UHECR and GRB Neutrinos : incomplete revolutions ?

Two Astronomy in search of their sources

- Most-all GRBs do not trace UHE neutrino events
- UHECR maps do not trace expected local Universe; only Cen A?
- GZK neutrinos are not observed yet
- UHECR may be most Fe: no much directionality; possible lightest He nuclei: smeared map
- UHE ICECUBE neutrino events: new revolution
- Glashow resonance and double bang, missing

D.Fargion, Rome, 23-5-14

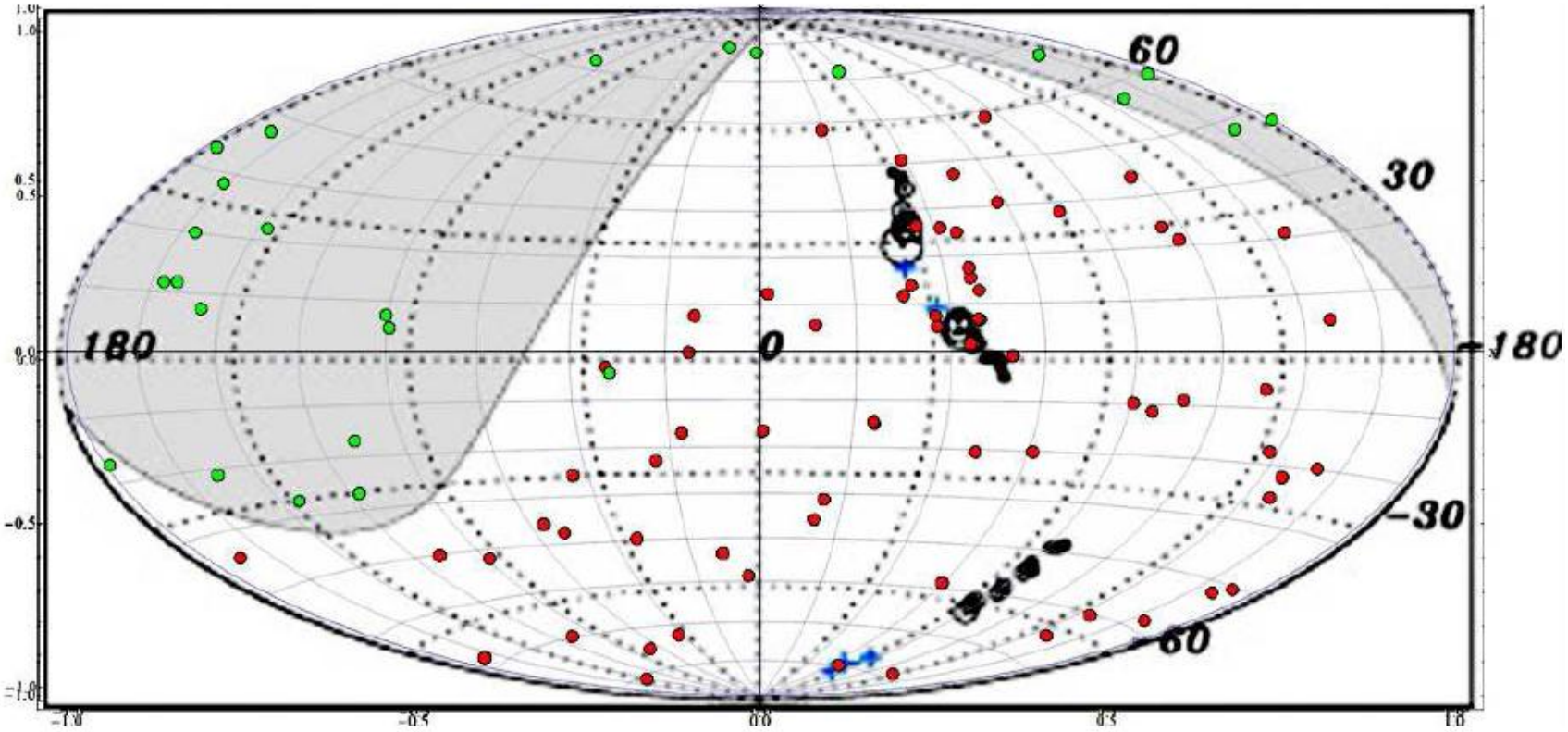
Historical Hopes

- A century ago, Rossi, COSMIC RAYS, charged, deflected, smeared, mysterious sources.
- Half century ago: UHECR, Linsley-Scarsi, hopes for undeflected proton for UHECR astronomy
- 40 years ago: UHE neutrino in cube km.
- 20 years ago : ZeV events; .AGASA..15 years HIRES-AUGER
- 7 years ago: UHECR GZK overlap Local Group?
- 1 year ago: PeVs-tens TeV ICECUBE events

UHECR news

- 2011: 69 events ….
- **Cen A** most clustered source
- Spread signals mostly NO proton, No Iron
- We : most He like lightest nuclei
- Multiplet secondaries of He foreseen 2009
- Multiplet at tens EeVs observed along Cen A
- Hints of Heavy nuclei from Vela and Cygnus

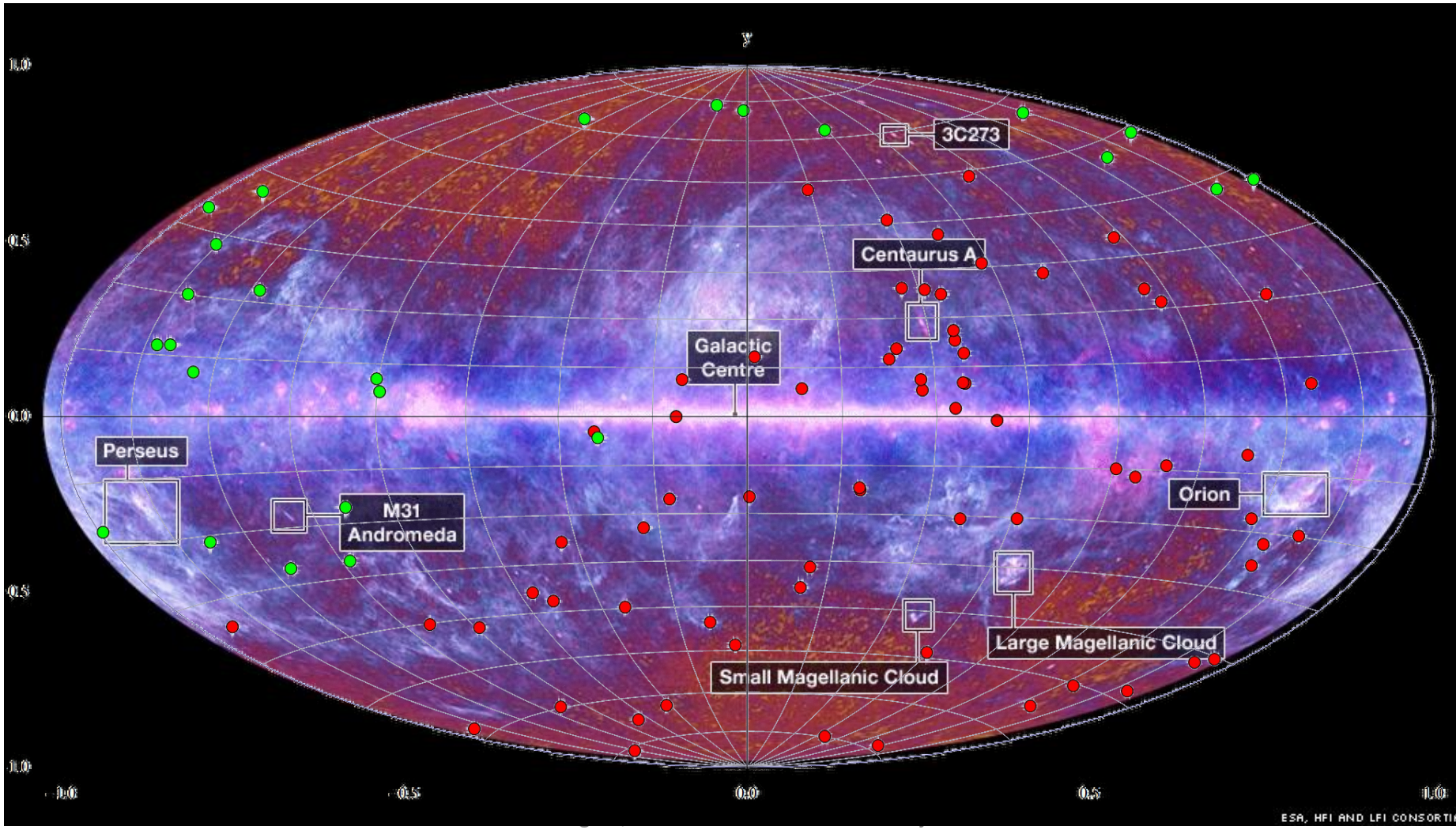
Last TA and AUGER and Multiplet events at 20 EeV…2009→.2011 Possible Lightest Nuclei : He



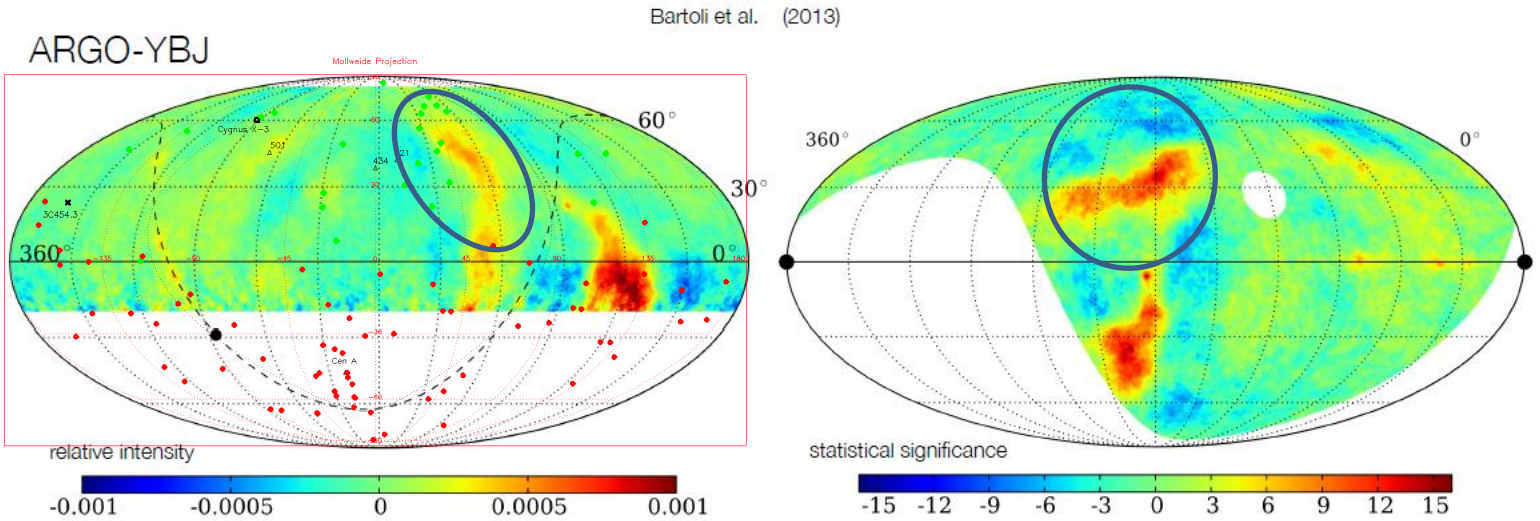
Hints of UHECR related to galactic Planck Maps

- Absence of UHECR in empty dust Planck map
- Possible clustering in Cen A
- Hints of Vela and Cygnus sources
- Galactic Center possible signals
- Most UHECR (excluded Cen A) mostly galactic?
- ARGO-ICECUBE Gamma TeV anisotropy related to radioactive UHECR (Ni,Co) decay ?

PLANCK AND AUGER with TA ..from 55 EeV: UHECR seat where Dust is



Additional anisotropy at TeVs
An Anti-GC Fountain centered on CRAB?



Crab centric Fountain?

