Modeling of Laser-wakefield Acceleration in the Lorentz boosted frame with UCLA PIC framework

P. Yu*, V. K. Decyk, X. Xu, F. S. Tsung, W. Lu, W. B. Mori

J. Vieira, R. A. Fonseca, L. O. Silva

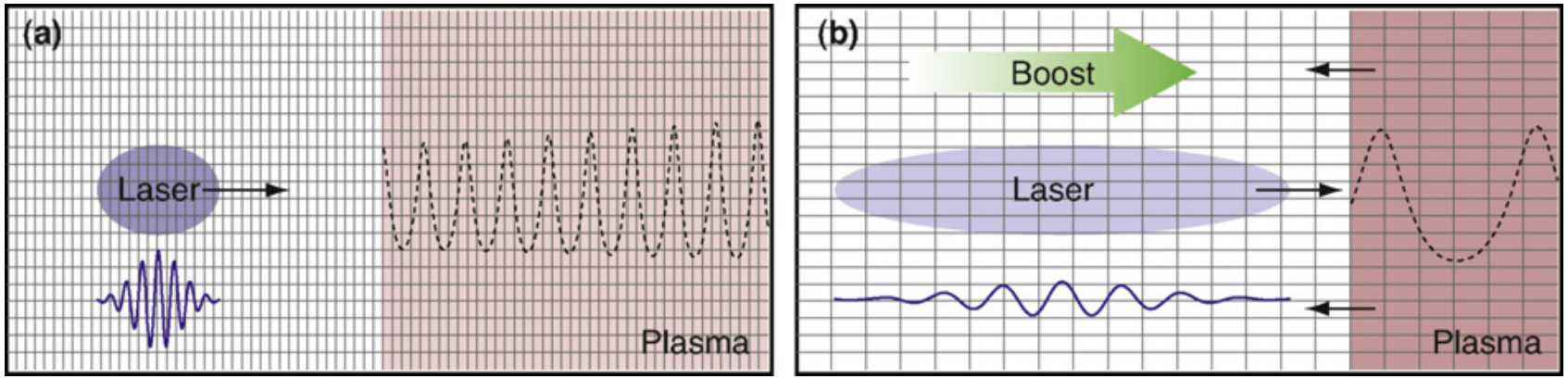
University of California Los Angeles, Los Angeles, CA 90095, USA

Tsinghua University, Beijing 100084, China

Instituto Superior Tecnico, 1049–001, Lisbon, Portugal

*tpc02@ucla.edu

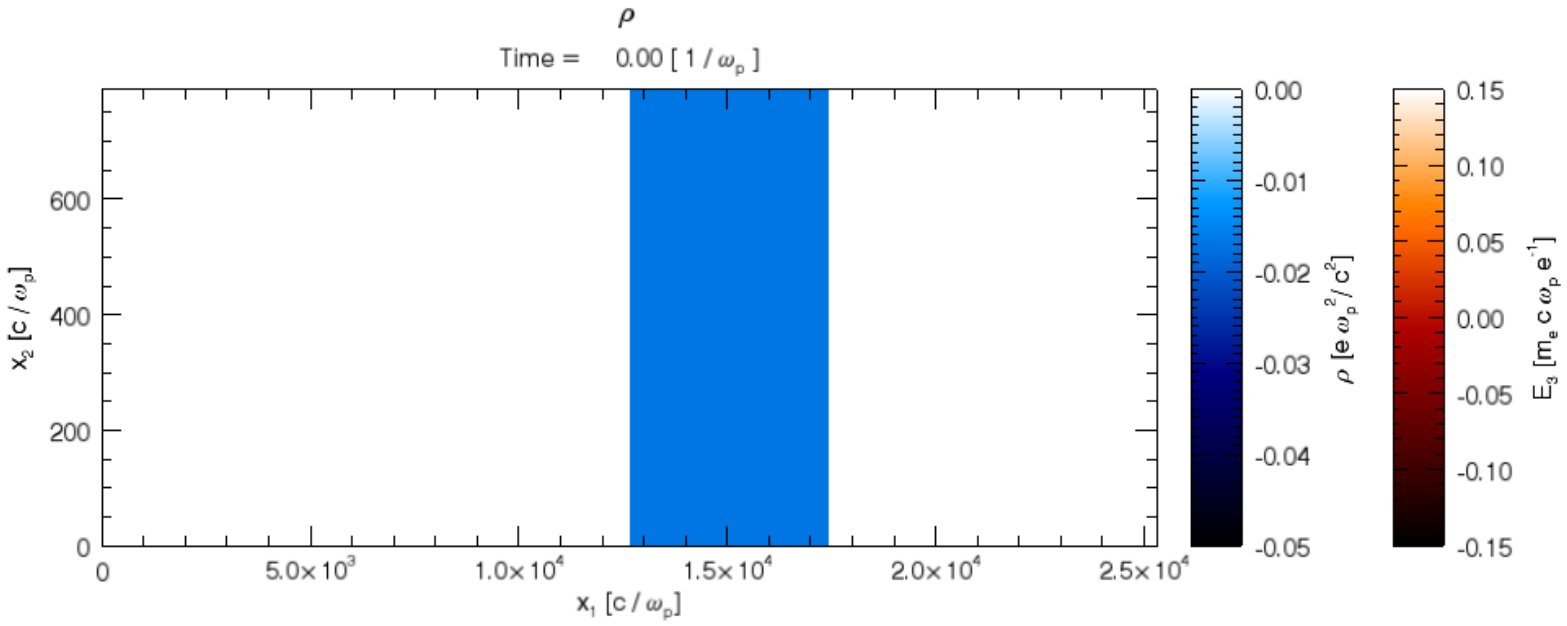
Simulation of LWFA in Lorentz boosted frame



- Illustration of numerical grid in (a) laboratory and (b) relativistic Lorentz frame (boosted frame) [1]. Courtesy S. F. Martins.

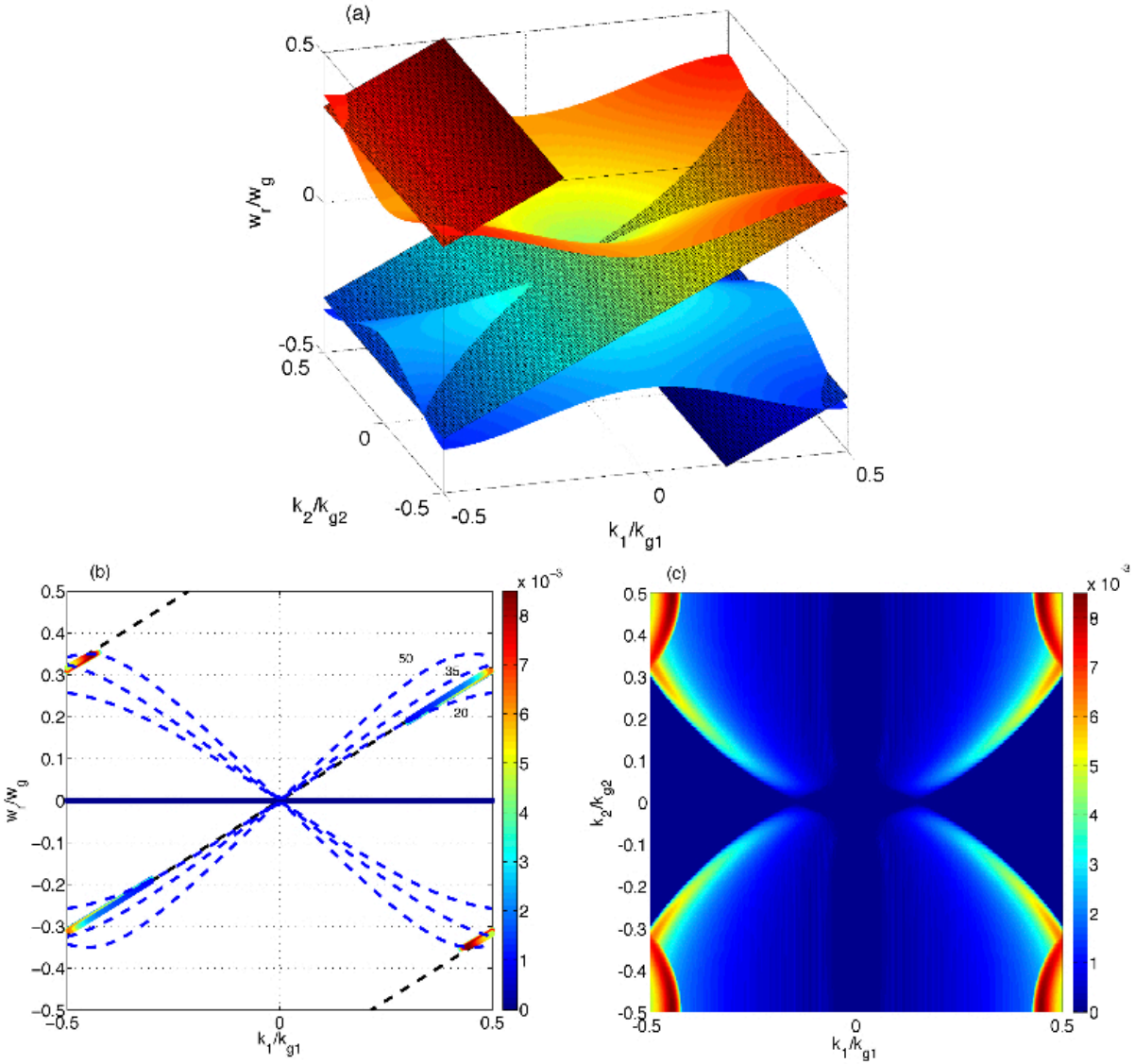
[1] J. -L. Vay, PRL 98, 130405 (2007); S. F. Martins, et. al., Nat. Phys. 6, 311 (2010)

