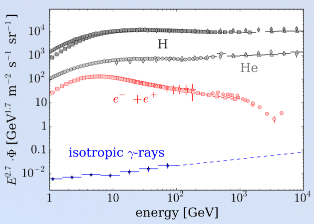
Towards a Measurement of e^+e^- with HAWC

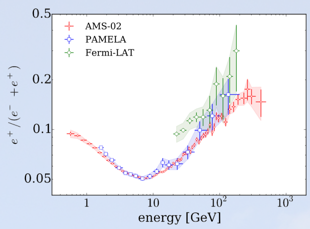
Segev BenZvi[a], Daniel Fiorino[b], Zigfried Hampel-Arias[b], and Mehr Un Nisa[a]
for the HAWC Collaboration
[a]University of Rochester, Rochester, NY, USA [b]University of Wisconsin-Madison, Madison, WI, USA

The High Altitude Water Cherenkov (HAWC) Observatory records the air showers produced by cosmic rays and γ rays at a rate of about 20 kHz. The large background of hadronic cosmic rays observed in the detector can be suppressed using topological cuts to preferentially select electromagnetic air showers. With these cuts it is possible to produce a sample of events dominated by γ rays and cosmic e± showers. HAWC is one of the few observatories currently able to observe e± showers above 1 TeV. We discuss the prospects for the measurement of the e± flux and e+ / e- charge separation above 1 TeV with HAWC.

The e^+e^- Flux and the Positron Fraction

Below 10 GeV the cosmic *e*± flux is a significant component of the all-particle cosmic-ray spectrum, but due to synchrotron and inverse Compton losses the leptonic flux decreases like $E^{-3.05}$ with a cutoff above 800 GeV. As a result, above several hundred GeV the electrons and positrons observed at Earth likely originate in nearby Galactic sources <1 kpc from the solar system.

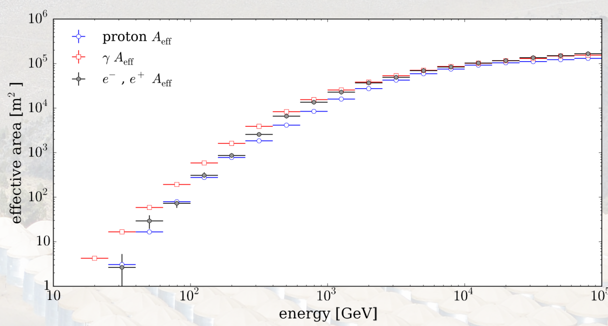




Similarly, the relative fraction of positrons in the *e*± flux hints at the presence of a nearby source of primary cosmic rays, perhaps ~100 pc from Earth. The *e*+ fraction has been observed to increase from 5% at 10 GeV to ~15% at 100 GeV. Extending the measurement of the *e*+ fraction to 1 TeV is well-motivated, since it could help discriminate between origin models of this "excess" positron flux.

The HAWC Gamma-Ray Observatory

HAWC is an air shower array located at 4100 m altitude and 19°N latitude in Sierra Negra, Mexico. The detector observes cosmic rays and γ rays from an instantaneous field of view of 2 sr with an all-sky rate of 20 kHz. Using simple topological cuts on the channels triggered by an air shower, it is possible to discriminate between hadronic showers produced by cosmic rays and electromagnetic showers produced by γ and *e*± primaries [1].



The effective area of HAWC to air showers produced by cosmic protons, γ rays, and *e*± events is shown above. The area was calculated by applying a channel multiplicity cut $N_{\rm hit} \geq 27$, a zenith cut θ ≤ 50°, and by removing showers reconstructed >2.5° from their true direction. Above several hundred GeV, where the HAWC array approaches full efficiency, the *e*± effective area is similar to the area for γ-ray showers. We expect to observe ~5×10^8 *e*± showers per year in HAWC (15 Hz rate) from 2/3 of the sky.

