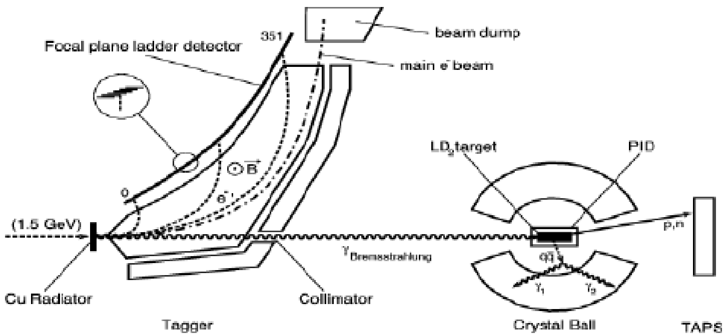
Status of A2 collaboration and potential of medium energy physics

The first stage of experiments(unpoliraized target) is completed
Physics program, Main results, new problems, exotic experiments
Now the second stage — experiments on polarized target) is in progress
First results and analysis
Analysis of results and resume – input in worldwide workshops
New generation of fasilities and experiments is oncoming.(pion beams are byproduct)
Electron and hadron fasilities, source of light mesons, whorkshops and mappuing out of program
Secondry hadron beams opportunity — currently world wide discussion
Current fasilities, new PILAC-from 10^9->10^10
Have we any chance to keep our position in medium energy physics.
MMF, ITEP, PNPI
Conclusion

Experimental sets for photoproduction experiments(A2)

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



measure: $E_\gamma = E_{e^-}^0 - E_{e^-}$

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

The main features of experimental sets for photoproduction experiments.
Taggers 1 or 2 for beam energy
Continious energy spectrum
No coincedences gamma-detector (prompt and random measurments)
Good beam energy resolution
Limit in FS resolution(gamma-detector)
Compton source — low intensity

Energy resolution 40 MeV for eta
20 MeV for pion

Experimental set of A2 collaboration

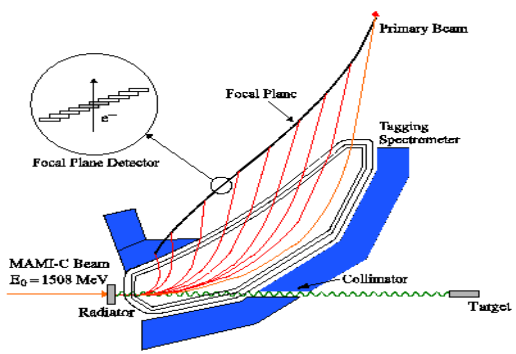
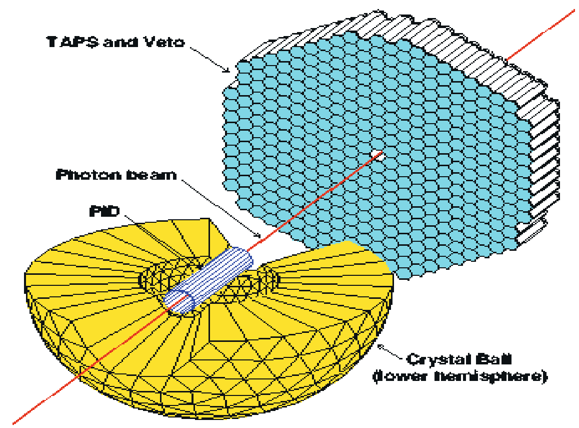
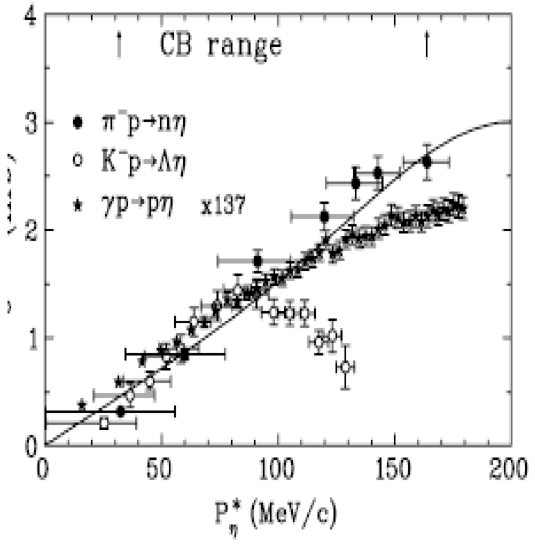


Figure 8: The Glasgow photon tagging spectrometer.



Now 2 tagger — for low and high energy beam - in operation. The main FS detector Crystal Ball is on the base of NaI crystals and about 30 years old. Now a problems witth a number of crystals.

Quality of photoproduction data



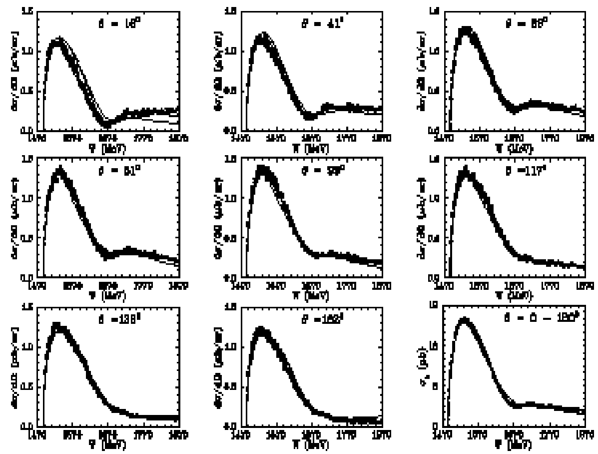


FIG. [illegible]: Fixed-angle excitation functions for $\gamma p \to \eta p$ as a function of the c.m. energy W shown for eight values of the η production angle and for the full angular range. Our data are shown by solid circles. The plotted uncertainties are statistical only. The notation of the PWA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

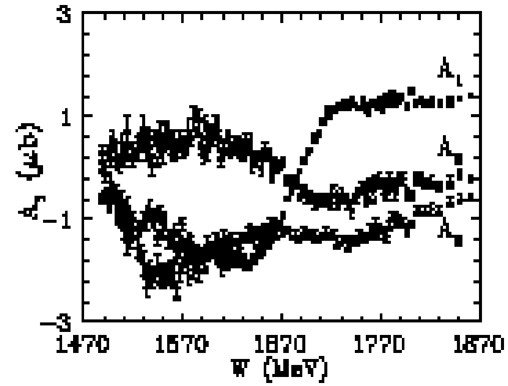
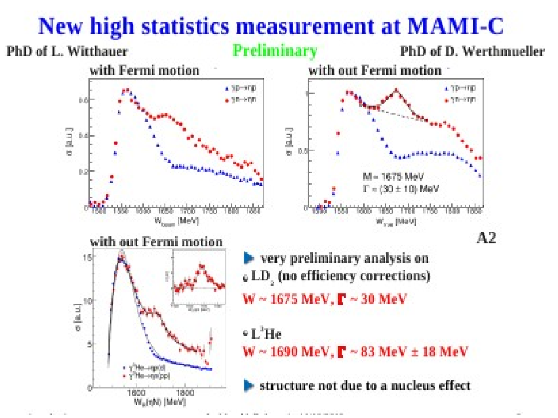
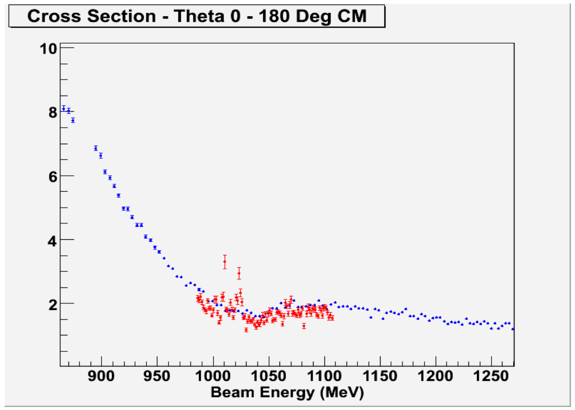


FIG. 8: Dominant Legendre coefficients from the fits to our differential cross sections. The coefficients are plotted as a function of the c.m. energy; A_1 is shown by solid circles, A_2 by open triangles, and A_3 by open circles.





Unprecendentet quality of data {from current reviews)

Quasifree Photoproduction of η Mesons off Protons and Neutrons BoGa group

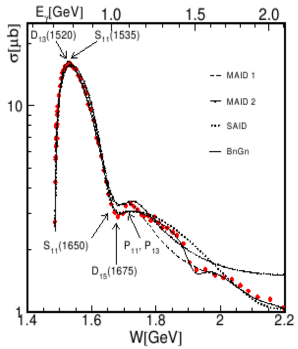
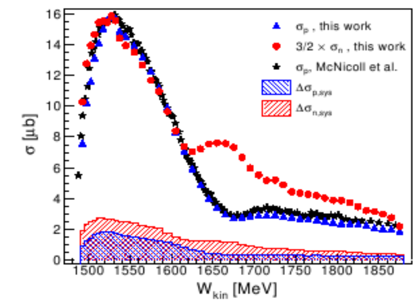
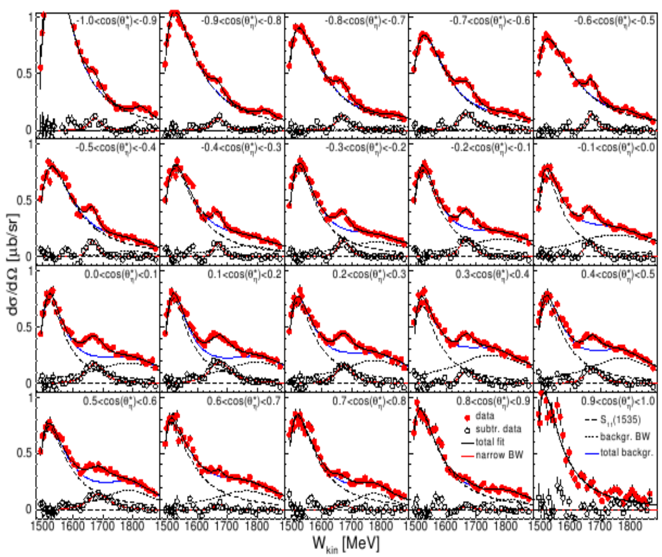


FIG. 1. (Color online) Total cross section for γp → ηp averaged over data from [5–13]. Model curves are from MAID 1 [14], MAID 2 [15], SAID [13], and BnGn [16].

FIG. 16. (Color online) Total cross sections as a function of the final-state invariant mass Wkin = m(ηN): Blue triangles: proton data. Red circles: neutron data scaled by 3/2. Black stars: free proton data from MAMI-C [13]. Hatched areas: total systematic uncertainties of proton (blue) and neutron (red) data.



The results for γn → ηn are of unprecedented statistical quality and confirm the existence of a peak in the total cross section at WR = (1670 ± 5) MeV with a width of ΓR = (50 ± 10) MeV. Correcting for the finite experi-

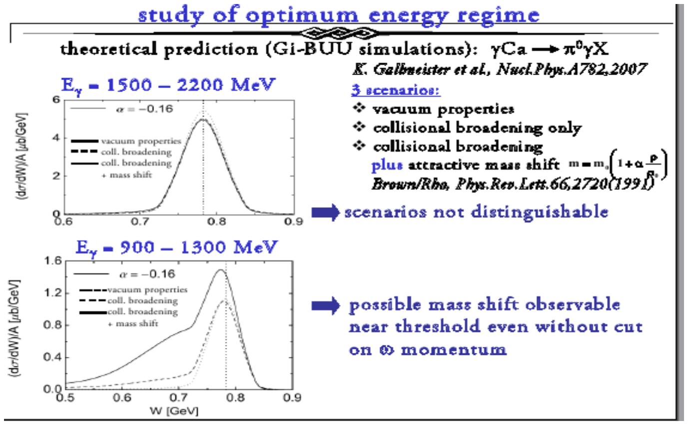


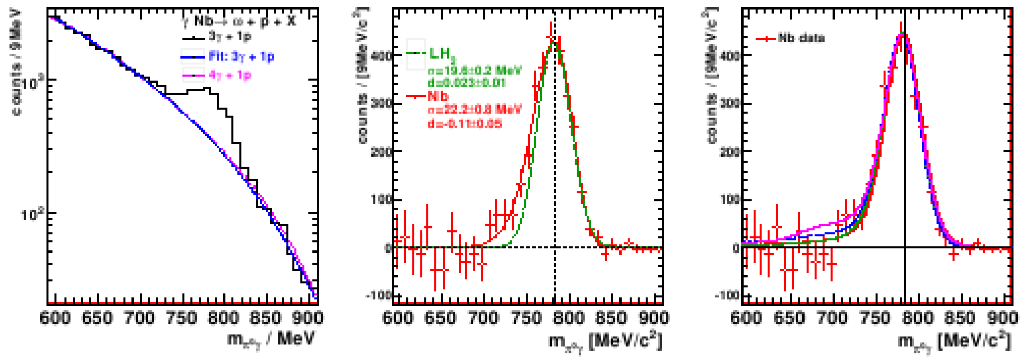
First results in the framework of the BnGn model [64] describe the data better with a scenario where the main effect is related to interferences in the S11 sector than with the introduction of a narrow P11 state. However, also in this approach contributions from other partial waves are needed to reproduce the non-trivial angular distributions.

