

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

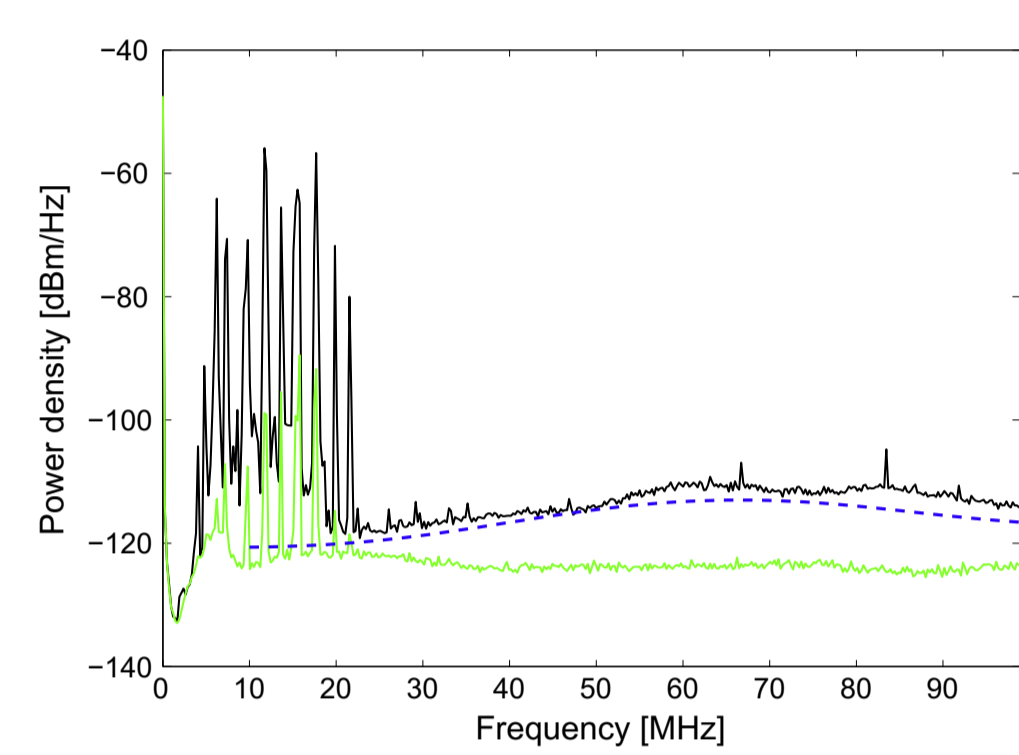
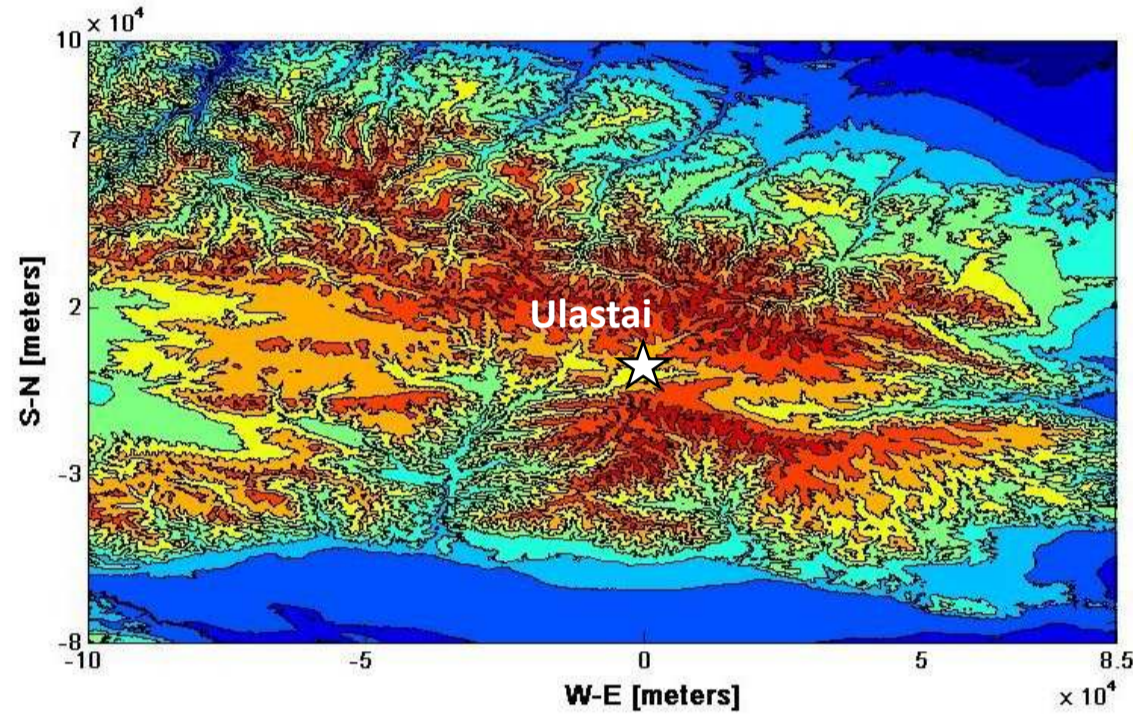
- ▶ The 21CMA Radio Interferometer:
 - ▶ Leading by Xiang-Ping Wu (NAO, CAS, China)
 - ▶ Located in the Tianshan Ulaistai Valley of North-Western China
 - ▶ Dedicated to the study of the re-ionization epoch of the Universe
 - ▶ Study the 21 cm emission from neutral hydrogen
 - ▶ Consist of 10287 [50-200 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:
 - ▶ NAO: J. Deng, J. Gu, T. Saugrin, X. Wu
 - ▶ IHEP: F. Hernandez, H. Hu
- ▶ French Group
 - ▶ Leader: Dr. Olivier Martineau-Huynh
 - ▶ member institutes:
 - ▶ LPNHE: O. Martineau-Huynh
 - ▶ SUBATECH: P. Lautridou, O. Ravel
 - ▶ LPC-Clermont: V. Niess

