ELECTRON COOLING FOR RHIC

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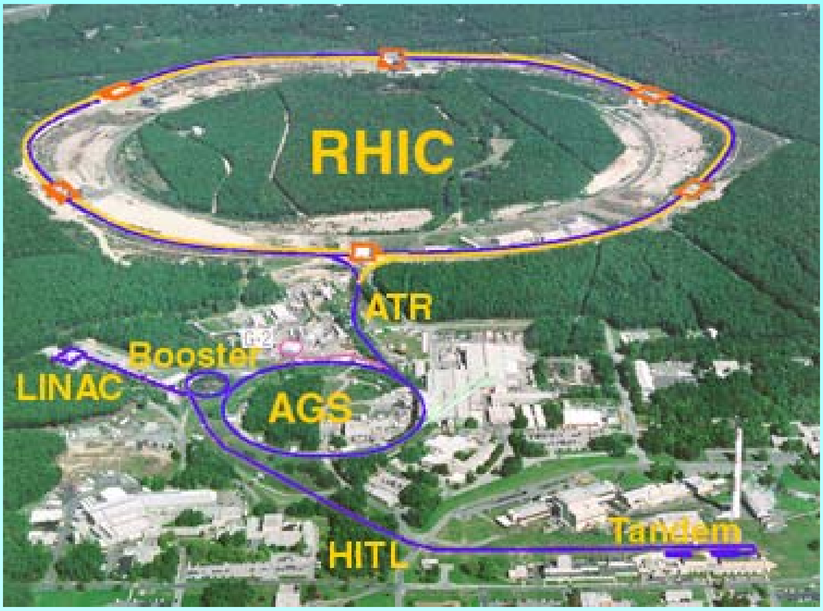

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Primary RHIC Gold Parameters (+Upgrade Values)

Parameter	Units	Value
Gold energy, E_{Au}	[GeV/u]	100
Proton energy, E_p	[GeV]	250
Number of collision points		6
Circumference	C [m]	3833
Revolution freq., F_{rev}	[kHz]	78.3
Dipole bend radius, ρ	[m]	243
Particles per bunch		10^9
Interaction Point β*	[m]	2 (1)
Number of bunches		60 (120)
95% emittance	[μm]	15 (6)
Average luminosity	$cm^{-2}sec^{-1}$	0.2 (8) 10^{27}

$$L = \frac{M}{120}\left(\frac{\xi}{.004}\right)^2\left(\frac{\sigma'^*}{.226\ [\mathrm{mrad}]}\right)^2 4.6\times10^{28}\ [\mathrm{cm}^{-2}\mathrm{s}^{-1}]$$

What Is Special about the RHIC Cooler?

- High energy cooling, ~50 MeV electron energy: Must use a linear electron accelerator.
- By-product: Discontinuous solenoid field, magnetized electron transport (as in FNAL recycler)
- Cooling of a collider: Collision noise, beam-beam parameters.
- Electron – ion Recombination.
- Beam disintegration.

Beam Disintegration

- This loss is dominated by bound electron-positron production and Coulomb dissociation in Au–Au collisions. At energies of 100 GeV/nucleon the cross section has been estimated[1] to be

  $\sigma=\sigma_{pair}+\sigma_{dis}=212\pm10$ b

  Leading to a luminosity decline:

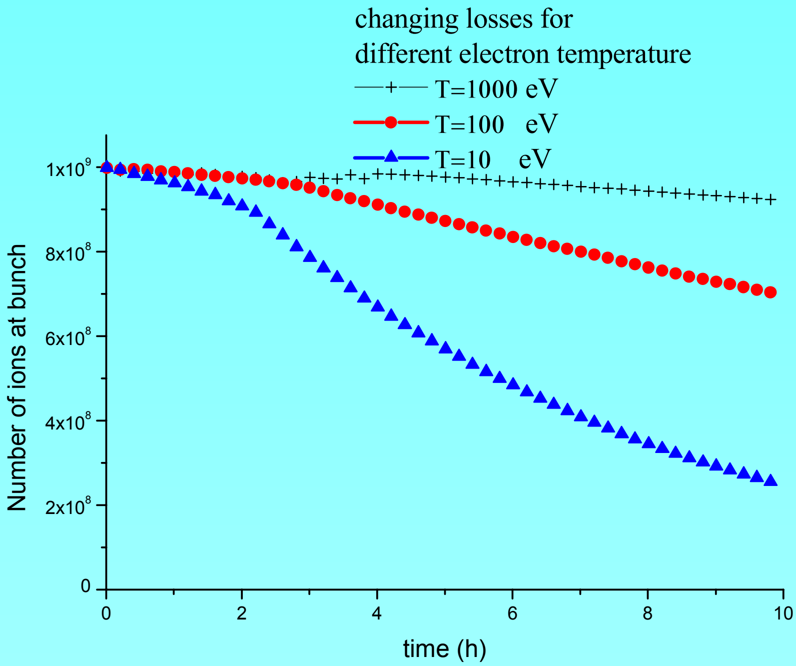
$$\langle L\rangle = \frac{L_0}{1+\frac{n_i L_0 \sigma}{M N_0} t}.$$

