

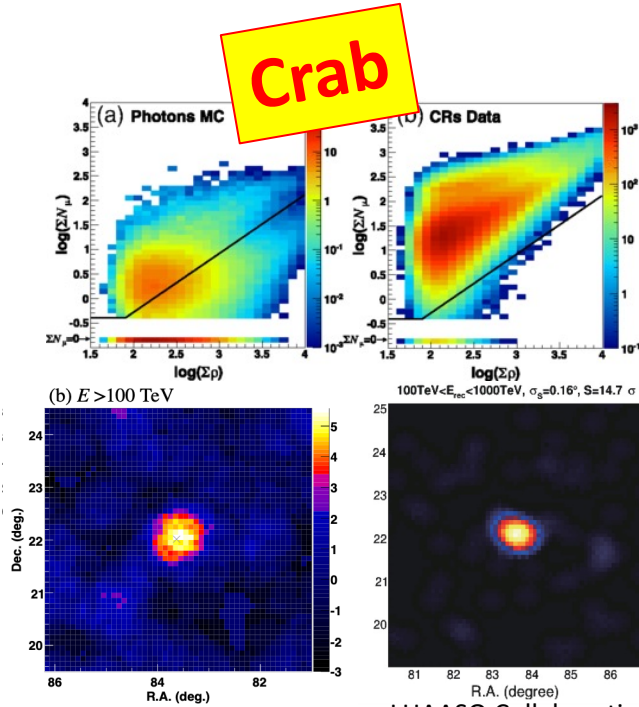
An aerial photograph showing a flooded landscape. In the center, there is a building with a prominent red roof. Surrounding it are various other structures, including smaller buildings and what appear to be storage containers or trailers in blue and yellow. The ground is mostly submerged in brown, murky water, with some patches of green vegetation visible. A network of white lines, possibly roads or paths, crisscrosses the area. The overall scene suggests a significant flood event.

Status Report of ALPACA: a new air shower array experiment for ultra-high-energy gamma-ray astronomy in the southern hemisphere

Sei Kato (Kyoto University)

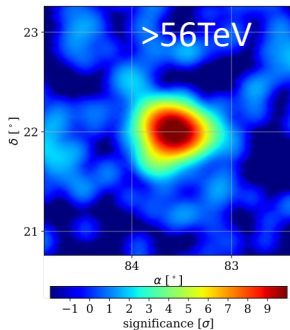
Search for UHE γ -ray sources and PeVatron candidates (2019~)

Tibet AS γ , HAWC, and LHAASO in the northern hemisphere

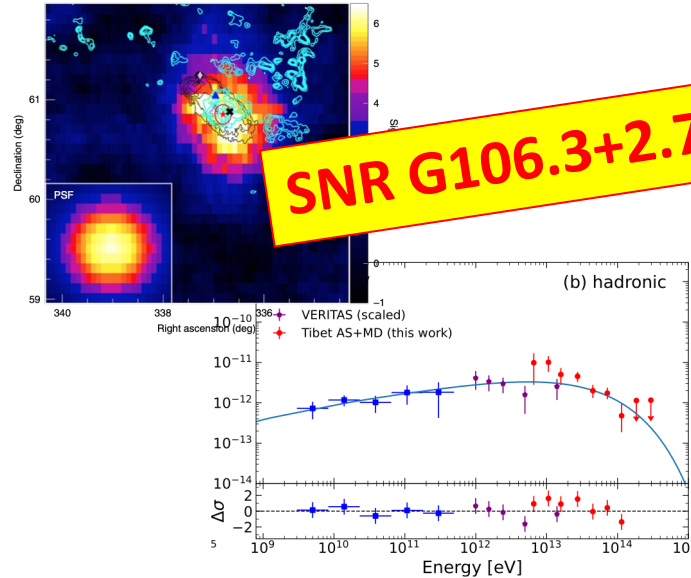


Crab

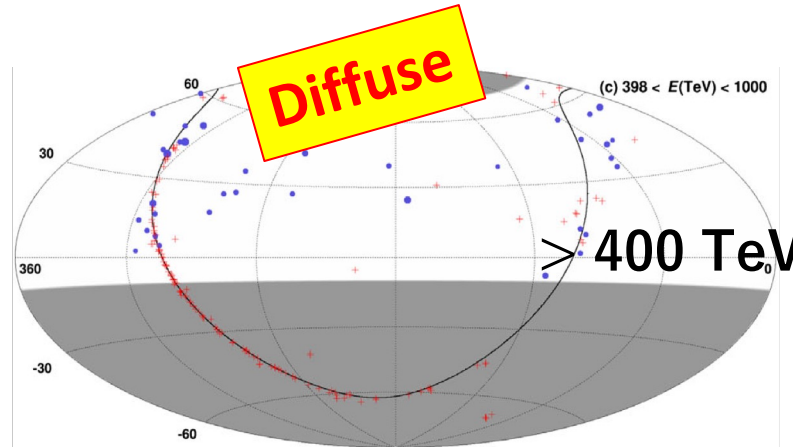
Tibet AS γ Collaboration,
PRL 123, 051101 (2019)



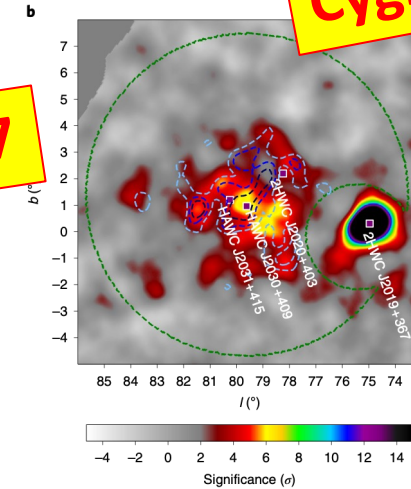
HAWC Collaboration, ApJ 881:134 (2019)



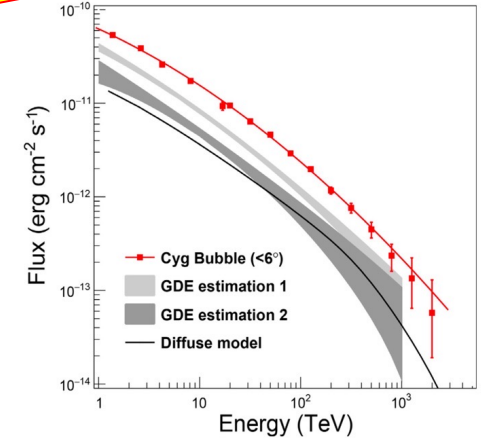
Tibet AS γ Collaboration, Nature Astron., 5, 460-464 (2021)



Tibet AS γ Collaboration, PRL 126, 141101 (2021)

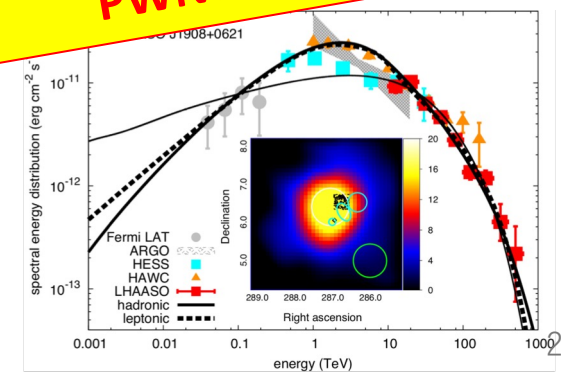


Abeysekara et al., Nature
Astronomy (2021)



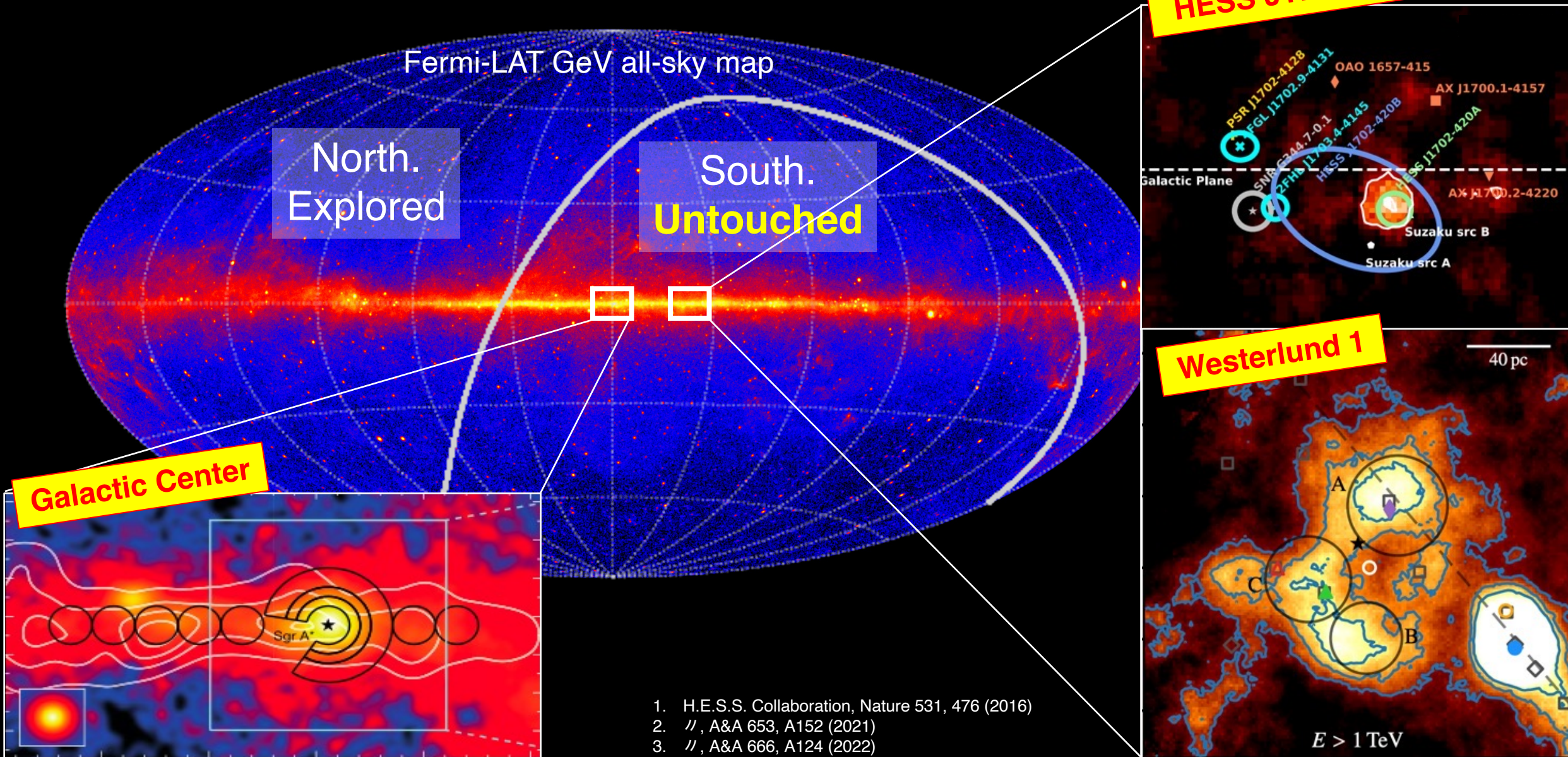
LHAASO Collaboration Sci. Bull. 69, 449 (2024)

**LHAASO J1908+0621
PWN? SNR?**



LHAASO Collaboration, Nature, 594, 33-36 (2021)

UHE γ -ray observation of the southern sky



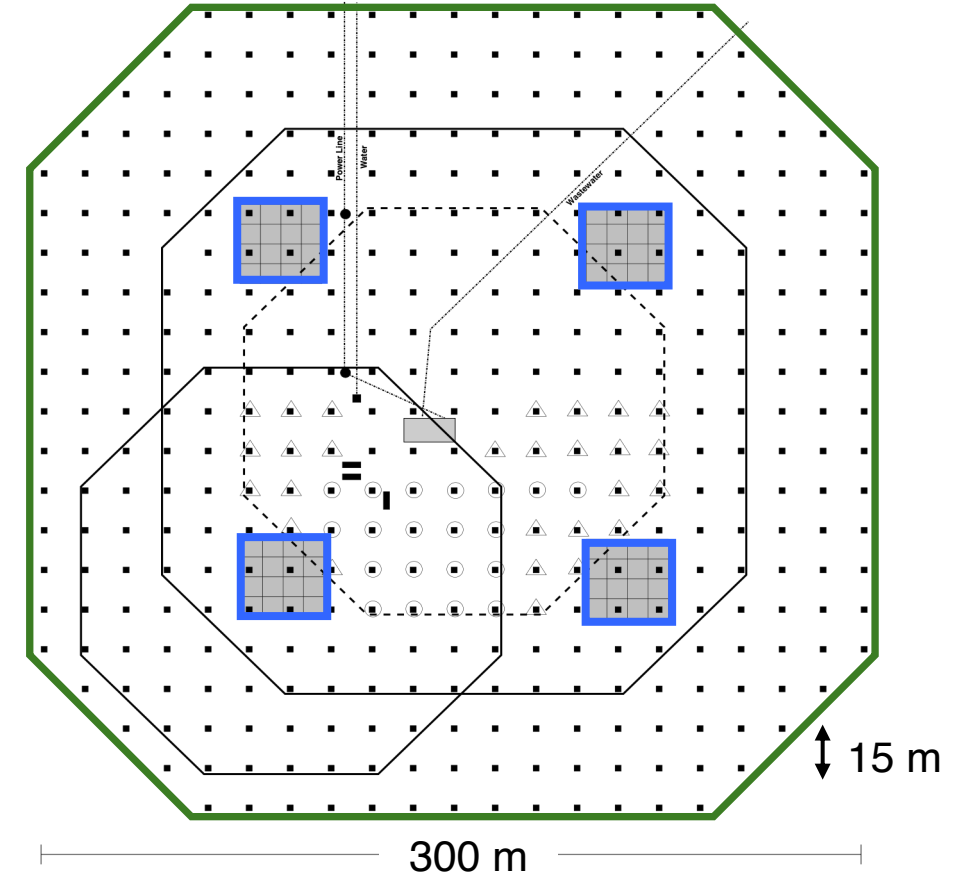
1. H.E.S.S. Collaboration, Nature 531, 476 (2016)
2. //, A&A 653, A152 (2021)
3. //, A&A 666, A124 (2022)

