令和3年度東京大学宇宙線研共同利用研究成果発表会

ボリビア・チャカルタヤ山宇宙線観測所における 高エネルギーγ線・宇宙線観測のための 空気シャワー実験

日本大学　塩見　昌司

2022年1月25日　10:25 - 10:45

令和 3年度ボリビア実験関係
共同利用研究採択課題一覧

F20 ボリビア・チャカルタヤ山宇宙線観測所における高エネルギーγ線・宇宙線観測のための空気シャワー実験（継続）
(常定芳基　大阪市立大学大学院理学研究科)

F21 アンデス高原における雷雲からの高エネルギー放射線の研究（継続）
(日比野欣也　神奈川大学工学部物理学教室)

F22 南半球で観測する宇宙線中の太陽の影を用いた太陽磁場の研究（継続）
(川田和正　東京大学宇宙線研究所)

F23 ボリビア・チャカルタヤ山宇宙線観測所における高エネルギー宇宙線異方性の研究（継続）
(佐古崇志　東京大学宇宙線研究所)

ボリビア実験関係共同利用研究
経費執行状況

研究費：　申請額 421.8万円　→　配分額 176.5万円

チャカルタヤ観測所運営分担金や

ALPACA(half)準備に使用。

旅費：　申請額 558.2万円　→　配分額 194万円

宇宙線研での国内研究打ち合わせに使用。

剰余は繰越予定

ご支援、どうもありがとうございます！

Activity in 2021

- **International conferences**

  36th International Cosmic Ray Conference（Berlin）, 7/15-22, online　　3 talks

  − Current status of ALPACA for exploring sub-PeV gamma-ray sky in Bolivia　ID777

  − A simulation study on the performance of the ALPAQUITA experiment　ID857

  − Half ALPACA and its sensitivity to sub-PeV gamma rays from the Galactic Center　ID947

- **Domestic conferences/meetings**

  JPS, 9/14-17, online　　2 talks

  − ALPACA実験22：Half ALPACA実験の性能評価シミュレーション2

  − ALPACA実験23：ALPAQUITA実験の性能評価シミュレーション7

  第一回CRCタウンミーティング, 8/10, online　　1 talk

Activity in 2022

- **Domestic conferences**

  ISEE合同研究集会「太陽地球環境と宇宙線モジュレーション」、「惑星間空間プラズマにおける波動現象」、及び太陽圏・宇宙線関連の共同研究成果報告会, 3/1-2　　1 talk

  JPS, 3/15-19,　　4 talks

  − ALPACA実験24：建設状況と2022年の計画

  − ALPACA実験25：ALPACA実験の性能評価シミュレーション

  − ALPACA実験26：ガンマ線強度推定におけるハドロン相互作用モデルによる不確定性

  − ALPACA実験27：光電子増倍管のダイナミックレンジの拡張

- **Refereed papers**

  Detectability of southern gamma-ray sources beyond 100 TeV with ALPAQUITA, the prototype experiment of ALPACA, Experimental Astronomy, 9/25, Published online

The ALPACA Collaboration

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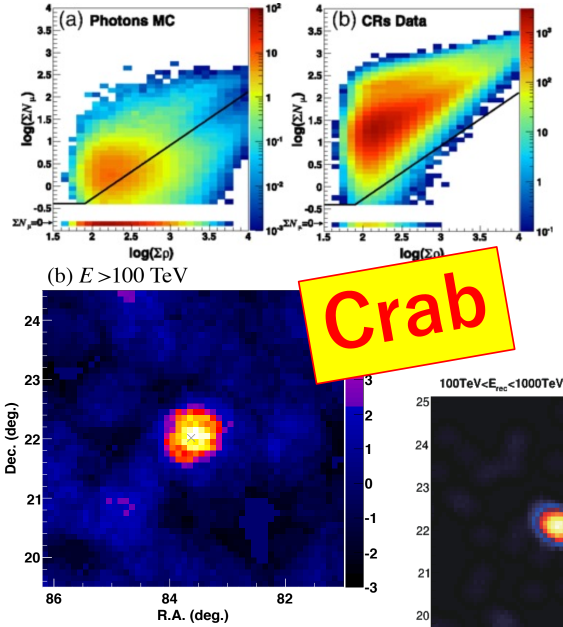
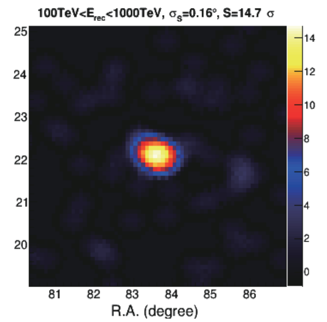
JAEA
H. Tsuchiya

今年度、メキシコのグアダラハラ大から客員教授としてグループメンバーであるエデュアルドさんが来所。（グループ会議の様子）

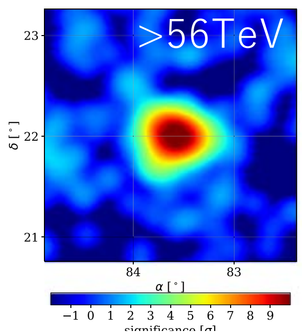
Dawn of sub-PeV gamma-ray astronomy



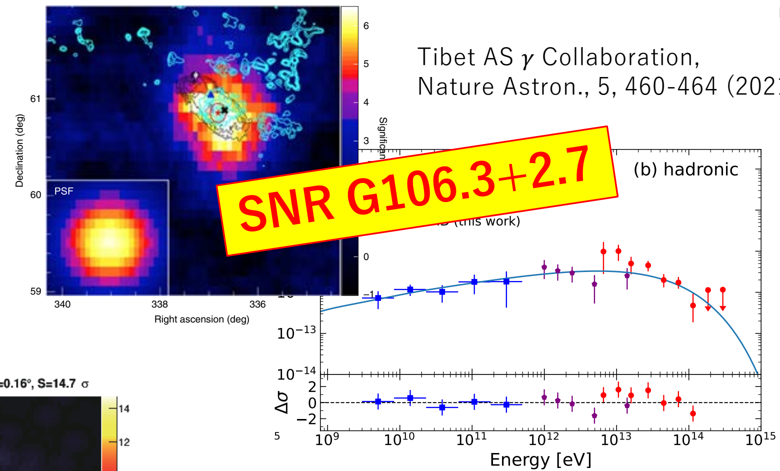
Tibet AS γ Collaboration,
PRL 123, 051101 (2019)



