H and He Capture from Random to Channeling Flux in Transmission of Si Crystal Foils

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For particles transmitted through (or emitted from) a mono-crystalline layer a channeling component can be observed in any geometry if the lowest energy losses are selected in the spectrum. This group of channeled particles can be selected even in the case of initially random flux distribution. However, without any energy-loss discrimination, the random flux distribution should be conserved after transmission through a crystal due to the reversibility of transverse energy fluctuations. It was the aim of the following experiment to check this theoretical prediction for very light particles because of the observation of channeling enhancement in experiments with heavy ions recently [1,2].

The experiment with protons has been performed at the 2.5 MV accelerator of the MPI/IPP at Garching. The proton beam after passing through a 0.8 mm aperture was directed to a $100\mu g/cm^2$ thick Au target. The scattered protons were detected near 120° scattering angle by a CR-39 plastic track detector. A mono-crystalline (100) Si membrane of 8.7 or 2.3 μm thickness was placed between the detector and the scattering foil, quite close to the latter, but out of the beam path to prevent any damage and distortion of the crystal foil. In this geometry the crystal was exposed to a low intensity random (both in angle and space) flux of scattered protons. The scattering angular distribution was flat within the solid angle covered by the detector (±4° in both directions). The distance between the crystal and the detector was 275 mm, providing an angular resolution of about 0.08°. The detector foil was etched after the irradiation in a 20% NaOH solution at 70°C in order to develop the proton tracks and visualize the crystallographic pattern near the ⟨100⟩ axis (an example is shown in fig. 1).

For the investigation of random flux transmission of α-particles through a thin Si crystal a radioactive ^{252}Cf source was used. In this case the track detector was placed at a distance of 530 mm from the source. Taking into account the 3 mm diameter of the active source spot an angular resolution of about 0.15^o can be estimated. Different Si thicknesses were used as well as different Al absorbers to lower the incidence energy of 6.1 MeV. After a typical exposure time of 6 days a track density of about 10^4tracks/mm^2 was accumulated.

The chosen geometries meet the requirement of a wide-angle random distribution of particles incidenting on the crystal, and also there is no energy selection for the particles detected on exit. Each proton or alpha produces one track at the detector surface, thus the detector's response is proportional to the number of particles and not to their energy, as is the case with photo-plates. The track patterns have been evaluated quantitatively by track density counting either by hand or by an automatic scanning system (Uni Siegen).

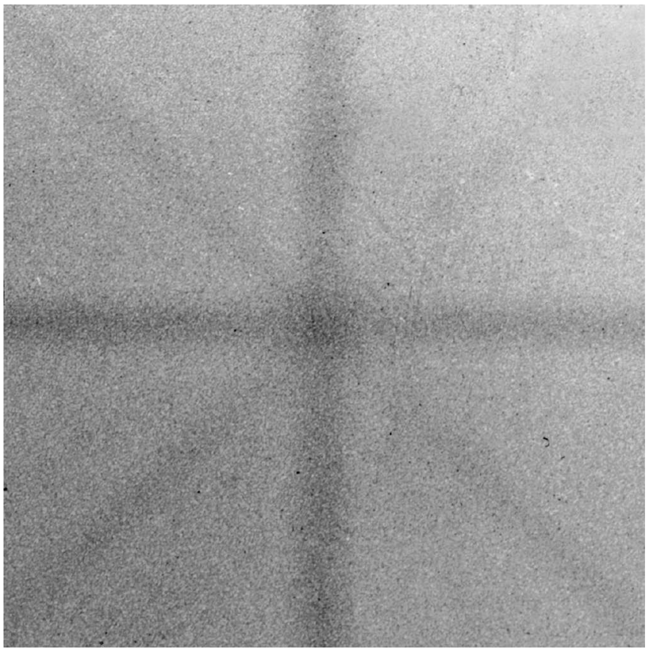

Fig. 1: Photographic reproduction of a flux distribution pattern on CR–39 from protons with a final energy of 0.28 MeV after transmission through a 2.3 μm thick Si crystal.

The proton beam energy was varied from 0.7 to 1.0 MeV, and the final energy after passing through the crystal changed from 0.12 to 0.6 MeV, respectively. Enhanced channeling patterns have been observed for the lowest energies (enhancement factor of 1.22 above random level) and an almost random distribution for 0.6 MeV. Similar results have been found for α-particles where the final energy varied from 4.1 to 0.6 MeV. Here the enhancement increased to a maximum value of 1.32. Thus, flux enhancement along the ⟨100⟩, (110) and (100) directions has been revealed for protons and alphas transmitted through a thin Si crystal. The dependence of the effect on the exit energy and thus on the effective charge state of the ions has also been proved. The results are in reasonable agreement with other measurements performed for heavier ions. The complete set of data confirms the interpretation of this phenomenon based on a charge-exchange mechanism as proposed by J.U.Andersen [2].

References

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[2] W. Assmann *et al.*, Phys. Rev. Lett. **83** (1999) 1759