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STUDY OF RELATIVISTIC HYPERNUCLEI PRODUCED IN NUCLEUS-NUCLEUS INTERACTIONS

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1. INTRODUCTION

The history of the hypernuclear physics has about four decades but information on hyperfragments (in particular, on their decay properties) appears to be rather scarce. For the time being only light hypernuclei ($_{\Lambda}A < 14$) were directly observed and identified by their decays. Since 1963 but two double hypernuclei were detected with a reliable identification. The lifetimes of hyperfragments were mostly measured for light $_{\Lambda}A$'s and with unsufficient accuracy. Different modes have been observed only for $_{\Lambda}A$'s with $Z \leq 7$ and their branching ratios are poorly known. Main obstacles in the way of progress of the mentioned investigations are due to low energies and short ranges of $_{\Lambda}A$'s, usually produced as fragments of target nuclei at rest.

To overcome these difficulties, a new experimental approach has been proposed [1-3] in which relativistic $_{\Lambda}A$'s could be produced as fragments of projectile nuclei accelerated to high energies.

Main advantages of this approach are the following:

— Mean decay ranges of such relativistic $_{\Lambda}A$'s are large enough (about 20 cm for $E_p \sim 4$ AGeV) to use rather thick targets and "dE/dx" charge detectors, including them in trigger;

— Velocities of produced $_{\Lambda}A$'s are very close to those of projectile-nucleus what provides favourable conditions for measurements of $_{\Lambda}A$-lifetimes and for analyses of their decays;

— Emission angles of relativistic $_{\Lambda}A$'s and their decay products are rather small (several degrees) what makes possible to use spectrometers with not large appertures.

The proposed approach, aiming to study $_{\Lambda}A$-production and their decays from ground states, should be considered not as a competitive method but as complementary one to the nice $(K\pi)$-exchange reaction successfully used for the excited states spectroscopy.

Relativistic hypernuclei have been detected in two experiments to date.

About 20 $_{\Lambda}O$ and $_{\Lambda}N$ hypernuclei were observed in spark chambers at Bevalac ($E_p = 2.1$ AGeV) [3], but their identification is rather ambiguous.

More than 20 very light $_{\Lambda}A$'s ($^{4}_{\Lambda}H$ and $^{3}_{\Lambda}H$) were detected with reliable identification in the streamer spectrometer at the Dubna synchrophasotron ($E_p = 3.7$ AGeV) [4], which provides much more favourable conditions for production and detection of relativistic $_{\Lambda}A$'s.

However, large memory and dead times of the used detectors set substantial limits on a beam intensity and for data taking rate. Moreover, interactions of projectile nuclei in the gas, filling the chambers, make practically impossible to discriminate background triggers due to these interactions, when many-body mesic and non-mesic hypernuclear decays are detected. To surmount the mentioned obstacles it has been suggested [5] to use spectrometers with fast coordinate and charge detectors, registering products of $_{\Lambda}A$ — decays from vacuum cavity.

2. EXPERIMENTAL SET-UP

A lay-out of the experimental set-up for the proposed investigations is shown in the figure. Its main element is the spectrometer "ANOMALON" which has been recently used to study the process of projectile nuclei fragmentation. The principal features of this spectrometer adapted for the proposed experiment are the following:

a) A CH-target-scintillator, M, (about 20% interaction length), which can be used as an active target to suppress high multiplicity interactions with C-nuclei;
b) Two MWPC's of three planes ($ПК_{1,2}$), Čerenkov ($\check{C}_{1\div4}$) and scintillation counters ($C_{1,2}$) will be used to control beam location and to measure the charge of projectile-nucleus and coordinates of its track;
c) Eight MWPC's $ПК_{3\div10}$ (6 of three and 2 of two planes) will be used to determine A/Z — ratio for fragments — products of production and of decay (by their rigidity in a magnetic field of СП-40);
d) A set of 30 Čerenkov charge detectors, Čr, will be used to measure Z of fragments.

