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Energy resolved positron and hadron spectrum produced by a negative stepped lightning leader

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Gamma-ray flashes with quantum energies up to 40 MeV and beams of electrons and positrons have been detected by satellites above thunderclouds. Some have been correlated with upward propagating negative lightning leaders. Babich [Geomag., 2007] estimates that a relativistic runaway electron avalanche could create a significant number of neutrons by a photonuclear reaction of the gamma-rays.
We here adopt the model of an upward moving negative stepped lightning leader by Xu et al [GRL, 2012]. We simulate the generation and dynamics of free electrons, of photons with energies above 1 MeV, of positrons, neutrons and also protons with a three dimensional, relativistic Monte Carlo code. For the photons, we include photoionization, Compton scattering, Rayleigh scattering, electron-positron pair production and photonuclear processes. The last two processes are relevant for photon energies above 1 MeV or 8 MeV, resp.
We present the angular distribution and the energy spectrum of positrons and their temporal evolution. We will also present the energy spectra of neutrons and protons at production altitude and show how their energy dissipates.
The photon number and spectrum depends on the appropriate Bremsstrahlung processes, and we will show how the inclusion of electron-electron Bremsstrahlung affects the number and energy spectrum of photons and thus the number and energy spectrum of positrons, neutrons and protons.