Impulsive High-Energy Particle Acceleration in the SOL2010-06-12T00:57 M2 X-ray Flare

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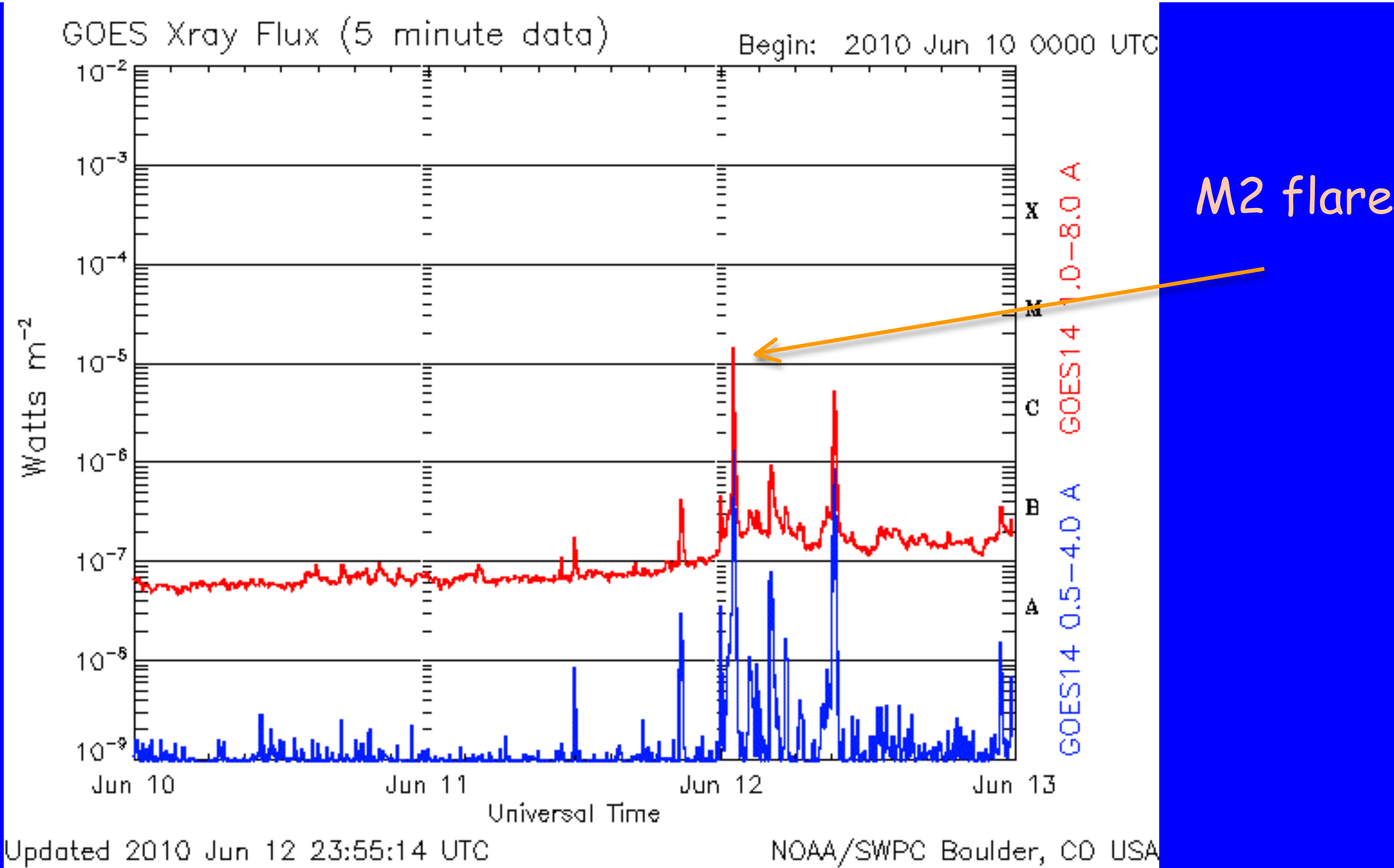
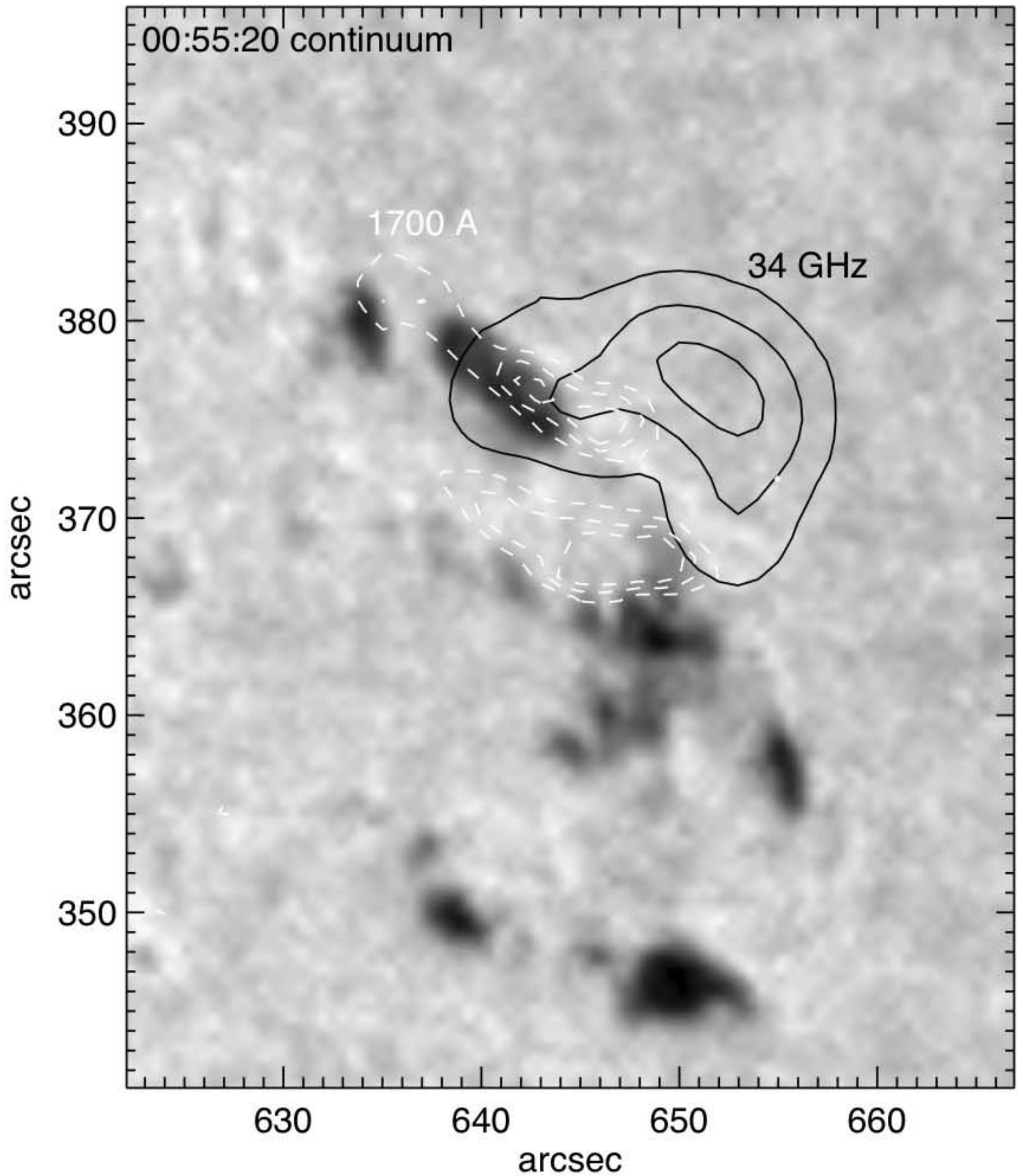
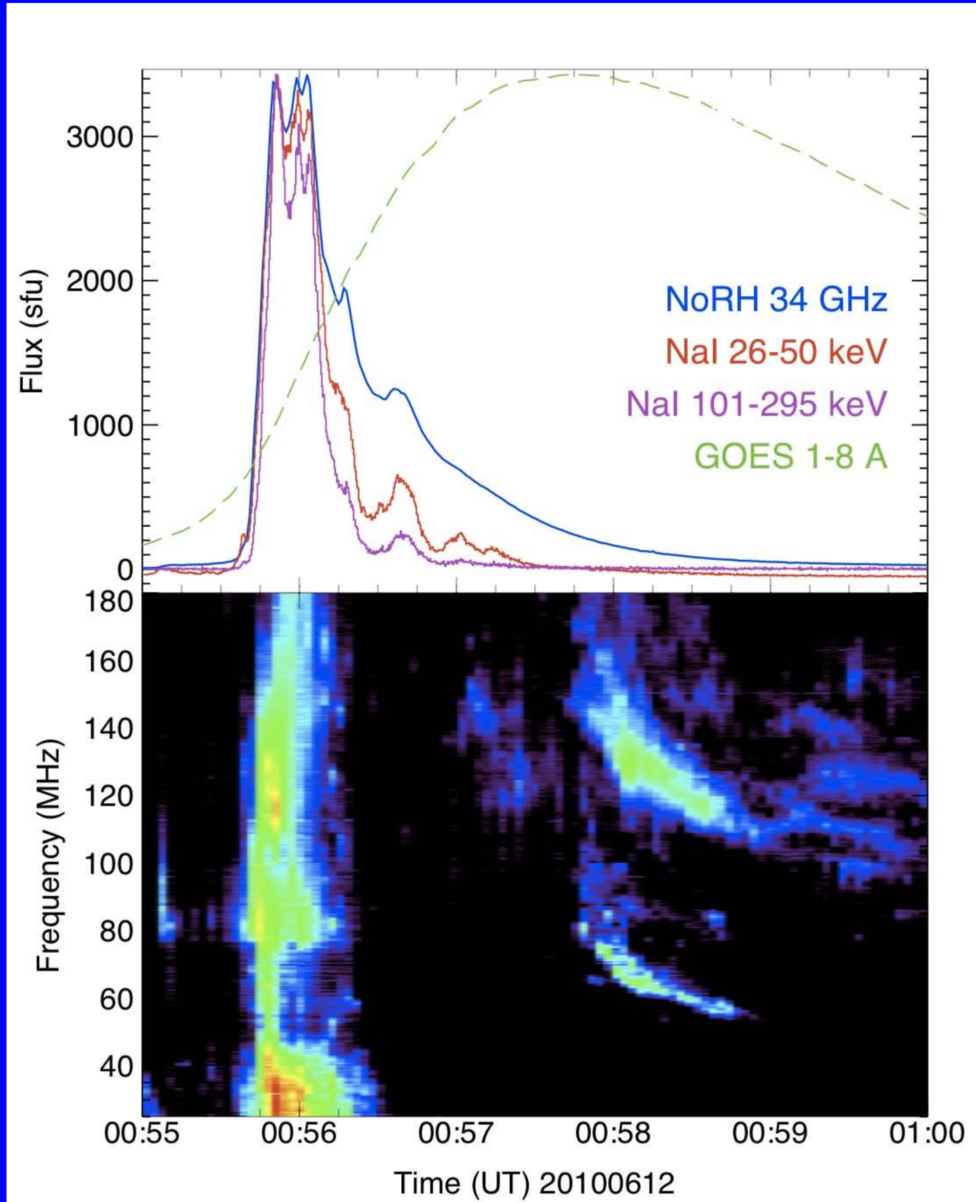


