1.0 Enhancing Simulation Capability for Electron Cooling in MEIC Project

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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.

The program to simulate the evolution of the macroscopic beam parameters under the intrabeam scattering (IBS) effect and/or electron cooling has been finished. Martini formula is implemented for the IBS rate calculation, and Parkhomchuk formula is implemented for the friction force calculation. The code is in object-oriented style, so that other formulas can be implemented easily in future. Dynamic simulation of the evolution process is divided into four steps: (1) Initialize the simulation environment; (2) Sample the ion beam; (3) Calculate the IBS rate and/or electron cooling rate; (4) Update the coordinates of the sample ions and the beam parameters. Both the RMS dynamic model and the model beam model in BETACOOL fit into this four-step procedure, which also provides flexibility for new models. The new program has been thoroughly benchmarked with BETACOOL in the following cases: IBS and/or cooling rate calculation, dynamic simulation with IBS and/or cooling effect(s) using different models. Both codes agree well with each other in all the cases. Examples are shown in figure 1 and figure 2. For a typical electron cooling process of MEIC, more than ten times improvement of efficiency than BETACOOL has been observed using the new program.

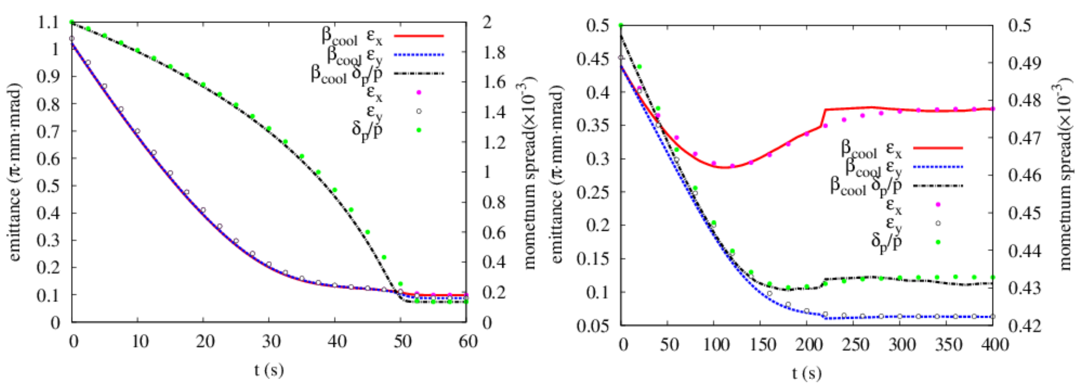
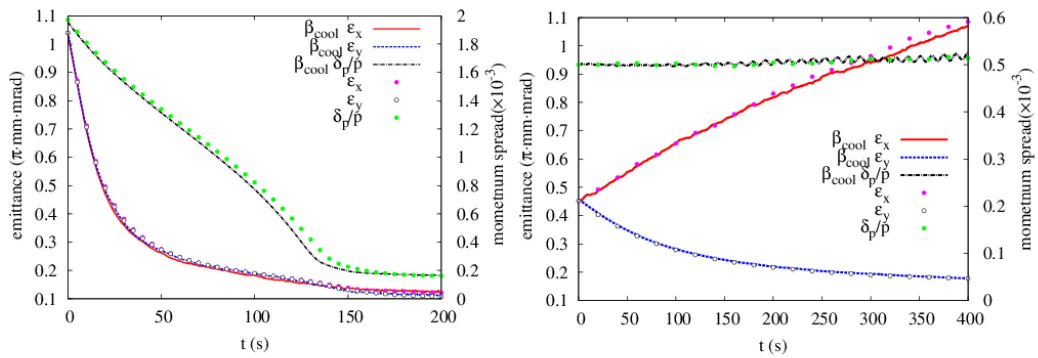


Figure 1: Emittance and momentum spread evolution under IBS and cooling for (left) coasting proton beam with DC cooling and (right) bunched proton beam with bunched cooling, benchmarked with the RMS dynamic model in BETACOOL.



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The program is adaptive to the shared memory systems such as a GPGPU (General Purpose Graphic Processing Unit) or a multiple-core CPU. The parallelization is based on thrust, a parallel algorithm library, which supports CUDA, TBB (Threading Building Blocks) and OpenMP. Without changing the source code, the program can be compiled for the aforesaid three platforms with proper respective compiler options. We have tested the program on a desktop PC with AMD Phenom ™ II X4 840t processor running at 2.9 GHz and NVidia GTX 660 ti GPU. For IBS rate computation with 100x100x100 grid, it takes 62 seconds using only the CPU and 7.8 seconds using both the CPU and the GPU, which is eight times faster. For electron cooling rate computation with 200,000 sample ions, it takes 0.15 seconds using only the CPU and 0.03 seconds using both the CPU and the GPU, which is five times faster.

For the single pass electron cooling simulation, we identify the following issues: fast Coulomb field solver, symplectic integrator, model of the near region collision, and repression of the diffusion. We have developed a fast Coulomb solver using the multiple level fast multipole algorithm. Currently we are testing the Hermite integrator for the symplectic integration.

Project Plan

In the following half year, we will finish the single pass electron cooling simulation. Firstly, we will develop a parallel symplectic particle tracking code. Then we will modify the code to properly treat the near region binary collision and the diffusion. Finally, we will benchmark the code with theoretical formulas for friction force calculation. We will also submit at least one paper for journal publication.

Budget

Publications

H. Zhang, *Electron Cooling Simulation Program Development for MEIC*, Proceedings of COOL Workshop 2015, Newport News, Virginia, September 28 - October 2, 2015.

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.

H. Zhang, *Traceless Totally Symmetric Tensor Based Fast Multipole Method for Space Charge Field Calculation*, FEIS-2: Femtosecond Electron Imaging and Spectroscopy, Lansing, Michigan, May 6-11, 2015.

H. Zhang, *Electron Cooling Simulation Program Development for MEIC*, COOL Workshop 2015, Newport News, Virginia, September 28 - October 2, 2015.

H. Zhang, *MEIC Staged Cooling Scheme and Simulation Studies,* MEIC Collaboration Meeting, Newport News, Virginia, October 05 – October 07, 2015

H. Zhang, *Progress in Electron Cooling Simulations and Code Development,* JLEIC Collaboration Meeting, Newport News, Virginia, March 29 – March 31, 2016