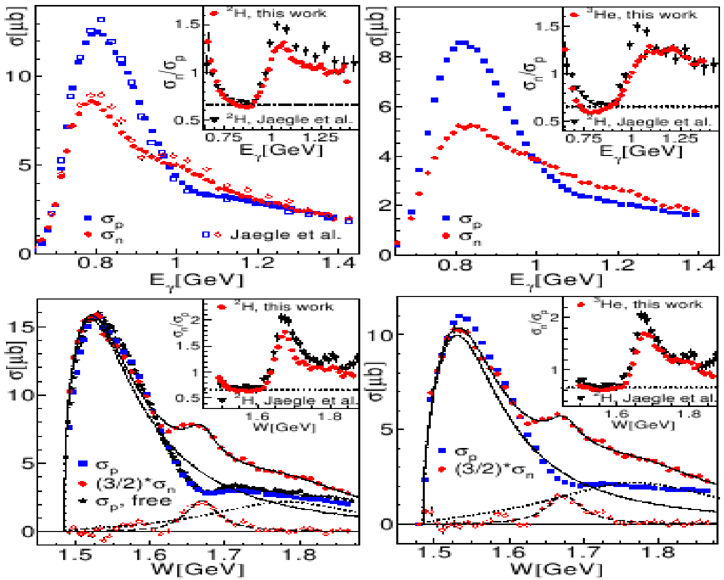


FIG. 1: Top: Total cross sections σp (coincident protons, solid blue squares) and σn (coincident neutrons, solid red circles) as function of incident photon energy Eγ . Left-hand side: deuterium target. Open blue squares and open red circles are σp and σn from Ref. [6]. Right-hand side: helium target. Bottom: same for cross sections as function of reconstructed ηN invariant mass W . Black stars: results for free proton [31]. The open red circles are present data after subtraction of the fitted S11 and background components. Curves: fit results for S11 resonance (dash-dotted), background (dotted), narrow structure (dashed), and full fit (solid). Inserts: σn /σp ratio from present work (red solid circles) and from Ref. [6] (solid black triangles).

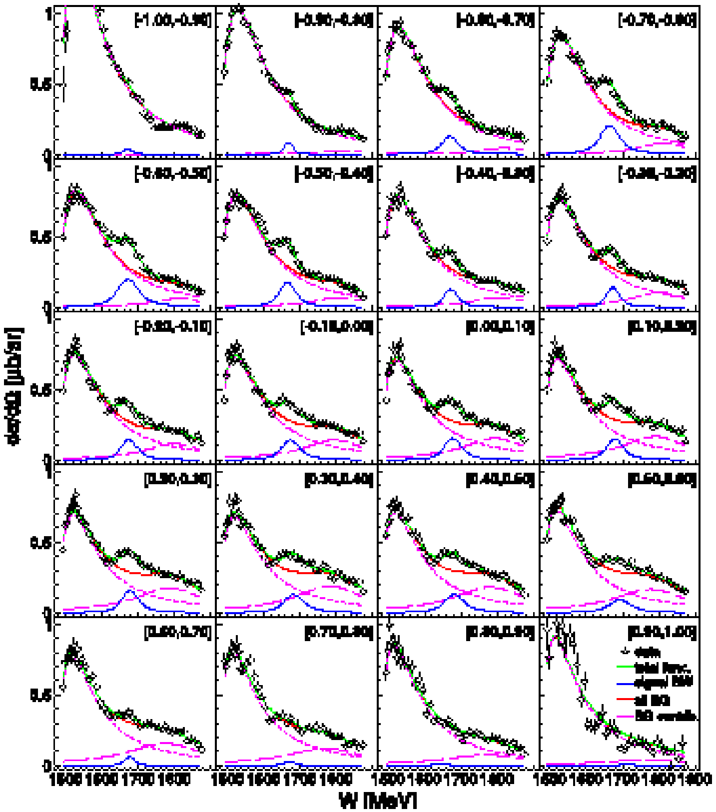


FIG. 3: Excitation functions for γn → nη for different ranges of cos(Θη) (from -1 to -0.9 in upper left corner to 0.9 to 1 in lower right corner). The fit curves are as in Fig. 1.

Recent result from A2 - - no angle dependencies of «neutron anomaly»

S(1880)pf

Precision measurment of eta photoproduction from proton by A2 collaboration

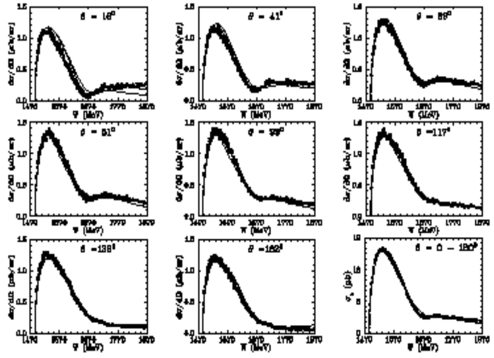


FIG. 10: Fixed-angle excitation functions for $\gamma p \to \eta p$ as a function of the c.m. energy W shown for eight values of the η production angle and for the full angular range. Our data are shown by solid circles. The plotted uncertainties are statistical only. The notation of the PWA solutions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

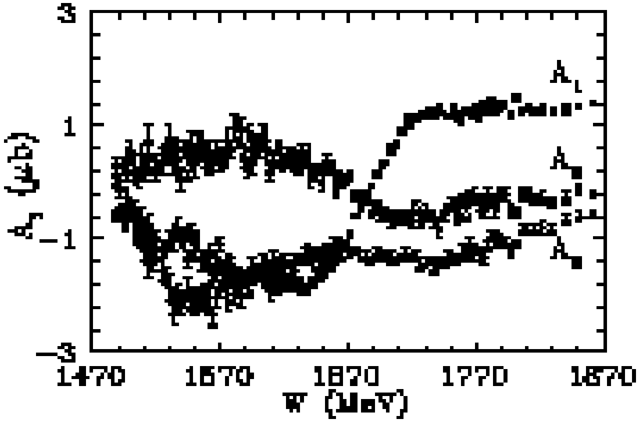
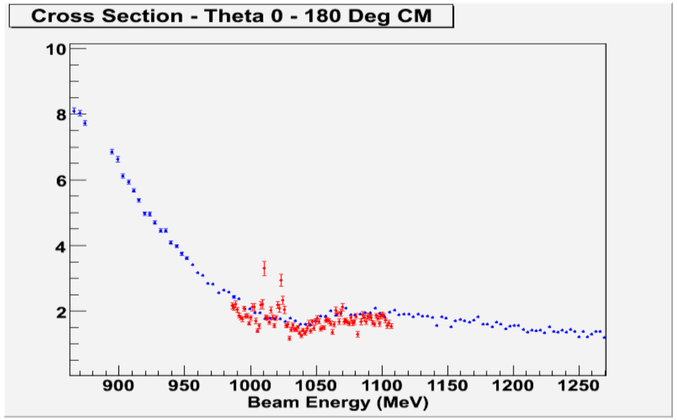


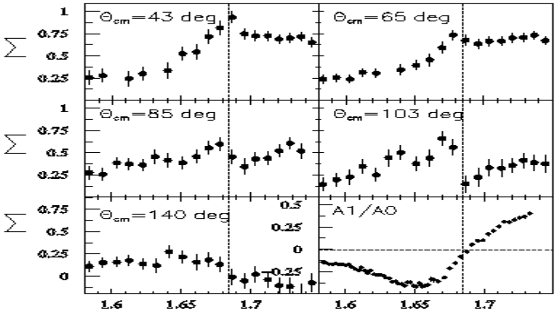
FIG. 8: Dominant Legendre coefficients from the fits to our differential cross sections. The coefficients are plotted as a function of the c.m. energy; A_1 is shown by solid circles, A_2 by open triangles, and A_3 by open circles.



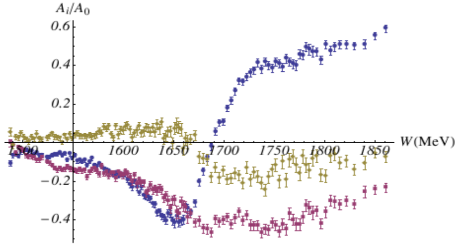
No narrow bump in high energy resolution beam(1 MeV). Also bump is not seen in total CS in high statistics 4 MeV experiment

On Narrow Nucleon Excitation N∗ (1685)

V. Kuznetsov1,2 , M.V. Polyakov3,4 and M. Th¨ rmann4



Photon beam asymmetry in γp → ηp
extracted from the GRAAL data,
The low right figure shows the ratio of
Legendre coefficient A1 /A0 (5)
extracted from data.



Coefficients Ai of the Legendre expansion normalized to the total cross section (to A0). The coefficients Ai are calculated using the data.

. Our analysis showed that the data of [26] may indicate an existence of new narrow N∗ (1685) resonance with Γtot ≤ 50 MeV and small resonance photocoupling in the range of BrηN Ap ∼ (0.3 − 3) · 10−3 GeV−1/2 . These parameters are in agreement with the analysis of the photon beam asymmetry in γp → ηp process ..

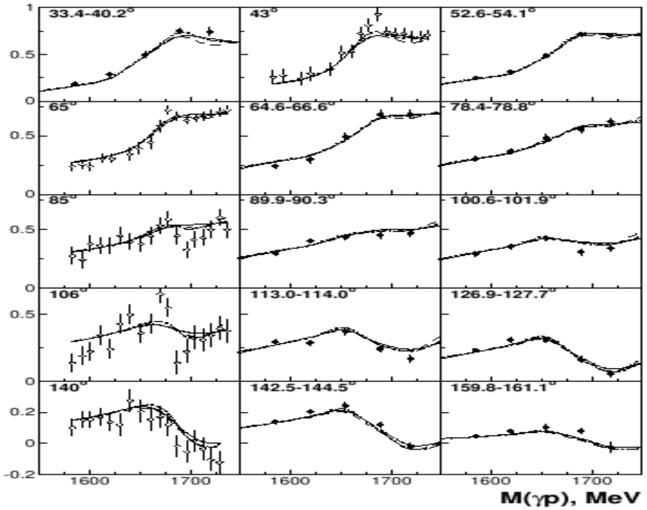
Status of R(1680)

Search for Narrow Nucleon Resonance in γp → ηp

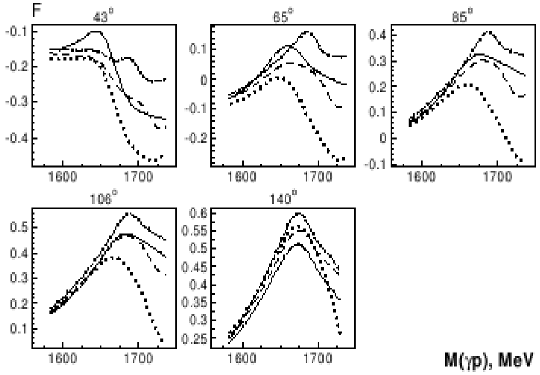
A.V. Anisovicha,b, E. Klemptb , V. Kuznetsovc,d, V.A. Nikonova,b, M.V. Polyakova,d,∗, A.V. Sarantseva,b, U. Thomab

We conclude that the new high precision data on γp → ηp cross section of Ref. [25] reveal an interesting structure in the mass region of 1660-1750 MeV. The relatively smooth angular distributions suggest that this structure can be interpreted within the P or S waves. The threshold of the ωp channel may effect the data and my contribute by a coupling of the two S 11 resonances to ωp and by a non-resonant γp → pω transition strength. A good fit of the data is achieved when the ωp channel is included even though the fit is unable to decide which of the two mechanisms is more important. Assigning the effect to the P-wave, the data can be explained only with introduction of a narrow resonance, in particular when the data [23, 24] on the beam asymmetry Σ are included. A narrow P11 resonance - interfering destructively within the P11 wave - would be preferred in this case.

High statistic polarization data on target asymmetry and on the double polarization variable F should provide the necessary constraints to define which partial wave is responsible for the structure observed in mass region of 1660-1750 MeV in the ηp cross section. In the end it may provide the information needed to decide whether or not a narrow baryon resonance exists in this mass range.



The description of the beam asymmetry data (shown at fixed angles) with our solutions. The open circles represent the data from [23, 24] and full circles the data from [36]. The center values of angular bins for [36] depend on the energy and are given as intervals (from the lowest energy to highest one). The full curve corresponds to the solution BG2010-02M, dashed curve to the P11 (+) solution and dashed-dotted curve to the P11 (−) solution.

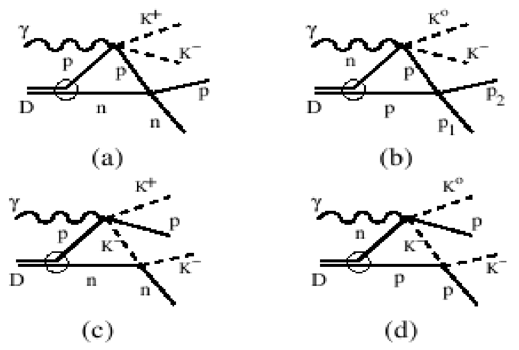


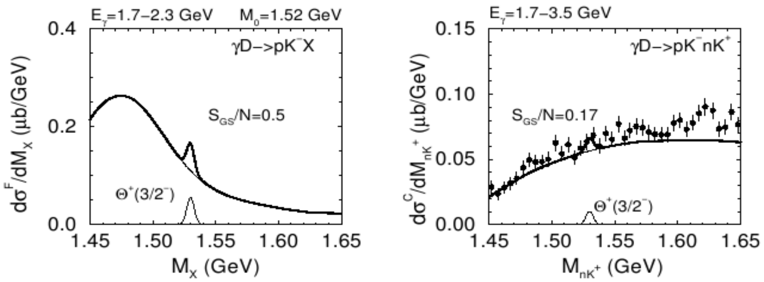
Prediction for the F-observable in the η photoproduction.
The full curves correspond to the solution with ωp channel included
to the S 11 partial wave, dashed curves to the P11 (+) solution, dushed-dotted
cucrves to the P11 (−) solution and dotted curves to the P13 solution.

Sammury;

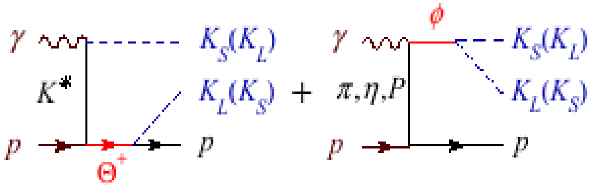
R(1680) really exist that confirmed by several collaborations
The precision mearsument of eta photoproduction of protonshows a new details of reaction.
The obtained data were analised by main PWA geoups(Bj-Ga, SAID, Phenomenological analysis but the only result is that existance of P11(1680) is preferable. Spin observables may help to solve problem.

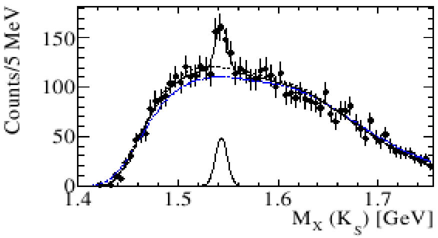
Possible explanation of existance(or not) of pentaquarks from world theoretical groups(ITEP, JINR, PNPI, JLAB)



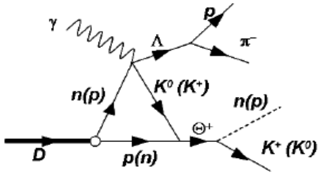


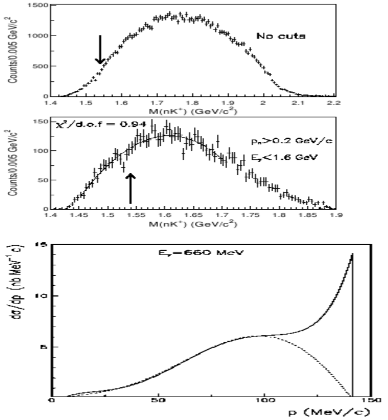
Titov



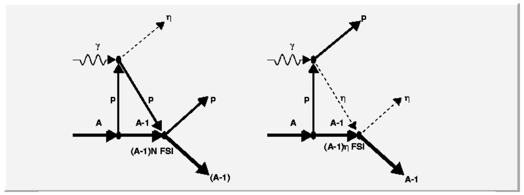


Aziimov Interference



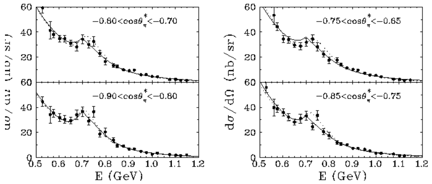


Sibirtsev FSI



Eta in intermedia state

Coherent production piD
peak due to eta production
In intermadiate state at
E = 0.7 GeV(W = 1500)



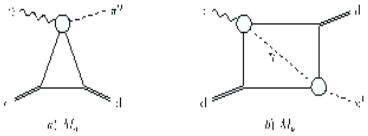


Fig. 1. Feynman diagrams for the $\gamma d \to \pi^0 d$ reaction considered in [24]: (a) single-scattering amplitude M_a; (b) double-scattering amplitude M_b. It was shown in [24] that (b) dominates over (a) at backward angles for $E_\gamma \sim 700$ MeV.

MesonNet 2013 International Workshop Mini-proceedings

arXiv:1308.2575v1 [hep-ph] 12 Aug 2013

The mini-proceedings of the MesonNet 2013 International Workshop held in Prague from June 17th to 19th , 2013, are presented. MesonNet is a research network within EU HadronPhysics3 project (1/2012 – 12/2014).

