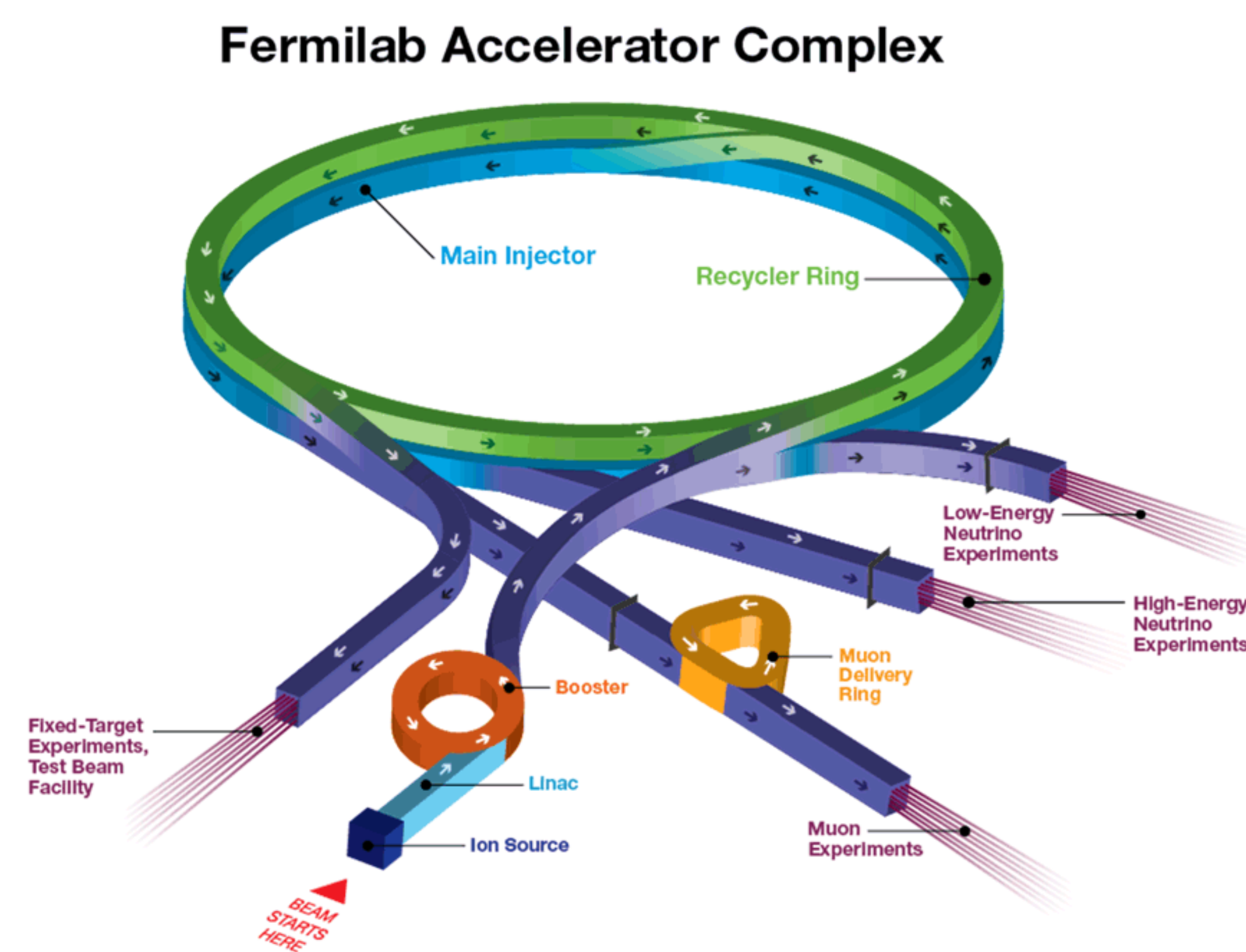


# Simulating Batch-on-Batch Slip-Stacking in the Fermilab Recycler Using a New Multiple Interacting Bunch Capability in Synergia

