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INITIAL OPERATION OF THE IHEP PROTON SYNCHROTRON WITH A NEW RING INJECTOR

Yu.M.Ado, E.A.Myae, A.A.Naumov, M.F.Ovchinnikov, O.N.Radin, V.A.Teplyakov, V.G.Tishin, E.F.Troyanov
USSR State Committee for Utilization of Atomic Energy
Institute for High Energy Physics, Serpukhov, USSR

The maximum achieved intensity at the IHEP 70 GeV proton synchrotron with a 100 MeV linac injection does not exceed $5.6\cdot10^{12}$ protons per pulse. The intensity is limited by low energy space charge effects. In order to increase the beam intensity a new injection system has been constructed and some systems of the main accelerator (RF system, vacuum system, magnet power supply) have been improved according to new requirements. A fast-cycling proton synchrotron—booster with a maximum energy of 1.5 GeV[1,2] is now used as a new injector. Fig. 1 shows schematically the layout of the booster and main accelerator.

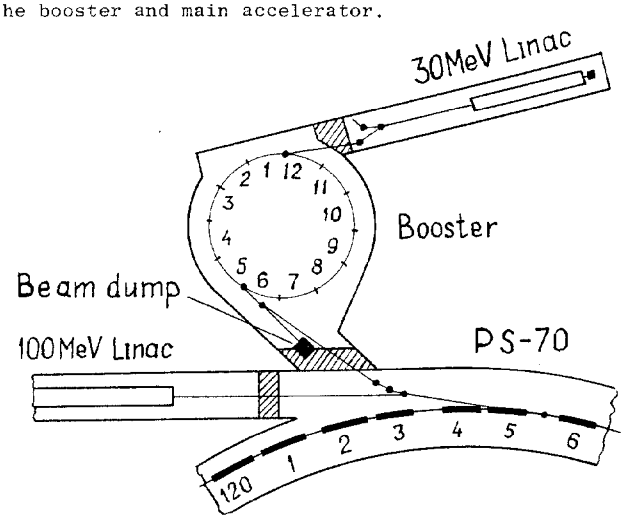

Fig. 1. Layout of booster and main accelerator.

The 30 MeV linac with radiofrequency quadrupole focussing [3] is developed as an injector for the booster. The linac accelerating structure consists of five cavities. A double H-resonator loaded by four axial-symmetric electrodes is used as the Linac First Section (LFS). Longitudinal capture efficiency of LFS is upto 97% of injected particles. Beam focussing is provided by a longitudinally uniform quadrupole component of the RF field. LFS transversal normalized acceptance is about 0.6πcm.mrad. RFQ focussing of FFDD type is used in the Linac Main Sections (LMS) providing 0.8πcm.mrad beam channel acceptance. The accelerator operates in a pulse-train mode, the beam pulse duration can be varied from 1 to 10 μs. Main linac parameters are given in Table 1.

Comissioning of the booster at the maximum designed energy of 1.5 GeV was performed earlier (see, for example, [4]). The achieved beam intensity of the booster is $3\cdot10^{11}$ ppp using single-turn injection. Main parameters of the booster are given in Table 2.

The booster is equipped with a single-turn ejection system. The local orbit distortion at the septum-magnet azimuth is created by three bump-magnets. The beam is thrown into the septum gap by a ferrite kicker-magnet. The achieved beam extraction efficiency is close to 100%.

Transfer channel ~70 m long provides the booster beam transportation to the main ring and matching of the transversal characteristics and dispertion of the injected beam to corresponding parameters of the main accelerator. The end part of the beam channel goes through fringing field of the main accelerator magnet. A special small-size pulsed magnet and a quadrupole are used to compensate the field influence onto the beam.

Table 1. 30 MeV RFQ linac parameters

Output energy	30 MeV
Pulse beam current	100 mA
90% beam emittance (normalized)	0.9π cm. mrad
Momentum spread (linac output/ after debuncher)	$\mp$0.8/0.3 %
Linac length	25.26 m
Vacuum tank diameter: LFS	0.6 m
LMS	0.4 m
LFS input energy	100 KeV
LFS output energy	2 MeV
LFS input beam current	250 mA
Radiofrequency	148.5 MHz
LMS synchronous phase	30°
RF peak power	3 x 5 MWt

During autonomous operation the booster beam is extracted onto the beam dump (2.6 m edge cube piled up of the steel slabs), placed at a side-branch of the beam transfer channel.

