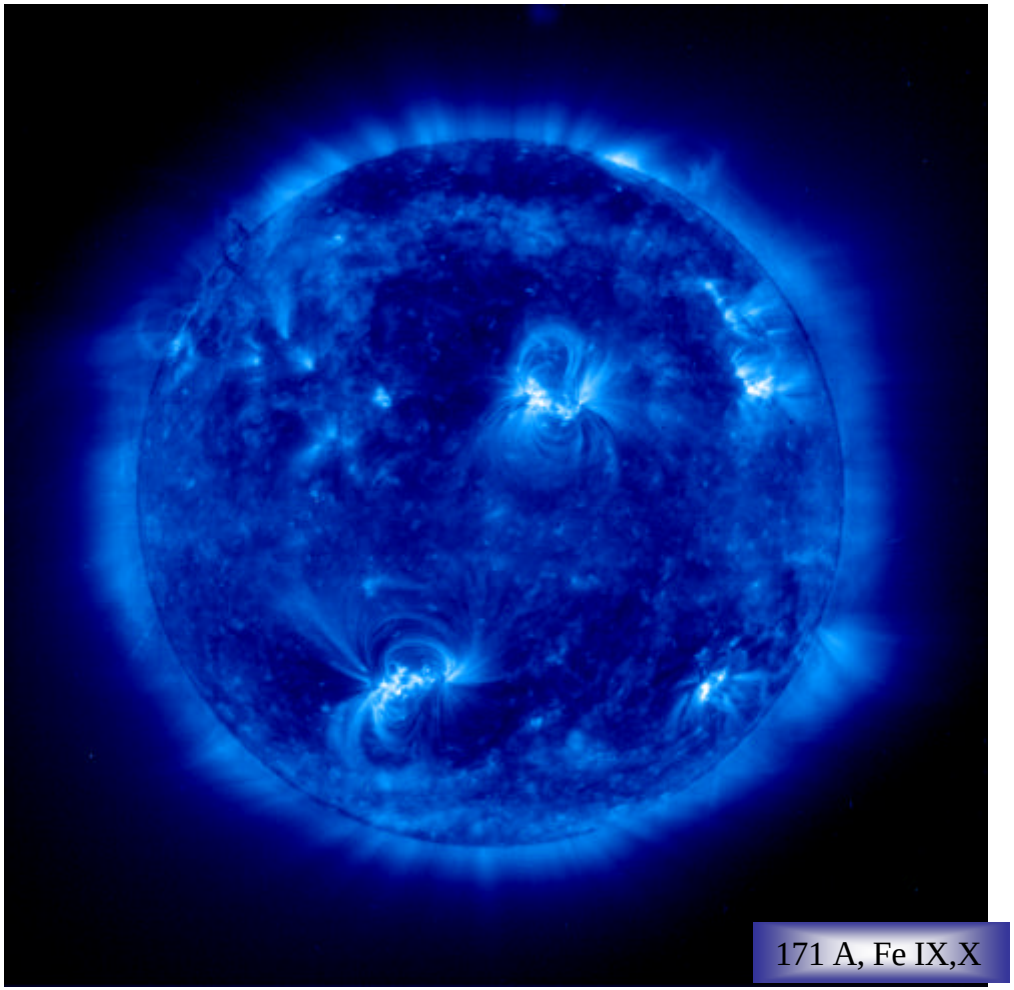
Nuclear line emission of the Oct. 28, 2003 flare with INTEGRAL/SPI

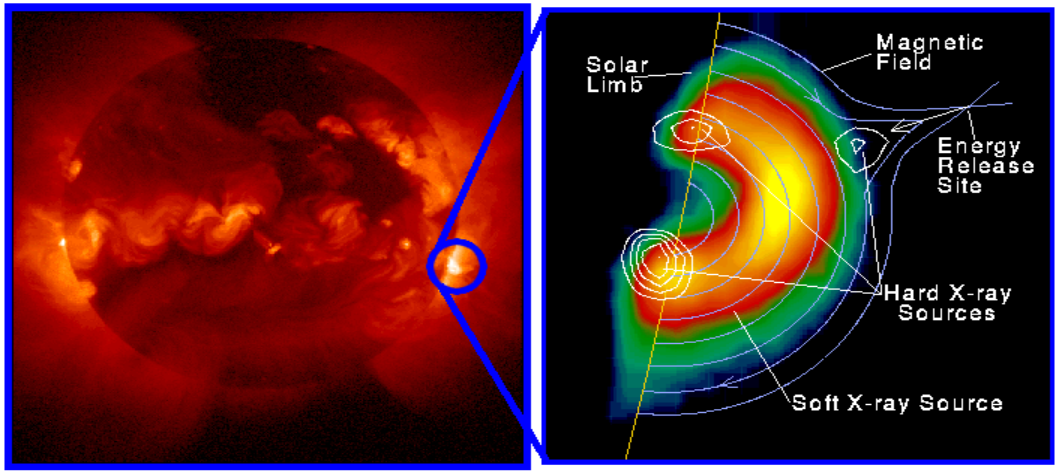
M. Gros, V. Tatischeff, J. Kiener, B. Cordier, C. Chapuis, G. Weidenspointner, G. Vedrenne, A. von Kienlin, R. Diehl, A. Bykov, M. Mendez



