HB2016
57th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams

MOPL006
HB2016
Malmö, Sweden
3-8 July 2016

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

BEAM DYNAMICS STUDY OF C-ADS INJECTOR-I WITH DEVELOPING P-TOPO CODE*

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Abstract

A parallelized, time-dependent 3D particle simulation code is developed to study the high-intensity beam dynamics in linear accelerators. The self-consistent space charge effect is taken into account using Particle-In-Cell (PIC) method. In this paper, the structure of program and the parallel strategy are demonstrated. Then, the benchmark of this code and calculation performance are shown. It is proved that the parallelized solvers used in this program are reliable and efficient. Finally, the code is used to study beam dynamics in C-ADS Injector-I at IHEP. The possible reasons for the differences between results given by separated codes are also proposed.

1. INTRODUCTION

A new particle simulation code Parallelized-Trace of Particle Orbits (P-TOPO) is now under development to study space charge effect at high intensity linacs. The motivation is to improve the efficiency and calculation capability, based on the OpenMP techniques, of the TOPO code. The internal interactive space charge filed between particles is solved with the classic PIC method.

The Injector-I of Chinese Accelerator Driven Sub-Critical System (C-ADS) project is composed of ECRIS, LEBT, RFQ, MEBT1, SC section and MEBT2, which is under beam commissioning in IHEP. Recently, a 10.1 MeV, 10.03 mA pulse beam is successfully achieve.

2. P-TOPO

- Developed with C++ language
- Parallelized based on the OpenMP techniques

The parallelization occurs mainly at
- getting internal field (PIC)
- getting external field
- particle pusher

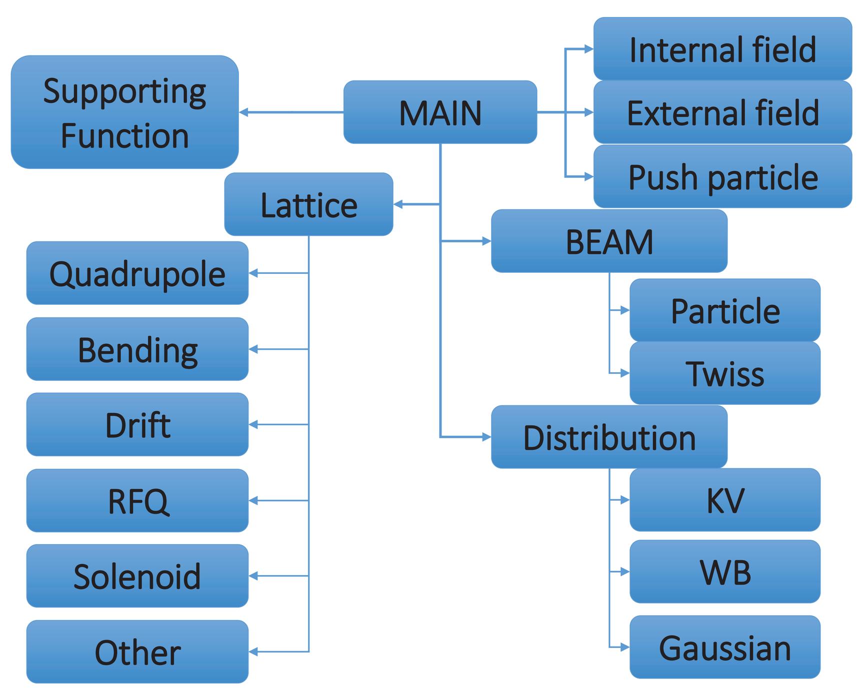

Figure 1: Layout of P-TOPO.

Taking the PIC module for example, it requires 4 steps to get the internal space charge field.
- In step 1 and step 4, the grid parallelization is taken and each thread handles different grids.
- In step 2 and step 3, the particle parallelization is taken the fftw library is used and the inner parallelization strategy of fftw is also taken combined with OpenMP.

Performance

A performance test with space charge is taken at a common PC with 4 cores. With the parallelization strategy, when the code runs in 4 threads, the speed is 3.6 times faster than that in single thread.