Introduction: Ulaistai Site for 21CMA and TREND



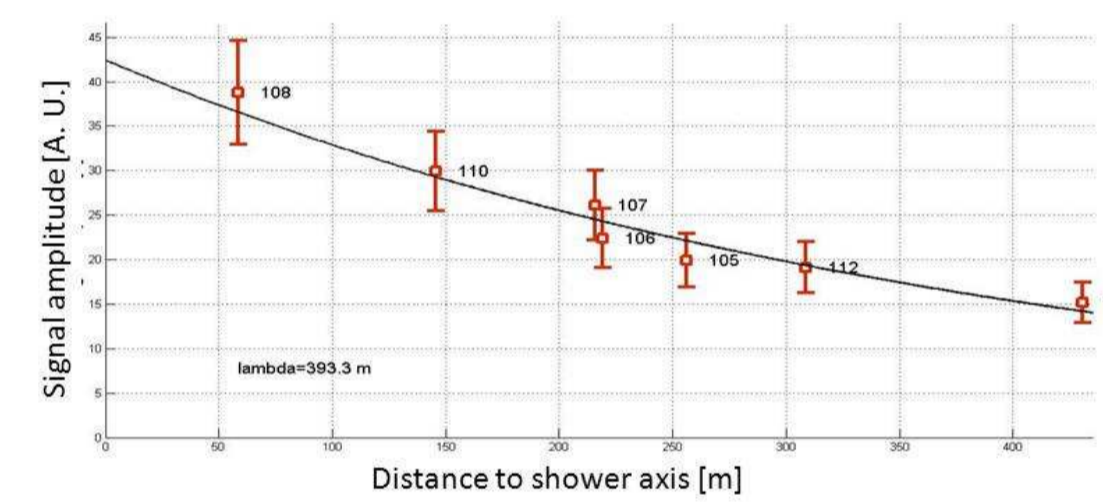
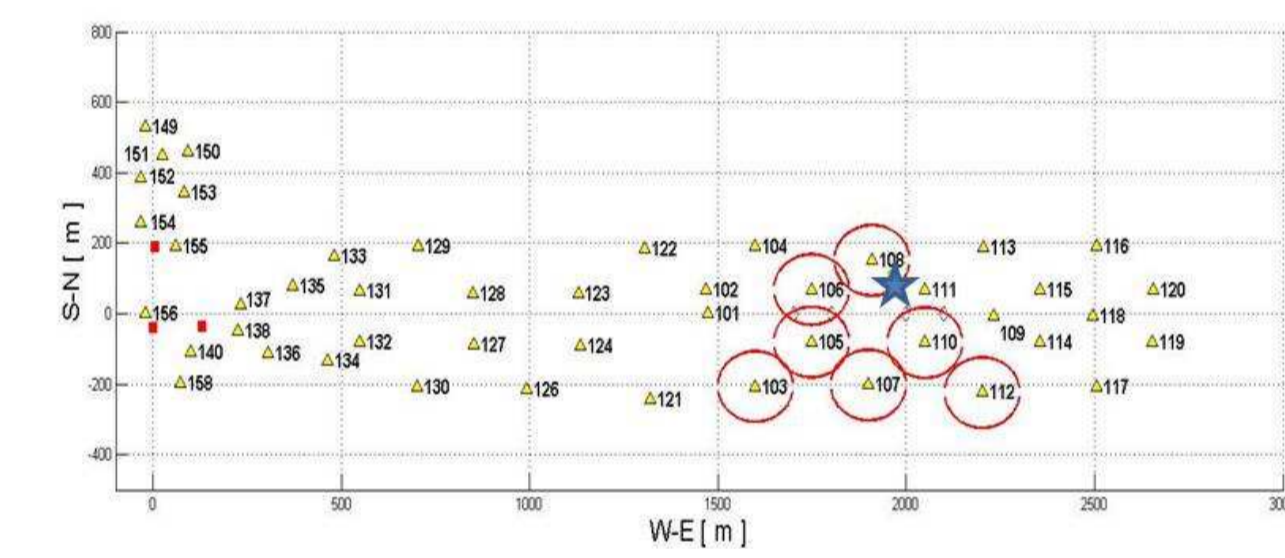
Measured emission (black); expected galactic background (blue)

