Emittance.
Some thoughts

Spectrometer meeting September 2024

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Motivation

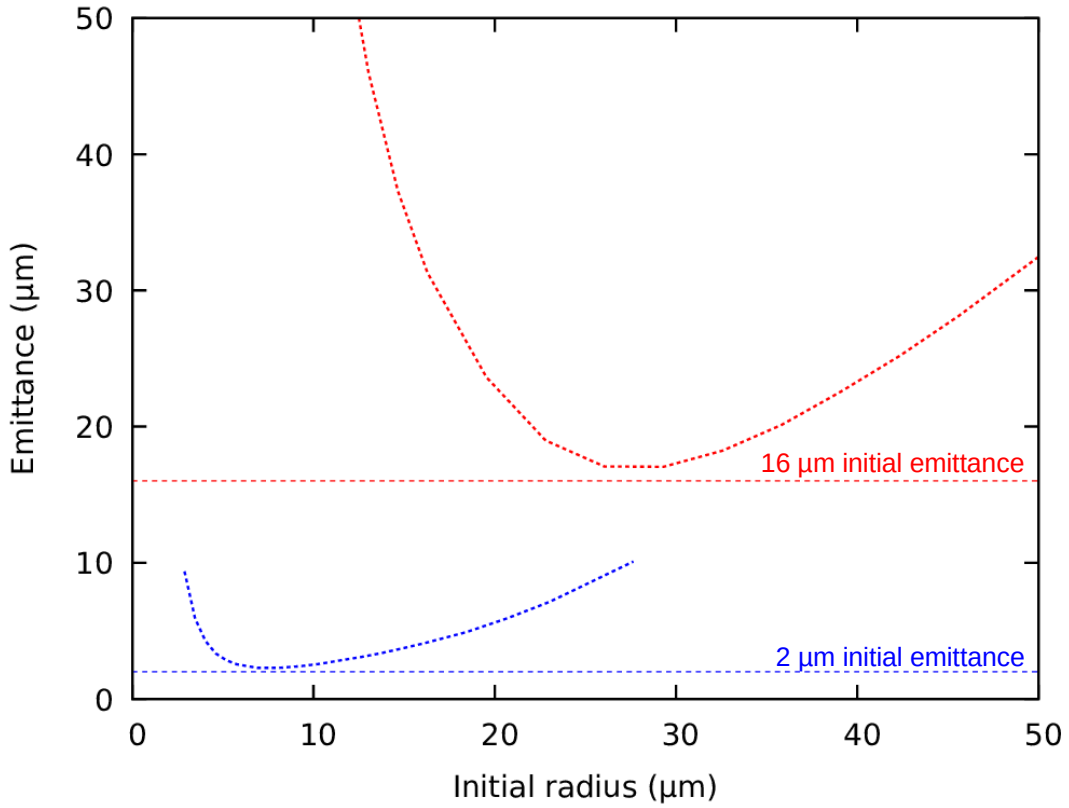
Run 2c will demonstrate emittance control

- requires the beam radius be matched to the wakefields

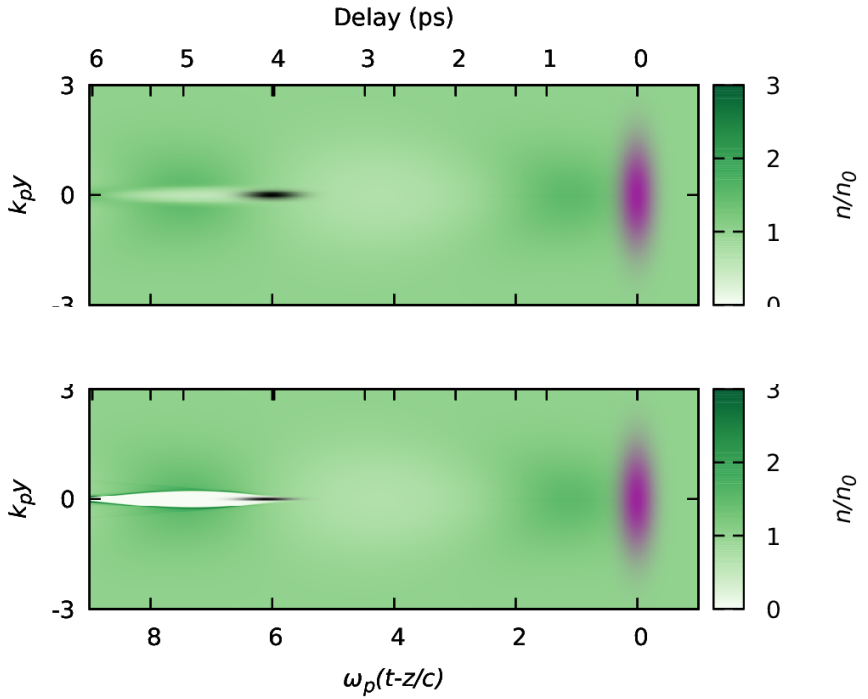
What can we expect in Run 2b?

- emittance growth
- self-matching?

