Investigation on the suppression of Intrabeam Scattering in the high intensity heavy ion beam with the help of longitudinal multi-bunch chain of electron

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Background

- Particle number expected in the storage ring.（1×10^{11}，$^{238}U^{92+}$）
- Lifetime of ion beam in the storage ring.
- Quality of ion beam in the storage ring.
- Experiments efficiency.

Motivation

- Maintain the intensity of ion beam（1×10^{11}，$^{238}U^{92+}$）
- Counteract and suppress the IBS in the heavy ion beam with high density .
- Prolong the lifetime of ion beam.
- Increase the efficiency of experiments.

Conditions

- The Ion source has ability to deliver the enough intensity high charge state heave ion beam.
- The injector can pre-accelerate this high intensity ion beam with high efficiency.
- The novel injection scheme (two plane painting) can accumulate higher intensity ion beam in the storage ring.
- The main accelerator can capture and accelerate this high intensity ion beam with high efficiency.
- This high intensity ion beam, can be extracted from the main accelerator.
- The final ion beam intensity or density at the experimental terminals?
- The lifetime of ion beam at the terminal?

Key point

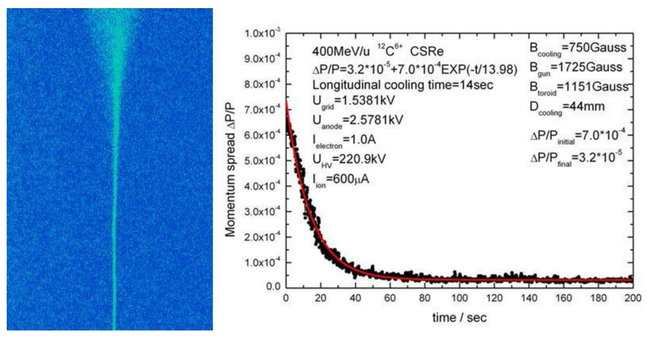
Low ion density without cooling.
Ion loss with cooling.

Compromise：

Cooling + less ion loss

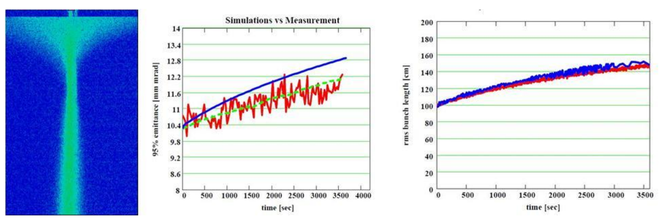
Problem：

The distribution of ion beam deviate from the initial Gaussian type under the electron cooling. A dense core and a long tail formed during the cooling.



Electron Cooling

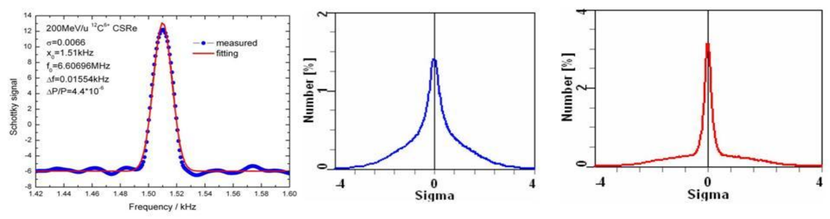
Problem description——Intrabeam Scattering



- The ion beam with certain energy, certain particle number, certain initial emittance and momentum spread was cooled down and approach to an equilibrium state.
- Cooling = Heating.
- The parameters of this equilibrium state depends on the many factors, such as lattice, ion beam, electron cooling etc..

Intrabeam Scattering

- more important for heavy ions than protons due to Z^4/A^2.
- more important for electrons than protons due to m^2.
- becomes more important for higher beam densities.



The distribution of ion beam deviate from the initial Gaussian type under the electron cooling

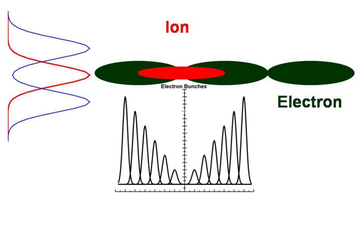
Possible Solution

- Conventional DC electron beam.
- Multi-bunch chain of electron.
- The stronger cooling was expected in the tail of ion beam and the weaker cooling was performed in the tail of ion beam.
- The particle outside will experience stronger cooling and will be driven back into the centre of ion beam.
- The weaker cooling in the centre of ion beam, avoid over-cooling.
- similar as hollow beam in transverse direction.
- Multi-bunch chain of electron with different longitudinal distribution.

