HEAVY ION CYCLOTRONS DEVELOPMENT AT JINR

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The cross sections of a wide range of nuclear reactions are 10^{-35} - 10^{-36} cm^2 and therefore it is necessary to provide at the target the beam intensity of 5 10^{12} - 1 10^{13} 1/sec during the whole week of accelerator running.

For the synthesis of superheavy elements the desired energies of ion beams should reach the Coulomb barrier level of 5.0 - 6 MeV/nucleon.

The U-400 accelerator is designed for these specific tasks. It accelerates heavy ions with charge to mass ratio of Z/A = 0.08 - 0.2. The ion mass in these experiments is less than 60. The PIG and ECR ion sources may be used presently as ion sources for cyclotron. The dependences of ion beam outputs from PIG[1].and ECR[5] sources on Z/A for ^{14}N, ^{40}Ca and ^{129}Xe are presented in fig. 1. The figure shows trat for the U-400 accelerator, using Z/A = 0.1 a PIG type source surpasses an ECR source in the ion beam intensity. The efficiency of beam utilization for accelerators with internal ion sources of the PIG type and phase range of 30-40° equals 1-3%.

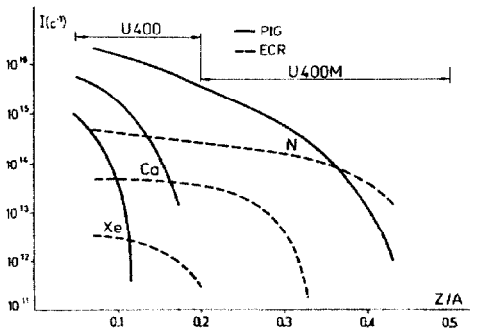

Fig. 1. The comparison of ion beam intensities for PIG and ECR sources at different Z/A

Fig. 2 presents the potentialities of a cyclotron with a PIG type internal source. All the operating JINR heavy ion cyclotrons use internal sources of the PIG type.

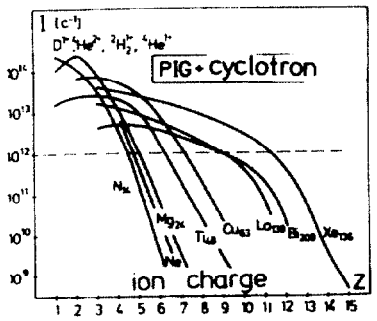

Fig. 2. The potentialities of a cyclotron using a PIG type source

The dependences of accelerated beam maximum intensities on ion masses for the U-200, U-300 and U-400 cyclotrons are presented in fig. 3.

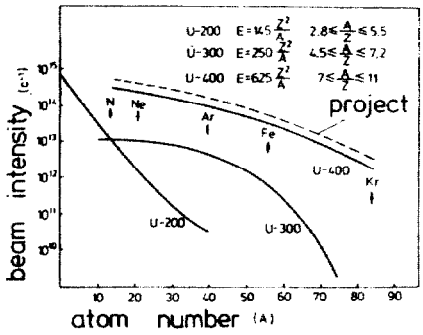

Fig. 3. The dependence of the maximum intensities of accelerated beams on the ion mass for U-200, U-300 and U-400 cyclotrons

Beam extraction from the U-300 cyclotron is performed with an electrostatic deflector. The extraction efficiency is approximately 50% for the phase range of 30-40°. Due to the increase of deflector leak-current up to 2.5 - 3 mA the extracted beam intensity is limited to 10^{13} c^{-1} (fig. 3).

Fig. 4 presents the dependence of deflector leak-current on the internal beam power of the U-300 cyclotron.

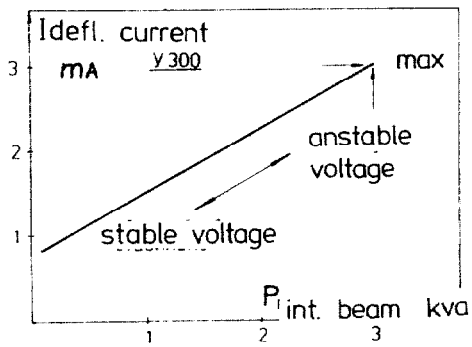

Fig. 4. The dependence of the deflector leak current on the power of the U-300 internal beam

The ion beam extraction in the U-400 cyclotron is performed by the method of charge exchange on a thin carbon foil of equilibrium thickness[3].