- ▶ Sit along two high altitude valleys
 - ▶ Situated at 2650 m altitude
 - ▶ Surrounded by up to 5000m mountains
- ▶ 25 000 km² of lowly populated mountains within reach

- ▶ Electromagnetic noise level:
 - ▶ Exceptionally low

Current Status of TREND Experiment

- ▶ Current Detector Array
 - ▶ 50-antenna (yellow triangle)
 - ▶ Effective area 1.2 km², running since March 2011
 - ▶ 3-scintillator (red square):
 - ▶ For offline validation

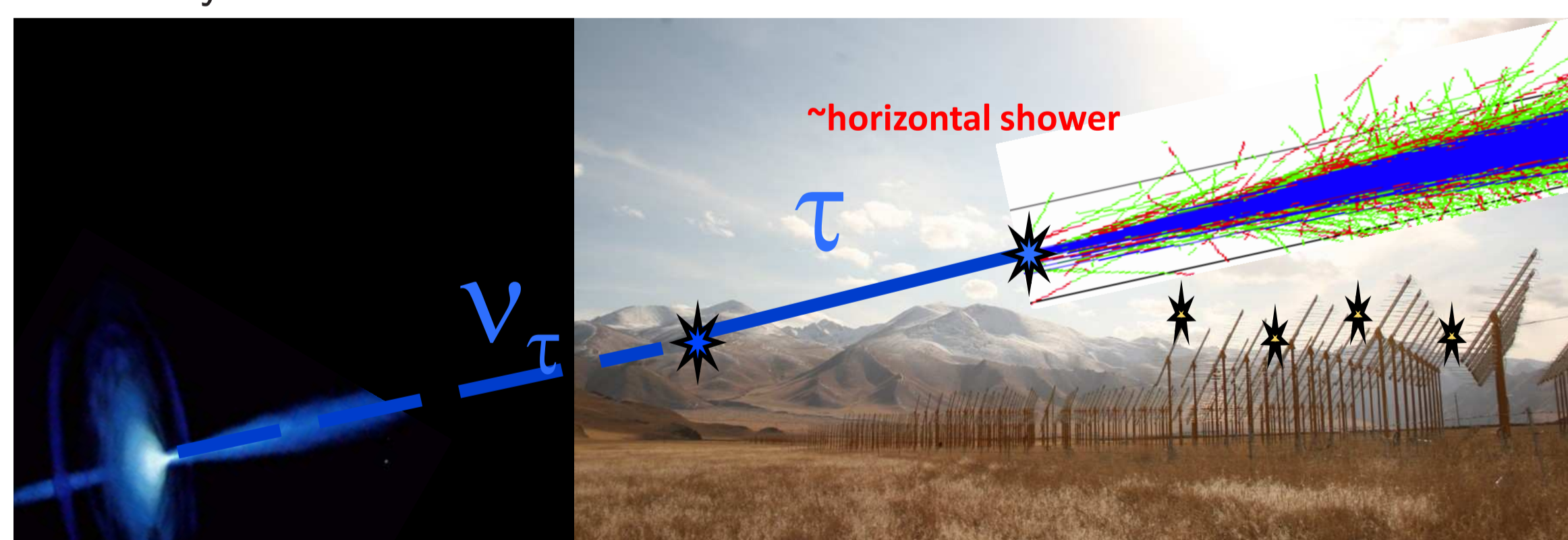


