Sterile Neutrinos Explaining the ANITA Anomaly

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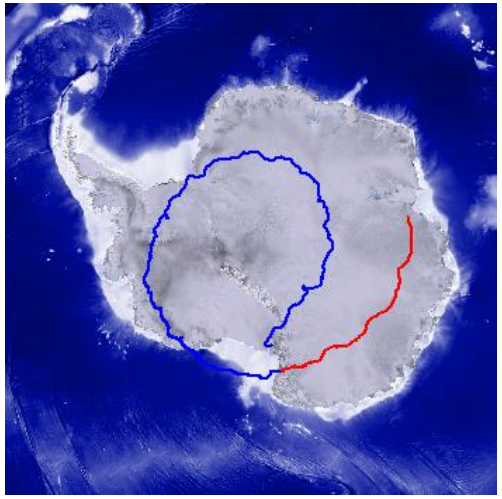
Outline

- 1. ANITA anomaly
- 2. Sterile neutrinos
- 3. IceCube null result
- 4. Summary

ANITA introduction



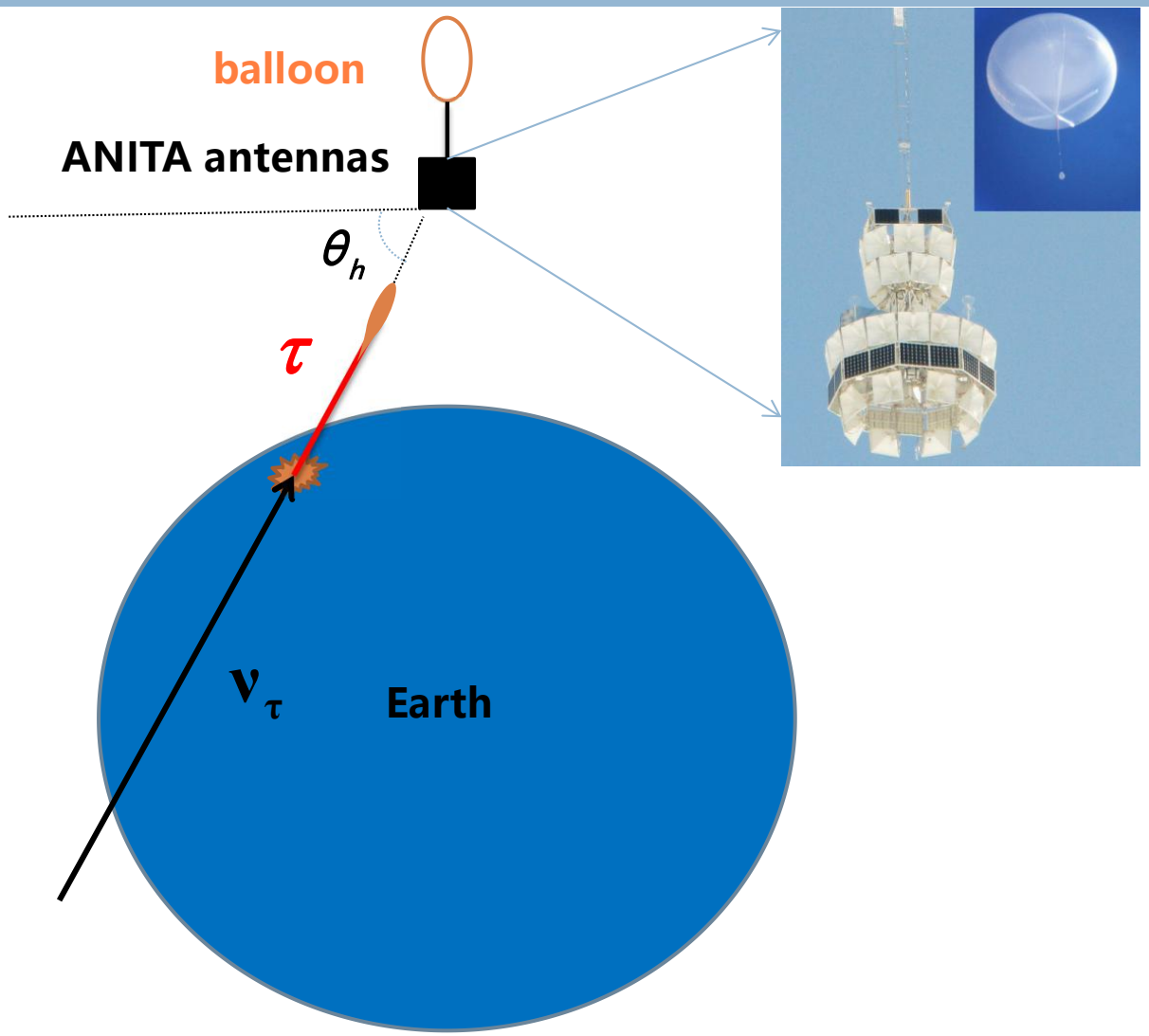
The ANITA (ANtarctic Impulsive Transient Antenna) is a NASA-sponsored balloon-borne neutrino telescope

