INFN Istituto Nazionale di Fisica Nucleare

Cosmic Ray International Seminar 2015

The LHAASO project: from γ-Ray Astronomy to Cosmic Rays

G. Di Sciascio for the LHAASO Collaboration
INFN - Roma Tor Vergata
disciascio@roma2.infn.it

CRIS2015 - Cosmic Ray International Seminar 2015
14^{th}-16^{th} September 2015, Gallipoli, ITALY

Outline

- What is LHAASO ?
- Why LHAASO ?
- The scientific case: open problems in Cosmic Ray Physics
- The LHAASO Experiment
- Status and prospects

What is LHAASO ?

The Large High Altitude Air Shower Observatory (LHAASO) project is a new generation all-sky instrument to investigate the '*cosmic ray connection*' through a combined study of Cosmic Rays and Gamma-Rays in the wide energy range 10^{11} -- 10^{17} eV.

LHAASO will consist of the following major components:

- 1 km^2 array (LHAASO-KM2A), including 5635 scintillator detectors, with 15 m spacing, for electromagnetic particle detection.
- An overlapping 1 km^2 array of 1221, 36 m^2 underground water Cherenkov tanks, with 30 m spacing, for muon detection (total sensitive area about 40,000 m^2).
- A close-packed, surface water Cherenkov detector facility with a total area of 90,000 m^2 (LHAASO-WCDA), four times that of HAWC.
- 24 wide field-of-view air Cherenkov (and fluorescence) telescopes (LHAASO-WFCTA).
- 452 close-packed burst detectors, located near the centre of the array, for detection of high energy secondary particles in the shower core region (LHAASO-SCDA).

The LHAASO site

The experiment will be located at 4400 m asl (600 g/cm^2) in the Haizishan (Lakes' Mountain) site, Sichuan province

Coordinates: 29° 21' 31'' N, 100° 08' 15'' E

700 km to Chengdu
50 km to Daocheng City (3700 m asl, guest house !)
10 km to airport

Questions to the knee energy range

Cosmic Ray sources (*'PeVatrons'*) → **Still open**

NO smoking guns from TeV gamma-ray astronomy !

Composition at the knee ?
Rigidity – dependent knee ? → **Still open**

Results still conflicting in the knee energy region !

Anisotropy ? → **Totally open**

No theory of CRs exists yet to explain observed anisotropy !

End of Galactic spectrum ?
Transition galactic - xgalactic ? → **Open**

Only hyphotheses

Hadronic interaction models ? → **Still uncertain**

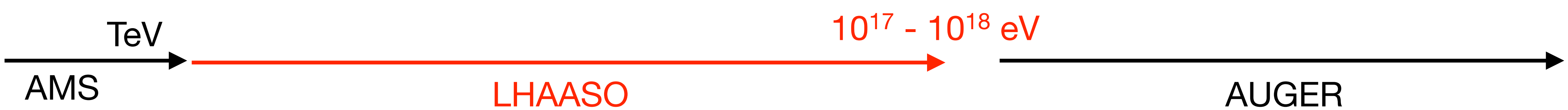
cross sections, diffractive, inelasticity

Why LHAASO ?

LHAASO will be the next generation ground-based experiment, capable of acting simultaneously as a Cosmic Ray Detector and a Gamma Ray Telescope.

✤ Cosmic Ray Physics ($10^{12} \rightarrow 10^{18}$ eV): precluded to Cherenkov Telescopes

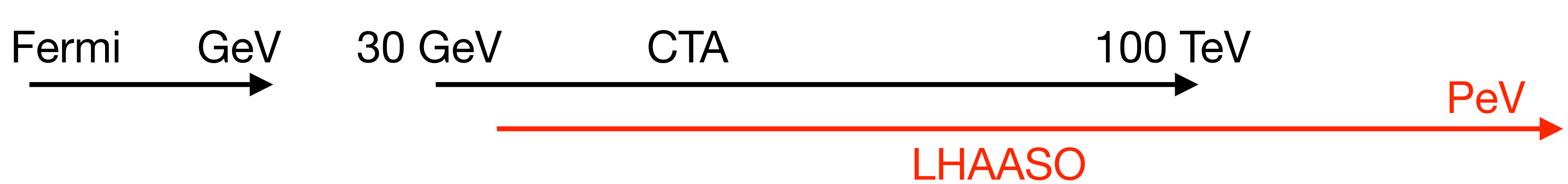
- CR energy spectrum
- Elemental composition
- Anisotropy

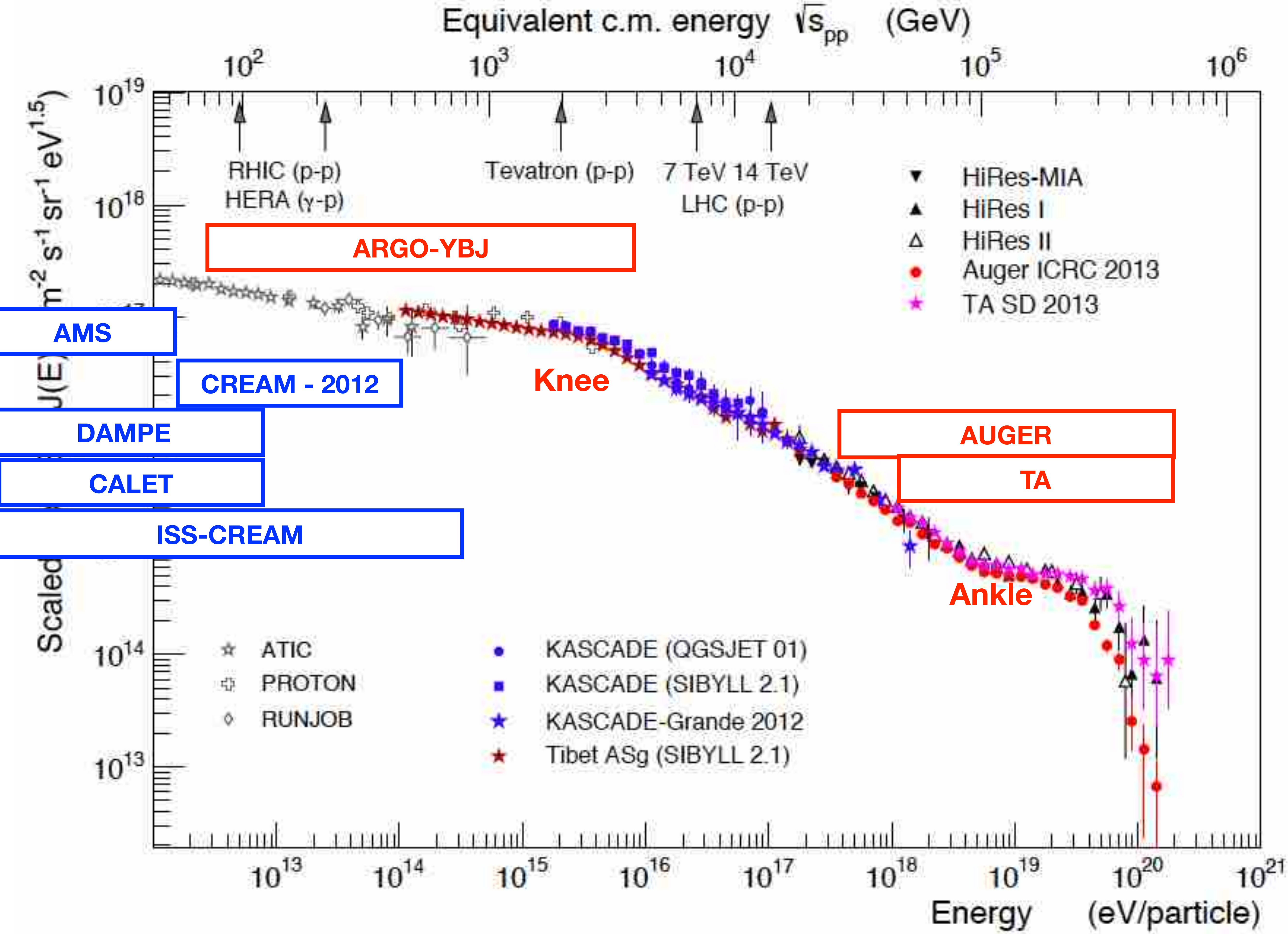


✤ Gamma-Ray Astronomy ($10^{11} \rightarrow 10^{15}$ eV): full sky continuous monitoring

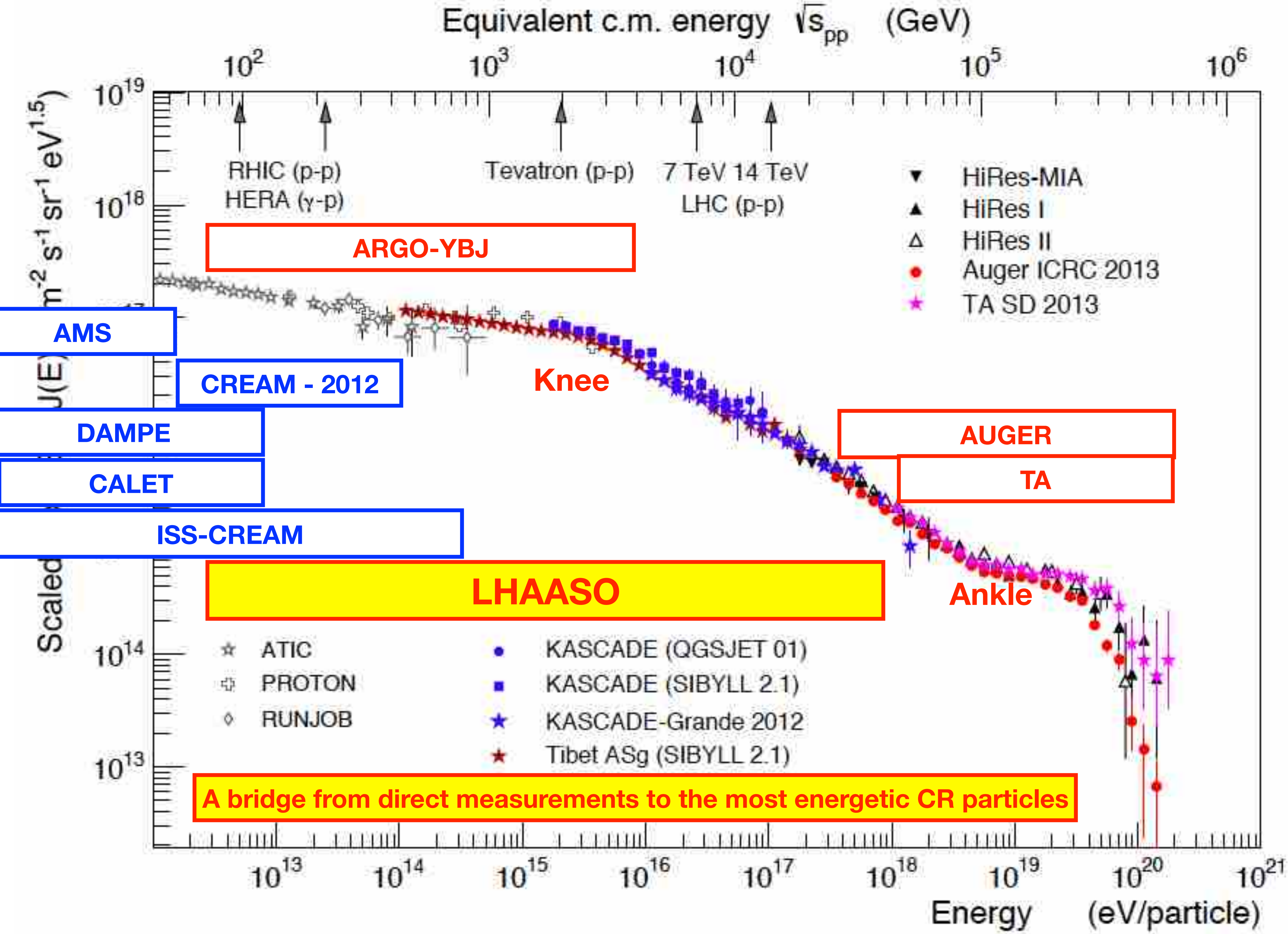
- *Below 20 TeV*: continuous monitoring of the Northern sky at < 0.01 of the Crab flux → Sky survey: complementarity with CTA

- *Above 20 TeV*: continuous monitoring of the Northern sky up to PeV with a sensitivity 2000x CTA for sky survey > 70 TeV→ search for PeV CR sources (*PeVatrons)*





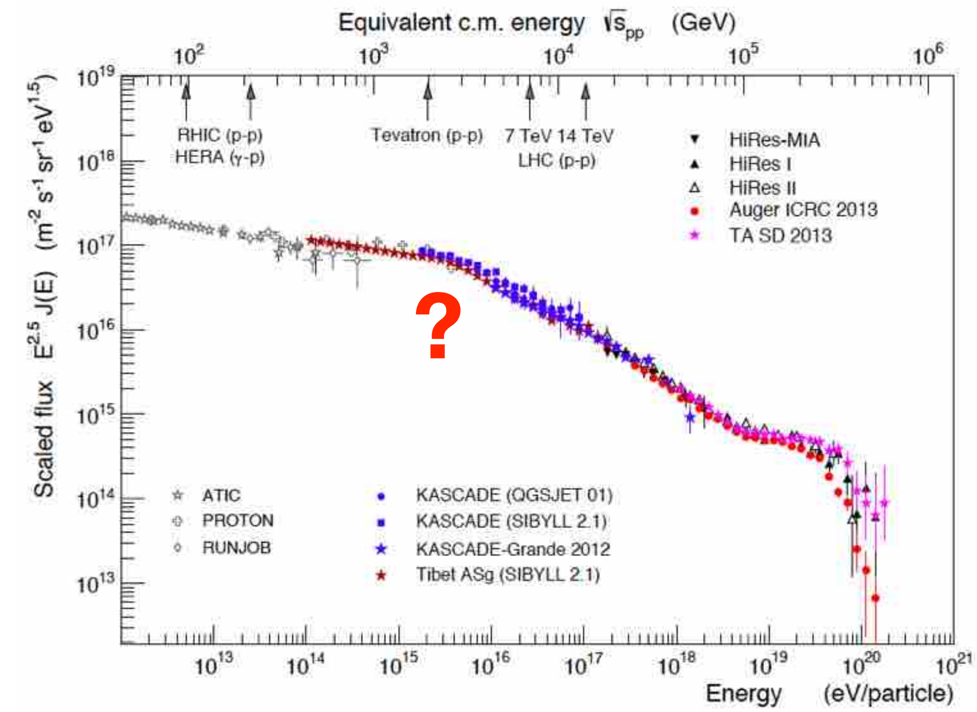
Equivalent c.m. energy $\sqrt{s_{pp}}$ (GeV)
RHIC (p-p)
HERA (γ-p)
Tevatron (p-p)
7 TeV 14 TeV
LHC (p-p)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
ARGO-YBJ
AMS
CREAM - 2012
DAMPE
CALET
ISS-CREAM
Knee
AUGER
TA
Ankle
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
Energy (eV/particle)



Equivalent c.m. energy $\sqrt{s_{pp}}$ (GeV)
RHIC (p-p)
HERA (γ-p)
Tevatron (p-p)
7 TeV 14 TeV
LHC (p-p)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
ARGO-YBJ
AMS
CREAM - 2012
DAMPE
CALET
ISS-CREAM
LHAASO
Knee
AUGER
TA
Ankle
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
A bridge from direct measurements to the most energetic CR particles
Energy (eV/particle)

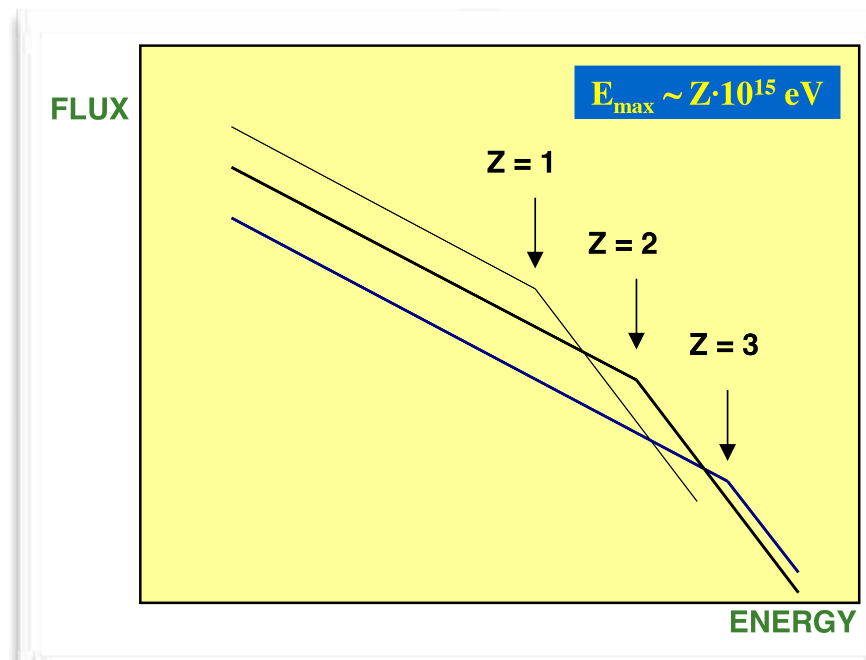
Approaching the knee

The origin of the *knee* in the all-particle spectrum of CRs is inextricably connected with the issue of the end of the Galactic CR spectrum and the transition to extragalactic CRs.

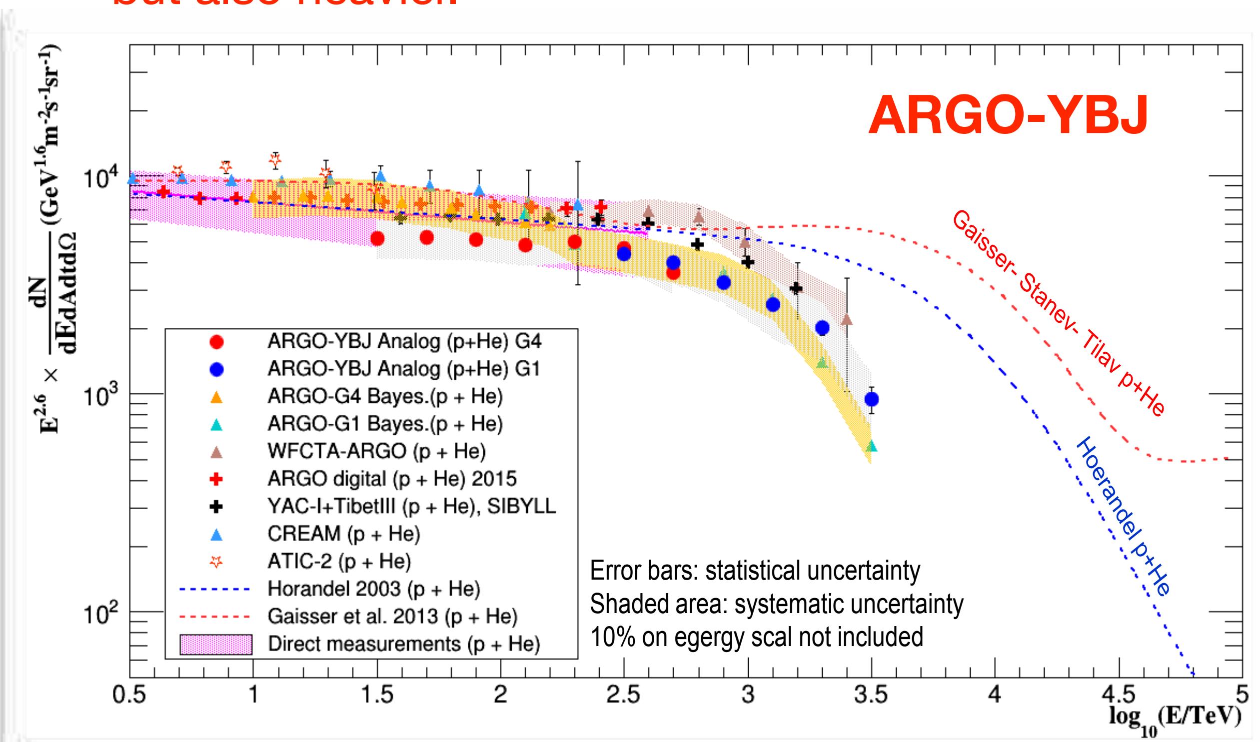


The standard model:

- Knee attributed to light (proton, helium) component
- Rigidity-dependent structure (Peters cycle): cut-offs at energies proportional to the nuclear charge $E_Z = Z \times 4.5$ PeV
- The sum of the flux of all elements with their individual cut-offs makes up the all-particle spectrum.
- Not only does the spectrum become steeper due to such a cutoff but also heavier.



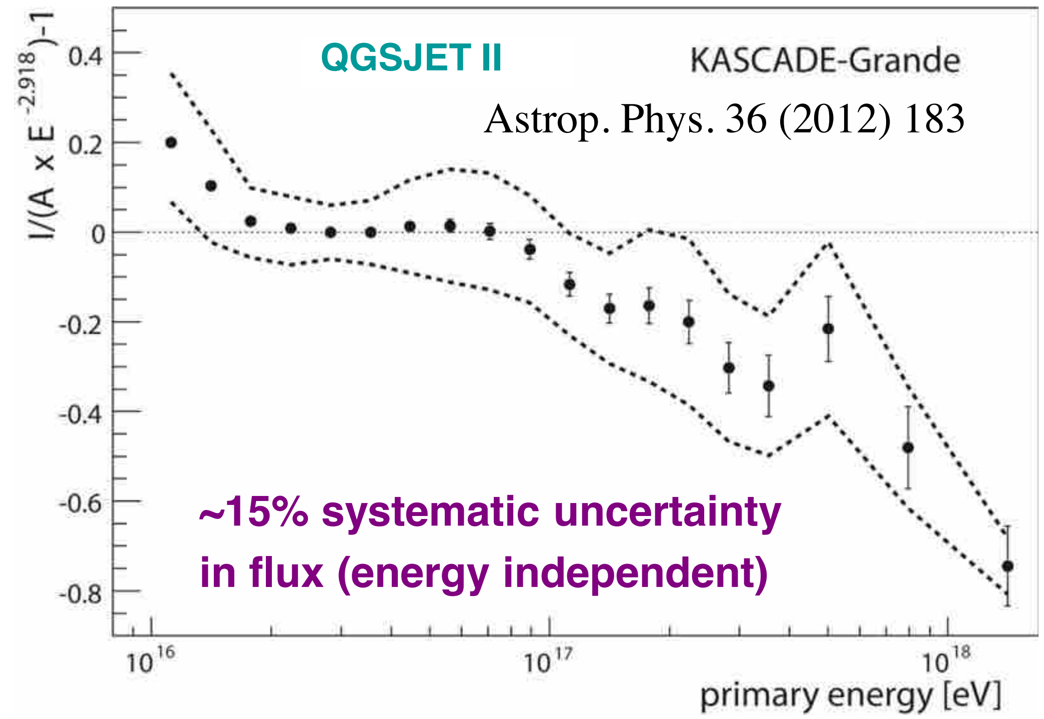
E_{max}(iron) = 26 · E_{max}(proton)

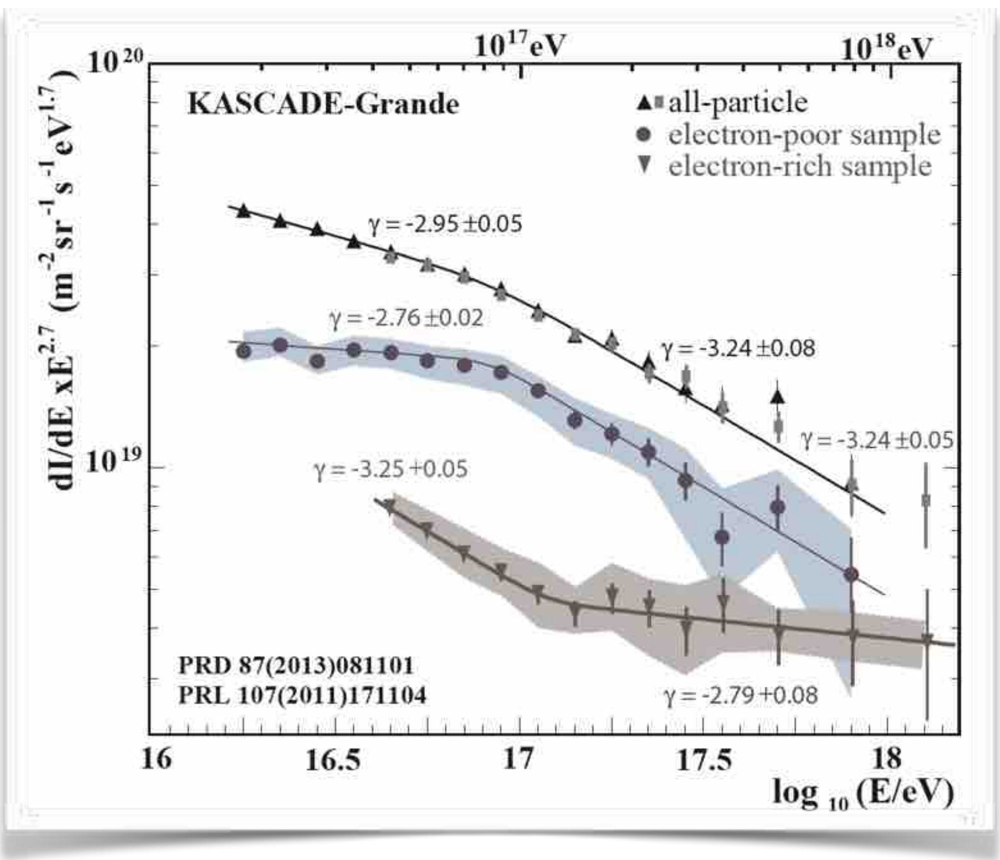


Experimental results still conflicting !

