The ALPACA Project

Masato Takita

for the ALPACA collaboration

@ISVHECRI2016, Moscow, Russia,

August 22, 2016

The ALPACA Experiment

Andes

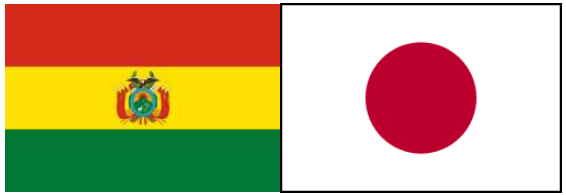
Large area

PArticle detector for

Cosmic ray physics and

Astronomy

The ALPACA Collaboration



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Outline of the ALPACA experiment

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

Expected budget -> 5 M USD not funded yet

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

AS Array ～83,000m^2 (~ 400 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!

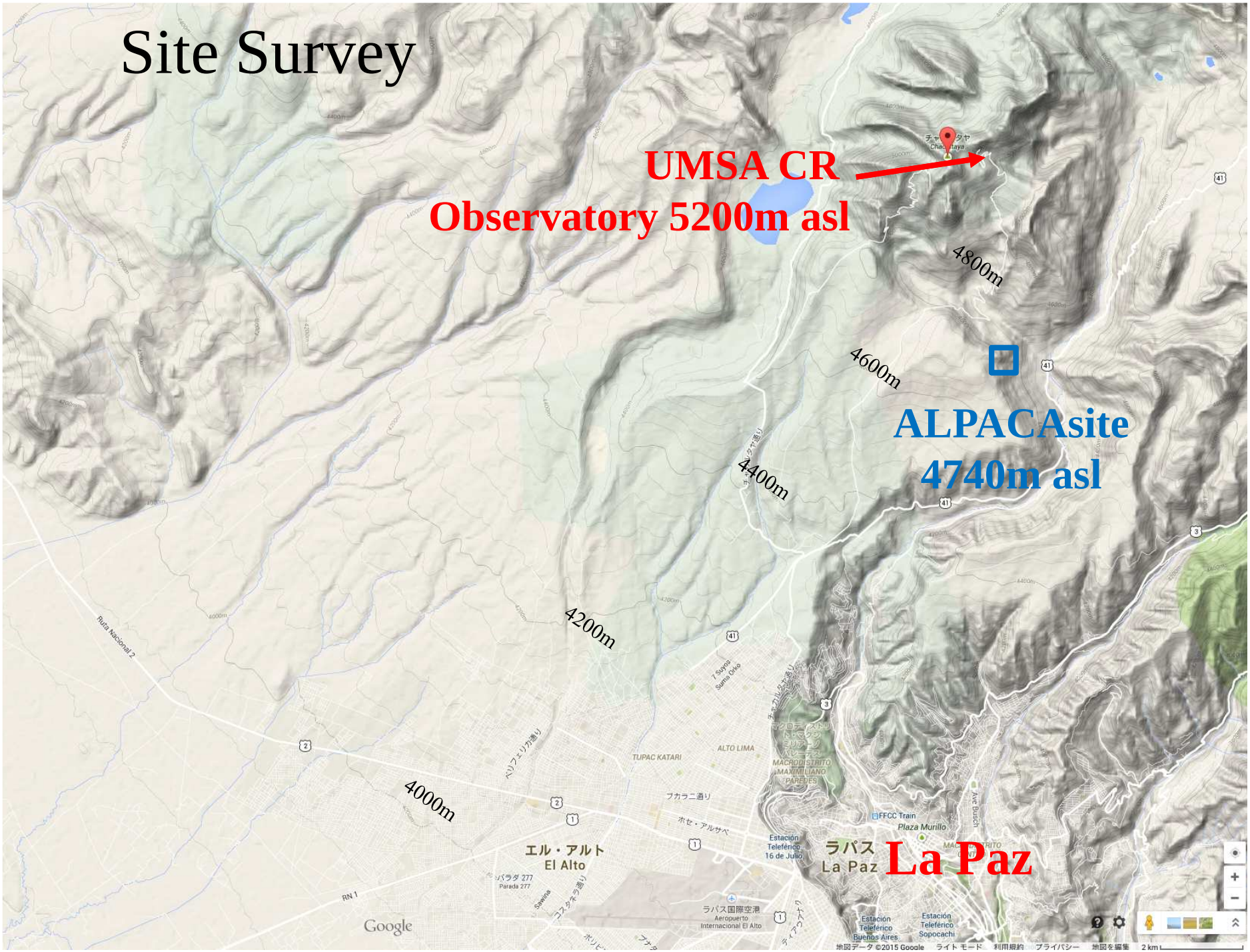
γ-ray point source sensitivity : ~15 % Crab/yr @30TeV

CR anisotropy, Sun shadow, Solar γ,

Chemical composition of CR around Knee

ALPACA Site

Mt. Chacaltaya, Bolivia


Site Survey
UMSA CR
Observatory 5200m asl
4800m
4600m
ALPACAsite
4740m asl
4400m
4200m
4000m
La Paz
El Alto
Google

