The ALPACA experiment: observing sub-PeV γ-rays in the Southern Hemisphere

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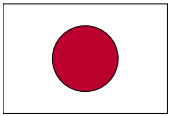
Rencontres du Vietnam: Windows on the Universe
10 August 2023

The ALPACA collaboration



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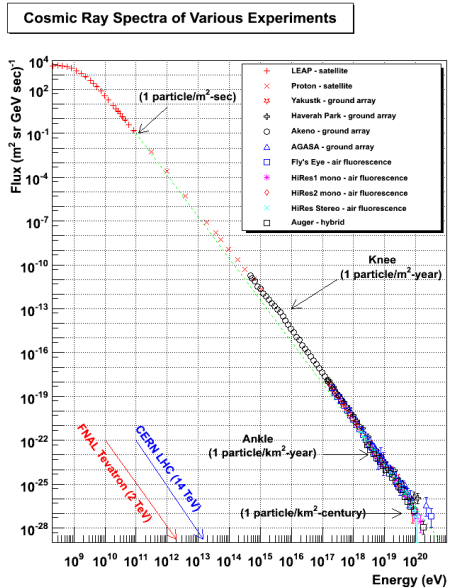
Andes Large Area PArticle detector for Cosmic ray physics and Astronomy

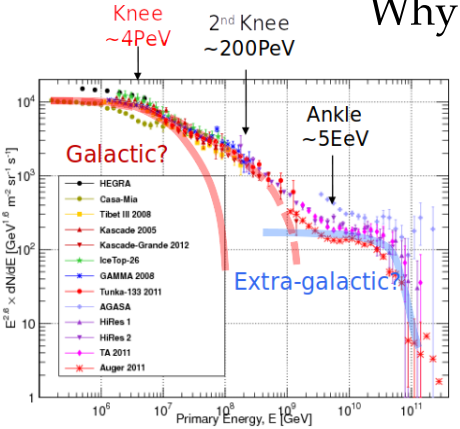
Why cosmic rays?

- Over 30 orders of magnitude in flux.
- Over 10 orders of magnitude in energy.



https://web.physics.utah.edu/ whanlon/spectrum.html

Why sub-PeV γ-rays?



Gaisser et al. Front.Phys.(Beijing) 8 (2013) 748

- Galactic protons are thought to be accelerated up to PeV (~knee).
  - Where are their origins?
  - Are CRs up to 100 PeV (~ 2nd knee) heavy nuclei?
- Diffuse γ-ray tell us the CR distribution in the galaxy.
- Highest energy γ-rays tell us the acceleration limit in energy/nucleon.

Especially in the southern hemisphere, near the Galactic center!!

- Where are CR sources?
- What is the maximum acceleration energy (/nucleon)?
- How do they propagate in the galaxy?

ALPACA experiment: Why Bolivian Andes?

- Flat and high altitude (4740 m).
- Galactic center (Site coordinates: $16°23'\mathbf{S}$, $68°8'\mathbf{W}$).
- Long-term collaboration Bolivia and Japan.

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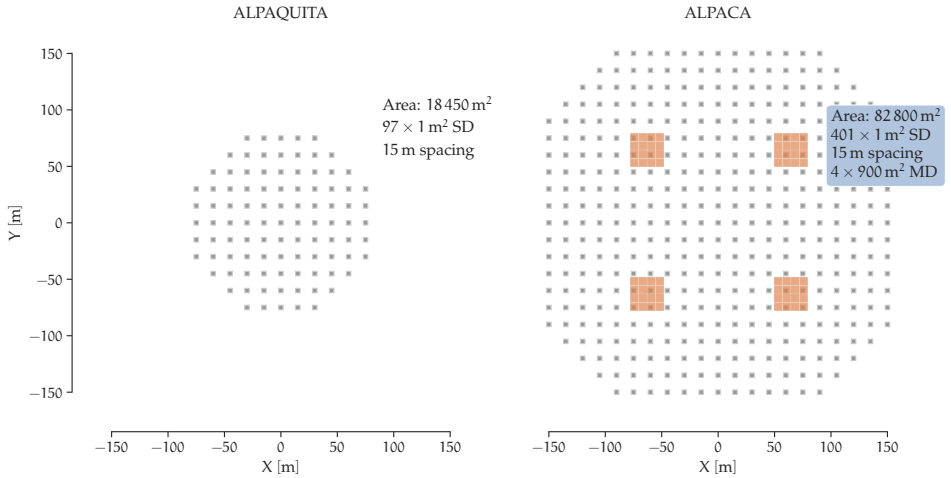
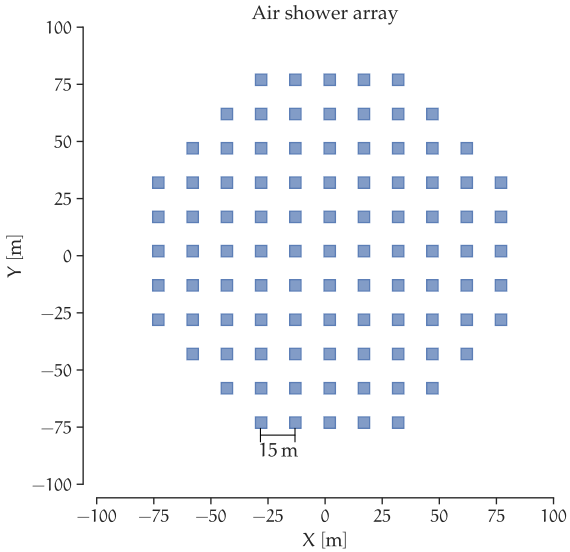
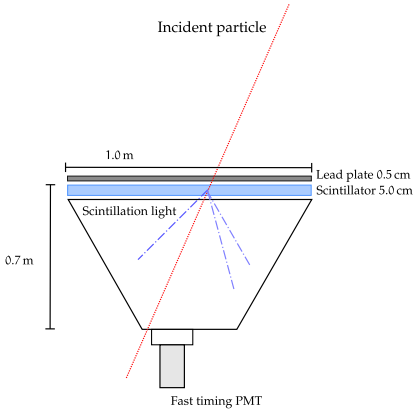
ALPACA experiment in steps