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## The Fermilab Recycler



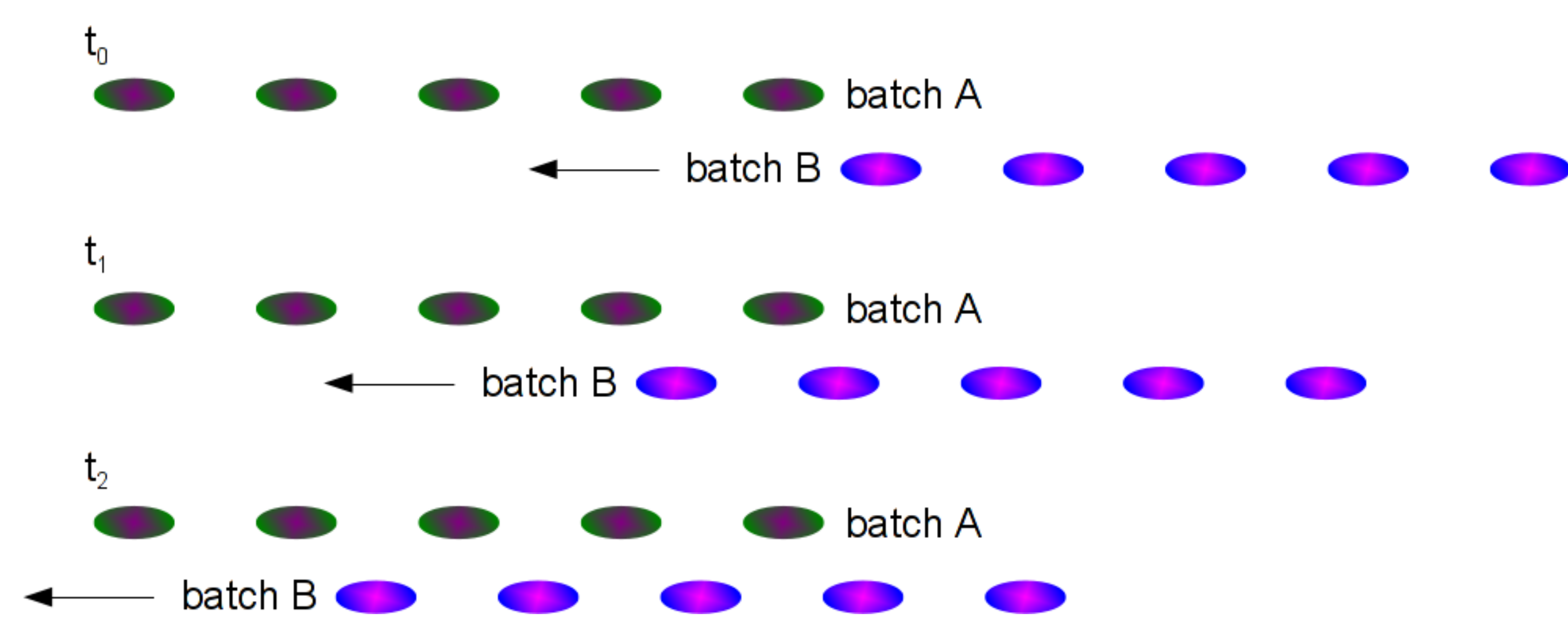
The Recycler is a 3.3 km long permanent magnet storage ring. It shares the Main Injector Tunnel.

The Fermilab Recycler (above) and Main Injector (below)

