New born UHECR versus future Tau Neutrino Astronomy

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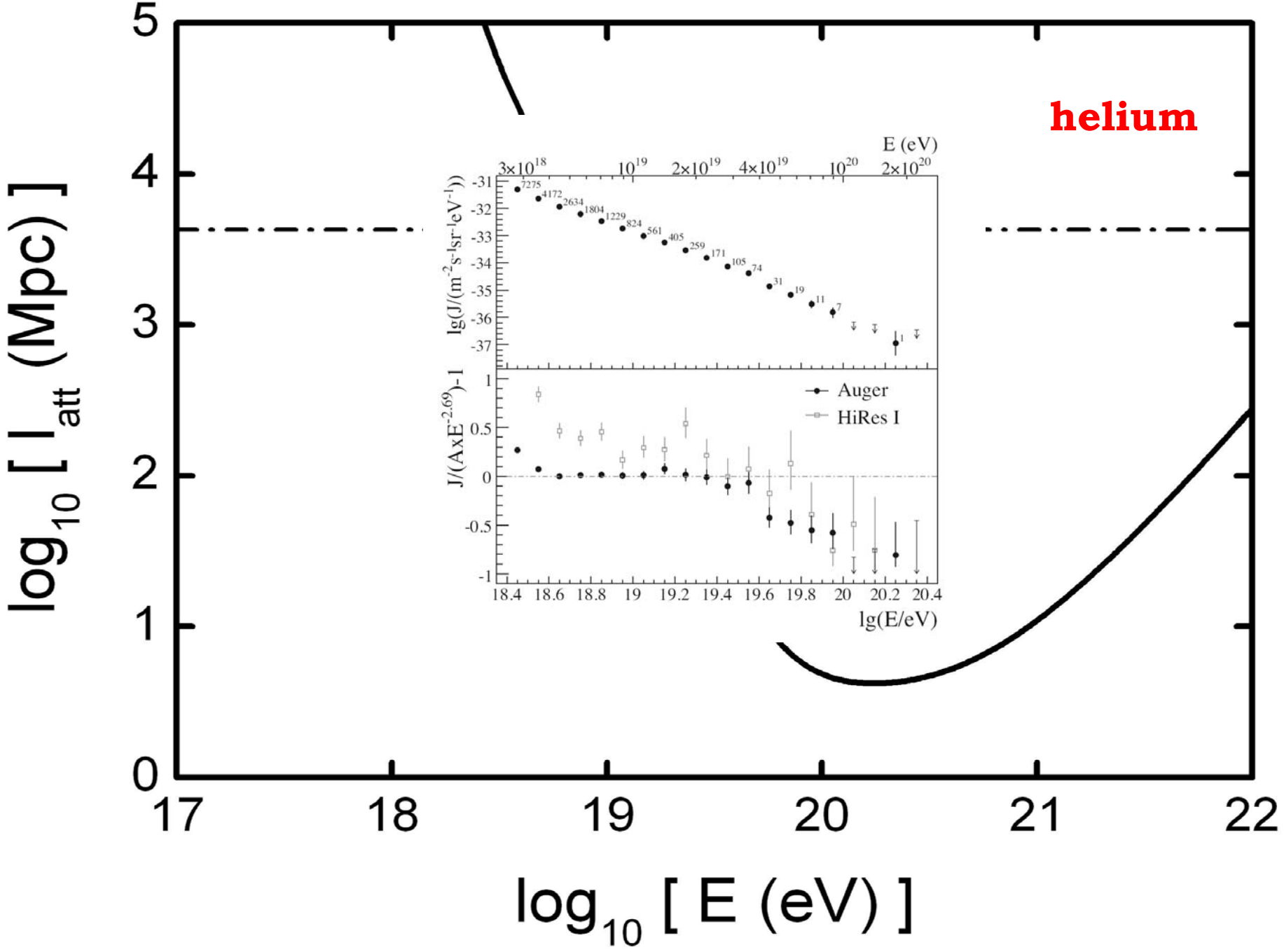
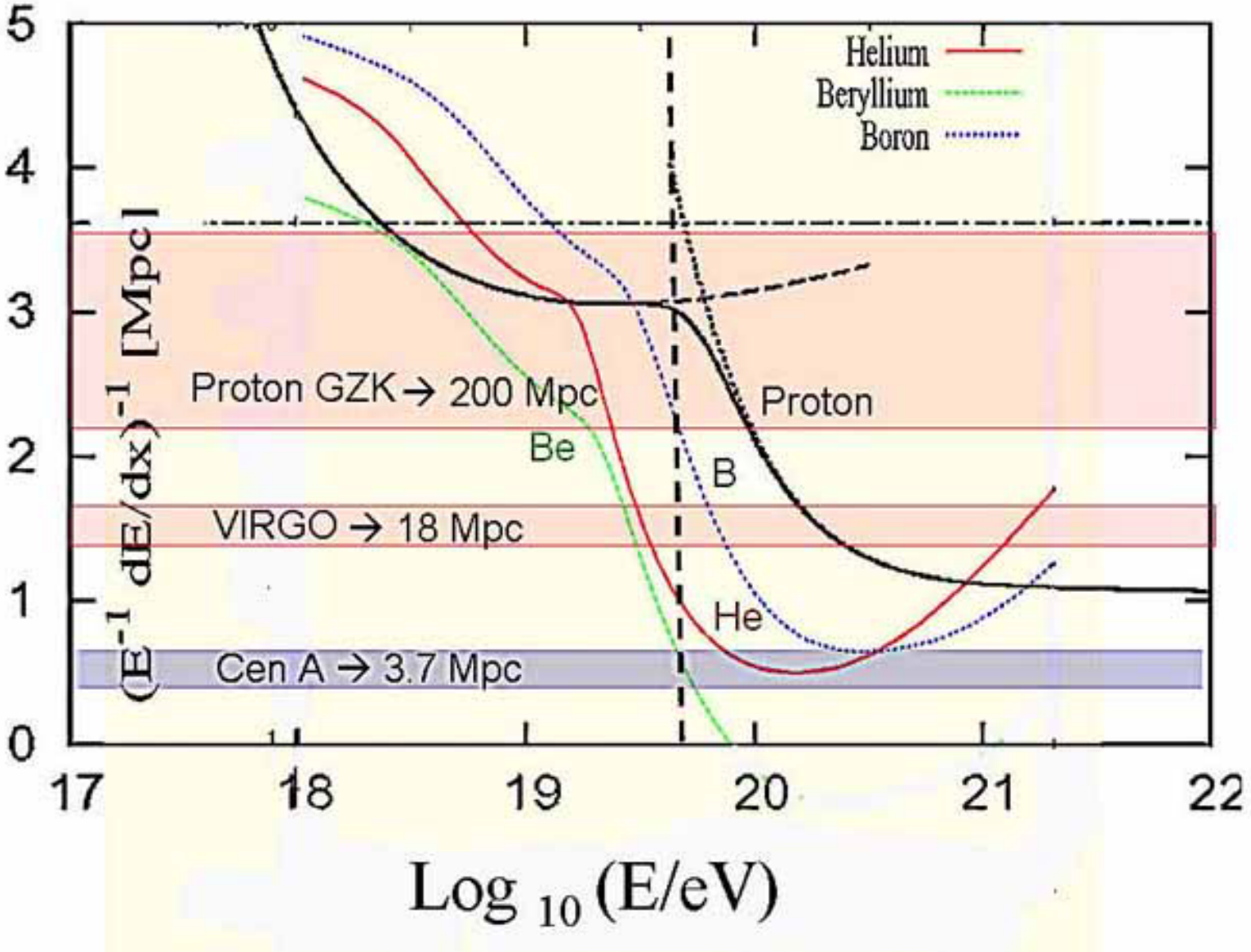
Outlook

- UHECR (if proton) may paint a new Astronomy
- AUGER Nov 2007 claimed such a GZK Sky Map
- However following composition and Virgo Absence
- UHECR Maps hint (to us) a light nuclei : He scenario
- Consequence: A very narrow Universe AUGER view
- The GZK – UHE cosmogenic neutrino flux EeV fade
- UHECR He-Li-Be nuclei fragment in tens EeV and making tens PeVs neutrinos GZK⟶
- Neutrino mass and mixing- the ν_μ **versus** ν_τ **appearence**
- Lightest Nuclei versus UHE spectra: EeV to PeVs
- Foreseen Event rates and Detection in AUGER and HEAT-AMIGA

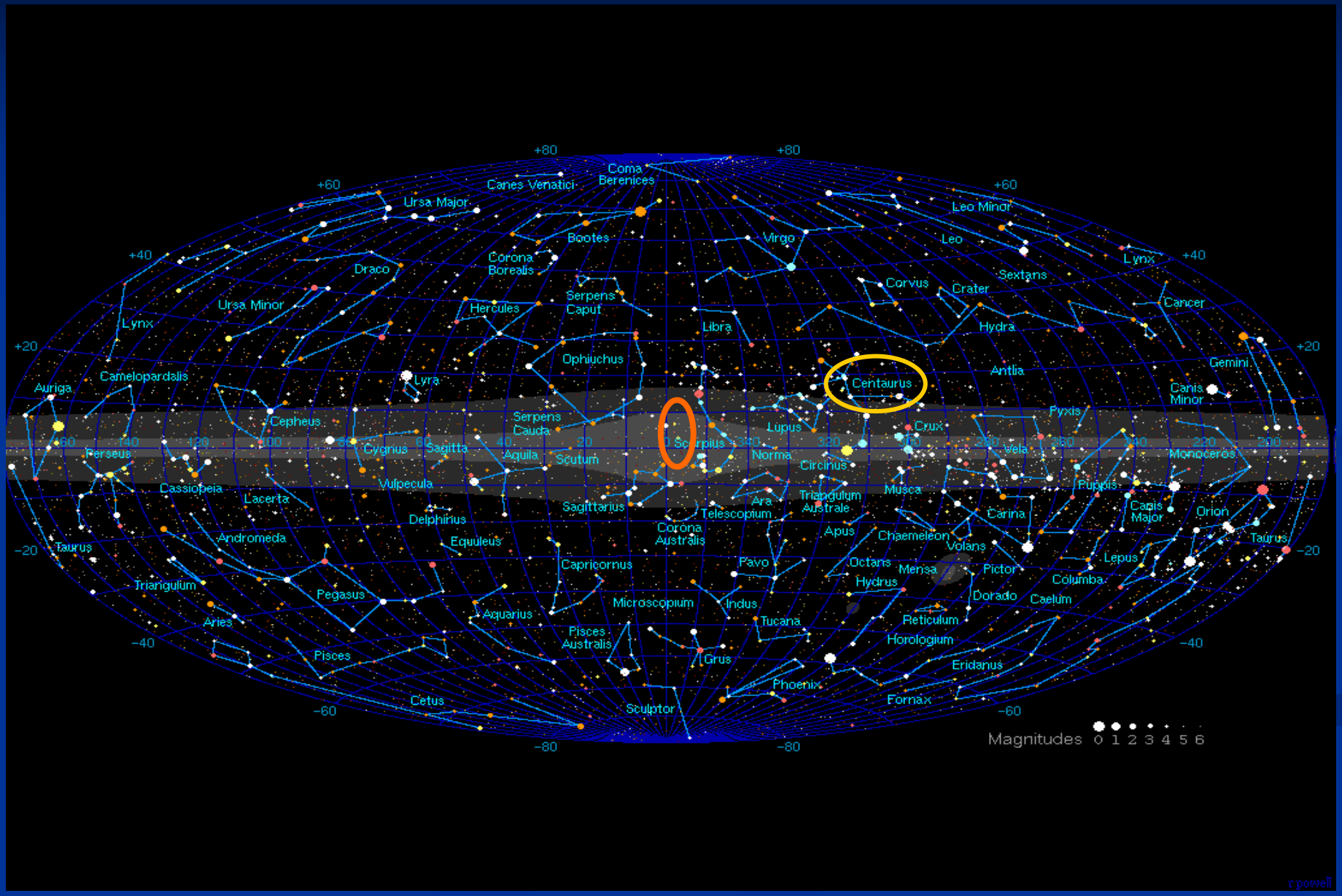

helium
log10 [latt (Mpc)]
log10 [E (eV)]
E (eV)
lg(J/(m-2s-1sr-1eV-1))
J/(AxE-2.69)-1
Auger
HiRes I
lg(E/eV)