- No possible by primary CR at TeVs..but
- Possible

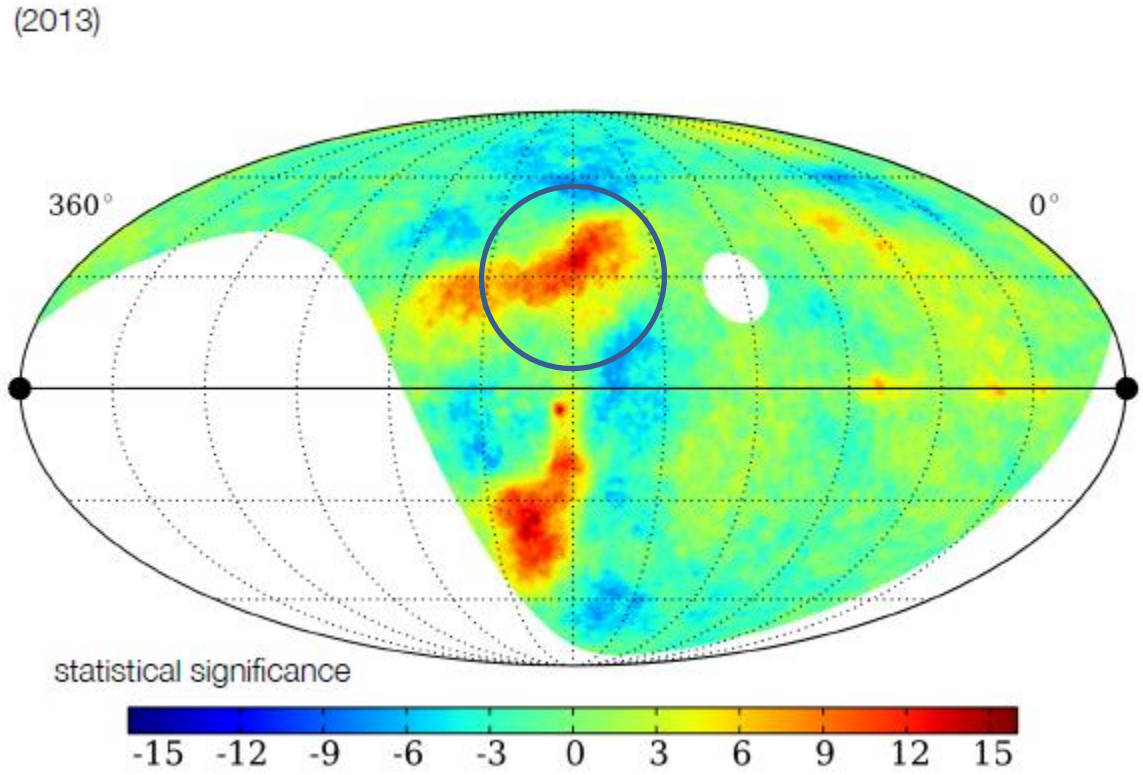
by UHECR

- Secondaries
- **Correlated wit**

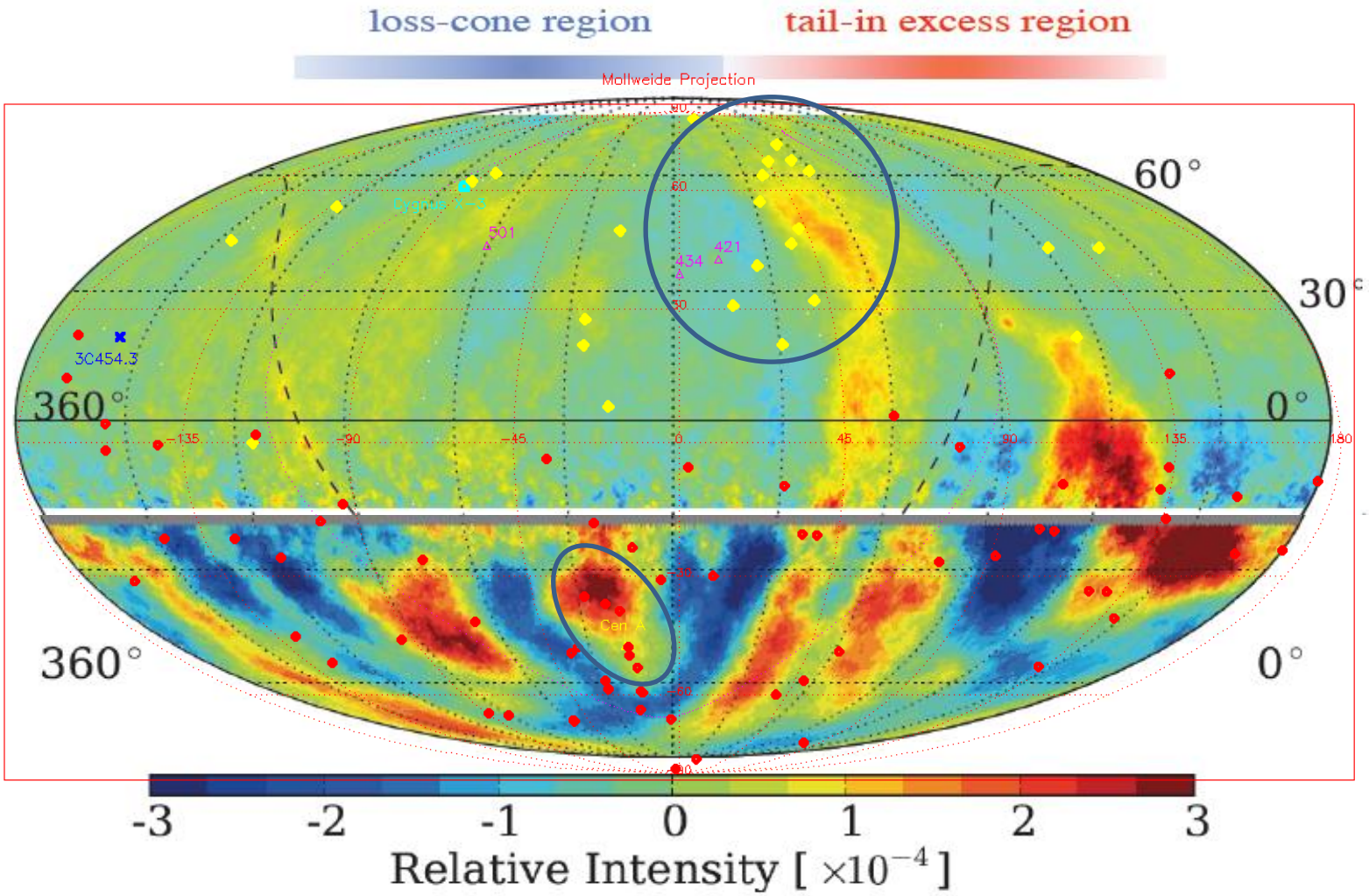
TA anisotropy?

Radioactive

UHECR



The Map CONNECTION: Up dated ARGO Ricap Di Sciascio and ICECUBE Desiati 2013



Neutrino May day 13 →Madison USA

2+ 26 events

If 10-12 of the 28 events are atmospheric than the 7 muon tracks must be mostly of those family.. But why the remaining 18 or 16 events are muon free..?

News by ICECUBE neutrino results

- No GRBs correlated in time (just three precursors)

  No Double Bangs

  No Glashow resonance at 6.3 PeV

  Need of a cut at few PeVs

No clustering at expected certain sources

28 Shower (smeared), 9 muon tracks

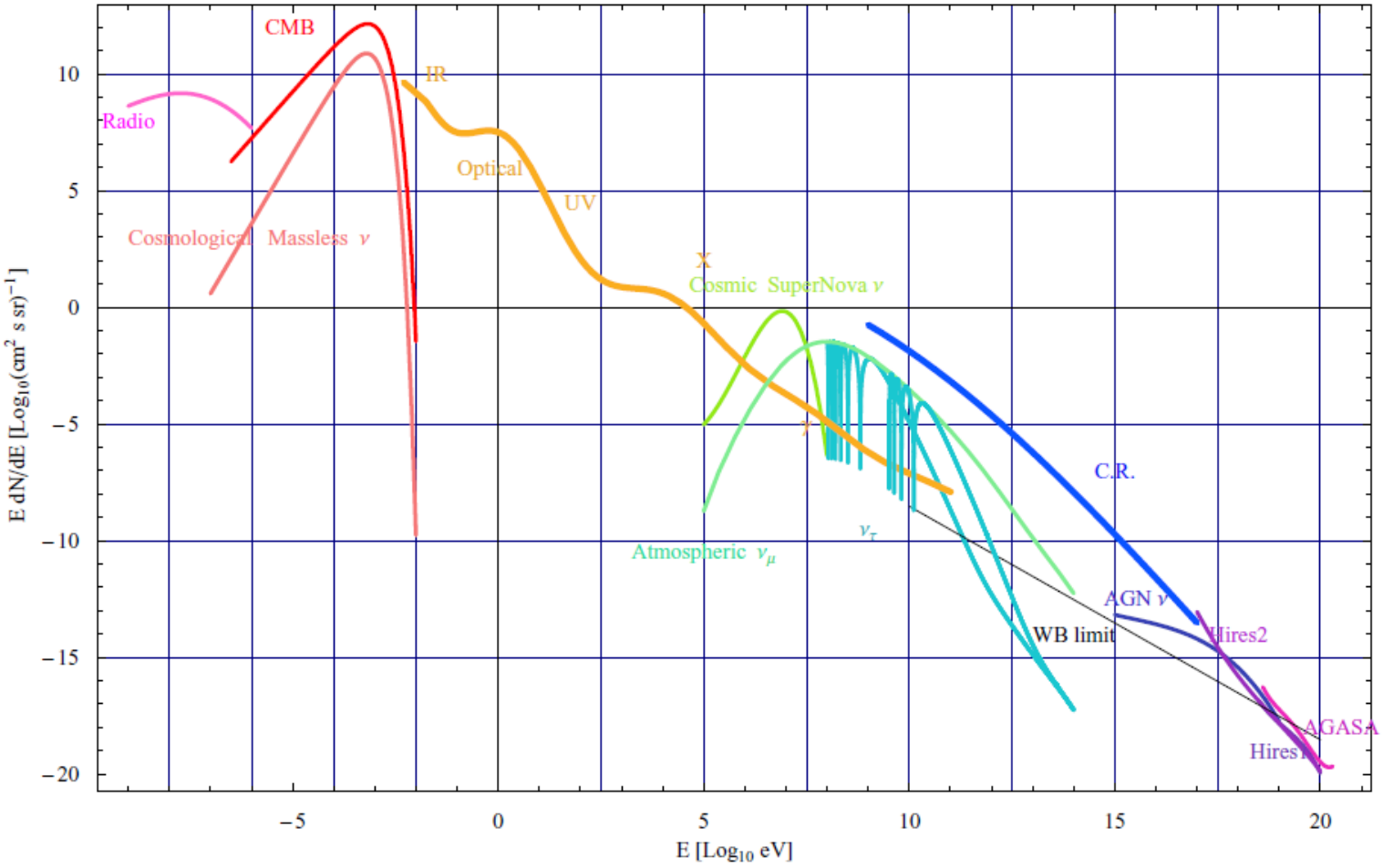
Harder spectra than atmospheric ones

BUT

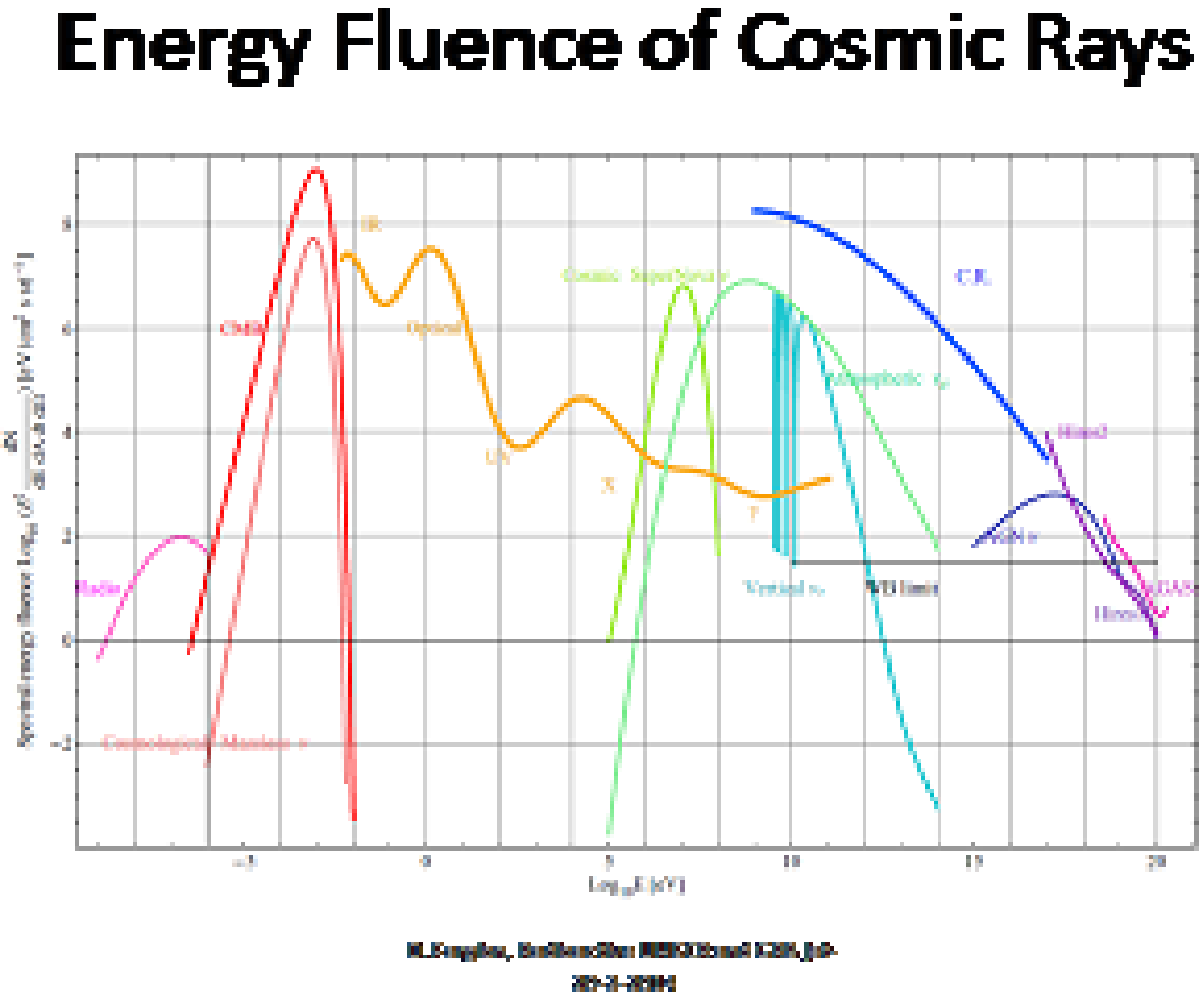
A flavor revolution : Inshowers Tau discovered even if hidden with electron and NC

