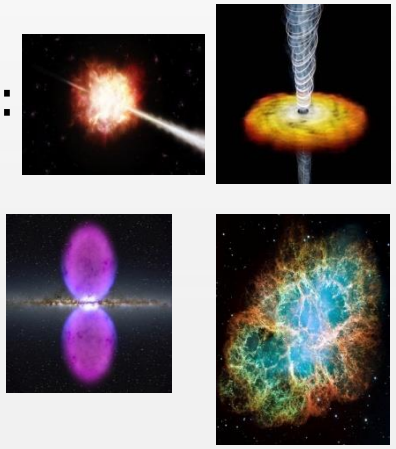
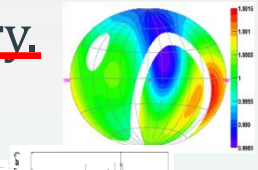
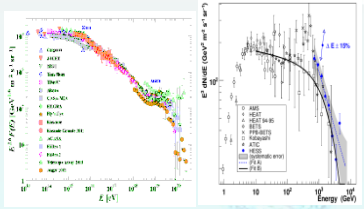
LHAASO
高海拔宇宙线观测站

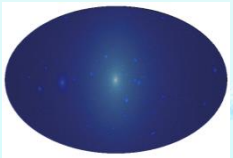
LHAASO plans and capabilities

Zhen Cao (IHEP CAS)/Yuri Stenkin (INR RAS)
for LHAASO collaboration

Physics of LHAASO

- VHE gamma sky survey (100 GeV-1 PeV):
  - Galactic sources;
  - Extragalactic sources & flares;
  - VHE emission from Gamma Ray Bursts;
  - Diffused Gamma rays.
- Spectrum measurement at the high end:
  - Nature of the acceleration: leptonic or hadronic;
  - Origin of cosmic rays – 100 years' mystery.
- Cosmic rays
  - Spectra of CR Species;
  - Anisotropy of VHE cosmic rays;
  - Cosmic electrons / positrons;
- Miscellaneous:
  - Gamma rays from dark matter;
  - Sun storm & IMF.

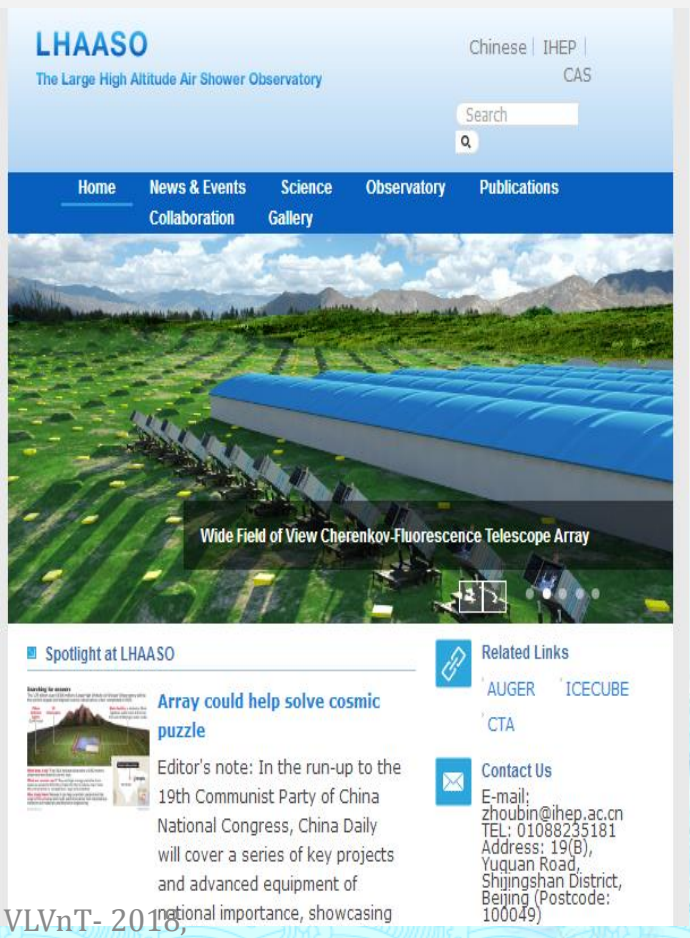



Large High Altitude Air Shower Observatory

LHAASO

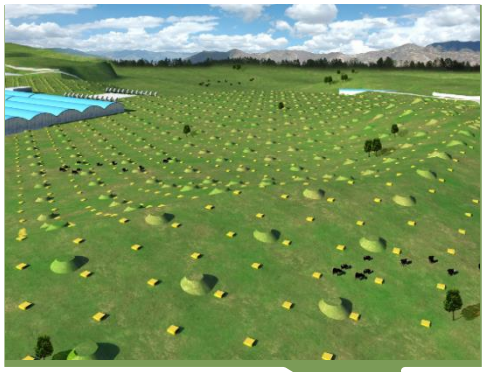
- General info is available at the web sites

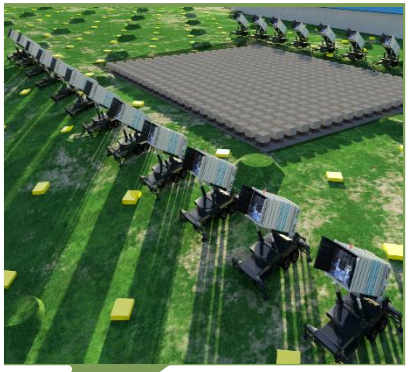
http://ihep.cas.cn/lhaaso （Chin） http://english.ihep.cas.cn/lhaaso （Eng）



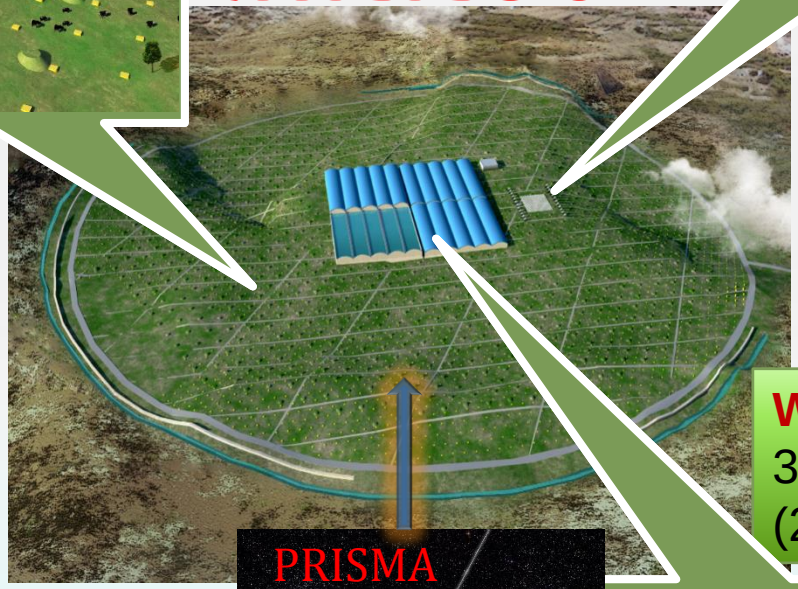
Large High Altitude Air Shower Observatory

LHAASO



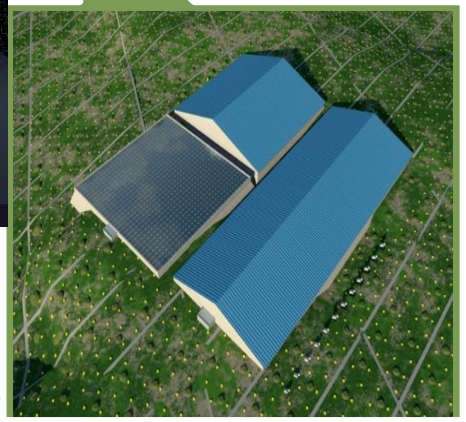


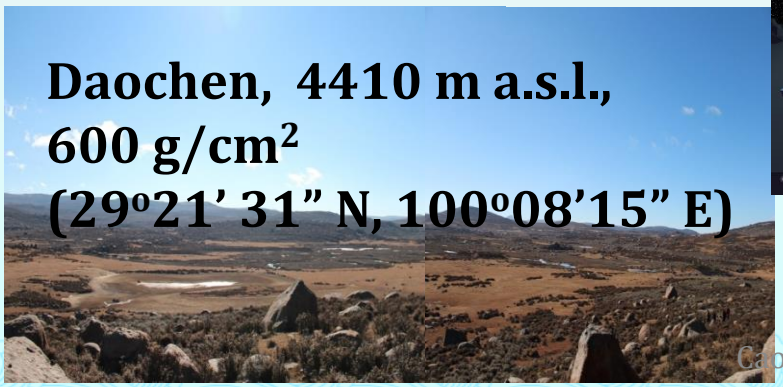
KM2A:
- **5195 Scin's: 1 m^2, 15m spacing**
- **1171 MDs: 36 m^2, 30m spacing**



WFCTA:
18 Cherenkov telescopes (1024 pixels/telescope)

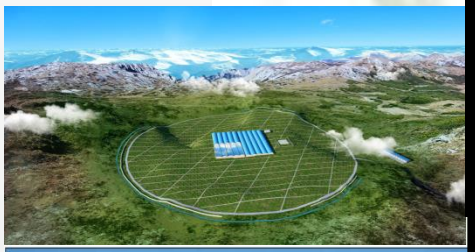
WCDA:
3120 cells (25m^2/cell)

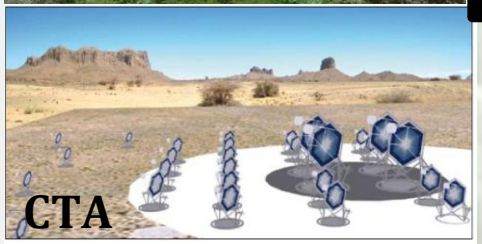


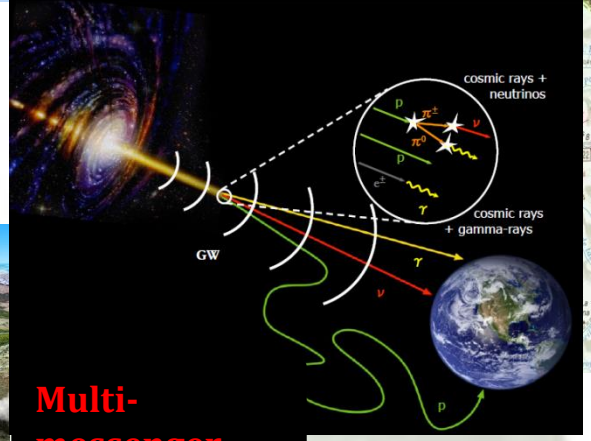


Daochen, 4410 m a.s.l., 600 g/cm^2 (29°21' 31" N, 100°08'15" E)

