The LHAASO GRB program

LHAASO
高海拔宇宙线观测站

Sixteenth Marcel Grossmann Meeting - MG16

Virtual Meeting - July 5-10, 2021

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on behalf of the LHAASO Collaboration

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Contents

- Status of HE and VHE of GRB Observation
- Introduction of the LHAASO experiment
- A new method for GRB detection using LHAASO-WCDA
- Search for HE emission from GRBs with WCDA-1

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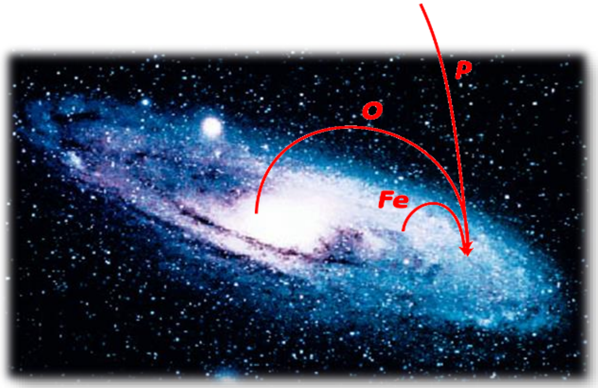
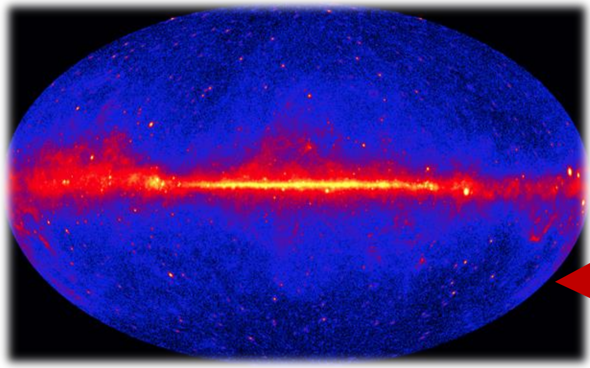
Gamma Ray Burst

Neutrinos

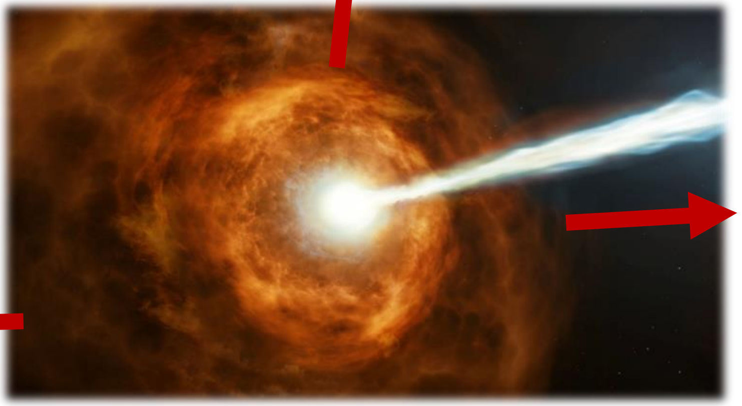
UHE cosmic rays



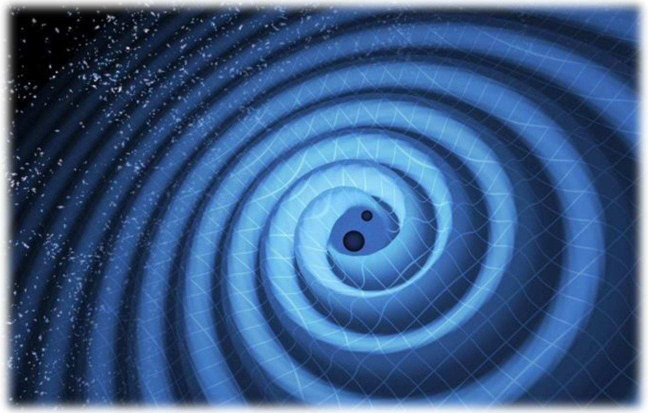
- Fireworks in the Universe;
- The most energetic phenomenon since Big Bang;
- binary star mergers or core-collapse of massive stars;



VHE gamma rays



Gamma Ray Burst



Gravitational Waves

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HE and VHE mission in GRBs

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Observation by satellite instruments:

- ◆186 GRBs by Fermi-LAT;
- ◆29 GRBs with emission above 10GeV;

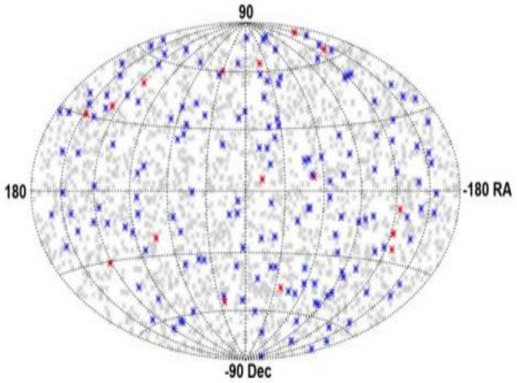
Ground-based experiments

- ◆6 GRBs and candidates reported by TeV cat;
- ◆Non-detection by EAS experiments

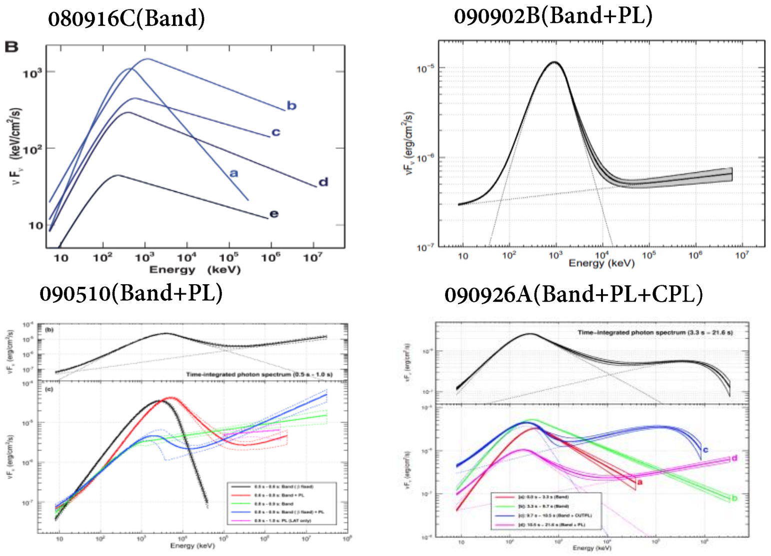
(1) Delayed emission and time dependent Spectrum in the prompt stage;

