

# Comparing Solar-Flare Acceleration of $>\sim 20$ MeV Protons and Electrons Above Various Energies

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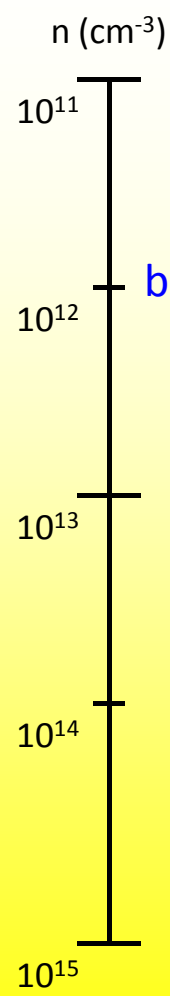
<sup>2</sup>SSL, UC Berkeley

# Gamma rays



electrons

protons,  
alphas,  
heavy ions



bremsstrahlung

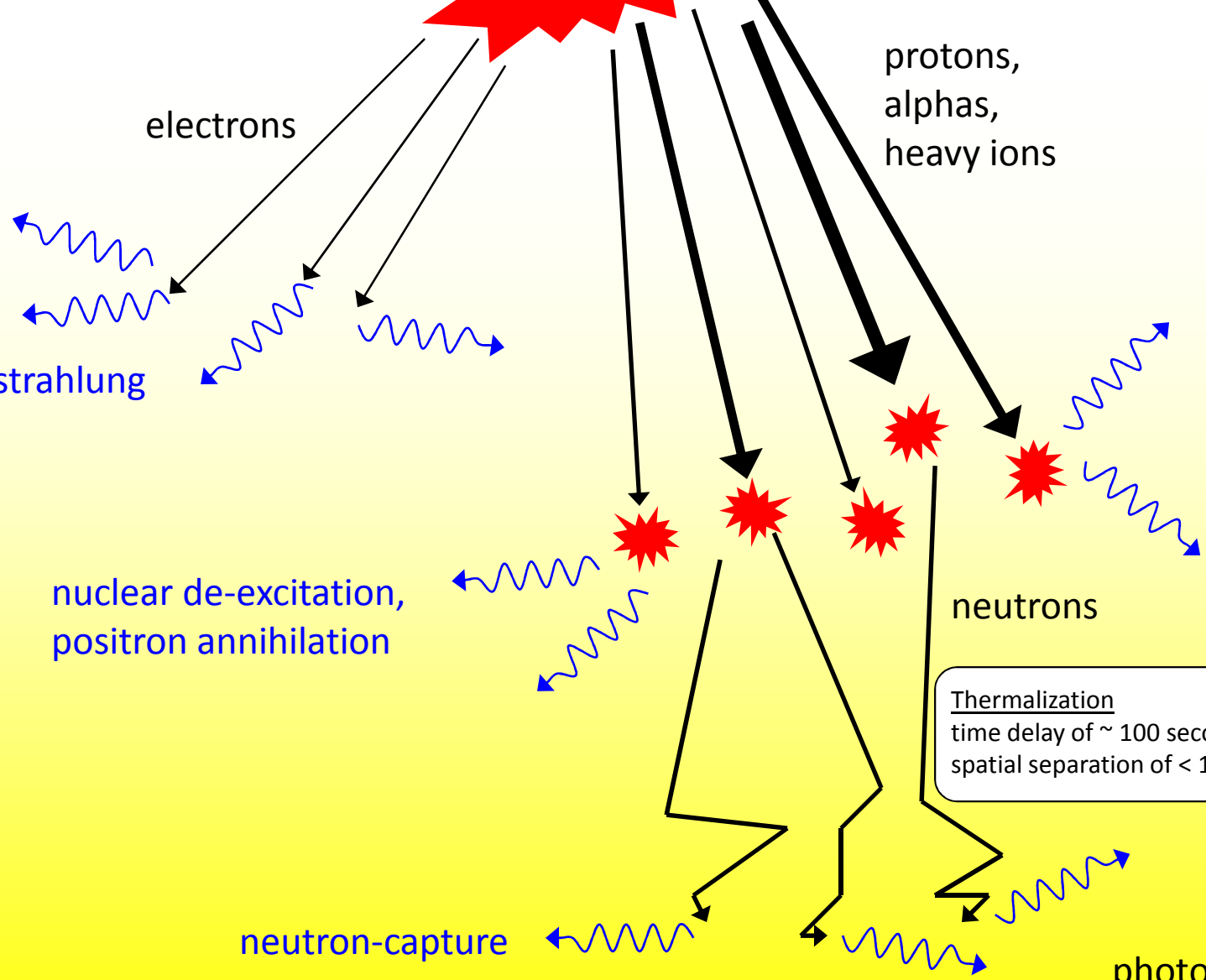
nuclear de-excitation,  
positron annihilation

