PROCEEDINGS OF SCIENCE

GeoSynchrotron Radiation from Earth Skimming Tau Neutrino Shower

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KWANG-CHANG LAI[*] [†]
Institute of Physics, National Chiao Tung University, Hsinchu, Taiwan
Leung Center for Cosmology and Particle Astrophysics, National Taiwan University, Taipei, Taiwan
E-mail: `kclai@mail.nctu.edu.tw`

Guey-Lin Lin [‡]
Institute of Physics, National Chiao Tung University, Hsinchu, Taiwan.
Leung Center for Cosmology and Particle Astrophysics, National Taiwan University, Taipei, Taiwan
E-mail:`glin@cc.nctu.edu.tw`

Tsung-Che Liu
Institute of Physics, National Chiao Tung University, Hsinchu, Taiwan
E-mail:`diewanger@gmail.com`

JiWoo Nam
Department of Physics, Ewha Womans University, Seoul, Korea
E-mail: `jiwoonam@gmail.com`

Chi-Chin Chen
Institute of Astrophysics, National Taiwan University, Taipei, Taiwan
E-mail:`b88202054@ntu.edu.tw`

Cosmogenic neutrinos[1] are expected from ultrahigh energy cosmic rays undergoing the GZK process[2, 3] and anticipated to be observed by detecting air showers from the decays of tau leptons. We use CORSIKA simulated shower structure to calculate the coherent geosynchrotron radio emissions of the tau decay showers above 10^{17}eV. We present the pattern and spectrum of radio waves and discuss their detections by radio antennae.

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1. Introduction

The origin of ultra-high energy cosmic rays remains a fundamental and unsolved problem in astroparticle physics. Promising clues could be provided by the associated high energy neutrinos since they would neither interact with intergalactic or interstellar media nor be deflected by the magnetic fields. Various detectors have been proposed for detecting high energy neutrinos. Some of them rely on measuring the air shower by the so-called earth-skimming ν_τ, for which horizontal showers are generated by the ensuing τ decay[4, 5]. In this paper, we investigate the shower properties by simulations. Equipped with the knowledge of the ν_τ induced air shower, we are able to calculate the induced geosynchrotron radiation.

In Sec. II, we present the CORSIKA[6] simulated shower profile to be employed in the calculation of geosynchrotron radiation in Sec. III. Our calculation is based on the coherent geosynchrotron emission scenario initiated in 1970's[7] and further developed by Huege and Falcke[8]. In Sec. IV, we summarize and conclude our work.

2. Air Shower Simulations

The tau decay induced air shower is initiated by the decay product. Using CORSIKA code, we simulate the shower initiated by electrons at five different energies. Table 1 presents the statistics of these simulations. The simulation shows that the shower particles reside in a shower thickness less than 1m. Compared with the radiation which traverses a distance of $\sim$ 10 km, the shower front at the shower maximum is treated as longitudinally coherent. The remaining structures are the lateral profile and Lorentz factor distribution representing the spatial and energy distribution of the shower particles.

Table 1: Shower statistics

Shower energy (eV)	number of e^- and e^+		
	Total	$\gamma = 1-100$	$\gamma = 1-1000$
10^{17}	7.32×10^7	4.54×10^7	6.79×10^7
$10^{17.5}$	2.23×10^7	1.34×10^8	1.99×10^8
10^{18}	7.10×10^8	4.41×10^8	6.55×10^8
$10^{18.5}$	2.15×10^8	1.32×10^9	1.98×10^9

Fig. 1 and 2 show the energy and position distributions of the shower particles at shower maximum for different energies. Both are displayed in the unit normalized to the total number at the corresponding energies.

3. Radio Properties

Having determined the spatial structure and energy distribution of shower particles, we can calculate the emission from the shower maximum. Fig. 3 depicts the expected electric field at different receiver locations. The interference pattern arises from the scale of the shower front. In

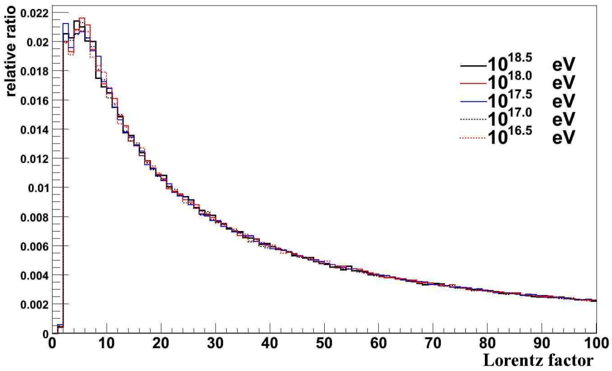

Figure 1: Normalized energy distribution of the shower particles at the shower maximum for different shower energies. The particle energy is represented by its Lorentz factor.

