High Energy Gamma-ray Emission, Energetic Electrons and Solar Proton Events.

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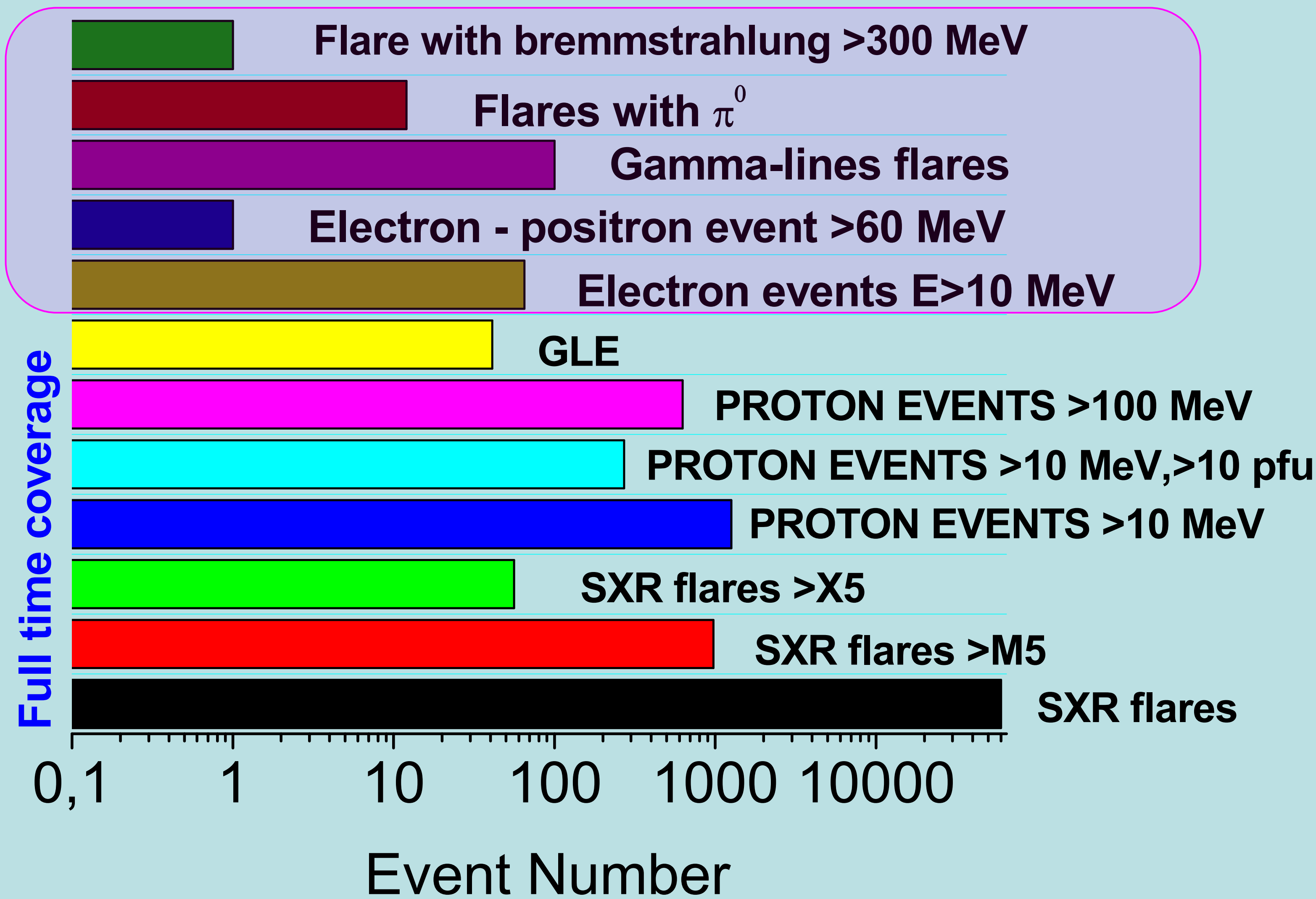
THE TOTAL NUMBER OF EVENTS Recorded at 1976-2006

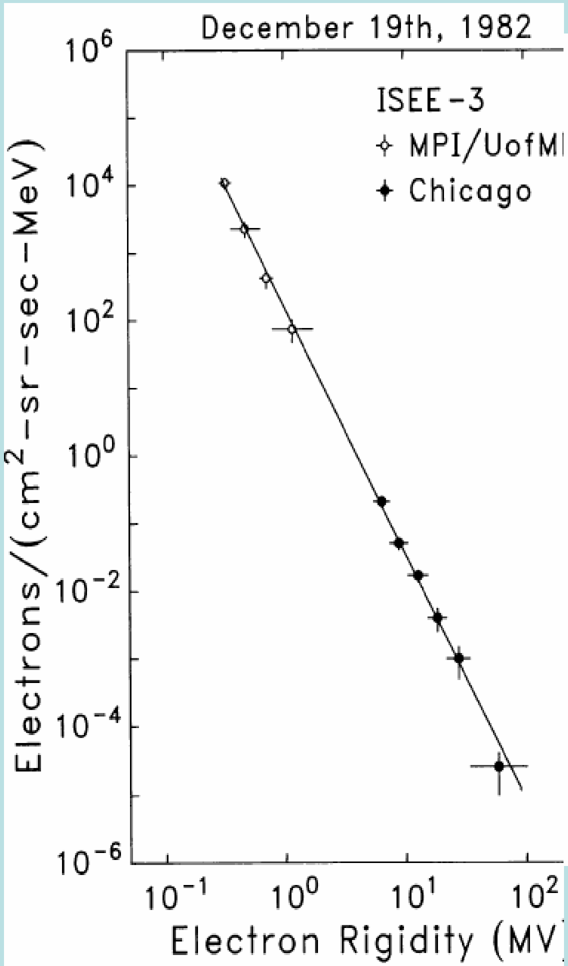


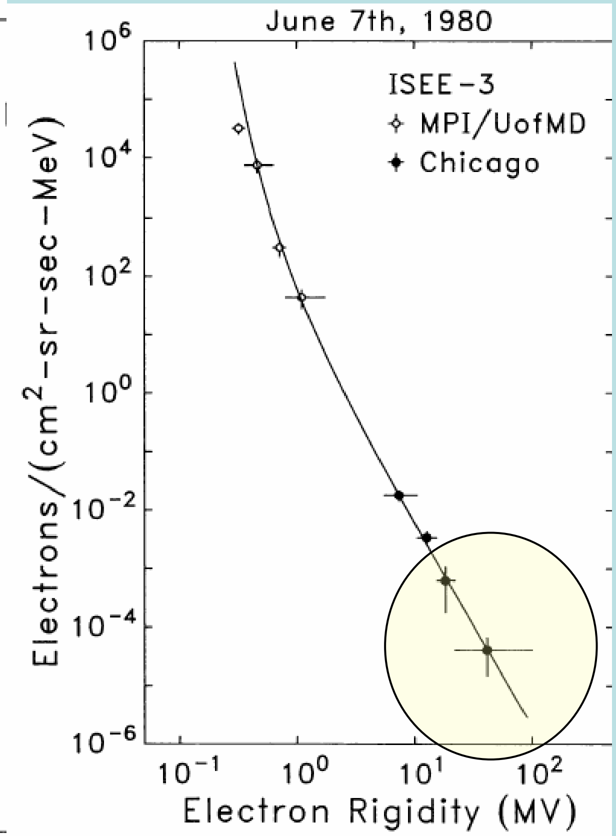
H.Zirin, 2000, High-Energy Solar physics- *Anticipated HESSI*.

