The GNN-internal MANTS meeting

Status of HUNT

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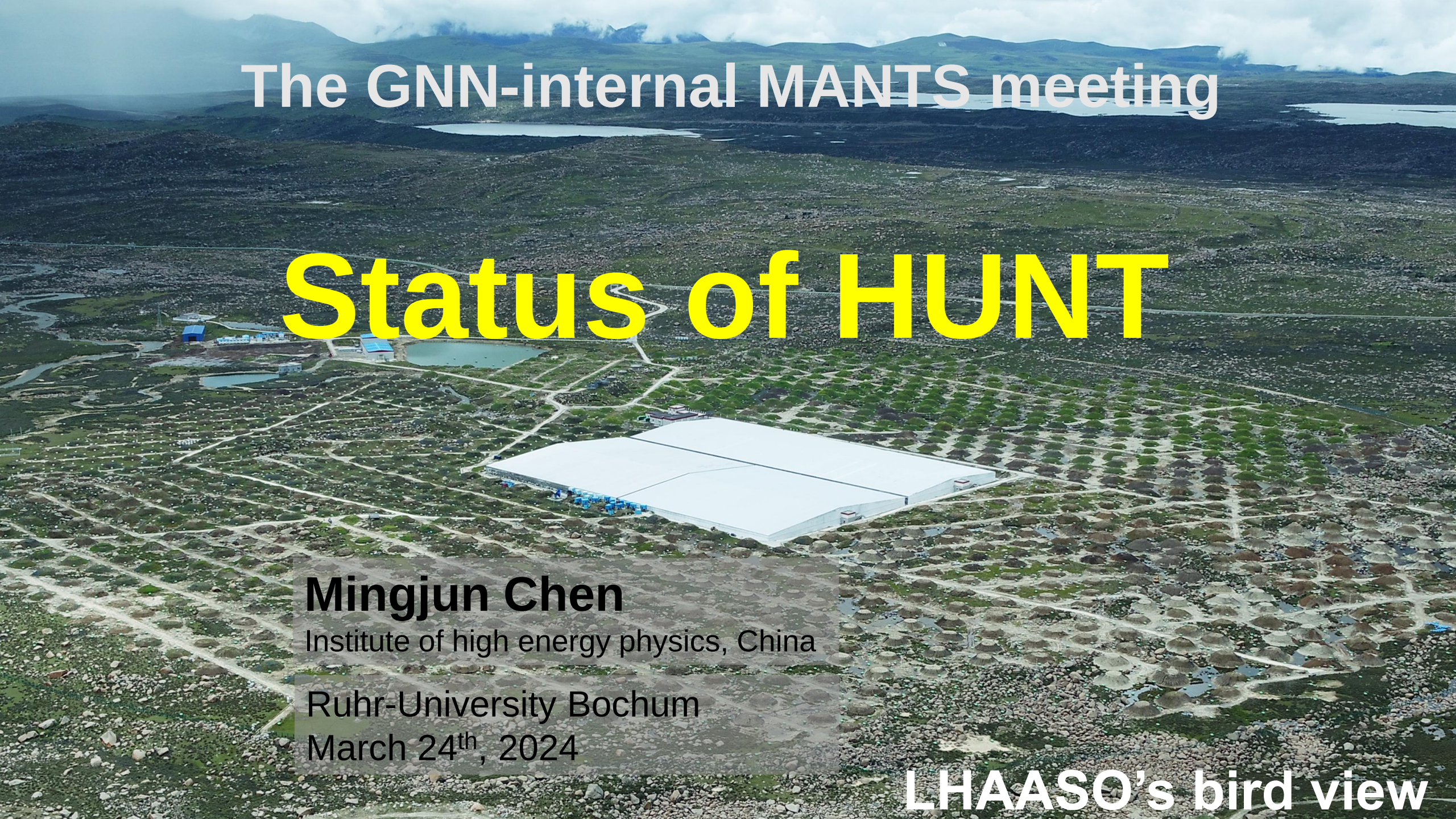


LHAASO's bird view

Content

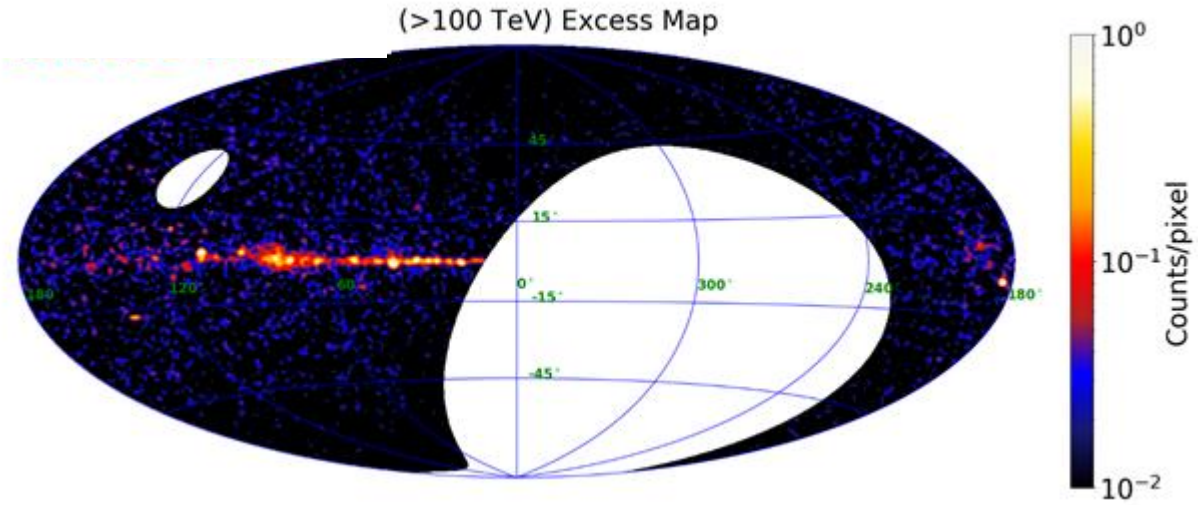
- Motivation
- HUNT project
- R&D work
- Summary

01 Motivation

Motivation

Neutrino observation will decisively solve the problem of the origin of cosmic rays!

- PeVatrons ⟹ neutrinos above 50 TeV & gamma-rays above 100 TeV.
- LHAASO observed tens of gamma-ray sources above 100 TeV.
- Gamma-rays above 100 TeV can be produced in both leptonic and hadronic scenarios.



Main process:

$$p + p \longrightarrow N(\pi^+ + \pi^- + \pi^0) + X$$

$$p + \gamma \longrightarrow n + \pi^+$$

$$\pi^+ \longrightarrow \nu_\mu + \mu^+ \longrightarrow \nu_\mu + (e^+ + \bar{\nu}_\mu + \nu_e)$$
$$\pi^- \longrightarrow \bar{\nu}_\mu + \mu^- \longrightarrow \bar{\nu}_\mu + (e^- + \nu_\mu + \bar{\nu}_e)$$
$$\pi^0 \longrightarrow 2\gamma$$

1st LHAASO Catalog: 43 UHE gamma-ray sources (>4σ).

* LHAASO Collaboration, 2021, Nature, 594, 33.
* LHAASO Collaboration, 2024, ApJS, 271, 25.