neutrons

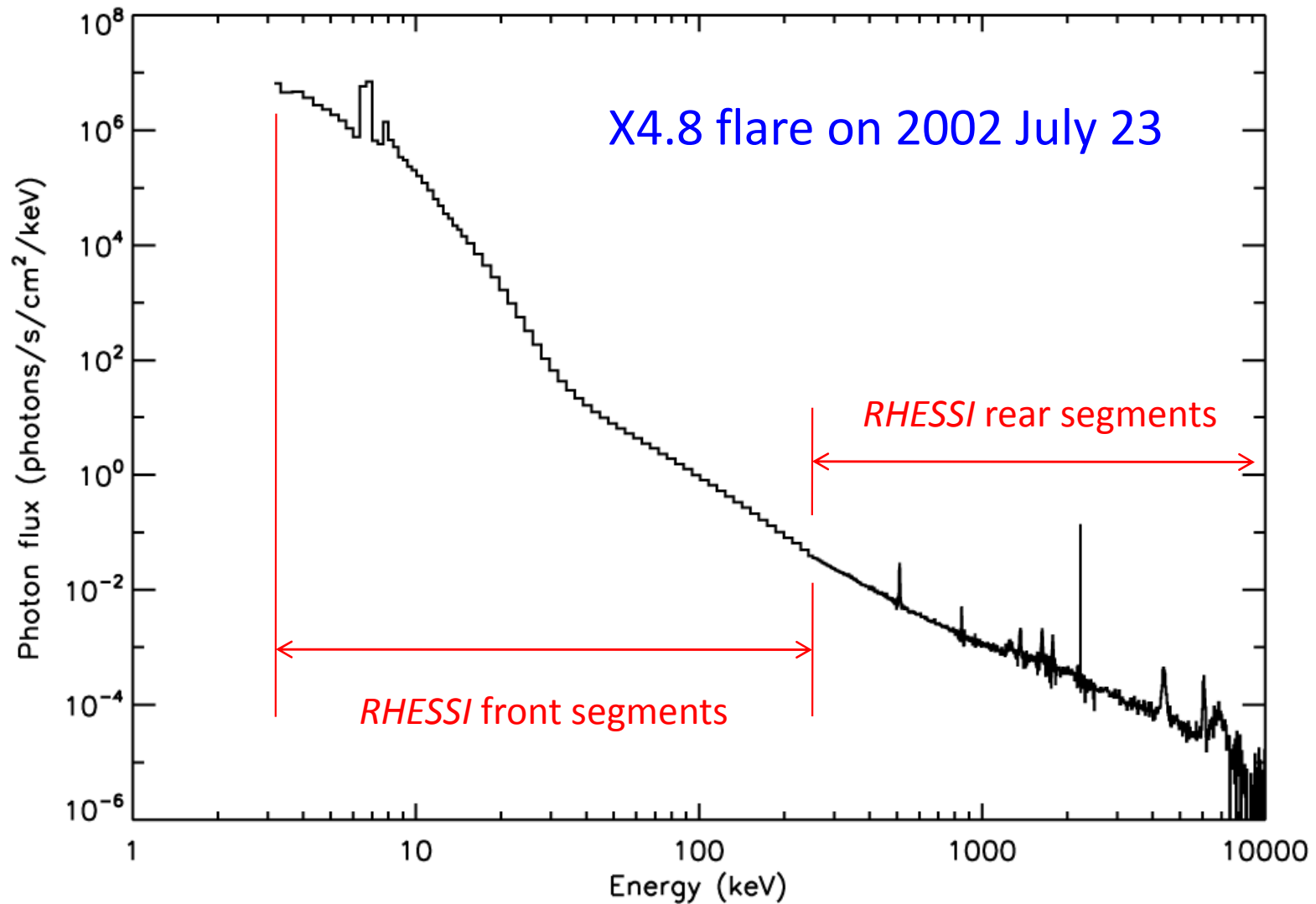
Thermalization  
time delay of ~ 100 seconds  
spatial separation of < 1 arcsec