ALPACA

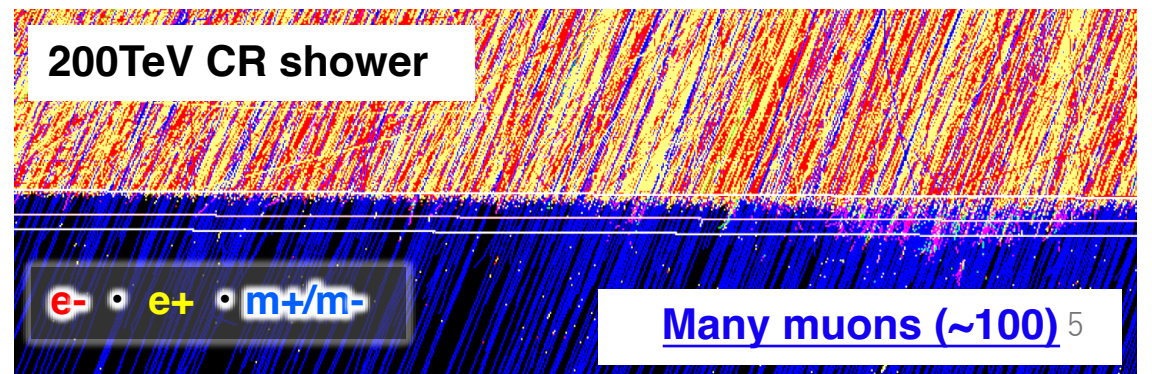
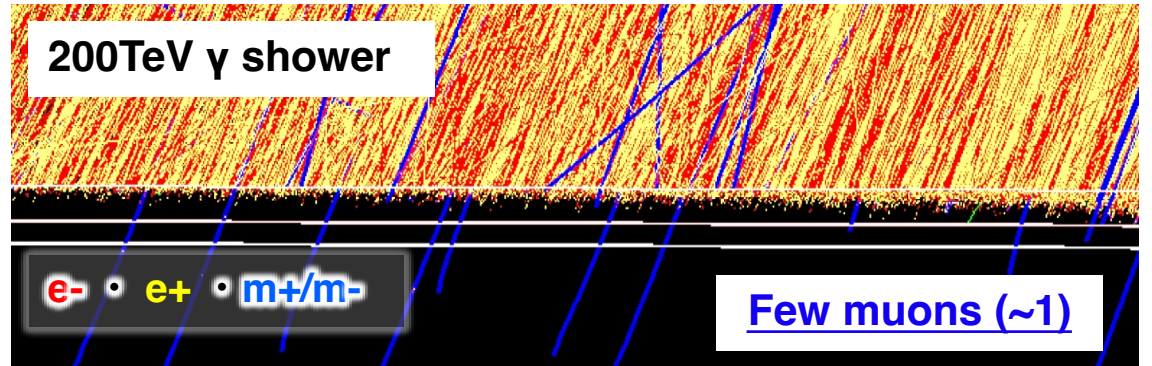
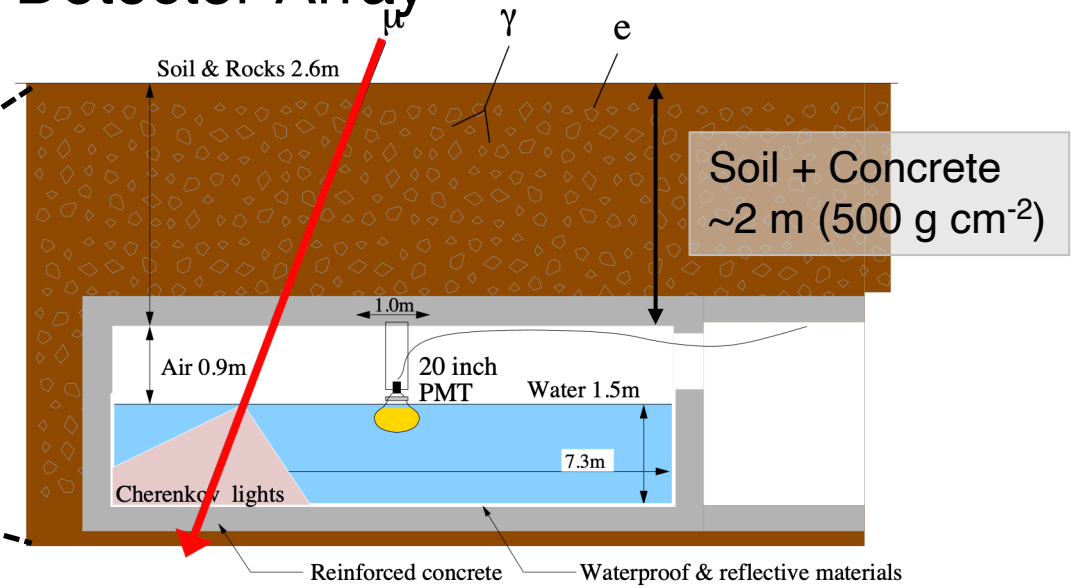
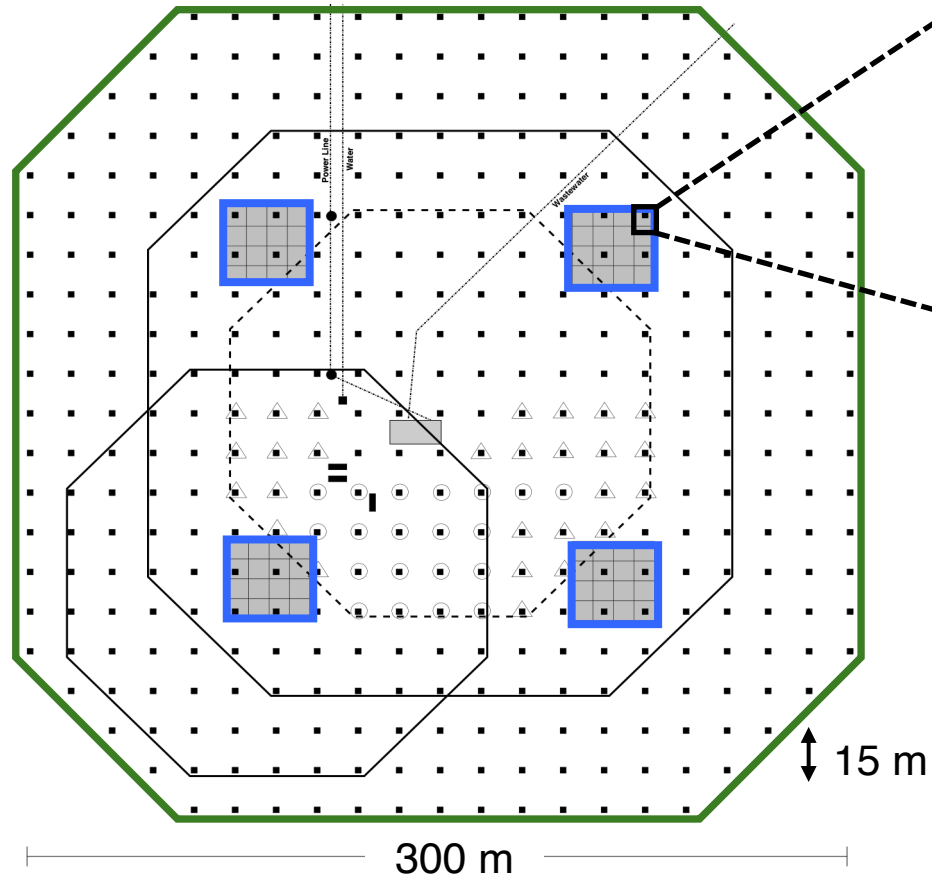
Andes Large area PArticle detector for Cosmic ray physics and Astronomy



- **Surface air shower array (83,000m²)**
401 x 1m² scintillation detectors
- **Underground muon detector array: (3,600m²)**
2.0 m ($\sim 16X_0$) soil overburden
58m² w/ 20" PMTs x 64 cells
- **Performance**
Angular resolution $\sim 0.2^{\circ}$, Energy resolution $\sim 20\%$ @ 100TeV
100% duty cycle & Wide F.O.V. $\sim 2 \text{ sr}$



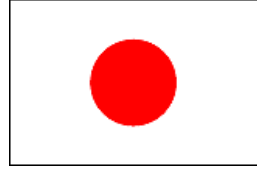
Underground Muon Detector Array



γ /CR separation by counting muons
 BG rejection power $> 99.9\%$ @ UHE range



The ALPACA Collaboration



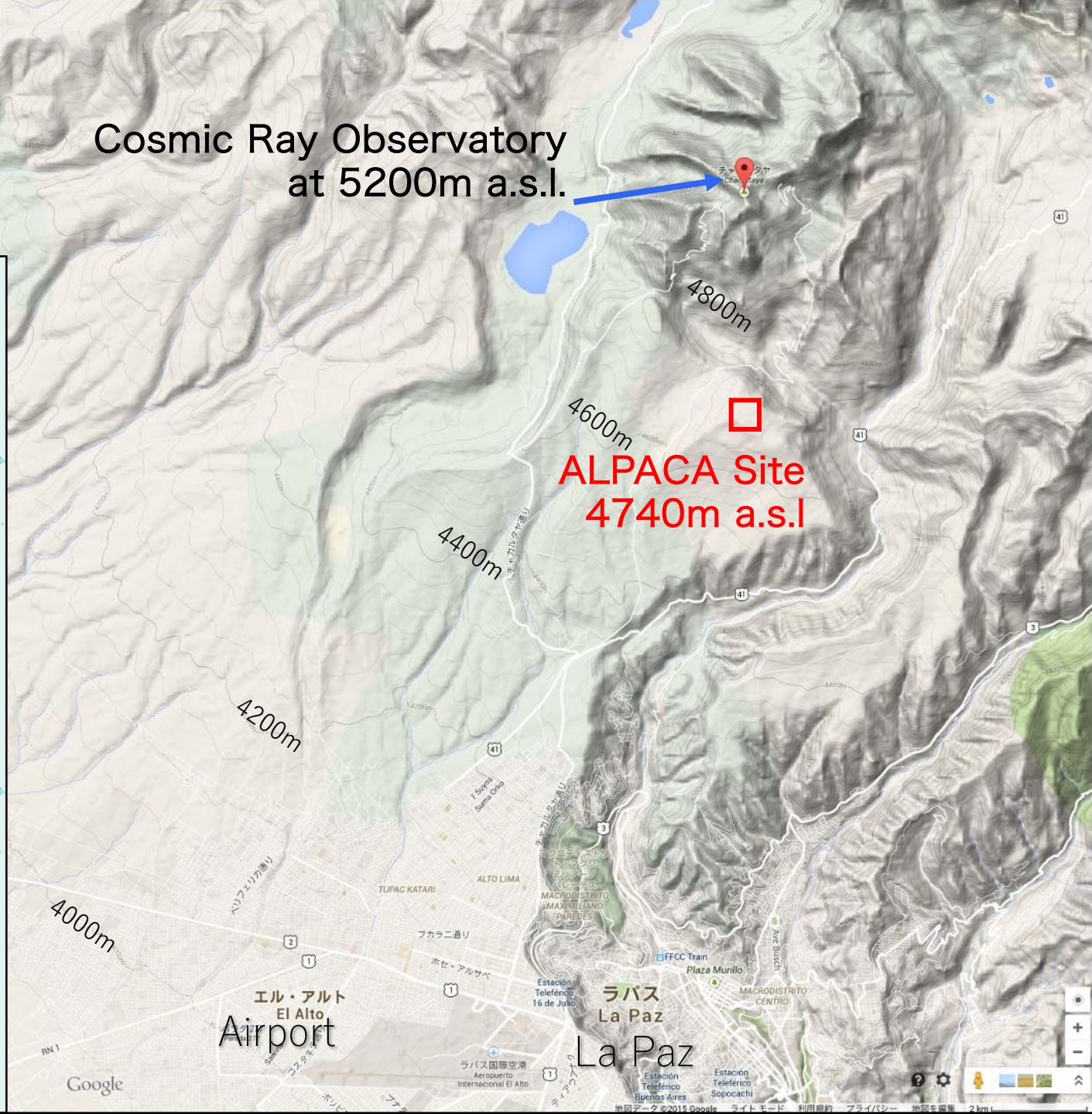
M. Anzorena¹, H. Asume¹, E. de la Fuente^{1,2,3}, K. Fujita⁴, R. Garcia⁵, Y. Hayashi⁶, K. Hibino⁷, R. Higuchi¹, J. Hochido⁸, N. Hotta⁹, G. Imaizumi¹, A. Jimenez-Meza³, Y. Katayose⁸, C. Kato¹⁰, S. Kato¹¹, T. Kawashima¹², K. Kawata¹, M. Kobayashi⁸, S. Kobayashi¹⁰, T. Koi¹³, H. Kojima¹⁴, P. Miranda¹⁵, S. Mitsuishi¹⁰, A. Mizuno¹, K. Munakata¹⁰, Y. Nakamura¹, M. Nishizawa¹⁶, S. Ogio¹, M. Ohishi¹, M. Ohnishi¹, A. Okumura¹, A. Oshima^{13,17}, M. Raljevic¹⁵, H. Rivera¹⁵, T. Saito¹⁸, T. Sako¹, T. K. Sako¹⁹, S. Shibata¹⁴, A. Shiomi²⁰, M. Subieta¹⁵, F. Sugimoto¹, N. Tajima⁵, W. Takano⁷, Y. Takeyama⁸, M. Takita¹, N. Tamaki¹, Y. Tameda⁴, H. Tanaka¹⁹, K. Tanaka²¹, Y. Terakado⁸, R. Ticona¹⁵, H. Tsuchiya²², Y. Tsunesada^{23,24}, S. Udo⁷, Y. Yamanaka¹, K. Yamazaki¹³ and Y. Yokoe¹

¹ICRR, U. of Tokyo, ²Dept. de Fís., CUCEI, Univ. de Guadalajara, ³Doct. en Tecn. de la Info., CUCEA, Univ. de Guadalajara, ⁴Fac. of Engn., Osaka Elec.-Comm. Univ., ⁵RIKEN, ⁶Dept. of Sci. and Tech., Shinshu Univ., ⁷Fac. of Engn., Kanagawa Univ., ⁸Fac. of Engn., Yokohama Natl. Univ., ⁹Utsunomiya Univ., ¹⁰Dept. of Phys., Shinshu Univ., ¹¹Dept. of Phys, Kyoto Univ., ¹²NICT, ¹³Coll. Engn., Chubu Univ., ¹⁴ Chubu Inn. Astro. Obs., Chubu Univ., ¹⁵IIF, UMSA, ¹⁶NII, ¹⁷Grad. Sch. of Engn., Chubu Univ., ¹⁸Tokyo Metro. Coll. of Ind. Tech., ¹⁹Dept. of Info. and Elec., Nagano Pref. Inst. of Tech., ²⁰Coll. of Ind. Tech., Nihon Univ., ²¹Hiroshima City Univ., ²²JAEA, ²³Grad. Sch. of Sci., Osaka Metro. Univ., ²⁴NYITEP, Osaka Metro. Univ.