Solving Auger puzzle:
UHECR GZK distances: the Virgo Absence

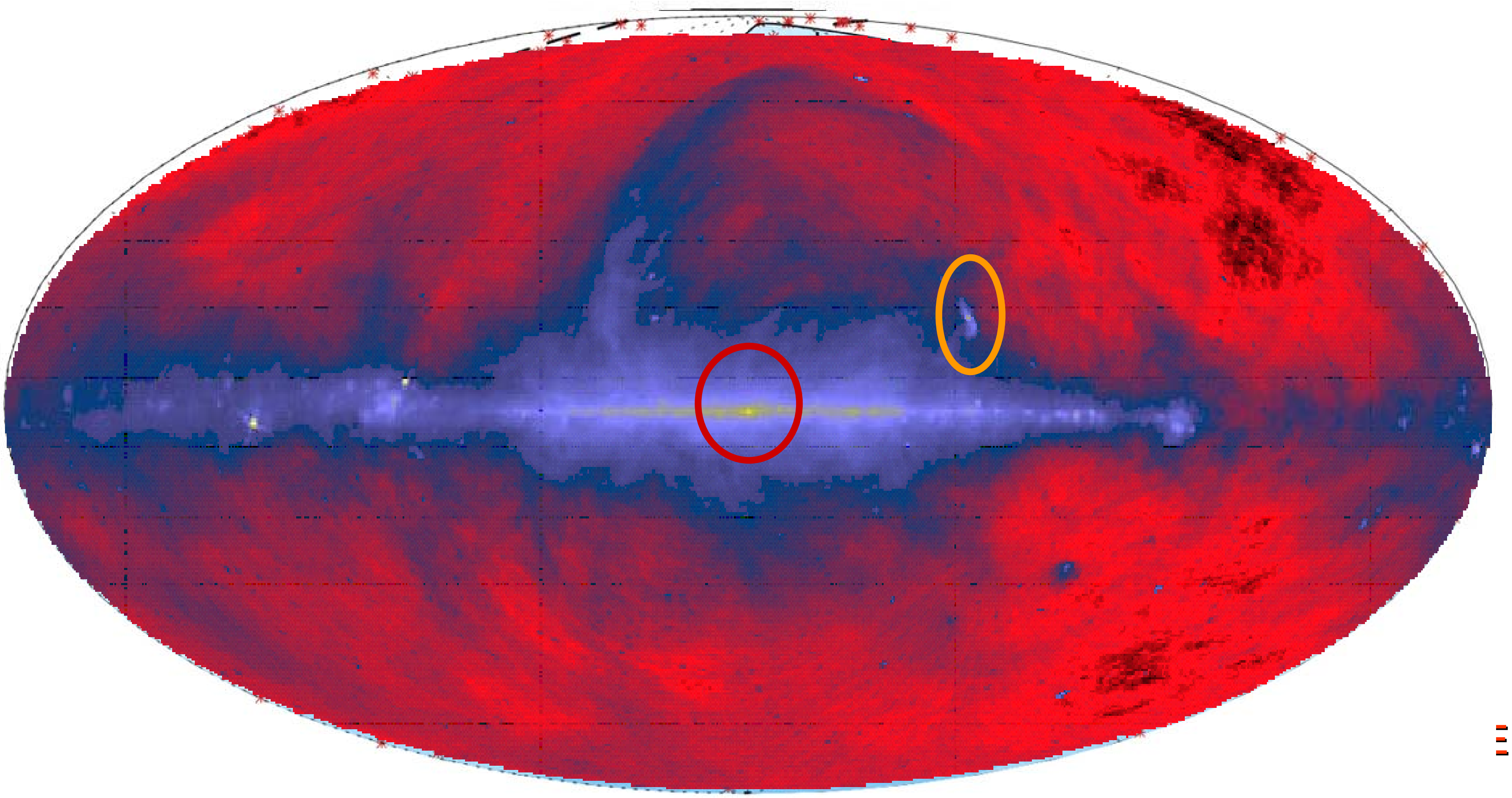


Sky over South: GC versus CenA

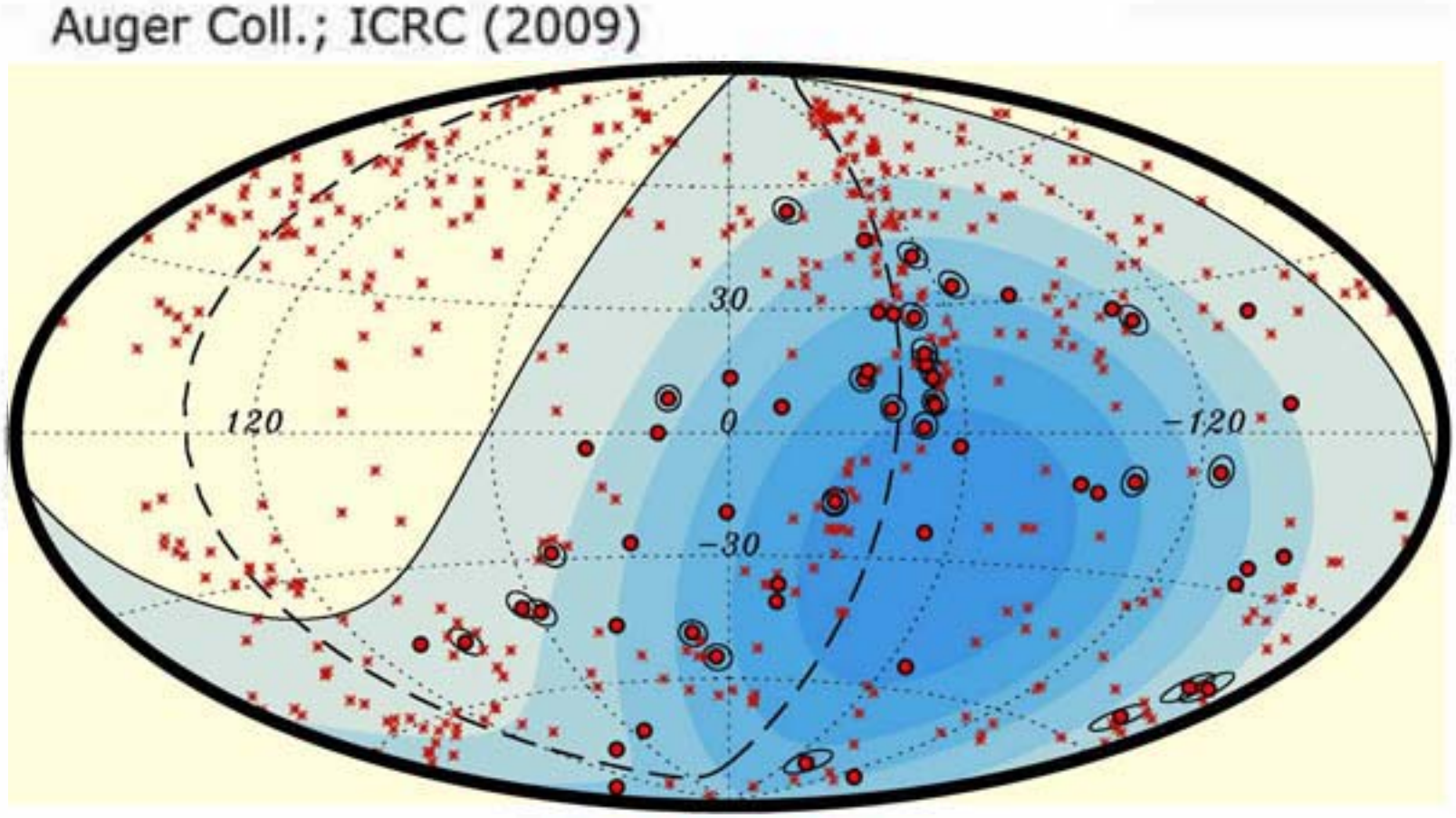
Normal Galactic coordinate view



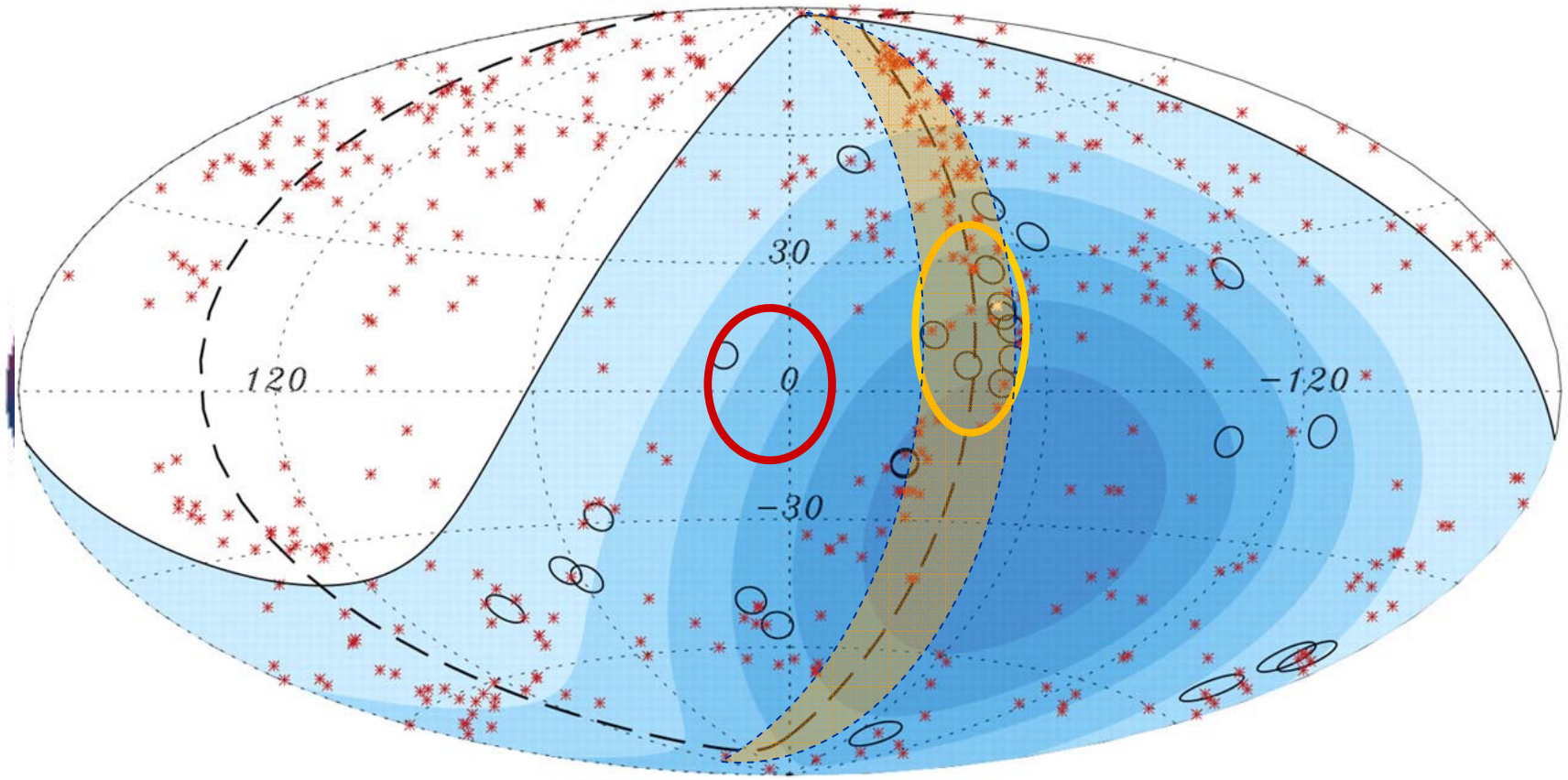
UHECR versus Radio Sources: A new Nearby Astronomy within GZK volume. The Supergalactic Plane at 80 Mpc? The VIRGO missing– CEN-A imprint at the AUGER map



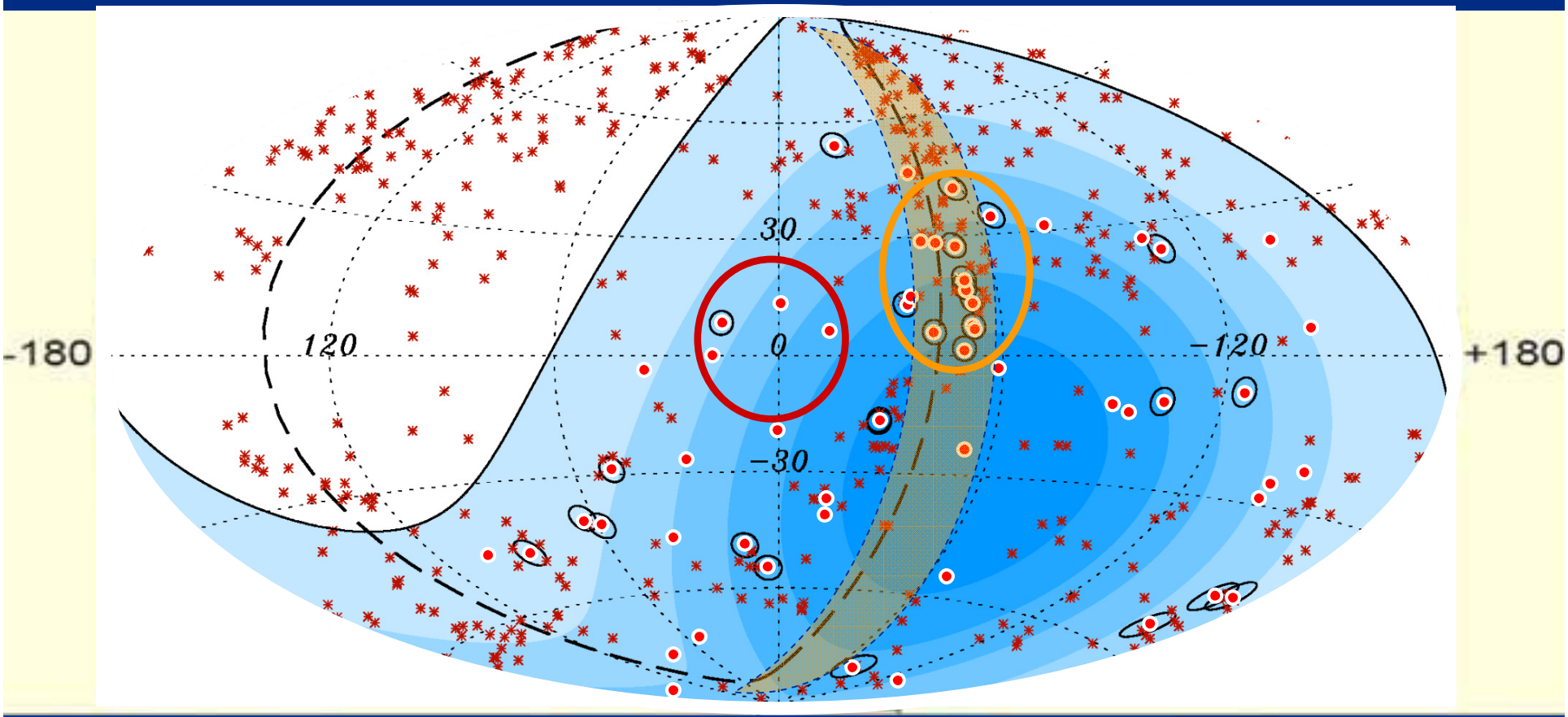
New Map Hep July 2009



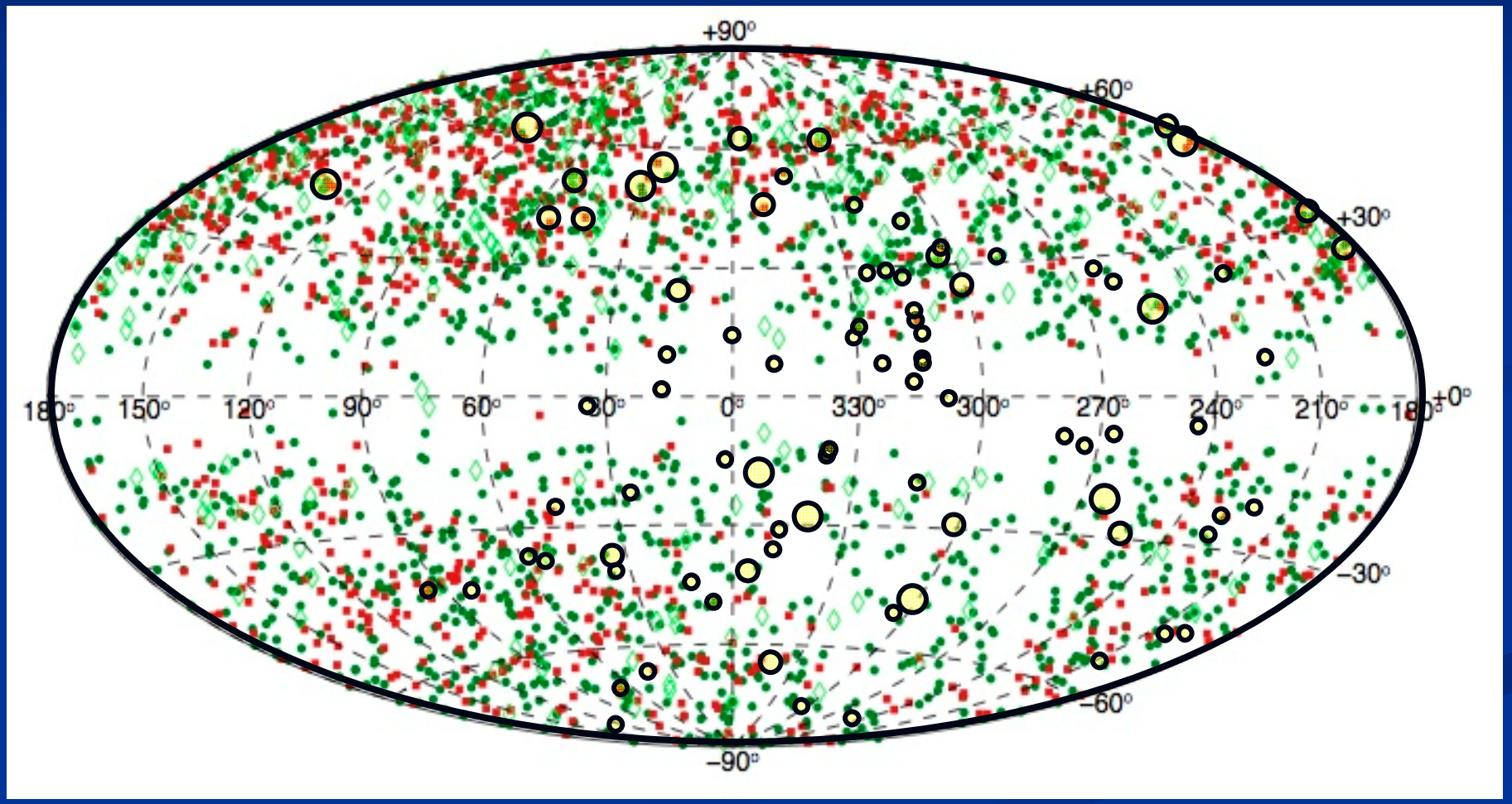
Understanding the radio versus UHECR Auger 2007 map



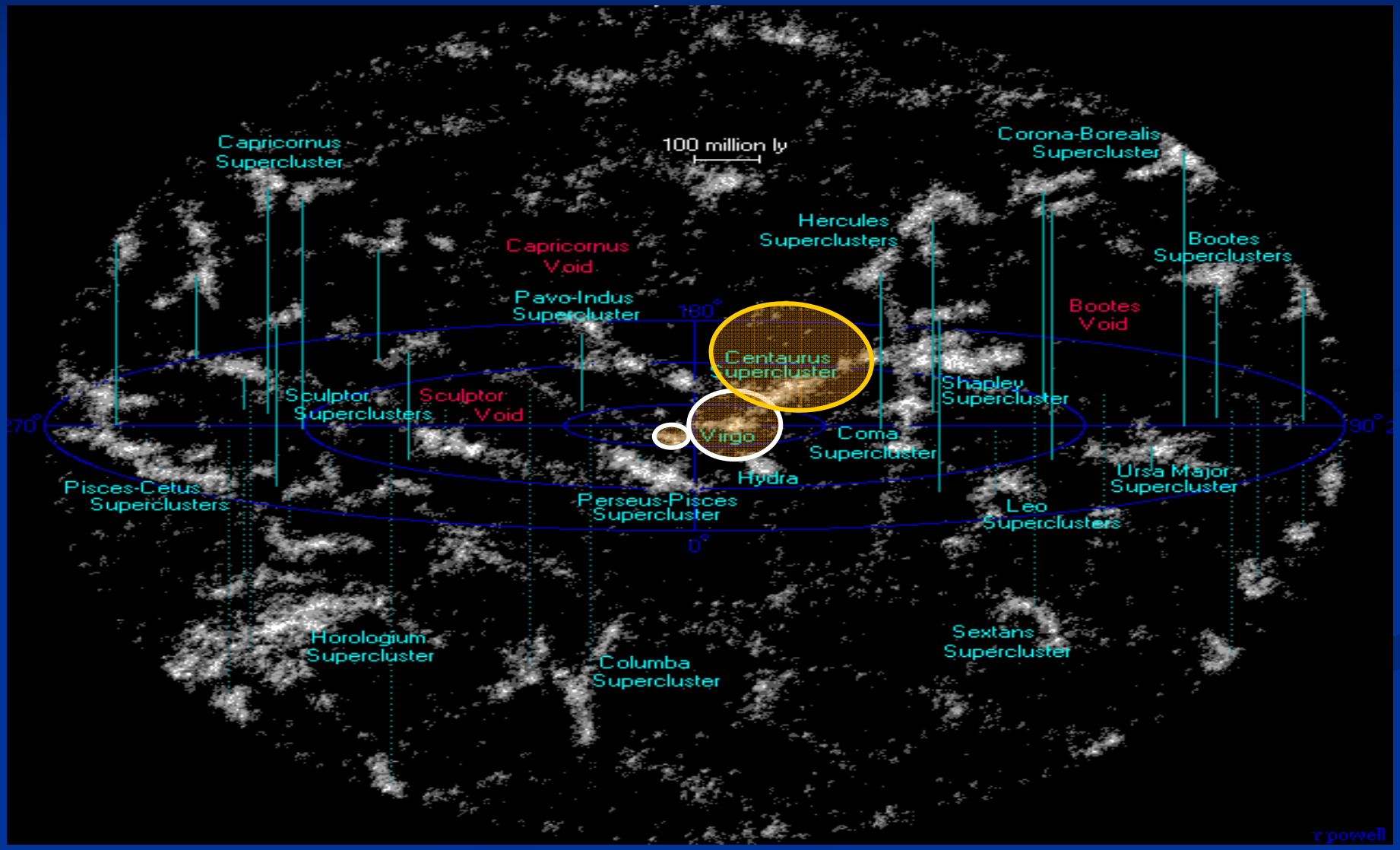
AUGER HEP 2009 –and OLD



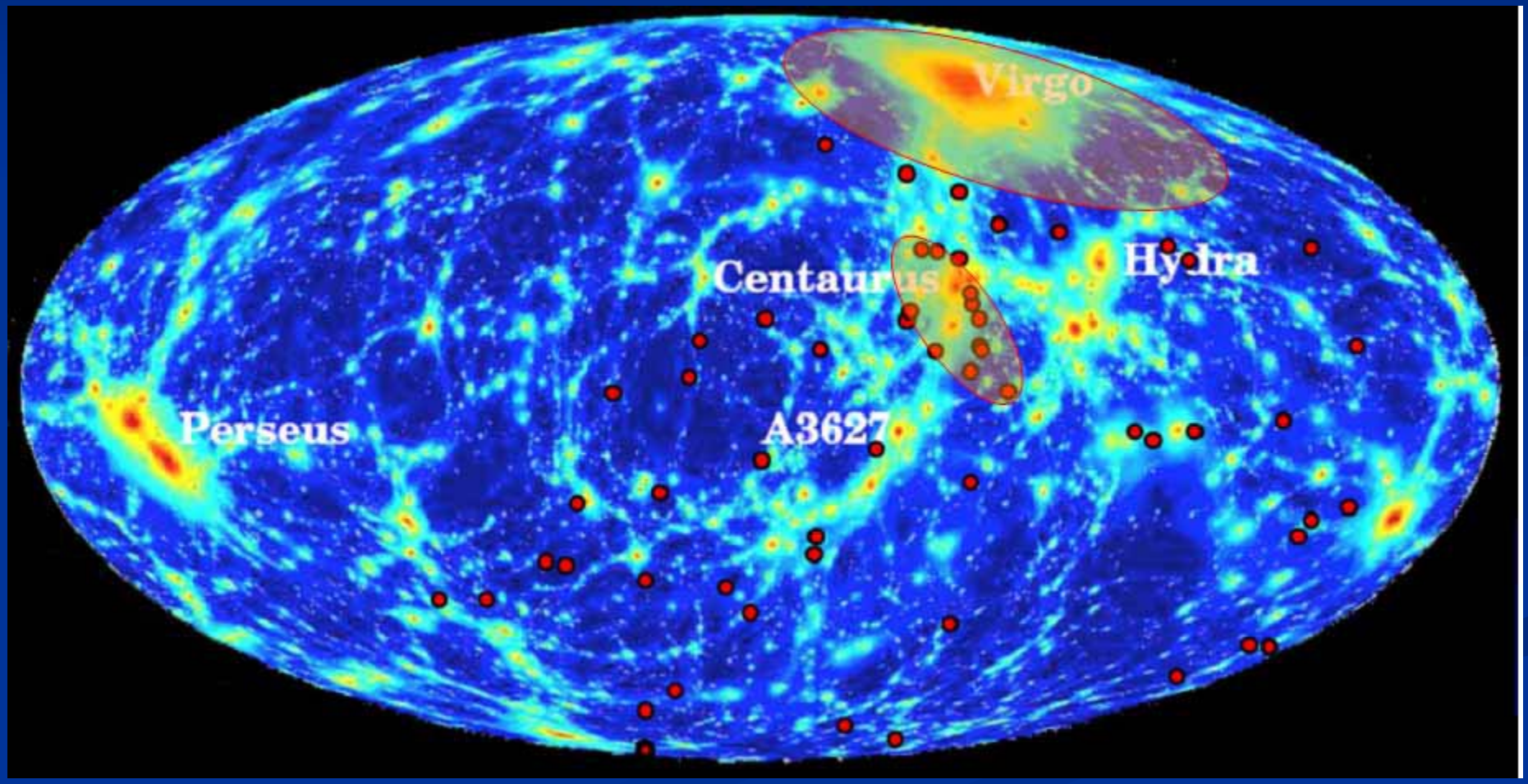
Auger-Hires-Field 2800 BL Lac Most well far from GZK Universe