neutron-capture

photosphere



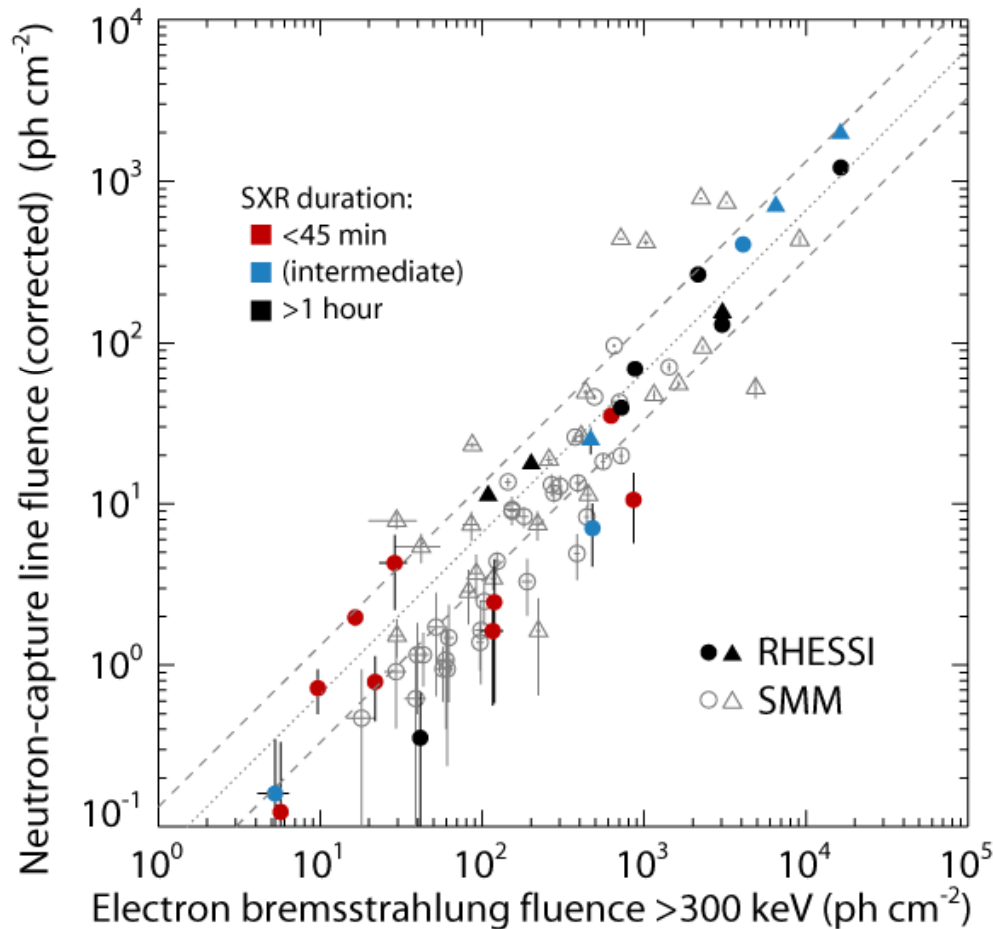
# Composite photon spectrum



# Comparing ions and electrons

- Do all flares accelerate ions and electrons?
- Flare-acceleration models do not typically predict a constrained ratio of ion and electron acceleration
- Use ion-associated and electron-associated emissions as measures of particle acceleration
- Observations from *RHESSI* and *SMM/GRS*

