Preliminary study on the LAT detection of Solar Neutrons

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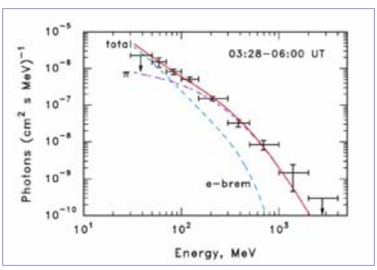
Abstract

GLAST LAT will detect several solar flares in gamma rays. Motivated by the CGRO results on neutrons emitted during a solar flare, we try to estimate the possibility of the LAT to detect solar neutrons. Besides gamma rays, neutrons could indeed interact in the LAT instrument and mimic a gamma-ray signal. An estimate of the contamination of gamma-ray detection in solar flares by the neutron component is given.

GLAST and solar physics

The solar activity could be monitored by LAT in conjunction with other instruments.

Solar activity is expected to rise in 2008 and peak as early as 2011.
GLAST is the only satellite capable of making solar observations of gamma-rays >30 MeV
Coordinated gamma-ray measurements with GBM (10 keV- 25 MeV) and RHESSI (1 keV – 20 MeV;
Comparison with solar energetic particle measurements on ACE, STEREO, SOHO, WIND and ground based neutron monitors, muon telescopes, Milagro
Ten's of high-energy flares will be observed.
~25% solar coverage (~60% with ToO)



The extraordinary solar flare of June 11, 1991 was the best example observed by EGRET. (Kanbach et al. 1993)

The importance of solar neutron measurements

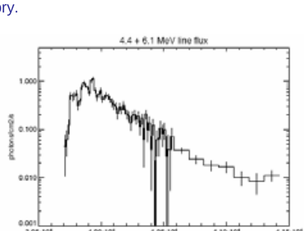
Gamma and neutron observations

They provide information about flare particle acceleration mechanisms.
Gamma and neutrons are produced by nuclear interactions of flare accelerated protons and ions with the solar atmosphere.
They yield direct information on flare particle energy spectrum and angular distribution.
(e.g Hua and Lingenfelter 1987)

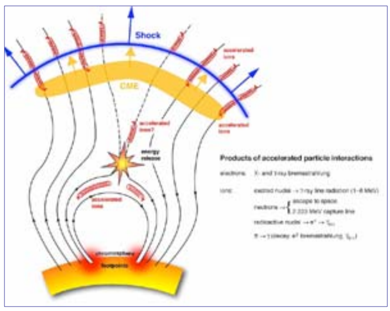
Spectra and angular dependence of solar neutron theoretical models calculated based on n-production cross section and propagation effects.

Solar neutron spectra in the simulation

The 4.4 + 6.1 MeV deexcitation line time history for the 2003 Oct 28 flare observed by INTEGRAL and RHESSI used to represent the ion acceleration time history.



The neutron spectra were calculated with parameters derived from the gamma-ray data available for this flare. The accelerated ion spcetral index was 3.85.



CGRO results

EGRET gamma observations

EGRET observed very intense flares that occurred in June 1991. The emission continued for several hours, and photons with energies ranging up to 2 GeV were detected (Kanbach et al. 1993; Schneid et al. 1993;) The long durations and persistence of the high energy emission led to speculation that particles either were impulsively accelerated and then efficiently stored in the loop, or they were accelerated for several hours. Spectral features suggest that both primary electrons and protons were involved.

COMPTEL gamma and neutron observations

The COMPTEL telescope could perform neutron imaging and spectroscopy in the energy range 10 – 120 MeV (McConnell 1994, Ryan et al 1994, Toner et al. 2001) These measurements showed that the neutron emission followed the impulsive flare phase.

OSSE gamma and neutron observations

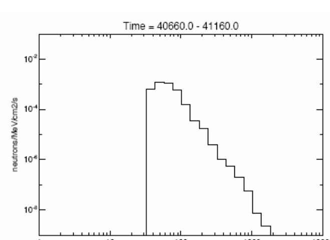
OSSE was sensitive to gamma rays and neutrons to > 150 MeV. Murphy et al. (2007) showed evidence that the accelerated ion spectrum in the 1991 June 4 flare was not an unbroken power law but rolled over at ~125 MeV per nucleon.

