

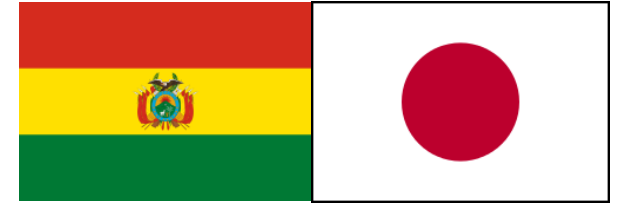
Introduction to  
Status of  
**ALPACA**

Andes Large area PArticle detector  
for Cosmic ray physics and Astronomy

**Design of ALPACA**  
**Prototype array ALPAQUITA**

Takashi Sako (ICRR, Univ. of Tokyo)  
for the ALPACA Collaboration

# The ALPACA Collaboration



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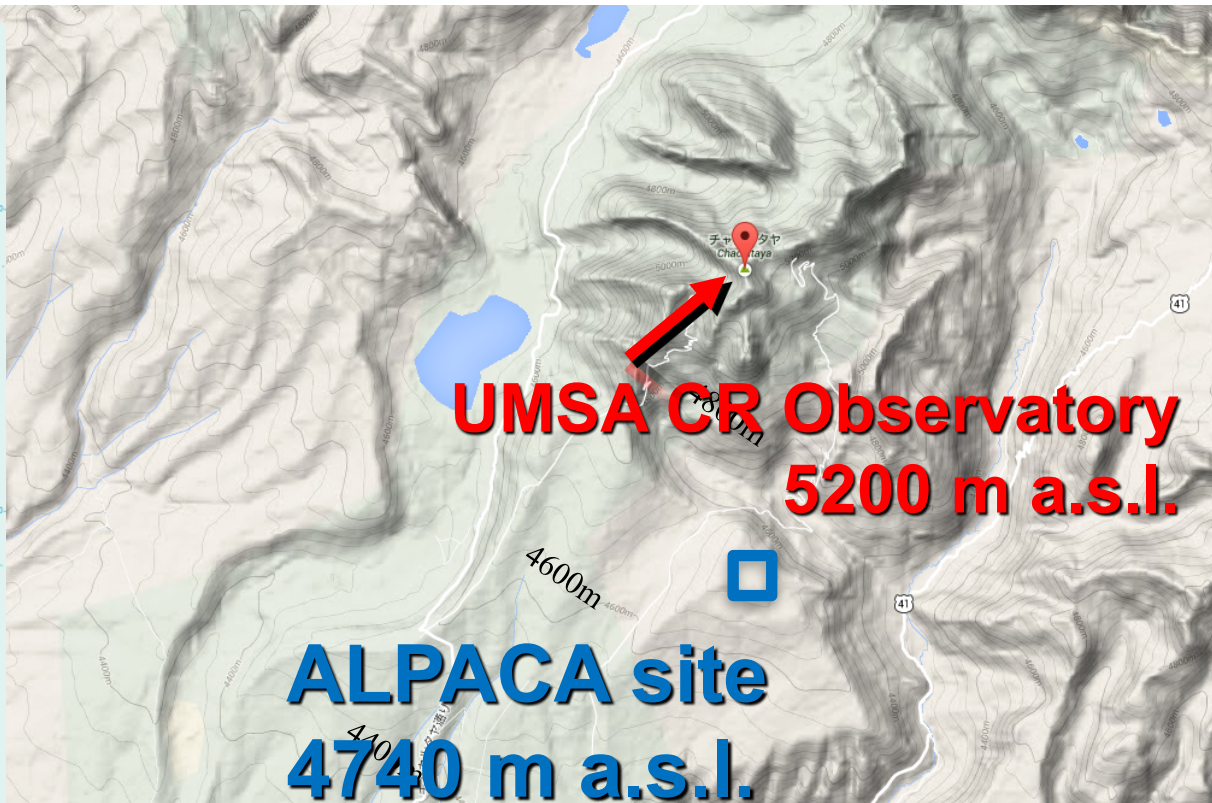
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Koichi TANAKA



**UMSA CR Observatory  
5200 m a.s.l.**

**ALPACA site  
4740 m a.s.l.**

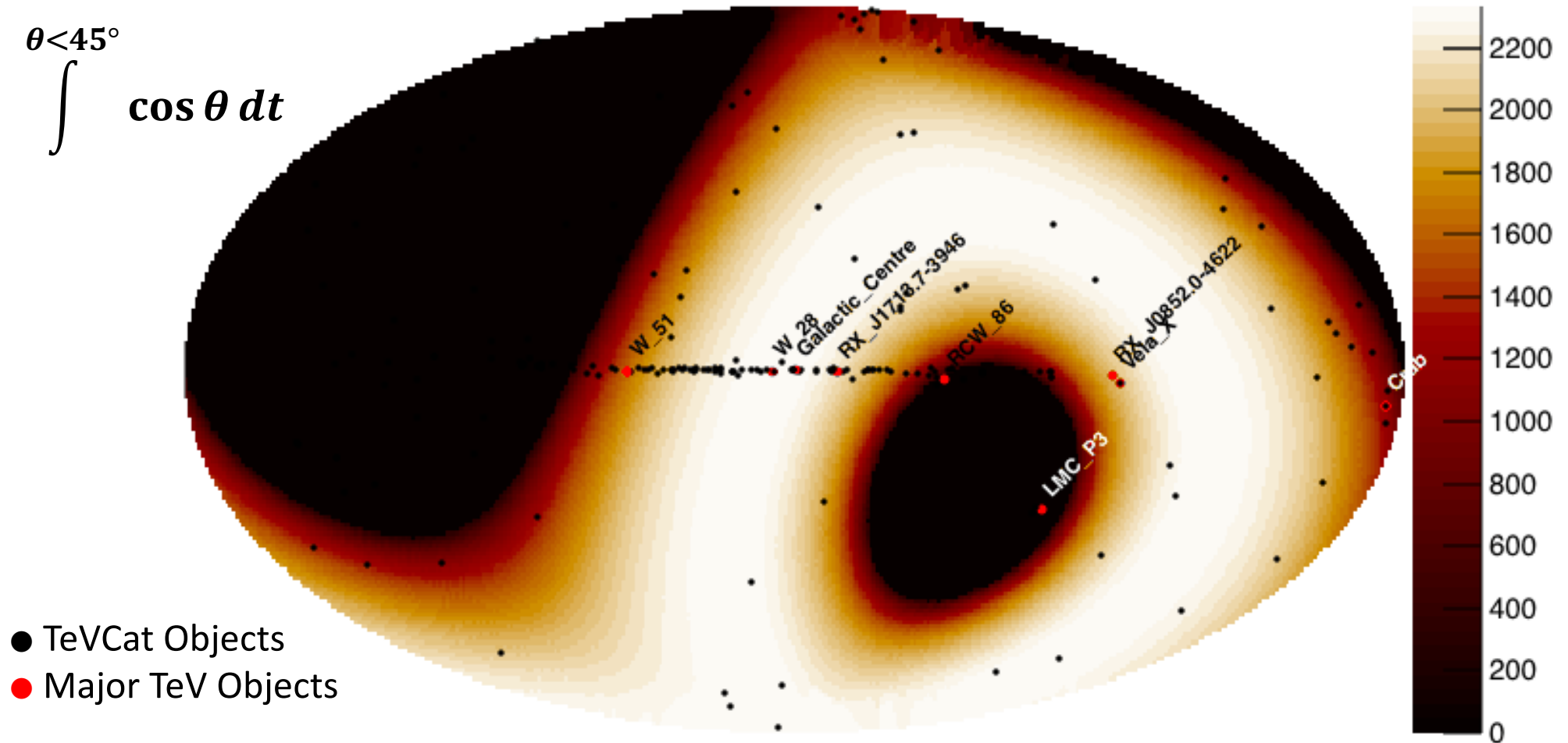
**4,740 m above sea level  
(16° 23' S, 68° 08' W)**



# ALPACA exposure (hours/year)

ALPACA exposure ( $\theta < 45^\circ$ )