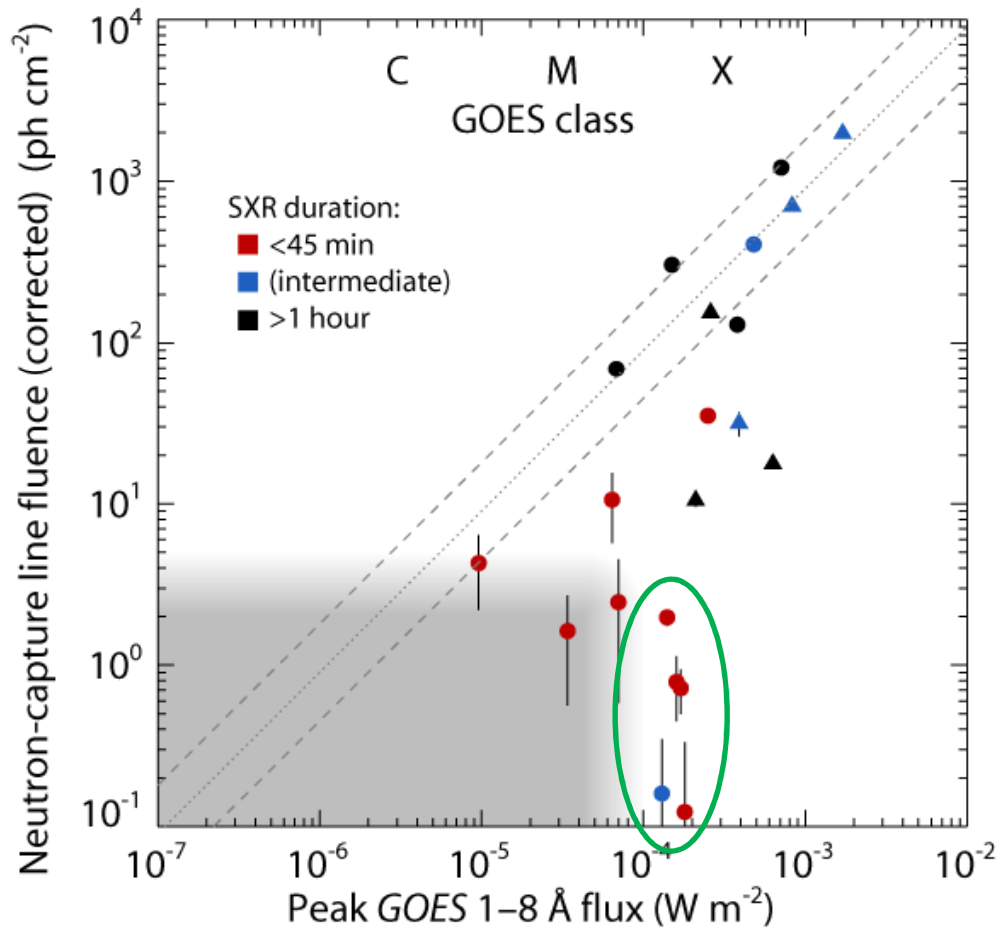
# Versus $>300$ keV electrons



(Shih et al. 2009, *ApJL*)

- Direct proportionality
- Dotted lines are factors of 2 from the best-fit line
- Some spread is due to incomplete coverage (triangles)
- Almost all flares fall within  $1\sigma$  of spread

