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STUDYING OF HYPERNUCLEI WITH NUCLOTRON BEAMS

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The hypernuclear program at Dubna was started in 1988 with investigation of the light-hypernuclei production and decay [1]. Nowadays, we are planning to measure lifetimes and production cross sections of $^{6}_{\Lambda}$He and $^{6}_{\Lambda}$H hypernuclei.

Гиперъядерная программа в Дубне началась в 1988 г. с изучения легких гиперъядер. В настоящее время планируется измерение времени жизни и сечения рождения гиперъядер $^{6}_{\Lambda}$He и $^{6}_{\Lambda}$H.

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1. MOTIVATION AND PLANS FOR HYPERNUCLEI RESEARCH

The proposed experiments will continue the hypernuclear experimental program started at Dubna in 1988 with the investigation of production and decay of hydrogen hypernuclei $^{4}_{\Lambda}$H and $^{3}_{\Lambda}$H using the GIBS spectrometer with a streamer chamber [2]. Based on the results of the first experiments and on theoretical predictions, a more extended program for hypernuclear research was proposed [3], including measurements of production cross sections and lifetimes, search for new species of hypernuclei, and investigation of interactions of «hypernuclear beam» with absorbers as a way to measure binding energy of loosely bound $^{3}_{\Lambda}$H or $^{6}_{\Lambda}$H hypernuclei. This program required significant improvements in both the spectrometer and the accelerator, because statistics of hypernuclear events in the first GIBS experiments was limited by slow response of the spectrometer based on a streamer chamber and relatively short extraction time of the Synchrophasotron. The design parameters of the new HyperNIS spectrometer based on proportional chambers, and the Nuclotron accelerator satisfied the requirements of the proposed studies.

More advanced second stage of the program will be devoted to studying nonmesonic decays of hypernuclei. We plan the experiment to measure the branching fractions $\Gamma\alpha\alpha$ for the exclusive decays of the $^{10}_{\Lambda}$Be and $^{10}_{\Lambda}$B hypernuclei. The branching fractions $\Gamma\alpha\alpha$ depend on various combinations of four matrix elements, hence their study offers a way to determine all needed matrix elements of the weak ΛN interaction. (This experiment is planned for the second stage, because of Nuclotron ability to accelerate particles, readout electronic of proportional chambers, and spectrometer shoulder.) In order to register pairs of alpha particles emitted within narrow angle, the spectrometer will need to be upgraded with high-resolution tracking detectors. However, such a sophisticated upgrade of the spectrometer will be rewarded with unique possibility of obtaining information about ΛN weak-interaction matrix elements. But the nearest among the planned experiments will study production of light hypernuclei (hydrogen and helium) with Li beam. As in the early GIBS experiments, the trigger will be based on the determination of charge of hypernuclei and decay products, selecting hypernuclei π^- decays with charge of the daughter nuclei larger than the charge of any beam nucleus fragment, i.e.,

$$ {}^{A}_{\Lambda}\mathrm{H} \to \mathrm{He} + \pi^- \quad \text{or} \quad {}^{A}_{\Lambda}\mathrm{H} \to {}^{A}\mathrm{Li} + \pi^-. $$

2. LAYOUT OF HYPERNIS SPECTROMETER

The schematic view of the HyperNIS spectrometer is presented in Fig. 1, where registration of particles in the main detectors is shown for the case of ${}^{6}_{\Lambda}\mathrm{He}$ production with ${}^{6}\mathrm{Li}$ beam using the chain of reactions:

$$ {}^{6}\mathrm{Li} + \mathrm{C} \to {}^{6}_{\Lambda}\mathrm{He} + \ldots \to {}^{6}\mathrm{Li} + \pi^-. $$

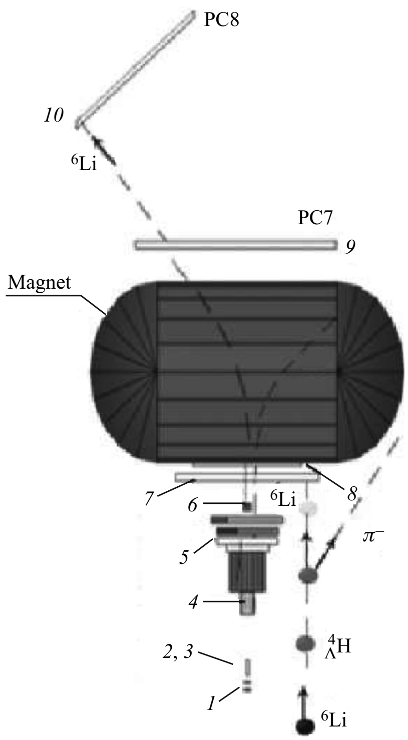

Fig. 1. Layout of HyperNIS spectrometer: *1* — monitors and counters of group A; *2* — target; *3* — counters B; *4* — vacuum vessel; *5* — PC1–PC4; *6* — counters C; *7* — PC5-6; *8* — RPC; *9* — PC7; *10* — PC8