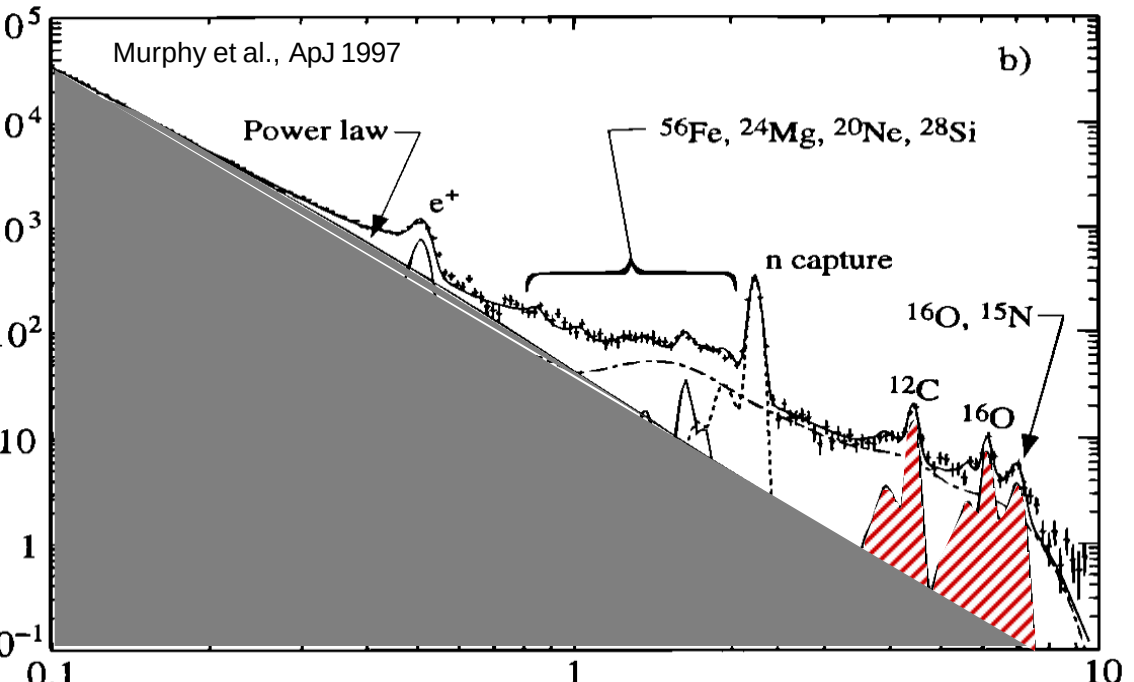
SOHO/EIT

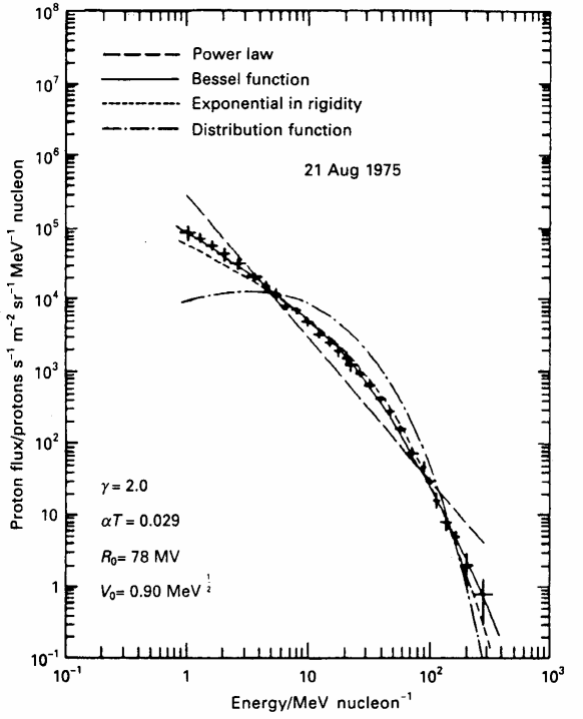
CEA Saclay
CSNSM Orsay
CESR Toulouse
MPE Garching
IOFFE St Petersburg
SRON Utrecht

gamma-ray emission of solar flares



Yohkoh X-ray Image of a Solar Flare, Combined Image in Soft X-rays (left) and Soft X-rays with Hard X-ray Contours (right). Jan 13, 1992.

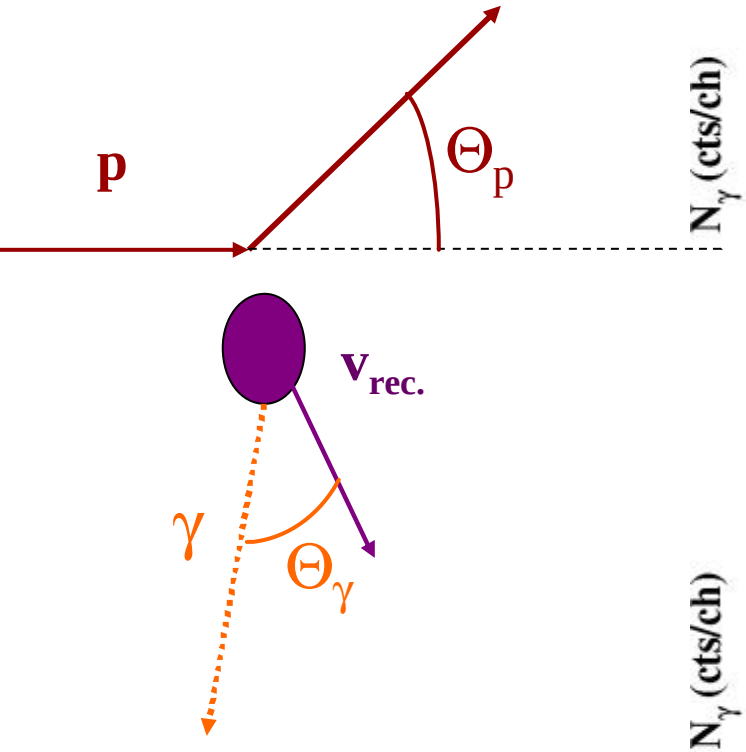




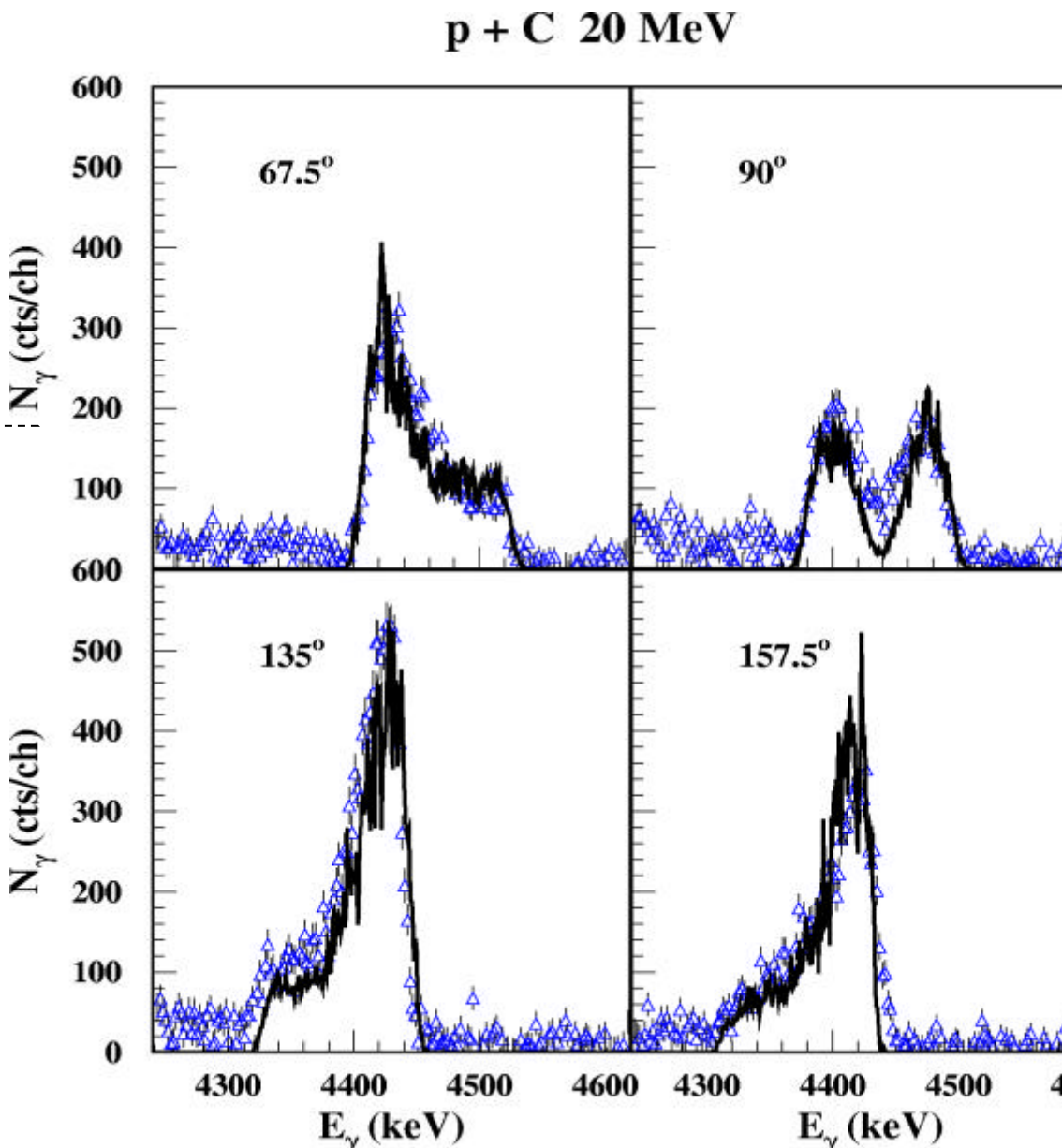
accelerated particles:
- **composition, spectrum**
- **angular distributions**
- **timing**
- **acceleration, transport**

