ON USING BENT SINGLE CRYSTALS FOR PROTON EXTRACTION FROM IHEP ACCELERATOR

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Abstract. The multiturn extraction of protons for physical experiments is realized. The crystal deflector is installed into the vacuum chamber of U-70. The simultaneous extraction of the accelerated protons using bent single crystal and secondaries from internal targets on the flat top of magnetic cycle is ensured. The results of the proton beam extraction in a common mode with the extraction of secondaries are given. The perspective of using bent single crystals at the IHEP accelerator is considered.

Introduction

The channeling effect in bent crystals [1] allows to significantly develop the methods of the beams extraction from the accelerators, including high energy machines. Proton beam was extracted using bent crystals from the Dubna synchrophasotron [2] and the IHEP proton synchrotron [3]. The work in this direction in progress at the SPS and Tevatron, possibility to use bent crystals in the UNK and SSC projects is being examined as well. With the bent crystal as an accelerator extraction element, in IHEP the 70-GeV proton beam was extracted to beam lines used to work with the negative secondaries. In some cases it allows one to extend significantly the physical research program. By now with the bent crystal used the intensity of the extracted proton beam of about 10^7 ppp during up to 2s is reached.

1. Beam Extraction Schemes

The extraction of protons from the accelerator into the existing beam lines of secondaries is possible if the crystal deflector is installed into the vacuum chamber on the definite accelerator asimuth and the appropriate closed orbit bumps for steering the beam on the crystal is made. Besides during extraction of protons with a bent crystal one should have a possibility for the other experimental facilities simultaneously to work with the secondary beams from the internal targets.

The region of the IHEP accelerator where the main beam lines of secondaries start (channels 2 and 4 having in turn many branches) is shown on fig.1. When using the crystal for the proton ejection purposes into beam line 2 the most suitable place of its installation is the region of strait section 25. The bending angle of a single crystal depends on the asimuth of installation and equals ~80 mrad for the case of the beginning of block 25 and ~60 mrad for the end of block 24 (see fig.1). The radial coordinate of the crystal equals +(55-60) mm from the central orbit that is considerably more as compared with "usual" internal targets T1 and T2 coordinates (up to 40 mm). The closed orbit bump shown on fig.1 (curve 1-1) is formed with the windings of blocks 20, 22, 26, 28 and gives a necessary beam deflection on the asimuth of the crystal.

At present the ejection of protons from block 25 is used but another crystal should be installed in the end of block 24 soon, that will allow, as it was noted, to diminish the single crystal deflecting angle as well as reduce the magnitude of the bump.

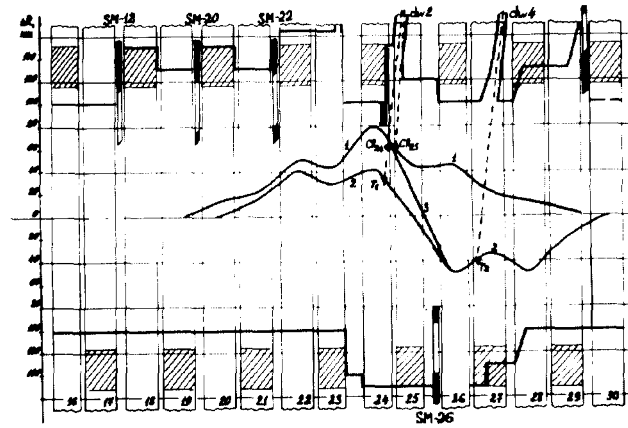

Fig. 1. The protons and secondary particles extraction scheme: 1-1 - closed orbit (c.o.) bump at the independent extraction by crystal, 2-2 - c.o. bump at the simultaneous sharing of the beam on T1 and T2, 1-3-2 - c.o. bump at the simultaneous extraction of protons and secondary particles.

