中山大學 物理与天文学院
SUN YAT-SEN UNIVERSITY SCHOOL OF PHYSICS AND ASTRONOMY

LHAASO
高海拔宇宙线观测站

The Contribution of LHAASO to the Multi-messenger Era

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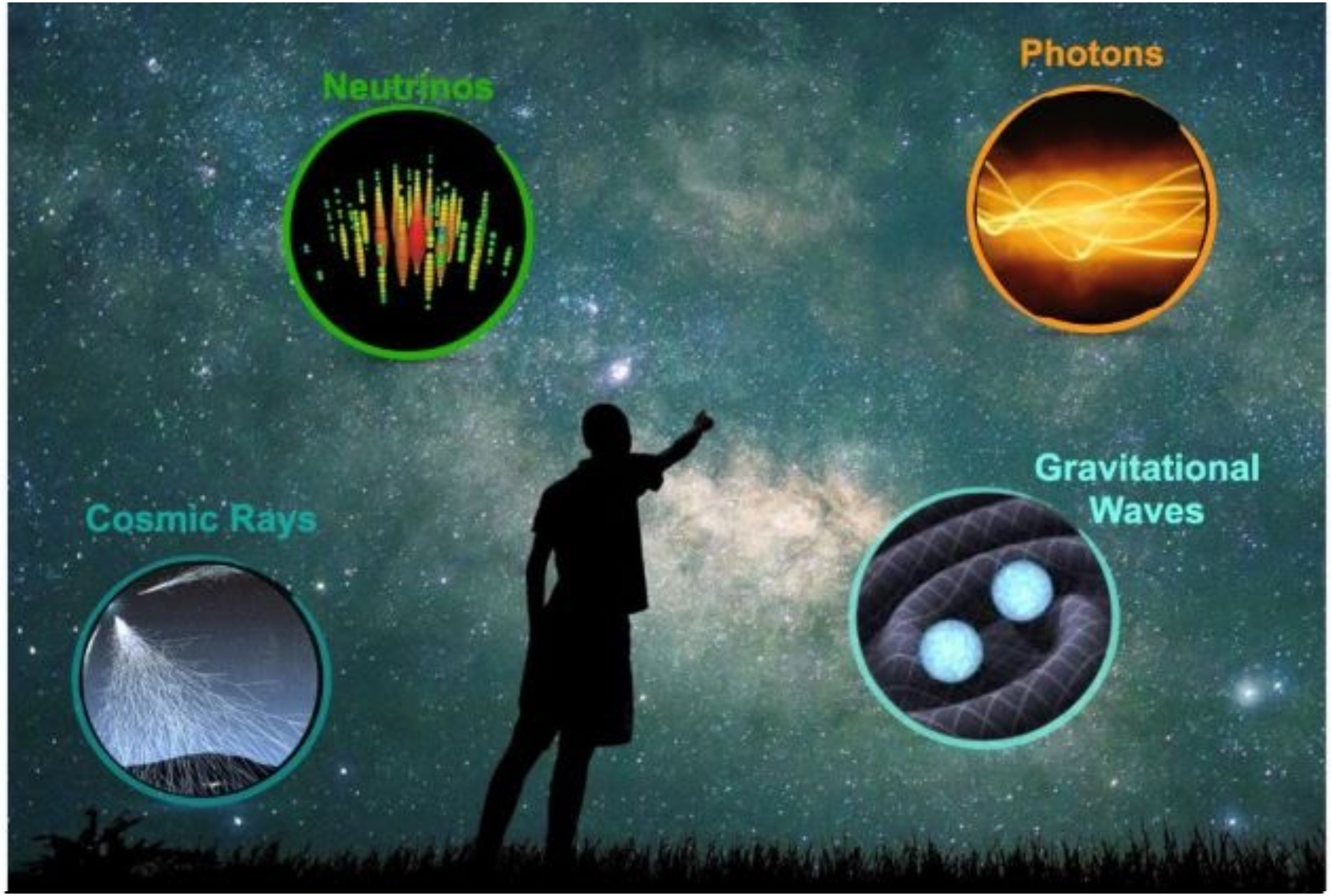
On behalf of the LHAASO Collaboration

FCPPL 2023.11.6

Multi-Messenger Framework

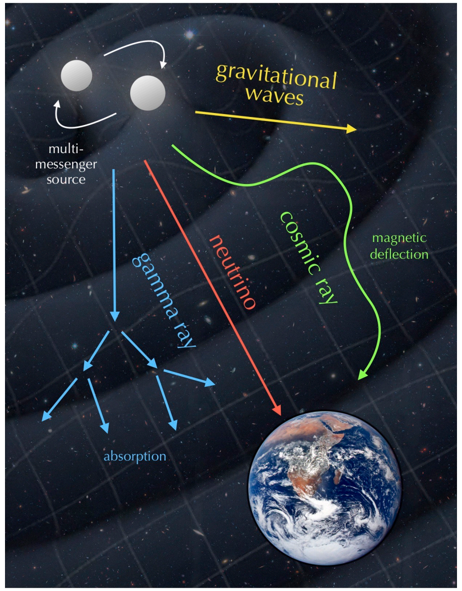


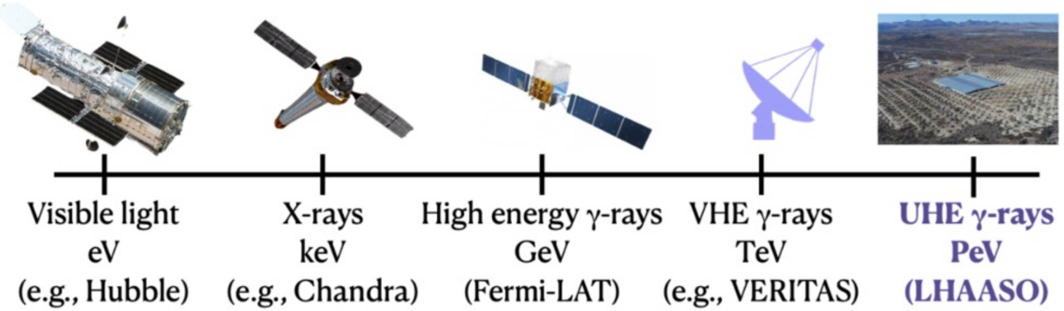
Credit: Irene Tamborra

Windows on the Universe bring electromagnetic wave, cosmic rays, neutrinos and gravitational waves together to probe the rich physics of extreme phenomena in the sky.

