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EMISSION OF FAST LIGHT PARTICLES IN $^{14}N + {}^{181}TA$ REACTIONAT 40 MEV/NUCLEON

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A brief description of the experimental setup to be used in the ion beams of the new U-400M accelerator at JINR is presented. The setup has been designed for study of very hot nuclear systems, which are produced in nucleus-nucleus collisions at intermediate energies. Angular distributions and energy spectra of light charged particles from the reaction $^{14}N + {}^{181}Ta$ at 40 MeV/nucleon were measured as a test of the experimental apparatus. The test results demonstrate that this experimental setup in combination with the high quality beams of the U-400M accelerator is a very powerful tool for a study of the mechanism of high-energy particle formation in the intermediate energy range.

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One of the main goals of the current research in nuclear physics in the intermediate energy domain is to improve our knowledge about the properties of nuclear matter at high density and temperature. The reactions with a high momentum transfer such as emission of very fast light charged particles or meson production could be used as a probe for the nuclear equation of state (EOS) in general, and also specifically for one of the most intriguing aspects of EOS: the existence of a nuclear liquid-gas phase transition. It is known that among several observables the energy distribution of light charged particles associated with heated nucleus decay and two particle small-angle correlations are sensitive to space-time evolution of hot nuclei and ultimately to phase transition. With the development of powerful detection systems, such as high efficiency 4π light charged particle detectors and close-packed detector arrays for the measurement of small-angle correlations it becomes possible to shed a light on the mechanism of the reactions with production of a very hot nuclear system.

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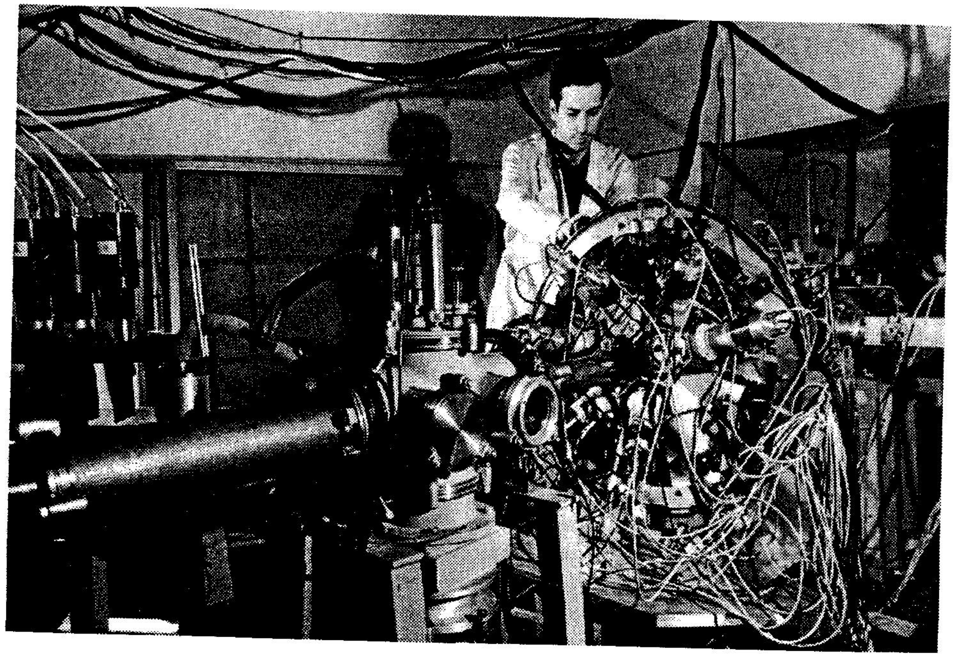

Fig. 1. A general view of the multidetector array in a beam line of the U-400M cyclotron.

Operation of the new heavy ion cyclotron U-400M in the JINR Flerov Laboratory of Nuclear Reactions in Dubna with high intensity ion beams up to 10^{13} sec^{-1}, with the energies up to 60 MeV per nucleon, with a wide range of accelerated ions, provides a good opportunity to study the production and decay of very hot nuclei. For effective utilization of accelerator's capabilities we used a 4π BGO-ball spectrometer and 19-module close-packed BGO-hodoscope for the study of light particle emission in nucleus-nucleus collisions. The main characteristics of the detectors are presented below.

