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INCREASE A BENT CRYSTAL EXTRACTION EFFICIENCY BY MEANS OF THIN INTERNAL TARGET

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Abstract

Results of the new regime tuning are reported. The efficiency estimates for different particle distributions on a bent crystal input for a concrete scheme of the IHEP accelerator proton beam extraction were made.

1 INTRODUCTION

The extraction efficiency for the protons extracted during direct steering of a proton beam on the bent crystal, istalled in the vacuum chamber of A-70, reaches $\sim 1.5 \cdot 10^{-4}$ [1]. It goes down noticeably if the intensity of the particles interacting with the crystal increases. Maximum number of particles that reach the experimental setup is $\sim 4.5 \cdot 10^6$ ppc and practically does not increase at steering $> 10^{11}$ ppc onto the crystal. But the extraction efficiency may be increased significantly by elastic scattering of the accelerated protons on the thin internal target (IT) [2] installed upstream of the crystal. The number of particles in the beam line is doubled and reaches 10^7 ppc.

2 EXPERIMENTAL RESULTS

The number of particles extracted from the accelerator by a bent crystal to one of the experimental setups (PROZA [3]) versus the coordinate of the thin IT preliminarily scattering the primary beam is shown in fig.1. The scheme of extraction as well as mutual disposition of the extracting elements (targets, crystals, etc.) are given somewhere else [1,4,5]. Curves 1,2,3 of fig.1 show how the extracted protons intensity depends on the closed orbit position on the target asimuth (coordinates 52, 54 and 56 mm, respectively). Curve 4 is the dependence of intensity of the accelerated beam interacting with the target versus its coordinate (i.e. on the beam-target depth intersection) under constant feedback loop gain of the steering system.

The dashed horizontal line shows the maximum number of particles extracted to the PROZA setup during direct steering the beam on the crystal, i.e. without preliminary scattering.

It follows from the presented data that the number of particles extracted to the beam line by a bent crystal increases two times if the beam is scattered by a thin IT.

The presence of the second maxima of the extracted intensity when moving the IT to the outside can possibly be explained by changing the beam particles density on the input of the crystal. There is also difference between the target and crystal coordinates of 2 mm, when the conditions of the maximum intensity extraction are realized.

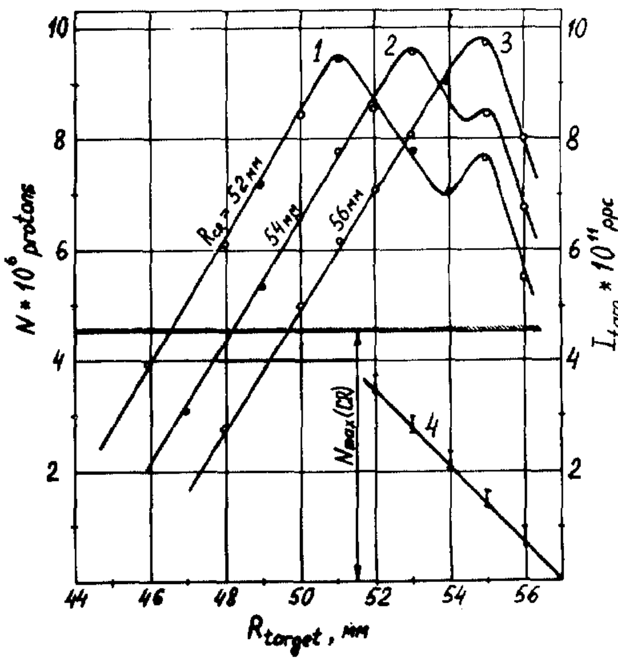

Figure 1: Number of particles extracted from the accelerator by bent crystal after scattering in a thin internal target. Curves 1, 2 and 3 correspond to different crystal coordinates from the central orbit. $N_{max}(CR)$ – the maximum number of particles extracted by the crystal without target. 4 – $I_{targ.} = f(R_{targs.})$.

The reported extraction mode was realized in the IHEP accelerator for the first time in January 1991 and after that it is continuously used [6].

