ALPACA

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ICRR, the University of Tokyo
for the ALPACA collaboration

CRC town meeting
@Research Complex, Kashiwa, U of Tokyo,
20/Oct/2018

The ALPACA Experiment

Andes

Large area

PArticle detector for

Cosmic ray physics and

Astronomy

The ALPACA Collaboration

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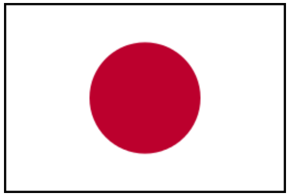
大阪市大理, サン・アンドレス大, 国立情報学研, 中部大工, 都立産業技術高専,
日本大生産工, 理研, 大阪電通大工, 広島市大情, 原子力機構



Outline of the ALPACA experiment

1)Experimental site: 4740m above sea level, near La Paz in Bolivia

Expected budget -> ~ 5 M (AS+MD) USD

Muon Detector ～ 5400m^2 (underground water Cherenkov type)

AS Array ～83,000m^2 (~ 401 x 1m^2 plastic scintillation detectors)

2) Target physics and astrophysics (AS + MD)

10-1000 TeV γ astronomy

(point & extended sources, PeVatron search, origin of CR)

CR rejection power: ~ 99.9 %@100TeV

Advantage to extended sources!

γ-ray point source sensitivity : ~15 % Crab/yr @30TeV

CR anisotropy, Chemical composition of CR around Knee,etc

Costs & Construction plan of ALPACA

AS + MD =5億円 + Running cost 1億円

Year 1: Preparation

Year 2 : Construction of MD

Year 3 : Construction of AS

Year 4 : Start data-taking

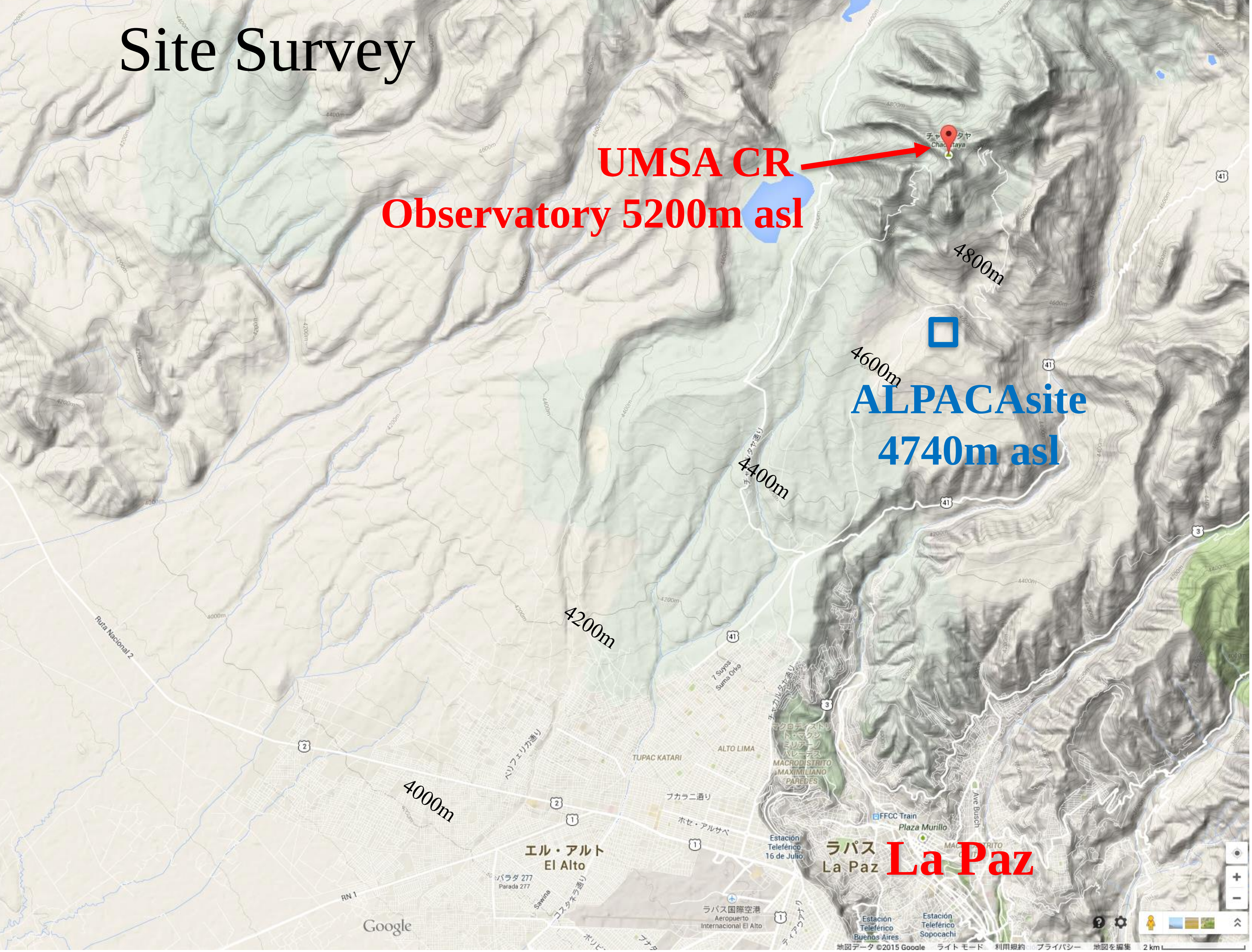
Observation will continue (5 – 10 years)

Cf: Detectors (Japan) + Infrastructure(Bolivia)

ALPACA Site

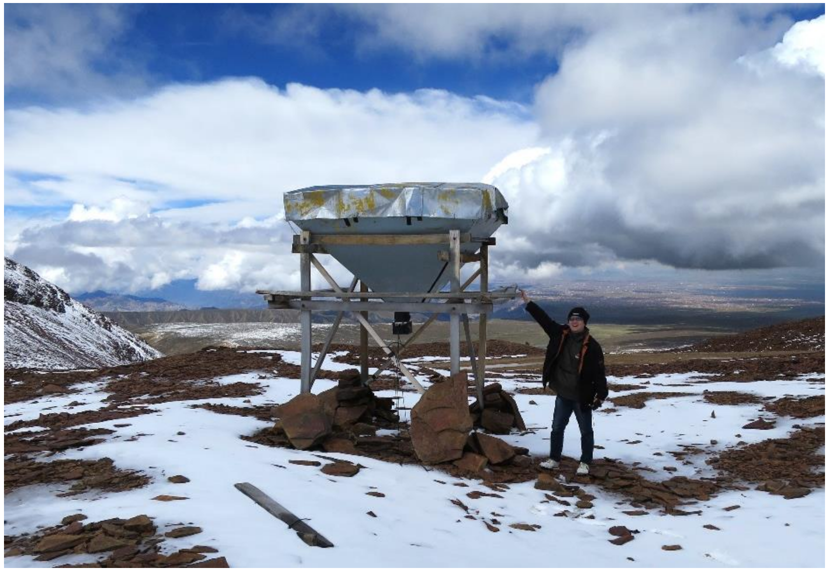
Mt. Chacaltaya, Bolivia

Site Survey


UMSA CR
Observatory 5200m asl
4800m
4600m
ALPACAsite
4740m asl
4400m
4200m
4000m
エル・アルト
El Alto
ラパス
La Paz
La Paz
Plaza Murillo
Google

UMSA Cosmic Ray Laboratory

- ✓ Mt Chacaltaya(5,200m asl)
- ✓ CR Lab at the highest altitude
- ✓ Discovery of charged pion
  C. F. Powell et al. in1947
  (1950 Nobel Prize)



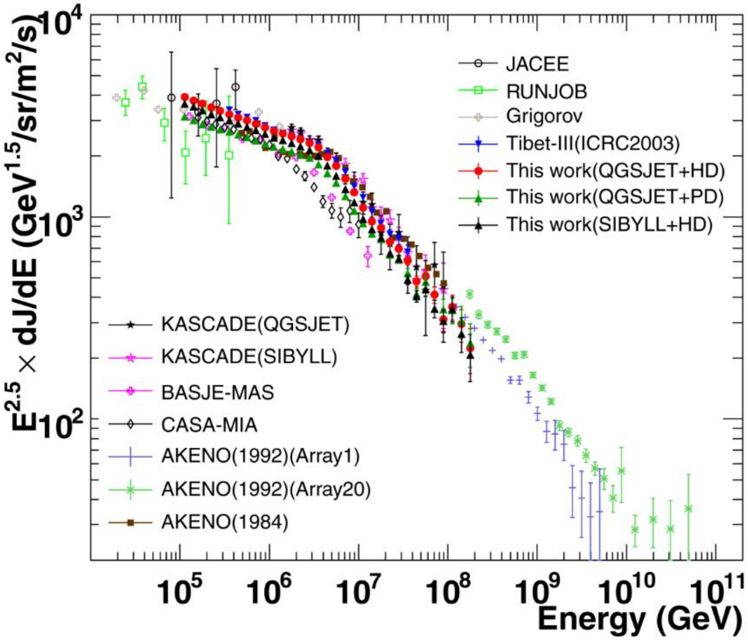
Main purpose of ALPACA

- 100 TeV γ-ray astronomy in South
- Locating origin of comic rays

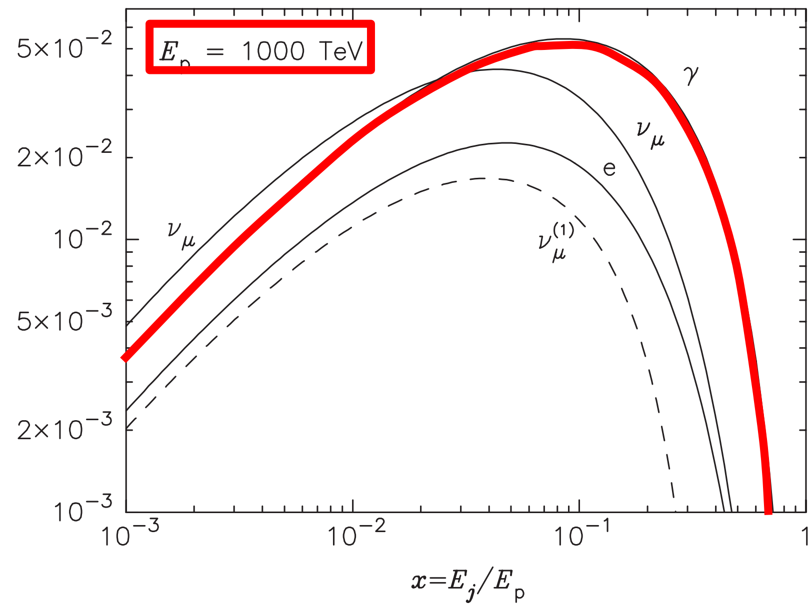
by detecting cosmic 100 TeV gamma rays
from cosmic ray accelerator in our galaxy:

PeVatrons!

Origin of Cosmic Rays at the Knee



$x^2F_j(x,E_p)$ *Kelner et al., PRD 74, 034018 (2006)*



✓CR acceleration up to several PeV is possible by shock wave acceleration mechanism at SNR
✓Knee-4PeV: of galactic origin!?

γ-ray energy spectrum

✓ CR + ISM→π^0 + …→2γ
✓ γ & ν produced with $E_{\gamma\&\nu}$ ~O(1/10 Ep_{max})

PeVatron = CR accelerator up to PeV region
Should be in our galaxy or very nearby extragalaxy, due to photon absorption!

Why in Bolivia

- Flat land at high altitude: (> 4000m)

  Cosmic rays absorbed in atmosphere before reaching sea level

- Galactic Center: Observable in the southern hemisphere (not in the northern hemisphere)

  Most promising candidate of the origin of cosmic rays

- Long-term collaboration between Bolivia and Japan (Good infrastructure: Electricity, water, road,...)

