Redeployment of the Haleakalā Neutron Monitor in Hawai‘i

Andrew Kuhlman[1], Veronica Bindi[2], Malcolm Colson[1], Jason Legere[1], Nikolay Nikonov[2], James Ryan[1]

[1]University of New Hampshire [2]University of Hawai‘i at Mānoa

Introduction

What is a Neutron Monitor?

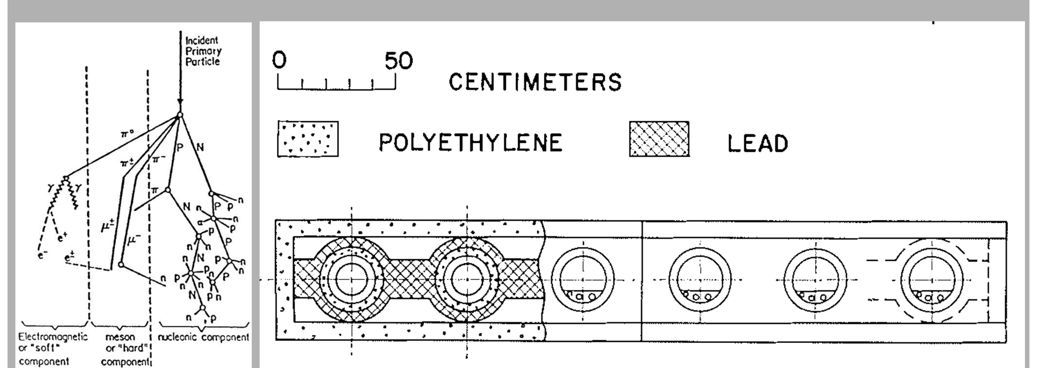

Figure 1. Left – the particles produced in a cosmic ray shower [1]. Right – the components of a neutron monitor [2].

Neutron monitors are ground-based particle detectors that are sensitive to nucleons from cosmic ray showers [1]. When a cosmic ray particle strikes molecules in the atmosphere, it can create secondary particles which can, in turn, create secondary particles of their own. This cascade of particles is known as a cosmic ray shower (figure 1 left).

A neutron monitor consists of several components (figure 1 right). The polyethylene reflector helps prevent background nucleons from the environment from entering the detector. The lead producer and polyethylene moderator increase the chances of detection. Finally, the proportional counter tube “counts” the neutrons that enter it.

The Global Neutron Monitor Network

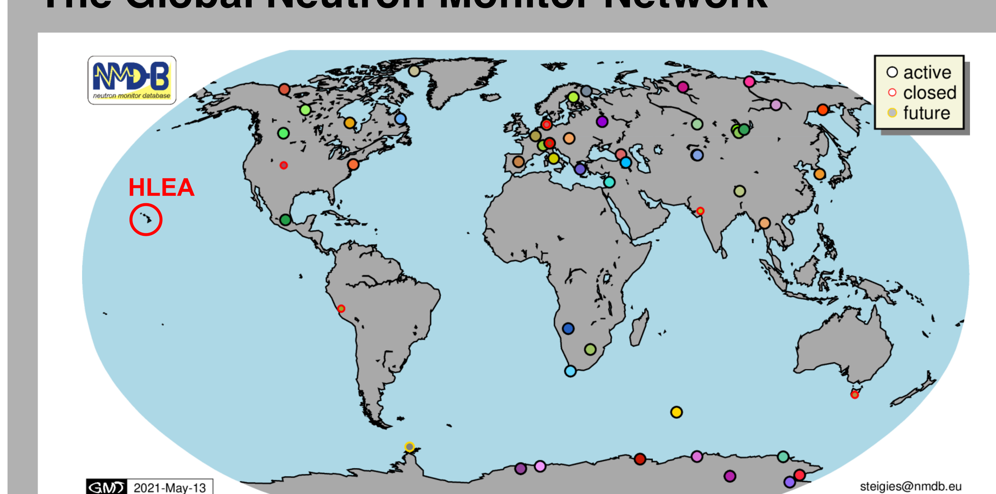

Figure 2. The global neutron monitor network. Hawai‘i is circled in red.