Table 2. Booster main parameters

Maximum proton energy	1.5 GeV
Beam intensity, ppp (design)	$1.7\cdot10^{12}$
Repetition rate during 30 pulse train	20 Hz
Orbit length	99.16 m
Number of cells	12
Cell lattice	OMOFODOFOM
Bending radius	5.73 m
Betatron tune: radial	3.85
vertical	3.80
Transition energy	2.55 GeV
Harmonic number	1
RF band	0.7467-2.791 MHz
Peak RF amplitude	60 kV
Vacuum chamber aperture in dipoles	14 x 6.1 cm
Number of injection turns	1 - 8

An 18 modulus ferrite kicker-magnet, each section being powered individually, is used for particle injection into the main accelerator.

The booster and the main accelerator operation mode is illustrated in fig. 2. The beam being accelerated in one booster cycle is injected into one of the 30 main accelerator buckets. A successive filling of the buckets is used. The transfer synchronisation system works out a pulse for triggering the kicker-magnets at the moment when the following conditions are fulfilled:

i) particle energy of the booster beam reaches a level corresponding to the main ring magnetic field;

ii) phase difference between booster and main ring RF's has a predefined value;

iii) the main accelerator bucket which the beam must be injected into has a proper azimuthal position.

B-train determines the booster beam extraction energy with an accuracy of 10^{-4}, while RF feed-back keeps the orbit mean radius constant within $\pm$ 2 mm.

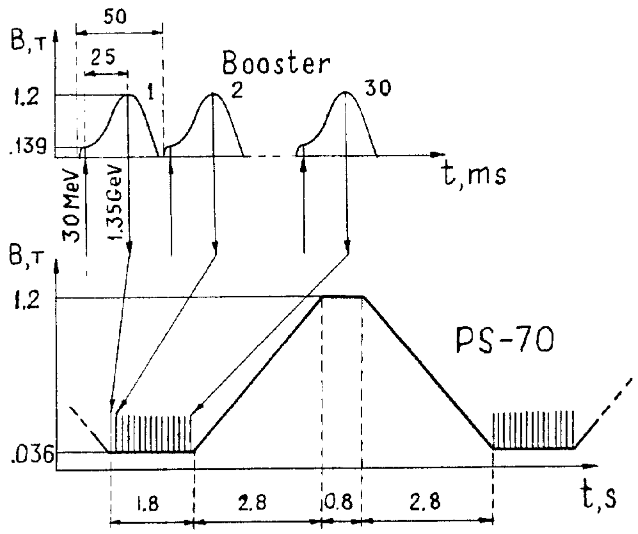

Fig. 2. Booster and main accelerator operation mode.

A mutual slide of the booster and main accelerator RF phases is used for the phase matching between the booster bunch and a chosen bucket of the main accelerator. To create such a slide the ratio of booster circumference to the main accelerator one was chosen equal to $1/15 \cdot 1.0025$. The time of phase matching does not exceed 145 μs and the corresponding phase error is $\pm 20^{\circ}$.

The IHEP accelerator complex with the booster as an injector was commissioned on the 27 December 1984.The booster beam parameters were as follows: proton energy - 1.3 GeV, emittance - 1π cm.mrad, beam momentum spread - $\pm$ 0.3%. Process of particles accumulation in the main ring is illustrated in fig. 3.

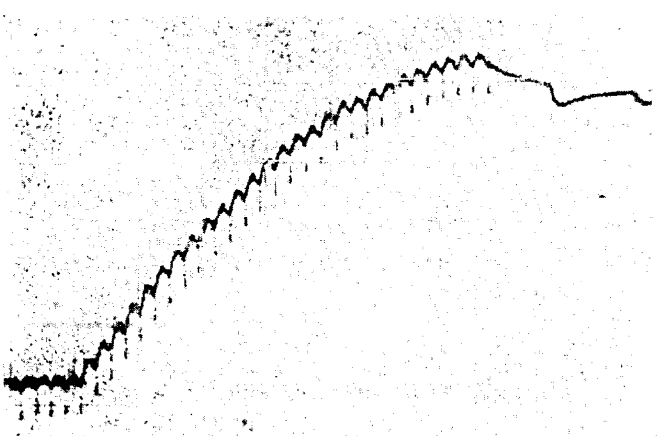

Fig. 3. Beam accumulation in main accelerator.

