Creation of a precision magnetic spectrometer SCAN-3 and research of non nucleon degrees of freedom in nuclei, nucleon correlations and nuclear fragmentation at the internal target of the Nuclotron.

Project SCAN-3

Collaboration

Institute of Physics, Slovak Academy of Sciences, Slovak republic

J.Kliman, V.Matousek, S.Gmutsa, I.Turzo

Horia Hulubei National Institute of R&D for Physics and Nuclear engineering (IFIN-HH Bucharest, Romania

I.Cruceru, F.Constantin, M.Cruceru, G.Niolescu, L.Ciolacu

Insitute for Space Science, Bucharest-Magurele, Romania

M. Paraipan

Joint Institute for Nuclear Research, Dubna, Russia

S.V. Afanasiev, Yu.S.Anisimov, A. A.Baldin, A.I.Berlev, D.K.Dryablov, B.V.Dubinchik, A.F.Elishev, O.V.Fateev, Z.A.Igamkulov, L.V.Karnyushina, Yu.F.Krechetov, I.V.Kudashkin, Z.P.Kuznecova, S.N.Kuznechov, A.I. Malakhov, V.A.Smirnov, S.S.Shimansky

Institute advanced studies «OMEGA», Dubna, Russia

A.A.Baldin, A.I.Berlev, I.V.Kudashkin,

Faculty of Science, University of P.J. Šafárik, Košice, Slovak republic

S. Vokál, J. Vrláková

Lebedev Physical Institute, Leninsky Prosect 53, Moscow, Russia

V.A.Baskov, A.I. Lebedev, A.I. L'vov, L.N. Pavlyuchenko, V.V. Polyansky, E.V.Rzhanov, S.S. Sidorin, G.A. Sokol

PTI, Tomsk, Russia

I.V.Glavanakov, A.N.Tabachenko

Jizzakh State Pedagogical Institute, Uzbekistan

D.M. Jomurodov, R.N. Bekmirzaev

Samarkand State University, Uzbekistan

R.M.Ibadov, M.U. Sultanov

General aims of the project

This project is aimed at studies of highly excited nuclear matter created in nuclei by a high-energy deuteron beam. The matter will be studied through observation the products of decay – pairs of energetic particles with a wide opening angle, close to 180^{o}.

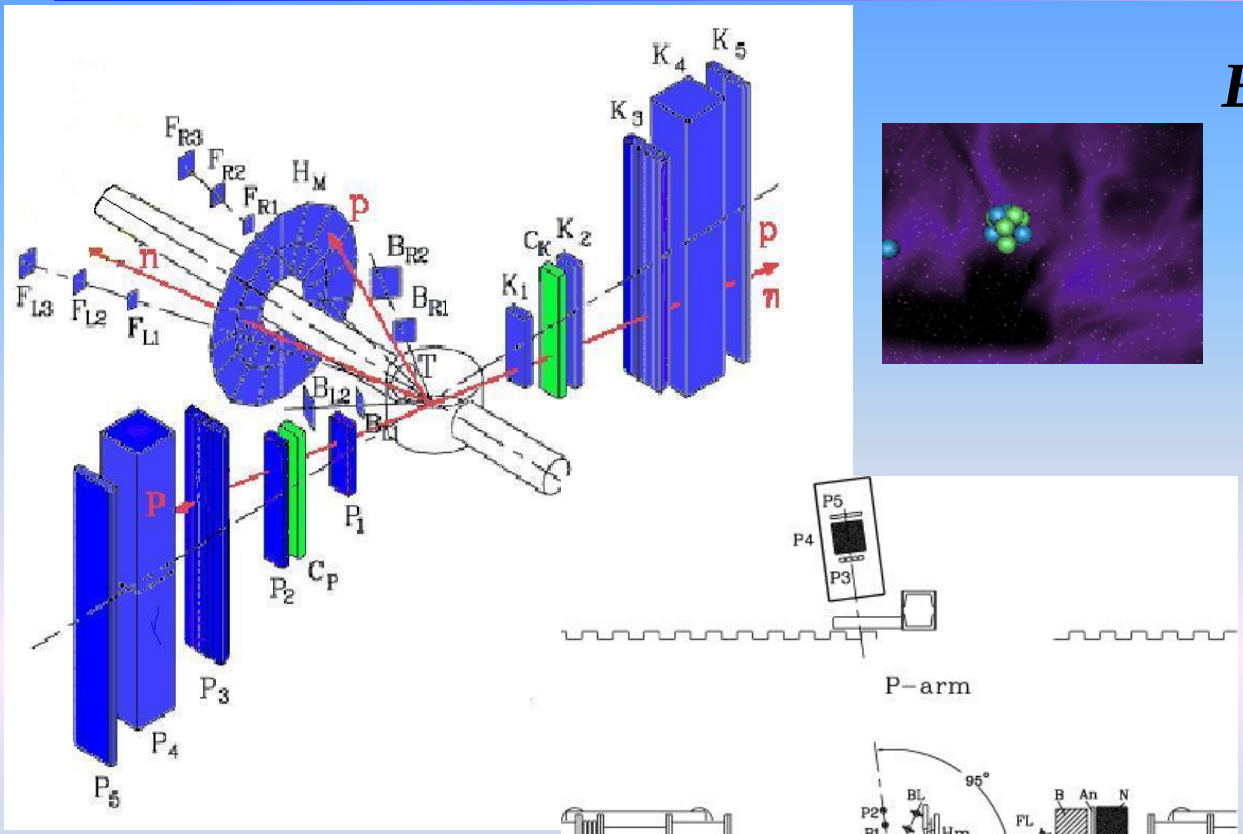
A new precision hybrid magnetic spectrometer SCAN-3 is to be built for detecting charged ($\pi^{\pm}$, $K^{\pm}$, p) and neutral (n) particles produced at the Nuclotron internal target in dA collisions. The spectrometry of such pairs will enable to studies of

