NUMERICAL STUDY OF THE CENTRE REGION ACCELERATION FOR THE RIC-30 CYCLOTRON

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The RIC-30 cyclotron was designed for acceleration of protons up to 30 MeV [1]. Since 1994 it has been used for production of radionuclides on internal target installed at a radius of 580 mm, where the beam energy equals 22 MeV. Final radius of acceleration is 655 mm. At present, in the long-time irradiation mode the beam current on target is 190...200 μA [2]. The main objective of the work is to attain a higher beam current due to optimizing configuring of components forming the central ion-optical system of the cyclotron.

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SOURCE DATA

The accelerating system of the RIC-30 cyclotron is a single 180° dee, to which RF voltage with amplitude of 48 kV and fixed frequency of 17.4 MHz is applied. Up to R=250 mm, the accelerating gap between the dee and the dummy dee is 30 mm. The discharge channel of the ion source and the extracting slit of the puller are 20 mm shifted along the dee edge relative to the pole center

Computations of three-dimensional electric field distribution have been done for several configurations of accelerating electrodes. The first version ("initial", the dee aperture-34 mm and dummy dee aperture-62 mm) corresponded to the working position of electrodes in the central area of acceleration. The second version ("symmetric", both the dee and dummy dee apertures-34 mm) differed from the first one in reduction of the dummy dee aperture to the aperture of the dee.

During optimizing computations of particle initial motion, we studied a version called "My-2", which differed from the "symmetric" one in the smaller dee aperture (20 mm) at the beam output from the dee. Radial length of the area of the dee reduced aperture was 50 mm (from R=20 mm, the puller edge, to R=70 mm).

Radial trajectories and vertical motion of particles with different start phases were computed during 6-7 beam turns in the uniform magnetic field. This approximation corresponds to the actual magnetic field of the RIC-30 cyclotron, in the central area of which the flatter starts to rise only at a radius of 80-100 mm [3]. Thus, till this radius vertical motion of particles on the RIC-30 cyclotron completely depends on the electric field.

RESULTS OF COMPUTATIONS

The most effective way to affect the vertical motion of ions in the center of the cyclotron is the change of electric field spatial distribution in the accelerating gap by varying the dee and dummy dee apertures. Focusing (at the dee and dummy dee outputs) and defocusing (at the dee and dummy dee inputs) effects of electric field dominate during initial turns in the direct vicinity of the ion source and the puller. In this area the electric field is of complicated spatial distribution. Therefore, to provide a higher reliability of results, it is important to apply a three-dimensional code for computation of the electric field distribution in the accelerating gap.

Fig.1 demonstrates, as an example, equipotentials of electric field (14 mm from the puller) for the initial version of the accelerating structure.

In this place the beam after the first half-turn leaves the dee, as is demonstrated in Fig.2. The figure shows orbits of the protons first turn in the median plane for the "initial" version. The initial start interval is 45°, from -31° to +14°.

Protons with start phases less than -31°and more than +14° has dropped out of the acceleration process. They arrive either to the puller or to the source. Fig.3 shows the initial orbits of protons with zero start phase for "initial" and "symmetric" versions.

The motion of the orbit curvature center area and area A with the strongest effect of electric field forces is displayed. It is seen that the "symmetric" version has some advantage in the orbit radius rise, i.e. energy gain. For these versions of the accelerating structure Fig.4 demonstrates distribution of vertical E_y and accelerating E_z components of electric field in the area A.

Despite an appreciable reduction of electric field defocusing effect in the "initial" structure, further computations have demonstrated that this structure does not offer any serious advantages over the "symmetric' one. Fig.5 depicts particle losses against the number of turns under acceleration in the "initial" and "symmetric" structures. Results have been obtained from integration of the motion equations for 600 particles uniformly distributed in an ellipse with y=7 mm, A_y =40 mrad semiaxes (the initial beam emittance is 280 π×mm×mrad) and phase interval of ±30°. As is seen from the presented data, somewhat lower beam losses during several first turns in the "initial" version are compensated in the "symmetric" version by reduced losses at subsequent beam turns. After the 7th turn, the number of particles fell out of the acceleration process was the same as in both the versions and amounted to 250. Thus, only 58% of the initial amount of particles have passed the initial 7 turns.

