ANGLE DEPENDENT ENERGY LOSSES OF AMORPHOUS MATERIALS FOR MEV PROTONS

N. Sakamoto, N. Shiomi and R. Ishiwari

Department of Physics, Nara Women's University, Nara

Abstract

Thin foils of Be, Al, Ag, Mylar and Cellophane were bombarded by a very sharply collimated proton beam at 6.9 MeV. Energy losses and multiple scattering yield have been measured as a function of emergence angles between 0° and 1.7°. Angular distributions of multiple scattered protons were well reproduced by Molière's theory. Relative energy losses, $\Delta E(\theta)/\Delta E(0)$, have been found to increase by 1-4% with increase of emergence angles. These results constitute the first evidence that measurements of an average quantity such as stopping power may yield information about the dependence of energy loss on the impact parameter of a proton relative to a lattice atom.

It is well established that particles incident at small angles to atomic rows and planes in single crystals exhibit anomalous energy loss rates[1]). This is a channeling effect on energy loss. Energy losses of channeled particles are smaller than those of particles which traverse in random direction because channeled particles are kept away from atoms and go through a region of lower electron density. In usual stopping power measurement polycrystaline or amorphous thin foils are used instead of single crystals. In this case we can select a particle trajectory and an average impact parameter of a particle relative to a lattice atom by defining very sharply the emergence angle of a particle. We have studyed the dependence of energy loss on the emergence angle of a proton with several solid targets. Results show a small but significant connection between energy loss and angular deflection of protons that have passed through thin solid foils.

The energy losses of 6.9 MeV protons in Be, Al, Ag, Mylar and Cellophane foils have been measured at six or seven emergence angles between 0° and 1.7°. Target thicknesses were from 4.4 to 6.5 mg/cm^2 and energy losses of protons in these targets were from 130 to 350 keV. Incident proton beam was collimated very sharply by a double slit system; a maxmum angular divergence was 0.048° at full width. A silicon surface barrier detector with 0.7 mm diameter slit was mounted 171 cm apart from the target and was movable perpendicularly to the beam direction in a range of 5 cm.

Experimental results of Be foil are shown in figure 1 as a typical example. In the upper half, angular distribution of multiple scattered protons is presented. Predictions of Molière's theory are given in a solid curve and an excellent agreement between the experiment and the theory is obtained. In the lower half, relative energy losses, $\Delta E(\theta)/\Delta E(0)$, are shown as a function of deflection angle of protons. As seen in the figure energy loss becomes larger with increasing emergence angle and the increase of energy loss amounts to about 3%. In other targets angular distributions of multiple scattered protons are well reproduced by Molière's theory and relative energy losses increase by 1-2% with the increase of emergence angle.

The measured increase of relative energy losses is too large to be explained by the following three corrections; 1) the increase of path length caused by multiple scattering[2]), 2) the increase of target thickness with increasing proton emergence angle, 3) the decrease of proton energy caused by a single Rutherford scattering. Another effect to be examined is a target texture. X-ray photographs showed that Be, Al and Ag targets had a little texture but Mylar and Cellophane targets were perfectly amorphous. From the fact that Mylar and Cellophane also show the energy loss increase with emergence angles, we can conclude that the origin of this phenomenon is not target texture effect but geometric effect of measurements. Therefore these results indicate a significant connection between stopping power and deflection angle of a proton; in other words an average impact parameter of a proton relative to a lattice atom. Unfortunately, up till now, the atempt of theoretical explanation of this phenomenon is unsuccessful.

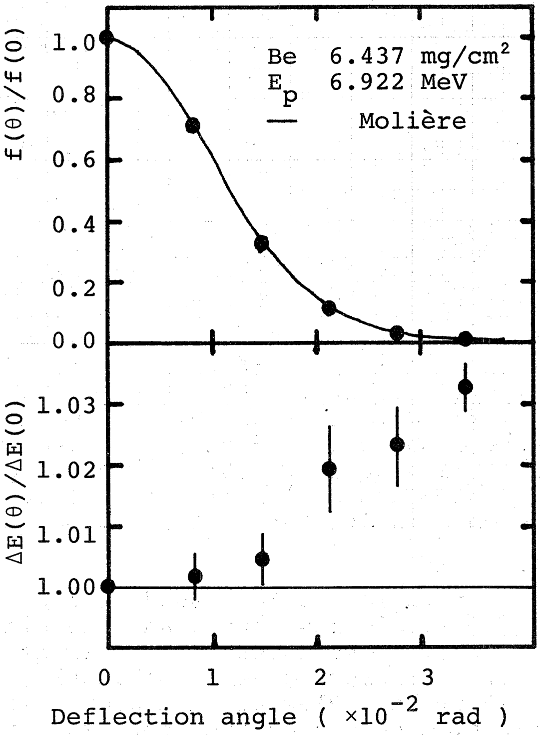

Fig. 1 Angular distribution and relative energy losses of multiple scattered protons as a function of deflection angle.

References

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2) B. Rossi and K. Greisen, Rev. Mod. Phys. 13(1941) 240. C.N. Yang, Phys. Rev. 84(1951) 599.