- low-energy ηA interaction and a search for η-bound states (η-mesic nuclei);
- the Δ-isobar produced and stopped inside the nuclear matter.

Beyond that detection of the pairs will enable to studies of

- *np* and *pp* correlations;
- single and pair cumulative processes;
- heavy nuclei fragmentation to low-energy fragments.

Project SCAN, 2006-2008



Experimental setup

K-arm

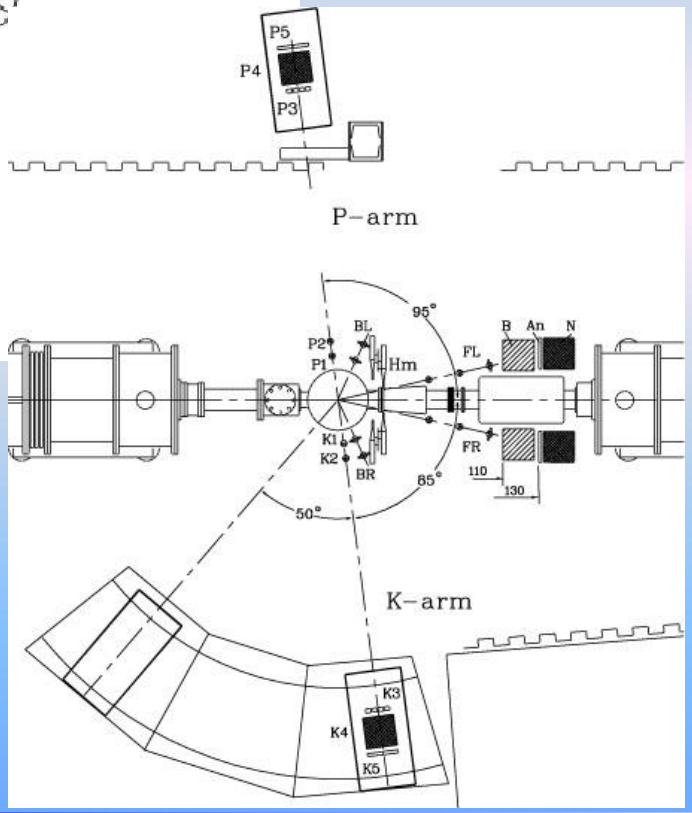
K1 - Start counter
K2 - Trigger & Cherenkov counters
K3 - TOF - wall
K4 - E-counter
K5 - Veto counter

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



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

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

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

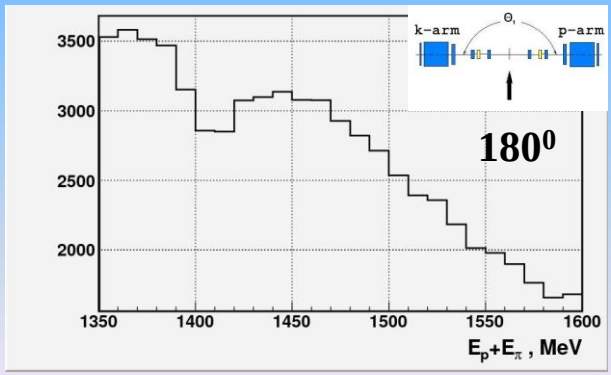
$$T_\pi \approx 350 \pm 30 MeV$$

afanasev@lhe.jinr.ru

Nuclotron based measurement of eta-nucleai.

