ALPACA

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ICRR, the University of Tokyo
for the ALPACA collaboration

External Review Committee
@ICRR, Kashiwa, U of Tokyo,
16/May/2019

The ALPACA Experiment

Andes

Large area

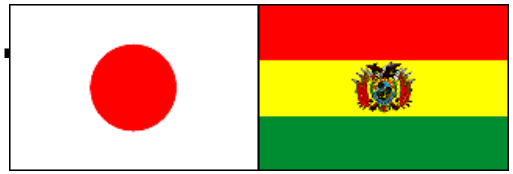
PArticle detector for

Cosmic ray physics and

Astronomy

Mostly members from BASJE, GRAPES-3, Tibet ASγ

The ALPACA Collabora



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Koichi TANAKA

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!

CR anisotropy, Sun shadow, Chemical composition of CR

around Knee, etc

Costs & Construction plan of ALPACA

Year 1: Preparation

Year 2 : Construction of MD

Year 3 : Construction of AS

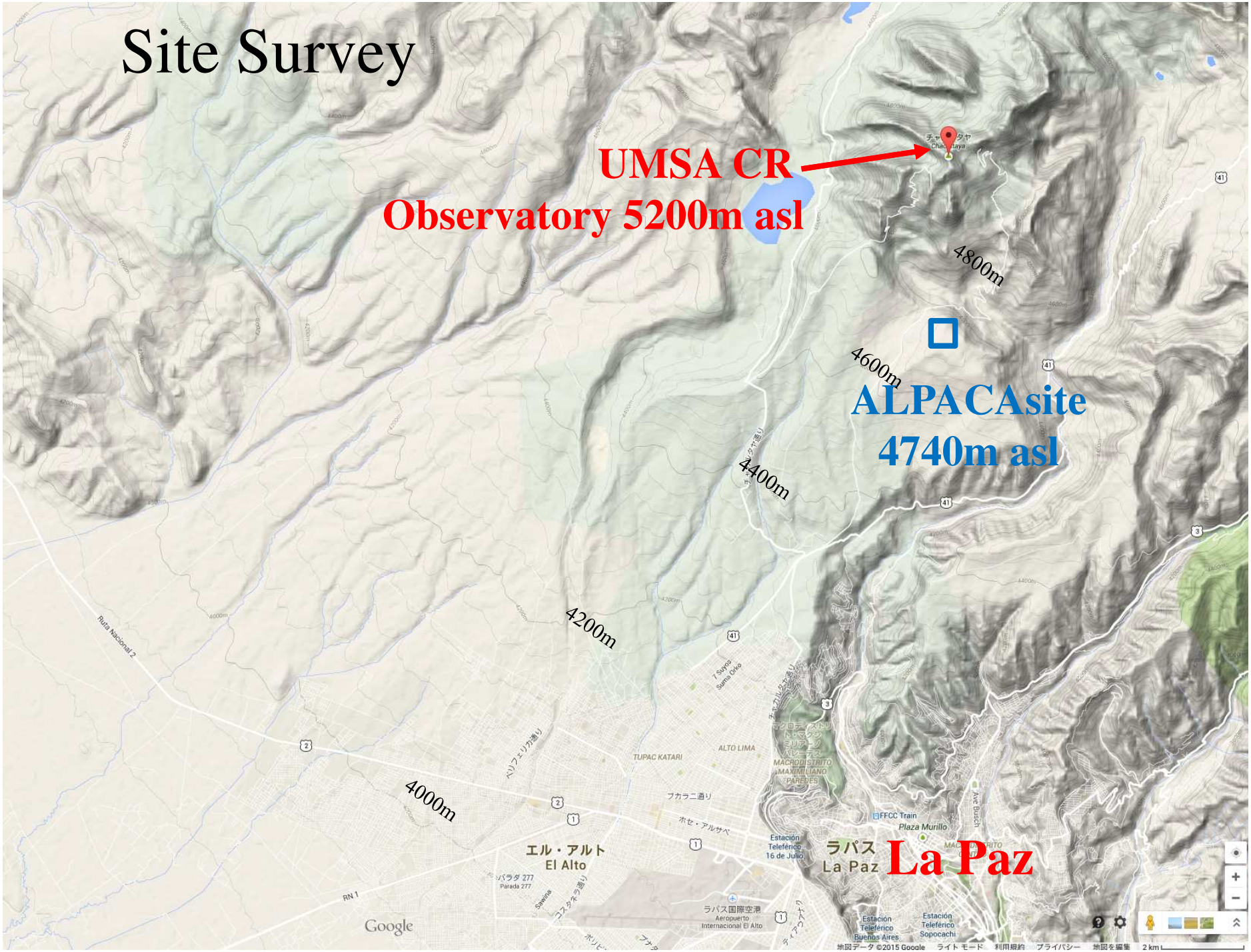
Year 4 : Start data-taking

Observation will continue (5 – 10 years)

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
La Paz
ラパス
La Paz
エル・アルト
El Alto
Google

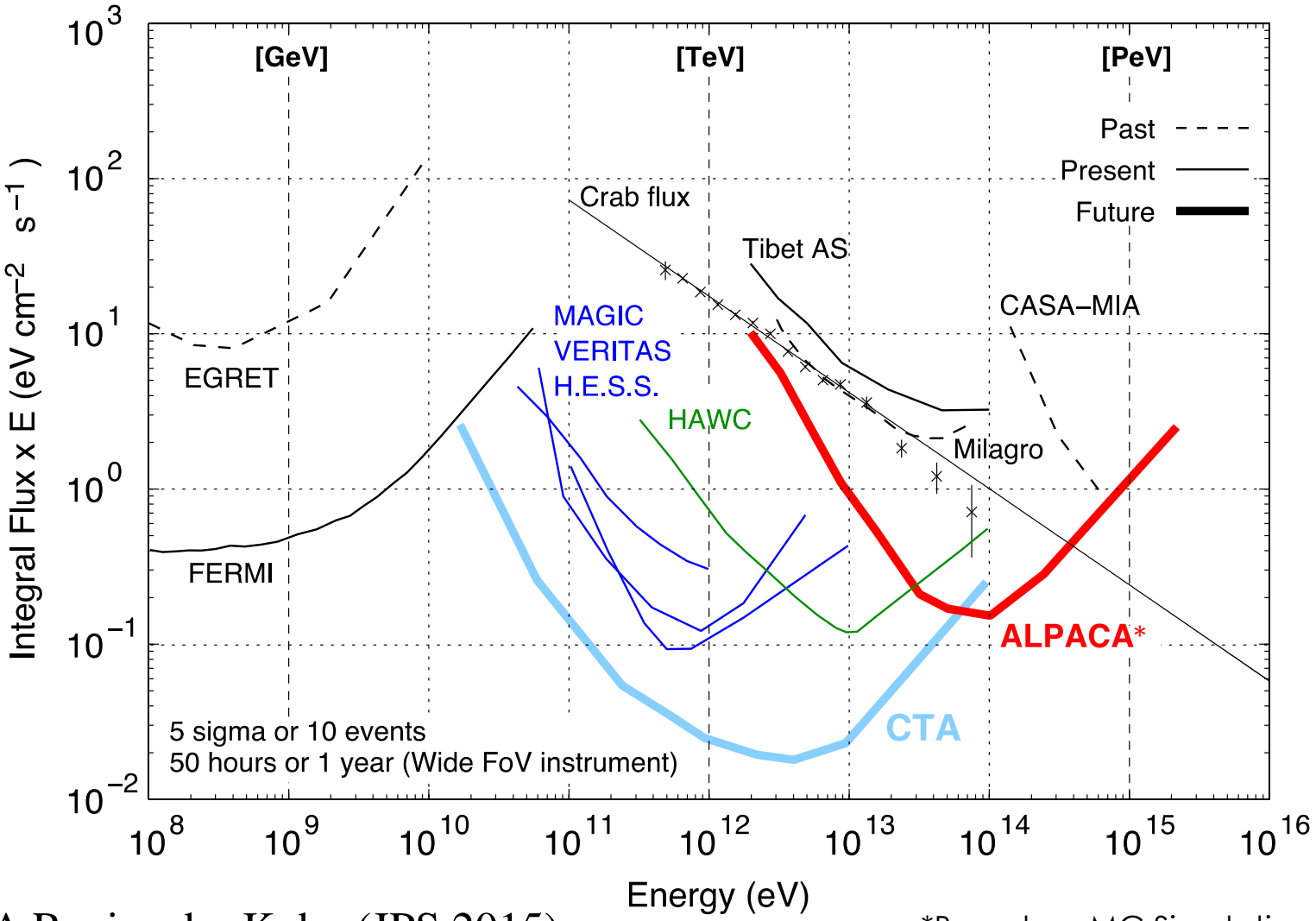
Main purpose of ALPACA

- 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!