As has been mentioned above, the " My2" version is characterized with a reduction of the dee output aperture to 20 mm, that results in more than twice increase of the electric field focusing component. Fig.6 demonstrates results of computations of particle losses under acceleration for the "My2" version. All data and conditions in-

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volved in the computations are completely identical to those shown in Fig.5 except electric field configuration. It is seen from the presented data that the amount of particles dropped out of the acceleration process decreased to 80. Thus, 87% of the initial amount of particles have passed 7 initial turns.

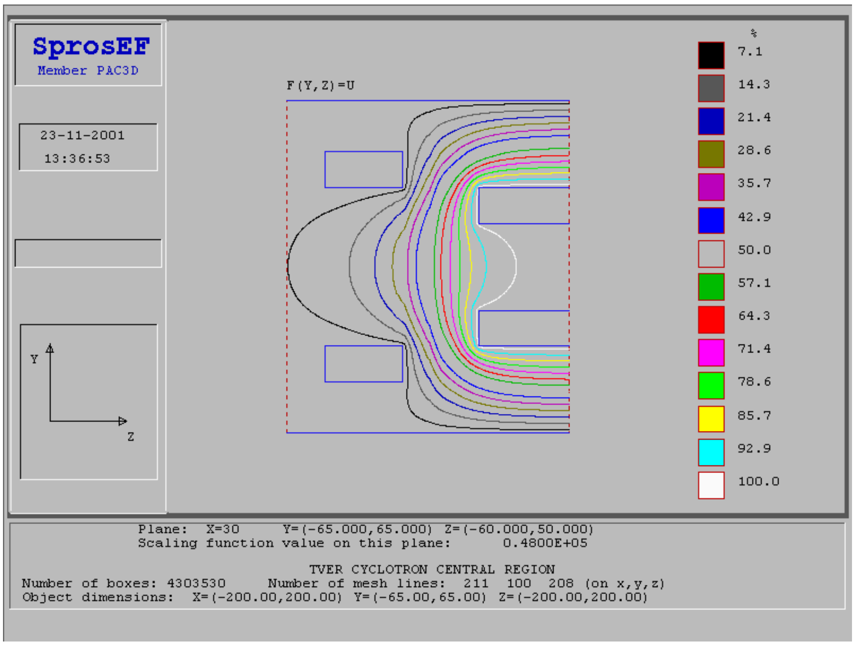

Fig.1. Equipotentials of electric field (14 mm from the puller). "Initial" version of the accelerating structure

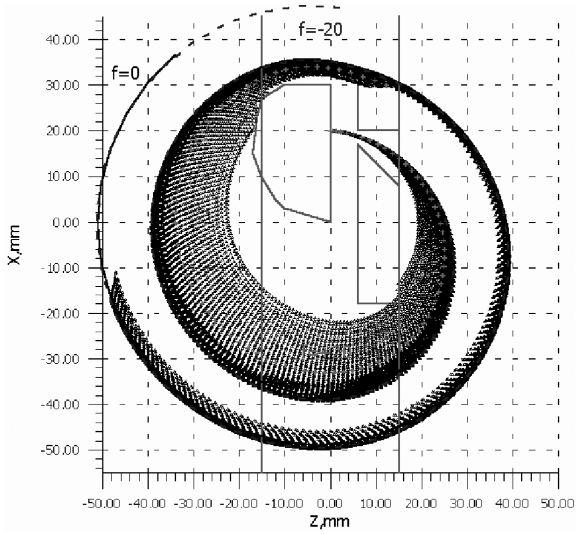

Fig.2. Orbits of the "initial" version of the accelerating structure. The dee accelerating voltage-48 kV

