Fast Ion Instability Simulations for CesrTA

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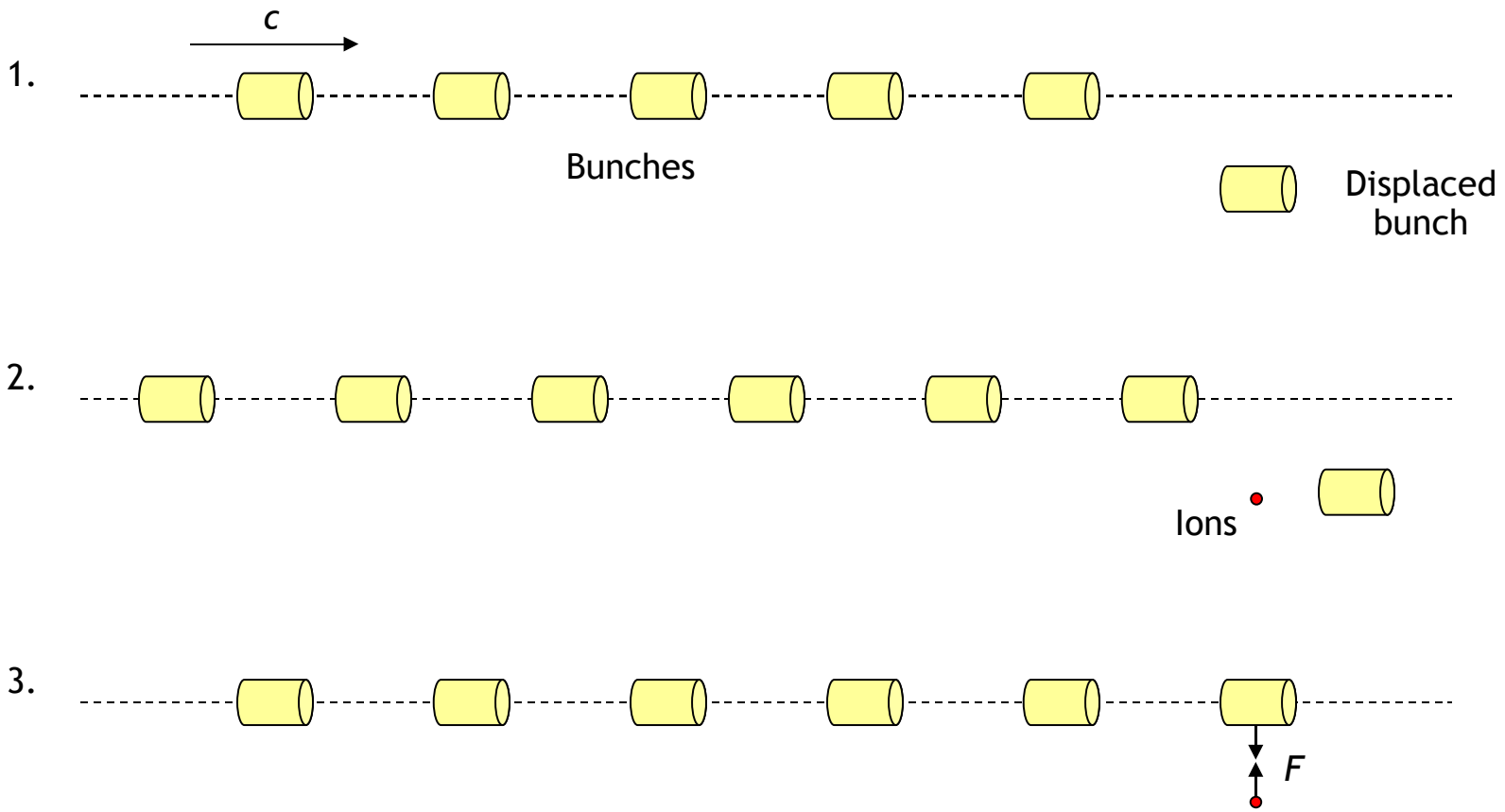
Fast Ion Instability (FII) Introduction

