

# Coasting beams simulations with space charge

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Science and  
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# What will I talk about?

- Coasting beams
- Transverse instabilities
- Collective effects
- How to simulate all of this
- Results

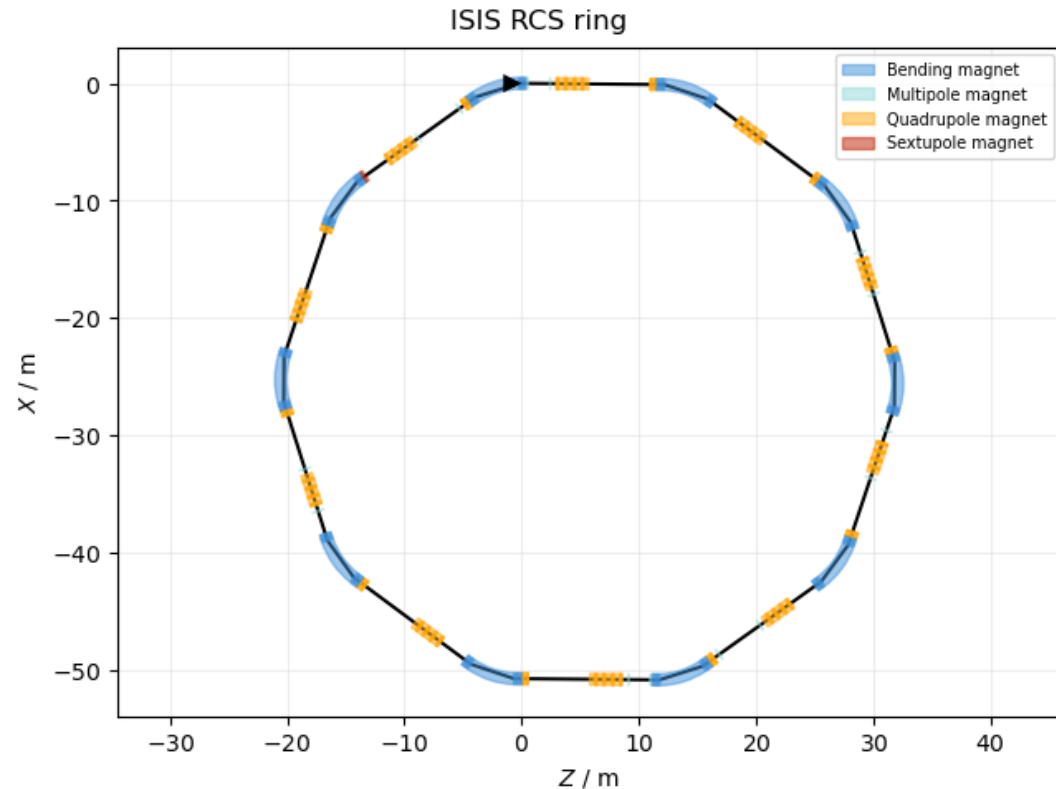
# What are coasting beams? Why do we care about them?

Particle beam configuration with:

- No acceleration
- No bunching
- No longitudinal focusing
- Fills up the whole ring

Interesting for:

- Impedance measurements
- Transition state between different bunching structures