3. CODE VERIFICATION AND BENCHMARKING

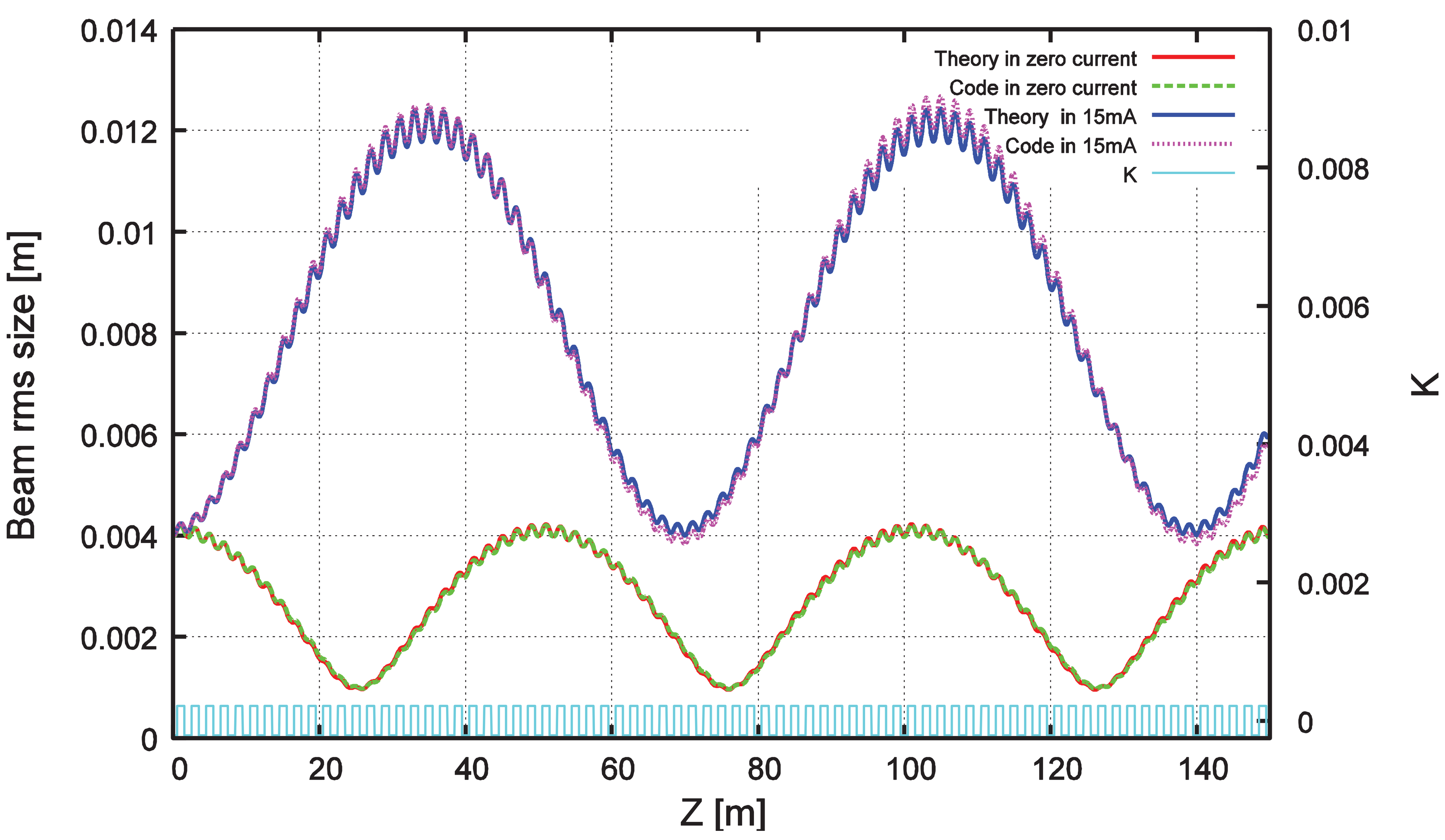

Figure 2: evolution of beam rms size given by P-TOPO and theory expectation in zero current and in 15mA in periodic focusing channel.

