Charge State Dependence of the Stopping Power of 60MeV ^{58}Ni Ions in Thin Carbon Foils and Gases

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Measurements of energy loss of 60MeV ^{58}Ni ions in dependence on the incident and analysed charge state (q_{in} and q_{ana}) in thin carbon foils und gases were performed using the Q3D magnetic spectrograph in transmission geometry [1,2]. An energy resolution of the combined system (ion beam, magnetic spectrograph and focal plane detector) of $\Delta E/E \leq 1 \cdot 10^{-4}$ was achieved.

Carbon foils ranging from 1.9 to 27.5 μg/cm^2 have been prepared at the target laboratory of the TUM. Details of the determination of their overall thickness including surface contamination are given in [3]. In order to examine differences of energy loss of heavy ions in solid and gaseous targets a differentially pumped gas target was developed. The evaluation for argon (gas thickness 1×10^{14} to 3×10^{17} at/cm^2) is given in [2].

In order to determine charge fractions $F(q)$ and the mean charge $\bar{q}$ behind the target in dependence on the incident charge state and target thickness a second detector (PIN diode) was used.

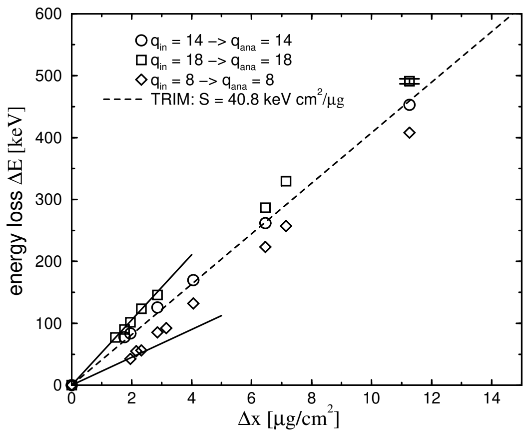

Fig. 1: Energy loss of 60MeV ^{58}Ni ions in thin carbon foils. Dashed line: tabulated stopping power by TRIM [4]. Solid line: linear fits for foil thickness below $3\,\mu$g/cm^2.

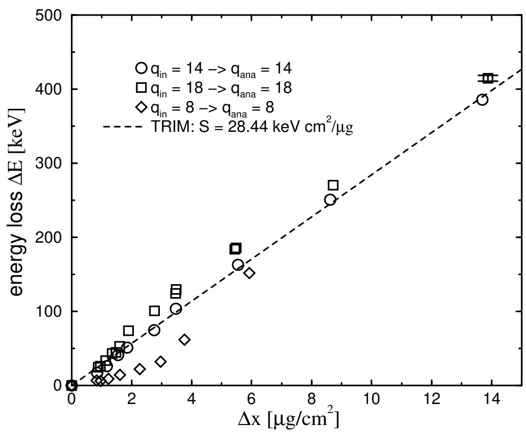

Fig. 2: Energy loss of 60MeV ^{58}Ni ions in argon gas. Dashed line: tabulated stopping power by TRIM [4].

In both cases (foils and gases) the stopping power $S = \Delta E/\Delta x$ for thin targets ($\Delta x \approx 2\,\mu$g/cm^2) deviates significantly from the value at larger thicknesses (figs. 1, 2). This deviation depends on the incident charge state and can be explained by charge changing effects in the vicinity of the target surface [2]. For thicker targets the stopping power coincides for all measured charge states (within 4%) because the charge of the incident ion has reached the mean charge $\bar{q}$ inside the target.

The stopping power for thin targets also deviates if the incident charge state is close to $\bar{q}$ inside the target. In this case charge changing effects are not important any longer and the deviation of the stopping power from the average value can be explained by a reduction of the dynamic screening near the target surface. The strange behavior of the stopping power of the incident charge state $q_{in} = 8+$ in argon is due to a selection of the impact parameter at small gas thicknesses [2].

For carbon the mean charge state $\bar{q}$ behind the foils was determined in dependence on the target thickness for $q_{in} = 18+$ by using a Gaussian charge state distribution [5].

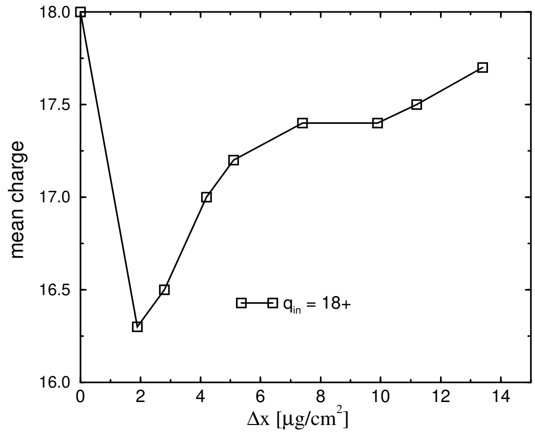

Fig. 3: Mean charge $\bar{q}$ of 60MeV ^{58}Ni ions behind carbon foils for the incident charge state $q_{in} = 18$.

In fig. 3 the mean charge $\bar{q}$ shows a minimum for a foil thickness below $1.9\,\mu$g/cm^2. This behavior is due to large electron capture cross sections and small loss cross sections which slowly increase the mean charge of the ion. A similar phenomenon was theoretically predicted by Maynard et al. [6] for 1.5 MeV/A ^{127}I in carbon.

References

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