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Very High Energy Solar Protons in the Sun's Atmosphere and at Earth: Gamma Ray Flares and Ground Level Events

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For energetic particles produced at or near the Sun, it is generally recognized that at least two distinct acceleration mechanisms are operating: (1) acceleration at coronal sites of magnetic reconnection, generally associated with flares and (2) acceleration at shocks driven by fast coronal mass ejections (CMEs). It is also generally recognized that both mechanisms can accelerate protons to multi-GeV energies, although the precise ways in which this comes about is still an area of active research. Moreover, when a very large solar energetic particle (SEP) event is observed in interplanetary space, both a large flare and the launch of a fast CME are observed nearly simultaneously (unless the flare occurs behind a limb). Numerous studies have tried to sort out how these two energetic phenomena might contribute to the particles observed in interplanetary space. Are the flare-accelerated particles confined to closed field lines? Or do some of them "leak" to open field lines, thereby allowing them to contribute to the interplanetary SEPs? If so, how large is the flare contribution relative to particles accelerated by the CME-driven shock? To date, there is no consensus on any of these issues, particularly at the highest energies, where the release of particles from the neighborhood of the Sun generally persists for only a short period of time. We report on our efforts to quantitatively address these issues by comparing the total emission of >300 MeV protons in GLEs and in their associated gamma-ray flares. To our knowledge, direct quantitative comparisons have never before been done at these energies. We will illustrate our methods and results using the 2001 April 15 event. We will also discuss how this analysis can constrain hypotheses on the relative contributions of flares and CMEs to the high-energy SEPs observed in interplanetary space.