NUMERICAL SIMULATION OF BEAM EXTRACTION FROM DC-72 AND U-400R CYCLOTRON BY STRIPPING

O.N. Borisov, G.G. Gulbekyan, D.Solivajs*
Flerov Laboratory of Nuclear Reaction, JINR, Dubna, Moscow reg., Russia
*DNPT FEI Slovakian Technical University Bratislava, Slovakia

Abstract

Numerical simulation results for beam extraction by stripping from DC-72 and U-400R cyclotron are considered. The possibilities of this method application are discussed.

EXTRACTION BY STRIPPING

This method is heavily used for negative ion beam extraction. A thin carbon foil is used to strip an ion's electrons and change the rotation direction. The efficiency of stripping extraction in this case can be ≈100%.

For positive ions the foil change the ion charge and rotation radius [2]. For certain foil positions the ions are extracted from cyclotron. The stripping method is very efficient for extraction light ions (≈100%). Stripping extraction of heavy ions is less efficient, since it is limited to only one of the charge state among which the beam is distributed after interaction with foil (≈25÷60%).

The self-developed "STRIPEX" computer code is used for simulation of the beam dynamic after stripping foil. It was assumed that the stripping foil is positioned along an equilibrium orbit, which is defined by ion energy and magnetic field. The magnetic field map is defined from measurements or from calculations.

The all extracted trajectories must crossing at joint point. It is necessary to find a position of the stripping foil.

The parameters of the beam after foil (emittances and energy spread) are defined by magnetic field level and ion type. Envelopes beam are calculated.

The results of the numerical beam simulation of bem extraction from U-400R and DC-72 cyclotrons are present.

U-400R CYCLOTRON

The isochronous U400 cyclotron has been in operation since 1978 [3]. At present time, some cyclotron parameters can be improved. First of all it is concern of the total acceleration efficiency and possibility to vary ion energy fluently at factor 5 for every mass to charge ratio A/Z by means of changing the RF frequency and the magnetic field. The width of ion energy region will be from 0.8 to 27 MeV/nucleon. The extracted trajectories shown in Fig.1.

The project of U400 modernization intends decreasing the magnetic field level at the cyclotron center from 1.93÷2.1T to 0.8÷1.8T. The working diagram and energy range of possible accelerated ions for the U400R are shown in Fig.2.

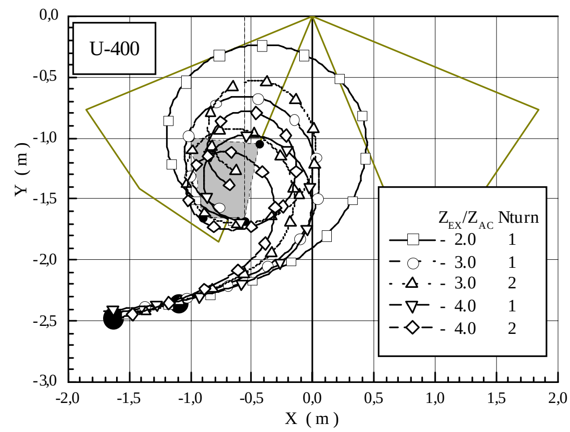

Fig.1: Heavy ions extraction by stripping from U-400 cyclotron (FLNR, JINR, Russia) at present time for various charge-excharge ratio and turn number