The global neutron monitor network consists of ~50 stations distributed around the globe (figure 2). Because of the attenuation of charged particles by the Earth’s magnetic field, which varies significantly with geomagnetic latitude and incoming particle direction, each neutron monitor is sensitive to different parts of the cosmic ray spectrum. Because of this, the global neutron monitor network essentially acts a giant spectrometer [3].

Solar Neutrons

During solar flares, high energy neutrons are produced in the solar atmosphere. These neutrons carry information about solar energetic particle acceleration and nuclear reactions happening in the solar atmosphere [4]. Some of these neutrons reach earth and cause particle showers that are detected by neutron monitors which are known as “solar neutron events”.

Preparing the Site

A lot of work had to be done at the summit to prepare the site for the arrival of the detector:

- Level the ground at the site
- Dig trenches for power lines and data lines that go from nearby buildings to the location of the detector
- Set up a panel for data and power lines
- Install concrete footings for the containers that house the detectors (both HLEA and Thimon)
- Clean up the site as per the rules and regulations attached to the summit, which include making sure the work is respectful of the wildlife, the environment, and the cultural and historic significance of the summit
- Schedule the work around nēnē nesting season on the mountain. A nēnē is the Hawaiian goose, the state bird of Hawai‘i.

Figure 3. Work being done to prepare the site on the summit of Haleakalā

Why Haleakalā?

The new neutron monitor, HLEA, has several advantages because of its unique location:

- **The detector’s location in tropical Hawai‘i** means that the detector’s location is at low latitude. Since solar neutrons are not affected by magnetic fields, the response of the detector to solar neutrons is dependent on the solar zenith angle, where an angle closer to vertical is more preferred. This means a tropical location like Hawai‘i is a great boon for solar neutron detection [5].
- **The detector’s location on the summit of Haleakalā** is also advantageous for solar neutron detection because of its high altitude. The atmosphere attenuates solar neutrons, so the number of observed neutrons increases exponentially with altitude [5]. Figure 4 shows the most recent solar neutron event measured by the old, deccomissioned Haleakalā neutron monitor.
- **The dectector’s location in the middle of the Pacific Ocean** helps fill in a significant geographical gap in the global neutron monitor network. Without HLEA, there are not any active neutron monitors between Thailand and Mexico City, a gap of ~162 degrees longitude.

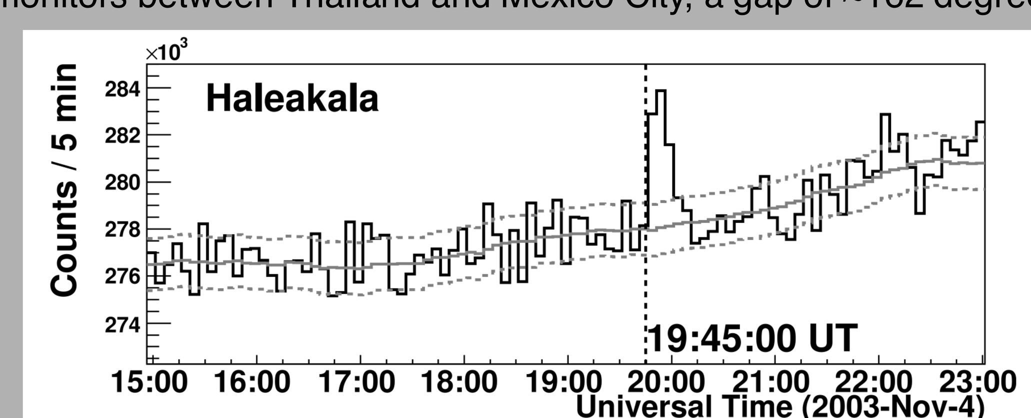

Figure 4. The most solar neutron event measured by the old, decommissioned Haleakalā neutron monitor.

Monitor Housing

The HLEA monitor is set up in a shipping container with two banks of 3 tubes on each side (figure 5).

The polyethylene from the old, decommissioned monitor was shipped from Hawai‘i to the University of New Hampshire to be reused in the new monitor. The polyethylene and ~9000 kg of newly manufactured lead rings were assembled at the University of New Hampshire in Durham, NH. The housing was secured, and the container was prepped for shipping. The container arrived in Hawai‘i on July 11, 2024.

