Boosted frame PIC simulations of LWFA: 
ultra-fast modeling of current experiments 
and first studies of acceleration towards the energy frontier

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Phenomenological models predict that the next generation of laser systems will enable the exploration of laser-plasma accelerators (LPA) in the 10+ GeV range. The complete 3D one-to-one numerical modeling of these configurations is not possible with standard simulation approaches. Performing particle-in-cell simulations in Lorentz frames other than the lab frame, recently demonstrated for particle beams by J.-L.Vay, was promising, but the numerical challenges of the relativistic particles in the presence of the laser radiation were significant. We have solved these numerical issues required to use boosted frames with lasers, and have performed benchmarks with simulations in the lab frame and with experiments. Furthermore we have explored the requirements to accelerate e-beams up to 40 GeV, with self-injected beams in the bubble/blow-out regime and with externally loaded beams. The work also demonstrates a path for LPA to reach the energy frontier, providing a qualitative leap in terms of the ability to model distances in the 10s cms - m scale and energies > 40 GeV. Even for smaller energy gains (~ 1 GeV) it provides a tool to reduce the turnover time of the simulations by factors above ~300. A manuscript with this work has been accepted for publication in Nature Physics.

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