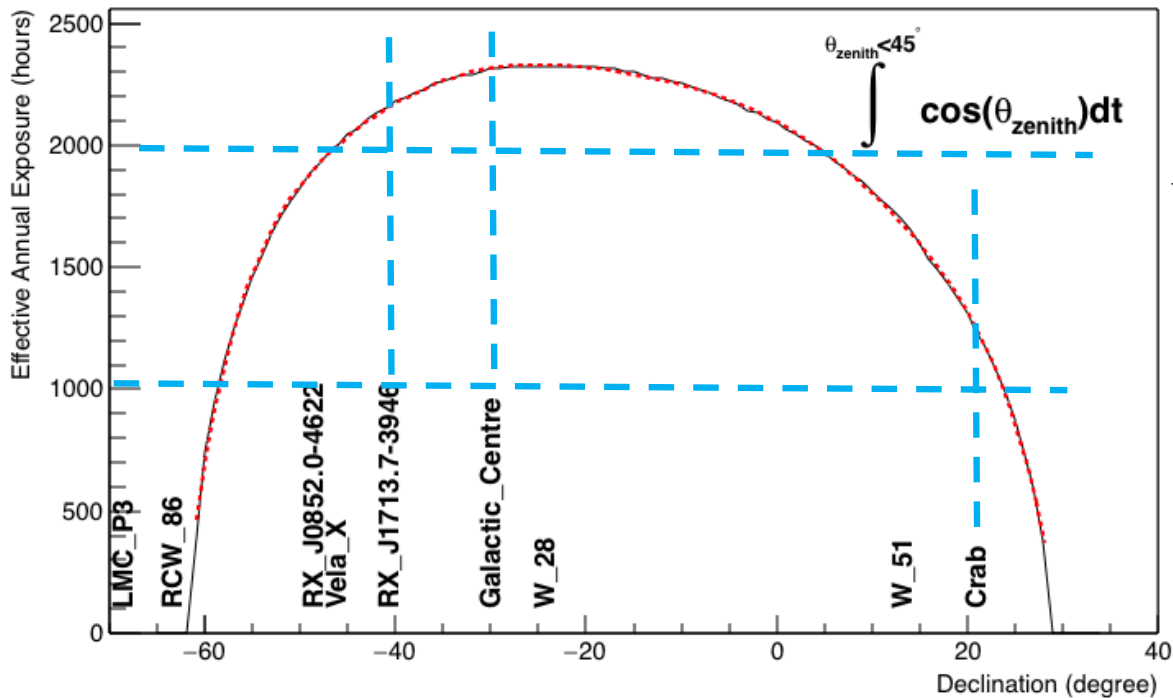
$$\int_{\theta < 45^\circ} \cos \theta dt$$



- TeVCat Objects
- Major TeV Objects

- Assuming  $\theta < 45^\circ$
- Geometrical decrease ( $\cos\theta$ ) is taken into account

# ALPACA exposure (hours/year)



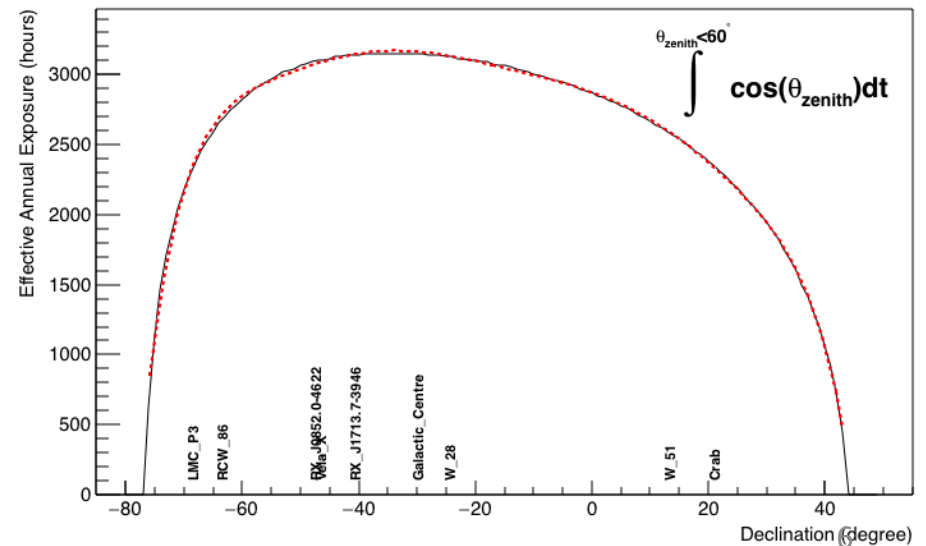
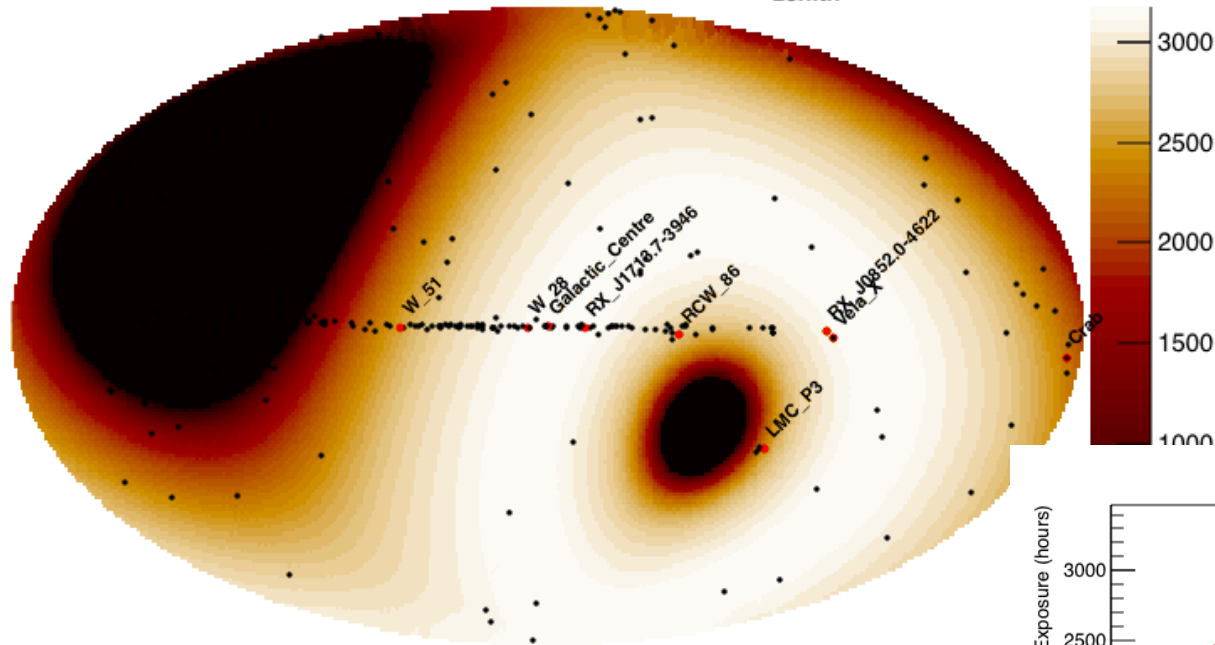
Object name	Declination (degree)	Exposure (hours/year)	
		$\theta < 45^\circ$	$\theta < 60^\circ$
Crab	22.0	1171	2299
W51	14.2	1634	2565
W28	-23.3	2331	3125
Galactic Center	-29.0	2322	3162
RX J1713.7-3946	-39.8	2176	3154
Vela	-45.6	2016	3099
RX J0852.0-4622	-46.4	1989	3090
RCW86	-62.4	0	2759
LMC	-67.6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

