THE IHEP ACCELERATING AND STORAGE COMPLEX. STATUS AND DEVELOPMENT

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INTRODUCTION

The construction of the IHEP Accelerating and Storage Complex is going on in accordance with the project reported earlier 1,2 This report presents the current status and plans for its further development.

The project envisages the operation of the complex as the 3000 GeV proton accelerator for fixed-target experiments and as the 3x3 TeV pp-collider.

The UNK is placed in the Ø 5.1 m underground ring tunnel 20.7 km in circumference. Its cross section is shown in fig. 1. The magnet system of the 1st stage of UNK (UNK-1), which is a slow booster, is constructed on the basis of conventional magnets, whereas those of the 2nd (UNK-2) and 3d (UNK-3) stages will be constructed on the basis of superconducting magnets.

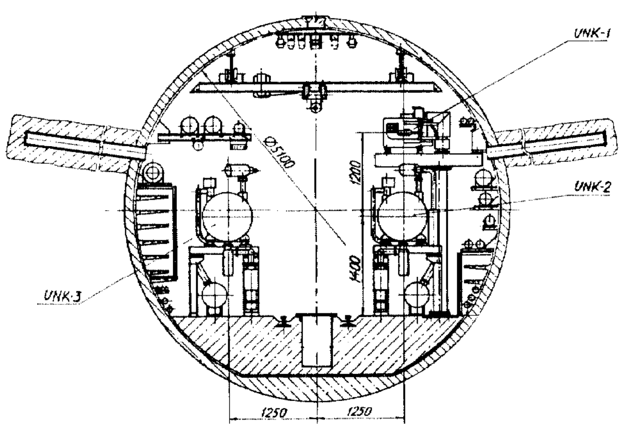

Fig. 1. Cross section of the UNK tunnel.

Figure 2 shows the scheme of the UNK lattice 3 . The orbits of UNK-1 and UNK-2 are located one under another, while those of UNK-2 and UNK-3 run along the opposite walls of the tunnel and interchange periodically. The UNK-2 and UNK-3 orbits will intersect in 4 matched straight sections, each 490 m long, MSS2, 3, 5, 6, intended for housing experimental facilities only. Another 2 straight sections are used for technological equipment: MSS1 will house the equipment for injection, beam abort, beam loss localization and the accelerating system, MSS4 will be occupied by the extraction system and those transferring the beam from UNK-1 into UNK-2 and UNK-3.

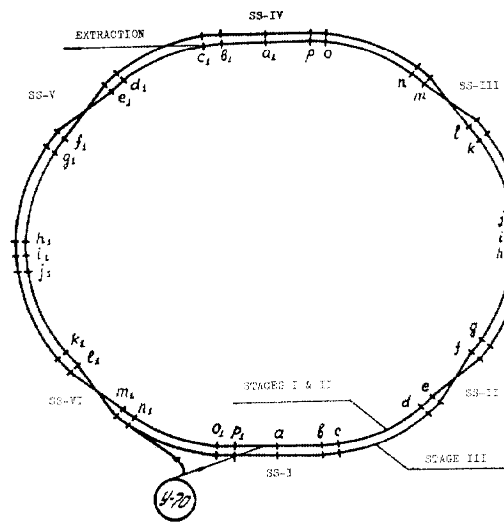

Fig. 2. Magnet lattice of UNK

The presently existing 70 GeV proton synchrotron (U-70), whose intensity is planned to be increased up to 5 10^{13} ppp, will be used as the injector for UNK. In the end of the acceleration cycle, the beam accelerated in U-70 is rebunched at the UNK accelerating frequency 200 MHz and transferred further into UNK-1 4 .

