103-cm COMPACT ISOCHRONOUS CYCLOTRON

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A B S T R A C T

The description of compact variable-energy isochronous cyclotron is given. At present the manufacturing of main units of the prototype of the accelerator has been accomplished in D.V.Efremov Scientific Research Institute of Electrophysical Apparatus (SRIEA).

The cyclotron is intended for acceleration of protons, ions of deuterium, helium-3 and helium-4 and can be used for production of radioactive isotopes, activation analysis and for investigation in the field of medicine, biology and nuclear physics.

INTRODUCTION

Below in table I the designed range of energy of different type particles at the 103-cm compact isochronous cyclotron is indicated:

Table 1

Particle type	Internal Beam Energy, MeV	External Beam Energy, MeV
Protons	2 ÷ 20	5 ÷ 18
Deuterium ions	1 ÷ 11	3 ÷ 10
He^{+2}-3 ions	4 ÷ 27	8 ÷ 24
He^{+2}-4 ions	2 ÷ 22	6 ÷ 20

The designed intensity of an external beam of hydrogen isotope ions is up to 50 μA and that of helium isotope ions is up to 25 μA. The target with small radial shifting allows to operate with an internal beam up to 6 kw (300 μA at 20 MeV, for example for protons).

In comparison with the original design [1] the maximum proton energy is increased and the range of energy of all ions into low value region is extended.

At accelerator design great attention was paid to the development of safe and simple installation by means of which one can obtain intensive high quality beams of different particles.

The cyclotron size with all auxiliary equipment allows to install it in usual areas. Thus, the size of shielding vault can be 6x6 m^2.

The accelerator can be provided by the beam transport system. The equipment of transport system involves quadrupole lenses, 45° bending magnets, pickups and beam positioning magnets, targets and ion tubes with vacuum pumps. For beam analysis the 115° analyzing magnet with energy resolution better than 0.1% is designed.

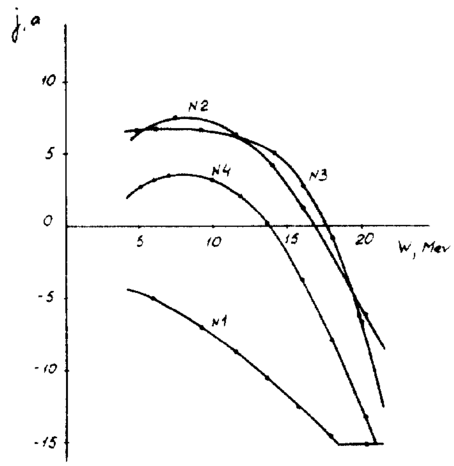
1. Electromagnet and magnetic field characteristics

Fig.1 shows a photograph of magnet with removed upper yoke. The sectors are covered by 6 mm copper plating with the four trim coils.

Fig.1. General view of the cyclotron electromagnet during assembly. The sectors and harmonic coils of the lower pole are shown.

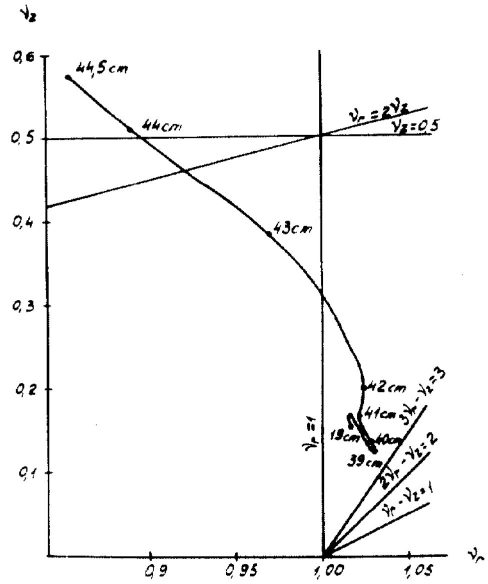
The magnet is supplied by a static device with the power up to 35 kw, providing long-term stability of the magnetic field at the level of ±0.01%.

Magnetic measurements were carried out at ten levels of magnet excitation between 7 and 15 kGs. Low operating induction and rounding of sector boundaries weakened the influence of saturation effects. So, in the given induction range the flutter value changes only by 3%, and the variations of average magnetic field strength at final radius (45 cm) in comparison with the field in the center are from - 2% at low induction to - 1% at high induction. This allowed to use small power trim coils. The contribution of each coil is not more than ±120 Gs at the current ±15A. The total supply power of four trim coils does not exceed 0,6 kw. Fig.2 shows the calculation results of current values in coils for designed proton energy range.



The currents in trim coils do not exceed the given limits for designed energy range of deuterium, He^{+2}-3 and He^{+2}-4 ions.

Fig.2
The diagram of current variation j in trim coils in the full mode of proton energy control W. The digits on the curves indicate coil numbers.



Harmonic coils in center region and in the zone of final radius allow to correct the first harmonic with amplitude up to 20 Gs without distortion of the average field. The measured amplitude of the first harmonic in the real field is 5÷8 Gs.

