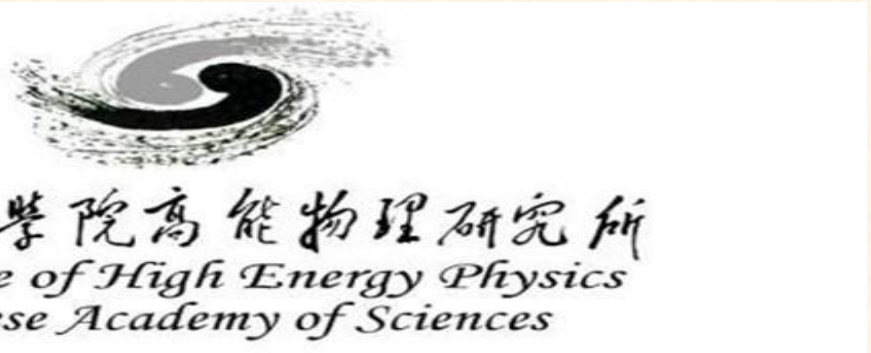
LHAASO performance and first result on extended emission from known halo

Songzhan Chen

on behalf of the LHAASO collaboration



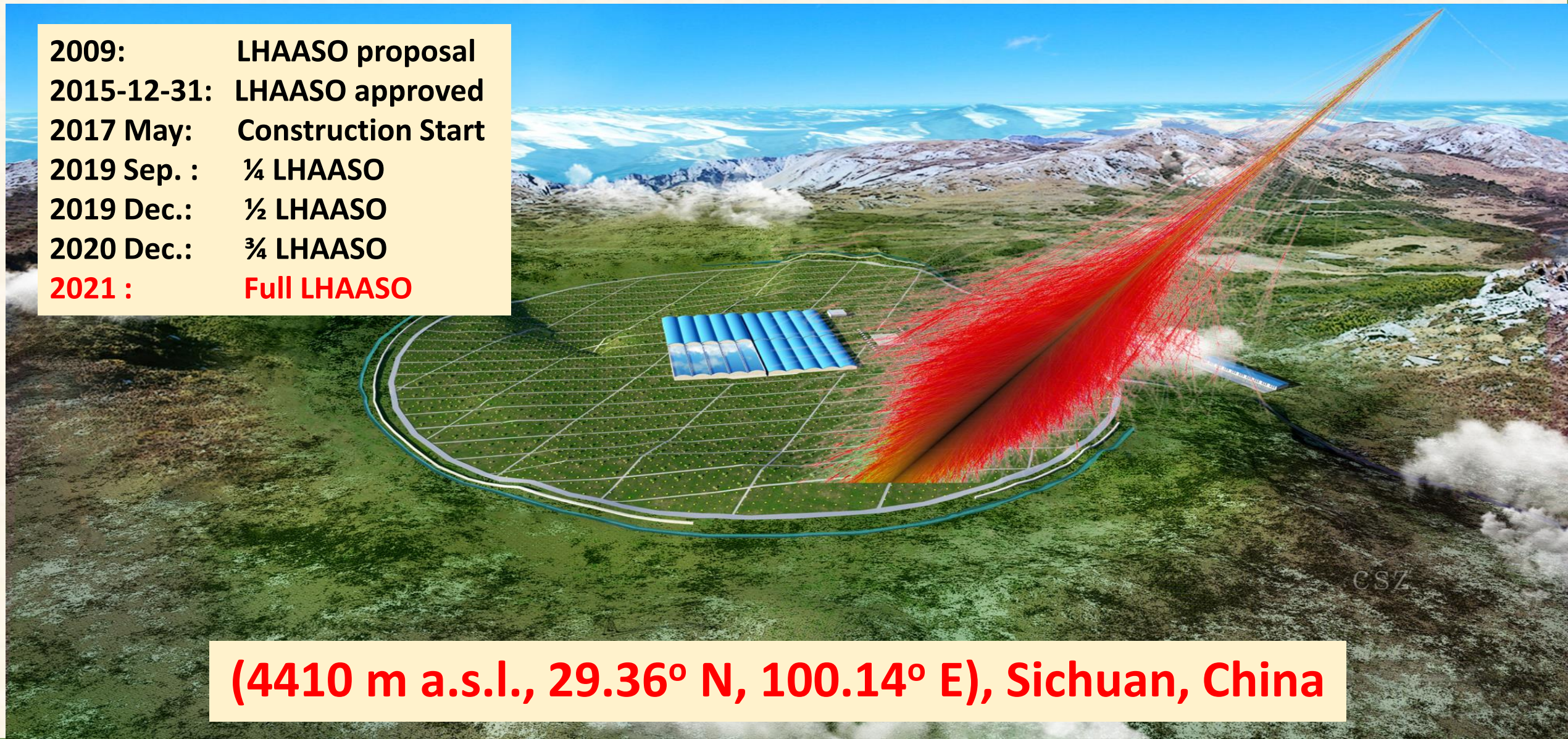
1st Workshop on Gamma-ray Halos around Pulsars,

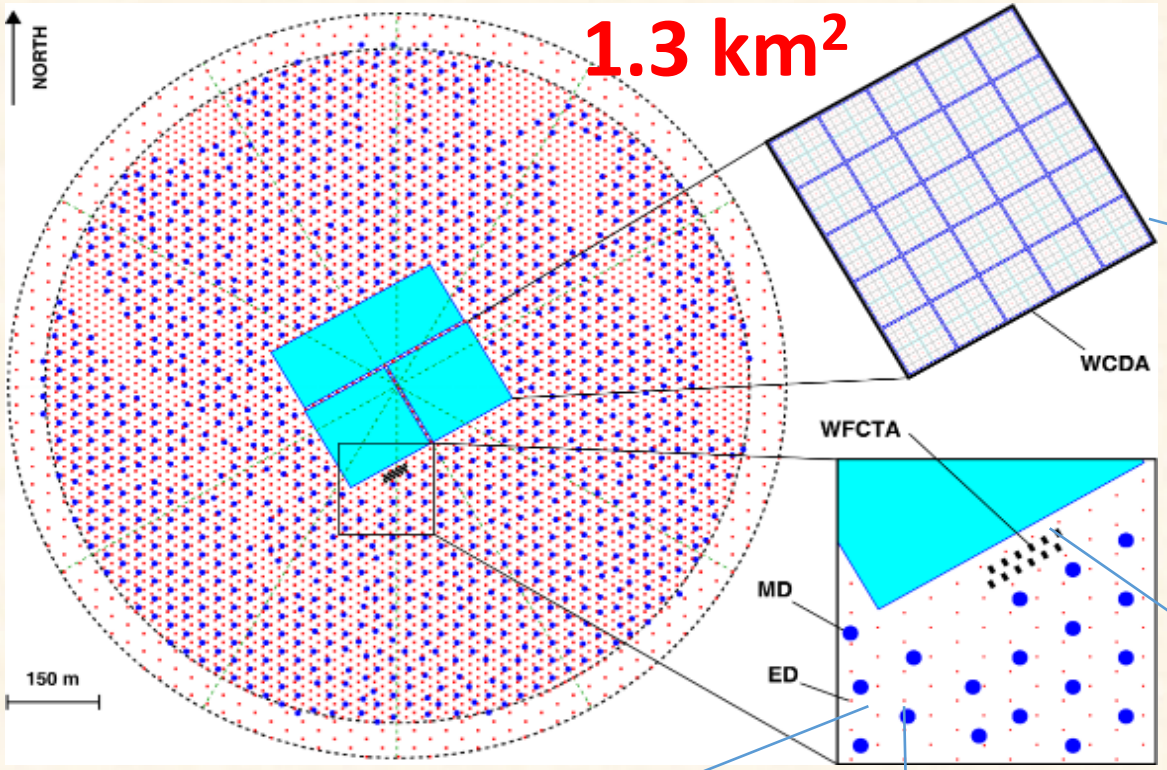
Outline

- 1. LHAASO experiment
- 2. LHAASO performances at >10 TeV
- 3. LHAASO first result on Halo
- 4. Summary