γ-ray sensitivity to point sources



CTA Review by Kubo (JPS 2015)

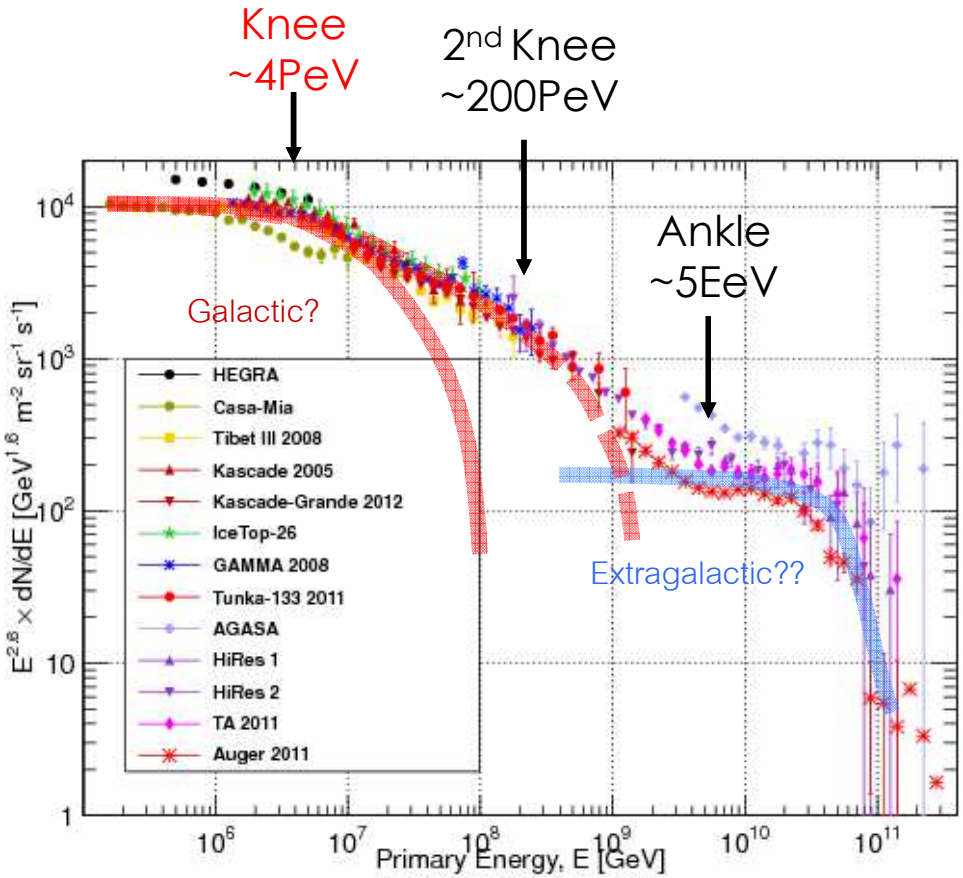
M.Daniel, Proc. of 28th Texas Sympo. (2015)

*Based on MC Simulation
For the Tibet AS+MD

Target γ Sources

- Young SNRs
- Galactic Center
- Dark accelerators (signal only >TeV region)
- Other sources: Diffuse γ on galactic plane,
  Fermi bubbles, solar disk γ,
  DM, etc

γ-ray observation: Origin of CR



Gaisser et al. Front.Phys.(Beijing) 8 (2013) 748

✓ Origin of galactic cosmic rays

→ SNR?? Galactic Center?

✓ Distance to Crab Nebula : 1000pc

gyro radius of 1000TeV proton: 0.3pc

✓ Indirect observation by g rays

High E electron + photon

Inverse Comption (IC) scatterings

and/or

High E proton + Interstellar Matter

(p + ISM → π^0 → 2γ)

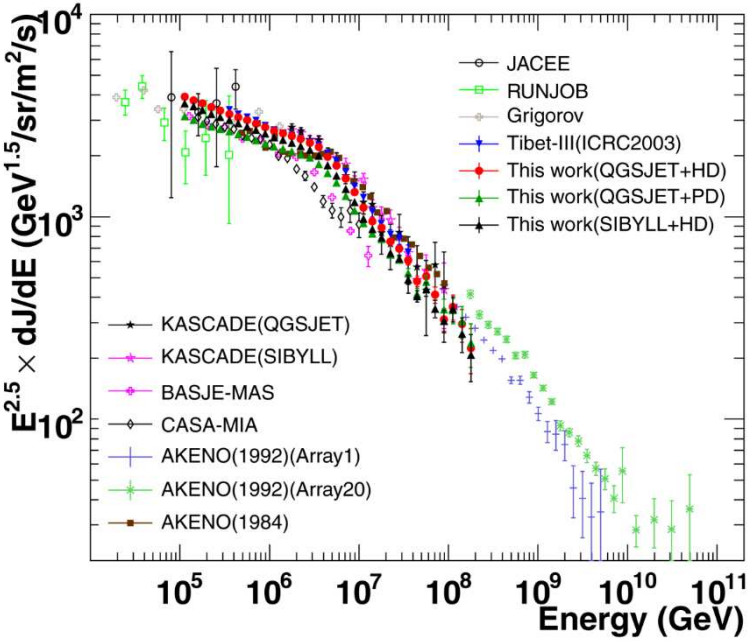
→ Extended γ-sources (+ molecular clouds)

with hard spectrum index (-2)

extending > 100TeV

Where, how, and up to what energy are cosmic rays accelerated in our galaxy?

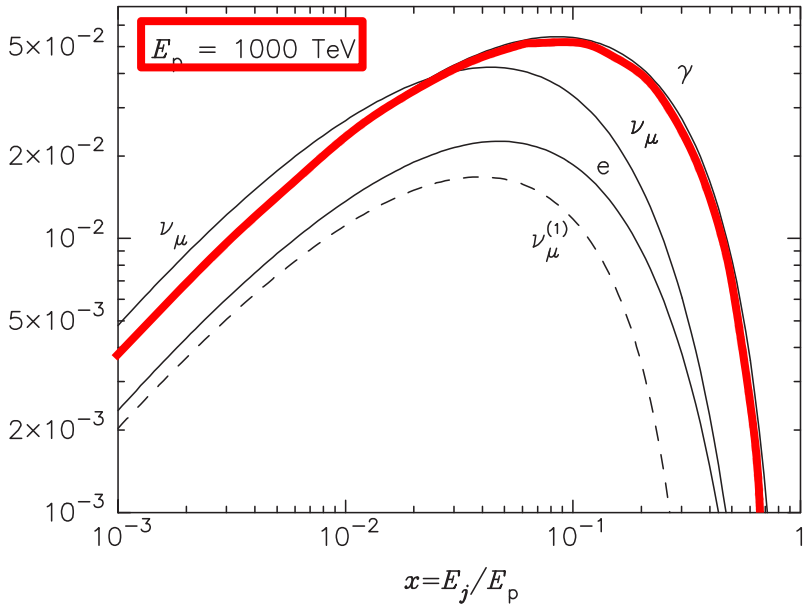
Origin of Cosmic Rays at the Knee



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

✓Knee-4PeV: of galactic origin!?

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



γ−ray energy spectrum

✓ CR+ISM→π^0+…→2γ

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

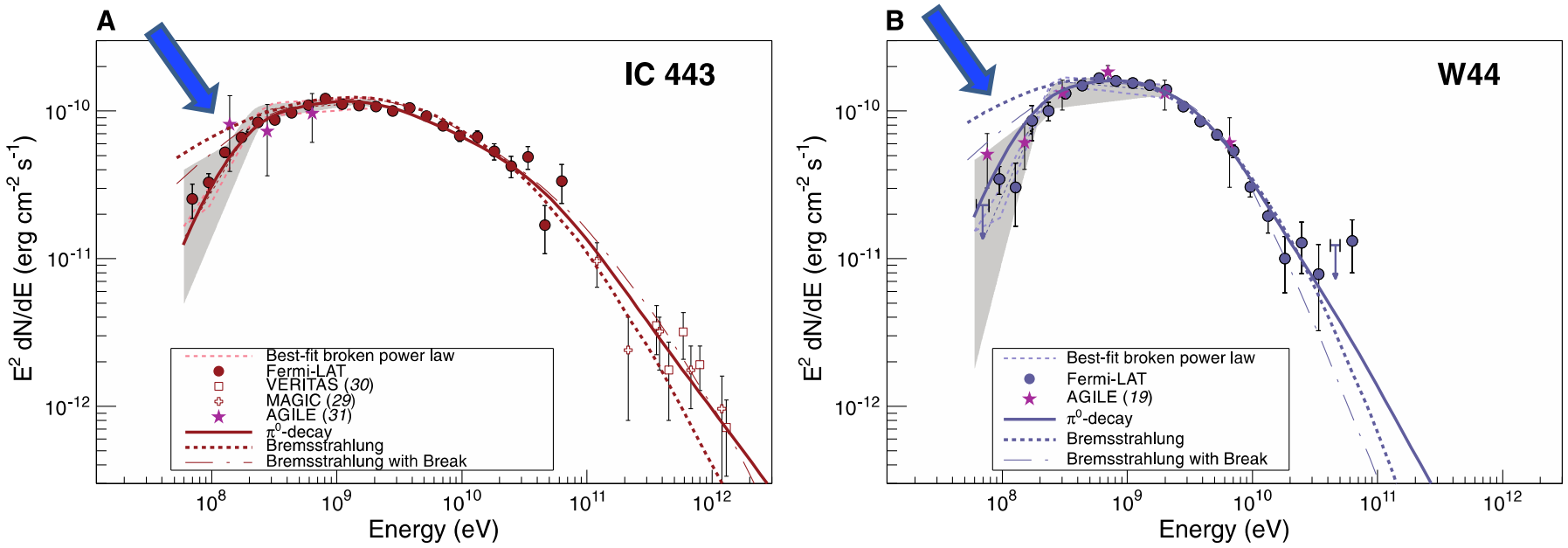
PeVatron = CR accelerator up to PeV region

Should be in our galaxy or very nearby extragalaxy, due to photon absorption!

