Characteristic for long GRBs with high energy component presence, which not required cosmological corrections

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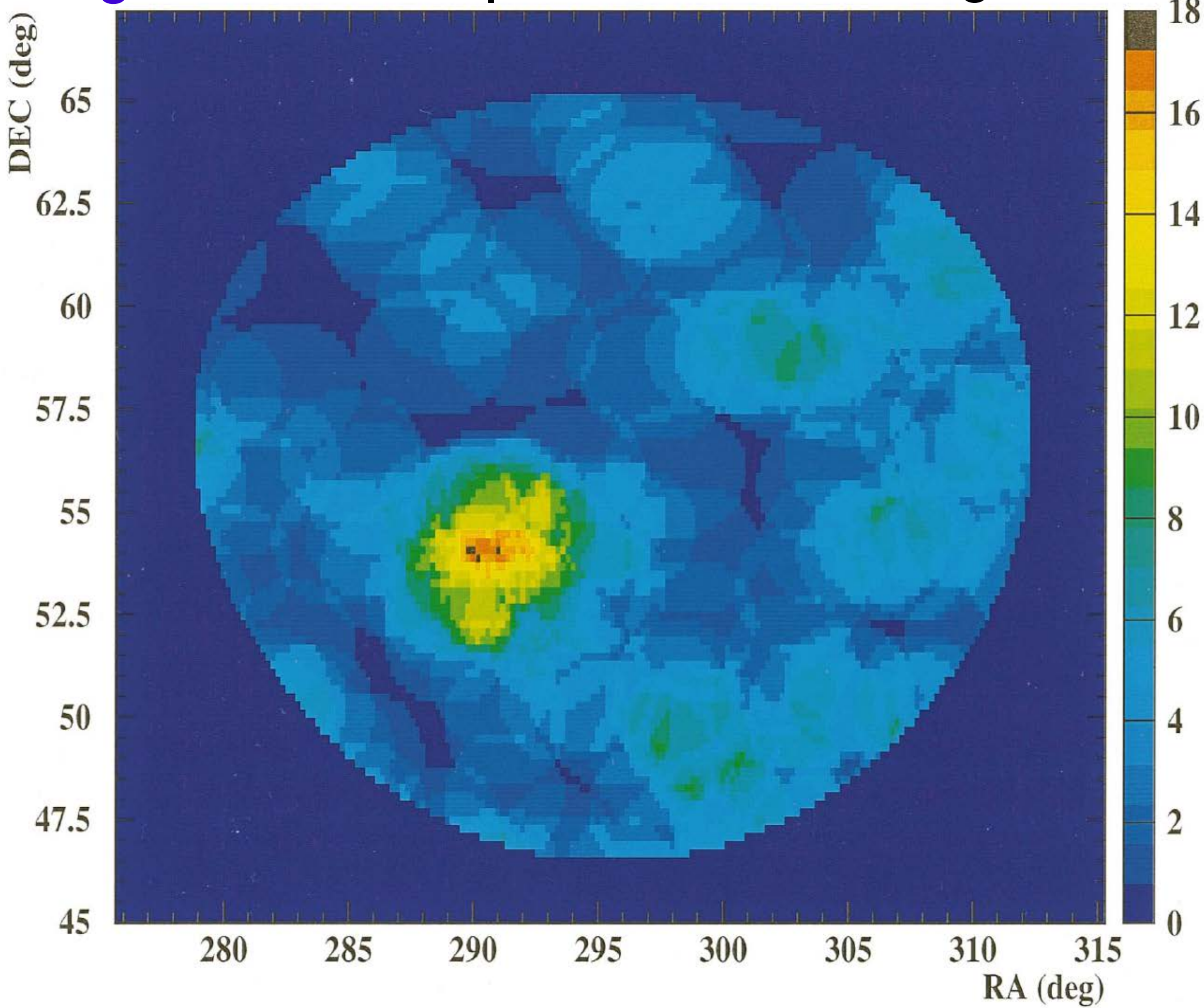
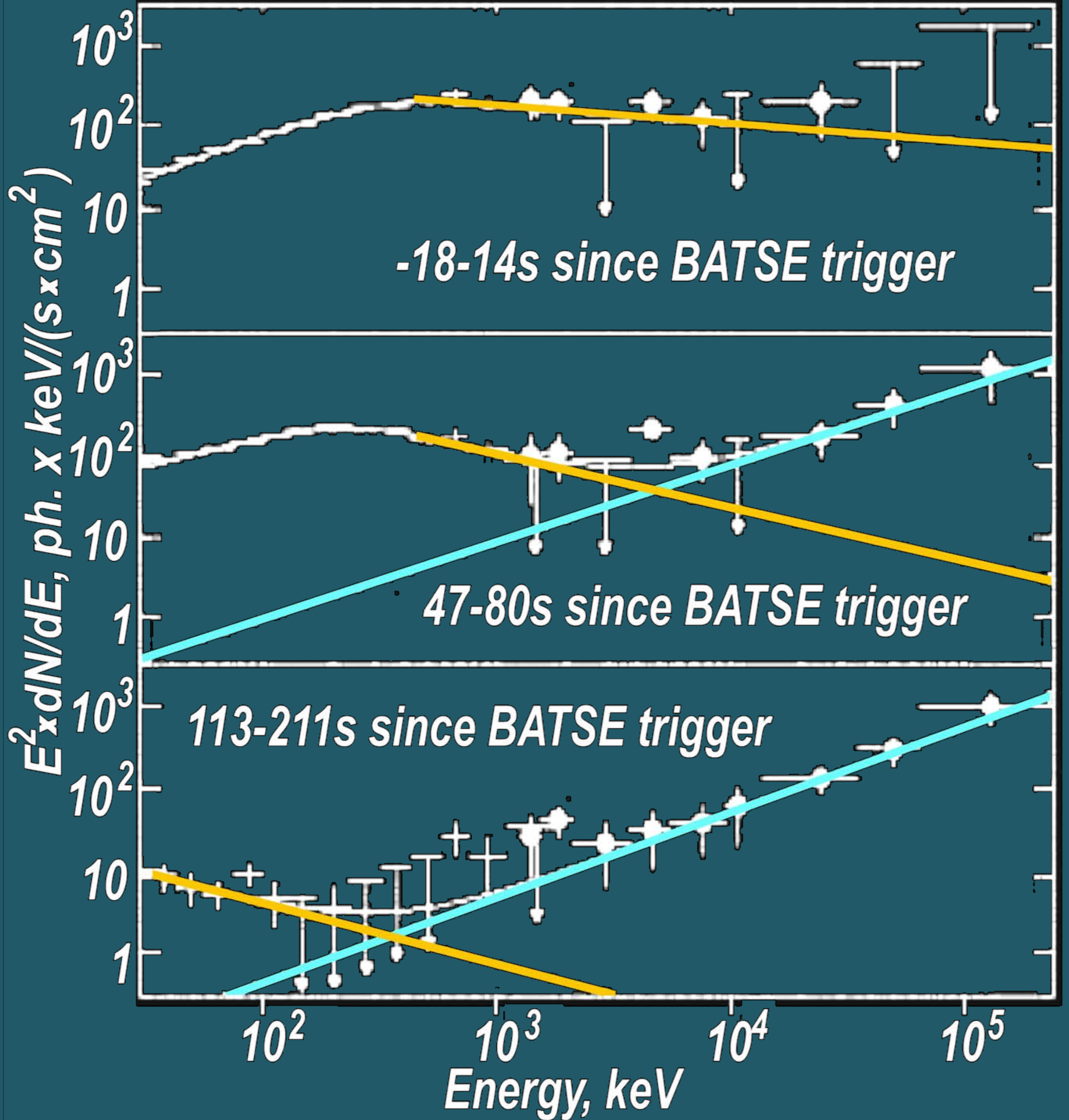
GRBs observed since the end of 1960th and now several thousands of events were listed in more than 20 catalogues as results of more than 40 satellites and ground experiments.