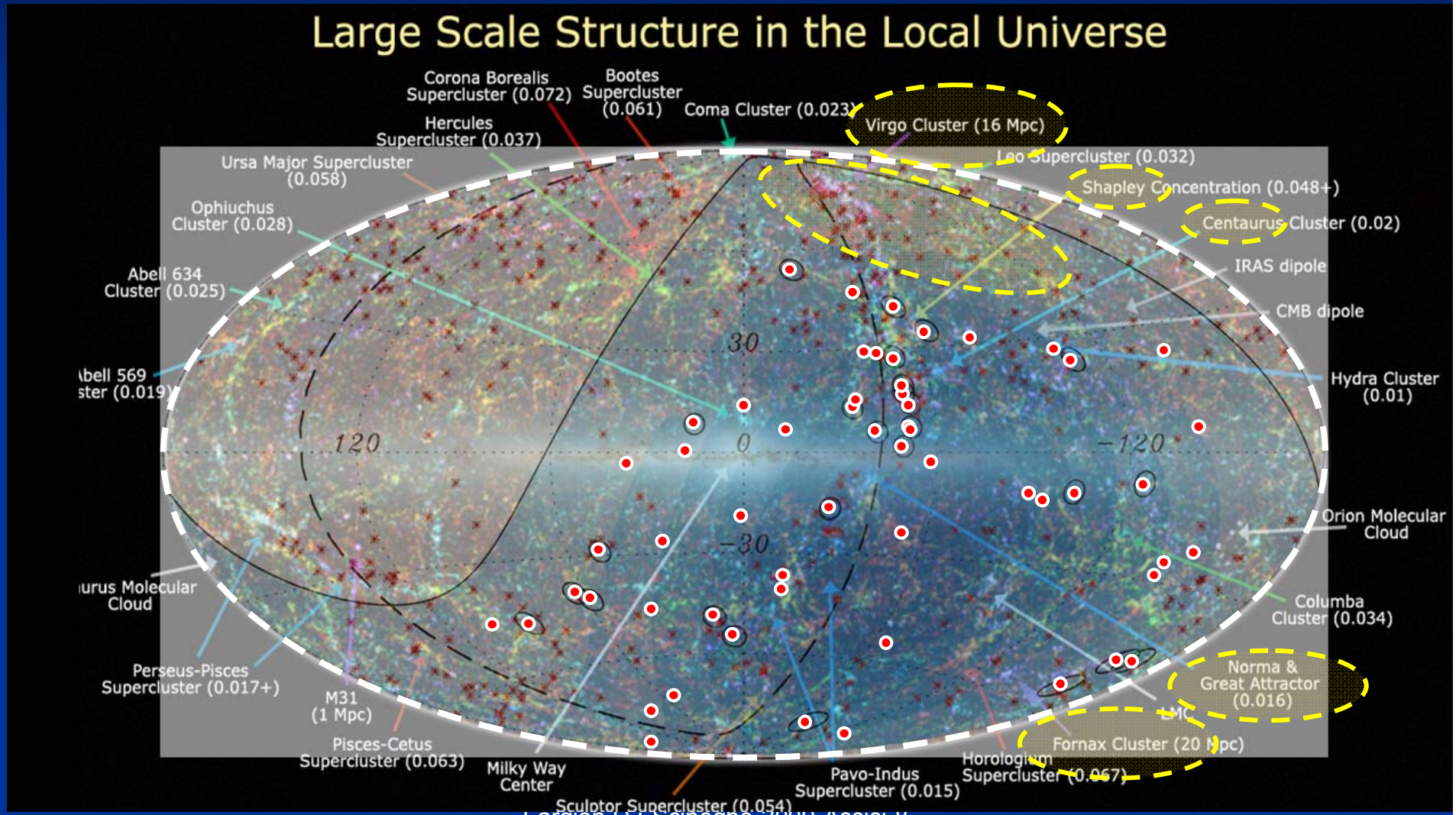
10% UNIVERSE size



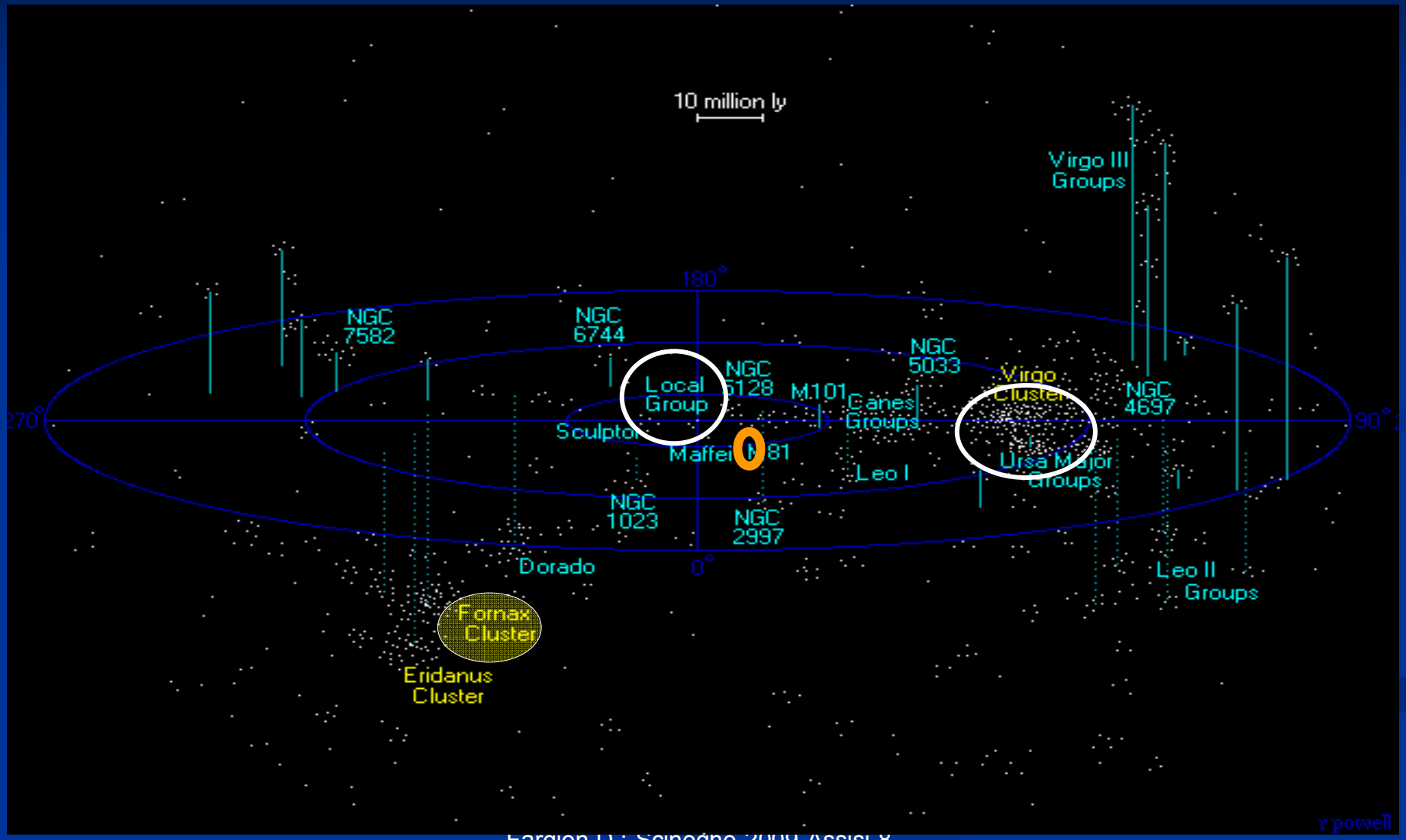
Wider clustering in Cen-A ?



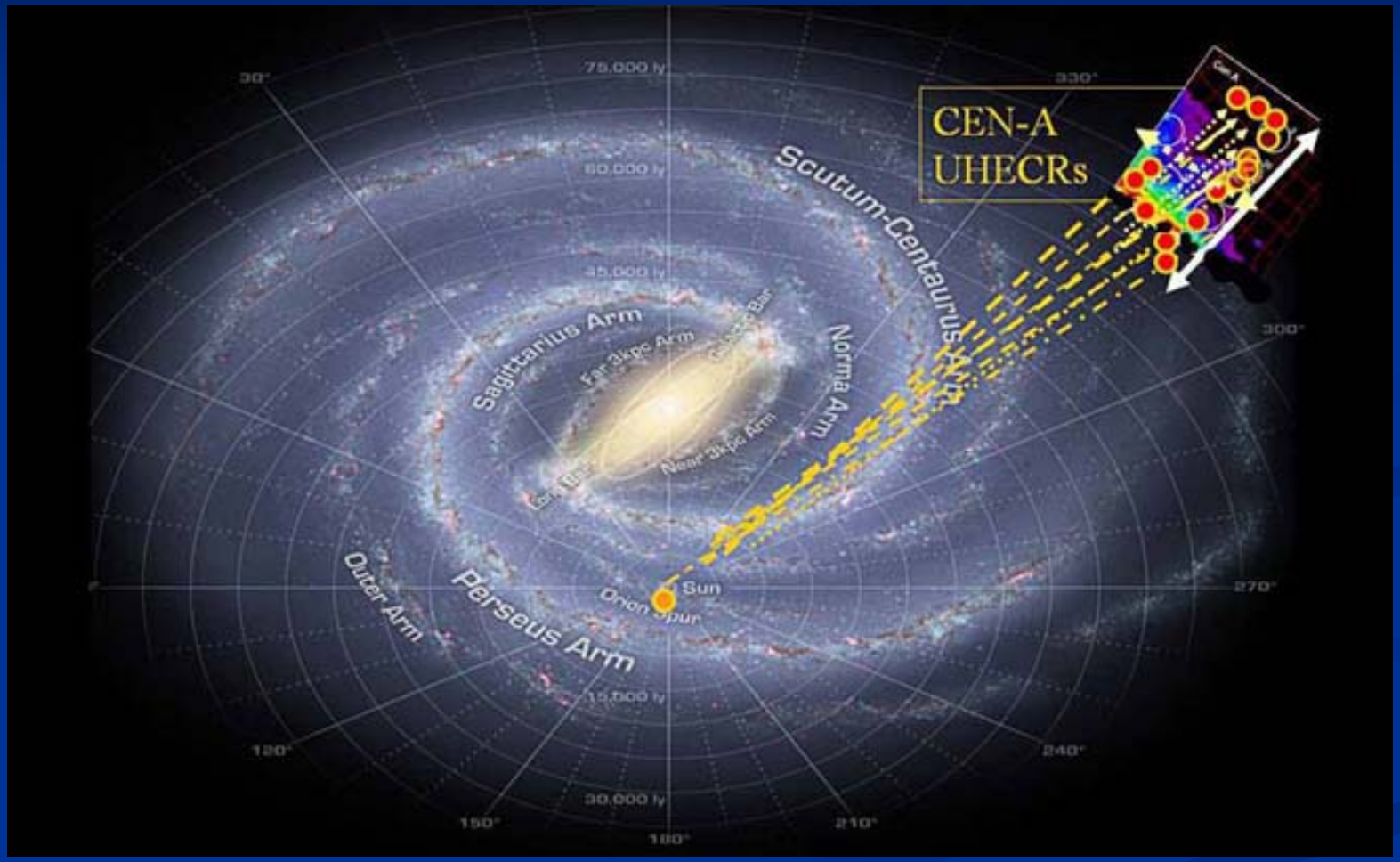
Univ-58-Map-no natural Local GZK sources



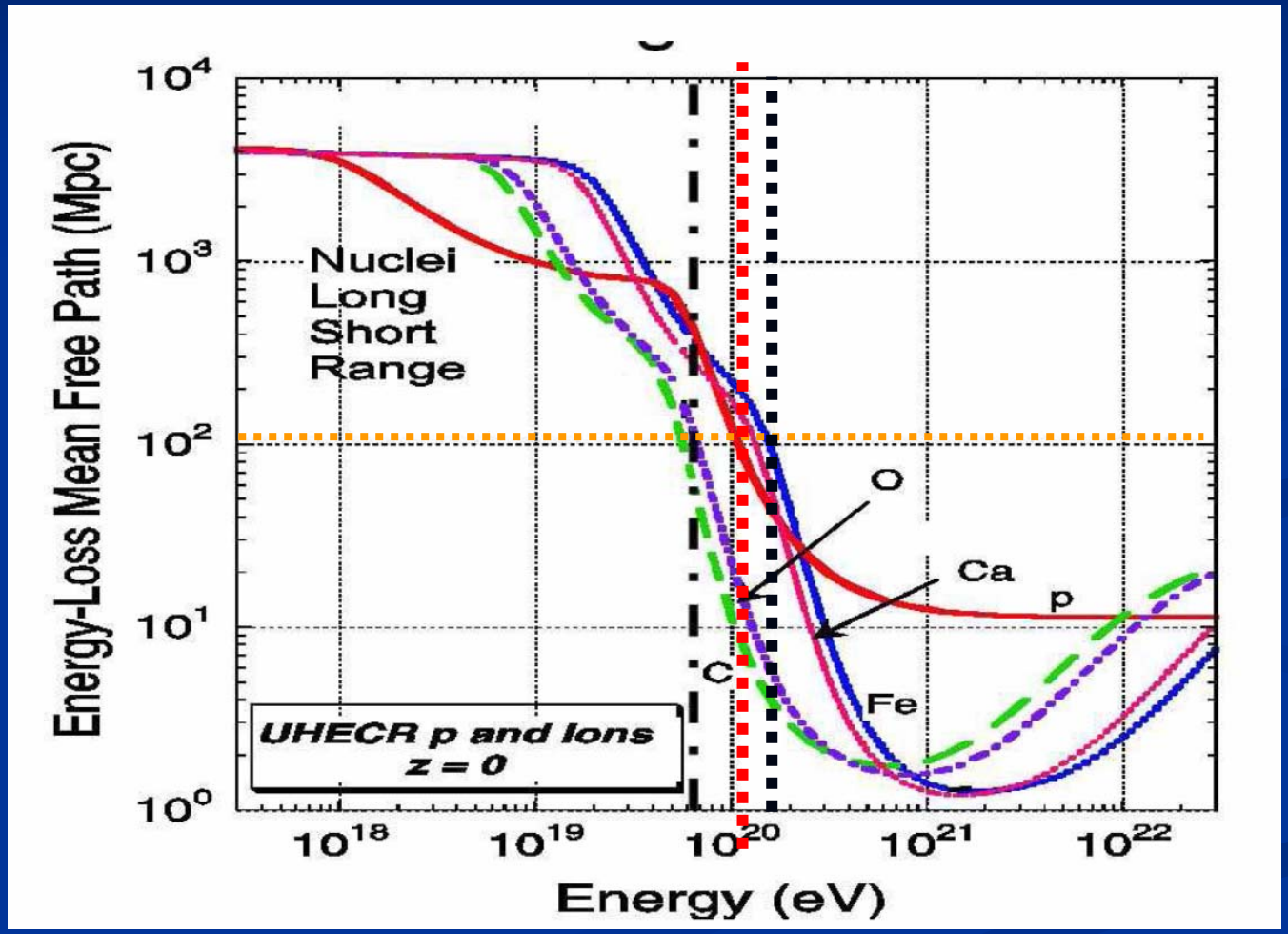
SGPlane


10 million ly
Virgo III
Groups
180°
NGC
7582
NGC
6744
NGC
5033
NGC
5128
Local
Group
M101
Canes
Groups
Virgo
Cluster
NGC
4697
270°
90°
Sculptor
Maffei
Leo I
Ursa Major
Groups
NGC
1023
NGC
2997
Dorado
0°
Leo II
Groups
Fornax
Cluster
Eridanus
Cluster
r powell

