EXTRACTION SIMULATION FOR CYCIAE-100

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Abstract

A 100 MeV H- compact cyclotron is under constructed in China Institute of Atomic Energy (CYCIAE-100). 75 MeV - 100 MeV proton beams with 200 μA beam intensity will be extracted in dual opposite directions by charge exchange stripping devices. The crossing point at the switching magnet center is fixed inside the magnetism yoke. The extracted beam distribution after stripping foil can be got from the multi-particle tracking code COMA. The extracted trajectories are simulated with the transfer matrix including the dispersion effects, which got from the GOBLN. The beam emittance, envelope, dispersion, energy spread, bunch length after stripping extraction and after the switch magnet are analyzed. The beam parameters after extraction are given by the extracting orbit simulation.

INTRODUCTION

A 100 MeV H- compact cyclotron is under constructed in China Institute of Atomic Energy (CYCIAE-100) [1-2]. 75 MeV - 100 MeV proton beams with 200 μA beam intensity will be extracted in dual opposite direction by charge exchange stripping devices. Two stripping probes with carbon foil are inserted radially in the opposite direction from the main magnet pole and the obtained two proton beams by charge exchange after stripping foil are transported into the crossing point in a switch magnet center separately under the fixed main magnetic field. The switch magnet is fixed between the adjacent yokes of main magnet in the direction of valley region. The extracted beam optic trajectories are studied in detail for the switch magnet inside the yoke.

The basic optic trajectories of extracted proton beams with various energies have been studied with the code CYCTR [3]. By comparing the optic calculating results for the extracted beam, the position of switch magnet is fixed according to the chosen position of stripping foil. The transfer matrix from the stripping foil to the crossing point is got from the code GOBLIN [4] including the dispersion effects. With the multi particle tracking code COMA [5], the phase space distributions on the stripping foil for the extracted beam are got. The distributions after the switch magnet are got from the transfer matrix, which is got from GOBLIN. The extracted beam parameters are given by the extracted optics calculation.

THE POSITIONS OF SWITCH MAGNET AND STRIPPING FOIL

The positions of the stripping points and the switch magnet are chosen by calculating the extraction trajectories of extracted proton beams after stripping foil for different energy with the code CYCTR. The main magnetic field used to calculate the extraction trajectories is assumed to have mid-plane symmetry for the CYCIAE-100, which is a compact isochronous cyclotron with 4 separate sectors. The extracted beam energy is chosen by the corresponding static equilibrium orbit, which is calculated with the code CYClOP [6].

For CYCIAE-100, the outer radius of magnetism yoke is 308Cm and the switch magnet locates at inside the magnetism yoke with (R=2.75m, THETA=100^0). Fig.1 shows the position of switch magnet and the extracted beam trajectories from the stripping foil to the switch magnet center for different energies. The red lines are the equilibrium orbits, corresponding the energies are from 20MeV to 100MeV and R200, R241 is the outer radius of pole resp. coil. Tab.1 shows the positions of stripping foil with the extraction energy between 70MeV and 100MeV. The stripping foil is at (R=1.597m, THETA=61.0^0) for 70MeV and (R=1.85m, THETA=63.4^0) for 100MeV. So, the stripping probe needs to be inserted radially from the magnetism pole at THETA=62.0^0 and the minimal radius of inserting the foil is 1.59m.

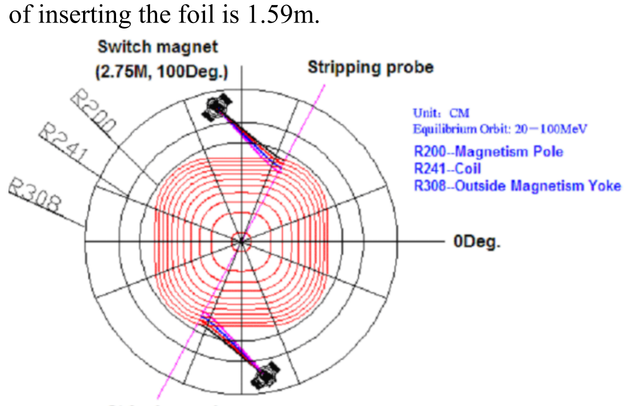

Figure 1: Stripping probe and position of switch magnet. (The red lines are equilibrium orbits).

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Table 1: Position of stripping foil with different extraction energy, switch magnet is located inside the magnetism yoke with (2.75m, 100^0).

