Workshop on Ghost Particle Hunting: Neutrino Physics and its Applications to World Peace

# HLEA and THIMON: Enhancing Neutron Monitor Data from the Summit of Haleakalā

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# Historical Legacy at Haleakalā – Prof. John Learned's Contributions

- In the 1980s, Prof. John Learned led pioneering cosmic ray research at the summit of Haleakalā.
- He helped establish the Haleakalā Gamma Ray Observatory, featuring a 10 m² multi-mirror Imaging Atmospheric Cherenkov Telescope.
- This innovative telescope detected Cherenkov light from atmospheric showers caused by very high-energy gamma rays and cosmic rays, prior to the development of modern observatories like H.E.S.S. or VERITAS.
- It detected signals from astrophysical sources like the Crab Pulsar and Cygnus X-3.

**Learned, J.G., Roberts, M.D., & Bower, C.R.** (1988). *The Haleakala Gamma Ray Observatory*. Nuclear Instruments and Methods in Physics Research Section A, 264(1-2), 130–135. https://doi.org/10.1016/0168-9002(88)90893-5

**Among the earliest serious efforts to develop air Cherenkov detection at a high-altitude site in the Pacific, contributing to the foundation for future gamma-ray and neutrino observatories.**

# John Learned’s work laid the foundation for Haleakalā’s role in cosmic ray


A group photo from the Dumand 1980 conference.
Left to right, it’s Fred Reines, Francis Halzen, John, Szentgyorgyi Andrew, Bob March, Leo Resvanis, and Ugo Camerini, just outside Watanabe Hall.


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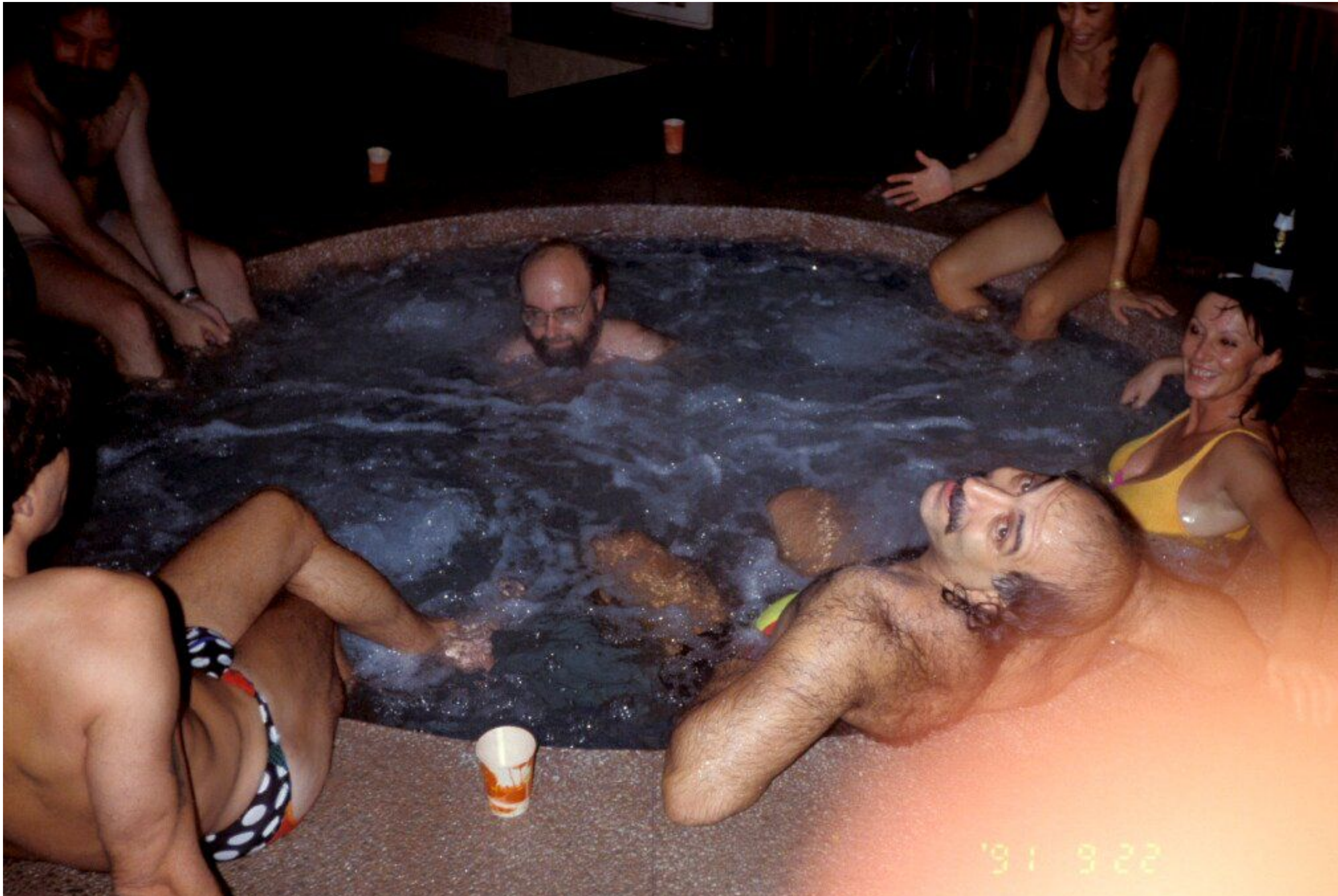
and
SAVE 10%


