Studies of electron-ion heating at LEReC

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BROOKHAVEN NATIONAL LABORATORY

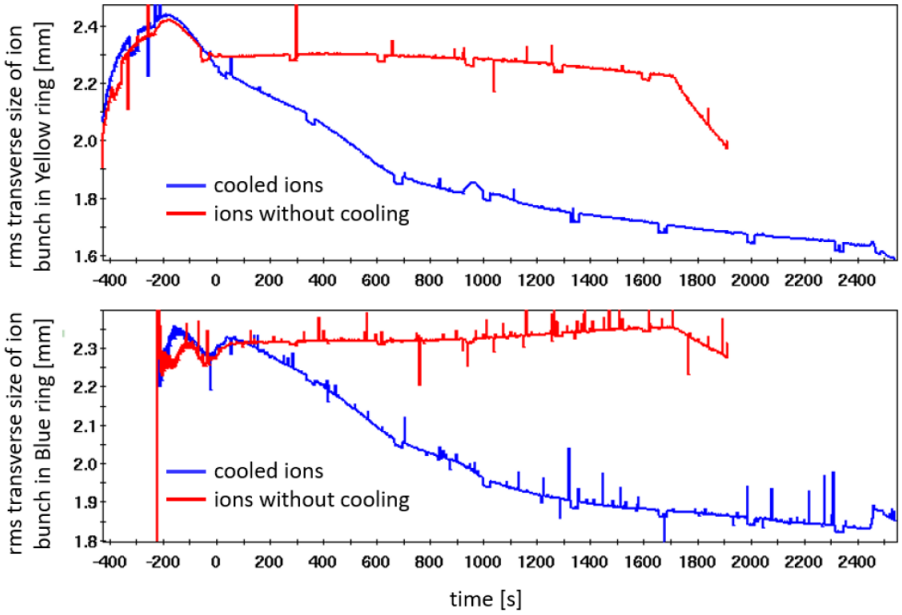
U.S. DEPARTMENT OF ENERGY

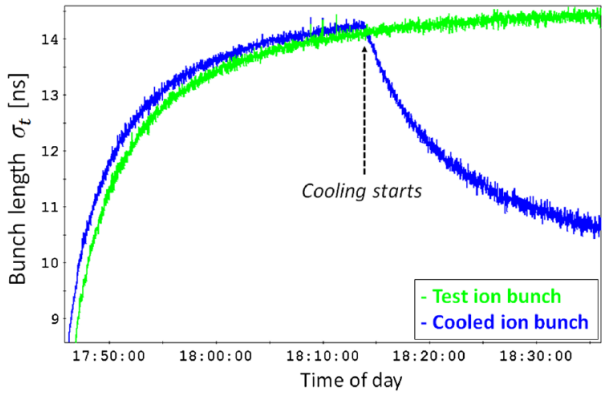
Outline

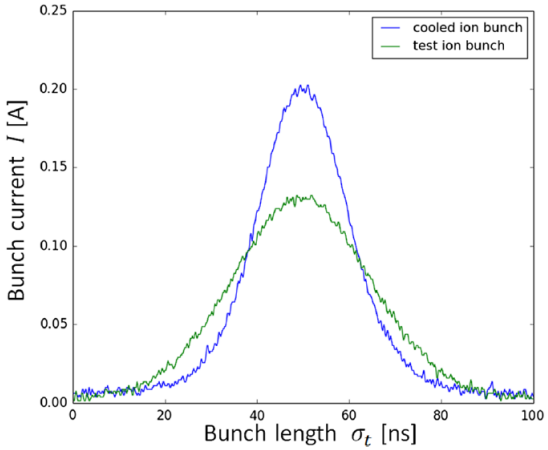
- What we mean when we say “heating”
- Possible explanations of the effect
- Studies plan

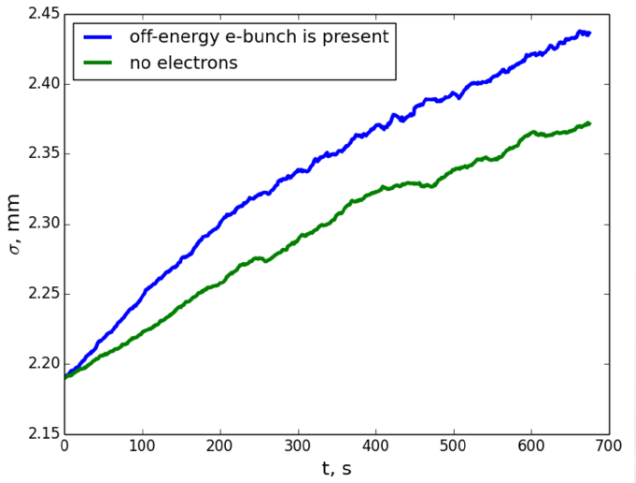
Electron-ion heating (EIH)

In addition to cooling, which is revealed as an increase in ion bunches' density in the presence of well-aligned, γ-matched e-bunches









We also have e-i heating, which is manifested by faster (than IBS-driven) growth in beam size in the presence of off-γ electrons as well as by some increase in ion losses.

