July 31 - August 5

ADVANCED ACCELERATOR CONCEPTS

2016

Gaylord National Convention Center, National Harbor, MD

UCLA

Comparison of the injection between boosted frame and lab frame simulations

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Aug 2th, 2016

PICKSC

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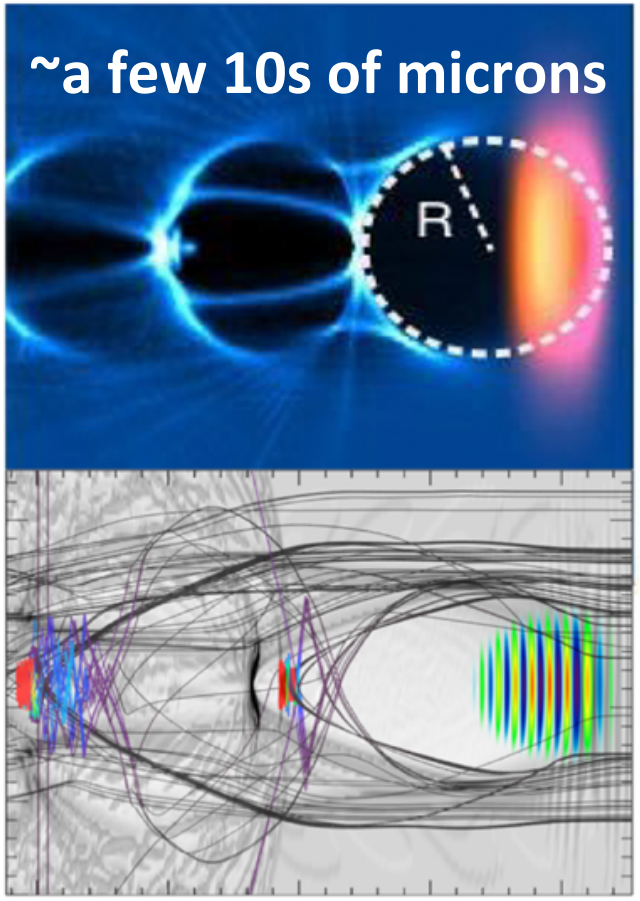
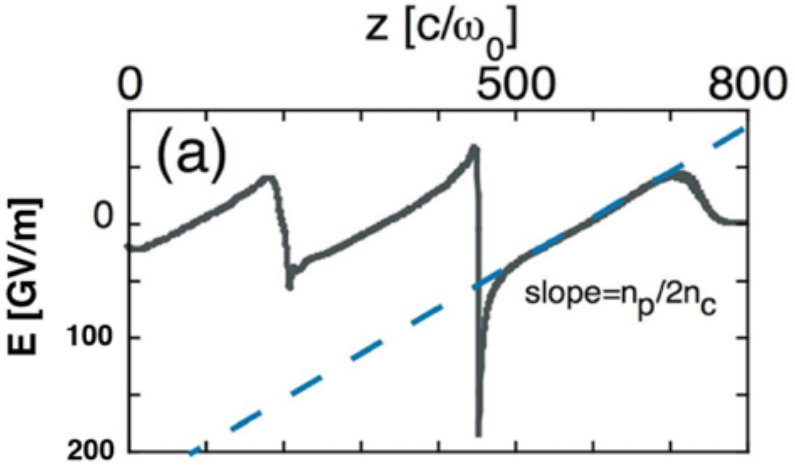
http://picksc.idre.ucla.edu/

Simulation in LWFA



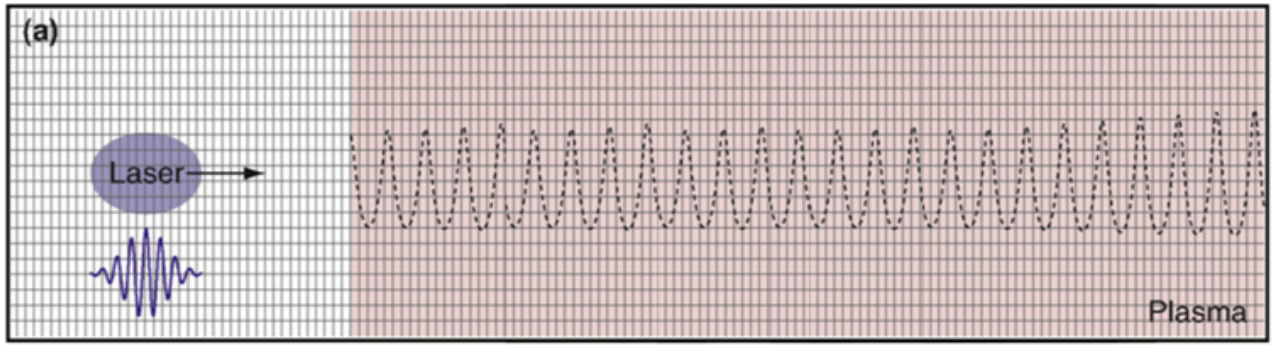


- plasma density highly modulated
- acceleration field highly nonlinear
- particle trajectories highly irregular

We rely on Particle-in-cell simulations to give us vision on the physics in LWFA.

[W. Lu, et. al., Phys. Rev. ST - AB 10, 061301 (2007)]

Lorentz boosted frame simulation of LWFA



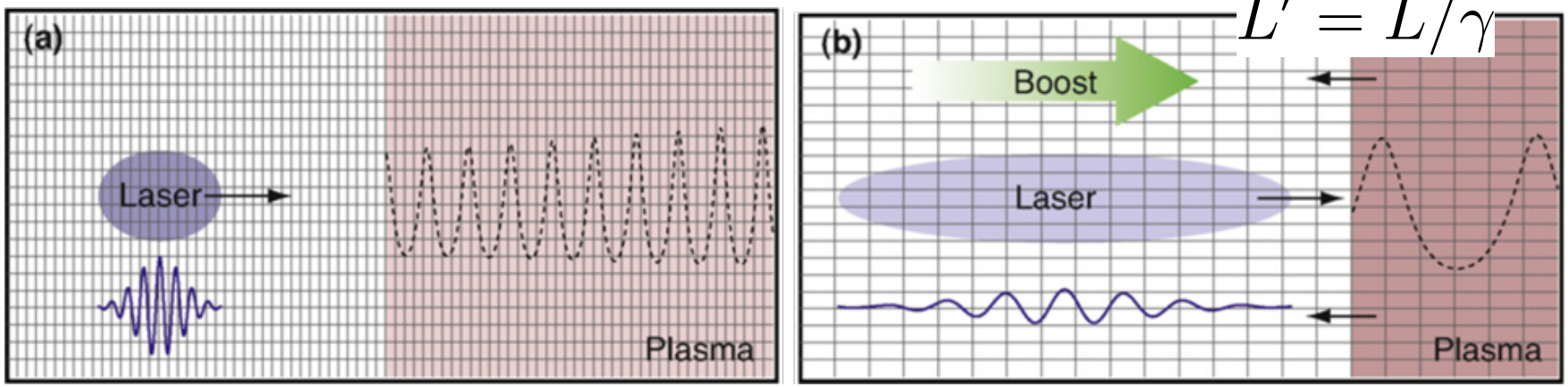
Beam energy	plasma column length	CPU-hours
1 GeV	0.09 m	~1 million
10 GeV	0.28 m	~100 million
100 GeV	9.00 m	~10 billion

- Quasi-Static Approximation + Ponderomotive Guiding Center
- Full PIC + Guiding Center
- **Lorentz boosted frame**