Run 2c



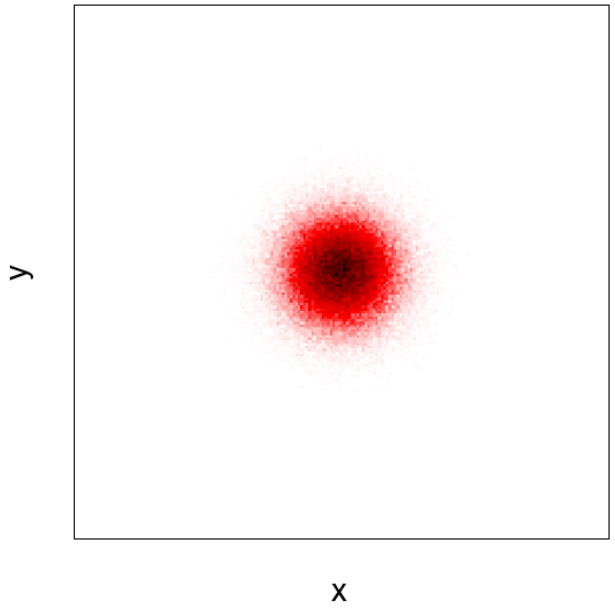
Projected normalized emittance after 10m acceleration for different initial radii



Low emittance:
blowout, matching

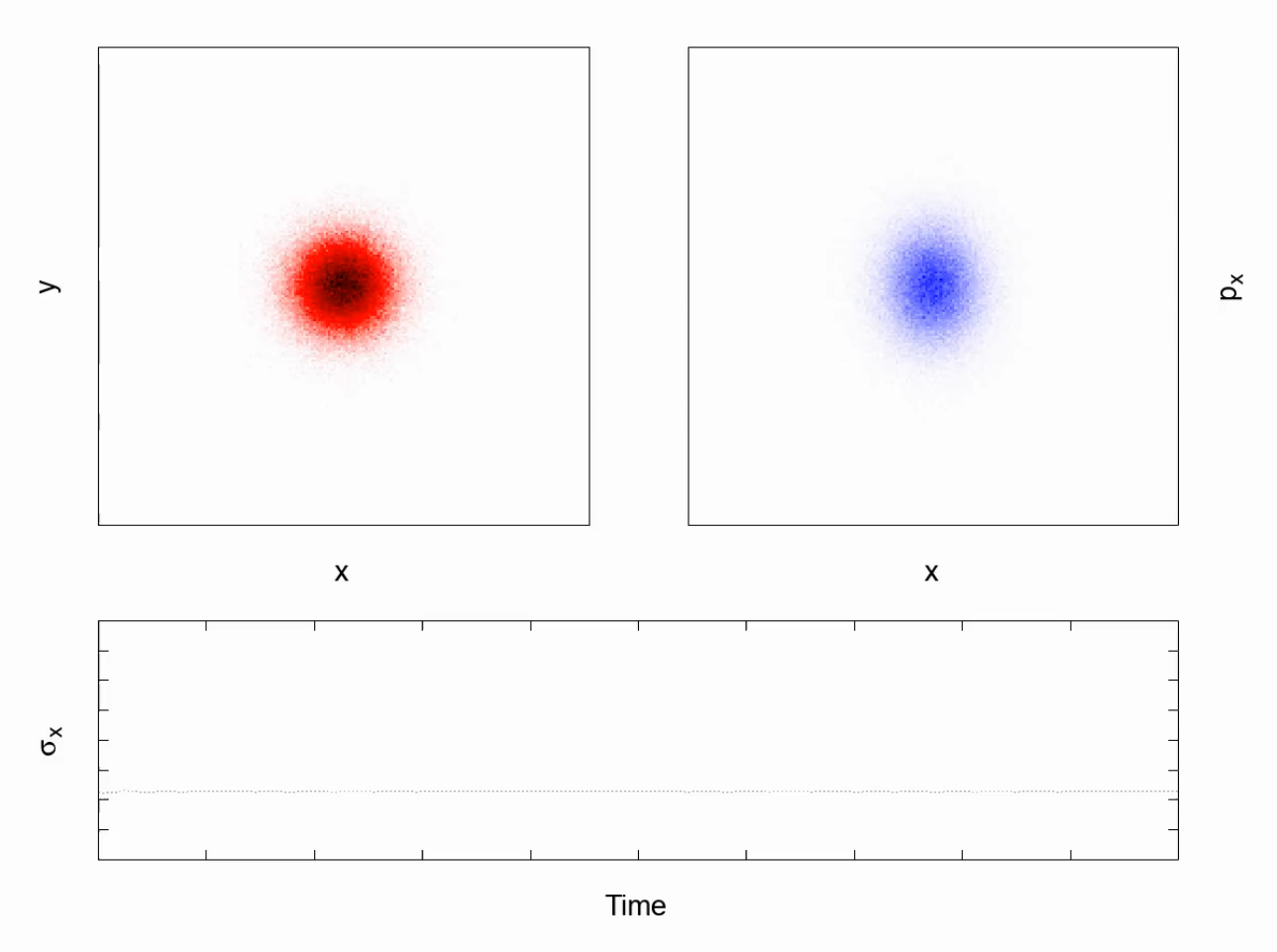
High emittance emittance:
quasi-matching