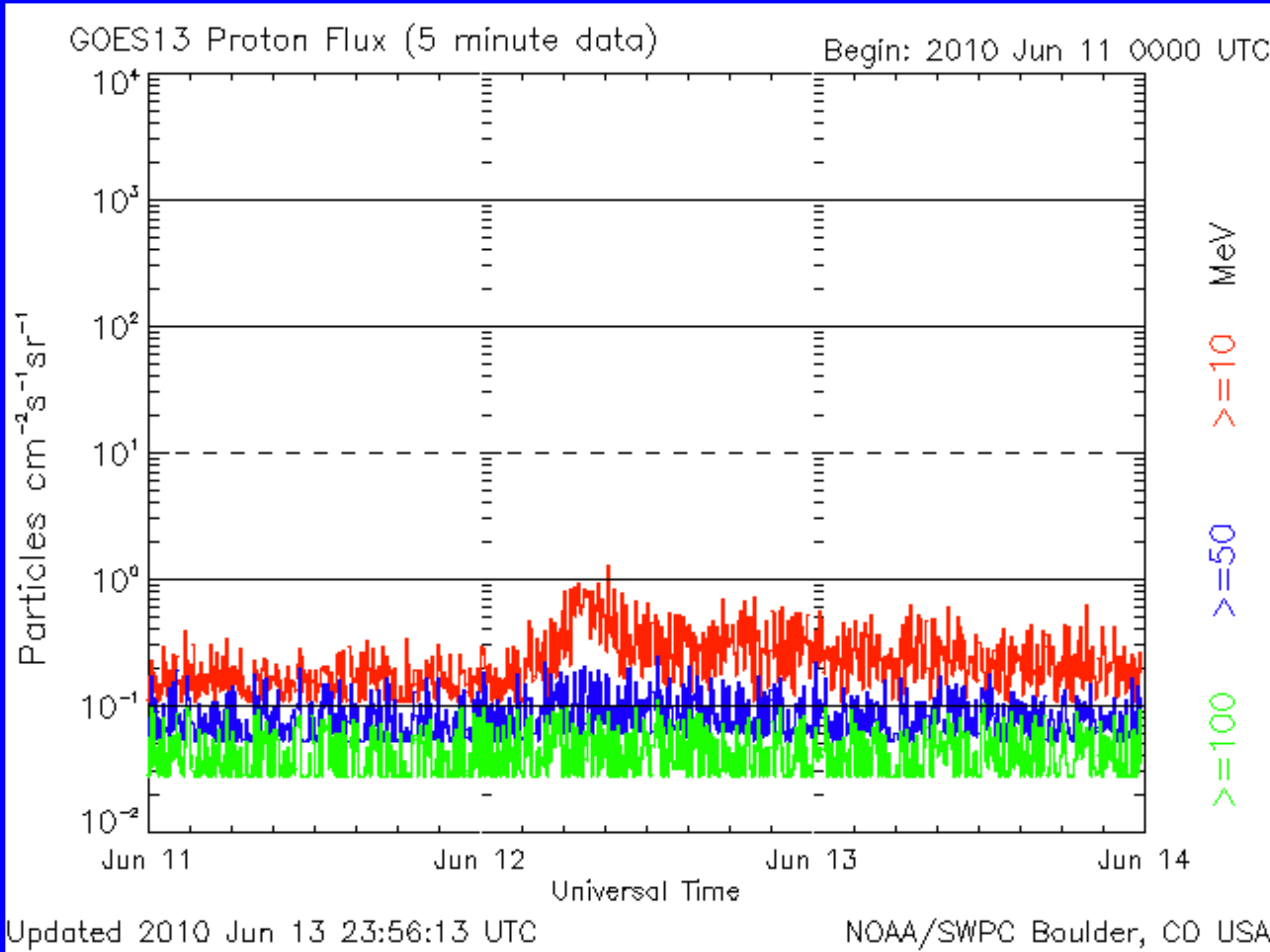
GOES soft X-ray rates on June 12, 2010

SDO HMI continuum with 1700 A and Nobeyama 34 GHz images over plotted. (Credit Stephen White et al. in preparation) suggest a compact loop length of ~10^4 km.

