ABOUT EXTRACTION OF 70-GEV PROTONS BY A BENT CRYSTAL FROM THE IHEP ACCELERATOR TO THE PROZA SETUP

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1 INTRODUCTION

In 1987, during investigation the polarization effects on the experimental setup PROZA, an indication on a possible discovery of an unknown phenomenon, the scaling asymmetry [1], was obtained. The interval of the investigated energies was not large: from 13 GeV at BNL [2] to 40 GeV at IHEP. It was very desirable to extend this region to the maximum of the IHEP accelerator energy – 70 GeV by extracting the accelerated proton beam onto the target of the experimental setup.

The extraction methods used before [3] could not ensure the required beam parameters. It was decided to investigate a possibility of the A-70 primary beam extraction by a bent crystal. For the first time an attempt to realize such extraction was made in Dubna (1984) with the 4.2, 6.0 and 7.5 GeV beam [4].

The first results of the 70 GeV proton extraction from the IHEP accelerator made in 1989 with the crystal of Si, istalled into the vacuum chamber of magnetic block 25 and bent by 80 mrad, were reported in [5]. Since 1990 the physical use of the new method of extraction was started and a few runs of polarization experiments on the PROZA setup were done.

The results of investigation both the regime of proton extraction to the PROZA setup and work of it simultaneously with extraction of the secondary particles from internal targets (IT) to other beam lines are reported in the article.

2 PECULIARITIES OF USING THE CRYSTAL

One of the peculiarities of using a crystal for the beam extraction to experimental setup is the position of it, $\sim 55-60$ mm from the central orbit (in the region of the beam envelope), that is more distant than the IT working coordinates (± 40 mm). To steer an A-70 primary beam onto the crystal a local distortion (bump) of the closed orbit was required. The bump is formed with an additional field ΔH generation into the magnetic gaps of four blocks 20, 22, 26, 28 [5,6]. Such an orbit bump gives a required beam deflection on the crystal asimuth and makes no aperture limitations through the accelerator.

Another peculiarity of the new method of ejection was the requirement to arrange a possibility of simultaneous work with the PROZA setup experimental setups of other beam lines (e.g. 4 and 18) with the secondary beams: on A-70, as a rule, 4-5 experimental setups use simultaneously beams from IT.

It should be noted, that for a beam steering onto the crystal one can also use a bump which is formed with blocks 20, 21, 26, 27. Such a bump in some regimes (e.g. at the simultaneous work with nonresonant slow extraction [7,8]) is more preferable.

We give here some parameters of the IHEP accelerated beam which allow one to estimate possible efficiency of extraction under direct steering of the beam onto the crystal 0.5 mm thick. For the intensity $\leq 10^{13}$ ppc[1] the beam emittance equals 1 mm·mrad and its angular divergence is about ± 0.2 mrad. For higher intensity of the beam its emittance reaches 2 mm·mrad and angular divergence of about ± 0.3 mrad. The critical channeling angle of the crystal is $\psi_c \sim \pm 25$ μrad.

3 EXPERIMENTAL RESULTS

The most important dependencies characterizing the efficiency of proton extraction by the bent crystal of block 25 of A-70 are shown in fig.1. Curves 1 and 2 show the number of particles extracted into the beam line versus the intensity of the beam interacting with the crystal for two cases mentioned above: when the bumps for steering the beam onto the crystal are formed with blocks 22, 28 or blocks 21, 27 respectively in addition to blocks 20, 26.

Curves 3 and 4 of fig.1 show respectively the extraction efficiency for the cases 1 and 2. It is seen that in the best case the extraction efficiency reaches $\sim 1.5 \cdot 10^{-4}$ that is in agreement with results reported in [9].