Lorentz boosted frame simulation of LWFA

plasma length contracts

$$L' = L/\gamma$$



~ micro meter ~ centimeter

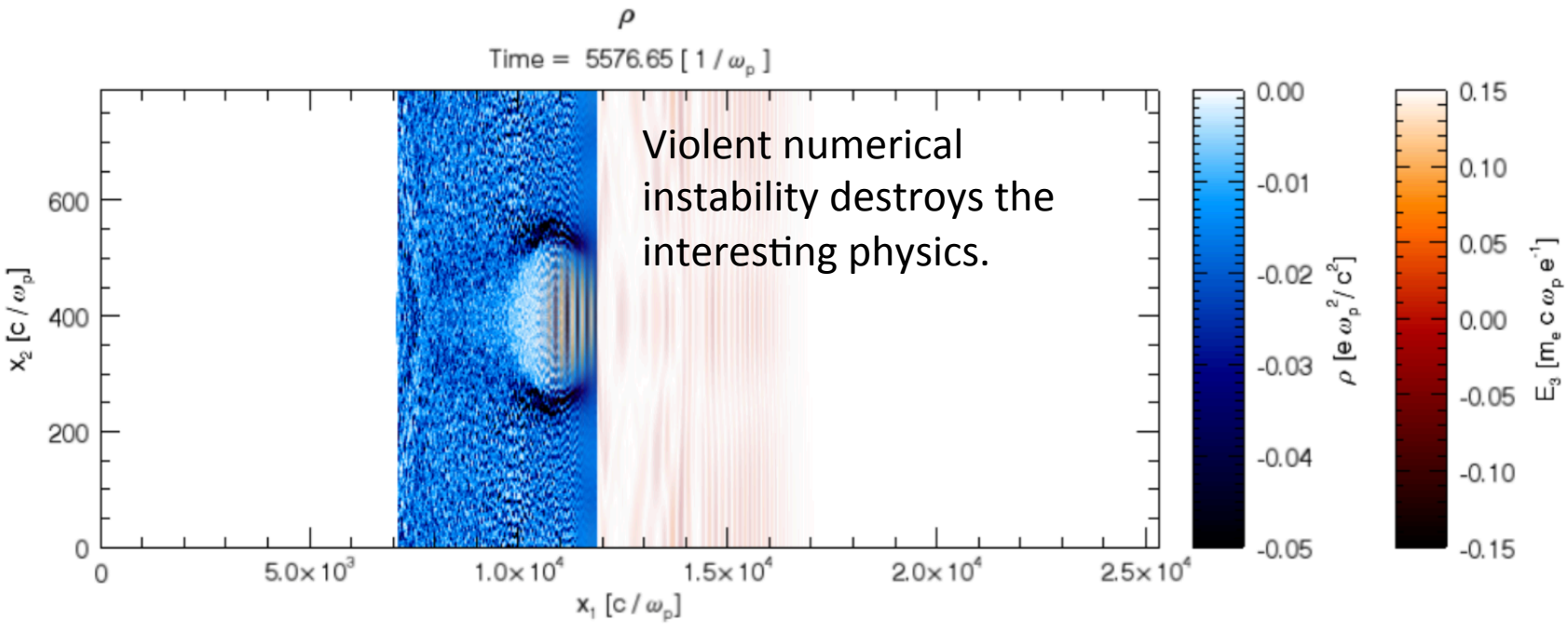
laser wavelength stretch

$$\lambda' = \gamma(1+\beta)\lambda$$

Speed up from Boosted frame: γ^2

W. Mori, et. al., NSF Proposal (1992).
J.-L. Vay, Phys. Rev. Lett., 98, 130405 (2007).

Numerical instability in relativistically drifting plasma

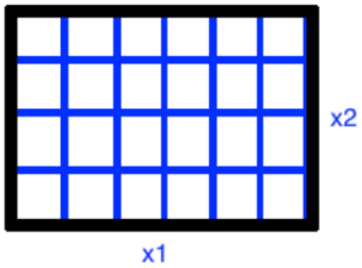


B. B. Godfrey and J.-L. Vay, J. Comp. Phys. 248 (2013) 33. And other papers from Godfrey and Vay.

X. Xu, P. Yu, et. al., Comp. Phys. Comm., 184 (2013) 2503. And other paper from Xu and Yu.

Hybrid Yee-FFT solver

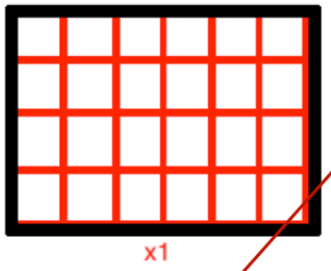
OSIRIS: FDTD solver



$$[k_1] = \frac{\sin(k_1 \Delta x_1/2)}{\Delta x_1/2}$$

$$[k_2] = \frac{\sin(k_2 \Delta x_2/2)}{\Delta x_2/2}$$

UPIC-EMMA: spectral solver



$$[k_1] = k_1$$

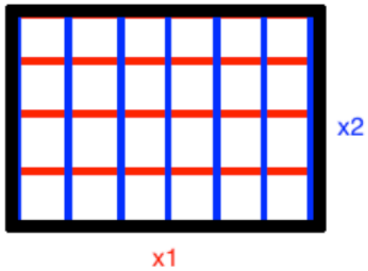
$$[k_2] = k_2$$

$$\frac{\partial}{\partial x_1} \quad \frac{\partial}{\partial x_2}$$

Current correction

$$\tilde{j}_1^{n+\frac{1}{2}} = \frac{\sin k_1 \Delta x_1/2}{k_1 \Delta x_1/2} j_1^{n+\frac{1}{2}}$$

Hybrid solver



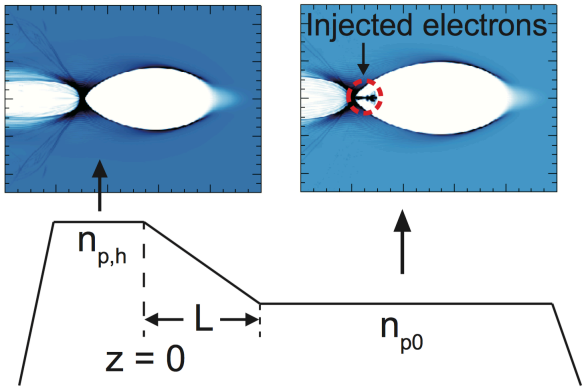
$$[k_2] = \frac{\sin(k_2 \Delta x_2/2)}{\Delta x_2/2}$$

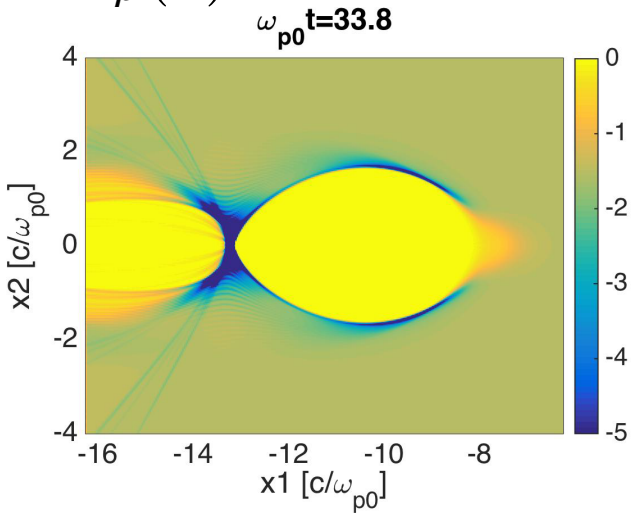
$$[k_1] = k_1$$

this idea can be extended to quasi-3d geometry.

