New status
of the project **“η-nuclei”**
at the Nuclotron

Dryablov D.K.

Collaboration

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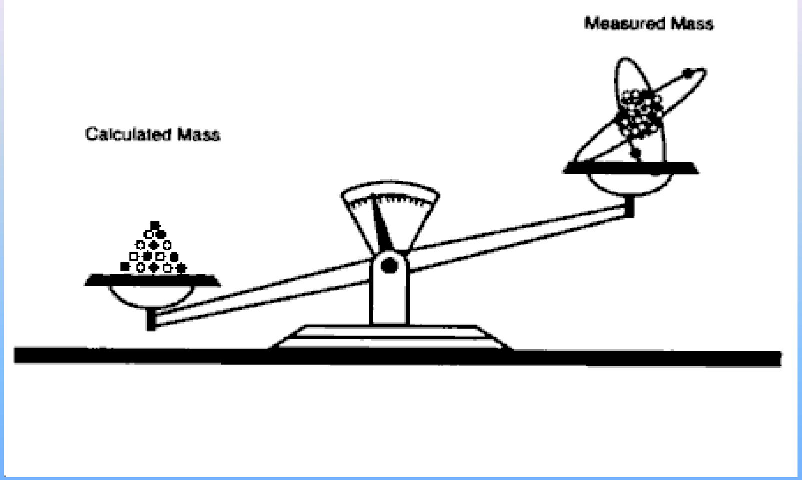
Motivation

The properties of hadrons in nuclear medium are one of the interesting topics of the modern hadron and nuclear physics. All nuclei have essentially smaller mass than sum of masses all neutrons and the protons formed nuclei. The difference of masses is a result of strong interaction between hadrons which formed composite system. It is possible to assume, that particles, distinct from nucleons such as an η - meson, in nuclear medium will have smaller mass than in a free state.



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η- & η'-mesic nuclei and $U_A(1)$ anomaly at finite density

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We discuss theoretically the possibility of observing the bound states of the η and $\eta'(958)$ mesons in nuclei. We apply the NJL model to study the η and η' meson properties at finite density and calculate the formation cross sections of the η and η' bound states with the Green function method for (γ,p) reaction. We also discuss the experimental feasibility at photon facilities like SPring-8. The contributions due to the ω meson production are also included to obtain the realistic (γ,p) spectra. We conclude that we can expect to observe resonance peaks in (γ,p) spectra for the formation of meson bound states and we can deduce new information on η and η' properties at finite density. These observations are believed to be essential to know the possible mass shift of η' and deduce new information on the effective restoration of the $U_A(1)$ anomaly in the nuclear medium.

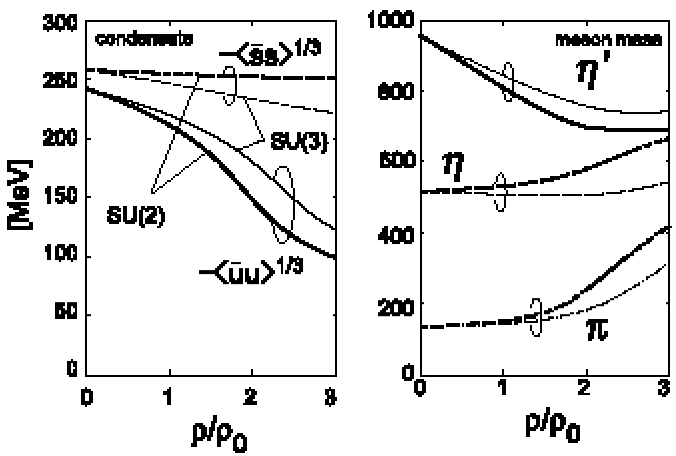


FIG. 3: Density dependence of the quark condensates (left panel) and the meson masses (right panel) are shown for the SU(2) symmetric matter (thick lines) and the SU(3) symmetric matter (thin lines). The nucleon density ρ is defined in Eq. (7) and ρ_0 is the normal nuclear density $\rho_0 = 0.17$ fm^{-3}.

CONCLUSIONS

The present evaluation is the first theoretical results for the formation reaction of the η- and η'-mesic nuclei based on the NJL model results to know the behavior of $U_A(1)$ anomaly in the medium. We believe that the present theoretical results is much important to stimulate both theoretical and experimental activities to study the $U_A(1)$ anomaly at finite density and to obtain the deeper insights of QCD symmetry breaking pattern and the meson mass spectrum.

K. Tsushima
Nuclear Physics A670 (2000) 198c-201 c ,
“Study o f ω, η, η' and D⁻-mesic nuclei”

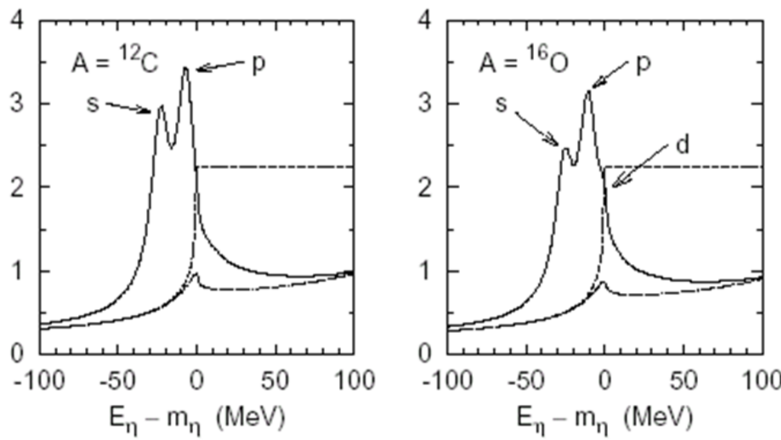
K. Tsushima , D.H. Lu , A.W. Thomas, K. Saito Physics Letters B 443 1998 26–32,
“Are η- and ω-nuclear states bound.”

Table 1

η, ω and η' bound state energies (in MeV), $E_j = Re(E_j^* - m_j)$ $(j = \eta, \omega, \eta')$, where all widths for the η' are set to zero. The eigenenergies are given by, $E_j^* = E_j + m_j - i\Gamma_j/2$.

		$\gamma_\eta = 0.5$		γ_ω=0.2		$\gamma_{\eta'} = 0$
		E_η	Γ_η	E_ω	Γ_ω	$E_{\eta'}$
$^{6}_{j}$He	1s	-10.7	14.5	-55.6	24.7	* (not calculated)
$^{11}_{j}$B	1s	-24.5	22.8	-80.8	28.8	*
$^{26}_{j}$Mg	1s	-38.8	28.5	-99.7	31.1	*
	1p	-17.8	23.1	-78.5	29.4	*
	2s	—	—	-42.8	24.8	*
$^{16}_{j}$O	1s	-32.6	26.7	-93.4	30.6	-41.3
	1p	-7.72	18.3	-64.7	27.8	-22.8
$^{40}_{j}$Ca	1s	-46.0	31.7	-111	33.1	-51.8
	1p	-26.8	26.8	-90.8	31.0	-38.5
	2s	-4.61	17.7	-65.5	28.9	-21.9
$^{90}_{j}$Zr	1s	-52.9	33.2	-117	33.4	-56.0
	1p	-40.0	30.5	-105	32.3	-47.7
	2s	-21.7	26.1	-86.4	30.7	-35.4
$^{208}_{j}$Pb	1s	-56.3	33.2	-118	33.1	-57.5
	1p	-48.3	31.8	-111	32.5	-52.6
	2s	-35.9	29.6	-100	31.7	-44.9

A. I. L'VOV nucl-th/9809054
PRODUCTION AND DECAY OF ETA -MESIC NUCLEI



Proposed mass shift for S_{11} $\Delta m(S_{11}) = (24\div30)_\eta + (8)_N$ =30-40 MeV In nuclear medium

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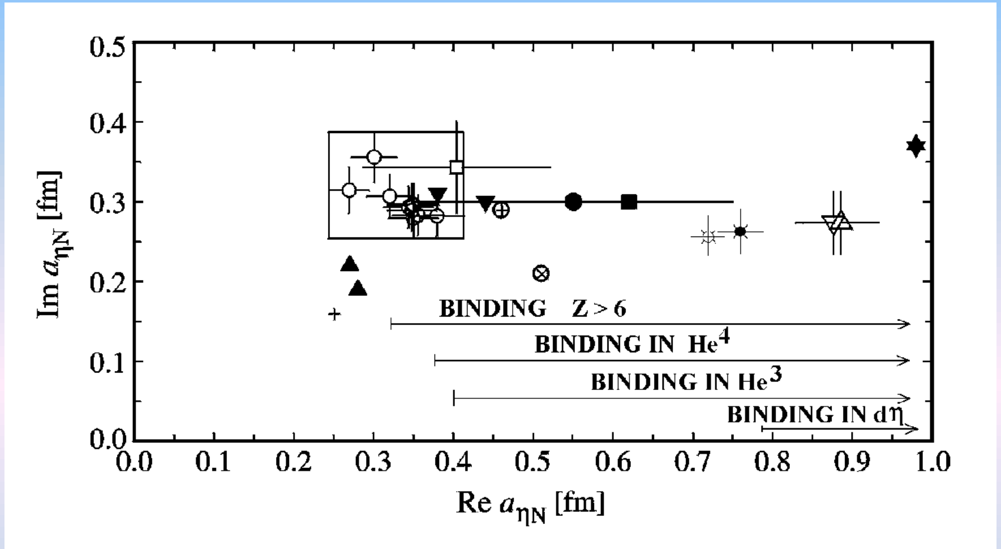
The problem of extremely poorly determined value of the real part of the ηN S-wave scattering length has been known for years, and the limits have been 0.2 fm< Real($a_{\eta N}$) <0.98 fm. *(Pic. from nucl-th/0009024)*



ηN S-wave scattering length.
The symbols for all extracted values are taken over from (*M.Batinic and A.Svarc, Few Body Syst. 20, 69 (1996);* **crossed empty circles** *(M.Batinic, et al., Physica Scripta 58, 15 (1998);* **crossed full circles - (***A.M.Green and S.Wycech, Phys. Rev. C 55, R2167 (1997))*
Lines given on the gure indicate for which values there is a probability for the -light nuclei bound states - (*S. Wycech, Workshop on Physics with the WASA Detector, S¨atra Brunn, June 17-19, 1996, Sweeden)*

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Production of light and medium η-nuclei is cased [1, 2] mainly by the subprocess $NN \to \eta X$ followed by a capture of the produced η-meson to a bound s-state (capture to a bound state with an excited orbital moment, if any, happens with lower probability because of a stronger suppression of the wave function of eta inside the nucleus). The final nucleon X has a large momentum and escapes from the nucleus. Decaying through the channel πN, the η-nucleus is seen as an intermediate state in the chain

$$\boldsymbol{d + A \to \eta(A-1) + X \to \pi + N + (A-2) + X.}$$

The life time of the bound eta is rather short; the width of the η-levels is about **20 to 30** MeV (***H.C. Chiang, E. Oset, and L.C. Liu, Phys. Rev. C44 (1991) 738***.) and covers most nuclear levels.

1] M. Kohno and H. Tanabe, Phys. Lett. B231 (1989) 219.
[2] A.I. Lebedev and V.A. Tryasuchev, J. Phys. G17 (1991) 1197.

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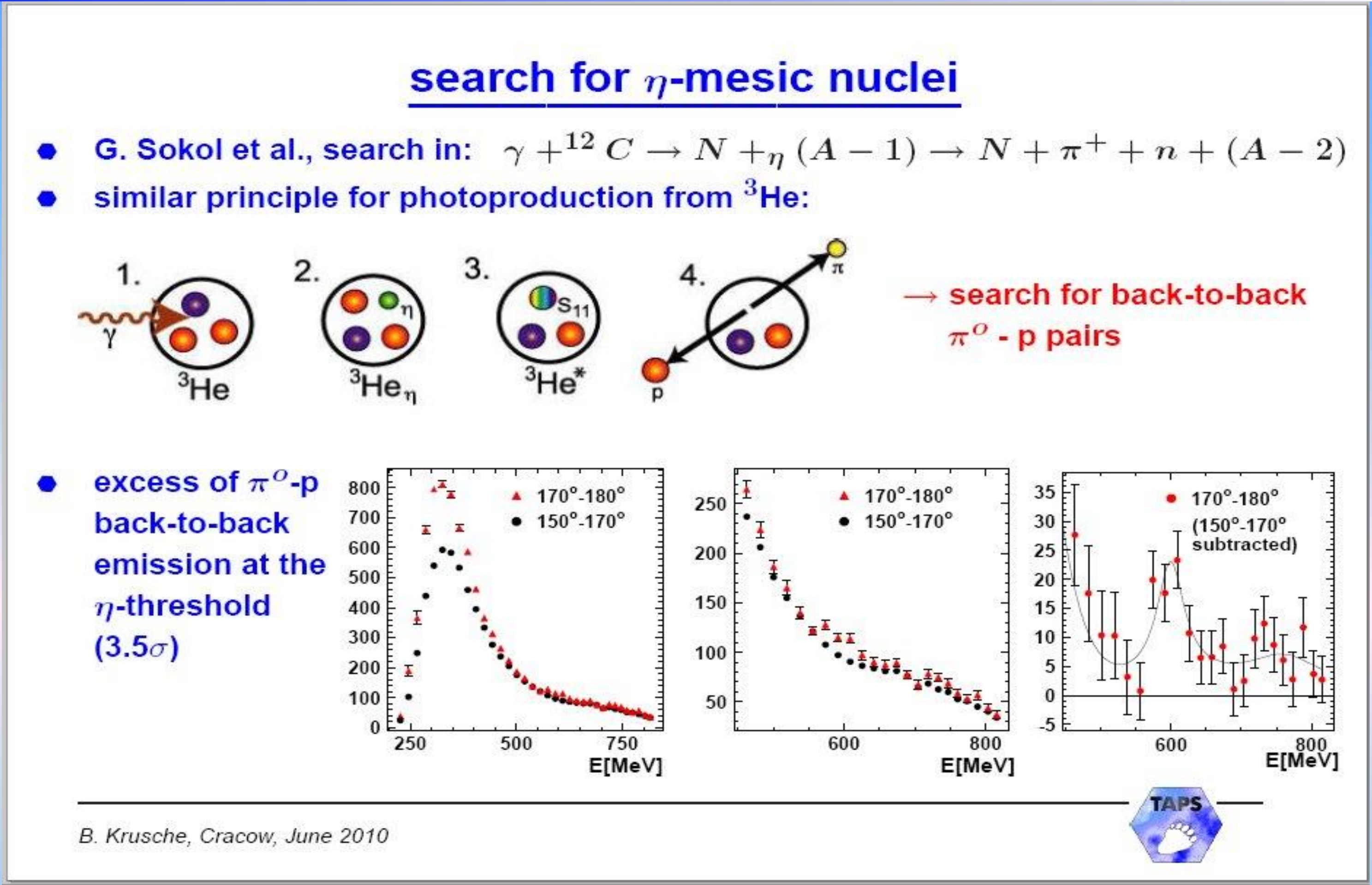
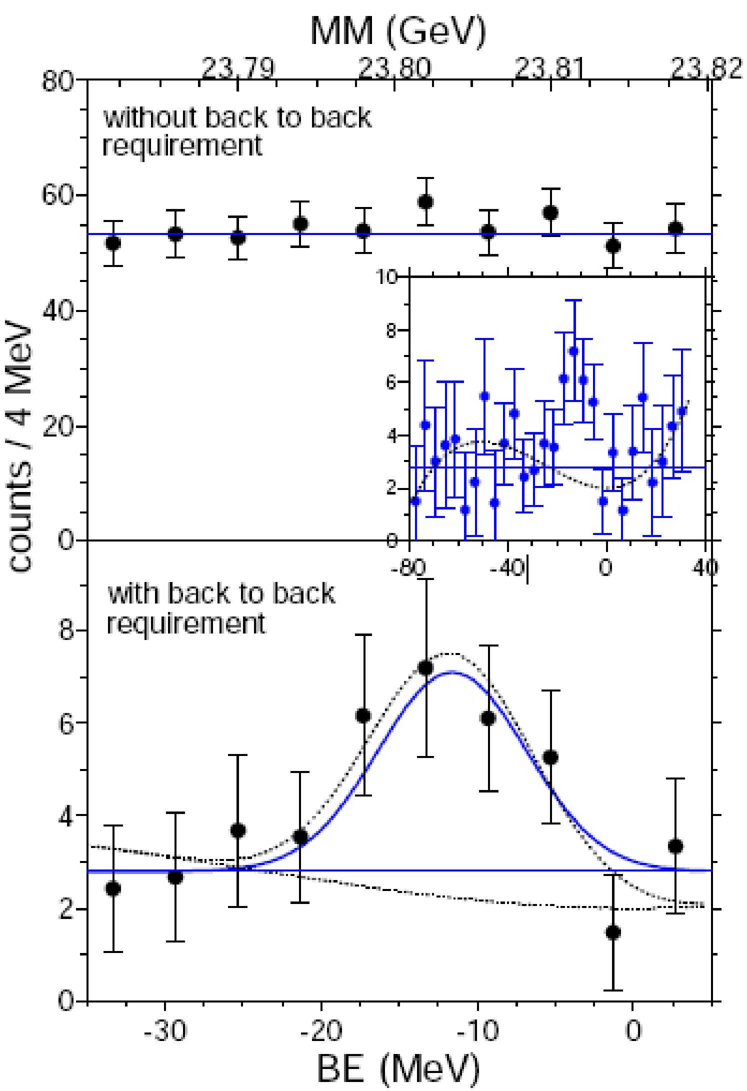
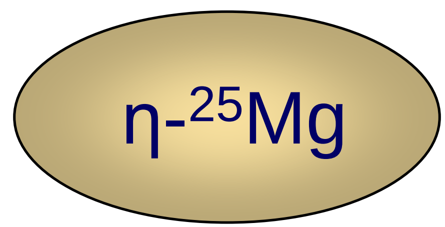


As for the experimental status of eta mesic states, some measurements which give a positive indication of the existence of η-mesic states have been reported in literature. One such experiment was performed by the TAPS collaboration on the photoproduction of η on ^{3}He, namely, $\gamma\ ^3He \rightarrow \pi^0 p\ X$, where one essentially sees the decay of a bound η in ^{3}He through the S_{11} resonance.

