THE SIMULATION OF STRIPPING EXTRACTION PROCESS FOR CYCIAE-100*

Shizhong An#, Fengping Guan, Ming Li, Sumin Wei, Tianjue Zhang, Jianjun Yang
China Institute of Atomic Energy, Beijing, 102413, P.R. China

Abstract

A 100 MeV H- compact cyclotron is under construction at China Institute of Atomic Energy (CYCIAE-100) and the first beam has been got on Jun. 25th this year. The proton beams of 75 MeV - 100 MeV at intensity of 200 µA will be extracted in dual opposite directions by charge exchange stripping devices. The two main parameters for the stripping extraction are the positions of stripping foil and combination magnet. For CYCIAE-100, the center of combination magnet is fixed at (R=2.75 m, θ=100°) and the extracted radii decide the positions of stripping foil for different extracted energies. In order to analyze the extracted proton beam parameters, the stripping extraction process for CYCIAE-100 is simulated in detail in this paper. The simulation is mainly done for the different RF acceptance or acceleration phase width. Due to the simulation results, the extraction turns are more for the large phase width and it will be reduced effectively with small phase width. The transverse beam distribution and the extracted beam profile are not affected by the initial phase width due to the simulation, that's the characters of the cyclotron with the stripping extraction mode.

INTRODUCTION

The project of Beijing Radioactivity Ion-beam Facility (BRIF) is being constructed at China Institute of Atomic Energy (CIAE) [1] [2]. A 100 MeV H- compact cyclotron (CYCIAE-100) with 200 µA beam intensity as a proton driving system of BRIF is going to the process of beam tunning and the first beam has been got on Jun. 25th this year. 75 MeV - 100 MeV proton beams will be extracted in dual opposite direction by charge exchange stripping devices. The extraction system for CYCIAE-100 includes the stripping probe system and the combination magnet [3]. Two stripping probes with carbon foil are inserted radially in the opposite directions from the hill gap region and the two proton beams after stripping are transported into the crossing point in a combination magnet center separately under the fixed main magnetic field. The combination magnet is fixed between the adjacent yokes of main magnet in the direction of valley region at (R=2.75 m, θ=100°). The stripping probe system is the most complex device among the individual devices for CYCIAE-100 and the structure of the foil changing system in the vacuum is adopted. The foil automatic changing machine is outside the magnetism yoke and 12 pieces foil can be changed in one time. Two combination magnets have been installed at the exit of extraction for the stripping system after finishing the magnet field measurements.

The positions of the stripping points for different extracted beam energies are fixed after the studying for the optical trajectories of the extracted beam [3]. In order to analyze the extracted proton beam parameters, the stripping extraction process for CYCIAE-100 is simulated in detail in this paper. The simulation is mainly done for the different RF acceptance or acceleration phase width with the fixed initial transverse emittances. The extracted beam parameters such as extracted turns, extracted beam energy spreads, extracted beam profiles, etc are compared in detail for the long accelerating bunch with phase width of $\Delta\varphi=\pm 20°$ and short bunch with phase width of $\Delta\varphi=\pm 2°$. Due to the simulation results, the extraction turns are more for the large phase width and it will be reduced effectively with small phase width. The phase width for the extracted bunch after stripping foil will be enlarged under the sine acceleration voltage form, but the energy spreads for the extracted beams with the different initial phase width are almost the same after stripping foil. The transverse beam distribution and the extracted beam profile are not affected by the initial phase width due to the simulation, that's the characters of the cyclotron with the stripping extraction mode.

THE POSITIONS OF STRIPPING FOIL

For CYCIAE-100, the outer radius of magnet yoke is 3.08 m and the combination magnet is located inside the yoke (R=2.75 m, θ=100º). The positions of the stripping points for different energies are calculated with the code CYCTR. The extracted beam energy is chosen by the corresponding static equilibrium orbit, which is calculated with the code CYClOP [4]. Figure 1 shows the position of combination magnet and the extracted beam trajectories from the stripping foil to the combination magnet center for different energies. The red lines are the equilibrium orbits, corresponding the energies are from 20 MeV to 100 MeV and the circles R200 and R241 are the outer

*Work supported by NSFC (Grant No. 11375273)
#szan@ciae.ac.cn

radii of the pole and the coil. Table1 shows the positions of stripping foil with the extraction energy between 70 MeV and 100 MeV [5].

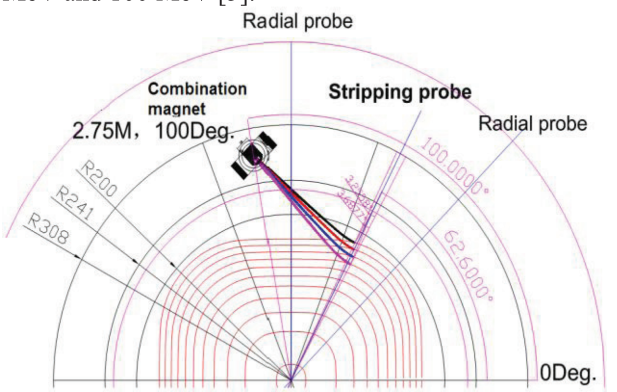

Figure 1: Positions of stripping points for extracted energy of 70MeV, 80MeV, 90MeV and 100MeV.