(2) Power-law decaying light curve and SSC emission in the afterglow;

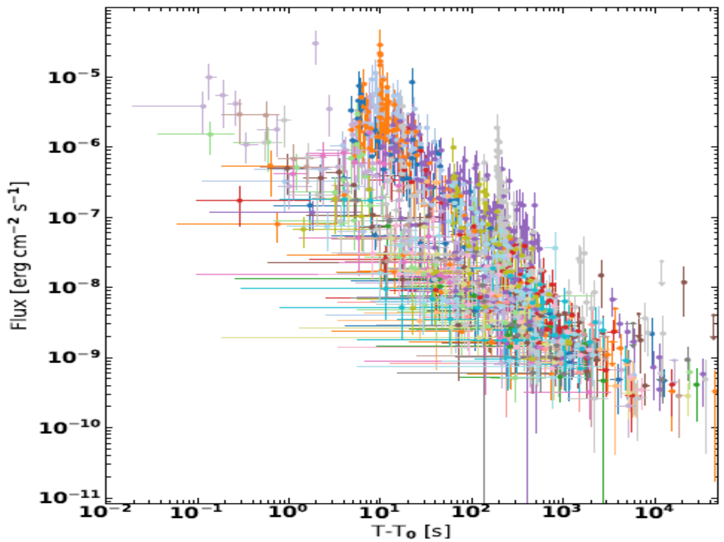
◆ HE and VHE are keys to probe physics and mechanisms from prompt to afterglow



2 FLGC@10 years



4 different GRBs' spectrum



Light curves by 186GRBs

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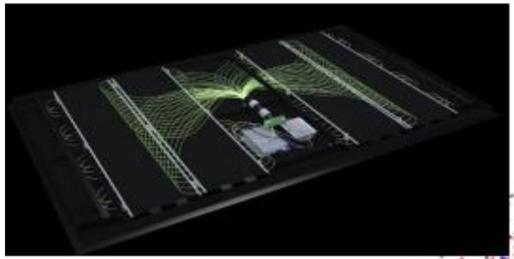
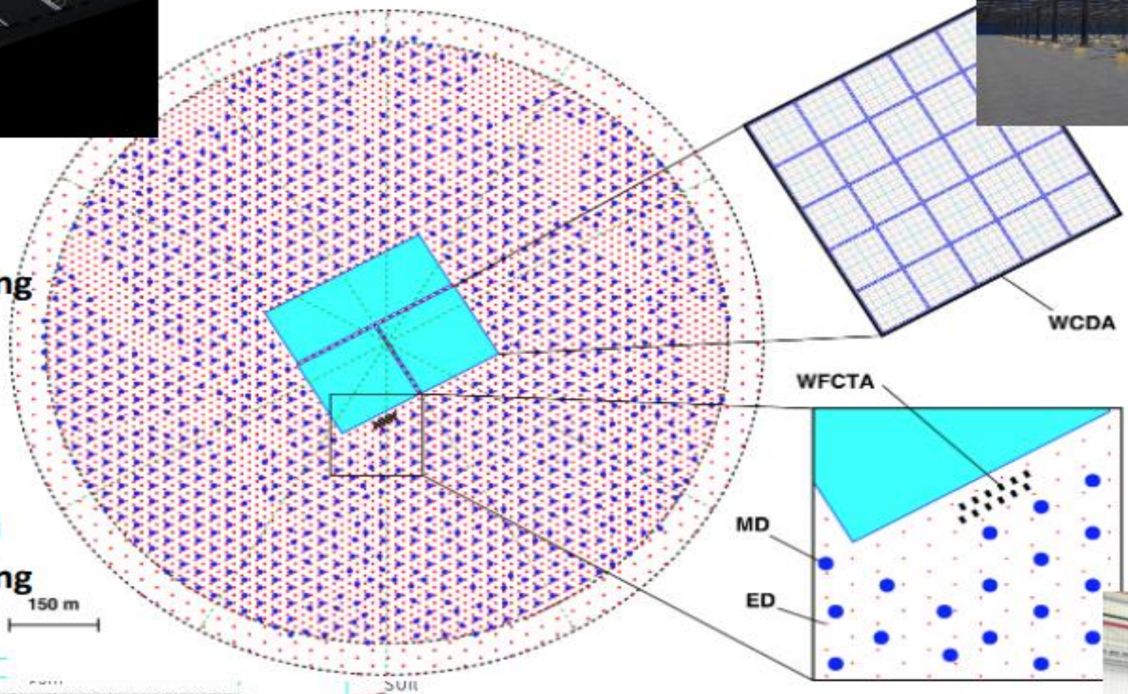
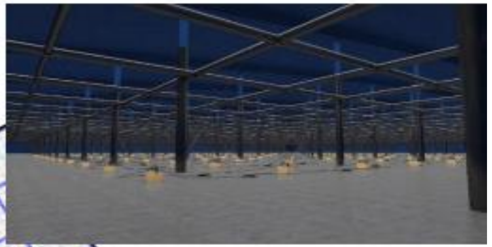
Large High Altitude Air Shower Observatory

covering 1.3 km^2



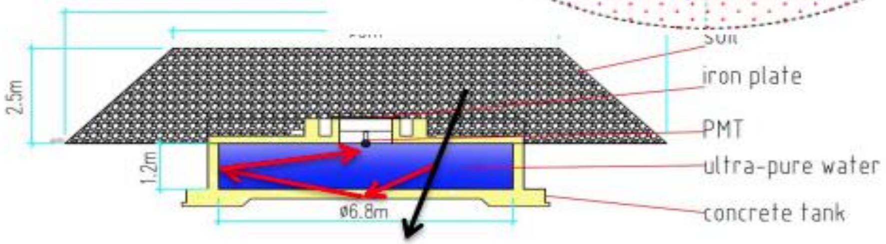
- 5195 EDs
  - 1 m^2 each
  - 15 m spacing