γ-ray observation : proton accelerating objects

SNR observation by Fermi-LAT

→ W44, IC443, W51 – Evidence for π^0 decays



Ackermann, et al (Fermi-LAT), Science (2013)

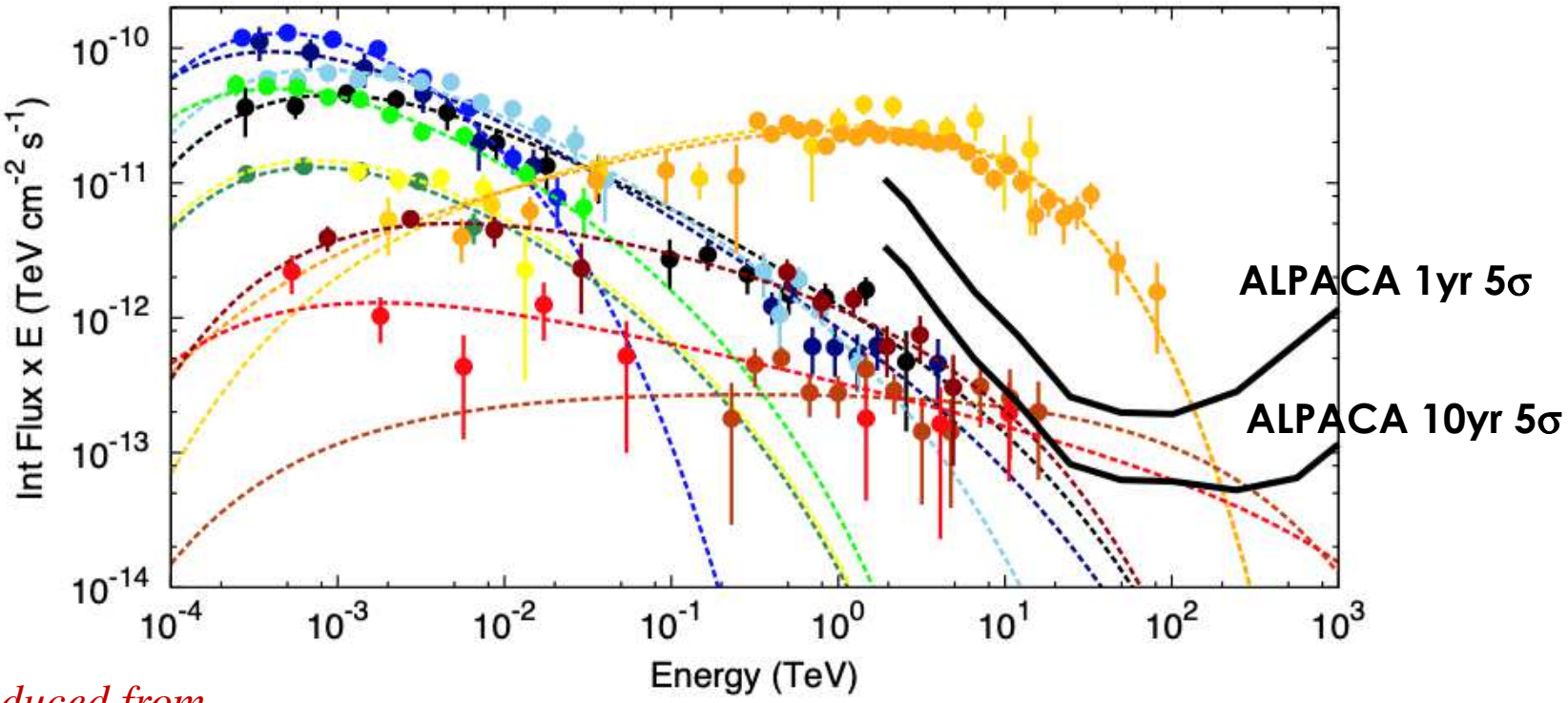
"Detection of the Characteristic Pion-Decay Signature in Supernova Remnants"

γ–Ray Observation : SNRs

$$\frac{E^{\gamma}_{\max}}{E^{p}_{\max}} \sim O(1/10)$$

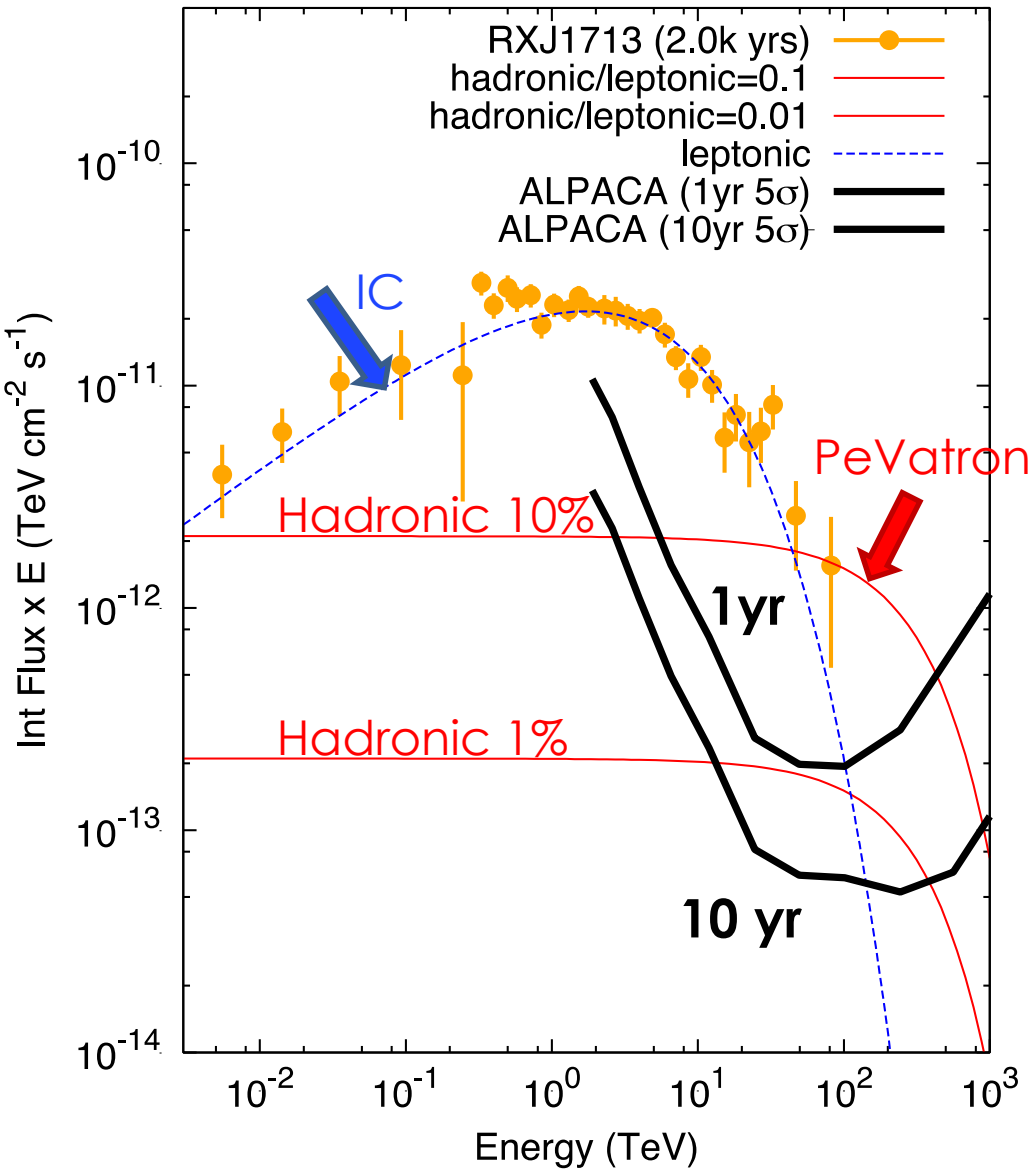
Probe of PeVatrons

10TeV – PeV



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

γ-Ray Observation : SNR (1 Example)