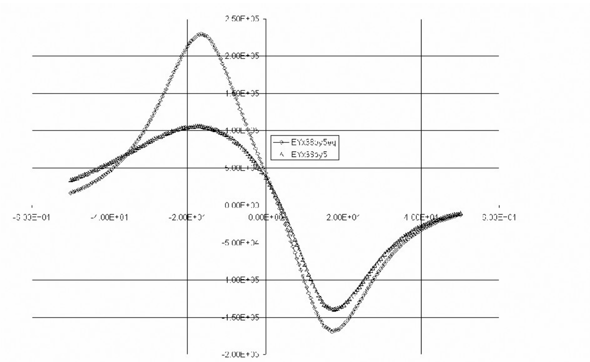

Fig.4,a. Distribution of electric field vertical components for "initial' and "symmetric" versions of the accelerating structure

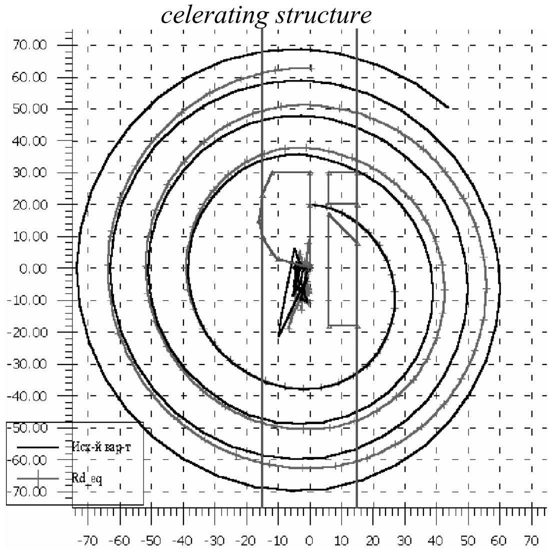

Fig.3. Orbits of protons with zero start phase for "initial" and "symmetric" versions of the accelerating structure. Dee voltage is 48 kV

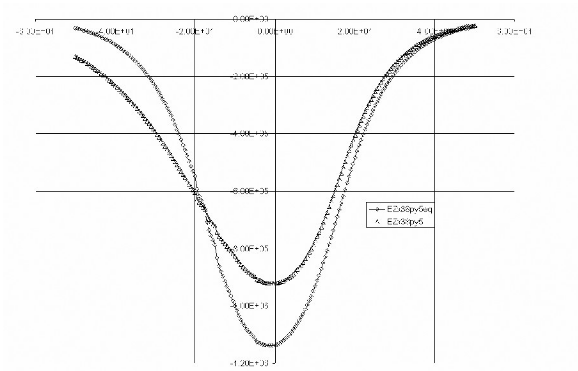

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Fig.4,b. Distribution of electric field accelerating components for "initial' and "symmetric" versions of the accelerating structure

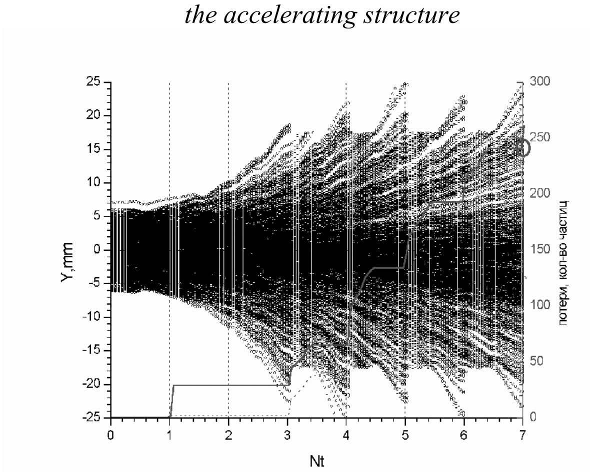

Fig.5a. Losses under acceleration in the "initial" version of the accelerating structure. At the input there are 600 particles with an emittance of 280 $\pi \times mm \times mrad$; the start interval is $\pm 30°$