If a hypernucleus was produced in a Li interaction with target (T), mesonic decay can be selected by trigger tuned to search for events with signal amplitude low in detectors B and much higher in detectors C (signals proportional to Z^2!). Background due to fragmentation is rejected because of low signal from detectors C. Tracking system approves that decay vertex was in vacuum. The electric charge of particles is measured by three groups of trigger scintillation counters A, B, and C, the tracking information is provided by sets of the proportional chambers PC1–PC6, and the time-of-flight of pions is measured by the resistive plate chambers RPC.

Beam position and intensity are controlled with monitors and counters of group A. The amplitudes of the signals in the trigger counters A, B, and C for the shown reactions

$$ {}^{6}\mathrm{Li} + \mathrm{C} \to {}^{6}_{\Lambda}\mathrm{He} + \ldots + \to {}^{6}\ \mathrm{Li} + \pi^- $$

will be proportional to ionization by 9, 4, and 9 minimum ionizing particles (MIPs), correspondingly. Setting the thresholds of the discriminators for these counters around the corresponding peaks provides an efficient and very selective trigger, because the majority of the noninteracting Li beam ions is rejected by the counters of group B, while most of fragmentation interactions is rejected by the counters of group C. An evacuated vessel is placed right after the target and counters B so that most of the detected decays of hypernuclei take place in vacuum to minimize potential contamination of selected events by interactions and background vertices in the fiducial volume.

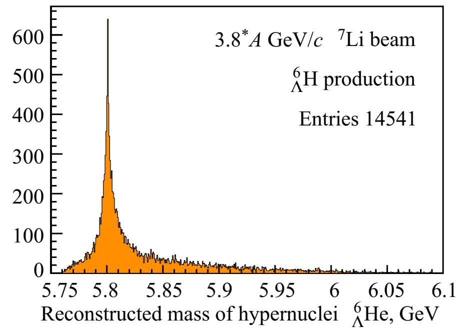

Fig. 2. Expected hypernuclei effective mass distribution for RPC resolution of 200 ps

Proportional chambers PC1–PC6 are used to check if there was a vertex inside the vacuum volume and to determine the position of the vertex. Momenta of slow pions are measured by the use of time-of-flight system. The start signal for the time-of-flight measurements is generated by a (special) scintillation counter placed near the target. The time resolution of this counter is relatively high, $\sigma \approx 50$ ps. Stop signals are provided by resistive plate chambers (RPC) with much worser time resolution $\sigma \approx 200$ ps. A set of 6 RPC detectors (48 pads, 20×15 cm) form a wall with total size of 1.9×0.9 m large enough to register hits of all the pions. Mean distance for TOF measurements is about 3 m, thus RPC resolution allows one to measure with sufficient resolution the momenta of about 50% pions. Expected distribution of reconstructed values of hypernuclei effective mass is shown in Fig. 2. Complimentary to the time-of-flight system, large fraction of high momenta pions will be detected in the minidrift chambers (MDC) when they will be installed in the magnet at later stages of the experiment (see Fig. 1).

3. RESULTS

The short test run with ^{6}Li beam was mainly devoted to trigger tuning and tests of tracking detectors of the spectrometer. Spectra in Fig. 3 were obtained using an Al target inserted in the beam at front of the spectrometer in order to irradiate all counters with a mixture of

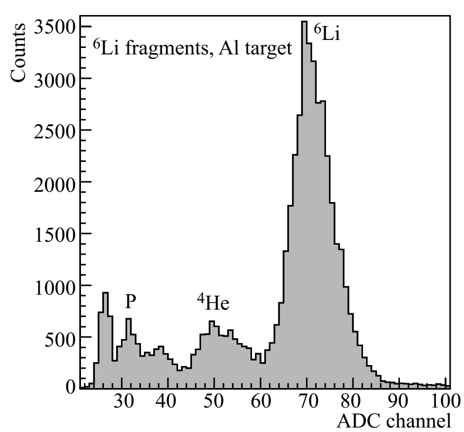

Fig. 3. Example of signal amplitude spectra obtained for C counters

lithium ions and their fragments, so that one could determine the amplitude resolution, test the linearity of the photomultiplier response, and tune the discriminator thresholds.

The results of the test run were encouraging, we confirmed that the trigger performance was stable over the extraction time, and determined that background suppression at the level of $2.5 \cdot 10^3$ is possible at the efficiency level of 95%.

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