# Tianshan Radio Experiment for Neutrino Detection

## Neutrino Sensitivity Study for A Giant Radio-detection Array

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NAO, CAS, China; LPNHE; LPC-Clermont, IN2P3, France

## Introduction: 21 CM-Array in China

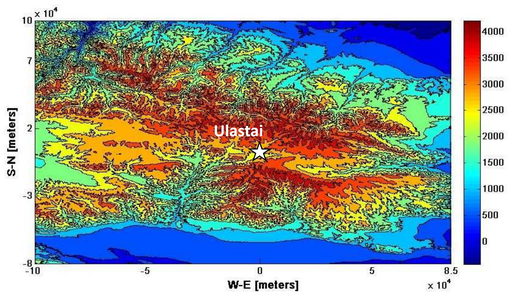
- The 21CMA Radio Interferometer:
  - Leading by Xiang-Ping Wu (NAO, CAS, China)
  - Located in the Tianshan Ulastai Valley of North-Western China
  - Dedicated to the study of the re-ionization epoch of the Universe
    - Study the 21 cm emission from neutral hydrogen
    - Consist of 10287 [50-200 MHz] antennas
    - 2 arms along the EW and NS directions ( 3 and 4 km length)

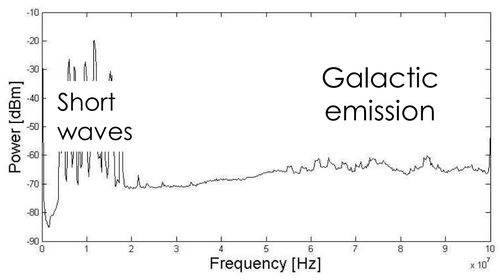
## Introduction: TREND Collaboration

China - France Collaboration, with O(10) collaborators

- Chinese Group
  - Leader: Prof. Wu Xiangping
  - member institutes:
    - NAOC: J. Deng, J. Gu, T. Saugrin, X. Wu
    - IHEP: F. Hernandez, H. Hu, H. Lin, Z. Liu
- French Group
  - Leader: Dr. Olivier Martineau-Huynh
  - member institutes:
    - LPNHE: O. Martineau-Huynh
    - SUBATECH:
    - LPC-Clermont: V. Niess

## Introduction: Ulastai Site for 21CMA and TREND

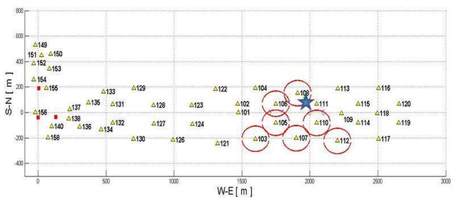


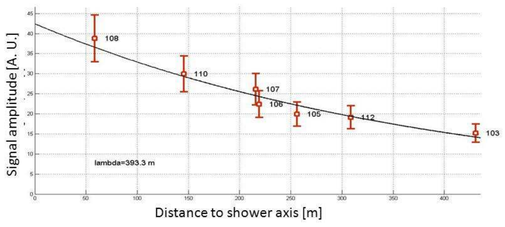




- Sit along two high altitude valleys
  - Situated at 2650 m altitude
  - Surrounded by up to 4200 m mountains
- 25 000 km$^2$ of lowly populated mountains within reach
- Exceptionally low electromagnetic noise level
- Atmospheric and galactic noise:
  - Set the limits on the suitable observation frequency band

## Current Status

- Current Detector Array
  - 50-antenna (yellow triangle)
  - 3-scintillator (red square)