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

Y(π,p)∝2.0 GeV/c²

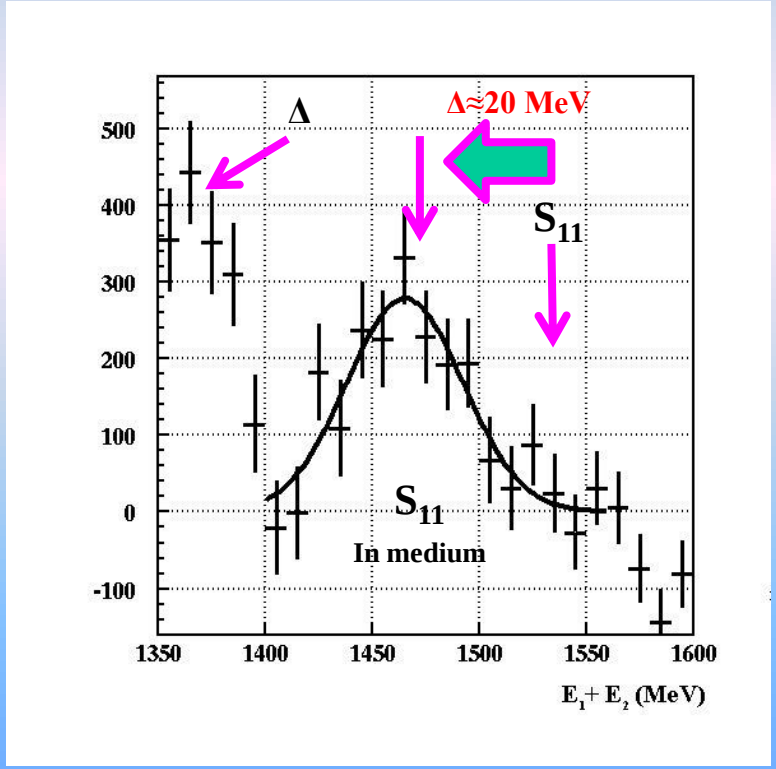


Total events under picks ≈2000

Best fit is Gaussian + constant

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

Distribution after rejection of the constant level



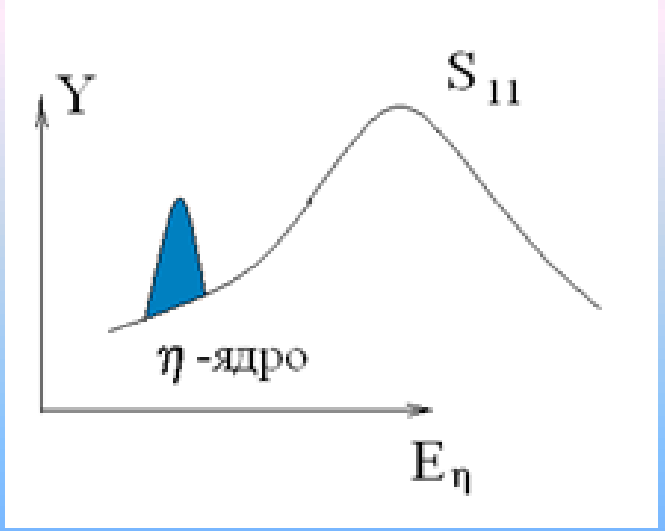
What we are looking for?

The interaction of the η-meson with a nucleon near threshold is mainly determined by the S_{11}, $J^P = ½^-$ 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.

