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MAGNETIC FIELD OF THE 40–80 MEV H− CYCLOTRON C-80: EXPERIMENTS AND CALCULATIONS

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The paper concerns to the final parameters of the magnetic field distribution of the new H-minus isochronous cyclotron C-80 and results of 3D computer calculations and experimental measurements before the installation of the vacuum chamber into the cyclotron gap.

The cyclotron C-80 with variably energy 40 - 80 MeV and current up to 100 μA is planned to be used as for applied physics program – for production of medicine isotopes, for therapy of eye melanoma and surface forms of cancer, for radiation resistance tests of electronic components – as well as for fundamental research in nuclear physics, solid state physics and biology.

GENERAL DESCRIPTION

- The magnetic field rigidity at the final orbit must reach Br = 13.2 kGs·m, which corresponds to 80 MeV energy of the proton beam.

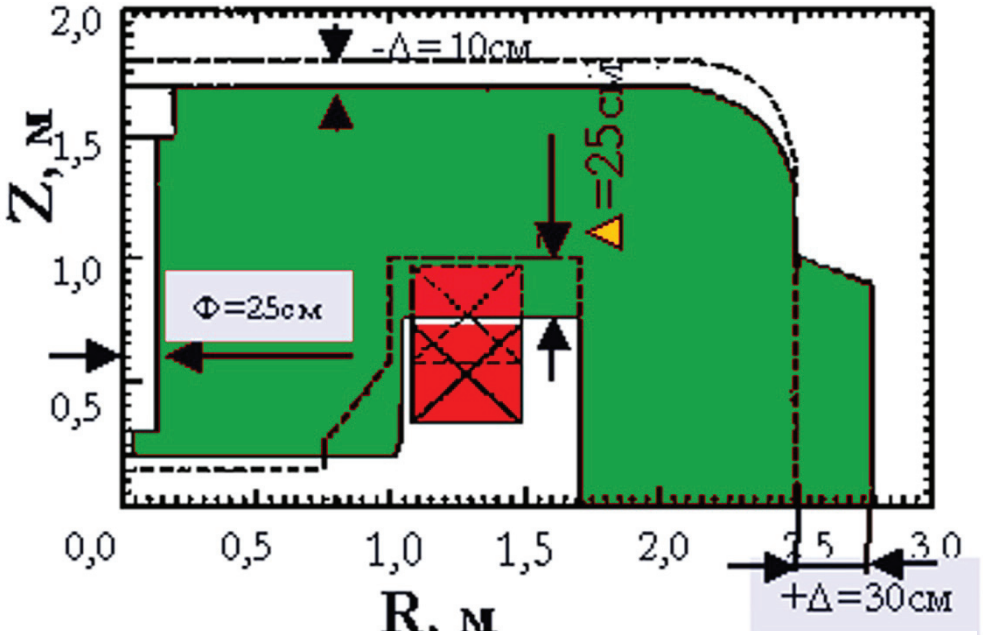
- For insuring the isochronism, the magnetic field averaged over the azimuth when going from the centre of the magnet to the final orbit should increase by ~8.5%.

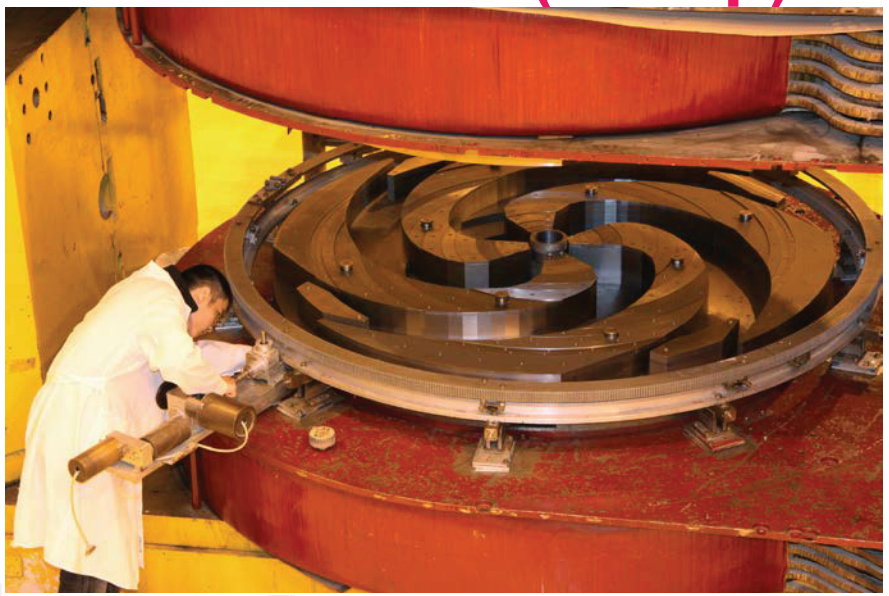
- The azimuthal variation of the magnetic field should provide the vertical and horizontal transversal focusing.

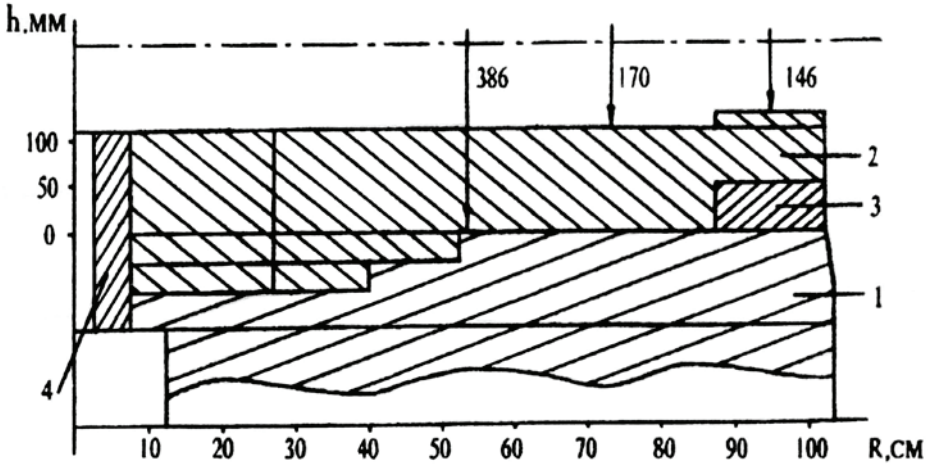
- Some room should be left for a high frequency system: the gap between the shims should be wider than 160 mm.