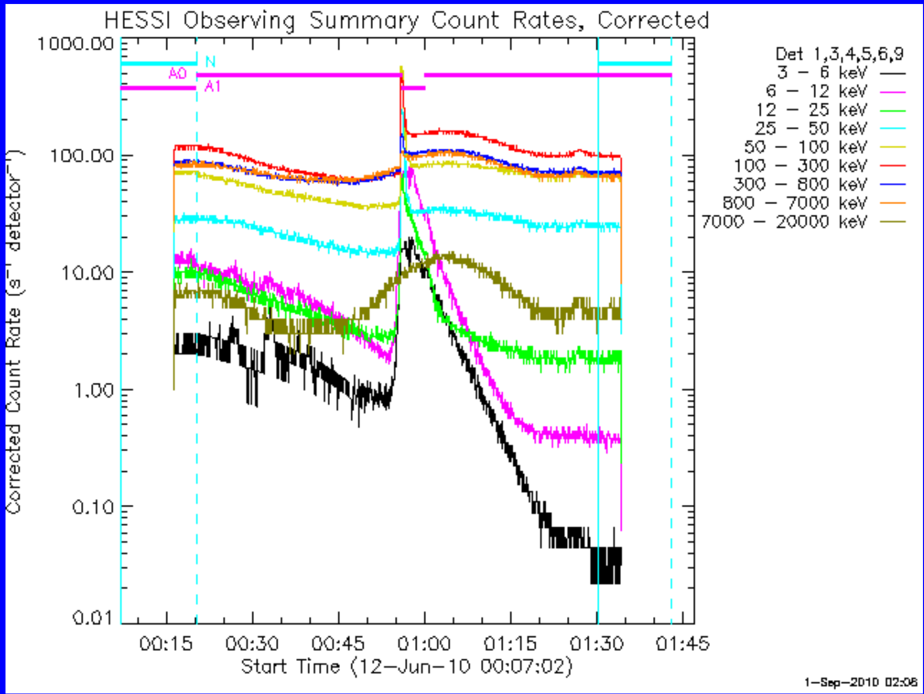


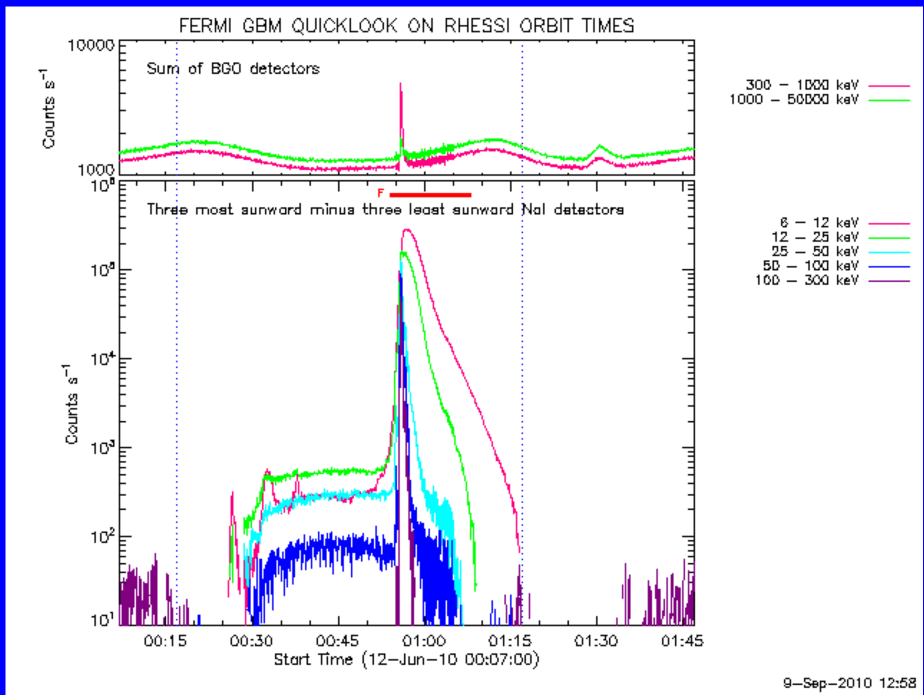
Microwave, GOES, and GBM NaI time profiles (top panel). Radio observations revealing type III (electron ejection) and type II (shock formation). (Credit Stephen White et al. in preparation)





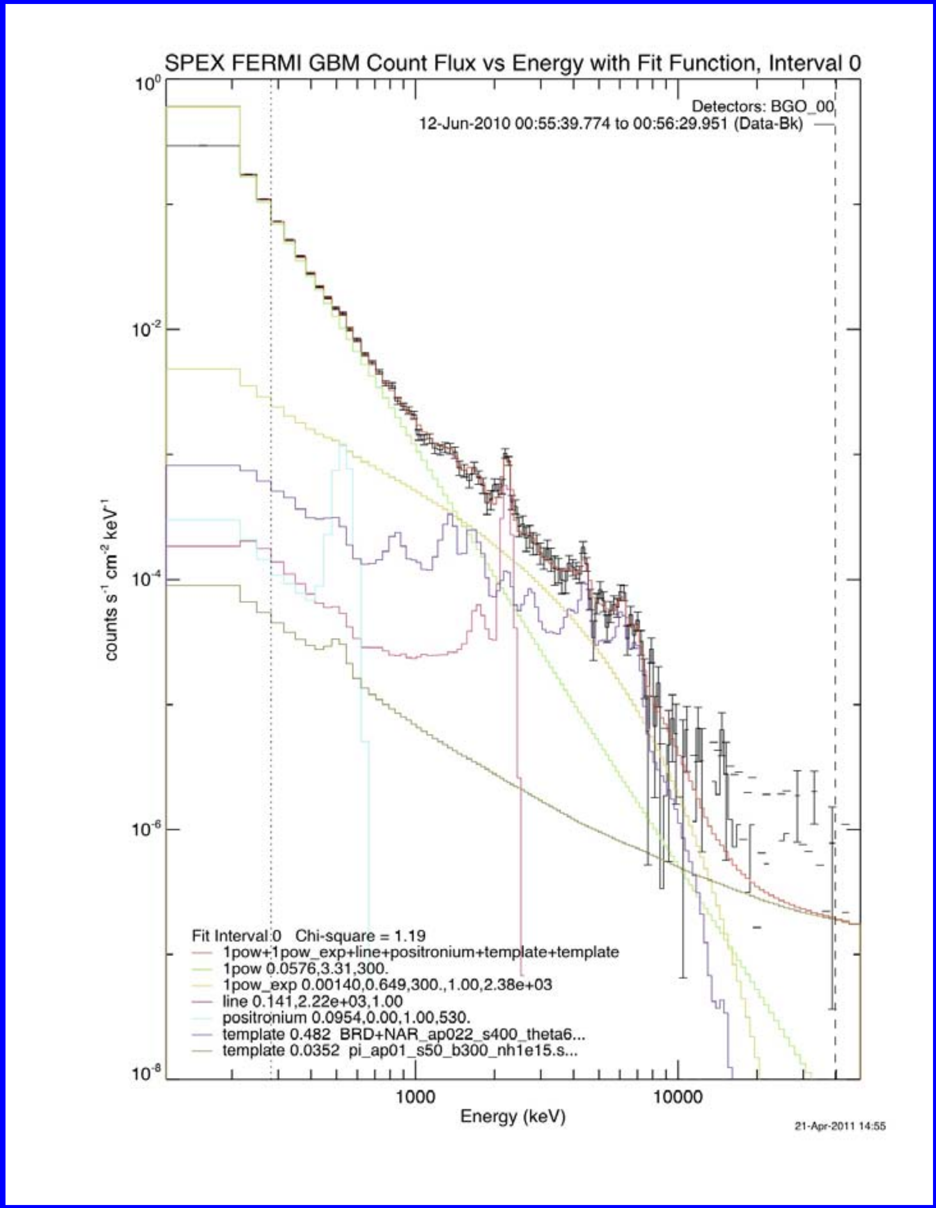
The 43 W location of the flare was magnetically well connected to Earth and there was a relatively weak SEP event with proton energies >50 MeV observed by GOES.



