UNK STATUS AND PLANS

G. Gurov, Institute for High Energy Physics, Protvino, Moscow Region, Russian Federation

The 3000 GeV proton Accelerating and Storage Complex (UNK) is now under construction at the Institute for High Energy Physics (IHEP), Protvino. 2.7-kilometer UNK Beam Transfer Line was commissioned with a 65 GeV proton beam during March, 1994. An overview of the project's status is given, and the construction progress is reported.

I. INTRODUCTION

Started in 1983, the original project of IHEP Accelerating and Storage Complex (UNK) implied, in its final design, construction of two accelerators in a tunnel of 21 km in circumference [1]. First, a conventional magnet synchrotron (UNK-1) to receive protons from the existing 70 GeV synchrotron (U-70) and accelerate the beam from 70 to 400 GeV. Second, a superconducting accelerator storage ring (UNK-2) to accelerate the beam to 3 TeV. Finally, these 3 TeV protons could collide with 400 GeV protons from the UNK-1, thus aiming at a collider physics with 2.2 TeV energies in the center-of-mass.

In an initial phase of operation, the approved laboratory program gives priority to a 3 TeV fixed target physics. To provide this mode of operation, 3 TeV accelerator option of UNK has been designed. It includes 400 GeV "warm" magnet ring (UNK-1) and a 3 TeV superconducting ring (UNK-2) [2].

Unfortunately, due to financial problems, the 3 TeV UNK-2 superconducting ring construction has been delayed. In January 1993, the Scientific Programme Committee of the Russian National Scientific Programme "High Energy Physics" took a decision to focus efforts on the earliest possible commissioning and running in of the conventional accelerator (UNK-1) which can be run up to 600 GeV for a fixed-target physics, the superconducting programme being kept atR&D level.

In spite of the constrained budget, the fabrication of the 600 GeV accelerator equipment (magnets, vacuum system, beam diagnostics, instrumentation, computer controls etc.) continues slowly but steadily. During March, 1994 the first milestone in the UNK programme has been reached - the commissioning of the new 2.7-kilometer UNK Beam Transfer Line (BTL) with a proton beam [3].

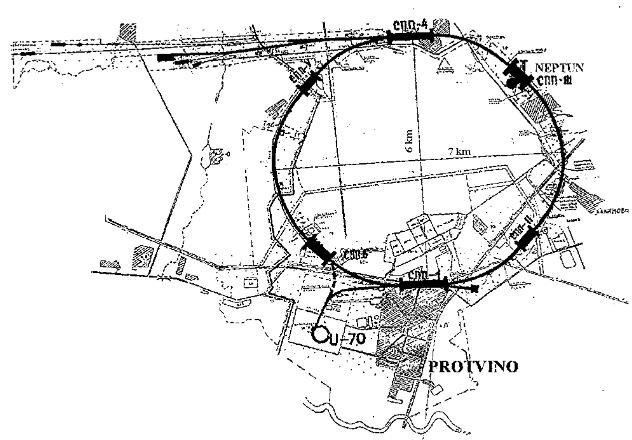

Figure 1: Ring layout.

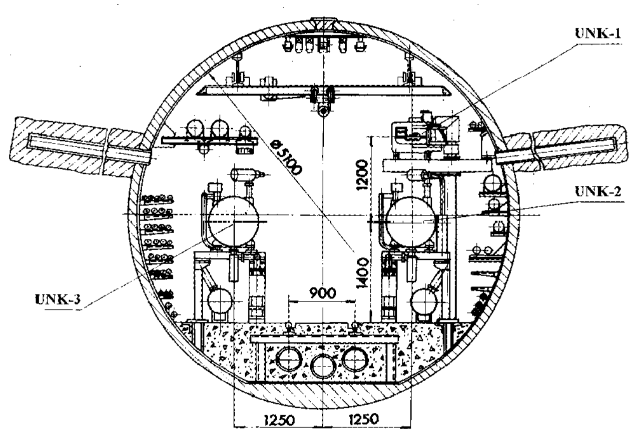

Figure 2: Tunnel cross-section.

II. BASIC CHARACTERISTICS

Originally, UNK-1 was designed as a slow booster for the UNK-2, the superconducting ring. Certain changes have been introduced during the last years into the design of the first stage of UNK (which is now referred to as UNK-600) in order to ensure its operation both, as a storage ring at 400 GeV and as an accelerator at 600 GeV. The storage ring option will be used for colliding of the circulating beam with an internal jet target placed in Straight Section 3 - experiment "NEPTUN" [4]. The accelerator option will be run for an external fixed target physics at 600 GeV.