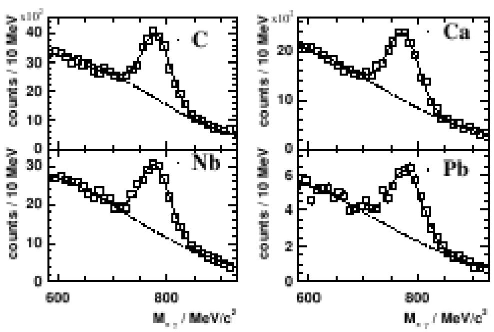
(Color online) Differential cross sections as a function of Wkin for different bins of cos(θη): Points: Original data (filled red circles) and background-subtracted data (open black circles). Curves: Total fit (solid black), S11 (1535) contribution (dashed black), integrated background Breit-Wigner (dotted black), total background (S11 (1535) + broad BW, solid blue) and narrow BW (solid red).

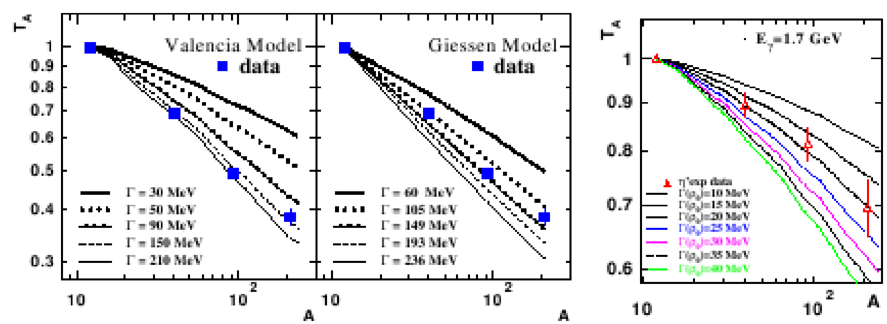
Angle dependences of bump to make PWA and find partial wave with resonance.
Next step — spin observables or experiments on a new generation facilities?
It is difficult to expect real improvment of exp data-systematic?

Medium modification – one of attractive task





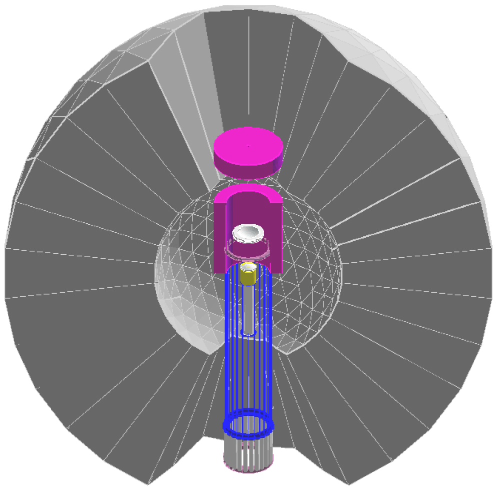


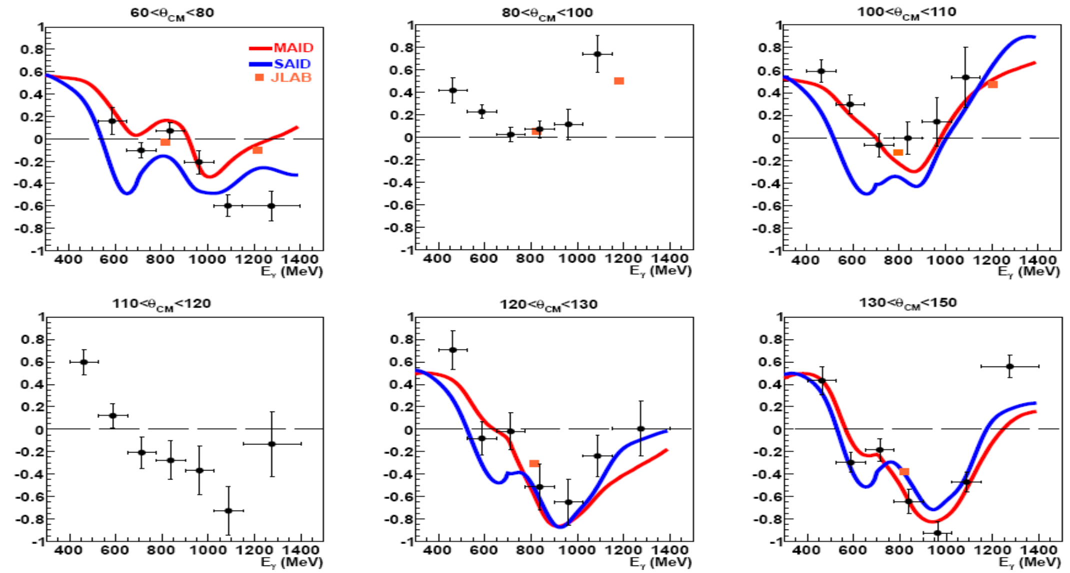


Results of study the line — shape and trancsperancy. No clear effects of medium modification.

Challenge for next generation experiments
High-presision in medium spectroscopy with invariant mass resolution about 1% in mesom mass region

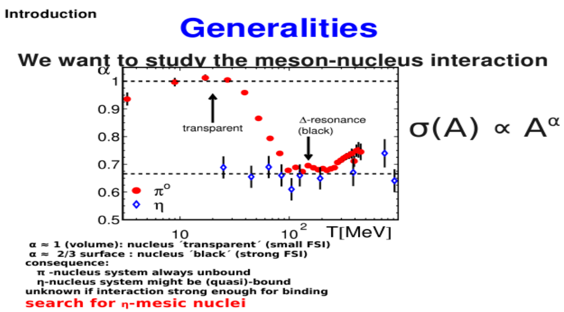
Experiment on double-scattering measurement
It is important for next generation of experiments
as energy losses 2 MeV/cm

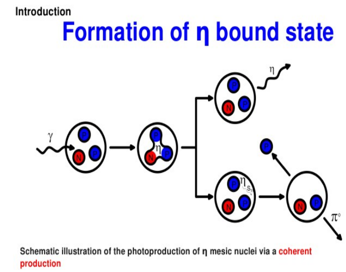


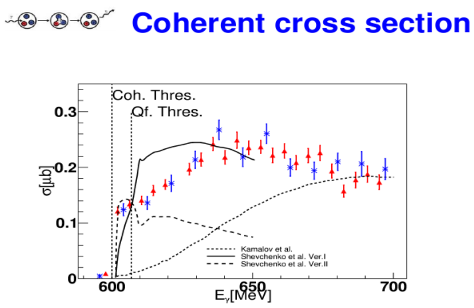


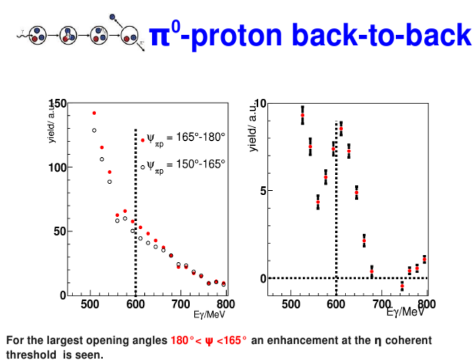
- C_x for π^0 has been measured
- Finalize C_x for η
- Complete measurement of P
- Fully implement kinematic fitting in data
  - Vertex corrections?
  - Improve sensitivity to $\eta \rightarrow 3\pi^0$
  - Use total energy/momentum constraint as a method of identifying useful scatters

η-photoproduction on ^{3}He: Search for η-mesic nuclei









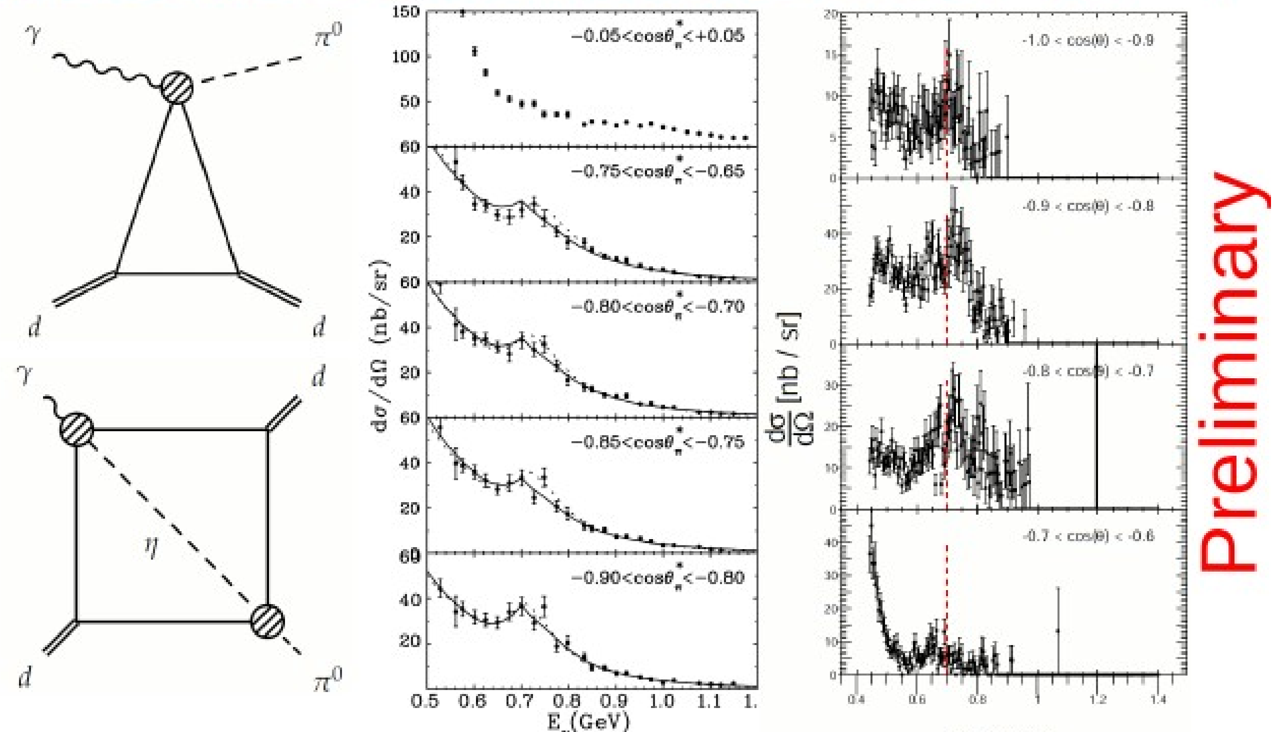
CONCLUSIONS

- The η coherent production was measured with much higher statistical quality and better control of systematic effects than in the previous experiment. A strong threshold enhancement of the cross-section was confirmed similar to the observation in the pd → ^{3}Heη reaction at COSY-ANKE.

- Good agreement with theoritical models(shevchenko)

- The oberved π^0-proton back-to-back emission seems to be a not conclusive method despite a more advanced analysis.

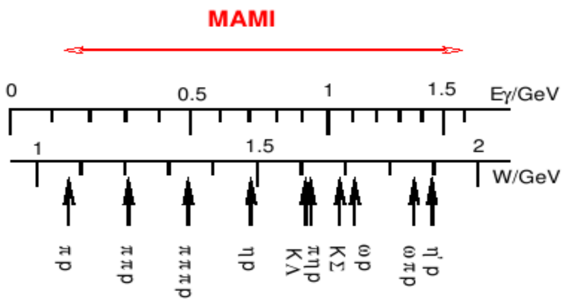
η Excitation in Intermediate State of $\mathrm{d}(\gamma,\pi^0)\mathrm{d}$

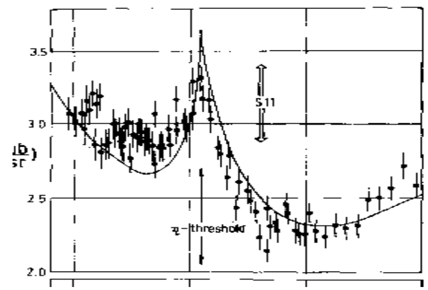


Y. Ilieva et al., CLAS, 2009

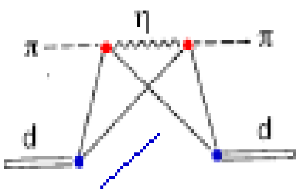
How we can really study of reaction mechanizm?