MesonNet is a research network within EU HadronPhysics3 project (1/2012 – 12/2014). The main objective is the coordination of light meson studies at different European accelerator research facilities: COSY (J¨lich), DAPHNE (Frascati), ELSA (Bonn), GSI (Darmstadt) and MAMI (Mainz).

The network includes also EU researchers carrying out experiments at VEPP-2000 (BINP), CEBAF (JLAB) and heavy flavor-factories (Babar, Belle II, BESIII experiments). The scope are processes involving lightest neutral mesons: π 0 , η, ω, η , φ and the lightest scalar resonances. The emphasis is on meson decay studies but we include also meson pro-

A2(MAINZ) involved in EU physics program andmicrotron and experimental set will be upgraded

η-η' physics as a sepreted branch:

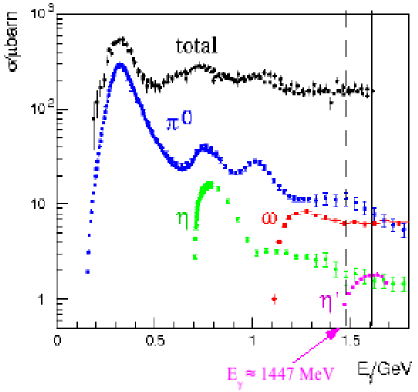
mass origin — gluon component
decays
amplituad(potential), vbound states
invisible deceys(dark matter) -MM (TC?) technique

No experiments with pion beam !

η' physics

η-η' physics — big gluon component?

Problem -precision study of η' meson in comparison with η meson
The precision study of η-meson demonstrated a new unknown feature of η-meson but good experimental data onη' — meson is absent. Ths program is included in future experiments of upgraded world fasilities as Jlab, KLOE and other.



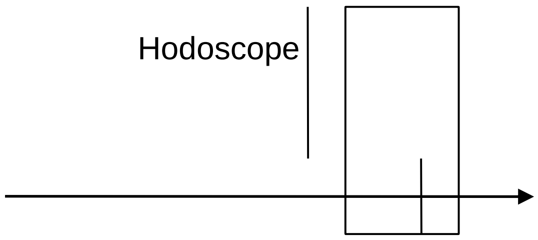
Tagger energy range: 4.7 to 93% of E_0

Maximum energy tagged for E_0=1604 MeV is 1491 MeV

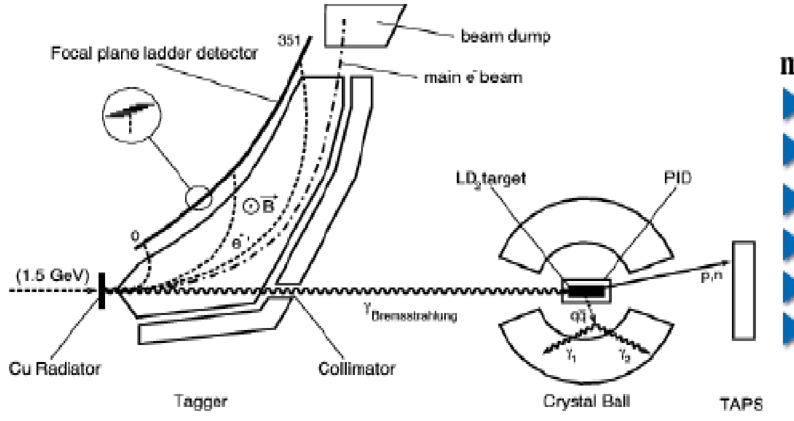
But:
- η' is an interesting field
- Studies of η' decays at high rates possible with the CB

ηn — R(1680)
η'n -- R(?) is resonance exist and its origin

High energy tagger



4π detectors and 4π trigger : ~ 1000 crystals + CPCs



measure: $E_\gamma = E^0_{e^-} - E_{e^-}$
- incident photon beam
- γ
- $\pi^{+/-}$
- proton
- neutron
- deuteron

Status of η-meason physics

Eta-meson production in the resonance energy region.

V. Shklyar,† H. Lenske, and U. Mosel

arXiv:1206.5414v2 [nucl-th] 22 Feb 2013

We perform an updated coupled-channel analysis of eta-meson production including all recent photoproduction data on the proton. The dip observed in the differential cross sections at c.m. energies W=1.68 GeV is explained by destructive interference between the S11 (1535) and S11 (1560) states. The effect from P11 (1710) is found to be small but still important to reproduce the correct shape of the differential cross section. For the π − N → ηN scattering we suggest a reaction mechanism in terms of the S11 (1535), S11 (1560), and P11 (1710) states. Our conclusion on the importance of the S11 (1535), S11 (1560), and P11 (1710) resonances in the eta-production reactions is in line with our previous results. No strong indication for a narrow state with a width of 15 MeV and the mass of 1680 MeV is found in the analysis. ηN scattering length is extracted and discussed.

V. Shklyar,† H. Lenske, and U. Mosel

Thresholds Eg - W

Etap 0.709 — 1.45

K0Sigma+ 1.05 - 1.7

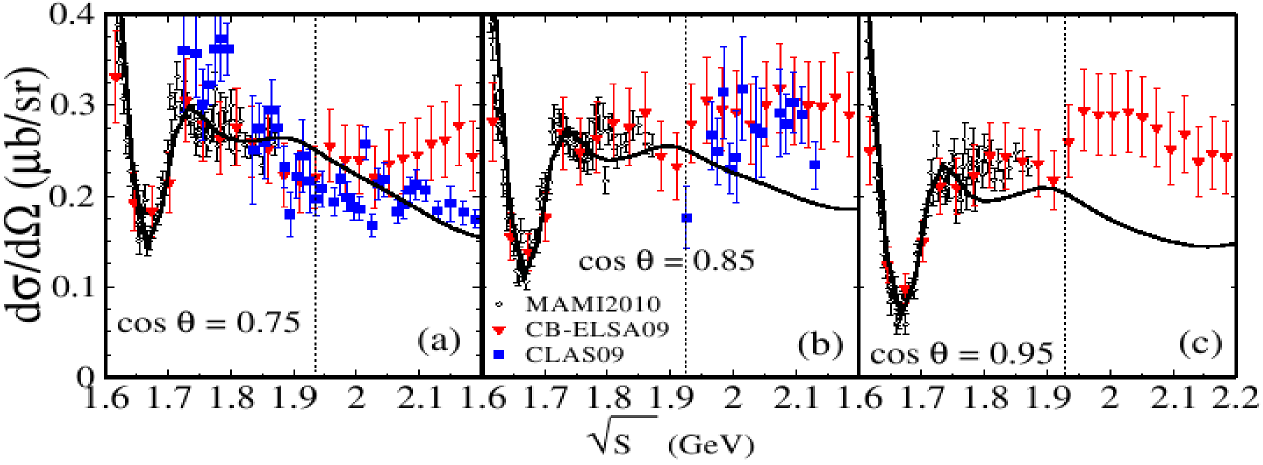
Omega 1.1

Eta' 1.45 — 1.9

K*Lambda 1.68 - 2.0

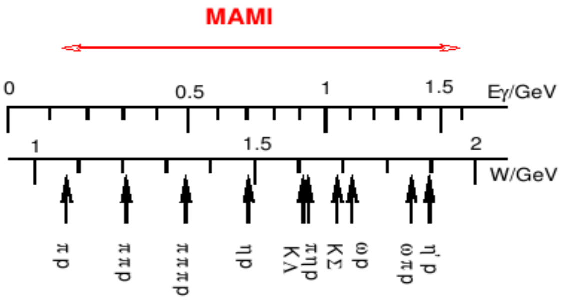
K*Sigma 1.85

R(Eta' n) 1.80 -



Differential ηp cross section as a function of c.m. energy at fixed forward angles. Data are taken from CLAS 2009:[43], CB-ELSA:[20], and MAMI2010:[35].

Cusp in eta photoproduction due to eta' threshold or gluon component?



Sammury:

The high-presision MAINZ data provide a new step in understanding of reaction dynamics and in the search for a signal from the weak resonances states

New resonance Eta'n W=2 GeV?

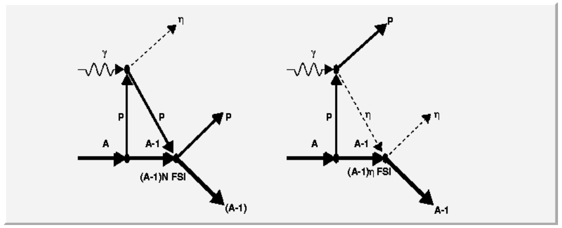
The new precision data from pion induced production are extrimly needed

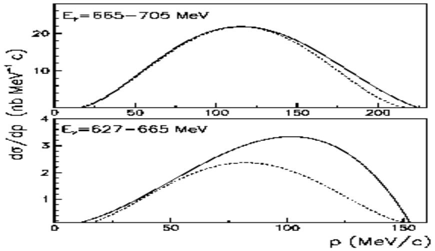
η' – mesons problem (similar to η -meson)

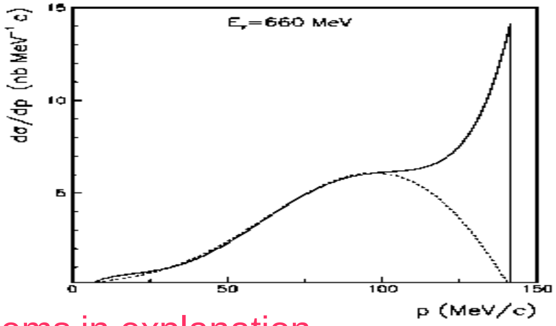
Now the most sophisticate anlysis of experimental data is performed by Gatchina group(PNPI-BONN)

Deuteron problems – we still need the experimental data with hing beam energy resolution for direct measurements of effets of η-meson rescattering and FSL

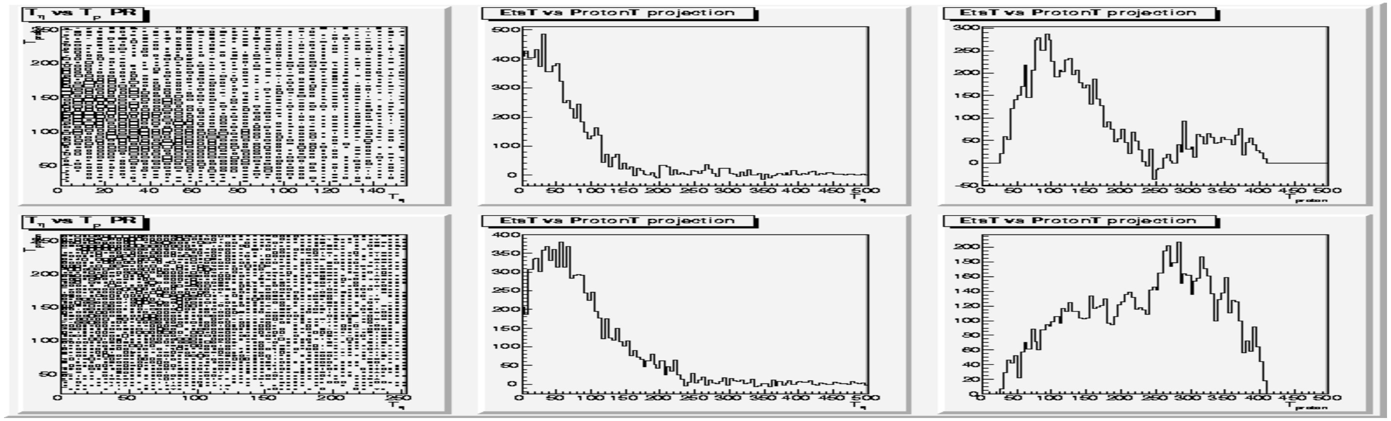
The high beam energy resolution permits to see the sharp changes in shapes of energy spectra predicted by calculations







Experimental data – more accurate data - more problems in explanation



Sammury:

Good beam energy resolution is extreemly needed

A2 data confirm the feature of eta production from deutron butnew data with beam energy resolution 1 MeV are needed.

Majority of results came from deutron target

Necessary and suffisient condition for using bound neutron fro deutron as a free neutron

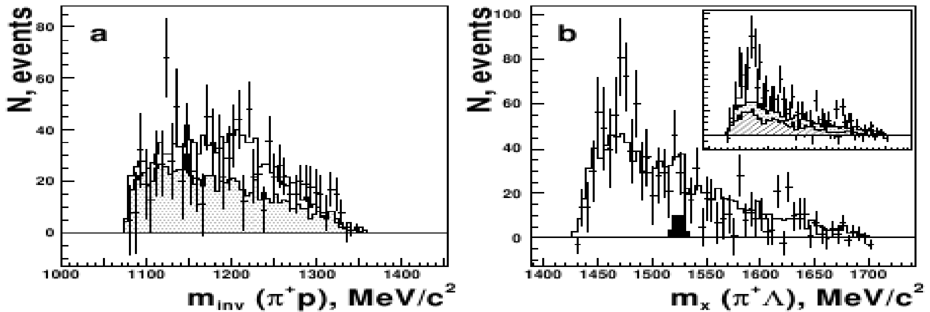
Hight precision data – more complicatd theoretical analysis

Sibirtsev PRC 65 044047

Recent results from reaction with strangeness

Investigation of the reaction pp → pK 0π +Λ in search of the pentaquark(COSY)

The reaction pp → pK 0 π + Λ has been studied with the ANKE spectrometer at COSY-J¨ lich at a beam momentum of 3.65 GeV/c in order to search for a possible signal of the pentaquark Θ+ (1540), decaying into the pK 0 system. By detecting four charged particles in the final state (π + , π − and two protons), the K 0 and the Λ have been reconstructed to tag strangeness production. It has been found that the π + Λ missing-mass spectrum displays no significant signal expected from the Θ+ (1540) excitation. The total cross section for the reaction pp → pK 0 π + Λ has been deduced, as well as an upper limit for the Θ+ production cross section. The intermediate Δ++ K 0 Λ state seems to provide a significant contribution to the reaction.



a) Invariant mass of π + p system. The dotted area is obtained from the simulations assuming phase space without intermediate resonances, and the solid lineis the sum of all the contributions. b) Missing mass spectrum of π + Λ system. The solid line denotes the sum of all the contributions. The inset shows individual contributions from non-resonant production (dotted) and from intermediate Δ++ (1232) (hatched).The black region corresponds to the maximum permissible Θ+ (1540)

Search for the Θ+ pentaquark in the γd → ΛnK + reaction measured with CLAS

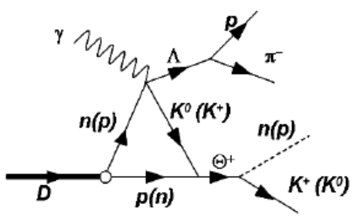
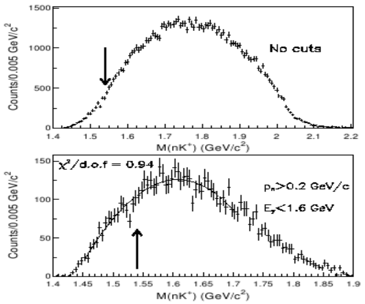


FIG. 1: A possible reaction mechanism for the photoproduction of ΛΘ+ on the deuteron.



Raw distributions of the invariant mass of the nK + system after channel selection. Top plot: no kinematical cutsare applied. Bottom plot: the Eγ < 1.6 GeV and pn >0.2 GeV/c kinematical cuts are applied. No statistically significant structure is visible in the mass rangearound 1.54 GeV/c2 , indicated by the arrows.

Recent results from reaction with strangeness

Measurement of K+ Λ photoproduction with fine center-of-mass energy resolution at MAMI-C

A precision measurement of the cross section for γ(p, K +)Λ has been obtained using the real photon tagging facility at MAMI-C and the Crystal Ball calorimeter. The measurement is made possible by a new K + decay tagging technique in which the weak decay products are characterised in the calorimeter. The γ(p, K +)Λ reaction is one of the most promising reactions to improve our knowledge of the excitation spectrum of the nucleon. The new data at backward Kaon angles provides evidence for the existence of the disputed P11 (1710) resonance and indicates its lifetime is longer than indicated in recent studies. No current partial wave analysis can accurately reproduce the narrow features in the cross section in the region of the speculative N∗ (1685).

The process γp → K + Λ has the lowest energy threshold for photoproduction reactions with final state particles containing strange valence quarks. This is a crucial channel as many models predict poorly established or “missing” resonances couple strongly to strange decay channels [12]. Isospin conservation implies that only N∗ and not Δ resonances contribute to the reaction, simplifying the interpretation of the data. The weak decay of the Λ allows access to its polarisation from the distribution of its decay particles and ensures that γp → K + Λ will be the first photoproduction reaction measured with a complete set of experimental observables, providing a benchmark channel for PWA studies.