Above few tens TeV all extragalactic

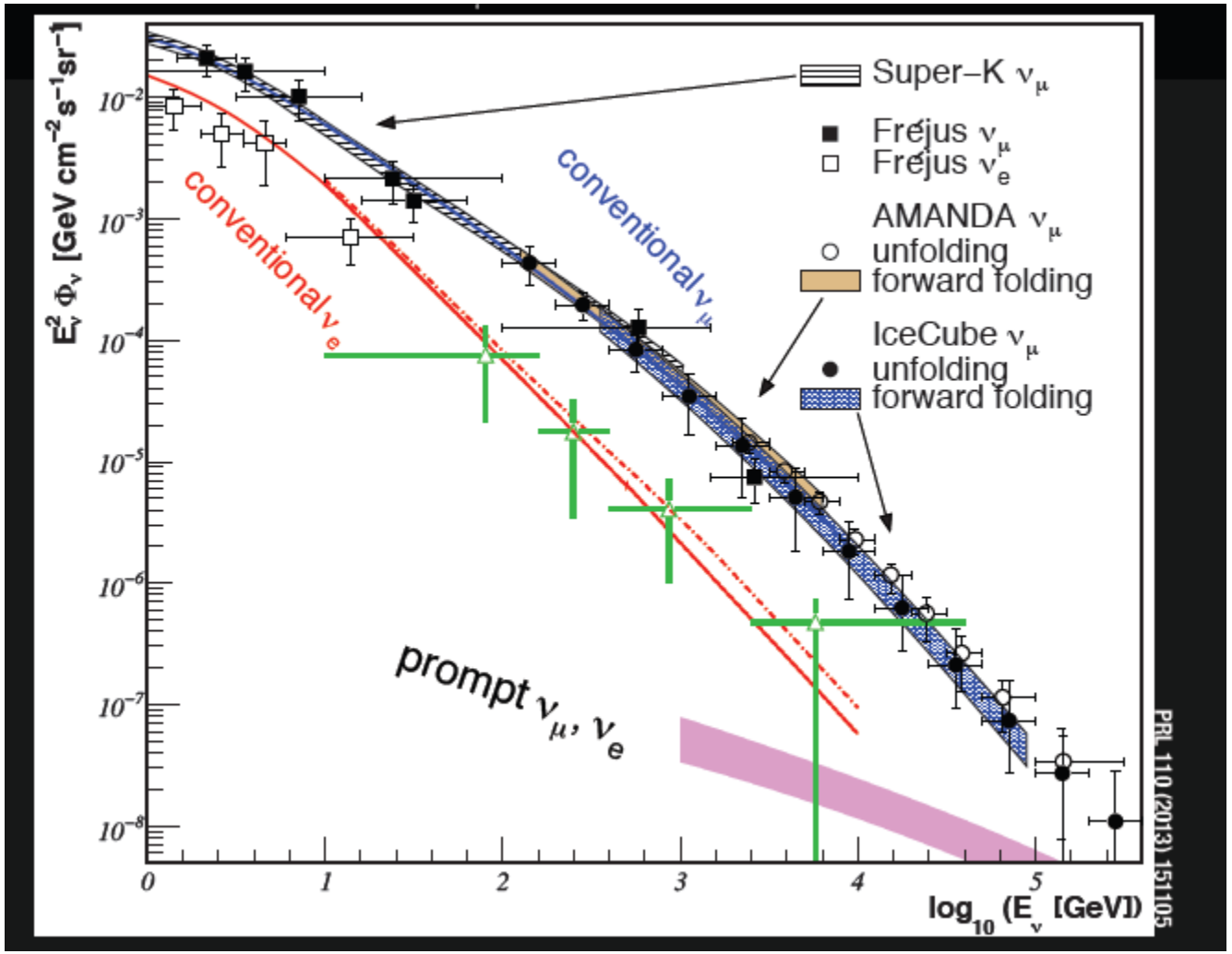
*Summary of CR Spectra:Cosmic Rays Number Flux as energy: Log dN/(dt.dA.dE.dsr)*dE*



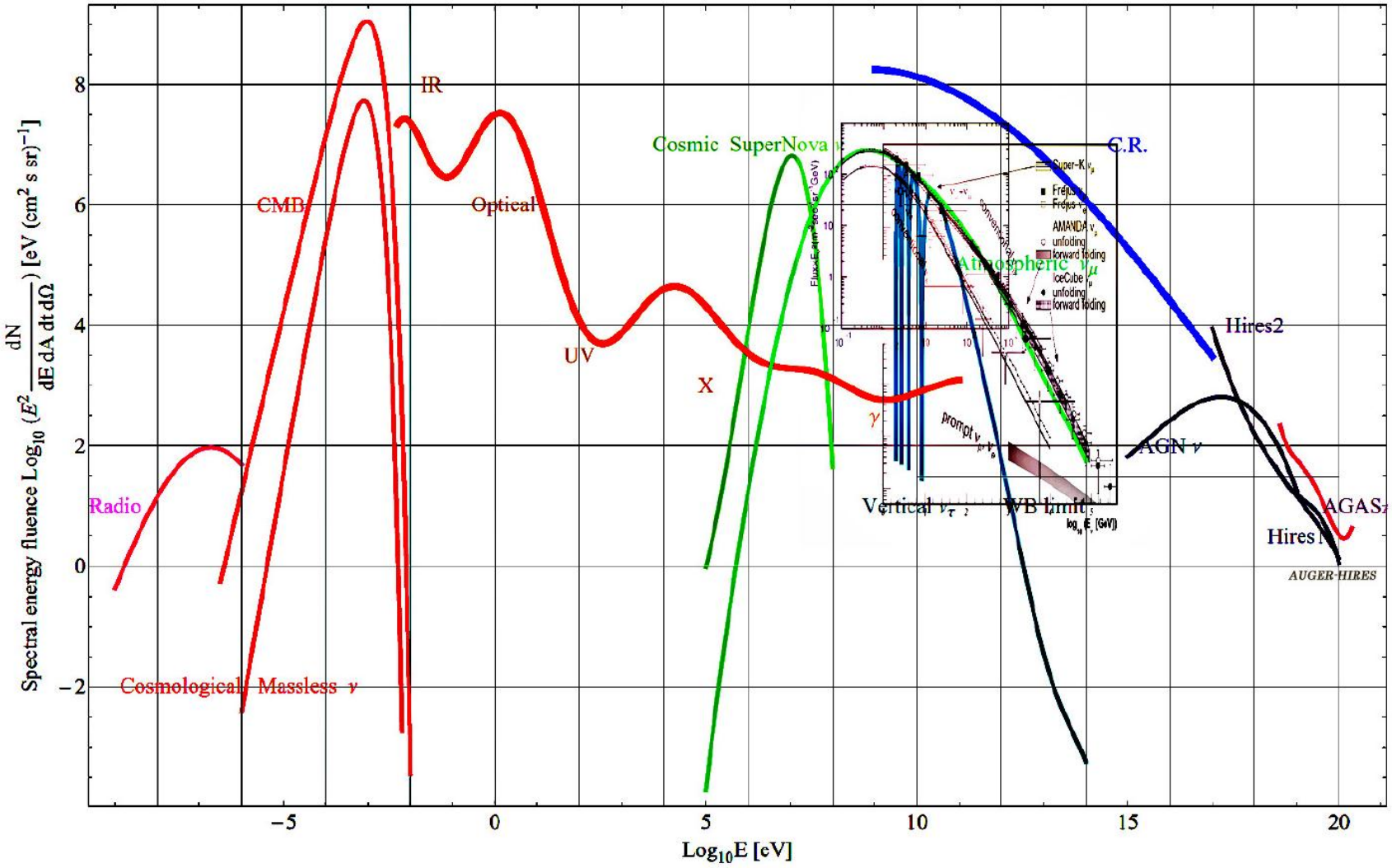
Energy fluence map



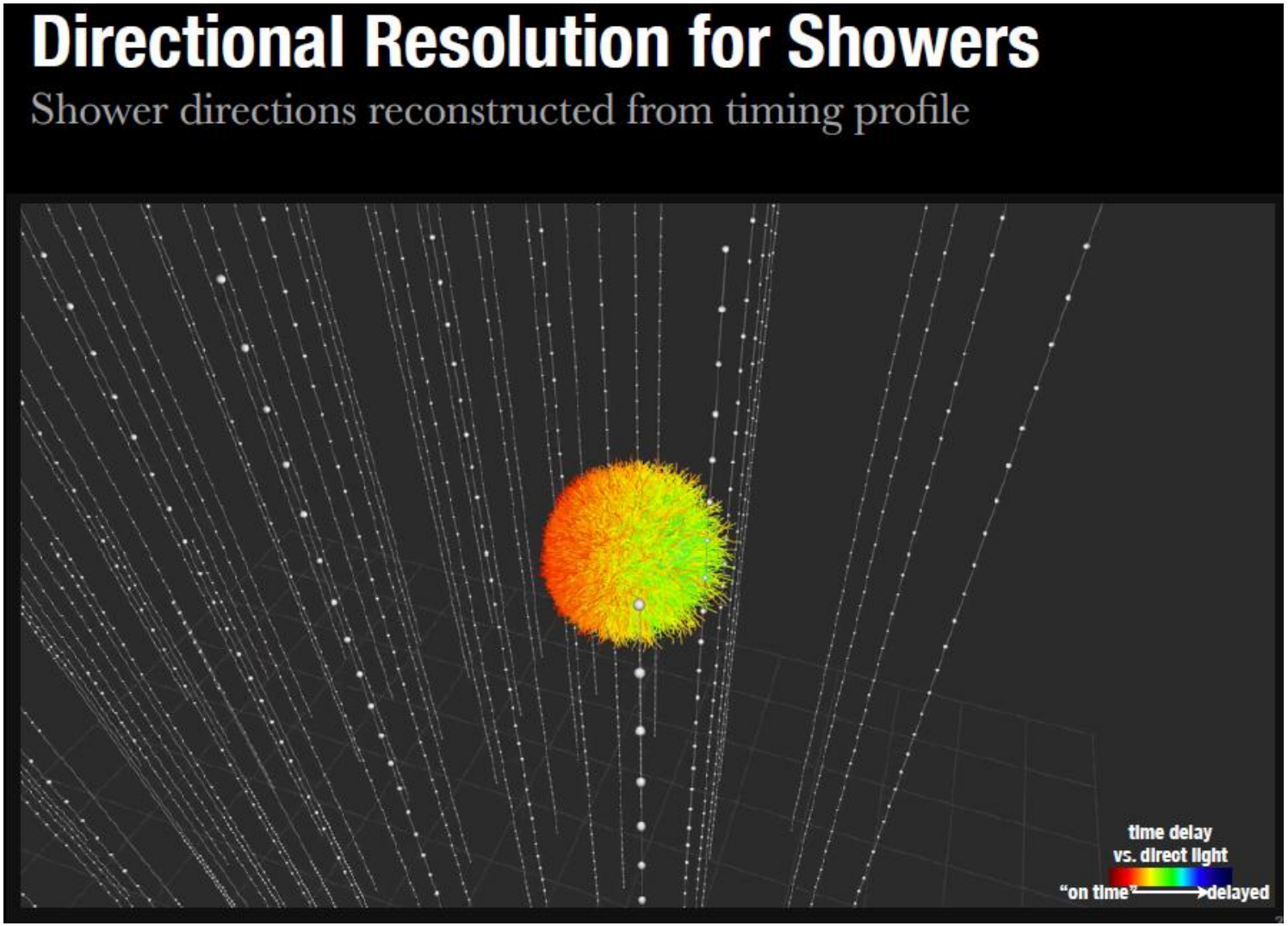
Reading new signal in a mess of cosmic rays noise secondaries



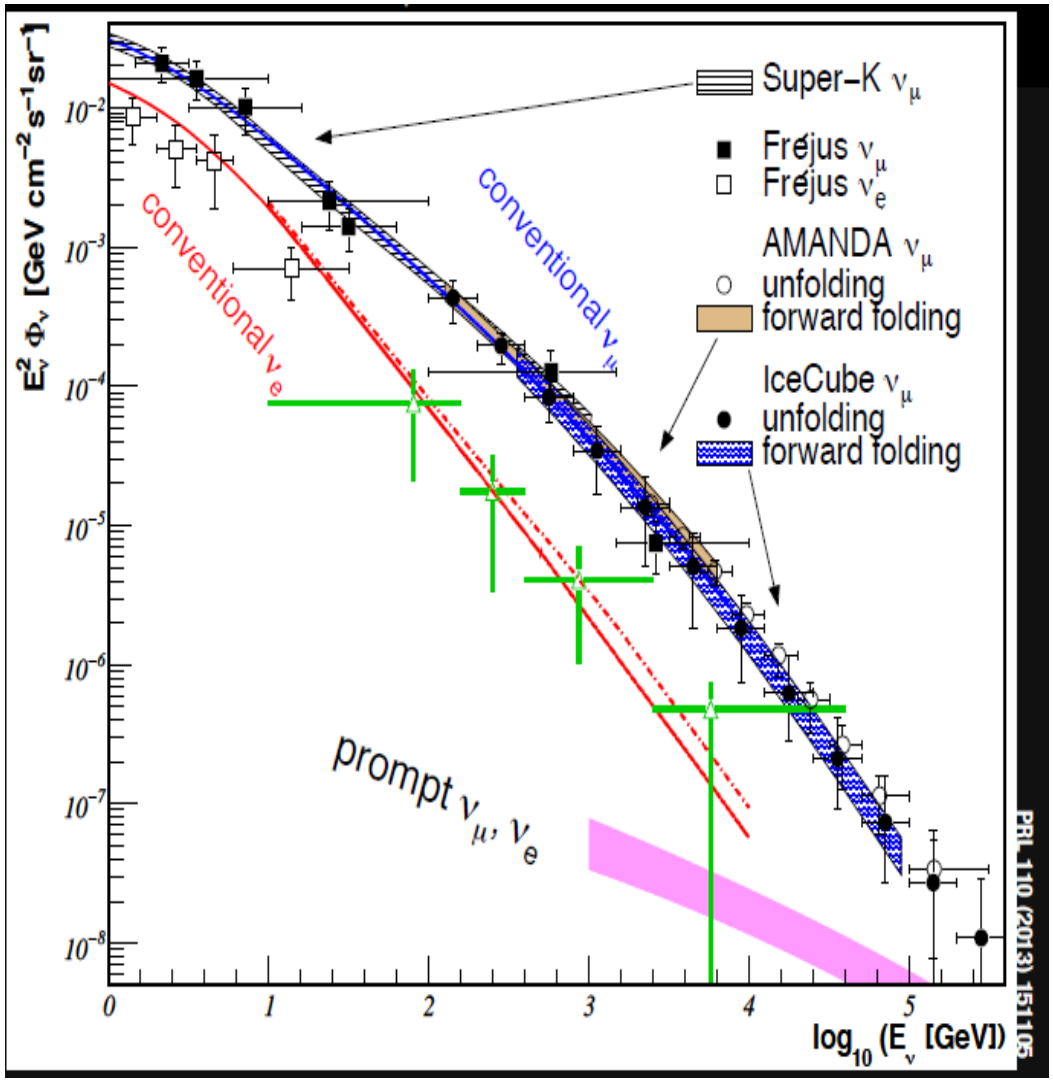
Why a new astronomy ? New windows to deep Universe and Cosmic Rays Sources



