Search for high energy gamma-ray bursts

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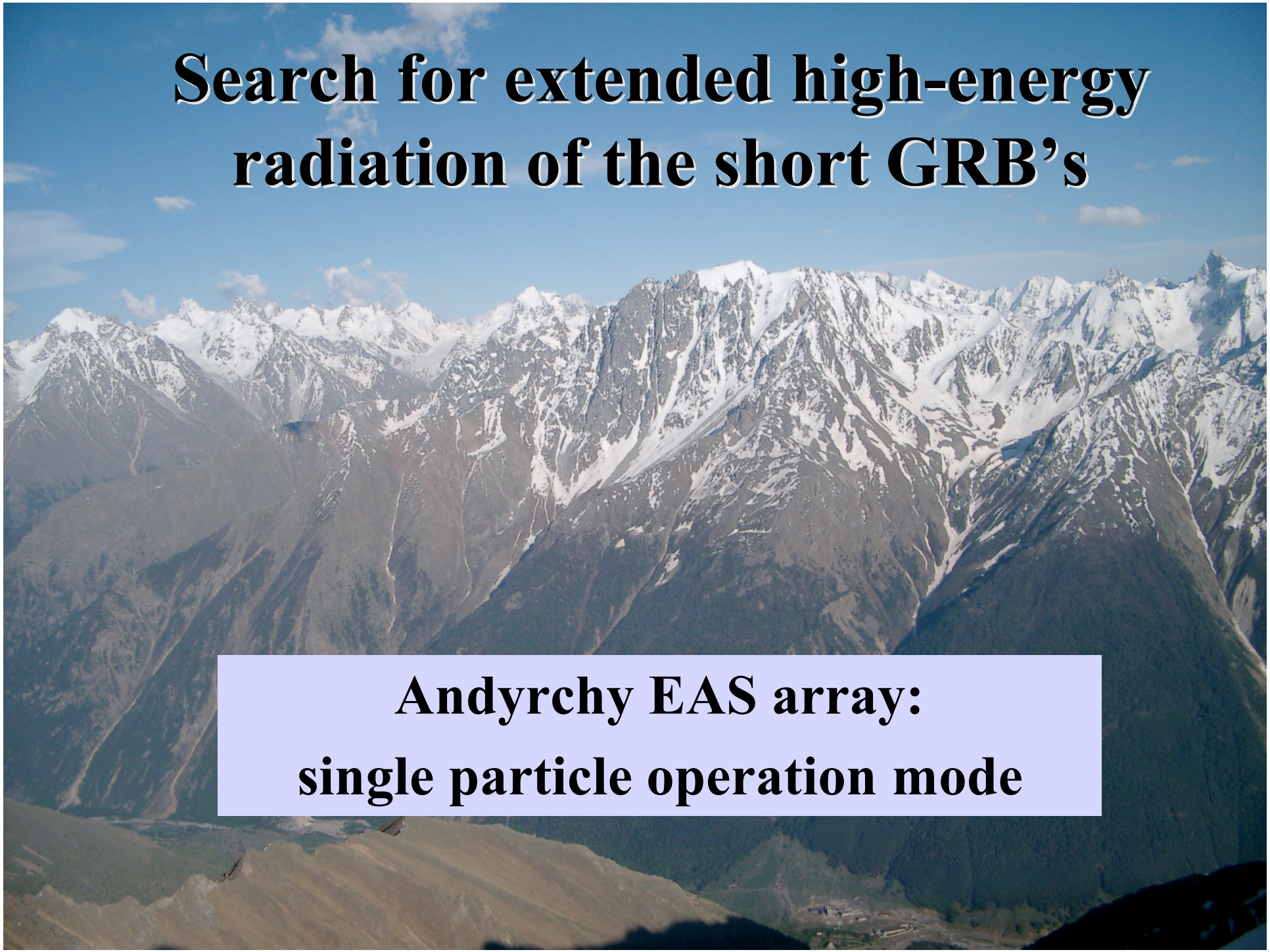

Search for extended high-energy radiation of the short GRB's
Andyrchy EAS array:
single particle operation mode

Extended emission in short GRB's

Experiment	Energy range, keV	The number of GRBs	Duration of the extended radiation, s
BATSE	25–110	76	100
BATSE	50–300	100	100
Konus	10–750	125	100
BeppoSAX	40–700	93	30
INTEGRAL	> 80	53	25
INTEGRAL	> 80	43	125

P.Yu. Minaev, A.S. Pozanenko,V.M. Loznikov, Astronomy Letters, 2010, v. 36, No. 8, p.1.
and references therein

"BATSE observations of gamma-ray burst tails"
V. Connaughton, Astrophys. Journal, 567, 1028 2002.

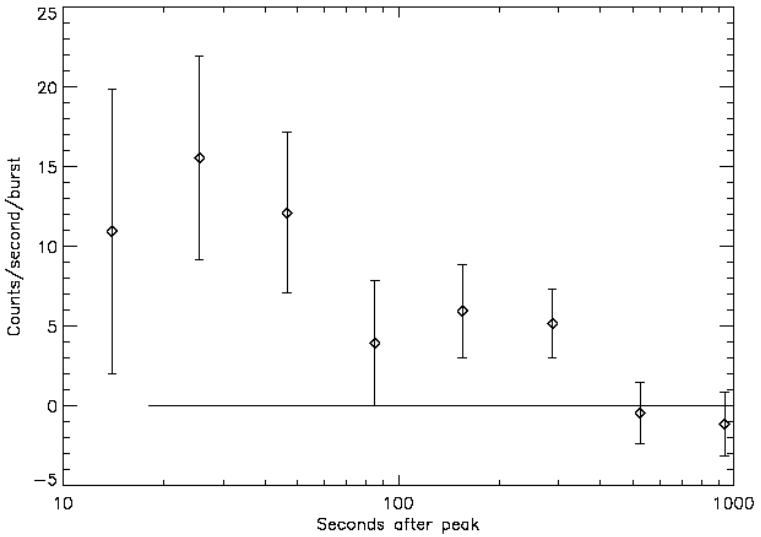
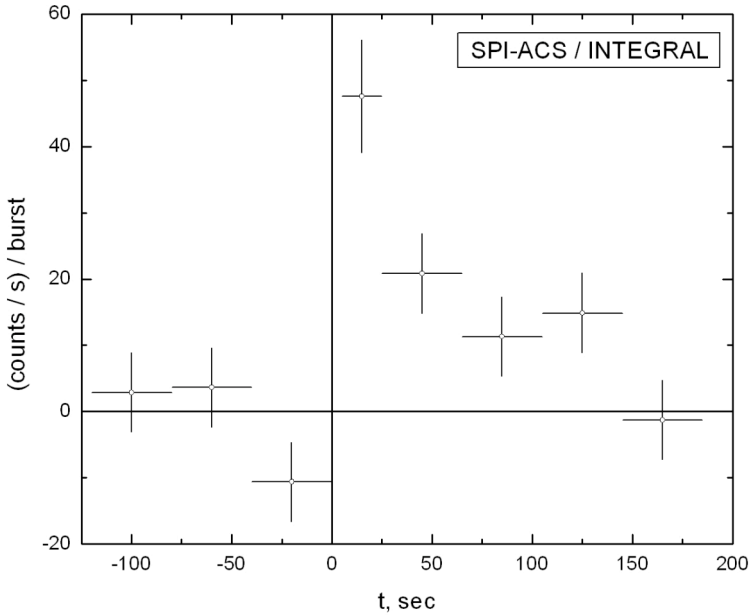


FIG. 7.—Light curve for 100 short (<1 s), summed, background-subtracted, BATSE bursts after peak alignment, with peak time suppressed.