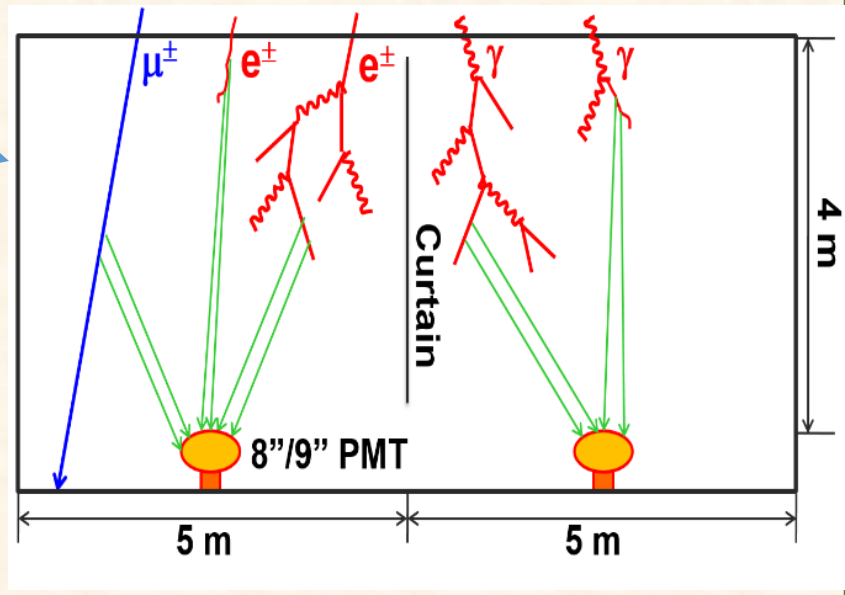
1. LHAASO experiment

LHAASO: Large High Altitude Air Shower Observatory



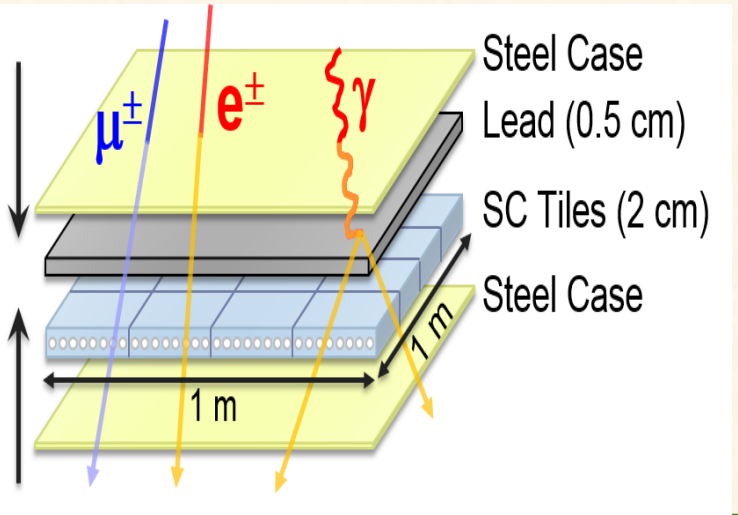


3120 WCDs (25m²/WCD)

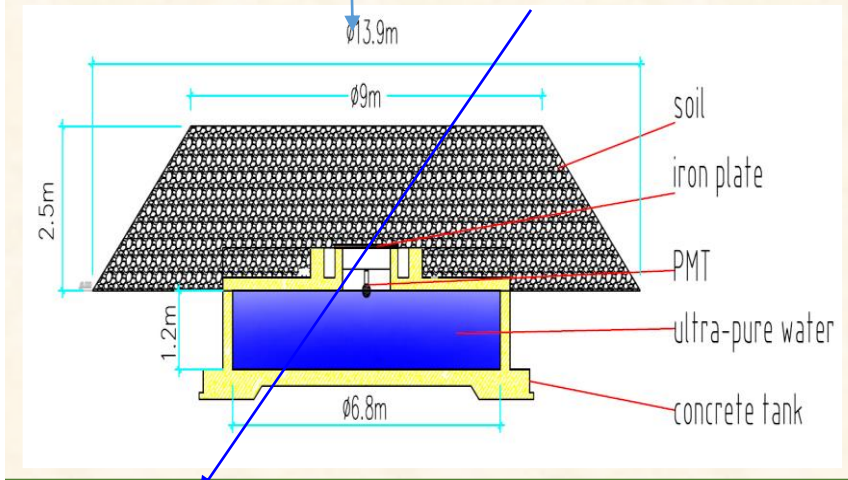


18 WFCTs

5195 EDs (1m²/ED)



1188 MDs (36m²/MD)

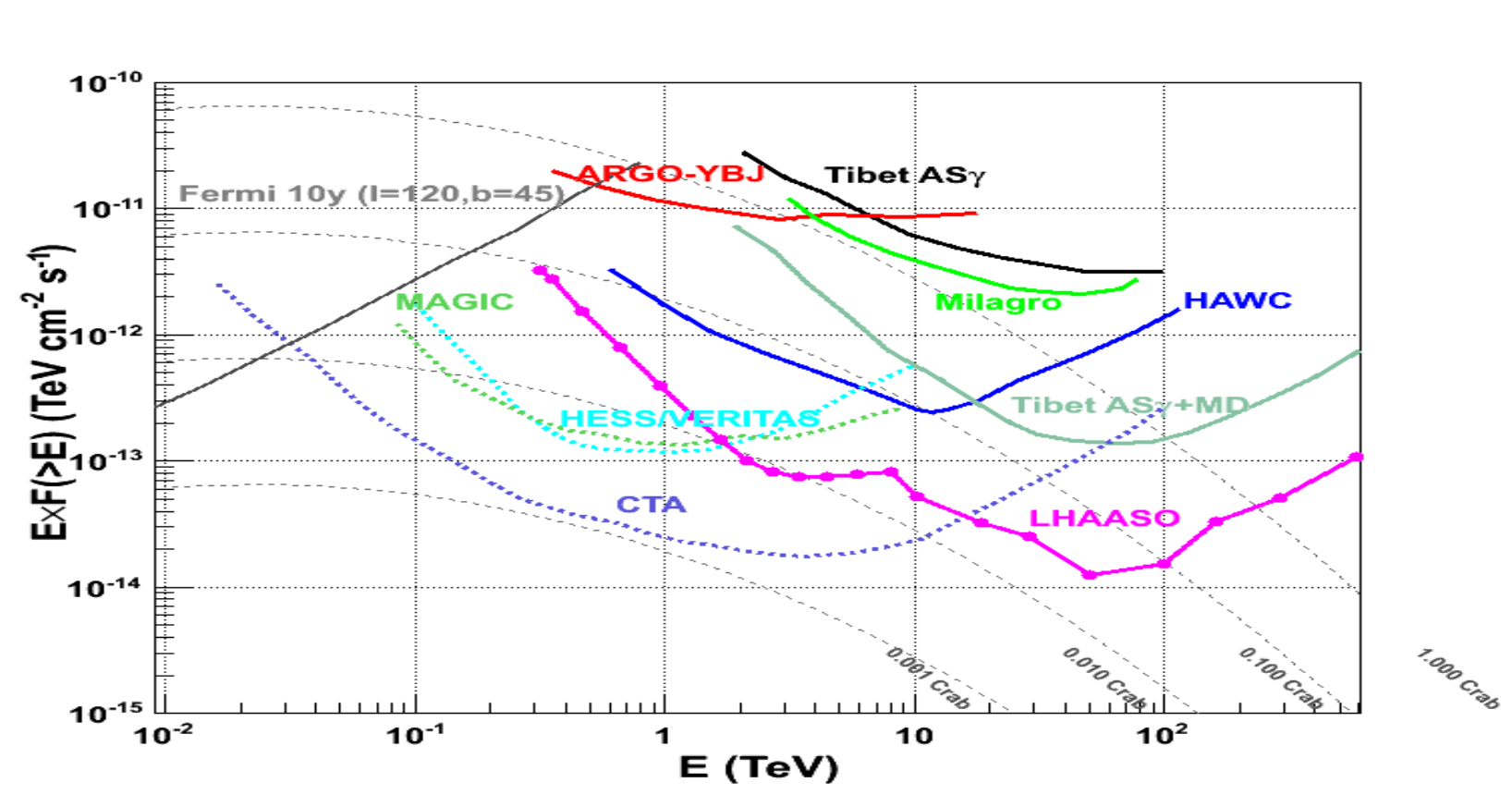


Main goals of LHAASO

- **WCDA: VHE gamma-ray survey (100 GeV-30 TeV)**
  - AGN, GRB, survey new source, …
- **KM2A: UHE gamma-ray survey (10TeV-1PeV)**
  - SNR, PWN, Superbubble, diffuse around 100TeV, …
- **WFCTA: Individual nuclei spectra (10TeV to EeV)**
  - Different configures
  - Combined with WCDA, KM2A

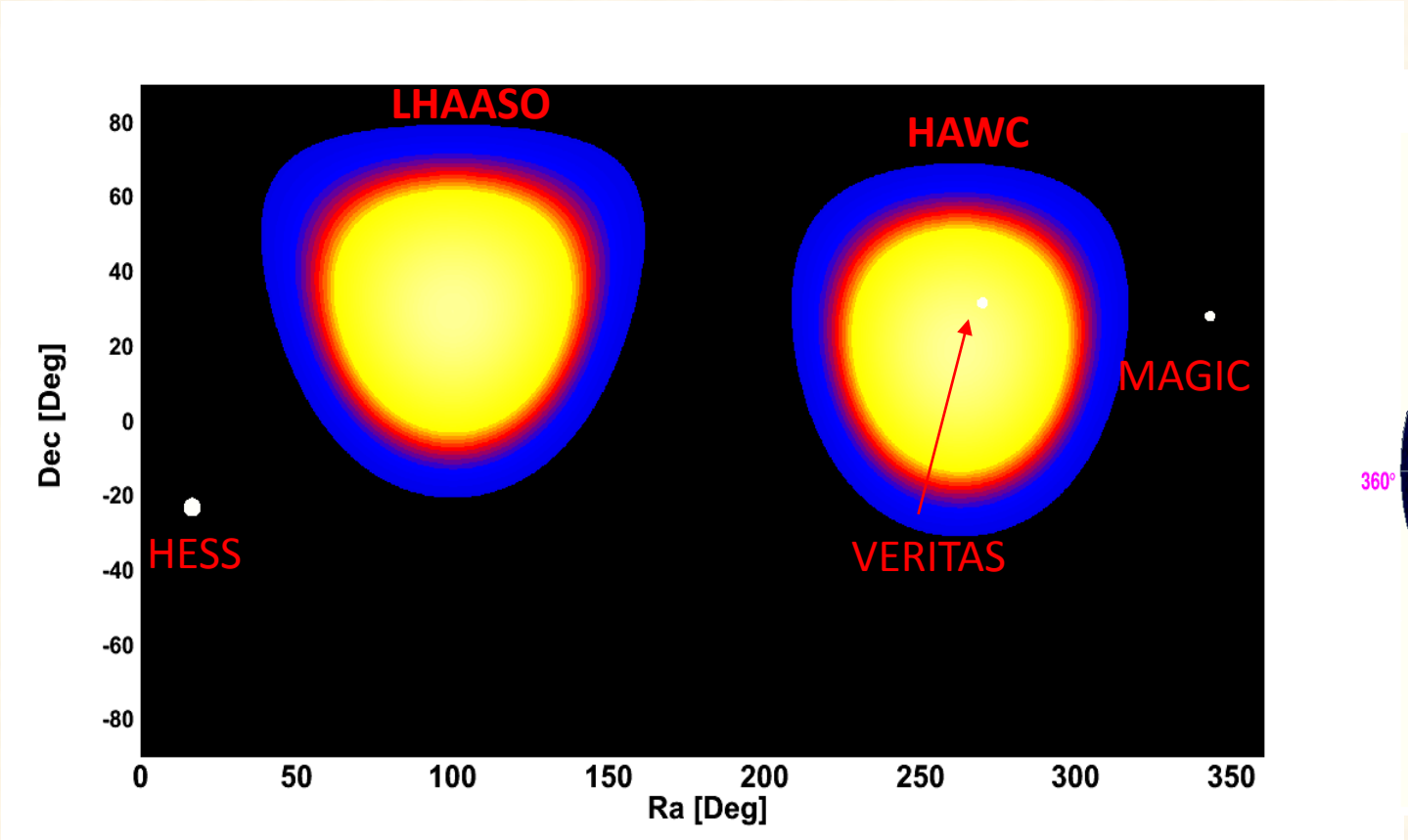
LHAASO: Sensitivity

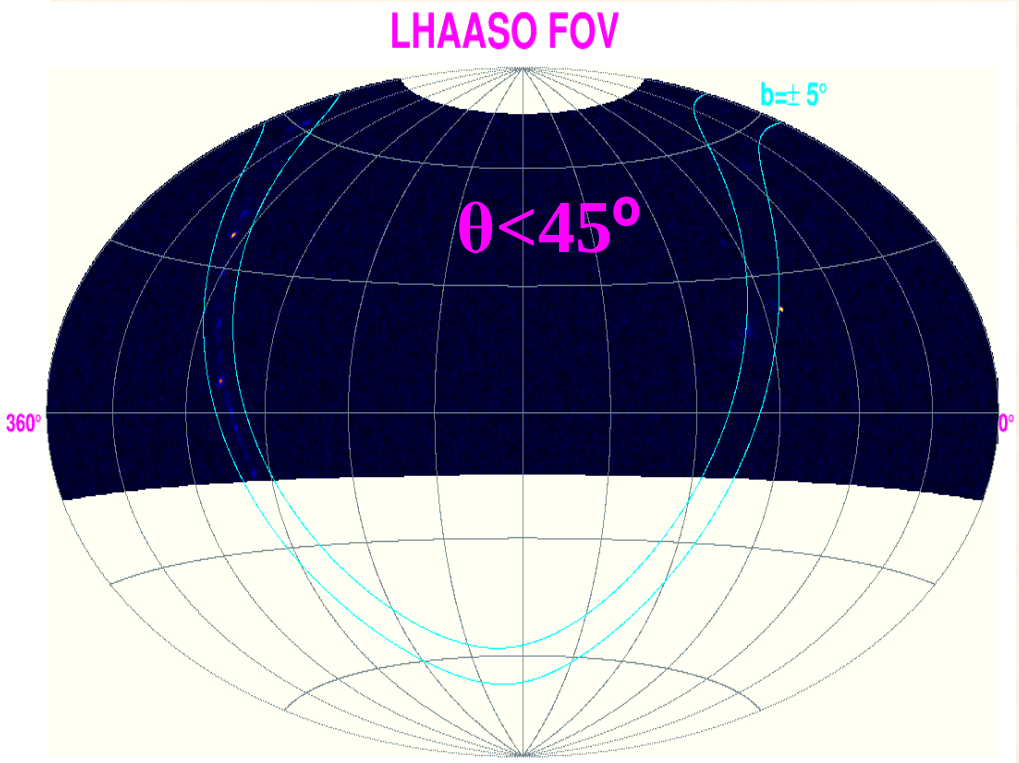
- **WCDA: 1% Crab unit at 2 TeV**
- **KM2A: Unprecedented sensitivity at energy above 20TeV.**



LHAASO-FOV

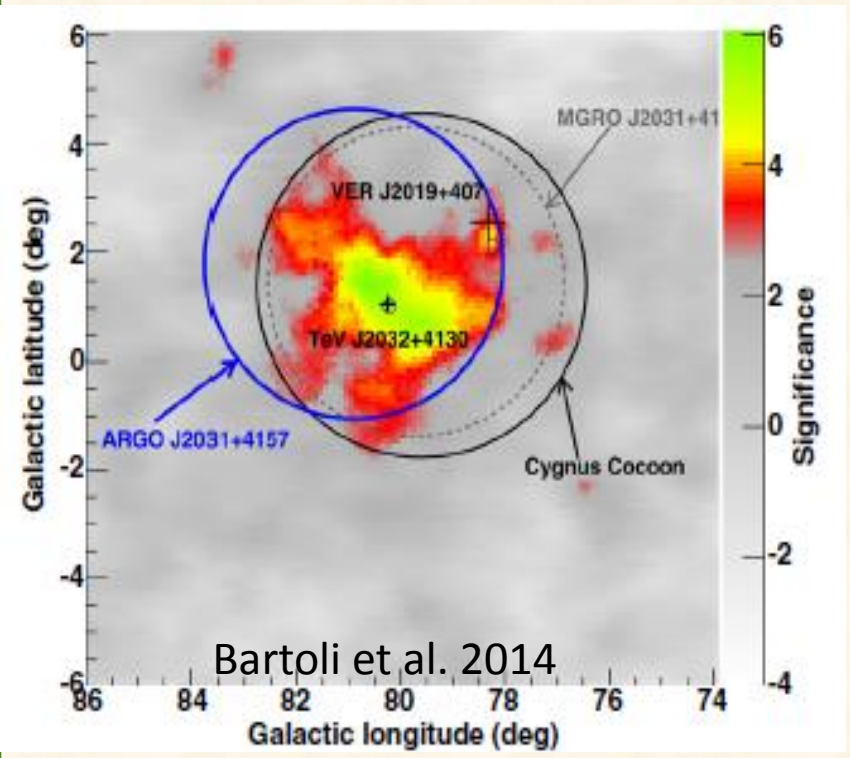
- 1/7 of the sky at each moment
- 60% of the sky every day





