1.0 Enhancing Simulation Capability for Electron Cooling in MEIC Project

Principal Investigator: He Zhang

Project Status

We proposed to develop a computational platform for modeling and simulation of electron cooling, which addresses (*i*) the bunched electron cooling of coasting ion beam, focusing on the evolution of the macroscopic beam parameters such as emittances and momentum spread, and (*ii*) single pass electron cooling process, focusing on the interaction between individual particles from microscopic view. The new platform will be adaptive to modern high performance hardware.

For (*ii*) single pass electron cooling simulation, one needs to correctly treat the following three problems: modeling the electron beam and the ion beam, tracking the particles, and calculating the binary collisions in near region. So far, we have put most of our effort on developing the mathematical tool for particle tracking, for which it is essential to calculate the field between the huge amount of charged particles accurately and efficiently. We have developed a new algorithm, using traceless totally symmetric Cartesian tensors to represent the Coulomb potential within the traditional multiple level fast multipole algorithm framework, which allows us to calculate the Coulomb field between millions of charged particles in a short time. A serial version code of the new algorithm has been finished. The results of a test run for 3D field calculation between 1,048,576 electrons on a laptop with Intel i7-3630QM processor are presented in table 1. We will parallelize the new algorithm on the CPU-GPU hybrid platform to further increase the efficiency.

Table 1. Calculate the 3D Coulomb field for 1048576 electrons using FMM

Distribution	Uniform				Gaussian			
Tensor Order	2	3	5	8	2	3	5	10
Time (s)	11.77	13.12	20.52	56.36	15.48	20.81	43.70	156.13
Relative Error	1.1E-2	4.5E-3	4.2E-4	9.6E-5	2.6E-2	7.1E-3	7.2E-4	7.4E-5

We have also made progress in developing (*i*) the bunched electron cooling of coasting ion beam module. A new code to calculate the intrabeam scattering (IBS) effect using Martini formula has been developed and benchmarked with BETACOOL for the both cases: coasting proton beam and Gaussian bunched proton beam. As shown in figure 1, the two codes agree very well. By avoiding unnecessary repeated calculations of some functions in the IBS rate integral, the new code achieves much better efficiency even without any parallelization. For

example, to simulate the IBS expansion during one hour for the proton beam in the MEIC collider ring, it takes 2 hours and 22 minutes using BETACOOL, while only 11 minutes , which is about ten times faster, using the new code on the same computer.
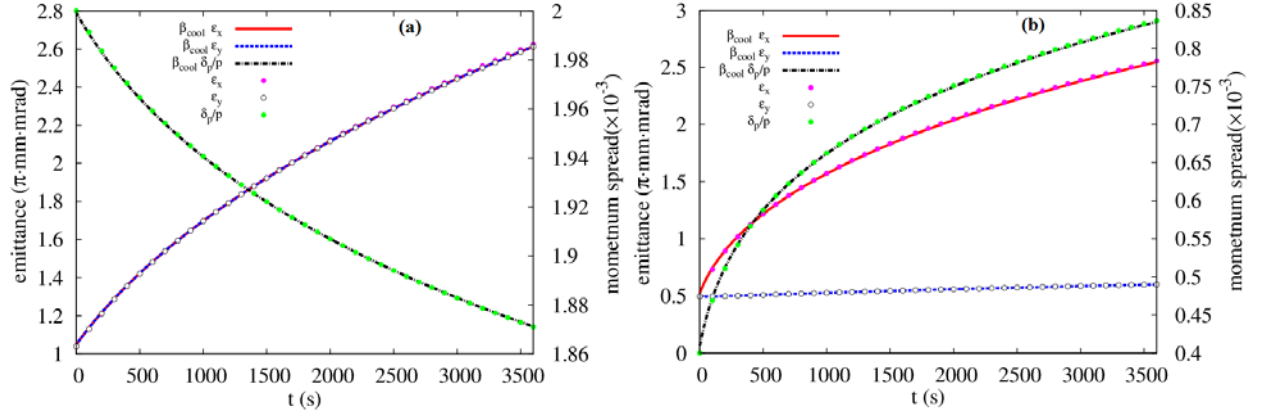

Figure 1, IBS calculation using Martini formula benchmarked with BETACOOL: (a) 0.8 GeV coasting proton beam in MEIC booster ring, (b) 30 GeV Gaussian bunched proton beam in MEIC collider ring.

Project Plan

This project is planned for two years. In the second half of the first year, we will work on the following two aspects:

1. Continue developing the bunched electron cooling of coasting ion beam module, including the friction force calculation by Parkhomchuk formula, model of DC and bunched electron beam, model of coasting and bunched ion beam, RMS method and model beam method for macroscopic cooling simulation.

2. Parallelize the tensor based fast multipole code. Finish a preliminary parallel code for multi-particle tracking, which scales well in at least tens of CPUs and GPUs. We want to make the mathematical tools ready by the end of the first fiscal year. Then in the second year, we will focus on correctly modeling the single pass cooling process and verifying the simulation results with theory and other simulation codes.

Budget

Publications

Workshops/Conferences

H. Huang, *Fast Multipole Method for Coulomb Interaction Based on Traceless Totally Symmetric Tensor*, American Physical Society April Meeting, Baltimore, Maryland, April 11-14, 2015.