The Large High Altitude Air Shower Observatory

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on behalf of the LHAASO collaboration

2015-10-27
Outline

- LHAASO: science and expectation
- Design of the LHAASO detectors
- Engineering array at YBJ
- Project approval status
- Summary
LHAASO is one of the 16 high-priority projects in the 12th Five-year Plan of China
Major Scientific Goals

• GAMMA RAY ASTRONOMY
  – Searching for GCR sources by measuring SED with an unprecedented sensitivity of 1% Crab unit at 50 TeV.
  – Searching for TeV gamma sources, especially extended and transient ones, with an unprecedented survey sensitivity of 1% Crab unit at 3TeV.

• COSMIC RAY PHYSICS
  – Energy spectra for individual compositions with energy from 10 TeV to 1 EeV, where the spectrum knees are located, by hybrid observation of showers at high altitude.
Measurement of air showers at high altitude

- HE: near X_{\text{max}} \rightarrow \text{lower fluctuation, better } \sigma_E

- Lower E_{\text{th}} \rightarrow \text{deeper, more sources}
Hybrid Detection of Extensive Air Showers by LHAASO

WFCTA:
- 18 telescopes
- 1024 pixels each

KM2A:
- 5195 EDs
- 1171 MDs

WCDA:
- 3000 cells
Sensitivity to gamma ray sources

- Integral: 1% Crab unit @3TeV & 50TeV
Hadronic vs. Leptonic

Cassionpeia A  Historical SNRs

IC443  interacting with molecular clouds
Acceleration limit of GCR sources

Cygnus Cocoon

$E^2 dN/dE$ (erg cm$^{-2}$ s$^{-1}$)

$E$ (eV)

- Fermi-LAT
- ARGO-YBJ
- Milagro
- LHAASO (model $E_c=150$ TeV)
- LHAASO (model $E_c=40$ TeV)
- LHAASO
- Model $E_c=150$ TeV
- Model $E_c=40$ TeV
GCR spectrum and density

Ec = 50 TeV

25° < l < 100°, |b|< 5°

Cygnus region

GCR spectrum and density

Ec = 50 TeV
Blue: Fe
Red: P

$\chi^2 / \text{ndf} = 20.17 / 18$
Constant $49.98 \pm 3.34$
Mean $-0.029 \pm 0.011$
Sigma $0.1899 \pm 0.0081$
Transnet Phenomena

Mrk 501

\[ E^2 F \text{ (TeV cm}^{-2}\text{s}^{-1}) \]

- Fermi-LAT long-term
- Fermi-LAT flare
- ARGO-YBJ long-term
- ARGO-YBJ flare
- LHAASO 1year
- LHAASO flare: fit ARGO-YBJ data
- LHAASO flare: fit Fermi data
- SSC model
Electromagnetic Particle Detector

- Uniformity for 5195 units: < 10%
- Stability within ±25°C: ±5%
Muon Detector

- Water Cherenkov detector underneath soil
**WCDA:** Survey of the VHE gamma ray sky

- $<1\% \, I_{\text{Crab}} \rightarrow 300\text{m} \times 300\text{m}$
WFCTA

- $32 \times 32$ pixels, $0.5^\circ$ each
- $4.7 \text{ m}^2$ collection area
- $<10^{16} \text{ eV}$
- $10^{16}-10^{17} \text{ eV}$
- $10^{17}-10^{18} \text{ eV}$
LHAASO detector timing

Over 7,000 detector units
Spread around 1km² area

0.5° Angular resolution for shower reconstruct from timing of hits TOF

Synchronous timing among detectors

1000m coax cable in 30°C change, Δ delay = 15ns!

**Time-stamp Synchronization**
Time stamps of >7,000 nodes to be aligned <500ps (rms).

**Frequency distribution & phase locking**
Distribute synchronous ADC clock with <100ps skew.

**Traceability & Real-time calibration**
Timing delay compensation due to environmental perturbation in hardware in real time.
“Triggerless” DAQ
---hybrid measurement of showers

• Triggering, building, (re-construction) and storage by online computers
Engineering Array @ YBJ

- ~1% of LHAASO
  - 42 EDs, 2 MDs, 9-unit WCDA, 2 telescopes
- Fully implementing the LHAASO designs, including WR-based clock distribution, “triggerless” DAQ, etc
- Has been in operation for more than 2 years.
WR performance

WR Switch
Grandmaster

WR Switch
Cute-WR

1Km

WR Switch
Cute-WR

30m

WR Switch
Cute-WR

1Km

WR Switch
Cute-WR

30m

WR Switch
Cute-WR

1Km

WR Switch
Cute-WR

30m

WR Switch
Cute-WR

1Km

Cascade topology

std dev = 90 ps

Measured histogram

WR CERN: 1ns
Example Showers
Event Rate and Moon Shadow

- Event rate agrees with MC and ARGO-YBJ
- Observed moon shadow by $5.8\sigma$ in 2 years.
Long-term Stability

- 2%/year $\rightarrow$ 17.8% in 10 years if the signal attenuates exponentially
LHAASO: project approval


- T1, permission notes for site (2013,12)
- T2, MOU between CAS and Sichuan (2014,8)
- T3, Proposal submit (2015,2)
- T4, Proposal review
- T5, official approval (2015)
- T6, feasibility approval (2016)

Prototype detectors test on site

Local support work, such as design for road, site and capital construction
Total Budget: 1,200 M

Project: 900 M (NDRC)
- Detector and assembly, test, partial operation, etc.

Local Matching: 300 M (Sichuan Province)
- Land, power, road, civil construction, etc.

- Local funding:
  - 100 M (2015)
  - 150 M (2016)
  - 50 M (2017)

- Operation money:
  - 1.2 M (2\textsuperscript{nd})
  - 4.8 M (3\textsuperscript{rd})
  - 6 M (4\textsuperscript{th})
## LHAASO Construction Schedule

<table>
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<th>Project</th>
<th>LHAASO Construction period (month)</th>
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<td>Capital construction</td>
<td>24</td>
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<tr>
<td>Detector production</td>
<td>36</td>
</tr>
<tr>
<td>Setup and test</td>
<td>36</td>
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<tr>
<td>Testing run</td>
<td>28</td>
</tr>
<tr>
<td>Full run</td>
<td>2</td>
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</tbody>
</table>

**Duration:** 4 years

**Different detectors will go parallel**

¼ will be finished and start to take data in 2 years
Activities @LHAASO site

- Mt. Haizi (4410 m a.s.l.), Sichuan, China
- 10 km from Yading Airport.

- Meteo-station
- Soil-temperature measurement
- MD sites
- Site boundary survey
- Deep geo-survey, July 2015

- Mt. Haizi (4410 m a.s.l.), Sichuan, China, July 2015
Summary and outlook

• The LHAASO is designed to fulfill the physical goals in gamma ray astronomy and cosmic ray physics
• Prototype arrays of ~1% LHAASO have been in operation at YBJ for more than 2 years
• The official approval of LHAASO is coming soon