High Altitude Water Cherenkov Observatory
FY14 Q 1 Report

Construction and Operations

Construction is proceeding well with 200 of the 300 water Cherenkov detectors built as of Feb 2014. LANL staff Brenda Dingus and LANL postdoc Patrick Younk spent 2 weeks at the site doing shift. Other work at the site included confirming that only 2 of the tanks are leaking water and these tanks have been know to leak since they were first installed. Also, worked on repairing wet photomultiplier tubes (PMTs) and retrofitting photomultiplier tube mounts in the first installed bladders.

LANL postdoc Patrick Younk and UCI technician Scott Delay (who is stationed at LANL) prepared 120 R5912 PMTs (gain matching, refurbishing, and packaging for shipment). This shipment is awaiting approval of the Mexican government and will bring the total number of PMTs shipped to 802 – enough for 200 WCDs.

LANL postdoc Patrick Younk designed and oversaw the construction of second set of custom jack stands for use in the construction of Water Cherenkov Detectors.

Analysis Techniques

We worked to understand the limitations of current HAWC analysis techniques. In particular the events are binned by the number of PMTs hit (NHIT) and maps of the sky are made for each of these bins (10 altogether). The larger NHIT bins may be sparsely populated even for time periods as long as a month. We developed a simulation to explore the regimes over which the current techniques are valid for calculating the significance of an excess. We found that with the weighting applied even in regimes where the Li-Ma formulation would be expected to be accurate (nEvents>~10), the method is incorrect. LANL is now leading the development of likelihood based analysis techniques that will not suffer from this limitation and can therefore be applied to searches for transient events as well. This multi-bin likelihood-based analysis allows us to more effectively use the Crab as a test beam to calibrate the detector. We have used this technique to estimate the anfular resolution in each NHIT bin. It will also allow us to discover fainter sources and shorter transient events.

Physics Analysis

LANL scientists worked with postdoc from Michigan State University to improve the modeling of the sensitivity of HAWC to primordial black holes. To date no optimization has been performed with regard to both background rejection parameter and the PMT threshold for the analysis. A paper on both the upper limit on nearby evaporating black holes using Milagro data and the sensitivity of HAWC is in progress.

We continue to guide a UC Irvine graduate student in the search for Q-Balls using HAWC. Q-Balls are a prediction of an inflationary universe with supersymmetry. Under certain conditions the Q-Balls formed in the early universe can be stable against decay, in which case they are a dark matter candidate to which HAWC is sensitive. Over this quarter we developed a GEANT4 simulation to mimic a Q-Ball passing through a HAWC tank by injecting anti-protons at rest in the detector according to the interaction cross section of the Q-Balls. To our knowledge this is the first time that such a detailed model of Q-Ball interactions has been done. We also developed a fitting algorithm to reconstruct event vertices (location of Q-Ball interactions with Oxygen nucleus) and fit the vertices into a track (to reduce the background from cosmic-ray muons).

Using the HAWC simulation framework, we have projected the sensitivity of HAWC to gamma-rays from dark matter (DM) annihilation from several astrophysical sources. With its large field-of-view, HAWC will be able to search for gamma-rays from DM annihilation in both point-sources of DM, such as dwarf spheroidal galaxies, and from more extended sources, including galaxy clusters. With its continuous large-angle sky coverage, HAWC can also search for astrophysical objects, which emit high-energy photons from DM annihilation but have not been observed at lower energies. The HAWC sensitivities to DM with masses of tens of TeV should be comparable to current experiments, and HAWC will give the most stringent measured cross-section limits on heavier DM. We currently have a paper in process, which discusses the HAWC projected sensitivity to various DM models and source classes in detail.

