ORBIT ANALYSIS OF A RING CYCLOTRON (II)

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The orbit properties of accelerated beams are analysed for a four spiral sector cyclotron and a four radial sector ring cyclotron. The injection radius and extraction radius are 135 cm and 370 cm, respectively. A constant acceleration voltage 1.0 MV/turn is assumed for the calculation. The azimuthal angle 0° is chosen on the valley center at injection radius. Two RF cavities are located at the angles of 90° and 270°. The differential equations of motion of a charged particle in the isochronous magnetic field are integrated azimuthally by using the Runge-Kutta-Gill method. The isochronous fields and associated parameters are obtained from other analysis[1]. We determined the equilibrium orbit with acceleration[2]. About ten orbits on the eigen ellipse, shifted to the equilibrium orbit with acceleration, are traced independently.

Fig. 1 shows the radial momentum of the accelerated beams. The radial momentum of the beams without acceleration is zero at valley center of the radial sector. The beam on the phase ellipse is oscillated around the equilibrium orbit with acceleration. The phase ellipse traced from injection to extraction is plotted in fig. 2. The beam emittance of the eigen ellipse is 50 mm·mrad at injection radius. The extraction energies for the spiral sectors and 32° radial sectors are 270 MeV and 250 MeV, respectively. Particles cross the resonance of the $\nu_r=4/3$ between 60 and 80 turns. The phase ellipse is slightly deformed in crossing this resonance as shown in the figure. Turn separations for the spiral sector and 32° radial sector magnets are 4.2 mm and 4.4 mm, respectively. Variations of radial phase space pattern with azimuthal angles are shown in fig. 3.
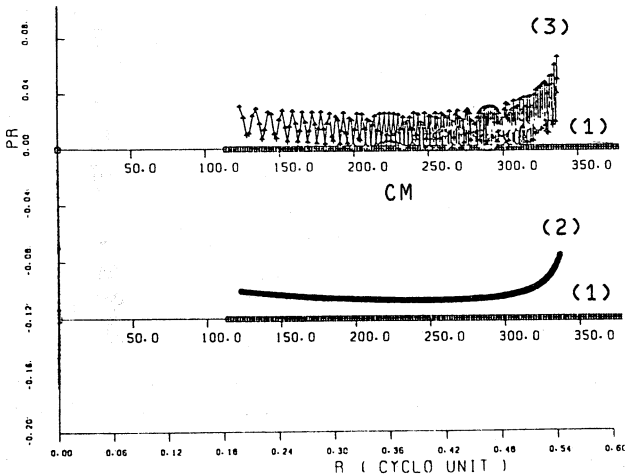

Fig. 1. The radial momentum observed on an azimuthal angle 0° for 250 MeV proton acceleration in the straight sectors; (1) the equilibrium orbit without acceleration, (2) the equilibrium orbit with acceleration, (3) a beam on the phase ellipse.
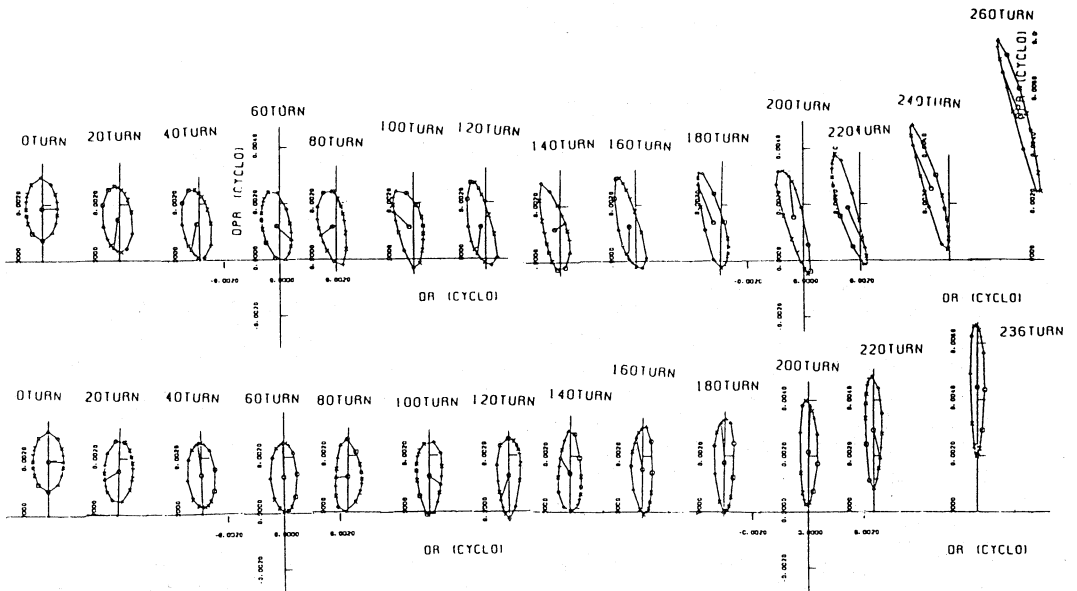
with acceleration.

Fig. 2. Radial phase space patterns, observed at an
         azimuthal angle 0°, are shown in every 20 turns
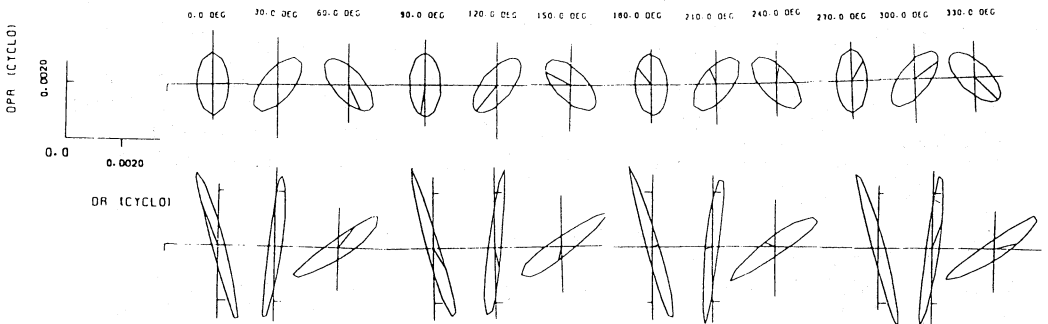   for the spiral sectors (upper) and 32° radial
         sectors (lower).

Fig. 3. Radial phase space patterns are shown in every 30°
         in azimuth for the spiral sector; injection
         (upper) and extraction (lower).

Reference

1)   M. Fuki et al., "Orbit Analysis of a Ring Cyclotron
     (I)", this conference.