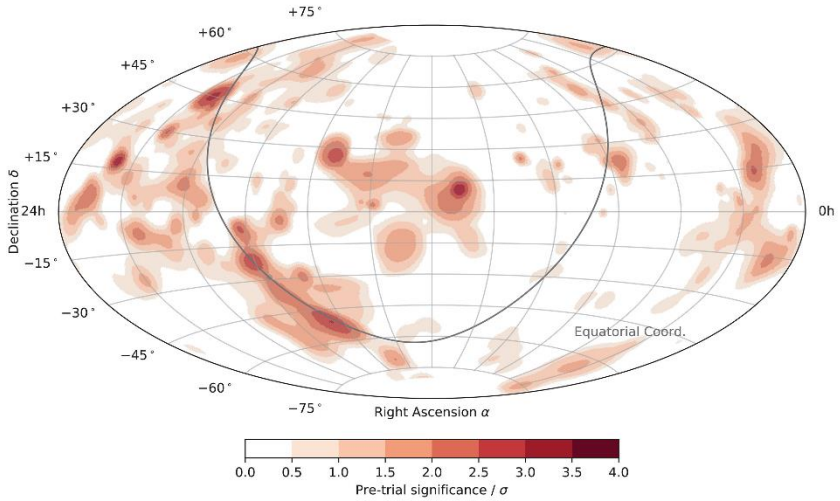
Status of neutrino astronomy

- **2013 The first discovery of astrophysical high-energy neutrinos.**

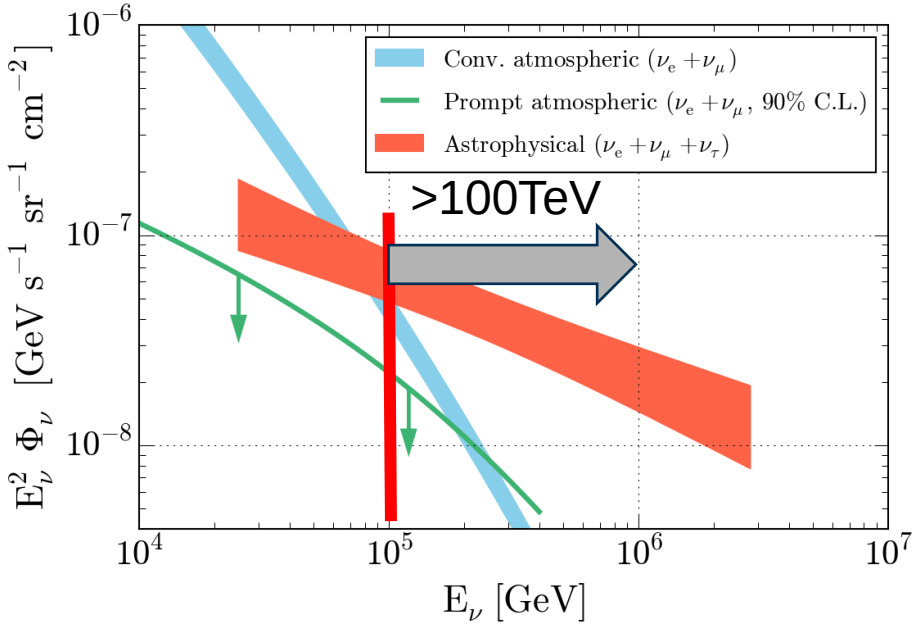
2018 First hint of association between neutrino excess and blazar TXS 0506+056 (3.5σ).

2019 The neutrinos from Seyfert II Galaxy NGC 1068 exceed the background at the level of 2.9σ.

- **2023 Signs of diffuse neutrinos in the milky way , ~4σ.**



All-sky point source search with ten years data.



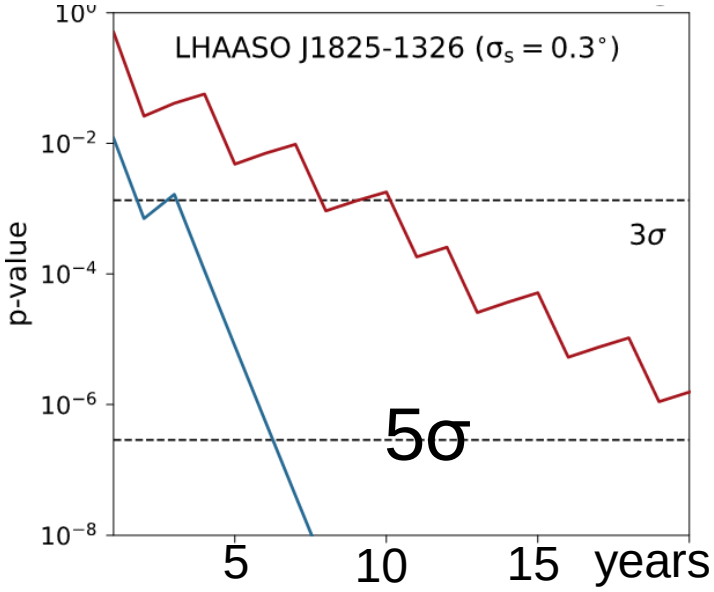
Energy spectrum of the astrophysical neutrino flux.

* IceCube Collaboration, 2023,Nature, 380, 6652

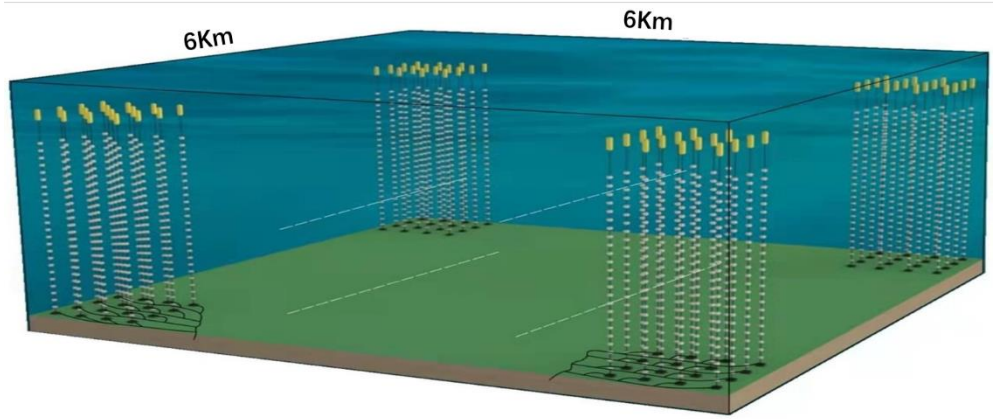
Detector Design

A ~30 km^3 neutrino telescope with 2,300 strings

Discover the neutrino sources(> 100 TeV) in a couples of years.



Expected neutrino flux: ~ 10^{-12} TeV/cm^2/s@100 TeV
Spectral index: ~ 3 @100 TeV



Specifications:

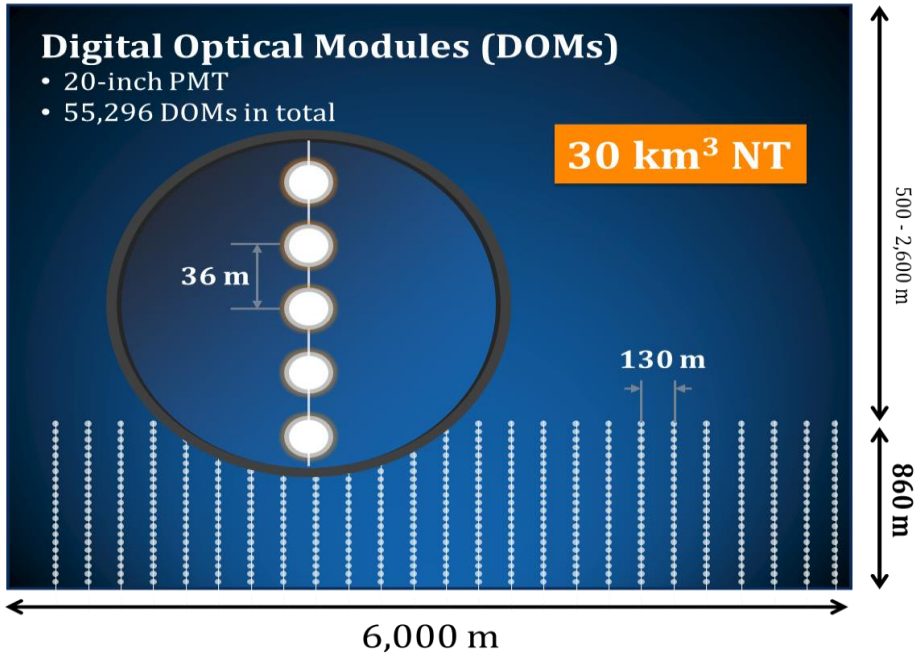
- Angular resolution: ~0.1° (tracks), <3°(cascades)
- Energy resolution: ΔlogE~0.3(tracks), ΔE~10-30% (cascades)

02 HUNT project

High-energy Underwater Neutrino Telescope

Preliminary design (λ_a~22 m@Baikal) :

- **Area:** 6×6 = 36 km^2, **~30 km^3**
- D_{string} ~ 130 m
- D_{OM} ~ 36 m
- Length ~ 860 m
- ~ 2,304 strings
- 24 OMs/string, **~55K OMs**



Possible layouts.