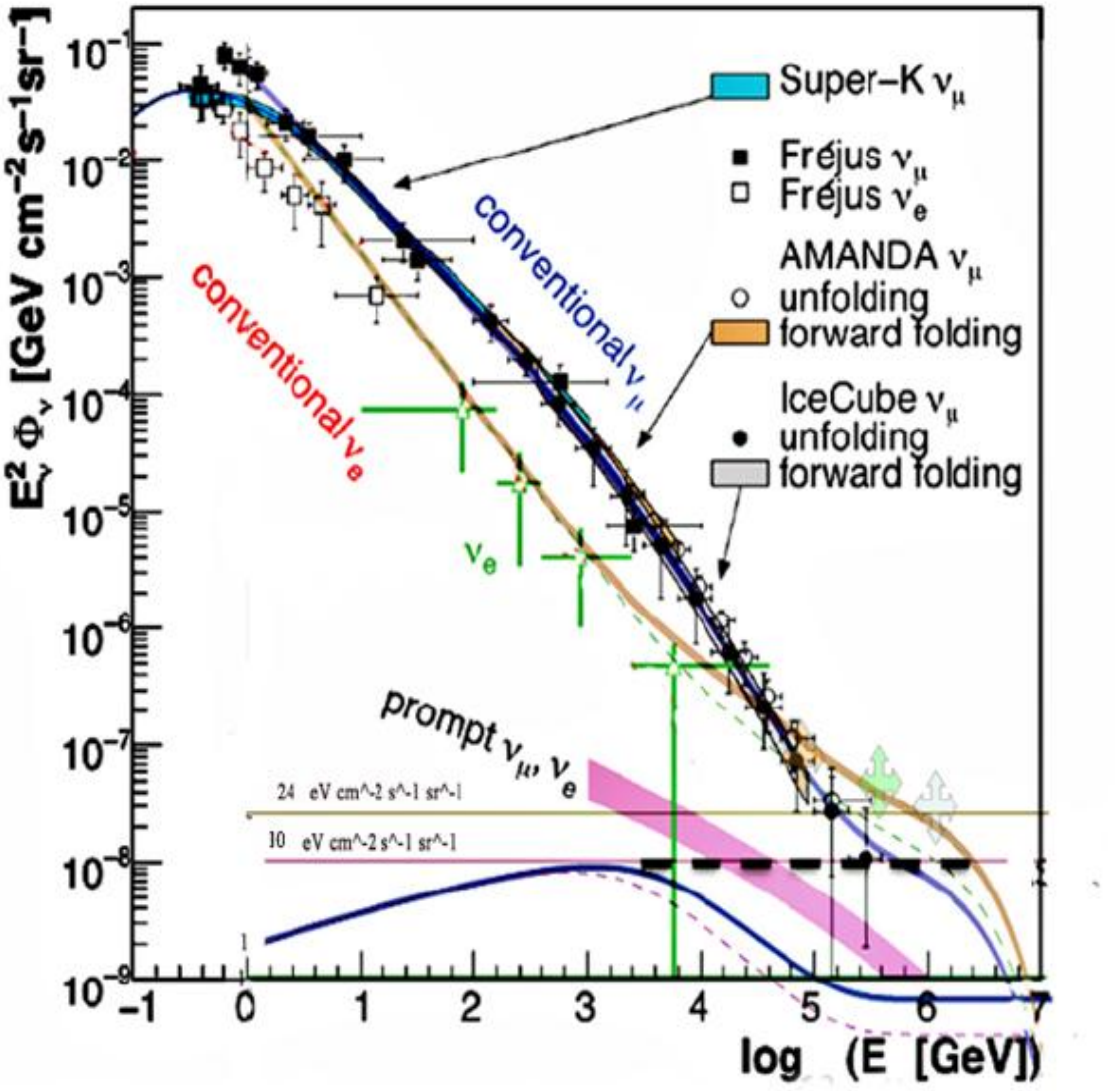
Mini revolution
Timing able to disentangle directions



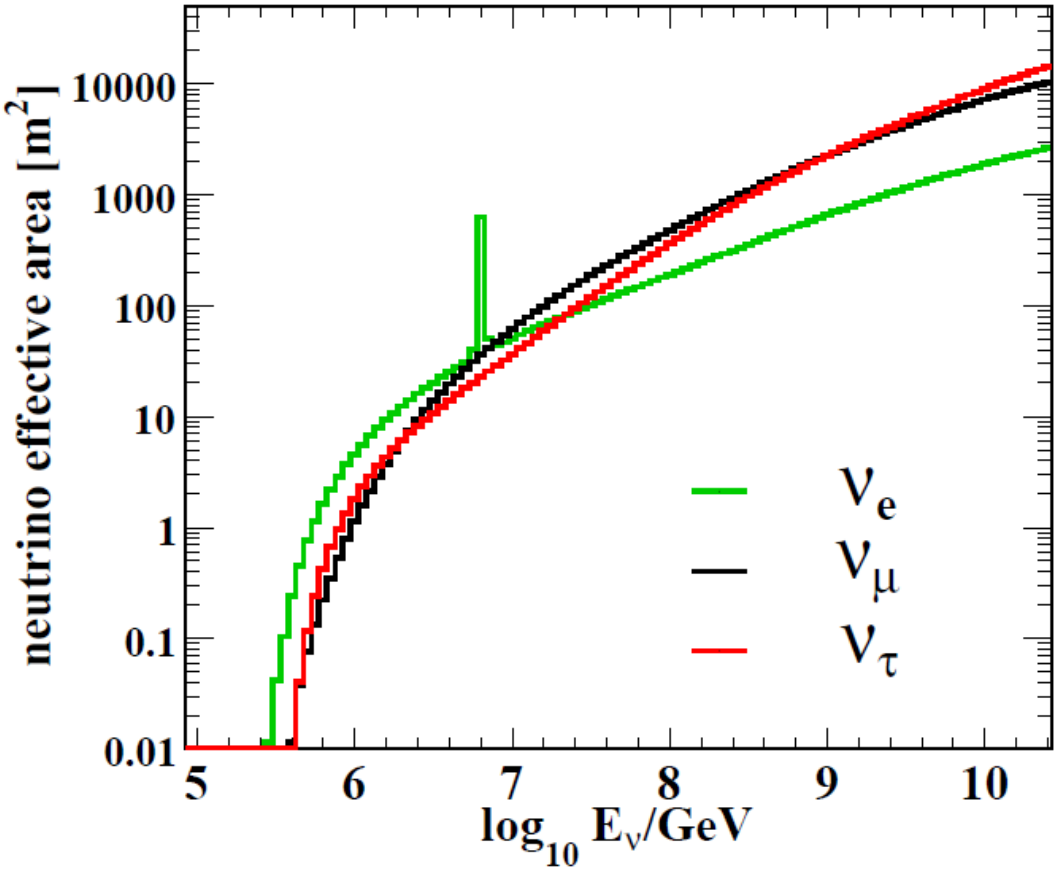
Spectra before

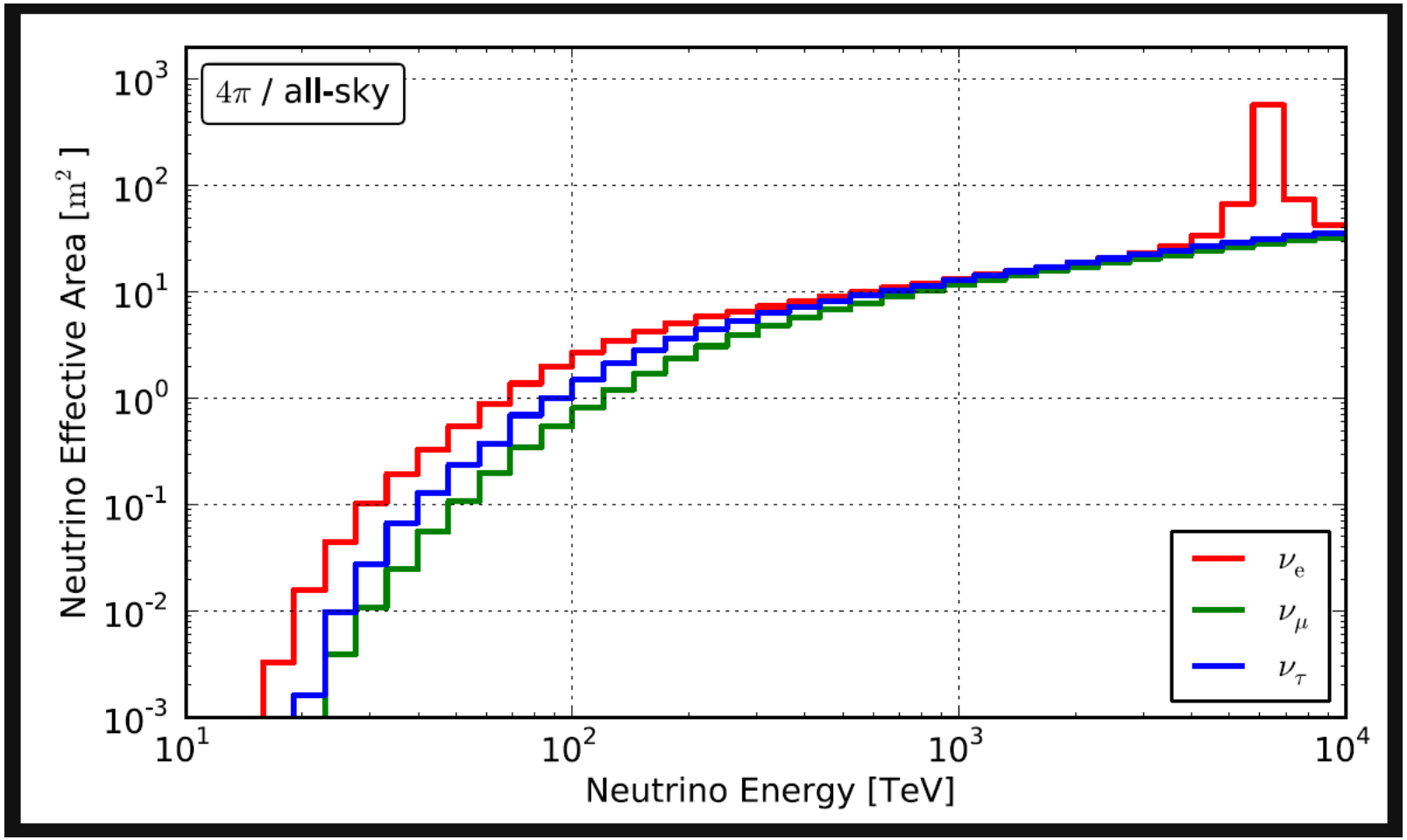


Wider spectra after: 2+ 26+(8+1)



The Glashow resonance




4π / all-sky
Neutrino Effective Area [m^2]
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^1
10^2
10^3
10^4
Neutrino Energy [TeV]
ν_e
ν_μ
ν_τ

A Flavor revolution

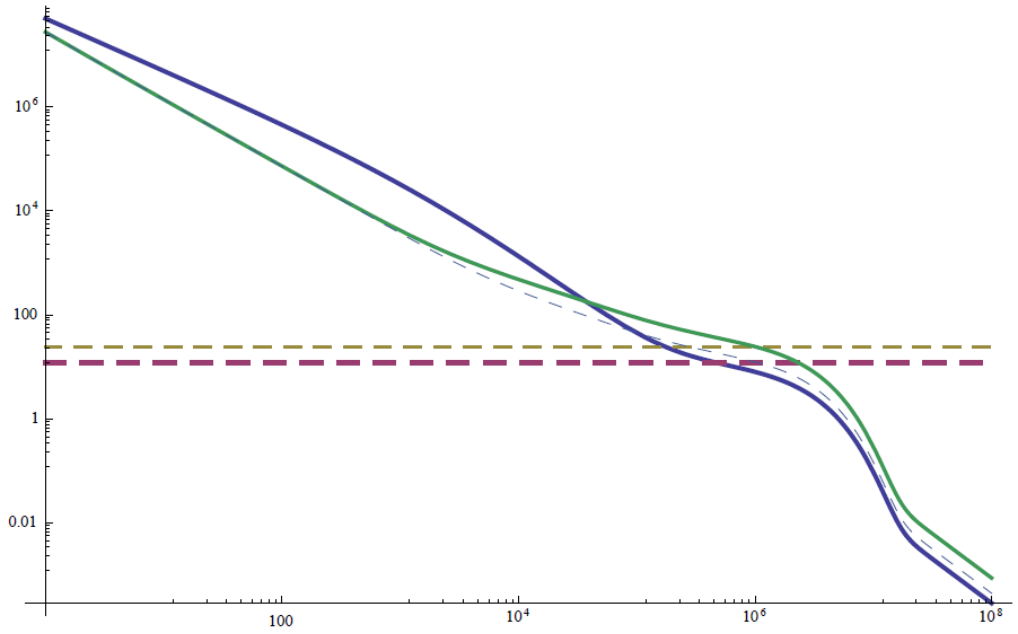
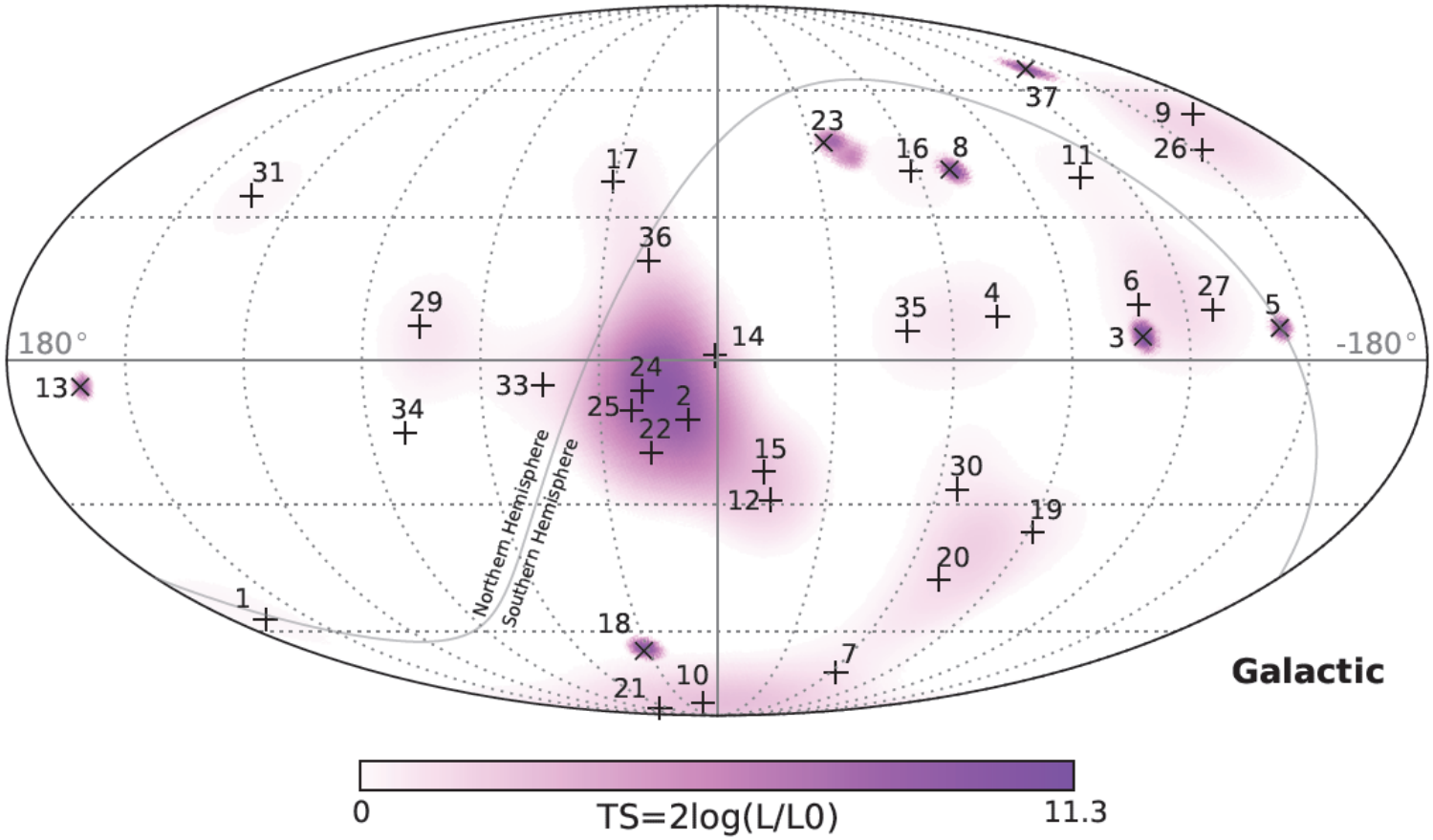