ALPACA Site



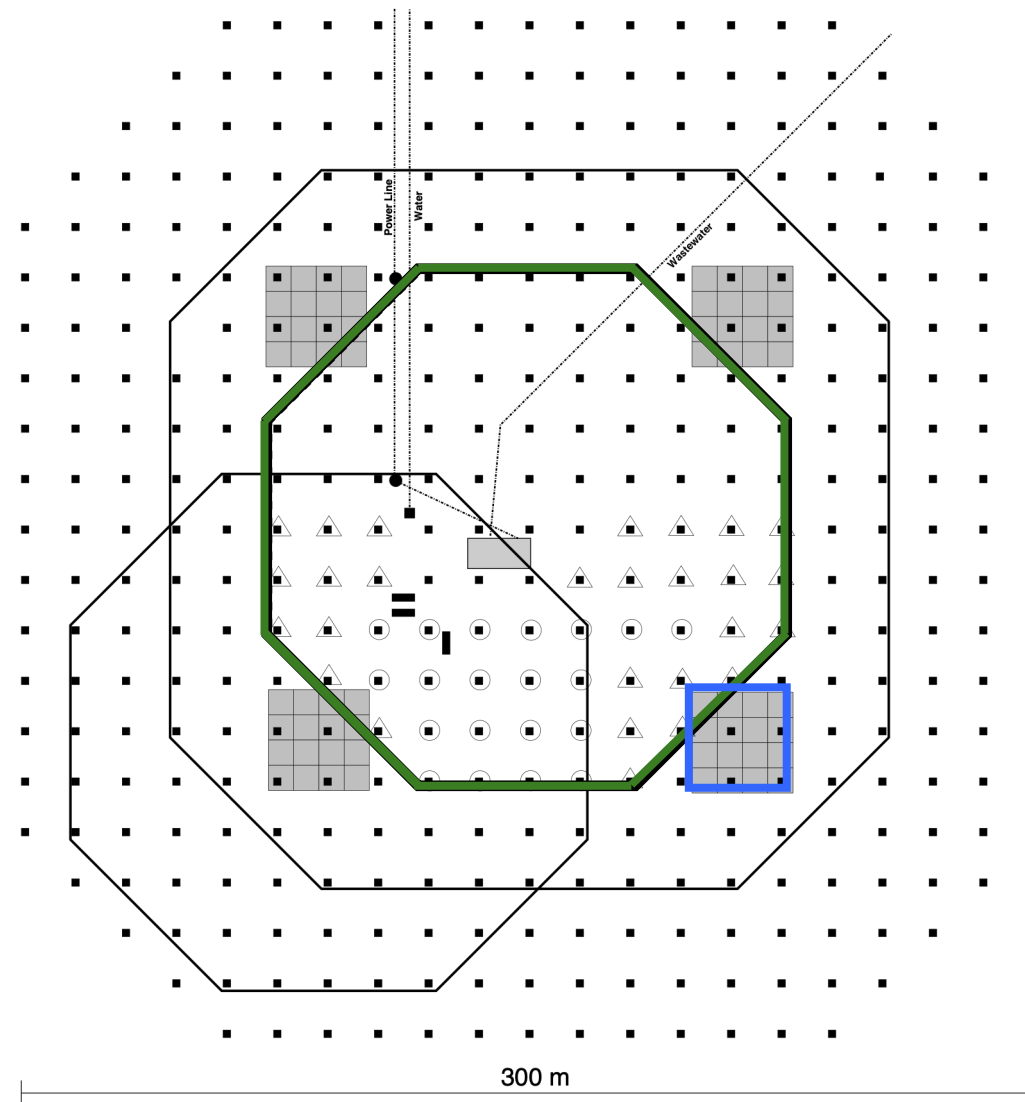
Bolivia • Chacaltaya plateau
(16° 23' S, 68° 08' W)



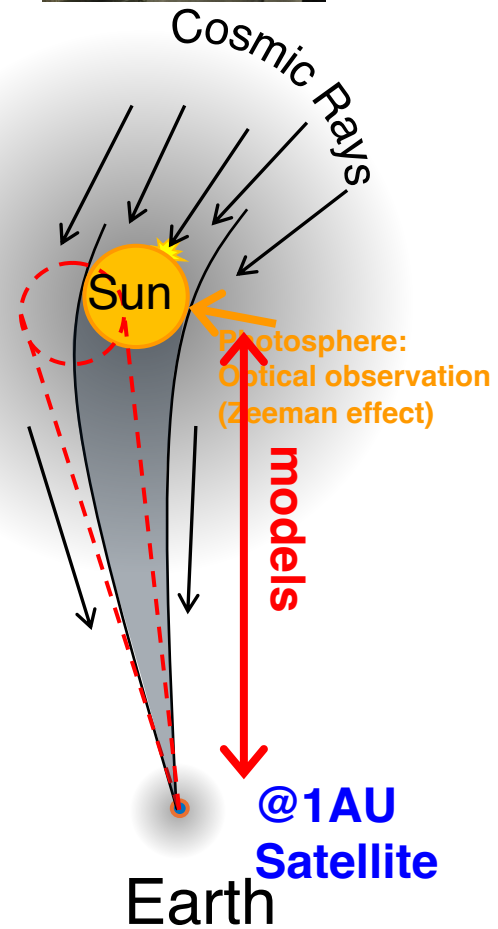
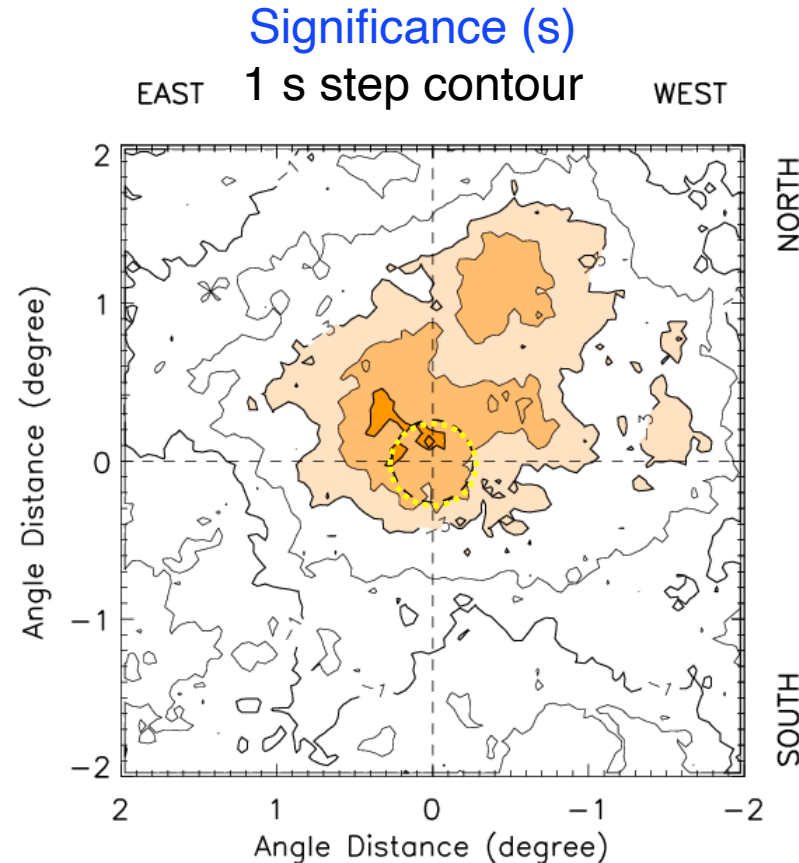
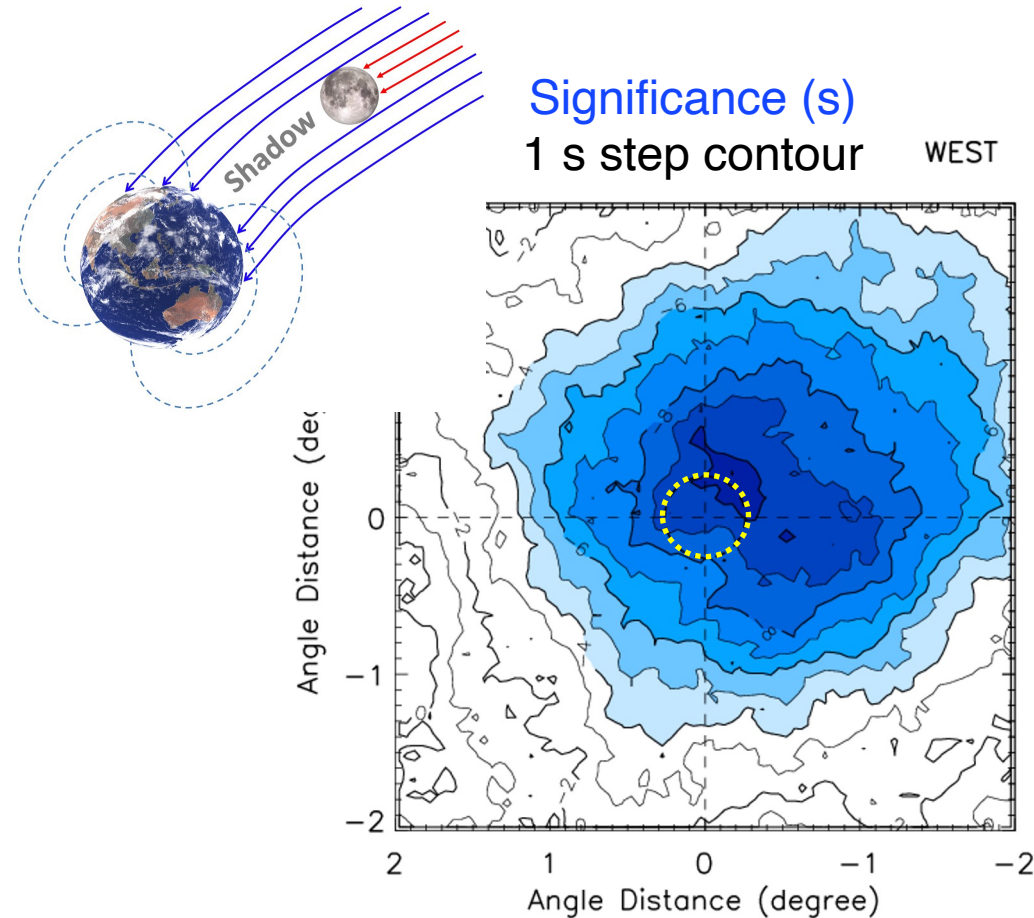
Prototype: ALPAQUITA



- **Surface air shower array (18,450m²)**
1/4 ALPACA with 97 AS detectors
Operation with the full array since 2023 Apr.
- **Underground muon detector array (900m²)**
Under construction. Will be completed in 2026



Shadows of Moon & Sun



- ✓ Moon shadow with $\sim 10s$ is consistent with the angular resolution
- ✓ Sun shadow with $\sim 5s$ is a clear evidence of turbulent solar and interplanetary magnetic field during active solar period

