Deflection of a beam of relativistic 53-GeV/*c* carbon nuclei by a curved silicon single crystal

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It has been demonstrated experimentally that the trajectories of relativistic nuclei can be controlled with a curved single crystal. Carbon nuclei with a momentum of 53 GeV/c, captured into planar channelling by a curved silicon single crystal, have been deflected through an angle of about 65 mrad.

After the turning of a charged-particle beam by means of channelling in a curved single crystal was predicted[1] and then experimentally established,[2] it became obvious that this effect would be of practical value in experimental high-energy physics.

In this letter we report a test of this effect for relativistic nuclei. An experiment was carried out at the synchrophasotron of the High-Energy Laboratory of the Joint Institute for Nuclear Research with the help of the single-arm scintillation magnetic spectrometer of the Scientific-Research Institute of Nuclear Physics, Moscow State University.

A beam of accelerated ^{12}C nuclei with a momentum $P_0 = 53$ GeV/c and an intensity of 10^5 nuclei/cycle was extracted from the synchrophasotron over a time of 0.3 s.

The single-arm scintillation magnetic spectrometer worked on line with an SM-3 computer. The arrangement of detectors is shown in Fig. 1. The apparatus includes scintillation counters $\overline{K}$, C, and $\overline{A}$; multichannel scintillation hodoscopes F_{xy}, B_{xy}, T_{xy}, S_{xy}, and P_x; analyzing magnet M; and goniometer G, with the curved silicon single crystal. The coordinate detectors were hodoscopes made of thin scintillators each having a cross-sectional area of 4×4 mm^2. The goniometer had a single degree of freedom: to rotate around the vertical axis. The minimum rotation step was 25×10^{-6} rad. The crystal, cut from a silicon bar with a resistivity $\rho\approx10$ k$\Omega\cdot$cm and a dislocation density $\sim10^2$ cm^{-2}, was a wafer with dimensions of $20\times10\times0.28$ mm, oriented with its large face parallel to a (111) crystallographic plane and cemented to a deformable holder. We used planar channelling.

The electronic triggering logic selected events which were detected in all hodoscopes. Counters $\overline{K}$ and $\overline{A}$ were connected in anticoincidence in order to reject operations due to background events. Counter C and hodoscope S_y were used to determine the charge of the primary and scattered particles. At the position of the crystal, the beam had dimensions of 1×1 cm and an angular divergence of about 4×10^{-3} rad in the XZ plane.

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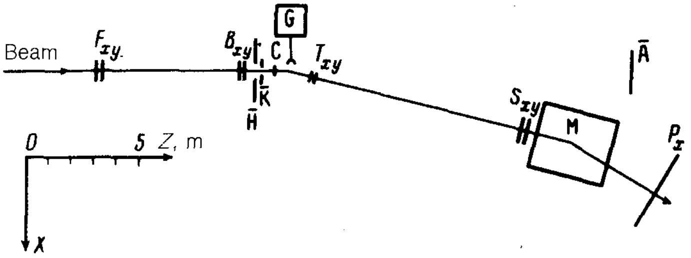

FIG. 1. Arrangement of the detectors of the scintillation magnetic spectrometer in the beam of relativistic ^{12}C nuclei.

To observe the effect, we turned the movable arm of the spectrometer $\sim 65\times10^{-3}$ rad away from the direction of the direct beam. With a disoriented crystal, the count rate of background operations did not exceed 0.2×10^{-6} per beam particle. The orientational effect was manifested as a peak in the distribution of responses from the channels of hodoscope S_x. The triggering rate increased to 0.3×10^{-4}. In the analysis, we required effective operation of all of the X-plane hodoscopes, and we also required that the ionization loss in detectors C and S_y correspond to a charge $Z\geqslant6$.