solar atmosphere
- **composition**

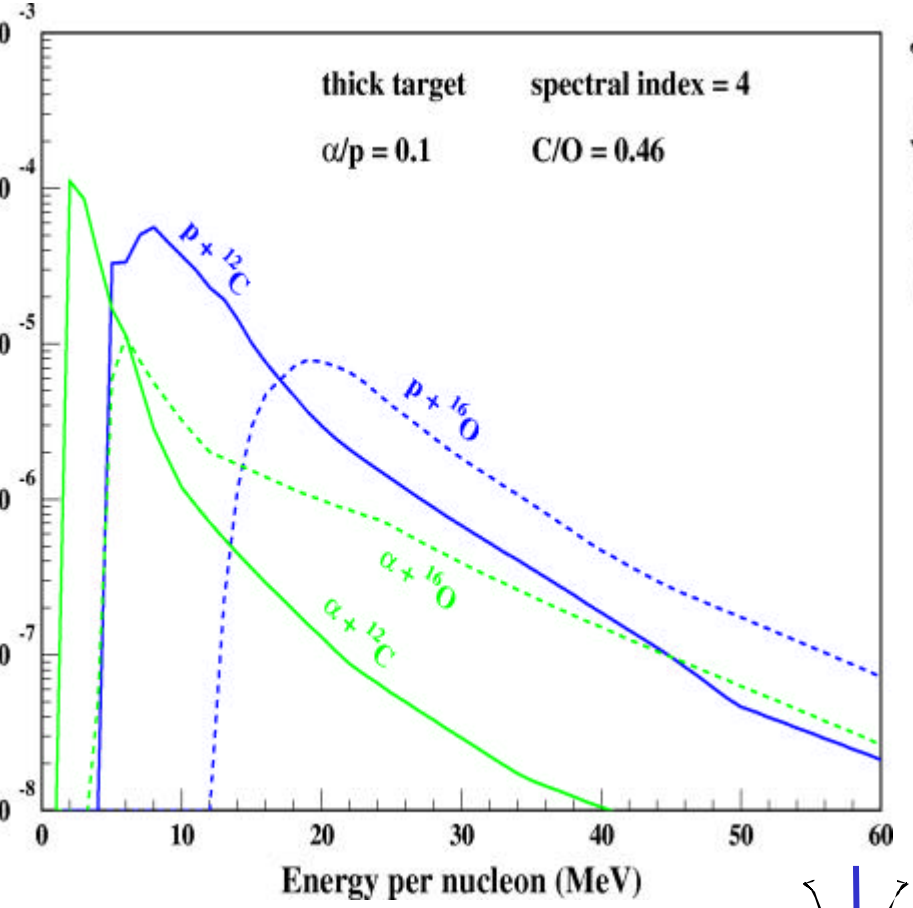
new with Ge: gamma-ray line profiles

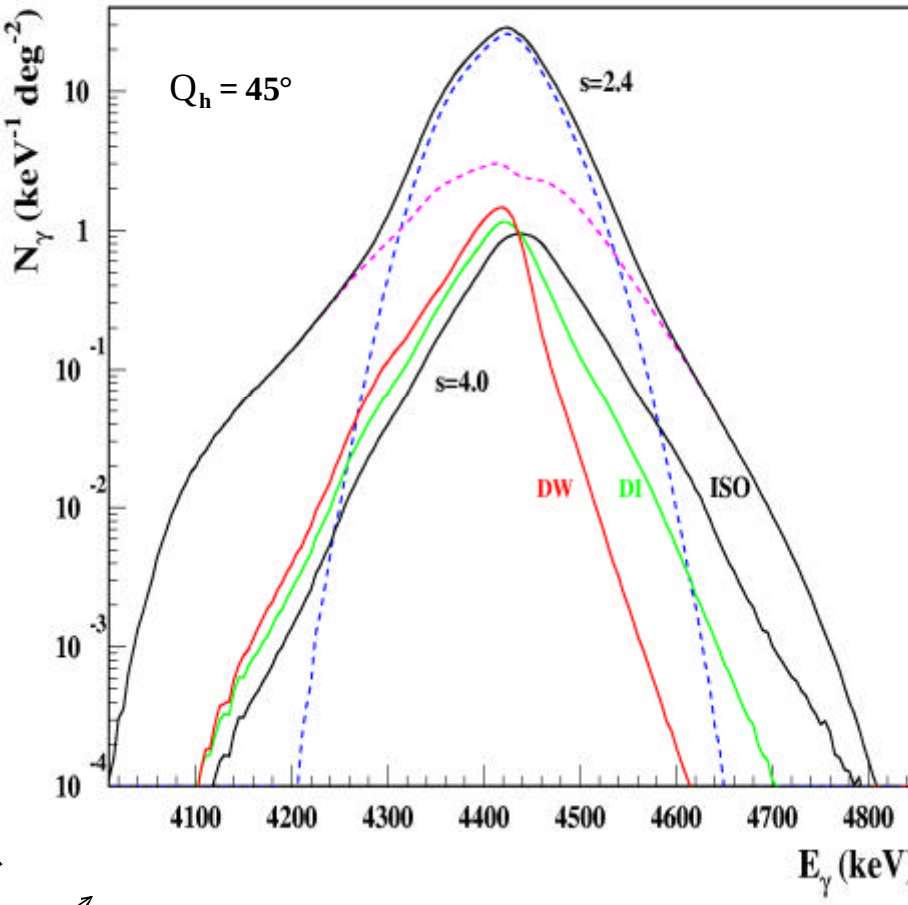


$d^3s/dW_p dW_g dE_p$

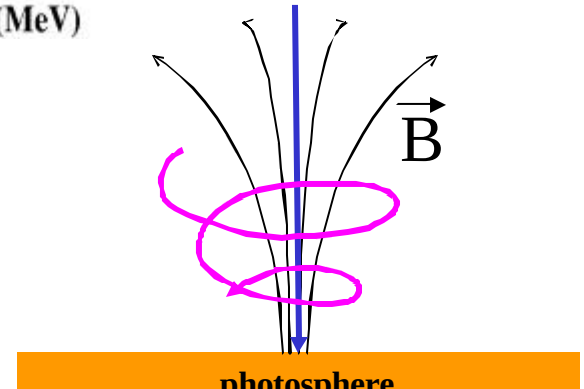


4.44 MeV gamma-ray line in flares





Particle angular distributions relative to normal to sun's surface:



