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

D. Fargion [1], A. Aiello [2], R. Conversano
[1] *Physics Department, Rome University 1, and INFN, Rome1, P.za Aldo Moro 2 Rome, ITALY*
[2] *Physics Department, Rome University 1*

Abstract

Ultra High Energy (UHE) Tau neutrino may lead to a very peculiar imprint in future underground Km^3 detectors in water and ice as well as in air: rarest secondary tau tracks and decay which may exceed the muon ones. Indeed Bremsstrahlung at high energy lead to longer tracks for heavier leptons. Radiation lenght grows nearly with the square of the lepton mass. Indeed electrons are too light and their trace in matter is negligible (decimeters) muon are much better observed, while tau are too short life time and short range to be found. However, because relativistic time expansion, UHE tau traces in matter, above $10^{17}\ eV$, are relativistically boosted overcoming the corresponding muon tracks, already bounded by bremsstrahlung logaritmic regime. The tau crossing for Kms in water or ice may be confused with common muon tracks; their tau decay may be missunderstood as muonic catastrophic brehmstrallung interactions. To economize UHE tau dicovery, we suggest to look the tau decay in air into the deep valleys montains, like Canyons or deep in escavation mines where horizontal air showers induce fluoresce or Cerenkov lights. The mountain valley width screens from horizontal secondary muons. The valley height increases the solid angle view. The horizontal air Kms-size gap offer a strong discriminator to filter UHE muons against tau. Tens event a year at PeV (W resonance peak) energies in Km^3 excavation gap should be observable . Hunting air shower in the night toward high mountains in Canyons or in a deep excavation may be the best and cheapest way to discover UHE neutrinos , either born by electron antineutrino scattering on electrons at PeV energies, or by direct tau neutrino possibly relic of muonic flavour oscillation even at EeV energies.

1 Introduction:

Ultrahigh energy , UHE, neutrino astrophysics deals mainly with muonic and elettronic ones because they are the natural secondaries of pion decays. Indeed UHE, tau and associated neutrino taus are harder to be born by proton-proton interactions in active galactic nuclei (AGN). Moreover their secondary charged tau in the detectors are difficult to be noticed because of their extremely brief timelife $3*10^{-13} sec$ and consequent short tracks $5\ mm \left(\frac{E}{100 GeV}\right)$. Nevertheless these arguments hold only at "low" ($E_\nu \ll 10^5 GeV$) energies. There are at least three valid argument that favour a dominant key role of UHE and neutrino astrophysics contrary to popular believes:

1) The main stopping power for charged leptons, the bremsstrahlung radiation and associated pair production, is responsible for the (charged) lepton lenghts. The bremsstrahlung (and pair production) radiation is proportional (out of a logaritmic term) to the square of the lepton mass. The heavier the mass the longer the lepton track length. For this reason the longest tracks should be the tau ones R_τ as soon as the Lorentz boosted lifetimes and tracks, growing linearly with energies, will reach the corresponding, (bremhstrallung bounded by logaritmic growth) muon lenghts R_μ. The peculiar phenomena (in the rock) occurs at energy $E = 10^8 GeV$. The longer tau traces makes UHE more detectable than muon ones. The tau dominance occurs in a wide energy windows: $10(18)\ eV < E < 10(22)\ eV$, within and above GZK cutoff (Fargion et al.1999)

2) On the other side the UHE source may be naturally born by neutrino oscillation at widest neutrino mass ranges, (because of the huge cosmic distances) and at the maximal mixing angles, as strongly suggested by last Superkamiokande data.

$$L_{\nu_\mu \to \nu_\tau} = 1.23 \cdot 10^{13} cm \left(\frac{E_\nu}{10^{17} eV}\right) \left(\frac{\triangle m_{ij}}{eV}\right)^{-2} \ll L_{galaxy} \ll L_{cosmic}. \quad (1)$$

3) While UHE tau are able to decay in air at bounded

$$R_{\tau_0} = 5Km \left(\frac{E_\tau}{10^8 GeV} \right) \tag{2}$$

distances in Earth, the corresponding muon tracks, being able to travel above ten thousand kms, fly longer with no decay above the atmosphere. The difference may be revealed in Km^3 void traps like deep canyons or valley.
4) Antineutrino electron scattering on matter electrons in the W boson resonant peak, at PeV energies, will produce the largest crossections and also secondary tau. Their signal must be observable even if no mixing and no neutrino tau sources are available.
5) Tau tracks, because of their boosted radiation lengths, grow linearly with energy (with respect to muon tracks) up to two order of magnitude above muons ($E > 4 \cdot 10^{10}\, GeV$) bounded by corresponding radiative pair production length $R_{R\,\tau}$. However the presence of weak interaction between UHE (as well as with matter nuclei grows, leading at $E = 4 \cdot 10^9\ GeV$, to a more restrictive interaction length than radiative one $R_{W\,\tau}$, for secondary taus as shown in figure below reaching a peak in the R_τ curve.
As shown in (Gandhi et al. 1998) above the PeV energies expected neutrino might lead to few events in Km^3 detectors in most neutrino flux models. The relevant lepton tracks in the detectors are the following:

$$R_{R_\tau} \cong 1033\ Km \left(\frac{\rho_r}{5}\right)^{-1} \left\{ 1 + \frac{\ln \left[\left(\frac{E_\tau}{10^8\ \mathrm{GeV}}\right) \left(\frac{E_\tau^{\min}}{10^4\ \mathrm{GeV}}\right)^{-1} \right]}{(\ln\ 10^4)} \right\} . \tag{3}$$

$$R_{W_\tau} = \frac{1}{\sigma N_A \rho_r} \simeq 2.6 \cdot 10^3\ \mathrm{Km} \left(\frac{\rho_r}{5}\right)^{-1} \left(\frac{E_\tau}{10^8\ \mathrm{GeV}}\right)^{-0.363} . \tag{4}$$

$$R_\tau = \left(\frac{1}{R_{R_\tau}} + \frac{1}{R_{\tau_o}} + \frac{1}{R_{W\tau}} \right)^{-1} . \tag{5}$$

$$R_\mu \left(E_\mu \gg 10^4\ GeV\right) \simeq 7.9 Km \left(\frac{\rho_r}{3}\right) \ln \left(\frac{E_\mu}{10^8\ GeV}\right) . \tag{6}$$