A large solid angle detector, the LAMPF BGO-ball, has been used to detect the reaction products for this study. Detailed information on the BGO-ball can be found in Ref. [1]. The BGO-ball consists of 30 phoswich detectors. The detectors of the array were of pentagonal and hexagonal shape and are tightly packed to form a truncated icosahedron of 32 sides. Two of the 32 sides are opened for the beam entry and exit. The detectors are distributed around the inner radius of 6.1 cm from the center of the array to the center of each crystal face, and are arranged in six groups centered at the laboratory scattering angles $\theta = 37°, 63°, 79°, 102°, 116°$ and 142°. Each detector has a solid angle of about $\frac{1}{32} \times 4\pi$ sr and is supported in a 0.5-mm-thick electro-formed nickel can, which has a 0.05-mm-thick entrance window. Each detector consisted of

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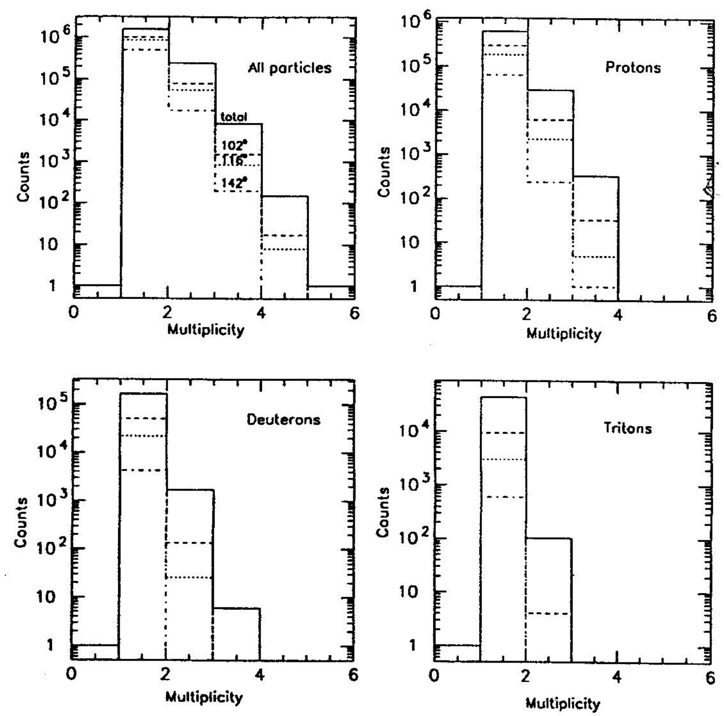

Fig. 2. The inclusive energy spectra of p, d, t measured at different scattering angles θ = 37°, 63°, 79°, 102°, 116° and 142°.

a 3-mm-thick NE102 plastic scintillator optically coupled to the front of a 5.6-cm-thick bismuth germanate (BGO) crystal, with a 7.62-cm-diameter photomultiplier tube behind. Since the decay constant of the BGO scintillator is much longer than that of the plastic scintillator (250 ns vs 1.5 ns), the anode signal is time sliced to provide both ΔE (fast) and E (slow) signals for the charged particle identification (pions, protons, deuterons etc.), and for the identification of neutrons and gamma rays. The crystal is thick enough to stop the protons of up to 185-MeV energy. The time resolution of the