floating around $35\,\mathrm{km}$ above the Antarctica

detecting the UHE neutrinos $\geq \mathrm{EeV}$ through Askaryan effect as well as the radio signal of the extensive air shower (can also measuring the UHE cosmic rays)

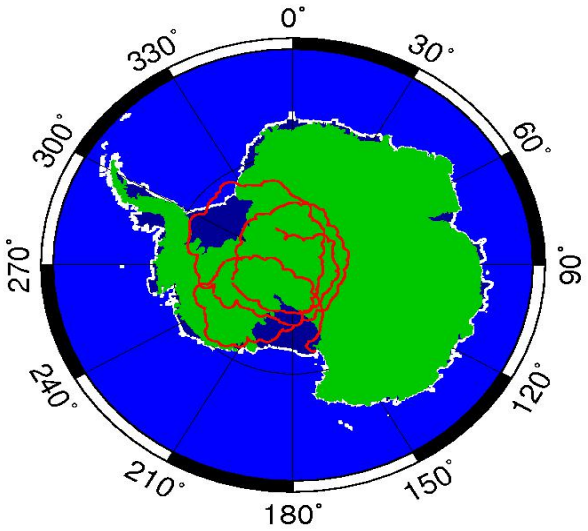
having observed more than 20 UHE cosmic ray events already. Two of them are very unexpected

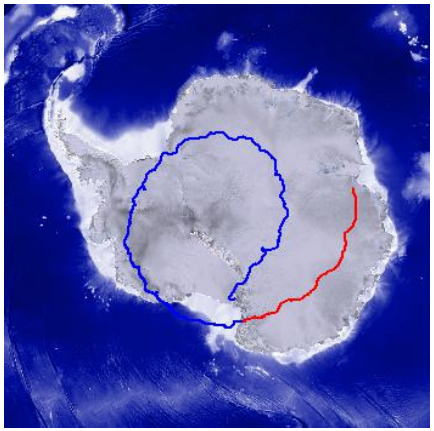
ANITA upgoing events



ANITA upgoing events

event,flight	3985267,ANITA-I	15717147,ANITA-III
date	2006-12-28	2014-12-20
altitude	2.56 km	2.75 km
angle θ_h	-27.4±0.3°	-35.0±0.3°
shower energy	0.6±0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV
chord length	5800 km	7300 km





ANITA upgoing events

attenuation effect

$\nu-\mathrm{N}$ SM cross section at EeV : $\sigma \approx 10^{-32}\ \mathrm{cm}^2$
corresponding to an attenuation length of $L_{\mathrm{CC}} \approx 1700\ \mathrm{kmwe}$

For 3985627, attenuation factor 10^{-6}
For 15717147, attenuation factor 10^{-13}

To evade the IceCube constraint on the EeV scale neutrino flux, the attenuation length should be around $7000\ \mathrm{km} \sim 3\times10^{4}\ \mathrm{kmwe}$, the cross section should be suppressed by a factor of 18.

