JINR PHASOTRON

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Summary

JINR 680 MeV proton phasotron was put into operation in 1985, and in 1986 over 2700 hours of its running time were spent for physical experiments. The achieved intensity of the internal beam is 5 μA, that of the external beam is 2.5 μA. Beam stretching by means of the C-electrode allows a uniform external beam within 85% of the modulation period. A more effective extraction system with an electrostatic deflector is under development. It must increase the extraction efficiency up to 90%.

Difference of JINR phasotron [1] from other accelerators of this kind is that its magnetic field [2,3] radially grows, and spatial stability of accelerated particles is achieved owing to spiral variation of the field along the azimuth.

The radially growing magnetic field allows noticeable reduction of the required frequency range of the accelerating voltage; allowing an increase of both accelerating voltage and modulation rate, which must finally lead to higher intensity of accelerated particles.

Table 1 lists the main parameters of the accelerator as they were designed and achieved (late in 1986).

A general view of the accelerator is shown in Fig. 1, the magnetic system design can be seen in Fig. 2, and Fig. 2.(1-4) shows characteristics of the magnetic field. A peculiar feature of the phasotron is the magnetic field "bump" [4] (Fig. 2.2) in the central region. This structure allows vertical focussing of particles in the region of small radii and as a result considerably more tolerance for field axial asymmetry. At the same time this dependence produces two zones of phase motion instability. The numerical analysis of particle motion and the experiment have shown that the beam crosses these zones without great loss of accelerated particles.

Table 1

		Design	Exp.
E	MeV	680	680
R_k	cm	270	270
B_k	T	1.630	1.630
B_o	T	1.199	1.199
f_k	MHz	14.41	13.90
f_H	MHz	18.18	18.65
$U_{acc.}$	kV	50	40
F	Hz	600	250
$l_{int.}$	μA	10↑50	5
$l_{ext.}$	μA	5↑25	2.5
Duty cycle		85%	85%

The resonance system of the accelerator [5] consists of a dee and a rotating capacitor (Fig. 3) which allows variation of the resonance frequency from 18.65 MHz to 13.90 MHz (the operating frequency range is 18.18 MHz-14.41 MHz) (Fig. 3.1). The accelerating voltage at the dee with an amplitude up to 50 kV is provided by a powerful (500 kW) high-frequency self-excited oscillator.

The accelerating voltage amplitude is programmed in time by the anode modulator.

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Fig. 4 shows the frequency and amplitude of the voltage as a function of time (radius).

An ion source with a closed discharge column is used as a source of protons. Cyclotron optics of the first turn increases the extracted current and improves beam quality.

To extract the beam [6], regenerative build-up of radial oscillations by means of a peeler (Fig. 2.5) and a regenerator (Fig. 2.6) is used. Owing to this build-up, particles are thrown into the extraction channel. A plan view of the extraction system is in Fig. 3. The magnetic field in this channel is 4.7 kGauss lower than in the orbit. A ferro-current section with a septum 4 mm thick serves as the first (input) section of the channel (Fig. 2.7). This system gives a 50% extraction efficiency if amplitudes of radial oscillations do not exceed 20 mm, and amplitudes of vertical oscillations do not exceed 5 mm. Extracted beam dimensions do not exceed 2 x 1 cm^2 (Fig. 3.4).

To improve the time structure of the beam, a beam stretching system with a C-electrode [8] is used. The resonance system of the C-electrode has a bandpass 70 kHz for the frequency about 14.5 mHz. The C-electrode voltage frequency and amplitude are programmed by electronic circuits. To balance frequency programmes of the accelerating voltage at the dee for different blades of the capacitor, individual time delays were used for starting the C-electrode programme. The extracted beam is stretched by this system within 85% of

