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DYNAMIC VACUUM SIMULATION FOR THE BRing

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Abstract

A new large scale accelerator facility is being designed by Institute of Modern Physics (IMP) in Lanzhou, which is named as the High Intensity heavy-ion Accelerator Facility (HIAF). This project consists of ion sources, Linac accelerator, synchrotrons (BRing) and several experimental terminals. During the operation of BRing, the heavy ion beams will be easily lost at the vacuum chamber along the BRing and in turn leads to an increase in beam loss rate. In order to control the dynamic vacuum effects induced by the lost beams and design the collimation system for the BRing in the HIAF project, a newly developed simulation program (ColBeam) and GSI's simulation code StrahlSim are both conducted and the dynamic vacuum simulation result is calculated by the StrahlSim. According to the simulation result, 3×10^{11} ppp particles is the maximum beam intensity can be extracted for the current designed BRing vacuum system and collimation system. Higher beam intensity can reach to 5×10^{11} ppp when the Non Evaporable Getter (NEG) coating technology must be implemented for the dipole and quadrupole chamber.

INTRODUCTION

The HIAF project consists of ion sources, Linac accelerator, synchrotrons and several experimental terminals. The Superconducting Electron-Cyclotron-Resonance ion source (SECR) is used to provide highly charged ion beams, and the Lanzhou Intense Proton Source (LIPS) is used to provide H_2^+ beam. The superconducting ion Linac accelerator (iLinac) is designed to accelerate ions with the charge-mass ratio Z/A=1/7 to the energy of 17 MeV/u. Ions provided by iLinac will be cooled, accumulated and accelerated to the required intensity and energy in the Booster Ring (BRing), then fast extracted and transferred either to the external targets or the Spectrometer Ring (SRing) [1]. The layout of the HIAF project is shown in Fig. 1.

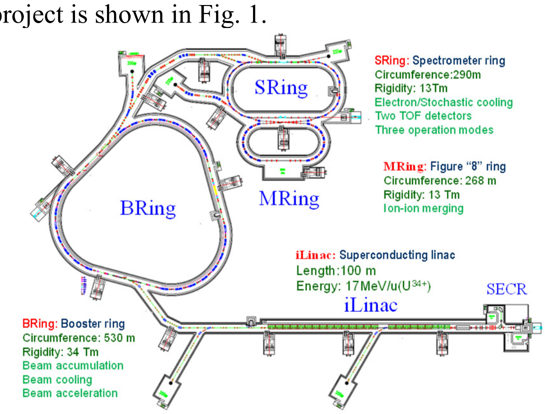

Figure 1: Layout of HIAF project.

BRing AND ITS VACUUM SYSTEM

BRing Lattice and Basic Parameters

The circumference of the BRing is 569.1 meters with three arc sections acts as a charge separator providing a peaked distribution of ionization beam loss and with three long straight sections to provide adequate space for the injection, extraction system and the RF system. A number of different lattice structures have been investigated with respect to the fraction of ions controlled by the collimators and the collimator distance from the beam edge. The final chosen doublet structure assured an almost hundred percent control of single ionized beam ions without affecting the machine acceptance. The beta function and dispersion function of one super cell are shown in Fig. 2.

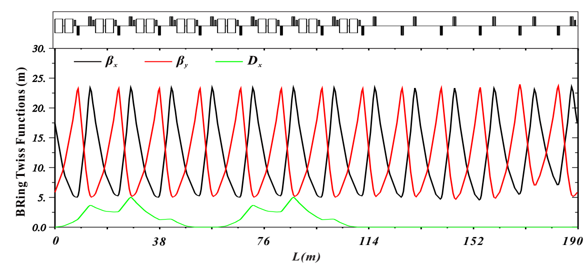

Figure 2: The beta and dispersion function of BRing.

The dipole magnets of BRing adopt traditional technology room temperature yoke magnet and the maximum magnetic field can reach up to 1.6 T. Eight bumpers are divided into two groups, which one group in horizontal and the other group in vertical plane, together with a tilted electrostatic septum are used for the two-plane painting injection. Two kickers located in one straight section are used for the fast extraction. Moreover, the stored ions can be exacted slowly and homogeneously by the slow extraction system consisted of sextupoles, RF excitation and electrostatic septum. An RF cavity with a range of frequency from 0.2MHz to 1.4MHz installed in another dispersion-free straight section is used to capture and accelerate ions.

The BRing dipole magnetic field data cycle of the reference beam uranium $^{238}U^{35+}$ for the fast extraction is shown in Fig. 3.

