The ALPACA experiment

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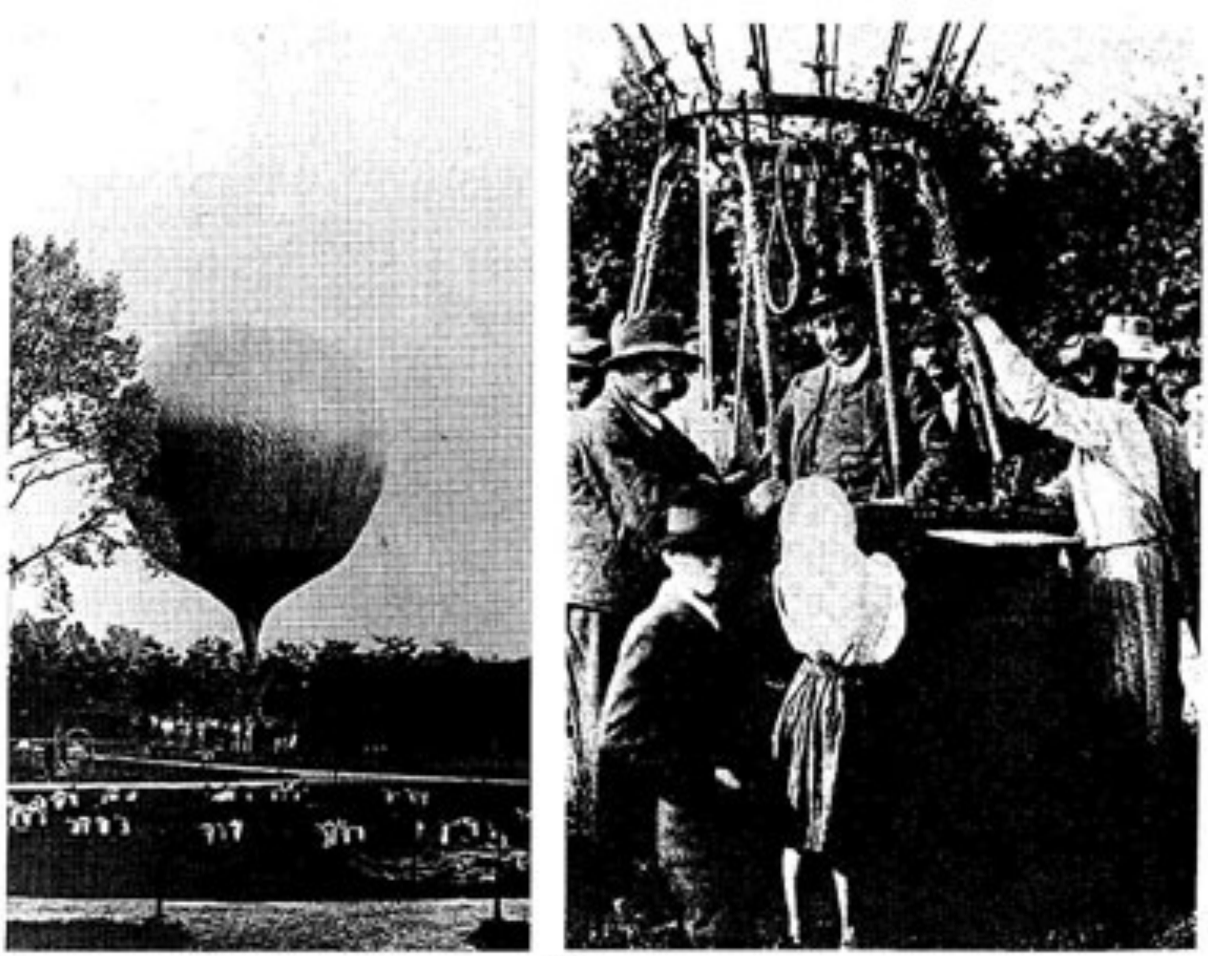
Contents

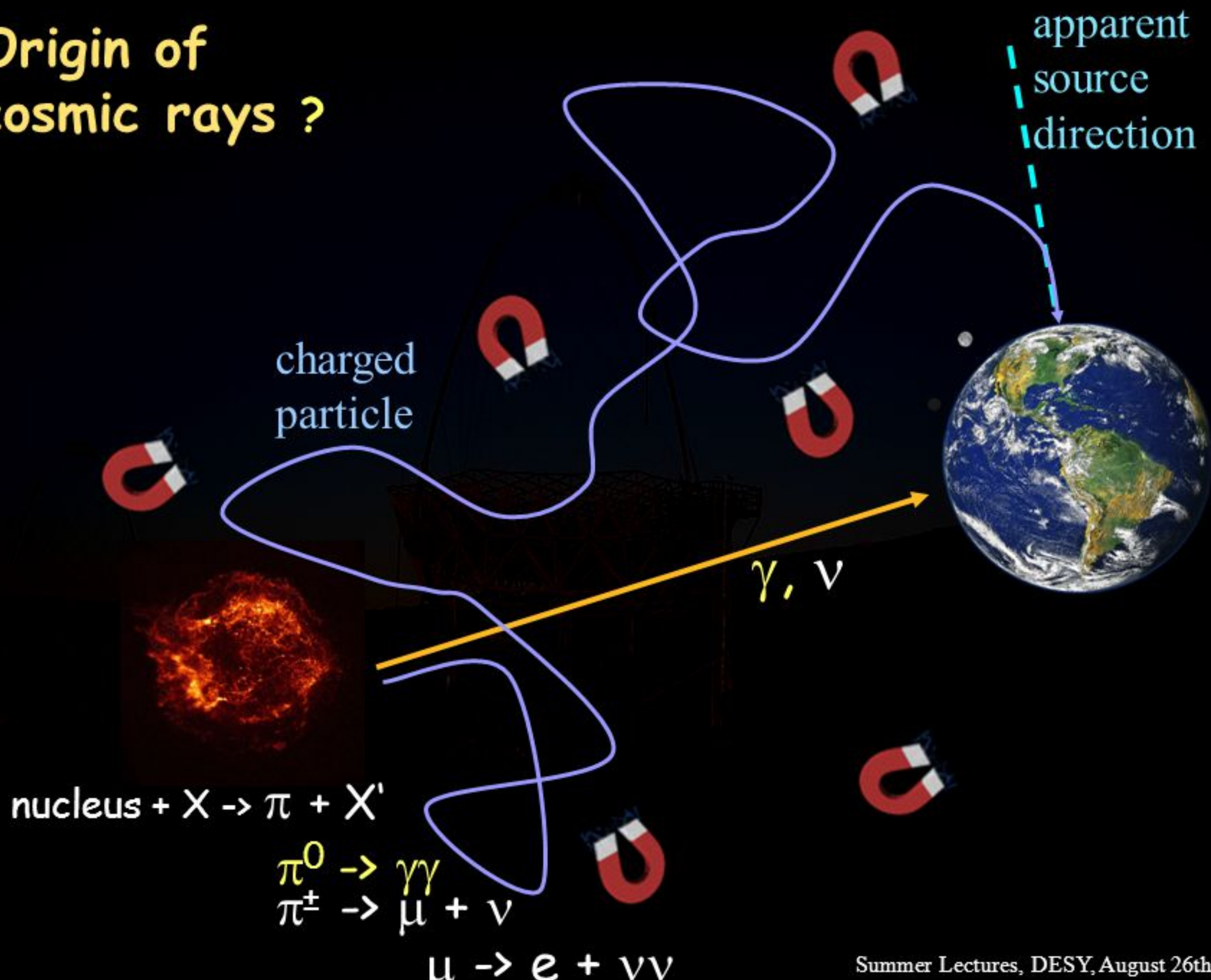
Discovery of cosmic rays by Victor HESS (1912)



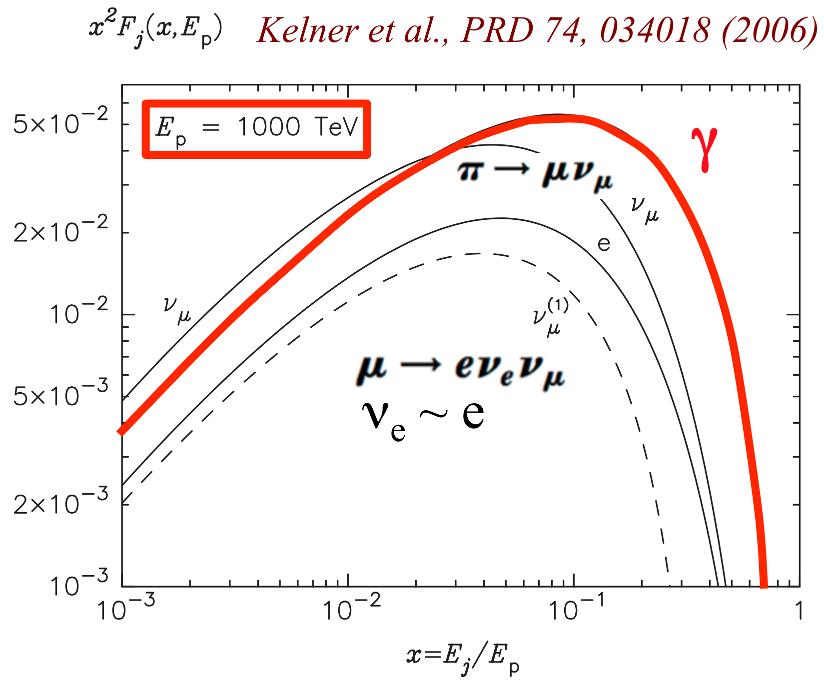
(a) (b)

Cosmic rays: Particles from outer space (H, He, C, N, O,…Fe nuclei)

Origin of cosmic rays ?