- Vacuum chamber residual gas (CO, H_2) is ionized by the beam
- Positive ions are trapped in an electron beam's potential and oscillate
- Ions from early bunches affect later bunches
- Transverse deviations at the train head are carried along the train by the ions

Train Tail Disturbance



FII Details

- The ion motion: 0.1 – 1 MHz, nonrelativistic
- The ions cause betatron oscillations in the beam
  - Betatron amplitude grows with time and bunch number
- FII causes emittance blowup
- Time gaps in between trains clear the ions

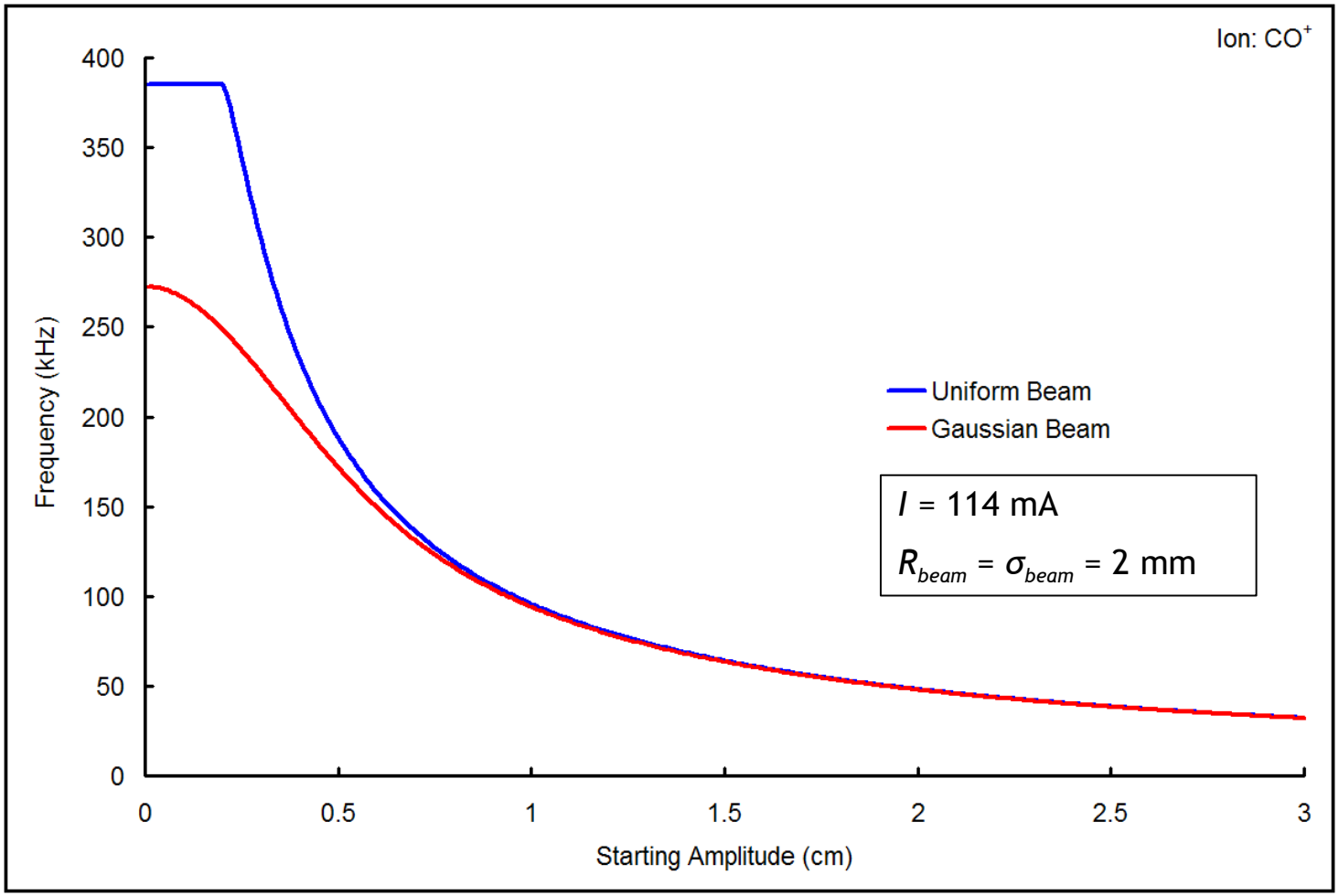
Project Purpose

- CESR high energy physics will end in 2008; convert CESR into a test accelerator for the ILC damping rings (CesrTA)
- Subroutine library used to model CESR (Bmad) does not include account for FII
- FII will be studied in CesrTA with experiments and simulations, but the simulations need to be developed