100 short GRB's
(T_{90} < 1 s)
50 – 300 keV
$\Delta t = 100$ s

"Extended emission in short gamma-ray bursts registered by SPI-ACS of INTEGRAL observatory"
P.Yu. Minaev, A.S. Pozanenko,V.M. Loznikov,
Astronomy Letters, 36, 1, 2010.

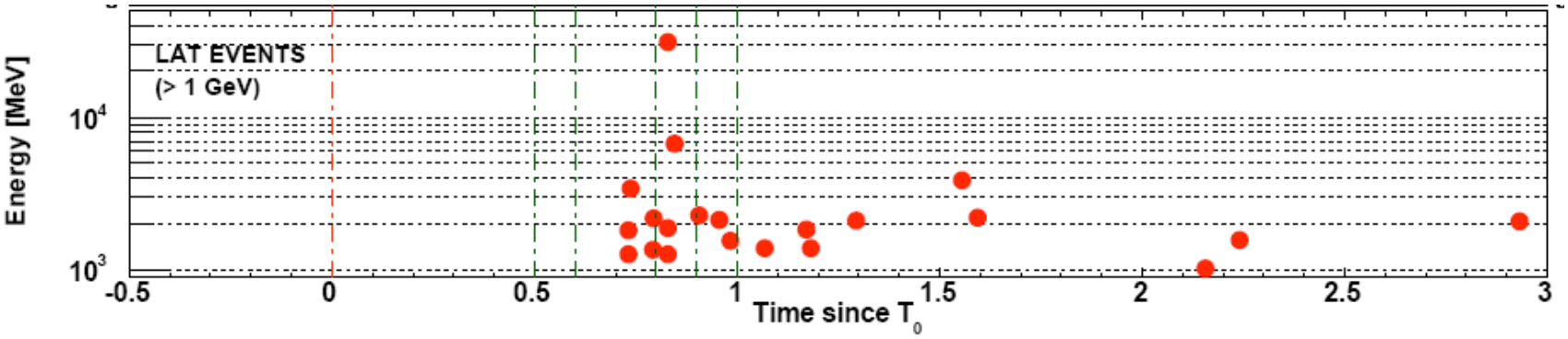


156 short GRB's
(T_{90} < 2 s)
80 keV – 10 MeV
$\Delta t_1 = 25$ s && $\Delta t_2 = 125$ s

Fermi-LAT

GRB 090510: $E_{max} \approx 31$ GeV

GRB 080124B: Emax ≈ 3.1 GeV



GRB 090510

T_0 + 1 sec.: 62 γ with E > 100 MeV && 12 γ with E > 1 GeV

T_0 + 1 min.: 191 γ with E > 100 MeV && 30 γ with E > 1 GeV

"Similar to several of the long bursts seen by the LAT, GRB 090510 shows a high energy extended emission component that is detected by the LAT as late as 200 s after the GBM trigger."

M. Ackermann et al., arXiv:1005.2141v1 [astro-ph.HE], 2010.

(Fermi Observations of GRB 090510: A Short Hard Gamma-Ray Burst with an Additional, Hard Power-Law Component from 10 keV to GeV Energies)

Search for GRB's with $E_\gamma \approx 1$ GeV – 1 TeV: ground-based arrays working in single particle operation mode.

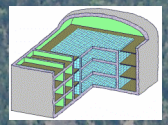
Andyrchy EAS array
h ≈ 2000 m a.s.l.
S_{tot} = 37 m^2
(37 plastic scintillation detectors: 1 m × 1 m × 0.05 m)

1996 – 2006
2290.1 days of live time
Total count rate: $\langle\omega\rangle = 11390\ s^{-1}$