→**DI: dN(Q)/dW = cst** Q = 0°-90

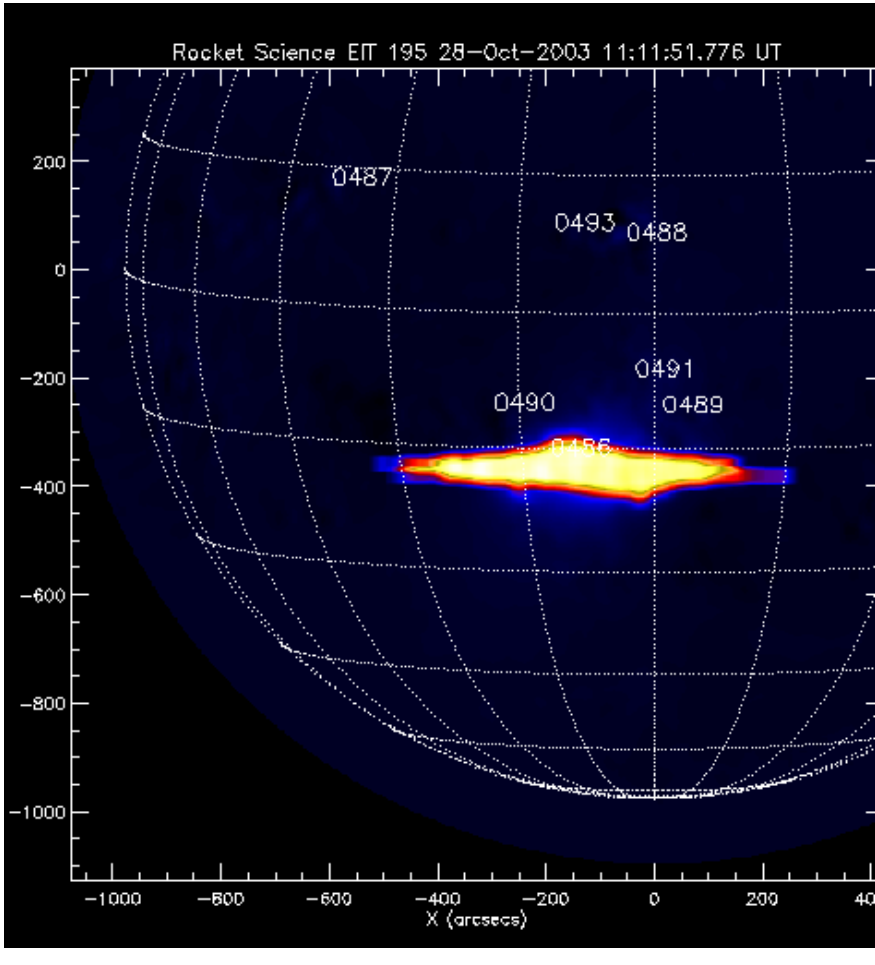
→**DW: dN(Q)/dW = exp(-Q/DQ)**

→**FAN: dN(Q)/dW = sin⁶(Q)**

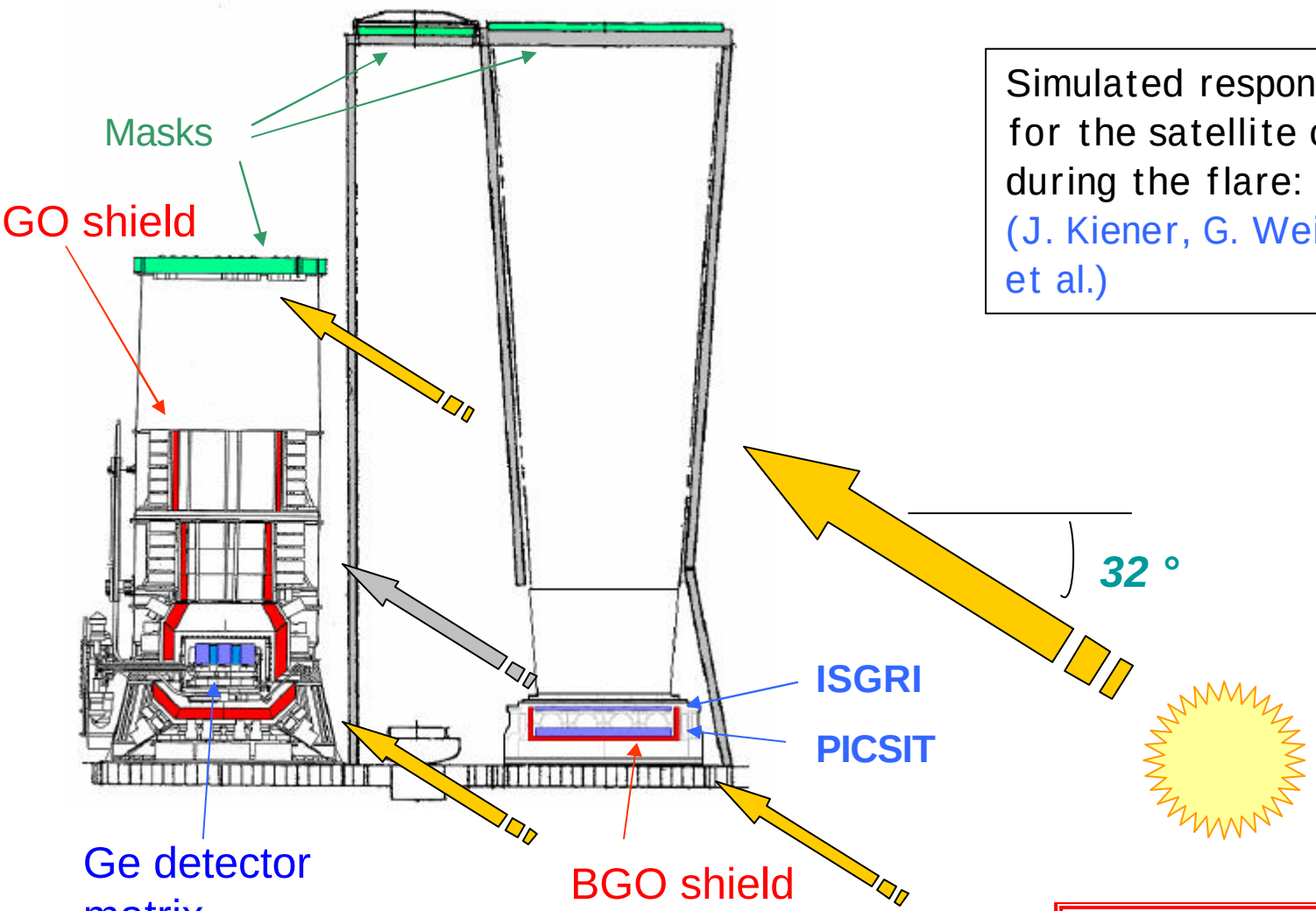
→**ISO: isotropic**

SPI observation of the October 28 Solar Flare

1. High solar activity: 6 flares of class X from Oct 28 to Nov 4
2. Oct 28 flare (X17.2)
   - Position : S18E20
   - X-rays :
     - start : 09:51
     - max : 11:10
     - end : 11:24
3. During INTEGRAL observation of IC443 (rev 127; PI: A. Bykov)
4. SPI data: T = 10:48 – 11:38



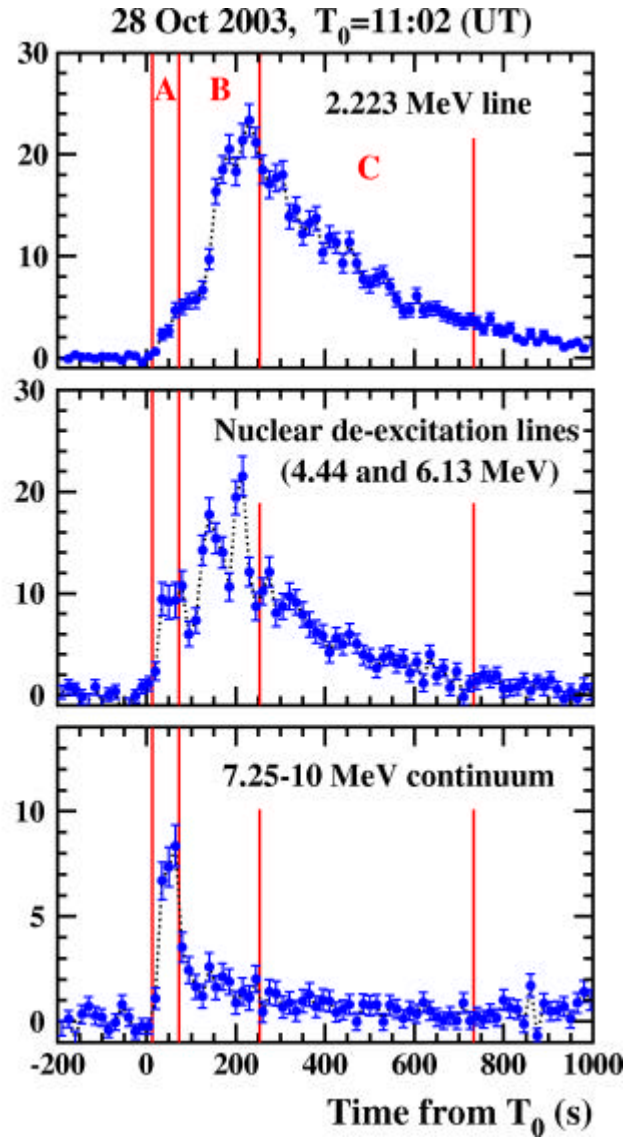
SPI observation of the October 28 Solar Flare