  Since 1962 in the field of cosmic rays, for example, BASJE

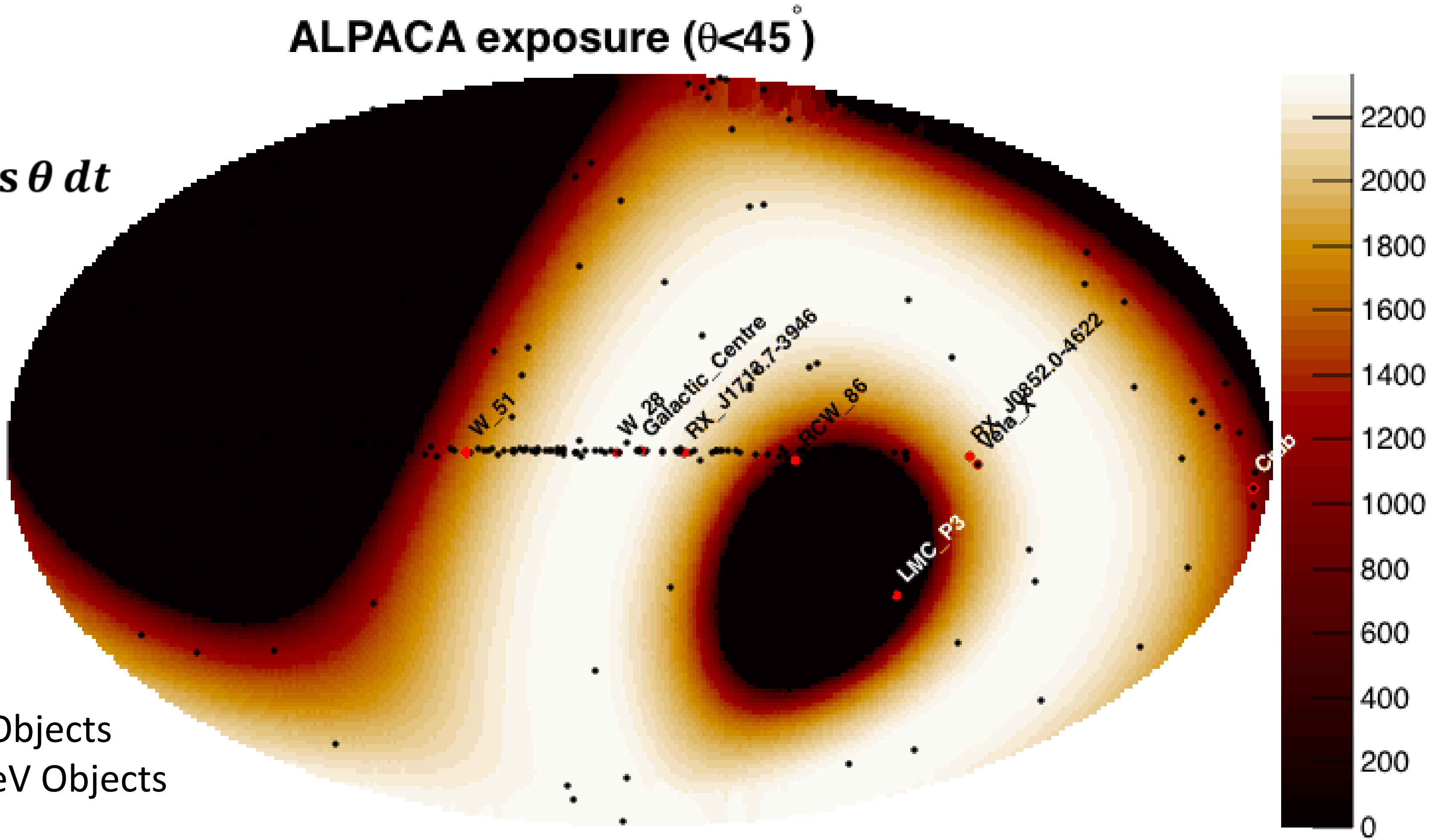
Experimental Cite : Cerro Estuqueria

（500m x 500m flat within ~+- 1 deg.)

4,740 m above sea level (16˚23’S, 68˚08’W)

ALPACA exposure (hours/year)

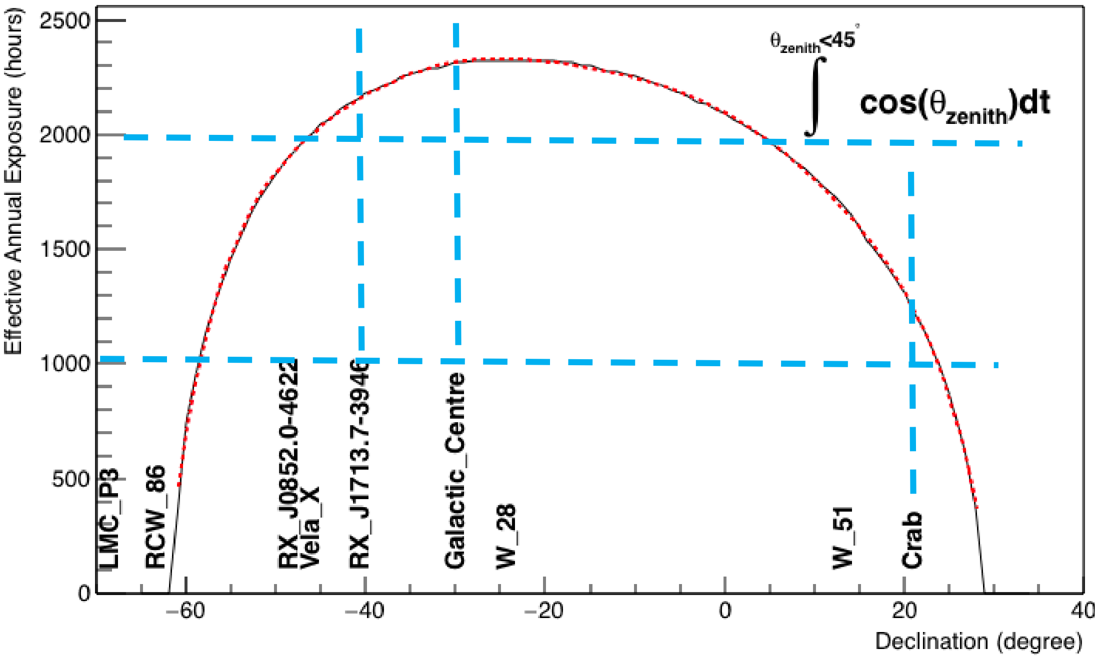
$$\int^{\theta<45^\circ} \cos\theta \, dt$$



- TeVCat Objects
- Major TeV Objects

- Assuming θ<45°
- Geometrical decrease (cosθ) is taken into account

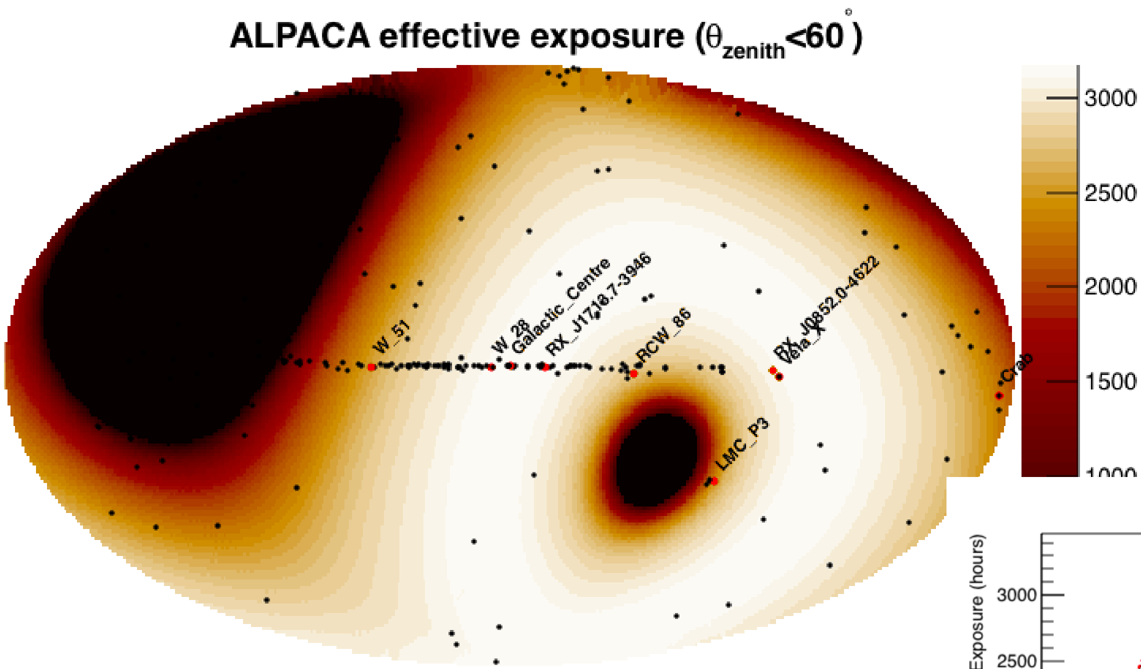
ALPACA exposure (hours/year)

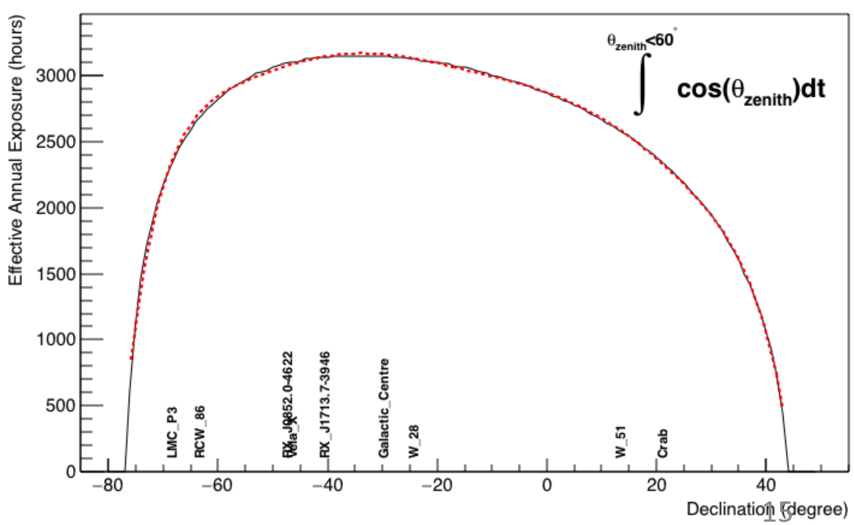


Object name	Declination (degree)	Exposure (hours/year) $\theta < 45°$	$\theta < 60°$
Crab	22.0	1171	2299
W51	14.2	1634	2565
W28	-23.3	2331	3125
Galactic Center	-29.0	2322	3162
RX J1713.7-3946	-39.8	2176	3154
Vela	-45.6	2016	3099
RX J0852.0-4622	-46.4	1989	3090
RCW86	-62.4	0	2759
LMC	-67.6	0	2438