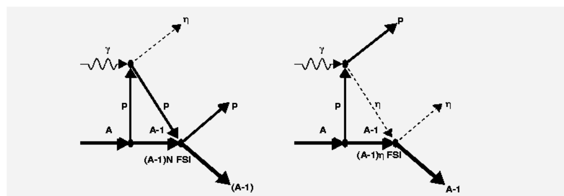
Why the high beam resolution is extremly needed?

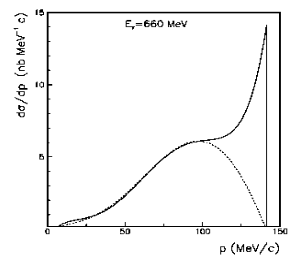




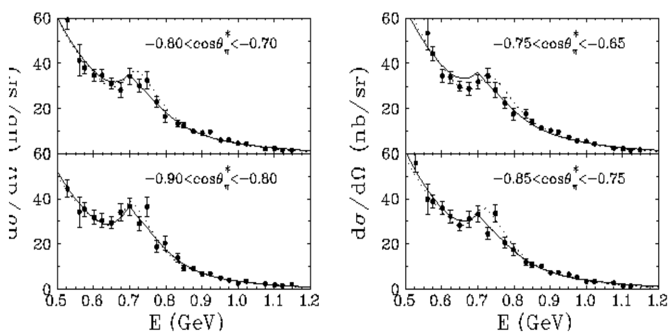
Cusp effect inenergy range about 10 MeV so we need beam energy resolution about 1 MeV

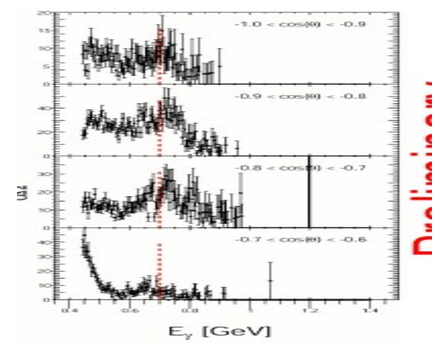






Effectof FSI in eta photoproduction from deutron. Beam energy rasolution must be about 1 MeV and energy resolution of FS should be about 5 MeV - it is possible for recpil proton





Effects of eta production in intermadiate state for coherent pion photoproduction from CLAS and A2

One of the main goals of oncoming experiments from new generation facilities is a seach of small and narrow signals from exoytic resonanses so the mentioned effects must be taken into account in mapping out of future experiments. The usial way — comparison of results from frem a free and bound nucleons is not enough for new precise experiments.

Spin observables — second stage of program

Measurement of the transverse target and beam-target asymmetries in η meson photoproduction at MAMI

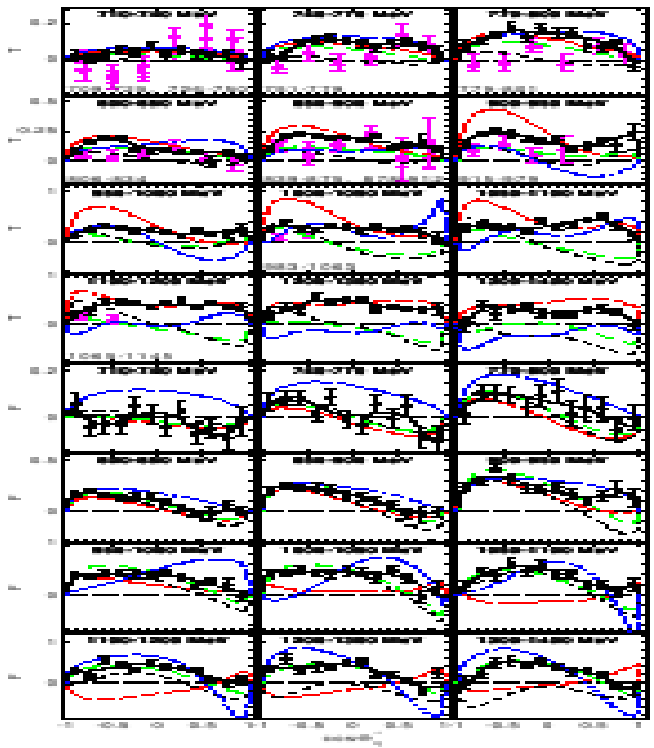
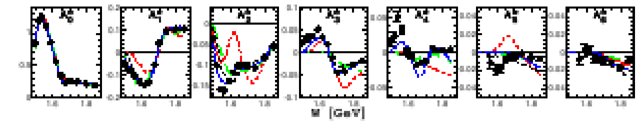


FIG. 2: (Color online) T and F asymmetries. The new results with statistical uncertainties (black circles) are compared to existing data from Bonn [13] (magenta triangles) and existing PWA predictions (red dashed: η-MAID [4], green long-dashed: Giessen model [8], black dashed-dotted: BG2011-02 [7], blue dotted: SAID GE09 [10]). The result of our Legendre fit is shown by the black curves, Eq. 3. The energy labels on the top of each panel indicate the photon energy bins for our data. The values at the bottom give the corresponding bins of [13].



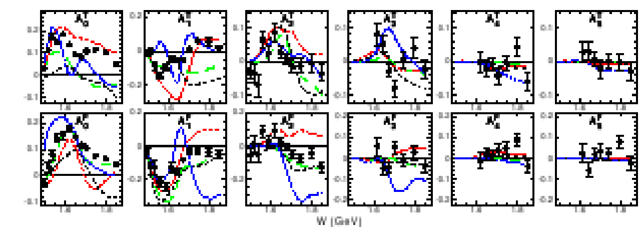


FIG. 4: (Color online) Legendre coefficients [μb/sr] up to ℓmax = 3 from our fits to the product of the new asymmetries with the differential cross section from [10]: T dσ/dΩ (upper row) and F dσ/dΩ (lower row).
Notations for the curves are the sameas in Fig. 2

Data analysis
Too big energy step
BoGa analysis to make a final conclusion.
Classic approach -full experiment
New facilities — small energy step
Effects of interest arwe small
New analysis ideas - **New Tools**
Sophisticated Computers,
Reaction simulation
mapping of experiments

Up to now the obtained data are attract worldwide attention of femous theoretical groups

BoGa group

Interference phenomena in the J P = 1/2− -wave in η photoproduction

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arXiv:1501.02093v1 [nucl-ex] 9 Jan 2015

Abstract. The recent precise experimental results for the photoproduction of η-mesons off the neutron measured with the Crystal Ball/TAPS calorimeter at the MAMI accelerator have been investigated in detail in the framework of the Bonn-Gatchina coupled channel model. The main result is that the narrow structure observed in the excitation function of γn → nη can be reproduced fully with a particular interference pattern in the J P = 1/2− partial wave. Introduction of the narrow resonance N (1685) with the properties reported in earlier publications deteriorates the quality of the fit.

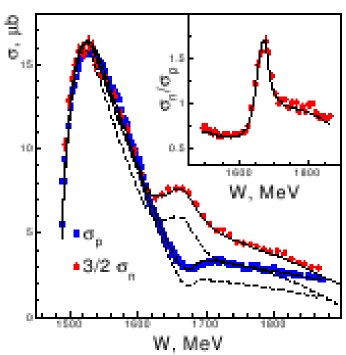

Fig. 1. (color online) The total cross section for γn → ηn, γp → ηp, and their ratio as functions of the ηN invariant mass. The solid curves represent our final fits, dashed curves the J P = 1/2− contributions.

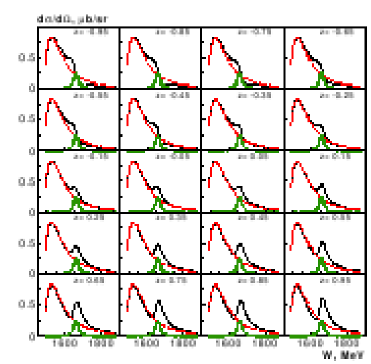

Fig. 4. (color online) Energy distributions at fixed angles (in bins of z = cos Θη) in the case of the interference between J P = 1/2− and J P = 1/2+ states. The contributions of the J P = 1/2− partial wave are shown with dashed (red) curves and J P = 1/2+ with dotted (green) curves.

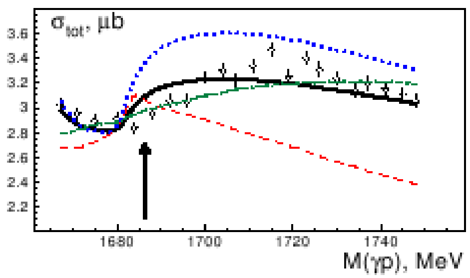

Fig. 6. (Color online) Total cross section for γp → ηp. Solid (black) curve: best fit; dashed-dotted (green) curve: fit with zero coupling to the KΣ final state; dotted (blue) curve: coupling of N (1650)1/2− → KΣ doubled; dashed (red) curve: coupling of N (1650)1/2− → KΣ with negative sign. The arrow indicates the position of the KΣ threshold.

The first attempt to include cusp
Energy step 8 MeV is not enougyh to determine cusp shape
There is not idea to find cusp in data proceccing

ii) The anomaly at 1685 MeV in the total cross section of the reaction γp → ηp could be traced quantitatively to the opening of the K Σ threshold. Since data on γp → K Σ are included in the Bonn-Gatchina partial wave analysis, there is no free parameter available to fit the shape of the anomaly in the γp → ηp cross section. The small size of this anomaly rules out the possibility that the K Σ threshold might be responsible for the narrow bump observed in the γn → ηn total cross section.

The new and very precise data from MAMI enabled us to a much more solid partial-wave analysis of the γn → nη reaction. Our fit results show that the bump in the total cross section and also the behavior of the angular distributions can be understood quantitatively as interference between the two well-known resonances in the J P = 1/2− wave, the N (1535)1/2− and the N (1650)1/2− states. This fit requires, however, that the sign of the electromagnetic A1/2 helicity coupling of the N (1650) is inversed for the neutron with respect to the current PDG [5] entry and also with respect to previous analyses in the framework of the BnGa model [26].

Radiative Decay Width of Neutral non-Strange Baryons from PWA GW-ITEP

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Maxim A. Martemyanov2, and Vladimir E. Tarasov2

Abstract. An overview of the GW SAID and ITEP groups effort to analyze pion photoproduction on the neutron-target will be given. The disentanglement the isoscalar and isovector EM couplings of N* and □* resonances does require compatible data on both proton and neutron targets. The final-state interaction plays a critical role in the state-of-the-art analysis in extraction of the $\gamma n \to \pi N$ data from the deuteron target experiments. It is important component of the current JLab, MAMI-C, SPring-8, ELSA, and ELPH programs.

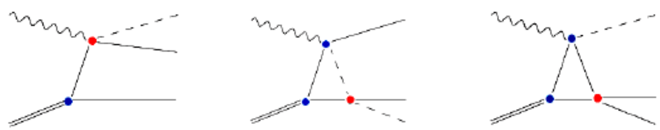


Figure 2: Feynman diagrams for the leading components of the $\gamma d \to \pi$ pp amplitude. (a) Impulse approximation (IA), (b) pp-FSI, and (c) πN-FSI. Filled black circles show FSI vertices. Wavy, dashed, solid, and double lines correspond to the photons, pions, nucleons , and deuterons, respectively.

Resonance	$nA_{1/2}$	Resonance	$nA_{1/2}$	$nA_{3/2}$	Ref.
$N(1535)1/2^-$	−58± 6	$N(1520)3/2^-$	−46± 6	−115± 5	SAID GB12
	−60± 3		−47± 2	−125± 2	SAID SN11
	−93±11		−49± 8	−113±12	BnGa13
	−49± 3		−38± 3	−101± 4	Kent12
	−46±27		−59± 9	−139±11	PDG14
$N(1650)1/2^-$	−40±10	$N(1675)5/2^-$	−58± 2	−80± 5	SAID GB12
	−26± 8		−42± 2	−60± 2	SAID SN11
	25±20		−60± 7	−88±10	BnGa13
	11± 2		−40± 4	−68± 4	Kent12
	−15±21		−43±12	−58±13	PDG14
$N(1440)1/2^+$	48± 4	$N(1680)5/2^+$	26± 4	−29± 2	SAID GB12
	45±15		50± 4	−47± 2	SAID SN11
	43±12		34± 6	−44± 9	BnGa13
	40± 5		29± 2	−59± 2	Kent12
	40±10		29±10	−33± 9	PDG14

Table 1. Neutron helicity amplitudes A1/2 and A3/2 (in [(GeV)−1/2 ◊ 10−3] units) from the SAID GB12 [14] (first row), previous SAID SN11 [21] (second row), recent BnGa13 by the Bonn-Gatchina group [25] (third row), recent Kent12 by the Kent State Univ. group [26] (forth row), and average values from the PDG14 [1] (fifth row).