Density Downramp injection - Introduction

- "Accordion effect"[1]: $\lambda_{wake} \propto n_p(z)^{-1/2}$





- S. Bulanov[2] et al. (1998), and H. Suk[3] et al. (2001) studied the injection process using 1D analysis.
- Beam brightness from 3D PIC simulations:
- We (2013) showed an injected electrons beam with **10^{19}** A/m^2/rad^2;
- J. Grebenyuk et al. (2014)@**0.35×10^{17}** A/m^2/rad^2.

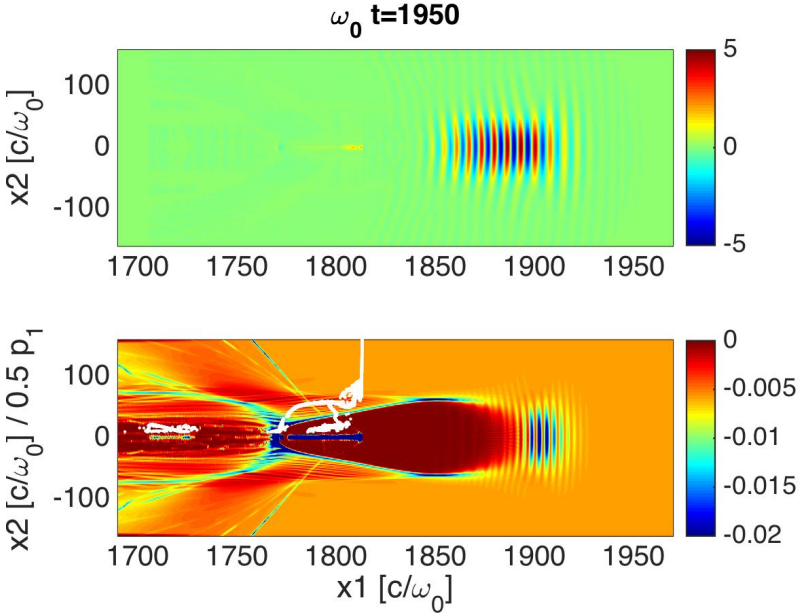
[1]T. Katsouleas, Phys. Rev. A 33, 2056 (1986); [2]S. Bulanov, et al., Phys. Rev. E 58, R5257 (1998); [3]H. Suk, et al., Phys. Rev. Lett. 86, 1011 (2001); [4]FACET-II Proposal v6 (2013); [5]J. Grebenyuk et al., NIMA 740, 246 (2014).

Simulation setup (Hybrid Solver)

- Laser: LP, a_0=4, polynomial (τ_{rise}=τ_{fall}=25.4 fs, τ_{flat}=0 fs), Gaussian (w_0=4.8 microns)
- Plasma: n_{p0}=10^{19} cm^{-3}

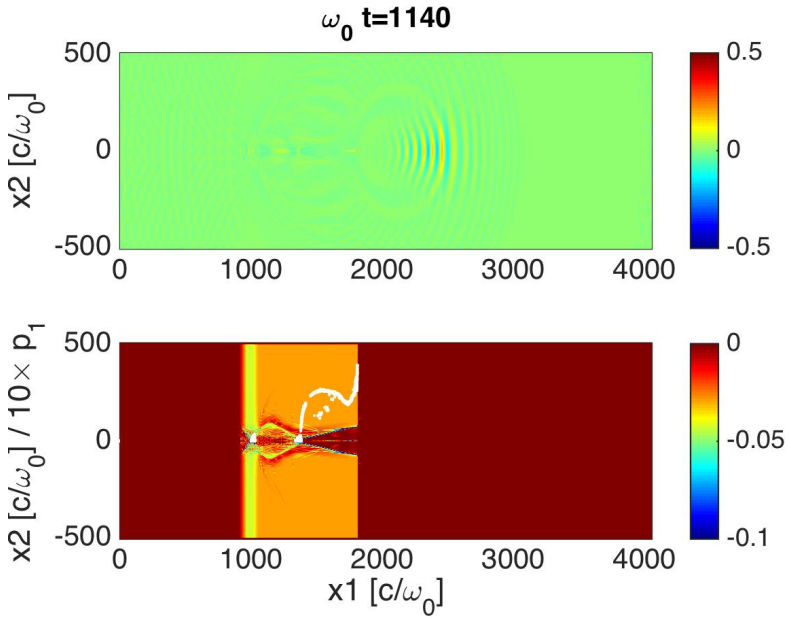
- lab frame

dx=[0.2, 2, 2], dt=0.05



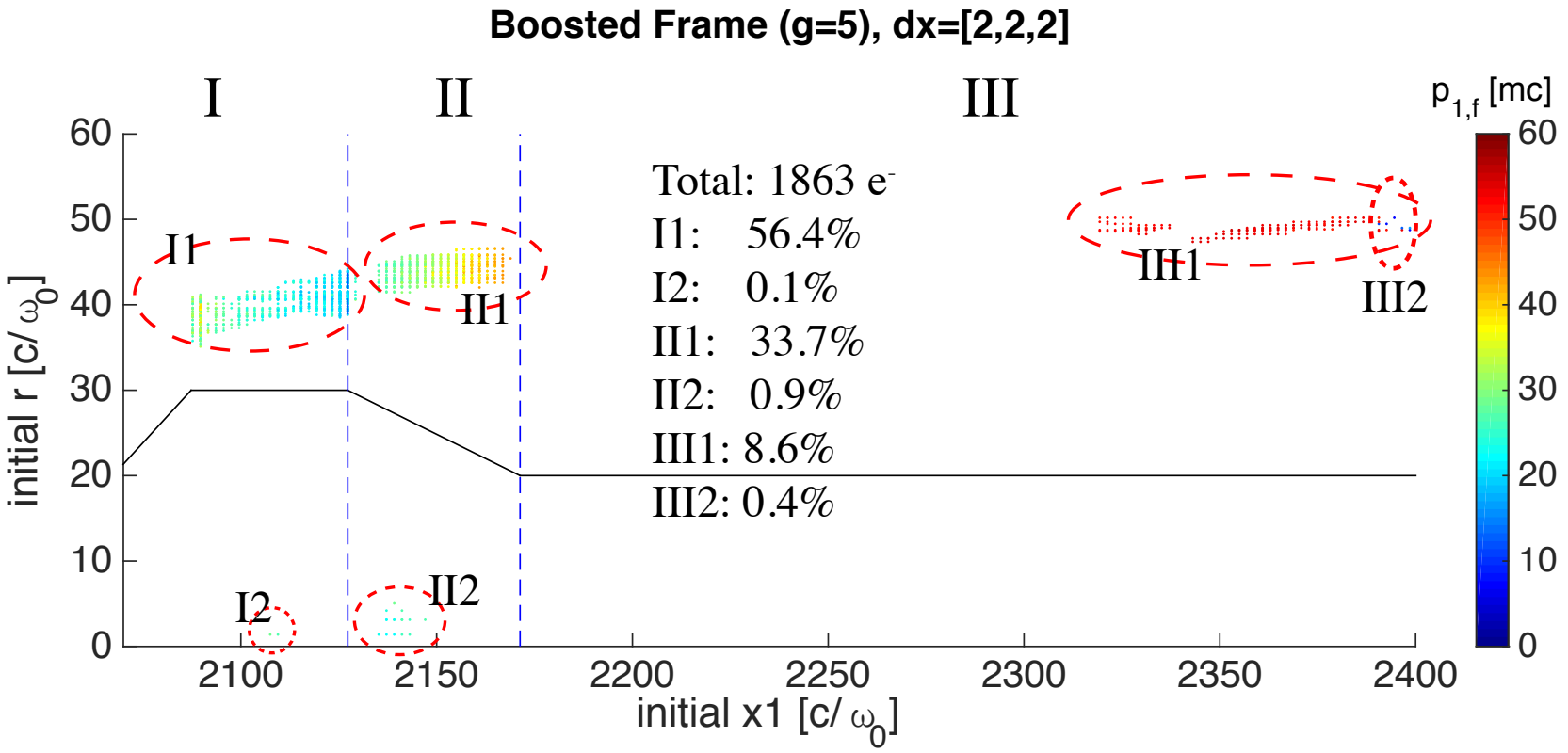
- boosted frame (Y_b=5)