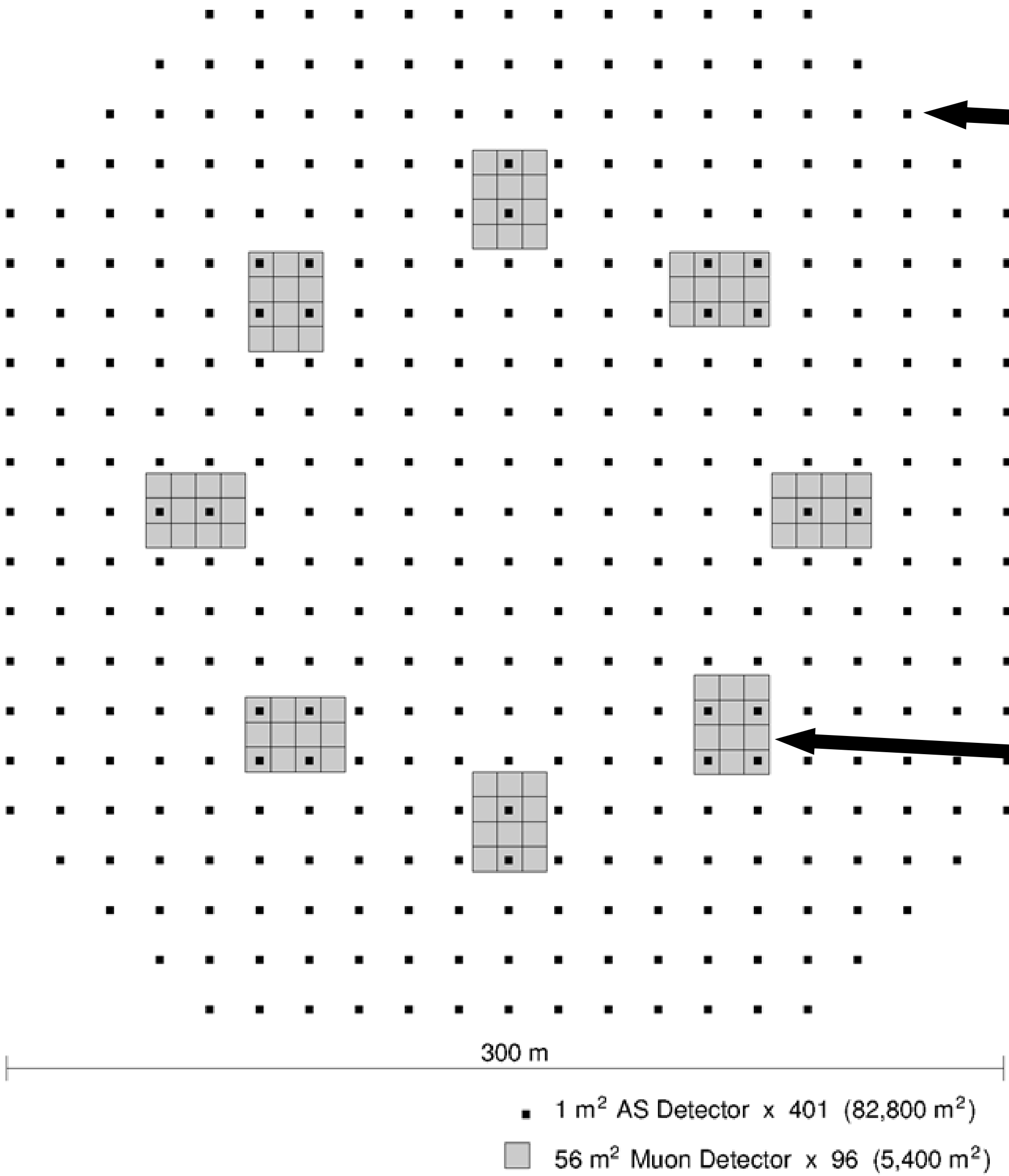
- Galactic Center, RX J1713 : >2,000 hours/year (θ<45°)
- >1,000 hours/year for Crab
- θ<60° allows 3000 hours/year
    - Effects on threshold energy, resolution must be studied

ALPACA exposure (hours/year) θ<60°





Schematic view of ALPACA



Air Shower Array

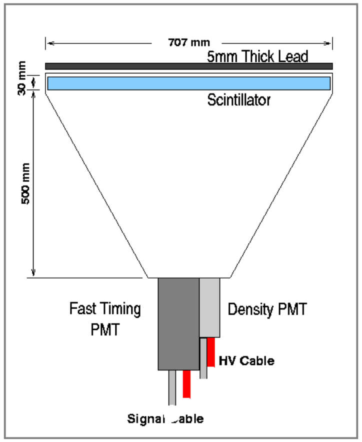


Image of 1m^2 plastic scintillation detector

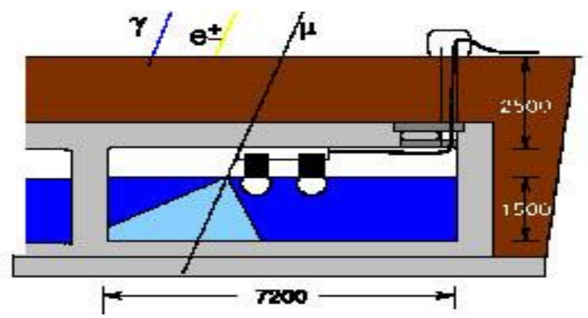


Image of unit (56m^2) underground water Cherenkov muon detector

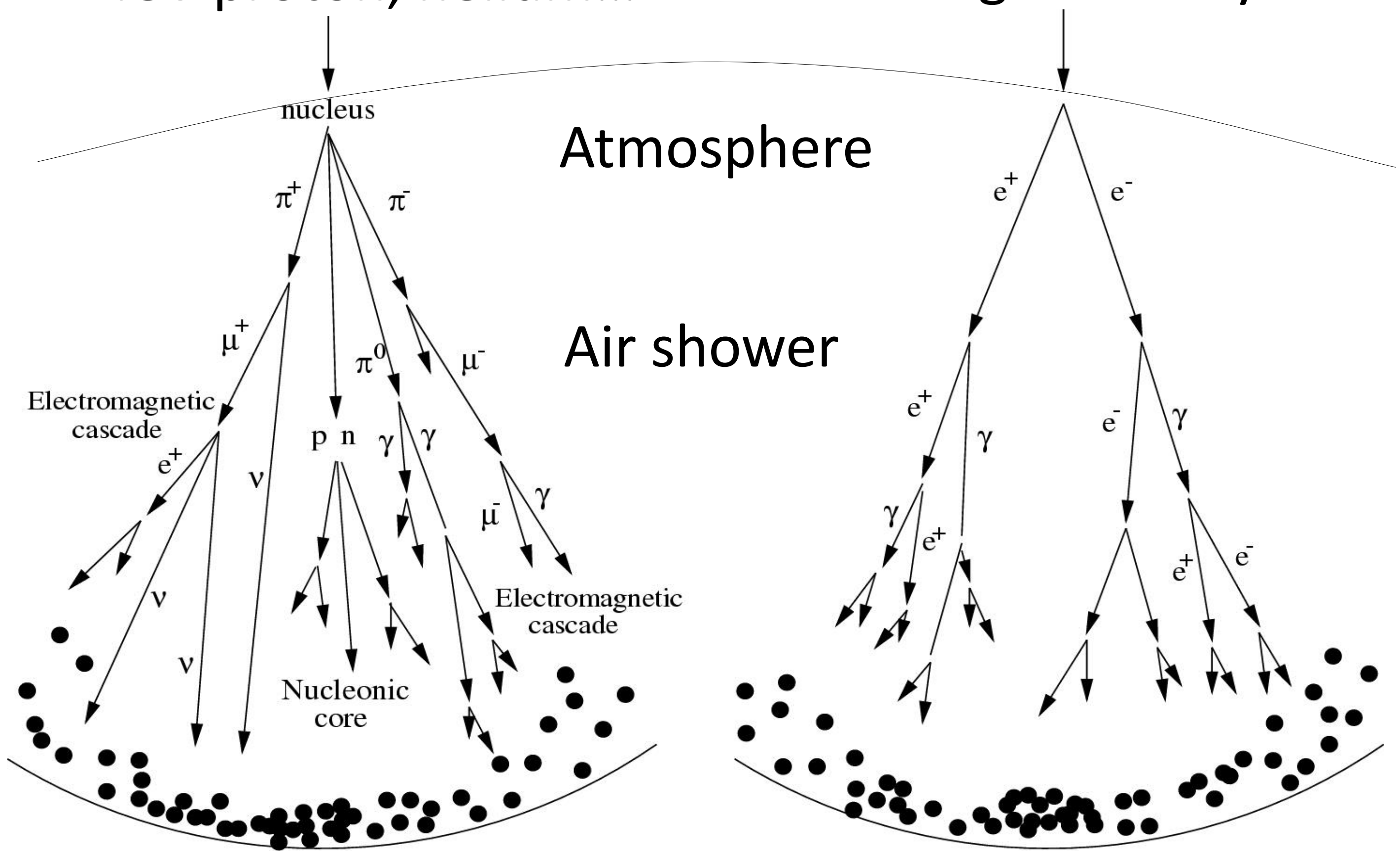
Performance of ALPACA air shower array

Location:	4,740 m above sea level (16°23'S, 68°08'W)
# of scintillation detectors	1 m^2 x 401 detectors
Effective area	~83,000 m^2
Modal energy	~5TeV
Angular resolution	~0.2° @100 TeV
Energy resolution	~20-25% @100TeV
Field of view	~2 sr