Search for the η-mesic nuclei in a recoil-free transfer reaction COSY-GEM Collaboration



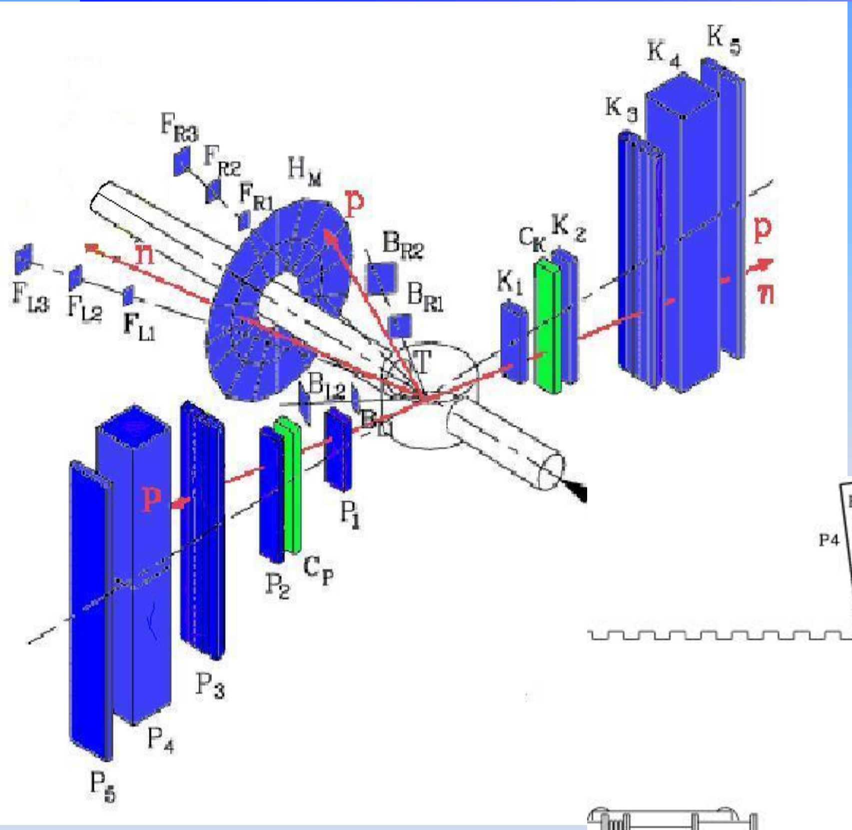
The other one is a bit more recent measurement from COSY on the p $^{27}Al \rightarrow {}^{3}He$ X reaction in a recoil free kinematic setup, where one observes in coincidence with ^{3}He, the decay of a possible bound η-^{25}Mg state, again, through the S_{11} resonance.

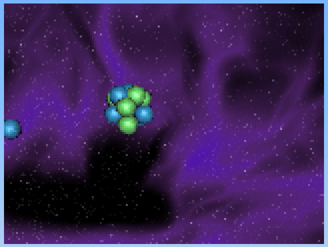


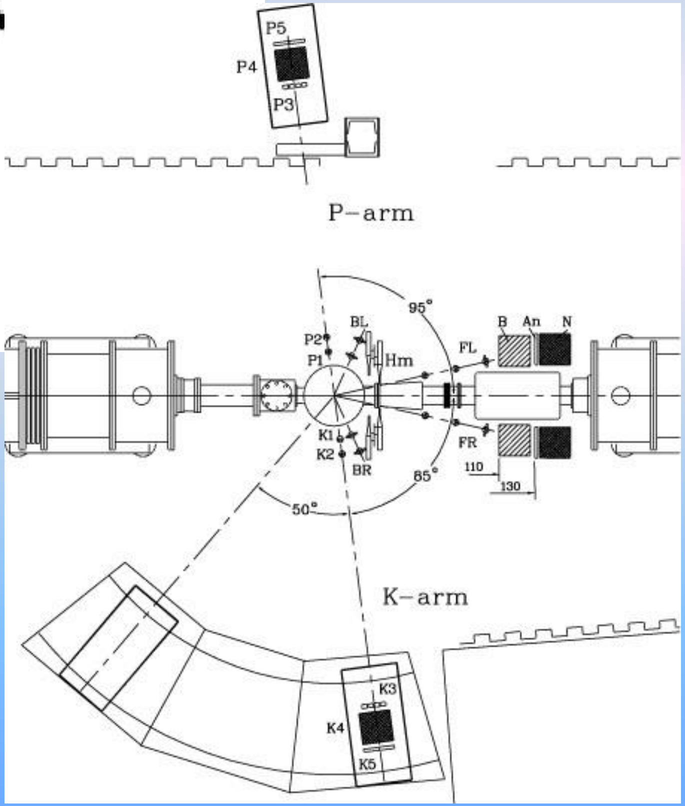
$$p + {}^{27}Al \rightarrow {}^{3}He + \pi^{-} + p + X$$

A. Budzanowski et al., Phys. Rev. C 79 (2009)

Experimental setup SCAN







K-arm

K1 - Start counter
K2 - Trigger & Cherenkov counters
K3 - TOF - wall
K4 - E-counter
K5 - Veto counter

P-arm

P1 - Start counter
P2 - Trigger & Cherenkov counters
P3 - TOF - wall
P4 - E-counter
P5 - Veto counter

Hm - Ring counter
N - Neutron detector
An - Neutron-Veto

FL,FR,BL,BR - Monitors

$$S_{11} \to \pi p$$

$$\Theta_{\pi p} = 180^0 \pm 10^0$$

$$T_p \approx 110 \pm 10 MeV$$

$$T_\pi \approx 350 \pm 30 MeV$$

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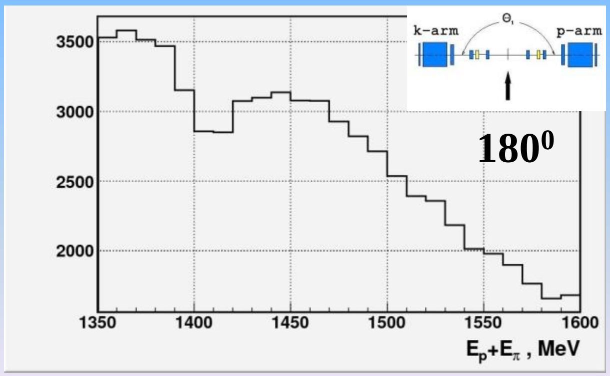
Nuclotron based measurement of eta-nucleai.

Effective mass formation in dC reaction at the energy 2.0 GeV/nuc

$Y(\pi,p) \propto 2.0$ GeV/c^2

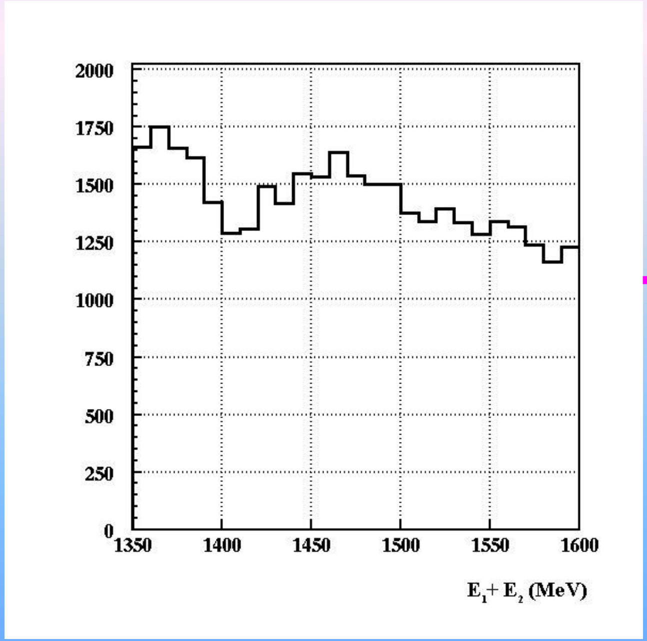


Best fit is Gaussian + constant

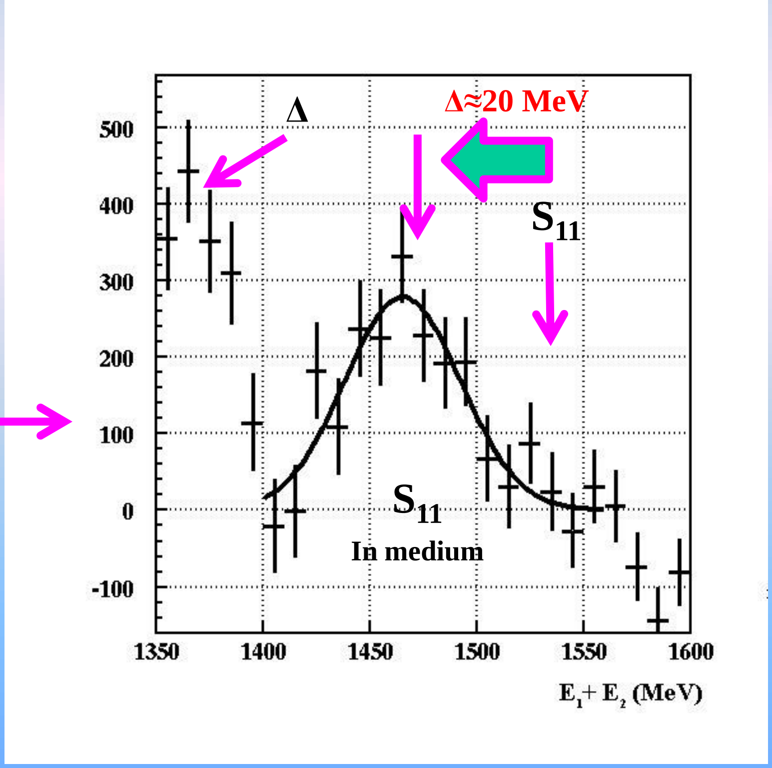
Mean	**1465.1 MeV**
Sigma	**27.2 MeV**
Constant	**1310**

Total events under picks ≈2000

N(1535)S_{11}
$I(J^P)=1/2$ ($1/2^-$)
$L(\eta,\pi)$ =0
Mass m=1520 to 1550 (≈1535) MeV
Full width Γ=100 to 250 (≈150) MeV



Distribution after rejection of the constant level



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What we are looking for?

Determination of the η-nuclei according to their decay products.

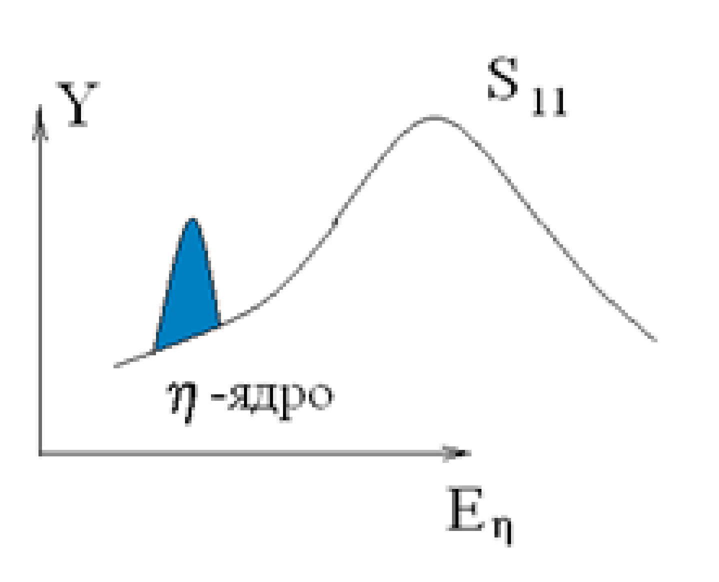
It is important to recognize that if we register πN pair with approximately equal but opposite momentum components, even with some suitable total energy $E\pi + E_N \approx m_\eta + m_N = 1486$ MeV, it does not necessarily mean that we have registered the decay products of the η-mesic nucleus.

The criterion of a bound η-meson is the condition for the πN pair's total energy, which should be below the threshold: $E\pi + E_N < 1486$ MeV

πN pair production from η-meson annihilation occurs in the process $\eta + N_i \rightarrow \pi + N$, the mechanism of which is determined by the excitation and decay of the intermediate nucleon resonance S_{11}(1535):

$$\eta + N_i \rightarrow S_{11} \rightarrow \pi + N.$$

Next criterion of a bound η-meson is the width of the peak in the distribution of πN pairs which is not related to the width of the resonance S_{11} (1535).



possible pairs of final particles

in the decay of η-nuclei are followings:

$(\eta p) \rightarrow \pi^0 p$, $(\eta p) \rightarrow \pi^+ n$, $(\eta n) \rightarrow \pi^0 n$, $(\eta n) \rightarrow \pi^- p$,
$(\eta pp) \rightarrow pp$, $(\eta pn) \rightarrow pn$, $(\eta nn) \rightarrow nn$.

$$d + A \rightarrow \eta(A-1) + X \rightarrow \pi + N + X.$$

1) η-meson production
2) To produce stable nucleus-rest from target
3) Effective capture of the meson
4) To measure the products of decay

Recoil-free transfer reactions are most acceptable to the successful formation of the η-nuclei.

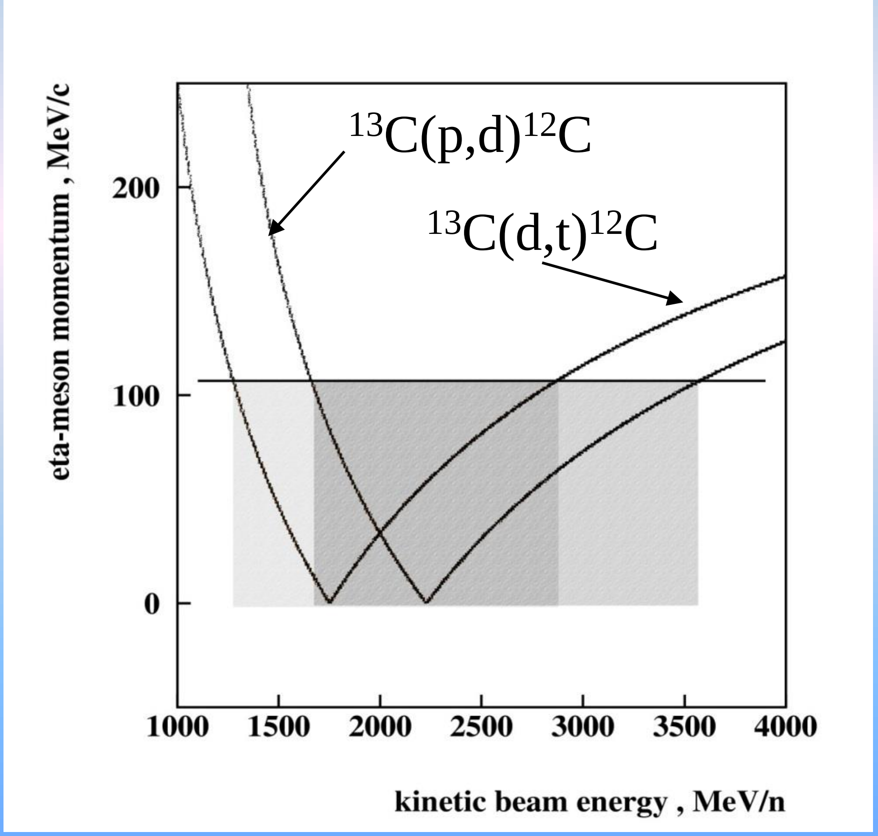
$$d+A \rightarrow t+\eta_{p=0} + (A\text{-}1)_{p=0}$$