What can VHE gamma-ray observation provide?

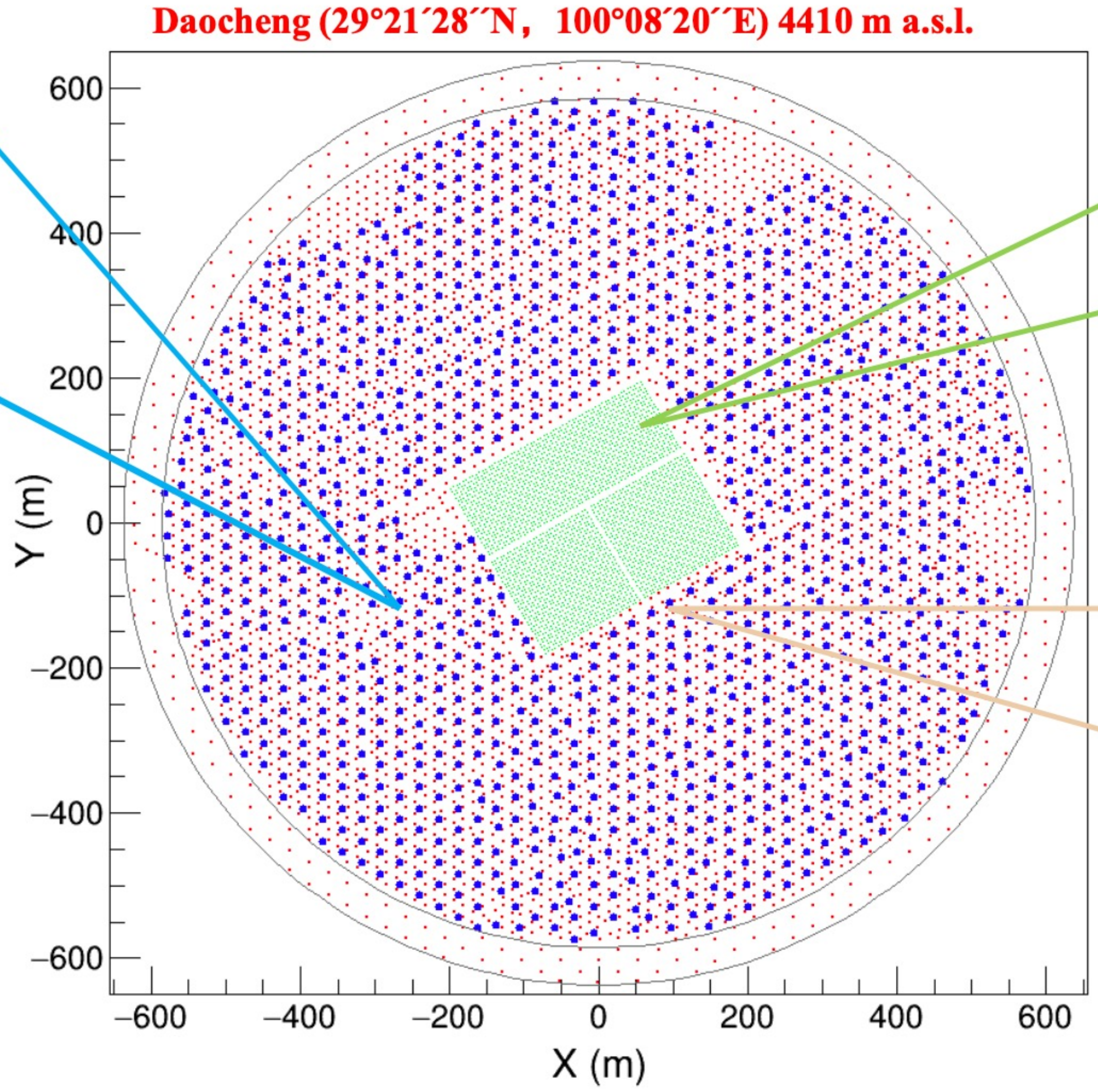
- The origin of the high-energy cosmic rays
  – Galactic or Extragalactic
- Acceleration mechanism under extreme astrophysical conditions
  – Astrophysical radiation and particles propagation
  – Source properties
- Study of cosmology and fundamental physics
  – Indirect detection of dark matter
  – Lorentz Invariance Violation
  – Galaxy evolution and Extragalactic Background Light

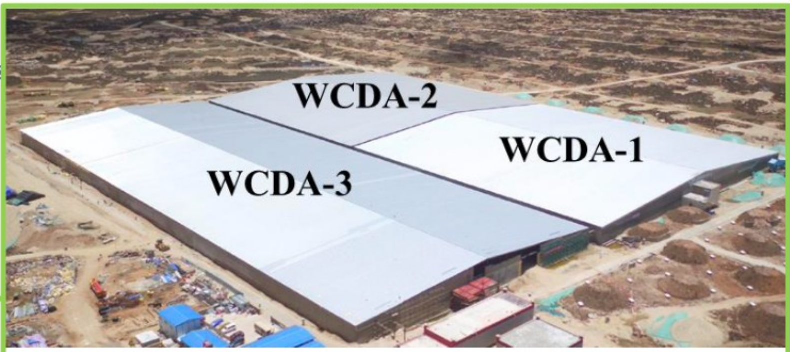




The LHAASO Detector Array

KM2A: (1.3 km^2)
Electromagnetic Particle Detectors (ED)
Muon Detectors (MD)

