UPGRADING 70 GeV IHEP ACCELERATOR AS UNK INJECTOR

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Introduction

The 70-GeV accelerator will be used as an injector for the 3 TeV UNK complex under construction now. U-70 consists of the main ring and the 1.5 GeV fast cycling synchrotron - injector, booster, which includes 30-MeV RFQ linac. The booster fills one RF-bucket of the main ring each cycle and its repetition rate is 16.7 Hz. So the U-70 filling time is 1.8 sec.

To meet stringent requirements for the UNK beam parameters and also because of U-70 is an old machine - 23 years in service, one needs to rebuild a number of the main accelerator systems.

Beam Parameters

The UNK project proposes two UNK modes of operation [1]:

- fixed target mode - FT (intensity - upto $6\cdot10^{14}$ ppp),
- PxP colliding mode (luminosity - upto $4\cdot10^{32}$ cm^{-2} s^{-1}).

The U-70 beam parameters for both modes of UNK are given in Table 1.

Table 1

Mode	U-70 intensity		Energy, GeV		Normaliz. emittances (95%)	
	total	per pulse	in-ject	ext-ract	transvers. (π·mm·mrad)	longitud. (eV·s)
FT	$5\cdot10^{13}$	$17\cdot10^{11}$	1.5	65	150	1.3
PxP	$1\cdot10^{13}$	$3.5\cdot10^{11}$	1.5	65	30	1.0

As the UNK injector U-70 will operate at 65 GeV so as to decrease the effects of magnetic block saturation and also to save the magnetic field correction currents.

It was assumed that each specific part of the injection complex cycle, i.e. injection into the booster, acceleration in the booster, injection into the U-70 and acceleration in U-70, will provide an increase of transversal and longitudinal emittances, as presented in Table 2.

Tables 1 and 2 show that for PxP beam one needs small value of beam emittance, and either single-turn injection of ~80 mA proton beam or charge-exchange injection is necessary for the booster. To achive the designed intensity for FT mode we shall have to use proton multiturn injection or more extended charge-exchange H^- injection. Since the charge-exchange injection allows one to "paint" booster acceptance more uniformly and decrease Coulomb space charge shift we foresee the CEI in the upgrading project.

The betatron Coulomb shifts for the Gaussian distribution of the beam are given in Table 3.

For both machines the Coulomb shifts are rather large, and correction of numerous resonances is quite necessary (at least for the U-70 machine).

Table 2

For 95% of current		Linac 30 MeV	Booster (inject.)	Booster 1.5 GeV	U-70 (GeV) 1.5	U-70 (GeV) 65
FT	trans. emitt. (π·mm·mrad)	10	75	95	120	150
FT	long. emitt. (eV·s)	0.30	0.4	0.55	0.75	1.3
PxP	trans. emitt. (π·mm·mrad)	10	15	19	24	30
PxP	long. emitt. (eV·s)	0.30	0.4	0.55	0.75	1.0

Table 3

	Booster (30 MeV)		U-70 (1.5 GeV)	
	FT	PxP	FT	PxP
Emittances (horiz. x vert.) $(\pi\cdot mm\cdot mrad)^2$	75x25	15x15	120x40	24x24
Q_H	0.18	0.14	0.14	0.10
Q_V	0.31	0.16	0.25	0.13

Space charge effects could be decreased by a factor of two if one increases the booster injection energy from 30 MeV to 60 MeV. This proposal is under consideration now. In this case the H^- injection would be the best one. We need 20 mA H^--current and pulse duration of 20 μs. For example, for 15 crossings of 10^{-6} m thick Al stripping foil the r.m.s. beam emittance increases by 2.5 mm·mrad.

Beam injection into U-70 is a delicate business because of large Q_V-shift and long beam circulation (1.8 s) at 0.038 T injection magnetic field. One need to meet the parameters of Table 3 taking into account the transversal oscillation coupling.

U-70 Magnetic Field Correction

We will have to upgrade the now-existing correction system [2] and the reasons for that are as follows:

- because of long beam circulating time at injection much better correction of betatron resonances is necessary, but the existing pole-face windings (PFW) do not provide sufficient accuracy of the magnetic field;
- "strength" of PFW is not high enough to compensate the large negative chromaticity at high field level caused by iron saturation;
- some PFWs suffered from radiation for 23 years of the accelerator operation and must be replaced.

New PFW are planned for all magnetic blocks and will consist of 72 conductor bars instead of 31 bars used now. The windings will create "normal" magnetic multipole components up to the 4-th order, i.e. quadrupolar, sextupolar and octupolar fields, and also "skew" winding (dipolar, sextupolar and octupolar) may be created on each block. The thickness of a new PFW is 20 mm instead of 11 mm used now.

Vacuum System

The existing vacuum system must be replaced by a new one for the following reasons:

- to minimize residual gas beam scattering we need vacuum $5\cdot10^{-8}$ torr (now - $5\cdot10^{-7}$ torr);
- vacuum chamber used now is a corrugated one and creates large coupling impedance - as it was calculated, hundreds of Ohms instead of 10-15 Ohms;
- because of PFW thickness (20 mm) it is necessary to decrease the chamber vertical aperture to 100 mm (now - 115 mm).

The new vacuum chamber will be "smooth" one and with minimum places, where the chamber aperture is "nonstandard". Standard apertures are HxV - 200x x100 mm and ideal chamber acceptances - 233x58 $(\pi\cdot$mm$\cdot$ $\cdot$mrad$)^2$.

Upgrading Some Other Systems

The U-70 accelerating system must be seriously improved. The system consists of 40 cavities which at present put limitation on the intensity, and it is $1.5\cdot10^{13}$ ppp because of longitudinal coherent instability. To increase the intensity we must reduce the shunt impedance of the cavities by a factor of 2-3, i.e. to $\leq$ 1 kΩ per cavity. Also the active wideband damping system is necessary. One of the task of the damping system is to compensate injection missteering, to minimize coherent injection oscillations.

Besides the vacuum chamber, a considerable part of beam diagnostics must be replaced, including pick-up electrodes for close orbit measurement.

We plan also to provide full reconstruction of the control system of the UNK injection complex.

References

1 A.I.Ageev et al. UNK Status. Proc. of XIII Int. Conf. on High Energy Accel., Novosibirsk, v. 2, p. 332, (1987).

2 Yu.M.Ado et al. Reconstruction of Magnetic Field Correction System of the IHEP Accelerator. Proc. of X Int. Conf. on High Energy Acc., Protvino, v. 2, p. 308, (1977).