$$P_p = P_d \quad E_d = 2.22 MeV$$

$$^{13}C + d = {}^{12}C + t + \eta + Q$$
$$Q = 1.3\ MeV$$

$$p+A \rightarrow d+\eta_{p=0} + (A\text{-}1)_{p=0}$$

$$P_d = P_t \quad E_t = 6.25 MeV$$



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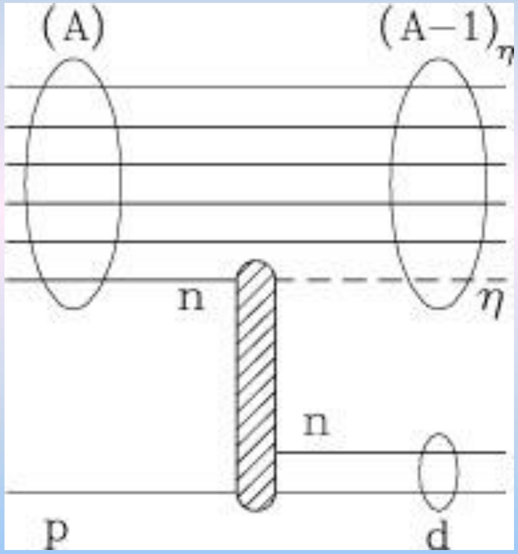
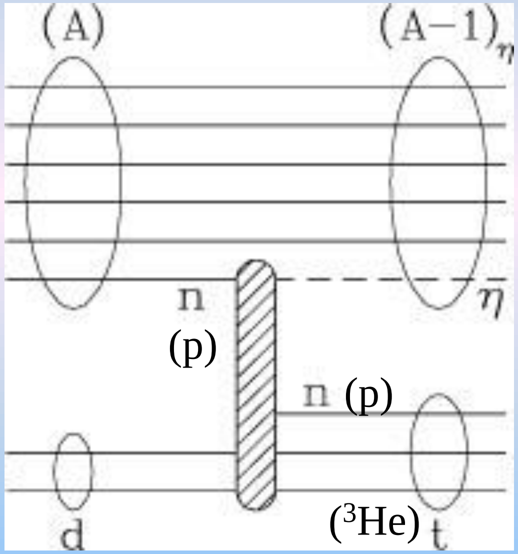
$$p + A \rightarrow d + \eta_{p=0} + (A\text{-}1)_{p=0}$$

$$d + A \rightarrow t + \eta_{p=0} + (A\text{-}1)_{p=0}$$

$$d + A \rightarrow {}^3He + \eta_{p=0} + (A\text{-}1)_{p=0}$$





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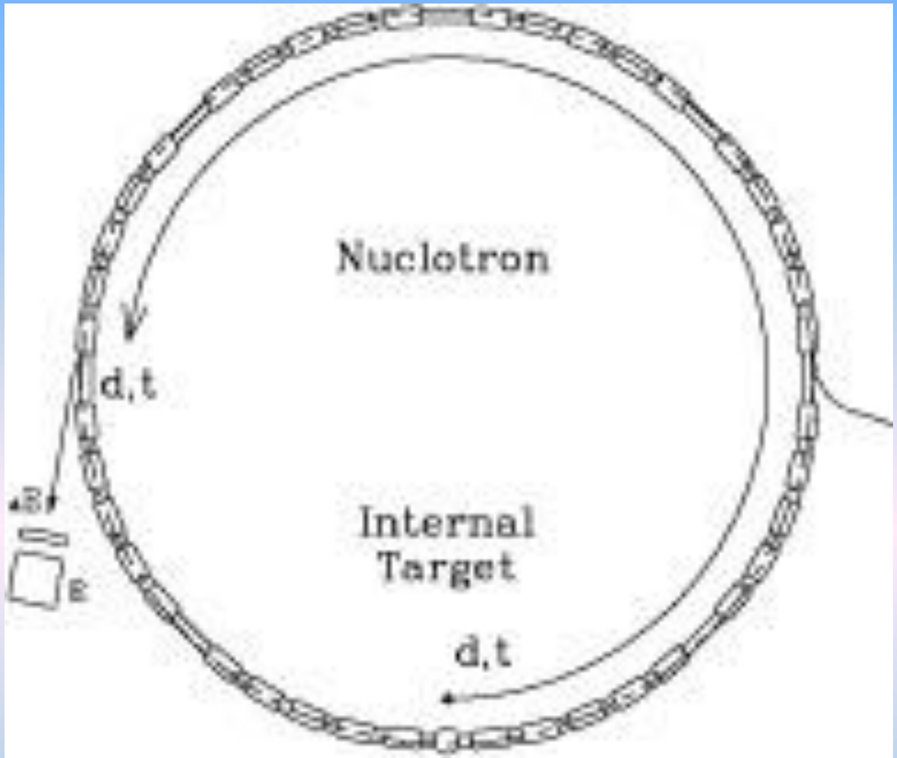
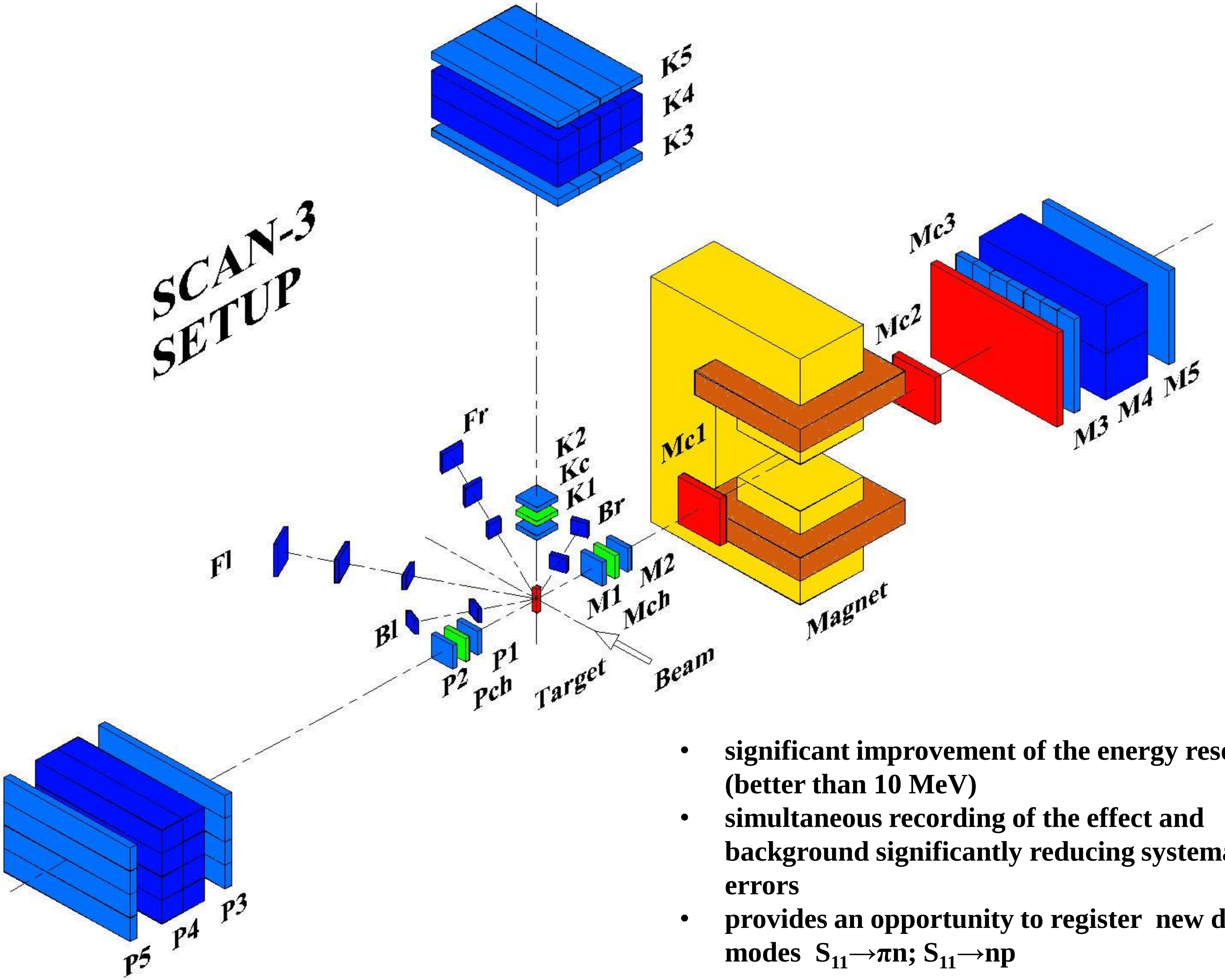
dP/P<10^{-4}(10^{-3})

p+A→ d+$_{\eta}$(A - 1)→*p+p(π)+d+...*





- significant improvement of the energy resolution (better than 10 MeV)
- simultaneous recording of the effect and background significantly reducing systematic errors
- provides an opportunity to register new decay modes $S_{11}\to\pi n$; $S_{11}\to np$

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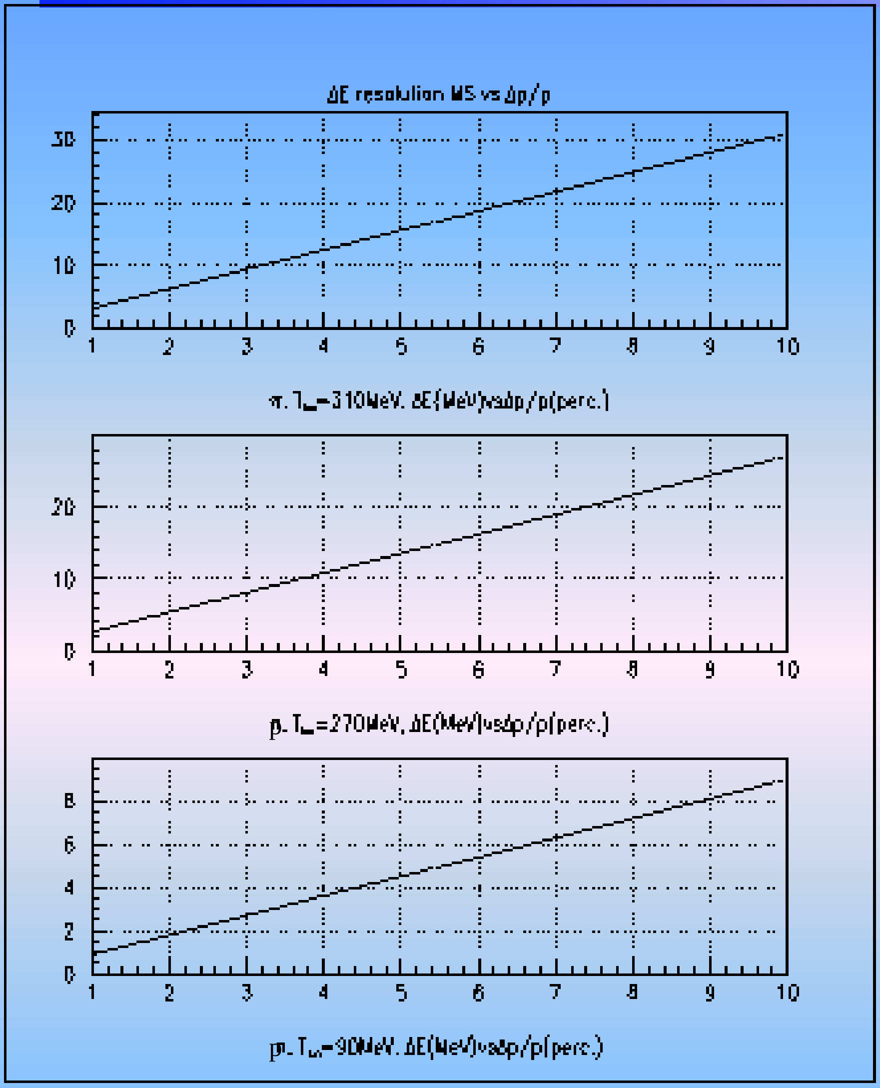

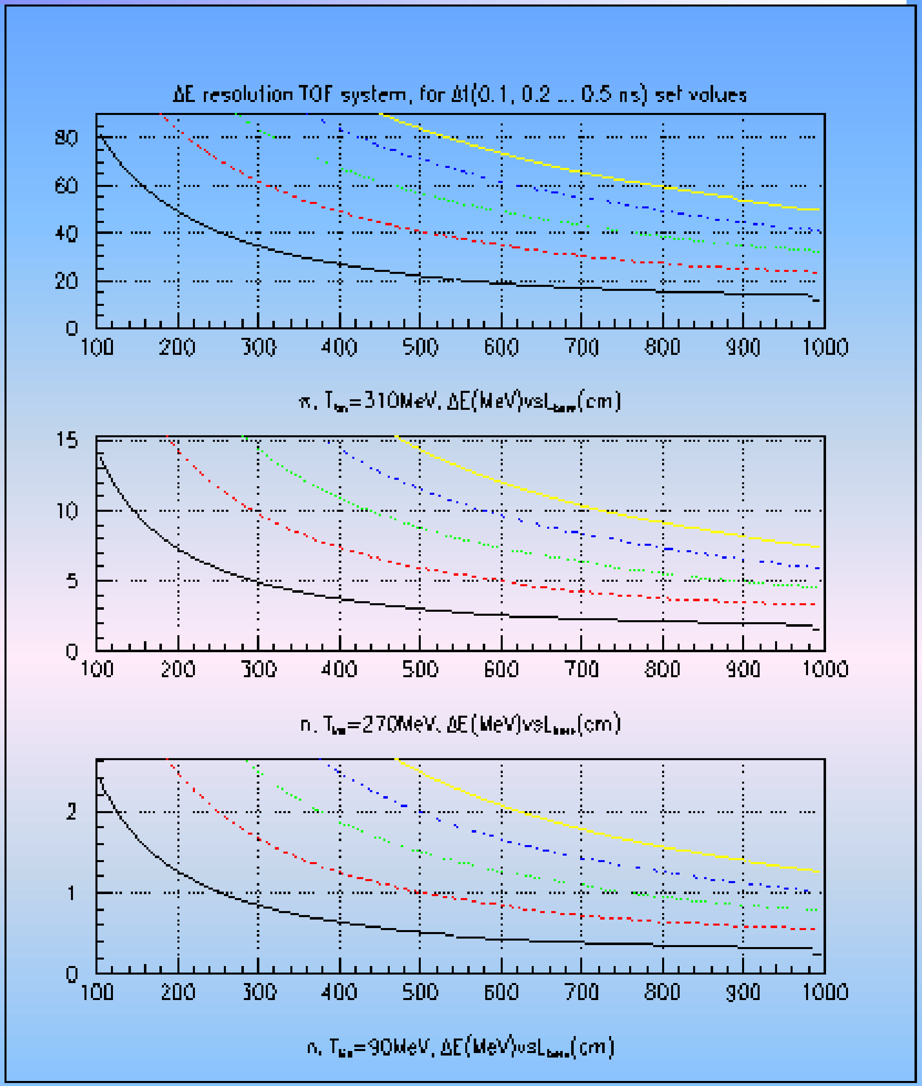

The dependence of energy resolution (MeV) for the PC π-mesons and protons of various energies from its relative momentum resolution (%).

Energy resolution of the TOF-system depending on the base of passage for a discrete set of time resolution of the detectors (black-0.1ns, red-0.2ns, green-0.3ns, blue-0.4ns, yellow-0.5 ns) .