- ▶ Cosmic ray candidate
 - ▶ Identified with radio data only

TREND Future Path

Radio Detection of Neutrinos from Behind the Tianshan Mountain

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

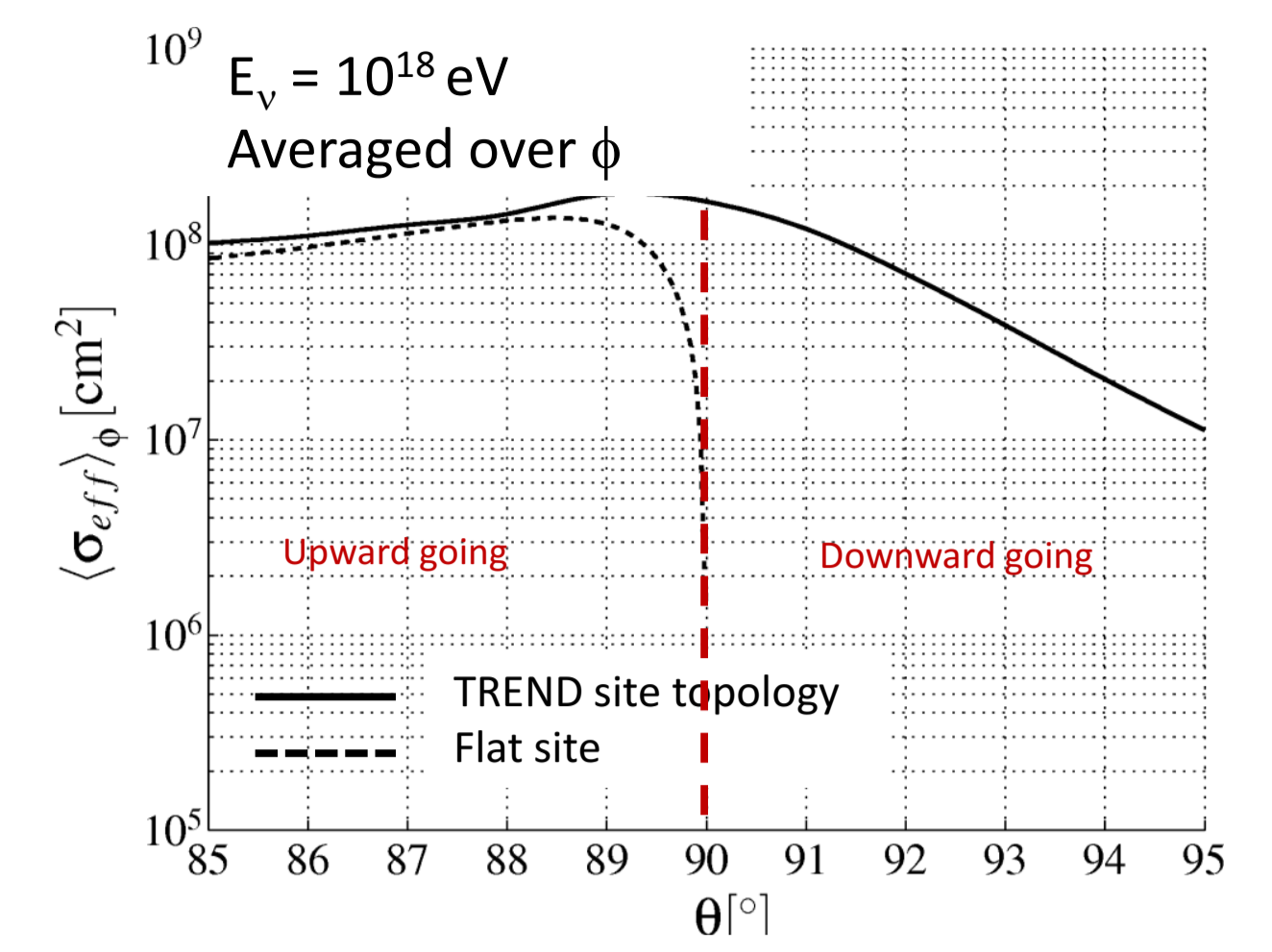


Scientific Motivation and Advantage of Radio Detection

- ▶ Ultra High Energy Cosmic Rays (UHECR):
 - ▶ Most energetic particles in the Universe
 - ▶ 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