Origin of Cosmic Rays at the Knee



CR spectrum

✓ CR acceleration up to >PeV energies is possible by SNR shock waves

γ-ray spectrum

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

10 – 1000 TeV γ-ray observation:
key to locate cosmic-ray accelerators inside our galaxy / very nearby extragalaxy

➡ **ALPACA experiment**

Contents

1) Motivation: 10—1000 TeV γ-ray observation

2) **Overview**

3) Main expected results from the ALPACA experiment

4) Other interesting research subjects

5) Current status

6) Summary

The ALPACA Experiment

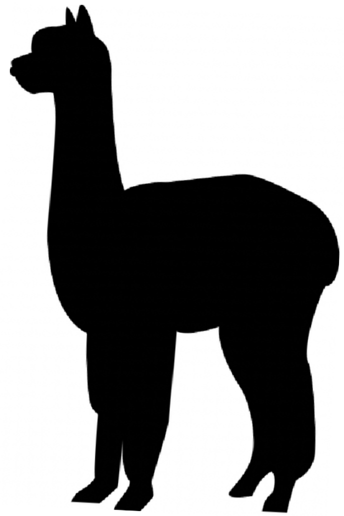
Andes

Large area

PArticle detector for

Cosmic ray physics and

Astronomy



The ALPACA Collaboration

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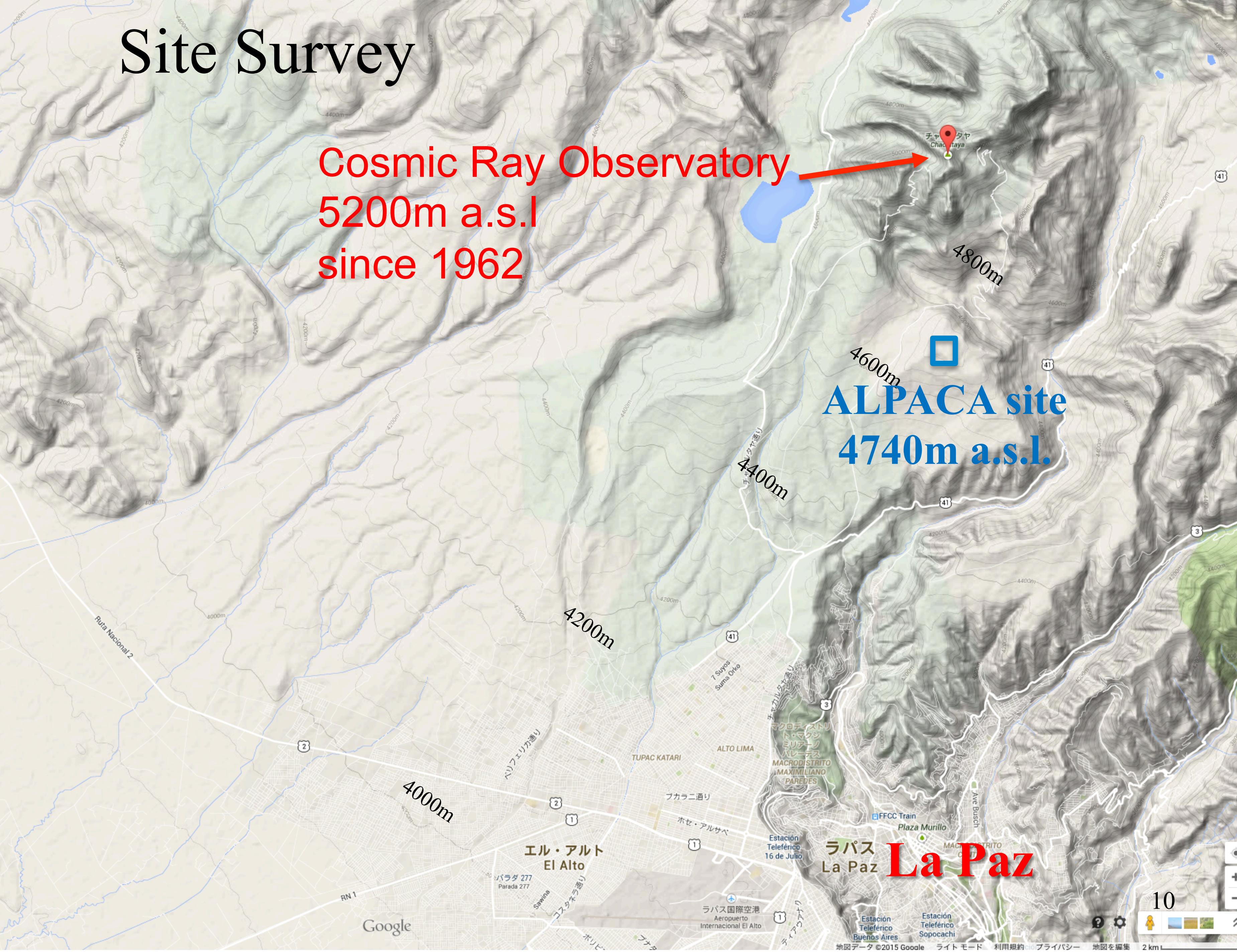
ALPACA Site

Mt. Chacaltaya, Bolivia

Site Survey


Cosmic Ray Observatory
5200m a.s.l
since 1962
4800m
4600m
ALPACA site
4740m a.s.l.
4400m
4200m
4000m
エル・アルト
El Alto
ラパス
La Paz
La Paz
Plaza Murillo
FFCC Train
TUPAC KATARI
ALTO LIMA
Ruta Nacional 2
Google

Experimental Cite : Cerro Estuquería

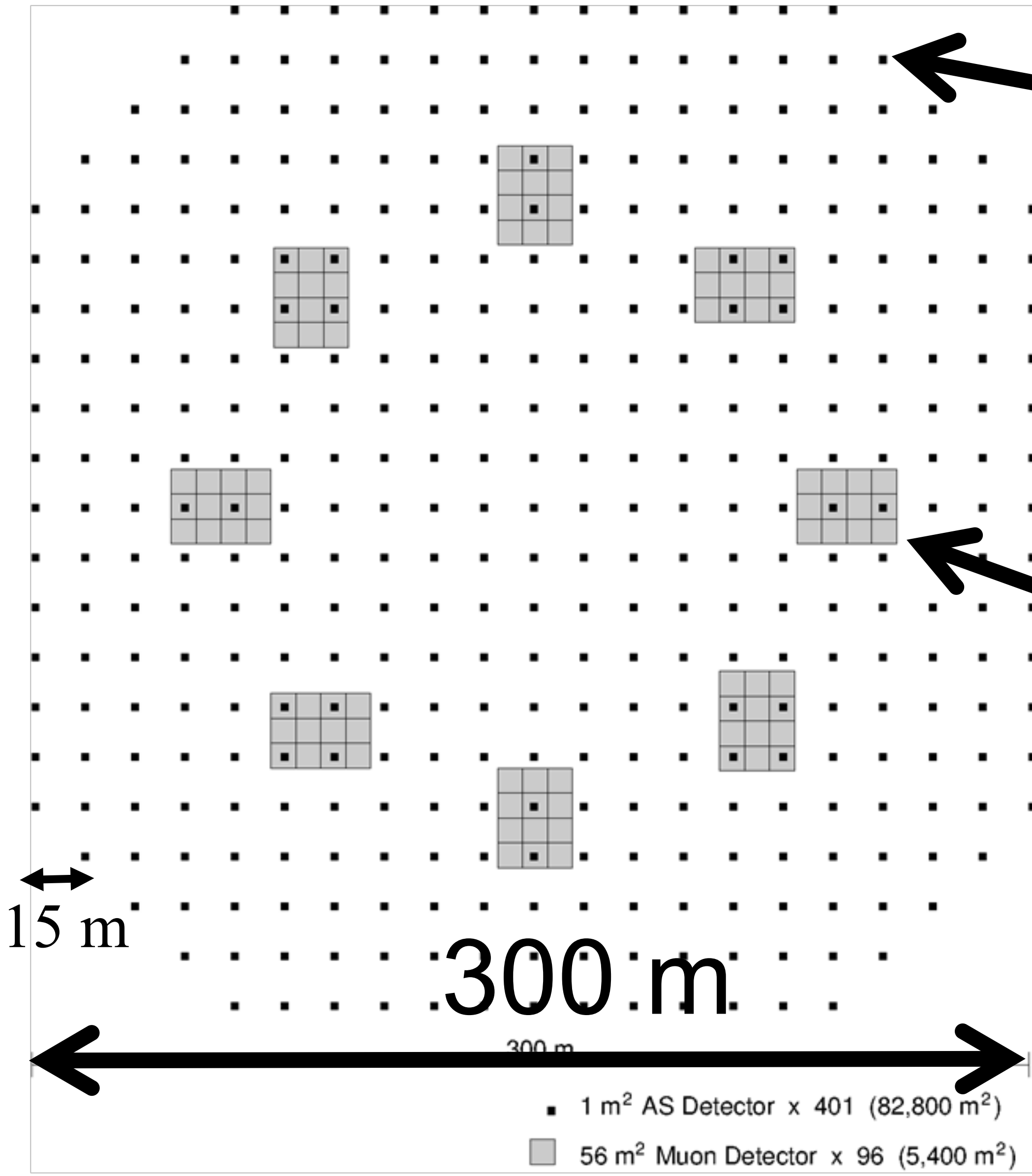
(500m x 500m, flat within ~±1 deg.)

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

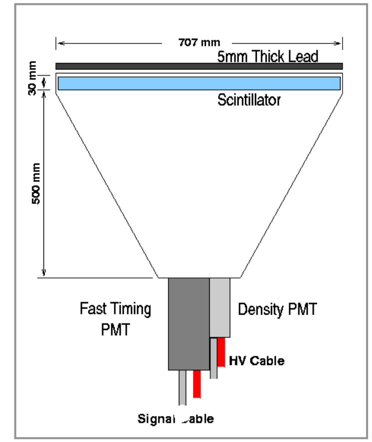
Why in Bolivia

- Long-term collaboration between Bolivia and Japan
  - — Since 1962 in the field of cosmic rays
- Galactic Center observable in the southern hemisphere
  - — Very promising candidate for the origin of cosmic rays
- Vast & flat land at high altitude > 4000m
  - — aiming at air-shower observation above 10 TeV
- Electric power lines easily accessible
- Abundant water for water tanks of the observatory
  - — BG CR rejection for γ-ray observation with high sensitivity

