Simulation of electron cooling dynamic

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Dynamics codes

- **BetaCool code:**

  Has extensive library of formulas for the friction force and IBS to simulate cooling dynamics (cooling+ibs+…) for RHIC.

- **SimCool code:**

  Uses VP empiric formula for friction force and gas-diffusion formula for IBS to simulate electron cooling dynamics.

SimCool

1. Cooling – individual particles
2. IBS – i.p. but based on rms rates

+: Can treat time evaluation of distributions but maaaany questions:

-: 1) Questions about IBS **+**

2) Needed synchrotron motion **+**

3) Needed accurate treatment **+** of bunch shortening and impact on IBS

4) other

BetaCool

Cooling – rms rates

IBS – rms rates

-: didn't treat evoluation of distribution

In present working version: **+**

1) SimCool approach is implemented **+**

2) Various treatments of IBS: **+**

2.1) i.p. based on rms rates

2.2) detailed

2.3) direct- Molecular Dynamics

converge to similar and reliable predictions

BetaCool using released version based on rms rates

- Basic simulations were done for RHIC with released version of the code – one can find that most optimistic cooling can be obtained using D-S formulas compared to VP empiric formula

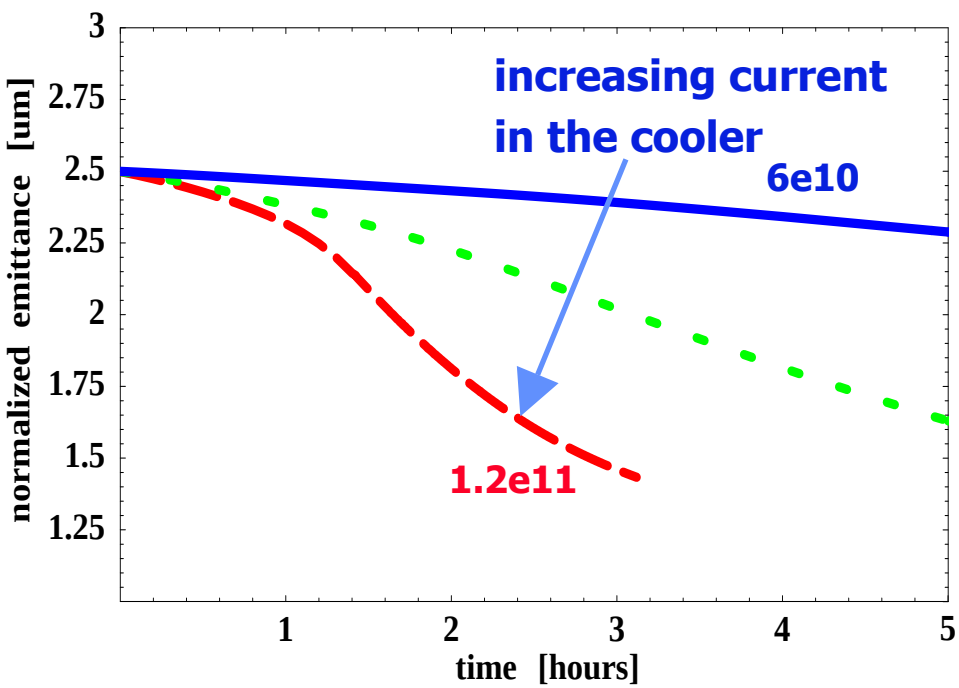
different formulas applied to rms parameters

