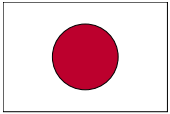
The ALPACA experiment: observing sub-PeV γ-rays in the Southern Hemisphere

Marcos Anzorena (ICRR) for the ALPACA collaboration
anzorena@icrr.u-tokyo.ac.jp

27th European Cosmic Ray Symposium
27 July 2022

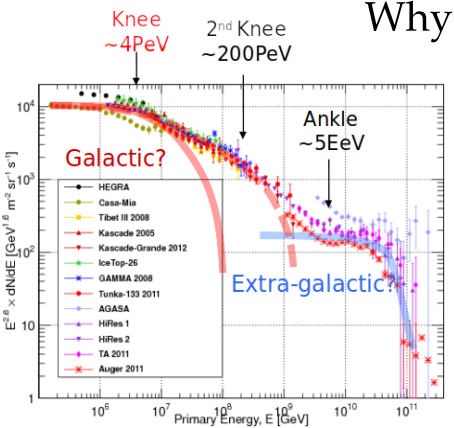
The ALPACA collaboration



M. Anzorena [A], C. A. H. Condori [C], E. de la Fuente [D], A. Gomi [E], Y. Hayashi [B], K. Hibino [F], N. Hotta [G], A. Jimenez-Meza [D], Y. Katayose [E], C. Kato [B], S. Kato [A], I. Kawahara [E], T. Kawashima [A], K. Kawata [A], T. Koi [H], H. Kojima [I], D. Kurashige [E], R. Mayta [J,K], P. Miranda [C], K. Munakata [B], K. Nagaya [E], Y. Nakamura [A], C. Nina [C], M. Nishizawa [M], R. Noguchi [E], S. Ogio [A], M. Ohnishi [A], S. Okukawa [E], A. Oshima [H], M. Raljevich [C], H. Rivera [C], T. Saito [N], Y. Sakakibara [E], T. Sako [A], T. K. Sako [A], T. Sasaki [F], S. Shibata [I], A. Shiomi [L], M. Subieta [C], N. Tajima [O], W. Takano [F], M. Takita [A], Y. Tameda [P], K. Tanaka [Q], R. Ticona [C], I. Toledano-Juarez [D], H. Tsuchiya [R], Y. Tsunesada [J,K], S. Udo [F], K. Yamazaki [H], Y. Yokoe [A] et al. (The ALPACA Collaboration)

ICRR, Univ. of Tokyo [A], Dept. of Phys., Shinshu Univ.[B], IIF, UMSA [C], Univ. de Guadalajara [D], Fac. of Engn., Yokohama Natl. Univ.[E], Fac. of Engn., Kanagawa Univ.[F], Utsunomiya Univ.[G], Coll. of Engn., Chubu Univ.[H], Astro. Obs., Chubu Univ.[I], Grad. Sch. of Sci., Osaka Metro. Univ.[J], NITEP, Osaka Metro. Univ.[K], Coll. of Ind. Tech., Nihon Univ.[L], NII [M], Tokyo Metro. Coll. of Ind. Tech.[N], RIKEN [O], Fac. of Engn., Osaka Electro-Comm. Univ.[P], Fac. of Info. Sci., Hiroshima City Univ.[Q], JAEA [R]

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?

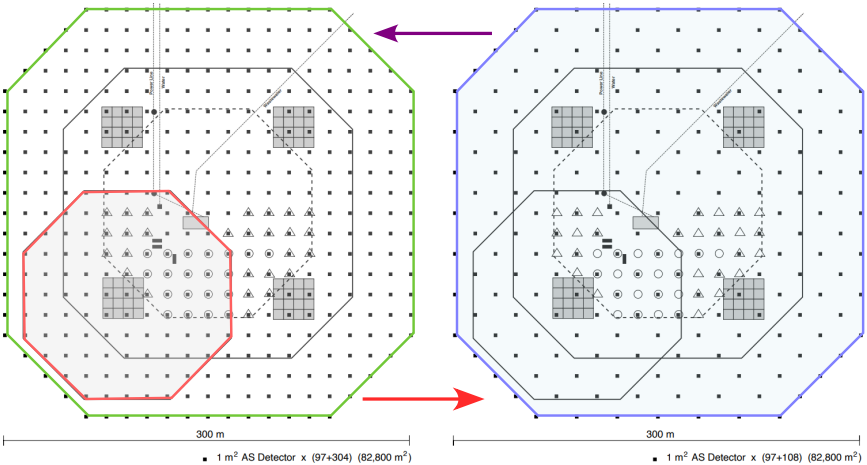
ALPACA experiment: Andes Large area PArticle detector for Cosmic ray physics and Astronomy

- Why Bolivia?
- Flat and high altitude ($4740\,\mathrm{m}$).
- Galactic center.
- Long-term collaboration between Bolivia and Japan.