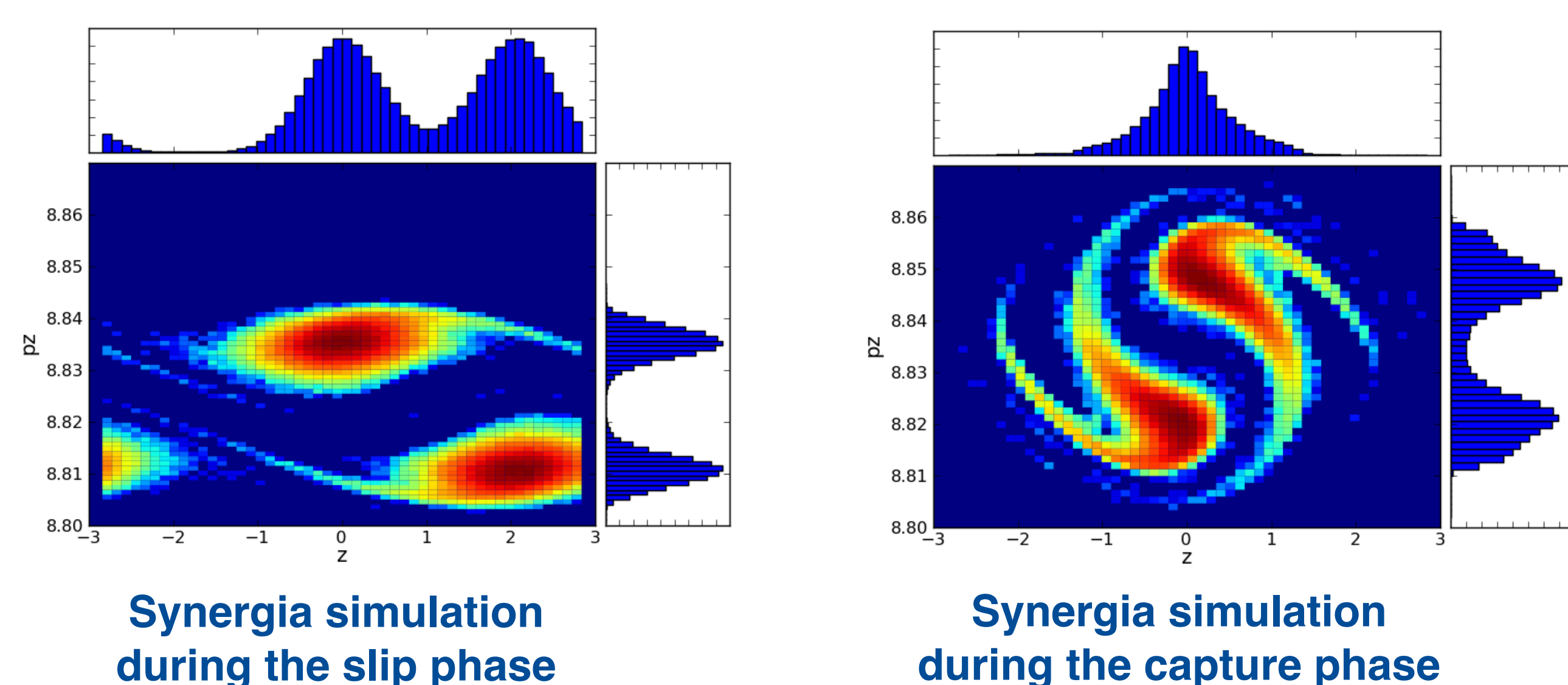


## Slip Stacking

During slip stacking, the Recycler will receive six batches of 80 bunches each from the Fermilab Booster at its central momentum. These batches will be decelerated to a lower momentum by detuning one of two RF cavities in the Recycler, then combined with six new batches to form combined high-intensity bunches.



