SELECTION OF OPTIMAL BENT CRYSTAL PARAMETERS FOR EXTRACTING ELECTRONS FROM THE DESY II SYNCHROTRON

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Based on numerical simulations of 6 GeV electron propagation through bent crystals with different orientations relative to the particle incidence direction, as well as varying bending radii and thicknesses, a comparison of the deflection efficiency of 6 GeV electrons in planar and axial orientations of the bent crystal was carried out. The optimal parameters for the most efficient particle deflection were determined.

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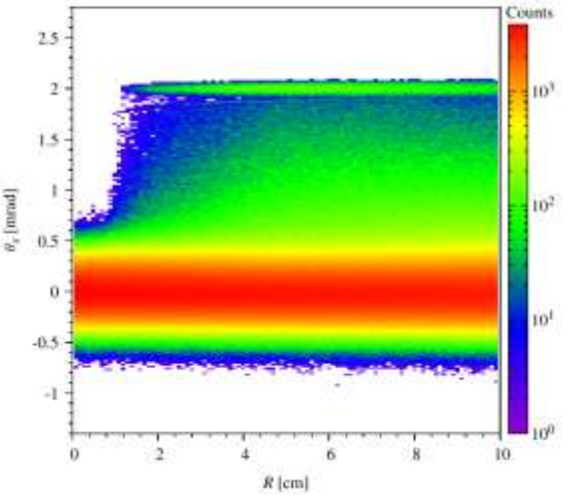
INTRODUCTION

In many circular accelerators of charged particles, some experiments are carried out not on the main beam but on secondary beams, which are obtained either by extracting a fraction of the particles from the accelerator ring or through a double conversion process. In particular, in the DESY II booster synchrotron, thin carbon fibers are positioned in the DESY II beam orbit, generating bremsstrahlung radiation as electrons pass through them [1]. The photons of this radiation exit the accelerator ring and hit a metal target, where electron-positron pairs are produced and used as a source for the secondary particle beam, on which experiments are carried out.

In [2], it was demonstrated that this double conversion scheme can be replaced by extracting particles from the halo of the electron beam using planar channeling in a bent crystal. In the current study, we investigate the possibility of optimizing the crystal orientation, bending radius, and thickness to ensure the most efficient particle deflection.

DEFLECTION OF ELECTRONS

To determine the optimal parameters of a bent crystal for the most efficient electron deflection, a comparison was conducted between the efficiency of planar channeling in a bent crystal [3, 4] and the Grinenko-Shul'ga [5] mechanism, which is associated with particle deflection in the field of atomic strings of the bent crystal. Based on computer simulation of high-energy charged particles motion in bent oriented crystal, a preliminary study was carried out on the efficiency of deflecting a 6 GeV electron beam using a bent crystal in planar and axial orientations. Similar to the approach in [2], the deflection angle required to extract particles from the accelerator was assumed to be 1.75 mrad. Beam profiles were obtained after passing of electrons through the bent crystal for crystal bending radii ranging from 1 mm to 5 m. Based on these profiles, the dependencies of the number of particles deflected at the specified angle on the crystal bending radius were constructed. These dependencies are shown in Fig. 1 for two planar orientations of the bent crystal relative to the electron beam incident on it: (111) and (110). The color in the figures shows the number of particles deflected by a certain angle. Bending angle of the crystal was 2 mrad. It is clearly seen that the number of particles deflected by an angle greater than 1.75 mrad in the case of the planar orientation (111) is significantly greater than in the case of the planar orientation (110).



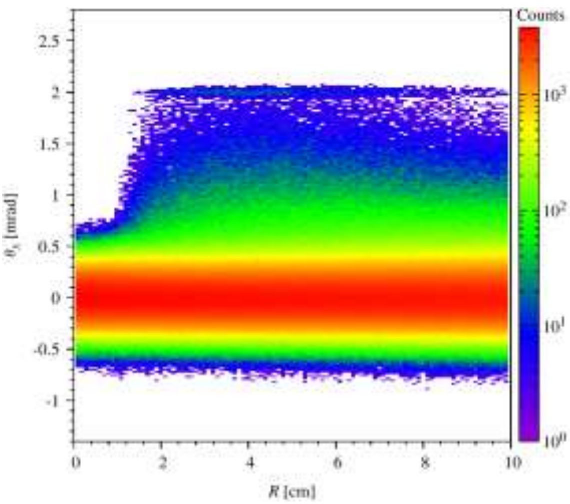


Fig. 1. The dependence of deflection angle of electrons on the radius of curvature of the crystal for planar (111) (top) and (110) (bottom) orientation of the crystal towards the incoming particle beam. Bending angle of the crystal was 2 mrad

A similar comparison of the dependence of the number of deflected particles on the crystal bending radius for planar and axial orientations is shown in Fig. 2. It is evident that the planar (111) orientation again corresponds to higher efficiency in deflecting electrons at an angle exceeding 1.75 mrad. However, it is important to note that planar channeling and the

Grinenko-Shul'ga deflection mechanism, which is realized in the case of the axial crystal orientation, have different optimal bending radius values [6, 7]. At an electron energy of 6 GeV, the optimal radius for the axial crystal orientation is significantly greater than 10 cm. Therefore, the maximum number of deflected particles for the axial crystal orientation in Fig. 2 corresponds not to stochastic deflection but to axial channeling.

