Energetic Particle Properties from Gamma-Ray Line Observations in Solar Flares

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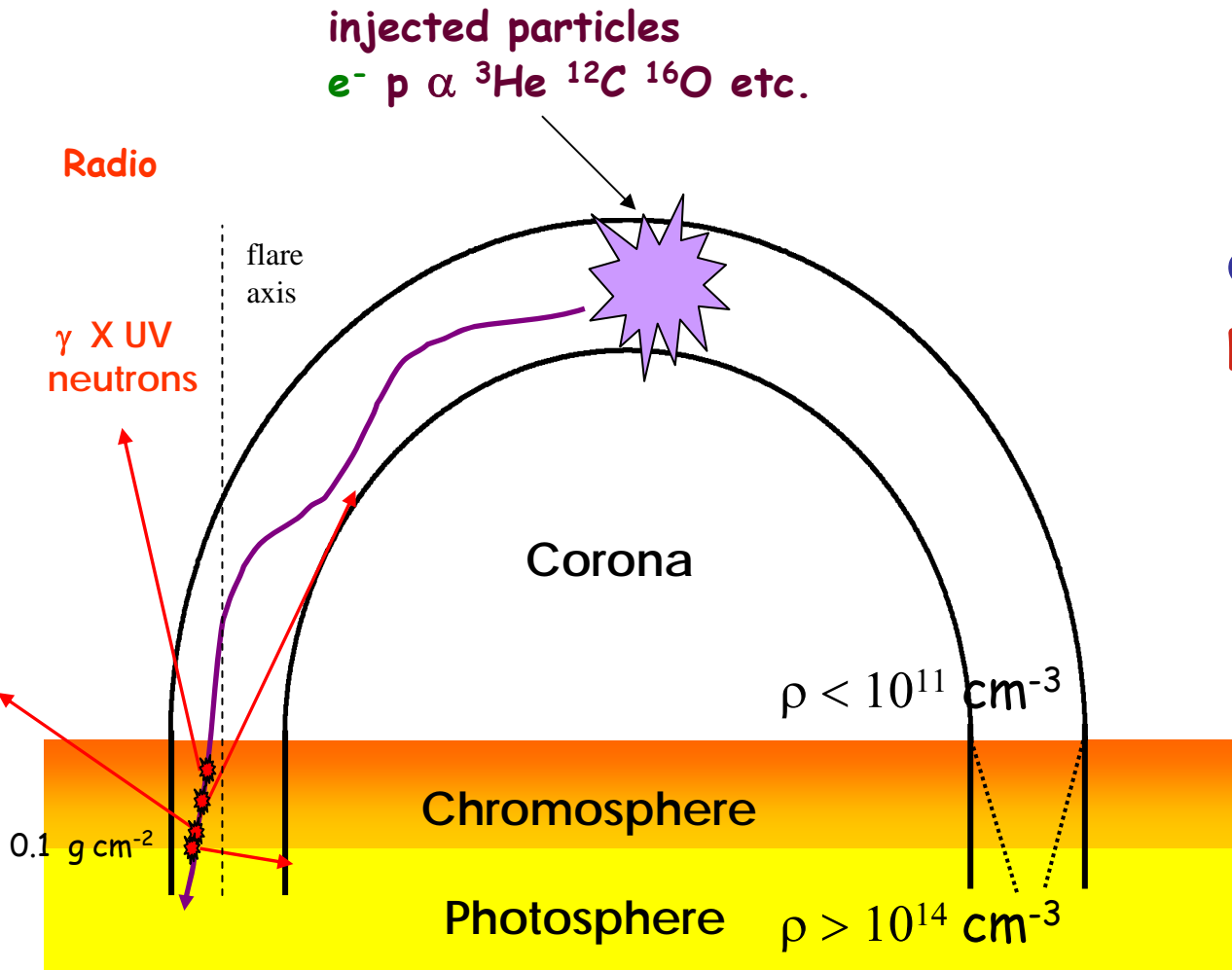M. Gros (SAp/CEA Saclay)
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solar flare model

injected particles
e⁻ p α **³He ¹²C ¹⁶O etc.**

Radio

γ X UV
neutrons

flare
axis

Corona

$\rho < 10^{11}$ cm⁻³

0.1 g cm⁻²

Chromosphere

Photosphere $\rho > 10^{14}$ cm⁻³

Principal γ-ray lines

$\alpha + \alpha$ (~0.45 MeV)

p,α + ¹²C   (4.44 MeV)

   + ¹⁶O   (6.13 MeV)

   + ²⁰Ne (1.63 MeV)

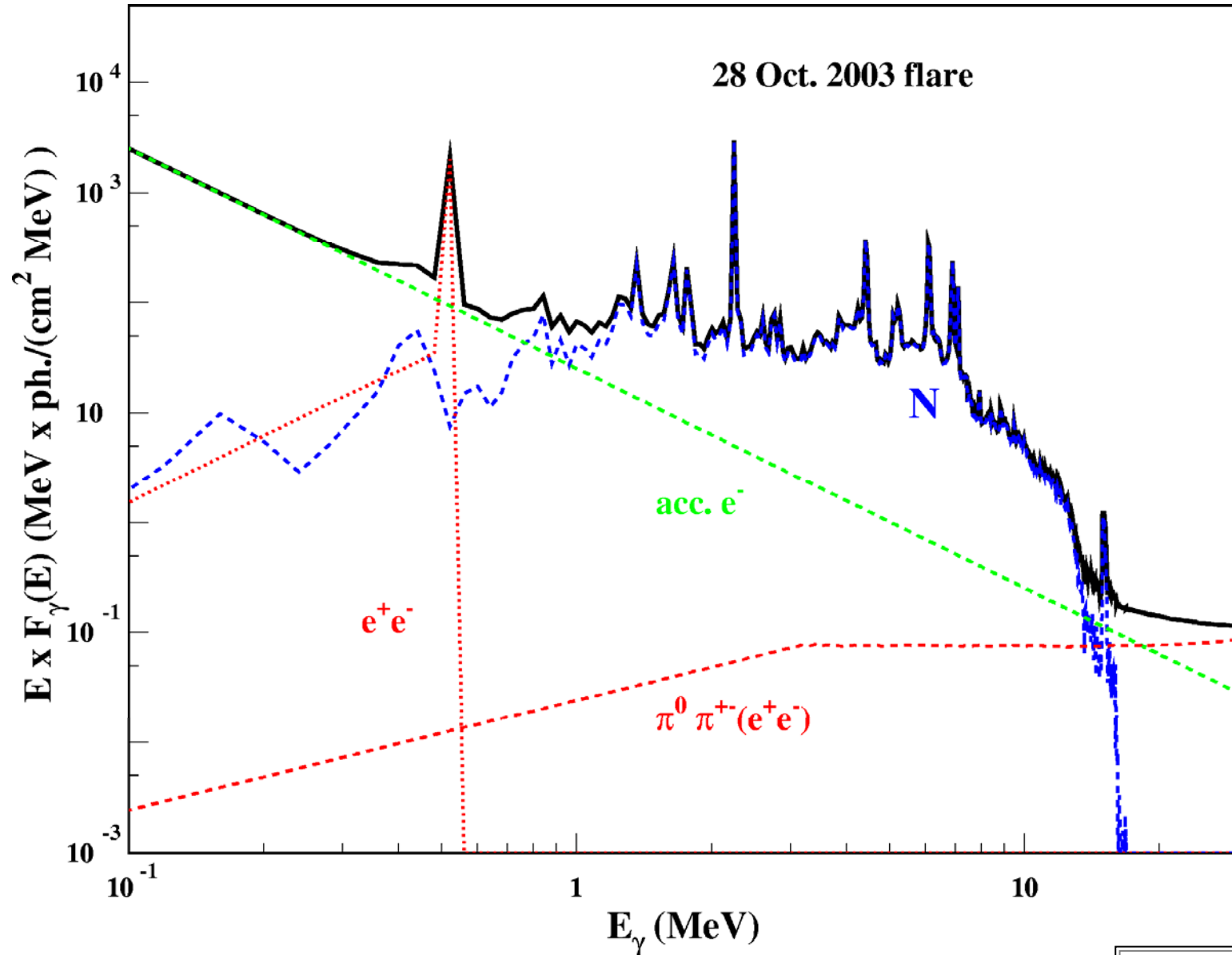   + ²⁴Mg (1.37 MeV)

