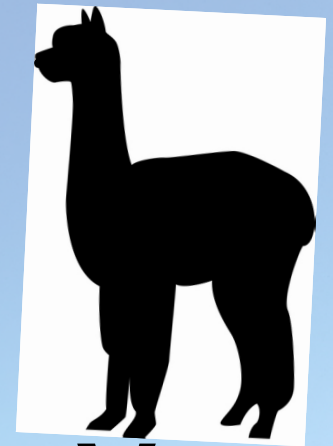


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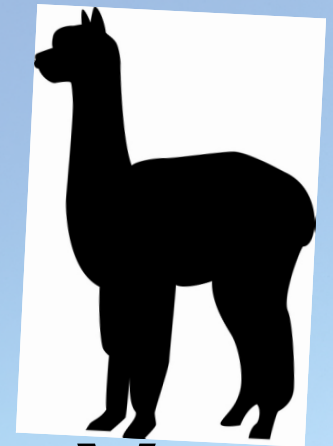
A new air shower array experiment to explore 100TeV gamma-ray sky in Bolivia



Takashi Sako (University of Tokyo)
for the ALPACA Collaboration

ALPACA :

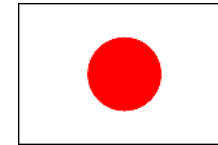
A new air shower array experiment to explore 100TeV gamma-ray sky in Bolivia



Search for P_{TeV} Particle accelerators

Takashi Sako (University of Tokyo)
for the ALPACA Collaboration

The ALPACA Collaboration



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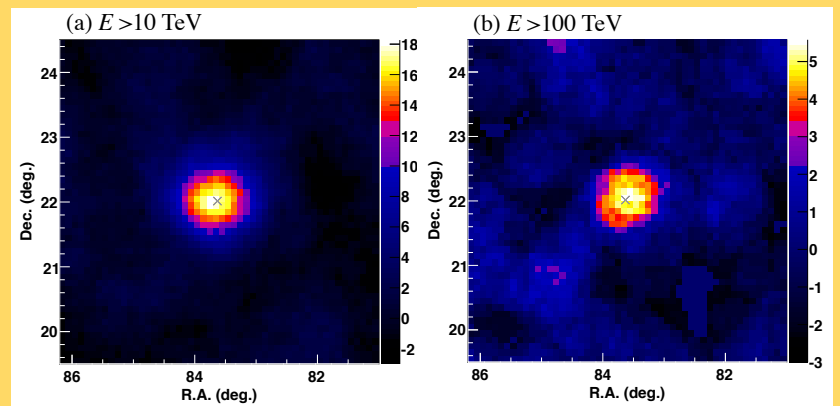
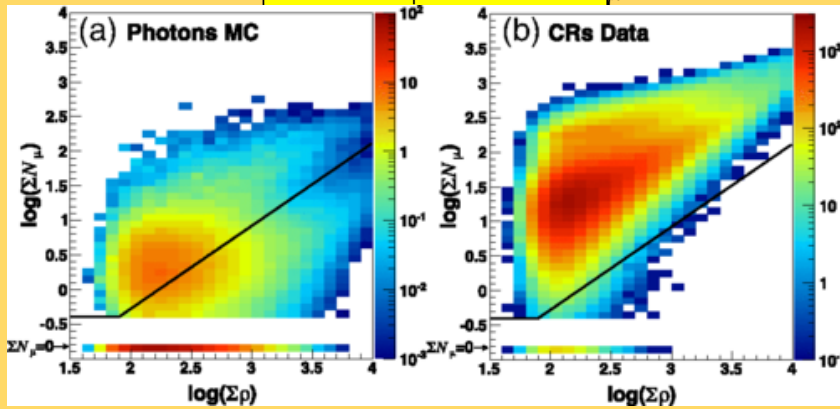
Key Lab of Particle Astroparticle Physics, IHEP, CAS, China

Yoshiaki NAKAMURA

100TeV γ fever in 2019

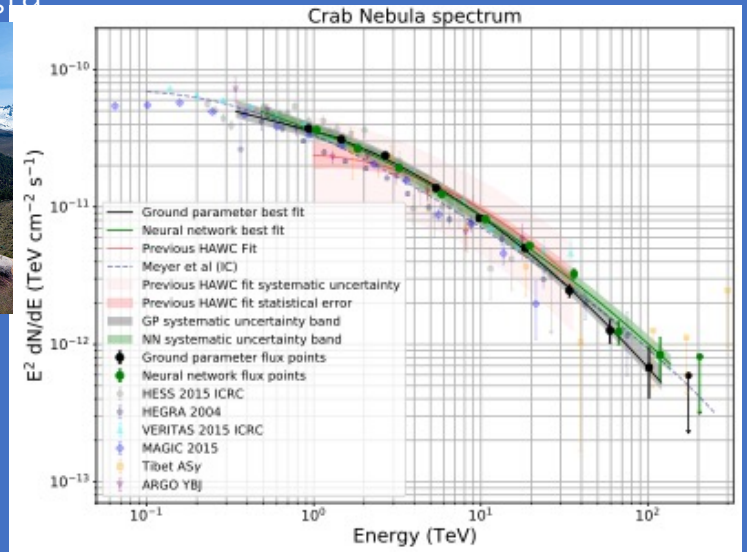
Tibet AS γ in Tibet, China

$N_{\text{shower particle}}$ vs. N_{μ}

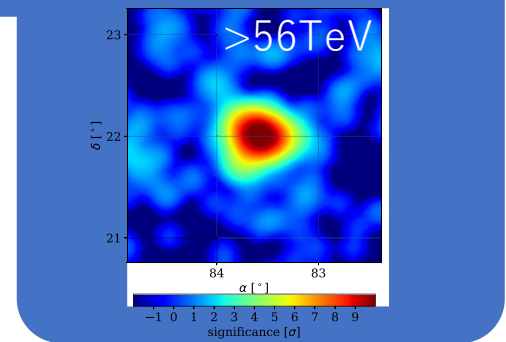
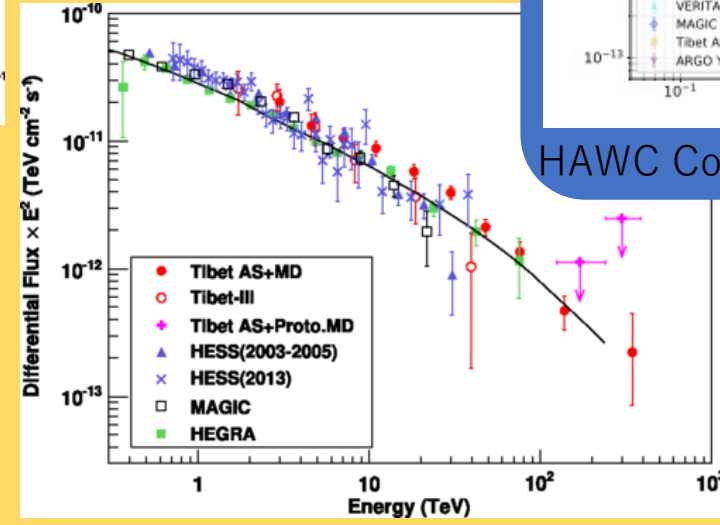


