



**Search for VHE GRBs
with **triggerless** data from
full LHAASO-WCDA**

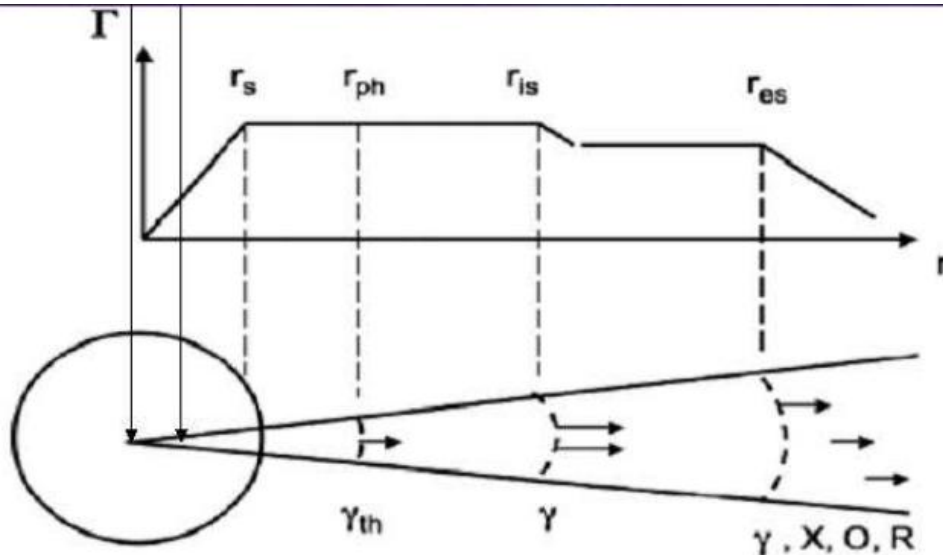
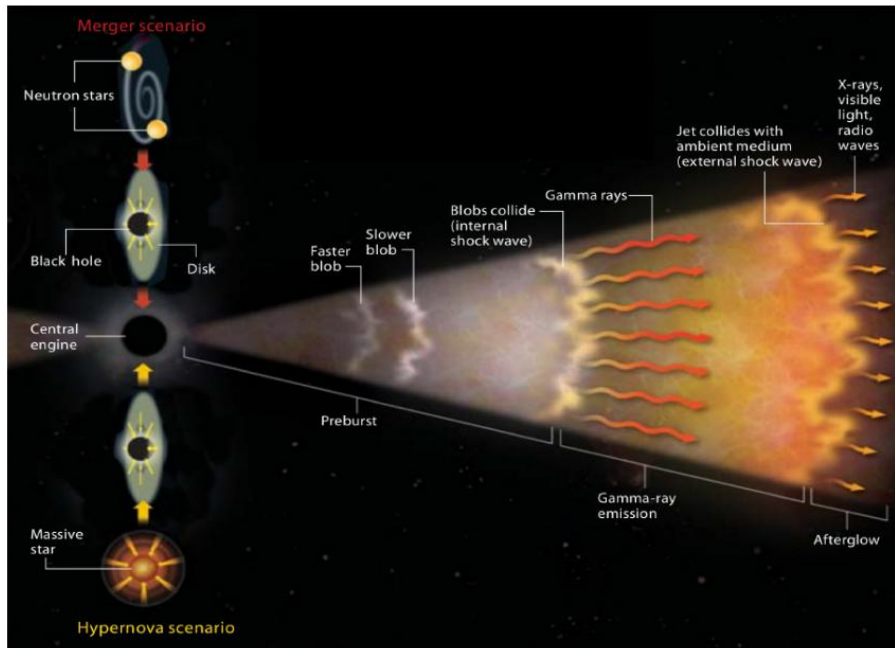
Yu-Hua Yao, Hua Yue, Han-Rong Wu,
Yi-Qing Guo, Hong-Bo Hu

2021/10/14

Outline

- Introduction
- LHAASO
- Data & Method
- Results
- Conclusion

GRB physics in the VHE band



- VHE afterglow:
 - radiation mechanisms
 - environment

- VHE prompt:
 - relativistic jets
 - bulk Lorentz factor
 - internal compactness
 - radiation mechanisms

- probe of many aspects:
 - LIV, EBL
 - UHECRS and neutrinos

Efforts on VHE GRBs

satelites experiments
 ➤ small effective area



ASy

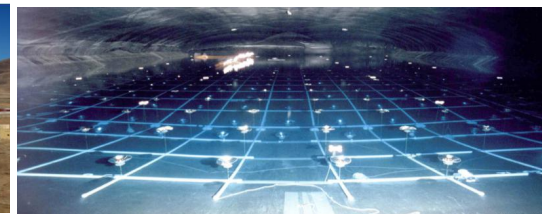
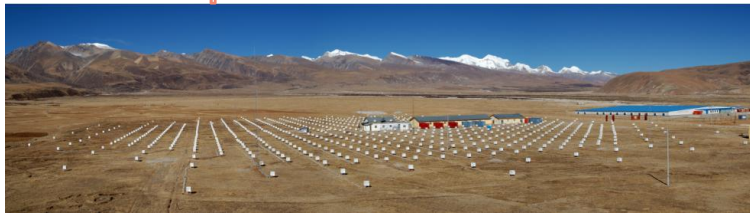
ARGO-YBJ

Milagro 及 Milagrito

Whipple

1990-2010

➤ low sensitivity



IACTs:

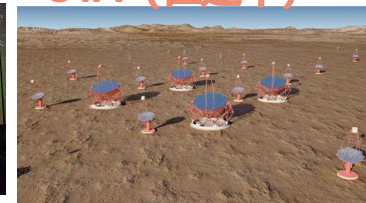
➤ high sensitivity
 ➤ small FOV
 ➤ low duty cycle

VERITAS

H.E.S.S.

MAGIC

CTA (在建中)

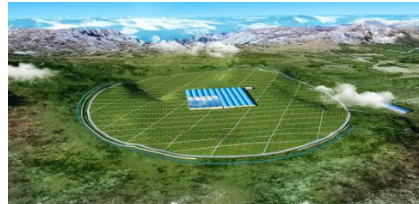


HAWC

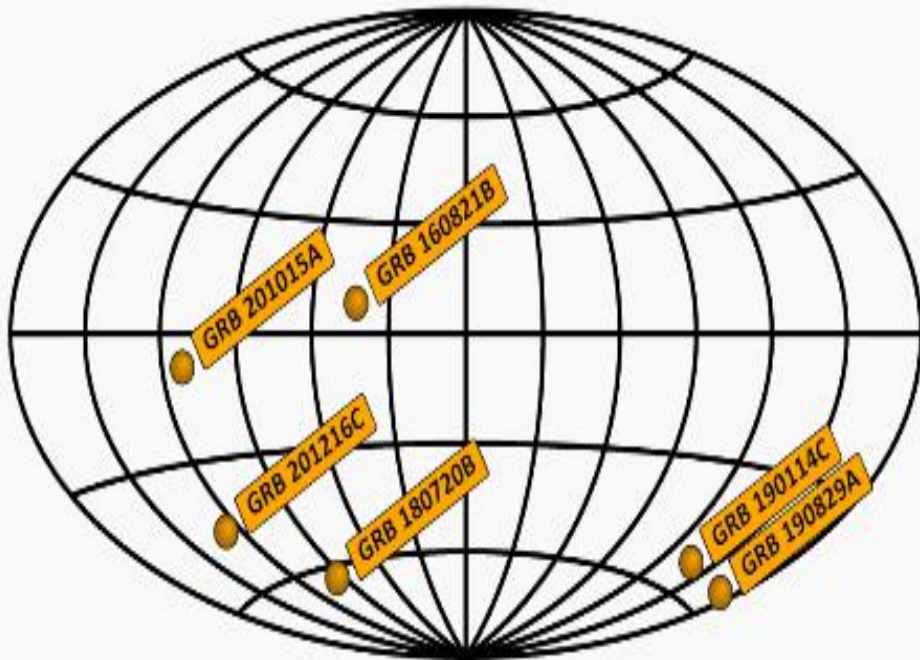
LHAASO

AS array:

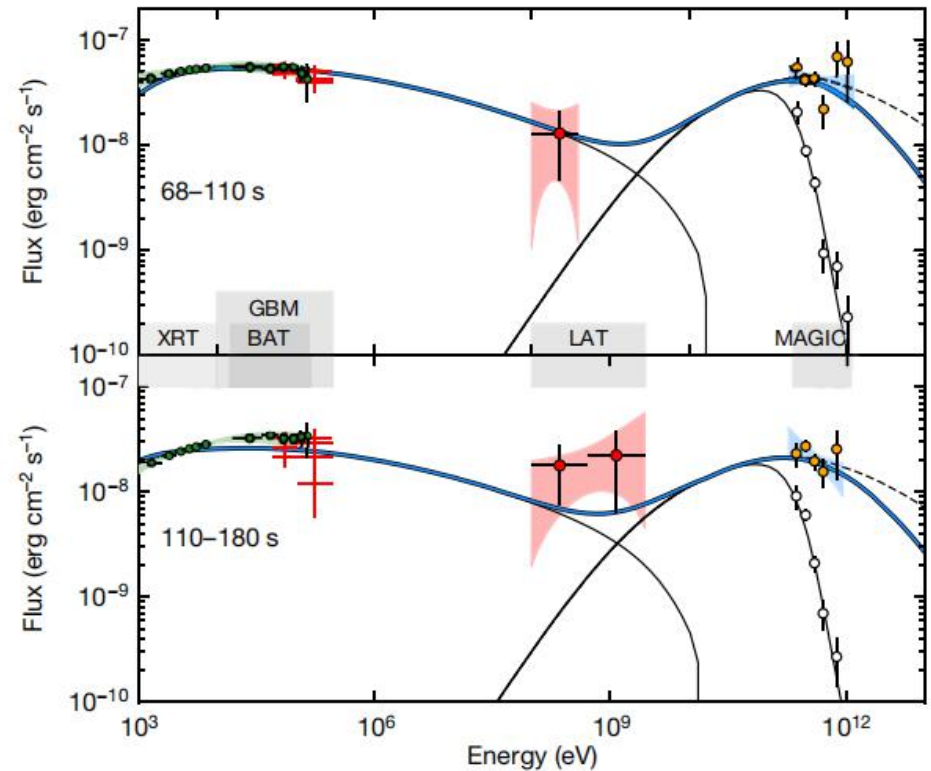
➤ high duty cycle
 ➤ large FOV



Detection of VHE afterglow

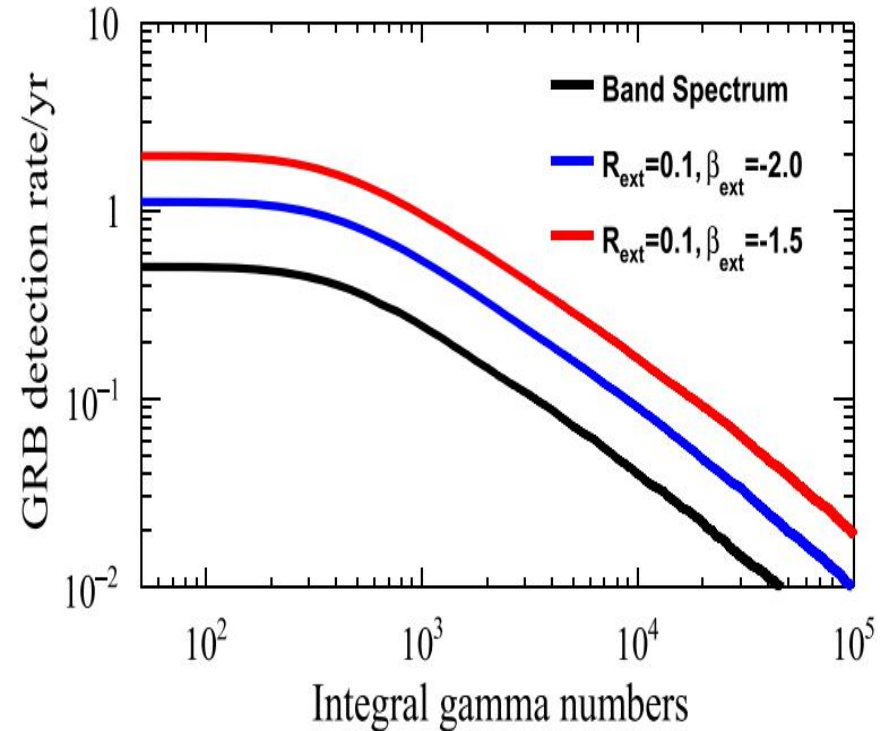
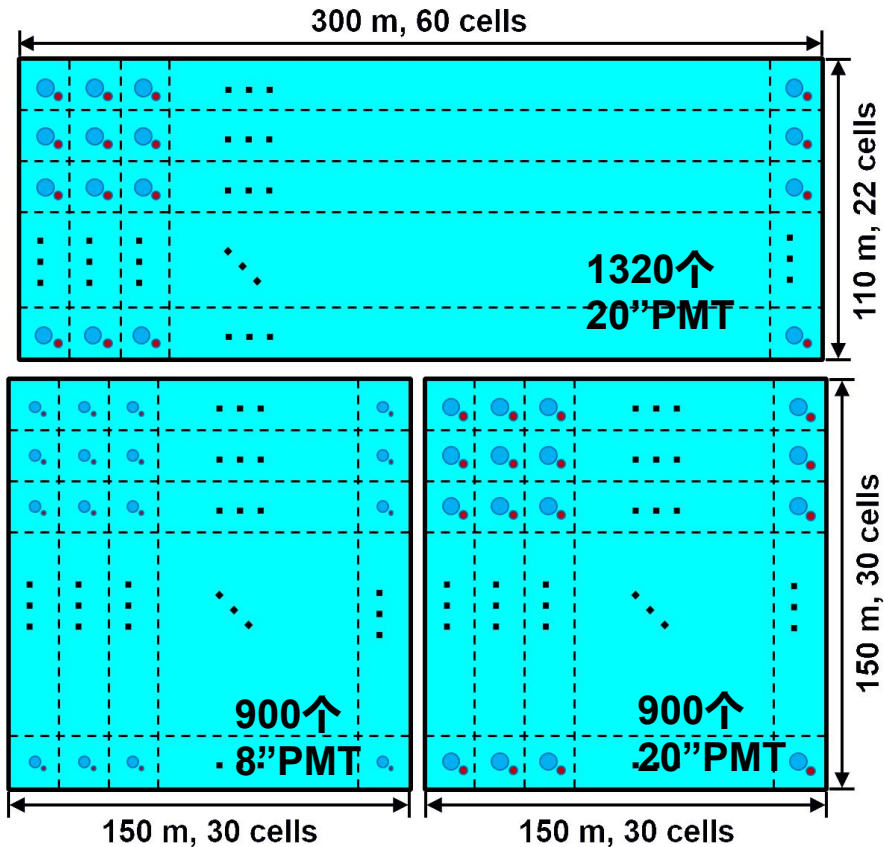


GRB 190114C @ MAGIC



- IACTs have opened a window of VHE observation for GRB afterglow
- Several GRBs have been detected with VHE afterglow emissions.