The injection conditions were not stable enough during the first runs. As a result considerable beam losses took place as one can see from Table 3 showing a beam intensity at various stages of acceleration. Besides the linac beam current was lowered down to 50 mA. Some measures are planned to be taken in the near future to reduce beam losses and reach significantly higher intensity.

Table 3. Beam intensity at various acceleration stages (in 10^{12} protons per main accelerator cycle)

Linac	Booster		Main accelerator	
	inject.	extract.	accumul.	accelerat.
12	11	6.5	4.5	4

Photos (fig. 4-9) show the view of some systems of the injection complex and main accelerator.

References

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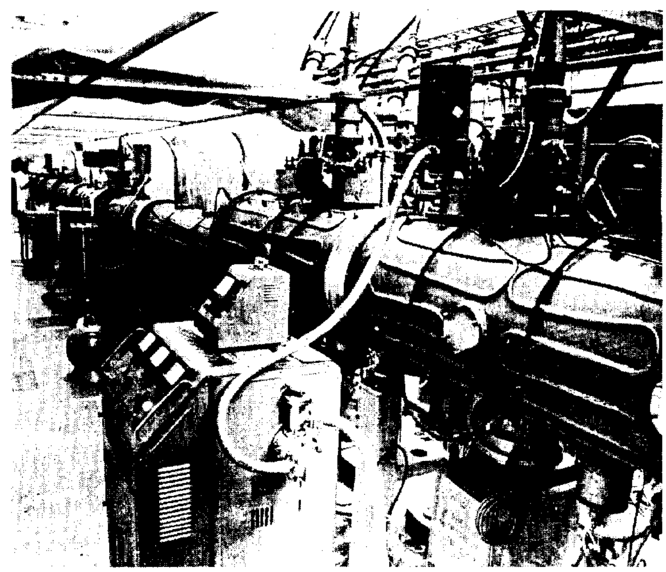

Fig. 4. 30 MeV RFQ linac.

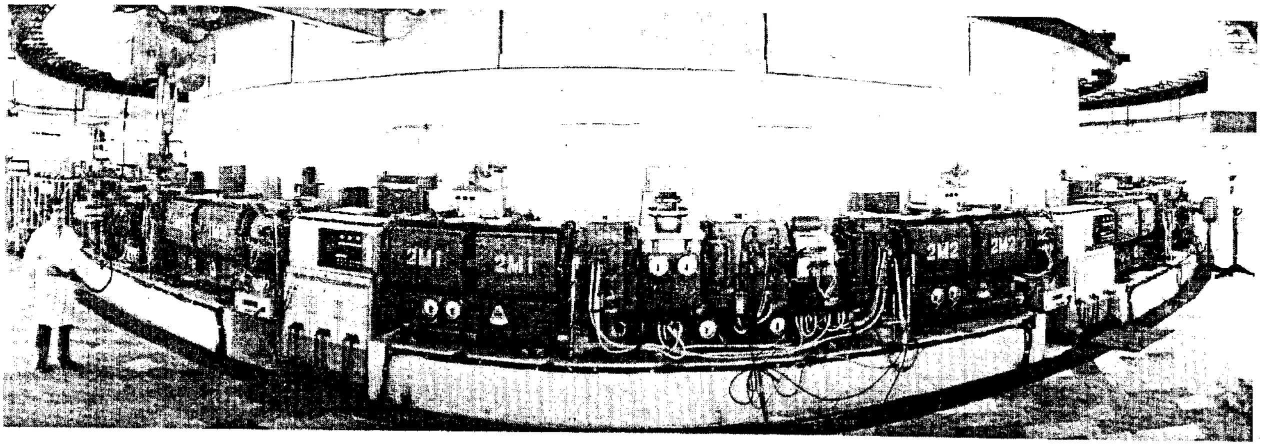

Fig. 5. Booster ring.