□ The differential cross section for the processes □n→□□p was extracted from new CLAS and MAMI-B measurements accounting for Fermi motion effects in the IA as well as NN- and □N-FSI effects beyond the IA.
□ Consequential calculations of the FSI corrections, as developed by the GW-ITEP Collaboration, was applied.
□ New cross sections departed significantly from our predictions, at the higher energies, and greatly modified the fit result.
□ New □n→□□p and □n→□0n data will provide a critical constraint on the determination of the multipoles and EM couplings of low-lying baryon resonances using the PWA and coupled channel techniques.
□ Polarized measurements at JLab/JLab12, MAMI, SPring-8, ELSA, and ELPH will help to bring more physics in.
□ FSI corrections need to apply.

Summary of A2 status

The new unprecendable quality experimental data of A2 collaboration are obtaind and attracted worldwide attention in its interpretatione and erected a lot of new problems . The interpritatin of a new data still in progress.The hunting for exotic states remaine the one of the key task of medium energy physics. It becomes clear that a hunting for exitic states needs a specific experiments — expected low cross-section, suppression of physics background The results of A2 collaboration are under discussion of an annual world workshops (MesonNet2014, for example) devoted to experimental programs of next generation facilities. The first conclusion — the hunting for exotic states must be based on a new generation experiment mapped out for this specific tasks.
The new generation experiments needs a new tools — specific computers, physics processes simulation, mapping out of specific experiments. This problems are now under discussion on specific workshops (Analysis Tools for Next-Generation Hadron Spectroscopy Experiments)

A second exciting observation was a narrow structure in the excitation function of η photoproduction off the neutron at W = 1670 MeV [16–19]. The position coincides with a dip observed in the γp → ηp total cross section [10]. The interpretations discussed in the literature include new narrow resonances, an interference between 1/2− resonances, or coupled channel effects due to the opening of KΛ and KΣ channels.

There is no evidence for any narrow structure. However,
all existing solutions from various partial wave analyses fail to reproduce the new data. We therefore expect a significant impact on future analyses and on our understanding of the dynamics of η photoproduction.

Anomaly from Bonn is not confirmed
Disagreement with any prediction
Analysis with new data — all amplitude may be changed and specified

In spite of unorecendented quality of obtained experimental data tha majority of problems are not solved and a new generation of experiments are extrimly nedded.

New generation of facilities   Current important meetings

XV International Conference on Hadron Spectroscopy (Hadron 2013)
November 4-8 2013 Nara, Japan

MesonNet 2014 International Workshop
Mini-proceedings

Analysis Tools for Next-Generation Hadron Spectroscopy Experiments

Facilities for meson production and decays ($M \leq 1$ GeV):

- Crystal Ball, MAMI-C, Mainz (γN)
- Crystal Barrel, BGO-OD, ELSA, Bonn (γN)
- KLOE-2, Daϕne, Frascati (e^+e^-)
- WASA, COSY, Jülich (pp, pd)
- HADES, GSI, Darmstad (pp, πp)

- Experimentalist at VEPP-2000 (BINP), CEBAF (JLAB), B-factories (Babar, Belle, Belle II)
- Theory centers: Barcelona, Bern, Bonn, Giessen, GSI, JINR, Jülich, Lisbon, London, Lund, Praha, Rosendorf, Uppsala, Valencia, Zagreb.

Worldwide discussion on meson beams have started

PHYSICS OPPORTUNITIES WITH MESON BEAMS
William J. Briscoea,1 , Michael Döringa,2 , Helmut Haberzettla,3 , D. Mark Manleyb,4 , Megumi Narukic,5 , Igor I. Strakovskya,6 , Eric S. Swansond,7

arXiv:1412.6393v1 [hep-ph] 19 Dec 2014

What is about Russia — can we keep our activity in meson physics&
Good example EPECUR — relatively simple experiment but is mentiond in worldwide reviews
PNPI -- have we any chance to be mentioned?

New generation of facilities

Hadron beams: COMPASS, VES, and PANDA

COMPASS [41, 42] is a high-energy hadron physics experiment at the Super Proton Synchrotron at CERN involving about 220 physicists from 13 countries and 24 institutions. One of the purposes of this experiment is to study hadron spectroscopy using high-intensity hadron beams of 150–250 GeV by diffractive, central, and Coulomb production reactions. Final states containing charged and neutral particles are detected with high resolution over a wide angular

Electron beams: CLAS, ELSA, MAMI, SPring-8, and JLAB12

In the last 20 years electron accelerators such as CEBAF at JLab, ELSA at Bonn, MAMI at Mainz, and SPring-8 in Japan, have considerably improved in the delivery of electron and photon beams of high intensity and quality to enable coincidence measurements for hadron spectroscopy. New detectors and targets have been designed and commissioned. We are now in a situation where the photo- and electroproduction of pseudoscalar mesons carry the highest potential to investigate the baryonic spectrum. In addition to the resonance positions and strong residues, which describe couplings to decay channels, the electromagnetic couplings and transition form factors are also being investigated.

Annihilation reactions: Belle-II, BES-III, CMD-3, LHCb, and SND

Annihilation of e+ e− and p¯ have been historically important additions to the host of reactions in hadron spec- p troscopy. The early experiments in the SLAC-LBL e+ e− storage ring (SPEAR) produced many of the first measurements in the charmonium spectrum. They were followed by, among others, CLEO, BaBar, Belle, BES-III, CMD-3 and SND, with the latter three still in operation. Charmonium decay data sets have been supplemented by bottomonium decay data and open-flavor D and B meson decays. Proton–antiproton annihilation was studied at the Low Energy Antiproton Ring (LEAR) at CERN and new experiments at center-of-mass energies above charm threshold are planned for the FAIR facility (see the description of PANDA in the fixed target experiments section). LHCb is exploiting the highest energy ever reached by the LHC to produce a huge number of mesons and study their decays.

The experimental program of current facilities are rather similar an include the followed items

Exiotic states — pentaquart, hibrids ...
In-medium Properties of Hadrons
Meson Bound States
Pseudoscalar Mesons in Nucleus
Vector Meson Mass in Nucleus
In-medium Properties of Hadrons
Spectroscopy of η-, η′, ω - nucleus bound states

Facilities for meson production and decays ($M \leq 1$ GeV):

- Crystal Ball, MAMI-C, Mainz (γN)
- Crystal Barrel, BGO-OD, ELSA, Bonn (γN)
- KLOE-2, Daϕne, Frascati (e^+e^-)
- WASA, COSY, Jülich (pp, pd)
- HADES, GSI, Darmstad (pp, πp)

- Experimentalist at VEPP-2000 (BINP), CEBAF (JLAB), B-factories (Babar, Belle, Belle II)

The experimental program of every facility has own specific features in frame of common physics program. What can we do in current mainstrem?

Processes of interest

Experimental set
High resolution pion channel
Forward detector
CsJ crystall rearrangement
LH target upgrade

Physics program
Cusp effects in CEX reaction
CEX on bound neutron
eta-production on bound neutron
FSI study
Coherent pi and eta production on light nuclei

γ + A → π + A **γ + A → η + A**	**real coherent production on gemme beams**
γ + D → π + D **γ + D → η + D** **π + D → π + D**	**effect of eta in intermadiate state**
π + D → η + D	**isotopic breaking (comp with inclusive)**
π + A → η + A	**'coherent' production**
π + A → η + N + (A -1)	**quasi-free production**
π + A → N + [η + (A -1)]	**quasi-free production with bound state production**

Physics Potential 0n the Mesons Beams

The medium energy community initiated a new attention to experiments on meson beams. The meson beams were the main source of our knowledge of baryon resonances but now the data from meson beams old and pure in comparison with photoproduction data. Results of medium energy workshops strongly stresses the importance of new high quality experimental data from meson beams that complete or even produse the first step af analysis. So the preliminary review of new physics from meson beams and opportunity of creation of next generation meson beams are extremly supported by by all collaboration of medium energy physics and is actively developing

Current Hadronic Projects

It is important to recognize that current and forthcoming hadronic projects are largely complementary to the proposed hadron beam facility. We summarize the status of the J-PARC, HADES, COMPASS, and PANDA efforts here.

HADES at GSI collected unpolarized data for $\pi^- p \rightarrow \pi^- p$, $\pi^+ \pi^- n$, $\pi^0 \pi^- p$, $\pi^0 \pi^0 n$, $e^+ e^- n$ in August and September of 2014. EPECUR at ITEP collected unpolarized differential cross-section data for $\pi^\pm p \rightarrow \pi^\pm p$ back to 2009–2011. There is no chance to continue this program due to the accident with the ITEP 10-GeV proton synchrotron [201].

The COMPASS experiment at the CERN SPS is focused on the study of hadronic structure and spectroscopy. The primary tools are a high intensity muon beam and a 190 GeV pion beam. Currently, hadron structure is being probed by Drell-Yan measurements with transversely polarized protons. Measurements of generalized parton distributions and semi-inclusive deep inelastic scattering will start in 2015 and run through 2017 [202].

The PANDA experiment will be one of the key projects at the Facility for Antiproton and Ion Research (FAIR) currently under construction at GSI. PANDA is focused on studies of hadron structure, strange baryon spectroscopy, and hadron interactions. Antiprotons produced by a primary proton beam will be filled into the High Energy Storage Ring (HESR), where they will undergo collisions with the fixed target inside the PANDA detector. There is special interest in investigating the time-like form factor of the proton, searches for glueballs, hybrids, molecules, and tetraquarks, and investigations of in-medium effects. The HESR with PANDA and Electron Cooler will allow the storage of 10^{10} - 10^{11} antiprotons with momentum resolution $dp/p < 4◊10^{-5}$. The momentum range for antiprotons will cover 1.5 to 15 GeV/c and the electron range will be up to 9 GeV/c.

The main features of a new generation of meson beam experiments

The achivments of previous experiments -starting point for discussion

Rutherford Laboratory

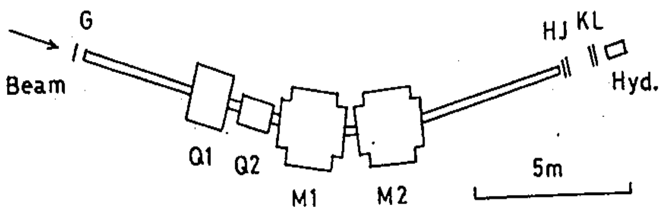
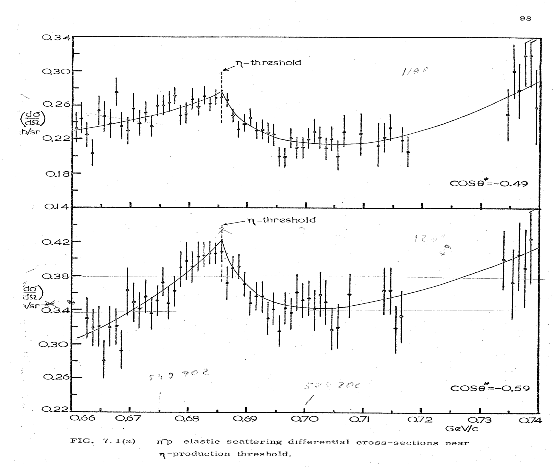
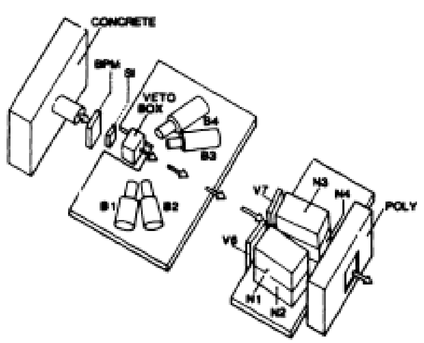
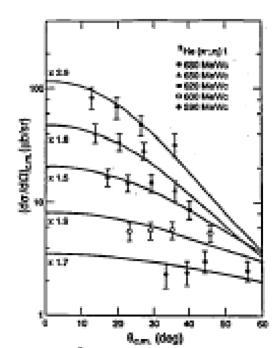


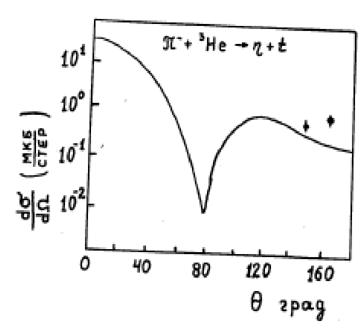
Fig. 1. The momentum spectrometer. The trajectory of a beam particle was registered in the five multiwire proportional chambers, G, H, J, K, L. G and H were at conjugate points with unit magnification, so that to a first approximation the momentum of a particle was determined by its relative positions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



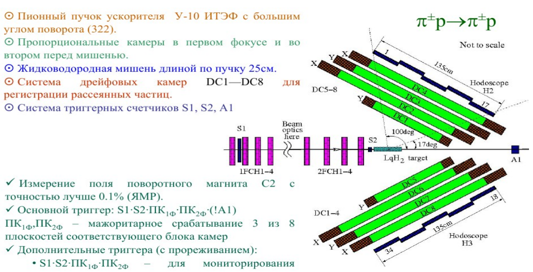
LAMP eta study -energy is not enough for eta study