Temporal variation of Shadow's position, depth, and shape



K. Fujita

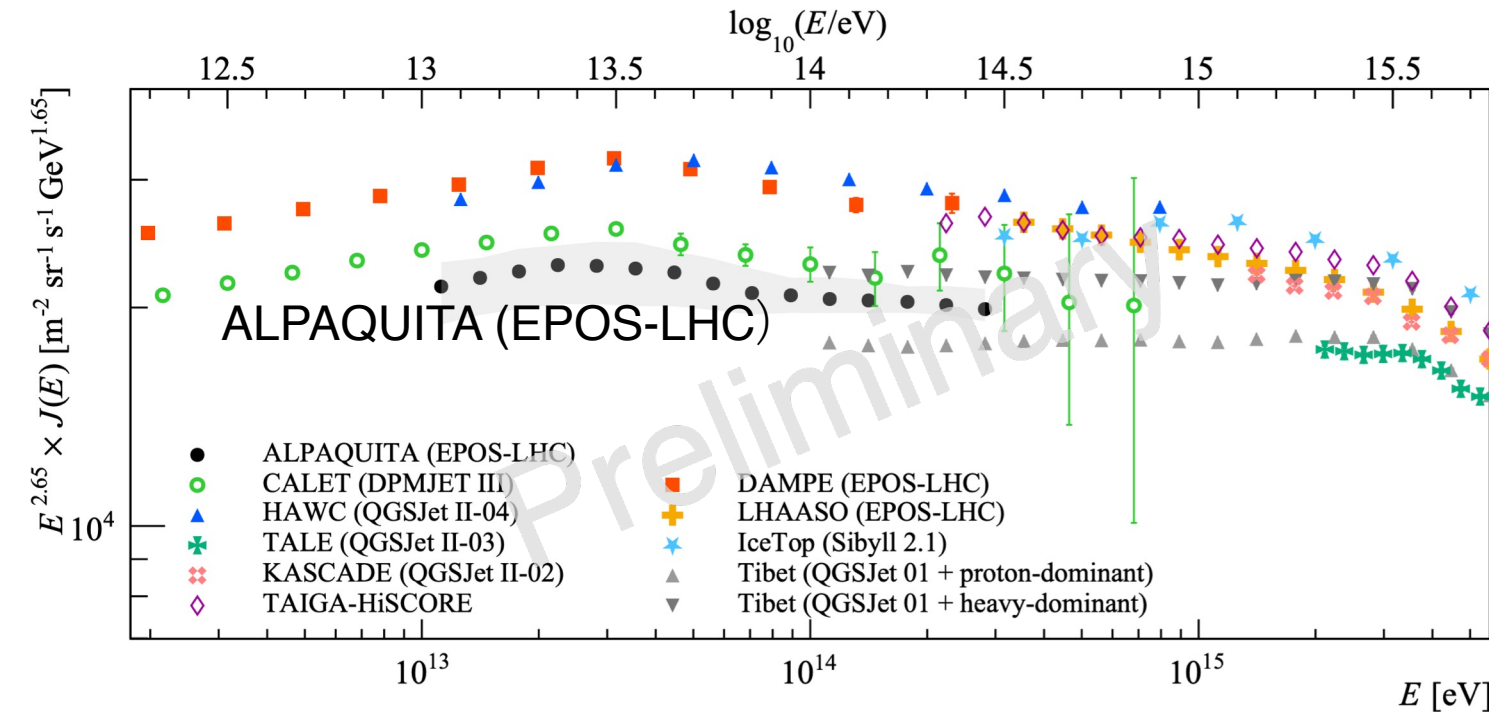


T. Kawashima

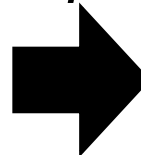
CR Observation

Anisotropy Kawashima, PhD thesis

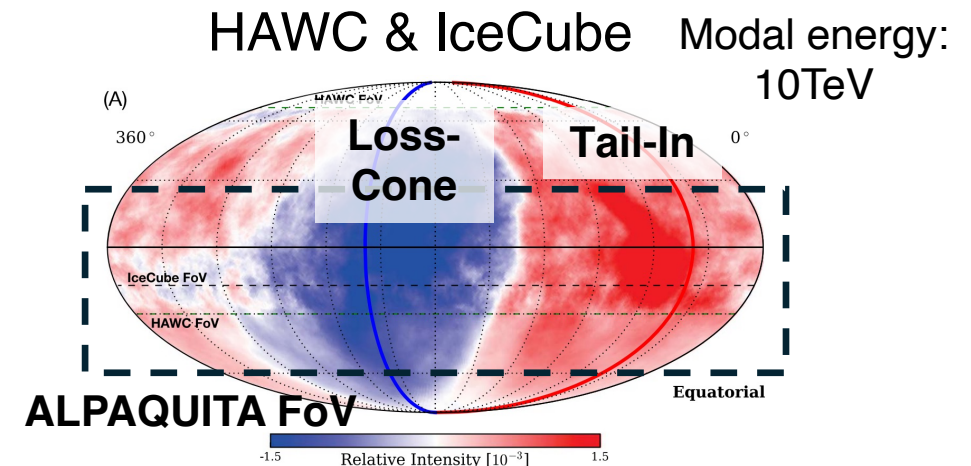
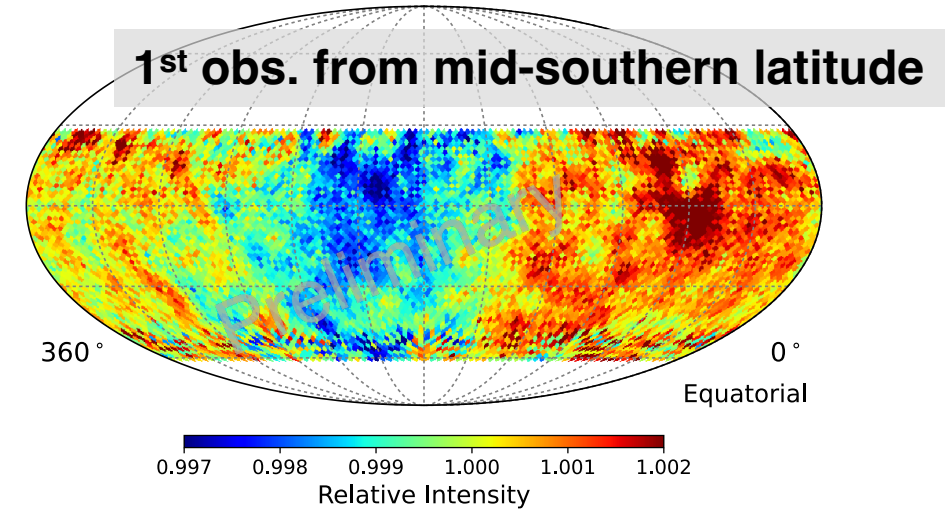
All-particle energy spectrum Submitted to PRD



See the talk by K. Fujita @ 16:00 3rd Sept.

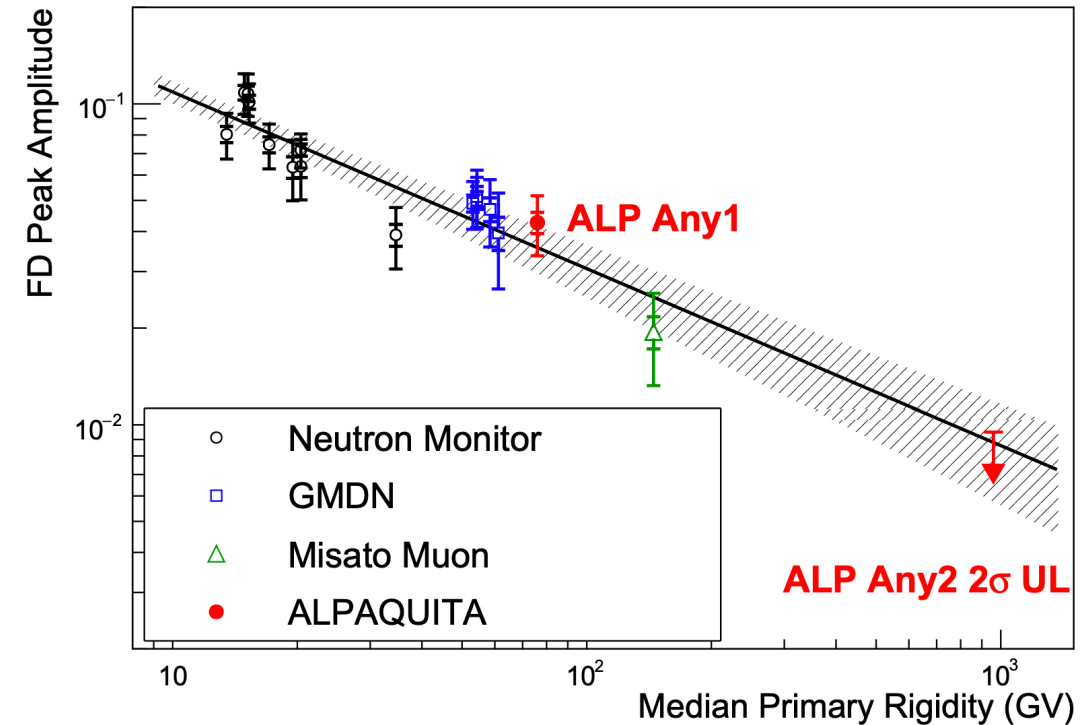
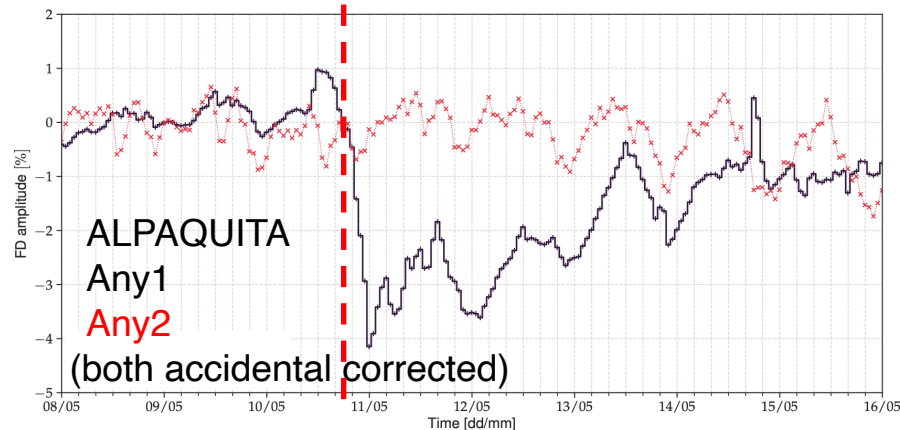
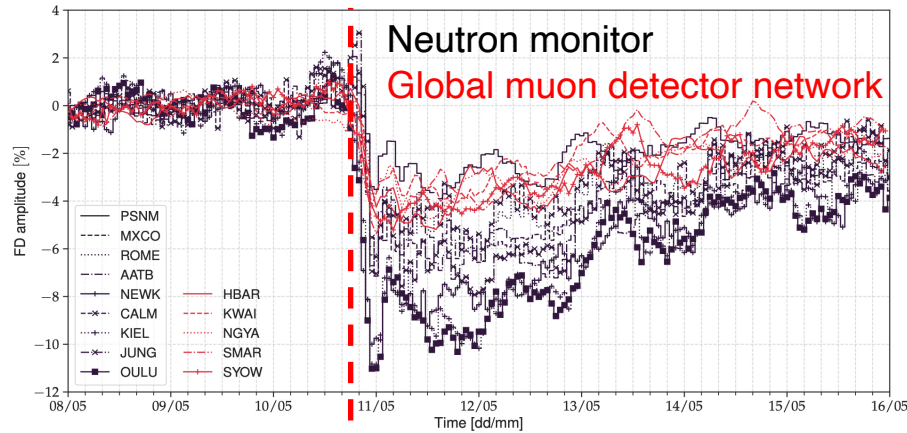
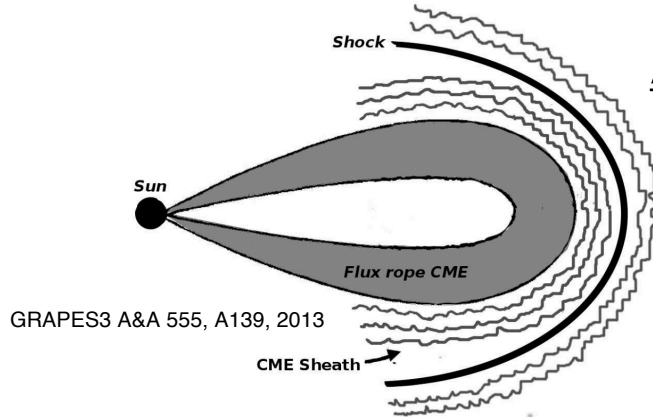


ALPAQUITA (10TeV)



Observation of Forbush Decrease

Anzorena et al., ApJ 998, 16 (2026)



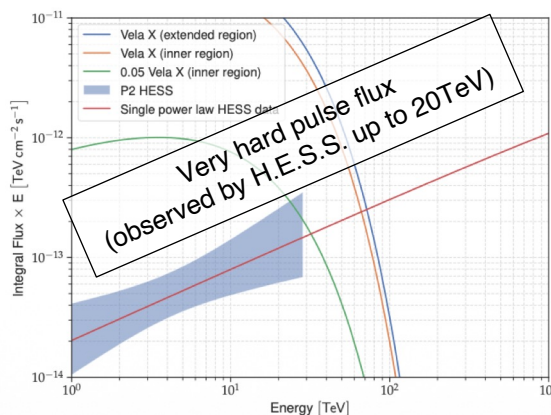
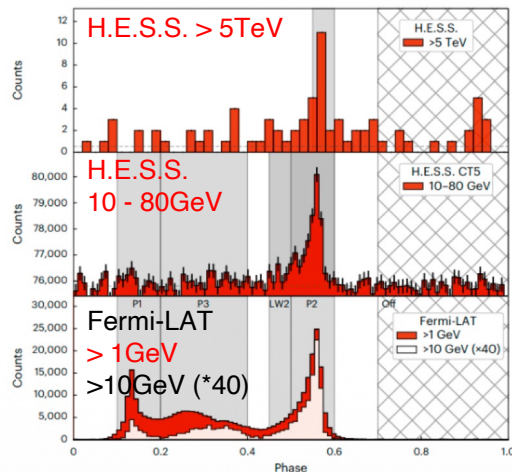
Constraint on the rigidity spectrum in the highest rigidity range
Unique study of CR propagation with AS array detectors