Firstly evidence of TeV emission: GRB 970417a using data from the Milagrito: several photons with energies ~650 GeV were detected (Atkins,2000) prompt emission?



Number of events registered by Milagrito during T_{90} in overlapping 17.6 radius bins in the vicinity of GRB 970417a



The energy spectra of GRB941017: second component of Band model and approximations for high energy part

Spectrum of this GRB has additional non-Band component in the high energy region. up to 200 MeV

Spectral index of the HE component: $\gamma\approx-1$

Cut-off at higher energies: where?

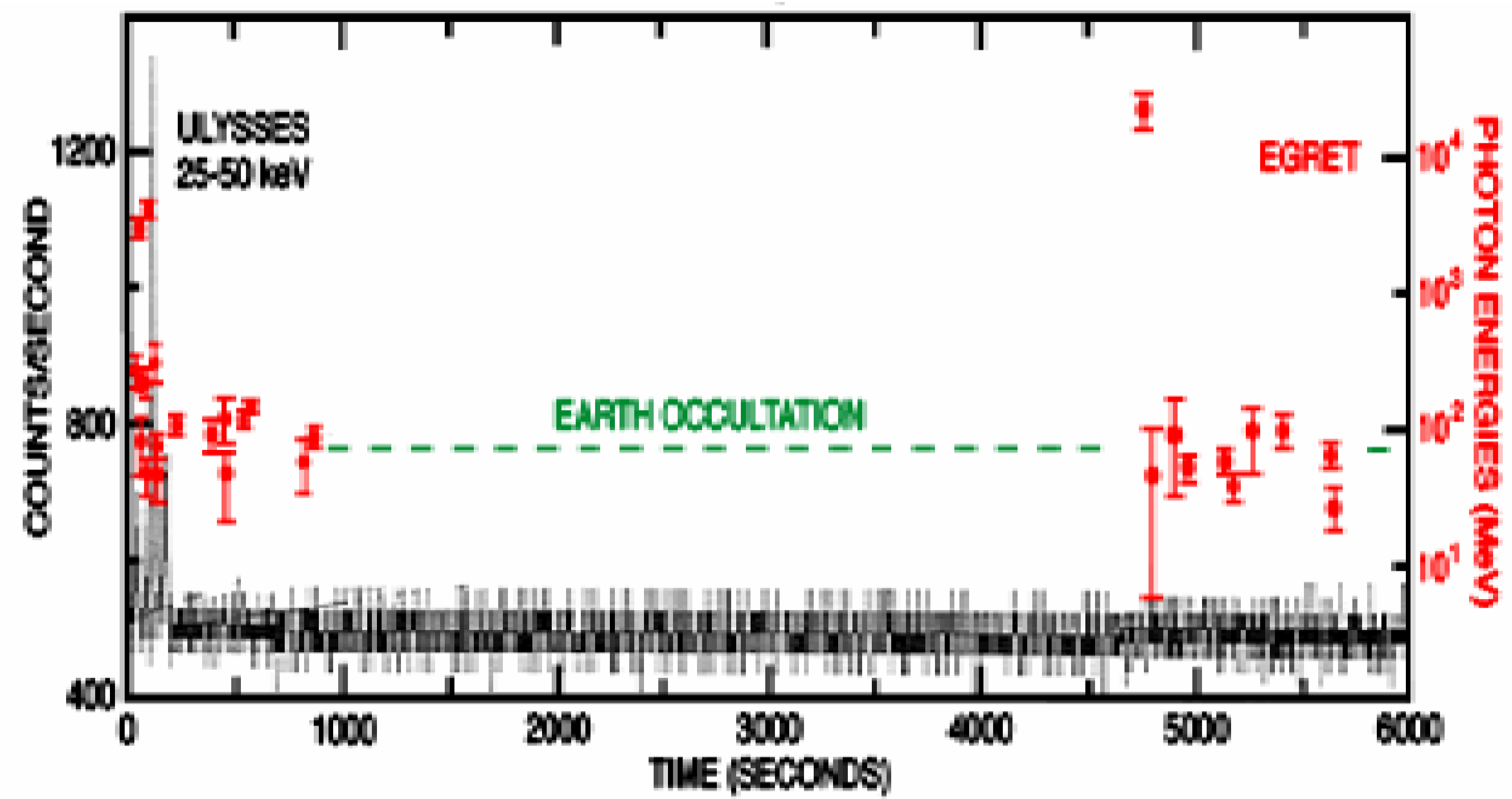
The difference between these two types of spectral shapes is well seen.

2 spectral breaks were introduced in prompt emission of GRBs
E1 – between 2 components of Band model
E2 – corresponds to HE component