dx=[2, 2, 2], dt=0.6



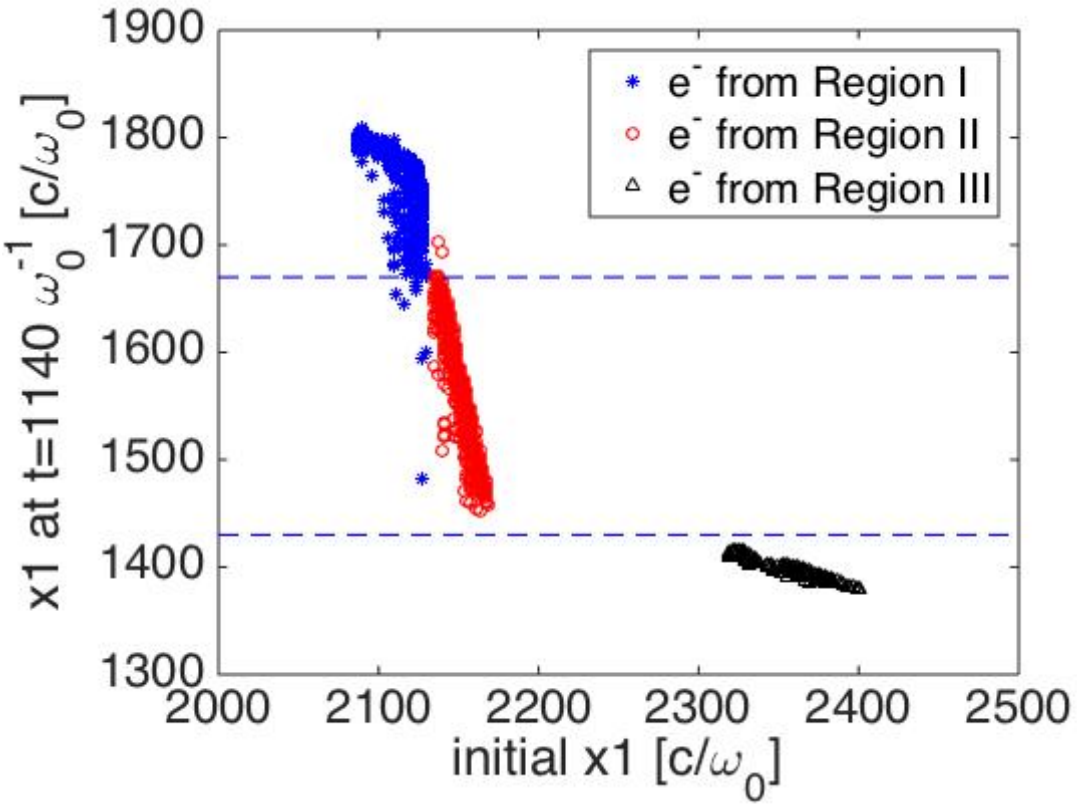
Boosted Frame Results

- Initial positions of the injected electrons



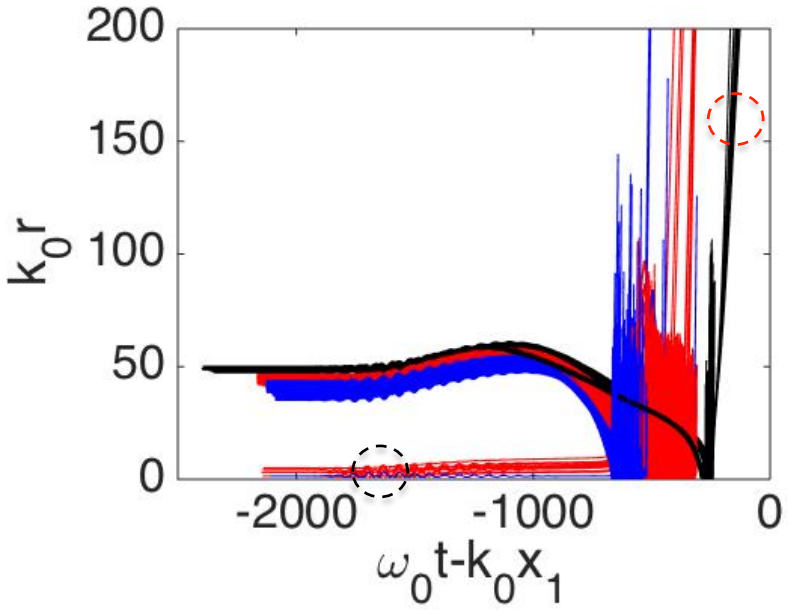
Boosted Frame Results

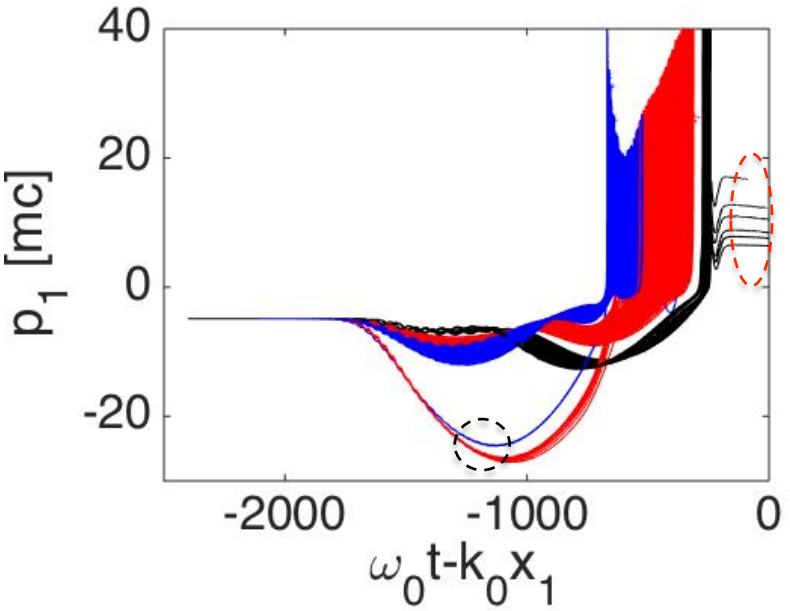
- Initial positions of the injected electrons



Boosted Frame Results (cont'd)

