THE KAZAKHSTAN 1.5 METER SECTOR-FOCUSED VARIABLE-ENERGY CYCLOTRON

A. A. Arzumanov, E. A. Meleshko,
R. A. Meshcherov, L. M. Nemenov

Institute of Nuclear Physics,
Academy of Sciences Kazak SSR

(Presented by L. M. Nemenov)

1. INTRODUCTION

At the beginning of 1961 we concluded the studies on the 1.5 meter cyclotron of the Institute of Atomic Energy imeni I. V. Kurchatov*. The azimuthal magnetic field, with a strength variation of about ±15 percent, was generated by three sectors approximately 60° wide. At the inner surface of each cover of the accelerator chamber we mounted eight correcting coils. Each coil had its individual electrical power supply. This coil system allowed one to correct the average value of the magnetic field strength along the radius and fixed the acceleration and extraction of ions over a wide range of values of the magnetic field strength. The correction of the median plane of the magnetic field and the control of the first harmonic of the azimuthal inhomogeneity were also carried out by means of current windings. The changes in the wave length of the oscillations of the resonant circuit over the 23.1--38.3 m band were achieved by shifts in the position of the shorting elements.

The ion beam extraction from the accelerator chamber was carried out by means of a deflector system with an inhomogeneous electric field. The extraction coefficient under various accelerating conditions varied from 25 up to 60 percent. The ion currents in the extracted beam were of the order of 50--400 μA. Deuterons were accelerated and extracted from the accelerator chamber with an energy of 31.5 MeV and a current of approximately 70 μA. The energy of the ions was controlled within the 5--17 kOe range of values for the magnetic field.

2. GENERAL INFORMATION ABOUT THE RECONSTRUCTED CYCLOTRON

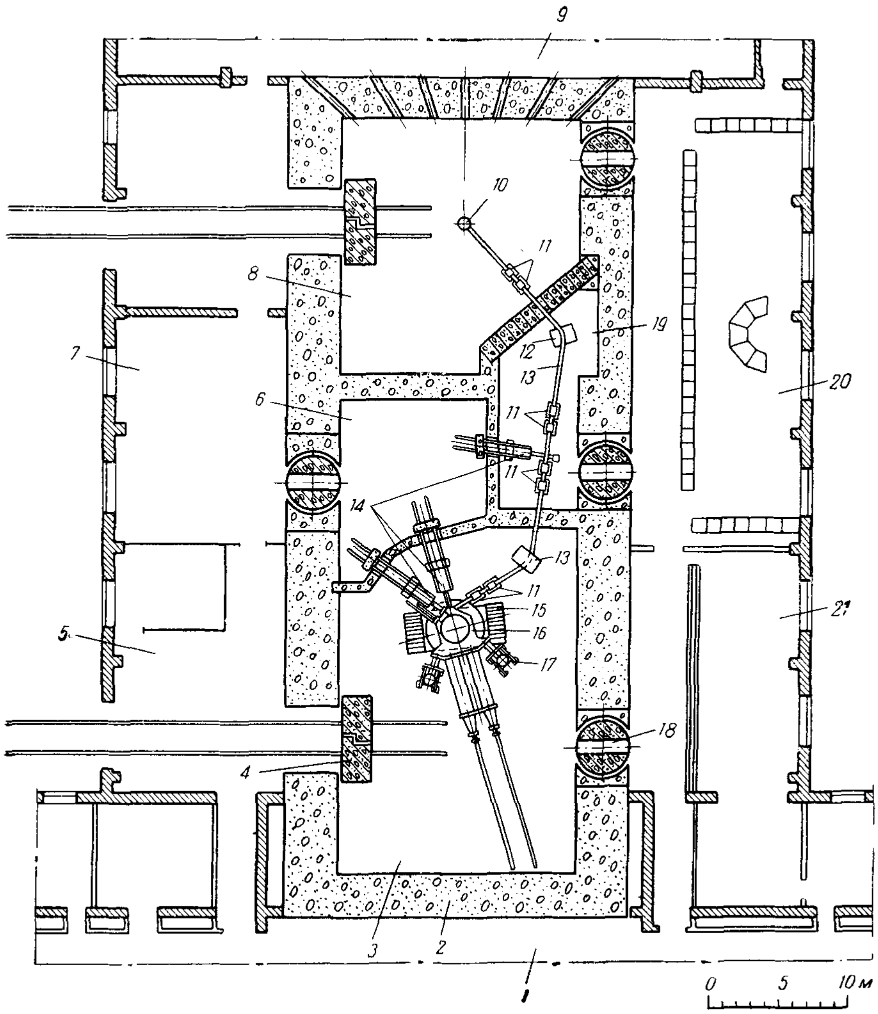
Presently, at the Institute of Nuclear Physics, Academy of Sciences Kazak SSR we are finishing up the construction of the 1.5 meter cyclotron described in Section 1 earmarked for the production