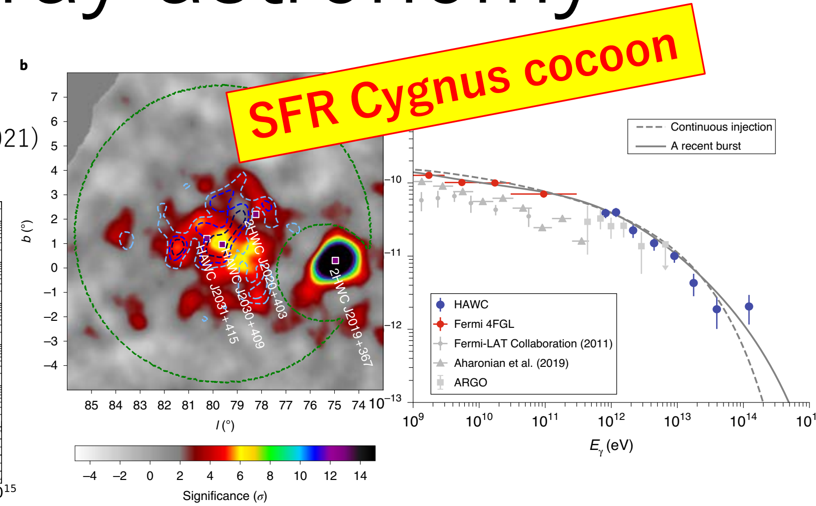
LHAASO Collaboration,
Chin. Phys. C45, 023002 (2021)



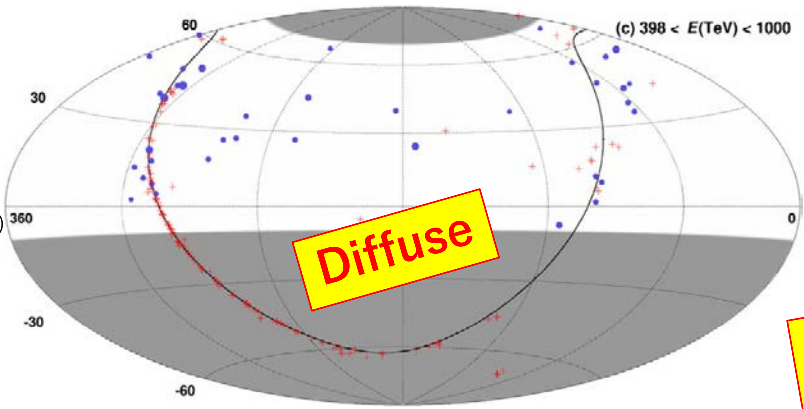
HAWC Collaboration,
ApJ 881:134 (2019)



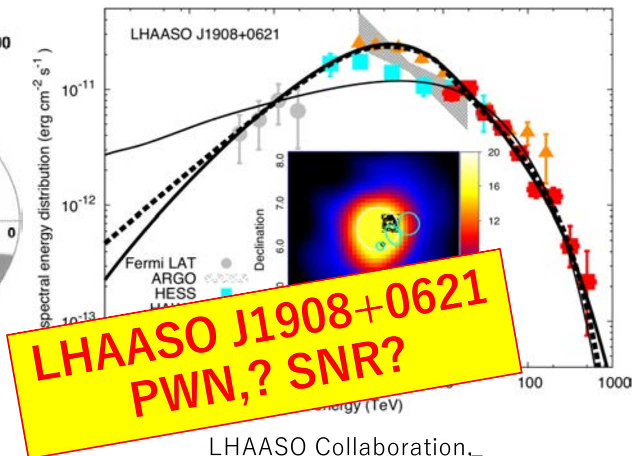
Tibet AS γ Collaboration,
Nature Astron., 5, 460-464 (2021)



HAWC Collaboration, Nature Astron., 5, 465-471 (2021)



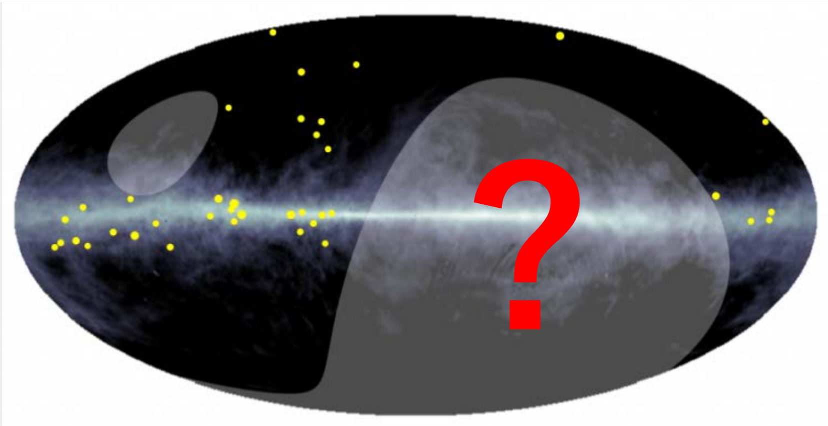
Tibet AS γ Collaboration, PRL 126, 141101 (2021)



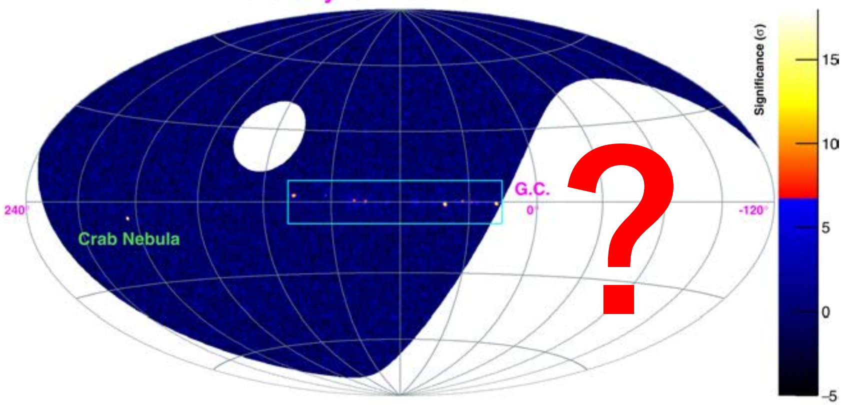
LHAASO Collaboration,
Nature, 594, 33-36 (2021)

Let us go to south!

