A real-time monitoring on TeV extragalatic transients with the LHAASO-WCDA detector

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TeV Particle Astrophysics @ 26-30 August 2024

outline

Motivation

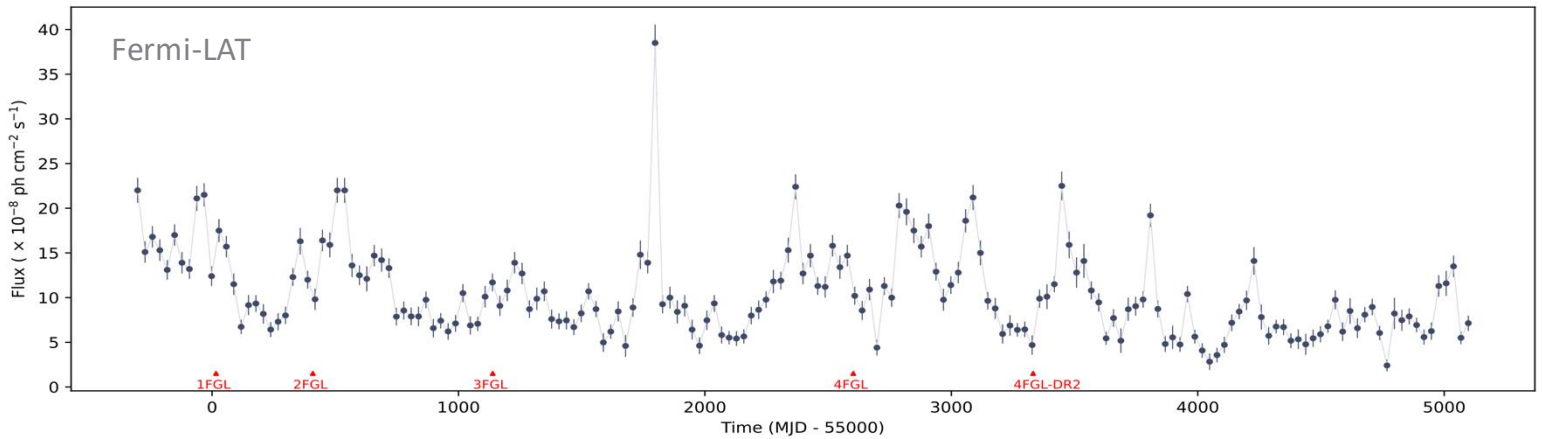
Real-time flaring monitoring

- monitoring scheme
- running status

Prospect @ Transients detection and alert

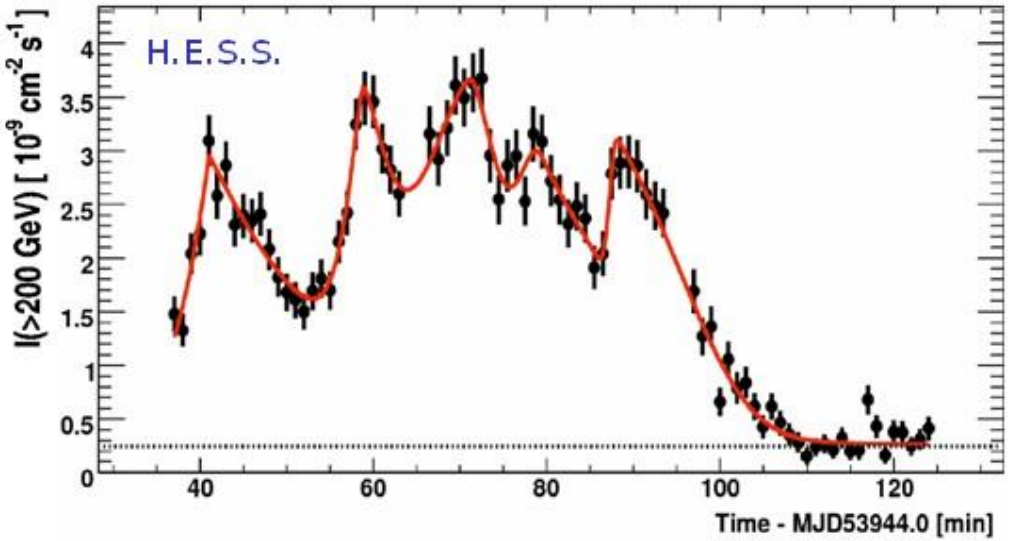
- trigger data
- triggerless data

HE & VHE light curve of PKS 2155-304



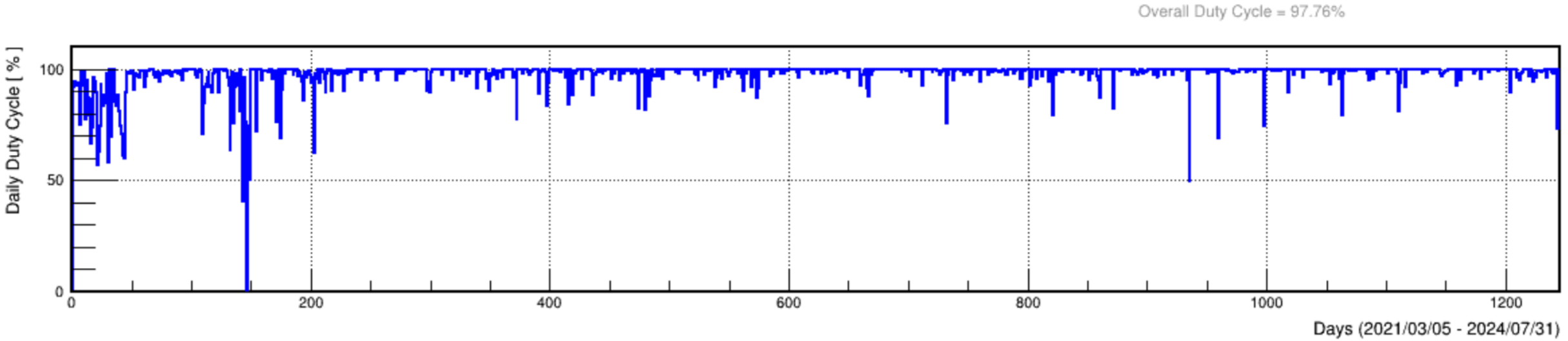
- **Amplitude**
  - Large to a few orders;
- **Timescale**
  - Minutes to years

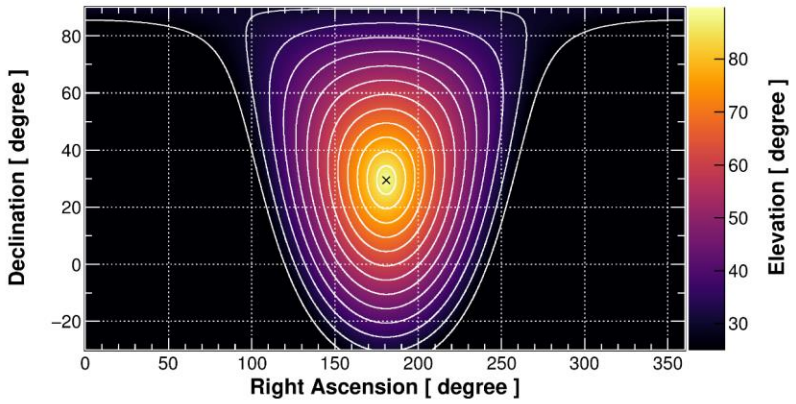
- To probe
  - Unbiased more samples collections;
  - found variable features
  - understand physics behind if possible, such as acceleration mechanism in jets ;

