# Low Energy RHIC electron Cooling (LEReC):

## APEX: Dispersive Cooling studies

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June 25, 2021

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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 for LEReC parameters

Second order effect,
due to electron density distribution
(requires large ion dispersion)

Due to gradient of longitudinal force

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

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

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

# Dispersive cooling for LEReC parameters

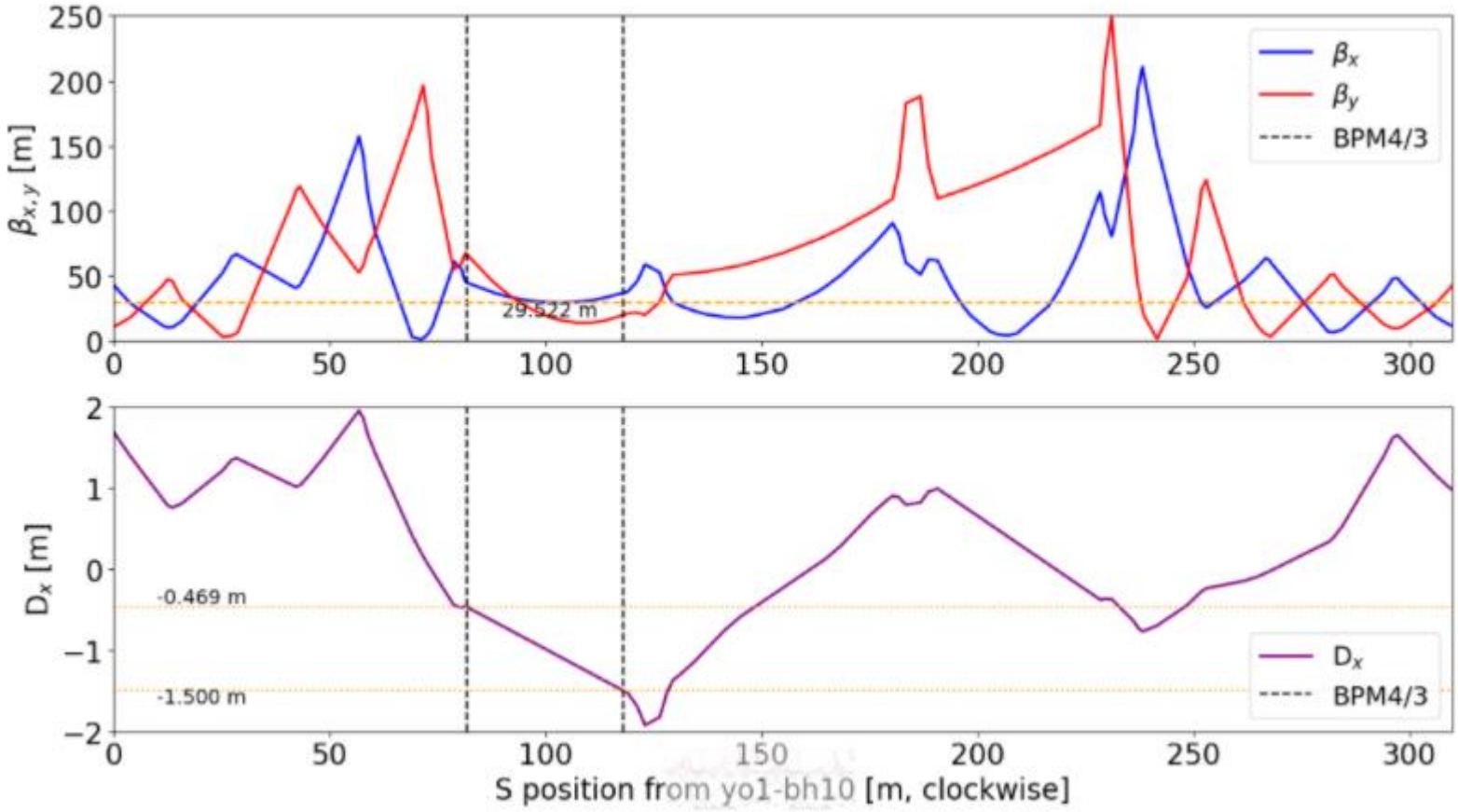
a) Baseline:
dp/p_i=3e-4 (typical 9MHz RF), new lattice with Di around 2m:
dp/p_e=1e-3, De=0
Both terms are small, no additions to transverse cooling

b) Redistribution due to De:

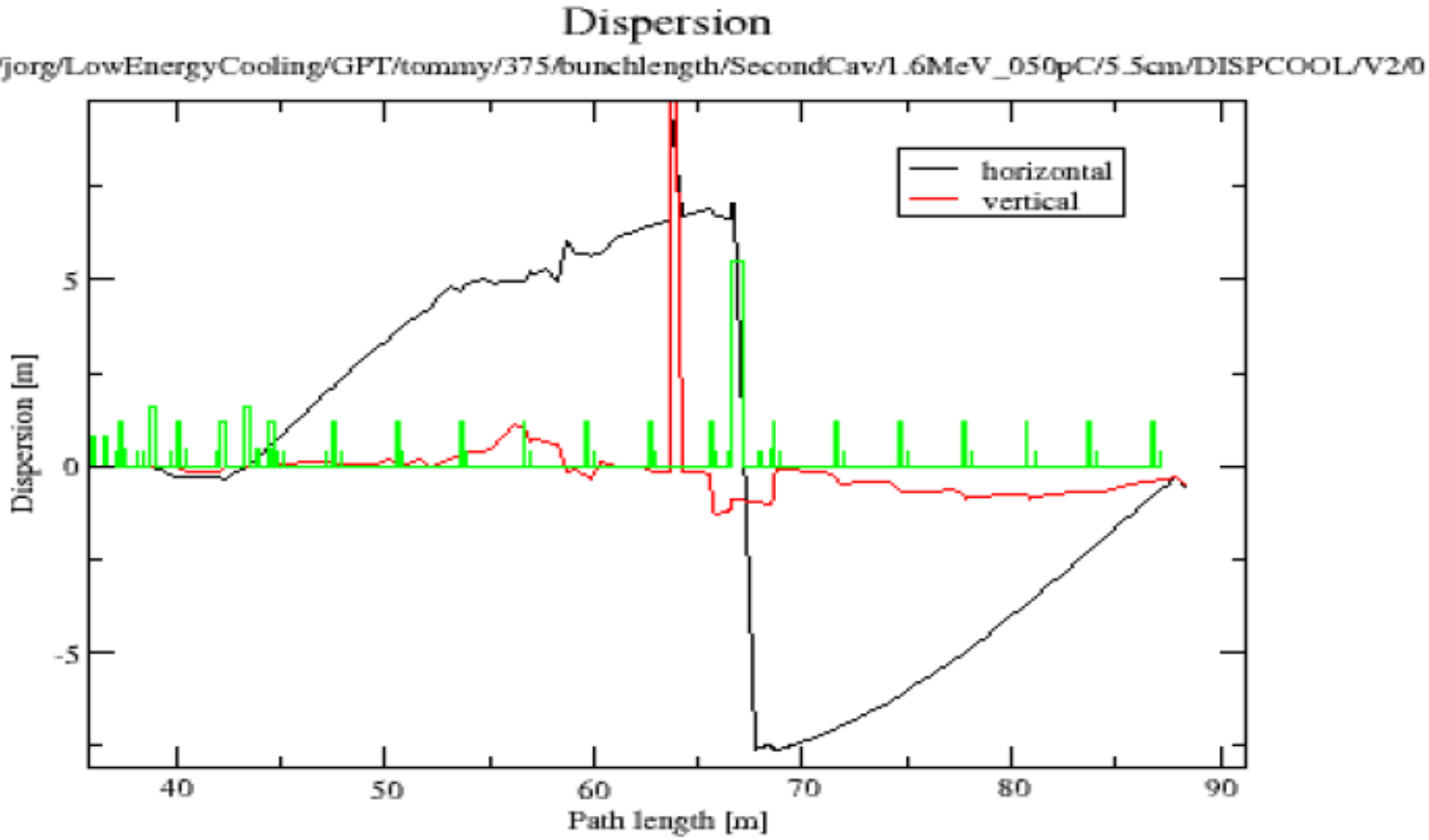
Introducing electron dispersion should start decrease longitudinal cooling rate and start to increase transverse cooling rate.

**For De=5m - > k – 20-30% effect compared to a)**

# RHIC lattice with 1.5m dispersion in cooling section



# LEReC lattice with 5m electron dispersion in cooling section



# We had three short sessions to setup experiment and explore some parameters

1. June 11:

Developed ion beam lattice with 1.4m dispersion.

Developed electron beam lattices with dispersions of 2 and 8 meters.

Measured electron beam parameters.

2. June 18:

Implemented electron beam lattice with 2.7m dispersion.