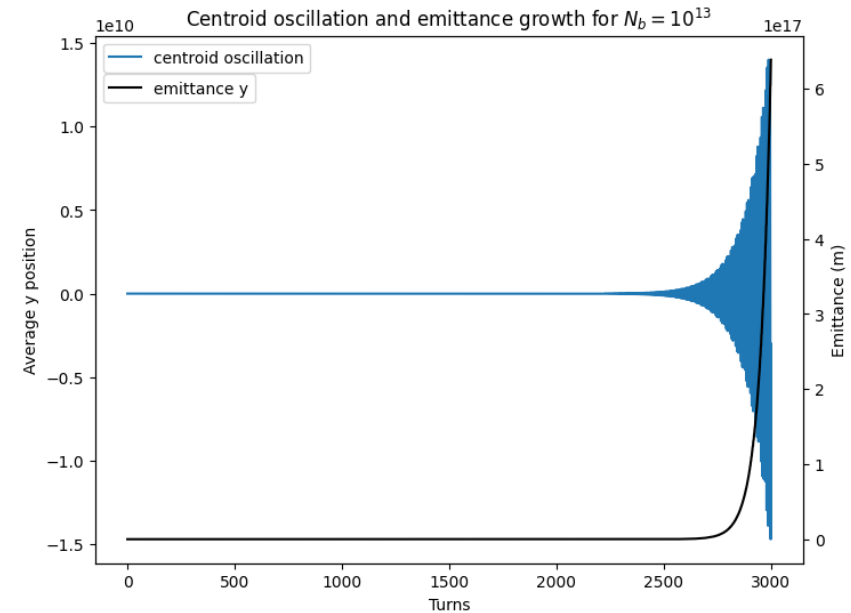
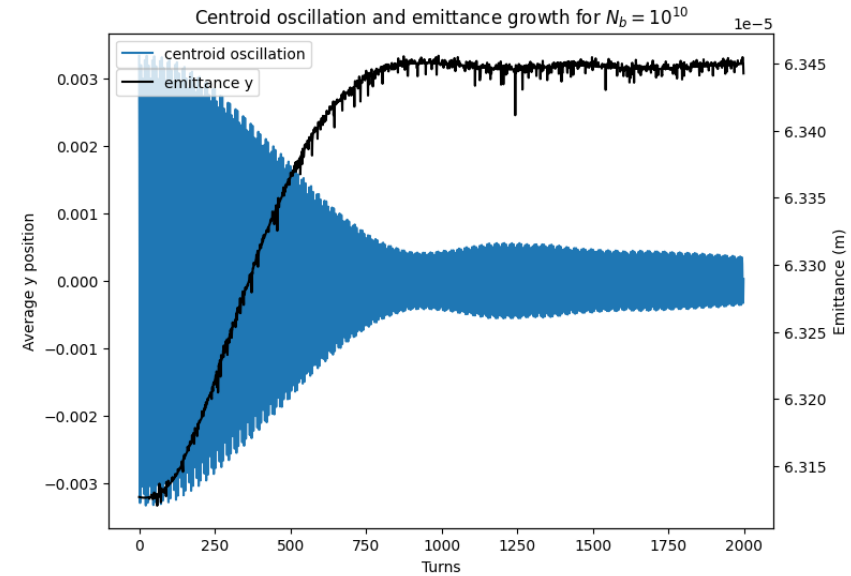


# What are transverse instabilities?

Wakefields drive instabilities:

$$\frac{d^2 y}{ds^2} + \left(\frac{Q_0}{R}\right)^2 y = \frac{1}{\gamma m v^2} \left( \frac{\partial \langle F_{beam} \rangle}{\partial y} \bigg|_{\bar{y}=0} y + \frac{\partial \langle F_{beam} \rangle}{\partial \bar{y}} \bigg|_{y=0} \bar{y} \right)$$

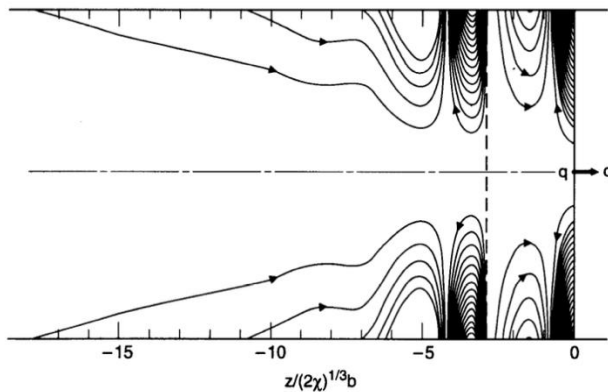
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# Key players in collective effects

## Wakefields

- Electromagnetic wake created by the resistive and non-smooth elements along the accelerator.
- Resonators and Resistive walls.