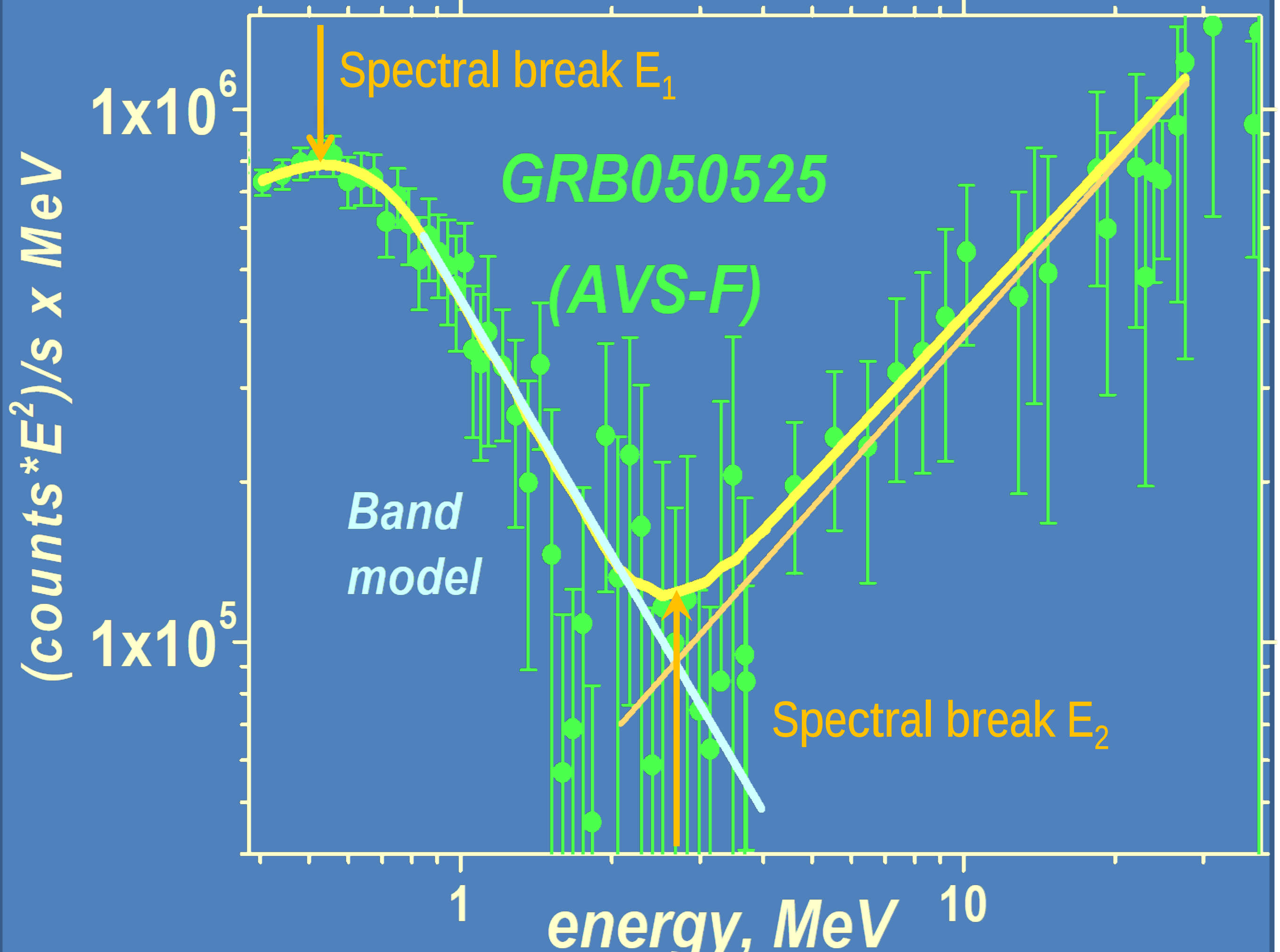
GRB940217 (BATSE trigger #2831**, t_{90}≈150s) – first HE afterglow**

➢ **γ-ray emission (> 50 MeV) till 1.5 hours after start of burst, highest-observed energy: 18 GeV**

➢ **temporal profiles with different time structure in various energy bands → extended high energy emission**



Registration of GRB940217 by EGRET and ULYSESS



The energy spectrum of GRB050525 by AVS-F data: second component of Band model and approximation for high energy part

CORONAS-F/AVS-F (2001-2005)

The summarized spectrum of GRB050525 has additional component in the high energy region too

$E_{break}=2.4\pm0.1$ MeV

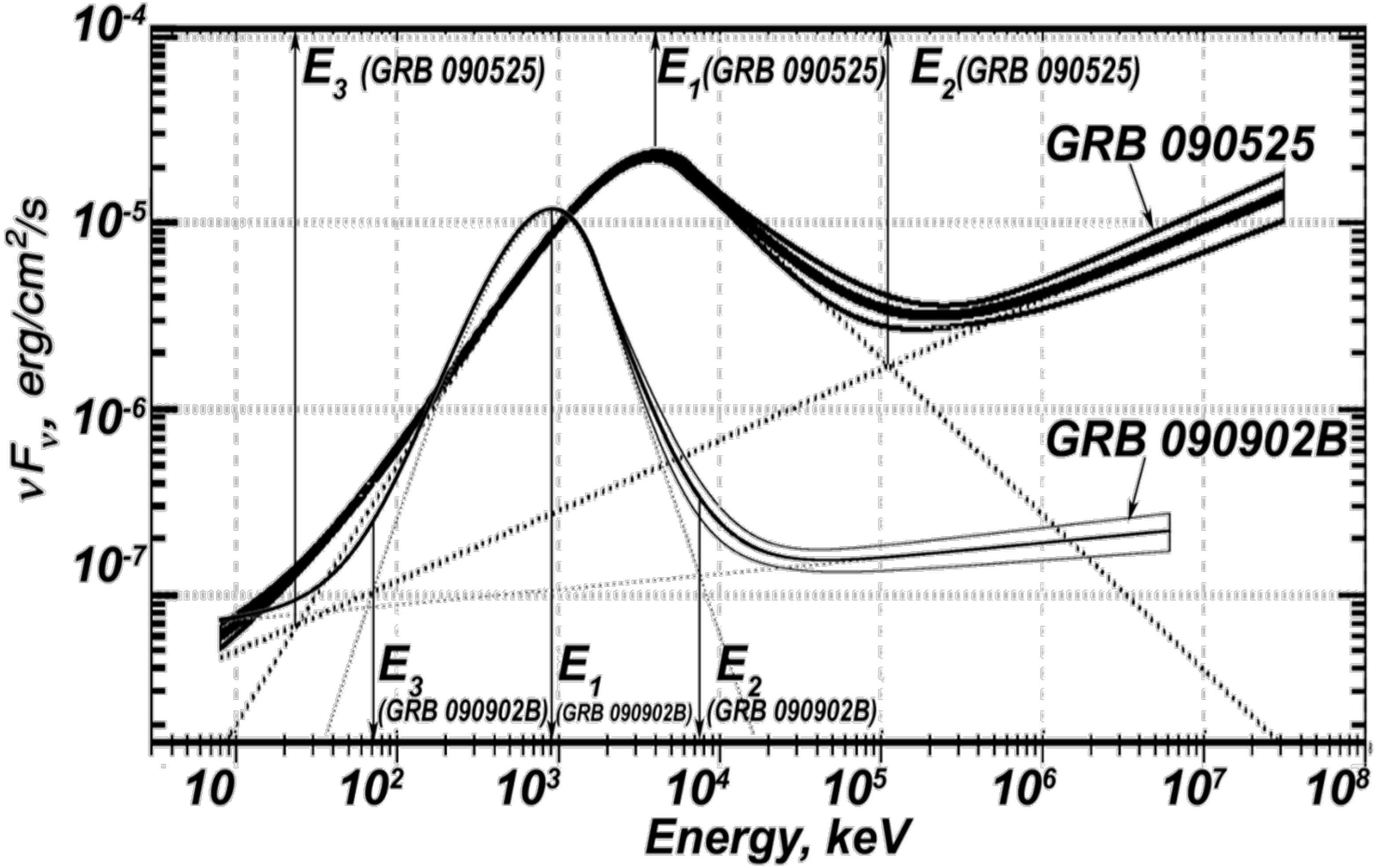
Analysis of CGRO and CORONAS-F databases

↓

$\mathbf{E_{break}\sim 3\div 30}$ **MeV**

Next step: Fermi & AGILE: third spectral breaks should be introduced
E3 - low energy component (tens of keV).
But: E1 – between 2 components of Band mode
E2 – corresponds to HE component

totally 3 spectral breaks



Extension of HE component to low energy region down to tens keV?