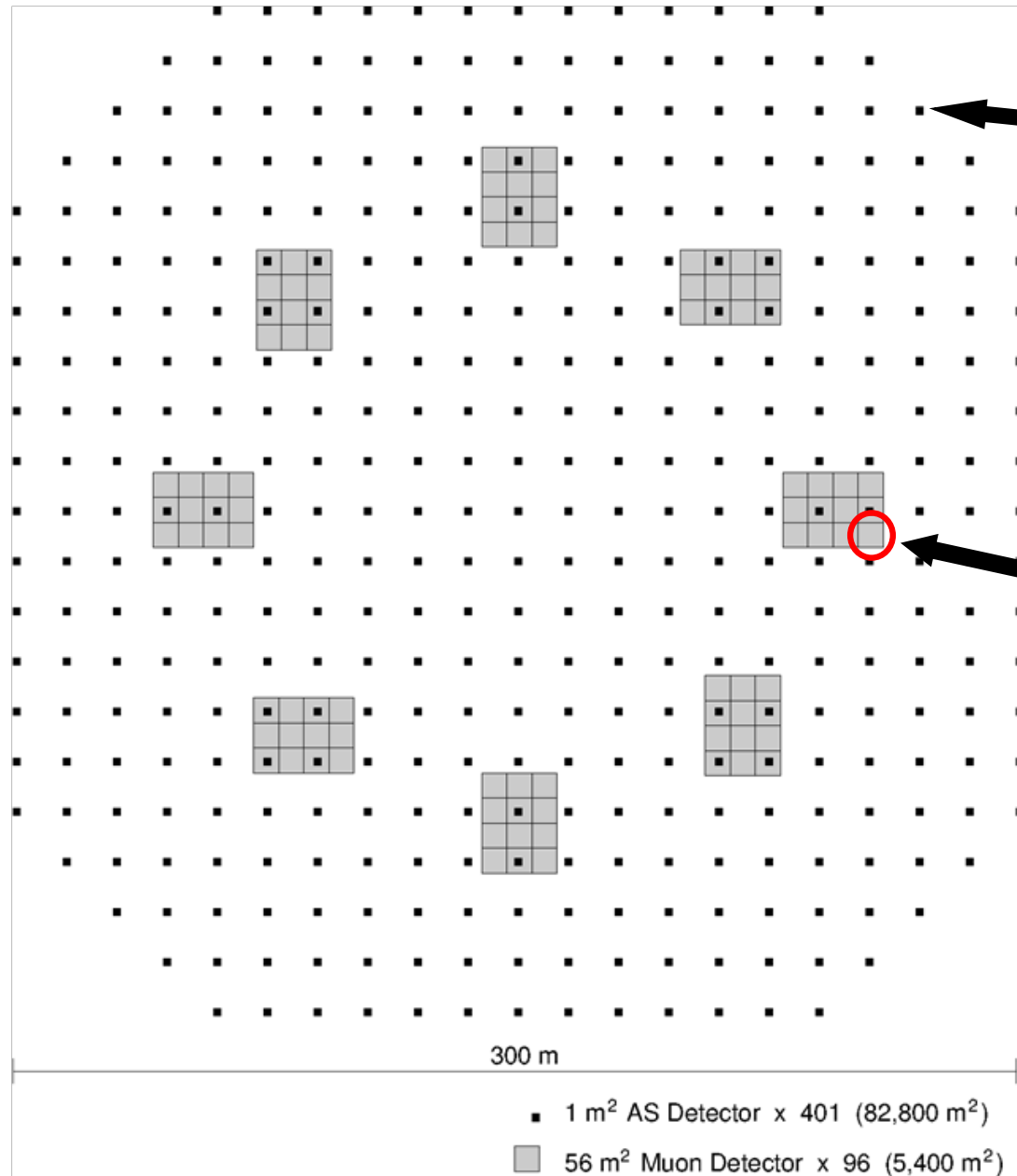
# ALPACA exposure (hours/year)

$\theta < 60^\circ$

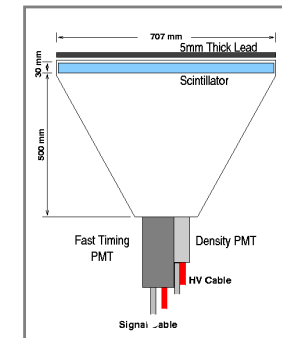
ALPACA effective exposure ( $\theta_{\text{zenith}} < 60^\circ$ )



# ALPACA array design

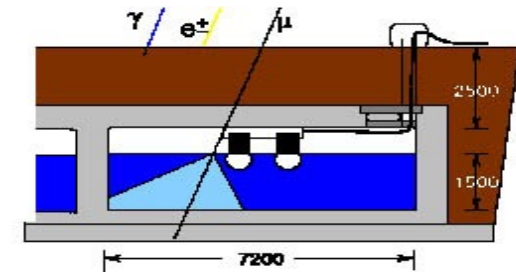


AS



401 of 1m<sup>2</sup> scintillation counters cover 300mx300m (82,800 m<sup>2</sup>)

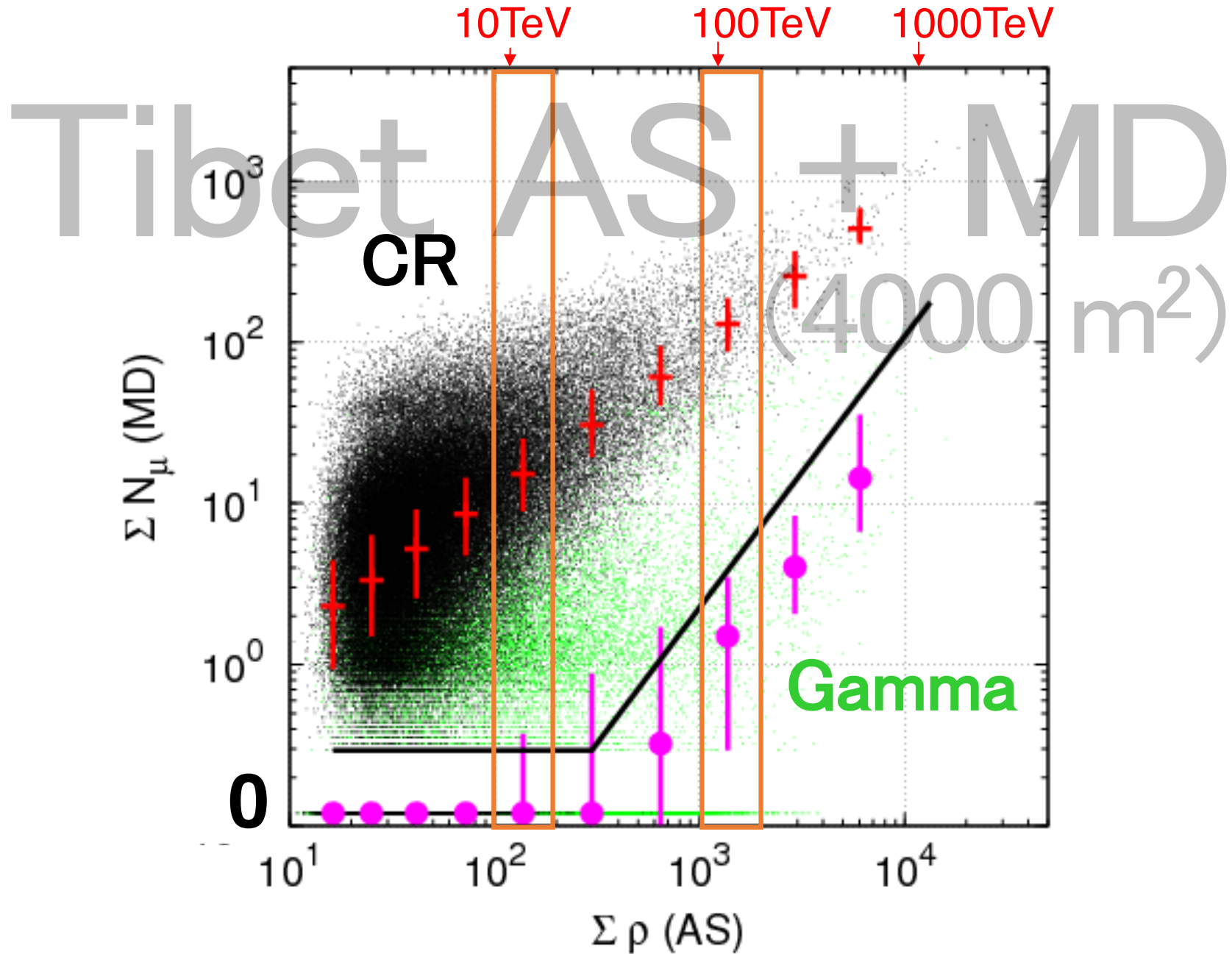
MD



96 units of 56m<sup>2</sup> (5,400m<sup>2</sup>) water Cherenkov muon detectors 2.5m under ground

