FIRST RESULT OF STUDY OF 70 GEV PROTON BEAM FOCUSING BY BENT CRYSTAL

A.S.Denisov, O.L.Fedin, M.A.Gordeeva, M.P.Gur'ev, Yu.P.Platonov, A.I.Schetkovsky, V.V.Skorobogatov, A.I.Smirnov, V.I.Baranov*, Yu.A.Chesnokov*, V.V.Dudenko*, N.A.Galyaev*, V.I.Kotov*, S.V.Tsarik*, V.N.Zapolsky*

* Institute for High Energy Physics, Protvino, Moscow region

Nowadays bent crystals are widely applied to deflect high energy particle beams. Beam focusing may be another important application of these crystals. Different techniques may be used for this purpose. One of them is beam focusing by a thin bent crystal oriented transversely to the crystallographic planes [1]. It should be noted that with this technique used, strictly speaking, particles whose trajectories cross on the same line are selected rather than the parallel beam is focused. Another possible approach exploits the effect of plane deformation in a thick crystal when being compressed. A disadvantage of these techniques is the background from the unchannelled beam fraction. In this work, the technique of focusing parallel beam into a strip has been realized. In this case, the beam is also deflected by a noticeable angle, thus allowing one to obtain pure focused beams.

The idea of the technique presented is in the fact that the surface of the back end face of the bent crystal should have a specific shape for the tangentials to the crystallographic planes to cross the same line on this surface. In the case of the crystallographic planes bent to conform a cylinder of radius R (fig.1), it is necessary that the line with the curvature centers OO' be placed on the surface of the cylinder to the shape of which the crystal end face is treated. In the case of an ideally bent and perfectly cut crystal, the beam size at the focus point is determined by the focal distance $L = (4r^2 - R^2)^{1/2}$ multiplied by the the doubled critical channelling angle Ψ. Since this angle is fairly small (i.e. $\Psi = 0.02 - 0.002$ *mrad* for 100 *GeV*—10 *TeV* particles during planar channelling in silicon), and the technology of crystal bending and treatment enables one to obtain a focal distance of ≈ 1 *m*, the attainable beam dimensions are a few tens microns in the GeV energy range and

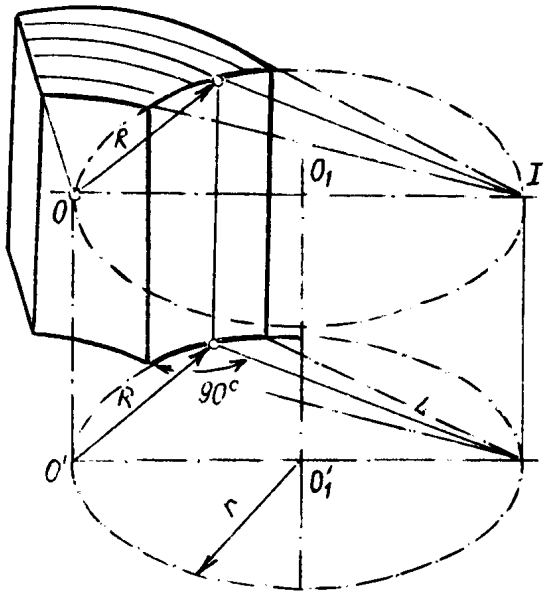

Fig.1. Principle of focusing beam by crystal: OO' — line on which curvature centers of crystallographic planes are situated; O1O1 — axis of cylinder of radius r to which crystal end face was treated; 11' — focal line on which tangentials to bent planes meet according to well-know geometrical theorem