KASCADE-Grande

- spectrum all-particle not a single power law
- hardening of the spectrum above 10^{16}eV
- steepening close to 10^{17}eV (2.1 σ)



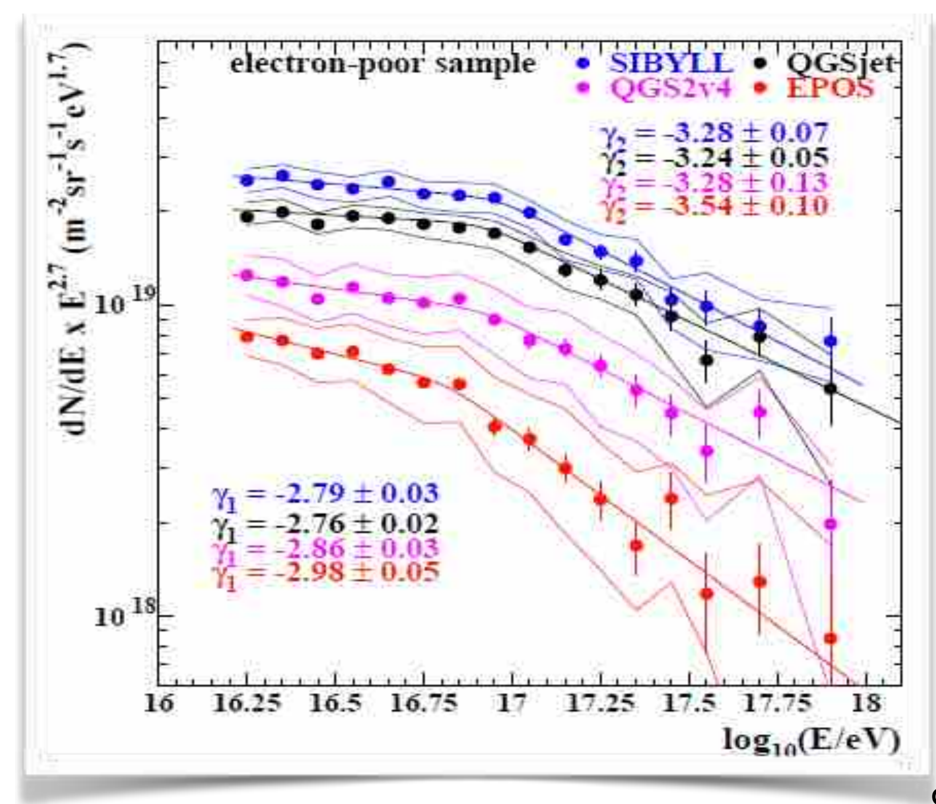


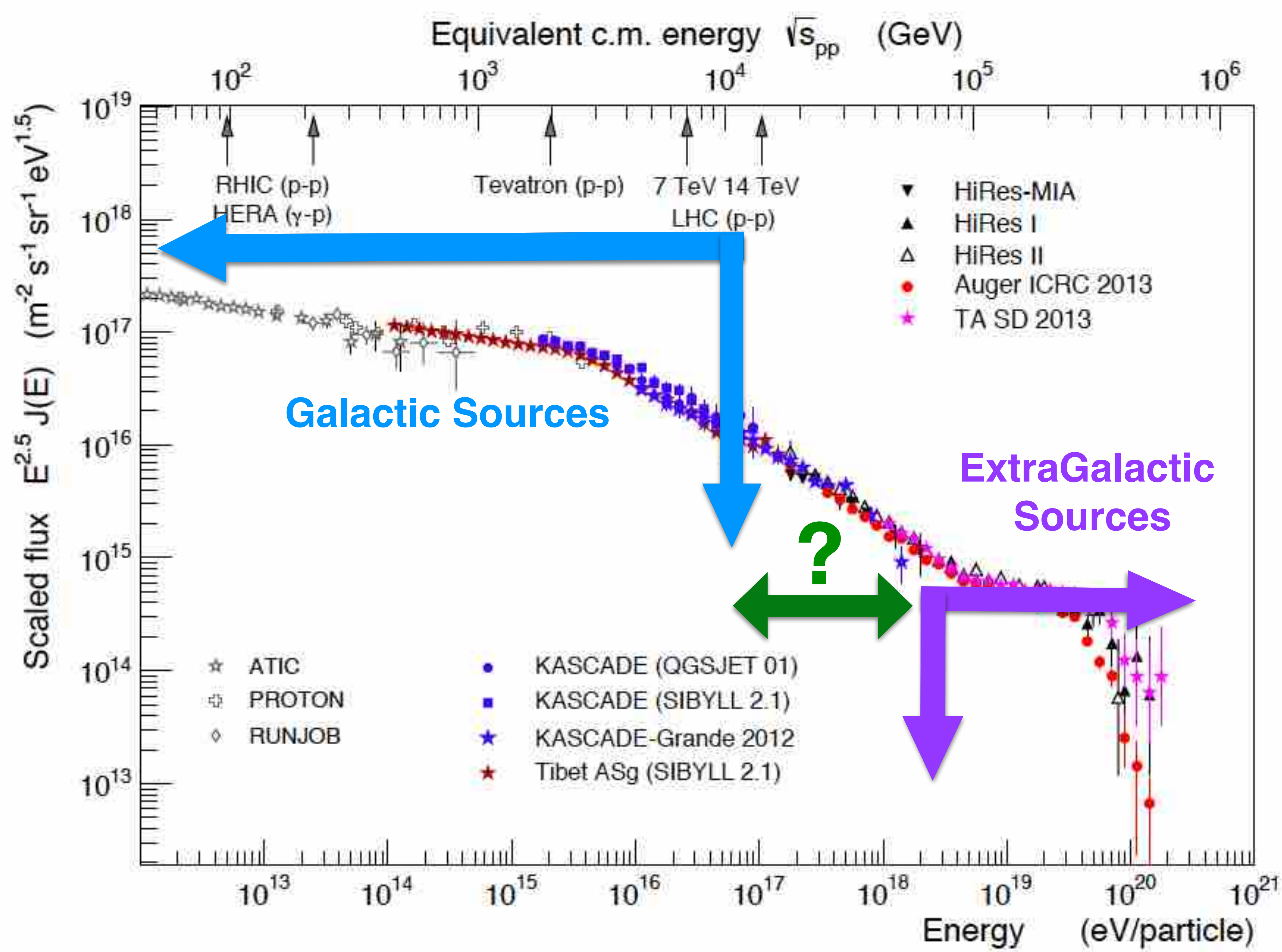
Phys.Rev.Lett. 107 (2011) 171104
Phys.Rev.D (R) 87 (2013) 081101

- steepening due to heavy primaries (3.5 σ)
- hardening at $10^{17.08}$ eV (5.8 σ) in light spectrum
- slope change from γ = -3.25 to γ = -2.79 !

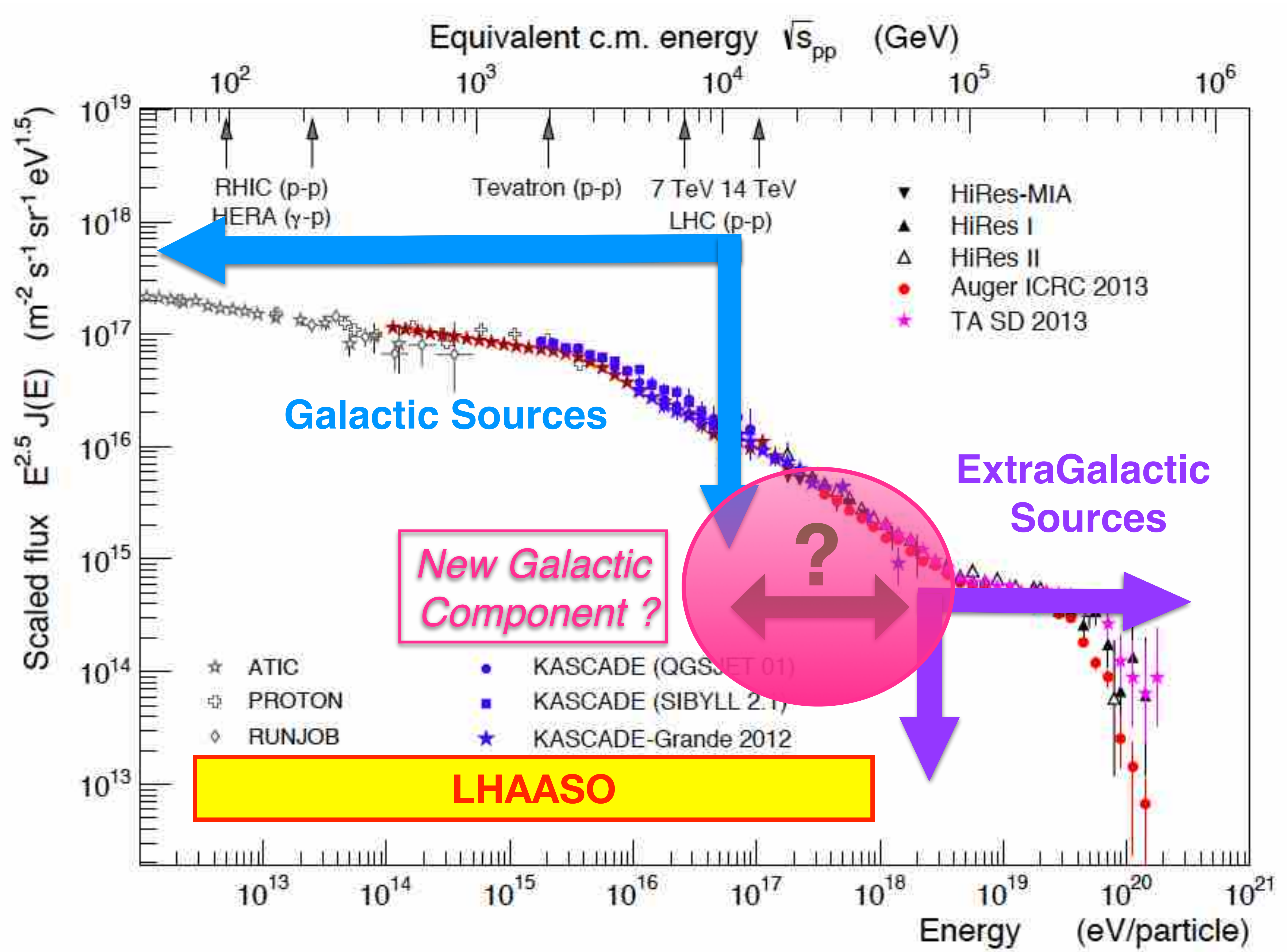
✦ relative abundances different for different high-energy hadronic interaction models

Adv. Sp. Res. 53 (2014) 1456





Equivalent c.m. energy $\sqrt{s_{pp}}$ (GeV)
10^2
10^3
10^4
10^5
10^6
RHIC (p-p)
HERA (γ-p)
Tevatron (p-p)
7 TeV 14 TeV
LHC (p-p)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
Galactic Sources
ExtraGalactic Sources
?
Scaled flux $E^{2.5}$ J(E) $(m^{-2} s^{-1} sr^{-1} eV^{1.5})$
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Energy (eV/particle)



Equivalent c.m. energy $\sqrt{s_{pp}}$ (GeV)
10^2
10^3
10^4
10^5
10^6
RHIC (p-p)
HERA (γ-p)
Tevatron (p-p)
7 TeV 14 TeV
LHC (p-p)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
Scaled flux $E^{2.5}$ J(E) ($m^{-2} s^{-1} sr^{-1} eV^{1.5}$)
Galactic Sources
ExtraGalactic Sources
New Galactic Component ?
?
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
LHAASO
Energy (eV/particle)

LHAASO vs other EAS arrays

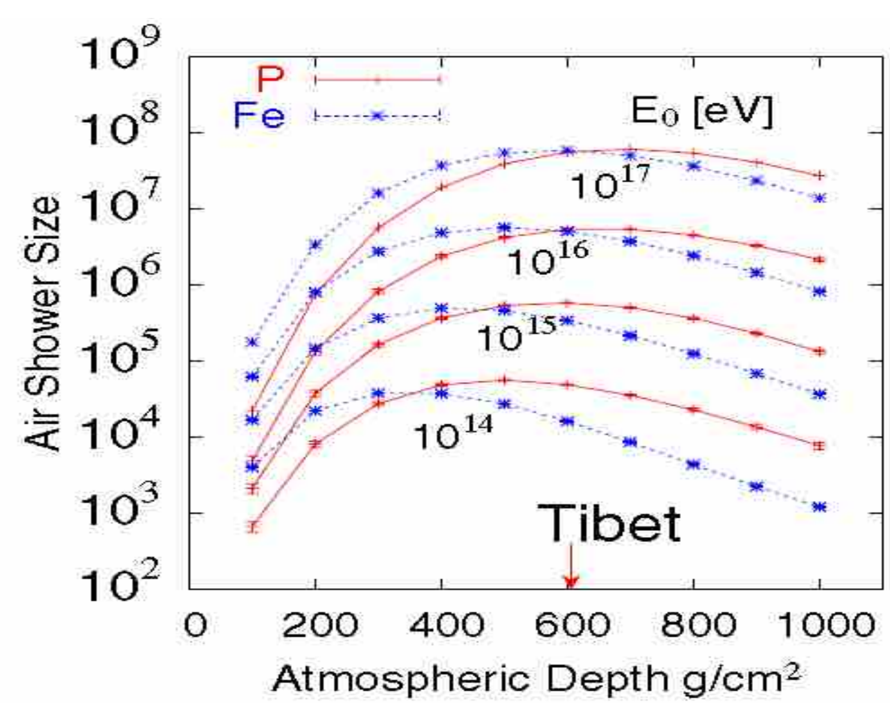
	Altitude (m)	e.m. Detection Area (m^2)	Instrumented Area (m^2)	Coverage
KASCADE	110	5×10^2	4×10^4	1.2×10^{-2}
IceTop	2835	4×10^2	10^6	4×10^{-4}
KASCADE-Grande	110	370	5×10^5	7×10^{-4}
LHAASO	**4410**	$\mathbf{5\times10^3}$	$\mathbf{10^6}$	$\mathbf{5\times10^{-3}}$
		μ Detection Area (m^2)	**Instrumented Area (m^2)**	**Coverage**
KASCADE	110	6×10^2	4×10^4	1.5×10^{-2}
LHAASO	**4410**	$\mathbf{4.4\times10^4}$	$\mathbf{10^6}$	$\mathbf{4.4\times10^{-2}}$

✓ LHAASO will operate with a coverage similar to KASCADE (about %) over a much larger effective area.

✓ The detection area of muon detectors is about 70 times larger than KASCADE (coverage 5%) !

✓ Redundancy: different detectors to study hadronic models dependence

- Working at high altitude (4410 m asl):
  1. *p and Fe produce showers with similar size*
  2. *Small fluctuations*: shower maximum
  3. *Low energy threshold*: absolute energy scale calibration with the Moon Shadow technique and overposition with direct measurements (➜ ARGO-YBJ)



Take Home Message - 1

- Energy range 10^{14} - 10^{18} eV crucial
- Experimental results still conflicting !

Homework

✓ Spectra of individual mass groups !!

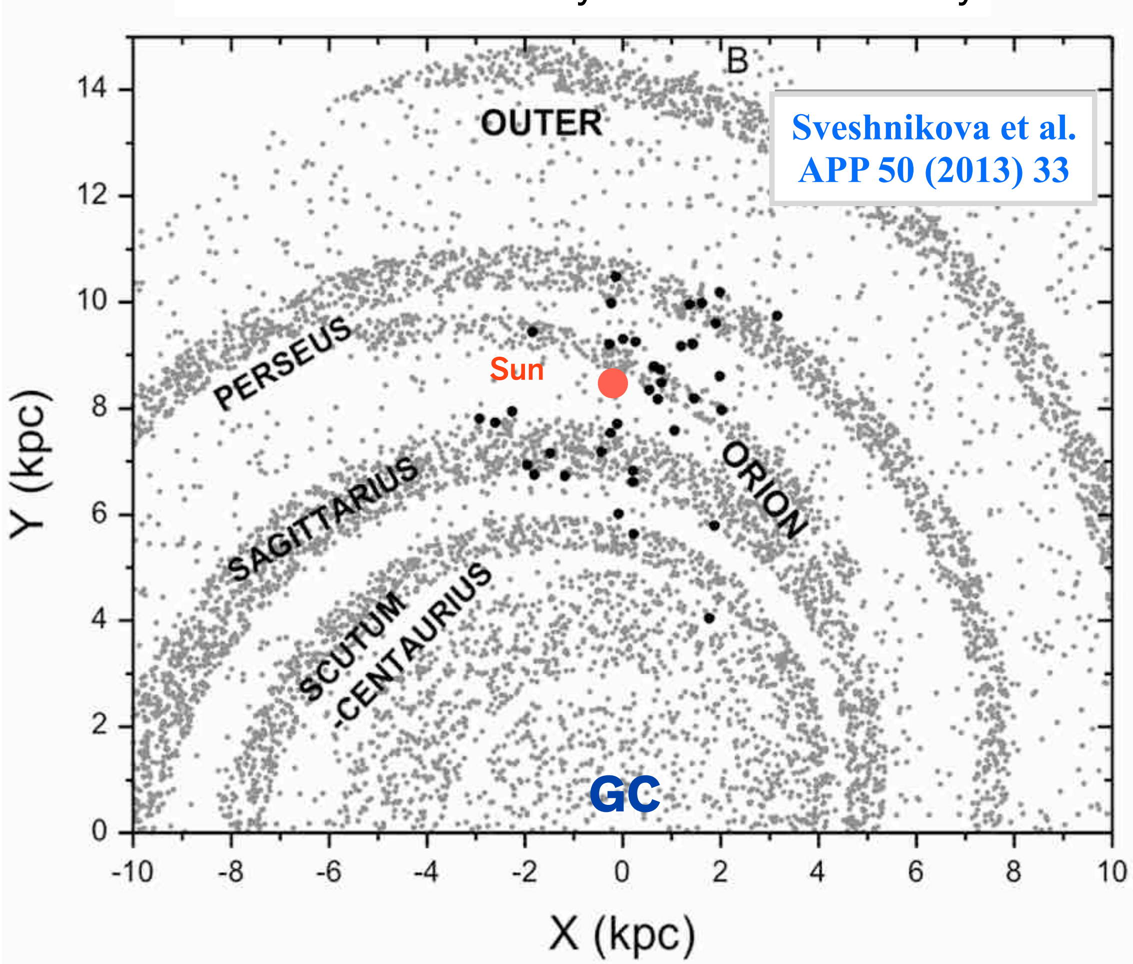
✓ Multi-parameter EAS measurements to validate hadronic interaction models

✓ The right observation altitude !

✓ Absolute energy scale calibration: low energy threshold !

Cosmic Ray diffusive propagation and anisotropy

Distribution of nearby SNRs in the Galaxy



Galactic Cosmic Rays

- Accelerated in SNRs
- Propagate diffusively

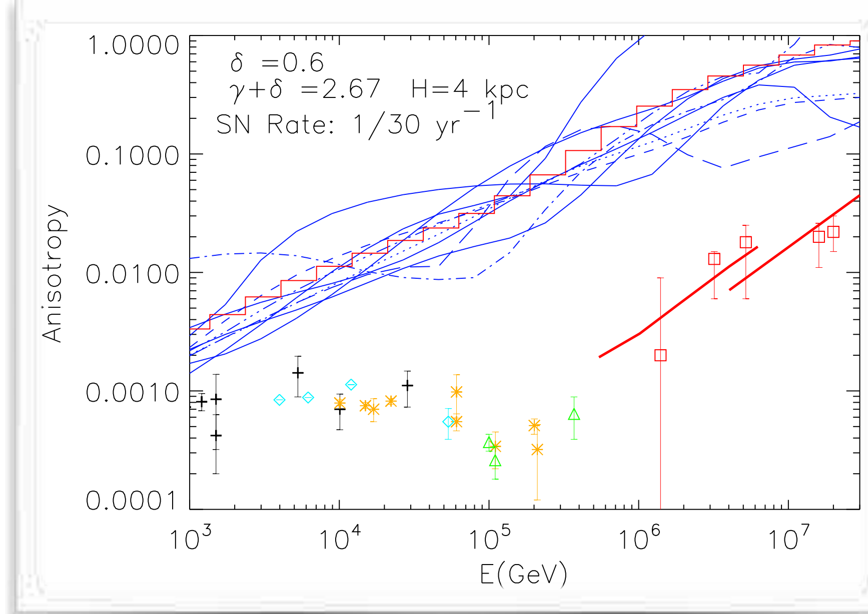
Consequences for anisotropy

- CR density gradients are visible as anisotropy
- Anisotropy amplitude $\lesssim 10^{-2}$
- Amplitude increases with energy
- Dipole shape
- Phase pointing towards the most significant sources

Generally speaking, the dipole component of the anisotropy is believed to be a tracer of the CR source distribution, with the largest contribution from the nearest ones.

Measuring the anisotropy of CRs provides important information on the propagation mechanisms and the identification of their sources.

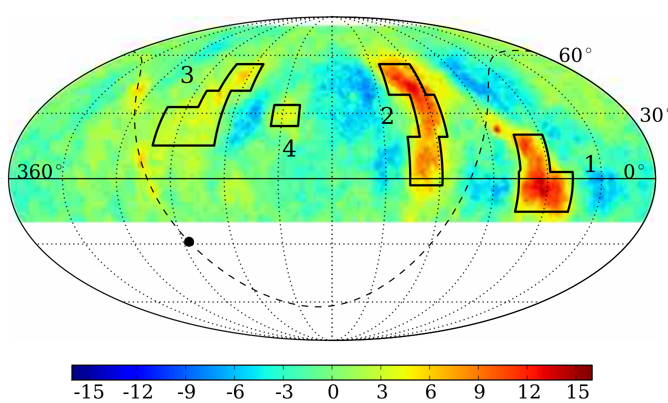
The CR anisotropy ‘problems’

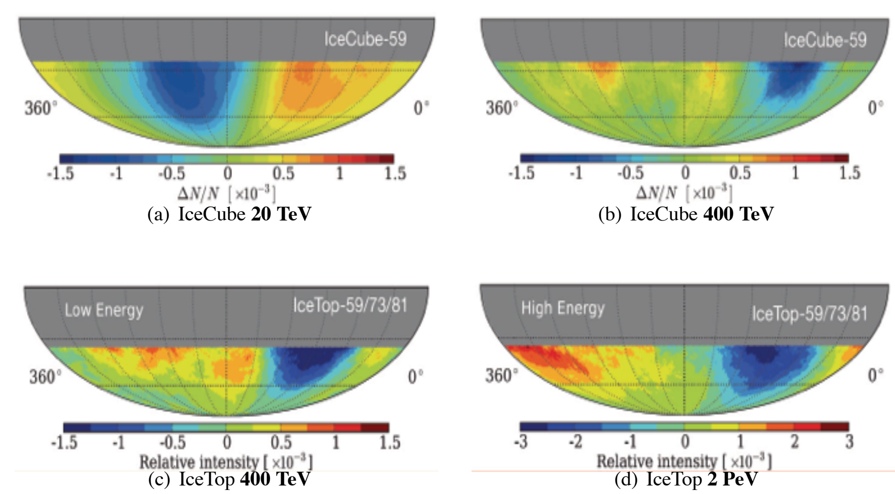


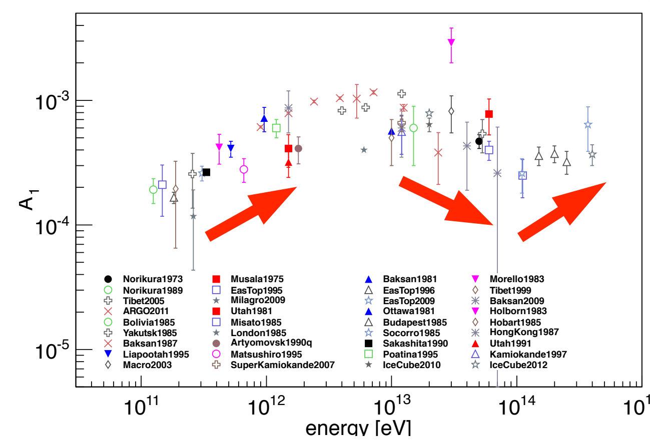
- Observed anisotropy much smaller than expectations according to diffusive models

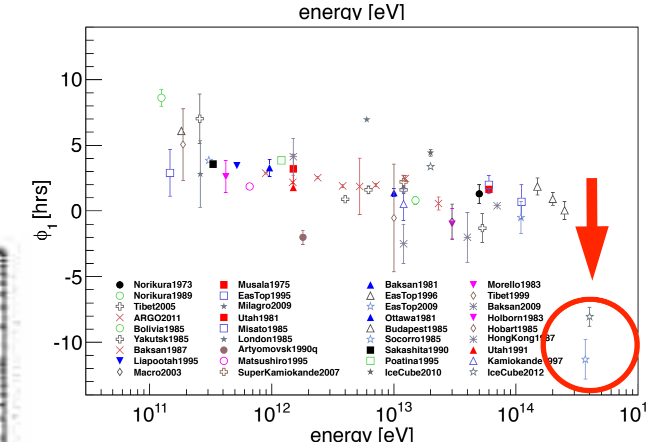
- Unexpected evolution with energy, ‘dramatic’ above 100 TeV

ARGO-YBJ





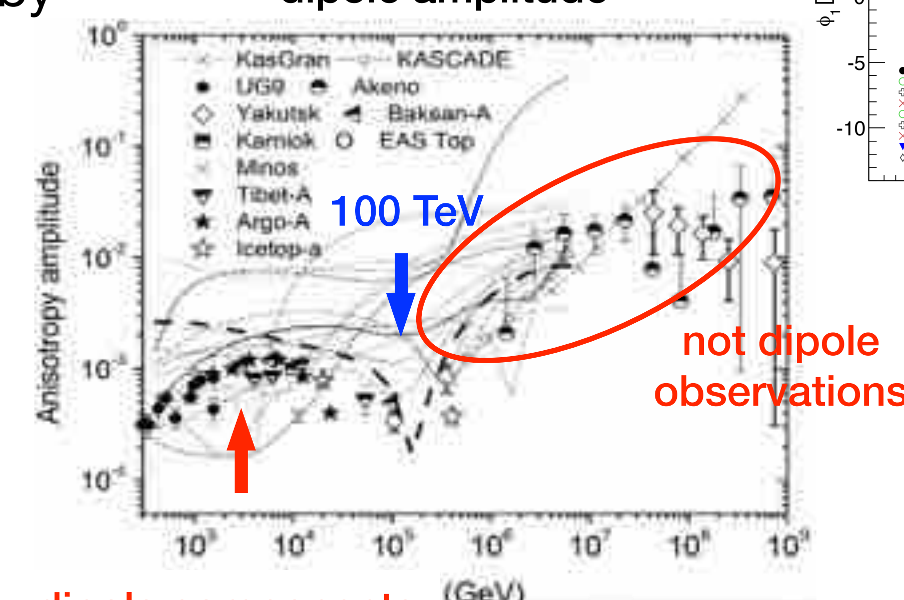




- Anisotropy not a simple dipole as foresee by diffusive models: small scale structures

- Dipole component no more dominant above 100 TeV

dipole amplitude



dipole components of the anisotropy

Energy Spectrum, Anisotropy & Mass Composition

A *combined measurement* of CR energy spectrum, mass composition and anisotropy inevitably probes the properties and spatial distribution of their sources as well as of the long propagation journey through the magnetized medium.