Tibet AS γ Collaboration, PRL 123, 051101 (2019)

HAWC in Sierra Negra

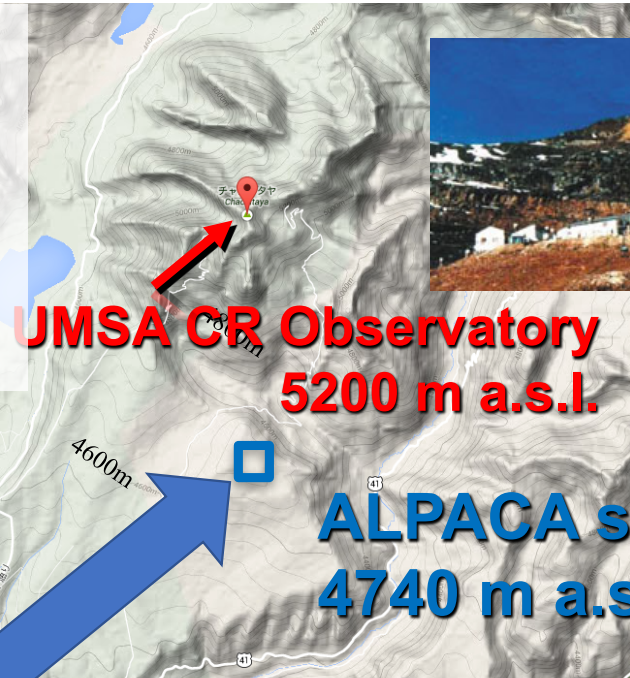


HAWC Collaboration, ApJ 881:134 (2019)



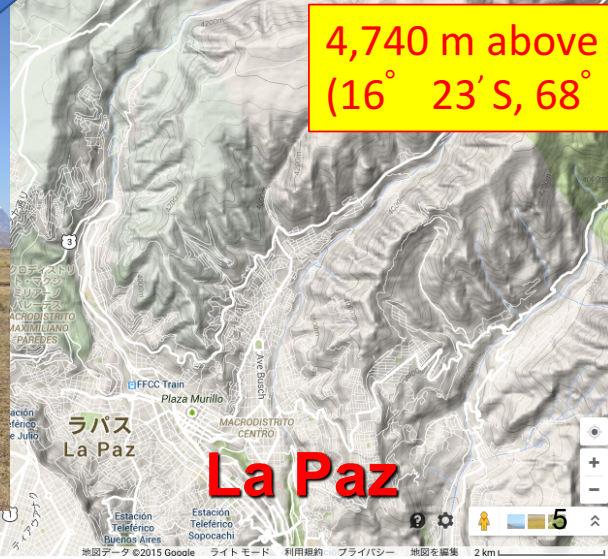
ALPACA

(Andes Large area Particle detector
for Cosmic ray physics and Astronomy)
Mt. Chacaltaya, Bolivia

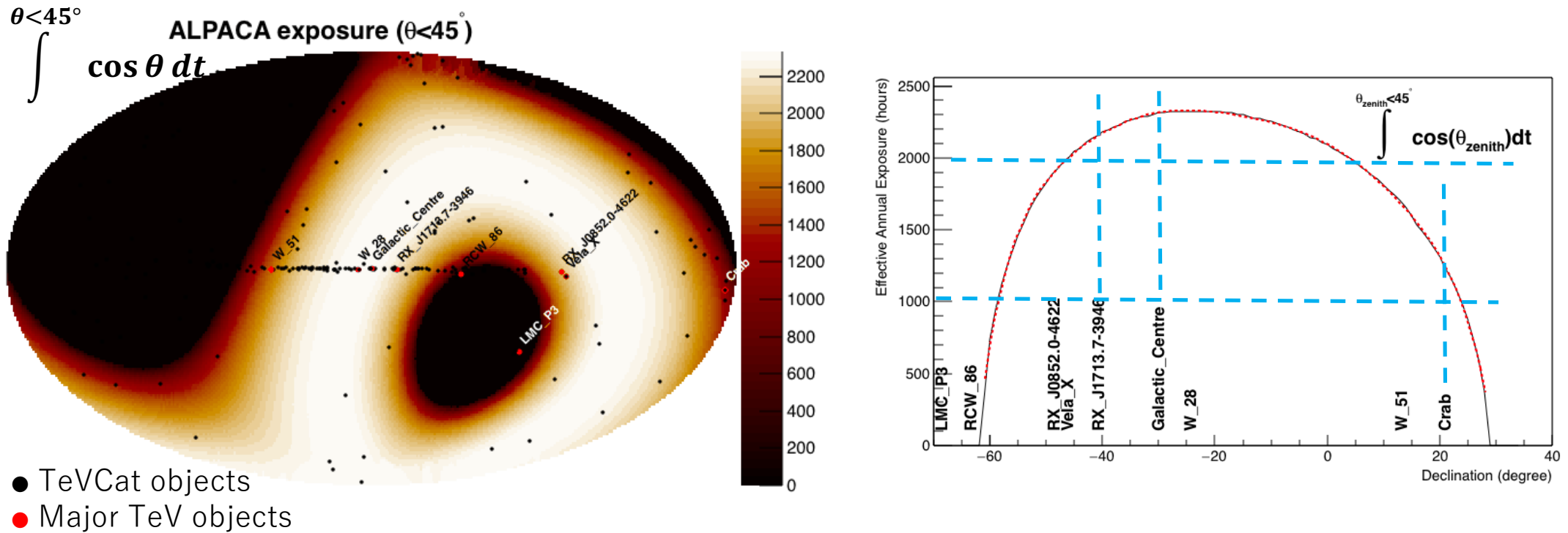


ALPACA site
4740 m a.s.l.