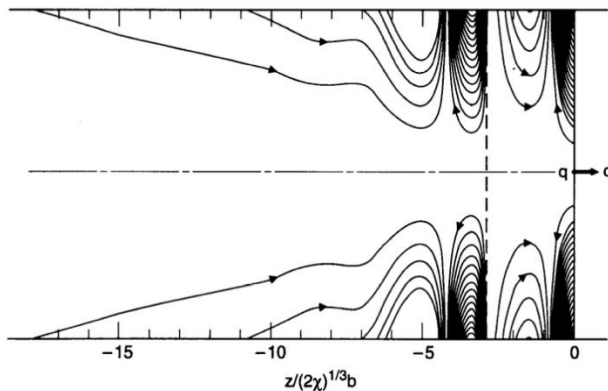


[1]

# Key players in collective effects

## Wakefields

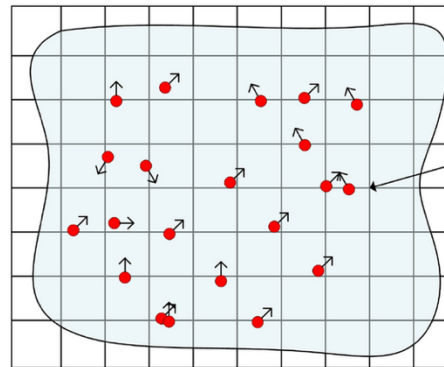
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[1]

## Space Charge

- Mean field theory of Coulomb interactions.
- Incoherent effect (different from every particle, averages to zero for collective motion).

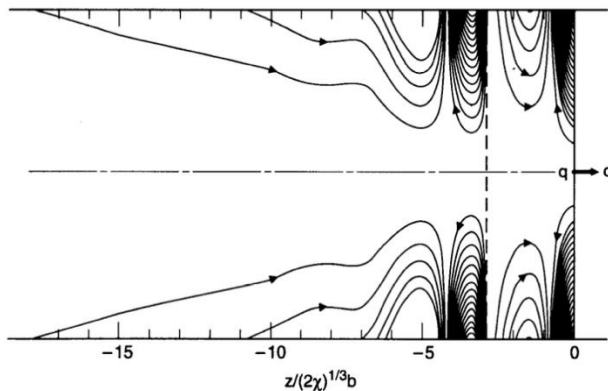


[2]

# Key players in collective effects

## Wakefields

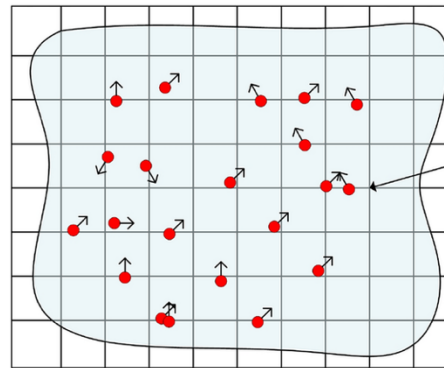
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[1]

## Space Charge

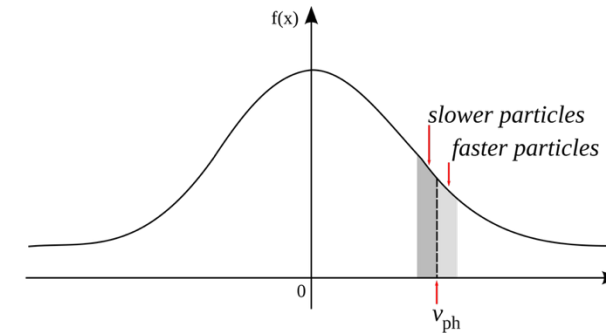
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[2]

## Landau Damping

- Particles that oscillate at frequencies different from the collective mode, draw energy from it, damping it.
- Damping of collective modes.