- ***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***

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

- ***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).***



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 can be estimated:

T_π = = **313 MeV**

T_N = = **94 MeV,**

p_π = **431 MeV/c,**

Besides the πN mode, η-nuclei can decay with emission of NN pairs due to the reaction

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

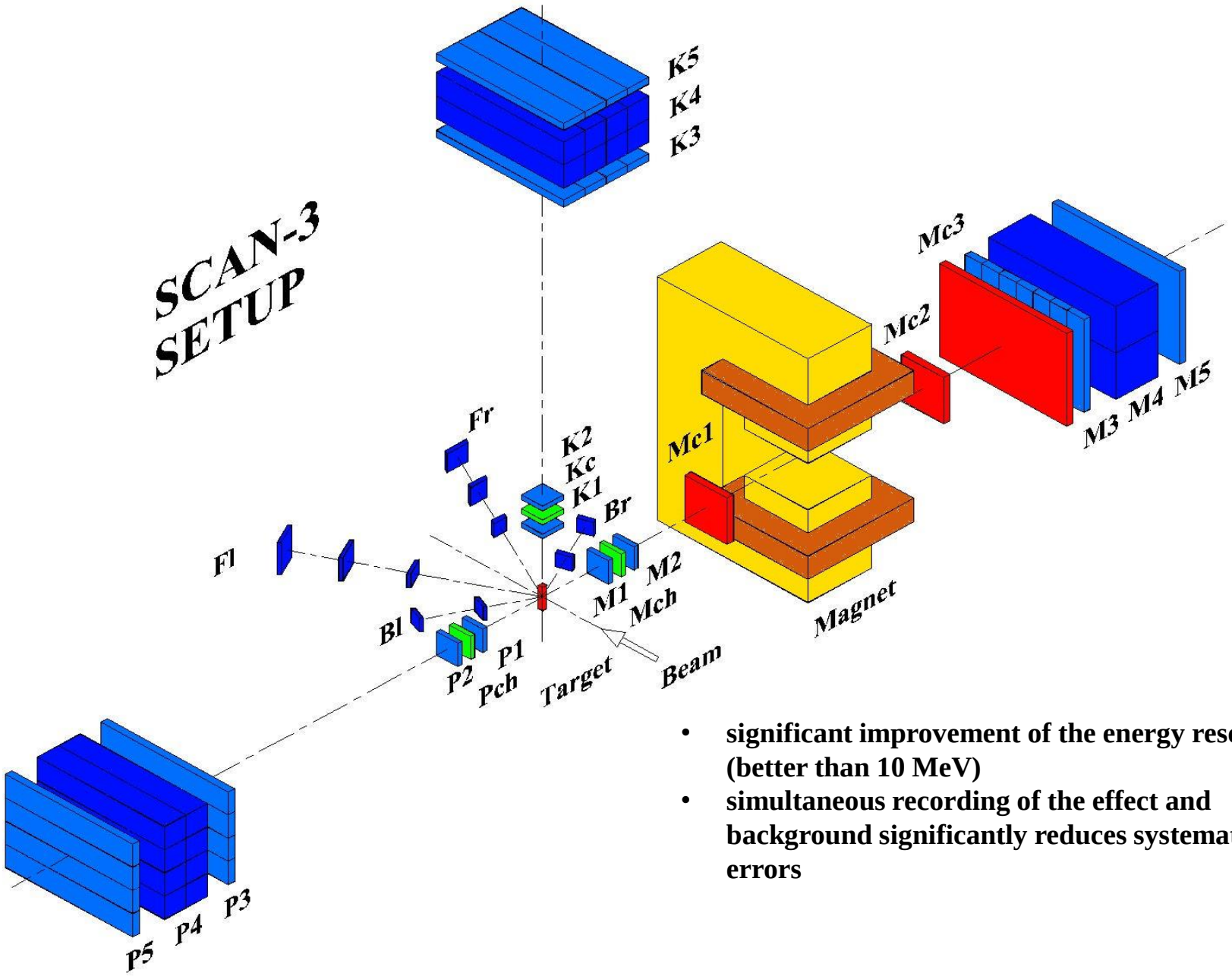
The rate of this decay channel is expected to be compatible with the rate of the channel π^-p.
Isotopic contents of the emerging NN system is