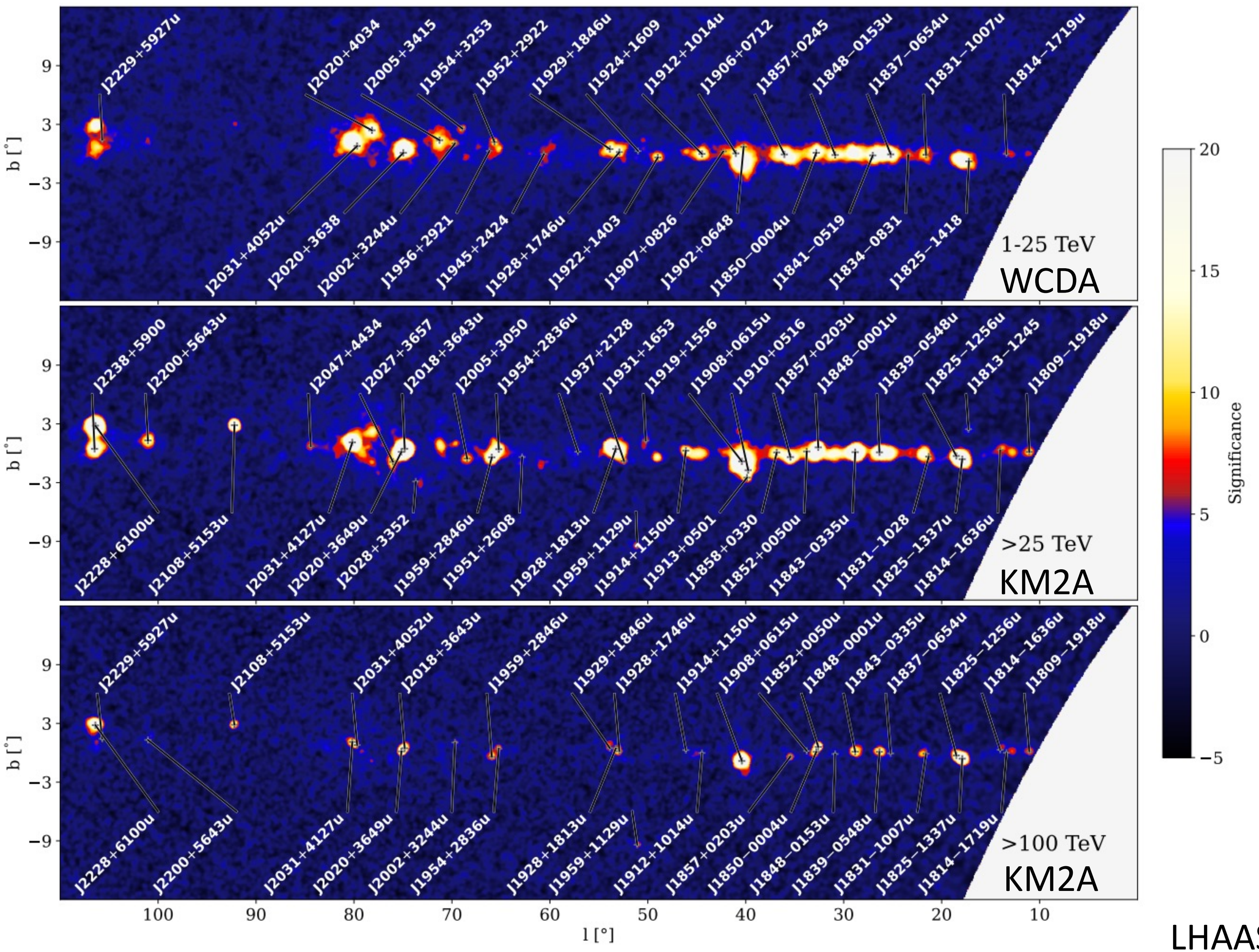




WCDA: (78,000 m^2)
Water Cherenkov Detector Array

WFCTA: (18)
Wide-Field Air Cherenkov Telescope Array

The first catalog of γ-ray sources detected by LHAASO

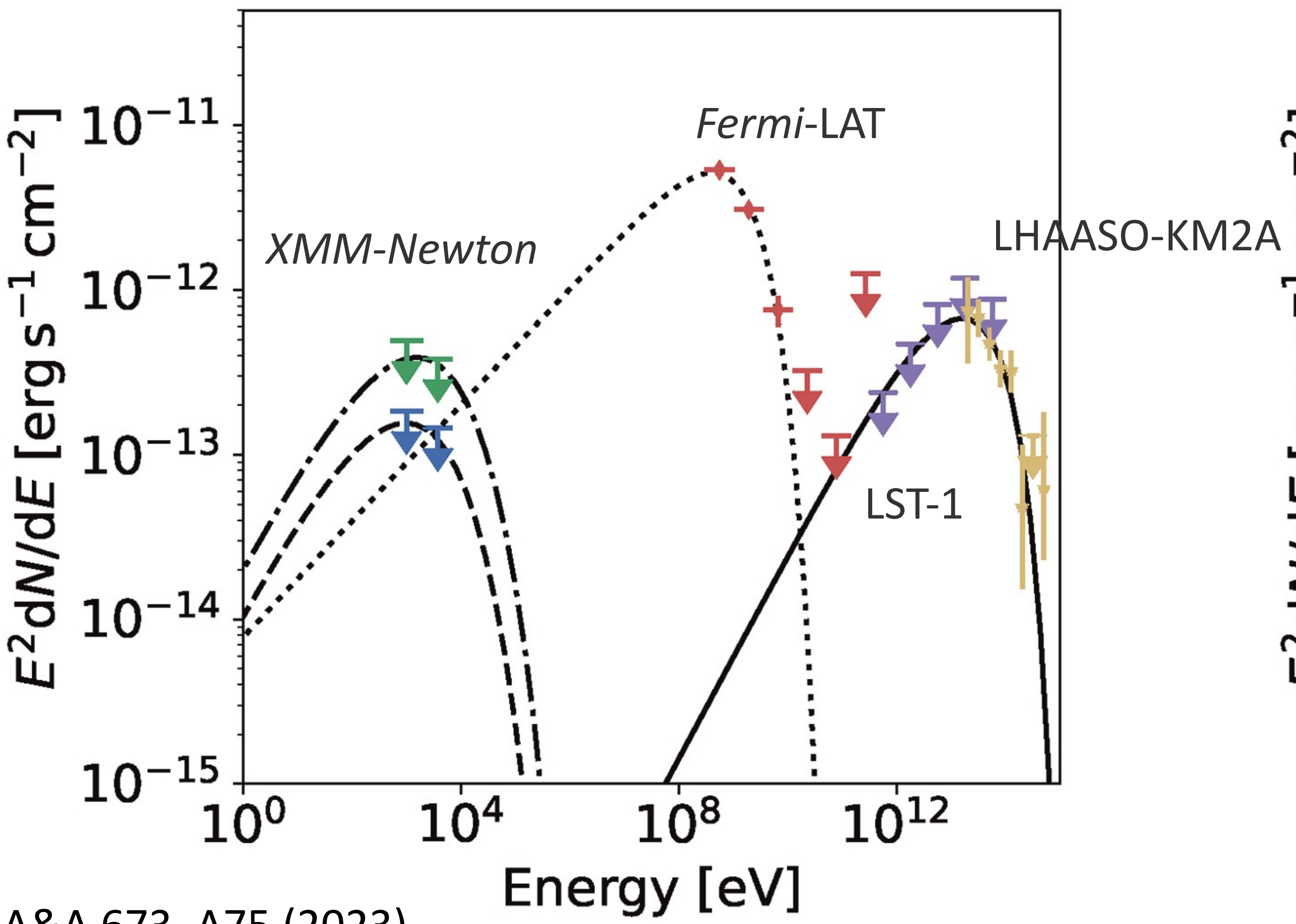


- Covering declination from −20° to 80 °
- Containing 90 sources with extended size smaller than 2°, significance > 5σ.