PRESENT TIME: 170 Fermi/LAT GRBs, 61 AGILE/MCAL

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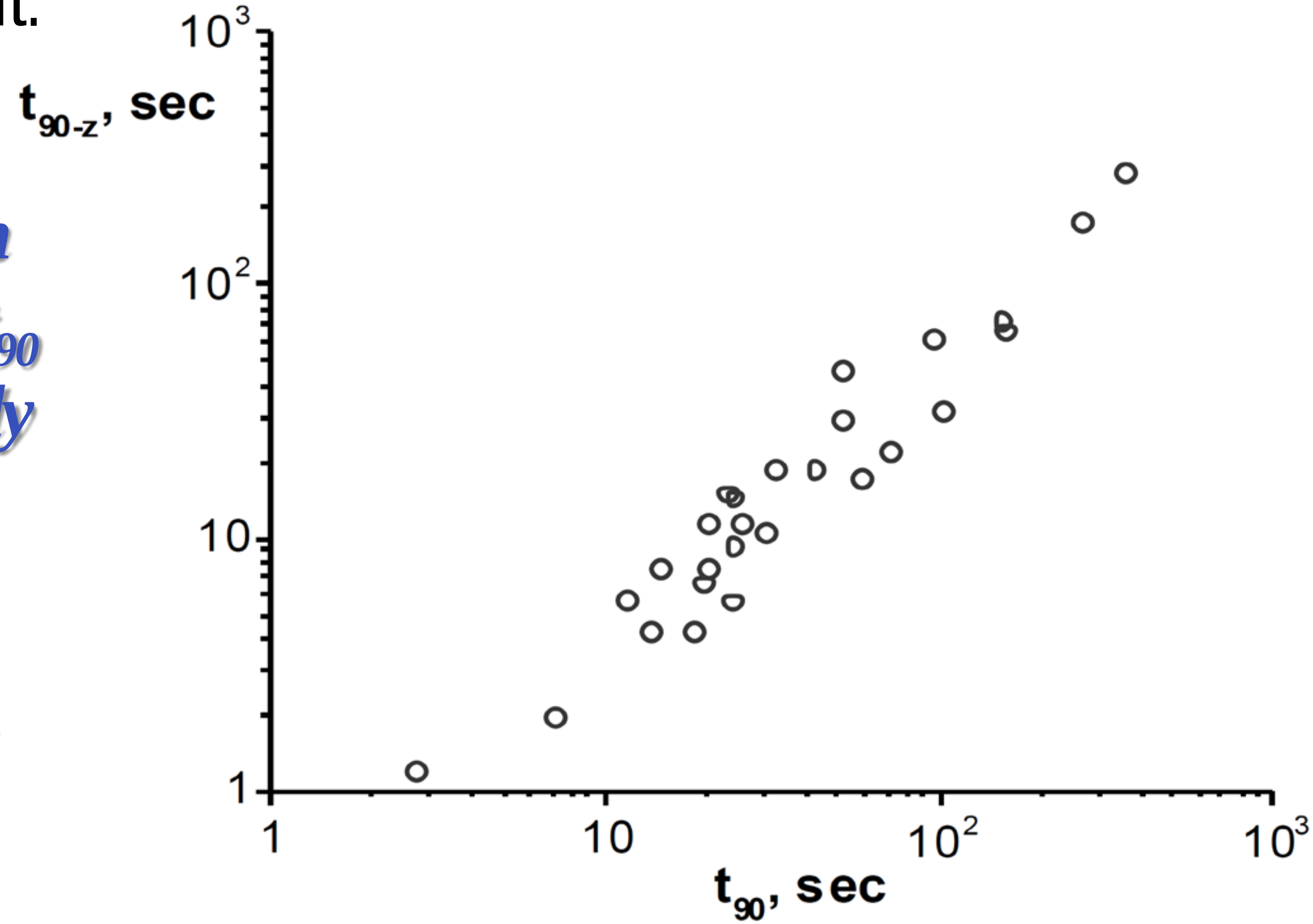
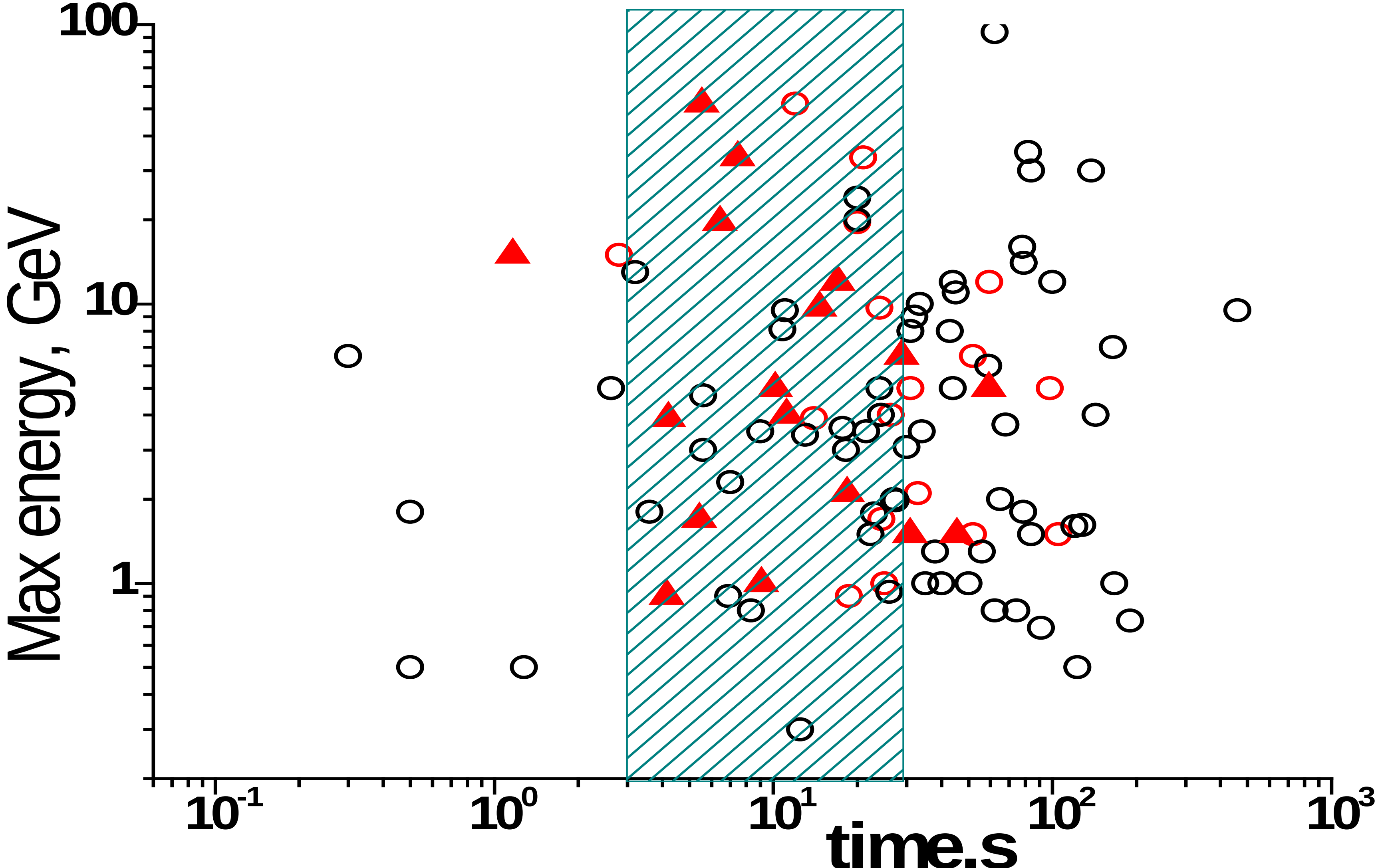
But GRBs sources' origins nature is cosmological – see redshift corresponding columns in catalogues. Therefore correction to cosmological dilation of GRBs duration should be consider because of real cosmological sources time properties should be investigated only taking into account its redshift.