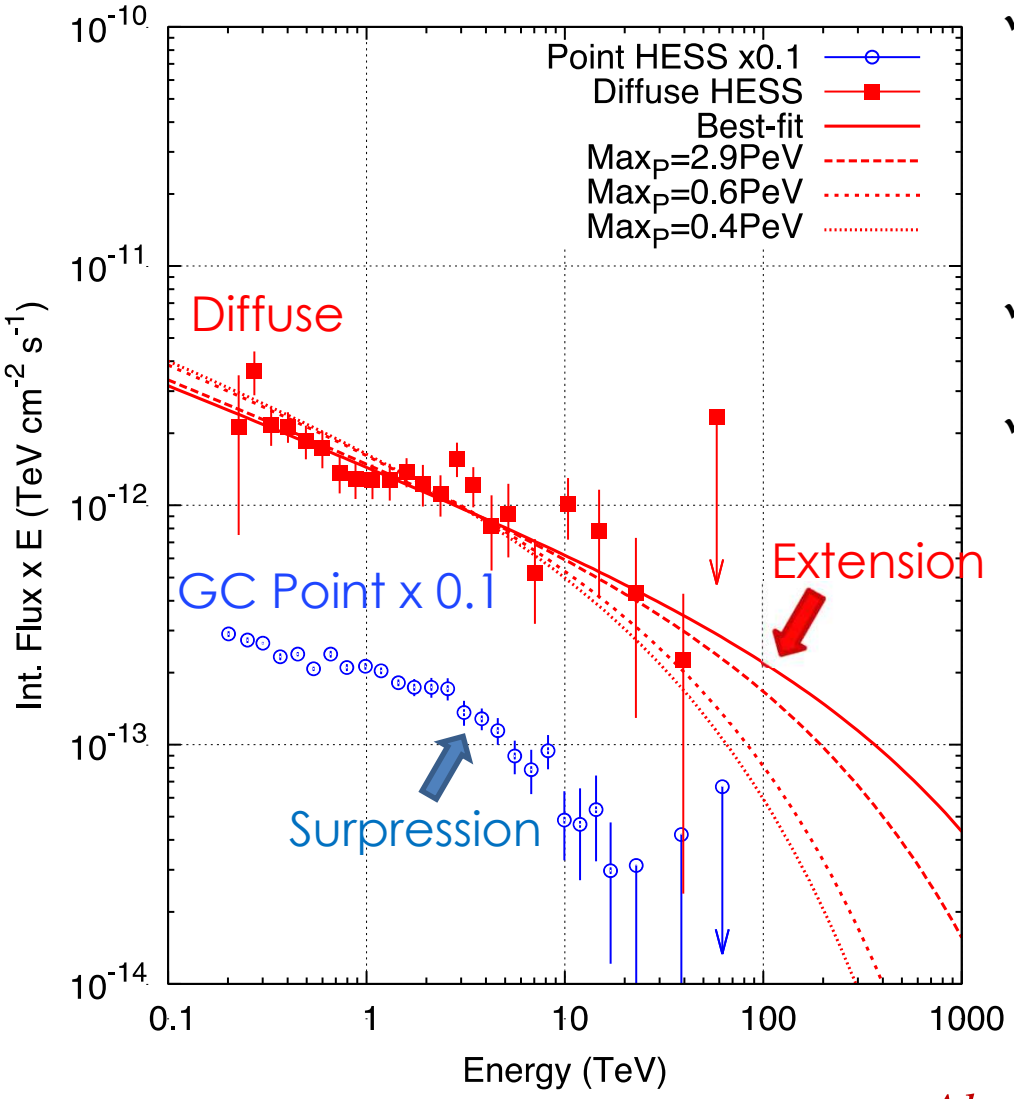


RX J1713.7-3946

- ✓ Fermi-LAT hard index Γ=~1.5 suggesting electron (IC) origin？
- ✓ If IC origin -> B=20μG
- ✓ Filament structure and flux time variability by X rays-> B>100μG needed？
- ✓ Proton origin -> Locally possible?
- ✓ If spectral bump -> Good evidence for proton origin

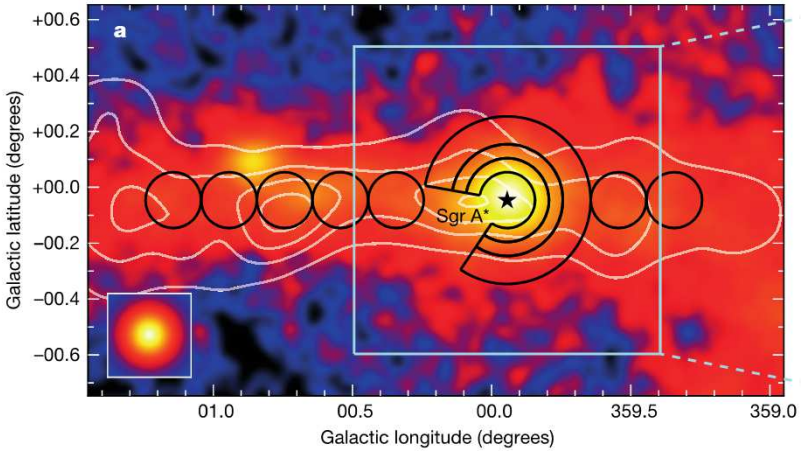
Acero+, ApJ, 840, 74 (2017)

γ-Ray Observation : Galactic Center (GC)



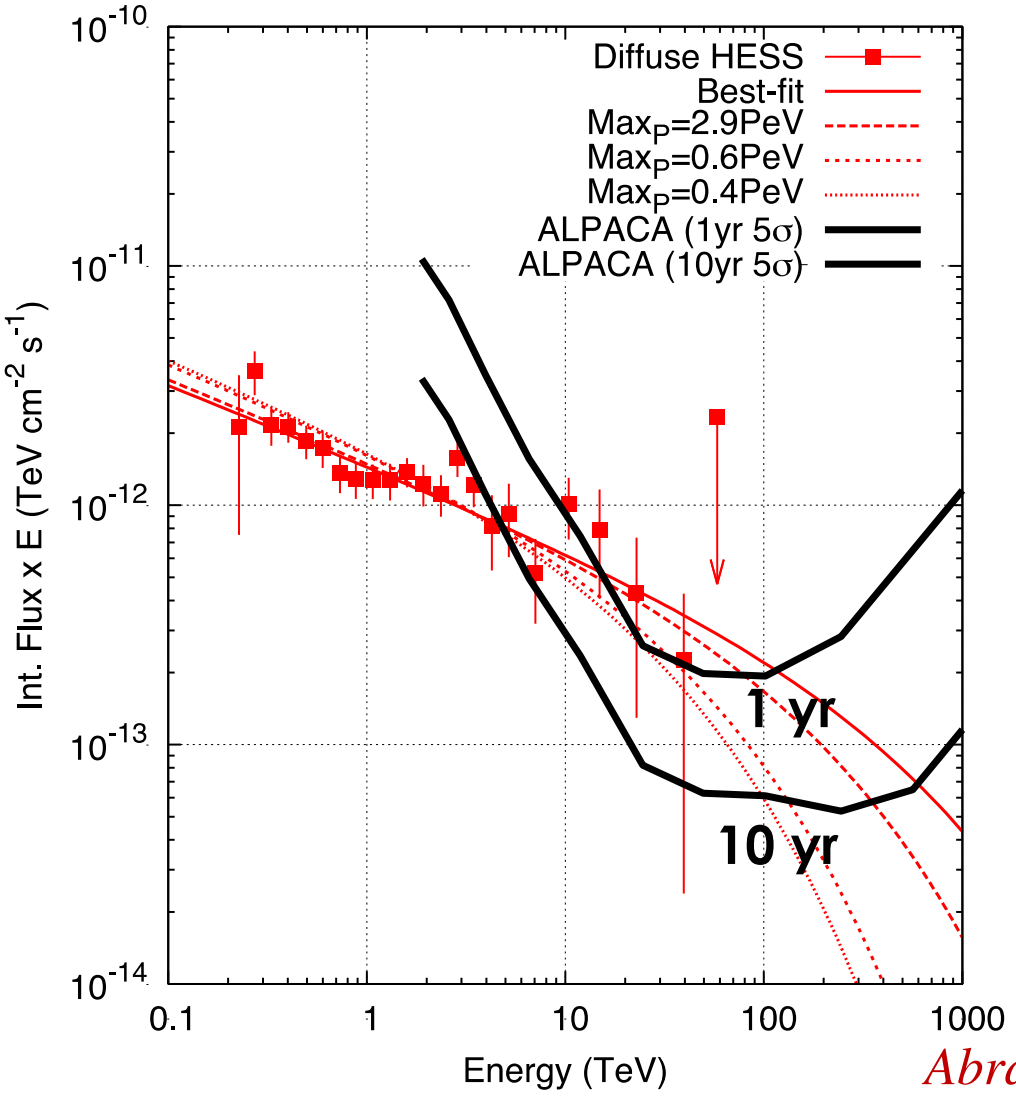
- ✓ Spacially extended γ-ray emission
  → Hard spectrum & extension
  Not explained by electron origin due to large Sync.&IC energy loss
- ✓ High possibility of γ rays >100TeV
- ✓ Spectral cut off?
  →Maximum proton energy?

$$\frac{E^{\gamma}_{\max}}{E^{p}_{\max}} \sim O(1/10)$$



Abramowski+ (H.E.S.S.), Nature (2016)
"Acceleration of petaelectronvolt protons in the Galactic Centre"

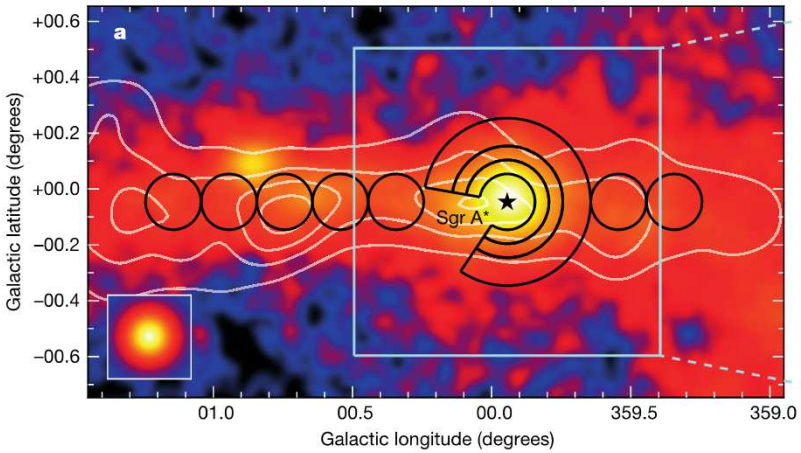
γ–Ray Observation : Galactic Center (GC)



Detection of Sub-PeV γ !
→ PeVatron!