Figure 4: Energy Fluency for ν_e,$\bar{\nu}_e$,ν_τ $\bar{\nu}_\tau$ flavor Φ_{ν_e},Φ_{ν_μ} in $eVcm^{-2}s^{-1}sr^{-1}$ unity, as a function of the neutrino energy in GeV within a log-log graph. Note that the horizontal twin dashed lines stand for the observed fluency at highest ICECUBE energy for one or two flavor. The thin dashed curve describe the role of one (of the two) showering flavor fluency by present description model

Today ICECUBE updated 3d year: 37 events

Observation of High-Energy Astrophysical Neutrinos in Three Years of IceCube Data

arXiv:1405.5303v1 [astro-ph.HE] 21 May 2014



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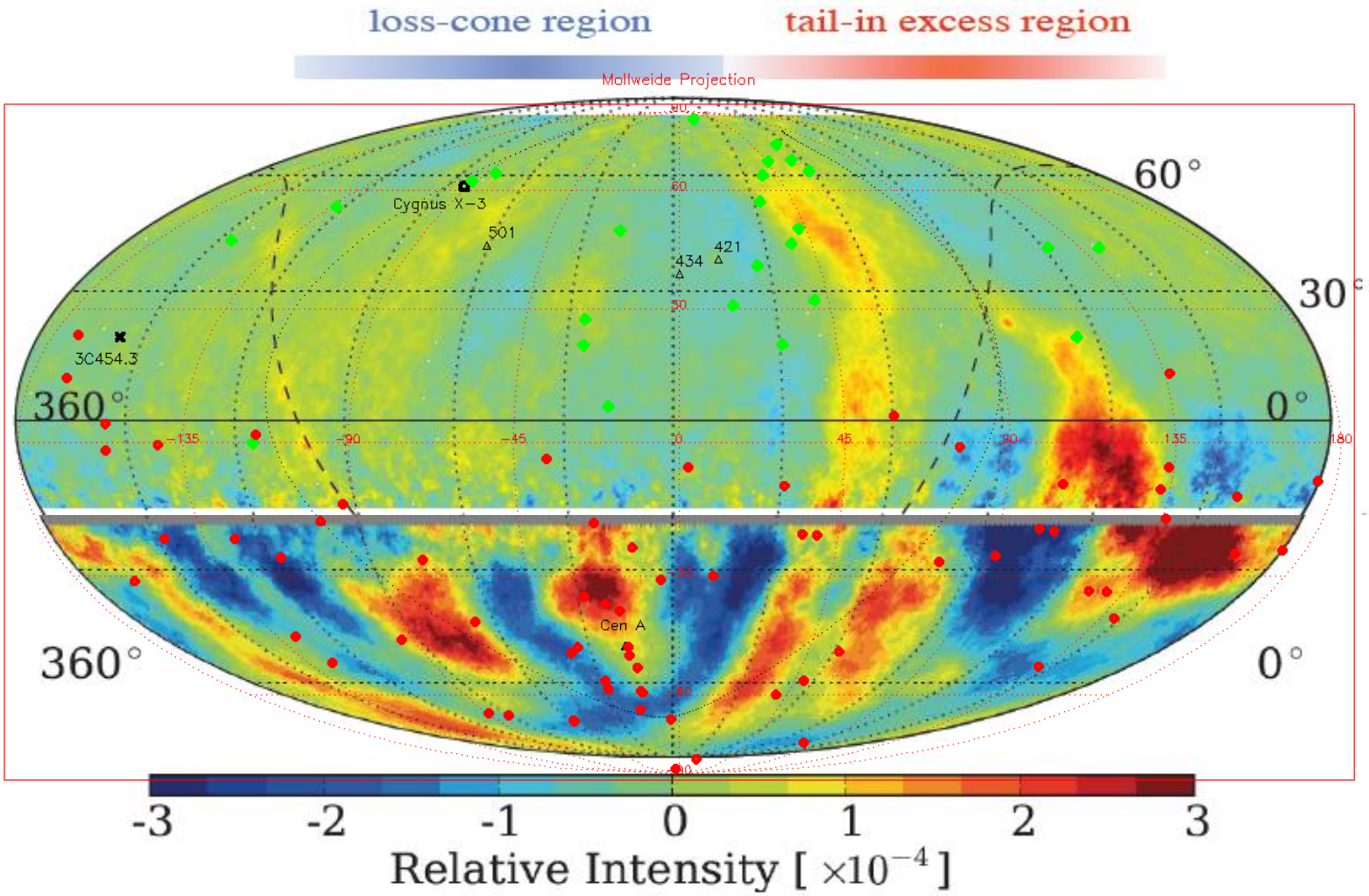
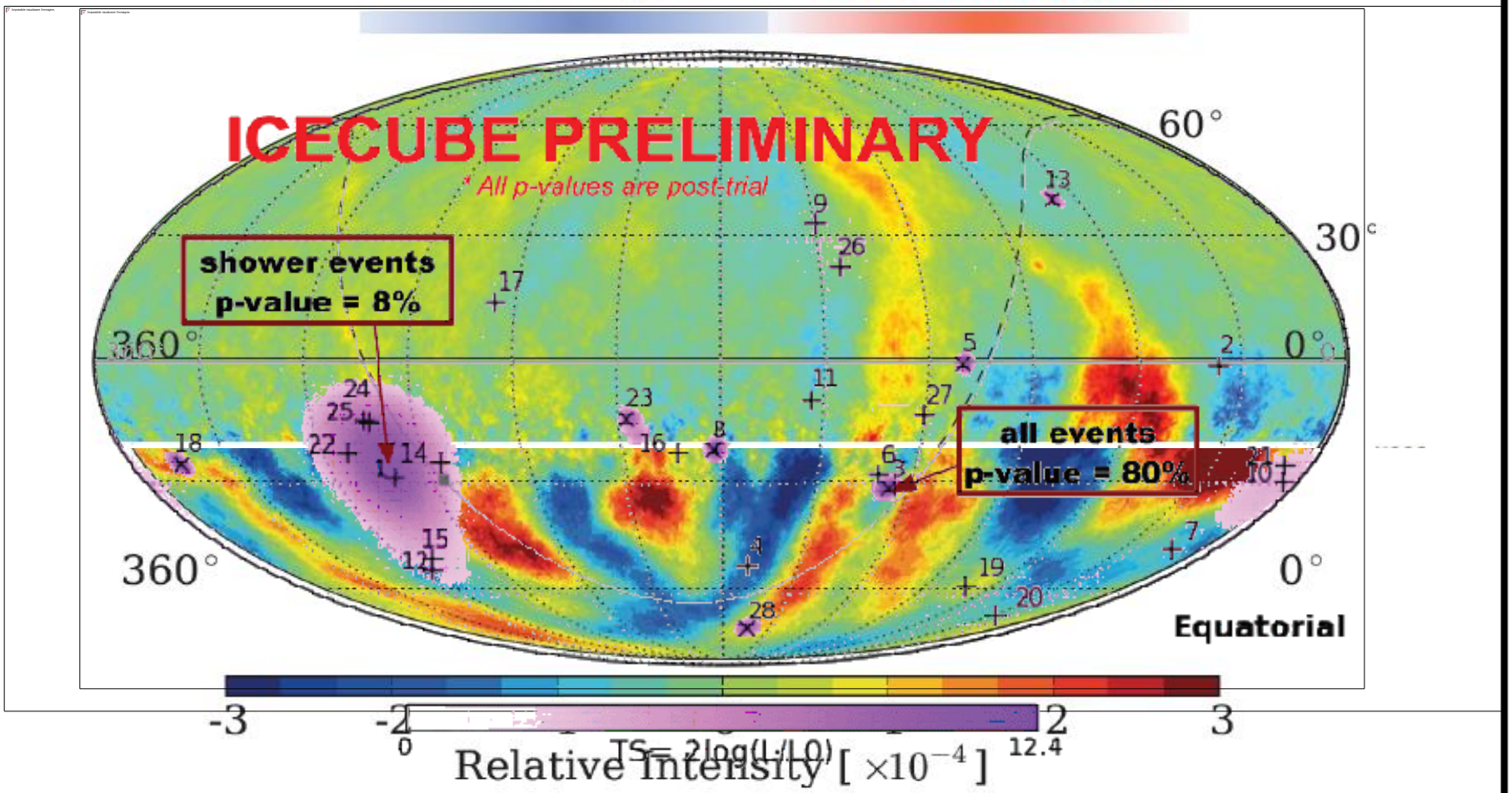
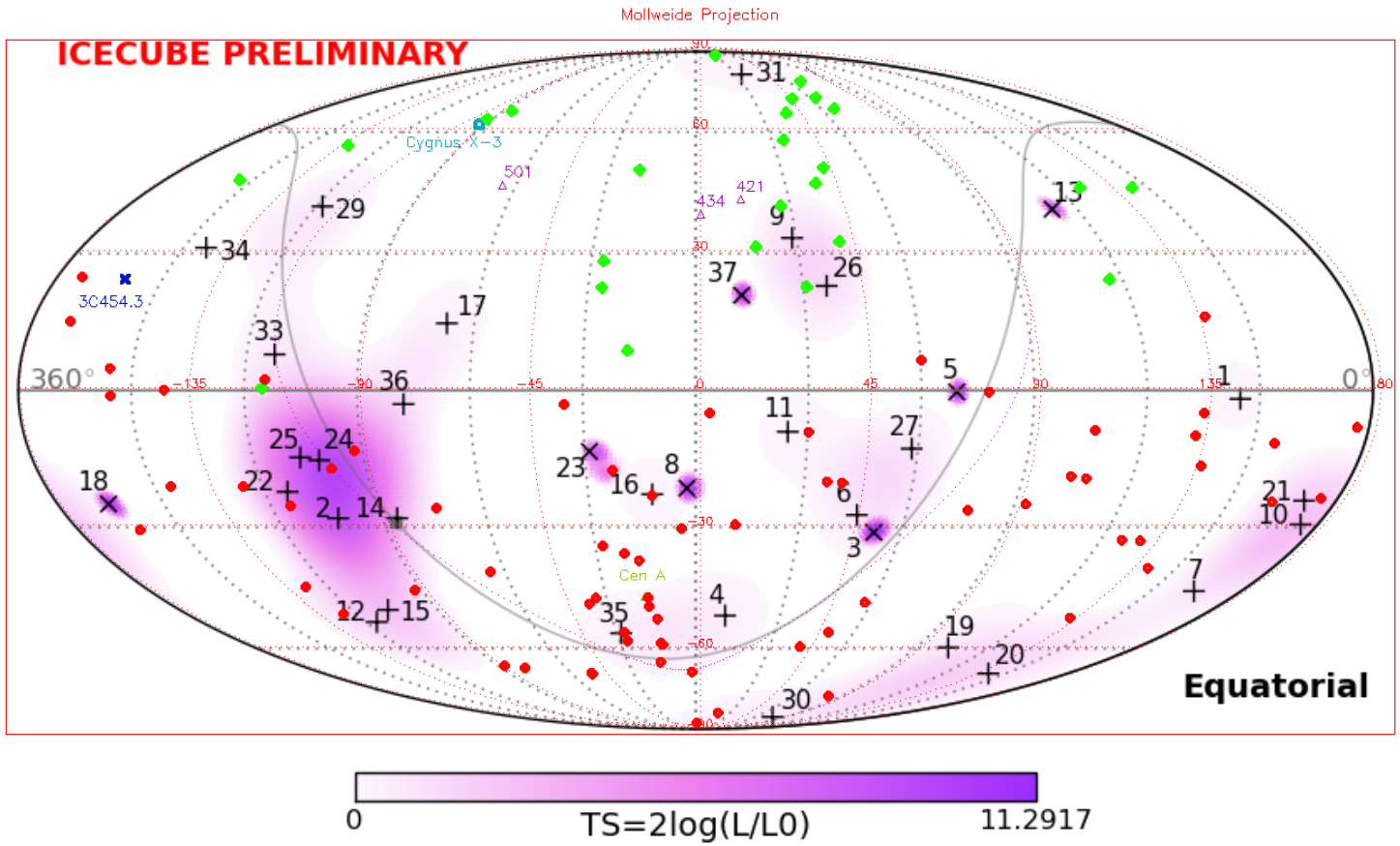