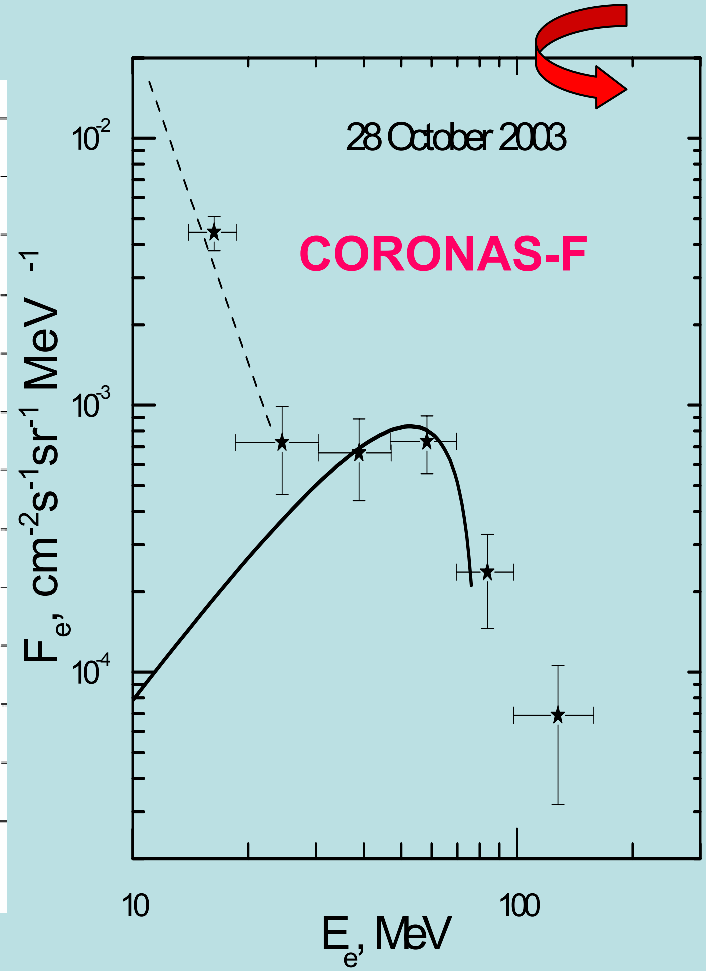
While we perforce use the GOES data there is no reason to believe it represents the true flare “importance”. The GOES value is a peak value, roughly the time integral of the hard X-ray input, which is probably the primary energy input. But peak values give no weight to extended energy input. This exaggerates the apparent effects of long duration flares. The input is much larger than that implied by the peak value.

Interplanetary electrons- Positrons???