Possible explanation for different extraction efficiencies (see fig.1):

– decrease of the efficiency (both curves 3 and 4) can be explained with increase the beam divergence when the crystal goes deeper ito the beam,

– increase of the extraction efficiency (curve 4) is due to variations of the input angles of particles captured into channeling mode under steering a beam onto the crystal. Since the bump used in this case is not equivalent to the case of curve 3, the extracted intensity increases. But it takes place only when the crystal goes from the halo into the densed part of a beam and only till an angular beam divergence becomes much more than the critical channeling angle ψ_c.

[1] ppc – protons per cycle.

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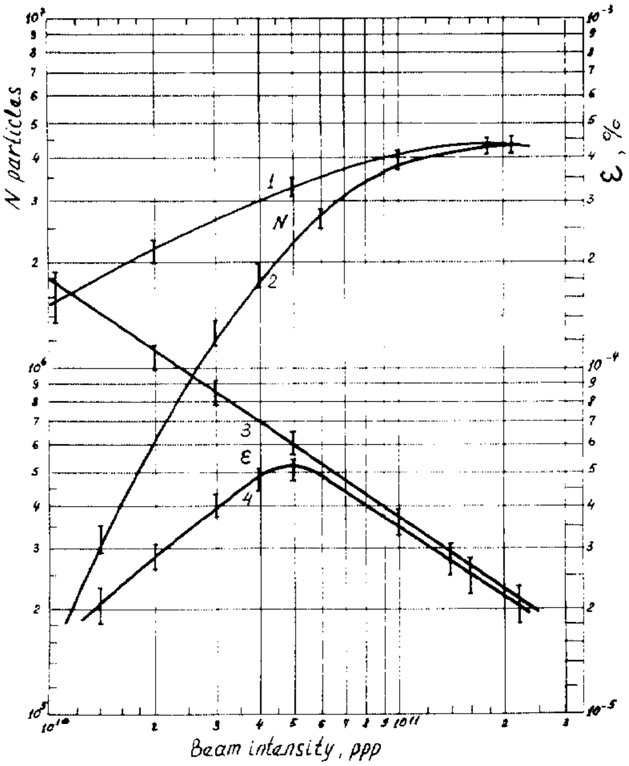

Figure 1: Number of particles into the beam line and extracting efficiency versus intensity of a beam interacting with the crystal for two regimes: 1,3 - c.o. bump is formed with blocks 22,28; 2,4 - with blocks 21,27 in addition to blocks 20,26.