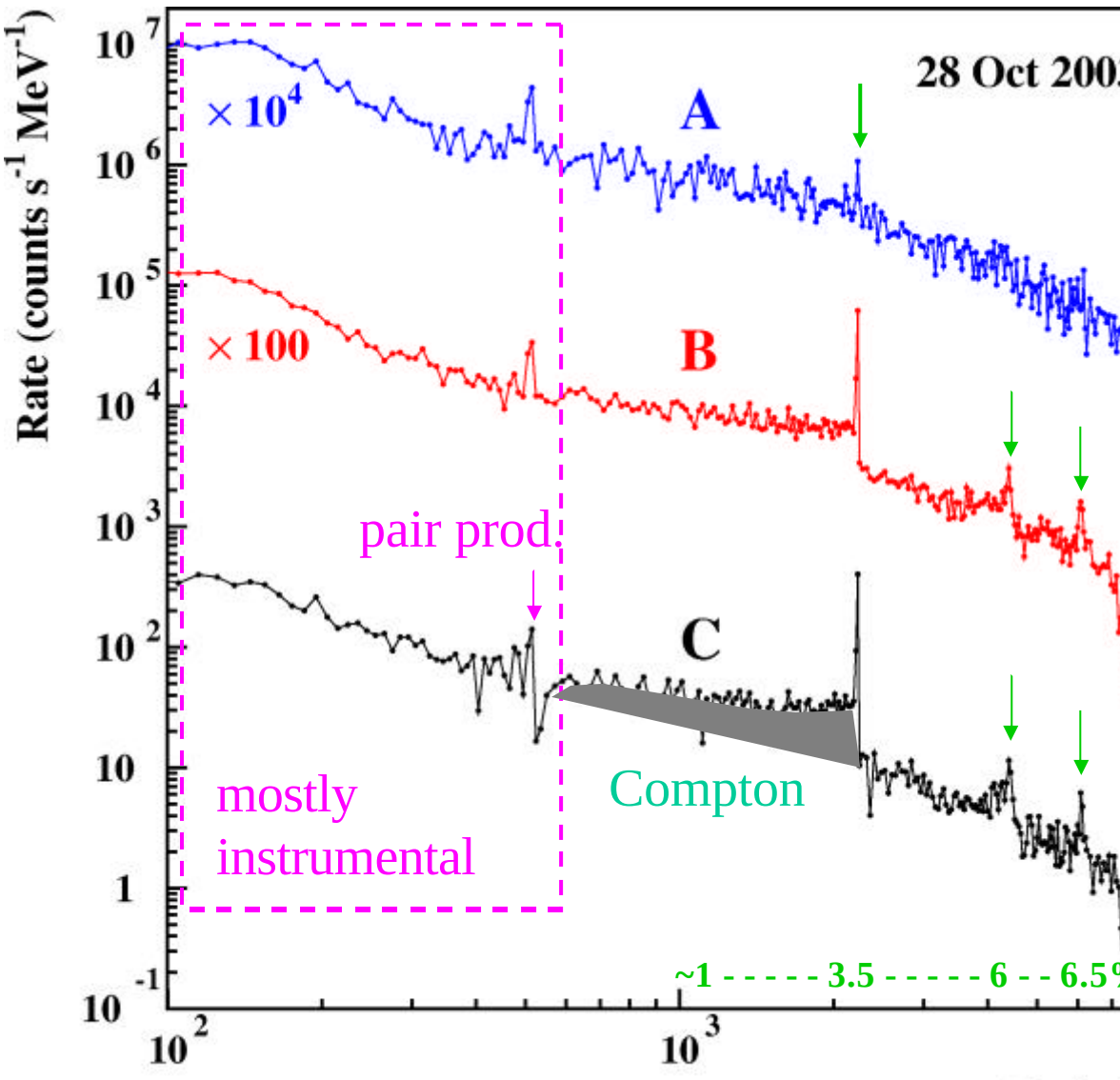


Simulated response function for the satellite configuration during the flare: in progress (J. Kiener, G. Weidenspointner et al.)