$$\approx 5\%\ pp,\ \approx 5\%\ nn,\ \approx 90\%\ pn$$

Such *pn* pairs having the kinetic energies

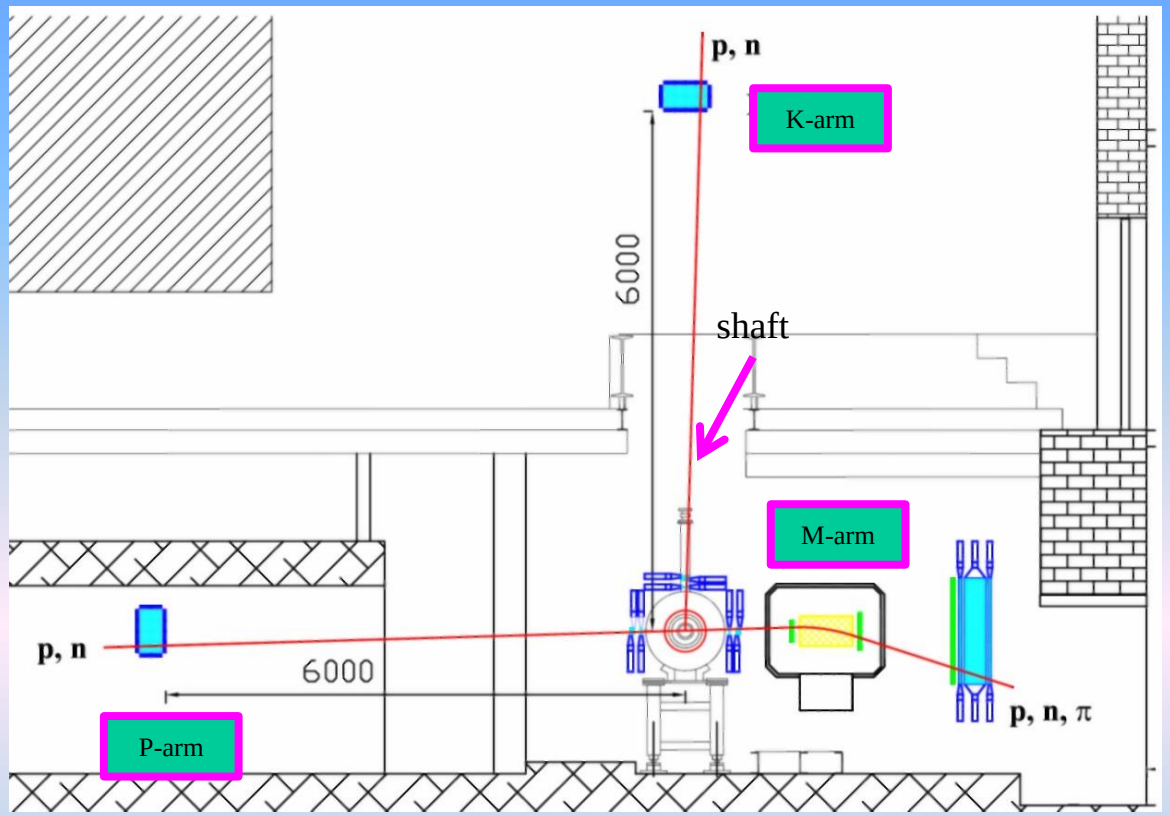
$$T_p \approx T_n \approx 270\ \text{MeV}$$

