Extended Gamma-Ray Emission of the Solar Flares in June 1991

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this report can be accessed at http://wwwgro.unh.edu:8080/users/grank/GROUP/groupdocu.html

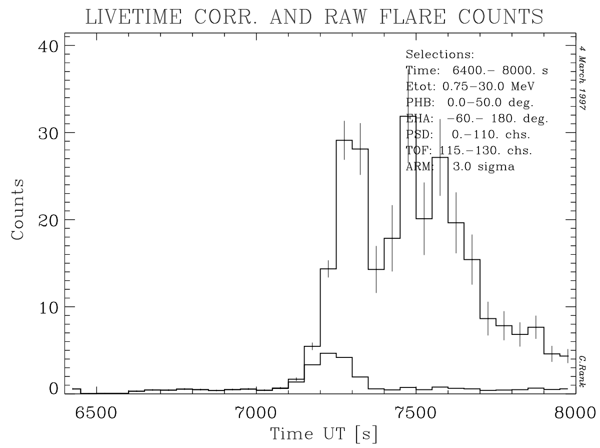
This report gives an update on the analysis of the extended emission of the June 1991 flares and summarizes the conclusions of the paper for the 25th ICRC.

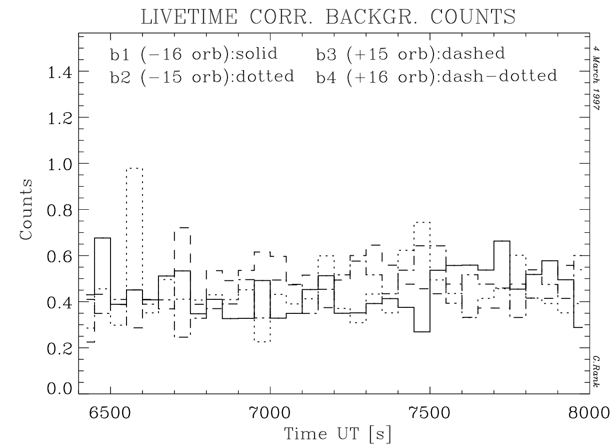
Six major X-class flares occured in June 1991.
During the TOO period (9–15 June) three af them have been observed in the COMPTEL telescope mode: the flares on 9, 11 and 15 June 1991. Extended Emission was found in the flares on 11 and 15 June.
Since the publication of the first long-term time profile the analysis has been improved in some ways. This report also contains first results on extended emission that can be seen in the 9 June flare.

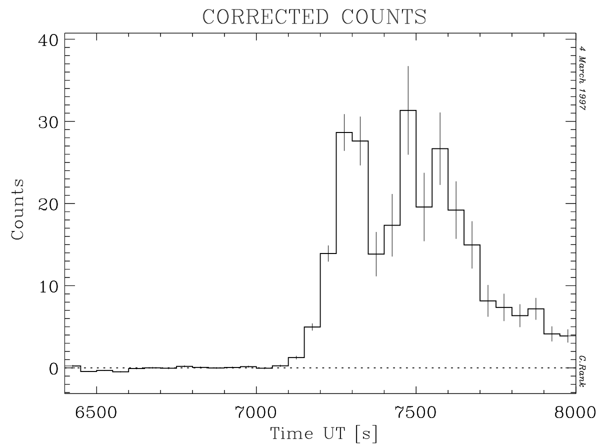
Procedure of solar flare analysis:

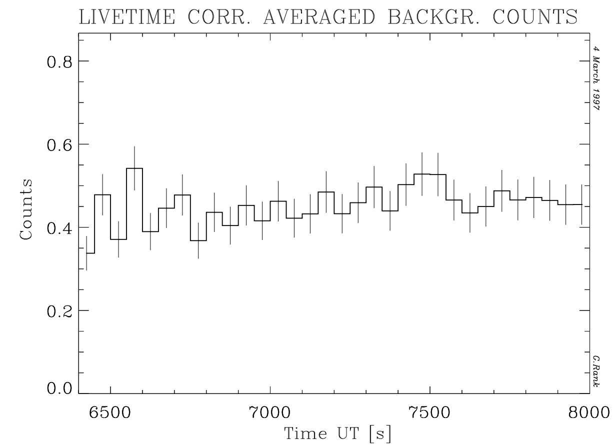
TECHNIQUE:	CHANGES:
— define time interval for flare.	
— define periods 15 and 16 orbits before and after the flare to be used as background.	
— read flare and background events from EVP files, select events.	• Improved TOF calculation. • Different EHA calculation.
— correct for livetime.	• Indications for systematic errors in livetime calculation.
— subtract background.	
— use MEMSYS to deconvolve count rate spectrum into flux spectrum.	• More detailed energy response simulation.