- 32 new TeV sources
- 43 sources are detected with E > 100 TeV emission at > 4σ significance level.

LHAASO Collaboration, arXiv:2305.17030

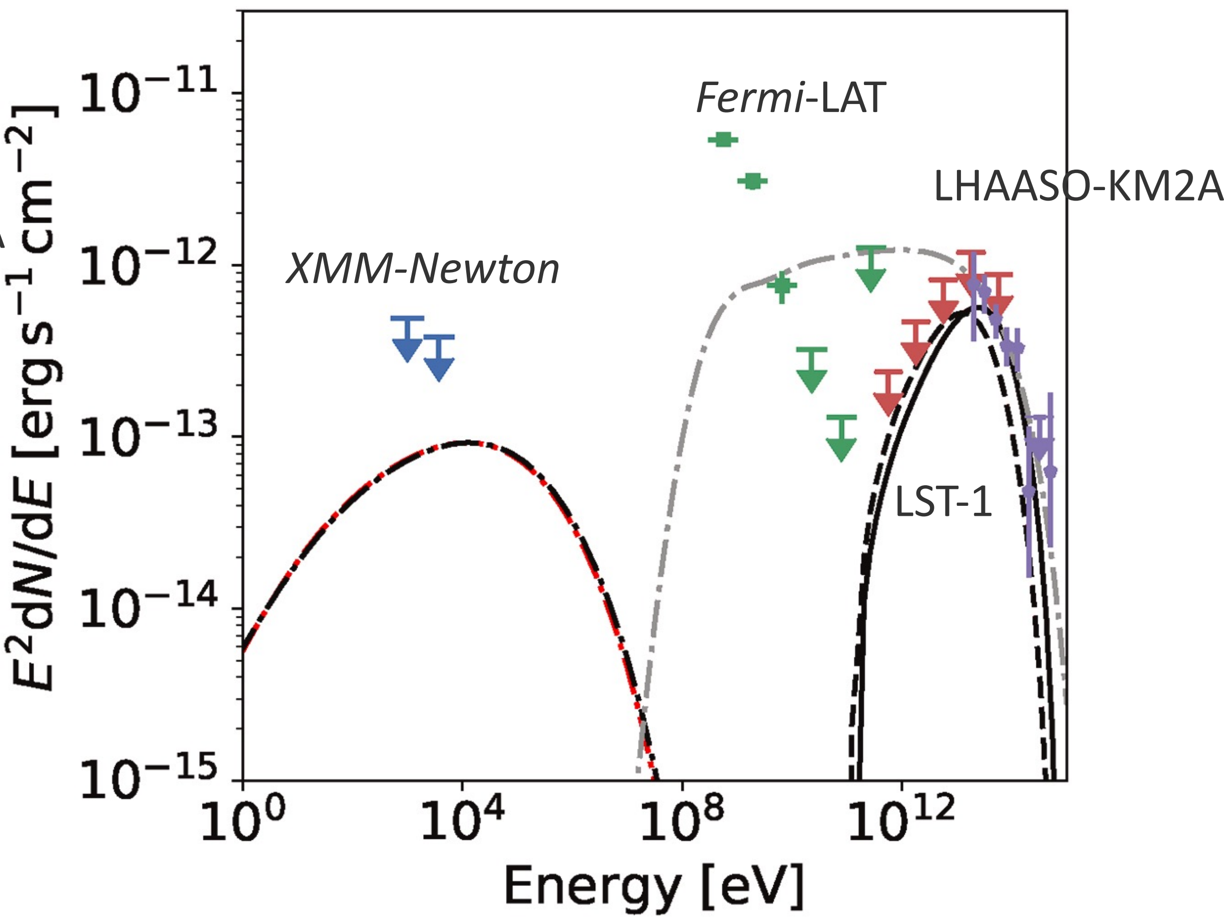
LHAASO J2108+5157

Observation of LHAASO J2108+5157 in the X-ray band with *XMM-Newton* and at TeV energies with the Large-Sized Telescope prototype (LST-1) and Fermi-LAT data.