Coherent and Random deflections



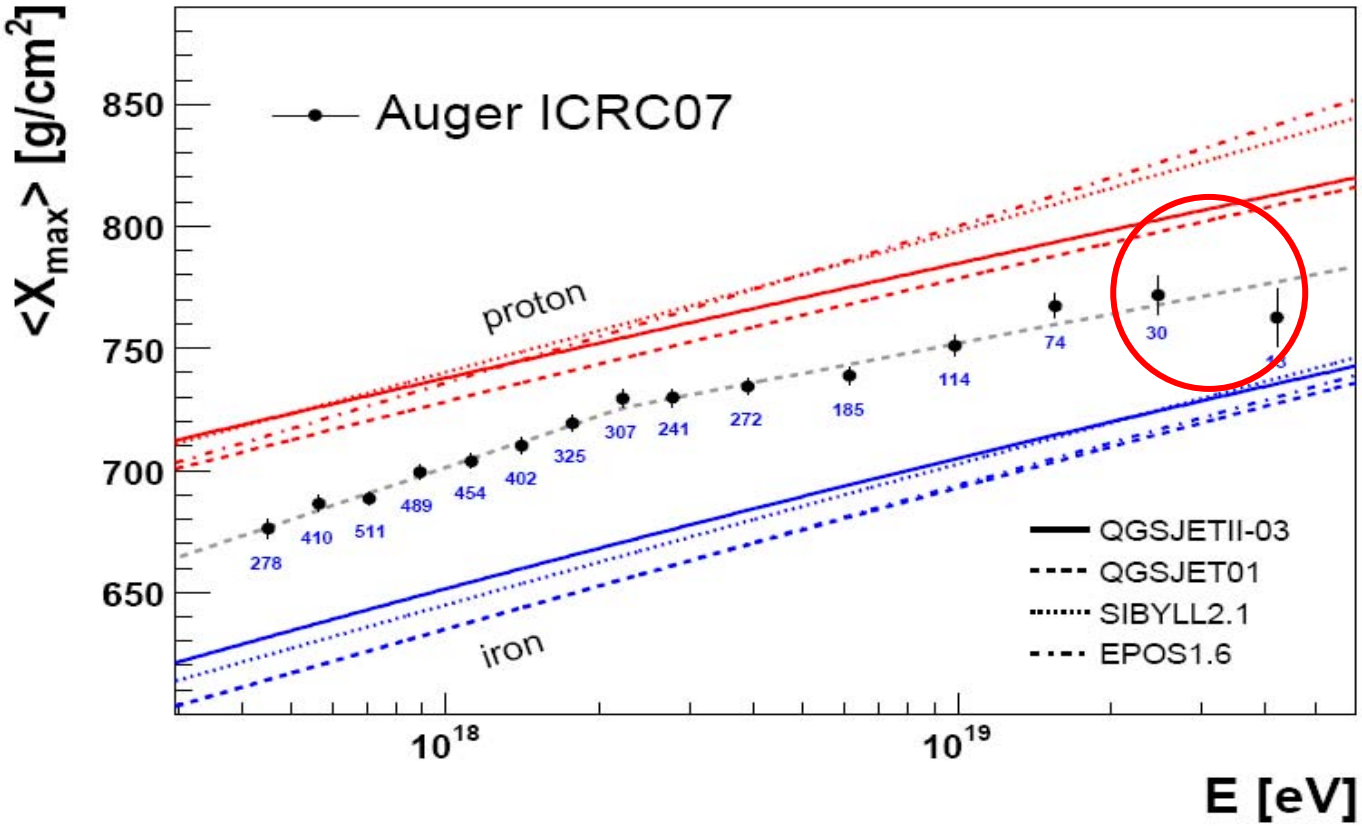
GZK- Nuclei different cut-off



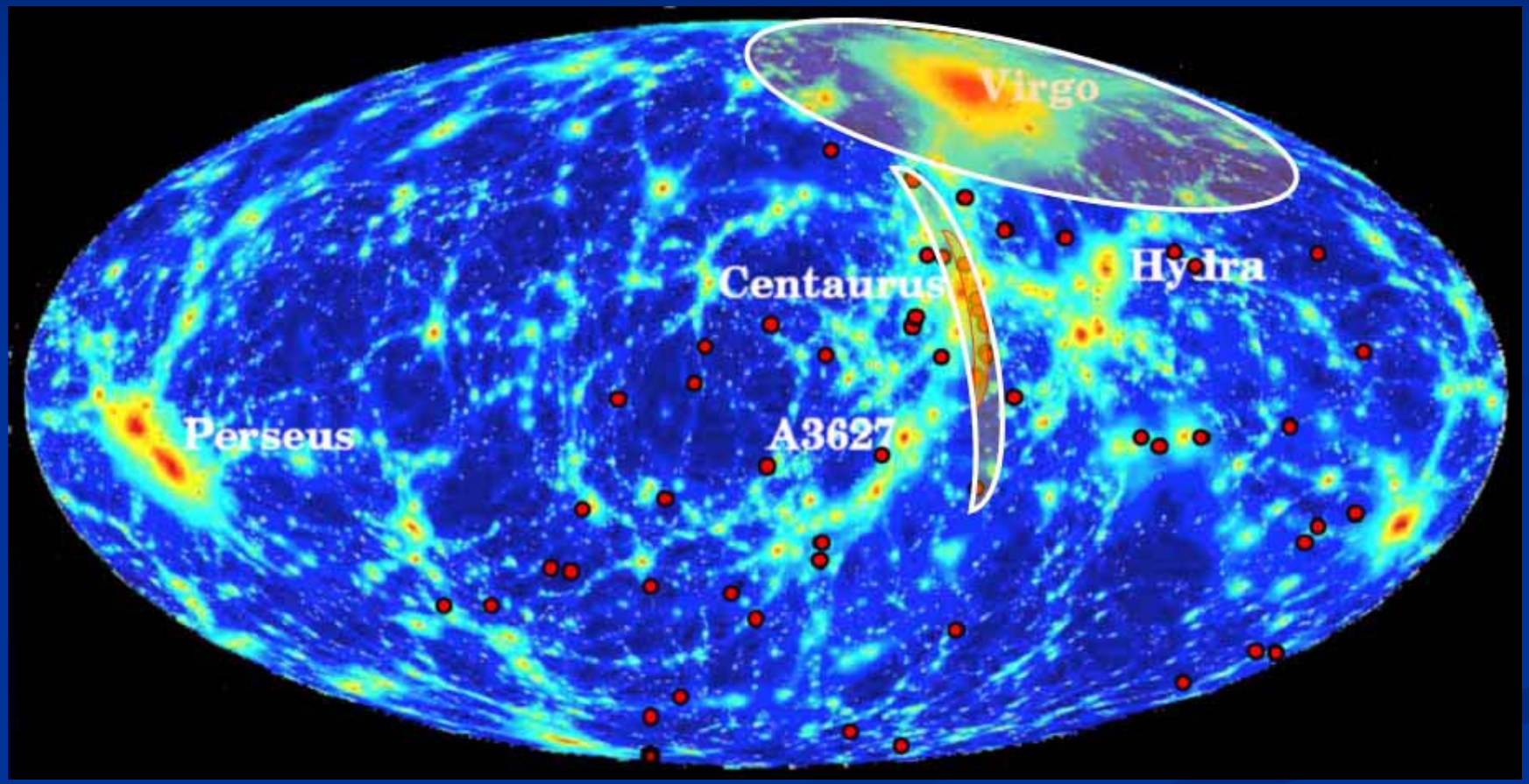
AUGER Michael Unger , Pierre Auger 2007

1. AUGER Composition puzzle

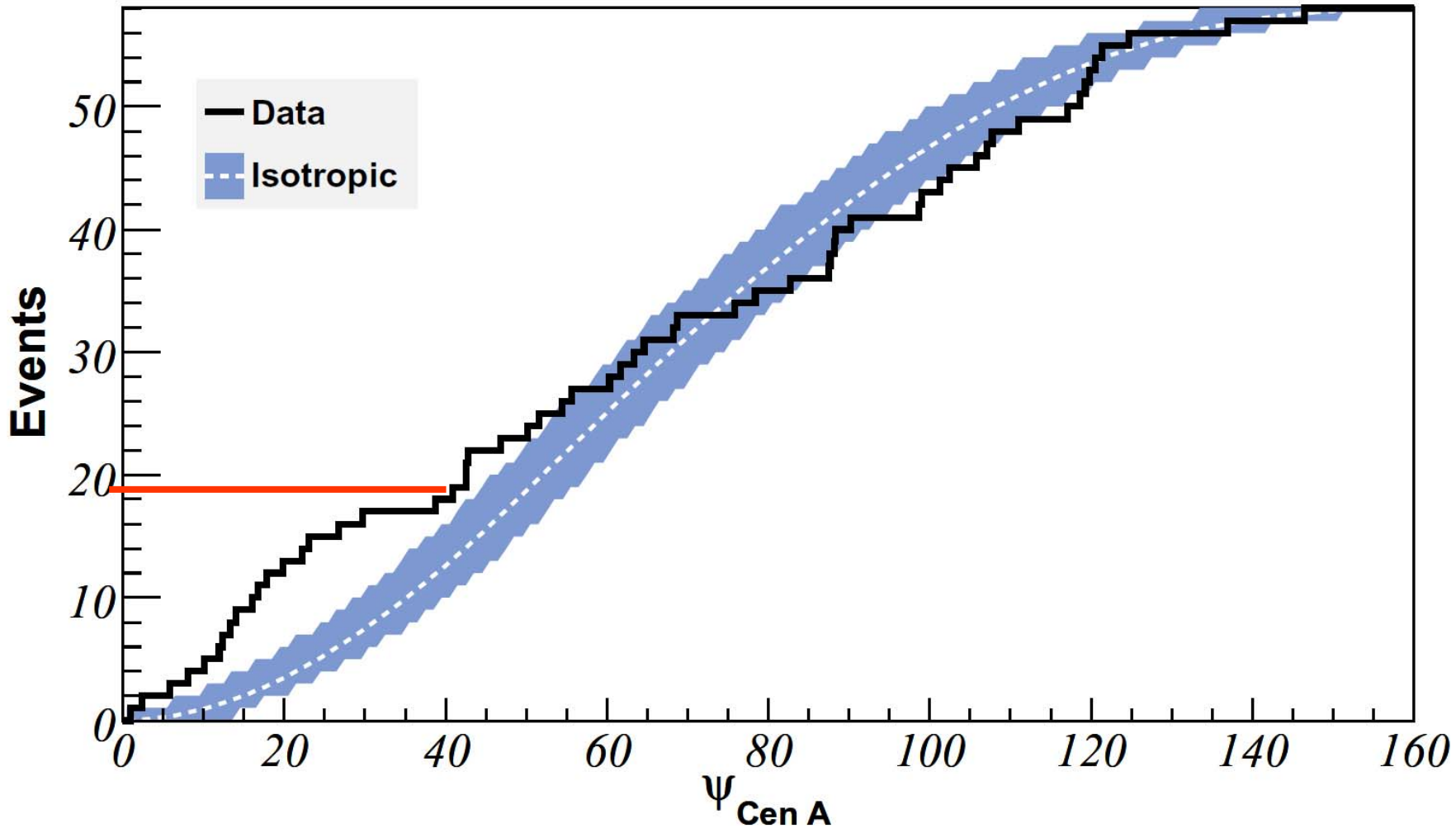
30TH INTERNATIONAL COSMIC RAY CONFERENCE



Clustering along CenA and absence of Virgo



Cen A clustering by last ICRC09 AUGER (unpublished) Maps Almost 37% +- 10% on 2007 and 31% +-9% on 2009: a persistent 1/3 signal



Coherent and random bending

$$\delta_{Coh-p} \simeq 2.3^\circ \cdot \frac{Z}{Z_H} \cdot \left(\frac{6 \cdot 10^{19} eV}{E_{CR}}\right)\left(\frac{B}{3 \cdot \mu G}\right)\frac{l_c}{kpc} \qquad (1)$$

The corresponding coherent bending of an Helium UHECR at same energy, within a galactic magnetic field in a wider nearby coherent length of $l_c = 2 \cdot kpc$ is

$$\delta_{Coh-He} \simeq 9.2^\circ \cdot \frac{Z}{Z_{He}} \cdot \left(\frac{6 \cdot 10^{19} eV}{E_{CR}}\right)\left(\frac{B}{3 \cdot \mu G}\right)\frac{l_c}{2kpc} \qquad (2)$$

The heavier of lightest nuclei that may be bounded from Virgo, Be, is bent by $\delta_{Coh-Be} \simeq 18.4^\circ \cdot \frac{Z}{Z_{Be}} \cdot \left(\frac{6 \cdot 10^{19} eV}{E_{CR}}\right)\left(\frac{B}{3 \cdot \mu G}\right)\frac{l_c}{2kpc}$. It should be noticed that the galactic magnetic field nearby and along Cen_A direction is described by spiral galactic fields along the Milky Way Plane and (toward Cen A) as a plume (vertical to galactic plane). Both fields act respectively to bend the charges either coherently and-or randomly. We believe that the vertical

Random slalom on galactic arms

The incoherent random angle bending a δ_{rm} while crossing a Galactic diameter of $L \simeq 20kpc$ within a characteristic coherent length $l_c \simeq 2kpc$ is

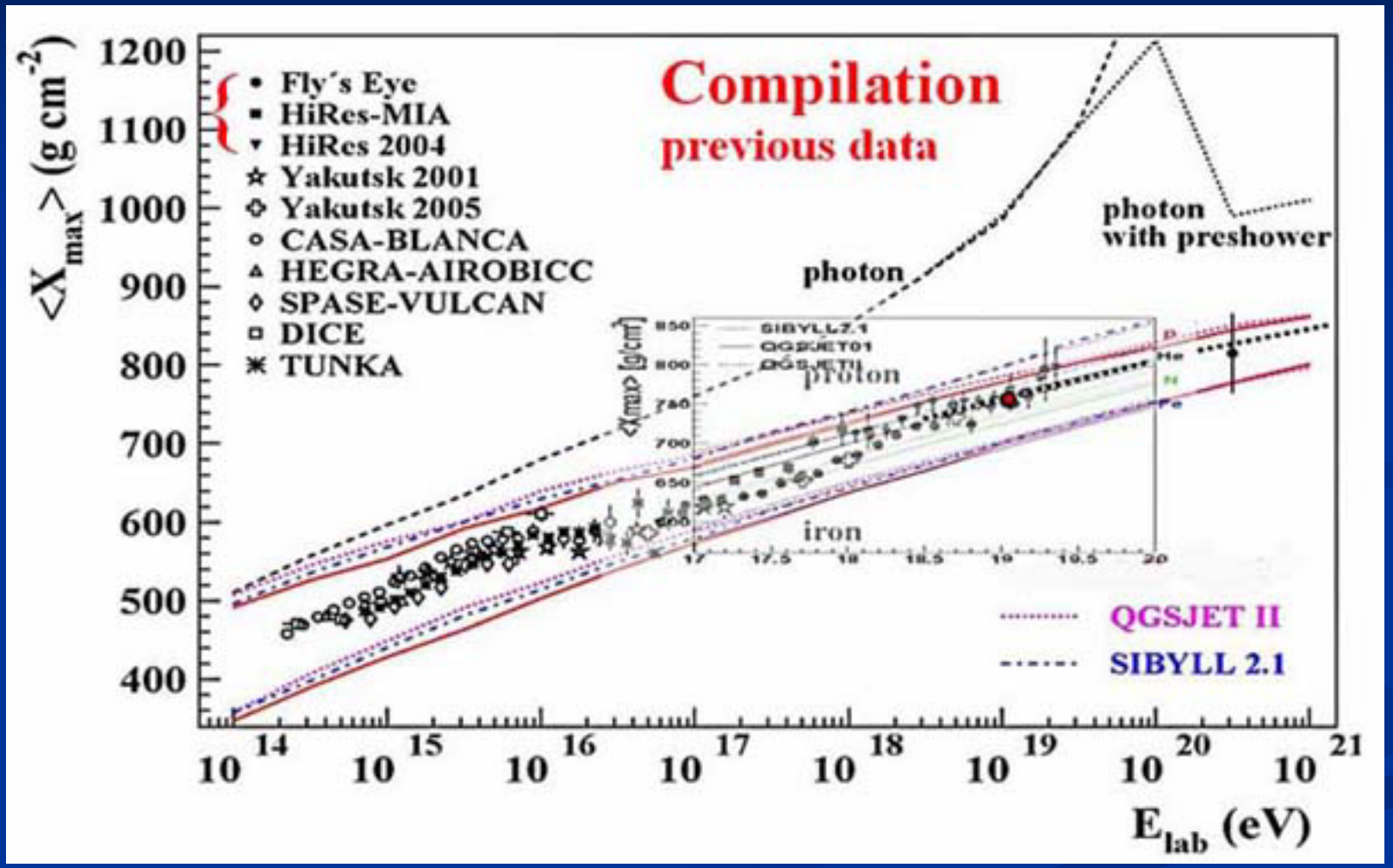
$$\delta_{rm-p} \simeq 8^\circ \cdot \frac{Z}{Z_H} \cdot \left(\frac{6 \cdot 10^{19} eV}{E_{CR}}\right)\left(\frac{B}{3 \cdot \mu G}\right) \sqrt{\frac{L}{20kpc}} \sqrt{\frac{l_c}{2kpc}} \quad (3)$$

$$\delta_{rm-He} \simeq 16^\circ \cdot \frac{Z}{Z_{He^2}} \cdot \left(\frac{6 \cdot 10^{19} eV}{E_{CR}}\right)\left(\frac{B}{3 \cdot \mu G}\right) \sqrt{\frac{L}{20kpc}} \sqrt{\frac{l_c}{2kpc}} \quad (4)$$

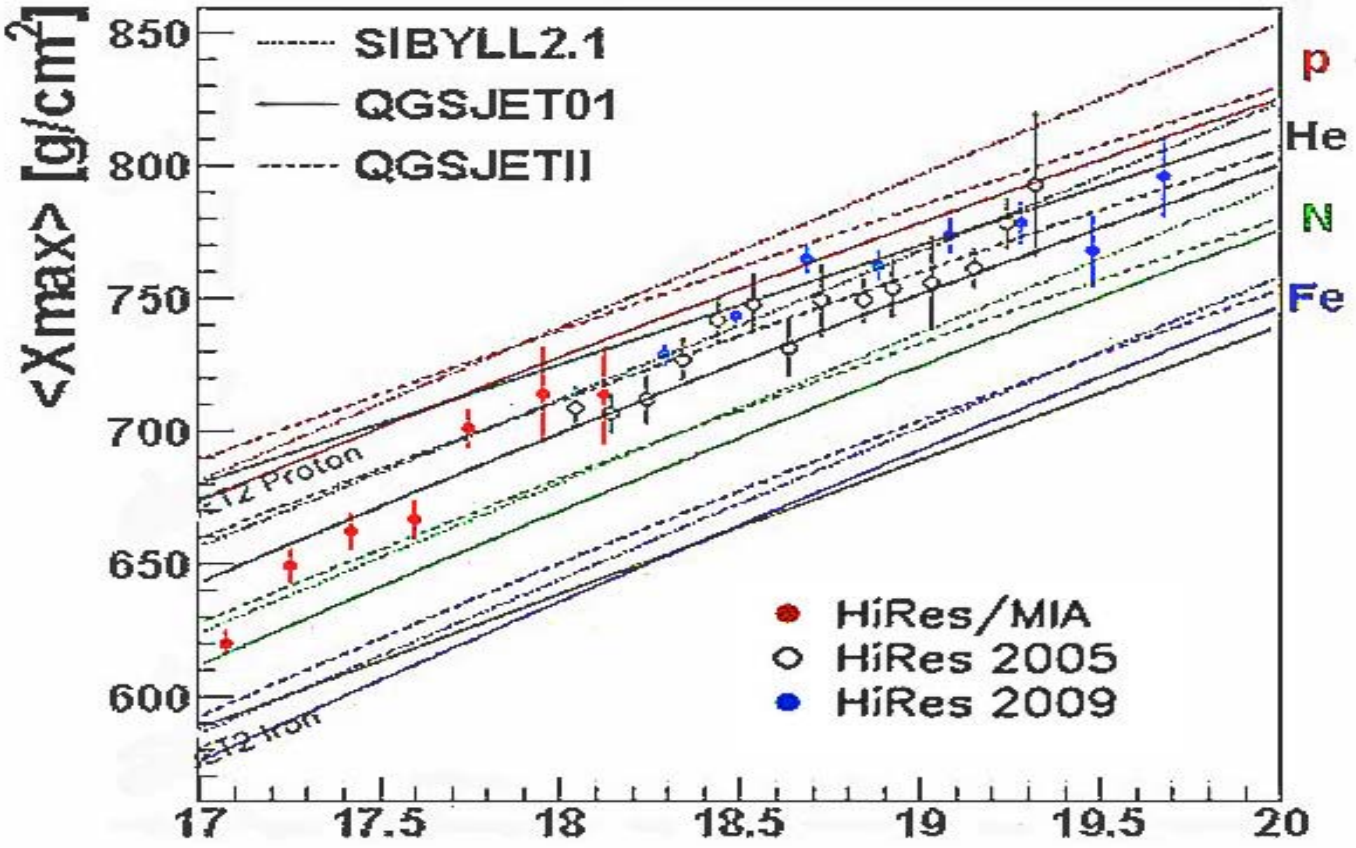
He-Be-Bo Lightest Nuclei

The heavier (but still lightest nuclei) bounded from Virgo are Li and Be: $\delta_{rm-Li} \simeq 24^\circ \cdot \frac{Z}{Z_{Li^3}} \cdot (\frac{6\cdot 10^{19} eV}{E_{CR}})(\frac{B}{3\cdot \mu G}) \sqrt{\frac{L}{20kpc}} \sqrt{\frac{l_c}{2kpc}}$, $\delta_{rm-Be} \simeq 32^\circ \cdot \frac{Z}{Z_{Be^4}} \cdot (\frac{6\cdot 10^{19} eV}{E_{CR}})(\frac{B}{3\cdot \mu G}) \sqrt{\frac{L}{20kpc}} \sqrt{\frac{l_c}{2kpc}}$. It should be noted that the present anisotropy above GZK energy $5.5\cdot 10^{19} eV$ might leave a tail of signals: indeed the photo disruption of He into deuterium, Tritium, He^3 and protons (and unstable neutrons), might rise as clustered events at half or quater of the energy. It is important to look for correlated tails of events, possibly in correlated strings at low $\simeq 1.5 - 3 \cdot 10^{19} eV$ along the Cen_A train of events. In conclusion He like UHECR maybe bent by a characteristic as large as $\delta_{rm-He} + \delta_{Coh-He} \simeq 25.2^\circ$. Well within the observed CenA main event spread.

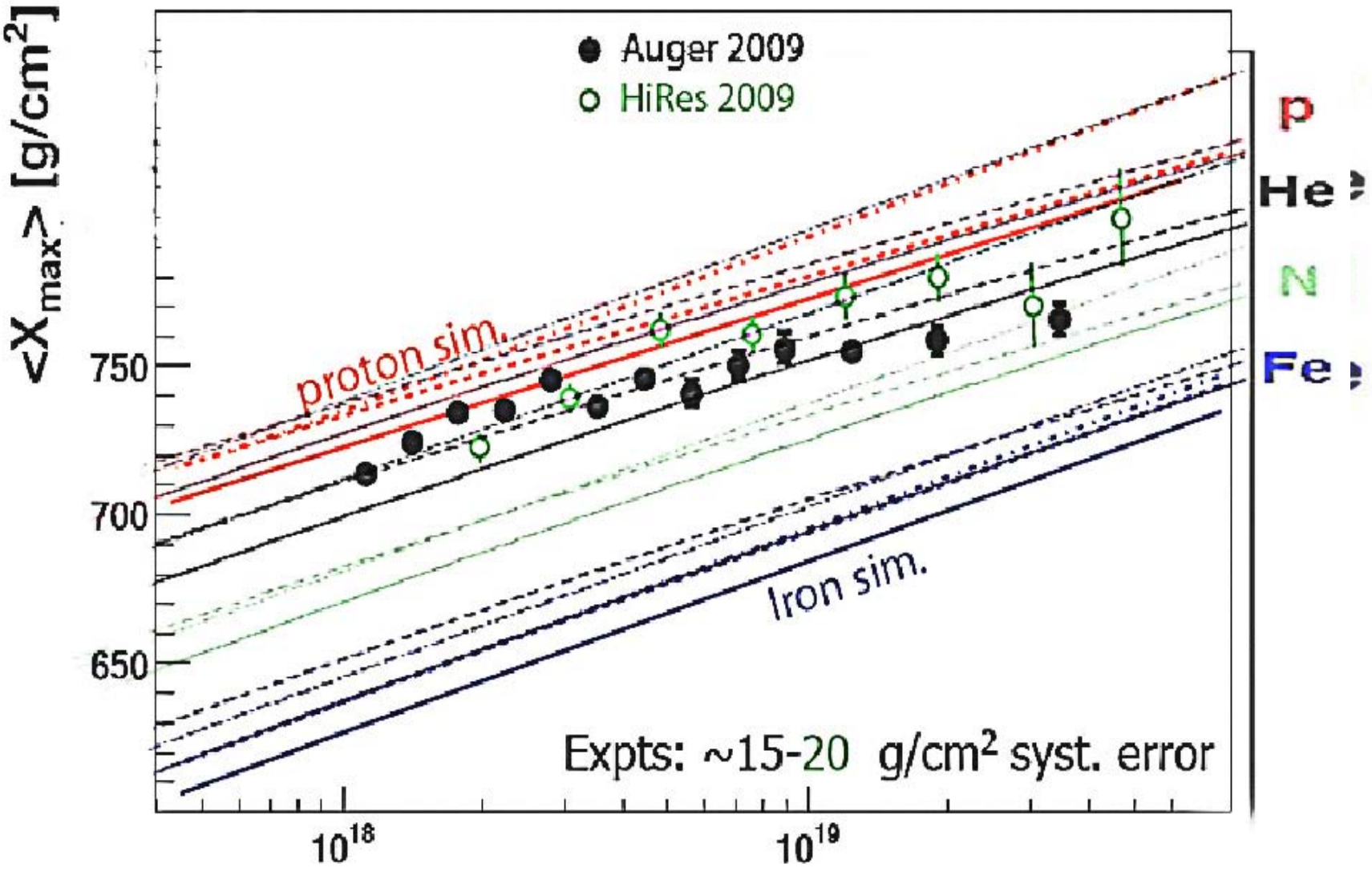
Oldest and recent compositions



Auger-Hires-ICRC 09



Composition AUGER-Hires Taup-Blois-Hep 09



2. VIRGO ABSENCE and CEN_A large spread events

- The absence of VIRGO cluster led Gorbunov (and us) puzzled. Where is Virgo in UHECR map?
- **Why GZK cut earlier than expected 100 EeV for proton**
- A spread of multiplet along near < 4 Mpc Cen_A : maybe no signals more far than 10 Mpc? The proton and Fe must come from farer distances. Conclusion 31.12.2007:

→Consequences on Neutrino Spectra and Flux

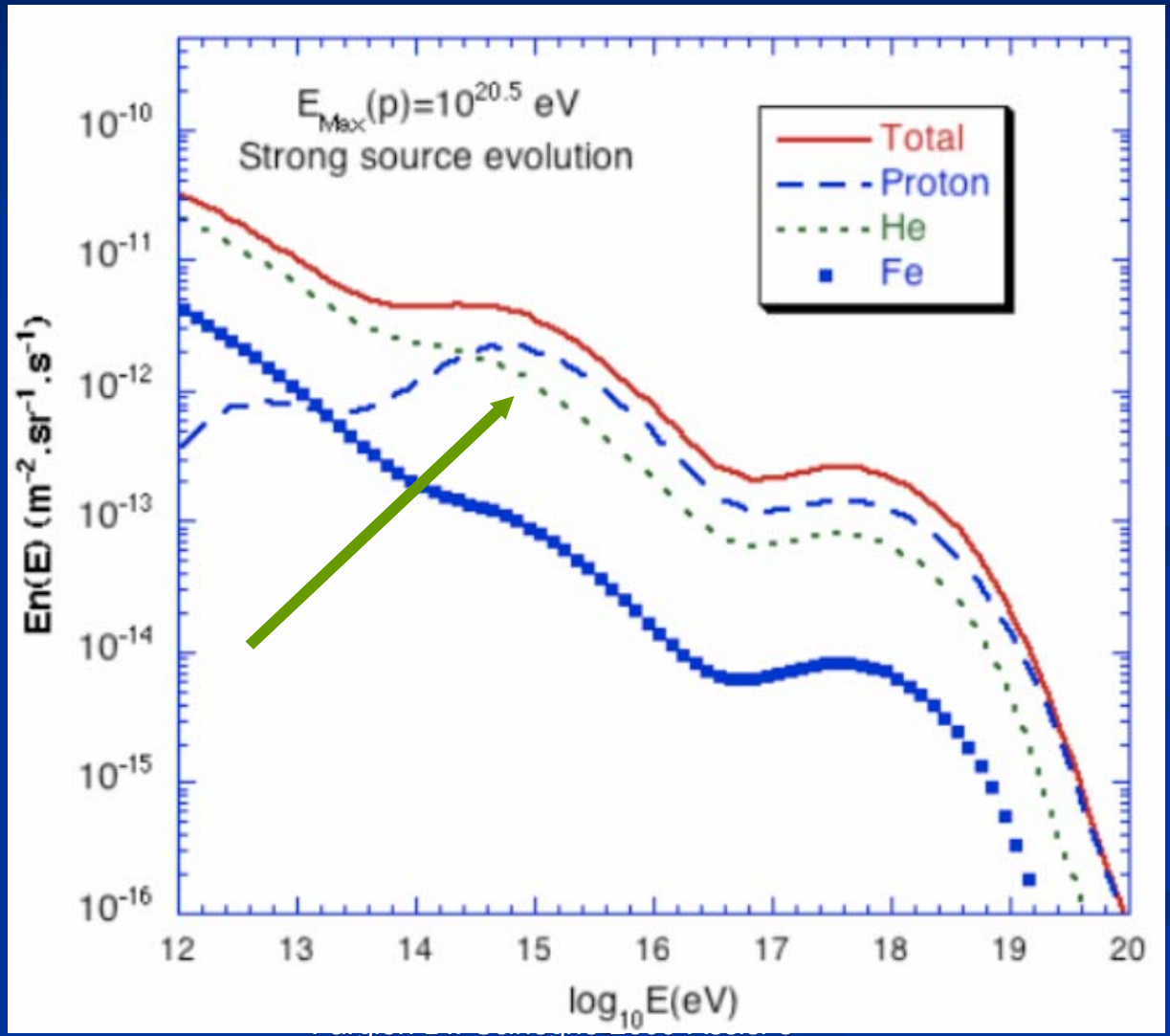
Last archive 0908.2650

- **Coherent and random UHECR Spectroscopy of Lightest Nuclei along *CenA*: Shadows on GZK Tau Neutrinos spread in a near sky and time earlier papers**
- **LIGHTEST NUCLEI as He, Be maybe the main signals (DF. Physica Scripta 2008, DF et al Nucl PhyB 09)**

The UHECR-UHE neutrino Connection

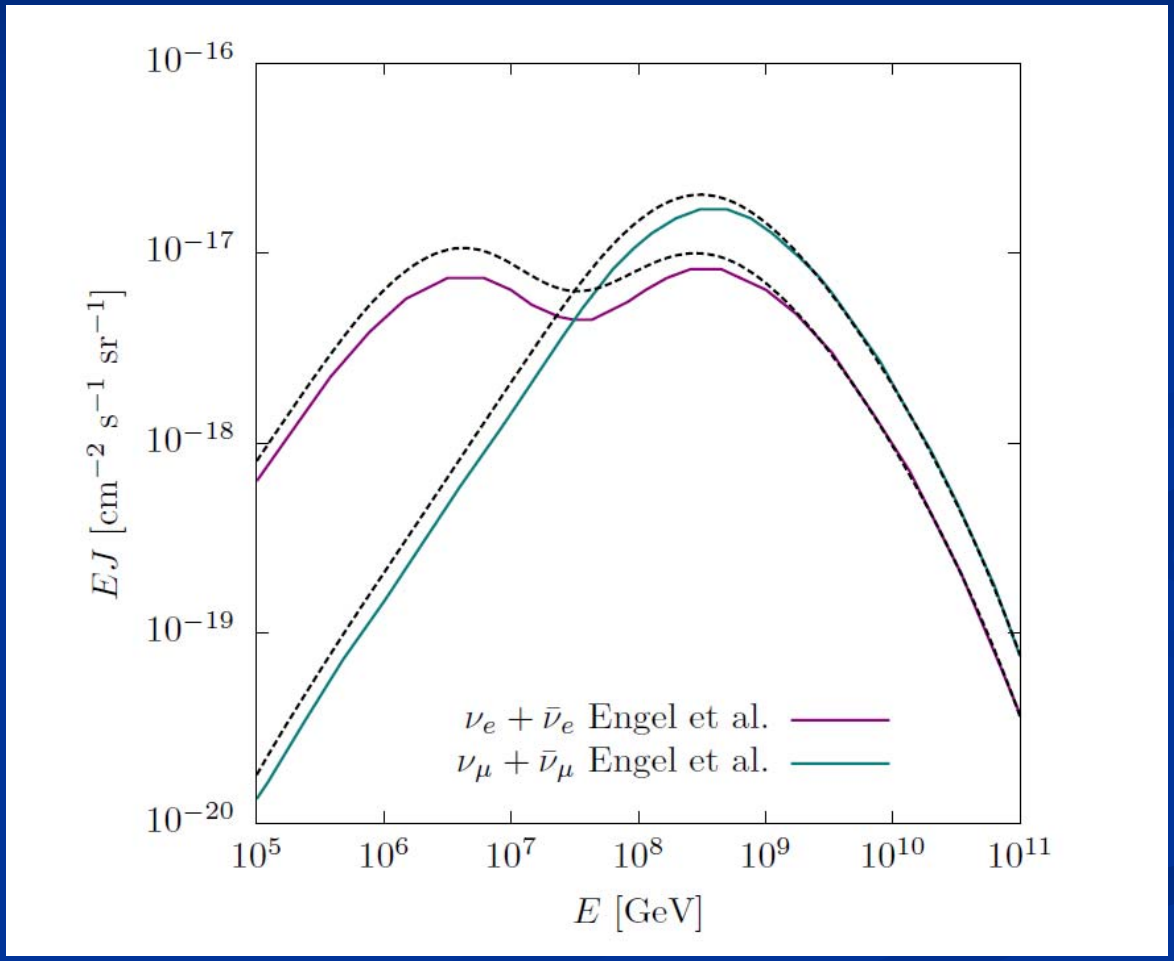
- UHECR Map may mimic a UHE nu map
- UHECR Composition imply GZK nu
- Versus UHE nu spectra
- UHE Neutrino GZK different maps
- UHE Tau Neutrino discover at AUGER and Hires Fluorescence telescopes

First new predictions for He

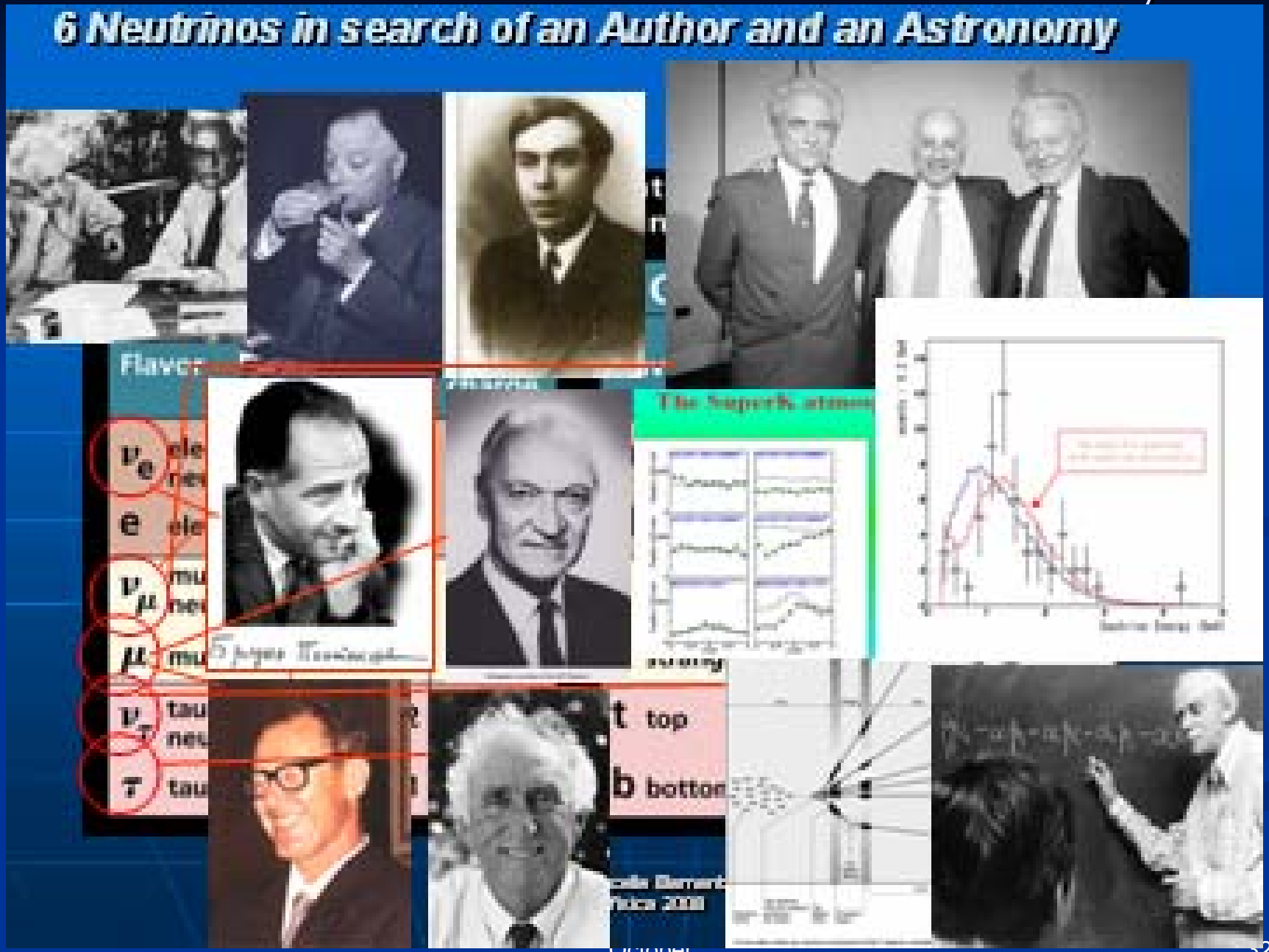


arXiv:0902.3993v1 [astro-ph.HE] 24 Feb 2009

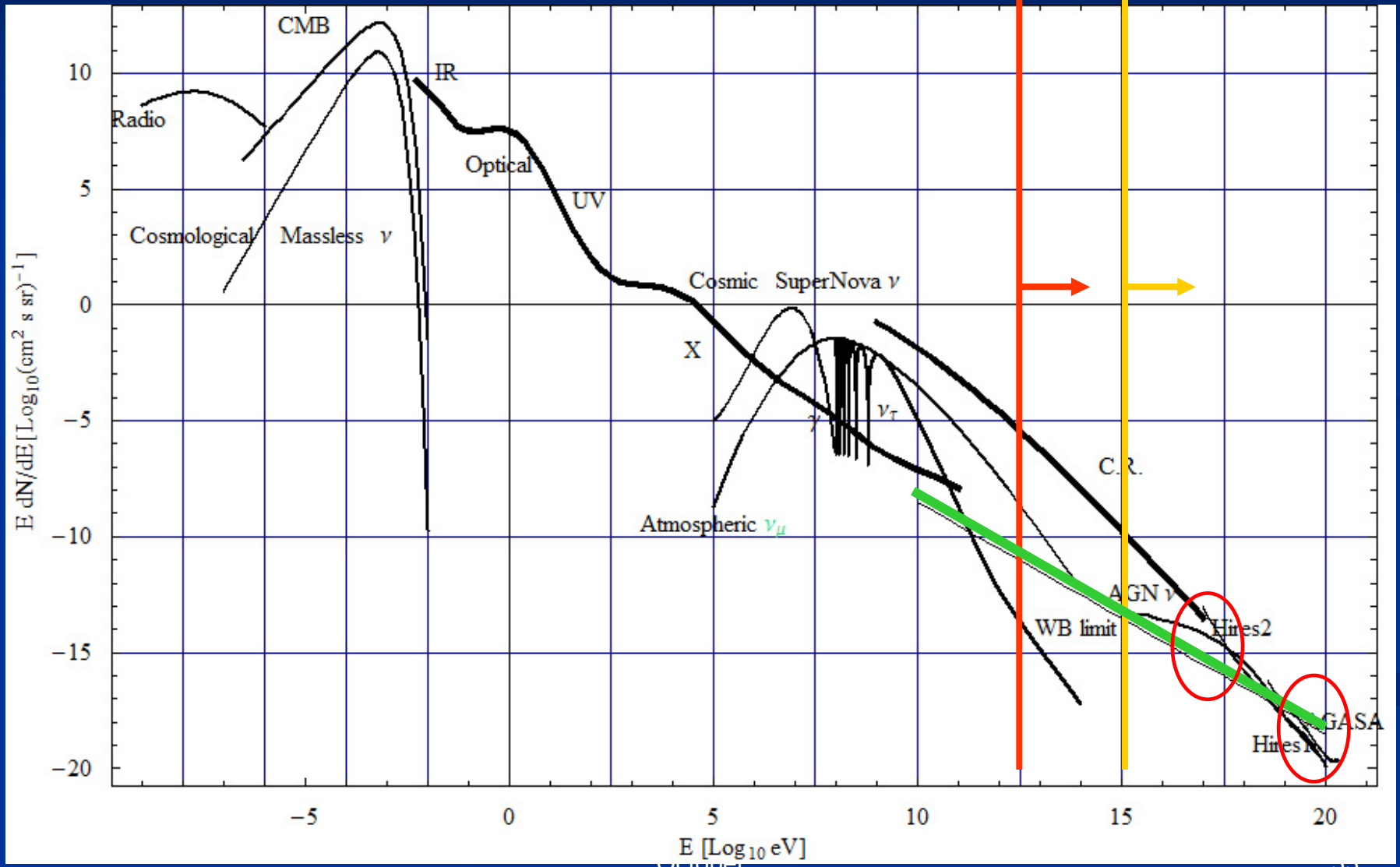
Less EeV more tens PeV



No one but 6 Neutrinos Astronomy



Photons versus Cosmic Rays (UHECR) and UHE neutrino Astronomy



UHE Neutrino Astronomy

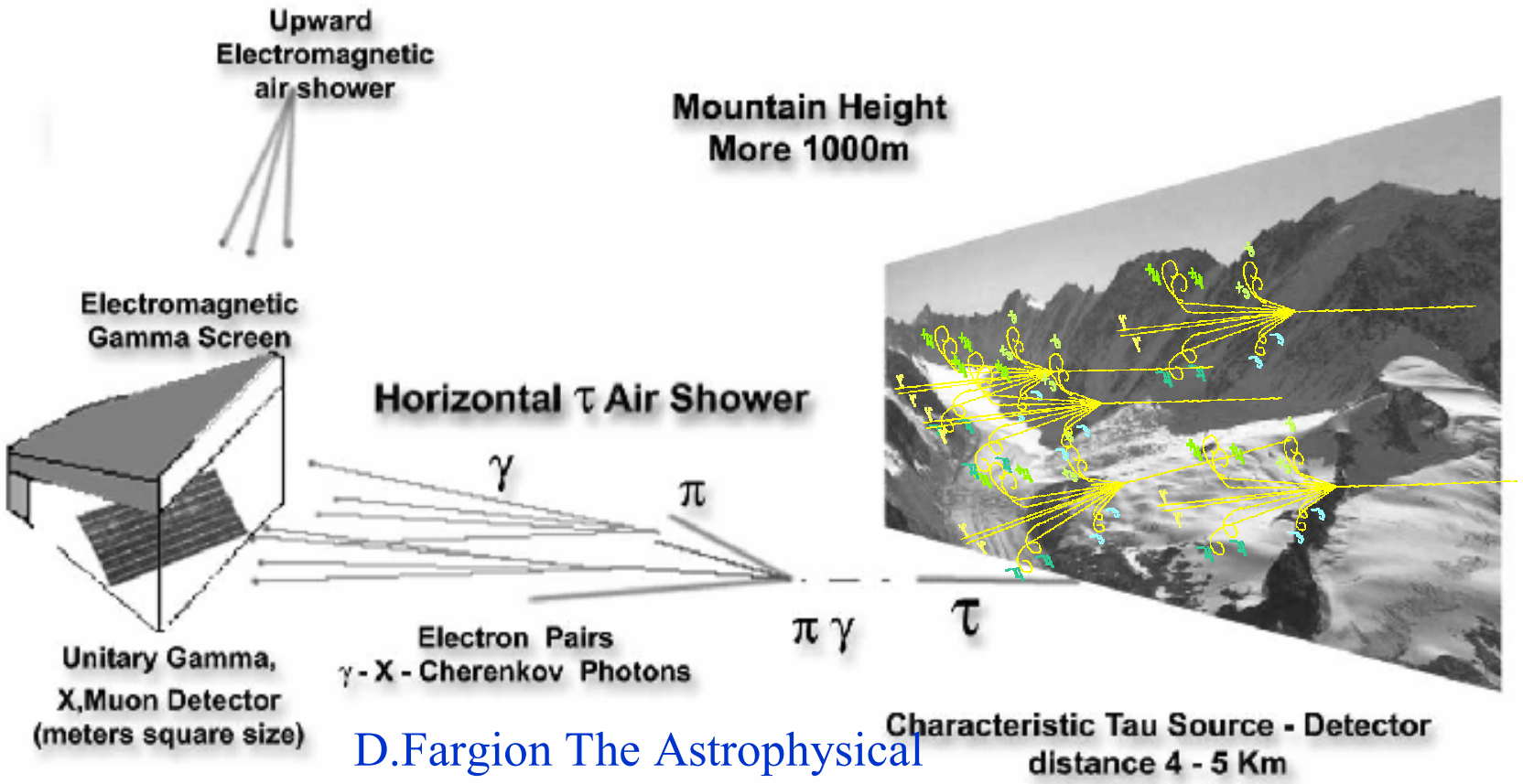
- Electron tracks: too short; good for MeVs-GeVs
- Muon tracks , fine at TeV, polluted from above;
- Muon neutrinos above tens TeV opaque from Earth below. ICE cube not at best for horizontal, where , anyway, prompt atmospheric neutrino noise also shine.
- Tau above PeVs up to tens EeV may skim at horizons: No atmospheric noise above tens TeV.
- Tau escaping a mountain or the Earth may decay in flight leading to an amplified Tau Airshowers (huge)