Established high-current electron beam operation with De=2.7m lattice.

Performed first measured of heating/cooling with electron dispersion and without electron dispersion

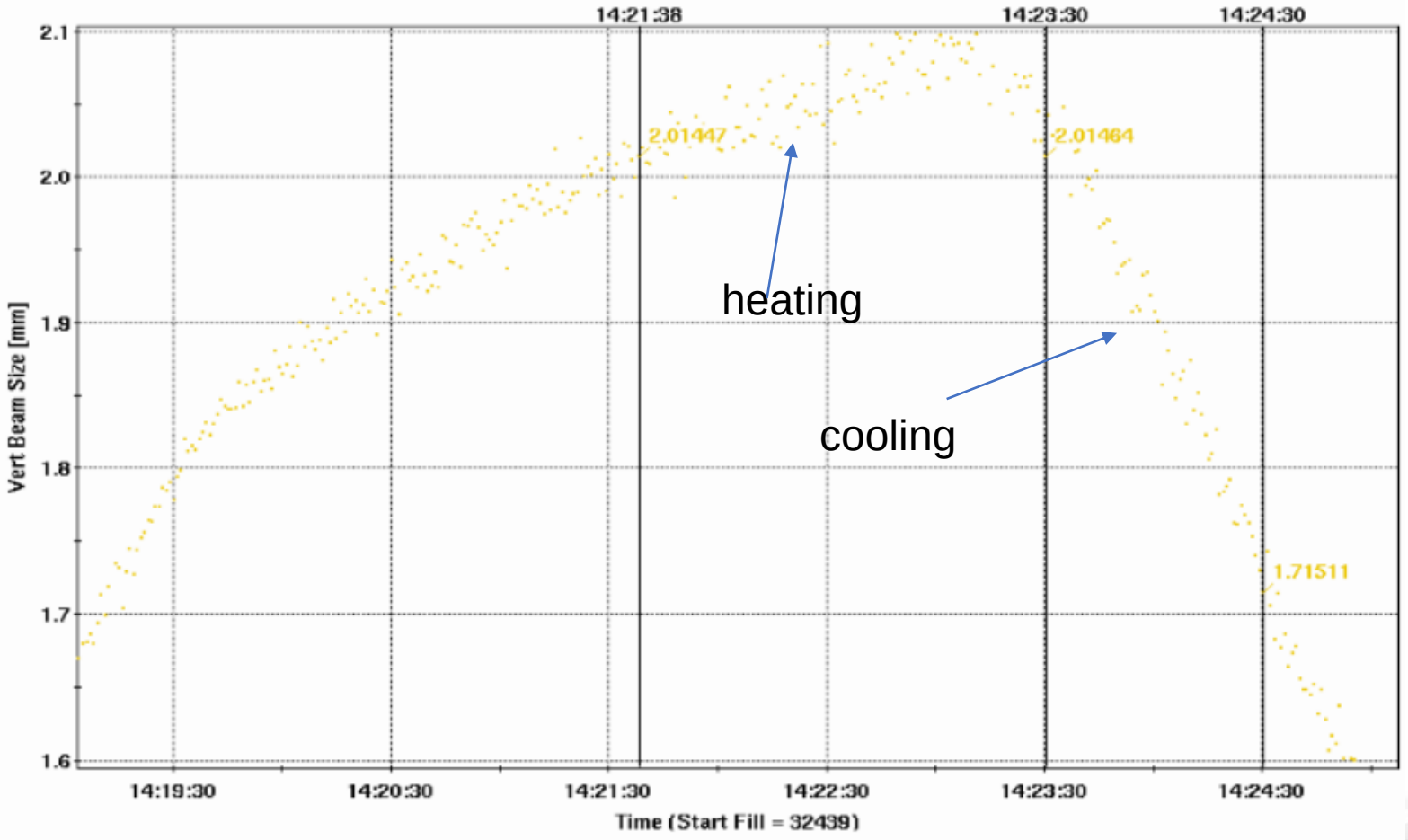
3. June 24:

Measured electron beam parameters with introduced electron energy spread, needed to enhance observation of redistribution effect.
Performed heating/cooling measurements