4,740 m above sea level
(16° 23' S, 68° 08' W)

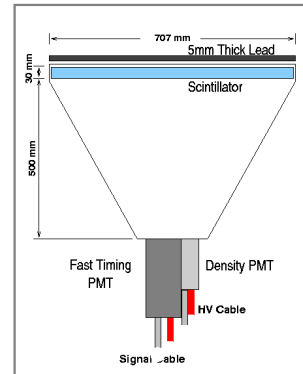
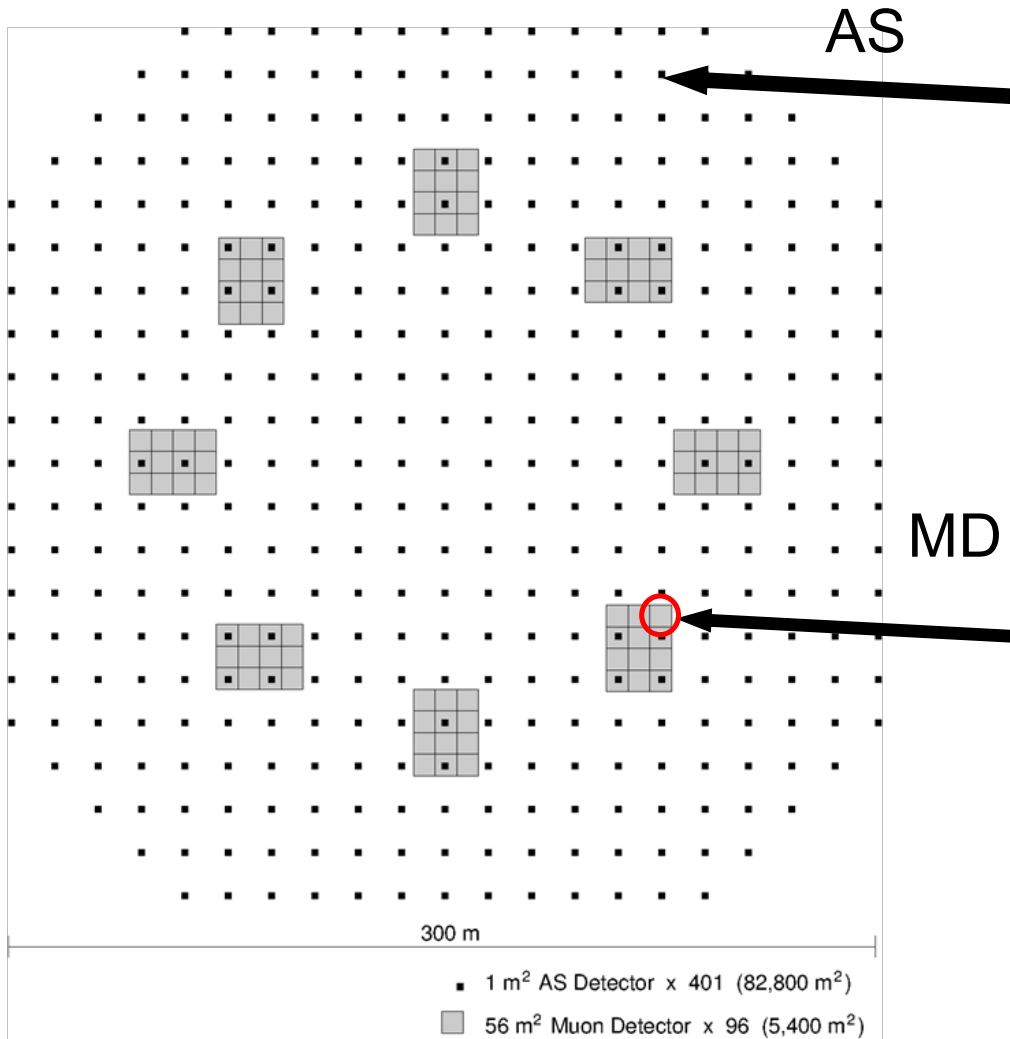


ALPACA exposure (hours/year)

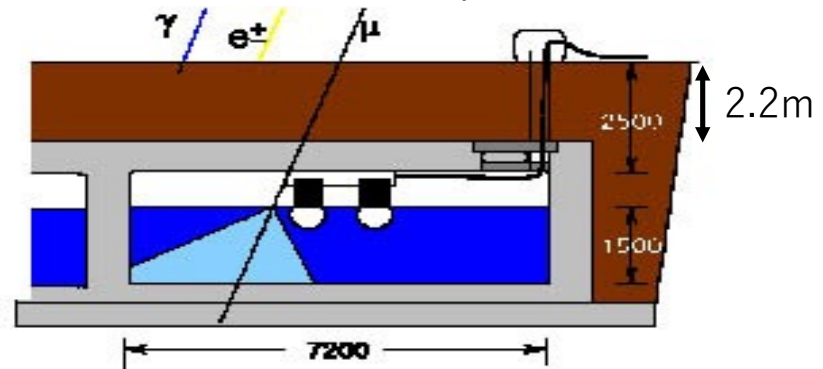


- Observation time (hour/year) with zenith angle $\theta < 45^\circ$
- > 2000 hours/year observations for major objects including Galactic center

Array layout of ALPACA



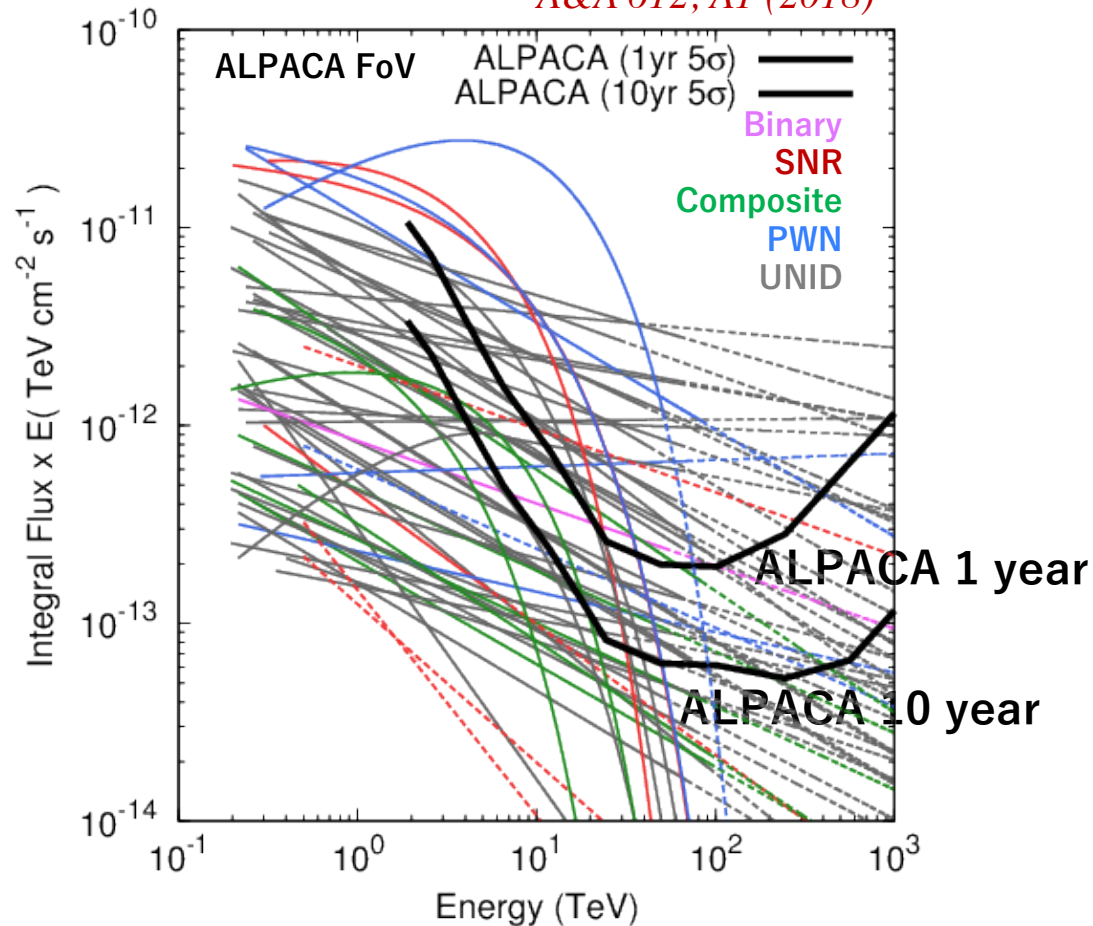
- 400 x 1m² plastic scintillators
- (7mx8m unit) x 12 x 8 (TBD) underground water Cherenkov muon detectors (5400m²)
- 2.2m underground (1GeV muon threshold)