Baksan Neutrino Observatory

Andyrchy EAS array

Karpet-2
EAS array

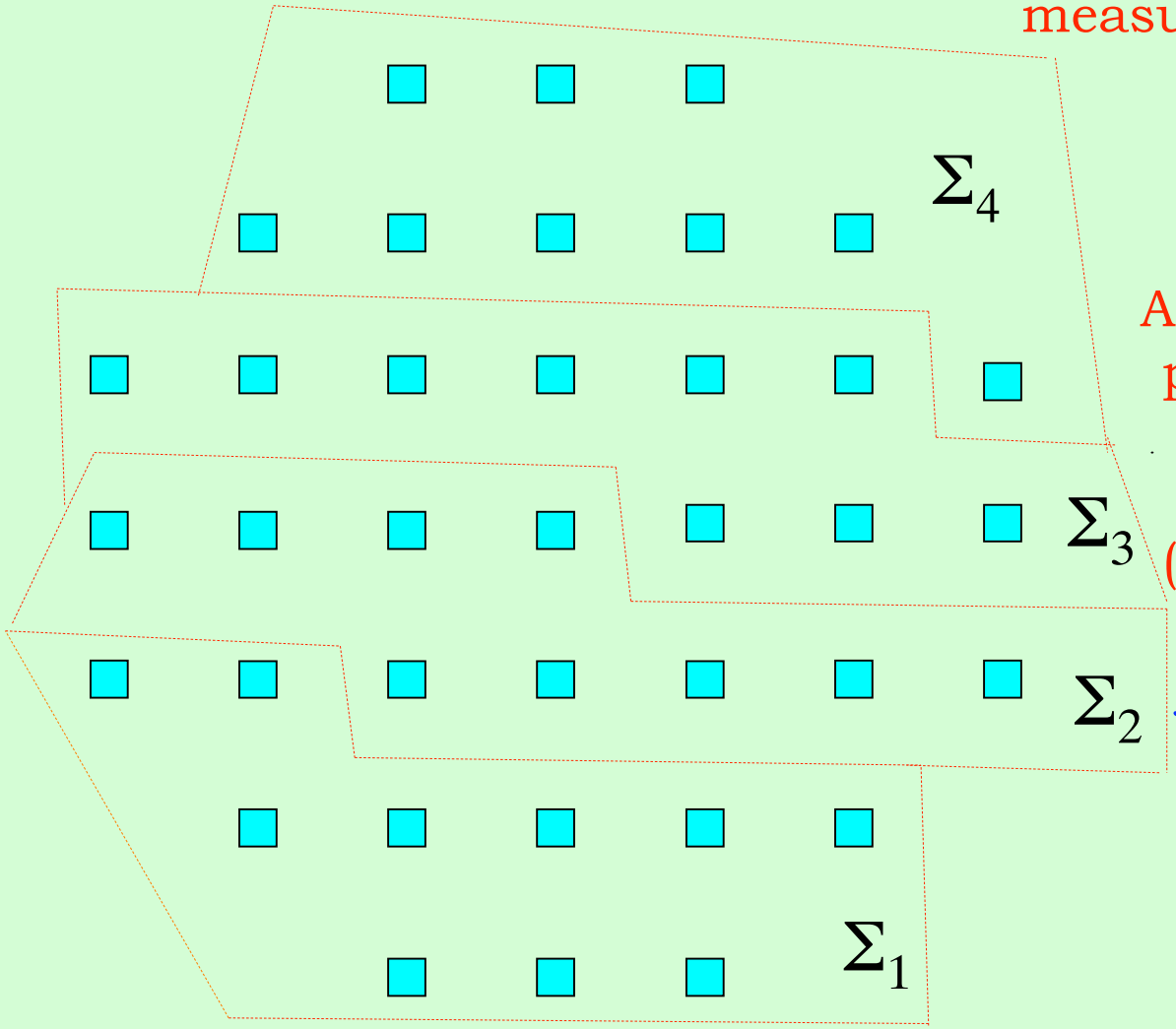


BUST

Tunnel
entrance

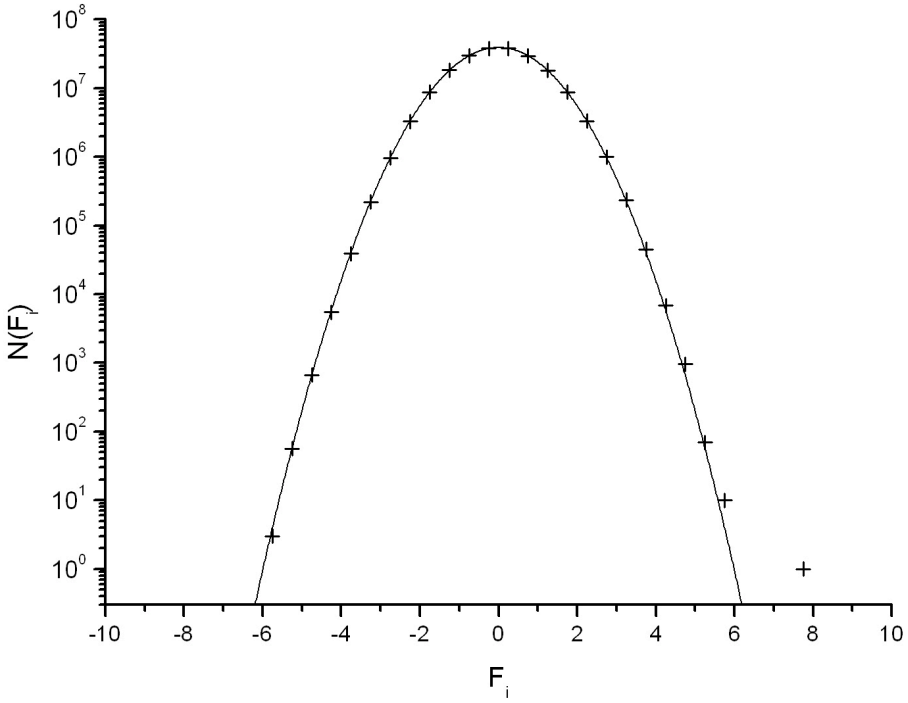
The “Andyrchy” EAS array: Single particle operation mode

The count rate of “Andyrchy” array detectors (37 m^2) is measured once per second (~11390/sec).



A check of stability is provided by means of simultaneous measurements (also once per second) of the counts rates of *four parts* of the array.

Sky survey: 1996 – 2006
2290.1 days of live time, $\omega = 11390\ \ s^{-1}$



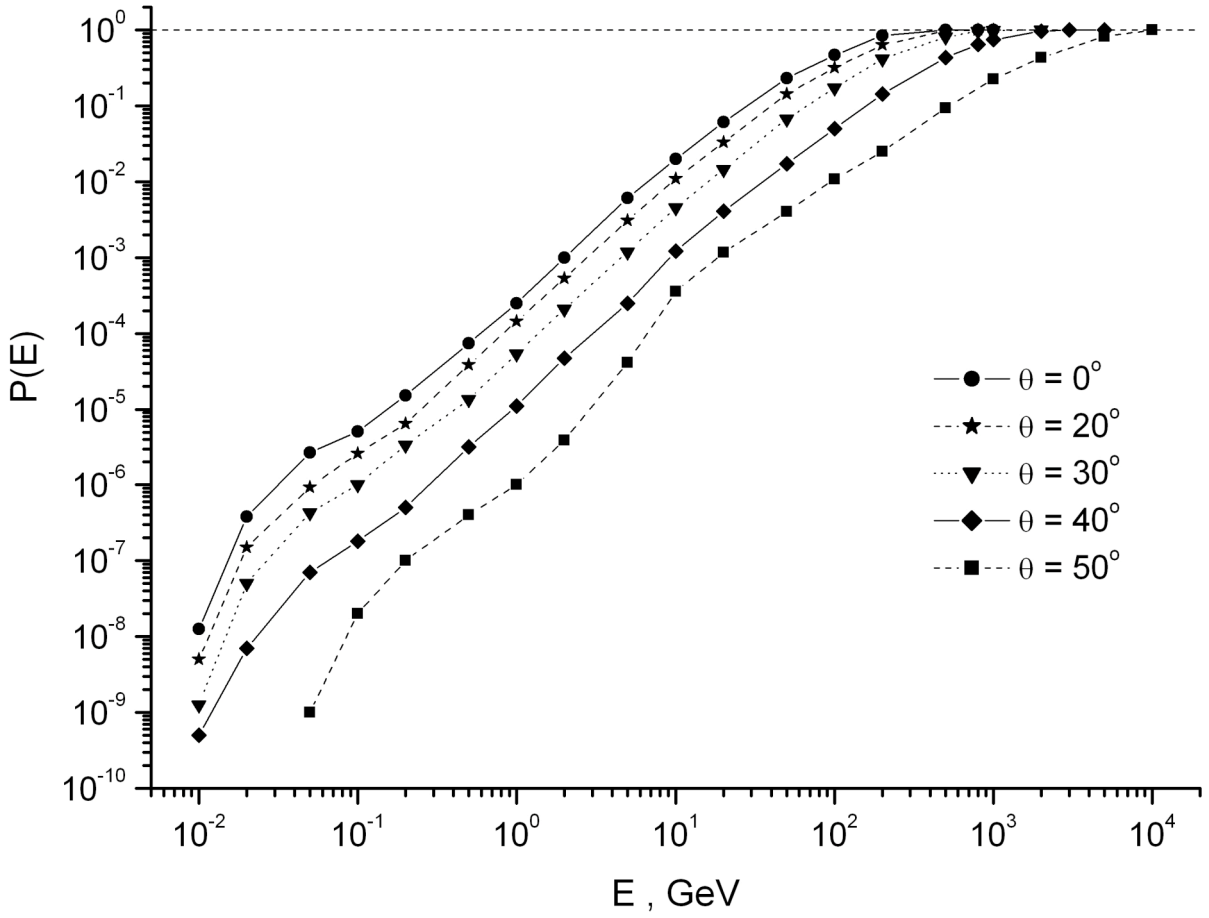
$$F_i = \frac{N_i - \overline{N}}{\sqrt{\overline{N}}}$$