$\pi^{\pm} \rightarrow \mu^{\pm} \rightarrow e^{\pm}$ decay process



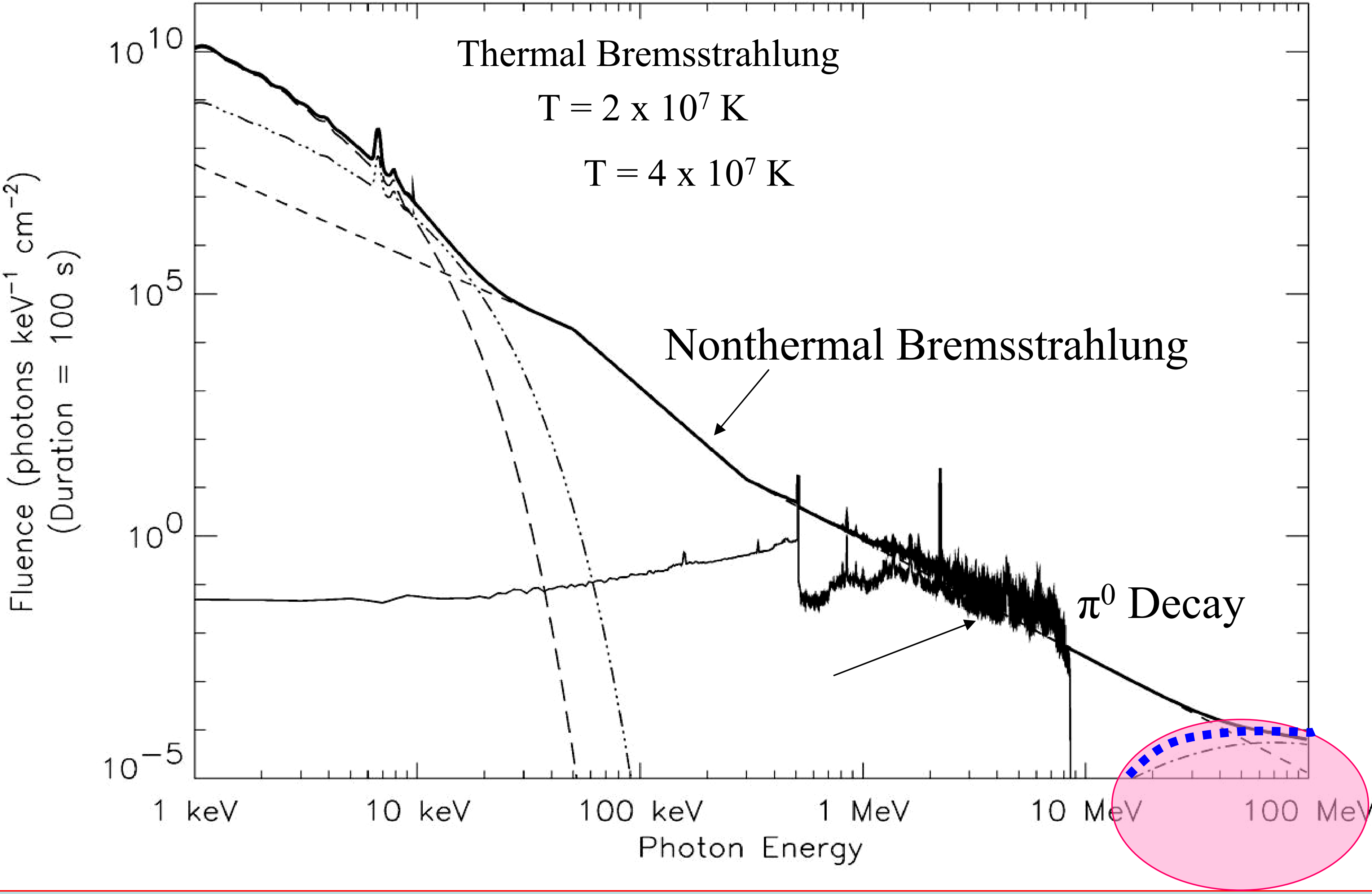




Kuznetzov et al., in press

P. Evenson et al., Ap. J., 299: L107-110

Composite Solar Flare Spectrum

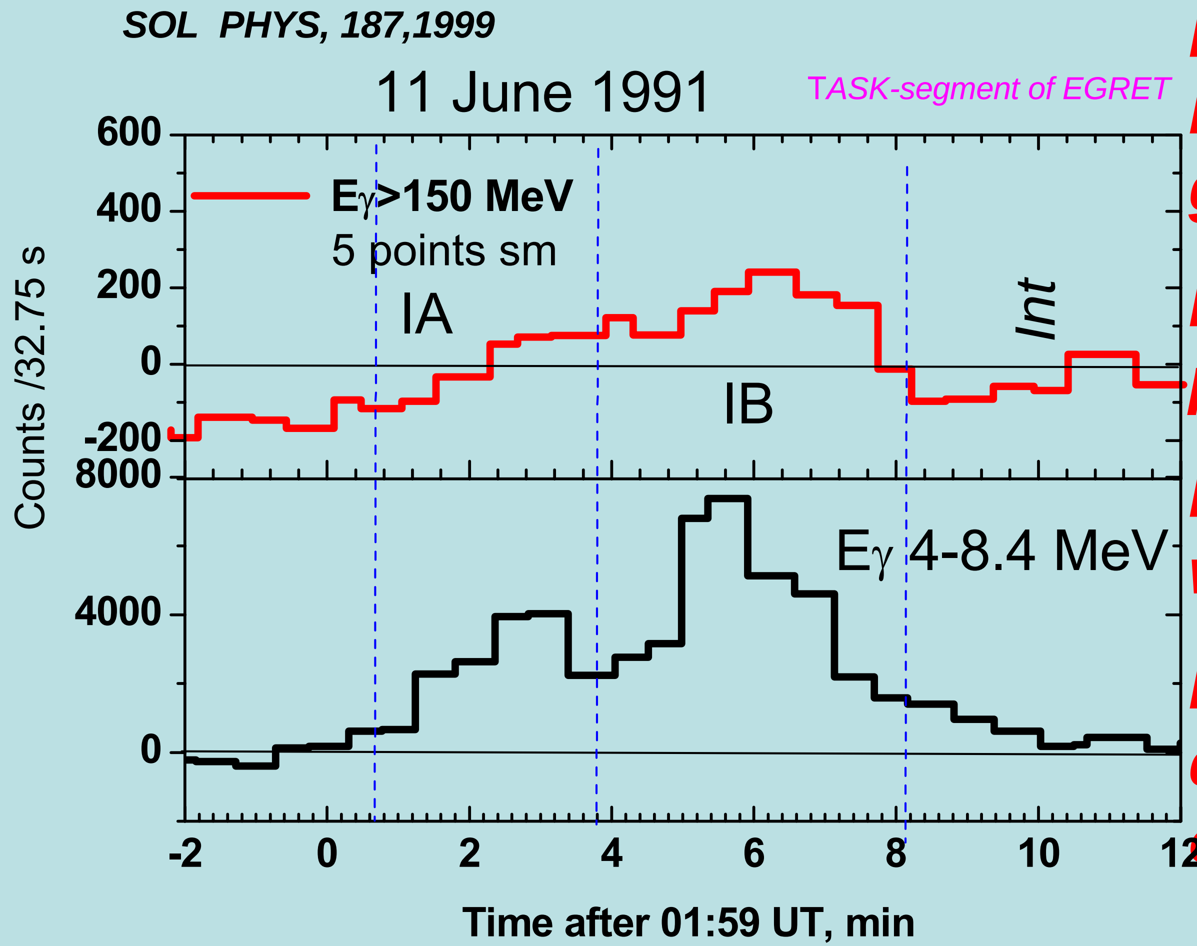


A broad pion-decay emission observation gives us the exact time of the appearance of high-energy protons in the solar atmosphere that in its turn allows us to compare promptly the time interval when protons have been born with the arrival time of high-energy neutrons and charged particles and calculate the escaping time interval of these particles.

Gamma-ray Emission Flares with $E\gamma > 60$ MeV

№№	Date	Flare position	Spacecraft/ Experiment	References	GLE
1	21 June 1980	W90 N20	SMM/GRS	Forrest et al., 1985	
2	3 June 1982	E72 S09	SMM/GRS	E.L. Chupp et al., 1982,1988	
3	16 Dec 1988	E37 N26	SMM/GRS	P.P. Dunphy and E.L. Chupp, 1992,	
4	24 May 1990	W76 N36	GRANAT/PHEBUS	R. Talon et al., 1993, Vilmer, 2003	GLE 48
5	26 March 1991	W23 S09	GAMMA/GAMMA-1	V. Akimov et al.,1991,1995	
6	11 June 1991	W17 N31	CGRO/EGRET	G. Kanbach et al.,1992,1991, 1999	GLE 51
7	15 June 1991	W69 N33	GAMMA/GAMMA-1	V. Akimov et al.,1991,1993	GLE 52
8	25 August 2001	W32 S17	CORONAS-F/ SONG	S. Kuznetzov et al, 2004	
9	28 October 2003	W08 S16	CORONAS-F/ SONG	S. Kuznetzov et al, 2004, 2006	GLE 65
10	04 November 2003	W83 S19	CORONAS-F/ SONG	S .Kuznetzov et al, 2004	
11	20 January 2005	W61 N14	CORONAS-F/ SONG	S. Kuznetzov et al,	GLE