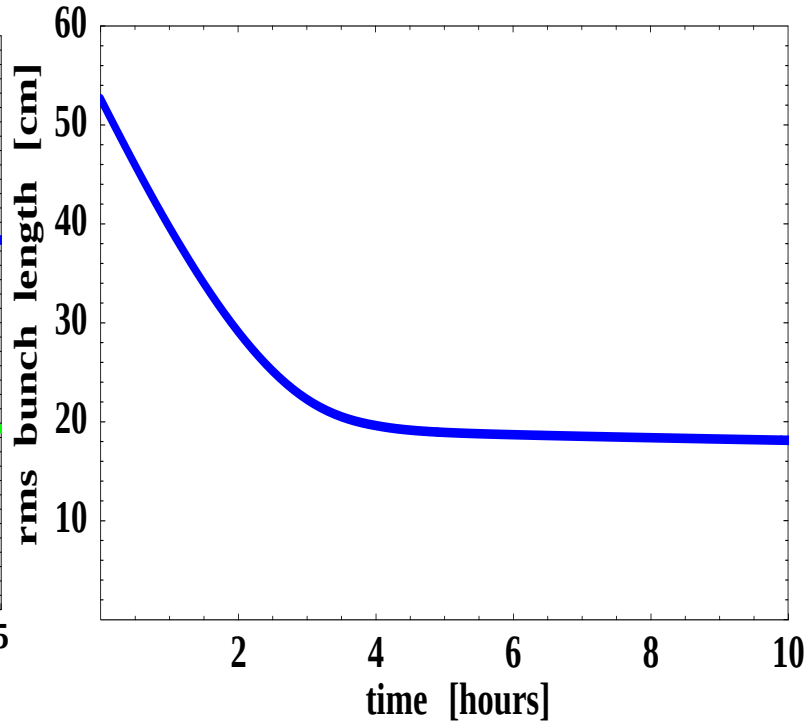
Cooling time was slower than predicted with SimCool code: main reason – different logic in using cooling force – unchanged ion distribution.

Simulation only of a beam core (1 sigma) showed cooling dynamics and FAST cooling times similar to SimCool.

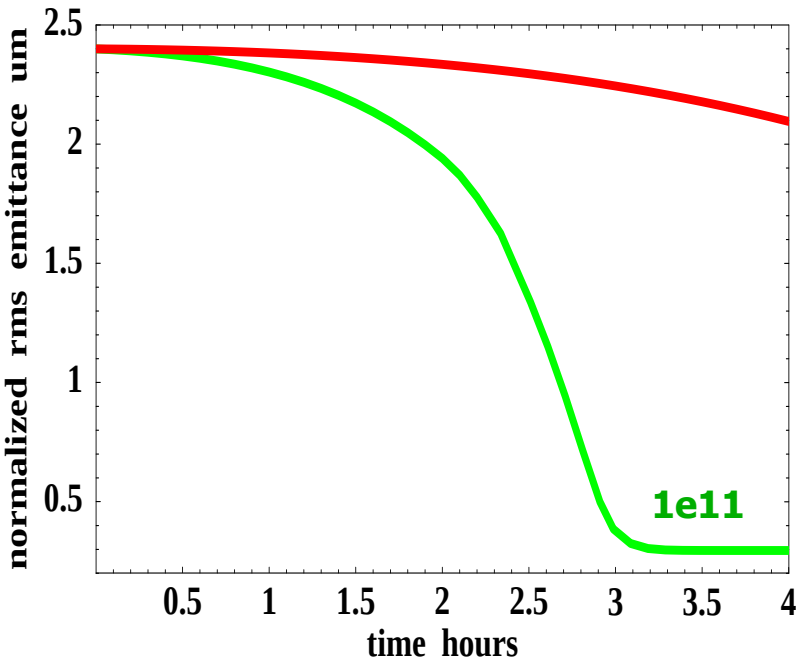
Present implementation of SimCool approach in BetaCool code also leads to fast cooling of beam core – benchmarking in progress