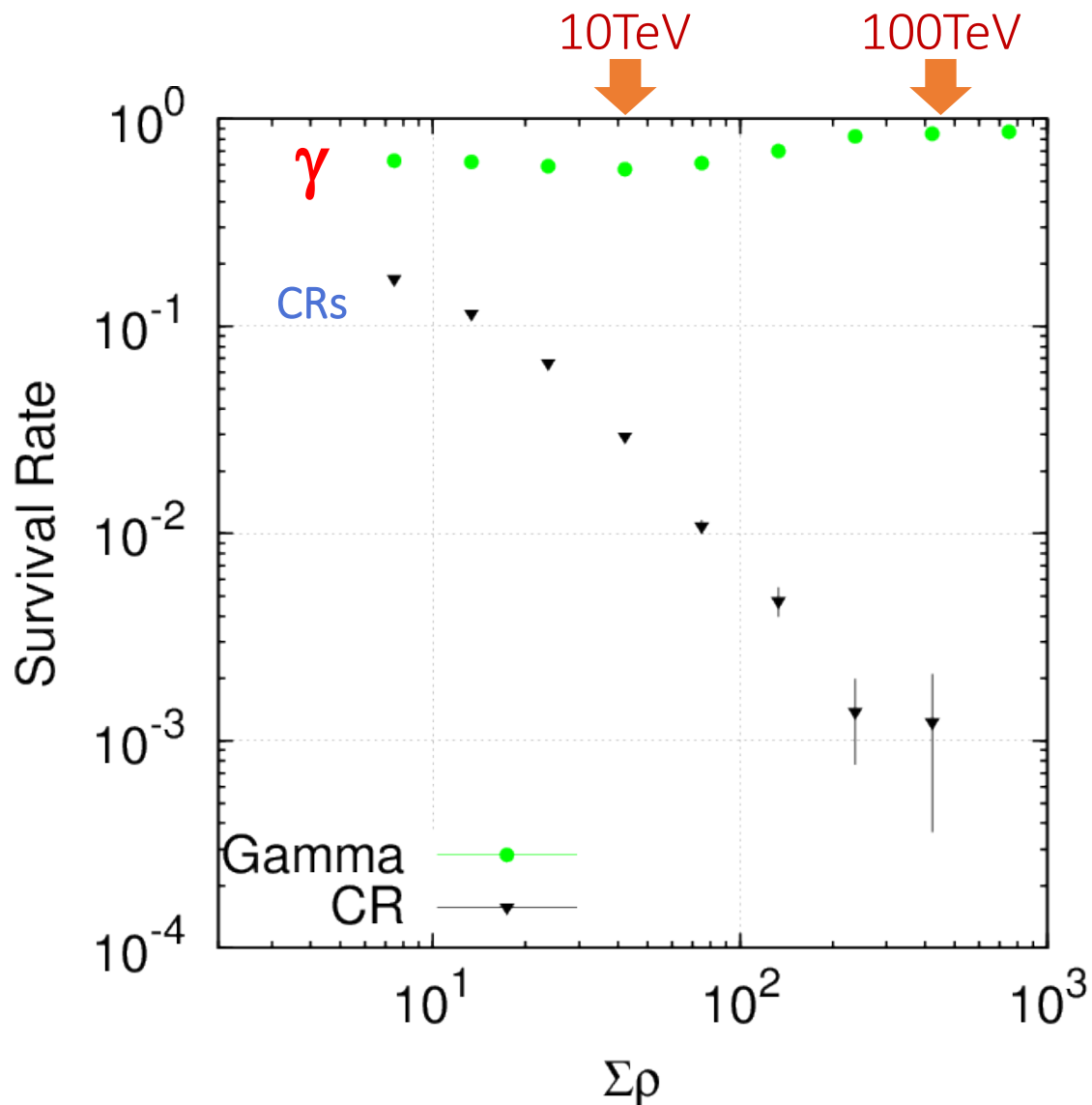
- Good p/ $\gamma$  separation
- Good composition study

# $\Sigma\rho$ vs $\Sigma N_\mu$ (simulation)





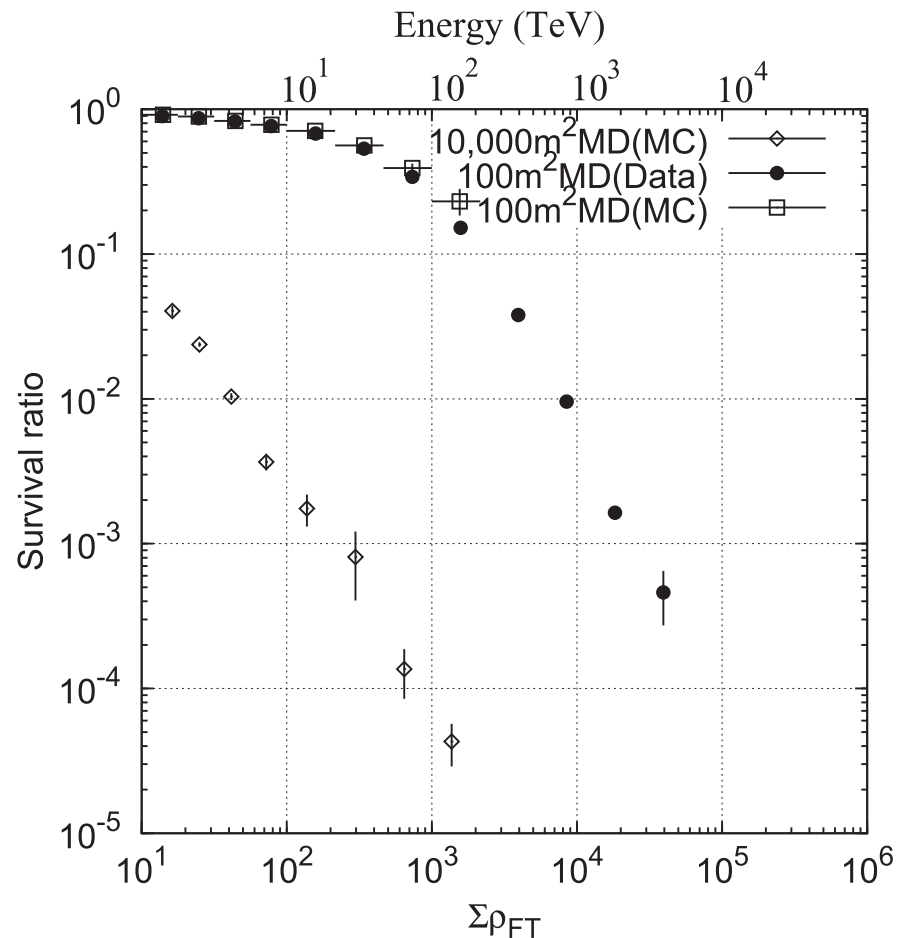
# Survival Ratio After Muon Cut



MC simulation  
(AS 83000m<sup>2</sup> + MD 5400m<sup>2</sup>)  
Muon cut optimized, assuming  
Crab-like spectrum at  $\delta=-30^\circ$

- ✓ Cosmic rays will be rejected by  $\sim 99.9\%$  @100TeV
- ✓ Gamma rays will be kept over  $90\%$ @100TeV

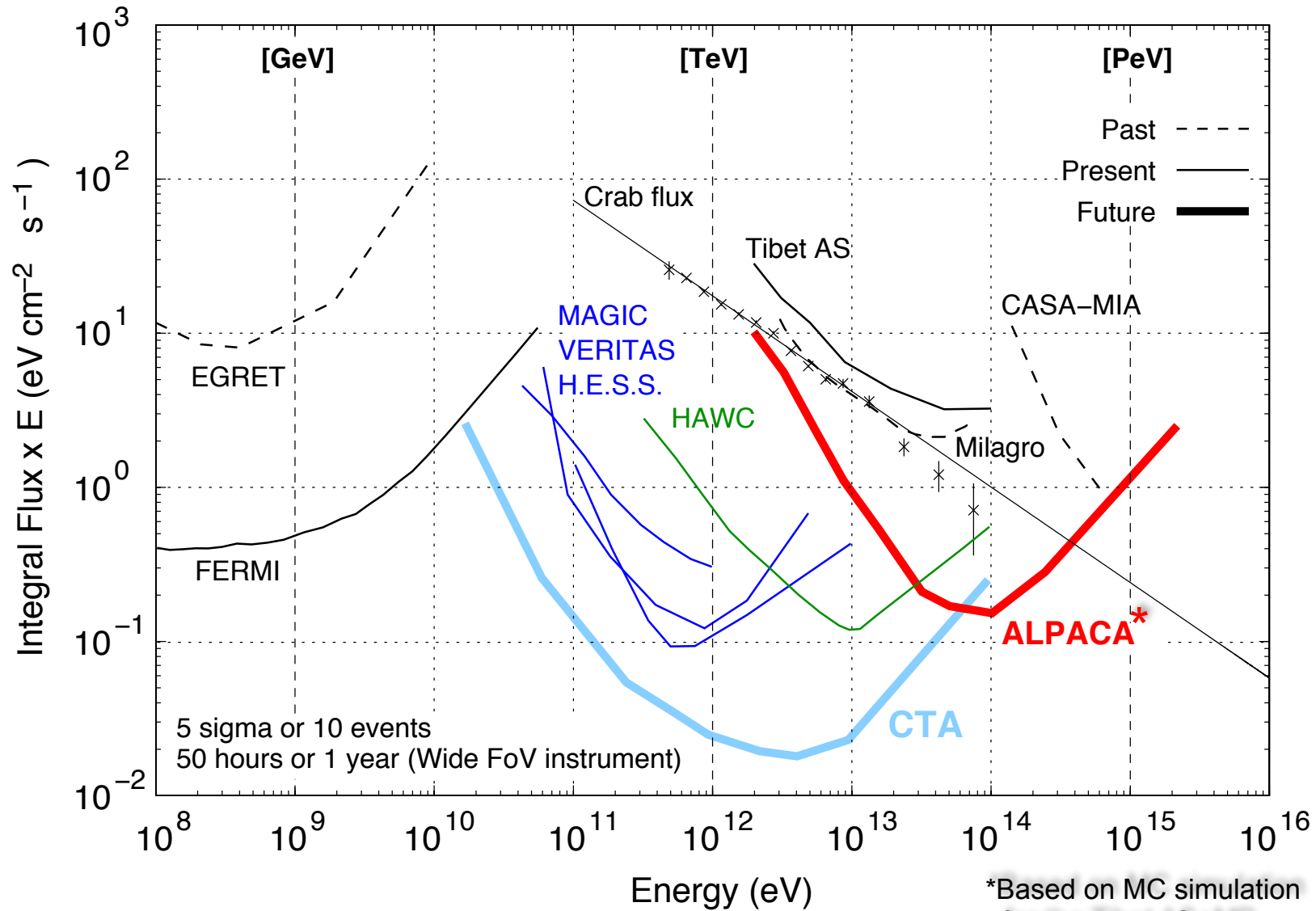
# Tibet MD (100m<sup>2</sup>) prototype real data