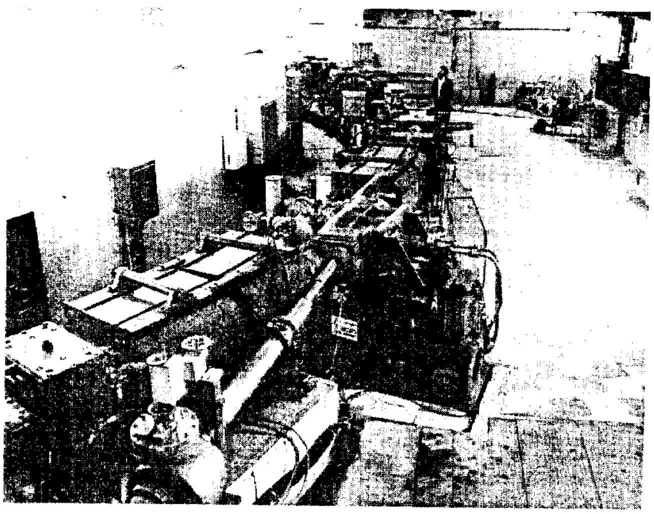

Fig. 6. Booster, beam injection area.

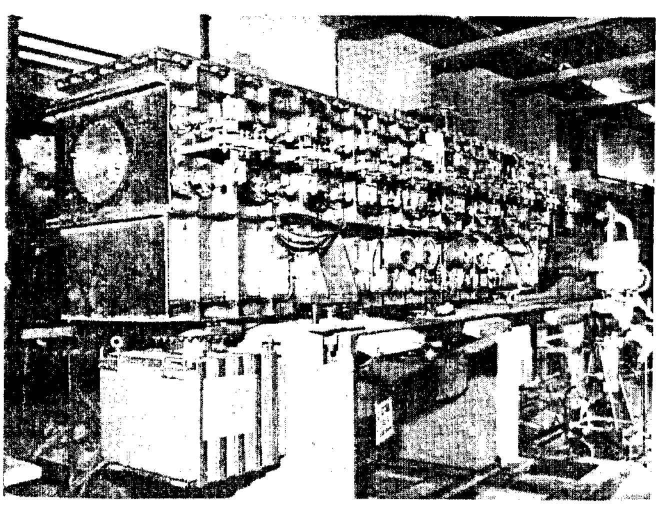

Fig. 7. Injection kicker-magnet.

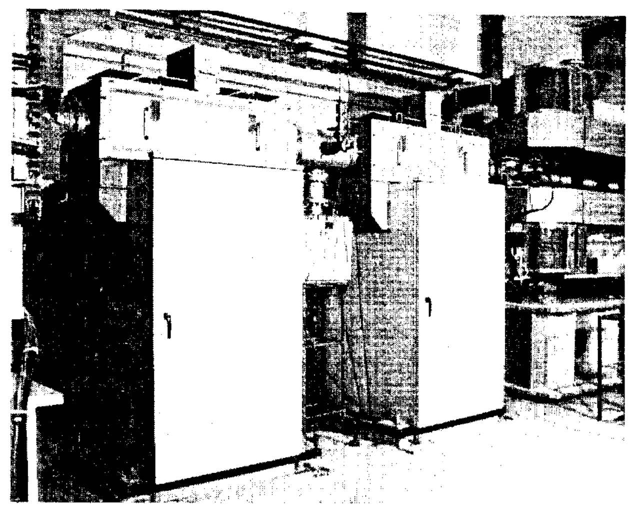

Fig. 8. Main accelerator RF cavities.

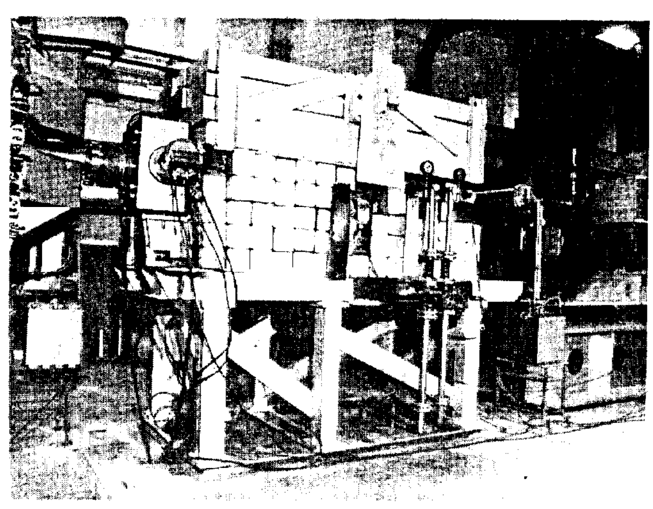

Fig. 9. Main accelerator beam scraper.