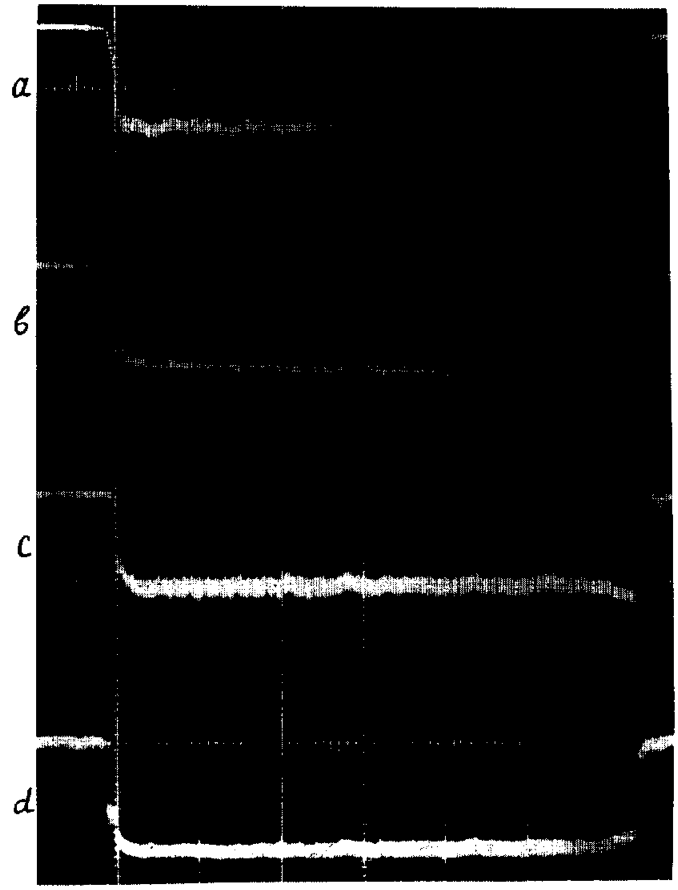

Figure 2: The oscillograms of simultaneous extraction from the accelerator different particles for different experiments. a) and d) – extraction of 70-GeV protons by the bent crystal and nonresonant slow extraction, respectively; b) and c) – extraction of 40-GeV secondary beams from the IT. Time scale – 200 ms/div.

Fig.2 gives an impression about duration and quality of the beams when accelerated protons and secondaries are extracted simultaneously from the accelerator to different beam lines for the different experiments. The traces a) and d) of the oscillograms – a time structure of the 70-GeV proton beam extracted to the PROZA (beam line 14) by the bent crystal and to FODS-2 (beam line 22) in the nonresonant slow extraction mode [7,8]. The traces b) and c) – a time structure of the 40 GeV secondary particle beams extracted to the setups GAMS, MIS JINR (beam line 4) and GIPERON (beam line 18) from IT installed respectively into magnetic blocks 27 and 35 of A-70. Fig.2 confirms an investigated earlier possibility of proton extraction to the PROZA facility by the bent crystal of block 25 simultaneously with extraction of particles for different experiments by other methods of extraction in the same accelerator cycle. A high quality of the extracted beam time structure is reached due to use of the thin IT [10] preliminary scattering beam before steering it on the crystal.

A proton beam was formed with the existing focusing elements of beam line 14 forming negative hadron beams (mainly the π^--mesons) with the momentum ≤ 40 GeV/c.

Possibility to compare, in the target region of the experimental setup PROZA, spatial and angular distributions of the 70-GeV proton beam extracted by the bent crystal and π^--mesons of the 40 GeV energy from the IT of block 24 is presented on figs.3 and 4. Fig.3 gives a spatial distribution, fig.4 – an angular one in horizontal and vertical planes (a and b, respectively).

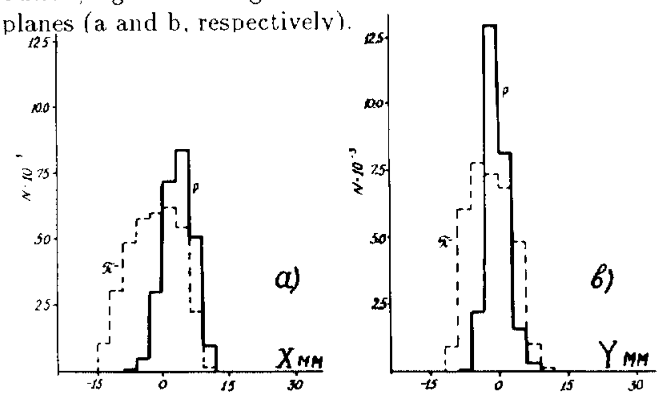

Figure 3: The spatial distributions of the 70-GeV protons and 40-GeV π^--mesons at 3.1 m before the target of the experimental setup.