Schematic view of ALPACA

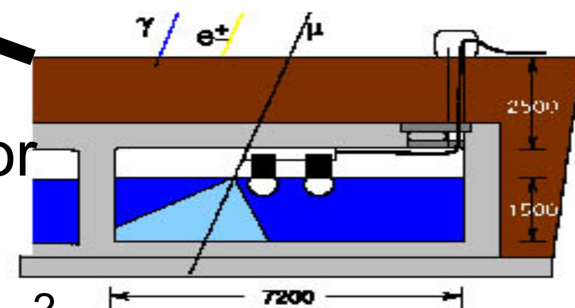


Air Shower Array 83,000 m^2



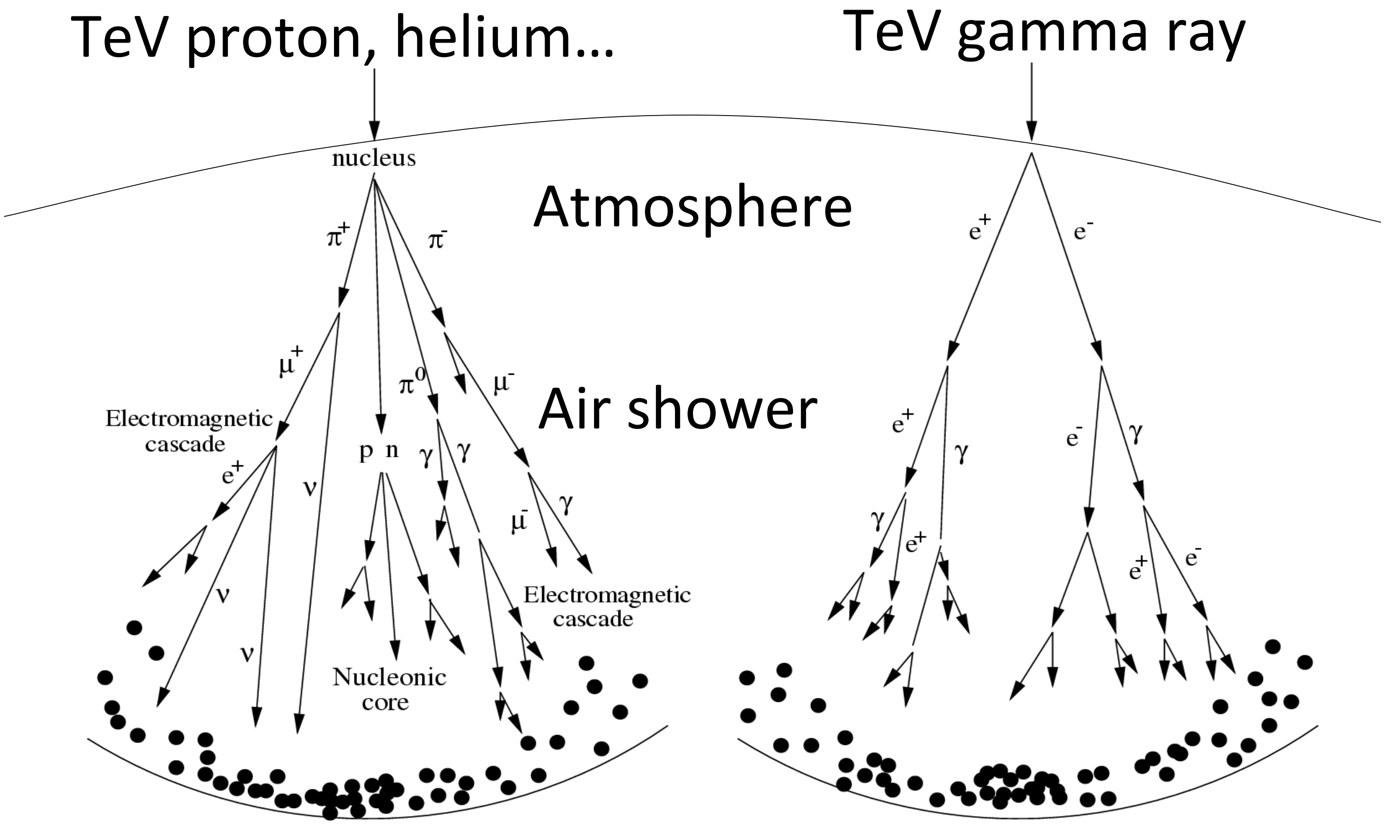
1 m^2 plastic scintillation detector

Muon Detector Array 5,400 m^2



56 m^2 underground water−tank muon detector

MD array: γ/CR discrimination by the number of muons

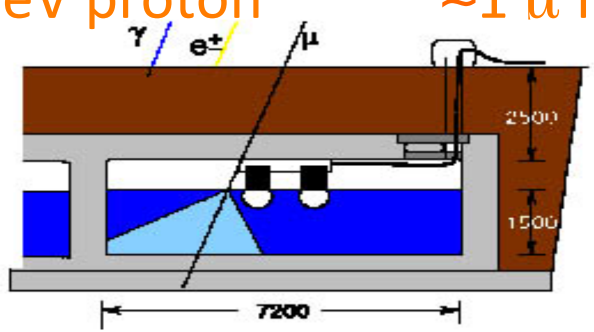


Number of muons within <100m from air−shower core

~50 μ for 100 TeV proton

~1 μ for 100 TeV γ

Muon detector unit



Performance of ALPACA

Location: 4,740 m above sea level
La Paz, Bolivia (16°23' S, 68°08' W)

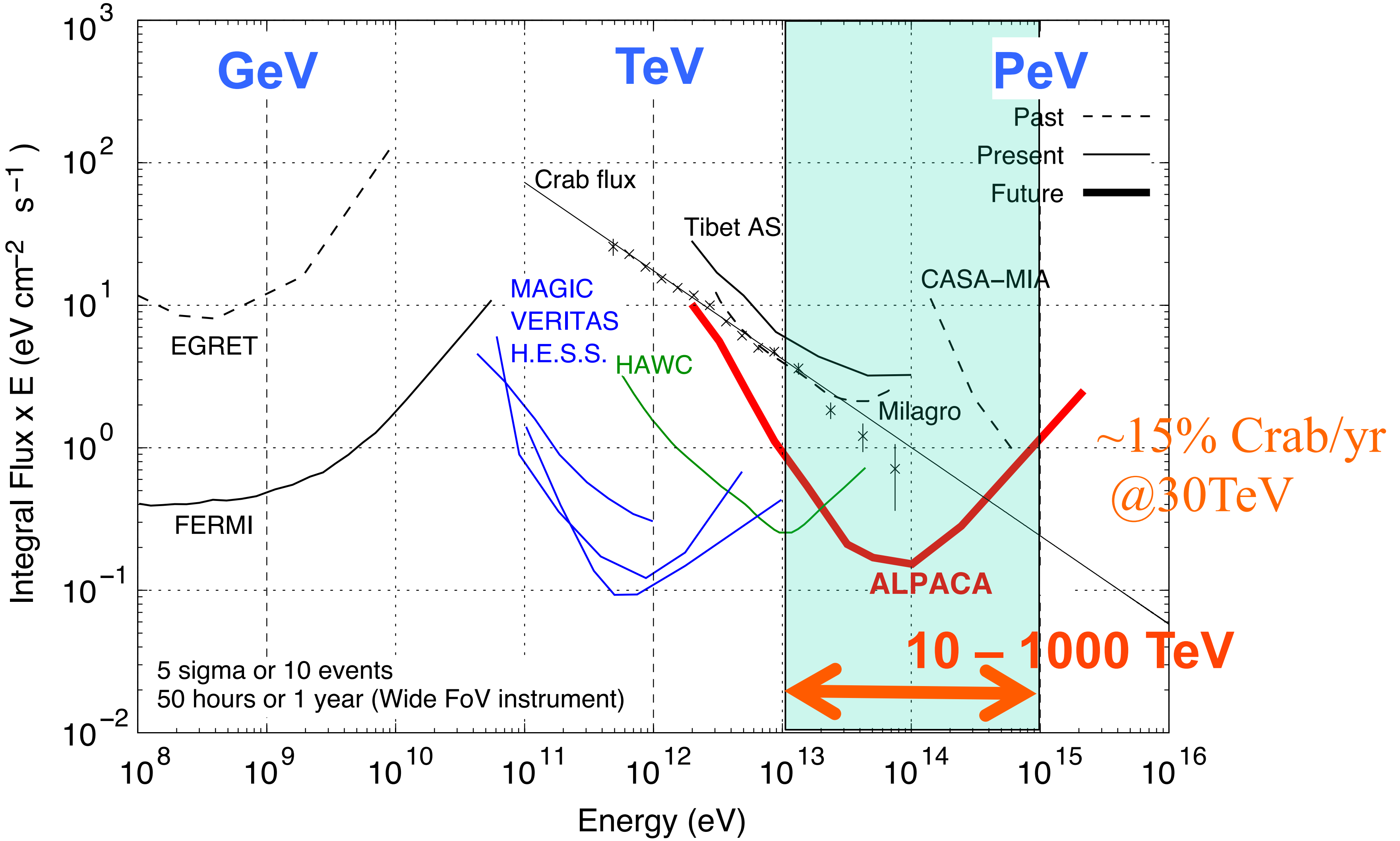
AS (air shower) array

scintillation detectors	1 m^2 x 401
effective area	83,000 m^2
angular resolution	0.2° @100 TeV
energy resolution	30% @100TeV
duty cycle	> 90%
field of view (FoV)	~ 2 sr

MD (muon detector) array

water Cerenkov detectors	56 m^2 x 96 (5,400 m^2)
CR rejection power	> 99.9%@100 TeV
γ-ray efficiency	~ 90 %@100 TeV