Angular resolution : 0.2° @ 100TeV
 Energy resolution : 20% @ 100TeV

ALPACA sensitivity to the H.E.S.S. sources

A&A 612, A1 (2018)



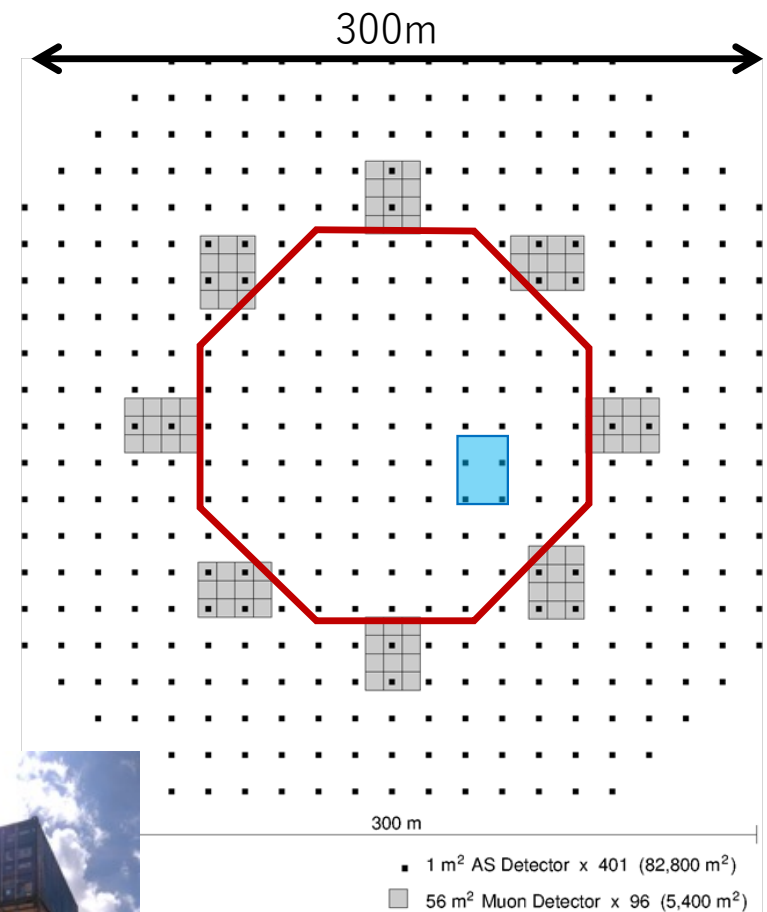
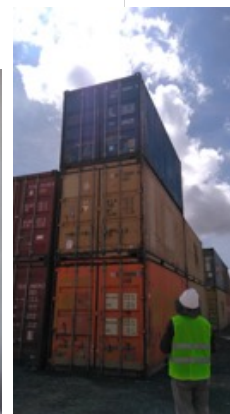
- Solid lines : observed results by H.E.S.S.
- Dashed lines : extrapolation from the H.E.S.S. results
- Many 10TeV objects with hard spectra
→ Possible PeVatrons
- Variety of categories, not only SNRs
- Even no-detection determines the maximum energy

current status

– ALPAQUITA –

(little ALPACA, ALPACA-chan)

- Prototype array of ALPACA
 - 20% area of full ALPACA with 97 surface detectors
 - 1 underground muon detector (700-1000m²) to be constructed in 2020 (position TBD)
- Purpose
 - Detection of bright gamma-ray sources
 - Cosmic-ray anisotropy in the Southern hemisphere, space weather study