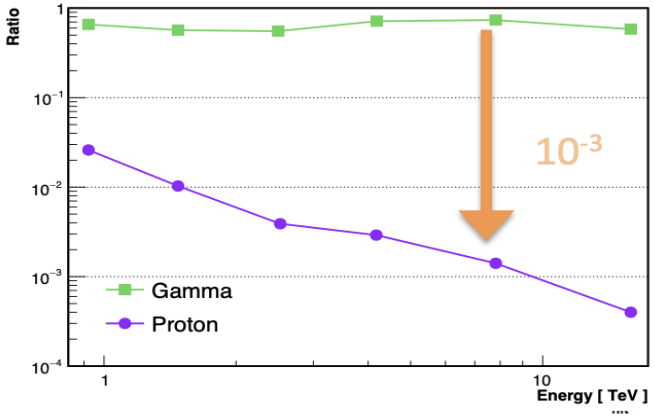


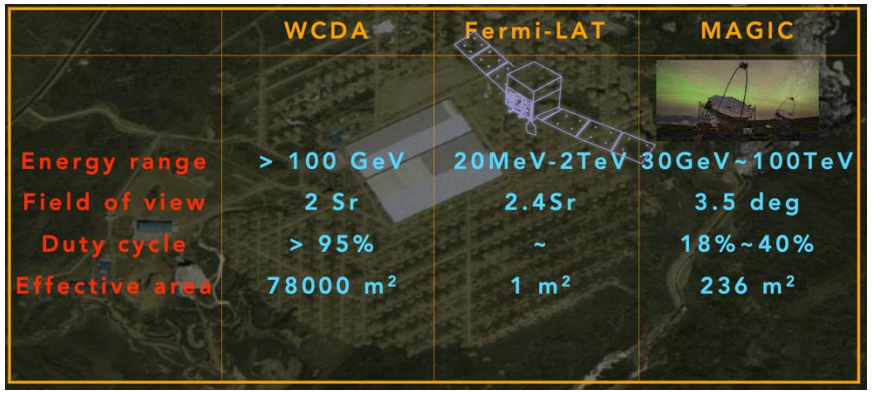
VHE details in the huge flare in 2006

LHAASO-WCDA features









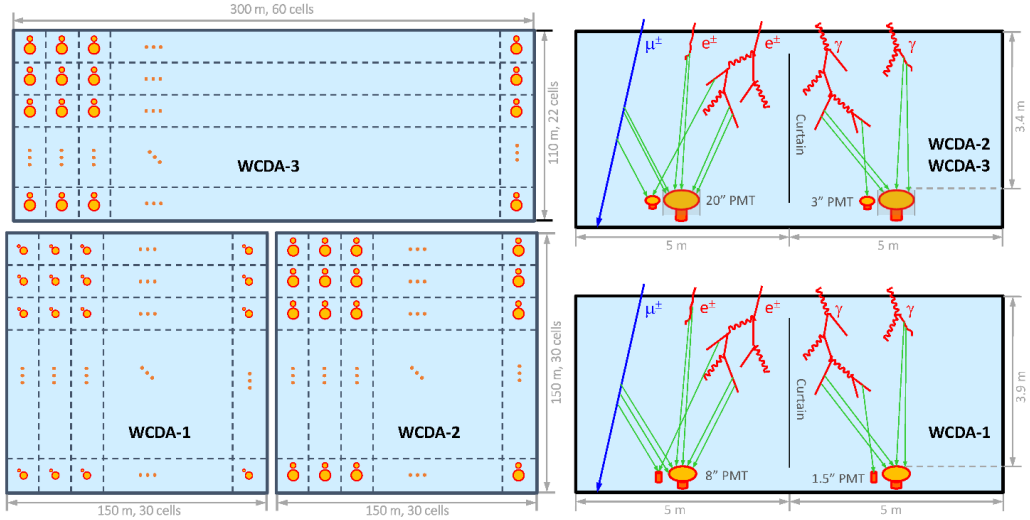
A good facility to do transient phenomena monitoring

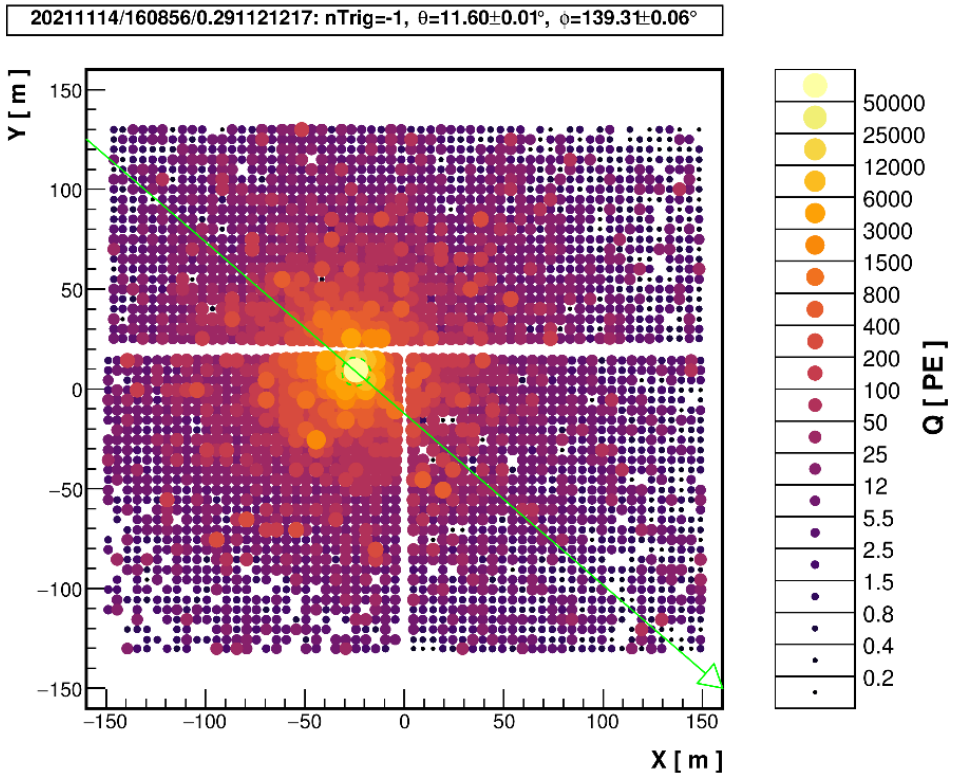
WCDA features：

- Full duty cycle (>98%)
- Wide field of view (~2 steradians)
- Low threshold (>100GeV)
- Good sensitivity

targets:

- Unbiased more samples collections
- Earlier warning
- muti-wavelength observation