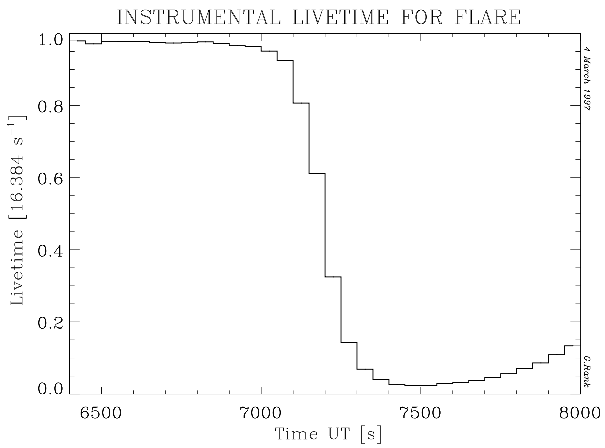
TIME PROFILE PLOTS

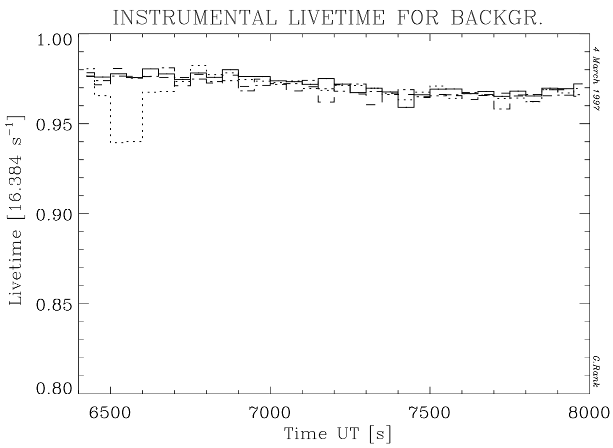




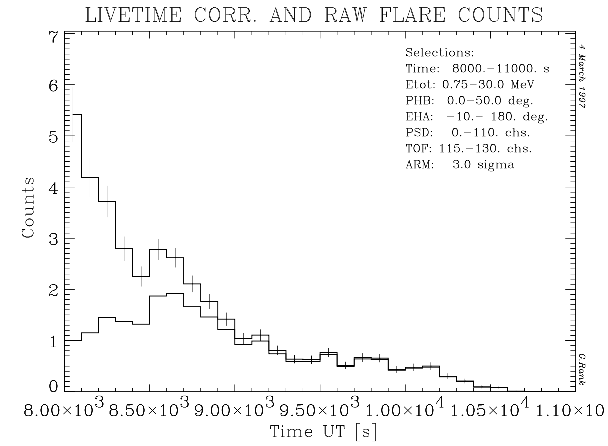


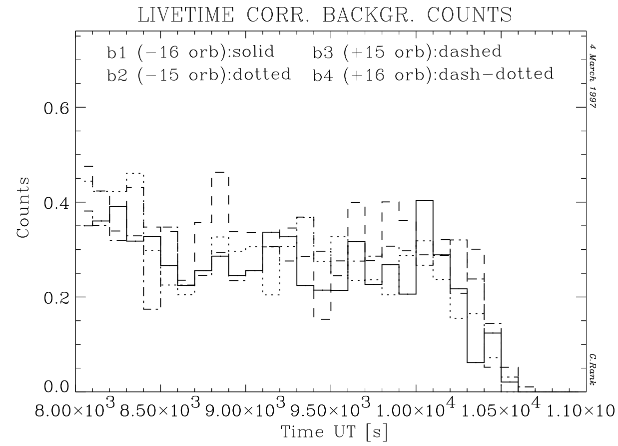


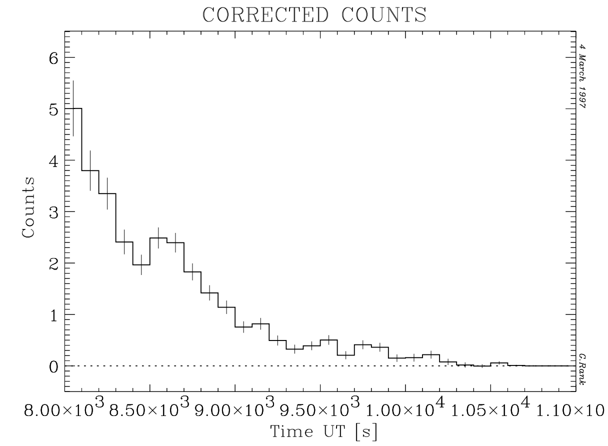


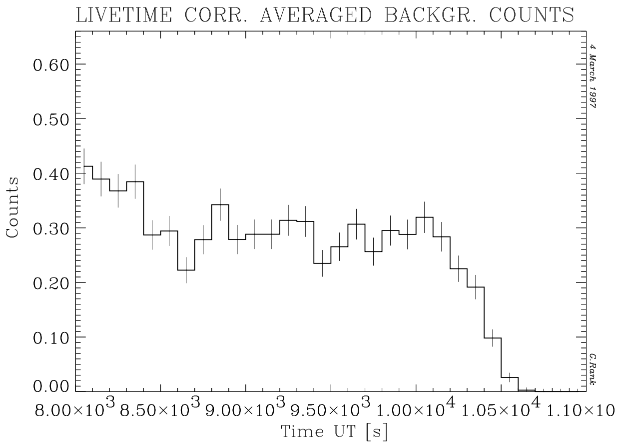


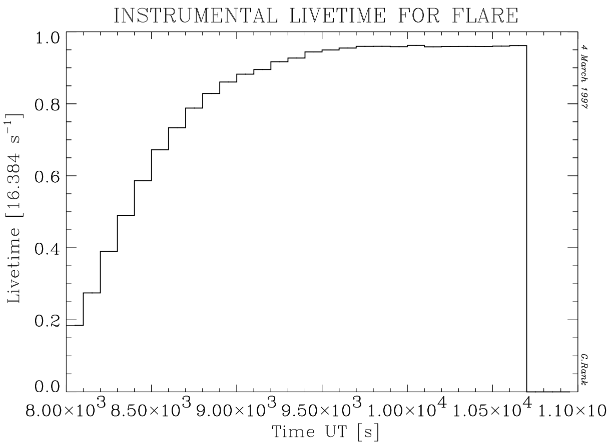
