Space Charge Effects of High Intensity Beams at BRing

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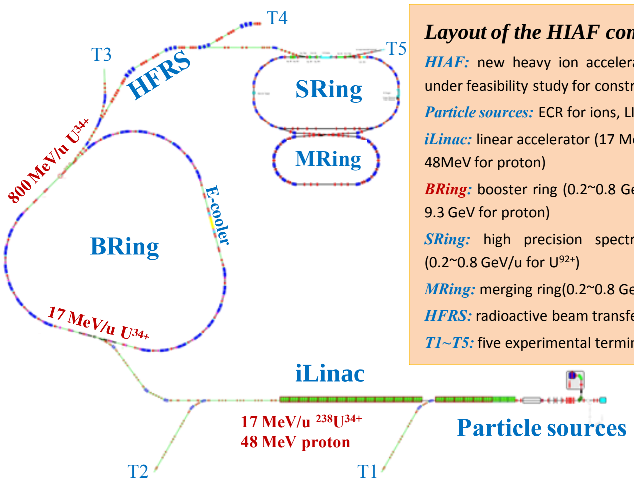
Abstract: Space charge effects perform one of the main intensity limitations for low energy synchrotron. Large tune spread and crossing resonance stop-bands can hardly be avoided for intensive heavy ion beam at high intensity. Several subjects like Betatron and structure resonance, and tune spread are discussed. Simulations are carried out for $^{238}U^{34+}$ focusing on emittance and intensity change during RF capture at the injection energy at the booster ring of the High Intensity heavy ion Accelerator Facility (HIAF).



Layout of the HIAF complex

HIAF: new heavy ion accelerator complex under feasibility study for construction

Particle sources: ECR for ions, LIPS for proton

iLinac: linear accelerator (17 MeV/u for U^{34+}, 48MeV for proton)

BRing: booster ring (0.2~0.8 GeV/u for U^{34+}, 9.3 GeV for proton)

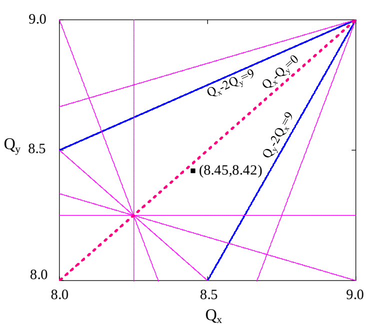
SRing: high precision spectrometer ring (0.2~0.8 GeV/u for U^{92+})

MRing: merging ring(0.2~0.8 GeV/u for U^{92+})

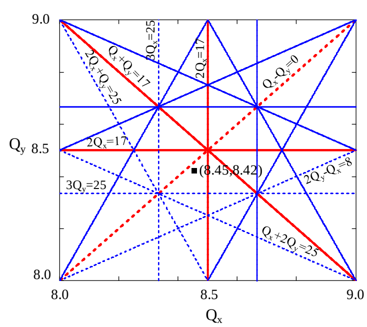
HFRS: radioactive beam transfer line

T1~T5: five experimental terminals.

RESONANCES AT TUNE SPACE

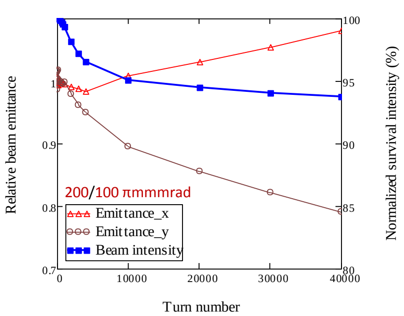


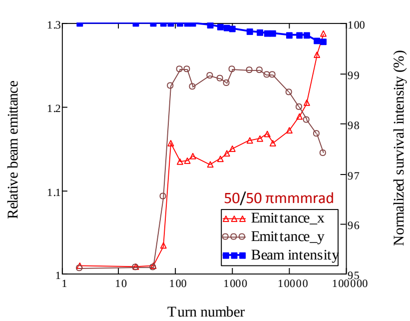
Structure resonances: 3rd order (blue), 4th order (pink); linear coupling resonance (red dash)



Betatron resonances: 2nd order (red), 3rd order (blue); resonances to be compensated (dash).