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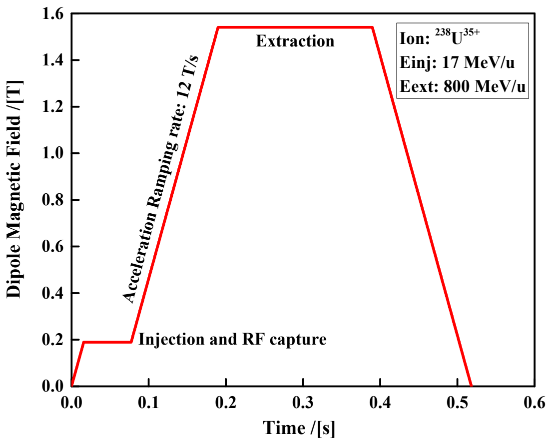

Figure 3: dipole magnetic field data cycle of the $^{238}U^{35+}$ for the fast extraction mode.

BRing Vacuum System Design

The total inner surface of the BRing vacuum system is about 450 m^2 and total volume is 11000 L. The all-metal gate valves divide into six sections for separate equipment installment and replacement. All ring components of these sections have to be manufactured of UHV-compatible materials to allow bake-out at the temperature of 300°C [2]. A baking system with the temperature at 300°C for at least 24h will be necessary to obtain a stainless steel outgassing rate of low 10^{-13} to10^{-14} Torr.l.s^{-1}.cm^{-2} as required for BRing.

The evacuation of the BRing vacuum system from atmospheric pressure is done with oil-free roughing and turbo-molecular pumps down to about 10^{-8} mbar. Sputter ion pumps (SIP), titanium sublimation pumps (TSP) and NEG pumps are distributed around the synchrotron ring to reach the designed vacuum pressure goal. Sputter ion pumps with pumping speeds of 200~400 l/s remove non-getterable gases such as methane and argon. Titanium sublimation pumps have a high capacity for hydrogen at very low pressure, where the residual gas is mainly H_2 (90%). The NEXTorr is an extremely compact pump which integrates sputter ion pump and NEG pump technologies with larger pumping speed and capacity to sorb gases very effectively down to the XHV level [3]. A schematic drawing of the vacuum layout of one super period of BRing is shown in Fig. 4.

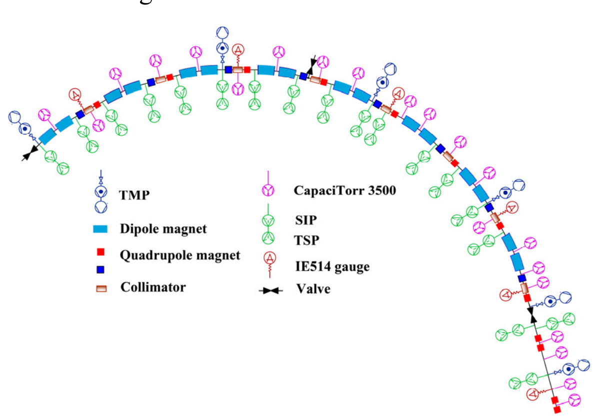

Figure 4: Schematic vacuum layout of one super period of BRing.

BEAM LOSS DISTRIBUTION

Beam Loss Distribution

In order to simulate the charge exchange driven by the beam loss and dynamic vacuum effects in heavy ion synchrotrons, GSI firstly developed a program package named StrahlSim during the past few years [4]. With the scientific collaboration between GSI and IMP, a new program package (ColBeam) designed for optimizing the collimation efficiency is developed by taking different types of errors into account in the accelerator.

With a constant static vacuum pressure around the ring, the beam trajectory for one electron-loss $^{238}U^{36+}$ is illustrated in Fig. 5(a) with the parameters shown in Table 1. The loss position and intensity of the charge exchanged particle at each point is counted and shown in Fig. 5(b). Semi logarithmic coordinate system is employed to illustrate the beam loss intensity at each position along the BRing. In Fig. 5 (a), the X-axis is the longitudinal positions of the BRing and Y-axis is the logarithmic value of the lost beam intensity at each position.

Table 1: Basic Parameters for Simulation

Reference ion	$^{238}U^{35+}$
Energy (MeV)	17
Transverse Tune (Qx/Qy)	9.47/9.43
Horizontal emittance (pi mm.mrad) 5-sigma	100
Vertical emittance (pi mm.mrad) 5-sigma	60
Momentum deviation for $^{238}U^{32+}$	~10^{-4}
Charge exchanged ion (Coasting beam)	$^{238}U^{34+}$ and $^{238}U^{36+}$

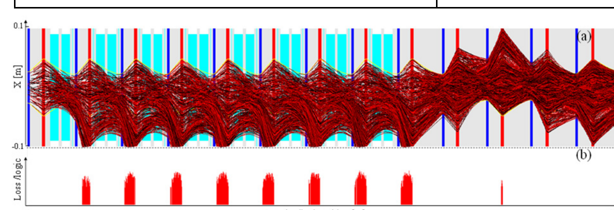

Figure 5: Simulation results for one capture-loss $^{238}U^{36+}$: (a) Beam loss trajectory. (b) Beam losses distribution. Loss/logic means: the logarithmic value of the lost beam intensity at each position.