Figure 2 shows distributions in the scattering angle in the XZ plane and in the angle through which the momentum vector rotates in the field of the analyzing magnet

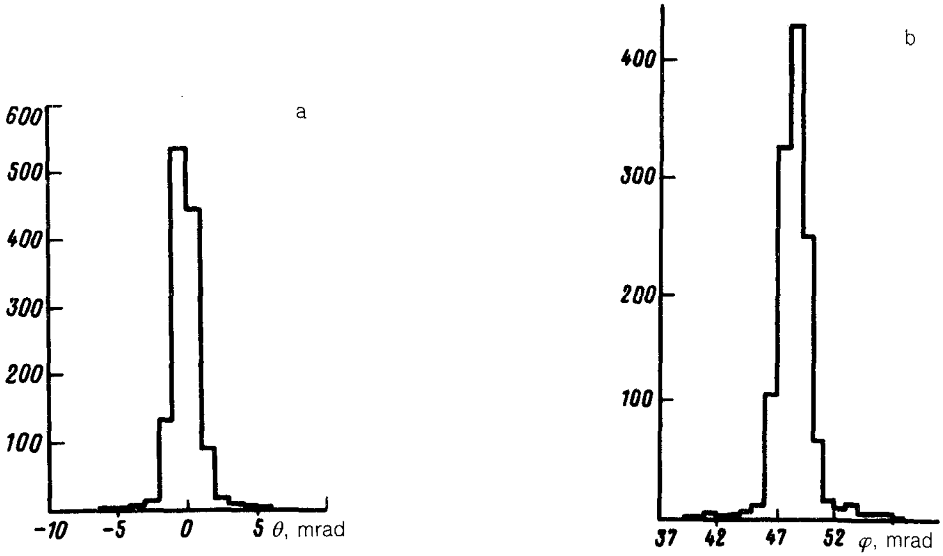

FIG. 2. The crystal has been withdrawn from the beam. a—Distribution of the primary nuclei in the scattering angle θ in the XZ plane; b—distribution in the angle (φ) through which the momenta of the primary nuclei are rotated in the field of the analyzing magnet. Here and below, the number of events is plotted along the ordinate.

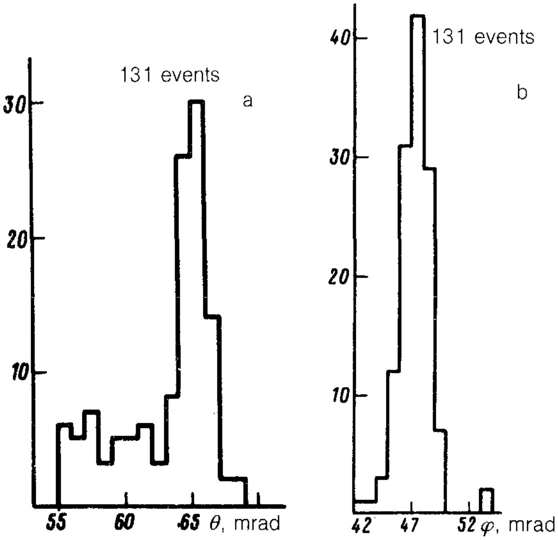

FIG. 3. The crystal is oriented along the beam. a—Distribution in the scattering angle θ in the XZ plane; b—distribution in the angle (φ) through which the momenta of the scattered nuclei are rotated in the field of the analyzing magnet.

according to measurements carried out for primary ^{12}C nuclei with a momentum $P_0 = 53$ GeV/c. In the case of planar channelling, the angle between the momentum of a particle and the channelling plane does not exceed the critical value $\varphi_c = \sqrt{2u/Pv}$, where u is the depth of the interplanar potential, P is the momentum, and v is the velocity of the particle.

In silicon, for the (111) plane, and for $Z = 6$, the depth of the potential is $u = 134$ eV, so the width of the angular distribution of the channeled carbon nuclei with a momentum of $P_0 = 53$ GeV/c does not exceed $2\varphi_c \approx 1.4 \times 10^{-4}$ rad. The deflection effect was identified as the presence of a peak in the distribution in the scattering angle in XZ plane for nuclei with a momentum P_0 and $Z = 6$ (Fig. 3). The width of the peaks in Fig. 3, a and b, is determined by the resolution of the spectrometer. The background to the left of the peak in the angular distribution is attributed to a dechannelling of nuclei in the tail of the crystal. It can be seen from Fig. 3b that these nuclei also have a momentum of P_0. It follows that the curved silicon crystal deflects carbon nuclei through an angle of $(65 \pm 1) \times 10^{-3}$ rad by virtue of a planar-channelling effect.

This has been the first experimental demonstration that the trajectories of relativistic nuclei can be controlled by means of curved single crystals.

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