Numerical instability in boosted frame simulation

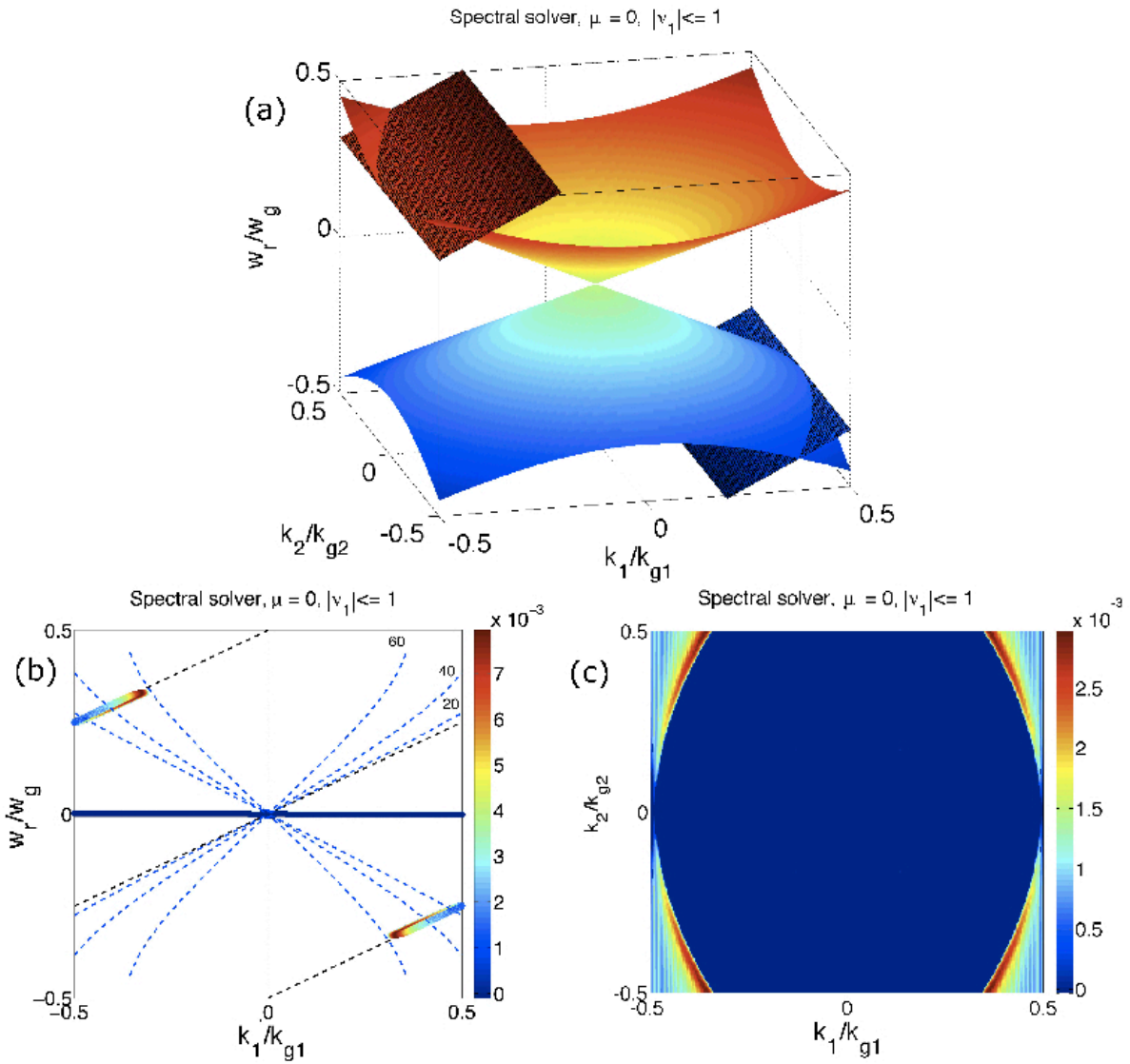


- We found that the instability is induced by the relativistic drifting plasma in the simulation.

