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CALCULATION OF THE BEAM DYNAMICS IN THE CENTRAL REGION OF THE CYCLOTRON GIC

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As is well known, the central region of a cyclotron determines to a great extend intensity and quality of a beam. In this connection the large attention is being given to the analysis of the beam dynamics in the central region and optimum design.

The calculation of particles dynamics was carried out by using the program similar that was successfully applied to design of the central region with an internal source [1]. Program has been modernised to calculate dynamics in a cyclotron with external injection. Main input data for calculation are electrical and magnetic fields. The magnetic field is described by the formula:

$$B(r,\varphi) = \bar{B}(r) + A_4(r) \times \cos\left(4 \times (\varphi + \eta\ (r))\right)\ ,$$

where $\bar{B}(r)$ – the average magnetic field is planning to be found as a result of calculation, and the amplitude $A_4(r)$ and phase $\eta(r)$ of a main harmonic have been measured on model 1:8. On Fig.1 and Fig.2 the amplitude $A_4(r)$, phase $\eta(r)$ and parameters of an average magnetic field $\bar{B}(r)$ are indicated. The electrical field in an accelerating gap is described in a 2-D approximation and presented as a Gauss distribution similarly to how it has been offered in [1-3]. Following input data have been used in calculations:

Injection energy	20 keV
Number of dee	2
Dee voltage amplitude	60 kV
Harmonic f_{rf}/f_{ion}	2
Dee apperture	±15 mm
Angular dee extension	90°
Accelerating gap	20 mm

Correctly designed central region should provide:

- isochronous acceleration of particles with a high gain of energy per turn;
- good centring of a beam, i.e. small value of coherent oscillations of a beam as a whole;
- focusing in an axial plane;
- small free oscillations of particles in the horizontal region.

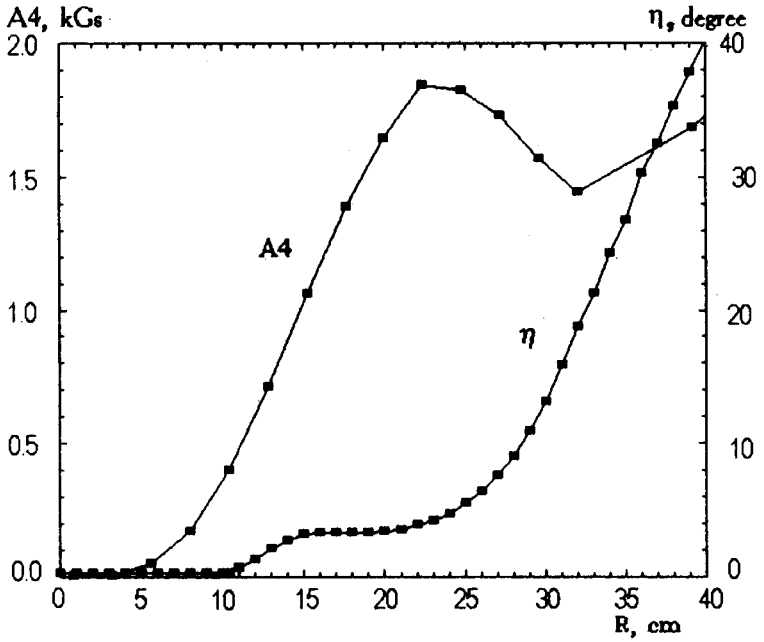

Fig.1. The amplitude A_4 and phase η of the main harmonic of the magnetic field at central region

