Advanced Computing for 21st Century Accelerator Science and Technology:
Advanced Methods and Capabilities in Terascale Beam Dynamics Simulation

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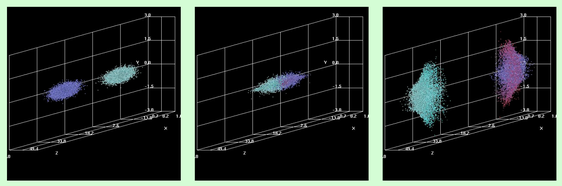
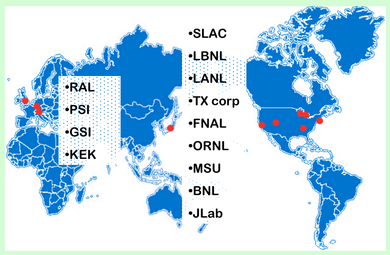
Developing a Comprehensive Terascale Capability for Modeling Beam Dynamics in Next-Generation Accelerators

Community Codes and Frameworks

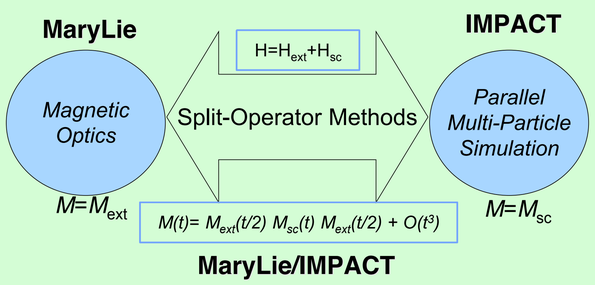
- **Physics Capabilities:** Nonlinear optical effects, space-charge effects, beam-beam effects,wake-field effects, Coulomb collisional effects,CSR
- **Parallel Codes and Frameworks:**
  - BeamBeam3D: Simulation of beams in colliders
  - IMPACT: Space-charge effects in linacs
  - MaryLie/IMPACT: Space-charge effects in linacs and rings
  - Synergia: Extensible integration framework for accelerator modeling

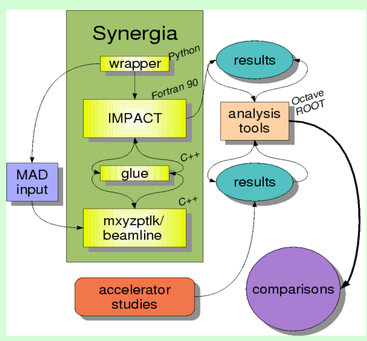


Simulation of colliding beams: BeamBeam3D



Project Codes are gaining acceptance throughout the community. Example: IMPACT site list.



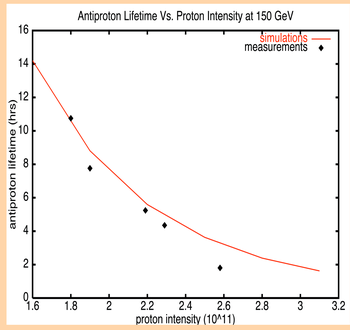


Synergia Framework Block Diagram

Modeling Beam-Beam Effects

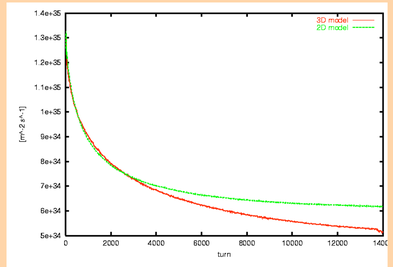
Tevatron Modeling using BeamBeam3D

- Large computing requirement: each point requires 12 hrs x 1024 procs
- Preliminary results show good agreement for pbar lifetime vs proton intensity



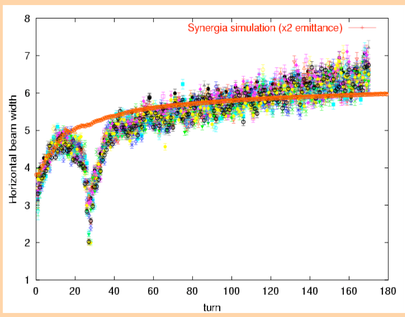
PEP-II Modeling

- Collaborative study/comparison of beam-beam codes (LBNL/SLAC/KEK)
- Predicted luminosity sensitive to # of slices in simulation