$\Delta T = 900$ s

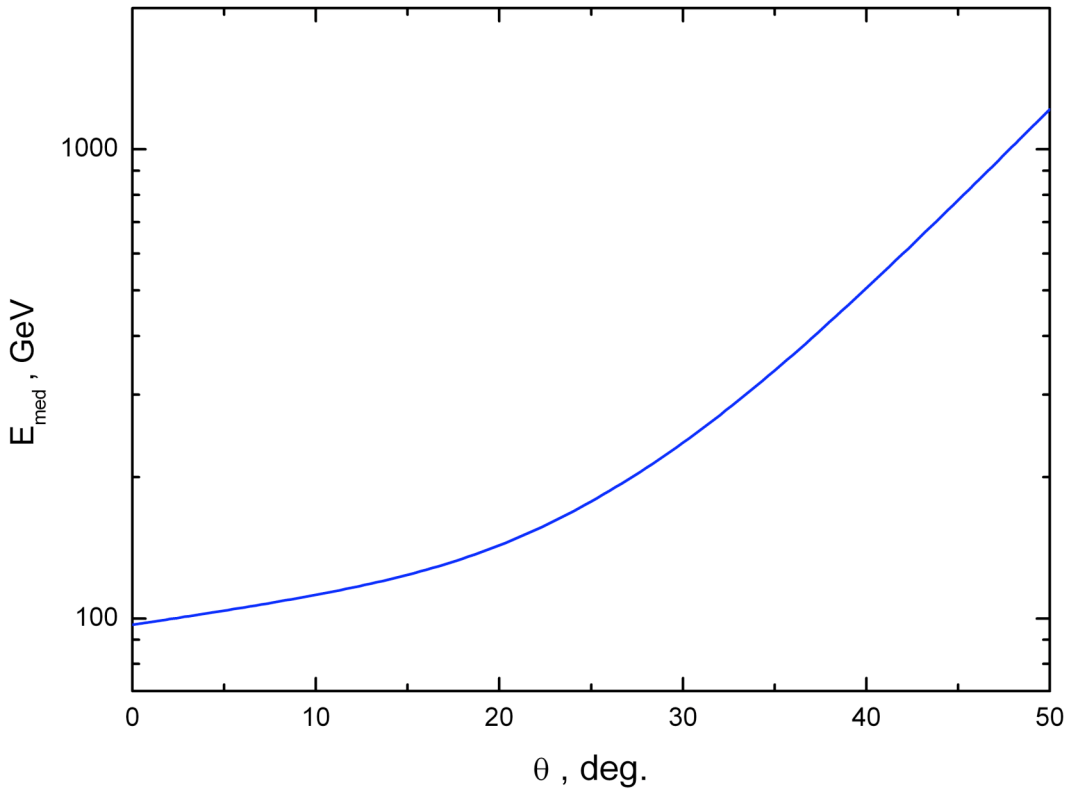
$\Delta t = 1$ s

F_i=7.9: Year 2002, day 107, Run 82 - synchronous electromagnetic noise emerging in the power cables of the recording system or that induced on the signal cables of all array detectors (V.B. Petkov et al., JETP, **110**, 406, 2010)

The probabilities P(E, θ) to detect a signal from gamma-rays with primary energy E and zenith angle θ in infinite area “Andyrchy” detector were calculated by means of a simulation of electromagnetic cascades in the atmosphere and in the detectors.
CORSIKA v.6900 + AndyrDet



Median energy as a function of zenith angle for power law primary spectrum with index $\gamma = -1.92$



In this work we will use power law spectrum with an index of -1.92:
GRB 090510, Fermi-LAT, 0.9 s – 1.0 s
(M. Ackermann et al., arXiv:1005.2141v1 [astro-ph.HE], 2010)

Data selection

- Only the GRBs to be found in the field of view of Andyrchy (i.e. with $\theta \leq 50°$) array were taken into account.
- The total count rate of all array detectors was measured in the interval [-650, +900] seconds around trigger time of the burst.
- During the period 1996 – 2006: 179 GRBs
- 29 short GRBs with $T_{90} < 2$ c

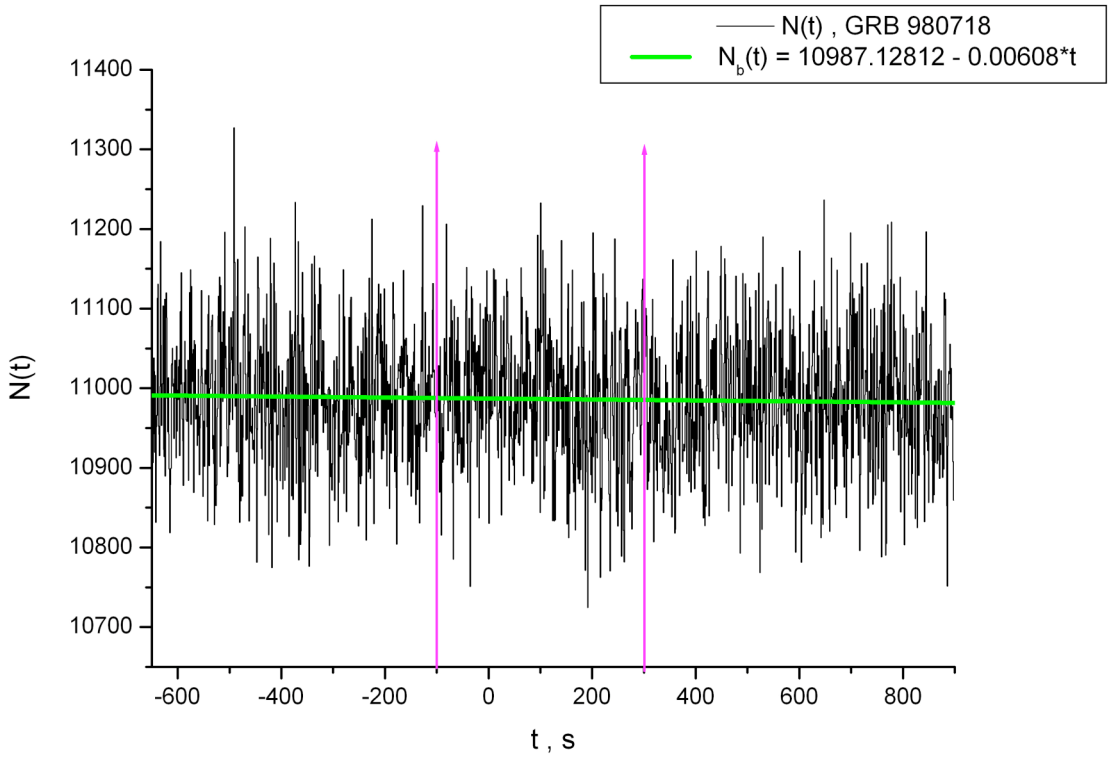
The number of the short GRBs for different zenith angle ranges