Sensitivity to γ-ray Point Source



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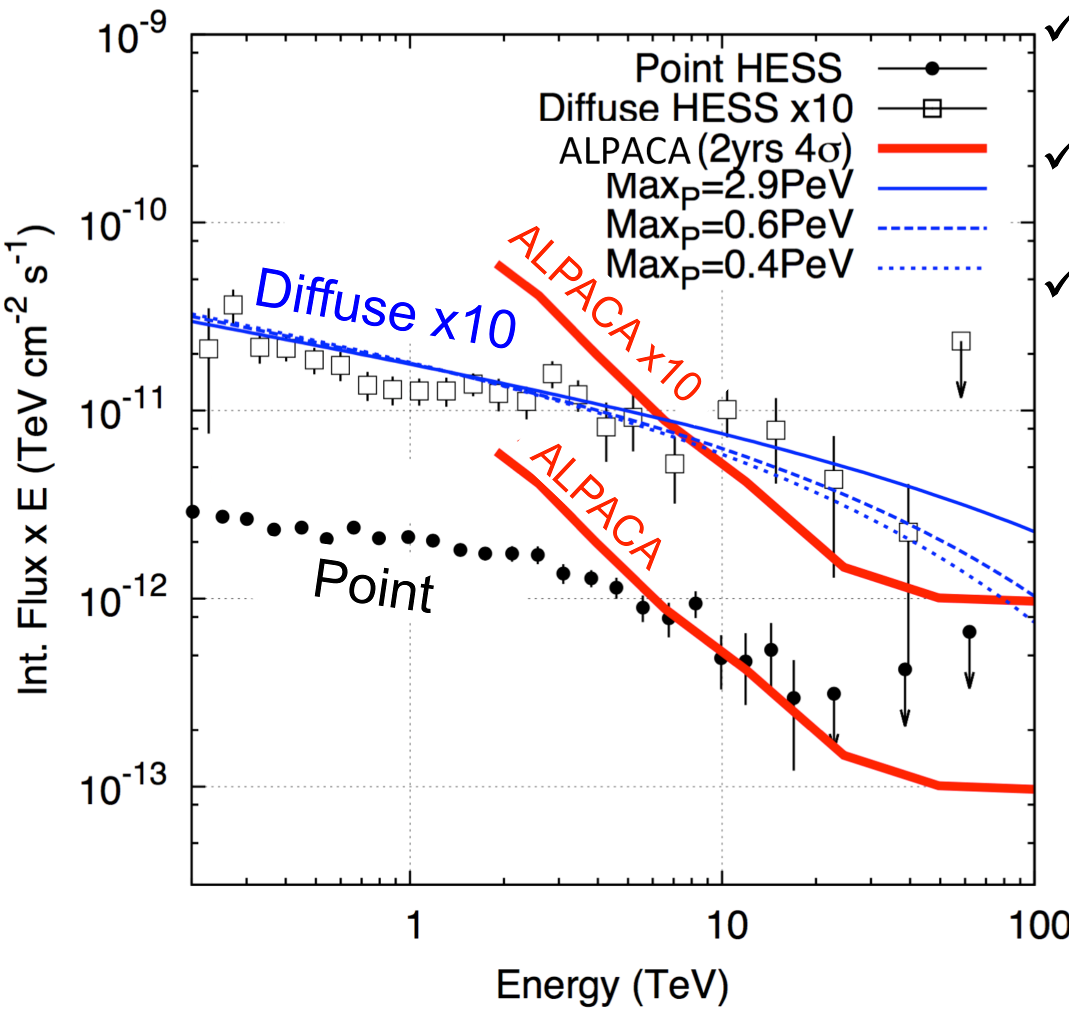
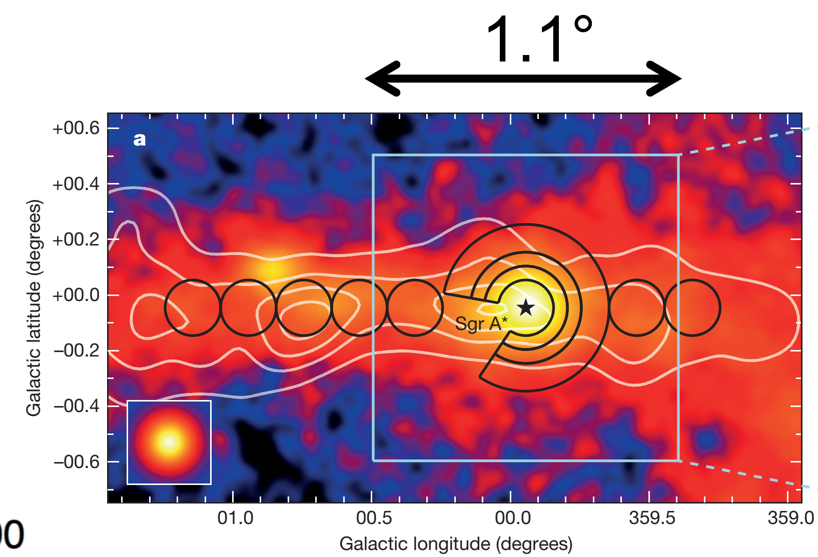
Galactic Center



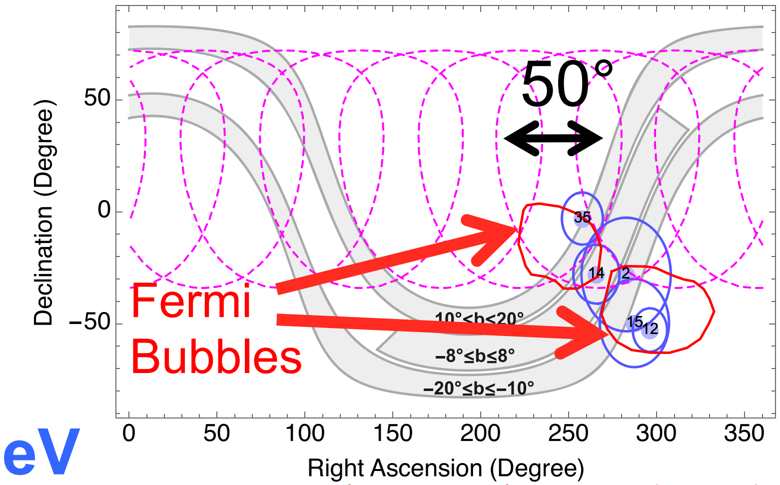
- ✓ Diffuse γ-rays detected
- ✓ >100 TeV γ-rays expected
- ✓ Promising candidate for CR accelerator up to the knee



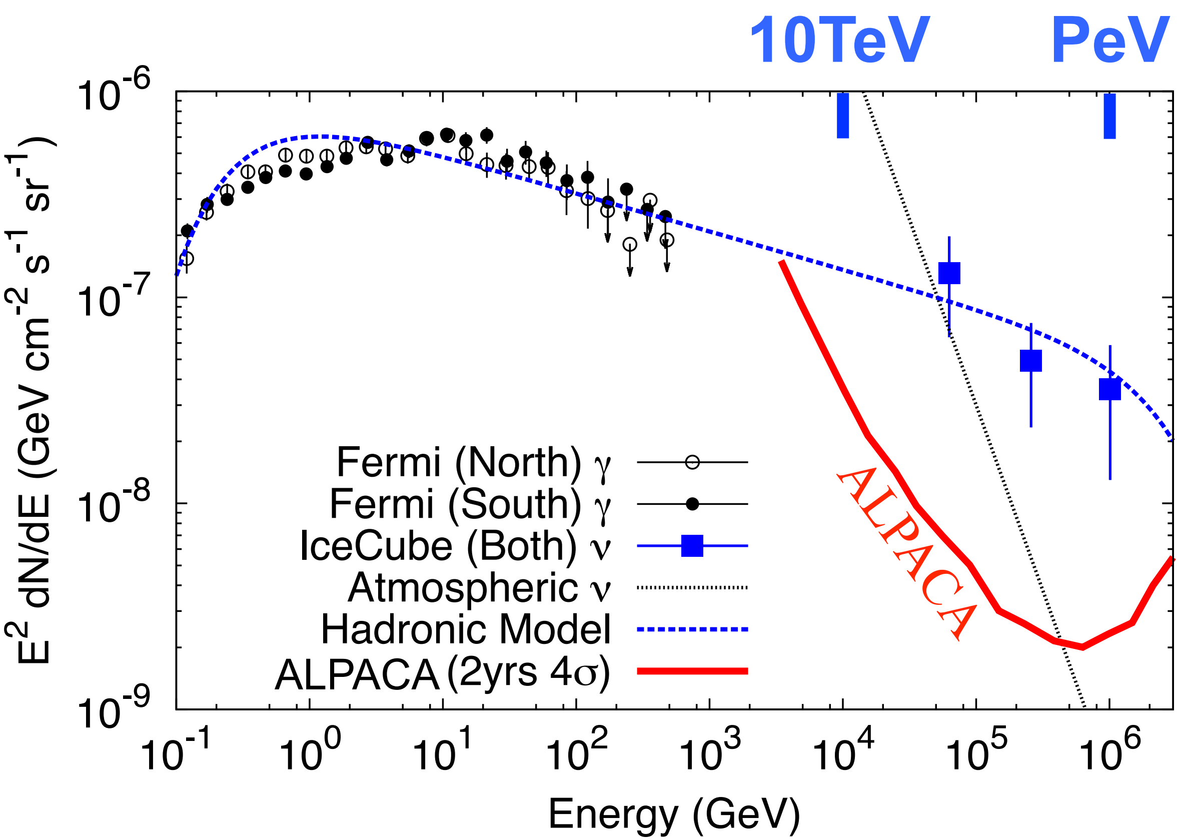
Abramowski, et al, Nature (2016)

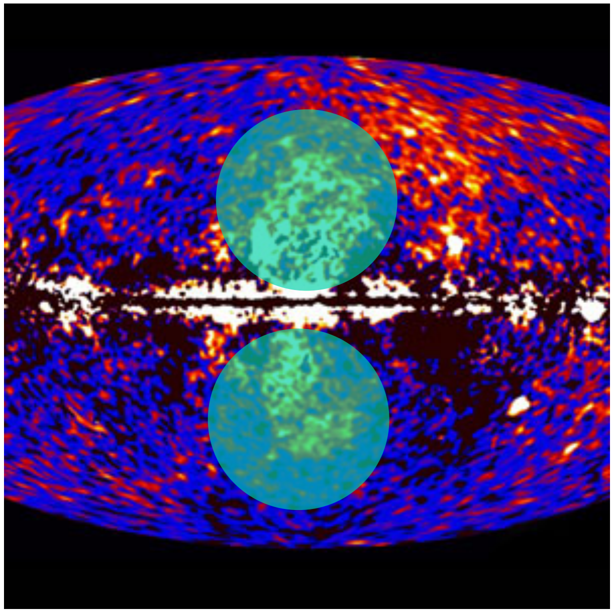
Fermi Bubbles

- ✓ Very extended (~0.8sr) sources north & south sides of Galactic Center
- ✓ Difficult for IACTs to cover them all
- ✓ 100TeV γ-rays expected if IceCube ν's are of CR origin



