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Particle Astronomy from Antarctica

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Abstract. A brief review of astroparticle activities in Antarctica is presented including balloon cosmic rays detectors and use of the clear ice sheet for large neutrino telescopes.

1. Introduction

Despite difficult logistics and harsh surroundings, Antarctica offers some unique opportunities as a platform for particle astronomy. The huge ice sheet is an excellent medium for large Cherenkov detectors for cosmic neutrinos. A particle detector has 24 hours coverage of astronomical objects, the magnetic cut-off for charged cosmic rays is very low, the unique wind conditions at high altitudes can be used for long duration balloon flights. The combination of air shower detectors for cosmic rays on the surface above a large neutrino telescope is not possible anywhere else.

2. High energy Cosmic ray detectors in Antarctica

The high energy cosmic rays bombarding the atmosphere are still a mystery 90 years after their discovery. Finding the sources of the cosmic rays is one of the main goals in particle astronomy. The chemical composition of the particles is important information about the sources of the cosmic rays. Since the cosmic ray particles will interact high up in the atmosphere it is necessary to put the detectors at high altitudes or in space in order to directly identify the incoming particles. The flux of particles is steeply falling and at 10^{15} eV it is only one particle per m^2 per year. The energy range around 10^{15} eV is specially interesting since the slope of the spectrum is steepening at a few times 10^{15} eV (the so-called 'knee'). Several cosmic ray experiments are launching balloons at the McMurdo station in Antarctica to an altitude of 35 km where only about 5-10 g/cm^2 of the atmosphere remains. The balloons travel with the wind in a circular path and return to McMurdo after 15-20 days. It is possible to make multiple turns allowing even longer exposure times. These experiments are able to directly identify the chemical composition of the incoming cosmic ray particles: ATIC (sensitive to H–Fe at $10^{10} - 10^{14}$ eV), CREAM (H–Fe, $10^{12} - 5 \cdot 10^{15}$ eV), TIGER (Fe–Zr, $10^8 - 10^{10}$ eV) and TRACER (O–Fe, -10^{14} eV). The sensitive area is, however, only a few square metres which limits the sensitivity above energies of 10^{15} eV. For higher cosmic ray energies large surface based air shower detectors are used. At the South Pole the SPASE-II telescope has been running for several

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years in coincidence with the AMANDA neutrino telescope (see below). The neutrino telescope is measuring the muon flux in the cosmic ray shower while the SPASE telescope measures the electron component in the shower. Knowing both the electron and muon components in the shower gives information about the chemical component of the primary cosmic ray particle. A recent review of cosmic ray balloon experiments can be found in Wefel (2003).

3. Neutrino telescopes in Antarctica

The worlds largest neutrino telescope, AMANDA, is situated 1500 m to 2000 m deep in the ice sheet at the Amundsen-Scott base at the South Pole and is searching for high energy neutrinos from cosmic sources. The neutrinos will point back to the source without being deflected by the magnetic field in space. The telescope consists of 677 optical sensors deployed in 19 strings and was completed in February 2000. The optical sensors are recording the Cherenkov light emitted from neutrino induced interactions in the ice. The ice is very transparent to optical light at large depths. The angular resolution for muon neutrinos is in the order of a few degrees. About three atmospheric neutrinos are observed per day. The main goals are to search for the highest energy cosmic ray sources and for neutrinos from dark matter annihilation in the center of the Earth and the Sun. The most sensitive limits so far for cosmic neutrino sources, diffuse neutrino flux, neutrinos from GRBs etc have been published by AMANDA. See review talk by Köpke (2003) at ICRC 2003.

Despite the large size of AMANDA it might not be enough to detect the cosmic neutrinos. The one cubic kilometer neutrino telescope IceCube will start to be constructed at the same site as AMANDA in 2004/2005 and it is expected to be completed in 2009. The IceCube telescope will consist of 4800 optical modules deployed in 80 strings at depths between 1400 m and 2400 m. On the surface above IceCube an air shower telescope, IceTop will be constructed. The IceCube strings will take data in coincidence with the AMANDA telescope allowing an increased sensitivity for cosmic neutrinos already from the beginning of the construction.

The possibility to use radio waves generated by high energy neutrino interactions in the ice have been investigated in the RICE experiment at the South Pole. The transmission of radio waves in ice is better than for optical light allowing larger spacing between sensors. The energy threshold is, however, higher for radio waves (>10 PeV). An experiment using both the large ice sheet of Antarctica and the balloon facilities in Antarctica is ANITA which in 2006 will search for very short radio pulses generated by high energy neutrinos in the ice sheet. The observable area is in the order of a million km^2 .

References

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