PROGRESS IN MANUFACTURING MAIN NUCLOTRON EXTRACTION ELEMENTS

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Abstract

Advance in manufacturing the electrostatic septum deflector, the first stage of the nuclotron extraction system, and the second one consisting of two Lambertson magnets with SC windings is described. The proposed method allows one to decrease the leakage magnetic fields disturbing a circulating beam from five to six times. The bump coils for the dipoles with a wide aperture are described, as well.

1 INTRODUCTION

The Beam Extraction System (BES) of the JINR Nuclotron [1, 2] a superconducting synchrotron, is intended to eject ion beams over the range of energies from 200 MeV/amu up to about 6 GeV/amu. The extraction process is realized by the excitation of the third order radial betatron oscillation resonance $Q_x = 20/3$. Introducing particles into the resonance is performed by means of two pairs of sextupole lenses providing the 20–th harmonic of perturbation and 4 quadrupole lenses changing the radial betatron frequency from $Q_x = 6.78$ to $Q_x = 6.66$.

The BES is designed as a high efficiency system with an extraction coefficient exceeding 95% and a time spill duration from several hundred microseconds to 10 seconds and more. The BES has two stages of beam deflection. These are an electrostatic septum and a Lambertson magnet consisting of two sections.

2 STATUS AND MANUFACTURING THE EQUIPMENT OF THE BEAM EXTRACTION SYSTEM

Manufacturing the BES began together with all ring parts. But dramatic events in the JINR Member-States early in the 90–th led to a very difficult financial situation, and it was resolved to put off manufacturing and installation of the Extraction System until a later time. The Nuclotron was constructed in 1987–1992, and up to now it has had several runs of operation for commissioning and accelerator research to raise the beam intensity and physics experiments using the internal target, as well.

Now, together with the research object of reaching the project parameters, the next step of work comprises manufacturing, testing and installation of the BES in the accelerator ring. About 50% of the BES equipment has been manufactured to date.

The lenses for the resonance excitation of a beam were made by the same technology as the regular quadrupole lenses [3] having an iron yoke and superconducting coils. The configuration of the quadrupole lenses is the same as that of the regular ones, but they are shorter in length. The cross section of the sextupole lense is shown in Fig 1. All the resonance lenses were bench tested and installed in the ring.

The electrostatic septum (ES) is a convential one similar to the appliances used at other Laboratories [4]. During the ES engineering design, we had fruitful contacts with the accelerator staff of IHEP, Protvino, whose version was used as a prototype. The length of the ES is 3 m. The gap between the septum made of tungsten-rhenium wires 0.1 mm thick and the negative electrode can be changed from 10 to 30 mm. A HV tension of 200 to 250 kV is supplied to the negative titanium electrode (Fig.2 and 3). through the insulator which was placed because of a small distance between the tunnel walls at an angle of $45°$. Vacuum inside the chamber is provided with both magnet discharge pumps and pipes for the reversal helium flow.

Manufacturing of the ES anode is being completed, and the parts of the ejection straight section have mainly been made. The cathode having the Rogovsky shape is under machining after which a preliminary test and oxiding of its surface will be made.

The Lambertson magnet [5] consisting of two sections 1.5 m each deflects an extracted beam in the vertical plane at an

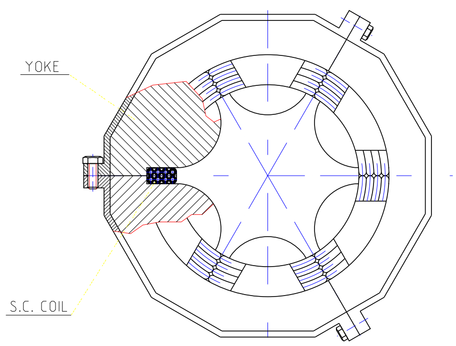

Figure 1: Cross–section of the sextupole superconducting extraction lense

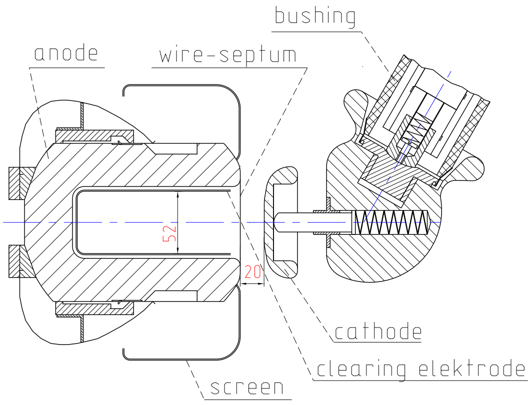

Figure 2: Schematic drawing of the electrostatic septum

Figure 3: View of the ES anode and cathode

angle of 110 mrad to the level of the experimental halls (Fig. 4). It is designed to switch its superconducting windings in a series with the ones of the regular dipoles. Such a connection permanently provides the field level for deflecting the beam at any time of a magnetic cycle required for the extraction.