p/γ discrimination by counting # of muons

TeV proton, helium…

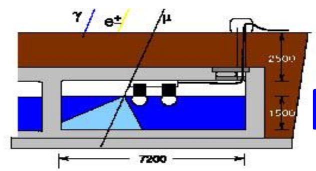
TeV gamma ray



# of muon within <100m from core

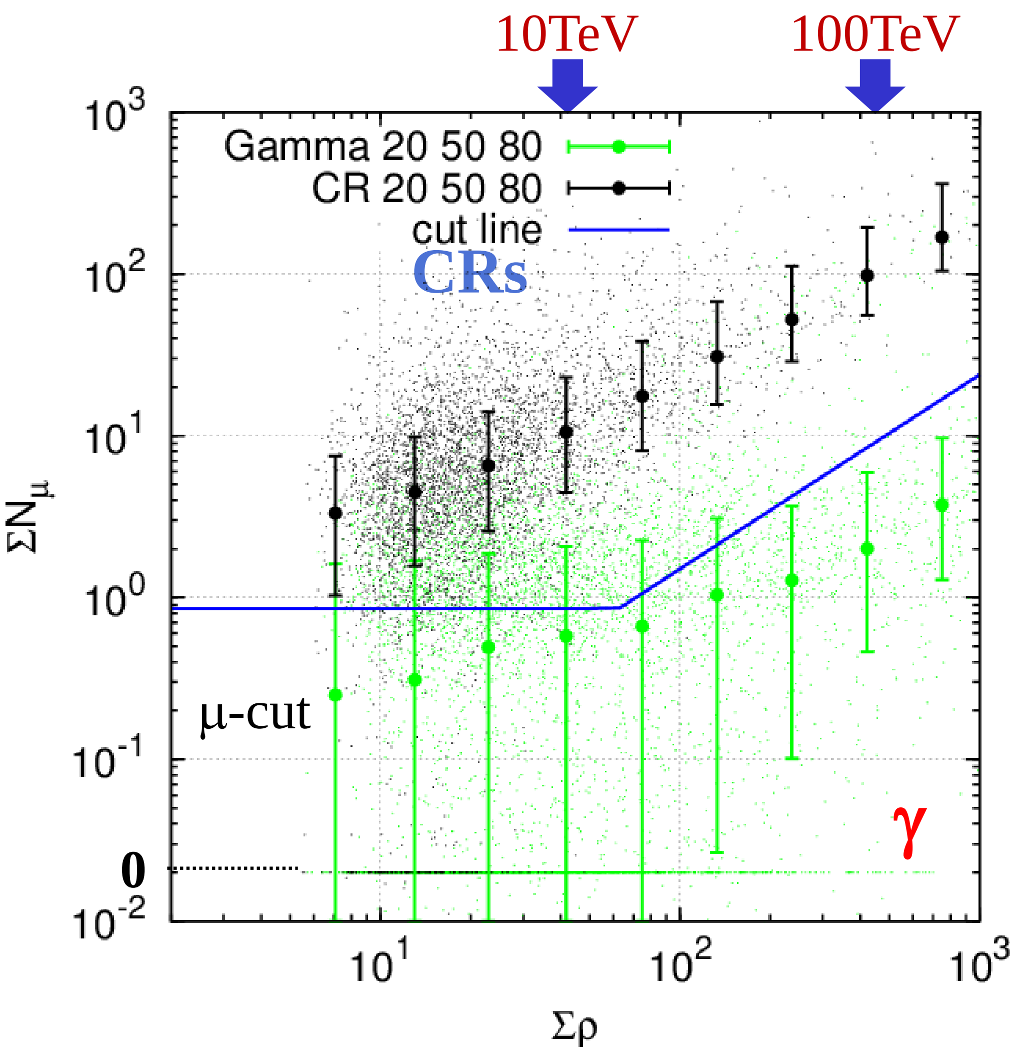
~ 50 μ for 100 TeV proton

~ 1 μ for 100 TeV γ



Muon detector

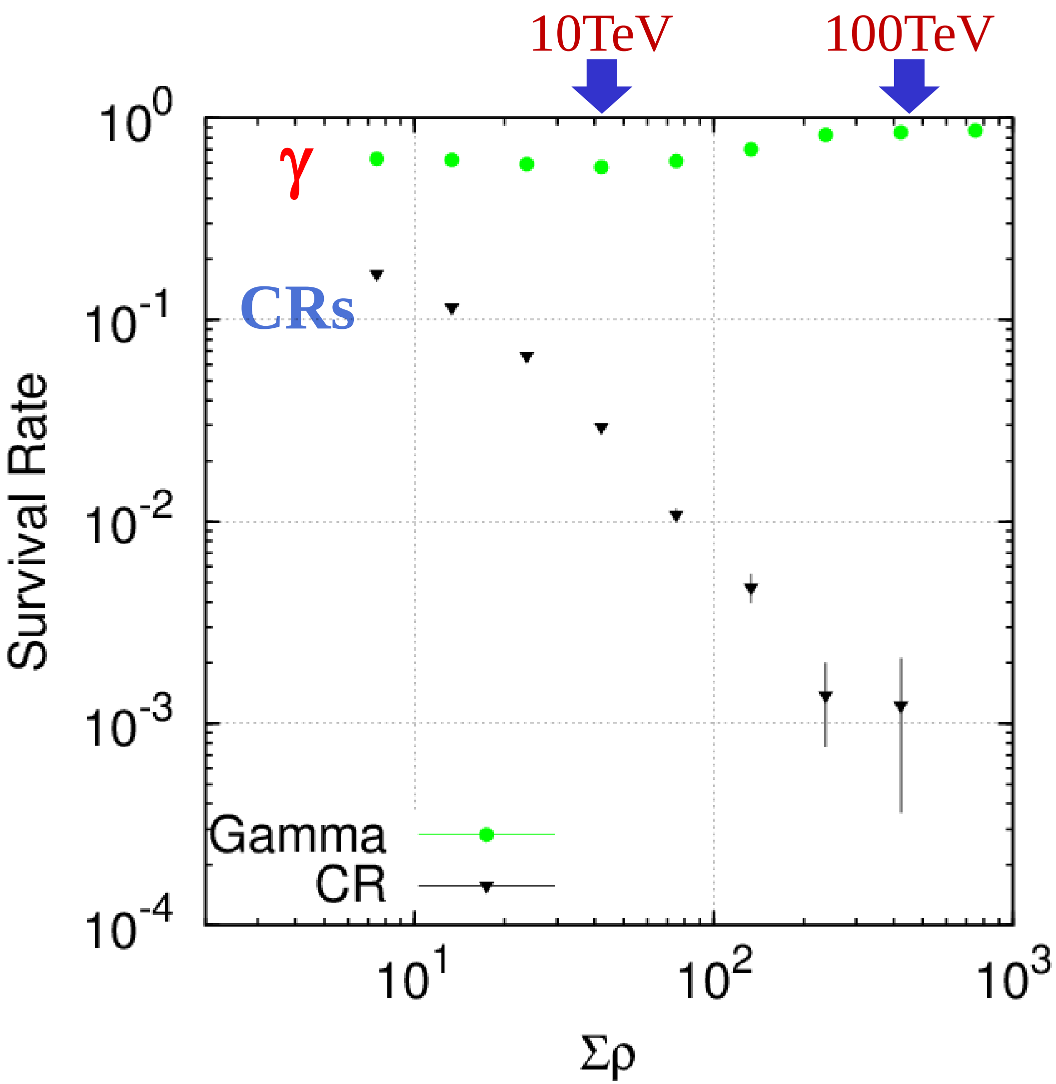
of Muons vs. Energy



ALPACA full MC simulation
(AS 83000m^2 + MD 5400m^2)
Muon cut optimized, assuming
Crab-like spectrum at δ=-30°

- ✓ Half of γ-ray events below 10 TeV have no muon signal (No muon events are plotted as 0.2)
- ✓ Blue lines indicate optimized muon cuts

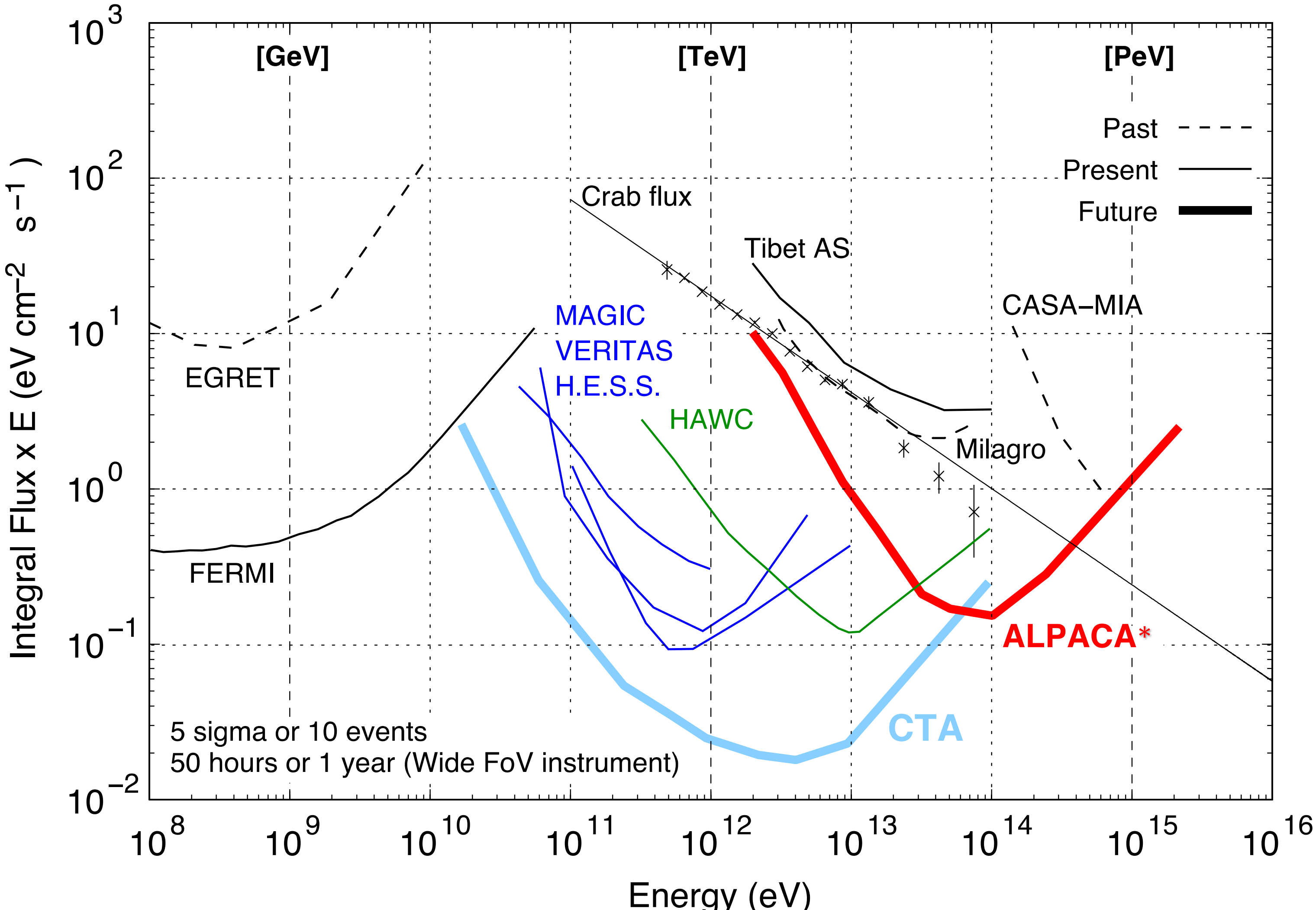
Survival Ratio After Muon Cut



ALPACA full MC simulation
(AS 83000m^2 + MD 5400m^2)
Muon cut optimized, assuming
Crab-like spectrum at δ=-30°

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

ガンマ線点源に対する感度



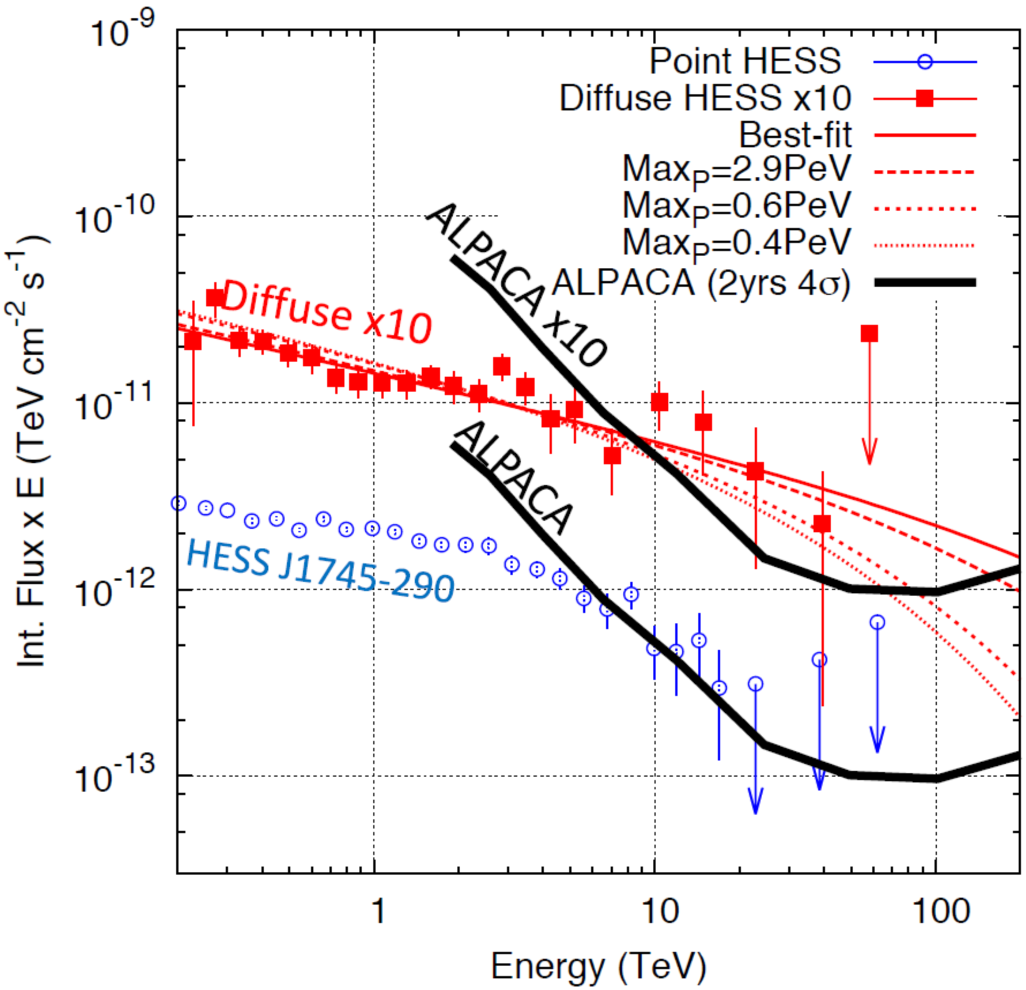
CTA Review by Kubo (JPS 2015)
M.Daniel, Proc. of 28th Texas Sympo. (2015)

*Based on MC Simulation
For the Tibet AS+MD

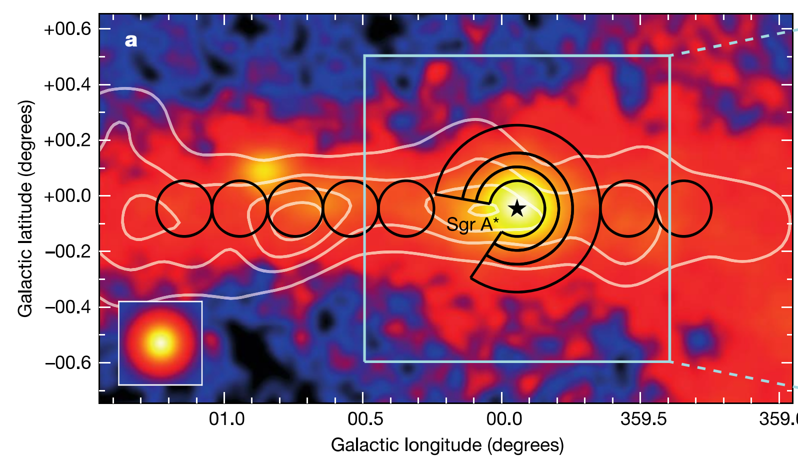
Target γ Sources

- Galactic Center
- Fermi Bubbles
- Young SNR
- Other Galactic Point-like Sources
- Nearby Extragalactic Sources

Galactic Center as PeVatron?