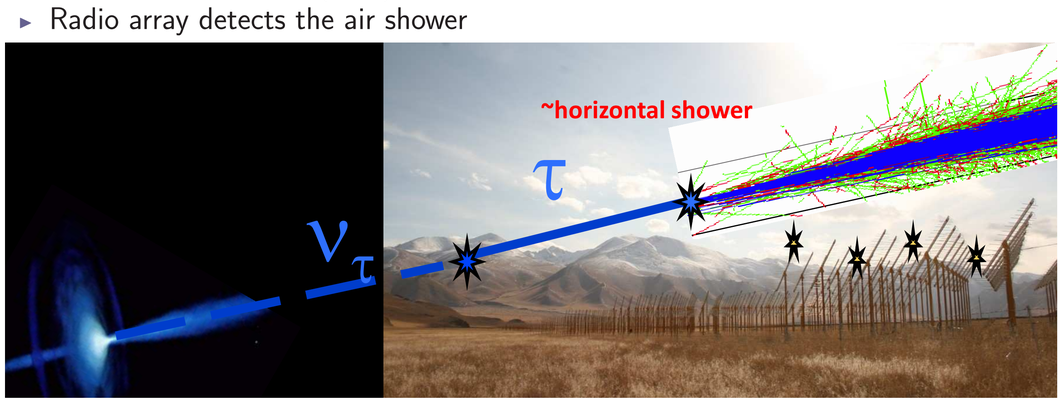




- Cosmic Ray Candidates

## TREND Future Path:

Radio Detection of Neutrinos from Behind the Tianshan Mountain

- Detection mechanism for the tau neutrinos ($\nu_\tau$):
  - Earth-skimming $\nu_\tau$ penetrates the Earth
  - $\nu_\tau$ interacts in rocks to produce tau lepton ($\tau$)
  - $\tau$ escapes the Earth and decays in the atmosphere
  - Extensive Air Shower (EAS) generated in the atmosphere
  - Radio array detects the air shower

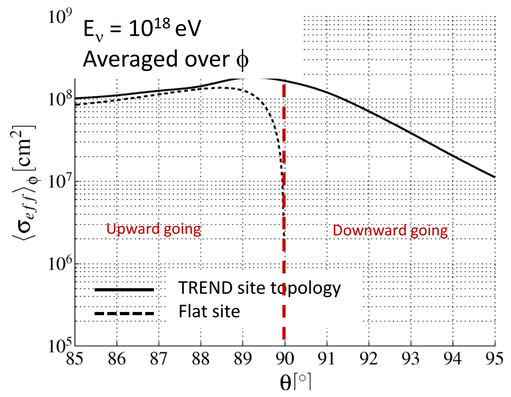



## Motivation

- Ultra High Energy Cosmic Rays (UHECR):
  - Most energetic particles in the Universe
    - Energy $> \mathbf{10^{16}}$ eV
  - What are the possible sources of UHECR?
- Ultra High Energy Neutrinos:
  - Several models for origin of highest energy cosmic rays:
    - Also predict significant neutrino fluxes
  - Neutrinos have their straight-line propagation out of the galaxy:
    - Very 'clean' probe (no deflection / no interaction)
- Advantage of Radio Detection:
  - Low price + stable setup
    - Easy to maintain
    - Easy to extend and built large array for sensitivity needed
  - Maximum observation cycle, independent of weather condition

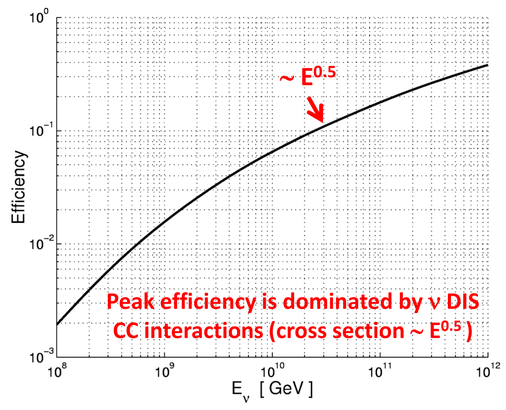
## Role of the Tianshan Mountain Ranges

- For upward going neutrinos:
  - Additional target meterial from surrounding rocks
- Adding downward neutrinos:
  - TREND topology Doubles the effective surface