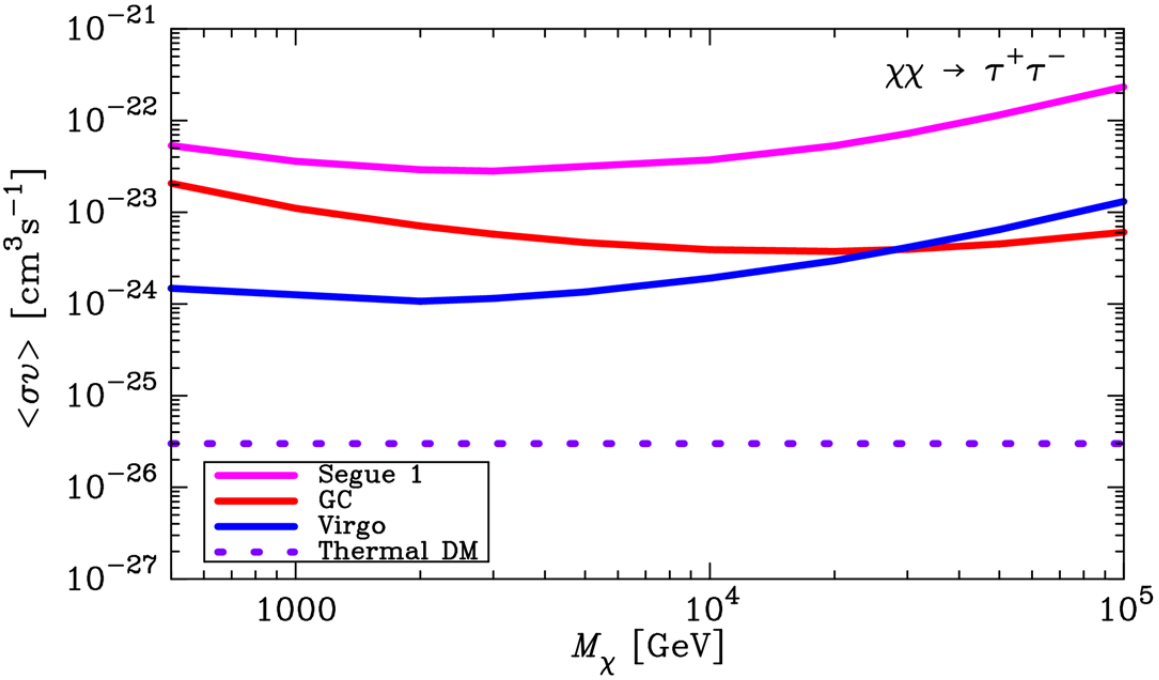

Figure 1: The expected HAWC sensitivity to leptonic DM after 5 years of observations. The limits from three source classes are shown: the Segue 1 dwarf galaxy, the center of the Milky Way, and the Virgo galaxy cluster. For comparison,

the expected DM annihilation cross-section for thermal WIMP dark matter is also shown.

Papers.
Though not directly related to HAWC a Milagro paper was accepted for publication during this review period. This was an analysis of the long-term average flux from Mrk421 with Milagro. This average flux was combined with previously published flare measurements to determine the TeV duty cycle of Mrk421. We found that the TeV duty cycle was consistent with the x-ray duty cycle, though the uncertainties are large. When this technique is applied to HAWC we should be sensitive to a non-leptonic component to the flare states of active galaxies. This method will be applicable to all AGN detected by HAWC (note we have already detected Mrk 421 and Mrk 501 with HAWC).

Invited Talks:
G. Sinnis, "The HAWC TeV Gamma-Ray Observatory", The Violent Universe, sponsored by the IOP, October 2013, London, UK
G. Sinnis, "TeV Gammaa-Ray Astrophysics", Cosmology and Particle Astrophysics, November 2013, Honolulu, HI
G. Sinnis, "TeV Astrophysics with HAWC", seminar UCLA, November 2013
B. Dingus, "Observing the TeV Universe with HAWC" Texas Symposium, Dec 2013
B. Dingus, "Observing the TeV Universe with HAWC" Seminar Southern Methodist University, Dec 2013