3120 WCDs
- 25 m^2 each

- 1171 MDs
  - 36 m^2 each
  - 30 m spacing



18 WFCTs

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Large High Altitude Air Shower Observatory

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- **Origin of GCRs**

Searching for GCR sources by measuring SED with an unprecedented sensitivity of 1%ICrab at 50 TeV

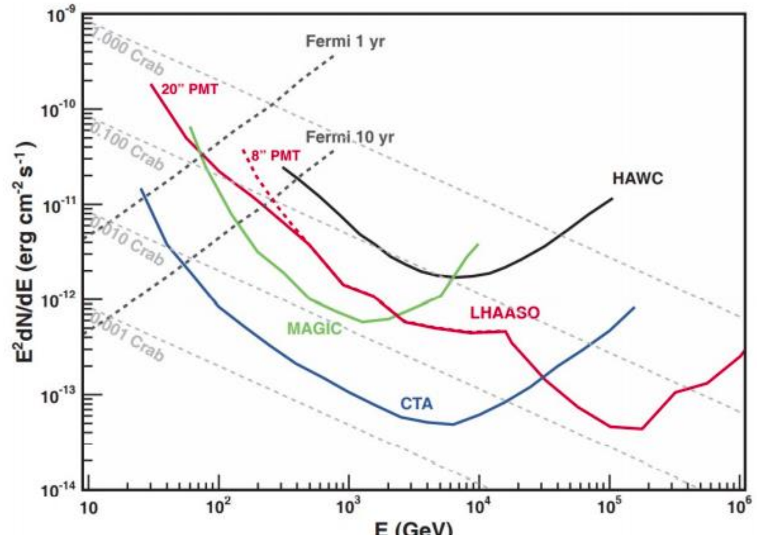
Energy spectra for individual compositions with energy from 10 TeV to 1 EeV, where the spectrum knees are located

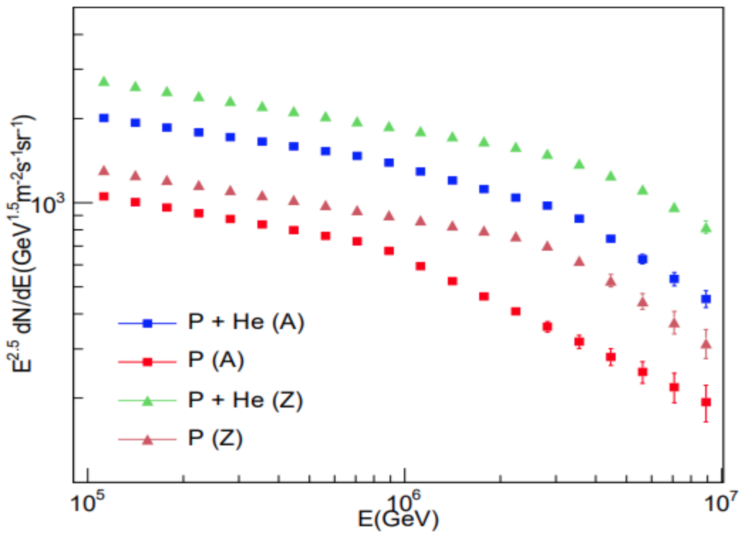
- **Gamma ray astronomy**

Searching for TeV γ sources, especially extended and transient ones, with an unprecedented survey sensitivity of 1% ICrab at 3TeV.

- **New physics frontier**

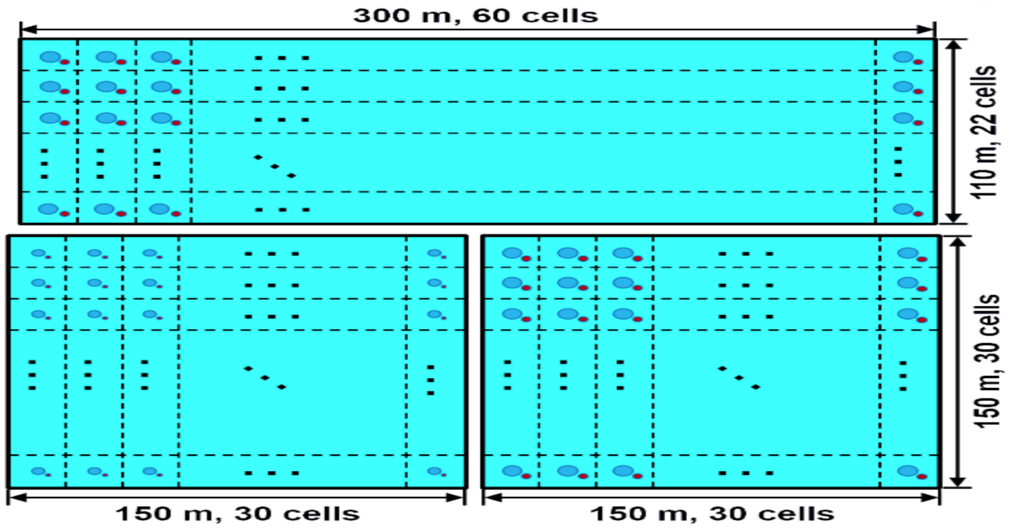
dark matter, Lorentz invariance, new physics beyond LHC energy, etc