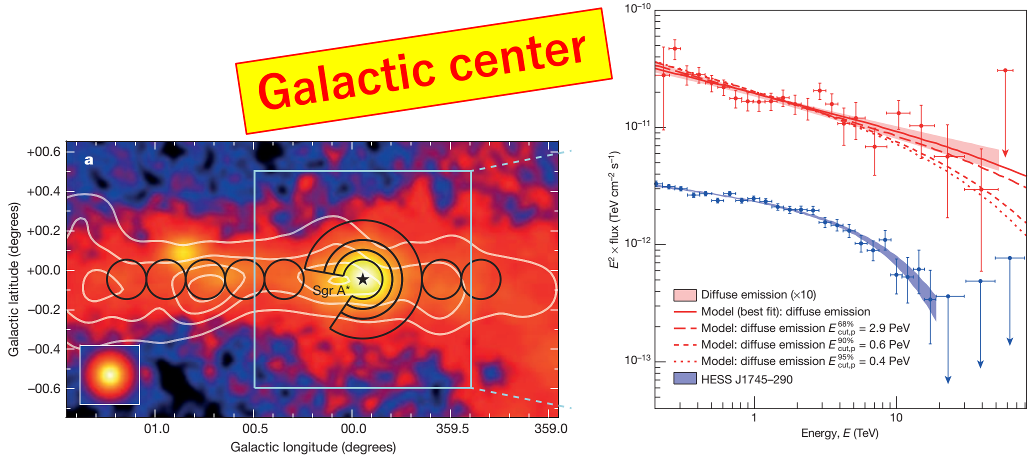
Tibet ASγ >100TeV diffuse γ



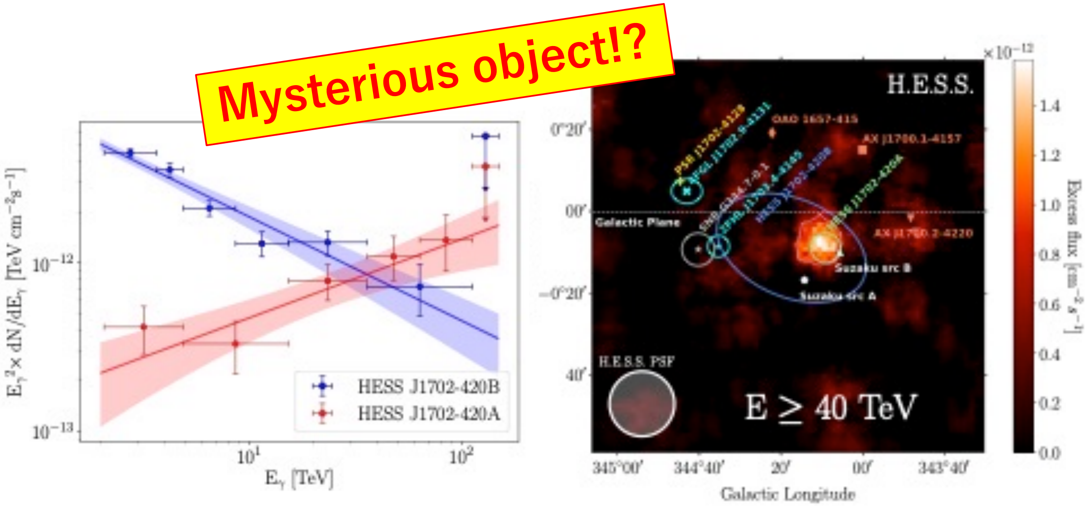
LHAASO Sky @ >100 TeV



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



HESS Collaboration, Nature, 531, 476-479 (2016)



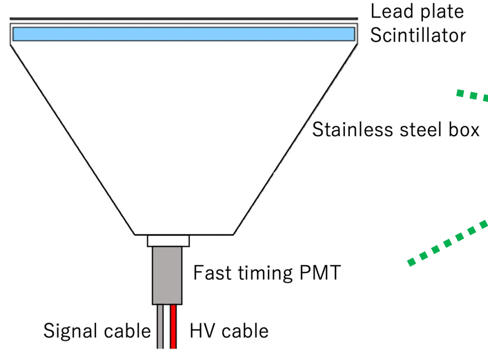
HESS Collaboration, arXiv:2106.06405 (2021)

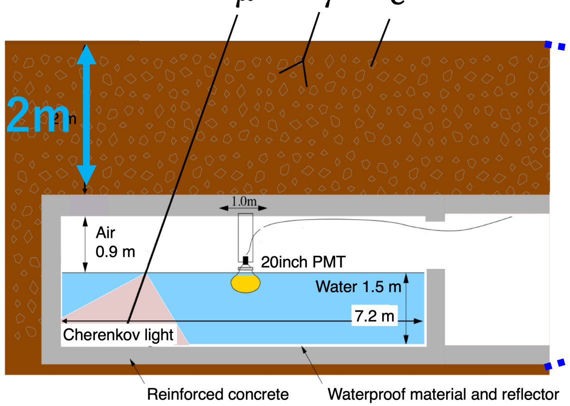

ALPACA
(Andes Large area PArticle detector
for Cosmic ray physics and Astronomy)
Mt. Chacaltaya, Bolivia
UMSA CR Observatory
5200 m a.s.l.
ALPACA site
4740 m a.s.l.
4,740 m above sea level
(16° 23′ S, 68° 08′ W)
4600m
4400m
La Paz
PERU
BOLIVIA
BRAZIL
PARAGUAY
CHILE
ARGENTINA
URUGUAY
South Pacific Ocean
South Atlantic Ocean
Google

