CENTRAL REGION DESIGN OF A BABY CYCLOTRON

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Abstract

Baby cyclotrons are widely used in short lived β+ radioactive isotope production. A 11 MeV baby cyclotron for PET isotope production was designed and is in construction in CAEP now. Central region design is one of the most important parts of cyclotron design work. In this paper, central region design of the 11 MeV baby cyclotron, including design processes and design results, is reported.

INTRODUCTION

PET (Positron emission tomography) becomes more and more widely used in China. A project was started in the end of 2007 in CAEP, to design and construct a 11 MeV baby proton cyclotron for PET isotope production. Main design parameters of the 11 MeV cyclotron are listed below [1].

Table 1: Main design parameters of the 11 MeV cyclotron in CAEP

Mag-net	Number of sectors	4	Ion source	Type	H-, Internal PIG
	Hill gap /cm	3.8			
	Hill angle /Deg	58			
	Valley gap /cm	140			
	Radius of the pole /cm	45	Central region	Accepted RF Phase /Deg	0-40
	B_{avg} /Tesla	1.18	Extraction	Type	Carbon foil
RF	Number of Dees	2		Number of stations	2
	Dee voltage /kV	42 or 37		Radius /cm	40
	Frequency /MHz	72	Vaccum	Pressure /Pa	1×10^{-3}
	RF power /kW	~10		Pump speed /Ls^{-1}	≥4000

CENTRAL REGION DESIGN

Firstly, the magnetic field map is calculated by Opera3D [2]. The magnetic field map is shown in Fig1. Then, a H- ion with equilibrium momentum starts to decelerate from the extraction radius to central region. Slightly adjusting the dee voltage, we can make that the ion decelerates to rest exactly at the center of the magnet. The position and direction of first several gaps, are recorded as the initial central region electrode position and direction. Then, the CAD model of the central region is constructed, and the electric field map is calculated by MAFIA. The electric field map of median plane is shown in Fig2. Particles are emitted from the slit of ion source, and the Dee serves as the puller. After that, the beam trajectories are calculated by a particle tracking code written in c++. Finally, the first several gaps are adjusted adaptively to improve the accepted RF phase and to improve the centralization.

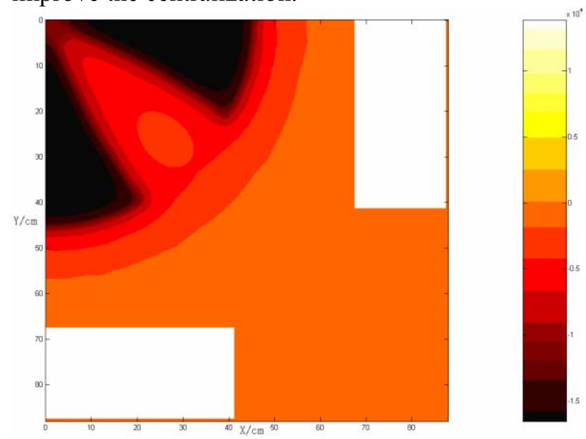


Figure 1: magnetic field map of the median plane

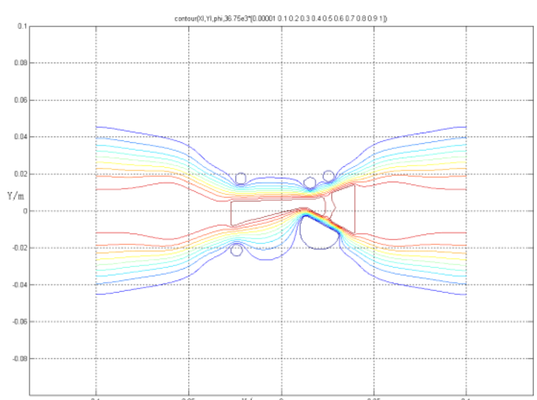


Figure 2: electric field map of the median plane

PARTICLE TRACKING

The beam tracking was done with a code written in c++ by our team. The code synchronizes the magnetic field computed by Opera and electric field computed by MAFIA, and tracks the particles by 4th order Runge-Kutta fixed step method.

H- ions start with zero momentum, from the position of the ion source slit. The width and height of the slit is .4mm and 5mm respectively. After optimization of the first several gaps, all particle emitted from the ion source slit and with initial RF phase of 0-40 degree can be accelerated in central region. The orbit, vertical motion, and energy gain are shown in figure 3-5. The vertical gap of the central region is 12mm, so the maximum expansion factor of the vertical beam size in central region is 2.5. Fig4 shows, the maximum expansion factor is only about 1.7 and all particles emitted with 0-40 degree RF phase will pass through the central region without loss due to vertical motion.

