BEAM EXTRACTION. Program "ORBITA-1" has been developed for an investigation beam optic at the extraction. It was investigated as well stripping extraction as an extraction H^--ions by using electrostatic deflector. It was performed the calculation the beam property after stripping. It was carried out preliminary calculations of the magnetic channel optic and the selection of the field reduction and focusing gradients in the channel sections.

CONCLUSION. Coming from the presented data it may be concluded that for two last years a considerable advances have been made in the design and development of the cyclotron components. However the factory manufacture of the most expensive component such that a vacuum chamber, pumps, an acceleration system is frozen by deficiency financing. The next-future tasks are accomplishment the pole tips manufacture and start of the magnetic measurements.

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DESIGN AND OPTIMIZATION THE MAGNET AND MAGNETIC STRUCTURE FOR THE 80 MeV H^- ISOHRONOUS CYCLOTRON

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Introduction. The design and construction of the 75 - 80 MeV H^- cyclotron is being in progress at PNPI [1]. To reduce the expenditure the cyclotron magnet has been designed to use the iron of the model magnet SP-72 of the operating 1 GeV synchrocyclotron.

Reguirements. The cyclotron magnetic field must meet some requirements. The magnetic rigidity on the final orbit must achieve Br = 13.2 kGs·m that corresponds to the 80 MeV energy. For isochronism it must be provided 8.5 % increasing of the azimuthally averaged magnetic field from center to final orbit. The azimuthal variation of the magnetic field must provide for z-focusing and permissible values of the horizontal ν_x as well as vertical ν_z oscillation frequencies. The value of the magnetic field in the hill must be as low as possible to confine the magnetic dissociation of the H^- ions in the limit of 5 %. To give the

room for the accelerator high frequency system the gap between shims must be more than 140-150 mm.

Selection final radius and gaps. The model magnet SP-72 had the following characteristics: diameter of the cone poles equal to 1.5m; gap equal to 289 mm; nominal excitation current equal to 1.2kA. The modernization of the magnet SP-72 has been done on the base calculation on the 2D code POISSON [2]. In order to decrease the magnetic field on the final orbits at given Br the diameter of the pole has been increased up to 2 m. In such a case we have: r_f=0.9 m, $\langle B_f \rangle$ = 14.67 kGs, B_0 = 13.52 kGs. The base problem under the design the cyclotron magnet is a selection the averaged gap, excitation current and also the hill and valley gaps. Set of the axially symmetric magnets has been calculated with the averaged gaps $2g_0$ = 260, 300 and 360 mm, with the corresponding set of excitation currents and the ring shims which provided the same $< B(r) >$ corresponding the isochronous magnetic field for 80 MeV energy at the radius r_f = 0.9 m. From these calculations it was estimated also that 1 cm thickness of shim on the last ring corresponds to the field $\sim$ 1 kGs. On the base of the above consideration variant with average gap 300 mm and excitation current I=1200 A has been selected. That variant provides isochronous field and the minimum gap of hill $\sim$ 150 mm and valley gap $\sim$ 380 mm.

The next step was an optimization of magnet yoke. The calculations have showed that $\sim$ 30% increasing of the pole radius from 0.75 m to 1 m causes the increasing of the magnetic flow up to more than 1.6 of previons value and saturation the iron in the pole. Therefore the cross section of the yoke has been increased by 16% and the height of the side pillar decreased by 0.5 m. These procedures allowed decrease the maximum field in the magnet yoke down to 23.5 kGs, decrease the exitation current down to 800 A and reduce power supply down to 120 kW. The dimensions of the reconstracted magnet with comparison the magnet SP-72 are shown at Fig.1.

Flatter as a parameter having been determined by the azimuthal magnetic field distribution can not be exactly calculated by 2D program. However it is possible to make estimations if the azimuthal edge effect is represented as radial edge effect. The results of the flatter estimation for the constant thickness of the hill were presented as a plot of the flatter value on unitless value $X = r\Delta\varphi/2g_H$, where r - radius, $\Delta\varphi$ - azimuthal extention of the sector and $2g_H$ - hill gap. Introduction the unitless parameter X allows to estimate the flatter decreasing under introducing the spirallity. Also the numerical value of the flatter decreasing can be estimated by using the same plot if insted of parameter X to substitute the effective value $X_{eff} = Xcos\gamma$, where γ is a spirallity angle. This approach has been applied under the selection azimuthal structure of the magnetic field of the isochronous cyclotron at Gatchina [3,4]. The four-sector structure of the magnetic field has been chosen. For H^- cyclotron it is advantageous to use magnetic structure with small value of the flatter and high spirallity to decrease the magnetic field in hill. Two variants of the magnetic structure have been examined: F=0.04, spirallity angle $\gamma = 55^0$, amplitude of the field variation 4.14 kGs and F=0.025, $\gamma = 65^0$, 3.28 kGs on the final orbits respectively.

After the detail investigation of H^- ion dissociation in the cyclotron field variant with larger spirallity angle has been chosen as providing for lower magnetic field in the hill and as a consequence the smaller losses of H^- ions from the dissociation. In this case the losses of H^- ions are in limit of 5%.