SIMULATION OF BEAM EMITTANCE AND SURVIVAL INTENSITY





Relative emittance change in horizontal ("△") and vertical ("○") plane after filling up transverse acceptance or cooling to 50/50 πmmmrad at the BRing, and normalized survival beam intensity ("■") during RF capture process from coasting.

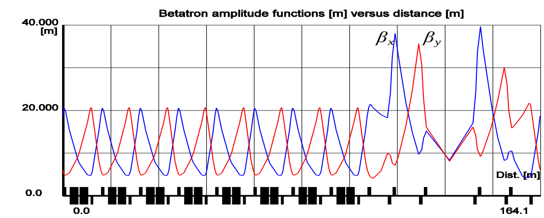
Tracking 10^4 macro particles or $1.0\cdot10^{11}$ $^{238}U^{34+}$ under 2.5D space charge model at injection energy of 17 MeV/u. Lost ions collected by elliptical "Aperture limit" (41mm, 50mm).

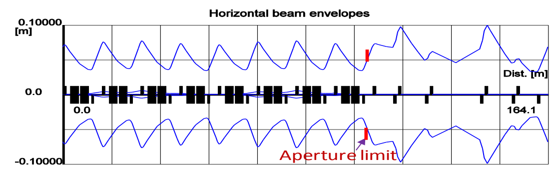
Upper left: linear coupling resonance -- vertical emittance starts growth from about 1000 turns or 8.7 ms while the horizontal one decreases simultaneously; beam loss reaches 6%.

Lower left: fast blow up -- emittance growth of 15% at horizontal and 25% at vertical in 100 turns at beginning of RF capture. Linear coupling resonance -- emittance exchange also occurs but 15% slower than the case before. Beam loss only 0.4%.

Less loss attribute to the shrinkage of transverse emittance while larger beam loss at upper case ascribe to beam emittance very close to acceptance.

Basic parameters of the BRing		
Circumference	492.53 m	
Super-periodicity	3	
Acceptance (x/y,δp/p)	200/100 πmmmrad, ±0.5%	
Particle type	Proton	$^{238}U^{34+}$
Injection energy	48 MeV	17 MeV/u
Intensity	$1.0\cdot10^{12}$	$1.0\cdot10^{11}$
Betatron tune	(11.45,11.42)	(8.45,8.42)
Cycle mode	EX+PT (fast)	PT (fast), PT+EC (slow)

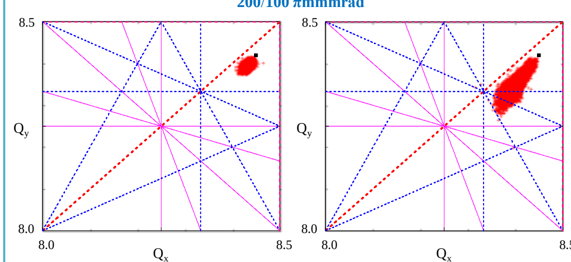




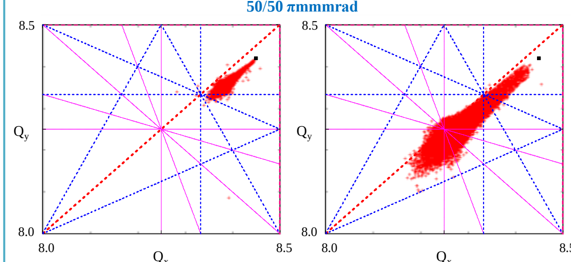
Twiss parameters and horizontal beam envelope for one super-period at the BRing

SIMULATION OF TUNE SPREAD

200/100 πmmmrad



50/50 πmmmrad



Tune spread of coasting (left) and bunched (right) for $1.0\cdot10^{11}$ number of U^{34+}.
a). Crossing resonance stop-bands for bunched beam while coasting not.
b). Spreads width by simulation is nearly a half comparing to calculation.

CONCLUSION

The structure and Betatron resonances are discussed for the nominal working point of the BRing at injection energy . Tune spreads of two cases at design intensity are evaluated by calculation but twice the width comparing to simulation. Transverse emittance exchange occurs from about turn 1000 in tracking of RF bunching at the two operation cycle modes. Shrinkage of transverse emittance by electron cooling is helpful for reducing beam loss when linear coupling resonance is involved.

OUTLOOK

Further study is considered for the BRing with near actual transverse and longitudinal distribution, and field errors at the injection energy. Compensation of resonances is suggested but more details for technical design are required.

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