Time profile in different phases of the flare on 11 June 1991

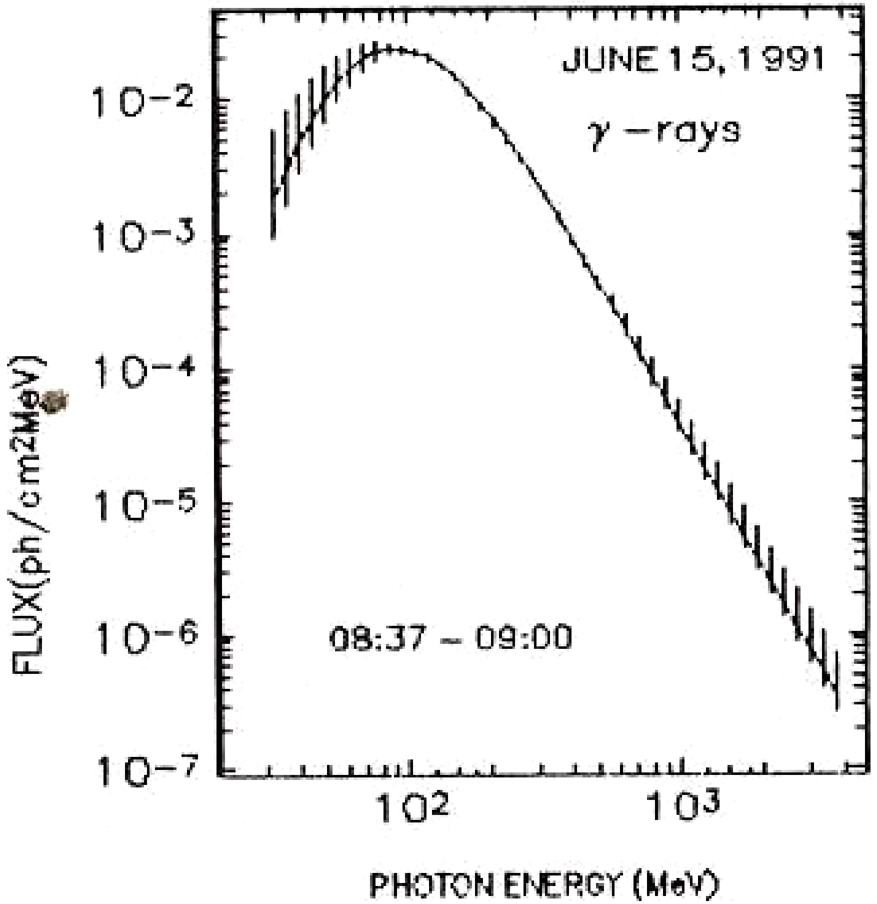


Phase I A-mainly bremsstrahlung and gamma-lines

Phase 1B-intense π^0 production

Intermediate phase with low intensity

Phase II long lasting delayed phase with obvious π^0 excess



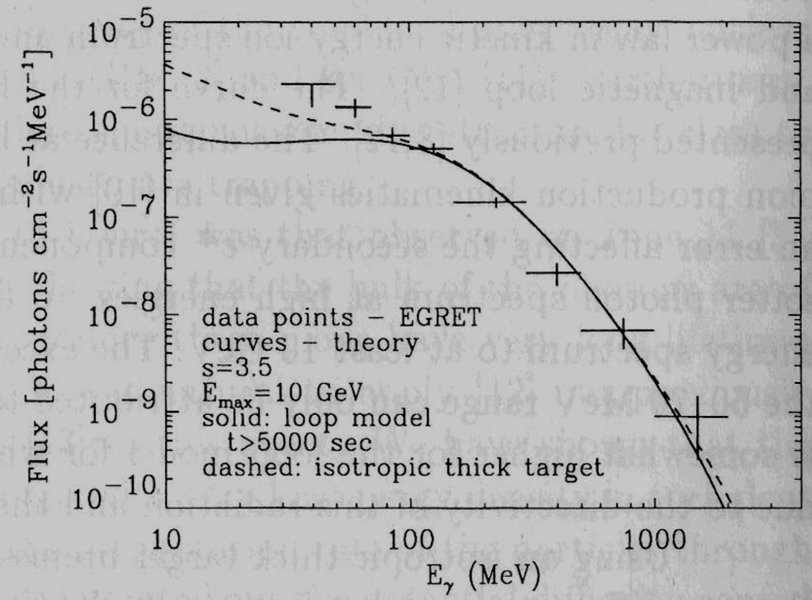
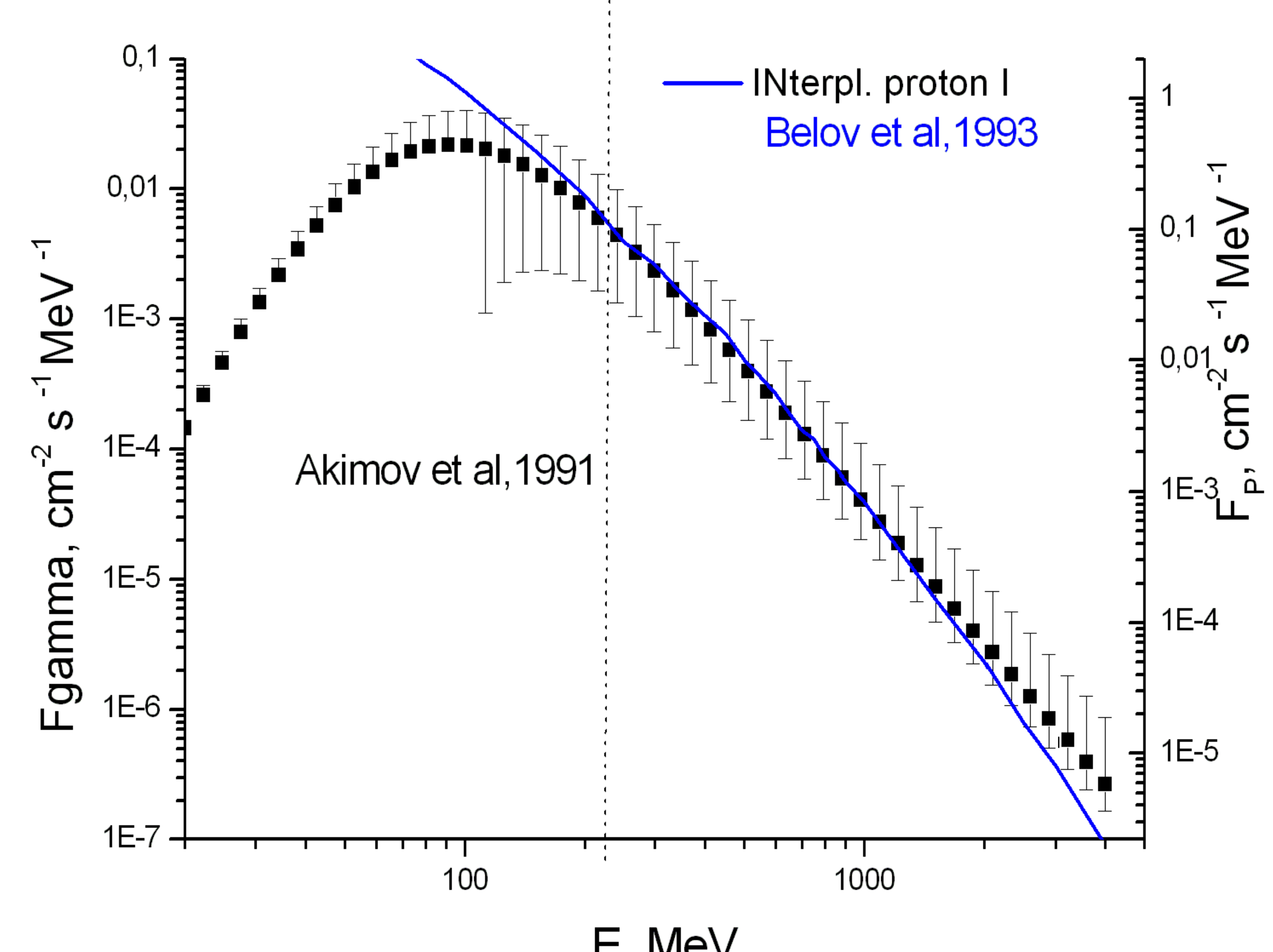


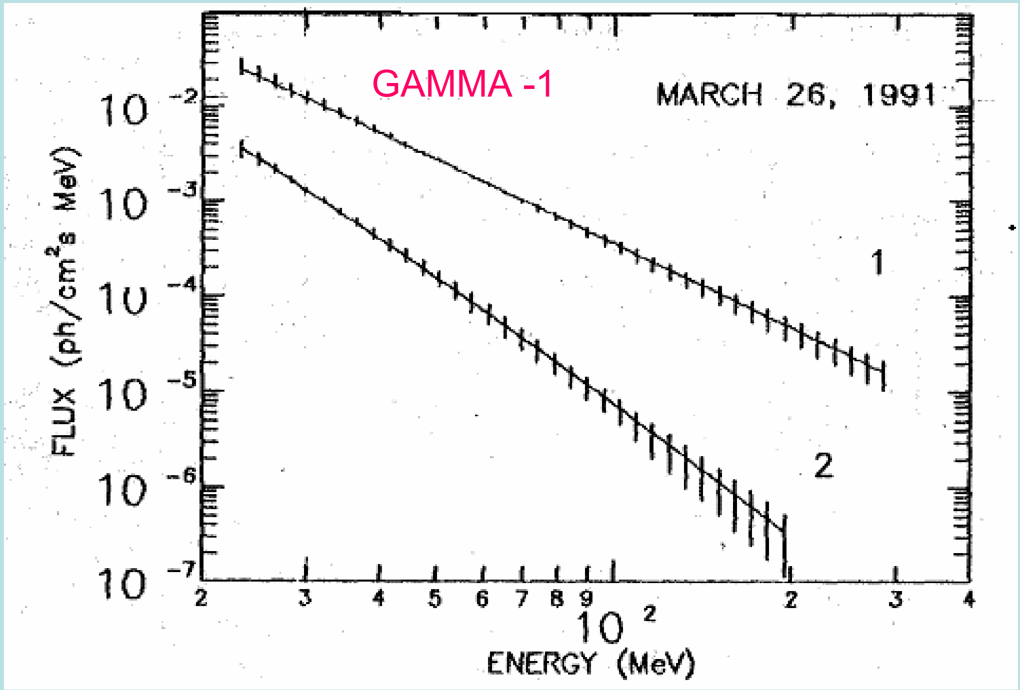
Fig. 2 Gamma ray energy spectrum for the June 11 flare.

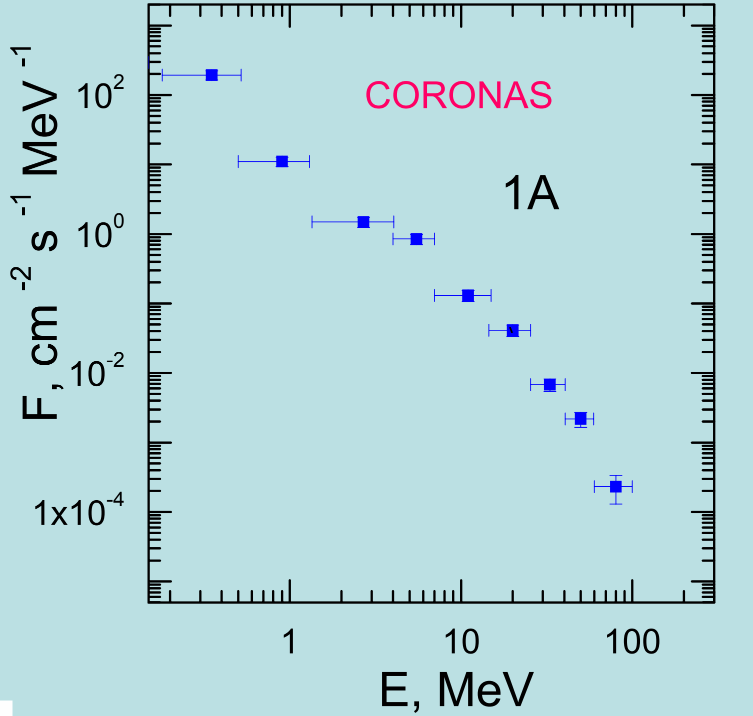
Energy spectrum in the long lasting delayed phase of the 11 June 1991 flare measured by EGRET