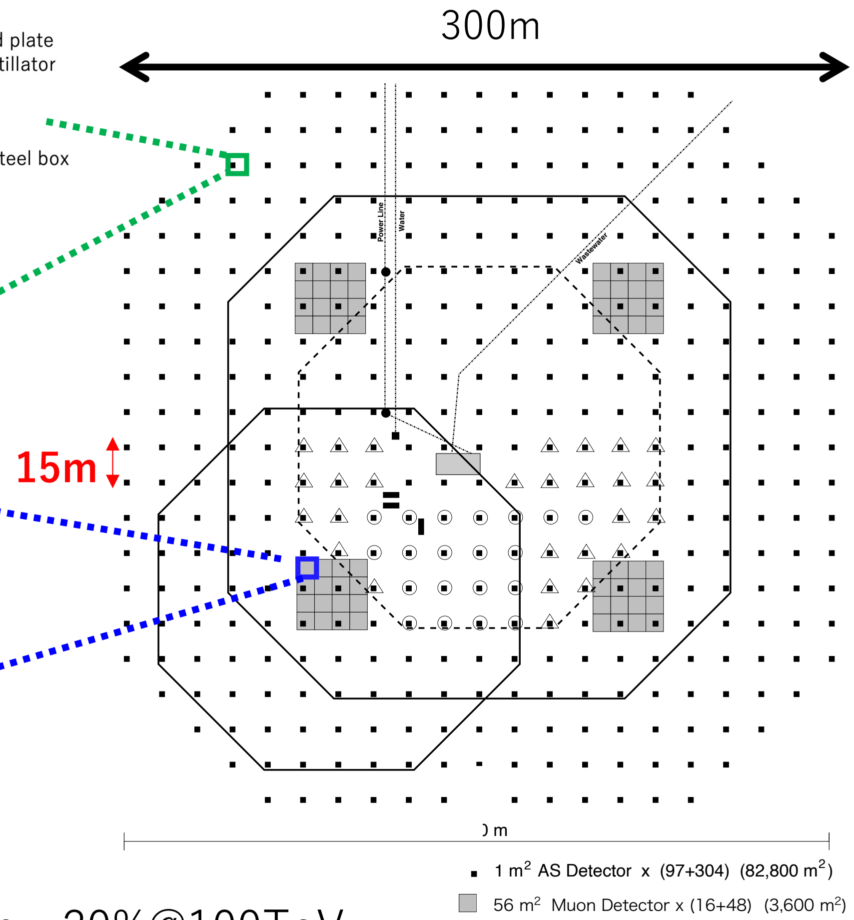
Original ALPACA design

1. **Array coverage 82,800m^2**
   = 401 x 1m^2 plastic scintillators

2. **Underground water Cherenkov muon detector (MD) 3600m^2**
   Soil over 2m (~16X_0)
   = 56m^2 with 20”ϕ PMT x 64 cells

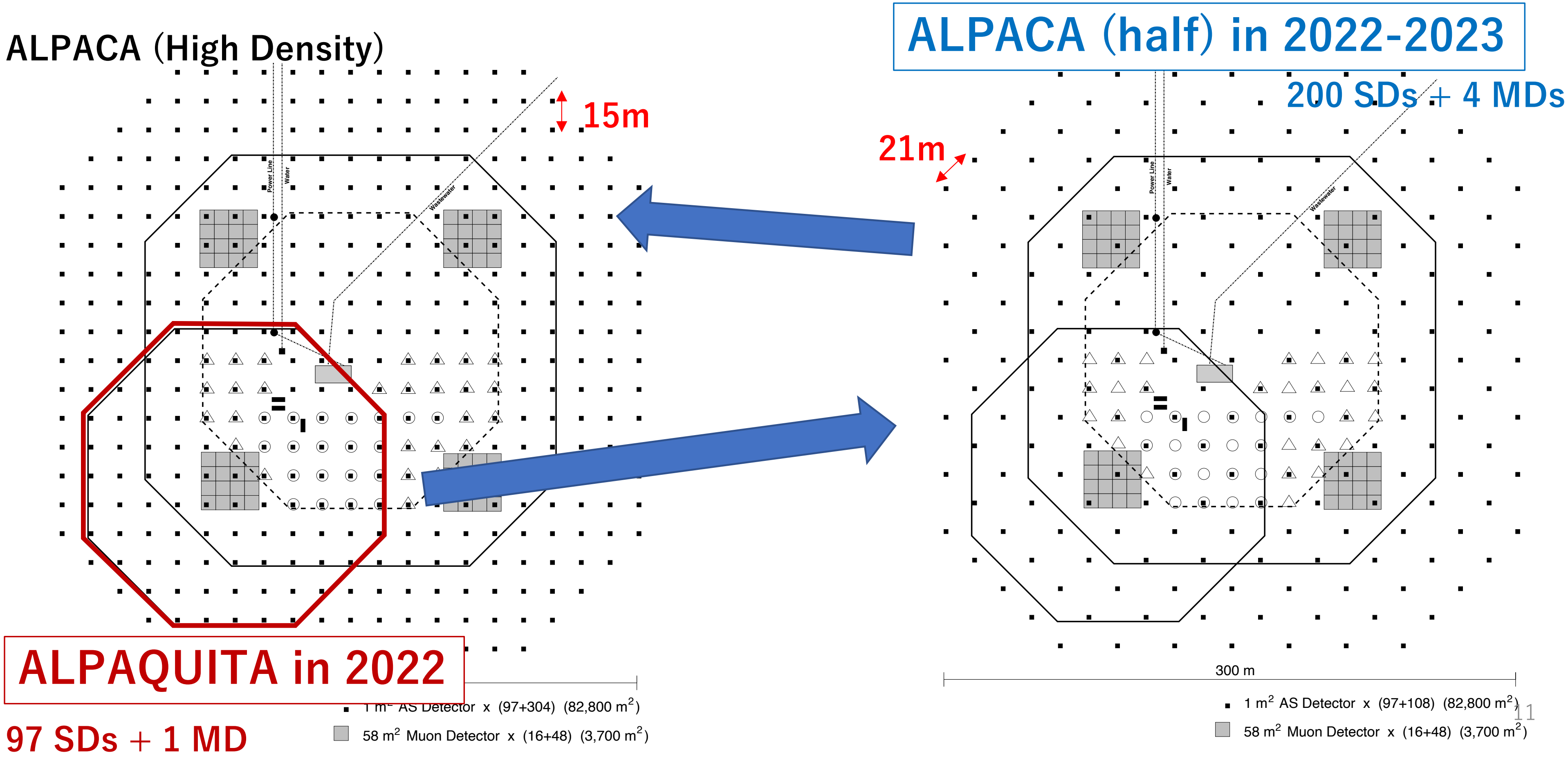






- ✓ Cosmic-ray BG rejection power >99.9% @100TeV.
- ✓ Angular resolution ~0.2° @100TeV, Energy resolution ~20%@100TeV
- ✓ 100% duty cycle, FOV θ_{zen}<40° (well studied), θ_{zen}<60° (in study)