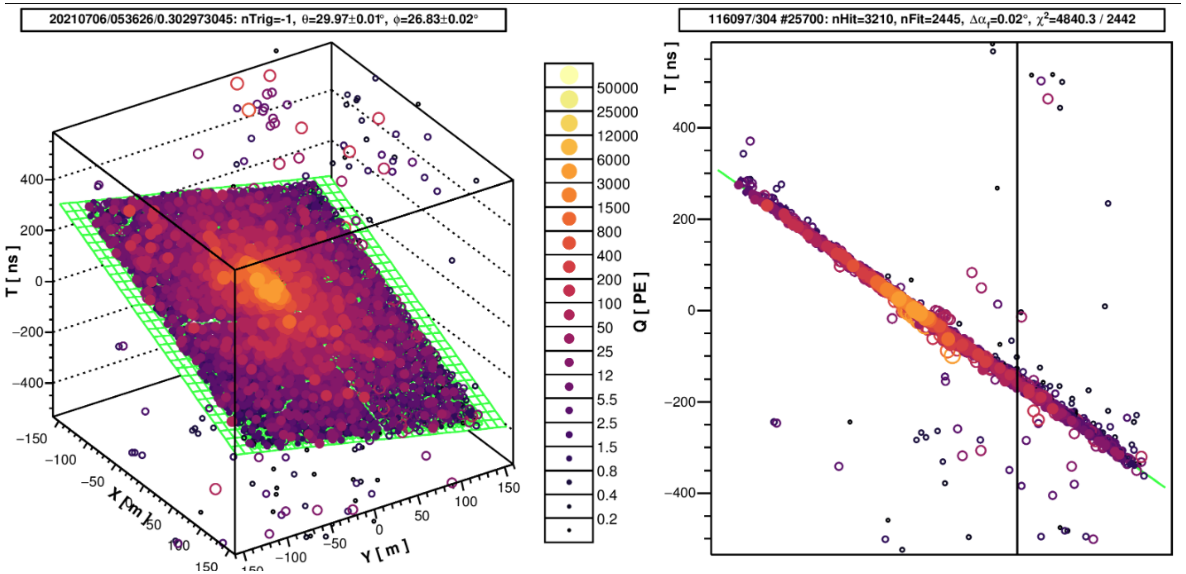




Water Cherenkov Detector Array

- Area: 7,8000 m², 3 pools ;
- Water depth: 4.5 m;
- Detector unit: 5 m × 5 m;
- PMT size:
  - **WCDA1(1.5inch+8inch)**
  - **WCDA2+3(3inch+20inch)**





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Water Cherenkov Detector Array

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Advantages:

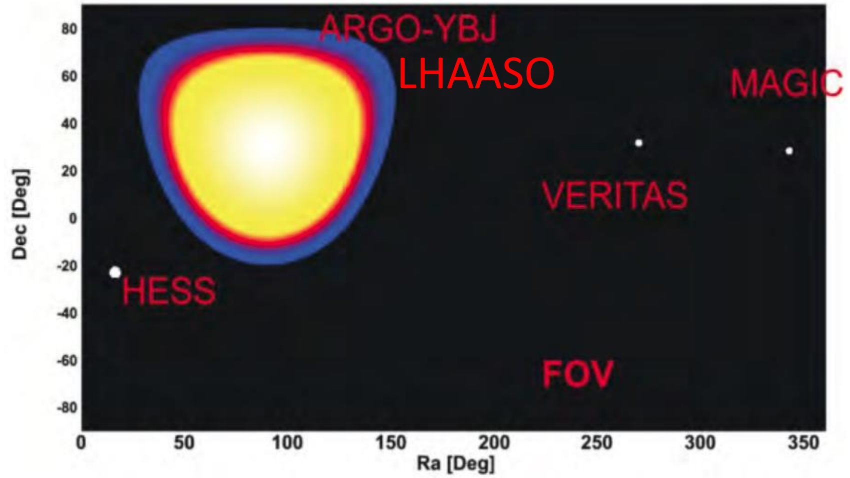
(1)wide FOV, almost full duty cycle compared to IACT experiments;

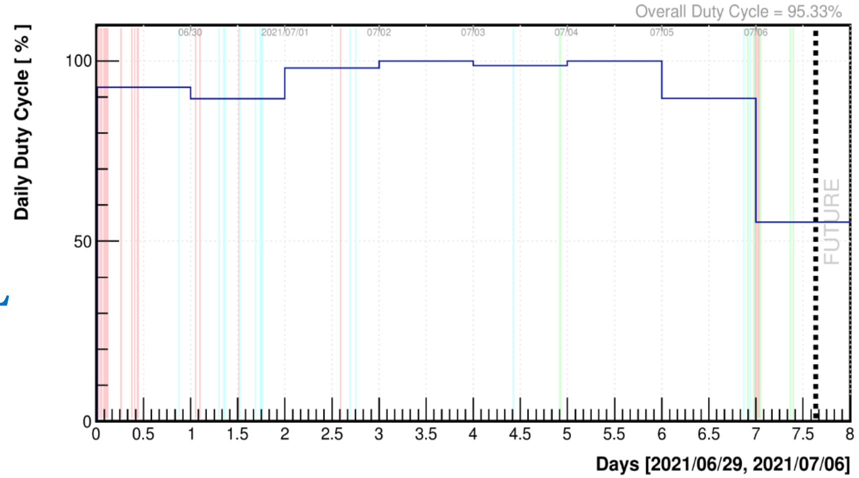
(2)Flexible trigger logic(3 modes):

- ◆ Simple Multiple Trigger:
  time window to filter noise （Twin=300ns,Nhit≥20)
- ◆ Pattern Trigger:
  time and space window(Twin=300ns,Rwin=60m,Nhit≥11)
- ◆ Triggerless:
  all the hits to be saved(charge, time and position)

Disadvantages:

With a short observing distance since the high energy threshold(the higher the energy, the more serious the EBL absorption), which is unfavorable to GRB observation