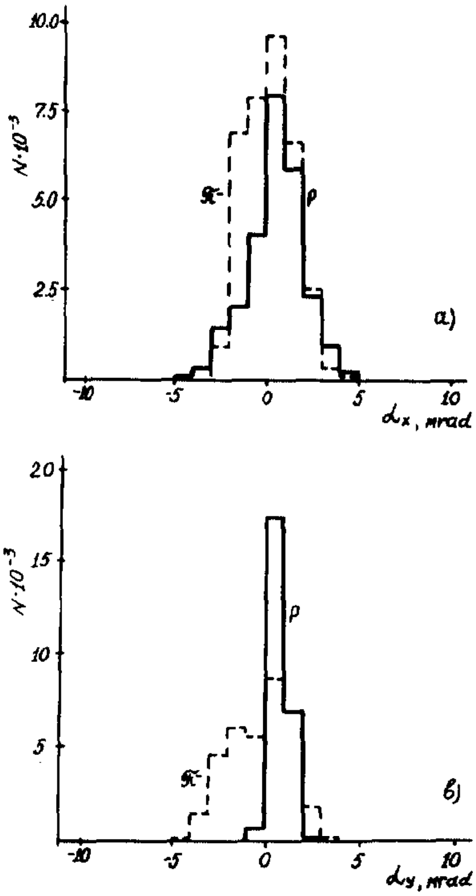

Figure 4: The angular distribution of the proton and π^--meson beams on target of the experimental setup.

It is seen that the transverse distribution of the proton beam is about 2 times narrower than that of the pion beam, the proton beam has as well less angular divergence. Fig.5 shows the phase ellipses of the 70-GeV proton beam and the 40-GeV π^--mesons in two planes (a and b, respectively) at about 3.1 m before a target of the experimental setup. A percentage of the beam contained into ellipses and the appropriate area in $mm \cdot mrad$ are shown there also. One can see that in this case there is a substantial improvement of the proton beam parameters comparing to the π^--meson beam parameters. So, the phase space area of the proton beam is 2 times smaller in XX'-plane and about 4 times – in YY'-plane. Such parameters of the formed beam satisfy well the requirements of the polarization research on the experimental setup PROZA.

4 CONCLUSION

Experience during a long time (a few runs in 1990-1992 more than a month each) of the new method of the maximum energy protons extraction by a bent crystal for the physical experiments gained for the first time at the IHEP allows us to make conclusion about its reliability, high stability of the beam parameters, compatibility of it with other methods and modes of particle extraction. Simplicity of using bent crystals, possibility of mounting them in any region of the accelerator vacuum chamber as well as possibility of using the existing beam lines suggest an expedience of their wide use for beam extraction both on the IHEP accelerator and on other machines of higher energies.

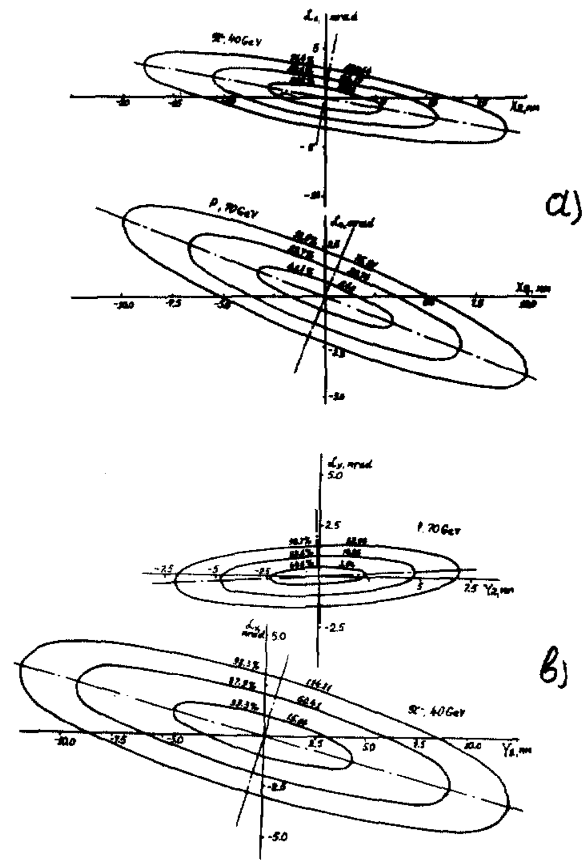

Figure 5: Phase ellipses of the proton and π^--meson beams at 3.1 m before a target of the experimental setup: a) – in horizontal plane, b) – in vertical plane.

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