During the injection 72 s flatbottom, the UNK-600 orbit will be filled consecutively with 12 beam pulses of the presently existing 70 GeV proton accelerator which will be operated as an injector into the UNK. The maximal intensity to be stacked can be as large as 6×10^{14} protons. On stacking, the beam will be accelerated in UNK-600 up to 600 GeV. The field rise time is 20 s, the extraction flattop is 20 s. The possibility of a slow resonant extraction with uniform spill over a period of 1 to 20 s, a fast resonant extraction in the range of 1 to 3 ms and a singleturn extraction are planned. The total cycle length is 120 s, the mean beam intensity is 5×10^{12} pps.

The accelerator ring will be installed on top in an underground tunnel of 5.1 m in diameter and 20.77 km in circumference. Fig.1 shows the ring layout and the extracted beam areas for a fixed target physics. Fig.2 shows the equipment installed inside the tunnel.

Specifications of the UNK-600 is given in Table 1.

Table 1. UNK-600 specifications.

Peak energy, GeV	600
Injection energy, GeV	65
Orbit length, m	20771.9
Maximum field, T	1
Injection field, T	0.108
Acceleration time, s	20
Flattop time, s	20
Total cycle duration, s	120
Harmonic number	13860
RF frequency, MHz	200
Peak RF voltage, MV	7
Transition energy, GeV	42
Beam intensity	$6 \cdot 10^{14}$
Average beam current, A	1.4

The space left in the main ring tunnel and surface buildings, power of the substations and the infrastructure available make it possible to consider as a long-term perspective the development of a collider version of the accelerator complex in which 3 TeV protons would collide with 400 GeV protons from the booster ring, and construction, in future, of a second 3 TeV superconducting ring (UNK-3) with a view to arrange 3×3 TeV colliding beams.

III. CONSTRUCTION OF UNK-600

A. Beam Transfer Line

The 2.7-kilometer UNK Beam Transfer Line (BTL) will eventually transfer beam from the U-70 to the UNK-600 (fig.3). BTL was designed for proton energies between 60 and 70 GeV, momentum spread 2×10^{-3} and beam emittance 2 mm.mrad. The U-70 fast ejecton system for BTL includes a full aperture kicker, two septum magnets and a bump system for closed orbit distortion. The BTL consists of a matching section for adjusting the beam to a bend section, a 64-degree bend section and a second matching section to adjust the beam parameters to the UNK lattice. The considerable distance between the UNK ring and U-70 injector is a result of the geological conditions on the IHEP site.

The BTL lattice has a strong focusing FODO structure with 88 quadrupoles, 52 dipoles and 56 corrector magnets. The UNK orbit plane is 6 m below then that of U-70. Beam diagnostics

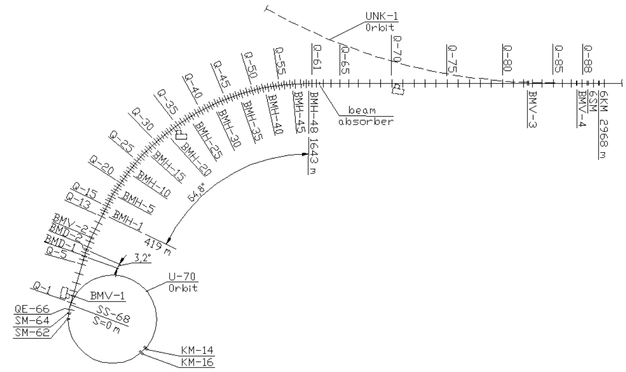

Figure 3: Beam transfer line.