The Map CONNECTION: Up dated ARGO Ricap Di Sciascio and ICECUBE Desiati 2013

Skymap: No Significant Clustering



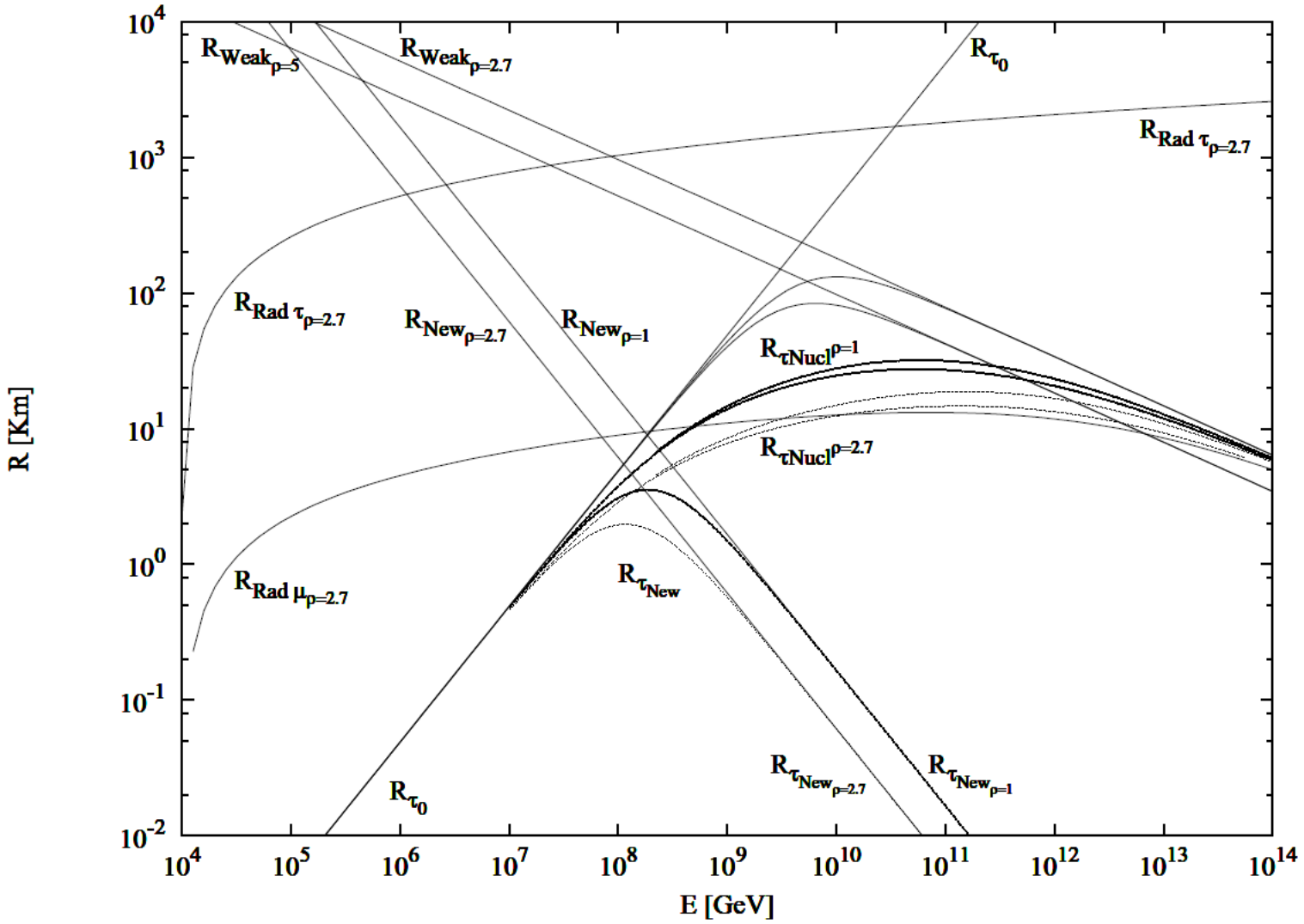
Possible Clustering at Vela and GC? The role of UHECR?



What next?

- More events than shower smooth ones
- Much better directionality
- Muons neutrino can be the best candidates
- External ones are born in wider volumes
- Muons above 30 TeV by muon neutrinos may be born within larger distances and volumes
- 9 Observed muons may be amplified by 50-60 crossing UHE TeV muons
- Such Tracks show Solid angle hundred times smaller

Muon lenght


R [Km]
E [GeV]
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14}
$R_{Weak_{\rho=5}}$
$R_{Weak_{\rho=2.7}}$
R_{τ_0}
$R_{Rad\ \tau_{\rho=2.7}}$
$R_{Rad\ \tau_{\rho=2.7}}$
$R_{New_{\rho=2.7}}$
$R_{New_{\rho=1}}$
$R_{\tau Nucl^{\rho=1}}$
$R_{\tau Nucl^{\rho=2.7}}$
$R_{Rad\ \mu_{\rho=2.7}}$
$R_{\tau_{New}}$
R_{τ_0}
$R_{\tau_{New_{\rho=2.7}}}$
$R_{\tau_{New_{\rho=1}}}$

arXiv:1404.5914

2 Contained versus crossing muons at TeVs-PeV

The high energy muon μ , $\bar{\mu}$ are the most penetrating muons (up to EeV energy where τ , $\bar{\tau}$ become the winning leptons) and they may be originated well outside the same ICECUBE volume. Their larger size detection simply amplify the ν_μ neutrino volume and their presence: the energy losses of the muons is (within TeVs-PeVs energy) reasonable foreseen, growing proportionally to the muon energy, therefore linking their emission photon number to their energy and its μ length to the logarithmic energy growth; these distances are leading to a larger volume and a wider rate of crossing muon neutrino events. The muon distance in the water or ice may be described [8] within (TeV-PeV) by this simple phenomenological law:

$$L_\mu \simeq L_o \cdot [1 + \frac{3}{2} \log \frac{E_\mu}{TeV}]; \tag{1}$$

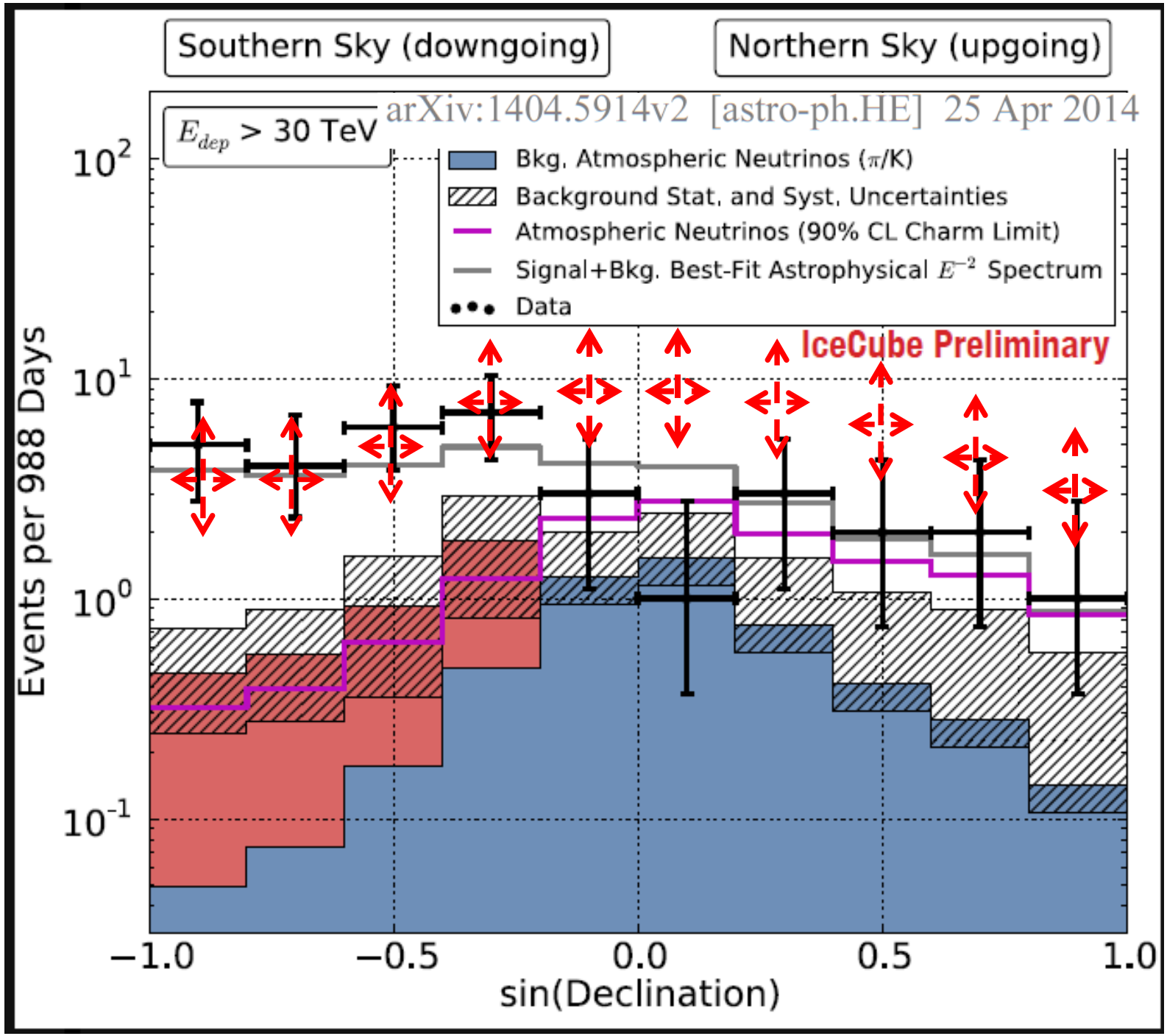
3 Probability to find pairs, triplets in the μ sky

Let us estimate for present (approximated) 54 forecast crossing UHE muons events, each of them occupying a tiny solid angle of area a (for a muon resolution angle $\theta \simeq 1^o$), $a \simeq \frac{\pi}{57^2} \simeq 9.7 \cdot 10^{-4} sr.$ respect the whole area $A = 4 \cdot \pi$ sky, is: $\frac{a}{A} = \frac{\Delta\Omega}{\Omega}$; this ratio, $\epsilon = \frac{a}{A}$ is very small:

$$\epsilon \simeq \frac{\pi \cdot \theta^2}{4\pi} \simeq 10^{-4}$$

The last enhanced approximation takes place because we considered (again as a zero order approximation) at $30 - 50$ TeV energy, a partial neutrino opacity to the Earth reducing the whole observable sky from 4π to nearly 3π. Therefore the probability to overlap with any other different neutrino event maybe estimated. It is more convenient to estimate first the probability P_{non} *to not observe* any overlapping (doublet, triplet, poker))in the sky; This value is:

$$P_{non} = 1 \cdot (1 - \epsilon) \cdot (1 - 2\epsilon)...(1 - (n-1)\epsilon); \tag{2}$$


Southern Sky (downgoing)
Northern Sky (upgoing)
arXiv:1404.5914v2 [astro-ph.HE] 25 Apr 2014
E_{dep} > 30 TeV
Bkg. Atmospheric Neutrinos (π/K)
Background Stat. and Syst. Uncertainties
Atmospheric Neutrinos (90% CL Charm Limit)
Signal+Bkg. Best-Fit Astrophysical E^{-2} Spectrum
Data
IceCube Preliminary
Events per 988 Days
10^2
10^1
10^0
10^{-1}
−1.0
−0.5
0.0
0.5
1.0
sin(Declination)

More pairs, more Astronomy

$$P_{\geq 2} = 1 - P_0 - P_1 \simeq [1 - e^{-\epsilon \cdot \frac{n\cdot(n-1)}{2}}(1 + \epsilon \cdot \frac{(n-1)(n-2)}{2})] \tag{5}$$

This result in such a first forecast may be also written as follows:

$$P_{\geq 2} \simeq [\epsilon \cdot \frac{(n-1)^2}{2}]^2 = 1.97\% \tag{6}$$

Therefore the finding of two or more pairs may reduce the probability to be a chance (or viceversa it may confirm the ν self correlation) at a small percent. Three pairs as we may expect reduce this probability at nearly below 0.4%; the same presence of just one triplet may also reduce the probability to be a chances as small as $P_3 \simeq 0.07\%$. A quadruplet or more multiplets might drive the neutrino astronomy even to a potential test of flavor ratio estimates, a revolution now, beyond to our most optimistic dreams.

In conclusion:

Flavor Neutrino Revolution and Crossing muons as a cornestone in Neutrino Astronomy

arXiv:1310.3543 DF and Paolo Paggi
Flavor revolution at ICECUBE horizons?
NIMA Volume 753, 21 July 2014, Pages 9—13

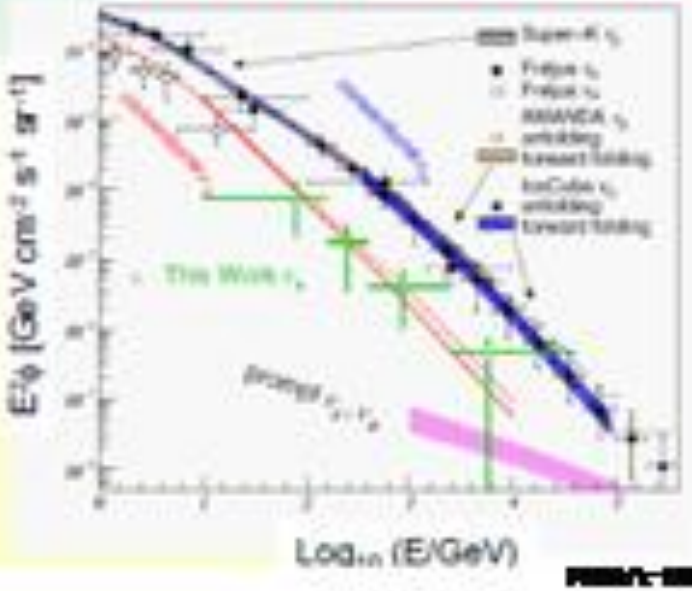
arXiv:1404.5914 DF
Crossing muons in Icecube at highest energy:
Cornerstone to neutrino astronomy

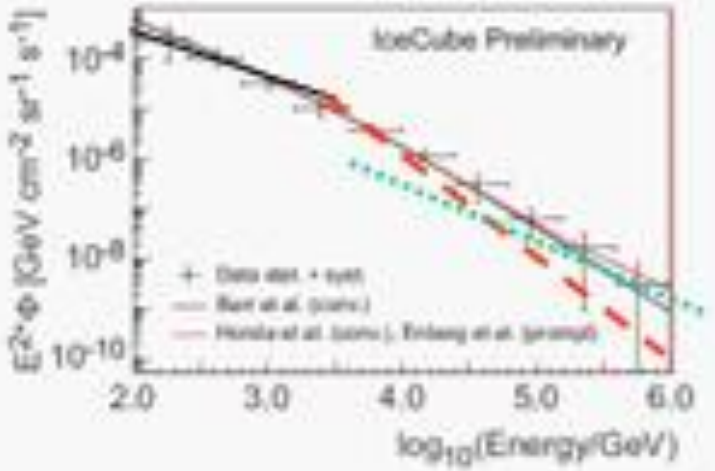
Thank you for the kind attention

Atmospheric neutrinos measurements

- ν_e flux measured from 80 GeV to 6 TeV
  - Showers in DeepCore; rest of IceCube is veto
- ν_μ measured up to 1 PeV
  - Not yet sensitive to prompt component
  - Dominated by systematic uncertainties
- ~ 5% seasonal rate variation seen for ν_μ from Antarctica