M. Anzorena

Preliminary gamma-ray analysis

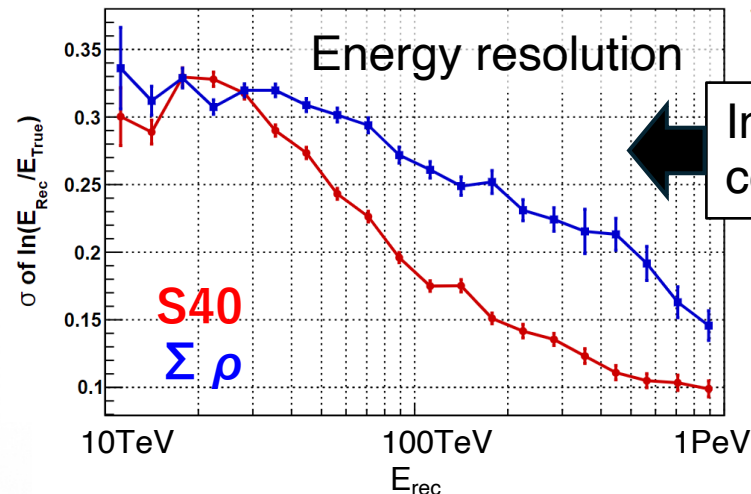
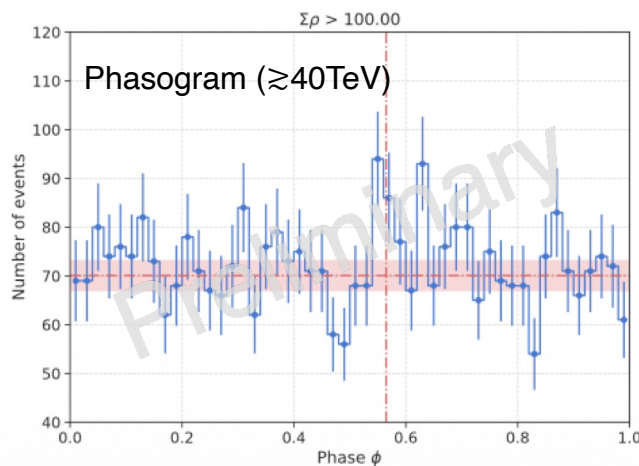
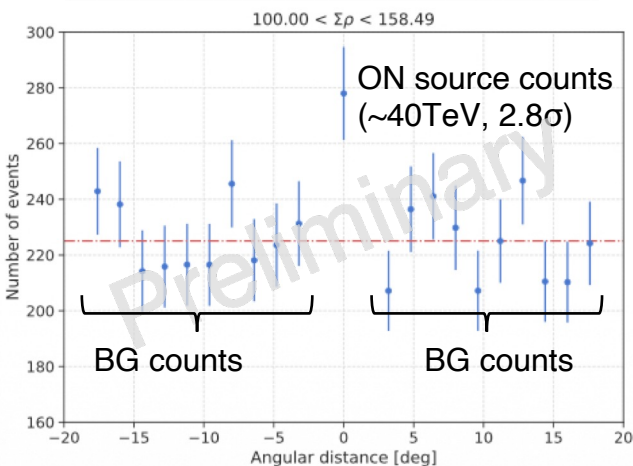
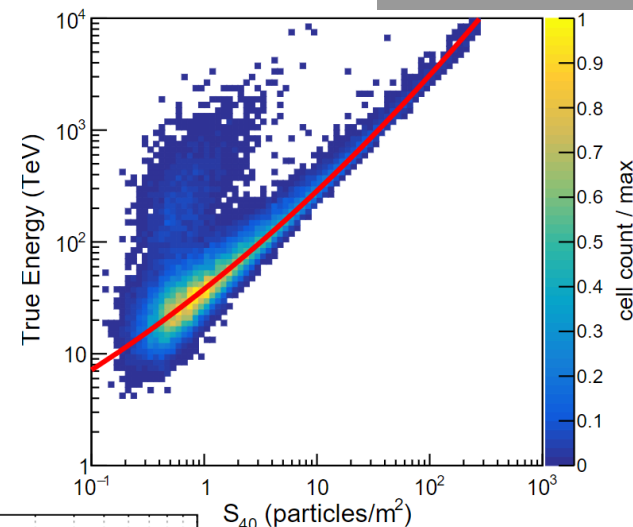
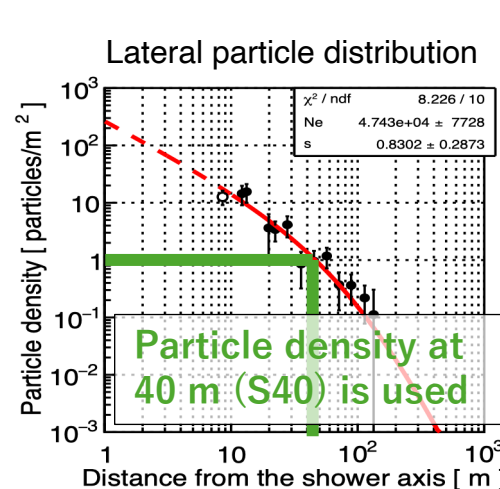
Search for hard γ -ray pulses from Vela X
Anzorena et al. JPS (2026)



Optimization of γ -ray energy estimate
(Yamanaka et al. in prep.)



Y. Yamanaka

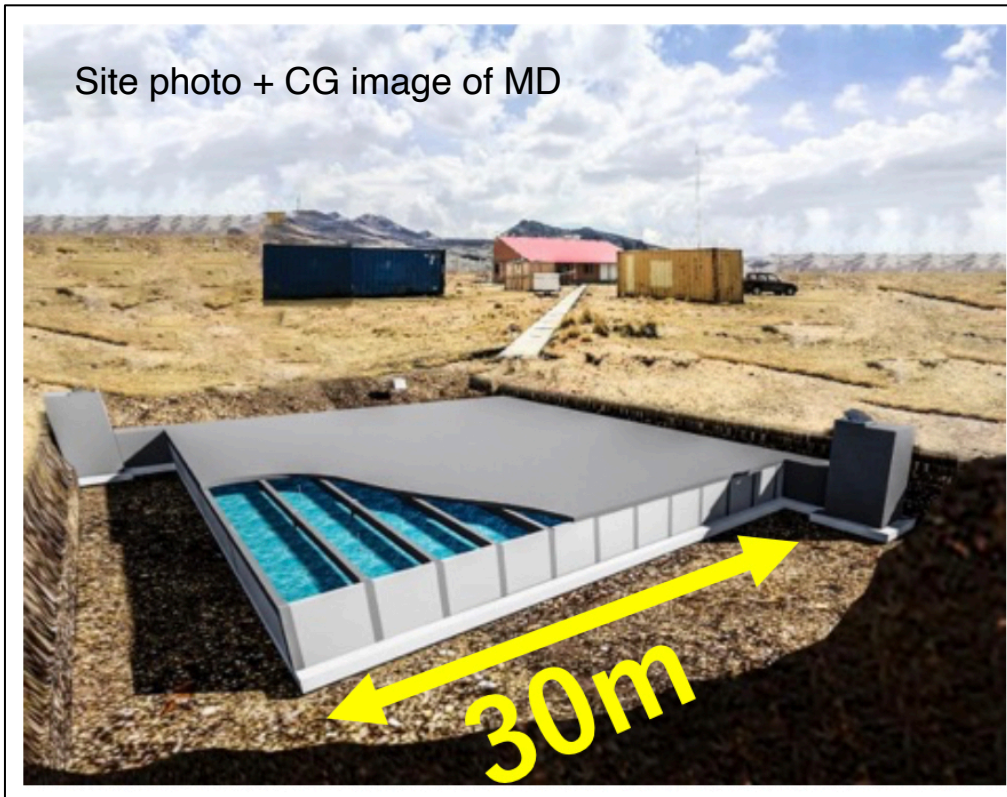


Improvement from a conventional estimate!

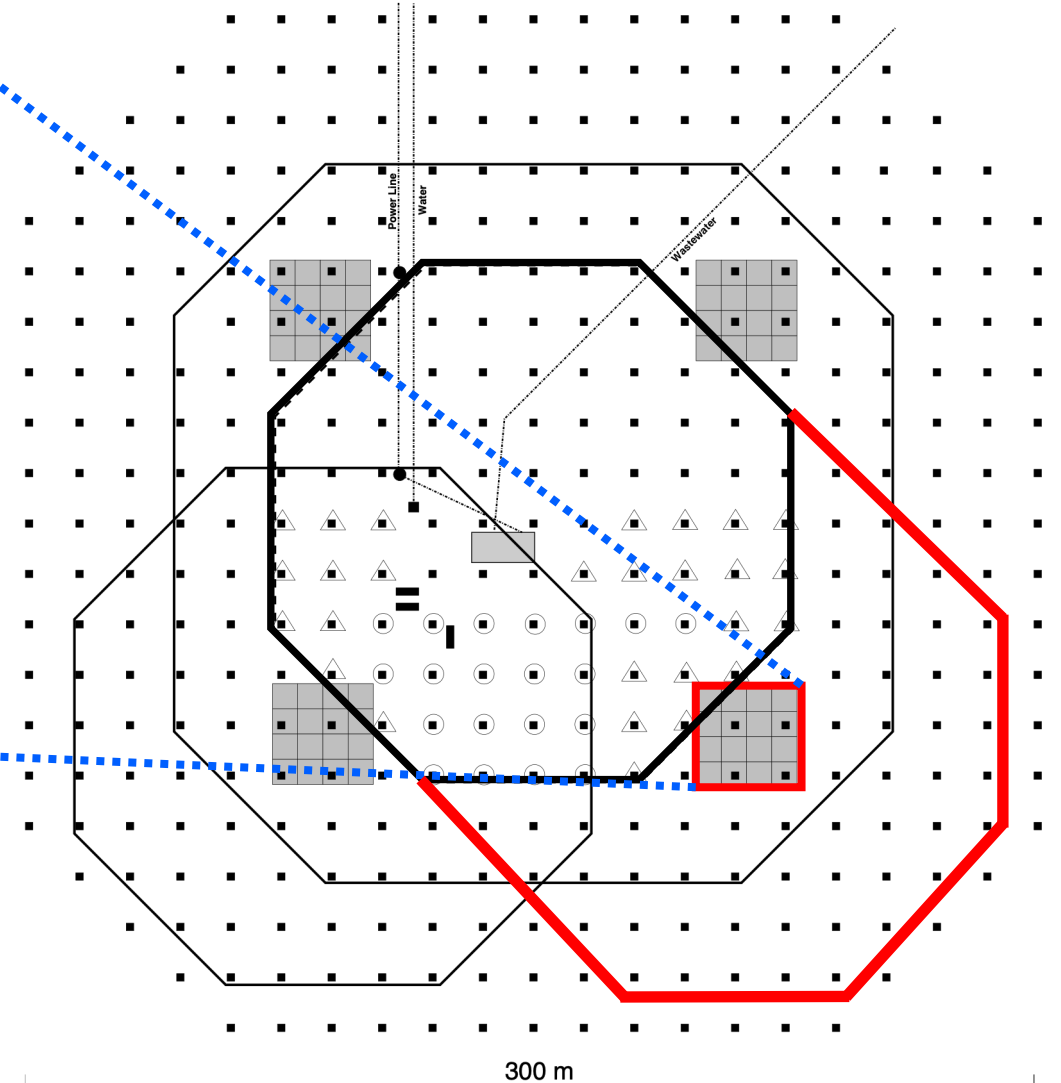
See the talk by Y. Yamanaka after this talk



Construction of Underground Muon Detectors

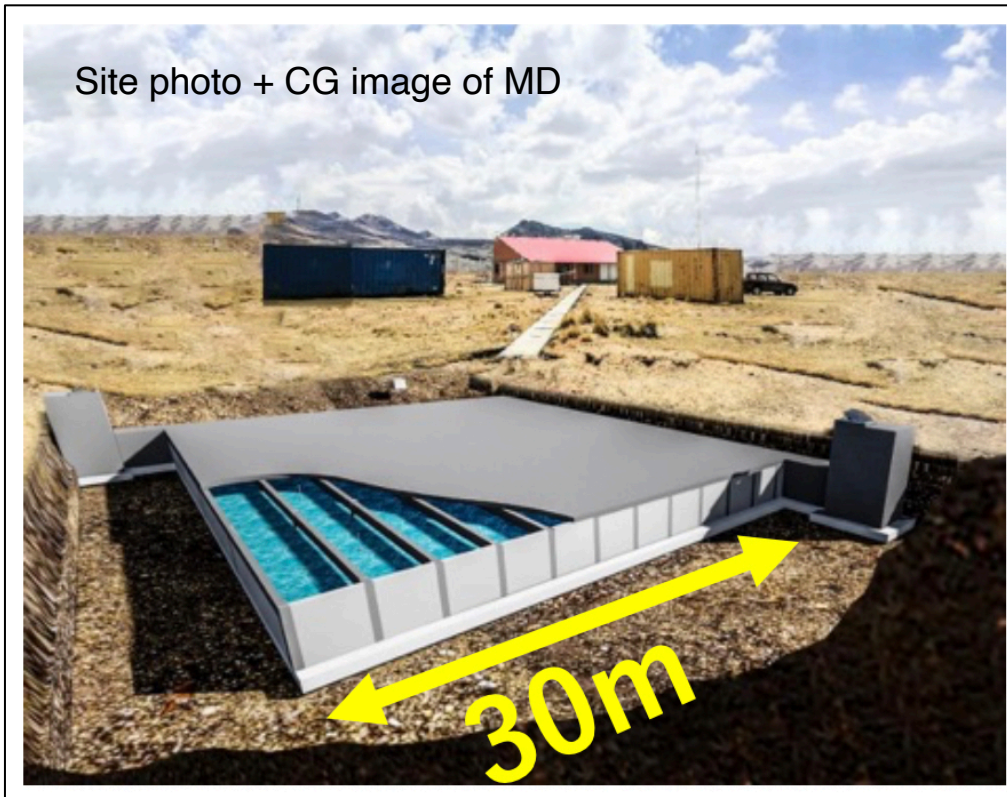


1. Construction of the Southwest MD (ongoing)
2. Extension of SDs in the Southwest area (2026)
3. Construction of the other three MDs (ongoing)
4. Extension of SDs in the whole area (2027)



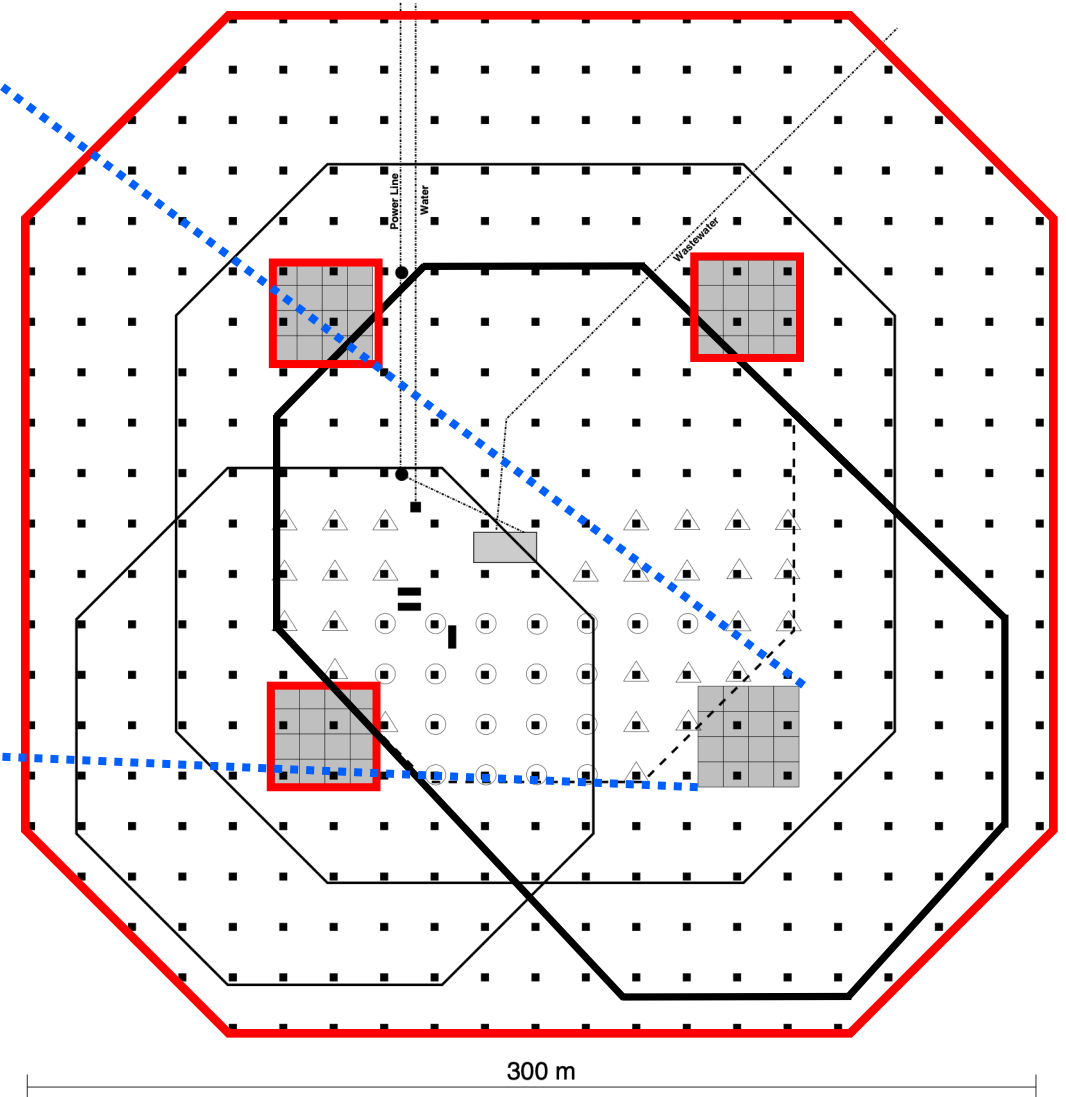
γ ray obs. with ALPAQUITA will start in 2026!