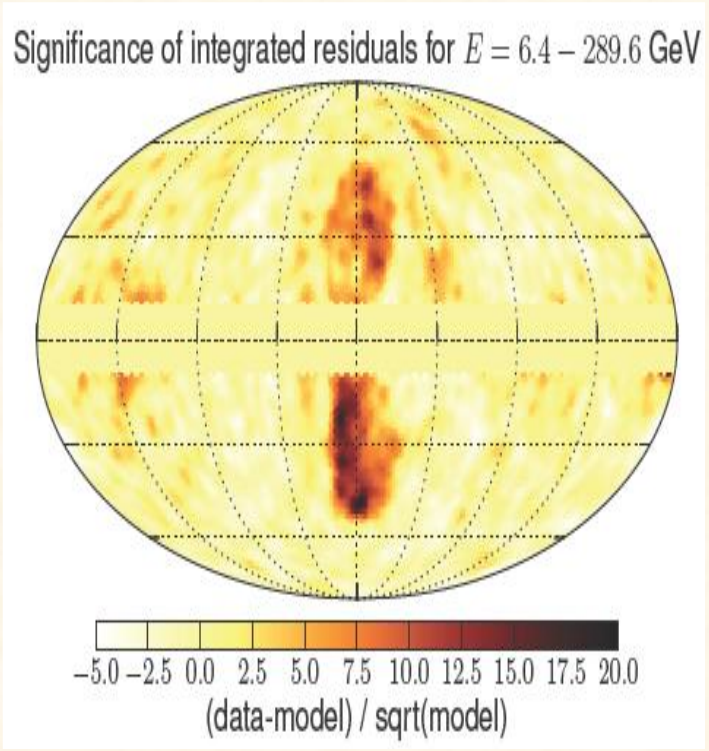
Large FOV is important to observe extended sources