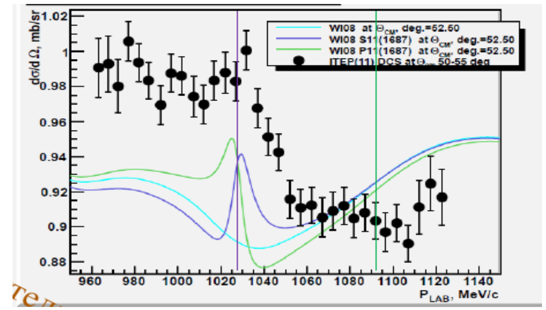


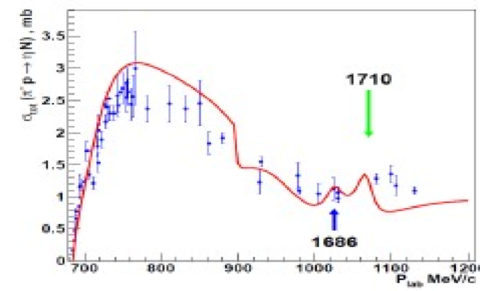




EPECUR is mentioned as experiment with unprecedented accuracy but stopped by accident
The experiment of new generation - why?
High resolution beam, attractive physics problem, adequate experimental set, unprecendentent statistics, physics model for analysis





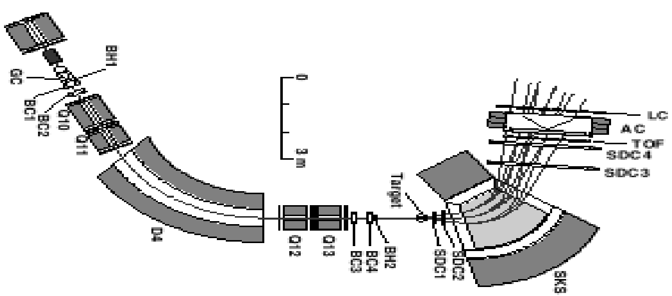


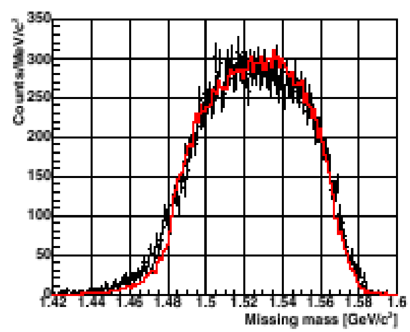
JPARC spectromets — searching for pentaquark.

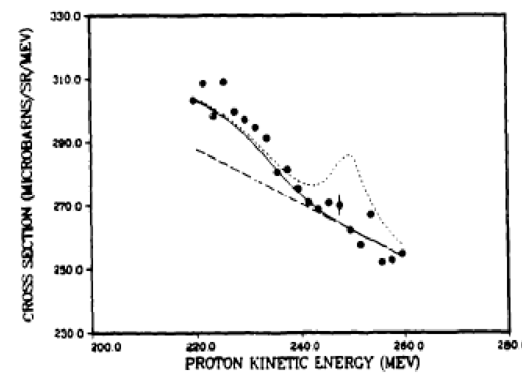
Total cross-section of the π-p→ηn reaction. Data points from Ref. [10]. Red line shows present calculations.(Gridnev)

The KEK J-PARC Hadron Facility is designed as a multipurpose experimental facility for a wide range of particle and nuclear physics programs, aiming to provide the world highest intensity secondary beams.

. The expected intensity is 1.4 ◊106 K− /pulse
10 **6 pions/spill)6 s)







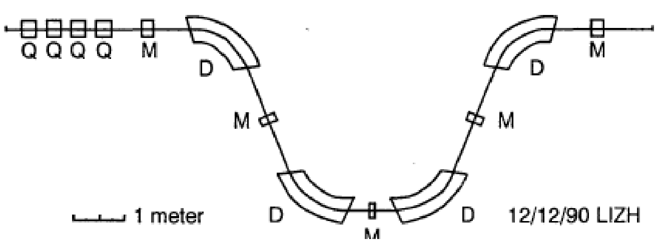
BNL and PNPI — big input in data collection
MMF and PNPI are not mentioned

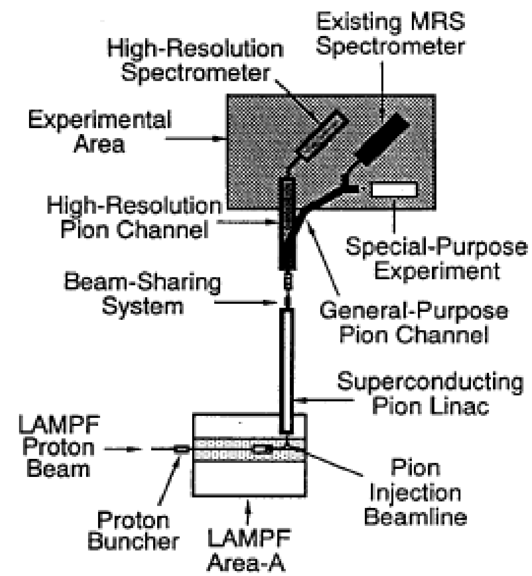
Experiment BNL

PILAC: A PION LINAC FACILITY FOR I-GEV PION PHYSICS AT LAMPF

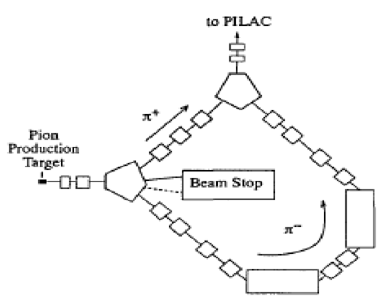
A design study for a Pion Linac (PILAC) at LAMPF is underway at Los Alamos. We present here a reference design for a system of pion source, linac, and high-resolution beam line and spectrometer that will provide log pions per second on target and 200-keV resolution for the (sct,K+) reaction at 0.92 GeV. A general-purpose beam line that delivers both positive and negative pions in the energy range 0.4-1.1 GeV is included, thus opening up the possibility of a broad experimental program as is discussed in this report. A kicker-based beam sharing system allows delivery of beam to both beamlines simultaneously with independent sign and energy control. Because the pion linac acts like an rf particle separator, all beams produced by PILAC will be free of electron (or positron) and proton contamination.

1.)A-hypemuclear physics via the (sc,K) reaction;
2.) A-nucleon scattering at threshold;
3.) rare decays of x and q;
4.) pion-nucleus elastic and inelastic scattering with 0.4-1.1 GeV pions; and
5.) baryon resonances.





. Concept for PILAC facility at LAMPF.



. Possible design for simultaneous n?and st- injection line for PILAC.

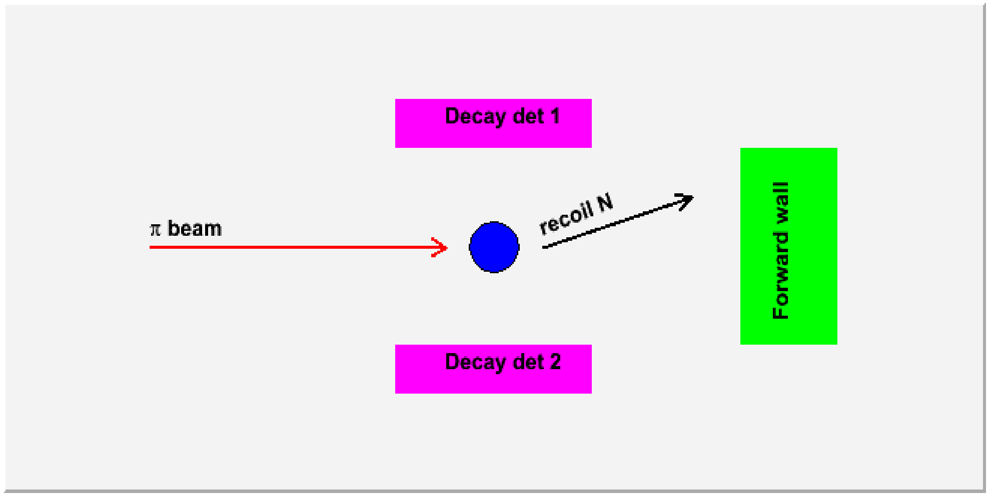
Old PILAC project : energy up to 1.2 GeV intensity up to 10^9 pion/s
New PILAC project : energy up to 1.5 GeV intensity up to 10^10 pion/s
new type of experiments pi-pi scattering

Experimental set

To combine the advantages of BNL, LPI and MAINZ eperimental set and TC technique

Two problems — statistics and sinal/background ratio

Experiment principle



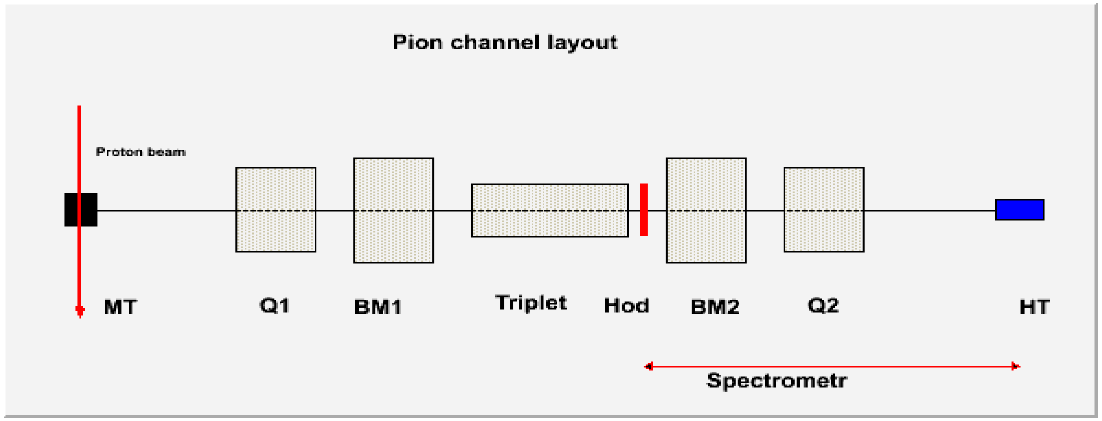
CsI(Tl)
Density(g/cm3) 4.53
Rad Length(cm) 1.85
dE/dx mip((Mev/cm) 5.6

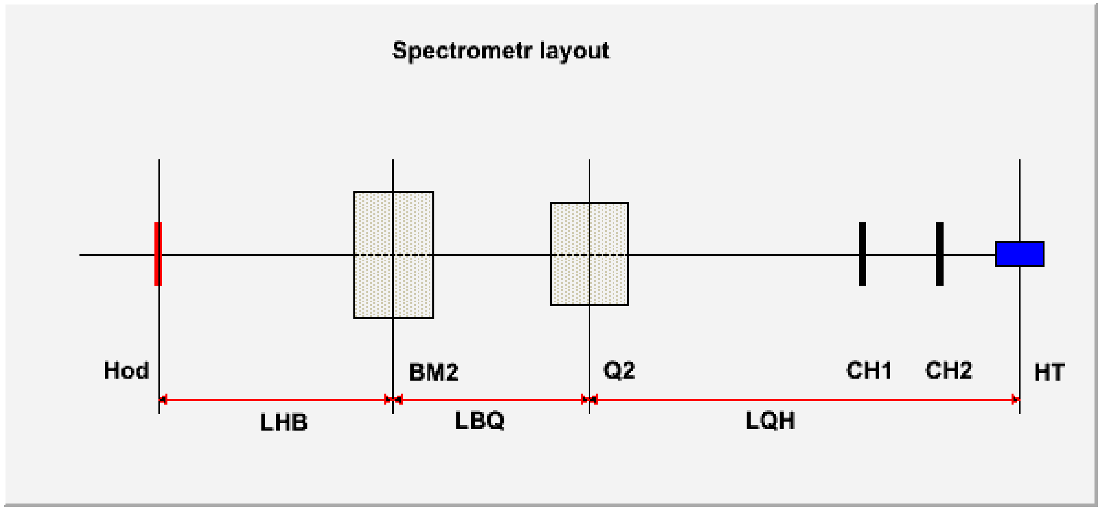
Two main types of experiments
High resolution forward detector
Real meson spectrometr

Continious gamma beam — limitation of counter rate
Pion beam — clean eta signal
Pi+ and Pi- beam
Amplitude of PiN is well-known