Sensitivity to the Isotropic e± Flux above 1 TeV

In HAWC, the detection of the isotropic flux of *e*± is affected by three sources of background:

1. Isotropic extragalactic γ rays
2. Gamma rays from point sources and Galactic diffuse emission
3. Isotropic hadronic cosmic rays

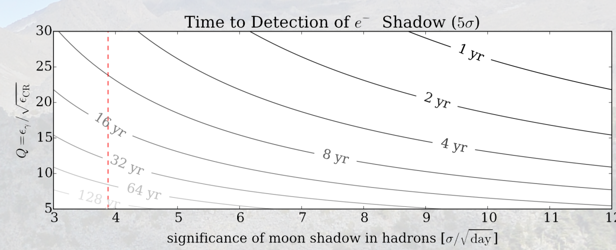
Based on measurements below 100 GeV, the isotropic extragalactic γ-ray flux is not expected to compete with the *e*± flux below ~10 TeV. Moreover, Galactic γ rays can be removed by masking out point sources and the Galactic Plane.

In contrast, the cosmic-ray background is a major hurdle for measuring the *e*± flux. The current γ-hadron separation power (defined by the selection efficiencies ε_γ and ε_{CR}) is $Q = \varepsilon_\gamma/\sqrt{\varepsilon_{CR}} \approx 5$. A value $Q \approx 30$ is needed to achieve a S/N ratio of 1:1, which is likely needed to observe an isotropic flux. Reaching *Q*=10 is achievable in HAWC; $Q \approx 30$ is possible and will be the focus of future work [2,3].

Charge Discrimination: Observing the Moon Shadow

HAWC is capable of discriminating *e*+ and *e*- showers by observing the shadow of the Moon in the *e*± flux. The average deflection of cosmic rays of charge *Z* and energy *E* at the location of HAWC is given by $\delta\theta \approx 1.6°\times Z\times(E/\mathrm{TeV})^{-1}$ [4].

The median energy of cosmic rays observed with HAWC is 2 TeV [5], so the expected geomagnetic deflection is 0.8°, larger than the diameter of the Moon and the angular resolution of the detector.



Using the significance of the Moon shadow observed in cosmic rays σ_{CR}, the ratio of the cosmic-ray and *e*± fluxes, and the *Q* value of the analysis, we can estimate the expected time to see the Moon shadow in *e*- with HAWC. Given reasonable improvements to *Q* and the angular resolution of the detector, it should be possible to observe the Moon shadow during the 5-year run of the experiment.

References

1. A. Smith, *HAWC: Design, Operation, Reconstruction, and Analysis*, ICRC15
2. Z. Hampel-Arias, *Gamma-Hadron Separation with Pairwise Compactness*, ICRC15
3. T. Capistrán, *Gamma-Hadron Separation with Neural Networks*, ICRC15
4. S. BenZvi, *An All-Sky Simulation of the Response of HAWC*, Proc. ICRC 2013
5. D. Fiorino, *Observation of Anisotropy of Cosmic Rays with HAWC*, ICRC15

Acknowledgments

We acknowledge the support from: the US National Science Foundation (NSF); the US Department of Energy Office of High-Energy Physics; the Laboratory Directed Research and Development (LDRD) program of Los Alamos National Laboratory; Consejo Nacional de Ciencia y Tecnología (CONACyT), Mexico (grants 260378, 55155, 105666, 122331, 132197, 167281, 167733); Red de Física de Altas Energías, Mexico; DGAPA-UNAM (grants IG100414-3, IN108713, IN121309, IN115409, IN111315); VIEP-BUAP (grant 161-EXC-2011); the University of Wisconsin Alumni Research Foundation; the Institute of Geophysics, Planetary Physics, and Signatures at Los Alamos National Laboratory; the Luc Binette Foundation UNAM Postdoctoral Fellowship program.

Web: http://www.hawc-observatory.org

Contact: sybenzvi@pas.rochester.edu, fiorino@icecube.wisc.edu
zhampel@icecube.wisc.edu, mehr@pas.rochester.edu

A complete author list for the HAWC Collaboration can be found at
http://www.hawc-observatory.org/collaboration/icrc2015.php