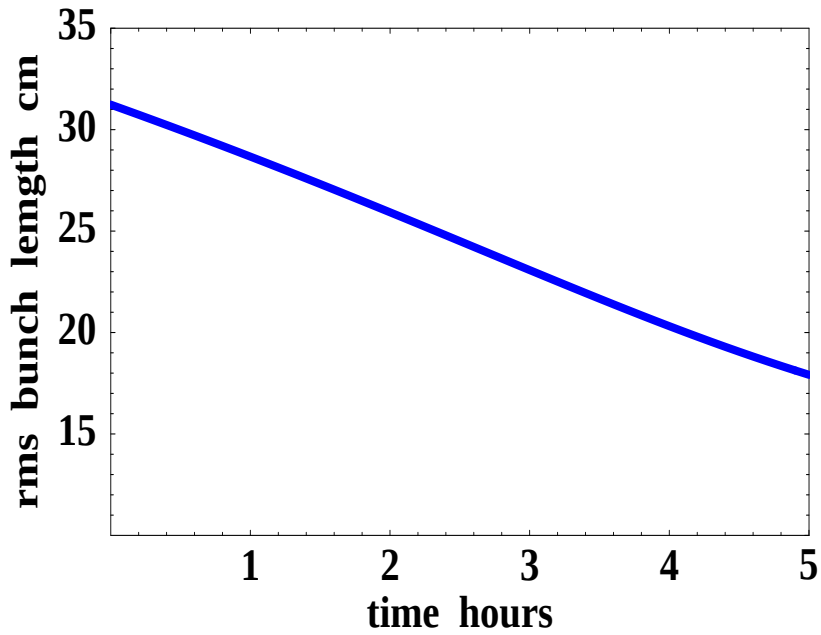
Cooling of Au at 100 GeV using BetaCool – based on cooling of full distribution (rms approach)





Cooling of protons (two-stage)

