Advanced Computing for 21st Century Accelerator Science and Technology

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Our vision: to develop a comprehensive terascale Accelerator Simulation Environment that will revolutionize how advanced computing is used to design next-generation accelerators, to maximize the performance of existing accelerators, and to advance the frontiers of accelerator technology

Motivation

Accelerators are Important to the Office of Science

Accelerators are Crucial to Scientific Discoveries in High Energy Physics, Nuclear Physics, Materials Science, and Biological Science

"Violated particles reveal quirks of antimatter"

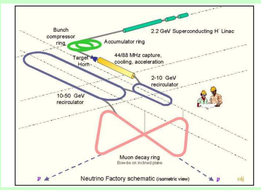
"Rewriting the Standard Model?"

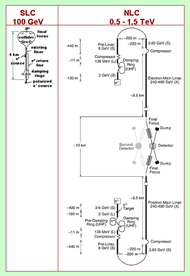
"Biologists and other researchers are lining up at synchrotrons to probe materials and molecules with hard x-rays"

"Fermilab collider shakes Standard Model"

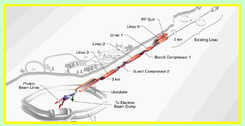
Opportunities at Next-Generation Accelerator Facilities

Exploring physics beyond the Standard Model. Are there new particles? New interactions?





Research using intense, ultra-short pulses of x-ray radiation (4th generation light source): fundamental quantum mechanics; atomic, molecular, and optical physics; chemistry; materials science; biology



Accelerator Simulation Environment

This project is developing a comprehensive terascale simulation capability, the Accelerator Simulation Environment (ASE), whose components will enable accelerator physicists and engineers to address a broad range of important issues in next-generation accelerators and their design, as well as optimizing the performance of existing accelerators.

The new set of parallel, portable, reusable, object-based software components will have an impact in three areas:

- Designing next-generation accelerators, e.g NLC, a neutrino factory
- Optimizing existing accelerators, e.g the Tevatron, FNAL Booster
- Developing new accelerator technologies such as laser- and plasma-based accelerators

ASE - Target Applications

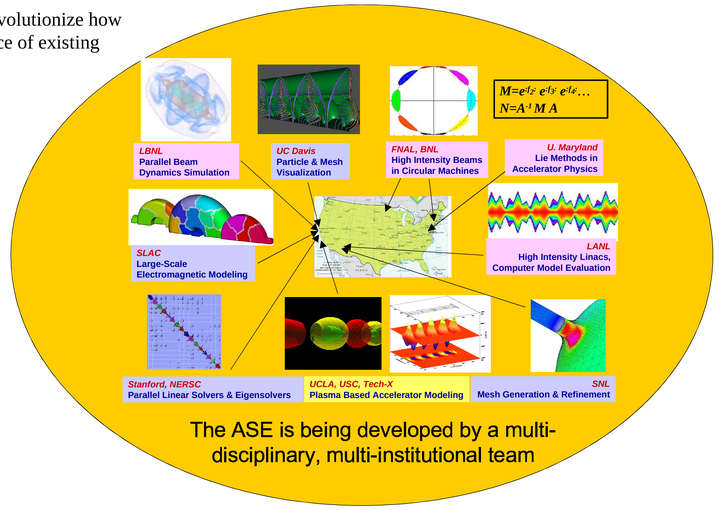
Development of the ASE will be guided by target applications that are computationally challenging, have maximum impact on HENP projects, and will serve as test-beds for the ASE.

- **Large-scale Beam Dynamics Simulations for improving the performance of**
  - > colliders (e.g. the Tevatron, RHIC)
  - > high intensity drivers (e.g. the FNAL Booster and BNL AGS)
- **Full-scale Modeling of Large Accelerating Structures**
  - > PEP-II interaction region to study beam heating
  - > entire NLC accelerator structure to calculate wakefields
- **Large-scale PIC Simulations of**
  - > plasma wakefield accelerators
  - > laser wakefield accelerators, including particle injection, capture, and acceleration

ASE – Deliverables

The ASE is concentrating on three areas:

- **Beam Dynamics (BD) –** development of modules for treating multiple beam phenomena (such as space charge effects, high-order optical effects, beam-beam collisions, wakefields, intrabeam scattering, and ionization cooling), and their incorporation into a parallel, extensible beam dynamics package.
- **Electromagnetics (EM) –** development of three 3D parallel field solvers that use unstructured grids to conform to complex geometries:
  - > Omega3P – Eigenmode code
  - > Tau3P – Time-Domain code
  - > Phi3P – Statics code
- **Advanced Accelerators (AA) –** development of the OSIRIS, VORPAL/XOOPIC and quickPIC codes for modeling laser- and plasma-based accelerators.



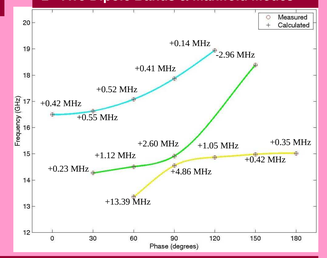
The ASE is being developed by a multi-disciplinary, multi-institutional team

Collaboration Highlights

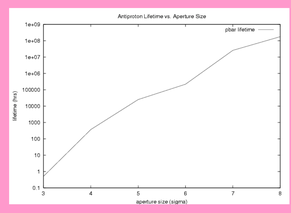
Modeling a 6-cell Stack of the NLC Structure with Omega3P – Validation Against Data (SLAC)

Quadrant of the RDDS 6-cell Stack for NLC

1st Two Dipole Bands & Manifold Modes



Simulation Performed on NERSC's IBM SP2: Elements = 275K, DOF = 1.7Million, Number of processors = 48, CPU Time = 1 hr

Modeling beam-beam effects in the Tevatron (LBNL)

New code modules can model beam-beam effects to high accuracy over long distances. Both weak-strong and strong-strong options are available.