N_i= number of IPs, M= number of bunches

N_0= number of ions per bunch

1. A. J. Baltz, M. J. Rhoades-Brown, and J. Weneser, Phys. Rev. E **54**, 4233 (1996).

Electron – Ion Recombination



$$\alpha_{rec} = 3.02\times10^{-13}\frac{Z_i^2}{\sqrt{T_e}}\left[\ln\left(\frac{11.32Z_i}{\sqrt{T_e}}\right)+0.14\left(\frac{T_e}{Z_i^2}\right)^{1/3}\right]$$

M.Bell, J.S.Bell Particle Accelerator 12 p.49 (1982)

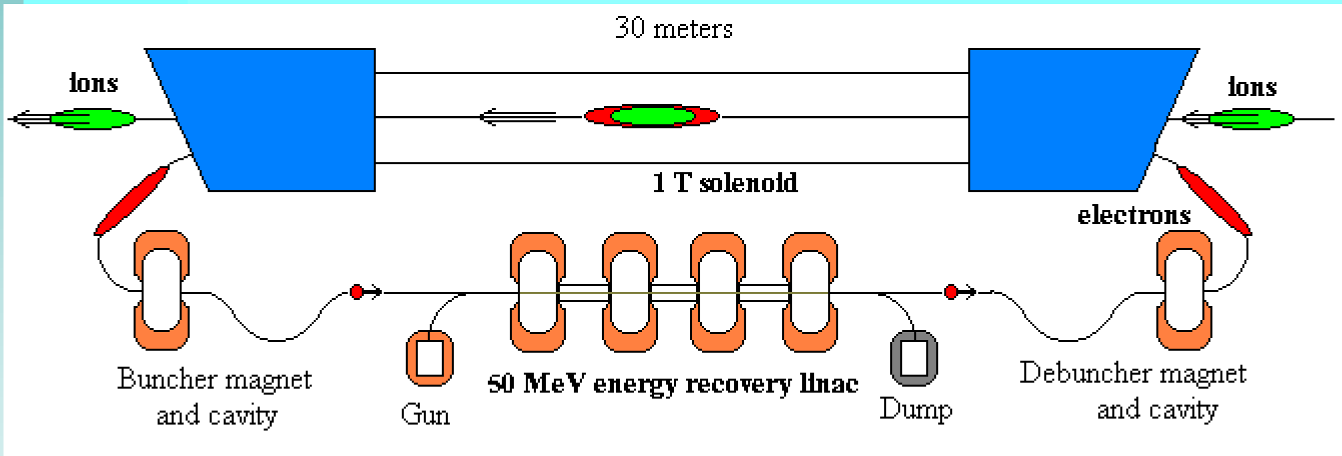
The Bell formula was verified in various experiments on NAP-M (protons) and SIS (Bi^{+67}).

High-Energy Electron-Cooling Issues

- We have to operate high-current electron ERL (low energy, 50 MeV, but ~100 mA).
- The beam quality has to be high.
- How to generate, transport and match a "magnetized" beam without continuous magnetic field.
- How to de-bunch (then re-bunch) the beam to obtain low energy spread.
- We need high-precision manufacturing and alignment of a long superconducting solenoid.
- Cooling with hot electrons.