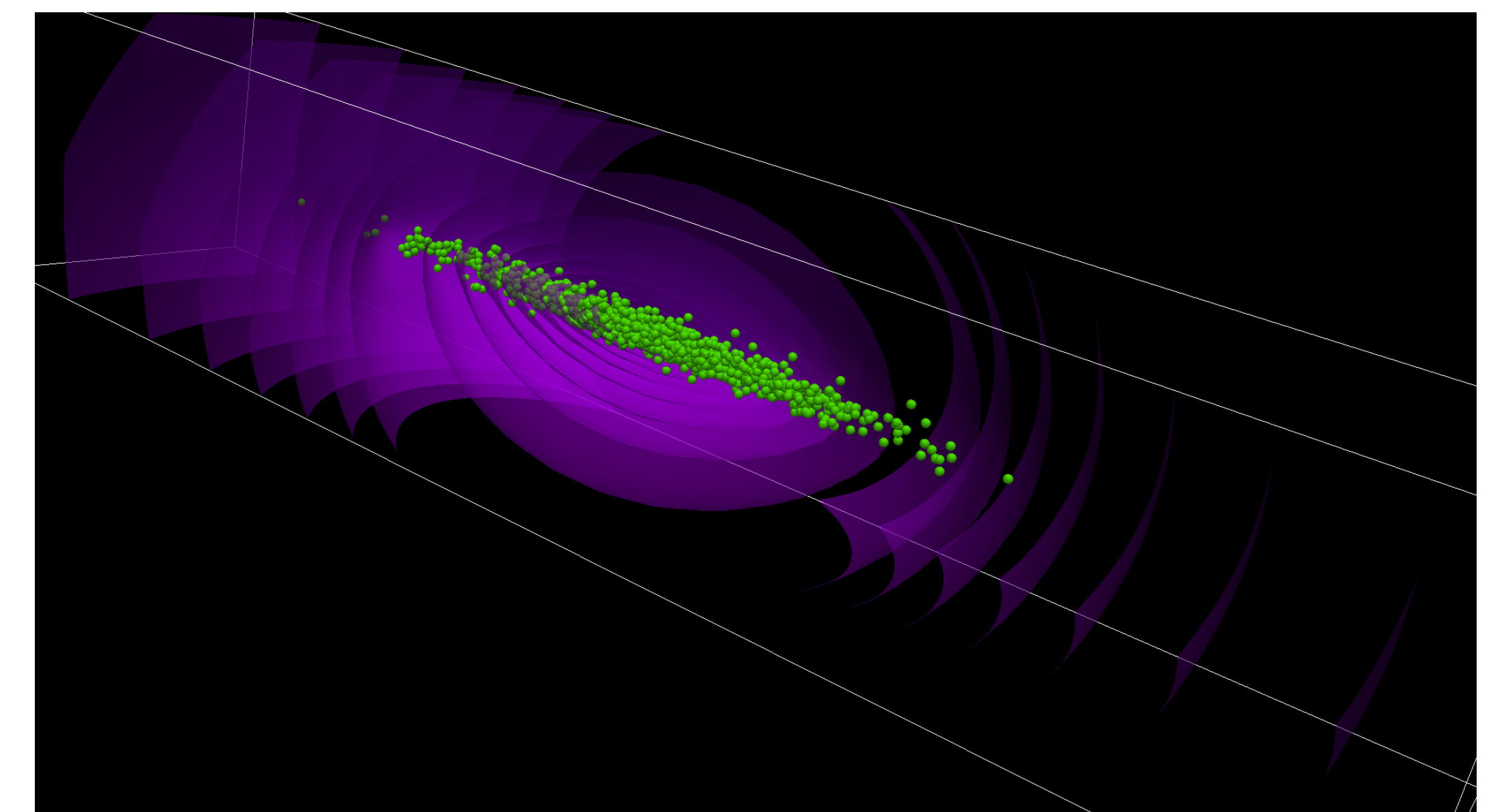
The first Synergia simulations of slip stacking utilized periodic boundary conditions to simulate a continuous stream of bunches.



## Synergia

<https://goo.gl/pAS5Zd>

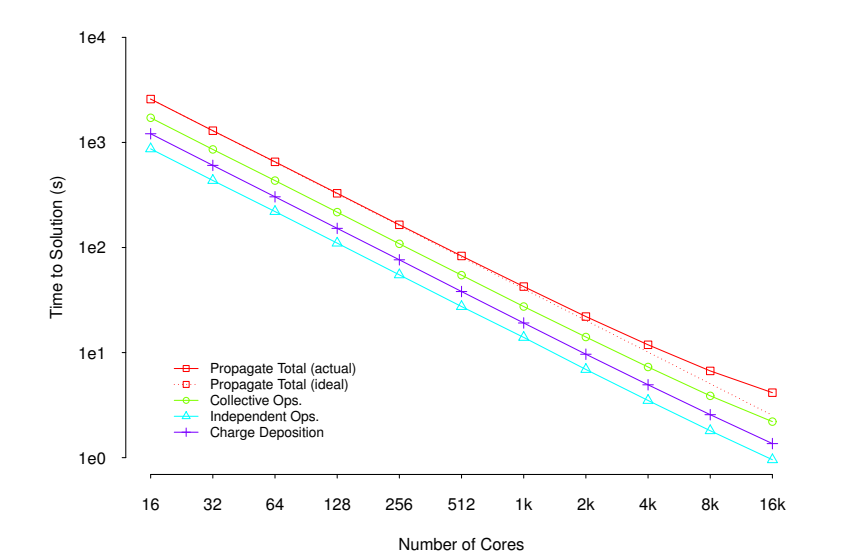
Synergia single-bunch simulation with particles (green, downsampled by 1000x) and space charge fields (purple)



Synergia is an accelerator simulation framework designed to scale from desktop computer to massively parallel supercomputers. Synergia supports fully symplectic particle tracking through linear and non-linear lattice elements with arbitrary apertures. It specializes in combining single-particle tracking with a variety of collective effects for the simulation of intensity-dependent physics.

