Low Energy RHIC electron Cooling (LEReC):

APEX: Dispersive Cooling studies

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Goals of experiment

In many high-energy cooling applications, such as for the EIC, the strongest demand is on the transverse cooling. The transverse cooling can be enhanced at the expense of the longitudinal cooling using dispersion in the cooling section.

There are several possibilities which can provide such redistribution:

1) use of ions dispersion function with non-uniform electron density distribution
2) use of ions dispersion in combination with the electrons dispersion
3) transverse offset of electron beam with respect to ion beam providing gradient of the cooling force in the cooling section.

The goals of these experiments is systematic study of all these possibilities (1,2,3) of dispersive cooling and redistribution process.

Dispersive cooling example for ring-cooler for EIC

- Redistribution of longitudinal cooling to the transverse direction, is effectively used in the design of Ring-based cooler for the EIC

$$\frac{\langle \Delta\epsilon_x \rangle}{\epsilon_{x,rms}} = -\frac{M}{\sqrt{\sigma_{ex}^2 + \sigma_{ix}^2 + D_i^2\delta_{ip}^2 + D_e^2\delta_{ep}^2}}\left[C_x + \frac{C_p(D_i^2\delta_{ip}^2 + D_iD_e\delta_{ep}^2)}{\sigma_{ex}^2 + \sigma_{ix}^2 + D_i^2\delta_{ip}^2 + D_e^2\delta_{ep}^2}\right]$$

Dispersion effect on the cooling rates

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$$\frac{\langle \Delta\delta \rangle}{\delta_p} = -\frac{M}{\sqrt{\sigma_{ex}^2 + \sigma_{ix}^2 + D_i^2\delta_{ip}^2 + D_e^2\delta_{ep}^2}}\left[C_p - \frac{C_p(D_i^2\delta_{ip}^2 + D_iD_e\delta_{ep}^2)}{\sigma_{ex}^2 + \sigma_{ix}^2 + D_i^2\delta_{ip}^2 + D_e^2\delta_{ep}^2}\right]$$

$$M = \frac{eN_{e0}}{(2\pi)^{3/2}\sqrt{(\sigma_{ey}^2 + \sigma_{iy}^2)(\sigma_{es}^2 + \sigma_{is}^2)}}$$

Simulation for ring-based cooler for EIC for protons at 275GeV

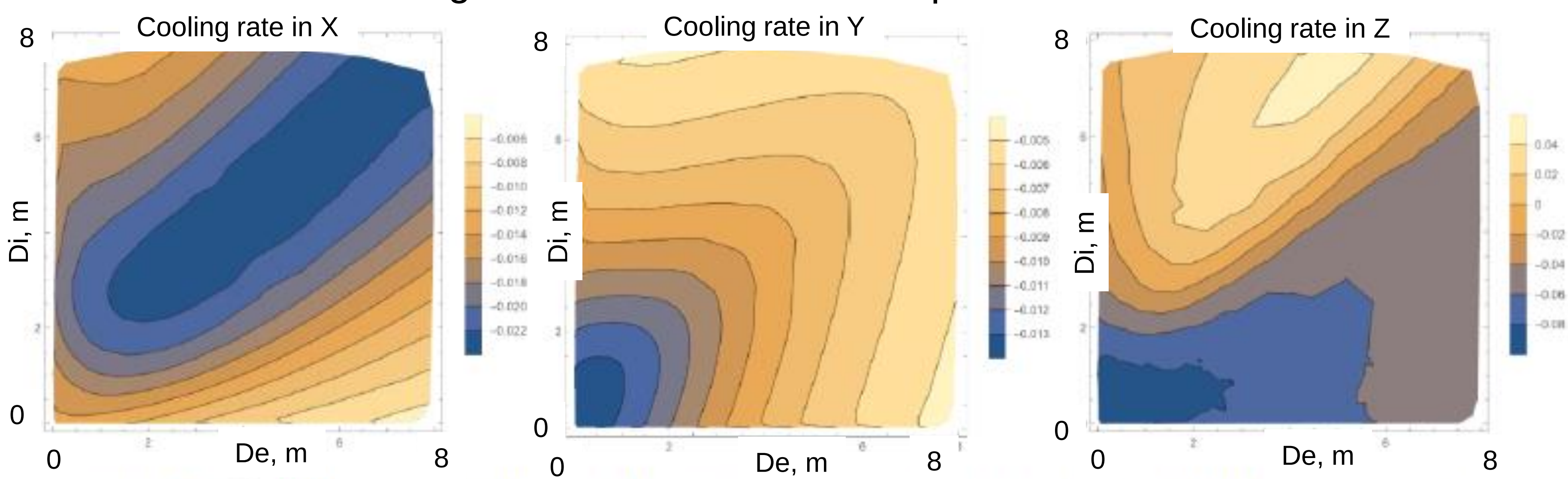

Fig. 3. Simulation result of the cooling rates in three dimensions. (Unit of the dispersion: m)