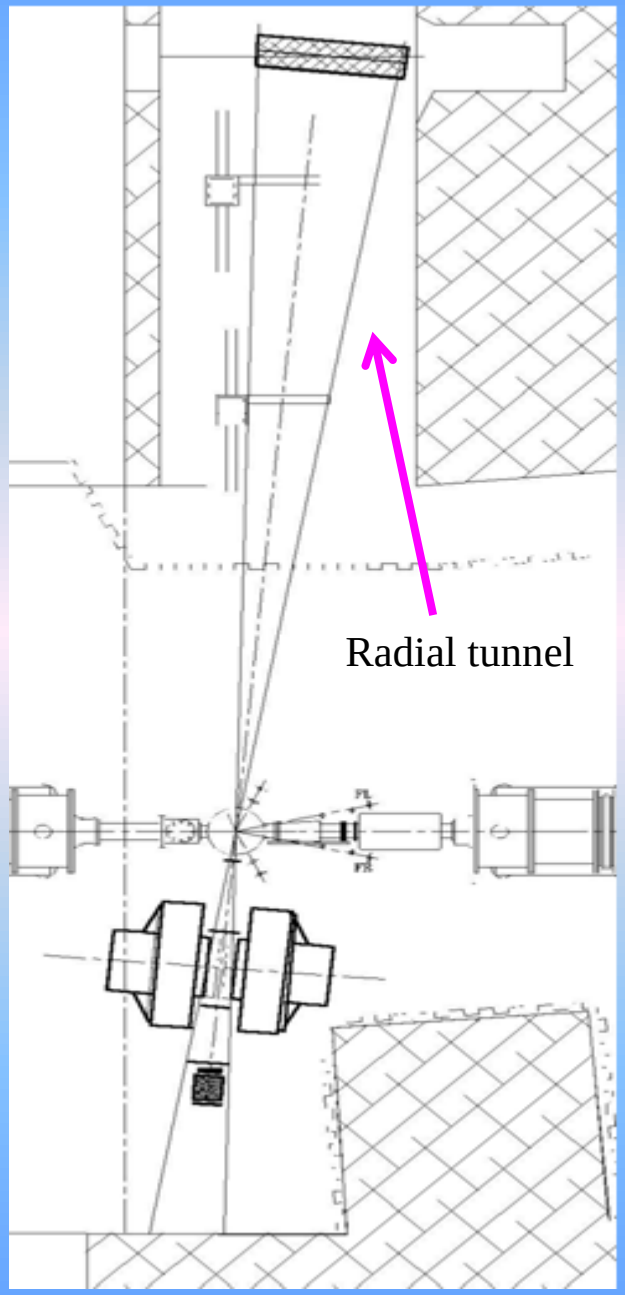
Experimental setup



- **significant improvement of the energy resolution (better than 10 MeV)**
- **simultaneous recording of the effect and background significantly reduces systematic errors**

Location of spectrometer





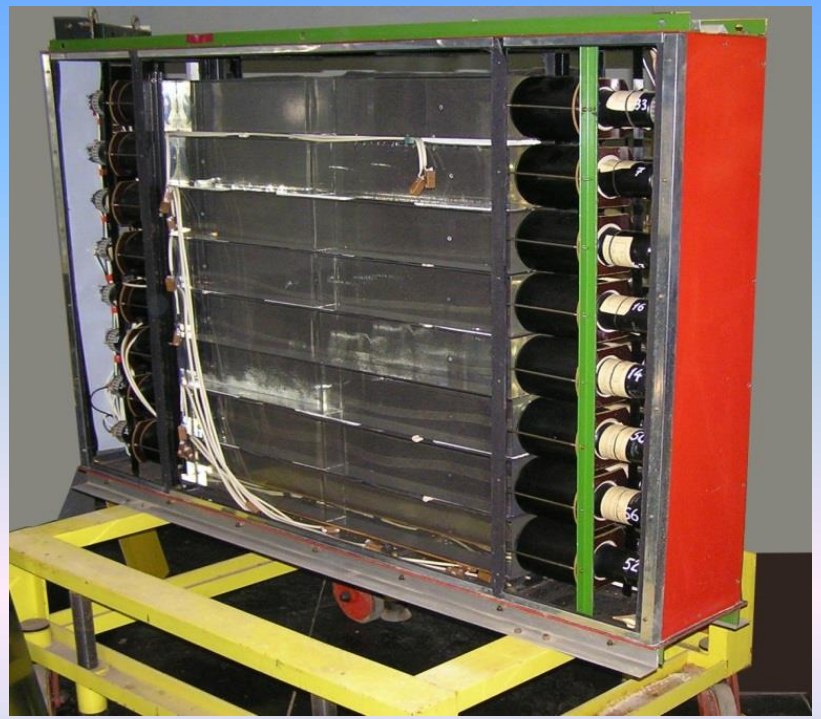
Neutron detectors

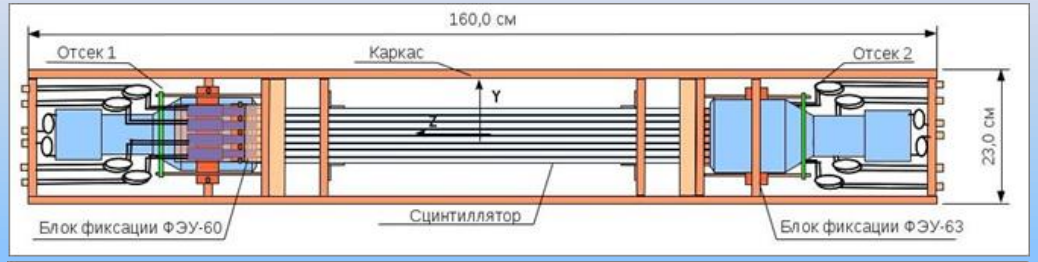
Energy resolution $\delta E_N \leq 10$ **МэВ**.