For more details see (Fargion 1997). The deep valley which we consider as the ideal Km^3 detectors for horizontal tau air showers are found in South Africa diamond mines of Kimberley. There are also very good candidate large deep valley in Nevada, the Inyo Valley within White and Whitney Mountains, near the Death Valley. In Italy we suggest the deep valley in the Glacier du Miage at Mont Blanc. We consider also the nearby Mer de Glace and the Glacier d'Argentier in the same mountain at French side. The estimated event rate for a given surface detector are larger than corresponding horizontal air shower rates because of the larger density and volumes of the calorimeter mountains responsible for the neutrino-nucleon interactions.
Even the (unexpected) absence of any tau showers in air in new neutrino detectors will imply puzzling constrains on SuperKamiokande data and astrophysical neutrino models. In conclusion, we believe that in future Km^3 telescope more surprises may (and must) come from neutrino tau and tau signals: the first direct ν_τ experimental evidence, its possible flavor mixing and the first possible spectacular insight at highest energetic ($\geq 10^8 \div 10^{11}\, GeV$) neutrino astrophysical frontiers.

2 Figures:

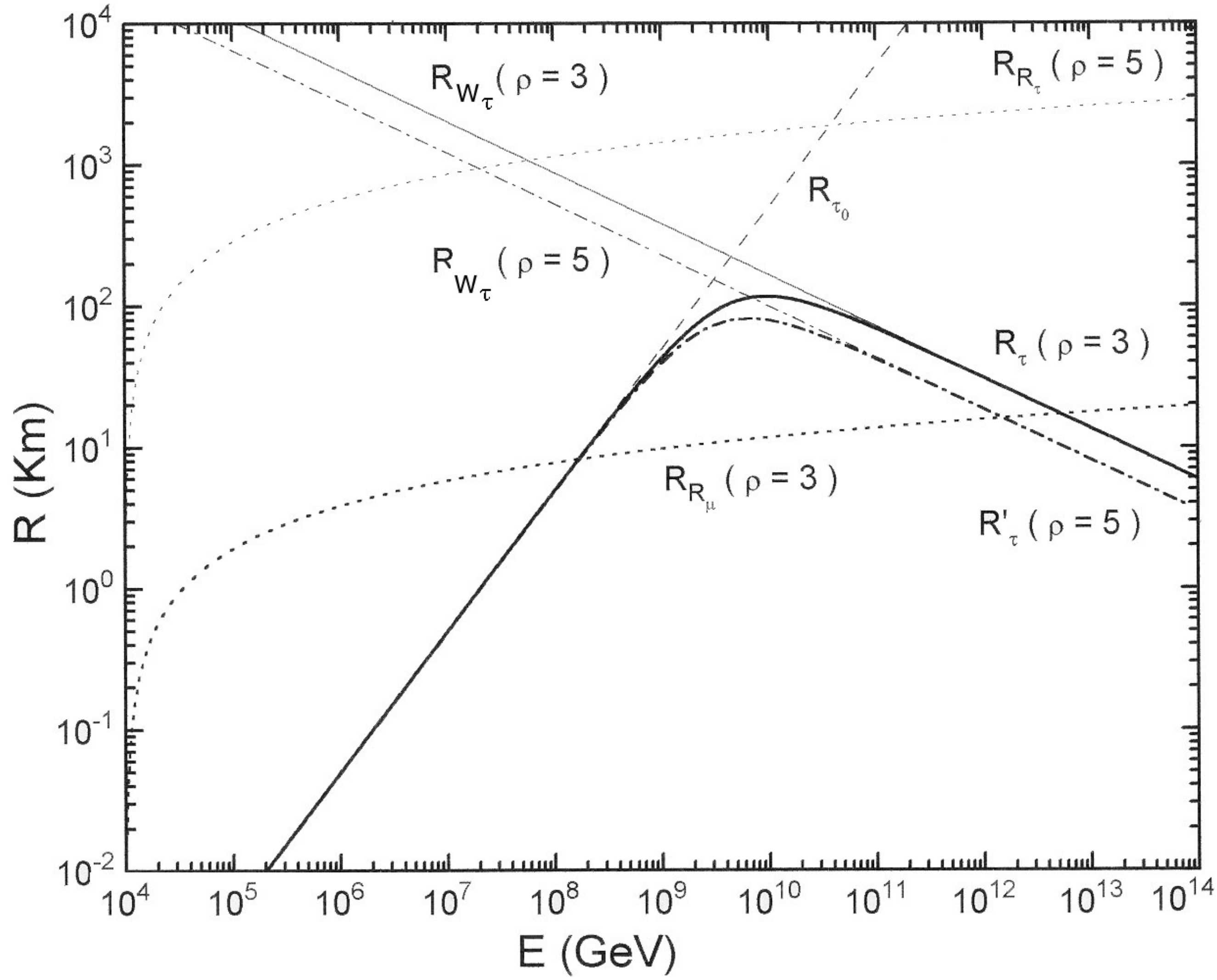

Figure 1:

References

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