TIME PROFILE PLOTS

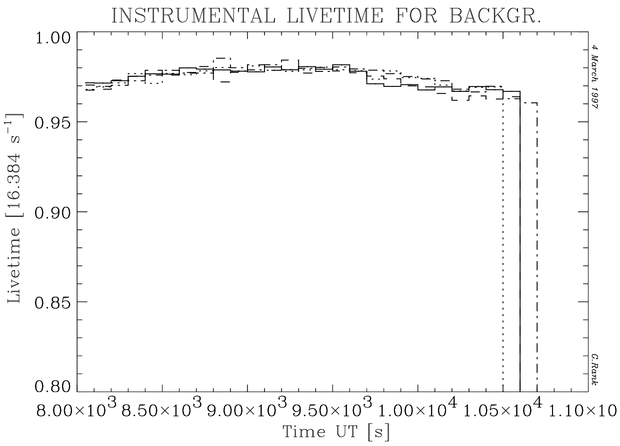




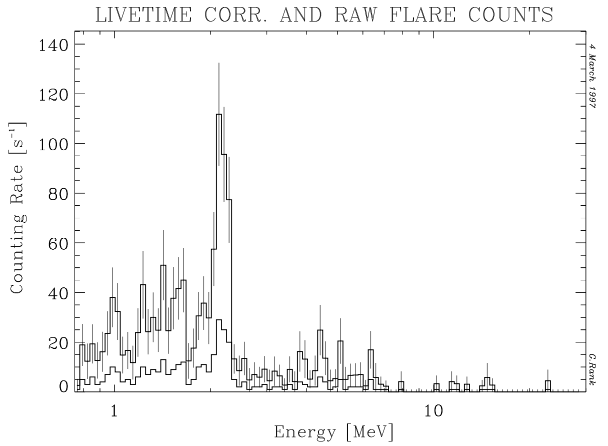


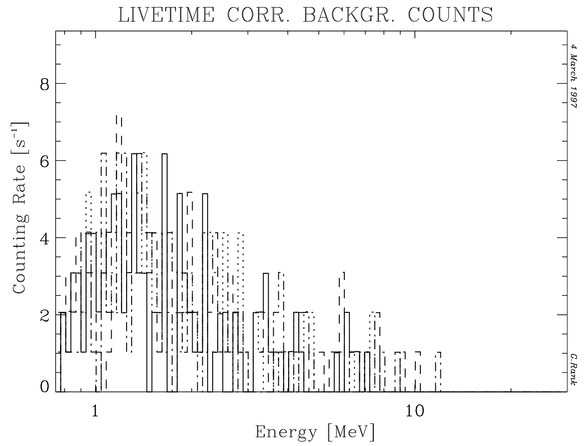


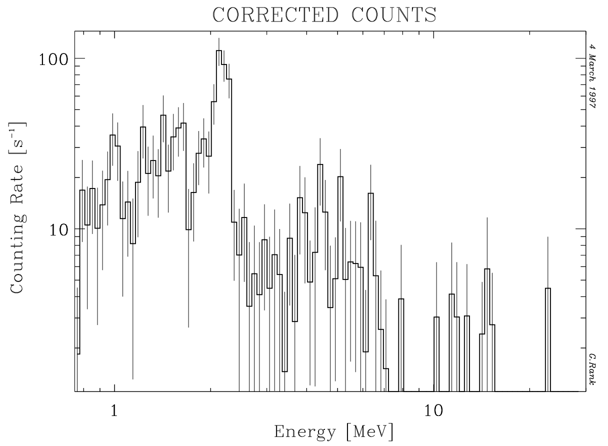


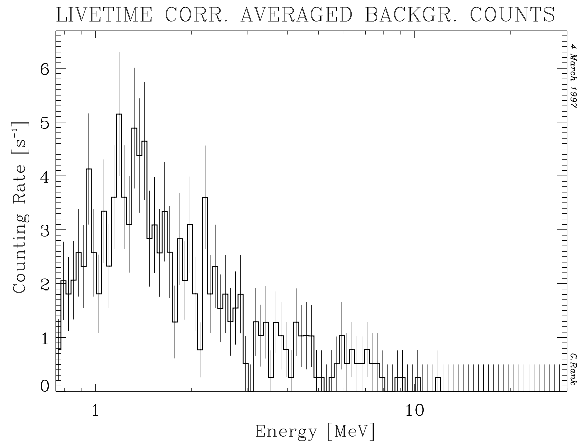


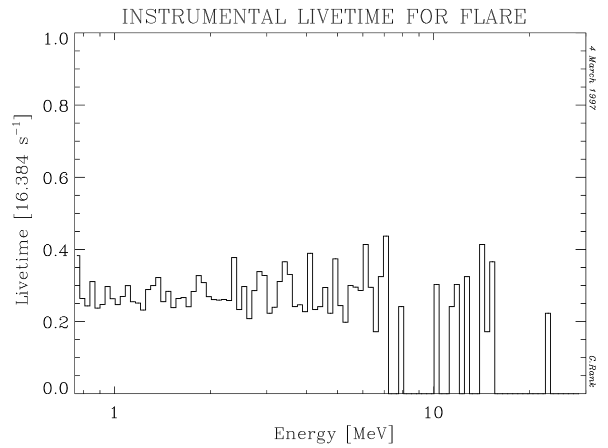
SPECTRAL PLOTS