Amenomori et al., ApJ, 813:98 (2015)

- ALPACA MD design 5,400 m<sup>2</sup>
- Tibet result of full MD is coming soon.

# Sensitivity to the Point Source

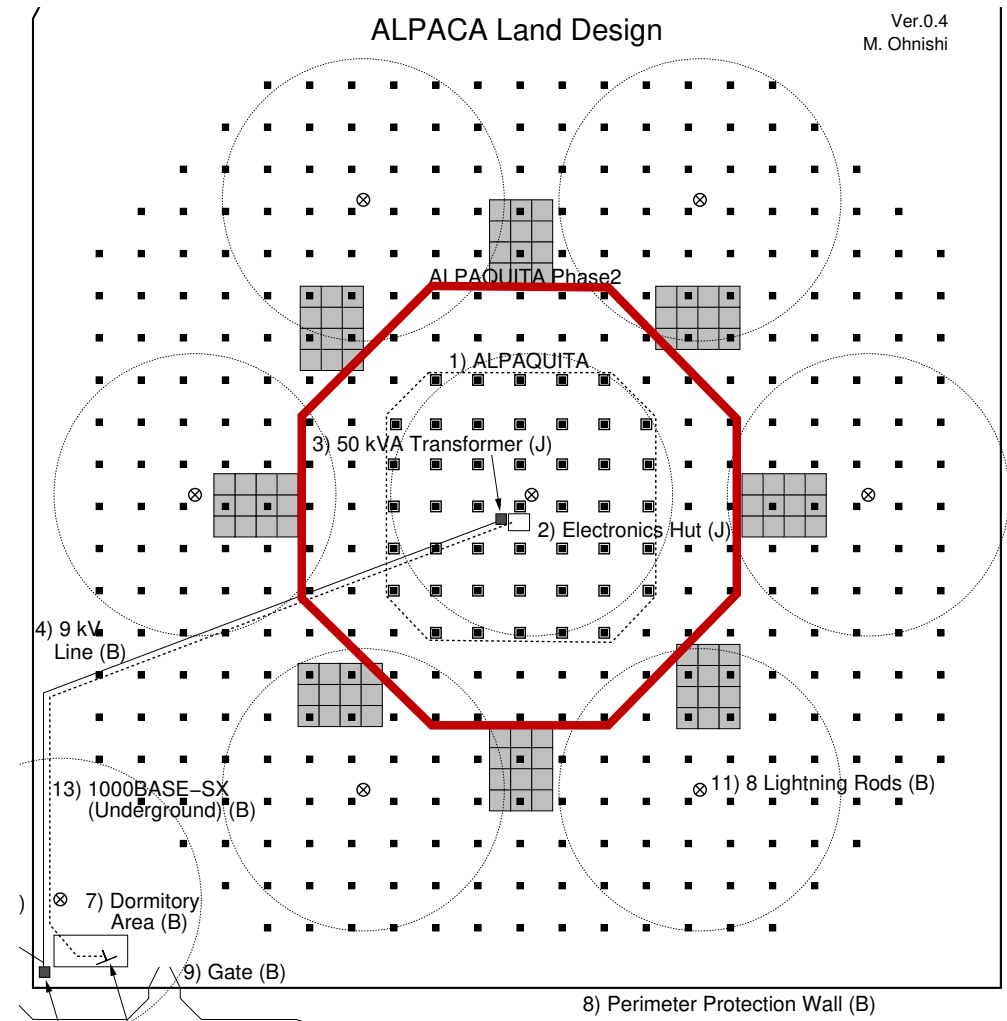


CTA Review by Kubo (JPS 2015)  
M. Daniel, Proc. of 28<sup>th</sup> Texas Sympo. (2015)

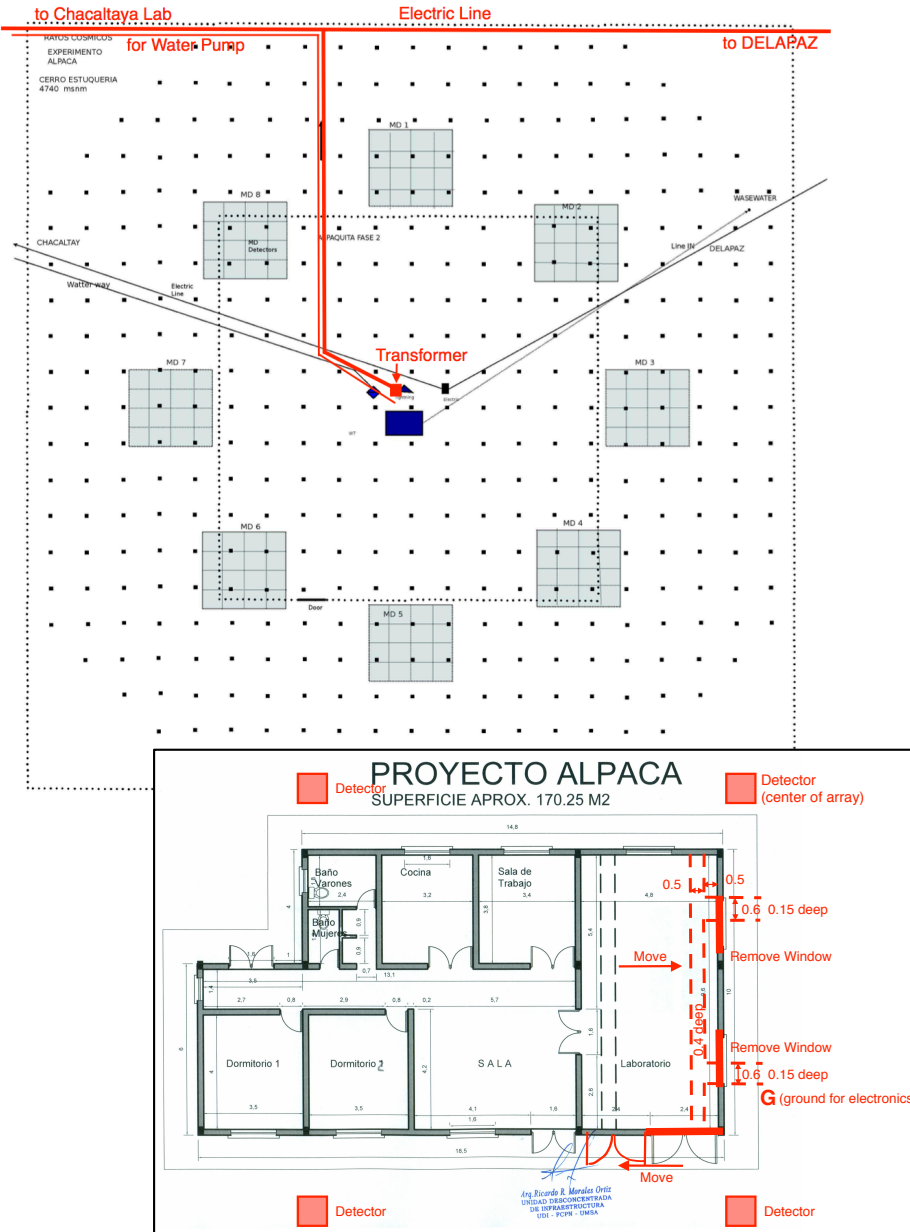
Dedicated ALPACA MC on going

# ALPAQUITA

- Prototype array with 100 SDs
  - 20% coverage of full ALPACA
  - No Muon Detector at this stage
- Establishing procedures in Bolivia
  - Construction
  - Import/Export
  - Infrastructure
- Some sciences
  - MD prototype in discussion