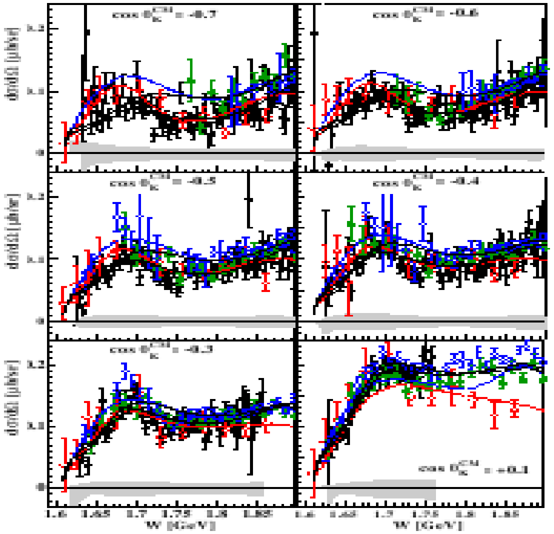
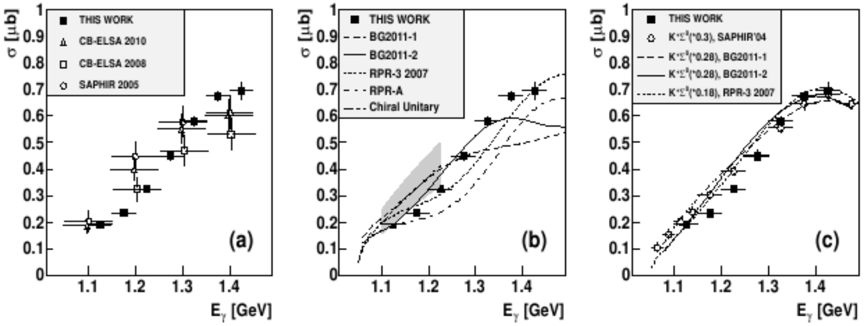


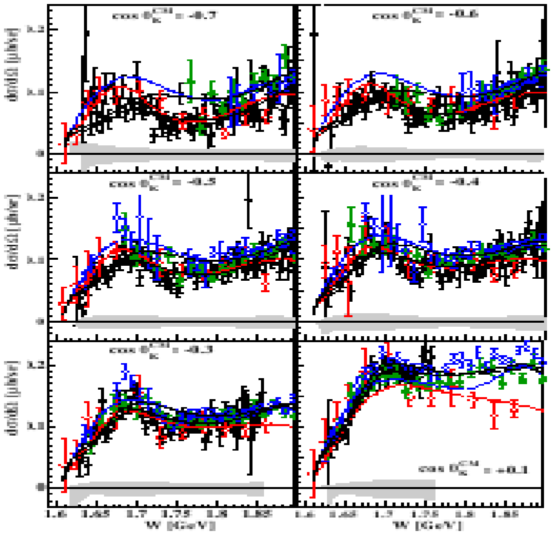
FIG. 5: (Color online) Differential γp → K + Λ cross sections versus W . Black filled circles is the current data with systematic errors plotted grey on the abscissa. Red open circles is SAPHIR et al. [13], green filled circles and blue open diamonds are CLAS data of McCracken et al. [16] and Bradford et al. [15] respectively. Dashed red lines show the fits from the KM PWA to SAPHIR data and blue dashed shows constrained KM fit based on JLAB data only [28]). Black dashed line is the current Bn-Ga solution [30] and Bn-Ga fit including new data is thick black line [31]. (The SAPHIR data has angle bins centered at $\cos\theta_K^{CM}$ backwards by 0.05 than the bins on the figure)

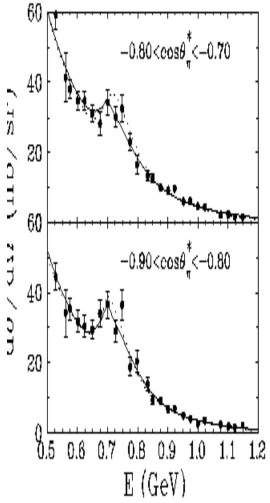
Measurement of the γp → K 0 Σ+ reaction with the Crystal Ball/TAPS detectors at the Mainz Microtro



Really the same problem -- cusp or resonance?

R(1680) — magic W?





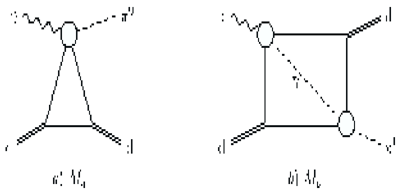


Fig. 1. Feynman diagrams for the $\gamma d \to \pi^0 d$ reaction considered in [24]: (a) single-scattering amplitude M_a; (b) double-scattering amplitude M_b. It was shown in [24] that (b) dominates over (a) at backward angles for $E_\gamma \sim 700$ MeV.

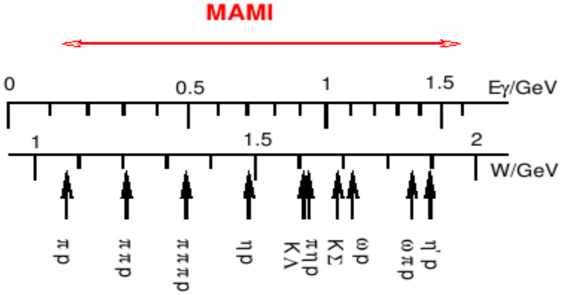
Example of intermadiare state with eta-meson

The nature of bump at 1680 MeV

1. Resonance 1680 Mew.
   The 'formation' type of experiment and the hidden strangness(like eta-meson) as atidecuplet member maifested.
2. Cusp effect due to Ksigma
3. ewta in intermadiate state

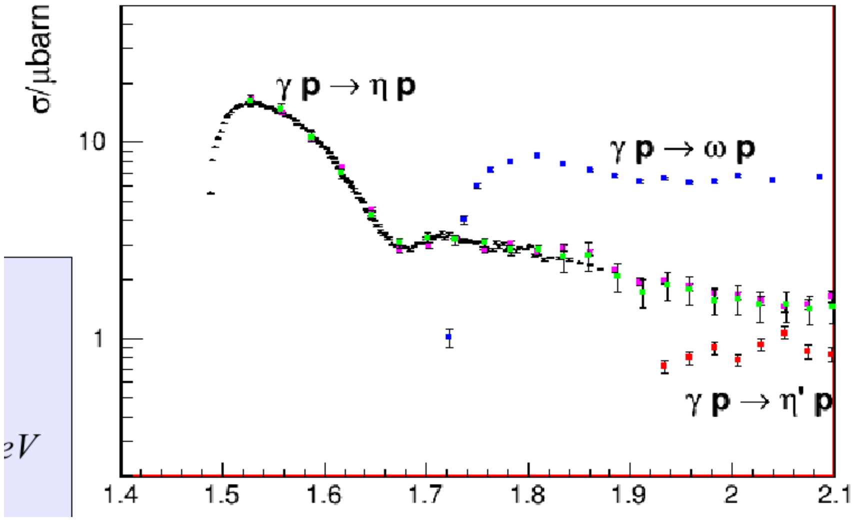
SAMMURY:
Another channel and magic W= 1680. What is a nature?

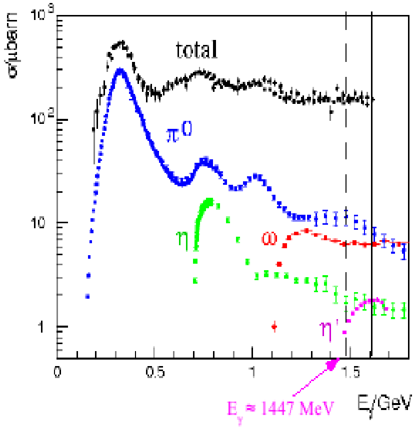
Quantum interference of particles and resonances



The study of sharp peaks must be understanded from theoretical and experimentals points of views.

Theory:
  Cusps effect (region of analyticl continuation, multy-channel cusps)
Experiment:
  Cusp in pi-p elastic — only one isolated inelastic channel -eta
  Amplitude is reconstructed w/o R and A observables





Tagger energy range: 4.7 to 93% of E_0

Maximum energy tagged
for E_0=1604 MeV is 1491 MeV

But:
- η' is an interesting field
- Studies of η' decays at high rates possible with the CB

Cusp in pi p elastic scattering due to eta-prodaction threshold

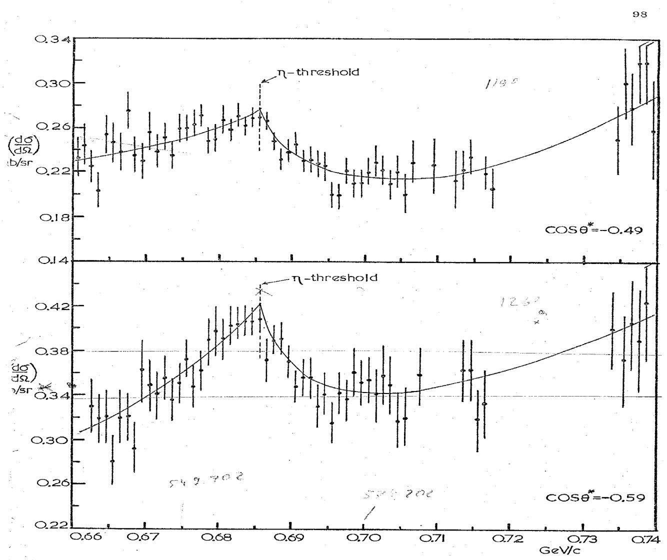


FIG. 7.1(a) π^-p elastic scattering differential cross-sections near η-production threshold.

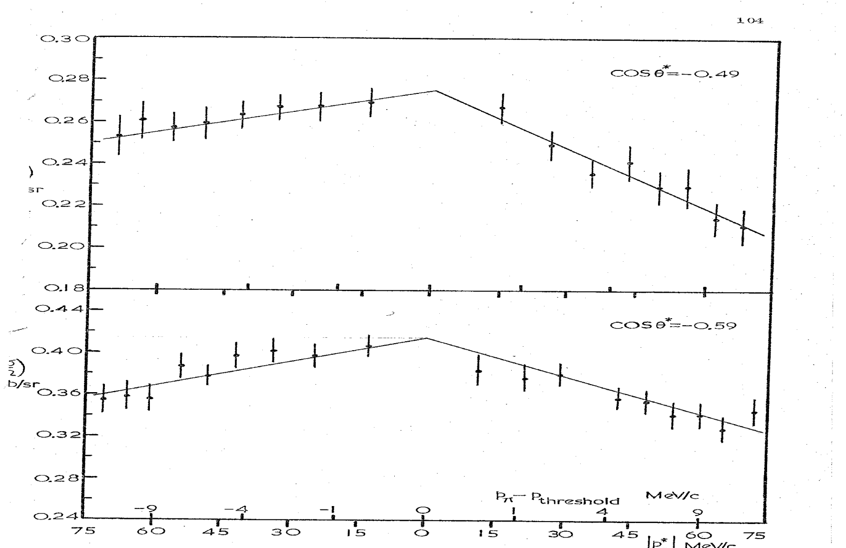


FIG. 7.2(a) Cusp in π^-p elastic scattering across the threshold for η-production.

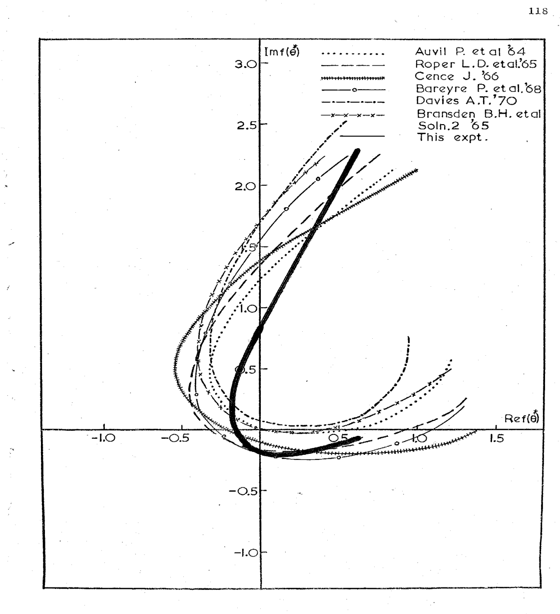


FIG. 7.6 Comparision of non-spin flip amplitude for π^-p elastic scattering at η-threshold from this experiment with different phase shift solutions.

D.Binnie et. al. Nucl.Phys.B161(1979) 1-13

Advantages:

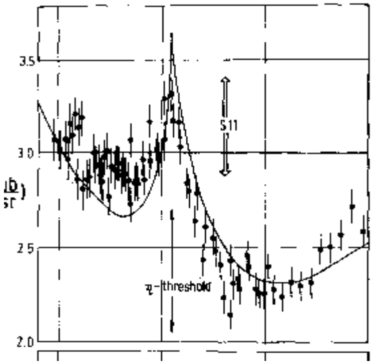
No other thresholds

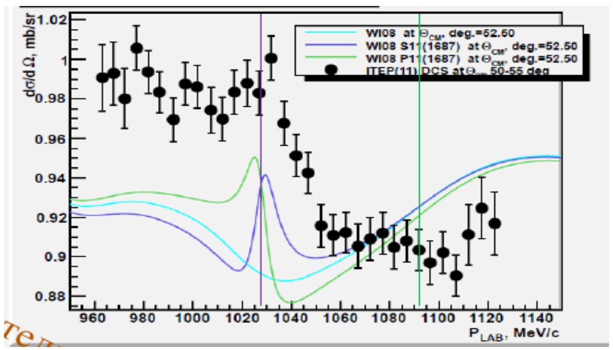
Neutral finalstate

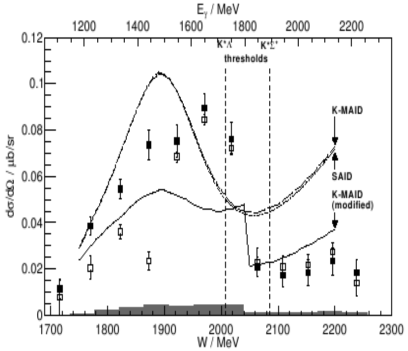
Cusp in charge-exchange and comparison of two channels

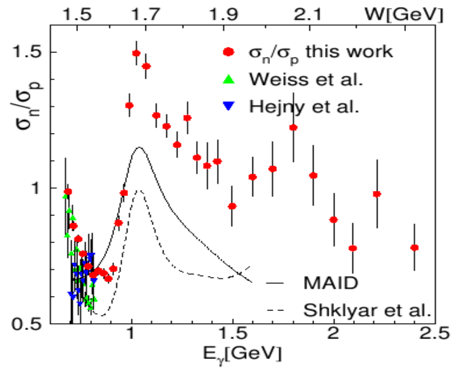
Examples of «cusp» effects

EISA – cusp from Eta EPECUR BONN-cusp?









$\pi^-p\to K^0\Sigma^0$ – 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

Total cross section for K 0 Σ+ photoproduction as a function of the centre-of-mass energy from the present experiment (full \\\\\\ squares) in comparison to the previous CrystalBarrel (open squares) [21] and SAPHIR (triangles) [22] data. The vertical lines indicate the K ∗ Λ and K ∗ Σ+ thresholds at W = 2007.4 and 2085.5 MeV, respectively. The

BONN. Comparison of quasi-free proton and neutron excitation function.

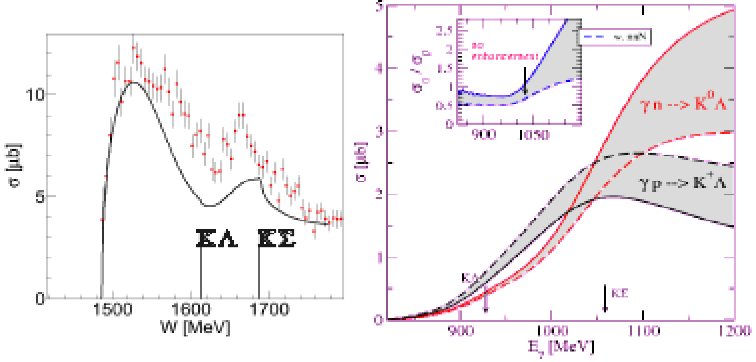
Different thresholds and particle charges

$$\gamma n(p) \to K^\circ\Lambda^\circ(p) \to \pi^\circ\pi^\circ\pi^\circ n(p)$$

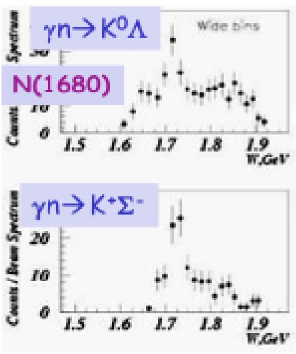
The «cusp» effect is clearly seen :
Rutherford Lab pi- p at eta-production threshold
clean cusp no other channels
EPECUR — pi- p at R(1680)
ELSA gp->pi p at eta-production threshold
MAMI gp->eta p at R(1680) production threshold

«Cusp» should be in S-state but gp->etap A1
Other A0
EPECUR -cusp or R(1680)?

