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THE JINR PHASOTRON: STATUS AND PROGRESS

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The synchrocyclotron of the Laboratory of Nuclear Problems (JINR) for 680 MeV protons with the beam intensity of 2.3 mA and beam extraction efficiency of 5-7% has been operatinal for 30 years. Since 1979 it has been under conversion.

The conversion is aimed at making a phasotron with spatial variation of the magnetic field using the building and the magnetic core of the former accelerator. The spatial variation of the magnetic field ensures vertical focusing of accelerated particles in the magnetic field growing along the radius, thus enabling to considerably reduce the frequency range of the accelerating voltage which would result in about 3-fold increase of the accelerating voltage and the cycle repetition. Both factors provide higher intensity of the accelerated proton beam. In addition the use of a highly effective extraction system and an ion hooded arc source with the improved central optics produce additional increase in external beams of protons, neutrons and mesons.

According to the conversion plan the whole accelerator equipment, including the electromagnet windings, pole tips, the accelerator chamber, the dee with the resonance line, rotating capacitor, r.f. generator, ion source, beam extraction system and auxiliary equipment will be replaced. Besides, we have envisaged the automatic control system for the accelerator based on minicomputers.

Up to date all the accelerator units have been assembled; the magnetic field which ensures the proton acceleration up to the extraction radius has been formed; the vacuum system has been adjusted and high vacuum achieved in the accelerator chamber; the r.f. system and the ion source are being adjusted.

Magnetic system

The work on assemblying the phasotron magnetic system and forming its magnetic field was carried out from August, 1980 to May, 1982.

Elements of the magnetic system (pole tips, chamber covers and spiral iron pieces), the schematic drawing of which is given in fig. 1, is installed in the 150 cm gap of the electromagnet with poles of 600 cm in diameter. The general idea of the magnetic system design is given in fig. 2.

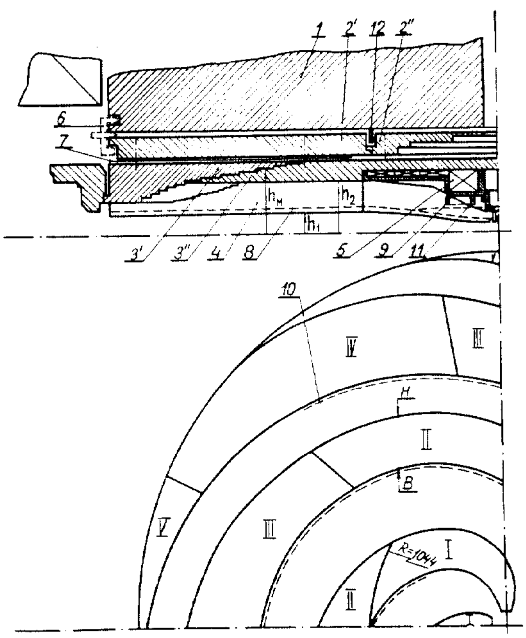

Fig. 1. The schematic drawing of the phasotron magnetic system. 1 - pole; 2 - external disk; 3 - internal disk; 4 - spiral iron pieces; 5 - concentric coils; 6 - external wedge-out device; 7 - sector iron pieces; 8 - correcting rods; 9 - harmonic coil; 10 - side straps; 11 - centre-placed sector iron pieces; 12 - centre-placed wedge-out device.

To decrease perturbations of the magnetic field, ferromagnetic and current elements are included in the system (positions 5,7-11 in fig. 1). Shimming of the magnetic field was carried out with the use of ferromagnetic elements only.