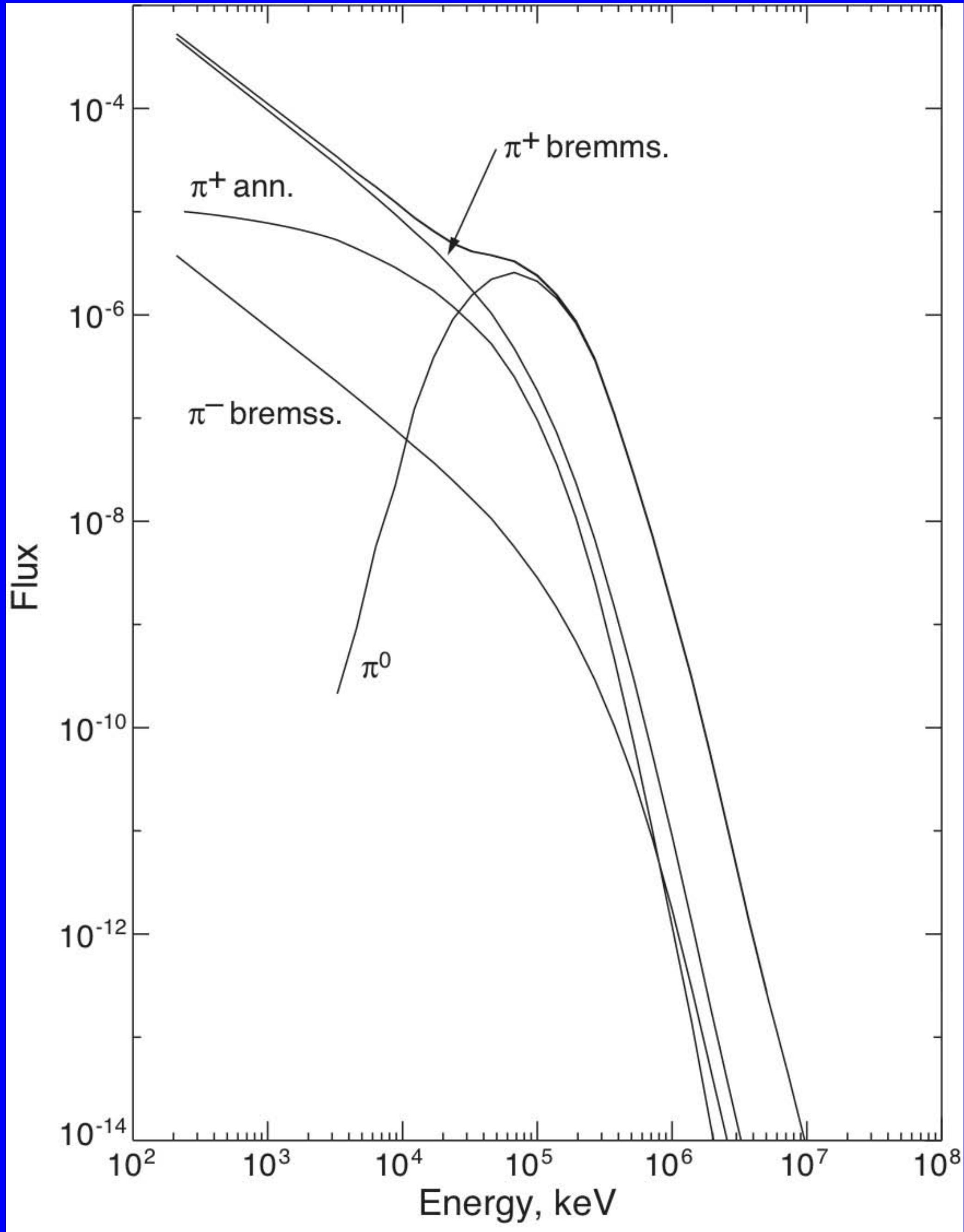


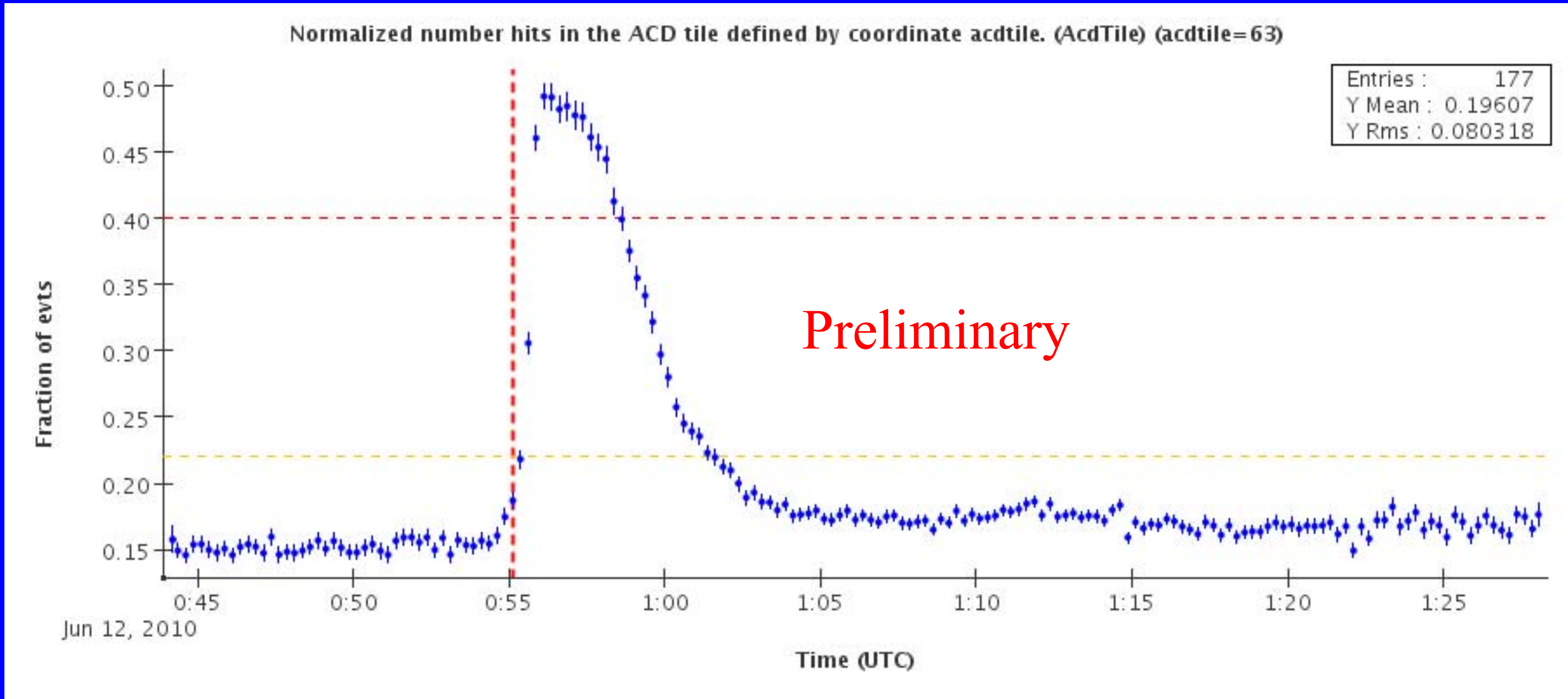
The flare was observed by both the RHESSI and Fermi GBM experiments. RHESSI was off-pointed performing a Crab Nebula observation. This affected knowledge of the detector response to the flare and prevented imaging.