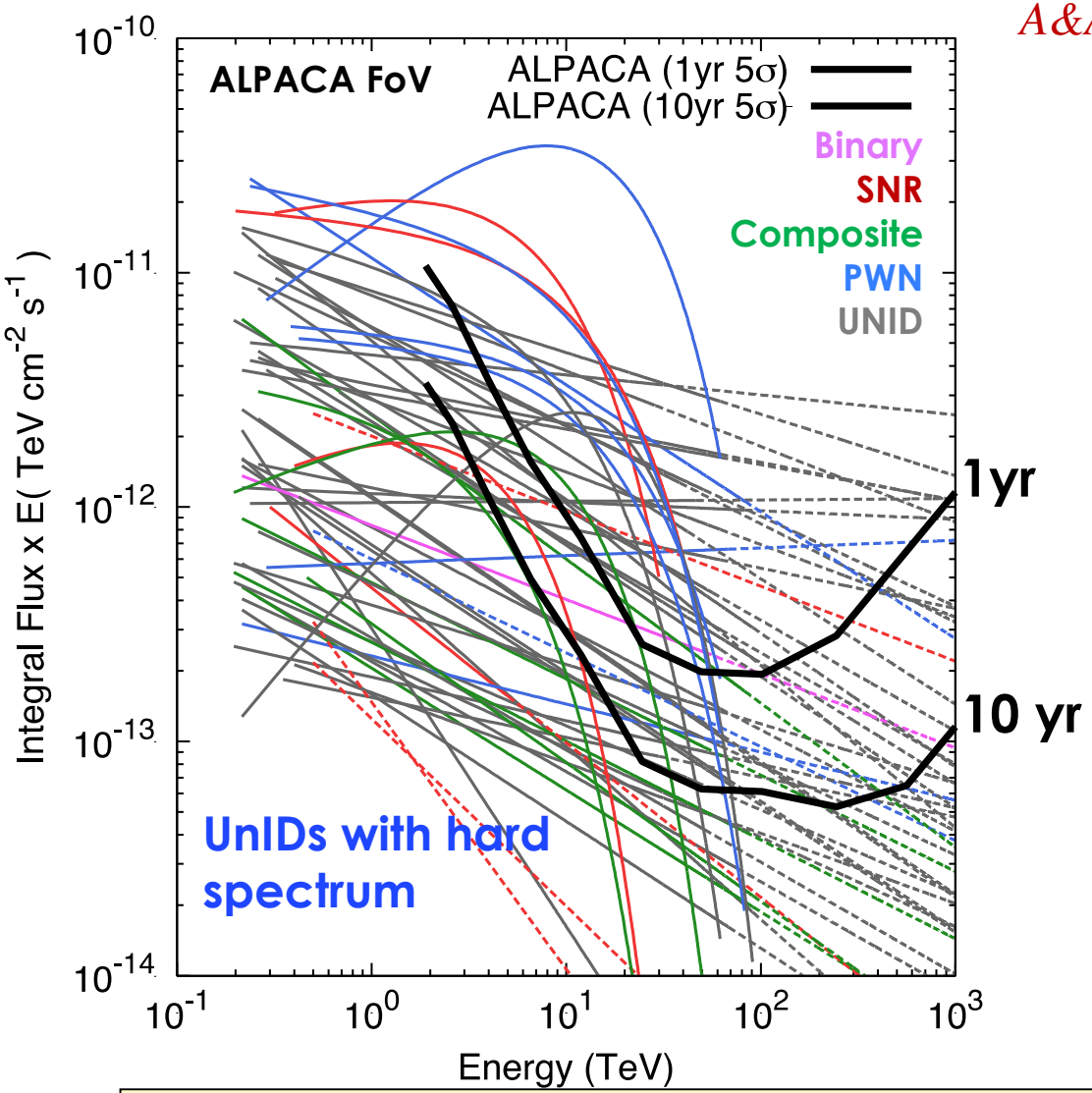
→ Can explain Knee-energy CR ?

$$\frac{E^{\gamma}_{\max}}{E^{p}_{\max}} \sim O(1/10)$$

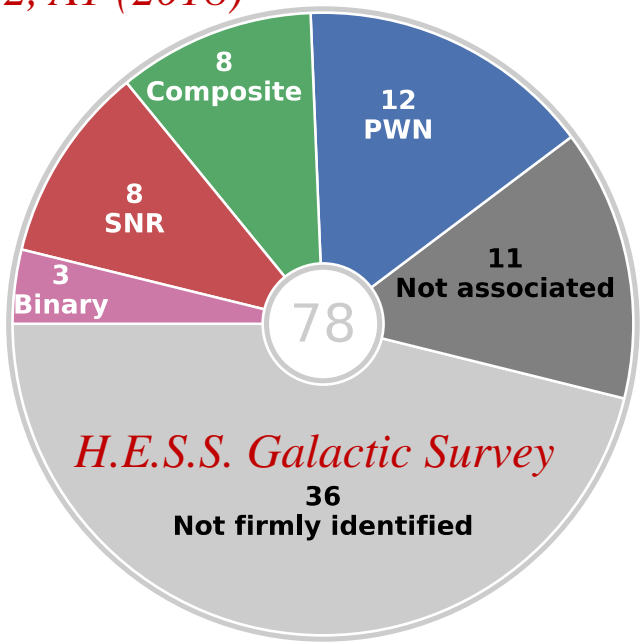


Abramowski+ (H.E.S.S.), Nature (2016)
"Acceleration of petaelectronvolt protons in the Galactic Centre"

γ-ray observation : Dark Accelerators



A&A 612, A1 (2018)