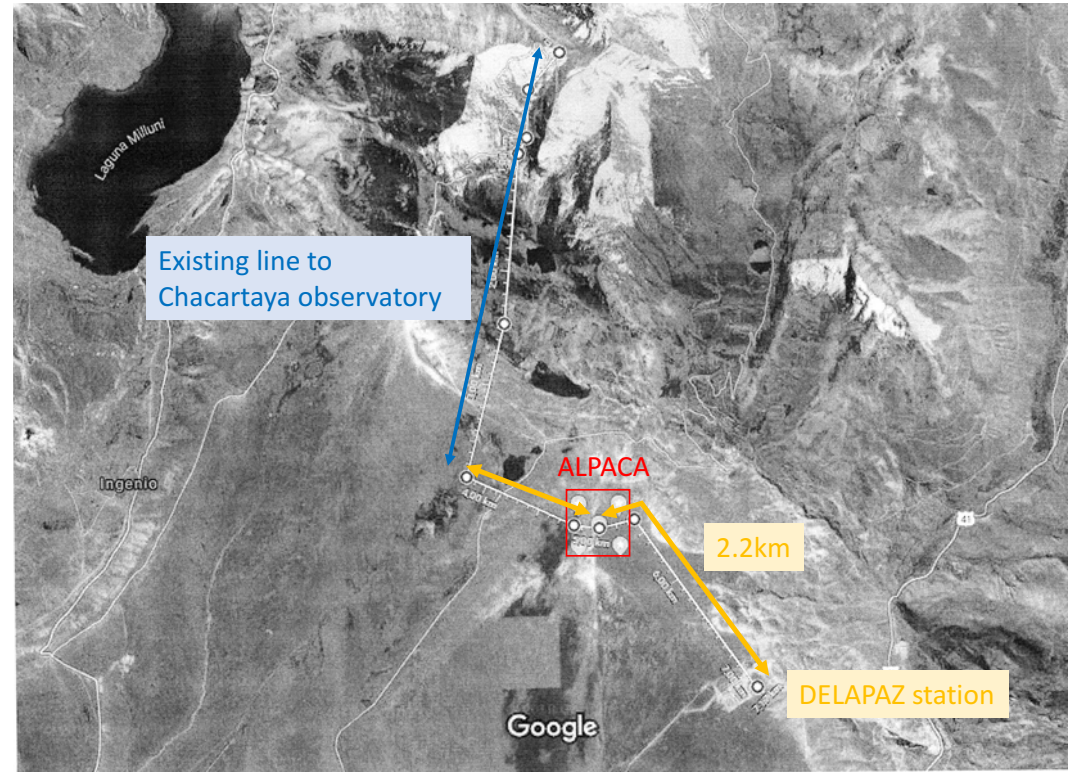
# ALPAQUITA & infrastructure



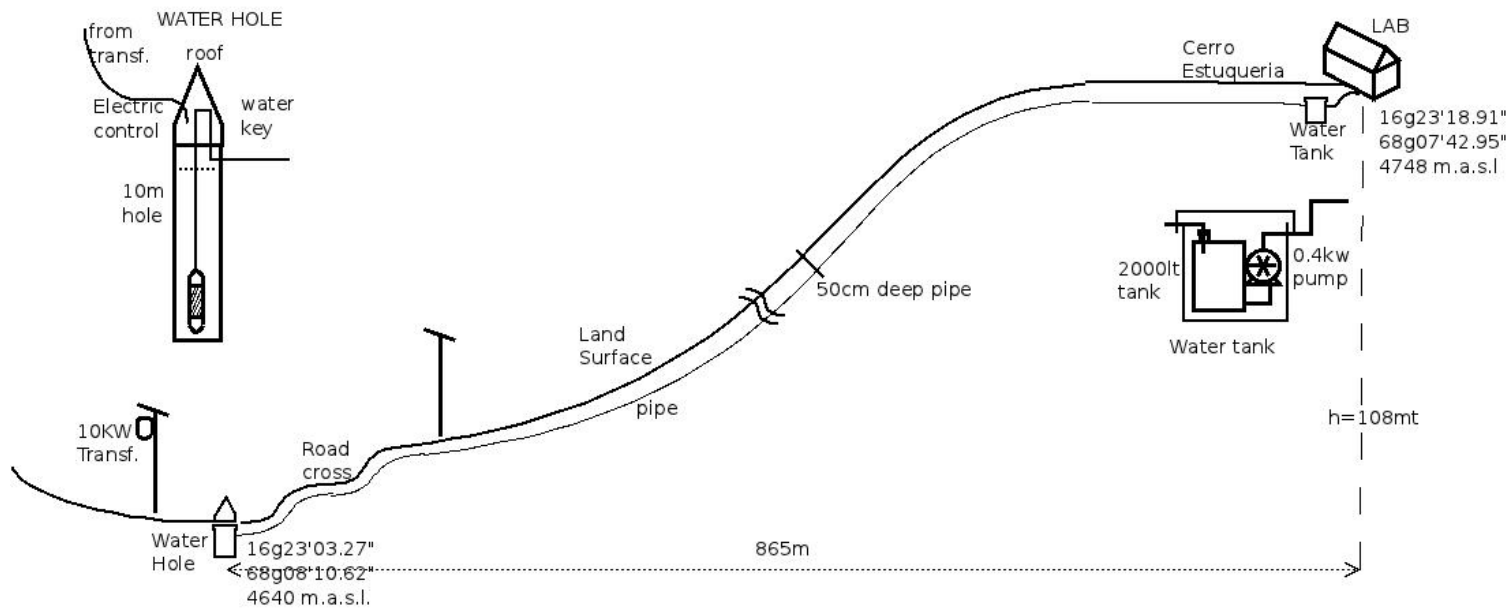
- Refurbish power line to the Chacartaya observatory
- Fence
- DAQ room, workshop and guardians hut
- Water system for life and MDs



# Power and water



ALPACA - WATER SYSTEM



# ALPAQUITA schedule

	7月	8月	9月	10月	11月	12月	2019年1月
物品輸送 (20ftコンテナx2)	横浜			チリ	観測 サイト		
7kV送電線							
フェンス (160m x4)							
エレキハット/ 番人小屋							
検出器架台							
避雷針/ WiFiアンテナ							
検出器 組み立て/設置							
DAQ/校正							