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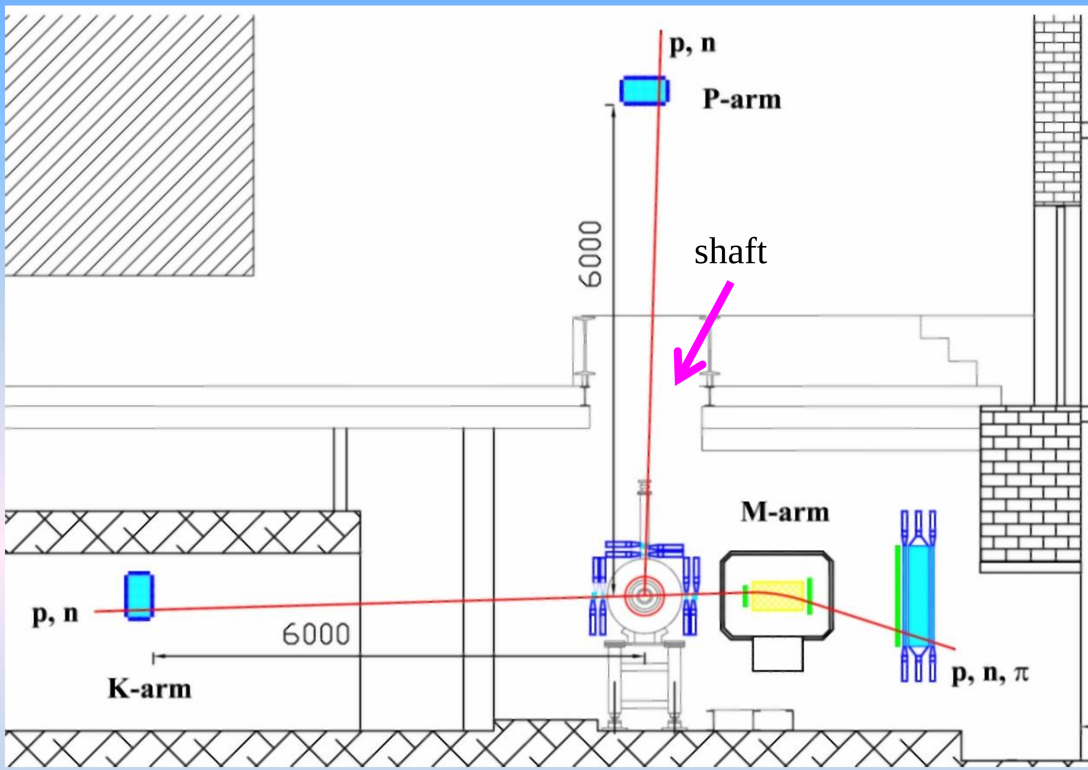
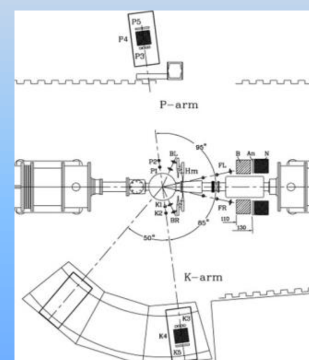
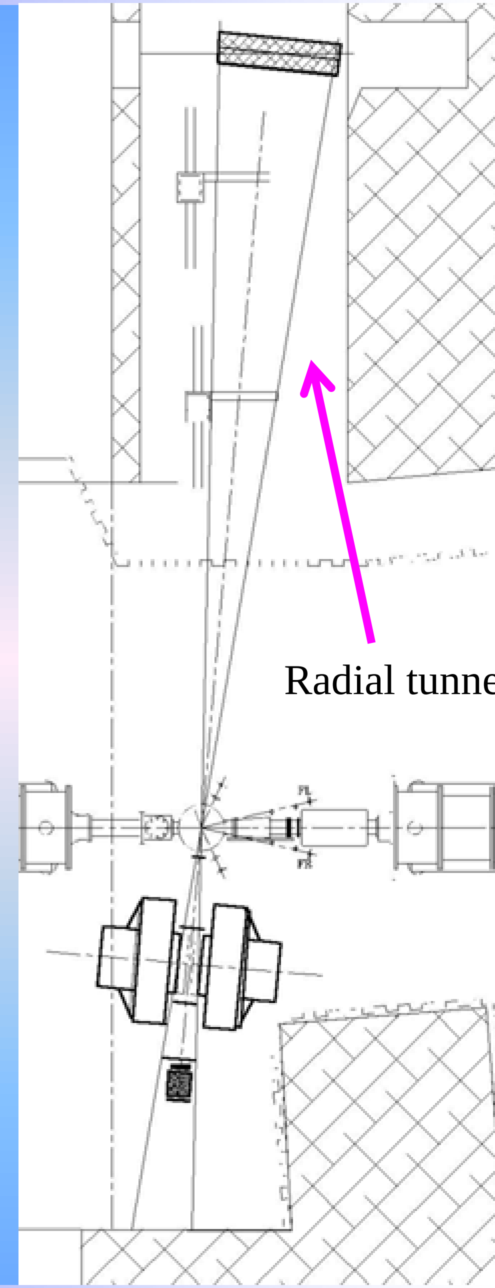
New proposal for η–nuclear study on nuclotron.







$\delta E = \delta(E_\pi + E_N) < 10$ MэВ.

$d + A_1 \rightarrow {}_{\eta}A_2(S_{11}) \rightarrow \pi^- + p + \ldots$

$d + A_1 \rightarrow {}_{\eta}A_2(S_{11}) \rightarrow \pi^+ + n + \ldots$

$d + A_1 \rightarrow {}_{\eta}A_2(\eta + d^*) \rightarrow p + n + \ldots$

$\eta + d \leftrightarrow p + n$

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Main components of the experimental setup

- existing set of detectors of the SCAN spectrometer
- updated system control of the target station with an integrated luminosity monitoring
- analyzing magnet for magnetic arm
- neutron detectors
- plan to use the ready-made drift chambers

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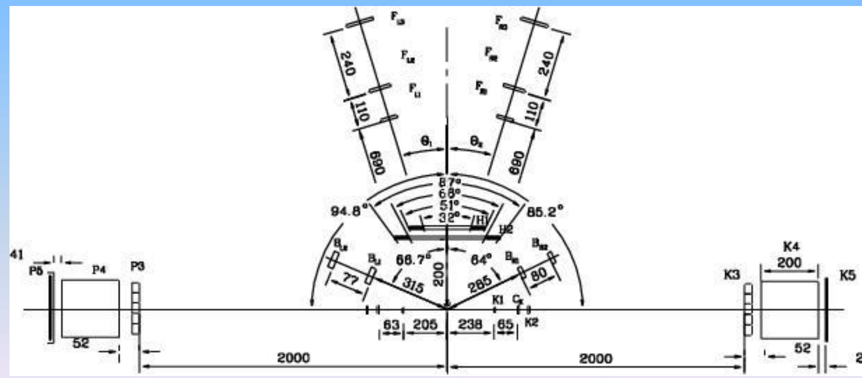
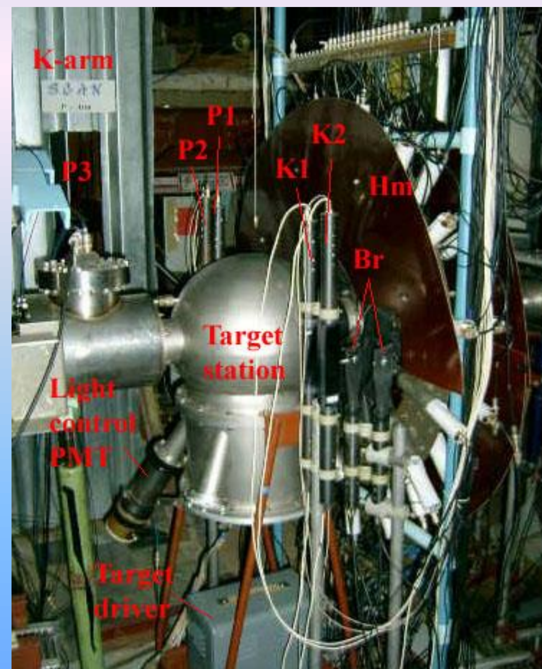
Existing set of detectors of the SCAN spectrometer

P-arm



K-arm



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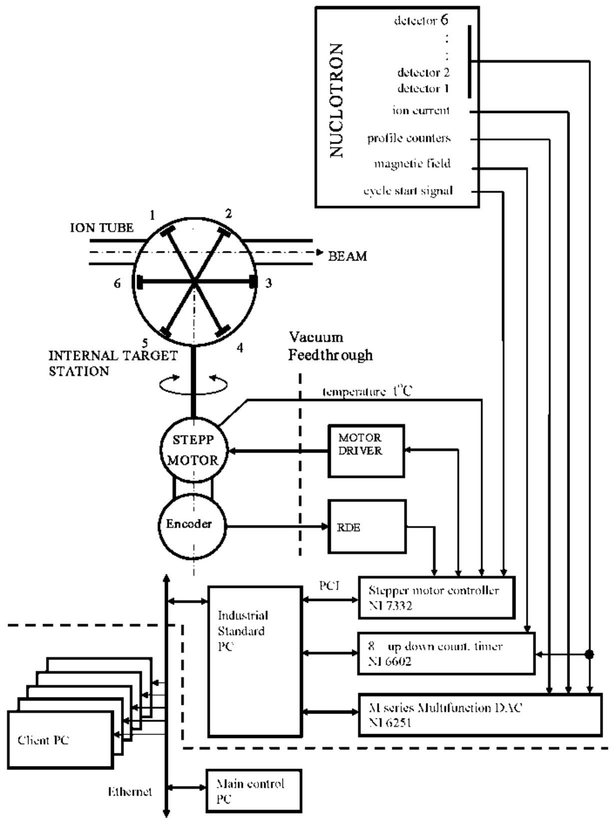
Updated system control of the target station with an integrated luminosity monitoring *(updated by PI SAS)*



Block scheme of the internal target station

Main parameters of the system

- Motor micro steps: 50 000 steps/ revolution,
  ~ 0.02 mm/step on the perimeter of targets holder,
- Encoder steps: 4096 steps/revolution, ~0.2 mm/step on the perimeter, max. 20 kS/s sampling rate
- on-demand position scan input signal
- 10 x Up/down counters: max. 80 MHz, 32 bits,
- 16 x ADC: 1 MS/s, 16 bits resolution,
- 2 x DAC: 2 MS/s, 16 bits resolution,
- 56 x bidirectional digital channels: 10 MHz max.

Previous version of the target (left) and the modernized system of targets (right) during the installation to the chamber of the accelerator (June 2013)

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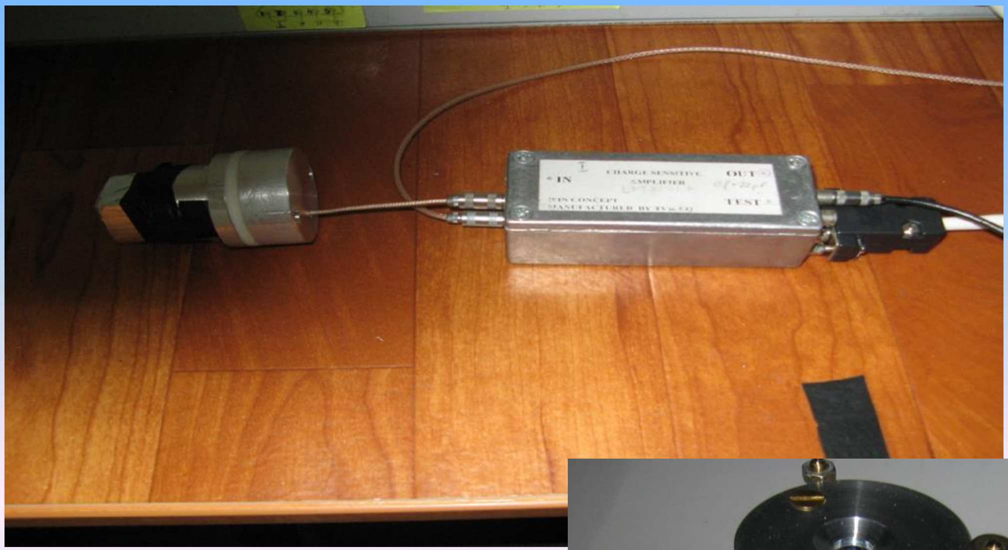
Monitor of luminosity



- The experimental structure contain the detector with CsI(Tl) scintillation coupled to PIN photodiode of large area and charge sensitive preamlifier connected to scintillation detector by through coaxial cable of 10 cm length.

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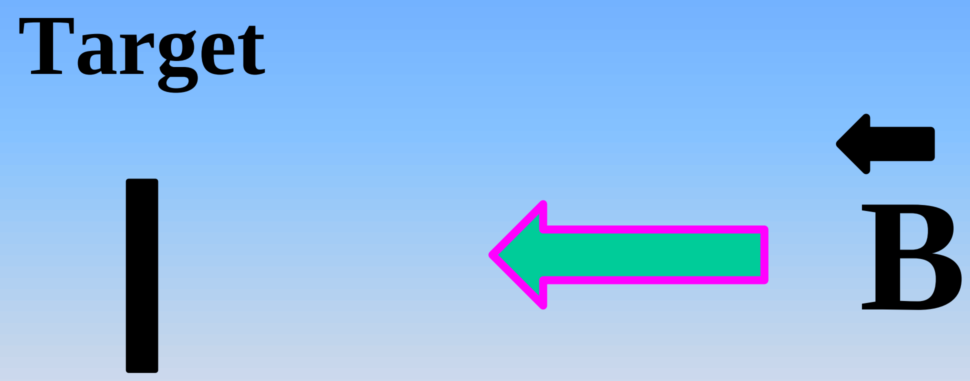
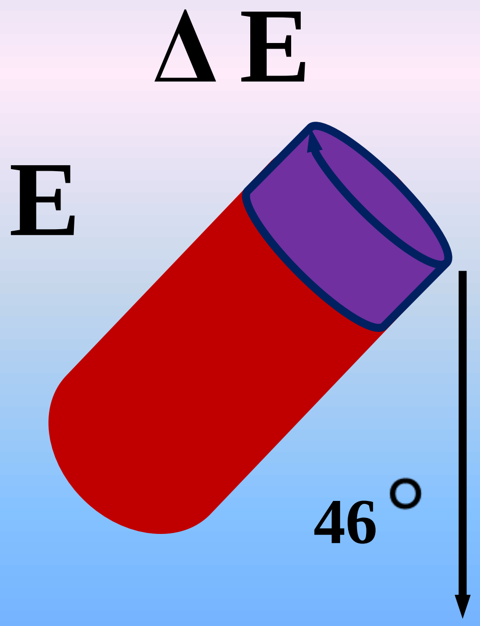
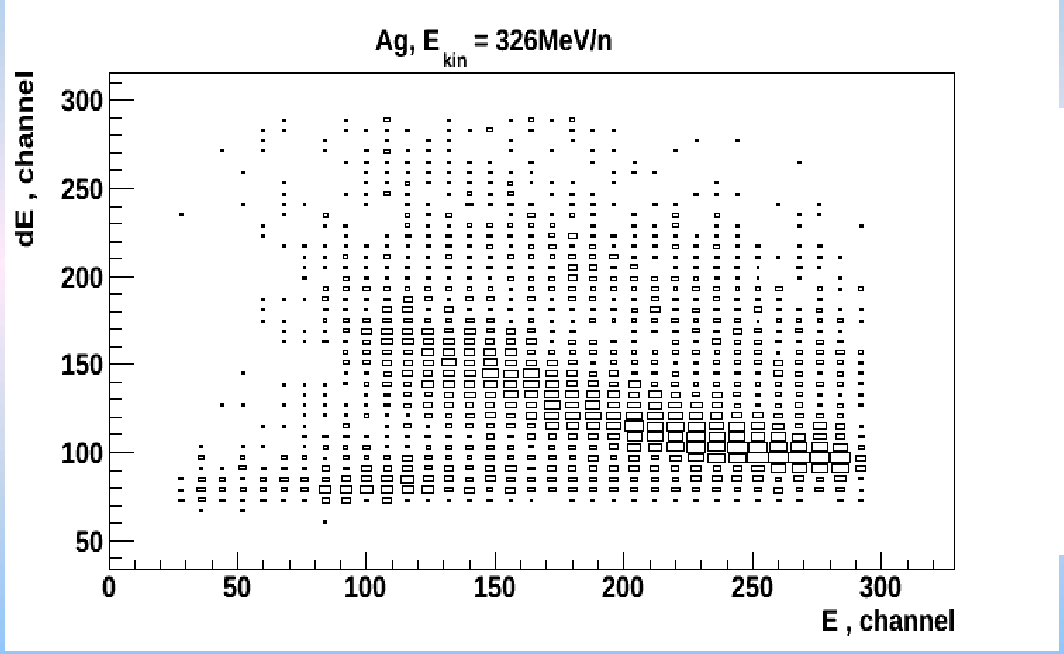