4. BEAM DYNAMICS STUDY OF INJECTOR-I.

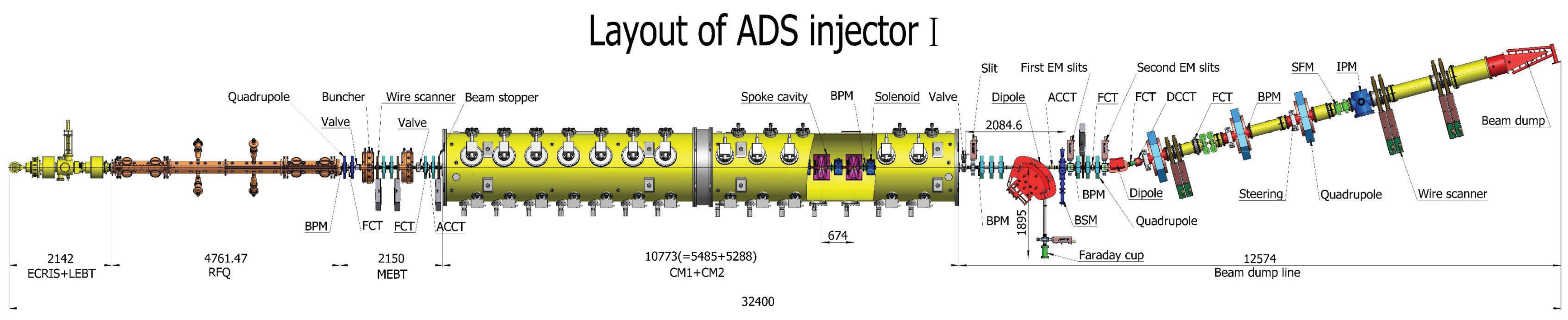

Figure 3: Layout of the ADS Injector-I testing facility

The P-TOPO simulation of RFQ and SC section separately with KV initial beam.

RFQ	
Designed Input Energy	35keV
Designed Output Energy	3.2 MeV
Emit. Nor. X or Y	0.2 pi*mm*mrad
SC section	
Designed Input Energy	3.2 MeV
Designed Output Energy	10 MeV
Emit. Nor. X or Y	0.2 pi*mm*mrad
Emit. Nor. Z	0.16 pi*mm*mrad

Both	
Frequency	325MHz
Current	15mA
Particles number	10K
Grid Number	64*64*32
Grid Size	3.5*sigma
Step per cycle	100

Table 1: Simulation parameters

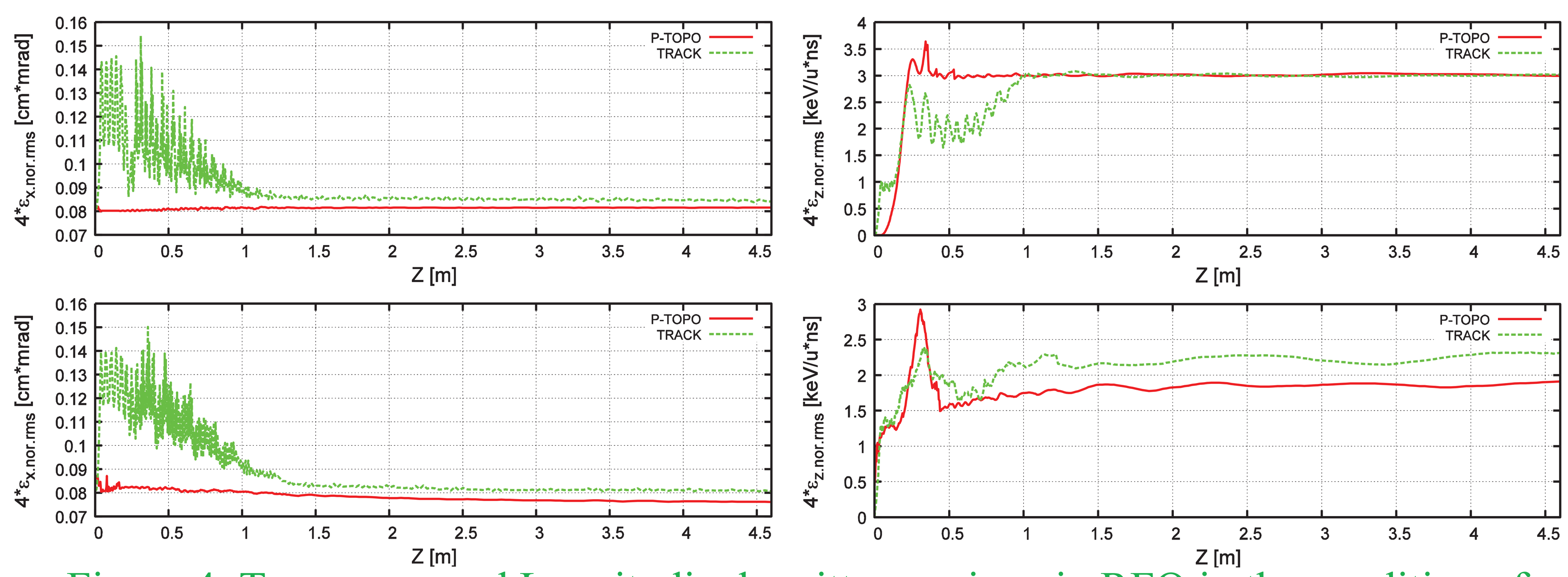

Figure 4: Transverse and Longitudinal emittance given in RFQ in the condition of 0mA (the left two figures) and 15mA(the right two figures)