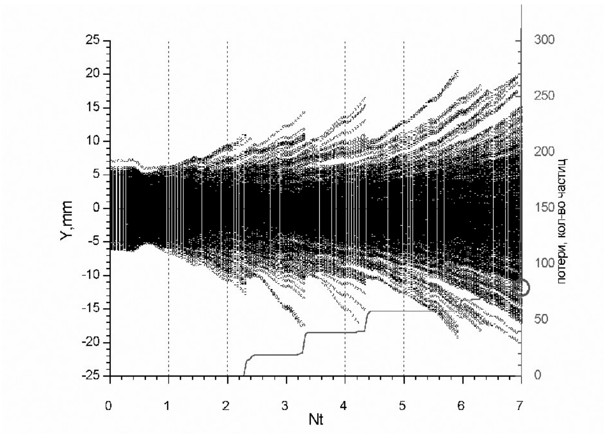

Fig.5,b. Losses under acceleration in the "symmetric" version of the accelerating structure. At the input there are 600 particles with an emittance of 280 $\pi \times mm \times mrad$;the start interval is $\pm 30°$

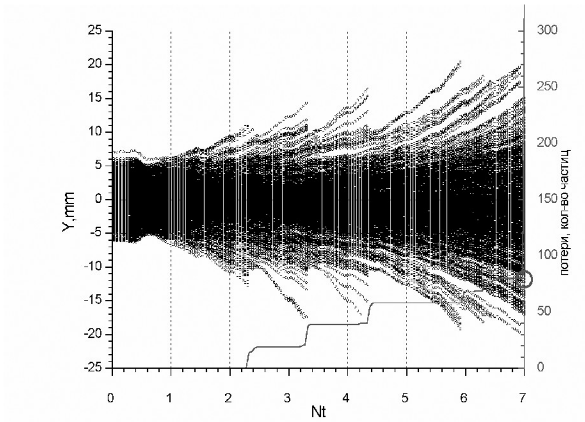

Fig. 6. Losses under acceleration for the "My2" version of the accelerating structure. At the input there are 600 particles with an emittance of 280 $\pi \times mm \times mrad$, the start interval is $\pm 30°$

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ЧИСЛЕННОЕ ИЗУЧЕНИЕ ЦЕНТРАЛЬНОЙ ОБЛАСТИ УСКОРЕНИЯ RIC-30 ЦИКЛОТРОНА

З.А. Андреева, Ю.А. Свистунов, С.А. Силаев, А.В. Степанов

RIC-30 циклотрон был разработан для ускорения протонов до 30 МэВ. С 1994 г. он использовался для производства радионуклидов на внутренней мишени, установленной на радиусе 580 мм, где энергия пучка равнялась 22 МэВ. Конечный радиус ускорения равен 655 мм. В настоящее время при длительном режиме облучения ток пучка на мишени – 190...200 мкА. Основной целью работы является получение более высокого тока пучка вследствие оптимизации конфигурации компонент, формирующих центральную ион-оптическую систему циклотрона.

ЧИСЛОВЕ ВИВЧЕННЯ ЦЕНТРАЛЬНОЇ ОБЛАСТІ ПРИСКОРЕННЯ RIC-30 ЦИКЛОТРОНА

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RIC-30 циклотрон був розроблений для прискорення протонів до 30 МеВ. З 1994 р. він використовувався для виробництва радіонуклідів на внутрішній мішені, встановленої на радіусі 580 мм, де енергія пучка дорівнювала 22 МеВ. Кінцевий радіус прискорення дорівнює 655 мм. В даний час при тривалому режимі опромінення струм пучка на мішені – 190...200 мкА. Основною метою роботи є одержання більш високого струму пучка внаслідок оптимізації конфігурації компонент, що формують центральну іон-оптичну систему циклотрона.