SECOND SLOW EXTRACTION OF RELATIVISTIC NUCLEAR BEAMS FROM THE SYNCHROPHASOTRON

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Abstract

The second system of slow extraction of light nuclear beams with an energy from 200 MeV/n to 3 GeV/n has been under operation at the Synchrophasotron (SPT) since 1988. To decrease the dimensions of a strongly divergent beam passing throuch the tringing field , gradient shims have been installed. This permits one to extract and to transport about 30% of a circulating beam. Such a limitation of the extraction coefficient is determined by a one stage deflecting system consisting of a septum-magnet and a quadrupole septum-lens. (The existing equipment of the straight sections does not allow the second stage of the inner transport line to be installed). During one cycle the operation of the second extraction with the first one (the extraction coefficient is about 90% and the energy 4 GeV/n) increases significantly the efficiency of operation of the SPT for nuclear research.

Introduction

The second direction of particle extraction was initially created at the SPT for the irradiation of bubble chambers[1]. This required a very low intensity over a short period of ejection time. Later on the spill time was increased, but the intensity in the beam transport line was no more than a few fractions of a per cent of the intensity at the septum-magnet due to a large cross section of the extracted beam at the exit of the ring magnet caused by its passage throuch the edge magnet field.

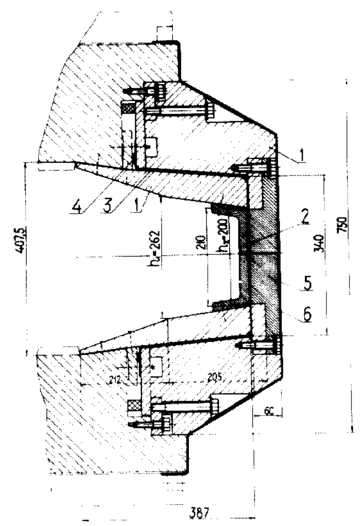
Since the number of physicists pretending to carry out experiments on SPT beams has substantially increased recently, the following task was put: to raise the intensity of the beam in the second experimental hall by more than an order of magnitude.

Calculation and Design

The essence of this work consists in changing the defocusing magnetic field for the focusing one by means of its shimming. Preliminary calculations have shown that a desirable result can be achieved if the region (4 m) of a more sharply decreasing field is replaced by an increasing one. In this case the beam crossed the alternate gradient fringing field as a focusing DFD--triplet.

The initial conditions at the input of the septum--magnet have been obtained by simulating of the resonance extraction at the SPT[2] for the main field, B_o, of 0.5 T and a momentum spread of $\pm 4\cdot 10^{-4}$. The particle motion downstream the septum-magnet was computed by the program simulating the magnetic field in the SPT quadrant taking into account desturbances and the fringing field[3]. At the first stage the shim gradient and its azimuthal extension, for which the beam size is minimum, were determined in a linear approximation. Taking engineering considerations into account, the optimum azimuthal length of the shims was taken as 3.8 m which corresponds to the distance between the windows of the SPT magnet yoke.

Next step was to compute the configuration of the shims[4] to provide the required gradient. The shape of the shims taken for calculation is shown in Fig.1. By varying the dimensions of h_1 and h_2, different forms of the magnetic field were obtained to take one of them as an optimum value. The results of computing are given in Fig.2. It is seen that the gradient is proportional to the main guide field only up to 0.6 T since further the effect of iron saturation shows itself appreciably.



1 - The shims,
2 and 5 - The struts,
3 - The wall of the high-vacuum chamber,
4 - The seal,
6 - The wall of the pre-vacuum chamber.

Fig.1. Cross-section of the shims

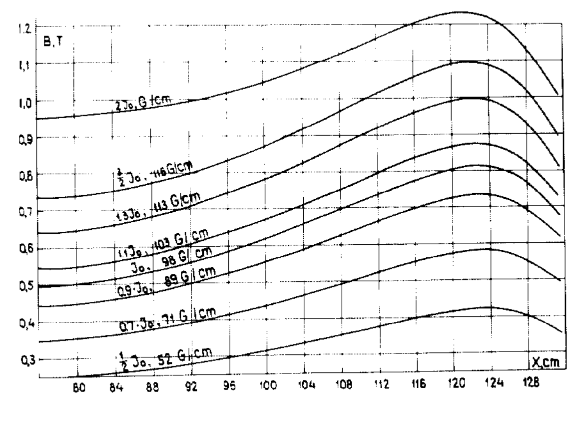


Fig.2. The distribution of the magnetic field in the shimming region at different currents in the SPT windings. J_o is current at B_o = 0.5 T