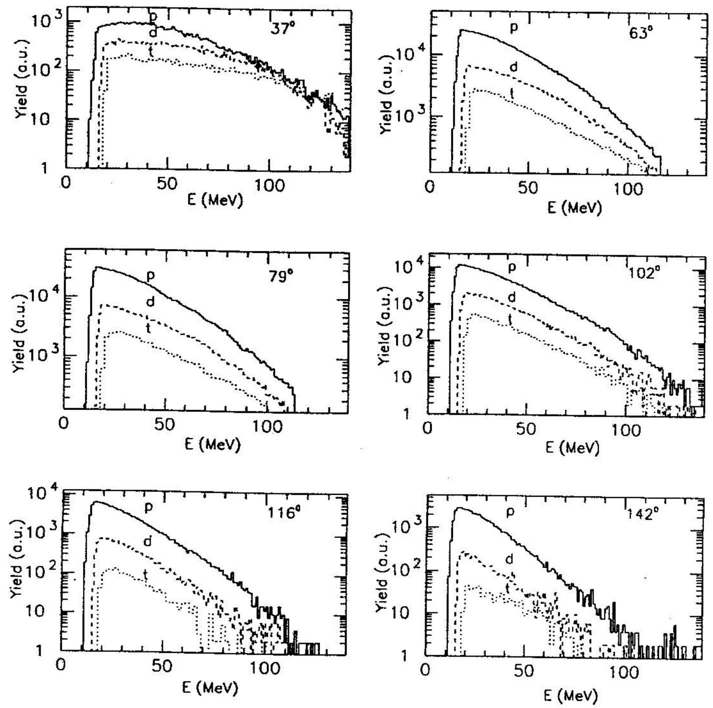

Fig. 3. The light particle multiplicity distributions. "All particles" means total multiplicity without particle identification, i.e. includes $\gamma, n, p, d, t, \alpha$ etc..

detectors is about 1 ns, which is sufficient to eliminate events with hits from different beam micro bursts. A general view of the BGO-ball in a beam line of the U-400M is shown in Fig. 1.

To calibrate the BGO-ball detectors the cosmic muons were used. To calculate the energy losses of cosmic muons in real detectors we used standard Monte Carlo technique based on the GEANT code [2]. For this simulation we used the known muon energy spectrum from Ref. [3]. The cosmic muons with an average energy of about

2 GeV with a trajectory along crystal axis through its center deposit about 60 MeV of their energy in the BGO crystal. For calibration run we selected events for which muon passed through the center of the BGO-ball. Measured energy loss spectrum is in a good agreement with the simulation. This calibration procedure could be done simultaneously with the real data taking, in time intervals between beam macro bursts, which is important for spectrometer stabilization.

The hodoscope for measuring small-angle two-particle correlations has been designed at the INP, Řež, Czech Republic. It consists of a close-packed hexagonal array of 19 plastic-BGO phoswich detectors. The thickness of plastic scintillators is 2 mm, the one of BGO is 8 cm.

The tests of the described experimental apparatus have been done in the ^{14}N induced reaction on a ^{181}Ta target of 5 mg/cm^2 areal density. This brief note presents very preliminary results of a test. Fig. 2 shows the inclusive energy spectra for protons, deuterons and tritons. The energy spectra exhibit exponential slopes, which become steeper with increasing detection angle. They are similar to those measured in other experiments with a wide range of energies and projectile-target combinations[4, 5]. Relative yields of lighter isotopes dominate in the observed energy range. Worth to note that even in a short test run we obtained the energy spectra changing within 3 – 4 orders of magnitude. It will allow us in the future to obtain a more accurate decomposition of the energy spectra within the "moving source" model to extract the "apparent" temperature of the emitting source. This parameter is needed to deduce the caloric equation of state $e^*(T)$, the relationship between excitation energy per nucleon e^* and temperature [6]. In addition, it became possible to measure high energy "tails" of the energy distribution. These studies can help to answer the question: what is the mechanism of such a very energetic particle formation?

To gain more insight into the reaction mechanism, in particular with respect to different "moving sources", multiplicity measurements are also important. Fig. 3 shows the distribution of the number of fired detectors per event ("raw" multiplicity). For this plot the events with the multiplicity ≥ 2 have been selected. In this measurement only 25 detectors of BGO-ball have been used. Even more information could be obtained from the angular dependence of the particle multiplicity distribution.

The preliminary results show that a combination of a high intensity beam of the U-400M with the efficient experimental technique opens the possibility to study currently discussed transition phenomena in the intermediate energy range in a more detailed and more conclusive way.

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