50s background-subtracted GBM/BGO spectrum was fit by a sum of a PL + PL*exp bremsstrahlung component, a nuclear de-excitation line component, Gaussian lines at 511 and 2223, and a pion-decay component.
(OSPEX fit thanks to Richard Schwartz and Kim Tolbert)

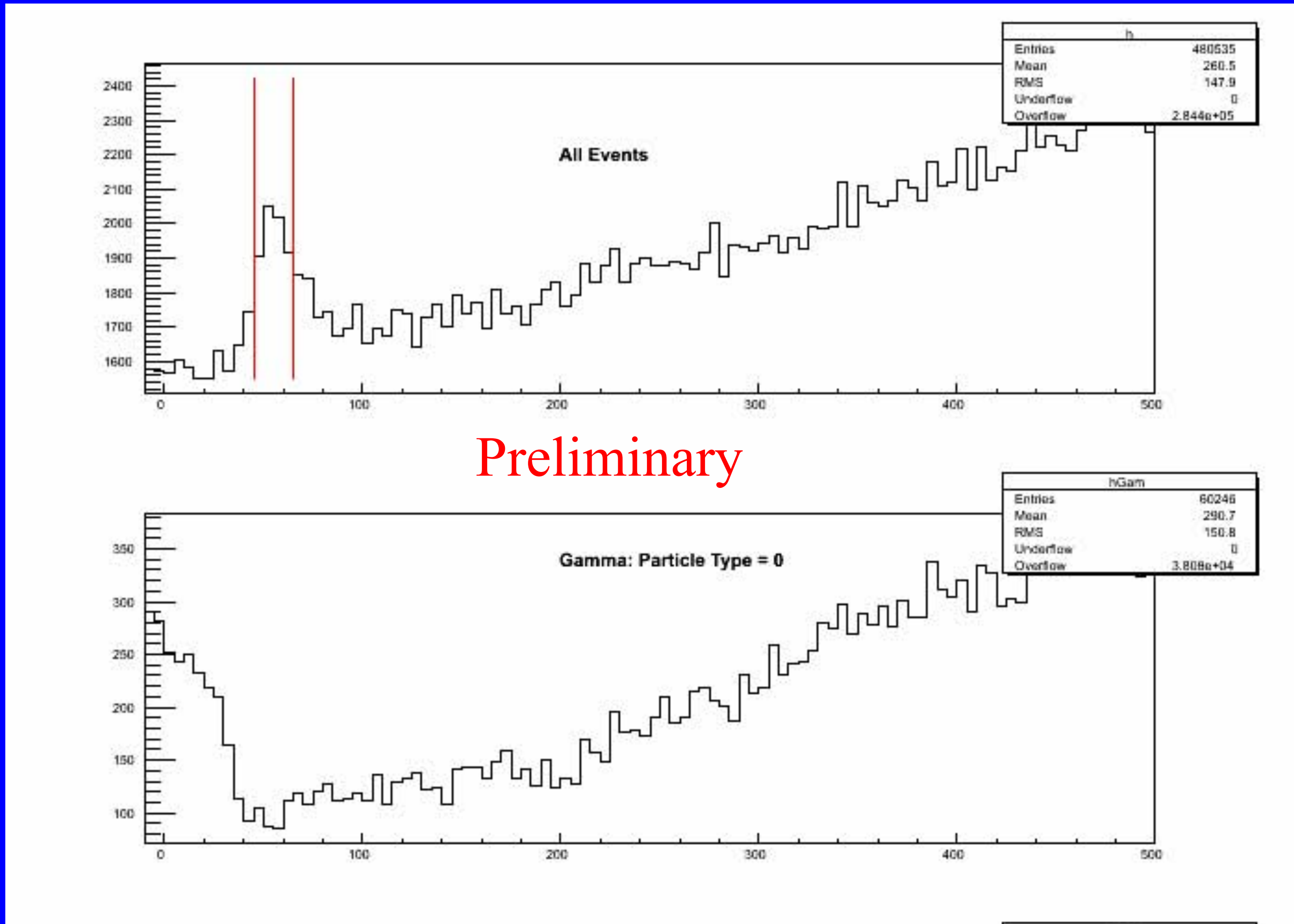


Calculated pion-decay spectrum derived from Murphy, Dermer, & Ramaty (1987) showing the contributions from neutral and charged pion decays. The neutron pion decay peak at ~70 MeV becomes dominated by both bremsstrahlung and annihilation in flight of positrons from positive pion-decays.