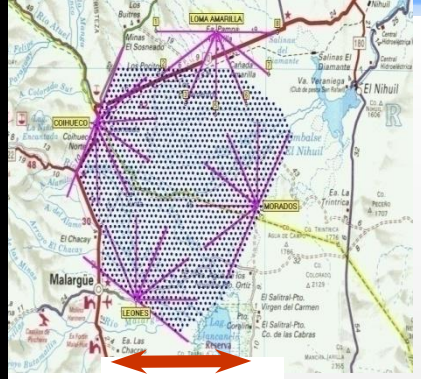
LHAASO
高海拔宇宙线观测站







Multi-messenger



50km

EHE CR Astronomy

TA, AUGER

JEM-EUSO

The question

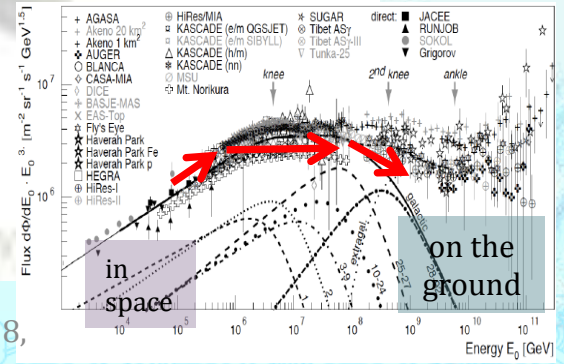
VHEγ Astronomy

LHAASO

CTA

CR Features: knees

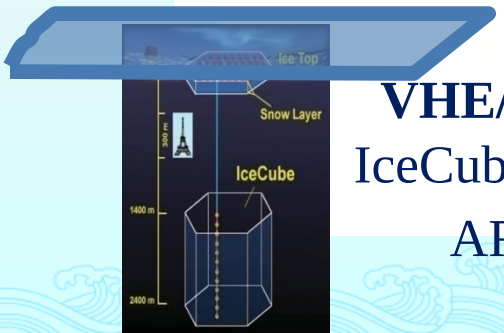
AMS02,Iss-CREAM,DAMPE,LHAASO……



in space

on the ground

5km

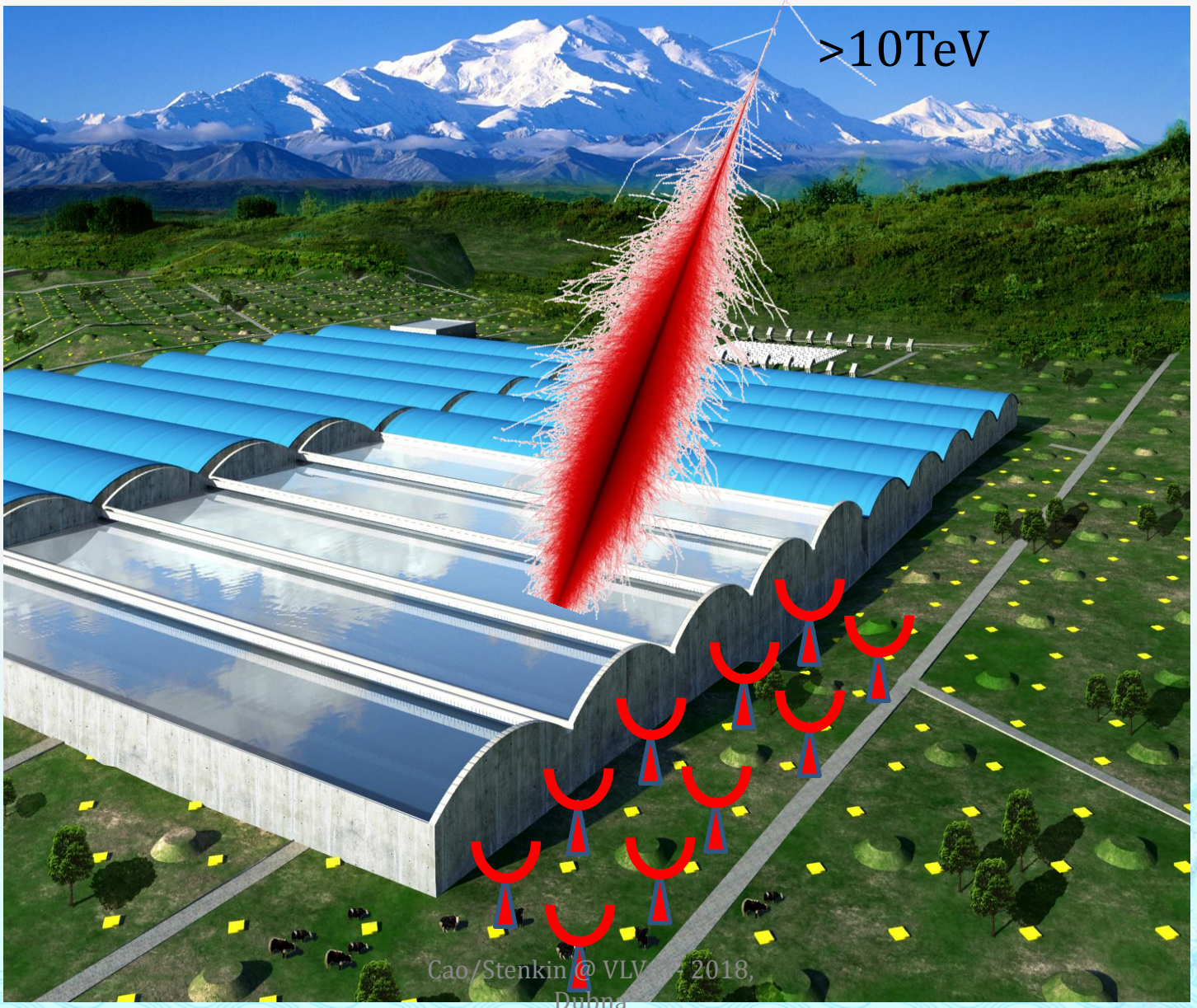


VHE/UHE Neutrinos

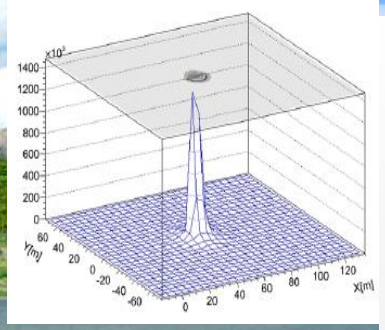
IceCube Gen2, KM3net

ARIANA ……

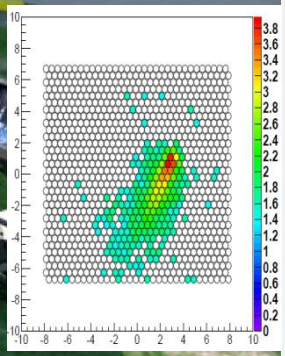
Hybrid Measurements of Showers



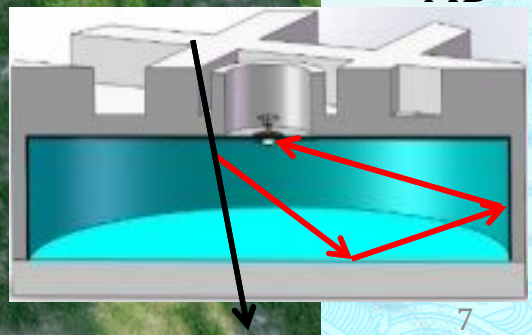
Prospects of P, He knees from 100TeV to 10PeV



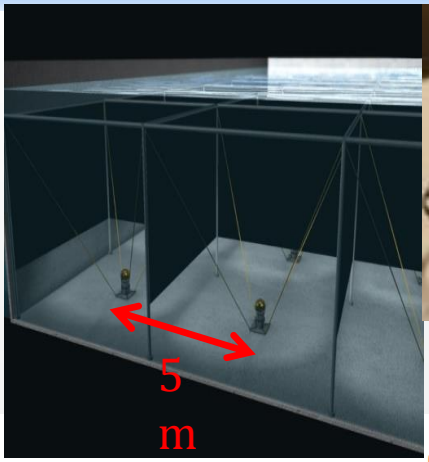
- **WCDA**
  - Core reconstruction: 3m
  - Arrival direction reconstruction: 0.3°
  - Energy flux near the core
- **WFCTA**
  - SIZE (total PE in image)
  - Width, Length
  - Distance between arrival directions to the image center
- **KM2A**
  - Ne & total Muon number
- **PRISMA**
  - Thermal neutrons

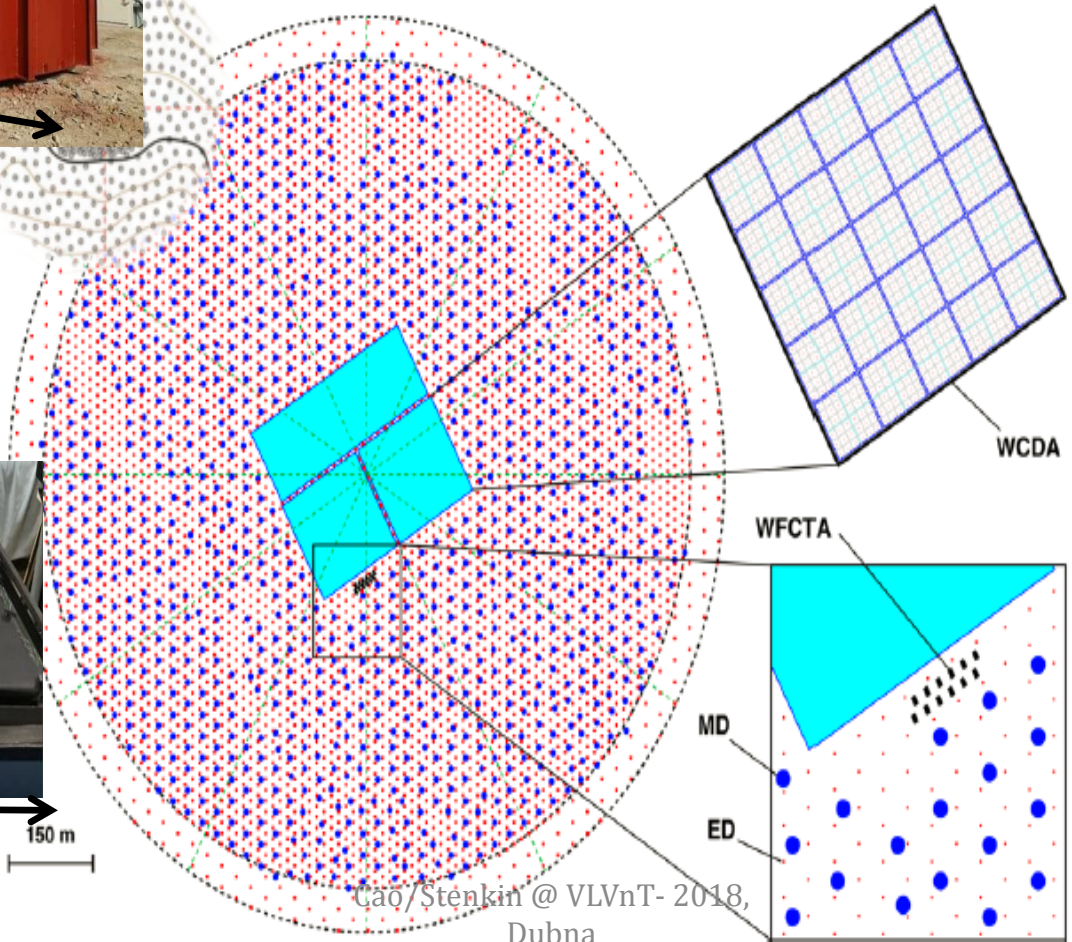


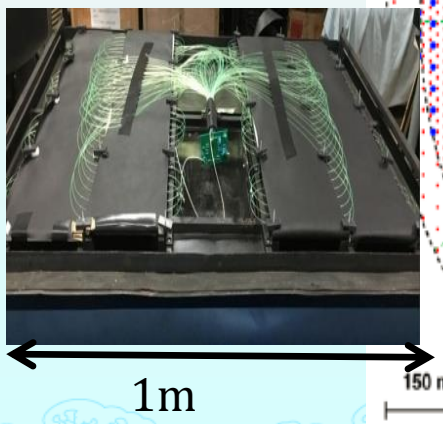
MD



Detector Layout in LHAASO







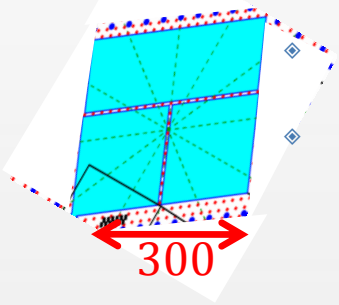
5195 Scintillators
- 1 m^2 each
- 15 m spacing