   etc.

¹H(n,γ) (2.22 MeV)

e⁺ e⁻   (0.51 MeV)

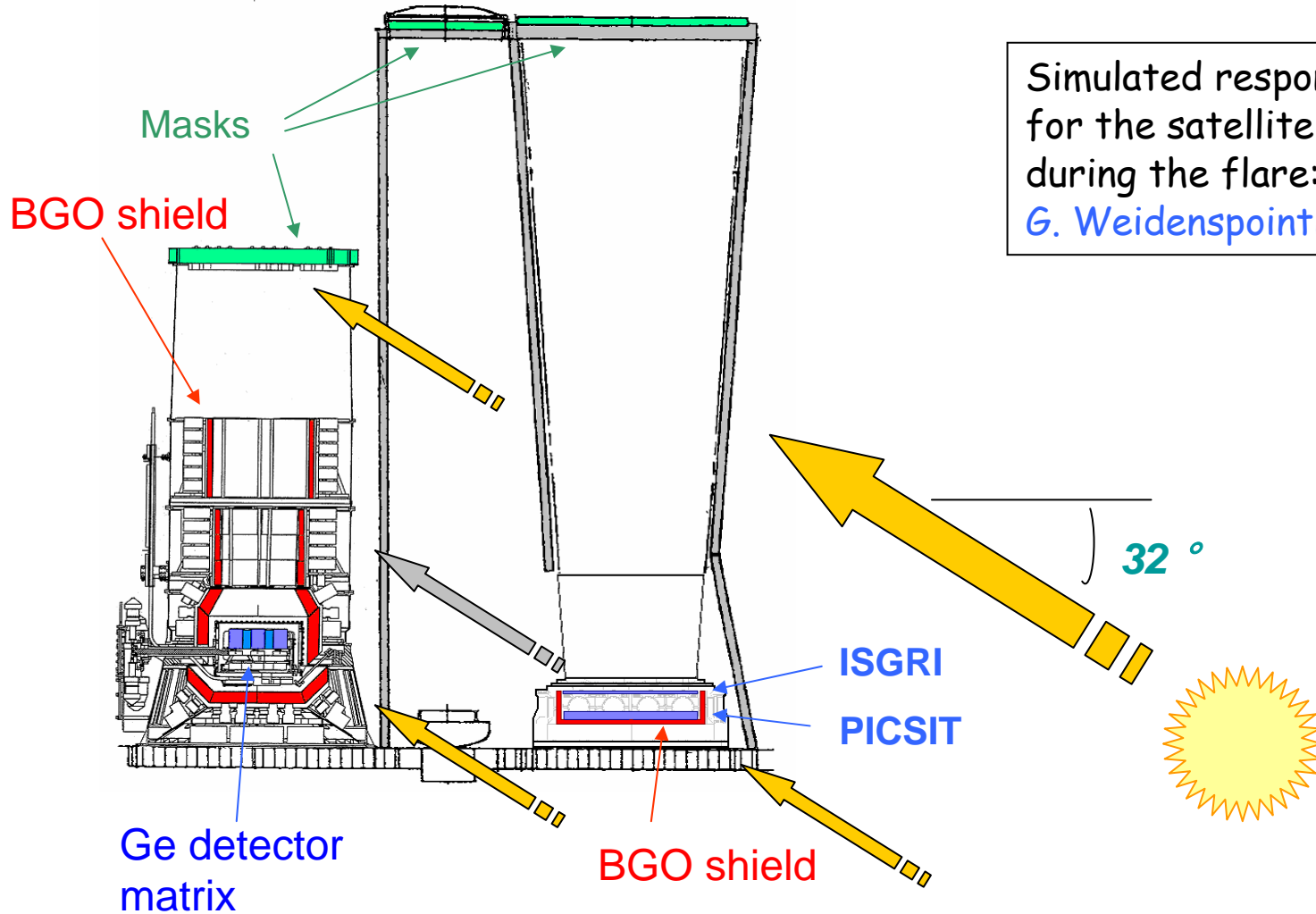**π^0**   (65 MeV)

Composition solar atmosphere :
H (90%), He(10%), O(0.06%) C(0.03%) etc.