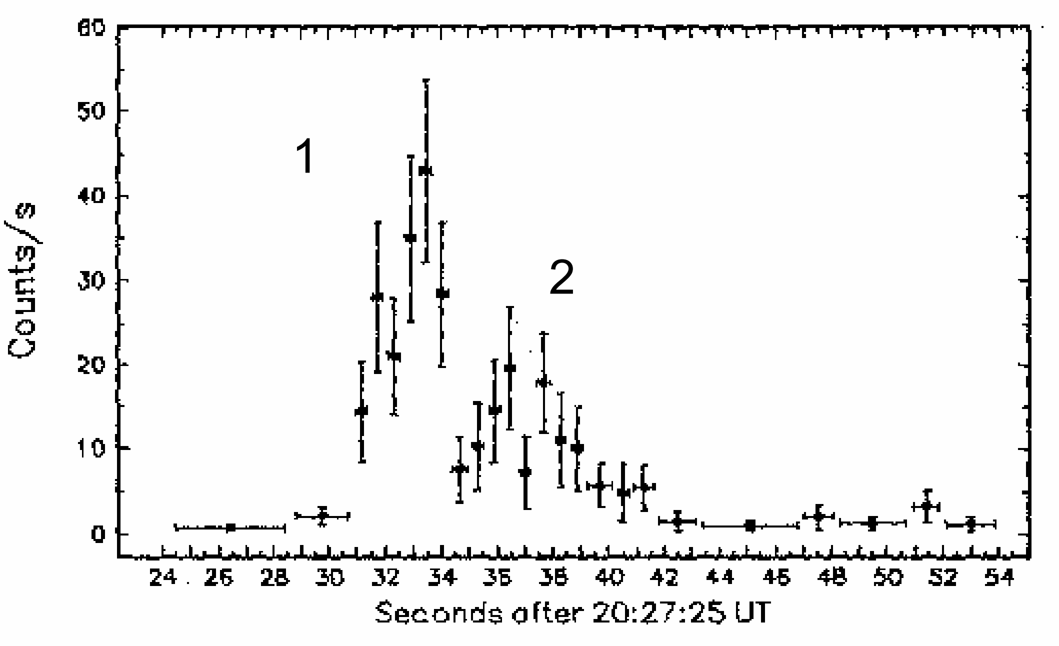
Energy spectrum in the long lasting delayed phase of the 15 June 1991 flare measured by Gamma- 1 .

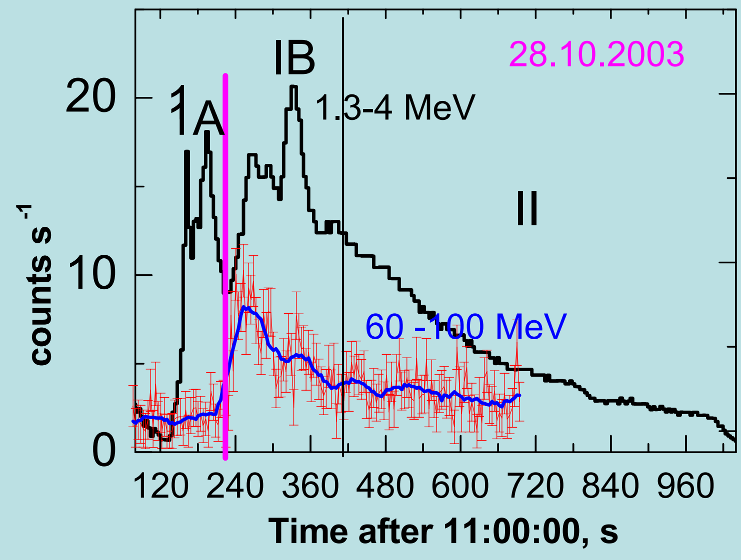


INterpl. proton I
Belov et al,1993
Akimov et al,1991
Fgamma, cm-2 s-1 MeV-1
FP, cm-2 s-1 MeV-1
0,1
0,01
1E-3
1E-4
1E-5
1E-6
1E-7
1
0,1
0,01
1E-3
1E-4
1E-5
100
1000
E, MeV


GAMMA -1
MARCH 26, 1991
FLUX (ph/cm^2s MeV)
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
1
2
2 3 4 5 6 7 8 9 10^2 2 3 4
ENERGY (MeV)