1171 Muon Detectors
- 36 m^2 each
- 30 m spacing

3000 Water Cherenkov Cells
- 25 m^2 each

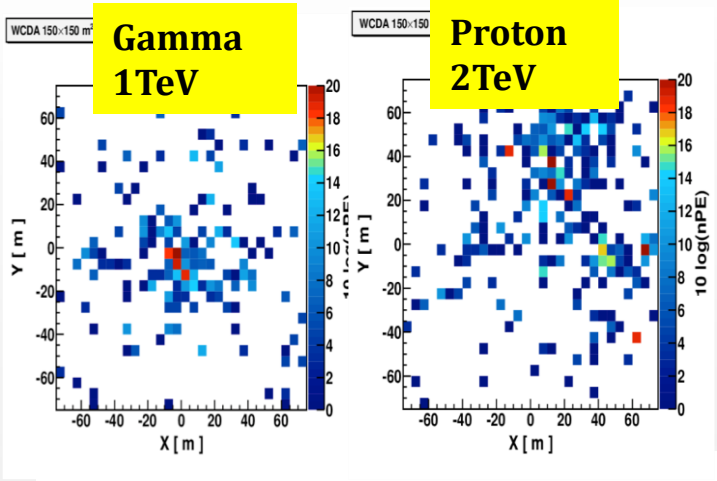
12 Wide Field Cherenkov Telescopes

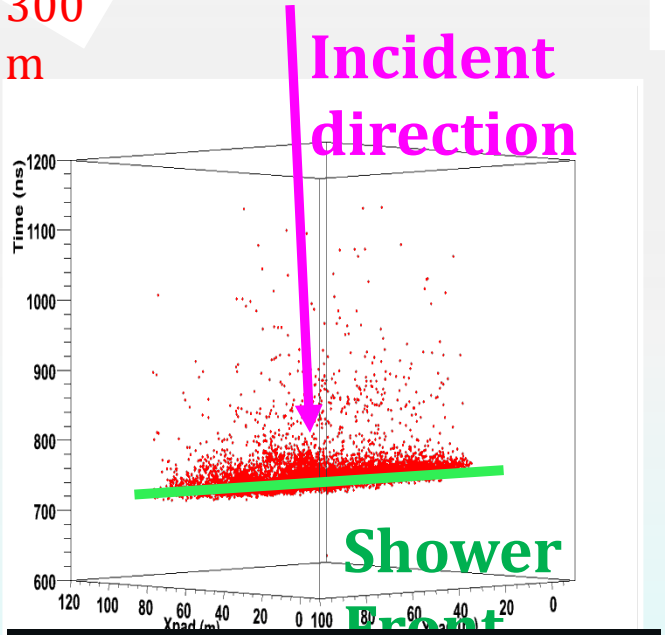
3 Pools

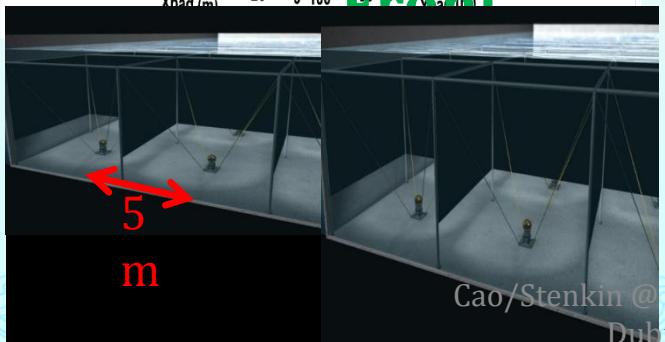


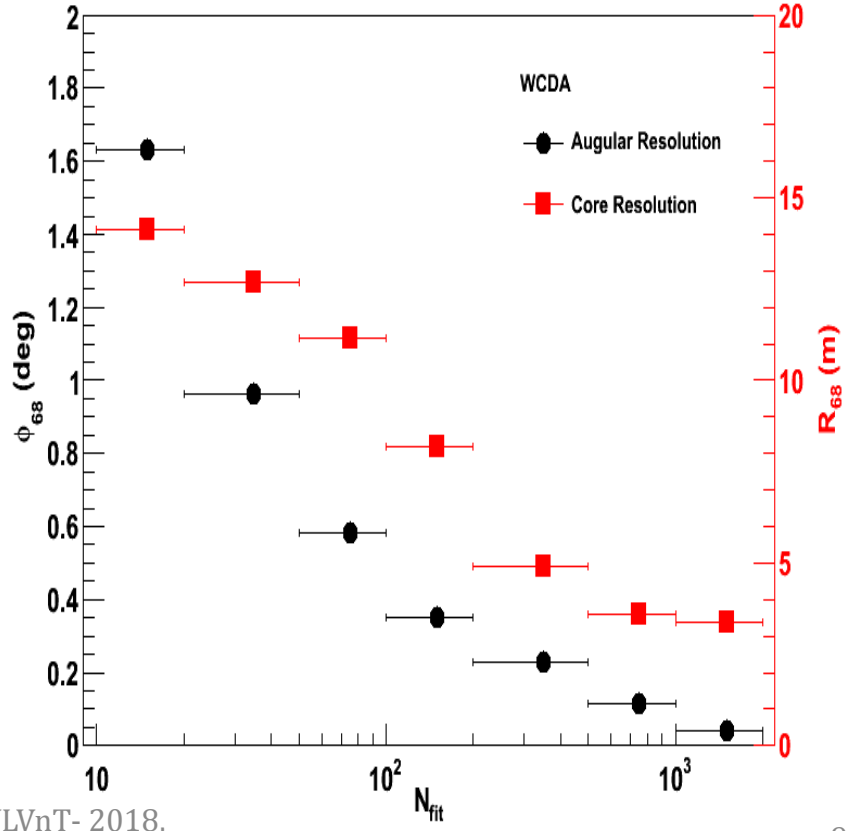
Measuring shower direction and location

Catching far muon signals in showers for γ/p









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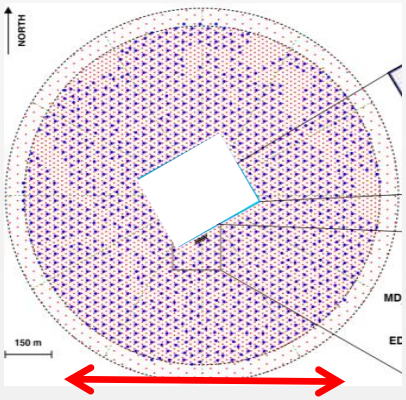
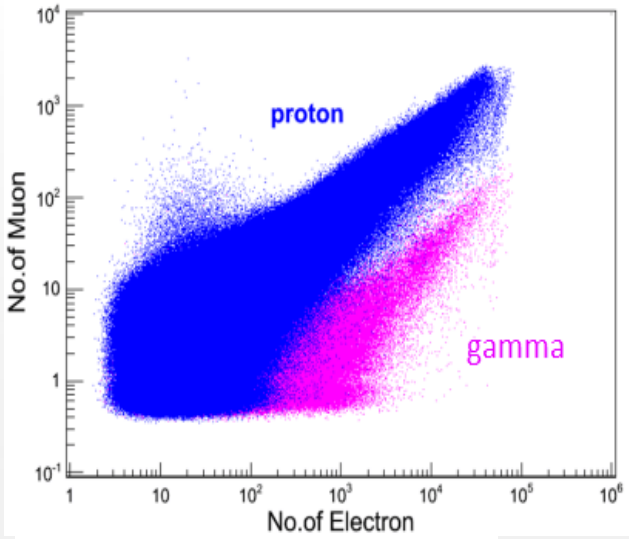
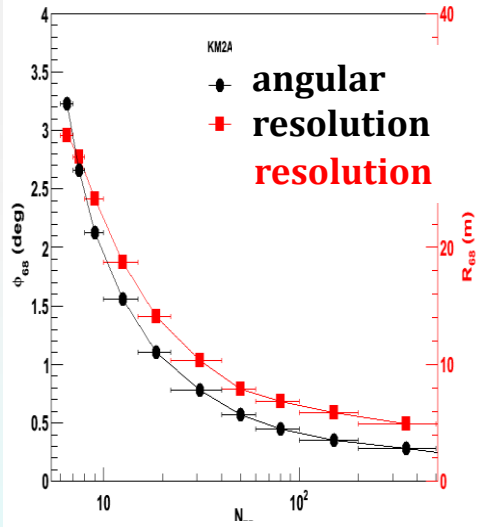
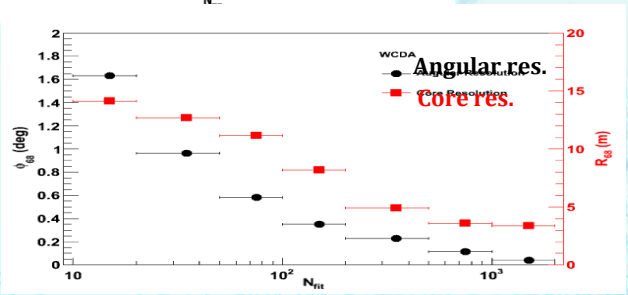


An Array of Scin. +MDs



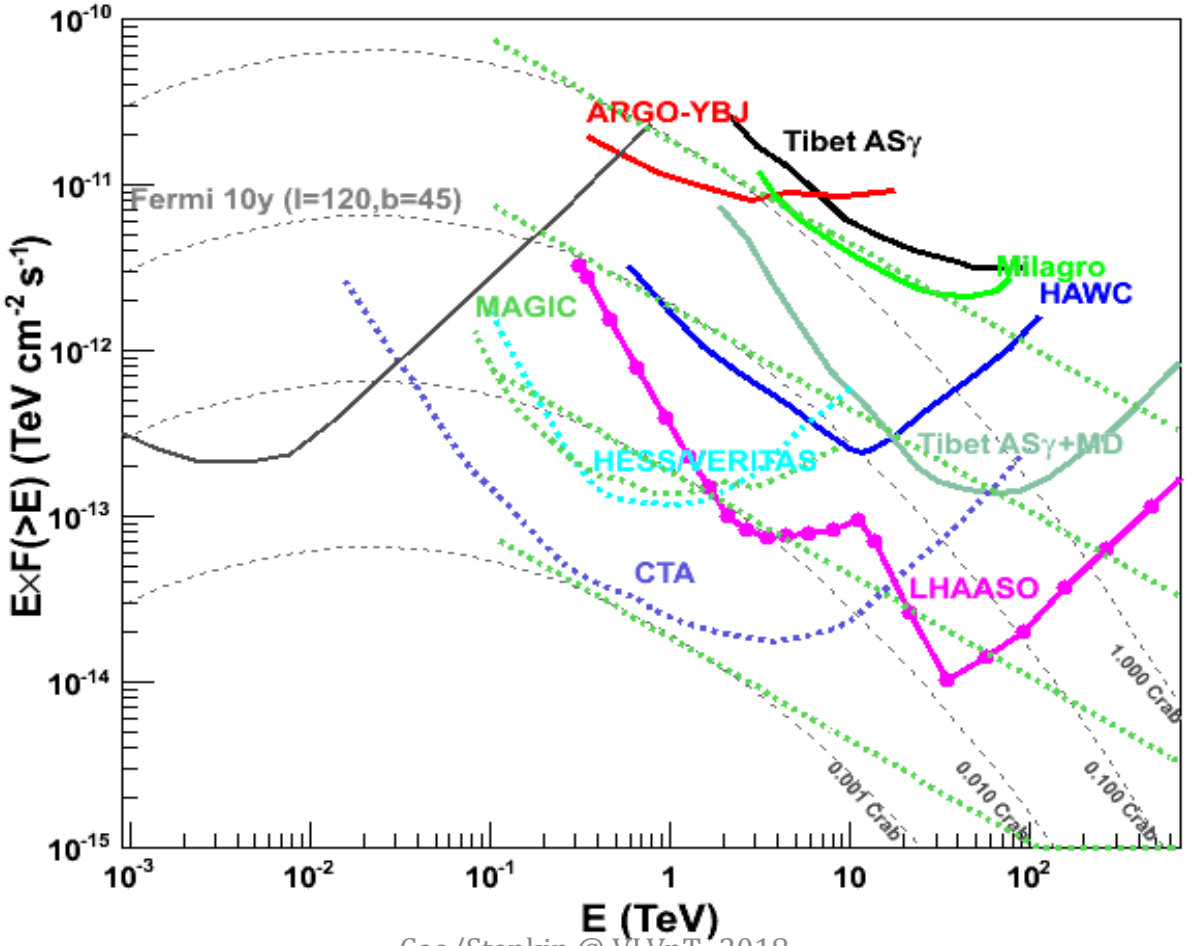
- Measuring shower direction and location
- Measuring μ–content with the largest MD array
- Clean γ selection