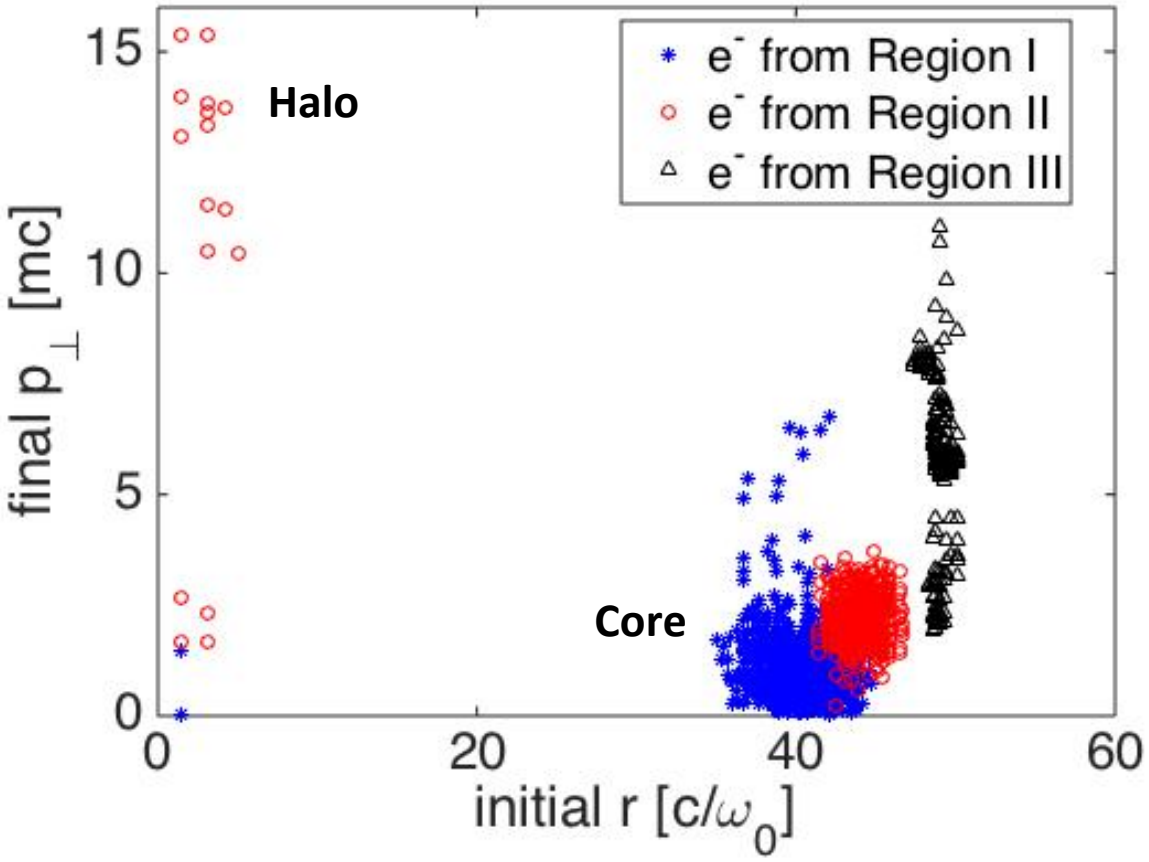
- Trajectories of the injected particles





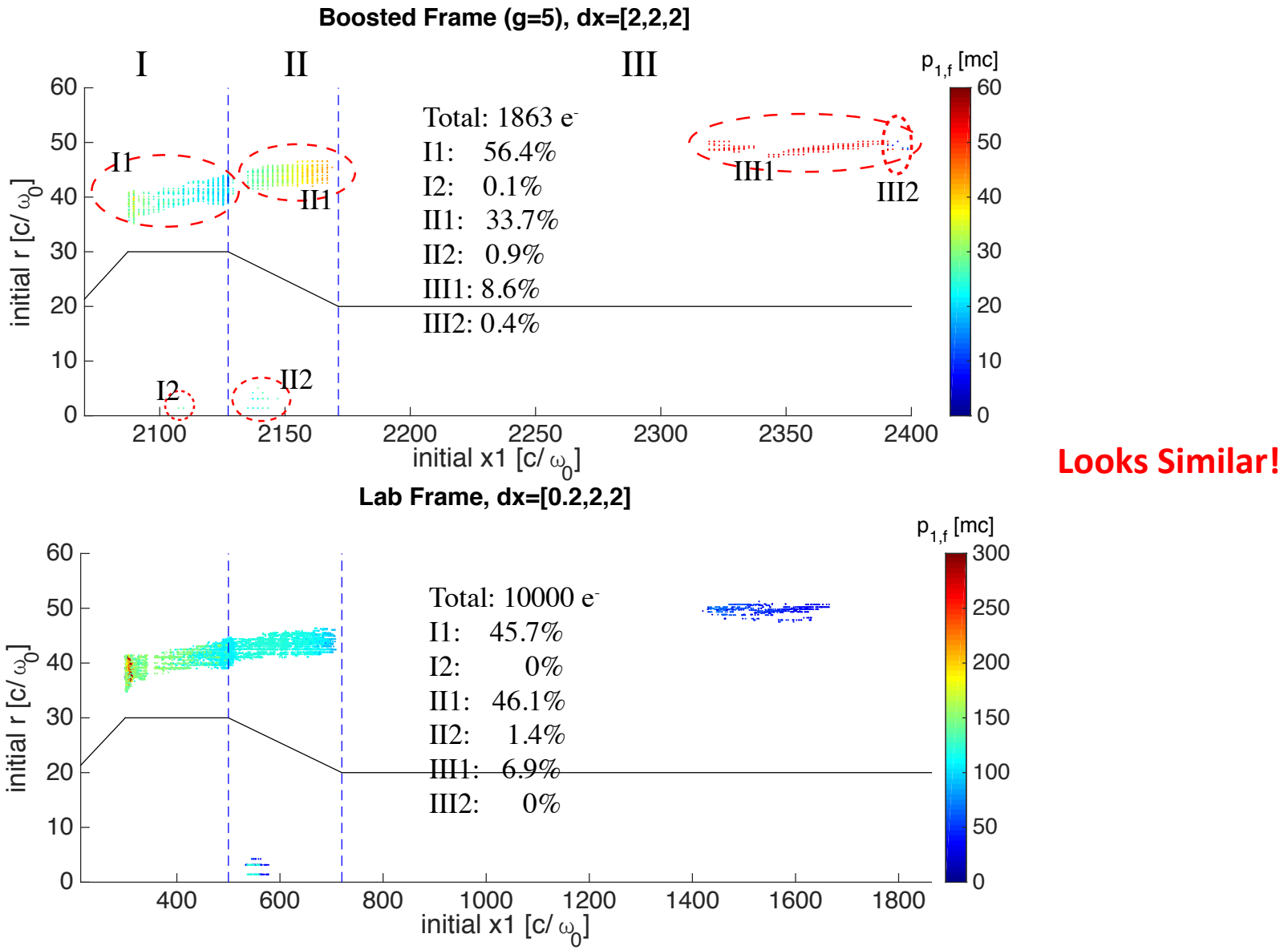
Boosted Frame Results (cont'd)

- The relation between p_{perp} and the initial r



The unique and the importance of the transverse motion we revealed before in self-injections.