The LHAASO-WCDA observation



Kang M.M. et al, ApJ, 2021

- Large FOV, high duty cycle
- Low energy threshold: high altitude+20" PMT+GRB mode
- Observation expectation of **VHE prompt emission**: 0.5~2 GRB / year

Our previous analysis on **WCDA1**

GRB 190829A

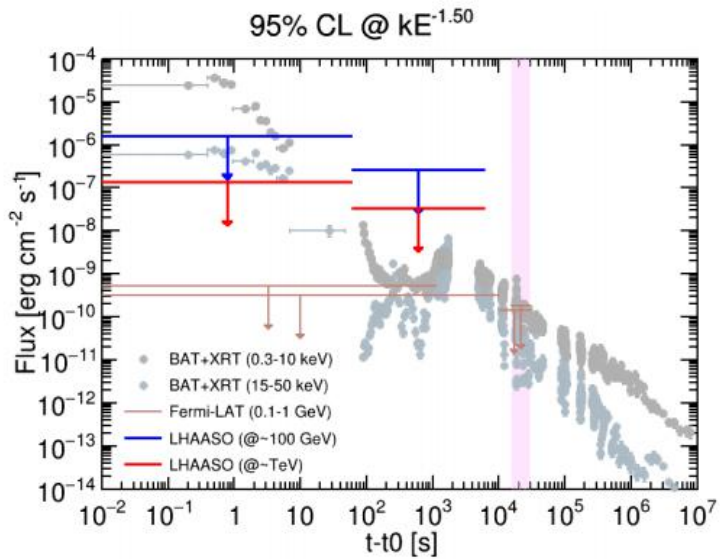


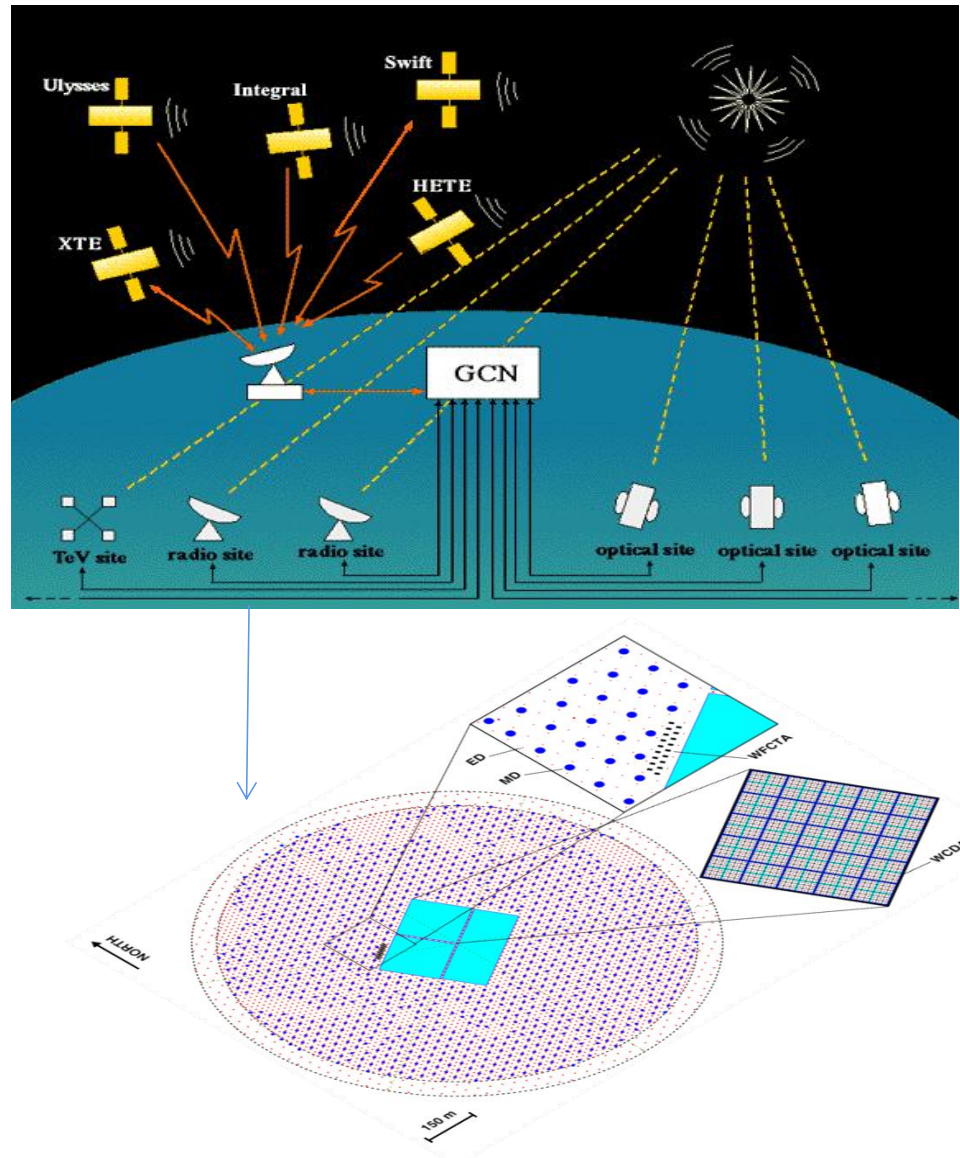
表 4.2 不同红移下 T_0 - T_{90} 和 T_{90} -6000s 时间范围内低能和高能流强上限列表

取数日期	天顶角 [°]	T_{90} [s]	$T_{90}, n_{\text{ftc}} < 60$		$T_{90}, n_{\text{ftc}} \geq 60$		0 - 6000s, $n_{\text{ftc}} < 60$		0 - 6000s, $n_{\text{ftc}} \geq 60$	
			F (z=0.1)	F (z=0.5)	F (z=0.1)	F (z=0.5)	F (z=0.1)	F (z=0.5)	F (z=0.1)	F (z=0.5)
			[erg cm ⁻²]	[erg cm ⁻²]	[erg cm ⁻²]	[erg cm ⁻²]	[erg cm ⁻²]	[erg cm ⁻²]	[erg cm ⁻²]	[erg cm ⁻²]
20190619	27.73	/	5.20E-05	1.23E-02	8.08E-07	1.91E-04	3.27E-04	7.71E-02	3.23E-06	7.63E-04
20190620	24.92	/	4.74E-04	1.08E-01	3.84E-06	8.74E-04	2.86E-03	6.52E-01	1.58E-05	3.59E-03
20190703	4.48	/	2.36E-04	1.18E-02	1.85E-06	9.18E-05	1.08E-03	5.38E-02	1.08E-05	5.39E-04
20191004	31.43	/	1.20E-03	5.49E-01	7.87E-06	3.60E-03	4.53E-03	2.07E+00	3.75E-05	1.72E-02
GRB191011A	31.33	/	1.09E-03	4.98E-01	4.15E-06	1.90E-03	5.46E-03	2.50E+00	4.38E-05	2.00E-02
GRB191017C	36.1	/	1.95E-03	1.57E+00	1.17E-05	9.42E-03	2.05E-02	1.65E+01	9.96E-05	8.01E-02
GRB191101B	47.09	/	1.14E-03	9.13E-01	1.67E-06	1.35E-03	9.42E-03	7.57E+00	7.20E-05	5.79E-02
GRB191115A	29.23	/	1.17E-03	5.16E-01	8.11E-06	3.59E-03	4.81E-03	2.13E+00	2.10E-05	9.29E-03
GRB191122A	25.29	/	3.14E-04	7.16E-02	3.45E-06	7.87E-04	3.25E-03	7.41E-01	2.44E-05	5.55E-03
GRB191125A	33.42	/	7.70E-04	3.52E-01	3.58E-06	1.64E-03	3.89E-03	1.78E+00	1.89E-05	8.65E-03
GRB200903C	34.93	/	5.25E-03	4.22E+00	2.41E-06	1.94E-03	2.89E-02	2.32E+01	5.62E-06	4.52E-03
GRB200906A	39.13	67.3	1.20E-02	1.59E+01	/	/	5.78E-02	7.67E+01	2.15E-05	2.85E-02
20200913	38.93	/	6.27E-03	8.32E+00	4.00E-06	5.31E-03	9.07E-02	1.20E+02	2.00E-05	2.66E-02
20200915	40.9	/	7.35E-03	9.87E+00	/	/	6.34E-02	8.53E+01	2.80E-05	3.77E-02
GRB200916A	35.49	76	1.72E-03	1.38E+00	/	/	4.71E-03	3.78E+00	8.20E-07	6.59E-04
GRB200919A	36.39	/	8.05E-03	6.47E+00	2.54E-06	2.04E-03	3.73E-02	3.00E+01	2.37E-05	1.90E-02
GRB201021A	31.73	/	3.15E-03	1.44E+00	1.41E-06	6.45E-04	1.10E-02	5.03E+00	1.32E-05	6.02E-03
20201030	26.48	/	1.26E-03	2.98E-01	7.70E-07	1.82E-04	2.24E-02	5.28E+00	1.03E-05	2.42E-03
GRB201031B	29.06	/	2.74E-03	1.21E+00	2.56E-06	1.13E-03	1.80E-02	7.97E+00	8.42E-06	3.72E-03
GRB201116A	34.09	/	1.50E-03	6.88E-01	1.59E-06	7.27E-04	1.23E-02	5.65E+00	4.77E-06	2.18E-03
20201119	37.75	/	4.23E-03	3.47E+00	3.03E-06	2.48E-03	2.28E-02	1.87E+01	6.06E-06	4.96E-03
20201123	41.47	/	6.90E-03	9.27E+00	/	/	6.87E-02	9.23E+01	4.05E-05	5.45E-02
GRB201128A	36.47	/	1.05E-02	8.47E+00	3.39E-06	2.73E-03	5.00E-02	4.02E+01	5.93E-06	4.77E-03
20201213	35.91	/	6.50E-03	8.62E+00	8.17E-06	1.08E-02	1.34E-01	1.78E+02	1.36E-05	1.81E-02

➤ GRB 190829A

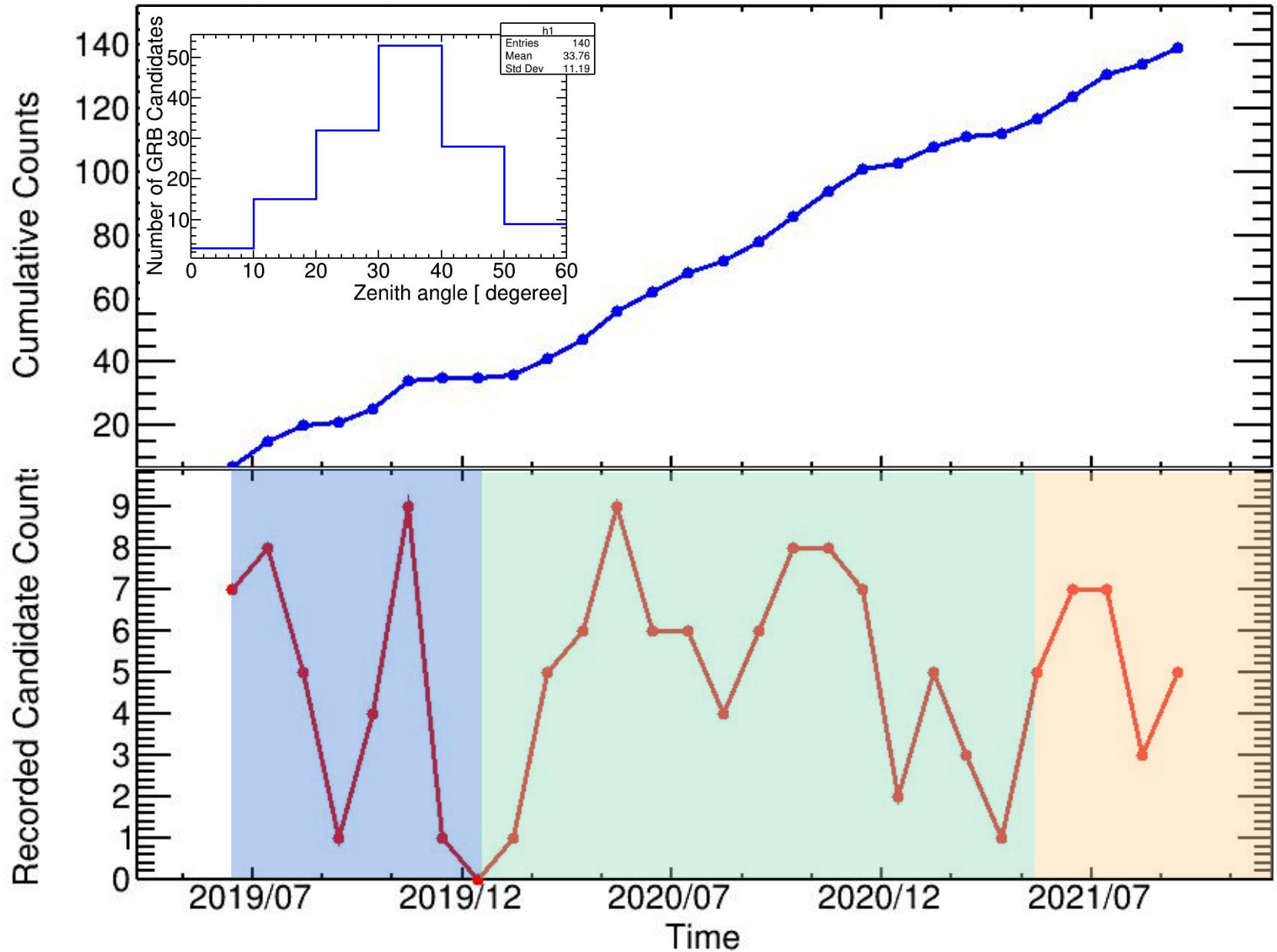
➤ Flux upper-limits of other follow-ups

LHAASO-WCDA GRB follow up



- LHAASO is able to react to GRB alerts thanks to a dedicated alert system receiving the external trigger provided by the GRB GCN
- Alerts from **Fermi and swift** experiments
- **Triggerless Data: hits information** on each PMT are stored between $T_0 - 0.5h$ and $T_0 + 2h$

Summary of observations (to sept. 2021)



Analysis Method

□ Hit--> Event

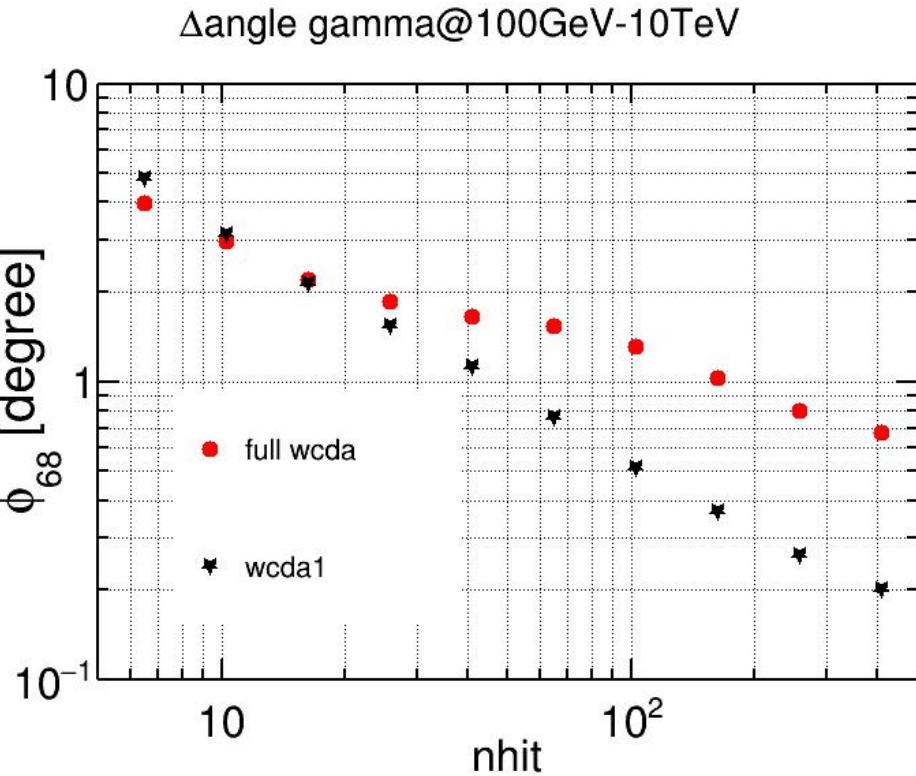
- Twin+Rwin: find seeds of events
- δT : determine an event

