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First fully kinetic full 3D AWAKE baseline scenario simulation

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The “Advanced Proton Driven Plasma Wakefield Acceleration Experiment” (AWAKE) aims to enable lepton acceleration via proton-driven wakefields. It comprises extensive numerical studies as well as experiments at the CERN laboratory.

The baseline scenario has a simulation domain of 0.81 cm in the x, 0.42 cm in the y, and 10 m in the z direction. The smallest scale in this domain is the plasma wavelength, which is about 1.25 mm and needs to be resolved. This makes the computational requirements of this experiment very intense.

Previous numerical studies were performed using reduced models, most prominently the axisymmetric approximation, which reduces the number of dimensions by one, resulting in a two dimensional problem. While this helps with reducing the computational demand, several important effects can not be accurately reproduced when using these approximations, most notably the hosing instability and the complex process of witness beam trapping in the emerging wakefield.

We present results for the first three dimensional simulation of this baseline scenario with a full model. The simulations took 22 Mch on the SuperMUC system and required substantial optimization efforts, including a host of inline evaluations, dynamic load balancing and a dynamic simulation domain.

After analyzing the files from the simulation, which have a total size of tens of TBs, we were able to obtain several important results. The simulation reproduces the self-modulation instability of the proton beam and does not show significant hosing. The accelerating gradient as well as the witness beam acceleration conform to the previous results using reduced models. From plotting specific witness beam trajectories we were able to deduce several important observations regarding the nature of the trapping process.

We will present the details of the simulation as well as figures showing its results and our subsequent observations.

Working group

Theory and computation

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