Optical module with 20-inch PMT

20-inch PMTs installed in LHAASO

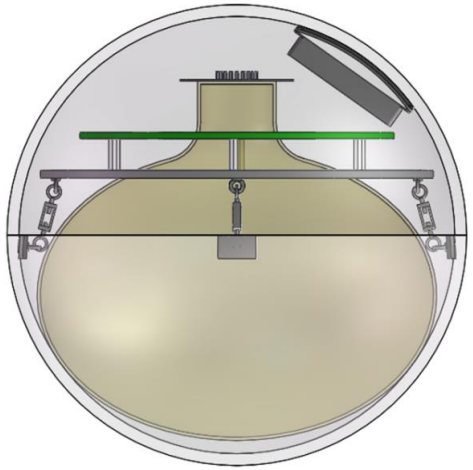
20-inch PMT:

TTS: ~7ns; QE: >25%

P/V: >2; Q: >100C

New OM is based on 20-inch PMT:
20-inch PMT in a 23-inch glass sphere.

- Large photosensitive surface
  Larger spacing between OMs
  Larger volume with the same number of PMTs



- Wide dynamic range : 1 - 2,000PEs; Digital waveform output with 0.5GHz; > 60 KHz capability for single OM.
- White Rabbit time synchronization system: <1ns.

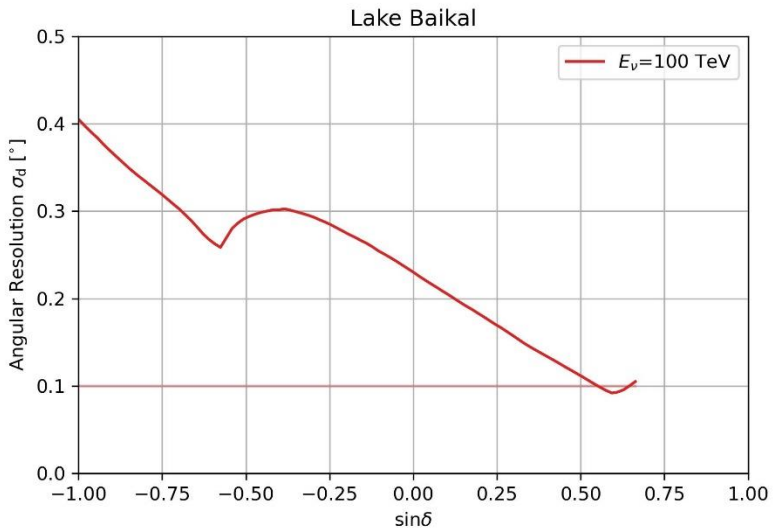
Candidate Site: Lake Baikal vs. South China Sea

	Lake Baikal	South China Sea
Absorption length	~20 m	**~25 m**
Depth	~1366 m	**~2500 m (better atmospheric muon background rejection)**
Deployment Cost	**~K$ /string**	High
Reparability	**Work on the ice (low cost)**	Difficult to be repaired
Power Supply cable	**~10 km cable**	~100 km cable or battery
Construction and Deployment	**~5 years (Feb. to Apr. every year)**	Rely on deep-ocean facilities

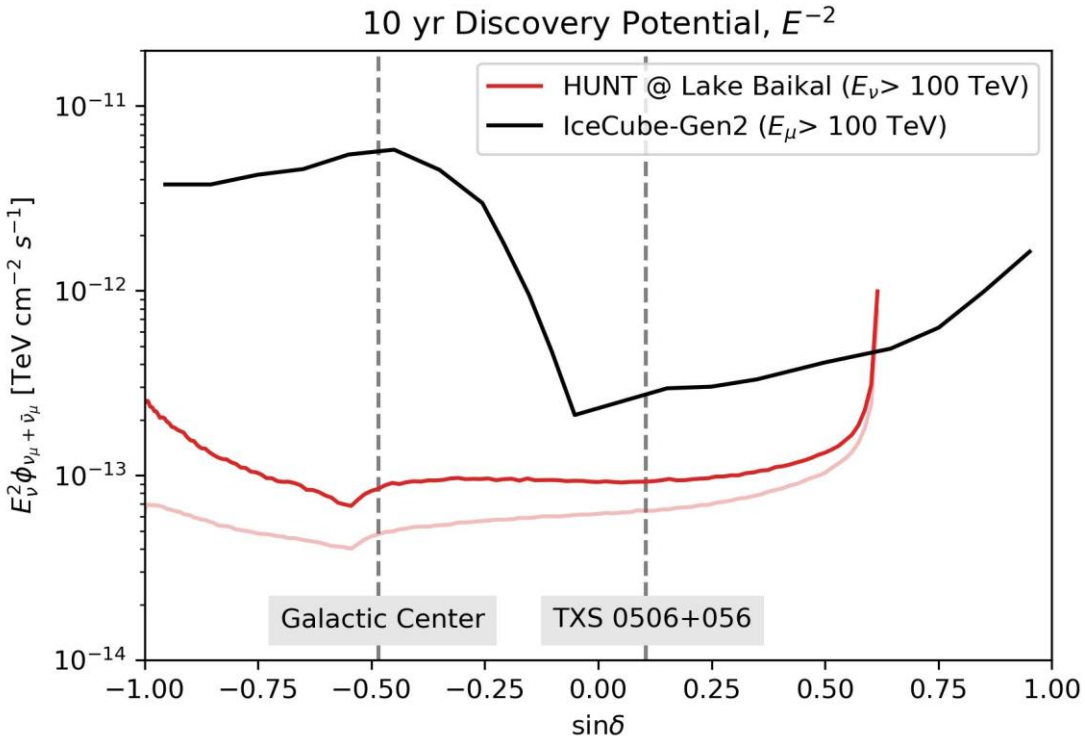
Discovery potential

Lake Baikal

- Up-going: zenith > 87 deg
- More sensitive to point-like sources with declination δ from -50 degree to 30 degree, especially for the Galactic center.



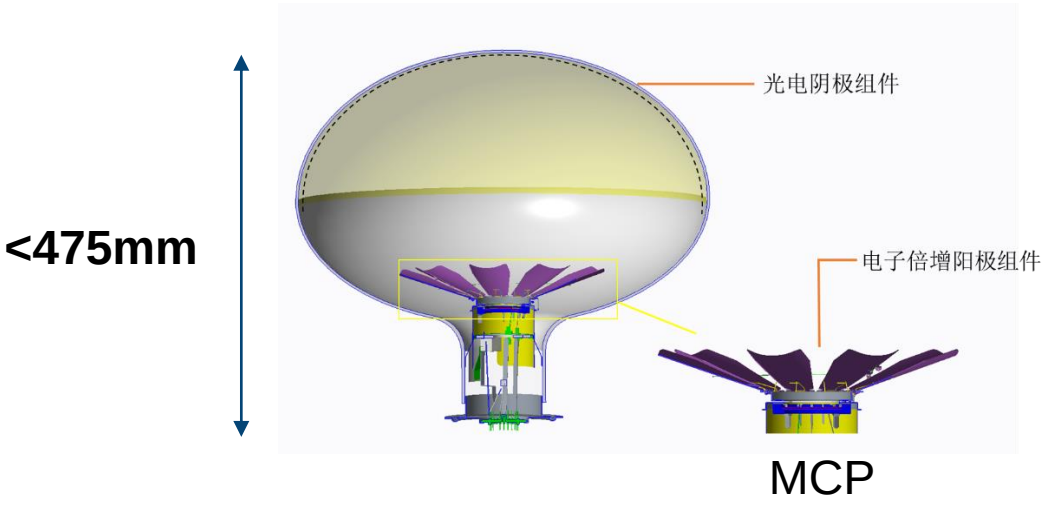
Angular resolution.