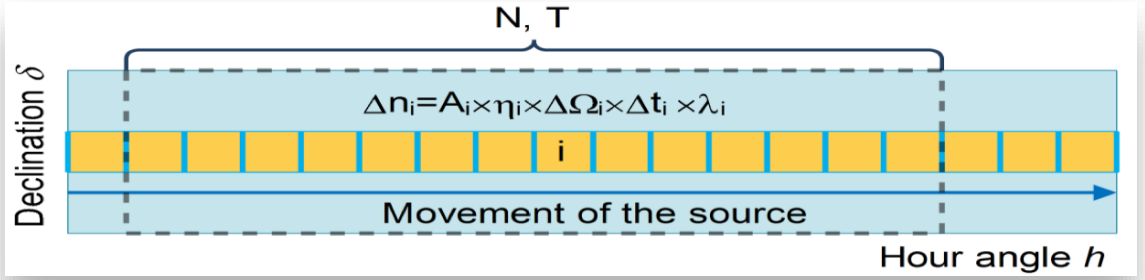


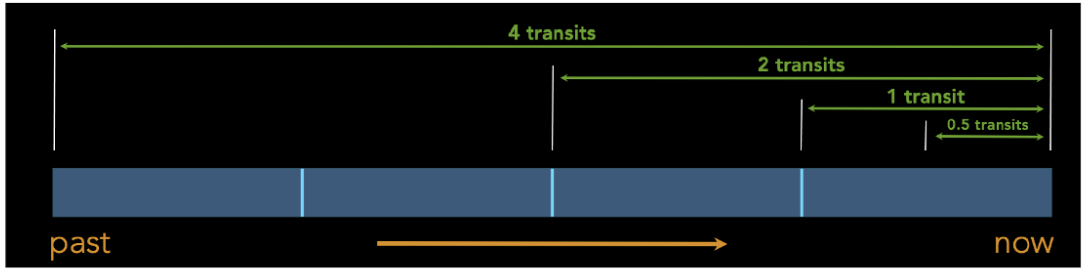


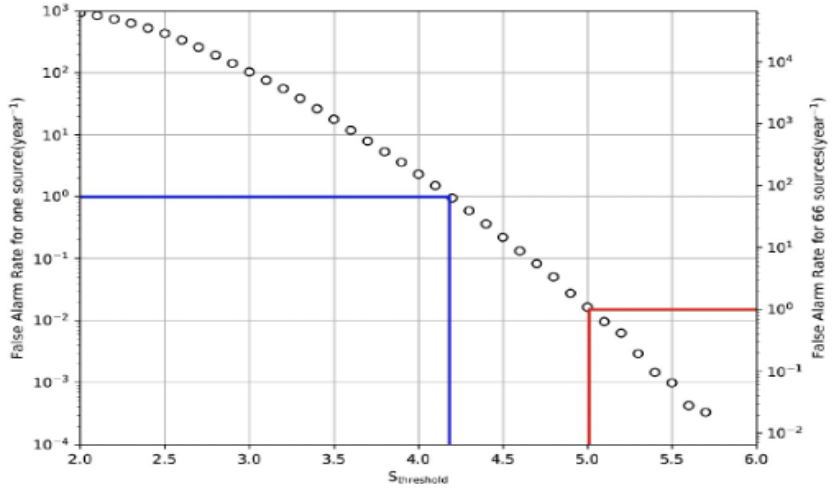
- Area:
  78,000 m^2
- Detector units:
  3120
- Energy Range:
  0.1-50 TeV

Search for excess

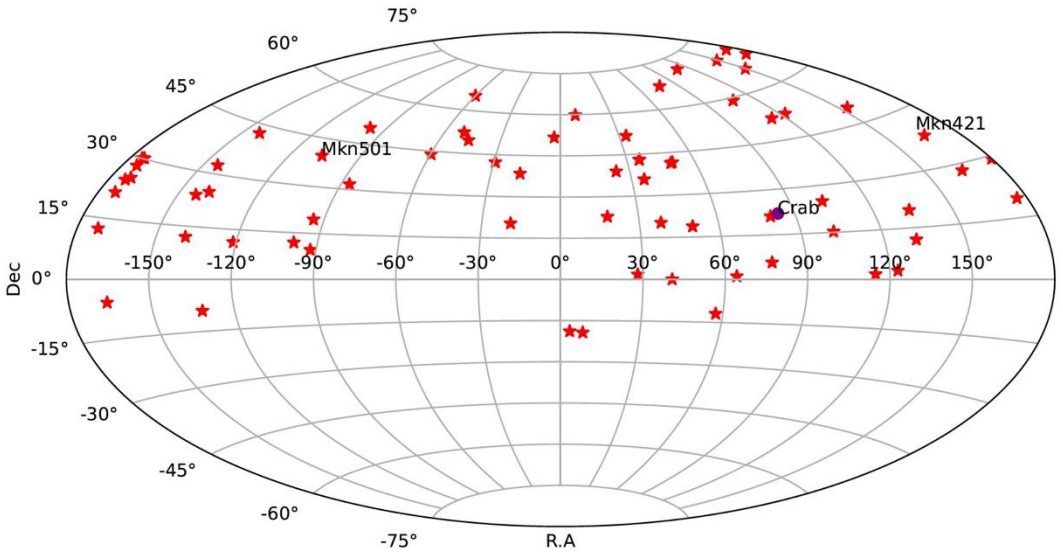
- Source selection
- Background estimation
  - 2 hours direct integration method to determine the background
- Predefined sky map
  - Space
    - The maximum searching distance between the source and grid center is set as 0.1 deg;
  - Duration:
    - 0.5,1,2,4 transits
- Alarm threshold
  - Based on MC simulation
  - Flase alarm rate