Construction plan of ALPACA

Year 1: Preparation

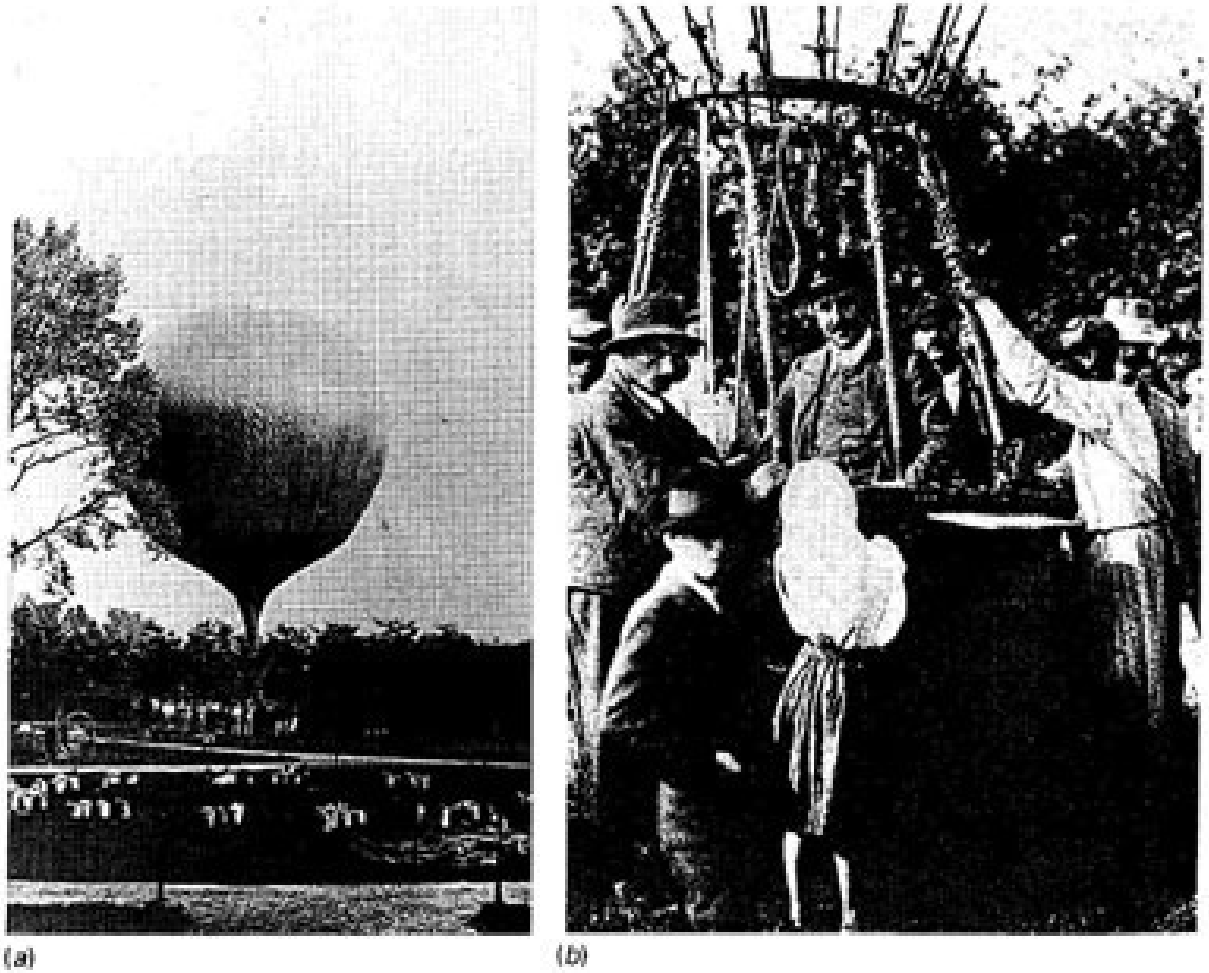
Year 2 : Construction of MD

Year 3: Construction of AS

Year 4: Start data-taking

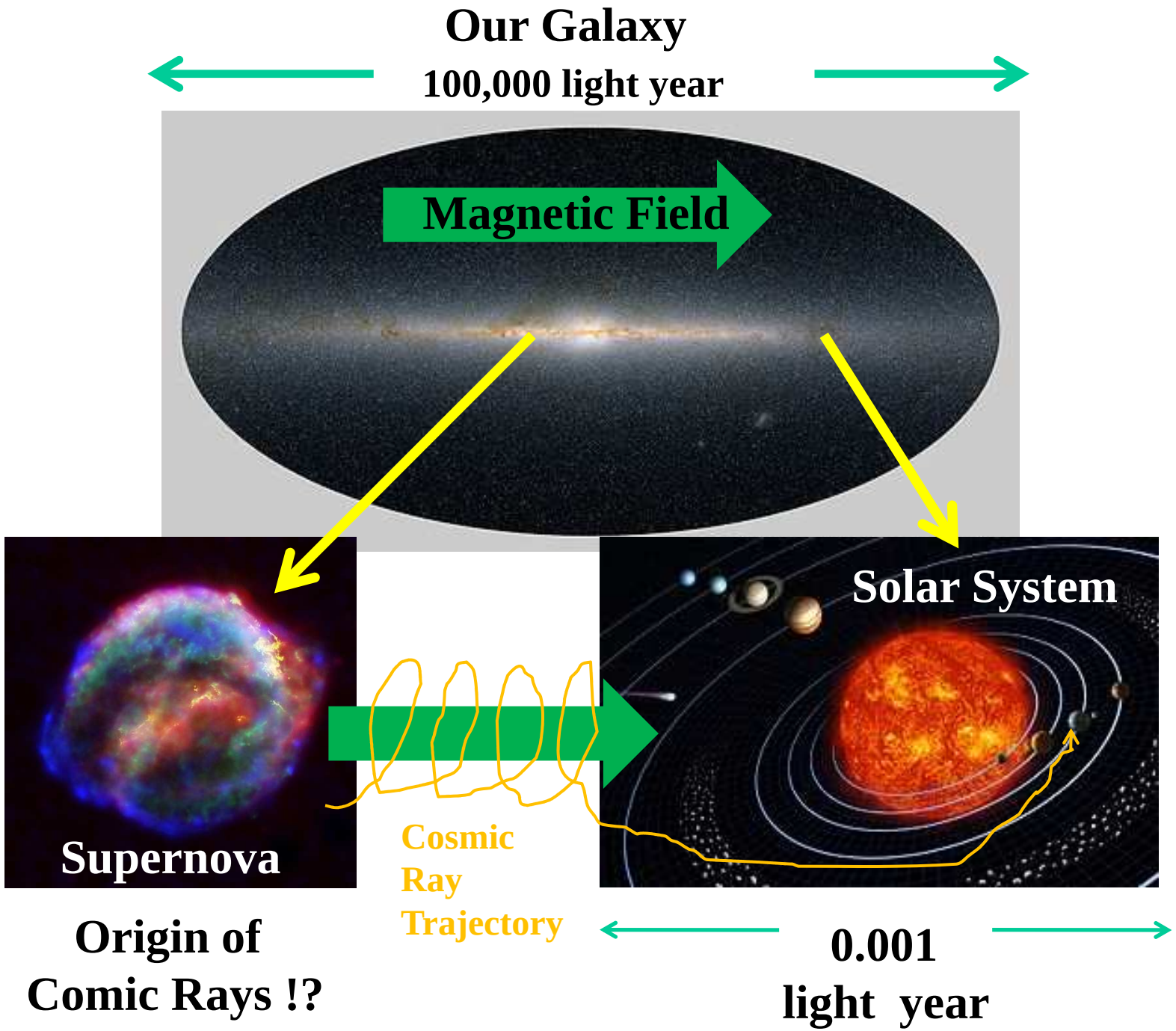
Observation will continue (5 – 10 years)

Discovery of cosmic rays by Victor HESS (in 1912) getting on a balloon

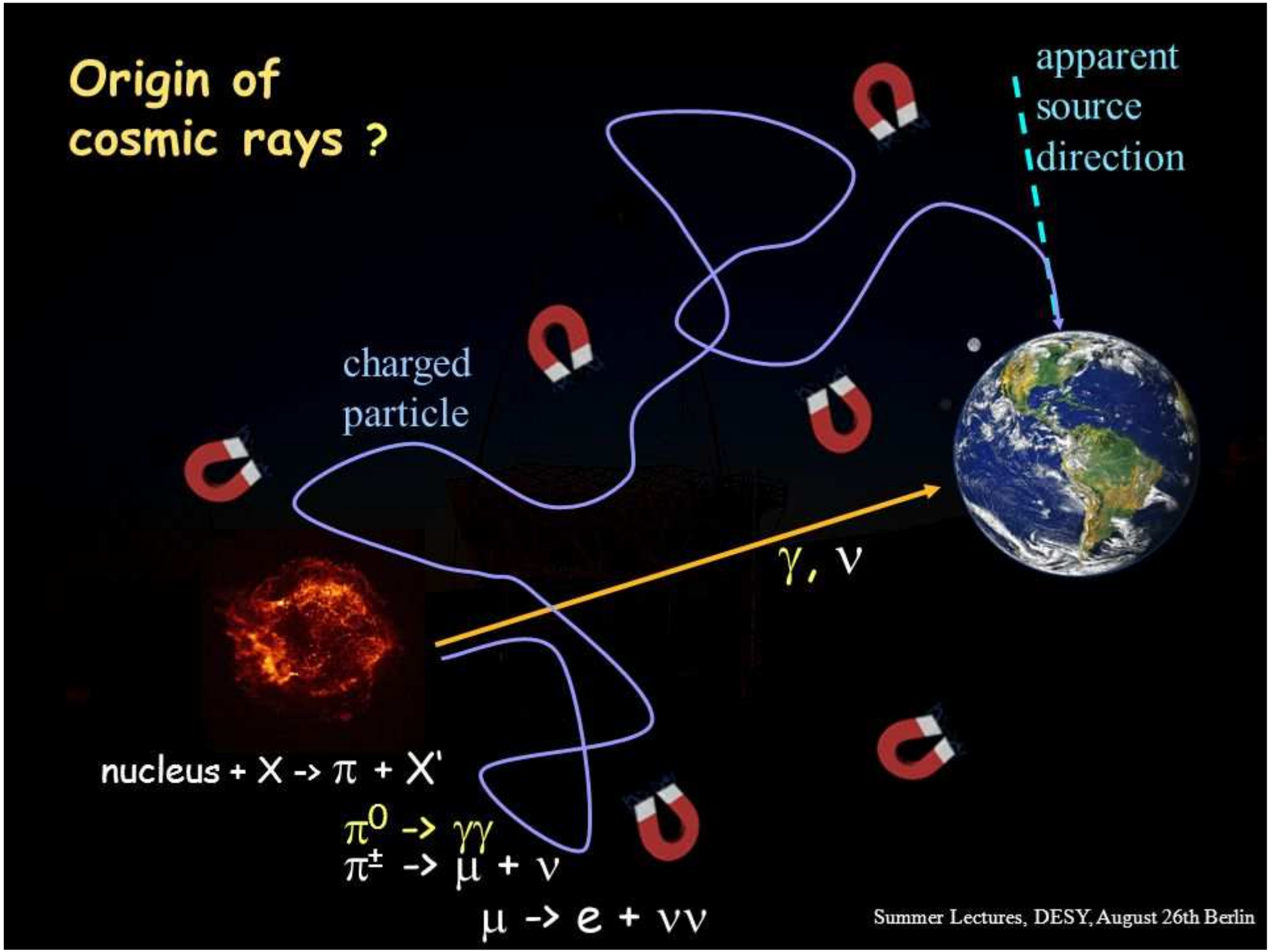


(a) (b)

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


Our Galaxy
100,000 light year
Magnetic Field
Solar System
Supernova
Cosmic
Ray
Trajectory
Origin of
Comic Rays !?
0.001
light year

Origin of cosmic rays ?



Main purpose of ALPACA

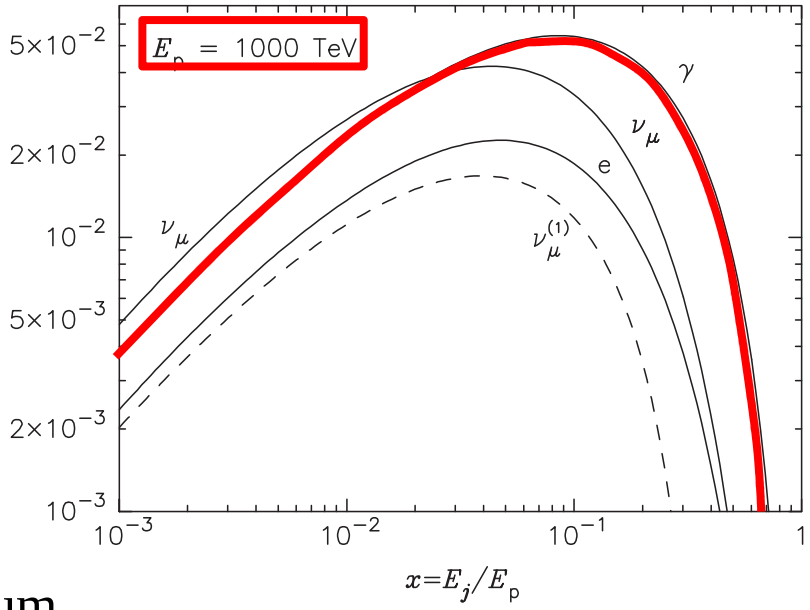
- Locating origin of comic rays

by detecting cosmic sub-PeV gamma rays
from cosmic ray accelerator in our galaxy:

PeVatrons!

Origin of Cosmic Rays at the Knee

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



<u>CR energy spectrum</u>

✓ CR acceleration up to several PeV is possible by shock wave acceleration mechanism at SNR

✓ Knee-4PeV: of galactic origin!?

<u>γ-ray energy spectrum</u>

✓ CR+ISM→π^0+…→2γ

✓ γ & ν produced with $E_{\gamma\&\nu} \sim O(1/10\ Ep_{max})$

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,…)