03 R&D work

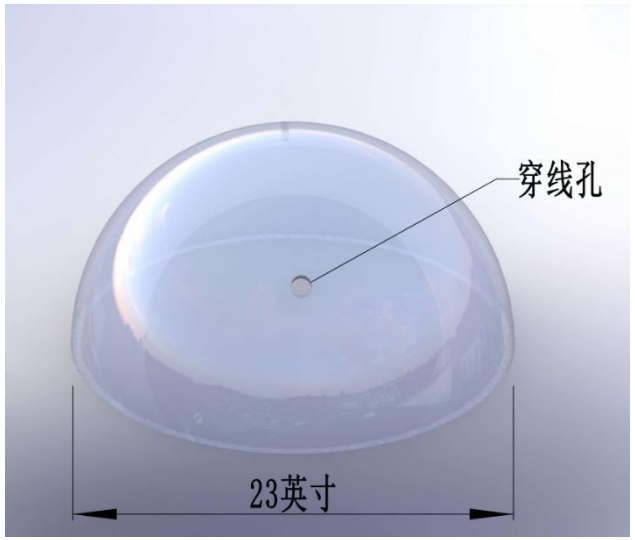
Critical equipment

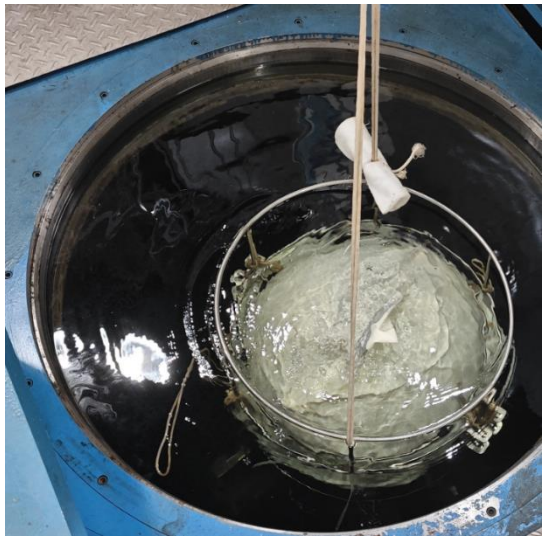
- New 20-inch PMT with short neck



Ten centimeters shorted.

- 23-inch glass sphere

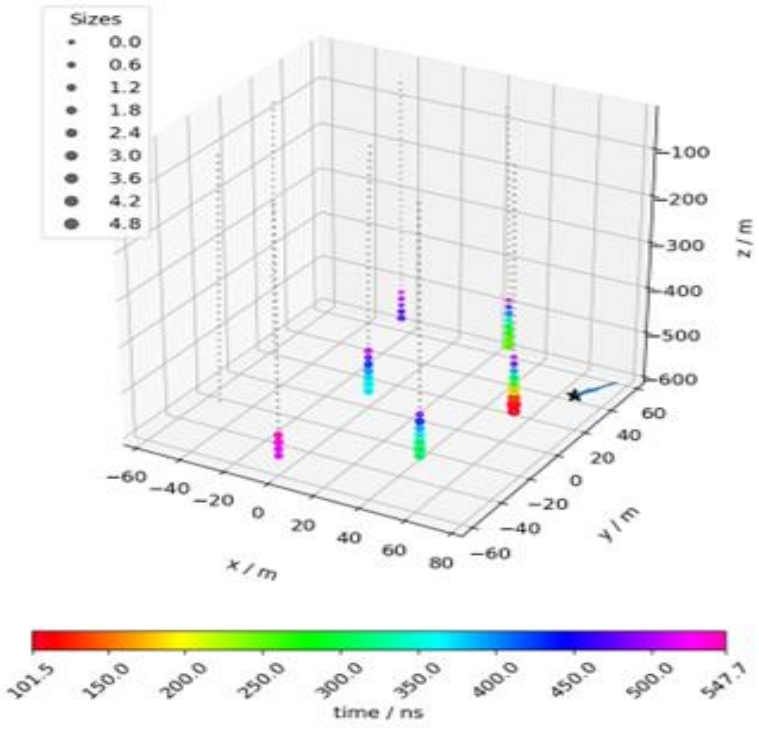


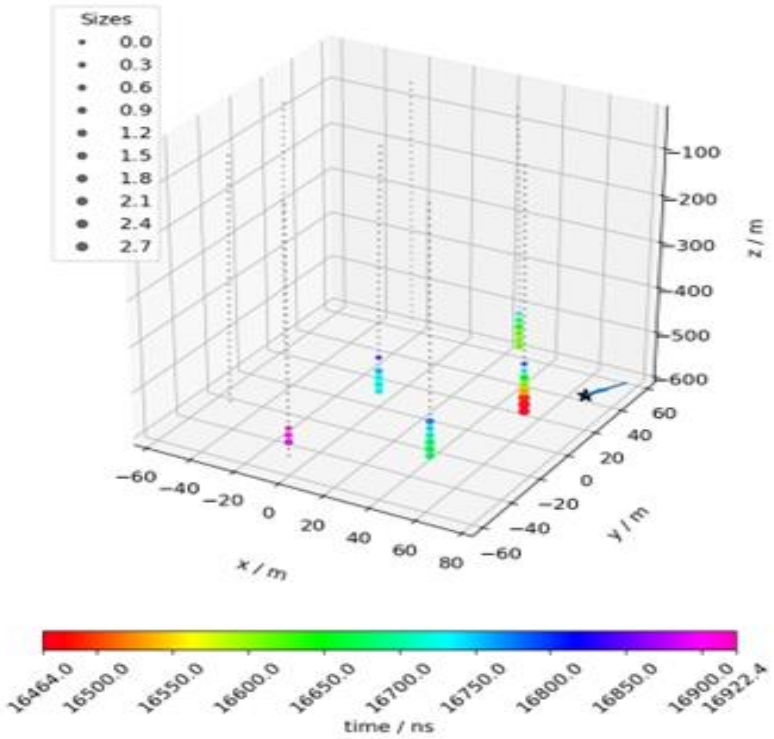


Passed 50Mpa pressure test.

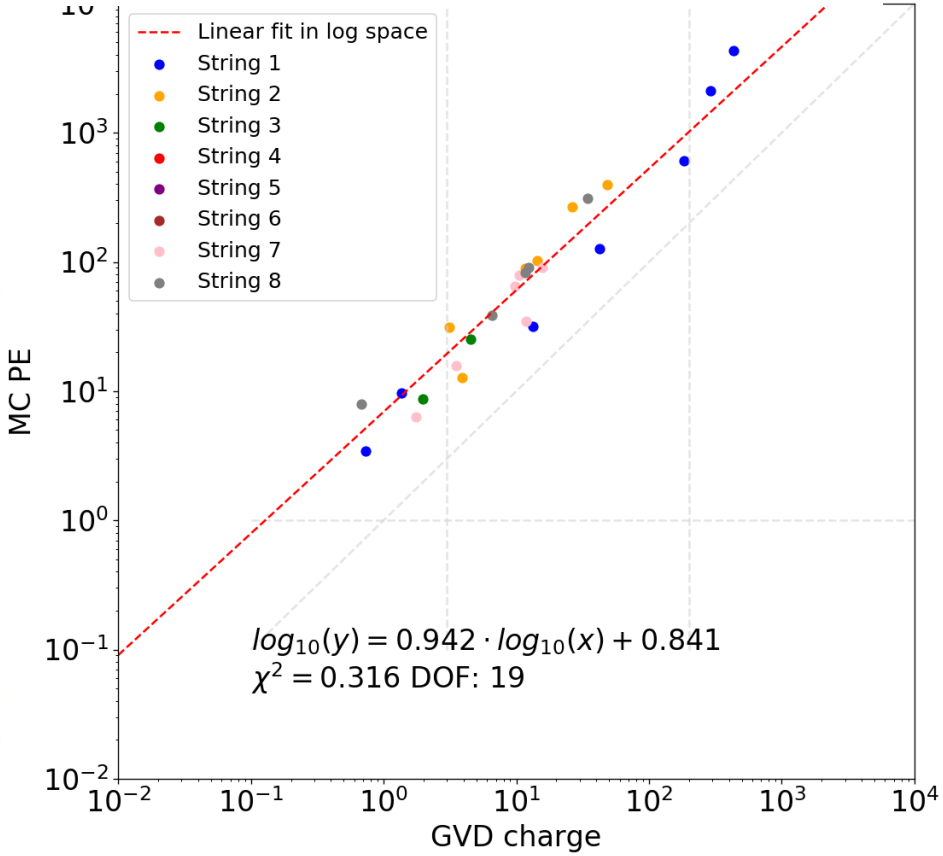
Reproduction of Baikal-GVD events by Geant4-based simulation program.