GRBs distribution on burst duration t_{90} and cosmologically corrected t_{90_z}

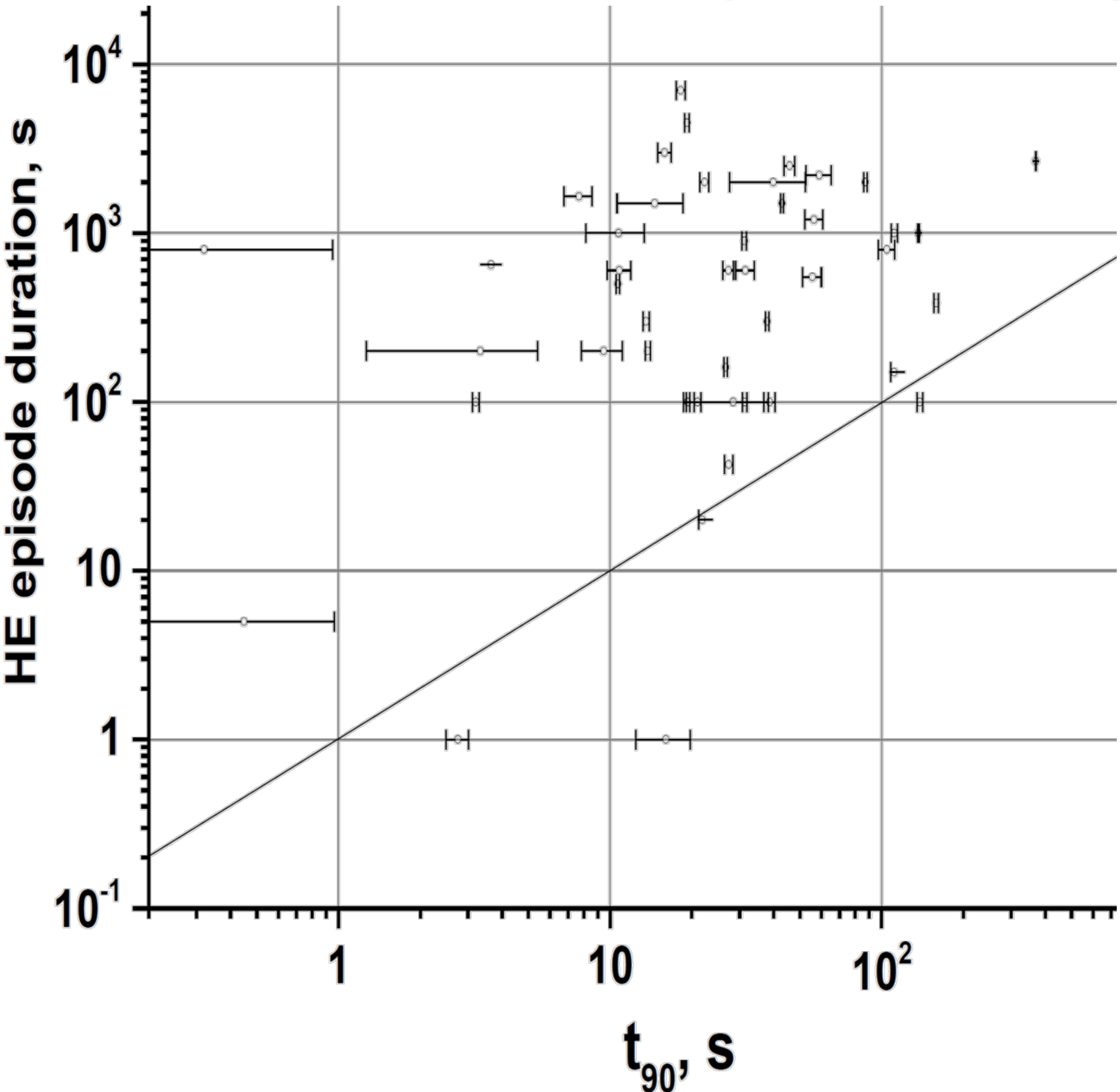
Duration of 2 GRB became less 2 s after correction





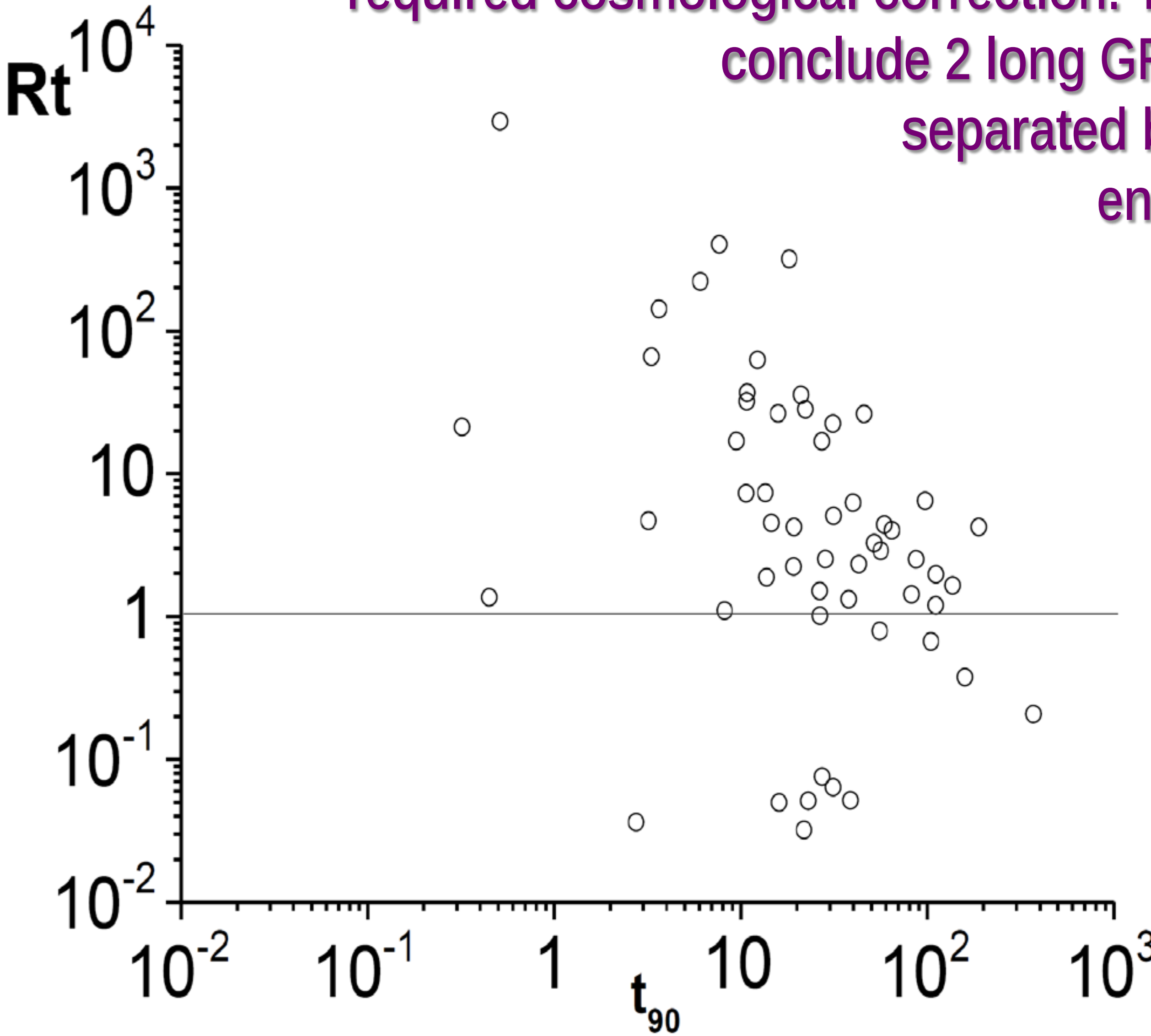
LAT GRBs distribution on burst duration and maximum registered energy (circles). Red circles shows events with known redshift and red triangles represent these burst duration t_{90} with cosmological correction and most part of bursts after this were shifted in dashed region with 2 s<t_{90}<30 s

