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3D hybrid simulations for run-away electrons from streamers

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X-ray and gamma ray bursts with quantum energies from hundreds of eV to tens of MeV have been observed in lightning and in long sparks in laboratory. In the lab, hard X-rays are observed during the streamer-leader phase. Therefore the generation of very energetic run-away electrons in streamers has to be investigated, and the consecutive generation of energetic photons through Bremsstrahlung. Following the precise electron energy distribution in the high field region of the streamer head requires a Monte Carlo approach. MC is also suited to study streamer branching triggered by particle fluctuations or streamer inception from few electrons. But a long streamer demands enormous computational power and storage while so-called super-particle methods create numerical artifacts. Fluid approximations, on the other hand, are computationally efficient in regions with large particle densities like the interior of a streamer finger. Therefore a hybrid model that couples fluid and particle model in suitable regions has been developed. The coupling needs a consistent description of the electron dynamics in particle and fluid model, especially in their buffer region. The consistency of the transport coefficients is studied both for swarms and for planar fronts. The fluid model has to be extended to include the non-local effects at the streamer ionization front. The 3D hybrid model can simulate long streamers while following the electron motion at the most active region. The correct prediction of run-away electrons requires reliable cross sections and differential cross sections, which is lacking in the energy range from tens of keV to MeV. We investigate the generation of run-away electrons and present how keV electrons are produced in a growing streamer. The work was performed together with U. Ebert, W. Hundsdorfer, W. Brok and J.J.A.M. van der Mullen.