GVD210117CA Vertex pos: (75.00, 28.00, −562.00), *dir*: (49.00, 57.00), *energy*: 246





Channel



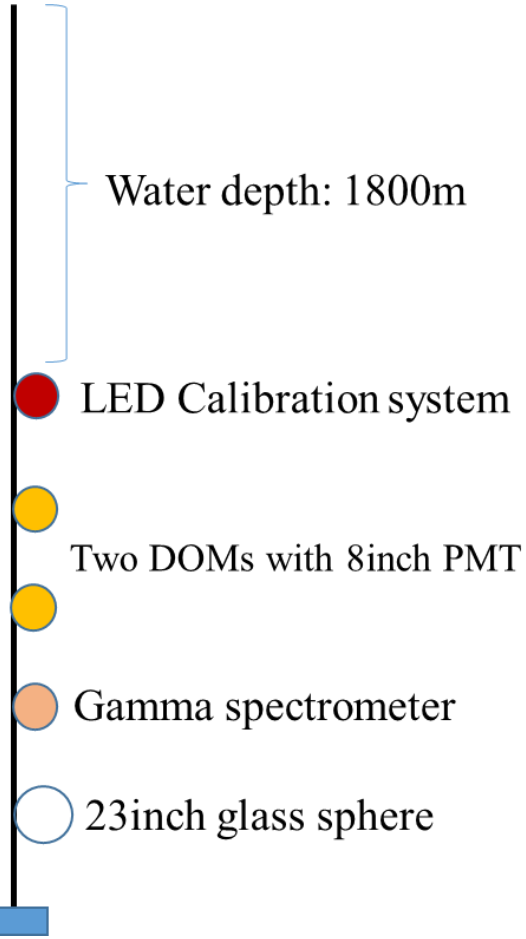
MC

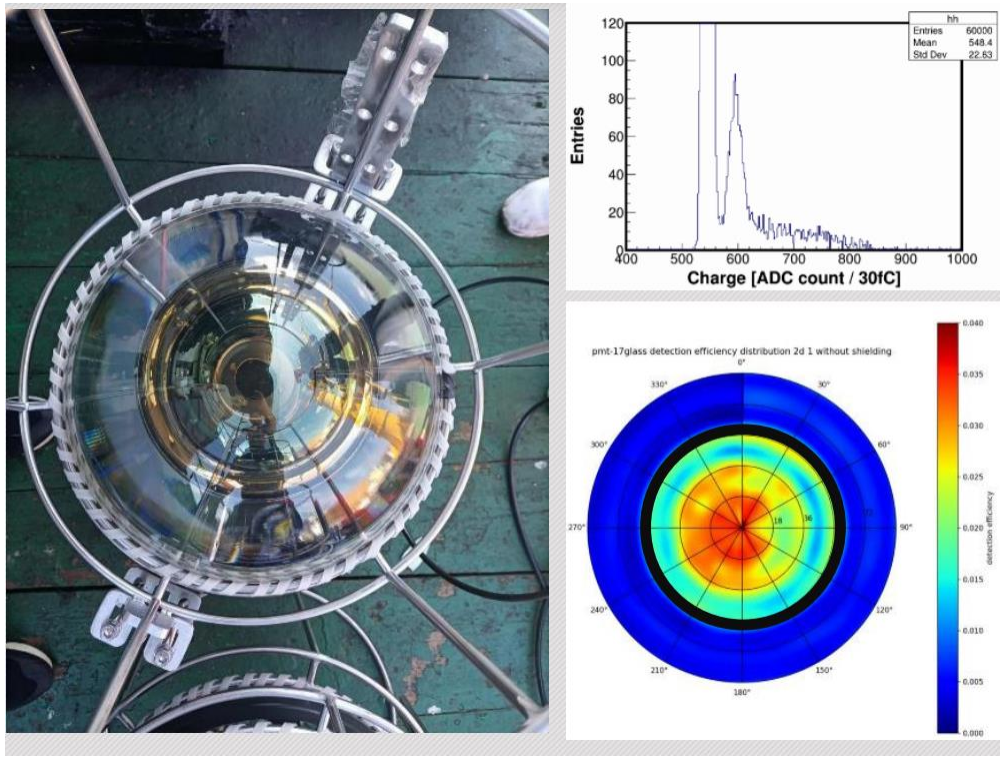
Real events

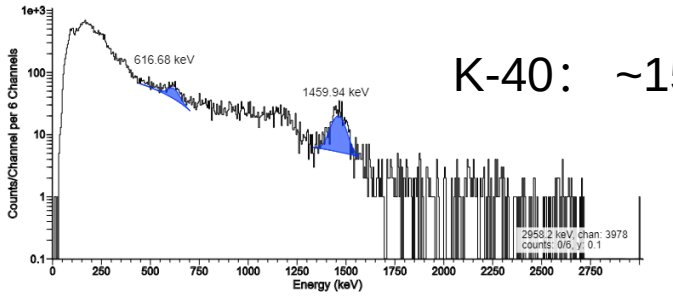
Submitted to CPC,2024

Prototype test in South China sea

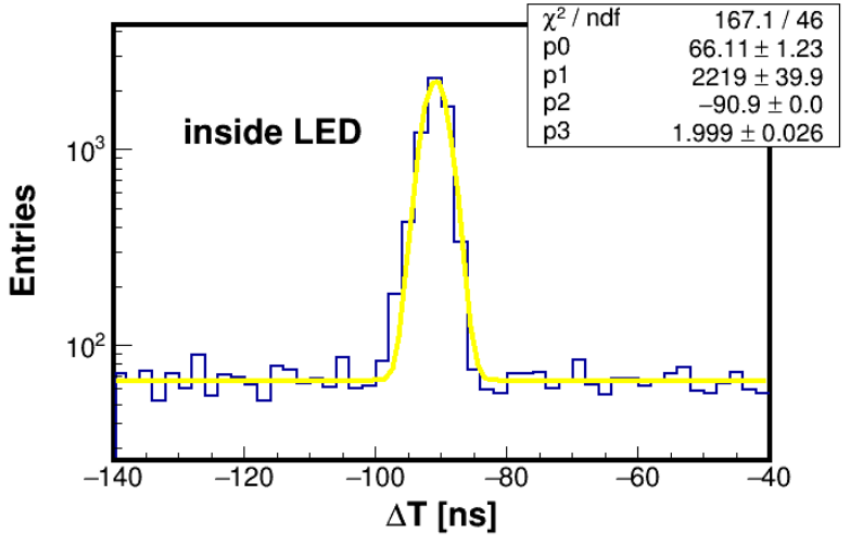
17^0 N, 113^o 20E





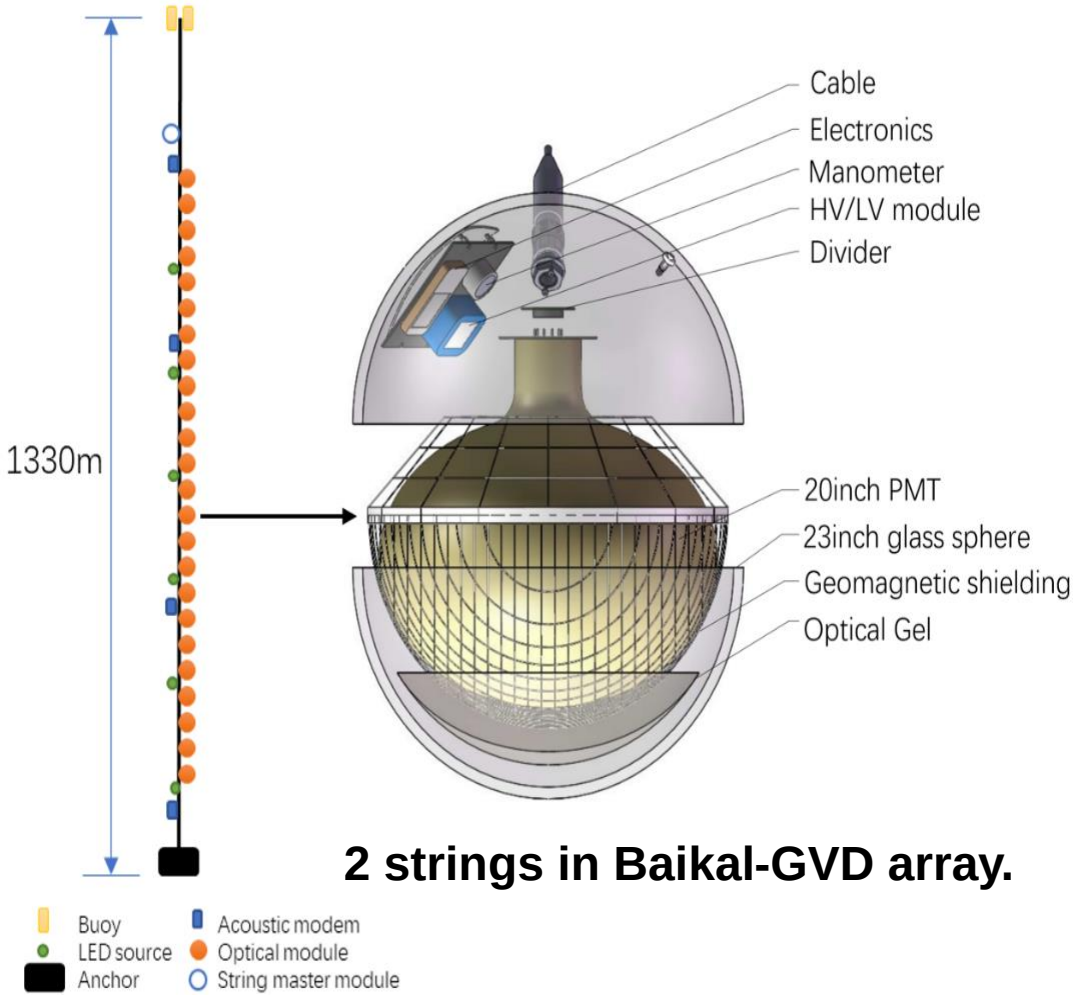


K-40： ~15Bq/L

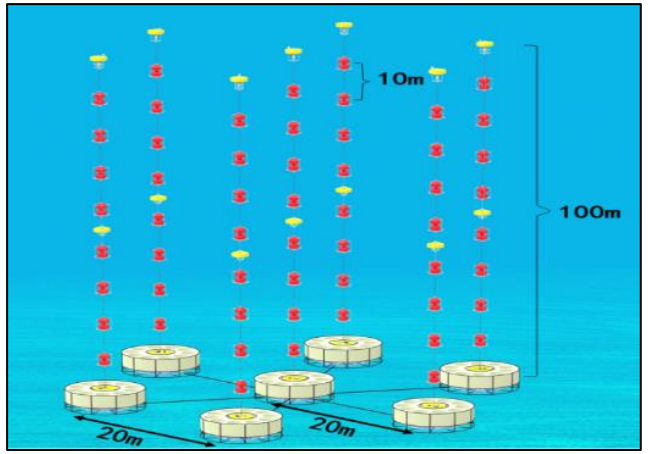


Time coincidence events.
(Dom: 20m)

Prototype string



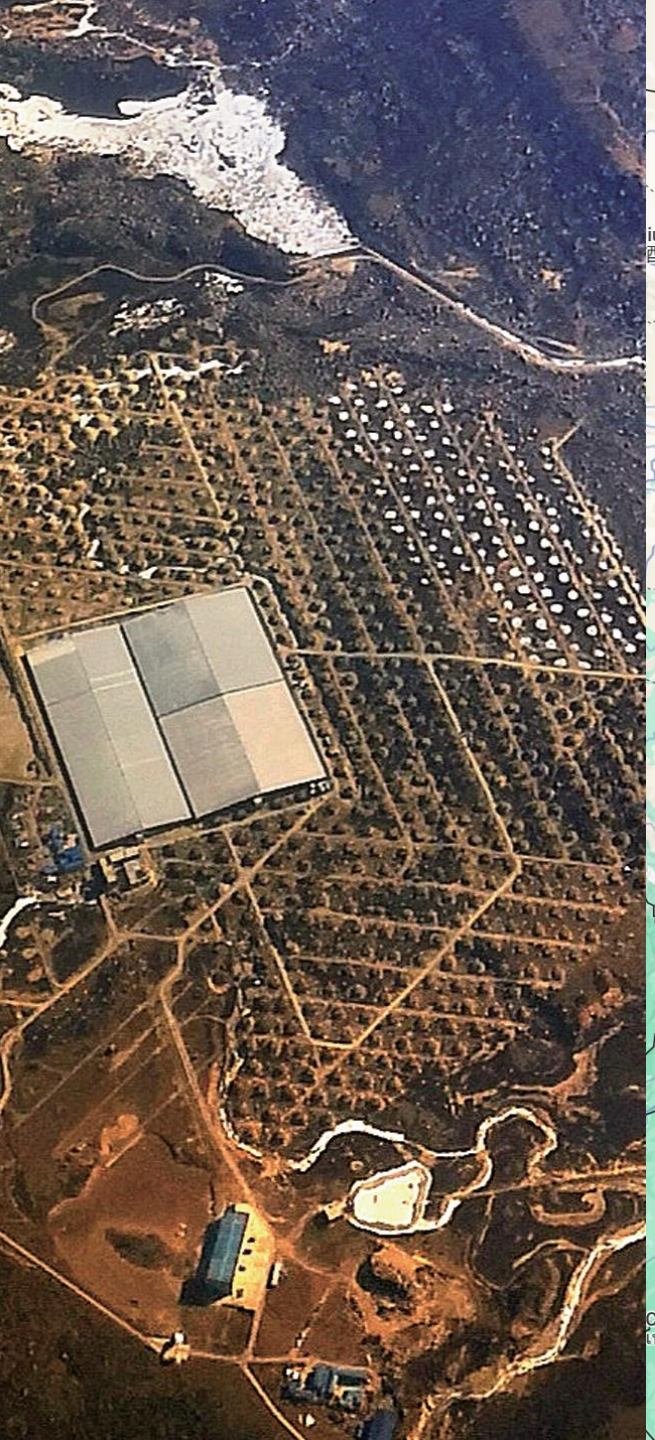
2 strings in Baikal-GVD array.



4 & 56 OMs will deployed in South China Sea.

Summary

- **Lots of great achievements in astrophysical neutrino observation. LHAASO discovered 43 UHE gamma-ray sources in the Milky Way.**
