Dynamic AMR for a Relativistic Electron Drift-Kinetic Solver Scalable PETSc-p4est Implementation and Implicit Time Stepping

- Adaptive mesh refinement (AMR) reduces simulation errors and computational cost by increasing the degrees of freedom only where needed
- Dynamic AMR coarsens and refines meshes to adapt over time as the solution evolves through the dynamical processes
- p4est is a parallel octree-based AMR library developed for aggressive adaptivity and extreme-scale applications
- We developed a new data management (DM) in PETSc that interfaces p4est with applications that require adaptivity
- Leverage PETSc's scalability and built-in functionality:
  - composable linear solvers and preconditioners, nonlinear solvers, approximations of Jacobians for Newton's method, coloring for finite difference gradients
  - advanced time integration in PETSc: implicit time stepping, adaptive time steps, multirate time stepping
  - parallel mesh and associated data managed by PETSc DM; discretization and physics are handled in application code
- Runaway electron (Fokker-Planck PDE) simulations are implemented by using the new DM, leveraging direct access to fast algorithms in p4est

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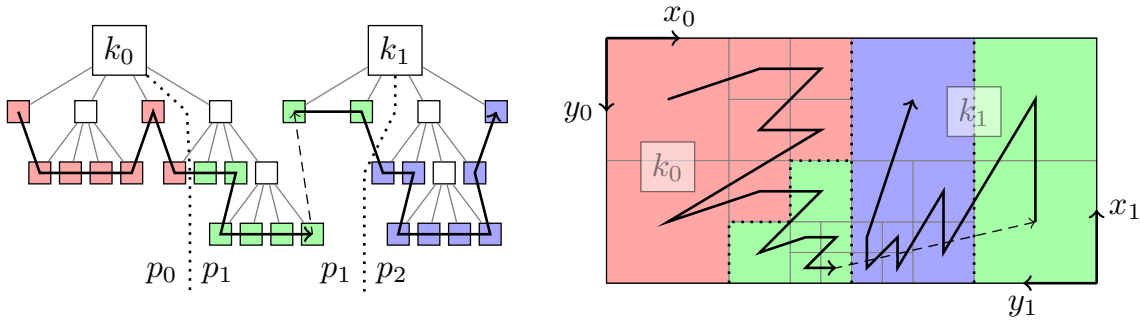
Parallel octree-based AMR. Left: Forest-of-trees topology with 2 trees and leaves are cells of the mesh. Right: Space filling curve to sequentialize cells of mesh. (Image credit: p4est)



Dynamic AMR in parallel. Each color represents one of 1024 MPI ranks. The aggressive adaptivity required by the application results in 12 levels of difference in refinement, which corresponds to 3 orders of magnitude difference in cell size.