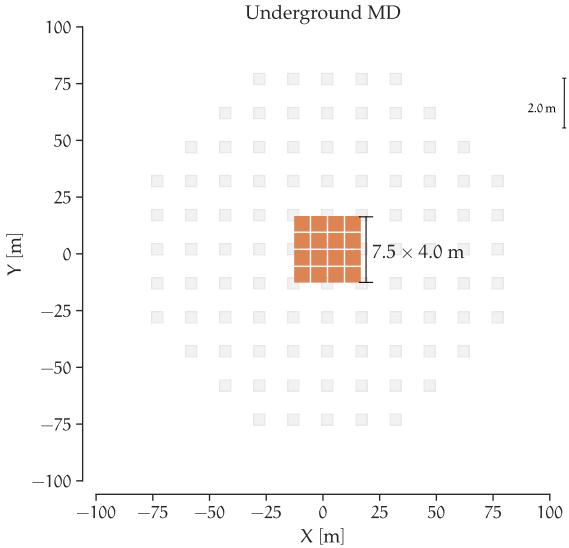
Experimental technique: Surface array detector

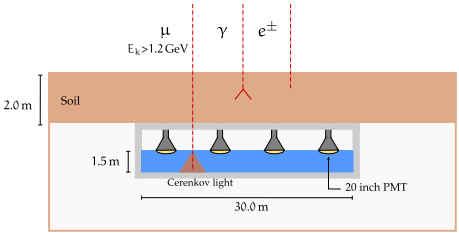


- Area coverage: 18 450 m^2
- Number of elements: 97
- Single-particle peak: 9.4 MeV



Experimental technique: Underground muon detector

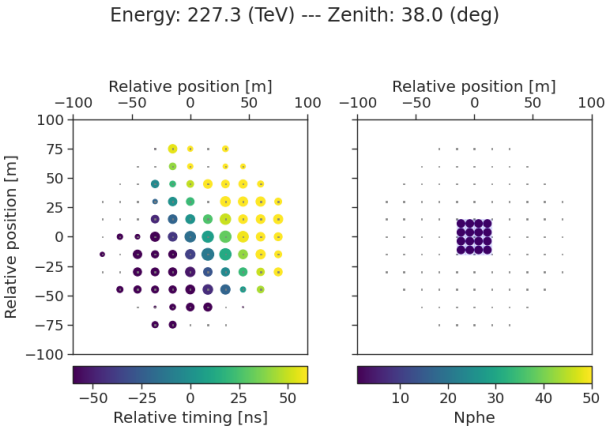




- Area coverage: 900 m^2
- Number of elements: 16 cells.
- Single-muon peak: 24 pe*

