

Comparing the Acceleration of Protons Above 30 MeV and Electrons Above 50 keV in Solar Flares

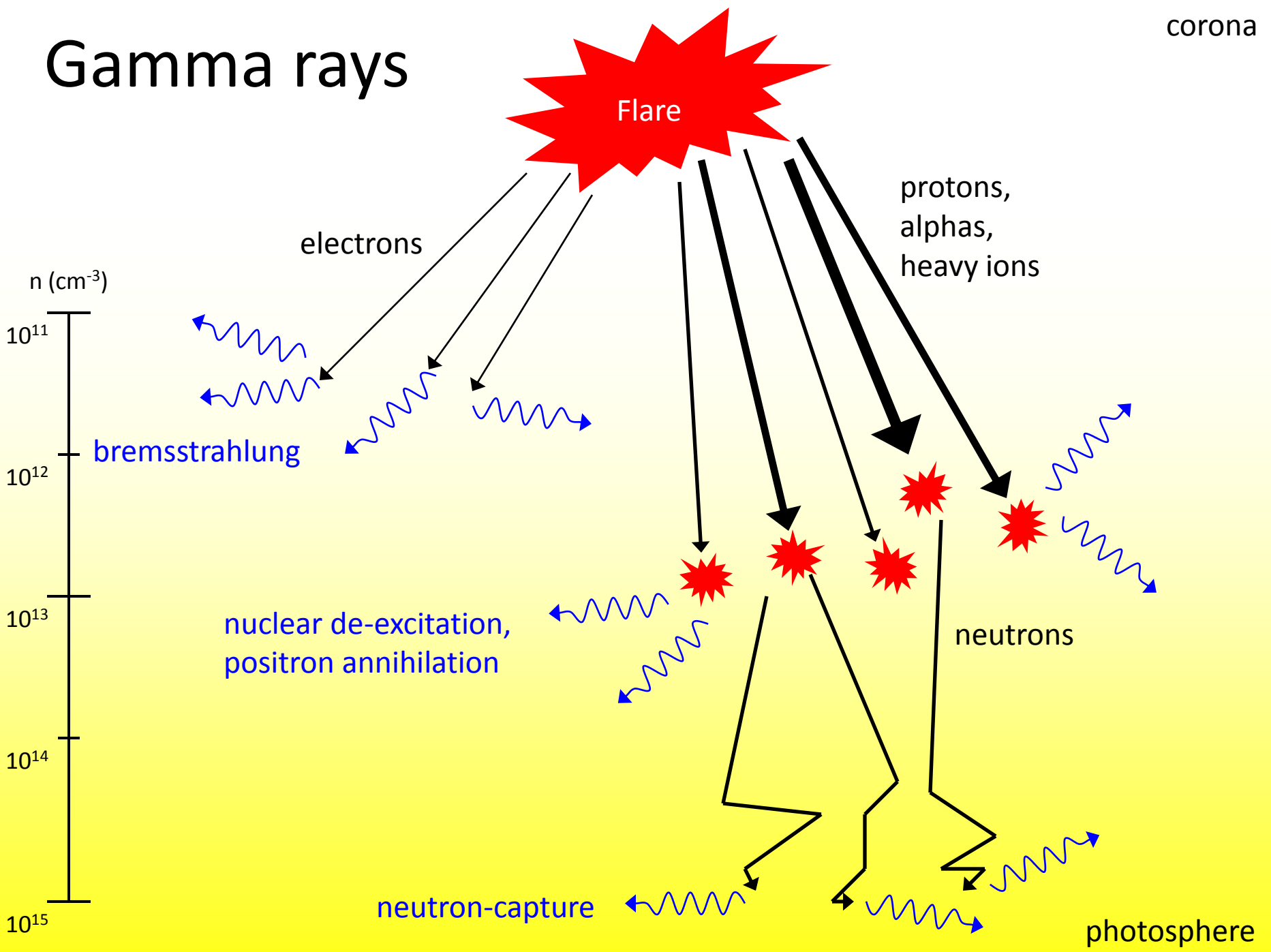
Albert Y. Shih¹, David M. Smith², Robert P. Lin¹

¹ Department of Physics and Space Sciences Laboratory, UC Berkeley, Berkeley, CA

² Department of Physics and Santa Cruz Institute for Particle Physics, UC Santa Cruz, Santa Cruz, CA