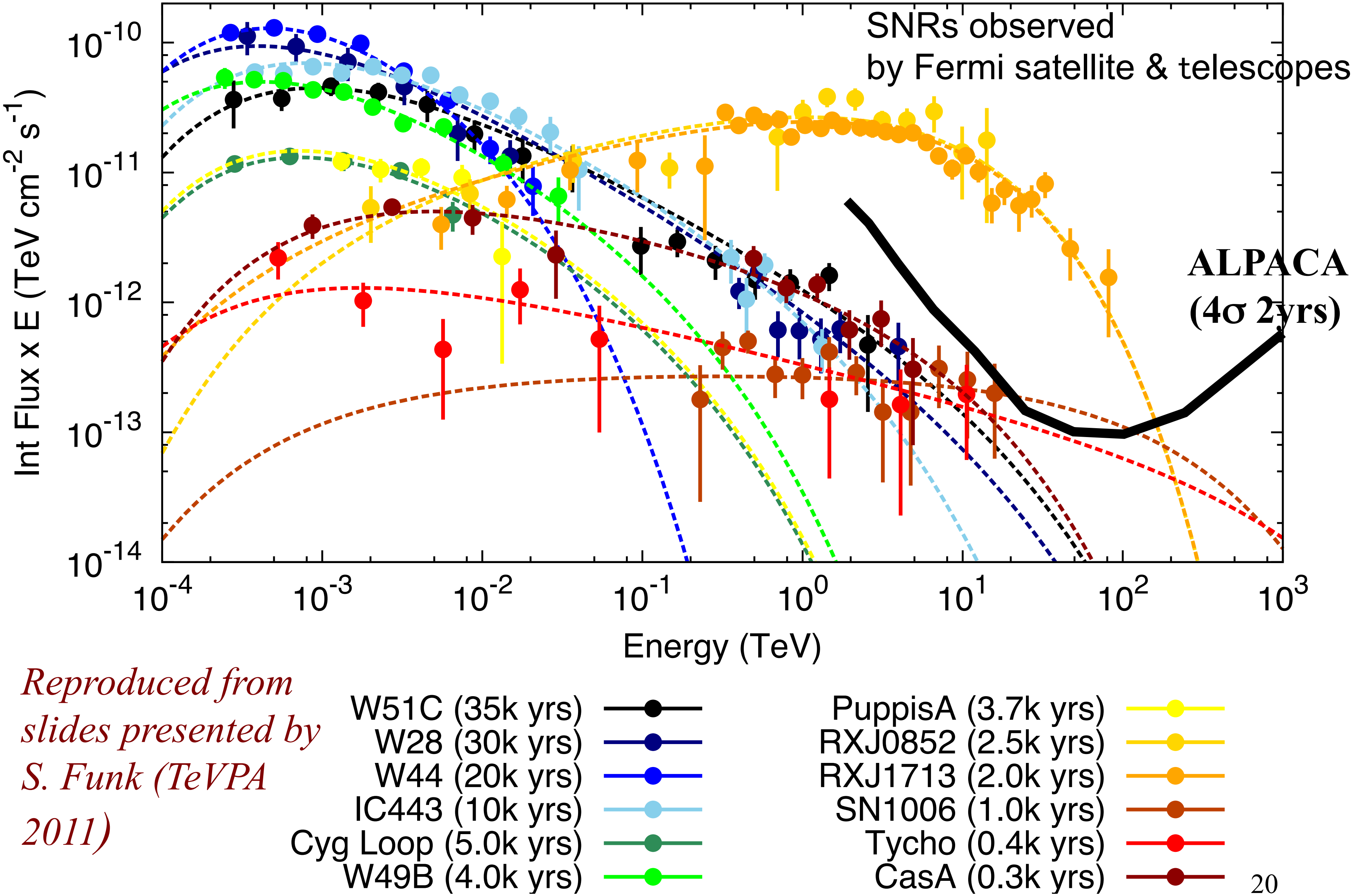
C. Lunardini, et al, PRD (2015)





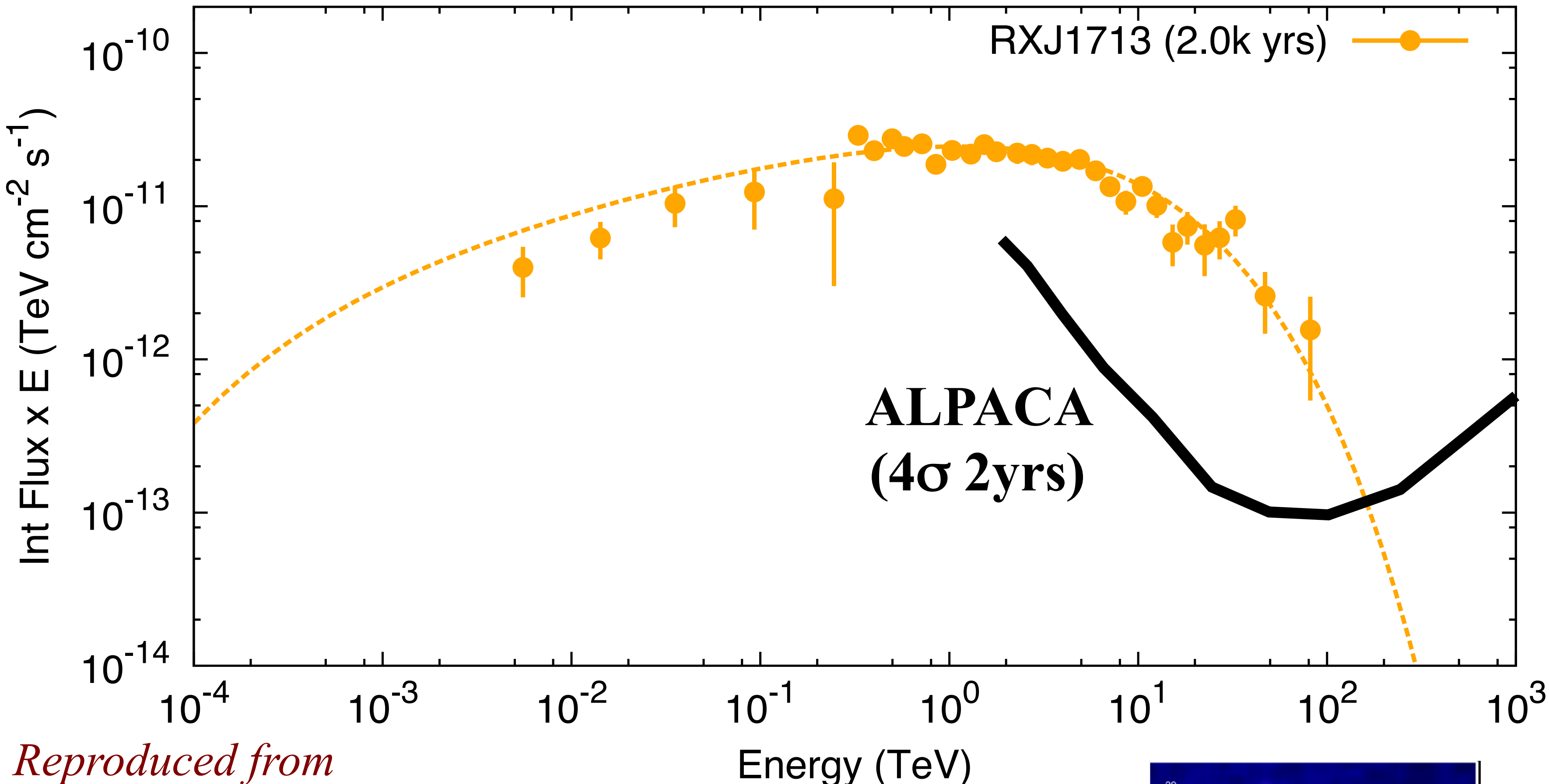
Bubbles observed by Fermi satellite

Young SNRs (1)



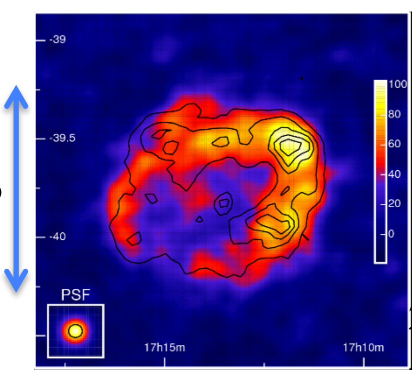
Reproduced from slides presented by S. Funk (TeVPA 2011)

Young SNRs (2) : RX J1713



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

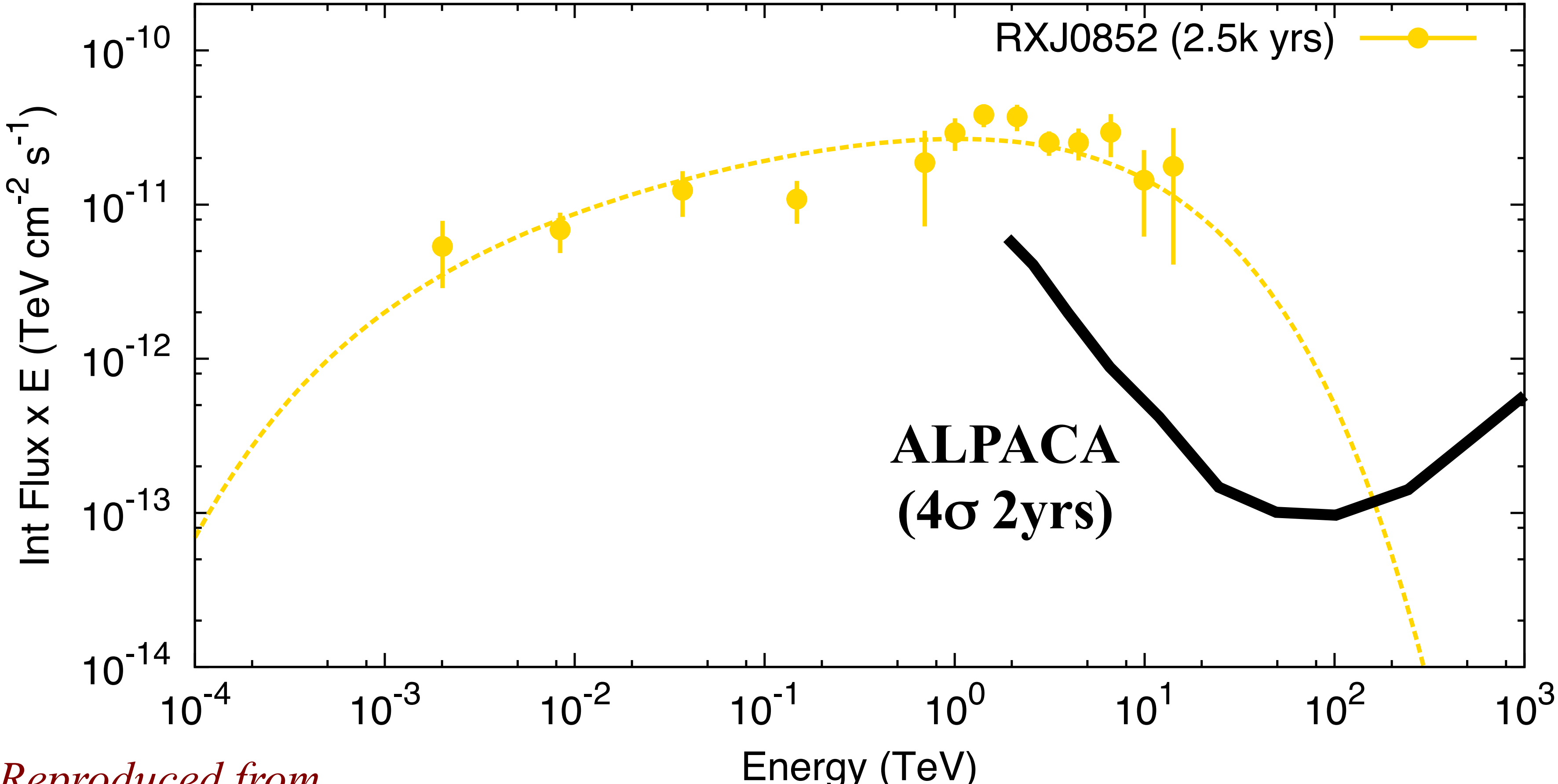
1.0°



Observed by Fermi & H.E.S.S.