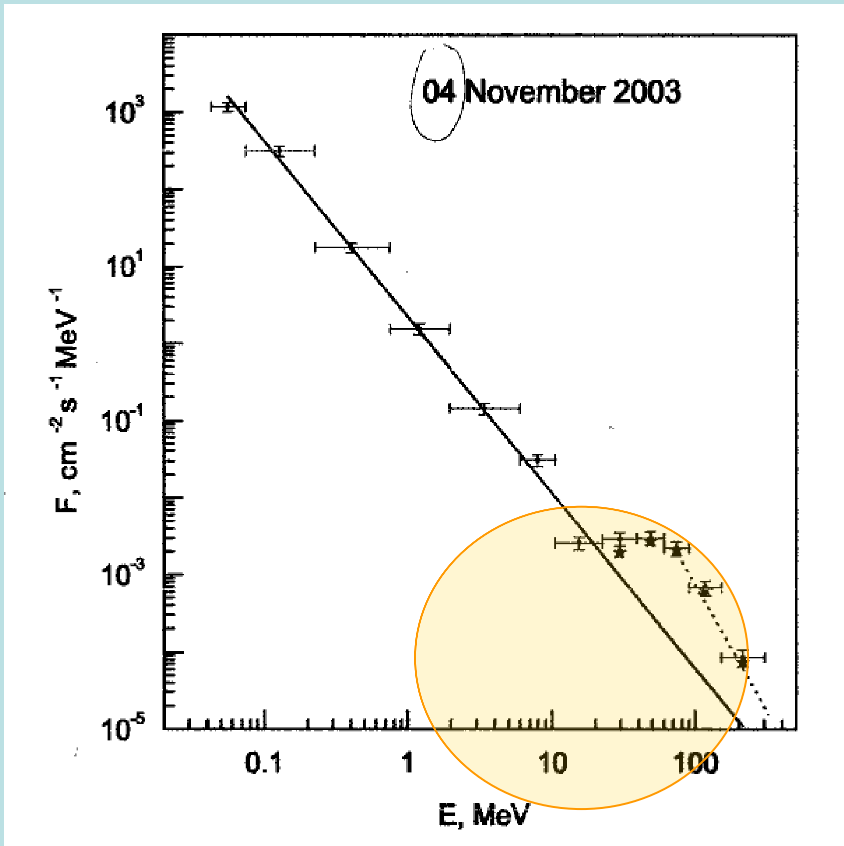

CORONAS
1A
F, cm^-2 s^-1 MeV^-1
10^2
10^0
10^-2
1x10^-4
1 10 100
E, MeV

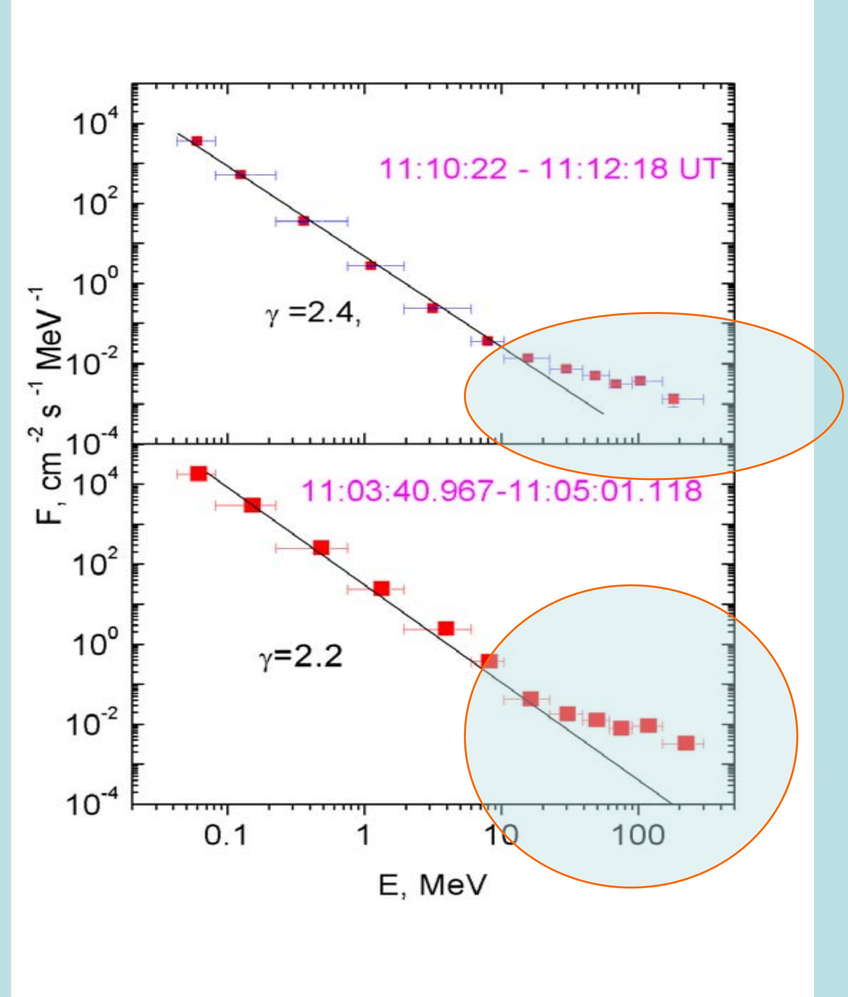

Counts/s
0 10 20 30 40 50 60
1
2
24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54
Seconds after 20:27:25 UT


28.10.2003
IB
1A
1.3-4 MeV
II
60 -100 MeV
counts s^-1
0 10 20
120 240 360 480 600 720 840 960
Time after 11:00:00, s

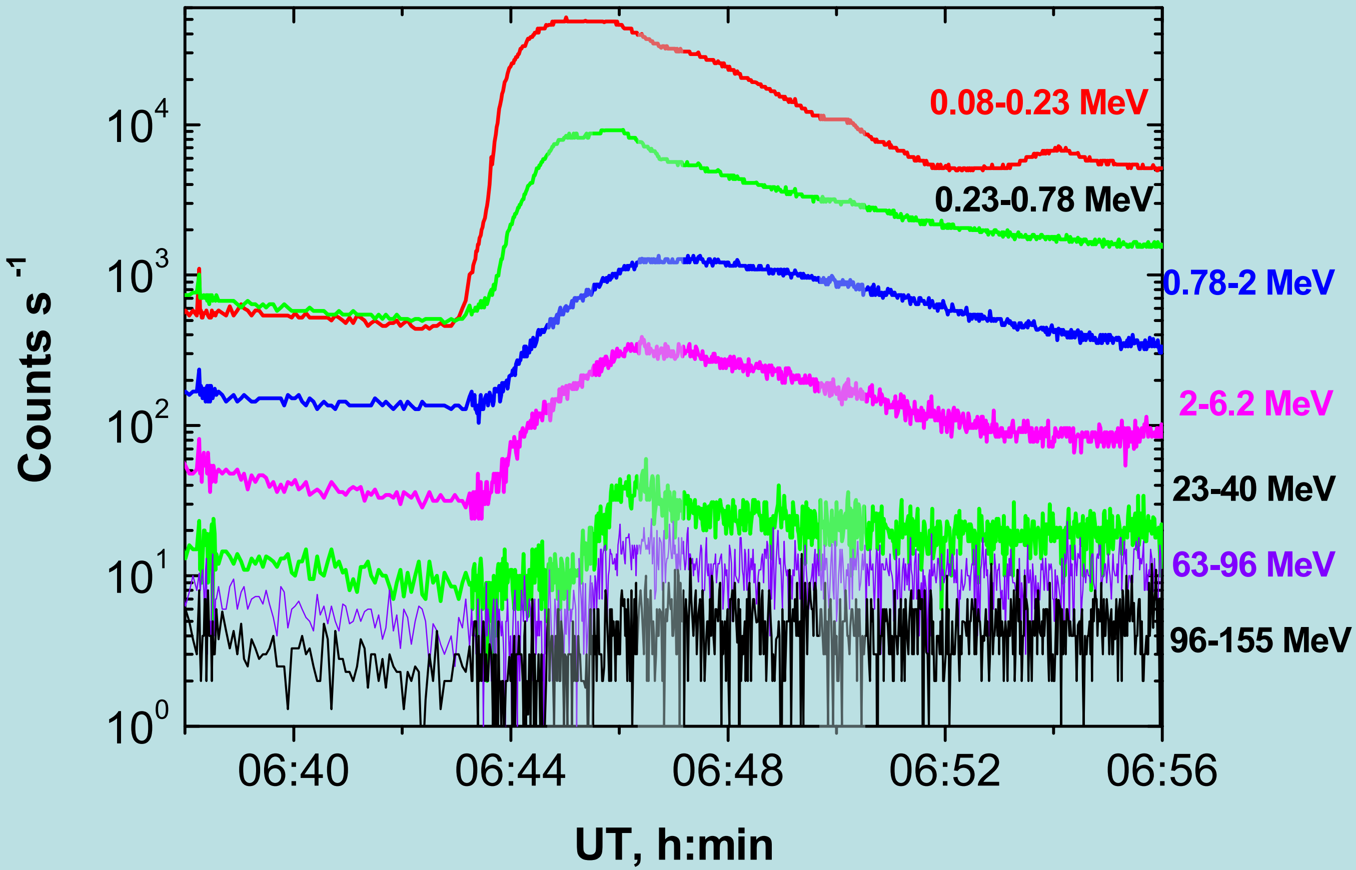
CORONAS-SONG DATA are available at the POSTER desk

π^0 excess in the phase IB of the flares 4 November and in the phases IB and II of 28October 2003 measured by SONG /CORONAS