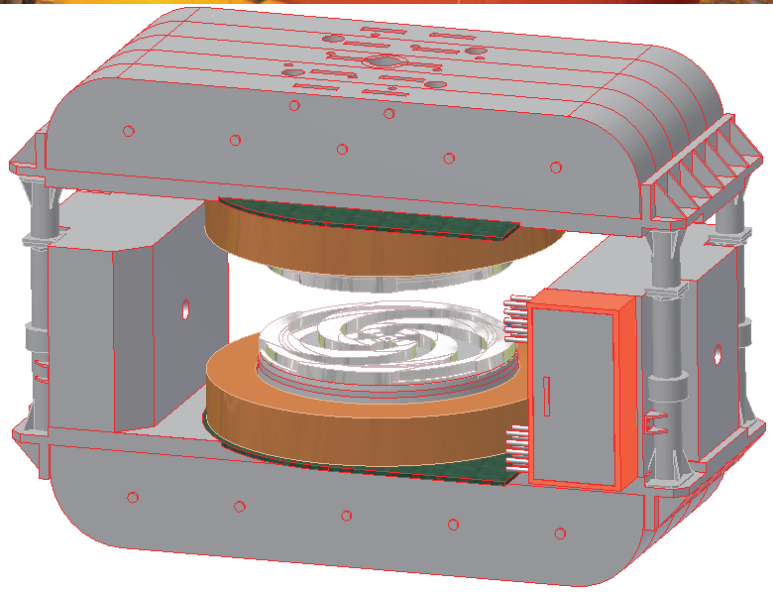
- In distinction from a standard cyclotron, there is an additional and essential requirement for an H– machine – to keep H-minus losses due to dissociation less than some percent.

2D CALCULATION AND OPTIMIZATION (1 step)