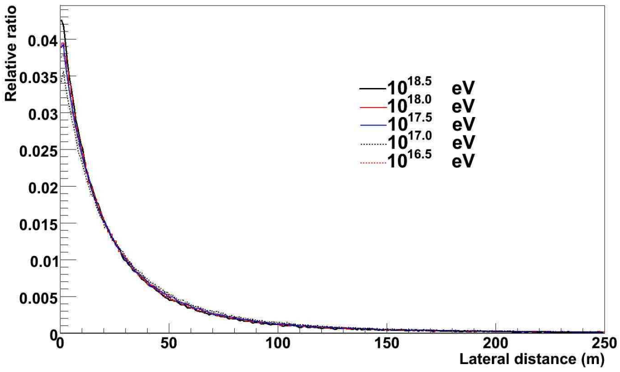

Figure 2: Normalized lateral distribution of the shower particles at the shower maximum for different shower energies. The lateral distance is from the shower illuminated area to the observational site.

Fig. 4, we calculate the pulse measured by the receiver with a given bandwidth. This plot indicates how large the separation between antennae can be for the current technology.

4. Summary

In this work, we investigate properties of the earth-skimming tau neutrino induced shower. The universal behavior of the shower particle allows a simple parametrization which will be helpful in future calculations of the geosynchrotron radiation. Our calculations also provide useful information for the future experiments.

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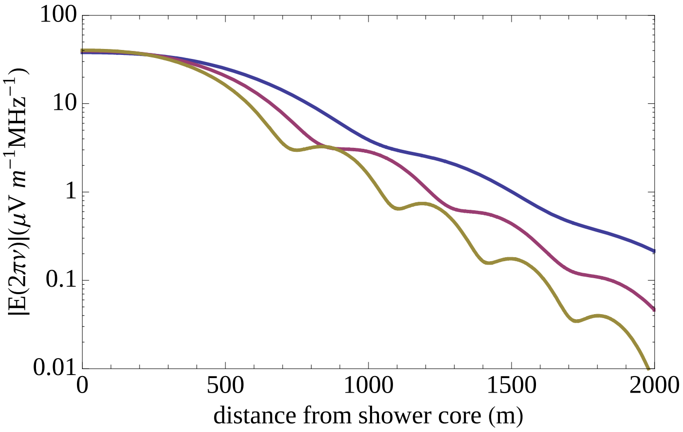

Figure 3: Off-set dependence of $|E(R, 2\pi \times \nu)|$ for the maximum of a 10^{17}eV shower at the observation distance of 10km. Curves in blue, red and yellow represent signals in observing frequencies of 50MHz, 75MHz and 100MHz, respectively.

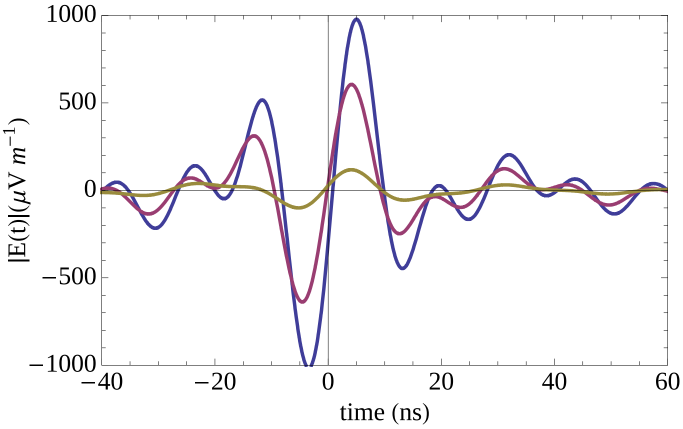

Figure 4: Reconstructed pulses from emission of a 10^{17}eV shower at the observation distance of 10km, using an idealized rectangular filter spanning $30-80$MHz. Curves in blue, red and yellow denote pulses measured at center, at lateral distances of 500m and 1000m, respectively.

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