Let us evaluate an extraction efficiency by using the experimental beam characteristics [7,8] and the concrete extraction conditions shown in fig.2.

Two cases are considered:

– direct steering of the beam onto the crystal (phase ellipses of r-plane are marked as $1'$ and 1), and

– preliminary steering of the beam onto the target (phase ellipses are 2 and $2'$) with the following hitting the

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crystal by the particles with large amplitudes.

The phase ellipses are shown for accelerator blocks 24 and 25 where the target and crystal are installed. The functions $\Phi(r)$ of the beam particle distribution normalized to 10^{12} protons are given also. The coordinates of the crystal and thin target can be seen on fig.2.

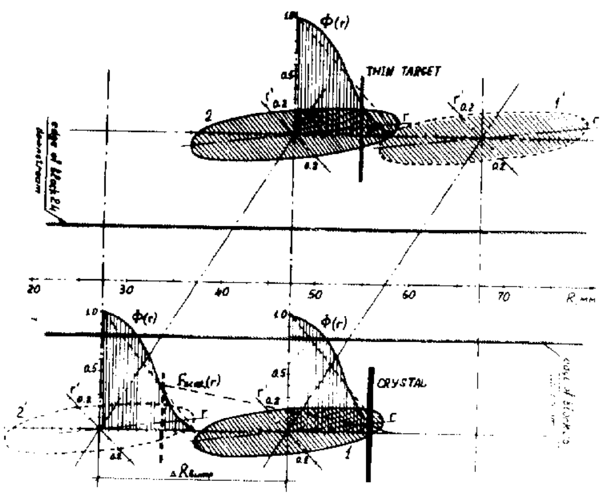

Figure 2: Geometry of the experiment on scattering particles by the thin target before extraction through the crystal of magnet block 25, and some of the beam characteristics. All the explanations are in the text.

To estimate the extraction efficiency, the $\sim 1.5 \cdot 10^{11}$ ppc intensity of the particles interacting with the thin target was taken. In order to simplify the estimates the curve $\Phi(r)$ has been changed by a linear function (shown with the broken lines). The shadows of the beam and scattering target on the crystal asimuth in block 25 for the second case are shown as ellipse $2'$ and broken and dashed vertical lines. The line $F_{scat}(r)$ is an approximation of the radial distribution dependence for the particles underwent the multiple coulomb and nuclear elastic scatterings after interaction with the target. The data on the scattering amplitudes are taken from [2,9]. At the major semiaxis of an ellipse $\sim$ 10 mm in case of a direct beam steering onto the crystal a linear particle density on it is $5 \cdot 10^{10}$ protons/mm, and the maximum value of the extraction efficiency is $\sim 1.5 \cdot 10^{-4}$ [1].

In the case of preliminary scattering of $\sim 1.5 \cdot 10^{11}$ protons by the thin target we will get accordingly $3 \cdot 10^{9}$ protons/mm which implies a decrease of particles density on the crystal $\sim$ 17 times. Taking into account that the extracted intensity increases twice we will get the extraction efficiency value $\sim 0.5\%$.

The confirmation of the estimates one can get from the direct comparison of the extraction efficiencies for both cases mentioned above.

a) extraction by the crystal without target.

The extraction efficiency is $\sim 1.5 \cdot 10^{-4}$ which corresponds to steering $\sim 1.5 \cdot 10^{10}$ onto the crystal or the beam linear density $\sim 3 \cdot 10^{10}$ protons/mm by the crystal thickness $\sim$ 0.5 mm. On the whole, taking into account that particle density is lowered to the edge of a distribution function, the data of the above mentioned estimations are in a satisfactory agreement obtained with experiment.

b) extraction during scattering the beam by thin target.

With the number of protons hitting the crystal $\sim 1.5 \cdot 10^{9}$, the extraction efficiency equals $\sim 0.7\%$ that is also close to the value a obtained above. The real extraction efficiency is expected to be noticeably higher with optimising the construction of the accelerator vacuum chamber and a head part of the beam line.

It seems to be the right time to already speak about using the considered slow extraction mode up to intensities $\sim 10^{8}$ protons/sec.

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