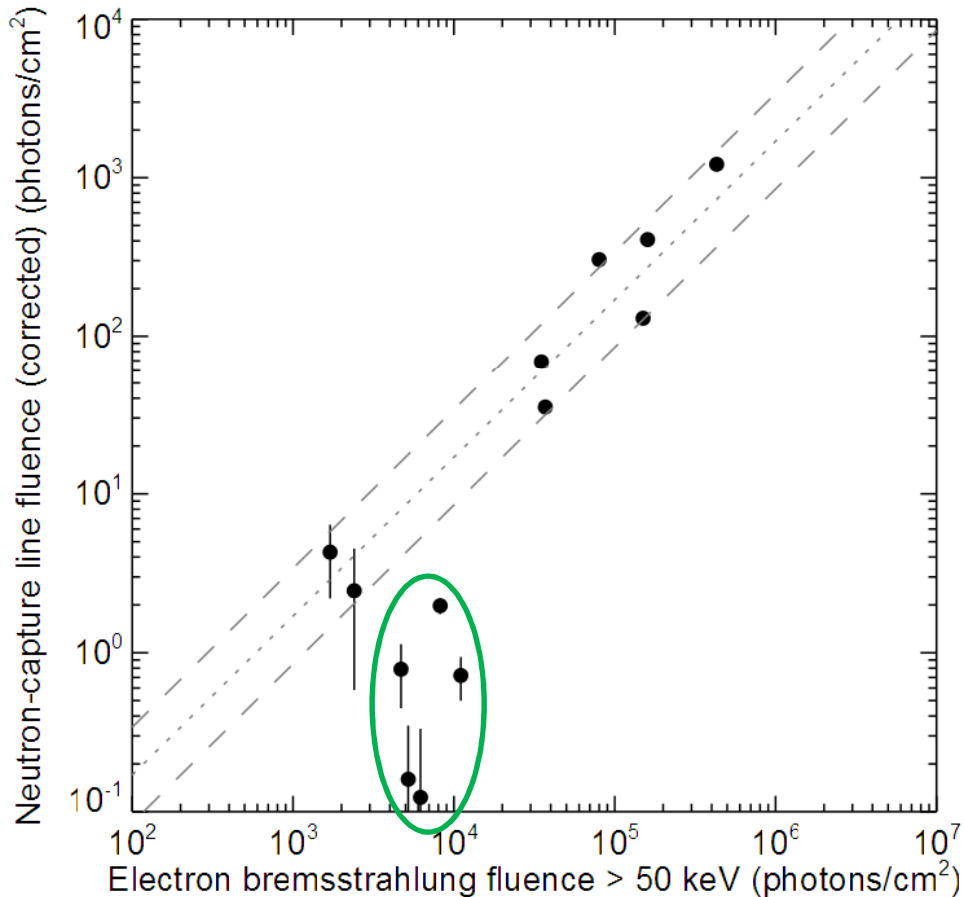
# Versus thermal emission



(Shih et al. 2009, *ApJL*)

