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The generation of Biermann battery fields in laser-plasma interactions and the interplay with the Weibel instability

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Recent experiments with intense lasers are probing the dynamics of self-generated large scale magnetic fields with unprecedented detail. In these scenarios the Biermann battery effect is critical to understand the field dynamics but a multi-dimensional detailed study of this mechanism was not present yet in the literature. Moreover, the interplay between the Biermann battery effect and plasma micro instabilities and the evolution of plasma turbulence is still unknown. In this work, particle-in-cell simulations are used to investigate the formation of magnetic fields, B, in plasmas with perpendicular electron density and temperature gradients. For system sizes, L, comparable to the ion skin depth, d_i, it is shown that $\beta \sim d_i/L$, consistent with the Biermann battery effect. However, for large L/d_i , it is found that the Weibel instability (due to electron temperature anisotropy) supersedes the Biermann battery as the main producer of B. The Weibel-produced fields saturate at a finite amplitude (plasma $\beta \sim 1$), independent of L. The magnetic energy spectra below the electron Larmor radius scale are well fitted by power law with slope $-16/3$, as predicted in Schekochihin et al., Astrophys. J. Suppl. Ser. 182, 310 (2009).The relevance of these results for several ongoing experiments is also discussed.