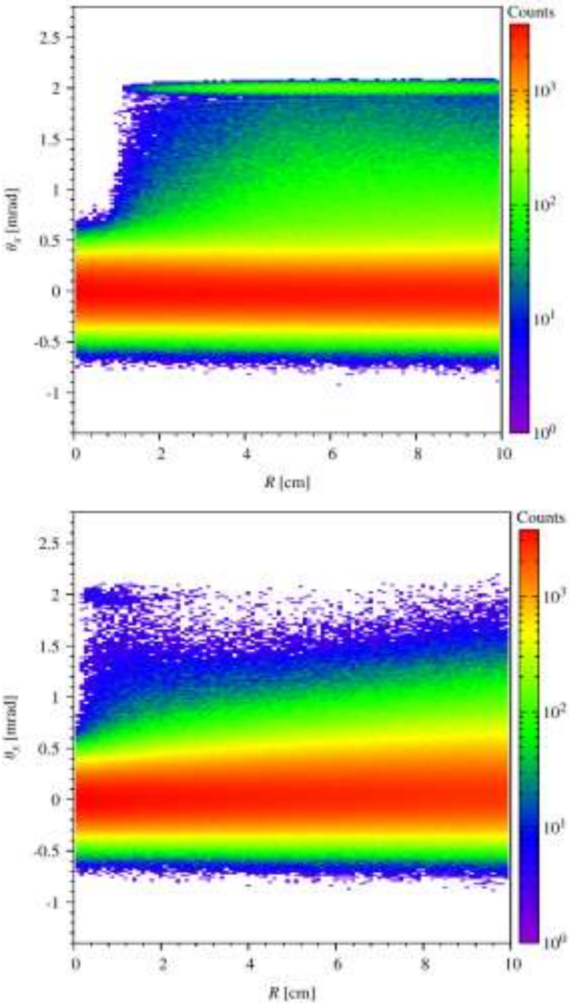


Fig. 2. The dependence of deflection angle of electrons on the radius of curvature of the crystal for planar (111) (top) and axial <110> (bottom) orientation of the crystal towards the incoming particle beam. Bending angle of the crystal was 2 mrad

To ensure a proper comparison of the efficiency of electron deflection by a crystal in planar and axial orientations, the crystal bending radius was increased to 5 m. The results are shown in Fig. 3. It is clearly visible that at a bending radius of approximately 2 m, the number of particles deflected at an angle exceeding 1.75 mrad in the case of axial crystal orientation significantly exceeds the number of deflected particles in the case of planar crystal orientation. We also observe that the optimal bending radius of the crystal, corresponding to the most efficient particle deflection for 6 GeV electrons, is significantly greater in the case of axial orientation compared to planar orientation.

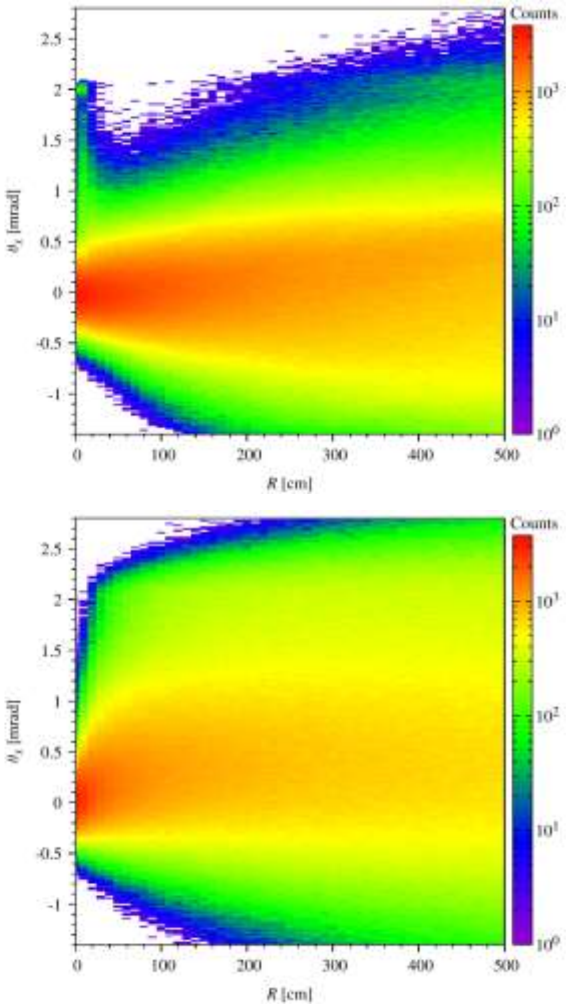


Fig. 3. The dependence of deflection angle of electrons on the radius of curvature of the crystal for planar (111) (top) and axial <110> (bottom) orientation of the crystal towards the incoming particle beam. Bending angle of the crystal was 2 mrad