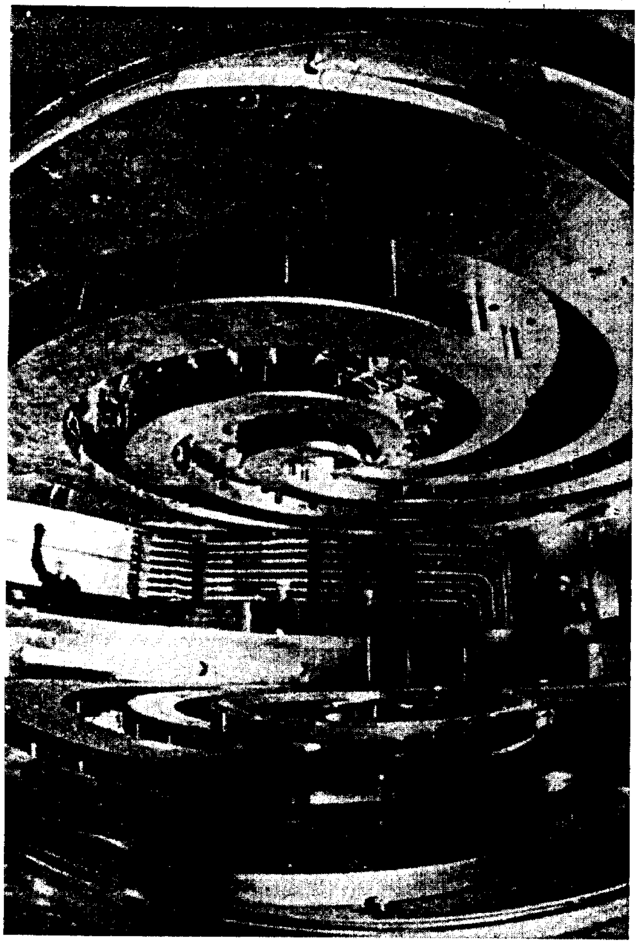

Fig. 2. The assembly procedure of the magnetic system.

The magnet system being assembled, deviation of average constituent of the magnet field vertical component from the required field amounted to 30 mTl (fig. 3, curve 5); shimming reduced the deviation down to 2 mTl (curve 6). The formed average magnet field (curve 1), the amplitude (curve 2) and the phase of the fourth harmonic ensure vertical and radial stability of the charged particle movement (curves 3,4) as well as their acceleration without phase losses in the whole region of working radii.

Amplitudes of lower (1-3) harmonics of the vertical component in the formed magnetic field does not exceed 2 mTl; an amplitude of the first harmonic is corrected down to 0.3 mTl in the central region of the accelerator ($7 \leq r < 30$ cm). It was done for better radial quality of the beam.

Amplitudes of radial components in the formed magnetic field do not exceed 1.5 mTl, thereby vertical distortion of the beam orbit should not exceed 1.5 mm. Similar results were obtained for harmonics of the azimuthal component of the phasotron magnetic field.

To extract the beam from the accelerator

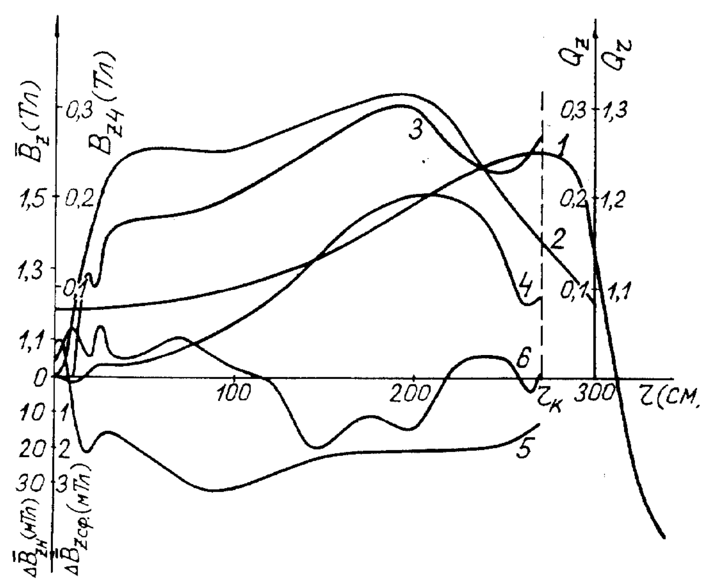

Fig. 3. Characteristics of the magnetic field. 1 - $\bar{B}_z$; 2 - B_{z4}; 3 - Q_z; 4 - Q_z; 5 - $\Delta\bar{B}_{z_i}$; 6 - ΔB_{zf}.

