

BGW Consortium Day on July 19

1. Project Title: Concept Development for Model-Driven Accelerators with Applications to Advanced Exotic Beam Laboratory (AEBL) and Other Hadron Linacs
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3. Introduction:

Presently no accelerator in the world may fully rely on a computer model for its operations. Inadequacy in modeling often results in delays in achieving design goals and a considerable amount of machine operating budget spent on beam tuning.

4. TRACK code

The beam dynamics code TRACK was developed at Argonne National Laboratory. It can be used in the research and development areas include, large scale fitting and optimizations, algorithms and parallelization, advanced scientific analysis and visualization, as well as, user friendly interfaces and documentation to make the code accessible to a large community of accelerator designers, researchers and operators. A part of this effort will be dedicated to making the code portable to a variety of platforms and scalable to petaflops and many thousands of processors.

We have successfully parallelized the TRACK code, and tested it thoroughly on several supercomputer platforms, such as BlueGene (BGL) at ANL, and IBM P4 at ARSC. Currently, we are able to simulate 10^8 particles using 1024 processors on BGL at ANL. Such high-statistics calculations are required for accurate simulation of space charge effects for intense beams and to study processes of beam halo formation and their mitigation. The most time consuming part of such simulations is solving the Poisson equation at the end of each integration step to determine the space charge fields. Therefore, the Poisson solver has been parallelized. Our current parallelization strategy is to distribute the particles across the processors. Each processor tracks its allocated particles and then computes the

contribution of these particles to the overall charge density. These contributions are combined to produce the charge density on a space charge grid, and the Poisson equation is solved in parallel.

5. Objectives:

We want to test the scalability of parallel TRACK code first, and identify the bottleneck in the code. Then we want to test the possibility of simulating 5×10^9 particles. This will enlarge the envelope to do beam dynamical simulations, and provide much more accurate information of beam inside an accelerator. This will also help optimize accelerator design, operation, etc. It will provide a new platform for simulation.

6. Results:

The parallel TRACK code is basically composed of two parts, particle tracking and Poisson solver. The Poisson equation is solved for space charge effects due to large number of charged particles in small beam bunch. We have investigated the parallel efficiency for these two parts, and the results are given in following.

(1). Particle Tracking

We can simulate 500 million particles on one rack system at BGL/ANL. It takes about 18 hours to simulate 100 million particles through 269 RFQ cells. Since the particles are distributed among all processors, and there is no communications between different processors, therefore the parallel efficiency of particle tracking is 100%. Using 10 racks BGW system, 5×10^9 could be simulated in theory. The larger number of particles is also possible, but we need to know more on the parallel efficiency of parallel Poisson solver.

(2). Poisson solver

In our simulation, Poisson equation is solved on relatively small mesh. They are usually 32^3 or 64^3 , and this has given us much difficulty to achieve high parallel efficiency. We have two implementations of the parallel Poisson solver, both doing domain decomposition. The first model has domain decomposition in two directions and the second model has domain decomposition in three directions. The second model has more flexibility to use large number of processors. From Table.1 to 4, due to small mesh, only one and two racks system can be used for parallel Poisson solver. Parallel performance is not so good due to the large ratio of communication time and computing time.

7. Summary:

We have tested parallel TRACK code on BGW systems, the particle tracking can be scaled to 20 racks easily, but parallel Poisson solver generates the bottleneck of the whole code. Two parallel Poisson solvers have been tested on BGW. 3d decomposition code shows more flexibility than 2d decomposition code. These benchmark results suggest that the parallel TRACK is not ready to run on

very large number of processors (~10,000), even it can be used to run on 1000 processors. We need to optimize code and explore different approaches to describe space charge effects.

NP	NPX	NPY	32^3	$32 \times 32 \times 64$	64^3	$64 \times 64 \times 128$
1	1	1	0.028	0.064	0.2574	0.5623
4	2	2	0.008	0.017	0.0701	0.1481
16	4	4	0.0026	0.0486	0.0175	0.0356
64	8	8	0.0028	0.0317	0.0062	0.011
256	16	16	0.0052	0.0516	0.0057	0.0063
1024	32	32				0.00552
NP	NPX	NPY	128^3	$128 \times 128 \times 256$	256^3	$256 \times 256 \times 512$
1	1	1	3.7	7.776		
4	2	2	0.61	1.98	8.32	16.1
16	4	4	0.14	0.305	2.03	4.1
64	8	8	0.033	0.074	0.31	0.6
256	16	16	0.0767	0.077	0.077	0.077
1024	32	32	0.0397	0.257	0.274	0.277

Table.1 Tests on parallel 2d decomposition Poisson Solver

NP	NPX	NPY	NPZ	32^3	$32 \times 32 \times 64$	64^3
1	1	1	1	0.01439	0.03	0.1486
2	1	1	2	0.01342	0.024	0.1063
8	2	2	2	0.0051	0.0087	0.0344
16	2	2	4	0.004	0.006	0.0228
64	4	4	4	0.0019		0.007329
128	4	4	8	0.002678		0.00687

Table.2 Tests on parallel 3d decomposition Poisson Solver (small mesh)

NP	NPX	NPY	NPZ	128^3	256^3
64	4	4	4	0.05312	0.4989
128	4	4	8	0.0303	0.2541
512	8	8	8	0.0221	0.0704
1024	8	8	16	0.0273	0.0397
4096	16	16	16	0.0249	0.01759

Table.3 Tests on parallel 3d decomposition Poisson Solver (middle mesh)

NP	NPX	NPY	NPX	256^3	128^3	256^3
4096	16	16	16	0.06228	0.08012	0.6595
8192	16	16	32	0.04342	0.0675	0.5195

Table.4 Tests on parallel 3d decomposition Poisson Solver (large mesh)