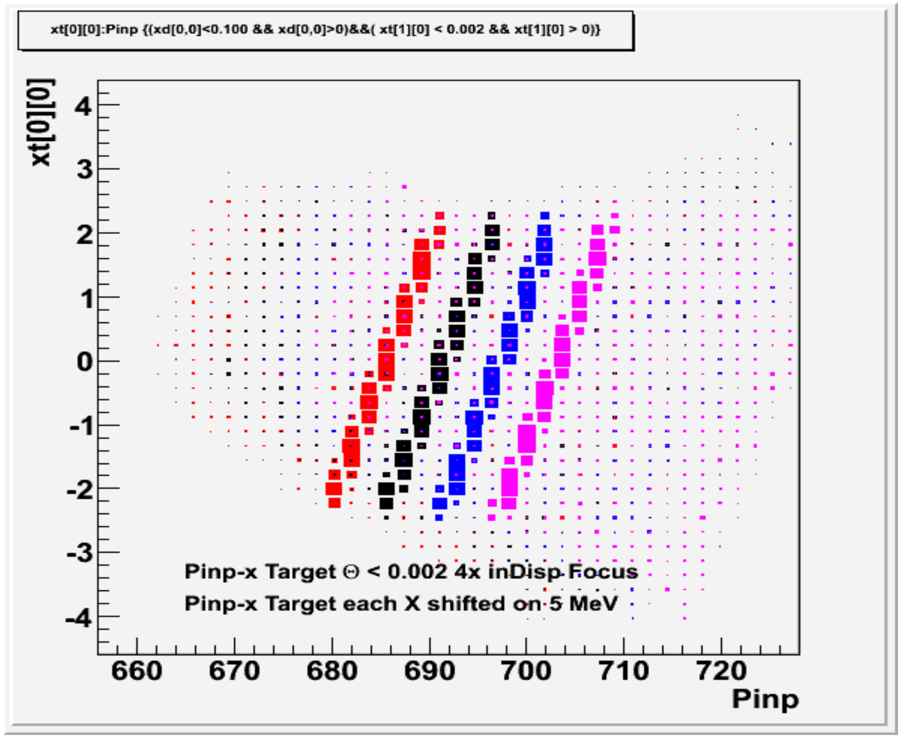
Aim — to reach momentum resolution of Rutherford Laboratory Channel (800 KeV)

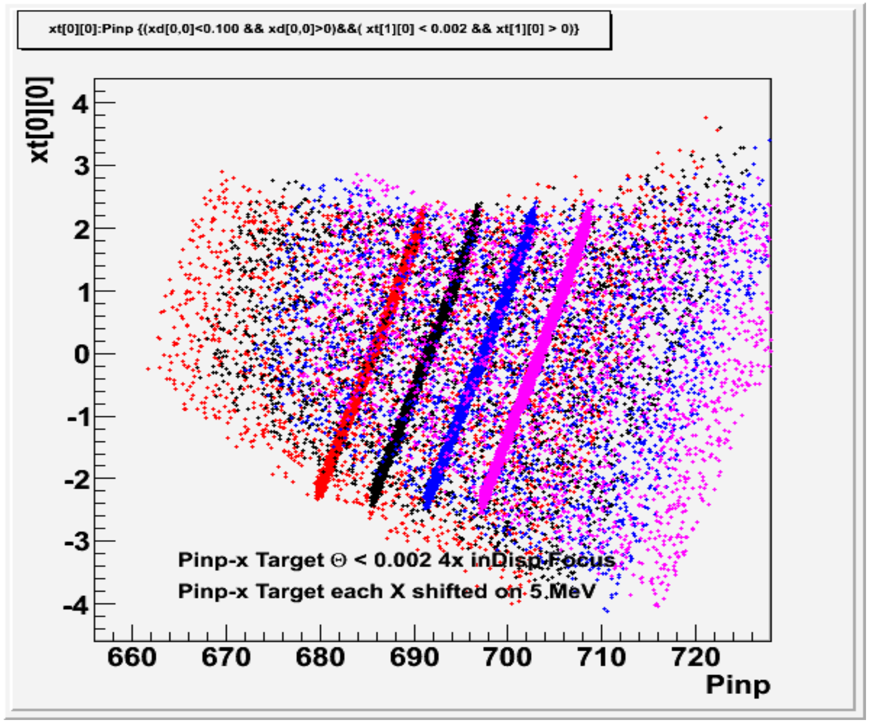
Meson channel upgrade





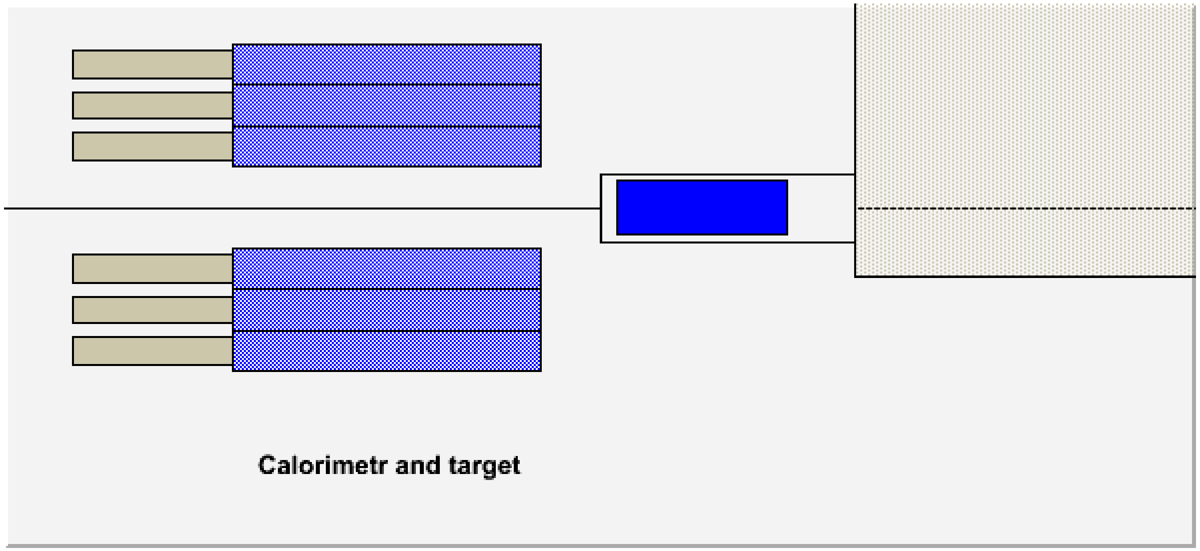
Chanel simulation (Bekrenev, Kozlenko, Filimonov)
The program MESON was upgraded

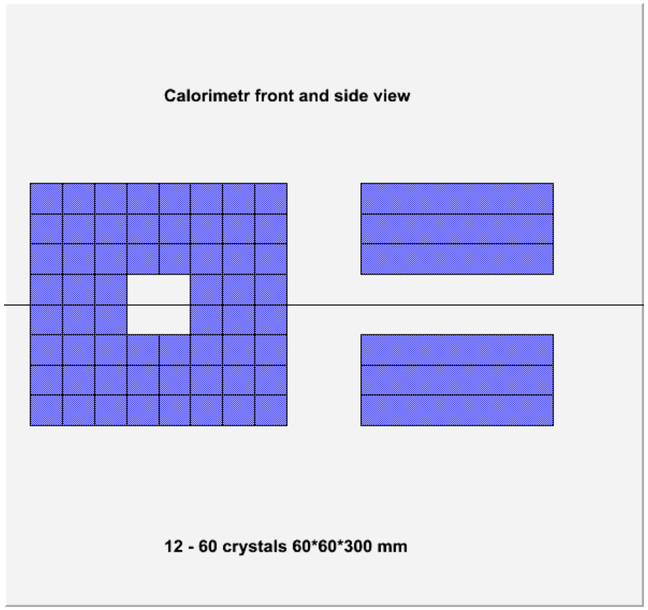


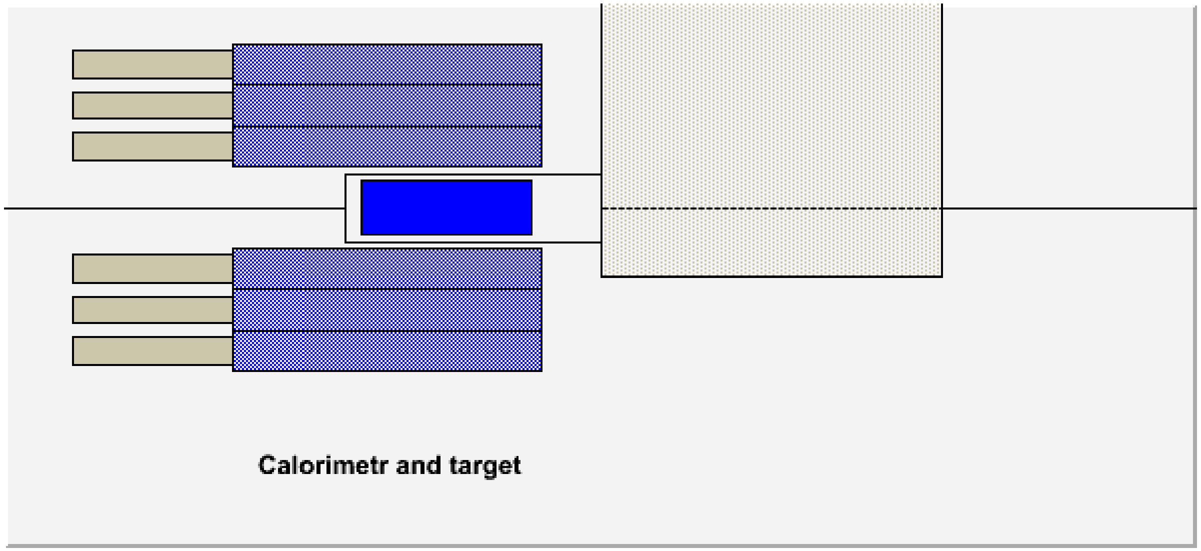


Target dispersion for 4 counters in Disp Focus. The lines shifted on 5 MeV for convinience. The resolution for each line is about 1 MeV
To increase distance bending magnet – target for better resolution.

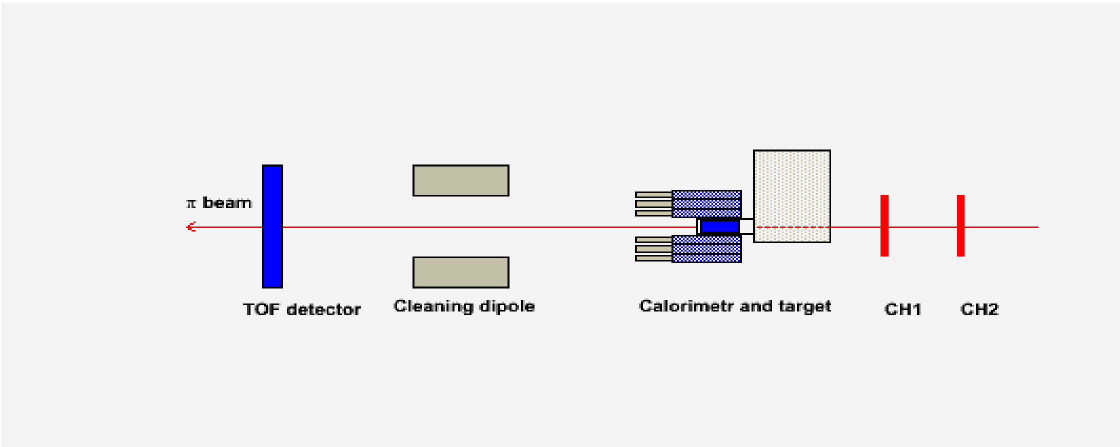
Calorimetr and target layout

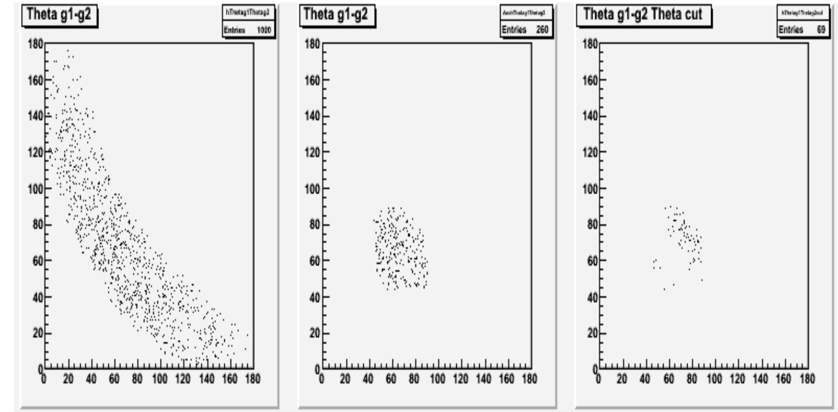






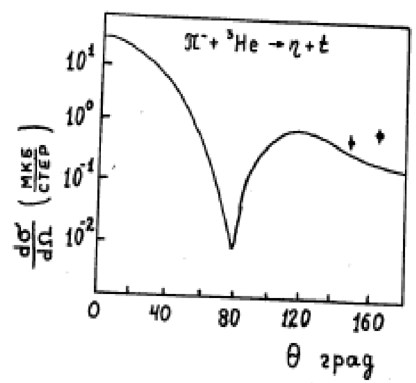
CsI(Tl) 60 crystals(60*60*30}
Density(g/cm3) 4.53
Rad Length(cm) 1.85
dE/dx mip((Mev/cm) 5.6
Target appendex





Counting rate for reaction pi- + 3He --> eta + T

acceptance 0.0015
stat errow 0.15 +- 0.005(3%)
3% -> 1000 10**4 full statistics
2 event/min —100 ev/hour 2000 ev/day
10**4 events --> 5 days
DCS pi + p -> eta + n 0.15 mb/sr
DCS pi- + 3He -> eta + t 10 mkb/sr
Ratio DCS 15
AcceptGG 0.26 26%
AcceptGGP 0.06 6 %
RatioAcc 0.06/0.0015 = 40
Cunting Rate CR = 300 ev/hour



Quality of LAMPF result

PROBLEMS:

Physics problem — to separate background reactions
To choose geometry
Experimental problems:
Experimentsents with hight beam energy resolution
Final state resolution

There are two main attractive probllems of medium energy physics:
eta – neutron anomaly
eta – nuclear bound state
Experimental problems to be solved before seaching of mentiond problems:
cusps problems
FSI problems
So we need higt beam resolution and final state high resolution
FS resolution mainly restricted byshower detector s resolution
Beam momentum is about 1 MeV

$\eta - \eta'$ physics -hidden strangness, gluon component, invisible decays and is included as a separate branch in physics program of all upgraded world experimental sets. Majority of experimental data were obtained and will be obtained from gamma beam of world laboratories.. So the pion beam of PNPI is the only facilities to obtaine experimental data on pion beam.