ALPACA site: the Chacaltaya plateau

- Coordinates:
- 16°23′**S**, 68°8′**W**
- 4740 m

ALPACA in steps (basic idea)



ALPAQUITA

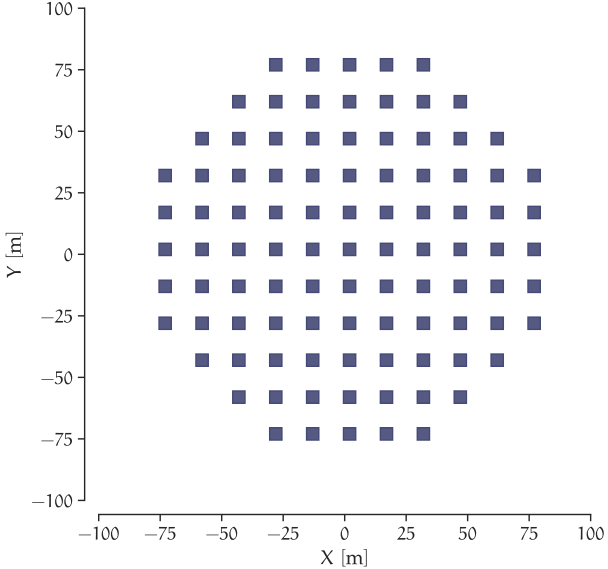
ALPACA (high density)

ALPACA (half density)

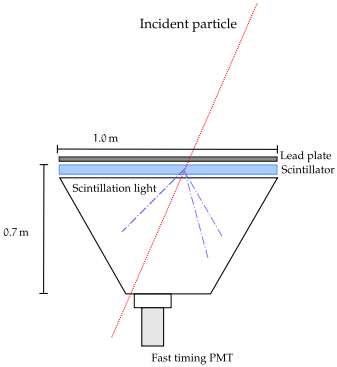
ALPACA in steps (some numbers)

- ALPAQUITA: $18\,450\,\mathrm{m}^2$, 97 surface detectors and 1 MD pool.
- ALPACA (half-density): $82\,800\,\mathrm{m}^2$, 200 surface detectors and 4 MD pools.
- ALPACA (high-density): $82\,800\,\mathrm{m}^2$, 400 surface detectors and 4 MD pools.

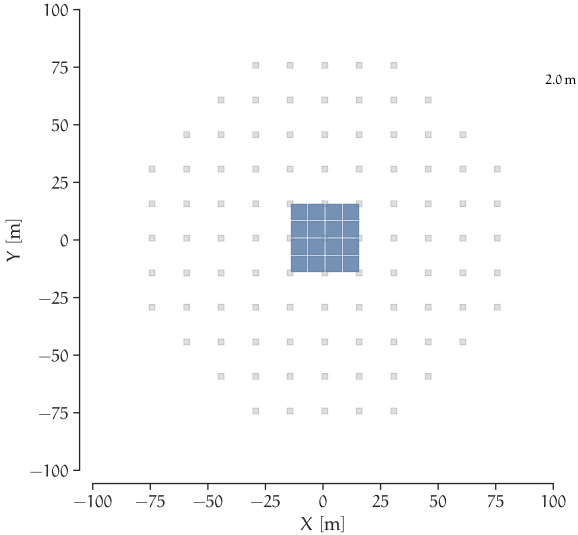
ALPAQUITA: Surface array detector

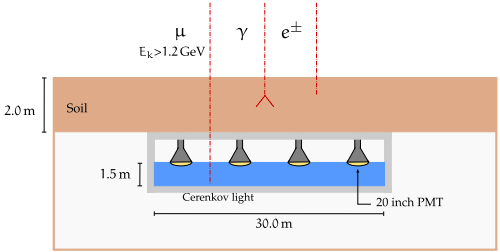


- Area coverage: 18 450 m^2
- Number of elements: 97
- Single-particle peak: 9.4 MeV