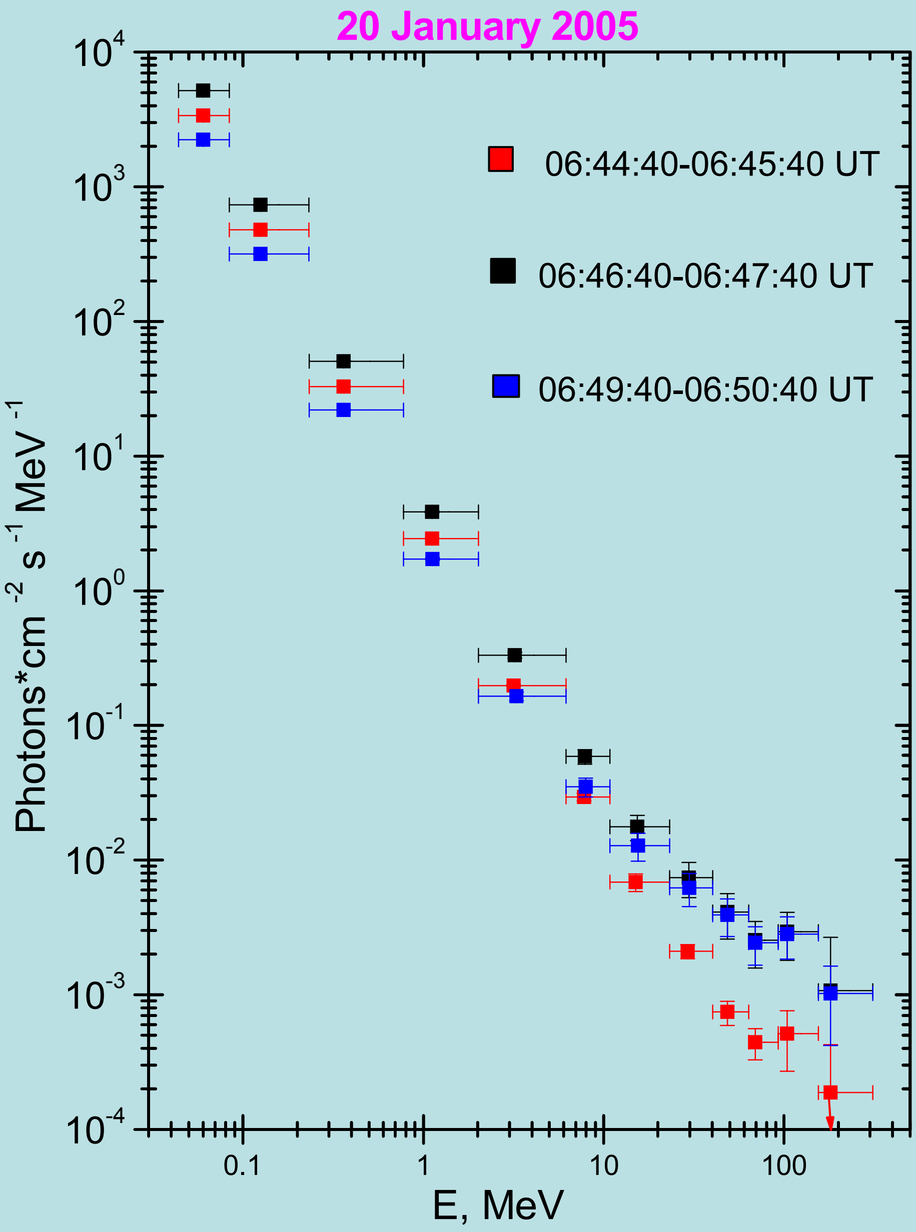




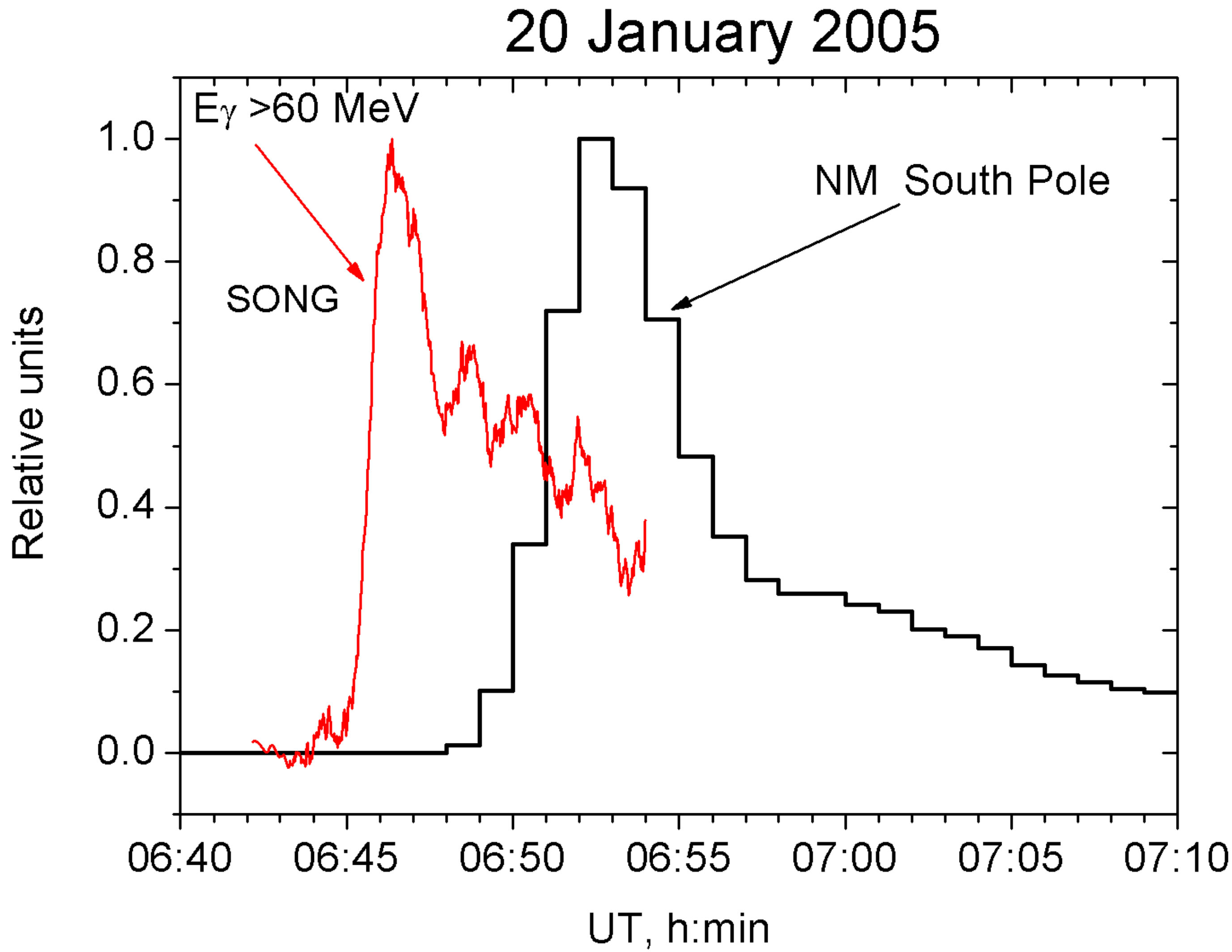
20 January 2005, SONG



Time profiles of the SONG channels counts rate. Background is not subtracted.

