Electron Cooling of Au Ion Beams at RHIC

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Based on:

Cooling simulation and experimental benchmarking for an rf-based electron cooler
H.Zhao et al.

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Outline

1. What is electron cooling?

2. How is it implemented and studied at RHIC?

3. What are the results from measurements and simulations?

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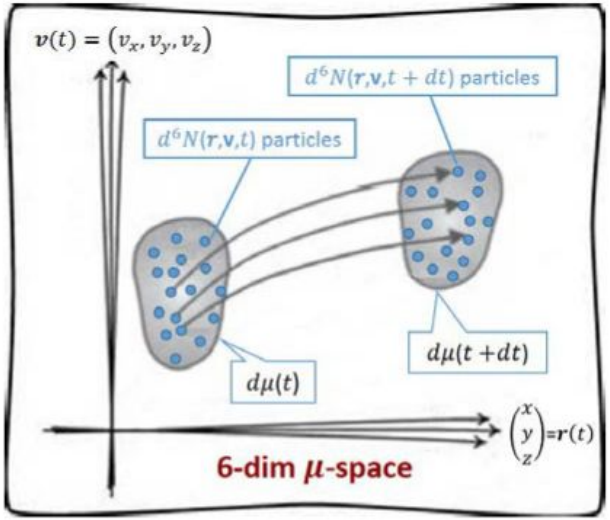
Electron cooling

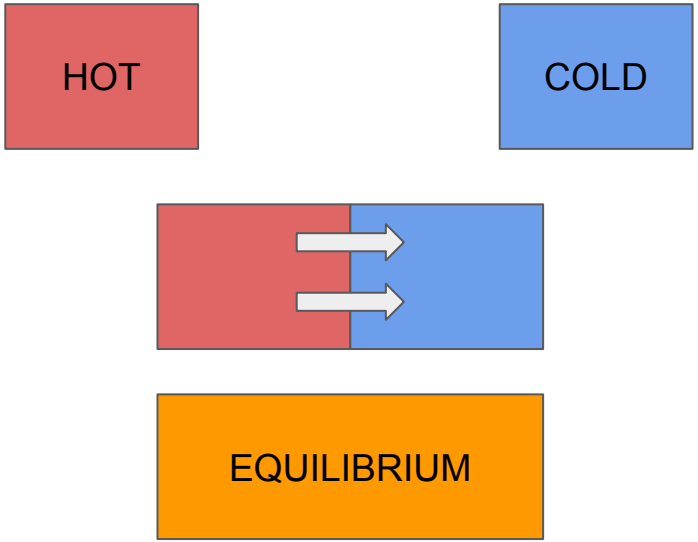
- Goal: reduce energy/momentum spread of a beam of ions, i.e.
  - Increase phase space density
  - reduce temperature
- Reasons: increase luminosity, increase beam lifetime...