ALPAQUITA: Underground muon detector

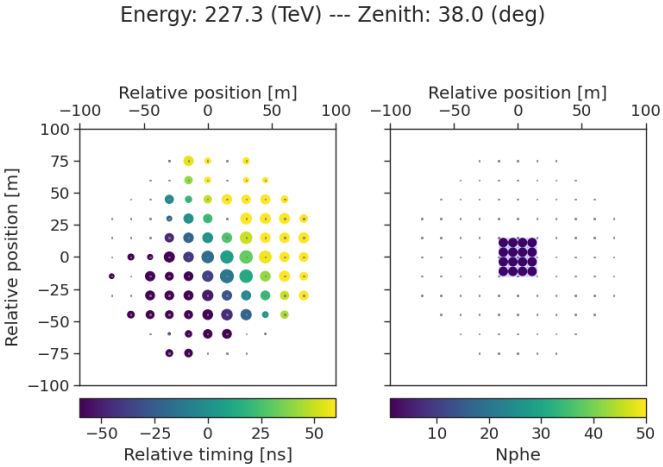




- Area coverage: 900 m^2
- Number of elements: 16 cells.
- Single-muon peak: 24 pe*

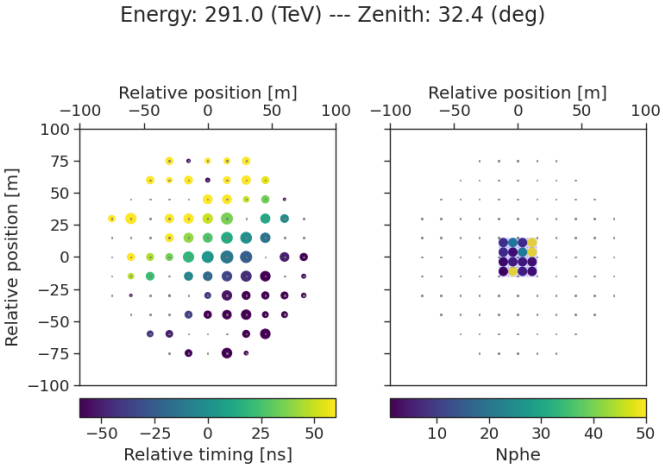
*S.Kato et al., Experimental Astronomy (2021) 52:85-107

ALPAQUITA: event map γ-ray



Left: SD signal, Right: Signal in MD pool

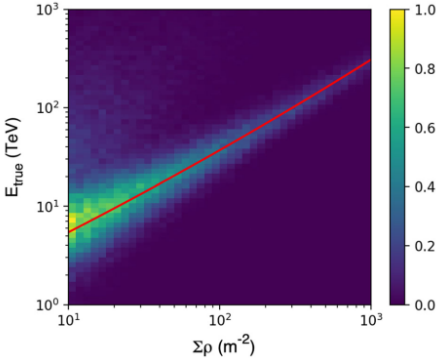
ALPAQUITA: event map CR-ray



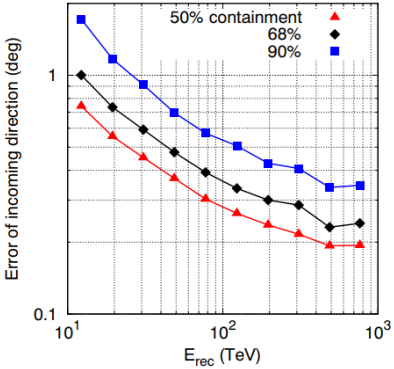
Left: SD signal, Right: Signal in MD pool