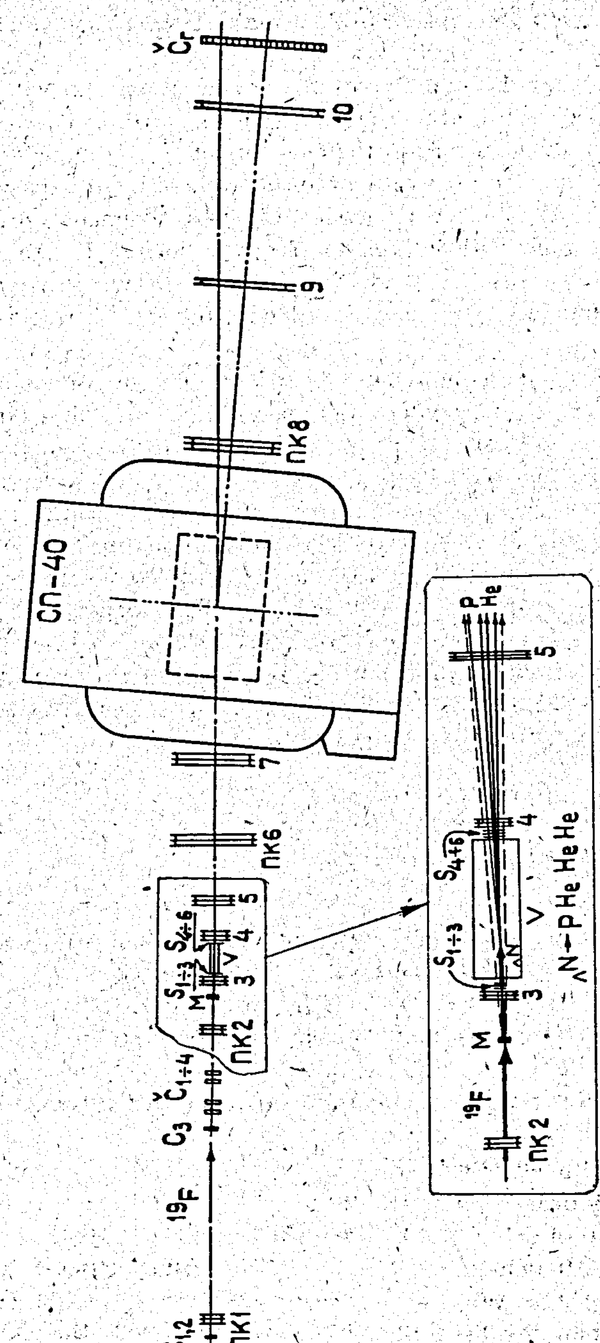
The spectrometer is equipped with the triggering system elaborated for $_{\Lambda}A$-decay detection, which includes:

— a vacuum cavity — volume, V, in which $_{\Lambda}A$'s will decay:
— two sets of 3 thin (~200 μm) Si — charge detectors (to be replaced by Si strips) inside of V ($S_{1\div3}$ and $S_{4\div6}$) will be used to detect the charge of $_{\Lambda}A$'s and of their decay products (multiplicities) before and after $_{\Lambda}A$-decay.

3. TRIGGERING AND EVENT ANALYSIS

Three levels of triggering will be used with a following logic:

— a decrease of charge, as a result of $_{\Lambda}A$-decay inside V, detected by S_{1-3} and S_{4-6};
— an increase of multiplicities detected by Si microstrips (placed in the sets S_{1-3} and S_{4-6});



A layout of the experimental set-up (with the decay $_{\Lambda}N \to p\,He\,He\,He$, in the vacuum cavity V, for example): СП-40 — analyzing magnet, $C_{1\div4}$ — scintillation counters for beam control, $\check{C}_{1-4}$ — Čerenkov charge detector, M — target, $S_{1\div6}$ — Si-charge detectors (Si-microstrips) of the triggering system, ПК 1 ÷10 — sets of MWPC, Čr — the hodoscope of the Čerenkov charge detectors.