Matched beam



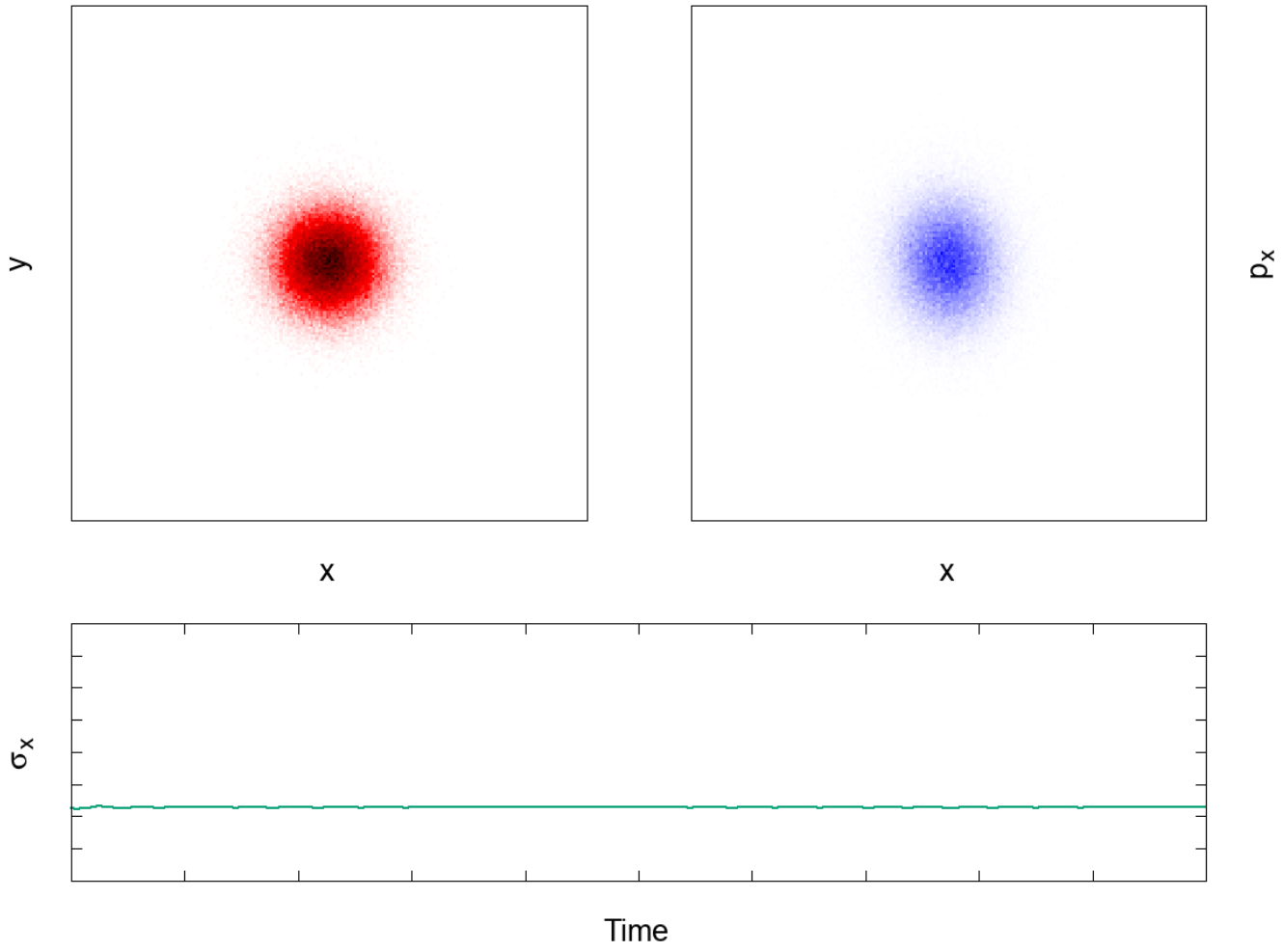
- A particle beam will naturally diverge. Can use focussing to maintain the beam size