Prospect for lowering energy threshold

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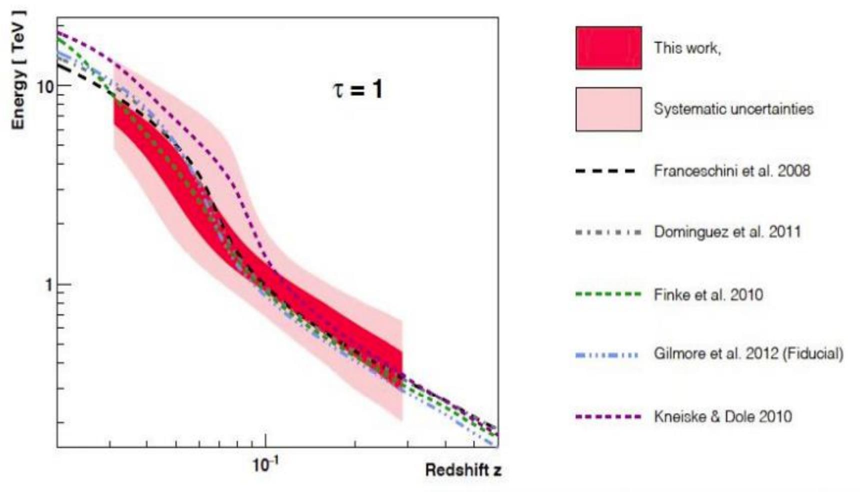
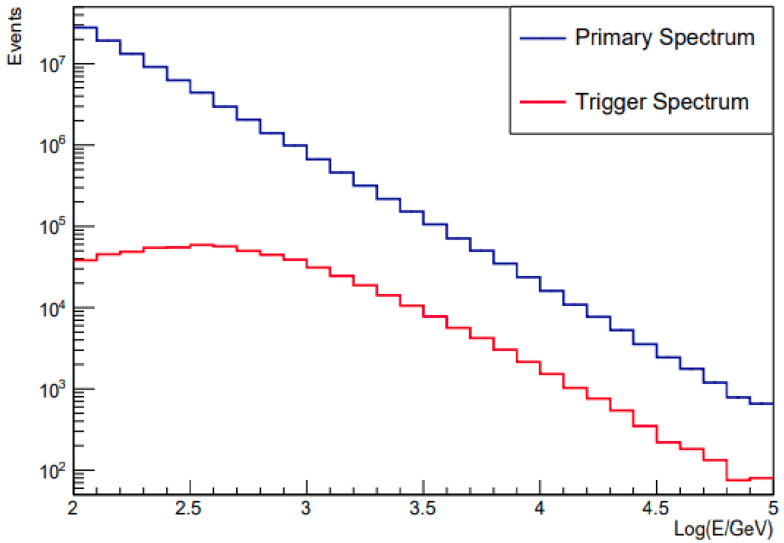
Energy-dependent observing distance



Energy threshold of WCDA： 400GeV



Redshift	Ratio of GRBs	Survival probability(TeV)	Survival probability(0.1TeV)
2	56%	2.7e-10	0.1
1	30%	2.2e-6	0.46
0.5	10%	2.0e-3	0.81
0.1	1.7%	0.38	**0.98**

Far distance and high energy threshold

↓

Lower the energy threshold

↓

Impossible for traditional trigger logic

How to lower energy threshold to about 100 GeV？

Line Of Shower Trigger method

(1) With a knowing direction of GRB(the alert):

$$l = \sin\theta * \cos\varphi\,,\quad m = \sin\theta\sin\varphi\,,\quad n = \cos\theta$$

(2)Arrival time of each hit(to the detector):

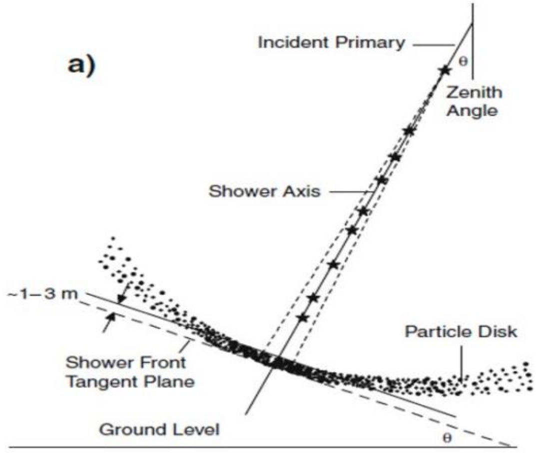
$$t_{exp} = \frac{l*x+m*y+nz}{c}$$

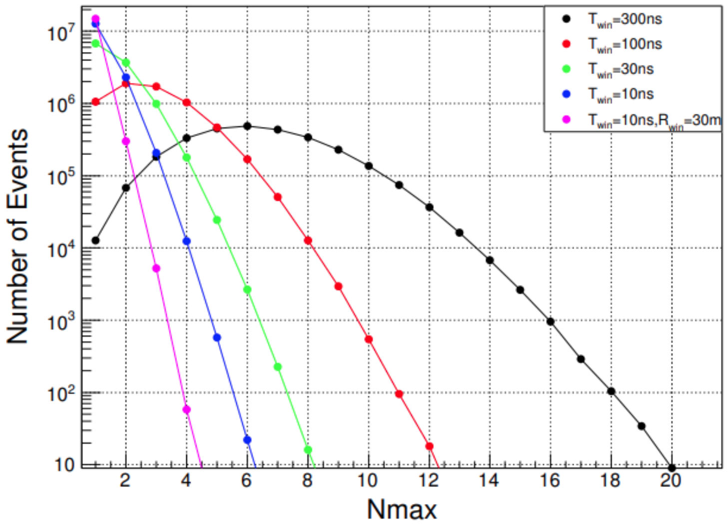
(3)Time corrected to the EAS front:

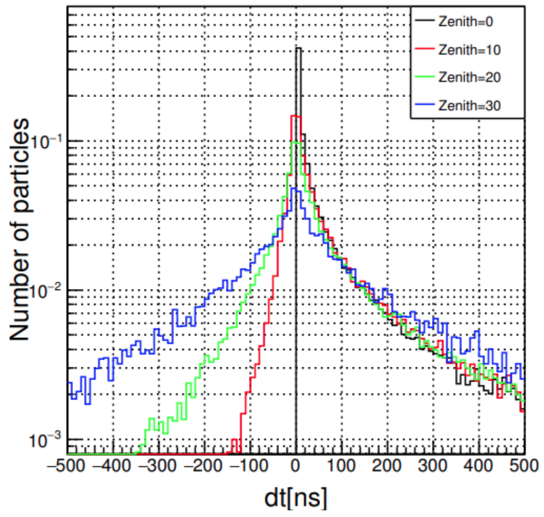
$$\delta t = t - t_{exp}$$

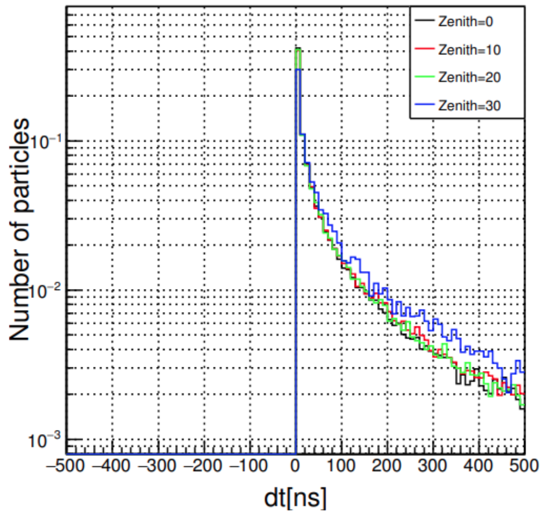
δt is about 3ns~10ns

With a time window compared to the shower thickness, we can reduce the multiplicity to 4 and noise rate below 100 Hz。









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Line Of Shower Trigger method

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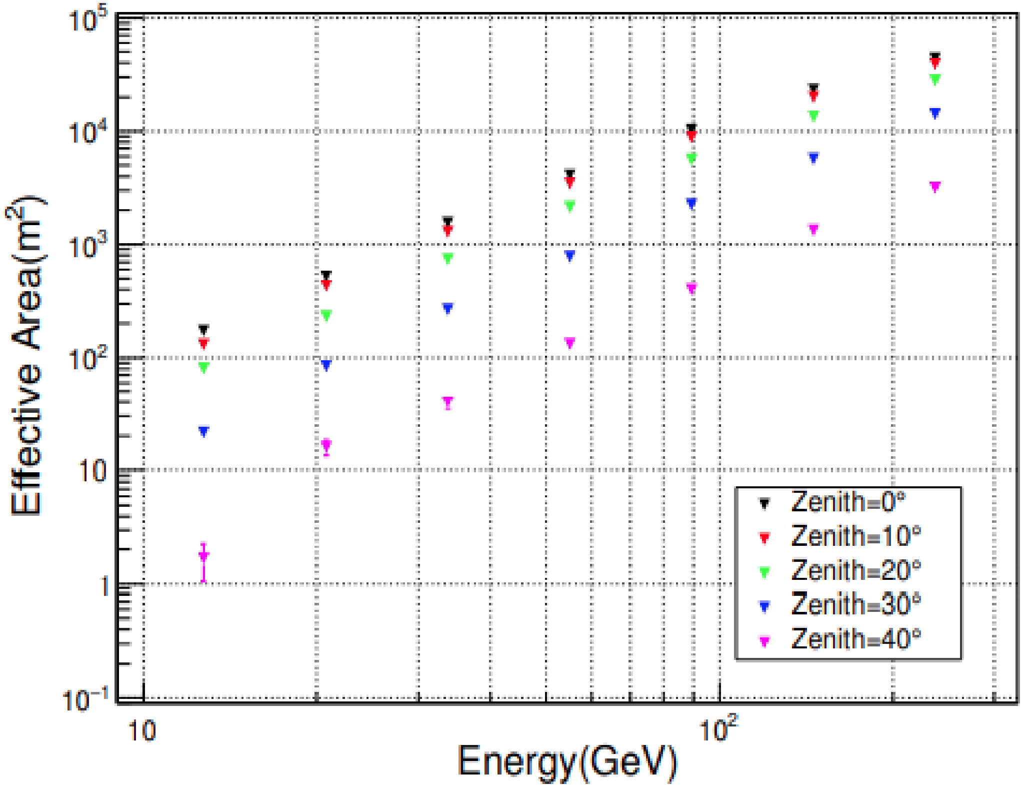
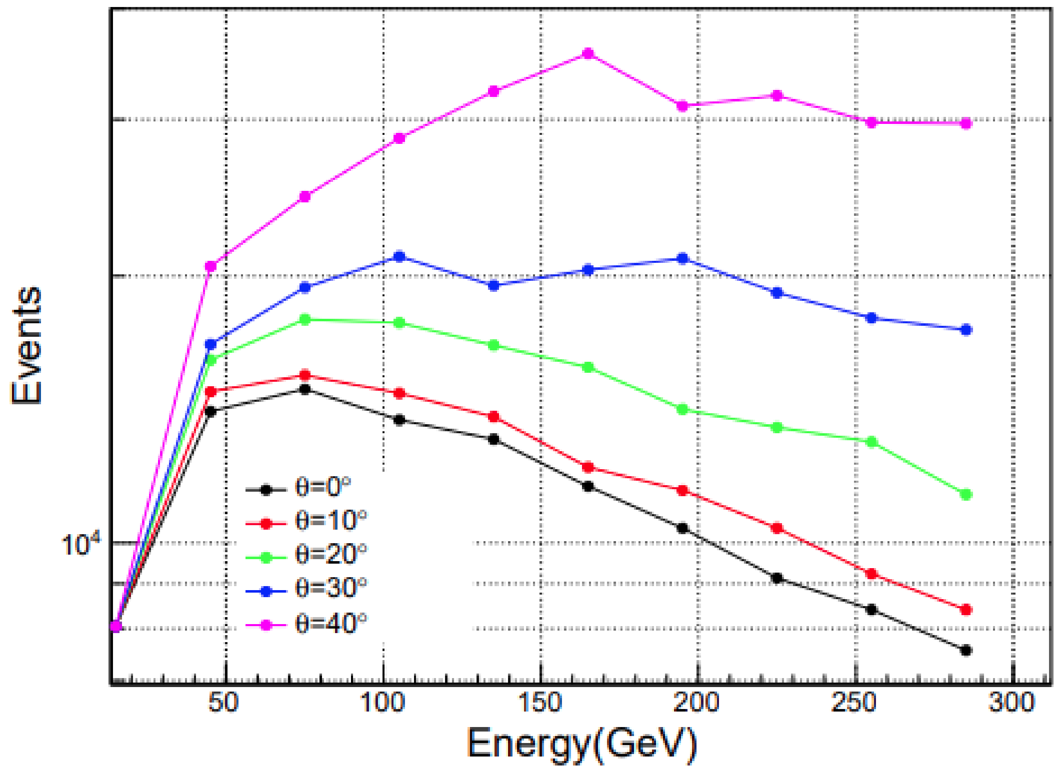