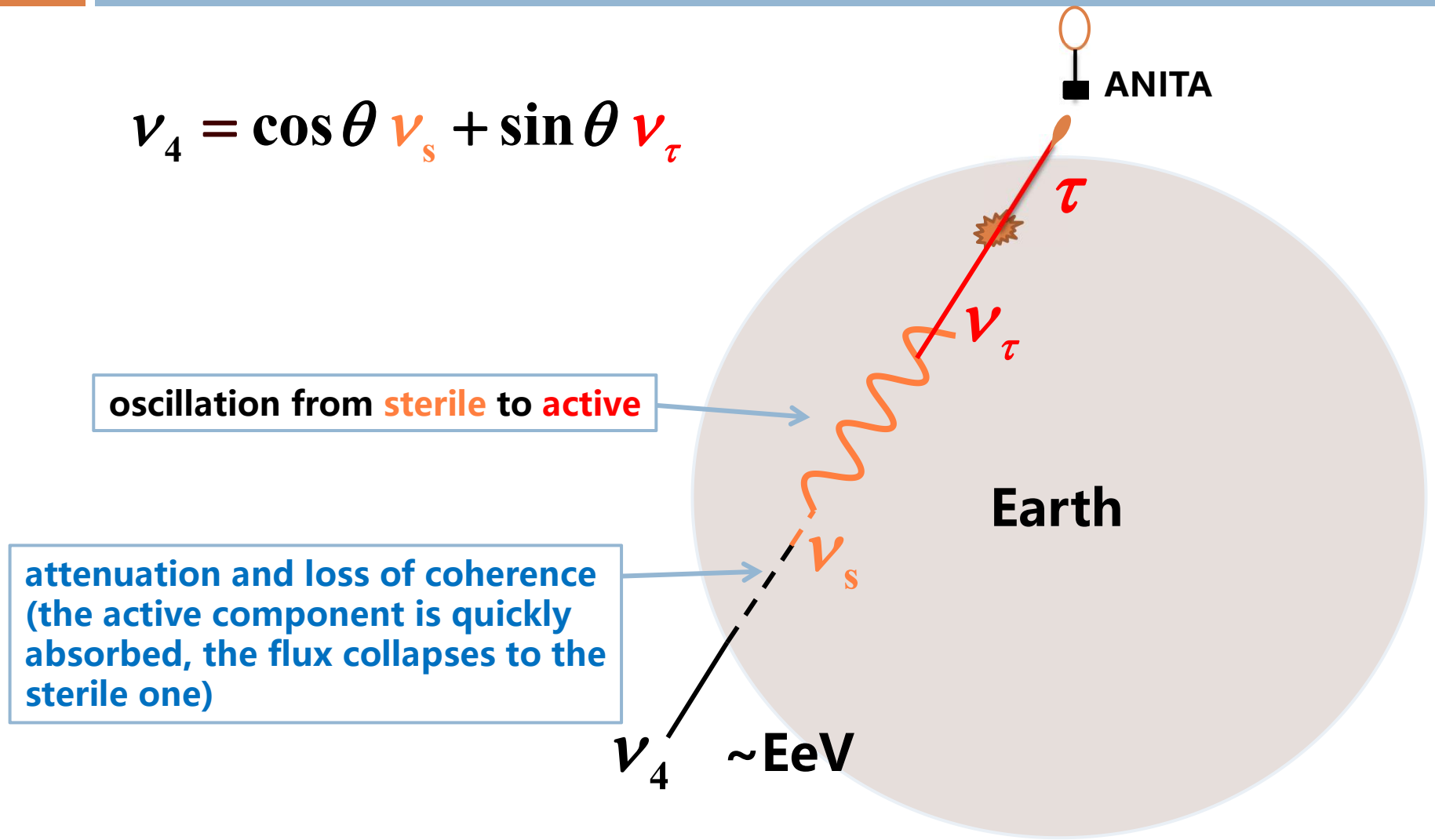
or the EeV neutrino flux is sterile?

Motivited by the seesaw mechanism;
keV sterile neutrino is a good candidate of warm dark matter;
Anomalies in neutrino experiments.

dark matter decays to sterile neutrinos as the source ?