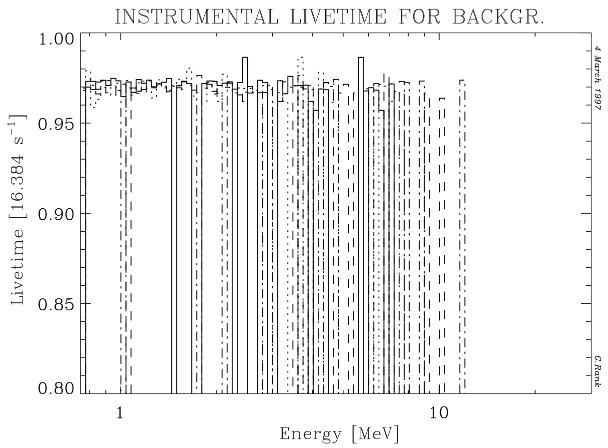


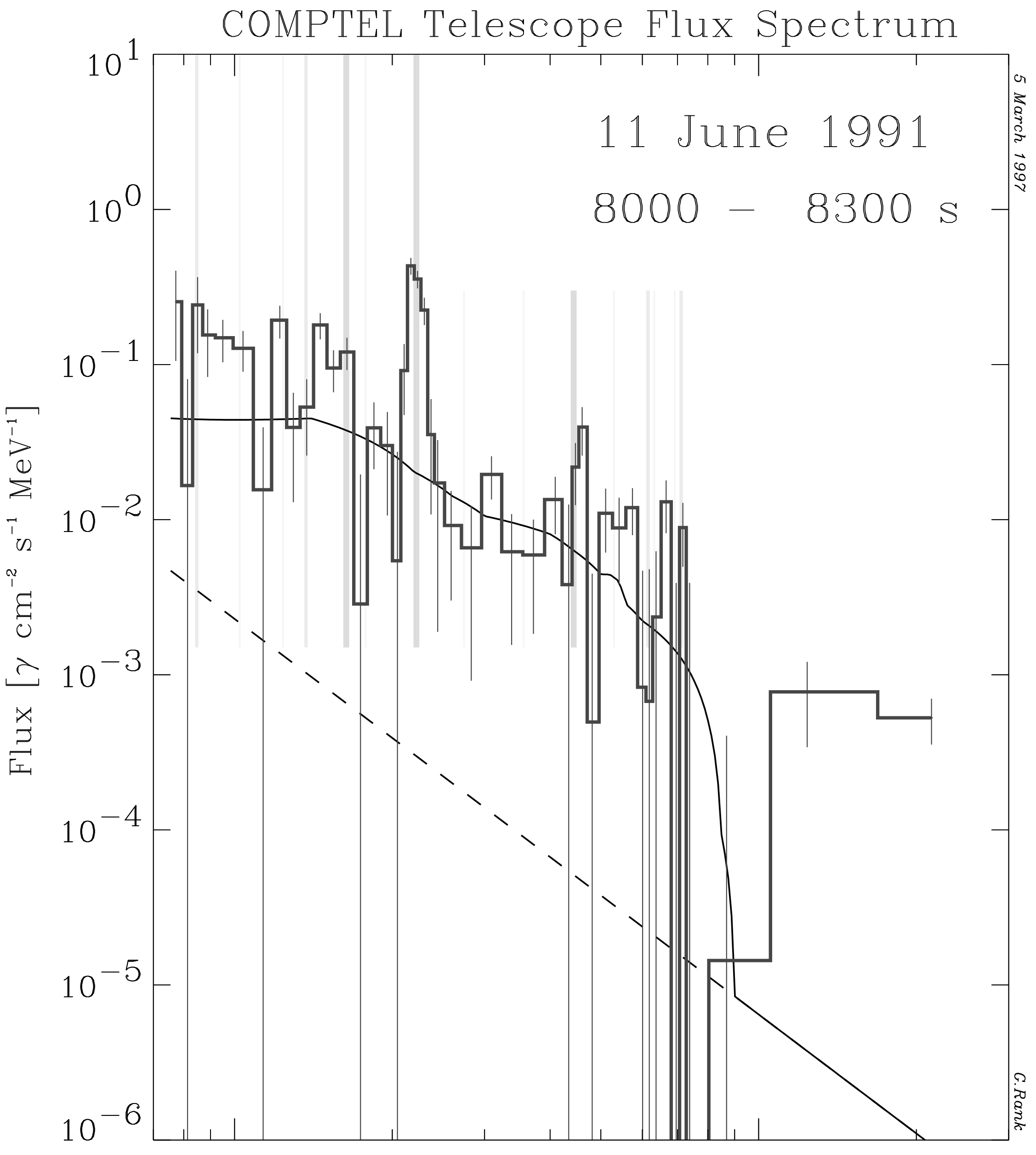






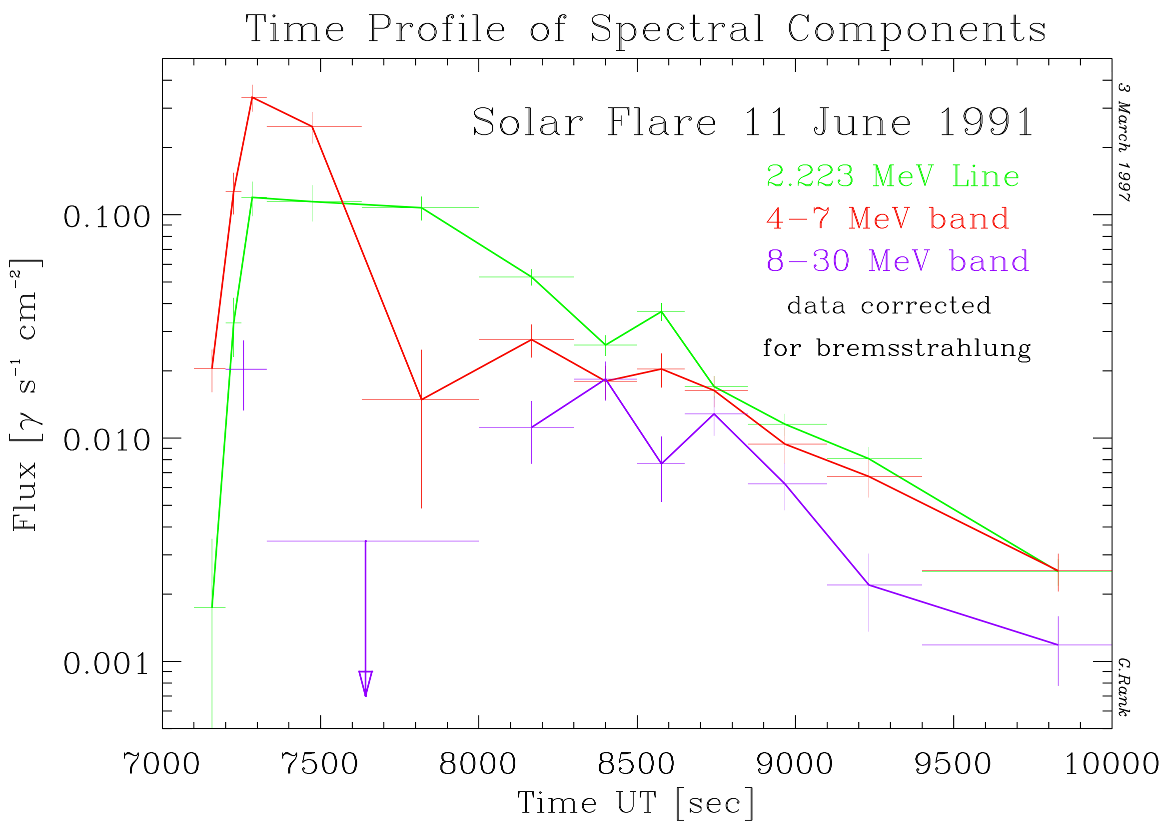





COMPTEL Telescope Flux Spectrum
11 June 1991
8000 – 8300 s
5 March 1997
C.Rank
Flux [γ cm⁻² s⁻¹ MeV⁻¹]
Energy [MeV]
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
1
10