Detector material arrived
at Bolivia early 2019

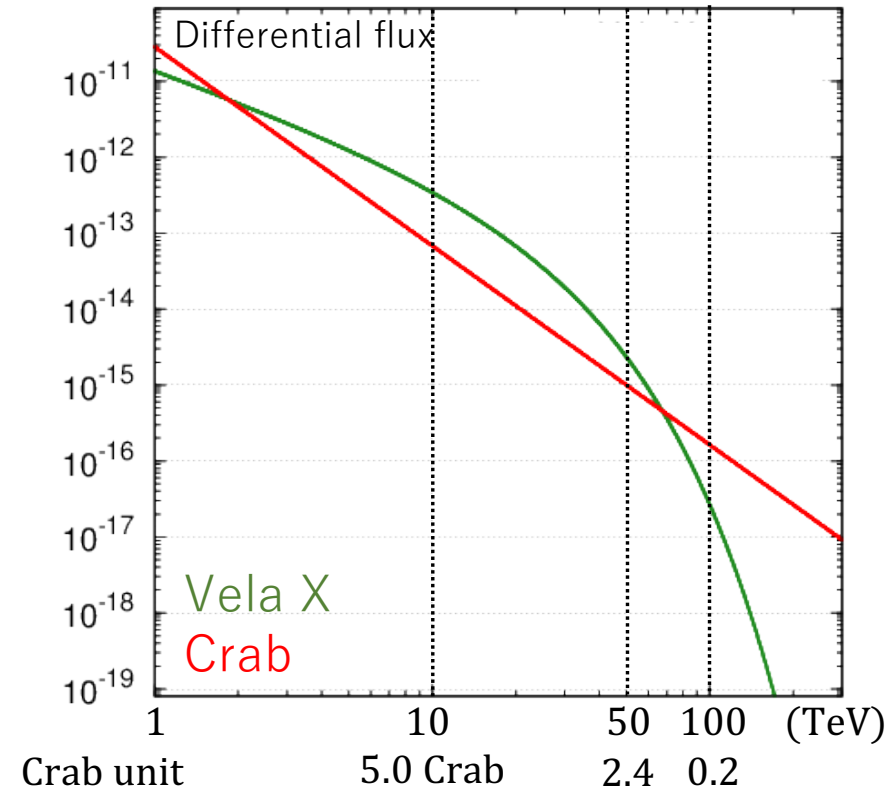
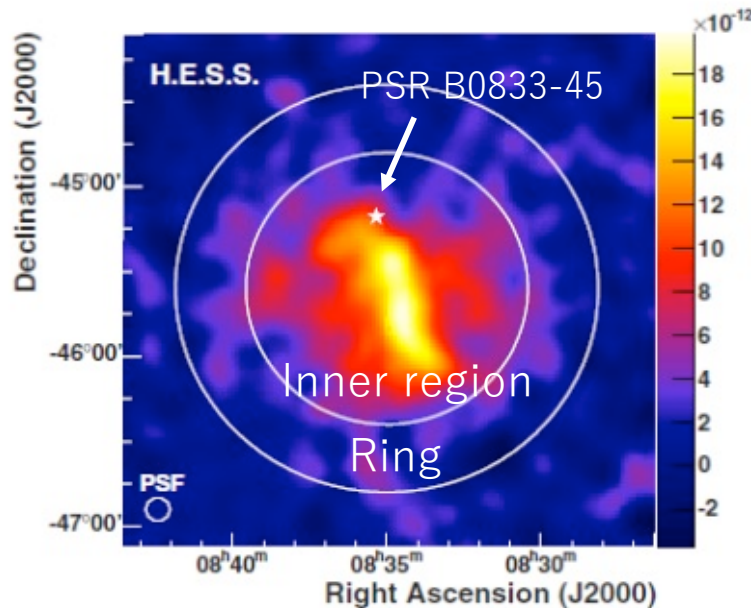
Sensitivity to Vela X ($(\alpha, \delta) = (08^h 35^m 00^s, -45^\circ 36' 00'')$)

Differential flux from inner region + ring :

(*H.E.S.S. A&A 548, A38, 2012*)

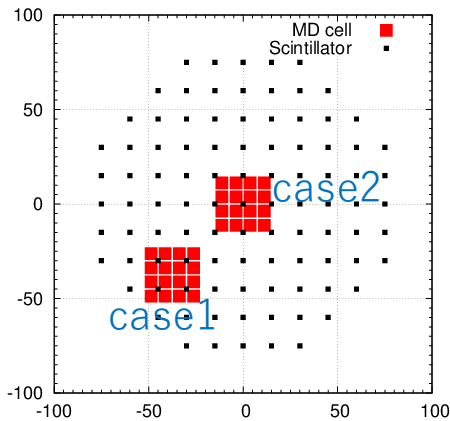
$$dN/dE = N_0 E^{-\Gamma} \exp(-E/E_{cut}) \text{ (TeV}^{-1}\text{cm}^{-2}\text{s}^{-1}\text{)}$$

$$N_0 = 2.1 \times 10^{-11} \text{ (TeV}^{-1}\text{cm}^{-2}\text{s}^{-1}\text{)}, E_{cut} = 14.0 \text{ TeV}, \Gamma = 1.32$$



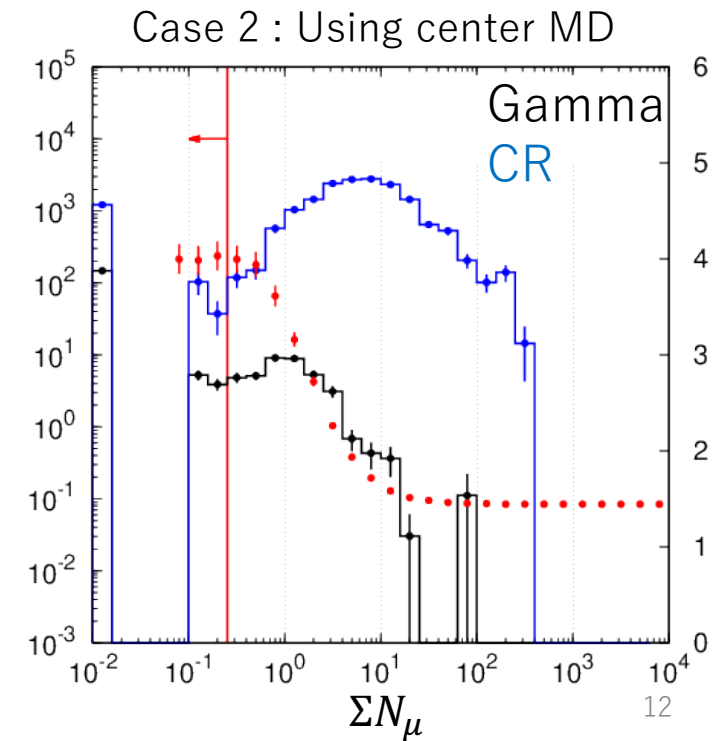
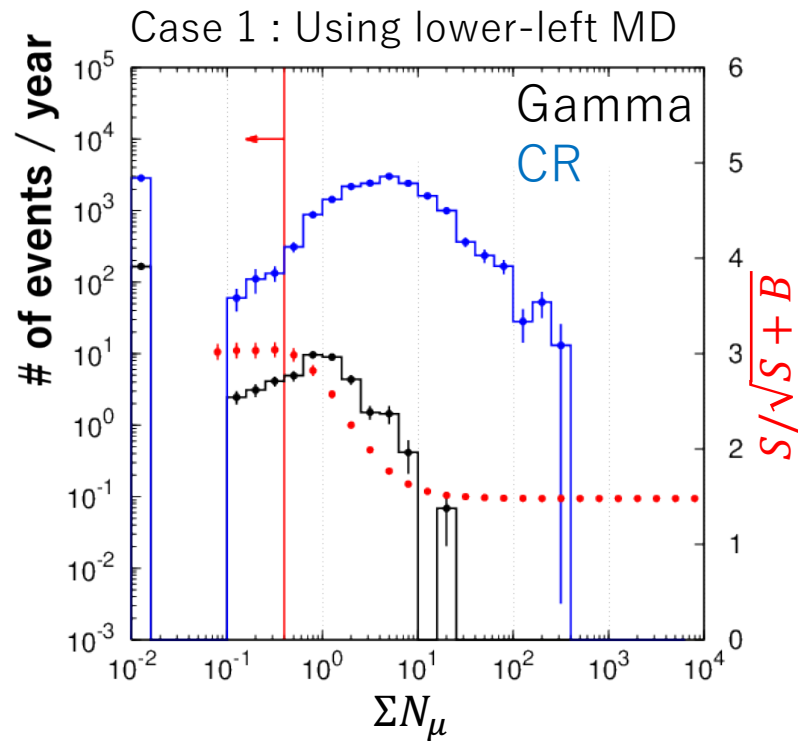
Optimization of MD location (study on going)