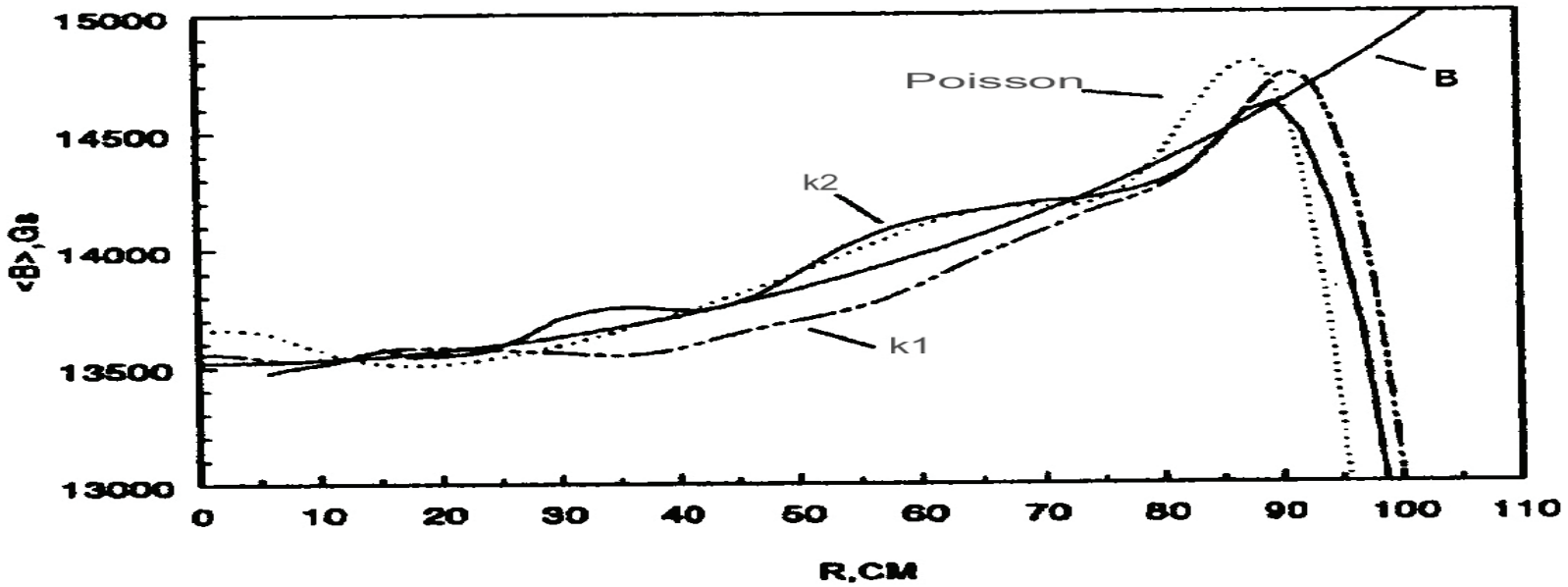




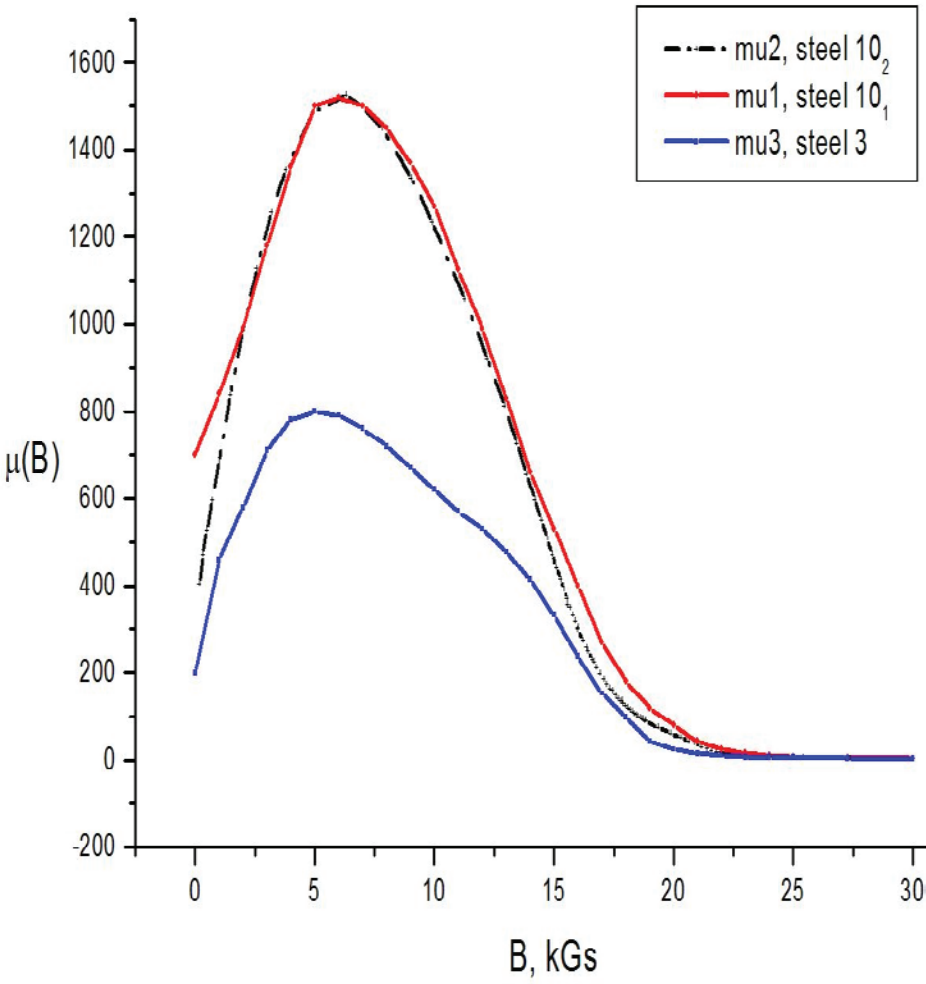
Magnetic measurements on the model with k_1= 1.3 (SP-72) and on the new model with scale k_2= 8

k	*F*	γ^{o}_{max}	$1+2\cdot tg^2\gamma$	$F\cdot(1+2\cdot tg^2\gamma)$	$A_{4max}(kGs)$
1.3	~0.04	55	5	0.203	~4.15
8	~0.025	65	10	0.255	~3.28

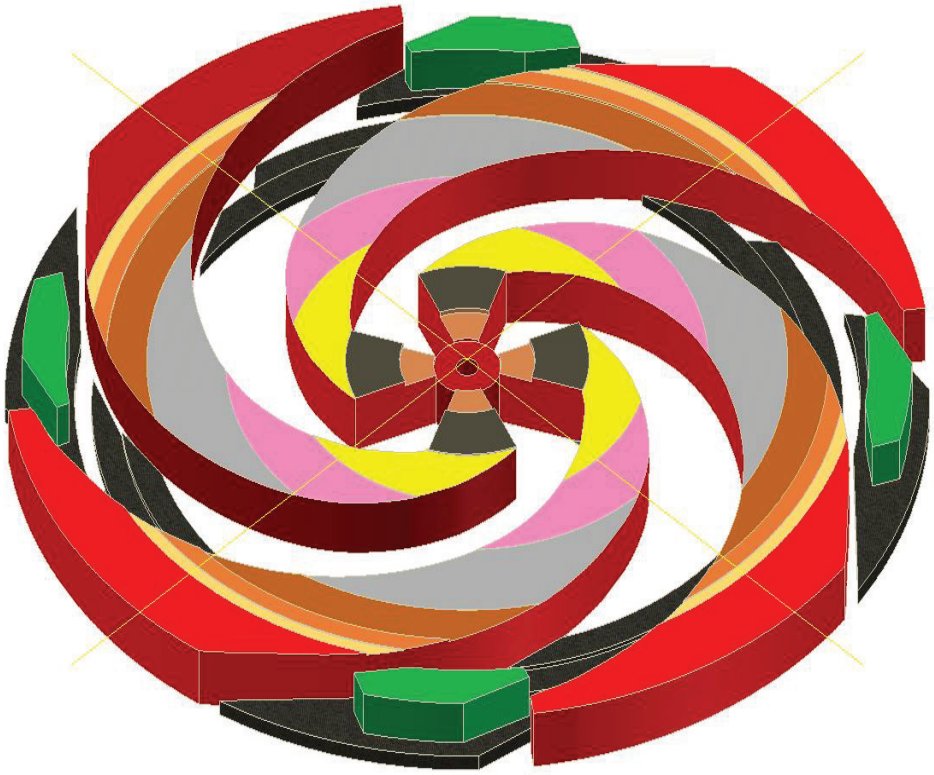
$$\nu_z^2 \approx -n + F\cdot\left(1+2\cdot tg^2\gamma\right) \qquad n \cong \frac{2\cdot W}{E_0} \qquad F = \frac{\overline{B}^2 - \left(\overline{B}\right)^2}{\overline{B}^2}$$



