Investigation of excited baryonic matter at the internal target of the Nuclotron

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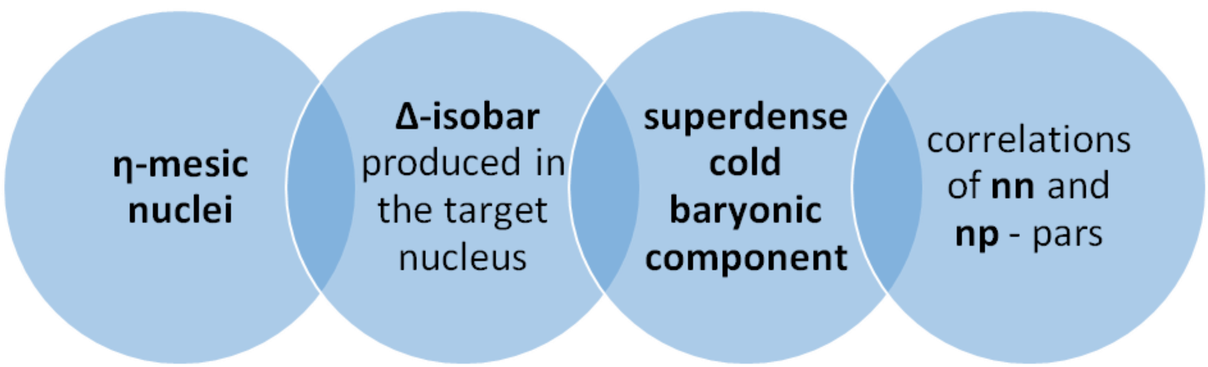
Introduction

The present project is directed on creation of a three-arm hybrid magnetic spectrometer SCAN3 for research of excited baryonic matter at the internal beam of the Nuclotron. The spectrometer is intended for registration and analysis charged particles (π, K, p) and neutral particles (n). The spectrometer is designed for research of the pairs of the particles emitted from an interaction point at an angle close to 180 degrees (so-called wide angular pair correlations). The possibility of registering such pairs allows the study of a wide range of physical phenomena:



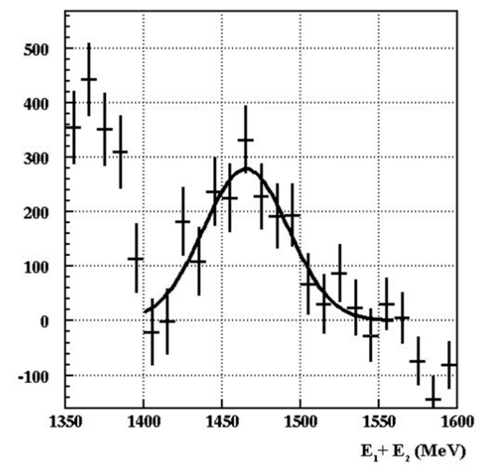
η-mesic nuclei

Physics of η-mesic nuclei is a new field of physics of particles and nuclei. η-mesic nuclei is a nuclear system having the η-meson bound in a nuclear by strong interaction with nucleons. Due to presence of a strong near-threshold nucleon resonance S_{11} (1535) in the ηN-channel slow η-mesons have a strong attraction with nucleons. As a result the slow η-meson is captured by the nucleus and forms η-meson nucleus, which in turn breaks up on πN or NN-pairs.

Studies of η-nuclei open up new possibilities for the study of ηN-interaction. All data of ηN-scattering are indirect and the results of these analyzes are affected by large theoretical uncertainties. η-nuclei allow to obtain a direct information about ηN-interaction.

One of the goals of the study of η-nuclear systems is investigation of S_{11} (1535) resonance in the nuclear medium. Mass and width of this resonance in the nuclear medium varies [1]. Understanding the effect of the nuclear medium on particles is an important and urgent problem.

The articles [2], [3], [4], [5] present an experiments to search for η-mesic nuclei.



In 2006-2010 a set of experimental data at two arms nonmagnetic time-of-flight setup SCAN2 and the internal d-beam of the Nuclotron (LHEP, JINR) had been obtained. The peaks in the invariant mass spectra of back-to-back $\pi^{-}p$ – pairs was observed [6]. The figure shows this distribution minus the background.

New project provides a significant increase of the energy resolution of the set up by including a magnetic spectrometer in the experimental installation and by increasing the time-of-flight base. The criterion of a bound η-meson is two factors: the total energy of the πN pairs from η-mesic nuclei decay should be below the threshold ($E_\pi + E_N < m_\eta + m_N$) and a narrow mass distribution of the πN pairs. The energy and width of this distribution will give information about the energy level of meson bound in a nucleus. This criterion of a bound η-meson can be illustrated by a simple potential model [7].

Δ-isobar

Isobar Δ (1232) is the lightest of the excited spin-isospin state of the nucleon, so this isobar plays an important role in many nuclear processes.

Usually Δ-isobar in the nucleus is considered in two significantly different ways. The most studied way is the quasi-free formation of isobars in the scattering of high-energy particles by atomic nucleus. Another aspect of the Δ-nuclear physics associated with isobaric configurations in the ground state of atomic nuclei, as part of the fundamental problem of the nucleon-nucleon interaction in the medium and short distances.

There is a third aspect that has hardly been studied and which will be investigated in the present project. This project will focus on search for and study of a quasi-bound Δ-nuclear state.