- ✓ Detection of diffuse component
- ✓ >100TeV γ−ray expected
- ✓ PeVatron candidate

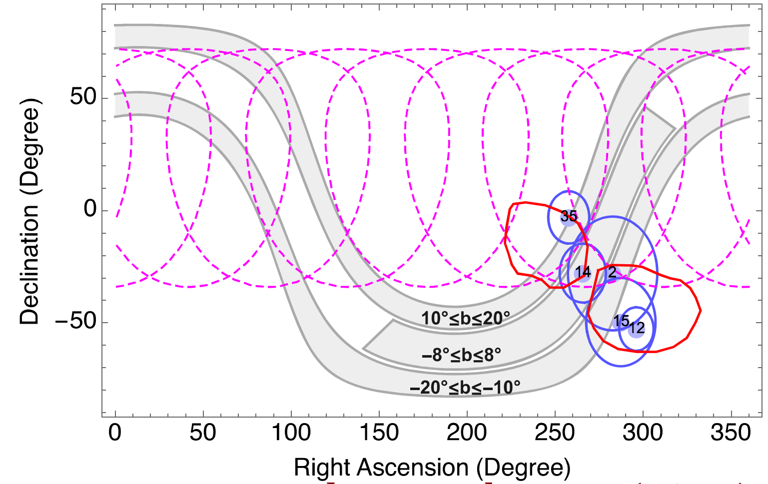


Abramowski, et al, Nature (2016)

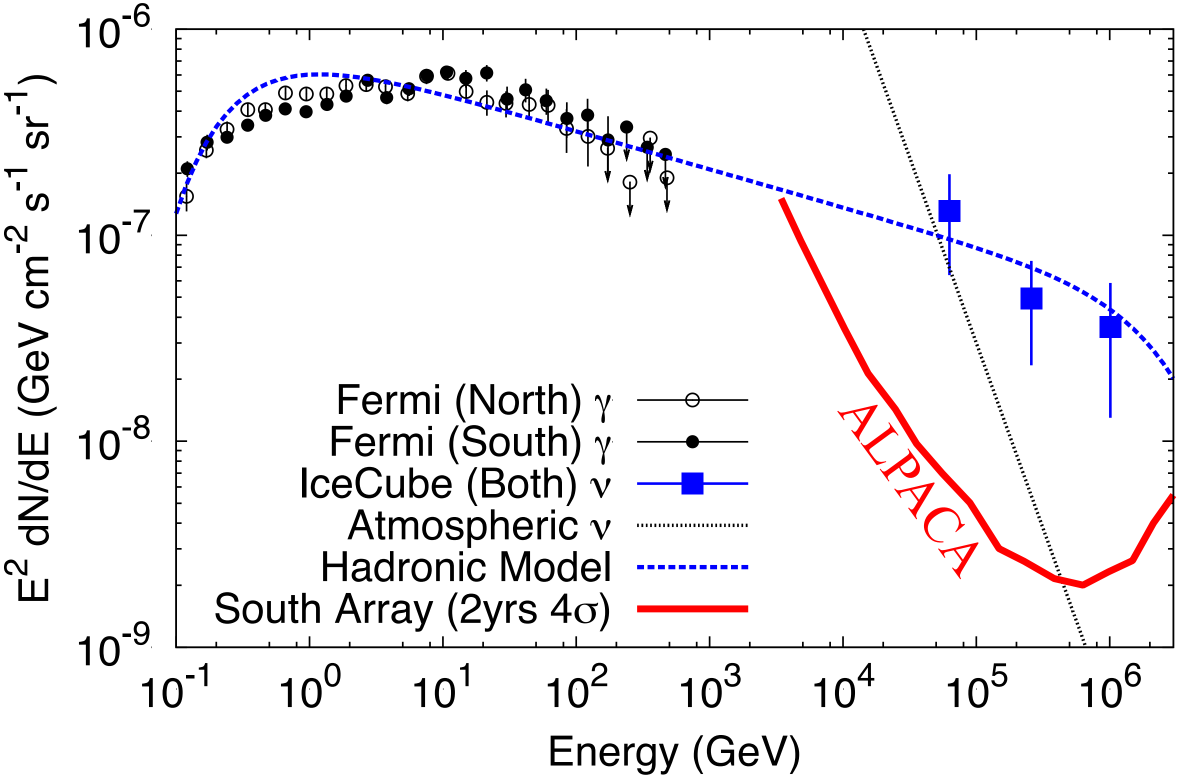
$\delta \sim -29°$

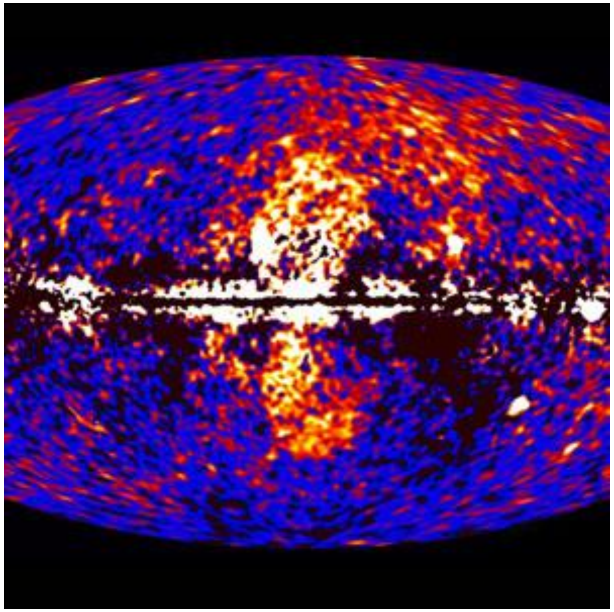
Fermi Bubbles

- ✓ sub-PeV γ rays expected, if sub-PeV ν's detected by IceCube are of hadronic origin.
- ✓ Fermi Bubbles: Very extended (~0.8sr) γ-ray sources difficult for IACTs to cover them all.



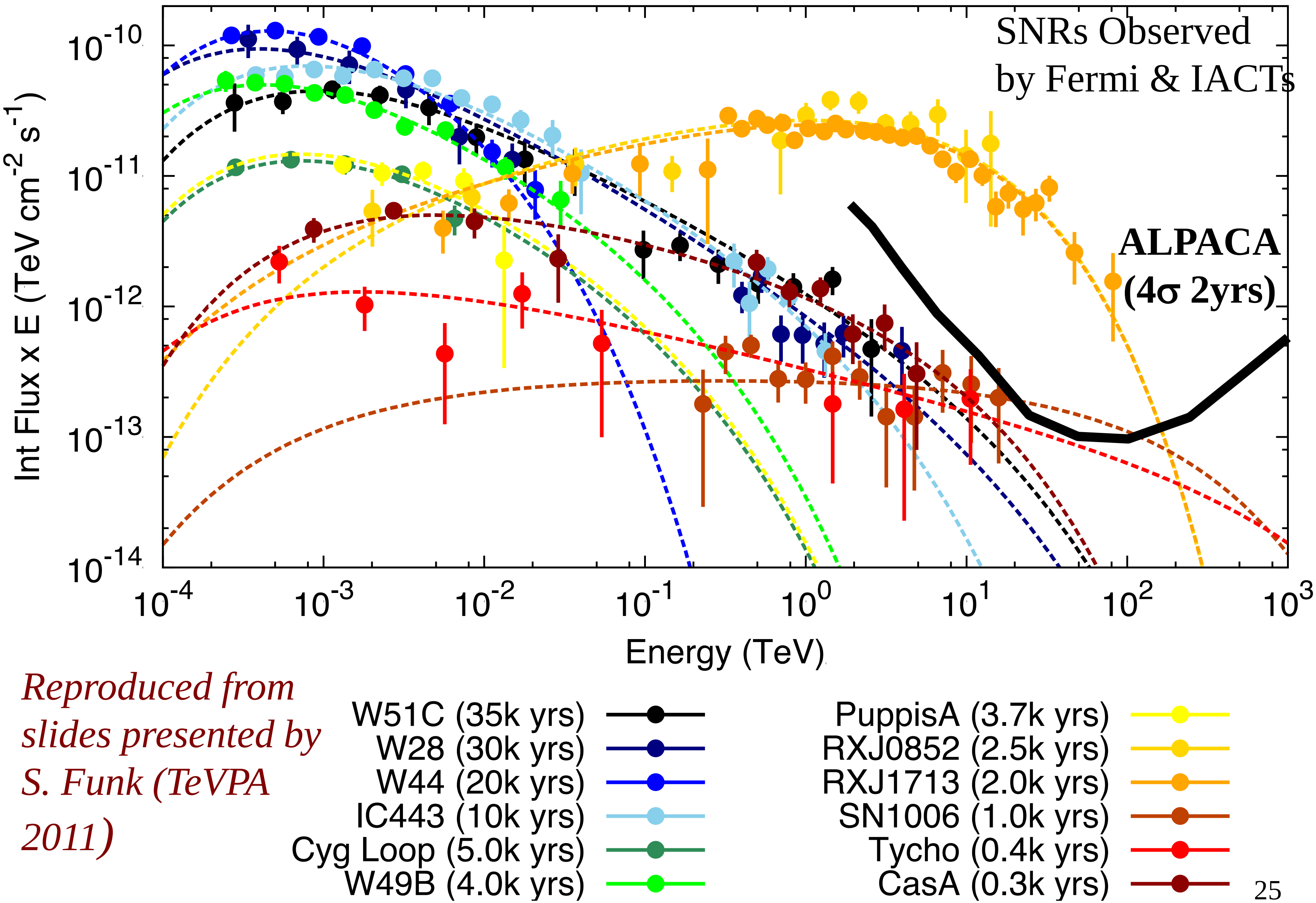
C. Lunardini, et al, PRD (2015)





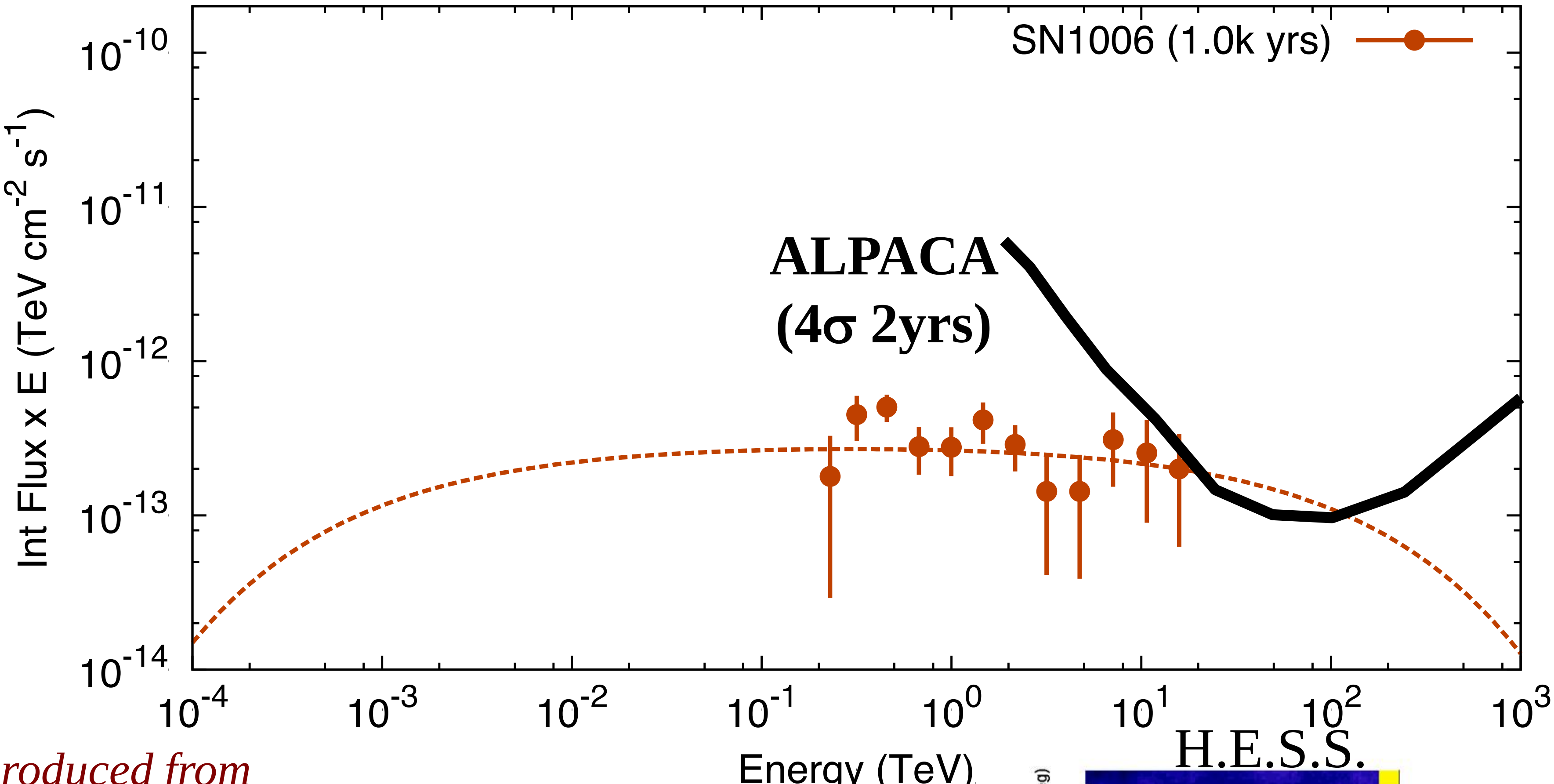
Bubbles observed by Fermi-LAT

Young SNRs

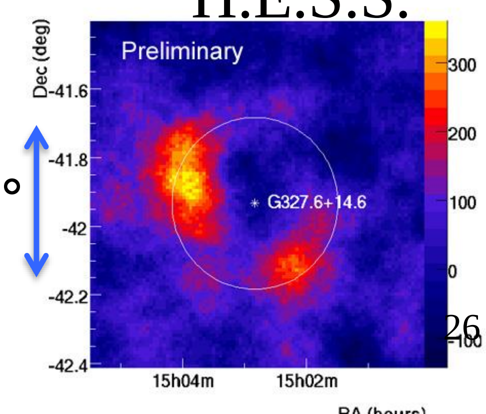


Reproduced from slides presented by S. Funk (TeVPA 2011)

Young SNRs



H.E.S.S.