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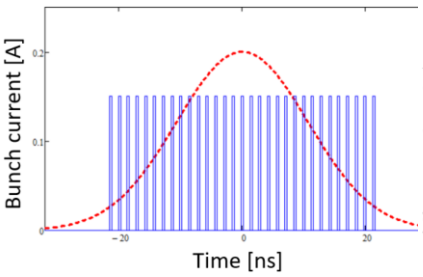
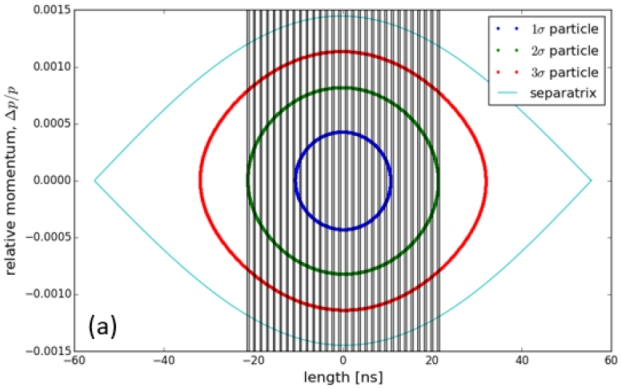
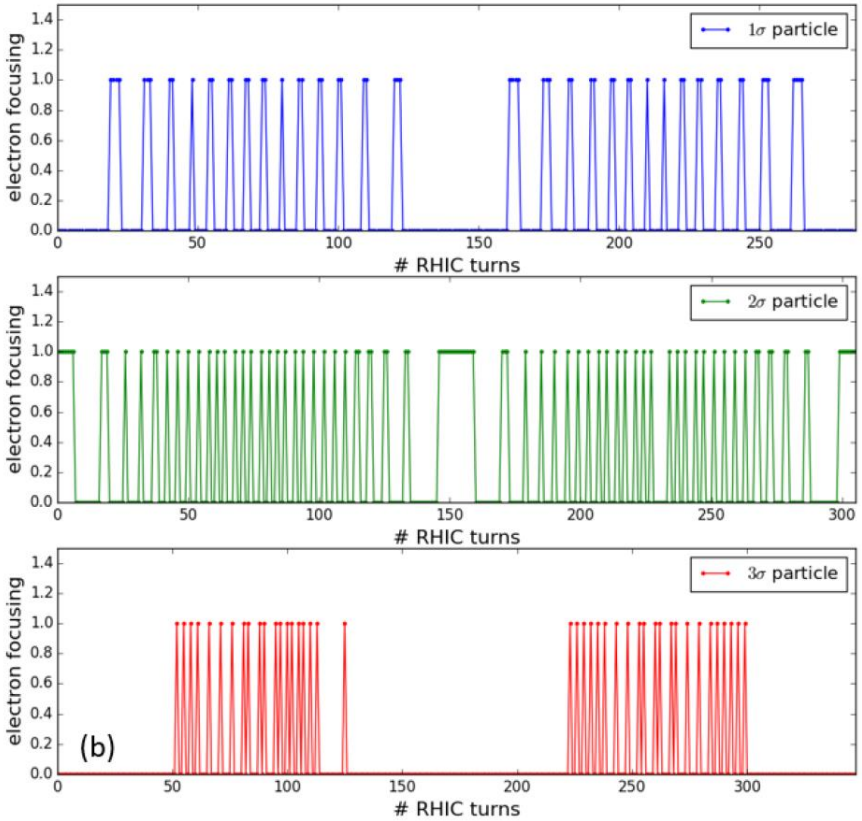
EIH explanations

- Focusing kicks from the space charge of e-bunches can drive **synchro-betatron resonances**. The heating effect occurs due to the IBS continuously “dragging” individual ions through the resonance conditions.







- If one treats “transitional” kicks (kick on one RHIC turn – no kick on the other turn and vice versa) as random kicks, then one ends up with a simple analytic formula describing the heating process:

$$\alpha_\epsilon = \frac{KB(\epsilon)I_e^2}{\beta^7\gamma^{7.5}} \qquad B(\epsilon) \propto \sigma_{re}^{-4}$$

“random walk model”

- Finally, **coherent excitations** (monochromatic instability) can cause additional losses. This effect is a subject of separate studies.

Dedicated studies plan

- We have a trove of operational data which tangle together a lot of various effects
- We need clean, unambiguous data that can be obtained only in dedicated studies.
- The studies will be performed with low intensity ions in the Yellow ring only
  - This minimizes the IBS and the i-e focusing, increases ions lifetime and removes beam-beam
  - We'll make intensity of 111 bunches as low as is still observable by the h-jet
- Cooling must be "detuned" for the studies. (2 hr)
  - A part of preparation is to find the best way to kill the cooling – energy offset (potential for circular attractor creation), increased energy spread (a weak knob), zig-zag trajectory?
- The most basic and the most important measurement is the heating rate vs. an e-bunch charge density. (4 hr)
- Another measurement is short bunches vs. long bunches with the same charge density (4 hr)
- We plan measuring the heating rate vs. the macro-bunch pattern (4 hr)
  - 10 bunches in the center
  - 10 bunches moved to 2σ
  - 20 bunches in the center vs. 10 bunches - gap - 10 bunches
- Dependence of heating on γ-factor probably should wait until next year

Summary

- The extra emittance growth and increased losses in the presence of electrons (electron-ion heating) is haunting LEReC and must be considered when designing realistic coolers for the EIC
- Dedicated studies of the EIH effect, proposed for this year shall take about 14 hr total