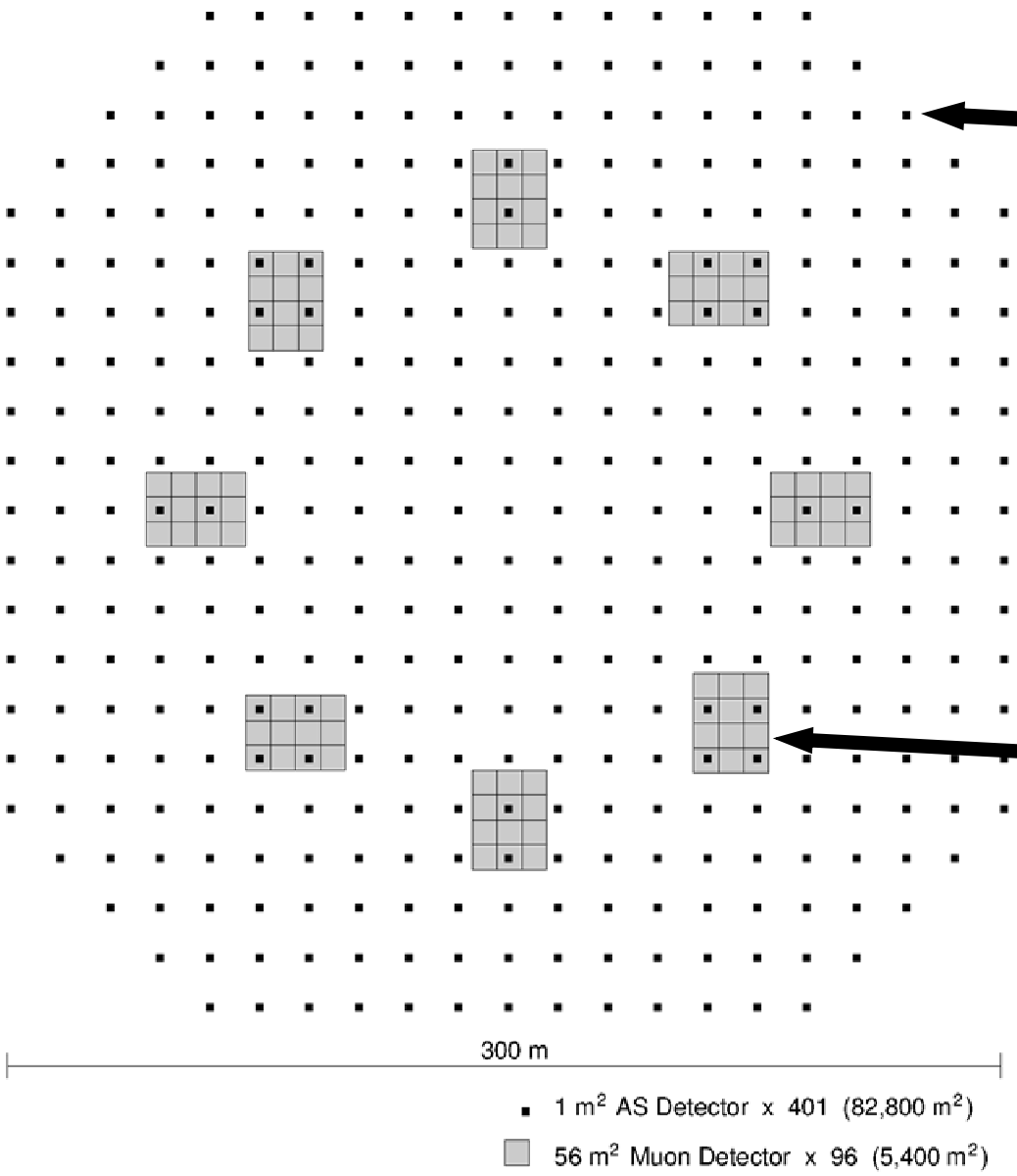
  Since 1962 in the field of cosmic rays, for example, BASJE

Experimental Cite : Cerro Estuqueria

（500m x 500m flat within ~+- 1 deg.)

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

Schematic view of ALPACA



AS

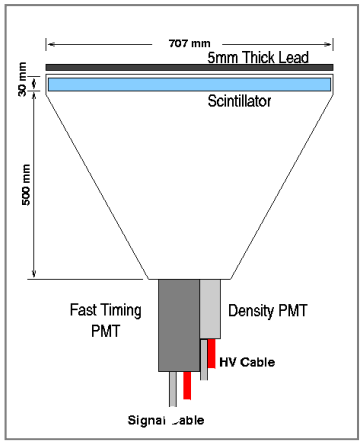


Image of 1m^2 plastic scintillation detector

MD

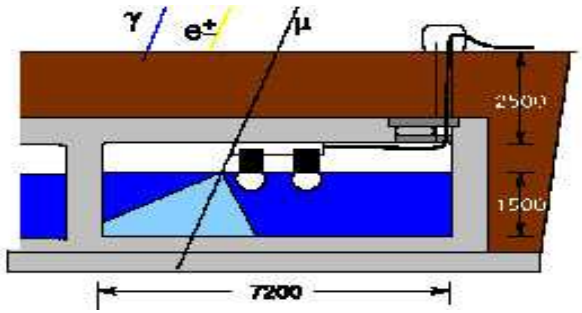
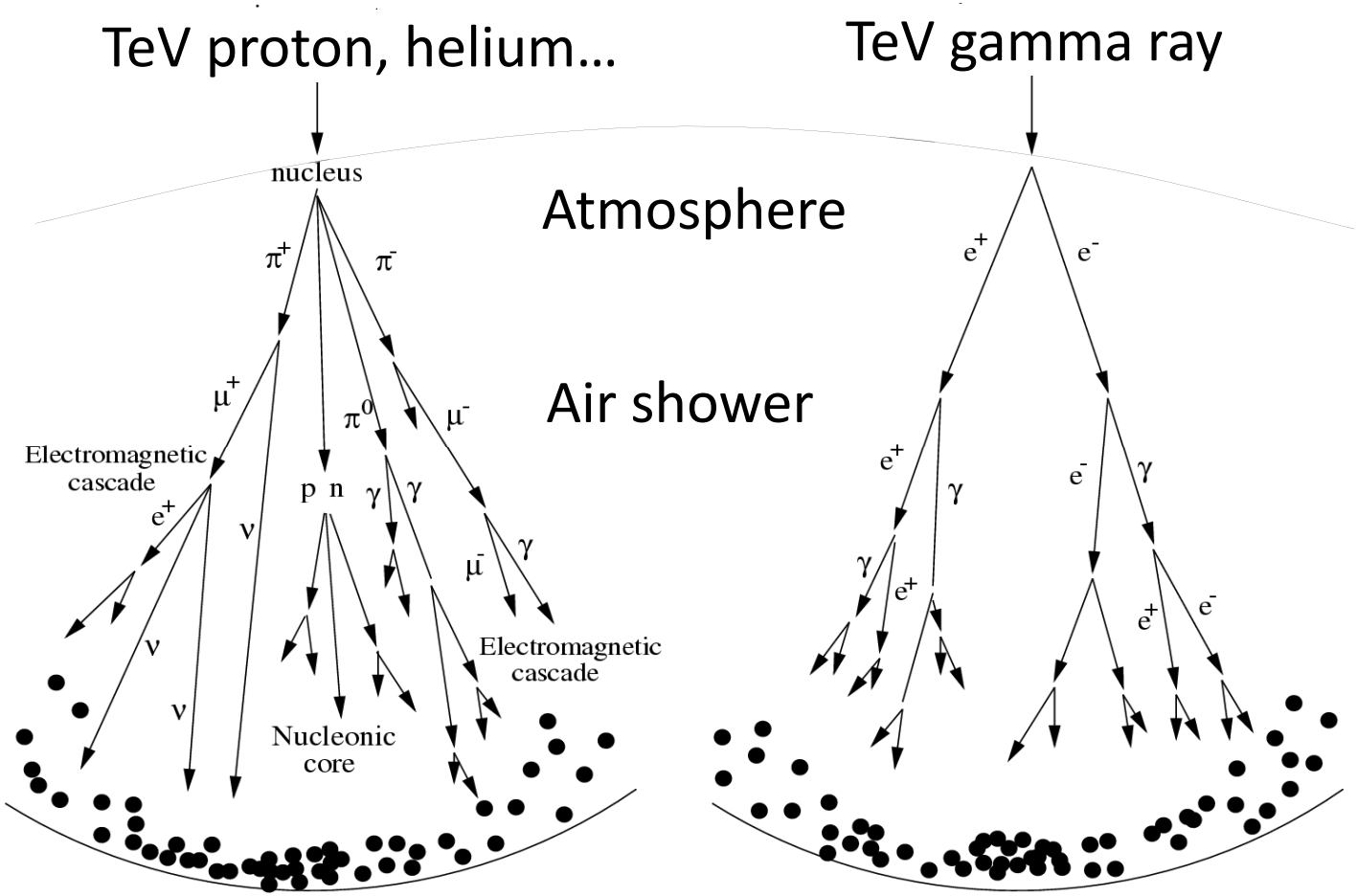


Image of unit (56m^2) underground water Cherenkov muon detector

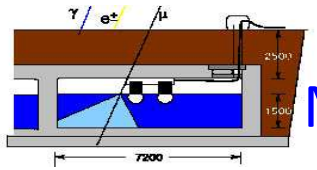
p/γ discrimination by counting # of muons