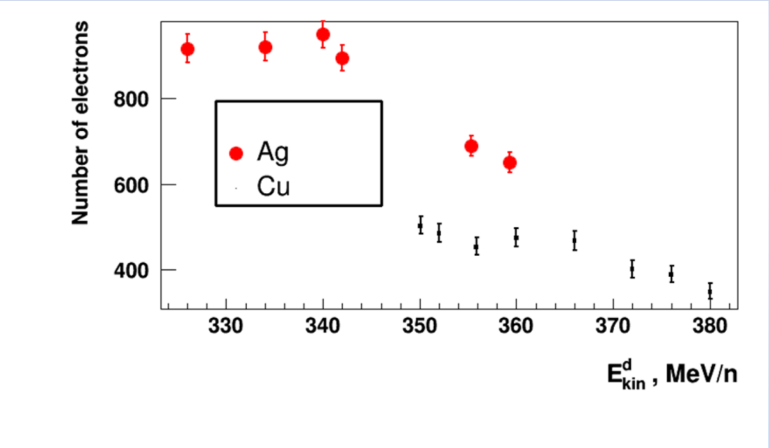


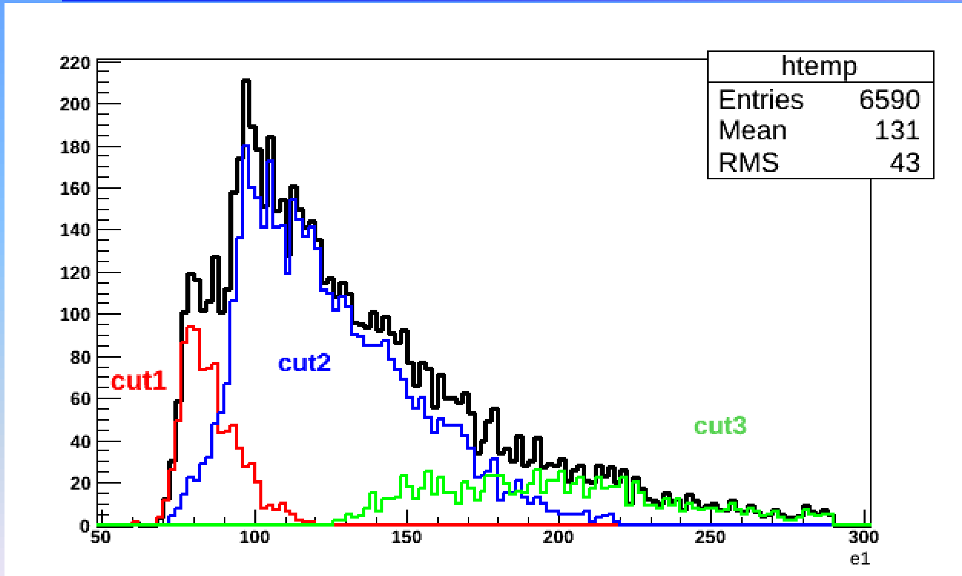
Δ E : Si , h=200 mkm

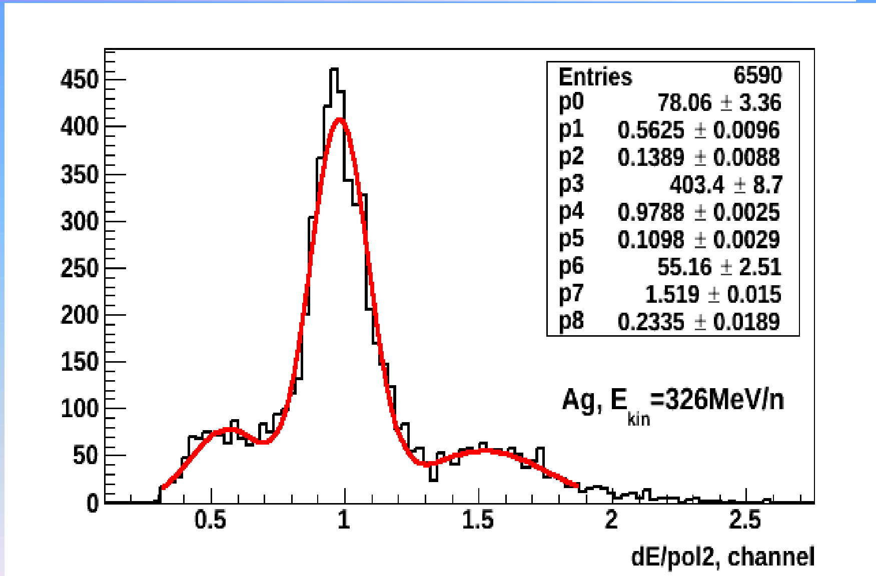
E: CsI(Tl) , h=33 mm

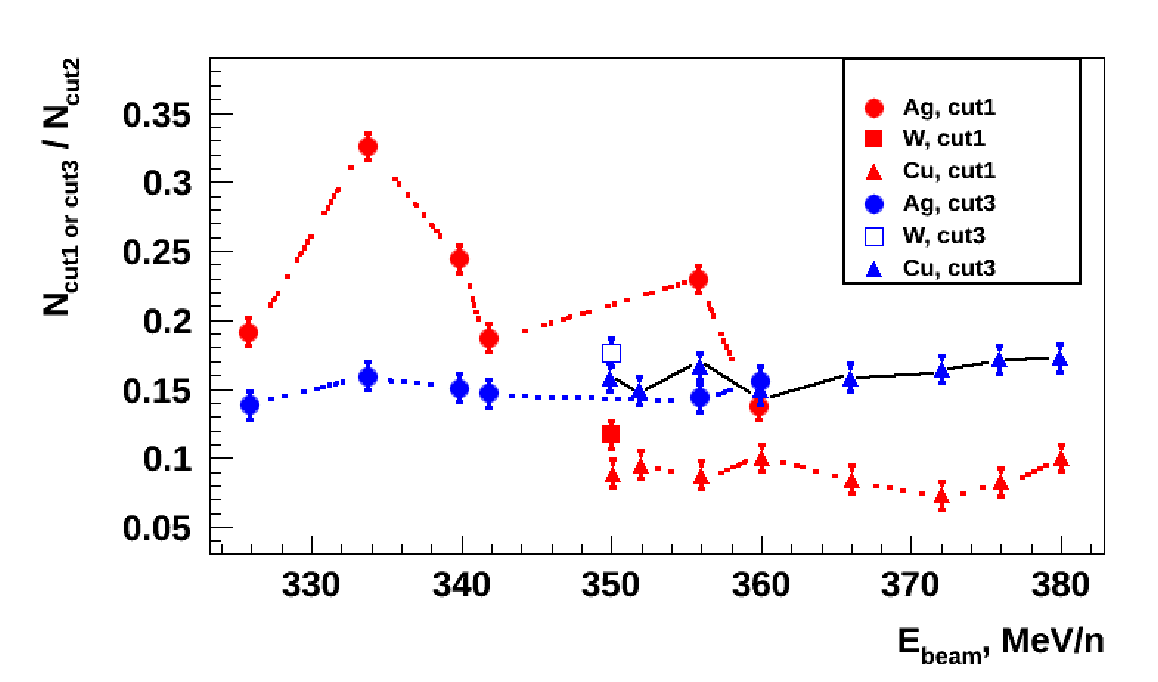
Target=Ag, E_{kin}^{d}=326 MeV/n











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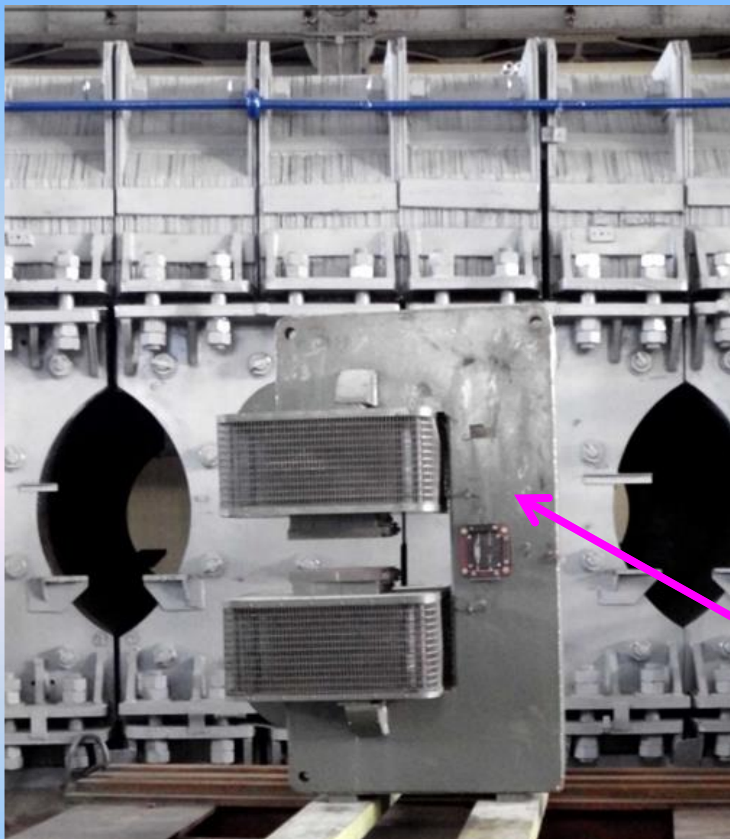
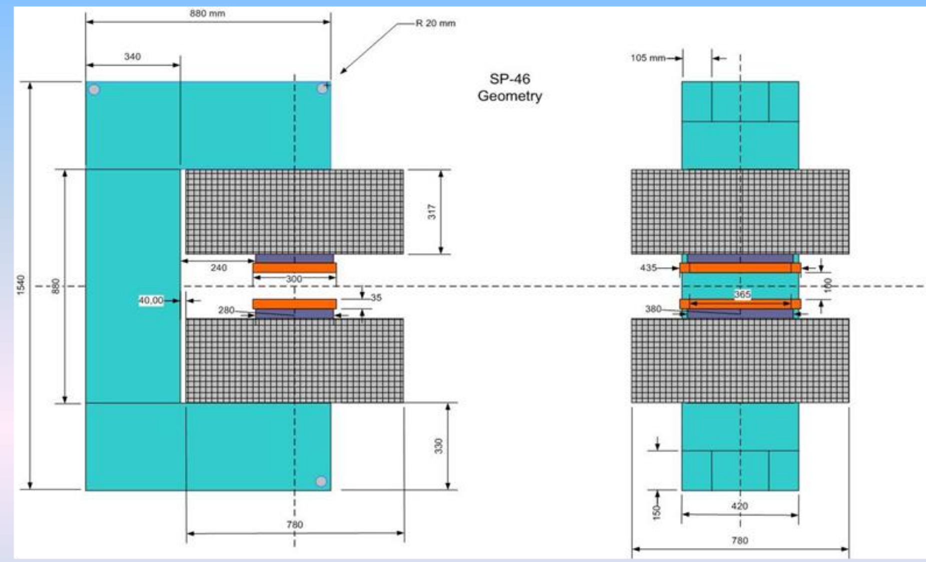
Analyzing magnet SP-46 for the magnetic arm.

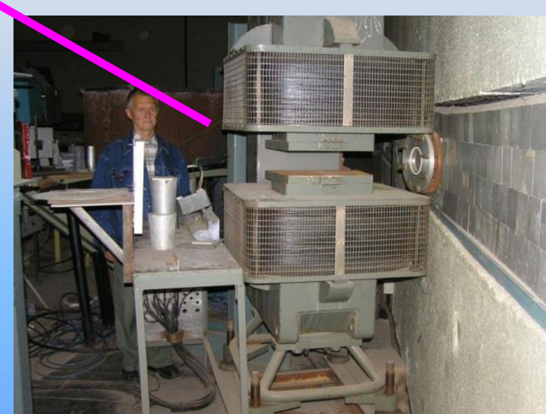
SP-46

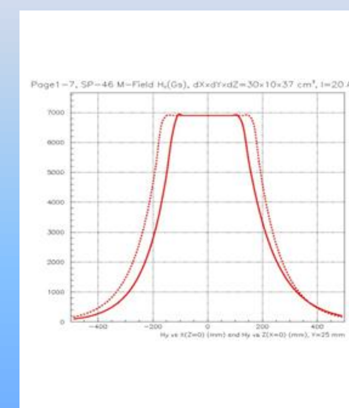
Magnetic volume - 100x300x420mm
Magnetic field - 7kGs





SP46 is delivered from LPI RAS to LHEP JINR in Jun 2013





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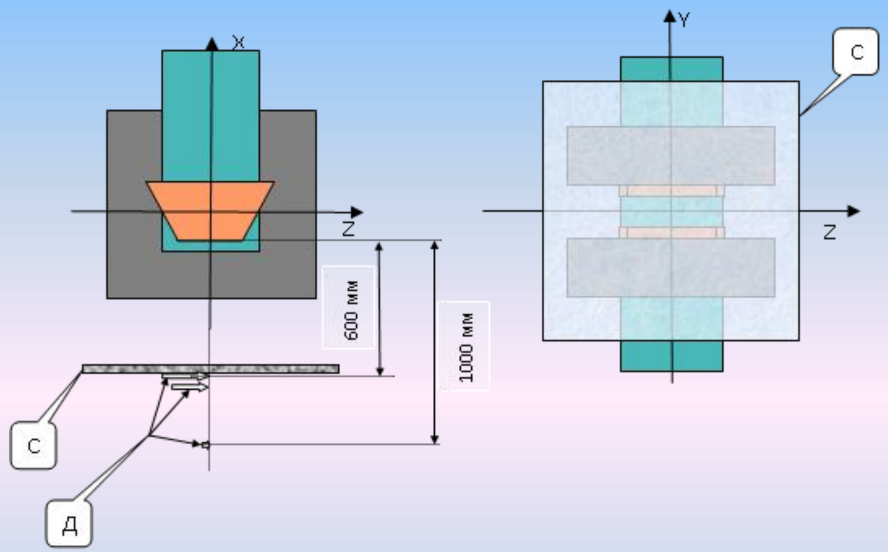
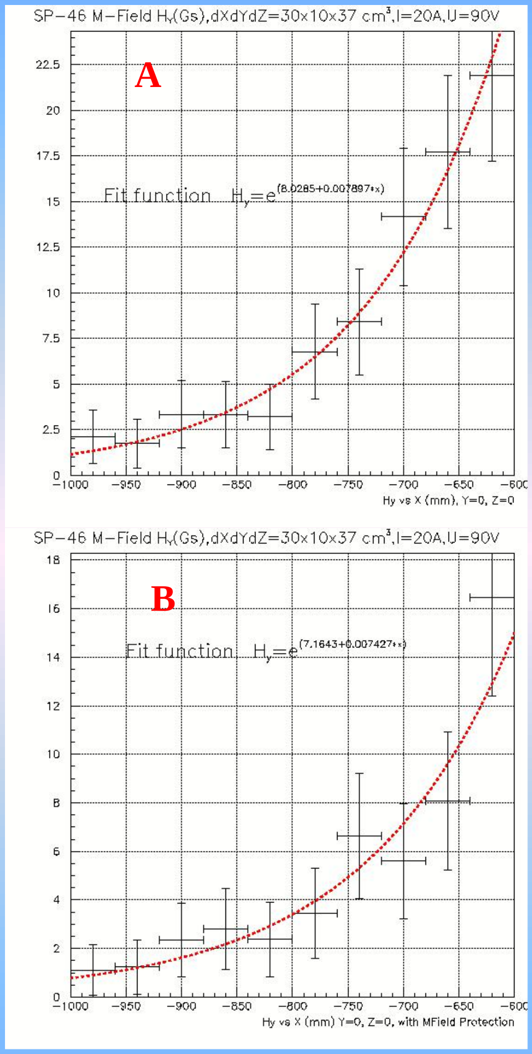
The measurement of the scattered magnetic fields



The scheme of induction measurements of the scattered field for magnet SP-46.
 D - the Hall probe position measurement,
 C - steel sheet 1000x1000x1mm.



The dependence of the longitudinal component of the induction field of the magnet SP-46, the distance from the shear plane pole. A)-no shield; B- used magnetic shield

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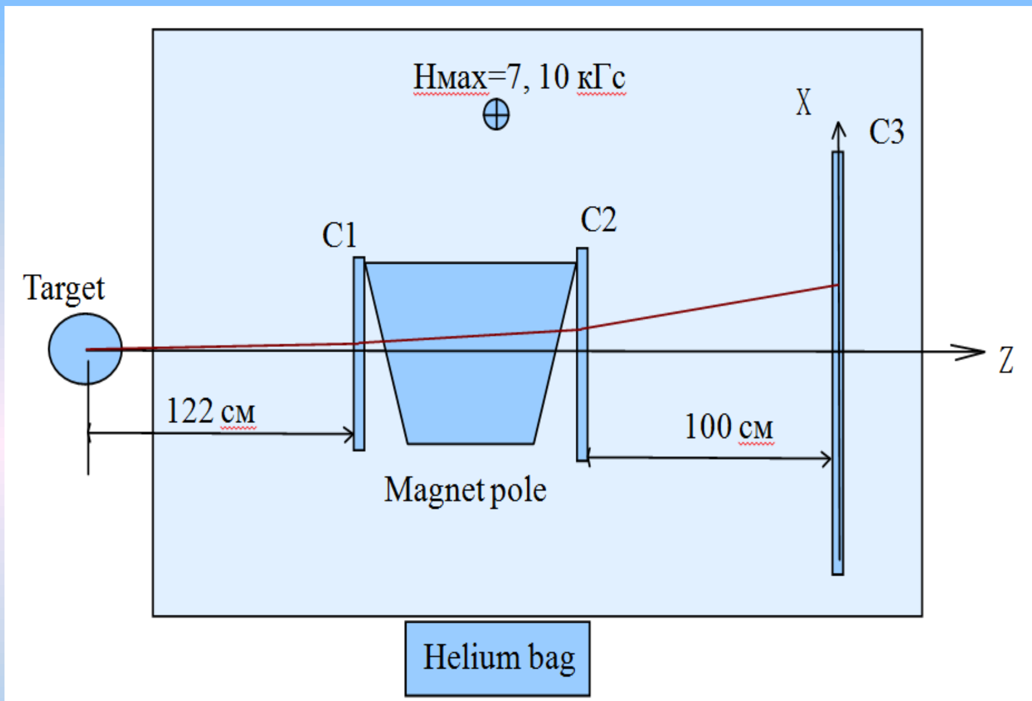
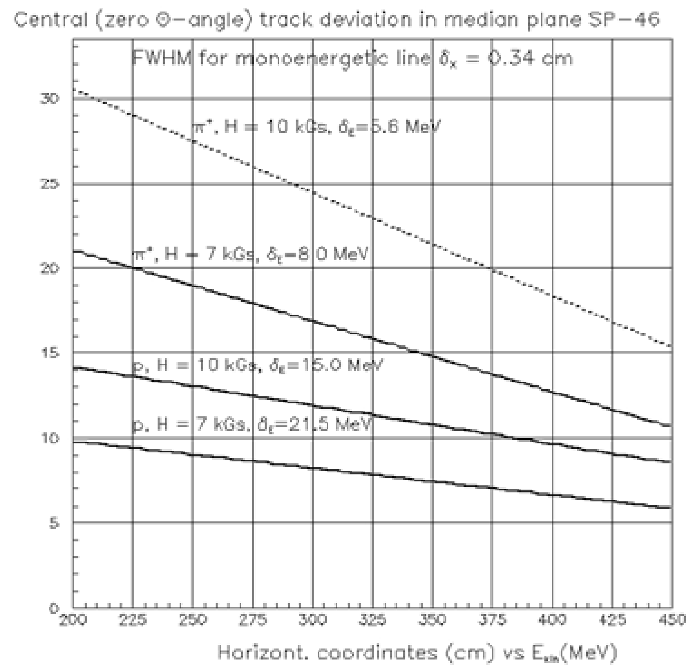
Distortion of π^+ and p of energy range of 200 – 425 MэB in the magnetic field of SP-46 magnet.