Matched beam



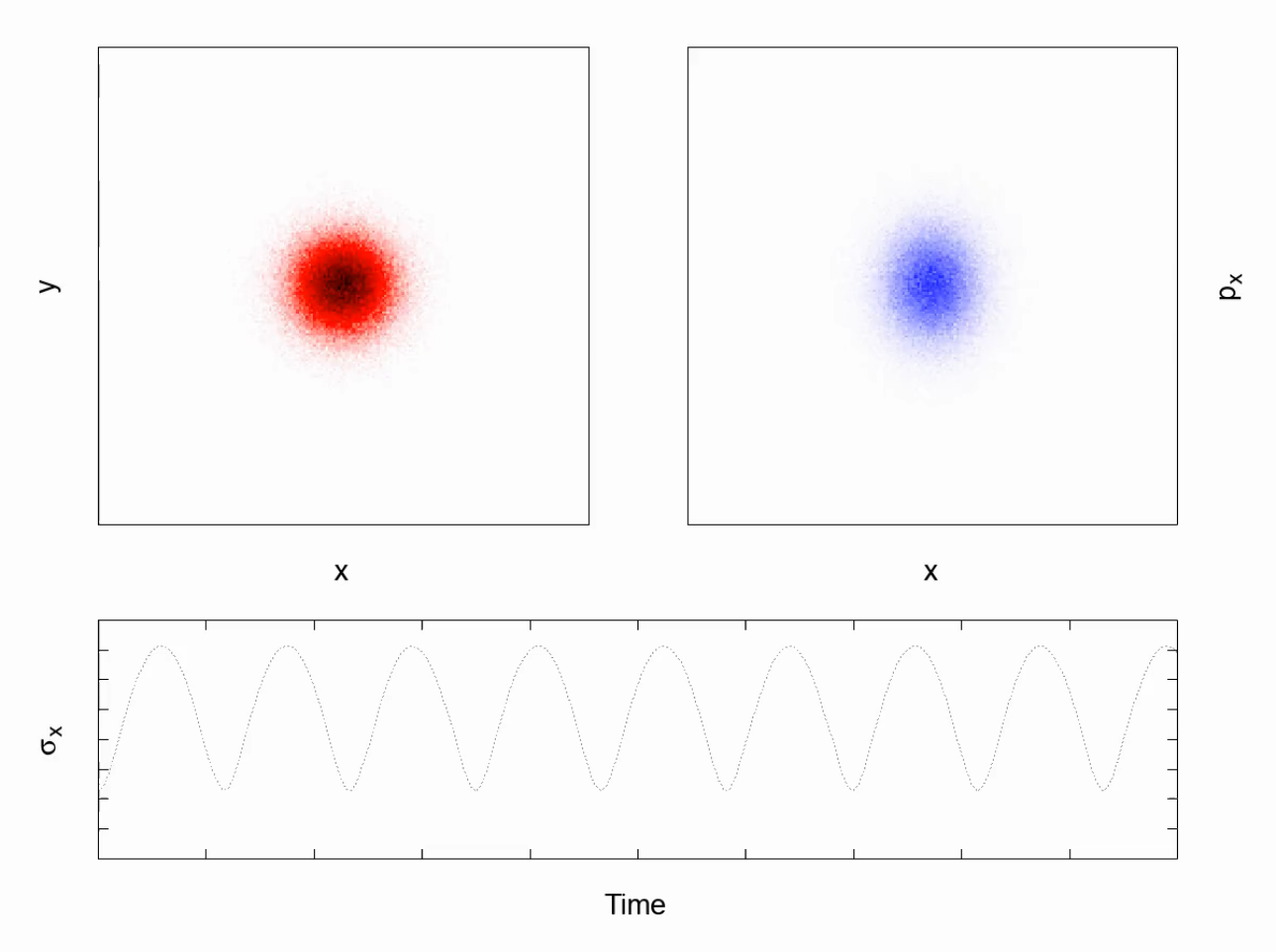
- A particle beam will naturally diverge. Can use focussing to maintain the beam size
- Chose radius such that focussing matches emittance pressure

Matched beam



- A particle beam will naturally diverge. Can use focussing to maintain the beam size
- Chose radius such that focussing matches emittance pressure
- No oscillations, adiabatic focussing