# of muon within <100m from core

~ 50 μ for 100 TeV proton

~ 1 μ for 100 TeV γ



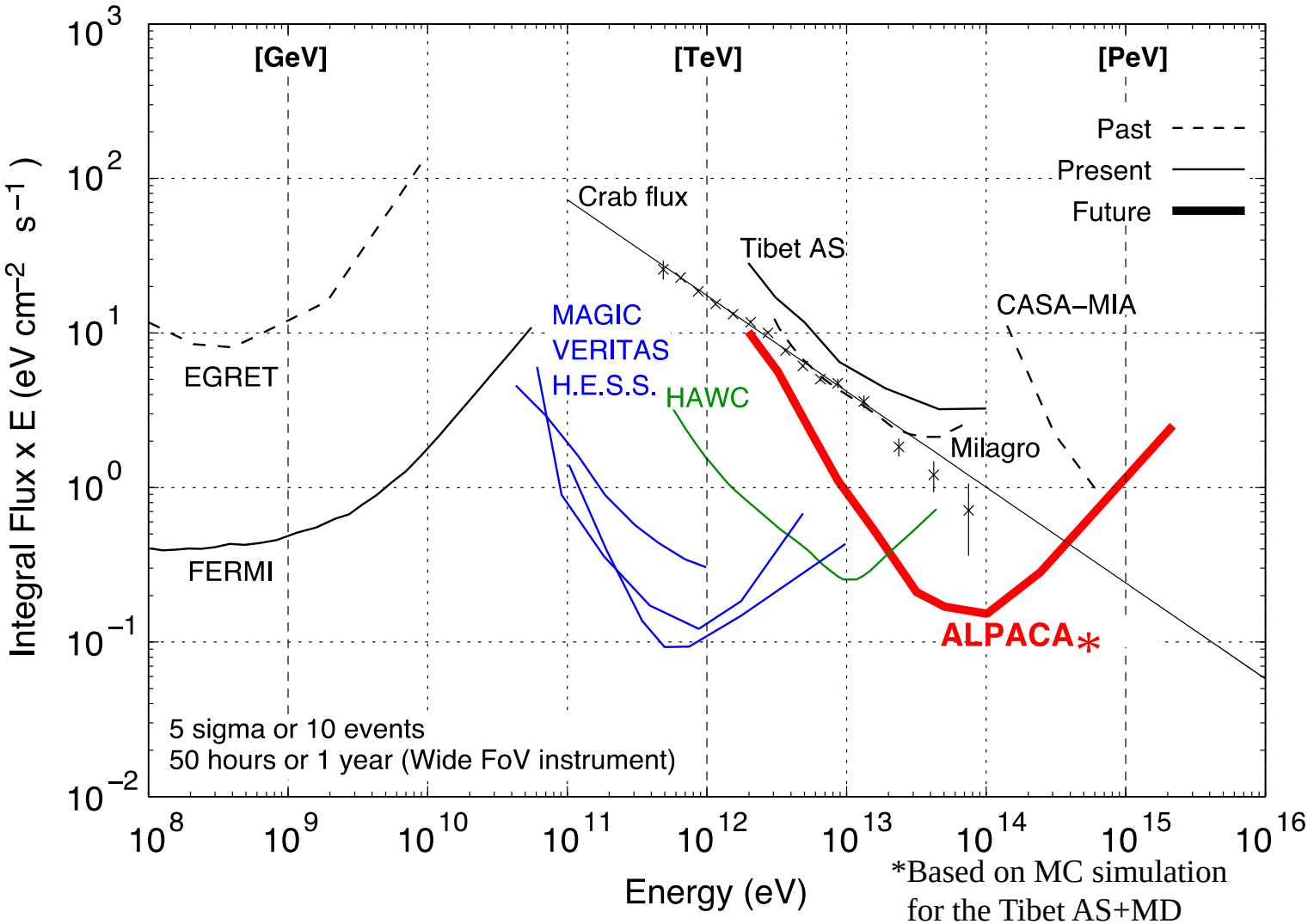
Muon detector

Performance of ALPACA

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

# of scintillation detectors	1 m^2 x 401 detectors
Effective area of	~83,000 m^2
modal energy	~5TeV
angular resolution	~0.2 @100 TeV
energy resolution	~30% @100TeV
field of view	~2 sr
CR rejection power (γ ray efficiency ~ 90 %)	>99.9%@100 TeV

Sensitivity to the Point Source



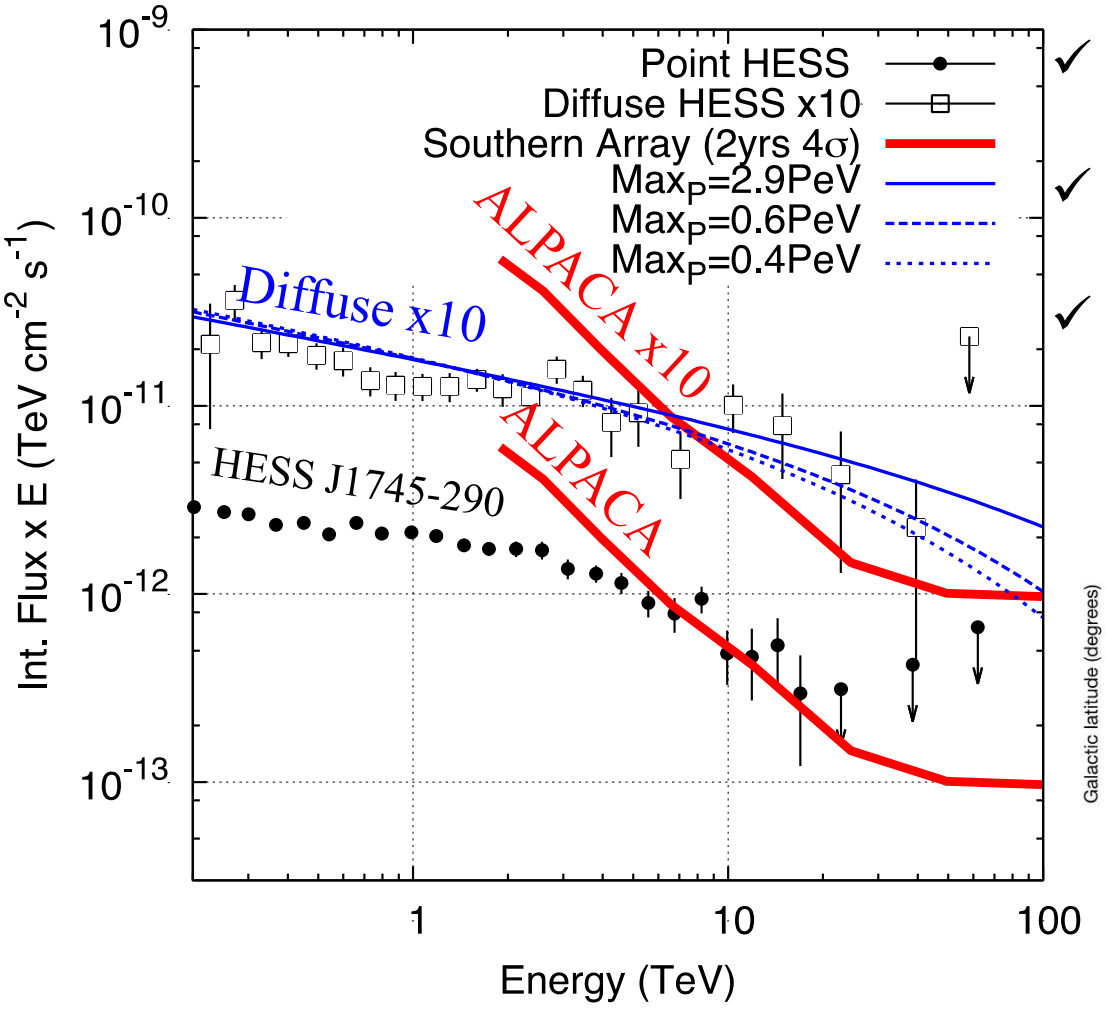
*Based on MC simulation for the Tibet AS+MD

Sub-PeV γ-ray astronomy in south

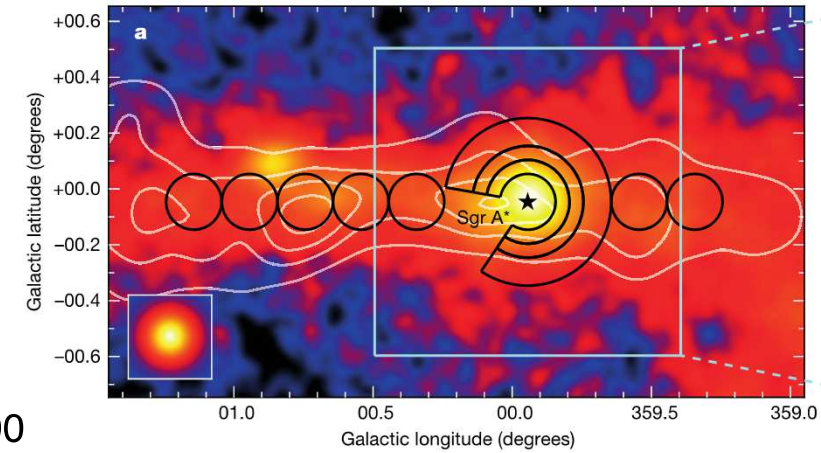
Target sources are:

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

Galactic Center as PeVatron!?



- ✓ Detection of diffuse component
- ✓ sub-PeV γ-ray expected
- ✓ Promising candidate for PeVatron

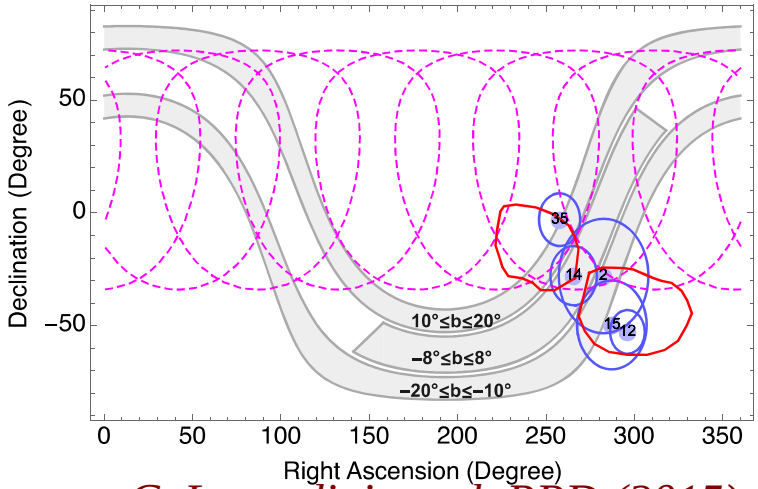


Abramowski, et al, Nature (2016)