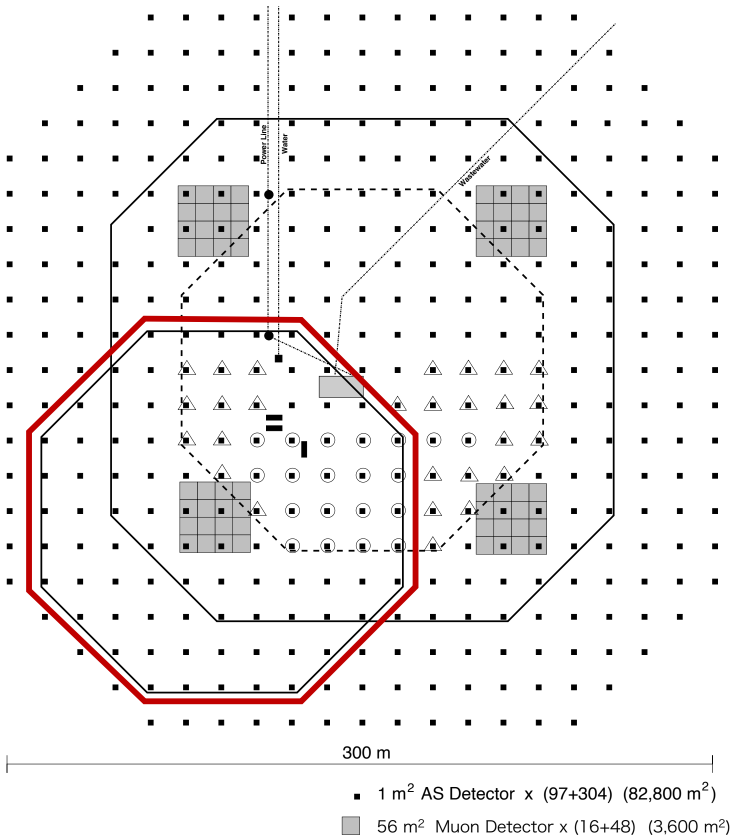
ALPACA staging

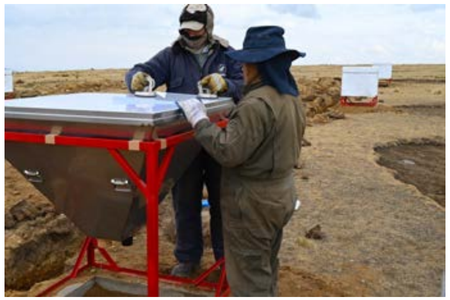


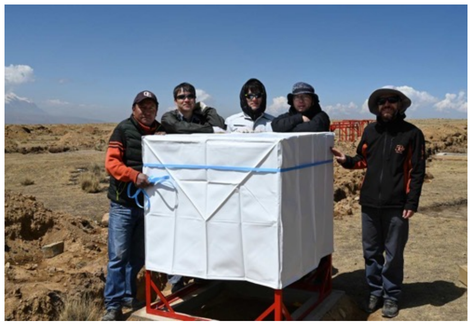
ALPAQUITA
(little ALPACA)

- Prototype array of 25% ALPACA area coverage
  - 97 surface detectors
  - 1 MD
- Targets
  - Infrastructure establishment
  - A few bright >100TeV sources
  - CR anisotropy

MD 設計済、まもなく工事開始

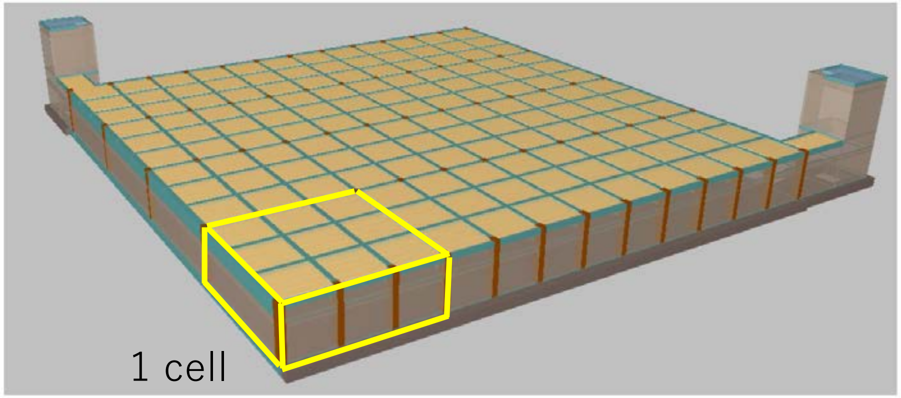


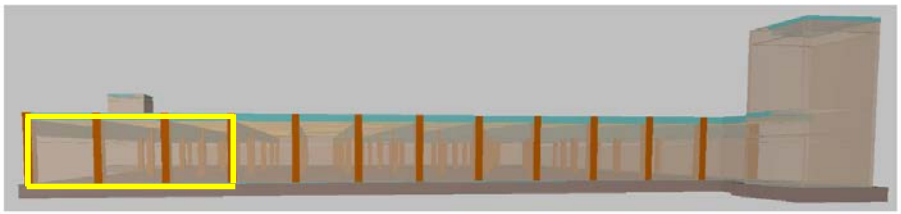


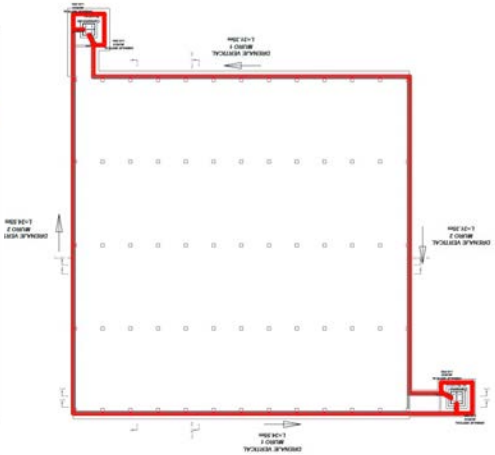


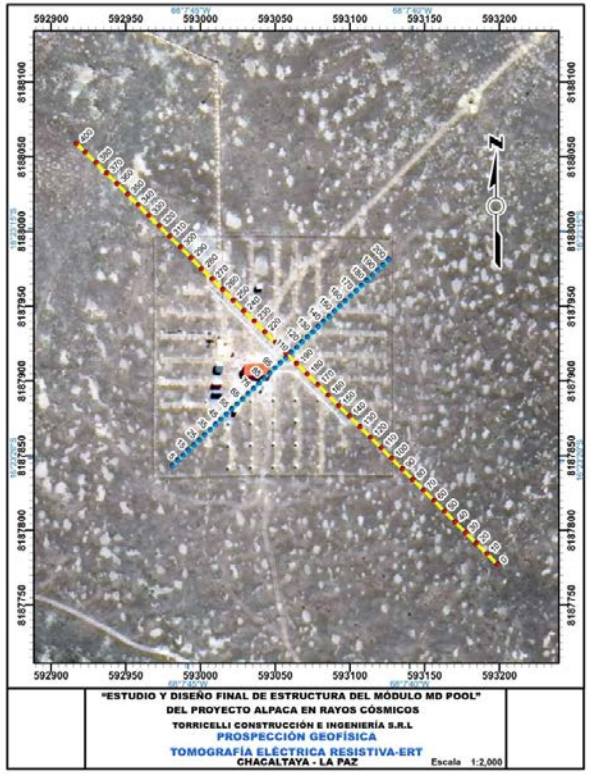
MD design (1 MD = 4 x 4 cells)