- **A 30 km^3 neutrino telescope proposed for the galactic HE neutrino detection.**
- **Start the prototype test in both Lake Baikal and South China Sea. CDR will be ready soon.**



Beijing

Chengdu

LHAASO

HongKong

JAPAN

China

Taiwan

North Korea

Japan

Philippine Sea

INNER MONGOLIA

JILIN

LIAONING

GANSU

NINGXIA

SHANXI

SHAANXI

SHANDONG

HENAN

JIANGSU

HUBEI

ANHUI

ZHEJIANG

SICHUAN

GUIZHOU

HUNAN

JIANGXI

FUJIAN

YUNNAN

GUANGXI

GUANGDONG

HAINAN

Laos

Changchun 长春市

Shenyang 沈阳市

Dalian 大连市

Pyongyang 평양

Yinchuan 银川市

Xining 西宁市

Lanzhou 兰州市

Xi'An 西安市

Jinan 济南市

Qingdao 青岛市

Fukuoka 福岡

Shanghai 上海

Wuhan 武汉市

Chongqing 重庆

Kunming 昆明市

Taipei 臺北

Hanoi

Haiphong

Chiang Mai

Vientiane

Google

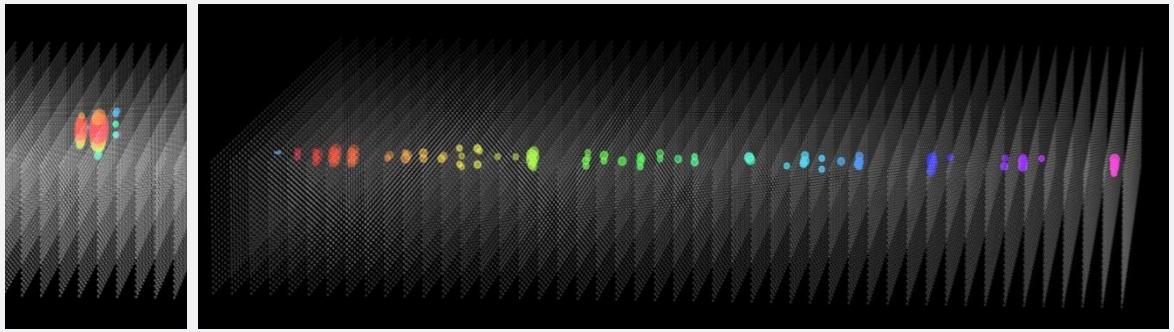
T h a n k s !