□ Event reconstruction

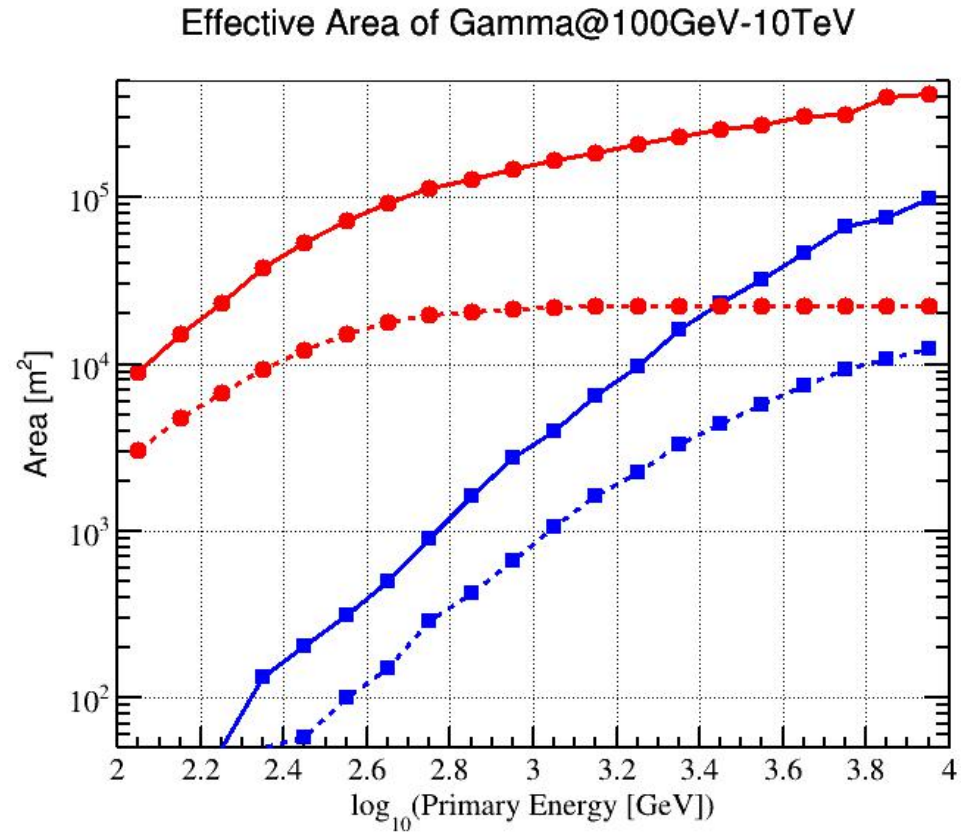
Pars	wcda1	full wcda
Twin	10ns	10ns
Rwin	20m	35m
δT	20ns	5ns