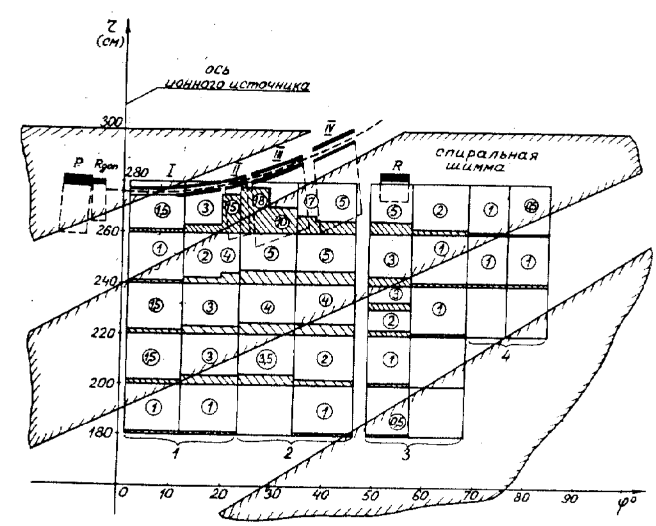

Fig. 4. The schematic lay-out of the extraction system and shaping elements in the accelerator chamber. P - Peeler; R - regenerator; $R_{ad.}$ - additional regenerator. i - current section of the channel; ii-iv - ferromagnetic sections; 1-4 - plates for iron pieces to be mounted on; 5 - thickness of iron pieces in mm.

the regenerative method of excitation and iron-current channel will be used (estimated extraction efficiency is 67%). The iron-current channel consists of one electromagnetic section and three ferromagnetic ones; the total angular length of the channel is about 45°, input being as far as 275 cm along the radius; the septum is 4 mm thick. Fig. 4 shows schematically the place of the channel in the accelerator chamber.

Perturbations produced by the channel in the accelerator magnetic field are shown in fig. 5. The perturbation zone is about 100° in azimuth and goes inside the chamber as far as 180 cm along the radius. To neutralize these perturbations a separate system of shaping elements was mounted above the cladding of the accelerator chamber (fig. 4). By means of this system the perturbations produced by channel in the magnetic field were reduced to a maximum of 2 mTl for an average field, and 0.5 mTl for the first harmonic. Additional field shaping in the extraction zone may be carried out, if necessary, with the help of iron pieces on channel sections.

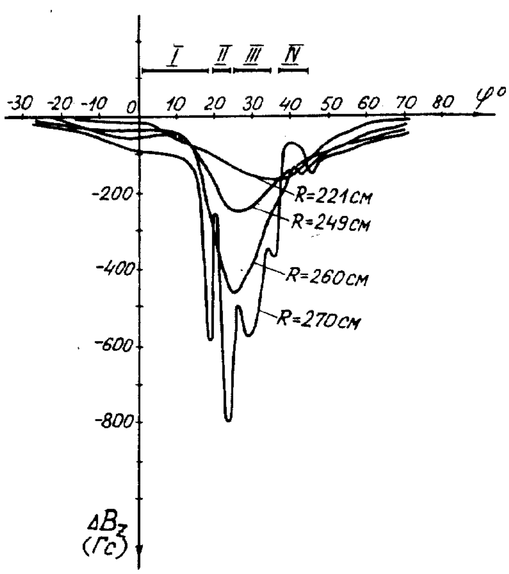

Fig. 5. Azimuthal distribution of magnet field perturbations produced by the extraction system; i-iv - positions of the channel sections.

Accelerating system

The resonance system of the phasotron consists of a flat homogeneous half-wave line (the dee is a part of the internal electrode of this line) and two identical rotating capacitors in one body. In figs. 6 and 7 one can see the assembly procedure of the r.f. system and to get some understanding about its design.

Accelerating voltage on the dee is produced by a powerful 500 kWt autogenerator, an anode modulator being employed to provide pulse mode of operation.

The measured dependence of the system resonance frequency upon the turning angle of the variator rotor is shown in fig. 8.