Beam mode and EM mode: Yee solver



Beam mode and EM mode: Spectral solver

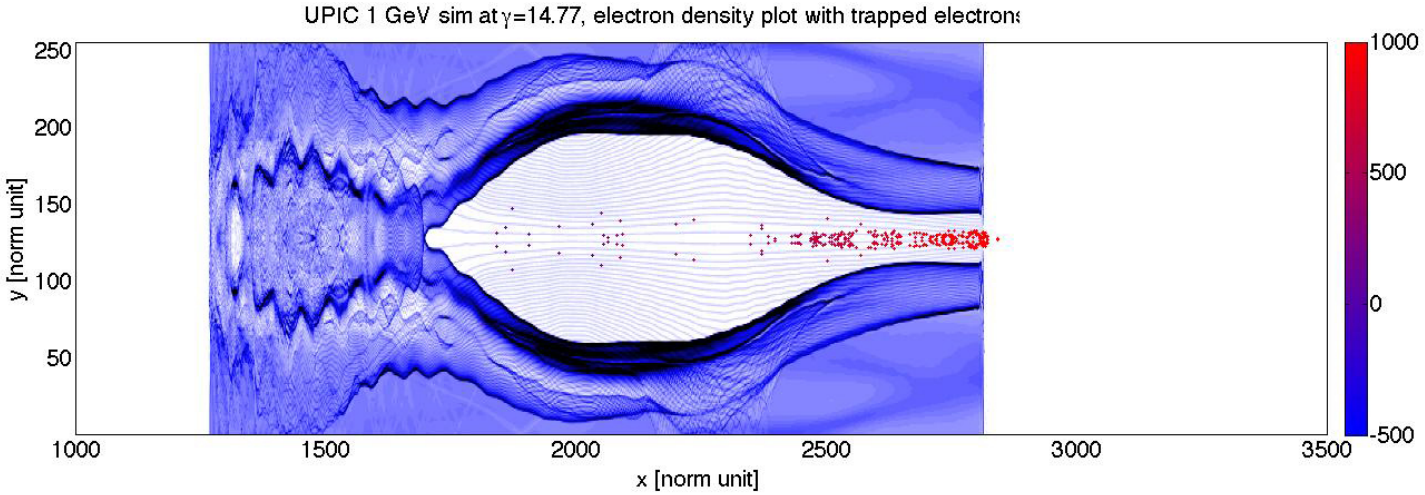


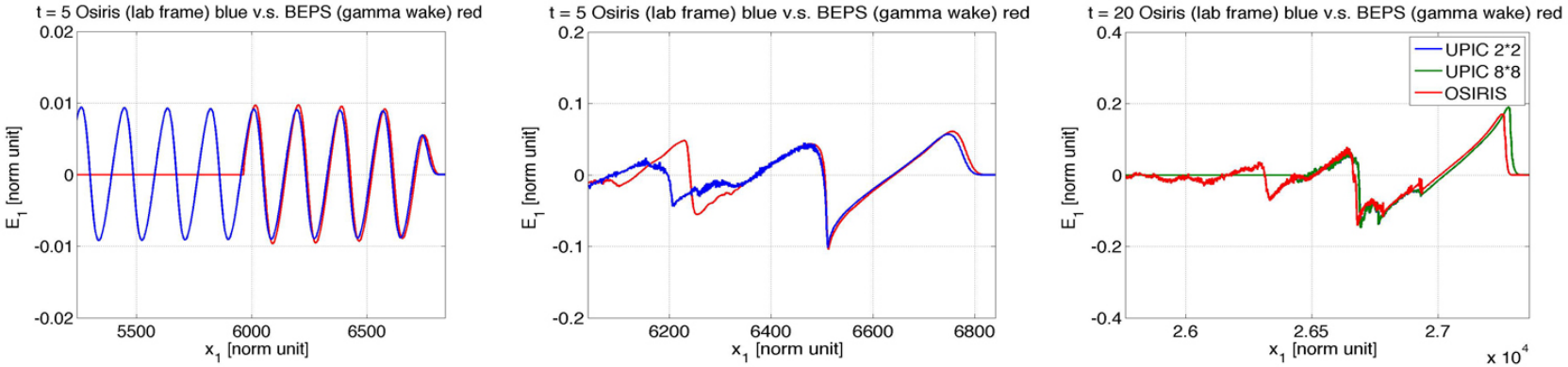
The plan

We need a parallel EM-PIC code with spectral solver!

Parallel UCLA PIC framework developed by Victor K. Decyk [V. K. Decyk, Comp. Phys. Comm. 177, 95 (2007)].

8 Weeks later ...

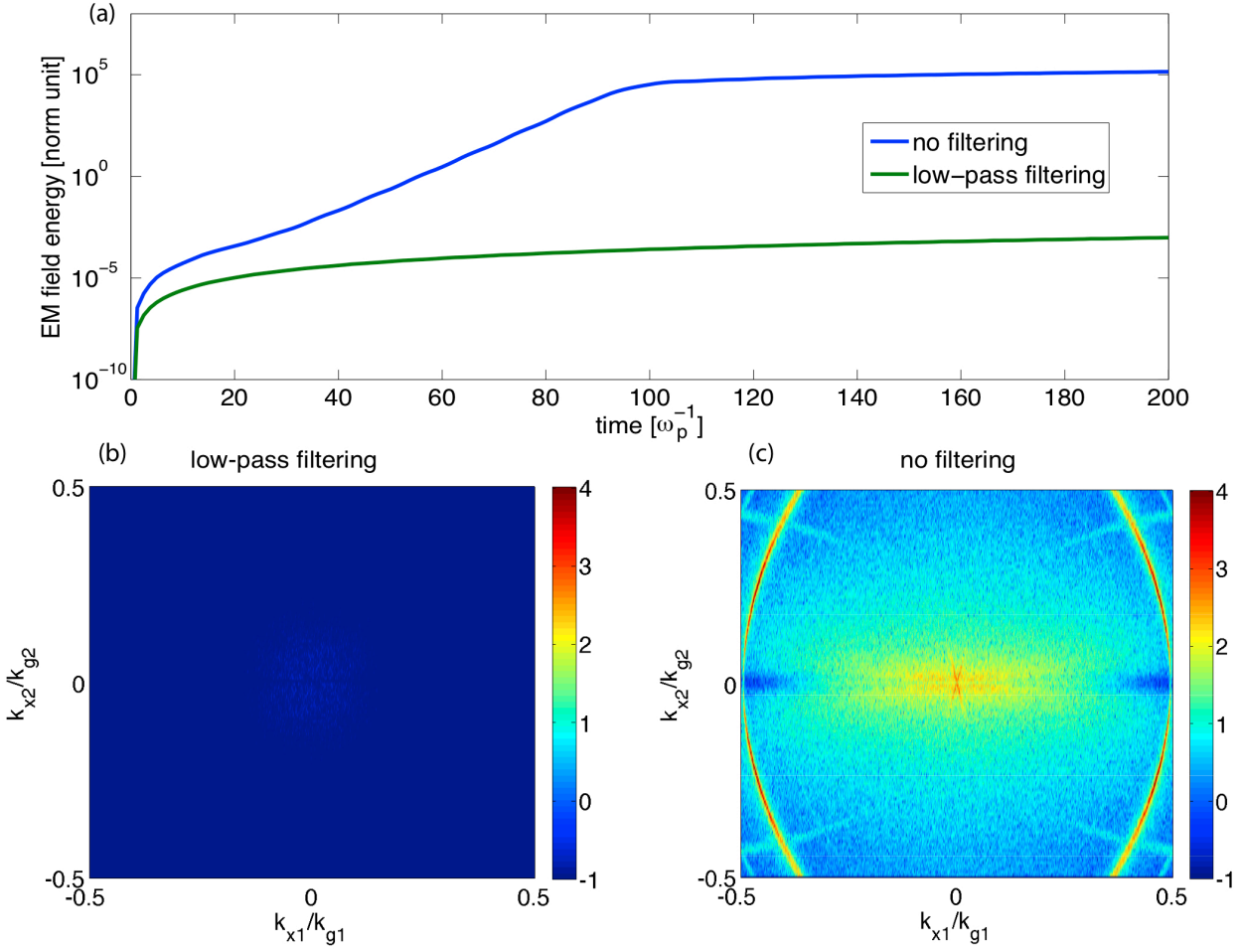




A code to study boosted frame LWFA

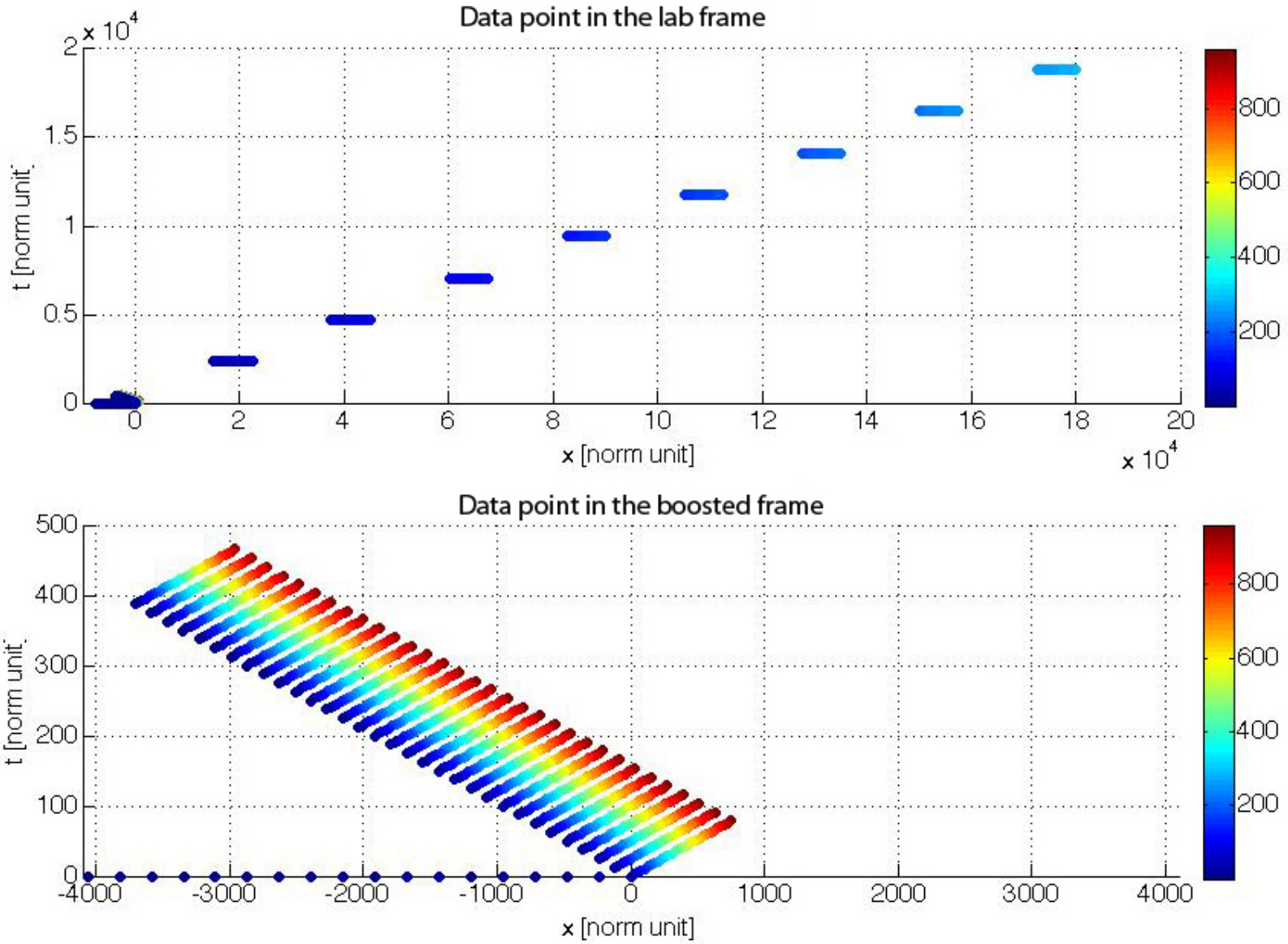
- 1D and 2D EM-PIC code using spectral solver;
- Runs parallel with Open MPI