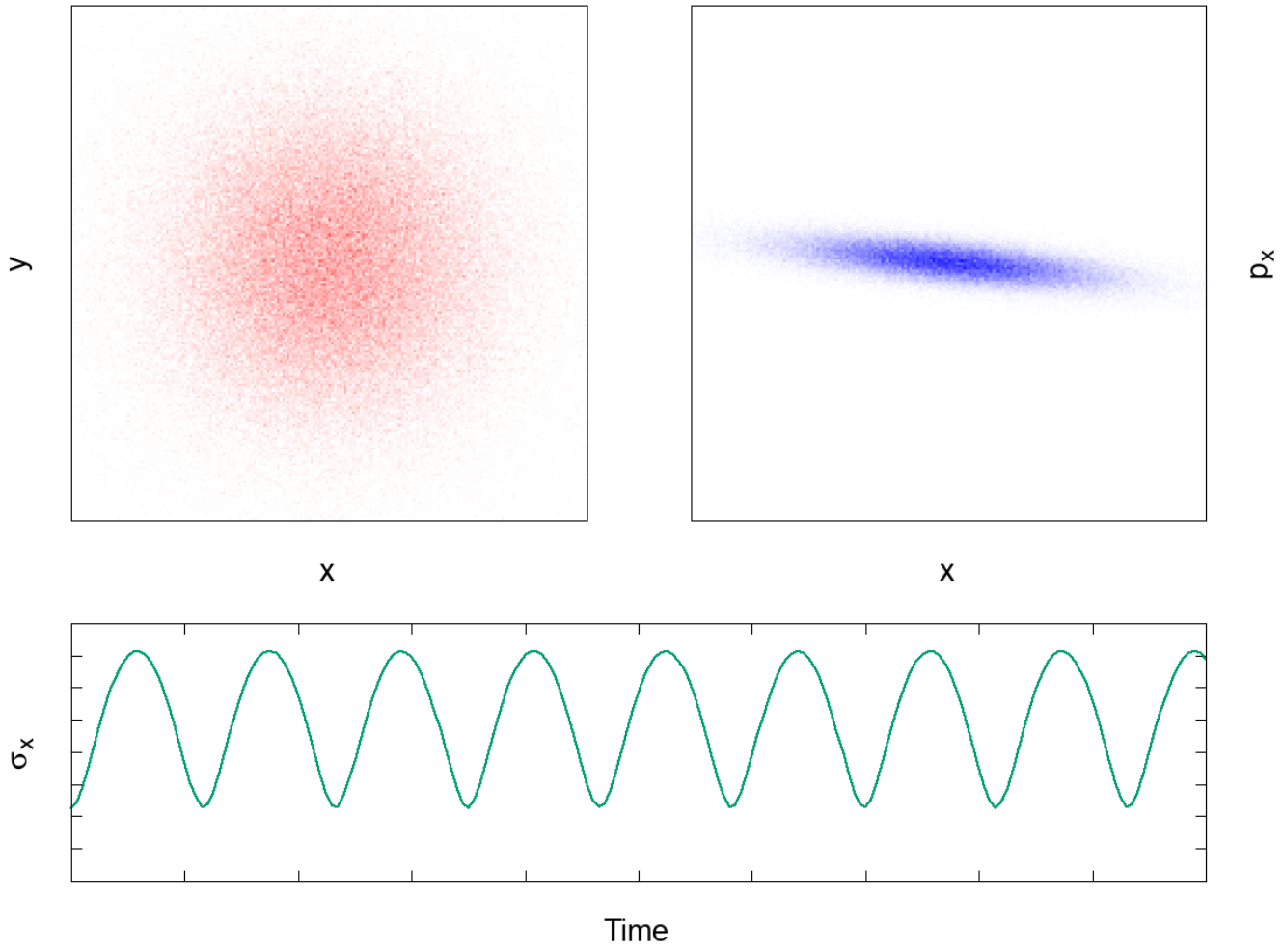
Mismatched beam



- A mismatched beam will oscillate
- For linear focussing, emittance is conserved*

* subject to terms and conditions