OPERATION IN ACCELERATION MODE

In this mode, UNK operates as a two-stage machine. UNK-1 stacks within 71.5 sec 12 successive beam pulses injected from U-70 and accelerates them to 400 GeV during 11 sec. Then, the beam is transferred by single-turn injection into the superconducting ring, UNK-2, to be accelerated to 3000 GeV during 40 sec. The beam is extracted from UNK-2 onto external targets during 40-sec flattop. Three extraction modes are foreseen: 40-sec slow extraction by means of the 3d-order resonance, fast resonance extraction of 10 pulses, each lasting 1-2 msec and arriving within 3-sec intervals, which may be combined with slow extraction, and single-turn fast extraction for neutrino experiments. The design extraction efficiency is 99%. The complete cycle of UNK lasts in this mode 120 sec, which provides a mean intensity of $5 \cdot 10^{12}$ protons/sec.

Table 1 presents the UNK parameters in acceleration mode.

Apart from extracting the beam onto external targets, the initial stage of the UNK construction envisages physics experiments using the circulating beam of both UNK-1 and UNK-2 with a jet hydrogen target setup to be housed in MSS3.

Table 1. UNK Parameters in Acceleration Mode

Parameter	UNK-1	UNK-2
Injection energy, GeV	70	400
Maximum energy, GeV	600	3000
Circumference, m	20771.8	20771.8
Injection field, T	0.116	0.67
Maximum field, T	1	5
Accelerating frequency, MHz	200	200
Circumferential voltage, MV	8	11
Transition energy, GeV	42	42
Maximum β-value, m	152	152
Maximum ψ-value, m	2.43	2.43

COLLIDING BEAMS IN UNK

When the choice of colliding beams for UNK was made in 1987, two versions were considered in detail: pp and pp-colliding beams 5 . Despite the attractive features of the pp version allowing one to use only one superconducting ring for colliding beams, its implementation will require the solution to a number of much more complicated theoretical and engineering problems as compared to the pp-version. Among these problems are: production and stochastic and electron cooling of the high-intensity antiproton beam, beam separation over the whole UNK circumference, the necessity to ensure a more reliable operation of the complex and fulfilment of more stringent requirements imposed on vacuum and the RF noises, etc. Alongside with these problems, the maximum design luminosity is more than an order of magnitude less than in the pp-mode.

The necessity of constructing the 2nd superconducting ring for the pp-collider will, apparently, meet no serious technical difficulties as long as it may be the replication of the 1st ring, UNK-2. Presently, powerful production facilities are being prepared for it. Besides, the basic infrastructure, cryogenics and power supplies envisaged in the project of the 3000 GeV machine have the necessary power reserve to provide for the pp-operation.

These were the considerations which favoured the pp-version presently under design.

In the pp-colliding mode, the beam is stacked and accelerated in UNK-1 according to the same pattern as in the accelerator mode. The beam accelerated in UNK-1 is transferred into UNK-2 and stacked there at 400 GeV. Then it is stacked in UNK-1 again but is injected from U-70 into UNK-1 in the opposite direction. The system for such an injection is placed in MSS6 (see fig. 2). The beam accelerated in UNK-1 to 400 GeV is transferred into UNK-3, then the beams are accelerated in UNK-2 and UNK-3 simultaneously up to 3 TeV and brought into collisions. Simultaneous acceleration is required because the collision sections contain common magnet elements -wide-aperture superconducting quadrupole lenses.

During acceleration, the magnet system in the collision region is retuned, with the value of β-function decreasing in the collision points by 7.5 times.

The whole stacking and acceleration procedure lasts no longer than 5 minutes, therefore it is sufficient to retain the luminosity lifetime of the colliding beams during an hour.

Table 2 presents the basic parameters of UNK in the pp-mode.

A possibility to attain such parameters is determined largely by those of the beam injected from U-70.