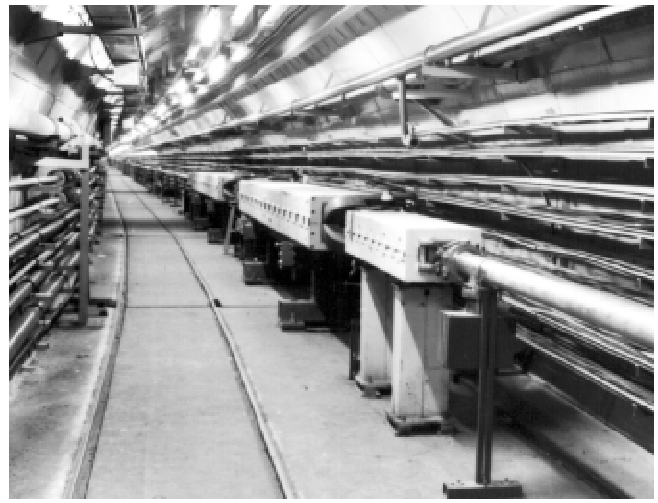

Figure 4: Beam transfer line tunnel.

include beam current monitors, 46 beam position monitors, 26 profile monitors, loss and halo monitors. The final U-70 radiofrequency is 6 MHz, while a 200 MHz accelerating system will be used for UNK. A recapturing station is installed in U-70 to match the extracted beam with the longitudinal phase space of the UNK [6].

The first BTL beam test was successfully carried out on 14 March 1994. A small fraction of normal U-70 beam intensity (5 bunches of 30) was accelerated to 65 GeV and recaptured by the U-70 200 MHz system with some further acceleration. Then U-70 beam was ejected and transferred to the BTL (fig.4). Using corrector magnets and adjusting the bending magnet current, the beam was negotiated through the BTL to a beam stop two kilometers from the ejection point. The beam size was in a good agreement with calculations.

A temporary PC-based control system was implemented for BTL commissioning, with four console computers and equipment controllers connected to the console via serial communication lines and line multiplexers. Magnet power supplies used more then 50 homemade equipment controllers. Beam instrumentation electronics was implemented in CAMAC with Intel auxiliary crate controllers inside.

At the same time a prototype UNK control system, developed in collaboration with CERN, was successfully tested. The system consists of an ULTRIX DEC station and a diskless front-end computer linked through MIL-1553 with equipment controllers. Good operational reliability and perfect flexibility in interface design were demonstrated [5].

B. Ring tunnel

The UNK tunnel shown in Fig.1 is completely excavated. The underground halls designed for the installation of the "NEPTUN" experimental facility and the extraction system equipment are under construction. Two sections of the main tunnel comprising about 1/4 of the ring are nearly finished (with utilities), in preparation for installation and testing of a section of UNK-600 with several hundred magnets. Construction of twenty surface buildings, surrounding the access shafts, now about 1/4 complete, but it is significantly behind schedule and work has nearly stopped because of the very constrained budget of the institute.

C. The equipment for UNK-600

Table 2 shows the current status with the production of the equipment for UNK-600. About 70% of the equipment has already been delivered to IHEP, but due to present financial difficulties further purchase of equipment has nearly ceased.

Table 2. UNK-600 equipment. April 1995

Equipment	Total Required	Available
Dipoles	2226	1500
Quadrupoles	522	522
Correctors	1180	1180
Main power converters	25	13
RF cavities	16	50%
RF power converters	8	8
RF amplifiers	8	3
Vacuum chamber	23.7 km	17 km
Beam pos. monitors	550	150

All the magnets meet the field quality requirements of UNK. These magnets will be tested, preassembled together with vacuum chambers, beam monitors etc. in modular units before being brought into the tunnel for fast installation (fig.5).

The 17 km vacuum chambers for the regular lattice cell with all the auxiliary vacuum equipment (ion getter and turbo pumps, gate valves, power supplies, vacuum measurement systems etc.) have been delivered. Preinstallation assembly and tests of the vacuum chambers are going on at test facilities. An entire period of the regular cell of the vacuum chamber has been tested. The 2×10^{-9} torr vacuum satisfying the requirements even of the collider mode was attained by applying a special technique of treating the chamber with an argon discharge without preliminary baking.

The RF accelerating system consists of 8 independent units. Each unit includes a doublet of cavities coupled by a quadrature hybrid and RF power amplifier located in a ground-level building. Each RF power amplifier delivers 800 KW RF power in CW operation by means four 250 kW power tetrode tubes coupled by hybrid junctions. All power supplies for RF system and 3 of 8 power amplifiers have been delivered from industry. The waveguides and accelerating cavities are manufactured at IHEP. About 50% of the waveguides and cavities components have been manufactured. One accelerating module of this type has been installed at U-70 in order to be used for rebunching the U-70 beam to the frequency of the UNK accelerating field [6].

Figure 5: UNK-600 dipoles stored in the test facility building.