Mismatched beam



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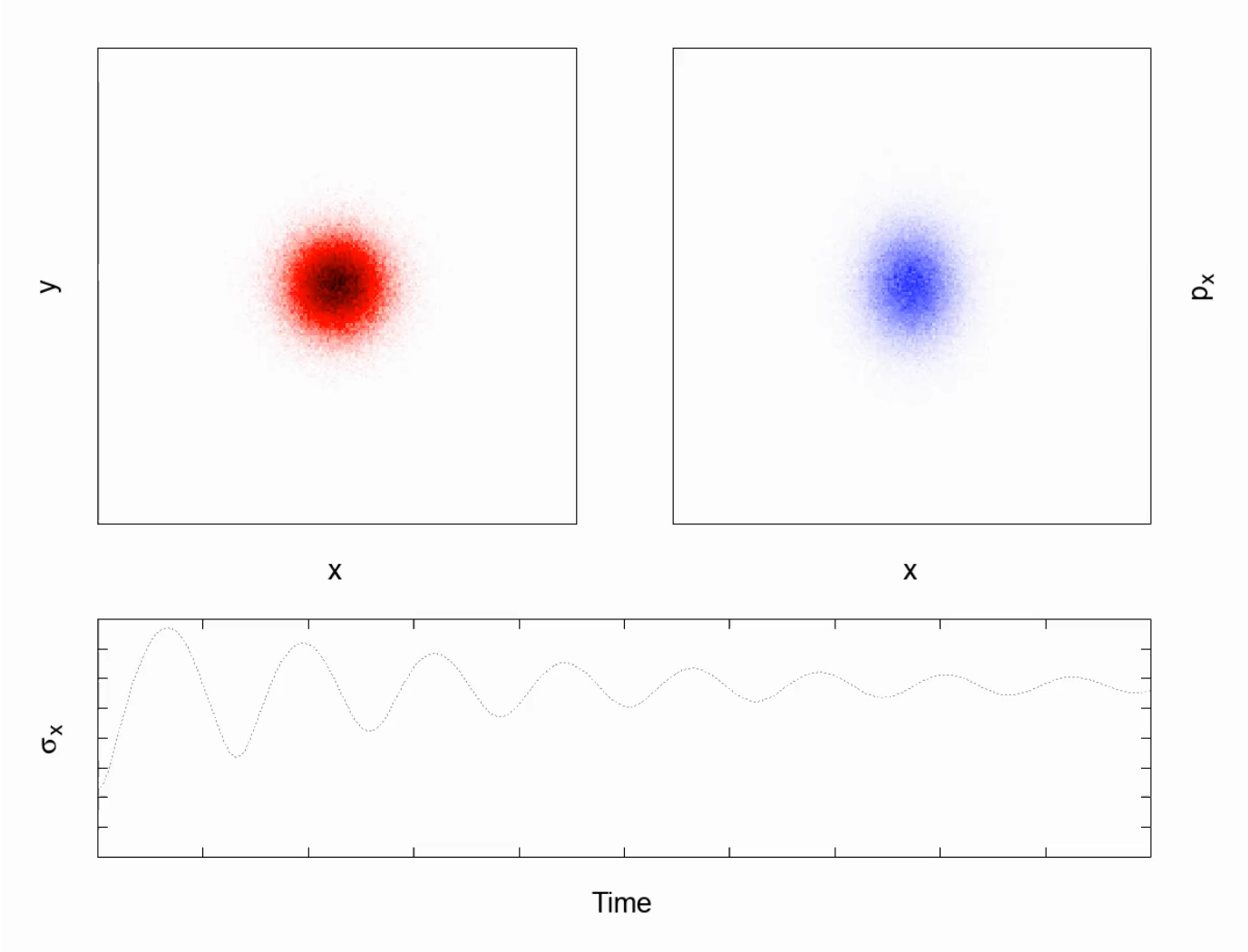
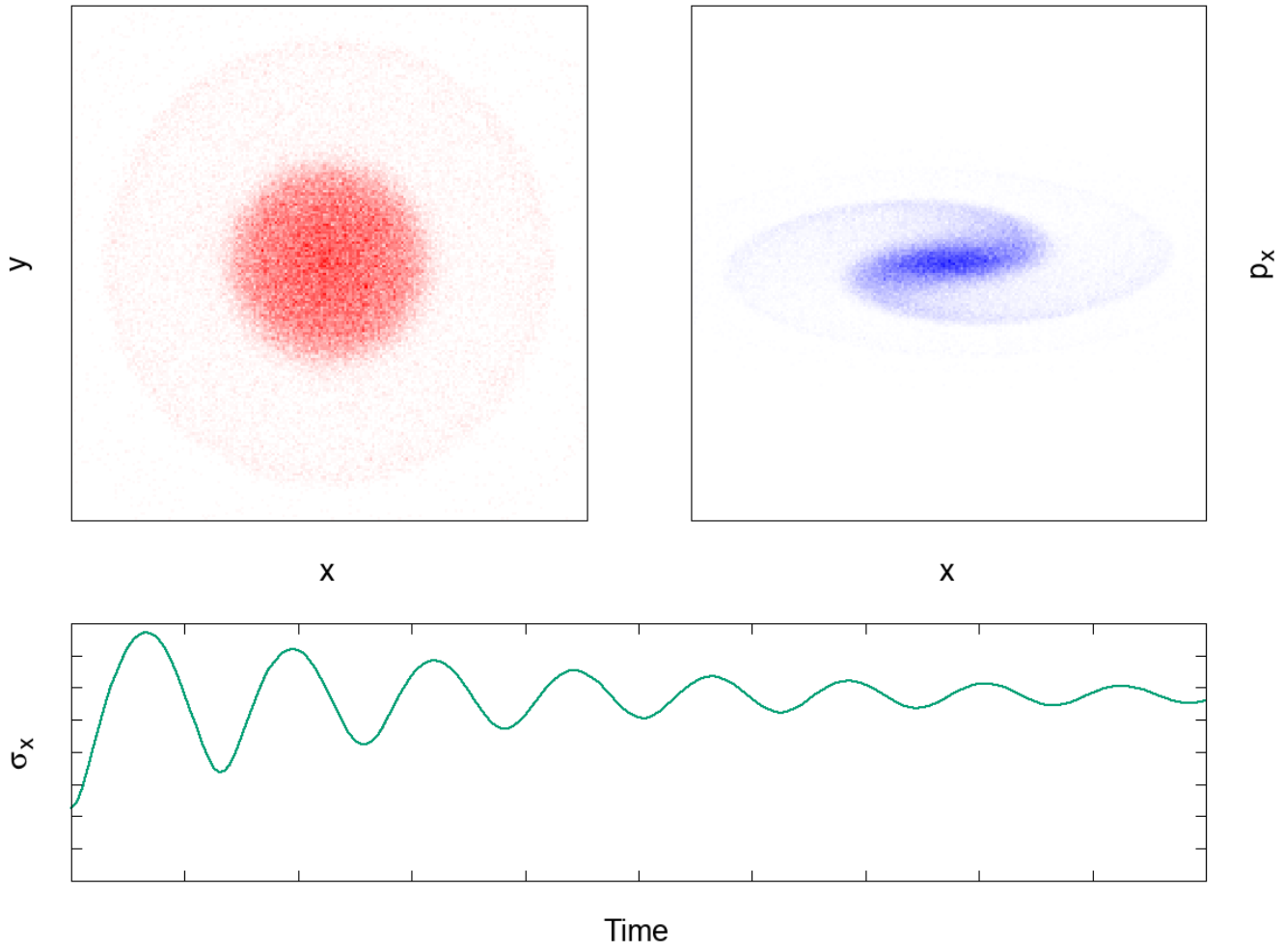
Mismatched beam II