Performance

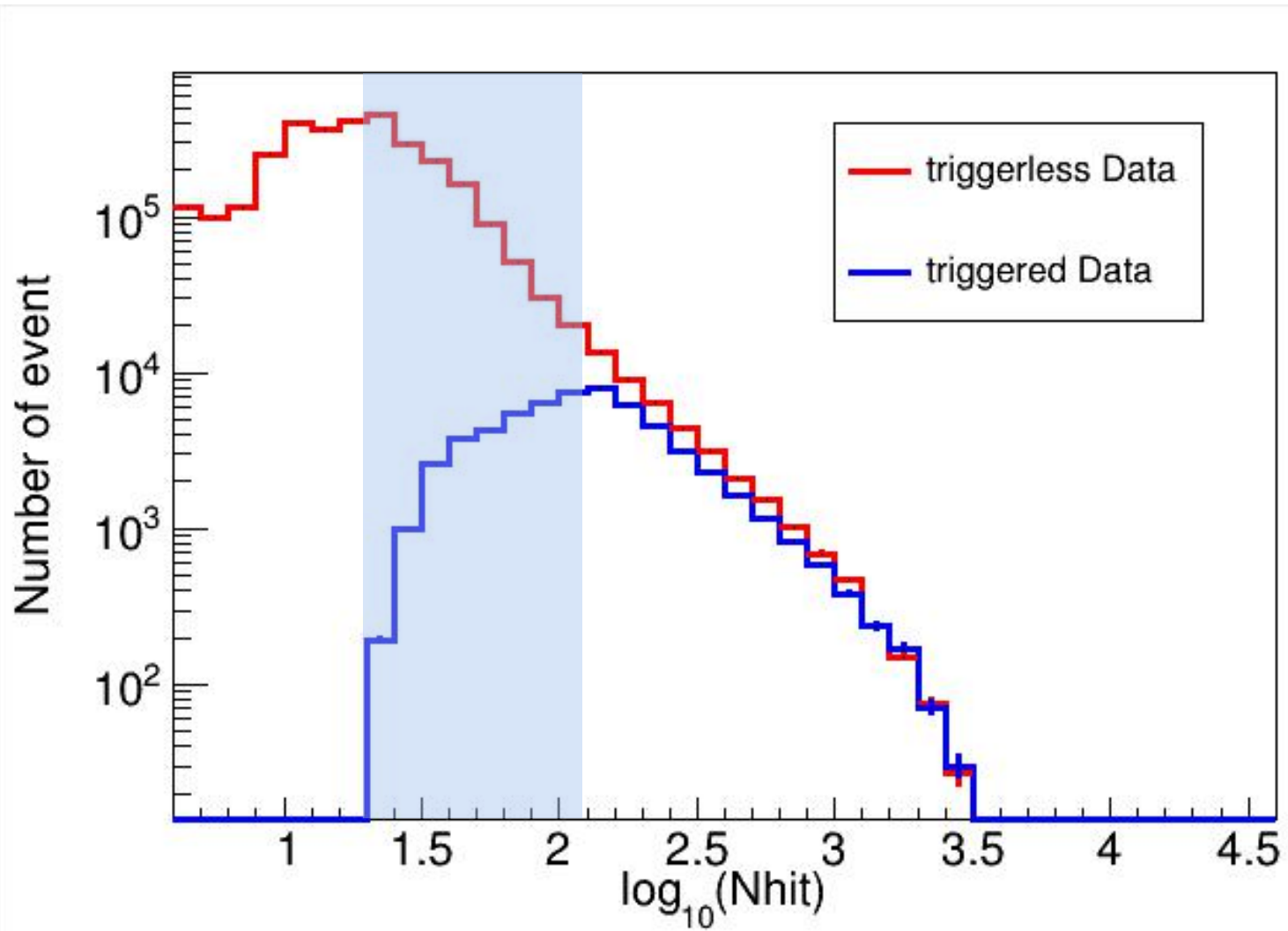
□ Angular resolution



□ Effective area

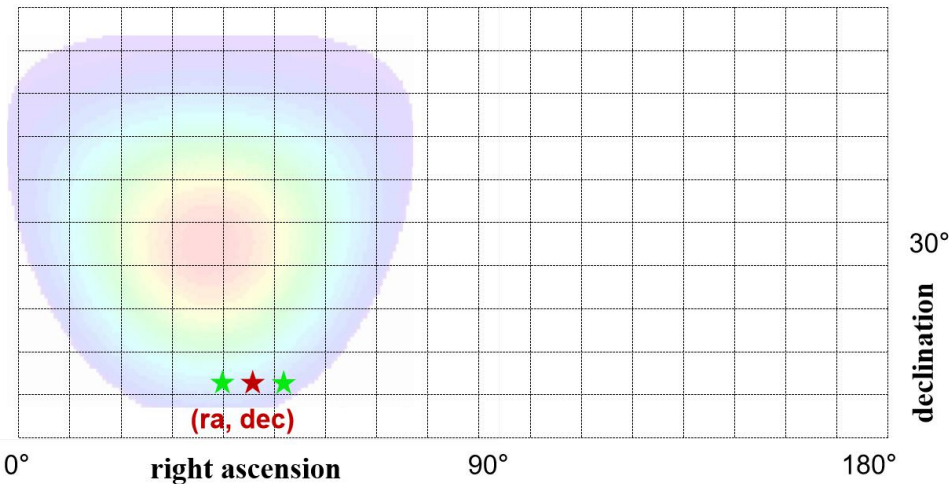


Data: compared with reduced data



➤nhit: 20 - 100

On-off and significance



□ 10 off sources

➤ estimate the background

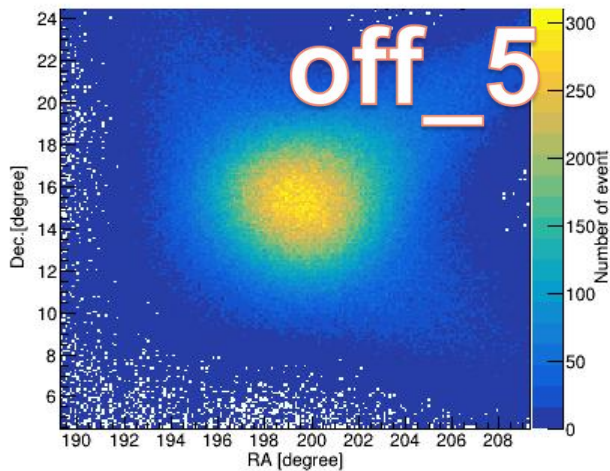
□ Significance

➤ Li-Ma formula

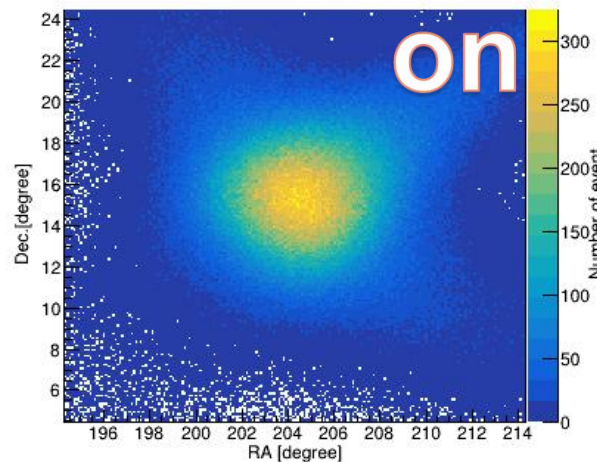
□ Aimed **at the prompt phase**

➤ T90/100s

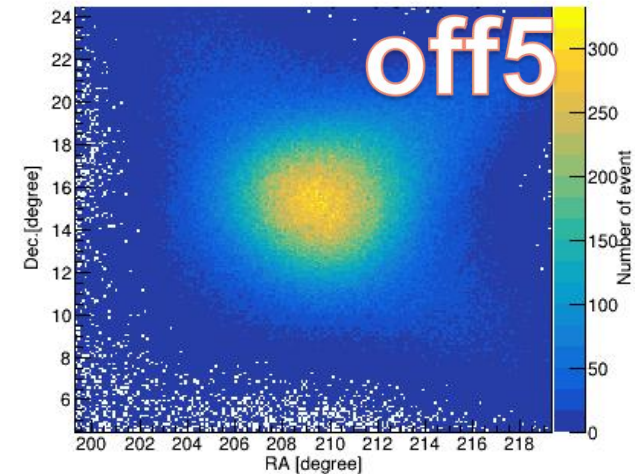
20210610_count_nfilt_20_50_hoff_5



20210610_count_nfilt_20_50_hon

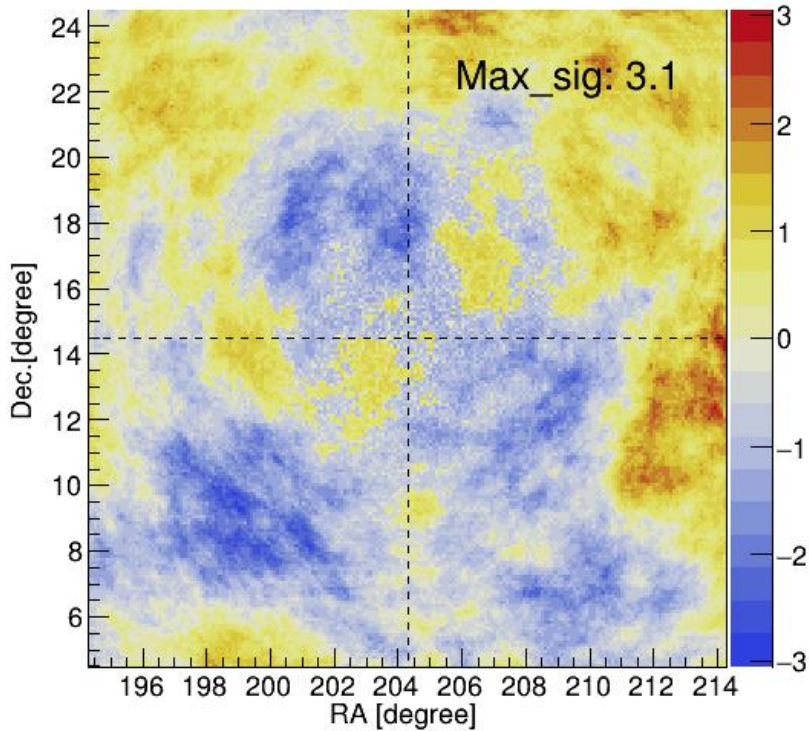


20210610_count_nfilt_20_50_hoff5



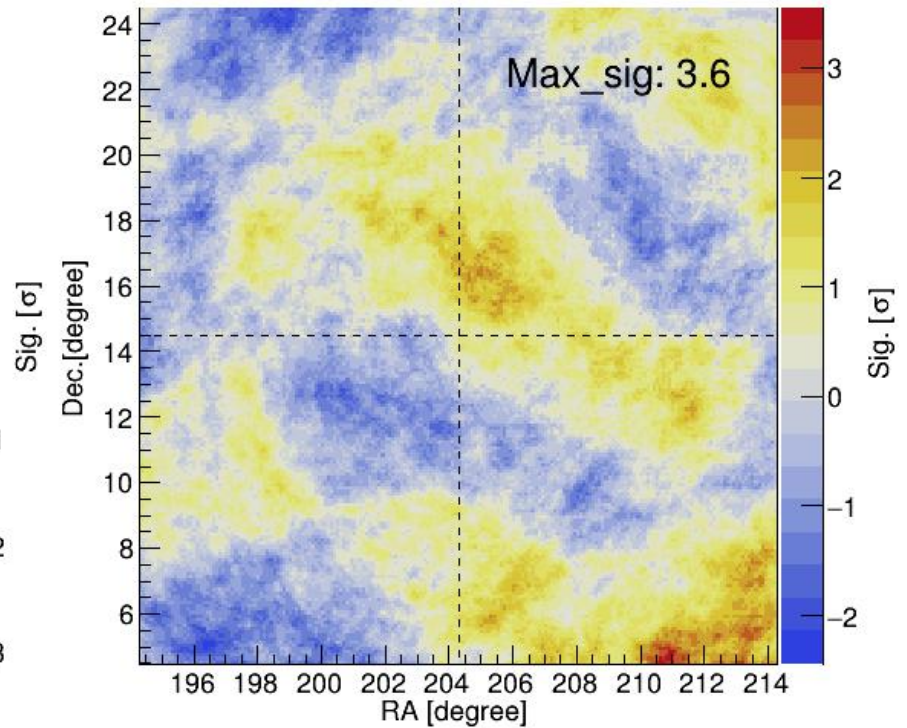
Sky Map of 20210610

20210610_smooth_3.0_nfilt_20_50



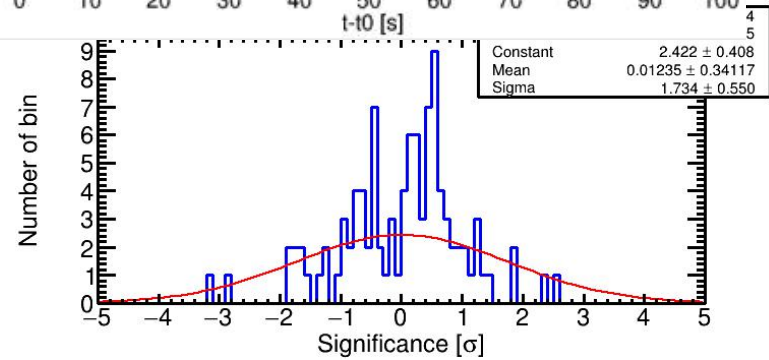
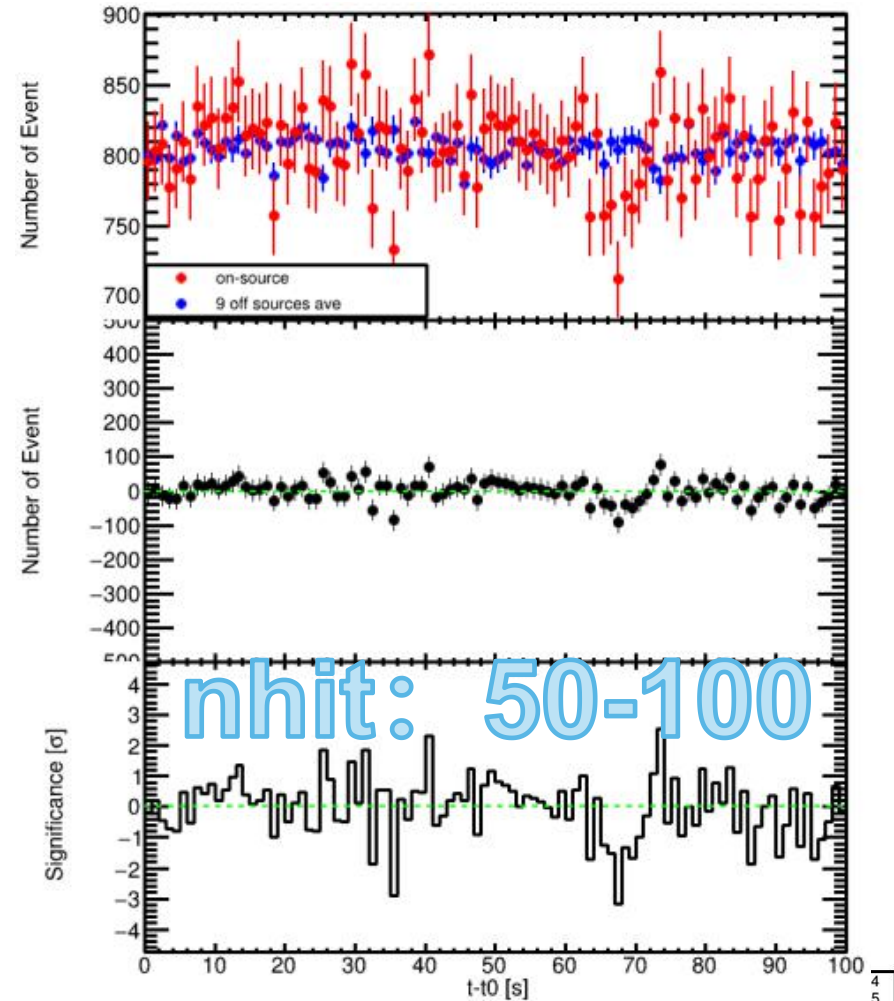
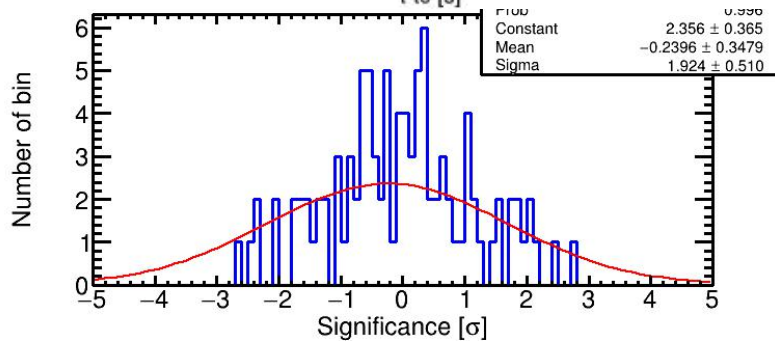
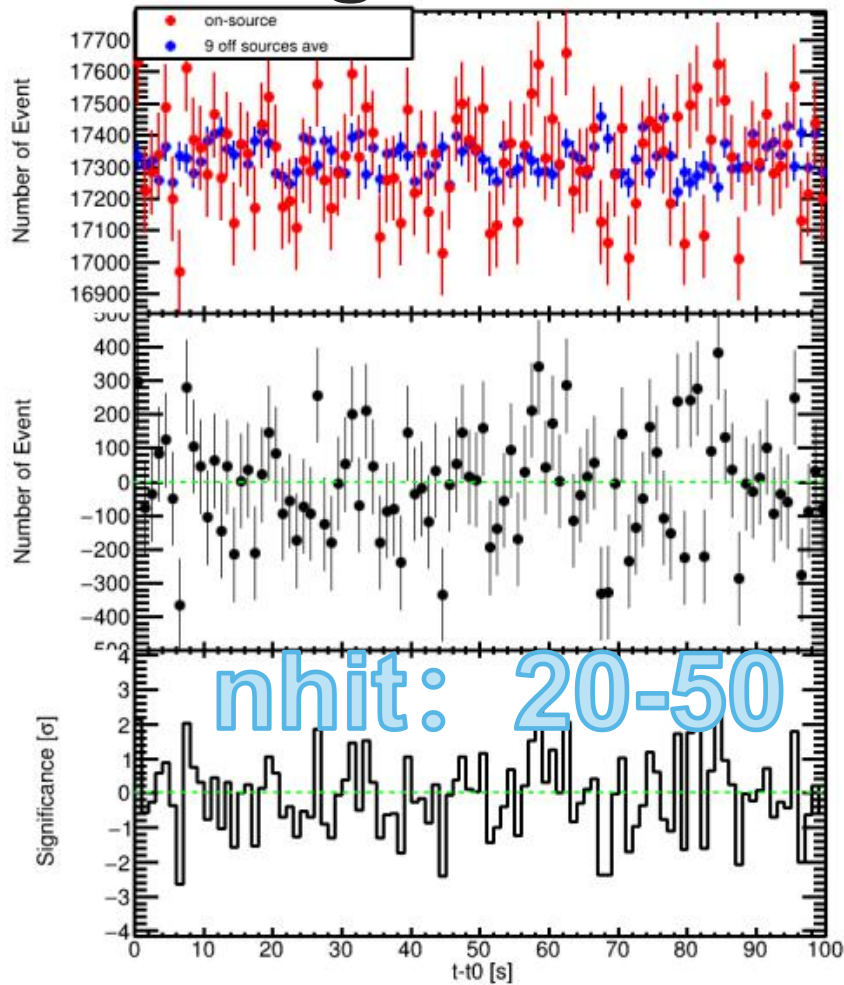
nhit: 20-50