TeV halo &
Super bubble

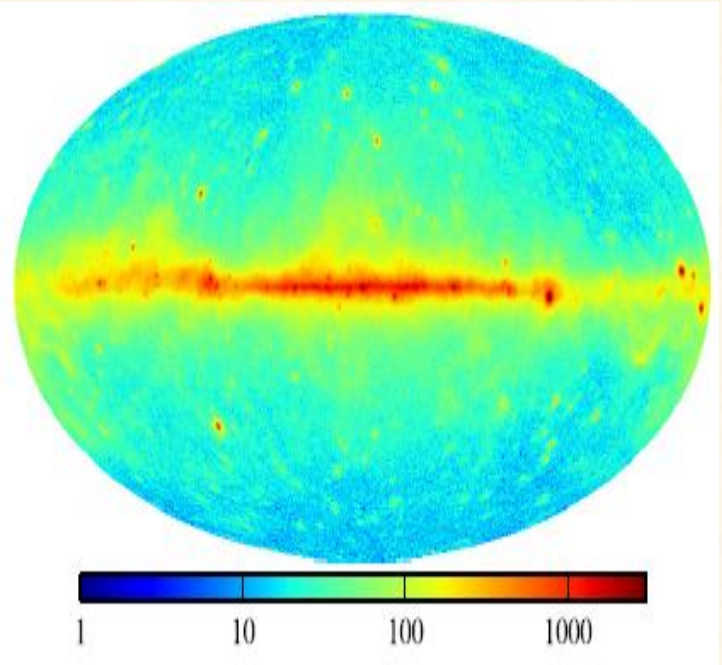


Bartoli et al. 2014

Fermi bubble



GP diffuse



Status of LHAASO-KM2A

1. First stage

   33 EDs, since 2018-02-03

2. ½ KM2A

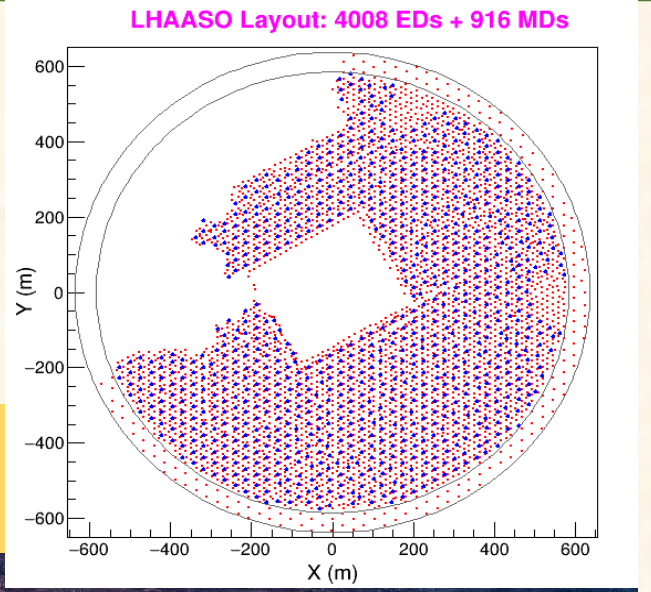
   2365 EDs+578 MDs

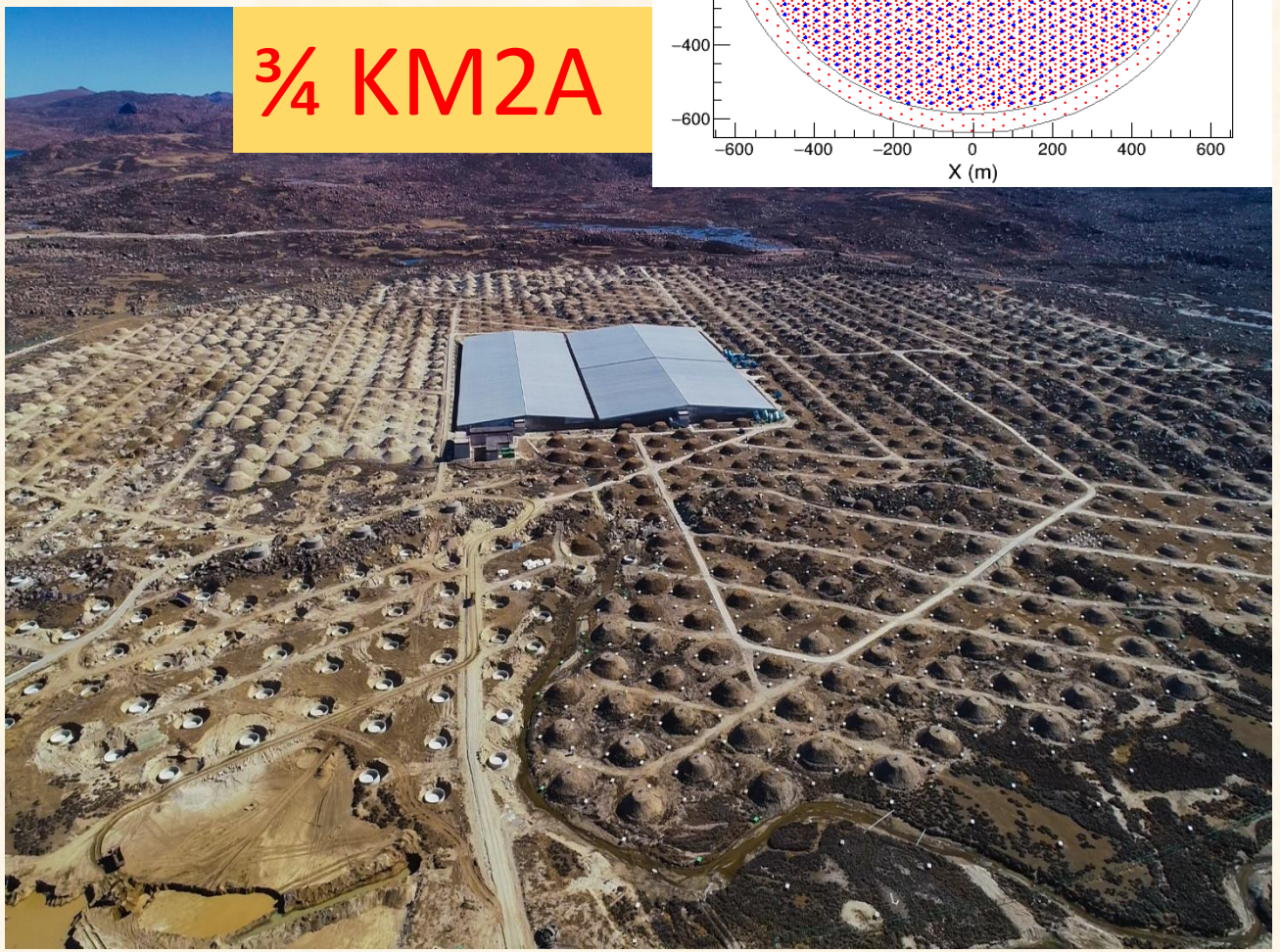
   since 2019-12-27

3. ¾ KM2A

   4008 EDs+916 MDs

   since 2020-12-1





Status of LHAASO-WCDA

- **Pool 1:**

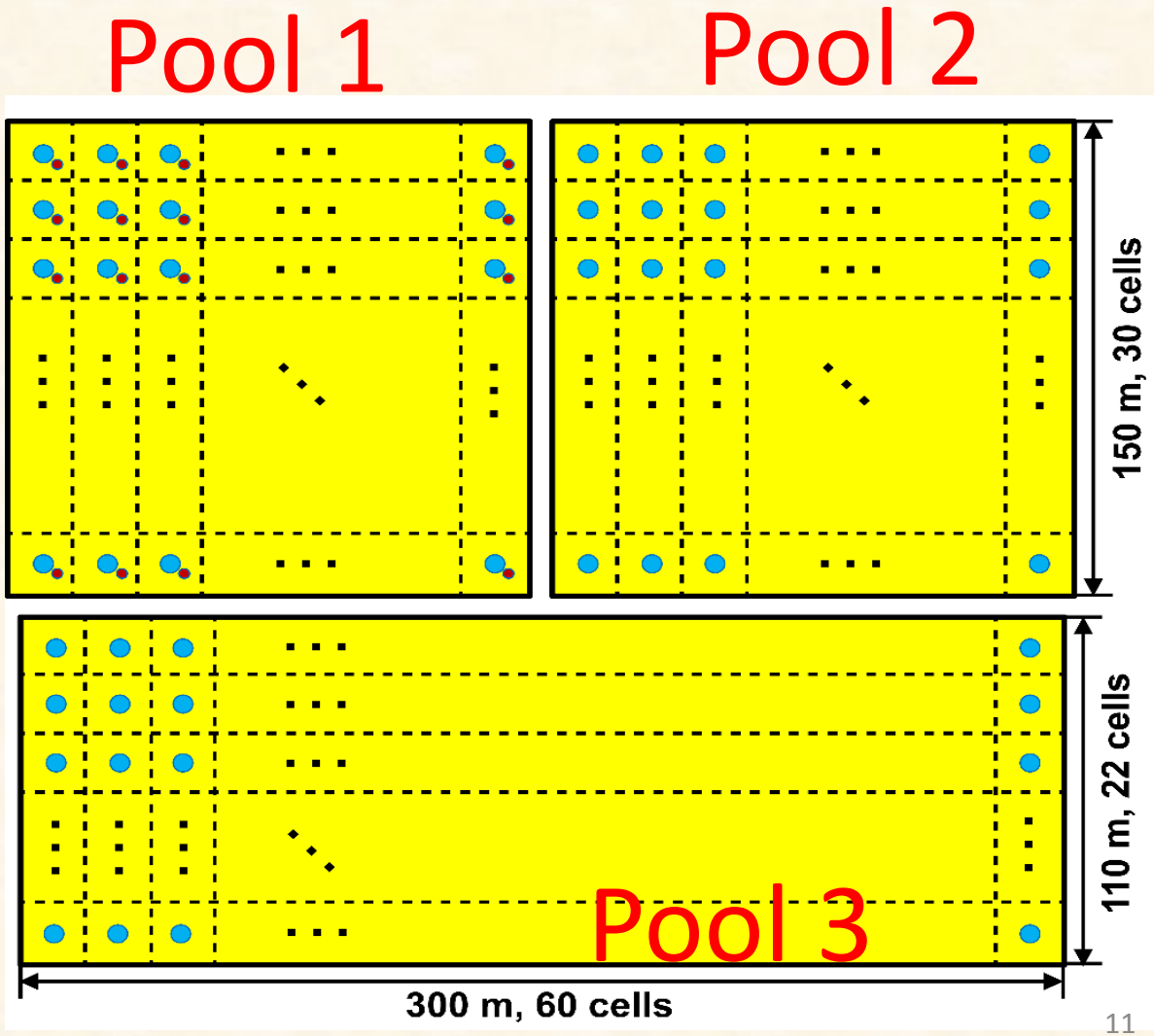
since 2019-04

- **Pool 2:**

since 2019-12

- **Pool 3:**

Water filling

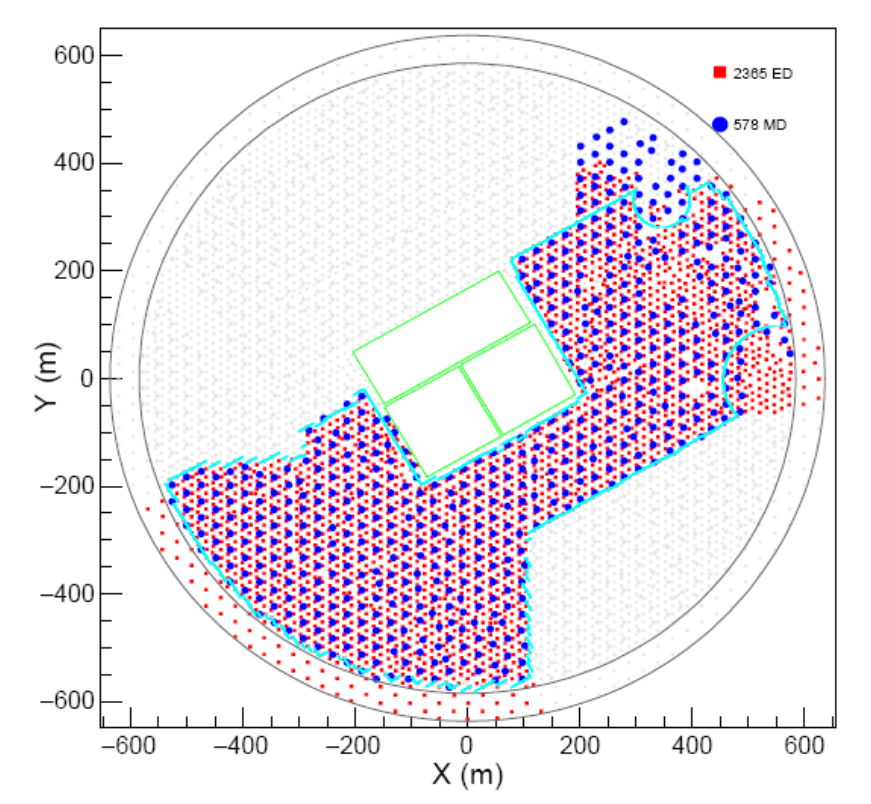


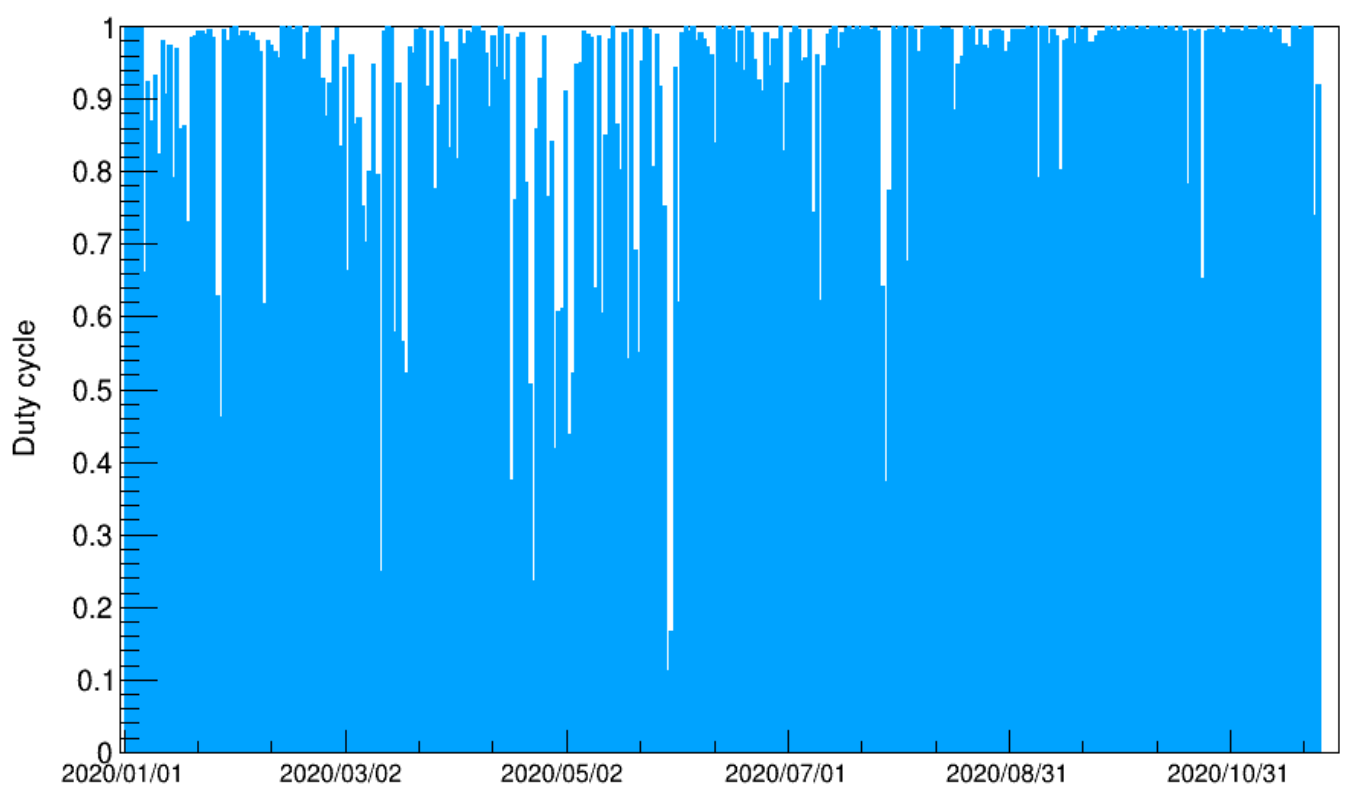
2. LHAASO performance at >10 TeV

½ LHAASO-KM2A Data

Fiducial area is ~0.4 km²

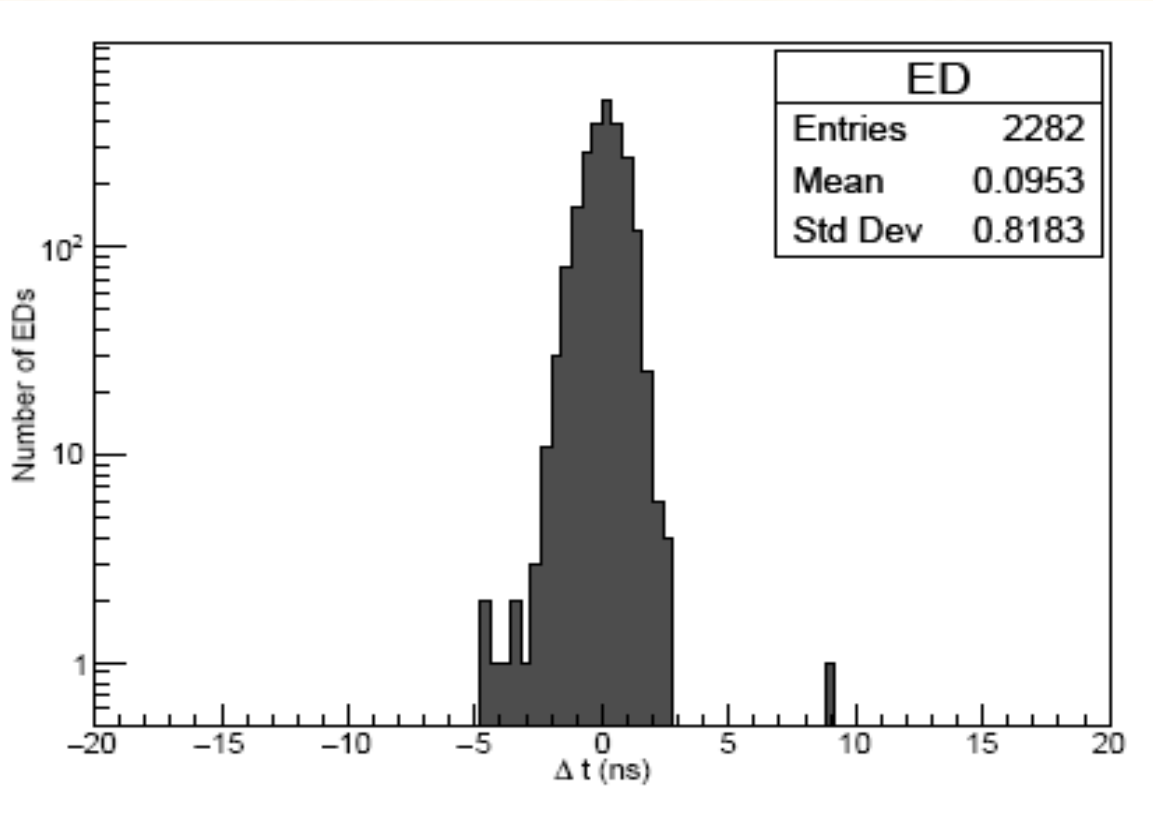
The duty cycle is nearly full recently !





Detector Time Calibration

- Time calibration --> Direction reconstruction.
- The TDC is synchronized via the White Rabbit (WR), with RMS=0.82ns.

