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## A statistical study of 90-MeV proton events observed with SOHO/ERNE

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To understand what kind of solar or interplanetary events are capable of producing solar energetic particle (SEP) events with proton energies  $> 90$  MeV, and where and when acceleration of such protons starts. We have selected 40 energetic proton events with intensities  $> 10^{-3} \text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1} \text{MeV}^{-1}$  at 93.8–94 MeV, detected by the Energetic and Relativistic Nuclei and Electrons (ERNE) instrument onboard SOHO during solar cycle 23, in 1997–2003. We have estimated the first injection times of the particles using two different methods, the fixed path length method (1.2 AU) and the velocity dispersion analysis. We evaluated the injection time results by comparing each to the estimated height of radio type II/IV burst emission, and then compared the estimated times and heights with related flare and coronal mass ejection (CME) characteristics. Results. We find that all the analysed proton events were associated with CMEs and 82% were associated with on-the-disk GOES X-ray flares (six of the seven non-associated were concluded to show behind-the-limb flaring). Radio type II/IV burst emission association was 95% (of the non-associated two events, one was completely void of radio emission and one showed metric continuum and tilted type III burst lane emission). Most of the first protons were injected when the CME leading edges were below 5 solar radii, and most of the protons reached their maximum intensity while the CMEs were above 10 solar radii. The maximum proton intensities were achieved much earlier than the possible passage of an interplanetary shock, suggesting that the majority of high-energy protons at 90 MeV were accelerated as a result of earlier processes. In roughly half of the events the CME front was above the estimated type II burst location. We suggest that in these cases the type II bursts may be related to CME interaction processes and shocks at the CME flanks.

### Collaboration

– not specified –

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