ITEP PROTON SYNCHROTRON RECONSTRUCTION

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Introduction

The ITEP 10 GeV Proton Synchrotron (U-10) is now being reconstructed into a proton and ion accelerator complex which would be able to accelerate ions of all atoms with various Z/A values /1,2/. The first stage of the reconstruction includes construction of an ion injector, of a beam transport line (from the new injector to the synchrotron), and modification of proton synchrotron systems neccessary for ion acceleration. In particular, we need to change the synchrotron vacuum chamber together with its pumping system to reach 10^{-10} Torr vacuum instead of 10^{-6} Torr now. All these modernizations are, practically, completed. In 1988, first ions of He^{2+} were injected into the synchrotron and accelerated successfully up to the energy 4.3 GeV/A. In this year we are going to try to accelerate some heavier ions obtained from the new injector. As we hope, light ions will be accelerated up to 4 GeV/A, and heavy ones (unfully stripped) - up to 1 GeV/A.

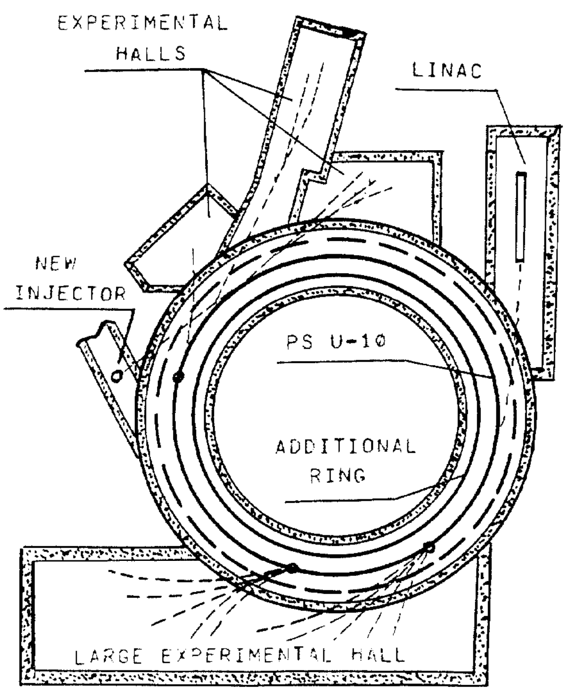

Fig. 1. ITEP accelerating complex.

We are installing now an additional magnetic ring in the tunnel of the proton synchrotron. With this ring finished, the acceleration scheme will be changed. Heavy ions first accelerated in the synchrotron with small charge values will be stripped by foil and saved in the new magnetic ring as long as the synchrotron systems are readjusted for the new charge value. Afterwards, the ions will be reinjected from the saving ring to the synchrotron and accelerated up to the maximum energy (3-3.5 GeV/A).

This paper will focus on the immediate future of the ITEP accelerating complex. Some words will be said also on the plans of its long term evolution.

<u>Acceleration of unfully stripped ions.</u> After the first stage of U-10 reconstruction is completed, unfully stripped heavy ions will be accelerated only. Such an acceleration scheme makes the ion injector simple and permits recharge extraction from the synchrotron. We pay for these advantages by rather severe vacuum requirements (10^{-10} Torr) and smaller energy of accelerated ions. The saving ring makes it possible to get (and to accelerate) fully stripped ions up to the maximum energy. The high vacuum requirements are inevitable but do not seem to be too troublesome with up-to-date vacuum technology.

<u>Heavy ion injector.</u> A simple resonator structure with few accelerating gaps can be affectivelly used for acceleration of ions with various Z/A values. We apply such a structure in the new injector of the synchrotron (Fig. 2). The injector contains one high voltage electrode only, but has four accelerating gaps. The maximum value of voltage is 3 MV. As was shown by calculation the momentum spread of 0.5% may we secured for Z/A values from 0.1 to 0.3. To optimize capture for different ion types, we alter the length of the grounded buncher electrode and the buncher voltage. The buncher is fed from the loop installed in the injector resonator tank.