Effective Area(Twin=10ns，Nhit≥4)



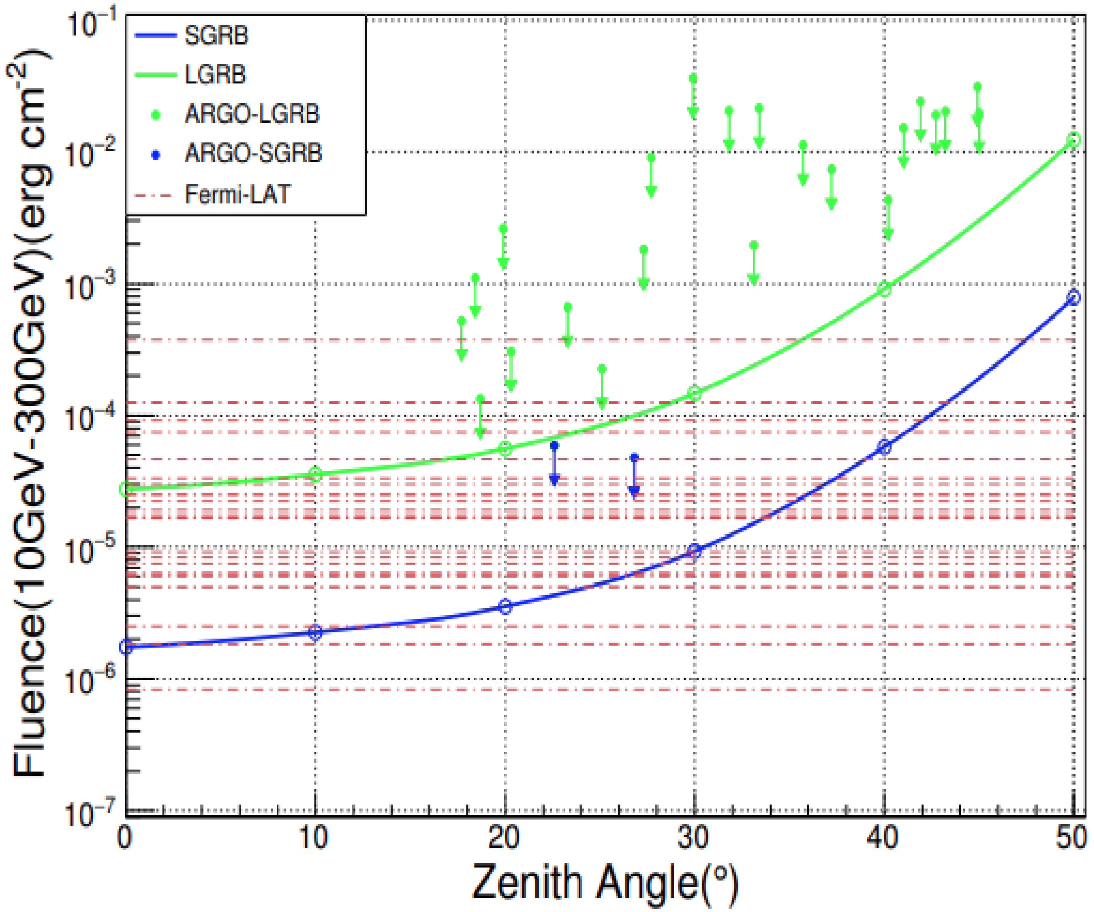
70GeV threshold @20°

Sensitivity of WCDA1

(1)Assuming duration of 50s(for LGRB and 0.2s for SGRB);

(2)For ARGO and Fermi-LAT normalizing energy to 10GeV-300GeV ;

(3)The full array will have an improvement of at least 4 times;



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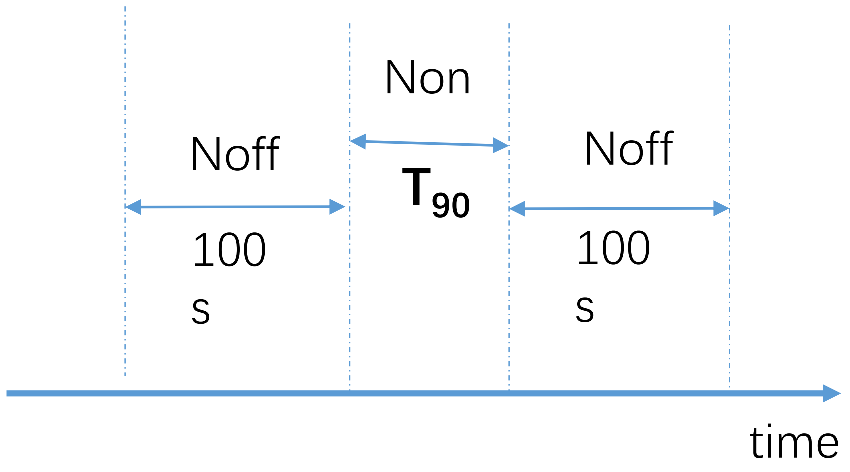
Search For HE from GRBs with WCDA1