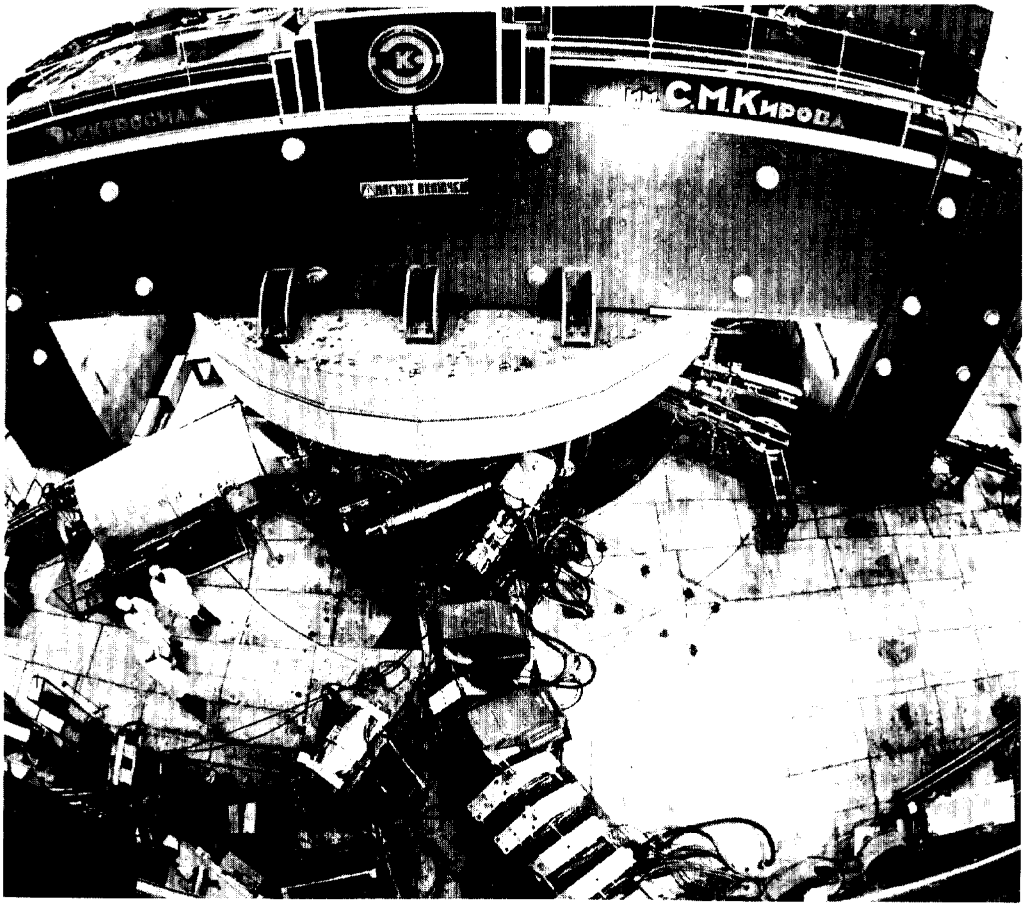

Fig. 1. General view of the phasotron.

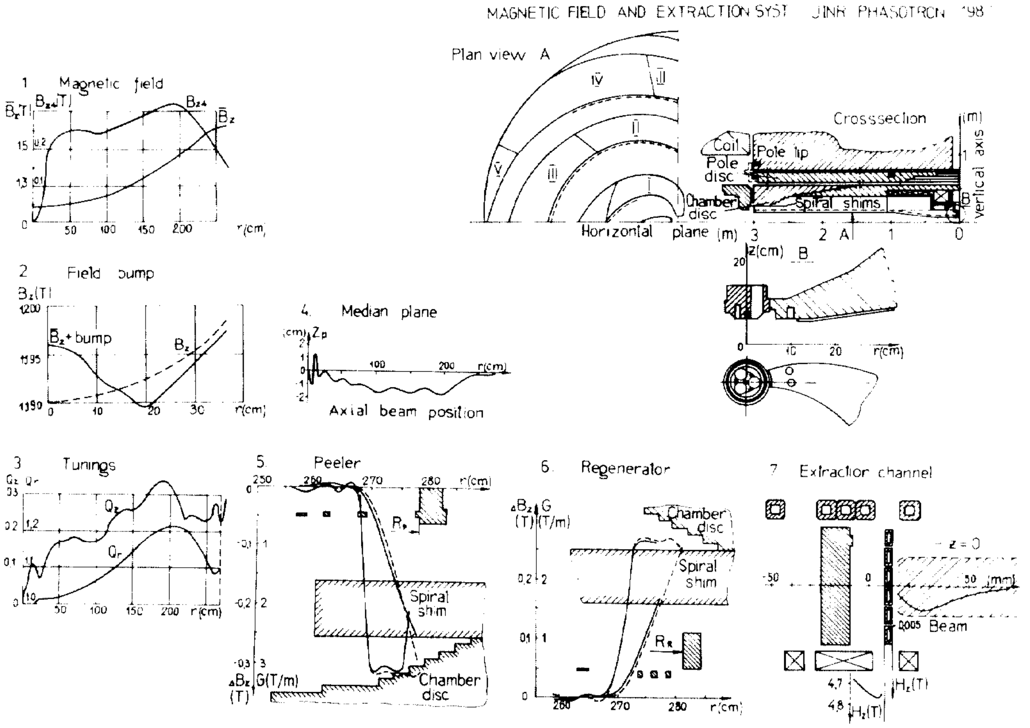

Fig. 2. Magnet system design and characteristics; extraction system characteristics.