Construction of Underground Muon Detectors



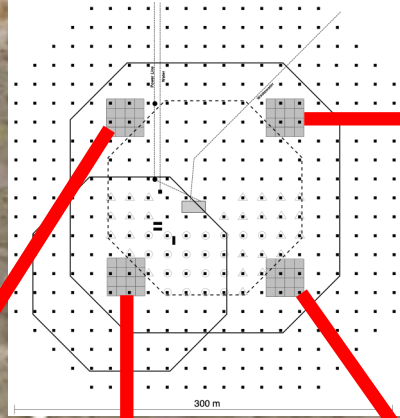
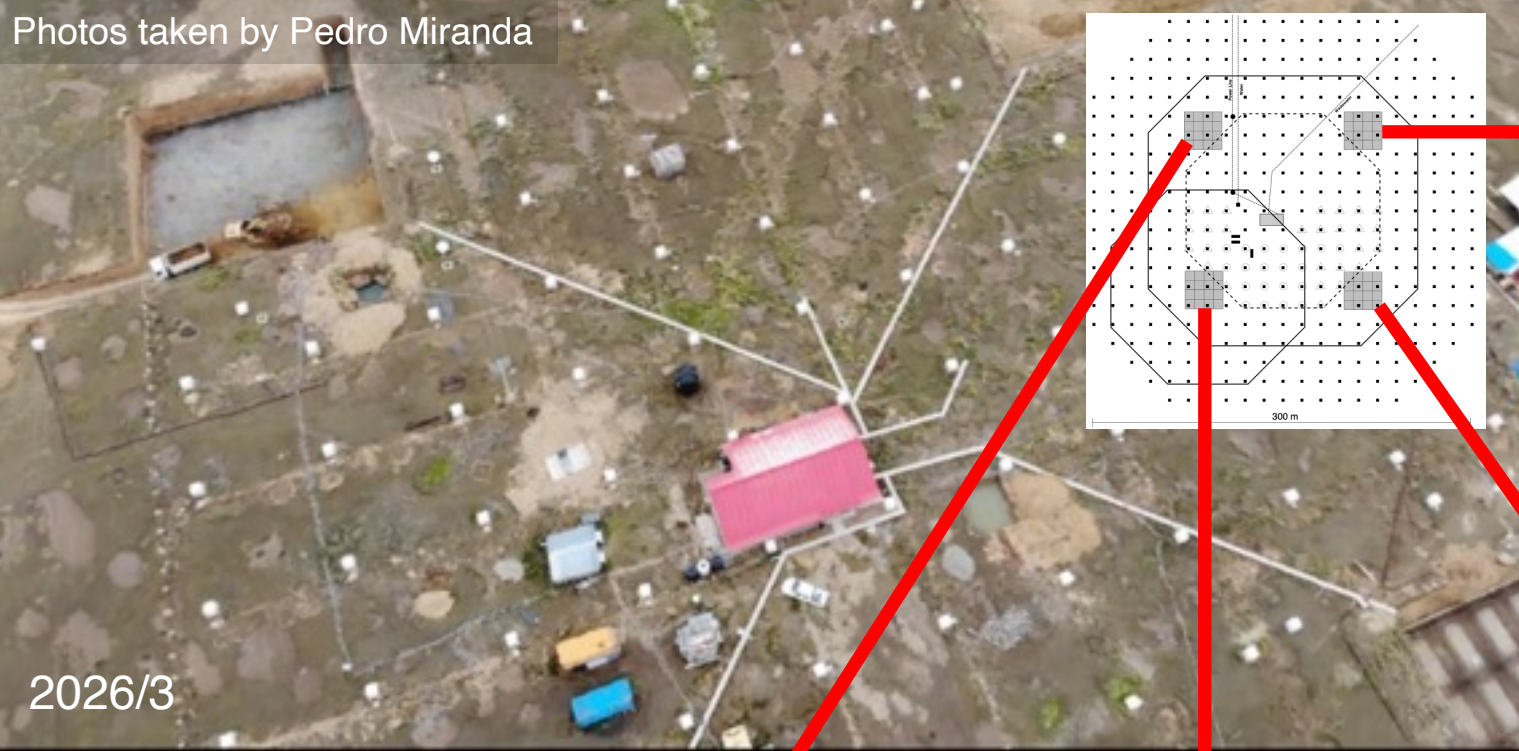
1. Construction of the Southwest MD (ongoing)
2. Extension of SDs in the Southwest area (2026)
3. Construction of the other three MDs (ongoing)
4. Extension of SDs in the whole area (2027)

ALPACA Obs. will start by 2027!!

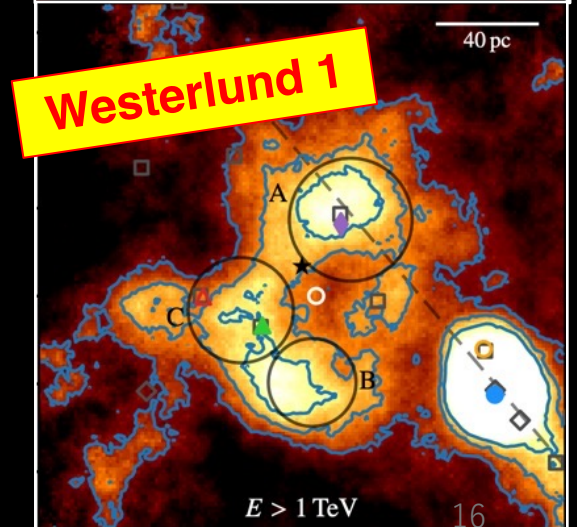
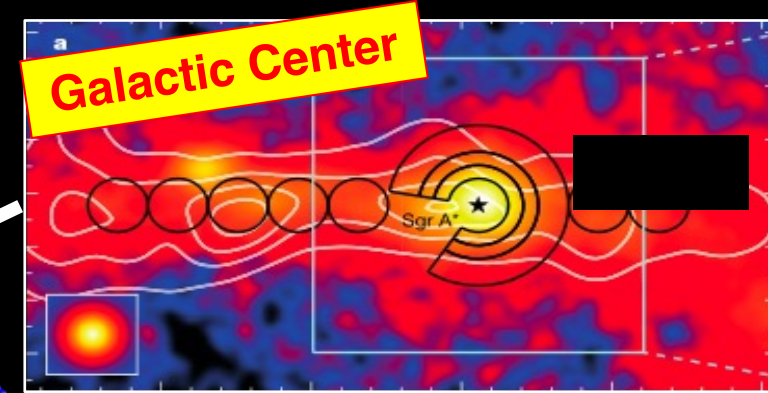
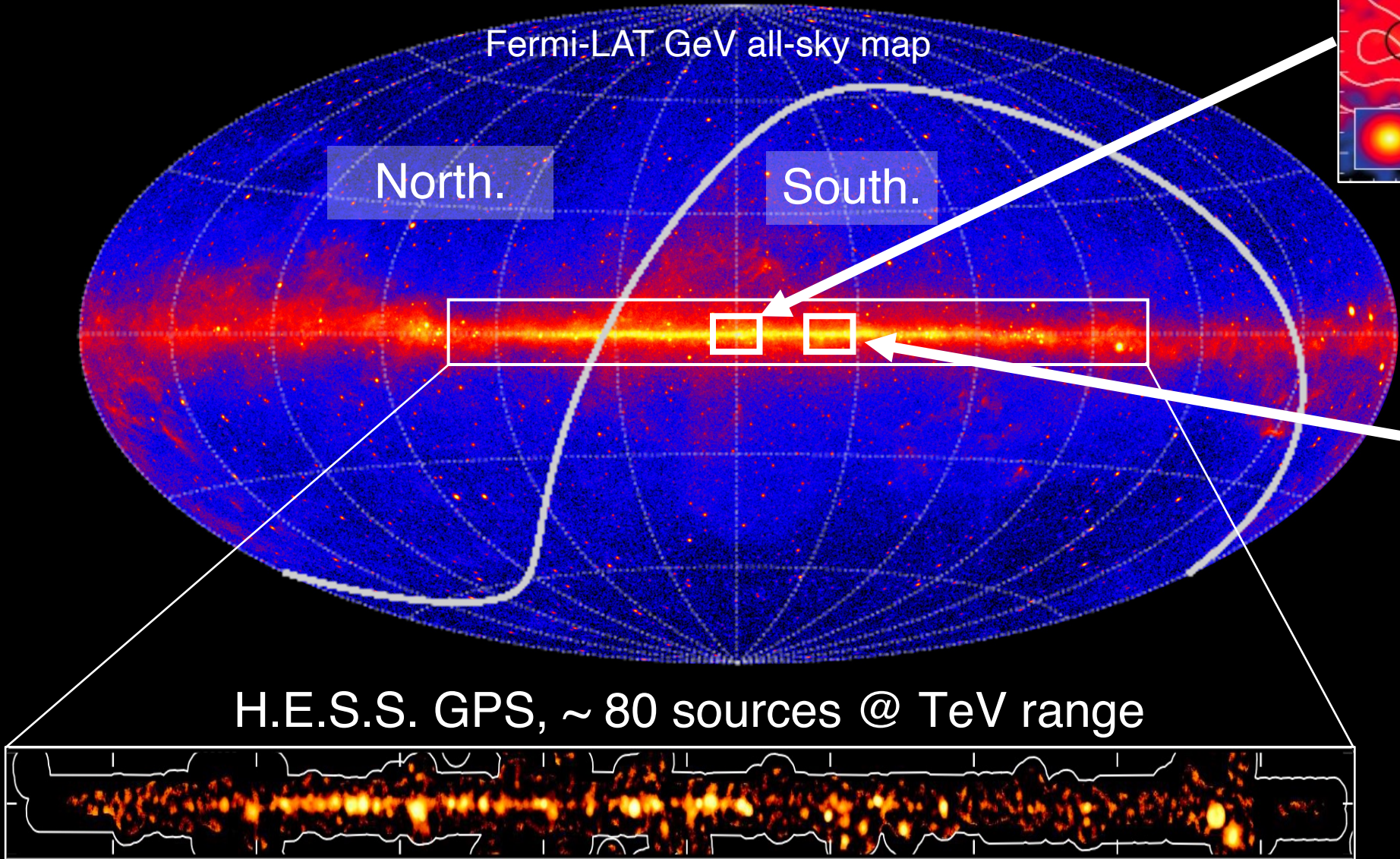


ALPAQUITA MD Construction (Jul. 2026)