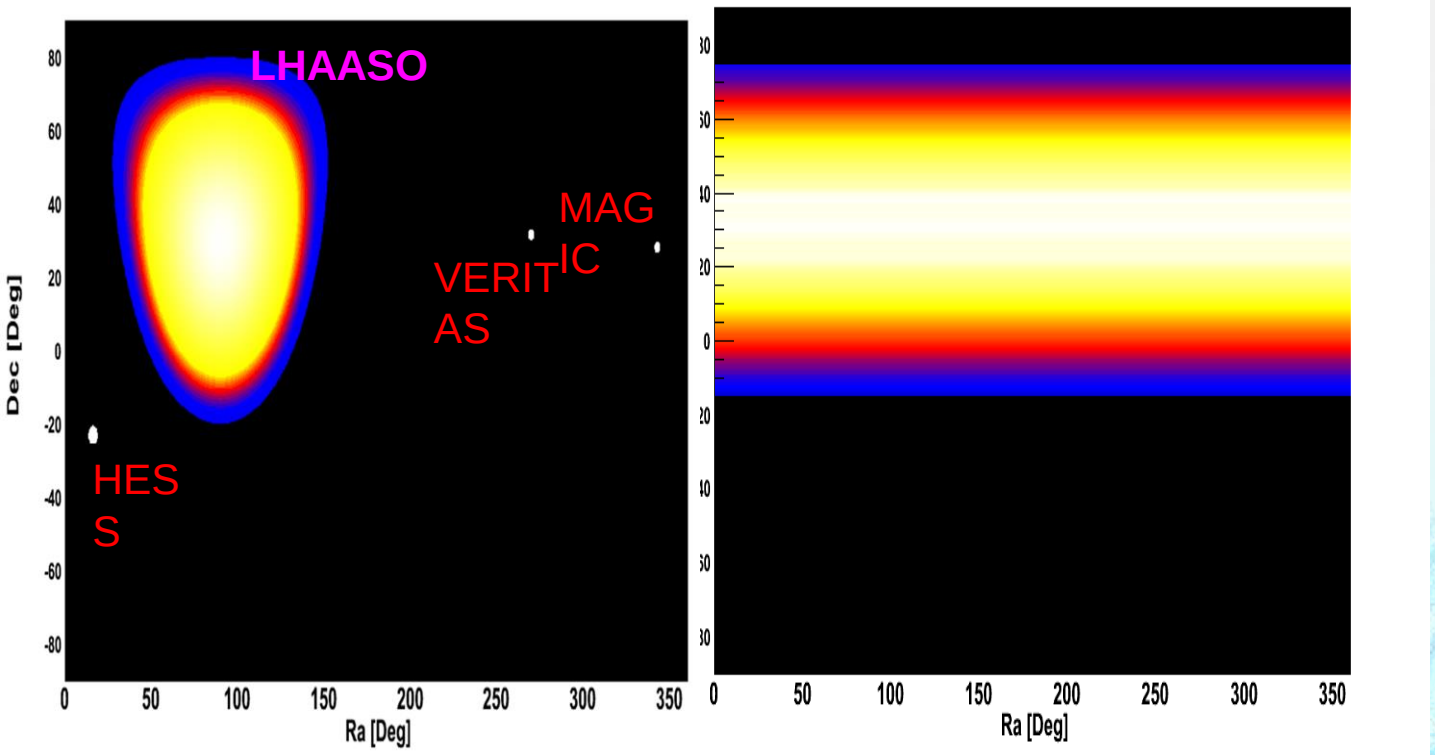
Sensitivity to gamma ray sources

- **Integral: 1% Crab unit @3TeV & 50TeV**



Wide FOV gamma ray astronomy

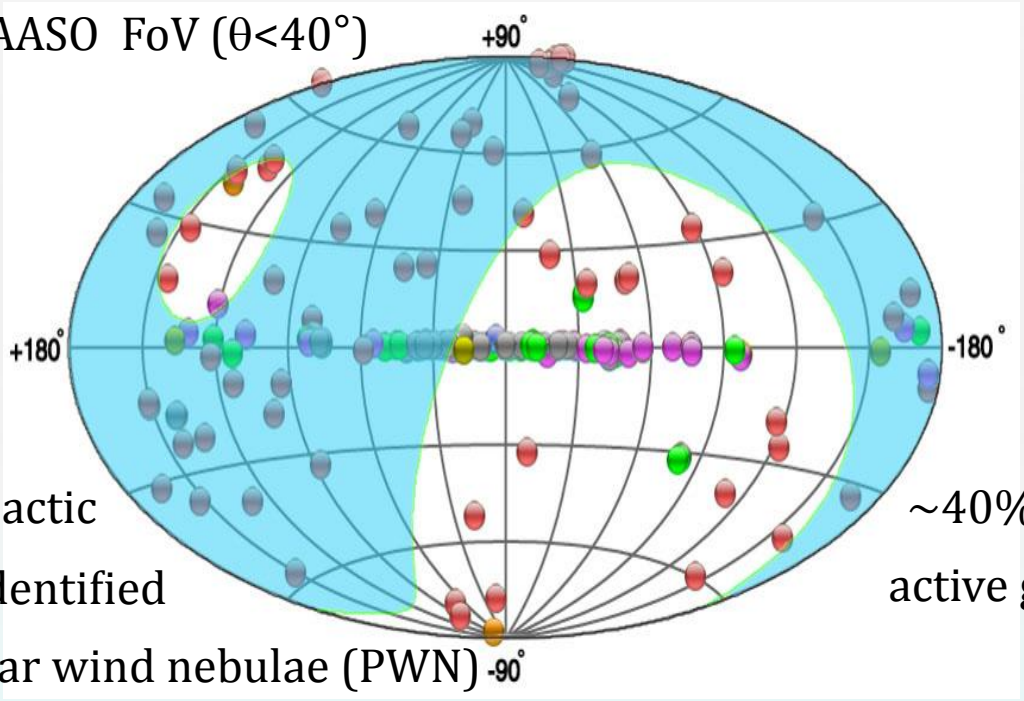
- High sensitivity
- Wide FoV:
  - 1/7 of the sky at any moment
  - 60% of the sky in every day (24 hrs)



Survey over 300 GeV-1 PeV for pevatrons

208 sources in TeV bend

119 in LHAASO FoV (θ<40°)



~60% Galactic

~40% extragalactic

~1/3 unidentified

active galactic nuclei

~1/3 pulsar wind nebulae (PWN)

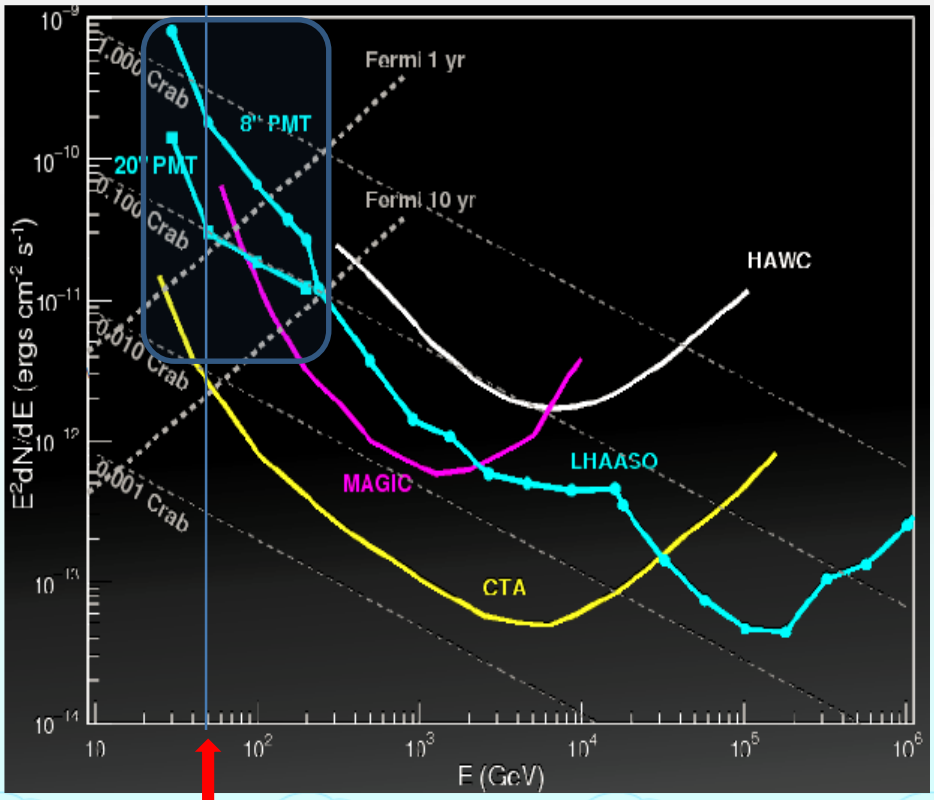
~1/3 supernova remnants, compact binary systems and massive star clusters

LHAASO FoV (θ< 40°)

Enhancement of the sensitivity below 100 GeV

- **Transient Phenomena : GRB、AGN-flares、N-N merge gravitational wave events ...**

- **20” PMTs with special PE collecting design in #2 and #3 ponds of WCDA**



50 GeV

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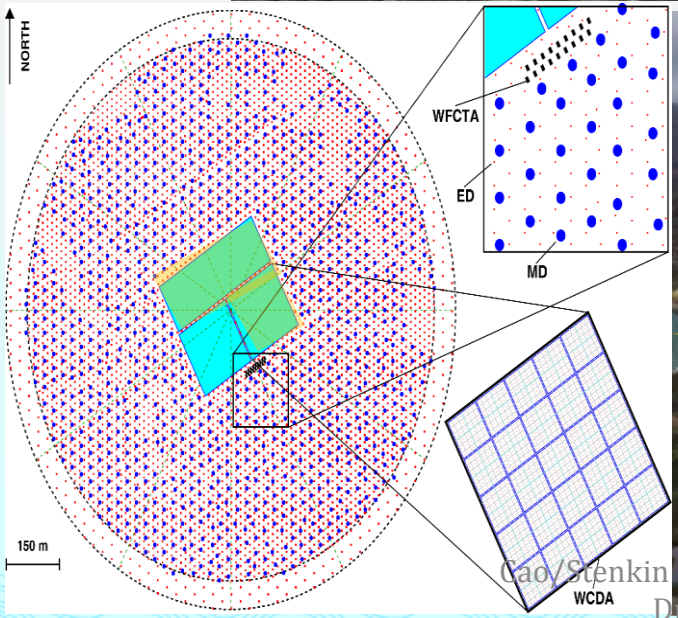


LHAASO on AGN flares

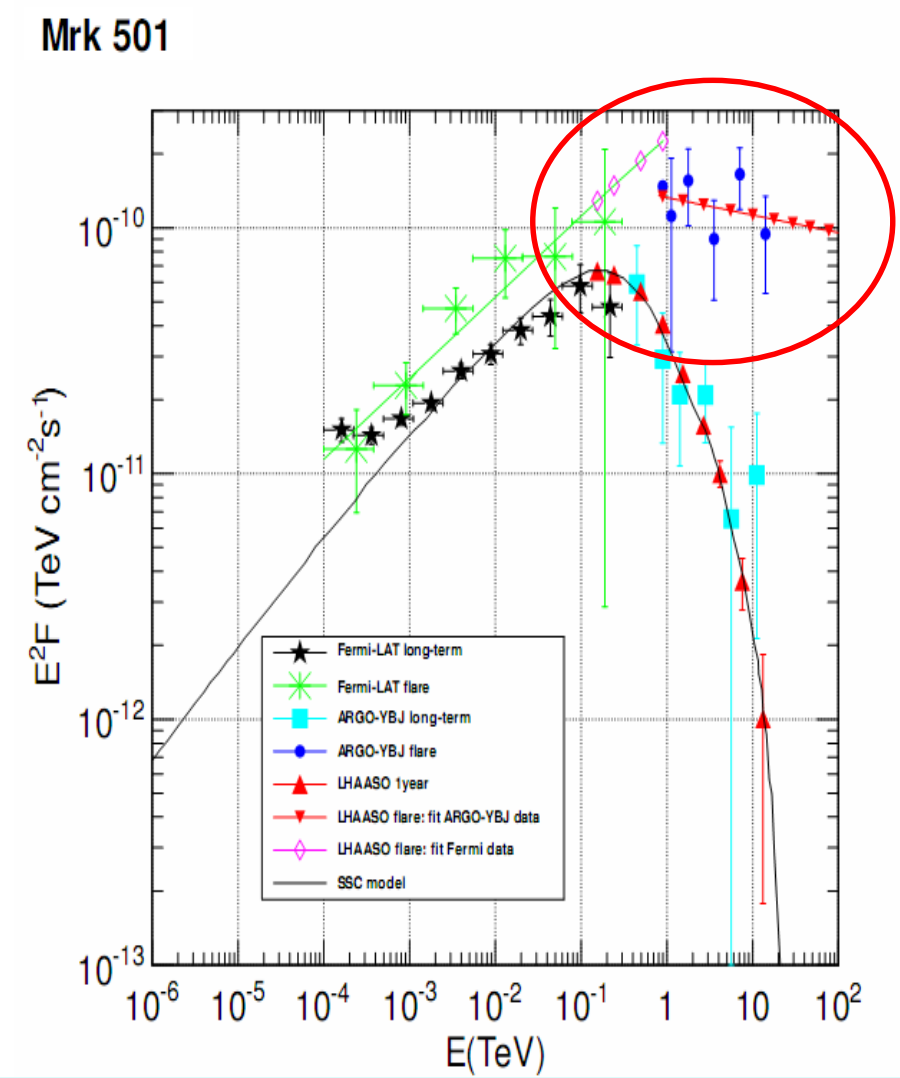
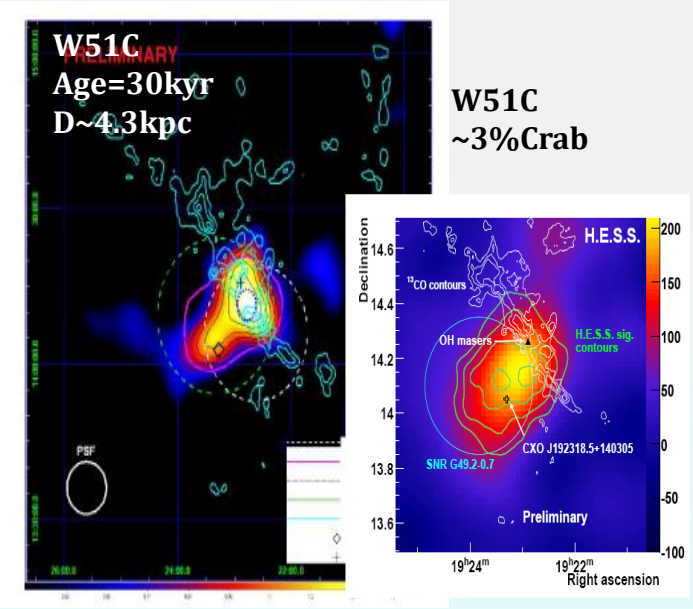