20210610_smooth_3.0_nfilt_50_100



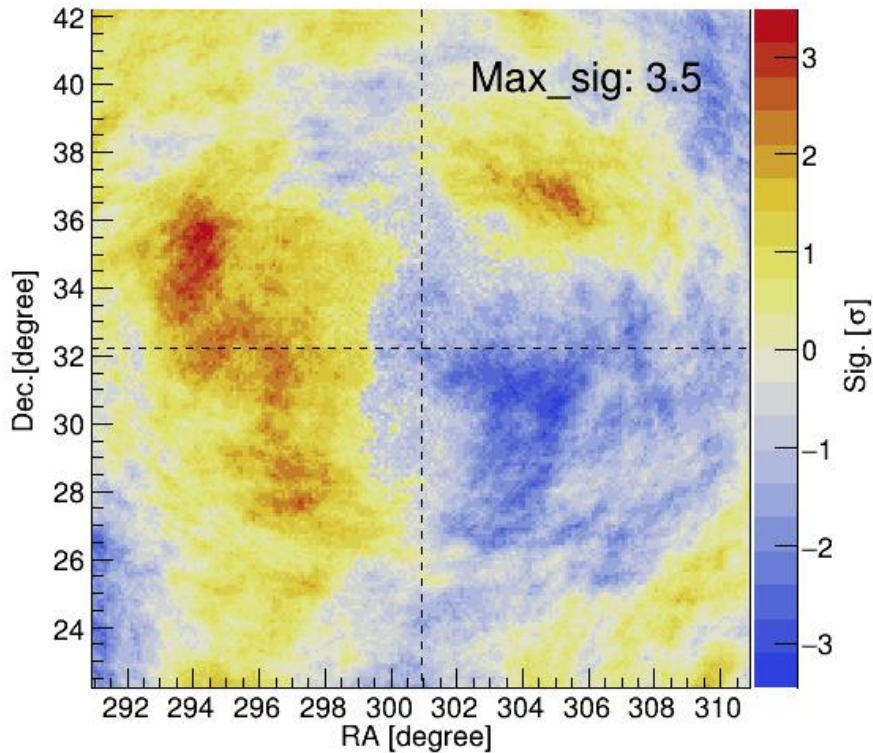
nhit: 50-100

Light Curve of 20210610



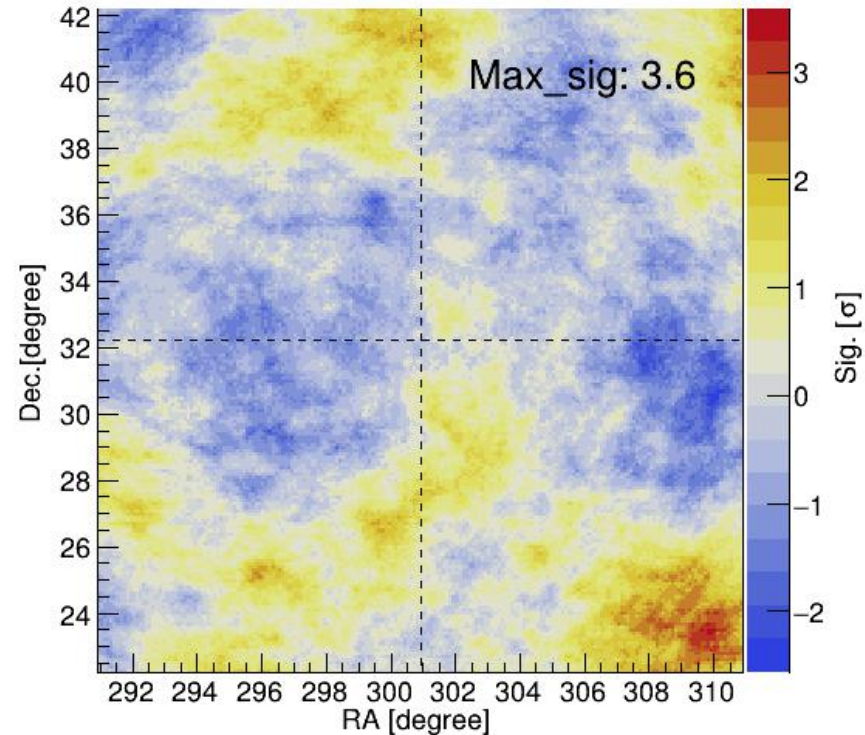
Sky Map of 20210707

20210707_smooth_3.0_nfilt_20_50



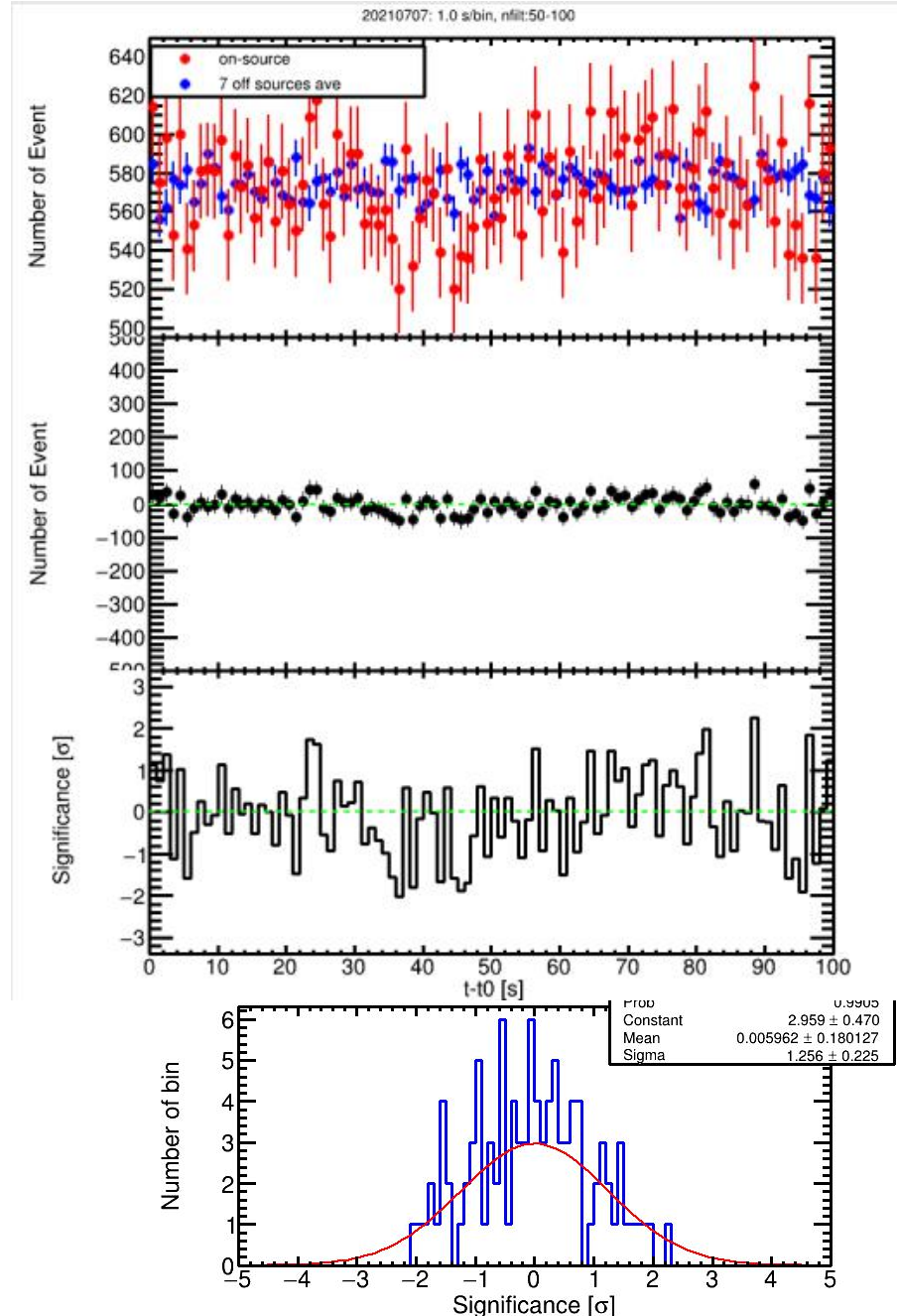
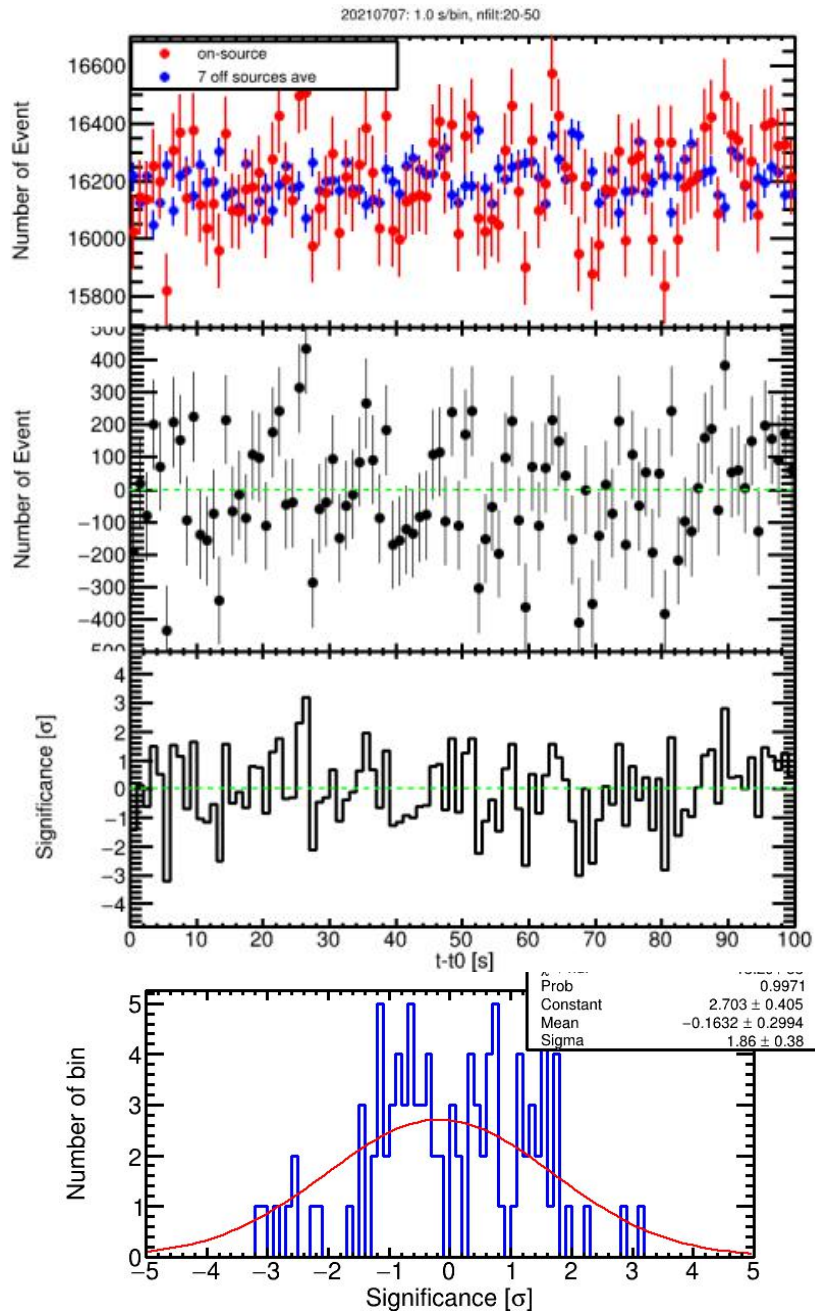
$nhit$: 20-50

20210707_smooth_3.0_nfilt_50_100



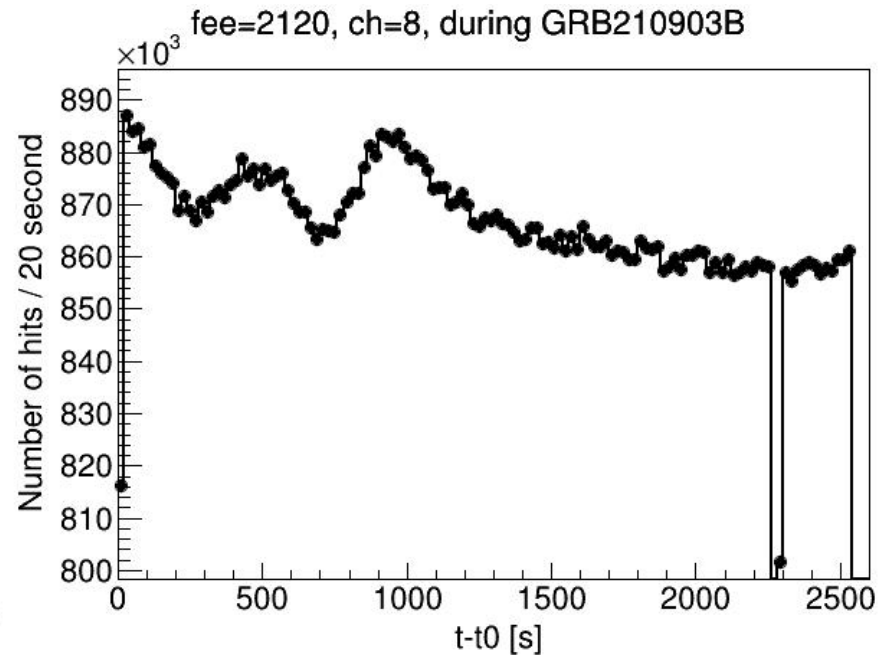
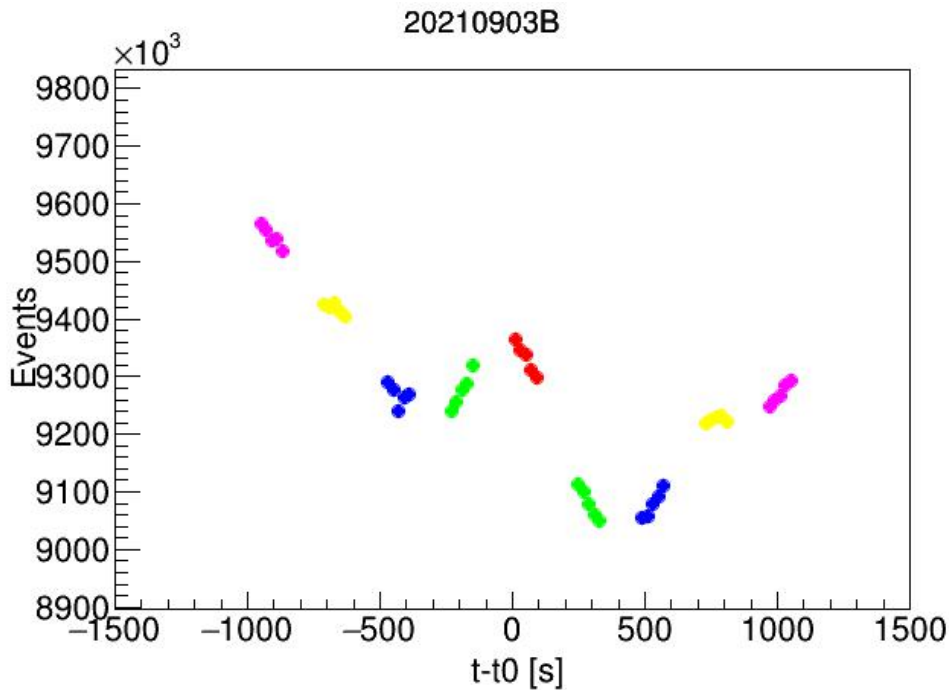
$nhit$: 50-100

Light Curve of 20210707



Some current research problems

drwxr-xr-x	1	lhaasospade	lhaaso	509G	Mar	9	2021	0308
drwxr-xr-x	1	lhaasospade	lhaaso	133G	Mar	25	2021	0324
drwxr-xr-x	1	lhaasospade	lhaaso	7.3T	Apr	26	09:50	0420
drwxr-xr-x	1	lhaasospade	lhaaso	7.7T	Aug	27	03:05	0524

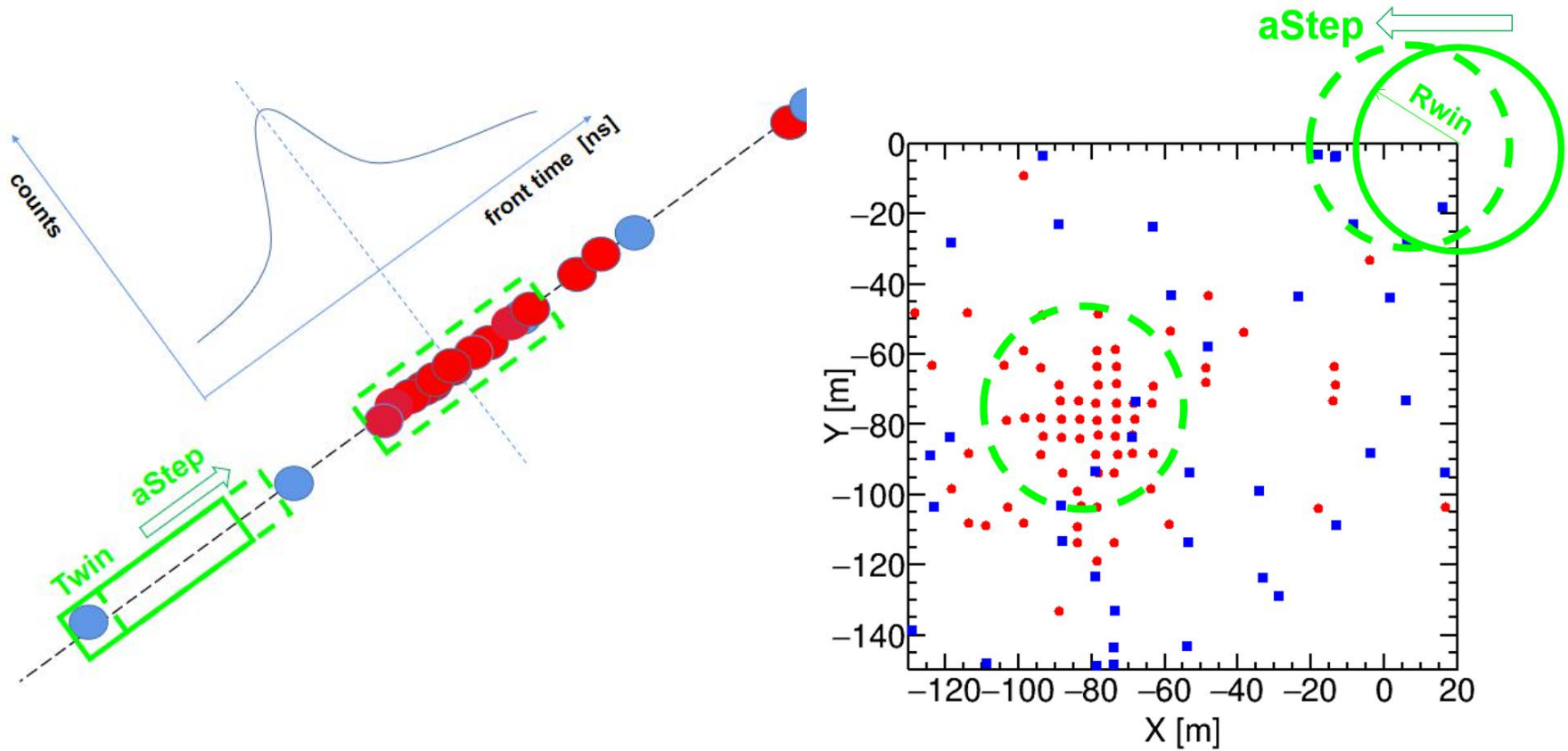


Conclusions . . . and the future

- **A full analysis package of triggerless data from full WCDA has been finished.** More detailed analysis are on the progress.
- We searched for **VHE prompt emission of 25 GRBs** and presented the preliminary results of 2 GRB candidates
- The performed analysis has shown a light curve and map distribution from the different GRB data sets compatible with the distribution expected from background hadronic events, **implying no significant VHE gamma-ray signal** for any of the observed GRB over the duration of LHAASO follow-up.
- **Additional efforts to improve the analysis in the very low energy band are being investigated.**

Backup slides

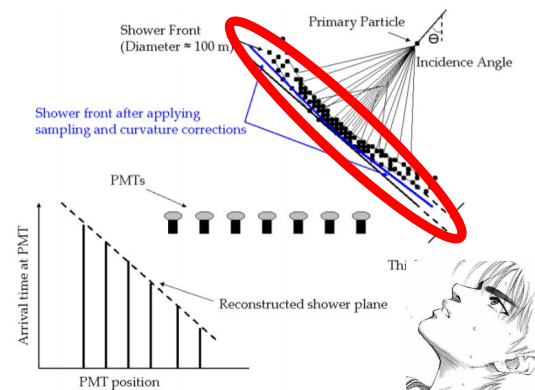
How to “see” gamma rays from GRB



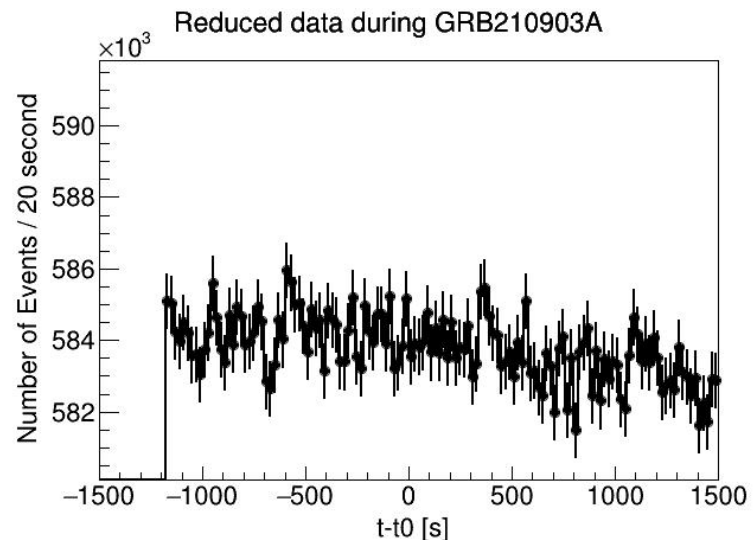
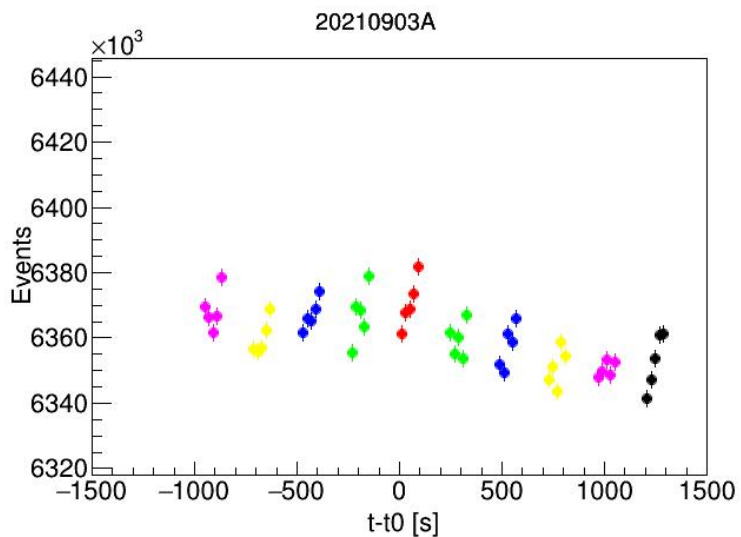
□ Hit--> Event