Emittance will grow if particles oscillate with different frequencies:

- restoring force is nonlinear
- bunch energy spread

Mismatched beam II



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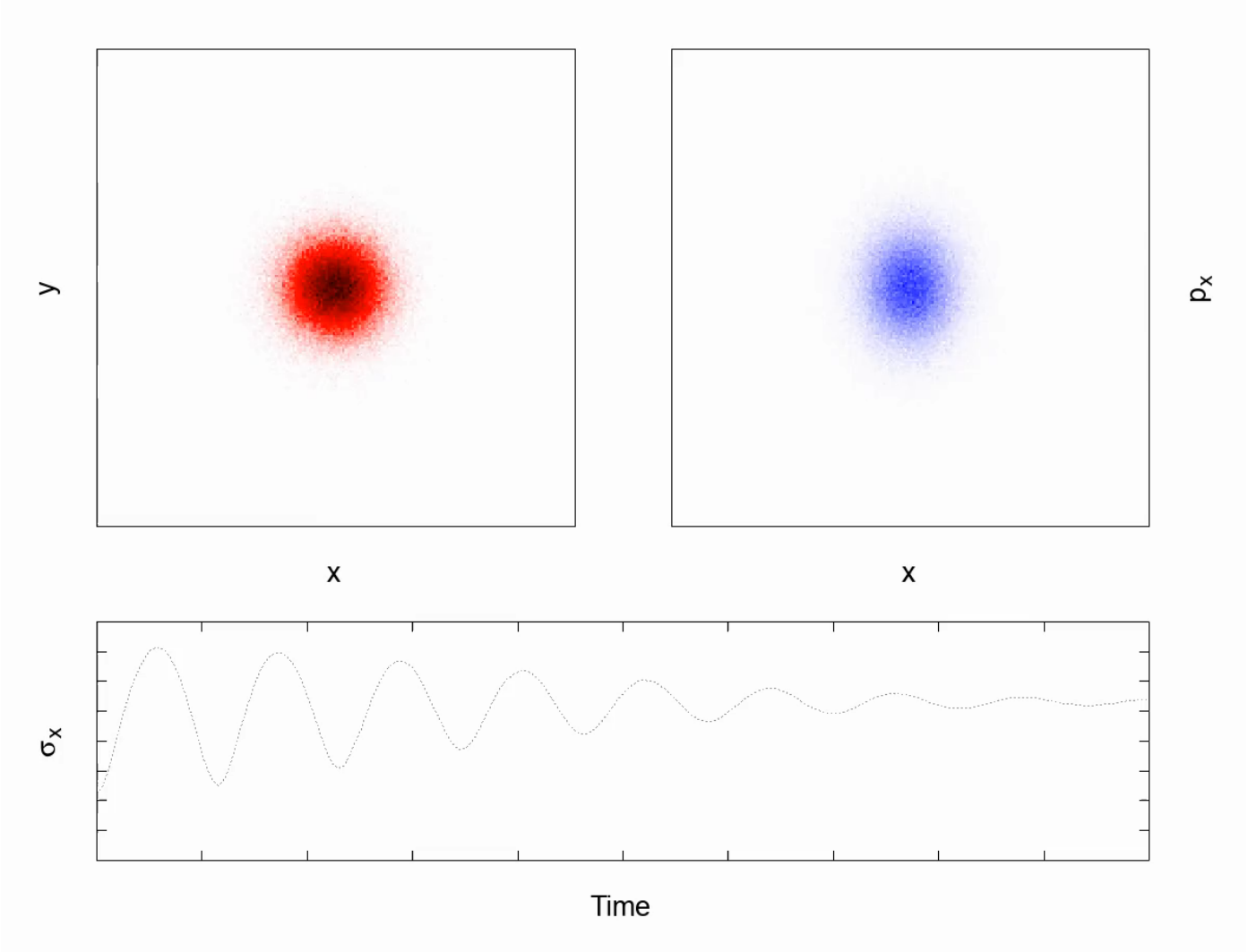
Mismatched beam III



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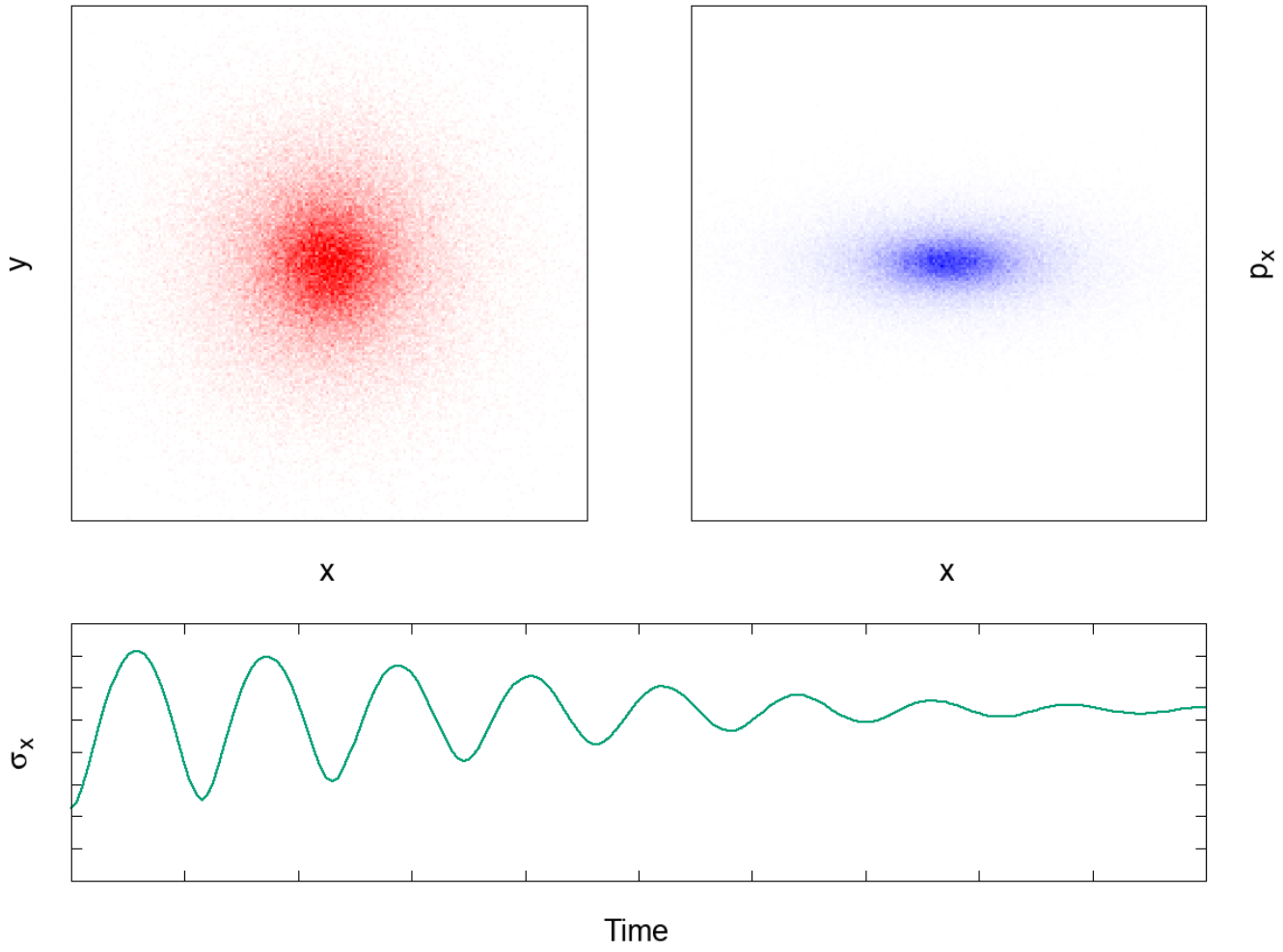
Mismatched beam III