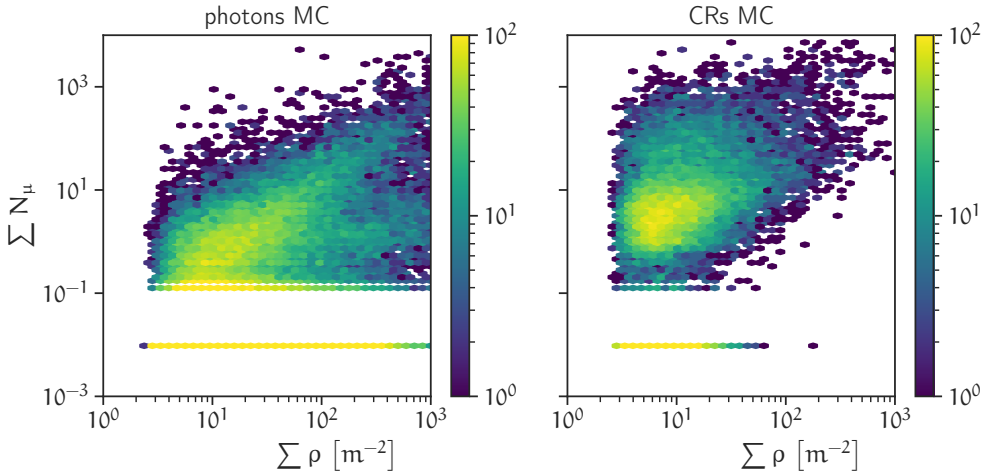
* S.Kato et al., Experimental Astronomy (2021) 52:85-107

Experimental technique: event reconstruction



Left: SD signal, Right: Signal in MD pool

Experimental technique: γ/CR separation

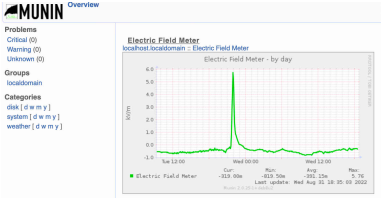


The road to ALPACA

Assembly finished and cabling (June 2022)

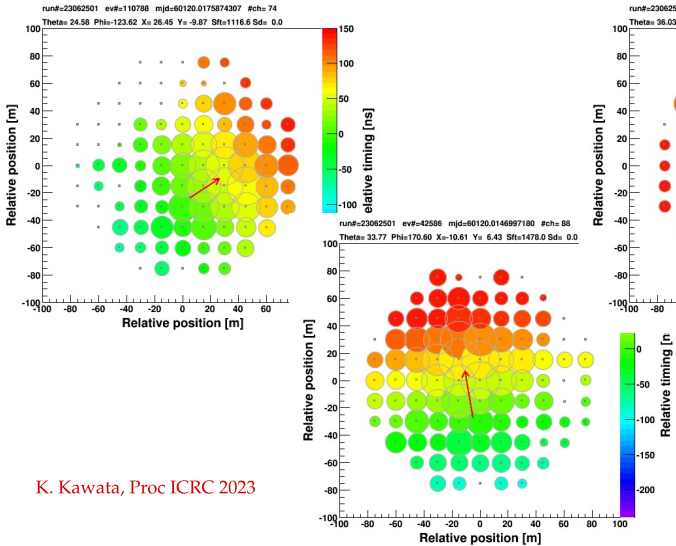
The road to ALPACA

Electic field and weather monitors (August 2022)



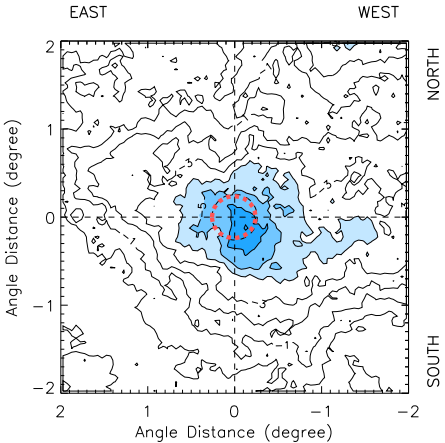
ALPAQUITA full operation April 2023

> 100 TeV Events !!!



K. Kawata, Proc ICRC 2023

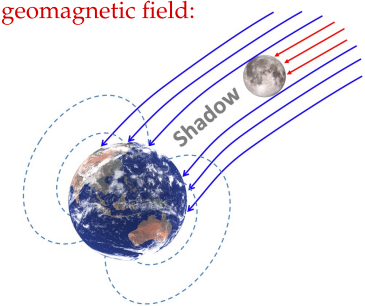
Moon shadow detection



K. Kawata, Proc ICRC 2023

Displacement by geomagnetic field:

$$\Delta\theta \sim \frac{1.6^\circ}{E[\mathrm{TeV}]}$$



- April 7 – July 16, 2023 (83 days).
- Cable length correction.
- Successfull detection at 6.7σ.
- Shift westward $\sim 0.2^\circ$ as expected.
- Confirmed $\sim 0.9^\circ$ resolution.

Summary

- Southern sub-PeV γ-ray sky is yet to be explored.
- ALPACA is a new air shower array under construction in Bolivia.
- We successfully detected Moon shadow with ALPAQUITA at 6.7σ.
- Angular resolution is estimated to be $\sim 0.9^{\circ}$.
- We will start the construction of one MD pool in 2023.
- We will start the operation of the full ALPACA array (4 MDs) in 2024.
- Observations of sub-PeV γ-rays in the Southern Hemisphere will begin soon.