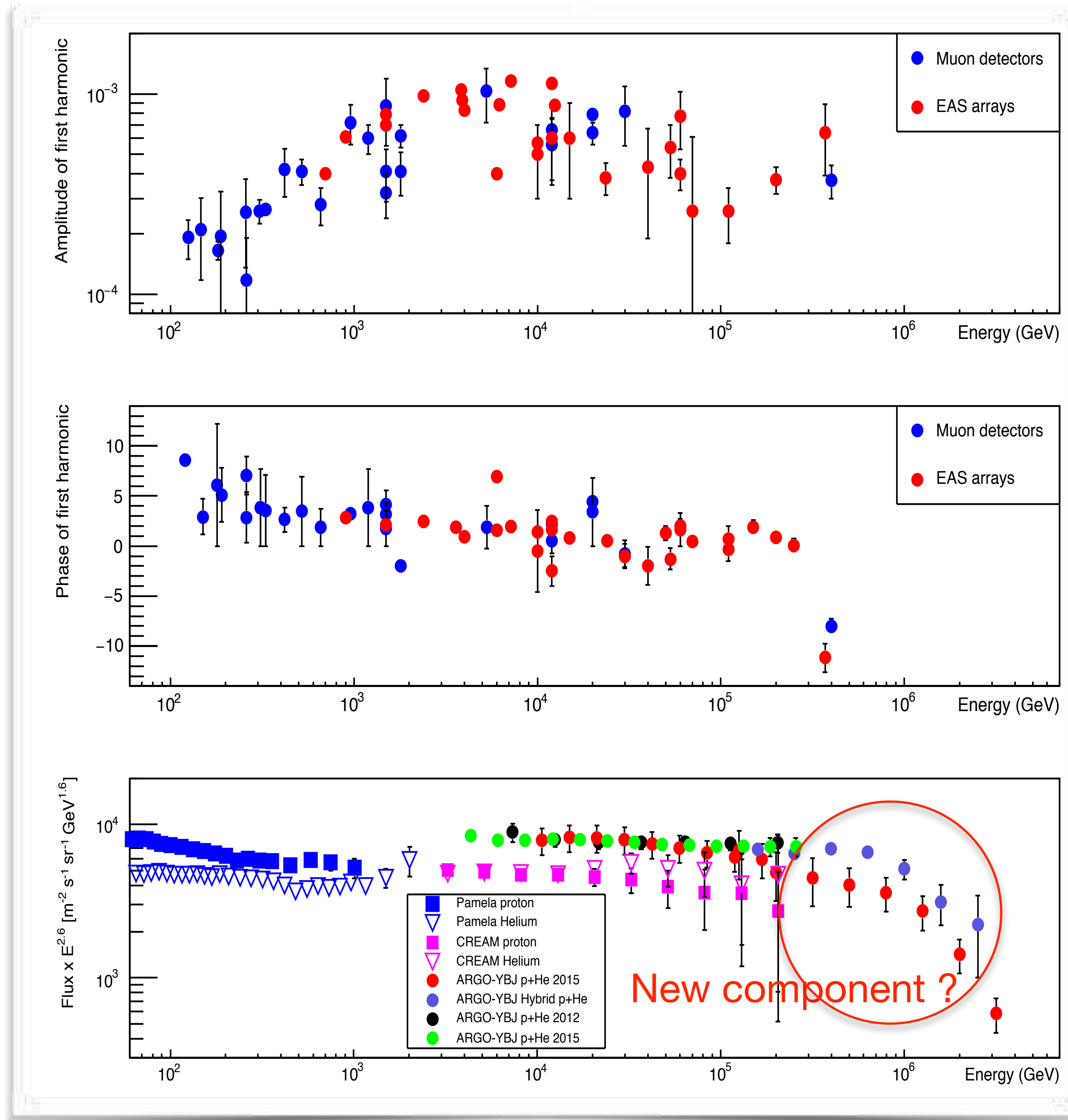
In fact, propagation of CRs in the galactic medium is known to affect their spectrum and direction distribution.

Non-dipolar structure of the anisotropy >100 TeV:

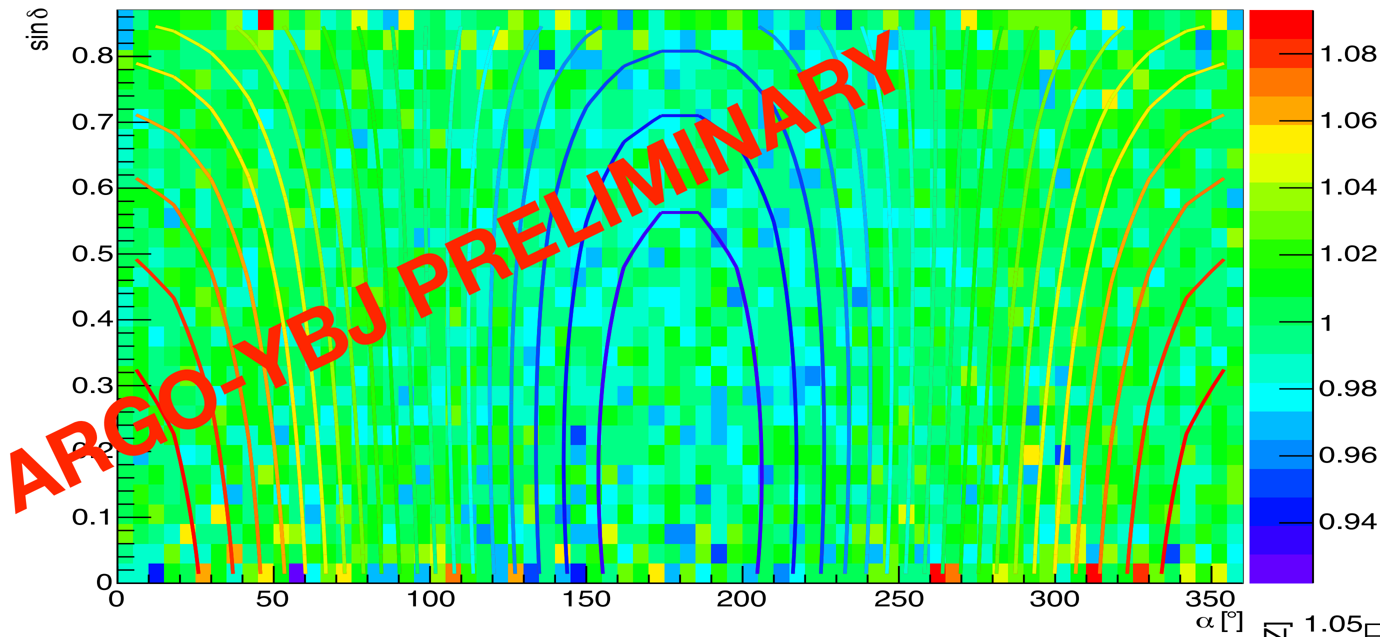
propagation effects from a given sources ?
heavier nuclei in the knee energy region ?

➡ study **correlation** between anisotropy & spectral features vs **primary mass**

Anisotropy for different primary particle masses crucial !



Anisotropy for p+He nuclei: ARGO-YBJ results



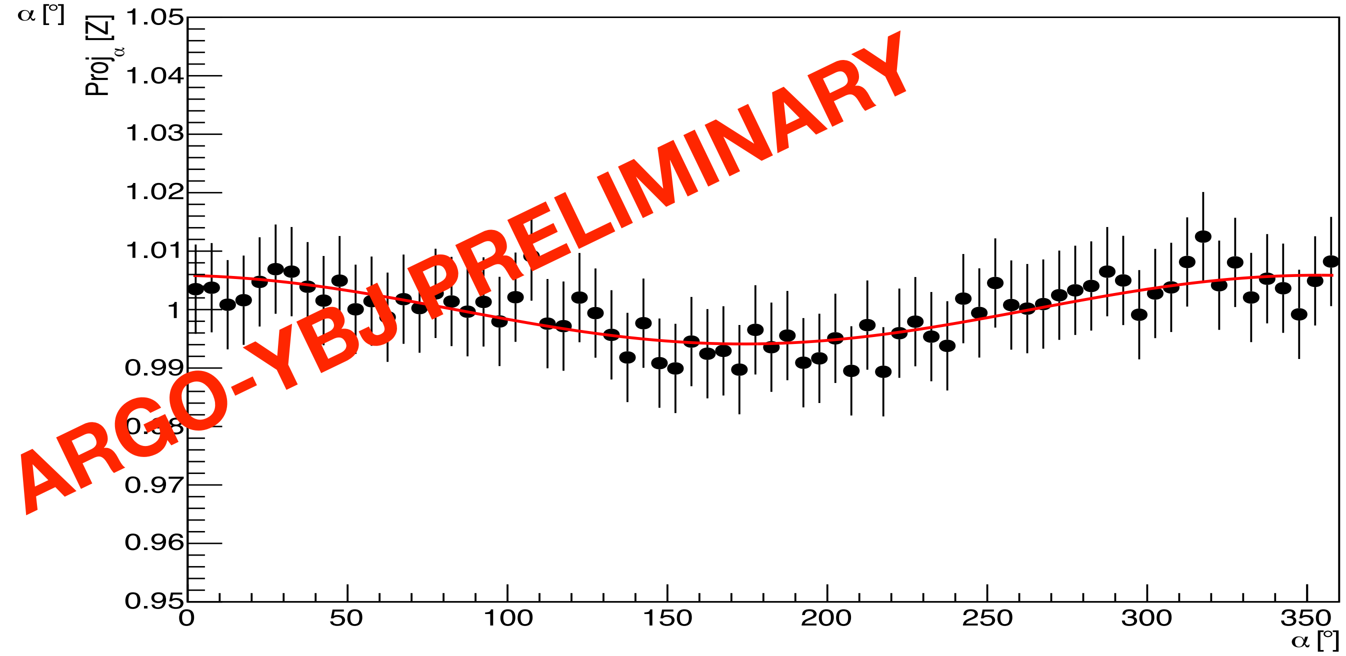
ICRC 2015 ID 524

The significance estimator suggested to fit a dipole function to the observed distribution.

Statistics really poor.

(p+He)-induced dipole amplitude less than 2% at 90% C.L

phase in right ascension: -6° ± 10°
(minimum coincident with the loss cone)



The analysis, yet at a preliminary stage, showed an interesting potential, outlining possible correlations between the known LSA structures and LIGHT-induced deviations from isotropy.

LHAASO, with 20x trigger rate, will be able to deepen and extend these observations.

Take Home Message - 2

- Anisotropy important to understand the origin and propagation of CRs and to probe the structure of the magnetic fields through which CRs travel.
- Anisotropy not a dipole.
- Anisotropy amplitude too small.

Homework

✓ High statistics in a large energy range (➜ 10^{16-17} eV)

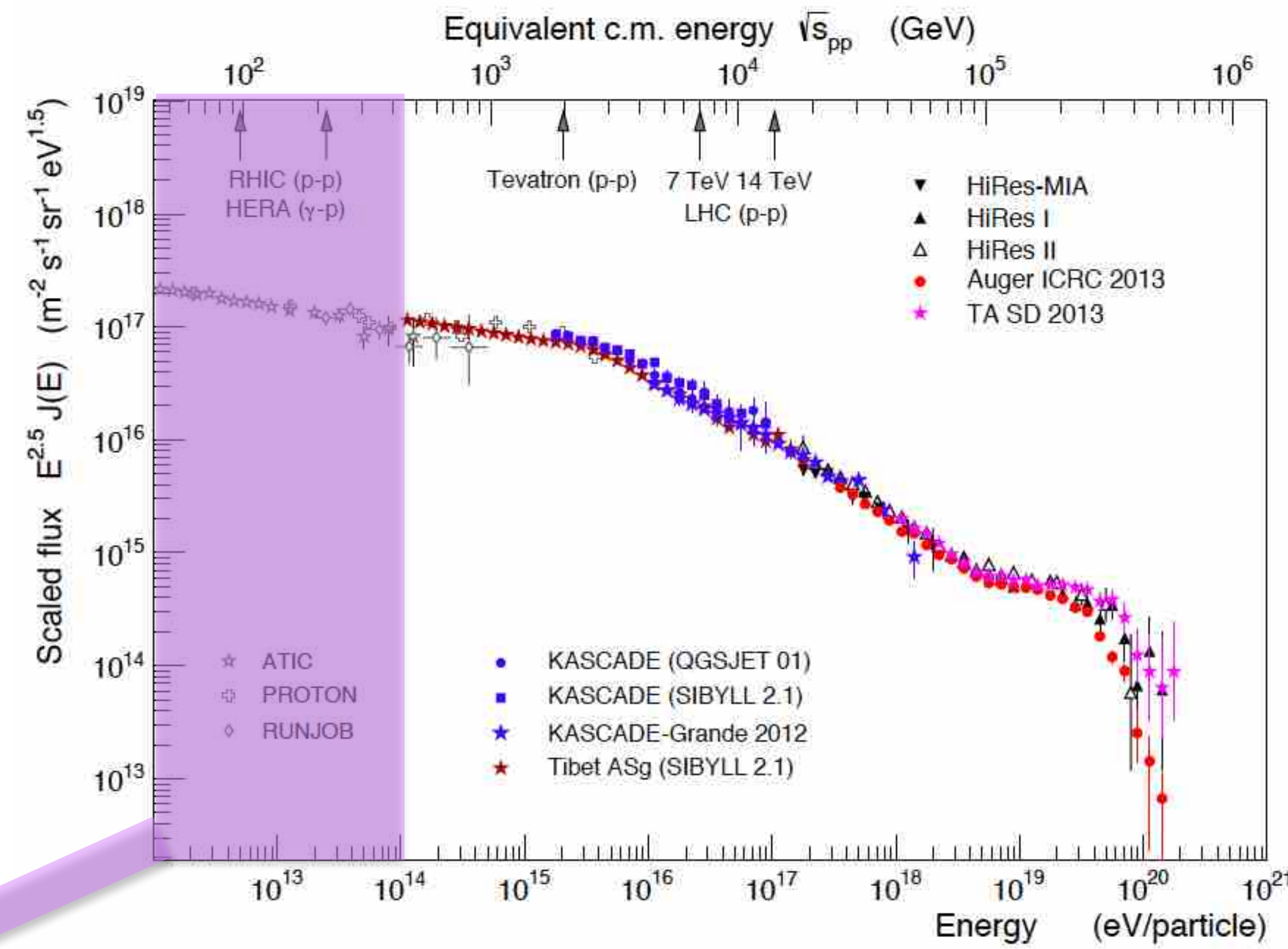
✓ The new frontier: *composition dependent anisotropy studies !!!*

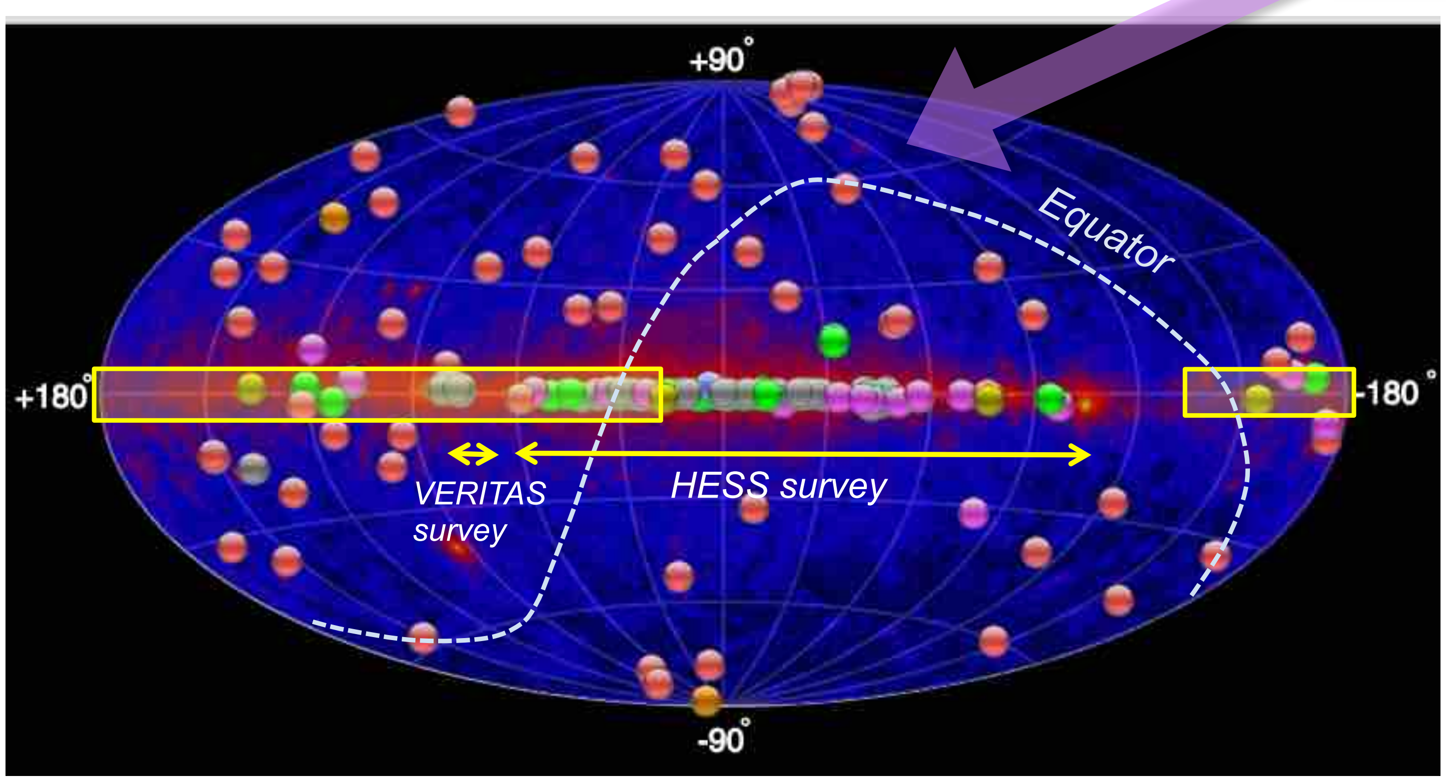
TeVatron Sky

$$p\ (p,\ \gamma) \longrightarrow \pi^0 + rest$$
$$\hookrightarrow \gamma\gamma$$

Gammas from Galactic Cosmic Rays: $E_\gamma \sim E_{CR}/10$

TeV Cosmic Rays
Photons > 100 GeV !





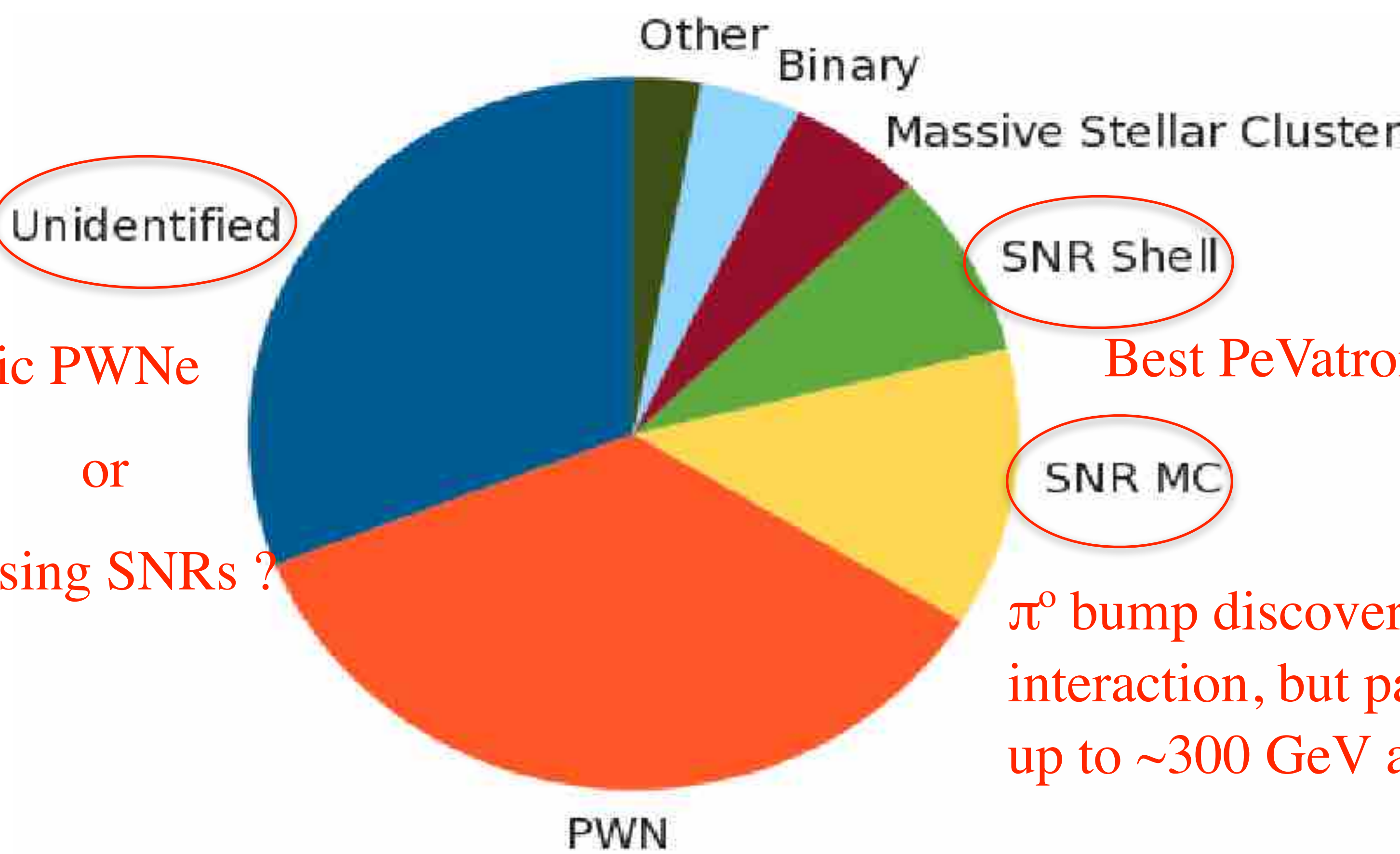
Visible Galactic Plane: l = 20° – 225°

Zenith angle < 40°

But *'smoking gun'* still missing…
leptonic ?
hadronic (CR sources) ?

Complex scenario: each source is individual and has a unique behaviour. In general one expects a combination of leptonic and hadronic emission !

Galactic TeV source populations



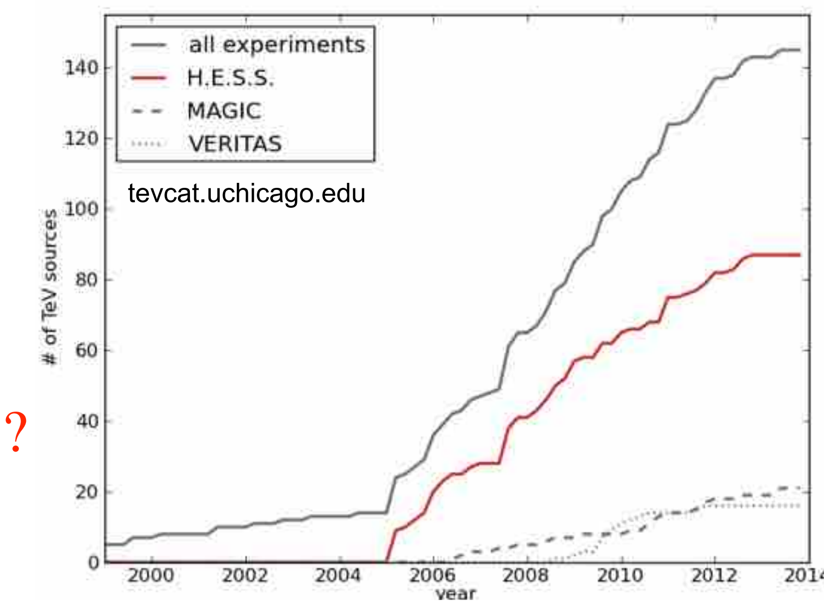
Relic PWNe

or

missing SNRs ?