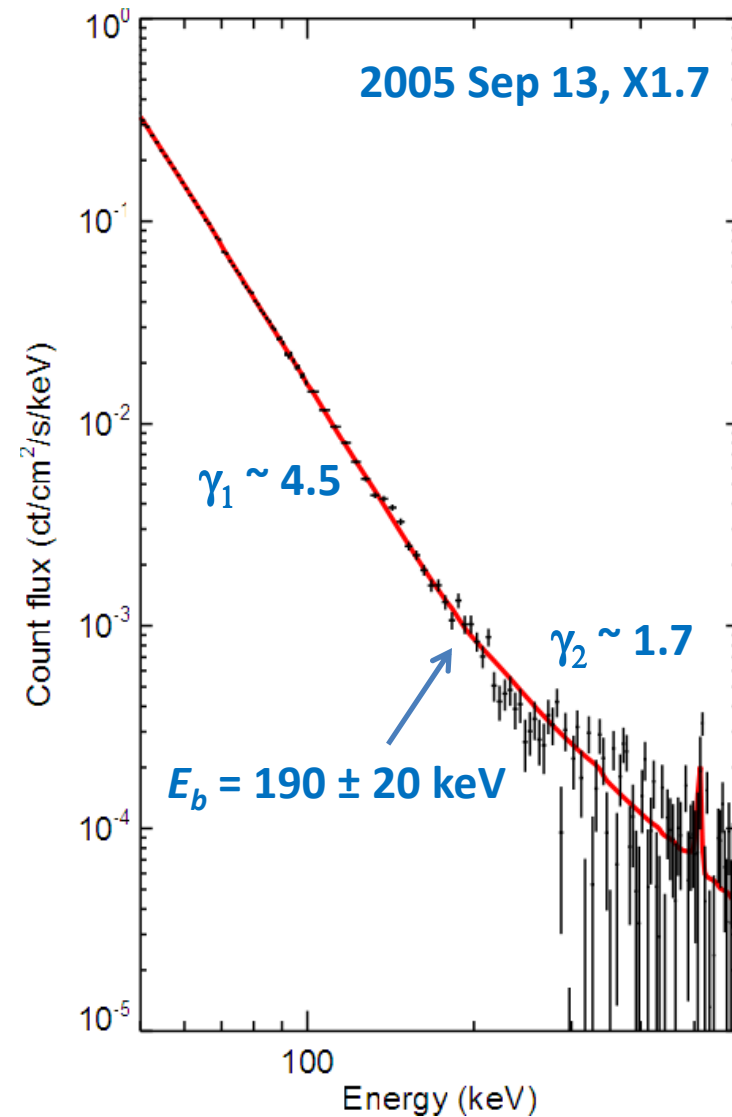
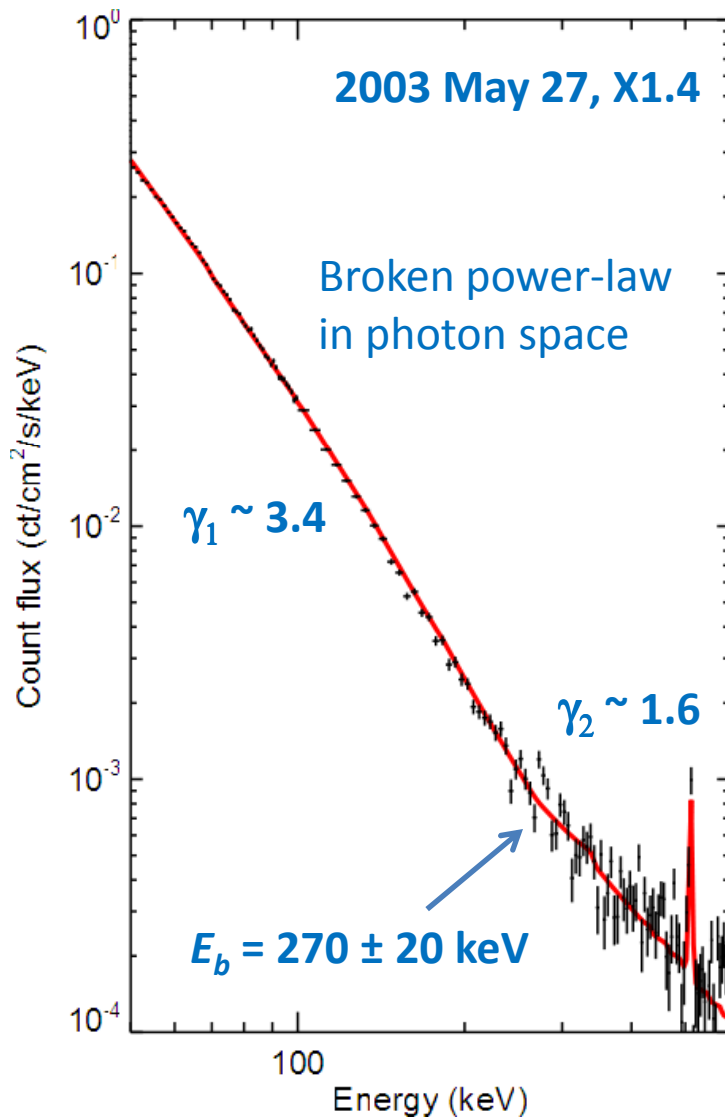
- *GOES* class (emission from hot plasma) as a measure of flare size
- Gray region has not been systematically searched
- Direct proportionality above a threshold?
- Below threshold: excess heating