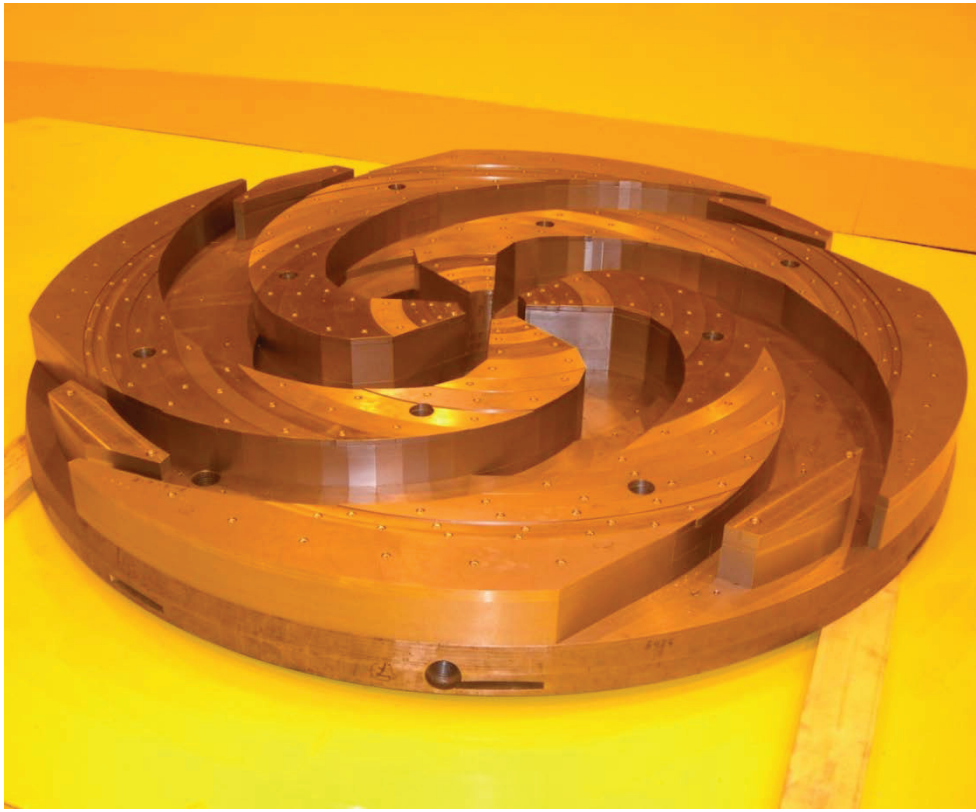
3D CALCULATION AND OPTIMIZATION

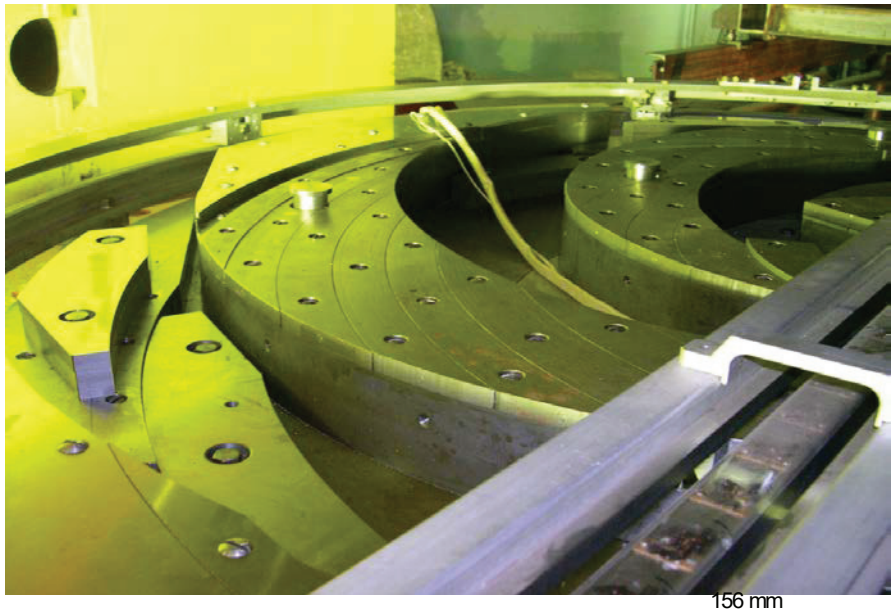


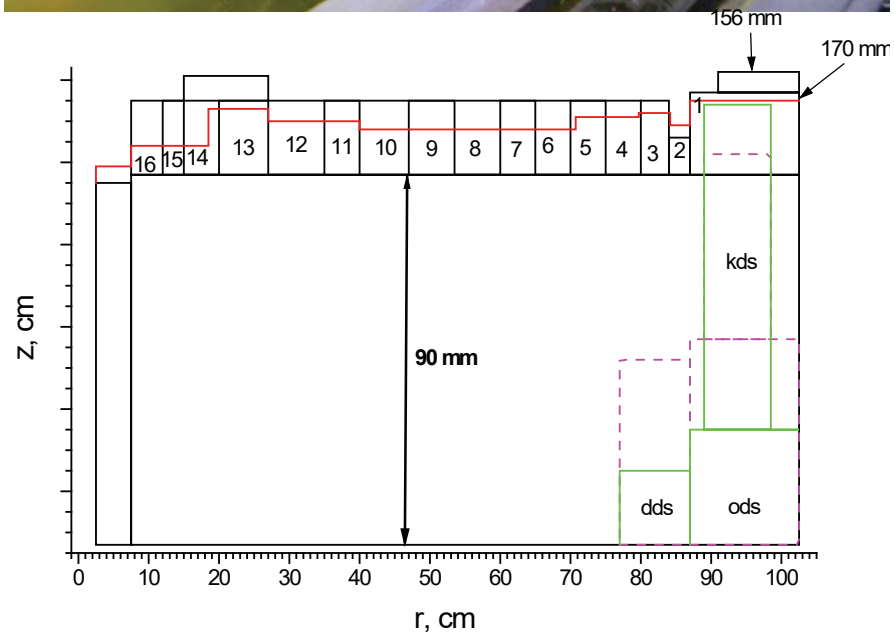
next step



end step







At the final stage

MERMAID

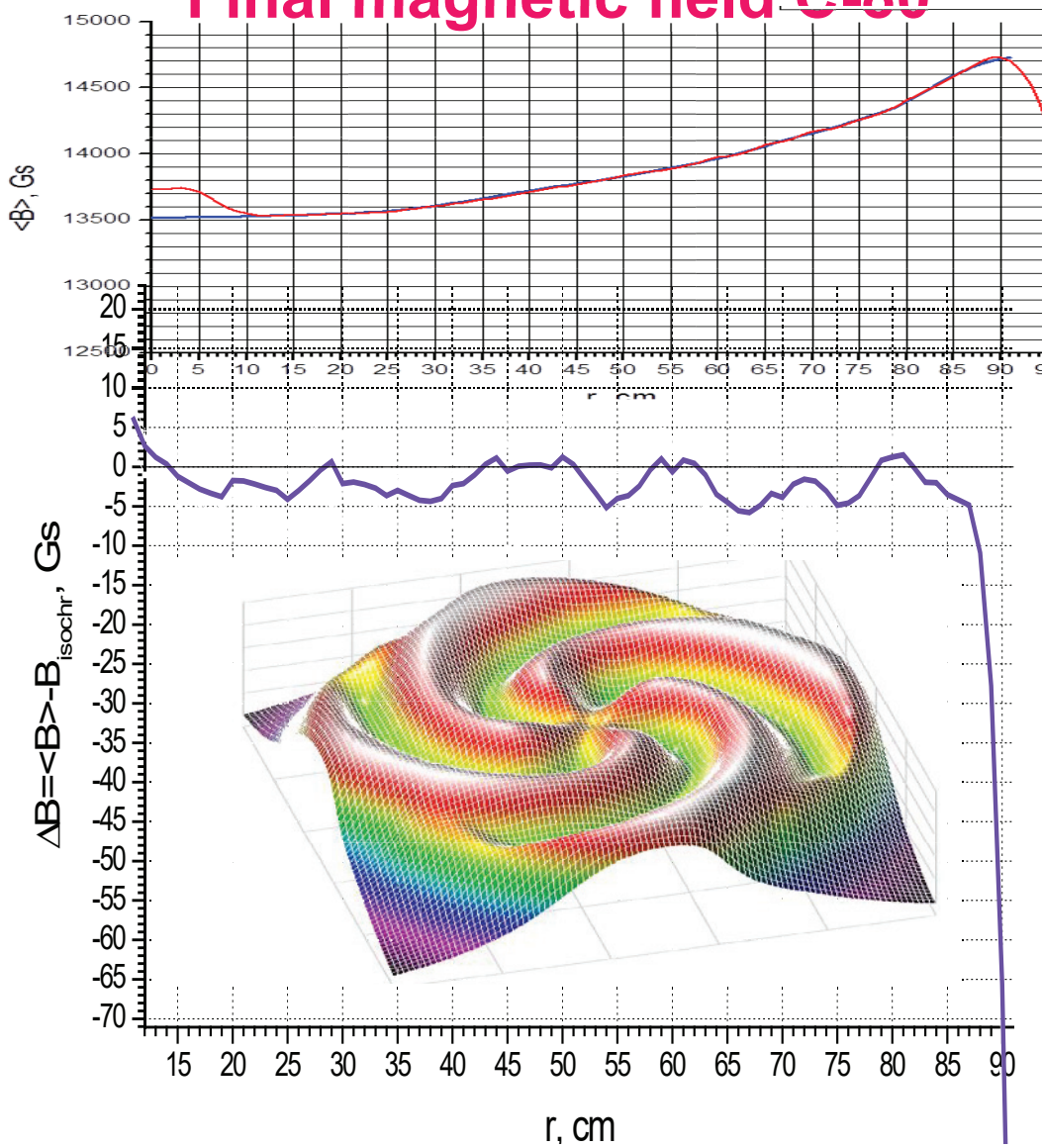
manufacture shims and their installation