Table 1. The number of the short GRBs for different zenith angle ranges

θ range	The number of GRBs	$\overline{\theta}$	$E_{med}(\overline{\theta})$, GeV
0 - 10	0	5°	99.3
10 - 20	4	15°	118.4
20 - 30	5	25°	175.6
30 - 40	6	35°	324.5
40 - 50	14	45°	746.7

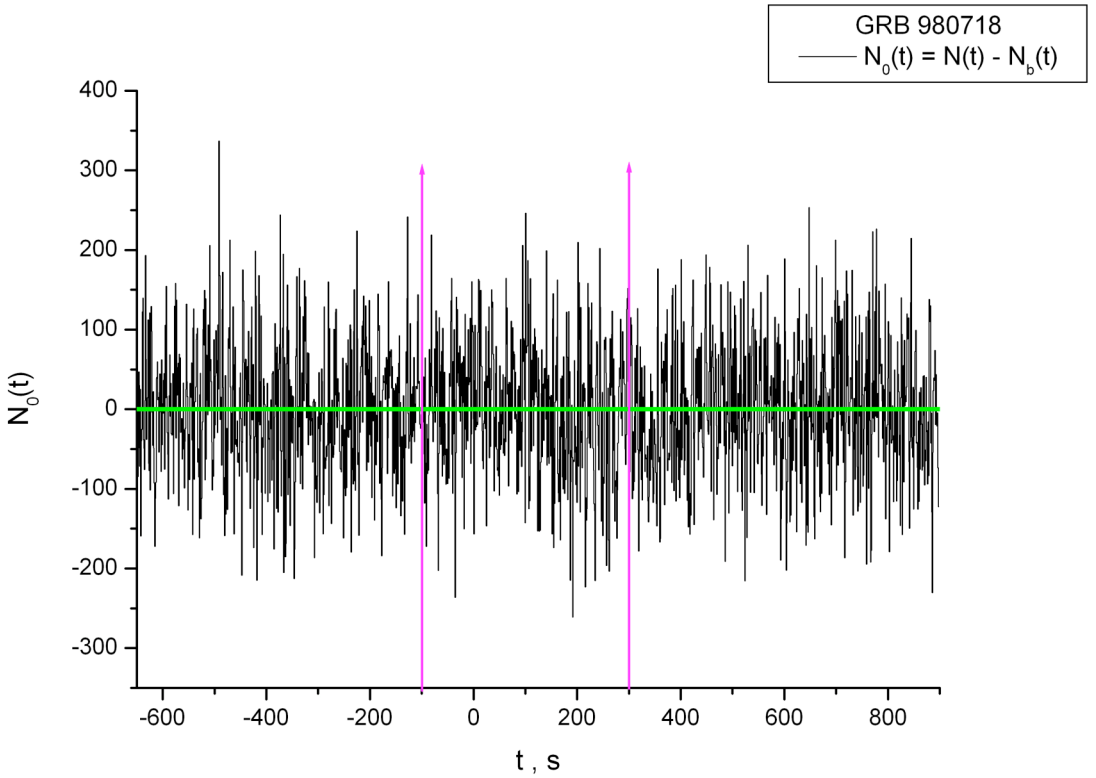
$t = T - T_0$

Background: [-650, -50] && [300, 900]



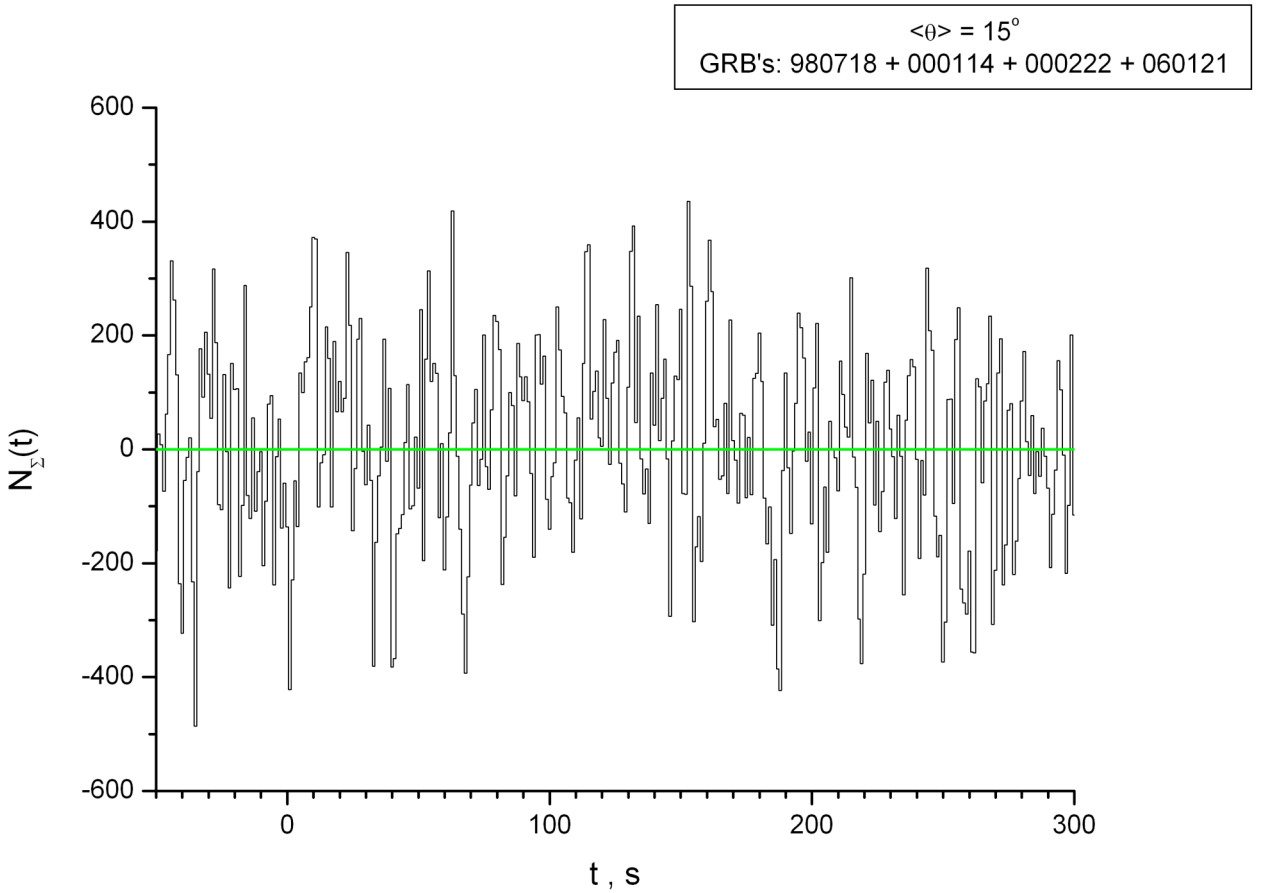
Because all sources of background modulation have typical time scales about hours, the linear fit have been used for background.