— a reconstruction of a vertex inside of V using the Si microstrips, MWPC's and fast precessors.

At the first stage of the experiment the triggering system will include sets of three Si-charge detectors (S_{1-3} and S_{4-6}). The error of charge measurement for such a set, estimated from the experiment /6/, is $\sigma_Z \sim 0.2$ e what provides a possibility of selecting (with necessary reliability) events with the production and decay of $_\Lambda A$ when charges of main fragments change by $\Delta Z = 2$. In addition the logic with increase of Z can be included in the triggering system to detect the decay $_\Lambda A_Z \to A_{Z+1} + \pi^-$ as in the experiment /4/. Special electronics will be used to detect $_\Lambda A$'s having different Z with the same trigger adjustment.

Background events will be eliminated by the reconstruction of a vertex in the vacuum cavity V what provides an indication of a decay inside of V. At present we do not know any disintegration process for nuclear fragments (besides $_\Lambda A$-decays) which could be accounted for the selected decay events (neglecting very dubious anomalons). Moreover there is a specific signature for $_\Lambda A$-decays, which proceed from two-body reaction $\Lambda p \to np$ and $\Lambda \to p \pi^-$, in nuclei with $p(\pi^-)$-emission at rather large angles correlated with momenta.

Nuclear fragments — products of $_\Lambda A$-decays will be identified by Z and A/Z in off-line analyses using recorded data from MWPC's and Čr.

At the next stage of development it is proposed to use a neutron counter which could help to distinguish between particular isotopes of the detected hypernucleus (for instance in events with no n-emission).

4. EXPECTED DATA TAKING RATES

The cross sections of $_\Lambda A$-production in nucleus-nucleus collisions have been recently calculated /3/ with the result $\sigma \simeq 9\ \mu b$ for $_\Lambda B$, $_\Lambda C$, $_\Lambda N$ from ^{19}FC — interactions at $E_p = 3.7$ AGeV. This provides a possibility of estimating the expected data taking rate in the proposed experiment under the following assumptions:

— a flux of 10^6 nuclei per 5 s. burst of the Nuclotron on CH-target of 20 % interaction length;
— the decay factor for the detected $_\Lambda A$'s ~ 0.4;
— the overall efficiency of the detectors ~ 0.5;
— the expected fraction of detected and identified $_\Lambda A$-decays ~ 0.1.

This gives about 10 detected $_\Lambda B$, $_\Lambda C$, $_\Lambda N$ hypernuclei per 1 hour of Nuclotron operation. The σ value at Nuclotron energy ($E_p \sim 6$ AGeV) will be essentially larger than the used one. On the other hand, this value for heavier $_\Lambda A$'s is expected to be smaller.

There is a hope that the use of sectioned Si-detectors (Si-microstrips) will allow one to increase the flux and data taking rate. Trigger background is estimated to be less than 100 per burst what cannot reduce data taking rates.

5. MAIN POINTS OF THE EXPERIMENT

a) The measurement of the hypernuclear lifetime (τ) and the study of its dependence on A(Z) provide very important information on the behaviour of strange baryons bound in nuclear matter.

The available data on τ for $_Z A$ with $Z \geq 6$ are scarce and contradictory. The value τ, reported for $^{16}_{\Lambda}O$ ($^{16}_{\Lambda}N$) /3/ appeared to be about 2 times smaller than those for $_\Lambda A$ with $Z \leq 6$. On the other hand the available data /7/ on τ for the heaviest $_\Lambda A$ ($_\Lambda Bi$, $_\Lambda U$) are also in the bad disagreement (by an order of magnitude). Thus the study τ versus Z of A is an urgent task which can be done by measuring decay ranges (R) of various relativistic $_\Lambda A$'s, which have nearly close velocities. Using $_\Lambda A$-decays with $p(\pi^-)$ emitted at $\theta > 3°$, for the vertex reconstruction in V, the accuracy, giving $\Delta R \lesssim 1 \div 2$ cm, can be obtained (for $<R> \sim 20$ cm) with hundreds $_\Lambda A$-decays, detected for each Z during a 100-200 h. run at the Nuclotron.