Solar Flare 11 June 1991

• **Detailed observations for a whole orbital daylight period.**



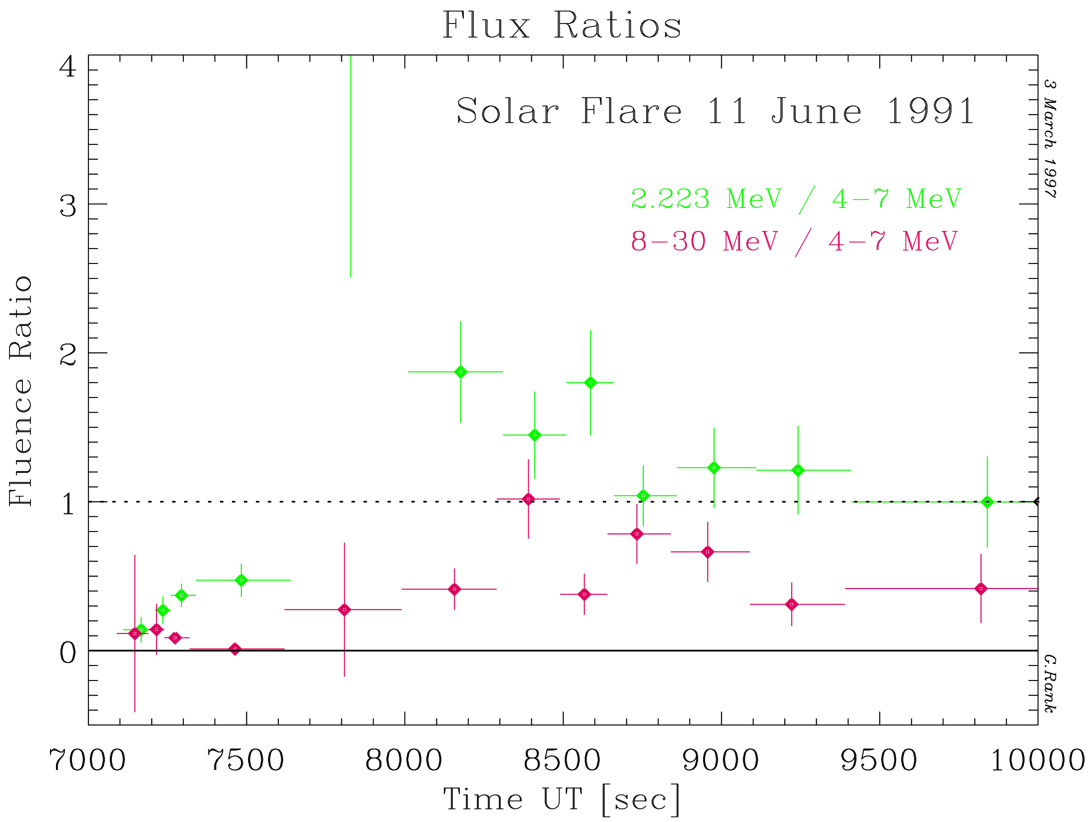
— The 2.2 MeV emission is well below the 4–7 MeV emission during the impulsive phase. It it well above during the extended phase.

— The transition from the impulsive to the extended phase can be studied. While the prompt gamma-ray flux nearly vanishes, the 2.2 MeV line shows rather strong emission.

— The flux in the 8–30 MeV band shows an early peak, but only an upper limit during the impulsive phase. Significant emission can be registered during the extended phase.

— Within the statistical uncertainties all three energy bands show similar exponential decay times after 8000 s UT.

• **Spectral Evolution.**

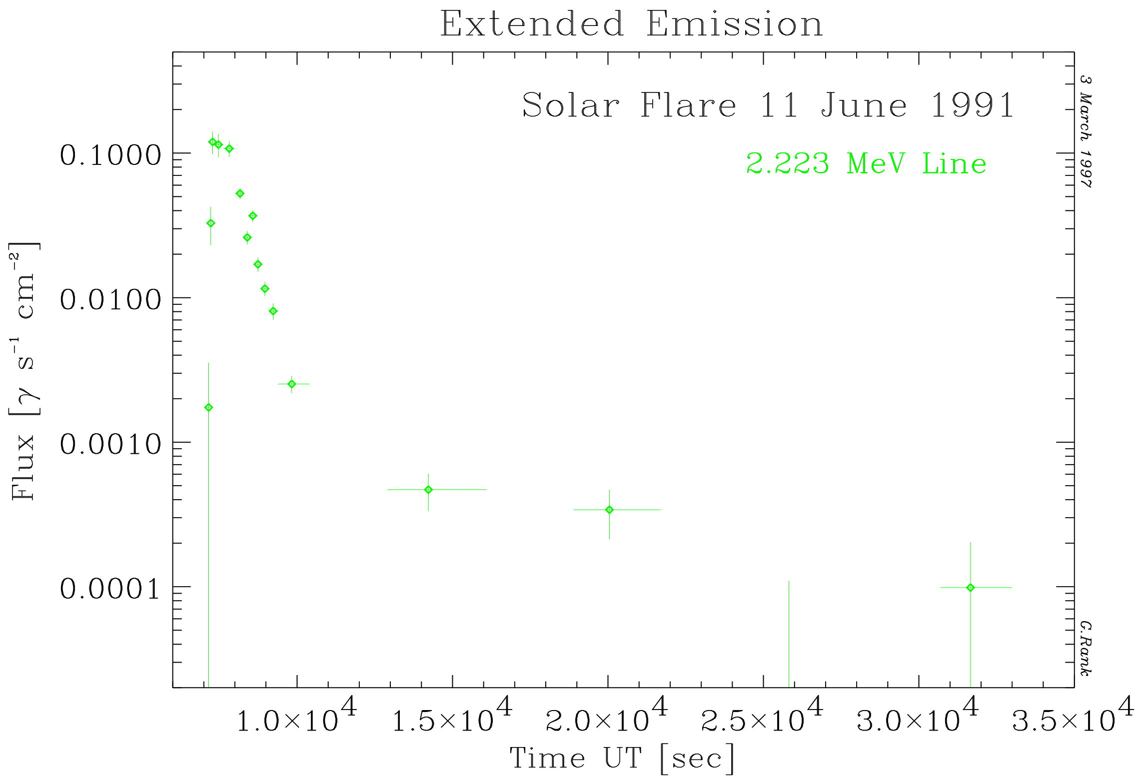


— The 2.2 MeV/4-7 MeV ratio is significantly higher in the extended phase, compared to the impulsive phase: indicates a harder spectrum.

— The 8-30 MeV/4-7 MeV ratio is significantly higher in the extended phase, compared to the impulsive phase: also indicates a harder spectrum.

— The very high 2.2 MeV/4-7 MeV ratio during the transition is not completely understood so far. Time-dependent modelling shows that long capture times of the neutrons during these phases could be an explanation. A study of the influence of low energy neutrons from a very soft spectrum is under way.

