CONCEPTION OF THE 200 MEV/U BOOSTER FOR THE NUCLOTRON

I.B.Issinsky and V.A.Mikhailov
Joint Institute for Nuclear Research, Dubna, USSR

Summary

The superconducting accelerator of heavy nuclei, Nuclotron /1/, which is now under construction, will have a linac as an injector in the first phase of operation. To increase substantially beam intensities, it is planned to construct a booster of a 200 MeV/u energy for nuclei (650 MeV for protons) (Fig.1). The Synchrophasotron should be replaced by this complex. The intensity of heavy ion beams has to be increased by more than a factor of 10 by means of multiturn injection into the booster and 5 injection cycles in the main ring. For protons and deuterons it will be up to 10^{13} ppp. One of long straight sections is designed for electron cooling which will decrease emittance by a factor of 10-100 and will give a momentum spread of 10^{-4} - 10^{-5}. Apart from the operation for the main ring, the booster can be used indepently for research on its inner, external (outer) targets.

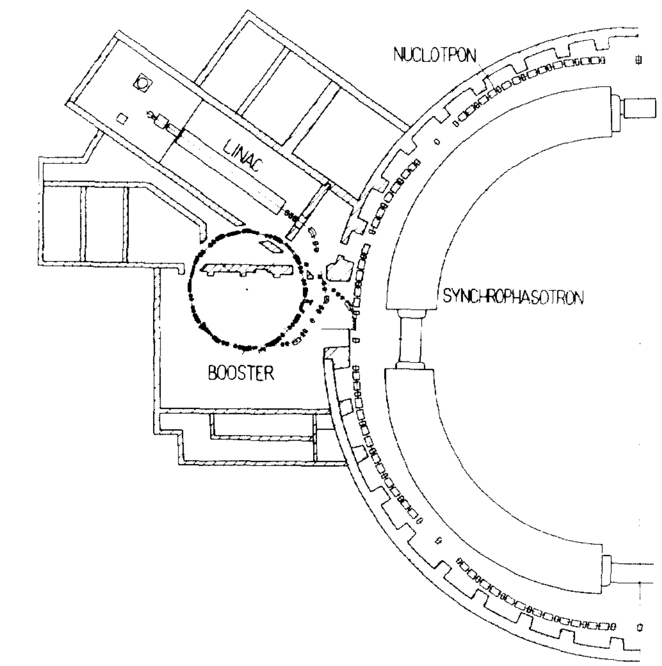

Fig.1. Layout of the booster

Operation and Main Characteristics of the Booster

A time diagram of the operation of the booster and the main ring is shown in Fig.2.

An ion beam from the linac is stored in the booster, and then after acceleration it is injected into the Nuclotron. The circumference of the booster constitutes 1/5 of the main ring one. This corresponds to five filling cycles in the Nuclotron. The repetition rate of the booster is fixed by the linac repetition rate which, in its turn, is determined by RF-power supply. After enlarging the latter, the repetition rate of the booster can be higher.

A simpler and frequently used method of ion storage in synchrotrons is the filling of its radial acceptance. The duration of injection, its efficiency and, respectively, the number of injected particles can be enlarged if a vertical acceptance is also used for partical storage.

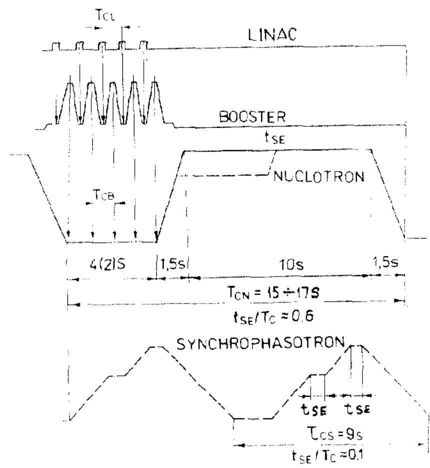

Fig.2. Time diagram of the operation of the accelerated complex.

In our case this advantage is realized by means of multiturn injection into the booster when a 4-dimensional phase volume is filled with the aid of the difference coupling resonance $Q_x - Q_z = 0$. When this resonance is excited by a longitudinal magnetic field, vertical and horizontal betatron oscillations are in phase. At a maximum of horizontal displacement of particles on the inflector azimuth their vertical displacement is maximum /2/ as well. If the inflector with a restricted vertical dimension is employed, the particles will go round it at more dangerous turns with large probability.

The time of multiturn injection is determined under the following conditions. The acceptance of the main ring matches a linac emittance of 40π mm·mrad. This means that the emittance of the beam ejected from the booster should be equal to or less than the linac emittance. Taking into account an adiabatic decrease of emittance during beam acceleration in the booster by K times, where $K=(B\rho)max$ / / $(B\rho)i$ is the ratio of magnetic rigidity for extraction and injection, the acceptance of the booster filled at multiturn injection should be $A_x = KE_x$, $A_z = KE_z$.

For a linac energy of 5 MeV/u it corresponds to K=6.65 and $A_x = A_z = 260\pi$ mm·mrad. Thus, for filling the booster acceptance, the storage of particles is possible during $K^2 = 44$ turns. For the period of particles turn T=1.6μs the time of injection is 70 μs (35μs for protons); this is much larger than the time of single turn injection into the Nuclotron which is equal to 8µs(4µs for protons, respectively).

