Nuclear astrophysics researches in an ion trap apparatus

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At low energies, far below Coulomb barrier, fusion nuclear reaction are very sensitive to its shape, which is usually in experiments modified by atomic electrons of target or both projectile and target particles. Project of Nuclear Astrophysics Researches in Ion Trap Apparatus(NARITA) aimed at construction of an installation and mesurementsof excitation functions for d)d,p)t reaction in the region $1.5 < E_{cm} < 12$keV and for ^{3}He(d,p)^{4}He reaction in the region $6.5 < E_{cm} < 15$ keV in the condition when both beam and target particles would be in bare nuclear states. Inspite of considerable efforts to manifest the electron screening effect in a low energy fusion reactions, the problem looks not like completely solved [1, 2, 3, 4, 5, 6]. There can be various difficulties: insufficient accuracy of the experimental data and of perfect of the theory. But from other side one has to mention that experimental data for cases of bare nuclides, participating in such fusion reactions, were not obtained till now. To diminish the screening effects and stopping power problems, the idea was given to use an Electron Beam Ion Source (EBIS) [7, 8] based installation for measurements of cross sections for bare nuclides case at low energies. Similar to an EBIS the BeTa apparatus proposed (see Fig. 1) consists of an electron gun, a drift tube structure, an electron collector (or an electron reflector for the Reflex mode of operation [9]), a cryo-magnetic system with a super conducting solenoid, an ion charge state analysis system and a super high vacuum system. Additionally to those BeTa has a system of semiconductor detectors for detection and spectrometry of charged products of the nuclear reactions under study (mostly protons), surrounding the trapped nuclei target region.

Two different type guns will be used: a) Pierce type gun with IrCe cathode of 1.4x10^{-6} A/V$^{3/2}$ perveance. b) The circularcathode gun with a cathode of 28mm radius and 1.5 mm width and of 200x10^{-6} A/V$^{3/2}$ perveance. The drift tube structure consists of two parts: The first part destined for surrounding a region of a nuclear beam production has a length about 50 cm and it is assembled from solid drift tube sections while the second one, destined for surroundinga region of the nuclear target is about 70 cm length and it consists from sections highly transparent for nuclear rection products. These two parts are separated from each other by means of the ion accelerator tube, forming the acceleration electric field lines along magnetic field lines.

1) To form the deuteron or ^{3}He^{++} targets a low intensity D_2 or ^{3}He gas fluxes to the nuclides target region of the drift tube structure are switched on.The corresponding pumping speed provides only about 3.5×10^9 molecules or aoms/cm^3 in the space, which is neverthless sufficient for the formation of the target by means of accumulation of ions. An axial ion confinementis provided by the potential barriers on the ends of the target regions of the drift tube structure. Taking into account the electron impact ionization cross sections for 8 keV electrons and theion trap capacity, the trap is filled with ions during about 6 ms. After such a period of accumulation time the nuclides targets get the final thickness equal to 3.6 x 10^{13} deuterons/cm^2 or 1.8 x 10^{13} ^{3}He^{++}/cm^2 correspondingly.

2) The deuteron (or ^{3}He^{++} nuclides) for a beam formation are produced in the corresponding region of the drift tube structure of about 50 cm length. On the first step of the project realization only deuteron beams are expected to use in the fusion reaction studies.

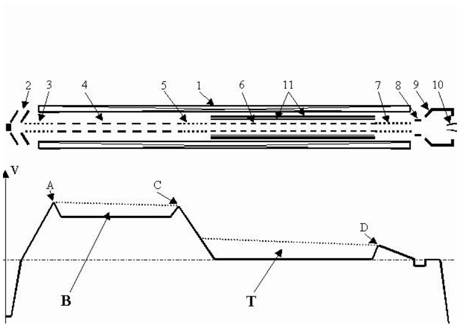

Figure 1:

Figure 1: Schematic view of the BeTa apparatus(up) and of the voltage (V) distribution along its axis (down).

The particles for the beams are produced by electron impact ionization of D_2 molecules, ion accumulation and further ionization to the deuteron states in the ion trap B, formed in this regionof the drift tube structure similar to that for target particles. The corresponding influx and pumping speed of the gas provide about 1.3 x 10^{11} molecule/cm^3 concentration in the beam production trap region. The 50 cm length deuteron trap is filled with deuterons during about 200 microsec, depending on the electron energy used. A necessary potential energy of the accumulated deuterons is provided by the corresponding voltage, which is applied to the beam production sections of the drift tube structure. The deuteron are slowly (during about 10 μsec) are extracted from the trap and are directed to the nuclear target via the acceleration tube. The slow ion extraction [9] due to a slow increase of the trap bottom potential provides in this case for deuterons only about 10-15 eV energy spread of the beam, directed to the target. Extracted ions travel mostly along the pre-axial part of an electron beam (and a target therefore). This provides the full beam-target overlap. As a result the pulse deuteron beam of the desired energy and about 40 μA equivalent DC ion current is obtained for the fusion nuclear reaction studies in the case of the use of the Pierce type electron gun. In the case of the ring cathodegun the equivalent deuteron current reaches 8 mA or more. In case of electron beam/pulse deuteron current mode of the BeTa operation one can expect an overall absolute accuracy about 5%. This installation has a possible application for other reactions such as ^{3}He + ^{3}He$\rightarrow$2p+α and p + ^{7}Be$\rightarrow \gamma$ + ^{7}Be+ 2α reactions.

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