High-Energy Gamma-Ray Emission, Energetic Electrons and Solar Proton Events

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The available measurements of temporal behavior of high-energy gamma-ray emission from solar flares are discussed. Gamma-rays above 50 MeV are mainly due to the decay of pions produced by accelerated ions with energies greater than several hundreds MeV/nucl. Thus, this emission indicates the appearance of high-energy nuclei in the corona. CORONAS-F observations of the gamma-ray emission with the characteristic spectrum of pion decay process gave a unique opportunity to compare the acceleration time of protons with E_p >300 - 400 MeV to the release time of high-energy protons measured at ground level by the neutron monitor (NM) network. Proton arrival time to the Earth is consistent with the time of pion decay high-energy gamma-ray emission appearance at the Sun. There is a brief consideration of accelerated electrons characteristics which produce the primary electron bremsstrahlung. Energy spectra of 0.04-100 MeV interplanetary electrons originating from solar flare are compared with the electron bremsstrahlung. Energetic proton measurements obtained from the GOES and IMP-8 satellites as well as from ground based NM are compared with the GOES soft X-ray measurements of the associated solar flares for the period 1975-2005. A broad range of phenomenology relating proton events to flares is given. The time frequency and size distributions of the peak intensities of the SPEs have been obtained over the entire mentioned period. The statistical analysis indicates that the probability and magnitude of the near-Earth proton enhancement depends critically on the flare's importance and its heliolongitude. It was also found that the heliolongitude determines frequently the character of the proton event time profile. In addition to intensity, duration and timing proton events were found to be related to the other flare properties such as longer loop lengths. A statistical analysis of solar flares with gamma-ray emission measured by Solar Maximum Mission and proton events occurrence was performed.