coupled mode channel explains the neutron anomaly

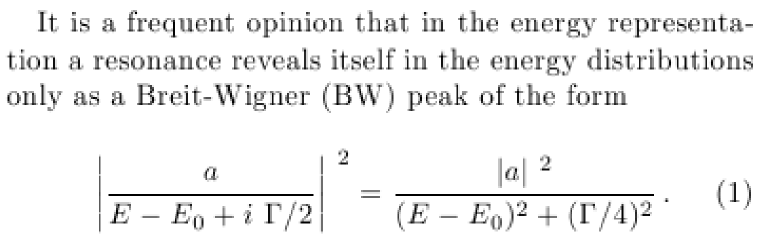


GRAAL results



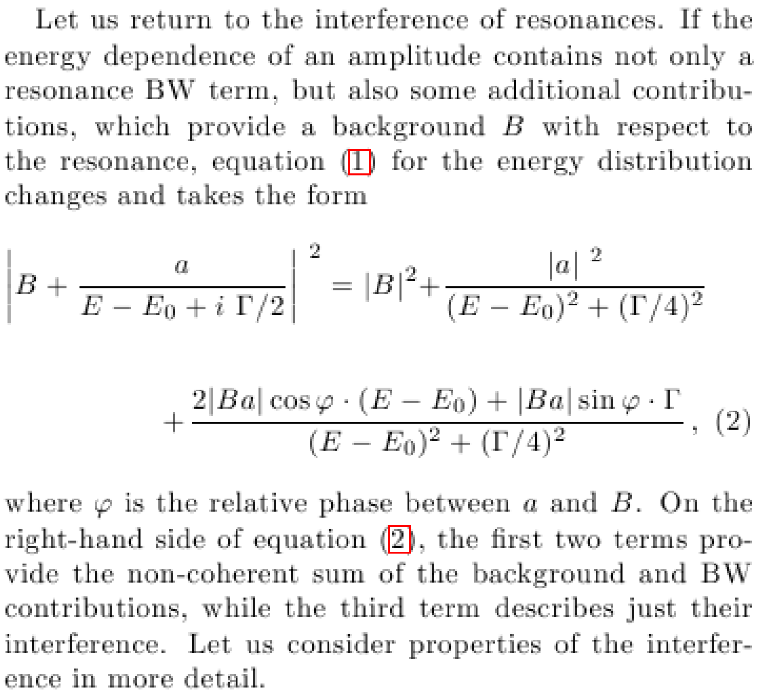
Quantum interference of particles and resonances
Azimov 2010

arXiv:hep-ph/0904.1376



It is a frequent opinion that in the energy representation a resonance reveals itself in the energy distributions only as a Breit-Wigner (BW) peak of the form

$$\left|\frac{a}{E-E_0+i\,\Gamma/2}\right|^2=\frac{|a|^2}{(E-E_0)^2+(\Gamma/4)^2}\,. \qquad (1)$$

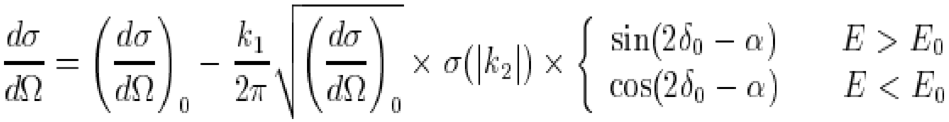


Let us return to the interference of resonances. If the energy dependence of an amplitude contains not only a resonance BW term, but also some additional contributions, which provide a background B with respect to the resonance, equation (1) for the energy distribution changes and takes the form

$$\left|B+\frac{a}{E-E_0+i\,\Gamma/2}\right|^2=|B|^2+\frac{|a|^2}{(E-E_0)^2+(\Gamma/4)^2}$$

$$+\frac{2|Ba|\cos\varphi\cdot(E-E_0)+|Ba|\sin\varphi\cdot\Gamma}{(E-E_0)^2+(\Gamma/4)^2}\,, \qquad (2)$$

where φ is the relative phase between a and B. On the right-hand side of equation (2), the first two terms provide the non-coherent sum of the background and BW contributions, while the third term describes just their interference. Let us consider properties of the interference in more detail.

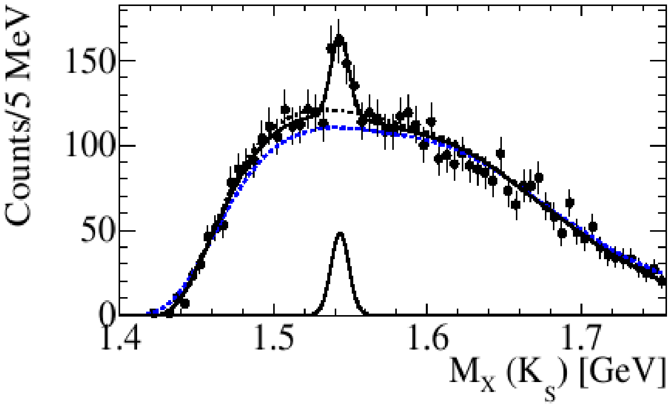


$$\frac{d\sigma}{d\Omega}=\left(\frac{d\sigma}{d\Omega}\right)_0-\frac{k_1}{2\pi}\sqrt{\left(\frac{d\sigma}{d\Omega}\right)_0}\times\sigma(|k_2|)\times\begin{cases}\sin(2\delta_0-\alpha) & E>E_0\\ \cos(2\delta_0-\alpha) & E<E_0\end{cases}$$

The new analysis of reaction γp → KS KL p [6] used the same data set as the earlier analysis [8] and was, to some extent, similar to it. In both analyses one kaon was

INTERFERENCE OF RESONANCES AND OBSERVATION OF THE Θ+ -PENTAQUARK
Azimov 2012

But even now one can rephrase Mark Twain’s letter to say: “The report of Θ+ ’s death was an exaggeration”.



InterfOfResPentaquark.pdf arXiv hep-ph 1210.7316 2012

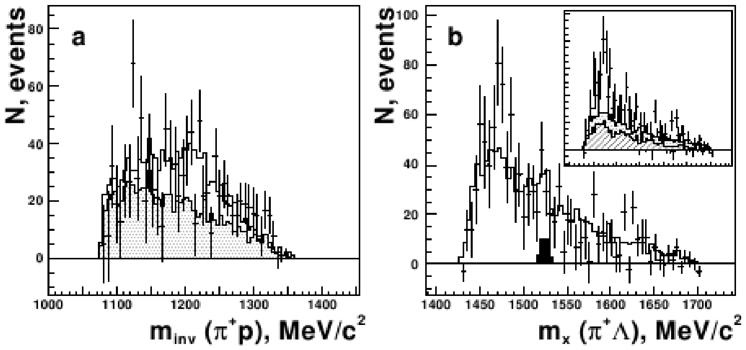
CLAS

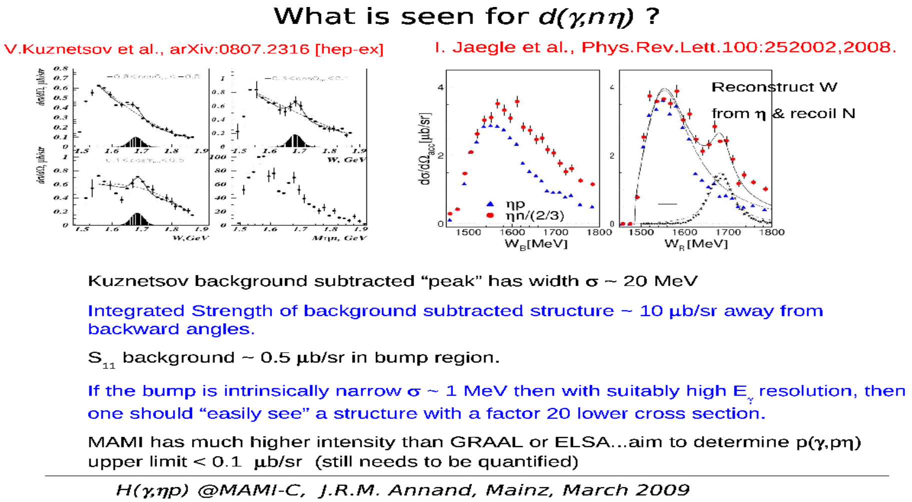
Sammury:

Interference in pi-p is clearly seen
Interference resonance-background should be tested
Multy-cnannef effects?

Experimental problems

How to improve ratio effect/backgrounnd?





What is seen for *d(γ,nη)* ?

V.Kuznetsov et al., arXiv:0807.2316 [hep-ex] I. Jaegle et al., Phys.Rev.Lett.100:252002,2008.

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

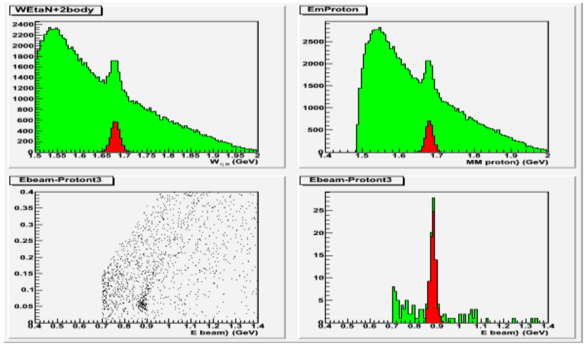
If the bump is intrinsically narrow σ ~ 1 MeV then with suitably high E_γ resolution, then one should “easily see” a structure with a factor 20 lower cross section.

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

TIPICAL RESULTS : cosy PP(left) AND Kuznetcov(right)

Experimental problem:
increase statistics
better ratio signal/background
better mass resolution — mainly determined by eta mass(50 Mev)



Pion beam -much better ratio signal/background

1+2->3+4   2 DOF
1+2->3+4+5 5 DOF

Pentaquark came from «production' experiment
Majority of exp. data(etaN) from «formation' experiments

Expected ratio signal/background
for TC technigue

Problem: experimental progress(beam energy rsolution and statistics display a much more complicated picture - a lot of sharp bumps in energy and angle dependencieses. The reason is a consecvences of better resolution (like cusp or spetial reaction mechanizm(eta in intermadiate state, FSI) or new narrow missing resonances. So we have got two problem — to obtaine a new peaks abd find reason of suth peaks
«»FORMATION» experiment — much more complicated picture in comparison with «PRODUCTION» experiment ??

Experimental methods of resonances study

A + B -> R -> C + D formation experiments (EPECUR) -extation function

Main features: reaction identification, good beam energy resolution
for measurment of resonances width good ratio signal/background

A + B -> R + D production experiments (PENTAQUARK) – MM IM

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**

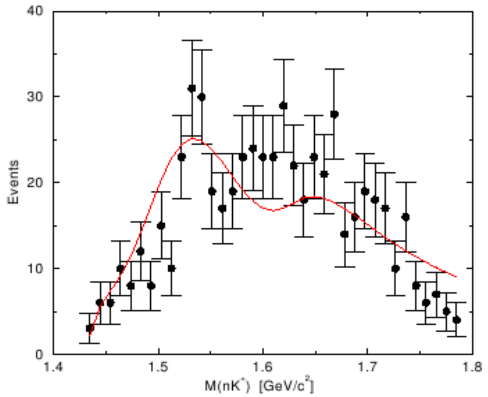
The stright way is to obtaine Dalitz plot in production experiment but usually the final state
particles are measured only partly. The Dalitz plot reflect a lot of reaction mehanizm as
FSI, rescattering so it is very easy to get kinematic bump due to not full solid angle or
misidentification final state particles(example – DIANA experiment)

The Evidence for a Pentaquark Signal and Kinematic Reflections arXiv 2003

Several recent experiments have reported evidence for a
narrow baryon resonance with positi
S
strangeness (Θ+) at a mass of 1.54 GeV/c2 . Baryons with
+1 cannot be conventional qqq
states
and the reports have thus generated much theoretical
speculation about the nature of possible S =
+1 baryons, including a 5-quark, or pentaquark,
interpretation.

We show that narrow enhancements
in the K + n effective mass spectrum can be generated as
kinematic reflections resulting from the
decay of mesons, such as the f2 (1275), the a2 (1320)
and the ρ3 (1690).

/Desktop/SeminarHEPD/SemHEPD27



Sammury and outlook

1. The existance of pentaquarks and nature of "neutron anomaly" is a challenging task of medium energy physics both from theoretical and experimental point of view. The one of theoretical pictures is the hadron is a mixture of three and five quarks components and it is a way to describe thr resonances spectrum. Up to now threr is not real confirmation on existance of pentaquarks and spetial experiments devoted to looking for pentaquarks

2. The numerous indicatio ns on existance of R1680 is still need confirmation . The width of R1680 is resolution dominated. The are indication on existance Eta' n resonance W(2070) or .pronounced structure is observed between K* L and K* Sigma thresholds

3. LMP – cusp problem elsstic and charge-exchange reaction. Now the program «Meson» for simulation of pion channel was modified for channel resolution study. Goal – to modify channel to rach r esolution ~ 1 MeV

4. R1540 – possible systematic? Negative and positive results out of statistics. No devoted experiments.

5. "The report of Θ+'s death was an exaggeration" (Azimov – Mark Twain)

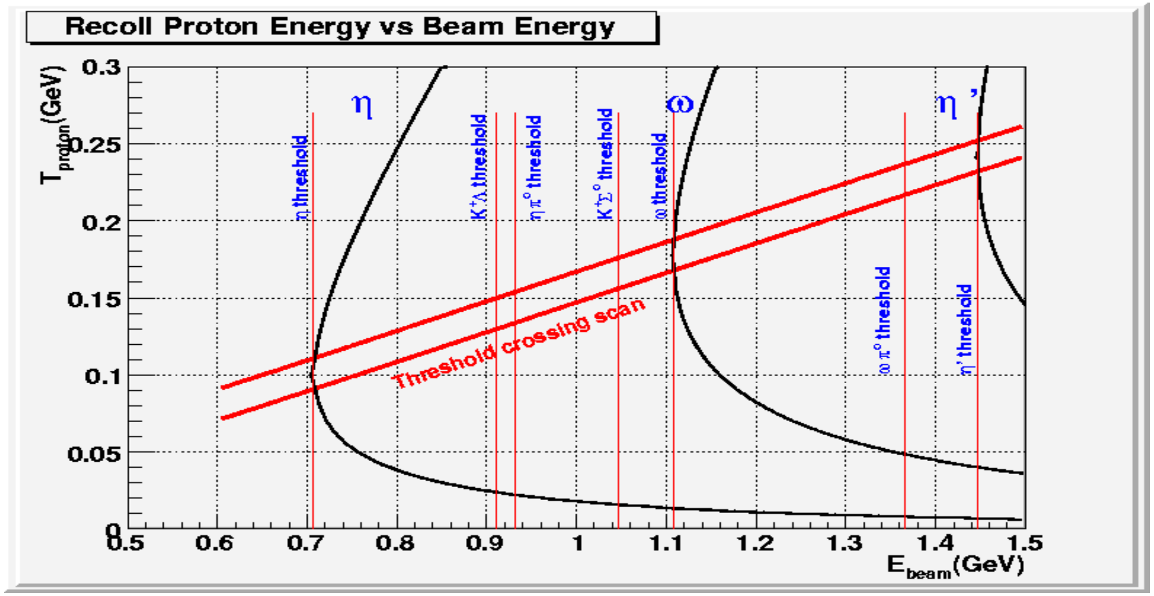
6. The main problem – is the observed narrow bumps really belong to antidecupret members(pentaquarks) or it is another nature of such narrow bums

7. The recent servays(2013) stress the lack of new high precision data from pion beams

.

Threshold — crossing technique

Threshold-crossing technique(TC) is other way of resonances study
Quazi TC method - -- limitedet number of kinematics vars



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

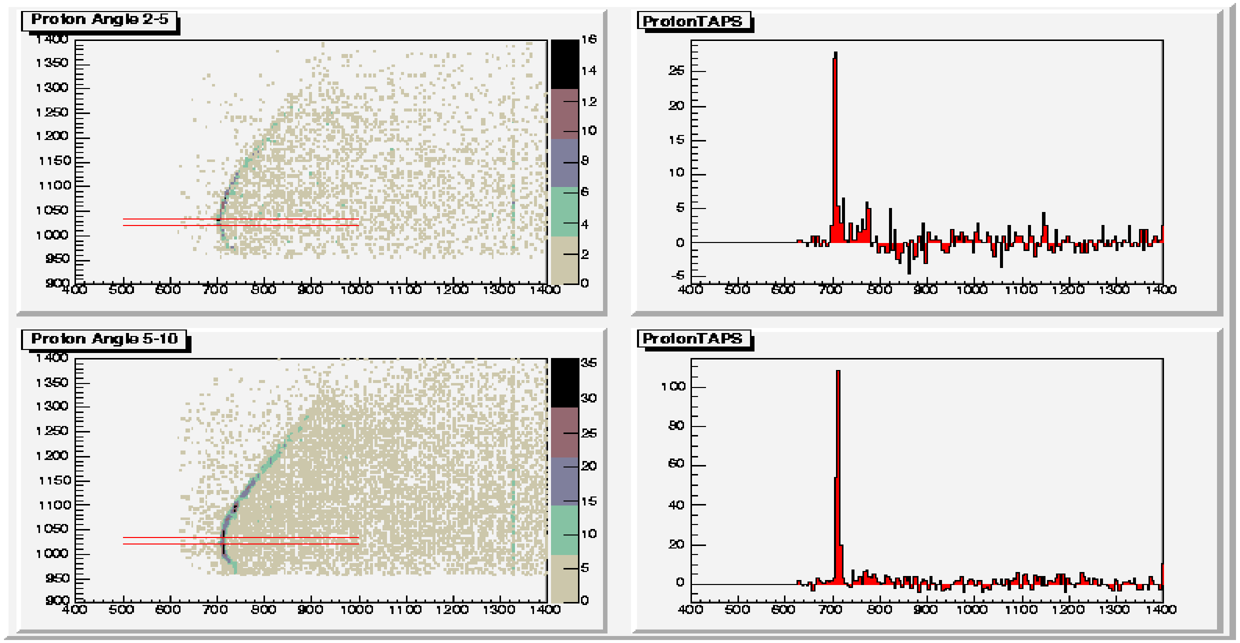
1.1 GeV — energy of R and ω- meson production threshold
Influence of ω and ρ — mesons productions.