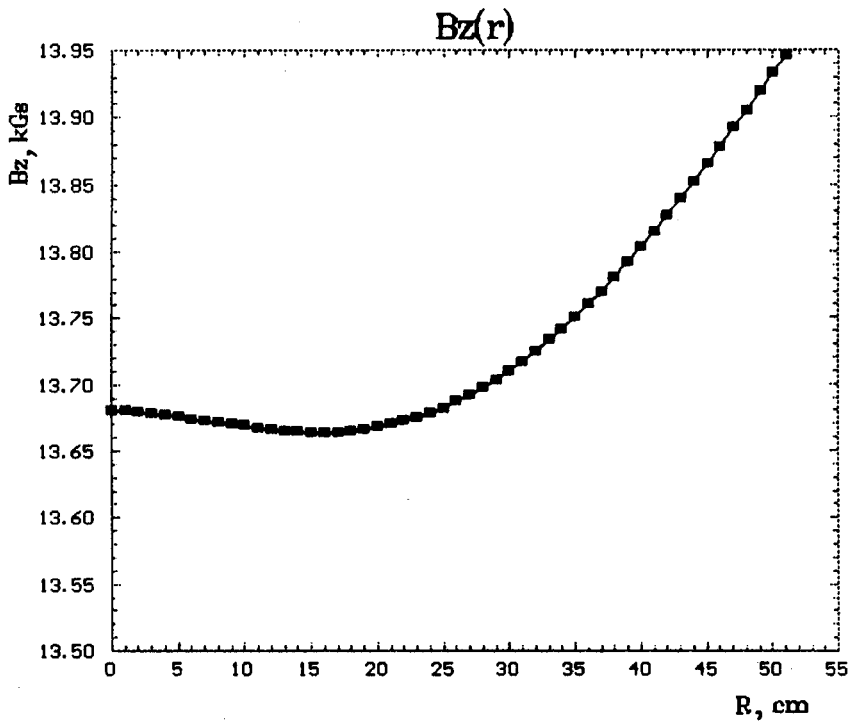

Fig.2. The azimutally averaged magnetic field at central region of cyclotron

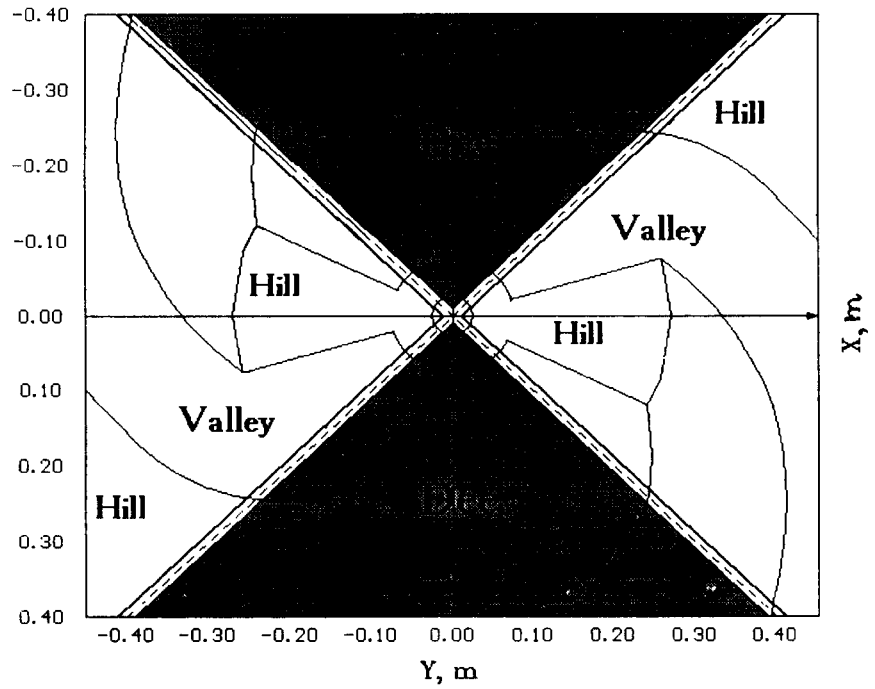

Fig.3. The relative position of the acceleration electrodes and spiral sectors