GRB 980718: after background substraction



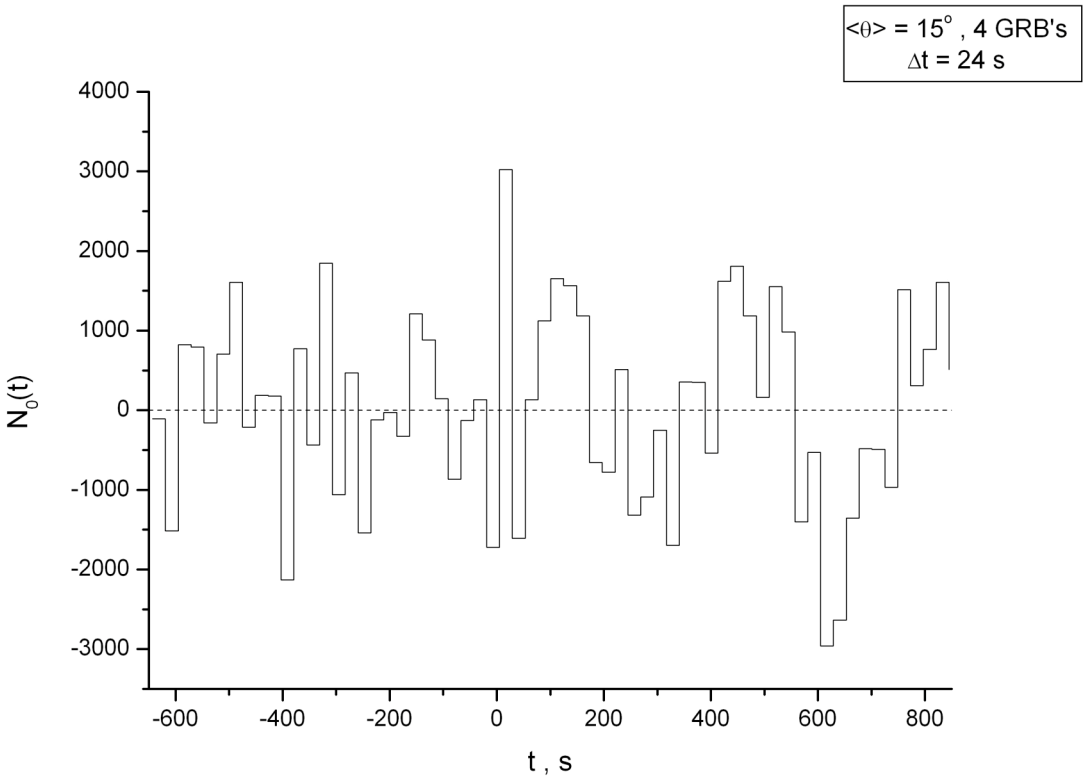
The light curve for each studied GRB was obtained as total count rate of the array
around trigger time after background substraction. The light curves corresponding to each GRB are aligned relative to GRBs trigger time.
These light curves was summed for different zenith angle ranges separately.

Epoch folding method



Light curve with time resolution of 1 s for 4 summed background-subtracted events with $\langle\theta\rangle = 15°$

$\langle\theta\rangle = 15^\circ$, $\Delta t = 24$ s

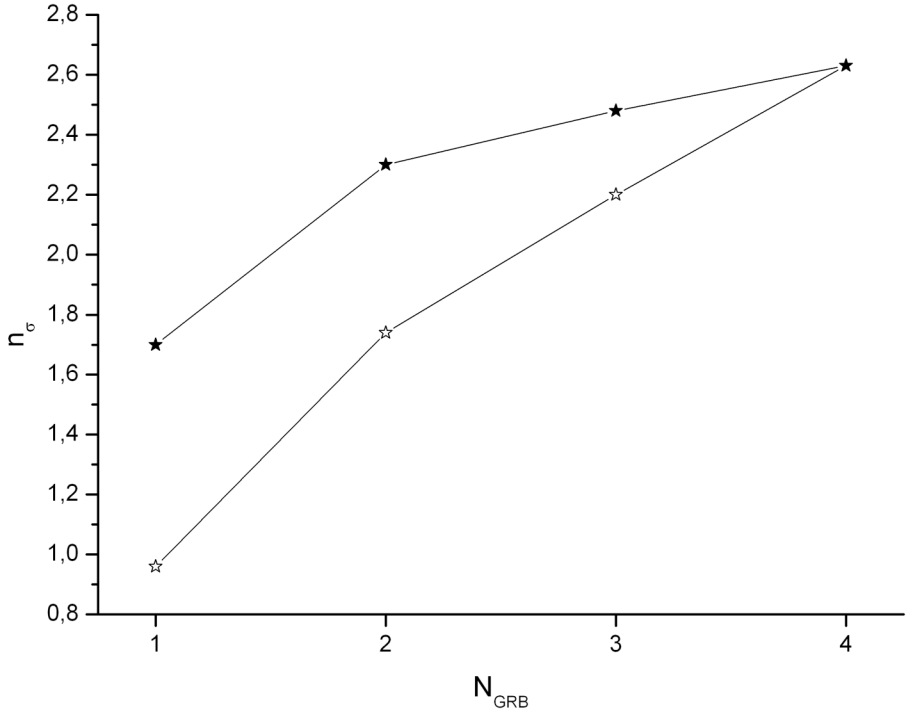


t = 5 s , Δt = 24 s
2.63 σ

t = 71 s , Δt = 110 s
1.84 σ

Summed light curve with time resolution of 24 s for 4 GRBs with <θ> = 15°.