Distortion of track in magnetic field as a function of particle type, kinetic energy and two values of the magnetic field Hмax=7 and 10 кГс.

Energy resolution (FWHM) for protons are 21,5 and 15 MeV, for pions – 8 and 5,6 MeV at the magnetic field 7 and 10 kHs accordingly.



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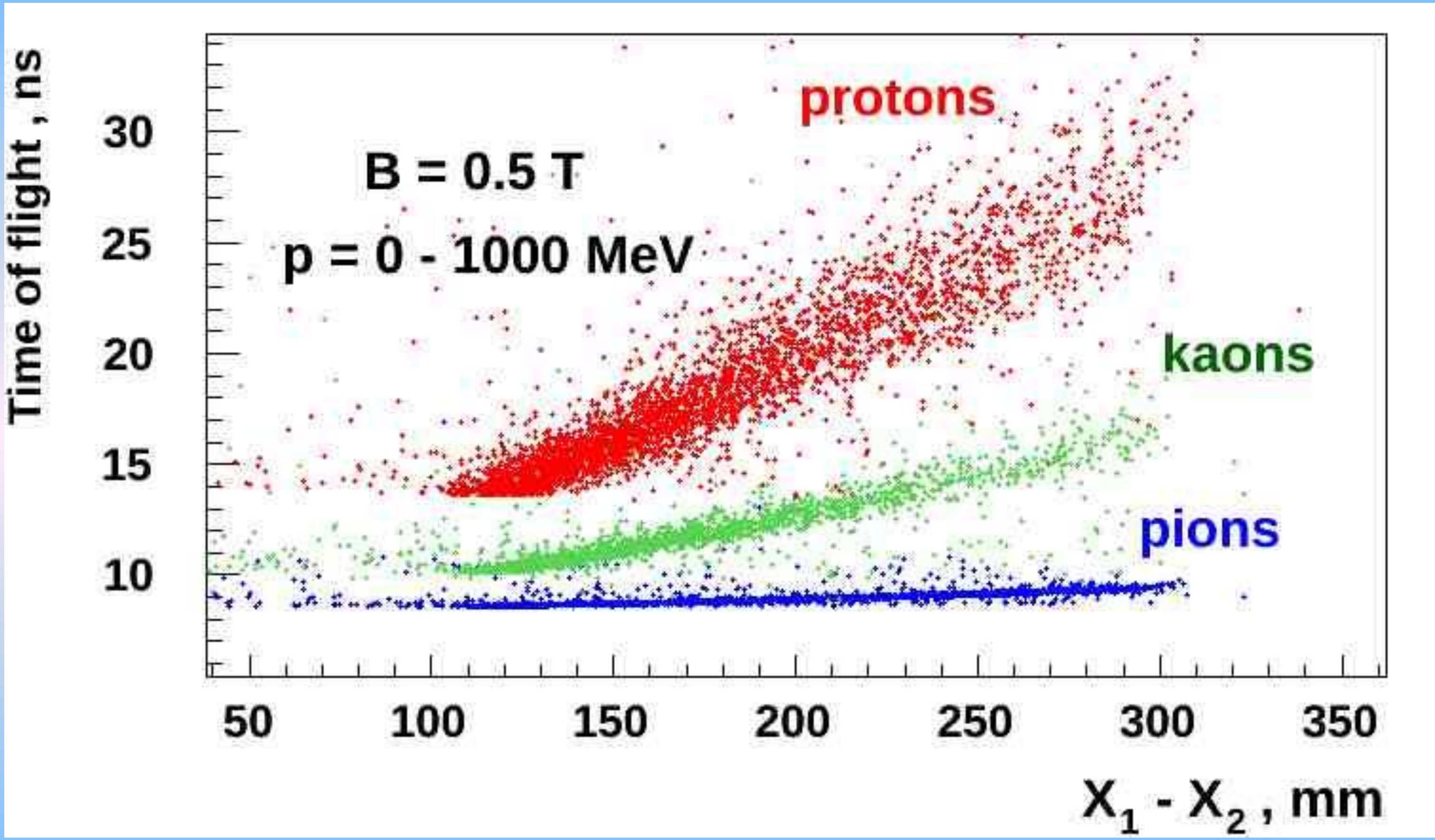
GEANT 4.10

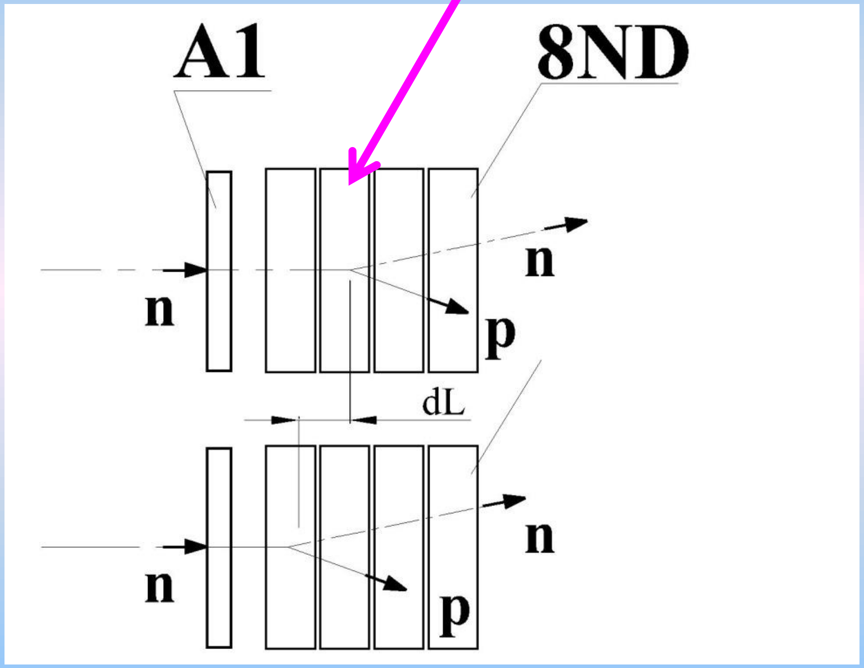


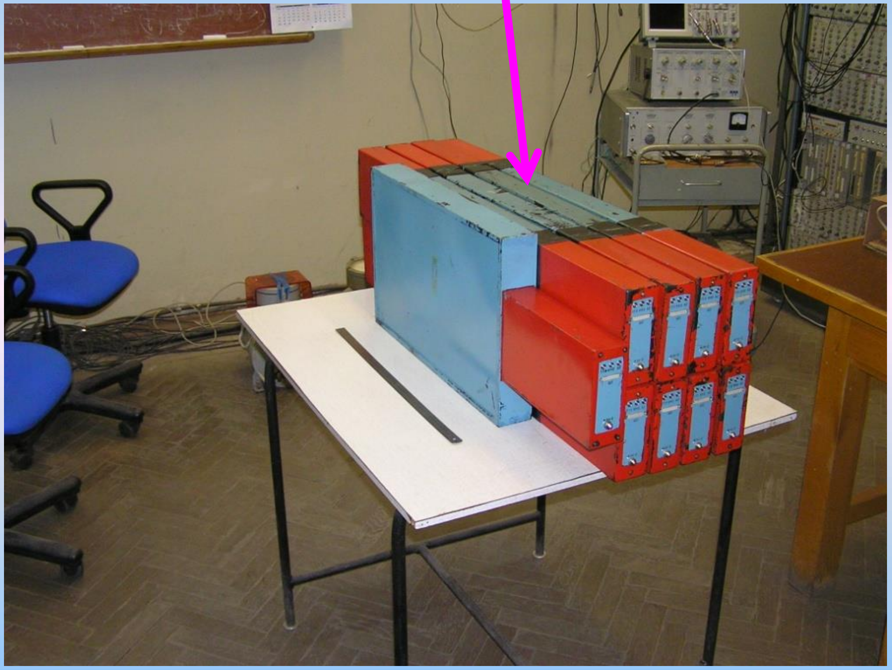
Time of flight , ns
30
25
20
15
10
B = 0.5 T
p = 0 - 1000 MeV
protons
kaons
pions
50
100
150
200
250
300
350
X1 - X2 , mm

Neutron detectors

Scintillator 500x130x50mm

Multi layers neutron counter
For first run test.





Summary from beam test:
TOF resolution vary from 0.27ns to 0.4ns with mean value is **0.31ns**

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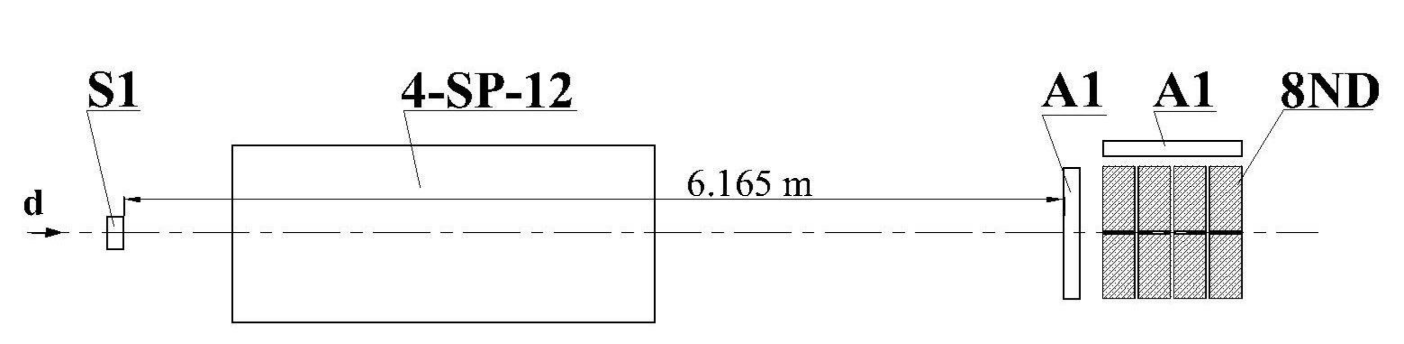
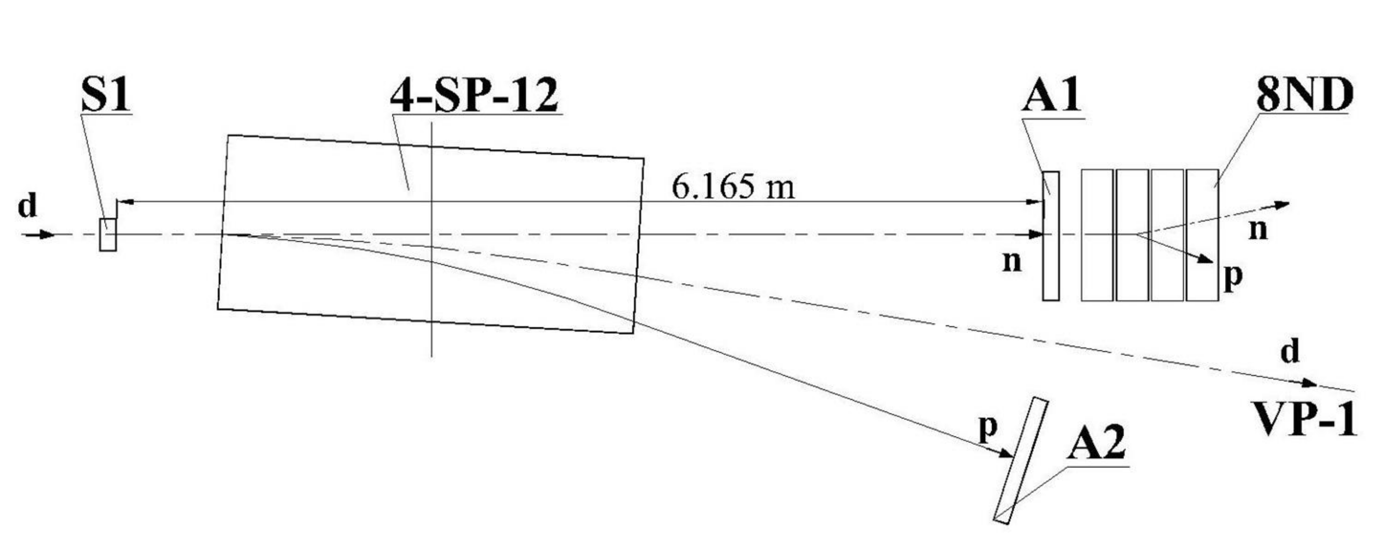
Test Setup
“MARUSIA”-area





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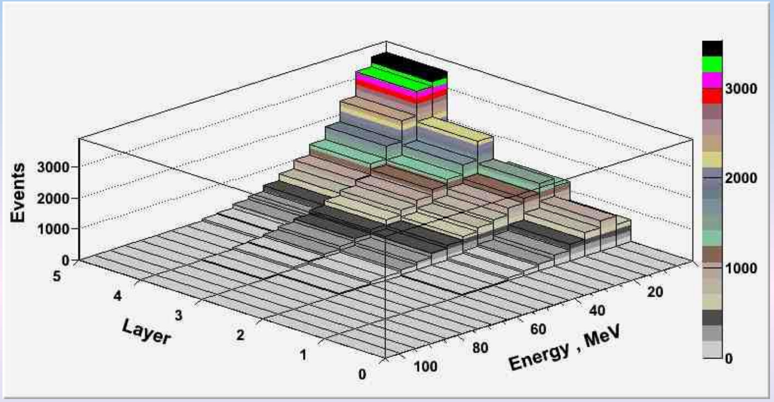
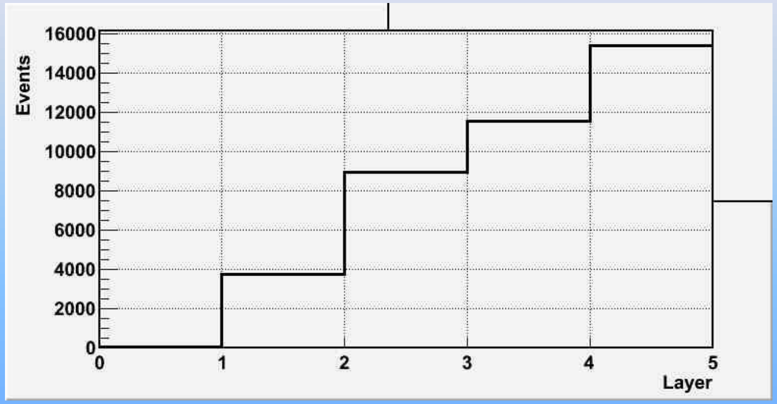
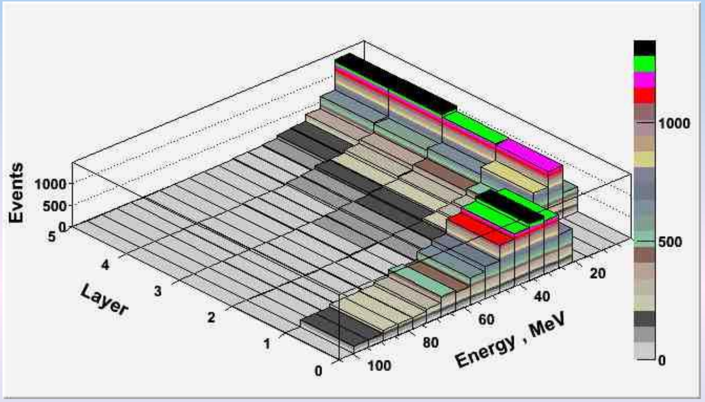
Energy deposition in layers