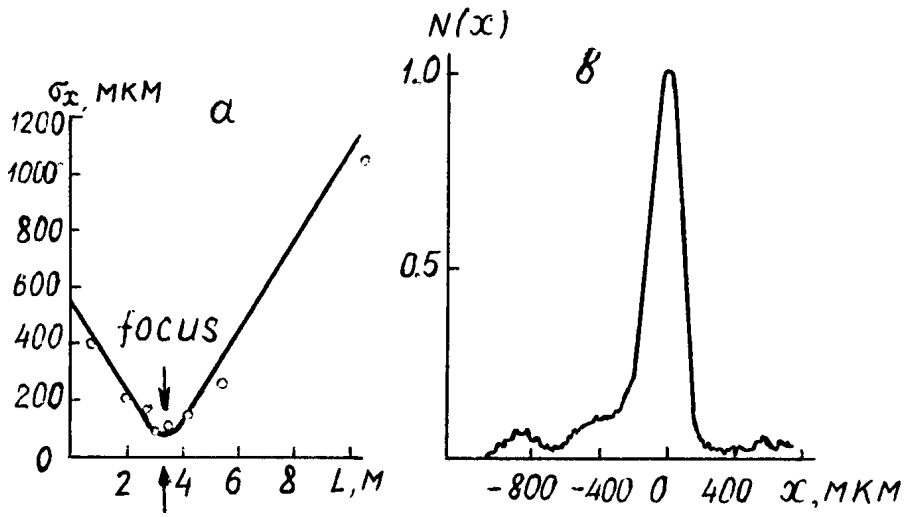

Fig.2*a,b*. Envelope of beam focused by crystal: points show experimental result, line corresponds to calculation for ideal focusing (*a*). Beam profile in crossover region (for case when photoemulsion was within 3.5 *m* from crystal). Microphotometer resolution was 15 μm (*b*)

a few microns in the *TeV* one. Note that the factor of linear magnification during focusing $F = 2L\Psi/H$, where H is a specific crystal width of ≈ 1 *mm*, may reach a few hundredths and a few thousandths, respectively.

The experiment on focusing was carried out at the IHEP accelerator with a 70 *GeV* proton beam. A silicon crystal of dimensions $H \times V \times Z = 2 \times 15 \times 70$ *mm* (width, height and length along the beam) of orientation {111} was used in this experiment. The crystal was bent to conform a cylinder of radius $R = 2.7$ *m* over a length of 65 *mm*, whereas its end face was treated so as to conform a cylinder of radius $r = 2.2$ *m* in such a way that the focal distance should be $L = 3.5$ *m*. A beam of $\sigma_x = 2$ *mm* width, having a small angular divergence $\sigma_\alpha = 0.1$ *mrad*, was incident on this crystal. The intesities of the direct beam and of that, bent by the crystal at an angle of 24 *mrad*, were measured by scintillation counters. With the optimal orientation of the crystal it deflected 3% of the particles of the direct beam. The focusing effect was recorded with the help of a few layers of nuclear photoemulsion placed at different distances from the back end face of the crystal. Fig.2*a* shows the beam envelope plotted as results of processing the exposed emulsions by a microphotometer. It is compared with the calculated envelope. Fig.2*b* shows the measured beam profile in the crossover region. Its width, $2\sigma_x = 200\,\mu m$, coincides with the calculated estimate to an accuracy of 15%. The beam halo may be related primarily to the deformations of the crystal as a result of its bending and to deviation of its shape from the perfect one. We hope to eliminate this effect during our further work. According to the data on processing the hotoemulsions, the contrast of the focus, i.e. the peak-background ratio, was 100.

The way the focusing technique was implemented in our work may be used to obtain pure micron-sized beams of the TeV energy range at accelerators of new generation. For this purpose to be accomplished, it is sufficient to transport the beam deflected by the crystal with the help of unity optics to the experimental setup.

Another important application of such a crystal focusing device is related to the inverted direction of particle motion, i.e. focusing from a point source into a parallel beam. Placing the focusing crystal within a few meters from an internal target of an accelerator made in the form of a filament, one may focus and deflect a great amount, $\approx 50\%$, of secondary particles produced on this target. According to some estimates, this technique may allow one to form secondary beams of an intensity of $\approx 10^8\ s^{-1}$ at the future colliders.

Reference

Andreev V.A. et al. //JETP Lett., 41. 1985. 408.