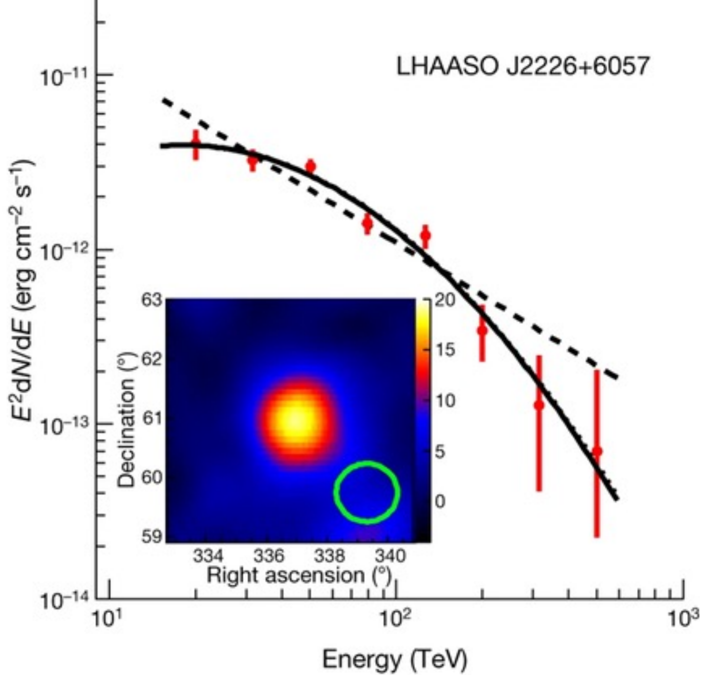
A&A 673, A75 (2023)

Leptonic scenario of emission



Hadronic scenario of emission

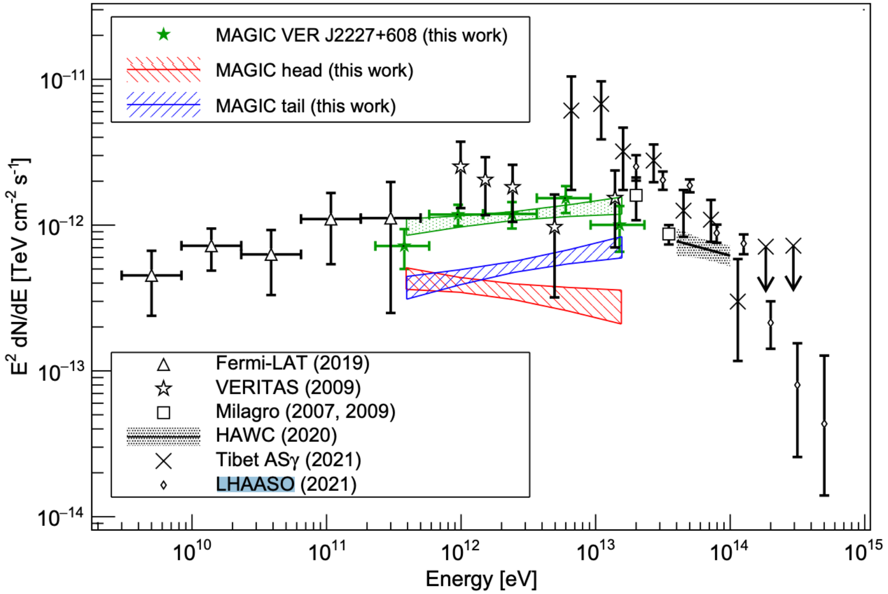
LHAASO J2226+6057

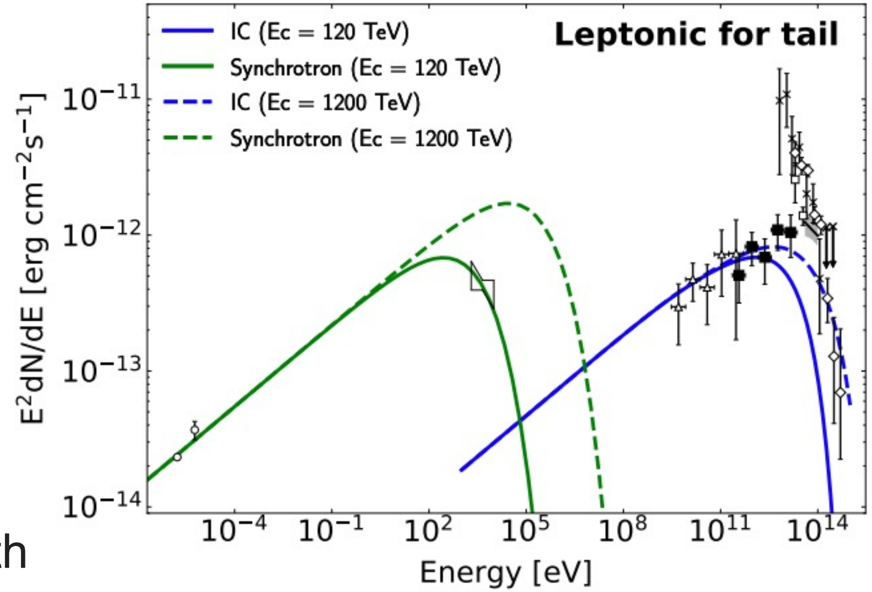


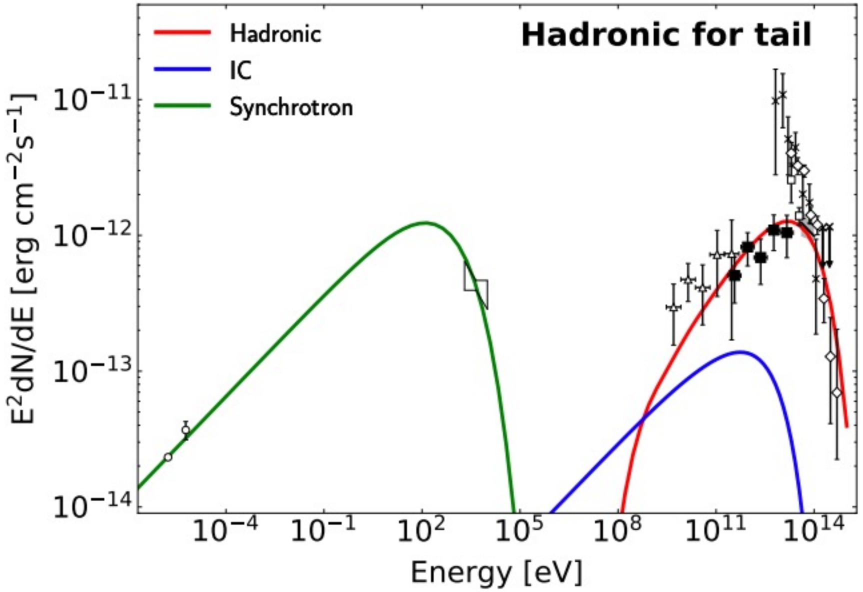
TeV counterparts: VER J2227+608/HAWC J2227+610

Tail: the SNR G106.3+2.7, with the associated MC
Head: Boomerang PWN

Assuming a completely hadronic origin, the neutrino fluxes are expected, but the IceCube sensitivity was insufficient to detect possible neutrino emissions.