- case1 : optimized for full ALPACA array
- case2 : optimized for ALPAQUITA only



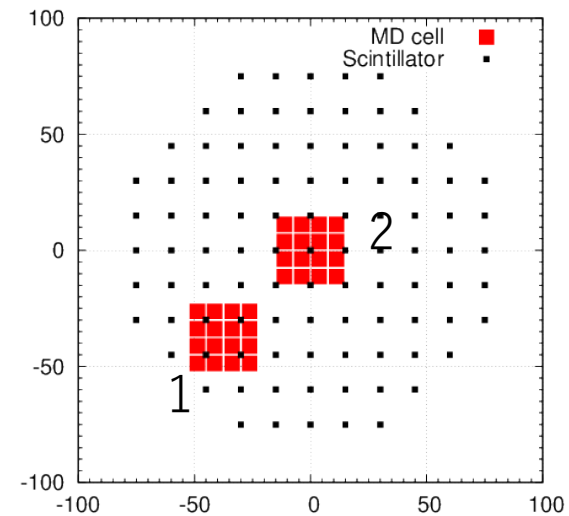
ΣN_μ : Total number of detected muons in one shower event

$\Sigma \rho$: Total number of particles [In $39.8 \leq \Sigma \rho < 63.1$ (~ 12 TeV)]



Bin-by-bin yearly detection significances (Vela X)

	Case 1 : Using lower-left MD	Case 2 : Using center MD
~ 8 TeV ($25.1 \leq \Sigma\rho < 39.8$)	2.52 ± 0.05	3.30 ± 0.08
~ 12 TeV ($39.8 \leq \Sigma\rho < 63.1$)	3.03 ± 0.08	3.98 ± 0.14
~ 18 TeV ($63.1 \leq \Sigma\rho < 100$)	3.83 ± 0.18	4.73 ± 0.28
~ 30 TeV ($100 \leq \Sigma\rho < 158$)	2.81 ± 0.06	3.80 ± 0.09



ALPAQUITA in October 2019



ALPAQUITA in October 2019



- All 97 basements placed
- Assembly of 20 detectors completed
- Cable channels finalized soon
- Assembly of all detectors, cabling, first data taking as soon as possible in 2020
- First muon detector in design, to be constructed in 2020

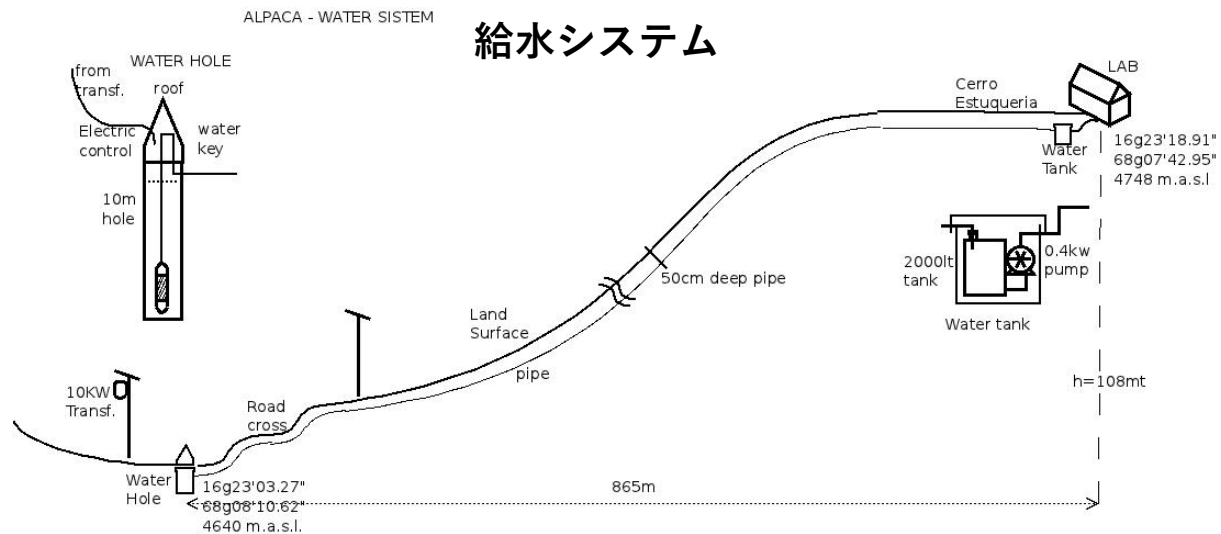
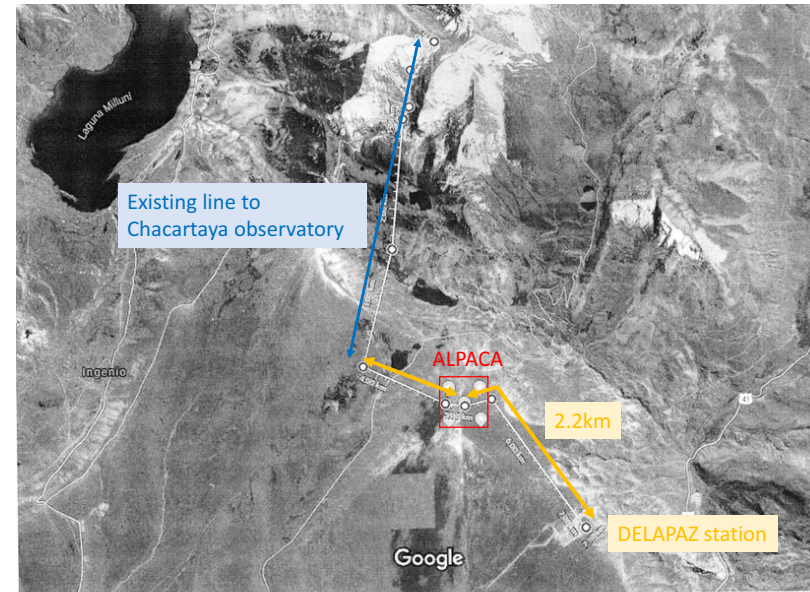
Summary

- **ALPACA is a new air shower array project to explore 100TeV sky in the Southern hemisphere**
- **Many H.E.S.S. sources can be studied at $>10\text{TeV}$**
 - **Systematic search of 100TeV emission and cutoff below 100TeV**
- **Prototype array ALPAQUITA under construction**
 - **surface array construction to be completed and operation starts early 2020**
 - **first muon detector construction in 2020**

