First experiments with radioactive beams at ACCULINNA-2 fragment separator

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First experiments with high intensive ^{8}He and ^{9}Li radioactive beams obtained at the new fragment separator ACCULINNA-2 [1] at the U-400M cyclotron were carried out in 2018/2019. The fragmentation reaction ^{11}B (33.4 AMeV) + Be (1 mm) was used for the production ^{8}He (I ~ 10^5 pps) and ^{9}Li (I ~ 10^6 pps) beams focused on the physical target (cryogenic D_2, T=27 K, P=1.1 atm and 2.4 atm, respectively) in a spot with a diameter of ~ 16 mm (FWHM).

A flagship experiment dedicated to search for the enigmatic nucleus ^{7}H and study of correlations between its decay products *t+4n* were the subject of the first run. The ^{8}He (26 AMeV) + d $\rightarrow$ ^{3}He + ^{7}H reaction was chosen to populate the ^{7}H ground and exited states. The key stone to detect low energy ^{3}He in the range of 9÷20 MeV was a set of four ΔE-E-E telescopes, each telescope being assembled out of three Si strip detectors – a 20-micron SSD and a couple of 1000-micron SSDs (where the second 1000-micron detector operated as veto), see Fig.1. Based on the preliminary data analysis one can conclude that the telescopes separate well the ^{3}He events in the presence of large amount of ^{4}He particles (Fig.2). To measure tritons moving at forward angles in narrow cone, $\theta \leq 6$ degrees, another telescope was installed at a far distance ~ 320 mm in front of the target. It consisted of one 1500-micron thick DSSD and a set of 16 CsI(Tl)/PMT modules. The triton telescope provided angular resolution ~ 0.5 degree and energy resolution ~ 2%. In addition, the array of 44 stilbene crystals [2] was used for neutron detection (TOF and angles) at forward direction.

Compared to the previous works [3, 4] dedicated to search for ^{7}H in the (d,^{3}He) reaction the novelty of the used setup was the measurement of the angles and energies of the tritons and neutrons with a good accuracy and the use of these data for correlation analysis. Events with a coincidence of the detected ^{3}He and ^{3}H were considered as candidates for the ^{7}H event. The number of coincidences of the decay products allowed us to estimate the reaction cross section. Measuring the spectra of ^{3}He recoils emitted at small angles allows one to reconstruct the ^{7}H missing-mass spectrum at a sensitivity level of $d\sigma/d\Omega \sim 5$ μb/sr. The angles and energies of ^{3}He and ^{3}H(n) as well obtained in coincidence were informative for the analysis of various correlations.

The second run was focused on the study of low-lying states of ^{10}Li populated in the reaction ^{9}Li(d,p)^{10}Li $\rightarrow$ n+^{9}Li. The principal value of this experiment was the detection of protons, emitted backwards in laboratory system, in coincidence with neutrons moving in forward direction, see Fig.3. To define energy resolution of this setup and normalization of the missing mass ^{10}Li spectrum the additional measurement in the reaction ^{6}He(d,p)^{7}He $\rightarrow$ n+^{6}He was carried out. Having a good statistics (about 500 triple coincidences *p*-*n*-^{9}Li) and experimental energy resolution of ~ 200 keV (FWHM) over the ^{10}Li excitation energy, new information about low-lying states of ^{10}Li is expected from these data, see Fig.4. It also should help to clarify the question mentioned recently by Cavallaro and co-authors regarding the high-lying structures at 1.5 and 2.9 MeV in the ^{10}Li spectrum [5].

Preliminary results of both measurements and nearest work plan at ACCULINNA-2 fragment separator will be reported as well.

1. A.S. Fomichev et al., Eur. Phys. J. A 54 (2018) 97.
2. A.A. Bezbakh et al., Instrum. Exp. Tech. 61 (2018) 631.
3. M.S. Golovkov et al., AIP Conf. Proceedings 912 (2007) 32.
4. E.Yu. Nikolskii et al., Phys. Rev. C 81 (2010) 064606.
5. M. Cavallaro et al., Phys. Rev. Lett. (2017) 012701.