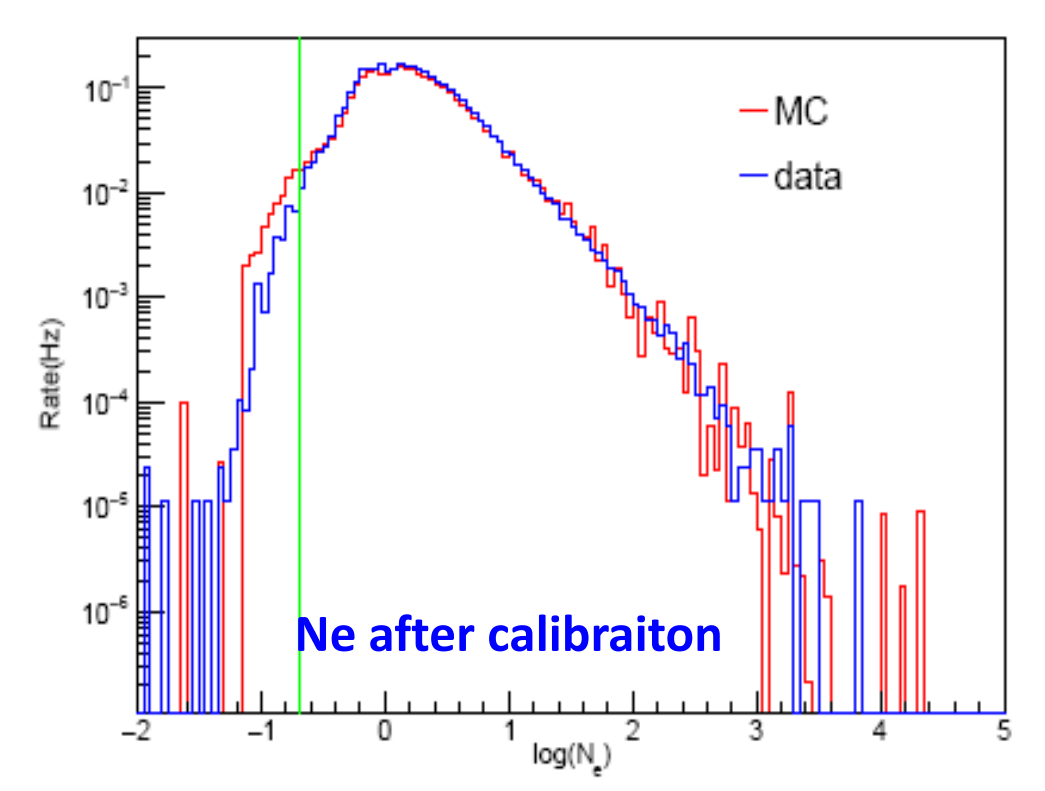


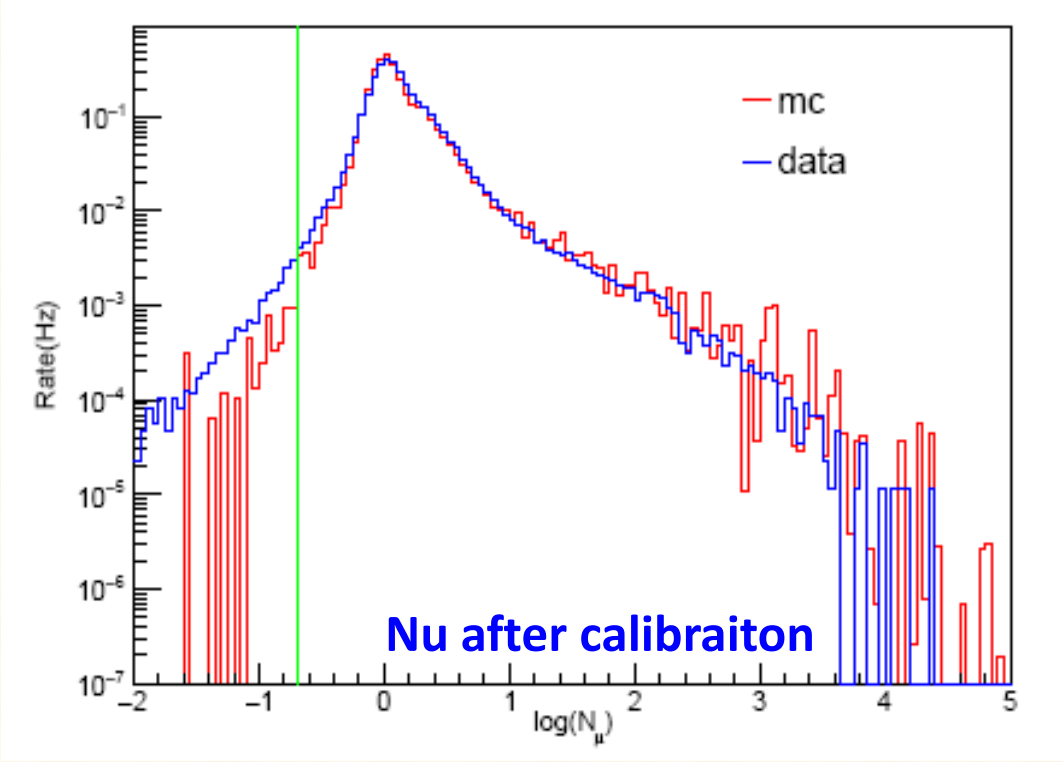
Timing calibration parameters

Detector Charge Calibration

- **Charge calibration --> Energy reconstruction.**
- **The typical charge (ADC) produced by a particle for each ED and MD was calibrated.**

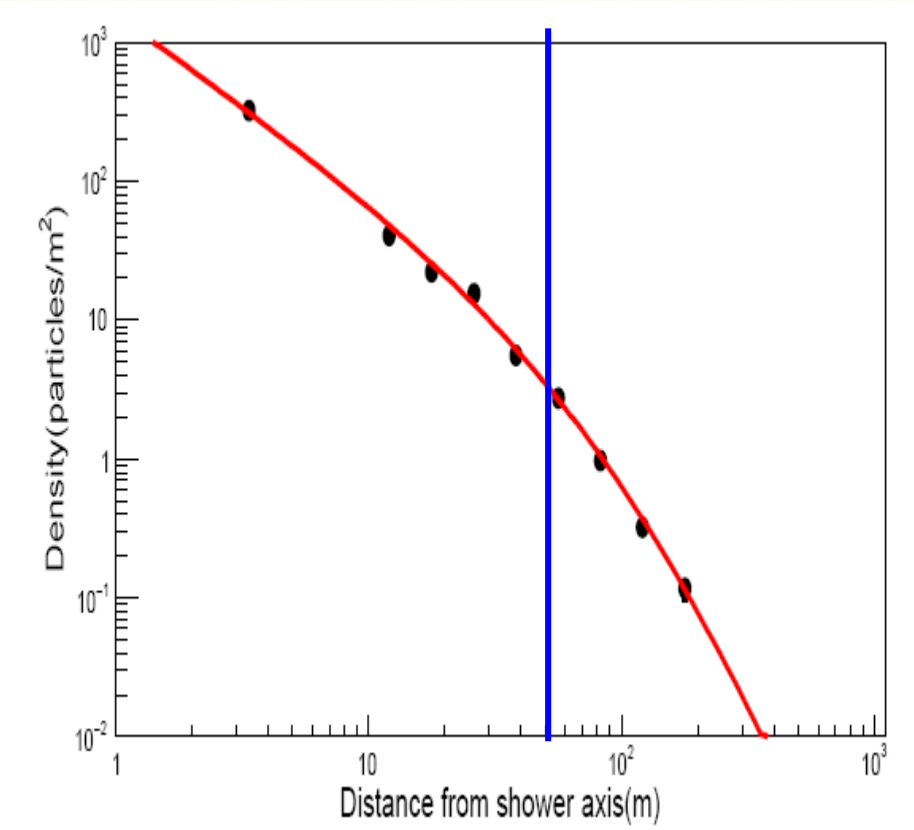
Data Vs MC





Energy reconstruction

r=50 m



NKG-like function to fit LDF

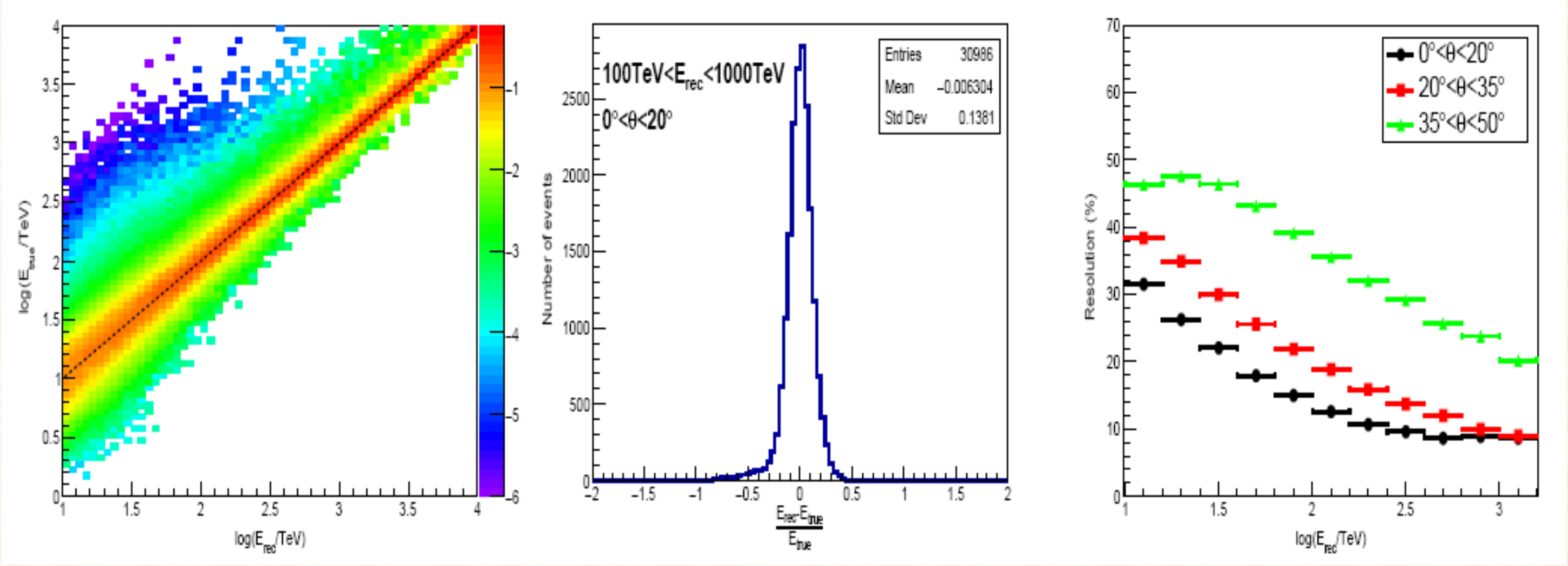
$$\rho(r) = \frac{N_{size}}{2\pi r_m^2} \frac{\Gamma(4.5-s)}{\Gamma(s-0.5)\Gamma(5-2s)} \left(\frac{r}{r_m}\right)^{s-2.5} \left(1+\frac{r}{r_m}\right)^{s-4.5}$$

ρ_{50} is used to reconstruct energy

$$\log(E_{rec}/TeV) = a(\theta)\cdot(\log(\rho_{50}))^2 + b(\theta)\cdot\log(\rho_{50}) + c(\theta)$$

Energy resolution

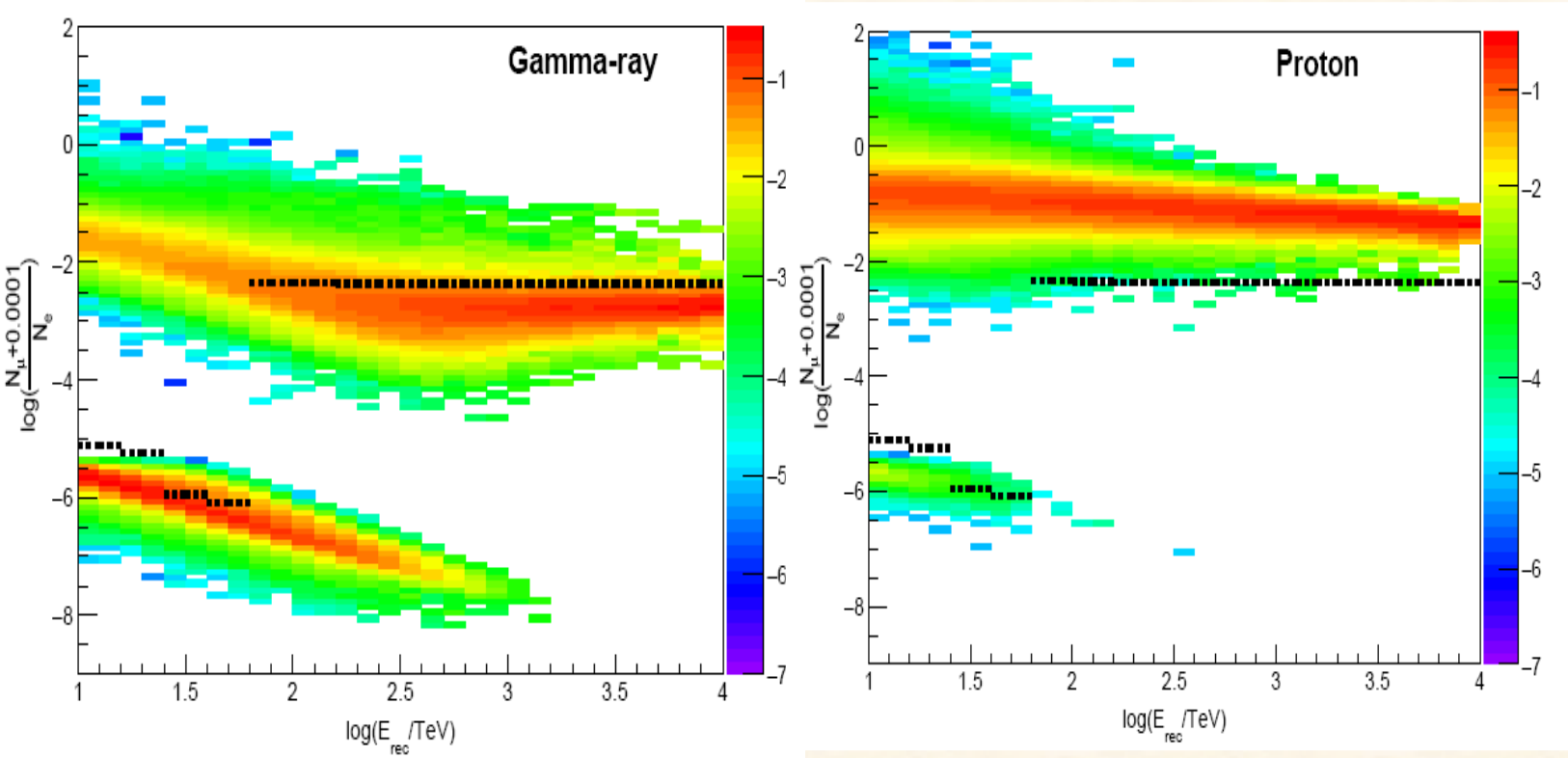
θ<20°: 24% @ 20 TeV, 13% @ 100 TeV.