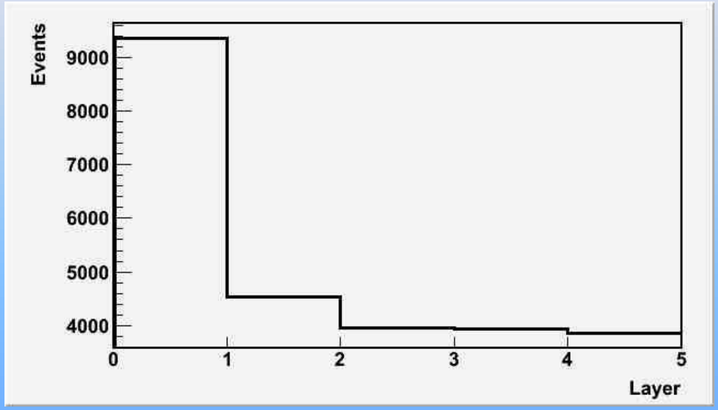
neutrons





Charged particles





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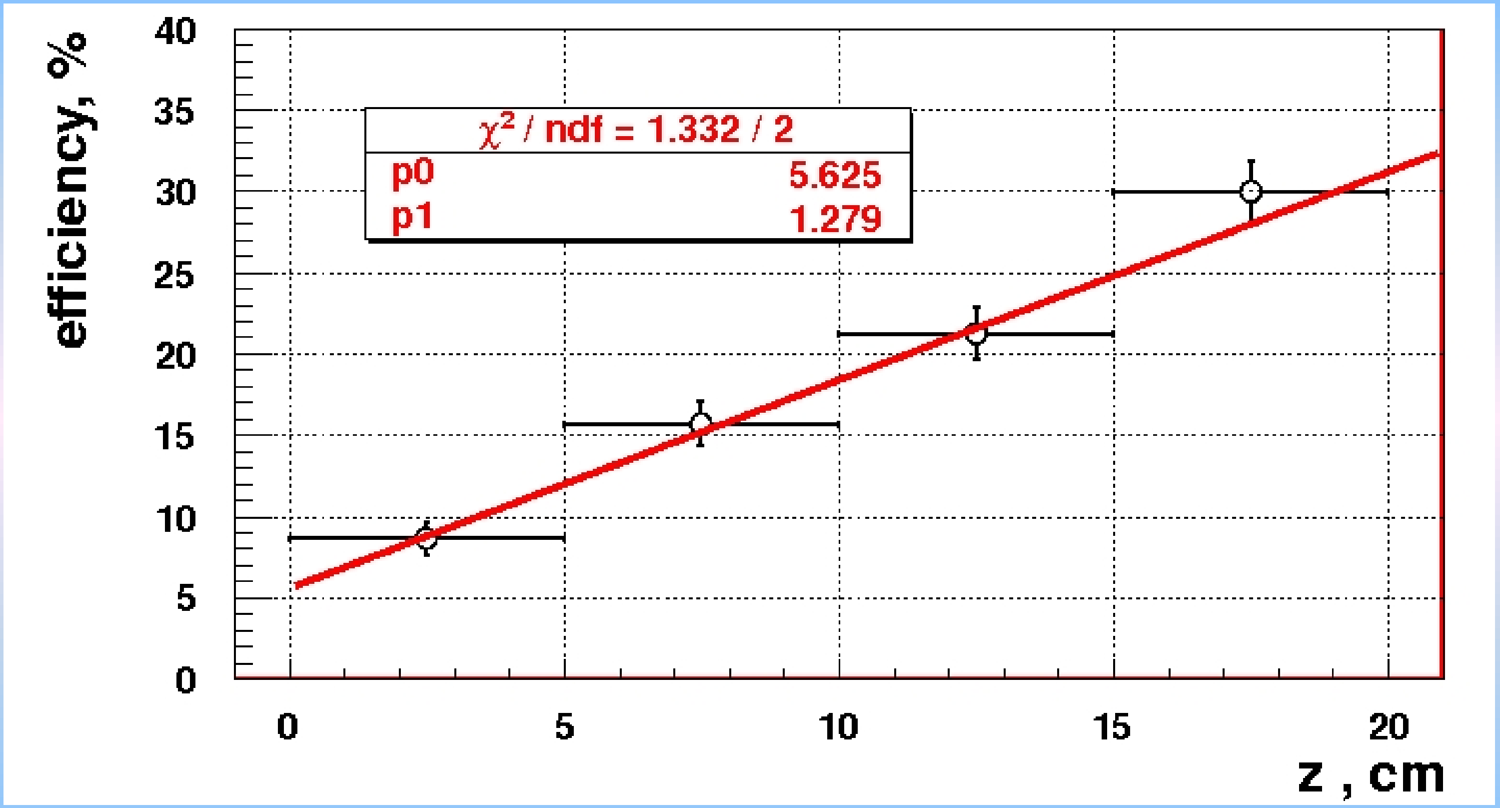

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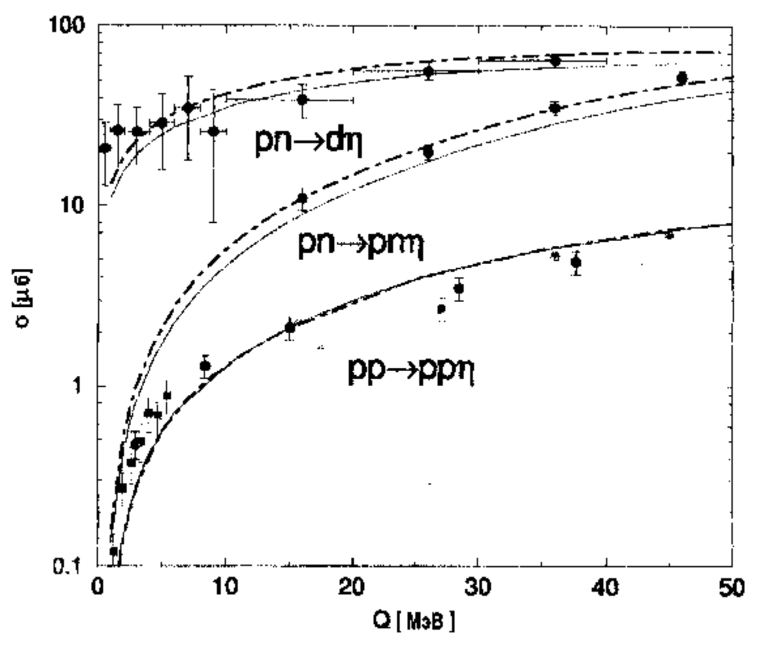
Estimates of the effect yield

$$Y(p,\pi^-) = L \bullet \sigma_\eta(N^{12}C \rightarrow N_1 N_2 n_\eta (A-1)) \bullet Br(\pi N) \bullet \xi \bullet \Omega_\pi \bullet n_c \bullet f(\Omega_p/\Omega_\pi)$$

σ_η - total cross section of eta-nuclei formation;
L - luminosity;
Ω_π - the solid angle;
ξ - the probability to have the πp pair
$f(\Omega_p/\Omega_\pi)$ - a geometric fraction;
$Br(\pi N)$ - the branching ratio of $S_{11}(1535)$ decay;
n_c - accelerator cycles per hour;

Production of η-mesons in nucleon-nucleon collisions
V. Baru,
PHYSICAL REVIEW C 67, 024002 (2003)



$Y(p\pi)$ ≈ 140 events/hour
$Y(pp)$ ≈ 2-3 events/hour
$Y(pn)$ ≈ 100 events/hour

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The main objective of the experiment are:

Detection of the η-mesic nuclei as resonance peak in a spectrum of total energy of the correlated pairs.

Definition of the cross-section of the η-mesic nuclei formation.

Measurements of the energy and A-dependence of the cross-section.

Definition of a binding energy of η-meson in a nucleus, it is key parameter characterizing potential of an attraction of the η-meson and nucleons at low energies.

Measuring of the ration of (π-p) and (pn) – events.

Definition of the ratio of resonances widths Γ(πN) and Γ(NN).

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Thank you
for
your attention!

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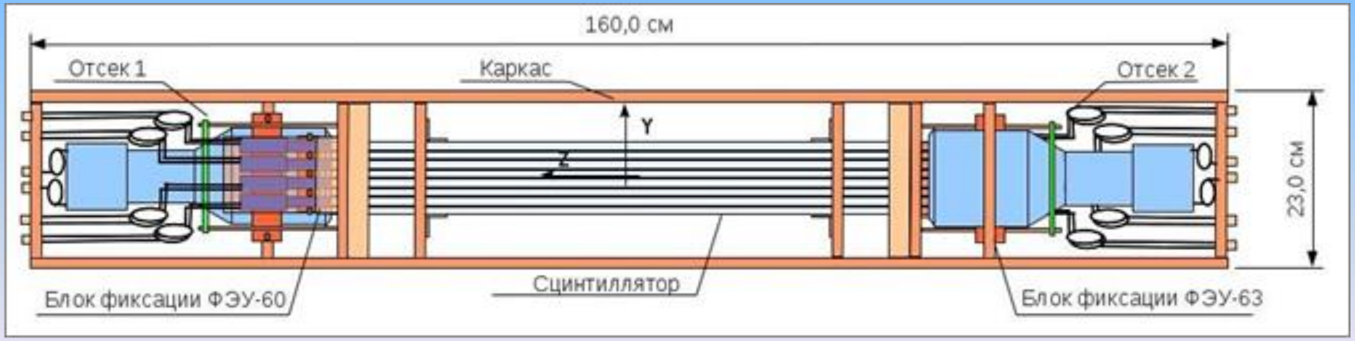
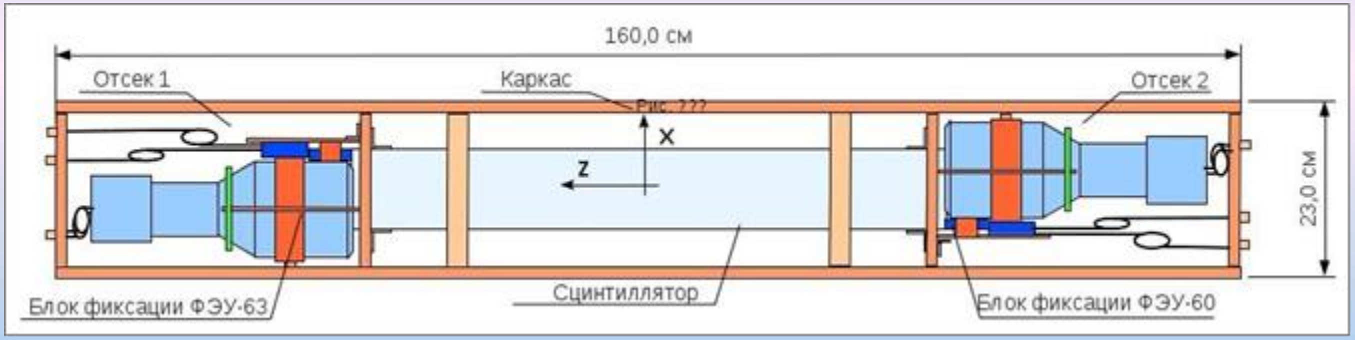
R&D for neutron counter





Preliminary date gave a time resolution is better then 200 ps for neutron detection.

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Summary

- The η meson due to its strong attractive interaction with a nucleon has turned out to be the most promising candidate for the exploration of exotic states of mesons and nuclei.
- A good estimate of the strength of the η-nucleon (ηN) interaction is crucial for the interpretation of the data on η meson production on nuclei and the theoretical prediction of η-mesic nuclei. With the possibility of obtaining η-nucleon elastic scattering data being ruled out due to the nonavailability of η beams,
- The few body treatment of the FSI shows that at the production vertex, the η meson could in principle be produced off-shell, undergo multiple elastic scatterings from the nucleus and then get converted to an on-shell η due to its interaction with the nucleus.
- The direct signal searches were carried out using protons, pions, photons and deuteron (JINR) incident on various light nuclei. Some experiments did see the signals indicating the existence of an η mesic state.
- The expectations from the future lie in the experiments planned at the J-PARC, MAMI, COSY and NUCLOTRON facilities.
- The nuclotron based experiment can provide measurement with rather good energy resolution and can study extra branching modes of decay.

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Physical aims

- a new field in studies on nuclear and particle physics.
- new data on the η-meson and the S_{11}(1535) resonance interactions with nucleons
- determination of the energy levels E_g (S_{11}) and E_g(η) and their widths $\Gamma_g(S_{11})$ and $\Gamma_g(\eta)$ in the η-nucleus
- determine mass shift $\Delta m(S_{11})$ and $\Delta m(\eta)$ in the nuclear medium
- a study $N\eta \rightarrow \eta N$
- determinations of the amplitude of the reaction $S_{11}\, N \rightarrow NN$

Согласен с учетом мнений В.И.Волкова и А.В.Бутенко
18.06.12

В.И. Волкову
А.В. Бутенко
Прошу проработать и согласовать в случае если не видите никаких "против"
08.02.12

Зам. директора по научной работе:

Трубникову Г. В.

Уважаемый Григорий Владимирович, для поведения прецизионных измерений на внутренней мишени нуклотрона свойств частиц в ядерной среде, планируется провести модернизацию спектрометра «СКАН», существенно улучшив импульсное разрешение установки. Самый оптимальный способ решения этой задачи это измерение импульсов частиц по отклонению в магнитном поле. Для этих целей коллаборация физиков, участвующих в этих исследованиях, предлагает установить в одном плече спектрометра «СКАН» магнит СП-46 на расстоянии 1м от оси нуклотрона.

Прошу дать экспертную оценку возможности использования магнита в плане влияния рассеянного поля от него на динамику пучка нуклотрона.

Схема планируемого расположения магнита и результаты измерения рассеянного магнитного поля приведены в приложении к этому письму.

С уважением
С.В.Афанасьев

14.11.2011

т. 903 288 32 62

С точки зрения влияния магнитного поля на пучок возражений нет.
В данной конфигурации оборудования в значительной степени осложнится обслуживание вакуумного оборудования участка внутренней мишени. Перекроется доступ в наружные смежные помещения (вакуумный склад и теплоузел)
(Бутенко)
27.06.12

Согласен в случае обеспечения перемещения конструкции.
07.06.12.

Установка экспериментального оборудования затруднит доступ к диагностической аппаратуре
(В.И.Волков)

Collaboration

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D.M. Jomurodov, R.N. Bekmirzaev,

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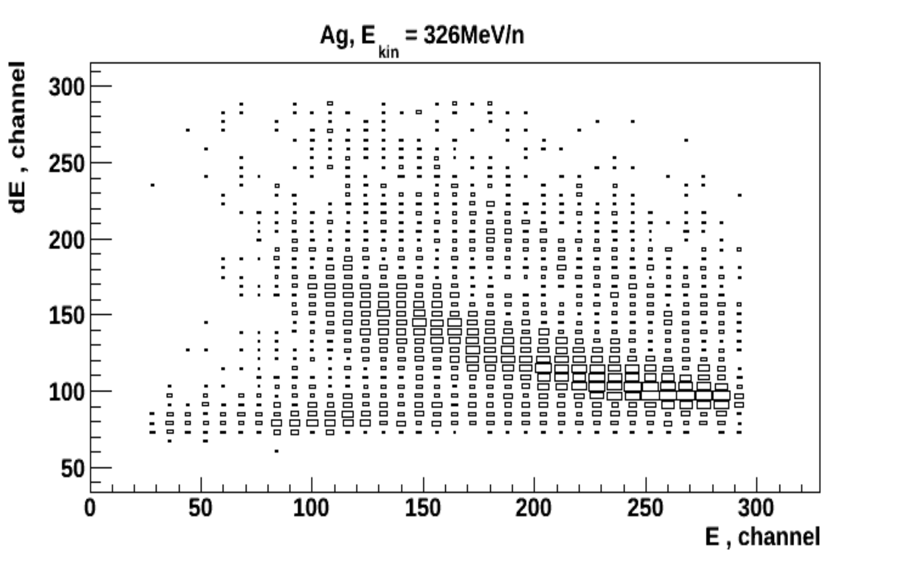
R.M.Ibadov, M.U. Sultanov,

Samarkand State University, Uzbekistan afanasev@lhe.jinr.ru

Outlook

- **Introduction**
- **Searches for unstable eta-mesic nuclei**
- **η-nucleon interaction and scattering amplitude**
- **Theoretical studies**
  - *Reaction mechanisms for meson production*
  - *Eta meson interaction with nuclei in the final state*
- ***Experimental searches***
  - *TAPS results*
  - *COSY measurements*
  - *SCAN dates*
- **Requirements to precision of their measurements**
- **New setup for the NUCLOTRON facility**
  - *To target requirement*
  - *Energy resolution*
  - *Space resolution*
- **Summary**

Target=Ag, E^{d}_{kin}=326 MeV/n



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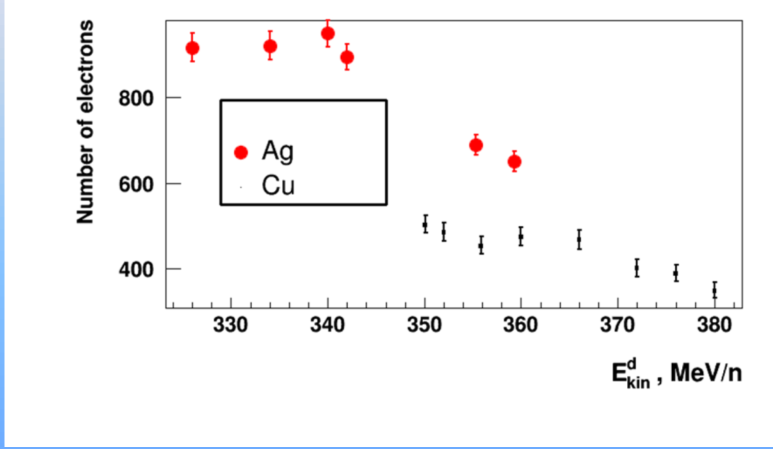

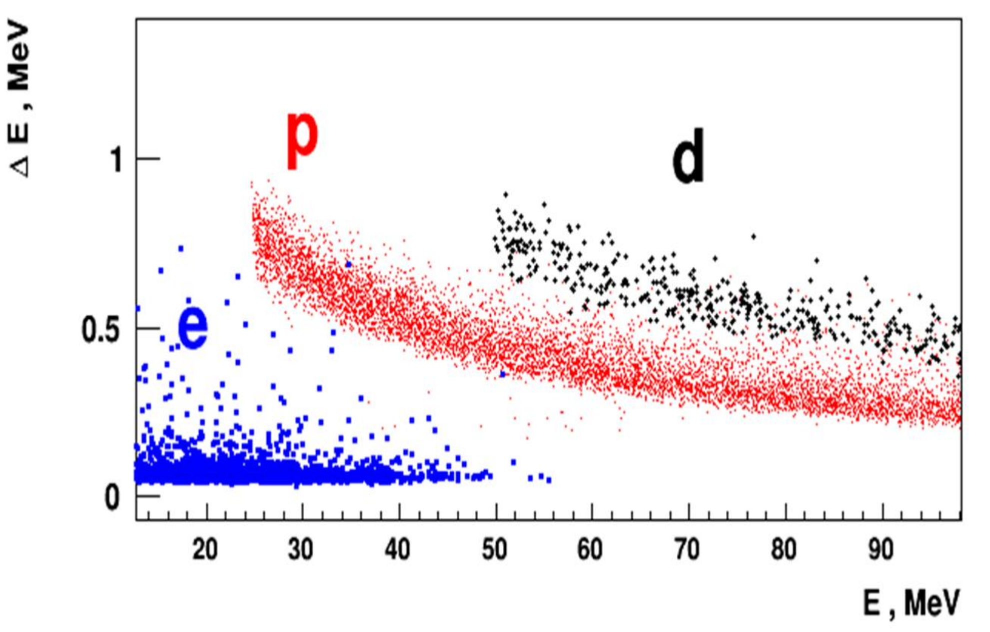

Meson related physics has always led to interesting findings in different ways. Though mesons are strongly interacting objects composed of quark - antiquark ($q\bar{q}$) pairs. ***The bonding of electrically charged mesons with nuclei leads to the formation of exotic atoms.*** For example, negatively charged pions or kaons could replace an electron in an outer orbital in a standard atom and get bound in the atom due to the Coulom interaction (π-meson atom, K-meson atom). After some transitions to lower states however, the meson comes within the range of the strong nuclear interaction and is absorbed on to the nucleus or lost in a nuclear reaction.

