Title
High Performance Computing in Accelerator Science: Past Successes. Future Challenges

Permalink
https://escholarship.org/uc/item/9kt153pw

Author
Ryne, R.

Publication Date
2011-10-24
High Performance Computing in Accelerator Science: Past Successes, Future Challenges

Lawrence Berkeley National Laboratory;

B. Carlsten, D. Higdon, N. Yampolsky,
Los Alamos National Laboratory

DISCLAIMER: This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Acknowledgements: This work was supported by the Director, Office of Science, High Energy Physics as well as Advanced Scientific Computing Research, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.
High Performance Computing in Accelerator Science:

Past Successes, Future Challenges


Importance of Accelerators and Accelerator Modeling

Particle accelerators are among the most versatile instruments of scientific discovery.

- Materials science
- Chemistry
- Biology
- High energy physics
- Nuclear physics

Particle accelerators have important applications in energy, environment, and national security:

- Interrogation systems to detect nuclear material, explosives in cargo
- Accelerator-driven energy production
- Enabling materials and organisms relevant to explosives in cargo
- Detecting nuclear material, high energy physics

Particle accelerators have a huge impact on the quality of people’s lives:

- Medical irradiation therapies
- Pharmaceutical drug design
- Medical radio-isotope production

Advanced computing is essential to advancing the frontiers of accelerator science and technology:

- Cost & risk reduction for upgrade and new projects
- Design optimization
- Testing new ideas, exploring & gaining insight where measurements are expensive or impossible

- Developing advanced accelerator concepts
- Laser-Plasma Accelerators (LPA’s) will revolutionize accelerator technology
- Compact LPA based accelerators: huge impact to US science, industry, medicine
- Strong supported computing for accelerator modeling

Future Challenges & Opportunities

- Accelerators
- Future light sources: advanced interrogation, beam manipulation, novel seeding schemes, energy recovery linacs, laser control, beam loss, halo
- LPAs: advanced beam quality control; 100 GeV-regime record on LPA collider
- Novel accelerators: ion colliders, PRH, muon accelerators

Modeling
- Particle-in-cell, hybrid systems - programmability, performance
- Scalability to -10^10 cores - algorithmic, resource scale I/O, data analysis, visualization
- Statistical methods for ray tracing
- RPR in control cites for near real-time feedback in experiments

Modeling Laser-Plasma Accelerators (LPA’s)

Laser-based free-electron laser (FEL) at SLAC
- Electron beam at SLAC: 10^11 electrons/shot, 10^14 cm^{-2}, 100 TW peak power
- 80 fs pulse, 10^12 cm^{-2}, 10^12 cm^{-2}
- Phase control of 20 fs pulse, 20 fs pulse, 20 fs pulse

Comparison of Large-Scale Simulations with Experiment

Argonne Wakefield Accelerator: Measurement vs. IMPACT Simulation

VLEPP-collider: Measurement vs. BeamBeam3D Simulation

Model Calibration & Forecasting

Parallel visualizations of coherent synchrotron radiation (CSR) using VisIt on Hopper

MJI + OpenMP analysis of computational kernels

High Performance I/O

Using SEPlas as data model for ease of use and high performance parallel writes on hopper
- IMPACT-2 22-Gflop file at 10,000 frames/sec at NERSC
- SEPlas write performance

Collaboration with ASCI funded ExaTF project Prabhat (LLNL), Koziol (HDF5) and Scheurer (PNNL)

Large Data Visualization

- Exploring massive data sets
- Billions of particles in 4D phase space, EM fields, 1000’s of time steps
- Study mechanisms of halo formation and emittance dilution
- Study complex processes in LPA’s

Collaboration with SciDAC

VACET (N. Bethel, P)

Data Analysis

- Using Enstelf to accelerate queries of interesting particles
- Halo particles, outer shell particles
- Using Parallel Enstelf infrastructure to measure queries on 10^13 dataset
- Resolved queries in 4-10 seconds
- Queries run on 7500 hopper cores