Figure 16: Expectation of the LHAASO project on Mrk501 [57], compared with the measurement of Fermi-LAT, ARGO-YBJ[27].

Central scientific target of LHAASO : Identifying Galactic Cosmic Ray Origins

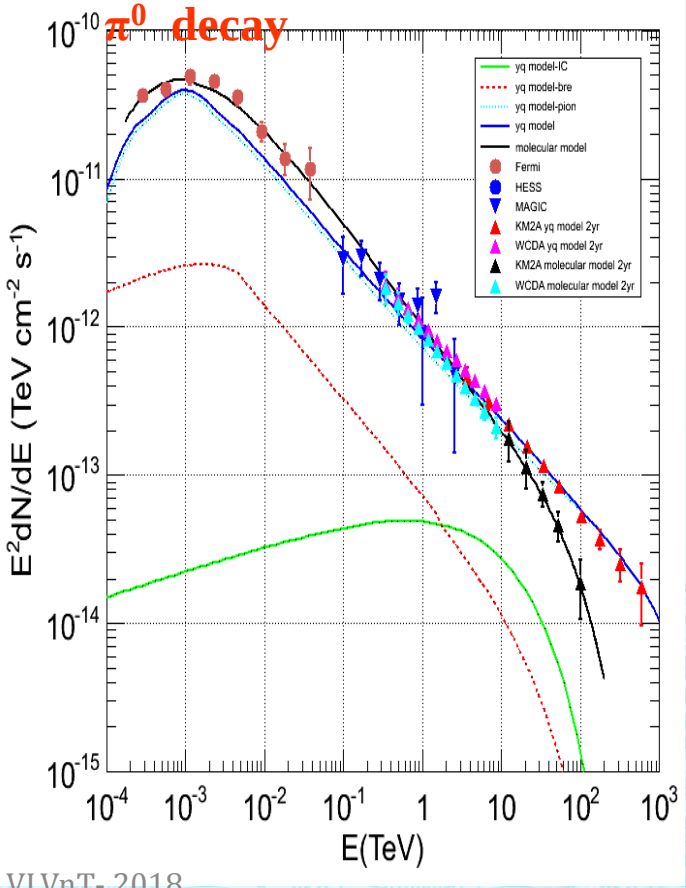
SNRs: for example W51C:

a "mixed-morphology" type of SNR, shocked atomic and molecular gases show the interaction between shock and molecular.



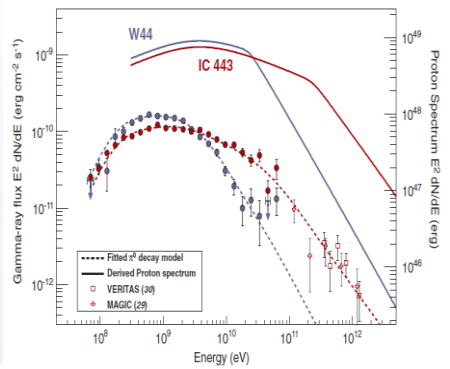
reference~ APJ, 761:133(2012) && Mon.Not.R.Astron.Soc, 421,935-942(2012)

