THE USE OF A CLASSICAL CYCLOTRON WITH 28 MeV PROTON ENERGY FOR THE PRODUCTION OF ^{201}Tl AND ^{68}Ge

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The use of steel shims made it possible to obtain in a classical 1.5-m cyclotron a proton beam with an energy of 28 MeV for the production of ^{201}Tl and ^{68}Ge.

1 Introduction

The Cyclotron Company Ltd. is the main producer of cyclotron-made radioisotopes and radiation sources based on them in Russia . High on the list of produced radioisotopes are ^{57}Co, ^{67}Ga, ^{109}Cd and some others. Radioisotopes are produced in a classical cyclotron with the following major specifications: diameter of pole face, 150 cm; resonance frequency, 16.1 MHz; maximum dee-to-dee potential, 250 kV; maximum proton and deuteron energy, 22 MeV; beam radius, 64 cm; average target grazing beam current, up to 700 μA (power dissipation, about 15 kW).

The Cyclotron Company Ltd. constantly extends the range of products and increases the cyclotron capacity. Among the most widely used radioisotopes is ^{201}Tl. However, it is desirable to have a proton energy of 28 MeV for its production, which is also favourable for the production of ^{68}Ge, since in this case the production rate is higher and costs are lower.

2 Increasing the proton beam energy

It is well known that the maximum energy of protons obtained in a classical cyclotron with axially symmetric magnetic field does not exceed 24 MeV. Switching to isochronous mode of operation requires that the cyclotron be shut down for a long time, which is unacceptable to us. The Cyclotron Company Ltd. is a commercial enterprise, and its cyclotron operates in irradiation mode for 7,000 hours per year, i.e. 80 % of the annual time limit.

We coped with the task differently. With minor modifications we managed to produce protons with an energy of 28 MeV after shutting down the cyclotron for a very short time. For this purpose, the oscillator frequency was increased to 17.8 MHz, and steel sector shims were inserted into a gap between the vacuum chamber and magnet poles (Fig. 1). The shape of magnetic field fall-off along the radius was measured using coils of the known sensitivity and Hall-effect sensors. Fig. 2 shows the obtained shape of magnetic field fall-off averaged over the azimuth angle (the radial distribution of the average magnetic field), with a magnetic field strength at the cyclotron center of 11,500 oersteds. As seen from the figure, the obtained shape of magnetic field fall-off makes possible the optimum acceleration of protons to a radius of 67 cm (the magnetic field fall-off is 1.4 %).

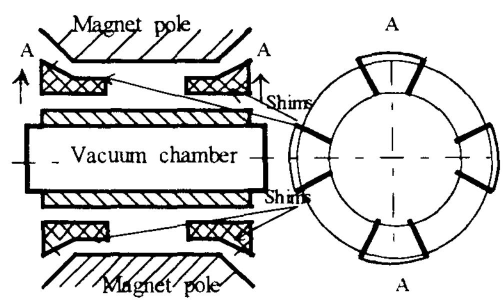

Fig. 1: The installation of steel shims.

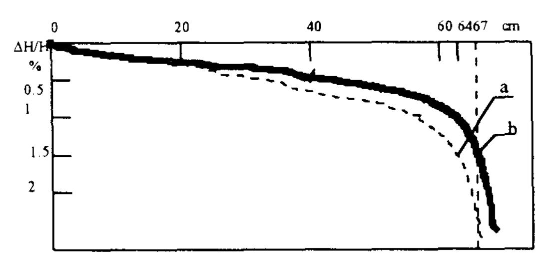

Fig. 2: The radial distribution of the average magnetic field (a – without shims, b – with shims).

Using a well-known formula [1]:

$$H \cdot r = \frac{1}{0.300}\,(T^2 + 2T \cdot E_0)^{1/2}$$

(Koersteds, cm, MeV),

which relates magnetic field strength (H), acceleration radius (r), energy of accelerated particles (T) and proton rest energy (E_0), and substituting the obtained values in this formula, we get an energy of 28 MeV for protons accelerated to this radius.

For a target installed in a radius of 67 cm the achievable beam intensity was 250 μA with a beam intensity in pulse of 3,000 μA for a centered orbit. The target was placed in a target assembly [2] at an angle of 9° to the incident beam. The vertical beam distribution in different acceleration radii was determined using a three-lamella probe. The radial beam distribution in the final acceleration radius was measured using a target probe, i.e. a probe, in which five vertical lamellas were placed in the position of further installation of the target. In the process of acceleration, the beam orbit center position was controlled by the method of two probes [3].

An infrared radiometer [4] was used for control of the target surface temperature in the process of bombardment. Using this radiometer, we determined not only the temperature, but also the temperature distribution over the target surface, which enabled us to prevent the target surface from overheating and damage in the process of bombardment.

Increasing the energy of accelerated protons to 28 MeV provides a possibility to carry out the production of ^{201}Tl and to increase the production rate of ^{68}Ge. The production methods are described below.

3 Production of ^{201}Tl

A thin target with a copper base and a surface coating of electroplated enriched ^{203}Tl is used for the production of ^{201}Tl. The proton energy decreases in the thallium layer from 28 to 21 MeV. The beam intensity on irradiation is 200 μA.

An extraction technique has been developed for isolating ^{201}Tl with the following characteristics: specific activity is no less than 1000 mCi/mg, radioisotope purity is no less than 99.8 % (^{202}Tl < 0.2 %), chemical impurities are no more than 0.5 μg/mCi for Fe and 0.2 μg/mCi for Cu.

4 Production of ^{68}Ge

For the production of ^{68}Ge we use a target with a copper base ? d Ga-Ni alloy (60 % of Ga and 40 % of Ni) applied on its surface by hot pressing. The beam intensity on the target surface is 200 μA. The target surface temperature does not exceed 210° C. An ingenious technique has been worked out for the target processing, which makes it possible to extract no less than 90 % of ^{68}Ge. The extracted product is a carrier-free ^{68}Ge in 0.5-1.0 M HCl with a radioisotope purity of no less than 99.8 % (^{71}Ge is not taken into consideration).

Using the produced ^{68}Ge, we manufactured generators of ^{68}Ga and radiation sources for calibrating positron emission tomographs.

5 Conclusion

Thus, with minor modifications we managed to produce protons with an energy of 28 MeV in a classical cyclotron without shutting down it for a long time and switching it to isochronous mode. This enabled us to master the production of ^{201}Tl and increase the production rate of ^{68}Ge.

References

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