magnetic measurements

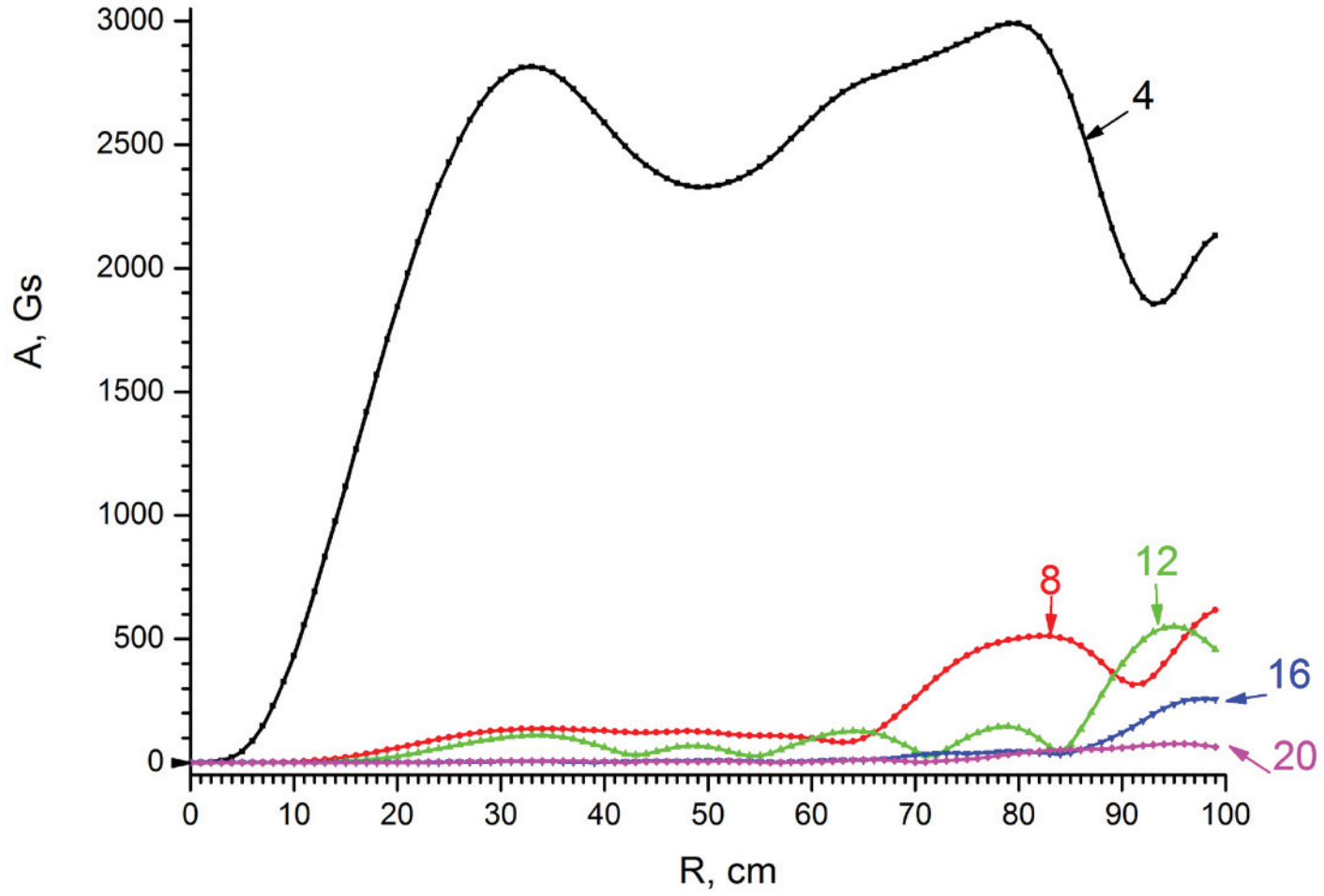
MAIN RESULTS

MAGNET	
Pole diameter	2 .05m
Valley gap	386 mm
Hill gap	163 mm
Magnetic field in centre	1.352 T
Flatter (max.)	0.025
Spiral angle (max.)	65 degree
Number of sectors	4
EXTRACTED BEAM	
Extraction radius	0.65-0.9 m
Energy (varied)	40-80 MeV
Extraction method	stripping