The emittance of the U-70 beam is presently larger than required. This is explained by large injection mismatches, space charge effects, in particular, strong longitudinal beam instability 6 . Therefore the following upgrading of the U-70 machine is required:

Table 2. Parameters of UNK Colliding Beams

Parameter	Value
Maximum energy, TeV	3x3
Intensity, ppp	$2.4\cdot10^{14}$
Number of bunches	8000
Number of particles per bunch	$3\cdot10^{10}$
RMS invariant transverse emittance, mm·mrad	6
RMS longitudinal bunch emittance, MeV/c·m	6
value at crossing points, m	1
RMS beam diameter at crossing point, mm	0.1
RMS bunch length, cm	10
Minimum bunch spacing, m	1.5
Stacking time, hrs	0.1
Collision time, hrs	1
Luminosity, $cm^{-2}sec^{-1}$	$4\cdot10^{32}$
Number of events per collision	0.35
Beam-beam tune shift	$6\cdot10^{-4}$
Space for detector, m	±20

- the corrugated vacuum chamber should be replaced by a smooth one with a view to reduce the longitudinal coupling impedance to 10 Ohm;
- the correction system should be upgraded;
- the H^- injection system must be developed;
- injection and extraction mismatches must be reduced by about an order of magnitude.

Presently, the upgrading of U-70 is designed.

DEVELOPMENT OF SUPERCONDUCTING MAGNETS

The design value of the magnetic field of UNK-2 and UNK-3 superconducting magnets is 5 T at 4.4 K. To substantiate the choice of UNK superconducting magnets for mass production, two types of dipoles have been studied: warm-iron design and cold-iron design. The design of the warm-iron magnet and results on its tests were reported previously 7 . Ten such full-scale dipoles have been manufactured and tested. Their field harmonics and mechanical stability satisfy the specifications.

Still, such dipoles have certain disadvantages. Among them are a large value of heat leaks, up to 2 W/m, and a complicated cryostat design. This is the reason why the warm-iron design was abandoned and the cold-iron one is presently being developed 9 . Figure 3 shows its cross section. The basic element of the

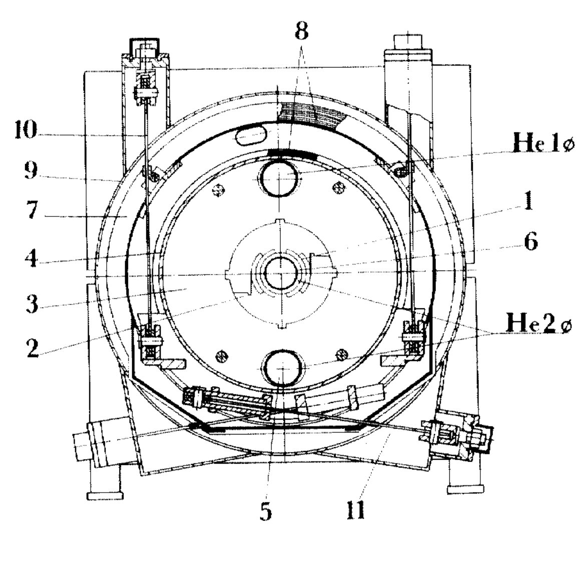

Fig. 3. Cross section of a cold-iron dipole.

dipole is a two-layer shell-type coil. The radius of the useful aperture is 35 mm. To cut the amount of the superconductor used, the coil and yoke diameters have been reduced as compared with the old design and also the number of wires in the cable was decreased from 23 to 19. The critical current density of the cable is $2.3 \cdot 10^5$ A/cm^2. The coil is collared as usual with stainless steel laminations and put together with the iron yoke into a helium vessel cooled by single-phase helium flow. The vessel is fixed into the warm vacuum tank with vertical suspensions and horizontal titanium-alloy tension rods. With this design, the value of heat release into the helium vessel is 2.5 times less than for a warm-iron magnet.

Disadvantages of a cold-iron magnet are an unavoidable increase of its warmup and cooldown times and also the effect of the iron yoke characteristics on the field quality.

Full-scale models of such a dipole are being tested now. The tests show that with the chosen cryogenic system for UNK, the cooldown takes about 50 hours and the warmup takes about 40 hours, which seems tolerable. Figure 4 shows the training curve for one of dipoles and fig. 5 gives the curve for the field - current ratio versus the field in the centre of the aperture.