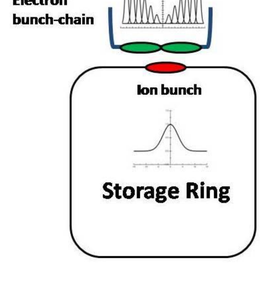
key technology

- Several independent power supplies will be delay triggered.
- Produce continuous multi-bunch chain.
- The strength of every single bunch will be adjustable.
- The longitudinal distribution of multi-bunch chain will be adjustable.
- The time sequence between ion pulse and multi-bunch chain of electron will be adjustable.

Proposed Idea

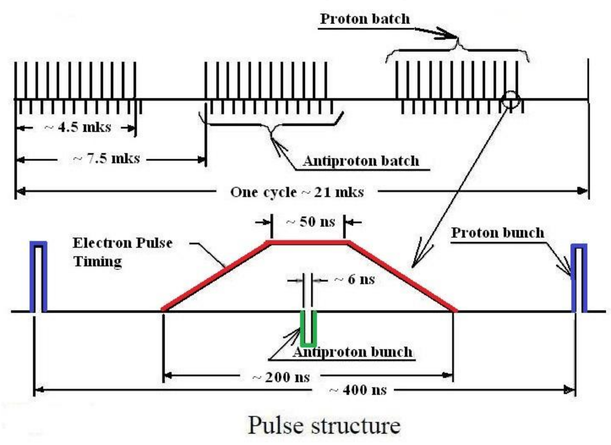


The distributions of ion bunch and electron multi-bunch in the transverse and longitudinal directions respectively

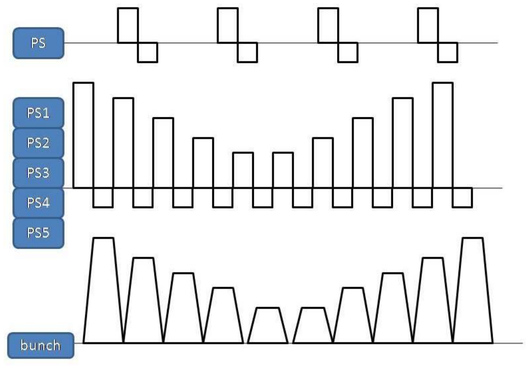


The realtion of ion pulse and multi-bunch chain of electron in the storage ring

Feasibility Analysis

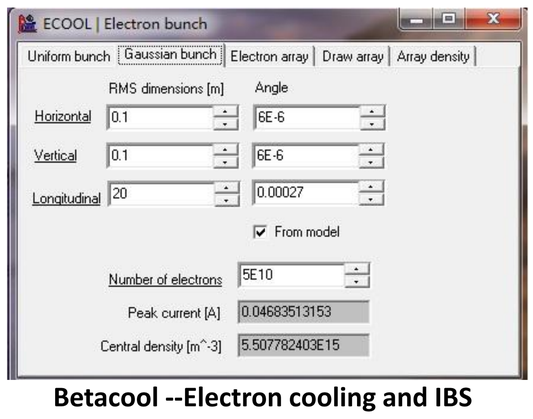


The temporal series between proton pulse, antiproton pulse and the electron pulse in the electron lens.

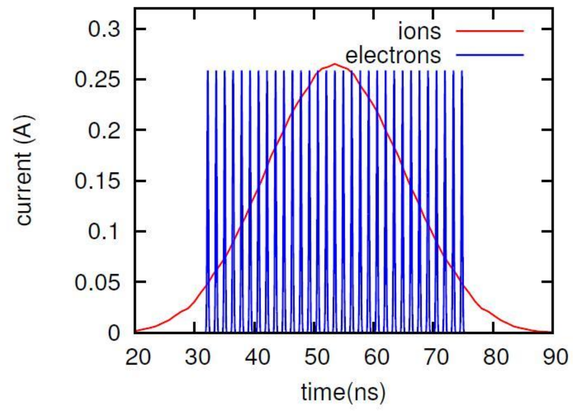


Ten electron bunches generated by five independent HV power supplies with the help of delay trigger