synthetic flare gamma-ray spectrum
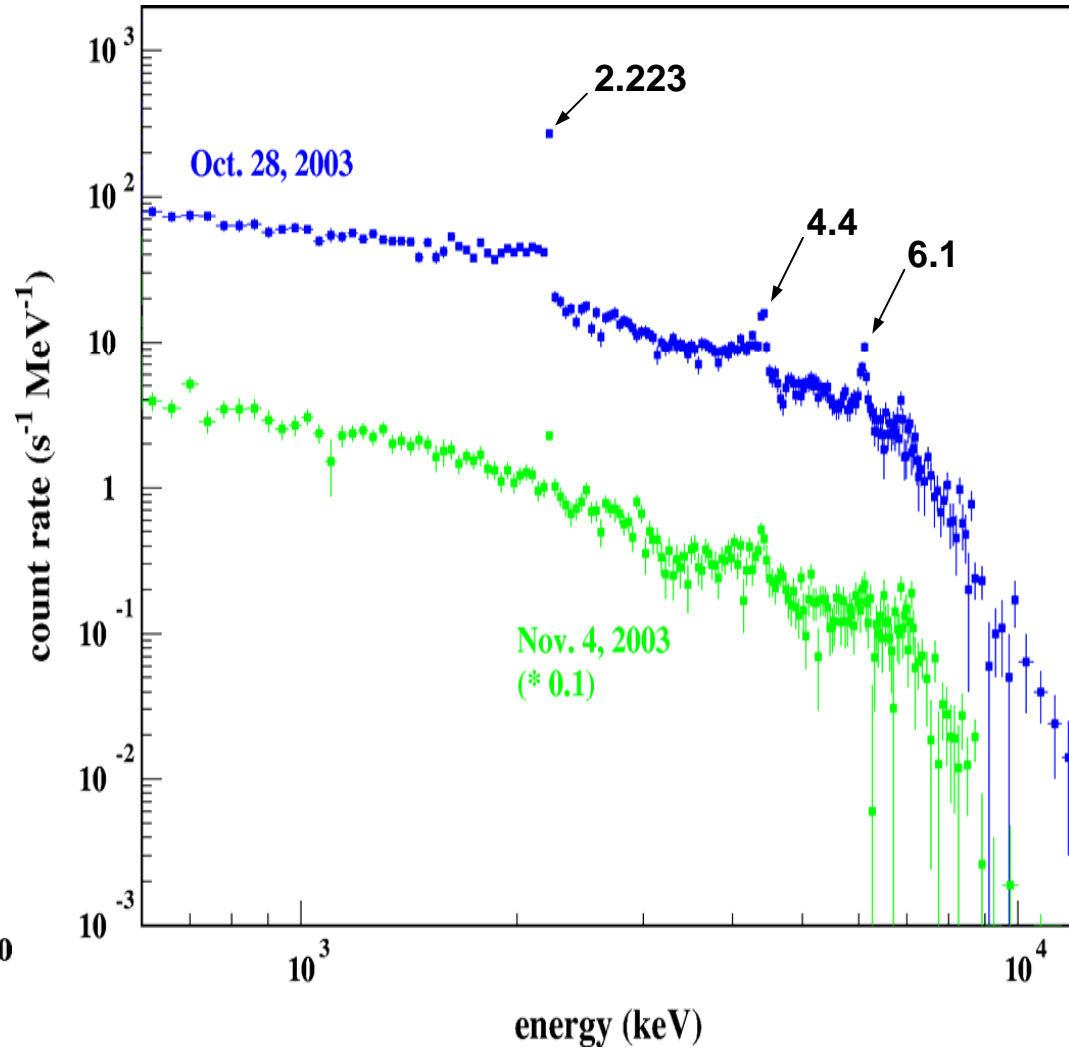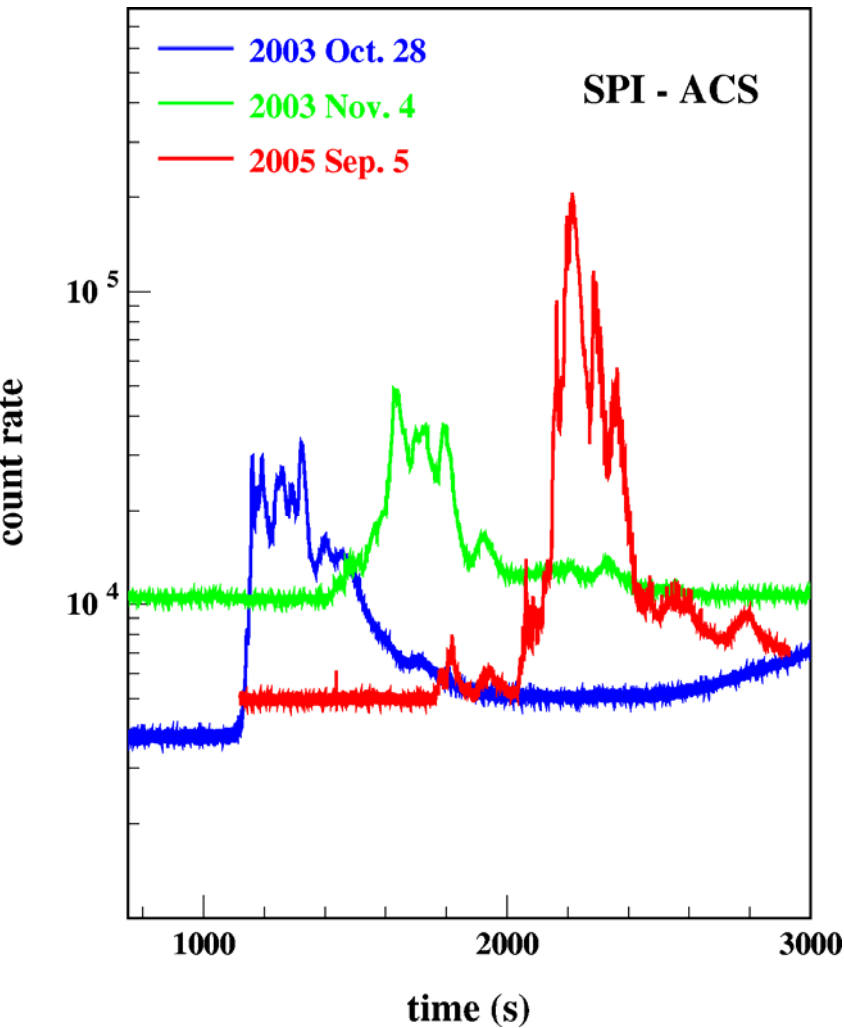