Mitigation of numerical instability

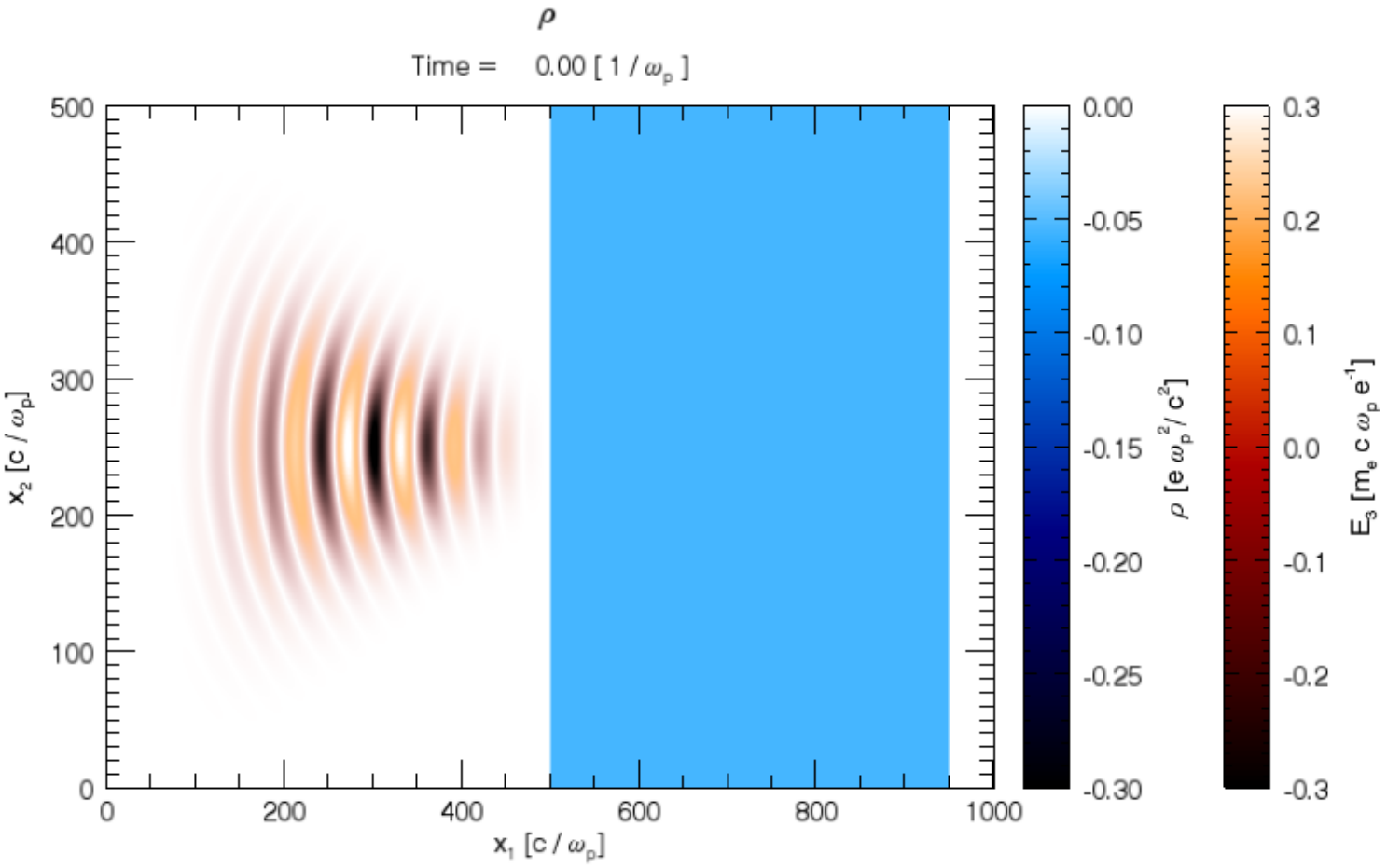


- We have tried ultra-high $\gamma \sim 20000$, and the low-pass filtering is still working well.