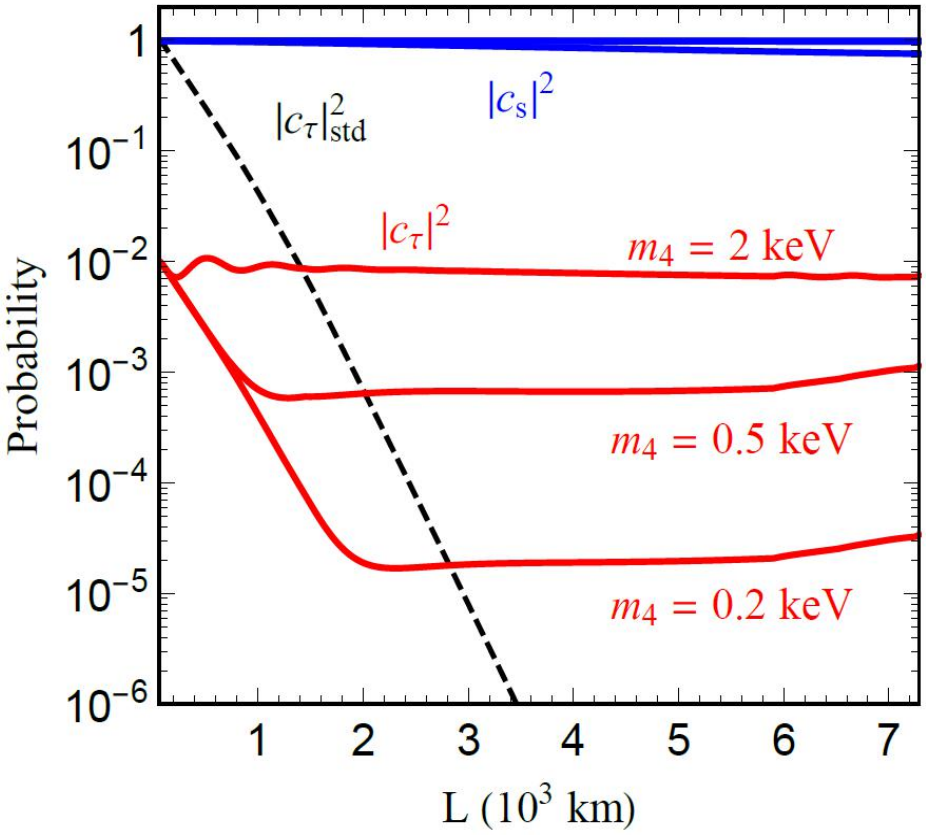
Sterile neutrinos

$$\nu_4 = \cos\theta\ \nu_s + \sin\theta\ \nu_\tau$$



Sterile neutrinos

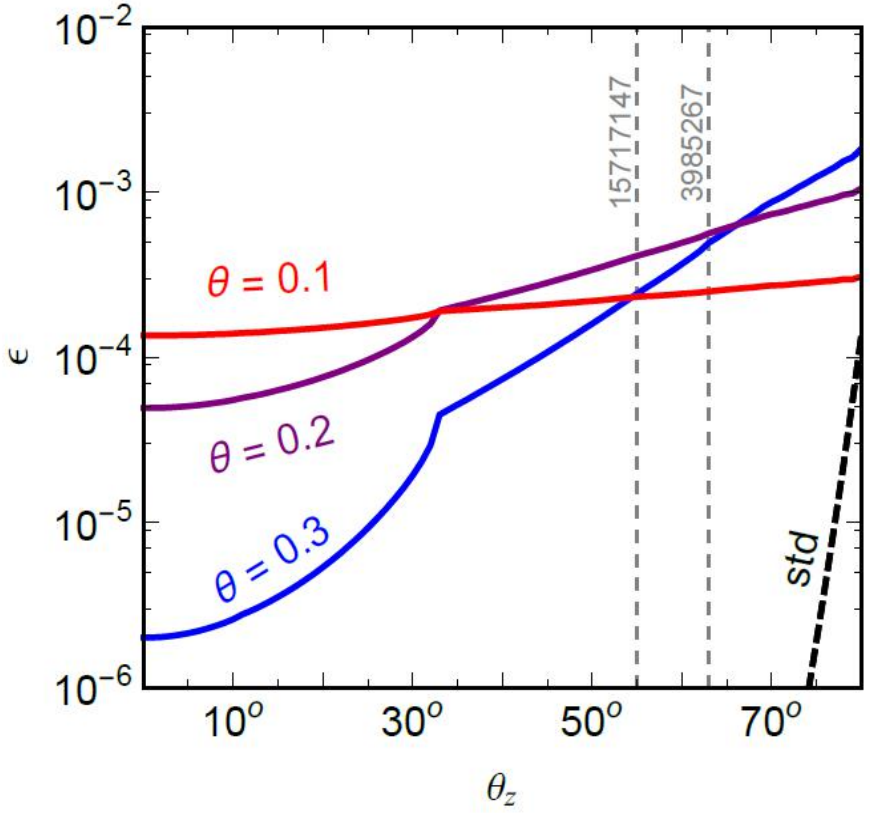
$$i\frac{\mathrm{d}}{\mathrm{d}t}\begin{pmatrix} c_\tau \\ c_\mathrm{s} \end{pmatrix} = \frac{1}{2E_\nu}\left[U\begin{pmatrix} m_1^2 & 0 \\ 0 & m_4^2 \end{pmatrix}U^\dagger + \begin{pmatrix} A_\mathrm{NC} & 0 \\ 0 & 0 \end{pmatrix} - i\begin{pmatrix} E_\nu/L_\mathrm{atten} & 0 \\ 0 & 0 \end{pmatrix}\right]\begin{pmatrix} c_\tau \\ c_\mathrm{s} \end{pmatrix}$$