地質調査　⇒　問題無し







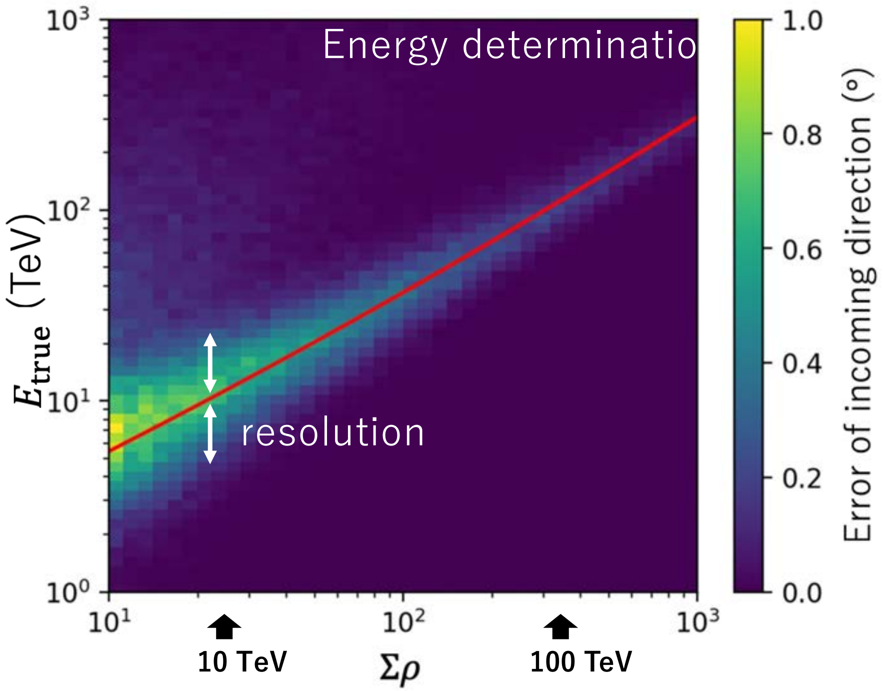


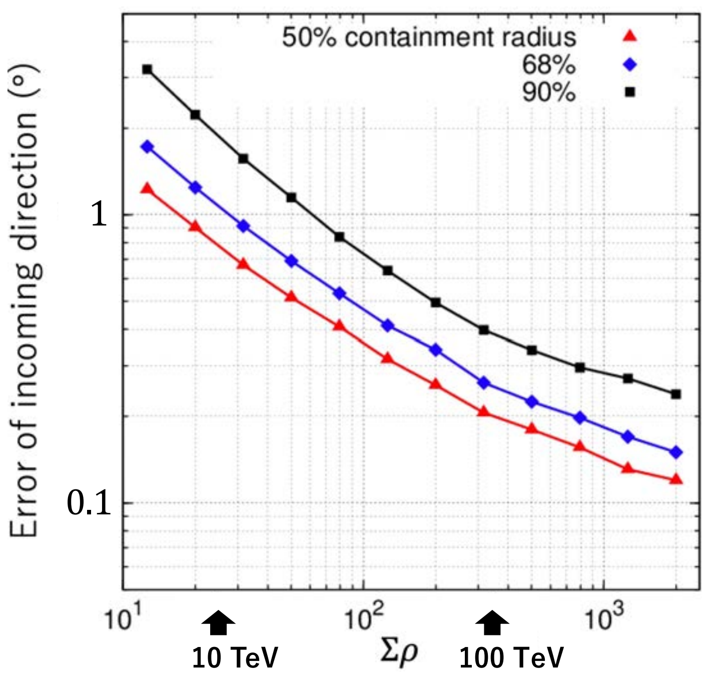
ALPAQUITA AS Array Performance for Gamma Rays

Target events: Gamma rays w/ $\Gamma = -2.5$ & $\theta_{\mathrm{true}} < 40°$

Trigger efficiency*	100% ≥20 TeV
Energy resolution	$+27\%$ -21% @ 100 TeV
Angular resolution	$\simeq 0.2°$ @ 100 TeV (50% containment)