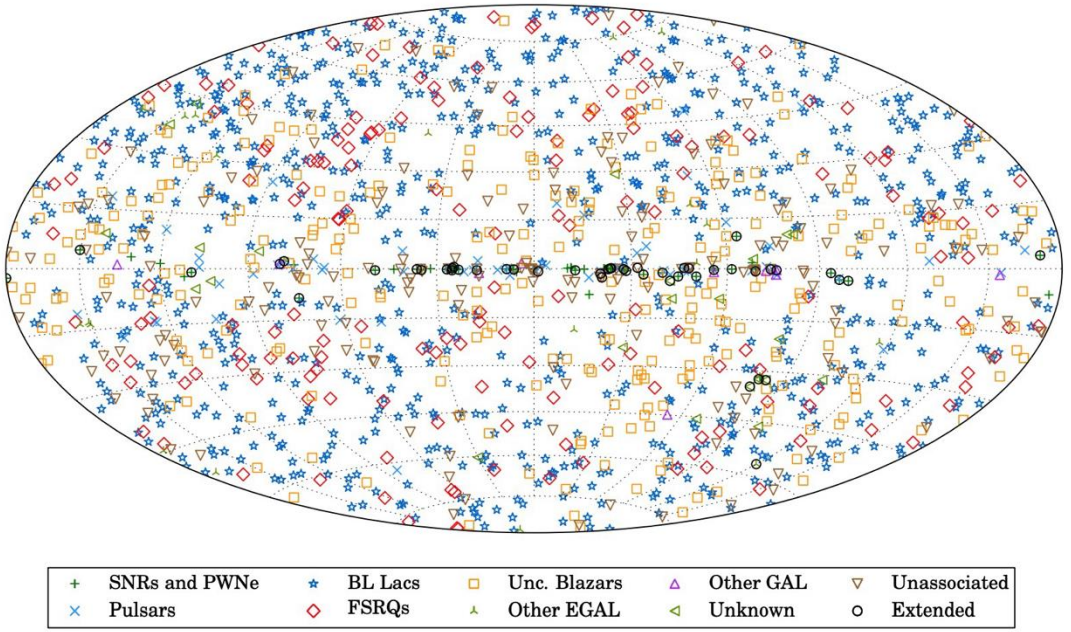






Candidate sources

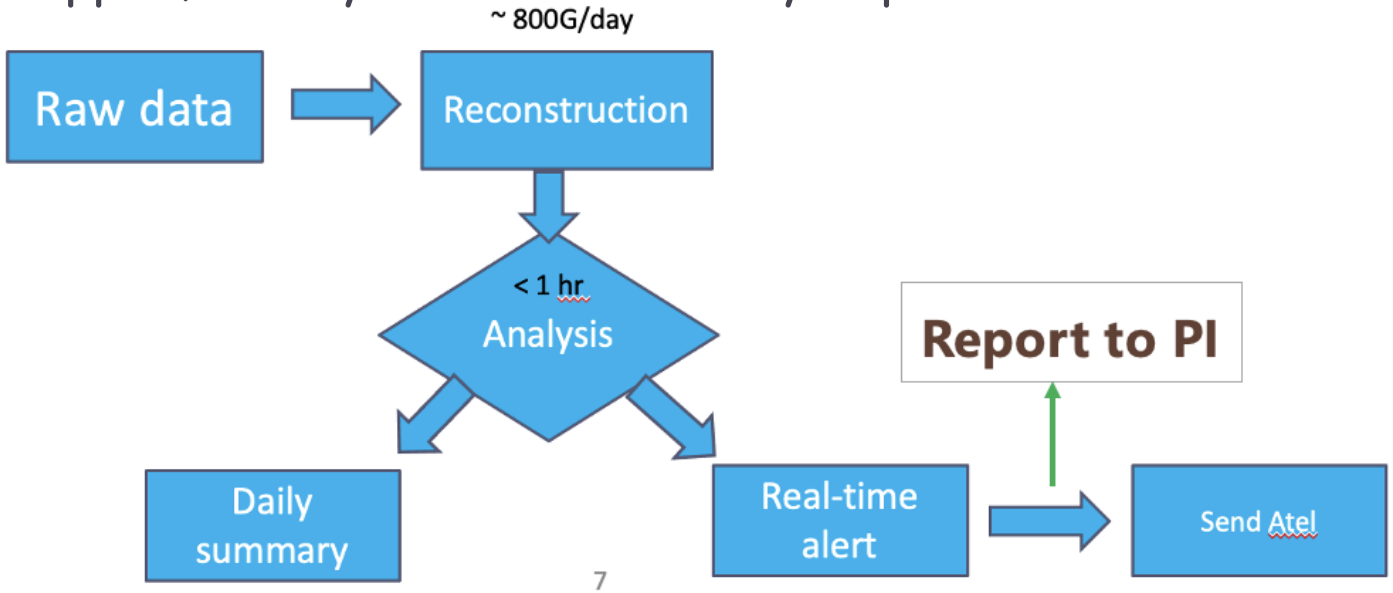




- Declination:[-16°,74°]
- 64 Sources from TeVCat: http://tevcat.uchicago.edu/
- 82 nearby 3FHL sources (with z<0.2)
- Mrk 421 & Mrk501

monitoring status

- The monitoring procedure has been preliminary established in the end of 2019 as just WCDA-1 data-taking.
- A more mature version is running for WCDA full array configuration in the Dec. of 2023.
- Continuous flares from two AGN sources, 1ES 1959+650 and IC 310, were triggered shortly after that…
- If nothing specially happen, a daily monitor summary report would be sent by Email



Automatic email alert & daily summary

AGN Flare Alert!!!

发起会议

2024-03-07 10:38:55

发件人： "项光漫"<gmxiang@ihep.ac.cn>

收件人： zham@ihep.ac.cn "项光漫"<gmxiang@ihep.ac.cn> zjn@shao.ac.cn yixing@shao.ac.cn

Detected 1 flare(s).

From IC310 .

Continue Flaring	Name	Position(R.A,Dec,J2000)	Sig_max(in sigma)	Duration	MJD	Flux(Crab Units > 1 TeV)	ON	BK
✗	IC310	49.09,41.21	5.58	1.0	60375.23 - 60375.57	0.6	133.0	78.01

Continue Flaring	Name	Position(R.A, Dec, J2000)	Sig_max(in sigma)	Duration	MJD	Flux(Crab Units > 1 TeV)	ON	BK
✗	Markarian421	166.11, 38.06	2.58	4.0	60482.43 - 60486.42	0.4	412.0	290.01
✗	Markarian501	253.43, 39.94	-0.22	1.0	60485.67 - 60486.66	0.1	85.0	73.44
✗	WComae	185.41, 28.38	1.31	4.0	60483.32 - 60486.64	0.1	375.0	350.04
✗	SHBLJ001355.9-185406	3.60, -18.96	2.69	4.0	60482.94 - 60486.01	2.6	13.0	5.50
✗	1ES0033+595	8.92, 59.91	0.97	4.0	60482.83 - 60486.15	0.1	139.0	127.70
✗	S20109+22	18.11, 22.79	3.51	0.5	60486.01 - 60486.17	0.7	56.0	33.50
✗	RGBJ0136+391	24.17, 39.21	0.80	0.5	60486.03 - 60486.20	0.1	39.0	34.15
✗	RGBJ0152+017	28.30, 1.75	1.33	4.0	60482.93 - 60486.16	0.2	147.0	131.29
✗	TXS0210+515	33.70, 51.64	0.55	4.0	60482.89 - 60486.23	0.0	211.0	203.02
✗	S30218+35	35.24, 36.01	0.38	2.0	60484.90 - 60486.23	0.0	158.0	153.22
✗	3C66A	35.72, 43.06	1.19	1.0	60485.89 - 60486.23	0.1	80.0	69.75
✗	MAGICJ0223+403	35.79, 43.16	1.28	0.5	60486.06 - 60486.23	0.2	46.0	37.75
✗	1ES0229+200	38.23, 20.22	0.04	2.0	60484.92 - 60486.22	0.0	150.0	149.46
✗	IC310	49.22, 41.36	1.65	0.5	60486.10 - 60486.27	0.3	43.0	32.97
✗	RBS0413	50.05, 18.76	0.00	4.0	60482.96 - 60486.25	0.0	287.0	286.97
✗	NGC1275	49.79, 41.51	1.29	0.5	60486.10 - 60486.27	0.2	42.0	34.08

Alert to the community

[Previous | Next | ADS]

LHAASO detects TeV Gamma-ray Activity from 1ES 1959+650

ATel #16437; *Guangman Xiang (SHAO), Min Zha (IHEP), Zhiguo Yao (IHEP), Jianeng Zhou (SHAO) and Yi Xing (SHAO) report on behalf of the LHAASO Collaboration*
on 9 Feb 2024; 08:30 UT
Credential Certification: Jianeng Zhou (zjn@shao.ac.cn)

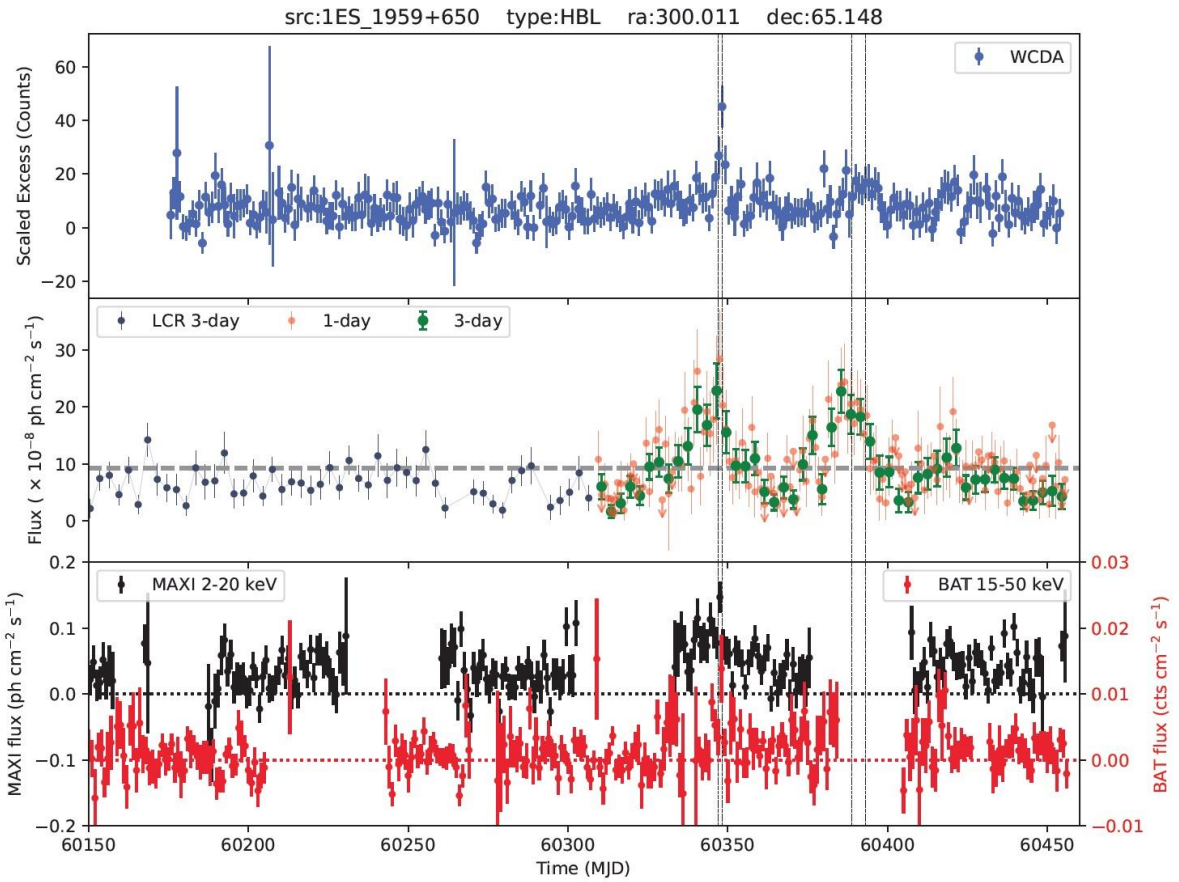
Subjects: Gamma Ray, TeV, VHE, UHE, AGN, Blazar