DYNAMIC VACUUM SIMULATION

Static Vacuum Pressure Profile

Before the dynamic simulation starts, the static vacuum pressure profile along the BRing is calculated by the StrahlSim. The pressure in the vacuum system of the BRing is initialled with a uniform start value along the ring. For the calculation, a total outgassing rate for stainless steel of 7×10^{-12} Torr.l.s^{-1}.cm^{-2}.

The static pressure profile of the BRing calculated by the StrahlSim is shown in Fig. 6 with and without NEG coating.

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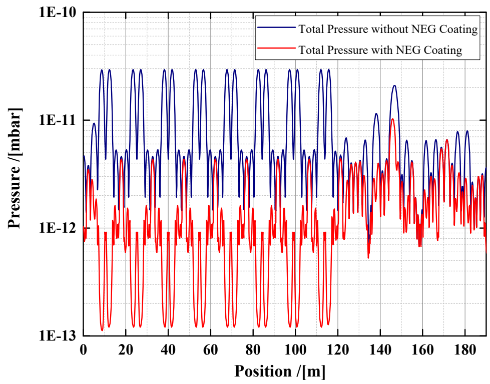

Figure 6: Static pressure profile along the BRing with and without NEG coating.

DYNAMIC VACUUM SIMULATION RESULT

Without ionization loss, the amount of extracted particles linearly depends on the number of injected particles [5]. Due to the dynamic vacuum effects, the transmission decreases with increasing beam intensity. Above a specific number of injected particles, the number of extracted particles decreases.

Without any systemic loss and NEG coating, 3×10^{11} ppp particles are injected into the BRing each time and the pressure is increased to 1×10^{-11} mbar to reach the equilibrium state. The number of particles evolution and the pressure in the BRing with beam intensity 3×10^{11} ppp is shown in Fig. 7.

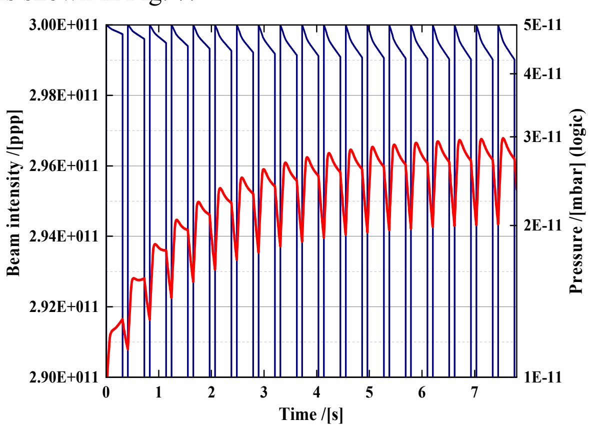

Figure 7: Extraction particle number and the pressure evolution with the synchrotron cycles for the injection beam intensity is 3×10^{11} ppp.

When the injection particles below 3×10^{11} ppp, the dependence of extraction particle number is linear because the desorption molecules can be pumped out. However, with the increasing of the injection particles numbers, the desorption molecules induced by the lost beam number is increasing and can't be pumped out as quickly as possible. Then the vacuum pressure in the synchrotron will not be stable and the ionization rate is increasing. The maximum extraction particle number in the BRing with the injection particle number can be seen in Fig. 8.

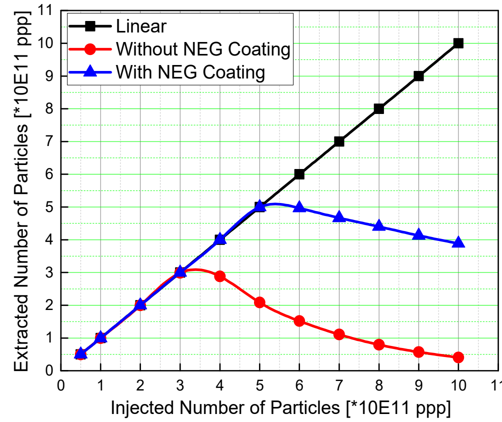

Figure 8: Extracted particle number evolution with injected number of particles.

CONCLUSION

Beam loss distribution induced by the charge exchanged in the BRing is calculated and present in this paper by using the HIAF simulation code ColBeam which have been verified by the GSI's simulation code StrahlSim. Dynamic vacuum evolution has been simulated by implemented of the StrahlSim based on the current vacuum system design to check the extraction particle number 3×10^{11} ppp whether it can be achieved or not. It is concluded that the design particle number goal can be achieved based on the current vacuum system and collimator system design. More extraction particle number in the BRing can be achieved by implemented the NEG coating technology on the dipole and quadrupole vacuum chamber.

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