Fig.1 shows also the case when protons are extracted with the crystal deflector into beam line 2 simultaneously with the extraction of secondaries from the internal target T2 (beam line 4) installed into magnetic block 27. During this mode of extraction the closed orbit (c.o.) bump should have the form shown with curve 1-3-2. One can see that in this case it is advisable to install the crystal on the radial coordinate +60 mm at the end of magnetic block 24.

There is the possibility of the protons extraction from the IHEP accelerator with the use of the bent crystal to another main line for secondaries - channel 4. In this case crystal deflector is installed near the middle of block 27 on 6.5 m from the beginning downstream. The bending angle ~85 mrad. There are the peculiarities of that scheme of ejection:

- the crystal deflector interact with the beam into the positive radial coordinates w.r.t. central orbit (the internal targets of block 27 generating of secondaries have the negative coordinates),
- the c.o. bump is formed by more complicated method than usual, because of too large working coordinates of the crystal (+50 mm into the defocusing block).

One need 8 blocks of accelerator (in region of blocks 23-32) at all to form the c.o. local distortions required. By this one get the best conditions for the particles capture into channeling, owing to the beam input angle into the crystal optimization.

Fig.2 shows the dependence of the beam coordinates (ΔR and $\Delta R'$) at the outlet of the accelerator on the bending angle of the crystal. ω here is the tolerated range of the crystal bend which ensures capturing of particles into the acceptance of the channel. As it is noted, beam line 4 is the main user of the secondary beams, therefore it is very important to widen the possibilities of the beam line, using the proton beam extraction by the bent crystal.

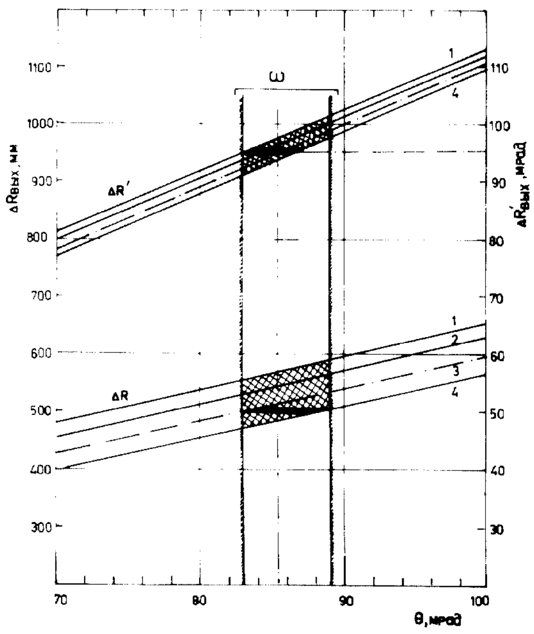

Fig.2. The dependence of the beam coordinates at the outlet of accelerator (SS-28) versus the single crystal bending angles.