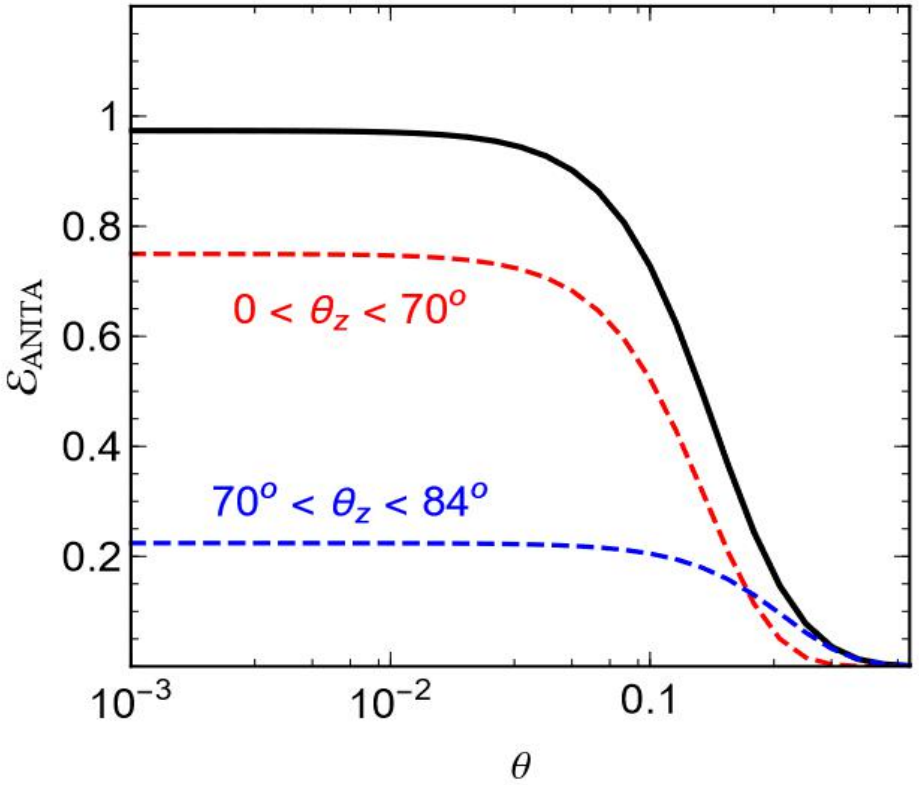
The active component with fraction $|c_\tau|^2$ can be regenerated by the oscillation of the sterile neutrino $\nu_\mathrm{s} \rightarrow \nu_\tau$

The sterile mass should be bigger than 1 keV to develop significant oscillation

Sterile neutrinos



The events can be uniformly distributed



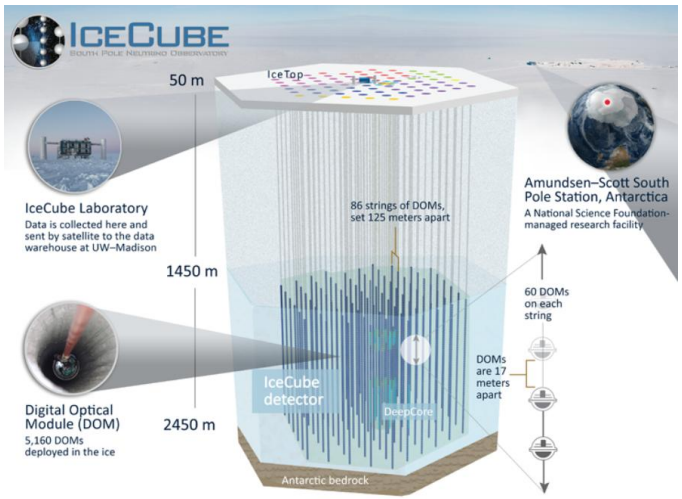
IceCube limit on the EeV neutrino flux

$$d\Phi_\nu / d\Omega \lesssim 2\times10^{-15}\,[0.1/\sin\theta]^2\,\mathrm{cm^{-2}s^{-1}sr^{-1}}$$

ANITA VS IceCube

$A_{gm}^{ANITA} \approx 4\,km^2, T_{ANITA} \approx 3\,months$ $A_{gm}^{IceCube} \approx 1\,km^2, T_{IceCube} \approx 6\,year$

$$\frac{\#\,events\ of\ IceCube}{\#\,events\ of\ ANITA} \approx 6$$



Null signal for IceCube

one observed upgoing PeV muon track event can be reinterpreted as an EeV tau track, but far from enough.

Summary

- The two upgoing EeV events of ANITA itself can be explained by very strong diffuse sterile flux.
- The IceCube should have observed 6 times such events if this is true.
- Could be some transient UHE neutrino source? Association not found.
- Dark matter decay in the Earth core? Same reason, NO.
- Could be ANITA experimental issues?
- If ANITA results are correct, what could be the solution?

Thanks for your attention !