Simulation

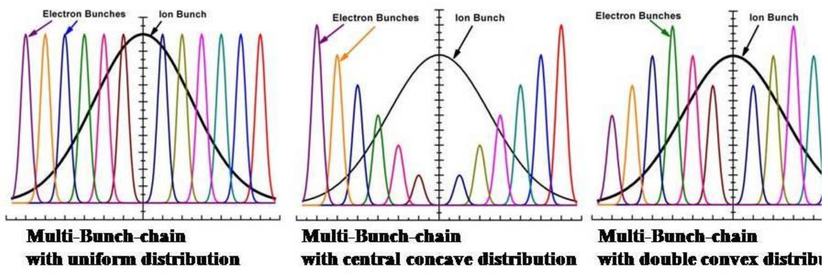


Betacool --Electron cooling and IBS simulation program developed in JINR

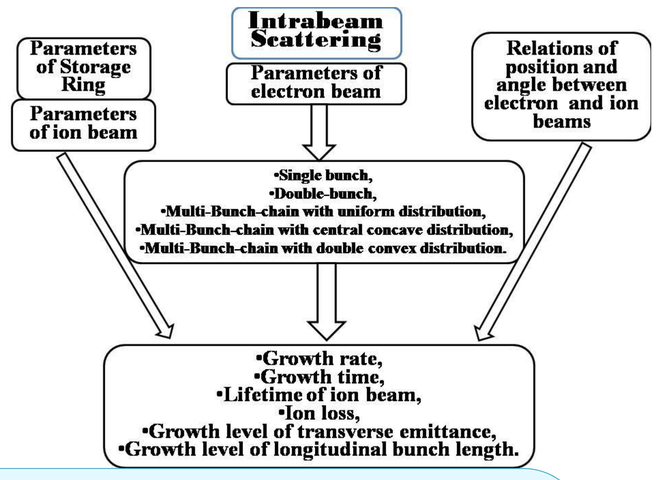


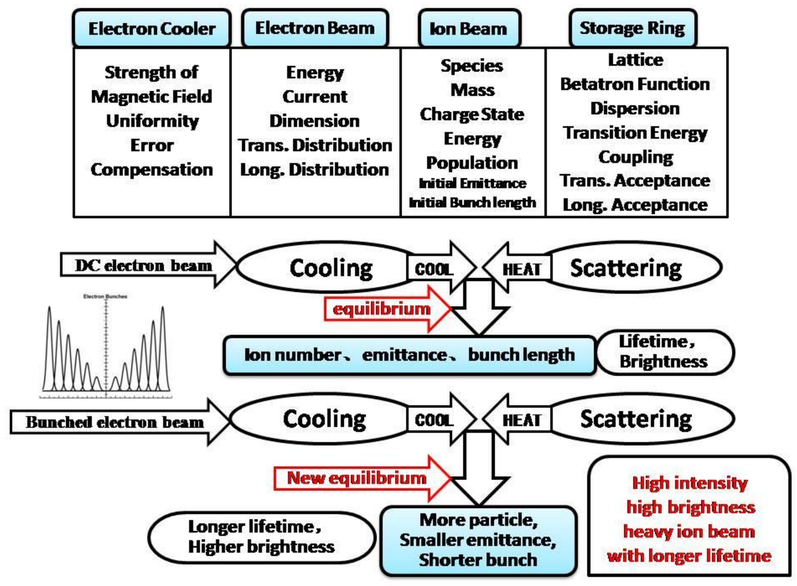
The distribution of one ion pulse and 31 uniform electron bunches

Experimental Investigation



The longitudinal distributions of ion bunch and electron multi-bun with different interval





Summary

- The conventional DC electron beam was replaced by multi-bunch chain of electron.
- Multi-bunch chain of electron with different longitudinal distribution.
- The stronger cooling was expected in the tail of ion beam and the weaker cooling was performed in the tail of ion beam.
- This solution was expected to decrease the ion loss and prolong the lifetime of ion beam.
- The ion beam density was maintained for longer time in the storage ring, and ensued the certain luminosity in the physics experiment terminals.
- This exploration was expected to provide some helpful information for the design of electron cooler and operation parameters and mode in the case of high density high charge state ion beam.

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