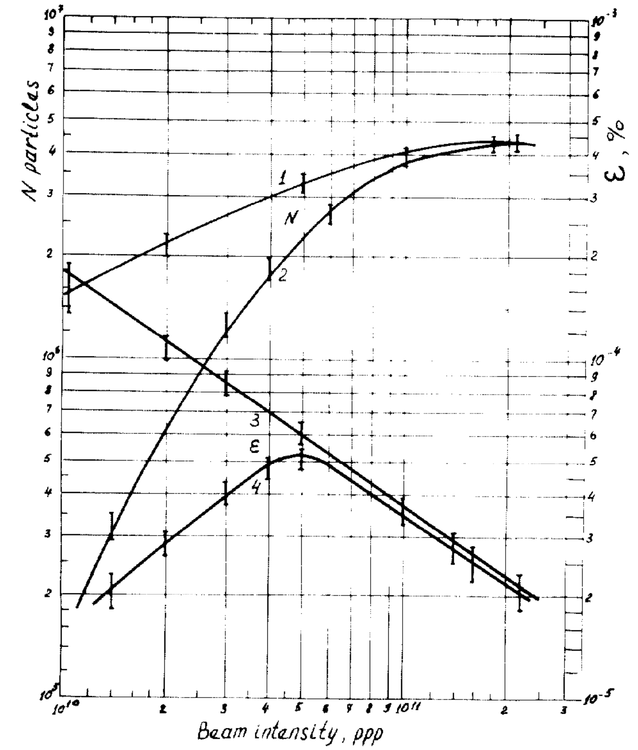

Fig. 3. The number of particles into the beam line and the protons extracting efficiency in dependence on the intensity of the beam interacting with the crystal for two modes: 1, 3 - c.o. bump is formed with the help of blocks 20, 22, 26, 28; 2, 4 - the blocks 20, 21, 26, 27 are working.

2. Experimental Results

While tuning the protons ejection into beam line 2, the crystal deflector was moved in the horizontal direction by the remotely controlled goniometer, which also allowed to optimize of its angle position.

The intensity registrated in the beam line was about $4\cdot10^6$ protons when steering $\sim10^{11}$ particles onto the crystal, i.e. the ejection efficiency was $\sim4\cdot10^{-5}$. Such relatively low value of the efficiency could be explained by the following factors:

- using the crystal with inclined sides (parallelogram shape), which makes the requirements for the crystal adjustment w.r.t. the beam less stringent, however the channeling efficiency worsens;
- beam dynamics under multiturn extraction, when a fraction of particles, scattered on the crystal, as on a standard target, turn out to be not captured into the channeling mode.

Quite recent results obtained with the crystal of rectangular shaped plate, yield better values for the efficiency - $8\cdot10^{-5}$. In this case up to $2\cdot10^6$ protons were obtained in the beam line at $\sim2.5\cdot10^{10}$ particles per accelerator cycle spilled onto the crystal. This work was done simultaneously with extracting secondaries into beam line 4, the crystal coordinate was r = = ~55 mm w.r.t. the central orbit.

Dependencies of the ejection efficiency for the protons extracted with the crystal deflector installed in block 25 are shown on fig.3. Curves 1 and 2 show the number of the extracted into the beam line particles versus the intensity of the beam interacting with the crystal for two cases.

In the first one (curve 1) the beam deflection to the crystal was made with the help of two pairs of magnetic blocks 20-26 and 22-28. Curve 2 shows the case, when the closed orbit bump is formed with the pairs of blocks 20-26 and 21-27. The lower intensity in the second case can be explained with the inlet angle to the crystal, which is not optimal. Nevertheless the second mode is more favourable when the crystal works simultaneously with the internal targets of the other channels.

Curves 3 and 4 of fig.3 show the extracting efficiency of the protons to beam line 14, which is a branch of channel 2, for cases 1 and 2, accordingly. It is seen that in the best case the extracting efficiency reaches $\sim1.5\cdot10^{-4}$ that is in accordance with the experimental results (see, e.g. [4]).

One should point out, that in the case considered there is a very weak dependence of the proton beam intensity in beam line 2 on the intensity level of the beam interacting with the internal target of beam channel 4 (the target T2 on fig.1). It maintains up to the intensity 10^{12} particles steered onto the target.

Conclusion

In view of the UNK construction it is supposed that on the existing accelerator the beam tests region will be expanded in order to make apparatus ready to work in the UNK energy region. In connection with this bent single crystals significantly expand the experimental possibilities. Together with the above-mentioned schemes of the protons extraction from the accelerator, using the bent crystals for division and forming of the beams in the beam lines (see e.g. [5]) seems important.

With the bent crystals the beam channeling efficiency really reaches the value more than 10^{-4}. It means that the standard level of the intensity, in the operation with internal targets, which causes the serious radiating problems may be diminished 100 times. The intensity of $\sim10^{10}$ ppp exists even in the halo of the accelerated beam [6]. These particles can be extracted from the accelerator with comparative ease.

The results of using the bent crystals confirm the satisfactory work of the schemes of the proton beam extraction as well as good compatibility of such modes of extraction with the other particles ejection methods.

References

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