*Efficiency for events w/ true core positions inside the AS array



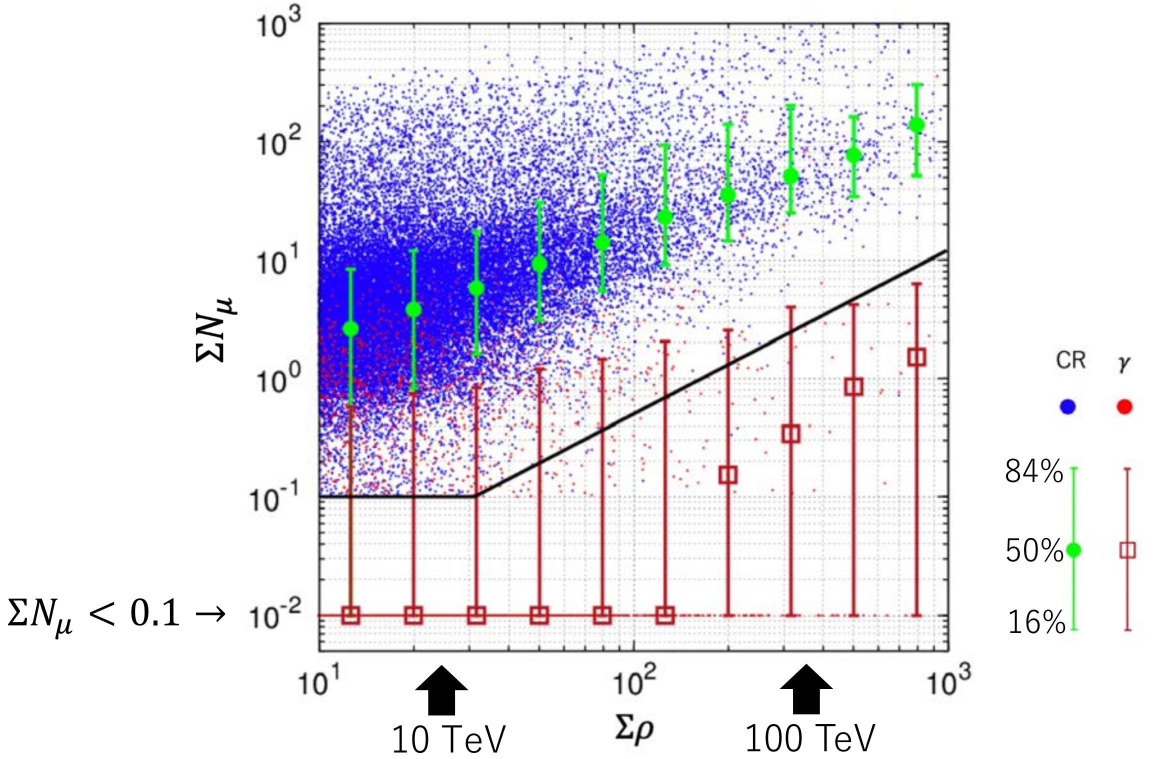


$\Sigma\rho$: Total density of particles recorded the AS array

Muon Selection Criterion

To maximize the detection significance of signal γ rays

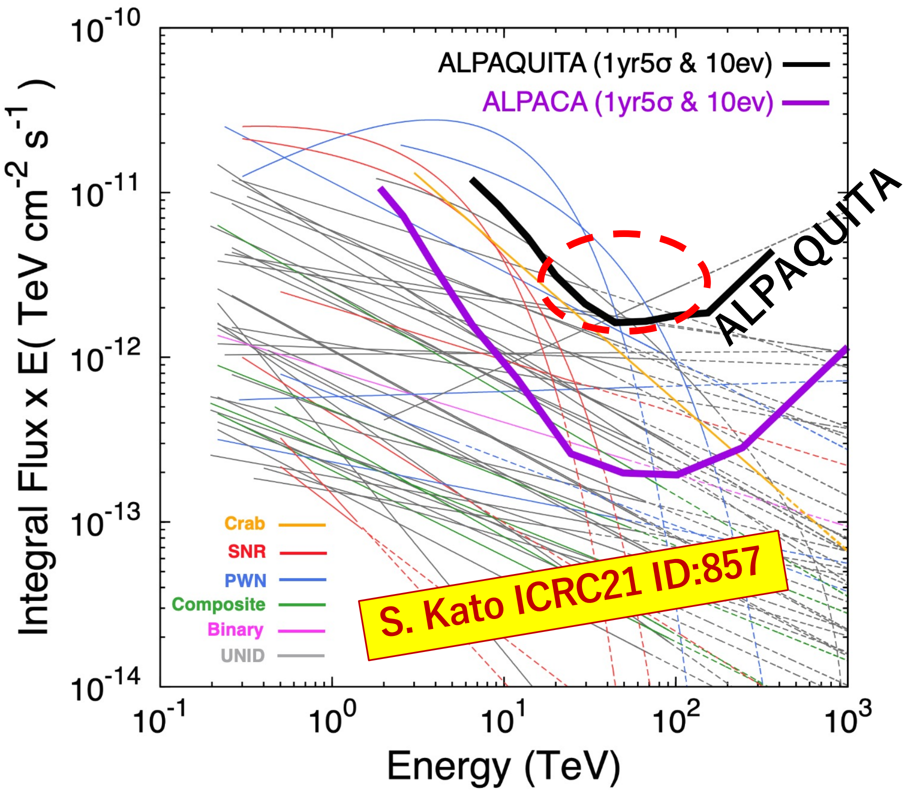
ΣN_μ : Total number of muons recorded with the muon detector

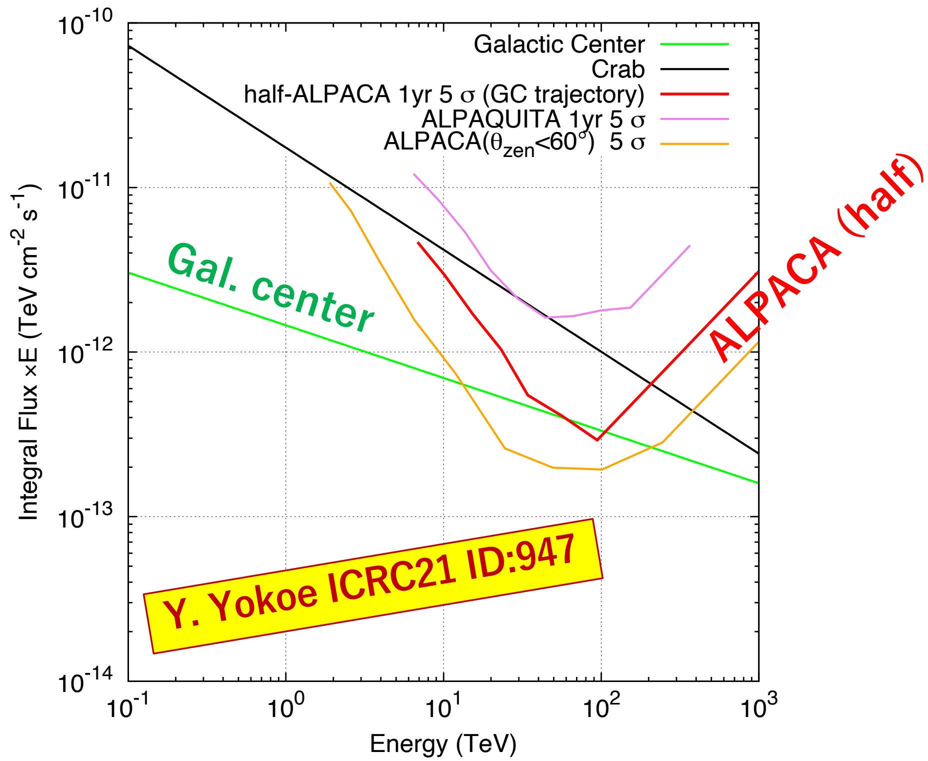


Survival ratio of gamma rays $\simeq 80$ % @100 TeV

Rejection power for BGCRs $\simeq 99.9$% @100 TeV γ. eq.

Sensitivities of ALPAQUITA, ALPACA (half) and ALPACA (HD)