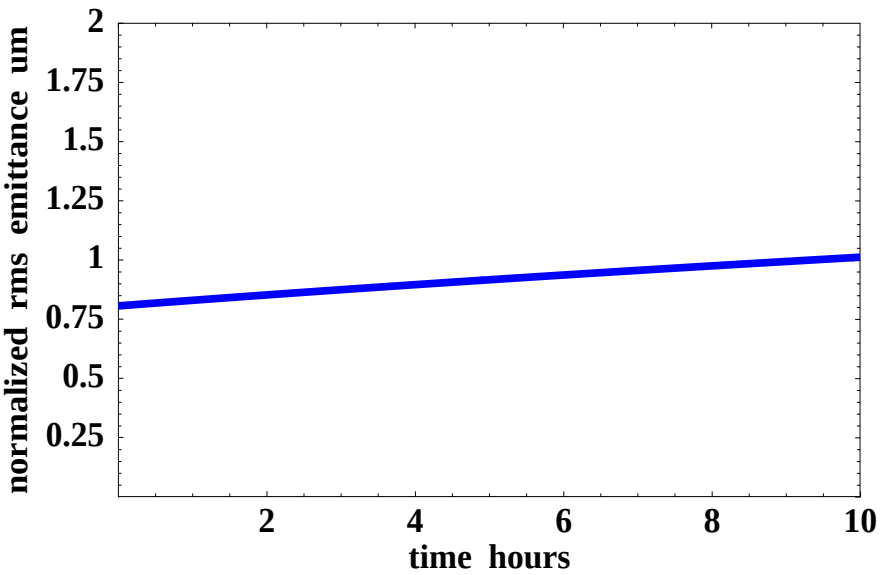




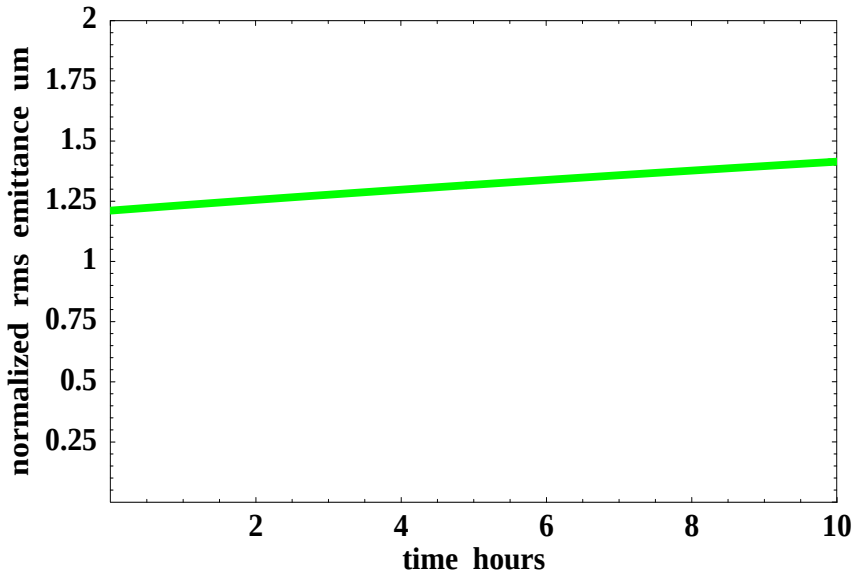
Cooling at 27GeV

Pre-cooled protons are then accelerated to 250 GeV

pre-cooled to rms emittance of 0.8 um



pre-cooled to rms emittance of 1.2 um



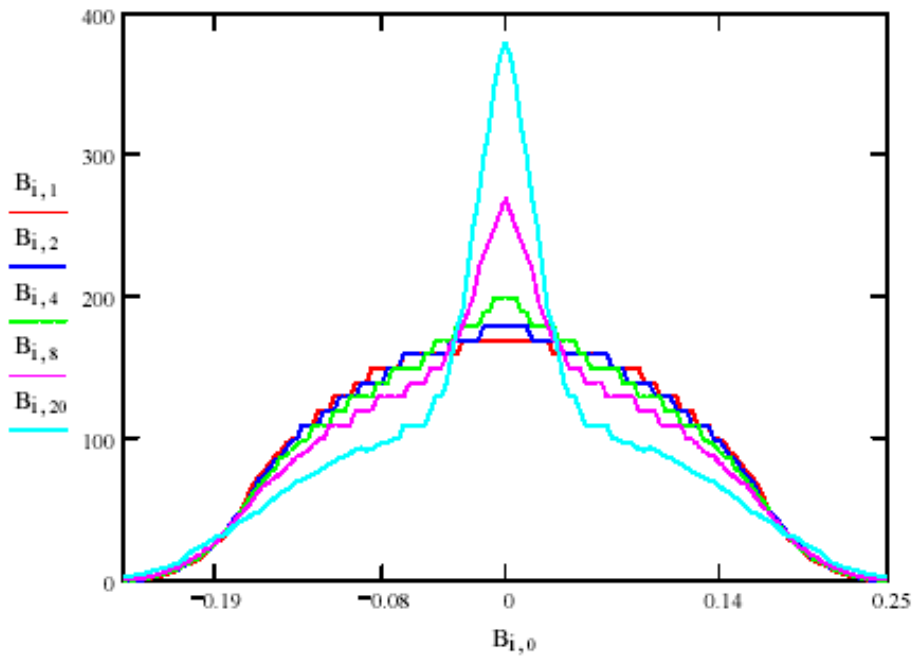
store at 250 GeV

Similar Cooling was applied even for higher beam intensities for eRHIC studies:

Np=2*10^11 and Nau=2*10^11

SimCool

typical cooling of beam core with SimCool code



Some modification of such cooling as a result of bunch length shortening and momentum are being benchmarked cooling

Progress

- We have better understanding of friction force formulas, especially empiric formula by VP and the role of V_effective.
- IBS formulas and its comparison.
- Effects of synchrotron motion and improved IBS models.

There are still some issues to be resolved: like impact of detailed IBS, etc.

However, it looks like cooling rate is determined by a chosen approach:

- Cool 95% of the beam, including tails

or

- Cool only center core of beam distribution, provided that beam tails do not lead to losses (or cooled by stochastic cooling) – determines luminosity and seems to be the right approach for cooling in a collider

Appendix: Impact of detailed IBS

1. IBS by itself:

Here detailed IBS does not give much:

Rate of detailed IBS gives additional function

Sqrt[π]*Exp(-x)*I_0(x): x=0 $\longrightarrow$ 1

x=1/2 $\longrightarrow$ **1**

x>>1 $\longrightarrow$ X^(-1/2)

So, if it replace by 1 – accurate description for 1σ.

If applied for particles outside 1σ ibs for tails is overestimated.

2. Start to play role when beam is rapidly cooled.

3. Seems to be taken into account in SimCool

This question is presently under study