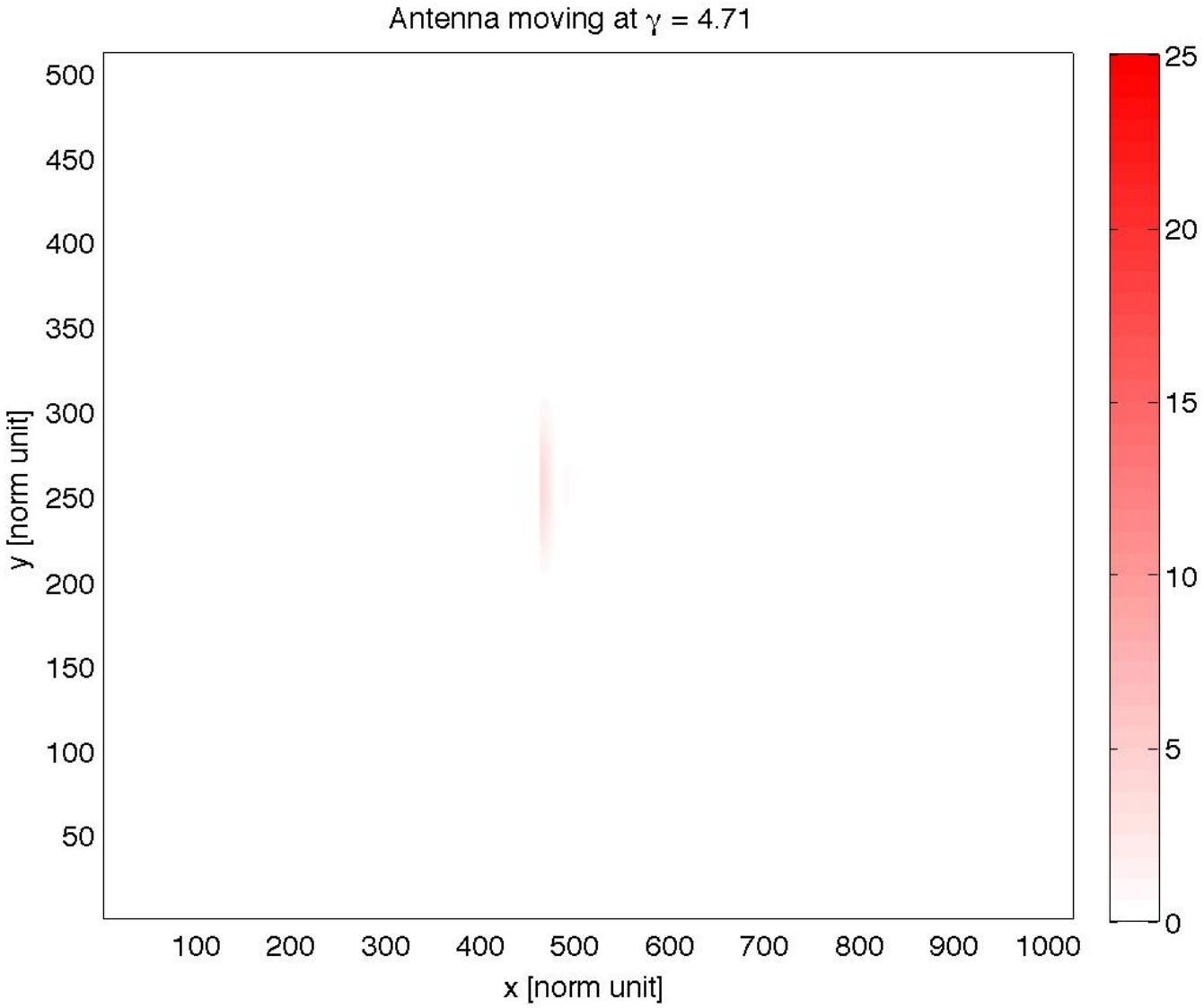
Hyperbolic Rotation in space-time



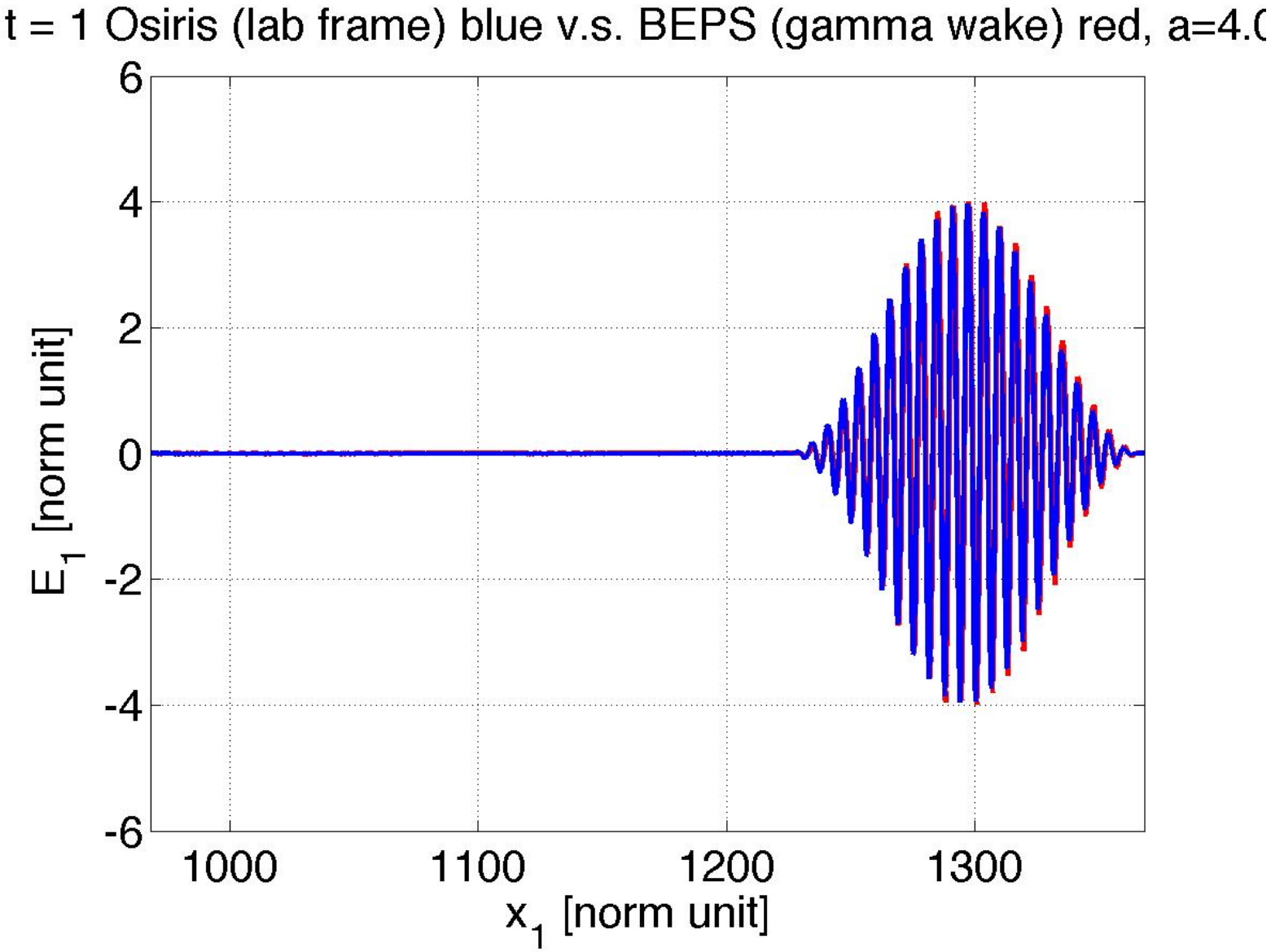
Simulation setup for LWFA



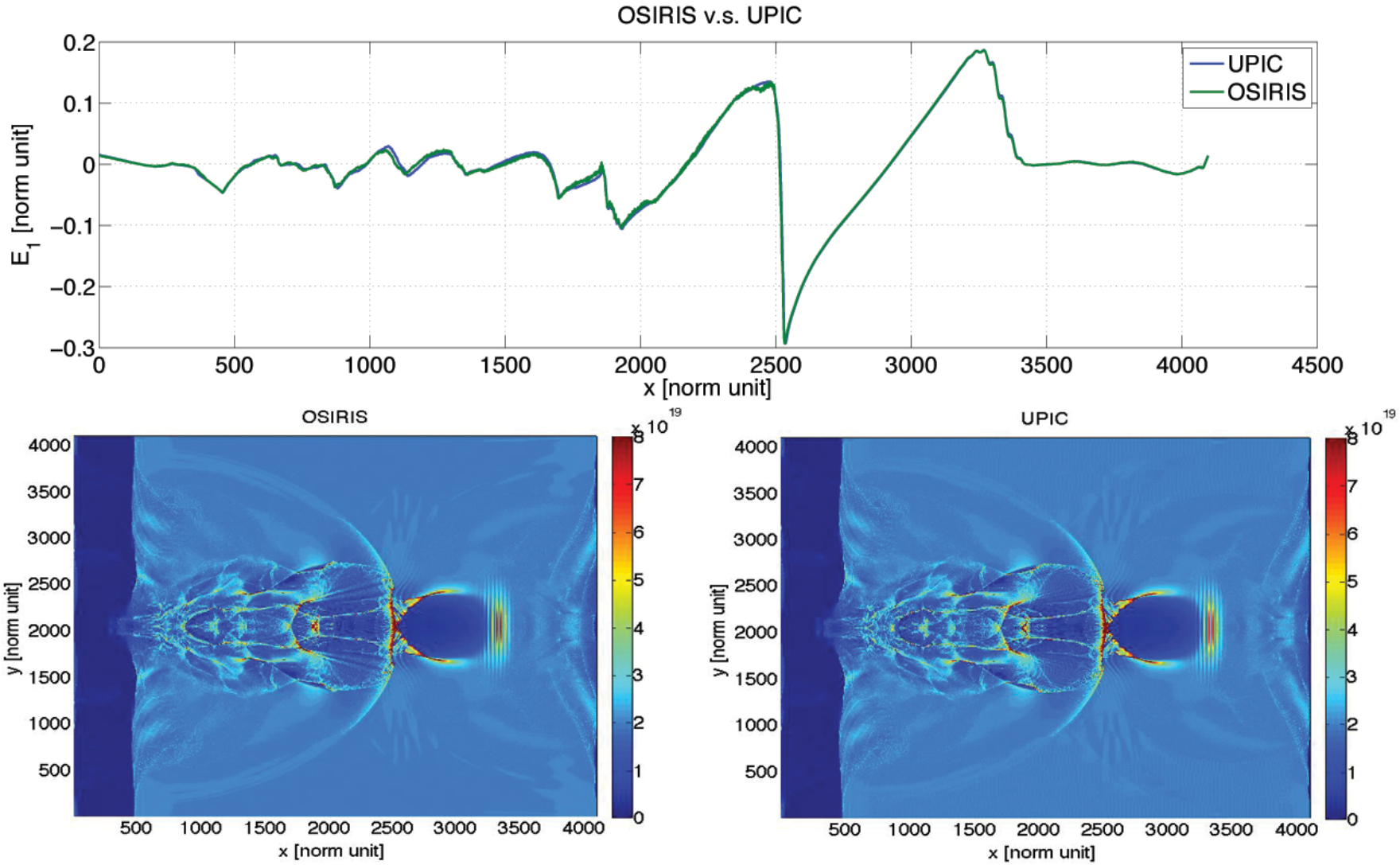
Moving antenna



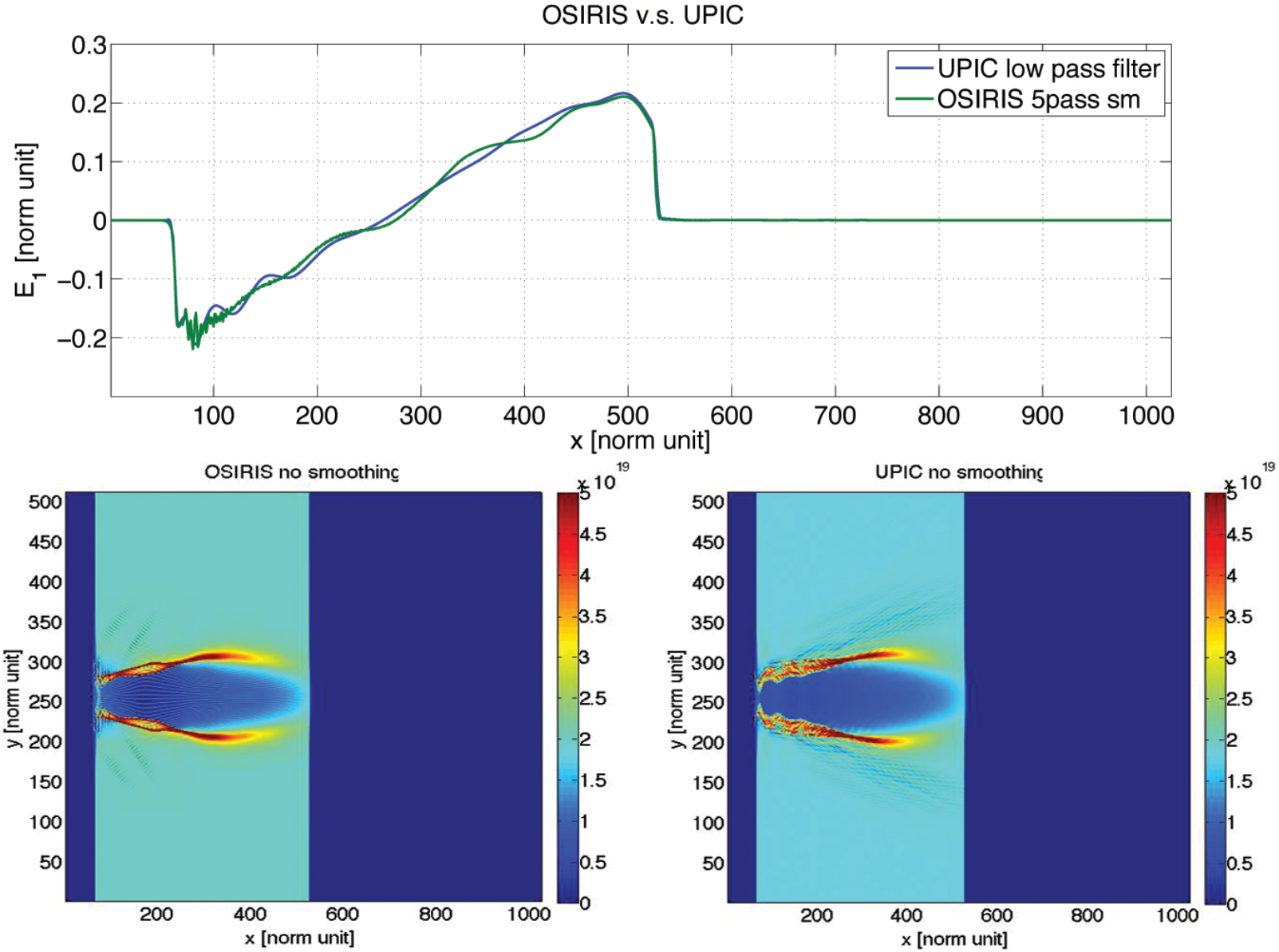
Benchmark with OSIRIS — moving antenna