Dec. ~ -40°

Young SNRs (3) : RX J0852

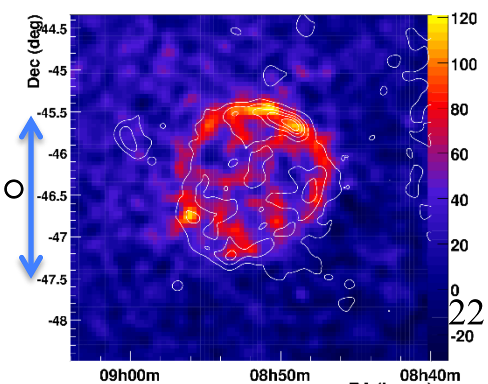


Reproduced from slides presented by S. Funk (TeVPA 2011)

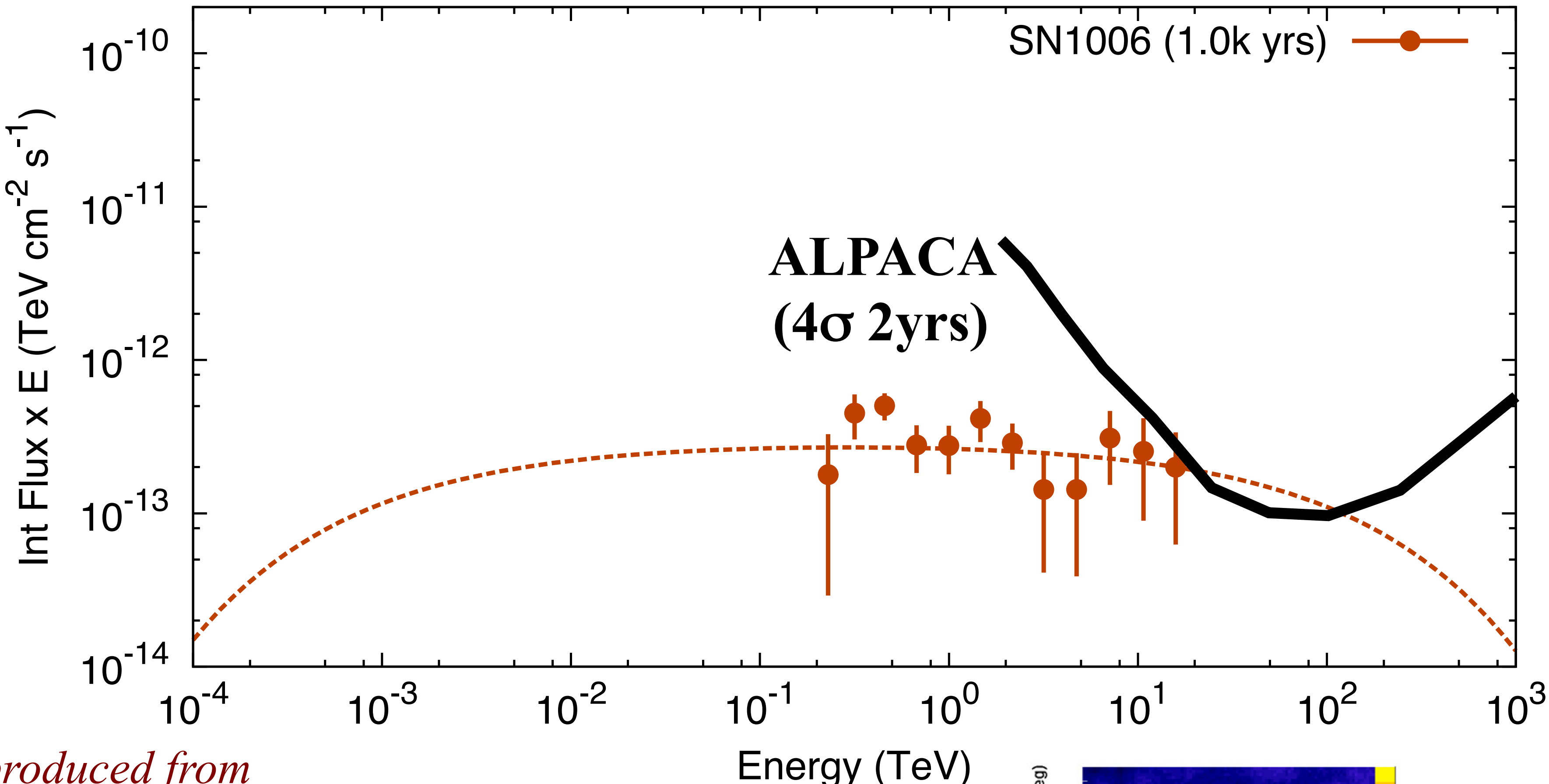
Observed by Fermi & H.E.S.S.

Dec ~ -46°

2.0°

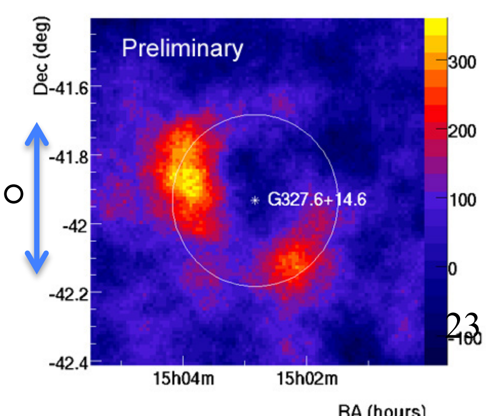


Young SNRs (4): SN 1006



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

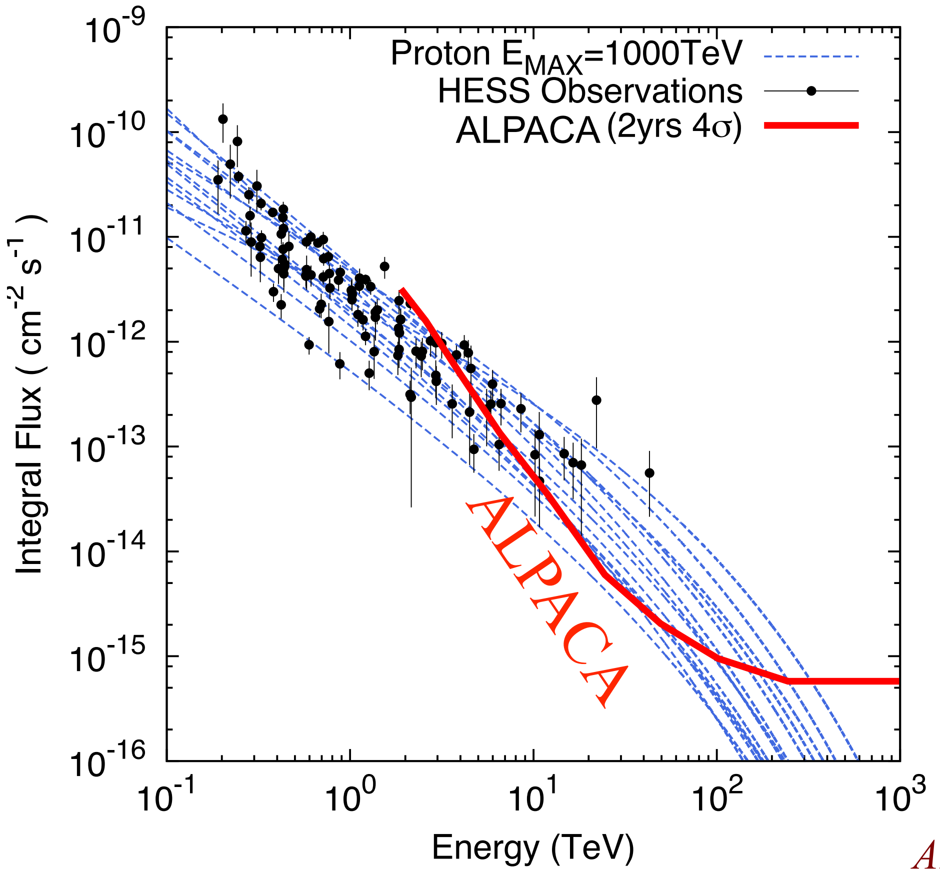
0.4°



Observed by H.E.S.S.