Detector Simulation

Simulation toolkits

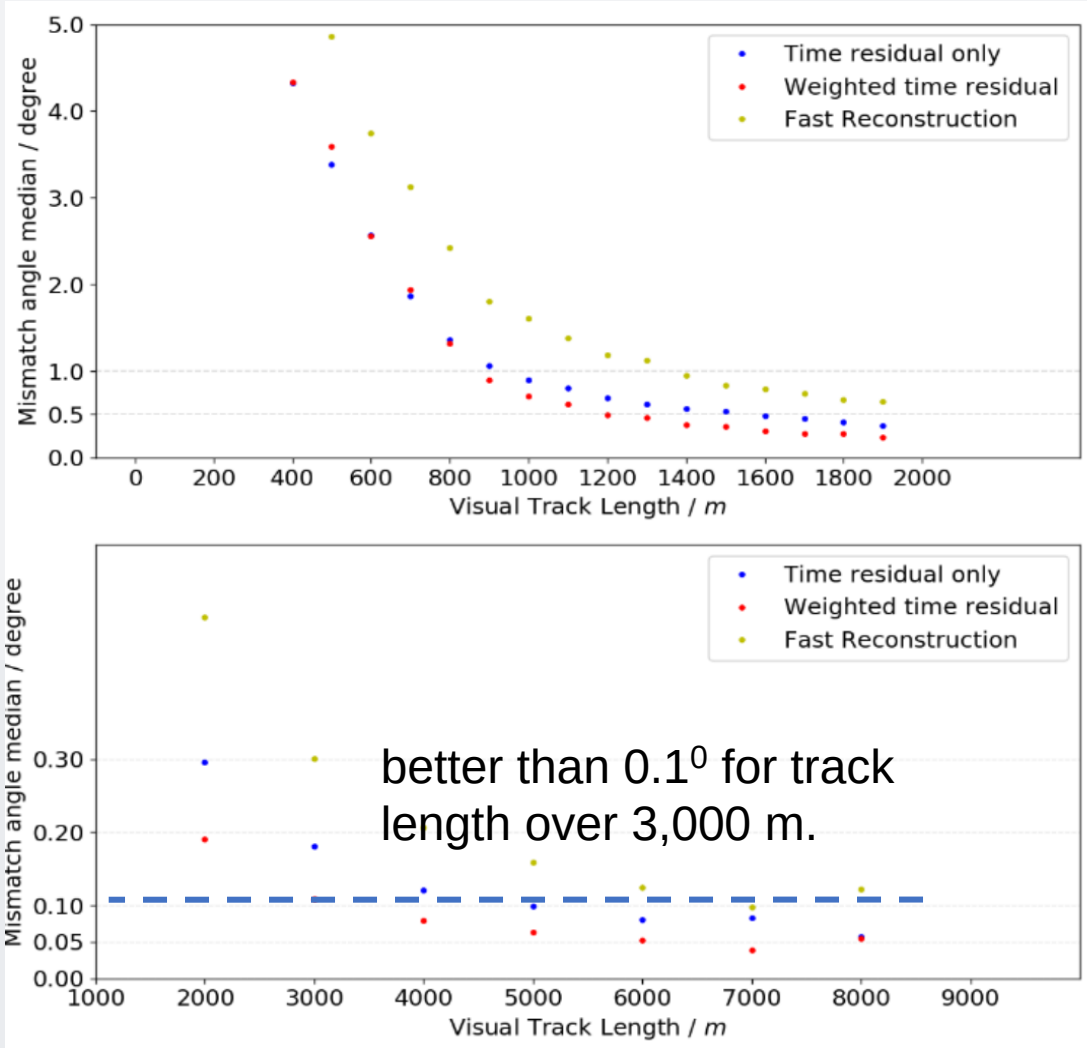
- Neutrino interaction package.
- **Geant4**: simulating interactions of neutrinos and the secondary particles.
- **Opticks**: a GPU accelerated optical photon simulation for Geant4 using NVIDIA OptiX (at least **11 times** faster than using Geant4 only).

Morphology



Left: Cascade event induced by an 1 PeV electron.
Right: Track event induced by an 100 TeV muon.

Angular Resolution

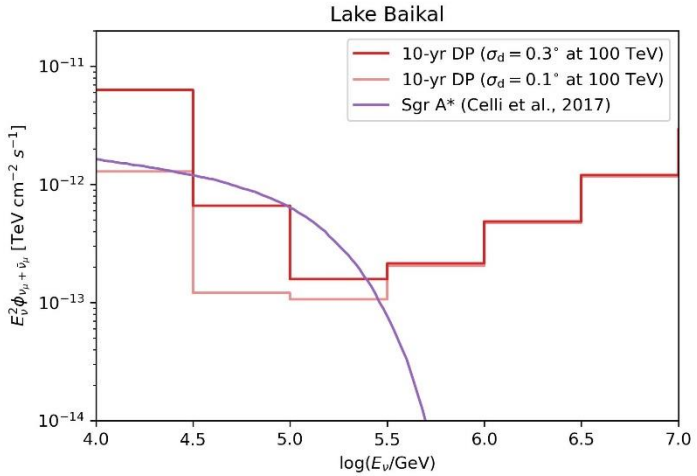


The median mismatch angle between simulated muon and reconstructed direction.

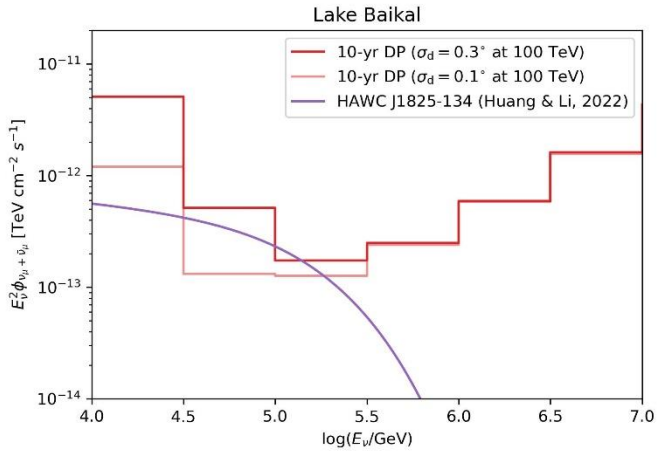
Upper: visual track length below 2,000 m.
Lower: visual track length above 2,000 m.

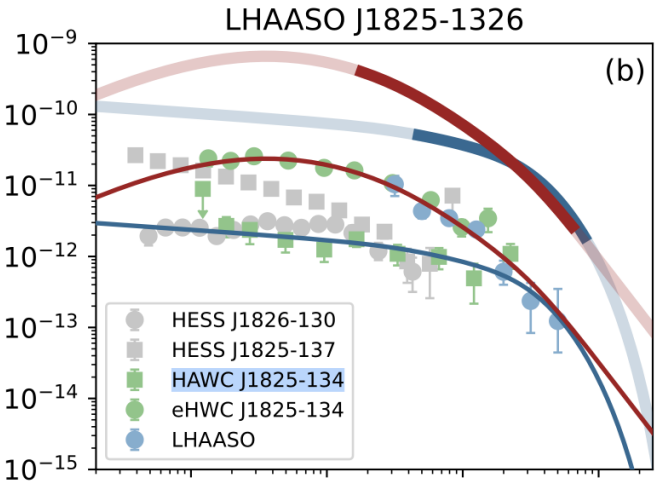
10-yr discovery potential

Sgr A* (δ=-29 deg)



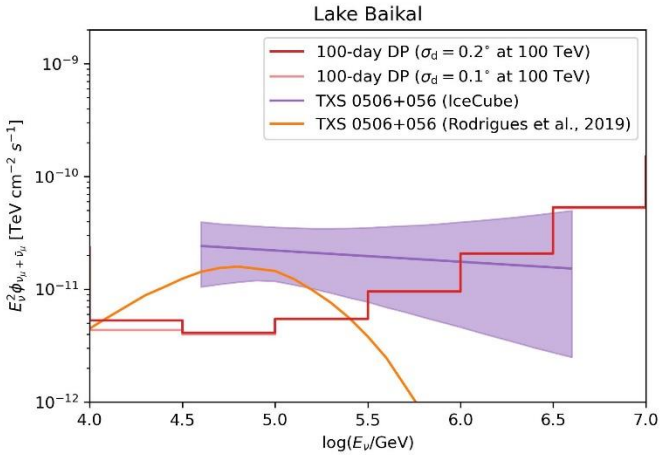
HAWC J1825-134 (δ=-13 deg)





LHAASO Source	σ_s [deg]	γ_1	γ_2	E_c [TeV]	Model
J1825-1326	0.30	2.40	0.45	—	LOGP
	0.0	2.13	—	286	ECPL

