Channeling transmission images for Ag ions passed through 1 μm Pt crystal

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As known, the transmission angular distribution of channelled particles through thin crystal carries the information on the mechanism of channeling and on the lattice potential. At axial alignment, the transmitted beam forms a narrow spot at 0°. When the de-orientation angle is growing, a so-called doughnut-ring like distribution appears around the axis. Then, the angular size of the ring is increasing, while more and more intensity fills the spot to the beam direction. Finally, the linking to the crystal axis vanishes, and the spot around the beam direction possesses the normal width of multiple scattering. This is the general scheme of the images transformation.

Peculiar behavior was observed for the crystal thickness comparable with the oscillatory wave-length of the channeling trajectory in ref. [1,2]. For such thin crystals the statistical equilibrium in transverse plane had not been reached, and sharp peaks were observed at definite values of polar and azimuthal angles. They were called "crystal rainbow". The trajectory phases should be randomized after several oscillations, and the rainbow has to be replaced by the axially symmetric doughnut.

For the relatively thick crystals, the multiple scattering spot becomes to be wide, and narrow feeding-in peaks appear at the planar and axial directions, see in [3] and citation within. The feeding-in reflects the statistical dissipative nature of the small angle scattering in presence of energy losses.

Until now, the transmission images had been studied mostly for protons [1,2,3], and at some extreme for relativistic electrons at 1.2 GeV [4]. However, the case of very heavy ions is not yet covered.

Channeling of the Ag ions in Pt crystal has been studied utilizing a "micro-beam". It has an intensity of $2 \cdot 10^3$ ions/s, a linear size of about 100 μm, and an angular divergence near-by 0.03°. The experiment included the measurement of energy spectra, angular distributions and charge states of the ions after the crystal, as a function of the beam incidence angle to the $\langle 100\rangle$ axis or (100) plane. Energy and angle distributions were recorded with a compact position sensitive ionization chamber. The charge state distributions are measured utilizing the Q3D magnetic spectrograph (for results see also this annual report).

A series of measurements for Ag + Pt interaction at initial energies of 100 and 220 MeV have been carried out, and an abundant variety of two-coordinate pictures has been observed. Four of them are shown in Fig. 1.

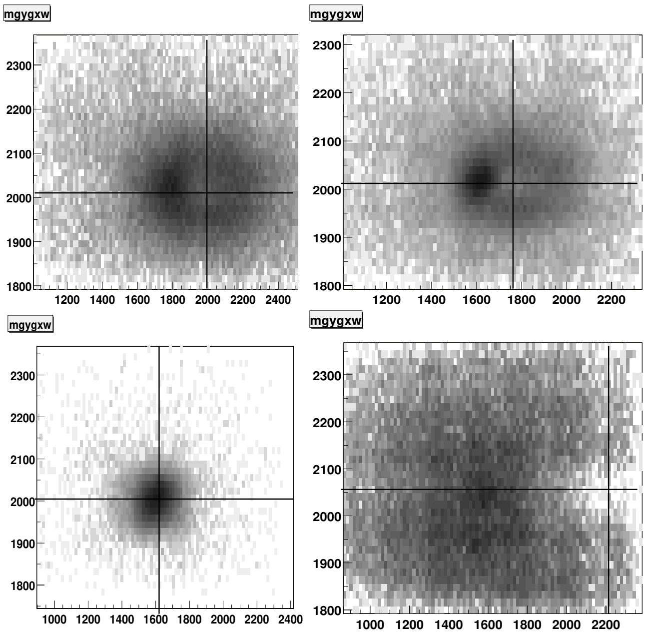

Fig. 1: Doughnut like distribution of Ag ions transmitted through a 1 μm Pt crystal (the cross indicates the $\langle 100\rangle$ axis): Top: (left) initial energy was 100 MeV 0.40° off the $\langle 100\rangle$-axis, (right) 220 MeV, 0.36° off axis. Bottom: (left) axially aligned, (right) random like at 1.16° off axis (the visible lattice structure comes from the detector); both at 100 MeV.

The general tendencies of the angular distribution transformation are established to be in agreement with the described above standard. In addition to the combination of doughnuts and spots, the blocking and feeding-in manifestations are also seen for scattered particles. Obviously, the 1 μm Pt crystal should not be identified as "thin" for such ions as Ag at (1-2) MeV/u. Indeed, the estimated wavelength of the trajectory is by (20-30) times shorter than the crystal thickness. After so many oscillations the trajectories are statistically equilibrated, and the exit phase is random.

There is no reason to expect rainbows, however doughnuts were indeed observed at both energies of the Ag ions. This means that the transverse energy is almost conserved in rough approximation from entrance to exit. Thus, the transverse energy seems to be an integral of motion during many oscillations, even in presence of strong perturbations. Multiple scattering, energy losses and charge state fluctuations are indeed strong for (1-2) MeV/u heavy ions. Still, regular channeling survives, and the observed doughnut like distribution does not contradict the earlier observed transverse cooling effect.

References

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