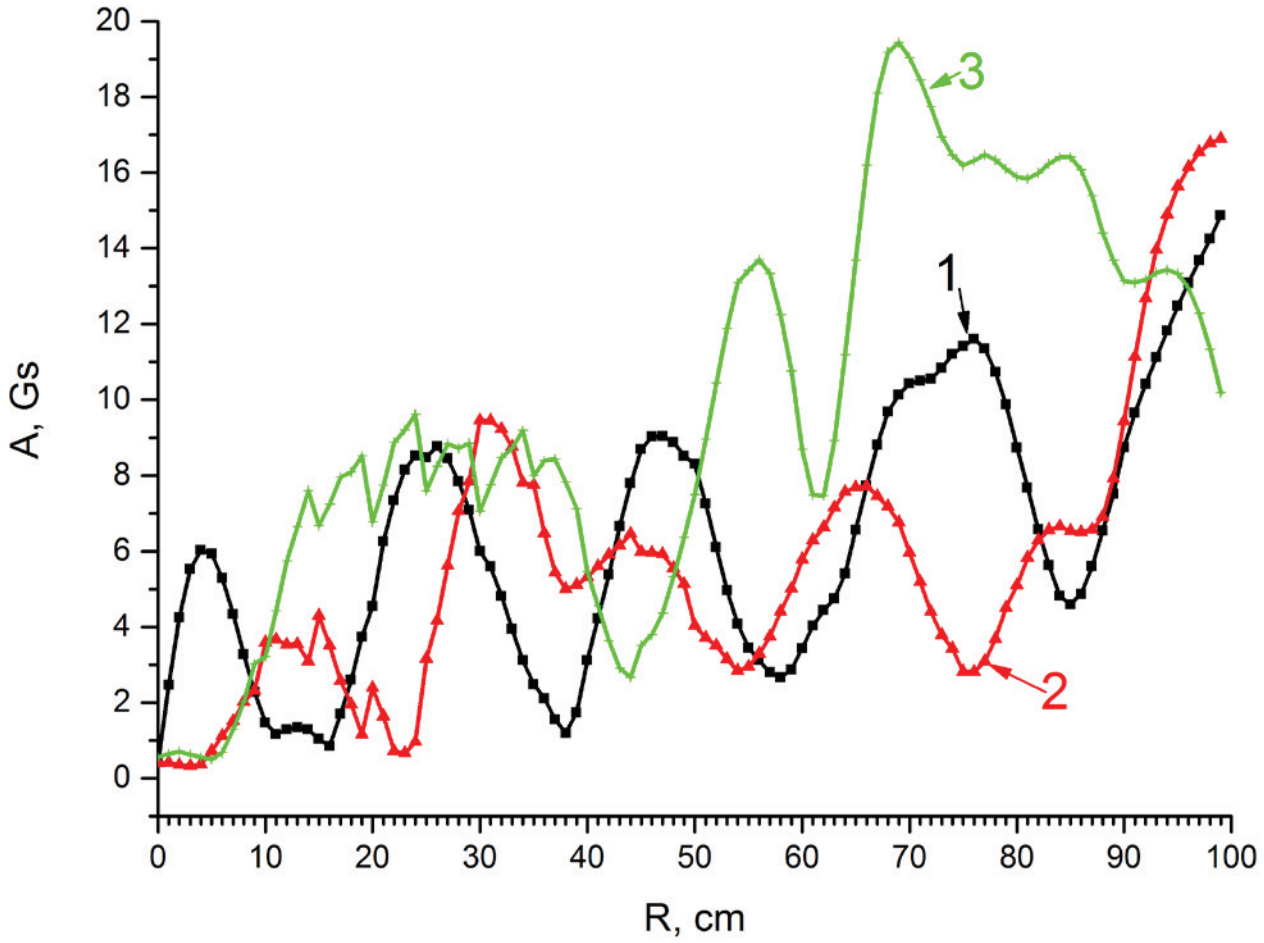
Final magnetic field C-80



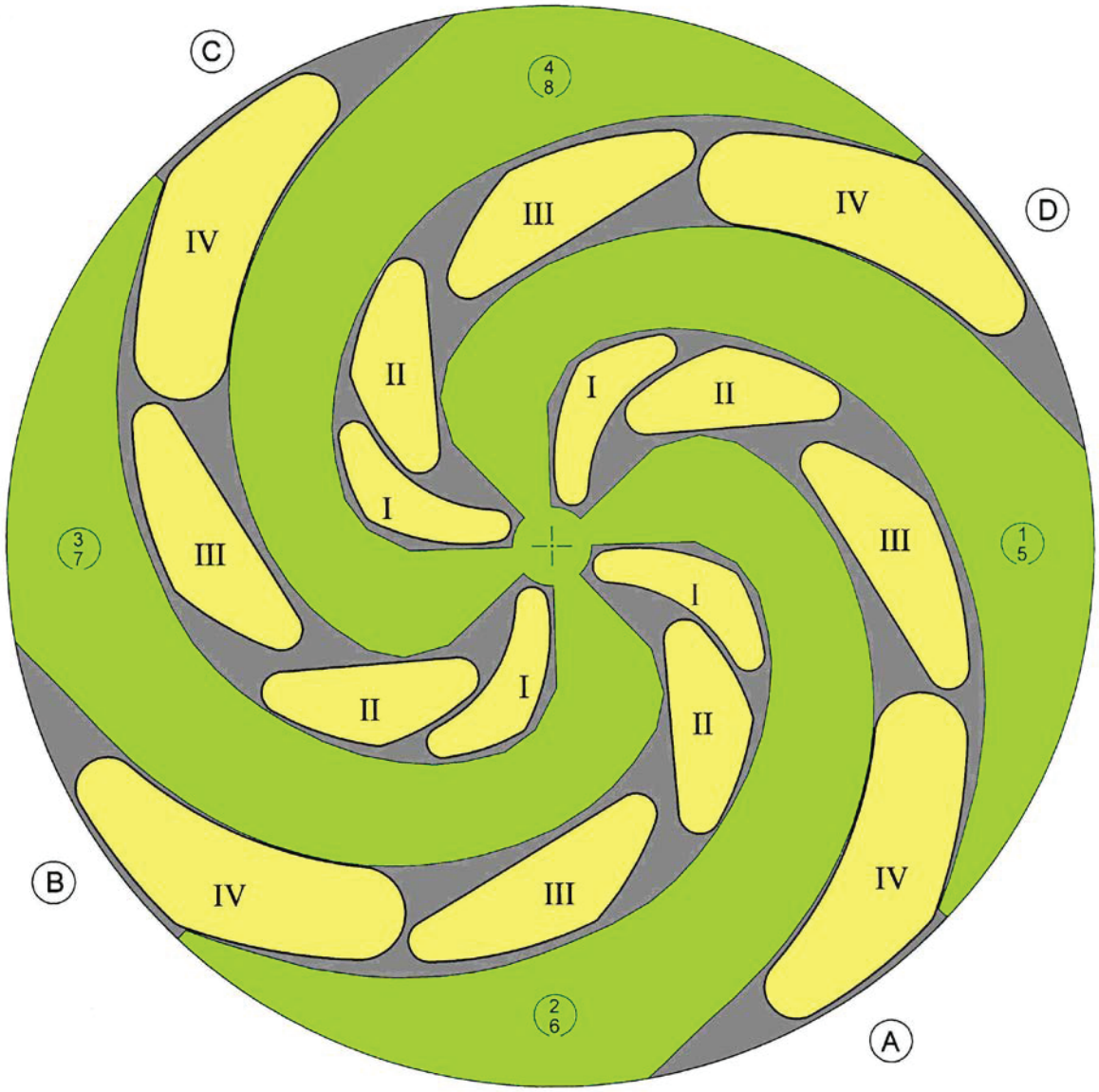
Main harmonics of the magnetic field C-80



A special attention was paid to reduce the lower harmonics.