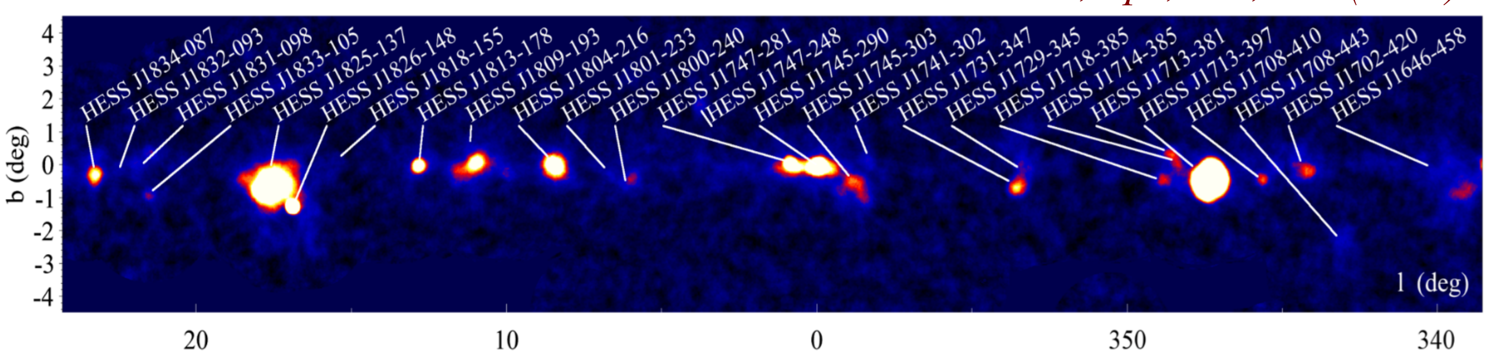
Dec ~ -42°

Other Galactic Sources

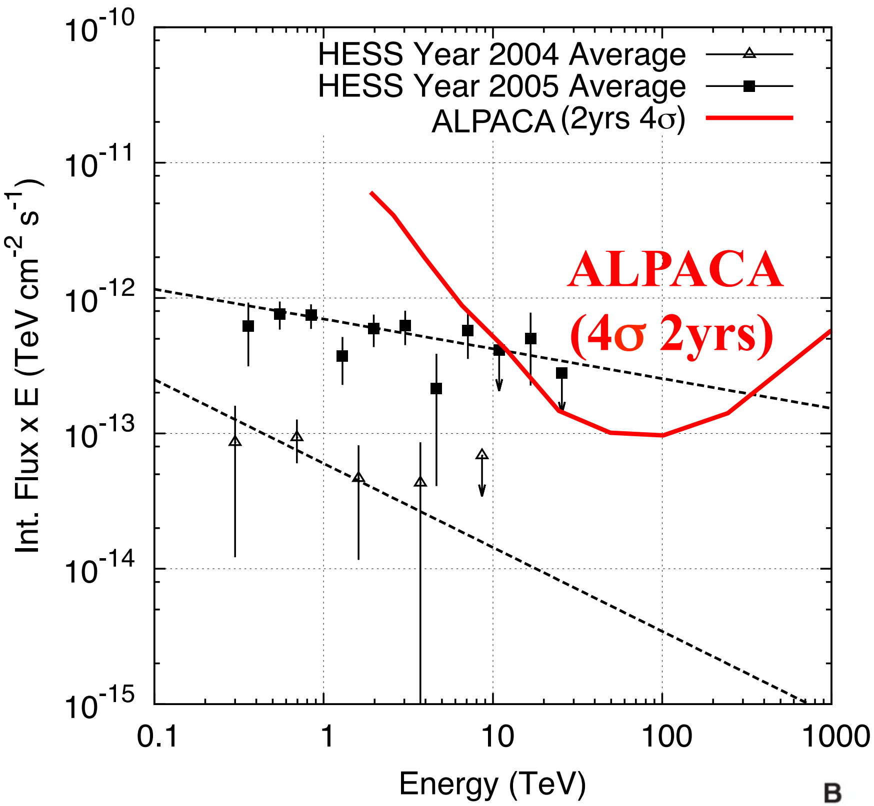


- ✓ More than dozen sources
- ✓ Dark sources in other wave lengths
- ✓ PWN candidates
- ✓ Diffuse γ from Galactic plane

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



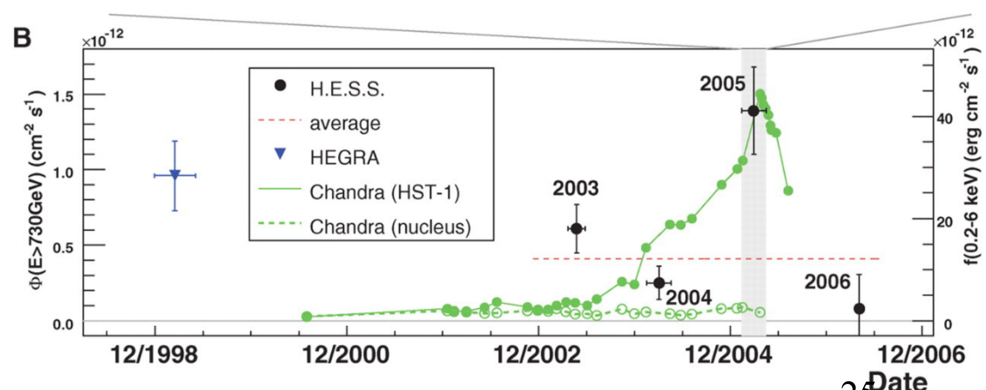
Nearby Extragalactic Source M87



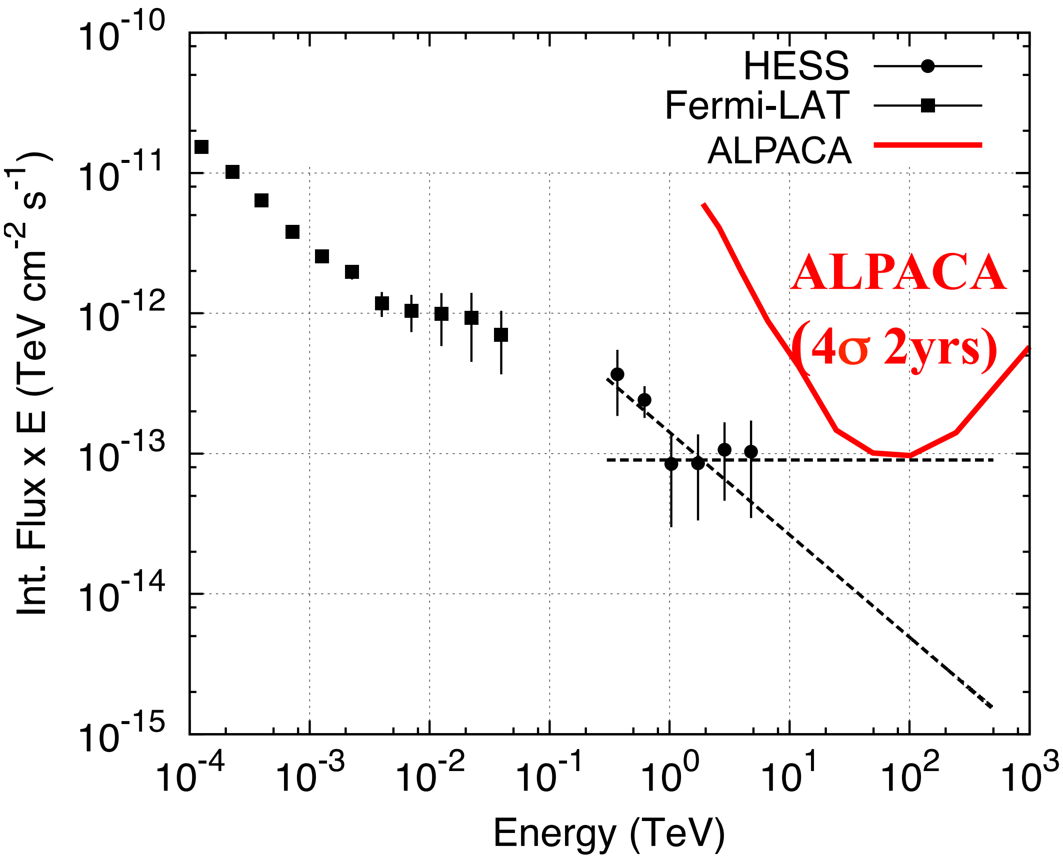
- ✓ Distance: z=0.0043 (16Mpc)
- ✓ Relativistic jet
- ✓ Long-term time variation 2004 – 2005 flare
- ✓ Hard spectrum at flare

$\delta \sim +12°$

Aharonian et al,
Science, 314, 1424 (2006)