Threshold — crossing technique

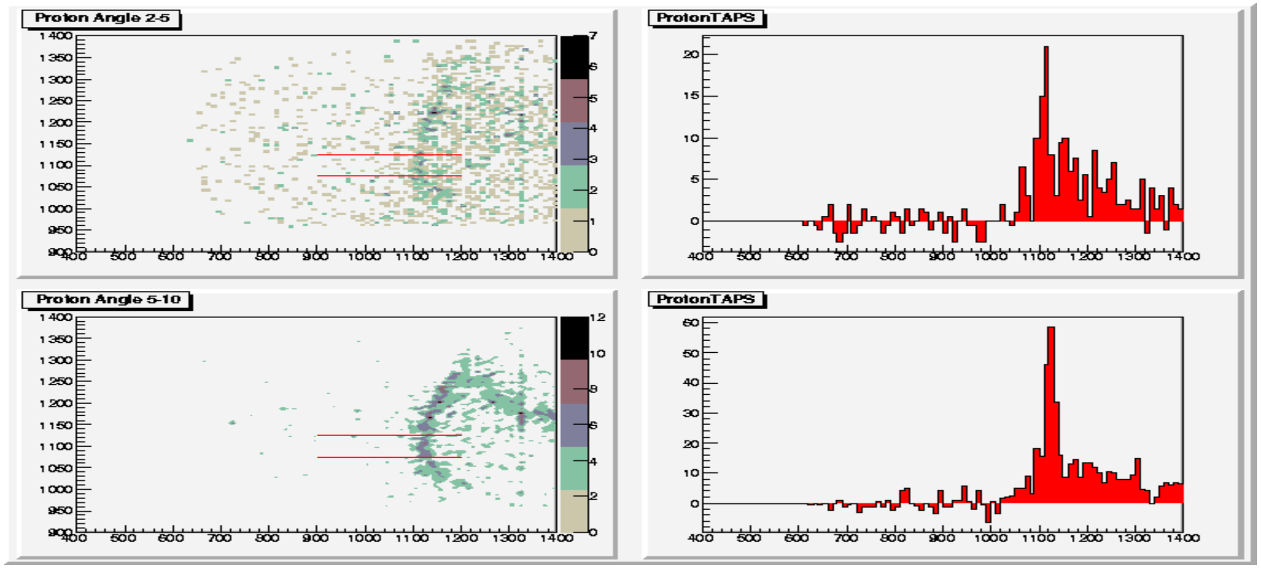
Experimental confirmation from η-meson photoproduction

The TC technique for reaction **$\gamma P \rightarrow \eta P$ and $\gamma P \rightarrow \omega P$**

Test of TC technique for measurements of resonances width



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

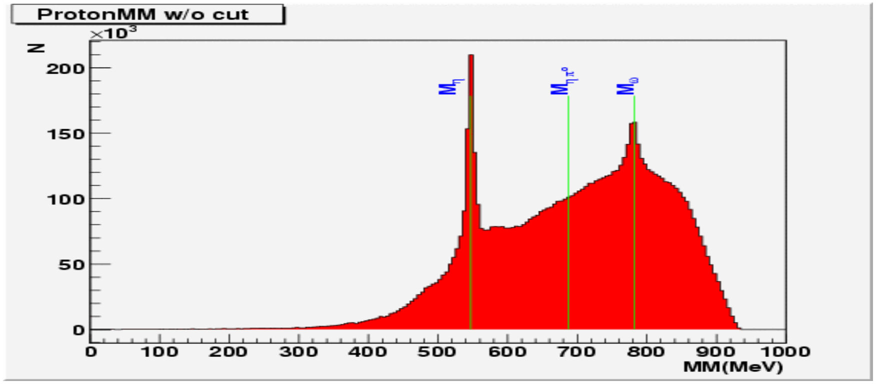


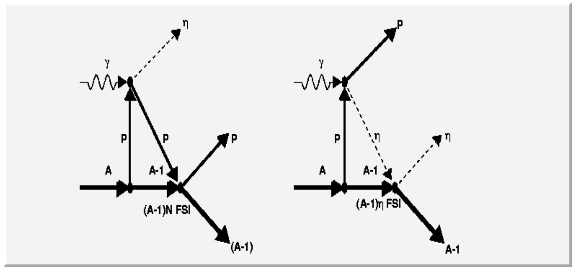
The experimental test ofTC technique confirmed the prospects of its using for study of narrow resonances. The accuracy of method depends on beam energy resolution.

Accuracy: width — 4 MeV
cross-section 5% from eta

Problem of deutron as neutron target

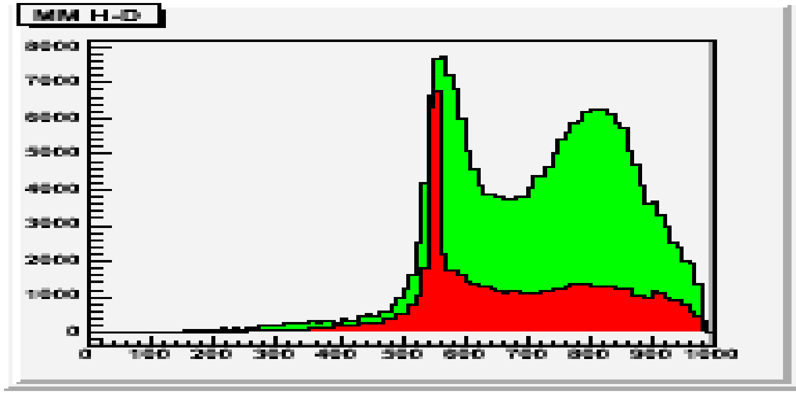
Deuteron target strong differences — not only Fermi, final results on cross-section strongly depends on applied cuts
IM and MM spectra fron H and D
TC for H and D



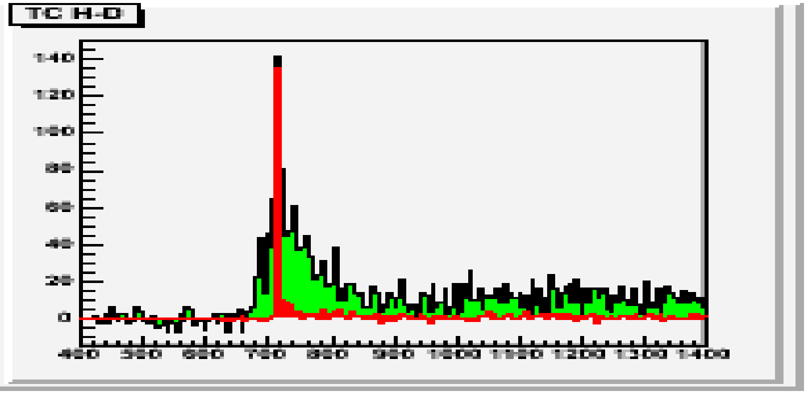


Main digrams for η - production

Problems: Fermi defolding, rescattering and FSI, effects out of shell
Cuts should reject FSIi
Strong influence of reaction mechanizm in deutron. TC removes rescattering and effect of Fermi motion is clear seen



Comparison of MM spectra for
H(red) and D(Green) target



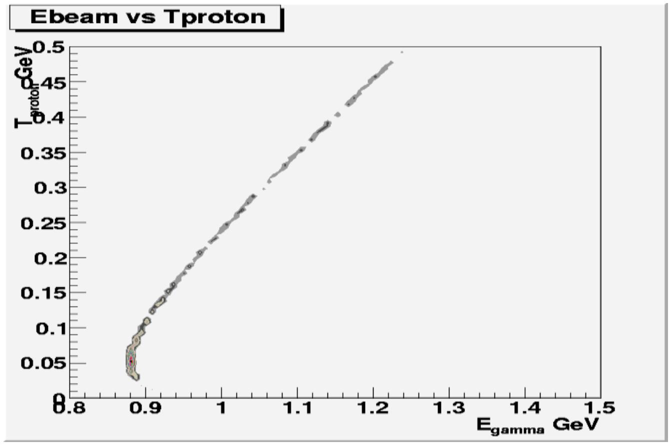
Comparison of TCspectra for
H(red) and D(Green) targets

TC permits to use main advantage of exp set — good beam energy resolution

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

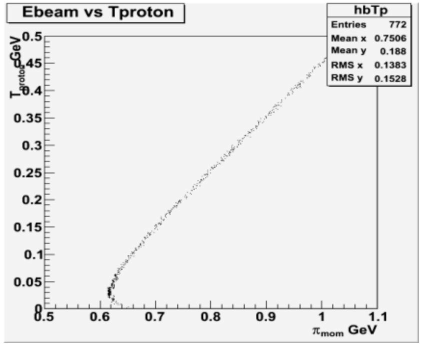
Threshold 0.88 GeV, nearest threshold 0.92 GeV — weak cusp influence

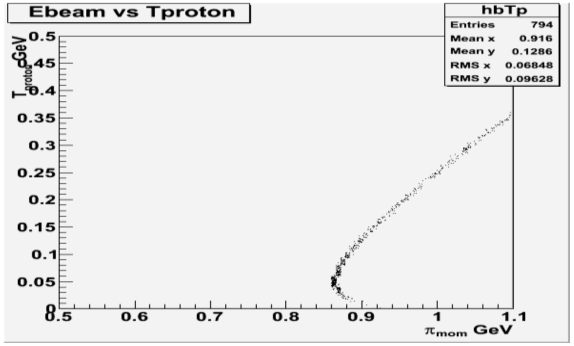
The TC method may be applied for pentaquark search for on D-target.
The experimental set must be added by proton detectors.

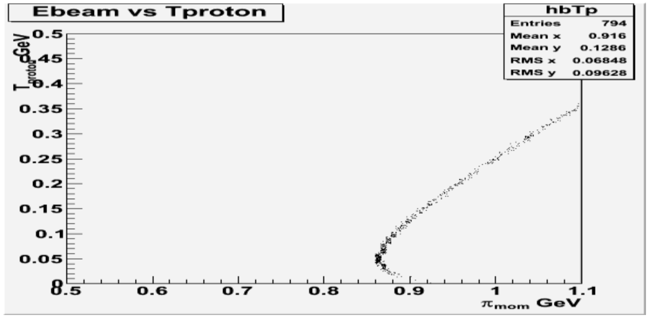
Simulation of R production on pion nd gamma beams
R(1680) and R(1500) and Comp R-> eta+N for different energy ranges
Problem:
eta- production TC background accurasity 5% (Tagger problems)
omega production – 5% to eta production
Expected R production - 0.1 to omega productio
It is easy to simulate know process but problem with unknown physical and experimental background(tagger problem for example)

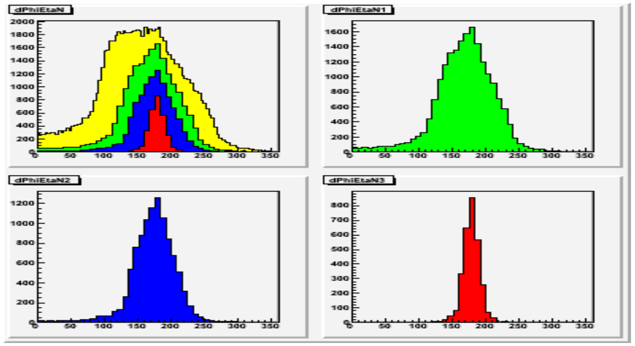
So we need to choose cuts for good ststistics and good ratio effect/background

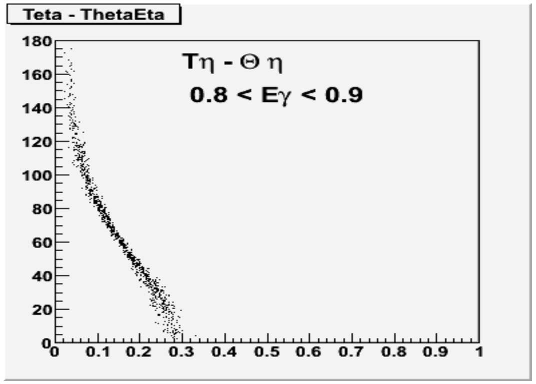
Kinematcs of R(1500) and R(1700) production on gamma and pion beam







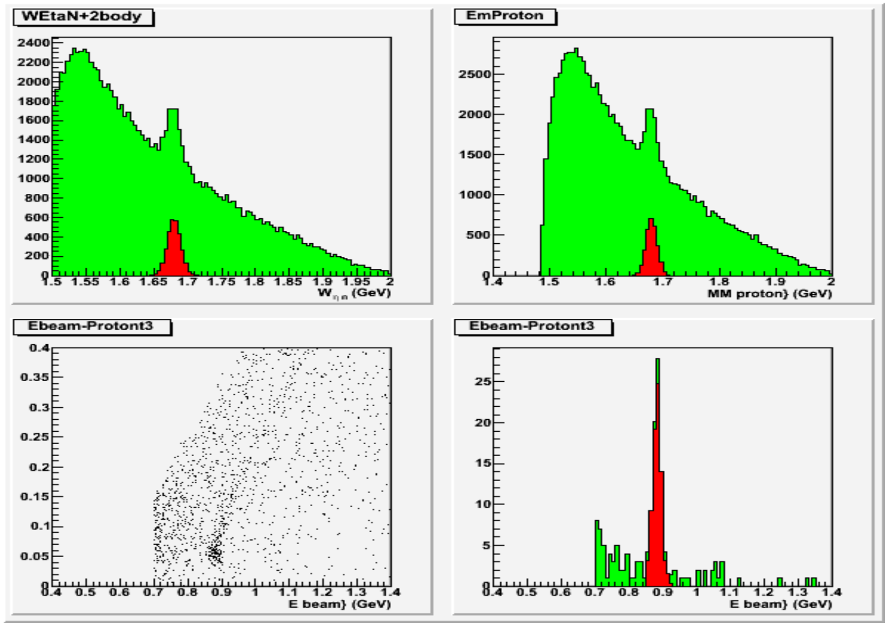


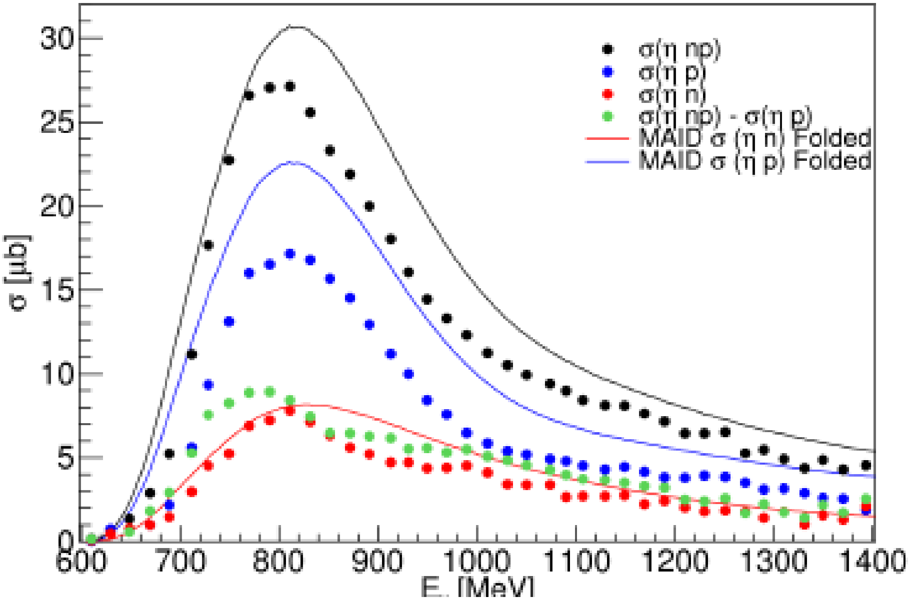


Problem-to choose cuts for the best effect/backgrou ratio

Main info for counting rate of reaction γD → RP

Couting rate is based on Kuznetsov result — resonance + 3 body final stae





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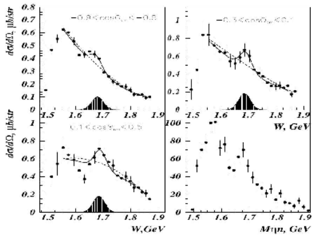
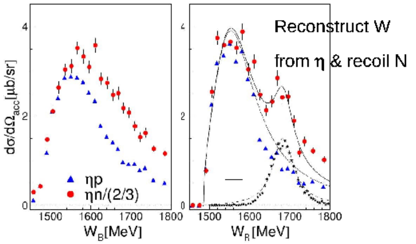




Reconstruct W

from η & recoil N

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

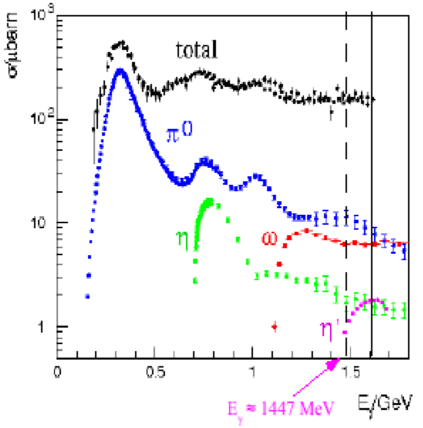
Integrated Strength of background subtracted structure ~ 10 μb/sr away from backward angles.