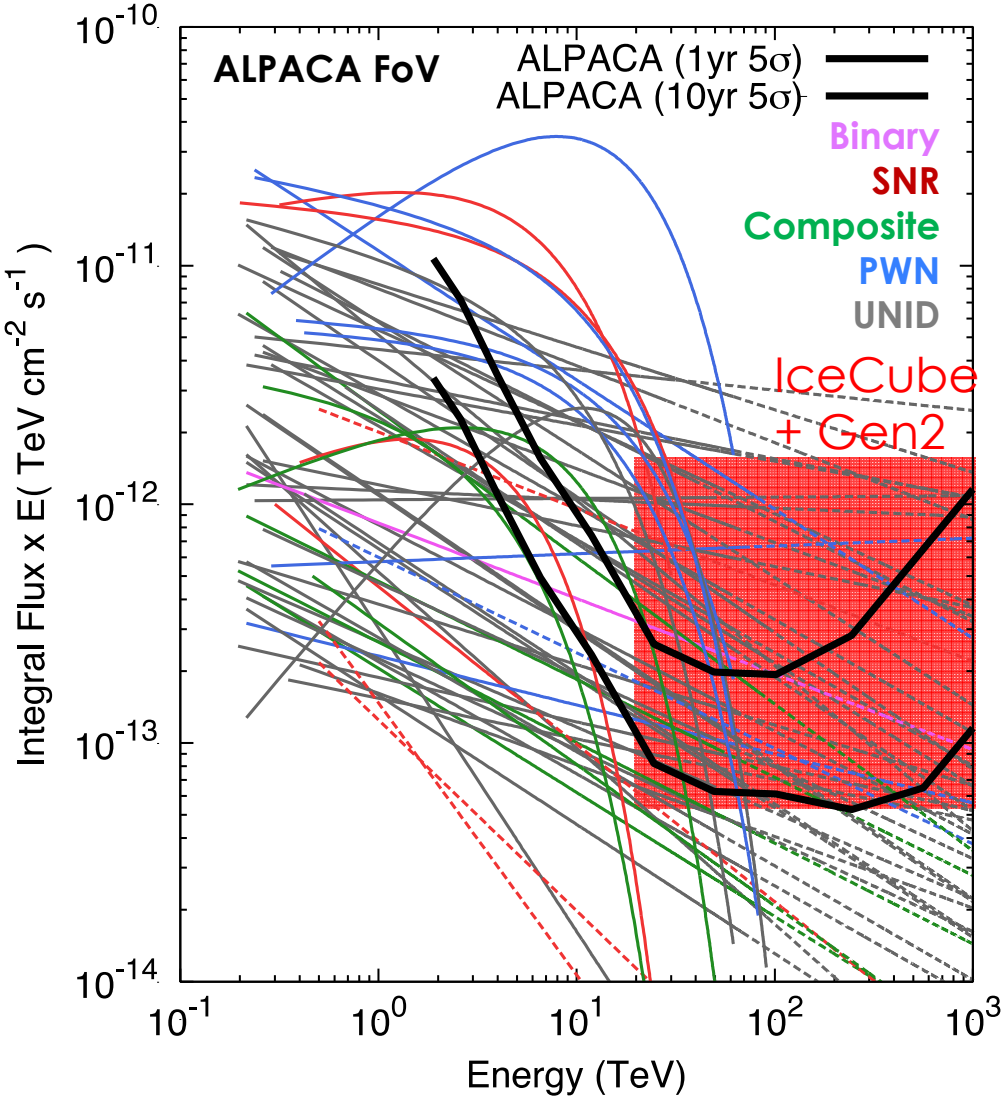


Extended γ-sources (+ molecula with hard spectrum index (−2) extending > 100TeV

→ PeVatron candidates

~30 sources extending above several x 10 TeV
-> PeVatron search

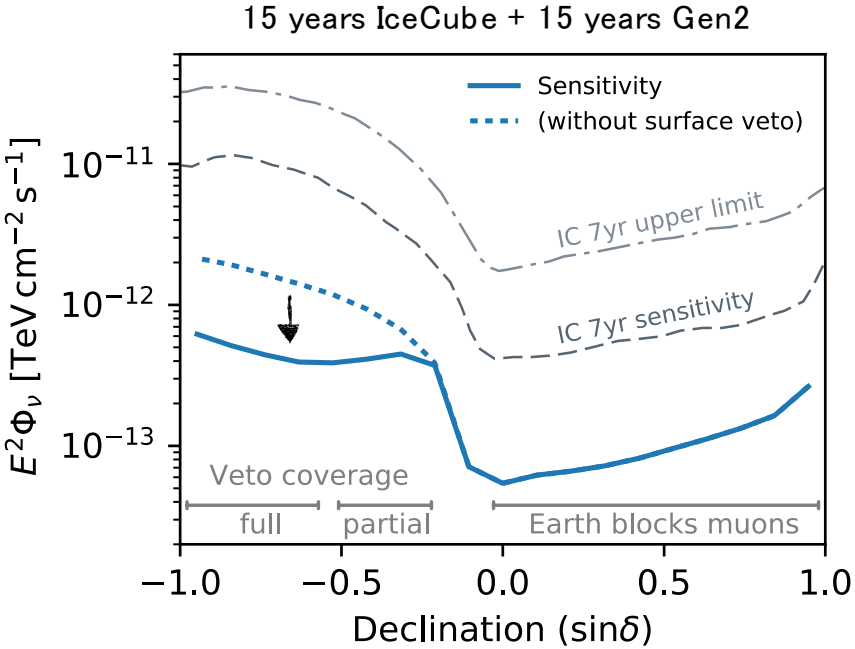
Very High Energy ν observation



- ✓ Galactic Sources :
  Flux$_\nu$ (>100TeV) ~= Flux$_\gamma$

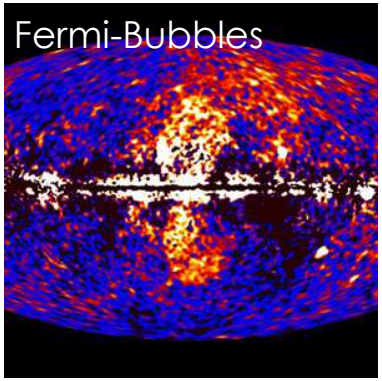
  $\pi^0 \rightarrow 2\gamma$
  $\pi^{+/-} \rightarrow \mu^{+/-} + \nu_\mu$
  $\mu^{+/-} \rightarrow e^{+/-} + \nu_e + \nu_\mu$

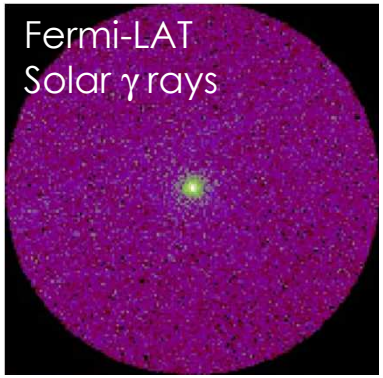
- ✓ IceCube + Gen2
  ALPACA energy region

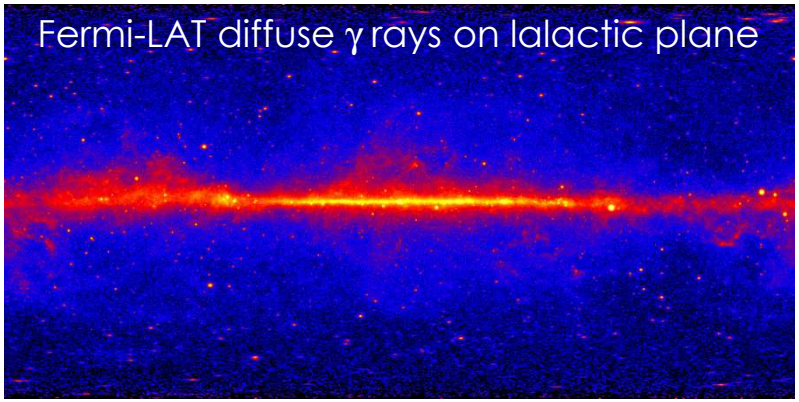


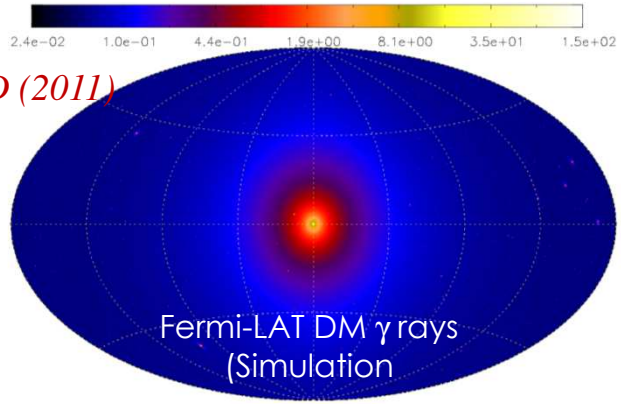
Jakob van Santen (ICRC 2017)

Other Targets > 10TeV









Pieri+, PRD (2011)

- ✓ Fermi Bubbles
  - Wide FoV observation、
  - Hard spectral index (~-2) around GC
- ✓ Galactic diffuse gamma
  - Wide FoV、Very bright in southern sky
- ✓ Solar disk gamma rays
  - Day time observation needed
  - ?CR origin? hard spectral index (~−2)
- ✓ Nearby AGN
  - >10TeVγ Wide FoV monitoring
  - Hard–spectral AGN at high z existing
- ✓ Very heavy dark-matter search
  - >10TeV GC, dwarf galaxies, SUN
  - Spherically extended γ-ray distibution

Wide FoV • Continuous Observation by ALPACA

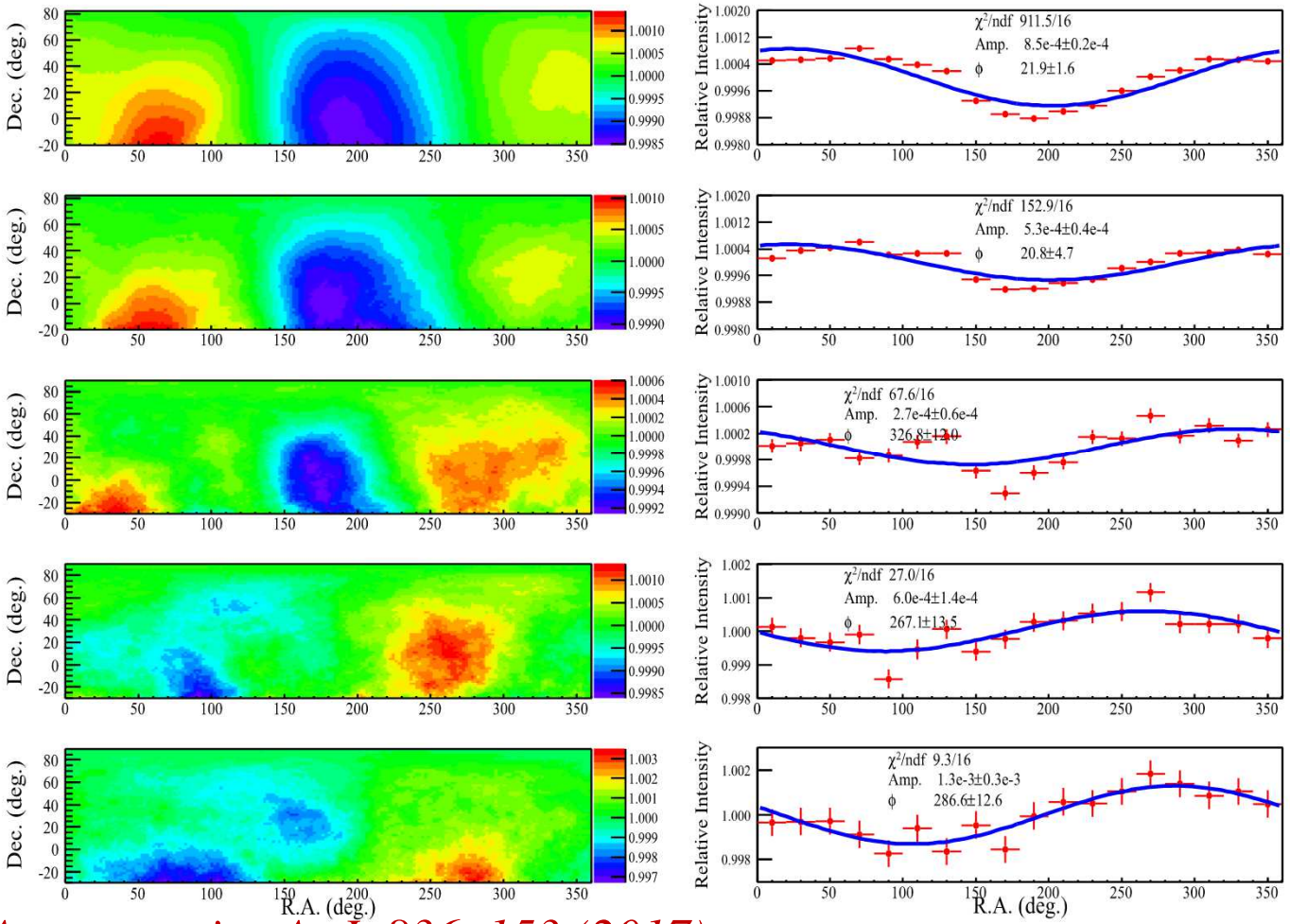
Other research themes

- 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）

CR anisotropy: Tibet ASγ (Northern sky)



15 TeV

50 TeV

100 TeV

300 TeV

1000 TeV

Amenomori+, ApJ, 836, 153 (2017)

~0.1% Anisotoropy → Origin？

Whole-sky Observation in wide energy range-> Important

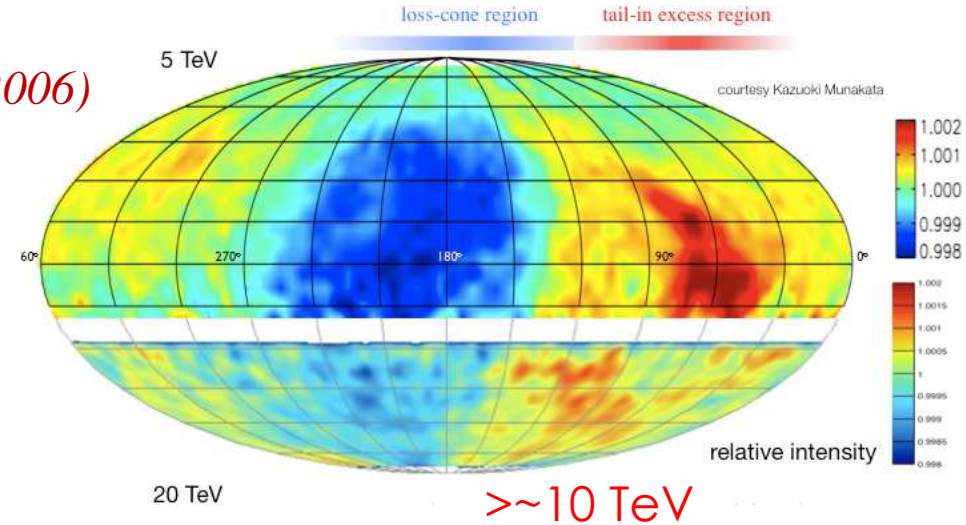
CR anisotropy: Southern sky

Amenomori+(Tibet ASγ), Science, 314, 439 (2006)
*Abbasi+(IceCube), ApJL, **718**, L194, (2010)*

Tibet + IceCube combined

→ CR distribution in Local interstellar medium (LISM)?