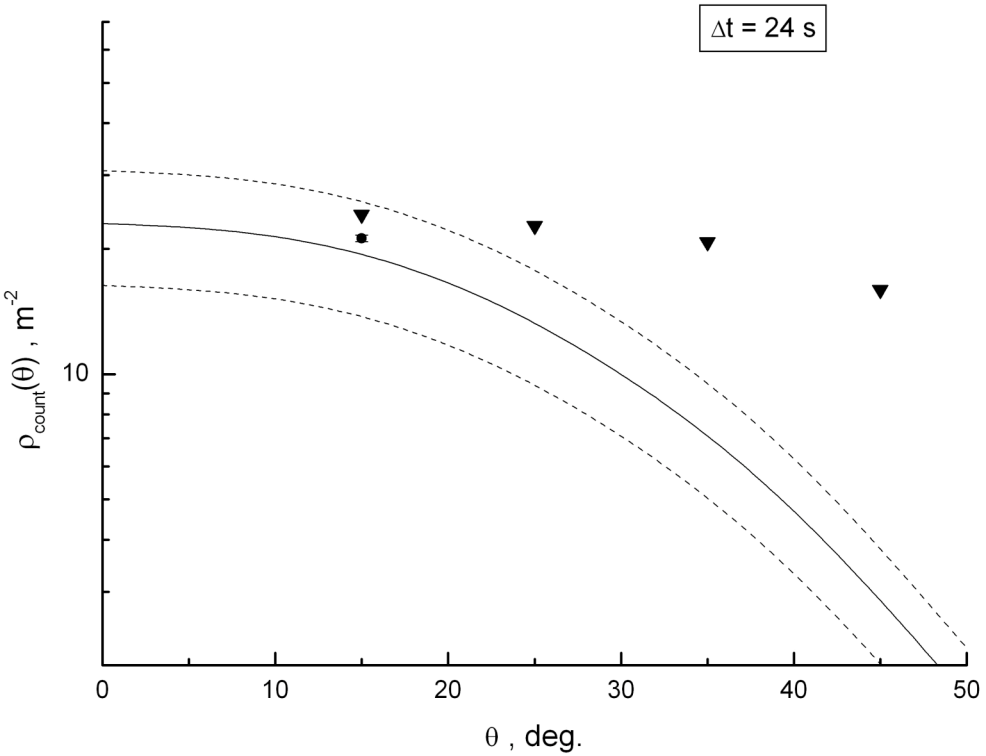
Significance of the peak with t=5 s and Δ t = 24 s
as function of the number of events in the GRBs combination
(4 GRBs, <θ> = 15°)



N_{GRBs}	Min. n_σ	Max. n_σ
1	0.96	1.7
2	1.74	2.3
3	2.2	2.48
4	2.63	2.63

It is not the proof, but it can be indication.

Mean counts density (per GRB and m^2) versus zenith angle



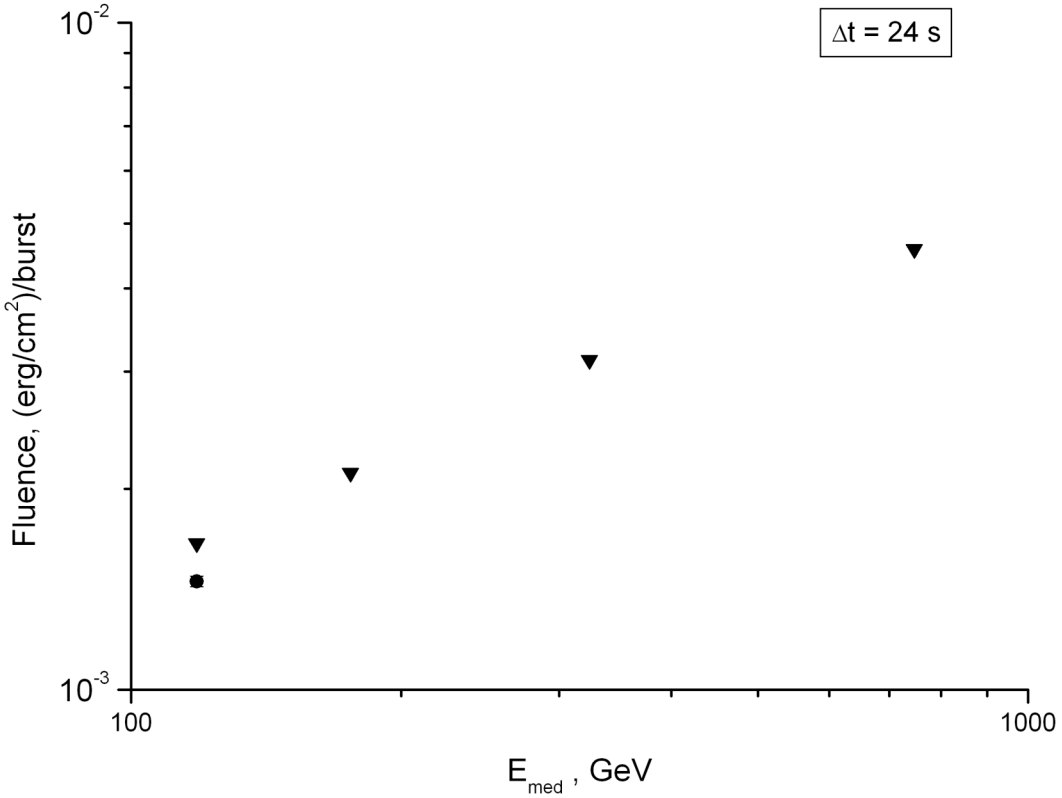
$$\overline{\rho}_{count} = \frac{N_{count}}{N_{GRB} \times S \times \cos\theta}$$

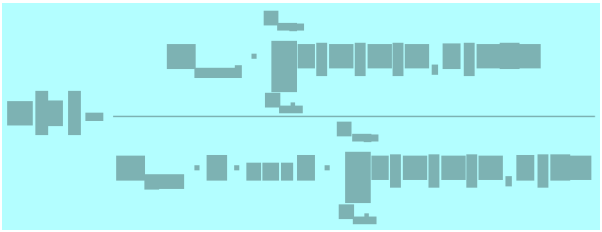
GRB 090510
$\Delta t = 0.9$ s – 1.0 s
$\gamma = -1.92$
(M. Ackermann et al., arXiv:1005.2141v1 [astro-ph.HE], 2010)

▼ - upper limit at 3σ level

● - supposed signal for <θ> = 15°

Upper limits for the energy fluence (per burst).