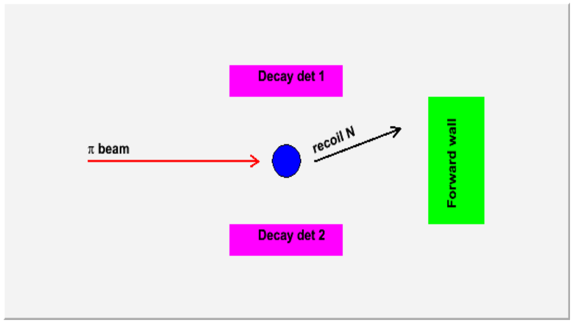
Pion beam — clean Eta signal and Eta nn or Eta pp final state(Eta np from gamma beam)

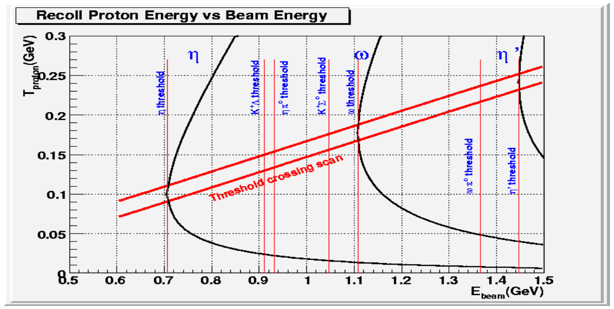
Pion beam cever the momentum range of interest(gamma beam – continious spectra)

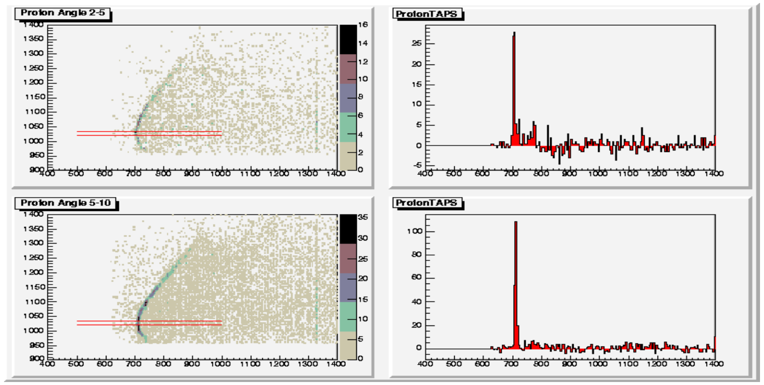
Eta production from hydrogen. TC and mass measurement ??
Eta prod from neutron
Cusp in charge-exchange
Quazi - free eta-production from deutron (n and p target)
FSI eta-n eta-p (how correctly we use bound neutron)
eta production from light nuclei
pi- + 3He --> eta + T(pi T=1 p<->n gamma T=0)
Quasi-free reaction
Charge symmetry breaking(CSB)
pi- +4He --> eta n +T
pi++4He --> eta p + 3He
pi- + 4He --> eta p + 3He --> p + (eta + 3He) --> p + (pi + p + D) eta abs
pi+ + 4He --> pi+ + n + 3He --> eta + p + 3He --> p + (eta + 3He) -> p + (pi- + p + 3n)
pi+ + 4He --> pi+ n + 3He --> eta + p + 3He -> p + (eta + 3He) -> p + (eta +p +D) p +(pi0 + p + D)
eta bound state(Exp BNL and FIAN) experiment on solid target CH2 - 12C
The same approximation as piD->eta np SL etaT eta3He
Cusp in eta decay

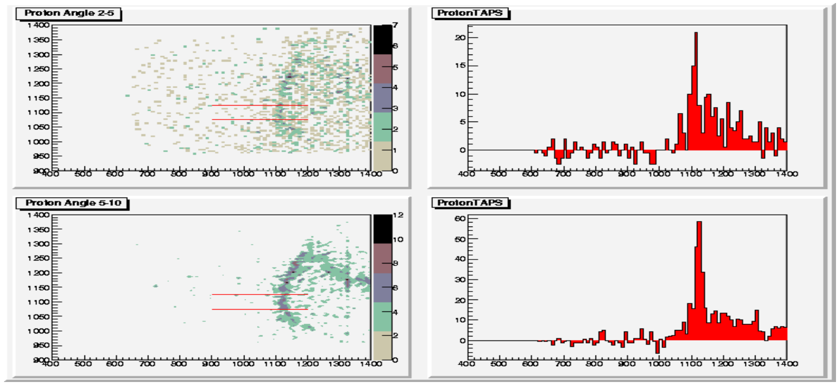
The main ideas of experimental set

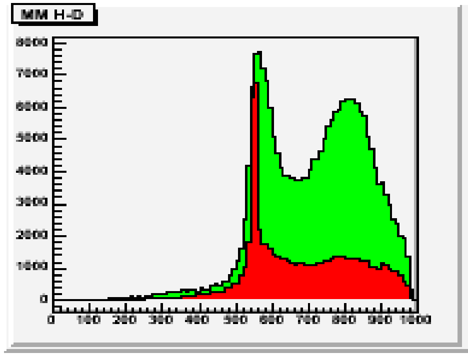
The main idea — the precision of data from high resolution beam and forward detector.
Array os CsI crysrals just for chanel selection

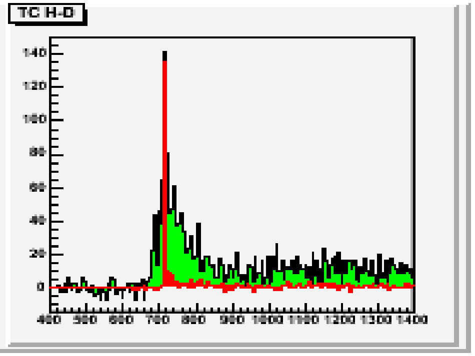












The main info from forward detector

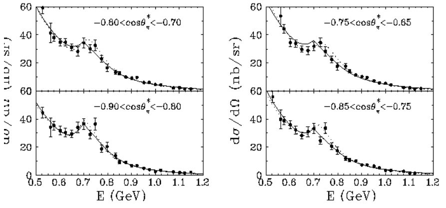
Sensivity for Fermi motion
Sensivity for width
Good ratiosignal/bg

The current outlook on experimental program on meson beam of PNPI

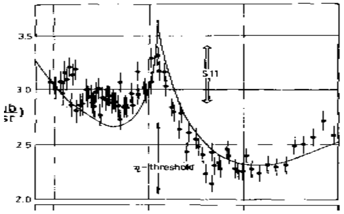
Processes of interest at PNPI meson beam

Possible effects

Process	Effect
$\gamma + A \rightarrow \pi + A$	real coherent production
$\gamma + A \rightarrow \eta + A$	on gemme beams
$\gamma + D \rightarrow \pi + D$	effect of eta in
$\gamma + D \rightarrow \eta + D$	intermadiate state
$\pi + D \rightarrow \pi + D$	
$\pi + D \rightarrow \eta + D$	isotopic breaking (comp with inclusive)

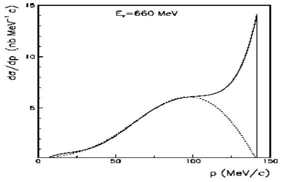


$\pi + P \rightarrow \pi + P$ 'cusp' in CEX



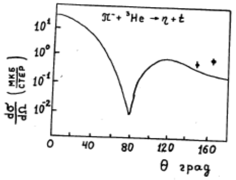
$\pi + A \rightarrow \eta + N + (A-1)$ quasi-free production

$\pi + A \rightarrow N + [\eta + (A-1)]$ quasi-free production with bound state production



$\pi + A \rightarrow \eta + A$ 'coherent' production

$\pi + 3He \rightarrow \eta + T$



Effects of interest are really exist and may be used for estimation of experiment accuracy on the first stage of experiments mapping out.

Current results from A2 collaboration

The experimental program was mapped out ten years ago and wos based on our undestanding of mediun energy physics problem and reflect classic approximation
accurate data - full data set - PSA as a main tool of data analysis
The unprecedentable quality of obtained data
A lot of problems just stressed and a new generation of experiments are needed

Conclusion

A2 collaboration is only group producing the presision experimental data
The processing of obtained data are still in progress by maaaaain theoretical groups/
Experimental program of A2 collaboration still in progress and continiousy specified by new obtained data
Crystall Ball is to old detector for further using espessially taking into account an uncoming new facilities.
The world workshops on program on new generation facilities is under stron g influence of obtained results of A2 collaboration
New tools for analysis is under discussion. The total cross-section is not enough for hunting on new exotic and to determine the quantum numbers of resonances from PWA.
New generation of meson facilities — how to be involved?
PILAC 10^9 pi/s J-PARC 10^6 pi/s
The upgrading of PNPI facilities — is it possible to keep PNPI as a member of medium energy community?
The upgradingmay be divaided into to several steps:
Pion channel, Forward detector,LH target, rearrangment of crystals, realeta - spectrometr

There are several **Hadronic projects** in Progress

EPECURE @ ITEP [2009-2011], **HADES** @ GSI [2013-2014], & **J-PARC** [2015+ ?]

EPECUR	HADES	J-PARC	PILAC ?	PNPI ?
$\pi^- p \to \pi^- p$, $K\Lambda$ $\pi^+ p \to \pi^+ p$	$\pi^- p \to \pi^- p$, $\pi^0 n$, $2\pi N$, KY, γn, $e^+e^- n$ $\pi^+ p \to \pi^+ p$, $2\pi N$	$\pi^\pm p \to \pi^\pm p$, $2\pi N$, KY		
Igor Alekseev	*Piotr Salabura*	*Ken Hicks*		

Status of A2 collaboration and potential of medium energy physics

Abstract

Now the first stage of experiments of A2 collaboration on unpolarized target is completed and experimental data are partly processed and published. This results strongly influenced on the second stage of experiments — data from polarized target -which now is in progress and first results are published. The obtained results are discussed at many workshops on perspectives of medium energy physics and strongly affected on experimental program of a new generation of facilities. This results also initiated a new interest to opportunity of secondary hadron beam in medium energy physics.
The review of obtained results and status of current experimental program of A2 collaboration and perspectives of medium energy physics are presented in this report.

Introduction

Medium energy physics is a critical tool for a test of QCD and our knowlege of resonances study. The experimental base for medium energy physics primly came from pion beams but over the past two decades, meson photo- and electroproduction data of unprecedented quality and quantity have been measured at electromagnetic facilities worldwide. Now a new generetion of medium energy facilities is under construction and A2 collaboration at MAINZ is almost only group that regulary produce new high quality experimental data. The first step of experimental program (as it was mapped out ten years ago) - experiments on unpolarized target - are almost completed and the second stage — experiments on polariszd target - started and first results are published .The obtained results attracted the world wide attention in its interpritation and a new problems arisd from this results. This problems are discussed at numerous workshops devoted to physics programs on uncoming new facilities. The new tools for next generation of experiments(specific computers, physics simulation, experiment mapping out for exotic states hunting) are under discussion on specific workshops. One of results of discussions is a new interest to secondary hadron beams as a source of a new data to complit a set of experimental data for solving of erectied problems. The problem for PNPI — how to be involved in world mainstrem -are presented for discution in this report.