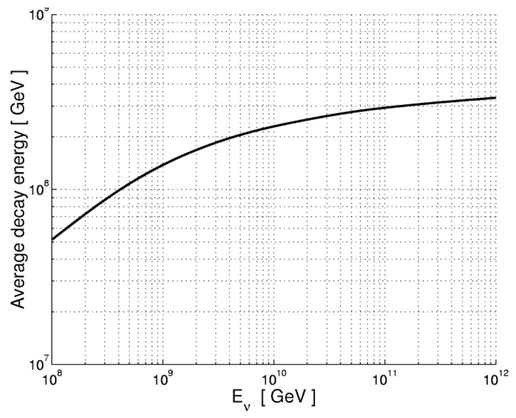



## Neutrino Sensitivity Study: Simulation Scheme

- Earth-skimming tau neutrinos:
  - Geometry modeling of the topology of TREND site
    - data from the NASA SRTM survey
    - Select an area of 200x200 km$^2$, centered on the TREND site
    - Take into account the Earth curvature
  - Physics simulation of $\nu_\tau$ interactions in the Earth rocks
    - Integrated cross-sections from Gaudi *et. al* (CTEQ4-DIS)
    - Inelasticity randomized with Pythia 6 + CTEQ5D-DIS LHAPDF
- Tau leptons:
  - $\tau$ propagation and energy loss: use GEANT4
    - Cross section following *Dutta et al.*
  - $\tau$ escape to air and decay in flight: use Pythia + TAUOLA



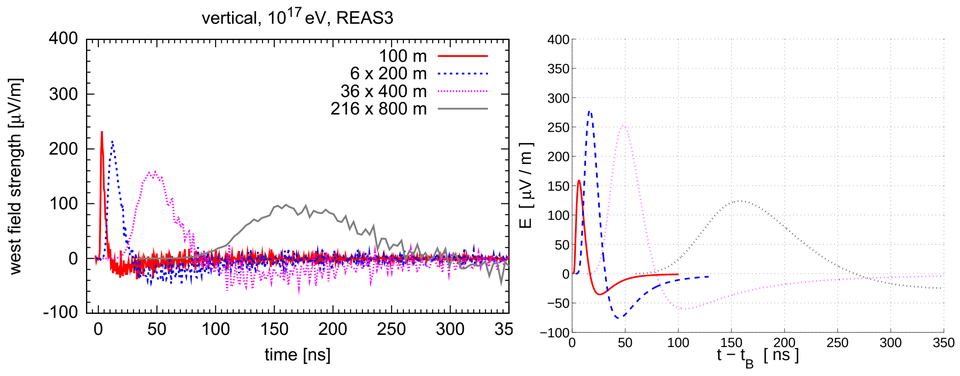

(a) $\nu_\tau$ conversion efficiency to $\tau$ decaying in the air




(b) Energy spectrum of $\tau$ at decay

## Air Shower and Radio Signal Simulation

- Extensive Air Shower Simulation: use CORSIKA
- Radio Emission:
  - two modeling methods:
    - MGMR by Werner et. al
    - REAS3 by by Ludwig & Huege
  - Follow the MGMR model with the full formalism
  - Take into account the 3 dominant sources of emission:
    - Drift current • Charge excess • Dipole moment
- Antenna Simulation: use Numerical Electromagnetics Code (NEC)




- Work in Progress:
  - MGMR MATLAB package vs REAS3 (by Ludwig & Huege):
    - comparison and validation
  - Prototype design, optimal array setup
  - background study / rejection
    - Multiple measurements (antennas) along the vertical direction
    - Trigger based on the ratio of 2 polarizations P1/P2 of an antenna
      - Background: identical polarization ratio
  - Computing resources for the full simulation chain: Clusters at NAOC and IHEP

## Perspectives

- Summary and Outlook
  - Perform the self-triggering detection of EAS at TREND
  - 21 CMA site well suited for measuring UHE $\nu_\tau$ induced showers
    - Excellent electromagnetic environment
    - Favorable site topology
  - Preliminary results from simulations show great potential:
    - for $\mathbf{10^{16} - 10^{20}}$ eV $\nu_\tau$
    - expect a sensitivity similar to existing (or planned) giant detectors
- Acknowledge the support of:
  - Chinese Academy of Sciences (CAS)
  - France-China Particle Physics Laboratory (FCPPL)

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