Best PeVatron candidates ?

π^0 bump discovery confirms hadronic interaction, but particle energies only up to ~300 GeV and steep spectra



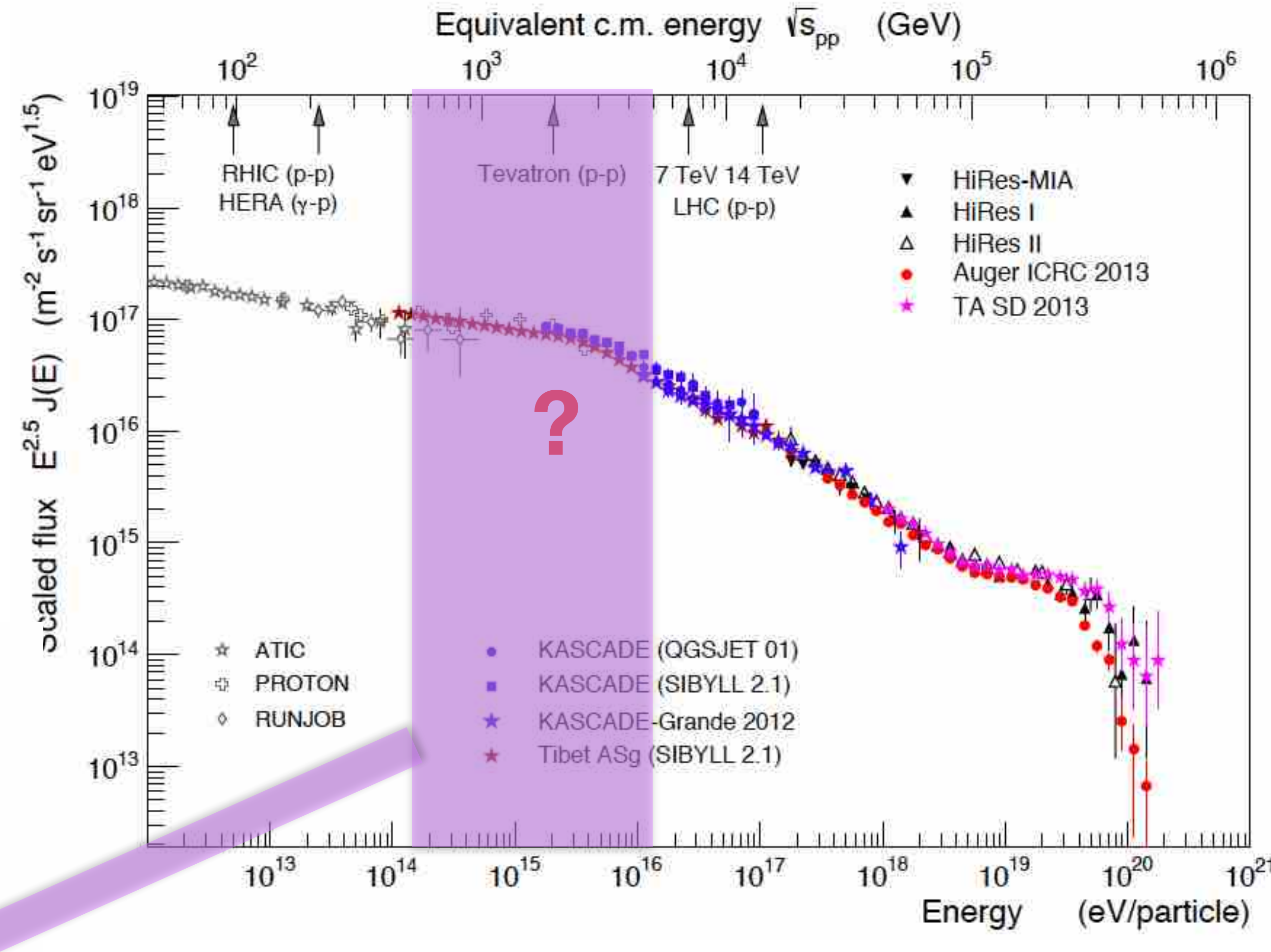
How complete is the Survey ?

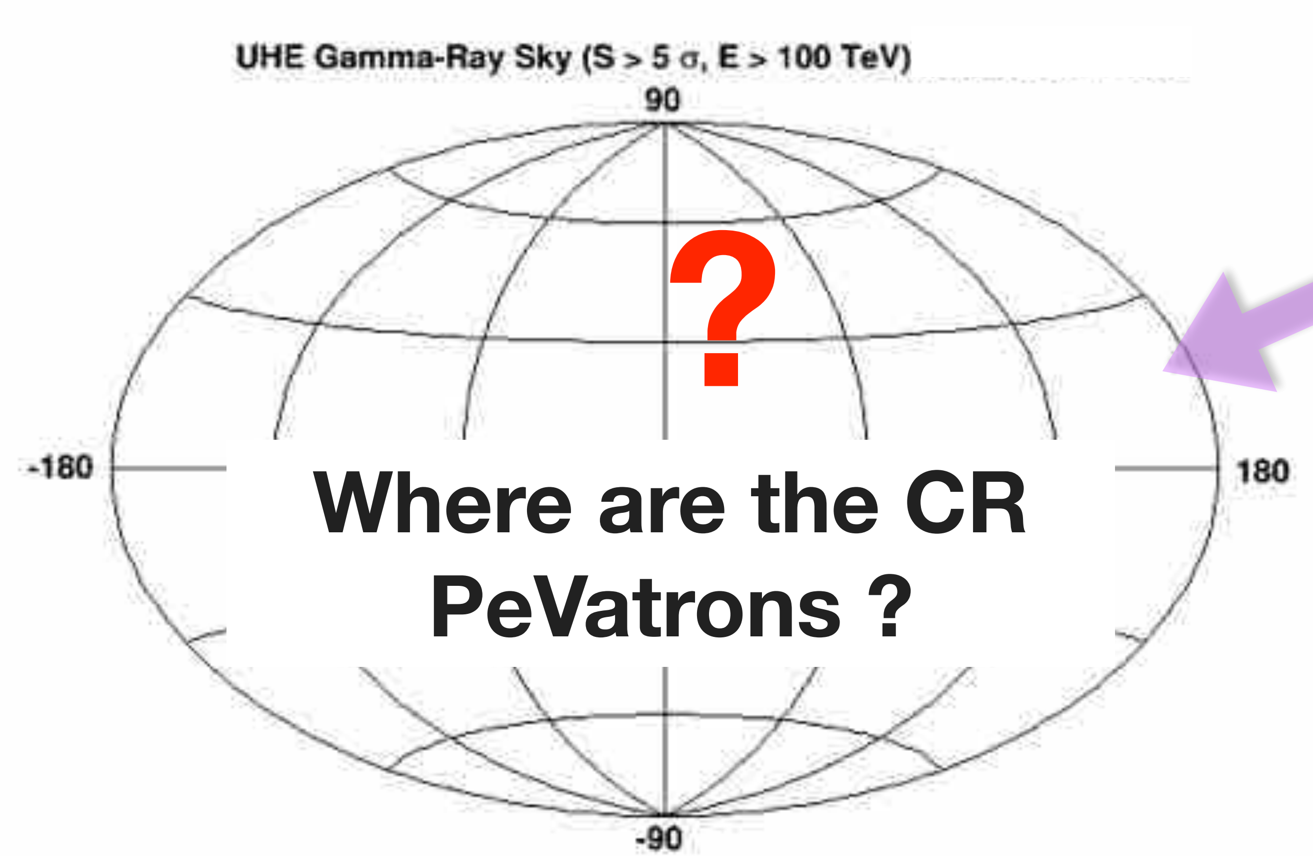
If there is a (bright) PeVatron out there, would we have detected it already?

- Wide field of view: all-sky survey provides un *unbiased map of the sky*
- High Energy survey

PeVatron Sky

PeV Cosmic Rays
Photons > 100 TeV !



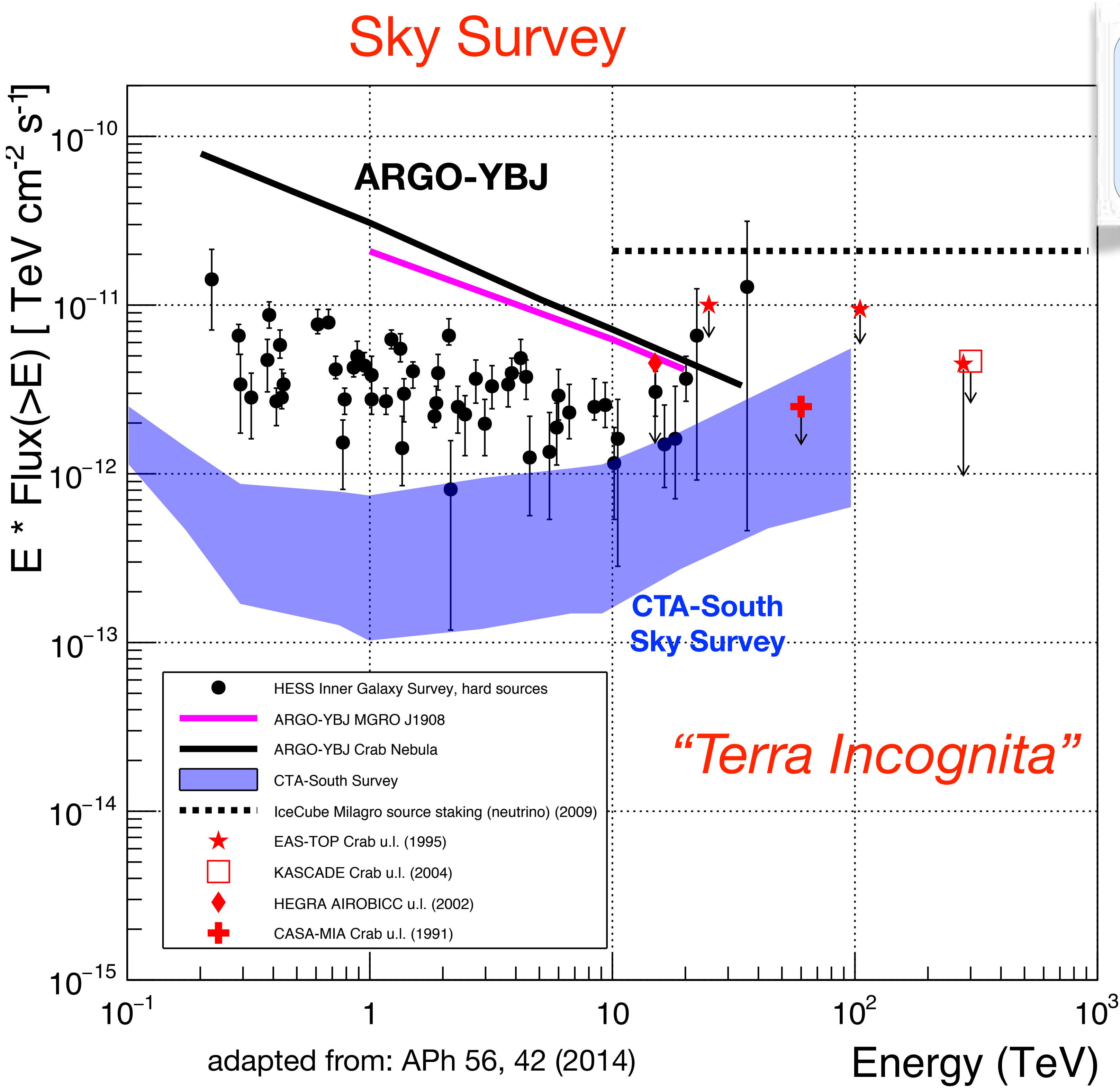


Bonus @ 100 TeV:

Hadronic spectra: *hard*
Leptonic spectra: *soft*
No hard IC gamma rays >100 TeV
IC in deep Klein-Nishina

★ A power law spectrum reaching 100 TeV without a cutoff is a very strong indication of the hadronic origin of the emission

Opening the PeVatron range



adapted from: APh 56, 42 (2014)

ASPERA recognizes the importance of

"development of ground-based wide-angle gamma-ray detectors"

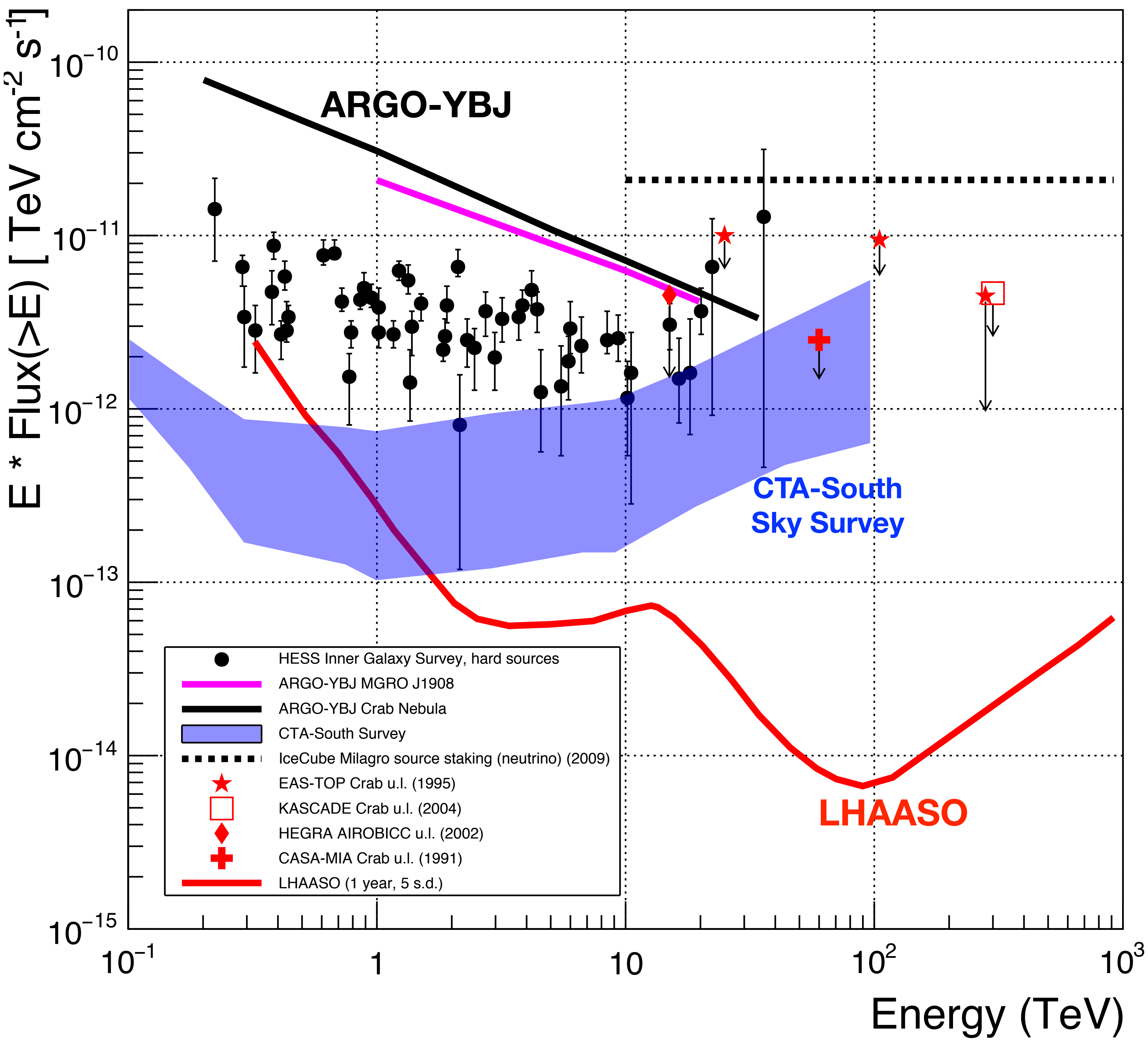
ASPERA

USA: VERITAS + HAWC

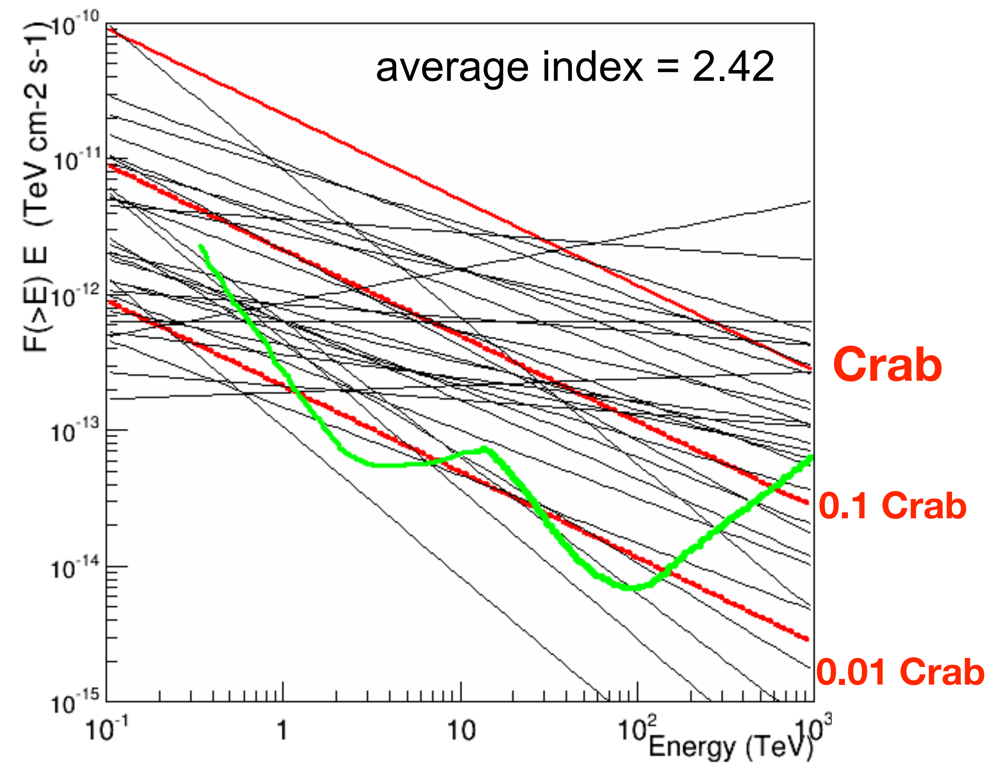
GERMANY: HESS + MAGIC + CTA + HiSCORE

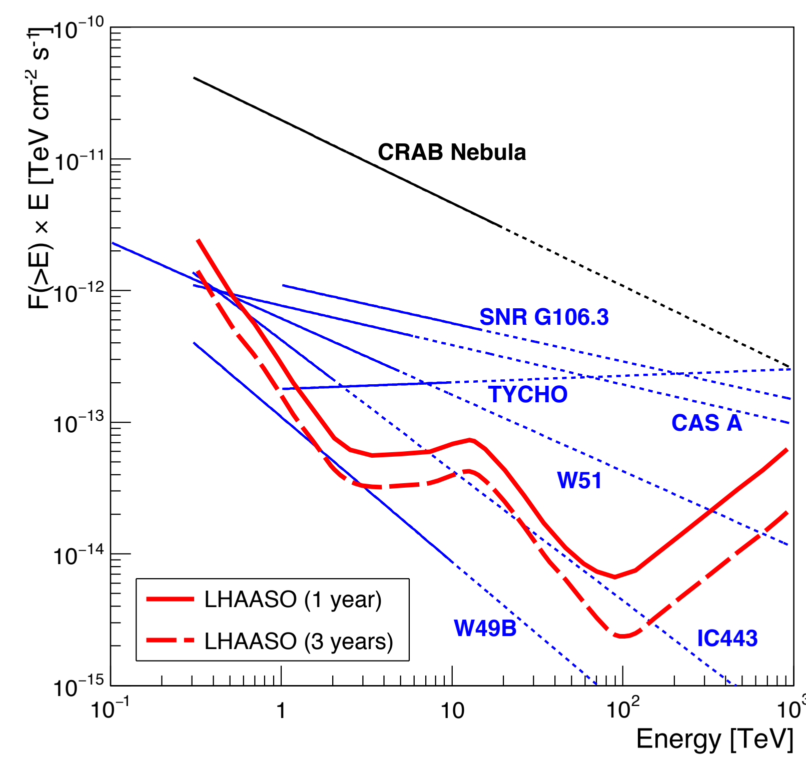
Extend energy range !
→ very large area
→ wide-angle γ-ray detectors

Opening the PeVatron range



Extrapolation of TeV spectra assuming no cutoff

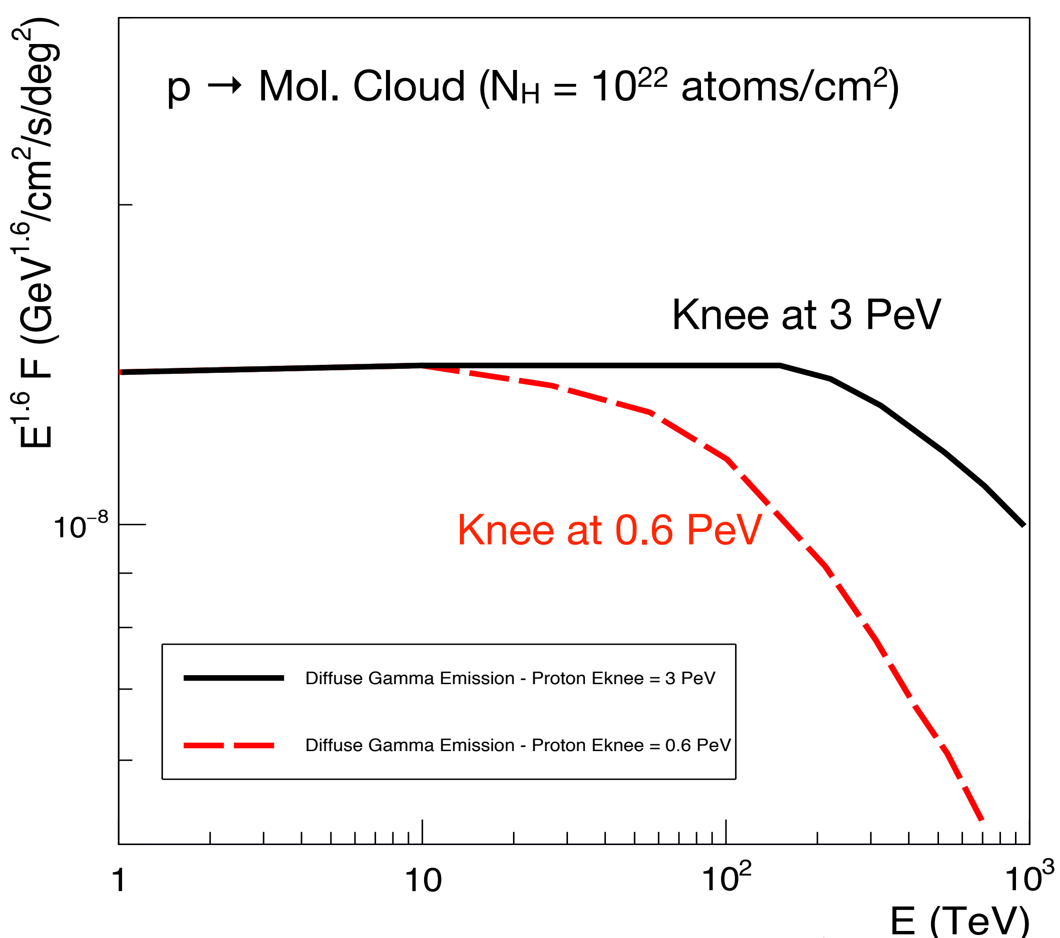




Diffuse γ-rays from the Galactic Plane

Diffuse γ-rays are produced by relativistic electrons by bremsstrahlung or inverse Compton scattering on bkg radiation fields, or by protons and nuclei via the decay of π^o produced in *hadronic interactions* with interstellar gas.
The space distribution of this emission can trace the location of the CR sources and the distribution of interstellar gas.

The intensity of diffuse Galactic gamma-rays for a standard CR spectrum with the knee at 3 PeV on a 'standard' molecular cloud.



If near some molecular cloud the knee is at 0.6 PeV, the spectrum of diffuse gamma rays from that region would follow the red dashed line.

Is the knee a source property, in which case we should see a corresponding spectral feature in the gamma-ray spectra of CR sources, or the result of propagation, so we should observe a *knee that is potentially dependent on location*, because the propagation properties depend on position in the Galaxy ?

Observing a location dependence of the knee energy (or of the spectral index !) would provide important clues on the nature of the knee.