Fig.3 shows the position of the operating point in coordinates ν_r, ν_z in the case of proton acceleration up to 18 MeV.

Fig.3. The operating line of proton acceleration mode up to maximum energy. In the given points the average orbit radii are indicated.

2. R.F. System

A picture of cyclotron resonance system is shown in fig.4. A panel-type cavity has frequency overlapping range from 8 to 24 Mc/S. The operating frequency is selected by changing the panel position. The accelerating dee voltage is 35 kv relative to ground.

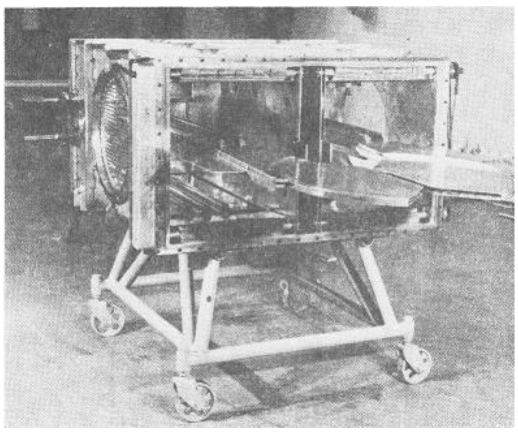


Fig.4
The resonance cyclotron system. Panel position corresponds to the minimum frequency of the accelerating voltage.

R.f. generator has three cascades: master signal cascade, intermediate wide band amplifier and powerful output cascades, placed on the cavity. The output power of r.f. generator is up to 80 kw.

3. Vacuum System, Ion Source, Beam Extraction System

Two diffusion pumps with total efficiency of 2.500 1/sec provide for vacuum up to $5 \cdot 10^{-6}$ torr in one hour after starting. There is a gas recovery system of expensive helium-3.

Ion source with hot cathode is inserted into the chamber axially to the magnet poles and has a remote control along the dee system within 15±4 mm relative to magnet axis.

The beam extraction system consists of electrostatic deflector with angular length of 37^{0}, placed in the spacing between the dees, and radial-focusing magnetic channel of ferromagnetic rods. The deflector position relative to magnetic structure, at the boundary "hill-valley" was defined from the point of view of obtaining the minimum radial beam divergence at sufficiently effective deflection from equilibrium orbit.

4. Beam Transport System

Quadrupole lens doublets, 45° bending magnets, beam positioning magnets and 115° analyzing magnet are especially designed for beam transport channels. The structure and equipment arrangement of beam transport track in each case is defined by specific conditions, for example, by existing areas Thus, fig.5 shows compact cyclotron equipment layout for the laboratory areas "Åbo Academy" in Turku (Finland).

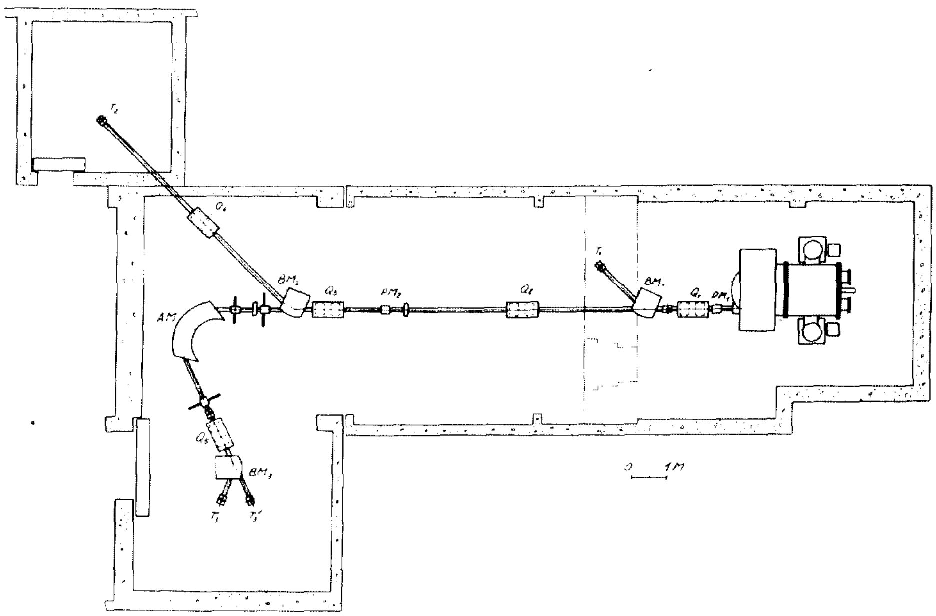


Fig.5. The layout of the compact cyclotron equipment for Turku University (Finland): Q - quadrupole; BM - bending magnet; AM - analyzing magnet; PM - beam positioning magnet; T - target.

The transport system includes the necessary vacuum equipment, as well as the pickups and targets. For the scheme, given in fig.5 the total consumed power from 3x380 V mains is about 300 kw.

REFERENCES

1. A.G.Alekseev et al. "Basic design parameters of a small size isochronous cyclotron". The Proceedings of V International conference on isochronous cyclotrons, Oxford, 1969, 559, London,1970.