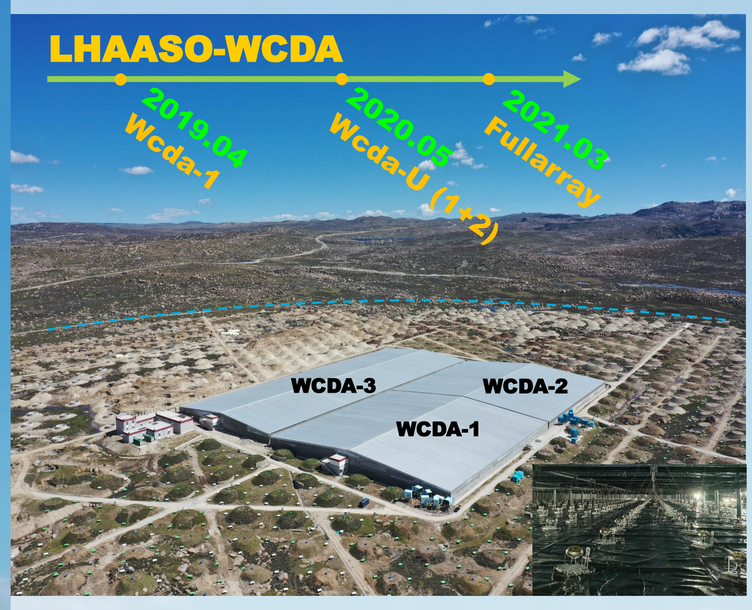
Sky survey of VHE gamma-ray sources with LHAASO-WCDA

Shicong Hu[a], Guangman Xiang[a,b], Zhen Wang[c], Hao Zhou[c], Min Zha[a], Zhiguo Yao[a]

[a] *Institute of High Energy Physics, Chinese Academy of Sciences, 100049, Beijing, China*
[b] *Shanghai Astronomical Observatory, Chinese Academy of Sciences, 200030, Shanghai, China*
[c] *Tsung-Dao Lee Institute, SHANGHAI JIAO TONG UNIVERSITY , 200240, Shanghai, China*

E-mail : hushicong@ihep.ac.cn

I. Introduction

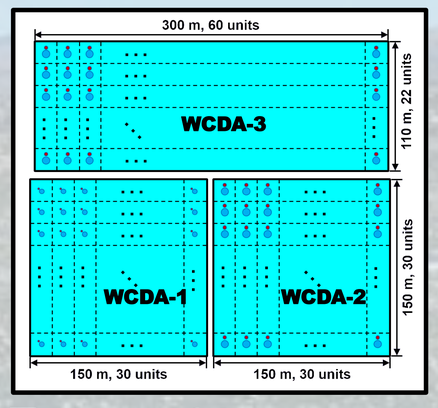


Ground-based detector array

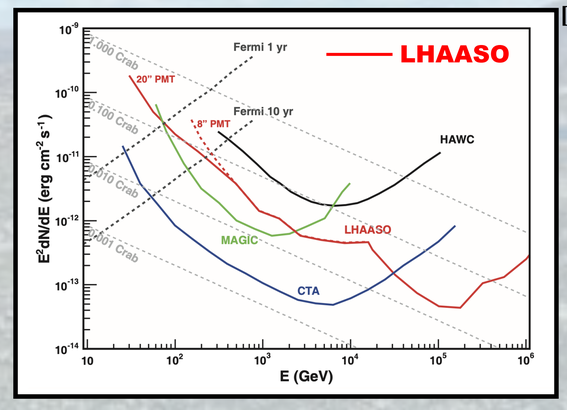
- ~100GeV - ~100TeV gamma-ray astronomy
- Large area : 78000 m^2
- Angular resolution: ~0.2°@10TeV
- Gamma/Proton discrimination : Q > 10