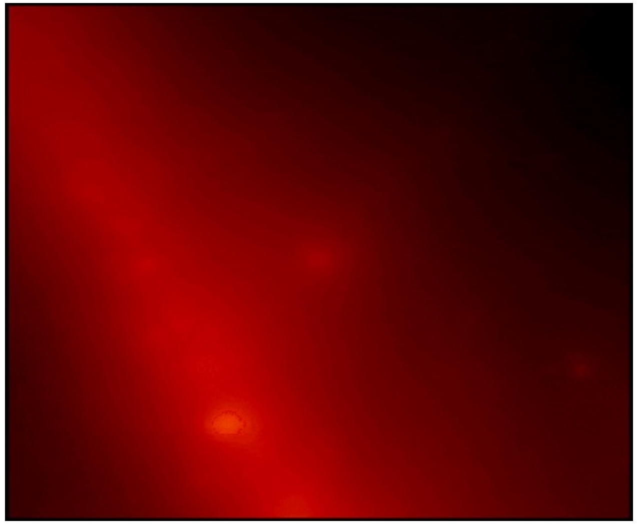


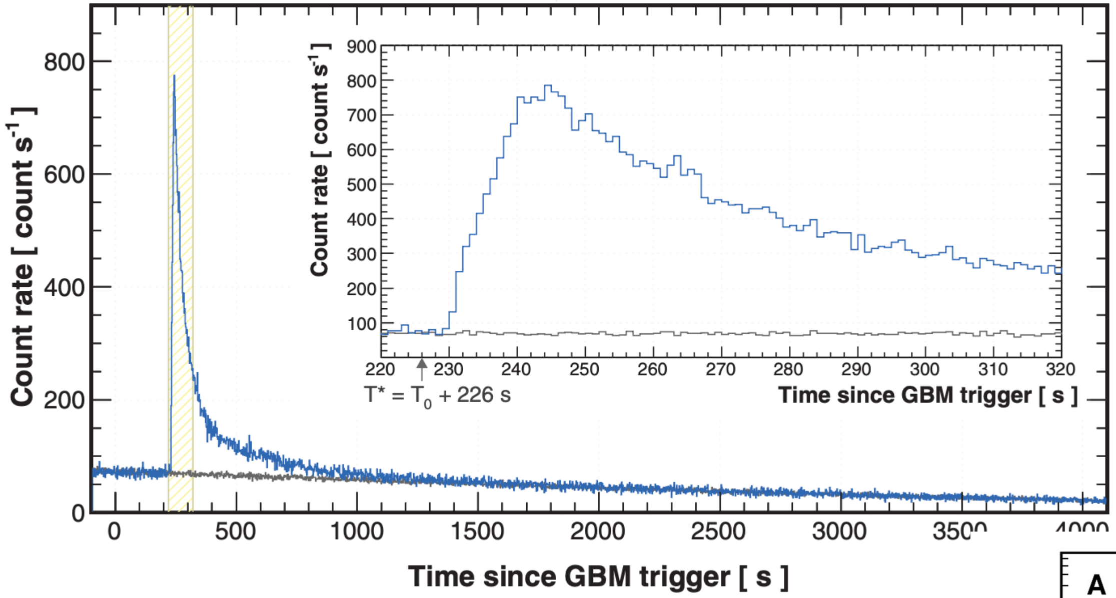




Magic Collaboration, A&A 671, A12 (2023)

Gamma Ray Burst



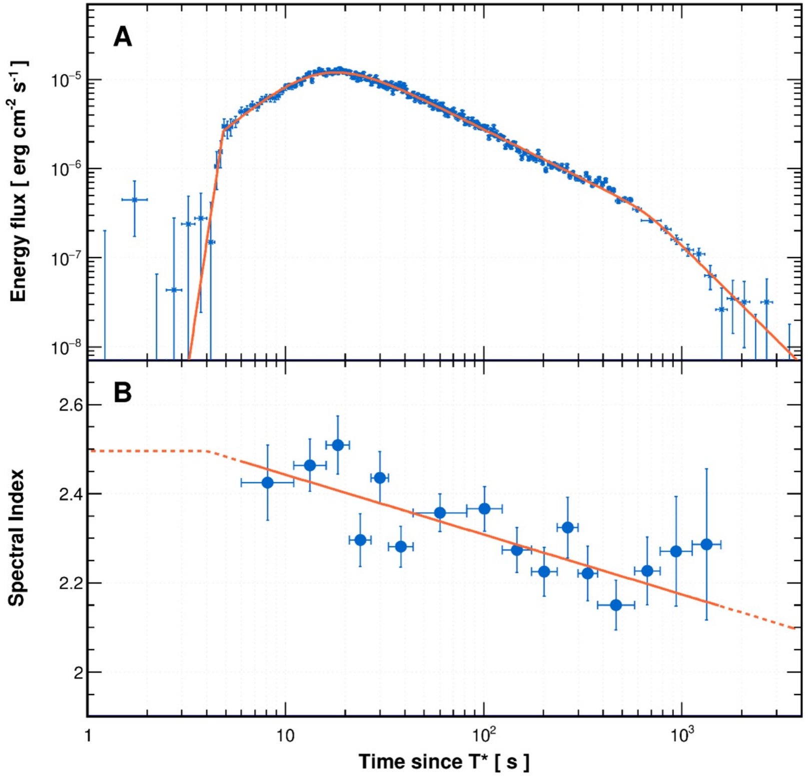


LHAASO precisely measures for the first time the entire light curve of high-energy photons from the afterglow of a GRB.