→ High Energy Observation of Diffuse Emission

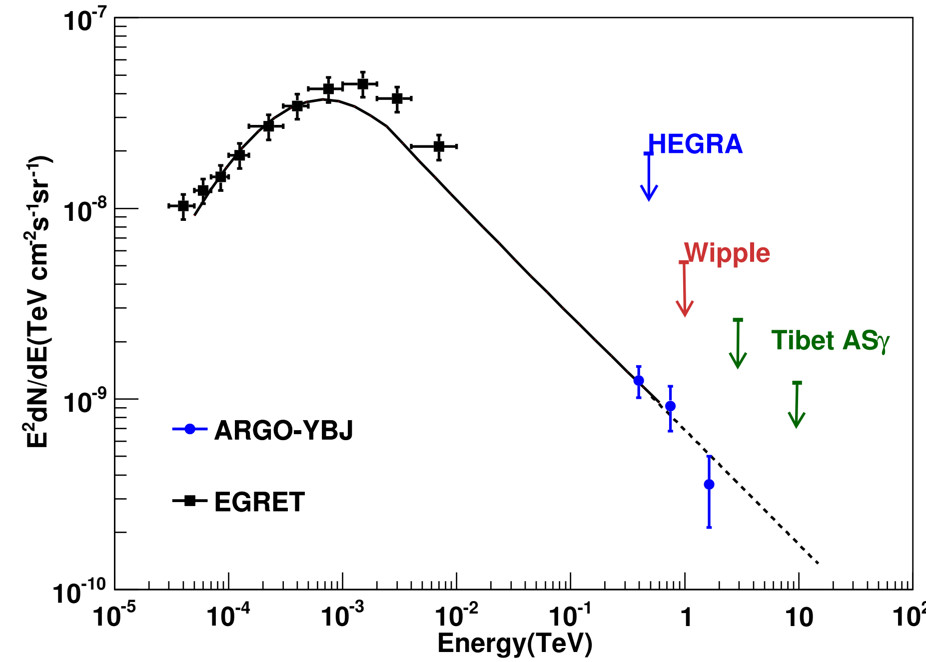
Diffuse γ Emission

Diffuse gamma-ray emission from the Galactic plane for |b| < 5°

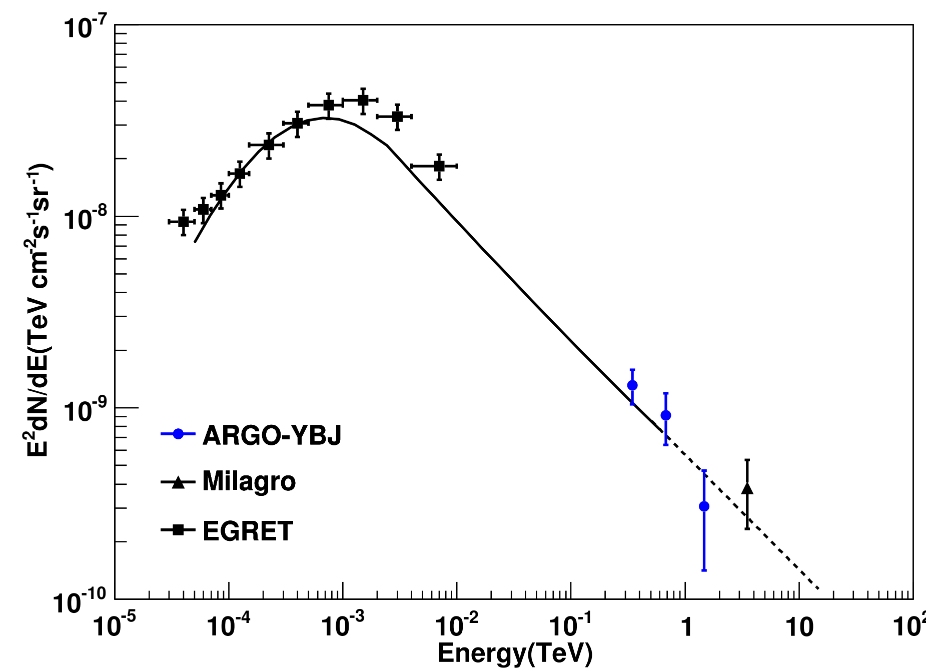
l Intervals	Significance	Spectral index	Energy(GeV)	Flux[a]
$25° < l < 100°$	6.9 s.d.	-2.80 ± 0.26	390	8.06 ± 1.49
			750	1.64 ± 0.43
			1640	0.13 ± 0.05
			1000[b]	0.60 ± 0.13
$40° < l < 100°$	6.1 s.d.	-2.90 ± 0.31	350	10.94 ± 2.23
			680	2.00 ± 0.60
			1470	0.14 ± 0.08
			1000[b]	0.52 ± 0.15
$65° < l < 85°$	4.1 s.d.	-2.65 ± 0.44	440	5.38 ± 1.70
			780	1.13 ± 0.60
			1730	0.15 ± 0.07
			1000[b]	0.62 ± 0.18
$25° < l < 65°$ & $85° < l < 100°$	5.6 s.d.	-2.89 ± 0.33	380	9.57 ± 2.18
			730	1.96 ± 0.59
			1600	0.12 ± 0.07
			1000[b]	0.60 ± 0.17
$130° < l < 200°$	-0.5 s.d.	–	–	< 5.7[c]

[a]In units of 10^{-9} TeV^{-1} cm^{-2} s^{-1} sr^{-1}.

$25° < l < 100°$; $|b| < 5°$



$40° < l < 100°$; $|b| < 5°$



Interestingly, the energy spectrum of the light component (p+He) up to 700 TeV measured by ARGO-YBJ follows the same spectral shape as that found in the Cygnus region.

A precise comparison of the spectrum of young CRs, as those supposed in the Cygnus region, with the spectrum of old CRs resident in other places of the Galactic plane, could help to determine the distribution of the sources of CRs.

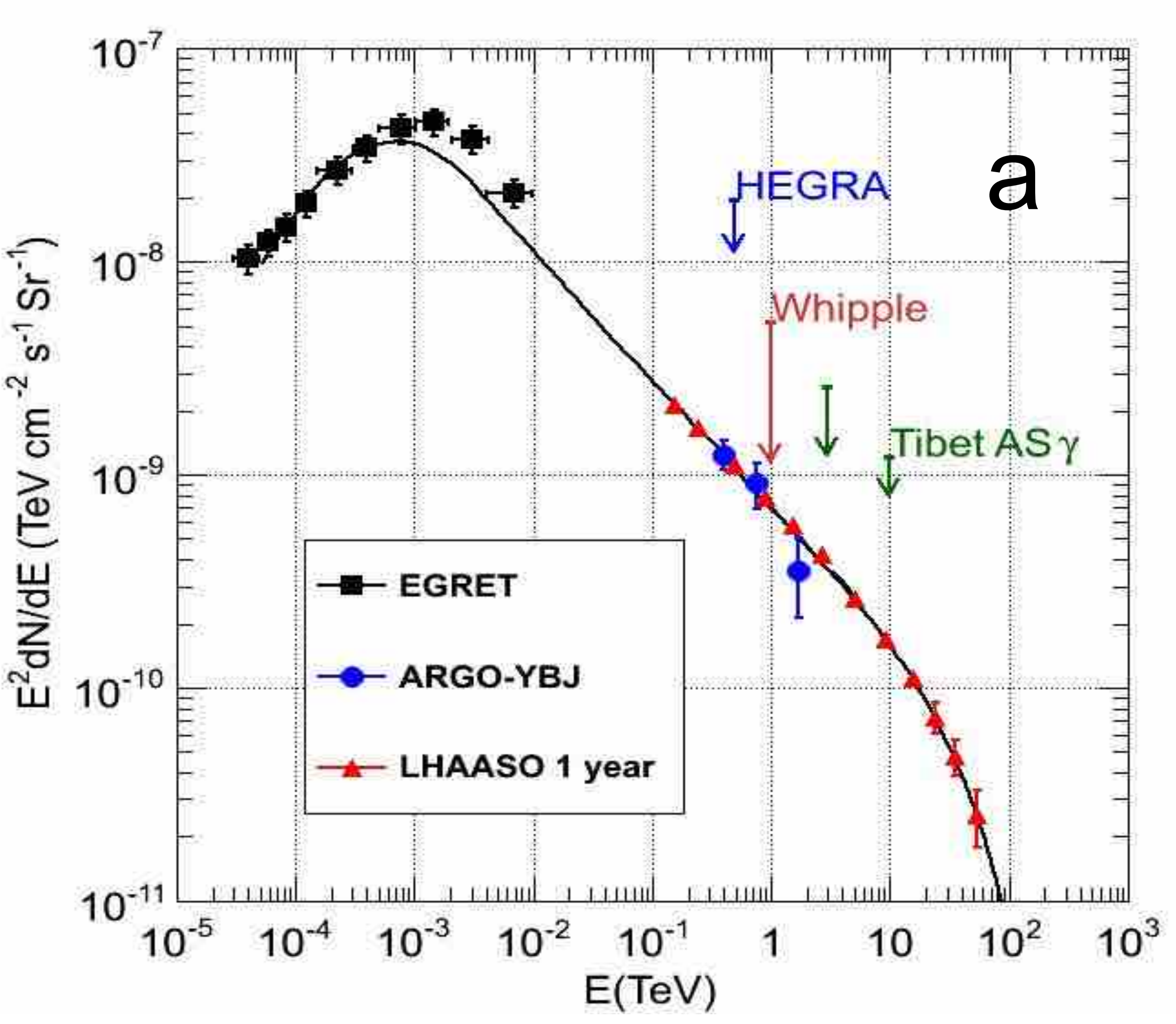
ApJ 806 (2015) 20

LHAASO sensitivity to diffuse γ-ray emission

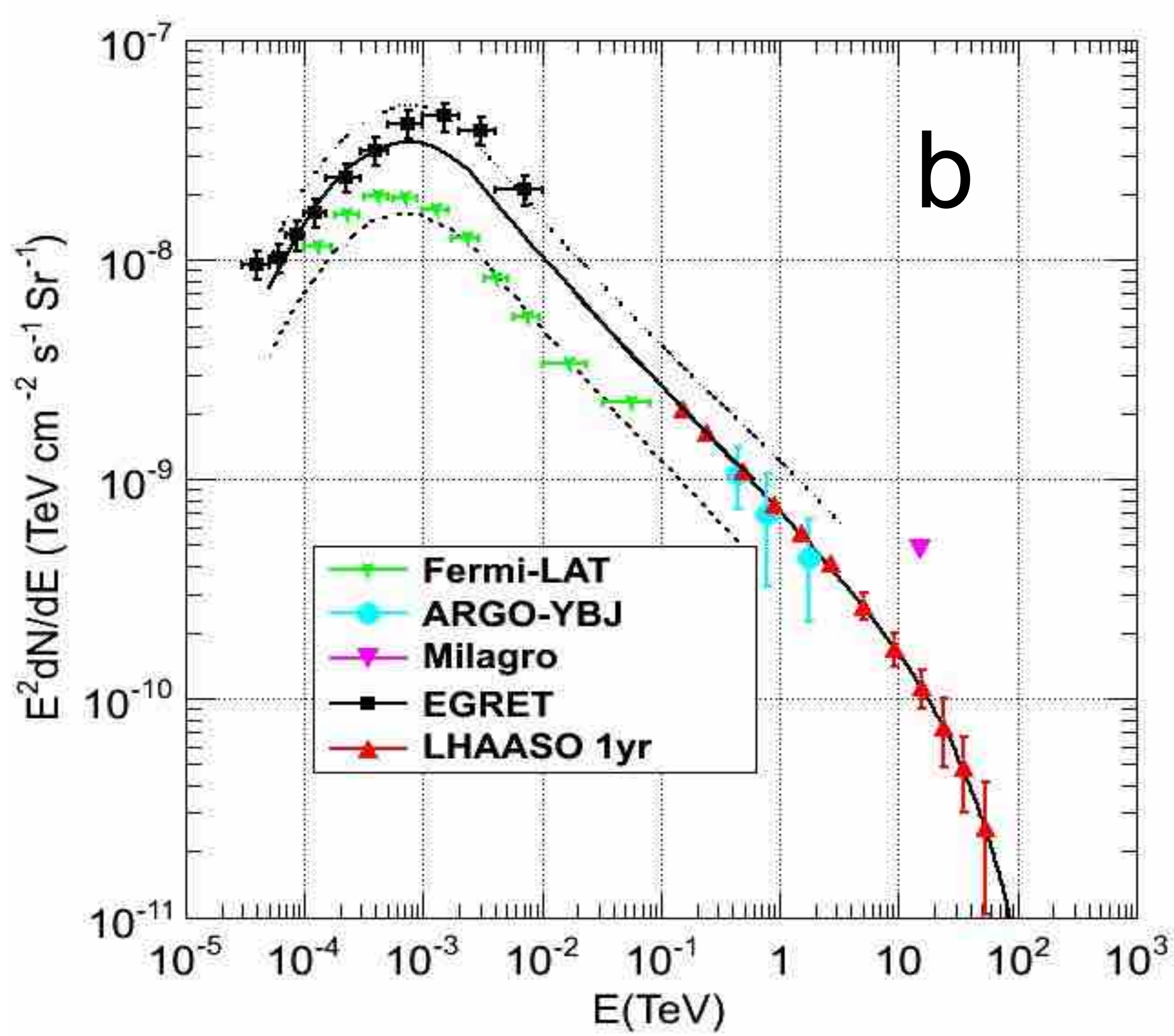
Gamma-ray diffuse emission with cutoff at 50 TeV

PRELIMINARY !!!

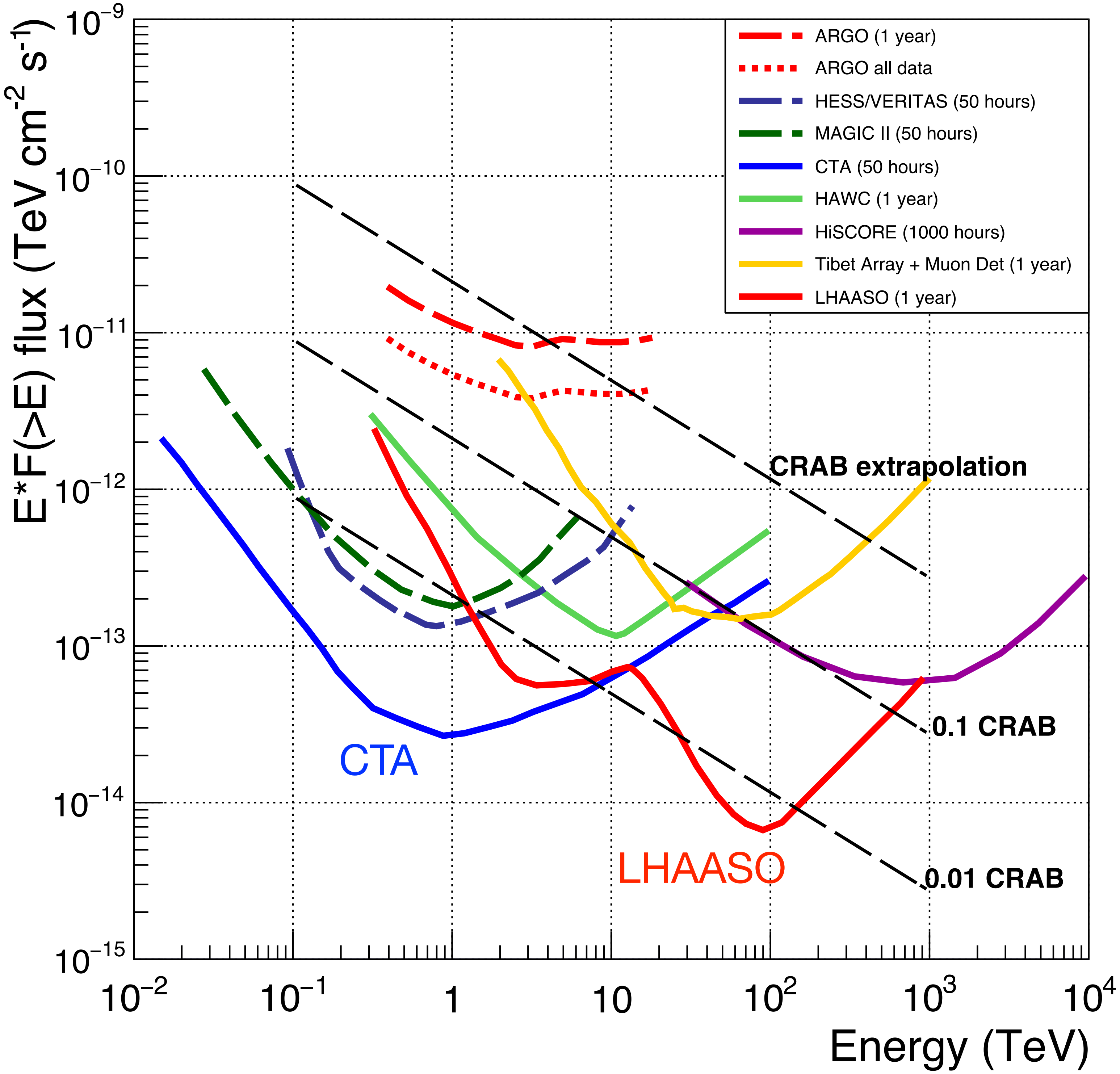
25° < l < 100°; |b| < 5°



Cygnus region: 65° < l < 85°; |b| < 5°



Sensitivity to gamma point sources



EAS-array: 5 s.d. in 1 year

Cherenkov: 5 s.d. in 50 h *on source*

★ 1 year for EAS arrays means:

(5 h × 365 d) ~1500 - 2200 of observation hours for each source (about 4-6 hours per day).

★ For Cherenkov:

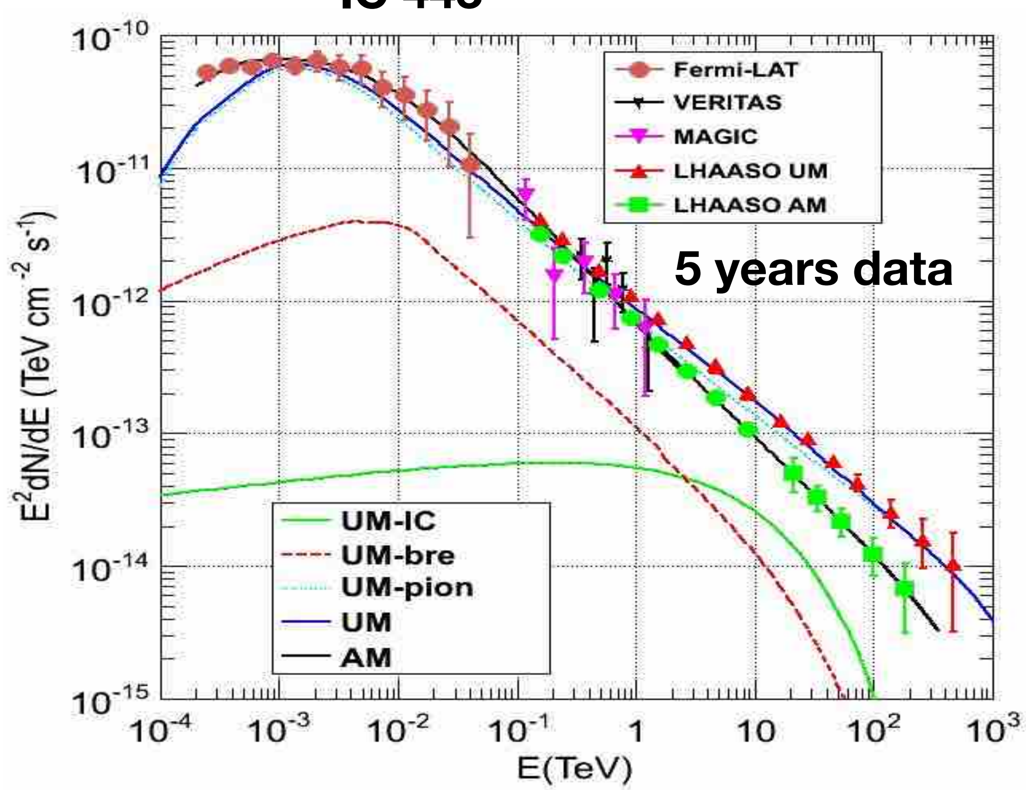
(5 h × 365 d) × d.c. (≈ 15%) ≈ 270 h / y for each source.

The big advantage of LHAASO

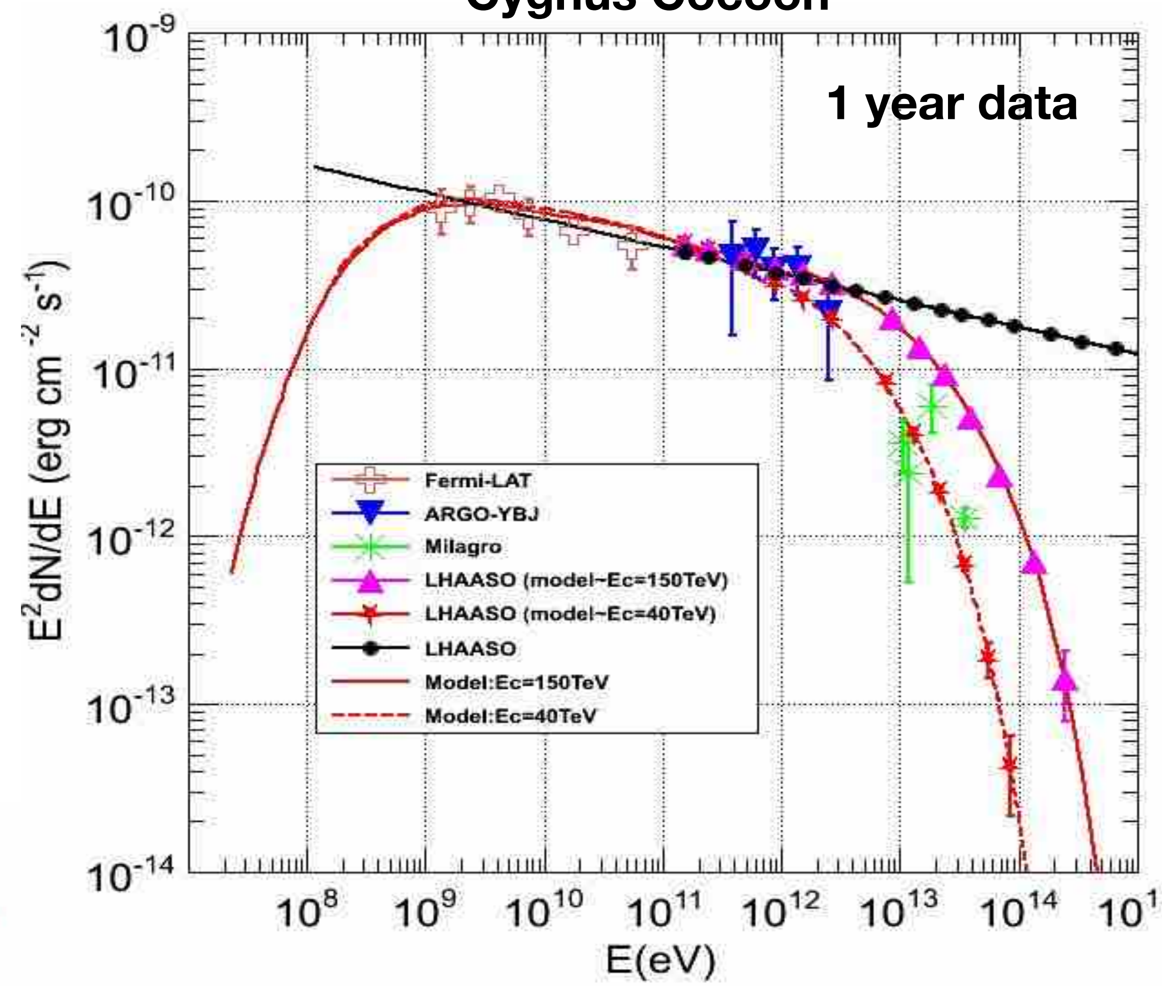
- High Energy (>10 TeV)
- Sky Survey

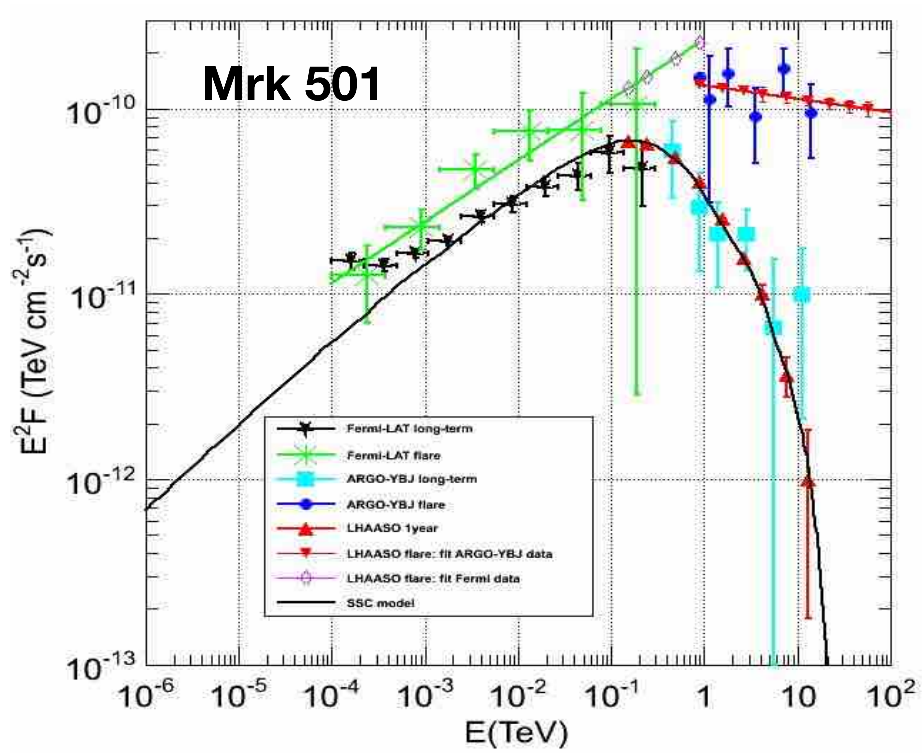
Spectra measurement with LHAASO

IC 443



Cygnus Cocoon





Take Home Message - 3

- Sky maps of the gamma-ray sky not unbiased.
- PeVatrons smoking gun signature still missing.
- Study of extended sources (Molecular Clouds, diffuse emission) very important.
- Monitoring of flaring emissions (GRBs, AGNs, etc) important

Homework

✓ All-sky survey instrument for an unbiased map of the sky.