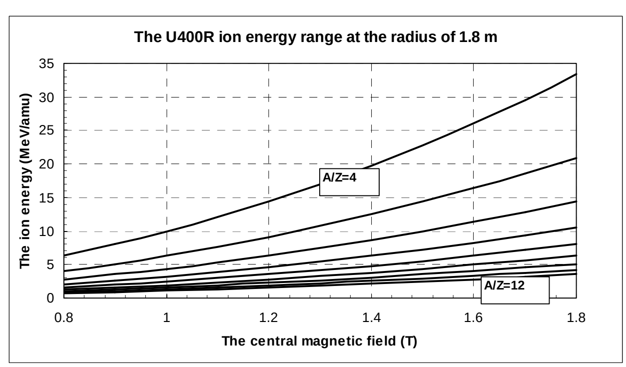

Fig.2: The energy range of possible accelerated ions

The results of numerical simulation of ion extraction by the stripping foil method shown in Fig.3. The calculations have been carried out for ions with A/Z=8, at the magnetic field levels of Bo=0.8÷1.2÷1.8 T and the charge exchange coefficients of Z_{out}/Z_{in}=2,0÷2,5÷3,0÷3,5. The beam emittances after the stripping foil taken equal to E_x=5÷10 π mm×mrad; E_z=4 π mm×mrad at the energy spread of δW=1.5%.

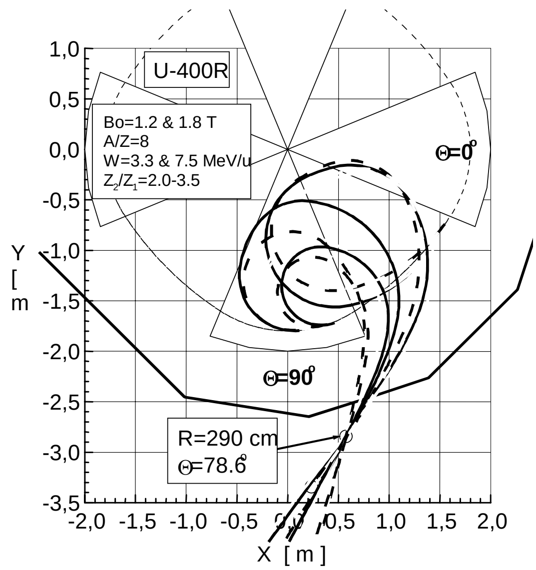

Fig.3: The scheme of the ion beam extraction by stripping foils with two separate foil probes. For B0=1,2÷1,8 T, W=3,3÷7,5 MeV/u, Z2/Z1=2÷3,5

After analyzing of the results, we decided to extract ions by mean of two separate foil probes. The first probe will extract ions with Z_{out}/Z_{in}=2,5÷3,0÷3,5 and the second one will extract ions with Z_{out}/Z_{in}=2,0÷2.5. Correspondingly, the total number of the foil probes to extract ions in two opposite directions will be 4 (2+2) pieces. The extracted efficiency of the method depends on the ion type, ion energy and extracted line in extracted ion spectrum. For heavy elements the efficiency is not more than 40%. The beam emittances at crossing point (R=290 cm) shown in Fig.4.

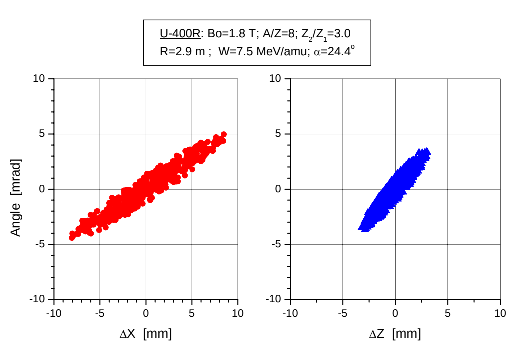

Fig.4: The beam emittances at crossing point (R=290 cm) for Z_{out}/Z_{in}=3,0

DC-72 CYCLOTRON

The isochronous DC-72 cyclotron is constructed in Flerov Laboratory of Nuclear Reaction for DNPT FEI Slovakian Technical University (Bratislava, Slovakia) [4]. The range of magnetic field level at the cyclotron center from 0.9T to 1.5T.The ions from **H⁻** (A/Z=1, W=72 MeV) to **^{129}Xe^{18}** (A/Z=7.2, W=2.7 MeV/u) are accelerated at the DC-72 cyclotron