E(MeV)	R(M)	THETA(Degree)
100	1.8523	63.41247
90	1.7748	62.5695
80	1.6903	61.8095
70	1.5967	61.0161

STRIPPING EXTRACTION SIMULATION WITH COMA

The extracted beam distribution just after stripping foil can be got from the multi-particle tracking code COMA. The H- beam is injected from the symmetry center of valley with azimuth $\theta=0^0$, and the beam will be tracked along the inserting direction of stripping probe with azimuth $\theta=61.02^0$. The initial beam energy is $E_0=1.49$MeV at the radius of R=23.1Cm. From the measurements results of IBA-30 and CIAE-30 [7], the choice of the initial normalized emittance of $\varepsilon_x=\varepsilon_z=4\pi$-mm-mrad for CYCIAE-100 used in the COMA is reasonable. The input phase space distributions are uniform in both transverse and longitudinal directions with the phase extension of $\Delta\varphi=\pm20^0$, but with zero energy spread, and 10920 macro particles are used. Fig.2 shows the realistic input phase space distribution. The switch magnet is fixed at the position of (2.75m, 100^0) and corresponding the stripping foil is at the radial position of (1.5967m, 61.02^0) for extraction energy of 70MeV and (1.85m, 63.4^0) for extraction energy of 100MeV. Fig.3 shows the extracted beam phase space distributions on the stripping foil with the energy of 70MeV resp. 100MeV. The results for the extracted energy of 70MeV are very similar as the case of 100MeV.

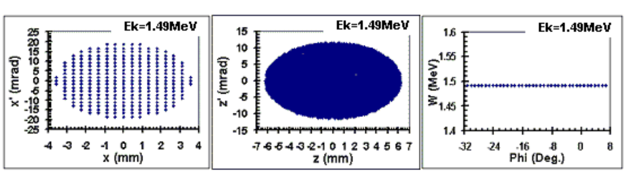

Figure 2: Initial phase space distribution with the normalized emittance of 4.0π-mm-mrad.

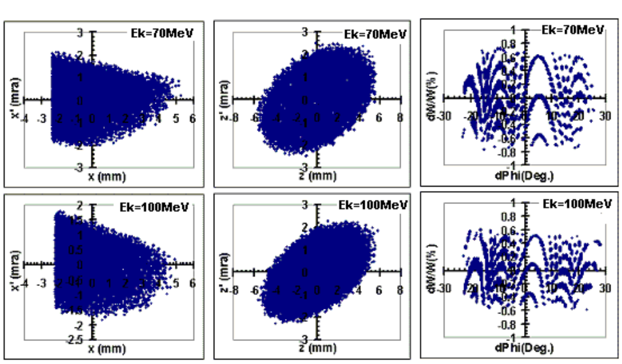

Figure 3: The extracted phase space distribution for 70MeV & 100MeV on the stripping foil

EXTRACTED TRAJECTORIES SIMULATION

With multi particles tracking code COMA, the extracted beam distribution can be got on the stripping foil. Then the extracted beam trajectories can be simulated with the transfer matrix including the dispersion effects, which is got from the code GOBLIN. For the extracted proton beam, the increasing of the beam emittance due to the stripping foil scattering is ignored here. For the extracted trajectories between stripping foil and switch magnet, the beam envelope and transverse emittance are studied in detail.

The extracting trajectories with switch magnet

The field of switch magnet is different for different extracted energy and the bending angle is $\pm5^0$. The field is zero for the extracted energy of 85MeV. Fig.4 shows the extraction trajectory including the fields of switch magnet for different extracted energy. With the different fields, the extracted beam with different energy after stripping foil will go through the crossing point of the switch magnet center and will be extracted along the same direction after crossing point.

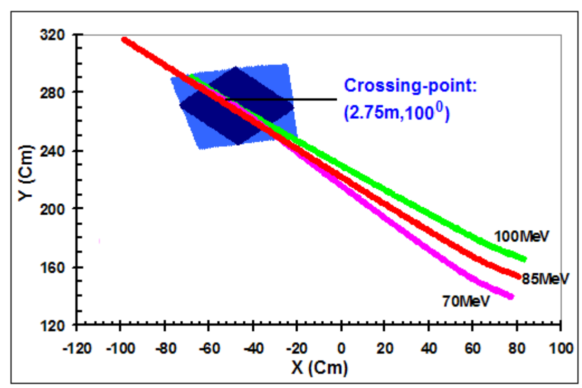

Figure 4: The extracted trajectories with the switch magnet fields for different energy.

