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Modeling of proton acceleration in a shock in application to a ground level enhancement

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The origin of high-energy (>500 MeV) solar protons responsible for the so-called ground level enhancements (GLEs) has been a long-standing problem. Solar flares and shock waves driven by coronal mass ejections (CMEs) are considered as the possible sources of such particles. Accurate numerical simulations of the involved particle acceleration constrained by observations should help in solving the puzzle. Here we present simulations of proton acceleration in a CME-driven shock coupled with a recently developed semi-empirical model of the shock in the 17 May 2012 GLE event. The employed particle acceleration simulation model accounts self-consistently for proton interactions with Alfvén waves in the foreshock. The simulations were conducted for a number of individual magnetic field lines characterized by different plasma conditions. The simulations have shown that the shock portions having the highest values of the scattering-center compression ratio in this event can indeed accelerate protons to GLE energies. Analysis of the delays between the flare onset and the production times of 1 GV protons for different field lines in the simulations and a subsequent comparison of those with the observed values indicate a possibility that quasi-perpendicular portions of the shock play the main role in producing relativistic protons.