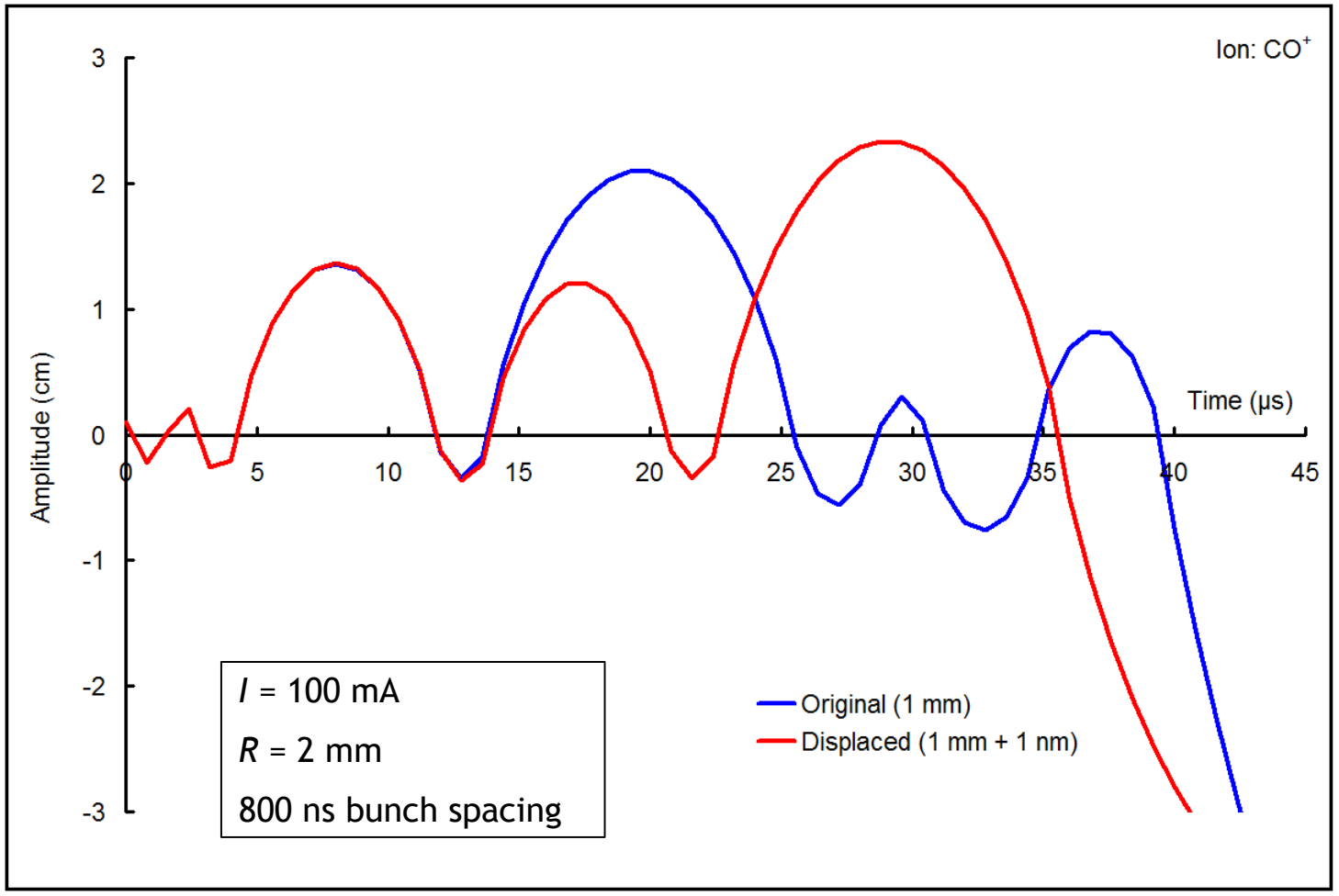
Initial Simulations

- Ion oscillating with uniform and Gaussian bunch charge distributions (solid and bunched beams)
- Assumptions:
  - Start ion from rest at some amplitude directly above a bunch
  - Vertical oscillation only
  - No initial velocity and no longitudinal velocity
  - No interactions in between bunches; the ion drifts at constant velocity
  - Constant beam centroid

Uniform/Gaussian Beam Comparison



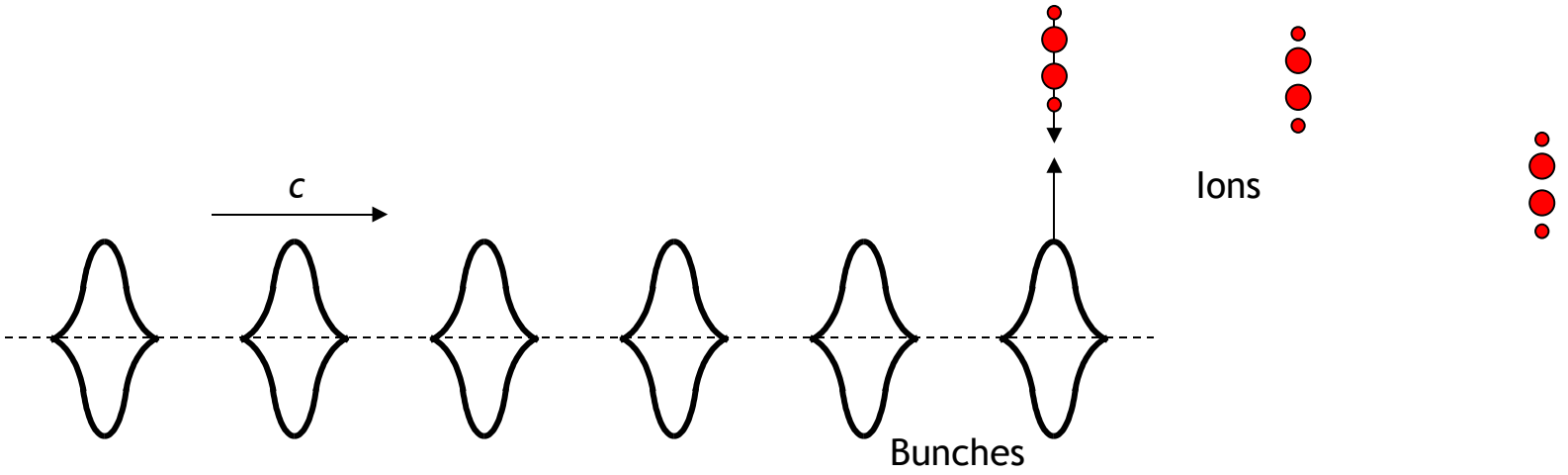
Ion Ejection



Simulation Extensions

- Ion “macroparticles” implemented
- Bunches allowed to be “kicked” by the ions, starting betatron oscillations
  - Ions affect bunch as a whole
- Many macroparticles at fixed longitudinal position included (Gaussian macroparticle distribution)
- Many macroparticle distributions at different longitudinal positions
  - Initial ion centroids determined by an imaginary “0^{th} bunch” with betatron oscillations
- Ion ejection for amplitudes beyond 3 cm