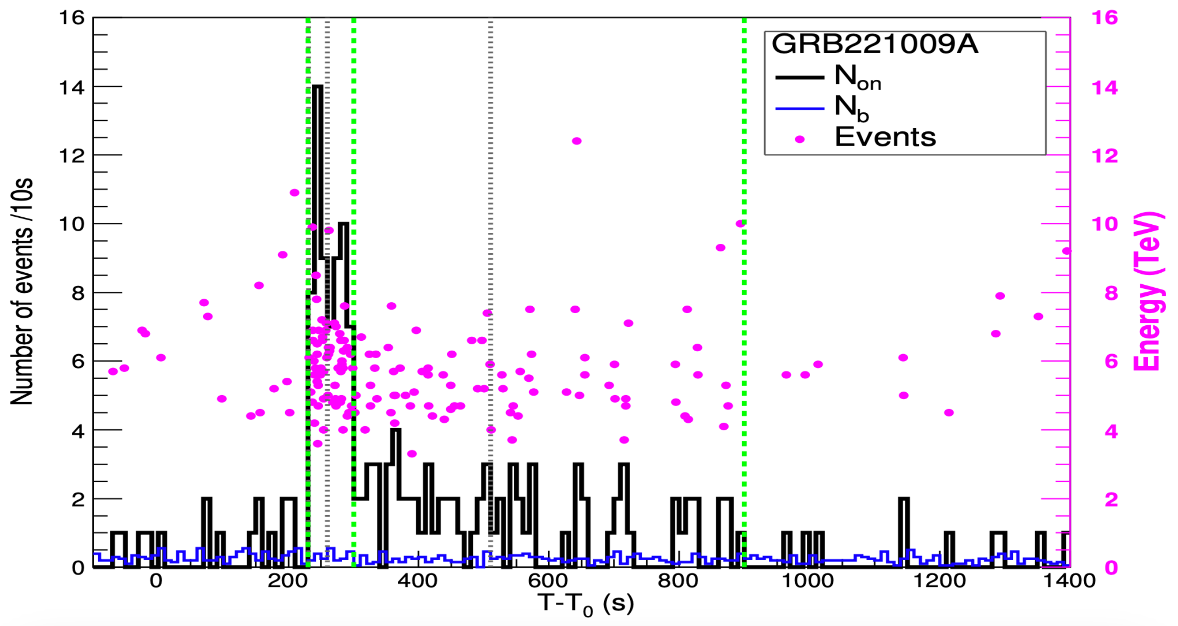
- 32667 GRB 221009A: Lulin SLT-40cm optical observations
- 32665 GRB 221009A: Upper limits from a neutrino search with IceCube
- 32664 GRB 221009A (Swift J1913.1+1946): Burke-Gaffney Observatory optical observations
- 32663 GRB221009A/Swift J1913.1+1946: SRG/ART-XC observation
- 32662 GRB 221009A / Swift J1913.1+1946: GIT detection of the optical afterglow
- 32661 GRB221009A/Swift J1913.1+1946: Solar Orbiter STIX measurements
- 32660 GRB221009A/Swift J1913.1+1946: INTEGRAL SPI/ACS observations
- 32658 GRB 221009A: Fermi-LAT refined analysis
- 32657 GRB 221009A (Swift J1913.1+1946): AGILE/GRID detection
- 32656 GRB 221009: Swift/UVOT Detection
- 32655 GRB221009A/Swift J1913.1+1946: ATA follow-up observations
- 32654 GRB 221009A or Swift J1913.1+1946: PRIME near-infrared detection
- 32653 GRB 221009A/Swift J1913.1+1946: AMI-LA observations
- 32652 GRB 221009A: REM optical and NIR detection of the afterglow
- 32651 GRB 221009A: Swift-XRT refined Analysis
- 32650 GRB 221009A (Swift J1913.1+1946): AGILE/MCAL detection
- 32648 GRB 221009A: Redshift from X-shooter/VLT
- 32647 GRB 221009A: Nanshan/NEXT photometry and Xinglong-2.16m spectroscopy
- 32646 GRB 221009A (Swift J1913.1+1946): MeerLICHT observations
- 32645 GRB 221009A (Swift J1913.1+1946): Mondy optical observations
- 32644 GRB 221009A BOOTES-2/TELMA and OSN optical detections
- 32642 GRB 221009A: Fermi GBM observation

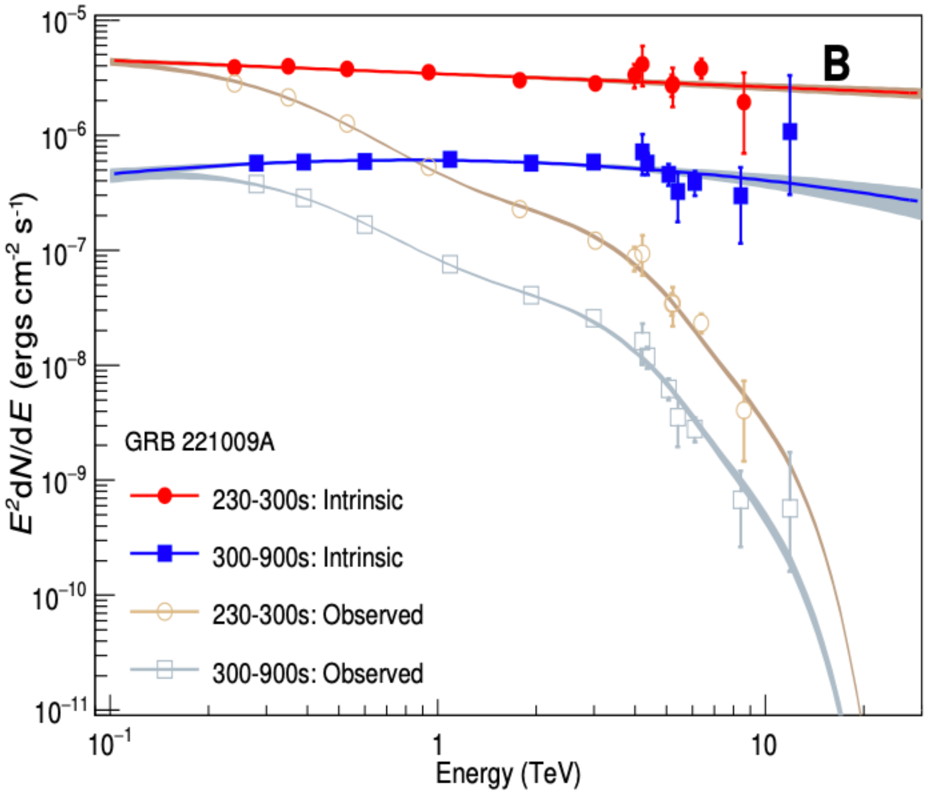
GRB 221009A is the brightest GRB ever detected.

