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SalSA: A Teraton UHE Neutrino Detector

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Abstract.
The observed spectrum of ultra-high energy cosmic rays virtually guarantees the presence of ultra-high energy neutrinos due to their interaction with the cosmic microwave background. Unlike cosmic rays, each of these neutrinos will point back directly to its source and will arrive at the Earth unattenuated, from sources perhaps as distant as $z = 20$. The neutrino telescopes currently under construction, should discover a handful of these events, probably too few for detailed study.

This paper describes how an array of VHF and UHF antennas embedded in a large salt dome, SalSA (Salt dome Shower Array) promises to yield a teraton detector (> 500 km^{3} ^{sr}) for contained neutrino events with energies above 10^{17} eV. Our simulations show that such a detector may observe several hundreds of these neutrinos over its lifetime with excellent angular resolution providing source locations.

Keywords: ultra high energy, neutrino, teraton, salt dome, Askaryan
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ULTRA HIGH ENERGY NEUTRINOS

The GZK process [1], in addition to the well known attenuation of cosmic ray energy, also predicts a flux of cosmic neutrinos as one of the decay products of the interaction. This interaction occurs when an UHE proton with sufficient energy interacts with a cosmic microwave background (CMB) photon at the Δ resonance. The pions produced further decay into leptons and neutrinos.

Above around 5×10^{19} eV, a cosmic ray proton will lose energy by repeated CMB interactions and be attenuated to around the threshold within a GZK sphere of around 500 mega parsecs. Cosmic rays with energy at and above the GZK threshold have been observed [2, 3] virtually guaranteeing the UHEν flux. Additionally, while charged cosmic rays can be deflected by magnetic fields, UHEνs arrive both unattenuated and undeflected allowing for acceleration source determination.

UHEν DETECTORS

Several experiments have put limits on the UHEν flux but none have claimed detection. Figure 1 (LHS) shows the predicted flux assuming the source is GZK protons [4], heavy ion GZK cosmic rays [5] and a topological defect model with $M_X = 1 \times 10^{24}$ eV [6]. Additionally, the figure also shows the limits on the neutrino flux set by the ANITA-lite test flight [7], RICE [8], GLUE [9] and FORTE [10] experiments.

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Askaryan Effect Radio Detection

In 1962, G. Askaryan realized that a large coherent Cerenkov signal would be created by an electromagnetic shower showering in matter [11]. The large matter (e^-) asymmetry created in the shower creates a very strong signal at radio wavelengths. The ANITA, GLUE, RICE and FORTE experiments are all based on the radio detection UHEν induced showers. Both the ANITA and RICE experiments look for radio signals in Antarctic ice. FORTE observes the earths surface looking for shallow showers and GLUE watched for radio Cerenkov coming from the lunar regolith.

The SalSA Detector

Our proposed detector, the Salt dome Shower Array (SalSA), mimics the RICE detector but deploys strings of radio antennas within a salt dome. Salt domes are created by the diapiric rise of salt deposits and are often in excess of 99% pure. Figure 2 shows a sketch of the SalSA detector within a salt dome together with an event display. The figure illustrates the multi-kilometer scale of salt domes. Since salt is around 2.4 more dense than ice, a significantly larger "ice equivalent" volume can be used. Salt domes exist around the world and many are located along the United States gulf coast.

The nominal SalSA detector consists of strings of antennas lowered into boreholes drilled into the salt. Each string consists 12 antenna nodes with each node consisting of 12 antennas (6 horizontal "slot" antennas and 6 vertical dipoles). The strings are spaced 250 m apart unless otherwise indicated. A trigger occurs when 5 nodes have 5 antennas with a signal 2.8σ above thermal noise.

Figure 1 (RHS) shows the projected sensitivity of the ANITA experiment [12] as well as several SalSA configurations including a 10×10, 4×4 and 2×2 array. Additionally, the 4×4 array with wider spacing between strings is shown. The number of expected events ranges from tens with the 2×2 array to hundreds with the 10×10 array. Further studies show an angular resolution (@10^{19} eV of arc seconds for the large array with resolution diminishing to degrees for the smallest array. Studies of cross section measurement, flavor ID and others can be found at `http://www.physics.ucla.edu/astroparticle/salsa/www/home/`.