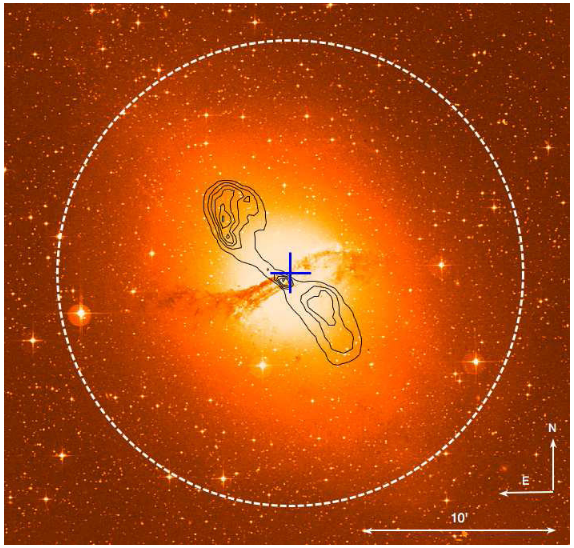


Nearby Extragalactic Source CenA



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

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



$\delta \sim -43°$

Contents

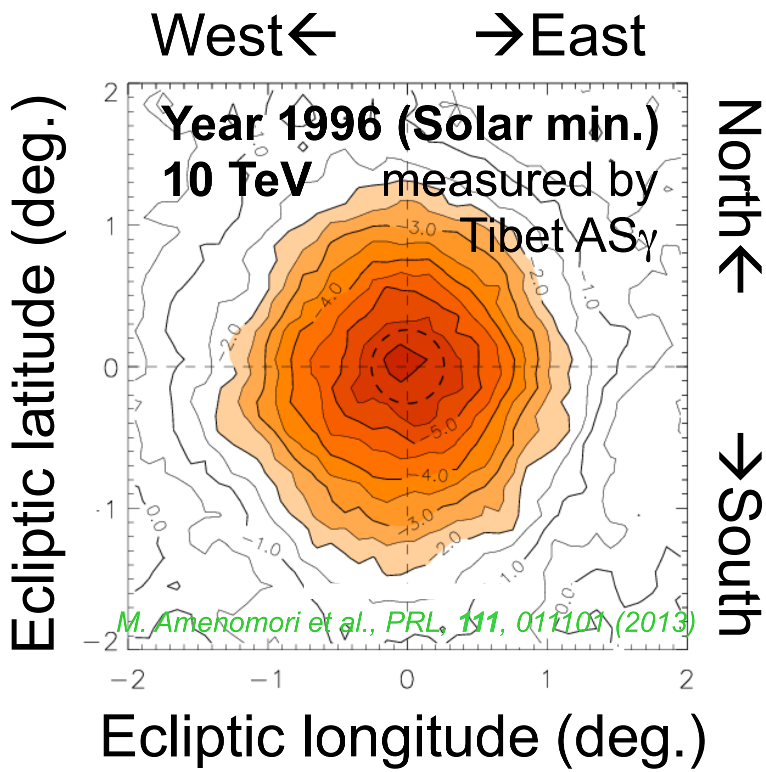
Other observations

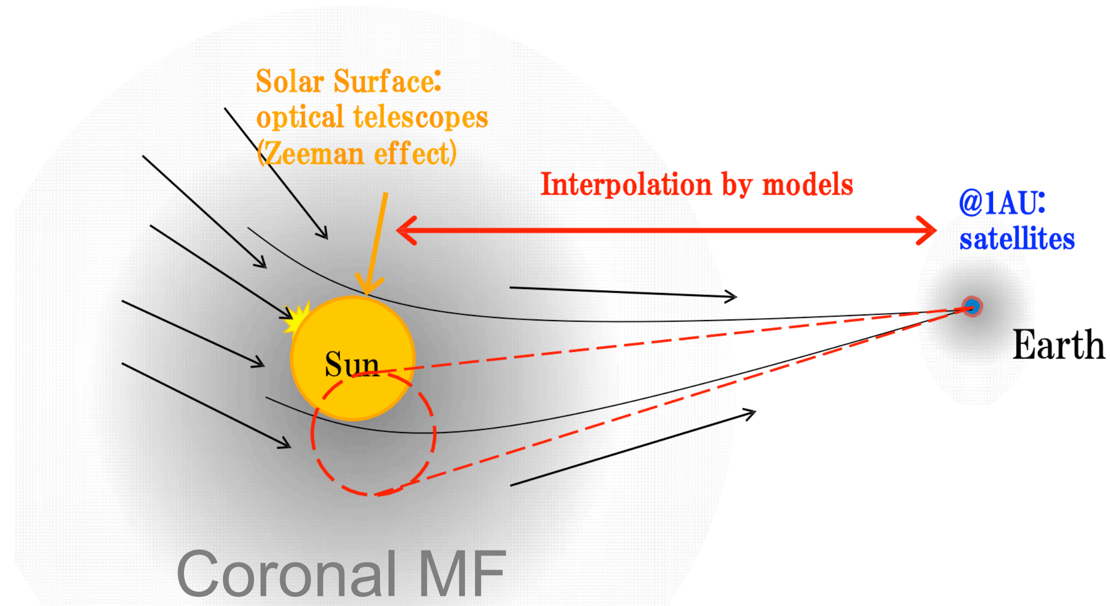
- CR anisotropy >TeV in the southern sky
  — Complementary to IceCube

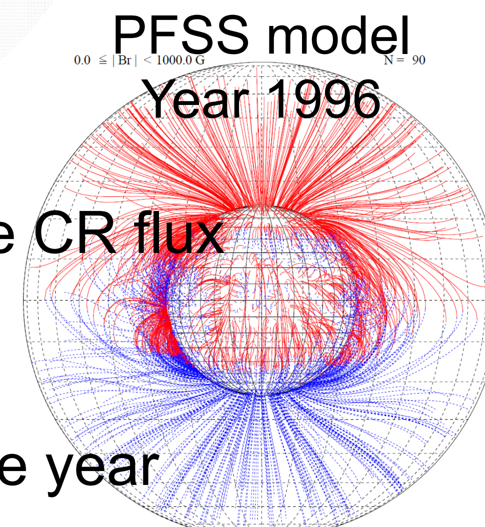
- Sun's shadow
  — Observable throughout the year

- γ-ray from solar disk
  — detected up to ~100 GeV by Fermi
  — CR + solar atmosphere $\rightarrow \pi^0 \rightarrow 2\gamma$

Sun’s shadow

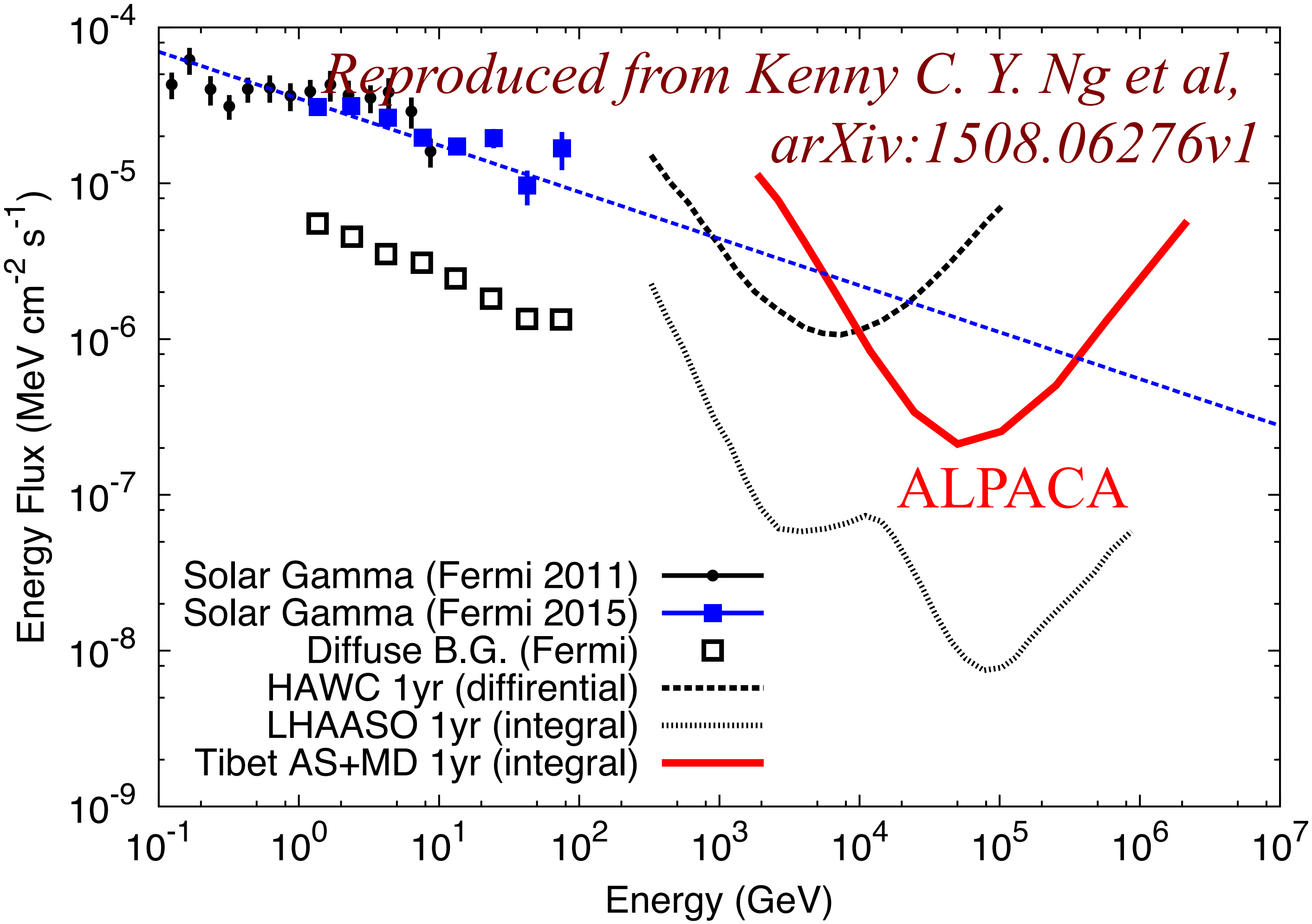






- ◆ Sun blocks CRs, casting a shadow (deficit) in the CR flux
- ◆ Sensitive to coronal magnetic field structure
- ◆ Sun in the field of view of ALPACA throughout the year
- ◆ Capable of examining coronal models with high statistics

Sensitivity to Solar Disk γ-Ray



Detectable, if the power-law spectrum extending up to >10 TeV

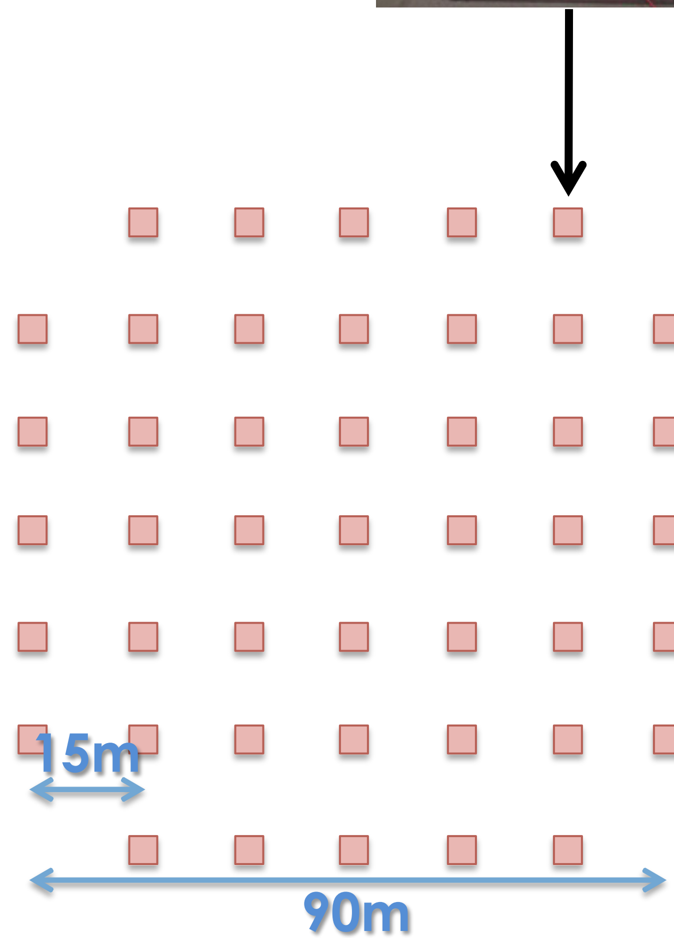
Contents

ALPAQUITA Array

(~ 1/10 scale ALPACA air-shower array)

Construction scheduled in 2017

Altitude	4,740 m
Spacing	15m
Scinti. Det.	1 m^2 x 45
Coverage	0.44 %
Effective area	7,650 m^2
Mode Energy	~5 TeV
Trigger rate	~150 Hz
Sidereal anisotropy	~10σ / yr
Moon’s shadow	~16σ / yr



Construction plan of ALPACA

Year 0 (2017): prototype AS array “ALPAQUITA”

(45 detectors; 7,650 m^2 ~ 1/10 scale)

Year 1: Preparation for full ALPACA

Year 2 : Construction of MD

Year 3 : Construction of AS

Year 4 : Start data-taking

Observation will continue for 5 – 10 years

Summary

ALPACA experiment

- 4740m above sea level, in La Paz, Bolivia (16°23'S, 68°08'W)
- Air Shower Array (83,000m^2) + Muon Detector Array (5,400m^2)
- Budget ~ 5M USD, not funded yet
- Prototype 1/10-scale AS array (ALPAQUITA) in 2017

Targets

- 10-1000 TeV γ-ray sources
  — G.C., FB, Young SNR, PWN, UNID, nearby AGN
  — γ-ray point source sensitivity : ~15% Crab/yr @30TeV
  — wide field of view, advantage for observation of extended sources
- CR anisotropy >TeV in the southern sky
- Sun's Shadow, γ-ray from solar disk

Thank you for your attention !