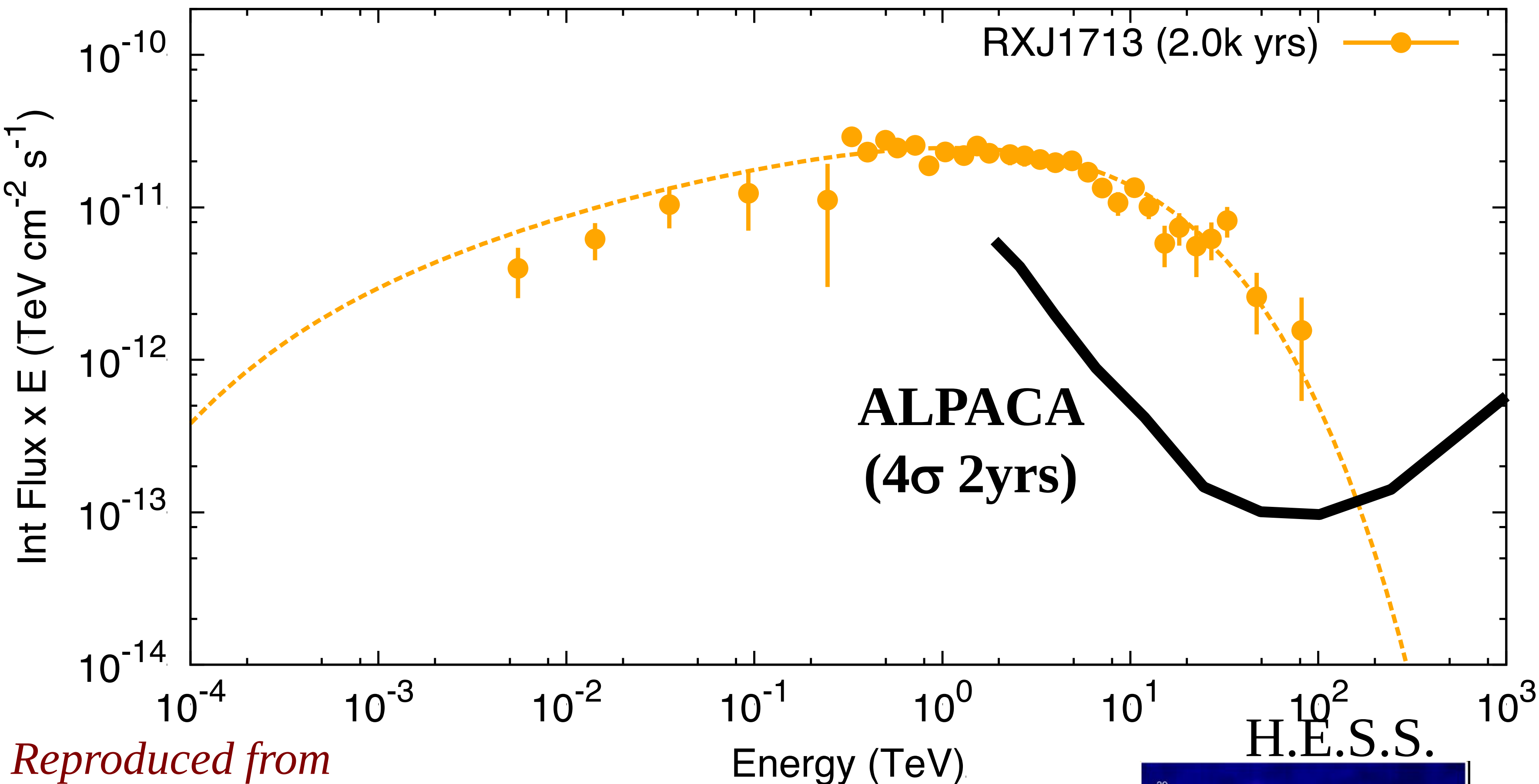
0.4°

Reproduced from slides presented by S. Funk (TeVPA 2011)

SNRs Observed by Fermi & IACTs

δ ~ -42°

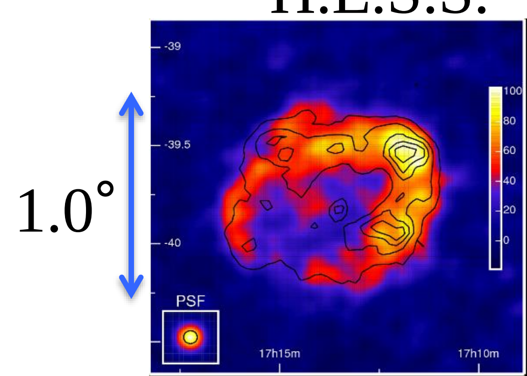
Young SNRs



Reproduced from slides presented by S. Funk (TeVPA 2011)

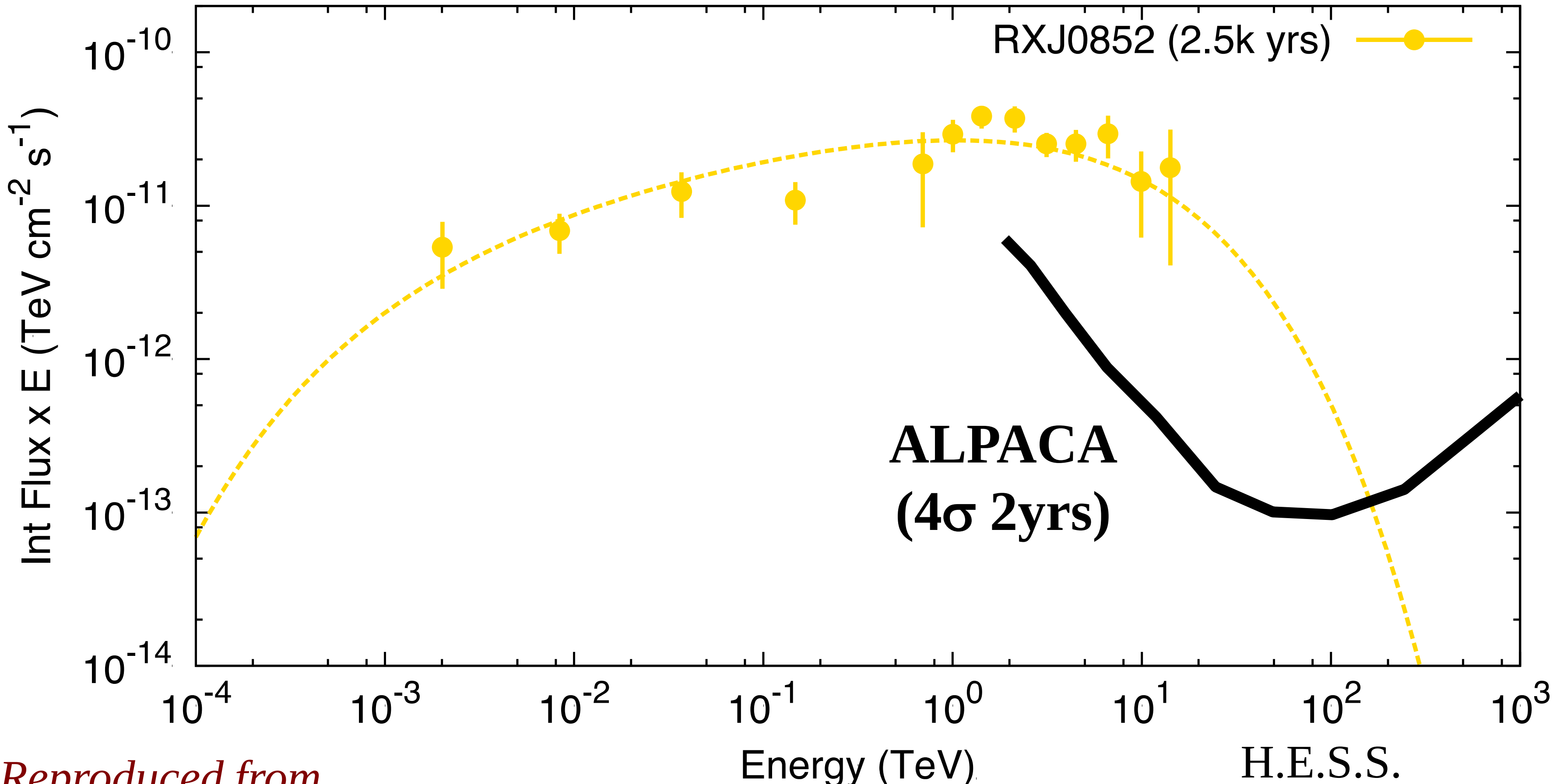
SNRs Observed by Fermi & IACTs

H.E.S.S.



δ ~ -40°

Young SNRs



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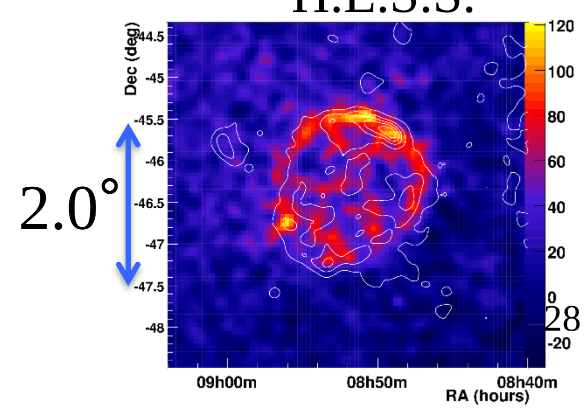
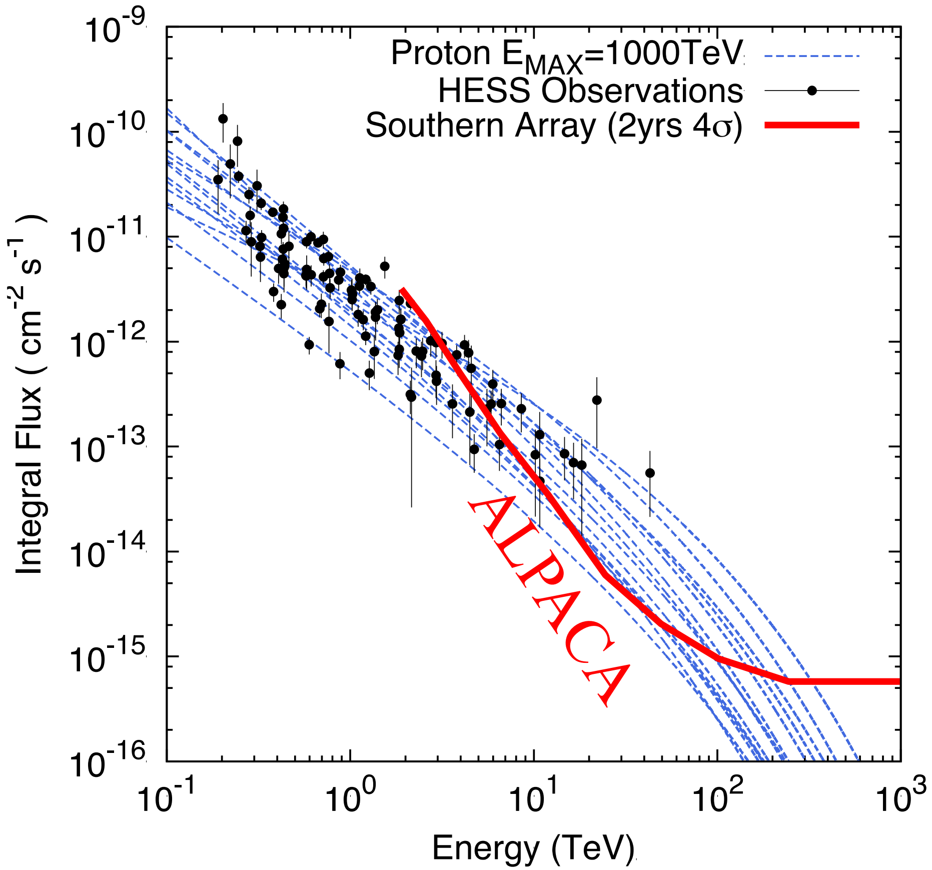
H.E.S.S.