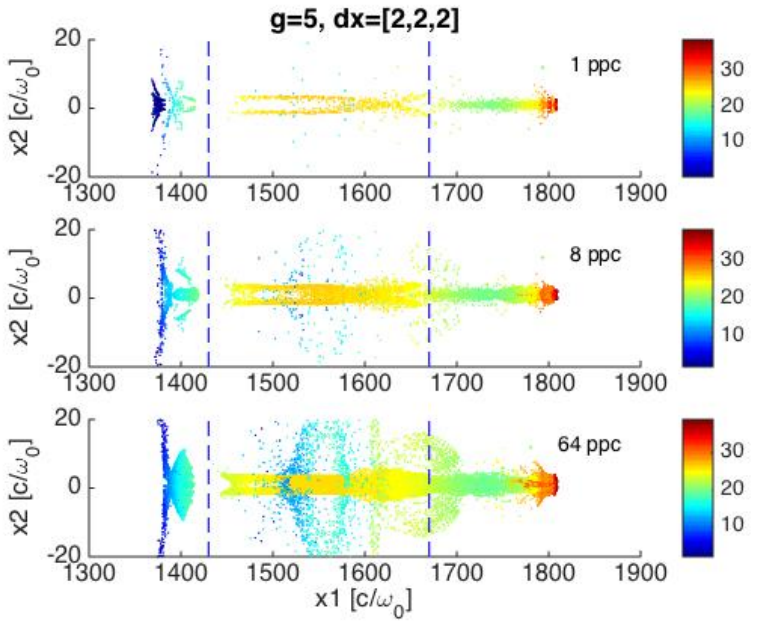
Comparisons of Boosted and Lab

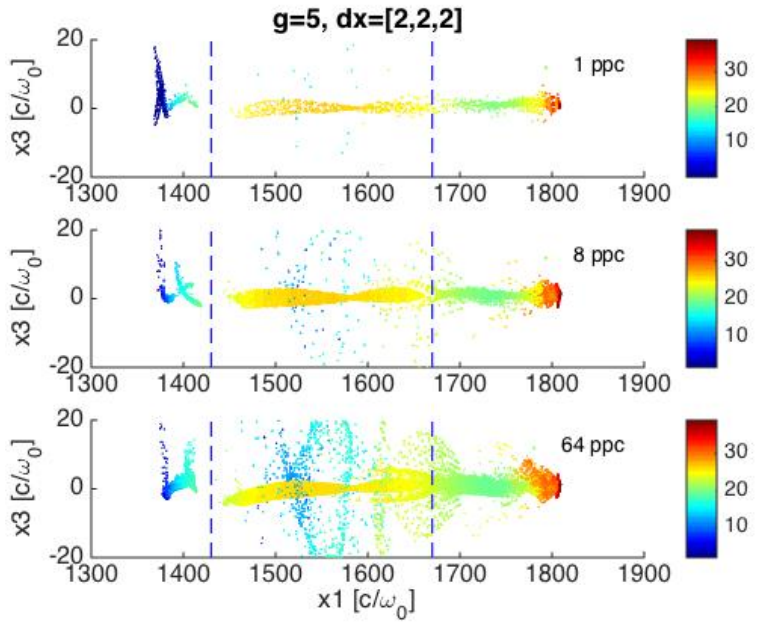


Looks Similar!

Comparisons of Boosted and Lab (cont'd)

- Increasing the ppc in Boosted Frame Simulations

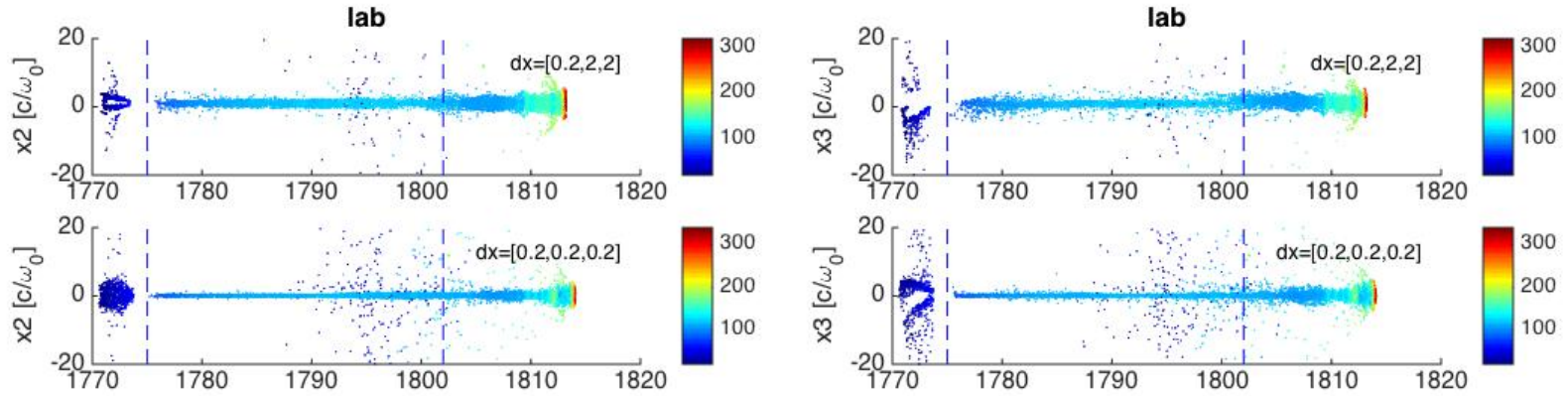




E. N. Nerush and I. Yu. Kostyukov, *Carrier-Envelope Phase Effects in Plasma-Based Electron Accleration with Few-Cycle Laser Pulses*, PRL 103, 035001 (2009).

Comparisons of Boosted and Lab (cont'd)

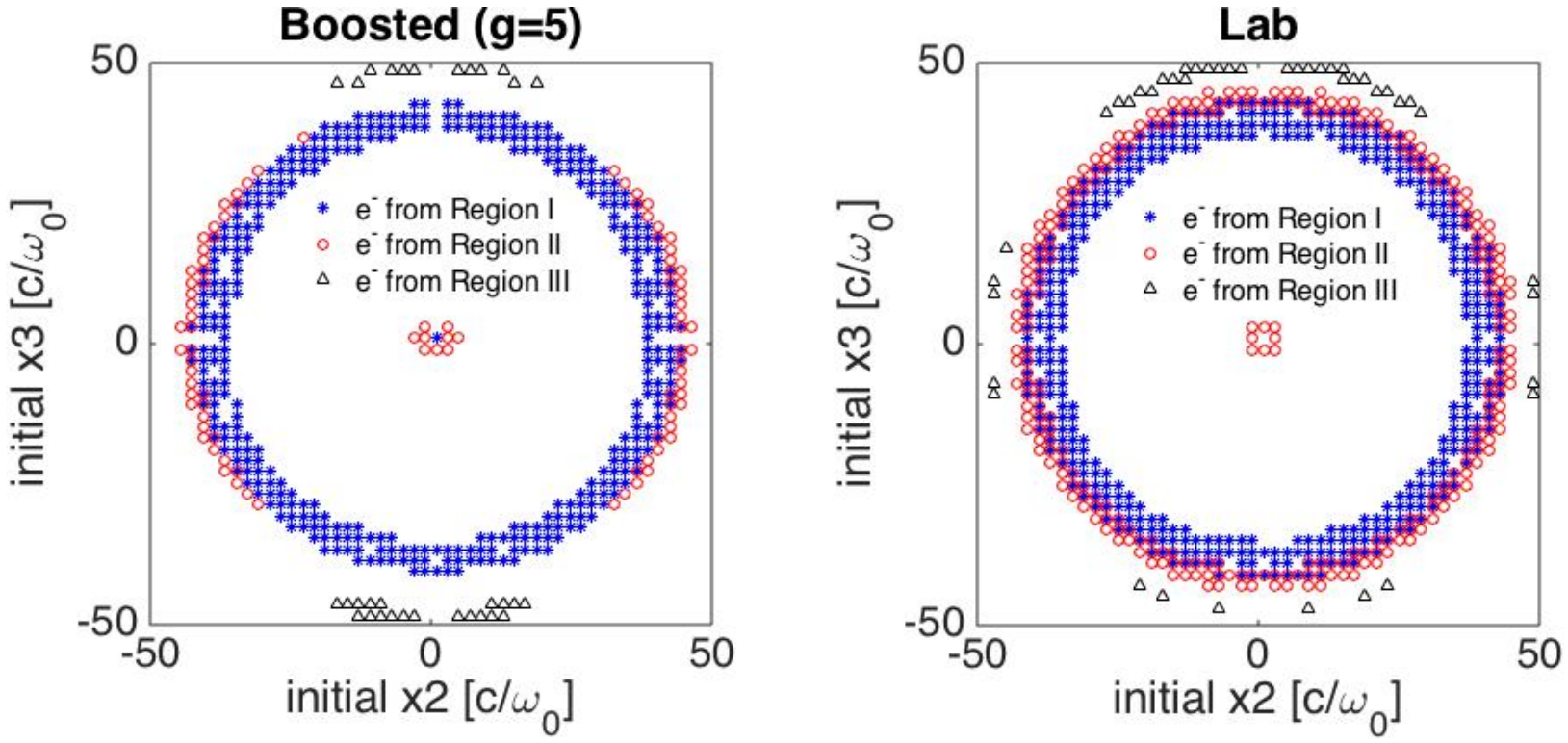
- Lab Frames Results



Less 'Hosing' phenomena is observed in the lab frame simulations.