BUY A CASE
and
SAVE 10%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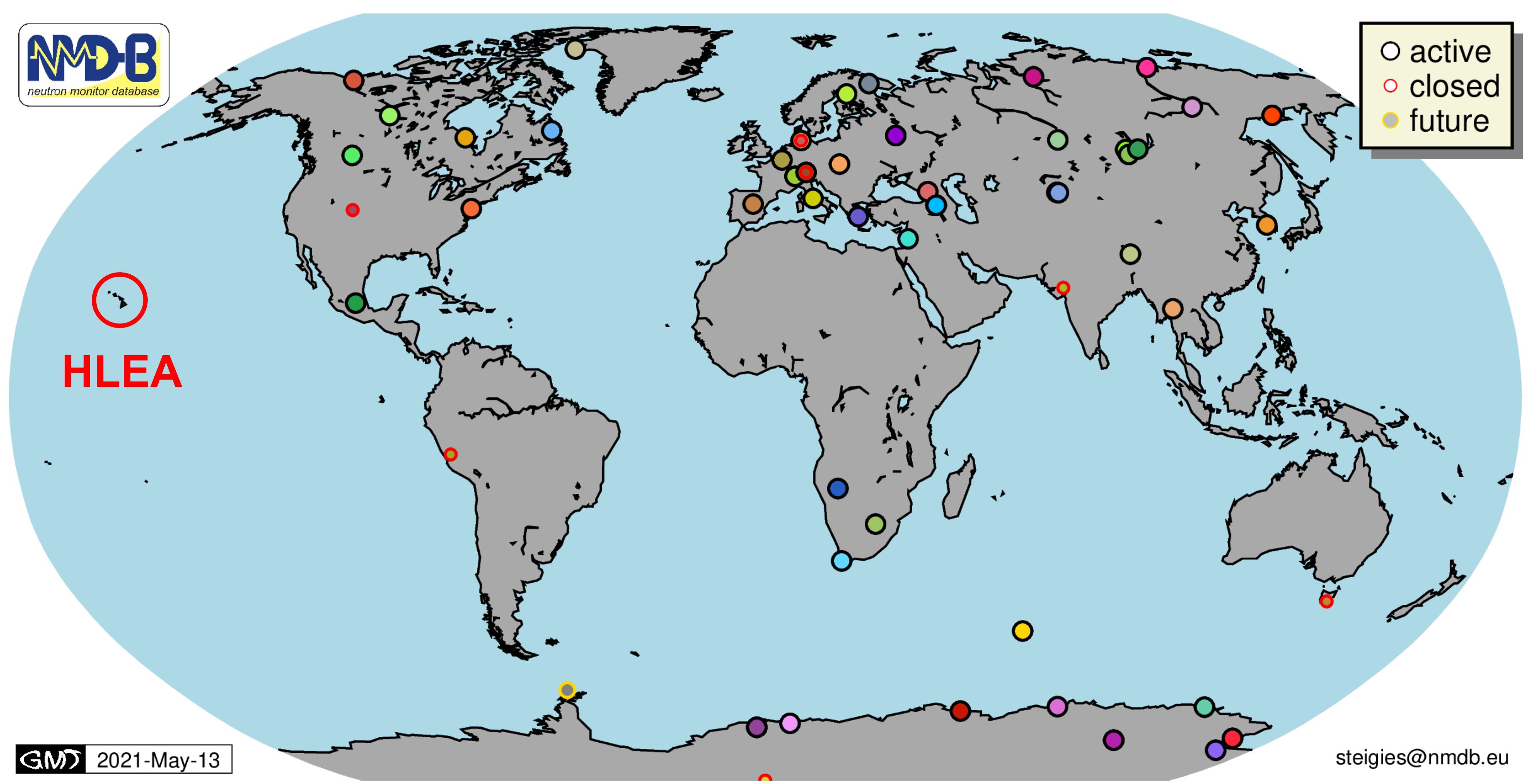
# Continue the legacy of cosmic rays: Redeployment of the Haleakala NM