- $T_{win}+R_{win}$: find seeds of events
- δT : determine an event

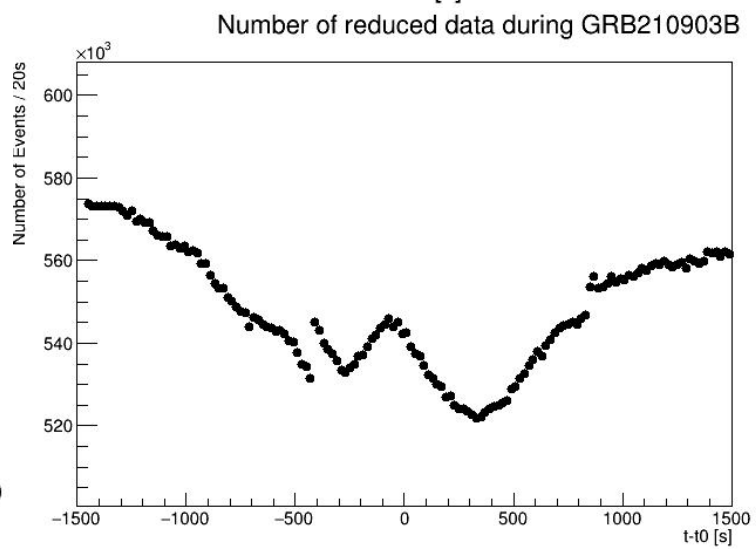
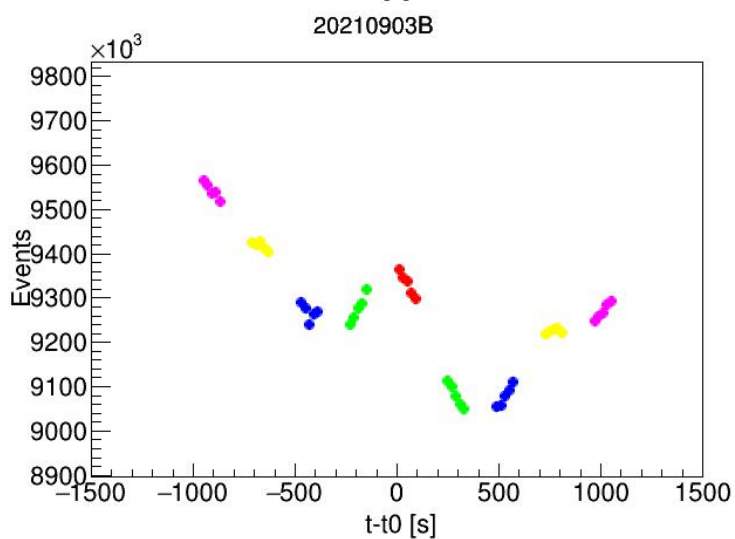
□ Event reconstruction



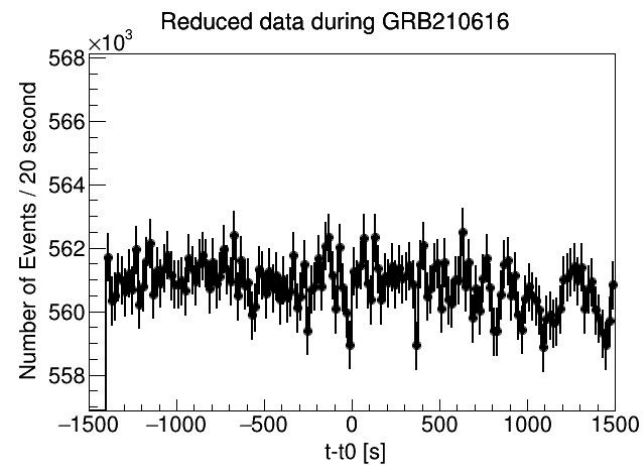
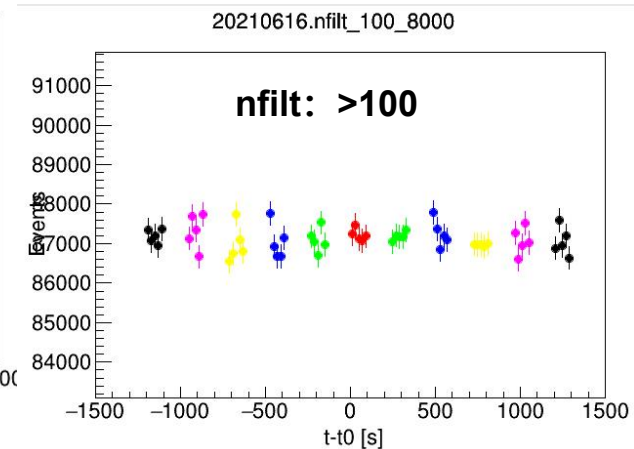
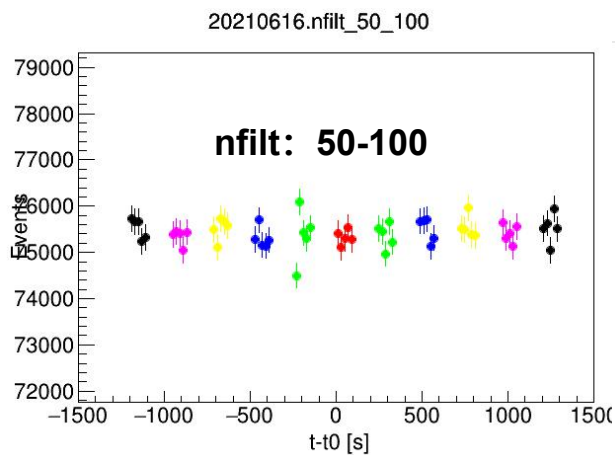
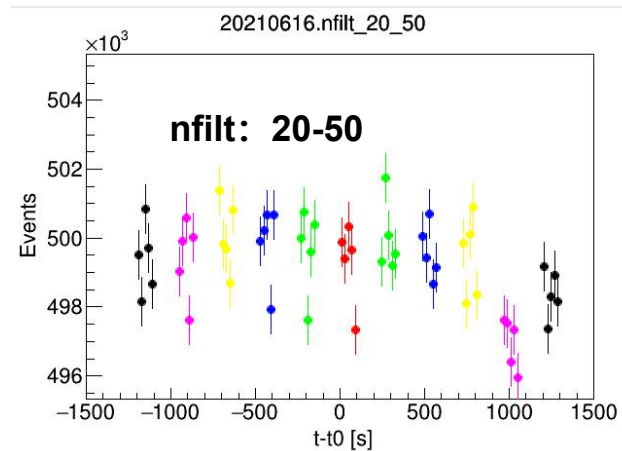
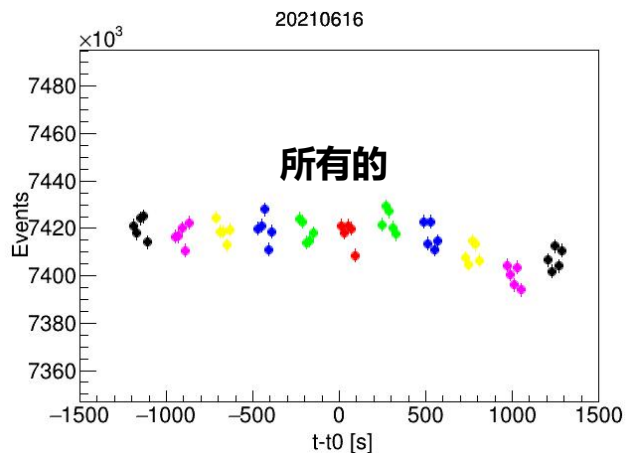
20210903A



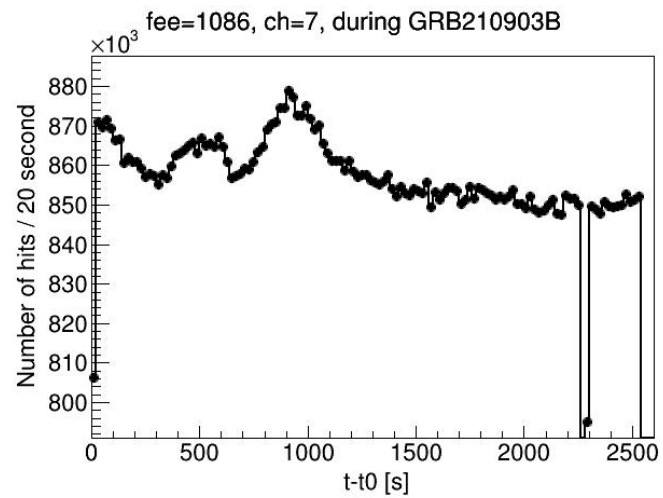
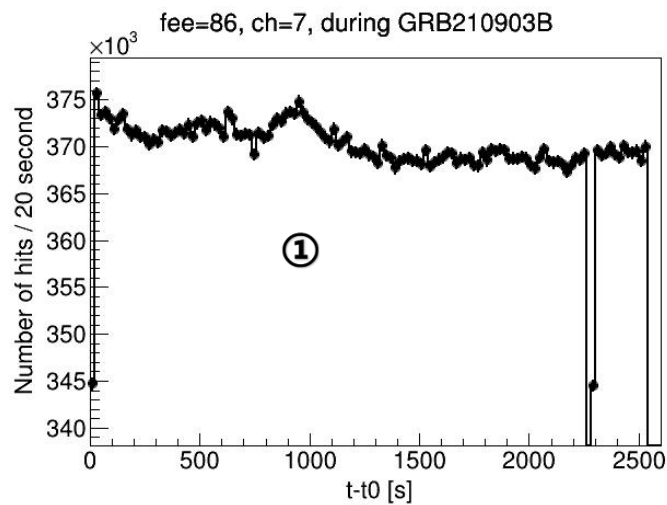
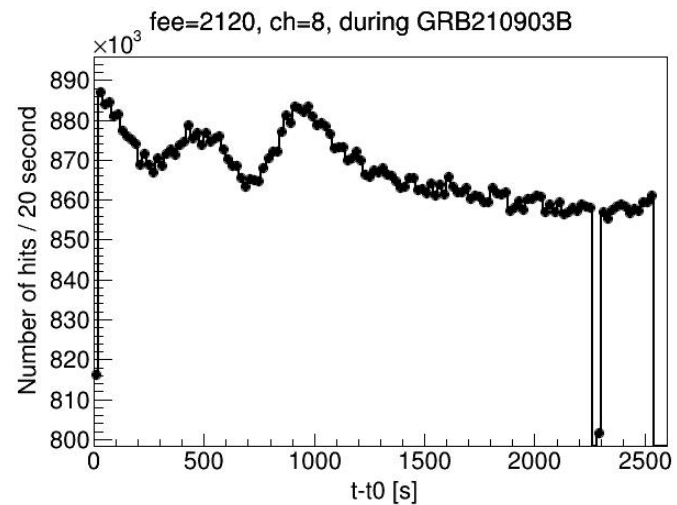
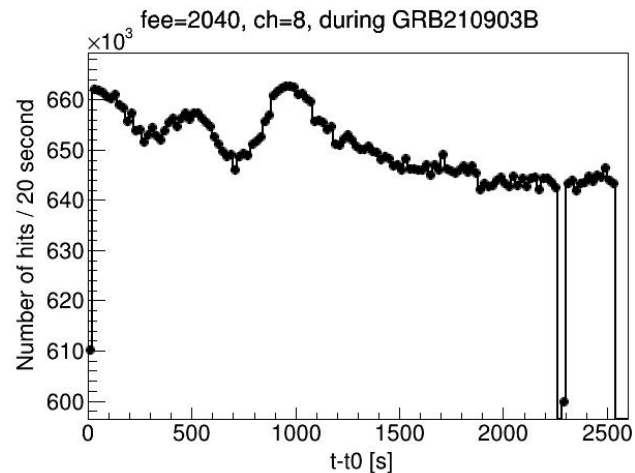
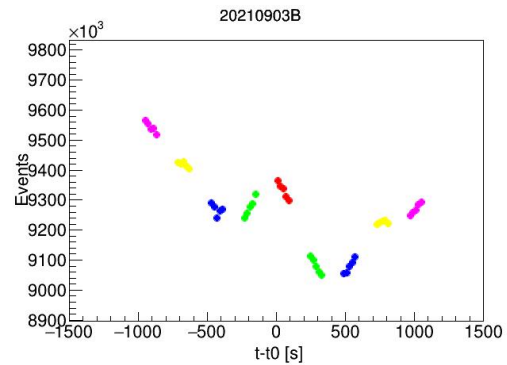
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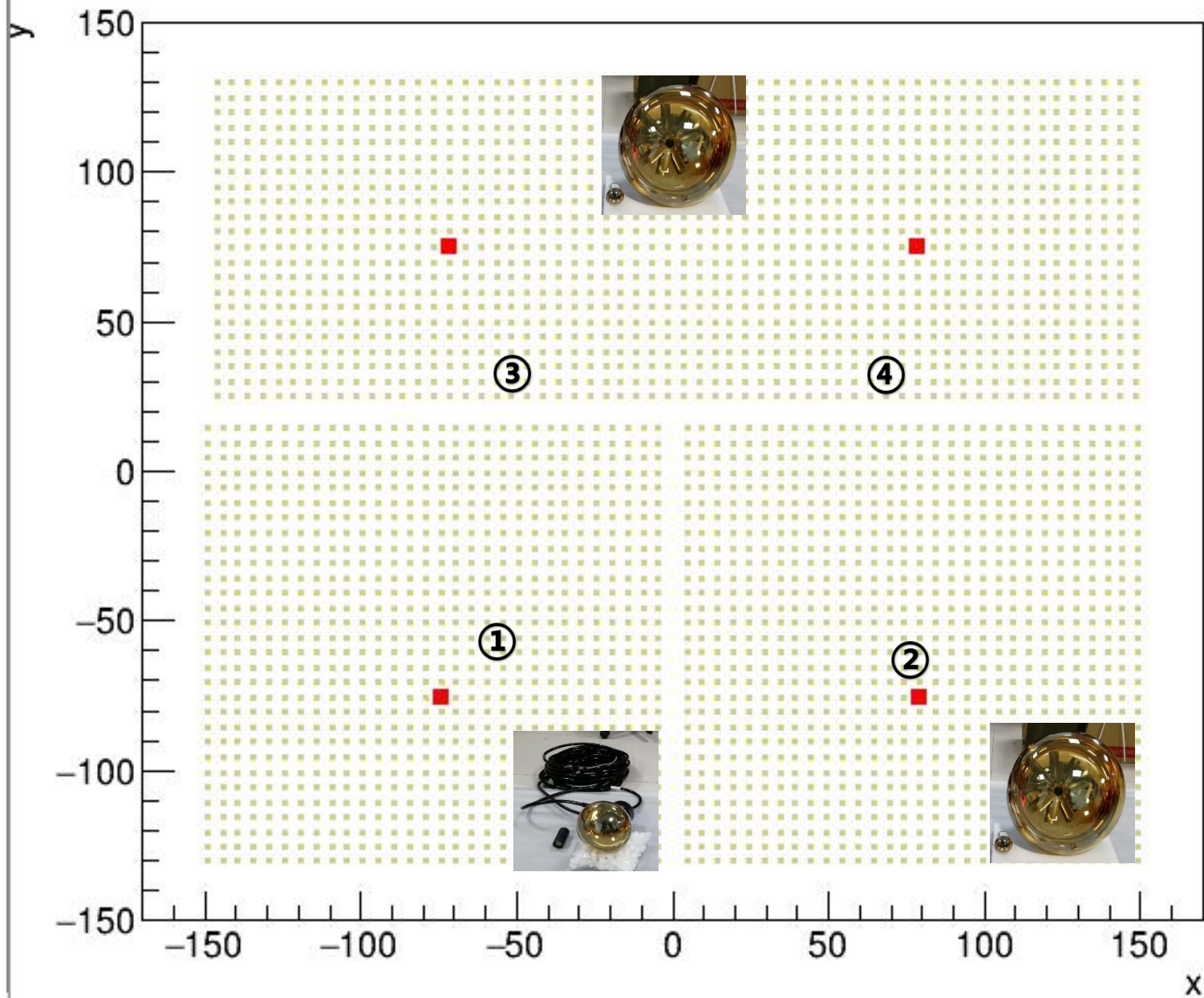
20210616