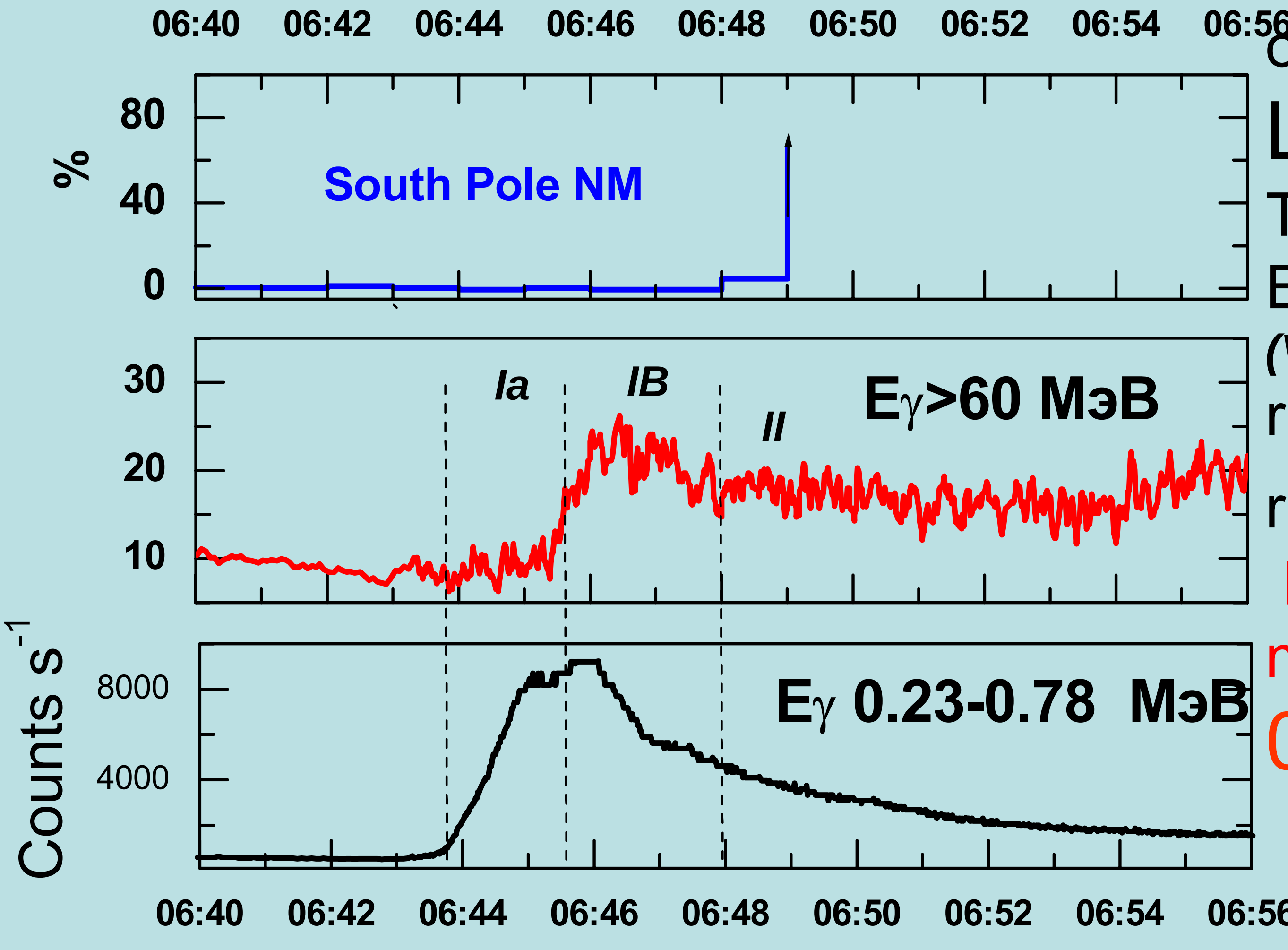


The photon spectra measured by SONG An appearance of gamma radiation caused by the pion decay is seen from 6:46:40 UT that indicates an existence of high-energy protons in the solar atmosphere.



The spectral peculiarity caused by pion decay becomes visible after 06:45:46 UT.
We defined the beginning of GLE as 06:48:30±00:00:30 UT. Then the time difference between the acceleration time and appearance of this particles at 1 AU is not more than 3 min.

20 January 2005



•R=0.984 AU,
γ-ray emission time of flight=490.5s

•The shortest path of protons
L1 =1.055R

Time delay of Ep=5 GeV *(Vp=0.987c)* relative to gamma-ray is 35 s

Escaping time must be not later 06:48 UT

Combined ground level and space experiments of many years have made it possible to collect a lot of homogeneous data of the active regions properties and of the different solar flares emissions and to perform the statistical analysis of the diverse data sets.

The search of the shape of the distribution functions has become the topic of a large body of research.

The distribution function differentiated with respect to any events - (spectrum) $\Psi(\Phi)$ is defined as:

$$\Psi(\Phi)=dN(\Phi)/d\Phi \qquad (1),$$

where N –total number of the events,

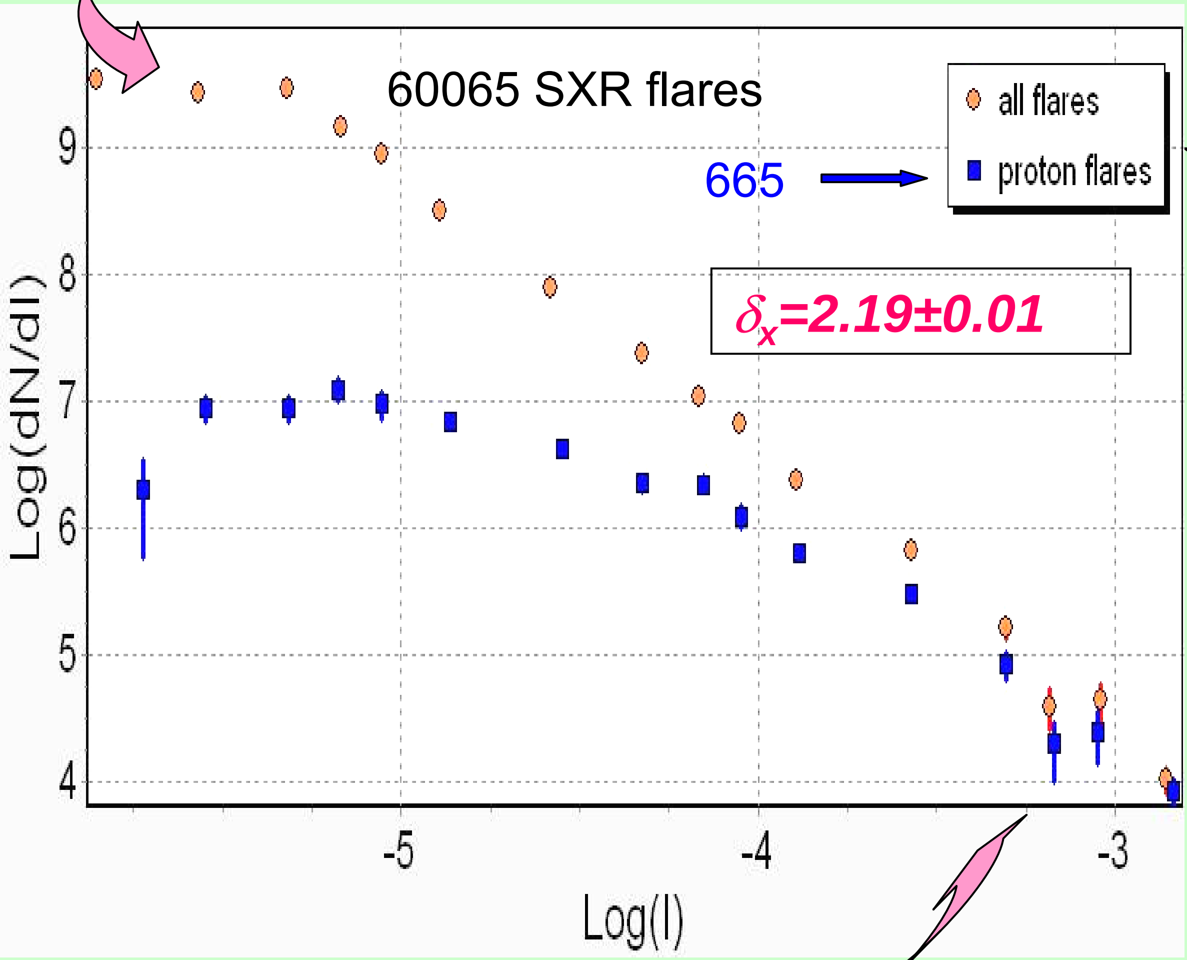
dN-number of events with Φ in the interval dΦ;

Φ- is any characteristic property of neutral emission of solar flare or charged particle fluxes – protons/ions/electrons of solar origin.

We cannot theoretically evaluate exactly the range of photons/particles fluxes where the observed distributions are adequate to reality

It was demonstrated that the form of any distribution is typical. It exhibits:

turnover or flattening in the smallest Φ values which are accessible for the measurements under review;



above the turnover the distribution can be represented by power law over several orders of magnitude where C and ν are constants determined from a least square fit to the data.

$\Psi_j(\Phi) = C_j \Phi^{-\nu}$:

feasible softening of the spectrum or break-point in the greatest values of Φ.

The absence of the remarkable steepening testifies that during observations period lasting 30 years a threshold of the highest flare's energy release has not yet been achieved. (Remember over the limb events, estimated as >X40 (Kane et al., AP. J. ,.446, L47,1995))

Have our present measurements progressed to this point?

Energetic particle distributions

- The studying of the peak size distributions of the electron and proton fluxes of solar flares has been made repeatedly using the different data sets.

Early data

$\nu \sim 1.15\text{-}1.3;$

It was found subsequently that the slope of peak size distributions of electrons and protons lies in the range of $\nu \sim$ 1.3-1.4 in spite of the big differences of fitted data sets.

- The scaling exponent was found
- ν**=2.19**±**0.01** of total SXR flares distribution;
- ν**=1.26**± **0.03** of total SPEs with Ep>10 MeV;
- ν**=**±**1.29** ± 0.03 of total SPEs with Ep>100 MeV

For the SPEs associated flares located at 15°-75°W

- ν**=1.34**±**0.02** of SPEs with Ep>10 MeV
- ν**=1.46**± **0.04** of SPEs with Ep>100 MeV

- *The conditions of protons acceleration, escaping from the acceleration regions and propagation are arranged in such a way that the peak size distributions of the SPEs formed as a result the power law dependencies. We stress that our SPEs distributions are based on measurement of the proton fluxes at 1 AU and so will not be the same as those for the events on the sun and at other distances from the sun due to both coronal and interplanetary propagation effect*