100d DP| TXS 0506+056 (δ=6 deg)



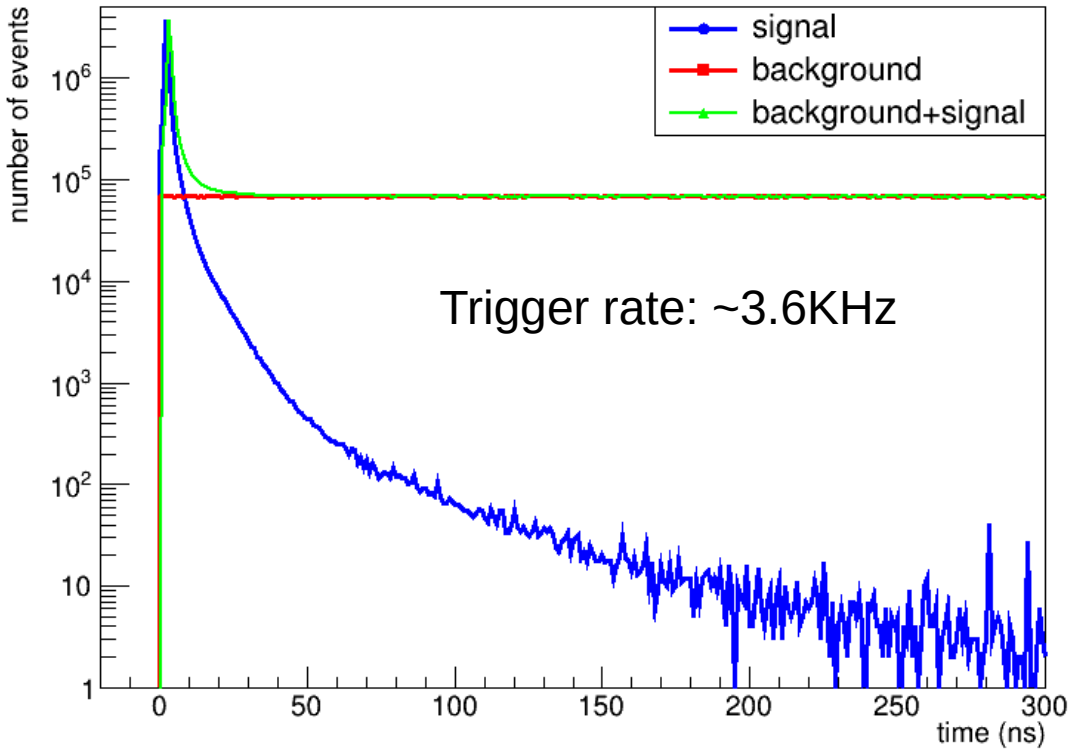
Purple band: muon neutrino flux during the 2014-2015 activity period for TXS 0506+056

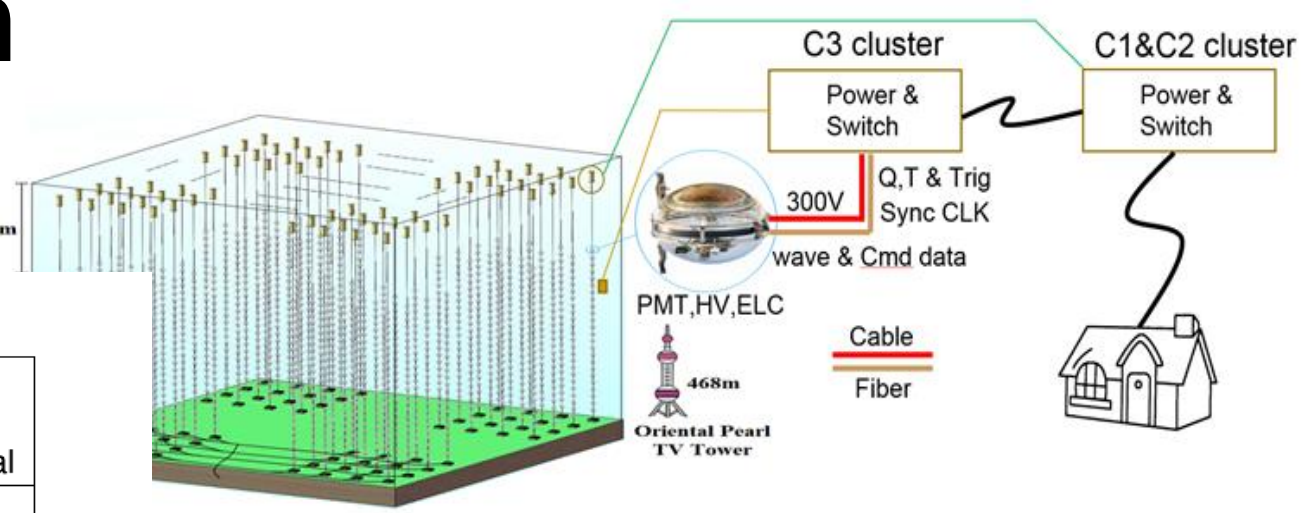
Orange line: muon neutrino flux during the flare period

Electronics system

电子学系统分布总体示意图

参数	设计指标





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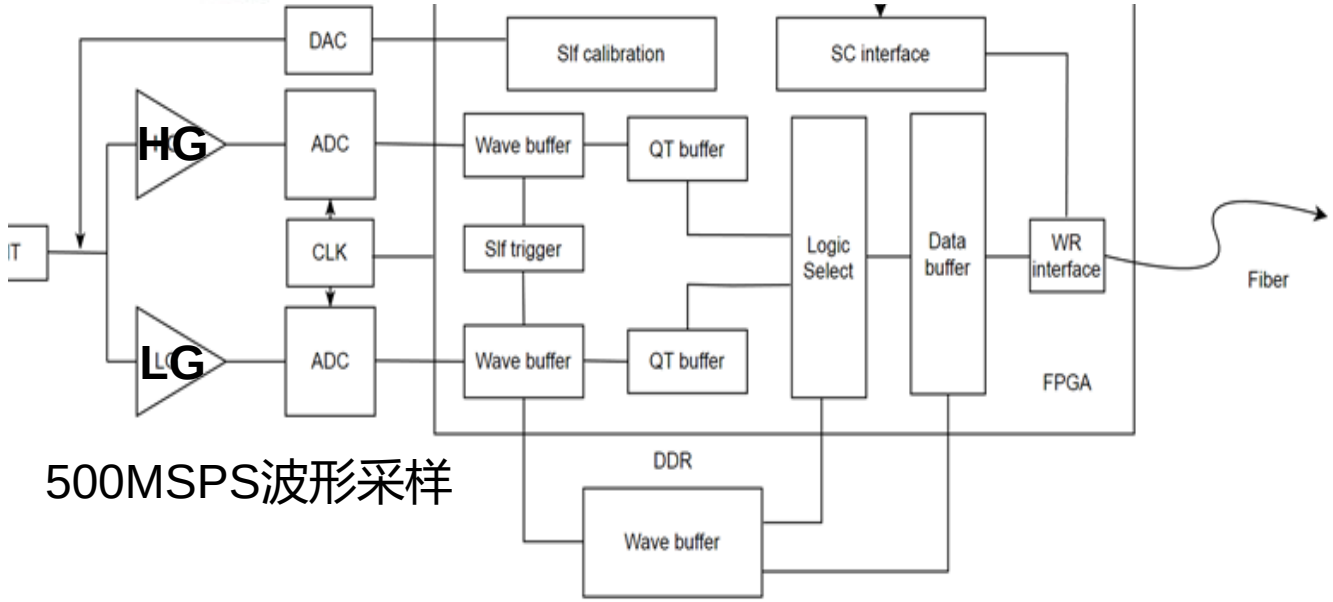

500MSPS波形采样

预计数据量：300MB/s

2,220 **20-in** PMTs deployed in LHAASO-WCDA

WCDA: Water Cherenkov Detector Array

- Excellent time performance: TTS ~ 7 ns
- High quantum efficiency: QE > 25%
- **The largest photosensitive area: 20 inch**
- Good Peak-to-valley ratio: P/V > 2.0
- Long lifetime: Q > 100 C

- Decrease the energy threshold from 300 GeV to 50 GeV
- Improve the sensitivity to transients sources
- Effective budget control
  - Made in China (NNV Technology Group Co., Ltd)