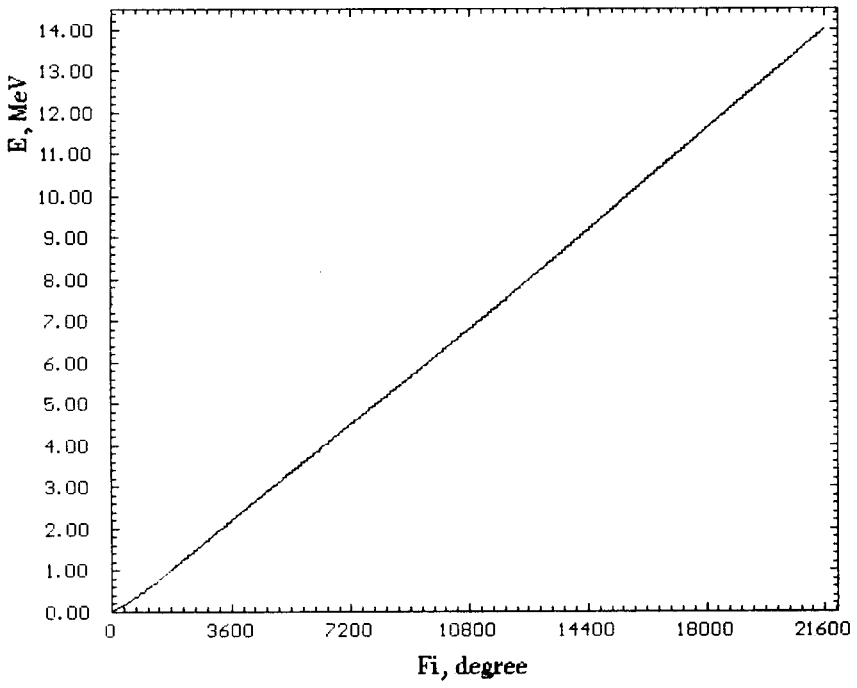

Fig.4. The energy gain of the particle with optimal phase

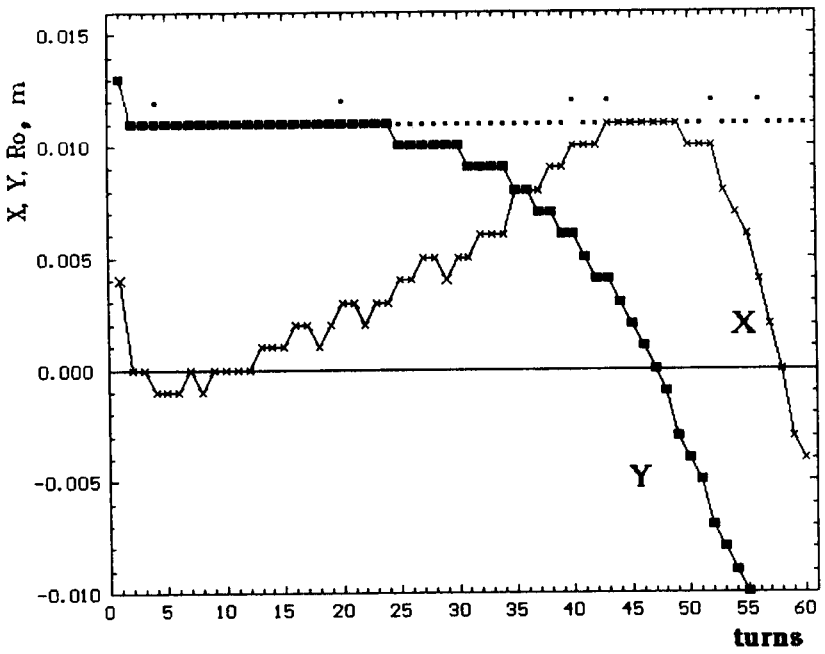

Fig.5. Coordinates X and Y of the orbit centre of curvature on dependence of turns number