Dispersive cooling for LEReC parameters

$$\frac{\langle \Delta\epsilon_x \rangle}{\epsilon_{x,rms}} = -\frac{M}{\sqrt{\sigma_{ex}^2 + \sigma_{ix}^2 + D_i^2\delta_{ip}^2 + D_e^2\delta_{ep}^2}} \left[C_x + \frac{C_p(D_i^2\delta_{ip}^2 + D_i D_e \delta_{ep}^2)}{\sigma_{ex}^2 + \sigma_{ix}^2 + D_i^2\delta_{ip}^2 + D_e^2\delta_{ep}^2} \right]$$

$$\frac{\langle \Delta\delta \rangle}{\delta_p} = -\frac{M}{\sqrt{\sigma_{ex}^2 + \sigma_{ix}^2 + D_i^2\delta_{ip}^2 + D_e^2\delta_{ep}^2}} \left[C_p - \frac{C_p(D_i^2\delta_{ip}^2 + D_i D_e \delta_{ep}^2)}{\sigma_{ex}^2 + \sigma_{ix}^2 + D_i^2\delta_{ip}^2 + D_e^2\delta_{ep}^2} \right]$$

$$M = \frac{eN_{e0}}{(2\pi)^{3/2}\sqrt{(\sigma_{ey}^2 + \sigma_{iy}^2)(\sigma_{es}^2 + \sigma_{is}^2)}}$$

Difficulty: large sigma of ion and electron beam.
Sigma_e^2 +Sigma_i^2: about [15-20] mm^2

1. Redistribution due to Di^2 (De=0):
   dp/p_i=1e-3, Di=2m-> k=D^2/20: 0.2 – 20% effect
   Di=4m-> k=0.4 - 40% effect
2. Redistribution due to De:
   keep dpi small, dp/p_e=1e-3, De=5m
   Di=2m k – 30% effect
   Di=3m k - 40% effect