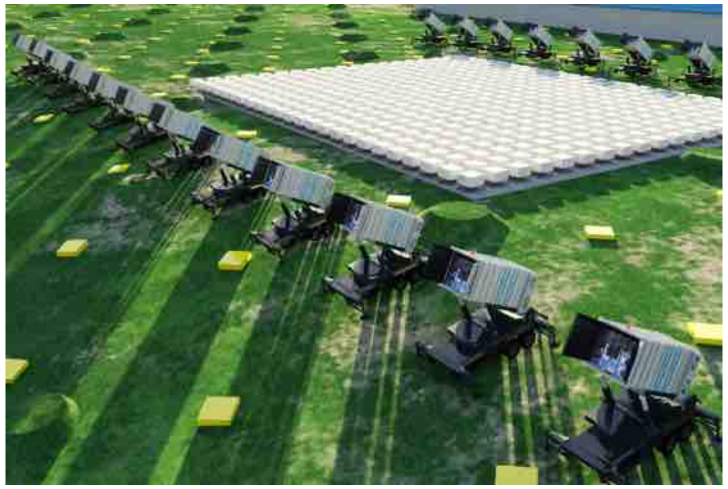
✓ Observation of gamma-ray sky in the 100 TeV region !

✓ Wide-angle instrument for very extended sources and diffuse emission.

✓ Survey for new, unexpected classes of VHE sources (‘*dark accelerator*’)

LHAASO main components

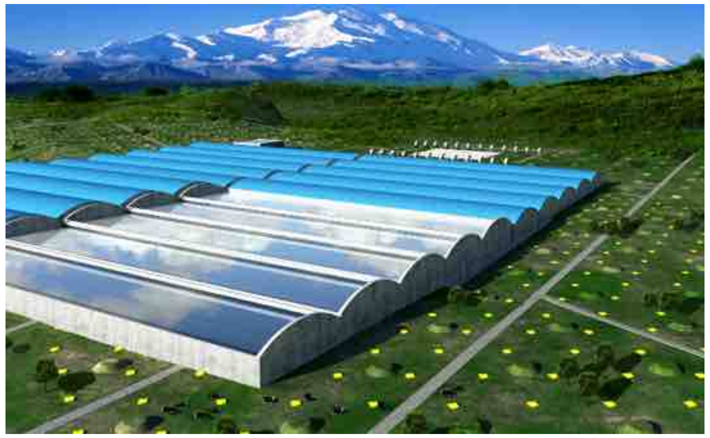
1 KM2A:
5635 EDs
1221 MDs



WFCTA:
24 telescopes
1024 pixels each

Coverage area: 1.3 km^2

WCDA:
3600 cells
90,000 m^2



SCDA:
452 detectors

Status of LHAASO

- LHAASO is one of the '*Five top priorities*' projects of the Strategic Plan of IHEP approved by the Chinese Academy of Sciences (CAS).

- The government of Sichuan province approved funding the total cost of the infrastructure construction: 300 M CNY.

- “The official approval of LHAASO drafted, waiting the chief of funding agency to sign on it”.

Schedule (August 2015)

★ July 2015: start of construction of infrastructures.
★ Nov. 2015: start of big scale construction.

★ Autumn/Winter 2016: start of construction of first quarter of WCDA and KM2A.

★ Winter 2018: start scientific operation of the first quarter of LHAASO.

★ 2021: conclusion of installation of main components.

Landscape of the LHAASO site

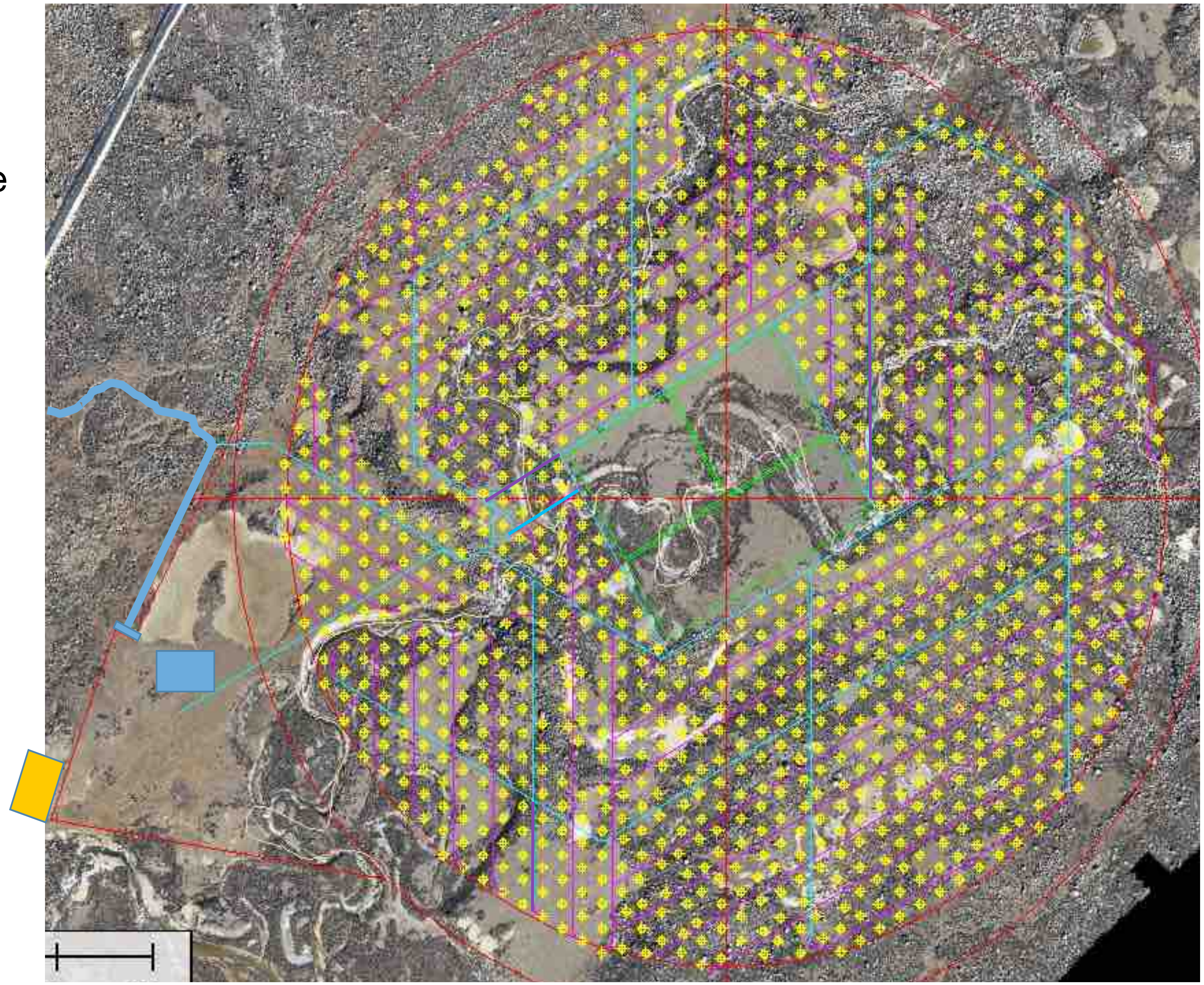
Mt. Haizi 4400 m asl, Sichuan province, China

Geo survey and weather monitoring

Updated layout after site survey

Roads under construction:

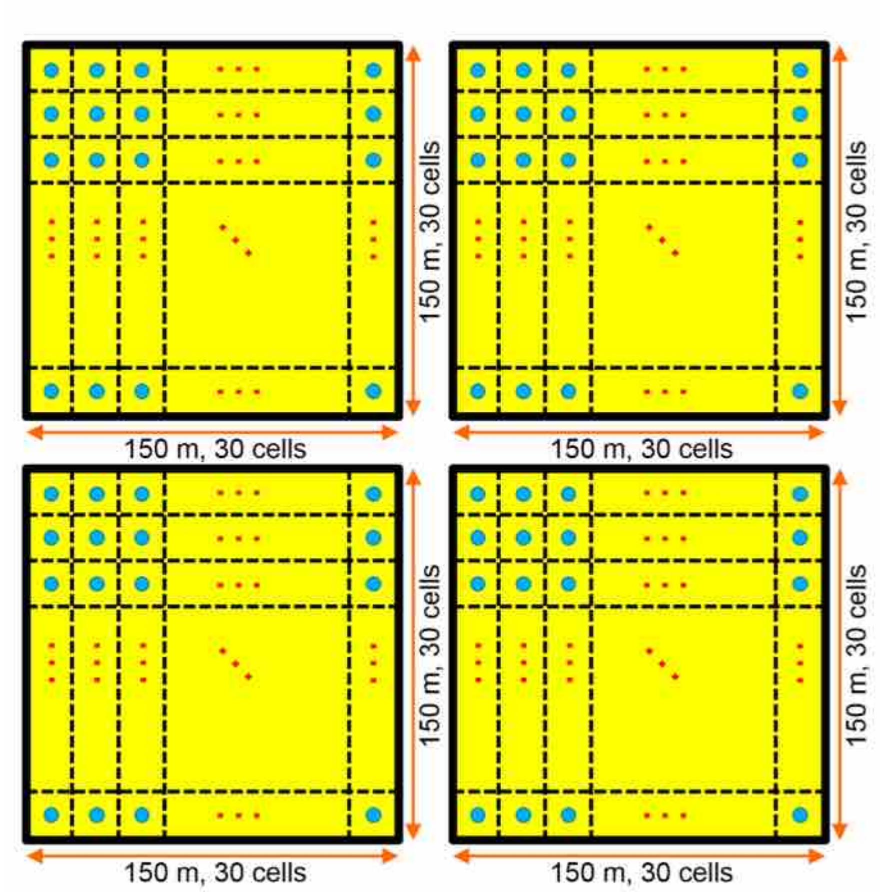
- Connection to S217
- Major transportation ways on site
- Paths to MDs

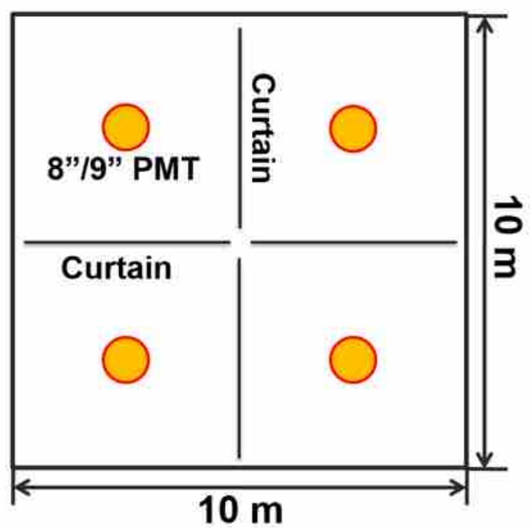


- Start of field preparation expected in **Dec. 2015.**
- Sites of MDs have been surveyed.
- 1146 MD sites (of the 1221 planned) confirmed and fixed after the survey.
- Position of EDs measured and fixed.
- Deep geo-survey for WCDA pools started in June.

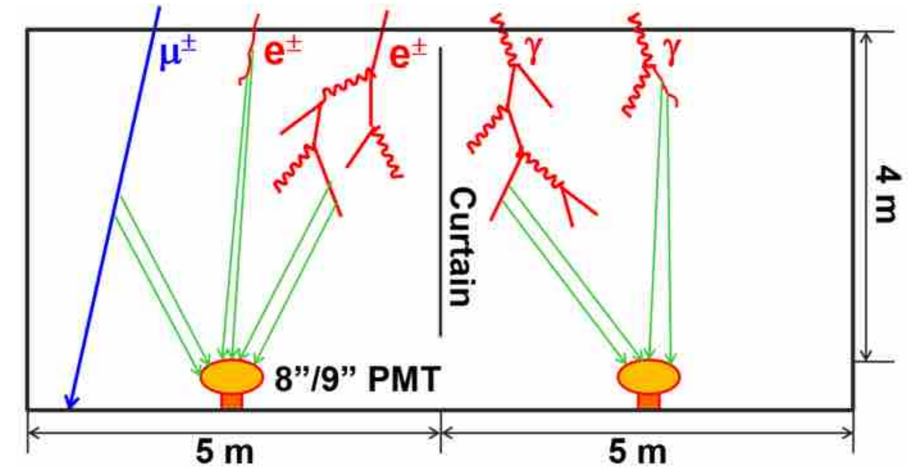
New MC simulations with the final layout under way

Water Cherenkov Detector Array





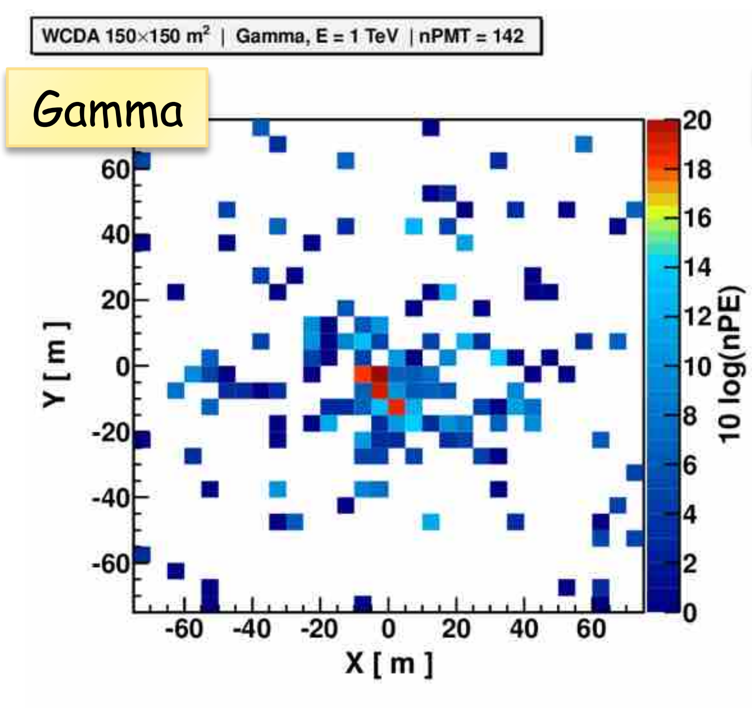
Cells separated by black curtains

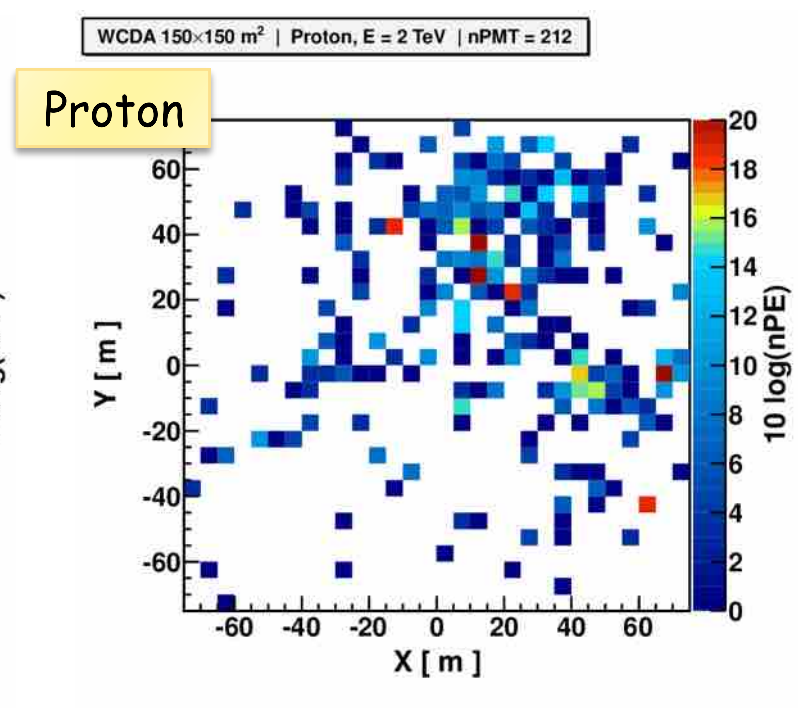


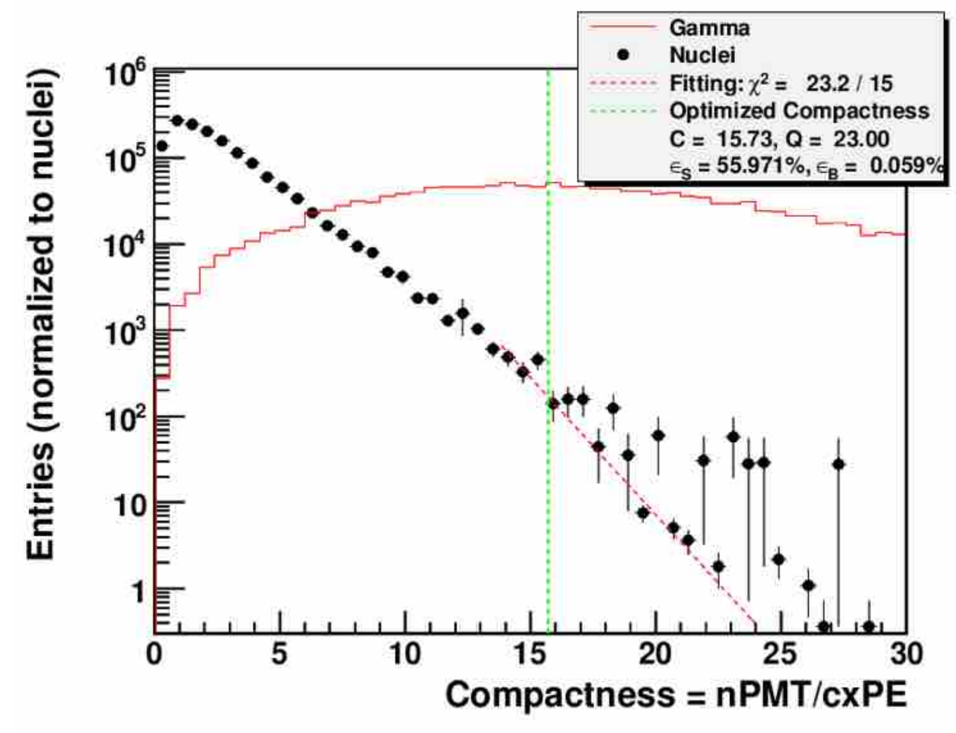
Item	Value
Cell area	25 m^2
Effective water depth	4 m
Water transparency	> 15 m (400 nm)
Precision of time measurement	0.5 ns
Dynamic range	1-4000 PEs
Time resolution	<2 ns
Charge resolution	40% @ 1 PE 5% @ 4000 PEs
Accuracy of charge calibration	<2%
Accuracy of time calibration	<0.2 ns
Total area	90,000 m^2
Total cells	3600

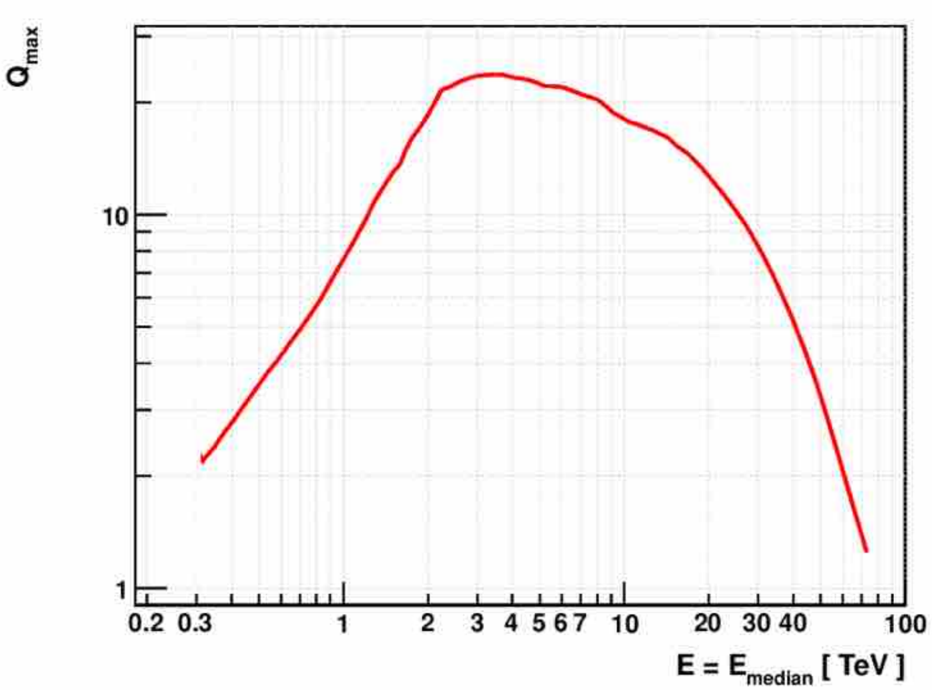
PMTs R5912 and XP1805 under test

Gamma/proton discrimination









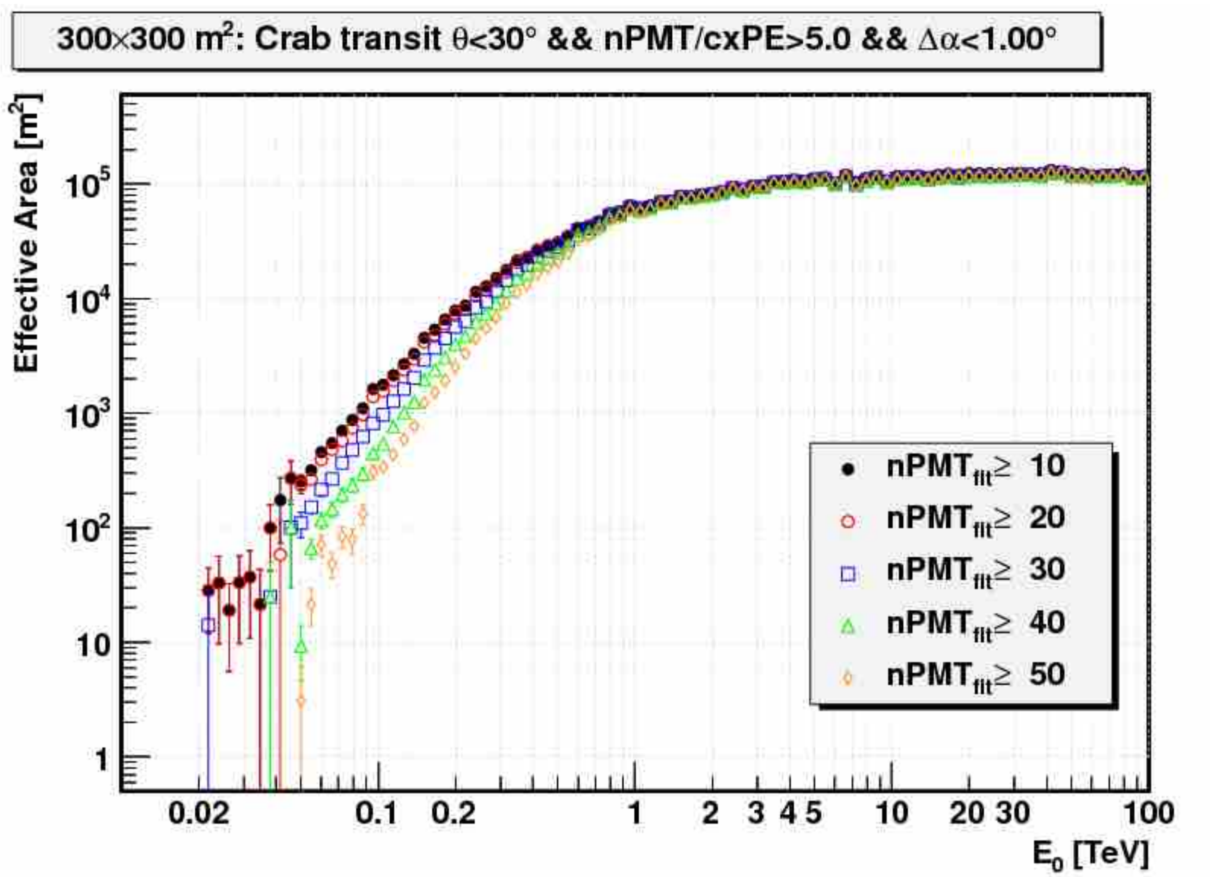
Brightest "sub-core":

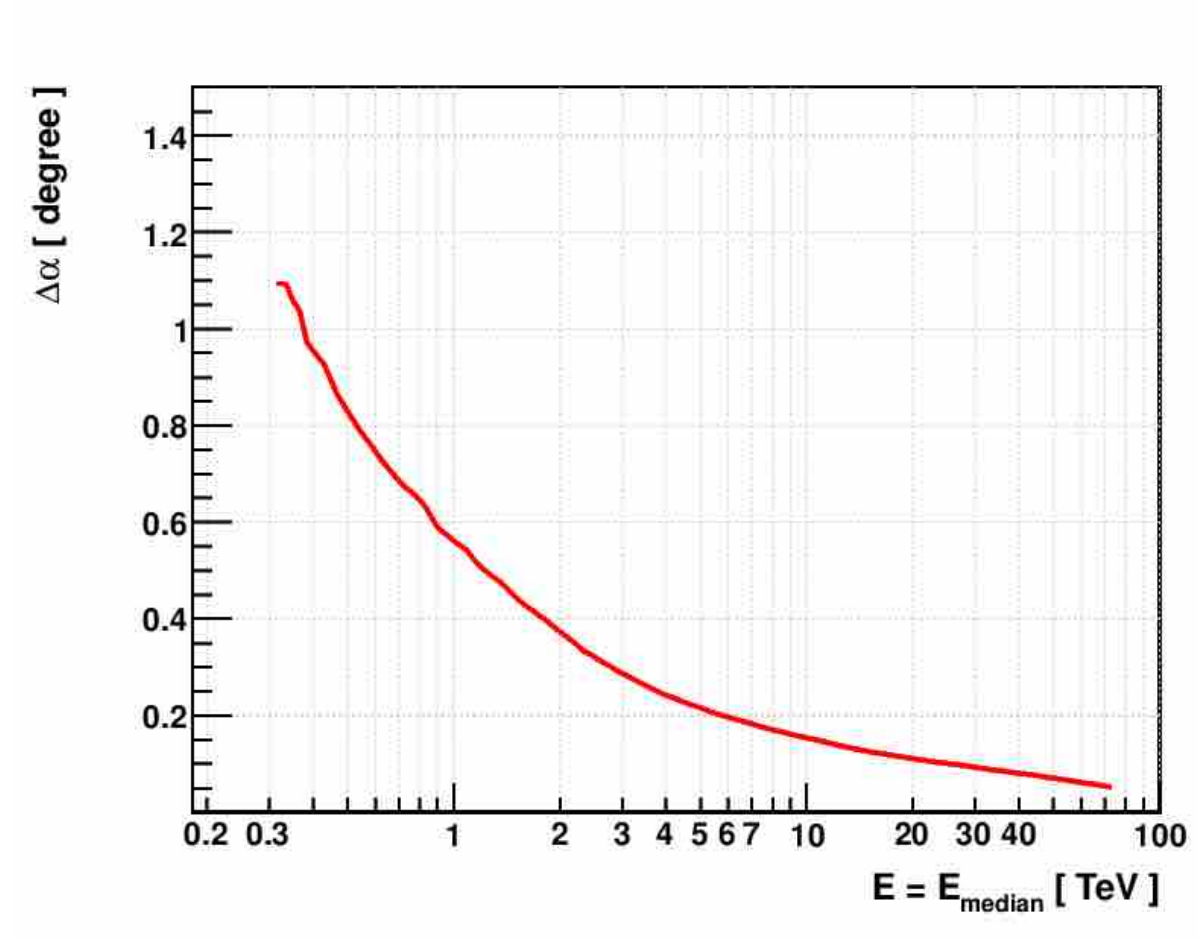
- Signal of the brightest PMT *outside the shower core region* (e.g., 45 m).