HE.6.1.10

Horizontal Tau air showers from mountains in deep valley: Traces of UHECR neutrino tau

ICRC 1999-Salth Lake_US

D. Fargion [1], A. Aiello [2], R. Conversano



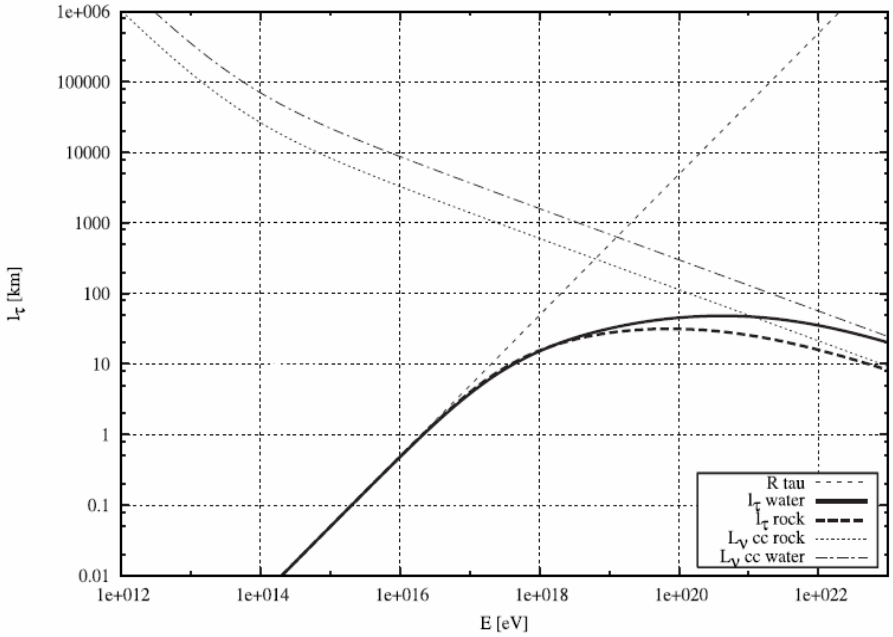
D.Fargion The Astrophysical Journal,570,p.909. 2002

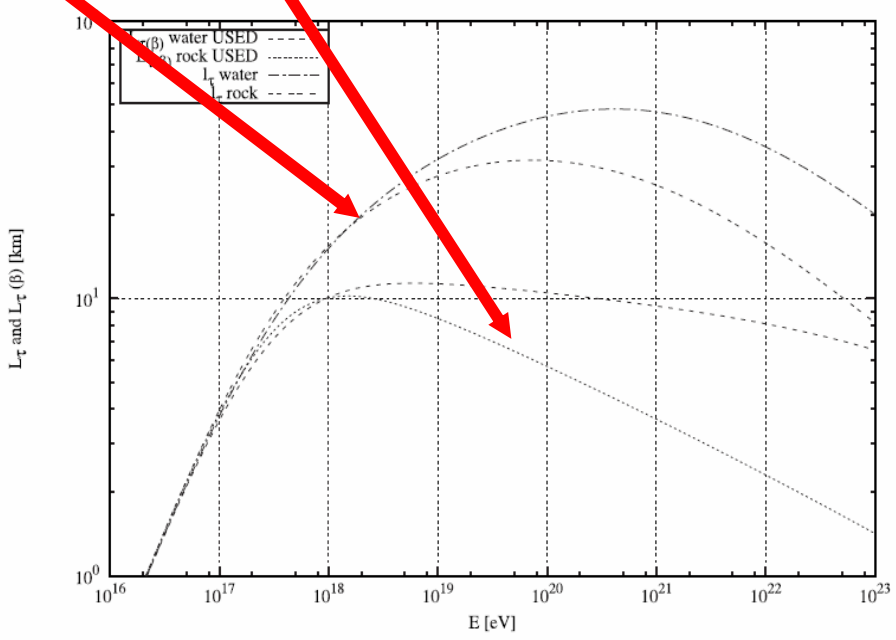
DISCOVERING ULTRA-HIGH-ENERGY NEUTRINOS THROUGH HORIZONTAL AND UPWARD τ AIR SHOWERS: EVIDENCE IN TERRESTRIAL GAMMA FLASHES?

Because mixing, even a minimal neutrino mass splitting guarantees the flavour transformation from Muon Neutrinos to the Tau Neutrinos. Galactic and cosmic distances are huge respect neutrino oscillation lenghts. Tau neutrinos are born by Muons ones

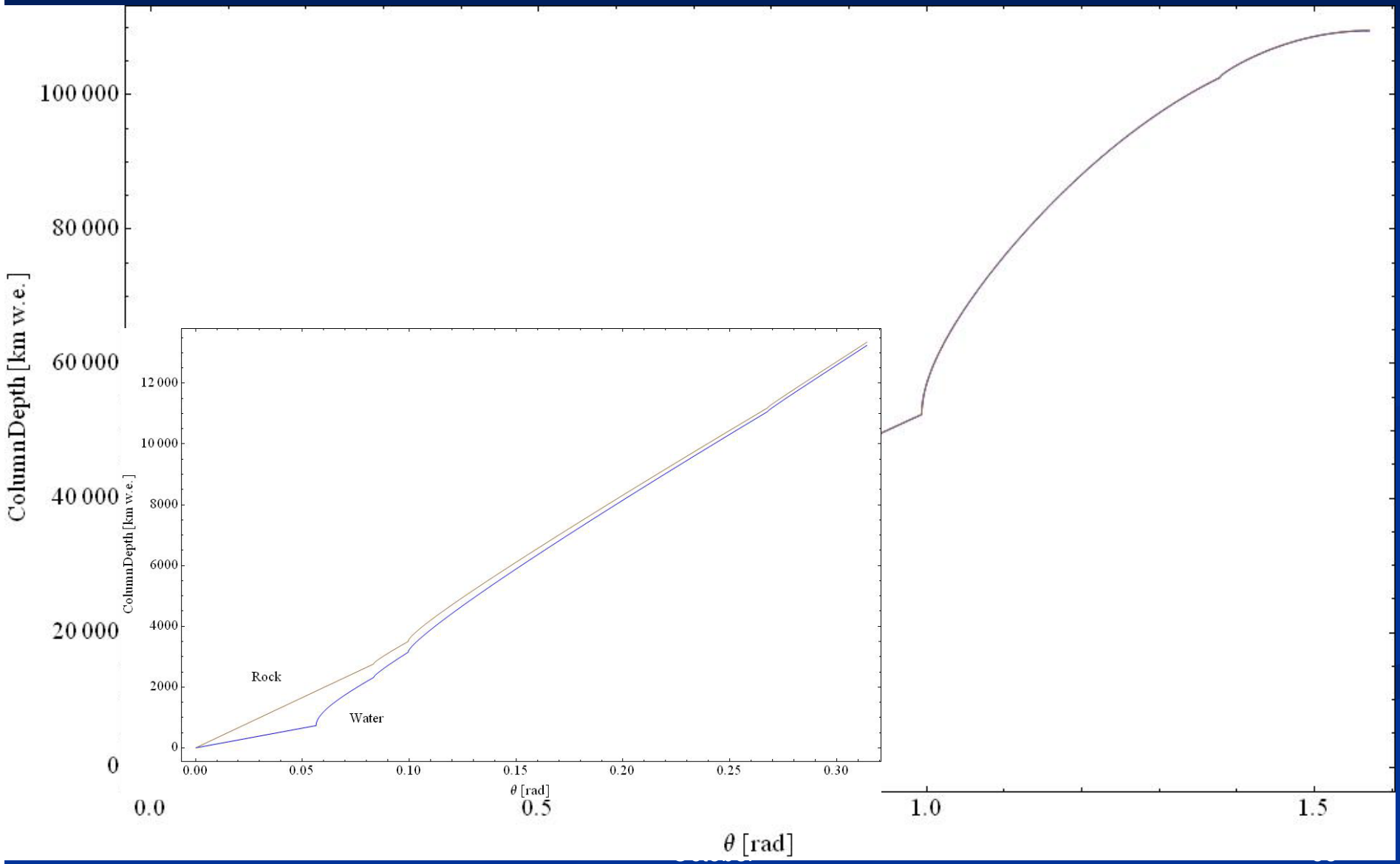
$$L_{\nu_\mu - \nu_\tau} = \boxed{8.3\,\mathrm{pc}} \left(\frac{E_\nu}{10^{19} eV} \right) \left(\frac{\Delta m^2_{ij}}{(10^{-2} eV)^2} \right)^{-1}$$

Long exausted- Shortest Hardest



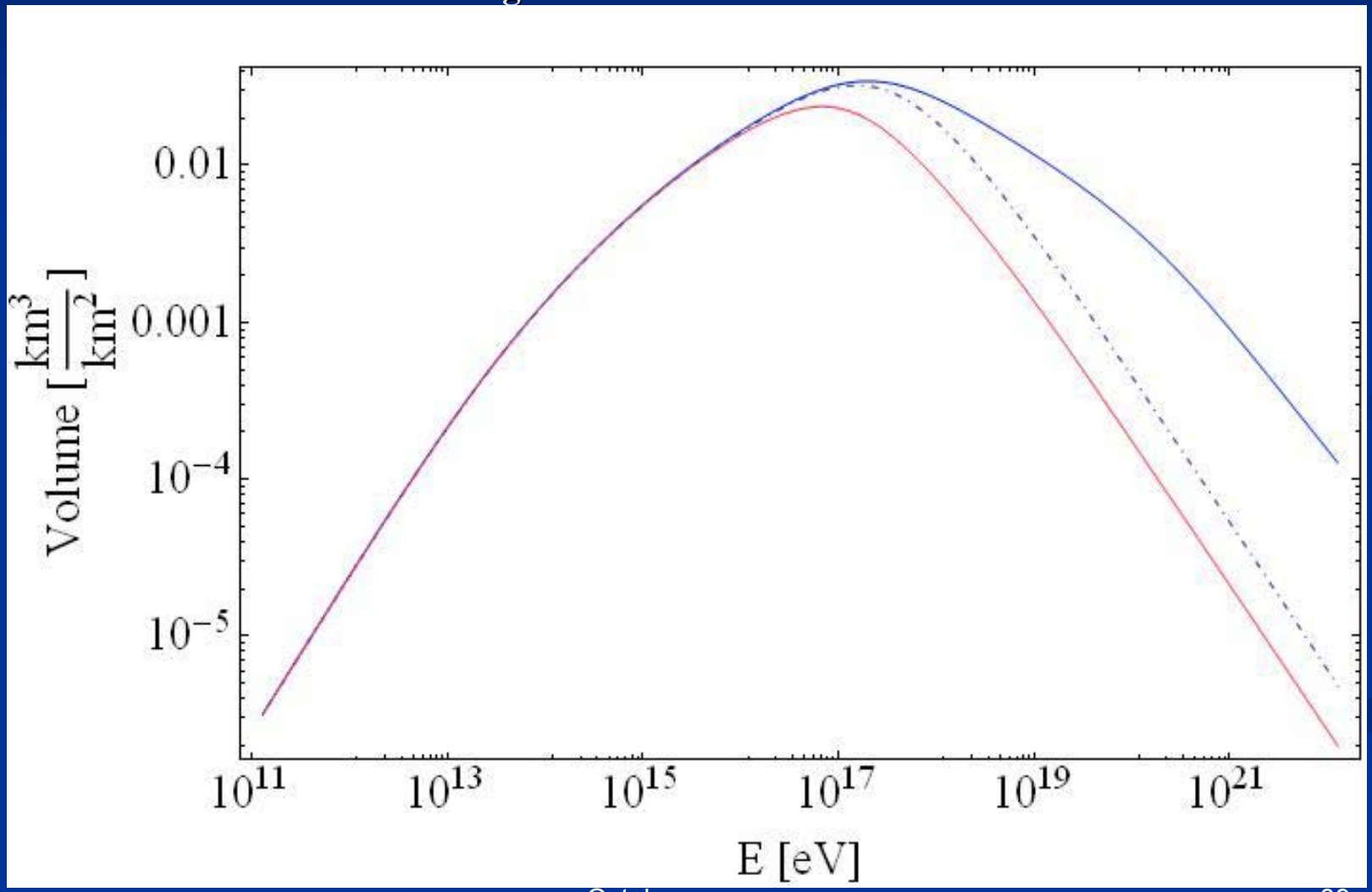


Inner Earth : Rock and-or Sea

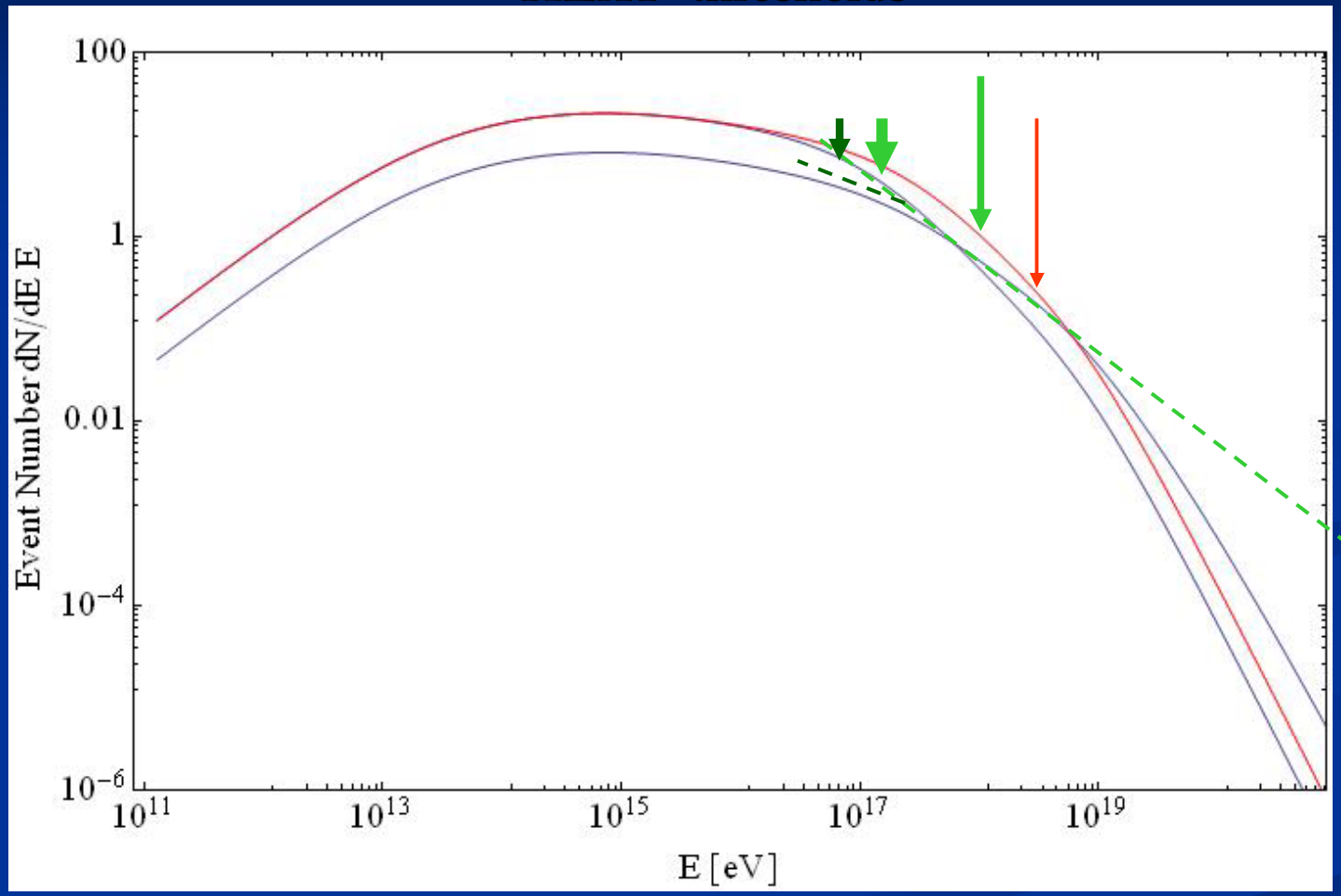


Volume of Tau update Energetic (red rock-blue water)

DFargion-D.D'armiento 09



Updated Event rate 3 years AUGER Fluorescence – Night time 10% .Dashed green : present Auger energy threshold. Green edge: AMIGA-HEAT thresholds



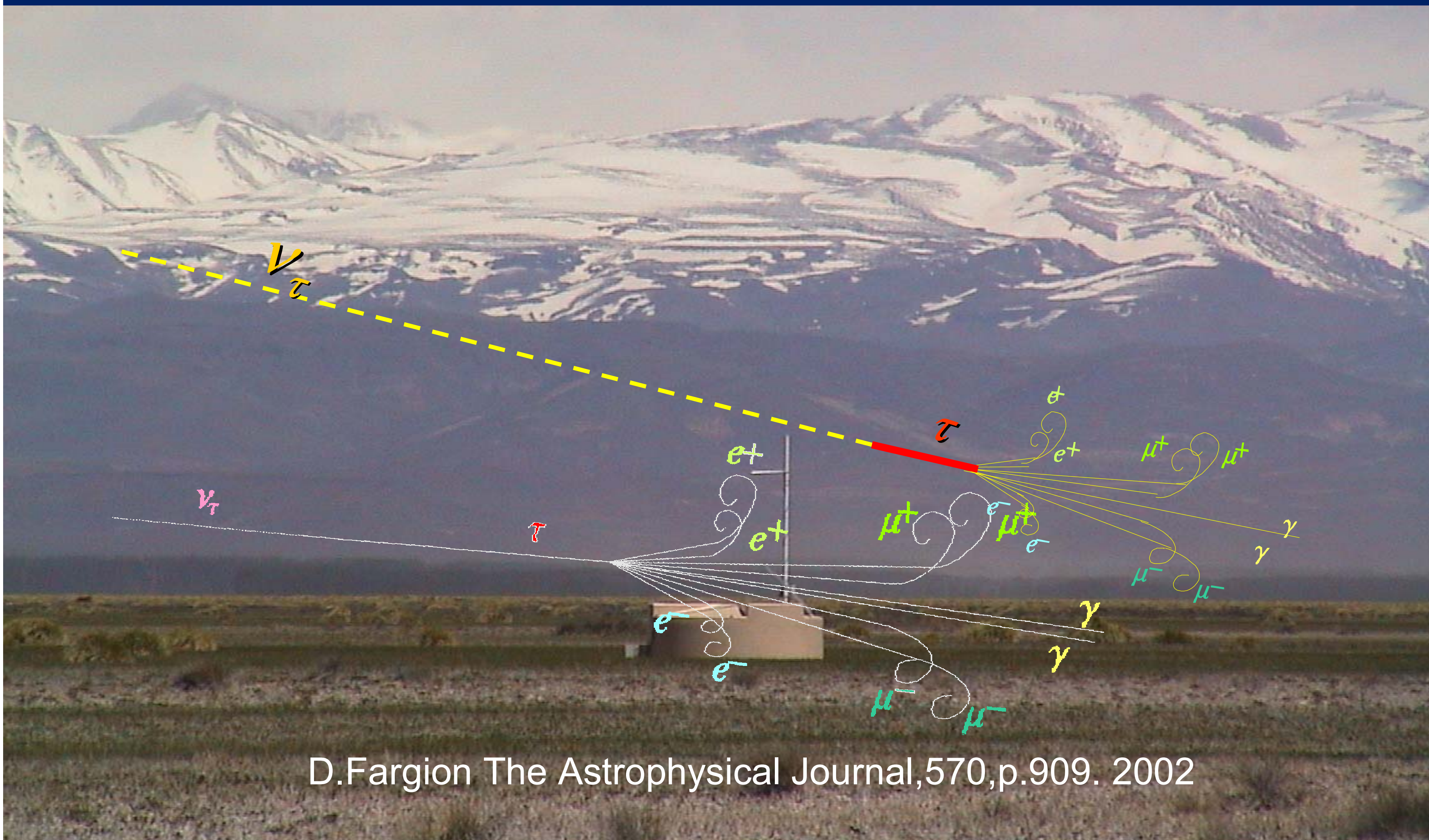
Tau Air-Showers: Astronomy versus Elementary Particle Tau

TABLE 1
TAU AIR SHOWER CHANNELS

Decay	Secondaries	Probability	Air-shower
$\tau \to \mu^- \bar{\nu}_\mu \nu_\tau$	μ^-	$\sim 17.4\%$	Unobservable
$\tau \to e^- \bar{\nu}_e \nu_\tau$	e^-	$\sim 17.8\%$	1 Electromagnetic
$\tau \to \pi^- \nu_\tau$	π^-	$\sim 11.8\%$	1 Hadronic
$\tau \to \pi^- \pi^0 \nu_\tau$	π^-, $\pi^0 \to 2\gamma$	$\sim 25.8\%$	1 Hadronic, 2 Electromagnetic
$\tau \to \pi^- 2\pi^0 \nu_\tau$	π^-, $2\pi^0 \to 4\gamma$	$\sim 10.79\%$	1 Hadronic, 4 Electromagnetic
$\tau \to \pi^- 3\pi^0 \nu_\tau$	π^-, $3\pi^0 \to 6\gamma$	$\sim 1.23\%$	1 Hadronic, 6 Electromagnetic
$\tau \to \pi^- \pi^- \pi^+ \nu_\tau$	$2\pi^-$, π^+	$\sim 10\%$	3 Hadronic
$\tau \to \pi^- \pi^+ \pi^- \pi^0$	$2\pi^-$, π^+, $\pi^0 \to 2\gamma$	$\sim 5.18\%$	3 Hadronic, 2 Electromagnetic

D.Fargion The Astrophysical Journal,570,p.909. 2002

The Ande Mountains as a target for detecting UHE neutrino tau by Horizontal Air-Showers at AUGER: ANDE SHADOWs (ring mask at horizons) on GZK Cosmic Rays from



MAGIC , while pointing a GRB , SGR or BL Lac Below The Horizons (~ 1% of the GRB-SGRs events) on rock behave (near EeV ■ ♦ energy) as a 75 km^3 NEUTRINO TELESCOPE

astro-ph/0511597
D. Fargion
Progh.Part.Nucl.Phys.57
(2006) 384-393.