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

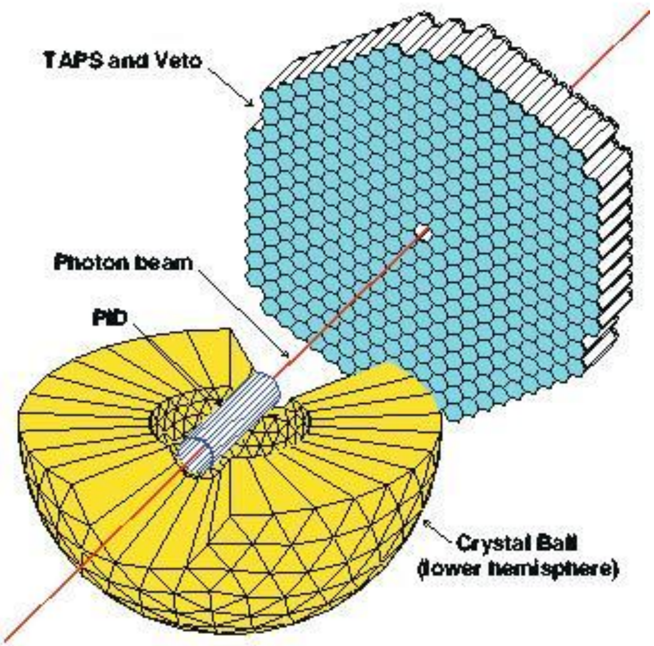


Tagger energy range: 4.7 to 93% of E_0

Maximum energy tagged
for E_0=1604 MeV is 1491 MeV

But:
- η' is an interesting field
- Studies of η' decays at high rates possible with the CB

Events reconstruction



Common cuts

3 clusters in CB and 1 cluster in TAPS

η or π in CB ω

coplanarity

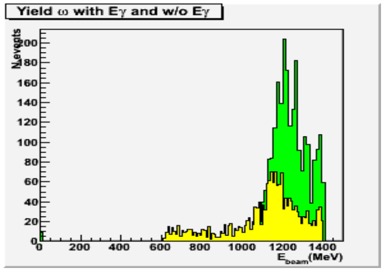
η or π in CB and third cluster in CB

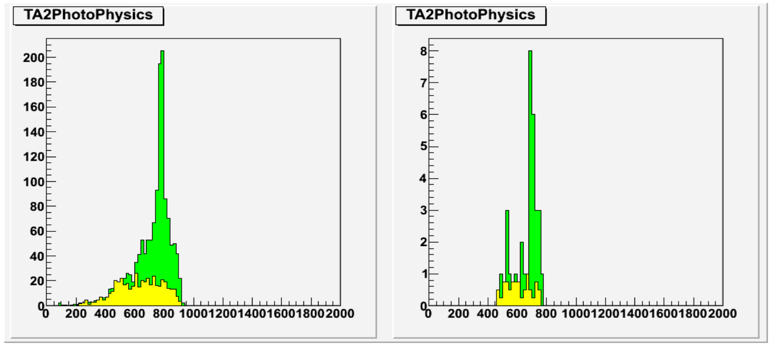
3 clusters in CB and cluster in TAPS

PID 1(charged) or 0(neutral)

Veto 1(charged) 0(neutral)

Reaction ID	(Veto PID)
γP → w(πγ)P	10
γD → R(ηN)P	10
γD → R(ηP)N	01





Test of reconstruction algorithm of omega yield

Left:

green — with Egamma

yellow — w/o Egamma

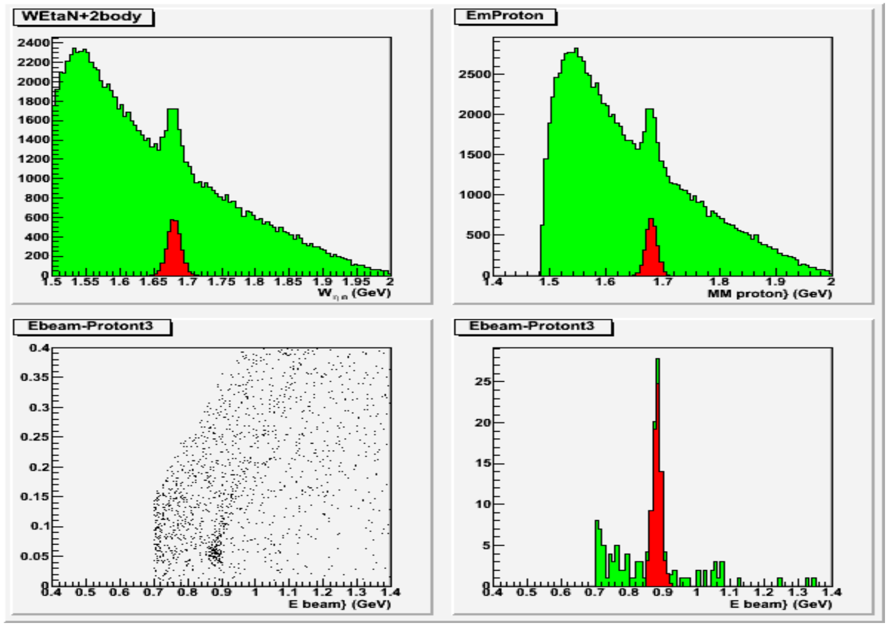
Rihgt:

left – with Egamma

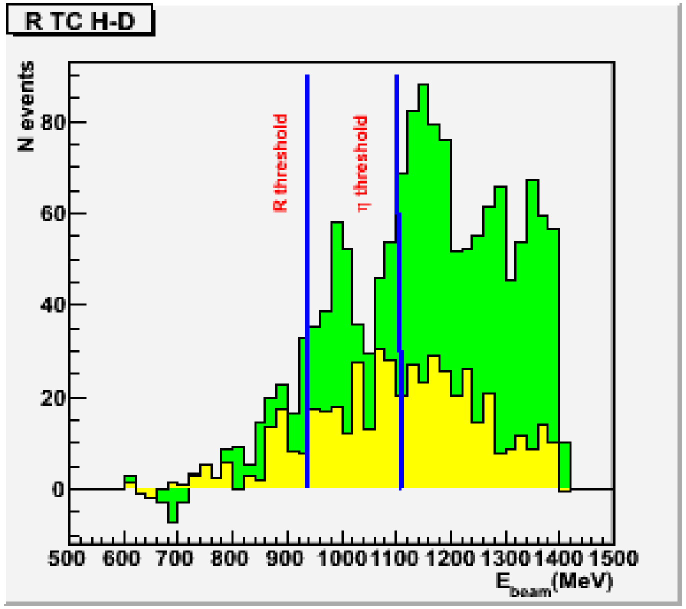
right – w/o Egamma

Reaction γP → w(πγ)P was used for algorithm test

TC for R(1680) production



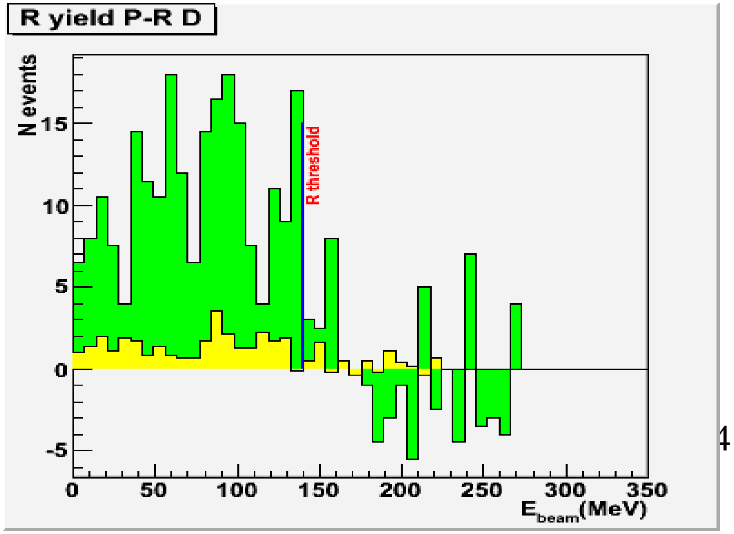
Simulation of R(1680)



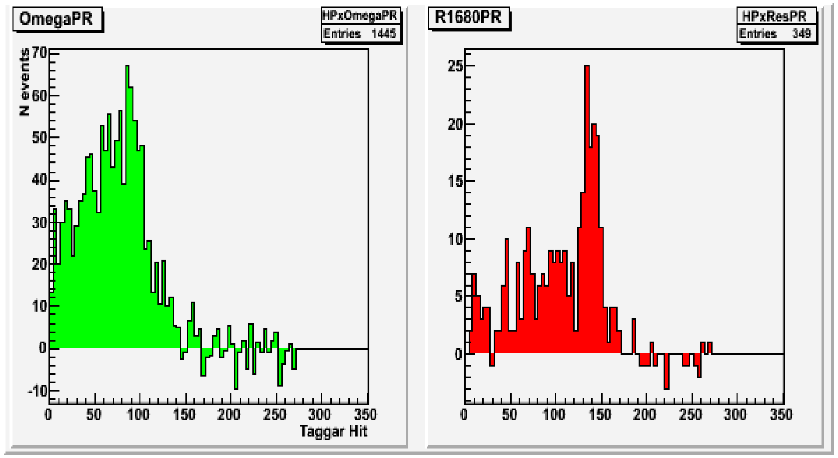
Experimental data for deutron(green) and hydrogen targets

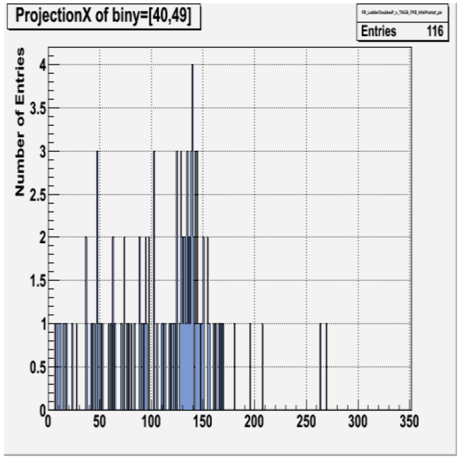
The width

of R peaks mainly is resolution dominated

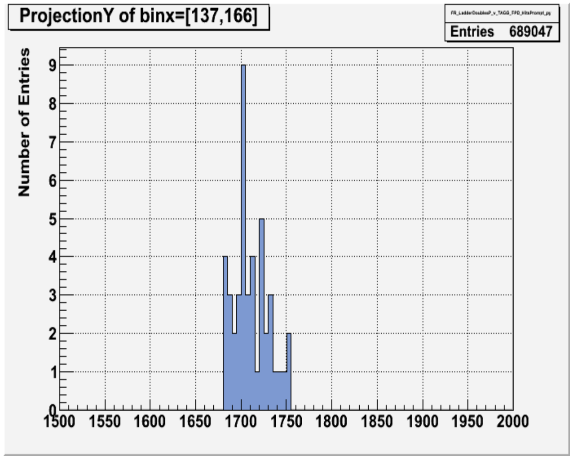


Reconstruction of γD→R(ηN)P





TC cut The width is dominated by R width



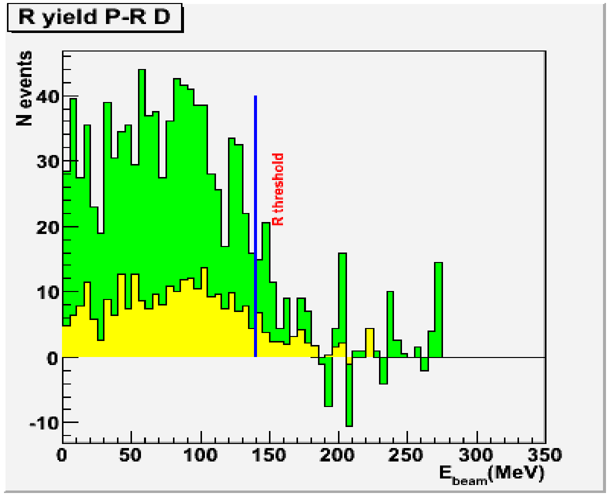
R width is 20 MeV

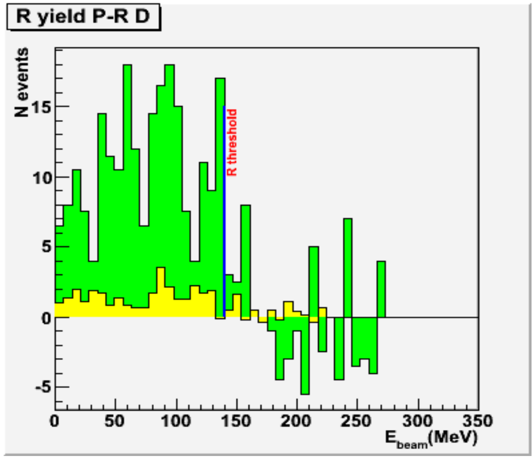
Reconstruction of γD→R(ηP)N

Ratio(branching) R -> n/p = 4

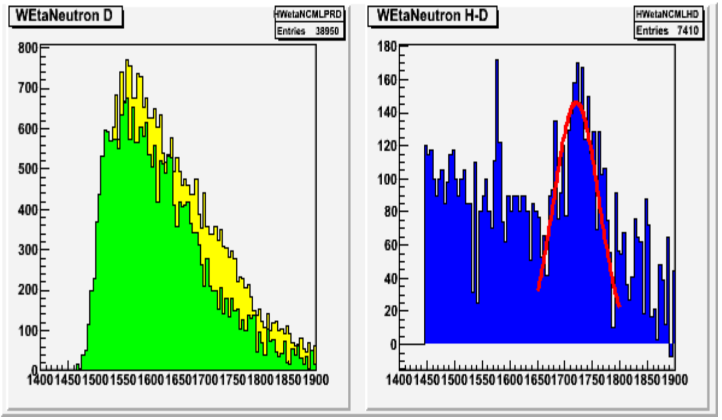
The difference of R(1680) yields from hydrogen and deutron targets

Really it is a cheking of reconstruction algorithm,
we expect kinematics fitting
from Kulbardis





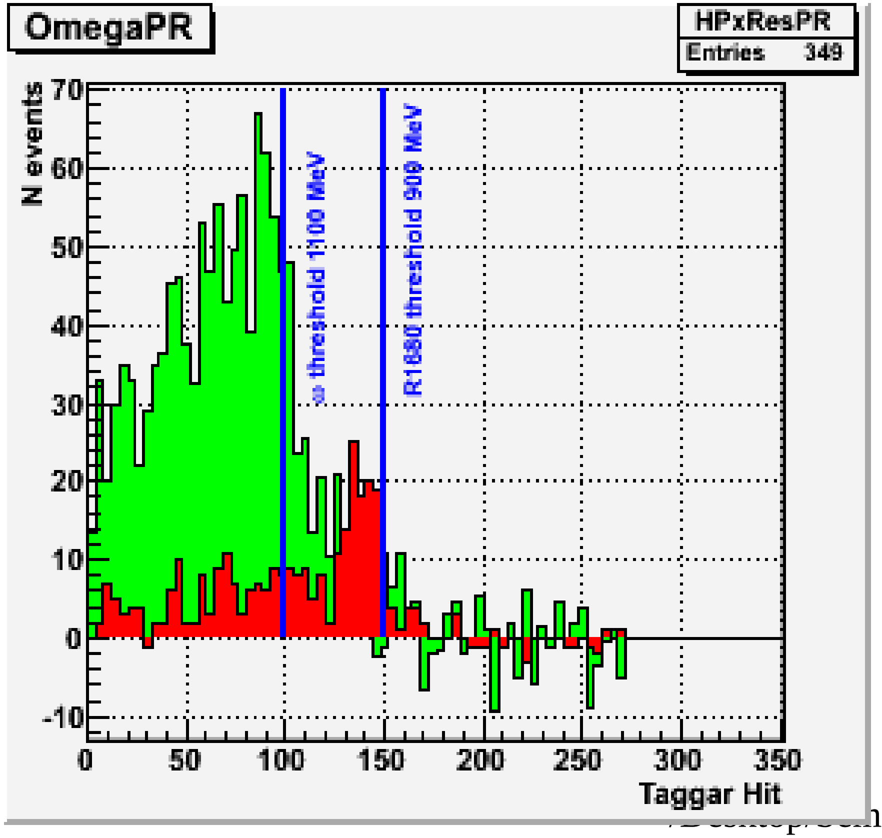
PD27

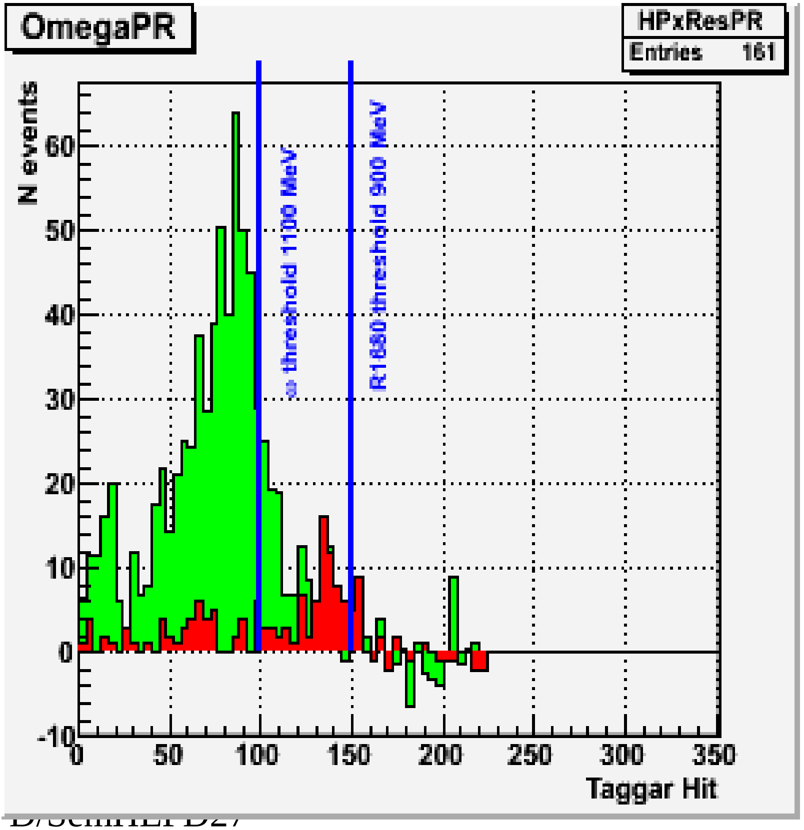


Comparison of counting rate s of reaction γD → RP and γP → ωP

γP → ωP CSω 10 μ Ϭ = 10 μb
γD → η pn Ϭ tot = 20 μb
Ϭ QF = 10 μb Ϭinel (γD → η pn) = 10 μb
Br ω -> πγ Brω = 8.9% BrR = 0.4
ωyield = CSω * Brω
Ratio Ϭinel (M1700)/Ϭinel = 0.04 neff = 0.4
Ryield = Ϭinel * Ratio * neff
R = Ryield/ωyield = CSω * Brω / Ϭinel * Ratio * neff *BrR= 10 * 0.09*0.4 / 10 * 0.04 * 0.4 = 0.22
R exp = 22 / 66 = 0.3