A half of the power supply units for the main ring magnet has been delivered. One of them is used to power the bending magnets of the Beam Transfer Line. The tests showed that the power supply requirements have been met.

A large number of relatively low-voltage power supplies for the correction magnets have been ordered from industry. The prototypes of commercial power supplies are undergoing tests and the requirements for their parameters are specified.

IV. THE DEVELOPMENT OF THE SUPERCONDUCTING PROGRAMME

The major elements of UNK-2 are the 2192 superconducting dipoles and 474 superconducting quadrupoles. The design of these magnets is complete [7],[8]. The dipole is a two-layer cold iron design with 80 mm bore. At the design field of 5.1 T the current is 5100 A which is quite conservative since the prototype models reach plateau values of between 6000 and 6400 A at 4.4 K. A pre-production batch of 25 prototype dipoles has been completed and tested and meets specifications [9]. The study performed shows that the magnets do "remember" the training after warmup and cooldown cycles. This ensures the required reserve for reliable operation of the UNK.

The detailed measurements of the field properties of the preserial batch dipoles were made. The results of this analysis show that the field quality is acceptable.

A full-scale SC quadrupole prototype has been manufactured and tested [8]. The first quench current level 6750 A was

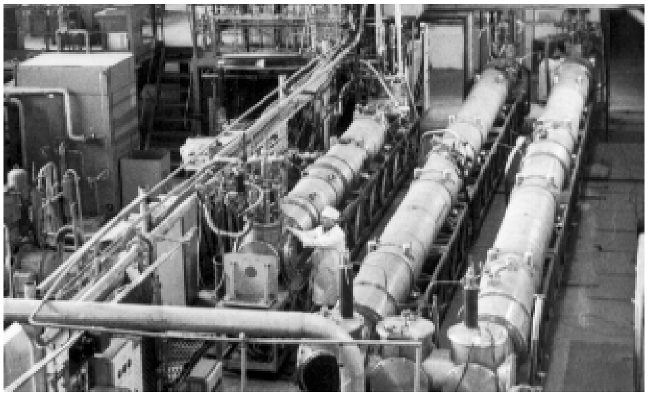

Figure 6: String of UNK SC dipoles.

attained, which is much higher than the maximum operating one in the UNK. The field measurements showed that the normal and skew nonlinearities were within the tolerances.

A large area of the magnet factory has been prepared for mass production of superconducting magnets. All magnets are to be cold tested, measured and trained. The testing facilities are designed to handle this. However, due to decision to cut short the superconducting program at R&D level this work has been brought to stop.

At present, the R&D SC programme is mainly aimed at the study the quench process in the string UNK SC dipoles [1] (fig.6). The programme includes the study of quench origin in some SC elements of the string, energy dissipation, temperature and pressure distribution during the quench, as well as test of prototypes of quench protection system [11]. A new type of quench detector based on magnetic modulator was tested with good results [12].

The first string tests demonstrated a good operation of UNK SC dipoles assembled in two quench protection units. Parameters of quench protection elements (quench stopper, safety leads, quench bypass switches) correspond to the requirements. The description of the string and new test results are presented elsewhere at this Conference [13].

V. UPGRADING U-70

The existing accelerator complex at Protvino consists of a 30 MeV linac, a 1.5 GeV fast cycling booster and a 70 GeV proton synchrotron. The beam produced by U-70 in its present status has a current, longitudinal and transverse emittances which do not satisfy completely the UNK requirements. Therefore, the program of upgrading U-70 has been initiated [14]. It involves extensive modification and up-grade of the 25-year old U-70 accelerator. These modifications include:

– Replacing the corrugated vacuum chamber with a smooth chamber to reduce impedance from 100–200 Ohms to 10 Ohms,

– Upgrading the correction system, including replacing all pole-face windings on magnets,

– Increasing the linac energy from 30 to 60 MeV,

– Constructing a new 20 mA H^- source,

– Replacing the main ring magnet power supply,

– Upgrading the RF system.

These modifications are presently in progress, 1/4 of the vacuum chamber has already been replaced.

VI. CONCLUSIONS

In this brief report the UNK status have been summarized. At the moment, second milestone is to complete the first section of the main ring. The most essential problem now is funding. In case of a sufficient funding (say, at the 1991 level), installation of the UNK-600 could be finished in 1998.

VII. REFERENCES

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