Schematic of the RHIC Cooler

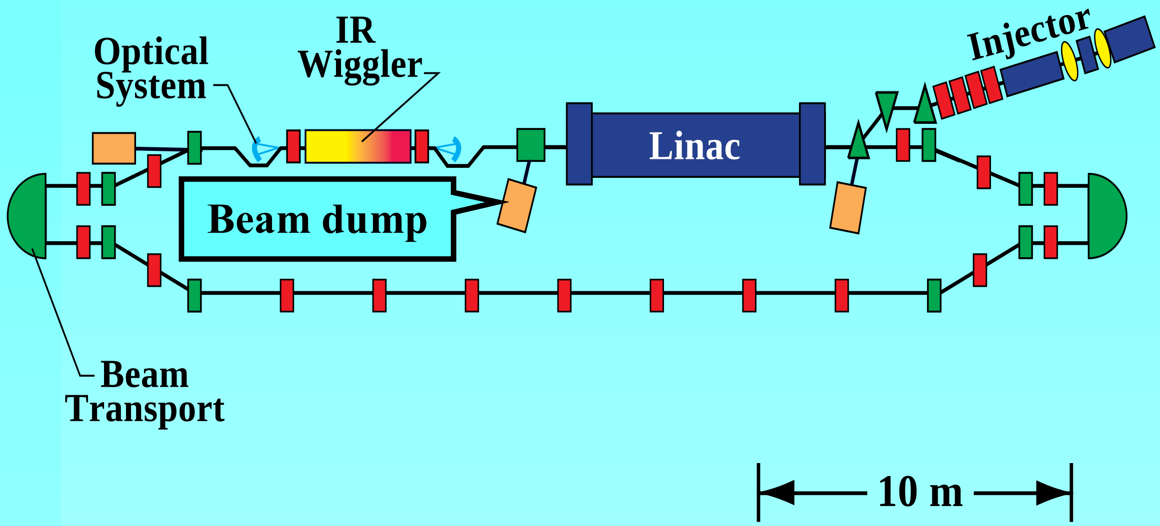
- Energy Recovery Linac
- Buncher - debuncher



> x10 increase in the integrated luminosity of RHIC, as well as better accumulation of rare species.

Energy Recovering Linac – the ticket to high-current

- JLab 50 MeV Energy Recovering Linac

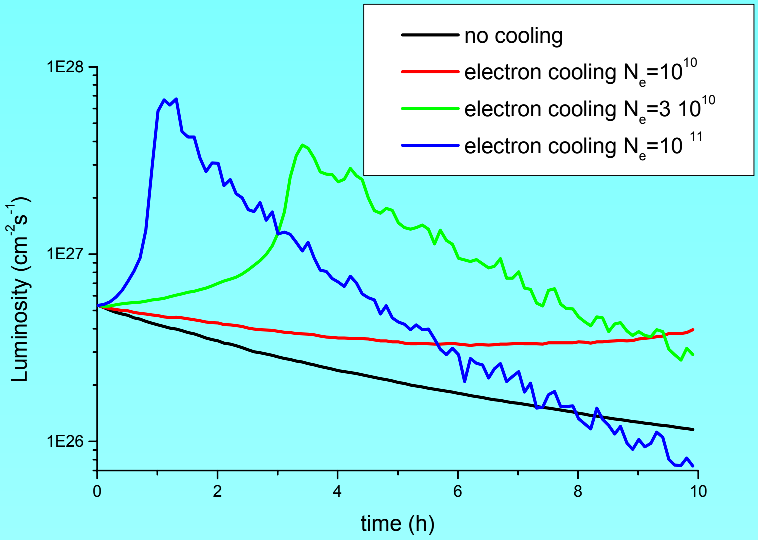


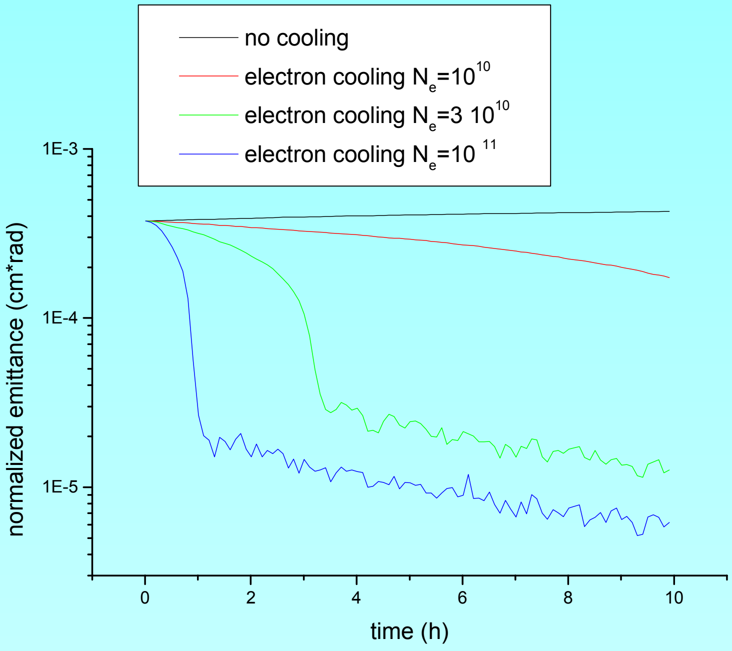
- Linac energy recovery extremely good (loss < 0.02%)
- 5 mA average current, limit – e-gun.
- ~200 mA is believed to be possible **without feedback**, well over 200 mA with B-factory style feedback.