• **Significant 2.2 MeV line emission for the following orbits.**



— The 2.2 MeV long-term time profile shows no major changes compared to former analysis.

— The signal in the 1. and 2. orbit after the flare improved slightly.

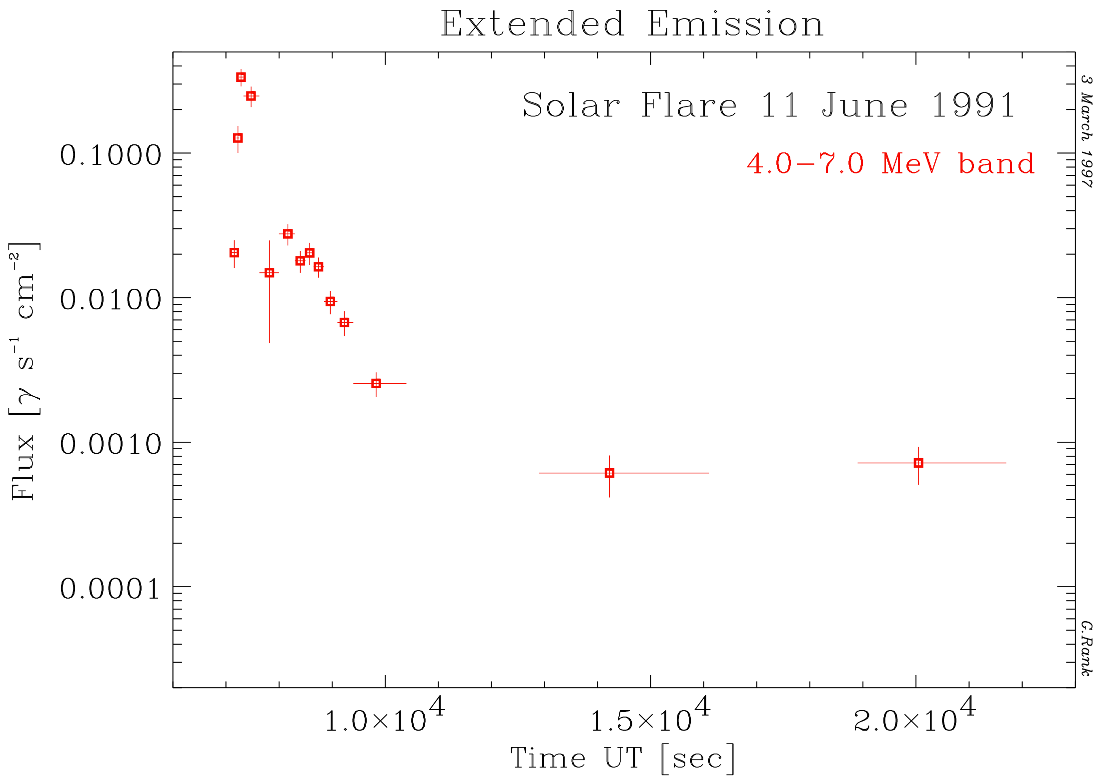
— The signal in the 3. orbit has decreased from $\sim 1.5\sigma$.

— The decay times are slightly modified and are now:

short decay time: 9.7 min (+0.8, -0.7), old value: 9.4 min

long decay time: 150 min (+/-50.0), old value: 220 min

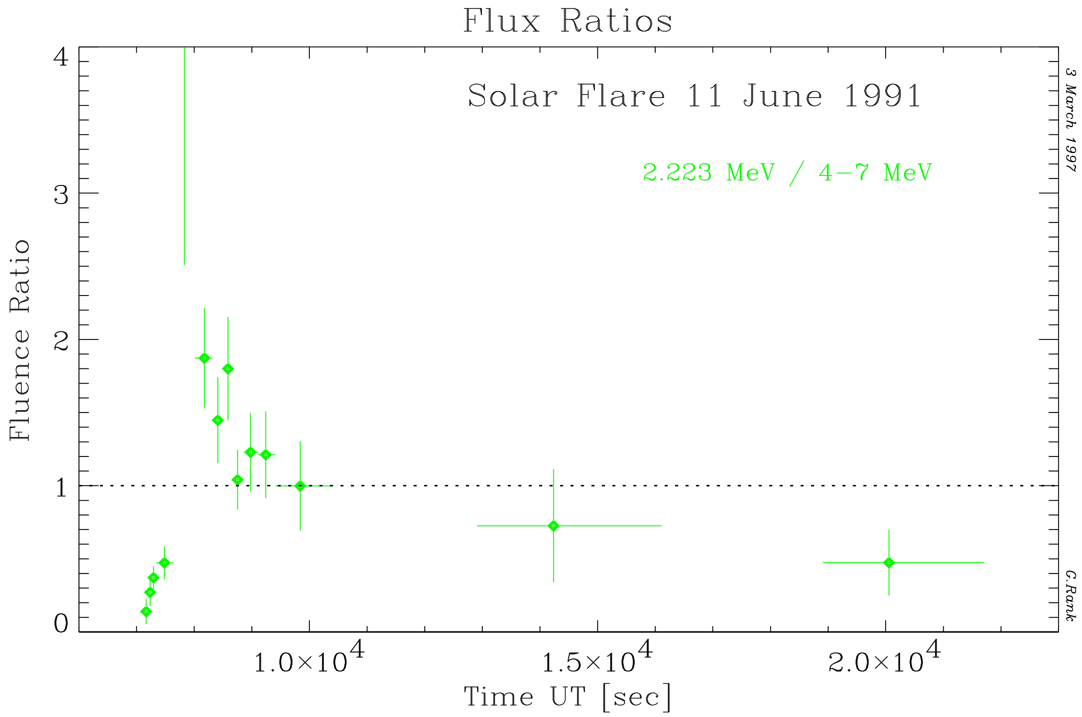
• **Significant 4–7 MeV emission for 2 following orbits.**



— we can now detect a significant signal in the 4–7 MeV band for the 2 following orbits. Still there is a discrepancy: MEM results show a 2σ excess, while a simple deconvolution with a diagonalized response matrix gives only a 1σ signal.

— this finding is important, because it allows us to compare different spectral feature for more than the flare orbit. Up to now the only comparison was between the 2.2 MeV line and the EGRET $>$50 MeV emission.