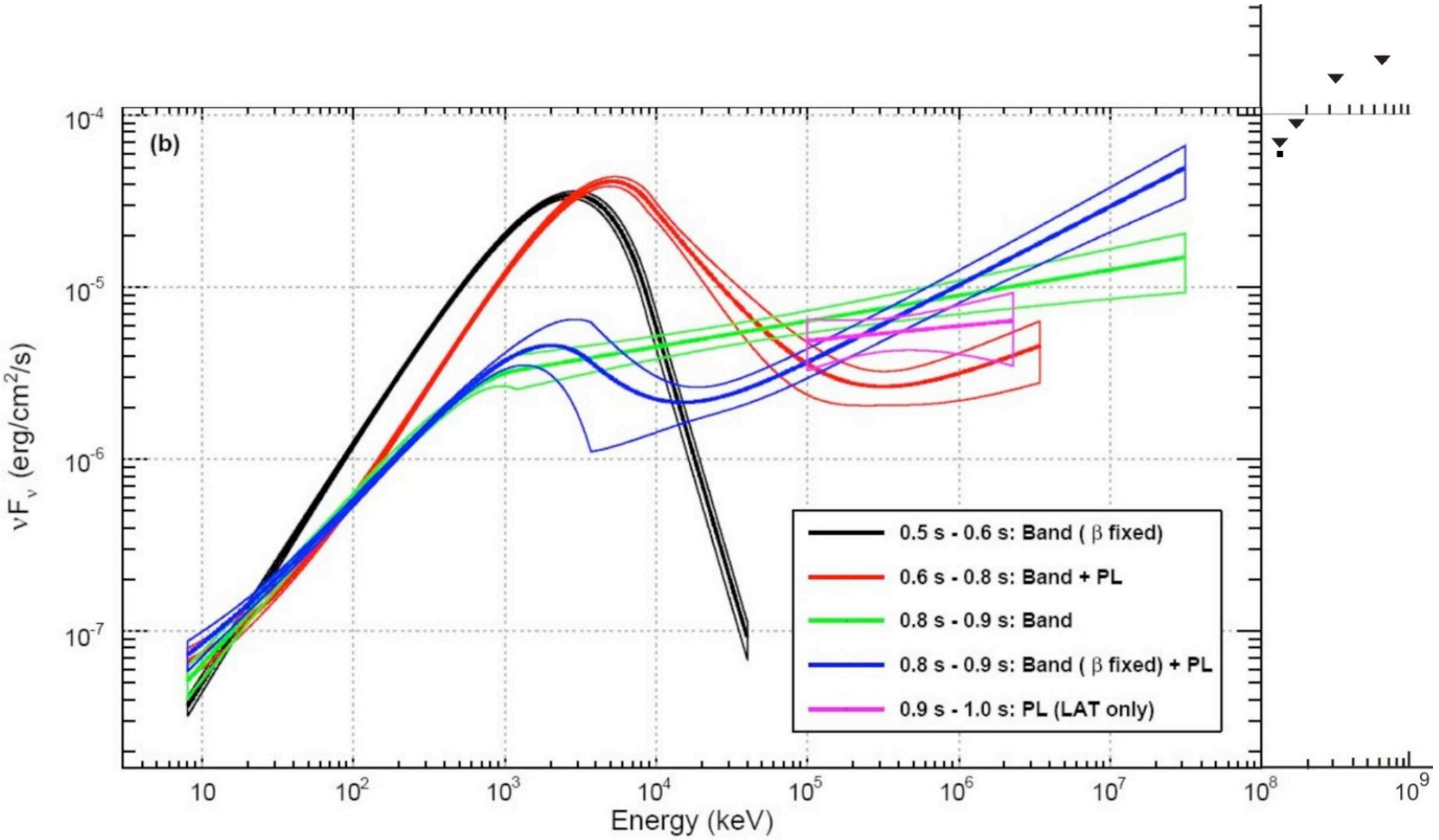
E_{min} = 1 GeV
E_{max} = 20000 GeV

▼ - upper limit at 3σ level

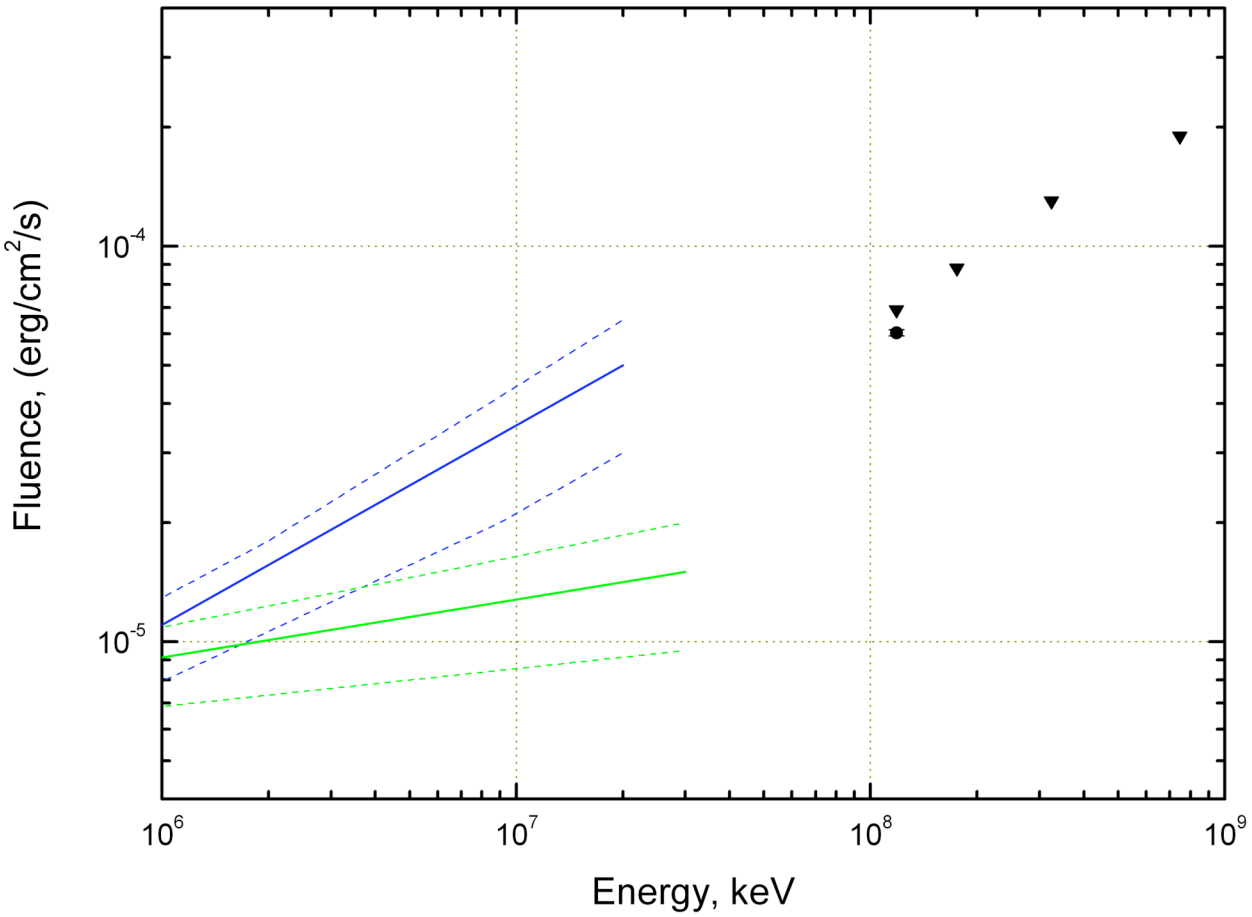
● - supposed signal for $\langle\theta\rangle = 15°$

Comparison with Fermi data (GRB 090510, prompt emission phase)

Our data – extended high-energy emission (per burst and per second)



Comparison with Fermi-LAT data (GRB 090510, prompt emission phase)
Our data – extended high-energy emission (per burst and per second)



Conclusions

- A search for extended radiation of the short gamma-ray bursts in the energy range 1 - 1000 GeV has been performed by Andyrchy EAS array with single particle technique.
- Using epoch folding method around trigger time of bursts the upper limits on the fluence of extended high-energy radiation are obtained.
- A supposed detection for extended high-energy radiation with duration of 24 s can be discussed.
- Our result does not contradict extrapolations of Fermi-LAT fluencies.