The container was scheduled to be transported to the summit of Haleakala shortly afterwards, but due to wildfires near the summit, the container is still waiting to go up the mountain.

Figure 5. Top – a rendering of the shipping container and the positions of the housing for 2 banks of HLEA tubes. Bottom – a photograph of one bank the HLEA monitor. The proportional counter tubes are still missing. The polyethylene reflector has been removed from the top to show the lead producer

Hardware and Software

Electronics In April 2024, front-end boards were installed on the 6 bare tubes that will eventually go into the monitor housing (figure 6). The boards consist of a pre-amp that converts the current pulse signal into a voltage pulse signal as well as a discriminator and an isolator that set the threshold and turn the analog signal into a TTL pulse. In addition, high voltage power supplies, low voltage power supplies, housekeeping sensors (pressure, temperature, humidity, voltage, current), and an NI cRIO 9035 (that runs the software and records the data) were integrated as well.

Software Software was developed by the University of New Hampshire to turn TTL pulses from the front-end boards and sensor outputs into recorded data.

Housekeeping The sensor data and pulse widths recorded on the cRIO are used to monitor environmental conditions and the health of the instrument. In addition, each container will be outfitted with a housekeeping PC which can remotely control the power, view the instrument live with USB cameras, and access housekeeping data (temperature, humidity, etc.) from the cRIO.

Dataflow The Haleakalā monitor will be connected to the internet via the Institute for Astronomy (University of Hawai‘i) network. From there, the data will be sent to the University of New Hampshire, the University of Delaware, and the University of Hawai‘i. The data will be processed and provided to the global neutron monitor network. Additionally, the data will be an integral part of a space weather center at the University of Hawai‘i where it will be used for space weather alerts and educational outreach.

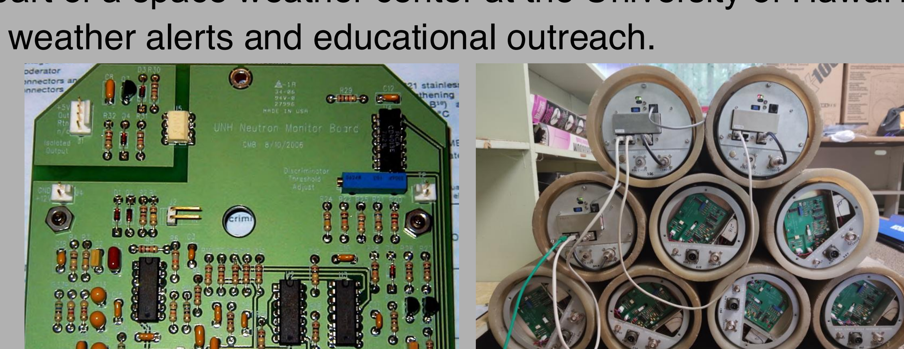

Figure 6. Left- the front-end electronics board. Right – 9 bare proportional counter tubes, 6 of which will go into HLEA and have been outfitted with the front-end boards. The other 3 tubes will go into Thimon and have been outfitted with electronics from the University of Delaware.

Thimon

Thimon is a decommissioned 3-tube neutron monitor that was used for latitude surveys provided by Chiang Mai University, Thailand (figure 7). Thimon will be outfitted with proportional counter tubes provided by the University of Hawai‘i and electronics provided by the University of Delaware.

By adding the 3 tubes from Thimon to the 6 tubes from HLEA, Thimon increases the effective area of the detector by 50%. Thimon and HLEA will function together on the summit of Haleakalā as a single instrument.

Figure 7. The Thimon monitor. The proportional counter tubes are not yet installed

Deployment Status

- The housing for the proportional counter tubes was constructed at the University of New Hampshire and has arrived in Hawai‘i.
- The site for the detector has been prepared on the summit of Haleakalā.
- The electronics and software were successfully integrated and tested.
- Once the wildfires subside, HLEA and Thimon will be moved to the summit of Haleakalā (figure 8) where they will be outfitted with tubes and electronics and become **fully operational in September 2024.**

Figure 8. The detector site after work was finished at the summit of Haleakalā

Acknowledgements

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