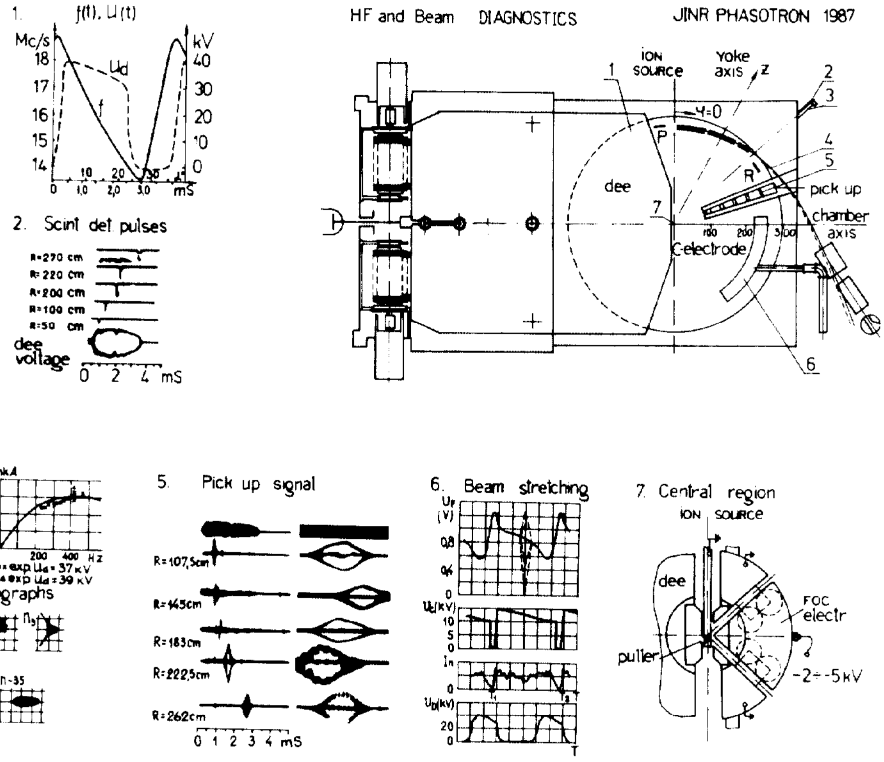

Fig. 3. Schematic views of HF, extraction and stretching systems; characteristics of the accelerating system and accelerated beam.

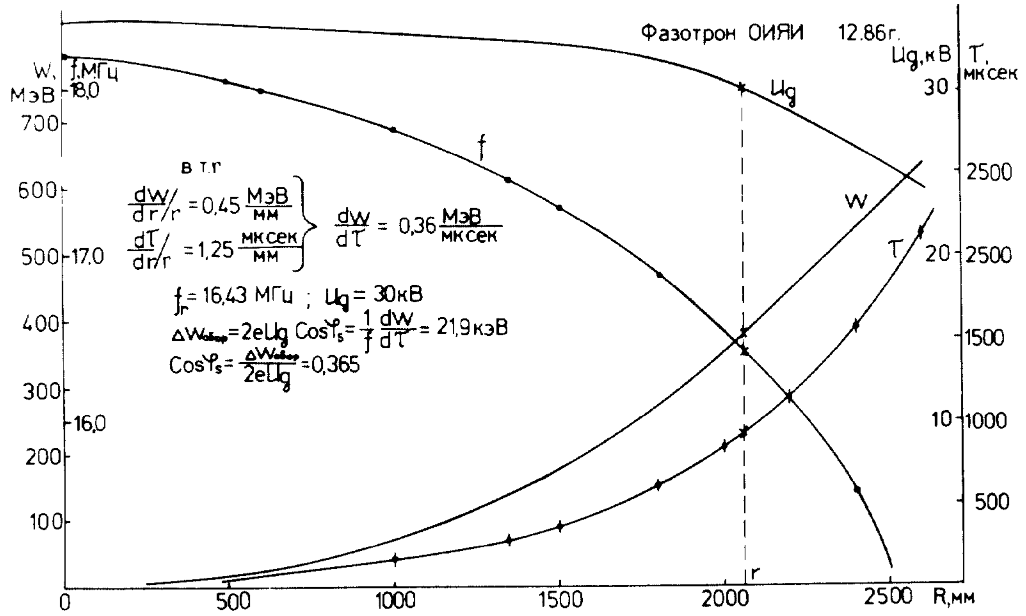

Fig. 4. Frequency and amplitude of the accelerating voltage, and acceleration time plotted against radius.