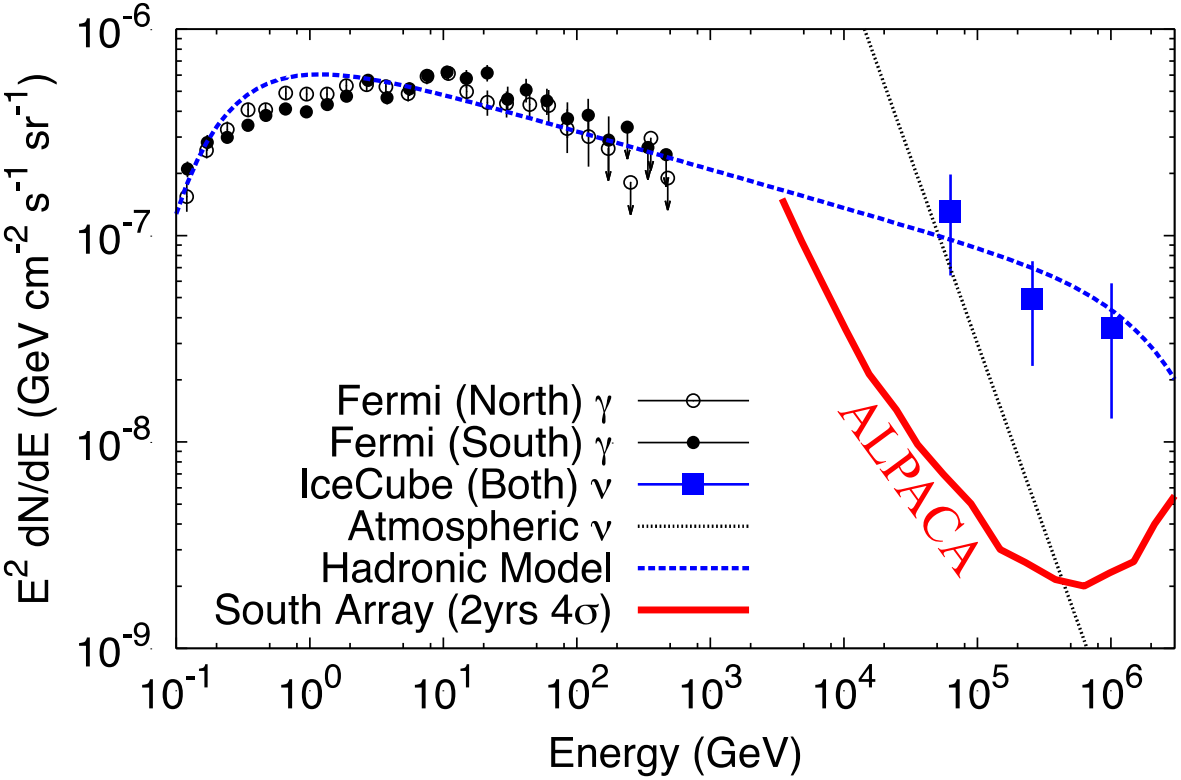
$\delta \sim -29^\circ$

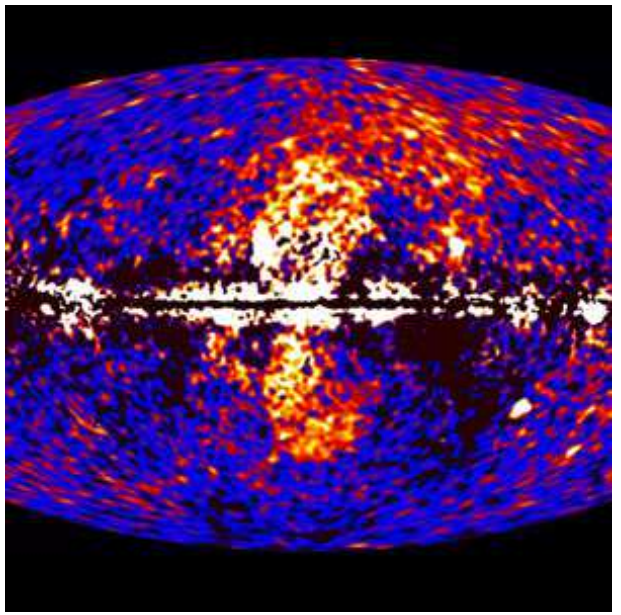
Fermi Bubbles

- ✓ 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.



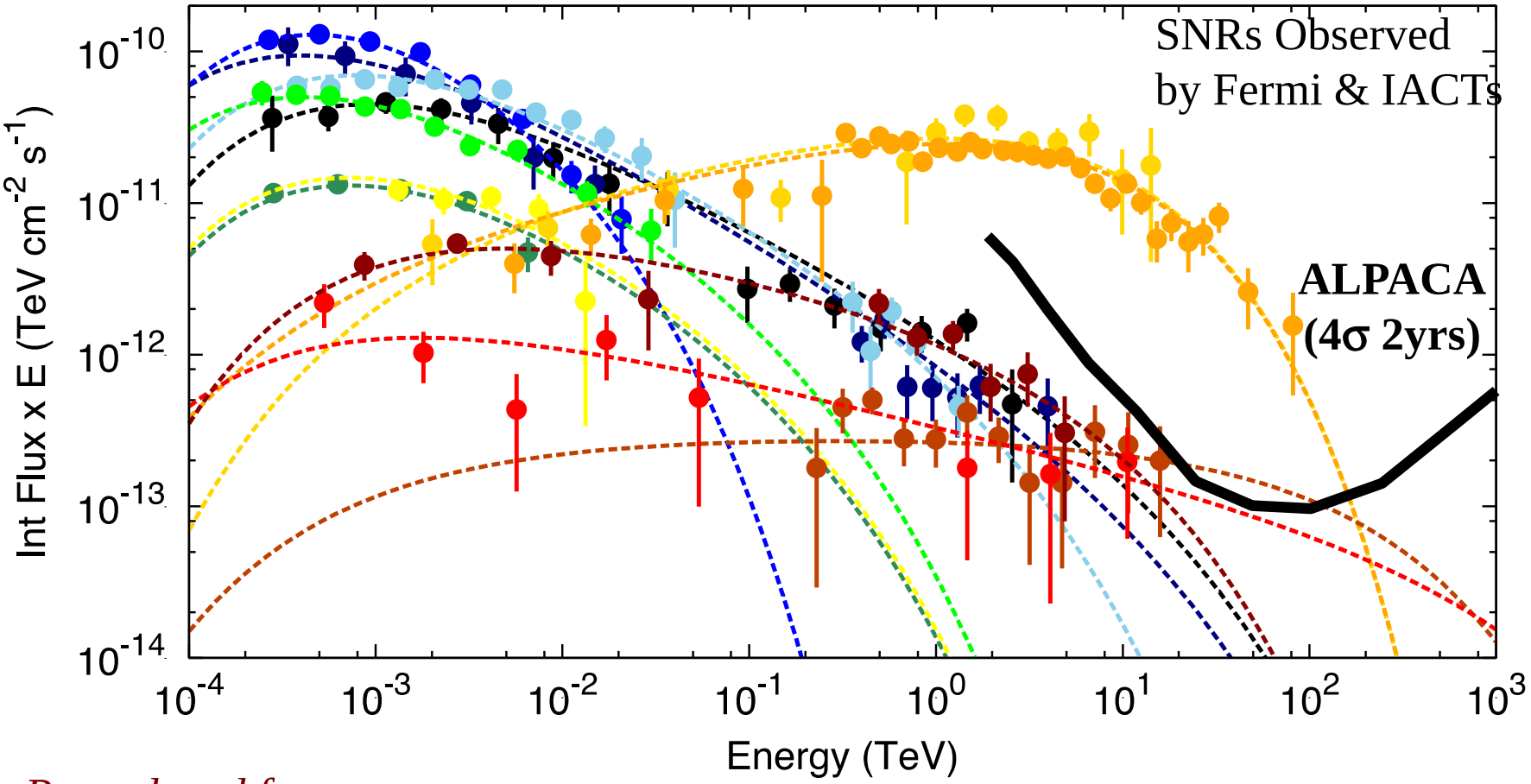
C. Lunardini, et al, PRD (2015)