28 Oct. 2003 flare

SPI observation of the 28 October 2003 solar flare
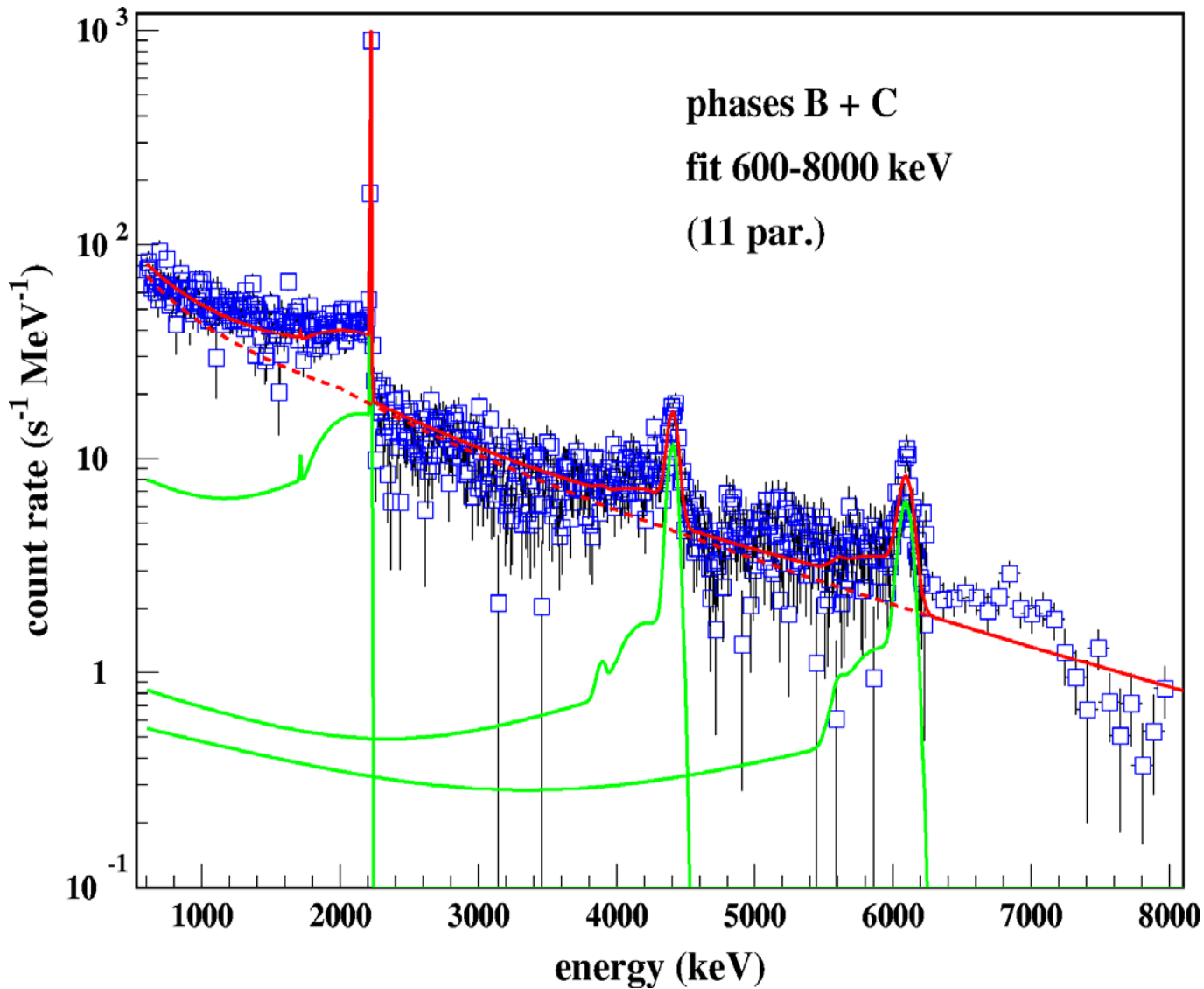## (4 November 2003 / 7 September 2005)

Masks

BGO shield

Simulated response function
for the satellite configuration
during the flare: (MGGPOD
G. Weidenspointner et al.)

32 °

ISGRI

PICSIT

Ge detector
matrix

BGO shield

spectra and time history

lines: 2.223 MeV [^{1}H(n,γ)], 4.4 MeV (^{12}C), 6.1 MeV (^{16}O)
others: ~7 MeV (^{16}O) ~1.5 MeV (^{20}Ne,^{24}Mg,^{28}Si)

spectrum fit

phases B + C

fit 600-8000 keV

(11 par.)

line fluences

$\Phi_{2.223}$ = 1286±132

$\Phi_{4.4}$ = 140±21
(141)
E = 4407±4 keV
FWHM = 88±10 keV

$\Phi_{6.1}$ = 130±21
(130)
E = 6102±7 keV
FWHM = 133±17 keV

The 2.2 MeV - 4.4 + 6.1 MeV line emission

$\Rightarrow$ Accelerated particle composition and energy spectrum (α/p, S)

$\Rightarrow$ Ambient abundances

$\Rightarrow$ (flare geometry, ambient ^{3}He <- timing)
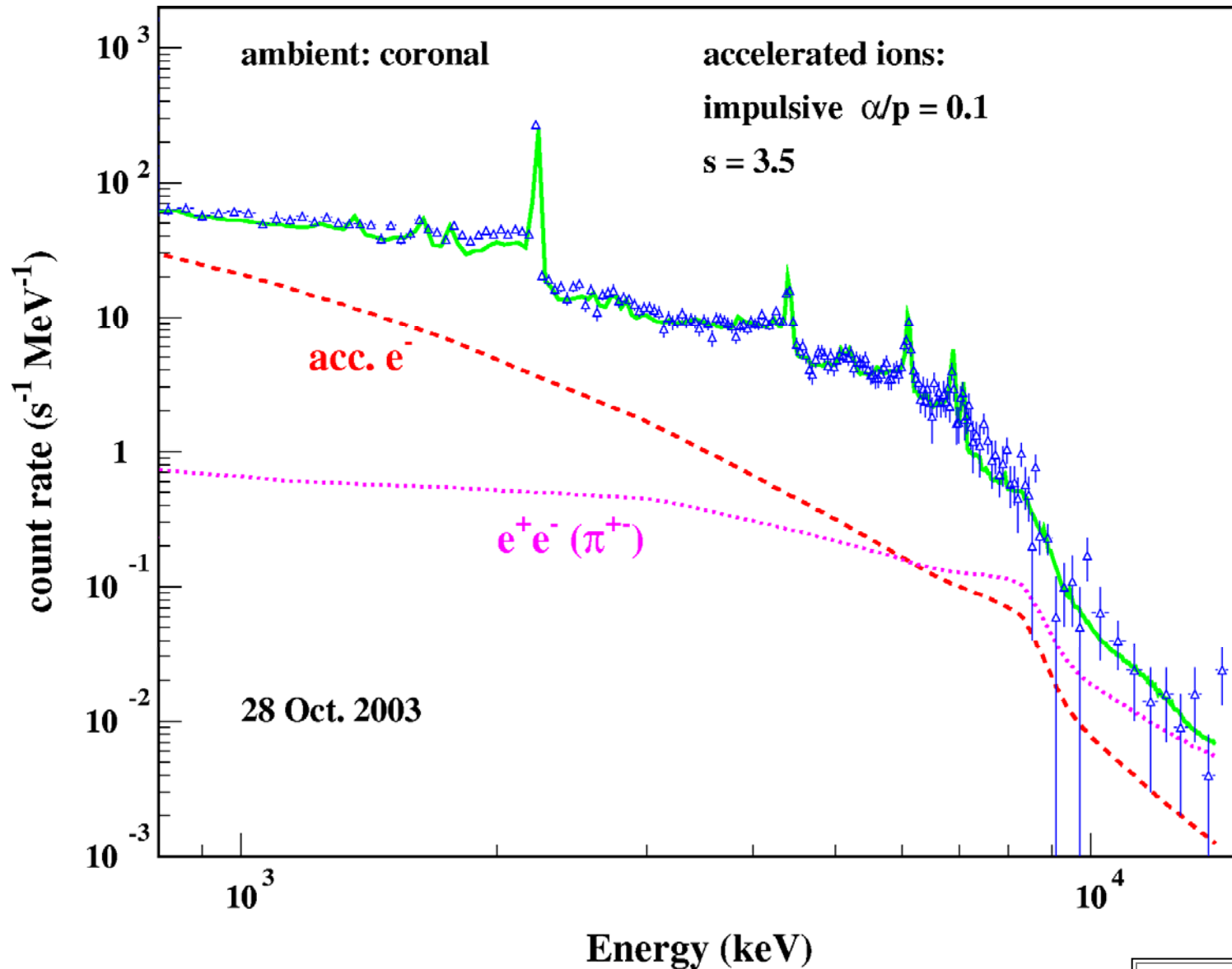