Influence of heliospheric magnetic field

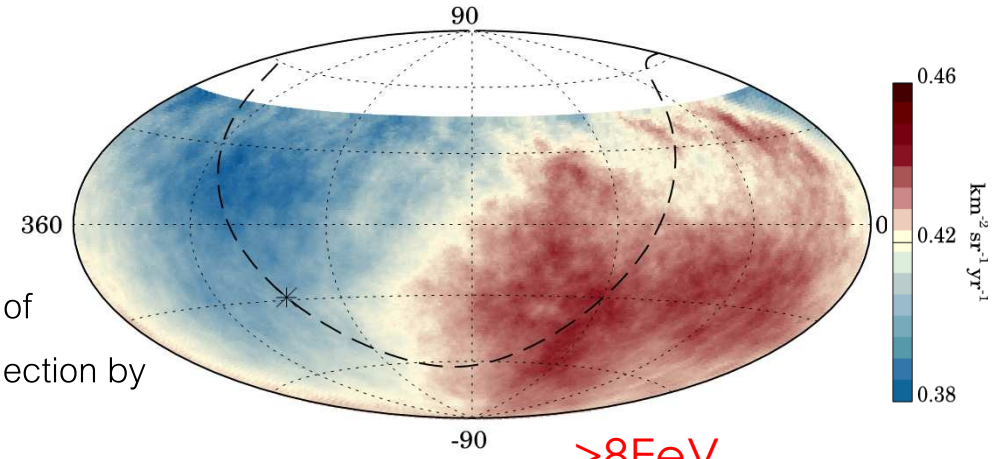


>~10 TeV

Auger Collabo., Science, 357, 1266 (2017)

Auger dipole distribution

→ Consistent with the direction in flux-weighted dipole of of 2MRS galaxy catalogue sources, considering deflection by galactic magnetic field



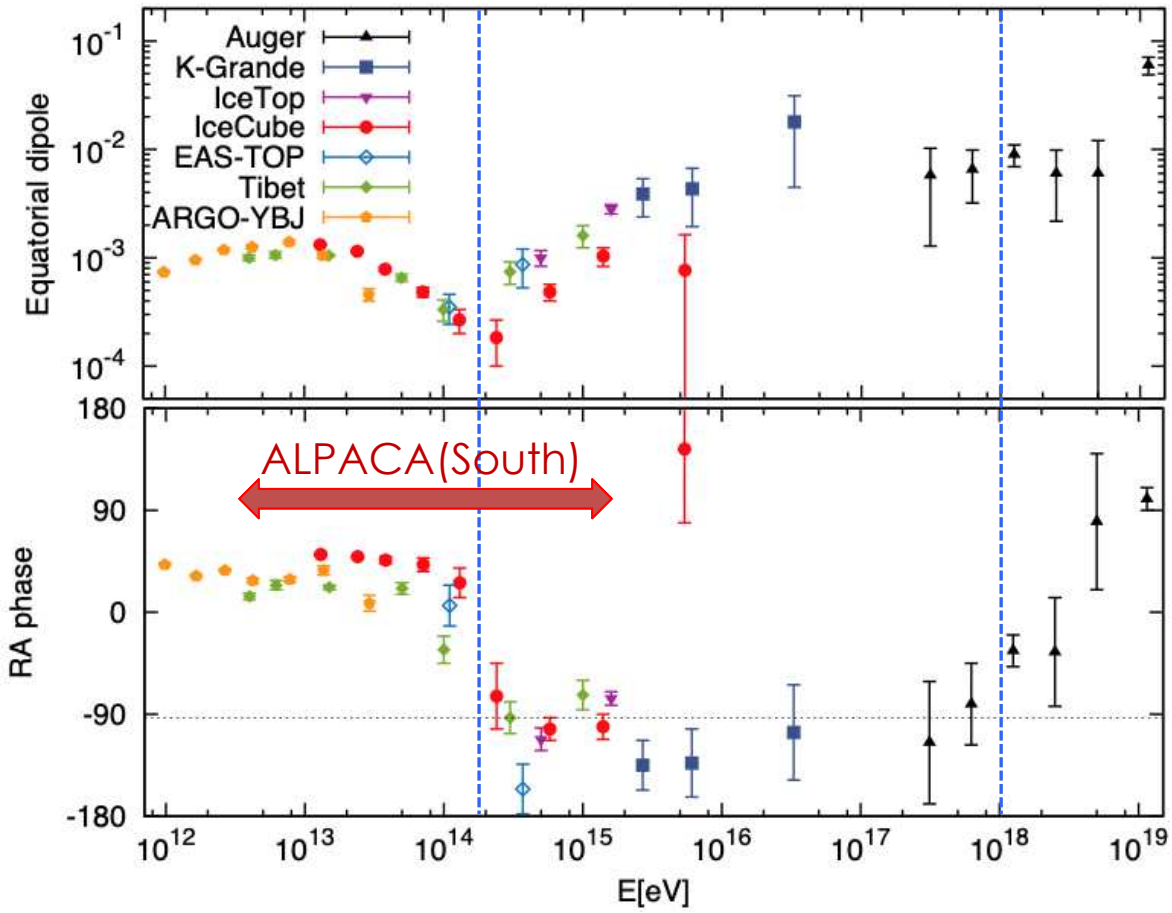
>8EeV

CR anistropy : Energy dependence

Local IM distribution
+ heliospheric magnetic field?

Source distribution in Galaxy?

Extragalactic Matter distribution
+ galactic magnetic field?



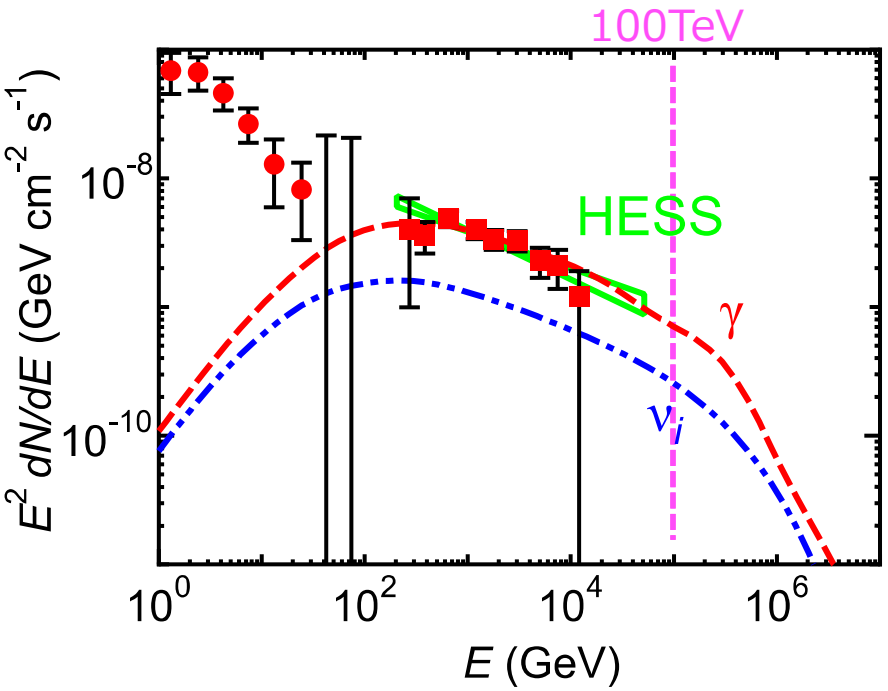
Mollerach & Roulet
arXiv:1710.11155

GC direction ?
Next page!