Referred to by ATel #: 16449, 16456, 16462

𝕏 Post

Utilizing the LHAASO-WCDA real-time alert system, here we report the detection of a TeV gamma-ray flare from 1ES 1959+650. LHAASO-WCDA observed gamma ray flux enhacement from the blazar starting at MJD 60347.02. Up to 60348.33 the accumulated significance reachs 8.7 s.d., with a flux of ~0.5 Crab Unit above 1 TeV. LHAASO is a multi-purpose Extensive Air Shower (EAS) array designed to detect gamma-rays and cosmic rays air showers in a wide energy range, from sub-TeV to beyond 1 PeV.

Related
16462 1ES 1959+650: Upper limits from a neutrino search with IceCube
16456 Gamma-ray flaring activity from the blazar 1ES 1959+650 observed by the Fermi-LAT
16449 Strong X-Ray Flare in the TeV-Detected Blazar 1ES 1959+650
16437 LHAASO detects TeV Gamma-ray Activity from 1ES 1959+650



- 1ES 1959+650: TeV orphan flare by Whipple and two spatially and temporally coincident neutrinos by AMANDA suggests a potential hadronic site.
- IceCube searched for neutrinos from 1ES 1959+650 during 2016 flare.

- After LHAASO-WCDA ATel @ 08/02/2024 about 1ES 1959+650 TeV flaring, several muti-wavelength and multi-messenger follow-up observations have been conducted by Swfit-XRT, Fermi-LAT, IceCube;

--continued

[Previous]

LHAASO detection of renewed TeV activity from the radio galaxy IC 310

ATel #16540; *Guangman Xiang (SHAO, IHEP), Min Zha (IHEP), Zhiguo Yao (IHEP), Jianeng Zhou (SHAO) and Yi Xing (SHAO) report on behalf of the LHAASO Collaboration*

*on **20 Mar 2024; 03:23 UT***

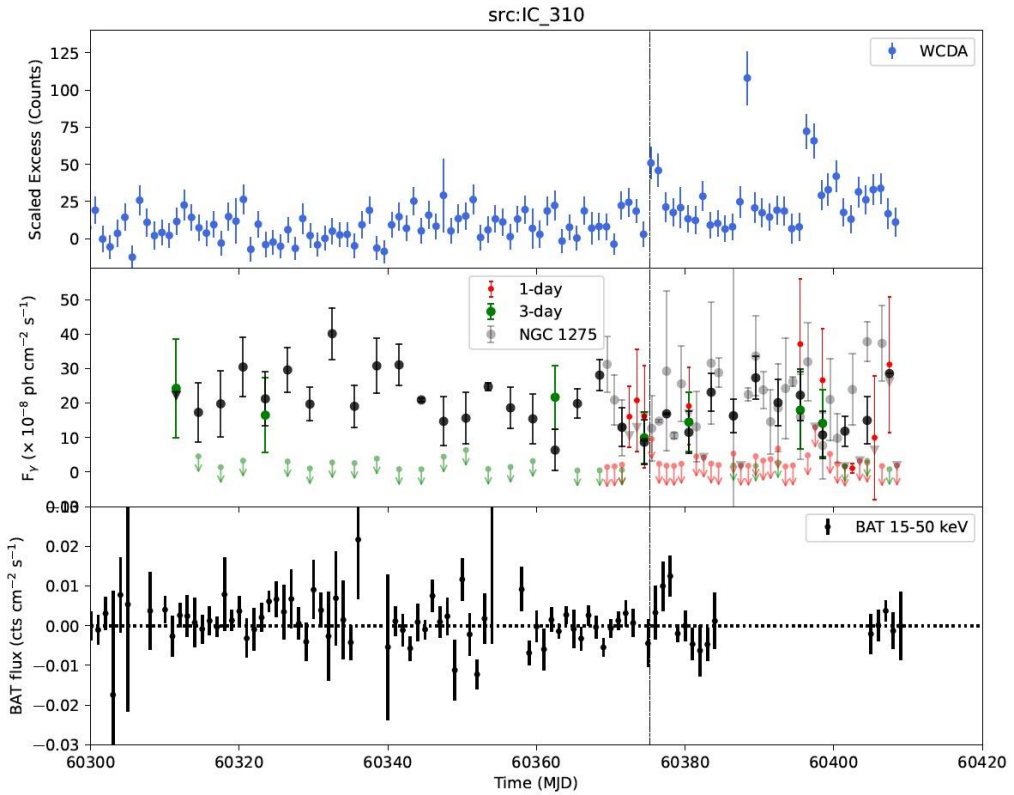
Credential Certification: Jianeng Zhou (zjn@shao.ac.cn)

Subjects: Gamma Ray, TeV, VHE, AGN, Transient

Post

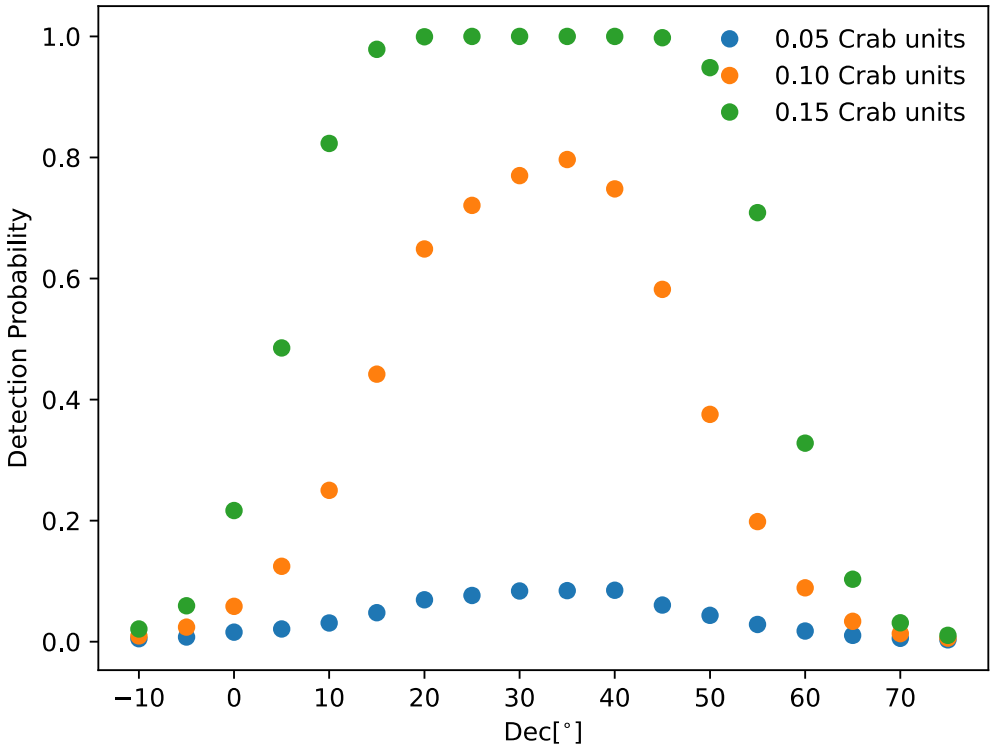
Utilizing the LHAASO-WCDA real-time alert system, we report the detection of renewed TeV gamma-ray activity from the galaxy IC 310. LHAASO-WCDA observed a gamma-ray flux enhancement from IC 310 initiated at MJD 60388.20. By MJD 60388.54, the accumulated significance reached 7.65 standard deviations, with a flux of approximately 1.3 Crab Unit above 1 TeV. The TeV gamma-ray activity had been alerted by LHAASO (ATel #16513) in March 6, 2024, VERITAS performed follow-up observations between March 10-13, 2024 (ATel #16535). We strongly encourage multi-band observation. LHAASO is a multi-purpose Extensive Air Shower (EAS) array designed to detect air showers induced by gamma-rays and cosmic rays across a wide energy range, spanning from sub-TeV to beyond 1 PeV.

