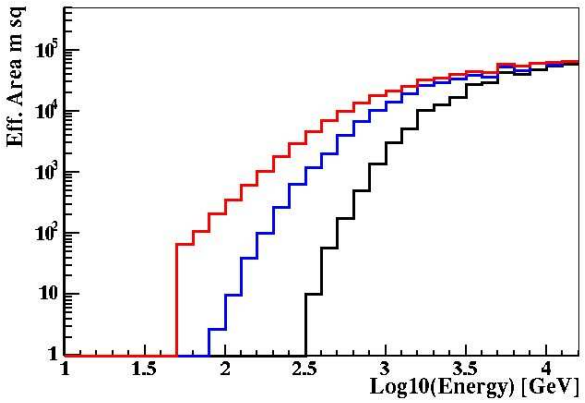

Fig. 1. HAWC effective area versus gamma-ray energy for three different levels of trigger multiplicity [20 (upper red line), 80 (blue line) and 200 (lower black line) PMT trigger] for a zenith angle <30° after applying the cosmic ray background rejection cut and requiring a reconstructed direction within 1°.

trigger multiplicities, see Figure 1. The larger size results in an improved angular resolution of two dimensional Gaussian sigma of 0.25°–0.4° depending on the number of PMTs hit because of a better determination of the shower front curvature and core location. The background rejection and efficiency also improves significantly, especially at low energies, because we can detect penetrating particles such as muons over a much larger area. The hadron rejection efficiency increases with energy so that at energies above about 2 TeV, HAWC will detect Crab-like sources with a S:B ratio of better than 1:1 which is unprecedented for an EAS detector. Finally, the optical isolation decreases the number of PMTs hit by light traveling horizontally across the array. Then, the number of PMTs hit not related to the shower decreases resulting in a better angular resolution and a lower trigger multiplicity.

This paper describes the capability of HAWC based on an extension of the Milagro simulation software package using CORSIKA and GEANT software. The simulation has been throughly tested by comparing it with Milagro data. And while the agreement with Milagro is very good, gamma-rays and background rates are scaled from measured values in Milagro by comparing the predictions of the HAWC and Milagro simulations. By doing this, potential systematic errors internal to the simulation from the air shower modeling, optical model, detection efficiency and in the measurements of gamma-ray fluxes and hadronic backgrounds provided by other experiments are removed giving us a high level of confidence in our results for HAWC.

2. CAPABILITIES

The position of the shower core on the ground is determined by fitting the distribution of pulse amplitudes to a standard lateral distribution profile. After the core is located, the PMT hit times are adjusted to account for the curvature of the shower front. The curvature is treated as a cone of slope ∼0.5°-1.0°, so misidentification of the core position leads to degraded angular resolution. The corrected PMT hit times are then fit to a plane to determine the incoming shower angle. The estimated angular resolution reaches a minimum of ∼0.1° above 5 TeV.

Hadronic showers are identified through the pattern of energy deposition in the array. While gamma-rays induced showers have compact cores with smoothly falling density, hadronic showers typically deposit large amounts of energy in distinct clumps far from the shower core. The Milagro compactness parameter, C, have been extended for HAWC. C is defined as the total number of PMTs hit divided by the largest pulse amplitude that is more than 40 m from the reconstructed core position. Gamma-ray and hadron induced showers have large and low values of C respectively. The hadron rejection efficiency increases with energy.

The energy resolution is limited by shower fluctuations in the atmosphere, as only the tails of EM showers are detected. When the effective area is less than the physical detector area, fluctuations in the shower development begin to dominate the response of the detector. It is impossible to distinguish between a low energy gamma ray that interacted deep in the atmosphere and a higher energy gamma ray that interacted higher in the atmosphere. Therefore the energy resolution of HAWC is strongly dependent upon the primary gamma ray energy. Showers with energies near or above the median (1 TeV) can be reconstructed with ∼30–40% resolution. Figure 2 demostrates the ability of Milagro to measure the Crab spectrum.

3. SCIENTIFIC GOALS

HAWC will monitor for >4 hours every day, every point in ∼2π sr of the sky. Over a 1(4) year observation period HAWC will perform an unbiased sky survey with a detection threshold of ∼40(20) mCrab (see Figure 3), enabling the monitoring of known sources, the discovery of new sources of known types, and the discovery of new classes of TeV gamma ray sources.

The HAWC sensitivity depends on the source spectrum as shown in Figure 4. HAWC sensitivity to extended sources surpasses that of imaging