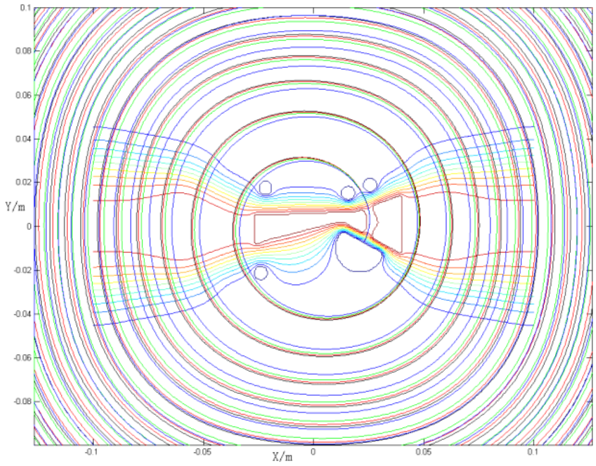


Figure 3: The trajectories of particles with initial RF phase of 0-40 degree. The black, red, green and blue are corresponding to 0, 20, 30, 40 initial RF phase respectively.

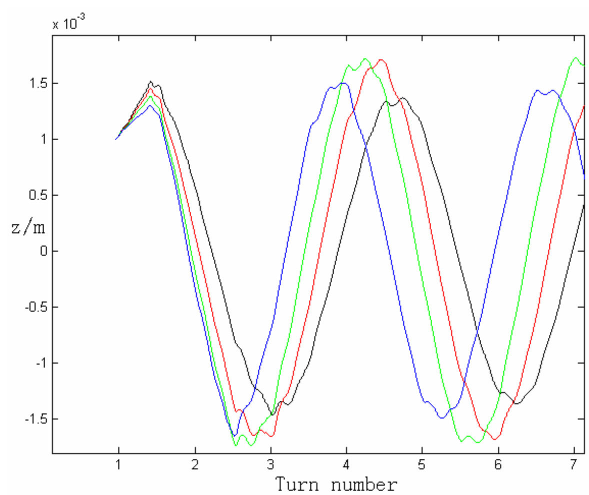


Figure 4: Vertical motion of particles with initial RF phase of 0-40 degree

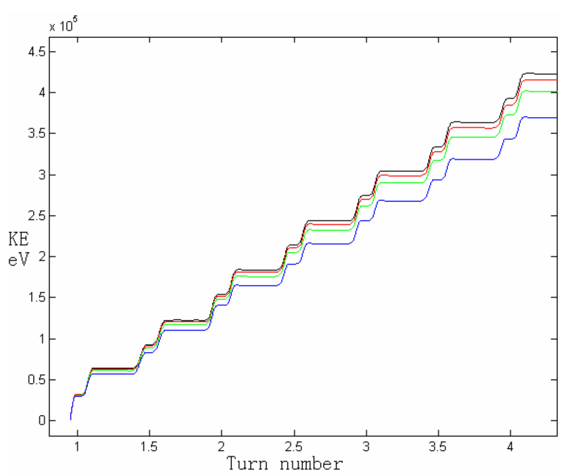
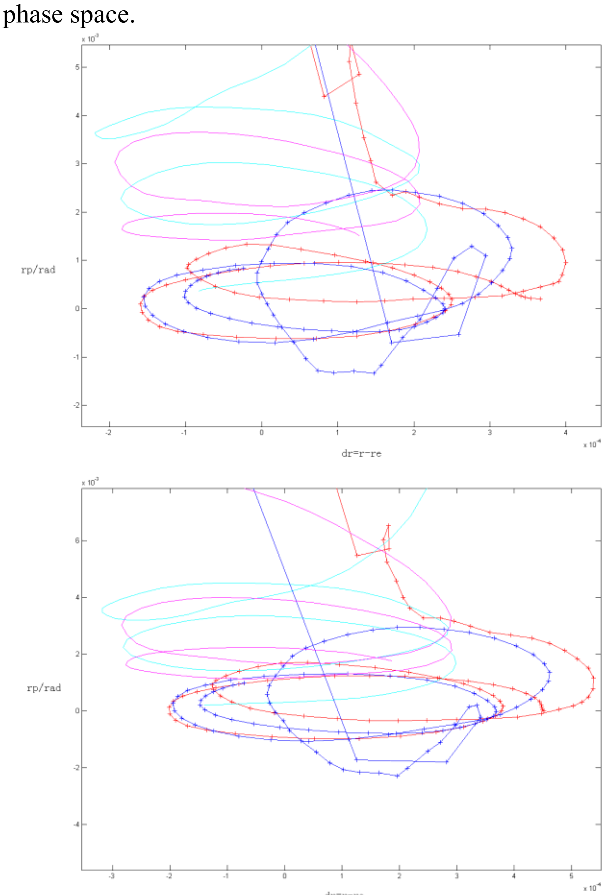


