Modeling of 450 MeV Carbon Cyclotron

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PSI is planing to build a new superconducting seperate-sector cyclotron for therapy purperse, which will accelerates the injected 250MeV/N Carbon(A=12.0, Z=6) particles to 450MeV/N at the extraction point. Mr. Joho and Negrazus give priliminay layout of the sectors structure and the shape of the sectors. The RF frequency is 100MHz and harmonic number is 12. the magnetic field at sector regin is homogeneous and its value is 4.0 Tesla. The inner radius of sector is 3.3m and outer radius is 4.5m.

To obtain the basical facusing characteristic of the magnetic field, OPAL-CYCL is firstly used to caculate the betatron oslication frequency, namely, betatron tune. To do this, a small code is developed to generate the fild map on median plan. As the fridge fields of two side edges is very important for facusing characteristic, especally on virtical direction, the Enge's empirical function (NIM A 540 (2005) 1-13) is used as an approach of fridge fields.

$$B_z(x,0) = B_{max}h(x) = B_{max}\frac{1}{1 + exp(c_0 + c_1x + c_2x^2 + c_3x^3 + c_4x^4 + c_5x^5)} \tag{1}$$

In our case, x is the azimuthal distance to the hard edge of magnet in units of the full gap of the sector magnet. $c_0 = -0.4785, c_1 = 2.9215, c_2 = -0.8683, c_3 = 0.2000, c_4 = -0.0300, c_5 = 0.0020$ Because 6 sectors are totally equal and the field is repeated after each 60 degree, only 1/6 field
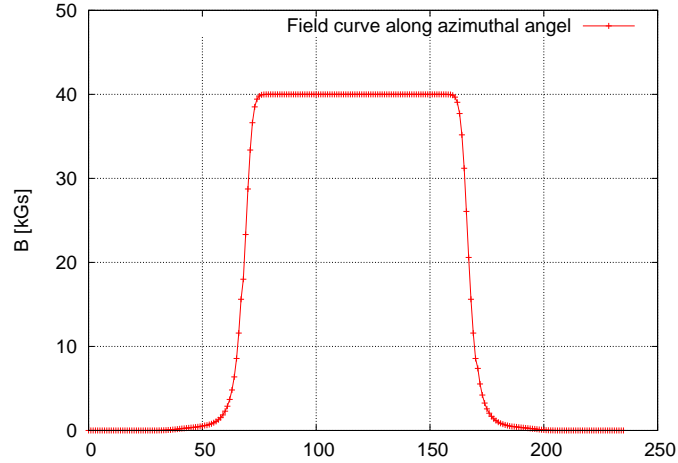

Figure 1: the generated field along azimuthal angle of Carbon Cyclotron

data is generated by the code and stored in memory when run OPAL-CYCL . For more detail of the setting for tuning calculation, one can refer to the OPAL User Guide.

Betatron tune is calculated from 250 MeV to 450 MeV after each 20 MeV. Firstly, run single particle tracking of OPAL-CYCL to scan the approximately matched initial conditions for each energy. Then run tune calculation mode of OPAL-CYCL . Figure2 shows the tune result and Figure3 shows the closed orbit result.
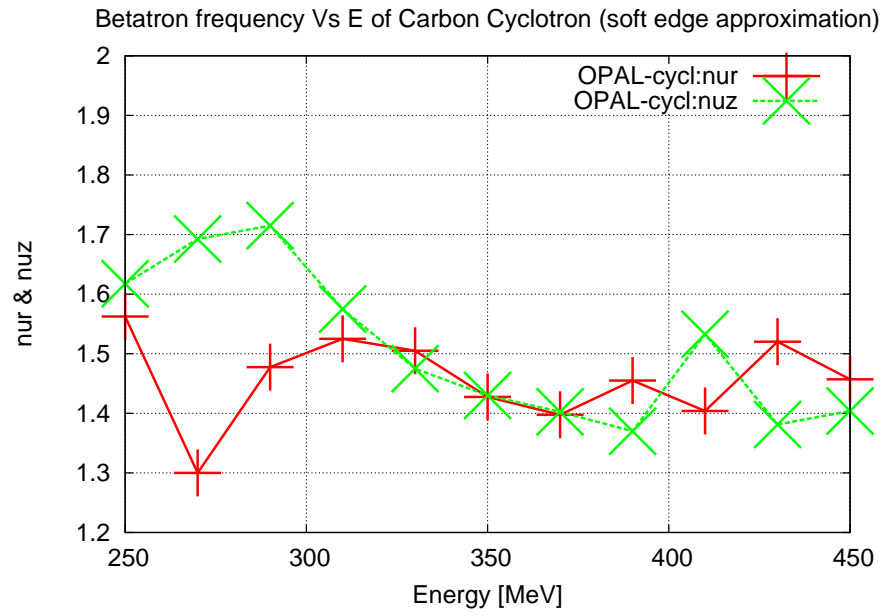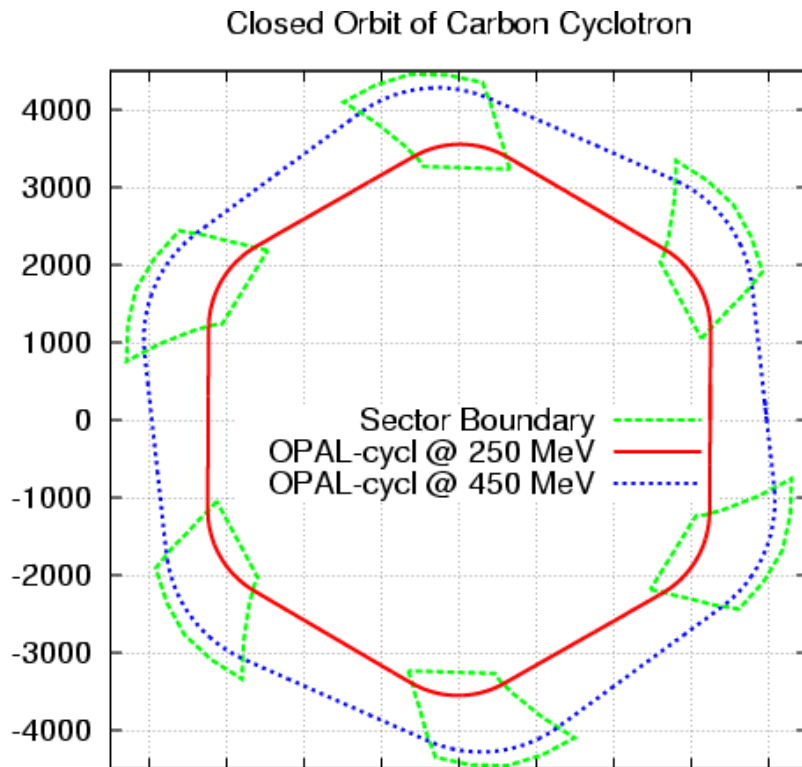
Figure 2: Tune of carbon cyclotron

Figure 3: Closed orbit of the mininal and maximal energy