Comparisons of Boosted and Lab (cont'd)

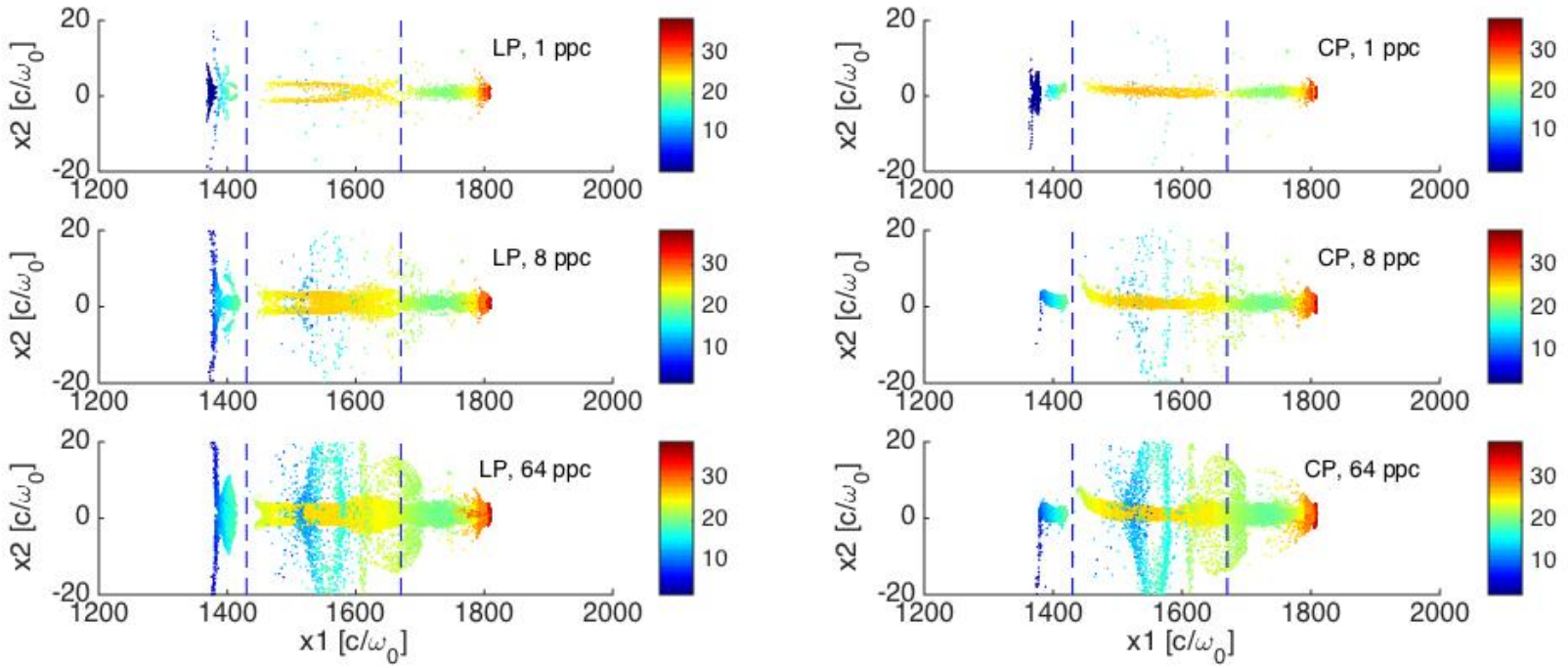
- Initial transverse positions



Comparisons of Boosted and Lab (cont'd)

- LP -> CP

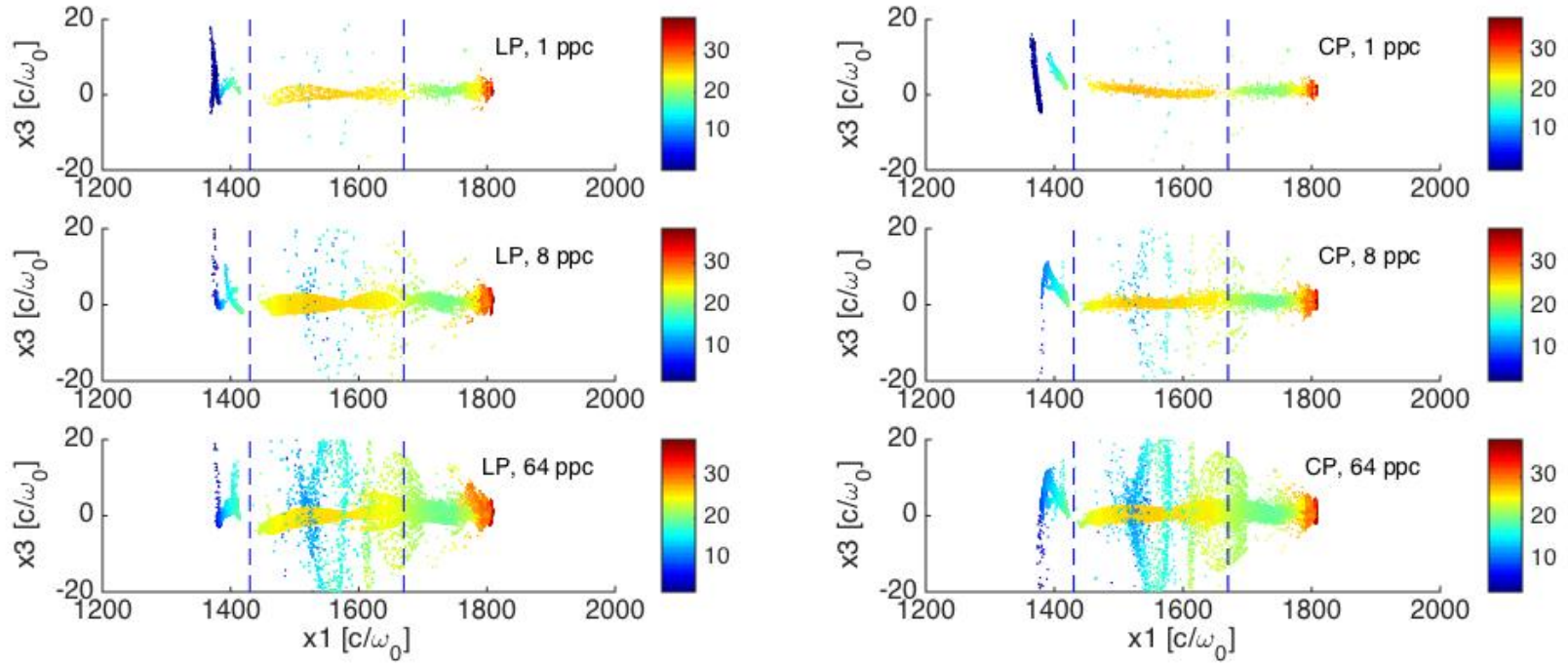
x1-x2 plane



Comparisons of Boosted and Lab (cont'd)