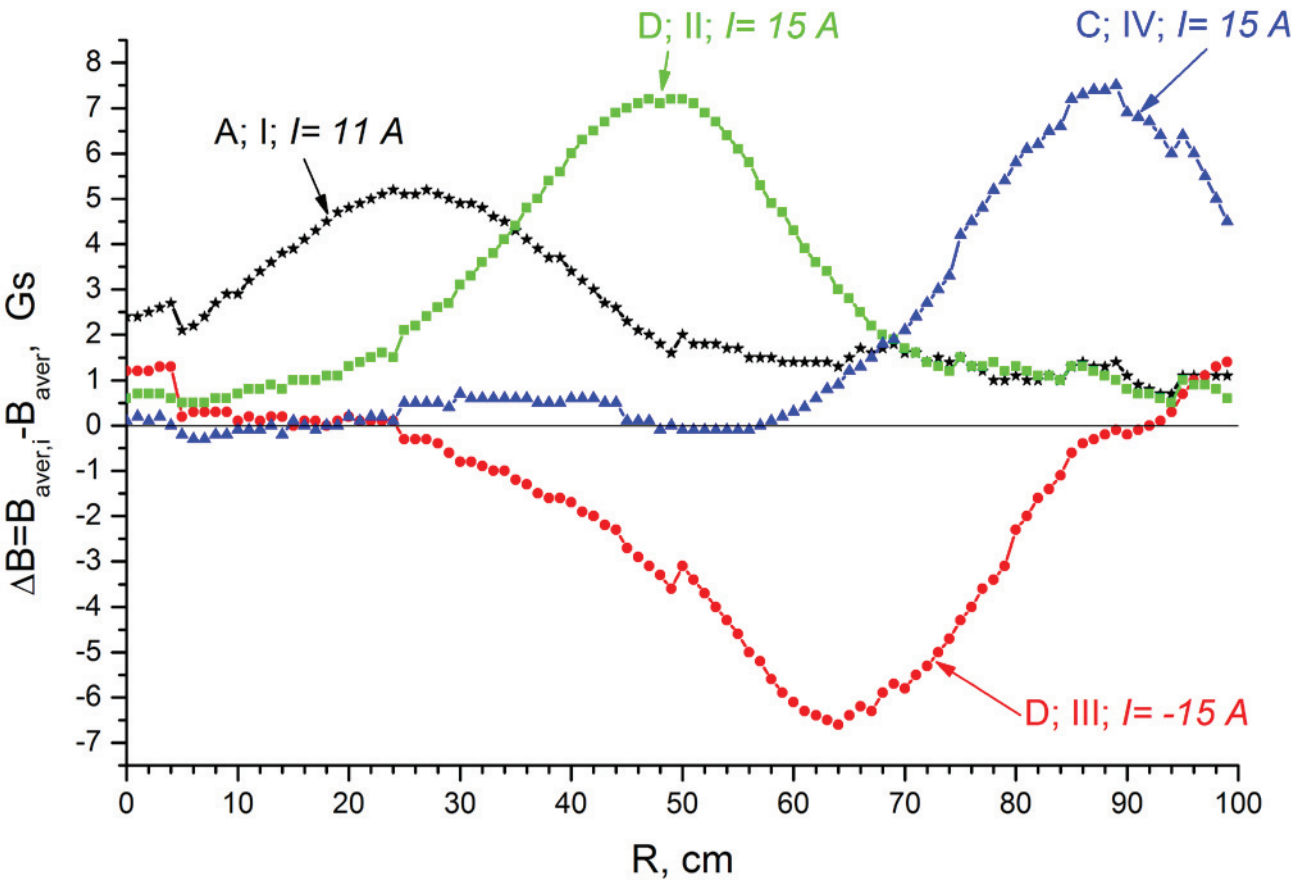


For an improvement of the accelerated beam orbits centering and reducing lower magnetic field harmonics, four pairs of azimuthal correcting coils were installed between the sectors at the radii 85–1025 mm.