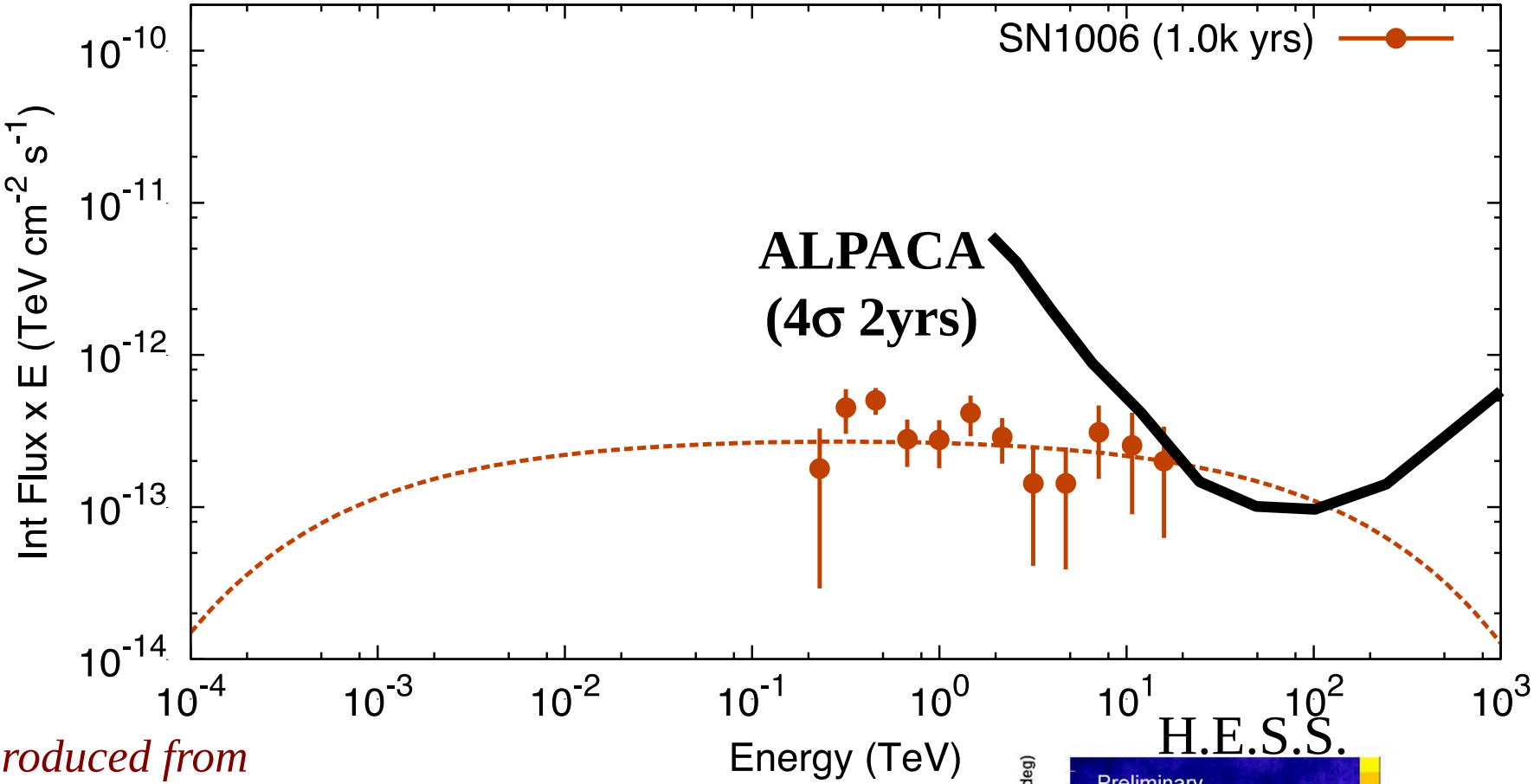
Bubbles observed by Fermi-LAT

Young SNRs



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

Young SNRs



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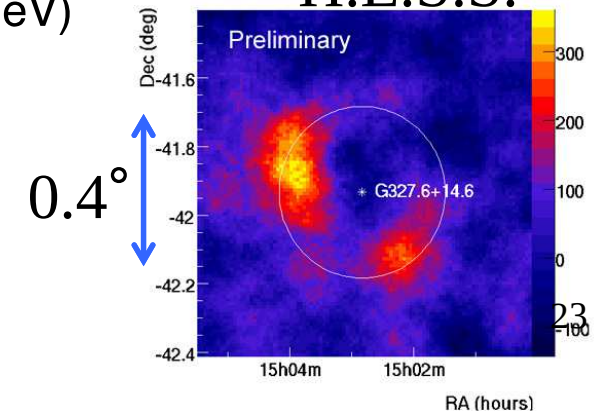
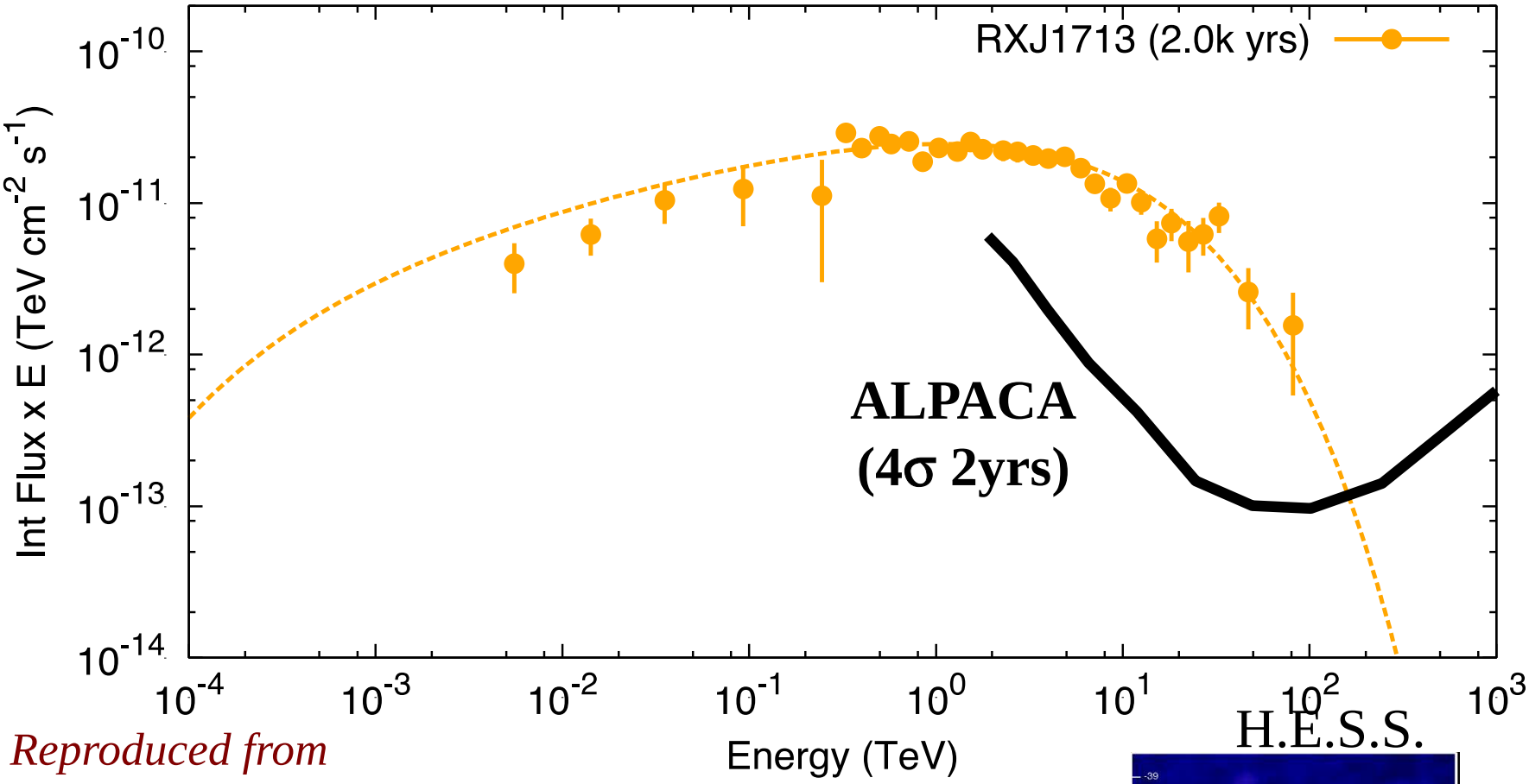
SNRs Observed by Fermi & IACTs

$\delta \sim -42^{\circ}$

H.E.S.S.



Young SNRs



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SNRs Observed by Fermi & IACTs

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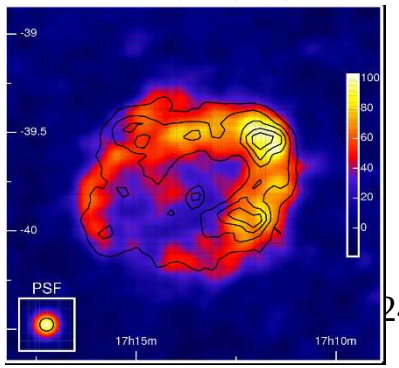
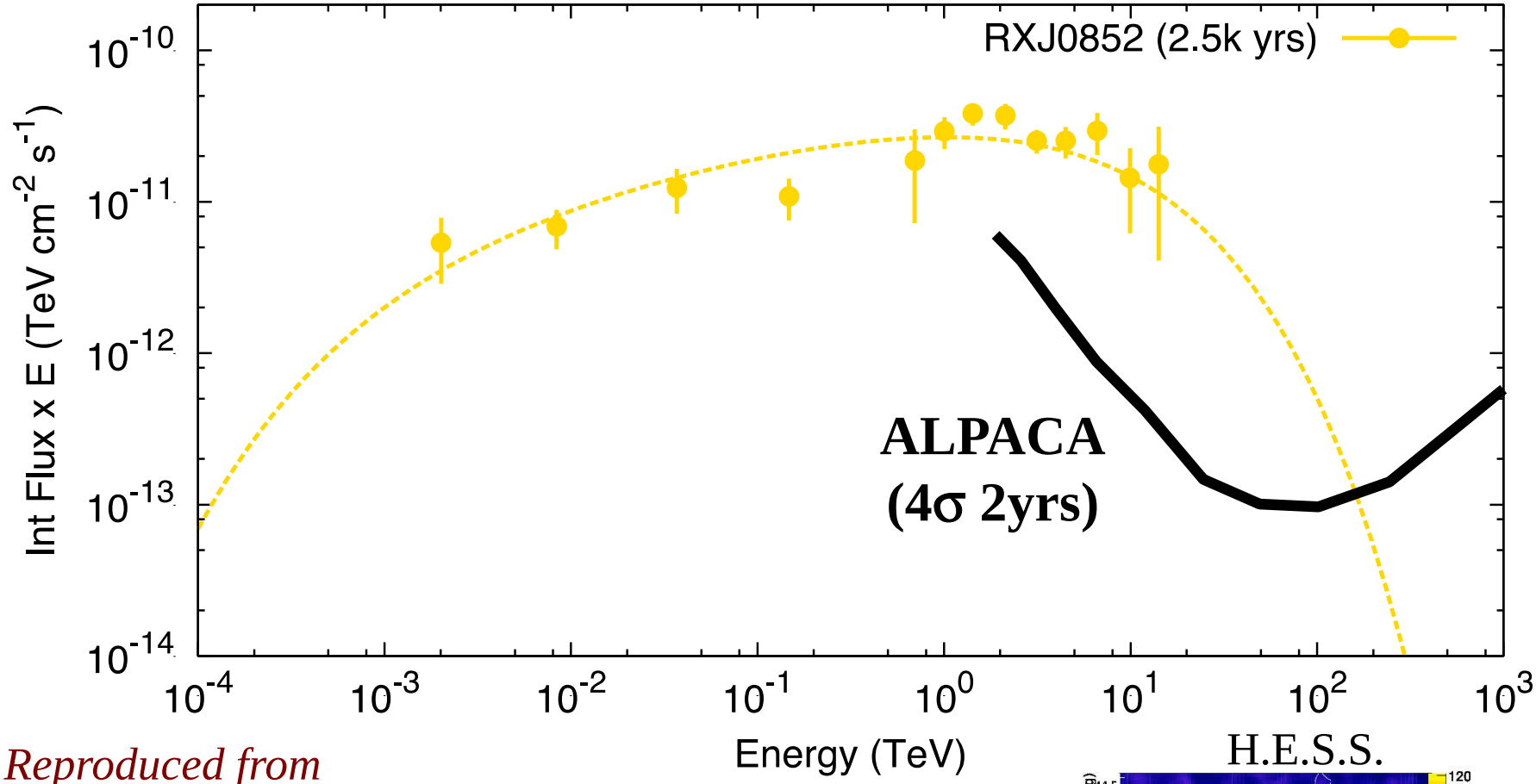


δ ~ -40°

Young SNRs



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SNRs Observed by Fermi & IACTs