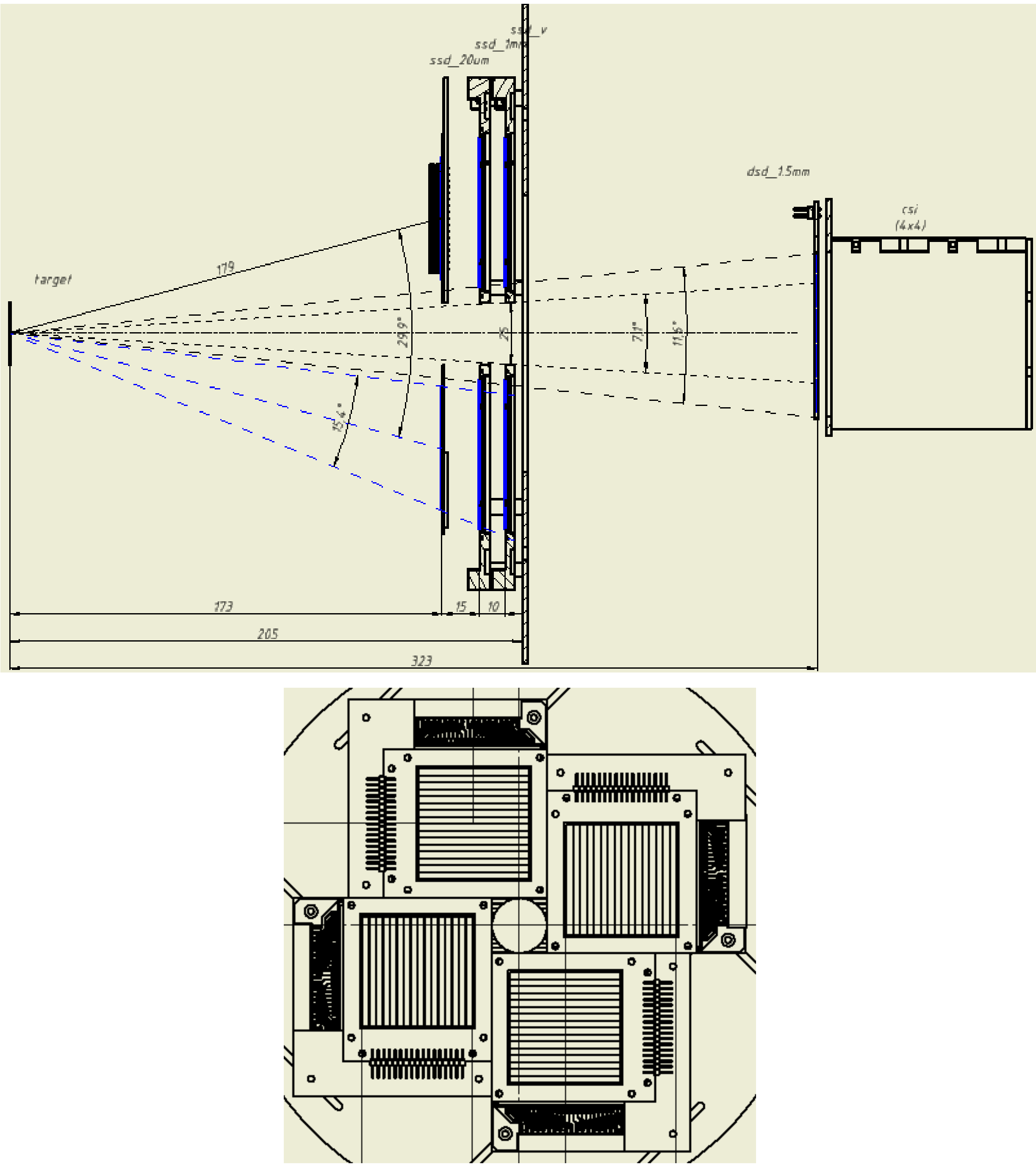

Fig. 1. Layout of the experimental setup for charged particles detection in the reaction $^{2}H(^{8}He,^{3}He)^{7}H$. Views from the side and from the front are correspond to the top and bottom panels, respectively.