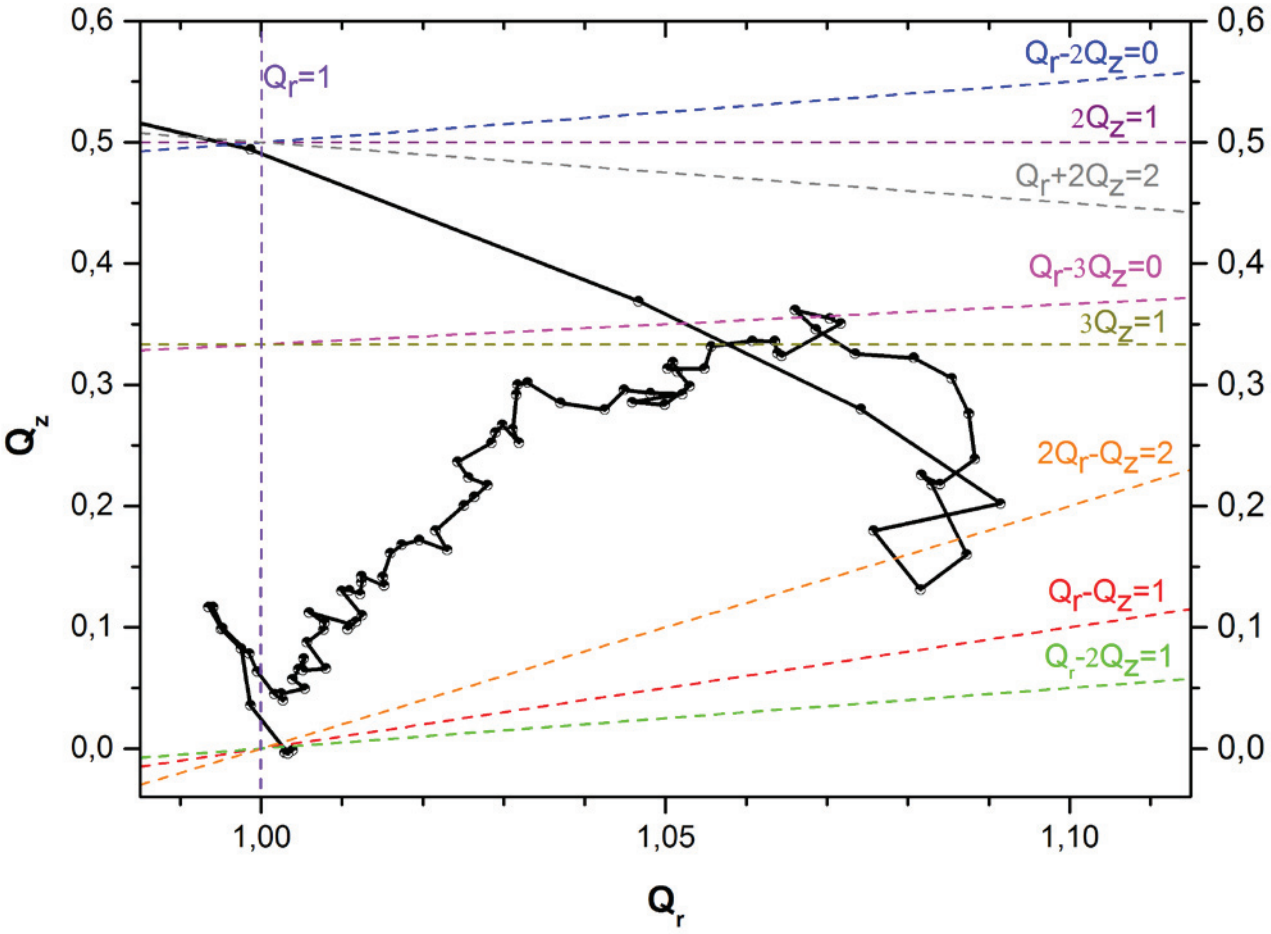


The magnetic fields of these four harmonic coils were measured and examined

The nominal currents in the harmonic coils of cyclotron C-80 were selected as follows:
I: I = ± 25 A,
II: I = ± 25 A,
III: I = ± 25 A,
IV: I = ± 42 A.



A special attention was paid to avoid dangerous resonances



CONCLUSION

Results of the final magnetic field distribution of the 80 MeV H-minus isochronous cyclotron at Gatchina are presented.

Main features and problems are connected with applying
the high spirality magnetic structure for acceleration of H– ions.

The formed structure permits to accelerate H– ions up to energy 80 MeV
using a rather small two-meter magnet,
the beam losses due to the ion dissociation being less than 3%.

As far as H-minus cyclotron operates at the fixed magnetic field,
the necessary field distribution was obtained by using iron correction shims only.

To obtain the necessary field distribution,
3D-computer calculations and successive magnetic measurements were very helpful.

In June 2016, a physical start-up of the C-80 cyclotron system was realized.

The design parameters of the cyclotron were obtained in November 2016.

Currently, intensive work is underway to develop and build a new ophthalmological tract. It will focus on the treatment of melanoma of the eye on a beam of protons with energy of 70 MeV, and will be used for the treatment of superficial forms of skin cancer.

Thank you for your attention

The number of ion turns in C-80 is about 400