Horizons distance d= 167 km √(h/2.2 km) Cerenkov
Shower opening angle ~ 0.3°

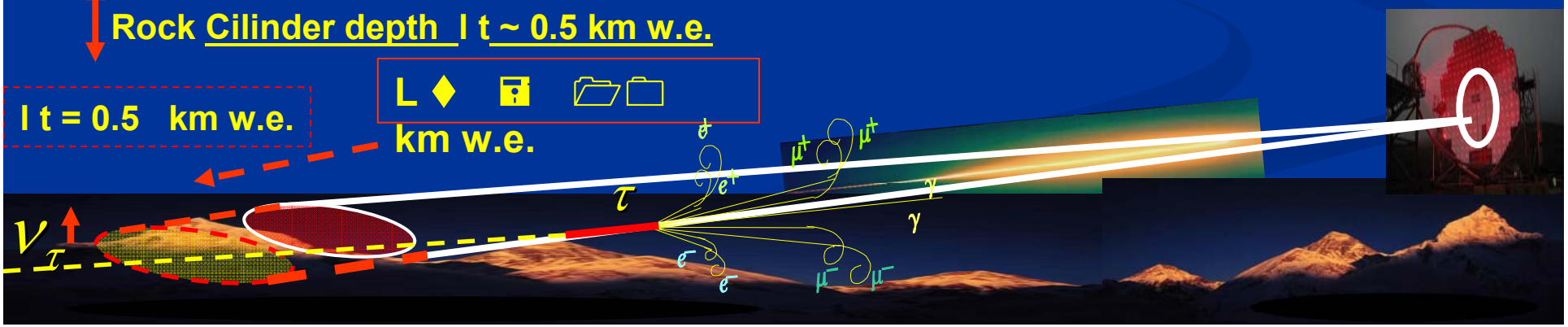
Inclined Conic Rock Base Area A ~ 3*50 =150 km^2

Inclined Rock Cilinder depth L ♦ ~ 10 km

Rock Cilinder depth l t ~ 0.5 km w.e.

l t = 0.5 km w.e.

L ♦ km w.e.

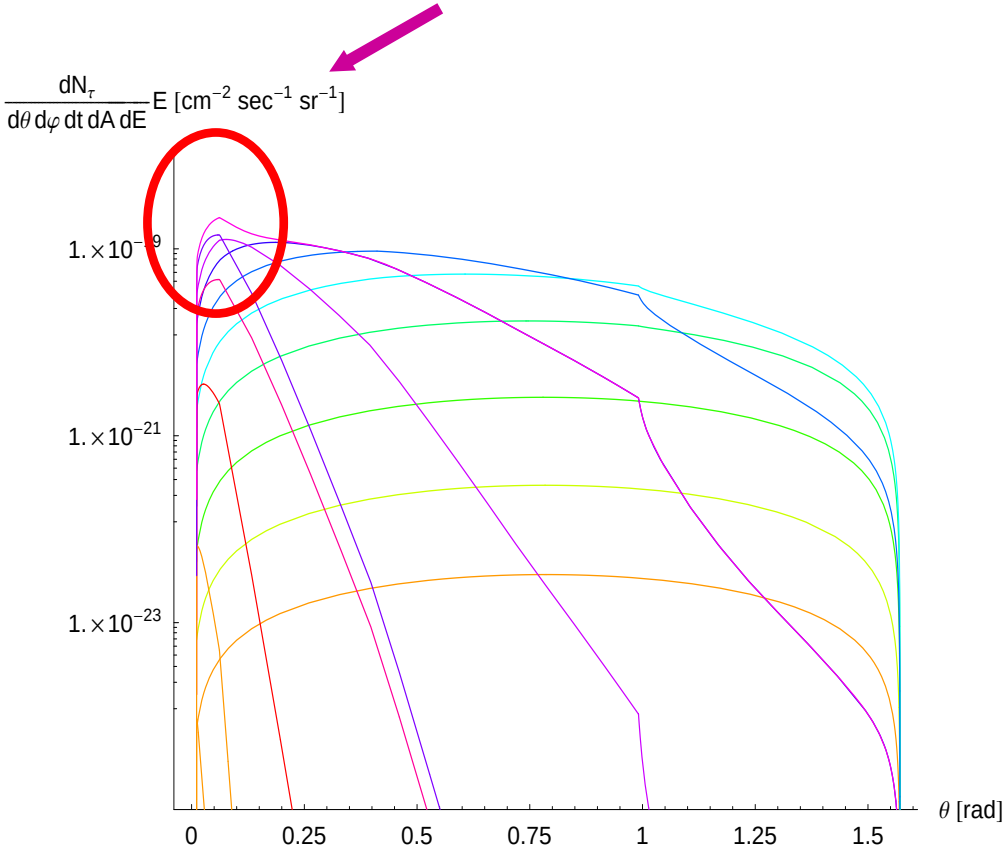


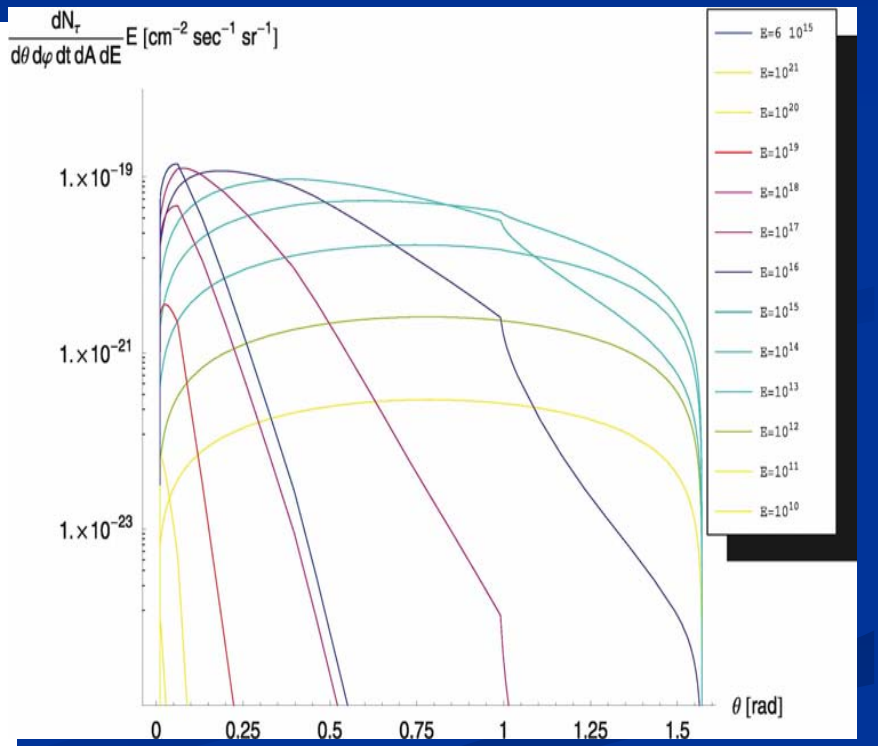
Detectors extended in deep valley : ARGO-Tibet-The Near Valley

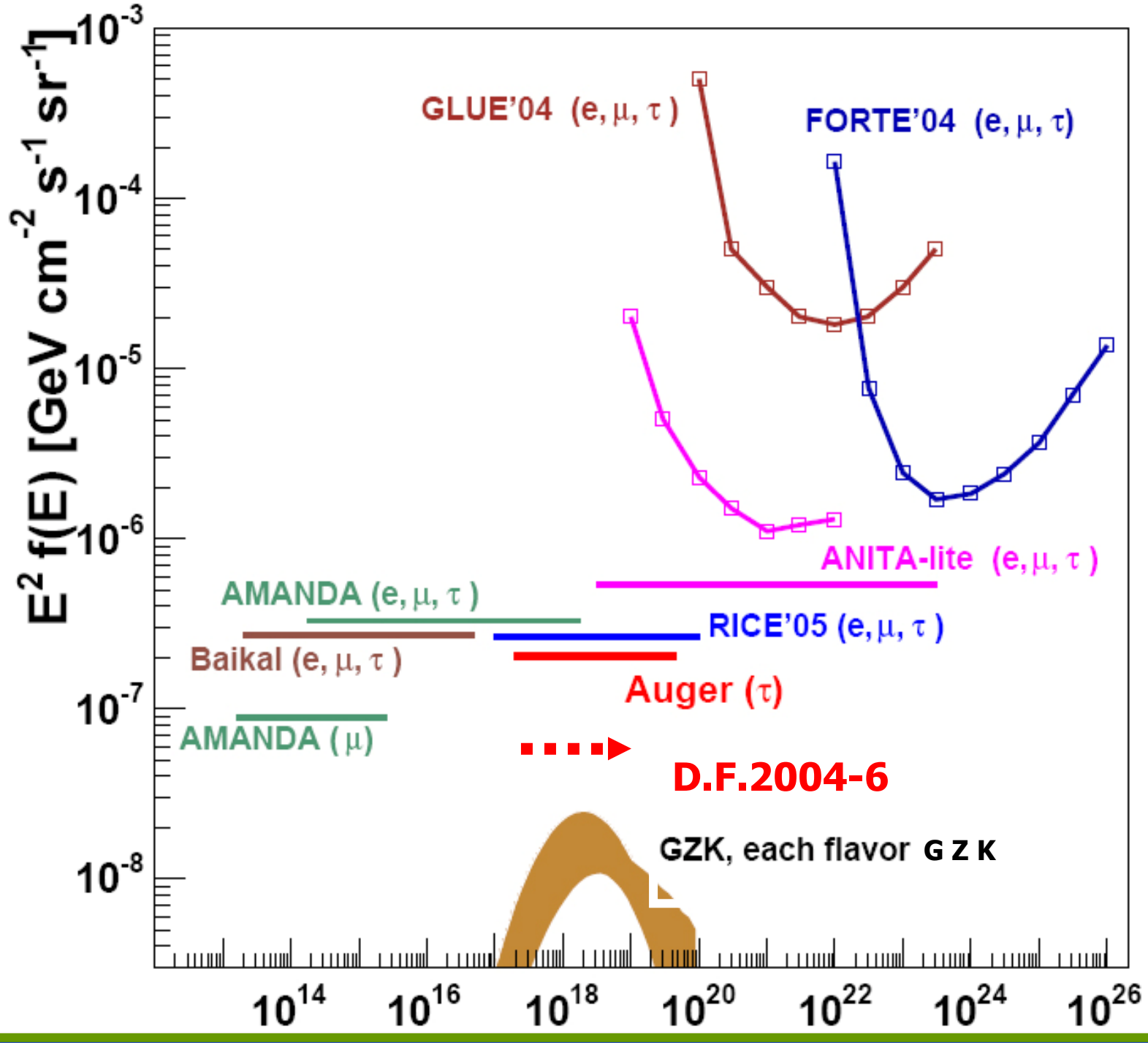
ν_τ Taus and Anti-ν_e into Taus: Testing CPT in our Universe

Upward Tau Air Showers from Earth , Authors: D. Fargion, et al.
Journal-ref: Astrophys.J. 613 (2004) 1285-1301 ;

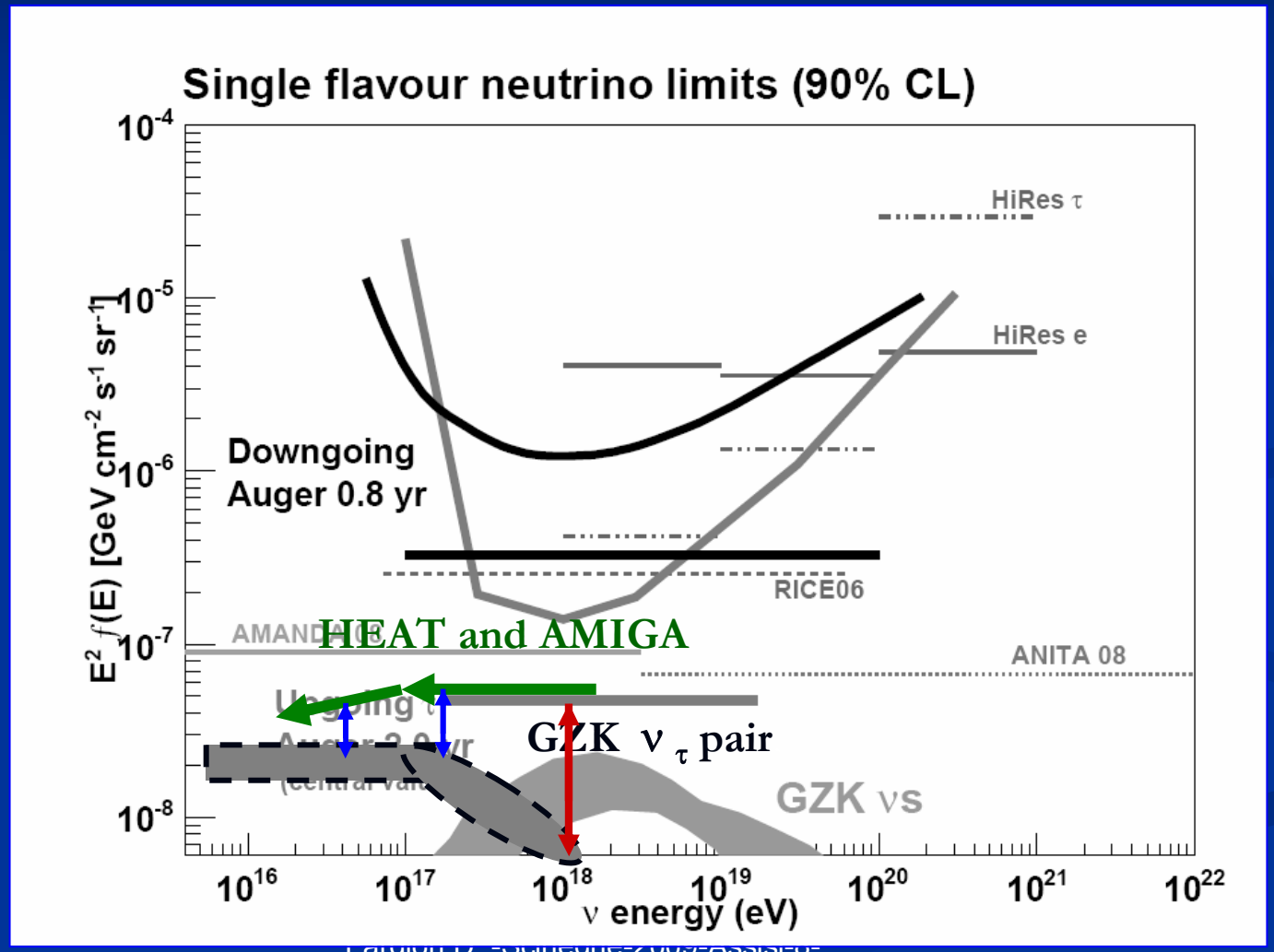
Nuclear Physics B. (Proc.Suppl.) 136 (2004) 119-128



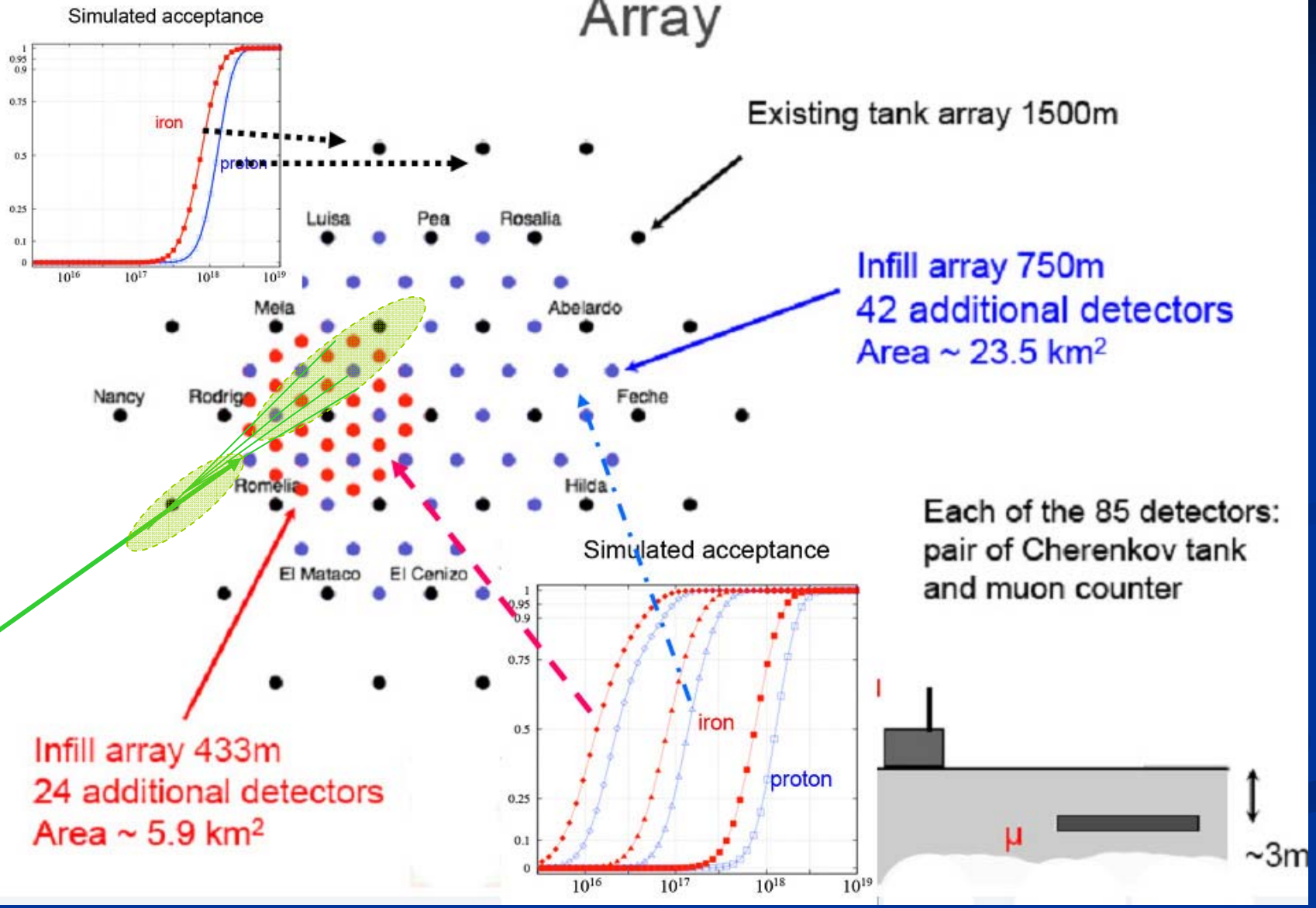



E^2 f(E) [GeV cm^{-2} s^{-1} sr^{-1}]
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
GLUE'04 (e, μ, τ)
FORTE'04 (e, μ, τ)
ANITA-lite (e, μ, τ)
AMANDA (e, μ, τ)
RICE'05 (e, μ, τ)
Baikal (e, μ, τ)
Auger (τ)
AMANDA (μ)
D.F.2004-6
GZK, each flavor G Z K
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
10^{24}
10^{26}