Liouville's Theorem

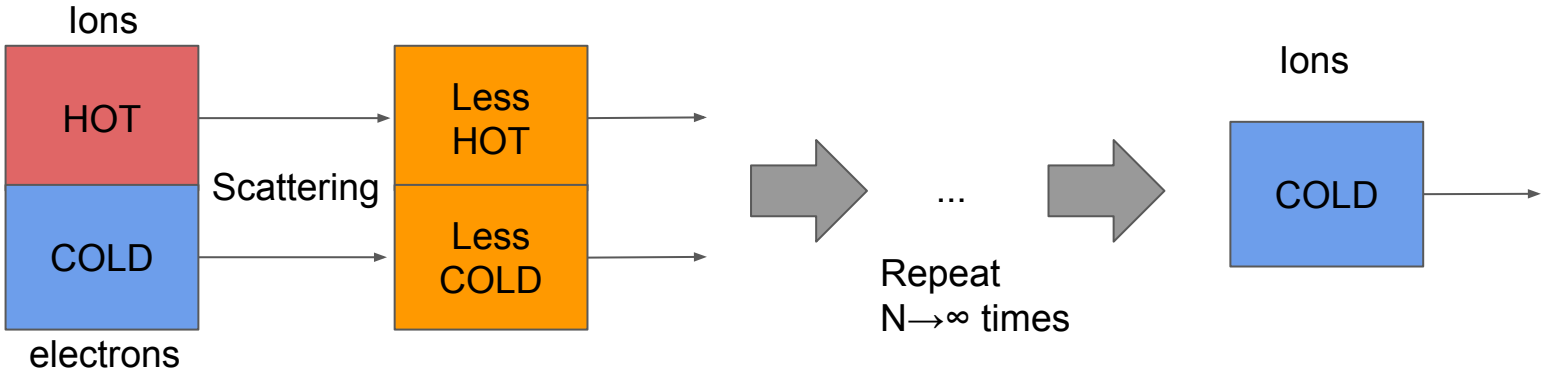


https://e-publishing.cern.ch/index.php/CYRSP/article/view/263

Thermodynamics

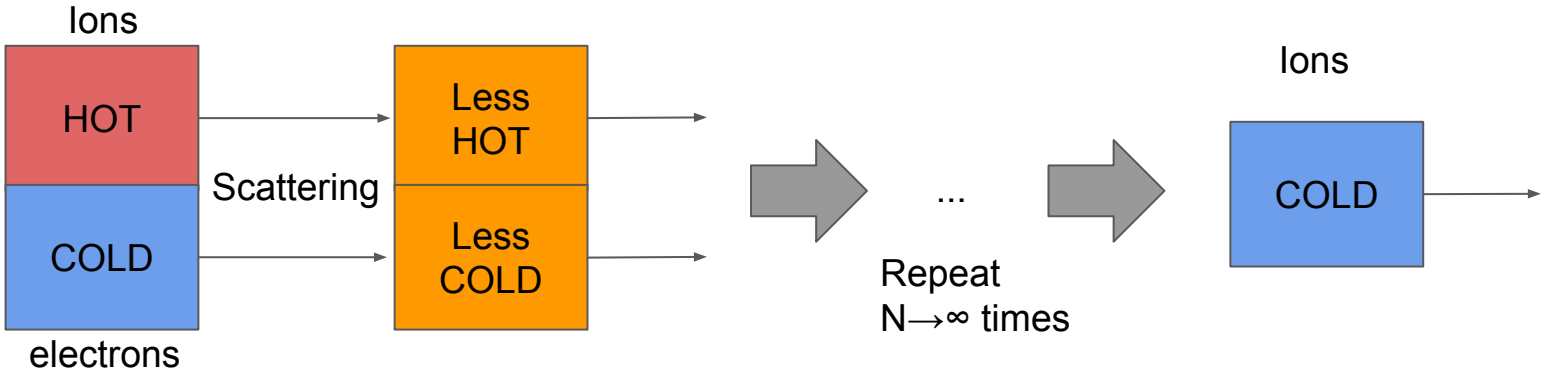


Electron cooling



1. Inject e- beam with $v_{electron} \cong v_{ion}$
2. Since $T \sim m \langle v^2 \rangle$ and $m_{ion} >> m_{electron}$ -> $T_{ion} >> T_{electron}$
3. $T_{ion} \rightarrow T_{equilibrium}$ via multiple Coulomb scattering
4. Replace e- beam and back to 1

Electron cooling



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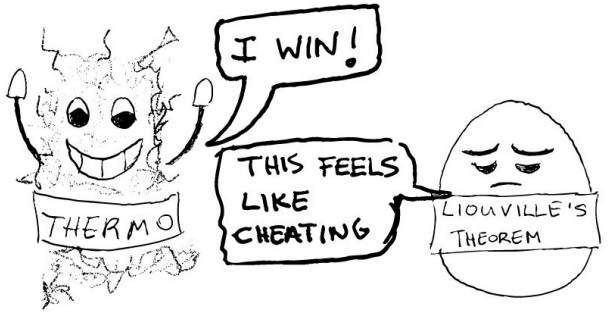