Power law spectral index S
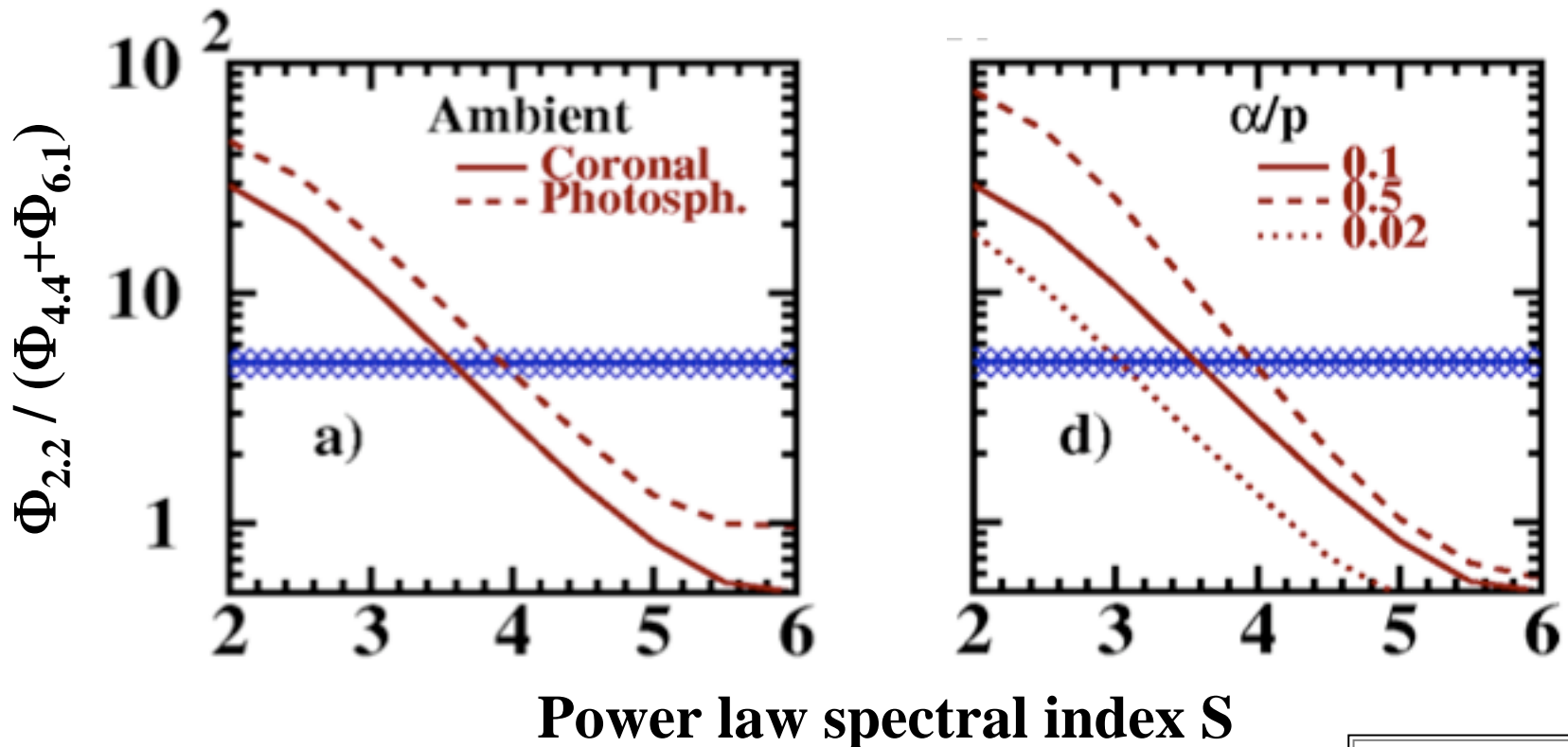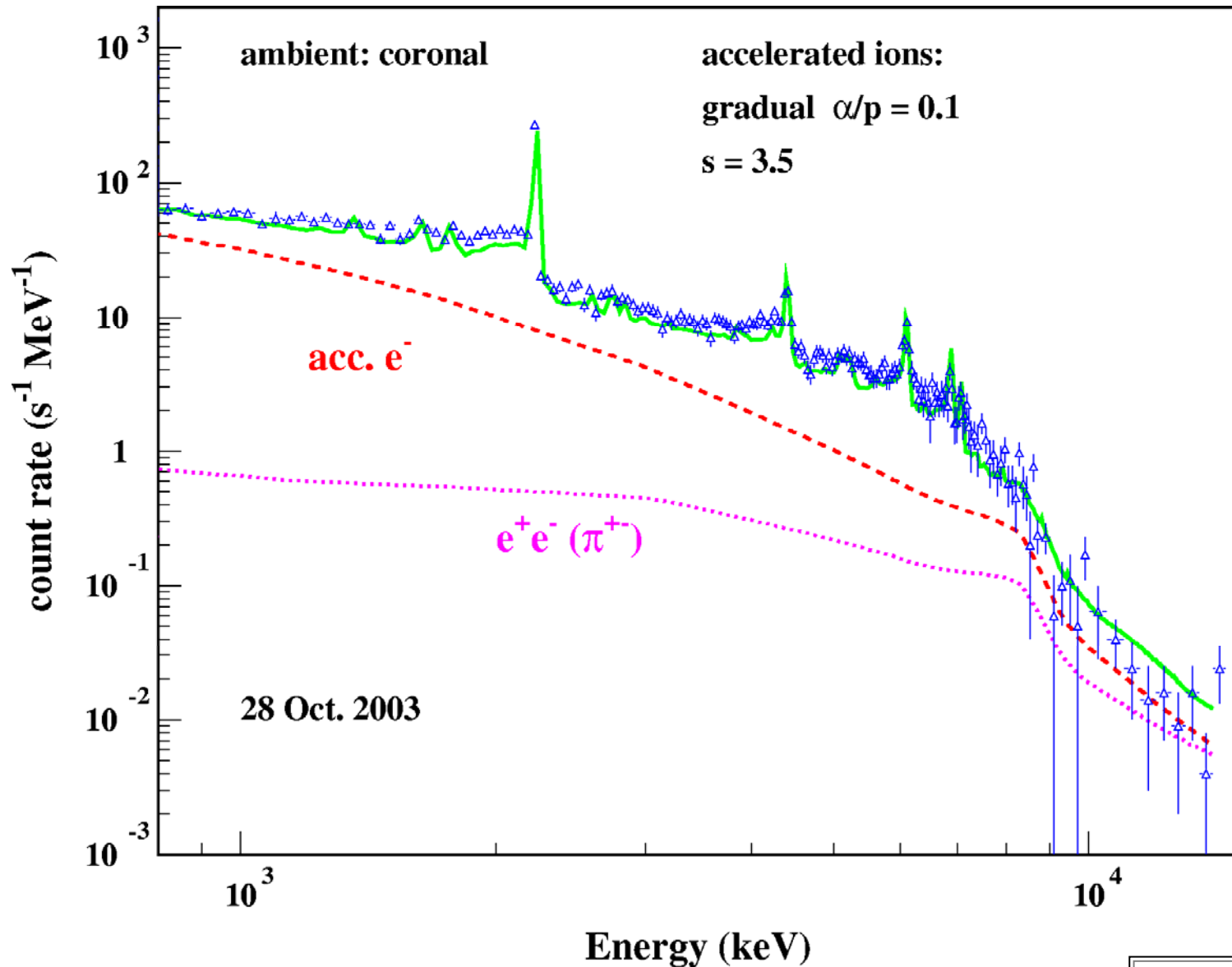
accelerated-particle composition
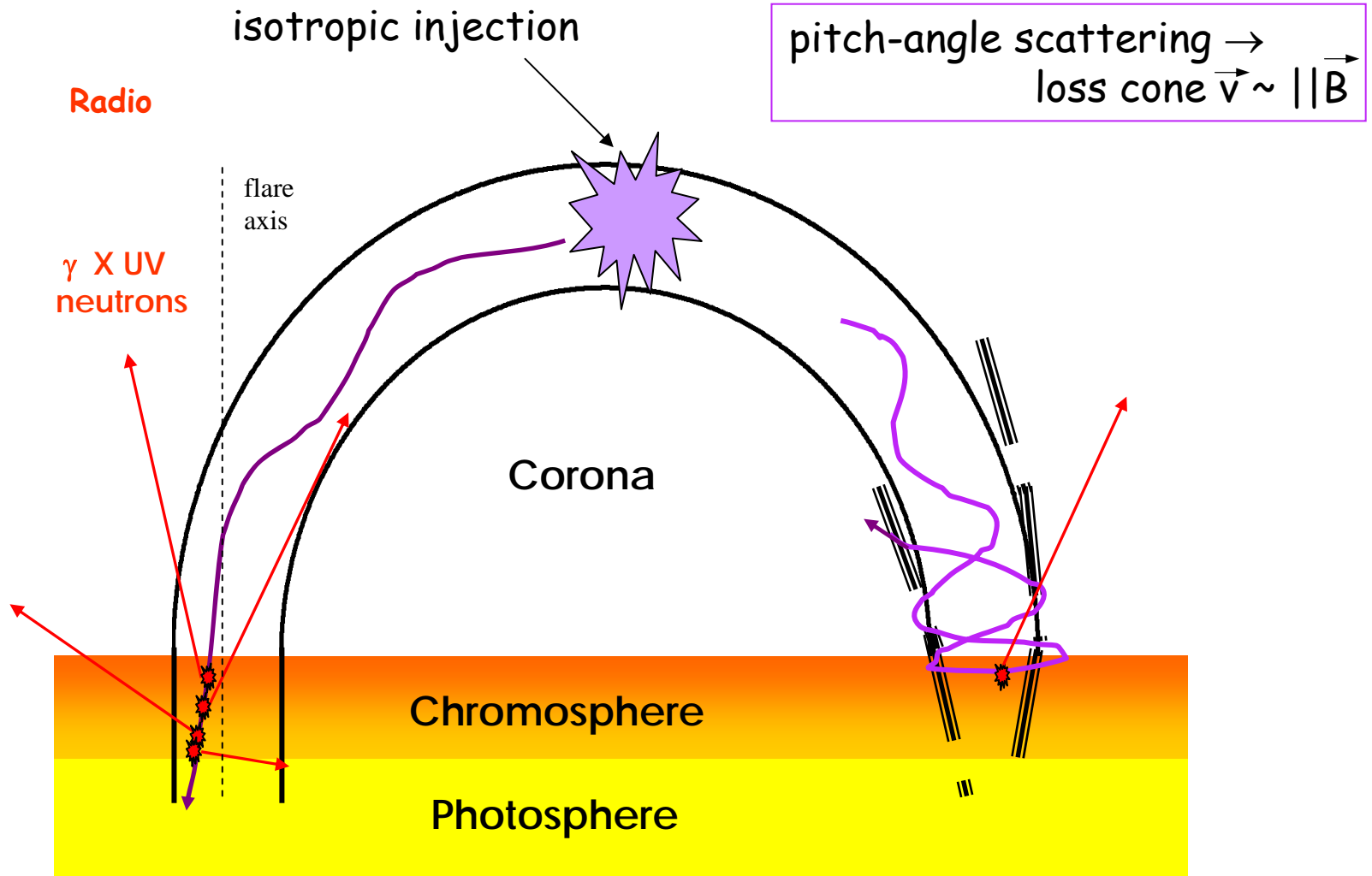