Emittance will grow if particles oscillate with different frequencies:

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Mismatched beam

A mismatched beam oscillates

Nonlinearities lead to phase mixing

For a mismatched beam, the emittance increases until a new matching condition is achieved (or you lose the beam)

Run 2b

We definitely don’t match, so emittance will initially grow.

Will we be able to observe emittance preservation?

Maybe.

Run 2b

Emittance is a statistical measure, so comparisons only make sense for the same population

- charge conservation with varying plasma length

Matching condition depends on focussing fields

- uniform wakefields with varying plasma length

Conclusions

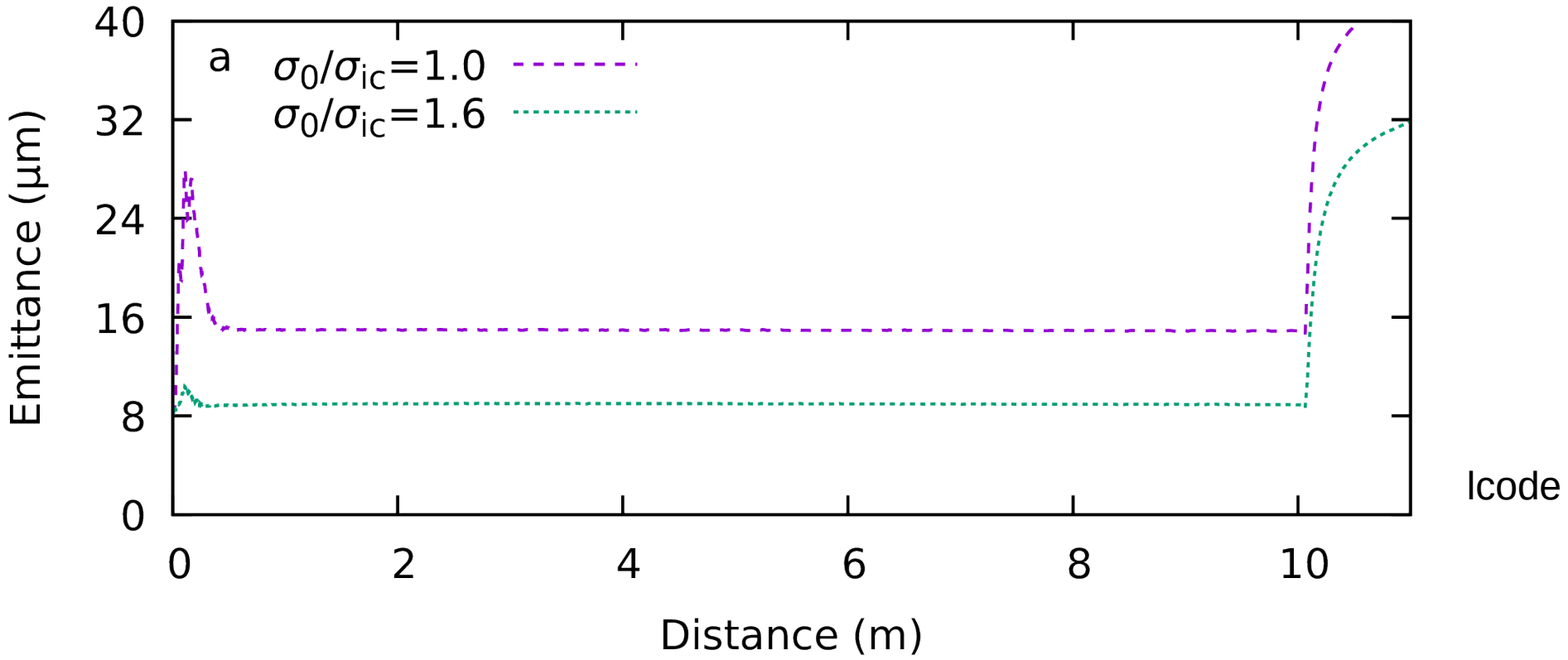
Run 2c will demonstrate emittance control by choosing the correct radius at injection (on axis!)

Run 2b will always see an initial emittance growth

Emittance preservation possible if we have

- Charge preservation with acceleration length
- Uniform wakefields with acceleration length

Off topic: Plasma ramp at exit



- Plasma filament can defocus the accelerated (multi-GeV) bunch
- Spoils emittance

Farmer, AWAKE Collaboration meeting, October 2022