SNRs Observed by Fermi & IACTs

$\delta \sim -46°$

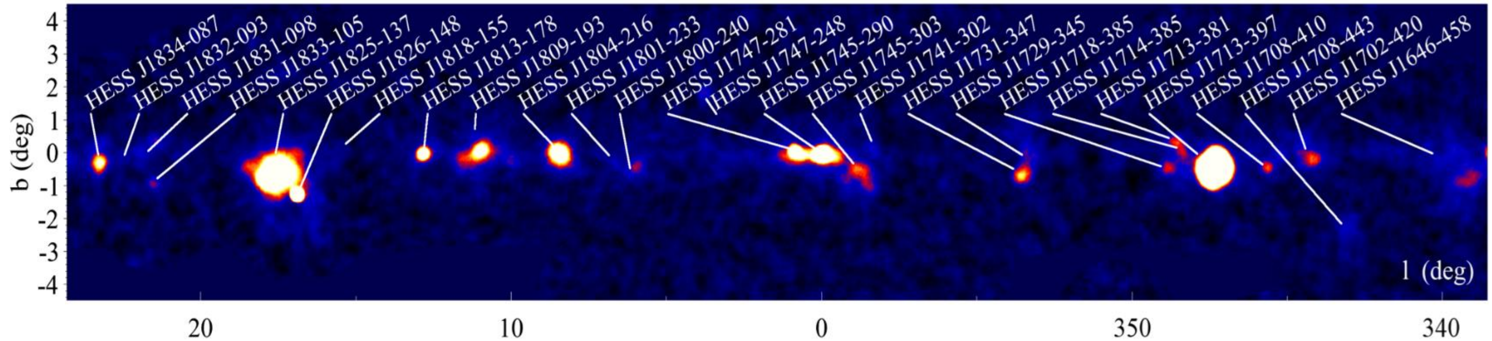
Other Galactic Sources



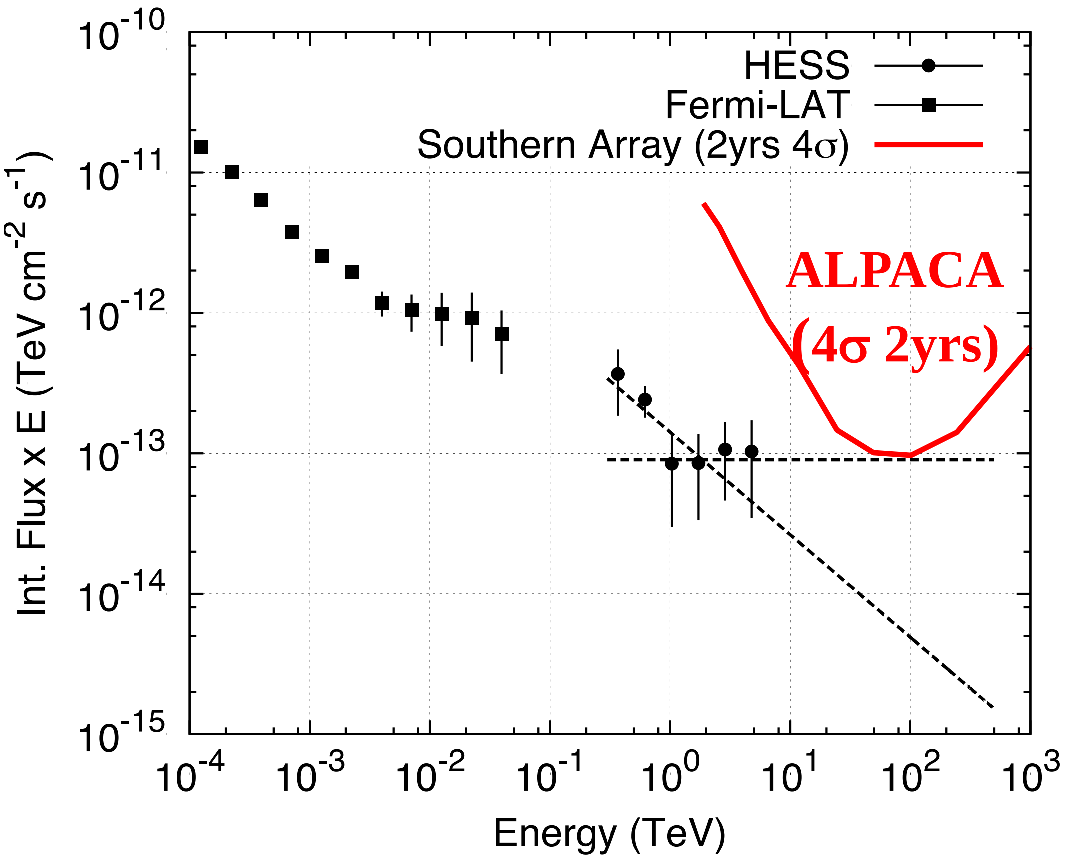
- ✓ More than dozen sources
- ✓ Many sources are dark in other wave length
  → Dark particle accelerator
- ✓ Many candidate of PWN (excess is located near pulsar)

Aharonian et al, ApJ, 636, 777 (2006)

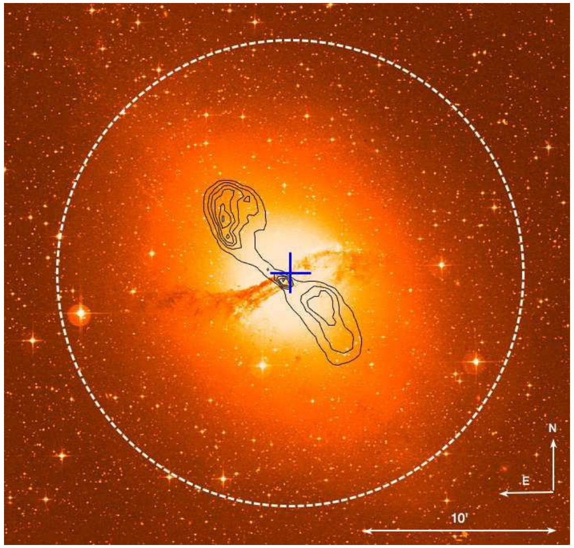
- ✓ Diffuse γ from Galactic plane



Nearby Extragalactic Source CenA



- ✓ Distance: 3.8Mpc very nearby!
- ✓ Relativistic jet
- ✓ Flat spectrum above TeV region?
- ✓ No significant time variation?



Aharonian et al, ApJ, 695, L40 (2009)
Sahakyan, et al, ApJ, 770, L6(2013)

$\delta \sim -43^\circ$

Other research themes

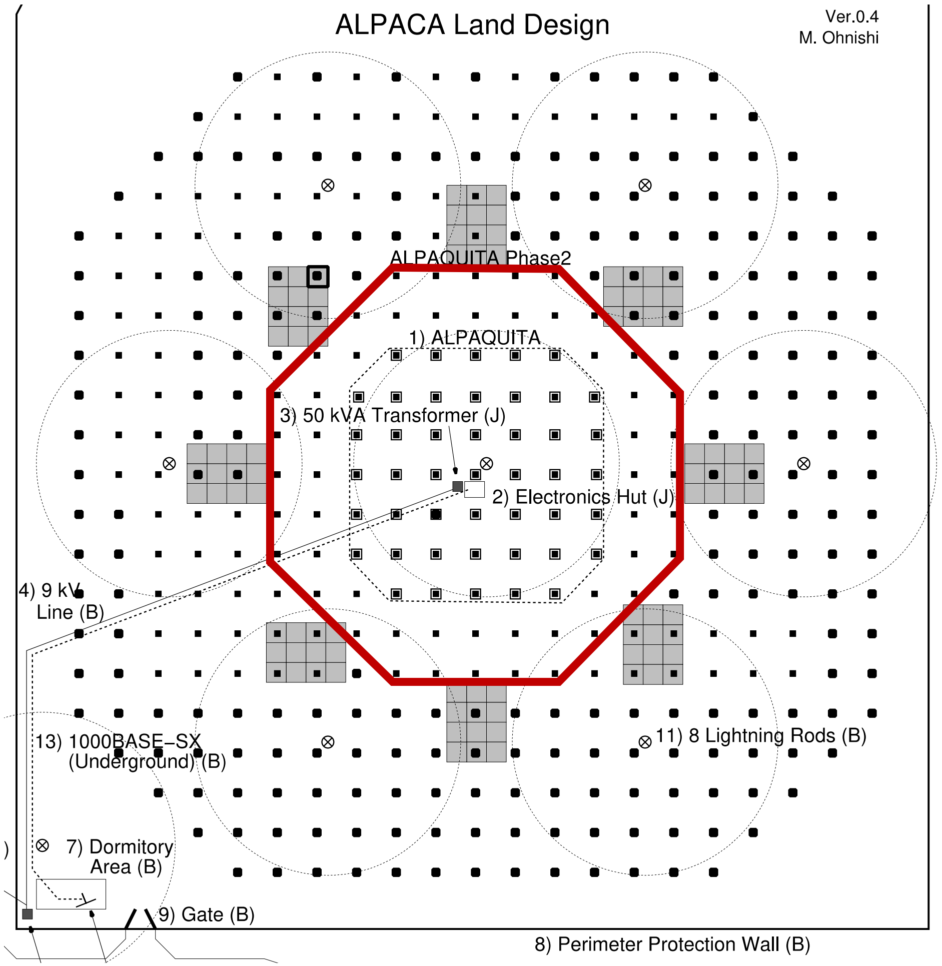
- CR anisotropy @ >TeV region in south
  (Complementary to IceCube)

- The Sun's shadow in south

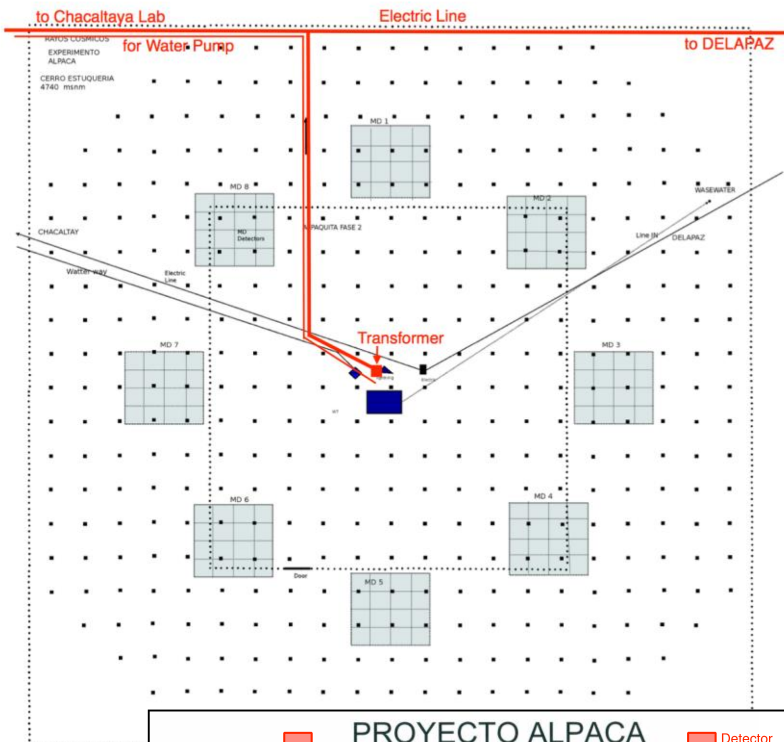
- Chemical composition of VHE CR (Knee)
  （AS+MD cf: Other AS experiments &LHC-f）

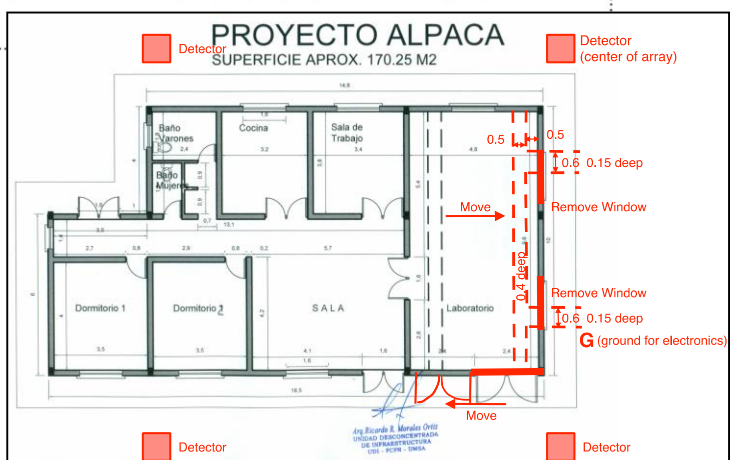
ALPAQUITA

- 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
  - Sun shadow
  - CR Anisotropy (TeV region)
  - Bright gamma-ray sources?



