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Modelization of Plasma Accelerators in the Exascale Era

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Plasma accelerators have demonstrated significant milestones, from producing 10 GeV electron beams in wake-field acceleration, high-gain free-electron laser operation, energy boosting of electrons, to reaching stable (ultra-short, nC-class) proton acceleration that enable studies of ultrahigh dose-rate radiobiology. Now, the community is setting sight on integrating plasma acceleration deep into future particle colliders and applications, such as a potential 10 TeV center-of-mass collider, Higgs factory, injection into rings for next-generation light sources, stable high-repetition rate operations, among others, which continue to set demanding research challenges on particle beam quality, repetition rate and reliability.

This presentation will discuss the current capabilities and latest trends in modeling plasma accelerators and integrated modeling of beamlines with plasma elements. With a need for detailed kinetic modeling from design to operations, a comprehensive and coordinated approach is needed to cover and optimize anything from the source to the end of the beam's lifetime. An important enabler are new technologies from Exascale Computing, providing (GPU) accelerated computing for accelerator and plasma physicists from laptops to supercomputers. Advances in open source modeling ecosystems and coupling to AI/ML with standardized data exchange now enable user-friendly model-building for integrated accelerators, combining theory, kinetic modeling and fast surrogate models.

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