Diamond dE-E-ToF-telescope for heavy ion reactions at the Coulomb barrier*

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Target of our interest is the study of heavy ion reactions, such as multinucleon transfer, quasi-fission and/or fusion-fission, at energies close to the Coulomb barrier as well as their possible application for the synthesis of new isotopes, especially in the high-Z neutron-rich region.

The conventional time-of-flight technique, combined with the dE-E method, allows us (in general) to identify the mass and the charge of the reaction products and to study the reaction kinematics. Nonetheless, studying heavy particles at low energies needs a special approach. There are some limitations: pulse hight defect, radiation hardness, etc. Moreover, heavy ions at low energy have very short ranges, which means that we have to find a very thin detector capable of measuring energy loss and time simultaneously.

Due to their unique properties (a good energy resolution comparable to silicon detectors, e.g. ΔE=20keV for alphas; time resolution on the order of few ten ps due to very high electron and hole mobilities, high count rate up to 10^9 due to very short rise and fall times ($\sim$20ps) and high radiation hardness[1]) diamonds are good candidates for this application. Very recently, Pomorski et al. succeeded in fabricating ultra-thin diamond membranes with only few micrometers thickness that are able to measure energy loss and produce simultaneously time signals with excellent resolution[2].

Based on these findings we initiated a program to investigate single crystal (sc) diamond detectors for identification of low-energy heavy ion reaction products. For this application we realized the very first dE-E-ToF telescope [3] which consists of 2 sc diamond detectors: ”dE/Start“ and ”E/Stop“. First measurements were carried out with a mixed nuclide α-source. The diamond ”dE/Start“-detector had a thickness of $\sim$4 μm and the diamond ”E/Stop“-detector $\sim$50 μm. The distance between the detectors was 14 mm. In Fig. 1a-1c the obtained result is shown. Fig. 1a shows the two-dimensional dE versus residual energy E_r spectrum measured with the mixed nuclide α-source. There are three well separated ridges which correspond to the three α-lines. Fig 1b shows the one-dimensional energy spectrum where line 1 is the energy loss in the membrane detector, line 2 is the residual energy measured in the stop detector and line 3 is the sum of dE and E_r for each event. Fig. 1c shows the time of flight spectrum.

Furthermore, we applied the diamond dE-E-ToF telescope to study reaction products from collisions of

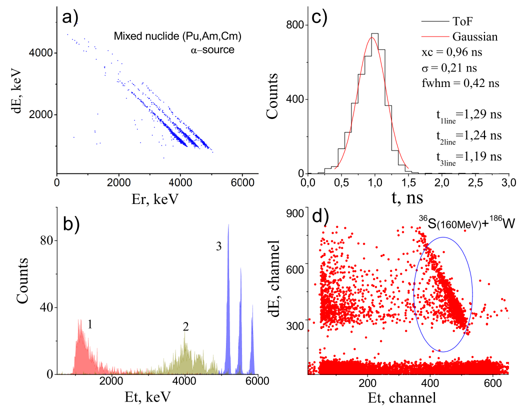

Figure 1: a) dE versus E_r spectrum of α-particles measured with diamond detectors b) Energy spectrum of α particles c) Time of flight spectrum of α-particles d) dE versus E_r spectrum measured in ^{36}S+^{186}W reactions at 160 MeV.

^{36}S+^{186}W at a beam energy of 160 MeV. The experiment was carried out at JINR Dubna where we installed the diamond dE-E-ToF telescope together with the CORSET-setup [4] which will be subject of a different report. Figure 1d shows the two-dimensional dE versus E spectrum of reaction products from S+W measured with the diamond detectors. The most intensive ridge corresponds to elastically scattered sulfur which passes through the membrane and loses about 20 MeV. The intensity of the elastically scattered W is 150 times lower than of S at the chosen detection angle of 20 degrees. Therefore, the W line is not visible in the spectrum.

Our first results are very encouraging and show that we are on the right track by utilizing ultra-thin sc diamond detectors as ”dE/Start“ combined with sc diamond stop counters for the A and Z identification of reaction products at the Coulomb barrier. Further studies are anticipated aiming at improved time and energy resolutions, radiation hardness, pulse hight defects, etc.

References

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