There exists yet another possibility for the formation of bound states of mesons and nuclei and this is when the meson-nucleus strong interaction is attractive. The eta (η) meson seems to satisfy this requirement. Its interaction with the nucleon in the s-wave (which proceeds through the formation of an $N^*(1535)$ nucleon resonance) was found to be attractive and formed of unstable states of eta mesons and nuclei.

The interaction of the η-meson with a nucleon near threshold is mainly determined by the S_{11}, J_(spin^{parity}) = $½^-$ resonance $N^*(1535)$, which is just 49 MeV above the ηN threshold (1486 MeV) and has a width Γ=150 MeV, thus covering the whole low energy region of the ηN interaction. As the S_{11}-resonance also decays to πN, γN and ππN channels involves its coupling to all these channels. Several such coupled channel calculations have been reported in literature***. All the calculations are report that the ηN interaction is strong and attractive in the s-wave.***

In addition to the studies of eta mesic quasibound states, huge efforts have also gone in understanding the eta producing reactions ***which explore the eta production vertex in these reactions and the effect of the eta interaction with other nuclei in the final state***. The reaction mechanisms used for eta production are usually based on models similar to those used for other mesons such as the pions and kaons.

Searches for unstable eta-mesic nuclei

The existence of an eta-mesic nucleus, i.e., a quasibound state of the η meson and a nucleus was predicted due to the attractive nature of the ηN interaction. Since its first mention in 1986, several experimental and theoretical searches have been performed for light as well as heavy eta-mesic nuclei. The experimental searches involve the production of η mesons and hence signals for the existence of eta-mesic states via their possible decay modes and final state interactions of eta mesons with nuclei. The theoretical works concentrate on the calculation of the eta-nucleus elastic scattering amplitudes and the solutions with η-nucleus potentials using different approaches.

η-nucleon interaction and scattering amplitude

The η-nucleon scattering length $a_{\eta N}$, which is the parametrization of the η-nucleon scattering amplitude at low energies is complex. Its imaginary part gives a measure of the reactive content of the cross section. Since through the detailed balance theorem, the $\eta N \to \pi N$ cross section can be related to the $\pi N \to \eta N$ cross section at an appropriate energy, the imaginary part of $a_{\eta N}$ can be determined directly by the pion-induced eta production data.

In (Arndt R A at.all Phys. Rev. C 72), using the optical theorem, a lower limit was set on the value of $\Im m$ (aηN). Using the recent threshold data (Prakhov S et al 2005 Phys. Rev. C 72), $\sigma_{\pi-p\to\eta n}/q_\eta$=15.2±0.8 μb/MeV, gives $\Im m(a\eta_N) \geq 0.172 \pm 0.009$ fm. In the above expressions, q_x is the centre of mass momentum of the particle x.

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Another calculation within a ***factorization approximation (FA)*** . The ηN centre of mass energy √s is assumed to be $\sqrt{s} = m_\eta + m_N - \Delta$ with Δ being an energy shift parameter. The calculations for Δ = 0, 10, 20, 30 MeV notice that for Δ = 30 MeV the FA results come quite close to the full off-shell calculations. The shift parameter Δ fitted from the πN scattering data was also found to be around 30 MeV. ***The downward shift implies that the ηN interaction in η-bound state formation takes place at energies about 30 MeV below the free space threshold***. Such a shift can lead to a reduction in the ηN attraction inside the nucleus and hence models using the ηN interaction in free space could actually be overestimating the η-nucleus binding energy.

The optical potential within the FA was recently used to explain the missing mass spectrum obtained in the recoil free transfer reaction $p(^{27}Al, ^{3}He)\pi p'X$ performed by the COSY-GEM collaboration and SCAN setup. The kinematics in this experiment were chosen in order to search for the η-mesic nucleus $^{25}Mg_\eta$ and $^{12}C_\eta$. The authors in (Haider Q and Liu L 2010 J. Phys. G 37) showed that the observed peak structure occurs due to coherent contributions from processes where an η binds to ^{25}Mg to form an intermediate $^{25}Mg_\eta$ or it emerges as a pion through $\eta p \rightarrow \pi^0 p$ scattering in ^{25}Mg without forming a quasibound state.

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arXiv:hep-ex/0609035 20sep 2006

η AND η' MESONS PRODUCTION AT COSY-11

P. Moskal[*,%,*], H.-H. Adam[#], A. Budzanowski[§], E. Czerwiński[*], R. Czyżykiewicz[*,%], D. Gil[*], D. Grzonka[%], M. Janusz[*,%], L. Jarczyk[*], B. Kamys[*], A. Khoukaz[#], P. Klaja[*,%], J. Majewski[*,%], W. Oelert[%], C. Piskor-Ignatowicz[*], J. Przerwa[*,%], J. Ritman[%], B. Rejdych[*], T. Rożek[+], T. Sefzick[%], M. Siemaszko[+], J. Smyrski[*], A. Täschner[#], P. Winter[×], M. Wolke[%], P. Wüstner[%], W. Zipper[+]

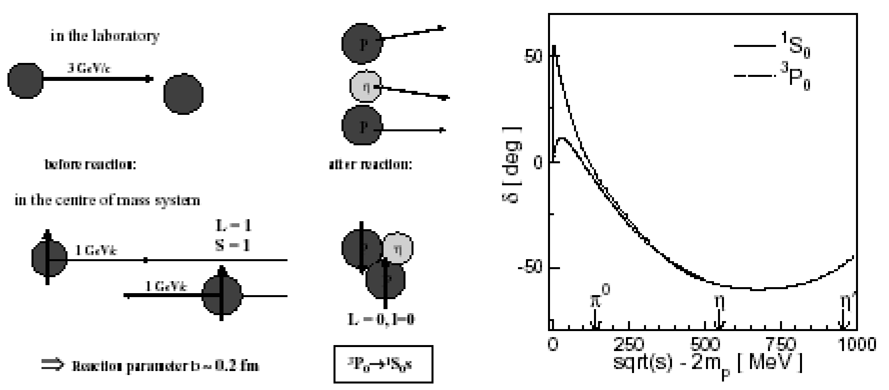

Fig. 1. (Left): Schematic view of the $pp \to pp\eta'$ process at threshold. (Right): The $^1S_0$ and $^3P_0$ phase-shifts of the nucleon-nucleon potential shown versus the centre-of-mass kinetic energy available in the proton-proton system. The values have been extracted from the SAID data base [12].

International Workshop on η–Nucleus Physics

May 8–12, 2006, Jülich, Germany

Expected characteristics of pairs from decay of η-nuclei and requirements to precisions of their measurements

The task of the experiment is the allocation and measurement of the narrow peaks in the energy distribution of pairs, which are products of η-nucleus decay.

Apparently, future experiments should assume that the peak width will be about 10 MeV, and therefore they should provide accurate measurements of particle energies will be not worse than ~ 3.5 MeV, so that the accuracy of the total energy of the pair will be at least 5-7 MeV. The effects of an broadening of observable peak, caused by energy dispersion in cause intra nuclear nucleons motion. This dispersion a increases observable width of peak by ~20 MeV. This moment is reduce the accuracy to the level of 10 MeV.

If we consider the process $\eta + N_i \rightarrow \pi + N$ with initial particles at rest, the kinetic energy, momentum and velocity of the secondary particles must be estimated:

$$T_\pi = E_\pi - m_\pi = (W^2 + m_\pi^2 - m_N^2)/(2W) - m_\pi = 313 \text{ MeV},$$
$$T_N = E_N - m_N = (W^2 + m_N^2 - m_\pi^2)/(2W) - m_N = 94 \text{ MeV},$$
$$p_\pi = p_N = [E_\pi^2 - m_\pi^2]^{1/2} = [E_N^2 - m_N^2]^{1/2} = 431 \text{ MeV/c},$$
$$\beta_\pi = p_\pi / E_\pi = 0.95,$$
$$\beta_N = p_N / E_N = 0.42.$$

Here $W = m_\eta + m_N = 1486$ MeV, also were used masses $m_\pi = 140$ MeV, $m_N = 939$ MeV, $m_\eta = 547$ MeV.

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It is necessary to mean that besides decay on channel πN η-nuclei can decay with emission NN pair. It occurs at the expense of an η-meson annihilation on pair of the intra nuclear nucleons

$$\eta + N_i + N_j \rightarrow N_1 + N_2$$

Velocity of this two-nucleon process and also one-nucleon process $\eta + N_i \rightarrow \pi + N$ were estimated by Kulpa and Wycech (see nucl-th/9807020 and Acta Phys. Pol. B29, 3077 (1998)), proceeding from the available data on cross sections of reverse reactions ($\pi^- p \rightarrow \eta n$, $pp \rightarrow \eta pp$, $pn \rightarrow \eta pn$, $pn \rightarrow \eta d$).

If such estimates are true, velocities of one-nucleon and two-nucleon decays of nucleus are not too strongly differ. The isotopic structure of the emitted particles are:

in the one-nucleon decay: 1/3 $\pi^+ n$, 1/6 $\pi^0 p$, 1/6 $\pi^0 n$, 1/3 $\pi^- p$
(since the isospin of η is equal 0 and consequently the full isospin of πN system is equal 1/2),

in the two-nucleon decay: ***≈5% pp, ≈5% nn, ≈90% pn***
(since the cross section of $pn \rightarrow \eta pn$ or ηd exceeds the cross section of $pp \rightarrow \eta pp$ near the threshold in 10 times).

These isotopic structures raise an output of the correlated pn-pairs in comparison with an output of correlated $\pi^+ n$ or $\pi^- p$-pairs and make these outputs are comparable.

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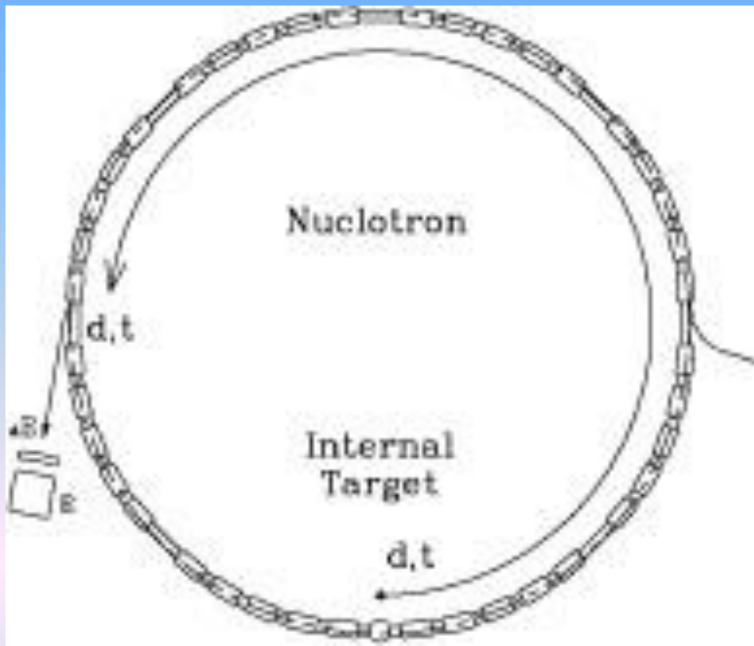
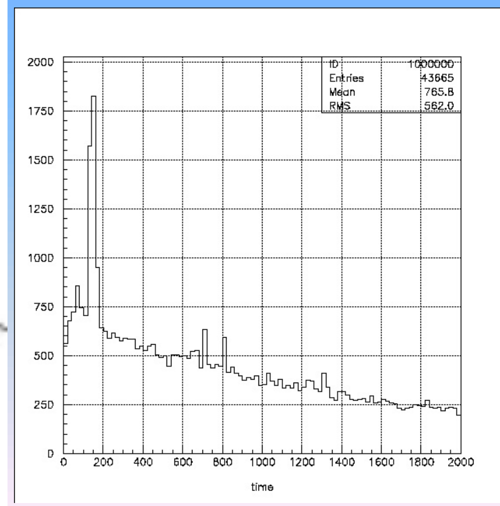
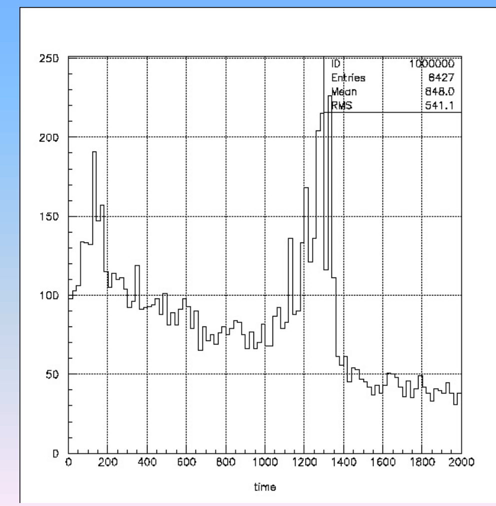
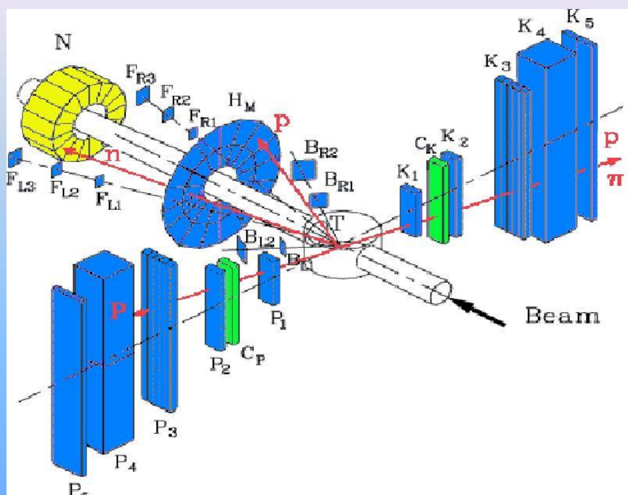
$dP/P<10^{-4}(10^{-3})$

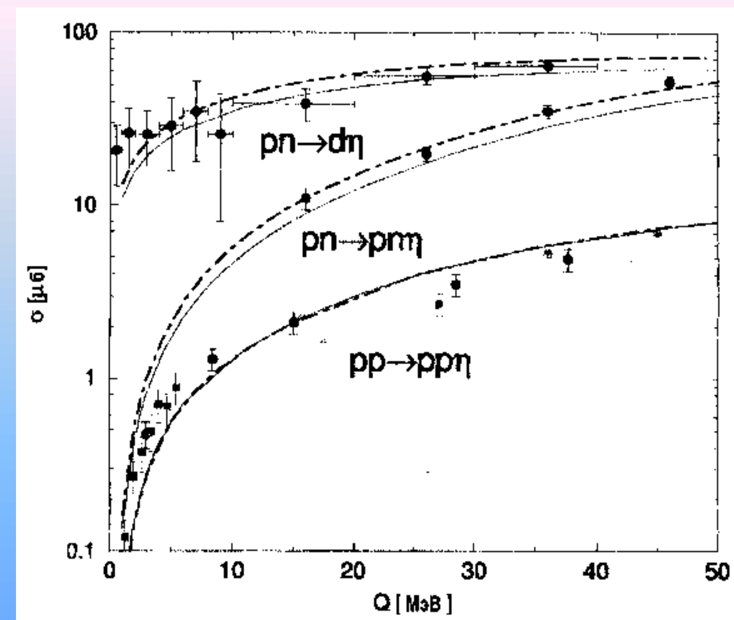
$p+A \rightarrow d+_{\eta}(A-1) \rightarrow p+p(\pi)+d+\dots$











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