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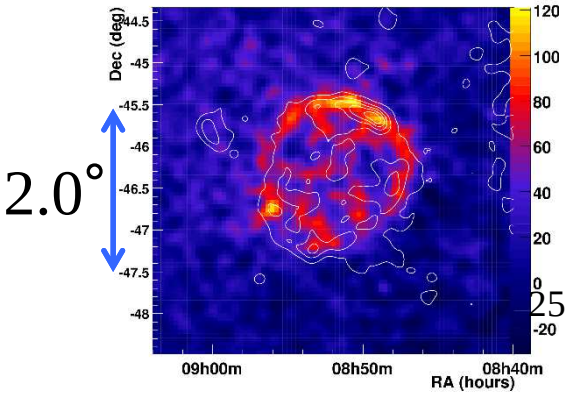
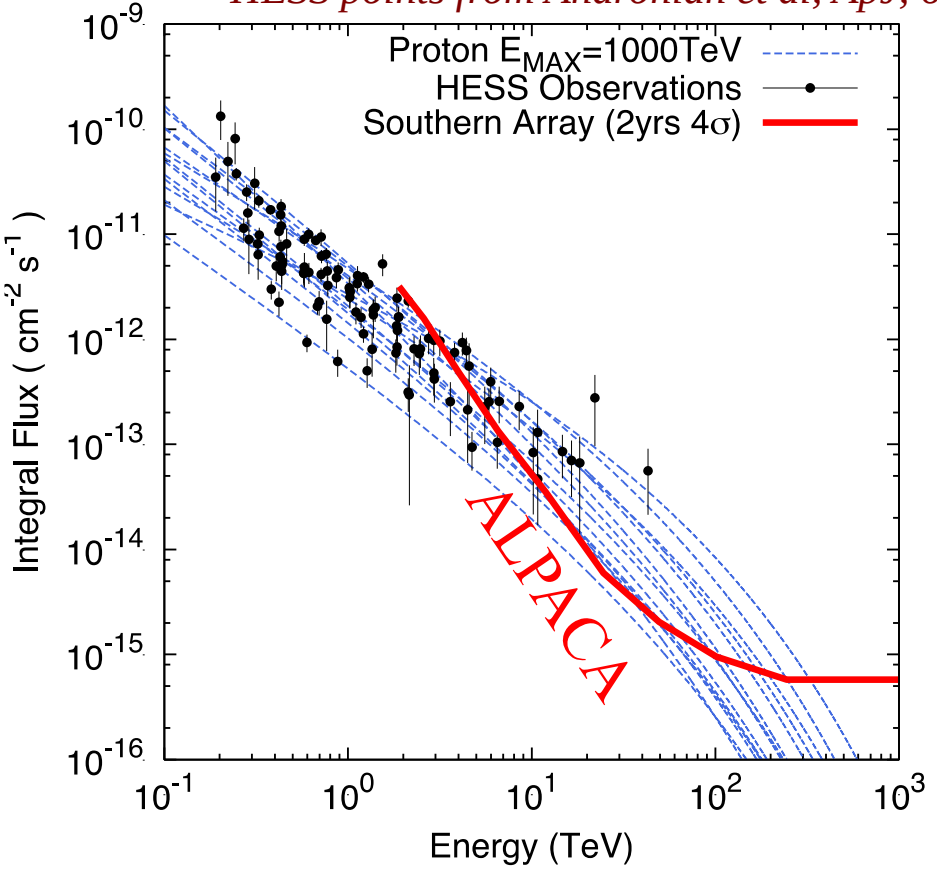


2.0°

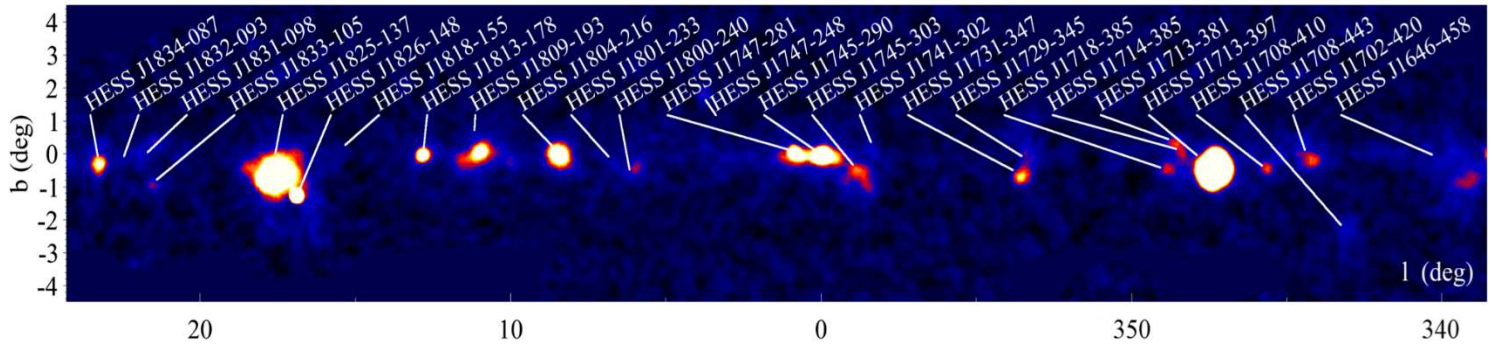
δ ~ -46°

Other Galactic Sources

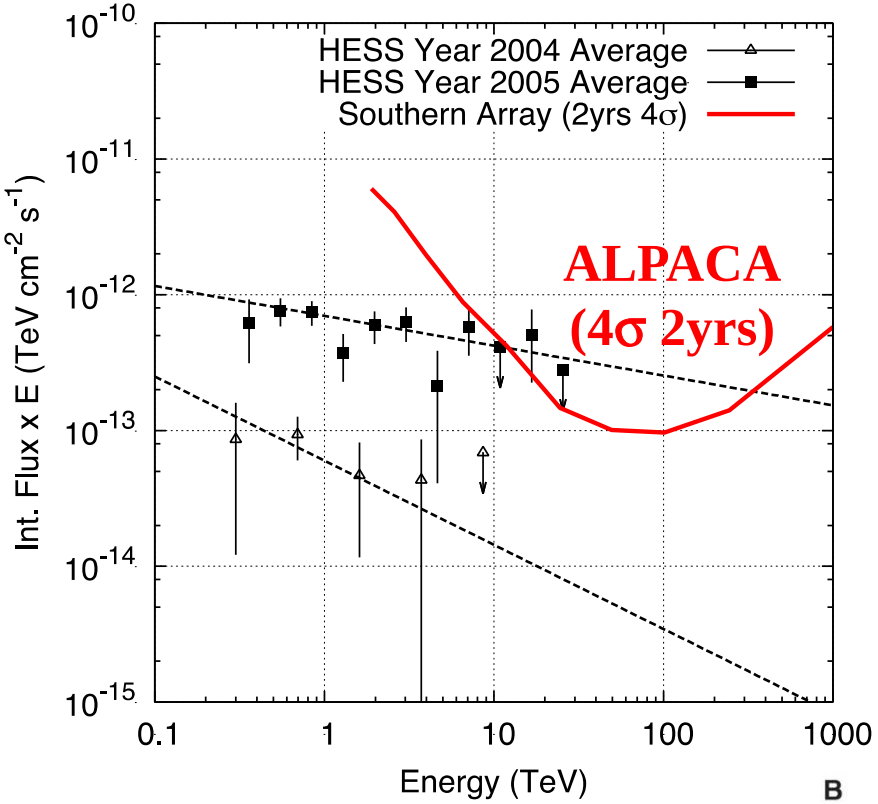
HESS points from Aharonian et al, ApJ, 636, 777 (2006)



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

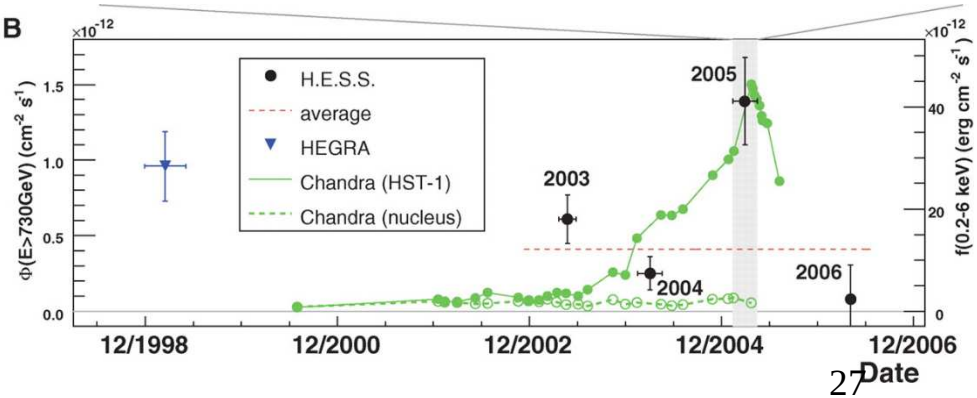


Nearby Extragalactic Source M87 $\delta \sim +12^\circ$

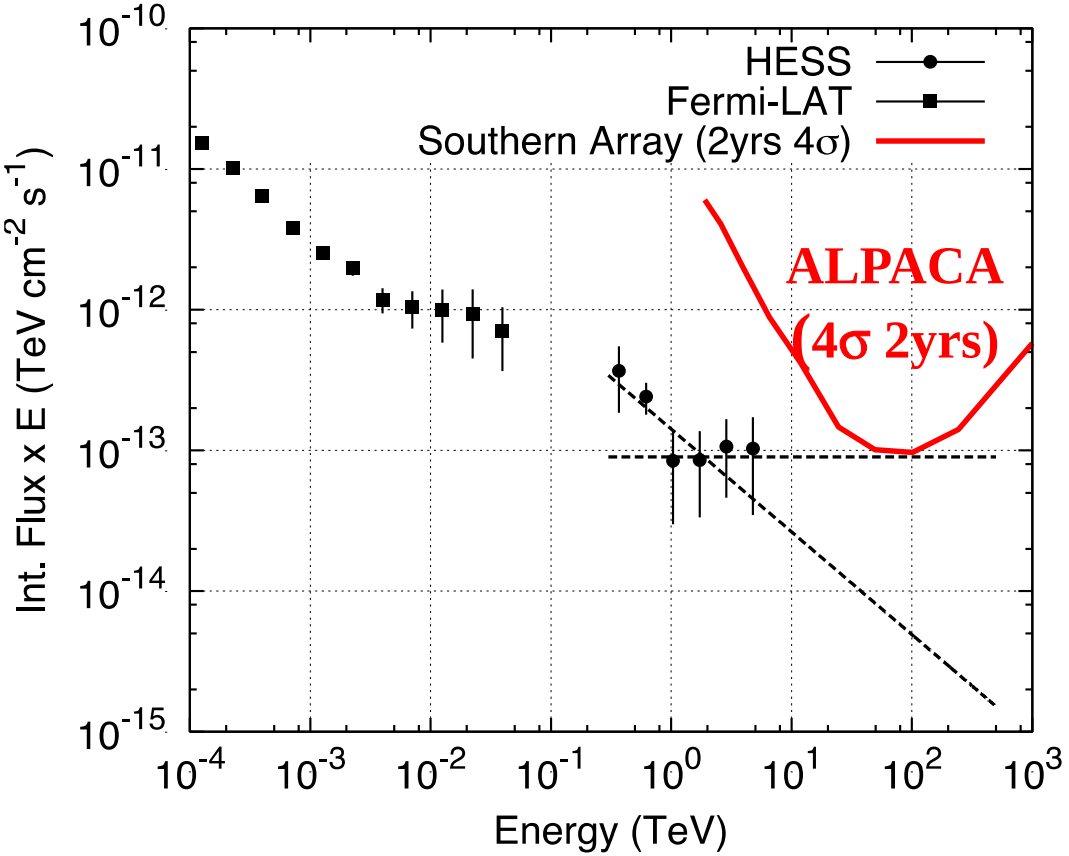


- ✓ Distance: z=0.0043 (16Mpc)
- ✓ Relativistic jet
- ✓ Long-term time variation 2004 – 2005 flare
- ✓ Hard spectrum at flare