It is possible to separate two subtypes of GRBs using value where high energy episode duration Is equal to burst t_{90}



The bursts distribution on high energy episode duration and t_{90}

Unfortunately only several tens of LAT GRBs has information both about redshifts and t_{90}. For next analysis we introduce new value Rt is ratio of maximum energy photon arrival time to burst duration and this value not required cosmological correction. The investigation results conclude 2 long GRBs subgroup existence separated by limit where maximum energy photon arrival time is equal to event t_{90}.



The distribution of LAT GRBs on Rt and t_{90}

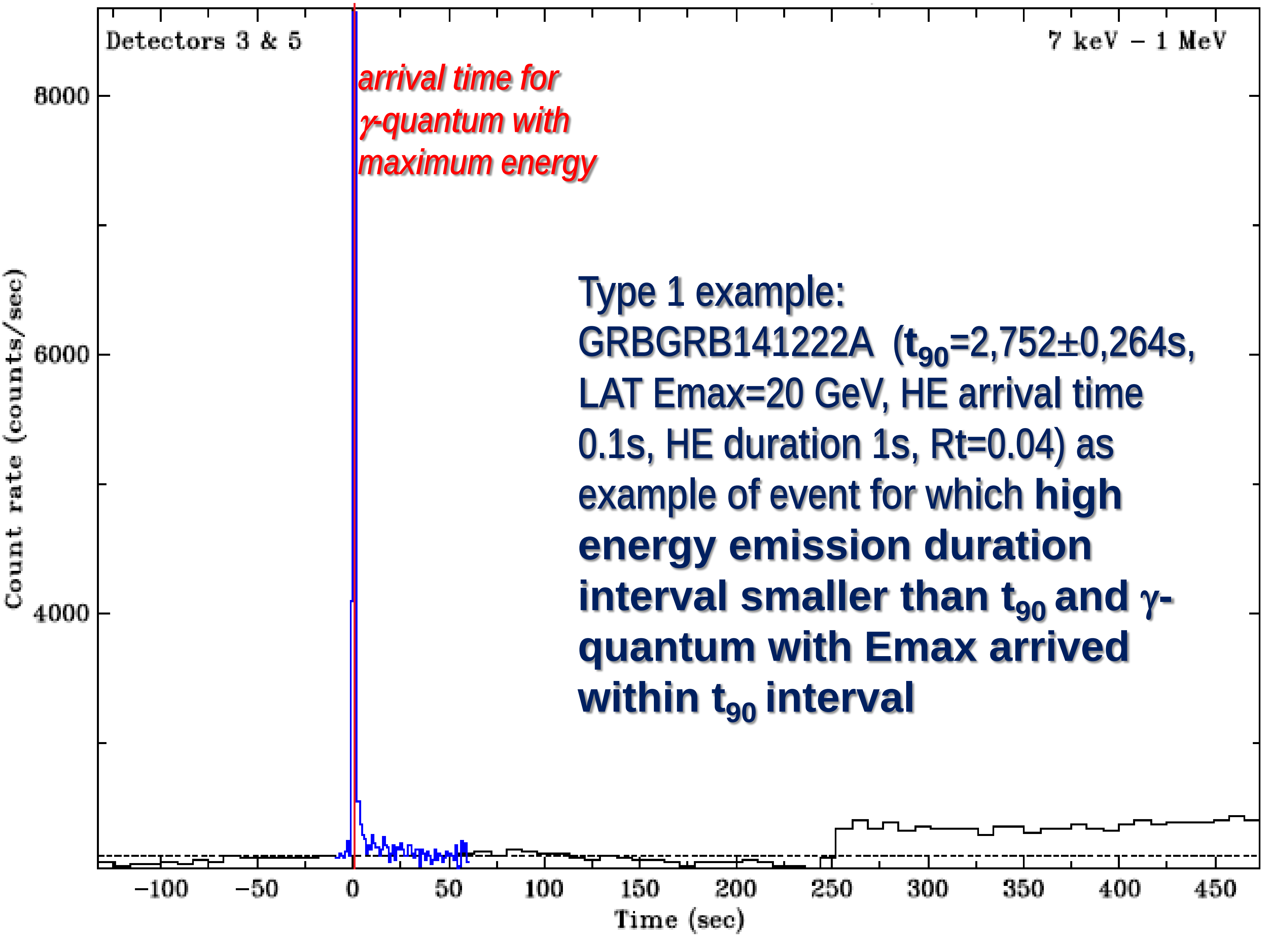
At least 2 groups of long GRBs could be separated using parameter Rt : for 25% events highest energy gammas detected within t_{90} interval, but for other 75% of bursts it registered more than 10 seconds later than one.

preliminary results of analysis allow concluding <u>three</u> types of GRBs with high energy emission registration without dependence of burst duration value:

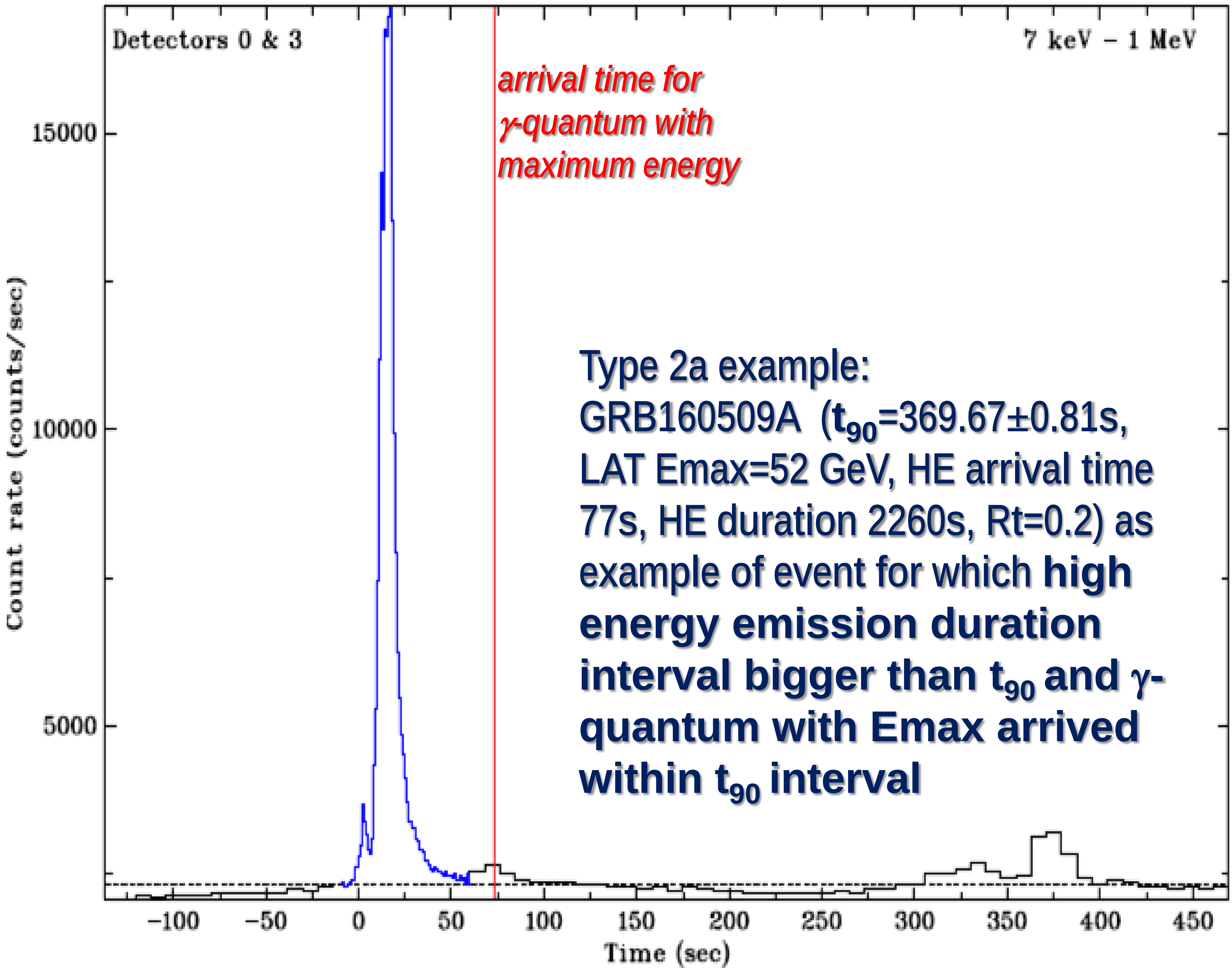
1. high energy emission duration interval smaller than t_{90}.
2. high energy emission duration interval bigger than t_{90}:

(a) γ-quantum with maximum energy arrived within t_{90},

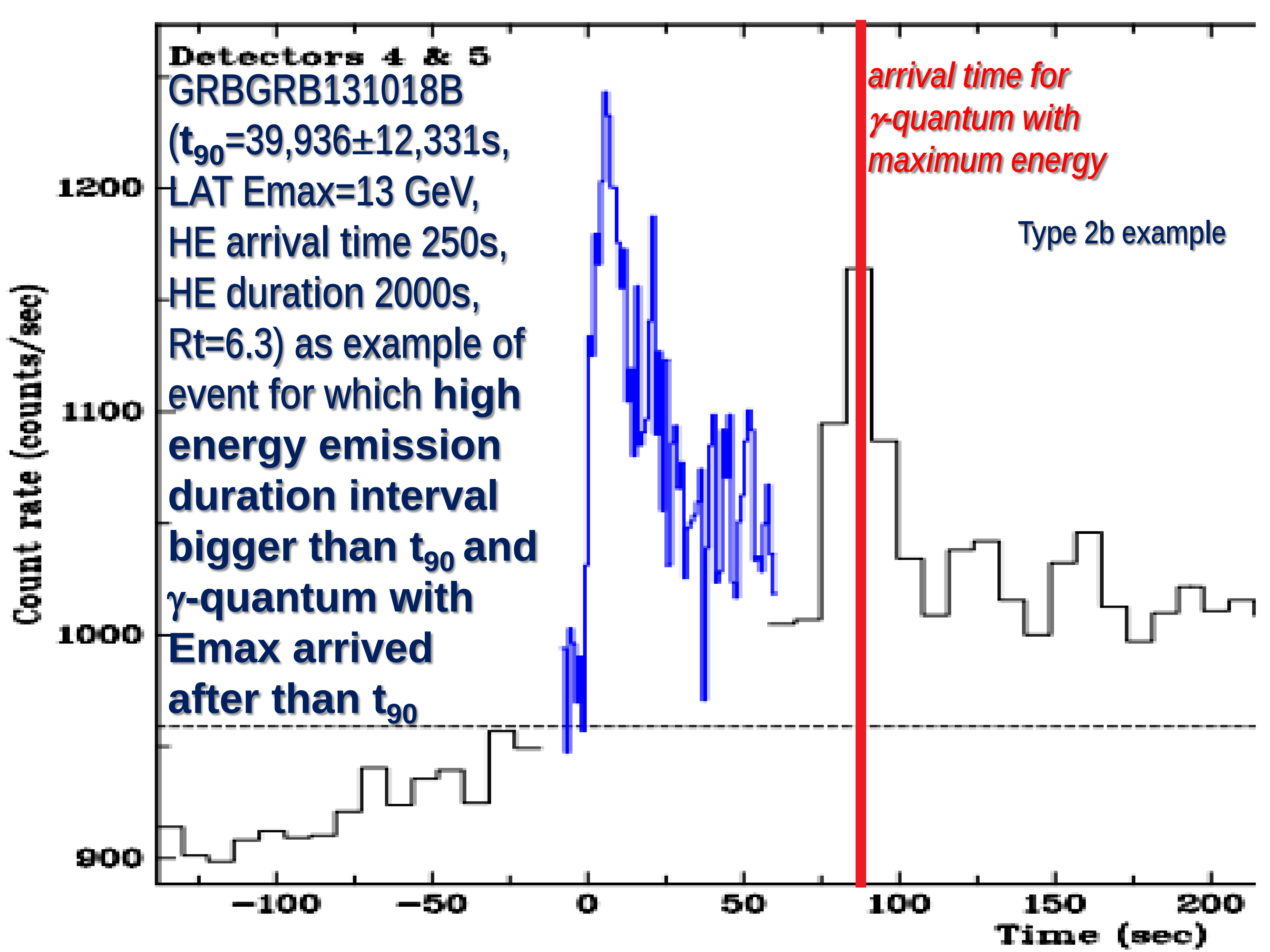
(b) such photon was registered later than t_{90}.