The effects of dispersion

The Dispersion is free inside the cyclotron due to the symmetric magnetic fields. But after the stripping foil, the proton beam will be extracted along the extraction trajectory. Due to the asymmetric magnetic field, the dispersion will be produced and this will lead to the emittance growth in x direction. The dispersion from stripping foil to the center of switch magnet (crossing point) will be got from GOBLIN. Fig.5 shows the dispersion for the energy of 70MeV and 100MeV with the switch magnet inside the yoke. The symbol of star in the plots is the position of the switch magnet and the symbol of triangular is the position of (3.3m, 100^0) after switch magnet.

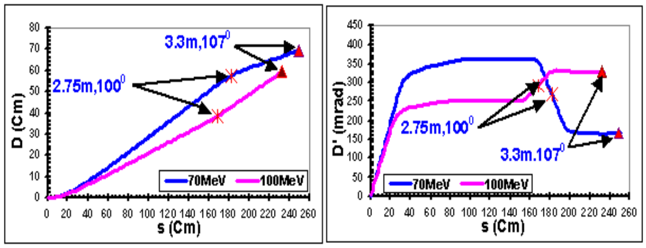

Figure 5: The dispersions for the switch magnet located at (2.75m, 100^0).

From the results, the dispersion will be large for the lower energy and longer distance before the crossing point. The field of switch magnet can cancel the dispersion partly for 70MeV, but increase the dispersion for 100MeV. So the switch magnet is helpful to the low energy, but harmful to the high energy.

The simulation results after the crossing point

With simulation results with COMA and the transfer matrix including the dispersion effects got from the code GOBLIN, the extracted phase space distributions at the position of (3.3m, 100^0) after the crossing point are shown in Fig.6.

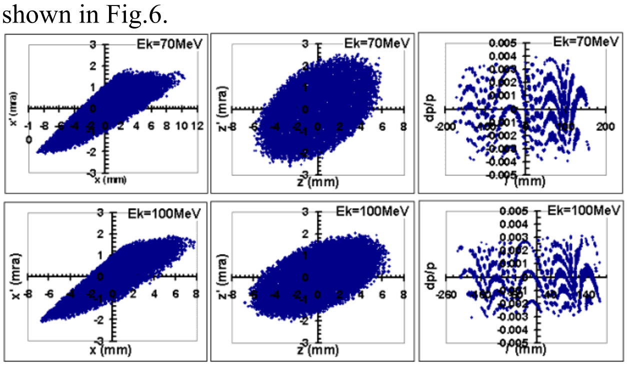

Figure 6: The phase space distributions at the position of (3.3m, 100^0) for 70MeV & 100MeV.

With the simulation results from COMA and extraction trajectory calculation, the normalized emittance and beam envelopes are shown in Tab.2.

SUMMARY

For CYCIAE-100, the extraction trajectories for different extracted energy are simulated in detail. From the simulation results, the initial normalized emittance of $\varepsilon_x=\varepsilon_z=4\pi$-mm-mrad used in the calculation is reasonable and the calculation results are close to the realistic case comparing with the measurement results of IBA and CIAE-30MeV. The dispersion effects to the beam are big in the horizontal direction and the emittance growth in the horizontal direction is mainly from the dispersion effects. The changes of emittance and beam envelope in the vertical direction are very slow. It will be helpful to make focusing and matching for the post transfer line to put the switch magnet inside the yoke. The dispersion for low energy can be cancelled partly with the switch magnet, but it will be worse for the high energy. The dispersion effects must be considered for the post transfer line matching.

Table 2: The normalized emittance and beam envelope at different positions for 70MeV & 100MeV.

Positions	Emittance	Energy /MeV	
		70	100
After foil	ε_x/π-mm-mrad	4.39	4.14
	x /mm	5.27	4.89
	ε_z/π-mm-mrad	5.53	6.22
	z /mm	5.63	5.82
Crossing point (2.75m, 100^0)	ε_x /π-mm-mrad	9.2	7.2
	x /mm	9.4	6.9
	ε_z /π-mm-mrad	5.7	6.4
	z /mm	5.6	6.4
Position of (3.3m, 100^0)	ε_x /π-mm-mrad	8.56	7.76
	x /mm	10.4	7.8
	ε_z /π-mm-mrad	5.68	6.5
	z /mm	5.7	6.8

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