Photos taken by Pedro Miranda

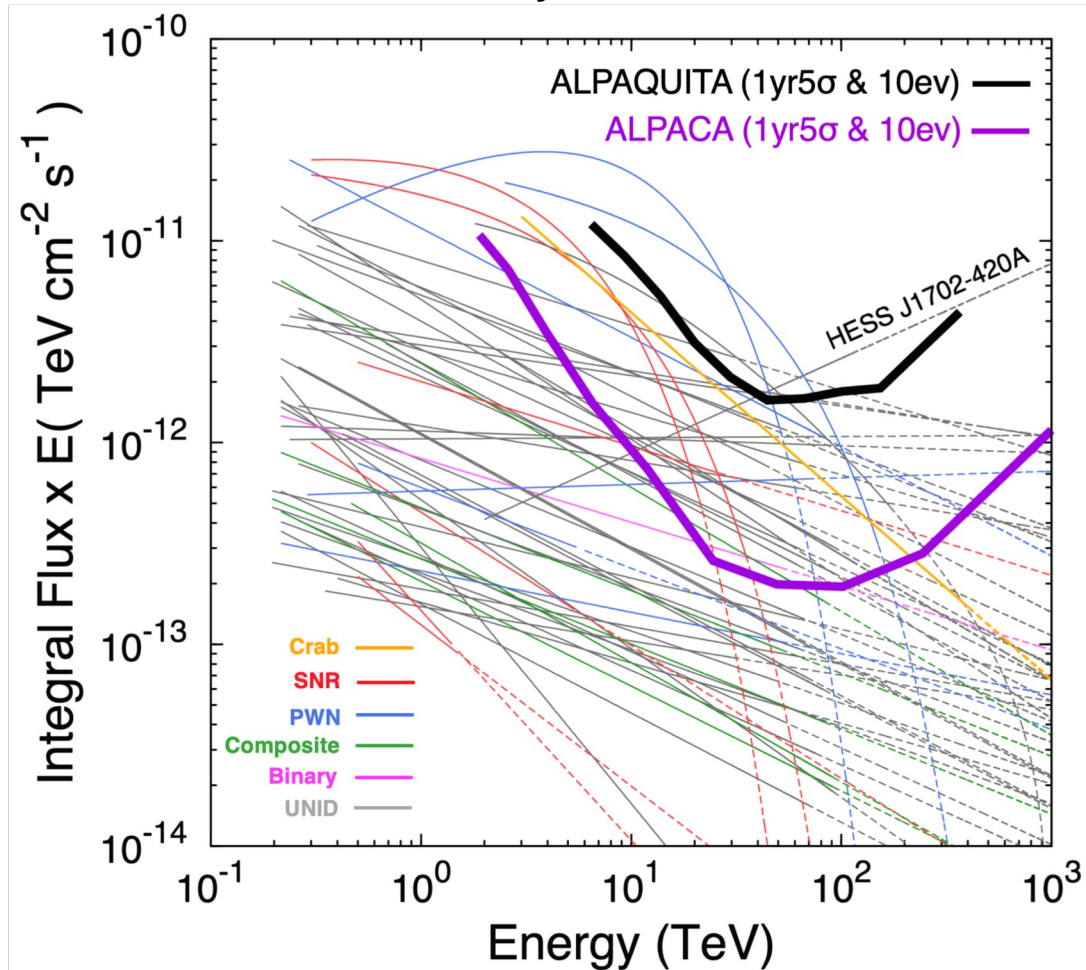


Detection of PeVatron Candidates



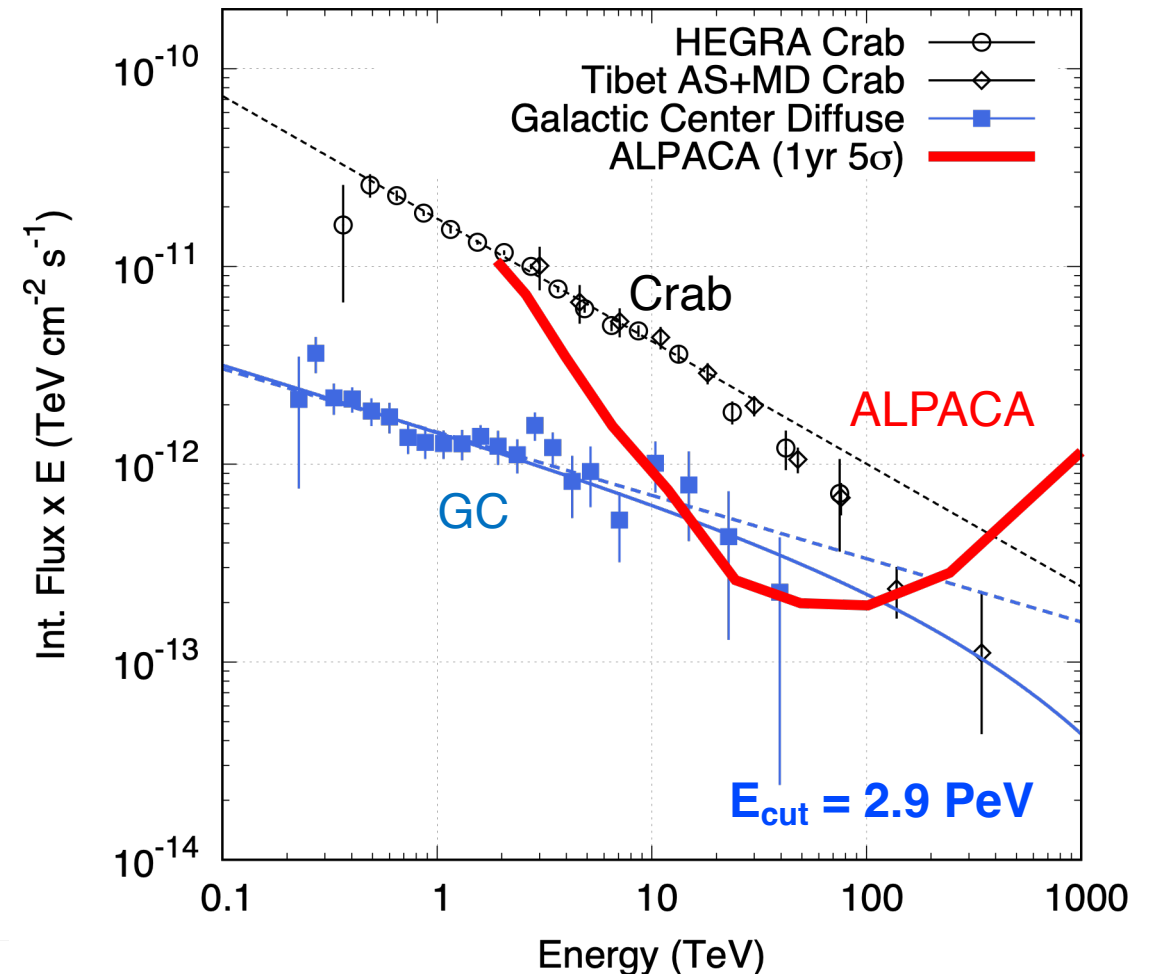
Sensitivity to Gamma-Ray Sources

Gamma-ray sources w/i F.O.V.



S.K et al., EXPA (2021) 52:85-107

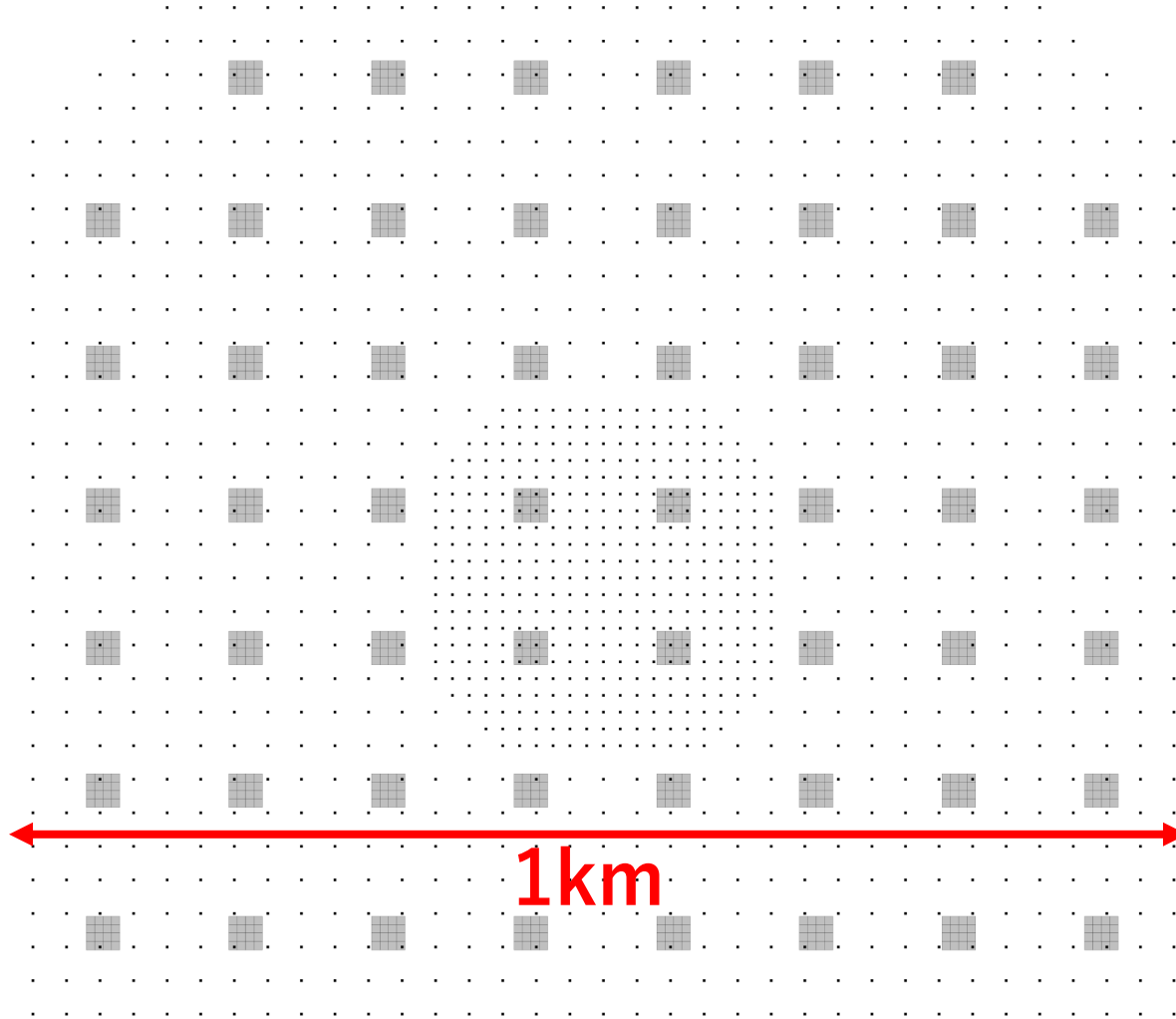
Galactic Center



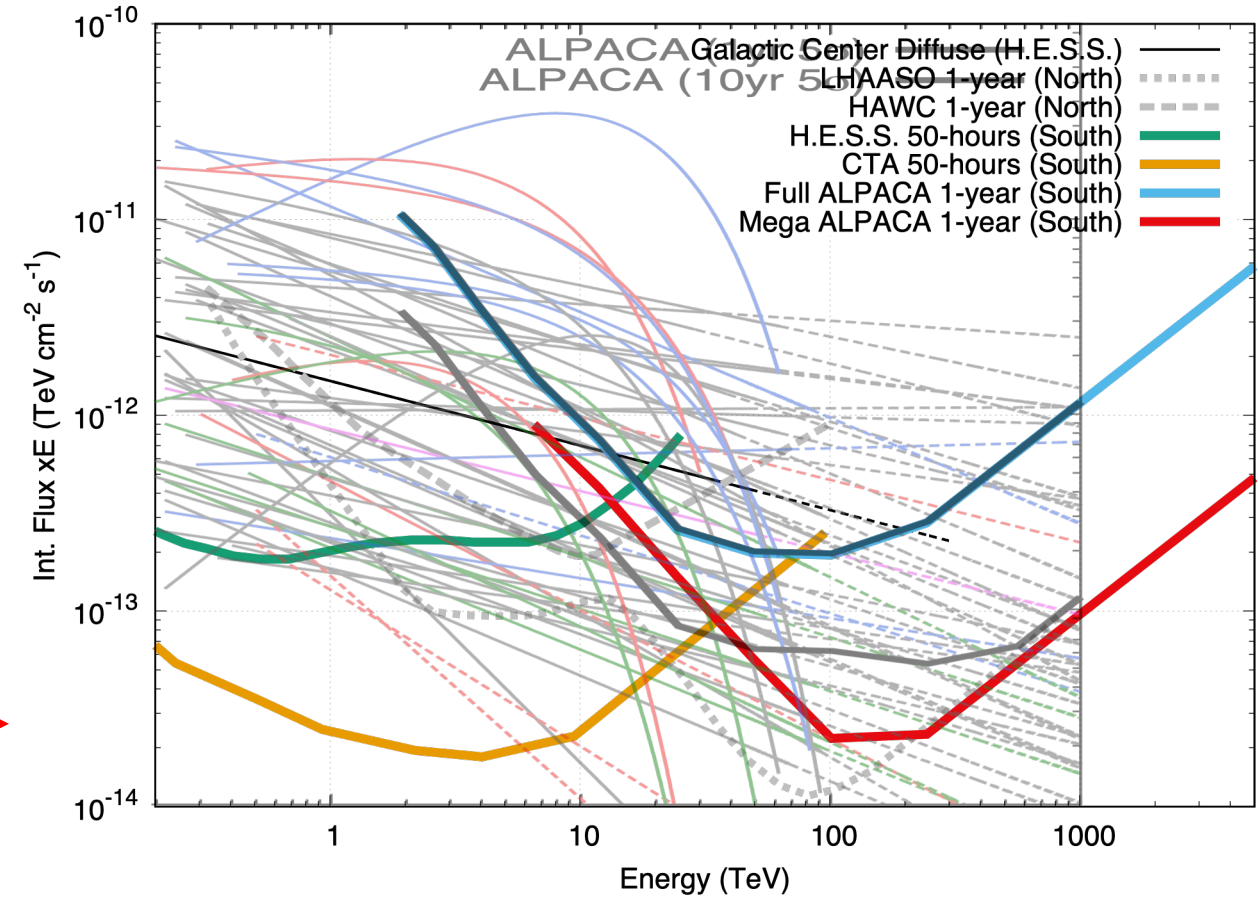


Beyond ALPACA → Mega (m²) ALPACA

Same MD coverage 4% as ALPACA



ALPACA Collaboration, PoS(ICRC2023)632



Where is the highest energy accelerator in our Galaxy?