PRL 110, 151105 (2013)





Fine ossia End

The (Very) High-Energy Tail

Searching for a signal above the atmospheric neutrino background

Signals and Backgrounds

Signal

- Dominated by showers (~80% per volume) from oscillations
- High energy (benchmark spectrum is typically E^{-2})
- Mostly in the Southern Sky due to absorption of high-energy neutrinos in the Earth

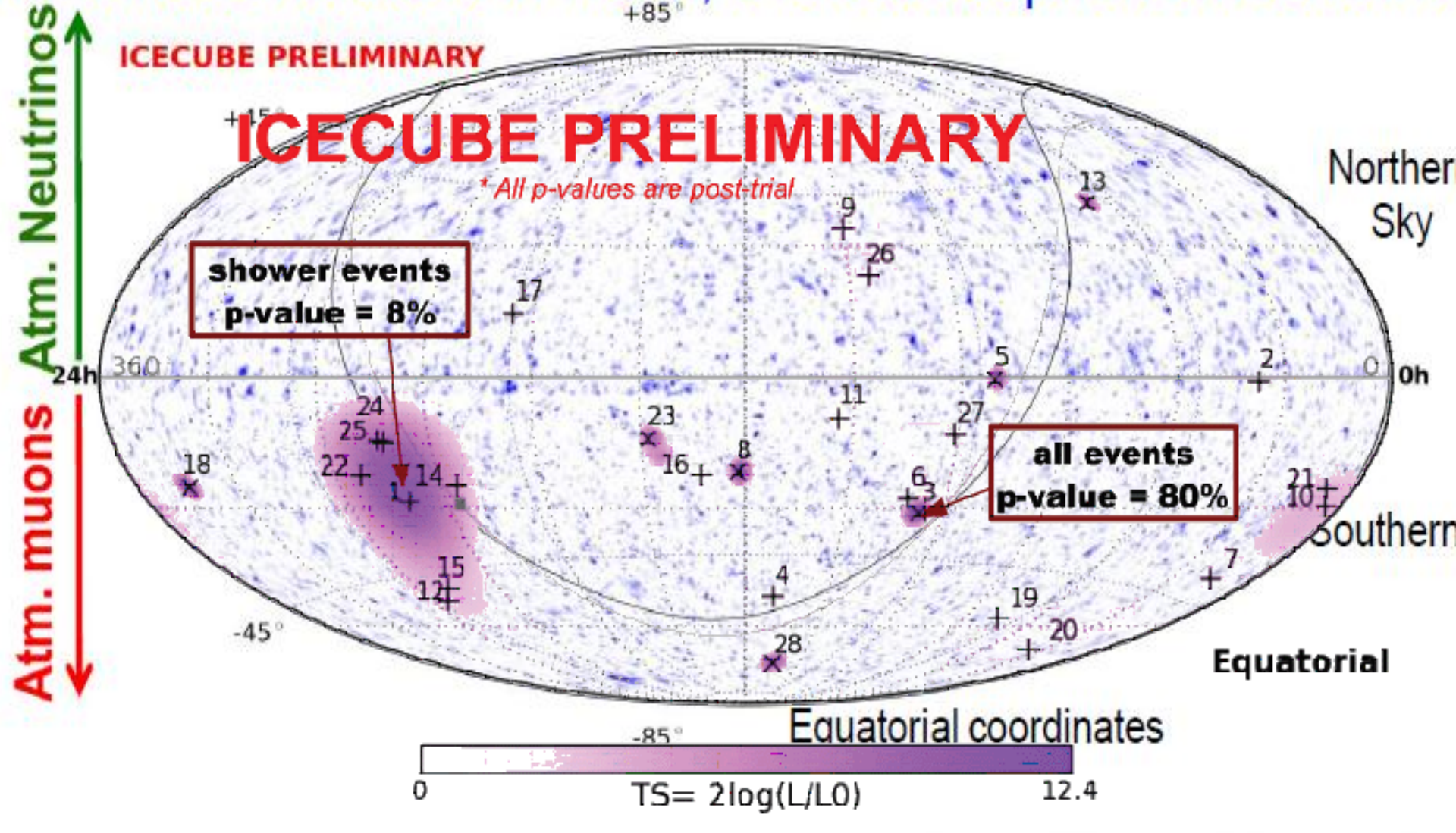
Background

- Track-like events from Cosmic Ray muons and atmospheric ν_μ
- Soft spectrum ($E^{-3.7}$ - $E^{-2.7}$)
- Muons in the Southern Sky, neutrinos from the North