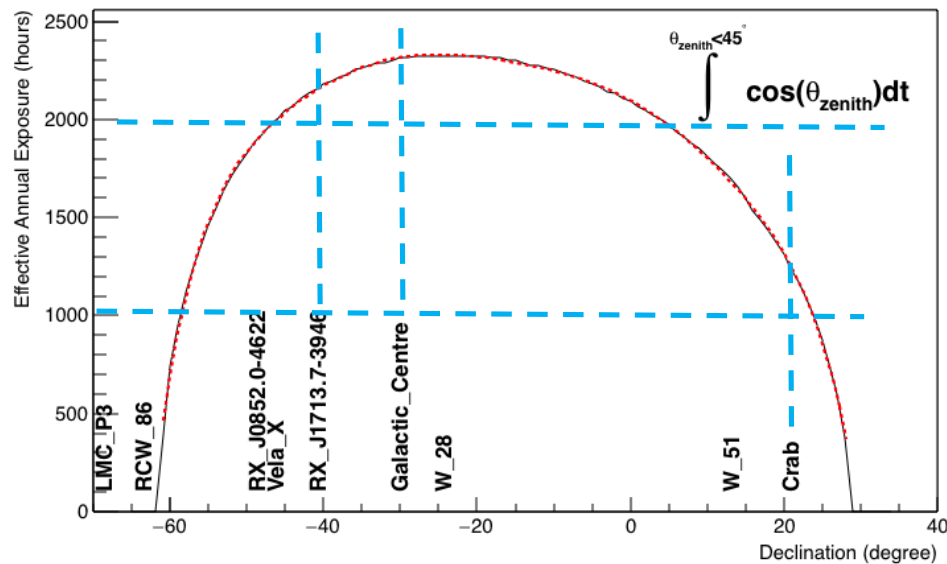
Backup

Power and water

- アレイ周りの柵の設置
- エレキ・作業用ハットの建設
- GPS測量による設置位置の最終確認
- 電力線の移動（これまでのチャカルタヤ観測所までのラインを移動）
- 取水用ポンプ、排水設備の設置



ALPACA exposure (hours/year)

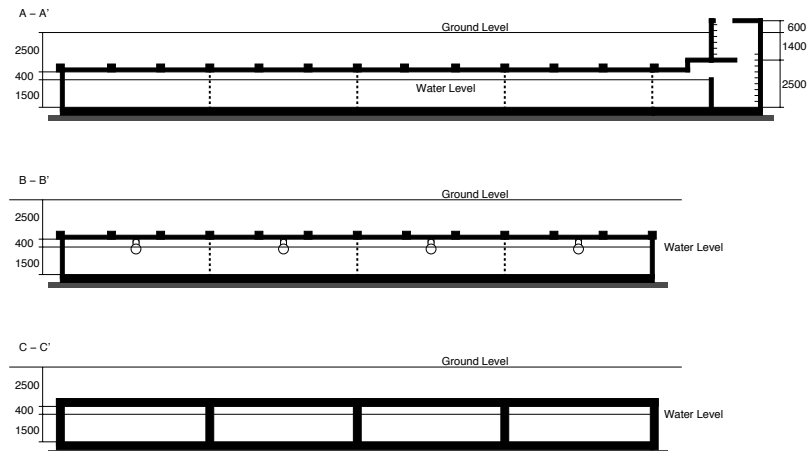
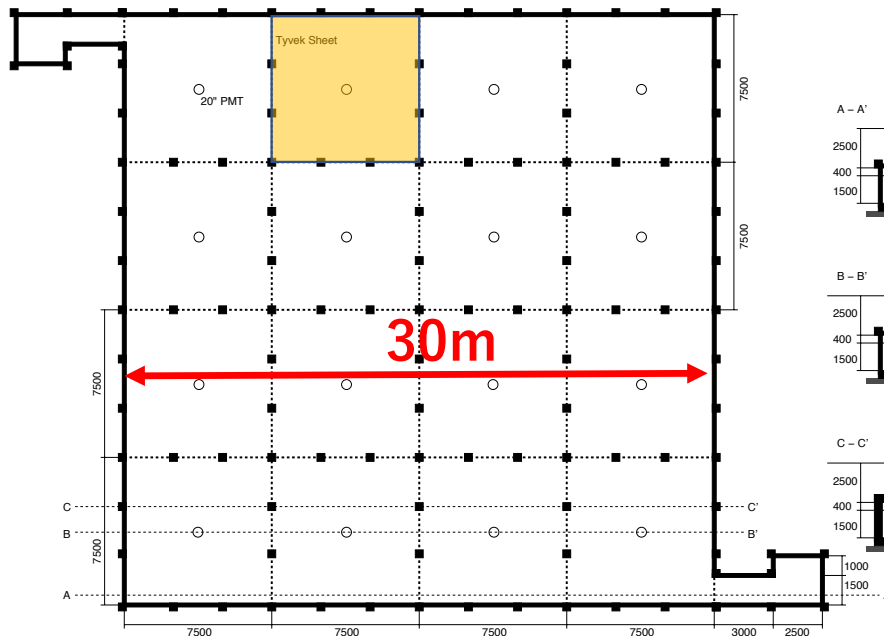
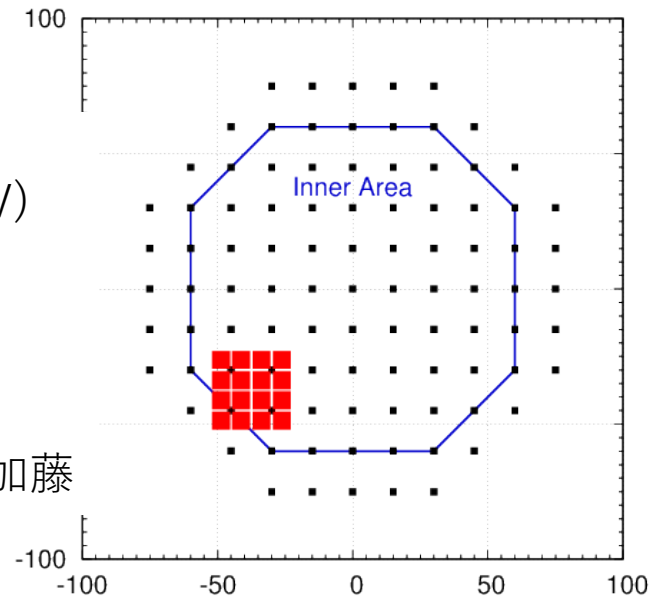


Object name	Declination (degree)	Exposure (hours/year)	
		$\theta < 45^\circ$	$\theta < 60^\circ$
Crab	22.0	1171	2299
W51	14.2	1634	2565
W28	-23.3	2331	3125
Galactic Center	-29.0	2322	3162
RX J1713.7-3946	-39.8	2176	3154
Vela	-45.6	2016	3099
RX J0852.0-4622	-46.4	1989	3090
RCW86	-62.4	0	2759
LMC	-67.6	0	2438