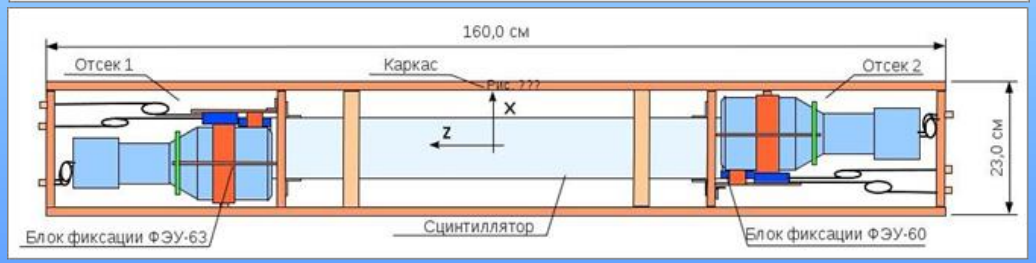
$$\delta E = \gamma^3 mc^2 \beta \delta\beta,$$

E_N=270 МэВ (β = 0.63 и γ = 1.29) L = 6м

$\delta\beta = 0.8*10^{-2}$ ⇒ { δt <0.4 нс
{ δL < 8 см







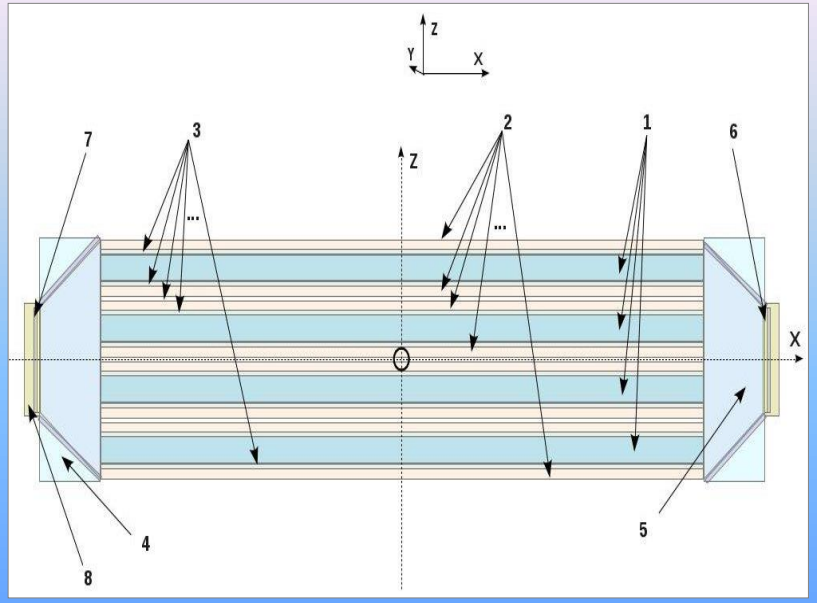
R&D for neutron counter

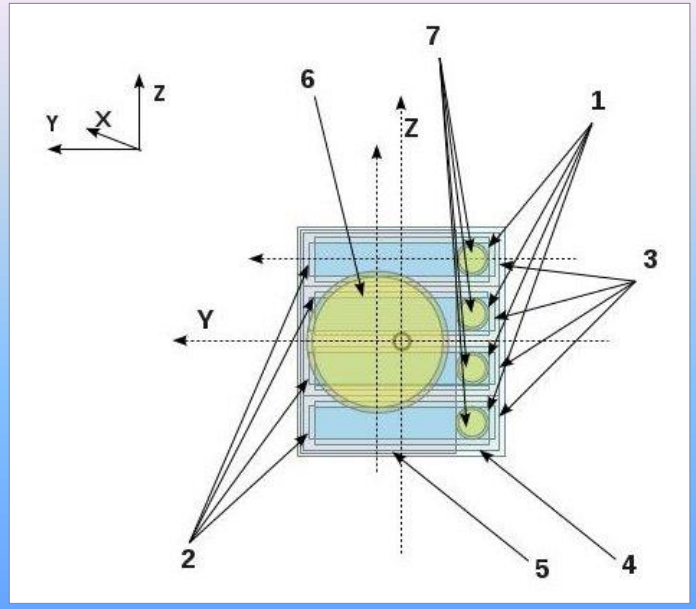
Preliminary data gave a time resolution is better then 300 ps for neutron detection.