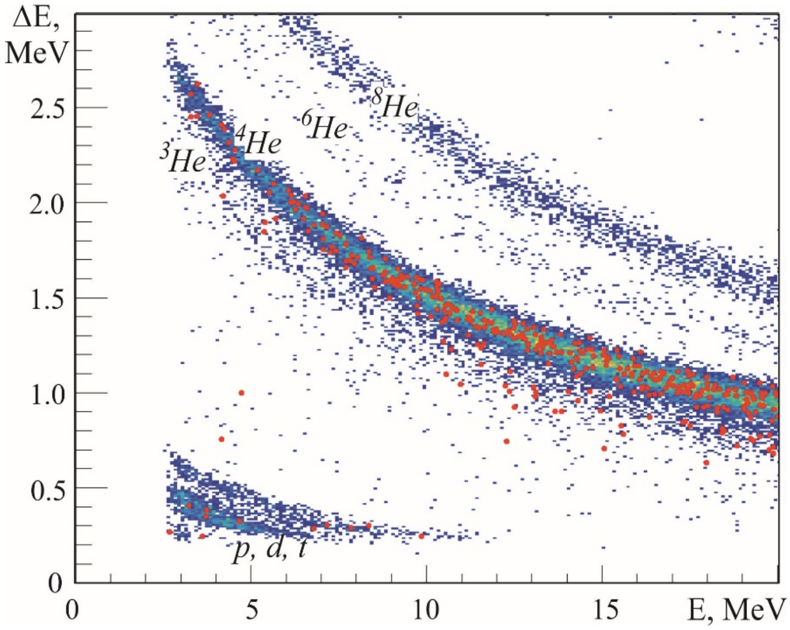

Fig. 2. Typical ID-plot for particle identification obtained from the measurements of energy losses in 20 μm Si detector and corresponding residual energies in 1000 μm Si detector. Coincidences with fast tritons ($E_t > 65$ MeV) are shown by red points.

