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Noninvariance of Space- and Time-Scale Ranges under a Lorentz Transformation and the Implications for the Study of Relativistic Interactions[1]

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We present an analysis which shows that the ranges of space and time scales spanned by a system are not invariant under Lorentz transformation [1]. This implies the existence of a frame of reference which minimizes an aggregate measure of the range of space and time scales. Such a frame is derived, for example, for the following cases: free electron laser, laser-plasma accelerator, and particle beams interacting with electron clouds. The implications for experimental, theoretical, and numerical studies are discussed. The most immediate relevance is the reduction by orders of magnitude in computer simulation run times for such systems. A speed-up of 1000 was obtained on a proof-of-principle Particle-In-Cell simulation of a relativistic proton beam experiencing a hose-like instability as propagating through a high density of electrons in a uniform focusing channel. We are in the process of upgrading our simulation tools to be in a position to perform simulations in the optimal frame, and apply them to actual situation for the identified areas of applications. We will present results, as available. [1] Phys. Rev. Lett. 98, 130405 (2007)

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