Type 1 example:
GRBGRB141222A (t_{90}=2,752±0,264s, LAT Emax=20 GeV, HE arrival time 0.1s, HE duration 1s, Rt=0.04) as example of event for which **high energy emission duration interval smaller than t_{90} and γ-quantum with Emax arrived within t_{90} interval**

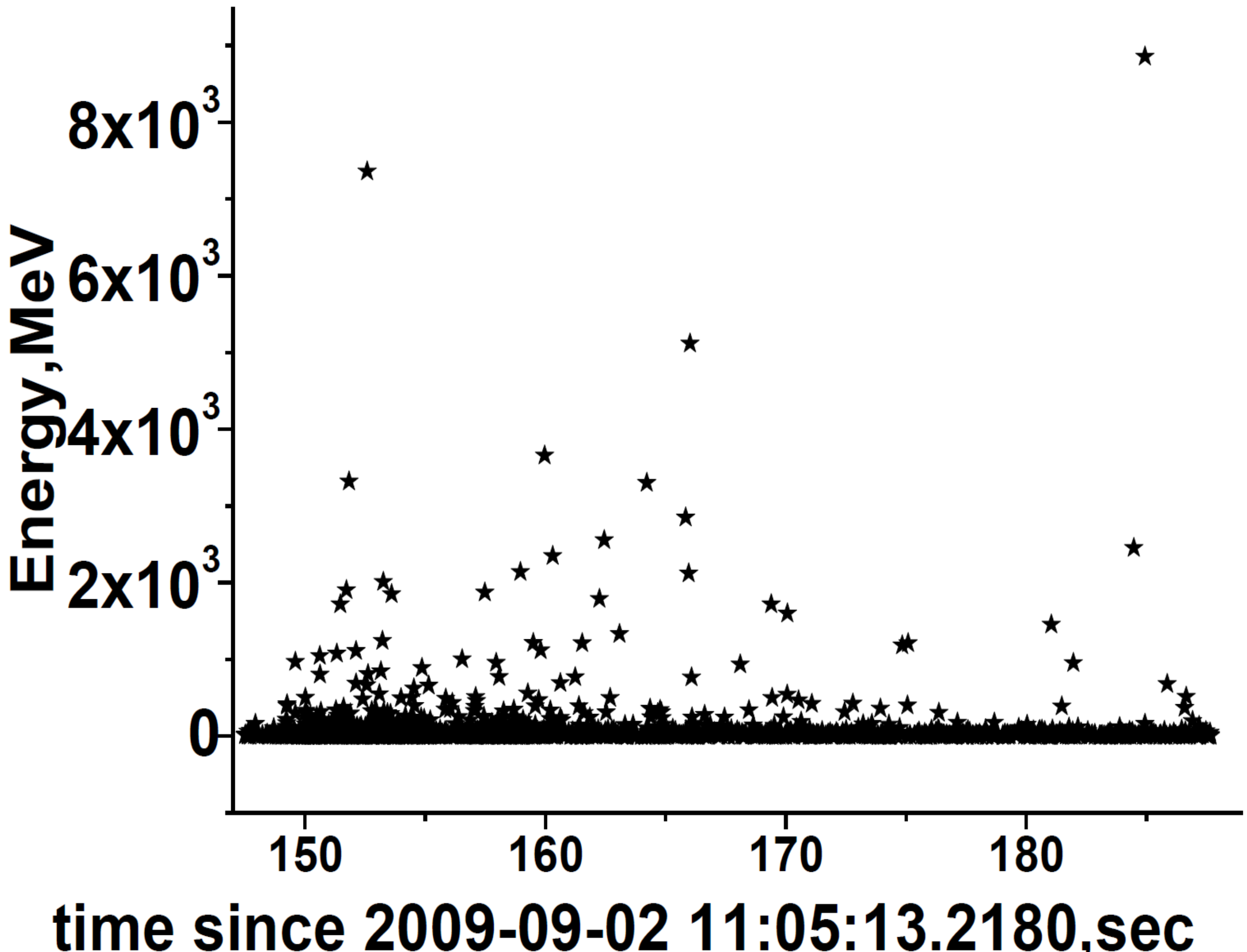


Type 2a example: GRB160509A (t_{90}=369.67±0.81s, LAT Emax=52 GeV, HE arrival time 77s, HE duration 2260s, Rt=0.2) as example of event for which **high energy emission duration interval bigger than t_{90} and γ-quantum with Emax arrived within t_{90} interval**



Detectors 4 & 5
GRBGRB131018B
(t90=39,936±12,331s,
LAT Emax=13 GeV,
HE arrival time 250s,
HE duration 2000s,
Rt=6.3) as example of
event for which high
energy emission
duration interval
bigger than t90 and
γ-quantum with
Emax arrived
after than t90
arrival time for
γ-quantum with
maximum energy
Type 2b example
Count rate (counts/sec)
1200
1100
1000
900
−100
−50
0
50
100
150
200
Time (sec)

Interval of high-energy emission during GRB lasting often so long that it mentioned as high energy afterglow, not prompt emission. For example, the high energy gamma-emission during of GRB090902 began after more than 100 sec following burst t_{90} end and photon with highest energy E~ 9 GeV was observed more than 50 s later.



The high energy afterglow of GRB090902

No sufficient correlation between Emax and Z during prompt emission

Long GRBs with subTeV emission has characteristics the same than 2b type:

- MAGIC start registration of GRB 190114C about 50 s after the trigger and detected > 300 GeV photons for the first 20 minutes from this burst with a significance higher than 20σ (Mirzoyan, 2019). GRB190114C is near long burst (z = 0.4245 and t_{90} ~120 s in low energy band)
- H.E.S.S. began observation of GRB 180720B at about 10 h after the burst trigger and **detected 100−440** GeV photons at such late time interval (Ruiz-Velasco, 2019). GRB 180720B is near long burst (z = 0.6535 and t_{90} ~150 s in low energy band)

and 1 type on preliminary results:

- Prompt emission during 190829A was detected by H.E.S.S. to in subTeV band. It is very near long burst z = 0.0785 +/- 0.005 (Fraija, 2020)

BUT During GRB 160821B MAGIC detected subTeV photons up to 10^4s after burst trigger (Palatiello et al, 2017). GRB160821B is near (z =0.16 short burst with HE afterglow: t_{90}= 0.48 ± 0.07 s in low energy band

CONCLUSIONS

Several thousands of gamma-ray bursts were observed by various experiments. During several GRBs very high-energy photons were detected both in space and ground-based experiments (up to some tens of GeV and up to some TeV, respectively). For example, GRB 190114C was detected by Fermi and MAGIC in very wide band up to subTeV energies.

Now GRB high energy γ-emission was observed both during short and long bursts, but photons in the band E>0.1TeV usually are observed only during long GRBs (now only one short GRB appear such emission).

GRBs mostly located at cosmological distances and cosmological correction should be used in duration investigation. But here we introduce new value Rt as ratio of maximum energy photon arrival time to burst duration in low energy band and it not required cosmological correction.

CONCLUSIONS

At least 2 groups of long GRBs could be separated using parameter Rt : for 25% events highest energy gammas detected within t_{90} interval, but for other 75% of bursts it registered more than 10 seconds later than one.

Moreover, preliminary results of analysis allow concluding <u>three</u> types of GRBs with high energy emission registration without dependence of burst duration value.
During first subtype events high energy emission duration interval smaller than t_{90}.
Second subtype characterized longer period of high energy emission than t_{90}. But second subtype bursts divided to 2 subgroups:
(a) γ-quantum with maximum energy arrived within t_{90},
(b) such photon was registered later than t_{90}.

Therefore, results of preliminary analyses allow conclude long GRBs population inhomogeneity.

Thank you for attention!