STATUS OF THE GATCHINA ISOCHRONOUS CYCLOTRON

N. K. Abrosimov, S. A. Artamonov, V. A. Volchenkov, A. A. Vorobiev, S. P. Dmitriev, V. A. Eliseev, E. M. Ivanov, Yu. T. Mironov, G. F. Mikheev, G. A. Riabov, V. P. Fominenko

1. Introduction

Synchrocyclotron is in operation in PNPI up to now that accelerates protons with energy 1 GeV at beam intensity 1 μA [1]. The accelerator is applied for studies in physics of elementary particles, nuclear physics as well as for proton therapy and radioisotope production for medicine, etc. In the situation when cardinal reconstruction of the main accelerator becomes non-realistic it was decided to concentrate on the more modest program and to build H^- cyclotron on the energy 70–80 MeV with intensity of the accelerated beam about 100 μkA using available infrastructure and experience.

2. Main Purposes of Isochronous Cyclotron

The main purposes of the project can be formulated as follows:
- Stimulation of the traditional program of the investigation of short lived isotopes far from stability region. The yield of such isotopes for 80 MeV, 100 μkA beam is about 10 times as many as for 1 GeV, 1 μkA proton beam;
- An increase in production of the high quality isotopes for medicine;
- An opportunity of organizing the ocular melonome irradiation facility;
- An opportunity of the isochronous cyclotron future usage as injector for the next stage of acceleration.

3. Main Parameters of Cyclotron

The main parameters of the cyclotron were published at [2, 3], and they are presented in Table 1.

A general view of the cyclotron is shown in Fig.1.

Arrangement of the new cyclotron in the experimental hall of the operating synchrocyclotron is presented in Fig 2.

4. Main Features of Project

i). To minimize the expenditures:
- The cyclotron is installed in a building of the operating synchrocyclotron and an attempt is made to use the existing building, biological shielding, electric power and water cooling systems, ventilation, 30 tons bridge crane, etc.;
- An iron yoke of the existing synchrocyclotron magnet model after significant modifications is used for the magnet system.

Table 1

Gatchina Cyclotron Parameters

MAGNET	Pole diameter	2.05 m
	Valley gap (max.)	386 mm
	Hill (min.)	146 mm
	Number of sectors	4
	Spiral angle (max.)	65
	Field in center	1.352 T
	Flatter (max.)	0.02
	Extraction radius	0.85–0.90 m
	Ampere-turns	$3.4 \cdot 10^5$
	Power	120 kW
	Weight	250 tones
RF SYSTEM	Frequency	41.2 MHz
	Voltage	60 kV
	Harmonic	2
	RF Power	$2 \cdot 40$ kW
VACUUM	Pressure	$10^{-7}(N_2)$, 10^{-6} Torr (H_2)
	Turbomolecular pumps	$2 \cdot 10$ m^3/s
	Evaporation getter pumps	$2 \cdot 60$ m^3/s (H_2)
	Cryopanel, two, N_2	$S = 0.3$ m
H^- SOURCES	Internal Ehlers Pig	
	External: surface plasma, pulsed	
	surface plasma, stationary	
	multipole source	
	voltage	20 kV
EXTRACTION	Energy	45–80 MeV
	Method	Stripping

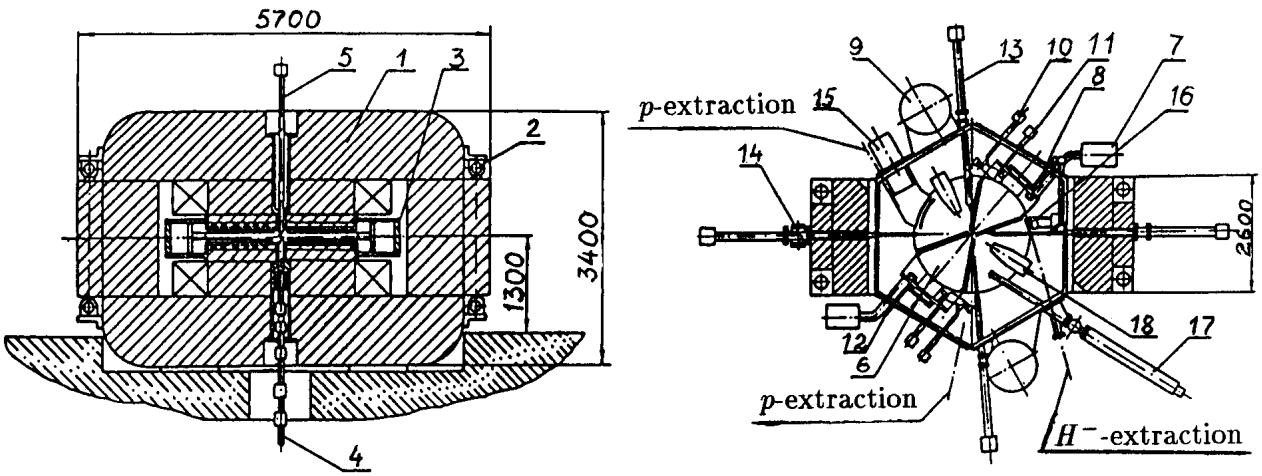

Fig.1. General view of cyclotron. 1 – Electromagnet, 2 – Hydraulic jack, 3 – Vacuum chamber, 4 – External injection system, 5 – Axial injection deflector, 6 – Resonance system (dee), 7 – Final cascade of RF generator, 8 – RF power input, 9 – Vacuum pump, 10 – Tuning condenser, 11 – Trimmer of automatic frequency tuning, 12 – RF probe, 13 – Diagnostics probe, 14 – Septum protection foil, 15 – Extraction system deflector, 16 – Magnetic channel, 17 – Stripping device, 18 – Criopannel

