SOME EFFECTS AT HIGH INTENSITIES AT THE 76-GeV PROTON SYNCHROTRON

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Abstract

Some peculiarities of the 76-GeV accelerator operation at intensities up to 2.5×10^{12} protons/pulse are being reported. Possible causes for increase of particle losses with beam intensity are discussed; besides the data on correction of some betatron oscillation resonances are presented.

The maximum intensity of the beam at the 76-GeV accelerator is 2.5×10^{12} protons/pulse at the present moment. In 1971 it was 2×10^{12} protons/pulse.[1] The intensity has mainly been increased due to multiturn injection, correction of some resonances of betatron oscillations, and suppression of transverse coherent instabilities of the beam. Further increase of the intensity is made difficult because of fast growth of particle losses at the initial stage of acceleration.

Particle Losses during Acceleration

To increase the beam intensity from 2×10^{12} protons/pulse up to 2.5×10^{12} protons/pulse it is necessary to double the circulating current, i.e., to increase the number of circulating particles from $\approx 5 \times 10^{12}$ up to 10^{13}. In Fig. 1 the dependence of the acceleration efficiency upon the increase of the beam intensity is shown (curve 1). The larger the number of injected particles, the lower the value of synchronous capturing (curve 2). However, the basic increase of beam losses takes place during the initial stage of acceleration, i.e., during the very first 30 msec (curve 3). These losses are not accompanied by any evident coherent effects in the case where the damping system for transverse coherent oscillations is on. To detect coherent effects, use was made of electrostatic induction electrodes which measured the position of the beam center-of-gravity and longitudinal dimensions of particle bunches, as well as of profile monitor. When the beam intensity is close to 2×10^{12}, it is necessary to damp oscillations in the horizontal direction as well as in the vertical one. Particle losses at the initial stage of acceleration depend on the pressure of residual gas in the accelerator chamber. The experimental data are presented in Fig. 2. (Operational vacuum in the chamber is 1×10^{-6} torr; in the experiments the vacuum became worse as some of the high vacuum titanium pumps were out.) It should be noted that at low intensity the dependence of beam losses on the vacuum is less distinct.

At the beginning of acceleration the role of non-coherent shift of betatron frequency is very great. From calculations it is clear that its value may be almost 0.5 or even more during the first milliseconds of the acceleration cycle.[2] This results in the fact that particles pass different resonances of betatron oscillations.

Betatron Oscillation Resonances

Correction of resonances is of great importance when the accelerator operates at high intensity. Earlier we reported on the experiments on correction of parametric resonances, $2Q_{r,z} = 19$,[3] and difference coupling resonance, $Q_r = Q_z$.[1] A correction system for summed coupling resonance, $Q_r + Q_z = 19$, has been created.

All the correction systems for betatron resonances foresee creation of local perturbations of the corresponding parameters of the accelerator magnetic field. The perturbations are created in such a way that the required harmonics would be created and no unwanted harmonics in the operational grid of betatron oscillations would arise. In Fig. 3 there is presented a diagram of the accelerator stability, which was obtained when correcting resonances $2Q_z = 19$ and $Q_r + Q_z = 19$. (The position of the operational point was varied by means of dc in the gradient correction system of the magnetic field; the intensity was measured at the end of the accelerating cycle; resonance $2Q_r = 19$ was not corrected.) From the diagram it follows that correction of the indicated resonances was realized well enough. Their natural width is equal to: $|P_{2Q_z = 19}| \approx 2 \times 10^{-2}$, $|P_{Q_r + Q_z = 19}| \approx 0.5 \times 10^{-2}$. The influence of resonances of higher order and quadratic resonances, in particular $3Q_r = 28$, $3Q_r = 29$, $2Q_r + Q_z = 29$, as well as of cubic ones, is illustrated in Fig. 3 where circles mean betatron oscillations at which decrease of the intensity as compared with the adjacent experimental points is observed. Resonances of high order near the accelerator point were studied particularly. The results are given in Fig. 4 for two cases. In the first case (solid line), resonance $3Q_r = 29$ was not corrected (its natural width is $|P_{3Q_z = 29}| \approx 1 \times 10^{-2}$ at the amplitude of betatron oscillations of 4 cm). In the second case (broken line), the indicated resonance was corrected with the help of a special system*. An approximate position of different resonances up to fourth order have also been shown. As is seen, practically each of them influences the beam dimensions and leads to particle losses.

Conclusion

The main directions of the investigations which could lead to decrease of particle losses during capturing and acceleration are as follows:

a. Investigation of the role of residual gas and improvement of the vacuum in the accelerator chamber.

b. Further correction of betatron oscillation resonances.

c. Investigation of coherent effects and development of the methods to suppress them.

d. Improvement of filling the longitudinal phase space of the accelerator.

e. Investigation of influence and correction of nonresonance parameters of the magnetic field.

