Observation of the first neutrino candidates with IceCube

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The IceCube neutrino observatory at the South Pole will consist of up to 4800 optical sensors - digital optical modules (DOMs), installed on 80 strings between the depths of 1400 to 2500 meters in the antarctic ice, and 320 sensors deployed on the ice surface directly above the strings. Each sensor consists of a 10 inch photomultiplier tube, connected to a waveform-recording digital data acquisition circuit capable of resolving pulses with nanosecond precision and having a dynamic range of at least 250 photoelectrons per 10 ns. The first sensors of the IceCube neutrino observatory - 60 on one string and 16 at four IceTop stations - were deployed during the austral summer of 2004-05. During 2005-06 season 8 more strings and 24 more IceTop stations were deployed, bringing the total number of deployed DOMs to 604.

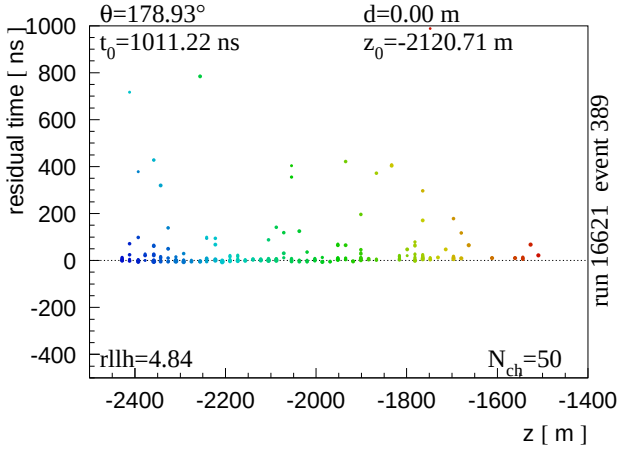

FIG. 1: Photon arrival residual times for the event with multiplicity 50 reconstructed as upgoing muon track.

About 99% of the muon data collected with the IceCube string in 2005 was reconstructed and searched for upward-going muon candidates possibly induced by muon or tau neutrinos [1]. A set of parameter cuts was applied to remove more uncertain, harder to reconstruct tracks, e.g., those that passed far from the string or appeared to represent a widely spread group of muons from a single cosmic-ray shower. These were satisfied by about 70% of reconstructed tracks, corresponding to about 164 days of run time. Additional cuts were developed to remove most of the remaining misreconstructed tracks by rejecting events for which the most likely upgoing hypothesis was comparable to the most likely downgoing hypothesis. These additional cuts were designed to keep most of the upgoing muon tracks.

Two upgoing tracks were found with high hit multiplicity, one with 35 and the other with 50 out of 60 DOMs hit. The observed track lengths correspond to minumum muon energies of 160 and 260 GeV respectively. These two events are reconstructed as muons traveling up with nadir angles of 1.16 $\pm$ 0.06^o and 0.87 $\pm$ 0.05^o degrees from the vertical, respectively. (The stated errors are statistical only; systematic errors may be larger.) Residual arrival times, i.e., time delays from reconstructed unscattered photon expectation, are plotted in Fig. 1 for one of these events. Almost every hit DOM received a direct (unscattered) hit, and many also recorded late (scattered) photons, more so in the dustier ice, and less in the clearer ice. Observation of two nearly vertical upward muons with String-21 in six months is consistent with expectations based on preliminary simulations.

Several events with multiplicities ranging from 8 to 11 were reconstructed as traveling up at larger angles. Confirmation of such events as upward-going neutrino-induced muons would require more information, such as will be available from adjacent strings in the future.

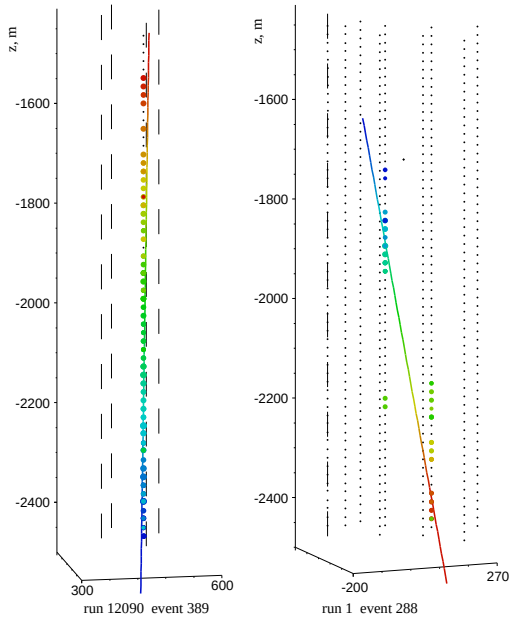

FIG. 2: Upgoing neutrino candidates: high-multiplicity event from year 2005 dataset (single string detector): left; an event from year 2006 (9 strings detector): right

We also applied the developed method to about a day of year 2006 data, resulting in 1 event found (which is consistent with expectation).

[1] A. Achtenberg et al., preprint astro-ph/0604450, to appear in *Astropart. Phys.*