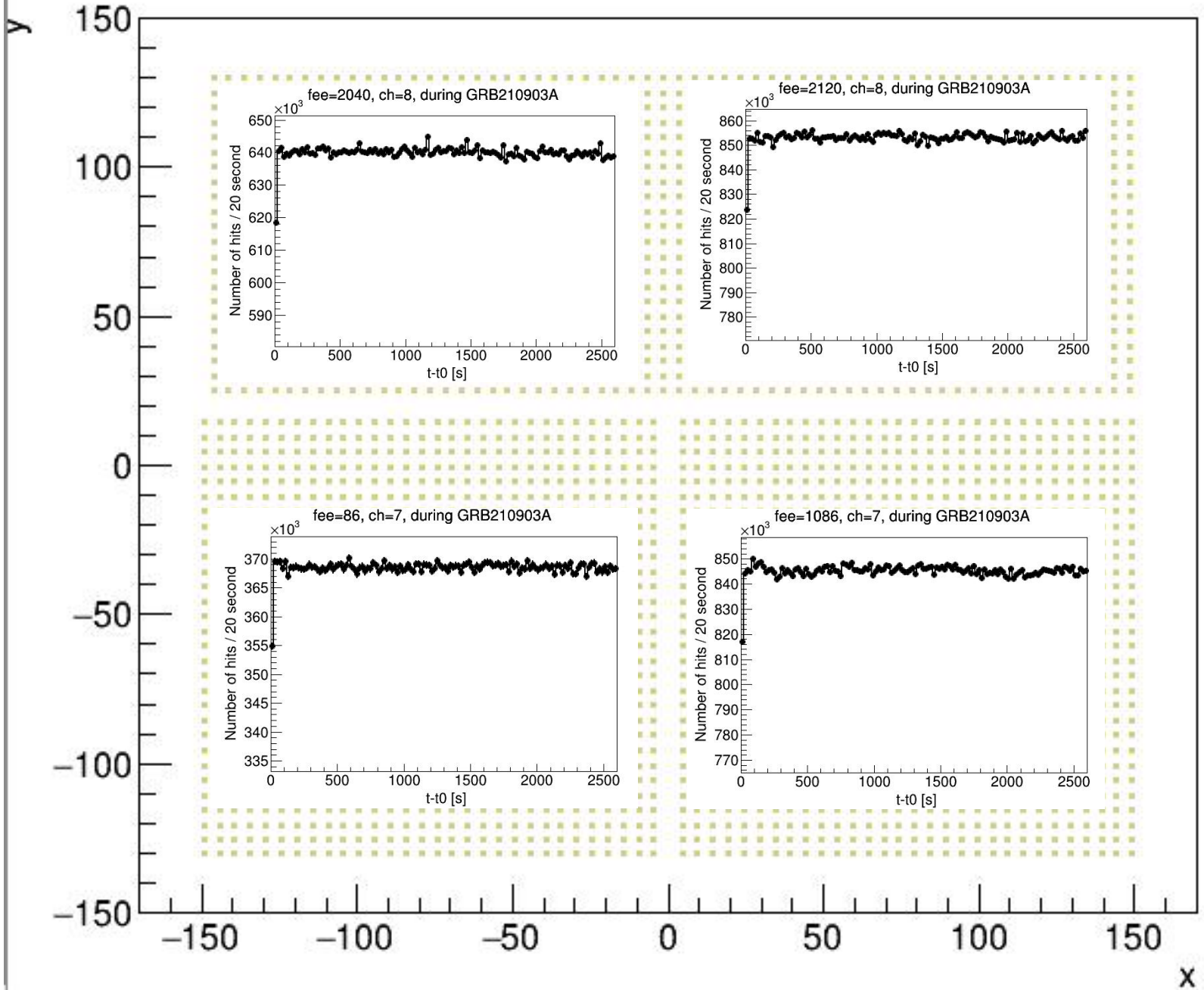
该变化对小nhit的影响较大



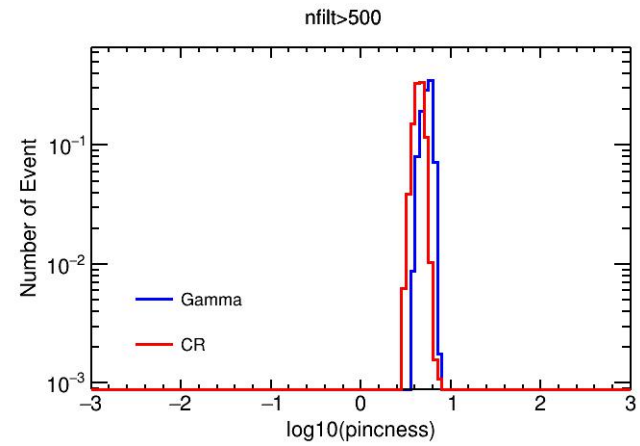
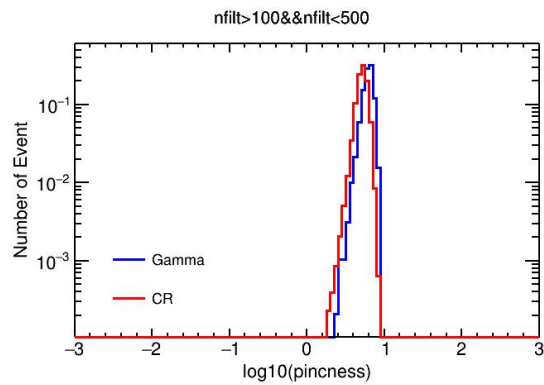
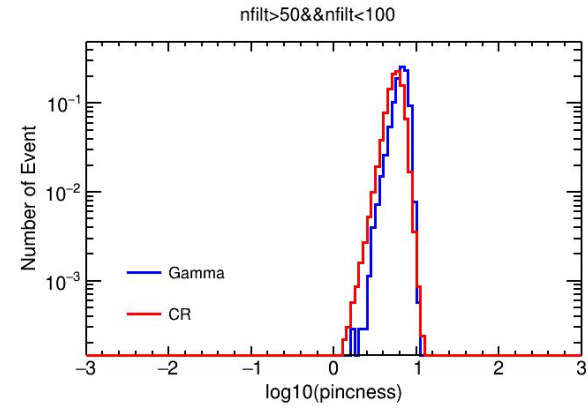
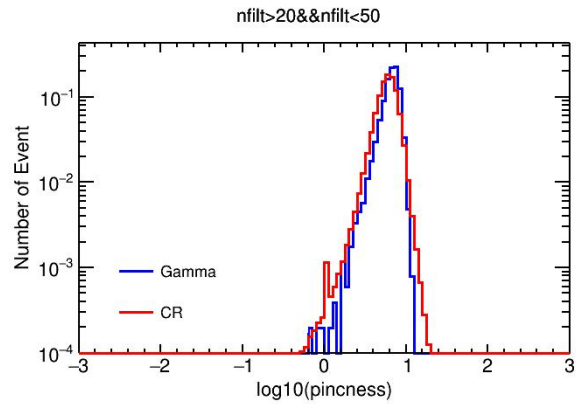
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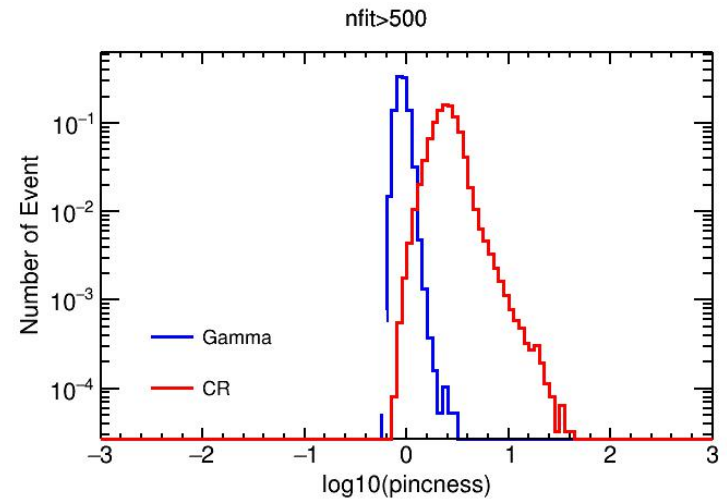
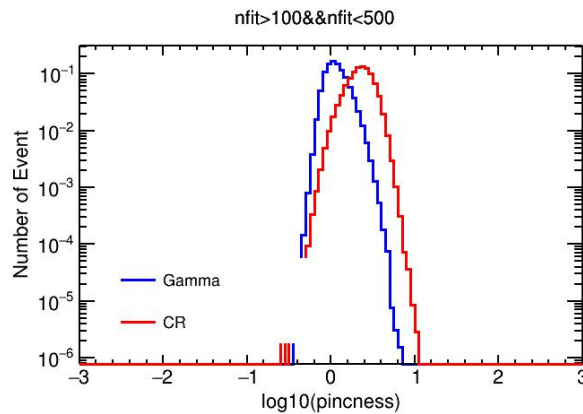
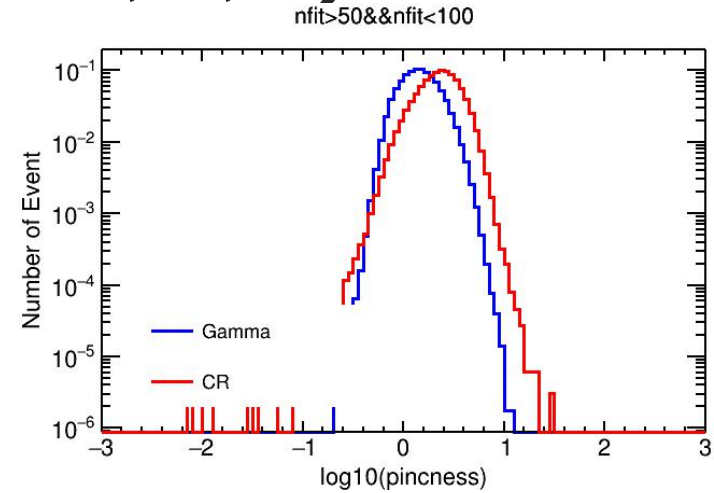
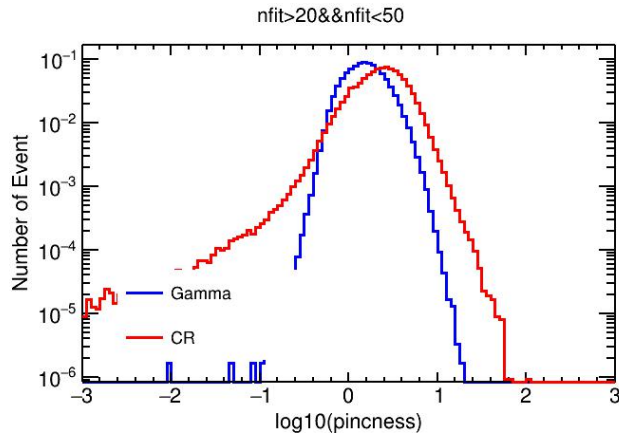
y:x



pinctness的分布 minPE (0.5,0.8,0.8)