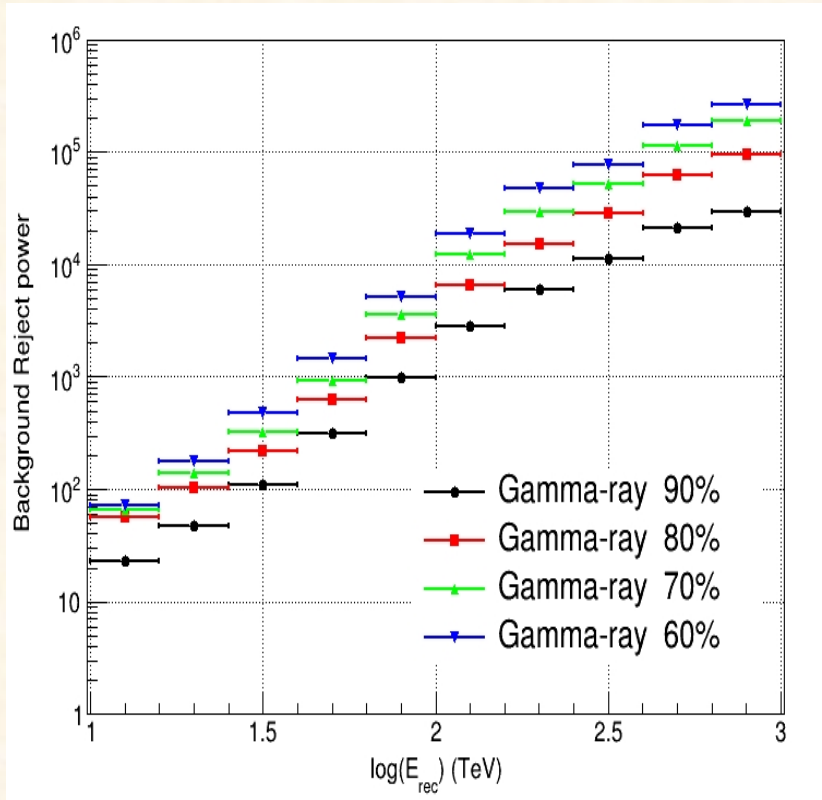


Gamma-ray/background discrimination(1)

$$R = \log\left(\frac{N_\mu + 0.0001}{N_e}\right)$$

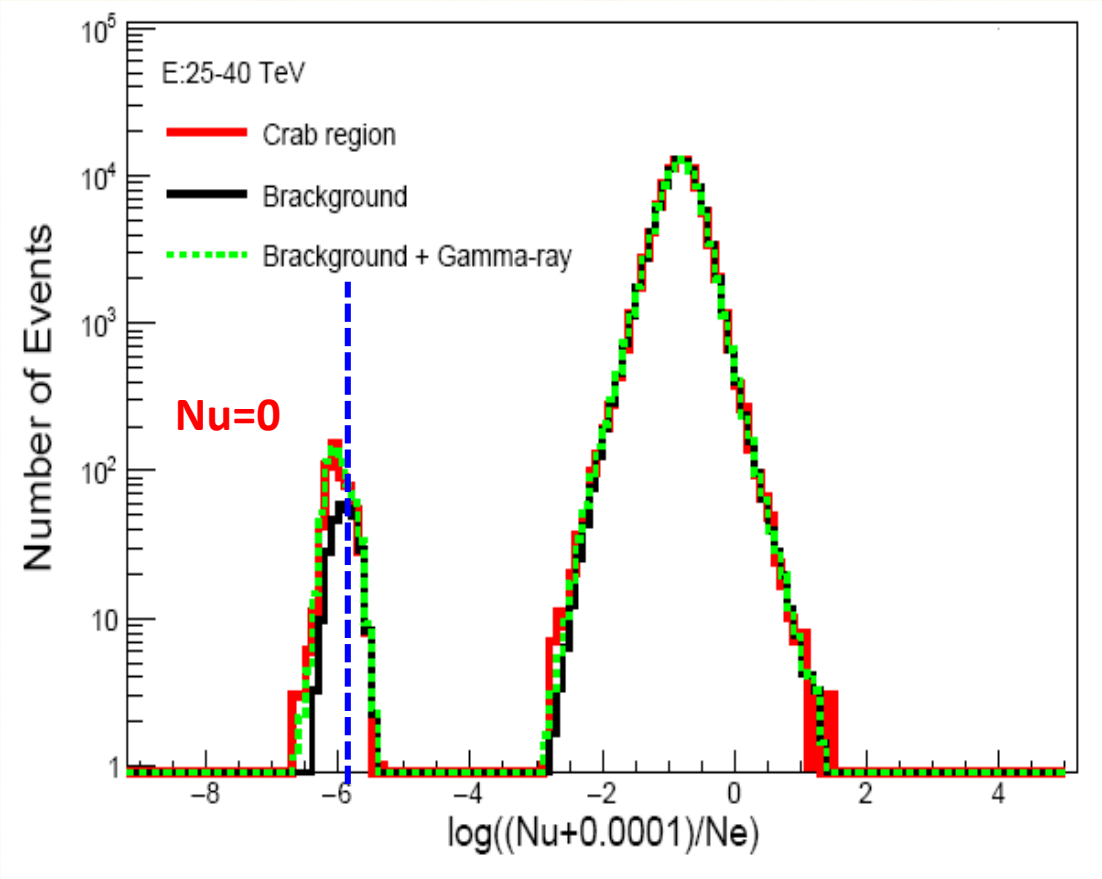
Background reject power
~10^4 @100TeV

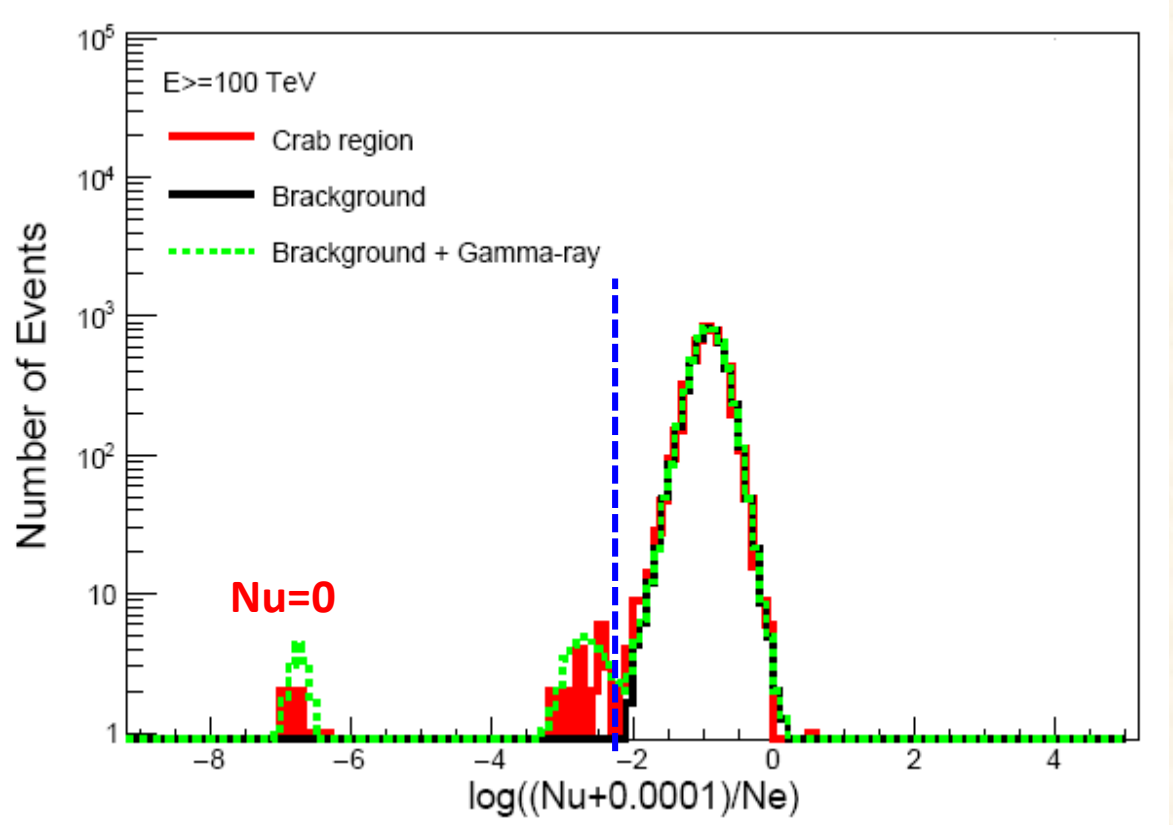




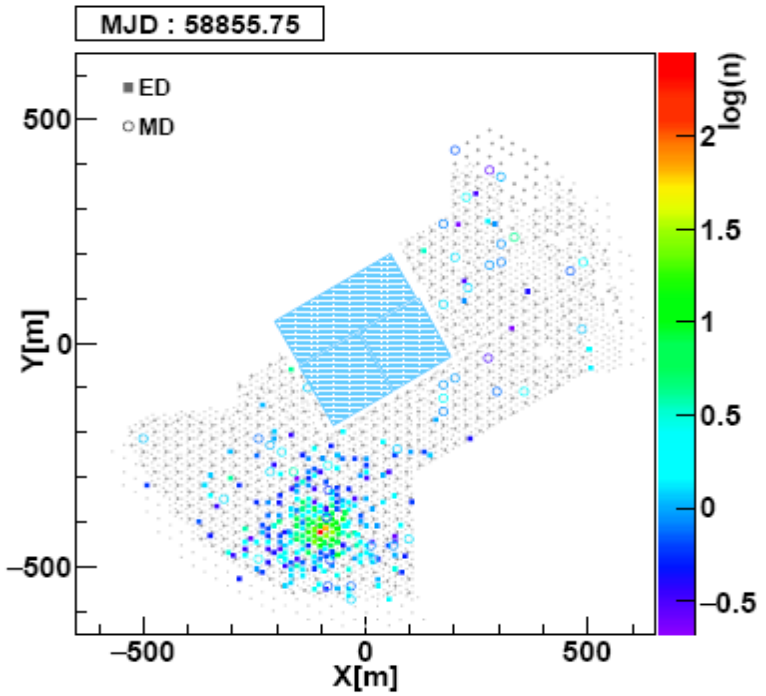
Gamma-ray/background discrimination(2)

Crab region Data vs MC

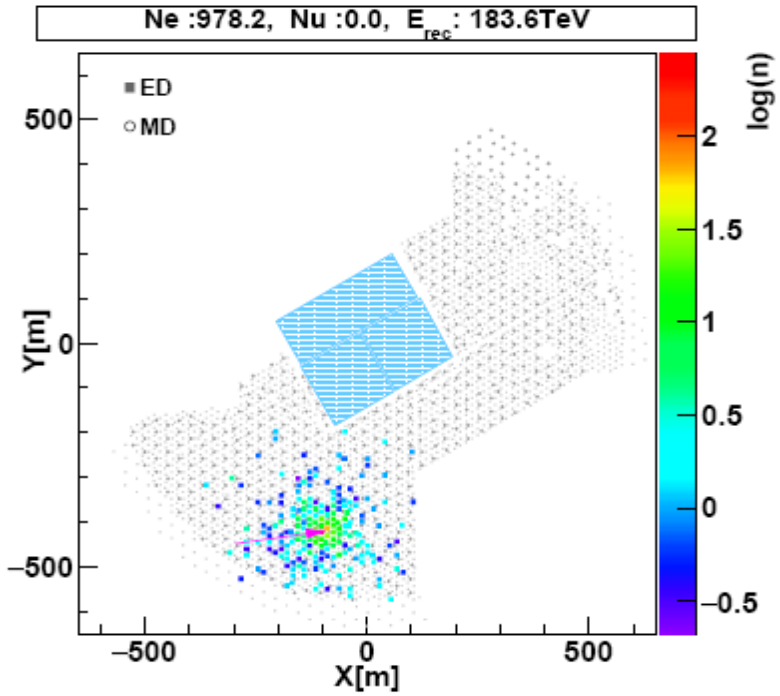




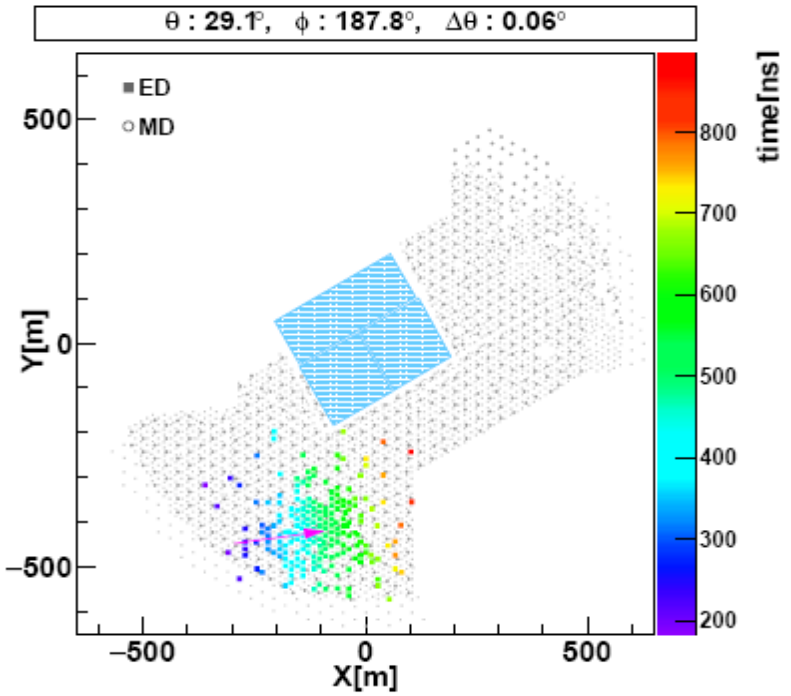
A Gamma-like event:
184±31 TeV from Crab