- **Long-term fluence ratio.**



— the ratio of the 2.2 MeV / 4-7 MeV emission can now be tracked for 3 consecutive orbits (more than 4 hours).

— During the extended phase the ratio indicates a slow decrease.

— The ratio is not varying substantially. This long-term stability allows us to discriminate between storage and acceleration models: for magnetically trapped particles the particle trapping times are highly energy dependent.

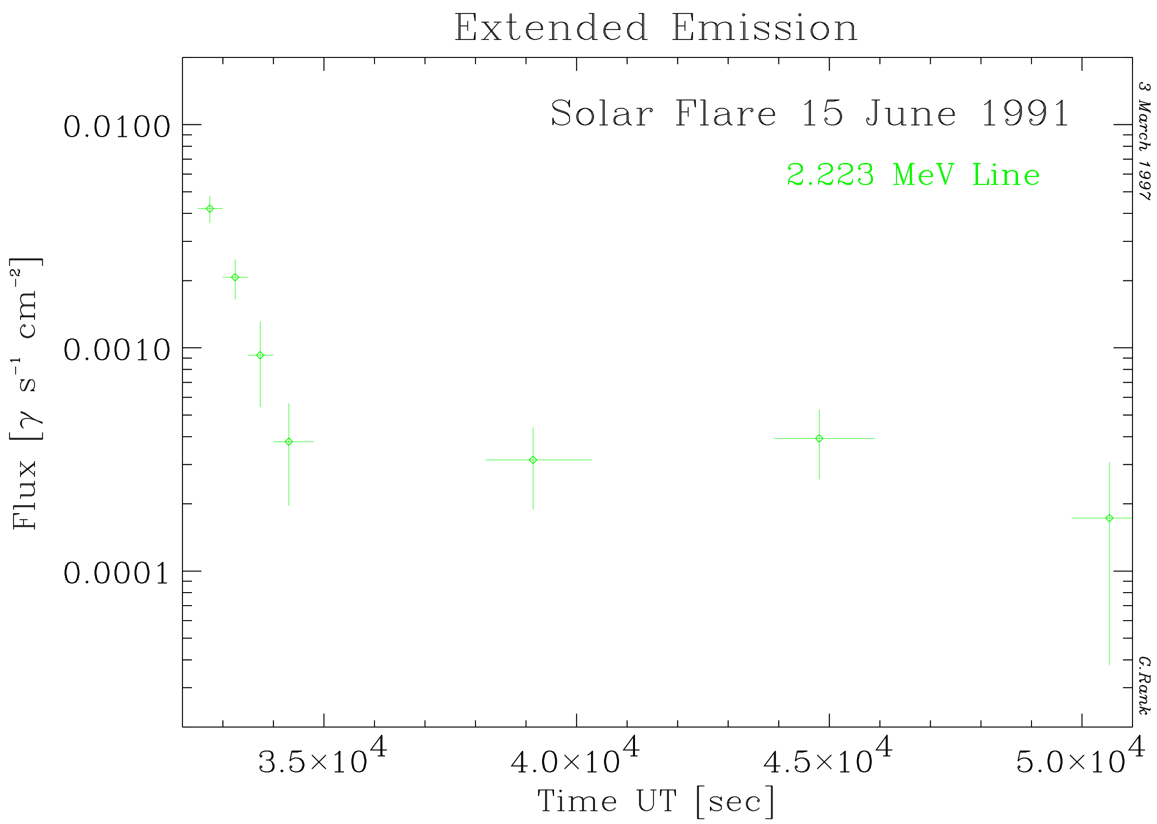
Trapping Times for diff. energies:

pitch angle cosine	Nucl. Lines	Pions
0.1	4800 s	120000 s
0.5	330 s	8300 s
0.7	72 s	1800 s

(from Rmaty, Mandzhavidze, Waterville Workshop, 1993)

Solar Flare 15 June 1991

• The impulsive phase of this flare was unobservable by CGRO. The extended emission seen in the 2.2 MeV line resembles the 11 June flare.



— The long-term time profile shows no major changes compared to former analysis.

— The signal in the 2. orbit after the flare is increased.

— The decay times are slightly modified and are now:

short decay time: 11.0 min (+3.4, -2.6), old value: 12.6 min

long decay time: 250 min (+/-100.0), old value: 180 min

Solar Flare 9 June 1991

• Count rates for the 9 June flare have been studied. So far no deconvolution has been done.

• First results clearly show an extended signal. The Flare has a short impulsive phase. Later the emission declines very slowly as seen in the 11 and 15 June events.

• The 4–7 MeV band gives a good signal-to-noise ratio for the following orbit. This will allow to put tight restraints on the spectral hardness late after the impulsive phase.

• Detailed observation possible for a whole orbital daylight period. Time profiles for 2.2 MeV line, 4–7 MeV band and 8–30 MeV band can be studied.

Conclusions for ICRC paper

• COMPTEL measures extended gamma-ray emission in the three solar flares on 9, 11 and 15 June 1991.

