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Noninvariance of Space- and Time-Scale Ranges under a Lorentz Transformation and the Implications for the Study of Advanced Accelerators

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For the interaction of relativistic species (matter or light), the ratio of larger to smaller space and time scales spanned by the entire system can be reduced by orders of magnitude if choosing the right Lorentz boosted frame as the frame of calculation [1]. This has application to three domains of relevance to the design of advanced accelerators: plasma wakefield accelerators, free electron laser, and the interaction of particle beams with electron clouds, where speedups ranging from two to five orders of magnitude have been reported for first-principle calculations. While the application of the new finding is simple in principle, standard numerical techniques may not perform equally, independently of the frame that is chosen for the calculation. For example, the standard 'Boris' particle pusher has proven to be inadequate for the modeling from first principles of the interaction of relativistic beams with electron clouds in any frame, and a new pusher had to be developed [2]. We will present the initial finding, how it can benefit the modeling of three areas of relevance to the design of advanced accelerator systems, and the numerical difficulties that have been encountered and their solutions, as well as examples of applications for the three cited areas. Applications to laser-based plasma accelerators and free-electron lasers are also discussed at this workshop respectively in [3] and [4].

[1] J.-L. Vay, *Phys. Rev. Lett.* **98**, 130405 (2007)

[2] J.-L. Vay, *Phys. Plasmas* **15**, 056701 (2008)

[3] D. L. Bruhwiler, This workshop, Session Plenary D

[4] W. M. Fawley, This workshop

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