The pulse duration of beams from the linac (which operates at the Synchrophasotron) using a laser source and an EBIS is equal to 10-25µs. This permits ions in the booster to be stored almost without losses. A considerable gain is also obtained by using a duaplasmatron and a polarized deuteron source which pulse duration is 400-500µs.

Table 1 gives pulse intensities of the Nuclotron for the linac and the booster as an injector and after the development of the ion sources. A planned layout of the booster-Nuclotron region is shown in Fig.1.

Table 1

Intensity of Nuclotron beams at various tapes of injection (ppp)

Beam	Sources	Injection form		
		Linac	Booster	Booster and developed ion sources
P	Duaplasmatron	$4\cdot10^{11}$	$1\cdot10^{13}$	$1\cdot10^{13}$
H_2^{1+}	Duaplasm.	$2\cdot10^{11}$	$5\cdot10^{12}$	$1\cdot10^{12}$
He_4^{2+}	Duaplasm.	$2\cdot10^{10}$	$5\cdot10^{11}$	$1\cdot10^{12}$
D	POLARIS	$5\cdot10^{8}$	$1\cdot10^{10}$	$5\cdot10^{10}$
C_{12}	Laser	$1\cdot10^{10}$	$1\cdot10^{11}$	$5\cdot10^{11}$
Mg_{24}	Laser	$6\cdot10^{8}$	$6\cdot10^{9}$	$3\cdot10^{10}$
Ar_{40}	EBIS	$2\cdot10^{5}$	$2\cdot10^{6}$	$1\cdot10^{7}$
Kr_{84}	EBIS	$4\cdot10^{4}$	$4\cdot10^{5}$	$2\cdot10^{6}$
Xe_{131}	EBIS	$2\cdot10^{4}$	$2\cdot10^{5}$	$1\cdot10^{6}$
U_{238}	EBIS	$1\cdot10^{4}$	$1\cdot10^{5}$	$5\cdot10^{5}$

The effective procedure improving significantly the parameters of a beam is electron cooling which makes it possible to reduce the pulse spread and emittance of circulating and extracted beams, to increase the efficiency of slow extraction at the Nuclotron and to provide better conditions for experiments on the beams of the booster.

The task of the acceleration of polarized deuterons will be decided comparatively easy since there are no depolarizing resonances up to the fourth order in that interval of energy and for betatron frequency oscillations $Q_x=Q_z=2.25$.

The acceleration of uranium ions specifies requirements for the pressure of residual gas which should be 10^{-10} Torr at beam losses of a few percent.

Machine Lattice

The booster lattice contains 6 cells (Fig.3). Each cell consists of a FOFDOD type quadrupole quartet and two sector dipole magnets. Two straight sections 2.6m and 0.9m in length are used to install the elements of the systems: injection, extraction, acceleration, correction, diagnostic and electron cooling.

The injection system includes a septum-magnet for preliminary bending of an injected beam, a septum-magnet, 4 bump-magnets to produce a local distortion of the orbit and a solenoid to excite the linear difference coupling resonance.

The fast one-turn extraction system consists of a 2m kicker and an extraction septum-magnet.

Taking into account the use of the vertical volume for storage, the apertures of the magnets are b x h = 192mm x 104mm for dipoles (Fig.4) and D=90mm for quadrupoles (D is inscribed circle radius).

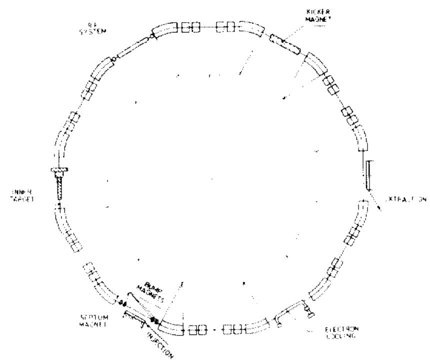

Fig.3. Lattice of the booster.

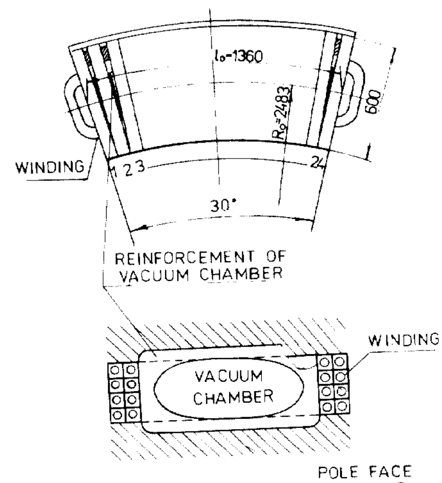

Fig.4. Draft of the dipole magnet.

The general booster parameters are given in Table 2.

Table 2

Injection energy	5 MeV/u
Max energy (q/A=0.5)	200 MeV/u
Charge limit	$2\cdot10^{12}A/q^2$ ppp
Injection time	70 µs
Circumference	50.52 m
Number of FOFDOD	6
Field in the dipoles (max)	1.73 T
Gradient in the quadrupoles(max)	7.74 T/m
Betatron frequency $Q_x \approx Q_z$	2.25
Acceptance $A_x = A_z$	260π mm·mrad
Emittance at extraction $E_x=E_z$	<40π mm·mrad

References

1. A.M.Baldin et al. IEEE Trans.Nucl.Sci.NS-30, N°4, 1983, p.3247.
2. A.M.Gromov and P.A.Cherenkov. Proceedings of the IIId Allunion Part.Accel. Conference, v.II, p.110, Moscow 1973 (in Russian).