Event reconstruction

Primary energy using energy deposit

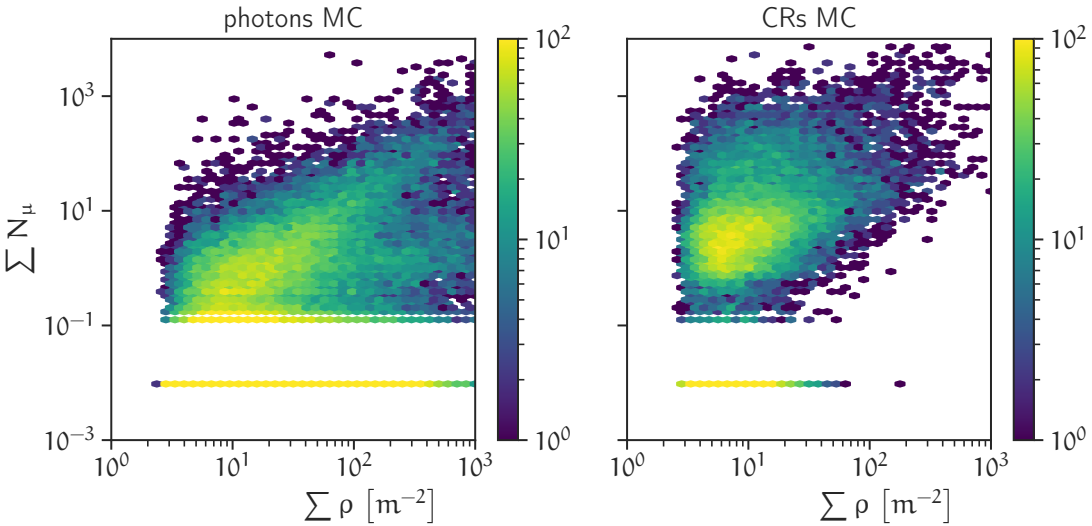


Arrival direction using particles timing



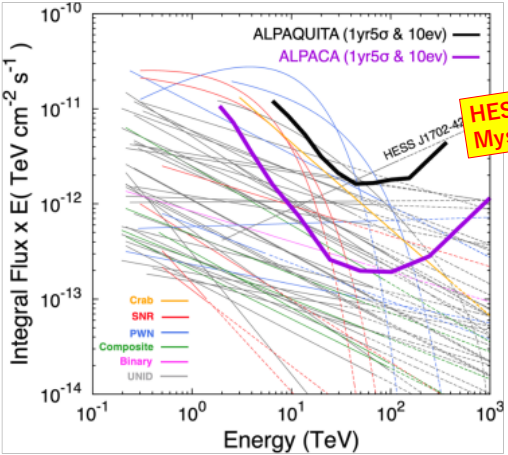
S.Kato et al., Experimental Astronomy (2021) 52:85-107

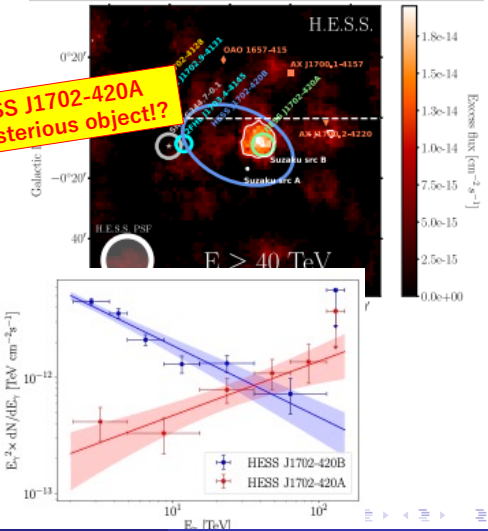
ALPAQUITA: γ/CR separation



ALPAQUITA sensitivity

HESS Collaboration, A&A 653, A152 (2021)

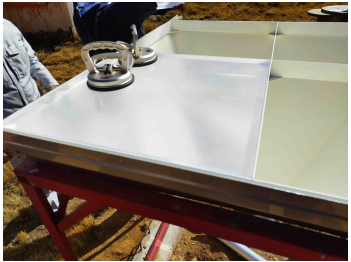




S.Kato et al., Experimental Astronomy (2021) 52:85-107

The road to ALPACA

Detector assemble and set-up

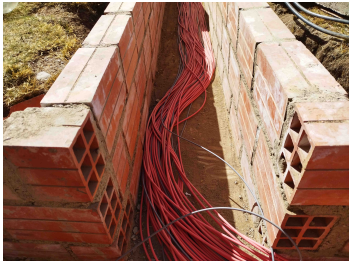


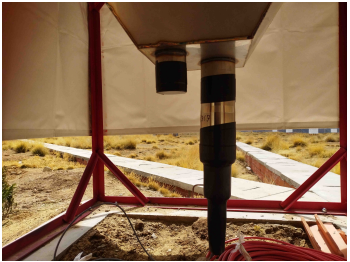
The road to ALPACA

Assembly finished and cabling

The road to ALPACA

DAQ electronics, cabling and installation of PMT





The road to ALPACA

- Installation of ALPAQUITA done in June 2022.
- Calibration and DAQ: August-September this year
- Construction of MD pool by the end of 2022 or early 2023.
- Second stage: ALPACA (half density).
- ALPACA (high density) is the final stage.