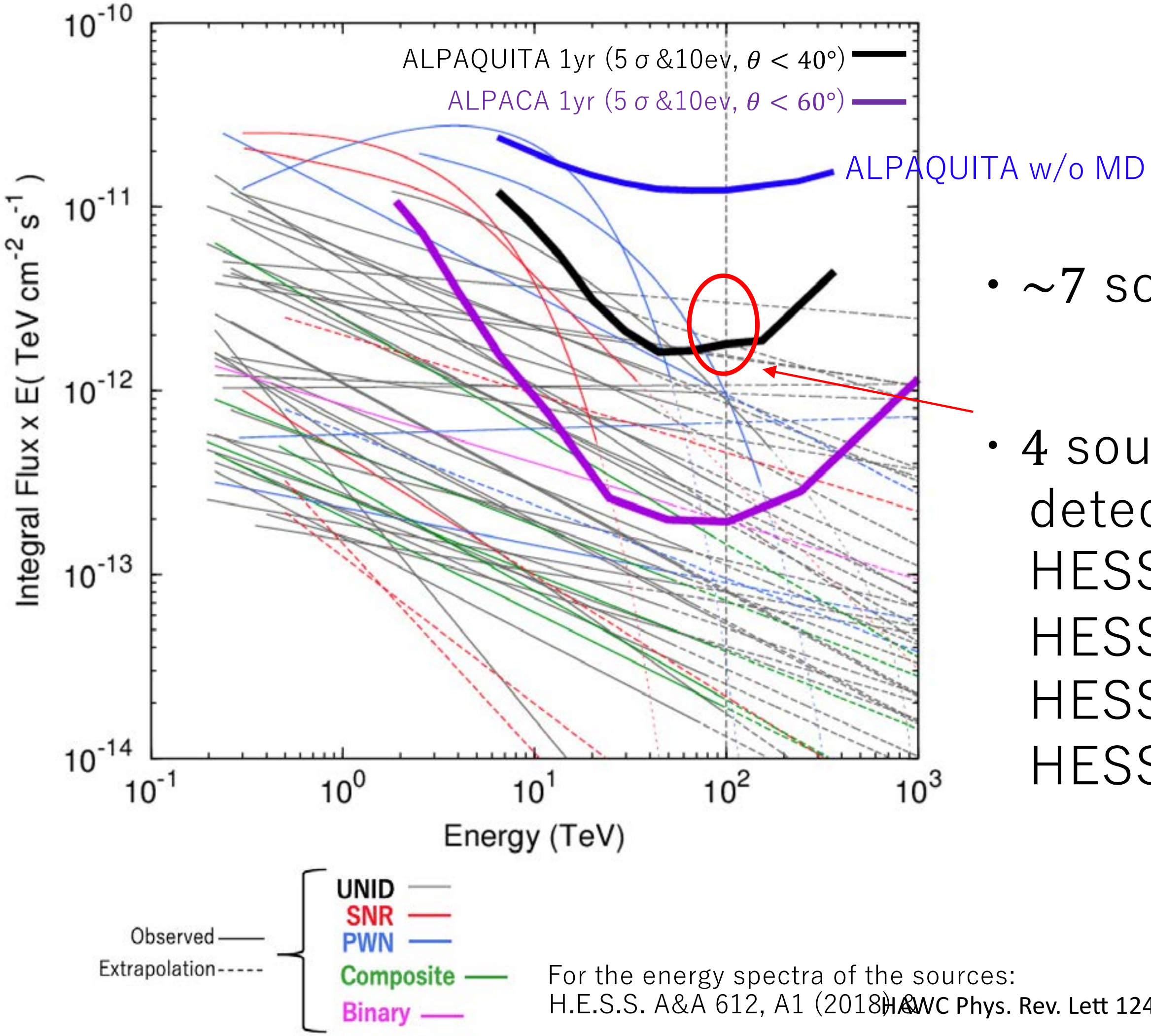




- ALPAQUITA can detect some sources in 1 year
- ALPACA (half) can touch the Galactic center flux in 1 year

Sensitivity to VHE Gamma-Ray Sources

Sensitivity curves in 1yr5 σ

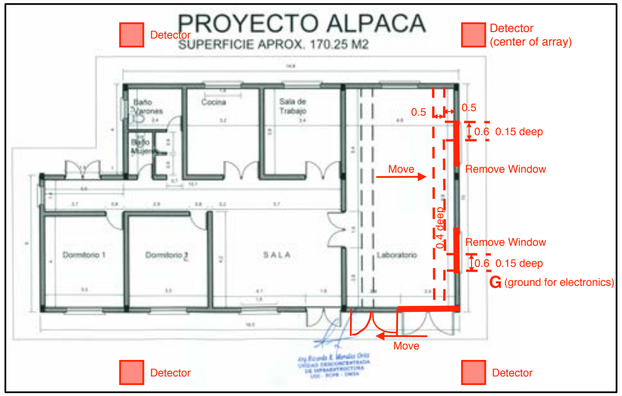


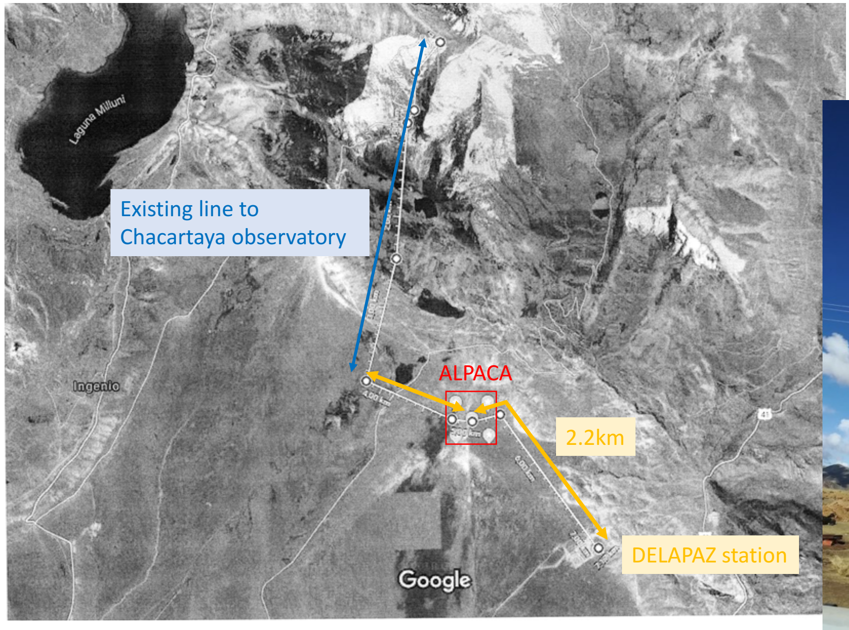
- ~7 sources in 1-yr obs. above 10 TeV
- 4 sources will be detected above 100 TeV !
  HESS J1616-508
  HESS J1702-420
  HESS J1708-443
  HESS J1843-033

For the energy spectra of the sources:
H.E.S.S. A&A 612, A1 (2018) & HAWC Phys. Rev. Lett 124, 021102 (2020)

ALPAQUITA & infrastructure

- Central electronics hut
- Perimeters
- Powerline（branch from the substation-Chacaltaya observatory line）
- Cable drains
- Lightning rods
- Long distance Wifi
- Water system





Laguna Milluni
Existing line to
Chacartaya observatory
Ingenio
ALPACA
2.2km
DELAPAZ station
Google

2021年10月

Summary

- ✓ **Sub-PeV gamma-ray astronomy is crucial to identify the PeV particle accelerators, PeVatrons**
  - Recent successes by Tibet ASγ, HAWC and LHAASO open a sub-PeV window in the northern sky
  - New experiment in the southern hemisphere is desired
  - Rich targets in south thanks to HESS up to 10TeV
- ✓ **ALPACA explores southern sky in Bolivia first time with the technic established by Tibet ASγ**
- ✓ **ALPAQUITA will start operation in 2022**
- ✓ **ALPACA (half) will start operation in 2022-2023, and eventually upgraded to ALPACA (HD)**
- ✓ **Mega ALPACA is discussed as a future plan to explore PeV energy range**

引き続き、ご支援のほどよろしくお願いいたします。