solar energetic particle (SEP) observations
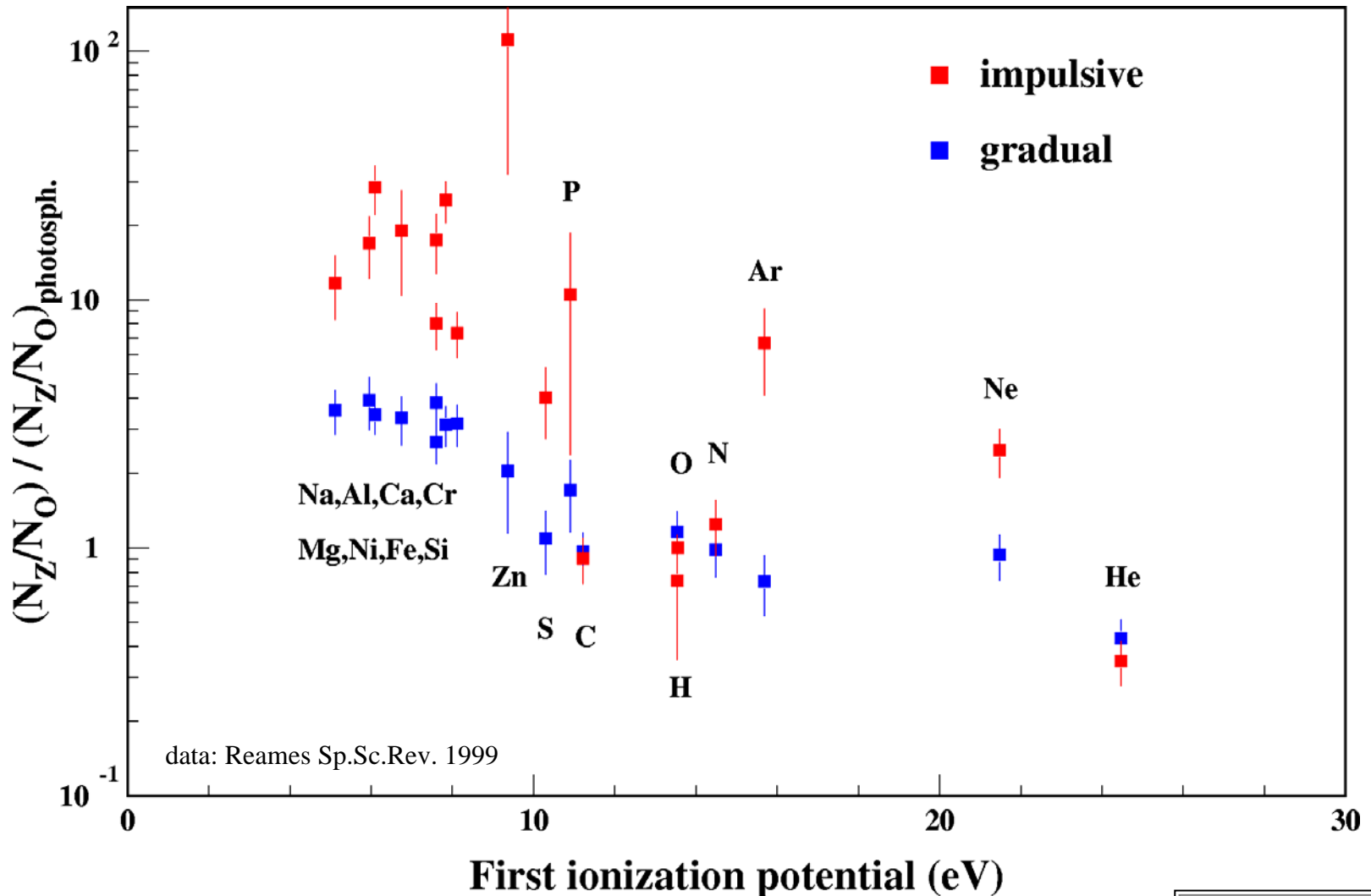
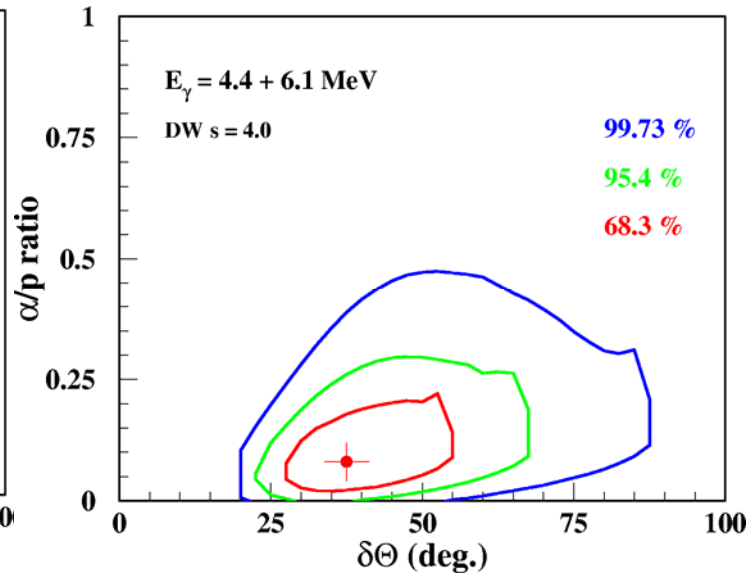# total nuclear line emission + leptons