Shower "Compactness" to reject cosmic ray background:

Q-factor: 7 @ 1 TeV; 22 @ 5 TeV.

Effective Area & Angular Resolution





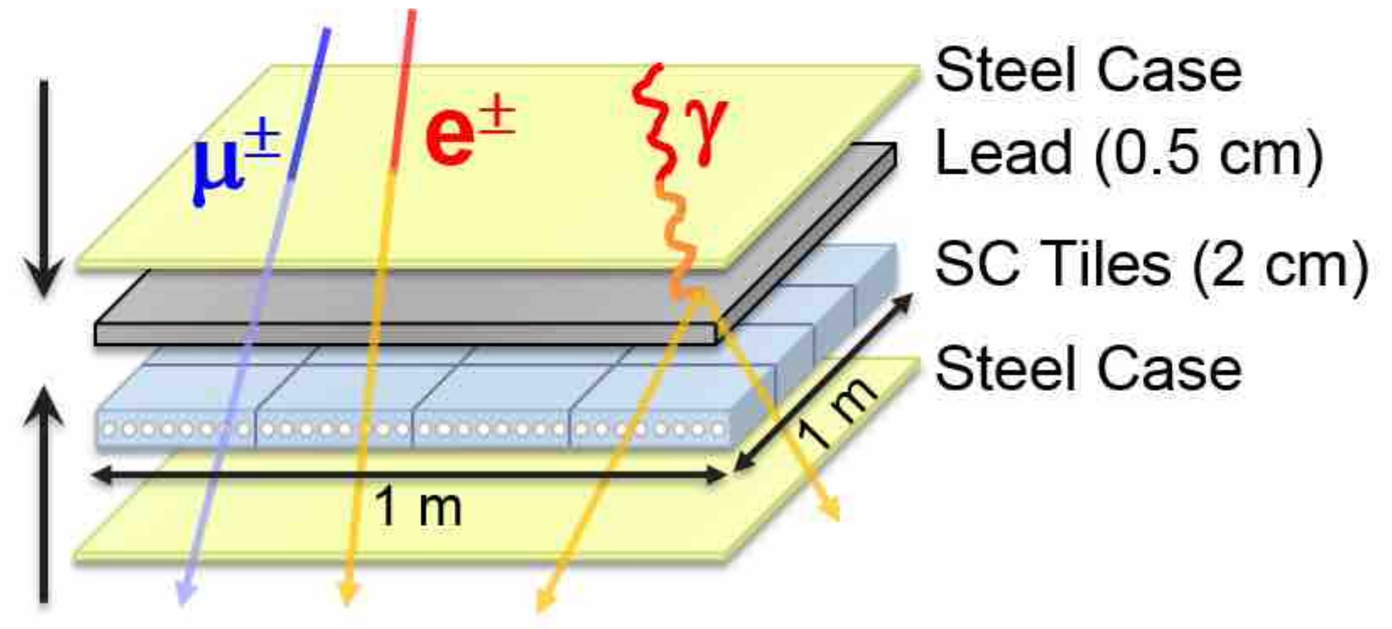
Effective area (internal events):

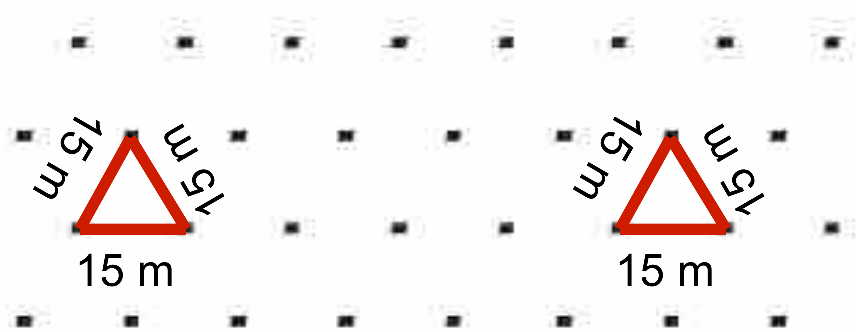
- ~1000 m^2 @ 100 GeV; >80,000 m^2 @ 5 TeV.

Angular resolution:

- Optimized bin size: 0.55° @ 1 TeV; 0.23° @ 5 TeV.

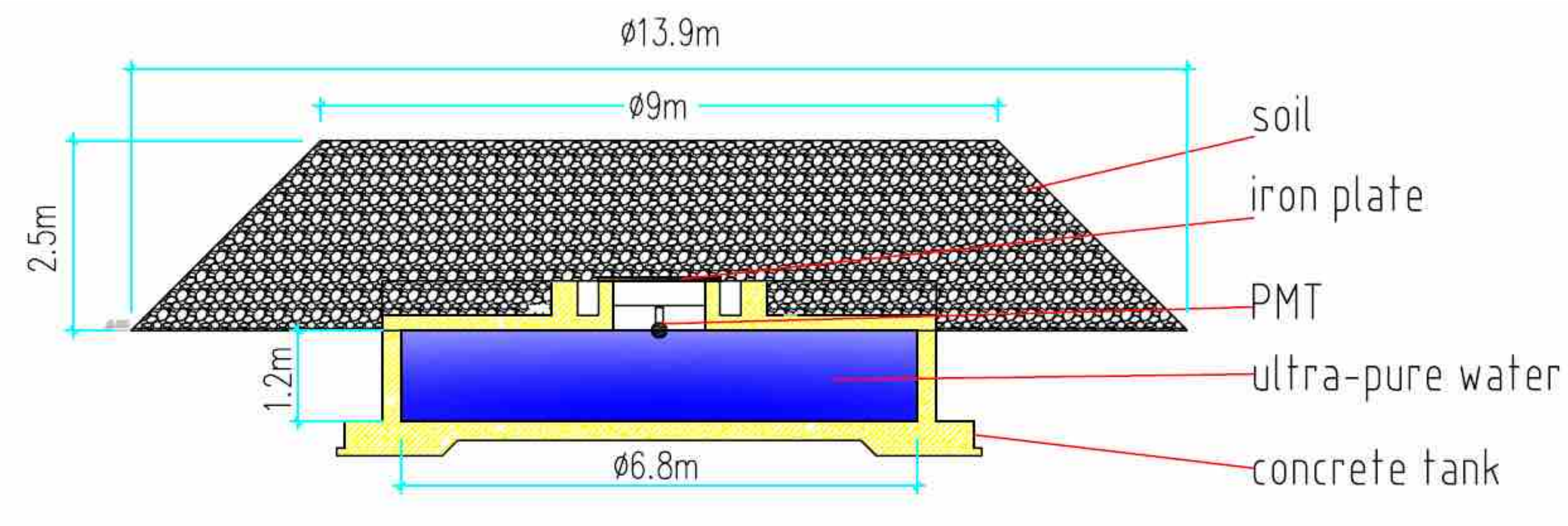
Electromagnetic particle Detector

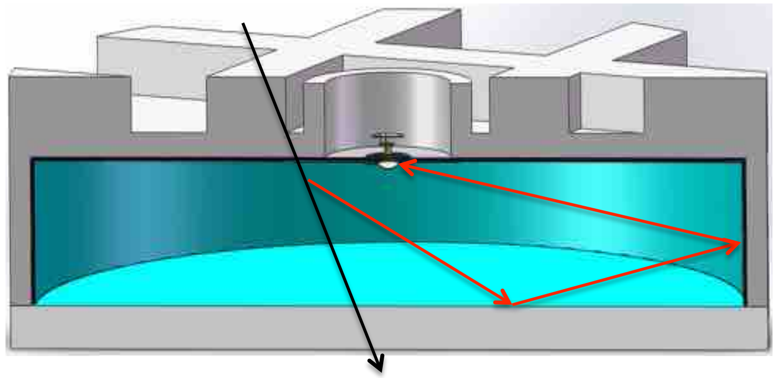




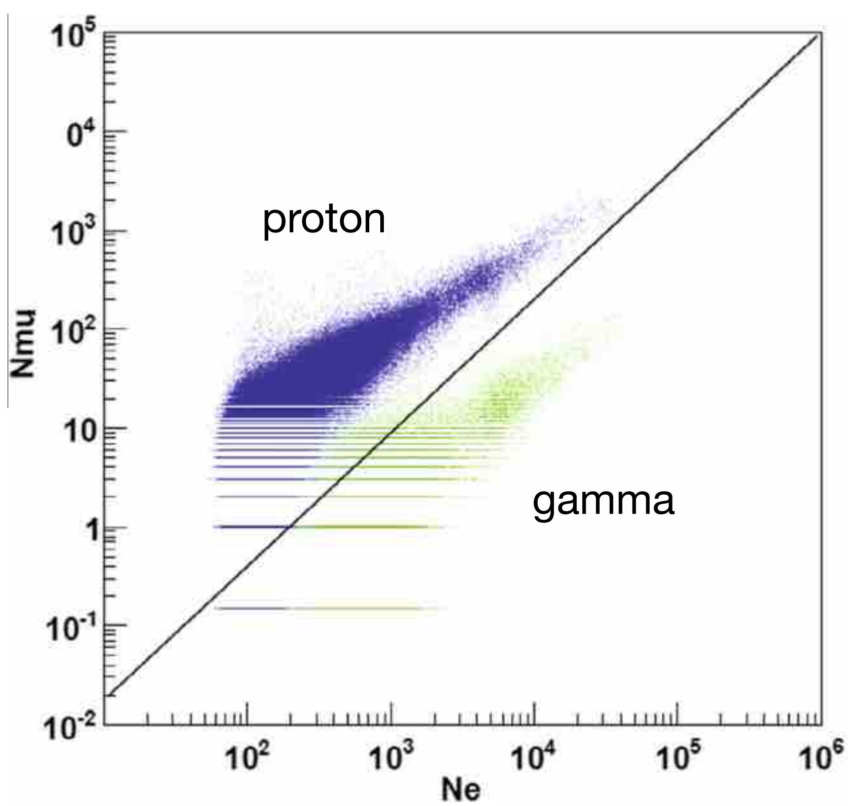
Item	Value
Effective area	1 m^2
Thickness of tiles	2.5 cm
Number of WLS fibers	32/tile×4 tile
Detection efficiency (> 5 MeV)	>95%
Dynamic range	1-10,000 particles
Time resolution	<2 ns
Particle counting resolution	25% @ 1 particle 5% @ 10,000 particles
Aging (<20%)	>10 years
Spacing	15 m
Total number of detectors	5635

Water Cherenkov Muon Detector





PMT: 8" or 9"



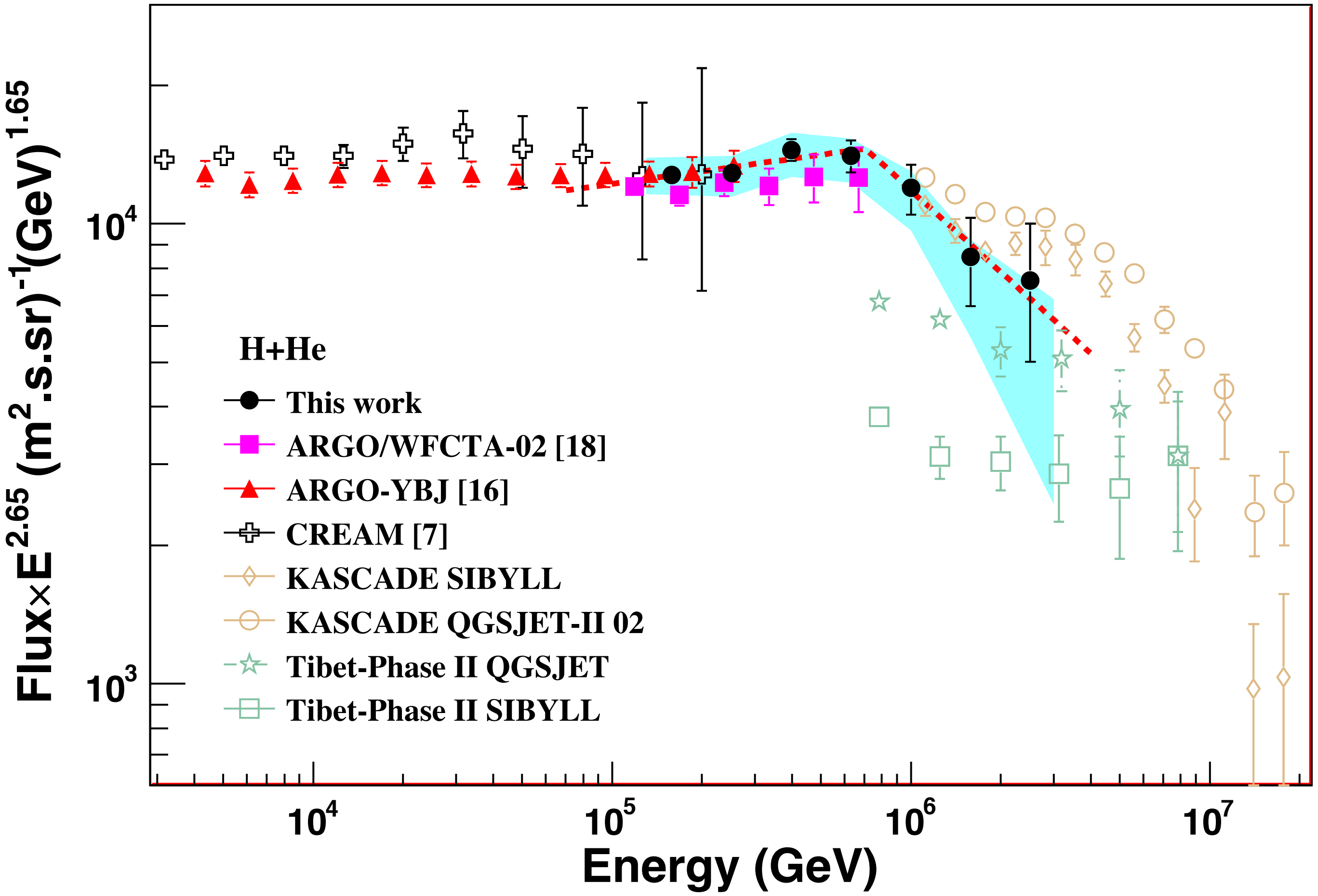
Item	Value
Area	36 m^2
Detection efficiency	>95%
Purity of N_μ	>95%
Time resolution	<10 ns
Dynamic range	1-10,000 particles
Particle counting resolution	25% @ 1 particle 5% @ 10,000 particles
Aging (<20%)	>10 years
Spacing	30 m
Total number of detectors	1221

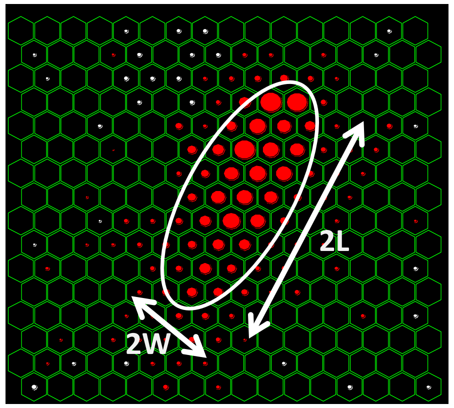
Wide field of view Cherenkov Telescope Array

24 telescopes (Cherenkov/Fluorescence)

- 5 m^2 spherical mirror
- 32 × 32 PMT array
- FOV: 14° × 16°
- Dynamic range: 10 - 35000 pe

p+He spectrum with ARGO-YBJ / WFCTA





- mirrors and Winston cones by Italian company: Media Lario Tech., INAF spin-off
- ASIC-based FEE from French collaborators (Orsay IPNO)
- HV by CAEN or German company, under discussion

Engineering Array at YBJ

1% - 10% of LHAASO in operation for more than 2 years at the ARGO-YBJ site

42 EDs, 2 MDs, 9-unit WCDA, 2 telescopes, 100 shower core detectors

Fully implemented the LHAASO design including White Rabbit-based clock distribution, “triggerless” DAQ, etc

Average water temperature: 4-6°C;
The lowest temperature: ~0.5°C

Chinese Physics C Vol. 38, No. 3 (2014) 036002

Engineering Array at YBJ

1% - 10% of LHAASO in operation for more than 2 years at the ARGO-YBJ site

42 EDs, 2 MDs, 9-unit WCDA, 2 telescopes, 100 shower core detectors

Fully implemented the LHAASO design including White Rabbit-based clock distribution, “triggerless” DAQ, etc

Average water temperature: 4-6°C;
The lowest temperature: ~0.5°C

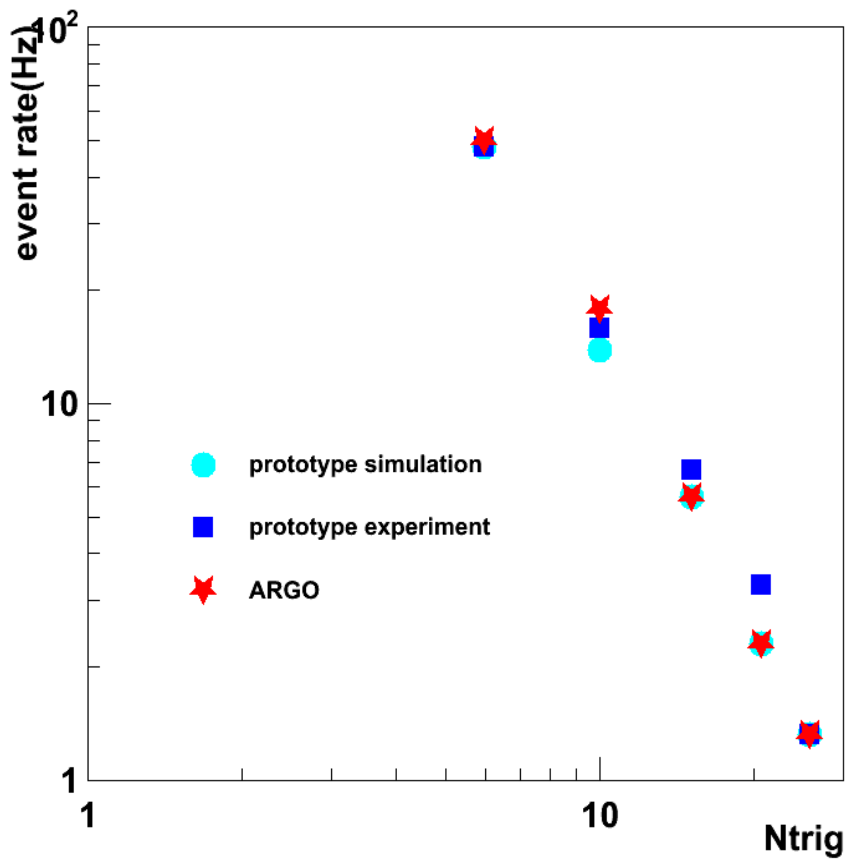
Chinese Physics C Vol. 38, No. 3 (2014) 036002

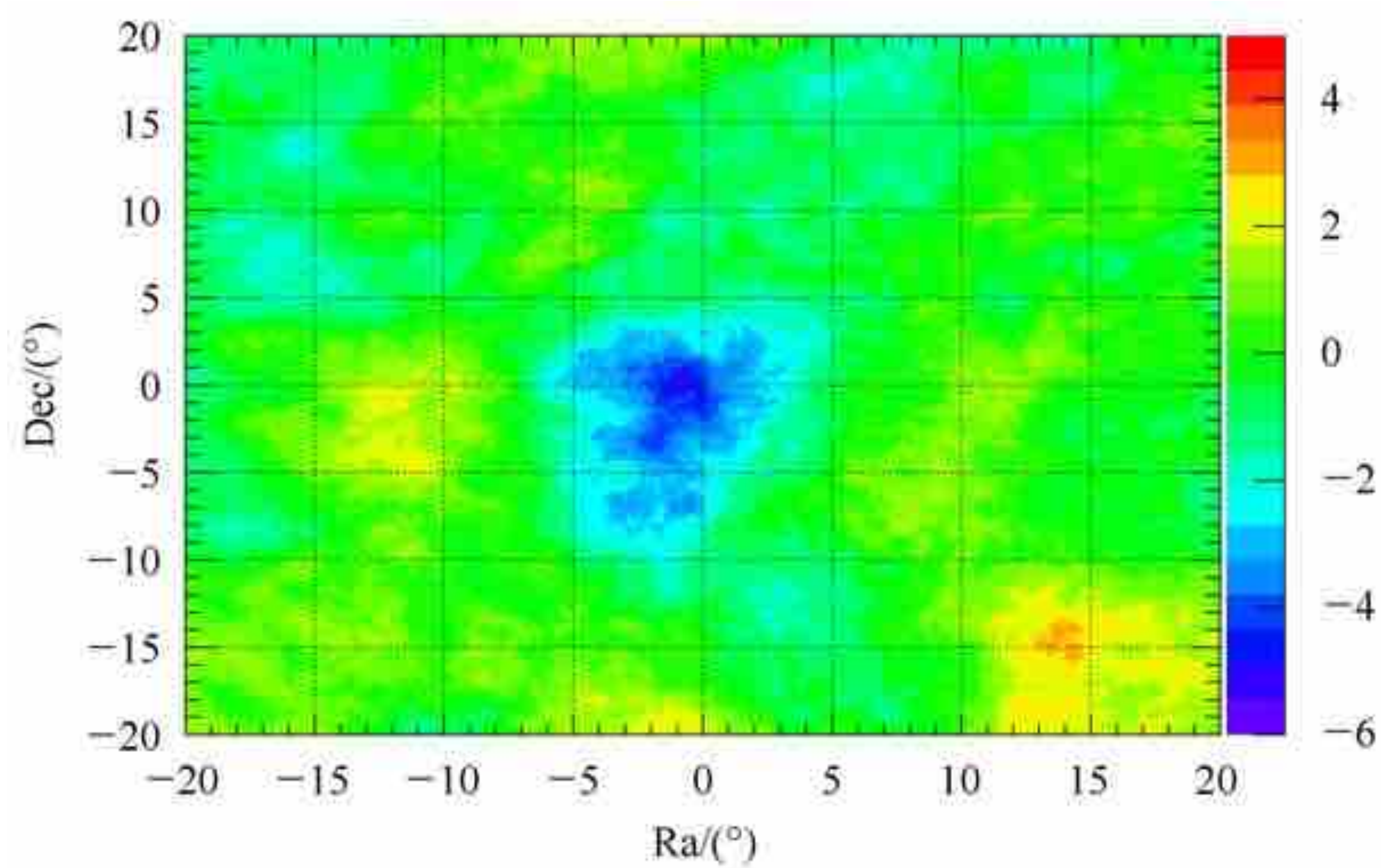
Event Rate and Moon Shadow

Scintillator array operated 2 years with ARGO-YBJ:

Event rate in agreement with MC and ARGO-YBJ

Moon shadow observed in 2 years at 5.8 s.d.





Chinese Physics C Vol. 38, No. 2 (2014) 026001

International Collaboration

ASIC-based FEE for telescopes

FRANCE: IPNO Orsay and **OMEGA**
Tiina Suomijärvi group:
ASIC-based FEE for Cherenkov telescopes
Simulations of muon detectors

CAS Project for the China-France collaboration approved (1.1 M CNY) last year

RUSSIA: INP, RAS
Yuri Stenkin group: Neutron detectors for hadron measurement (test of prototype at YBJ)
Alternative proposal for core detectors

THAILAND:
D. Ruffolo group: Solar Physics

ITALY: INFN
proposal for DAQ system of the experiment under discussion

Conclusions

The LHAASO experiment has very interesting prospects, being *able to deal with all the main open problems of cosmic ray physics at the same time.*

It is proposed to study CRs in a *unprecedented wide energy range 10^{11} - 10^{18} eV*, from those observable in space with AMS and approaching those investigated by AUGER, thus including, in addition to the 'knee', the whole region between 'knee' and 'ankle' where the galactic/extra-galactic CR transition is expected.

