NEW FORM OF EXPLOITATION OF CYCLOTRON U-120

J. Dobšíš, T. Fukátko, A. Hrdá, O. Karban, M. Krivánek, K. Kult

Nuclear Research Institute, Czechosl. Acad. Sci., Rež

Experiments carried out on the Nuclear Research Institute cyclotron U-120 showed that the energy of the output beam can be changed in the region 6.2–7.2 MeV/nucl without additional correction of the radial slope of the magnetic field (e.g. with the use of ferromagnetic shims suitable for an energy of 6.7 MeV/nucl). Using a combination of ring and disc shims, ions of atomic hydrogen were accelerated in the energy region 8.5–10.7 MeV and ions of \( ^3\)He\(^{2+} \) with energy 21 MeV. The intensities of these beams, except \( ^3\)He\(^{2+} \) having been accelerated in the economical regime of the ion source, reached as much as 100 pA behind the deflector. The possibility of smooth regulation of the energy without changing the classical character of the accelerator is also discussed.

1. INTRODUCTION

The U-120 cyclotron at the Nuclear Research Institute has been used since 1960 for experiments with accelerated ions \( \text{D}^+ \), \( \text{H}^+ \), \( \text{He}^{2+} \) with an energy of 6.7 MeV/nucl, but its possibilities are much wider, as can be seen from Fig. 1. The region of energy of accelerated ions is determined by the basic parameters of the cyclotron: being the frequency region of the RF generator (8.33–16.66 MHz [1]) for protons, and for ions with \( Z/A = 1/2 \) being the induction of the magnetic field which cannot exceed \( B_0_{\text{max}} = 1.55 \text{ Wb/m}^2 \).

Moreover, ions with energy about 1 MeV/nucl can be obtained by means of acceleration on the third harmonic. Acceleration of the heavier ions is limited first of all by the electric strength of the deflector.

2. ACCELERATION OF \( \text{D}^+ \), \( \text{H}^+ \) AND \( ^3\)He\(^{2+} \) ON THE BASIC FREQUENCY AND \( \text{D}^+ \) ON THE THIRD HARMONIC

The possibility of changing the energy of ions of an output beam without correcting the ferromagnetic shims has been investigated using deuterons and ions of \( \text{H}^+ \) [5]. At the same time the possibility was contemplated of substituting the energy attenuator by means of bremsstrahlung foils for the purpose of preserving the intensity as well as the optical features of the output beam. A couple of ring shims \( (5.5 \times 7.2/7.5 \times 3.6 \text{ mm}) \), corresponding to an energy of 6.7 MeV/nucl (e.g. for \( B_0 = 1.45 \text{ Wb/m}^2 \)), in this case ensured a radial slope of the magnetic field necessary for the beam focusing. At the edge points of the energy region \( 6.2–7.2/\text{MeV nucl} \) the intensity of the beam decreased to 25% of its value at 6.7 MeV/nucl.

For accelerating the ions of atomic hydrogen \( \text{H}^+ \) [2] disc- and ring-shims were used [3] ensuring the radial slope of the field on the final orbit lower than 2% for \( B_0 = 0.9 \text{ Wb/m}^2 \). The measured interval of the energy of protons with the intensity decrease to 30% was 8.7–10.7 MeV. After some adjustments of the RF system the energy of 10.7 MeV can be increased even more.
New Form of Exploitation of Cyclotron U-120

Using these shims the magnetic field was decreased to $B_0 = 0.63$ Wb/m², thus ensuring acceleration on the third harmonic ions $^2\text{H}^+$ and $^3\text{D}^+$ of energy $1.3$ MeV/nucl and intensity $10 \mu$A behind the deflector.

The acceleration of $^3\text{He}^{2+}$ ions was carried out in two energy regions, the first (Fig. 1) being for $B_0 = 1.45$ Wb/m² and $f = 14.2$ MHz, which corresponds to an energy of $31$ MeV. As the electric strength of the deflector prevented the voltage from being increased up to $85$ kV, necessary for outputting the beam, $^3\text{He}^{++}$ ions were used for bombardment of the inner Pt target. The external beam $^3\text{He}^{++}$ of energy $21$ MeV and intensity $3 \mu$A behind the deflector was obtained by decreasing the induction of the magnetic field to $B_0 = 1.08$ Wb/m² as well as by using a new combination of ferromagnetic shims (disc: $\phi 286 \times 8$ mm, ring: $3 \times 40$ mm).

Fig. 1. Operating region of the cyclotron U-120.

The radial slope of the magnetic field $\delta B(R)$, measured by Hall's probe and registered by a digital voltmeter, is shown for different values of $B_0$ in Fig. 2 [4]. The energy of the output beam was measured in the target chamber by means of a semiconducting detector after scattering on a carbon or a golden target. Impulses from the detector were recorded on a multichannel amplitude analyser. For energy calibration an alfa-ray-emitter Thsup{238}sup{+} was used.

Fig. 2. Course of the slope and index of the magnetic field for accelerating the $^3\text{He}^{++}$ ions at energy $20$ MeV for magnet current $250$ A (broken line); $350$ A (solid line).