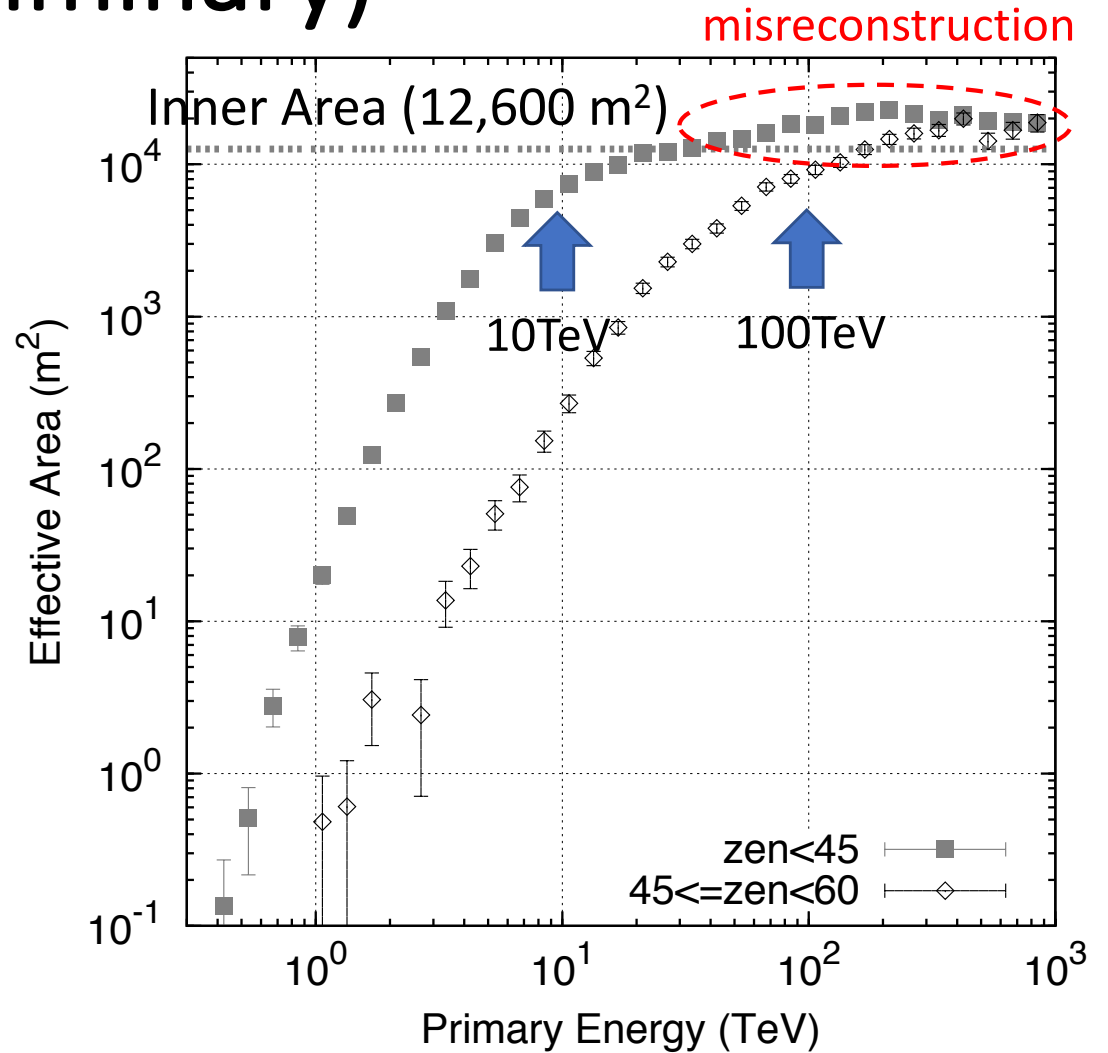
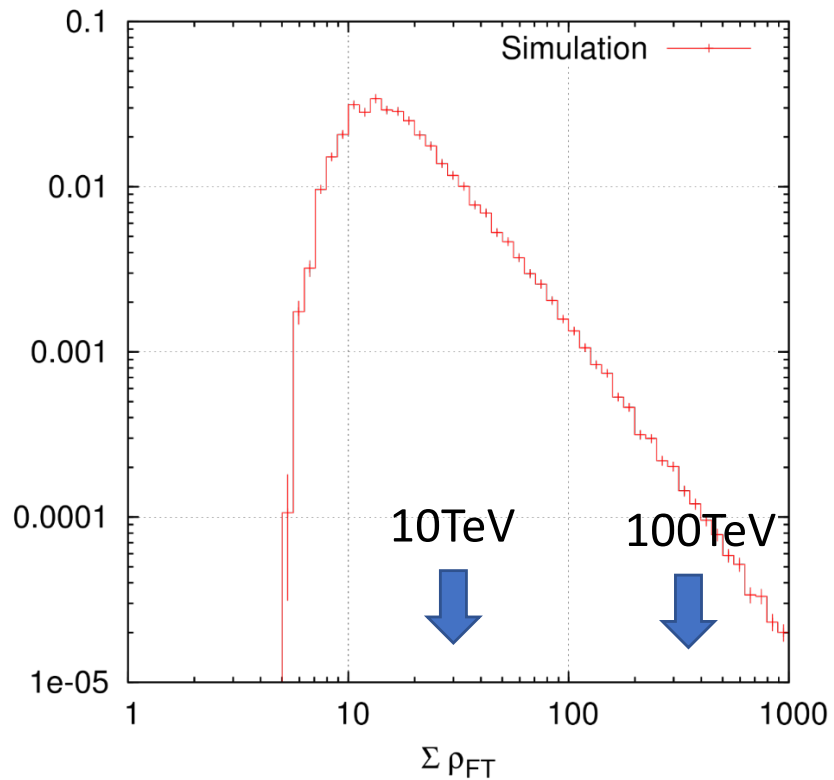
- 2018年度末にテスト観測開始、2019年度初期に最終調整、の予定

# Schedule of ALPAQUITA (no MD)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Infrastructure	Orange	Orange	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
Shipping	Light Blue	Yellow	Yellow	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
Construction	Light Blue	Light Blue	Light Blue	Light Blue	Orange	Orange	Light Blue	Light Blue
Commissioning	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Yellow	Yellow	Light Blue
Operation	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Orange



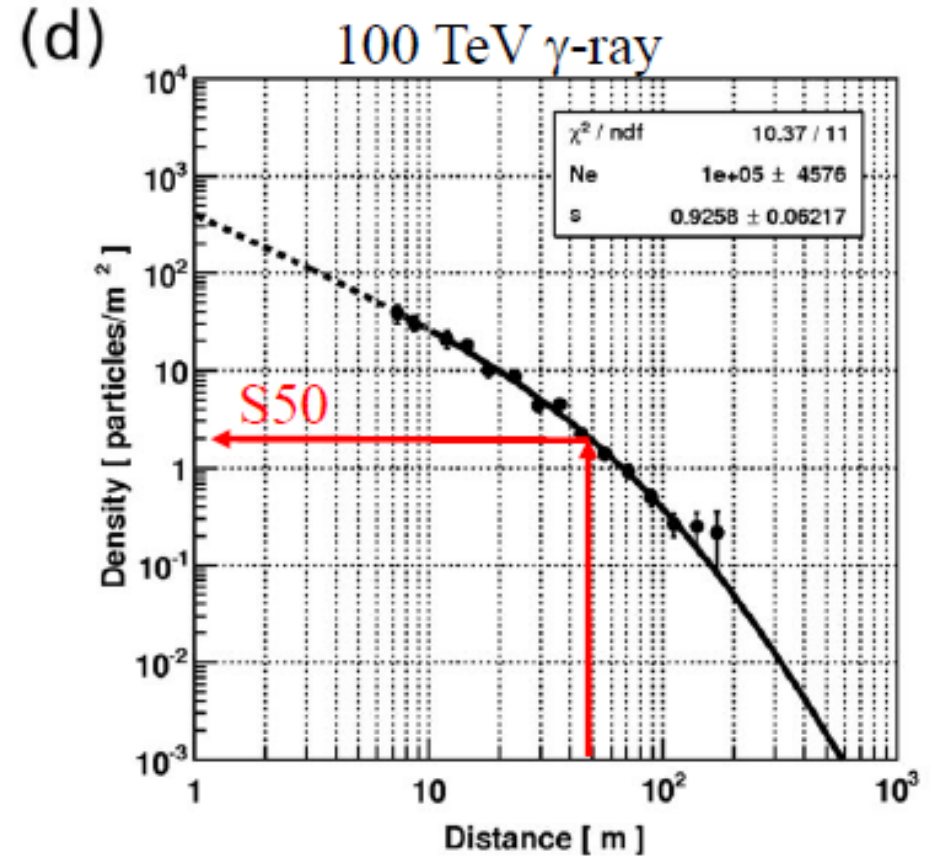
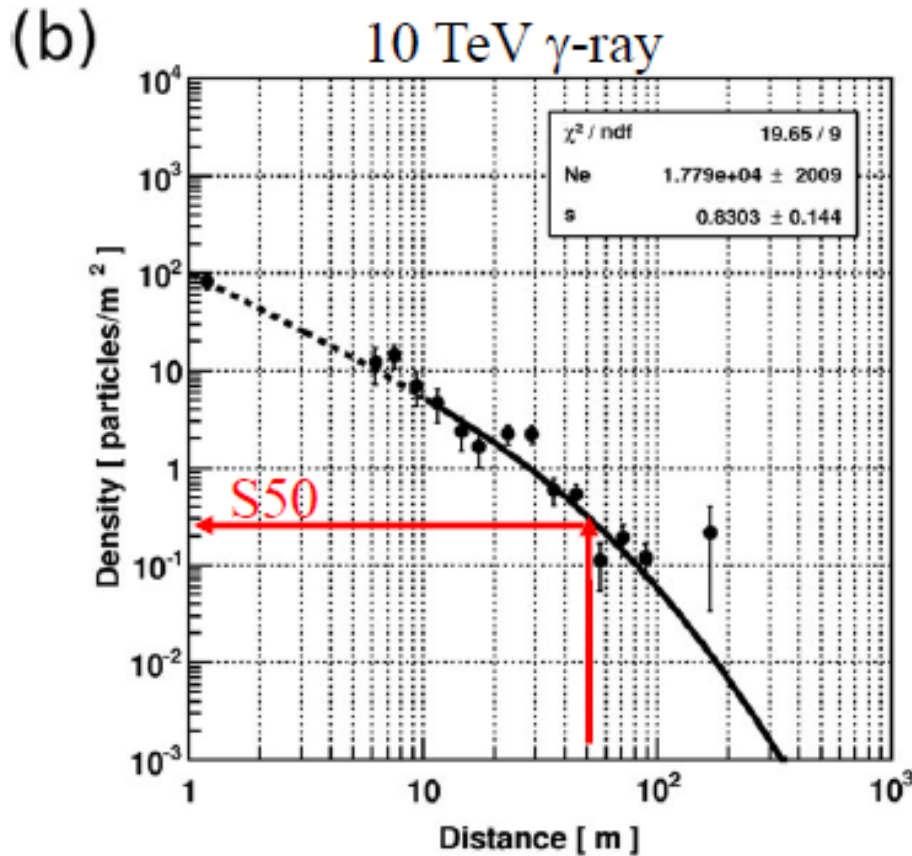
# ALPAQUITA MC Results (preliminary)