Abstract

Introduction

Current results from A2 collaboration

The experimental program of A2 collaboration was formulated about 10 years ago and was based on our understanding of medium energy phisics at that time. Now the first stage of this program is over and experimental data are partly processed and published. Unprecendenttted accuracy. New effects is seen.
Main problem(exotic resonances) is not solved
Exotic experiments — double scattering(to reduce energy losses in polarized target), coherent production, QB eta states. No clear results.
Result are using for mapping of new experiments
Currently the second stage of program— spin observables experiments-in progress and the first results are published. The results are in contradiction with PWA predictions.
Energy step is too ladge. The data should be included in PWA (it will be possible to explaine R(1680) as interferense of known resonances?

Physics problems

New generation of facylyties is oncoming and worldwide duscution on experimental programs are under dicsussion in numerous workshops.
Main problem — existing of the exotic resonences. Yet there are no thepretical arguments to forbit its existance .
Eta- eta' -decays(CP violation, invisible decay)
If such resonances exist the production CS is small and the width also can be narrow.
Conventional PWA tends to miss resonances (or cusos) with width < 30 MeV.
So it iis nessesary to unite experimental and theoretical efforts.
Exotic mesons Missing resonances Invisible decay η/η' mesons Medium modification
pi-pi interaction sharp effects at energy of 1680 Reaction mechanizm
Experiment s with high beam energy resolution.
Cusps imitation of new physics FSI and bound states eta in intermadiate states
Phase-shift analysis — new approaches and low systematics Dark matter- invisible decay of eta-eta'

Experimental sets

Main facilities(short review)Energy resolution of eta 40 MeV

Gamma beams Bremsstrahlung beams Continious spectrum Background limitation Laser beam

Tagger, Main detector(prompt and random data)

Status of current fasilities

Hadron fasilities Electron facilities Mpping of new experiments Curent analysis tools

Meson beams

The main set of experimentaldata for PWA came from pion beams. Now the quality of pion data is bad in comparison with current phton beams. It is a reason for medium energy community to pay attention on opportunity of meson beams and a worldwide discussion

about of percpectives of aecondry hadron beams .

Physics advantages of PB — simple and well-knowm piN-amplitude, another channels.

Clean signal from light meson, relible triggerfor data taking, low systematics.

Current hadron facilities

New LINAC — really new generation facilities.

ITEP pessimizm in world and optimizm in ITEP. Now poor data(Gridnev model)

MMF and PNPI is not mentioned in new proposals

Energy resolution1-2 MeV(ITEP) 850 KeV(RL)

Intensity up to 10^9 (LINAC)(compare with 10^6 from JPARC) reall y new generation of experiments

PNPI perspectives

Physics. Pion chanel. Experimental set LH target Crystals rearrangment, Real eta - spectrometr..

Conclusion

The russian facilities are even not mentioned in future oppotunities of medium energy physics.

ITEP — example of to attrack worldwide attention in spite of poor funding

To try to recover PNPI facility and to keep our input in medium energy physics

Several steps – pion channel, forward detector, crystal rearragment, real eta - spectromenntr

Analysis Tools for Next-Generation Hadron Spectroscopy Experiments

arXiv:1412.6393v1 [hep-ph] 19 Dec 2014

PREFACE

The series of workshops on New Partial-Wave Analysis Tools for Next-Generation Hadron Spectroscopy Experiments was initiated with the ATHOS 2012 meeting, which took place in Camogli, Italy, June 20–22, 2012. It was followed by ATHOS 2013 in Kloster Seeon near Munich, Germany, May 21–24, 2013. The third, ATHOS3, meeting is planned for April 13–17, 2015 at The George Washington University Virginia Science and Technology Campus, USA.

The workshops focus on the development of amplitude analysis tools for meson and baryon spectroscopy, and complement other programs in hadron spectroscopy organized in the recent past including the INT-JLab Workshop on Hadron Spectroscopy in Seattle in 2009, the International Workshop on Amplitude Analysis in Hadron Spectroscopy at the ECT*-Trento in 2011, the School on Amplitude Analysis in Modern Physics in Bad Honnef in 2011, the Jefferson Lab Advanced Study Institute Summer School in 2012, and the School on Concepts of Modern Amplitude Analysis Techniques in Flecken-Zechlin near Berlin in September 2013.

The aim of this document is to summarize the discussions that took place at the ATHOS 2012 and ATHOS 2013 meetings. We do not attempt a comprehensive review of the field of amplitude analysis, but offer a collection of thoughts that we hope may lay the ground for such a document.

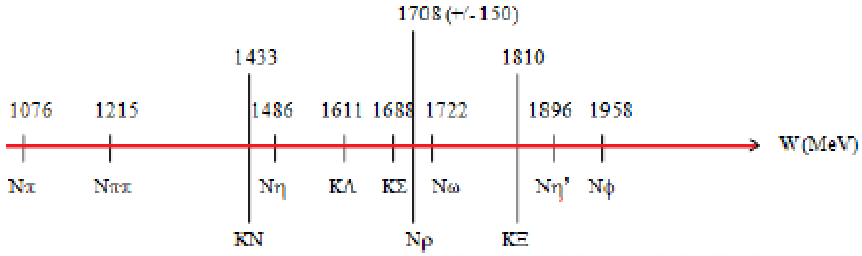
Tools

A. Incorporation of theoretical innovations
B. Efficient calculation of likelihood functions
C. Statistical evaluation of results
D. Existing fitting tools and collaborative code development

Current PWA miss narrow resonances

Secondary Beam Possibilities(Strakovsky)

- Baryon Spectroscopy
  - Why and How we are doing that
- $\pi N \rightarrow$ Inelastic
  - $\pi^- p \rightarrow \eta n$, KY, ωn
  - $\pi N \rightarrow 2\pi N$
  - $\pi^- p \rightarrow e^+ e^- n$
  - Current Hadronic Projects
- What EIC may Do



Too musch so called 'puzzles'(may be systematic or cusp)

There are several **Hadronic projects** in Progress

EPECURE @ ITEP [2009-2011], **HADES** @ GSI [2013-2014], & **J-PARC** [2015+ ?]

EPECUR

$\pi^- p \rightarrow \pi^- p$, $K\Lambda$
$\pi^+ p \rightarrow \pi^+ p$

Igor Alekseev

HADES

$\pi^- p \rightarrow \pi^- p, \pi^0 n, 2\pi N$, KY, γn, $e^+ e^- n$
$\pi^+ p \rightarrow \pi^+ p, 2\pi N$

Piotr Salabura

J-PARC

$\pi^{\pm} p \rightarrow \pi^{\pm} p, 2\pi N$, KY

Ken Hicks

MesonNet

EU network for light meson decay and production studies

7th Framework Programme HadronPhysics3
2012-2014

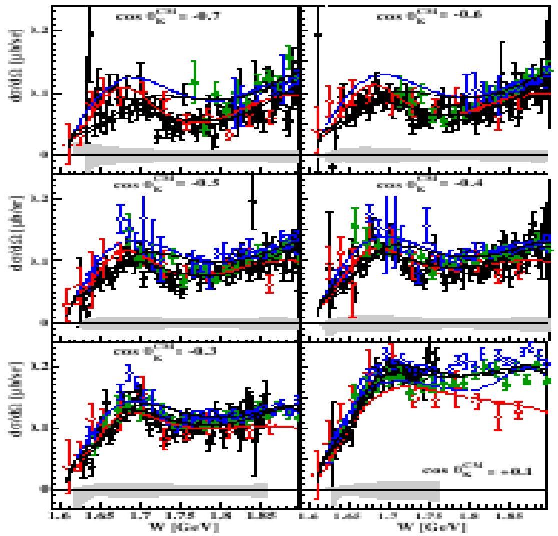
Sources of the mesons

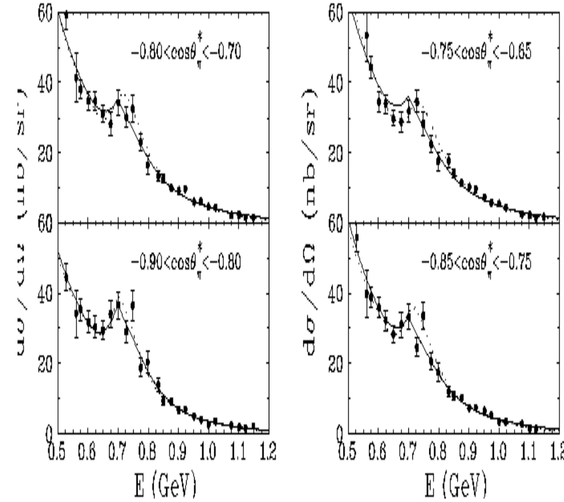
- Crystal Ball: $\gamma p \to p\eta$ — $3\times10^7\ \eta$
- KLOE: $e^+e^- \to \phi$ — $>10^{10}\ \phi$/year
- KLOE: $e^+e^- \to \phi \to \eta\gamma$ — $>10^8\ \eta$/year
- WASA: $pd \to {}^3\text{He}\eta$ $10\ \eta/s$ — $3\times10^7\ \eta$ decays
- WASA: $pp \to pp\eta$ $\geq 100\ \eta/s$ — $>10^8\ \eta$ decays
- WASA: $pp \to pp\pi^0$ $\approx 2500\pi^0/s$ — $\approx 10^9\ \pi^0$ decays

Three-body nature of N ∗ and Δ∗ resonances from sequential decay chains

arXiv:1501.02094v1 [nucl-ex] 9 Jan 2015

The N π 0 π 0 decays of positive-parity N ∗ and Δ∗ resonances at about 2 GeV are studied at ELSA by photoproduction of two neutral pions off protons. The data reveal clear evidence for several intermediate resonances: Δ(1232), N (1520)3/2− , and N (1680)5/2+ , with spin-parities J P = 3/2+ , 3/2− , and 5/2+ . The partial wave analysis (within the Bonn-Gatchina approach) identifies N (1440)1/2+ and the N (ππ)S−wave (abbreviated as N σ here) as further isobars, and assigns the final states to the formation of nucleon and Δ resonances and to non-resonant contributions. We observe the known Δ(1232)π decays of Δ(1910)1/2+ , Δ(1920)3/2+ , Δ(1905)5/2+ , Δ(1950)7/2+ , and of the corresponding spin-parity series in the nucleon sector, N (1880)1/2+ , N (1900)3/2+ , N (2000)5/2+ , and N (1990)7/2+ . For the nucleon resonances, these decay modes are reported here for the first time. Further new decay modes proceed via N (1440)1/2+ π, N (1520)3/2− π, N (1680)5/2+ π, and N σ. The latter decay modes are observed in the decay of N ∗ resonances and at most weakly in Δ∗ decays. It is argued that these decay modes provide evidence for a 3-quark nature of N ∗ resonances rather than a quark-diquark structure.





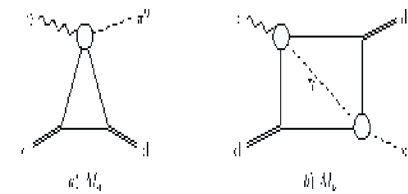
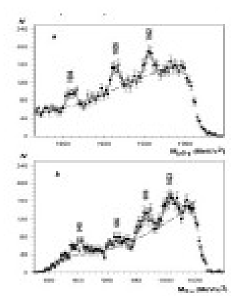
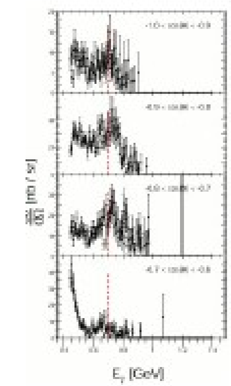
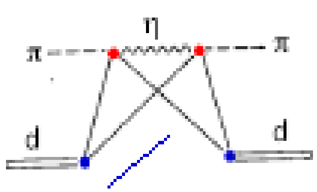
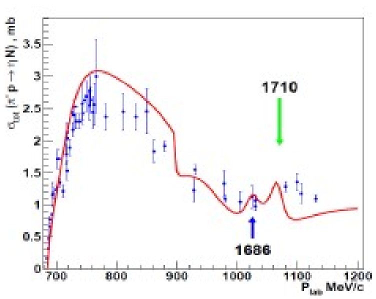


Fig. 1. Feynman diagrams for the $\gamma d \to \pi^0 d$ reaction considered in [24]: (a) single-scattering amplitude M_a; (b) double-scattering amplitude M_b. It was shown in [24] that (b) dominates over (a) at backward angles for $E_\gamma \sim 700$ MeV.









Total cross-section of the π-p→ηn reaction. Data points from Ref. [10]. Red line shows present calculations.(Gridnev)