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

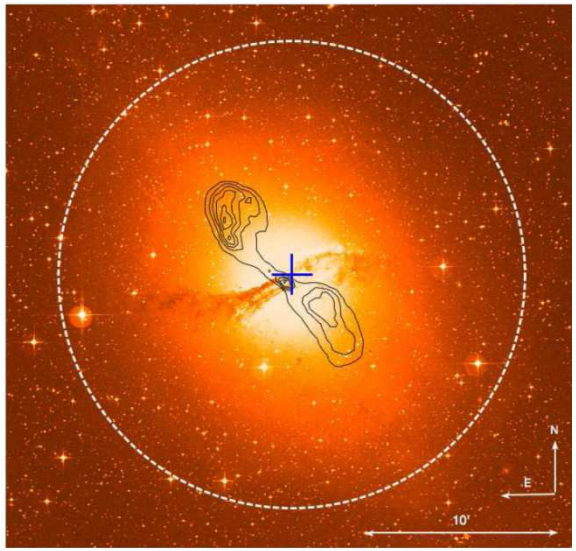


Nearby Extragalactic Source CenA



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?



$\delta \sim -43^{\circ}$

Other research themes

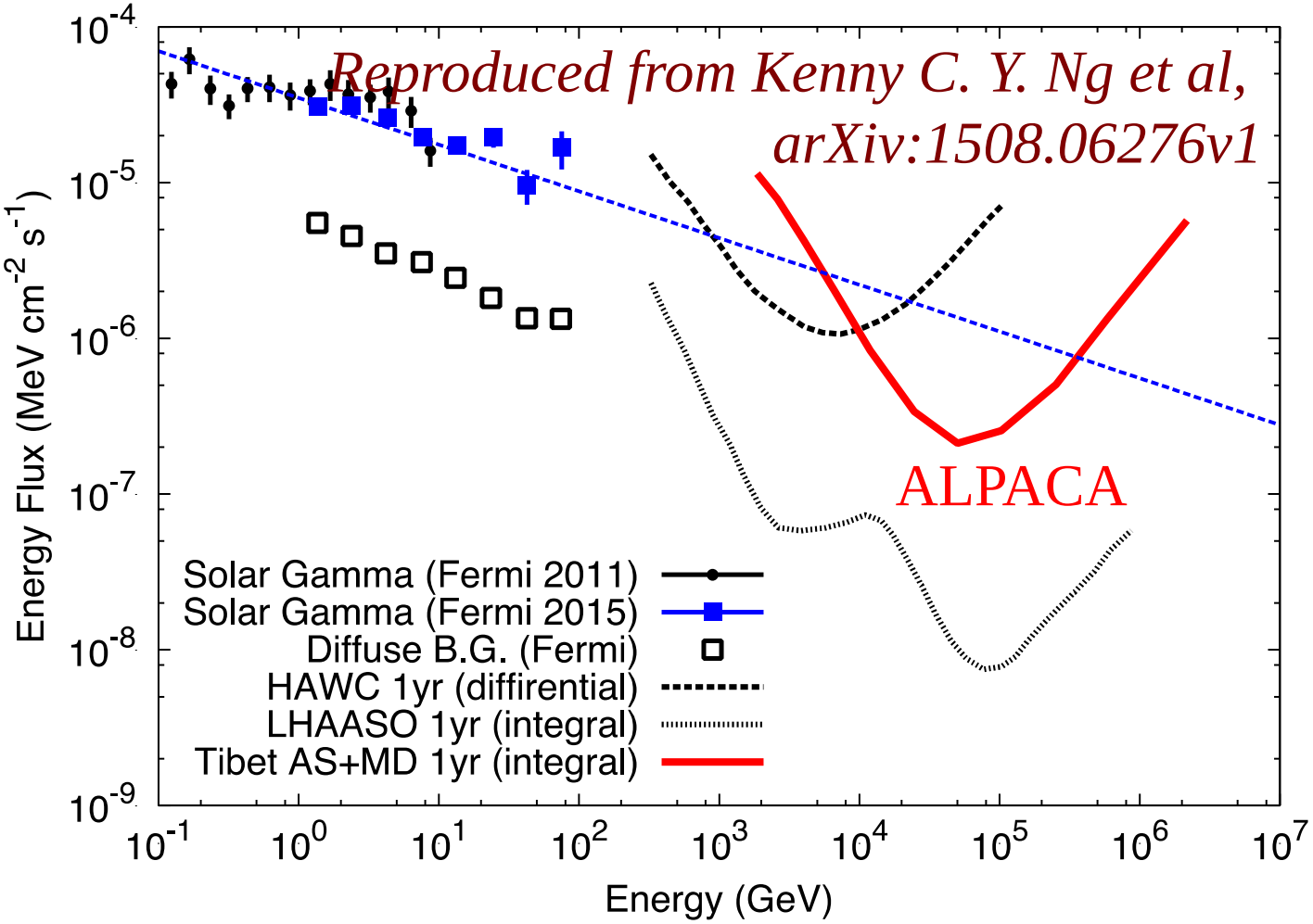
- CR anisotropy @ >TeV region in south
  (Complementary to IceCube)

- The Sun's shadow in south

- Solar γ
  Up to ~100 GeV Fermi detected,
  CR -> Solar atmosphere-> π^0 -> 2γ

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

Sensitivity to Solar Disk γ-Ray



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

Thank you for your attention!

ALPAQUITA (~1/10 AS) will be constructed in 2017

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Advantage to extended sources!

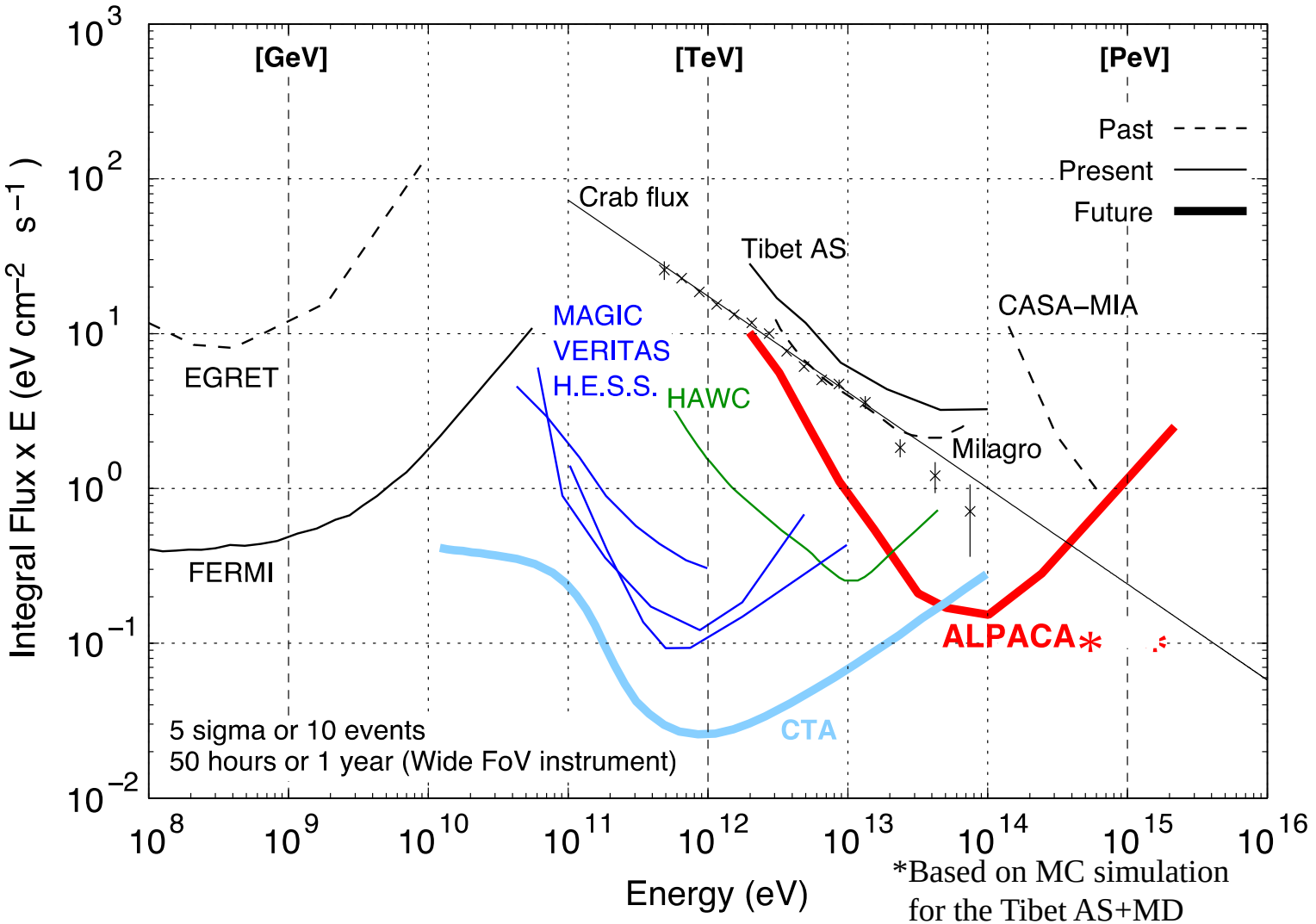
γ-ray point source sensitivity : ~15 % Crab/yr @30TeV

CR anisotropy, Sun shadow, Solar γ, CR chemical composition

3) ALPAQUITA (1/10 scale ALPACA AS , in 2017)

End

Sensitivity to the Point Source



*Based on MC simulation for the Tibet AS+MD

CAVEAT: CTA sensitivity is old!