Photoinjector Properties

- Laser control of electron bunch parameters: Charge, bunch size and distribution.
- Low energy spread and low emittance due to rapid acceleration.
- Bunch starts out short, no need for complicated low-energy bunching system.
- Boeing 433 MHz gun: 26 MV/m on cathode, duty factor 25%, 7 nC, 27 MHz PRF, emittance 10 mm-mrad, energy spread 100 KeV, bunch length 50 ps.

Luminosity and emittance for various cooling currents





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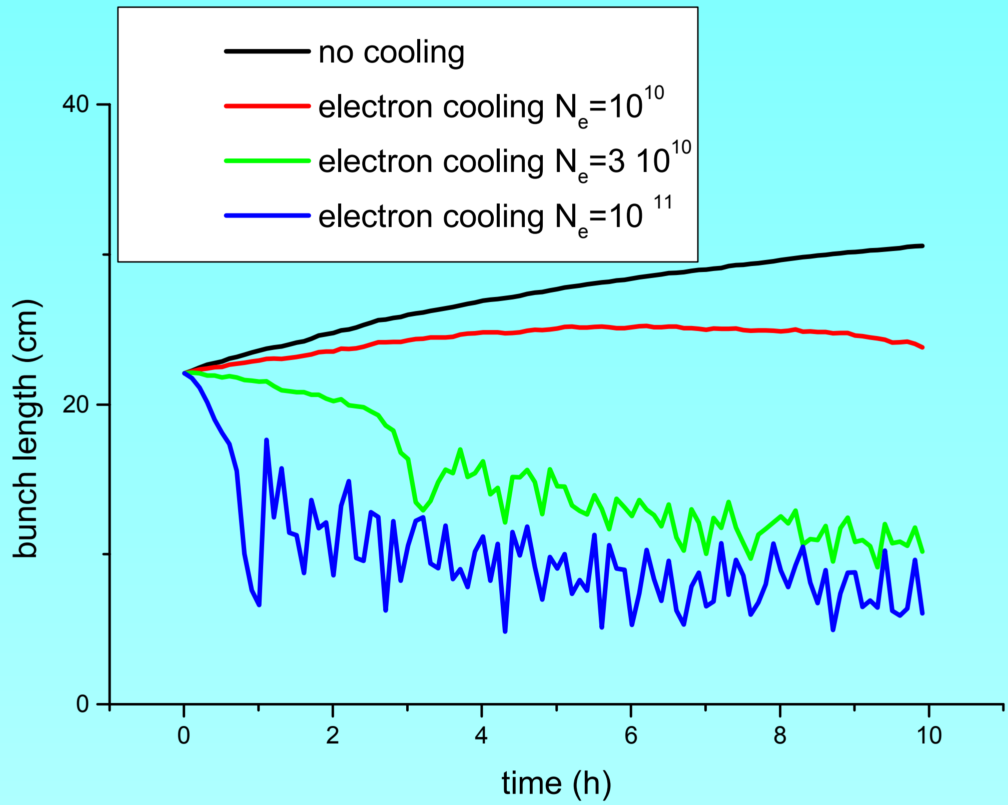
Bunch length vs. time for various electron currents