Current Simulation



Betatron Amplitude Growth

Ion: CO^+

10^{10} e^- / bunch

10^6 ions / distribution

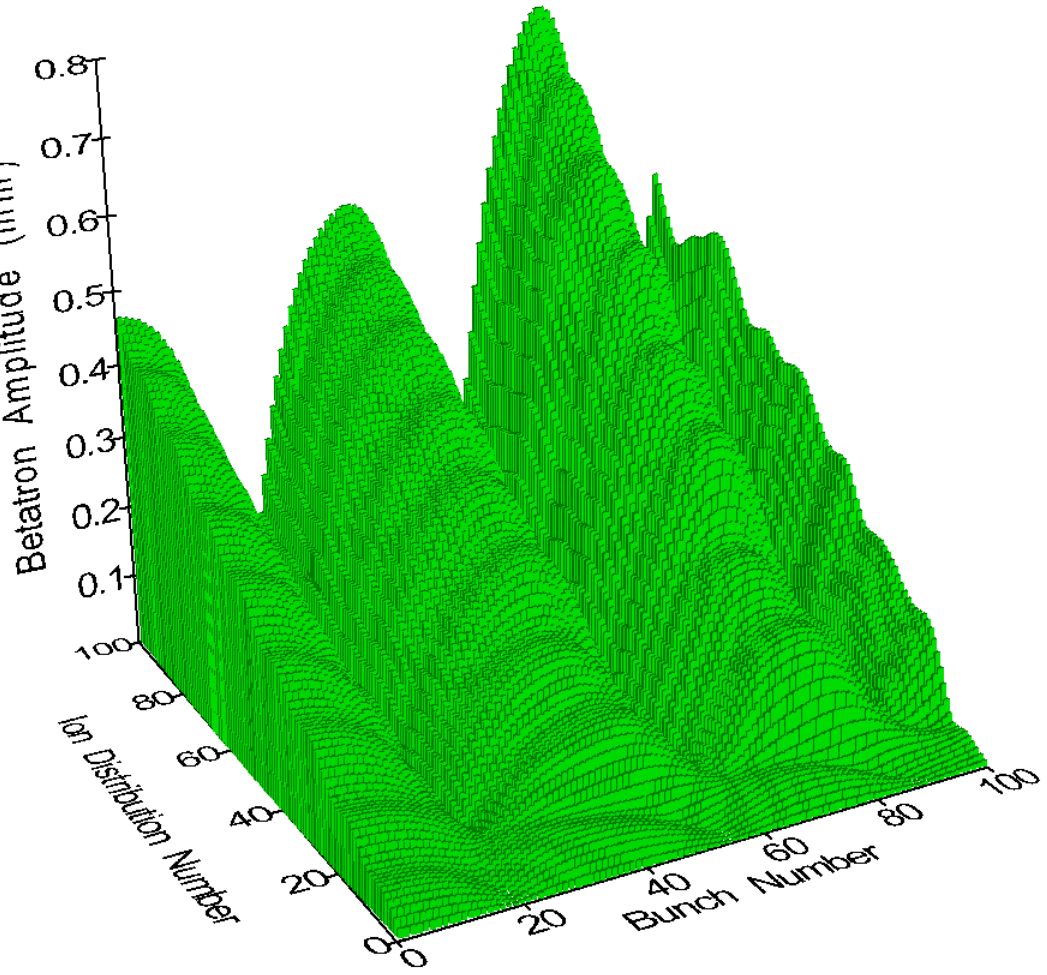
$\sigma_{beam} = \sigma_{ions} = 2$ mm

$\omega_\beta = 25.83$ MHz

14 ns bunch spacing

10 ns ion distribution spacing

Ion centroid within 0.1 mm of beam axis



Future Development

- Incorporate ion production – requires a change in program design
- Further generalize the program
  - Initial ion velocities
  - Horizontal movement
- Incorporate into Bmad