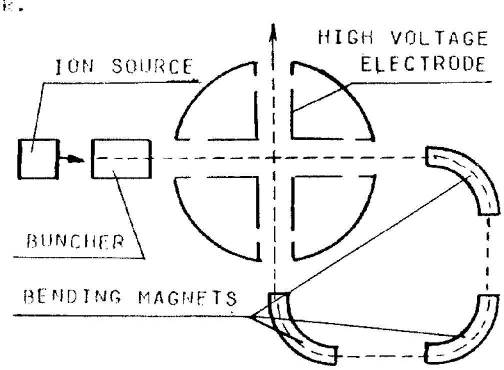

Fig. 2. Injector.

We are going to use several ion sources. Light ions (up to Ne or , may be, Ar) are extracted from an ordinary duoplazmotron source which secures high ion fluxes of rather low charge states (up to 3+). Some versions of laser ion sources and MEVVA ion source are being developed to produce ions from solid substances.

Beam transport line. Ion guide from the new injector to the synchrotron is assembled and tested. The ion guide is placed in the part of the synchrotron tunnel which is very densely occupied by bulky equipment of secondary beam transfer lines. The ion guide goes around the obstacles and contains five bendings. The parametrs of the transported beam are: energy - $24(Z/A)^2$ MeV/A, transverse emittance - 100 π mm mrad, momentum spread - 0.5%. The natural requirements to the ion guide are, as usually: to deminish the number of the focusing elements, to match the beam emittance to the acceptance of the synchrotron, to match the despersion functions of the beam and of the synchrotron, to secure achromatisity of the beam optics in the vertical plane.

In december 1988, we have tested the ion guide. The N^{+} beam was successfully transported from the new injector to the synchrotron.

R.f. frequency controll. One of the new synchrotron systems which was developed for ion acceleration is a rf-manipulation system /3/. As had been already mentioned, synchrotron has to accelerate ions with different Z/A ratios. The r.f. frequency manipulation system, therefore, has to be easily reajusted from one ion type to another. The intensity of ions , especially that of heavy ones, may be low. Accordingly, beam position observation and radial feedback system seem to be embarrassing.Therefore we wanted to reproduce the dependence of the r.f. frequency on the bending magnetic field as accuratly as possible even without radial feedback loop. The new system must permit also to change the harmonic number in the course of acceleration.

The new system and the algorithm of its tuning, as well as harmonic number change process have been tested with protons and He^{2+} ions. Relative deviations of frequency values (with broken feedback loops) from those given by calculation did not exceed 10^{-4} This accuracy is sufficient for acceleration .

In first experiments with He^{2+} acceleration made up to now we did not reach the desired efficiency by the beam harmonic number change accomplished at an intermidiate flat top of the magnetic cycle. The beam losses were near 40% and are explained by some shortcomings of the r.f. stations.

Vacuum system. Last year, we have changed the synchrotron vacuum chamber and its pumping system. The new vacuum system can be heated up to 400°C. For pumping, we use NMD pumps and getter elements which are stretched in the vacuum volume along the vacuum chamber walls. To get these elements we cover stainless steel tubes by porous titanium. The titanium is activated when the tubes are vacuum heated by electrical current. The absorbion capability of getter may be improved if stainless tubes are cooled by liquid nitrogen. We have reached 10^{-10} Torr in some sections of the synchrotron vacuum chamber. The average vacuum rate (10^{-8} Torr) is now defined by old type internal targets which will be substituted in a year.

Slow extraction. The third order betatron resonance will be used for slow beam extraction from the synchrotron. The resonance oscillations of the ions are exited in the vertical plane. The particles with big enough oscillation amplitudes jump over the iron septum of a Lambertson magnet with vertical magnetic field. The particles are deflected by the field radially, pass through the defocusing magnetic block of the synchrotron and get into the beam transfer line. As shown by calculation, in such a way we can reach high efficient slow extraction in spite of rather severe field nonlinearity in horizontal plane.

Acceleration of fully stripped ions. The ions of the elements of the end of Mendeleev table can not be fully stripped at the first injection to the synchrotron. Therefore the ions will not reach the maximum energy. It will be possible to strip them entirely when the saving magnetic ring installation will be finished. Understripped heavy ions accelerated in the synchrotron will be recharged in the foil placed in the ion guide linking the synchrotron with the saving ring and stay there as long as the syncnrotron systems are ready to accelerate ions with new charge values. Then the ions are reinjected into the synchrotron and accelerated there up to the maximum energy (3-3.5 GeV/A).