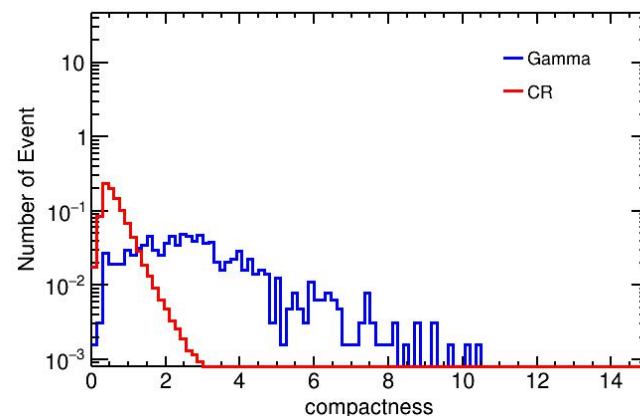
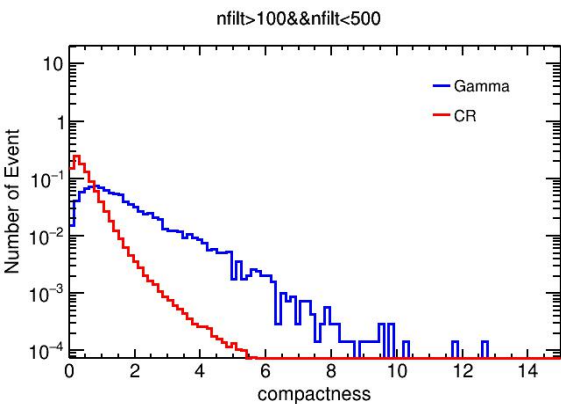
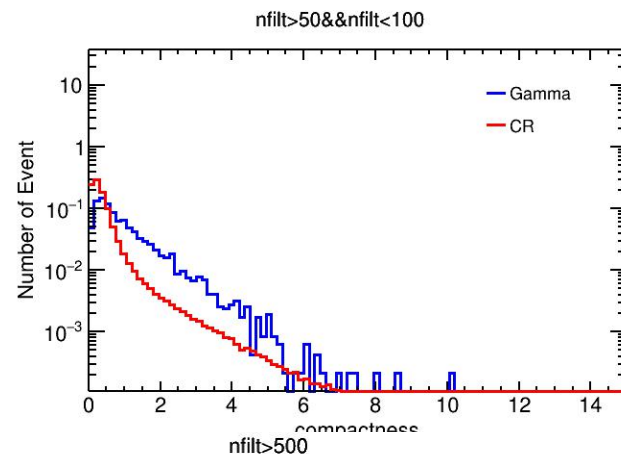
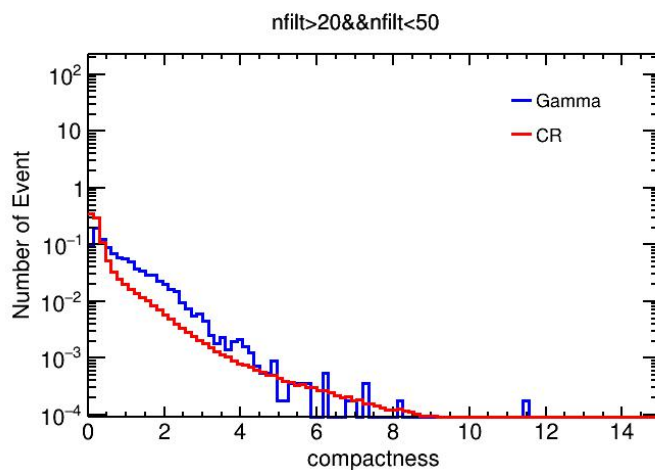


pincess: minPE (0.5,7,7)

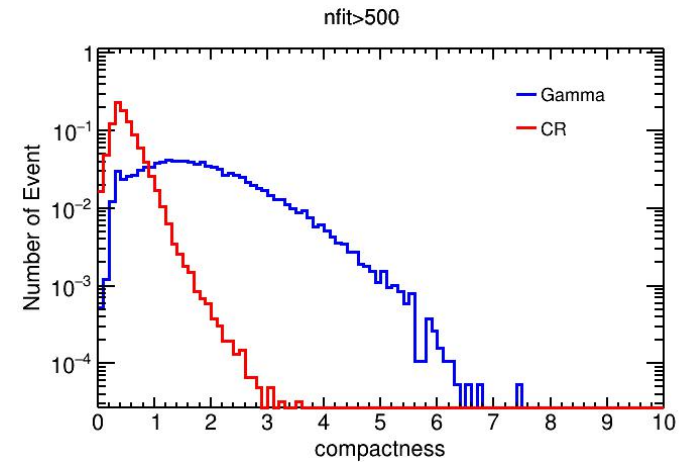
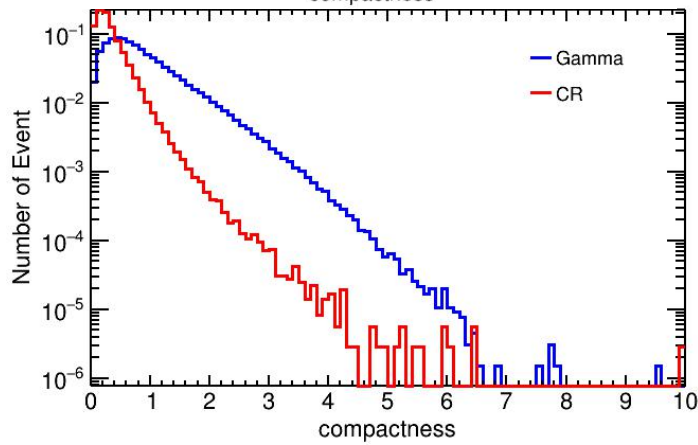
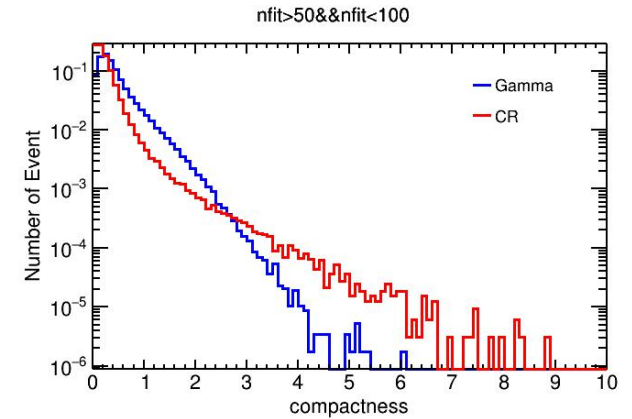
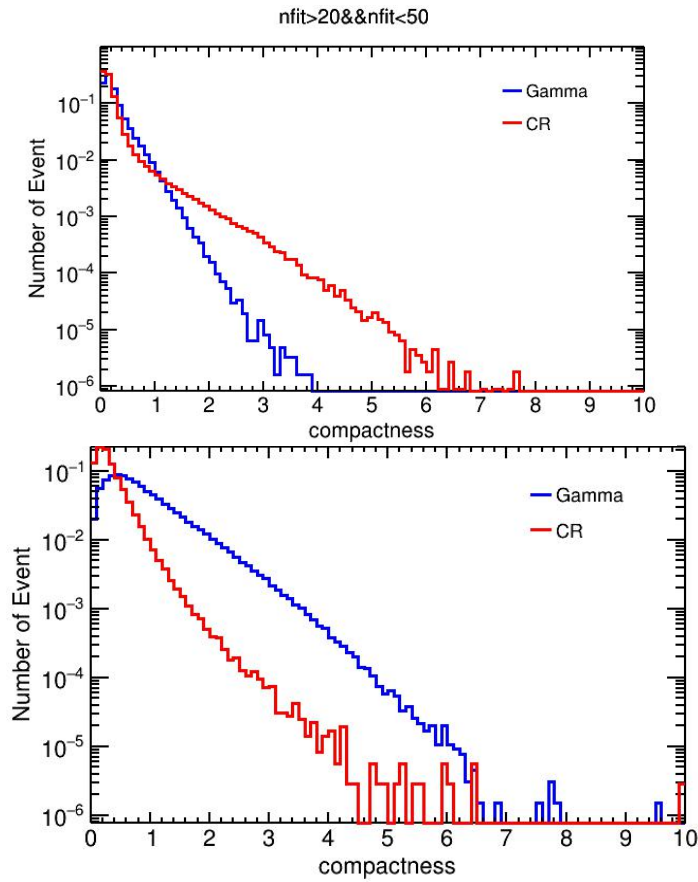


compactness的区分能力minPE (0.5,0.8,0.8)

疑问? (为什么 compactness有小于0的分布?)
45米之外没有hit, 从而最大电荷为初始值



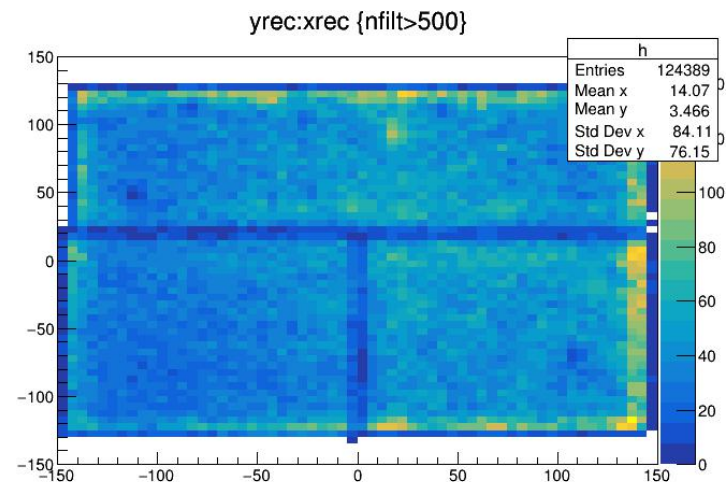
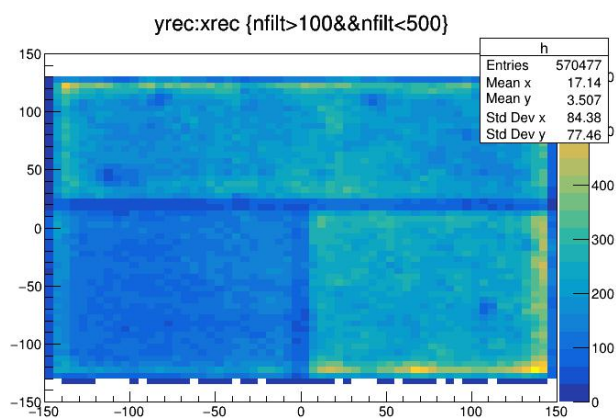
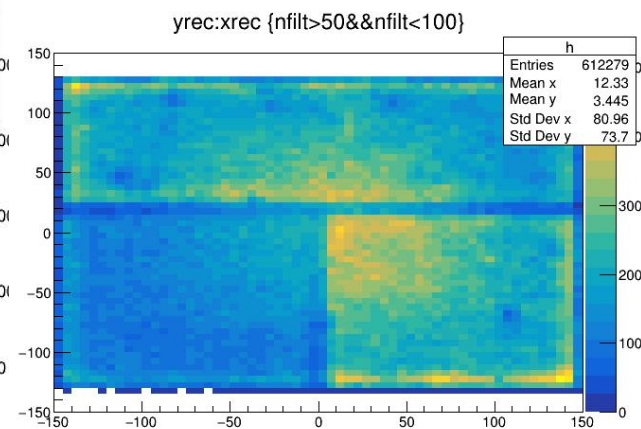
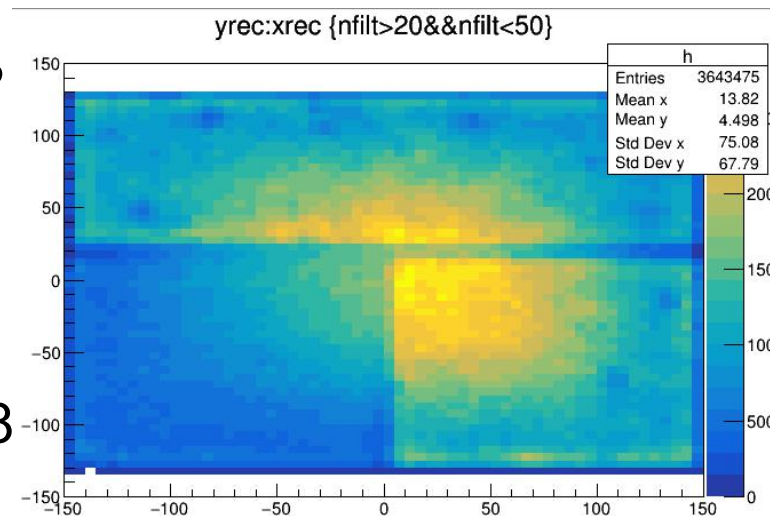
Compactness: minPE (0.5,7,7)



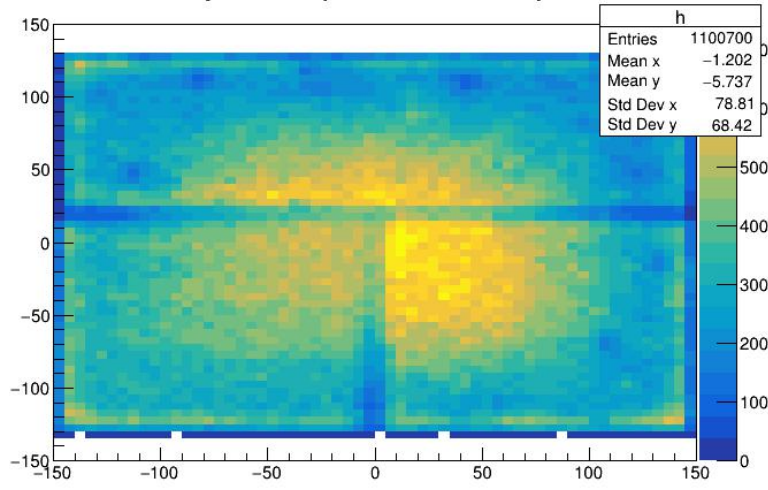
考虑使用平面拟合?

调节阈值?

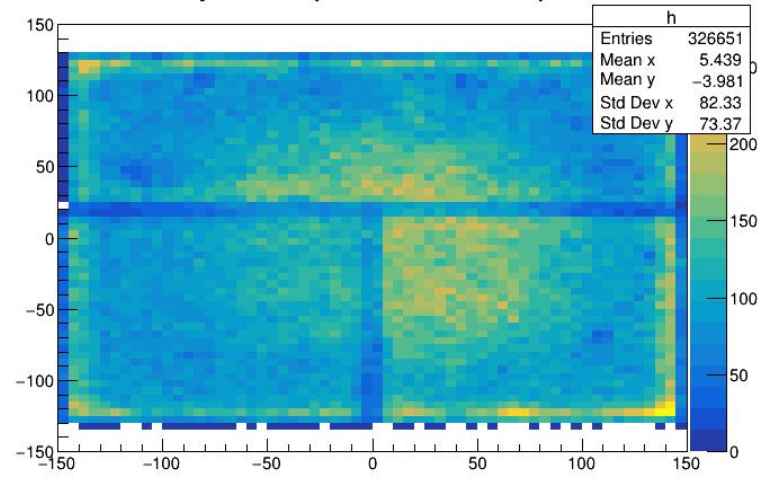
minPE: 0.3,0.8,0.8



yrec:xrec {nfilt>20&&nfilt<50}

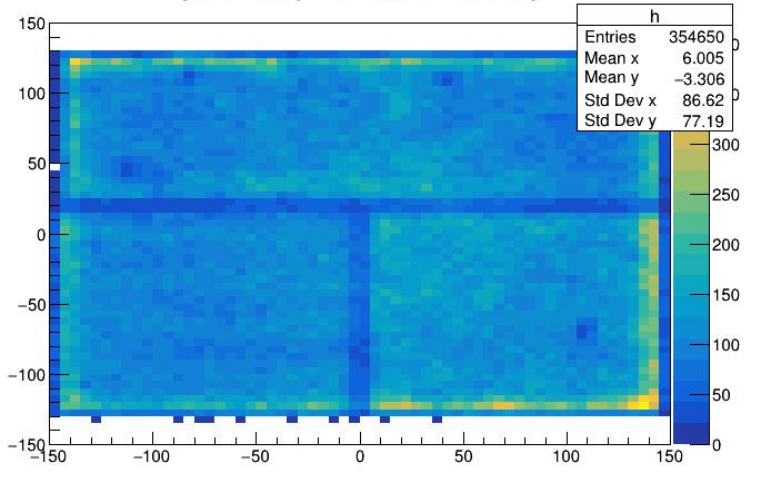


yrec:xrec {nfilt>50&&nfilt<100}



minPE:
0.5,7,7

yrec:xrec {nfilt>100&&nfilt<500}



yrec:xrec {nfilt>500}