Beyond PeV: Mega-ALPACA

Where is the highest energy accelerator in our Galaxy?

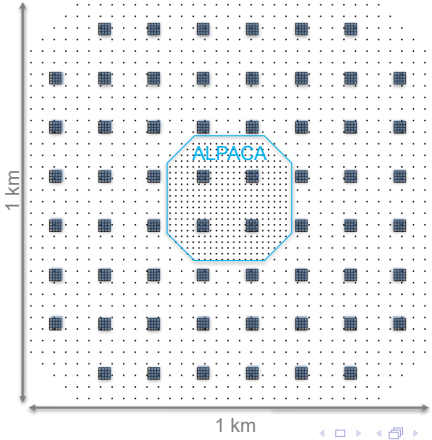
1 km^2 Array + MD

30 m spacing AS array
Area 1,011,600 m^2
# of det. 1185

15 m spacing AS array
Area 82,800 m^2
# of det. 313
(Additional to 15 m spacing)

# of total det. 1185 + 313 = 1498

Muon Detector (MD) Array
900 m^2 (16 Cells) x 60
= 54,000 m^2
# of cells 960

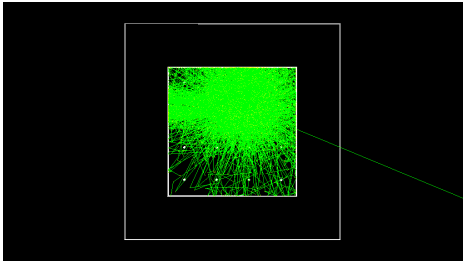


Summary

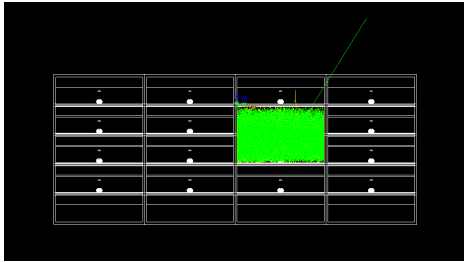
- Southern sub-PeV γ-ray sky is yet to be explored.
- ALPACA is a new air shower array under construction in Bolivia.
- First sub-PeV observation in the southern hemisphere.
- Observation with ALPAQUITA will start soon.
- Future extensions are on their way and the final goal will be Mega ALPACA.

BACKUP

Optimization of MD design



MD pool without cells



MD pool with cells

Development of trigger electronics

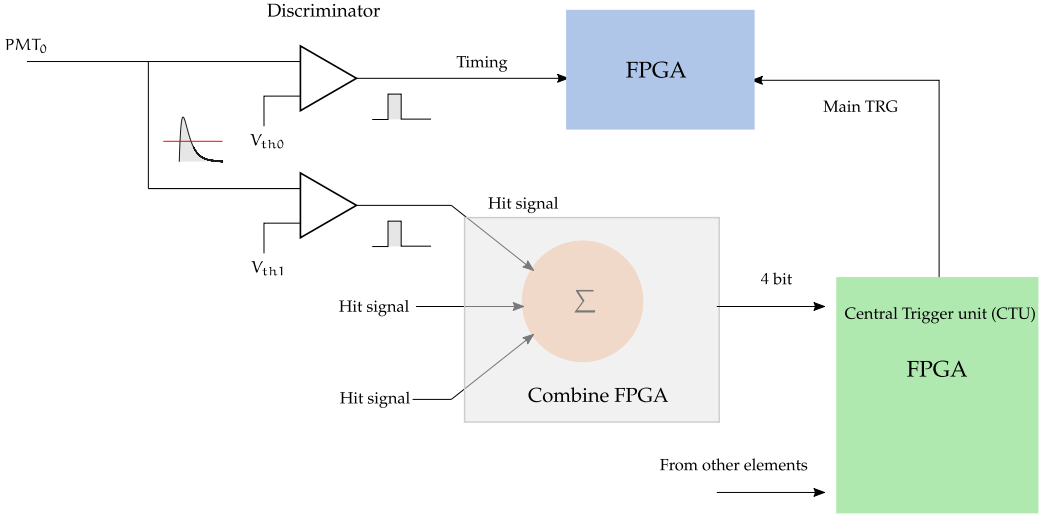


Diagram of trigger electronics.