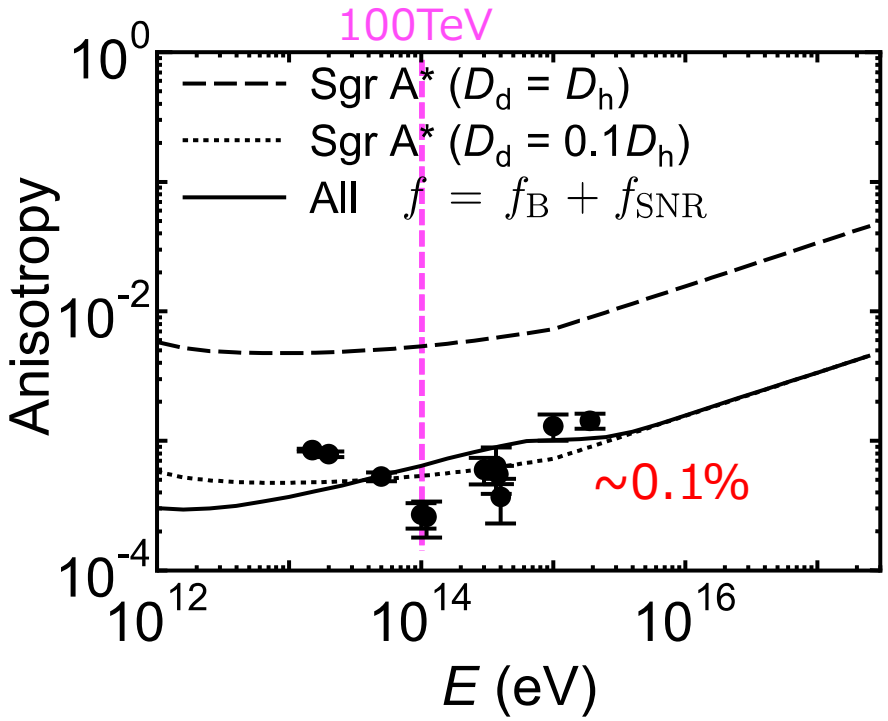
Wide energy range observation in both hemispheres: Important!

CR anisotropy around Galactic Center

Energy spectrum of γ and ν of CR origin



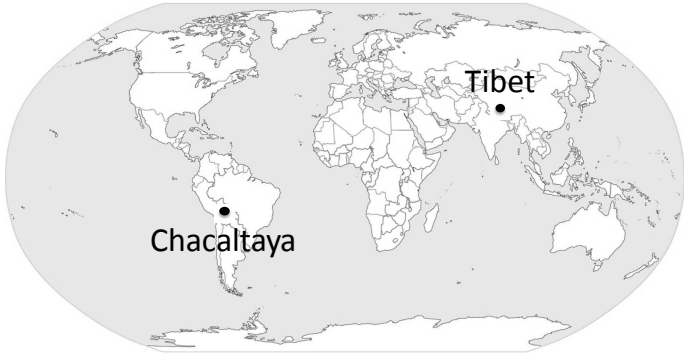
CR anisotropy

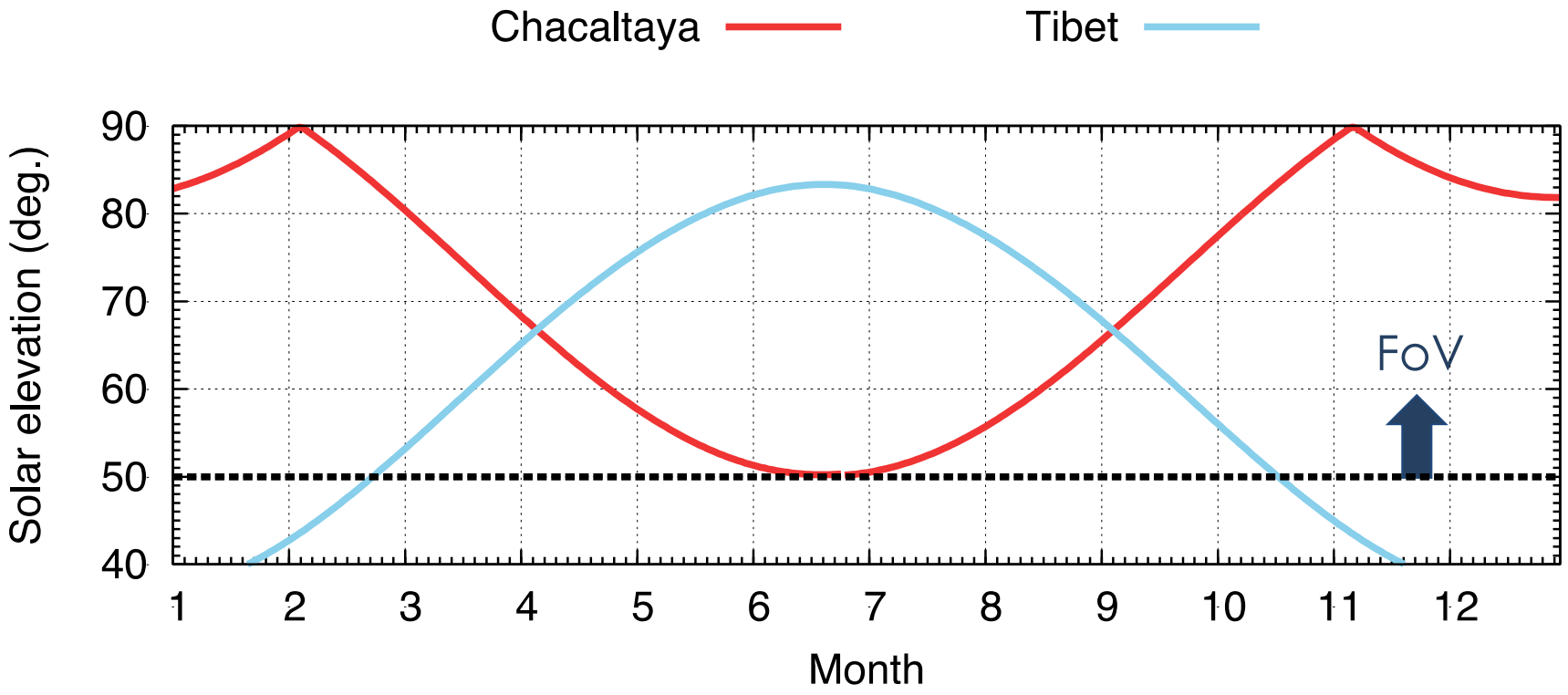


EASTOP((North)), Tibet(North), IceCube(South pole)
→ But, ALPACA: High sensitivity to GC direction

Fujita, Murase and Kimura, JCAP04(2017)037
Sagittarius A as an origin of the Galactic PeV cosmic rays?*

Sun shadow Observation by ALPACA





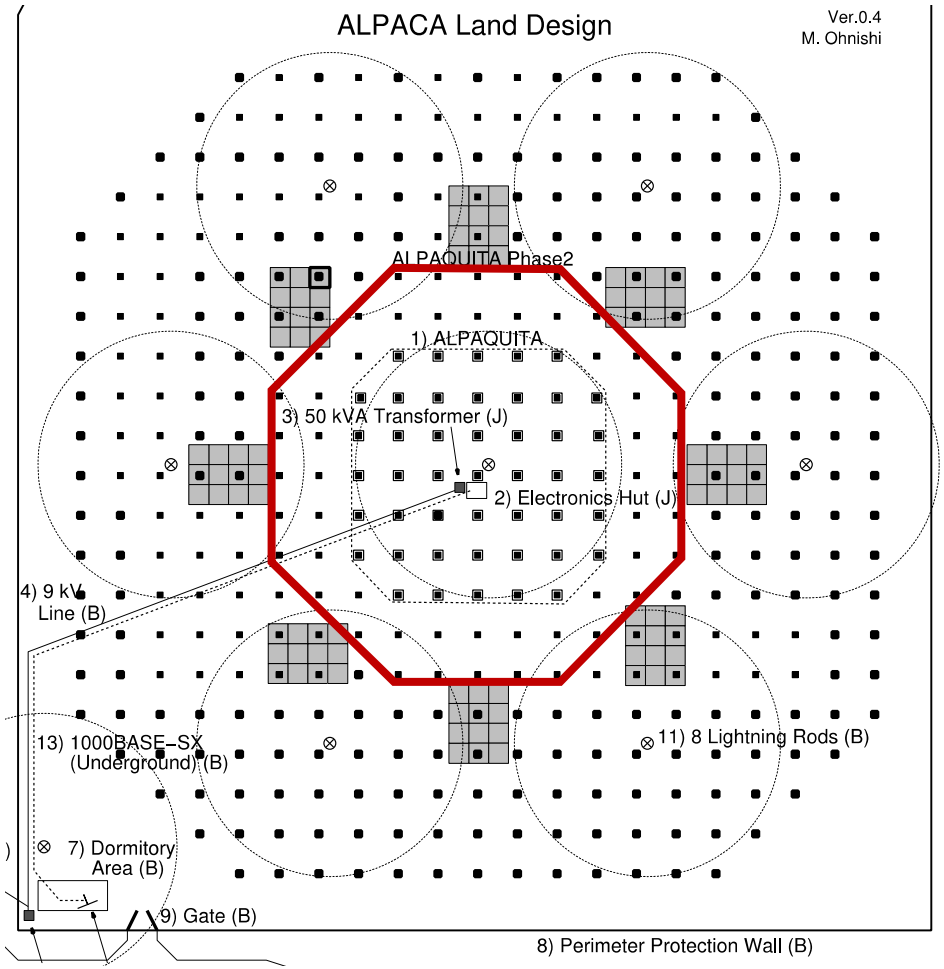
✓ ALPACA: Observation of Sun shadow possible for almost all the year
(Complete 1-yr coverage possible, together with Tibet observation)

ALPAQUITA

- Prototype array with ~100 SDs
- and ~1000m^{2}MD
  - ~20% of ALPACA AS in 2019
  - ~20% of ALPACA MD in 2020

- Establishing procedures in Bolivia
  - Construction
  - Import/Export
  - Infrastructure

- Expected sciences
  - Sun shadow
  - CR Anisotropy (TeV region)
  - Bright sub-PeV gamma-ray sources



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

CR anisotropy, Sun shadow, CR chemical composition, etc

3) ALPAQUITA (~20 % ALPACA AS , in 2019)

(~20% ALPACA MD, in 2020)

End