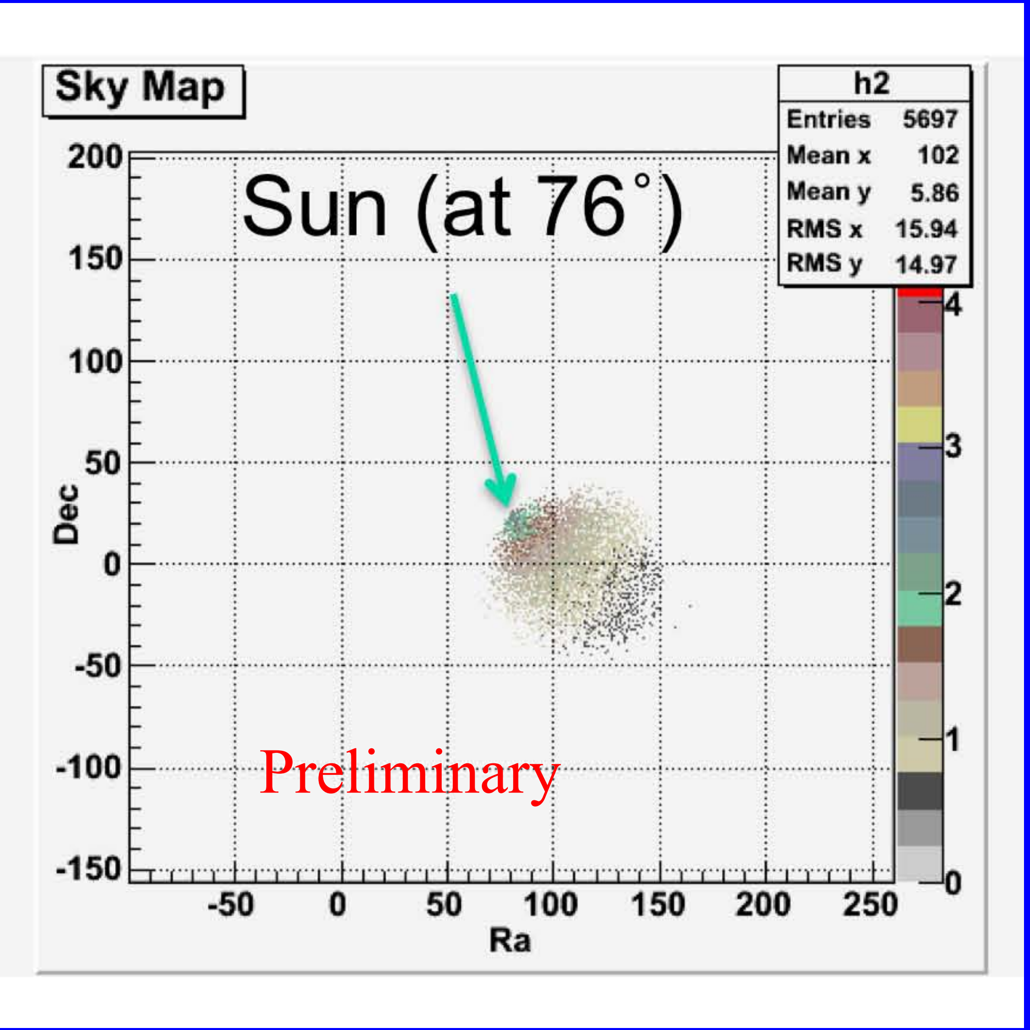


LAT anticoincidence rate >100 keV responding to solar flare hard X-rays (pulse pileup).

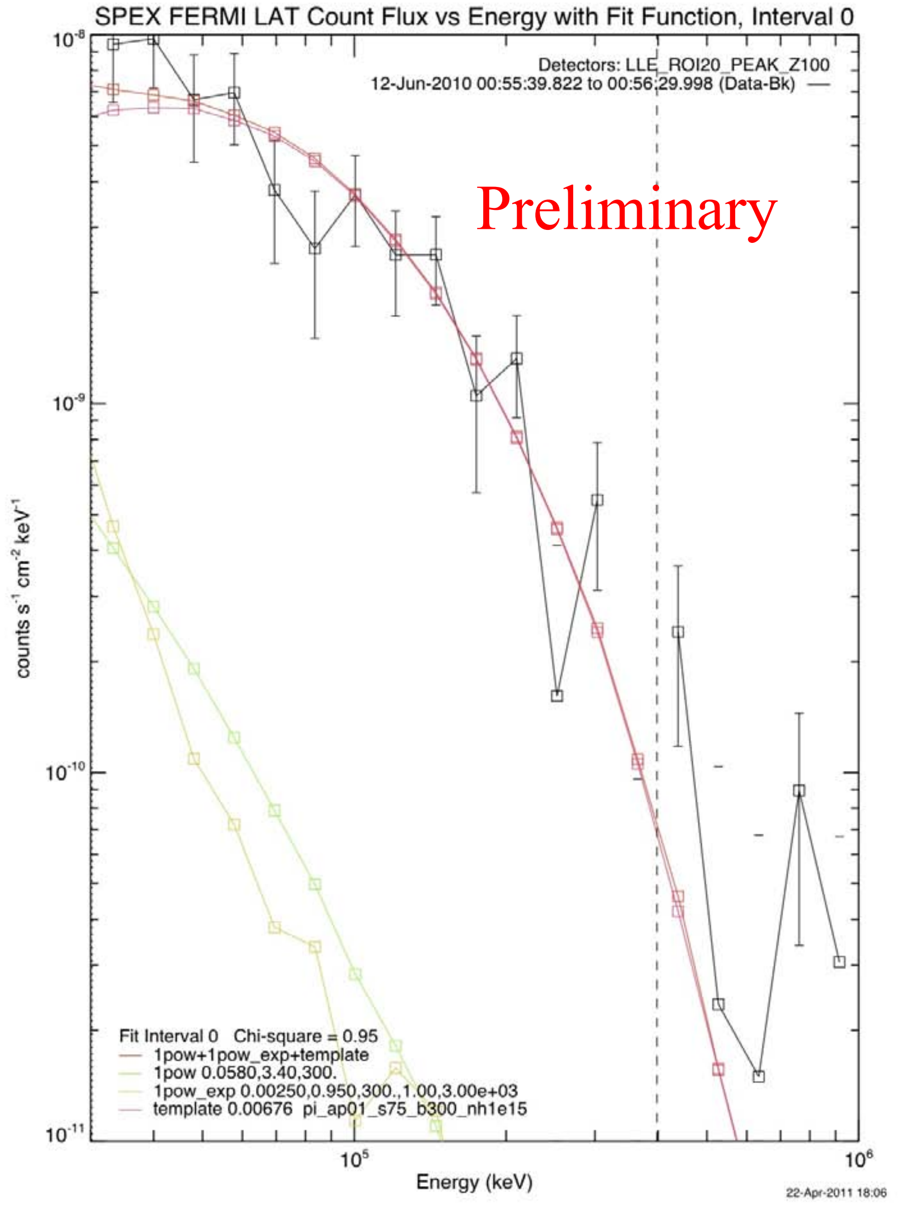


Flare was detectable in the total LAT event rate (top) but not in P6 and P7 data screened for ACD events.

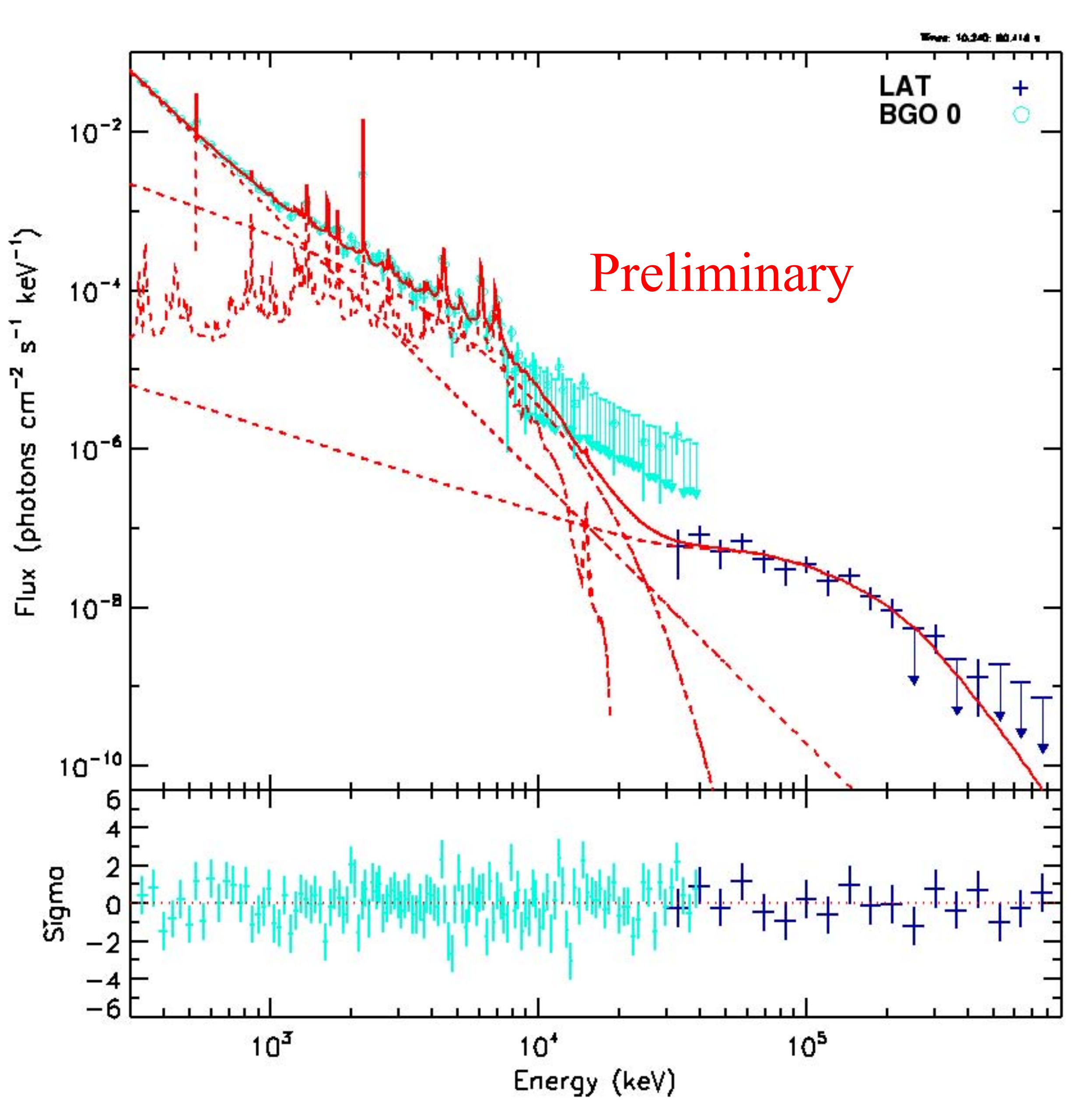
LAT Low Energy (LLE) technique enables study of the flare. LLE developed initially for bursts. Much work done to verify its reliability, detector response, etc. The ability to localize the source at the Sun provides confidence of the solar origin of the LAT emission. LLE will be discussed in other presentations.