Particle number map



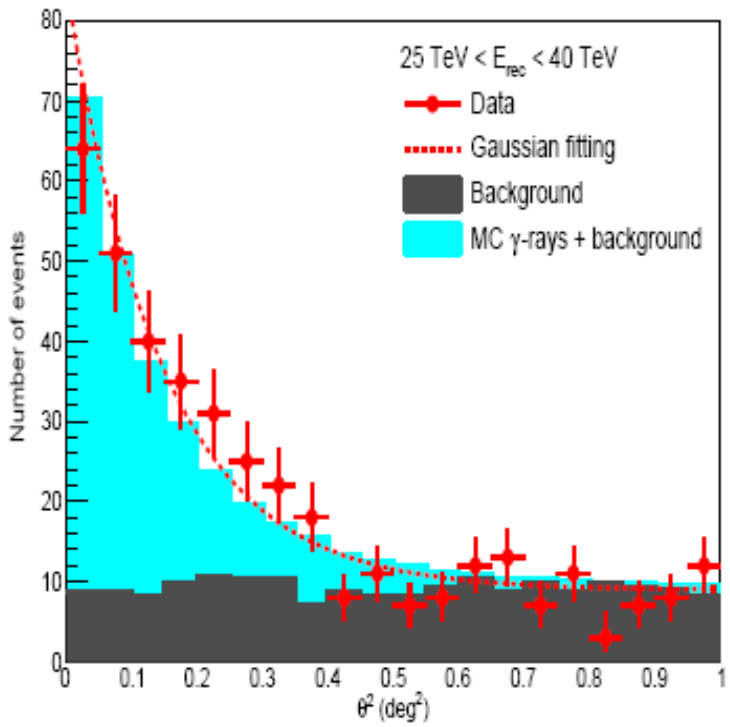
Particle number map
(with noise clean)