So we have got the reasonable agreement between expected and measured ratios of ω and R yields if the branching of decay R →ηn is 100%.
The other decay channel of R may change the expected ratio





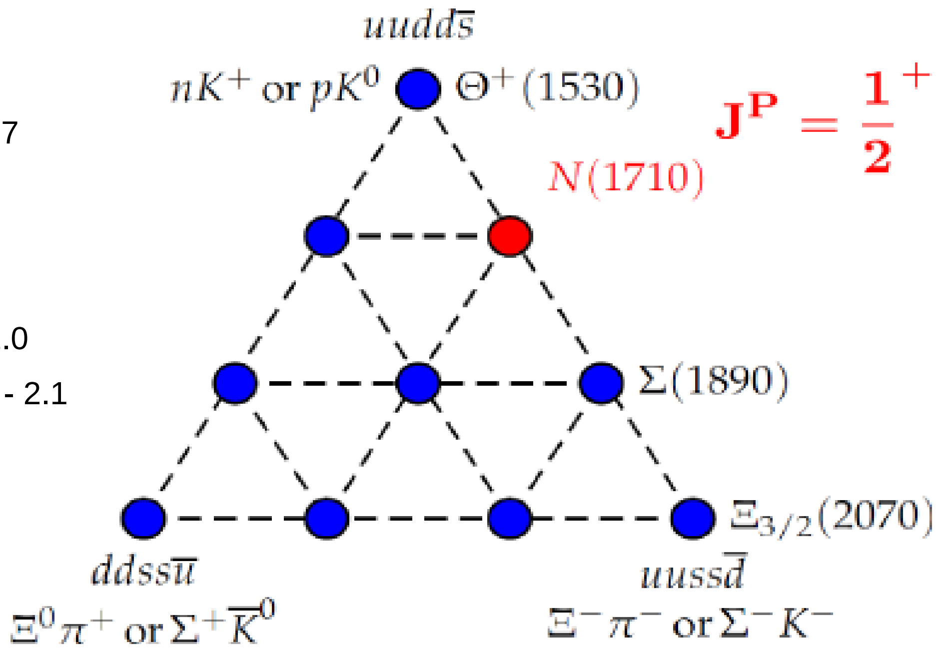
Sammury of recent results

Thresholds Eg - W
Etap 0.709 — 1.45

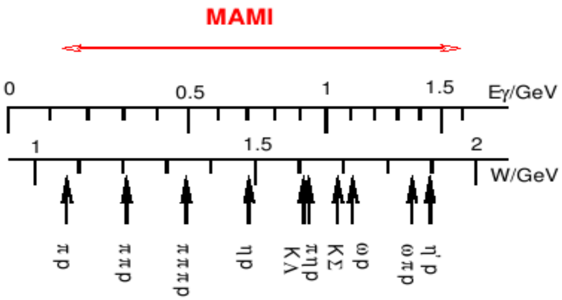
K0Sigma+ 1.05 - 1.7
Omega 1.1

Eta' 1.45 — 1.9

K*Lambda 1.68 - 2.0
K*Sigma 1.85
R(Eta' n) 1.80 - 2.1

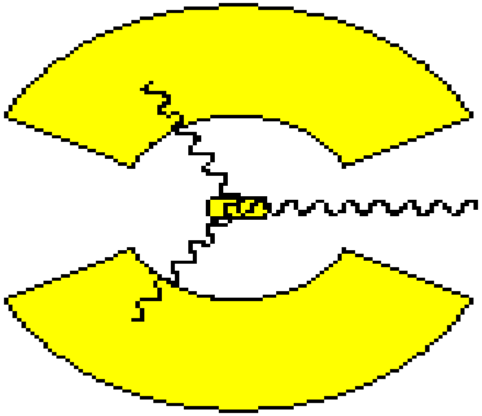


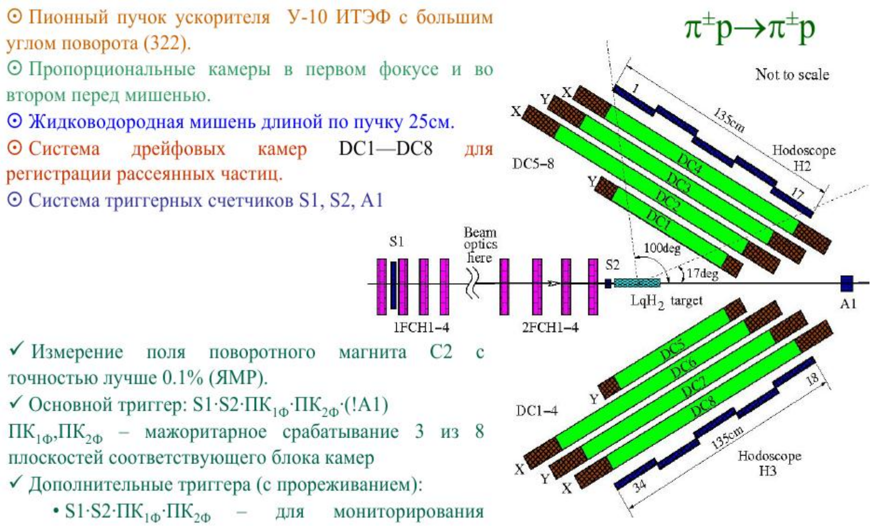
Reaction tresholds



nK+ CLAS -no signal
Ks p CLAS – interf signal
pK0 COSY — possible signal
neta — bump in DCS(MAINZ)
Klambda MAMI bump at W(1680)
Ksigma MAMI – no signal
peta — sharp changing in A1(MAINZ)
pip EPECUR pip-sharp effect at W(1680)
R(1890) ??
R(2079) BONN CUSP from K* L K* Sigma

No dedicated experiments on searching of R(1680) were performed
All results from reprecessing of old experimental data
Main features of problem – the increasing of experriment accuracy
leads to new problems in phenomenology(like a cusp problem)
Reprocessing data(CLAS,Bonn) for looking for R(1890), R(2070)?





⊙ 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):

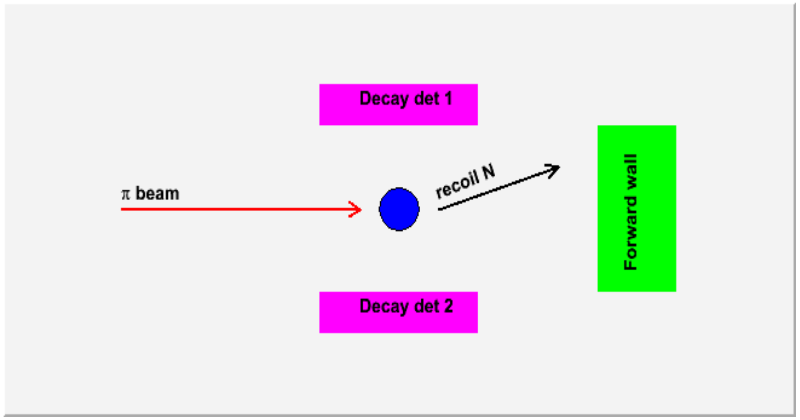
- $S1 \cdot S2 \cdot ПК_{1Ф} \cdot ПК_{2Ф}$ – для мониторирования

$\pi^{\pm}p \rightarrow \pi^{\pm}p$

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.



EPECUR

experiments on pion beam – much more clean signal from eta

π + P -> π + P formation experiment

π + D -> R + N production experiment

R -> ηN
πN

Pion Channel Status Main task is to improve momentum resolution

1. Program of Pion channel simulation is recovered on PCFARM(Kozlenko,Filimonov)

2, Method of experimental study of pion channel is developed(Preprint PNPI Bekrenev et al NP -40-1994 1982)

3. Sumachev analysis -(resolution is limitedet by multiple scattering

The best pion channel (Rutherford Lab(180 kev energy resolution)

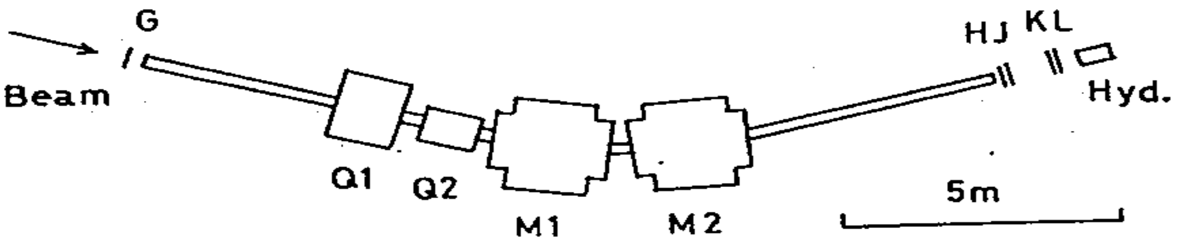


Fig. 1. The momentum spectrometer. The trajectory of a beam particle was registered in the five multiwire proportional chambers, G, H, J, K, L. G and H were at conjugate points with unit magnification, so that to a first approximation the momentum of a particle was determined by its relative positions in these two chambers. Note the long lever arm to H which gave a high momentum dispersion.

Results of pion channel study

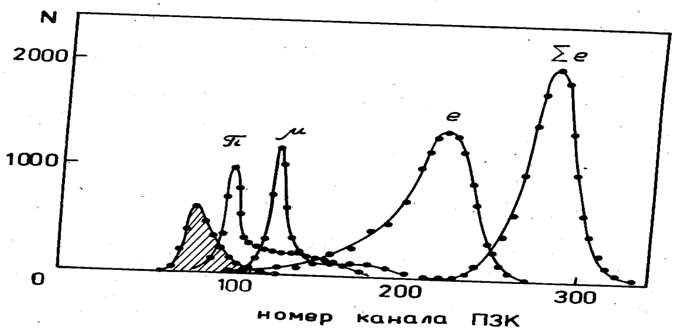


Рис.15. Амплитудный спектр, полученный при попадании на сборку пучка частиц с импульсом 200 МэВ/с.

Physics tasks:

1. Cusp in charge-exchange
2. «Deep» in charge-exchange
3. Level 4 MeV 0n 12C
4. 3He -> T

Outlook(PNPI)

1. Cusp problems

confirmation of cusp in elastic pi-p
cusp in charge-exchange
cusps description in both reactions

2. FSI in eta-production on deutron

pi+ + D-> eta + p + p — etaP FSI
pi- + D -> eta + n + n — etaN FSI

What is to be done:

1. Resolution of pion channel(~ 1 MeV)
2. Forward proton(neutron) detector

Advantages

Clean signal from eta-production
No other thresholds
Simple amplitude

The pentaquark problem needs a beam energy resolution ~ 1 MeV (expeted width of resonance) but thre are a lot of other reasons that may course an irregularity in cross sections. So the study of of this reasons is the additional task of experimental program.

The looking for pentaquarks is based on producing of strange final states so the high bean energy is needed but in this case we have a multy particle final state and as wos showned in numerous analysis the FSI of known resonances may produce an additional irregulatity in IM distribution.

Exotic - quark dynamic(like eta in intermadiate states) quarks moleculas

eta -> uu + dd + ss -> (uu + dd + s) + s virtual pentaguark + s
pi + D -> etaN(1540) + p (threshold 680 MeV/c, Trecoil proton 30 MeV)

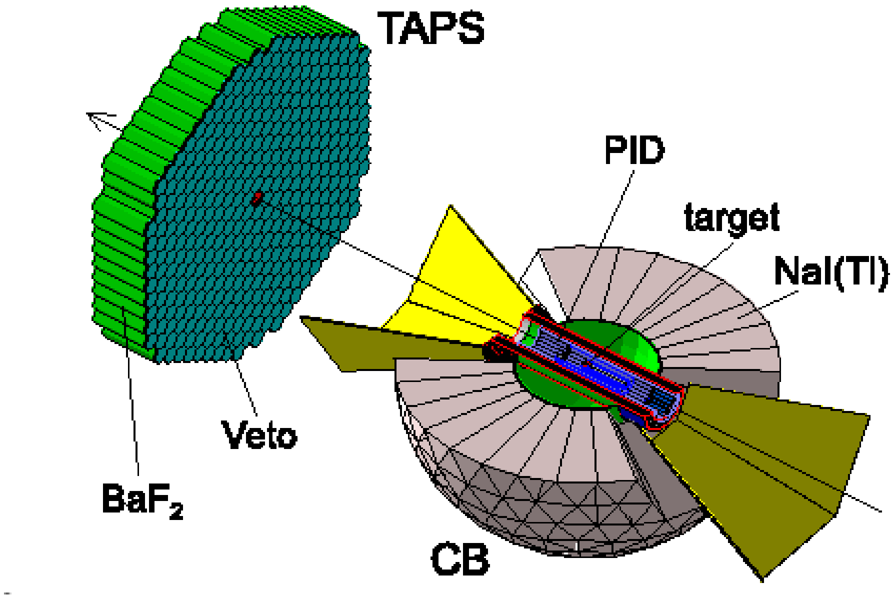
Sammury and outlook

1. The existance of pentaquarks and nature of “neutron anomaly” is a challenging task of medium energy physics both from theoretical and experimental point of view. The one of theoretical pictures is the hadron is a mixture of three and five quarks components and it is a way to describe the resonances spectrum. Up to now threr is not real confirmation on existance of pentaquarks and spetial experiments devoted to looking for pentaquarks
2. The existance of θ^+(1540) resonance is still under the question. The numerous theoretical and phenomenological work (JINR, ITEP, PNPI) devoted to explanetion why resonance is seen in some experiments and do not seen in other..
3. The numerous indicatio ns on existance of R1680 (“neutron anomaly”) is still need confirmation . The width of R1680 is resolution dominated. The are indication on existance Eta' n resonance W(2070) or .pronounced structure is observed between K* L and K* Sigma thresholds
4. The new independent method for llooking for R1680 is needed. Now the world loboratories re-analys data to understand the bump-like structures in various reactions but increasing of quality experimental data opens the new problem.
5. The experiments on pion beam of ITEP is perspective to study pentaquark problems.
6. The improving of pion channel of PNPI is needed for experiments on eta-mesonproduction.
7. High beam energy resolution are nessesary. FNAL project(Sadler)

Recent results from MAMI-C

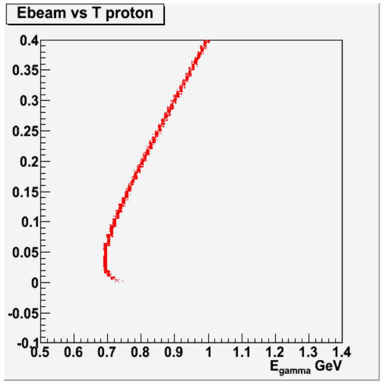
1. Ƞp at W(1680) problem
2. Ƞn from light nuclei
3. Klambda at W(1680)
4. gD->Rp or Rn — new results
5. New experiments with beam energy resolution 1 MeV

We must keep in mind progress in EU Hadron Physics Project

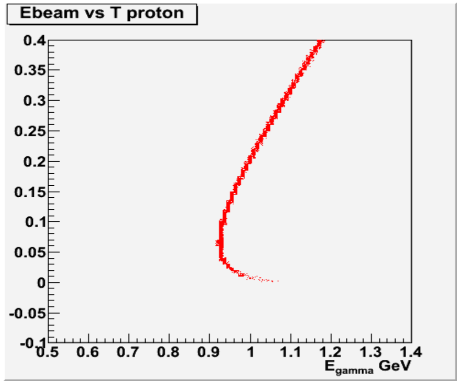


werthmueller.pdf

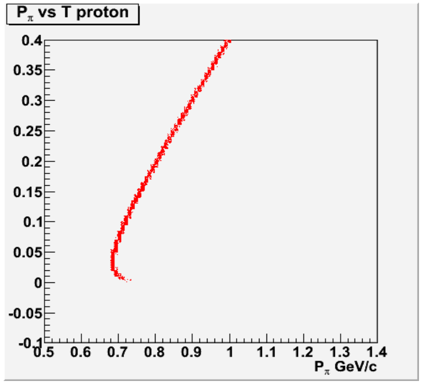
Kinematics of R(1540) TC



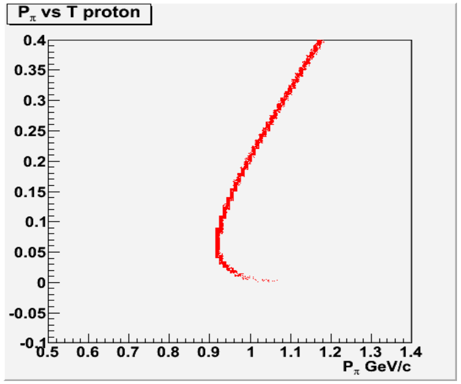
gD->R(1540)p



gD->R(1540)L(1102)