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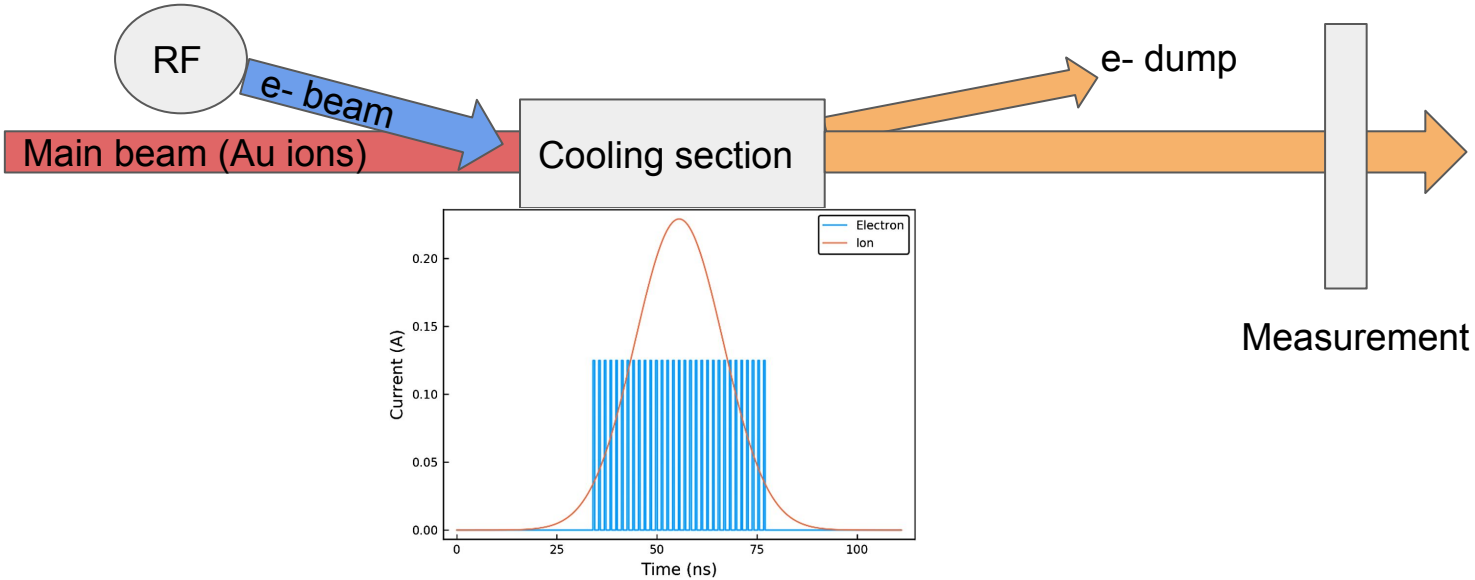
e- Cooling at RHIC

- **Goal: improve luminosity at very low energies**

- **First to use RF accelerated electron bunches**
  - No DC limit: can go to higher e- energies
  - e- beam has time structure: need to study effects -> In-house code developed ('TRACKIT')



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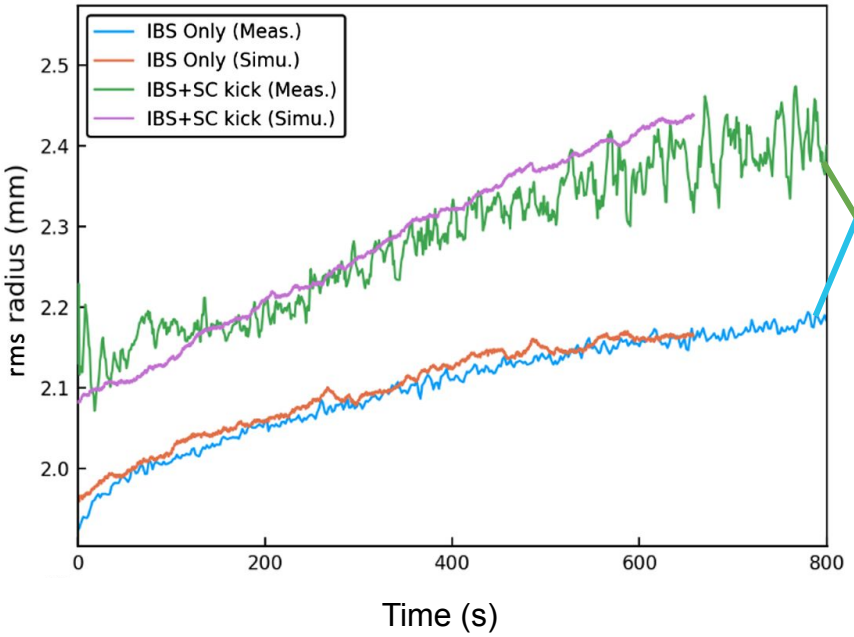
Results