total nuclear line emission + leptons

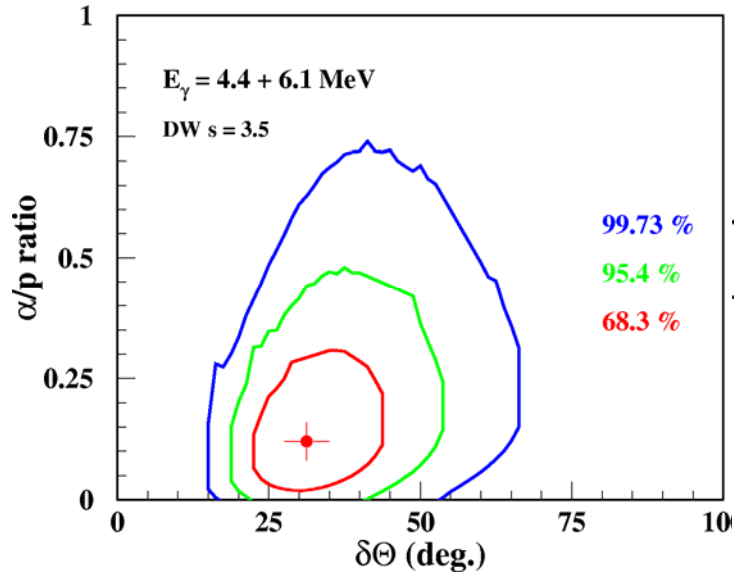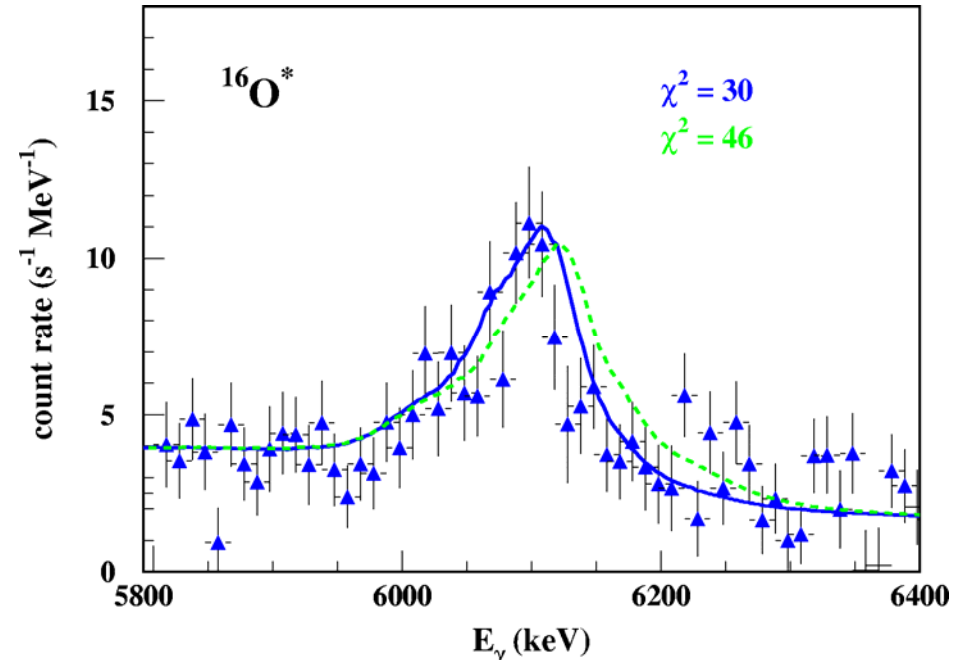# interactions particles - solar atmosphere