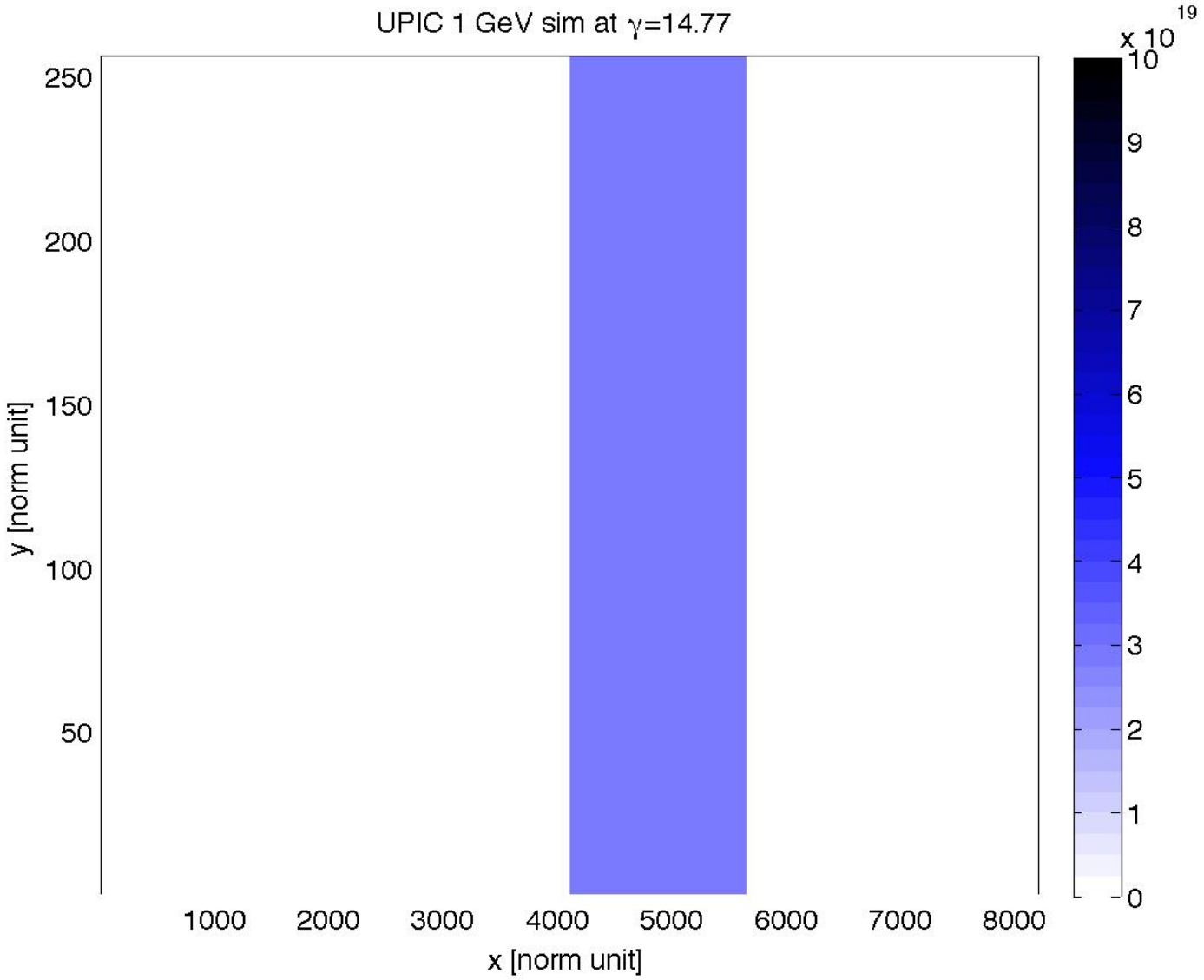
Benchmark with OSIRIS — lab frame



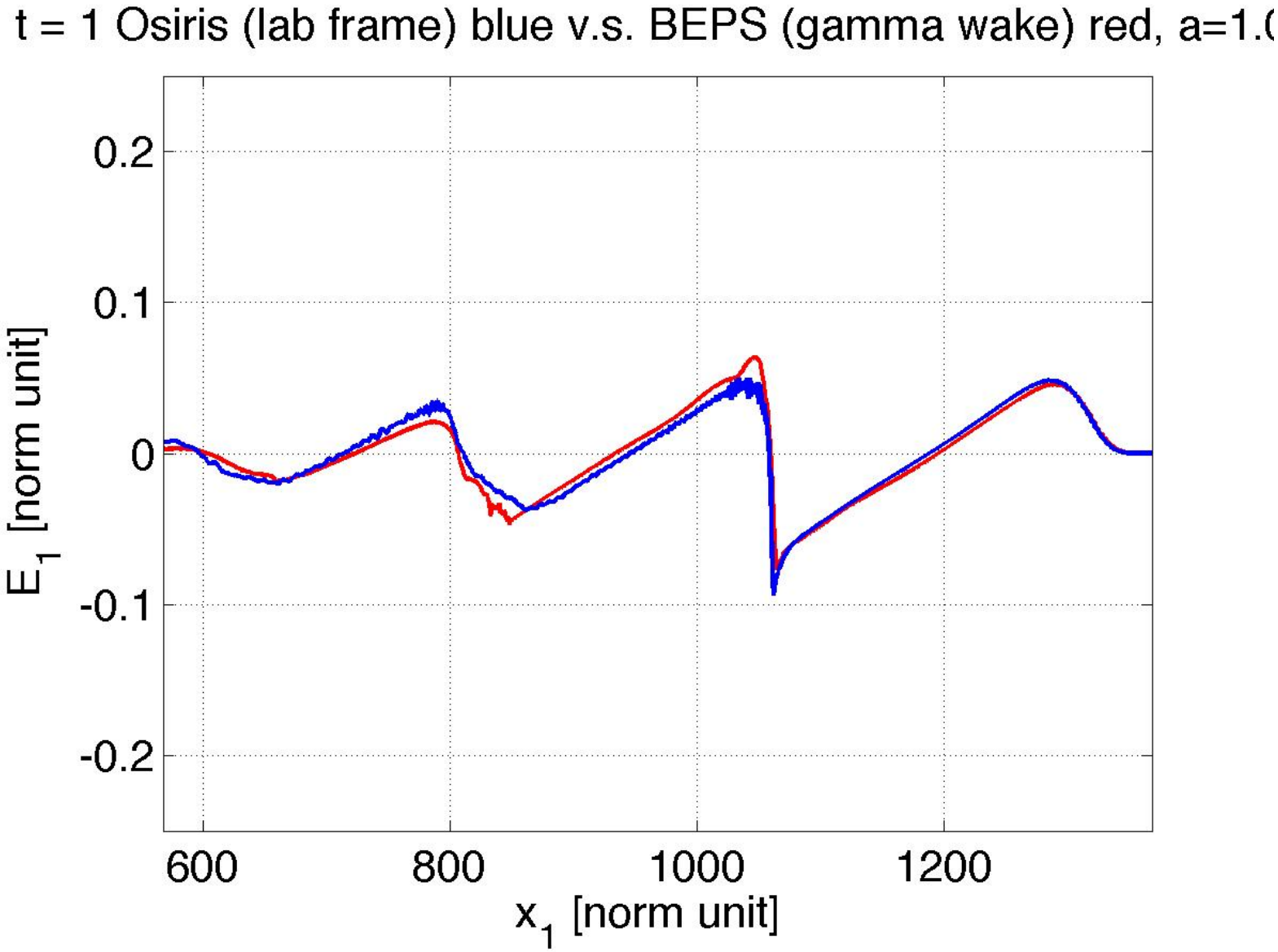
Benchmark with OSIRIS — boosted frame



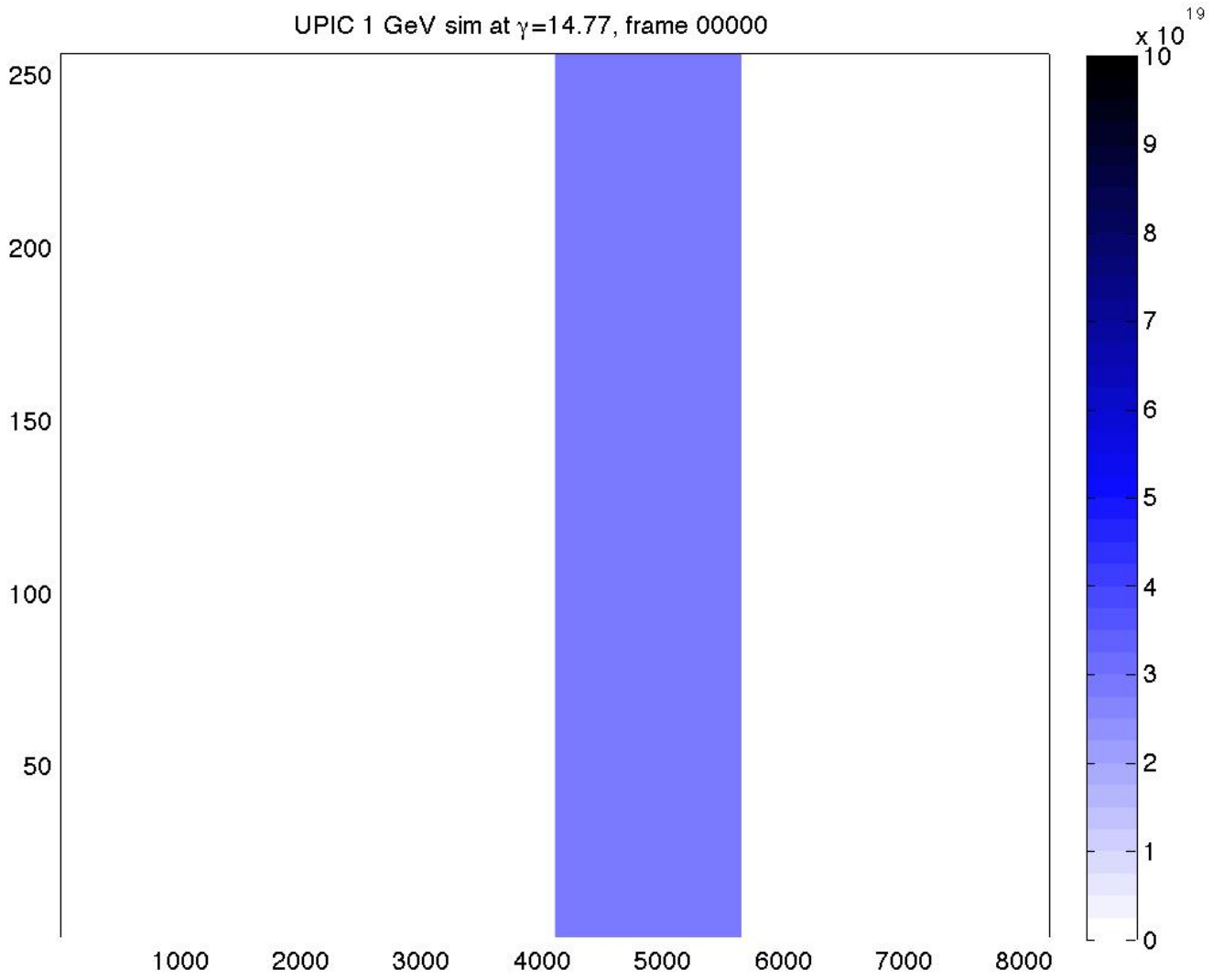
Case study: LWFA at 1 GeV, $a_0 = 4.0$



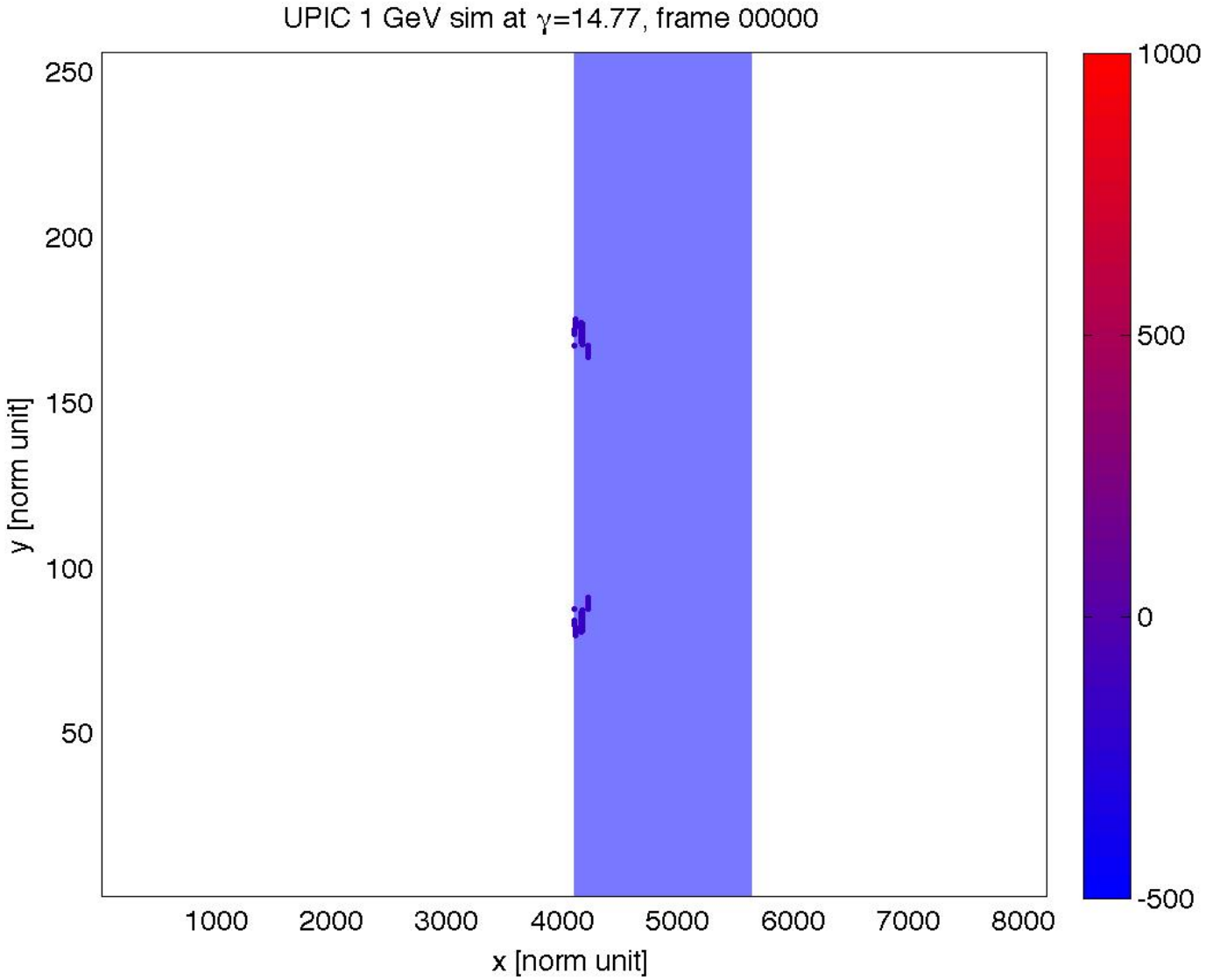
E_1 comparison: LWFA at 1 GeV, $a_0 = 4.0$