Badly tuned system can lead to increased heating



No e- beam

Intra Beam Scattering (IBS) leads to growth

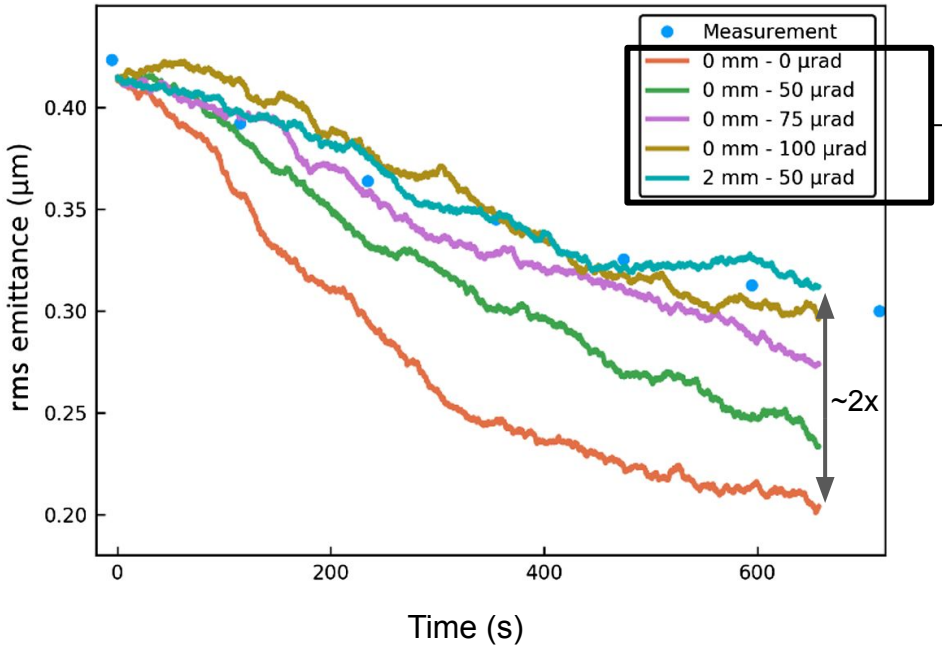
Mismatched e- beam: $v_{electron} \neq v_{ion}$

Growth increases due to space charge (SC) effects!

Good agreement between simulation and measurement

Results

Well tuned system can lead to net cooling



Simulations with Position - Angle misalignment between beams

- Alignment errors have strong influence in cooling
- Comparing to simulation
  - position offset ~ 0-2 mm
  - angle offset ~ 50-100 μrad

Conclusion

- RF accelerated electron cooling successfully implemented at RHIC

- Simulation code consistent with measurement

- Mismatched electron beam -> increased heating
- Matched electron beam -> net cooling

- If improve alignment -> improve cooling rate significantly

Thank you for your attention.

Appendix

Phase space picture: Intrabeam Scattering: Anatomy of the Theory, M. Martini; CERN, Geneva, Switzerland

e- Cooling at RHIC

- Optimisation is critical for effective cooling
- Development of code ‘TRACKIT’

Simulation workflow