---

*Arzumanov, A. A., Meshcherov, R. A., Mironov, E. S., Nemenov, L. M., Rybin, S. N., Kholmovskiĭ, Yu. A. _Atomnaya energiya_ (Atomic Energy), Vol 12, 12 (1962).

of intensive beams of protons, ions of molecular hydrogen, deuterons, α-particles, and multiply-charged ions.

The design of this device was developed by the Scientific-Research Institute of Electrical Physics Equipment imeni D. V. Efremov and the group of co-workers of the Institute of Atomic Energy imeni I. V. Kurchatov.



Layout of the ground floor of the cyclotron laboratory building and the disposition of the equipment:

1 -- Laboratory part of the setup; 2 -- concrete shielding; 3 -- main hall; 4 -- sliding gate; 5 -- hall for preparatory work; 6 -- hall for the remote control of target irradiation; 7 -- high-speed workshop; 8 -- experimental hall; 9 -- hall for work on fast neutron beams; 10 -- target position; 11 -- quadrupole magnetic lenses; 12 -- rotational magnets; 13 -- ion duct; 14 -- devices for target irradiation; 15 -- electromagnet; 16 -- accelerator chamber with resonant lines; 17 -- high vacuum pumps; 18 -- rotating doors; 19 -- points of intermediate focusing; 20 -- main control desk; 21 -- hf-generator space.

During the design of the cyclotron special attention was paid to the reliability of the shielding and the radiation protection technology. The control of the basic operations and the irradiation of targets for production of radioactive isotopes is carried out remotely by means of special mechanisms. For experimental work at the minimum level of cyclotron photon radiation, the ion beam is conducted through the main shielding wall into the experimental hall which is further equipped with separate shielding. The cyclotron laboratory is located within a two-story building with one level underground. The figure shows the layout of the ground level and indicates the distribution of the equipment. Part of the auxiliary equipment is mounted in the underground level.

The diameter of the pole pieces of the electromagnet is equal to 150 cm. The electromagnet windings are cooled by distilled water. The cover of the chamber is rigidly connected to the pole pieces of the electromagnet. The accelerator chamber is in two parts and can be dismantled. Rubber gaskets are used for sealing the body and the covers of the vacuum chamber.

The resonant loop of the cyclotron consists of two coaxial lines loaded by the dees. The shift of the dees in the vertical and horizontal planes and their rotation around the decoupling rods can be carried out by remotely controlled adjusting devices without affecting the vacuum. Changes in the wave length of oscillations of the resonant loop can be achieved over the 20--35 m region by shifting the shorting plates without disrupting the vacuum. The resonant system of the cyclotron is fed by about 300 kW of power from a multi-cascade generator. The potential difference between the dees may be raised up to approximately 150--200 kV.

For mounting convenience and for partial dismantling of the device the resonant lines with the dees may be rolled away from the accelerator chamber on a special cart and the dismantling of the system is then carried on outside the coils of the electromagnet.