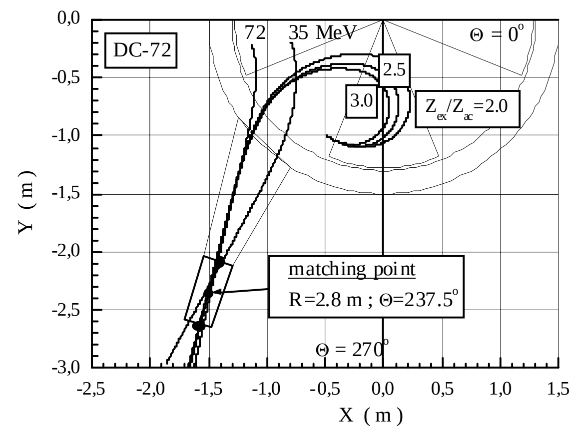

Fig. 5: Extracted trajectories for H⁻ ions (W=35÷72 MeV) and heavy ions (1.5÷30 MeV/u) from DC-72 cyclotron (Bratislava, Slovakia)

The extracted trajectories shown in Fig.5. The necessary foil position shown in Fig.6 and Fig.7. The beam emittances at crossing point (R=280 cm) for test ions shown in Fig.8 and Fig.9.

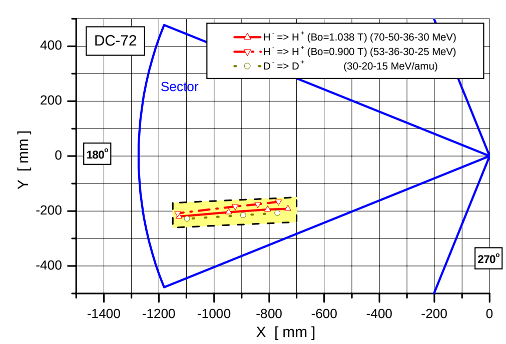

Fig.6:The area of stripping foil placement for **H⁻** ions extraction

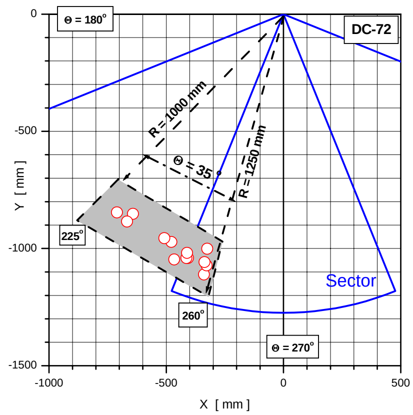

Fig.7: The area of stripping foil placement for positive ions extraction

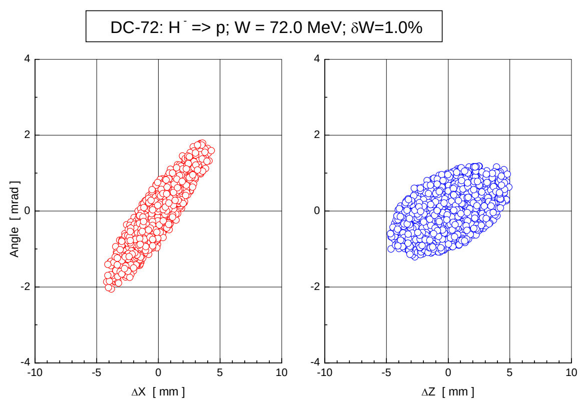

Fig.8: The beam emittances at crossing point (R=280 cm) for **H⁻** ions.

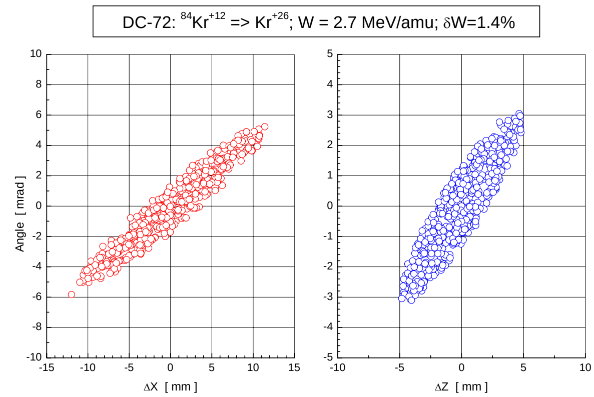

Fig.9: The beam emittances at crossing point (R=280 cm) for test heavy ion

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