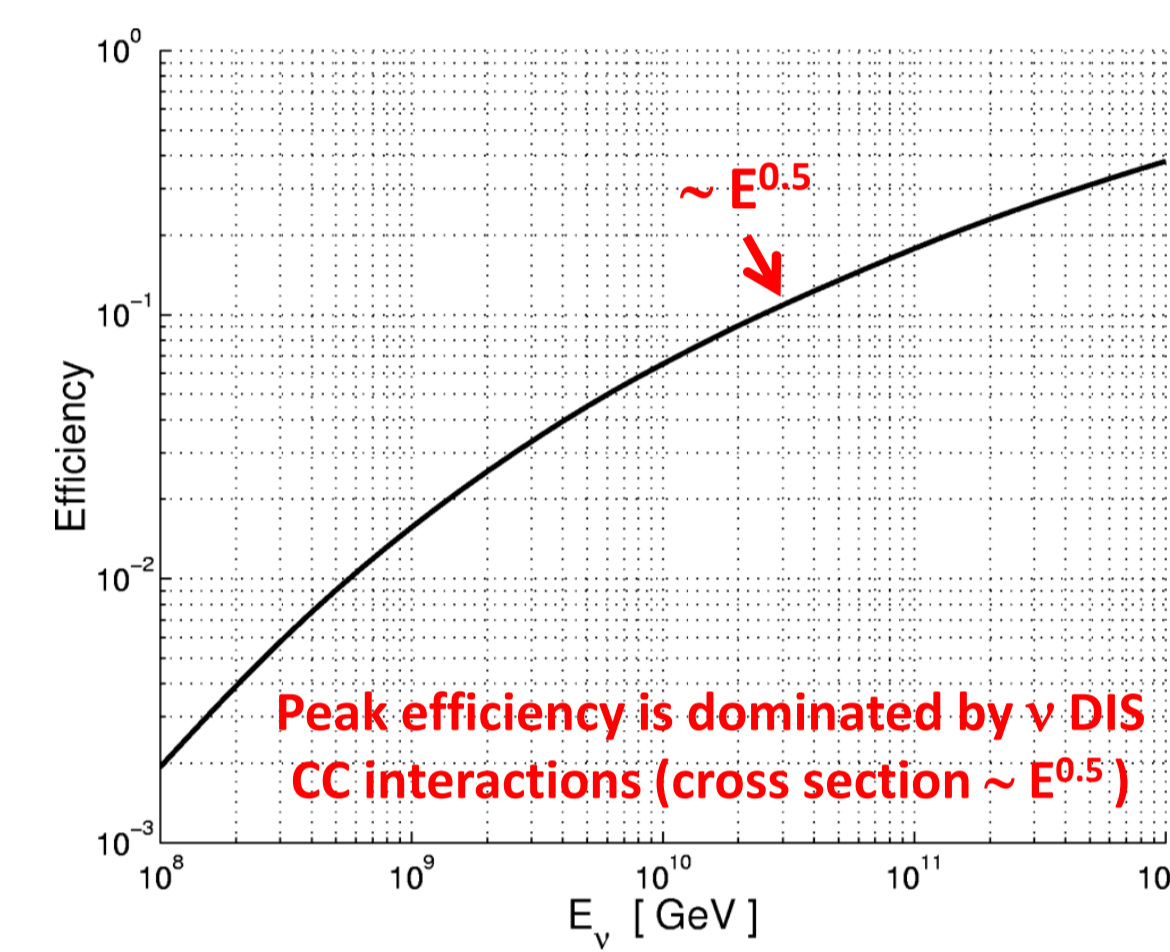
Role of the Tianshan Mountain Ranges

- ▶ For upward going neutrinos:
 - ▶ Additional target material from surrounding rocks
- ▶ Adding downward neutrinos:
 - ▶ TREND topology **Doubles** the effective surface
- ▶ Mountain also acts as a screen for standard cosmic rays backgrounds