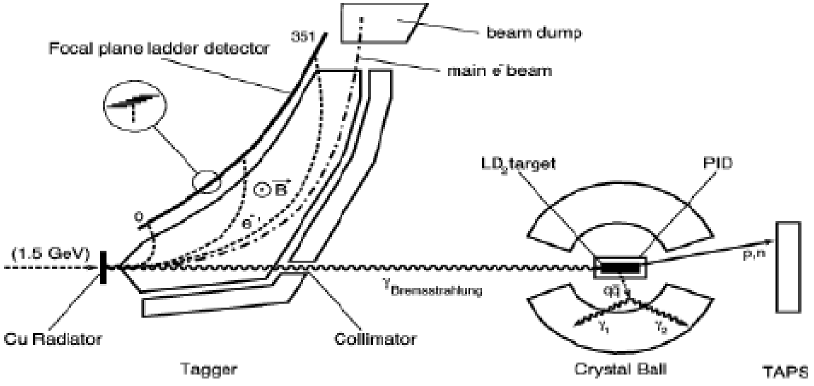


PiD->R(1540)p



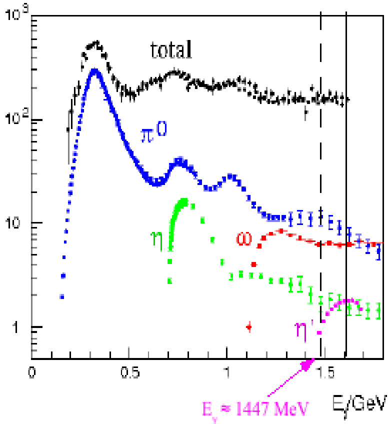
PiD->R(1540)L(1102)

4π detectors and 4π trigger : ~ 1000 crystals + CPCs



measure: $E_\gamma = E_e^0 - E_e$

- incident photon beam
- γ
- $\pi^{+/-}$
- proton
- neutron
- deuteron



Tagger energy range: 4.7 to 93% of E_0

Maximum energy tagged for E_0=1604 MeV is 1491 MeV

But:

- η' is an interesting field
- Studies of η' decays at high rates possible with the CB

/home/bekrenev/Macros/Sim/r1680/gDRX.C

/Desktop/SeminarHEPD/SemHEPD27

Sammury and outlook

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3. The new independent method for llooking for R1680 is needed.
Now the world loboratories re-analys data to understand the bump-like structures in various reactions but increasing of quality experimental data opens the new problem.
4. The threshold-crossing method was applied for searhing for R1680 in reaction γD->RP
5. The experimental data of A2 collaboration were processed for study of new method and searching for R1680.
6. The independent indication on existance of R1680 was obtained.
7. The decay channel R → ηp was founded
8. The independend processing of experimental data with kinematics fitting method is needed for confirmation of obtained results.
9. This method may be used for searchin for R1680 in experiments on pion beam of ITEP.
10. The ex]erimenta in full kinematics (neutron energy measurement) are needed.
11.Signal from R(1680,20) is clearly seen
12.Increase statistics of A2 collaboration
13. EPECUR – advantades, prospects and modification
14. LMP – cusp problem elsstic and charge-exchange reaction. Now the program «Meson» for simulation of pion channel was modified for channel resolution study. Goal – to modify channel to rach r esolution ~ 1 MeV
15. R1540 – possible systematic? Negative and positive results out of statistics. No devoted experiments.
16 “The report of Θ+'s death was an exaggeration” (Azimov – Mark Twain)
17. The main problem – is the observed narrow bumps really belong to antidecupret members(pentaquarks) or it is another nature of such narrow bums
.

θ

Role of the Final State Interactions in Extraction of Interaction Parameters

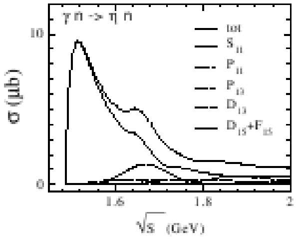
Strakovsky1 , W.J. Briscoe1 , D. Schott1 , R.L. Workman1 , A.E. Kudryavtsev1,2 , and V.E. Tarasov2

arXiv:1304.5896v1 [nucl-th] 22 Apr 2013

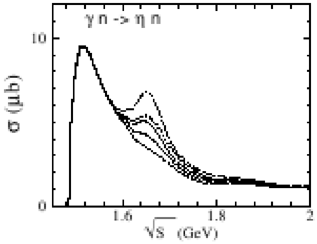
PWA tools in Hadronic Spectroscopy

test

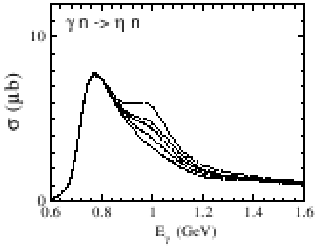
arXiv:nucl-th/0611036v2 12 Apr 2007



γn → ηn total and partial wave cross sections.
The kinks at 1.61 GeV and 1.72 GeV are the threshold effects coming
from KΛ and ωN .



γn → ηn total (left) calculated using the parameter set
and with different choice of the neutron helicity amplitudes
for the S11 (1650) and P11 (1710)
resonances: An (S11 (1650))=-24
(dashed), An (S11 (1650))=-16 (dashed-double-dotted), 1/2
An (S11 (1650))=+3 (dashed-dotted),
An (P11 (1710))=+17 (dotted),
where the 1/2 helicity amlitudes are given in 1/2 units of 10−3 GeV− 2 . 1/2



The cross sections as in the left part
but smeared out over the Fermi motio
inside the deuteron.

Res param were extracted from pion data
Now data from gamma obtained and.
Precise pion data are extremly nedded

What is to be done:
Cusp pics
Pion channel PNPI

arXiv:1204.6433v1 [hep-ex] 28 Apr 2012

EPECUR

The nature of the irregularity could be either connected to a narrow resonance with mass around 1690 MeV or to the threshold effect, caused by opening of the channel $\pi^- p \to K\Sigma$

arXiv:1304.5896v1 [nucl-th] 22 Apr 2013

PWA tools in Hadronic Spectroscopy

. Our idea is to search for P11(1700) in formation-type experiment on a pion beam 15 . Precise measurement of the beam momentum and fair statistics will allow us to do a scan with unprecedented invariant mass resolution. We plan to measure differential cross sections of the reactions $\pi^- p \to \pi^- p$ and $\pi^- p \to K_S \Lambda^0$ with high statistics and better than a MeV invariant mass resolution. If the resonance does exist our experiment will provide statistically significant result and we will measure its width with the precision better than 0.7 MeV.

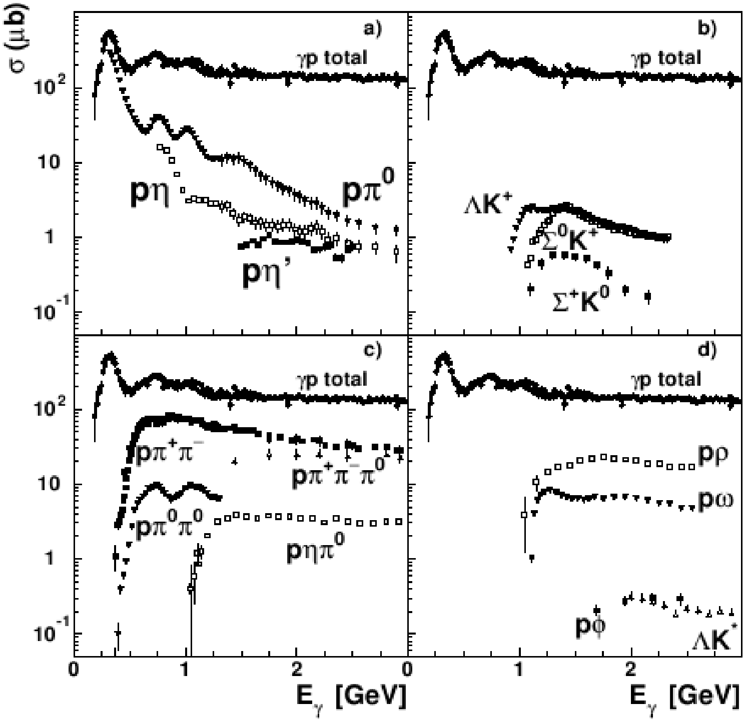
The nature of the irregularity could be either connected to a narrow resonance with mass around 1690 MeV and width of 5-10 MeV or to a threshold effect 17 , caused by opening of the channels $\pi^- p \to K^0 \Sigma^0$ ($\sqrt{s} = 1690.2$ MeV) and $\pi^- p \to K^+ \Sigma^-$ ($\sqrt{s} = 1691.1$ MeV). The resonance, if it is a memeber of the pentaquark antidecouplet, should be in P-wave, while the threshold effect should manifest itself in S-wave. The structure observed in the differential cross section is a result of an interference of a fast change in some partial wave with slow changing non-resonant backgound. We plan to collect large statistics in a narrow region pbeam = 1000−1070 MeV/c, which will allow us to plot data in more fine angle and energy binning in order to find out which wave is affected. Further analysis of the data already collected, including data collected with positive pions, is also under way.

THE IRREGULARITIES ARE OBSERVED IN π^- CHANNEL AND ABSENT IN π^+ CHANNEL

Role of the Final State Interactions in Extraction of Interaction Parameters

The question of the existence of multiquark hadrons has been raised at the beginning of the quark model, and is regularly revisited, either due to fleeting experimental evidence or to theoretical speculations. In the late 60's some analyses suggested a possible resonance with baryon number B = 1 and strangeness S = −1, opposite to that of the Λ or Σ hyperons.

2008b) from where we quote the final conclusion: The whole story - the discoveries themselves, the tidal wave of papers by theorists and phenomenologists that followed, and the eventual "undiscovery" - is a curious episode in the history of science. The evidence for a pentaquark interpretation (Kuznetsov, 2008) of a narrow peak in the nη invariant mass spectrum at 1680 MeV is weak; the peak is observed in photoproduction of



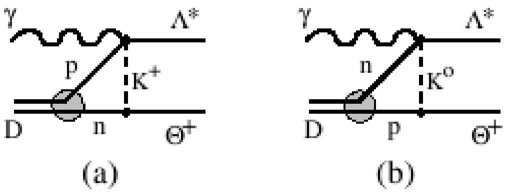
Role of the Final State Interactions in Extraction of Interaction Parameters

Sibirtsev PRC 65 044047

Θ+ formation in inclusive γD → pK − X

arXiv:nucl-th/0607054v1 26 Jul 2006 Titov JINR

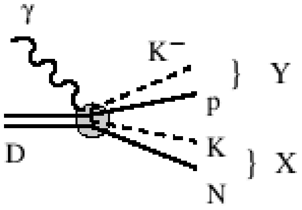
We analyze the possibility to produce an intermediate Θ+ via a KN → Θ+ formation process in γD → pK − X (X = nK + , pK 0) reactions at some specific kinematical conditions, in which a pK − pair is knocked out in the forward direction and its invariant mass is close to the mass of Λ∗ (Λ∗ ≡ Λ(1520)). The Θ+ signal may appear in the [γD, pK −] missing mass distribution. The ratio of the signal (cross section at the Θ+ peak position) to the smooth background processes varies from 0.7 to 2.5 depending on the spin and parity of Θ+ , and it decreases correspondingly if the pK − invariant mass is outside of the Λ∗ -resonance region. We analyze the recent CLAS search for the Θ+ in the γD → pK − nK + reaction and show that the conditions of this experiment greatly reduce the Θ+ formation process making it difficult to extract a Θ+ peak from the data.

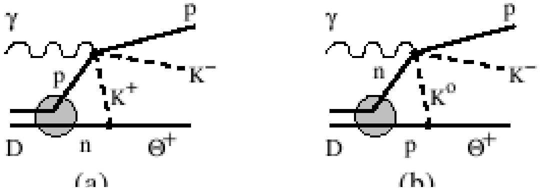


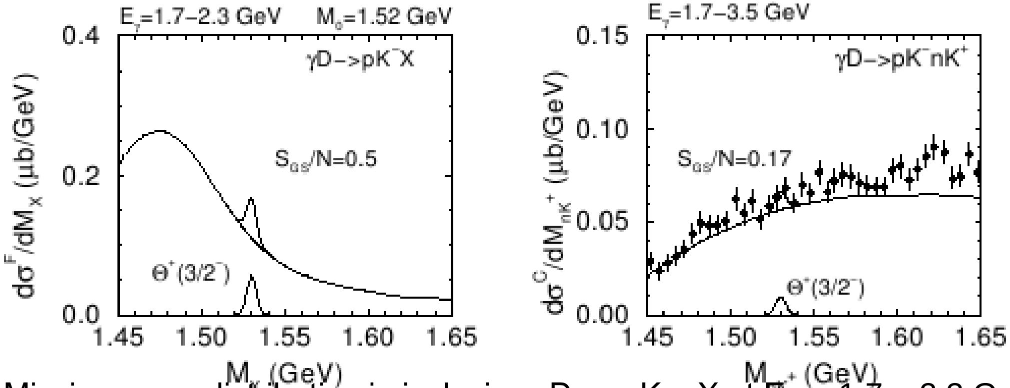
The pK − pair must be knocked out in the forward direction. In this case, the momentum of the recoil kaon is small, and it can merge with the slowly moving spectator nucleon to produce a Θ+ .

The CLAS experiment [7] to search for Θ+ was designed to study the direct γn → Θ+ K − → nK + K − reaction and, in principle, it does not satisfy the above conditions.

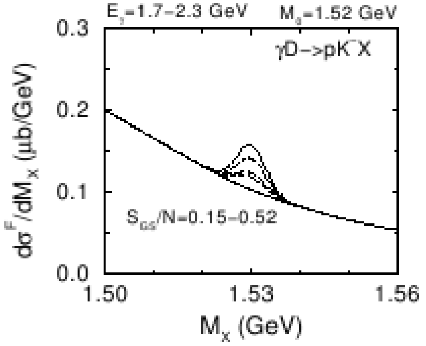
Reaction γD → pN K − K.



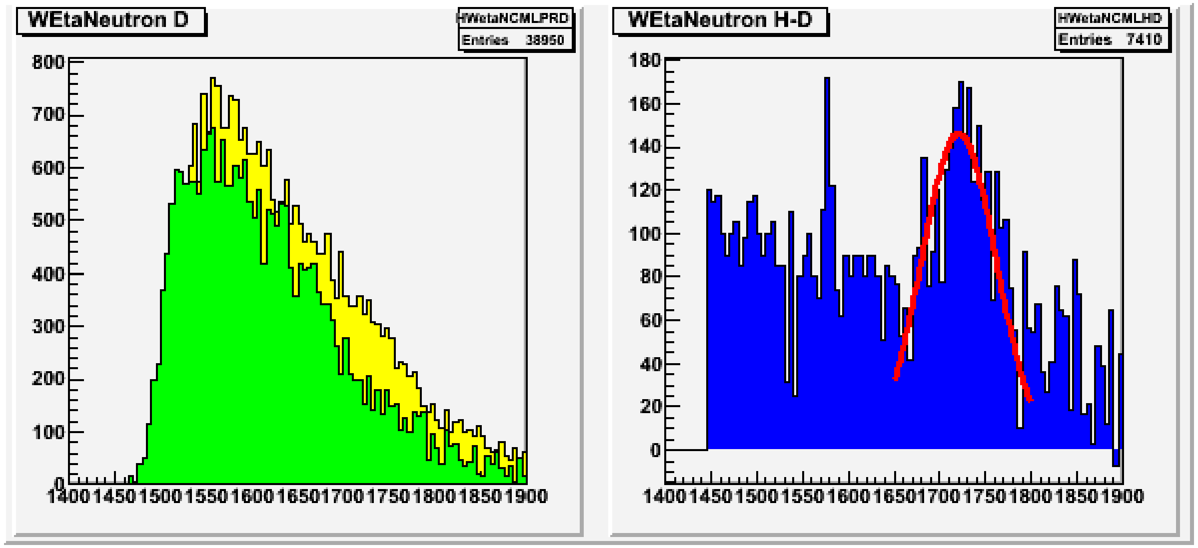




Left panel: Missing mass distribution in inclusive γD → pK − X at Eγ = 1.7 − 2.3 GeV and the pK − photoproduction angular cut (θpK − < 220 (c.m.s.)) and φ-meson cut. Right panel: nK + invariant mass distribution in exclusive γD → pK − nK + at Eγ = 1.7 − 3.5 GeV and for CLAS experimental conditions(i)-(v). Experimental data from Ref. [7]. In both cases, JΘ = 3/2− and the Θ+ signal is folded with a Gaussian resolution function with a width of 3 MeV.



The difference of R(1680) yields from hydrogen and deutron targets



Really it is a cheking of reconstruction algorithm, we expect kinematics fitting from Kulbardis