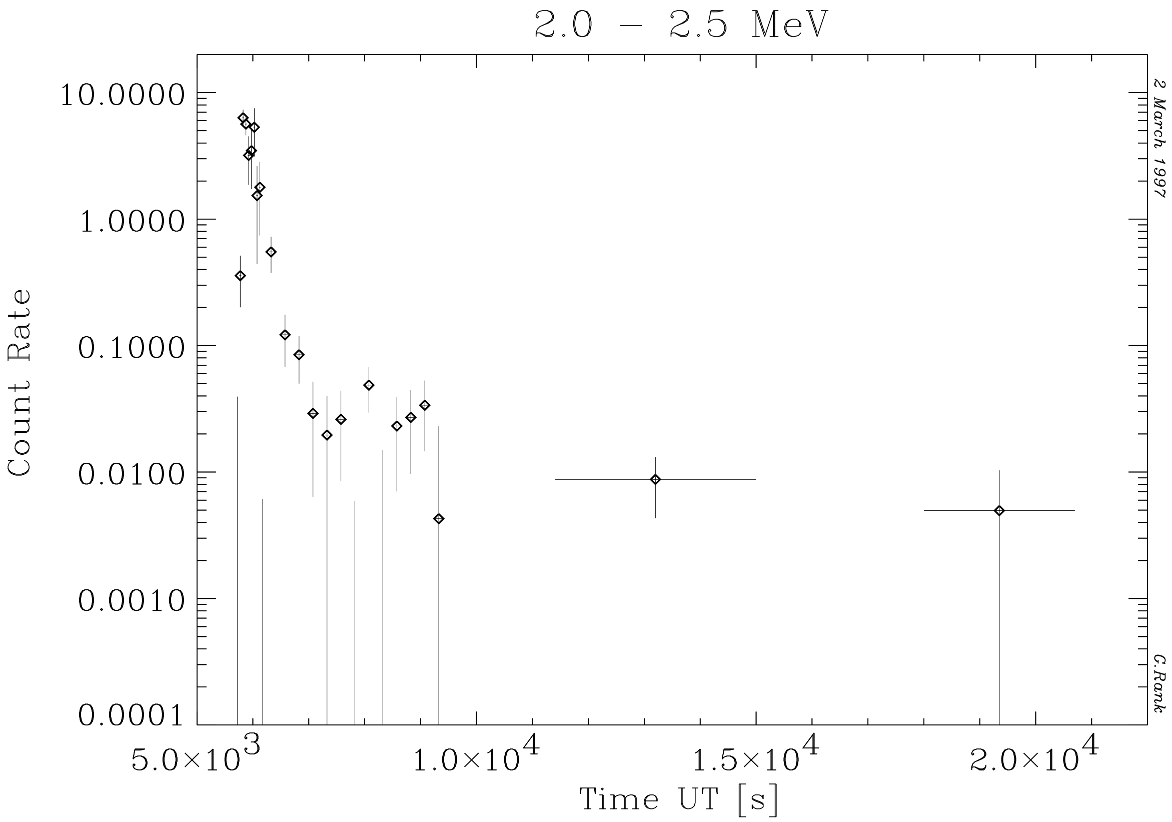
• The 9 and 11 June flares allow to study the emission during the impulsive phase and the transition to the extended phase. The spectrum during the extended phase is significantly harder.

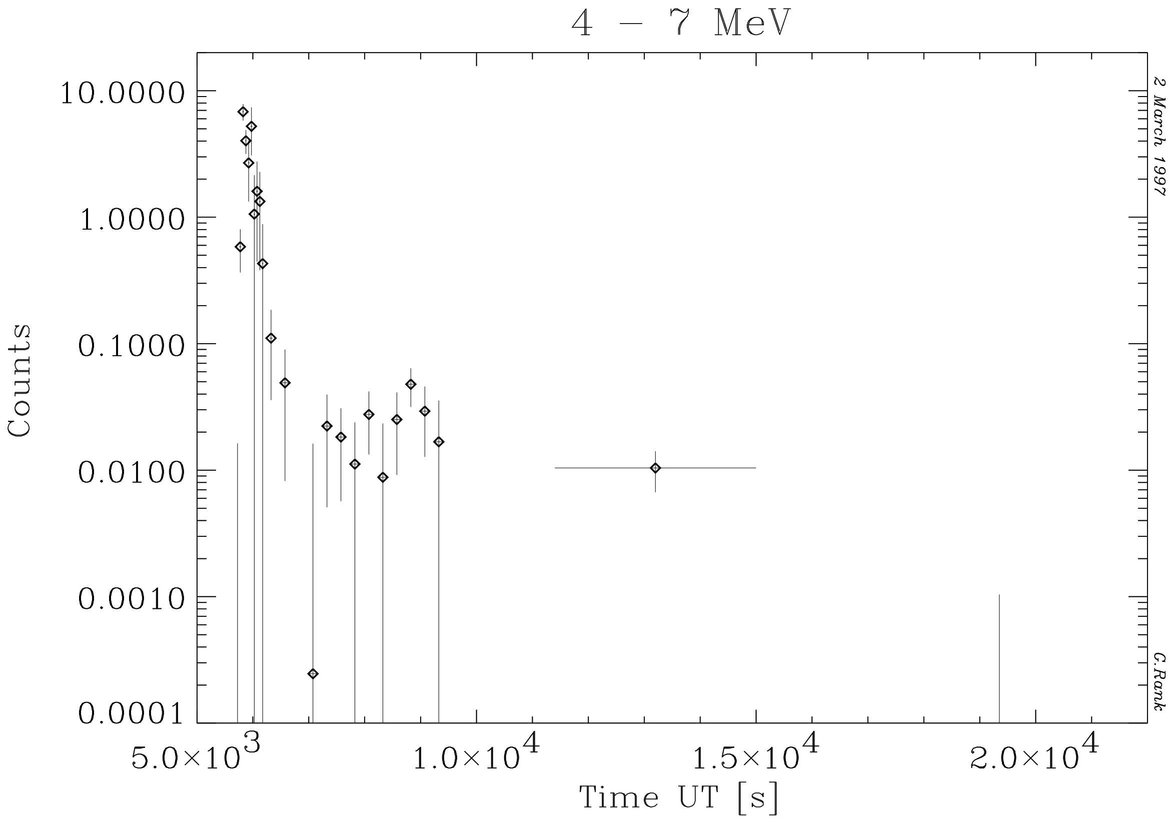
• The transition phase of the 11 June flare shows an unusually high value for the neutron capture time. This can be an indication of a very soft proton spectrum.

• The high energy emission in the COMPTEL range can be addressed to pionic emission. The bulk flux is observed during the extended phase.

• Our data allow to discriminate between magnetic trapping and continuous acceleration of particles:
Within the statistical uncertainties, we measure the same time profiles for the 2.2 MeV line and the 4–7 MeV. This is contrary to energy dependent storage times, as is predicted by storage models. Therefore our data favour continuous acceleration.

• COMPTEL data for the 11 June can be compared to EGRET $>$50 MeV measurements. The data for the 15 June flare can be compared to GAMMA-1 $>$50 MeV data. In both cases, the high and low energy time profiles show a similar behaviour and support the rejection of trapping models.


2.0 – 2.5 MeV
Count Rate
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
5.0×10³
1.0×10⁴
1.5×10⁴
2.0×10⁴
Time UT [s]
2 March 1997
C.Rank


4 – 7 MeV
Counts
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
5.0×10³
1.0×10⁴
1.5×10⁴
2.0×10⁴
Time UT [s]
2 March 1997
C.Rank