Gamma rays



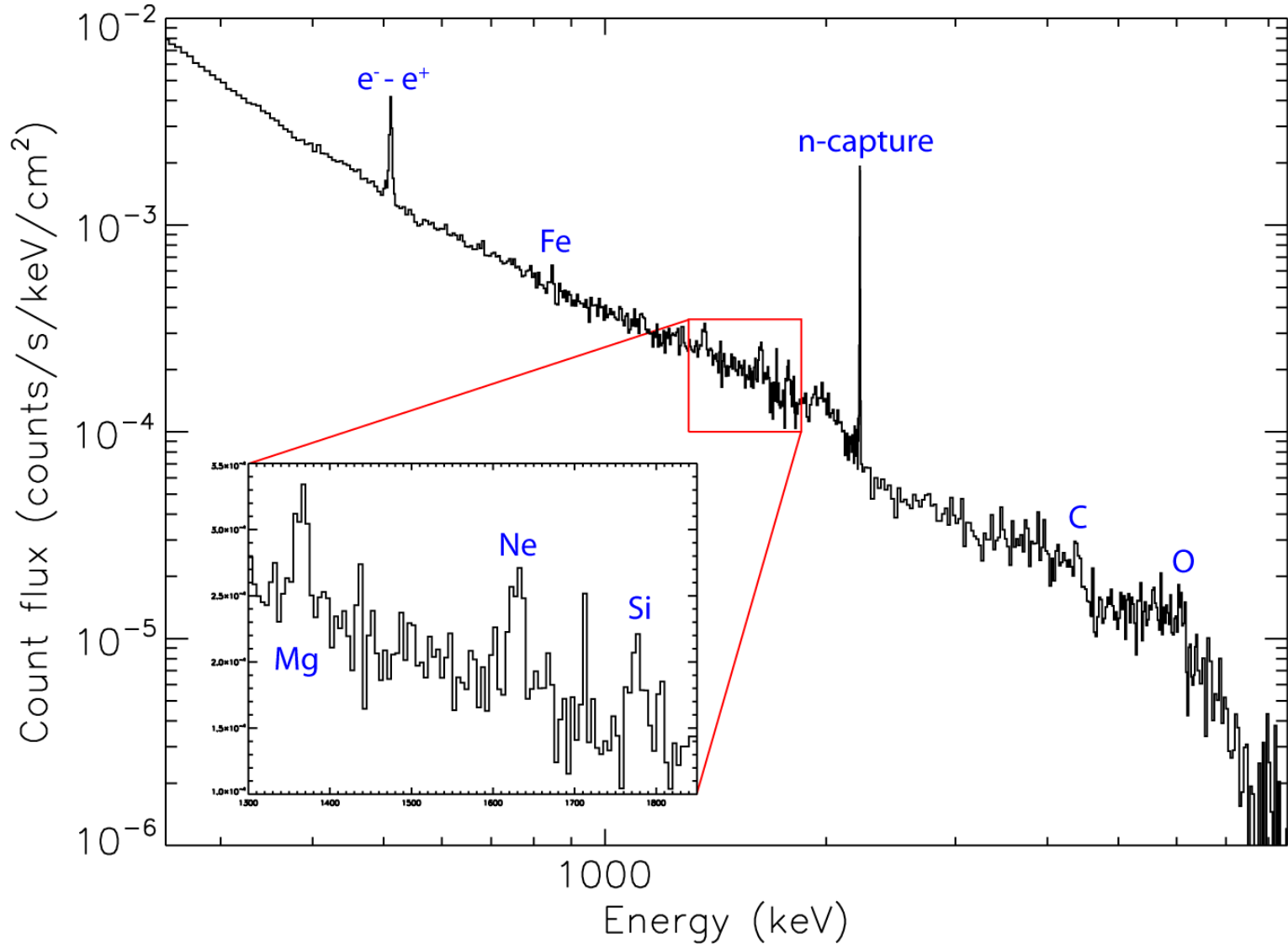
Considering ion acceleration

- Are solar gamma-ray-line flares different from other flares? (e.g. Cliver et al. 1994)
 - Sensitivity limits
 - *HXRBS* and *GRS* on *SMM*
- Second-step acceleration (e.g. Bai et al. 1983)
 - First-order Fermi acceleration due to the passage of a shock through a closed flare loop
 - Ion acceleration correlated with electron acceleration above certain energies

