STATUS REPORT ON THE 76 GeV IHEP ACCELERATOR

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In this report, significant information on the status and development of the 76 GeV proton synchrotron over the last two years is given. Part of the information pertaining to 1970 has been reported at the 2nd Russian Accelerator Conference 1).

From the beginning of 1970 until July 1971, the Accelerator has run with a beam for 6680 hours. 78 % of this has been used by physicists for experiments. The total shut down period was 14 % and this is distributed evenly amongst the principal accelerator systems. The average operating beam intensity has been at a level of 0.8×10^{12} protons/pulse. The accelerator has achieved 7 - 8 runs a year, the duration of each run being 20 to 45 days. In the summer of 1970 a 3 month shut down period was utilised, due principally to the need to complete building and wiring work for the fast ejection system.

Operational experience with the accelerator shows that most of the dynamic accelerator parameters demonstrate a satisfactory long term stability. For example, the shape of the "natural" equilibrium orbit does not alter significantly within the range of intermediate and high magnetic field levels. The difference between the data of 1968 2) and 1971 is not more than 3 mm (with the exception of some points which are of a mainly incidental character).

However, some magnetic field characteristics - in particular, within the injection region - fluctuate considerably. The main causes are the installation of new beam channels, the replacement of some sections of the vacuum chamber, alterations to the shielding in the beam channel areas, etc. In particular, the installation of massive chambers in a number of electromagnetic units demanded correction of the magnetic field level and of the gradients within these units, as well as correction of the value of the magnetic field parabolic non-linearity along with individual corrections of the field non-linearities within these units. At the present time, apart from the individual correction of magnetic field non-linearities 3), we are using a correction system which includes the majority of the units. In this mode, the linear dependence of the betatron oscillation on particle momentum is compensated. Recently, it has been found that, in addition to the existence of oscillation coupling at low magnetic field levels, there is also a strong coupling occuring between the radial and axial betatron oscillations at intermediate levels of the magnetic field. The difference between the betatron oscillation frequencies was 0.17 to 0.20, instead of the calculated value of 0.07. It has been found that the cause of this is the widening of the coupling resonance $Q_r - Q_z = 0$ which is caused by the radial displacement of the average magnetic field strength due to the difference between the currents in the upper and lower electromagnet windings. Elimination of oscillation coupling during the major part of the acceleration period improved the effectiveness of the accelerator acceptance and significantly increased the operating intensity of the accelerated beam, see Fig. 1.

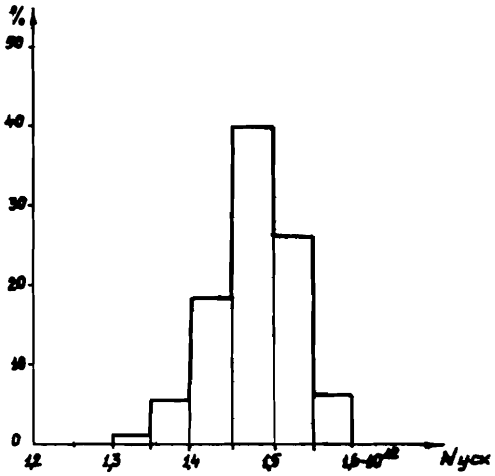

Fig. 1 Stability diagram of the Accelerator (during 300 cycles of acceleration)

At the same time the increase in intensity further retarded the speed of the magnetic field rise during the initial accelerating cycle from 5000 Gauss/sec to the value 3500 Gauss/sec. The reduction in the magnitude of the magnetic field rise is achieved by adjusting the main power supply generator excitations.

The maximum beam intensity was 1.8×10^{12} protons/pulse with single turn injection prior to July 1971. It is now 2.0×10^{12} protons/pulse. This intensity increase spotlights some beam instabilities.

Apart from the influence of the space charge on the frequency of the betatron oscillations during injection 4) the following instabilities have been found :

1. Close to the transition energy and considerably below it, oscillations to the shape of the accelerated beam bunches are excited.

2. Coherent transverse beam oscillations are excited below the transition energy. The threshold for the appearance of these instabilities and the magnitude of the oscillations are dependent upon the radial position of the proton beam.

3. When the accelerating voltage is off at the beginning of the magnetic field flat top, the beam is first debunched as usual. However, later on it bunches again with a multiplicity factor of 13 (the multiplicity factor of the RF system is 30) corresponding to the resonant frequency for the accelerating system at the beginning of the cycle. This effect is strongly dependent upon the beam intensity.