At beam intensities of 10^{12} - 6 10^{12} c^{-1} the foil temperature exceeds 2000°K and the foil is quickly distructed by carbon sublimation.

Thus, for the ^{40}Ar beam with the energy of 5 MeV/nucleon the foil lifetime (the foil working surface is 0.2 - 0.3 cm^2 and duty factor - 1/6) is 24 hrs for the intensity 3 10^{13} 1/sec, 2 - 3 hrs for the intensity 6 10^{13} 1/sec and 5 min for the intensity 1 10^{14} 1/sec.

For high intensities the foil lifetime does not depend on the method of its preparation.

Since the foil in the U-400 accelerator is changed once a day the intensity of the extracted beam does not exceed (1-2) 10^{13} c^{-1}.

We should mention the following shortcomings of accelerator operation in case a PIG type internal source is used:

1) small lifetime - 24 hrs
2) 50% losses caused by the charge exchange on the gas loaded into the source at the consumption $(0.2 - 1.0)10^{-2}$ tor.l.c^{-1}
3) the limitation of source dimensions
4) the provocation of rf electrical sparking from the dees as a result of a small distance between the ion source and the puller
5) high puller sputtering makes it essential to change the puller once a mouth.

Presently a possibility of axial injection of ion beams from PIG types sources in the U-400 accelerator is studied to exclude or decrease the abovementioned factors.

In the nearest future the operation of a PIG type source in the axial injection system of the U-200 cyclotron will be investigated[5]. The task of this investigation is to understand the dependence of the transportation efficiency in the axial injection channel and ion utilization in acceleration on the intensity i.e. the influence of the space charge.

Even in case the efficiency of the transportation system and of the ion utilization in acceleration will be on the level of 1% at the beam intensity of $2\ 10^{15}$ l/sec from a PIG type source we shall consider it worth while to build an axial injection system with a PIG type source for the U-400.cyclotron.

The JINR cyclotrons are being developped into a cyclotron complex U-400 - U-400M designed to produce ions ranging from oxygen to uranium with the energies from 115 up to 20 MeV/nucleon correspondingly[6].

The U-400M cyclotron can accelerate ions with Z/A from 0.2 up to 0.5. A schematic view of the cyclotron facility is presented in fig. 5.

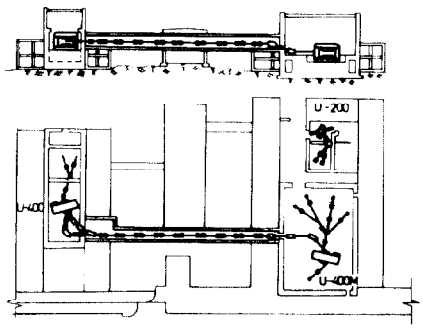

Fig. 5. A schematic view of the cyclotron complex U-400 - U-400M

The U-400M cyclotron is being designed as the second stage of the complex but we consider a possibility of its autonomous operation with a separate ion source.

It is clear from fig. 1 that it is possible to use a PIG type source in the U-400M cyclotron only for the acceleration of ions with masses below 20 at ranged energies. The use of ECR ion source for the U-400M accelerator opens new interesting opportunities. We think that in this case it is possible to obtain ion beams of the intensities presented in fig. 6.

The problem of obtaining accelerated beams the intensities of which exceed 10^{13} l/sec will depend on the results of beam space charge research.

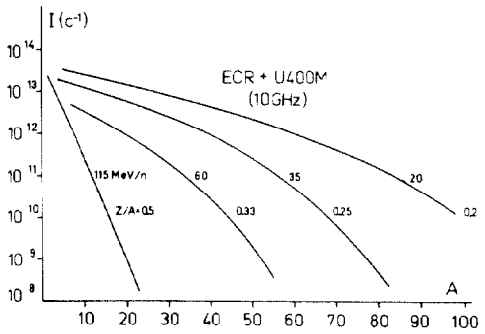

Fig. 6. The potentialities of U-400 cyclotron with an indipendent ECR source

References

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