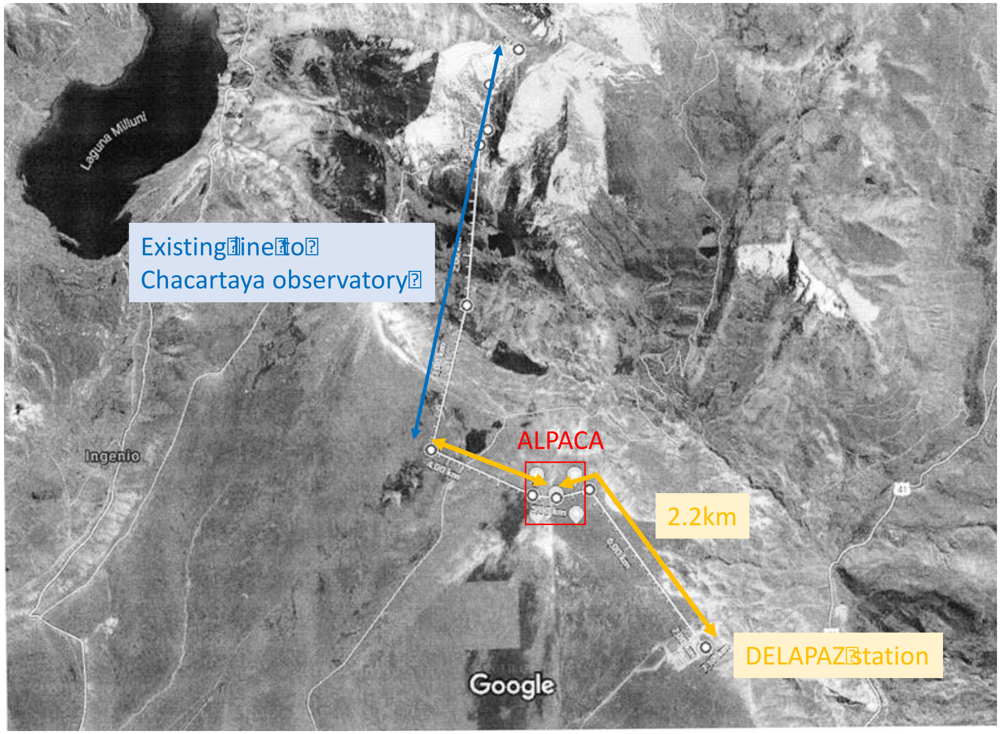
ALPAQUITA & infrastructure

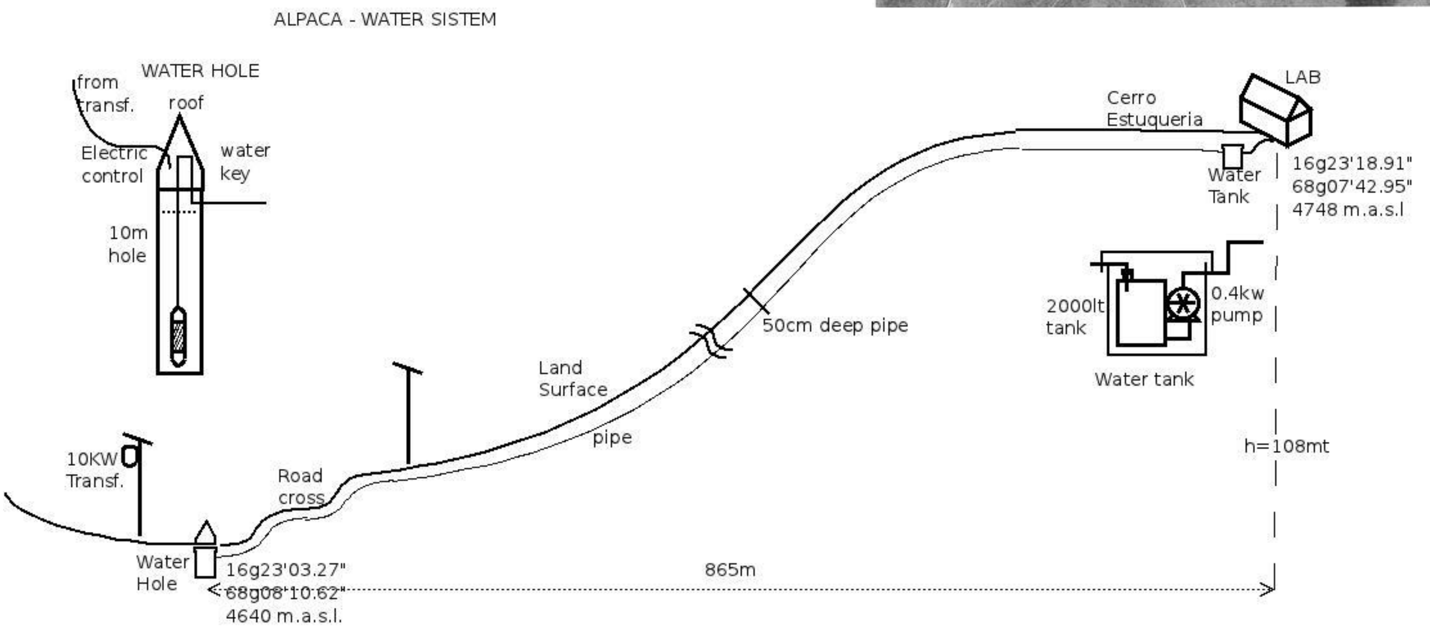




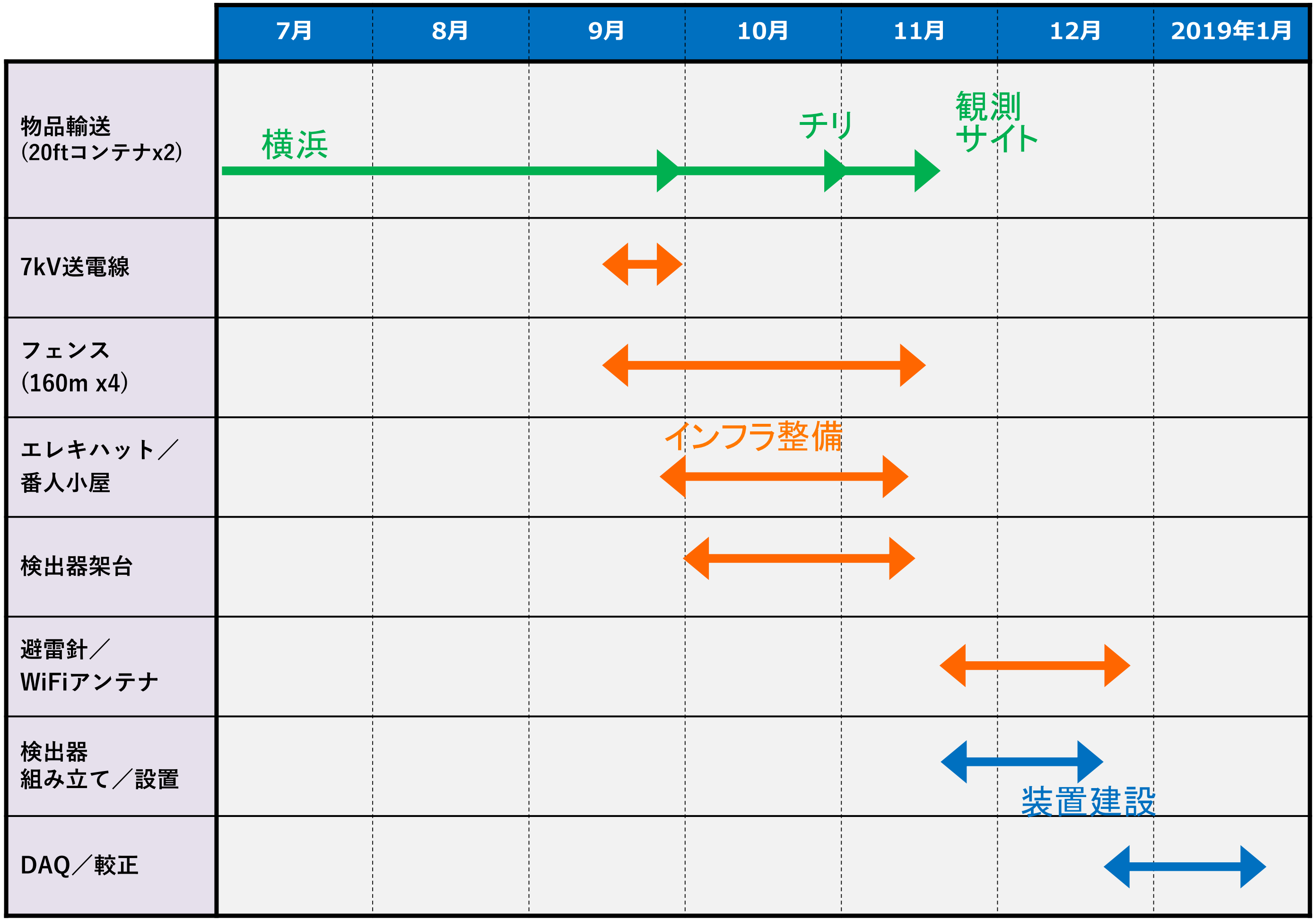
- Refurbish power line to the Chacartaya observatoty
- Fence
- DAQ room, workshop and guardians hut
- Water system for life and MDs

Power and water





ALPAQUITA schedule



- 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

Southern Gamma-ray Survey Observatory (SGSO) alliance

https://www.sgso-alliance.org/SGSOWiki/doku.php : メーリングリストは誰でも参加可

- 南半球高山に空気シャワーアレイを作り、24時間広視野ガンマ線観測を提案するグループの集まり
  - HAWC, LATTES, ALTO, STACEX, ALPACA
- 具体的なサイト、装置デザインは未定
  - 各小グループがそれぞれの特徴を紹介し合っている段階
  - GEANT4 codeを共有して最適検出器を検討する方向
  - ALMAサイト、アルゼンチンのQUBIC(CMB実験)サイト、等を検討
- 活動内容
  - サイエンスケースをまとめた white paperを準備中
  - 2020年の decadal surveyにサイエンスとしての重要性掲載を目標
  - 国際協力で「一つの」理想的な装置を作ろう
  - CTA Southと予算競合しないように
- ALPACAとの関係
  - SGSOの一員である。high energyに特化して一歩先に進んでいる。
  - ALPACAをSGSOのR&D拠点にする？

Thank you for your attention!

ALPAQUITA (~2/10 AS) will be constructed in FY2018

Summary

ALPACA:

1)Experimental site: 4740m above sea level, near La Paz in Bolivia

Expected budget -> ~5 M USD AS+MD + Running=5 + 1 億円

Muon Detector ～ 5400m^2 (underground water Cherenkov type)

AS Array ～83,000m^2 (~ 401 x 1m^2 plastic scintillation detectors)

2) Target physics and astrophysics (AS + MD)

10-1000TeV γ astronomy (point & extended sources, PeVatron, etc)

CR anisotropy, Sun shadow, CR chemical composition, etc

3) ALPAQUITA (2/10 scale ALPACA AS , in FY2018)

End