## Synergia single-bunch simulations

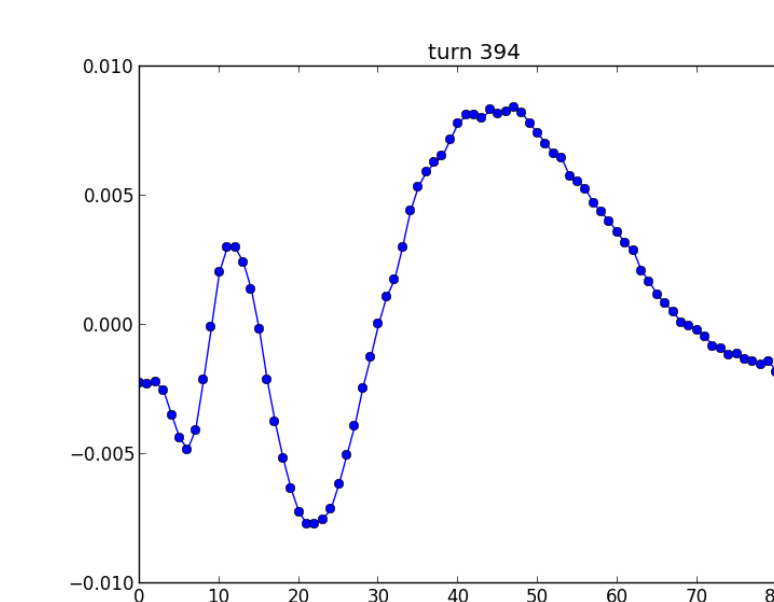
Synergia currently has single-bunch collective operators corresponding to space charge in a variety of approximations from simple analytical (Bassetti-Erskine) approximations to fully self-consistent three-dimensional approaches. Synergia also contains models for wakefields within the bunch for arbitrary external structures



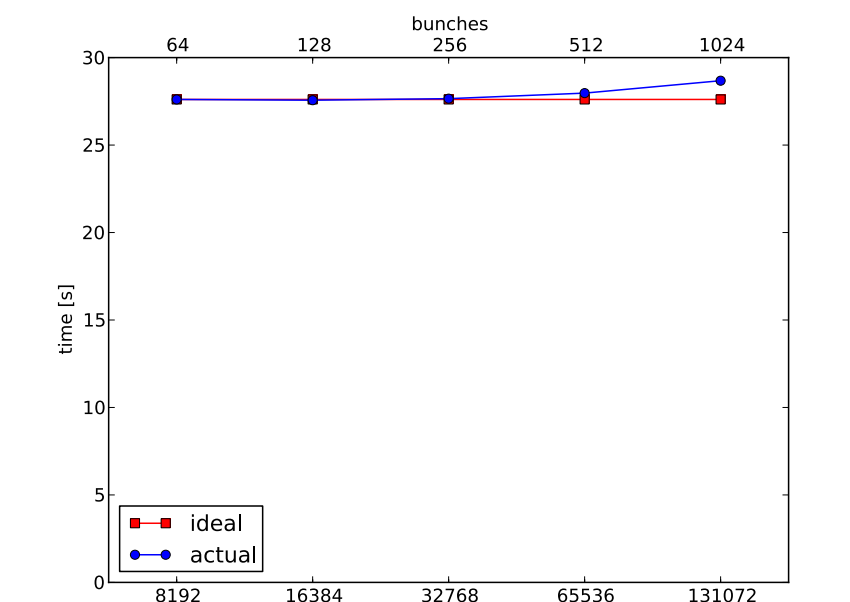
Single-bunch simulation scaling to 16,384 cores

## Synergia multi-bunch simulations

Large-scale multi-bunch simulations are a capability unique to Synergia. Multi-bunch simulations can include bunch-bunch coupling through wakefields, while including the single-bunch physics