GLAST simulations

Simulation of solar neutrons detection

A complete simulation of the LAT detection was setup using the complete LAT simulation chain.
A neutron spectral source was created with the derived temporal and spectral evolution.
Neutron are propagated through the LAT using G4 MC. The data collected by the LAT are analyzed with standard GLAST LAT tools

One of our objectives of this work is to derive information on solar neutrons in addition to removing them from the sample of gamma-ray events. .



Example of the calculated neutron spectrum arriving at the detector for the October 28 flare. The accumulation time (UT sod) is given at the top.

Gamma-ray emission by the Sun

It is known that solar flares produce gamma rays with energies greater than several MeV. The production of gamma-rays is understood to involve flare-accelerated charged-particle interactions with the ambient solar atmosphere (see, e.g., Ramaty & Murphy 1987; Hua & Lingenfelter 1987). Bremsstrahlung from energetic electrons accelerated by the flare or from the decay of $\pi^{\pm}$ secondaries produced by nuclear interactions yields gamma rays with a spectrum that extends to the energies of the primary particles. Proton and heavy ion interactions also produce gamma rays through π^0 decay, resulting in a spectrum that has a maximum at 68 MeV and is distinctly different from the bremsstrahlung spectrum.

The processes that accelerate the primary particles are not well known. Two that have been discussed frequently in the literature are stochastic acceleration through MHD turbulence and shocks (Ryan & Lee 1991; Forman et al. 1986). Particle acceleration is thought to occur in association with large magnetic loops that are energized by flares. For most flares the particles are trapped in a loop and their interactions near the loop footpooint generate gamma rays (Mandzhavidze & Ramaty 1992a,b).

GLAST contribution

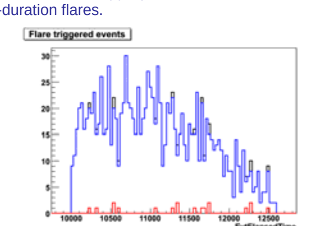
GLAST and gamma-ray observation of solar flares

GLAST will contribute in several ways to resolving the questions about where the acceleration takes place and the processes involved. For large flares with high energy emission extending to 1 GeV, GLAST will be able to image the interaction sites to less than 5´. Typical flares show footpoint separations from 10" to ~90". Imaging the gamma rays with larger error boxes may not determine whether they are extended or point-like. The ability to obtain the centroid of the emission to smaller error boxes can determine whether the high-energy emission is concentrated near the footpoints.

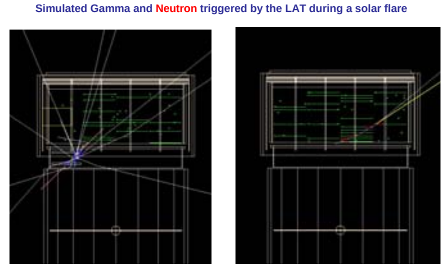
GLAST's sensitivity to much smaller solar events will reveal if they produce the same long duration emission as the large events.

LAT's sensitivity and dynamic range offer significant improvements for studying flare spectra and their time evolution. Electrons with energies as great as 50 MeV are not uncommon, but the emission from these particles tends to be short-lived in many flares. The gamma-ray spectrum in this case is a power law from bremsstrahlung interactions. A sharp break in the spectrum would be strong evidence for an acceleration mechanism involving electric fields.

If protons are accelerated, the spectra will have evidence of a π^0 bump at 68 MeV. Since the rate of energy loss by electrons is much larger than for protons, the relative time scales of electron and π^0 spectral variations indicates whether trapping or extended acceleration is responsible for long-duration flares.



Simulated Gamma and Neutron triggered by the LAT during a solar flare



Examples of neutron interacing in the LAT calorimeter and the LAT tracker

Work in progress

Better evaluation of neutron LAT response
Development of LAT data analysis chain of solar neutron
Correlation with gamma-ray flare analysis.