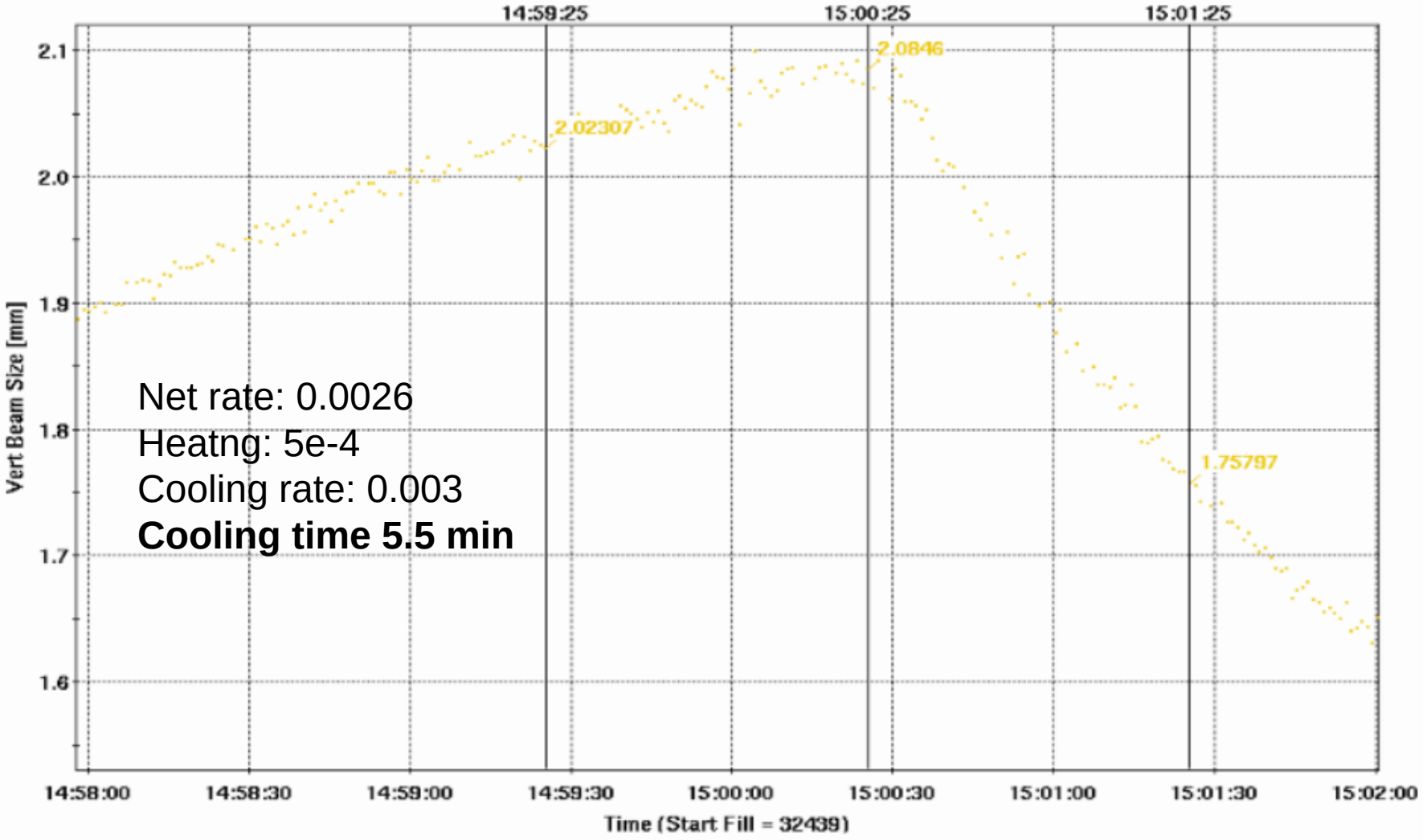
# APEX June 18: Di=1.4m, De=2.7m

Transverse beam size

**Cooling time: 5.5min**



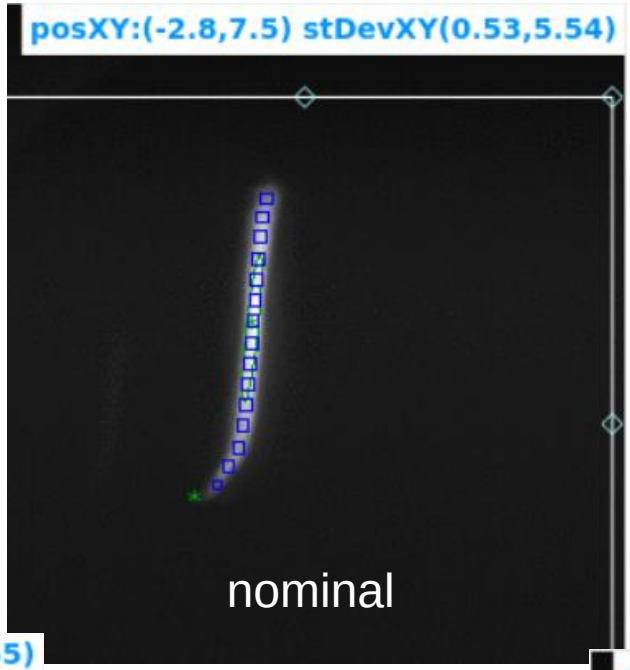
# APEX June 18: Di=1.4m, De=0 m

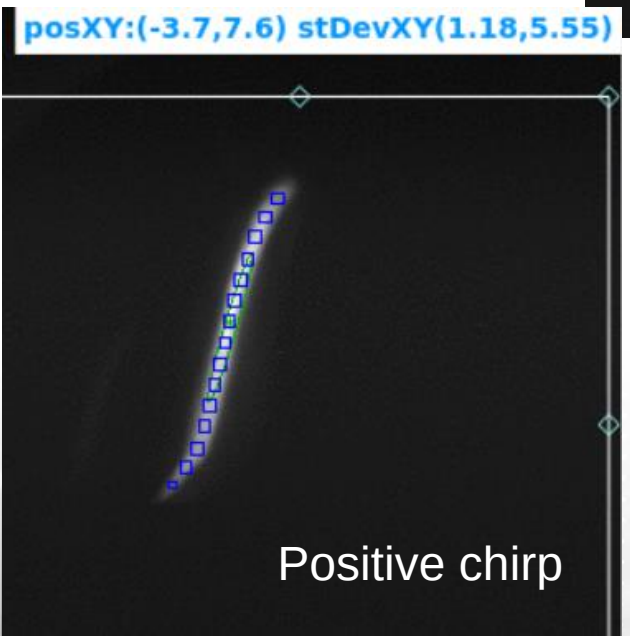


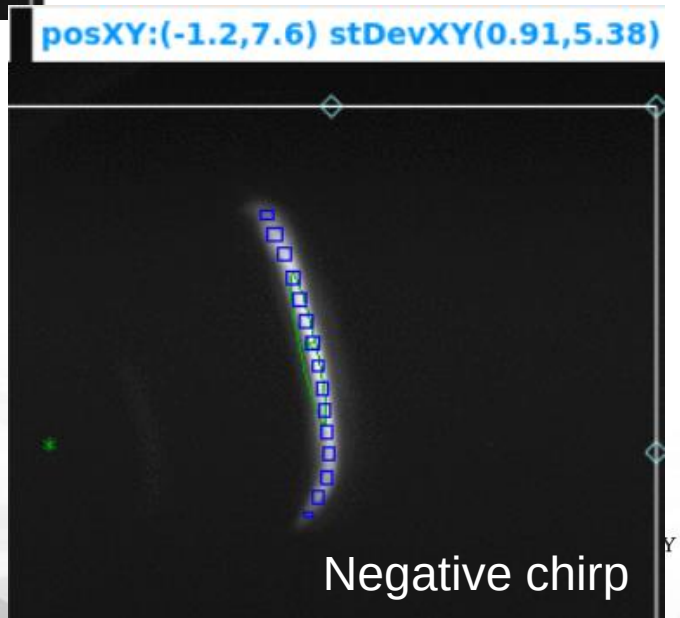
# Summary from June 18:

- Measured cooling rate is approximately the same for lattice with De and without De.
- This was expected since Di=1.4m is small, De=2.7m is also small,  dp/p electron is small as well.
- For larger dp/pe=1e-3 we expect about 10-15% redistribution with 2.7m electron dispersion.
- APEX on June 24 was devoted for measurements with different dp/pe.