Энергия нейтронов определяется по времени пролета на базе до 6 м.
Один модуль детектора - сборку из четырех протяженных пластических сцинтиллятора толщиной 3 см, с торцов временные фэу с диаметрами фотокатода около 100 мм. Для более точного определения базы пролета каждая пластина дополнительно просматриваться двумя фэу диаметром фотокатода около 2 см.

Моделирование одной пластины длиной до одного метра показало, что необходимое разрешение по энергии нейтронов около **5 МэВ в диапазоне около 100 МэВ** достигается при временном разрешении порядка **200 пс**.

Были исследованы временные характеристики сборки отдельных сцинтилляционных пластин с фэу **ФЭУ-63, *P*9814*B* и *XP*2020**, в качестве основных фотодетекторов в нейтронном канале. Приемлемые результаты получены **лишь с фэу XP2020**, временное разрешение на одной пластине порядка **250-280 пс**.





Для достижени необходимого временного разрешения было предложено использовать фэу из системы идентификации пластины.

В качестве кандидатов рассматриваются ФЭУ-85 и ФЭУ-87.

Проведено экспериментальное исследование временных характеристик этих фэу с разными делителями напряжения. ФЭУ-87 показал примерно на 20% более лучшее временное разрешение чем ФЭУ-85, однако эффективность регистрации света ФЭУ-85 примерно на 30 % процентов выше.

Выяснилось, что одновременное использование информации с фэу ***XP*2020 и ФЭУ-87** (или **ФЭУ-85**) уже позволяет достичь необходимый уровень временного, а значит и энергетического разрешения для нейтронного детектора.

Для выбора оптимального варианта сейчас проводятся дополнительные исследования.

В настоящее время для исследования элементов детектора нейтронов и заряженных частиц (протонов и легких ионов) используются:

• изотопный источник ^{90}Sr (*недостатки – непрерывный спектр электронов максимальной энергией всего 2.2 МэВ*);

• космическое излучение (*недостатки – низкая интенсивность*).

Плюсы работы на квазимоноэнергетическом пучке электронов (позитронов):

- высокая интенсивность;
- варьирование энергии электронов;
- хорошее координатное разрешение (*определяется мониторными счетчиками и годоскпом);*
- Дистанционное сканирование по площади детектора.

В результате, существенное сокращение времени создания детектора !

Name of components and system at plant, resources, funding sources			Cost of components (k$)	Proposals of laboratories on financing and resources		
				2017	2018	2019
Basic components and equipment		Dipole magnet	**65**	-	-	-
		Coordinate detectors				
		Drift chambers	**40**	**28**	-	-
		Proportional chambers	**15**	-	-	-
		Neutron detectors	**160**	-	-	-
		Scintillation counters	**45**	**1**	-	-
		Electronics of DAQ	**42**	**8**	**1**	**1**
		HV supply	**39**	-	-	-
		Gases support system	**25**	**1**	-	-
Essential resources	Hours	Model shop at JINR	-	-	-	-
		Laboratory ООЭП	**500**	**300**	**100**	**100**
		model shop	**160**	**100**	**20**	**40**
	hours	Accelerator Nuclotron	**1200**	**400**	**400**	**400**
		Computer	-	-	-	-
		Operating costs	**3**	**1**	**1**	**1**
Founding sources	Bud-get	budget costs, including currency account	**43**	**39**	**2**	**2**
	Founding sources	collaborates holding, grants, sponsors, agreements, other sources.	**391**			

Summary

As a result of project implementation we plan:

- to create a precision magnetic spectrometer for the measurement of correlated pairs with an energy resolution up to 4-5 MeV;
- studies of correlated hadron pairs ejected from the target in *d*A collisions;
- studies of the $S_{11}(1535)$ and $\Delta(1232)$ resonances in the nuclear matter;
- determination of binding energies and widths of η in nuclei;
- measurements of the cross section $\sigma(_{\eta}A)$ of η-nuclei formation in *d*A collisions; measurements of the A-dependence of $\sigma(_{\eta}A)$;
- measurements of relative rates of $\pi^{-}p$ и pN events;
- measurements of relative rates of $\pi^{+}p$, $\pi^{-}p$ and pN events.

Thank you
for attention!

afanasev@lhe.jinr.ru