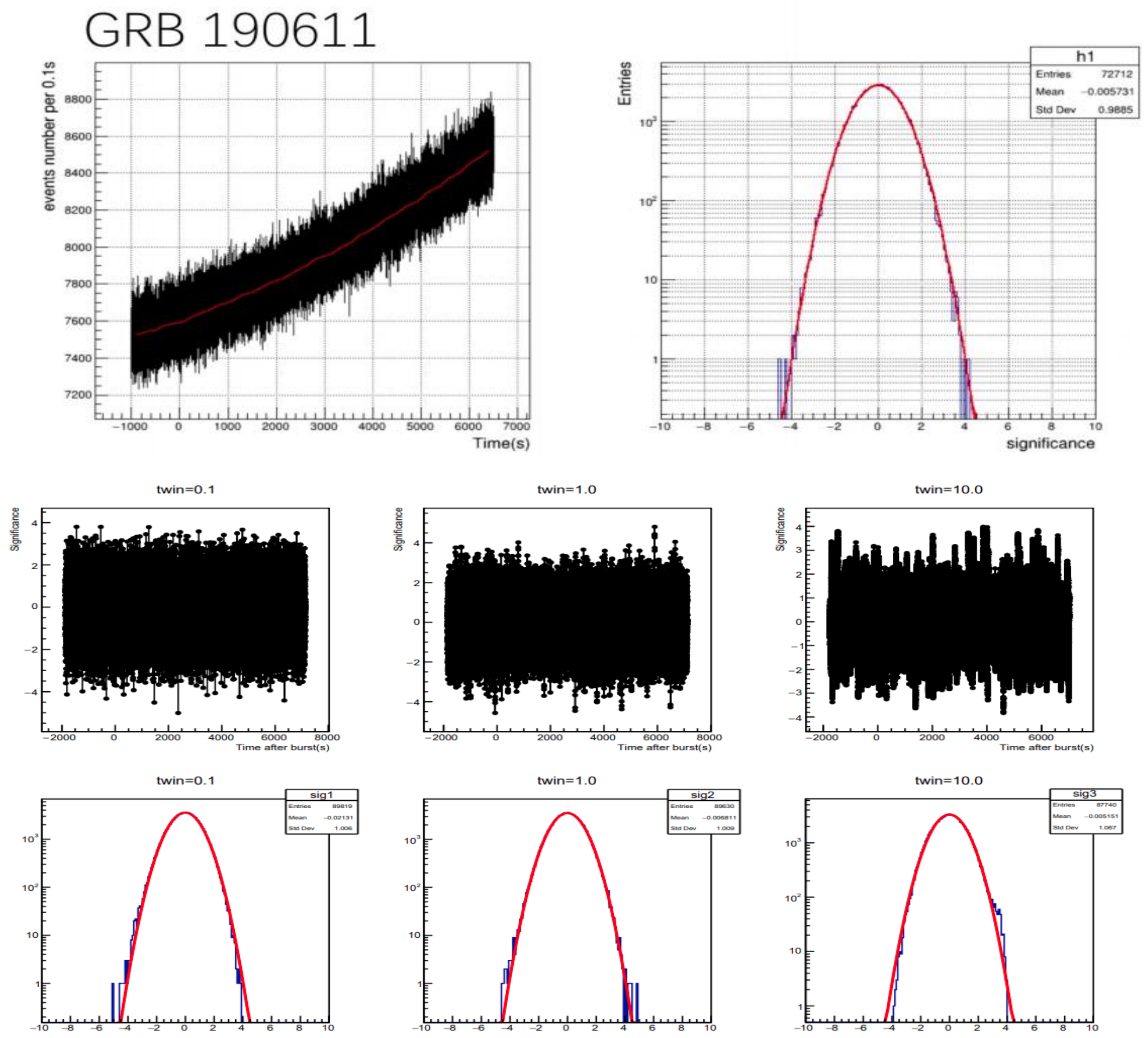
WCDA' GRB-Mode:

79 alerts from June, 2019, data selected from 10 of them;

100s before and 100s after T90 to do background estimation;

For non-detection in T90, a blind search with 0.1s, 1s and 10s are tried





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Results and discussion

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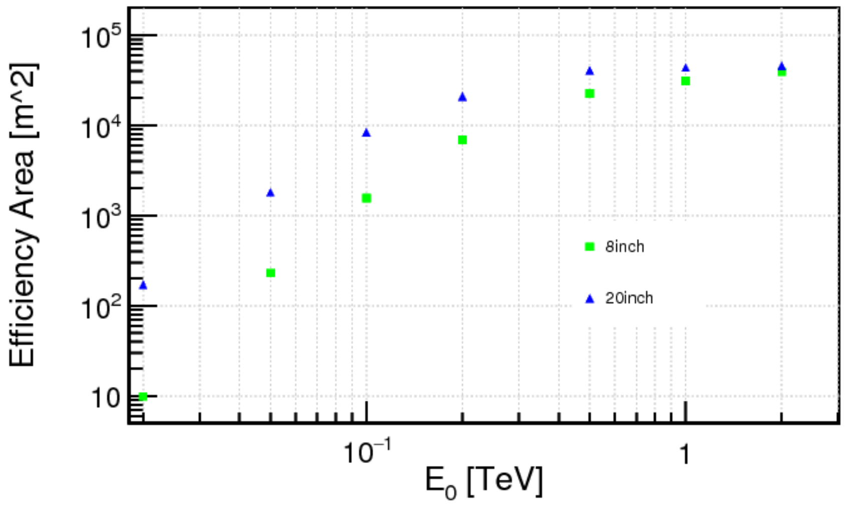
- ◆No significant excess were found in the 10 GRBs；
- ◆The Upper limits are higher than that of the GBM flux；
- ◆We still need to wait for bright GRBs with small redshift；



Name	$T_{90}(s)$	Zenith(°)	$F_{GBM}(erg/cm^2)$	$F_{upper}(erg/cm^2)$	Alert	redshift
190606	3.5	26.4	9.6E-7	3.4E-5	GBM	-
190611	37.8	47.9	1.1E-5	1.9E-3	GBM	-
190619	177.9	28.7	6.7E-6	1.5E-4	GBM	-
190620	51.7	25.2	5.1E-5	1.6E-4	GBM	-
190719	175.6	26.7	7.1E-6	3.9E-4	Swift	2.56
190930	185.8	38.1	1.5E-5	6.5E-4	GBM	-
191018	3.1	25.6	3.2E-7	2.1E-3	GBM	-
191125	77.3	42.6	4.9E-5	9.8E-4	GBM	-
191130	61.9	36.5	4.2E-6	3.3E-4	GBM	-
191203	0.8	46.3	1.0E-7	2.1E-4	GBM	-

99% CL upper limits for the 10 GRBs

- ◆By Upgrading 8 inch PMT to 20inch PMT, the energy threshold can be reduced further and the sensitivity can be improved a lot;
- ◆For GRBs with small distance like GRB 190829A , the traditional trigger mode is promising to catch them;

Thank you !