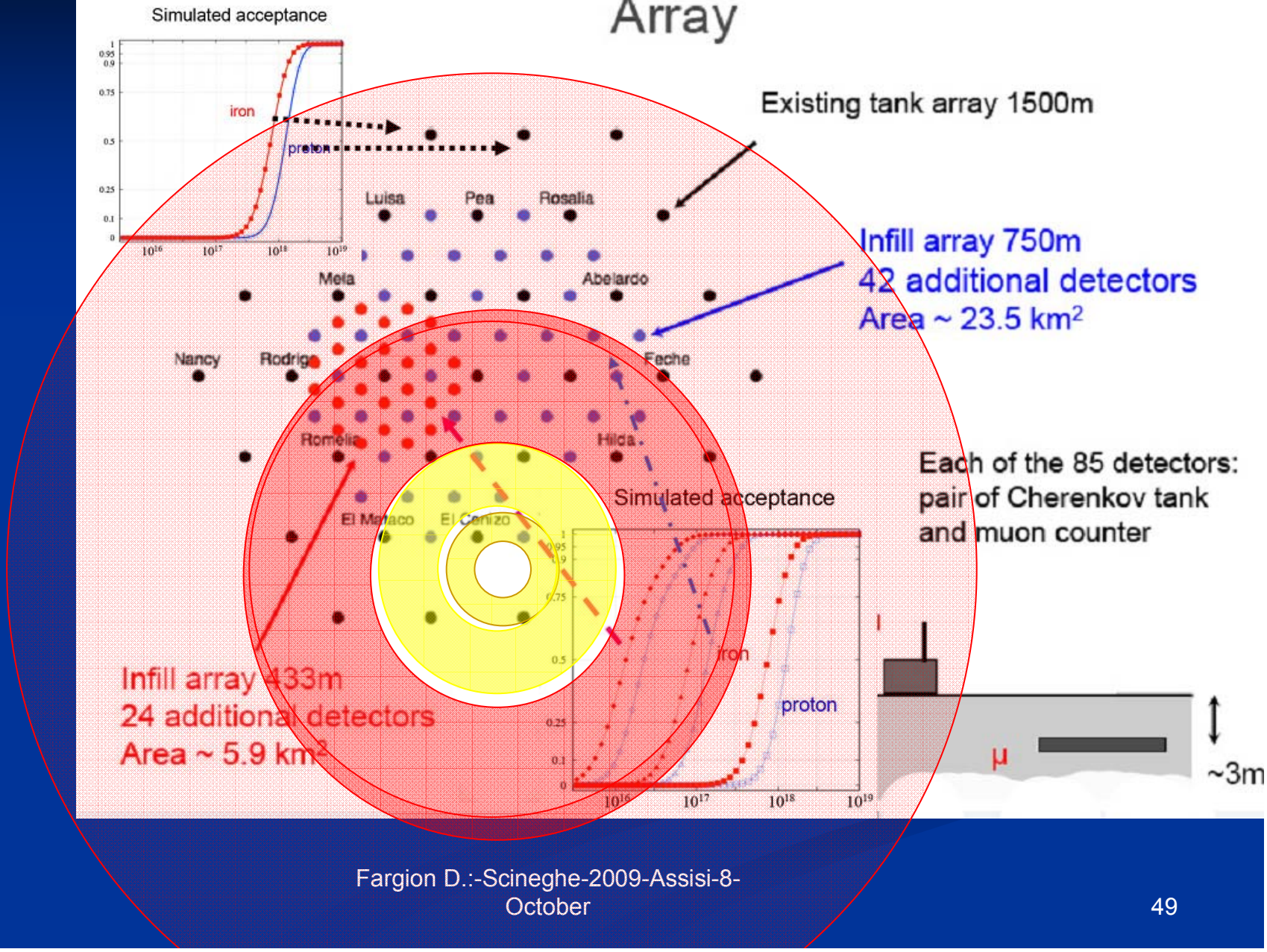
LAST auger icrc 2009 versus our expectations



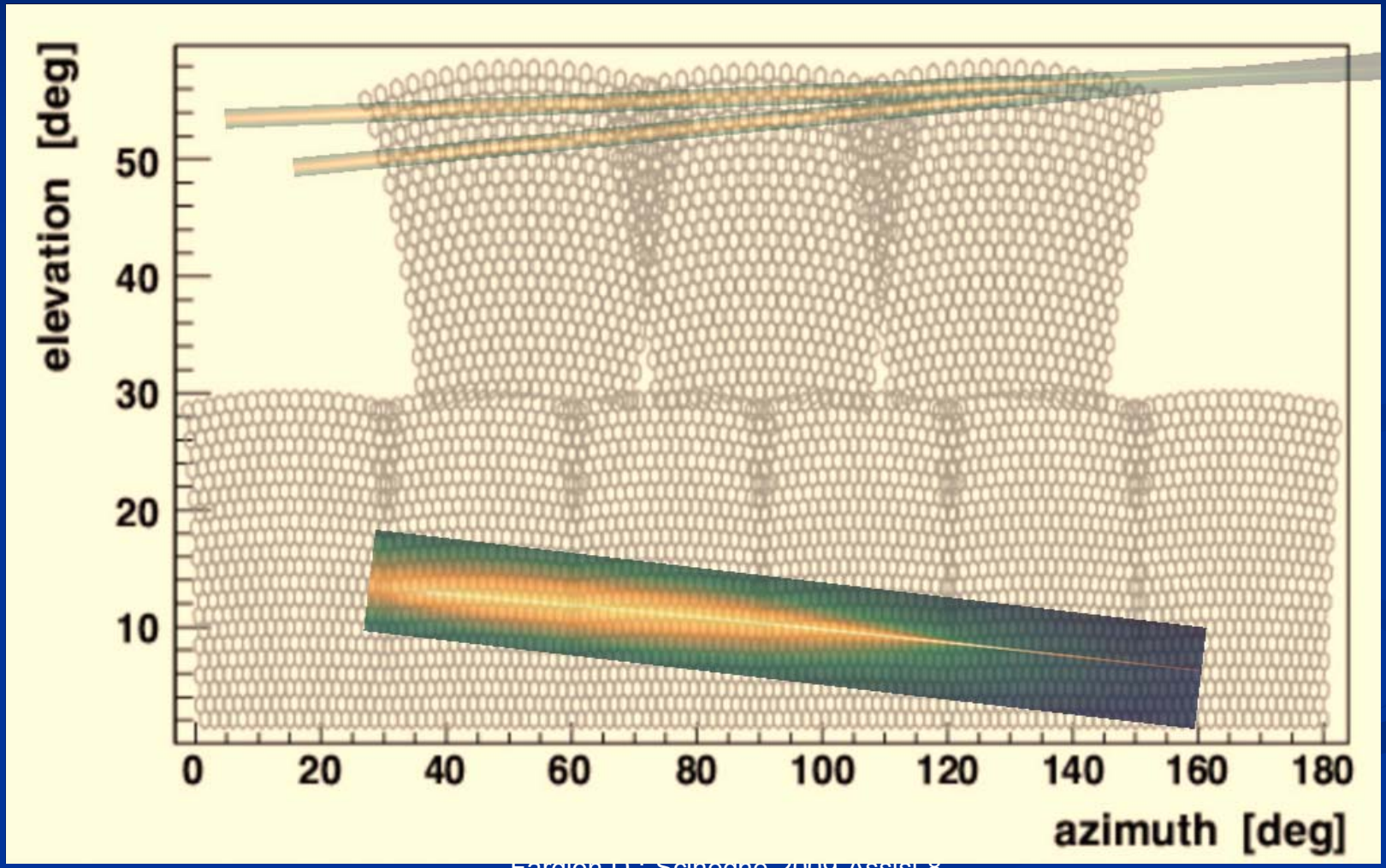
AMIGA: Auger Muons and Infill for the Ground Array

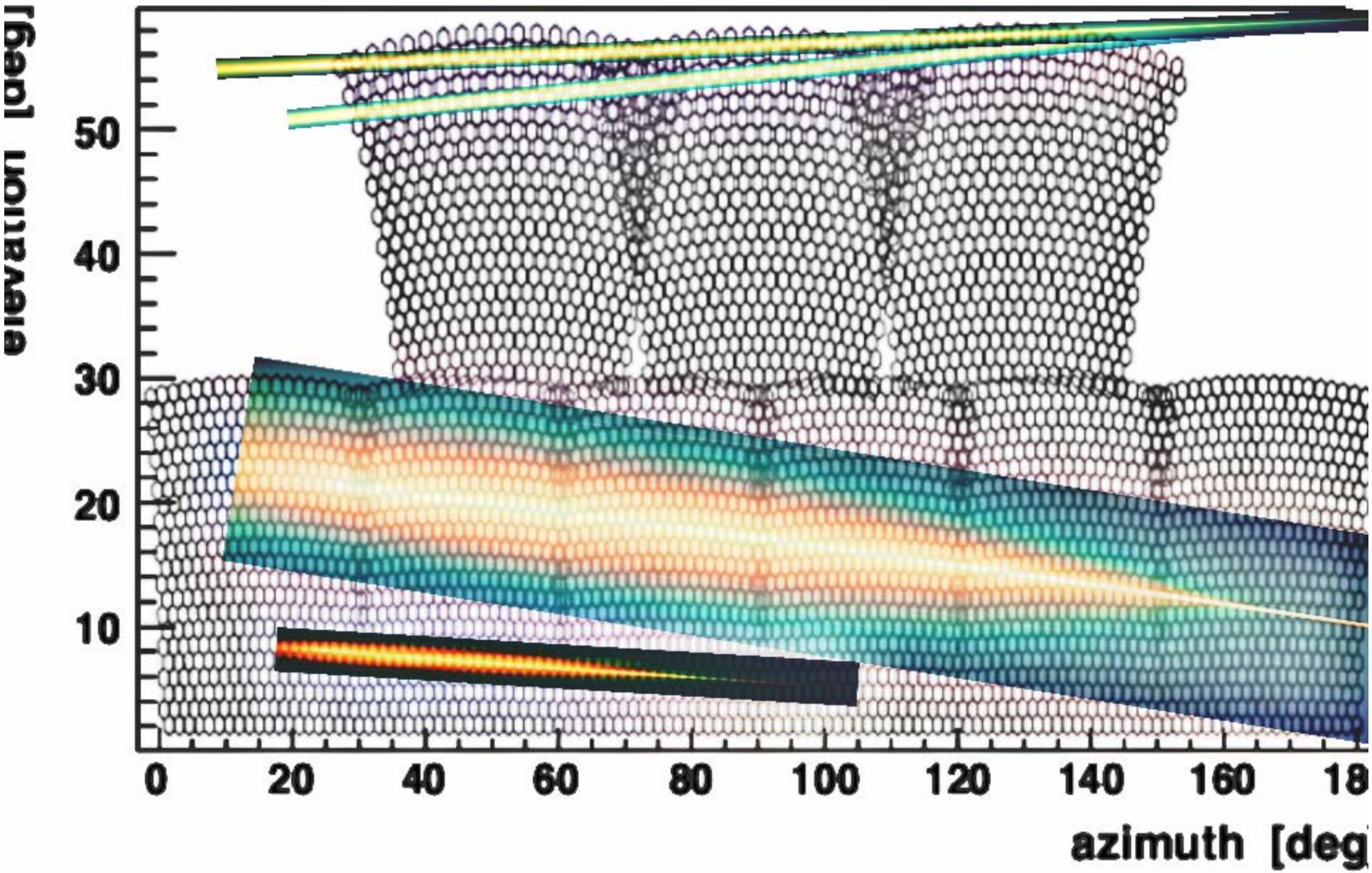


AMIGA: Auger Muons and Infill for the Ground Array

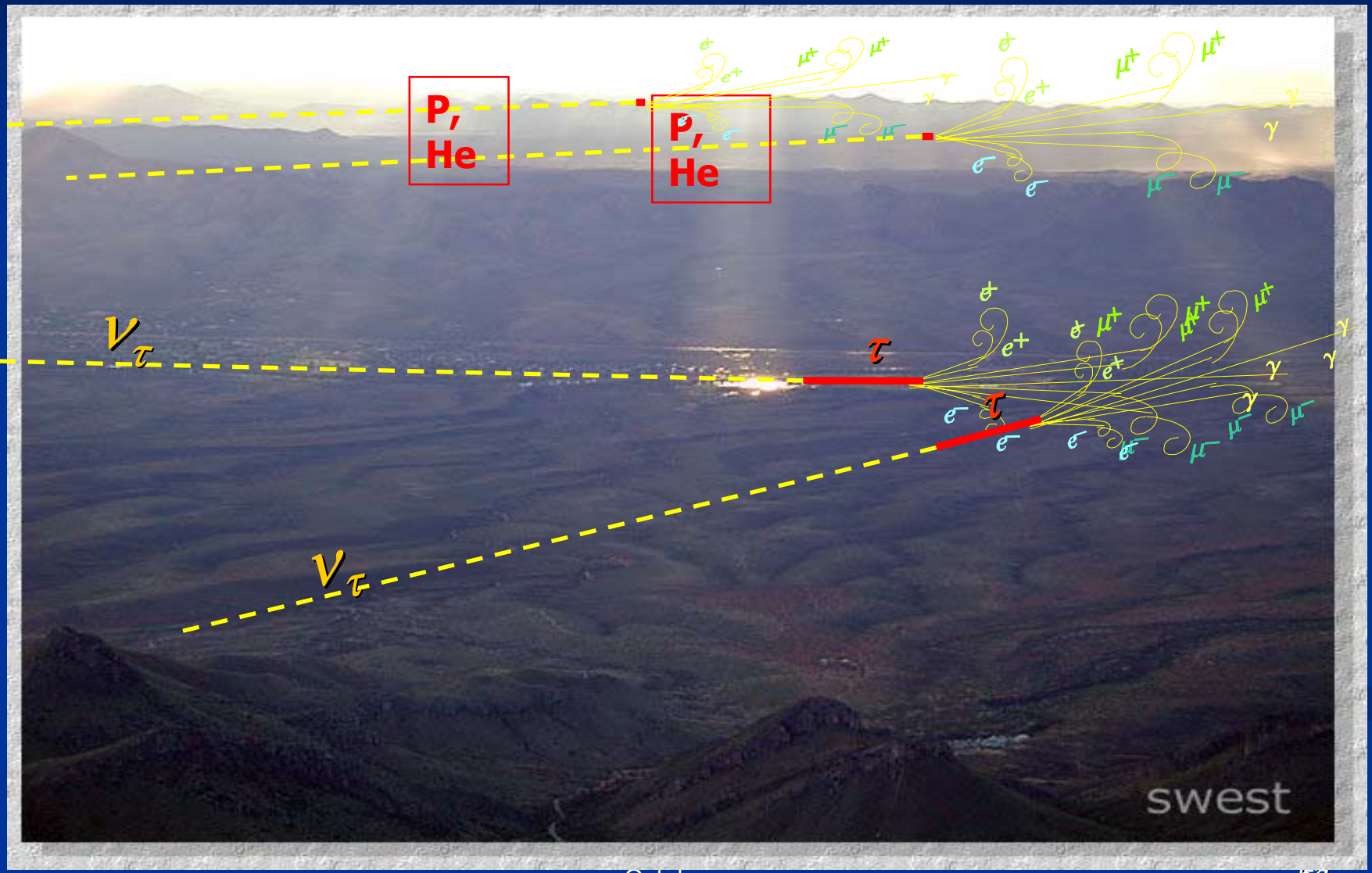


Hadron Air-Showering at far horizons versus Tau upgoing nearby




elevation [deg]
50
40
30
20
10
0
20
40
60
80
100
120
140
160
18
azimuth [deg

In Conclusion, while Nuclei shine up Horizontally, up-ward Tau air-Shower rise by a Neutrino Sky under our own Sky : the Earth ….Within a few years in AUGER-AMIGA-HEAT FD



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[1] K.H. Kampert,P.O.A., Ultra High-Energy Cosmic Ray Observations, HEP 2009;

[2] Pierre Auger Collaboration, Science 2007, vol.318, p.939-943

[3] D.Fargion Phys. Scr. 78 (2008) 045901, 1-4.

[4] D.Fargion,et al.26th ICRC,He 6.1.09,p.396-398.1999.(USA);

[5] D.Fargion , 2002, ApJ, 570, 909; D. Fargion , et all. 2004, ApJ, 613, 1285; D.Fargion et al., Nuclear Physics B (Proc. Suppl.)2004; D. Fargion, et all. Adv. in Space Res.,37 (2006) 2132-2138;,136 ,119; D.Fargion, J.Phys.Soc.Jpn.Vol.77 (2008) Suppl. B., p.1-15. D.Fargion Prog. Part. Nucl. Phys 57,2006,384-393; D. Fargion et al. Adv.Space Res. 37 (2006) 2132-2138; D.Fargion et al. Nucl.Inst. Meth.A, 588; 2008, 146-150.

[6] D.Fargion, D. D'Armiento, P. Paggi, S. Patri', Nuclear Physics B (Proc. Suppl.) 190 (2009) 162-166

[7] D.Fargion, D. D'Armiento,Venice "Neutrino Telescopes" 09.arXiv:0905.1517

Summary

- Tau Neutrino Astronomy by UHECR GZK at edge
- AUGER Maps at UHECR may hint for UHE tau Neutrino at EeV (nucleons)
- UHECR Mass Composition and Cen-A dominance hint for UHE Helium-Li-Be nature. Tails of FRAGMENT CLUSTERING at 15-45 EeV.
- Consequence in UHE neutrino spectra at tens PeV.
- Detection at hand in AMIGA and HEAT at best via Fluorescence Tau air-showers
- Soon EeV-maybe- earlier : Tens-PeV tau neutrino.

- Thank you

Where to read more

- **arXiv:0905.1517**
- Achievements and Mirages
- in Uhecr and Neutrino Astronomy
  - D.Fargion, D. D'Armiento
  - arXiv:0902.3290
    - Title: Lightest Nuclei in UHECR versus Tau Neutrino Astronomy
    - D. Fargion et al. / Nuclear Physics B (Proc. Suppl.) 190 (2009) 162_166
  - **arXiv:0801.0227**
    - **Light Nuclei solving Auger puzzles. The Cen-A imprint**
    - Authors: D. Fargion
    - Journal-ref: Phys. Scr. 78 (2008) 045901

- Thank you

Event Num in EUSO 3 years