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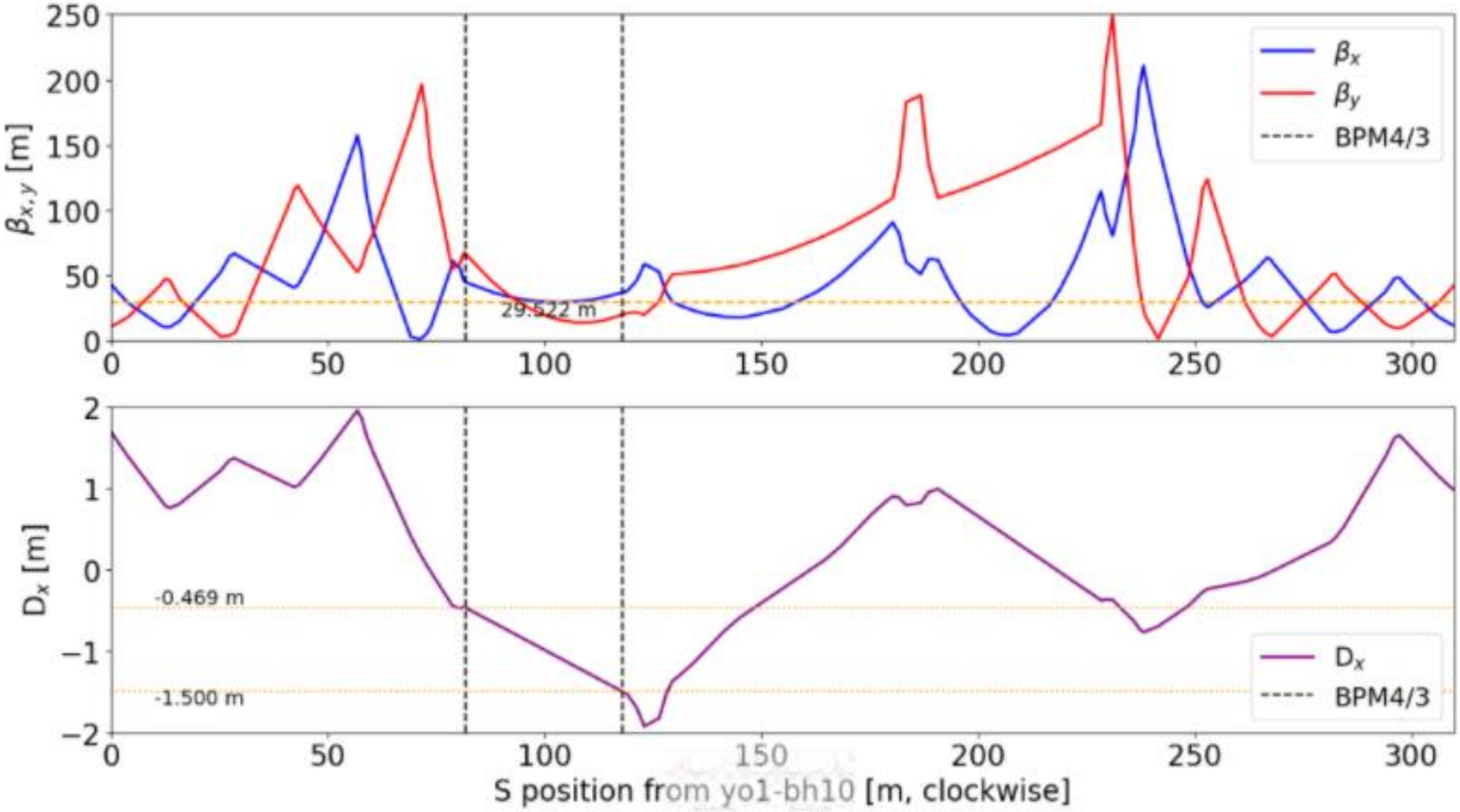
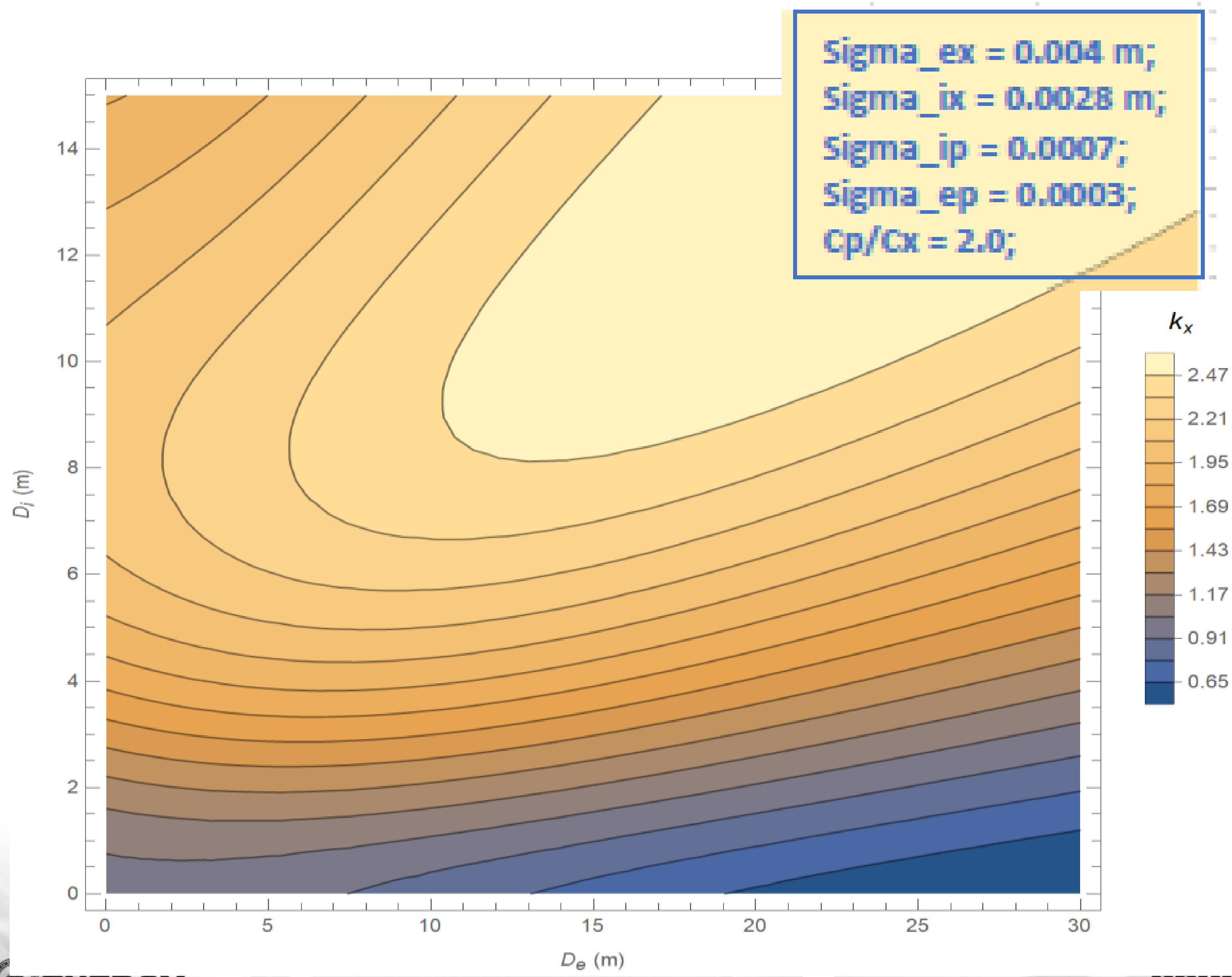
RHIC lattice with 1.5m dispersion in cooling section