[3]

# How can we simulate this?

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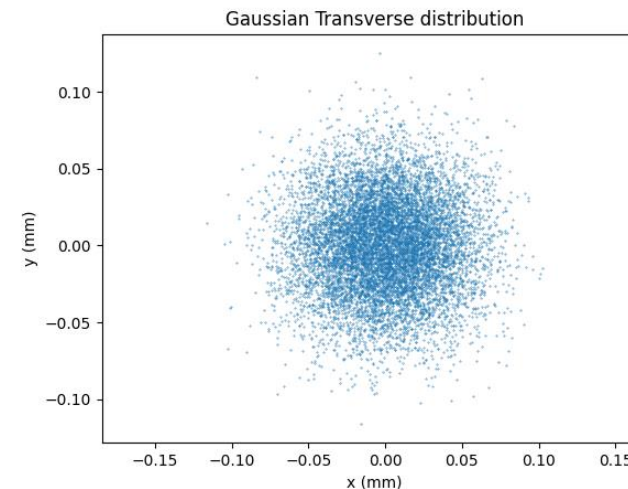
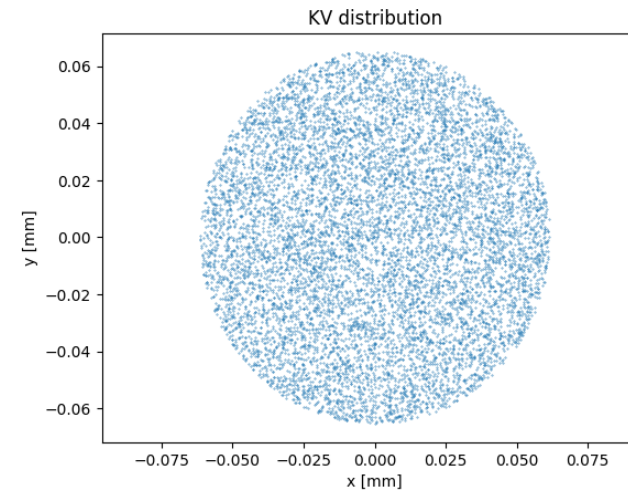
## LineMaps

- Tracking particles through lattice elements is often slow and not flexible.
- Instead we can use Twiss parameters applied as matrices.

## Particle in Cell (PIC)

- Numerical method for self-field force.
- Compute fields 100 times per turn.
- $N \log(N)$  computation time.

## Particle distributions



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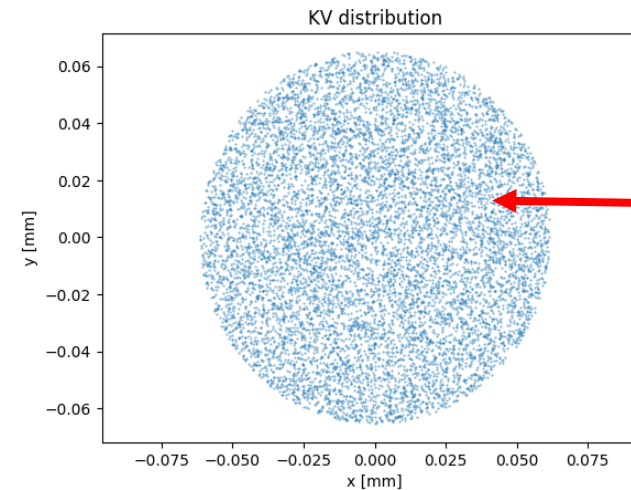
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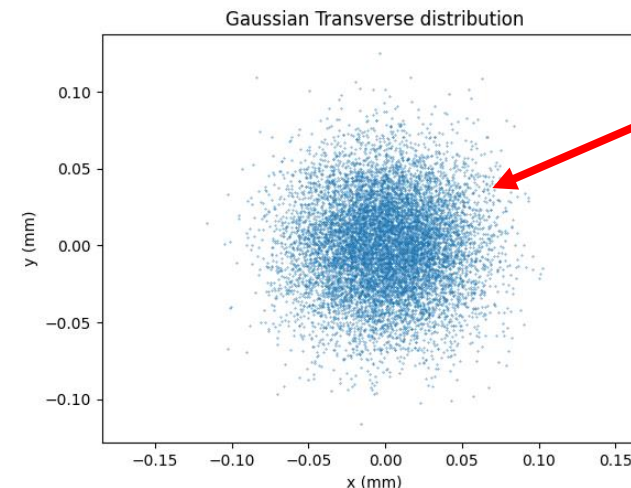
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## Particle distributions