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References

1. Yu. M. Ado et al., Proc. of the 8th Intern. Conf. on High-Energy Accelerators, p. 14, CERN, 1971.

2. Yu. M. Ado, E. A. Myae, Trudy VII Mezhd. konf. po uskorit., p. 265, Akad. nauk Arm. SSR, Erevan, 1970.

*The aperture of the vacuum chamber was limited and the spectrum width of betatron oscillations was narrowed by decreasing the number of injected particles and the accelerating voltage so as to improve sensitivity when measuring these curves.

3. Yu. M. Ado et al., Trudy II Vsesoyus. konf. po uskorit, Vol. I, p. 17, "Nauka," M, 1972.

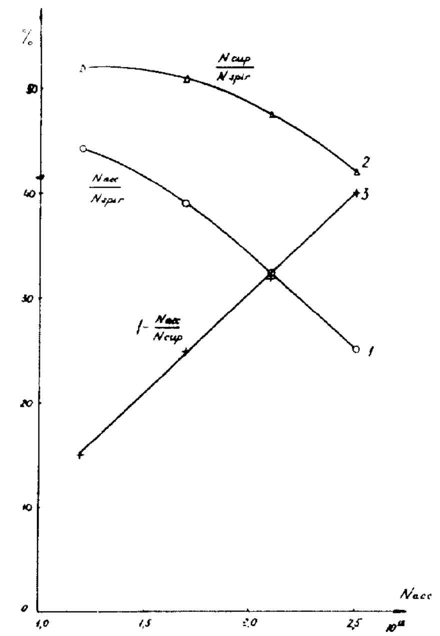

FIG. 1--Acceleration process efficiency depending on the accelerated beam intensity.

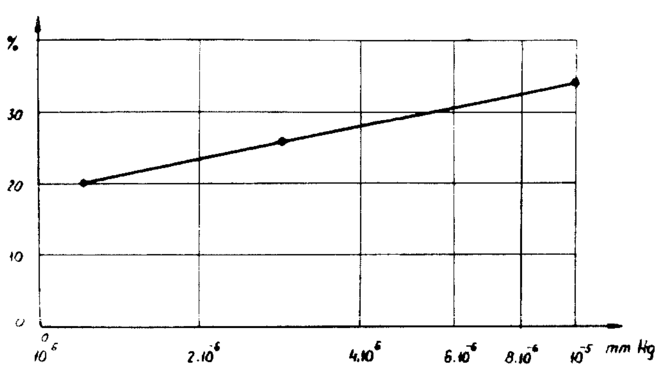

FIG. 2--Dependence of particle losses at the initial stage of acceleration on the residual pressure.

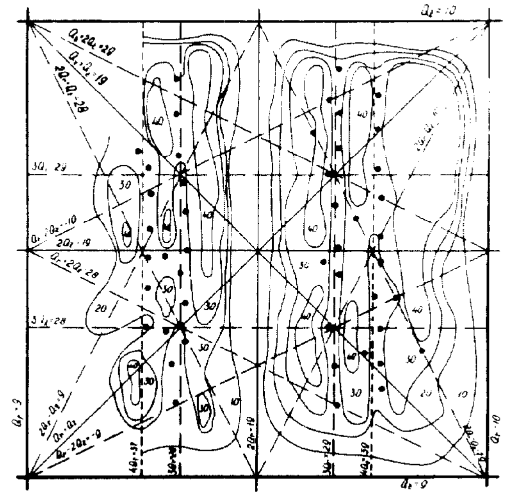

FIG. 3--The diagram of the accelerator stability when correcting resonances $2Q_z = 19$ and $Q_r + Q_z = 19$; the intensity within the contours has been indicated in relative units.

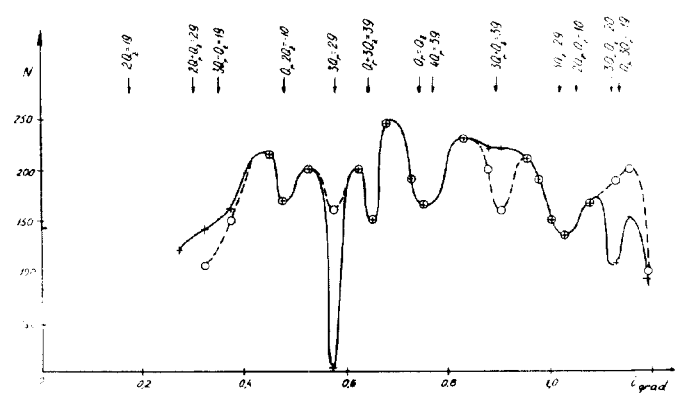

FIG. 4--The dependence of intensity on the position of the accelerator working point. (Along the abscissa axis there is plotted the current in the gradient correction system.)