For a more accurate comparison of the efficiency of electron deflection during planar channeling in a bent crystal and deflection in the field of atomic strings of the bent crystal, Fig. 4 shows the dependencies of the number of particles deflected by an angle exceeding 1.75 mrad on the crystal bending radius for different values of the crystal bending angle α. From these dependencies, it can be seen that in the case of planar channeling, the maximum number of electrons deflected by an angle of 1.75 mrad is achieved when the crystal bending angle is approximately 2 mrad and the bending radius is about 7 cm. In this case, the number of deflected particles is about one percent of the total number of particles incident on the crystal. In the case of the axial orientation of the bent crystal, the number of electrons deflected by an angle exceeding 1.75 mrad increases with the bending radius R. However, since for thin crystals the bending angle is equal to the ratio of the crystal thickness L to its bending radius, an increase in R also leads to an increase in L. As the crystal thickness increases, radiation and ionization energy losses of electrons in the crystal also grow. Therefore, in our analysis, we limit the bending radius to 5 m, at which the crystal thickness is about 1 cm (for α = 2 mrad). An important feature is that, starting from R values of about 2 m, a crystal with a bending angle of 2 mrad can deflect more than 10% of electrons by an angle exceeding 1.75 mrad.

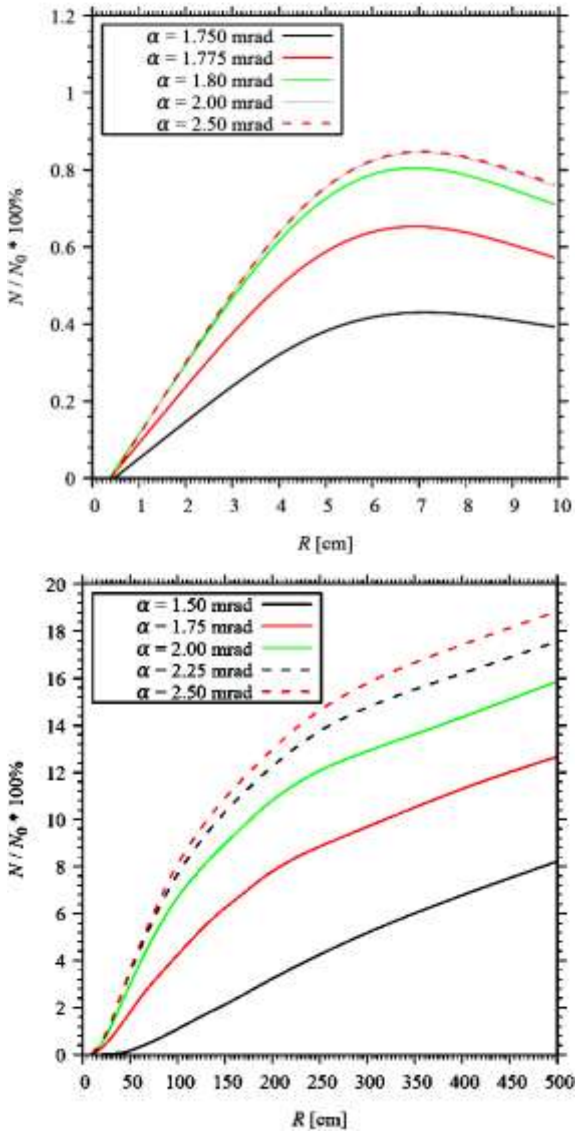


Fig. 4. The dependence of the ratio of electrons deflected by a bent crystal at an angle exceeding 1.75 mrad to the number of particles incident on the crystal on the bending radius of the crystal for different values of the bending angle α. The upper figure corresponds to the planar orientation of the crystal, while the lower one corresponds to the axial orientation

CONCLUSIONS

Preliminary results have been obtained on simulating the passage of a beam of electrons with an energy of 6 GeV in bent crystals at different types of crystal orientation relative to the beam in order to determine the most effective mechanism for deflection of the electron beam, as well as to search for optimal parameters of the device for the realization of slow electron beam extraction. The results showed that the axial orientation of the crystal allows for a many-fold increase in the number of deflected particles compared to the planar orientation of the crystal.

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