Summary

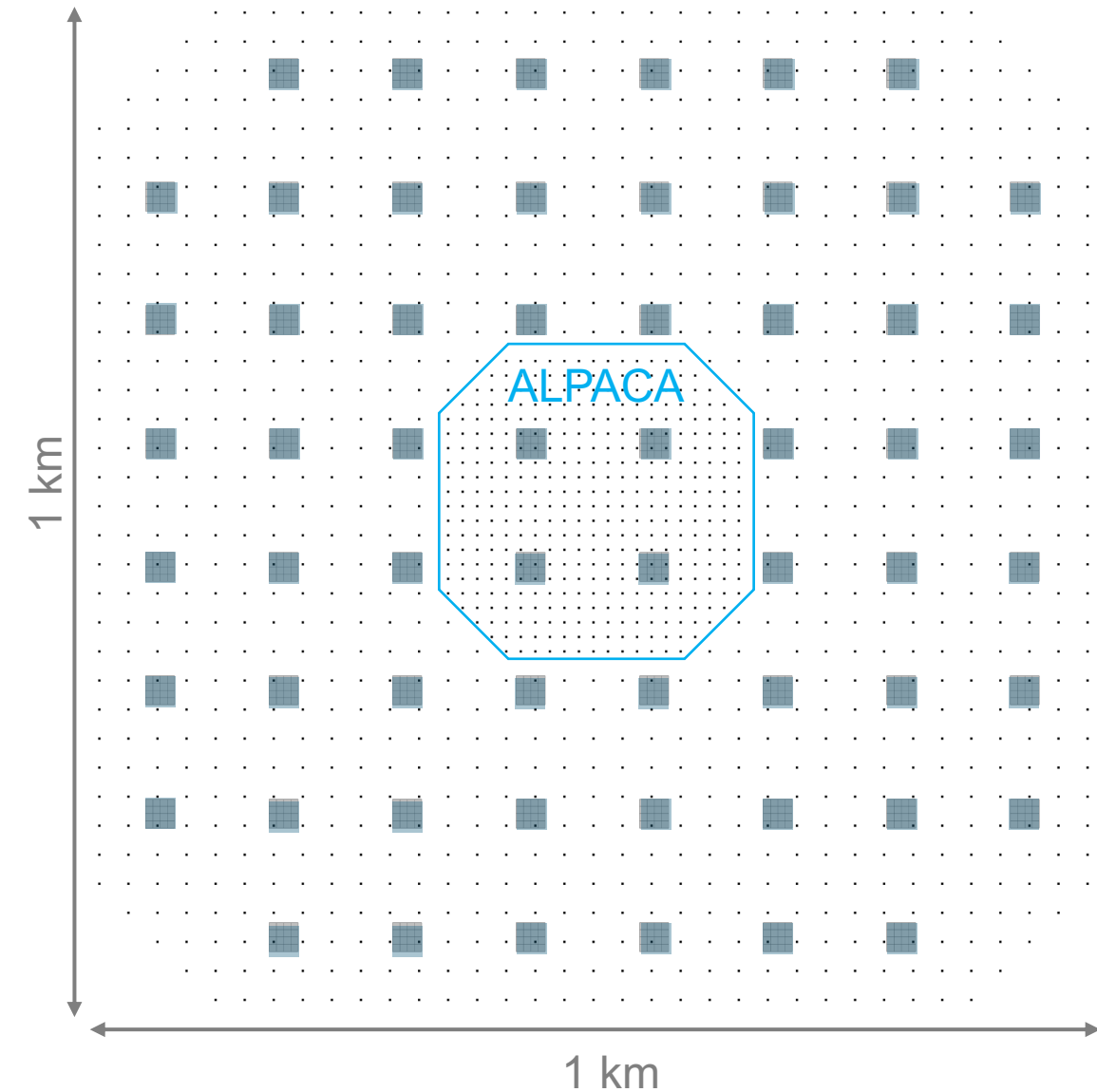
- ✓ UHE γ -ray astronomy to search for Galactic PeVatrons
- ✓ ALPACA will start UHE γ -ray observations in Bolivia in 2027
- ✓ An underground muon detector is being constructed for the prototype ALPAQUITA, aiming for the UHE γ -ray observations in 2026
- ✓ ALPAQUITA CR & gamma-ray analysis are ongoing

See the talks by Y. Yamanaka after this talk & K. Fujita @ 16:00 3rd Sept., & have a look on Anzorena et al. ApJ 998, 16 (2026) & upcoming publications

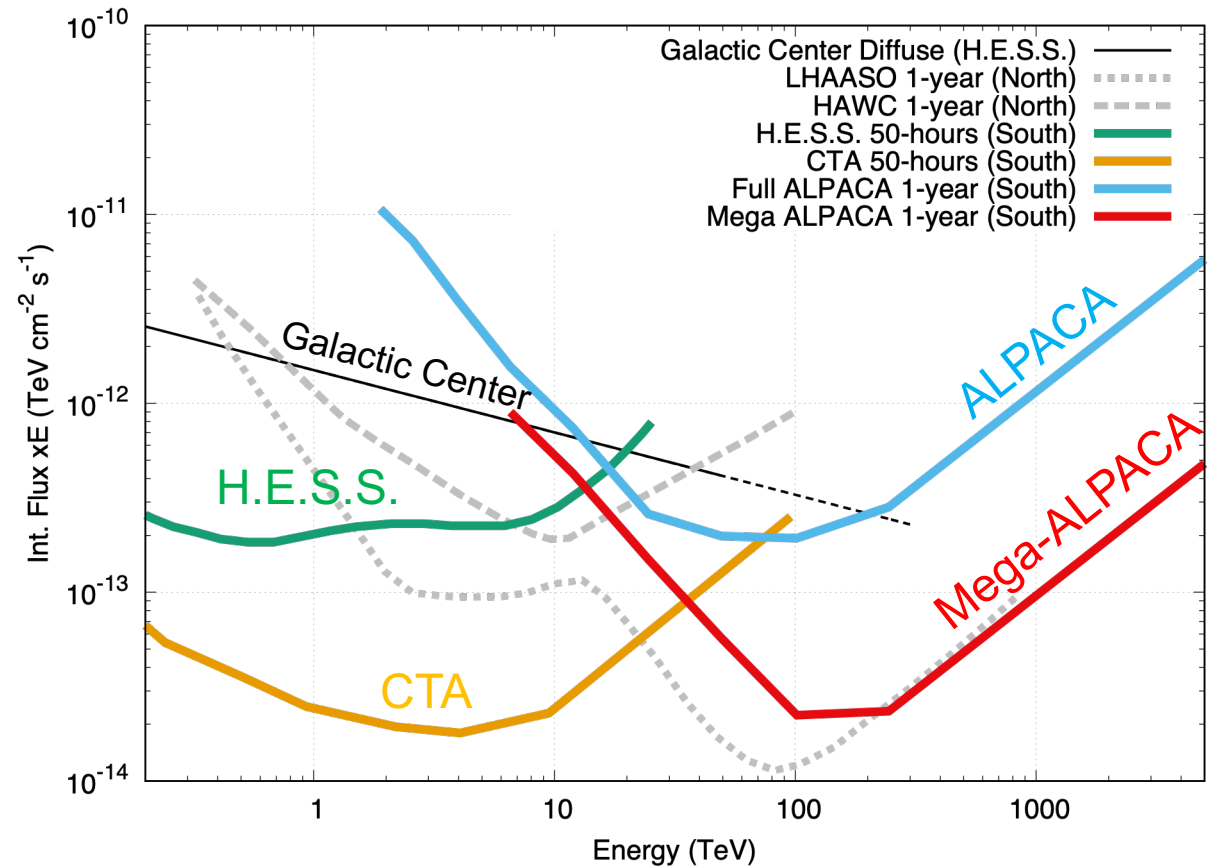
Backup Slides

Mega ALPACA

Sako et al., PoS(ICRC2023)632

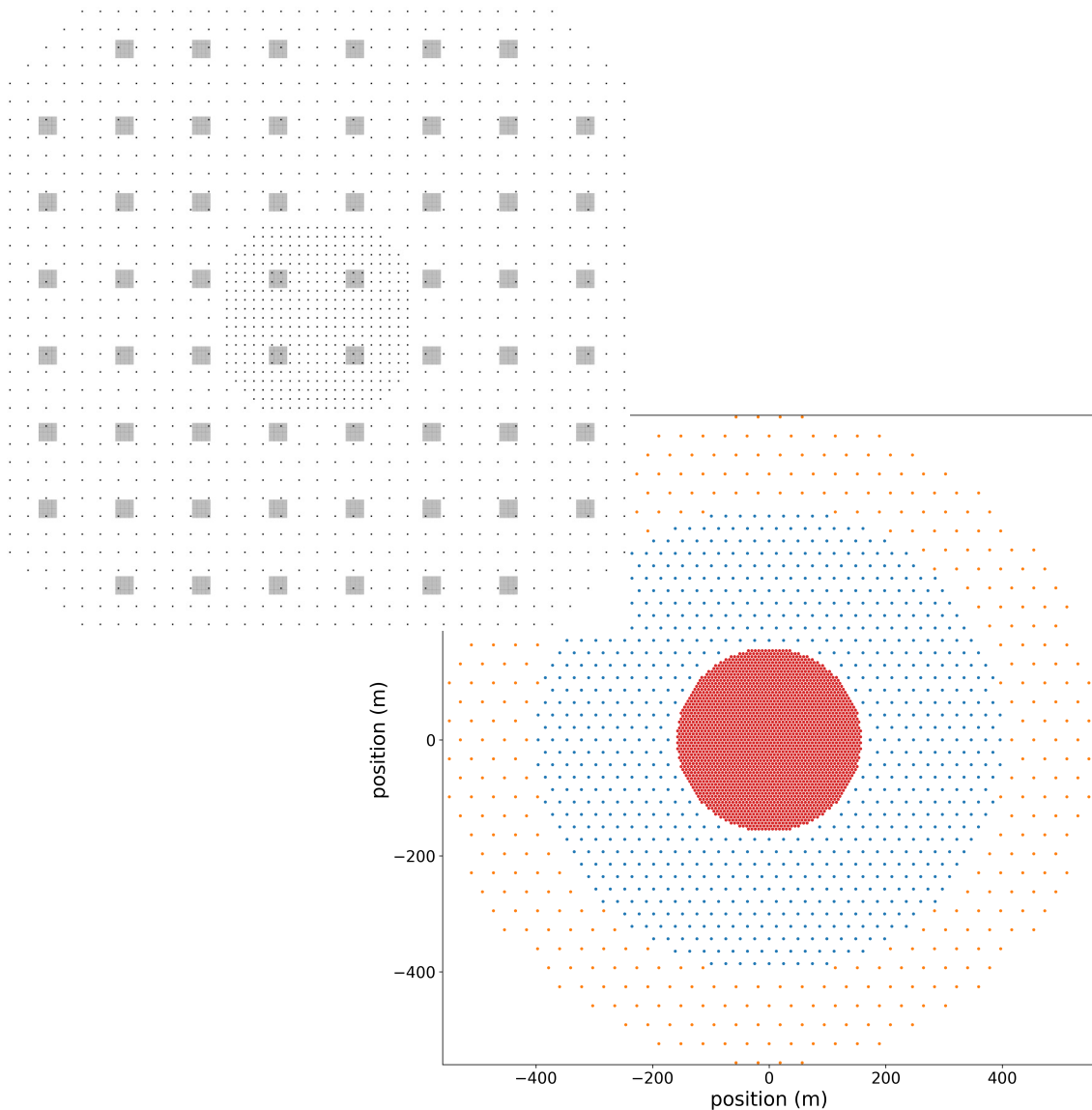


- 1 km² AS array: # of det. 1185
- Muon Detector (MD) Array:
900 m² (16 Cells) x 60 = **54,000 m²**

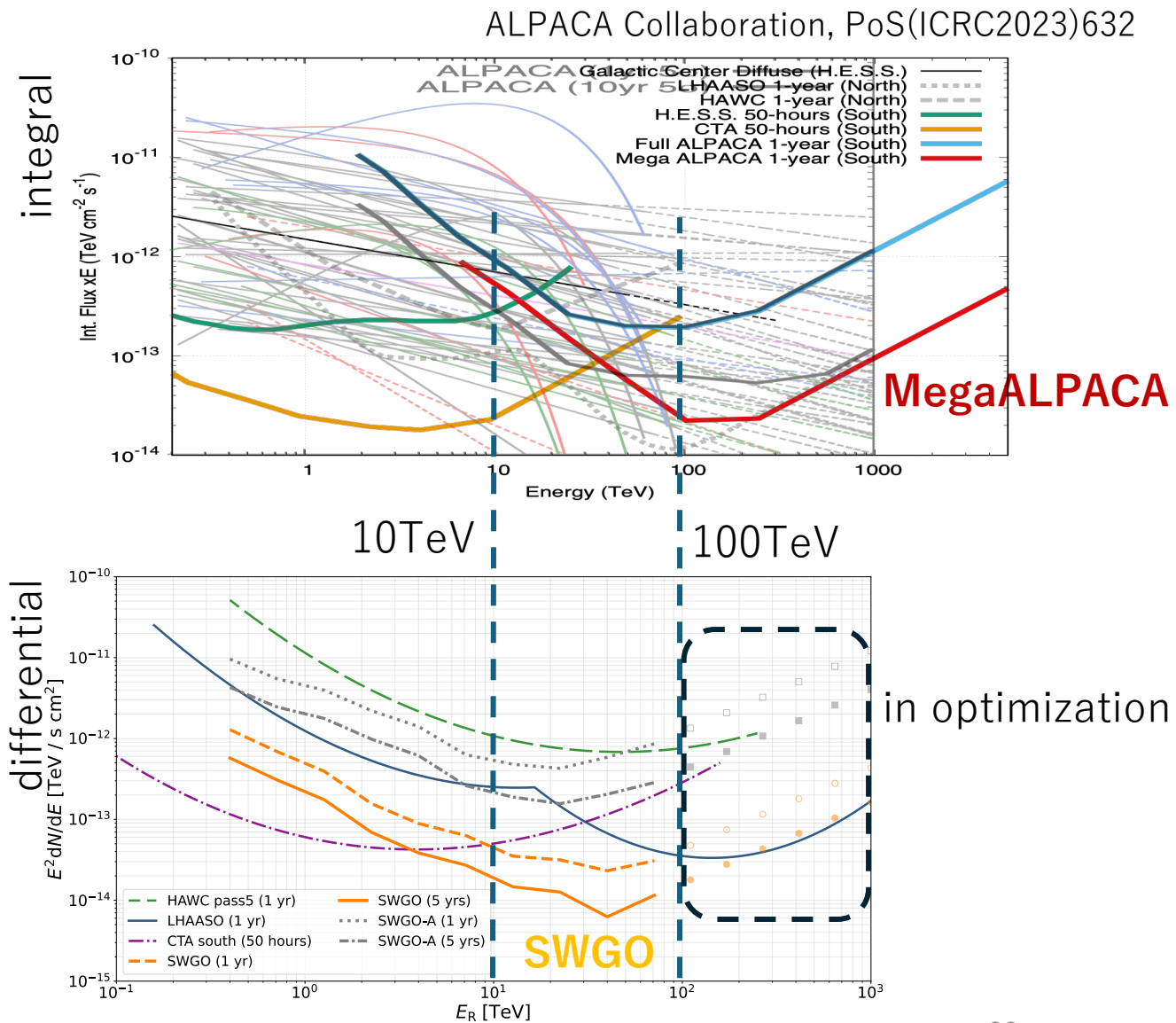




Mega ALPACA and SWGO



Lukas Nellen, UHECR2024



SWGO Collaboration, arXiv:2506.01786