At the same time it is proposed as a tool of great sensitivity - unprecedented above 30 TeV - to monitor *'all the sky all the time'* a gamma-ray domain extremely rich of sources variable at all wavelengths.

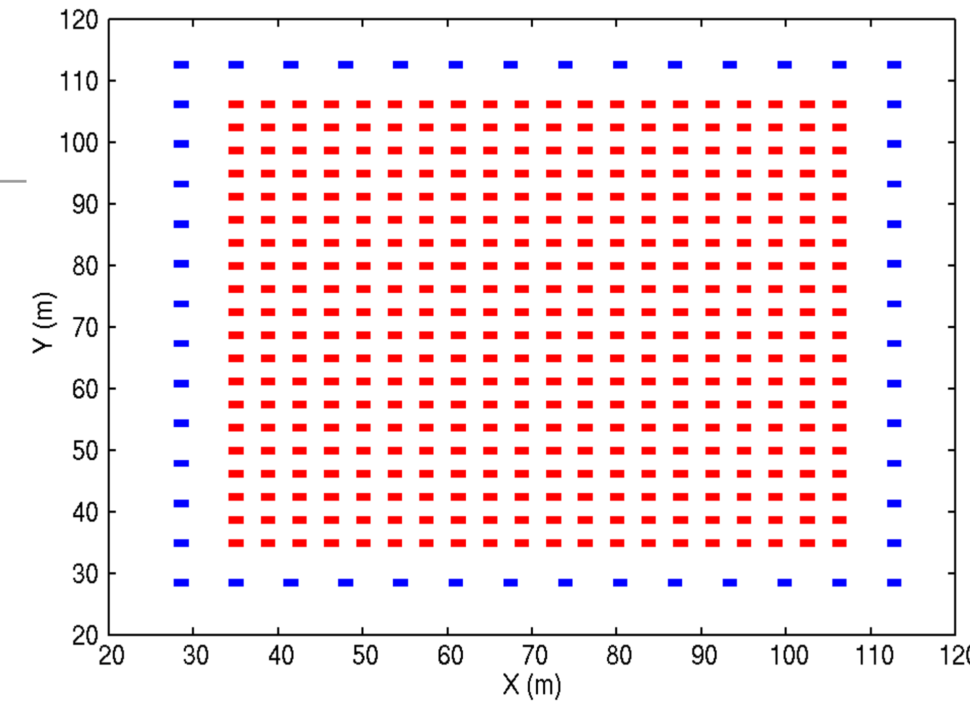
Construction of infrastructures started.

Commissioning of first quarter of the experiment (more sensitive than HAWC) expected in 2018.

Conclusion of installation of main components expected in 2021.

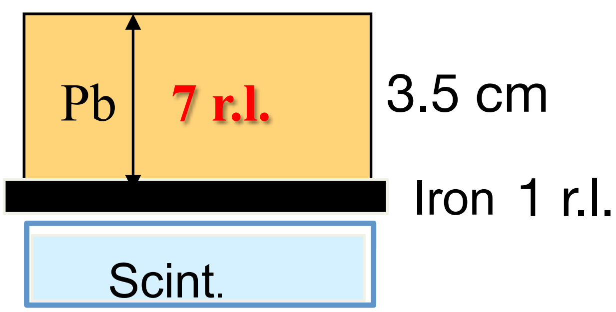
Shower Core Detector Array

- 425 close-packed burst detectors, located near the centre of the array, for the detection of high energy secondary particles in the shower core region.



- Number of SCD: $0.5\ m^2$ x 452
- Cover Area: 5170 m^2
- Energy region: 30 TeV - 10 PeV
- Core position resolution: 1.5 m @50 TeV

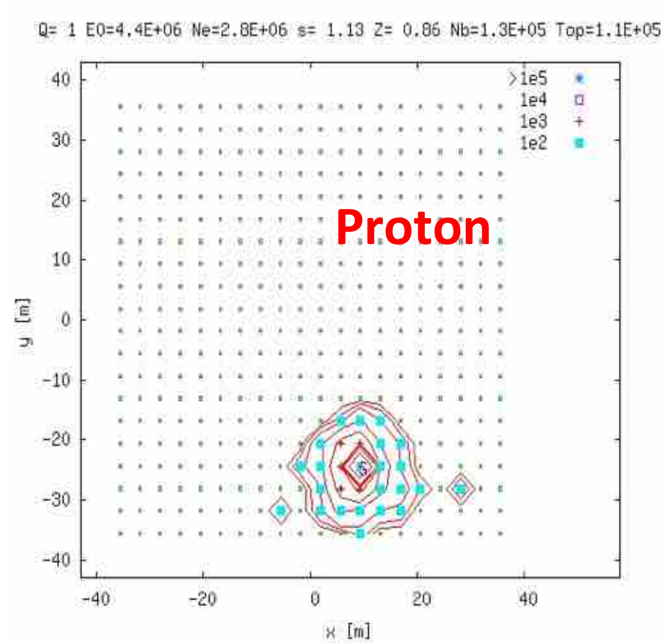
Burst Detector

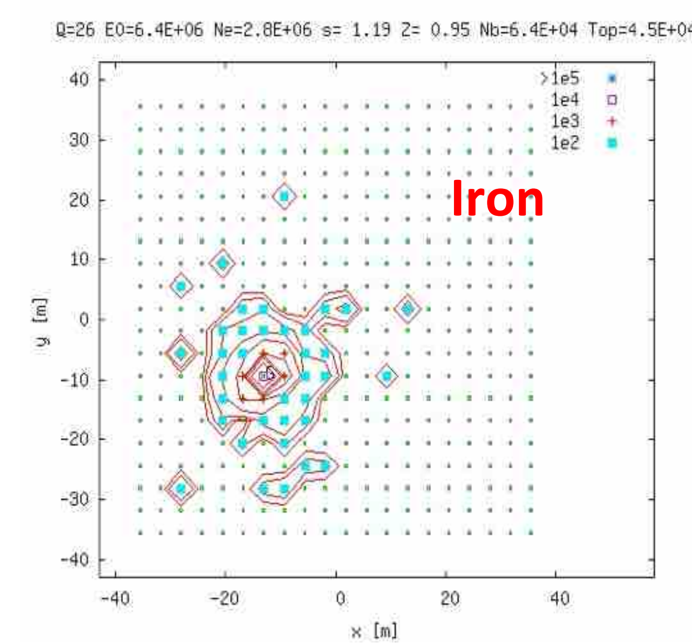


The burst detectors observe the electron size (burst size) under the lead plate induced by high energy e.m. particle in the shower core region

Each burst detector is constituted by 20 optically separated scintillator strips of 1.5 cm × 4 cm × 50 cm read out by two PMTs operated with different gains to achieve a wide dynamic range (1- 10^6 MIPs).

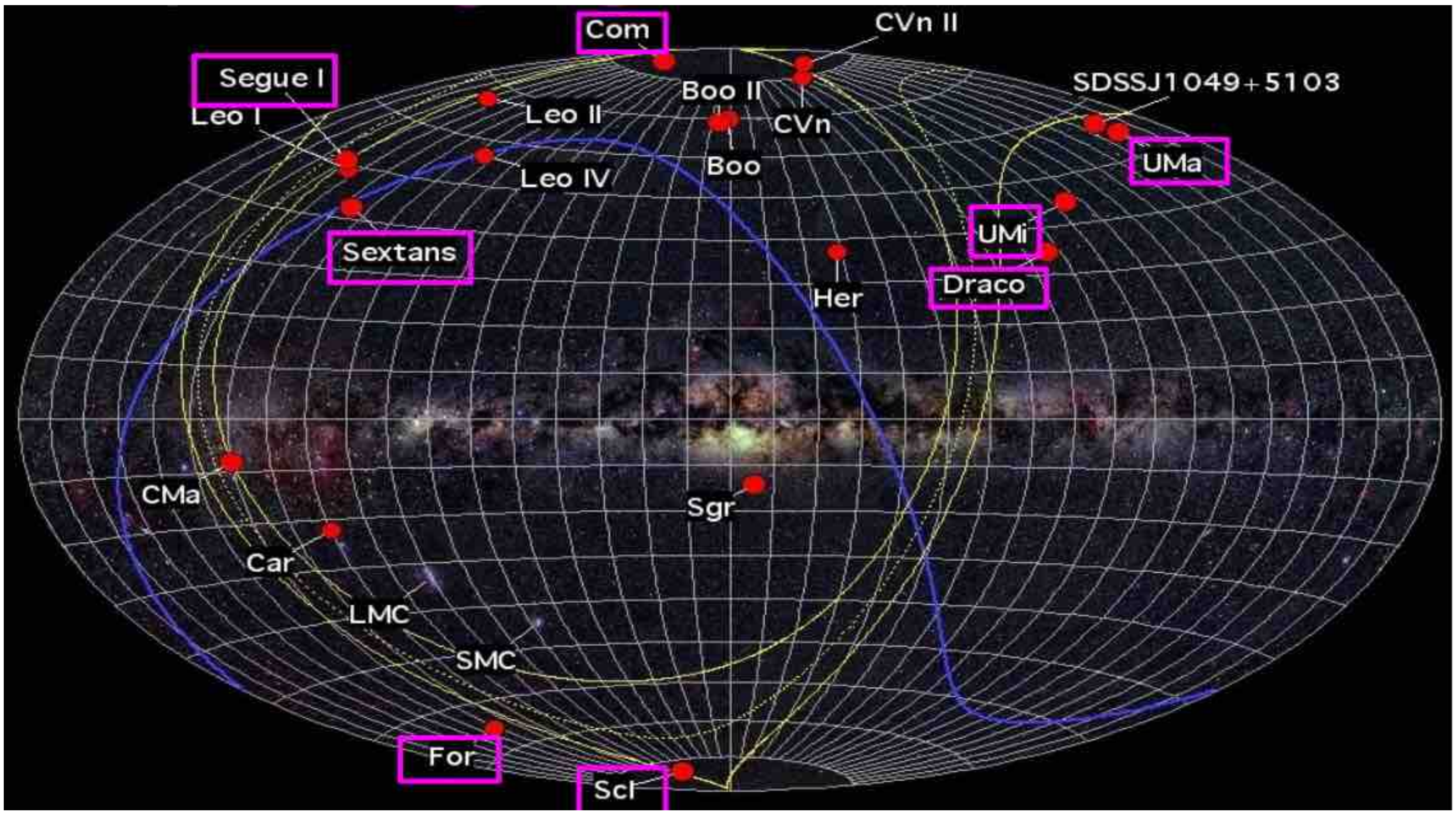
- Lead plate (80 cm X 50 cm X 7 rl)
- Iron plate (1 m X 1 m X 1 rl)





Dwarf Spheroidal galaxies (dSph)

Low luminosity galaxies that are companions to the Milky Way.
The total amount of mass inferred from the motions of stars in dSph is many times that which can be accounted for by the mass of the stars themselves ➡ this is seen as a sure sign of dark matter
Because of the extremely large amounts of dark matter in these objects, they may deserve the title *"most dark matter-dominated galaxies"*

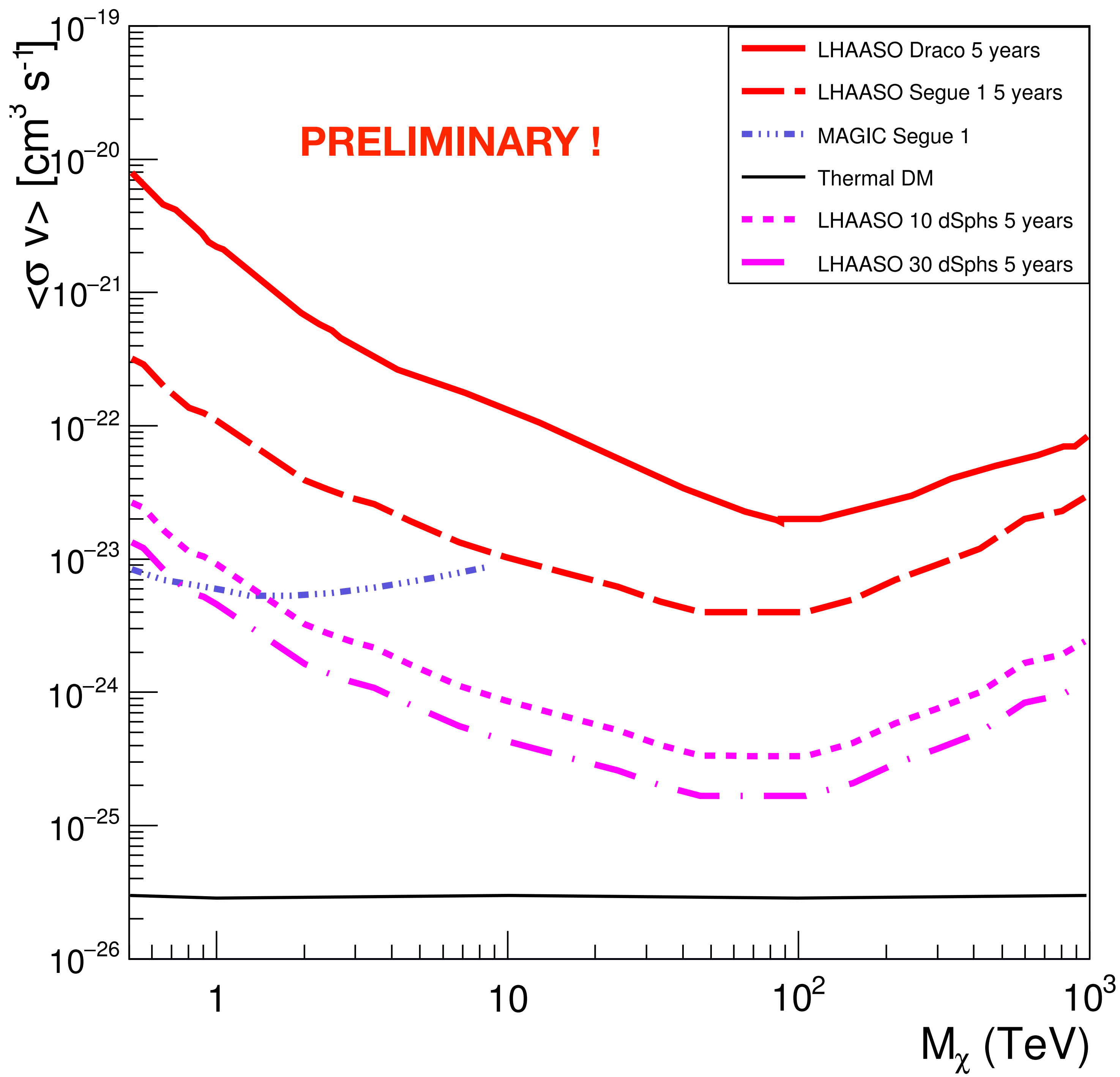


DM search with LHAASO

Caveat:

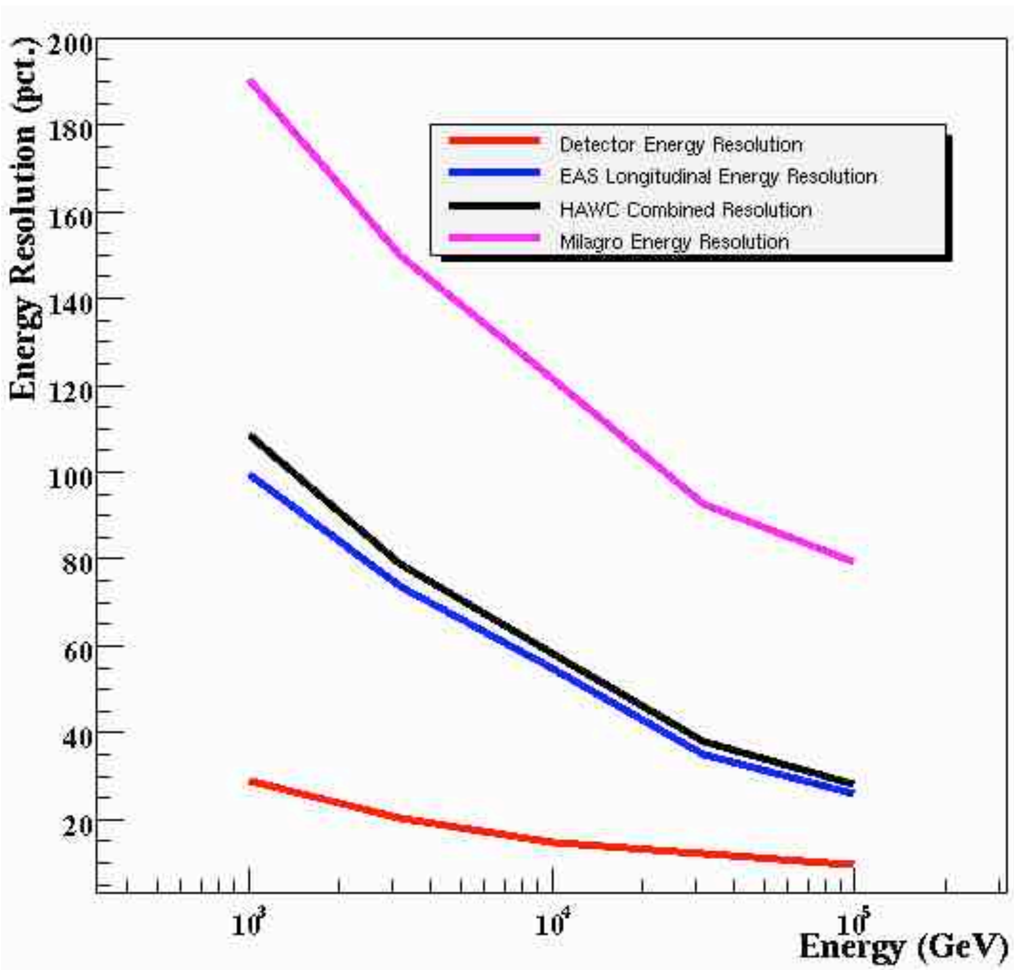
- 30 dSphs (3x) (supposing the observation of new dSphs)
- -10% from spatial extension (source extension increases the signal region at high energy)

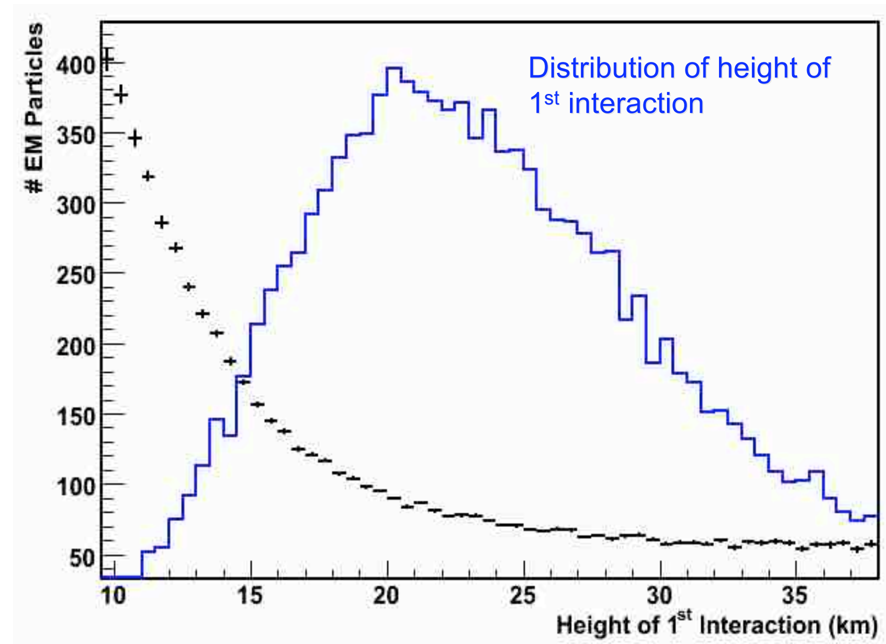
LHAASO advantage: combined analysis of different dwarf galaxies observed at the same time

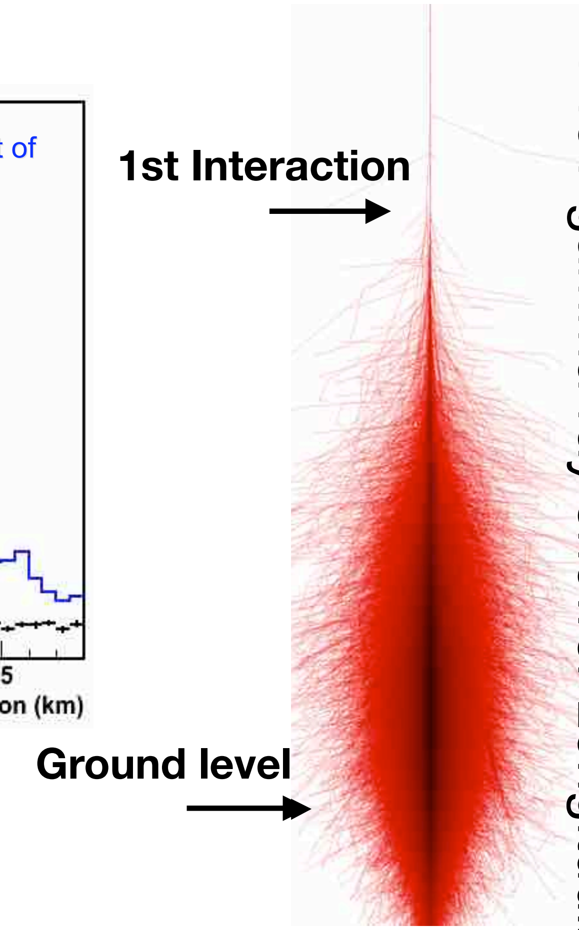


Energy Resolution

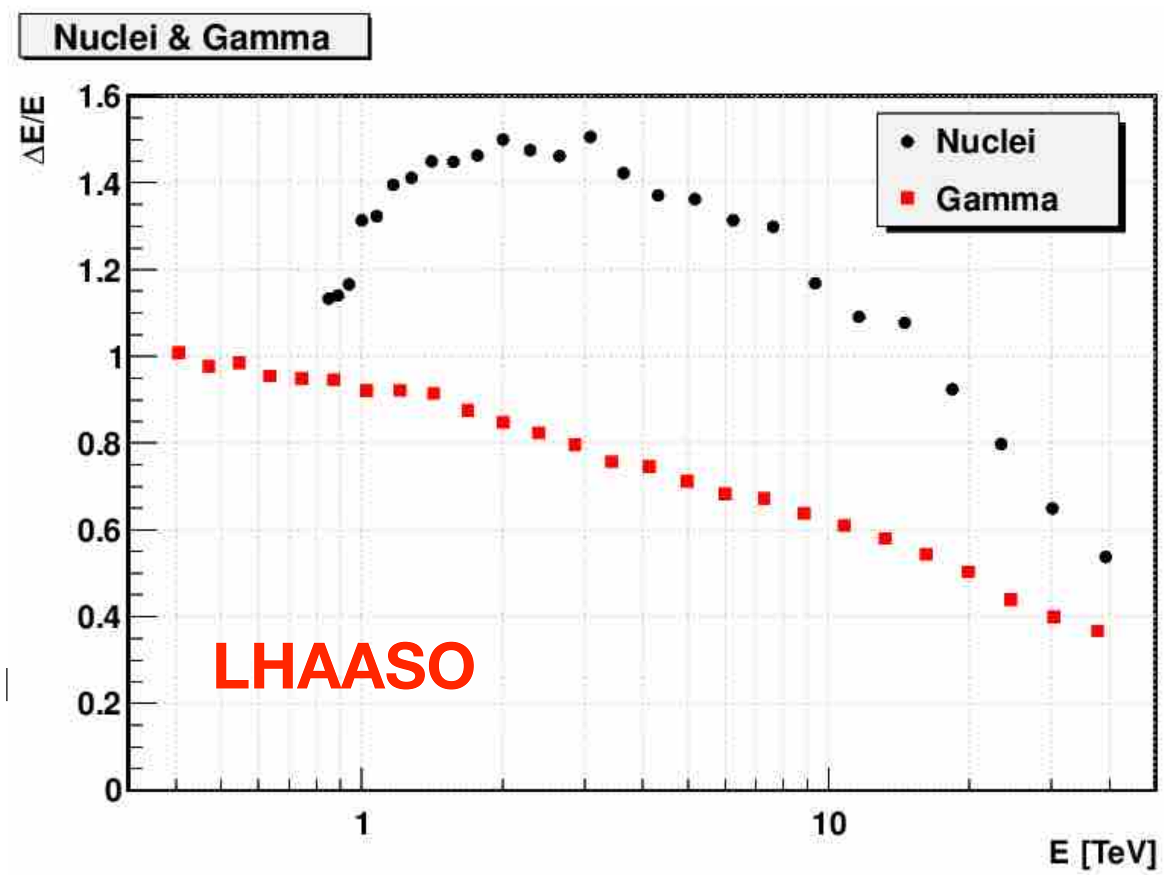
EAS arrays can measure energy at ground very well (< 20% resolution)







1 TeV gamma-ray shower Longitudinal Profile



Shower fluctuations (depth of 1st interaction) dominate energy resolution of EAS arrays.

Extended Source Sensitivity

≈ 70 % of TeV Galactic Sources are extended !

IACT's rely on angular resolution for excellent background rejection.

- When the source size is large compared to PSF, sensitivity is reduced by a factor of

$$\sim \sigma_{detector} / \sigma_{source}$$

Source larger than camera

- When the source size is large compared to the FOV, sensitivity is reduced by

$$\sim \sigma_{detector} / \sigma_{source}$$