→ **high sensitivity**

- Wide field of view : ~2 sr
- Duty cycle: >95%



Layout of detector array



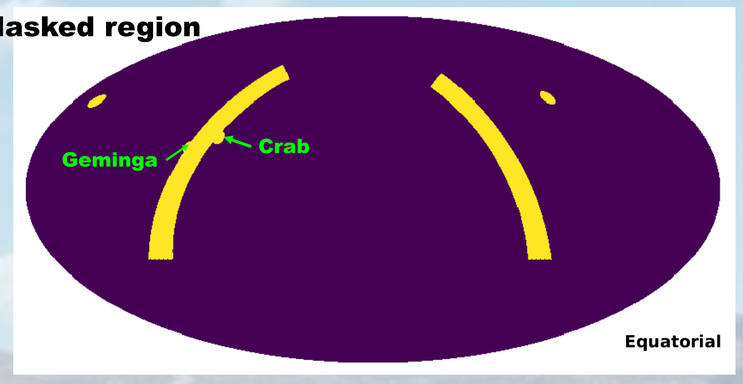
[1]

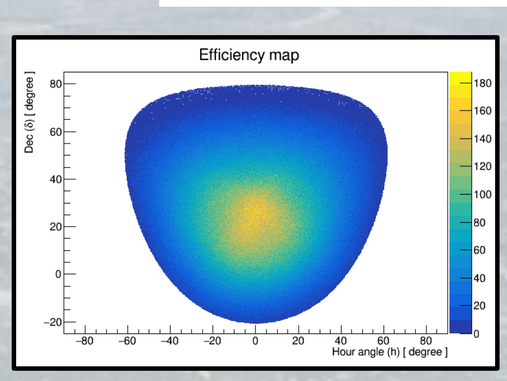
Differential sensitivity

II. Method – Part 1 Background estimation

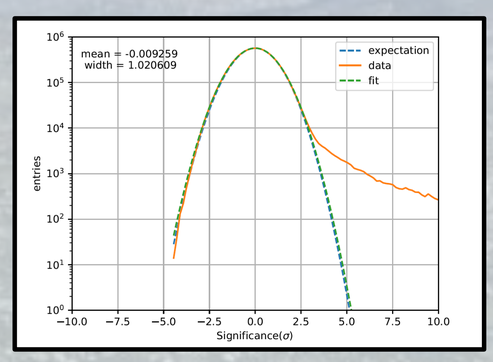
Direct integration method[2][3] : Background $B(\alpha,\delta)$ is the direct convolution of the efficiency map $\varepsilon(h,\delta)$ with the event rate $R(\alpha-h)$

- $B(\alpha,\delta)=\int \varepsilon(h,\delta)R(\alpha-h)\,\mathrm{d}h$
- Mask some sources to eliminate the influence of signal on background estimation





Example of $\varepsilon(h,\delta)$



Dis. of significance $S\sim N(0,1)$

III. Method – Part 2 Strategy for searching

Iteration based on maximum likelihood method[4]

- Skymap divided into pixels based on HEALPIX[5]
- Model of signal distribution: 2D gaussian model $f(\gamma;\alpha,\delta,\sigma)$
- Source spectrum : single power-law $F=I_0(E/E_0)^{-\beta}$

Observed signal distribution $f'(\gamma';\alpha,\delta,\sigma)$ is the convolution of F and $f(\gamma;\alpha,\delta,\sigma)$ with the detector response including Point Spread Function (PSF) and detection efficiency. *CORSIKA* and based on *GEANT4* software are used to simulate response of detector array to air showers.

- **Likelihood function**

For *j*th pixel in one of regions of interest (ROIs)

$$P(N_j;\lambda_j)=\frac{\lambda_j^{N_j}e^{-\lambda_j}}{N_j!},\lambda_j=b_j+\sum_k\gamma'_{jk}$$

in which b_j is the background events, γ'_{jk} is the expected gamma ray events from the *k*th sources, the log likelihood is

