MULTI DETECTOR SETUP "MAIS" FOR NUCLEAR ASTROPHYSICAL REACTION STUDIES. PRELIMINARY RESULTS

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Presently, a lot of attention is given to the update of the existing experimental database on astrophysical important nuclear reactions at low energies with more precise values of cross sections (astrophysical *S*-factors) as well as obtaining a new data using both stable and radioactive beams. In the report, the present-day methods of direct measuring the cross sections of the astrophysical relevant nuclear reactions are presented such as the detection of the "prompt" γ-quanta, characteristic radiation and decay radiation of the radioactive products of the reaction, mass-spectrometry methods.

More detailed description of the **M**ulti-detector **A**utomatized **I**nvestigating **S**ystem (MAIS) assembled at the beamline of the electrostatic accelerator EG-2 "SOKOL" of the RIAP of National University of Uzbekistan is presented which can be applied to the study of several astrophysical-important reactions with formation of the relatively short-lived radioactive nuclei.

The created setup (see Fig. 1) includes a compact evacuated target chamber and is equipped with the HP Ge detector of 40% efficiency, planar silicon detector (thickness 700 mkm, diameter of the entrance window 24 mm) and two scintillation NaI(Tl) detectors with dimensions 160×100 mm. It is intended for simultaneous measurement of the prompt gamma-ray angular distributions ("prompt" technique) and the decay products of the final nuclei formed in the nuclear reaction ("active" technique). The beam purity is insured by using the separating magnet before the MAIS setup. Comparison of the results (*S*-factor values) obtained by these two techniques allows to evaluate correctly the systematic errors and model uncertainties, and eventually to enlarge the reliability of extrapolation to the very low astrophysical relevant energies.

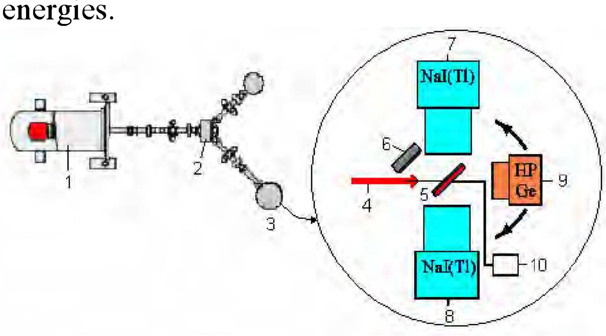

Fig. 1. *Layout of the setup on the accelerator beam guide. 1 – accelerator, 2 – separating magnet, 3 – four-detector setup, 4 – beam, 5 – target, 6 – Si-detector, 7, 8 - scintillation detectors, 9 – HP Ge detector, 10 – beam current integrator.*

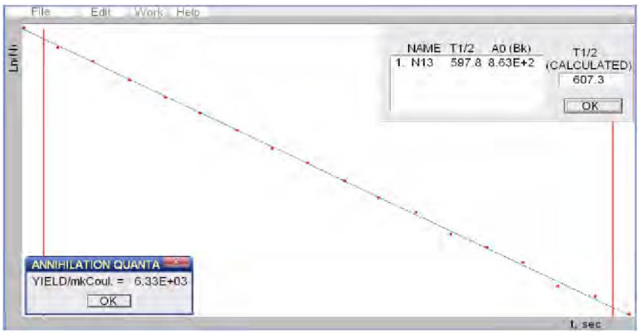

Fig. 2. *Appearance of the program VIN_MAIS at the PC screen.*

Data acquisition is done by the following way: a beam of projectiles is incident on a target (cooled by liquid N_2) during the time period ~ 2 ç 3 half-lives of the final nucleus of interest. The spectrometer with HP Ge - detector (fixed at the needed angle with respect to the beam direction) accumulates the spectrum of prompt gamma-quanta which accompany the reaction. Then, a beam is interrupted, and acquisition of prompt gamma-quanta spectrum as well as the beam current integration is stopped. At this stage, two programmed counters start to record the decay irradiation: β-particles are detected by Si-detector (placed inside the target chamber) and $\gamma\gamma$-coincidences of annihilation quanta are detected by two-arm scintillation spectrometer (if the formed nucleus decays by β^+-mode). Data acquisition is done during ~ 2 ç 3 half-life periods by a number of time intervals Δt which allows one to build the decay curve. Since the cross-section of astrophysical important reactions at sub-Coulomb energies is commonly small, procedures of the target irradiation and the acquisition of decay irradiation are repeated many times in the software programmable automatic mode until the required statistics is achieved.

The pilot experiments have been carried out to check the functionality of the setup and correctness of the obtained data. The $^{12}C(p,\gamma)^{13}N$ radiative capture was chosen as a testing reaction since its total cross section is known quite well (see [1] and references therein) in the region of the first resonance (E_R=456 keV, lab). The measurements were implemented using a thick carbon target at several energies within the region E_p~ 400ç550 keV (lab) as it is described above. In Fig.2, the result of treatment of the annihilation $\gamma\gamma$-coincidence data with the appropriate software VIN _MAIS is presented (E_p= 560 keV). Rejection of the deuteron component in the beam by separating magnet was checked to eliminate the contribution of the interfering reaction $^{12}C(d,n)^{13}N$ (Q=-280 keV). The obtained proton radiative capture yields were compared with the calculated ones by formula:

$$Y(E) = n_a \int_0^E dE' / S_x(E') \times \sigma(E')$$

where n_a is a flux of projectiles, $S_x(E')$ – specific energy loss of particle a in the target substance and $\sigma(E')$ is the energy dependence of the total proton capture cross section [1]. A good agreement of these values in the range of 10% was found.

A list of the astrophysical important reactions is proposed which are accessible to study by the MAIS method.

Reference

1. N. Burtebaev, S.B. Igamov, R.J. Peterson, R.Yarmukhamedov, D.M. Zazulin. Phys. Rev. C78, 035802 (2008).