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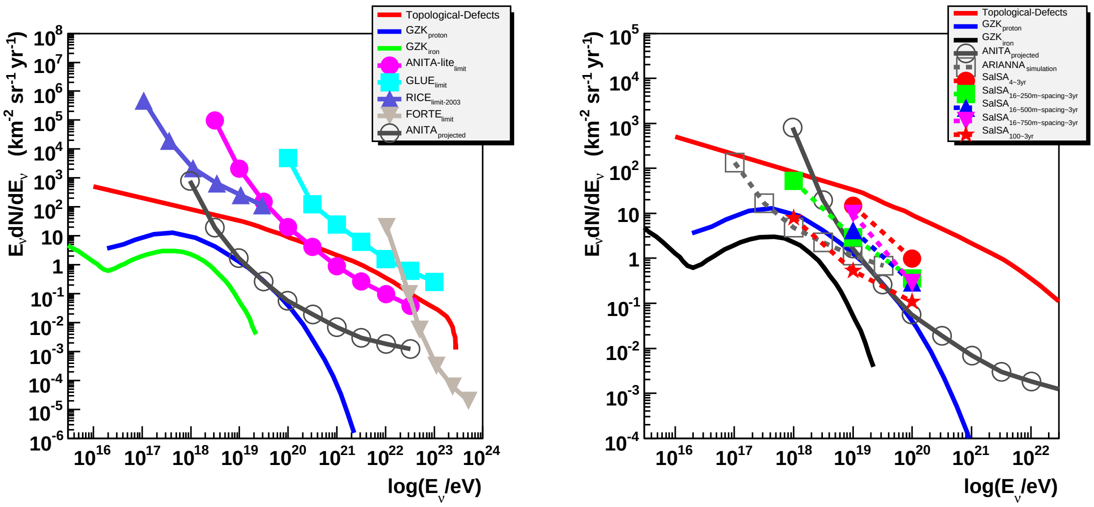

FIGURE 1. LHS: Predicted neutrino flux and current experimental limits. RHS: Predicted neutrino flux and projected sensitivity for ANITA and 3 year sensitivities for various SalSA configurations.

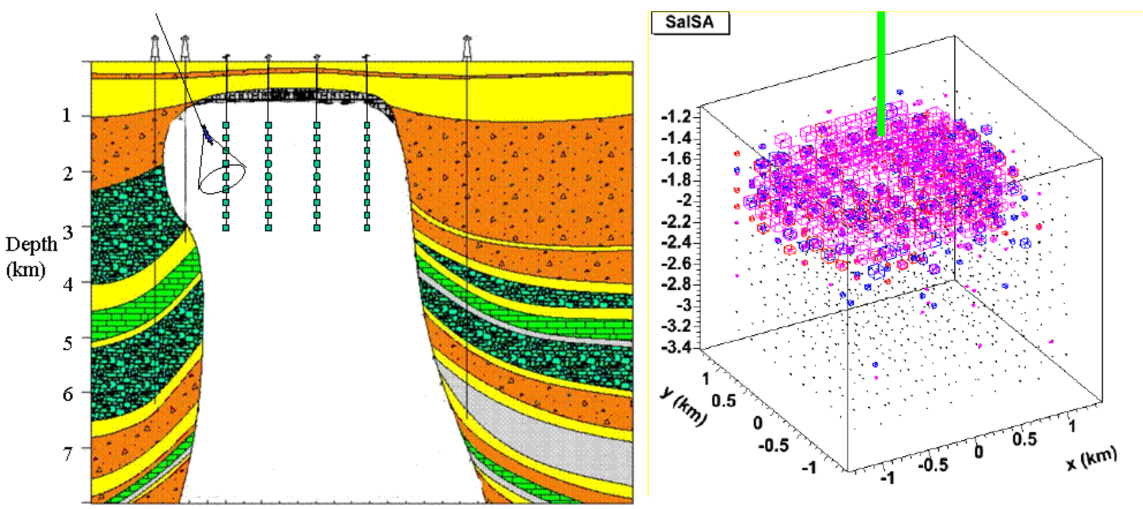

FIGURE 2. LHS: Schematic of the SalSA detector. RHS: $SalSA_{100}$ event display of a vertical event.

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