The beam extraction from the accelerating chamber is carried out by means of a deflector system using a nonuniform electric field. The extracted beam is then focused by two magnetic quadrupole lenses (see figure) and is further rotated through an angle of about 50° by a sector magnet. Two further magnetic lenses follow the rotating magnet. This system allows the production of an intermediate focus and the positioning of a movable diaphragm for beam monochromatization. The second part of the focusing system is similar to the first and consists likewise of four magnetic quadrupole lenses and a rotating magnet. This system focuses the beam of charged particles on the target location earmarked for fundamental physical investigations. From this location, through special openings in the shielding, one can extract (at different angles) the secondary beams of fast neutrons created during the collision with the target and having a flight path of 25 m.

The cyclotron can accelerate protons up to an energy of approximately 17 MeV, deuterons up to about 22 MeV. The current of the extracted beam is approximately 100 μA. The extraction coefficient of the deflecting system is about 30--40 percent.

3. THE BASIC PARAMETERS OF THE CYCLOTRON WITH SECTOR FOCUSING AND VARIABLE ENERGY

The cyclotron described in Section 2 is being reconstructed into an instrument with sector focusing and variable energy.

The azimuthal variation of the magnetic field strength is produced by three iron sectors with small "helicity." The gap between the sectors is about 160 mm, while between the depressed portions -- 390 mm. The depth of variation is about ±40 percent.

The correction of the shape and intensity of the magnetic field is secured by 19 current coils mounted on each of the covers of the chamber. The windings are protected from the discharge by cooled copper screens.

We designed three systems of coils. Two systems (nine coils) are placed within the depressions and allow the removal of unwanted azimuthal inhomogeneities of the magnetic field while increasing the depth of modulation and, consequently, strengthening the axial focusing. Two circular adjustment coils, distributed from the center towards the periphery, permitted the attainment of the necessary shape of the magnetic field for an isochronous acceleration of the ions.

Tests were carried out on a 1/5-scale model of the basic electromagnet and are not concluded yet. They will be continued later on a model 1/3 of its actual size.

The electromagnet should produce a maximum field strength at the center of the magnet of about 17 kOe. During the acceleration of the protons up to their maximum energy the mean field should increase towards the periphery by about 4 percent.

The resonant loop consists of wave guides loaded by a 6 cm high dee. The hf potential of the dee with respect to ground may be raised as high as to 100 kV. The dee position is remotely controlled.

The variations in wave length of the oscillations of the resonant loop can be carried out, without disturbing the vacuum, within the 12.5--37.5 m range by shifting the shorting element which is equipped with pneumatic contacts. Measurements on a full-scale wooden model covered with copper foil showed that the loop designed indeed covers the specified wave length range. The accelerator chamber is equipped with numerous probes which can be displaced by mechanisms controlled from the main console. The vacuum within the system is obtained by two oil-vapor pumps of 8000 ℓ/sec capacity each.

The ion source is of the slit type with an incandescent cathode, remotely controlled, and may be completely removed with the help of a gate valve without disturbing the vacuum. To allow the acceleration of polarized ions, the upper beam of the magnet and its pole piece have an opening 150 mm in diameter for the introduction of a vertical ion source. The charged particle beam is extracted by an electrostatic deflector system covering approximately 50° and a magnetic channel located within the depression.

The reconstructed cyclotron should produce accelerated protons from 5 up to 40 MeV, and deuterons from 10 to 32 MeV. The current of the extracted beam reaching the distant target should be of the order of 50--100 μA. The reconstructed cyclotron should be ready for operation in 1965.

DISCUSSION

R. S. Livingston

What special plans have you made to handle radioactivity?

L. M. Nemenov

Firstly, we have a very efficient concrete shield protecting us from radiation. Secondly, all copper parts are protected by graphite. Thirdly, all manipulations with the external targets are carried out automatically once they are positioned by the operator.