Table 1: Position Of Stripping Foil With Different Extraction Energy With Code CYCTRS.

Energy (MeV)	R (m)	θ (Deg.)
100	1.875	59.63
90	1.796	58.96
80	1.708	58.39
70	1.609	57.81

STRIPPING EXTRACTION SIMULATION FOR SMALL PHASE WIDTH

The extracted beam process simulations for 70MeV are done with the multi-particle tracking code COMA [6]. 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 $\theta=57.8^o$. The initial beam energy is E_0=1.49MeV at the radius of R=23.1Cm. The initial transverse normalized emittance of $\varepsilon_x=\varepsilon_z=0.23\pi$-mm-mrad are used. The input phase space distributions are uniform in both transverse and longitudinal directions with the phase extension of $\Delta\varphi=\pm2°$, but with zero energy spread.

Figure 2 shows the particle distribution for each turn. The simulaition results show, total 5 turns are needed to extract the whole bunch for the short bunch with the phase width of $\Delta\varphi=\pm2°$. Figure 3 shows the total extracted beam phase space distribution on the stripping foil. From the simulation, the particles will be extracted in the 209th turn and they will be extracted completely after 213th turn. About 8% particles will be extracted after 209th turn and 59.7% particles will be extracted after 210th turn. 66.3% particles will be extracted after 211th turn and almost 100% particles will be extracted after 212th turn. The energy spread is about +-0.6% and the phase extension is about 10° for the extracted beam distribution. Figure 4 shows the extracted particle distribution with the turns and the extracted beam profile on the stripping foil. The extracted beam distribution is Gaussion-like distribution and the extracted beam is distributed between 160 cm and 160.6 cm on the foil.

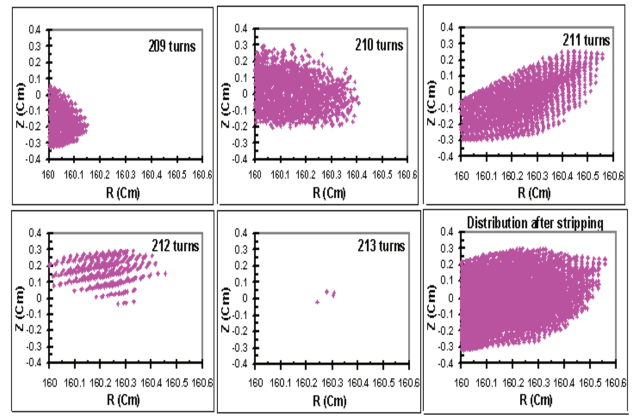

Figure 2: The extracted particle distribution for each turn.

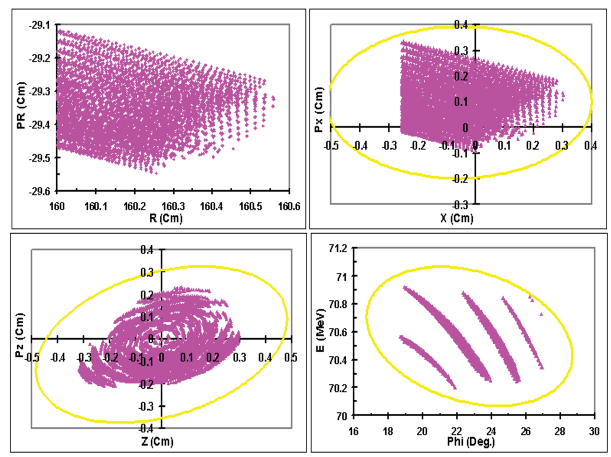

Figure 3: The total extracted beam distribution on the stripping foil. The yellow lines are the phase space boundary with 5 time realistic emittance.

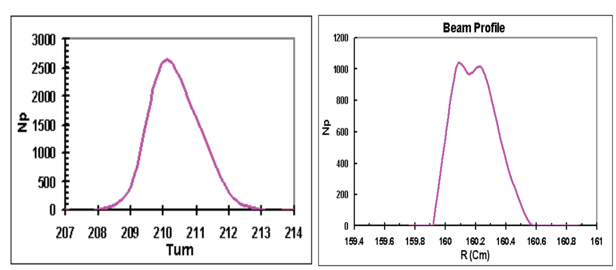

Figure 4: The extracted particle distribution and extracted beam profile on the stripping foil.

STRIPPING EXTRACTION SIMULATION FOR LARGE PHASE WIDTH

The stripping extraction process simulations for 70MeV beam for large phase width with the phase width of $\Delta\varphi=\pm20°$ are done with the multi-particle tracking code COMA too. Just the phase width is enlarged by factor 10 and other initial input simulation conditions are the same

ISBN 978-3-95450-171-7

as the case for the short bunch with the phase width of $\Delta\varphi=\pm 2°$.