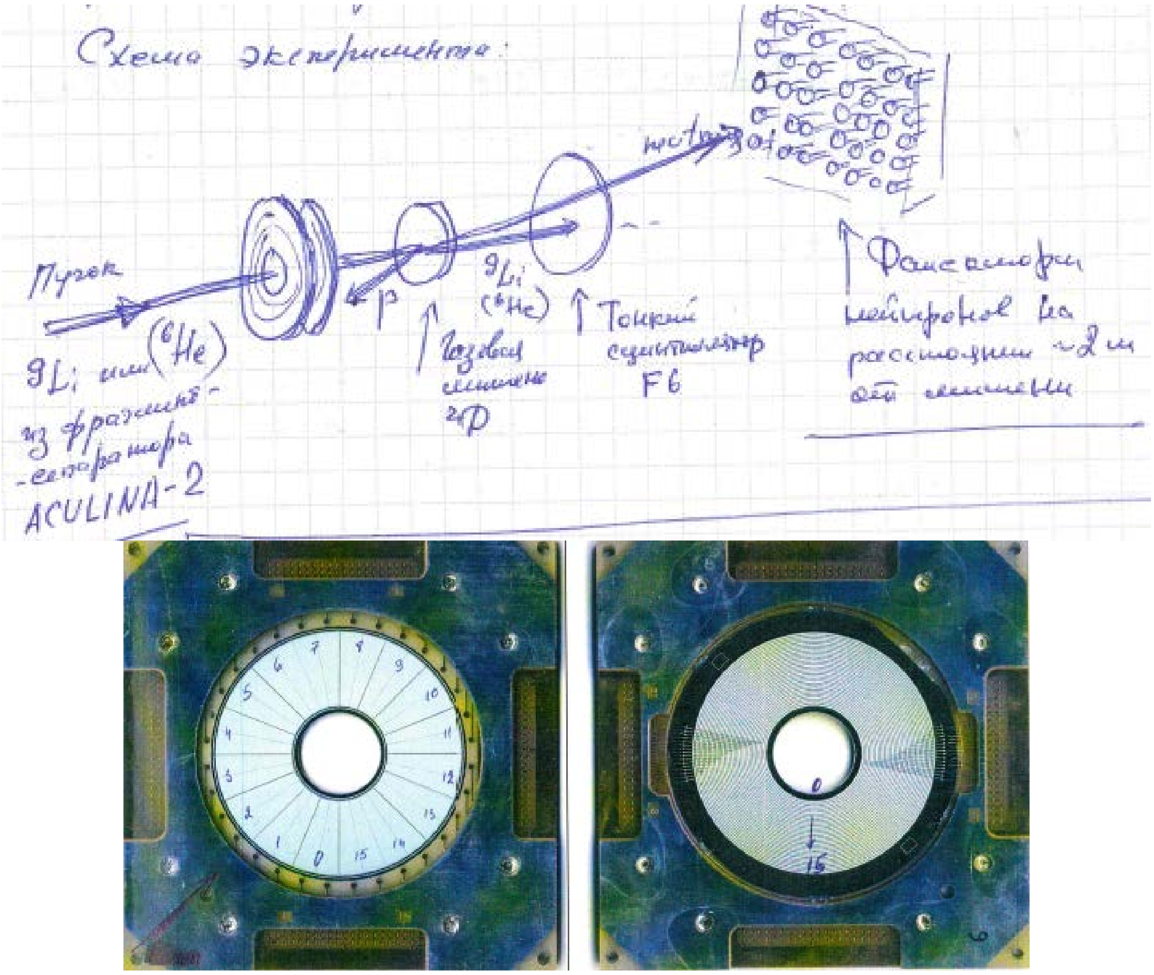

Fig. 3. Layout of the experimental setup for detection of charged particles and neutrons in the reactions $^9Li(d,p)^{10}Li \rightarrow n+^9Li$ and $^6He(d,p)^7He \rightarrow n+^6He$ (top panel). Annular DSSD (1000 μm thick segmented by 16 sectors and 16 rings) for protons detection (bottom panel).

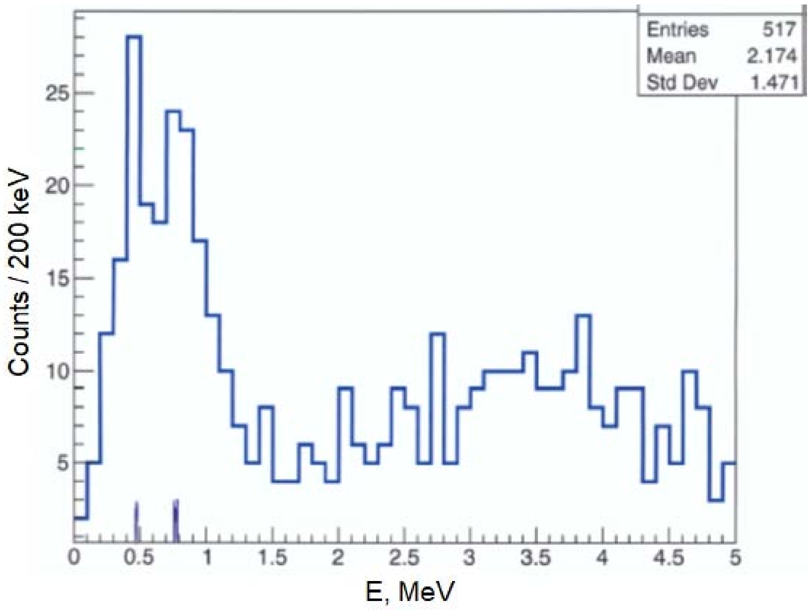

Fig. 4. Preliminary results of ^{10}Li study in the ^{9}Li(d,p)^{10}Li reaction at 28 MeV/nucleon based on the triple coincidences *p*-*n*-^{9}Li.