# Versus $>50$ keV electrons



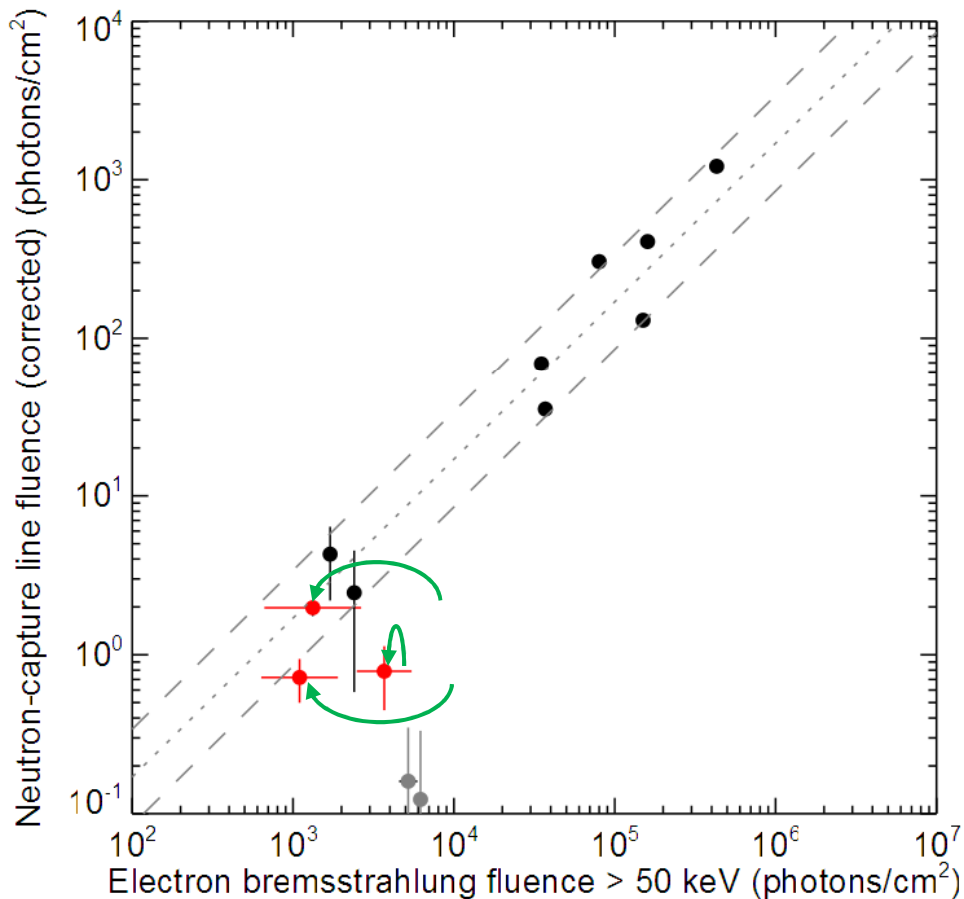
- Subset of the *RHESSI* flares that are easier to analyze
- Many flares show comparable correlation as with  $>300$  keV fluence
- Five flares appear to deviate significantly: excess  $>50$  keV?

# Flare count spectra: 50–600 keV





# Modified >50 keV correlation



- Now excluding the contribution of soft, low-energy bremsstrahlung
- Extrapolated the high-energy power law down to 50 keV
- The flares with good statistics correlate much better

# Conclusions

- $>\sim 20$  MeV ions and  $>300$  keV electrons are proportionally accelerated over  $>3$  orders of magnitude
- $>\sim 20$  MeV ions and  $>50$  keV electrons are not necessarily proportionally accelerated because of soft, low-energy components ( $<\sim 150\text{--}300$  keV)
- Excess thermal emission is possibly associated with this low-energy component