All results are preliminary

Spectra and time history



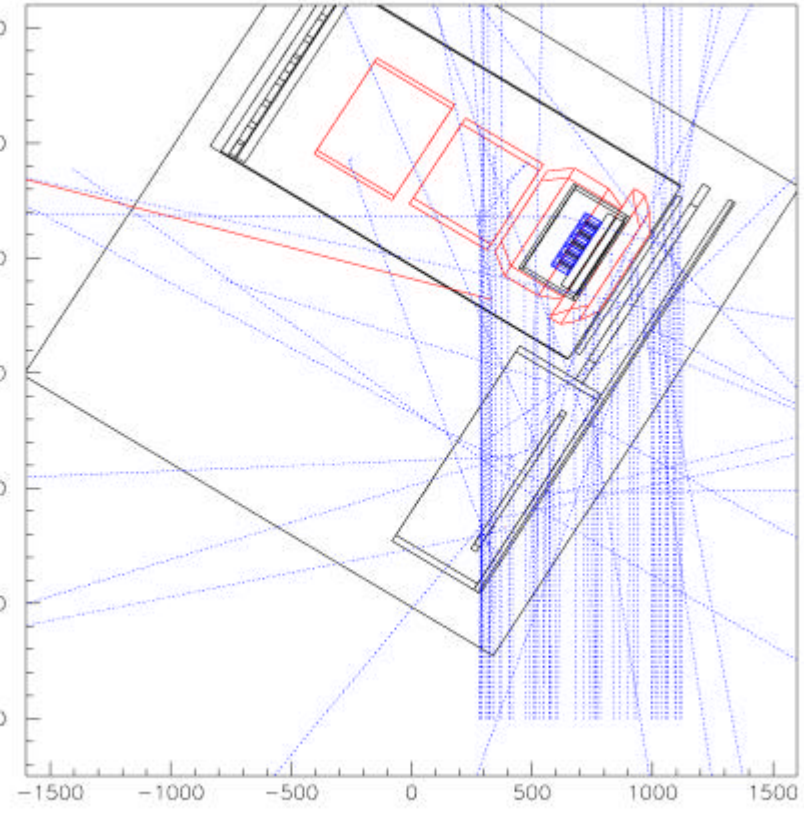


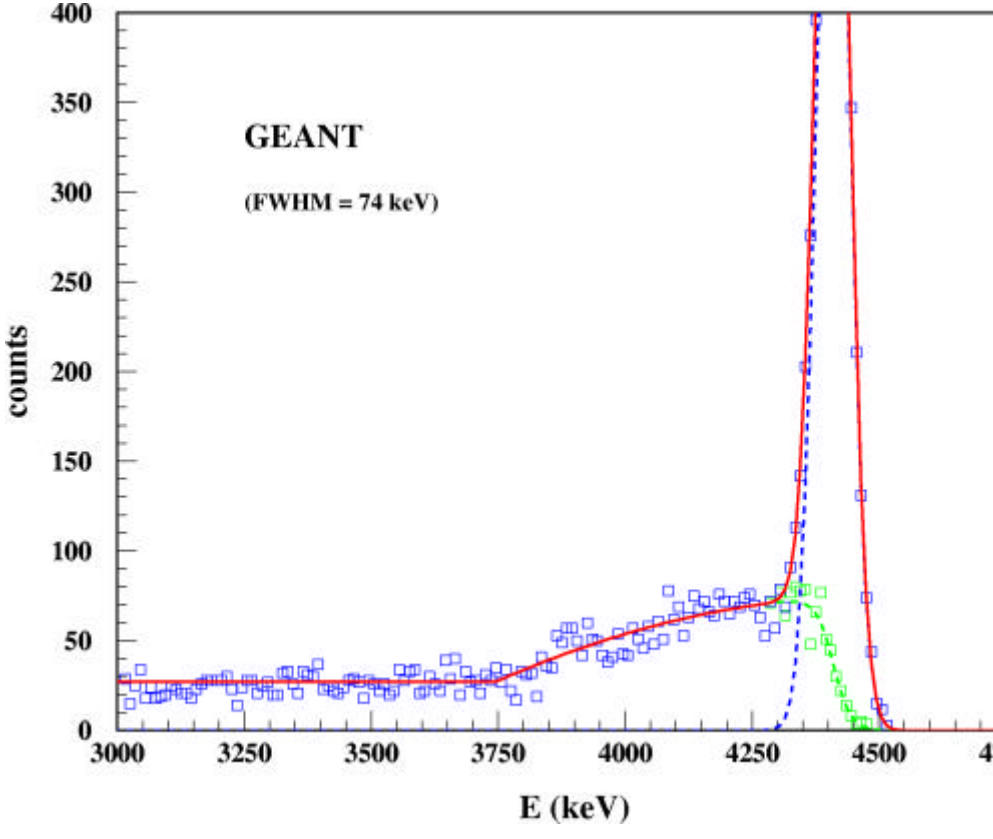
useable lines:

Compton component: GEANT simulations

normal (in Ge) + forward Compton scattering (cryostat)

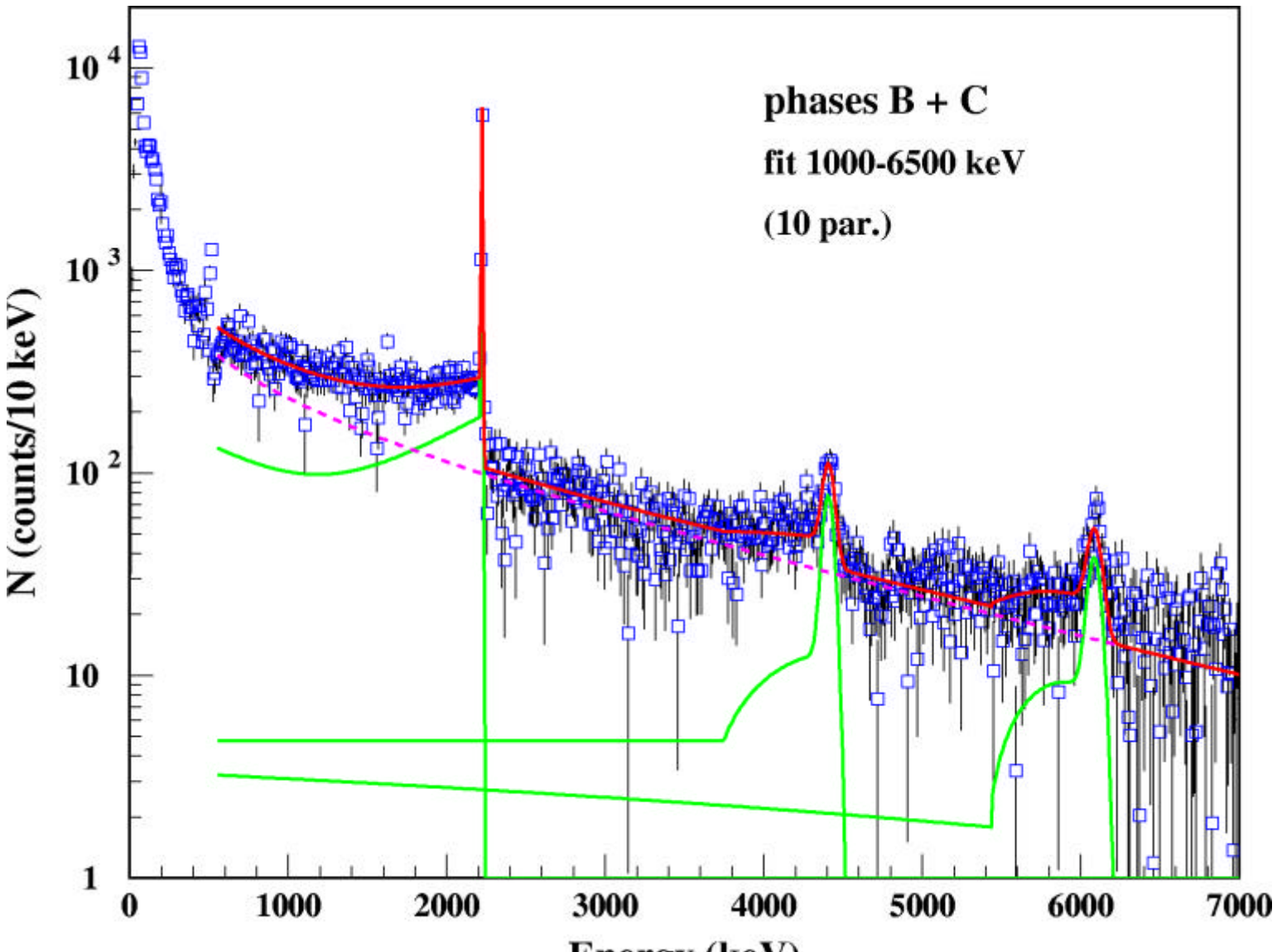
detector bench, BGO, cryostat+preamps, Ge-matrix, + (electronics, support structures)





fit of spectrum: 2223, 4410, 6090 keV + continuum

$N, s, N_{Co.}$ $N E^{-g-g'E}$



$C^2_{red} = 1.2$

4.4, 6.1 MeV line profiles:

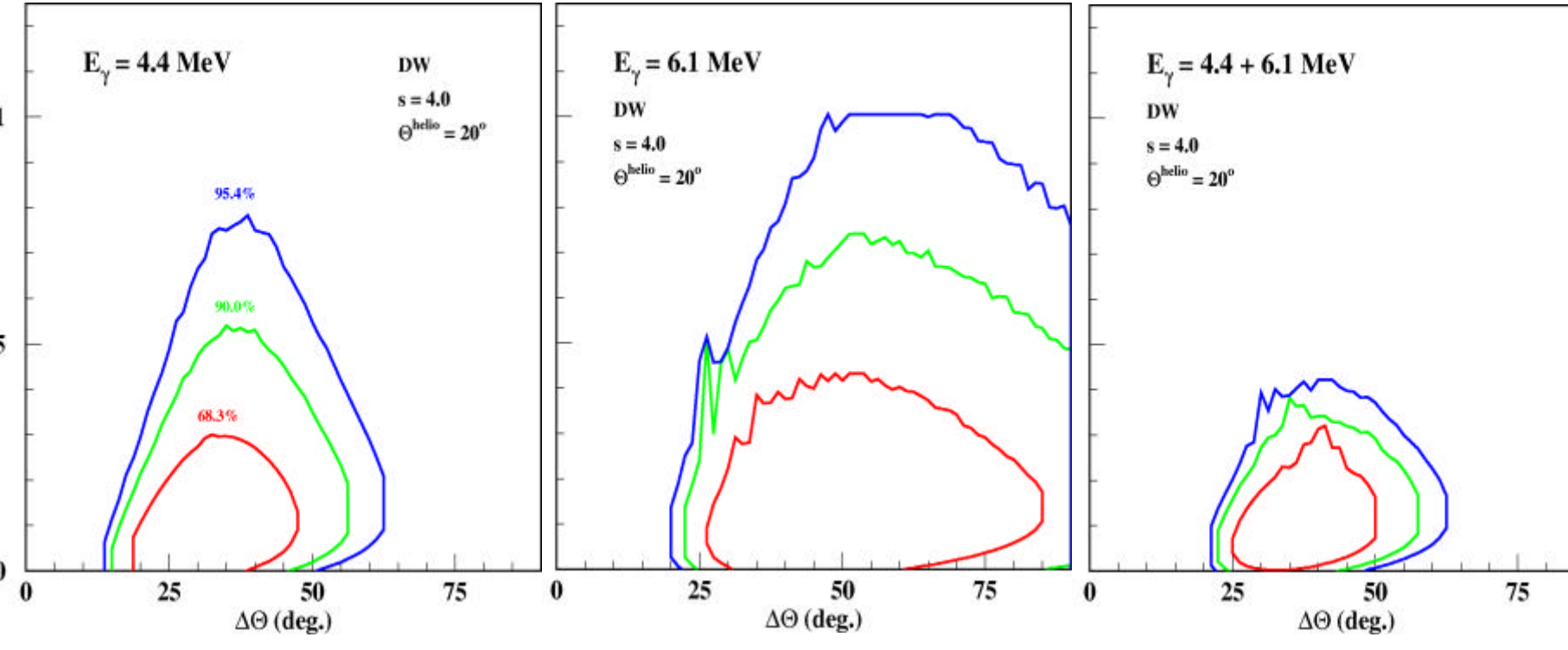
- **particle angular distribution:**

$dN/d\Omega = N_0 \exp(-Q/DQ)$ Q: particle mom. vector <-> flare normal

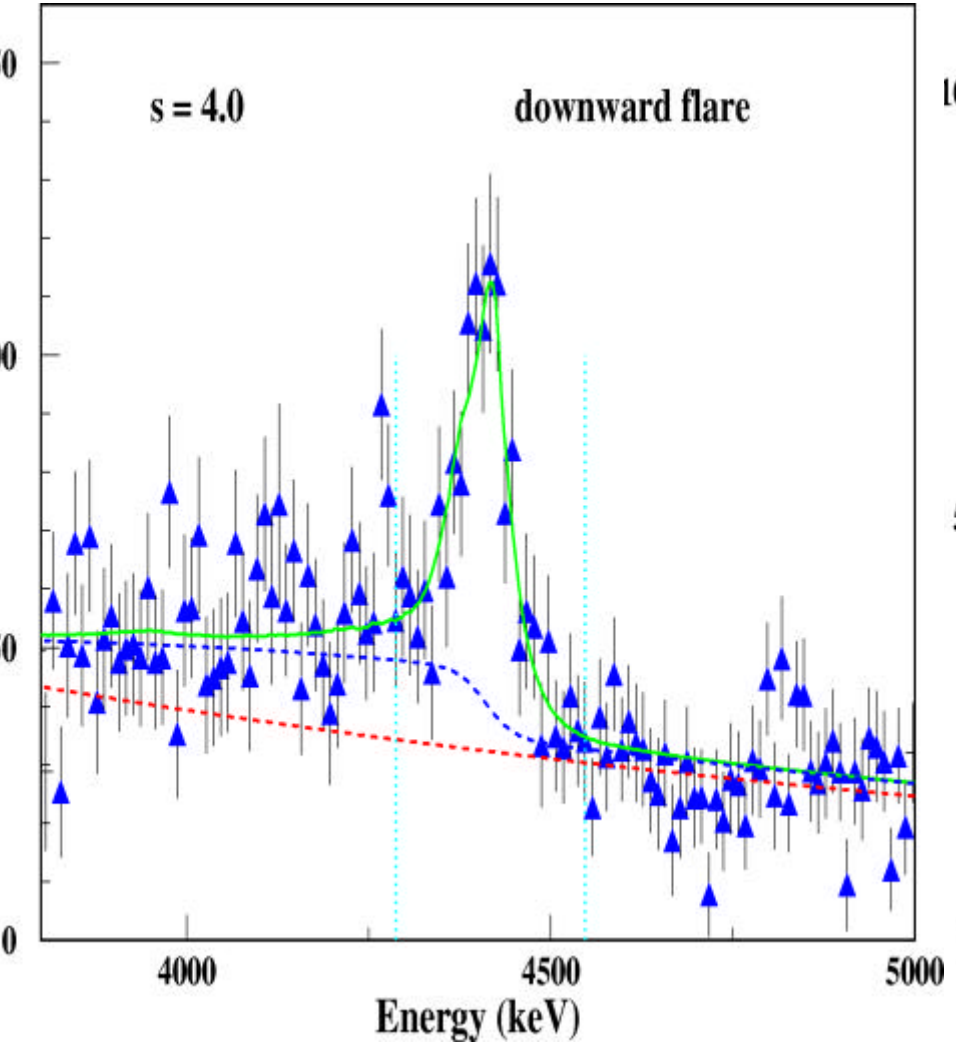
- **alpha-to-proton ratio**
- **spectral index from 4.4,6.1 MeV to 2.2 MeV line ratios**

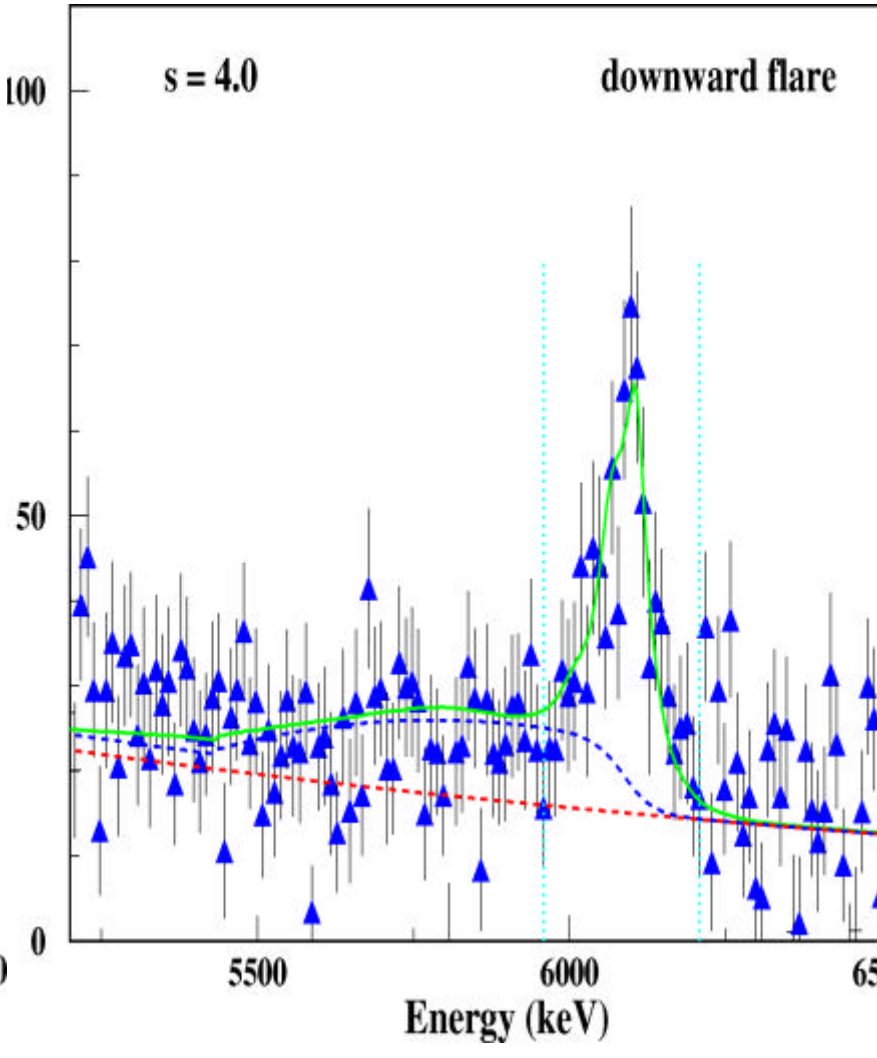
uncertainties: statistics + theoretical line shape (20% 4.4 - 40% 6.1)