b) The investigation of poorly studied non-mesic A-decays, proceeded due to $\Lambda N \to NN$ transition, provides the unique possibility of getting information on the 4 baryonic weak interaction and to examine how this process can be described by the recent theory. About 10^3 non-mesic decays of the lightest hypernuclei will be detected and carefully analysed for this purpose.

On the other hand this process is suggested to be a sensitive probe to investigate the structure of the nuclear core (particularly its quark structure). Such an investigation makes desirable to study various A-decay modes, to measure their branching ratio (especially the nonmesic-to-mesic decays ratio) which can be done using hundreds events for analysis.

The recent model calculations /9/ give rather large cross sections for double hypernuclei ($_{\Lambda\Lambda}A$) production in AA collisions (only $10 \div 30$ times smaller than for "usual" $_\Lambda A$). Even if these calculations overestimate real values by a factor of 10, the search for $_{\Lambda\Lambda}A$'s in beams of relativistic nuclei appears to be very promising. In this case one can expect to detect several $_{\Lambda\Lambda}A$'s with the above triggering system using two adjoined vacuum cavities (volumes).

The existence of double hypernuclei $^{10}_{\Lambda\Lambda}Be$ /9/ and $^{6}_{\Lambda\Lambda}He$ /10/ makes necessary to prevent their possible "strong" transition to $_{\Lambda\Lambda}H + (2)\,^4He$, where $_{\Lambda\Lambda}H$ — hypothetical dihyperon — six-quark state (uu dd ss). This set limites on the binding energy of $_{\Lambda\Lambda}H$: $B_{\Lambda\Lambda} \leq 10$ MeV. If so, the lifetime $\tau(_{\Lambda\Lambda}H) \sim 10^{-8} \div 10^{-9}$ s. is predicted /11/ with the main decay mode $_{\Lambda\Lambda}H \to$ $\to p\pi^- \Lambda \to p\pi^-$. Such a decay could be detected using the triggering system similar to that for $_{\Lambda\Lambda}A$ (two adjoined vacuum cavities with 3 sets of Si-microstrips). It is worthy to stress that surprisingly large $_{\Lambda\Lambda}H$ production cross sections are predicted for AA-collisions /12/. A detailed consideration of possibilities for $_{\Lambda\Lambda}H$ search in the framework of the proposed experiment is in progress now.

REFERENCES

1. Podgoretsky M. — JINR, 8309, Dubna, 1974, p.81.
2. Okonov E. — JINR, 8309, Dubna, 1974, p.104.
3. Nield K. et al. — Phys.Rev., 1976, C13, p.1263.
4. Avramenko S. et al. — Nuovo Cim., 1989, 102A, p.645.
5. Okonov E. — JINR, 1-87-191, Dubna, 1987.
6. Avdeichikov V. et al. — JINR, 1-84-486, Dubna, 1984.
7. Noga N. et al. — Yad.Phys., 1986, 43, p.1332;
   Bocquet J. et al. — CERN-EP-86-95, 87-11, Geneve, 1987.
8. Asai F., Bando H., Sano M. — Phys.Lett., 1984, 145B, p.19;
   Bando H. — In: Proc. of the 10 Europ.Symp.on Dynamics, Balatonfured, 1985.
9. Danysz M. et al. — Phys.Rev.Lett., 1963, 11, p.29.
10. Prowse D. et al. — Phys.Rev.Lett., 1966, 17, p.782.
11. Dover C. et al. — Phys.Rev., 1989, C40, p.115.
12. Sano M. — RIKEN-AF-NP-77, 1990.
13. Bando H. et al. — INS Rep.682, Tokyo, 1988.

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