The possible existence of Δ-nuclear was discussed in the 70s (for example, [8] and [9]).

We need more experimental studies of pion-nucleon pairs formation and nucleon-nucleon pairs formation in the kinematic region most sensitive to manifestations of Δ-nuclear. To determine the region we need a dynamic model of the formation of Δ-nuclear and correct inclusion of the background reaction mechanisms.

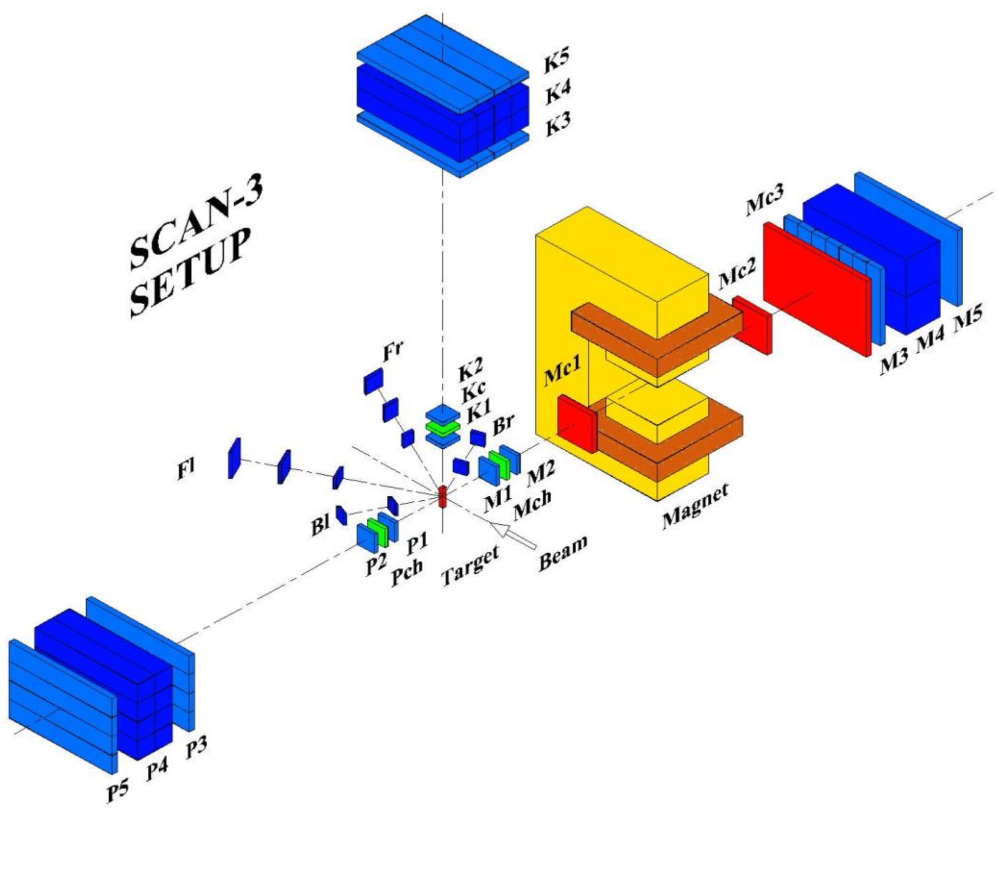
superdense cold baryonic component

Detailed studies of the inclusive particle production in the interaction of different beams and targets are carried out. The main result of this research is the detection of the high-density state (several times denser than the nucleon) in the nucleus. This state is not created in the collision, it exists as a superdense component of usual nuclear matter (for example, [10]).

Installation SCAN allows to study of the properties of cold superdense nuclear component. Location of detection arm allows to carry out research in the region of large P_T. In this region, large momentum transmission enable to detect short-lived systems in the kinematic region with a little background.

Experimental set-up

Three independent arm (M, P and K) are located in one plane with the target and are perpendicular to each other.



FR, FL, BR, BL - scintillator monitor counters;
P1,P2,P3, K1,K2K3, M1,M2,M3 - trigger time-of-flight scintillation detectors of P, K and M arms;
Pch, Kch, Mch – threshold Cherenkov detectors for p-π identification;
Magnet – magnet SP-46 with the 40cm magnetic track and field value up to 7-10kGs;
Mc1, Mc2 – biplanar drift chamber for precise measurement of the coordinates;
Mc3 – multiwire proportional chamber;
M4 – scintillation detector for complete absorption of the M-arm;
P4 and K4 – 2 sets of 8 scintillation detectors, which are used for the registration and spectrometry of neutrons;
P5, K5 и M5 – veto detectors for separation of fast particles.

The K-arm will be used for detection of background events while P and M arms will record the studied events. Two particle identification methods (TOF-E and rotation of a particle in the magnetic field) will be used. A unique feature of this setup is the presence of the neutron detectors that are not part of similar experimental installations in the world.

Research program.

Good knowledge of C++ programming language and the ROOT software (http://root.cern.ch) is greeted. Students are proposed to take part in the following themes of the project:

- ✓ Simulation of P or M – arm of SCAN3 using GEANT (version 3 or version 4) program. Determination of detector's characteristics (momentum acceptance for different particles, particles identification ……).
- ✓ Simulation of beam-target interaction using one of simulation programs (for example, UrQMD). Investigation of background for interested reactions.
- ✓ Testing and calibration of scintillation detectors.

The number of participating students is 1-2.

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