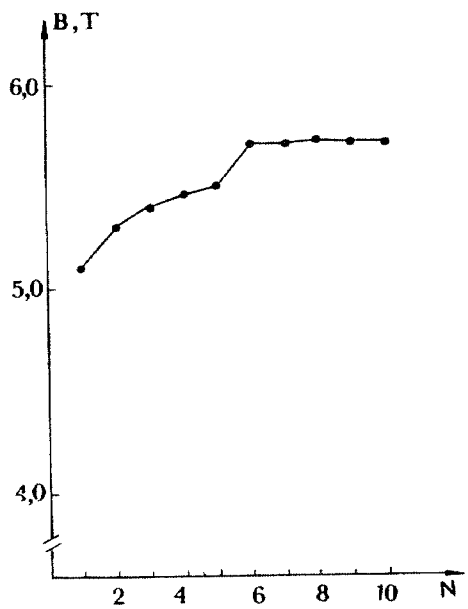

Fig. 4. Training curve for a cold-iron dipole.

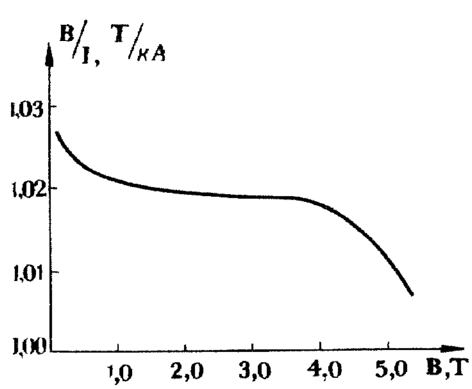

Fig. 5. Field - current ratio versus the field in the centre of a cold-iron dipole aperture.

CONSTRUCTION OF THE COMPLEX

The civil engeneering work is going on over the whole territory of the complex. Figure 6 shows the scheme of UNK underground structures and the present status.

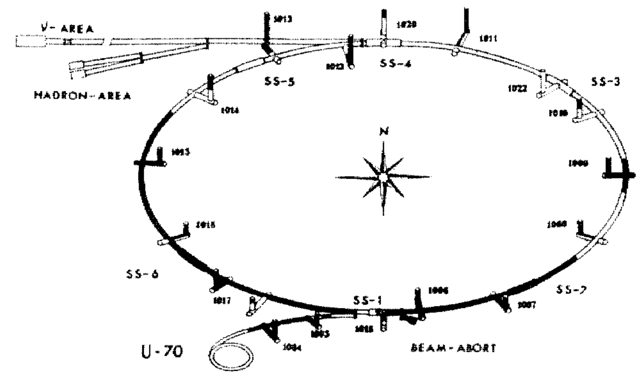

Fig. 6. Layout of the UNK underground structures and the present status. The dashed areas are for the completed sections of the UNK tunnel.

Eighteen construction sites for carrying out the work underground have been built. Out of 24 vertical shafts of the machine 12 are ready completely. Tunnelling is being done from 7 shafts in 12 directions. About 9 km of the ring tunnel and 1.6 km of the injection tunnel have been bored. The average tunnelling rate is 500 m/month. The tunnelling is supposed to be finished in 1990.

The construction is begun of 4 surface buildings (out of 20) designed for the technological systems of the paramount sections of UNK, i.e., the injection channel, the section for the regular structure of the warm ring magnet (UNK-1) and for the experimantal section of the superconducting ring magnet with the cryogenic system.

Orders for the mass production of the equipment for UNK-1 have been placed with the industry. Presently, first commercially-produced magnets, correctors and their power supplies are being tested. The delivery of this equipment will be started in 1989. The vacuum chamber for the injection channel has been manufactured and is tested now. The production of the vacuum chamber for the ring is begun.

The mass production of superconducting magnets for UNK-2 is planned to be started at IHEP in 1990 while the production of the equipment for the cryogenic system will be started in inductry in 1991.

The construction and installation work on the 3000 GeV machine is planned to be over in 1993.

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