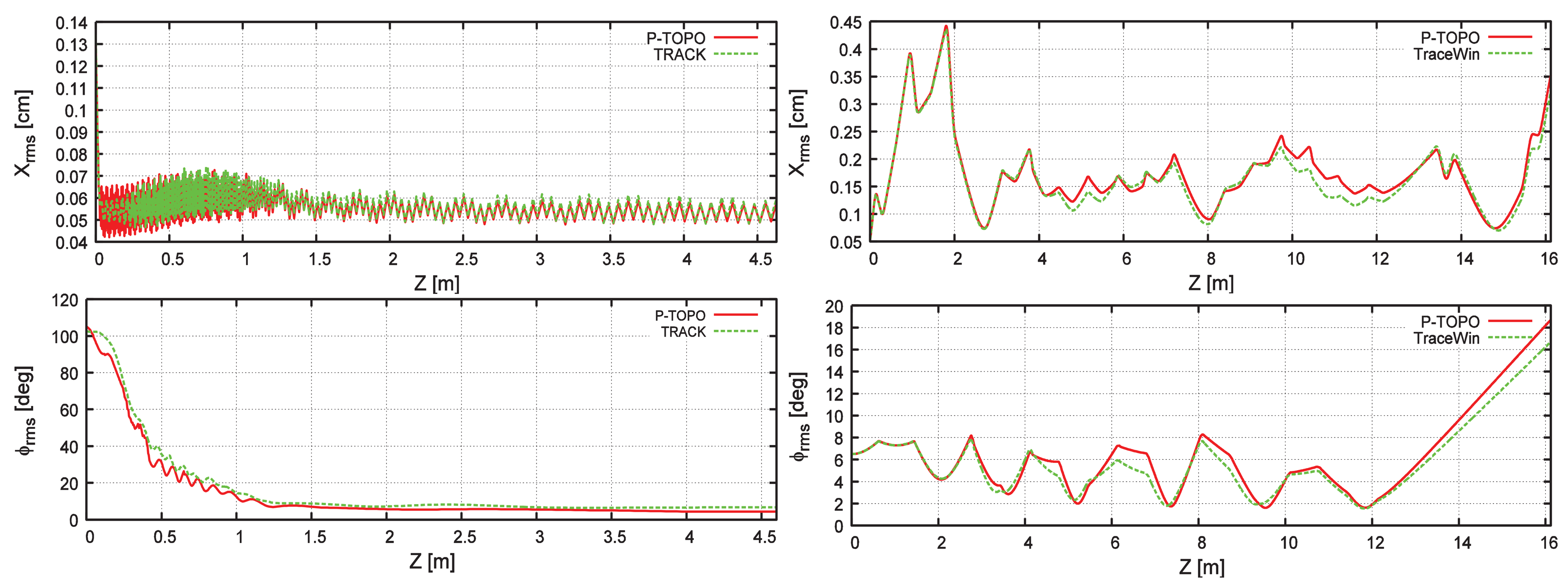

Figure 5: RMS beam size and phase envelop in the RFQ (the left two figures) and in the SC section (the right two figures) in condition of 15mA

Consist Well but discrepancy exists as:
- The P-TOPO code shows much smoother emittance variation.
- the amplitude of envelop got from P-TOPO is a little larger than that from TRACK at the beginning of RFQ cells an at the end of SC section.
- At the end of the RFQ, longitudinal phase given by TRACK is a little advanced than that given by P-TOPO.

Reasons for the difference between results:
- Initial beam distribution
- Differences of date processing and method
- The way to get the sync phase for field map
- Differences between T-code (P-TOPO) and Z-code (TRACK and TraceWin)
- The criteria for beam loss

5. Conclusion and Discussion

The P-TOPO code has been verified. The method used to get space charge force has been tested with point charge and is proved to be fast and accuracy. The result of FD structure simulation and its comparison with theory expectation illustrate that the code is reliable. Parallelized with OpenMP, the performance of the whole program is obviously better than single thread program. In the future, P-TOPO would be transplanted to the cluster in IHEP.

The P-TOPO code has been employed at the study of Injector-I of C-ADS. The RFQ and the other part is simulated separately. The P-TOPO simulation proves the current design is in control. No sufficient beam loss and emittance growth appear. In future study, efforts will be focused on comparison between simulation and experiments.

* Supported by the Ministry of Science and Technology of China under Grant no.2014CB845501.
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