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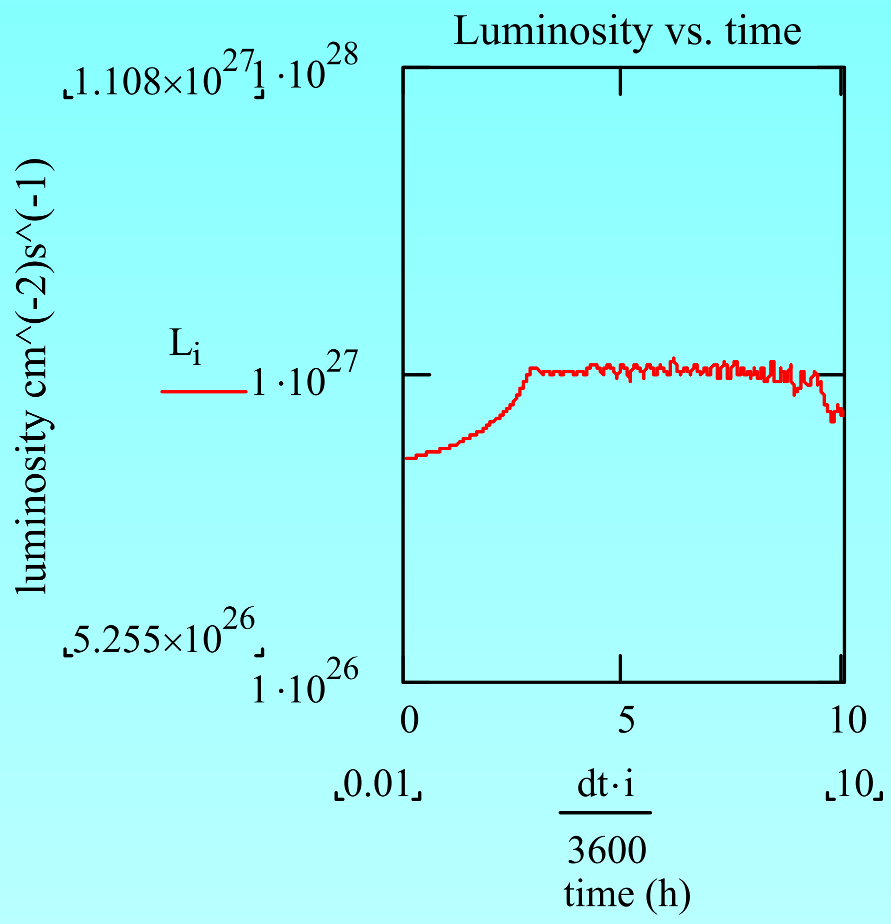
Simple control of cooling rate to stabilize luminosity



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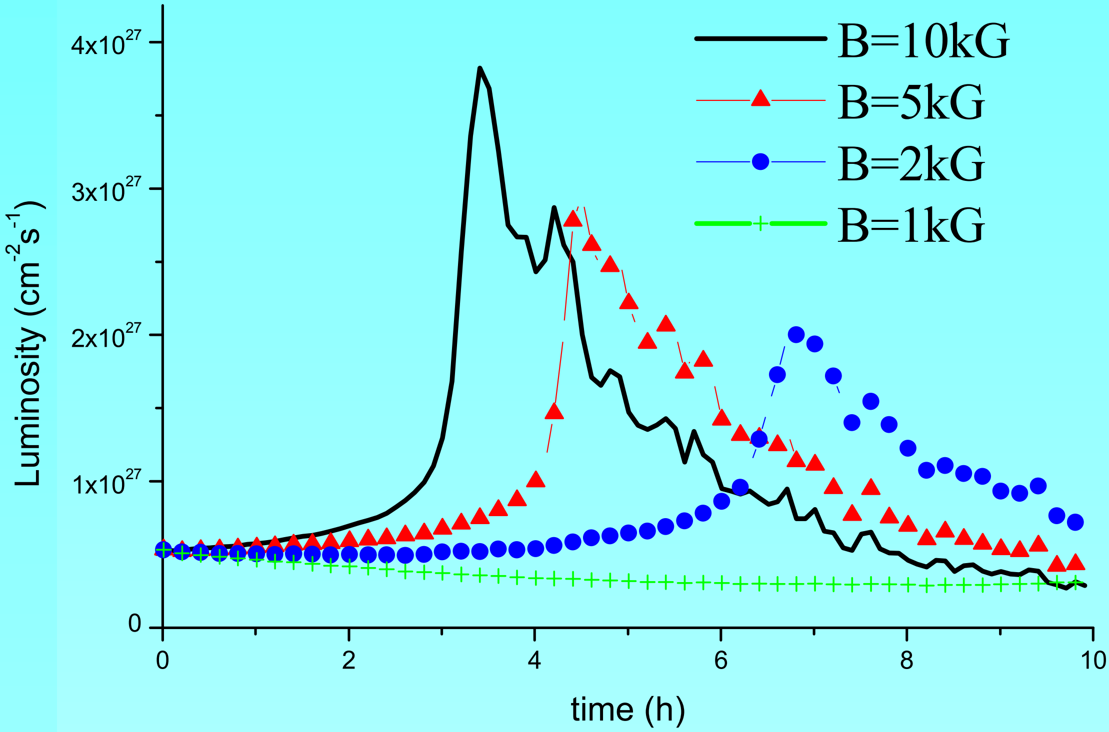
Cooling with Hot Electrons Requires a High Magnetic Field



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Summary

- High energy electron cooling of the RHIC collider is being pursued.
- Outstanding research issues:
  - Detailed design of the electron source.
  - Demonstrate energy recovery at ~100 mA average current.
  - Demonstrate the electron transport with magnetized electrons and debunching.
  - Design the solenoid / undulator.
  - Verify cooling with 1 KeV electrons.