LHAASO Collaboration, Science 380 (2023) 1390-1396, Arxiv 2310.08845



KM2A

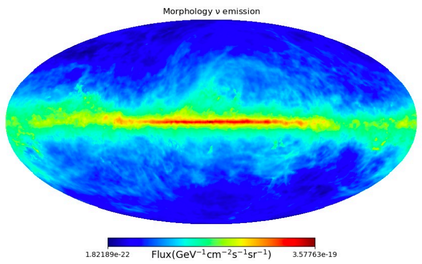


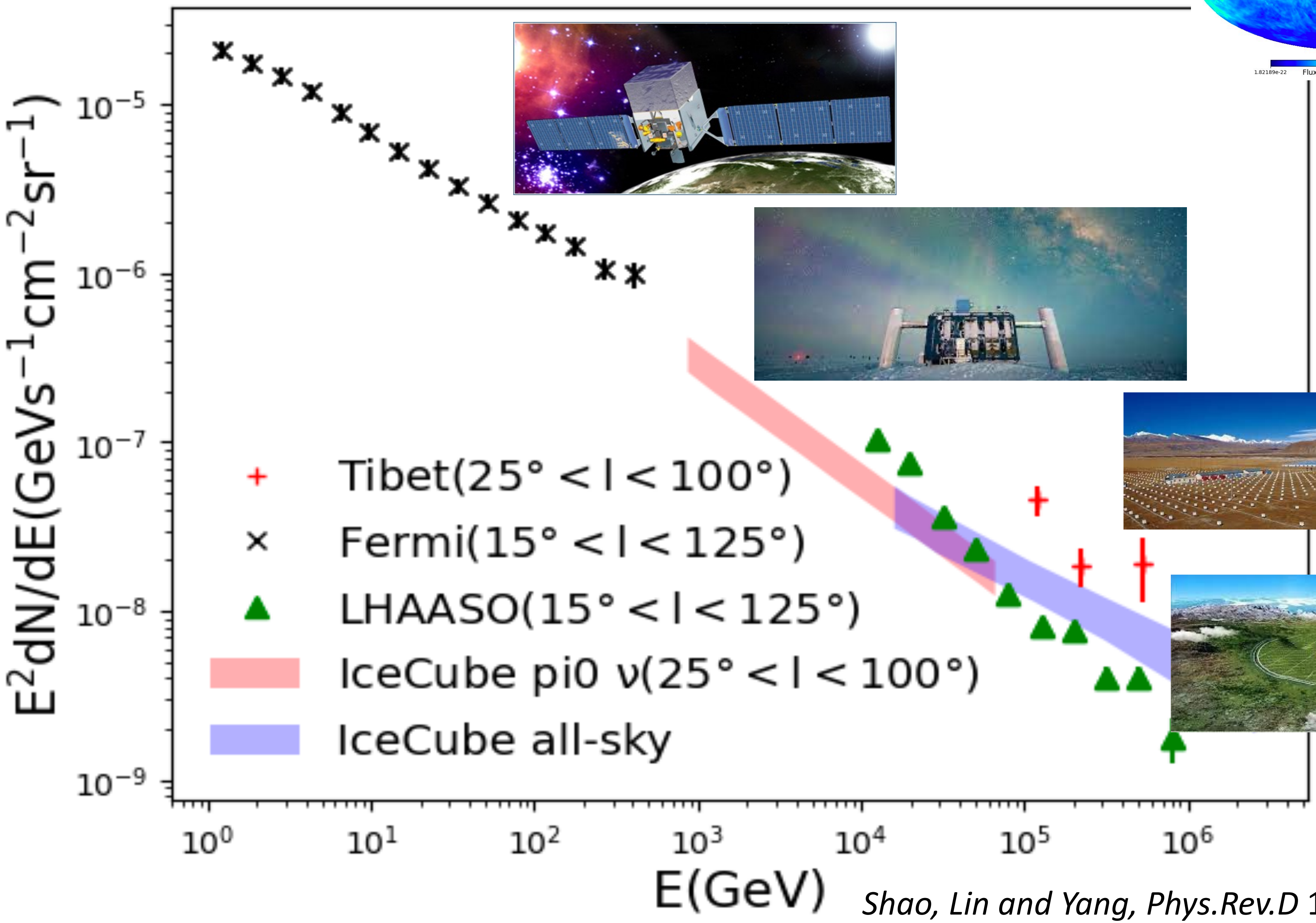


Started at T_0+230s with two flux peaks around T_0+245s and T_0+285s, decreased since T_0+300s and faded out after T_0+900s. During T_0+230s to T_0+900s, 142 events with energies above 3 TeV were detected, with an estimated background of 16.7.

- The highest energy observed from GRB ever.
- An external shock origin for the emission.
- Place strong constraints on new physics parameters.

Milky Way





Shao, Lin and Yang, Phys.Rev.D 108 (2023) 6

Take Home Messages

- LHAASO has made a great success in the VHE gamma-ray observation, extending the spectra of energy distribution to the highest regime.
- The gamma-ray together with neutrino observations are necessary to discriminate between leptonic and hadronic scenarios.
- The synergies between LHAASO and next-generation IACTs and neutrino telescopes are essential to explore the physical processes and reveal the Universe.