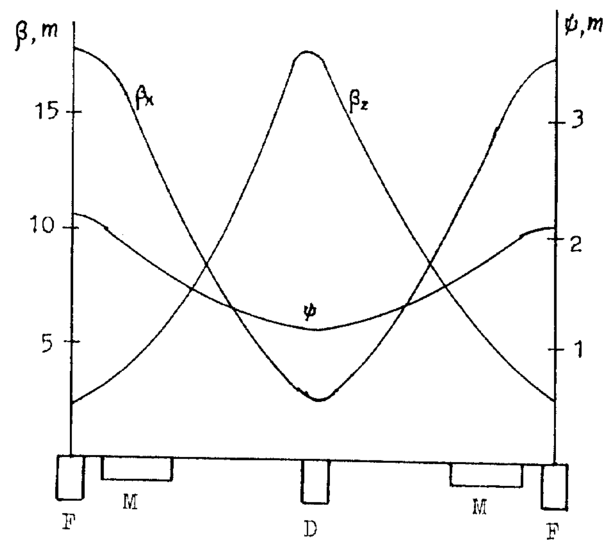

Fig. 3. The lattice function and the dispersion function.

The ring has FODO structure and consists of 21 cells formed by 42 bending magnets and 42 quadrupole lenses. The magnetic field in the ring is constant and there are no acceleration stations (small rf-voltage will be used for beam bunching only). Figure 3 shows the lattice functions and the dispersion function of the ring. Most of the bending and quadrupole magnets have been manufactured and are now installed in the synchrotron tunnel. Vacuum chamber production is started. The equipment of the beam transport channels (between the synchrotron and the saving ring), power supply systems, and the control system are constructed and being produced.

Control system. Control system of the heavy-ion accelerator complex is based on the existing proton synchrotron control system and is its logical development. Several mini-computers are linked at the same hierarchical level by a single communication line. Mini-computers are equiped with powerful storage devices and carry out the functions of the central processing and the data basing. The distributed equipment of the accelerator complex is communicated with the central processors by multidrop parallel busses. The length of busses is up to 400 m, bit-rate is 5 Mb/s. Interface crates connected to the multidrop bus, play the role of knot stations which may be used for modules incorporation and multidrop bus branching. We are goig to use several types of knot stations. Some of them are simple data transmitters between the multidrop bus and branch busses, and the ofbers can be drived by microprocessor, or contain multi-processor assemblies. To reduce the load of the multidrop busses some of the processor controlled knots are communicated by additional serial data links. Several types of microprocessor modules deal with local control of various types of accelerator equipment.

Outlook in the Future. Long-Term progress of ITEP accelerator complex is now under consideration and is not yet finally decided. We consider two main ways of development: to increase proton energy up to 15-60 GeV and beam intensity to $5\cdot 10^{12}-10^{14}$ p/s, or to construct an antiproton facility to generate more than 10^{7} $\bar{p}$/s of 30-40 GeV with $10^{-4}-10^{-5}$ monochromaticity . To have such an intensity of antiprotons one needs at least $2\cdot 10^{12}$ p/s - of the same energy. An interesting programm of experiments with such antiproton beams has been recently suggested /4/.

In the existing 250 m long tunnel, the proton energy of more than 15-17 GeV ($B\rho$ ≈50 Tm) can be reached with superconducting magnetic blocks only. But proton intensity of a superconducting synchrotron is rather severely limited becose of long ramping time of magnetic field. Even an optimistic estimation shows that ten acceleration cycles per minute lead to 10 W/m thermal losses in magnets what leads to a rather big cryogenic system. A higher intensity proton beam can only be produced by a conventional synchrotron with high repetition rate.

Ecological problems inevitably arising with high intensity accelerators have been up to now decided on the basis of the experience gathered at old accelerators with tens percents beam losses. Modern accelerator technology permits to diminish beam losses to 1-2% and to decrease losses occuring at random places to no more than o.1%. Therefore the possibility of acceleration of 10^{14} p/s (and may be even more) can be considered seriously. The places of possible beam losses certanly to be carefully chosen and well equipped to reduce outside radiation to a safe level.

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