After manufacturing, the Lambertson magnet had a bench test. Its first section, LM1 (Fig.5), was tested both at room

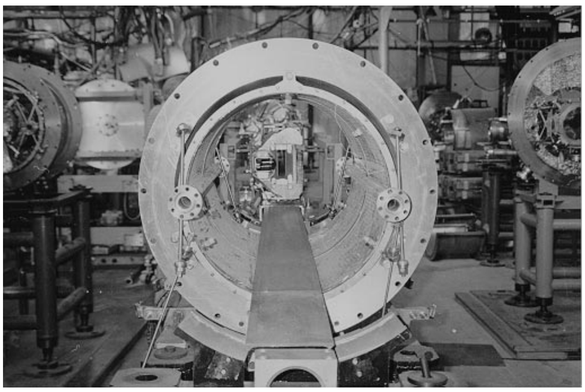

Figure 4: View of the Lambertson magnet

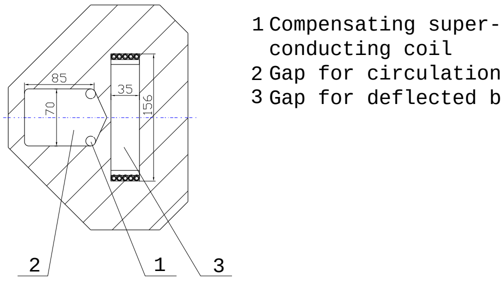

Figure 5: Cross–section of the first section of the Lambertson magnet

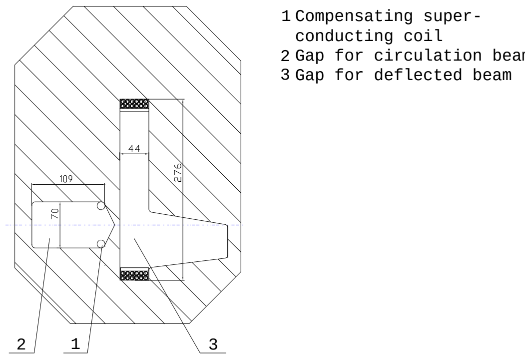

Figure 6: Cross–section of the second section of the Lambertson magnet

and a 4.6 K temperature. The leakage field in the gap for the circulating beam does not exceed 0.05% of the field in the regular dipole magnets, B_{dip}, corresponding to the beginning of acceleration and 0.25% of B_{dip} at maximum fields. The nonuniformity of the magnetic field in the gap for vertical beam bending is about 0.5% for high fields and can be assumed as tolerable.

The leakage field of the second section, LM2 (Fig. 6), measured at low fields is smaller than 0.1%. Measurements at high fields have not been carried out yet, but the performed field simulation has shown a value of 2–3%. Such a disturbing field would cause an orbit distortion of $\pm$ 20 mm [6].

In search of new means to overcome this, it was proposed to put the superconducting short–connected coils into the circulating beam gap which will allow one to get a suppressed magnetic flow there. This opposite sign magnetic flow enveloped by the coils and proportional to the value of the leakage field should always compensate it. In this case, the simulation of leakage fields shows that it is enough to use a one-turn coil placed in the vertical plane . The orbit distortion for a wide range of the magnetic field does not exceed

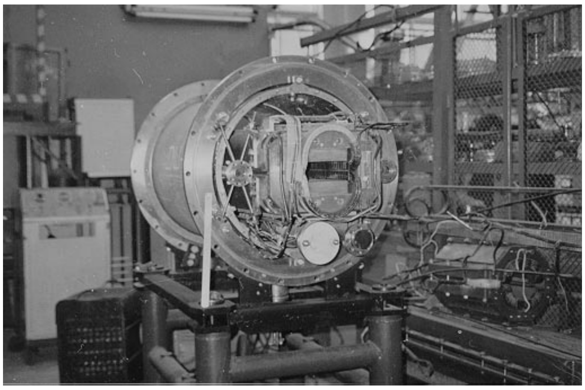

Figure 7: View of the wide aperture dipole magnet

of 0.1 mm and lies within ± 3 mm only for their maximum value of about 2 T.

The compensating coil is made of a cable consisting of a cupornickel pipe and superconducting wires wound on it. Such a cable is used in the Nuclotron regular ring magnets [3]. The compensating coil is assembled in the LM1 which has been prepared to check the calculated values. The work on manufacturing a similar coil for the LM2 is being performed.

The wide aperture dipole magnets (WAM) (Fig.7) should be installed in the ring on both sides of the 5–th straight section instead of 4 usual ones. Their aperture horizontal size is 35 mm larger than the ones in the regular dipoles. The additional space is used for the displaced circulating beam during the injection and the initial phase of acceleration since a part of the chamber transfer space is occupied by the ejection devices. A beam bump is created by means of the additional coils disposed in the gap near the main ones. The insulated conductors of these coils are fastened to the plates between the iron core and the main coil. Their cooling is carried out by contact with the main coil. Now the WAM iron cores are beeng manufactured, and a tentative winding is beeng prepared for testing. The other BES parts of such as vacuum tanks, screens and auxiliary equipment are beeng prepared to be installed in the ring.

3 CONCLUSION

The first tests have shown the extraction magnets are able for operation. A 10 s long duration of beam circulation in the last Nuclotron run has confirmed a good quality of the accelerator lattice for slow beam extraction.

4 REFERENCES

[1] A.M.Baldin et.al., IEEE Trans.Nucl.Sci., NS–30, No.4 1983, p.3247.

[2] B.V.Vasilishin, I.B.Issinsky, V.A.Mikhailov, The Scheme and Main Parameters of the Nuclotron Slow Extraction System, JINR Commun., 9–86–511, Dubna, 1986.

[3] A.M.Baldin et. al., Cryogenic System of the Nuclotron, JINR Commun. E9-93-273, Dubna,1993.

[4] J.Bleeker et. al., Proc. V Intern. Symp. on Discharges, Poland, 1972, p.377.

[5] M.P.May, M.A.Harrison, Lambertson magnet design for the Tevatron extraction channel, IEEE Trans.Nucl. Sci.,NS-30, 1983, p.2836.

[6] V.I.Chernikov et. al., Status of the Nuclotron Slow Extraction System, Part. Accel. Conf. and Intern. Conf. on High-Energy Accel., Dallas, 1–5 May, 1995.