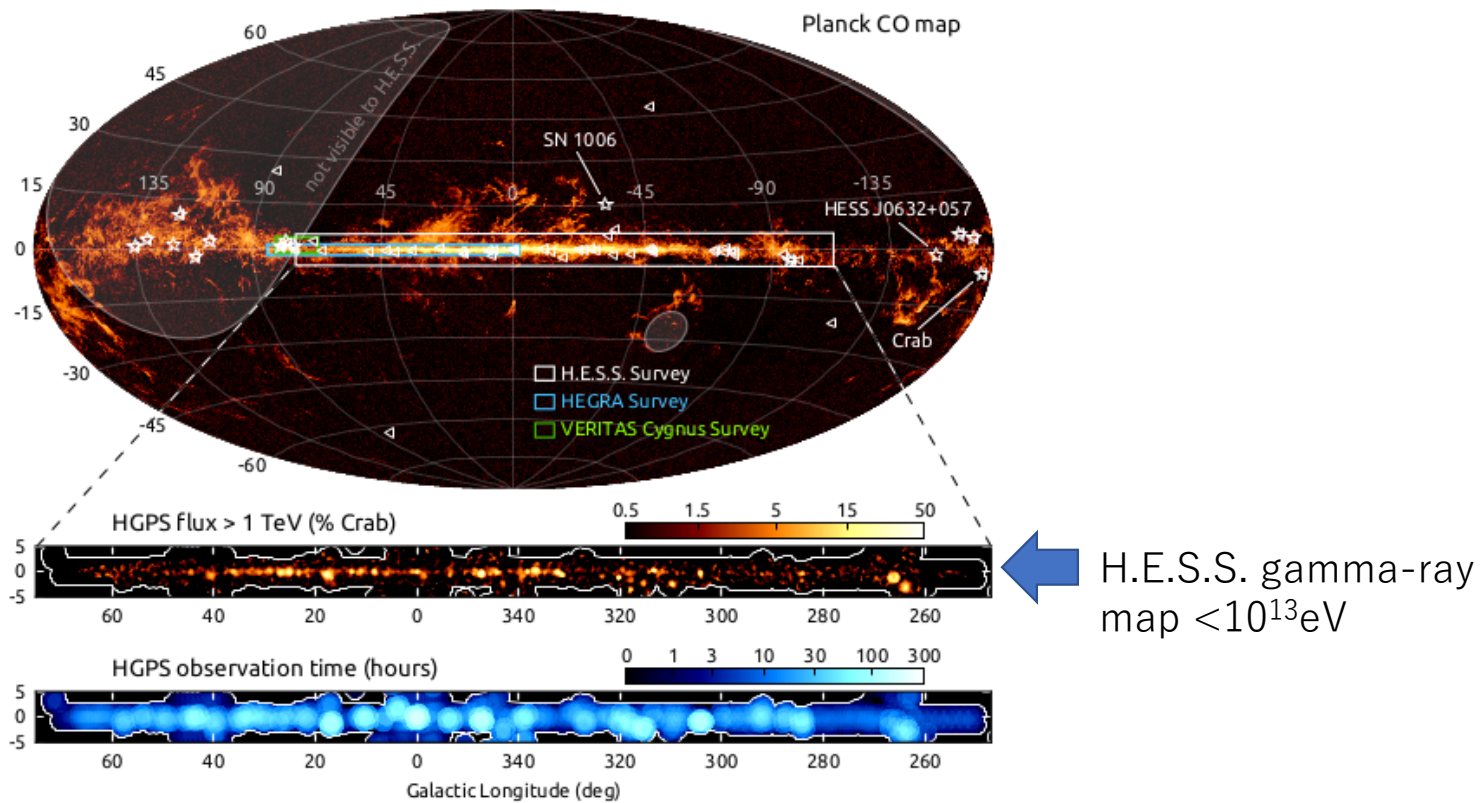
- Galactic Center, RX J1713 : >2,000 hours/year ($\theta < 45^\circ$)
- >1,000 hours/year for Crab
- $\theta < 60^\circ$ allows 3000 hours/year
 - Effects on threshold energy, resolution must be studied

ミュオン検出器

- 2020年度に建設予定
- 土盛り+コンクリート天井 2.5m ($E_\mu > 1\text{GeV}$)
- 7.5m×7.5mのユニットを16基
- 1ユニットあたりPMT 1本
- 内壁をタイベックシートで覆い集光
- 25 p.e./1 MIP (Tibet実績)
- Full ALPACAを考えた建設位置の検討 => 加藤



H.E.S.S. TeV Galactic Plane Survey

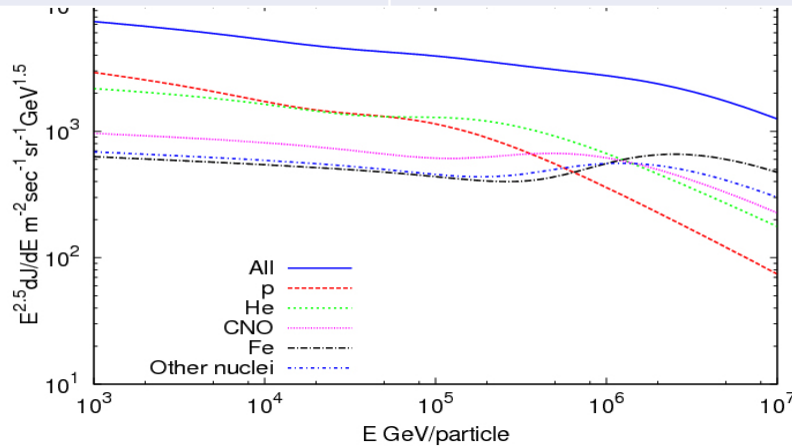


- Many gamma-ray sources along the Galactic plane
- Any source beyond 10^{14} eV?

Air shower simulation

Corsika7.6400 is used in a MC simulation

Simulation condition	γ -ray	Background CR
Total # of events	5.0×10^7 (27 yr for Vela X)	① $300\text{GeV} < E < 10\text{PeV} : 1.1 \times 10^9$ (0.6 yr for Vela X) ② $10\text{TeV} < E < 10\text{PeV} : 1.0 \times 10^8$ (18 yr for Vela X)
Energy range	$300\text{GeV} < E < 10\text{PeV}$	$300\text{GeV} < E < 10\text{PeV}$
Spectrum	$\propto E^{-2.0}$	See the figure below
Injected range (from the center of the array)	300m radius	300m radius



Cosmic-ray spectrum

(M. Shibata et al. ApJ, 716: 1076-1083, 2010)