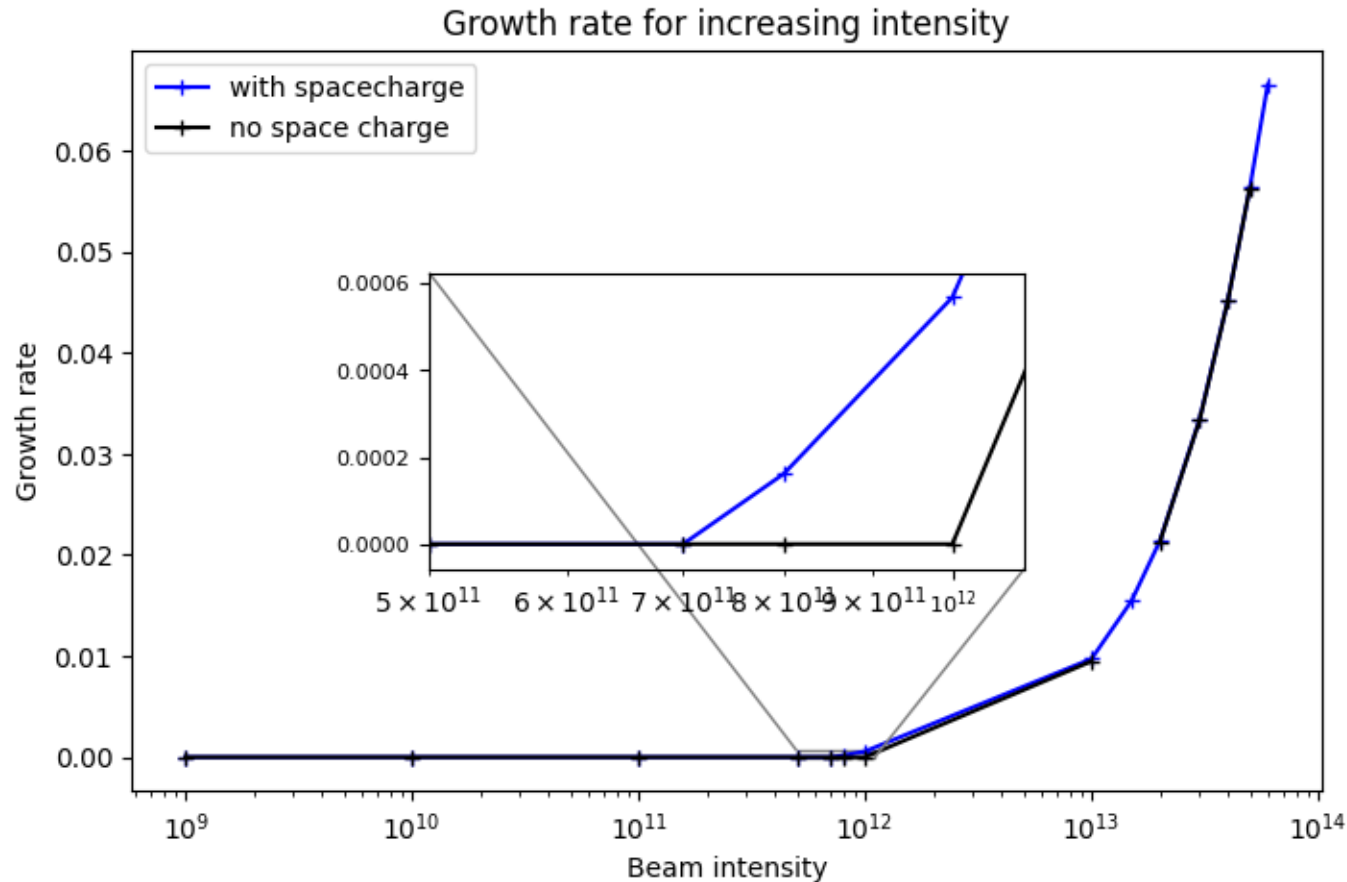
Self field at any point is linear with  $x/y$ .

