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Large Scale Fully Kinetic 3D PIC Simulation for the Awake Collaboration

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Abstract content
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The AWAKE collaboration proposes to use the beam generated by CERN's SPS to drive plasma wakefield acceleration and generate electrons in the TeV regime.
There have been extensive numerical investigations into the proposed setups using a lot of different methods and techniques. Nonetheless, a fully kinetic 3D simulation of the whole process has not yet been implemented, mainly due to the immense computational resources required for it. There are, however, several processes and instabilities which are not present in, e.g. cylindrically symmetrical simulations. Carefully chosen parameter ranges and setup parameters made sure that these processes will not affect the validity of the results. In order to verify these assumptions and to do a direct comparison between different theoretical models we prepared the current experimental setup using the particle-in-cell (PIC) code PSC.
We secured the necessary resources on the SuperMUC petascale system in Munich. The setup consists of a 30cm long ion beam traversing a 10m long plasma channel. The plasma wakefield will trigger a longitudinal instability, called self-modulation-instability (SMI), seeded by a large density gradient at the front of the beam. The SMI will then result in micro-bunching of the ion beam which will in turn lead too non-linear growth of the wakefield. An electron witness beam enters the wakefield via side-injection and is accelerated. A resolution of 130 points per plasma wavelength is necessary. The full simulation uses a moving window approach and consists of about 22 billion cells containing more than 66 billion quasi-particles running for about 2 million timesteps. Using a large fraction of the SuperMUC system, this simulation still takes several weeks to complete and produces about 300TB of data.
We describe the necessary software modifications needed to achieve a reasonable well scaling PIC solution to this problem as well as technical details and pitfalls we encountered.

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