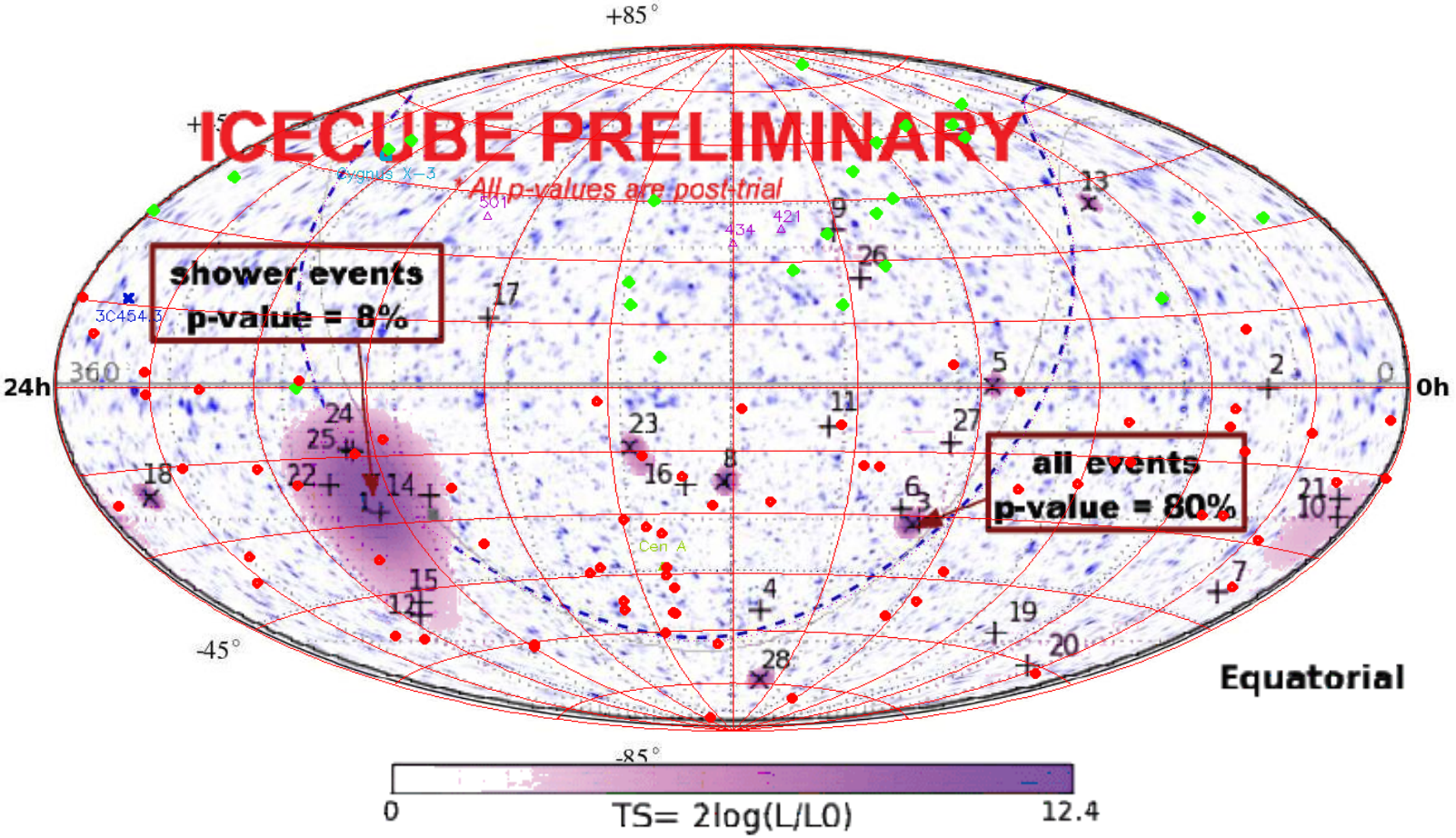
00 total events in 1371 days

Skymap: No Significant Clustering

neutrino candidates in North, 216k atmospheric muons in S



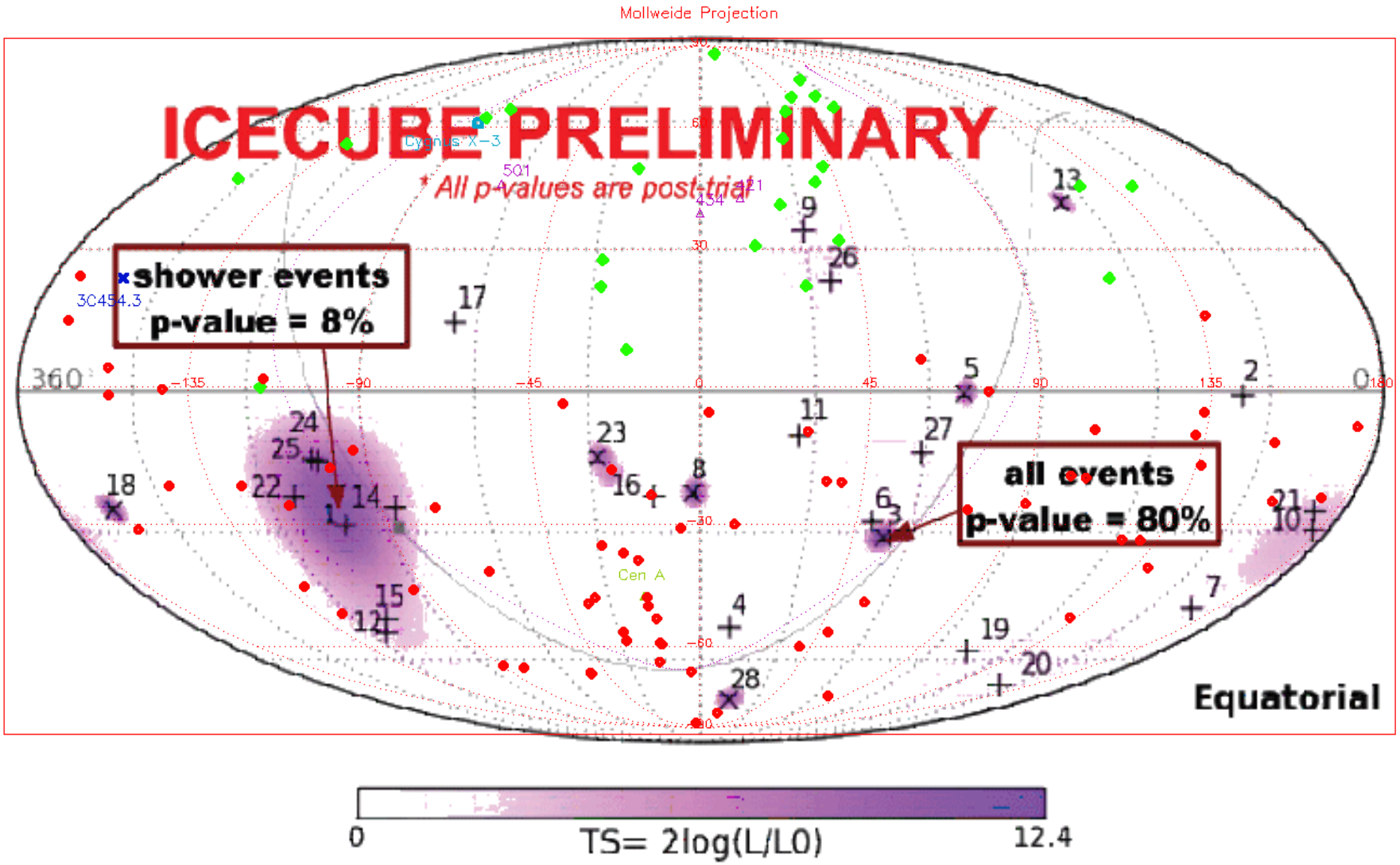
Skymap: No Significant Clustering



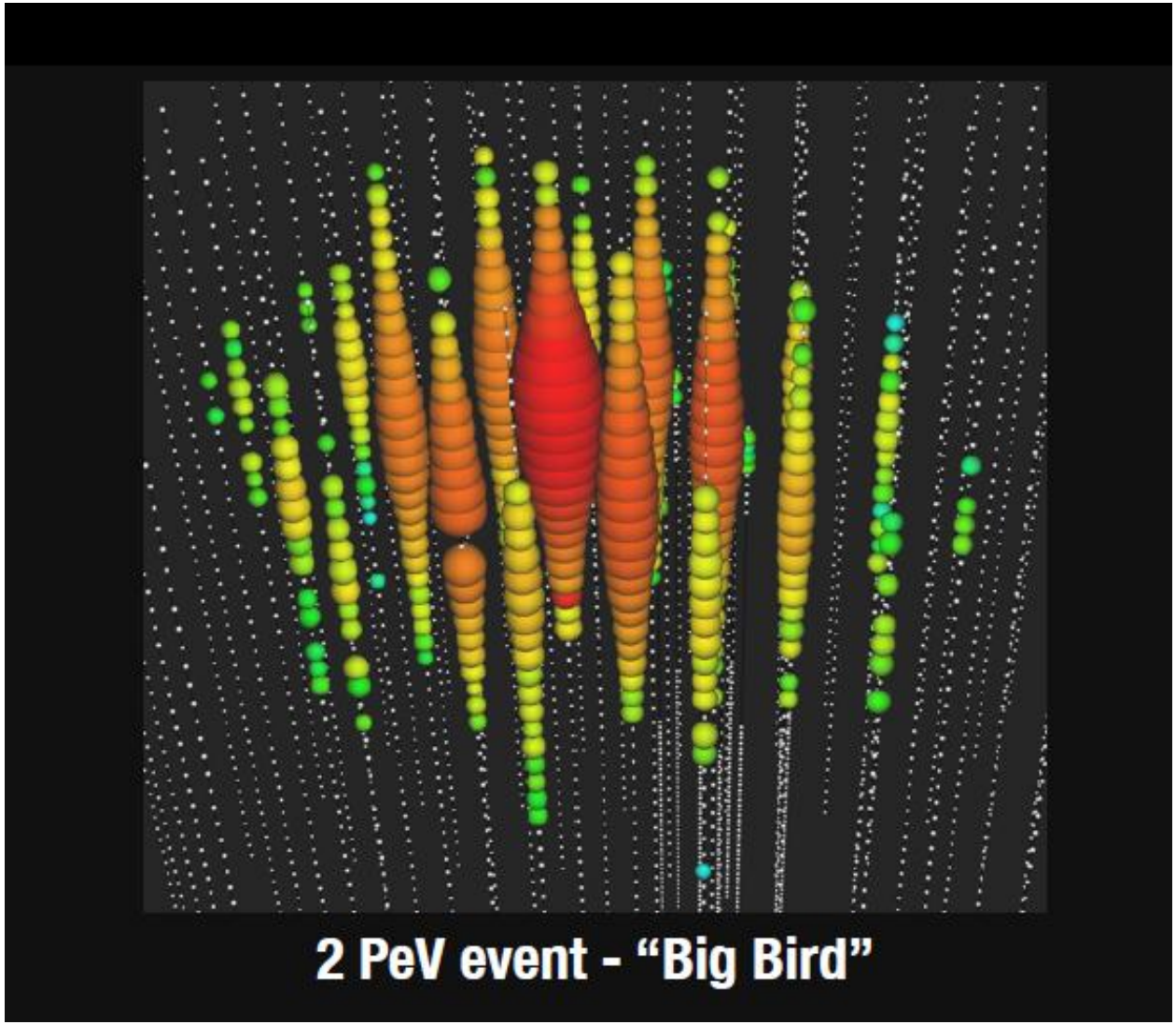
See: talk by Naoko Kurahashi Neilson

Parallele senza GRIGI

kymap: No Significant Clustering



A third 2-PeV event: Bird



Crossing muons in Icecube at highest energy: Cornerstone to ν Astronomy

arXiv:1404.5914v2 [astro-ph.HE] 25 Apr 2014

Daniele Fargion, [1]

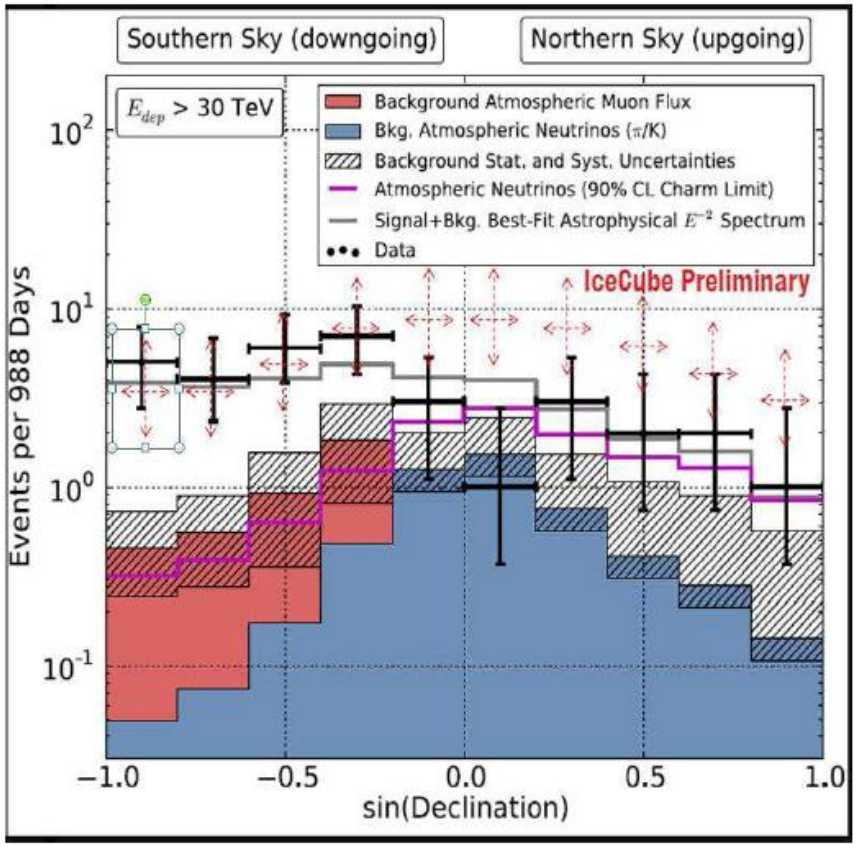
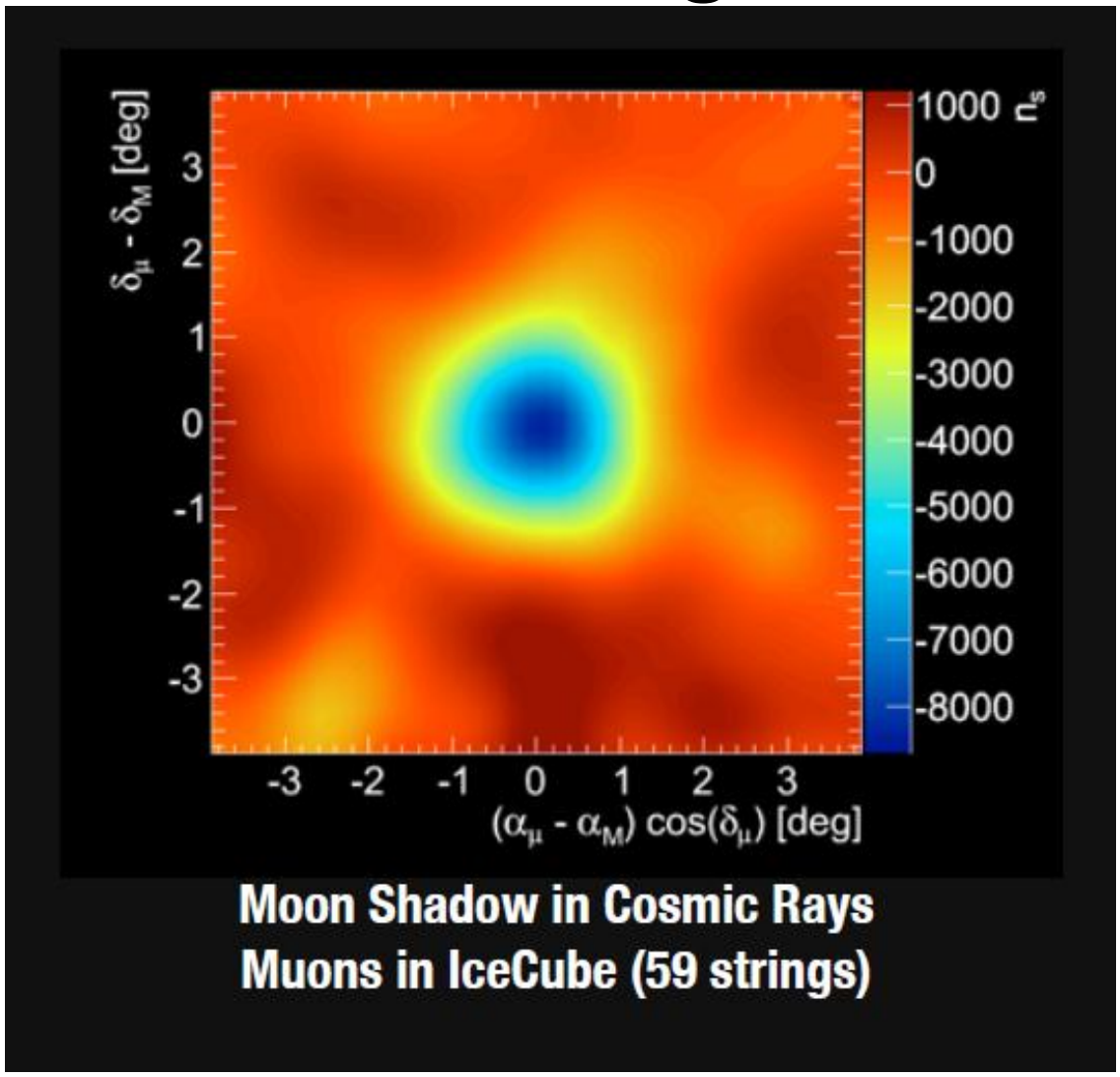
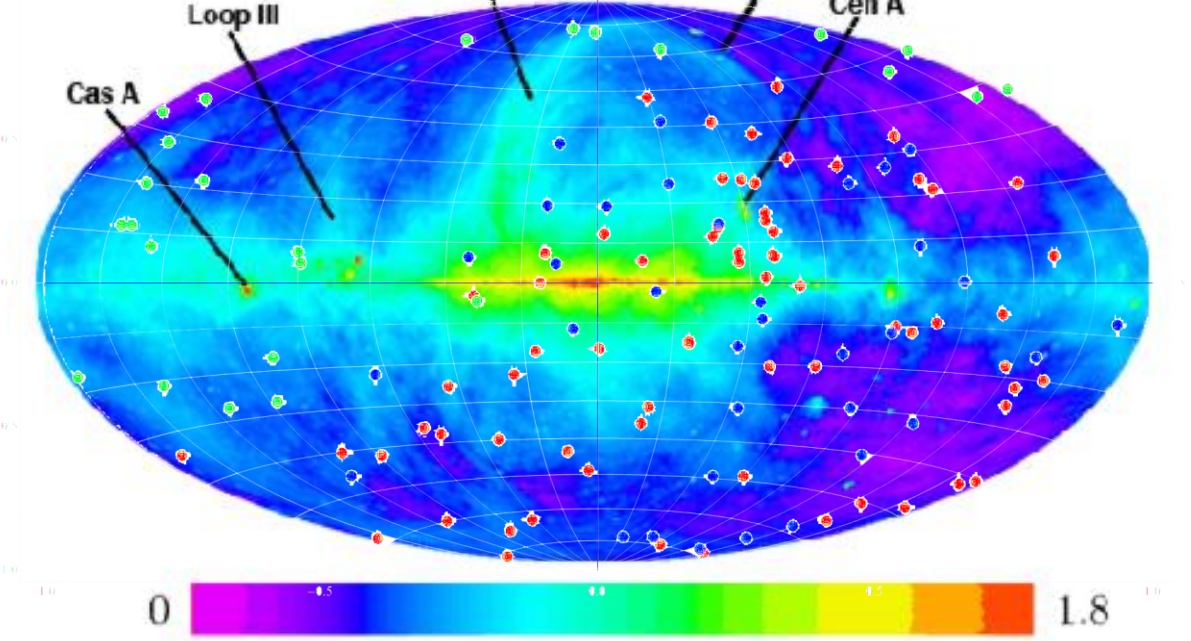
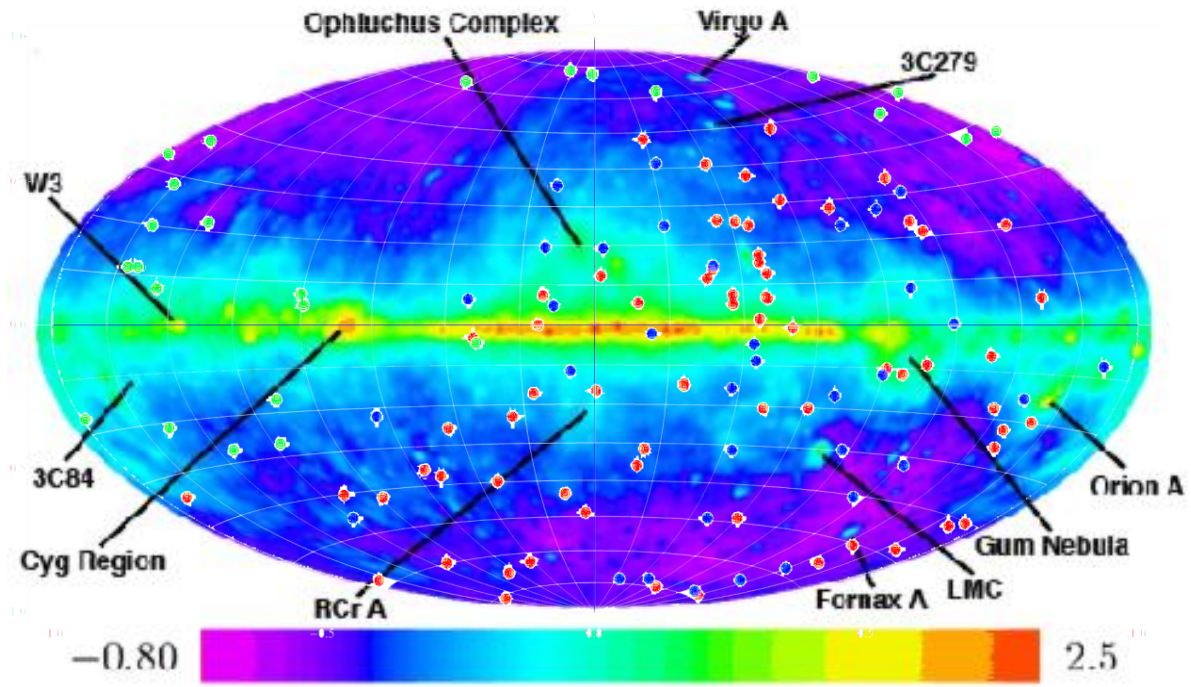


Figure 1: The dashed thin red crosses foresee the crossing muons numbers for three years in ICECUBE, assuming an energy threshold about $30 - 50$ TeV. Their total large (nearly 54) number and they track narrow beam may dig in the sky map correlations and multiplet clustering along known sources.

How can be sure on Directionality? Moon shadows, angular resolution




Loop III
Cas A
Cen A
0
1.8


Ophiuchus Complex
Virgo A
3C279
W3
3C84
Cyg Region
RCr A
Fornax A
LMC
Gum Nebula
Orion A
−0.80
2.5

A Fermi Fountain shadows?