Quadrupole-like effect



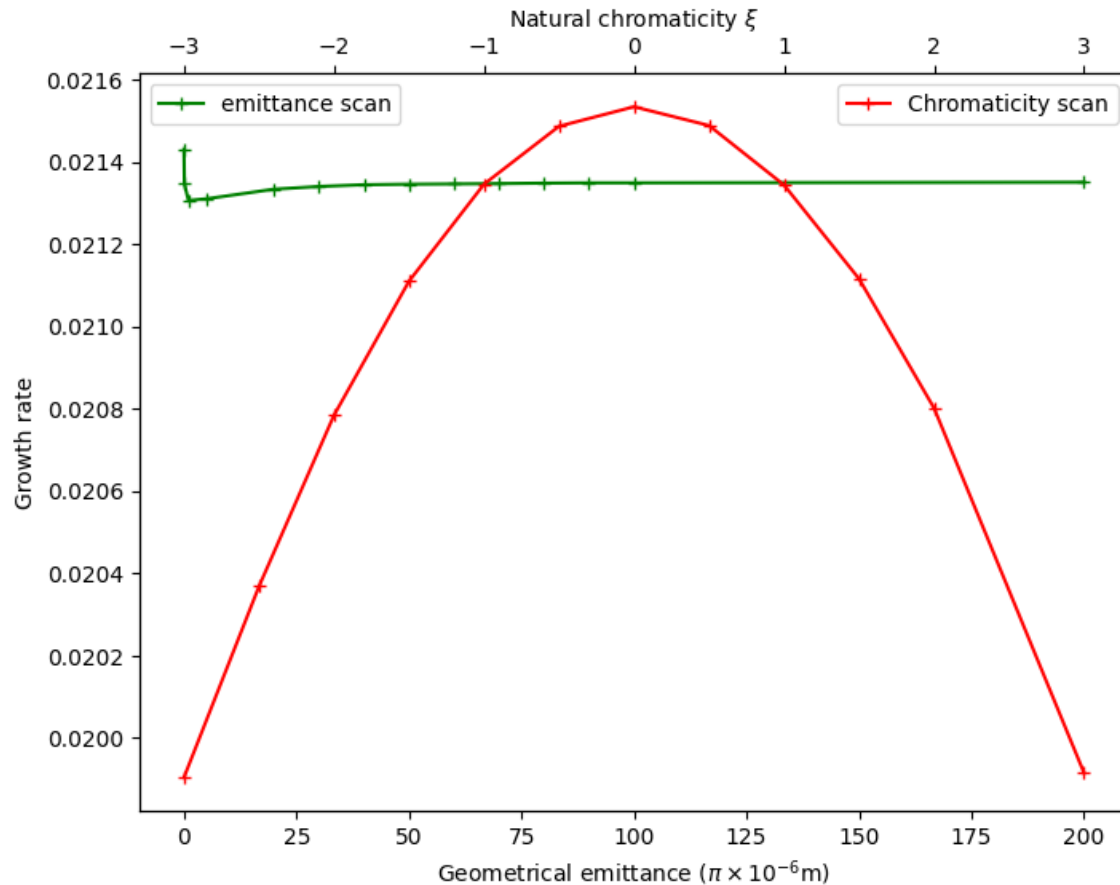
More realistic distribution

# So, what happens with coasting beams?



Actually space charge reduces Landau damping in coasting beams, and pushes back the instability threshold!

# Chromaticity and emittance influence the instability as well



It is also interesting to study how growing rate varies with chromaticity and emittance.

$$\text{Chromaticity } \xi = \frac{1}{Q_0} \frac{dQ}{d\delta}$$

How much the focusing changes for different energies.

Emittance  $\epsilon = \gamma x^2 + 2\alpha x x' + \beta x'^2$   
aka Area in phase space of the particle distribution.

# Questions?

# Tune shifts