These instabilities appear to be similar to those which have been observed elsewhere, see for example [5].

The increase in the accelerator beam intensity has made it necessary to improve the quality of the secondary beams generated from the internal targets. This involves firstly the time-prolonged beams for electronic experiments. The duration of the magnetic cycle flat-top was increased up to 2 sec at a stability of ± 3×10^{-4} and with the relative value of the main frequency harmonics (25, 50 and 150 Hz) not exceeding 3×10^{-5}. Under these conditions, the slow targetting system for the accelerated beam allows spilled particle beams to be obtained with a duration of up to 1.8 sec, and with an intensity modulation of 10 - 20 %. The influence of non-linear betatron oscillation resonances at radial positions of the accelerated beam results in a degradation of the beam time structure. To avoid this effect, some methods of suppressing the influence of non-linear resonances by correcting the magnetic field gradient at the end of the acceleration cycle were developed [6].

For irradiating the Bubble Chamber, a system has been worked out which allows both a fast beam spill on to the target to be achieved as well as control of the intensity of the particles which reach the Bubble Chamber [7]. This system is based upon the excitation of the rapidly increasing azimuthal asymmetry of the magnetic field using a pulse magnet located in the straight section. The increase in the magnet current, and consequently the beam targetting, is stopped by a signal from the counters after the required number of particles has passed through the chamber. Using this system, the 2 m Dubna Propane Chamber has been exposed to a negative pion beam of 40 GeV/c momentum and the Mirabelle Liquid Hydrogen Chamber to a diffraction scattered proton beam of 70 GeV/c momentum. A particle intensity at a level of 5 ± 2 particles within a time interval of not more than 500 μsec and with good background conditions was obtained. Apart from increasing the duration of the magnetic field flat-top, it appeared to be essential for efficient exploitation of the accelerator to include a second flat-top at an intermediate stage of the magnetic field with a duration of up to 0.5 sec, thus permitting experiments to be performed at intermediate energies. As a rule, during one acceleration cycle experiments are run with 4 internal targets, one operating at the intermediate flat-top, and the other three at maximum energy. There are considerable possibilities for expanding the number of experiments run if the accelerated beam is guided simultaneously on to 2 targets, provided that the two experiments performed in parallel are compatible for background conditions, (see Fig. 2). Usually, either a fast spill on to the Bubble Chamber or an electronic experiment is carried out before starting to run parallel experiments, (see Fig. 3). If the experimental conditions are not compatible and each one demands maximum beam spill time, a commutating device is used. This allows arbitrary programming of the operating target sequence and of the guidance system from cycle to cycle and also allows the sequence of operating the experimental systems to be changed.

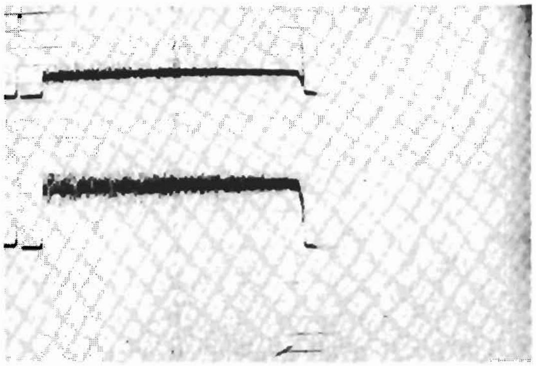

Fig. 2 The signals from the monitors for the secondary beams at simultaneous spill of the beam onto two internal targets. The duration of the secondaries is 1300 msec.

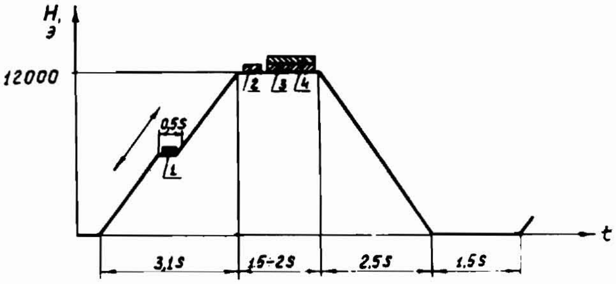

Fig. 3 The shape of the magnetic cycle with the intermediate flat-top.
1) Secondaries on the intermediate flat-top. Accelerated beam energy 20-50 GeV.
2) The first beam of secondaries on the main flat-top. Fast spill of the beam onto the target (0.5 msec) or slow movement onto the target during 300-500 msec.
3), 4) Slow spill of the beam onto two targets in parallel. The duration of the secondary beams is 1000-1500 msec.

References

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