- Assuming  $dN/dE \propto E^{-2}$
- Any4, >1.2 MIPs
- Core in array

- ~100% efficiency at
  - 20TeV ( $\theta < 45^\circ$ )
  - 150TeV ( $\theta < 60^\circ$ )

# Lateral Distribution of $\gamma$ -ray Induced AS (MC)



$\gamma$ -ray AS dominated by the EM component  $\rightarrow$  Fitting by original NKG function

$$\rho_{\text{NKG}}(r) = \frac{N_e}{r_m^2} \frac{\Gamma(4.5 - s)}{2\pi \Gamma(s) \Gamma(4.5 - 2s)} \left(\frac{r}{r_m}\right)^{s-2} \left(1 + \frac{r}{r_m}\right)^{s-4.5}$$

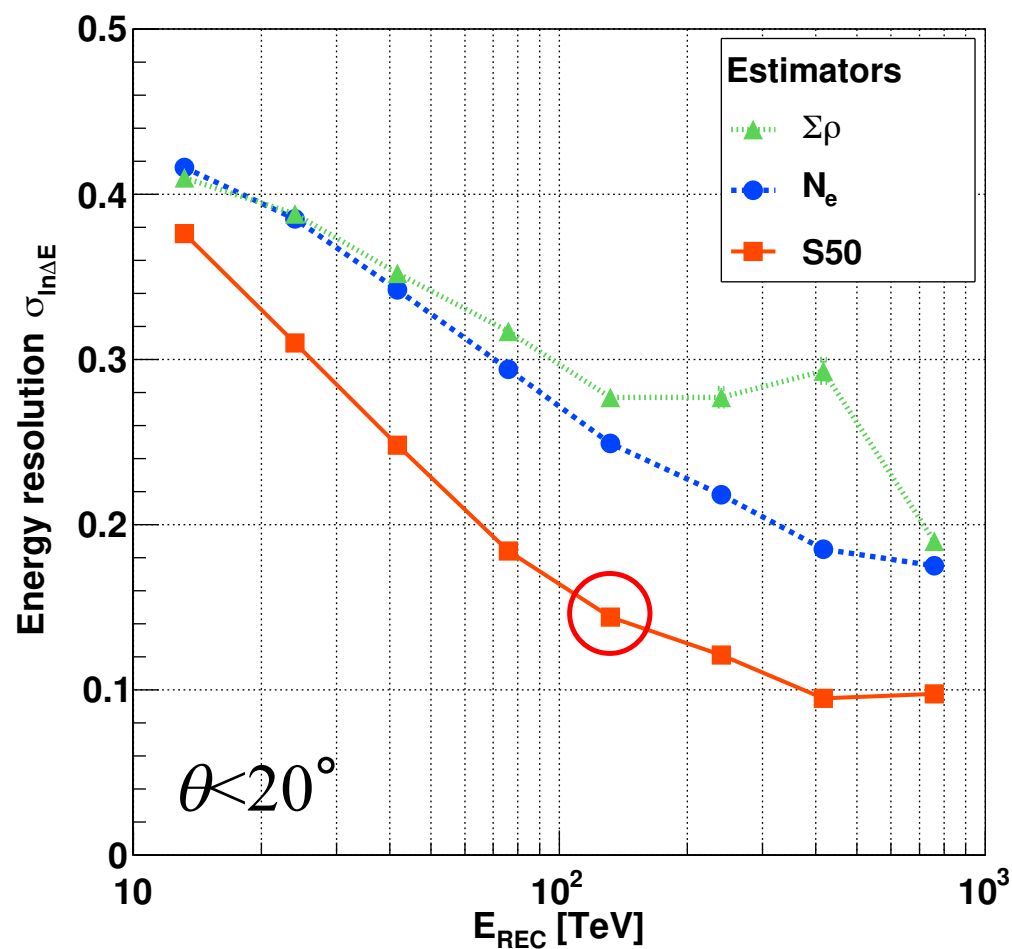
$N_e$  : Air shower size

*Kawata+ Exp Astron (2017)*

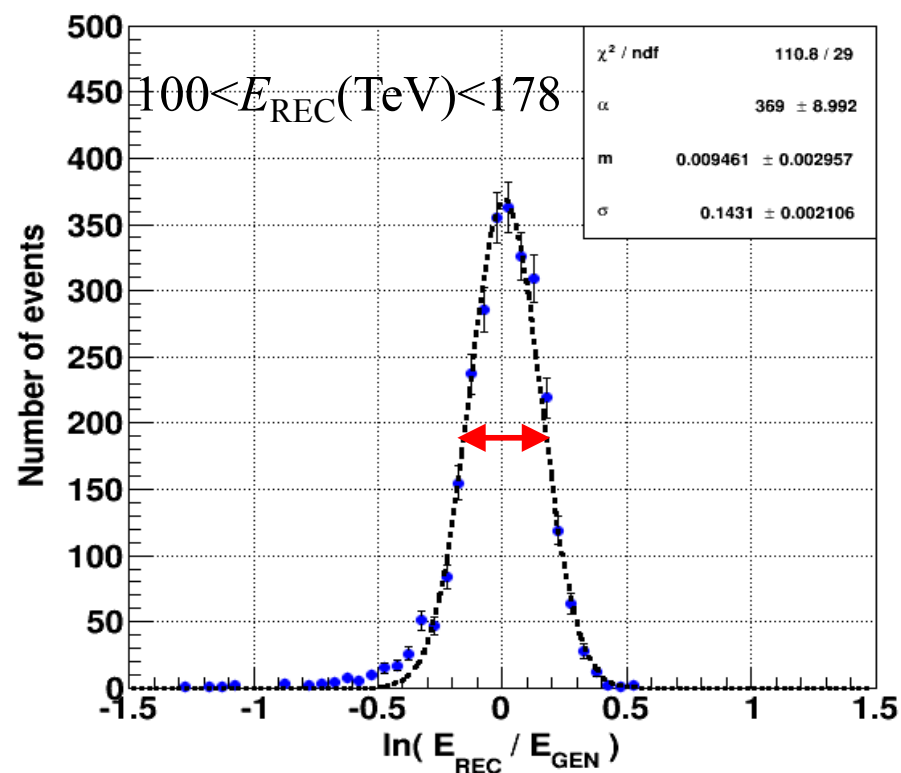
S50 : particle density at 50 m from the AS axis

(often used in the UHECR experiments AGASA:S600, TA:S800)

# Energy Resolutions by Different Estimators (MC)



✓  $\ln(E_{\text{REC}}/E_{\text{GEN}})$  Gaussian fitting  
 → standard deviation :  $\sigma_{\ln\Delta E}$



*Kawata+ Exp Astron (2017)*

# Summary

- ALPACA is a proposal of new array in Bolivia
  - At 16°S, 4740m
  - 82,800m<sup>2</sup> covered by 401 scintillation counters
  - 5,400m<sup>2</sup> underground water Cherenkov detectorsOptimized for 100TeV gamma-ray observations
- Prototype array ALPAQUITA is
  - 20% surface coverage of ALPACA
  - No muon detector (under consideration)
  - Infrastructure construction started
  - Array construction starts early 2019