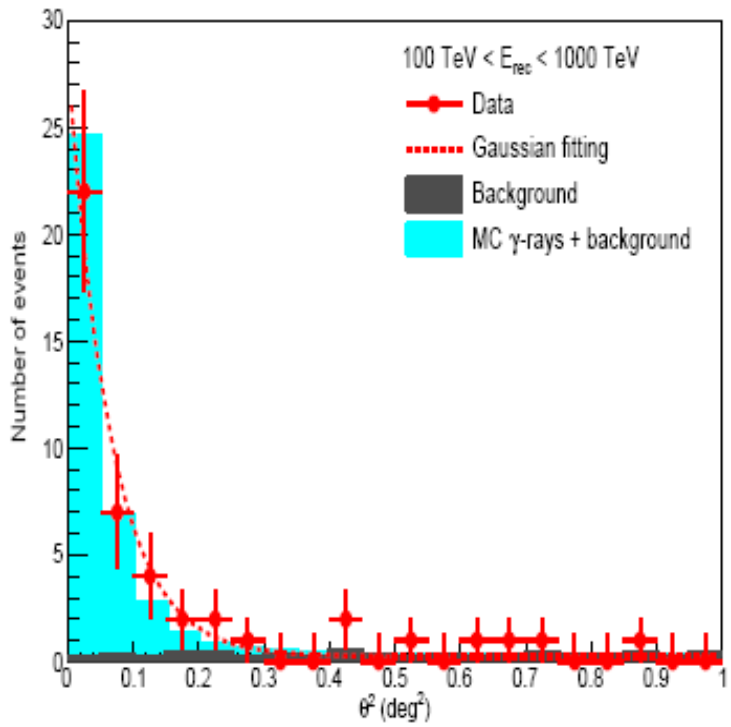


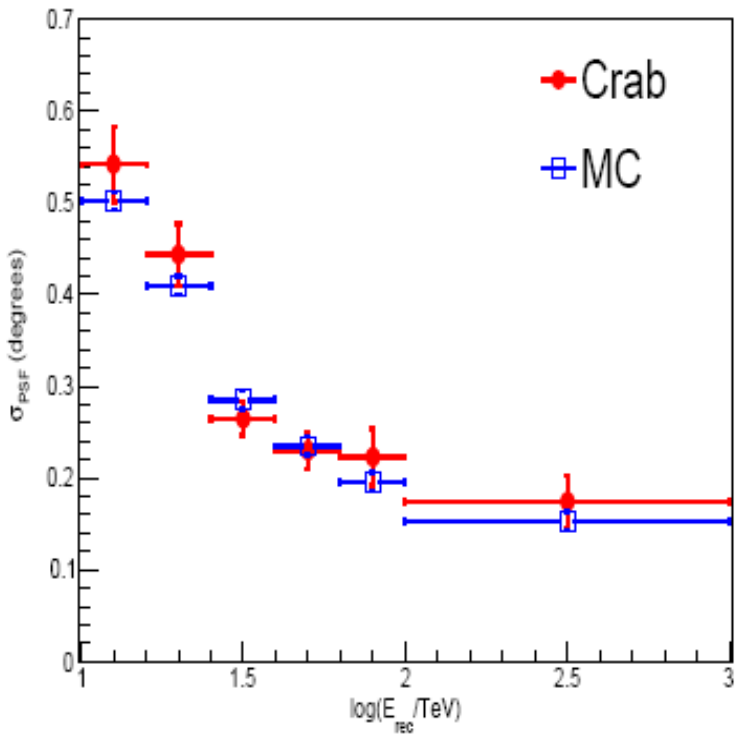
Particle arriving time map

Angular Resolution

σ=0.4° @20 TeV, σ=0.2° @100 TeV

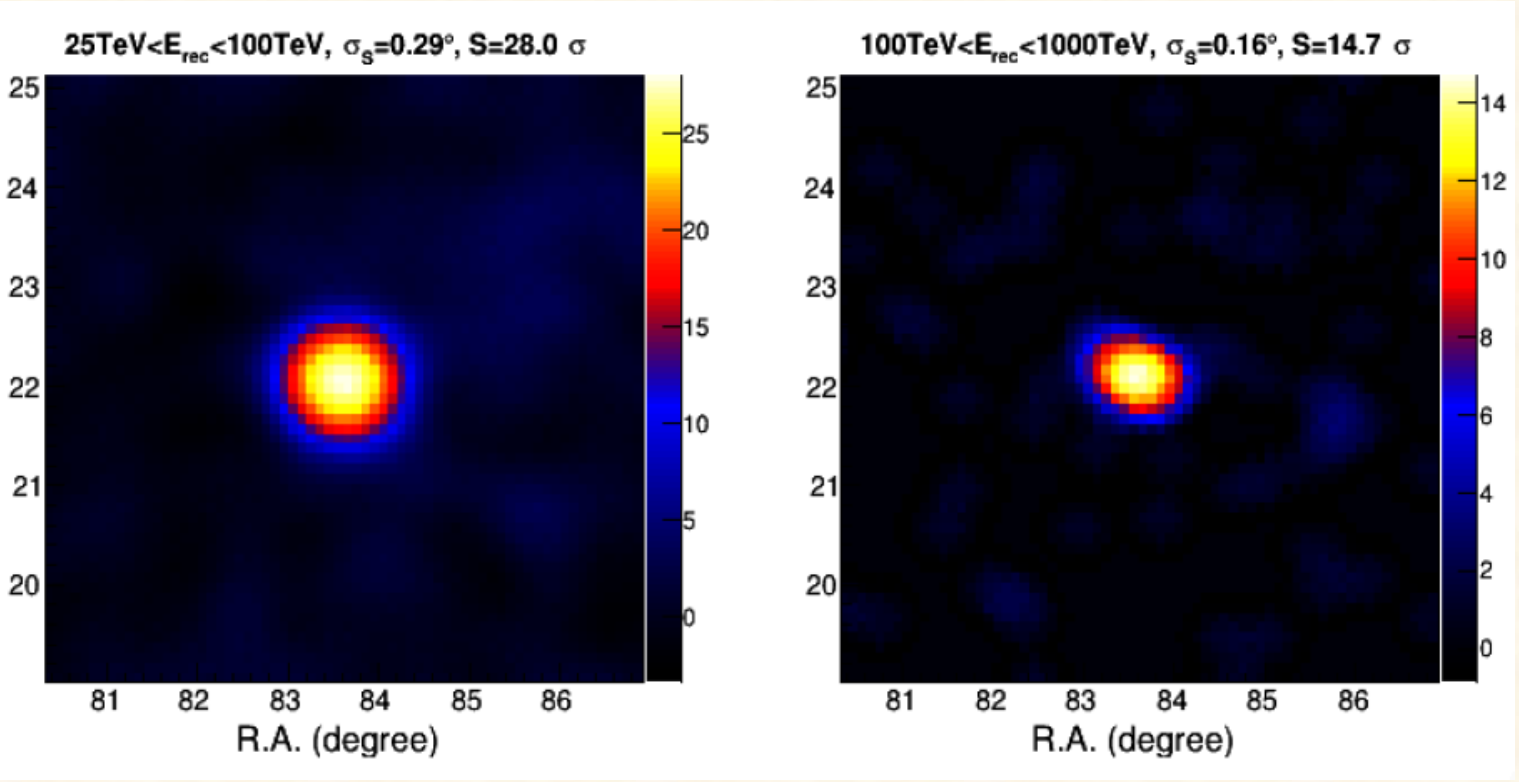


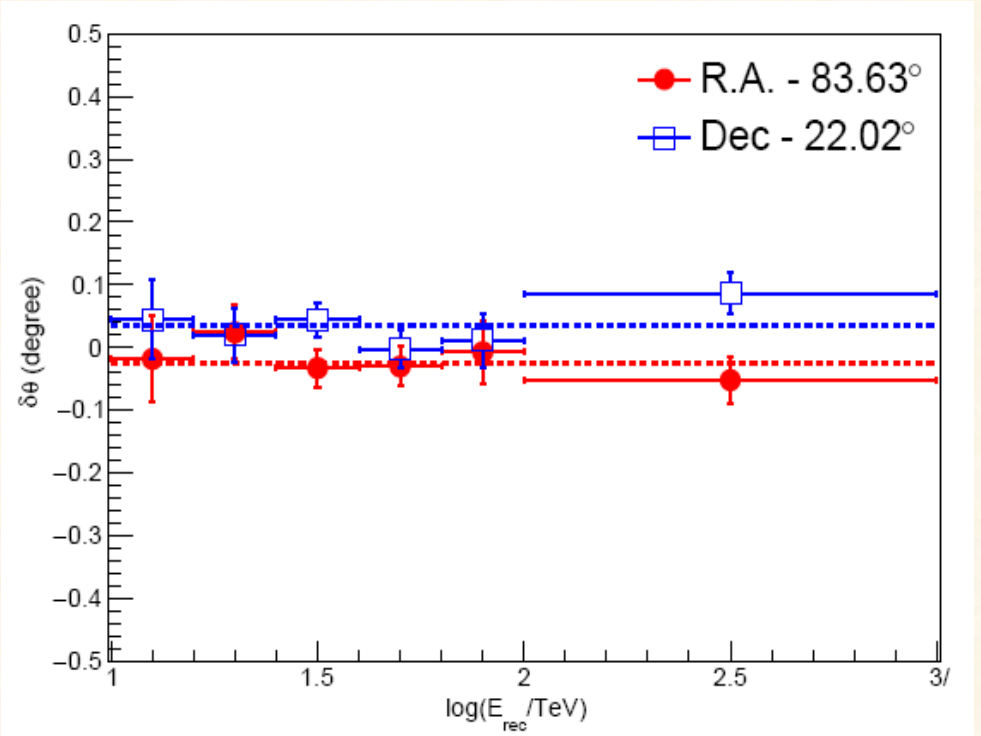




Pointing Accuracy

Using First 5 months data. Pointing error <0.1°



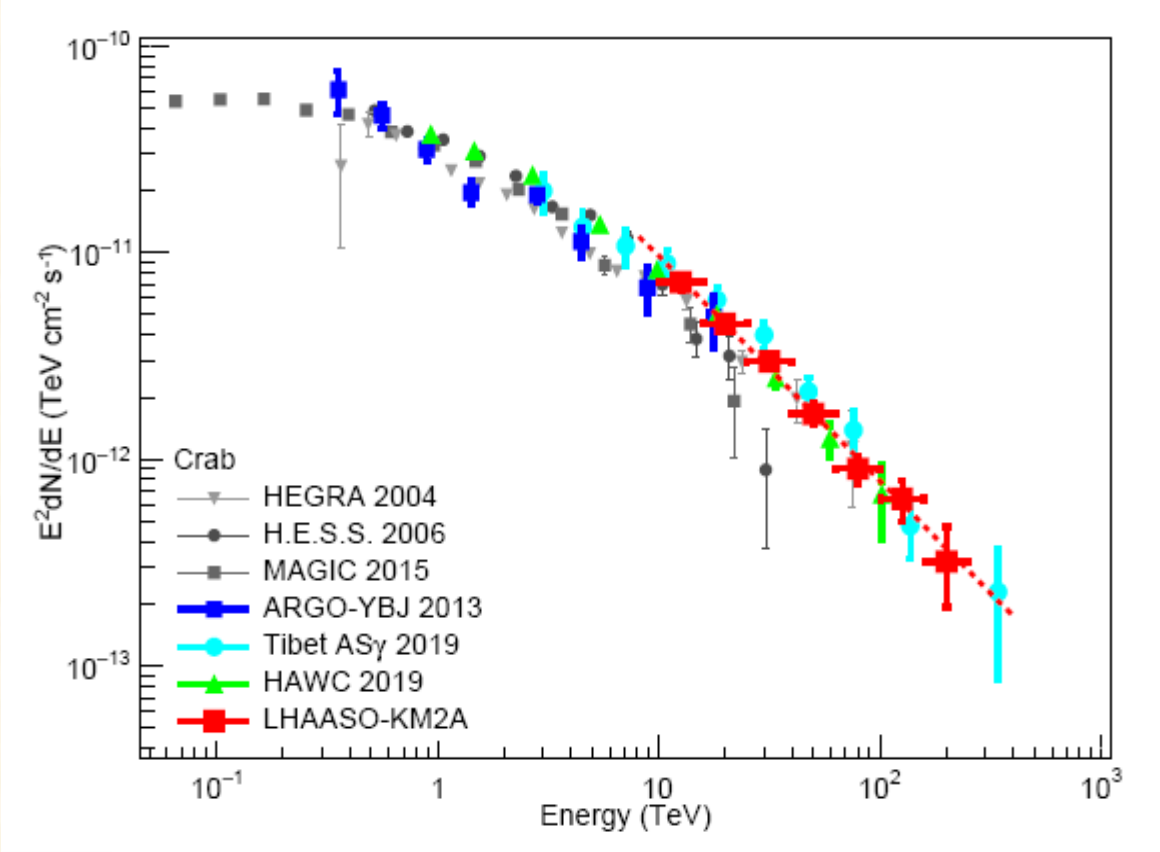


SED

Forward-folded procedue: least square method basing on Erec bins for both data and MC.

The SED is about independent of the presumed shape funtion.

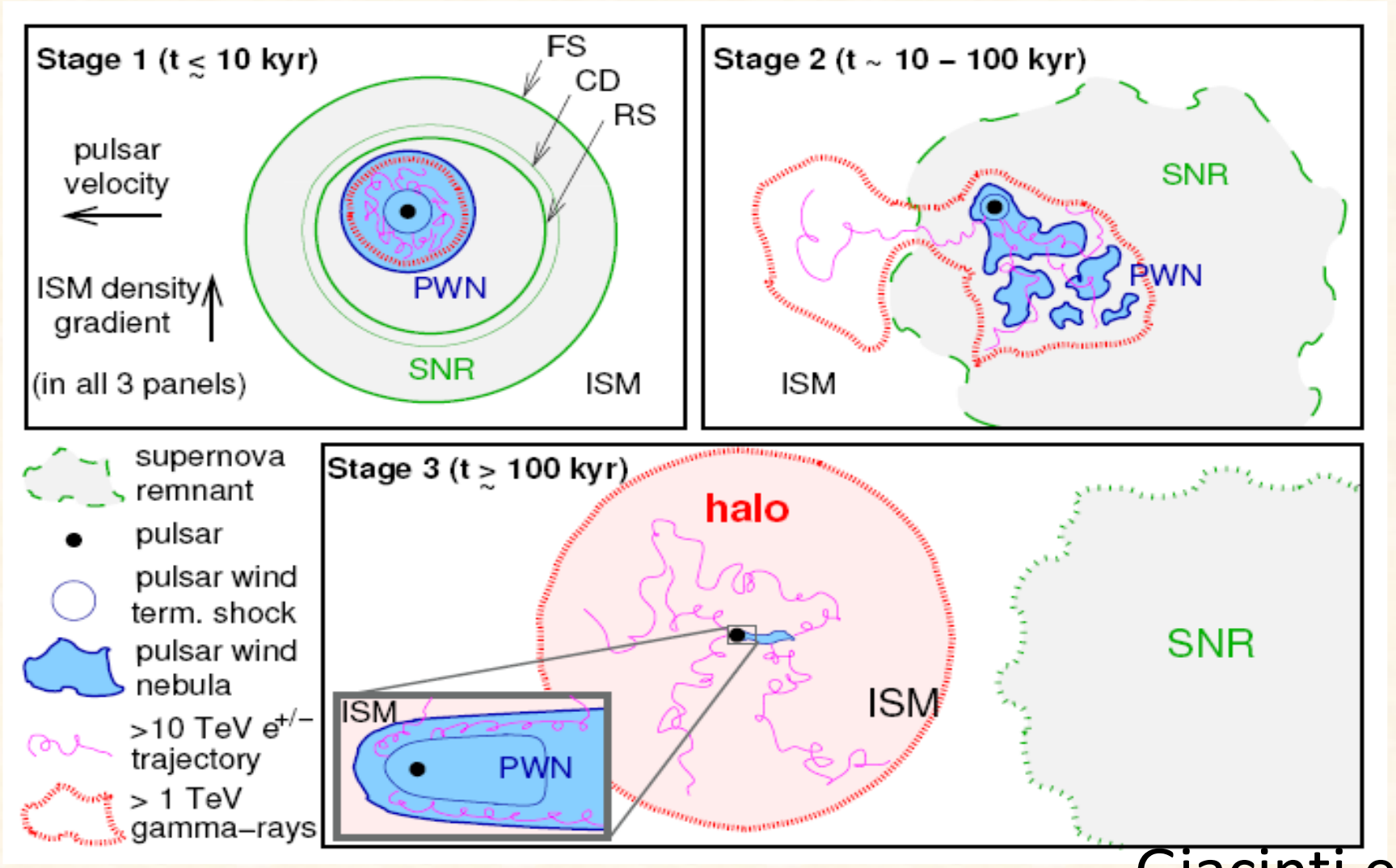
$$\chi^2 = \sum_{i=1}^{7} \left(\frac{N_{S_i} - N_{MC_i}(J,\alpha)}{\sigma_{N_{S_i}}} \right)^2$$



LHAASO coll. 2020
arXiv:2010.06205 [astro-ph.HE]

3. LHAASO first result on Halo

Gamma-ray Halos around Pulsars



Giacinti et al. 2019

LHAASO superiority on Halo observation

- **Large FOV :**

  Extended sources **(Geminga)**

- **Wide energy range (0.1-1000TeV):**

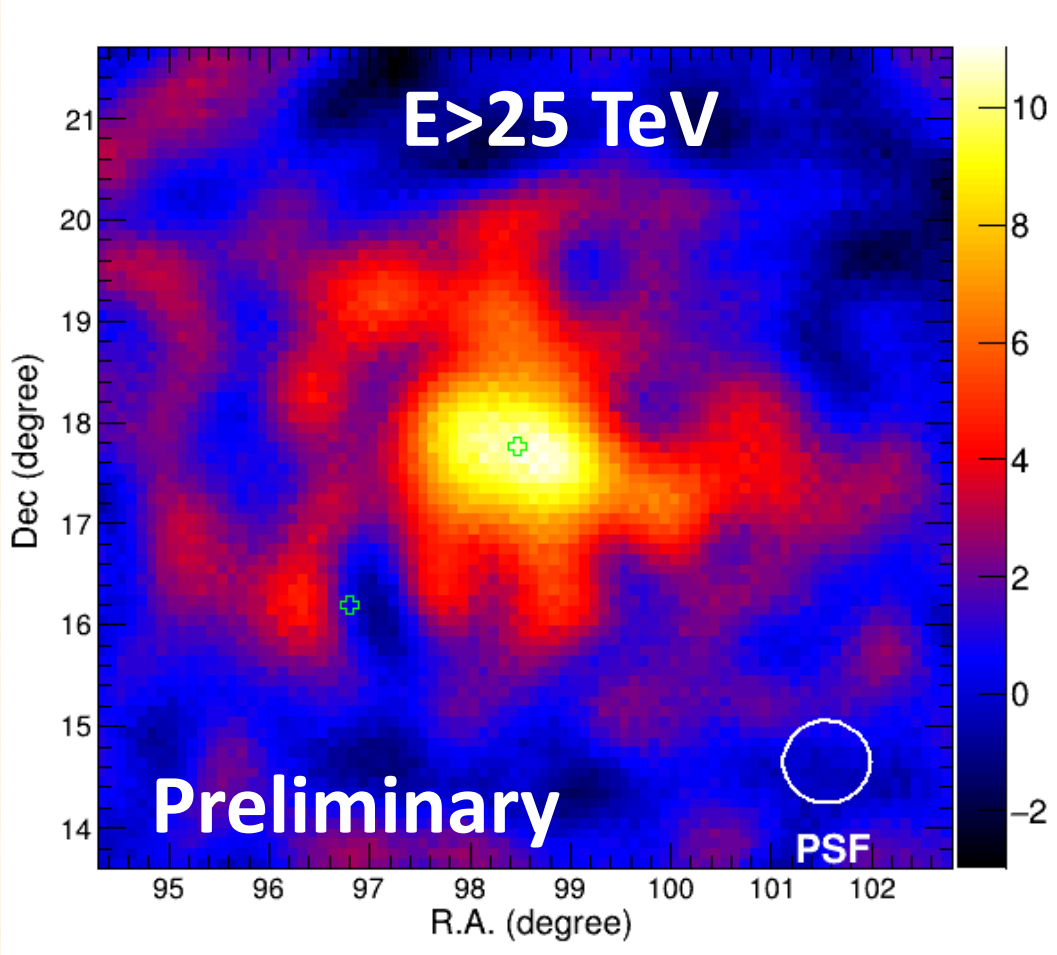
  Evolution of the morphology

- **Highest energy (>100TeV):**

  Cooling, Diffusion, Acceleration

Preliminary observation of Geminga

- Extended gamma-ray is significantly observed at energy above 25 TeV.
- More details morphology and SED are still under study.



Summary

- ½ LHAASO-KM2A has been operated for 11 months, and the sensitivity at energy above 100 TeV has significantly exceed Tibet ASγ and HAWC.
- The observation on Crab Nebula exhibit its performances, including angular resolution, energy resolution, gamma-ray/background discrimination power, pointing accuracy.
- First observation on the Geminga show its potential power on the TeV halo observation:

Thank you!