GeV&TeV~ dominated by π^0 decay



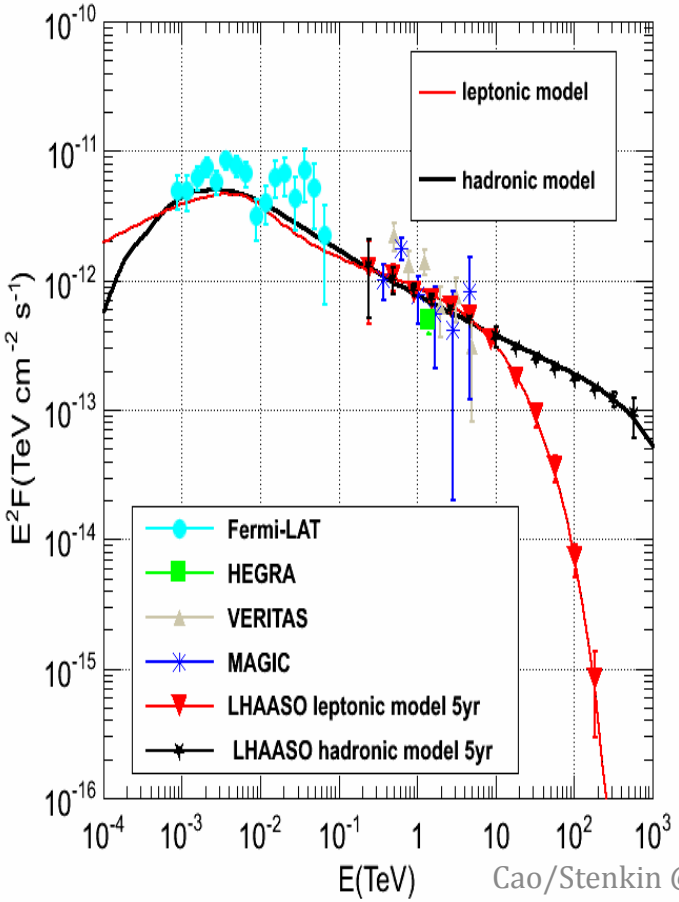
Hadronic vs. Leptonic

Characteristic signatures of π^0 decay: at highest energy by LHAASO

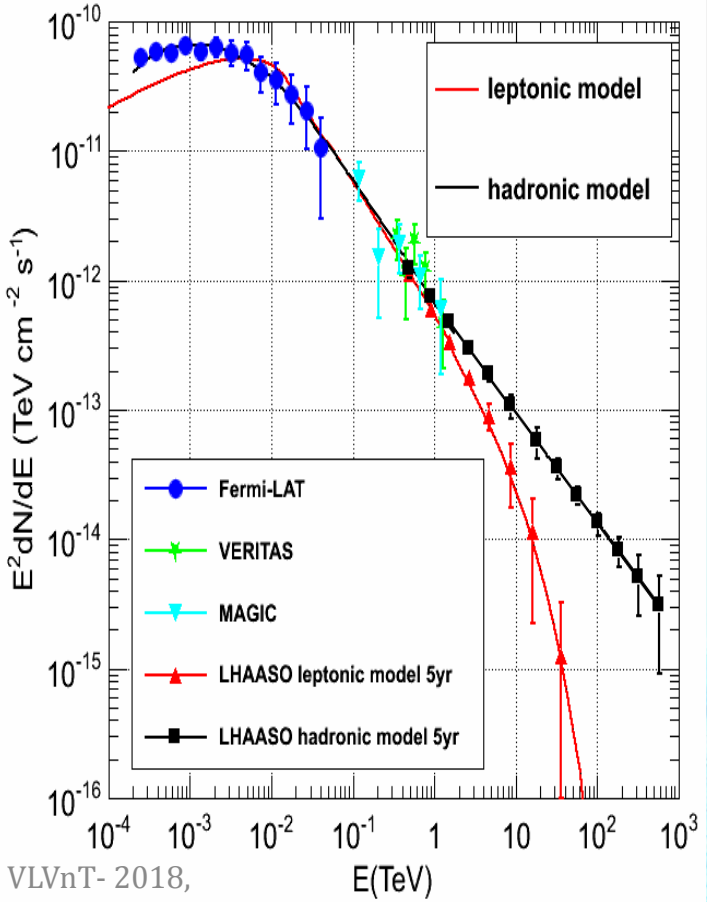


10.1126/science.1231160

Cassionpeia A Historical SNRs

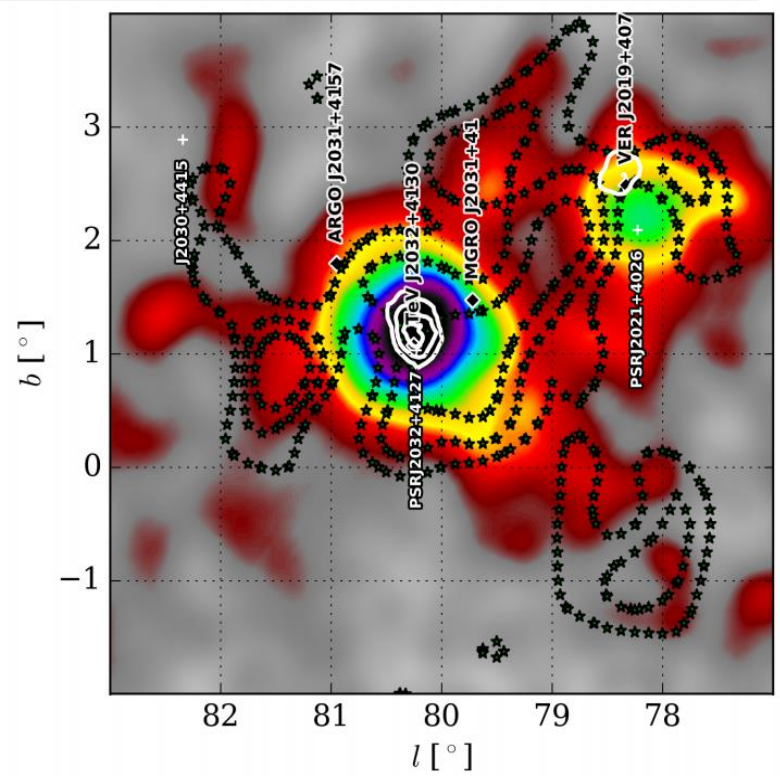


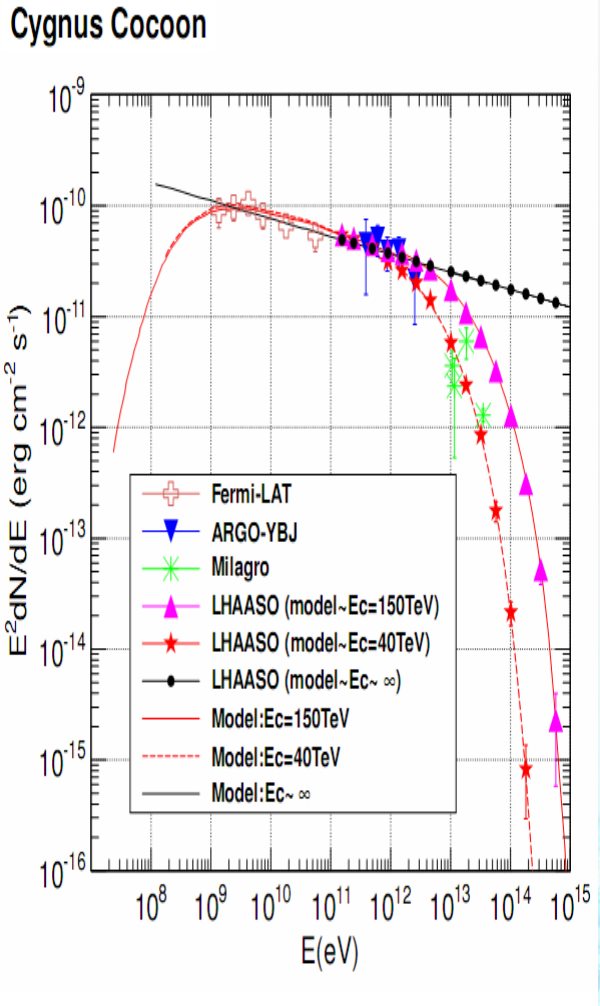
IC443 interacting with molecular clouds



Broad Objects: Cygnus region

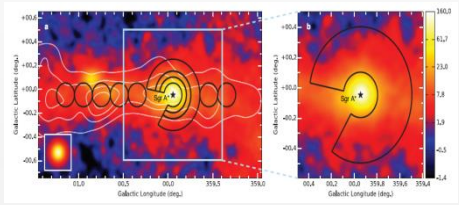
The 1st VHE supper-bubble by ARGO-YBJ



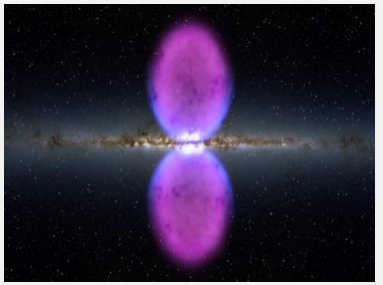


Overlapping sources？Morphological study？Multi-wavelength？

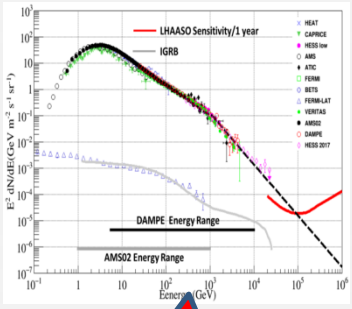
Many Topics in Astroparticle Physics



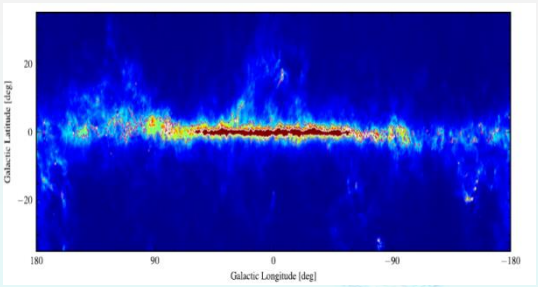
Galactic Center



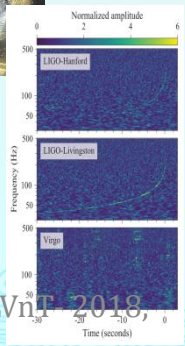
FERMI Bubble



e+e- spectrum

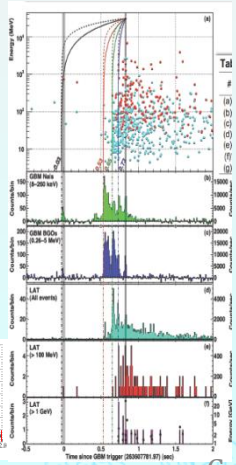


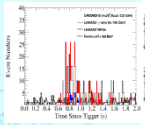
GW170817



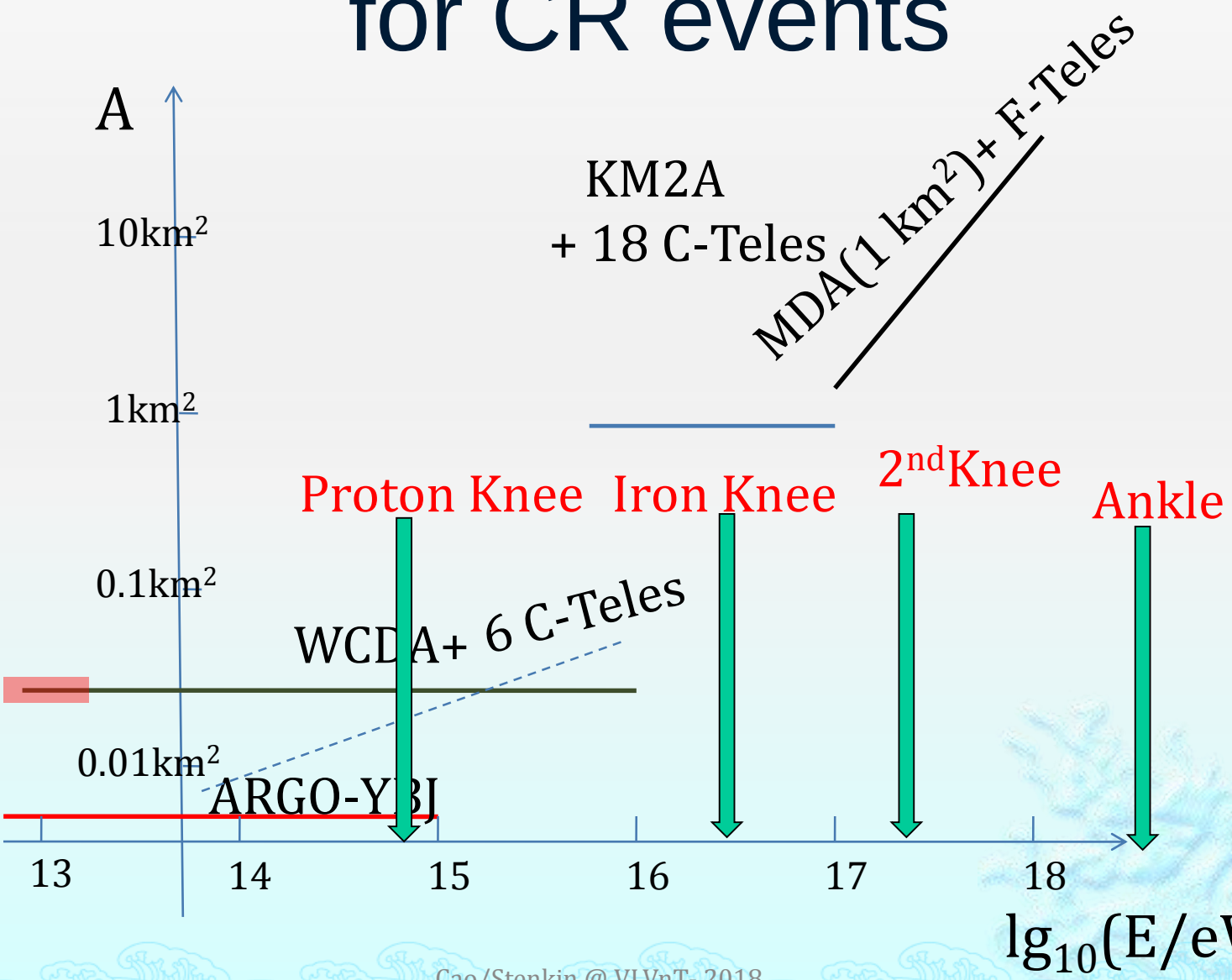
Diffuse γ Background

GRB 090501



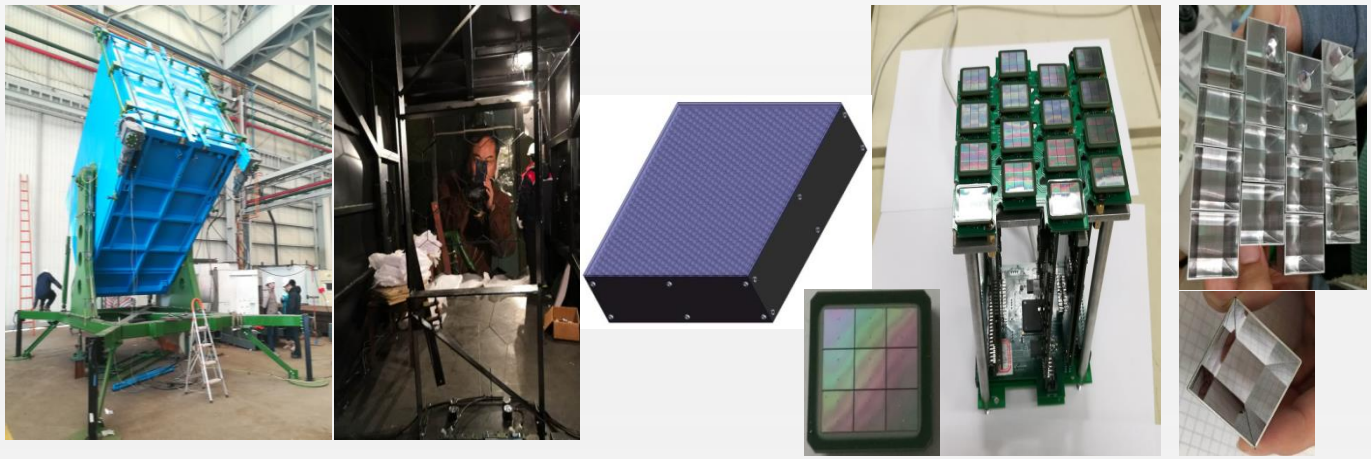


Aperture of LHAASO for CR events



Wide FoV C-Telescope Array

Fully portable telescopes allow reconfiguring the array for CR detection in 3 energy ranges



- Movable telescope housing
- Rotating from 0° to 90° in elevation

- 5 m^2 spherical aluminized mirror
- Reflectivity of 85%

- 32×32 SiPM array
- FoV of 16°×16°
- 0.5° pixel
- 1-4000 PE nonlinearity less than 5%

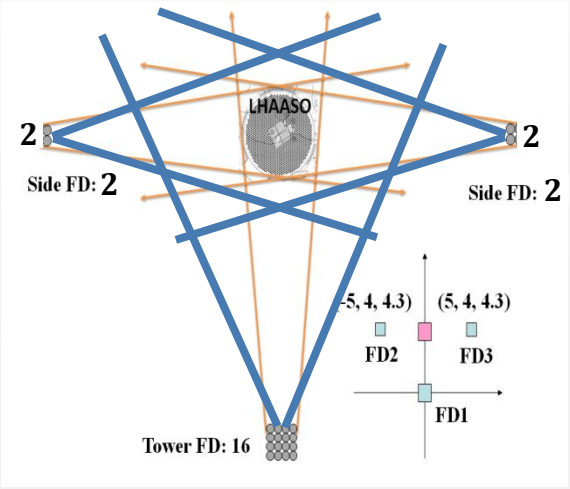
- 4×4 20μm SiPM sub-cluster
- 50 MHz FADC
- Temperature-compensation power supply
- T-stamp from WR network

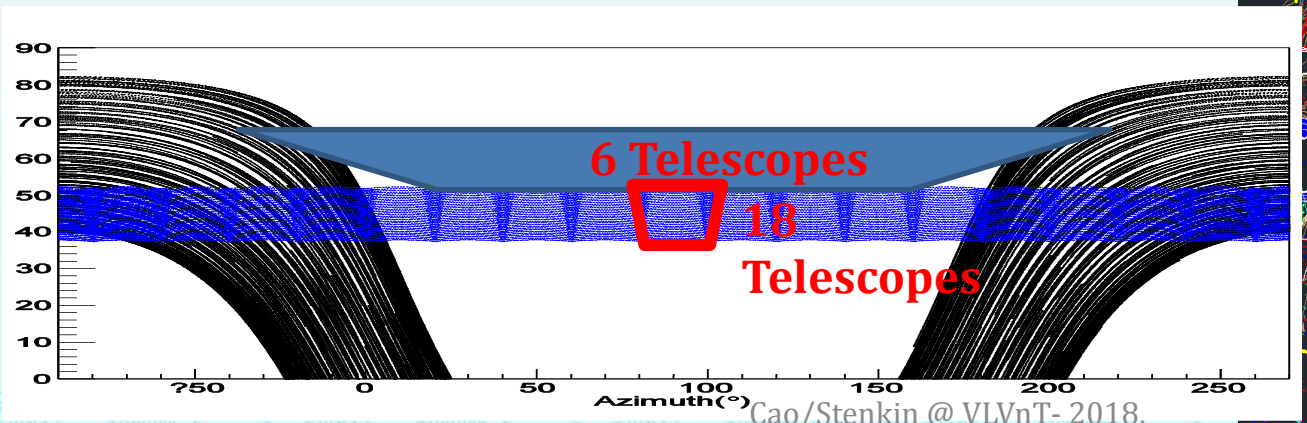
- Aluminized Winston cones
- Cut-off angle 30° with efficiency of 93%
- Filter transmission of 92% in 310-550 nm

