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Energy loss of ^{40}Ar in Au: Comparison of TOF-E and TOF–TOF method

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Abstract

Energy loss of ^{40}Ar ions in Au has been measured using two methods: TOF-E and TOF–TOF. The two methods are compared and discussed. The final results cover energy range 2–445 MeV (0.05–11 MeV/u) and give satisfactory agreement with SRIM 2003 predictions. Statistical error of the data is at the level of 1–2%.

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Keywords: Stopping power; dE/dx; Pulse height defect; Time of flight (TOF); Microchannel plate (MCP); ^{40}Ar; ^{nat}Au

1. Introduction

In our recent publication [1] we have reported some discrepancies in the energy loss of heavy ions at low energies (below 0.5 MeV/u). To check the source of these discrepancies and to further improve the quality and the energy range covered by our measurements we have repeated them using in parallel two different experimental methods. The first was the TOF-E method used by us previously [1–5]. The main weakness of this technique is the need to correct for the pulse height defects (PHD) [6–8] in silicon detector. While we have developed a reliable method to implement such correction [1] it should nevertheless be used with caution as it is significant (reaching up to 20–40%) and non-linear (sharply increases at low energies). As the result even a small inaccuracy in PHD compensation may lead to erroneous results. For that reason we have complemented

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our measurements with the second technique (TOF–TOF) that eliminates the use of a PHD-prone silicon detector. As the test case energy loss of ^{40}Ar ions in gold was chosen.

2. Experimental methods

The TOF-E method [1–5] uses semiconductor detector to extract ion energies before (E_i) and after (E_f) the stopping media. The role of the time of flight (TOF) spectrometer in this method is twofold: (i) to tag all of the registered ions with their initial velocities and (ii) to obtain energy calibration of the silicon detector at low energies where there are no available calibration points. This is important because the relative size of the pulse height defect (PHD) [1,6–8] at low energies is too large to make any reliable extrapolations from higher calibration points.

The second method (TOF–TOF) relies entirely on the velocity measurements in the extraction of E_i and E_f thus eliminating completely the need for the silicon detector. The experimental set-up is shown in Fig. 1. It has been modified from the original configuration [1–5] by adding of the third time pickoff detector in the middle of the TOF spectrometer. With the exception of the converter foil, the third detector was identical to the microchannel plate (MCP) based start- and stop detectors of the original TOF spectrometer [1]. In the third detector there was, instead of a thin carbon foil, a 0.505(16) mg/cm^2 Au foil. The details of the experimental set-up will be explained in a separate publication [9]. The procedure to determine the foil thickness has been explained before [1]. The experiment was carried out at the Department of Physics, University of Jyväskylä using 6 MeV/u ^{40}Ar beam from the $K = 130$ cyclotron. The beam was scattered on a foil to give a wide range of energies: 0.01–6 MeV/u (from the highest energy determined by kinematics down to our current detection threshold). The detection angle was fixed at 20° with the respect to the beam. Full details on the electronics, calibration procedures and on error analysis have been described previously [1,2].

3. Results

The results of the comparison of TOF-E versus TOF–TOF method are shown in Fig. 2. The open symbols indicate the data obtained with the TOF-E method; the solid symbols – the TOF–TOF approach. It is clear that TOF-E and TOF–TOF methods yield fully consistent results. We did not find systematic errors in either approach. The final experimental results are summarized in Table 1 and in Fig. 2 where also SRIM 2003 [10] predictions are plotted.

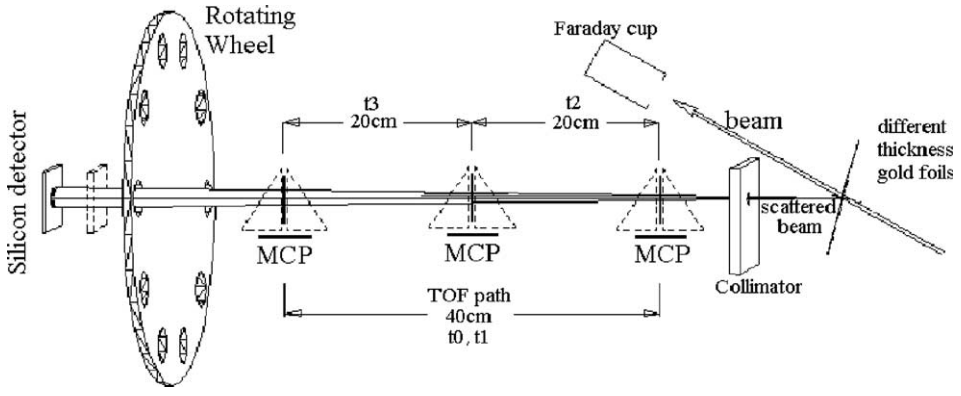

Fig. 1. The experimental set-up for simultaneous measurements of dE/dx values using TOF-E method (up to 9 sample foils in the rotating wheel) and TOF–TOF method (one sample only placed as the converter foil in the central MCP time pick-off detector).