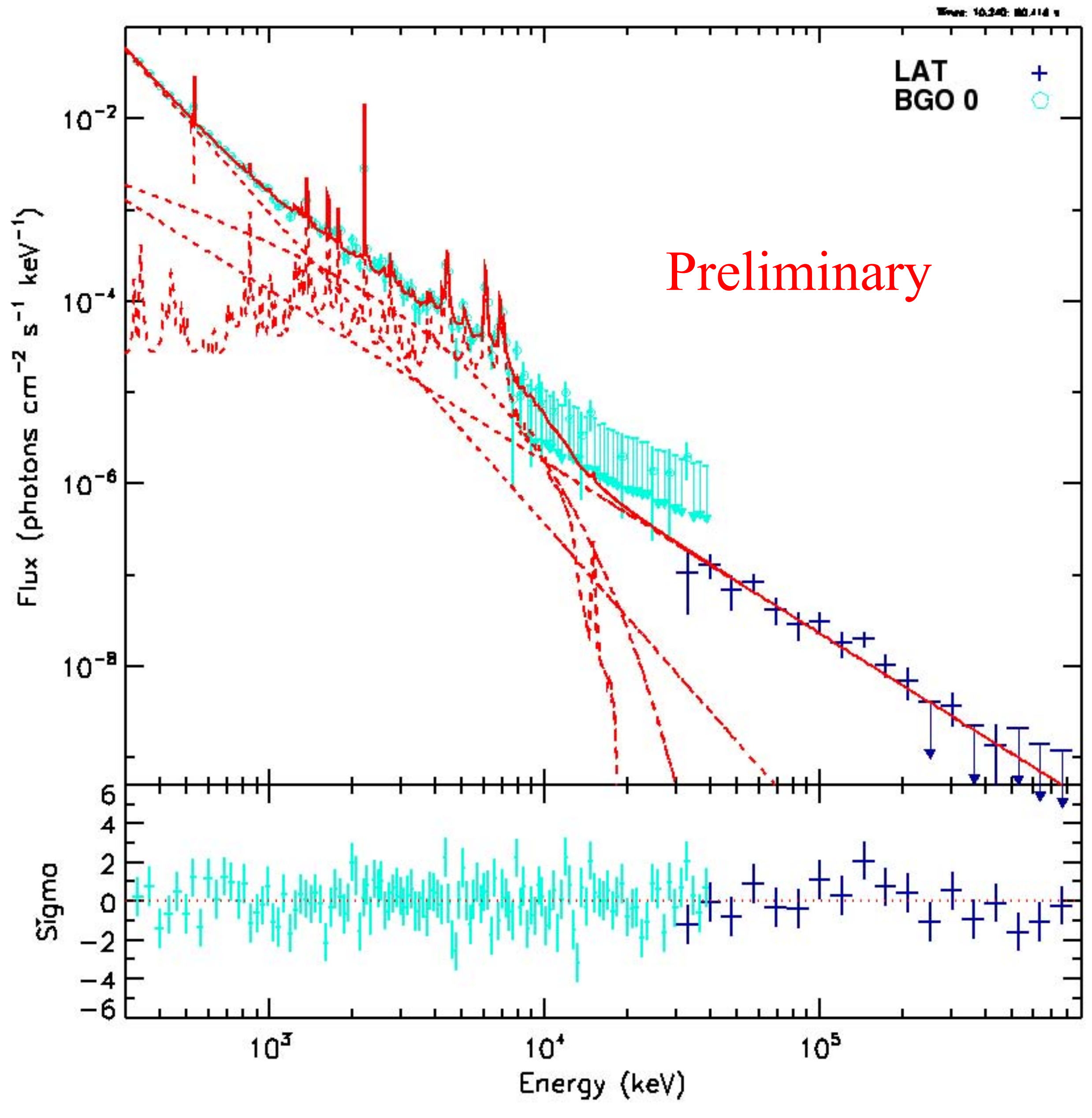
OSPEX fit to the LAT spectrum derived by N. Omodei over the 50s impulsive phase. The emission was fit with a pion-decay model. The fit indicates that the >300 MeV proton spectrum at the Sun was softer than a power law with index -4.5. Also shown are extensions of the GBM continua into the LAT energy range.