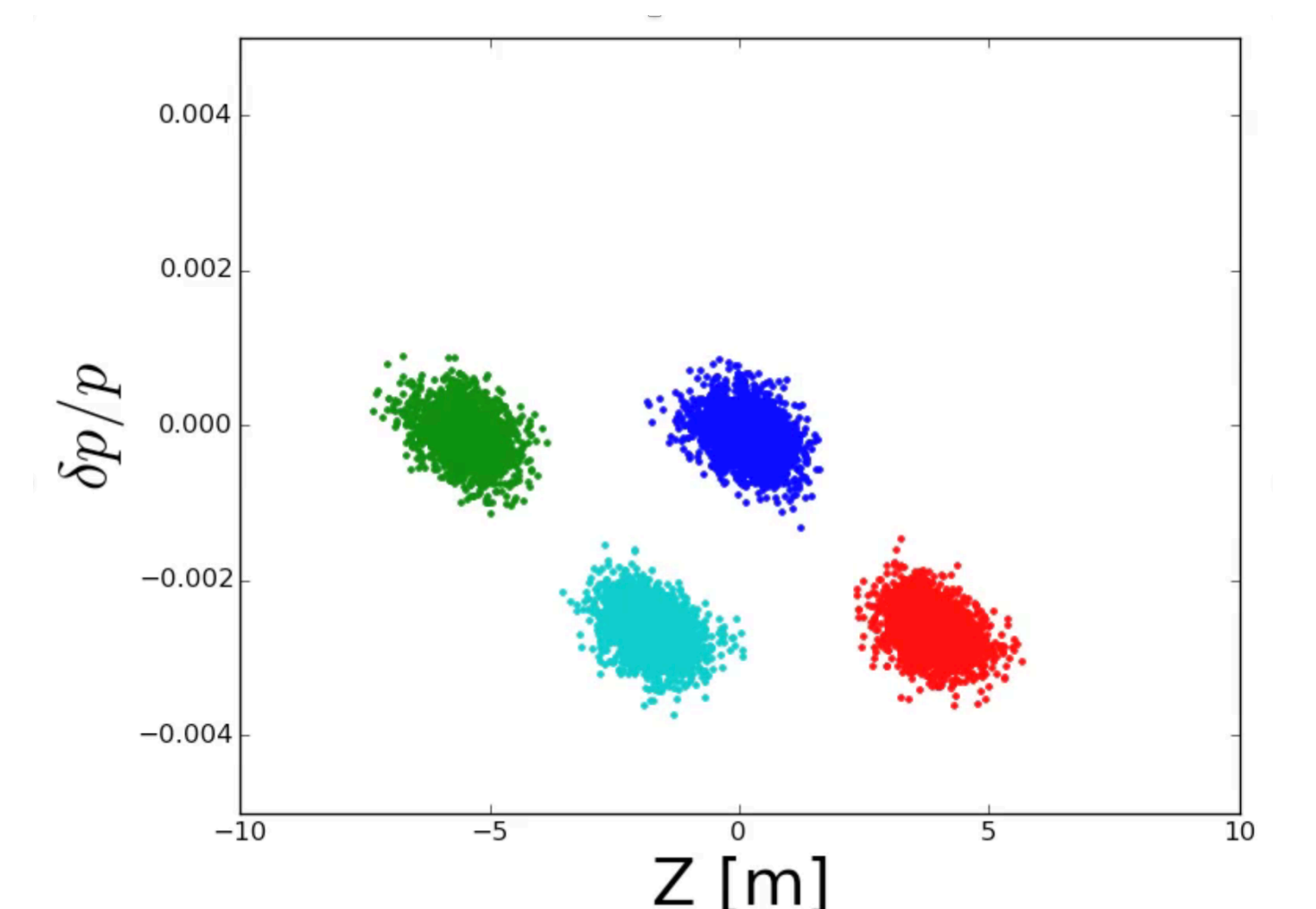
Multi-bunch structure in simulations of FNAL Booster



Multi-bunch simulation scaling to 131,072 cores

## Synergia dual-batch simulations

Dual-batch simulations are a new capability for Synergia. With it, we will be able to perform full 80-on-80 bunch slip stacking simulations for the Recycler.



First results from 2-on-2 dual batch simulations in the Recycler

## Future work



We have obtained a grant for 50 million core-hours on the Mira supercomputer to perform full 80-on-80 bunch slip stacking simulations of the recycler through the 2016 ASCR Leadership Computing Challenge (ALCC) Program.