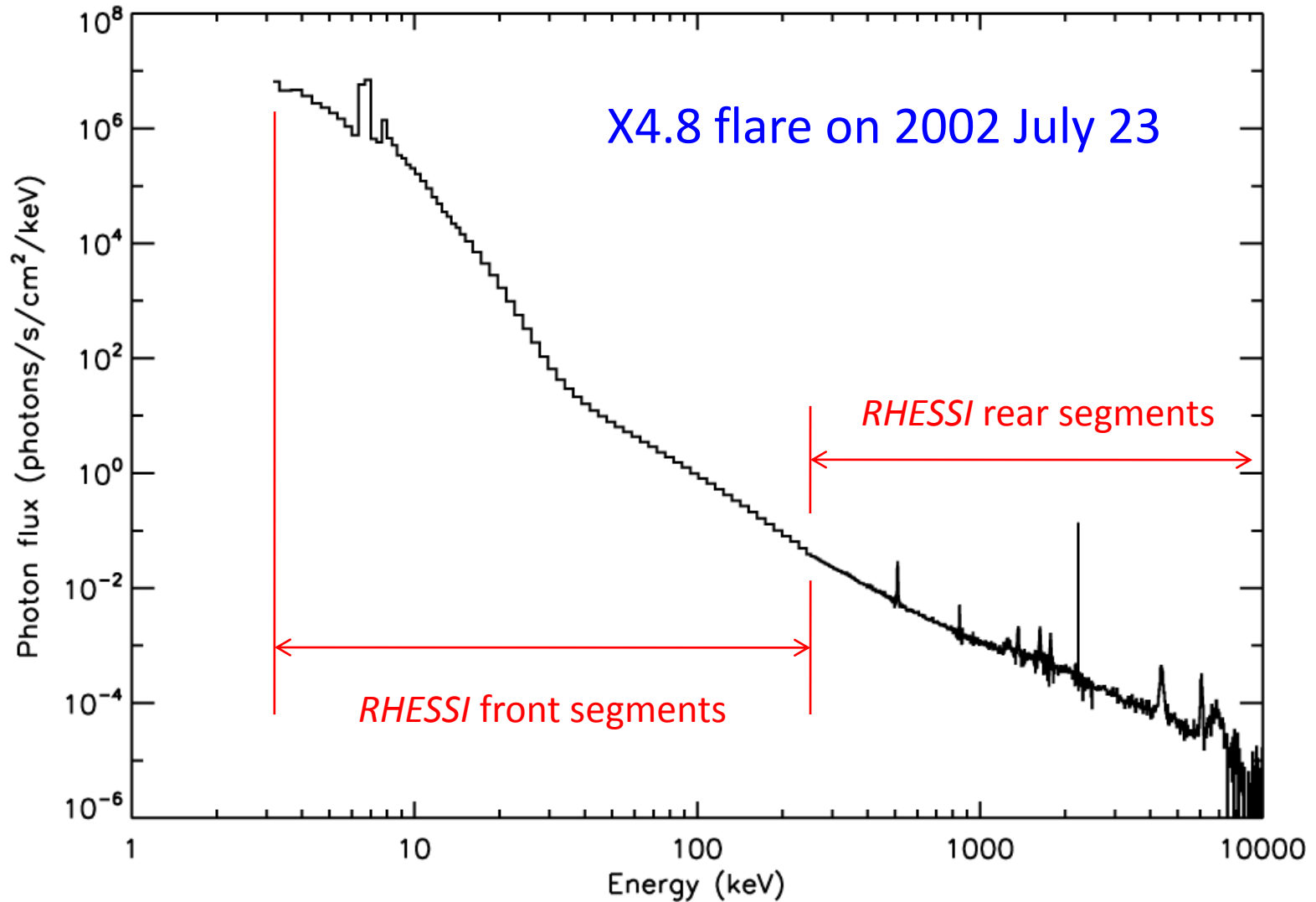
Analysis of *RHESSI* data

- Separate power-law fits to electron bremsstrahlung >50 keV and >300 keV
- Narrow 2.2 MeV neutron-capture line fluence
- Selection started with flares with significant >150 keV emission (from prior work)
- Limb-darkening correction due to Compton-scattering attenuation
- At-the-limb and over-the-limb flares excluded