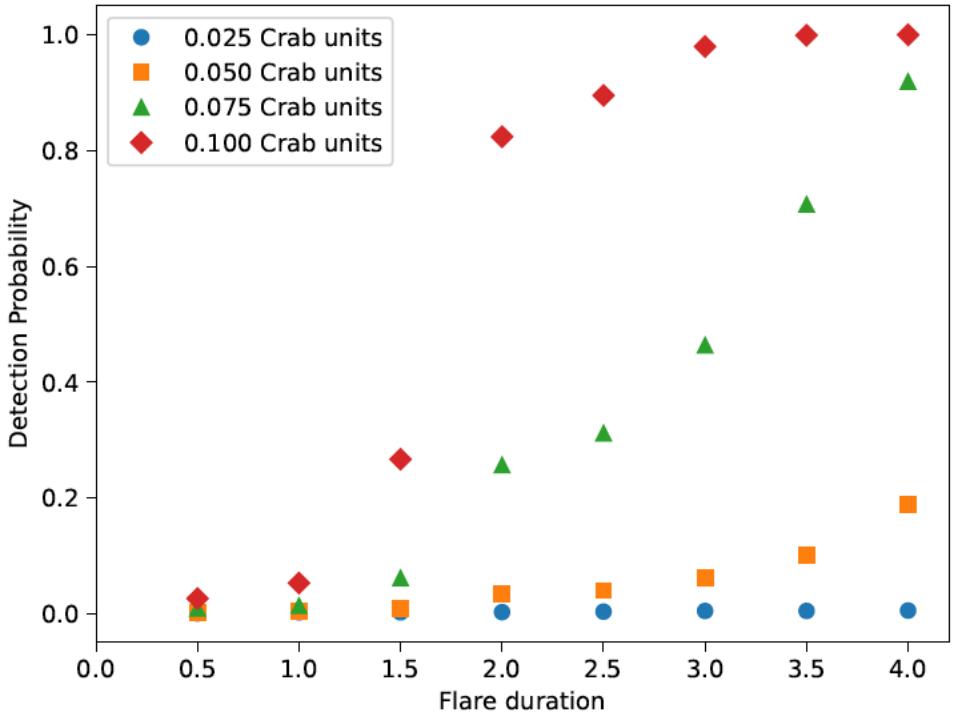
Related	
16540	LHAASO detection of renewed TeV activity from the radio galaxy IC 310
16535	VERITAS Detection of Elevated VHE Emission from IC 310
16513	LHAASO detects rapid variability in TeV Gamma-rays from the galaxy IC 310



- Alert side and the follow-up side made a first joint observation
  - Trigger data → Triggerless data

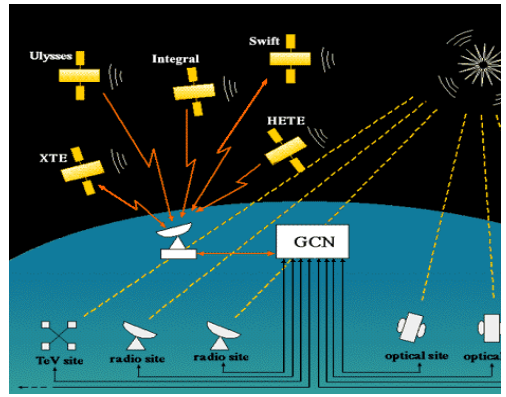
Flaring monitoring sensitivity



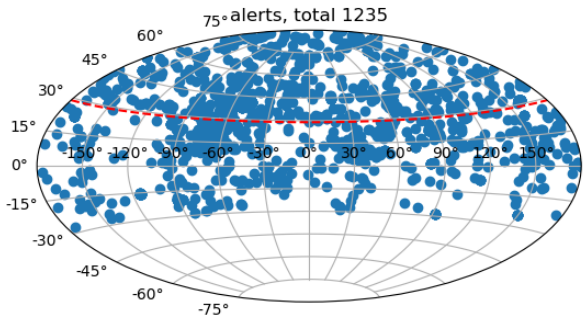


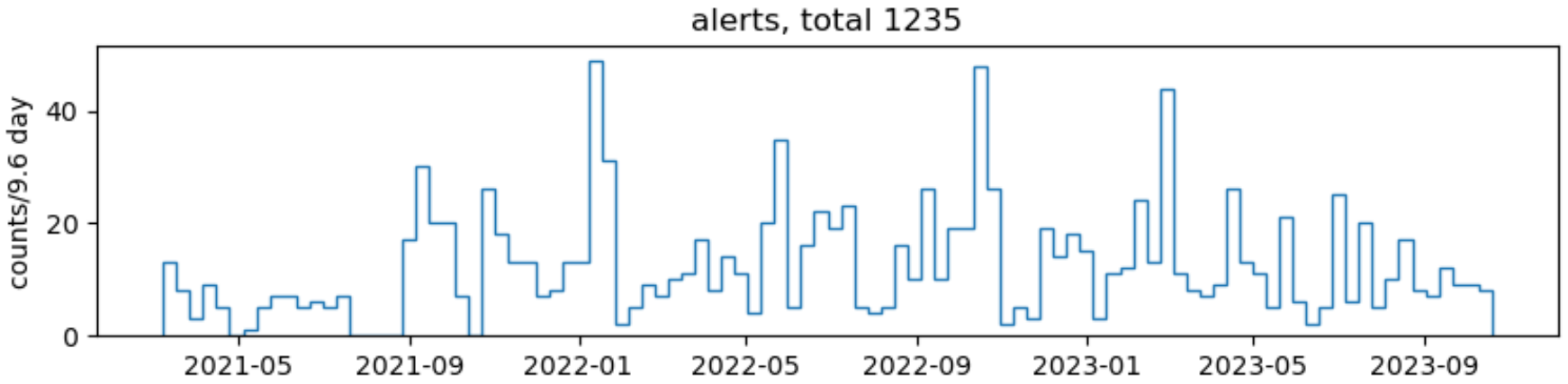
Prospect @ Transients detection and alert handling

- GRB/transients follow-up @ triggerless data
  - Receive a GCN alert inside LHAASO FOV
    - Alert rate: 2.5/week
  - Save (T0-0.5 h, T0 + 2 h) hours of data
  - (Npe, T) of 3120 detector units
  - Big data size → 7 TB/alert