- LP -> CP

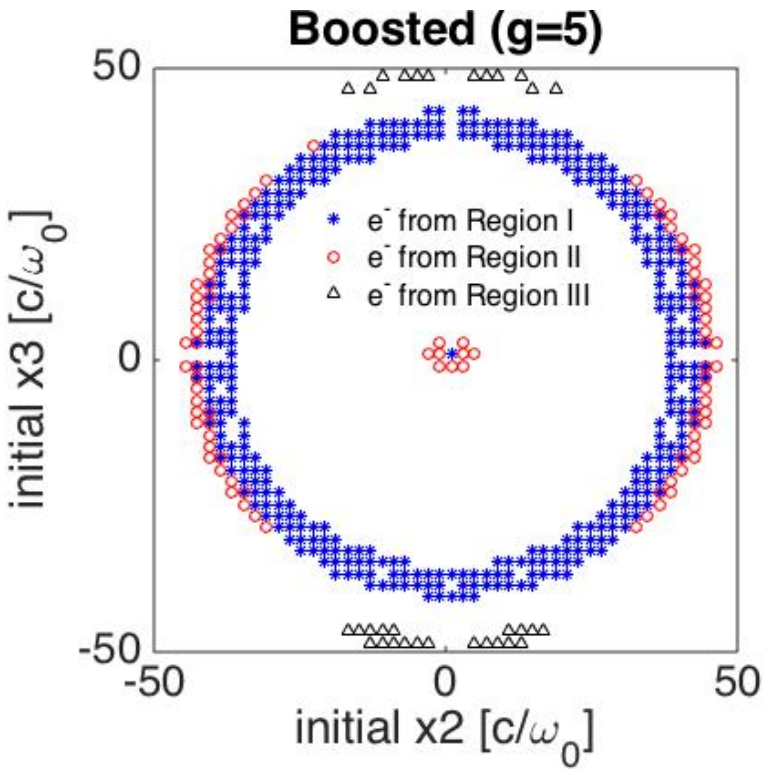
x1-x3 plane



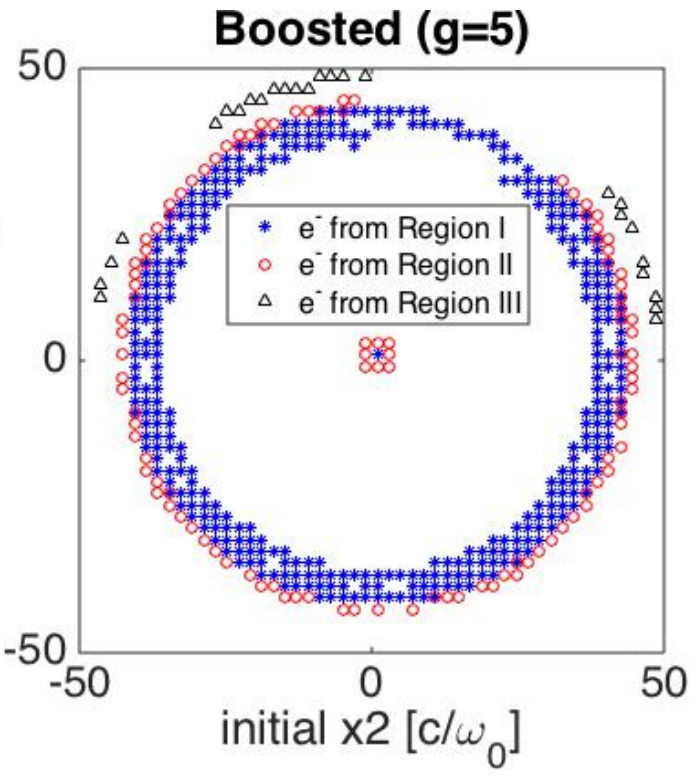
Comparisons of Boosted and Lab (cont'd)

- LP -> CP: initial transverse positions

LP

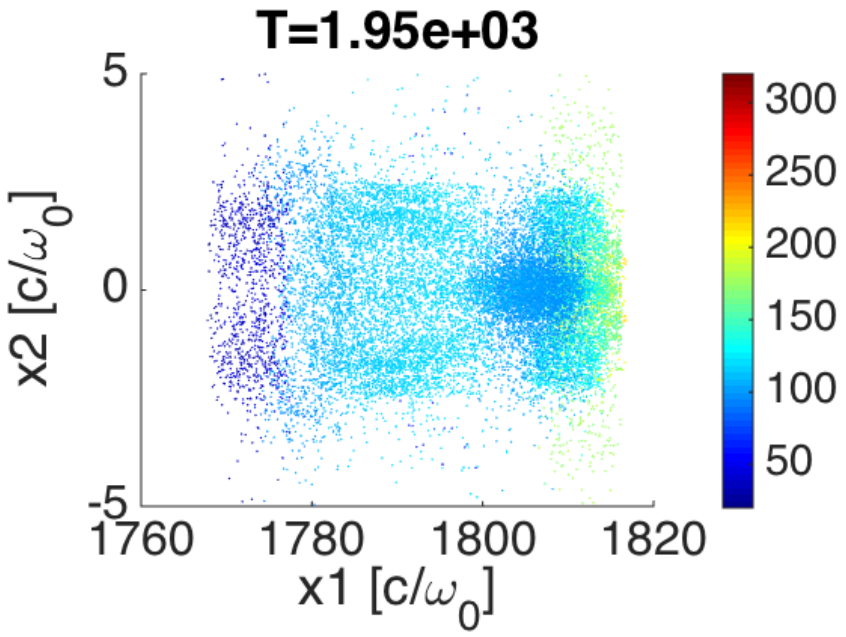


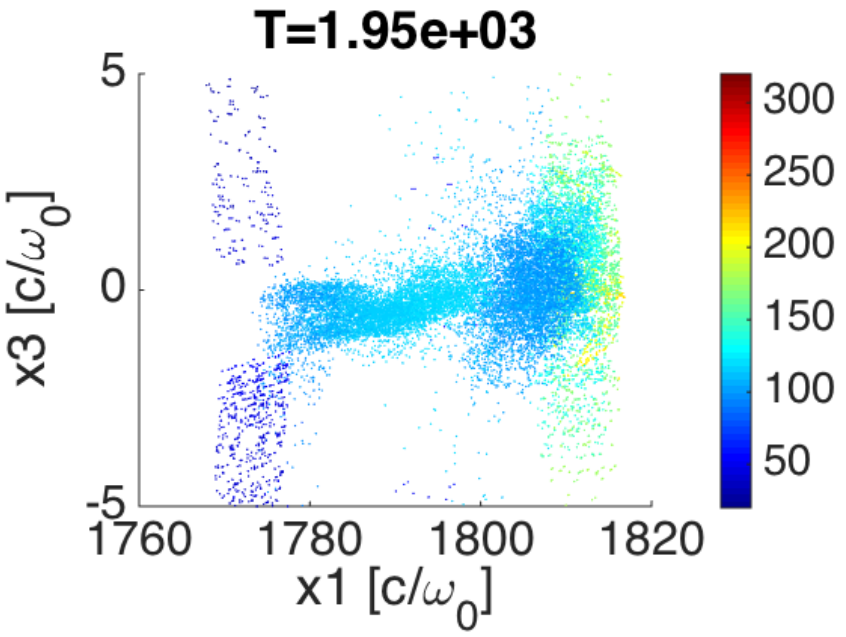
CP



Comparisons of Boosted and Lab (cont'd)

- Back to Lab: Boosted g=5, LP, 8 ppc





- Thanks!