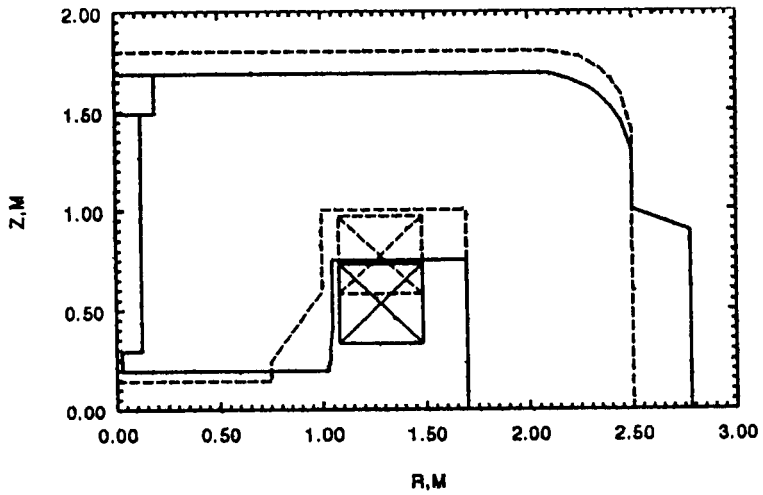

Fig.1. The reconstruction magnet SP-72 into magnet isochronous cyclotron GIC-80. Dotted line is a contour of the initial magnet and solid line is a result reconstruction

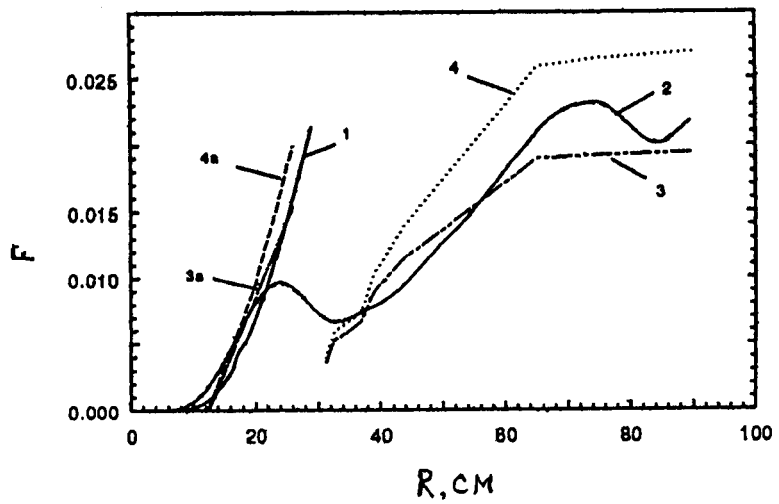

Fig.2. Flatter in dependence on cyclotron radius: *1* – the data of the measurements on model with straight sectors k = 1.36 (central part); *2* – the data of measurements on model with high spirallity k = 8; *3* – calculations on the base of proposed methodology with $2g_V$ = 284 mm, h_1 = 69 mm; *4* – calculations with $2g_V$ = 386 mm, h_1 = 108 mm; *3a*, *4a* — calculations with straight sectors

Model measurements. Simultaneonsly with numerical calculations the model measurements for direct investigation of the 3D effects and verification of the admitted approaches have been carried out. Two models with the scales $k_1 = 1.36, k_2 = 8$ and spirallity angles $\gamma_1 = 55^0, \gamma_2 = 65^0$ respectively have been examined. Model variants have the same azimuthal sector extension and sector thickness, as a resalt we have the same depedence the averaged magnetic field along radius. At Fig.2 is shown the dependence of the flatter on the radius as a result calculations and model measurements. As we can see the results of the measurements and calculations are in good agreement. Geometrical spirallity as well as corresponding to it magnetic spirallity are shown at Fig.3. The magnetic field spirallity lags behind the geometrical spirallity and it is the fact of special interest. At a maximum the

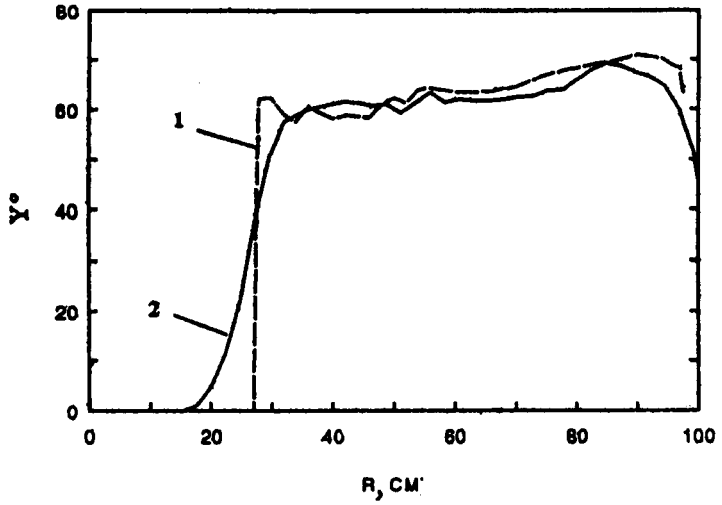

Fig.3. Spirallity angle in dependence on cyclotron radius: *1* — geometry data of k=8 model; *2* — experimental values

difference between effective and geometrical spiralliy angles reach approximately 7^0 that at $65^0 - 70^0$ corresponds to focusing decreasing by 50%.

At the end 1995 all magnet elements with the exeption of pole tips with sectors have been manufactured and assembled. The next–future tasks are the accomplishment of pole tips manufacture and start of the magnetic measurements.

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LOSSES OF H^- IONS DUE TO ELECTRO-MAGNETIC DISSOCIATION AND THEIR EFFECT ON SELECTION OF ISOCHRONOUS CYCLOTRON MAGNETIC STRUCTURE

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The acceleration of H^- ions has advantage in 100% extraction efficiency. But side by side with an obvious asset there is a shortcoming connected with H^- dissociation during acceleration.

The second electron of H^- ion has a very low binding-energy of ϵ_0= 0.755 eV [1] and can be easily detached in a strong electric field E. Such a field is arising in the own coordinate system when ion is moving at velocity $\vec{v}$ in magnetic field $\vec{B}$:

$$E = 0.3\ \beta\ \gamma\ B, \qquad (1)$$