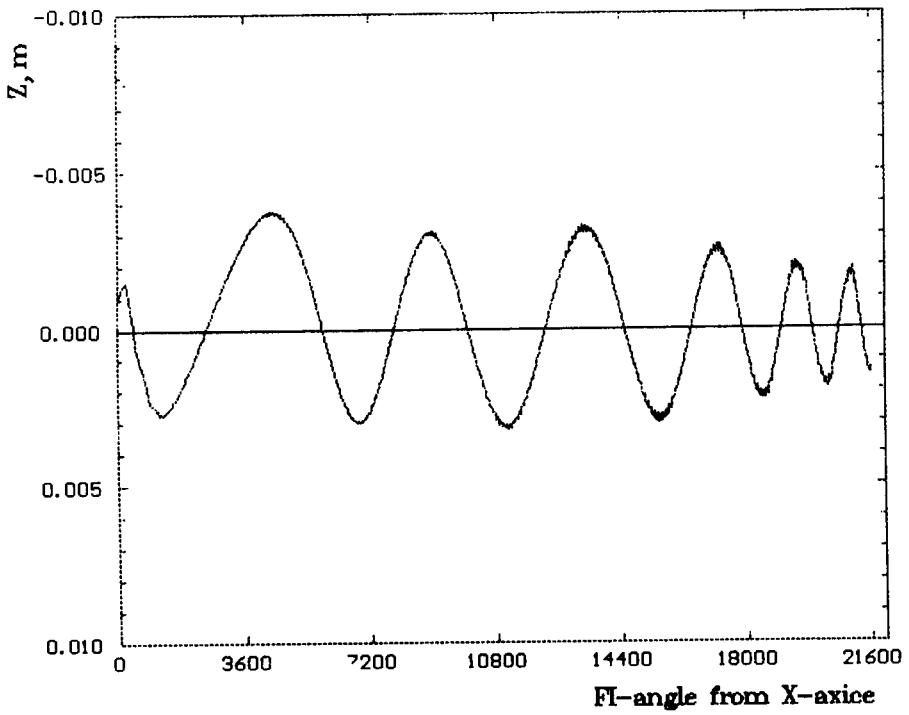

Fig.6. Z-motion of the successfully accelerated particle

The relative position of the accelerating electrodes and spiral sectors is shown on Fig.3. The first calculations have shown, that for Z-focusing on first turns more preferable dee with angular extent of 90° instead of 60°. The necessary isochronous magnetic field is submitted on Fig.2. The range of phases acceptable for acceleration makes 40° and has been determined basically by conditions of Z-movement. The central phase of a range is determined by a maximum energy gain after 60 revolutions. On Fig.4 the particle energy for an optimum phase of acceleration on during of 60 revolutions is submitted. Linear low of energy increase confirms an isohronism of a chosen magnetic field. On Fig.5 uncentring of orbits on dependence of the turns number is submitted. According to a presented data, the centre of curvature coincides a centre of a magnetic field with accuracy of 10 mm at $N = 60$ turns $E = 14$ MeV and $R = 400$ mm. Z-movement of a particle with a optimum phase of acceleration is submitted on Fig.6. In the present report the first preliminary data on particles dynamics in the central region of isohronous cyclotron GIC are presented. The further progress is connected to refinement of electrical field distribution on first turns and introduction of a corresponding corrections in the program.

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LOW ENERGY ACCELERATORS OF PNPI AND THEIR USING IN SCIENTIFIC AND APPLIED RESEARCHES

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There are some working accelerators in the PNPI: electrostatic accelerator (ESA) [1] and neutron generator (NG)[2]. The machines of such a type are used widely both in scientific and in applied investigations [3]. The researche works in the fields of solid state physics, radiation physics, radiobiology, element analysis of the matter are been leading in these accelerators. The base parameters of the accelerators are given in the tables 1, 2. Their opportunities have been broadened during the last years: in ESA deuterium and electron beams have been developed, in NG fast air-powered target transportation has been made.

The ESA is shown draftly in Fig.1. The ion tract with the length 15 m has ion-optical elements, beam control devices and analyzing magnet that makes it possible to form and to lead to the target ion beam with desired size and intensity as well as to stabilize its energy [1].