- Within 3 days triggerless data can be stored
  - More effective alerts can be followed-up observation

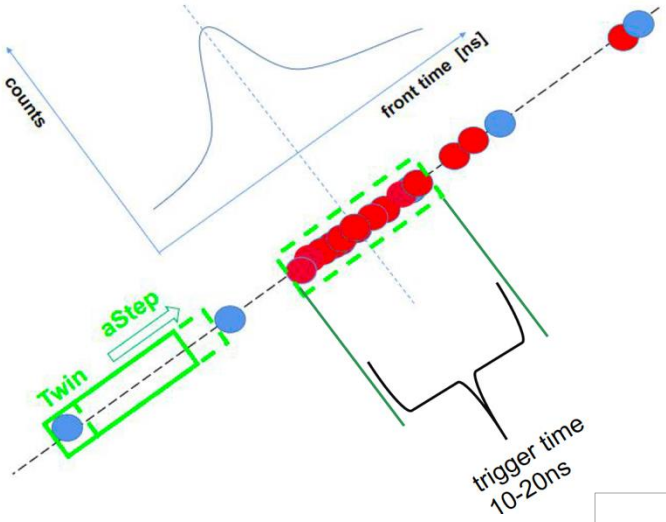


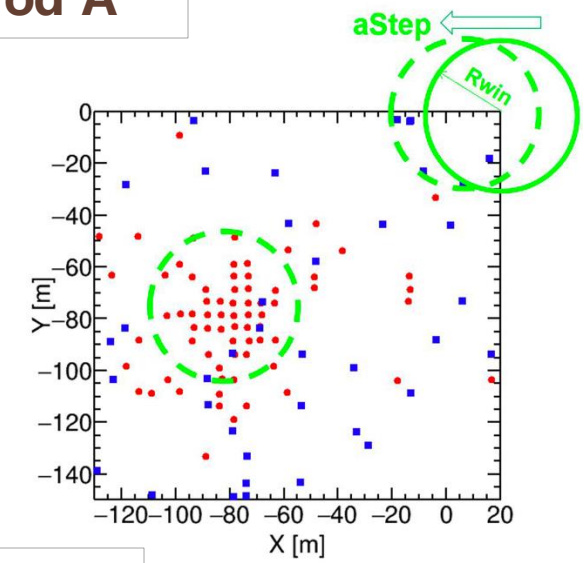


Analysis pipeline

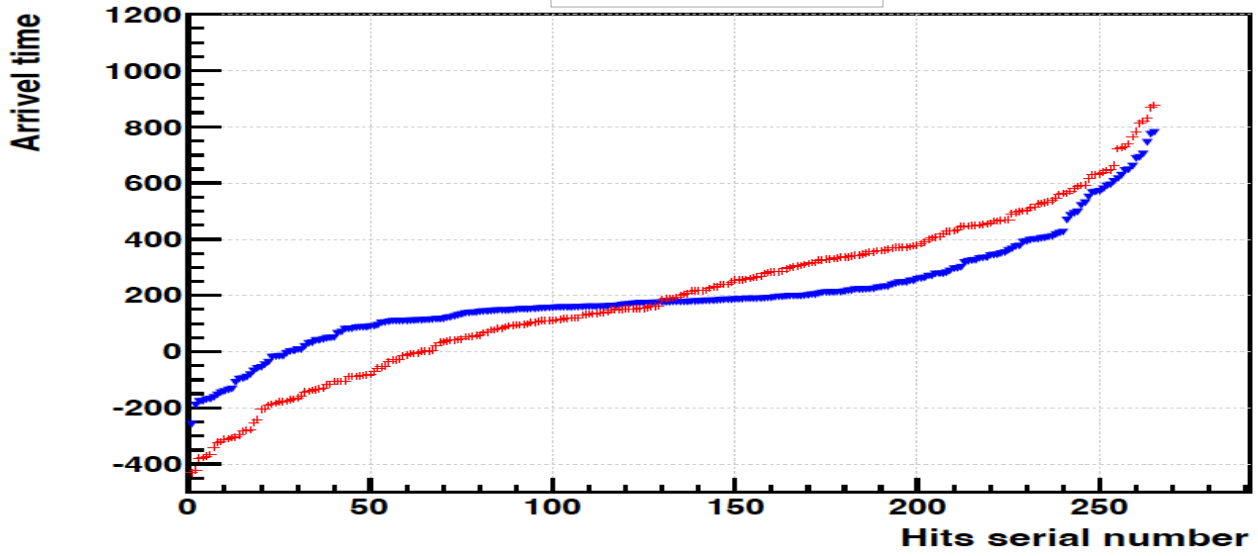
- Hits-to-Events re-trigger (A)
  - Time & window selection
  - 20 ns Twindow + 20 ns Tgap
  - R=20 m
- Hits-to-Events re-triger (B)
  - Twin=1000 ns + half overlap
- Event reconstruction/No reconst.
- Background estimation
- Searching excess
- Physics analysis
  - Flux upper limits