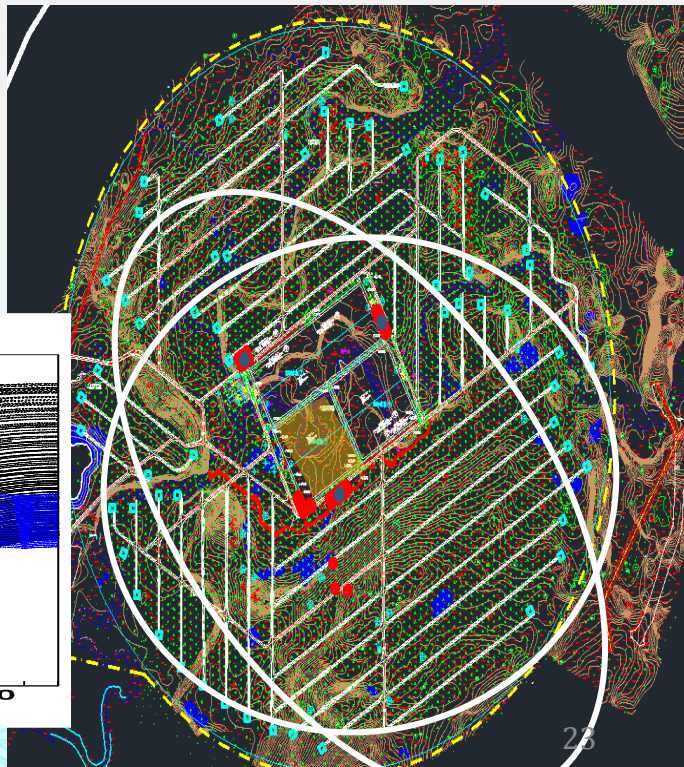
Elevation of 60 toward North with full-moon duty cycle >30% above 100 TeV

Layout for Three Energy Range

- **0.1-10 PeV in 2019**
  - pure proton and pure Helium spectra
  - 6 C-Tel's (60 in elevation) + 1st pool
- **1- 100 PeV in 2021**
  - Pure iron or heavy nuclei (MgAlSi+Fe) spectra
  - 18 C-Tel's (45 in elevation)+ Scin.+ MD array
- **>100 PeV in 2023**
  - 2nd knee
  - 20 F-tel's + MD array

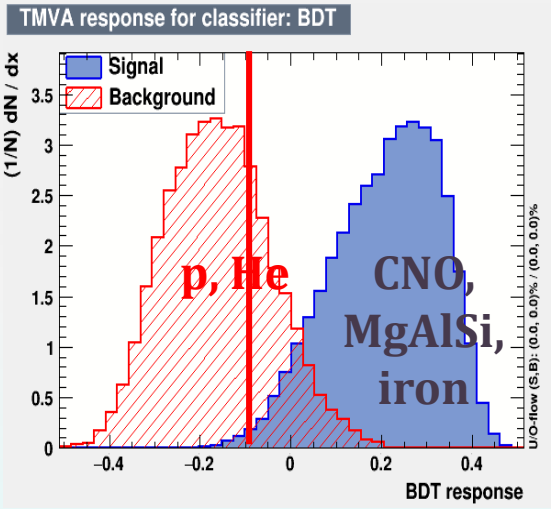


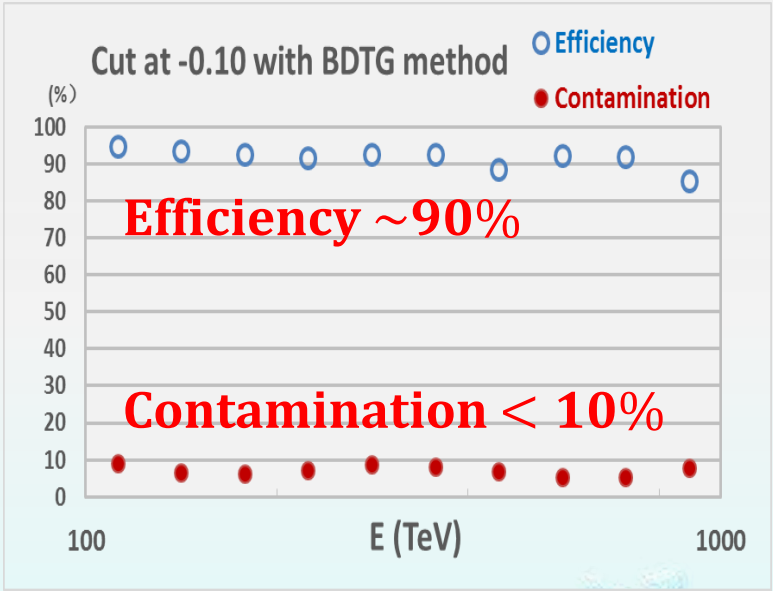




MVA method for p,He / heavy separation

With the Multi-Variate Analysis methods (e.g. neural networks and boosted decision trees), good separations for p/iron and p+He/heavy nuclides identification can be obtained.

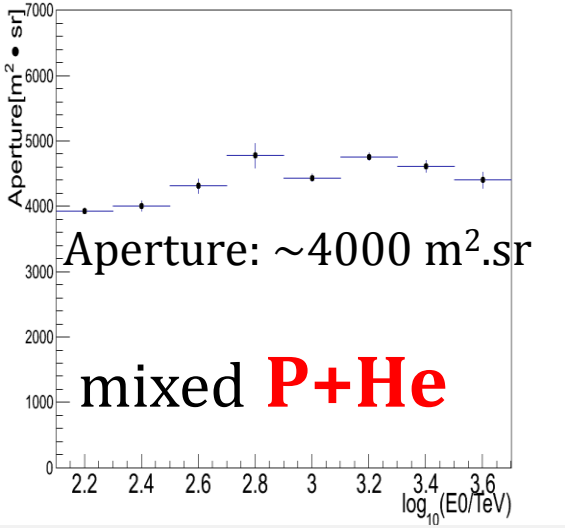


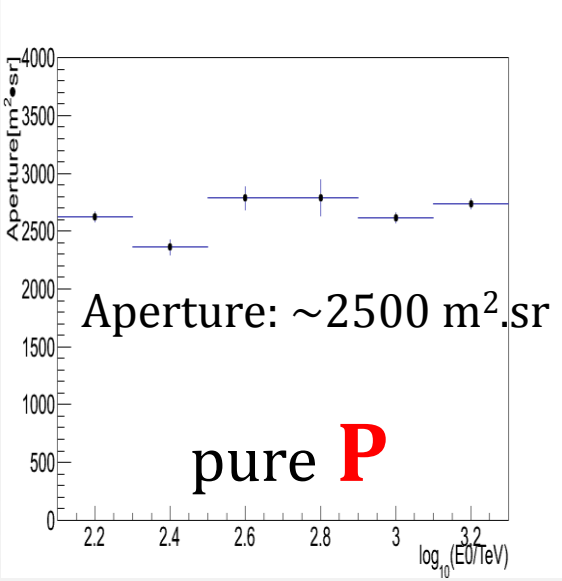


Separation of light (p+He) and heavy nuclei by the BDT (Boost Decision Trees) method.

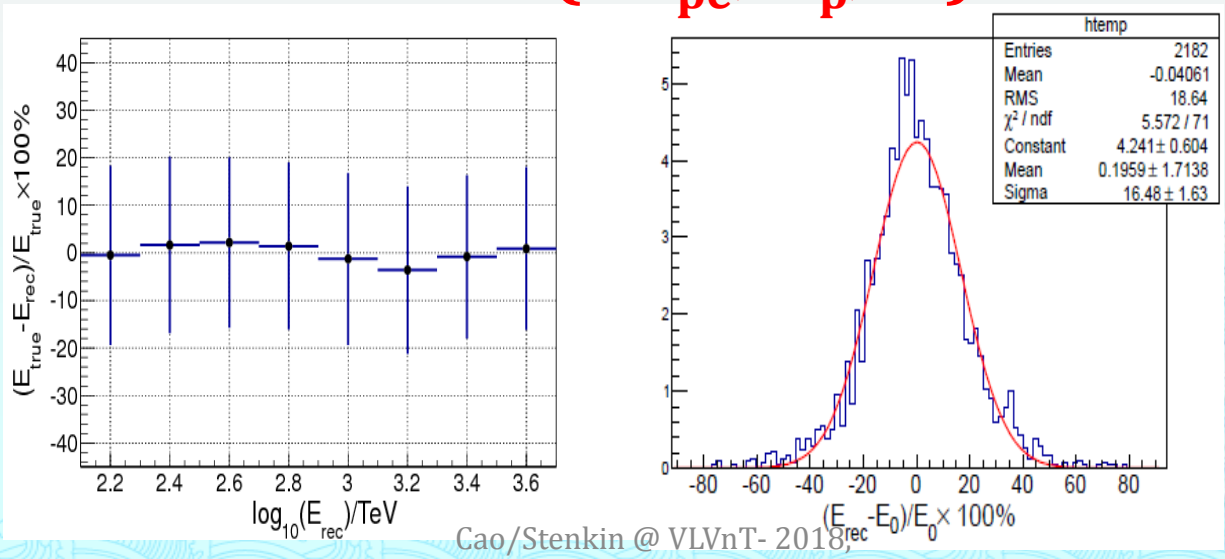
The contamination is calculated based on the Hörandel model.

Apertures and E-resolution



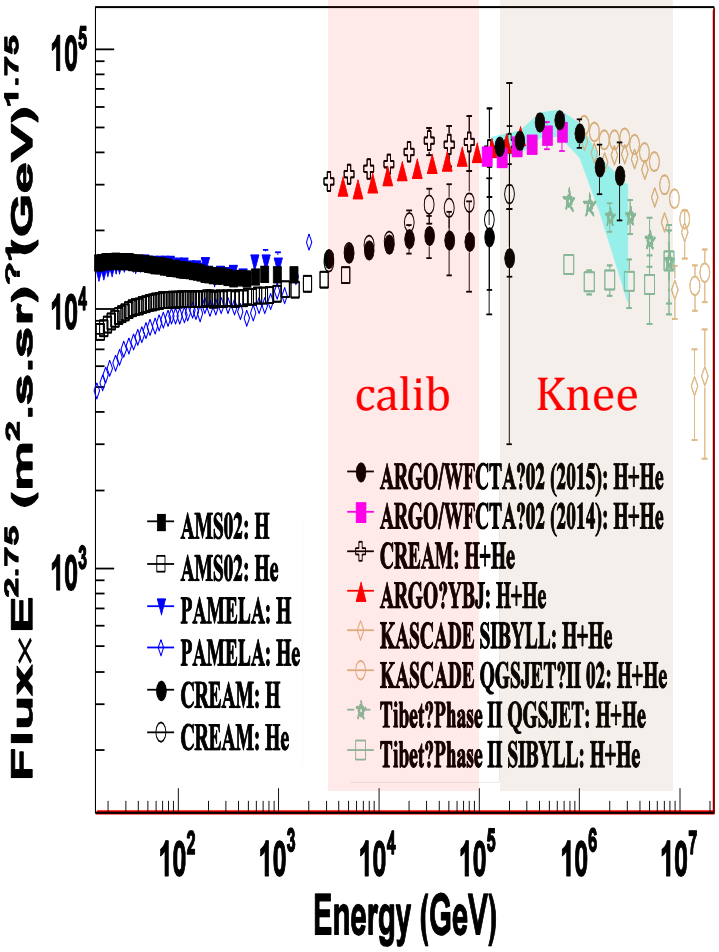


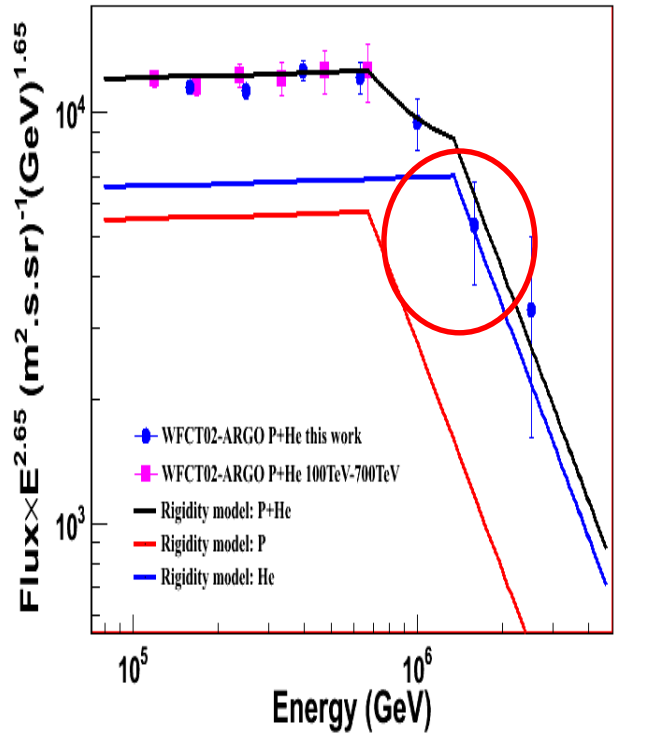
$$E = E(\Sigma N_{pe};\ R_p,\ \alpha)$$



Cosmic Ray Physics: Charged Nuclei knees of spectra of individual species

Using only two parameters, at ARGO-YBJ: E_{knee}-700 TeV, Phys.Rev.D 92092005 (2015)