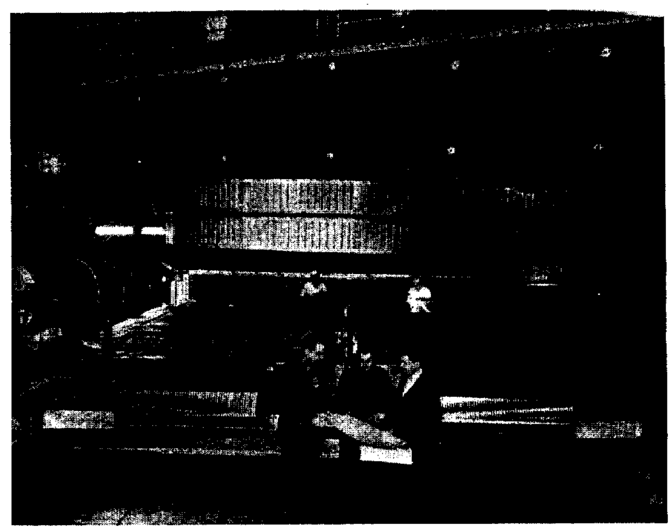

Fig. 6. Assembly procedure of the internal electrode of the resonance line. .

Fig. 7. Joining of the variator with the resonance line.

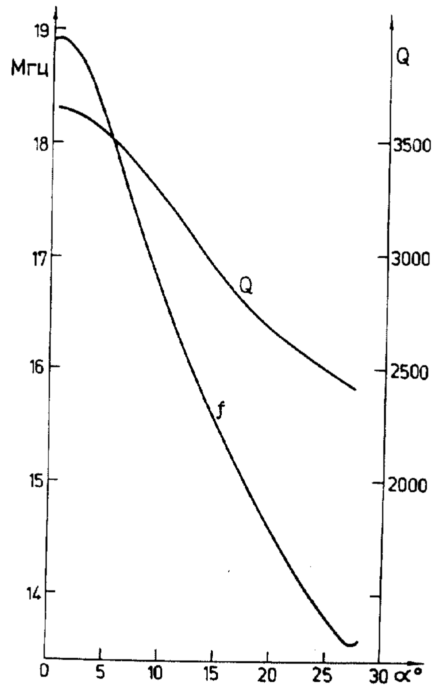

Fig. 8. Resonance frequency and Q-factor of the r.f. system plotted against the turning angle of the rotor.

The character of the dependence corresponds to the given one, and the frequency range exceeds the required one by 1 MHz, it will be reduced by decreasing the number of stator plates. Voltage distribution along the dee and the coefficient of voltage transformation from the generator to the dee are within the specified limits. The quality factor of the system is 3600 at the upper frequency and reduces to 2900 as frequency is being lowered.

The antogenerator and the anode modulator are tested in operation with the equivalent load. Now they are being adjusted as well as the resonance system.

Ion source

For our accelerator two ways to put the ion source in the working region are envisaged: a vertical one, through holes in the magnet yoke, and a horizontal one.

In the horizontal ion source a Penning type ion source with a heated cathode is used. This source is tested on the test bed and ensured 50-60 hr of cathode lifetime at 100 mA of the ion source current.

In the vertical ion source a cold hollow cathode is used, its lifetime being over 300 hours. Fig. 9 shows the horizontal ion source outside the accelerating chamber.

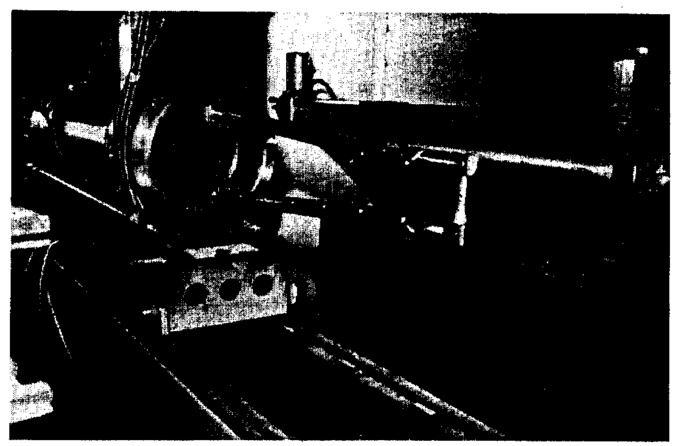

Fig. 9. The horizontal ion source outside the accelerating chamber.

Other units

The vacuum system, water-cooling system, electric power supply and stabilization system, probes to measure the beam parameters, control panel and radiation monitoring system are tested and ready for operation. We hope to perform the first beam acceleration in the phasotron in the first half of the year.