# June 24: introducing various energy spreads



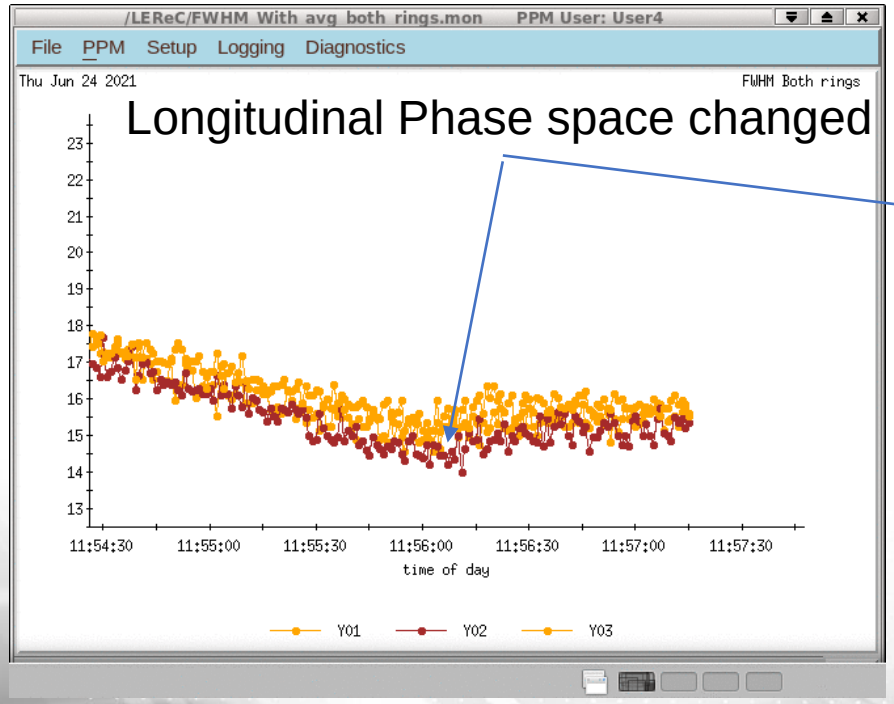



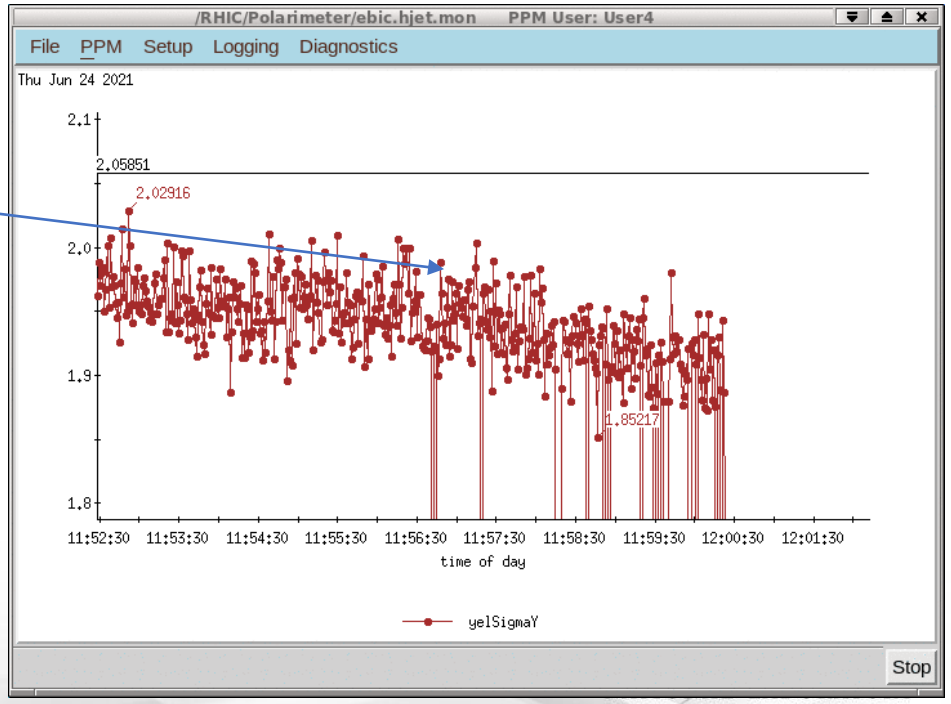
# APEX June 24: Di=1.4m, De=2.7m

To enhance a possibility to see redistribution we introduced such transverse angles in cooling section that transverse cooling is suppressed while there is still some longitudinal cooling.
Then when you introduce longitudinal energy spread which decreases longitudinal cooling one should expect to see increase in transverse cooling, if there is redistribution.

Bunch length




Transverse size



# Summary:

- Basic dispersive cooling setup was established
- First attempt with relatively low Di=1.4m and De=2.7m showed that we may have observed redistribution at low level.
- We can do more dedicated measurements with various dp/pe, as well as enhance this effect with larger electron dispersion De (5m, for example), and possibly even larger Di.
- Since many hours will be needed to explore various regimes and parameters, the plan is to do such experiments next year.
- But if extra few hours will be available during next APEX session or before the end of this run, we can try to get better measurement as well.