Modeling Space-Charge Effects

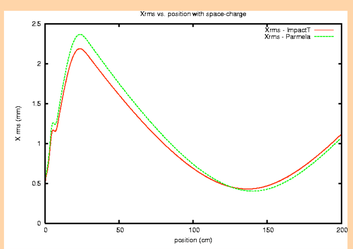
Fermilab Booster Modeling using Synergia



J. Amundson, P. Spentzouris, FNAL

RF Photoinjector Simulation using IMPACT-T

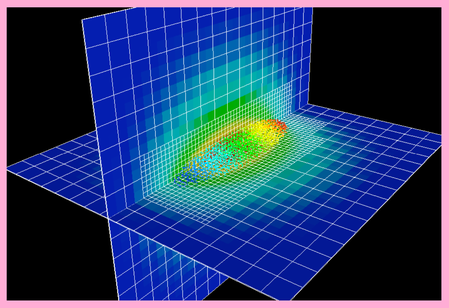
- **Parallel simulation w/ IMPACT-T using 1M particles is more than 2x faster than PARMELA using 100K particles**
  - **Good agreement for test case (azimuthal symmetry)**



Ji Qiang, LBNL

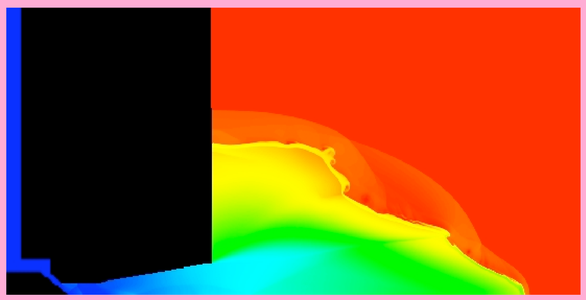
Collaboration with APDEC

AMR/PIC and Poisson Solvers



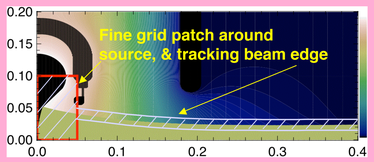
Courtesy of D. Serafini, P. Colella et al., LBNL

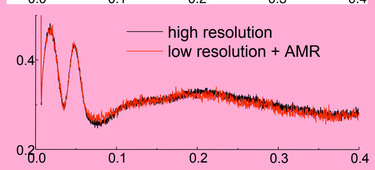
Embedded Boundary Methods for Gas Jet Modeling



axisymmetric jet expanding into vacuum. (The axis of symmetry is at the bottom). This uses AMR and APDEC's embedded boundary methods for gas dynamics.

Benefits from Collaboration with HIF Program

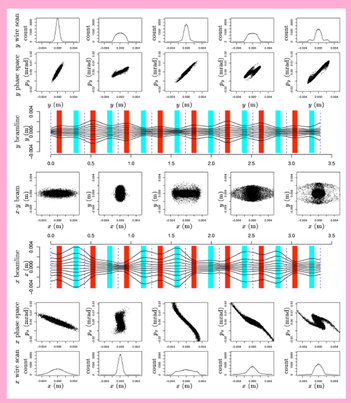




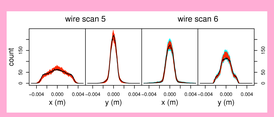
In this example, 4x savings in computational cost through use of Chombo/AMR

Courtesy of A. Friedman, P. Colella et al., LBNL

Statistical Methods for Calibration and Forecasting



Determining initial phase space distribution from 1D wire scan data (D. Higdon et al)



Simulation of a high intensity proton beam through a series of quadrupole magnets. Statistical techniques were used to combine 1D profile monitor data with simulations to infer the 4D beam distribution. The figure shows the 90% intervals for the predicted profile at scanner #6 (shaded regions), and, for comparison, the observed data (black line). Only data from the odd numbered scanners were used to make the prediction.