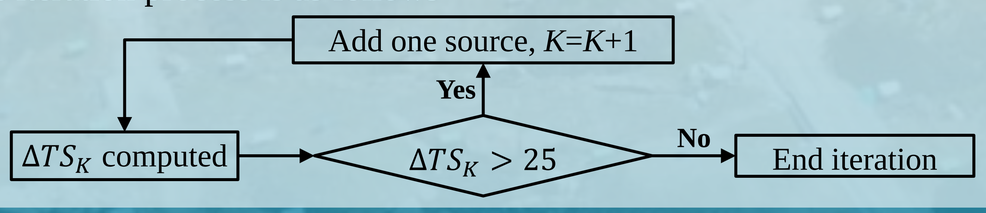
$$\ln\mathcal{L}(\boldsymbol{\Theta}|\boldsymbol{N})=\sum_j\left(N_j\ln\lambda_j-\lambda_j\right),\boldsymbol{\Theta}=(\alpha,\delta,\sigma,I_0,E_0)\ (\beta\text{ fixed to }-2.6)$$

- **Iteration**

The likelihood ratio of K+1 sources model compared to K sources model is defined by

$$\Delta TS_K=-2(\ln\mathcal{L}_K-\ln\mathcal{L}_{K+1}),(K=0,1,2\ldots)$$

The iteration process is as follows



IV. Results

Data

- Full array data, 20210305-0516 + 20210701-0911
- 122.5 Crab transits

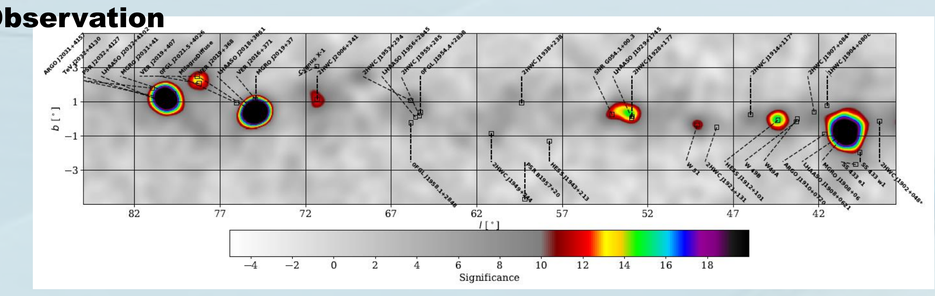
Event selection

- nhit>120 (median energy ~ 2TeV)
- Zenith angle < 50°

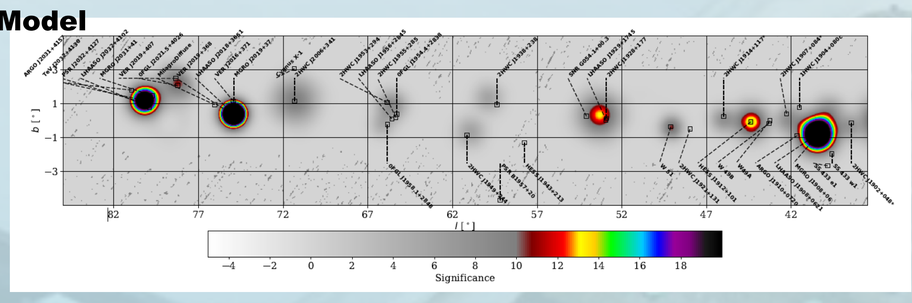
Results

- Only results of partial sky region are shown

Observation



Model



- After applying the iteration method to all ROIs :

TS	Number of sources	Number of new TeV sources
>36	37	3
>49	34	3

Here ‘new’ means that there are no known TeV sources within 1 degree around the source.

References

[1] arXiv:1905.02773v1 [astro-ph.HE] : THE LARGE HIGH ALTITUDE AIR SHOWER OBSERVATORY SCIENCE WHITE PAPER
[2] D .E. Alexandreas et.al., Nuclear Instruments and Methods in Physics Research A, 328 (1993), 570-577
[3] A. A. Abdo et. al., The Astrophysical Journal, 750 (2012), 63 (9pp)
[4] HAWC collaboration, The Astrophysical Journal, 817 (2016), 3 (10pp)
[5] K. M. Go´rski, et. al., The Astrophysical Journal, 622 (2005), 759–771

中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

LHAASO