ION SOURCE REVOLVED ON 8° ANGLE RELATIVELY DEE EDGE FOR CLASSIC CYCLOTRON.

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Beam dynamic inside classic cyclotron is calculated on the first orbits for several positions of ion source relatively dee edge. It is shown, that optimum range of initial phases captured into acceleration can be enlarged by revolution of ion source. The obtained phase range was traced to final radius along with the calculation of phase selection made by the proncipie of minimum of both phase loss and the loss caused by vertical oscillation. The larger range of initial phases allows to achieve higher beam currents. The experiment with new type of ion source let to reach beam intensity in the range 800 mkA inside cyclotron U150 under lower electric potential on dees and higher relative pulse duration.

1. Introduction.

The production of different kinds of cyclotron isotopes such as Co^{57}, Cd^{109} et cetera in limited time by cyclotrons with low energy of accelerated ions requires high beam currents. In the article, the method of partial enlargement of beam current by the change of central optics, namely, by revolution of ion source relatively extracting puller is proposed. The upgrade of central optics leads to additional phase clustering and, consequently, to increasing of the range of start phases captured into acceleration e.g. to high beam intensity.

2. The phase motion.

As it was shown in [1], in classic cyclotron with 1.5 meter pole diameter, after 3-4 first half-turns, only ions with phases in the range $(+32^0,-3^0)$ can be accelerated to the energy E_p=21 MeV. Acquiring less energy and moving on shorter trajectories, the positive phases intend to become negative and otherwise, the negative phases strive to be positive on first half-turn (n=1). This effect leads to phase clustering at n=4.

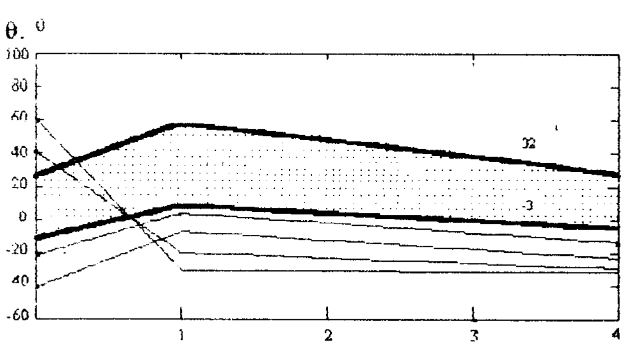

Fig.1. The dependence of initial ion phases θ on the number of first half-turns n. Normal position of ion sourse, α=0.

The effect can be boosted by revolution of ion source when ions are forced to move on longer trajectories. That let us to increase the range of start or initial phases of ions that can be captured into acceleration and be able to reach final radius. The enlargement of start phase range increases along with the angle of revolution, but if trajectory becomes too long, ion acquires too big phase shift and can not be accelerated up to final radius. In the system of reference shown on Fig.2 the equations of motion are:

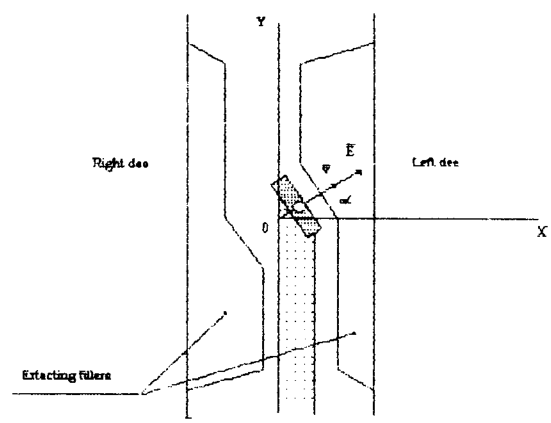

Fig.2. Ion source revolved on α relatively extracting puller.

$$\ddot{X}= A_1(E_x \cos(\omega_f t+\theta)- B_z \dot{Y})$$
$$\ddot{Y}= A_1(E_y \cos((\omega_f t+\theta)+B_z \dot{X}) \quad (2.1)$$

where: $A_1=q/m_0$- ion charge-mass ratio; $B_z(r)$- z-component of magnetic field on radius r measured with accuracy around 0.01%; E_x, E_y- components of electric field; ω_f- the frequency of RF amplifier; f=15.9 Mhz; θ_0 - initial phase shift of ion in the moment of its start from ion source. The calculations were carried out under following parameters: U_d= 180KV -voltage between dees ; d_{eff}= d/2=36mm; d-effective distance between dees. All parameteres were chosen for cyclotron producing isotope Co^{57} by proton bombardment of internal targets with E_p=18-21 MeV. when beam current is the main factor of cyclotron productivity The phase shift of accelerated ion was determined as time difference between the moment when ion crosses Y-axis and the moment of maximum of accelerating RF voltage on dee.