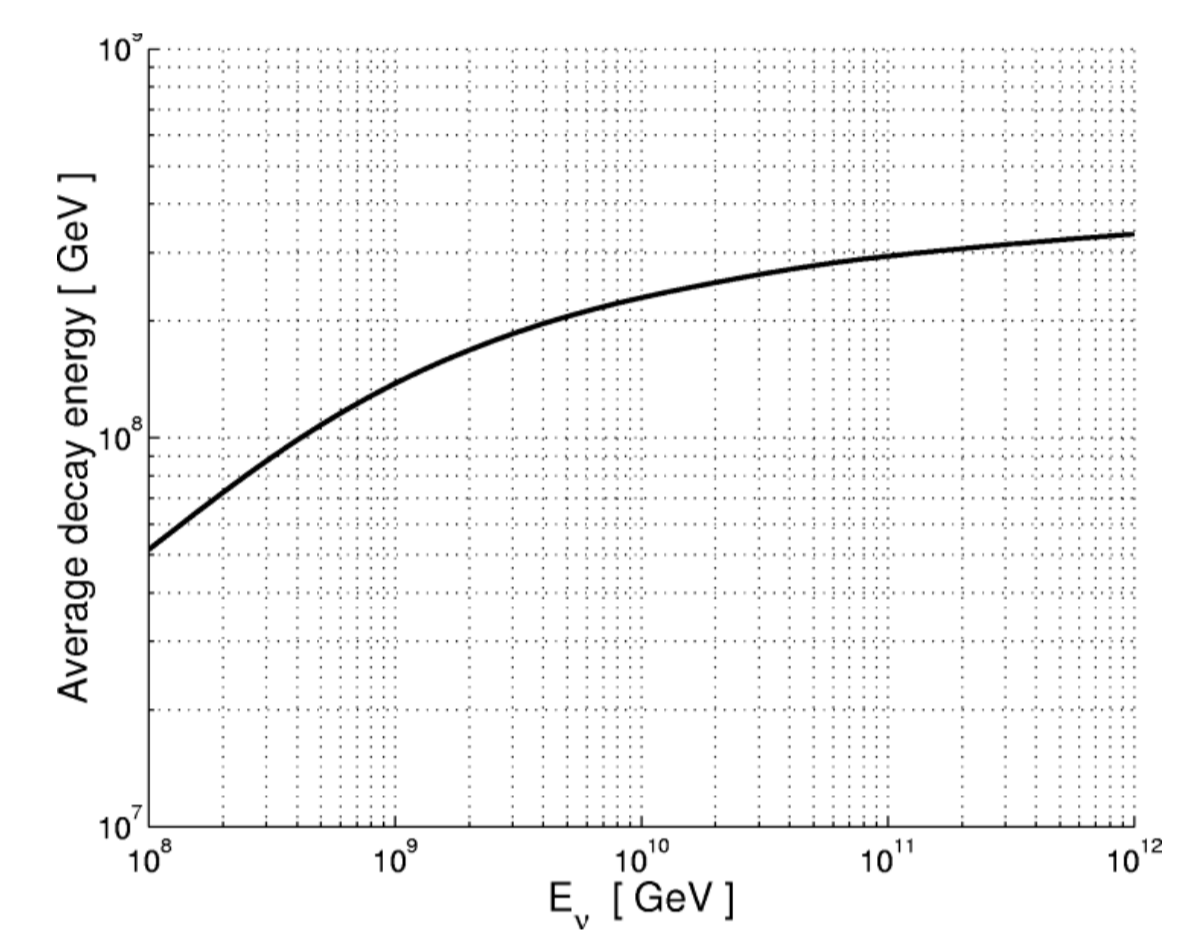


Neutrino Sensitivity Study: Simulation Scheme

- ▶ Earth-skimming tau neutrinos:
 - ▶ Geometry modeling of the topology of TREND site
 - ▶ data from the NASA SRTM survey
 - ▶ Select an area of 200x200 km², centered on the TREND site
 - ▶ Take into account of the Earth curvature
 - ▶ Physics simulation of ν_τ interactions in the Earth rocks
 - ▶ Integrated cross-sections from Gaudi *et. al* (CTEQ4-DIS)
 - ▶ Inelasticity randomized with Pythia 6 + CTEQ5D-DIS LHAPDF
- ▶ Tau leptons:
 - ▶ τ propagation and energy loss: use GEANT4
 - ▶ Cross section following *Dutta et al.*
 - ▶ τ escape to air and decay in flight: use Pythia + TAUOLA