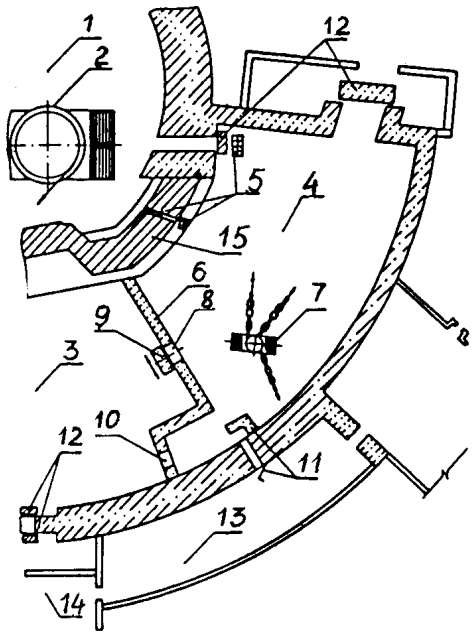

Fig.2. Scheme of cyclotron arrangement. 1 – Hall of synchrocyclotron, 2 – Synchrocyclotron, 3 – Experimental hall, 4 – Cyclotron hall, 5 – Additional shielding, 6 – Wall separating the cyclotron hall, 7 – Cyclotron, 8 – Opening for crane passage closed by a wheeled block, 9 – Crane cargo opening, 10 – Cyclotron hall entrance, 12 – Shielding doors, 13 – Control hall, 14 – Laboratories, 15 – Shielding wall from iron block

ii). Vertical focusing at the maximal energy has been achieved using very high value of the spiral angle (up to 65 degree) under rather modest value of the flatter. This kind of magnetic structure it is appropriate for the H^- cyclotrons because it grows less the field in the hill and as a consequence decreases the losses due to of H^- dissociation.

iii). A non-traditional vacuum chamber design. Magnet tips, the harmonic coils are located outside the vacuum chamber. This design facilitates problems of high vacuum production which is very important for H^- cyclotron.

5. Applied Programme on New Cyclotron

Energy of 75–80 MeV and possibility to regulate it are necessary for production of high quality isotopes using some reactions unattainable at lower energies. The Gatchina isochronous cyclotron may be used to produce large quantities of isotopes such as ^{18}F, ^{43}K, ^{52}Fe, ^{67}Ga, ^{111}In, ^{123}I, ^{201}Tl, ^{77}Br, etc., which could not be obtained with a help of nuclear reactors. In Table 2 are shown isotopes, the half-life time, demand of 30 St.Petersburg radiological hospitals per year, the accelerator time for production and cost of the produced radiopharmacentical preparation on Gatchina cyclotron.

Table 2

Isotope	$T_{1/2}$	demand for 10^3 Mbk/y	consumption of time (in h) to production/y	cost of radioisotopes (1000 $)
^{18}F	1.8 h	$(20–40)\cdot 10^3$	200–400	
^{43}K	22 h	400–800	200–400	
^{52}Fe	8 h	40–80	30–60	
^{67}Ga	3.3 d	300	70	348
^{111}In	2.8 d	860	450	2084
^{123}I	13 h	900	22	
^{201}Tl	3 d	700	95	970
^{77}Br	56 h	230	124	

Realization of this project should allow to meet the demand on short-lived radiopharmaceutical preparation for hospitals of North-West part of ex-USSR and may be Europe. The cost of the produced isotopes is so high that it is able to justify the expenditures on cyclotron creation during some years.

Another perspective direction of activity can be organization of the ocular melonome irradiation facility on the new cyclotron. For example, the cost of the melonome treatment on the PSI 72 MeV cyclotron is some millions dollars per year.

6. Present Status and Perspectives

The design of the main cyclotron systems is finished. The new accelerator hall with shielding wall and the basement construction has been accomplished. The magnet assembling is almost finished with the exception of pole tips and pole lifting system. The automatic system for magnet measurements based on the Hall probes is finished to be built.

The high frequency system is being simulated on models 1:2 and 1:1, the 41.2 MHz 15 kW generator was put into operation and the design of 40 kW final cascades of the generator has been finished.

The internal H^- ion source design is now being checked at a test bench, the evaporation getter pumps of NDMA-20 type are also under testing. The pulse external H^- ion source and the power supply system have been manufactured. The axial injection model construction has been started.

The directions of the research activity in the nearest future are as follows: finishing the magnet and beginning the magnet measurements and field correction; investigations of the external injection on the model and investigations of the central region of the cyclotron.

7. Summary

The project of 80 MeV isochronous cyclotron is in progress at PNPI. The design of the main cyclotron systems is almost finished and the realization of the project is about on half-way

done. The realization of the project offers ample scope for progress in both applied and fundamental nuclear physics programs on PNPI. Provided the financing be substantial, the first cyclotron beam could be generated in two–three years.

REFERENCES

1. *Abrosimov N.K. et al.* Proc.of the 7th All-Union Conference on Charged Particles Accelerators. Dubna, 1980. V.2. P.75.
2. *Abrosimov M.K. et al.* Proc.of the 13th Int.Conf. Vancouver, 1992. P.58.
3. *Abrosimov N.K. et al.* Proc.of the 13th Conference on Charged Particles Accelerators. Dubna, 1992. P.155.