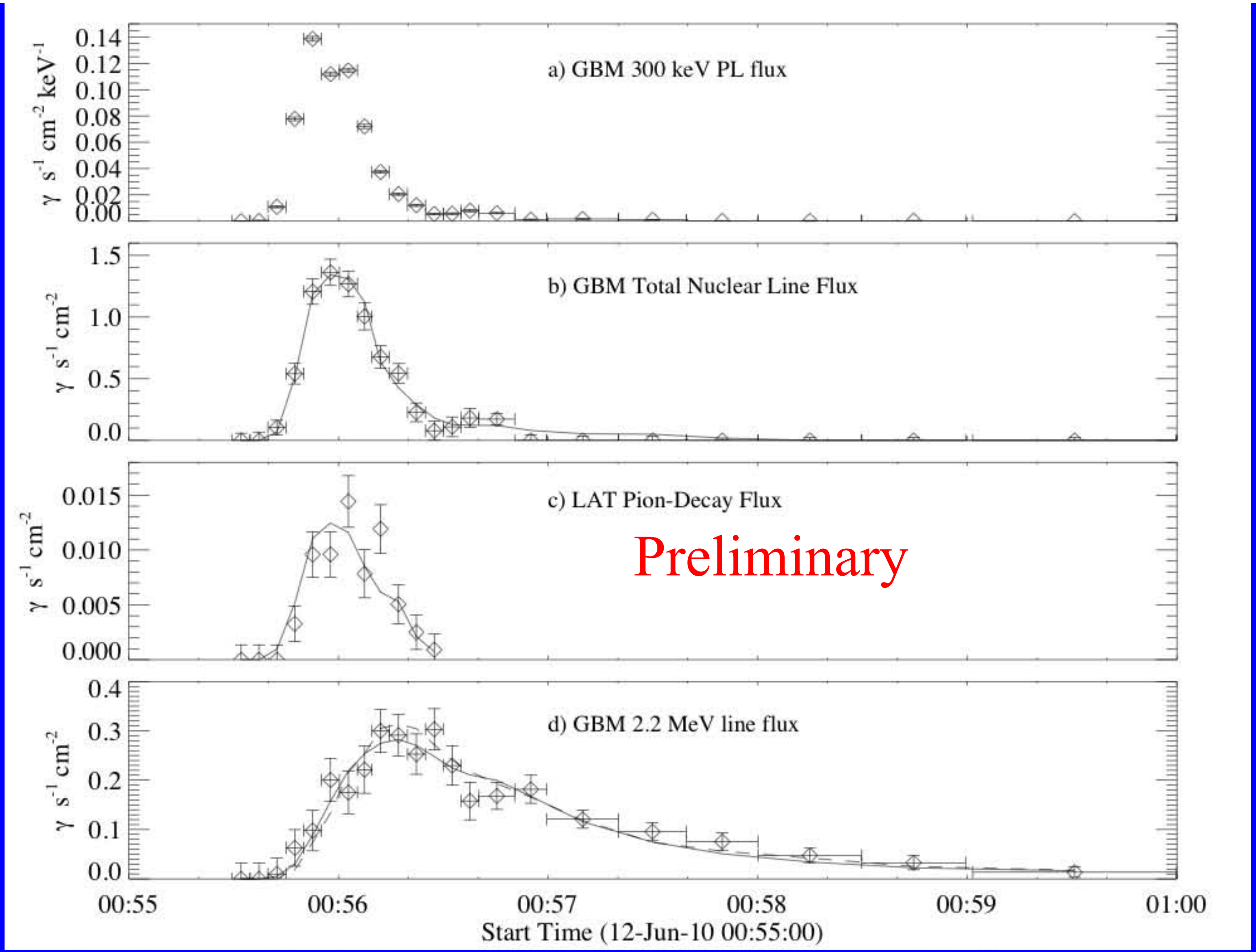


Joint fit of the GBM and LAT data using Rmfit (Michael Briggs, David Gruber, & Nicola Omodei) that agrees with fits done separately on the LAT and BGO detectors using OSPEX. Extension of the pion decay spectrum to the GBM range is too weak to be detected.



Joint fit LAT and GBM data using a power law to fit the LAT data. We cannot distinguish between a PL and pion-decay model for the emission. Neither would have been detectable by the GBM.





Time profiles of the low-energy bremsstrahlung, GBM total nuclear, LAT pion decay flux, and GBM 2.2-MeV line with fitted models over plotted (Ron Murphy).

SUMMARY

The M2-class solar flare, SOL2010-06-12T00:57, was modest in many respects yet exhibited remarkable acceleration of energetic particles.

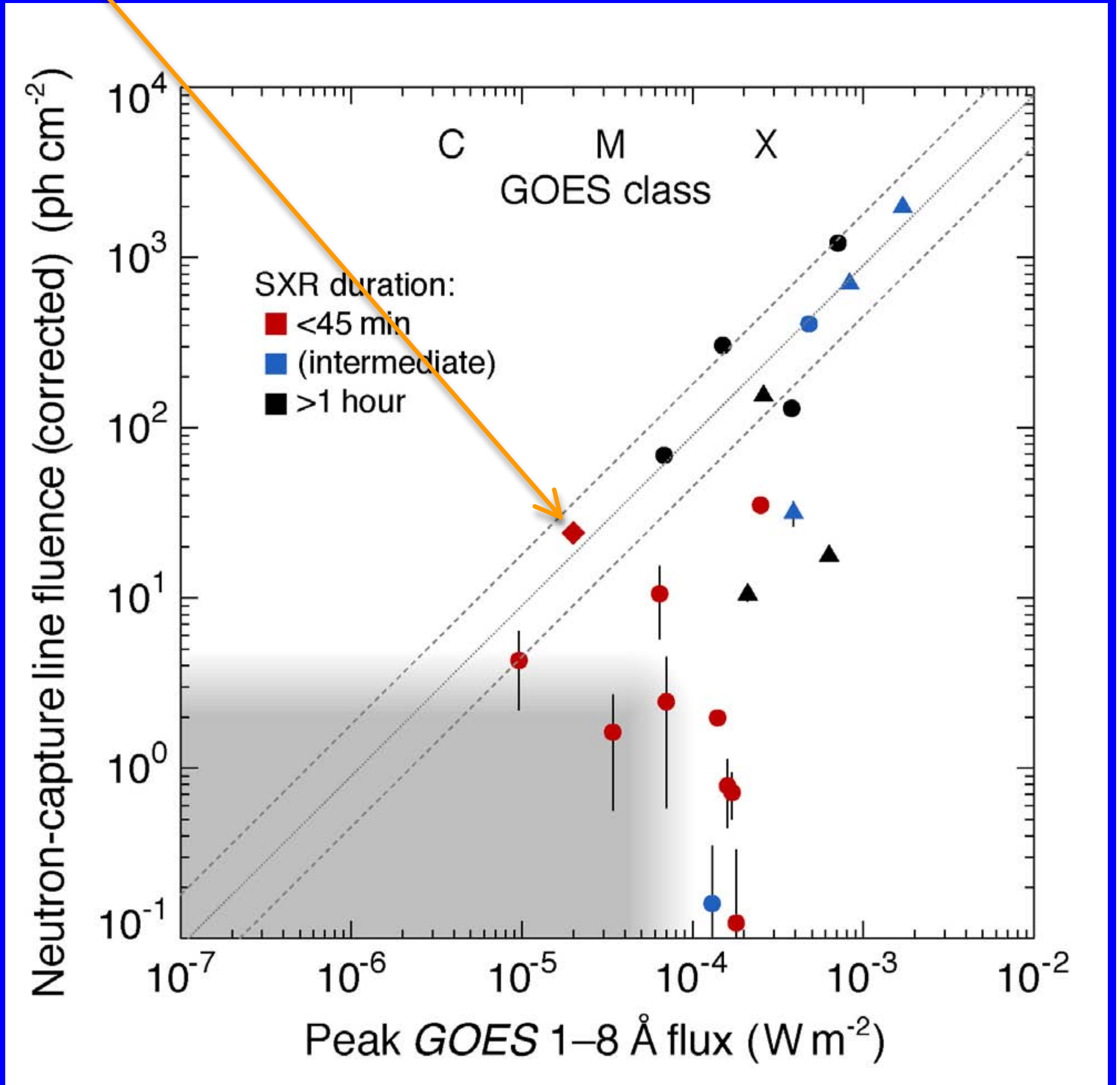
The flare produced an ~50 s impulsive burst of hard X-and gamma-ray emission up to at least 400 MeV.

The gamma-ray line fluence from this flare was about ten times higher than that typically observed from this modest class of X-ray flare.

Analysis of the combined nuclear line and high-energy gamma-ray emissions suggests that the accelerated proton spectrum at the Sun softened from a power-law index of ~-3.2 between ~5-50 MeV, to ~-4.5 between ~50-300 MeV, to one softer than ~-4.5 >300 MeV (Preliminary).

June 12 flare

GOES M2 X-ray flares are not normally prolific producers of gamma-radiation as shown by this correlation plot of RHESSI 2.2 MeV line fluence vs GOES class. (Credit Shih et al. 2009)



June 12 flare emission consistent with the correlation between >300 keV bremsstrahlung fluence and 2223 keV line fluence found in studies of SMM and RHESSI data (e.g. Shih et al. 2009)