isotropic injection

pitch-angle scattering →
loss cone $\vec{v} \sim ||\vec{B}$

Radio

flare
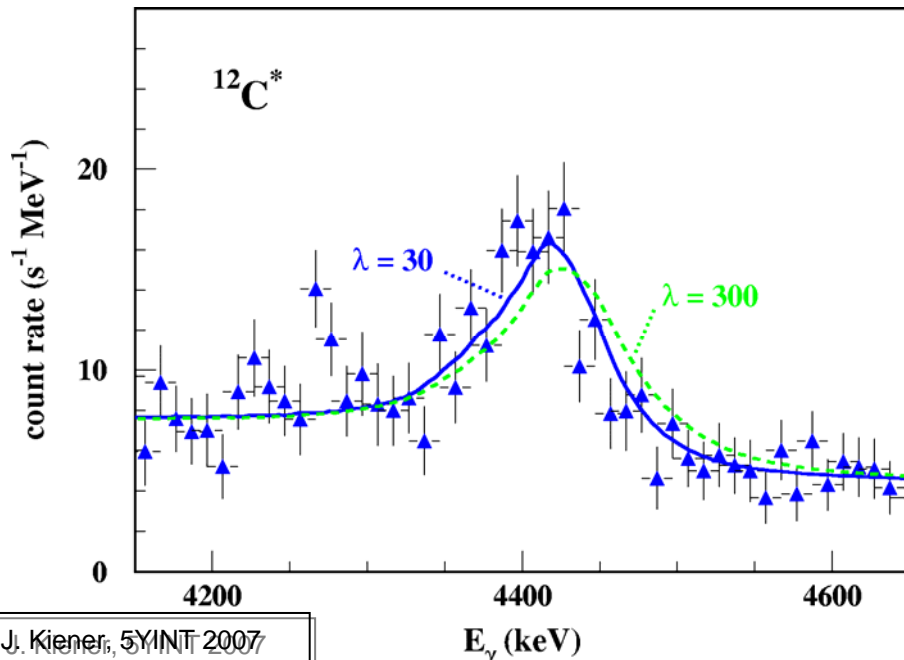axis

γ X UV
neutrons

Corona

Chromosphere

Photosphere

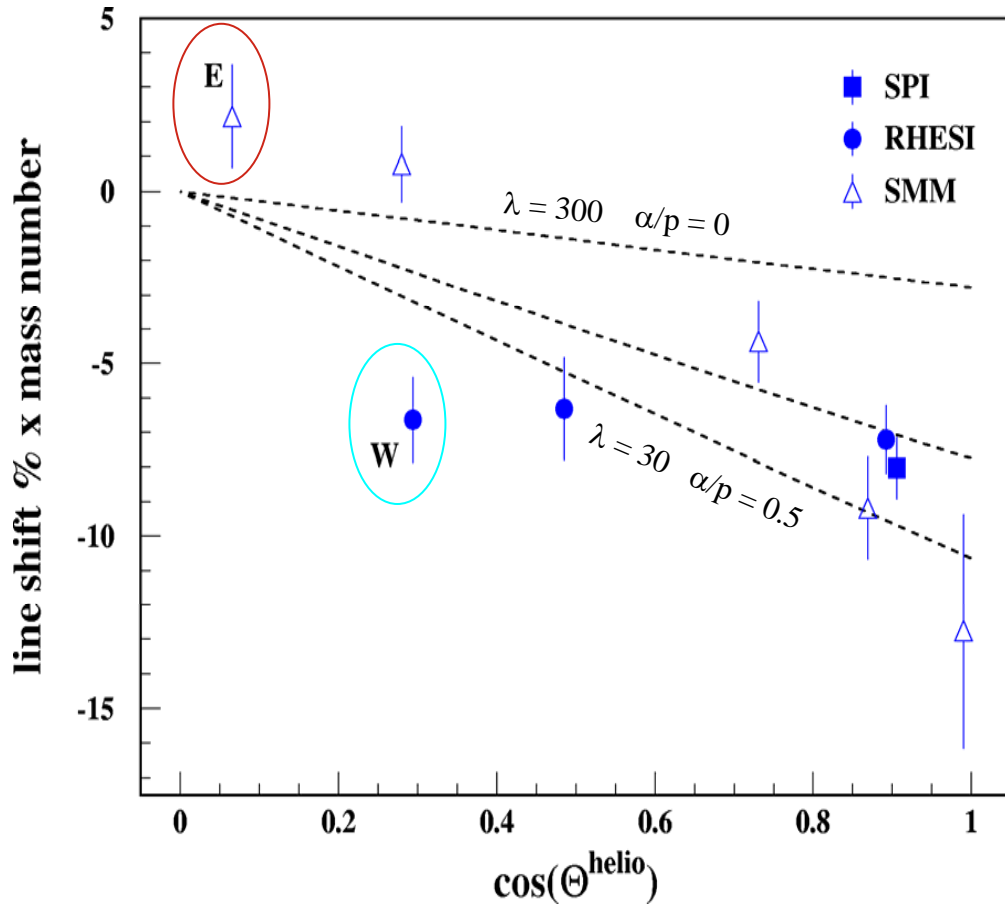Composition solar atmosphere :
H (90%), He(10%), O(0.06%) C(0.03%) etc.

gamma-ray line shape

line shifts

line shifts