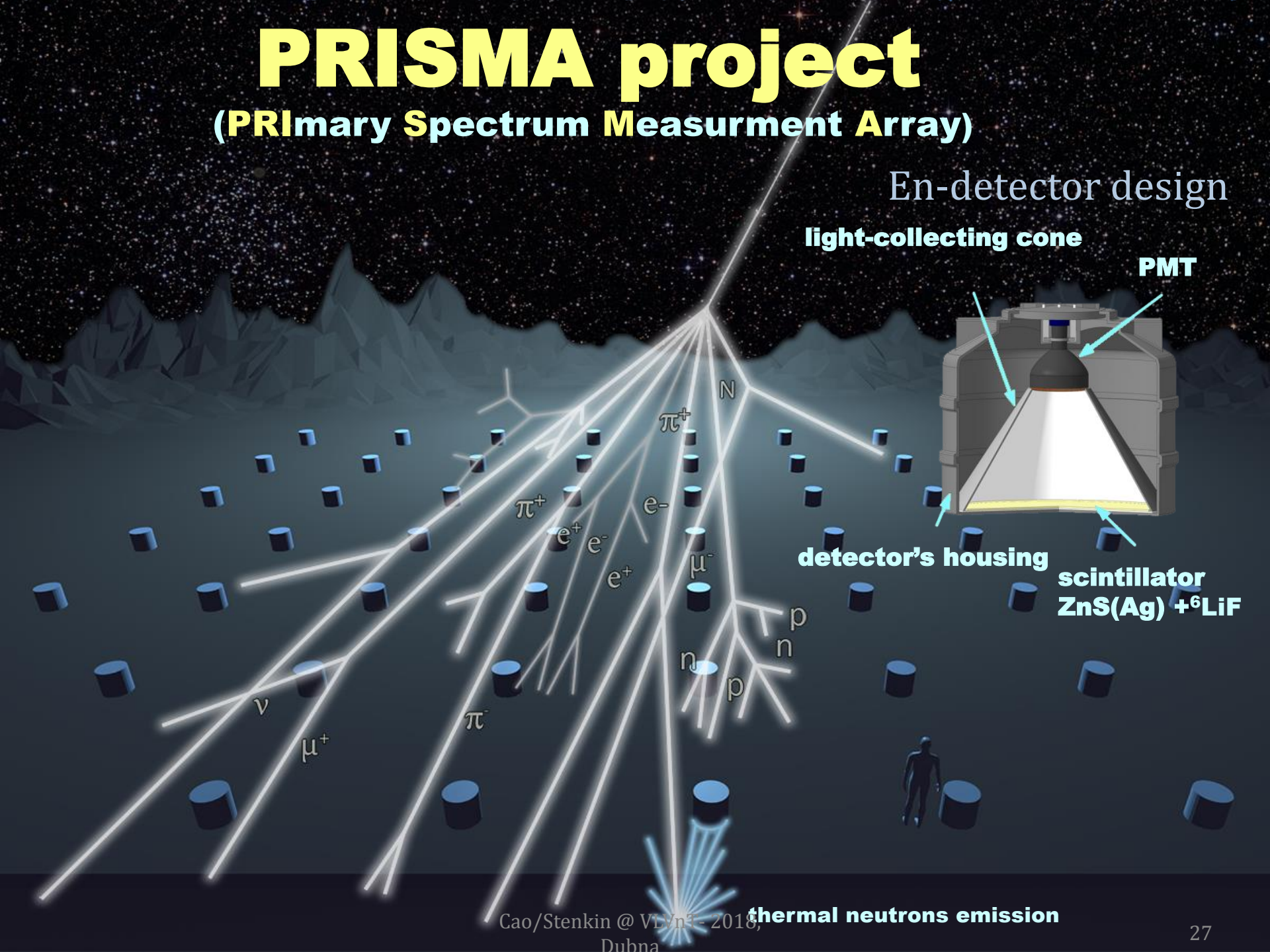




Proton spectrum with Rigidity model and H:He=1:1.2

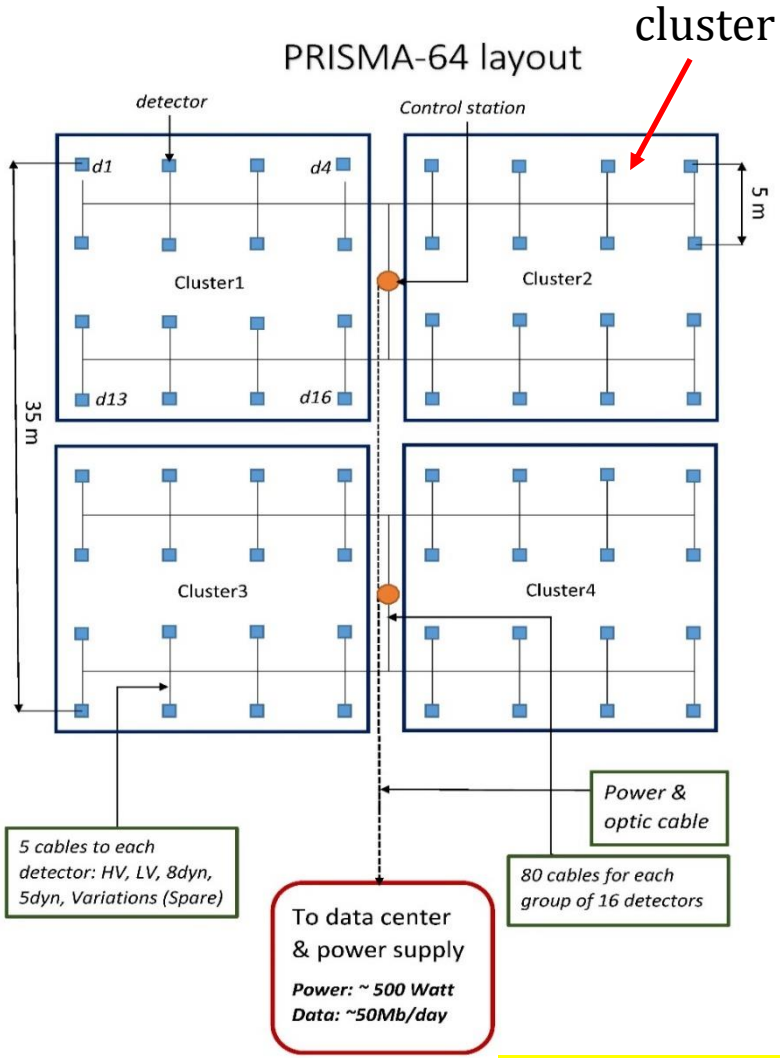
PRISMA project

(PRImary Spectrum Measurment Array)



PRISMA-LHAASO

The array of 64 en-detectors (4 clusters) under construction in conjunction with LHAASO project

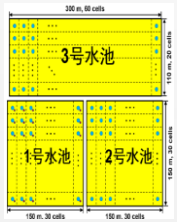


Future plan: 400 en-detectors (25 clusters)

EAS thermal neutron measurements

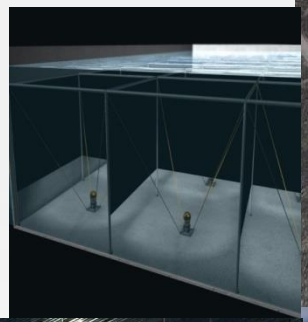
Construction

- #1 pool（150X150 m^2）is built 2018/04, #2 & #3 pools are started simultaneously



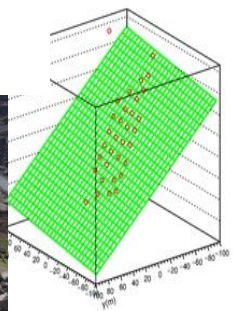
1st water pool

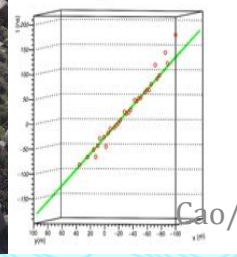
Installation Inside the pond

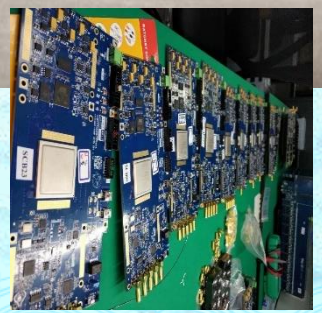


Construction: EDs and WR Switches

- 2018/02/04, first 33 scintillator detectors deployed.
- The 1st LHAASO event







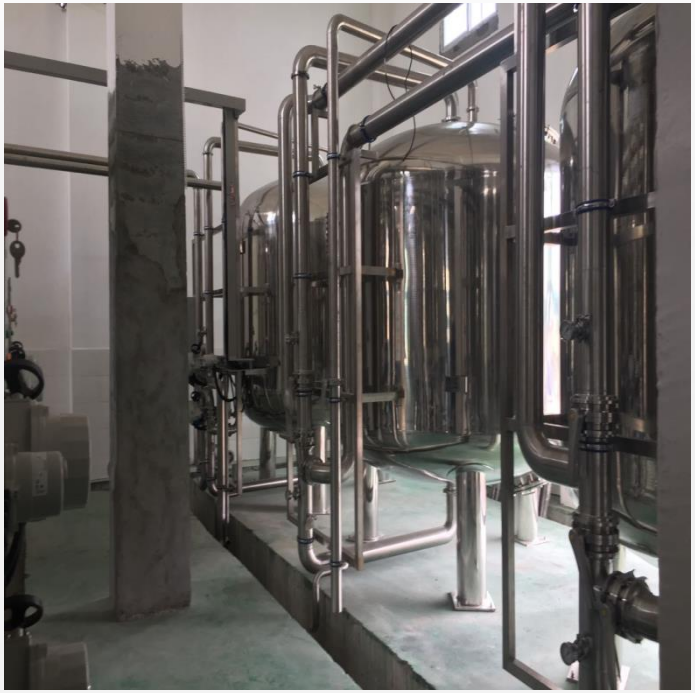
Construction of LHAASO-1/4

A few muon detectors are covered

1st muon detector

Liner

LHAASO
高海拔宇宙线观测站



Water purification & recycling system for 0.45M tons

Summary

- LHAASO observatory for gamma ray astronomy
  - Unique on 10 TeV gamma ray monitoring
  - Window for evidences of hadronic origin of cosmic rays
- Detector construction started June 2017 and infrastructure May 2016. ¼ of the array will be turned on for scientific operation next spring and the construction will be finished in 2021
- 20” PMTs in #2-3 pond will enhance the low energy sensitivity for extragalactic phenomena
- Measuring of neutron component will increase γ-shower selection and primary mass A estimation accuracy at E> 1 PeV
- LHAASO has been funded mainly by China with 20+ institutions joining the collaboration