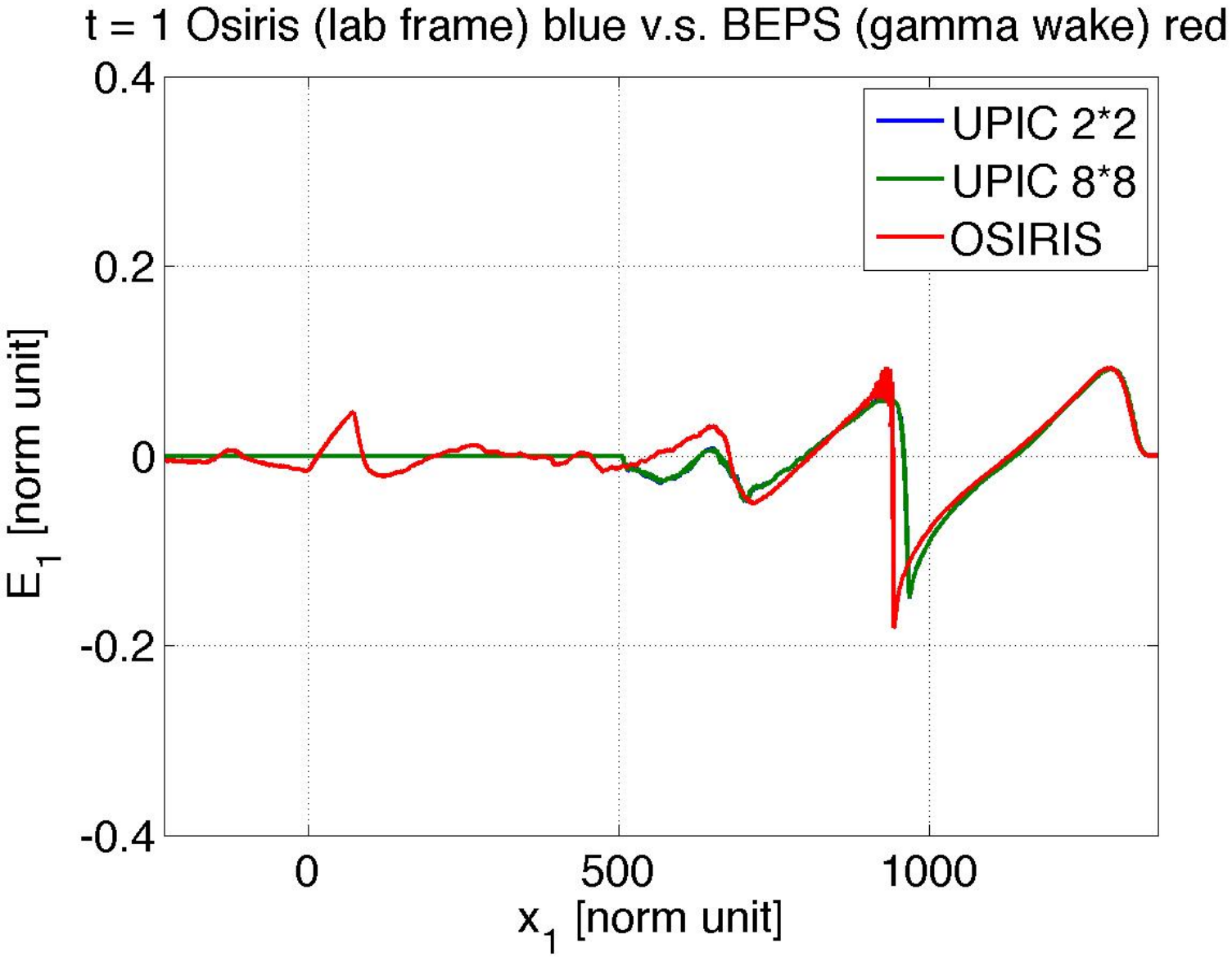
Self-injection case: LWFA at 1 GeV, $a_0 = 8.0$



Particle tracking: LWFA at 1 GeV, $a_0 = 8.0$



E_1 comparison: LWFA at 1 GeV, $a_0 = 8.0$



Conclusions and future work

- EM-PIC code with spectral solver is advantageous in mitigating the numerical instability induced by relativistic plasma drift.
- We are developing a parallel code with spectral solver to study LWFA.
- In the future we are considering
  (a) Making a 3D version based on the components of UPIC;
  (b) Adding the GPU capability;
  (c) Initializing a trailing particle beam.