$$\theta_k = \omega_f t_k - k\pi \qquad (2.2)$$

where; k- the number of half-turn; t_k- solution of the equation of Y-axis.

$$X(t_k) = 0 \qquad (2.3)$$

After a few half-turns we can neglect E_y- component and the equations of motion can be written as following:

$$\ddot{X} = A_1(E_x \cos(\omega_f t+\theta) - B_z \dot{Y})$$
$$\ddot{Y} = A_1 B_z \dot{X} \qquad (2.4)$$

All ions were traced up to final radius. The phase selection was made by restriction.

$$|\ \omega_f t+\theta\ | \le \pi/2 \qquad (2.5)$$

and vertical oscillations were described by[2]:

$$\ddot{Z} + \omega_f\, n(r)\, Z = 0 \qquad (2.6)$$

3.Discussion.

The results of the calculations are shown on Fig.3-Fig.5. The tendency of ion phases to negative values when α=0 (Fig.1) can be changed into oscillating mode by ion source revolution. When $\alpha=8^0$ (Fig.3) the oscillation of phase range reaches its maximum value so, more ions begin to be captured into acceleration with positive phases. After this point the oscillation effect become weaker (Fig.4) and the tendency of ions to start of acceleration with negative phases appears again. The dependence of initial phase range Δθ on the angle of revolution α is shown on Fig.5. The maximum size of Δθ -range: $\Delta\theta = 48^0$ [$+37^0$, -11^0] can be reached at $\alpha=8^0$ that is in 1.3 times bigger than for ordinary ion source position $\alpha=0^0$ when $\Delta\theta = 34^0$ [$+25^0$, -9^0]. The experiment with revolved Penning's type ion source was carried out on cyclotron U150II and let us to achieve 800mkA of internal beam current under lower electric potential on dees and higher relative pulse duration.

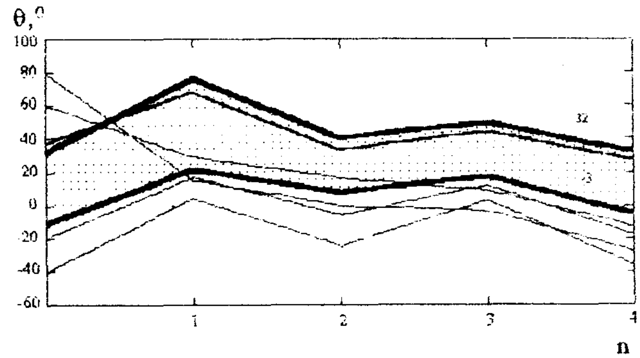

Fig.3. $\alpha=8^0$ position of ion source.

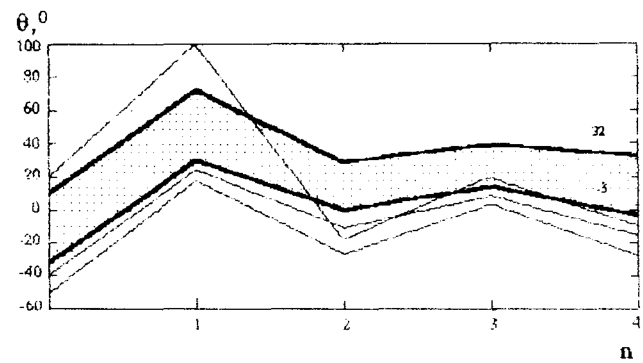

Fig.4. $\alpha=20^0$ - posotion of ion source.

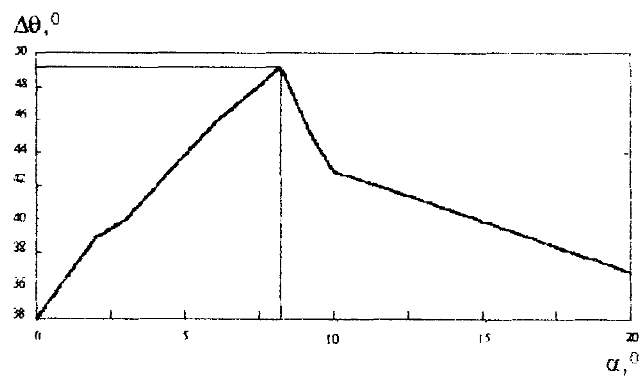

Fig.5. the dependence of phase range Δθ on revolution of ion source α.

4. References.

1. Krasnov N.N., Ognev A.A. et al, PTE, 4, Moscow, 1974(in Russian).

2. Proceedings of 14th International Conference CYCLOTRON'96, 1996, pp. 557-558