Method A

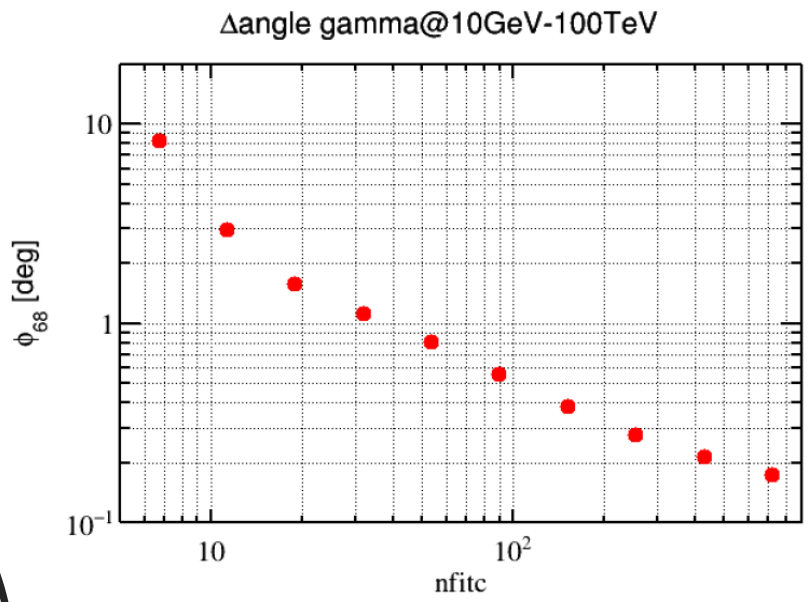


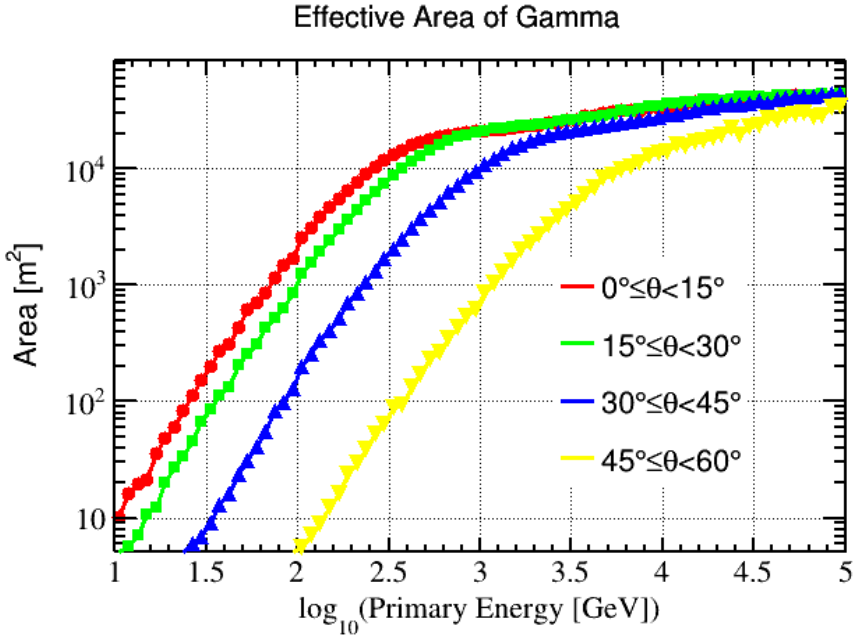


Method B



Results





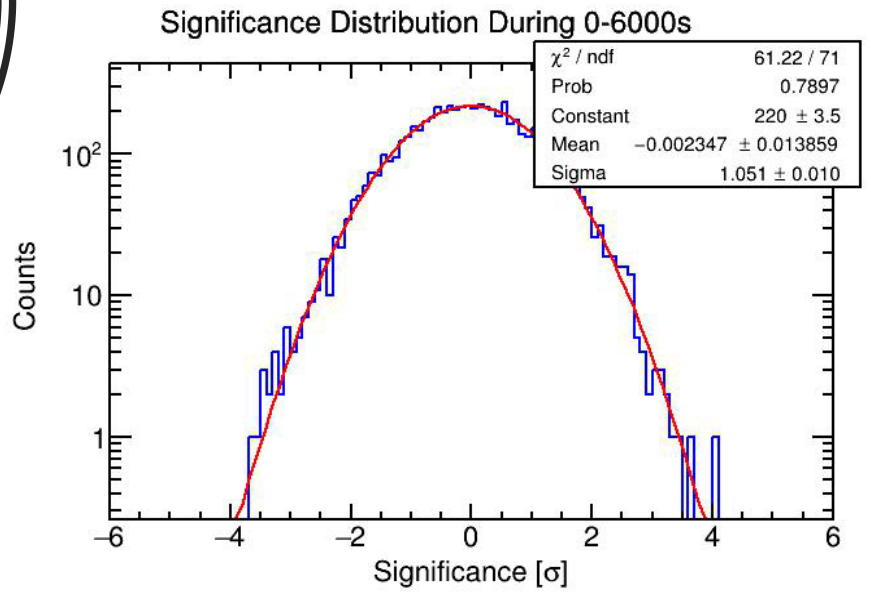


表 4.2 不同红移下T_0-T_{90}和T_{90}−6000s时间范围内低能和高能流强上限列表

取数日期	天顶角	T90	T_{90}, nfitc < 60		T_{90}, nfitc ≥ 60		0 − 6000s, nfitc < 60		0 − 6000s, nfitc ≥ 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)
	[o]	[s]	[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

Summary and outlook

- A real-time AGN flaring monitoring system has been operated since Dec. of 2023;
  - Several interesting flare-alert have been submitted;
    - Mrk421 / NGC 1275 / 1ES 1959+60 / IC310
- Another analysis packages of triggerless data have been operated;
  - No signifiant excess were detected besides GRB221009A.

- To-do-list
  - Further analysis of the variablity;
  - Optimization the monitoring system;
    - Expanding to all-sky variability monitoring;
    - More follow-up astrophysical targets based on multi-wavelength & multi-messenger alert are under discussion

LHAASO

KM2A:
5216 ED/1m^2 + 1188 MD/36m^2
Area: 1.3 km^2

UHE gamma ray astronomy

WFCTA:
18 telescopes

CR individual spectrum…

WCDA:
3 pools, 3120 cells/25m^2
area: 78,000 m^2

VHE gamma ray astronomy

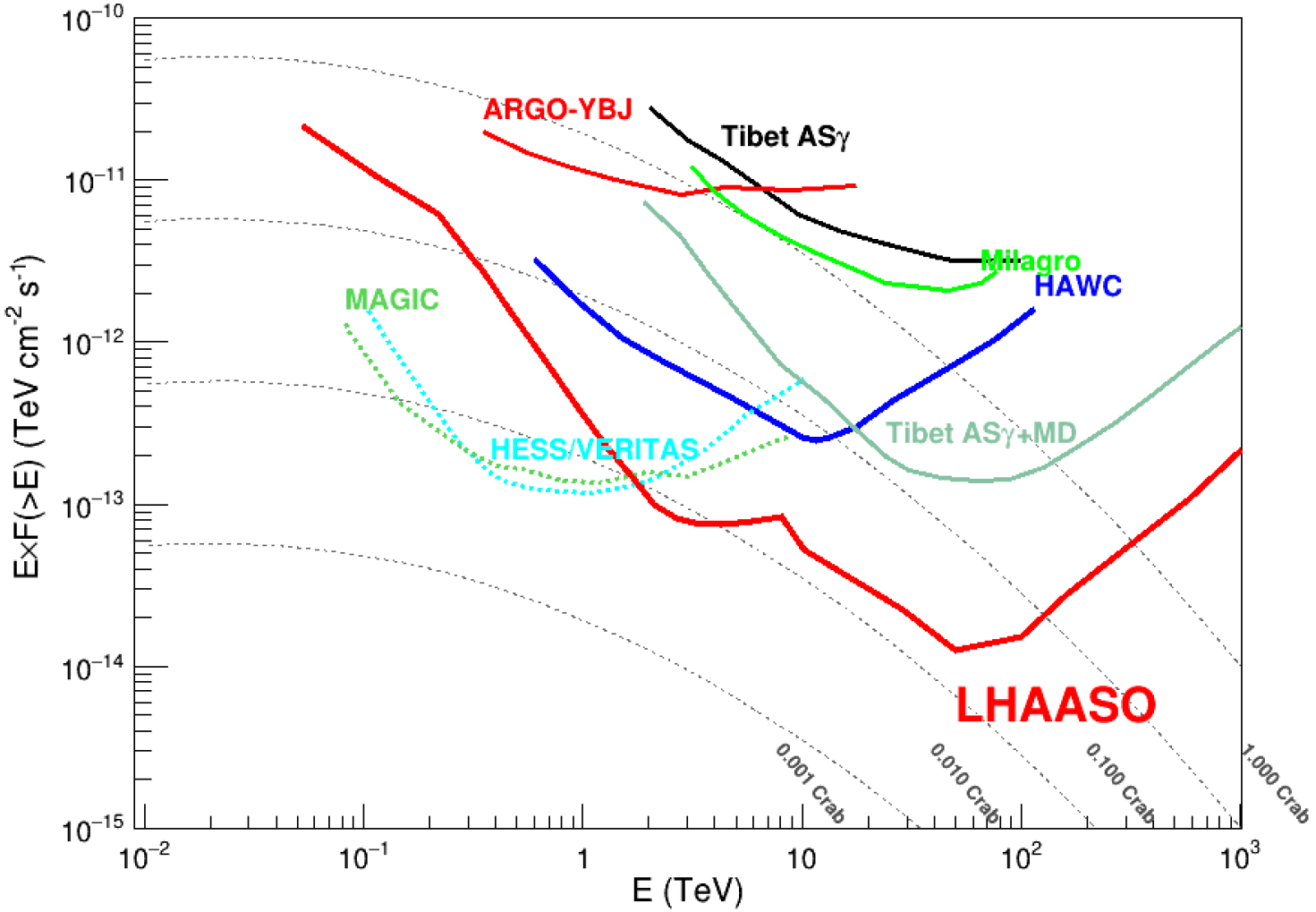
Some planed detectors

Neutron detectors

High energy IACTs

…

……


ARGO-YBJ
Tibet ASγ
Milagro
HAWC
MAGIC
HESS/VERITAS
Tibet ASγ+MD
LHAASO
0.001 Crab
0.010 Crab
0.100 Crab
1.000 Crab
E×F(>E) (TeV cm⁻² s⁻¹)
E (TeV)