Figure 5 shows the particle distributions just at the first turn extraction. From the simulation results, the particles are distributed at the radius range of 20 cm (140cm ~ 160cm). So, it needs about more than 60 turns to extract the whole long bunch with the phase width of $\Delta\varphi=\pm 20°$. From the simulation, the particles will be extracted in the 208th turn and they will be extracted completely after 265th turn. About 95% particles will be extracted after 20 turns, see figure 6. Figure 7 shows the total extracted beam phase space distribution on the stripping foil. The energy spread is about +-0.6% and the phase extension is about 55° for the extracted beam distribution. The extracted beam distribution is Gaussion-like distribution and the extracted beam is distributed between 160 cm and 160.6 cm on the foil too.

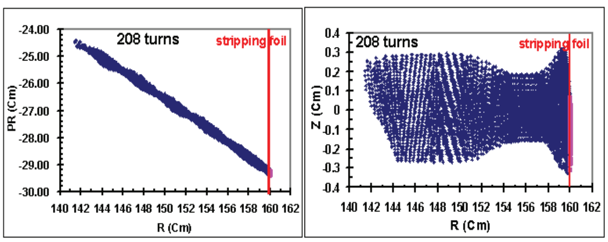

Figure 5: The particle distributions just at the first turn extraction.

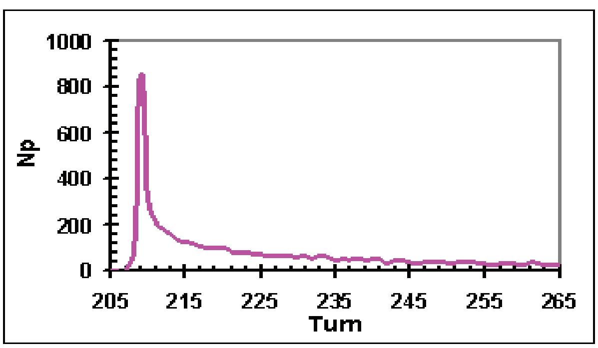

Figure 6: The extracted particle distributions with turns.

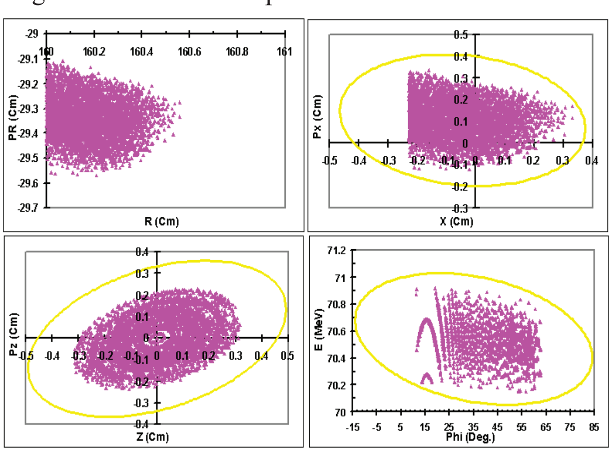

Figure 7: The total extracted beam distribution on the stripping foil. The yellow lines are the phase space boundary with 5 time realistic emittance.

SUMMARY

For CYCIAE-100, the stripping extraction process for long bunch with phase width of $\Delta\varphi=\pm 2°$ and short bunch with phase width of $\Delta\varphi=\pm 20°$ are simulated in detail. From the simulation results, RF acceptance for different bunch length is almost no effect to the transverse beam distribution. Large initial phase width will lead to more extracted turns and short initial phase width will lead to less extracted turns. It is very hard to get the single turn extraction for the compact cyclotron with the stripping extraction system even with very short bunch width if the sine waveform voltage is used for the acceleration. The transverse space distributions and the energy spread of the extracted beam are almost the same for the case of long initial phase width and short phase width. Large phase width means high beam intensity.

ACKNOWLEDGEMENTS

The authors are very much grateful to Dr. Yi-Nong Rao from TRIUM, who give us considerable help and providing materials concerning the cyclotron under design. Also the authors would like to give the grateful acknowledge to Dr. Gerardo Dutto, George Mackenzie, R. Baartman from TRIUM, Dr. Wernor. Joho from PSI, Jingyu Tang from IHEP-Beijing, for the extraction discussion and lots of useful suggestions.

REFERENCES

[1] Tianjue Zhang, et al., A New Project of Cyclotron Based Radioactive Ion-beam Facility, APAC 2004.
[2] Tianjue Zhang, et al, 100 MeV H- Cyclotron as an RIB Driving Accelerator, CYC 2004.
[3] Stripping extraction system for CYCIAE-100, CYCIAE Design note in Chinese, 2006.
[4] GOBLIN User Guide and Reference V3.3, TRI—CD-90-01, TRIUMF.
[5] Stripping Extraction Calculation and Simulation for CYCIAE-100, Shizhong An, Fengping Guan, etc, China Physics C (HEP & NP), 2009, 33(Suppl. Ⅱ).
[6] COMA – A Linear Motion Code for Cyclotron, C.J. Kost, G.H.Mackezie, IEEE Transactions on Nuclear Science, Vol.NS-22, No.3, June 1975.

ISBN 978-3-95450-171-7