$\alpha/p = 0.08 \qquad \Delta\Theta = 35°$



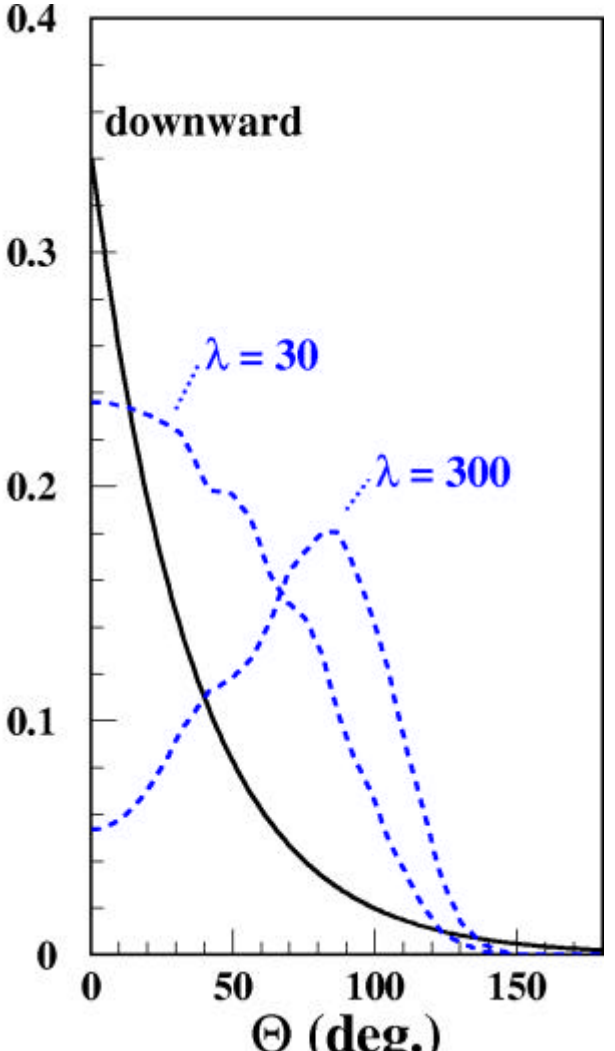
4.4, 6.1 MeV line profiles best fits

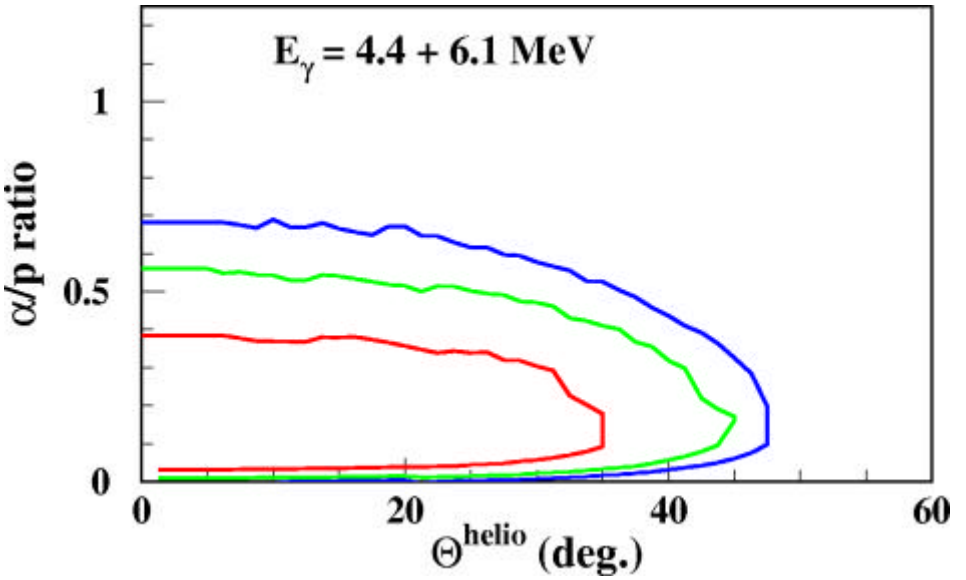


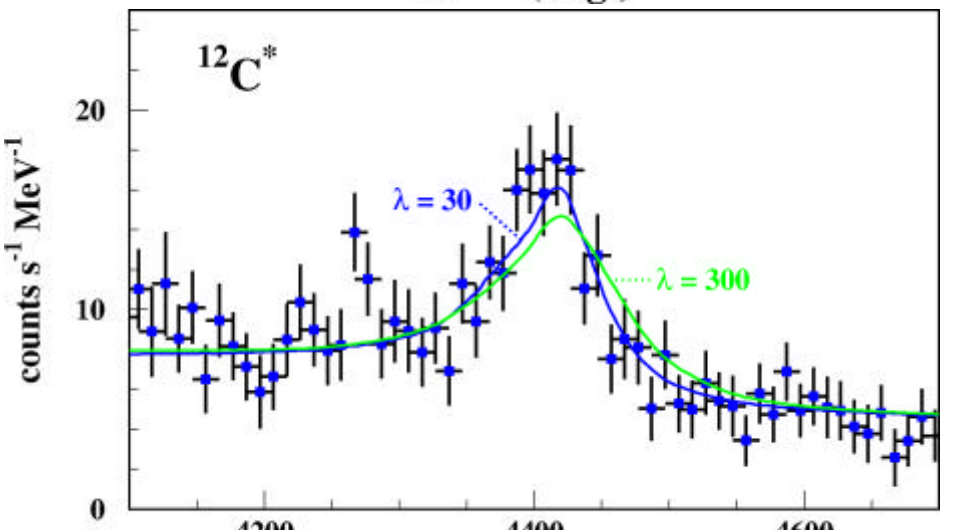


4.4, 6.1 MeV line profiles:

- heliocentric angle: line-of-sight <-> flare normal
- pitch-angle scattering (MHD turbulence) $\lambda := L_{mfp}/L_{arc}$







Conclusion

Limits on important flare parameters

accelerated particles:

- ***alpha-to-proton ratio (shape)***
- ***directional distribution (shape)***
- ***spectral index (line ratios)***
- ***electrons (continuum)***

interaction region:

- ***MHD turbulence (shape)***
- ***chromospheric C/O (line ratios***
- ***^{3}He abundance (2.2 MeV time profile)***

compare/complete with other instruments (RHESSI,KORONAS)
multi-wavelength analysis