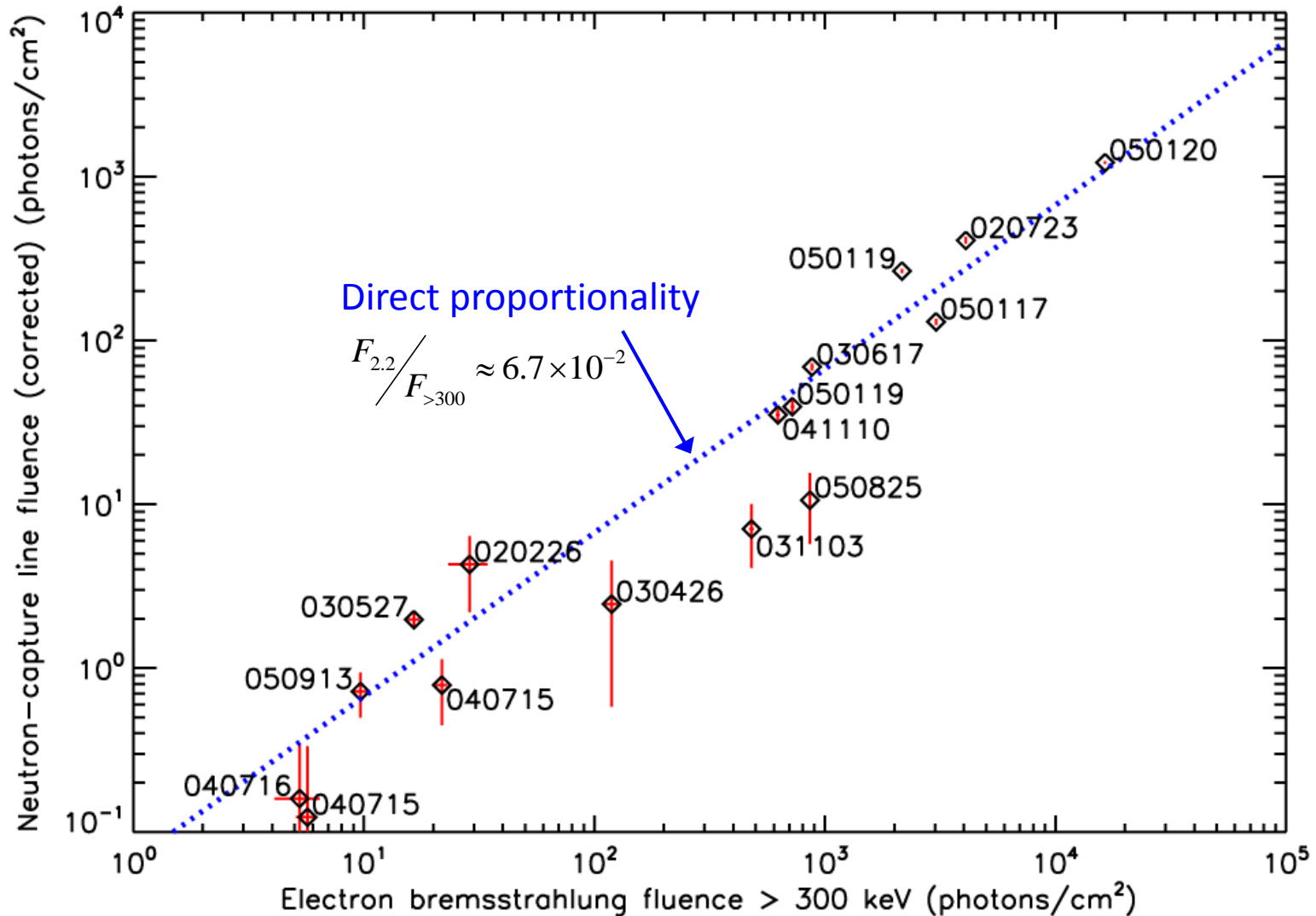
Example *RHESSI* γ -ray spectrum



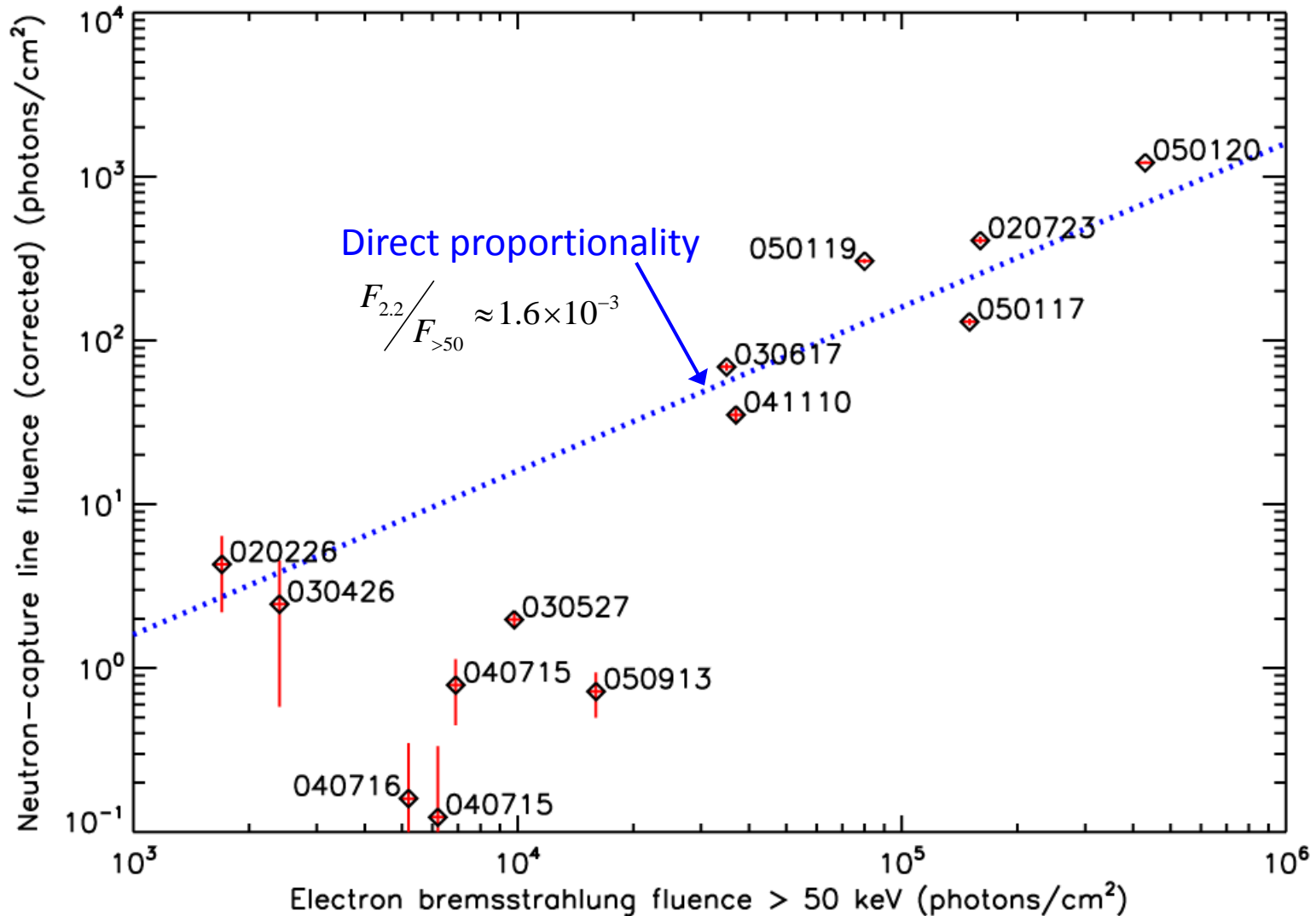
Composite photon spectrum



Protons versus >300 keV electrons



Protons versus >50 keV electrons



Date	GOES class	>1 hr	$\gamma_{>50}$	$\gamma_{>300}$	HA (°)	CME?	Type II?
2002 Feb 26	C9.6	N	3.40	2.56	79	none	N
2002 Jul 23	X4.8	N	3.11	2.72	73	fast	Y
2003 Apr 26	M7.0	N	2.77	2.86	73	slow	Y
2003 Jun 17	M6.8	Y	2.90	2.64	59	fast	Y
2004 Nov 10	X2.5	N	3.05	2.81	47	fast	Y
2005 Jan 17	X3.8	Y	3.34	2.54	34	fast	Y
2005 Jan 19	X1.5	Y	2.55	2.62, 2.36	51	fast	Y
2005 Jan 20	X7.1	Y	2.90	2.49	61	fast	Y

2003 May 27	X1.4	N	3.51	2.73	17	fast	Y
2004 Jul 15	X1.8	N	—	1.73	56	fast	N
2004 Jul 15	X1.6	N	3.54	2.05	46	none	N
2004 Jul 16	X1.3	N	4.41	3.17	43	none	N
2005 Sep 13	X1.7	N	4.27	1.82	18	fast	N

Conclusions

- Ion acceleration >30 MeV is correlated with relativistic electron acceleration >300 keV
- Ion acceleration >30 MeV is poorly correlated with electron acceleration >50 keV, with the possibility of two separate classes of flares
- The difference between the classes may be related to the spectral index at lower energies and the association with a type II burst