Under these conditions the simulation of beam transportation has shown that introducing the shims decreases substantially a vertical size (to 10 cm) and an angular divergence (to 10-14 mrad) at the exit of the quadrant, and these parameters are weakly dependent on the variation of the gradient and the azimuthal position of the shims. However, the horizontal characteristics of the beam are more sensitive to these parameters. Nevertheless, in the region of the gradient near 0.93 T/m the horizontal width of the beam is stable and suitable for further transportation. Its horizontal size and divergence at the head of the beam transport line are 4.4 cm and 6.2 mrad, respectively. The envelope of the beam in the horizontal (x) and vertical (z) planes inside the quadrant is shown in Fig.3. The effective emittance of the beam in both planes is about 70 $\cdot 10^{-6}$ mrad.

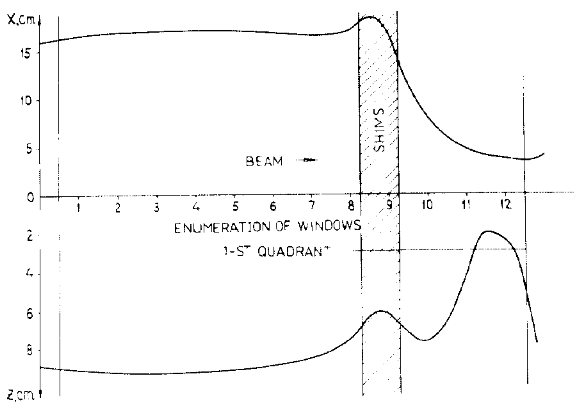


Fig.3. The horizontal and vertical beam envelopes inside the 1-st quadrant

Experiment

Work in the installation of the shims and new parts of the vacuum chamber was finished in the middle of last year. Fig.4 shows the shimming region of the SPT magnet under construction. The experiments performed with proton and carbon beams show a good agreement between the calculated and obtained values such as the position of the trace, the cross sections of the beam and an extraction coefficient of about 30%.

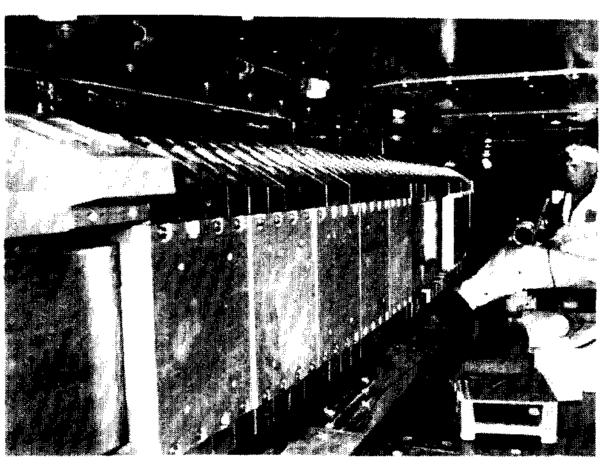


Fig.4. The view of the SPT vacuum chamber in the shimming region

Fig.5 shows a photograph of the extracted beam near the 11-th window.

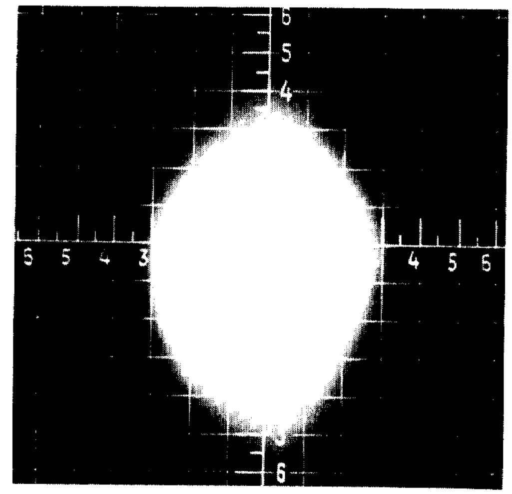


Fig.5. A photograph of the extracted beam. The scale is in cm

As expected, the beam extraction at the field above 0.6 T leads to increasing the beam cross section due to saturation effects, but the acceptance of the channel allows one to transport the beam without losses. In this case the radial position of the beam is corrected by changing the field in the septum-magnet and its position.

References

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