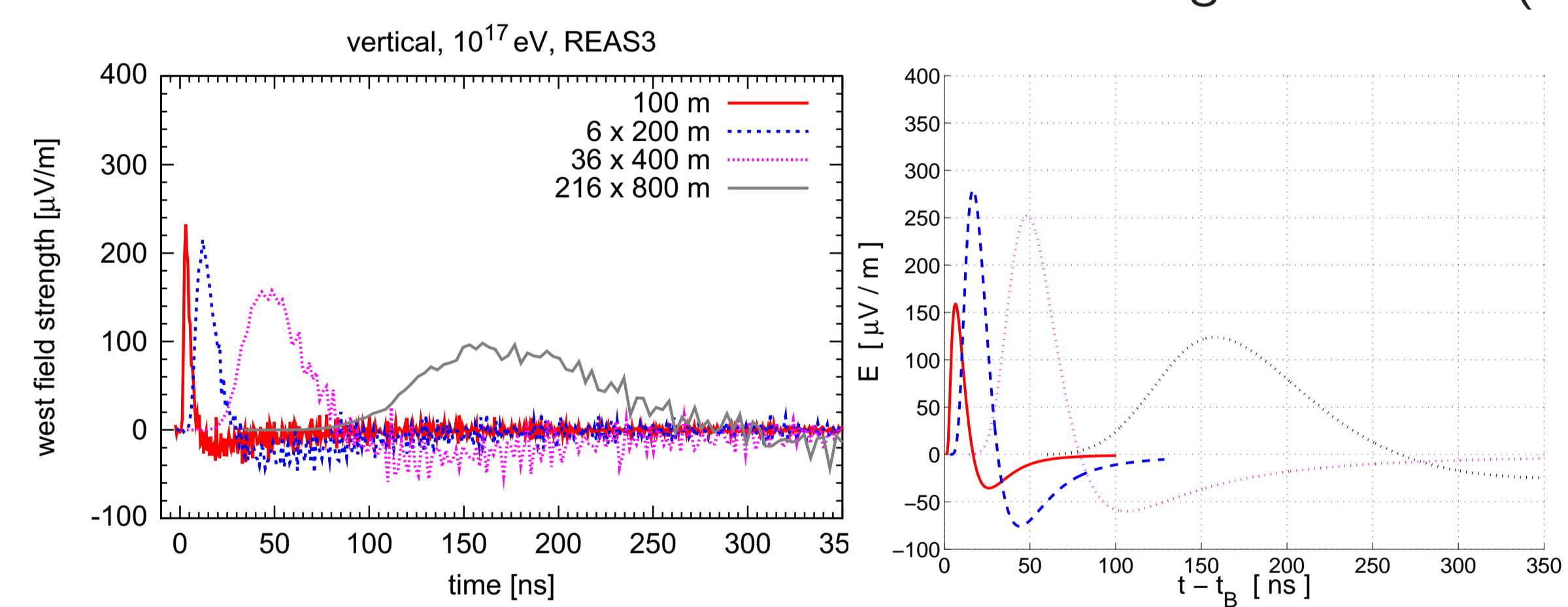
(a) ν_τ peak conversion efficiency for 30 km rocks



(b) τ energy spectrum for 30 km rocks

Air Shower and Radio Signal Simulation

- ▶ Extensive Air Shower Simulation: use CORSIKA
- ▶ Radio Emission:
 - ▶ two modeling methods:
 - ▶ MGMR by Werner *et. al*
 - ▶ REAS3 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

Perspectives

- ▶ Summary and Outlook
 - ▶ Self triggering detection and identification of EAS already performed by TREND
 - ▶ 21 CMA site well suited for measuring UHE ν_τ induced showers
 - ▶ Excellent electromagnetic environment
 - ▶ Favorable site topology
 - ▶ Preliminary results from simulations show great potential:
 - ▶ For $10^{16} - 10^{20}$ eV ν_τ
 - ▶ 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)
 - ▶ Computing Centers of: IHEP, IN2P3, NAO