Figure 5: Energy gain of particles with initial RF phase of 0-40 degree

CENTRALIZATION OF THE ORBIT

(dr=r-re, rp) phase space at the center of magnet valley is used to indicate the extent of the centralization of beam trajectories. (dr, rp) phase space with initial RF phase of 0, 20, 30, 40 degree are shown in Fig6. As another indication of the centralization, RF phase at the valley of the magnet VS turn number, which is another indication of the extent of the centralization of beam trajectories, is shown in Fig 7. From the (dr, rp) phase spaces, we can find that particles with 0-30 degree initial RF phase move with quite small dr, so they move quite close to equilibrium particle. For all particles with 0-40 degree initial RF phase, the centralization offset is less than 1 millimeter. In Fig7, the curve with 40 degree initial RF phase oscillates with larger amplitude than that with 0-30 degree initial RF phase. It implies that particles with 40 degree initial RF phase centralized not well as 0-30 degree initial RF phase. This is agree with the (dr, rp) phase space.



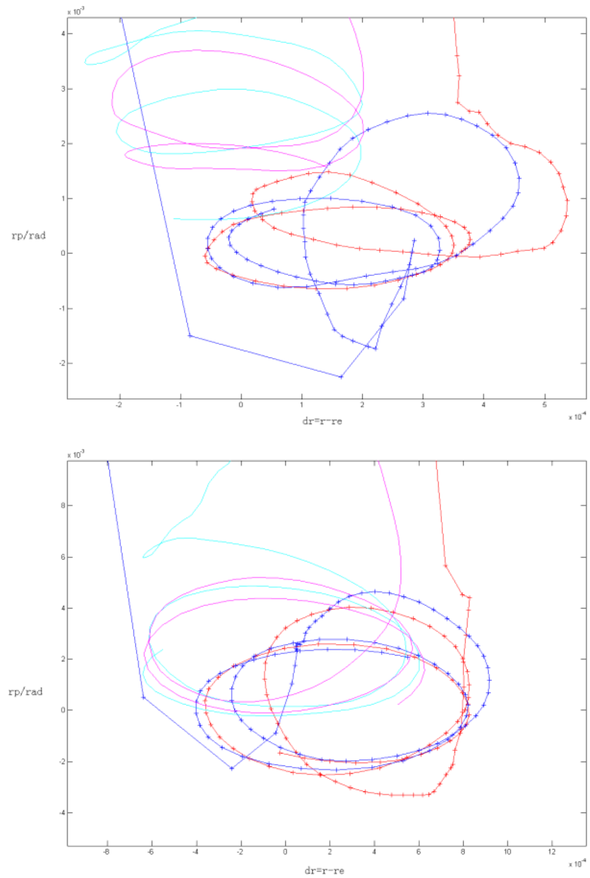


Figure 6: (dr, rp) phase space of the particle trajectories

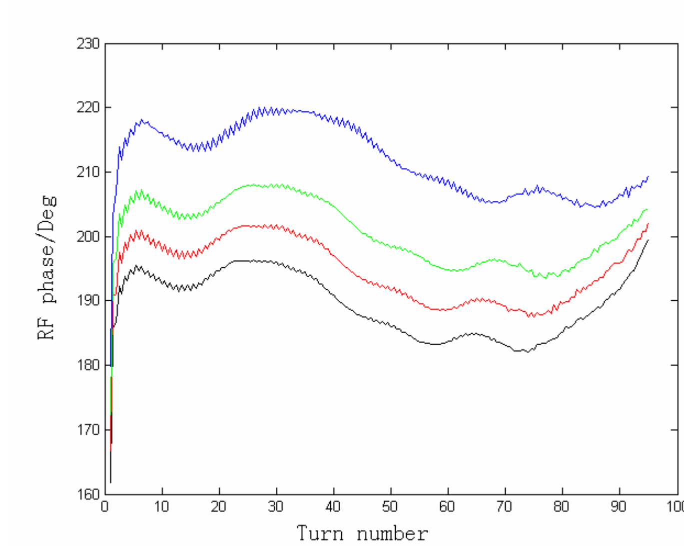


Figure 7: RF phase at the magnet valley VS turn number of the particle trajectories

DISCUSSION

Central region of a 11 MeV cyclotron was designed. Beam tracking was done with a code written in c++ by our team. The particles are emitted from the slit of ion source in rest. After several adaptive design processes, the accepted RF phase of the central region reached 40 degrees.

The beam dynamics in the first gap may be sophisticated because of the existence of the plasma in the first gap. But the beam tracking code neglects the plasma in the first gap, which may leads to errors of the simulation results.

REFERENCES

[1] He Xiaozhong et al. Annual Science and Technology Conference of CAEP, Mianyang, May, 2008.
[2] Opera user manual.