Dispersive cooling simulations for LEReC



Dispersive cooling on LEReC (1.6 MeV)

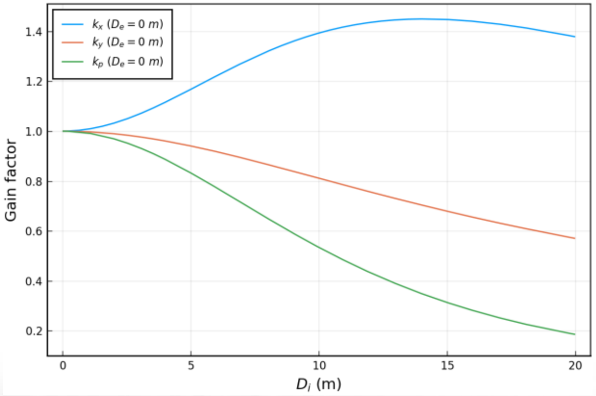
➢ **Estimate of cooling redistribution**

$$\lambda_x = -\hat{n}_{e0}\left(C_x + \frac{C_p D^2 \delta_p^2}{\sigma_{ex}^2 + \sigma_{ix}^2 + D^2\delta_p^2}\right)$$
$$\lambda_p = -\hat{n}_{e0}\left(C_p - \frac{C_p D^2 \delta_p^2}{\sigma_{ex}^2 + \sigma_{ix}^2 + D^2\delta_p^2}\right)$$

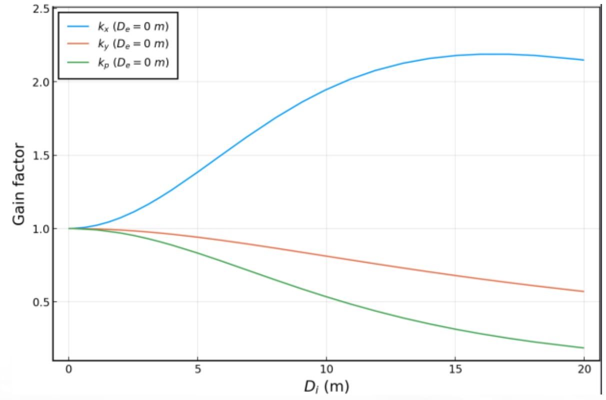
emitt_ix = 0.45e-6;
beta_ix = 20 m;
dpp_i = 3.6e-4;

emitt_ex = 0.4e-6;
beta_ex = 40 m;
dpp_e = 4e-4;

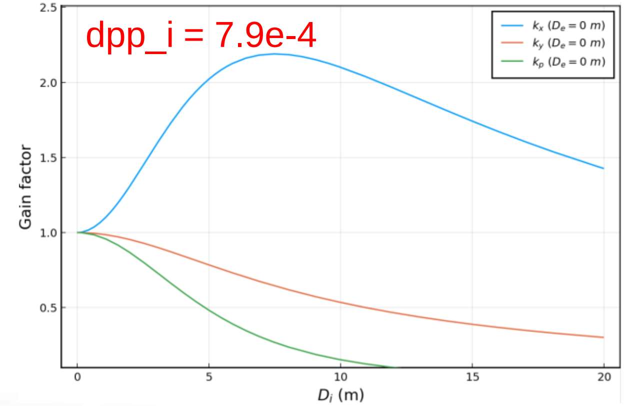
Cp/Cx=2.0



Cp/Cx=4.0



Cp/Cx=4.0



Plan

First 3 hours time request:

1) Implement lattice with ion dispersion in yellow cooling section
2) Measure beta functions and dipersion
3) For two different RF settings which will be used in experiment, measure IBS

Once ion lattice and beam parameters are established, the following time requests will be devoted to studies of cooling redistribution.