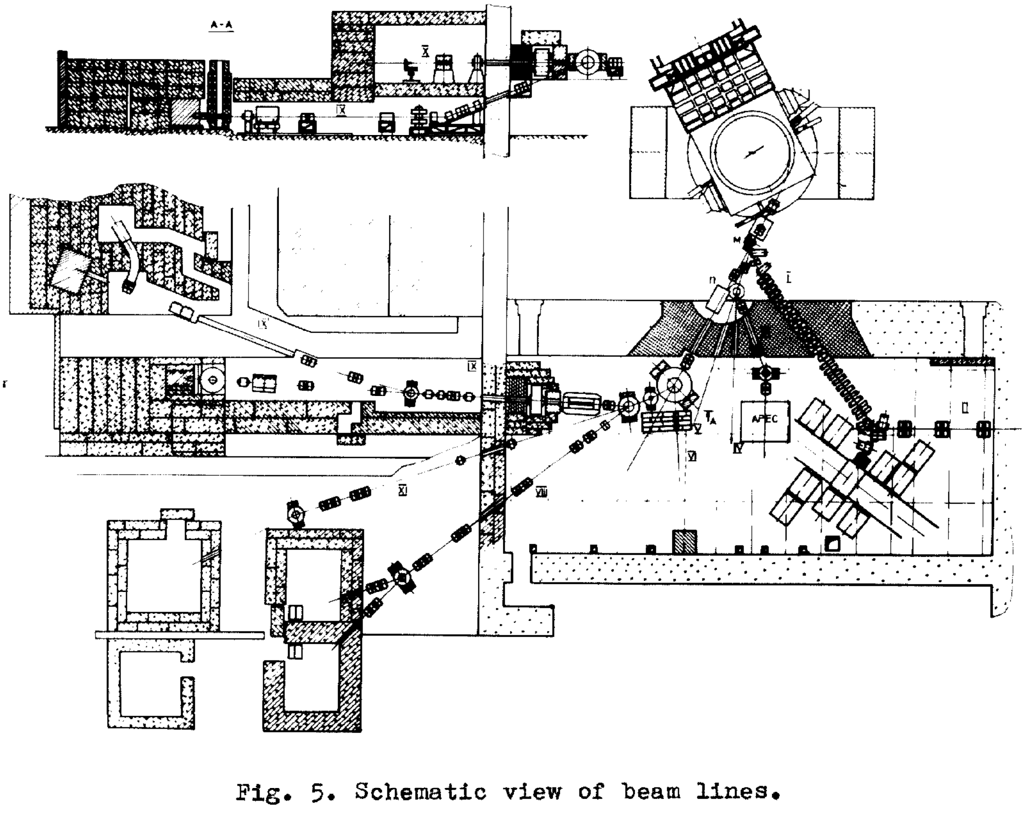

Fig. 5. Schematic view of beam lines.

the modulation period with good uniformity (Fig. 3.6), and beam losses do not exceed 50%.

To carry out beam diagnostics [9], current probes, including multibar ones, are used for small radii at the phasotron. Large radii are equipped with pick-up electrodes, whose signals (Fig. 3.5) allow determining beam intensity, phase length of the bunch and its vertical position. Secondary-emission multibar sensors are installed in the extraction channel to determine beam position and its relative intensity.

Absolute intensity is determined by the radioactivity induced in thin aluminium foils. To determine the external beam intensity, a calorimetric method is used.

There is a scintillation transducer outside the chamber. It measures neutron and gamma radiation due to interaction of the accelerated beam with chamber components and losses of particles during acceleration (Fig. 3.2). If the beam is delivered to a radially moving target, the scintillation transducer also provides other data on acceleration process. In particular, it is used to measure dependence of beam acceleration time and energy gain per turn upon radius (see Fig. 4).

Dependence of the beam intensity on repetition rate and on radius, measured by the current probe, is shown in Fig. 3.3.

Current at 5 μA is quite easily achieved under usual conditions. Current reaches 7 μA at higher ion source arc current, forced accelerating voltage, optimised capacitor repetition rate.

Late in 1986 we made an attempt to optimise central geometry of the accelerator. A focussing electrode was developed (Fig. 3.7), a controllable constant negative voltage up to 10 kV was applied to it (the shifting voltage at the dee was 2 kV). A record of 9.2 μA was obtained for the internal beam intensity at the optimum voltage of 4.6 kV at the focussing electrode. It was found, however, that increasing intensity in this way was accompanied by an increase in amplitudes of radial oscillations and by a consequent reduction of the beam extraction coefficient. These experiments will be continued.

Now phasotron experiments are carried out both with the extracted proton beam and with meson beams (Fig. 5) μSR studies have began at the 1st meson channel, μ-cathalysis experiments - at the 2nd one, study of rare decays - at the 3rd one. Nuclear spectroscopic investigations have began at the 9th proton channel; 100 MeV and 680 MeV proton beams are formed at the 8th and 10th channels for proton therapy of malignant tumours. The 6th proton channel is occupied with investigations of the Cherenkov radiation. In 1987 about 3000 hours of running time are planned for experiments.

Further upgrading of the accelerator is mainly associated with development of the electrostatic extraction system [7] of an efficiency about 90%. It must be installed next year.

References

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