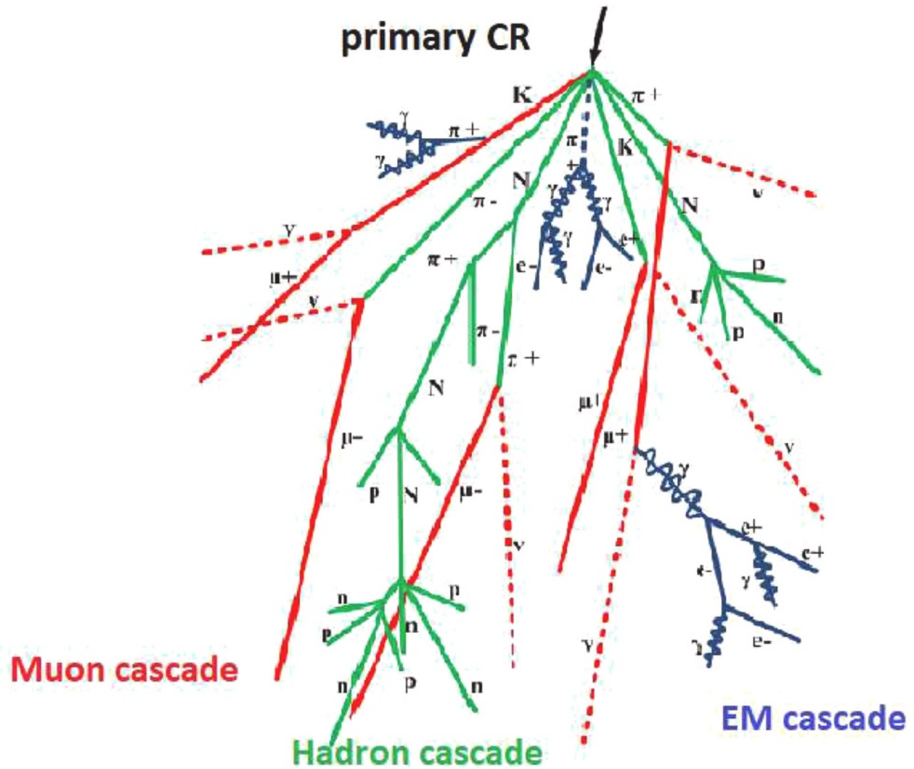
- Today, we continue this legacy with the installation of HLEA (2×3 NM64) and THIMON (3 NM64) neutron monitors at the summit.

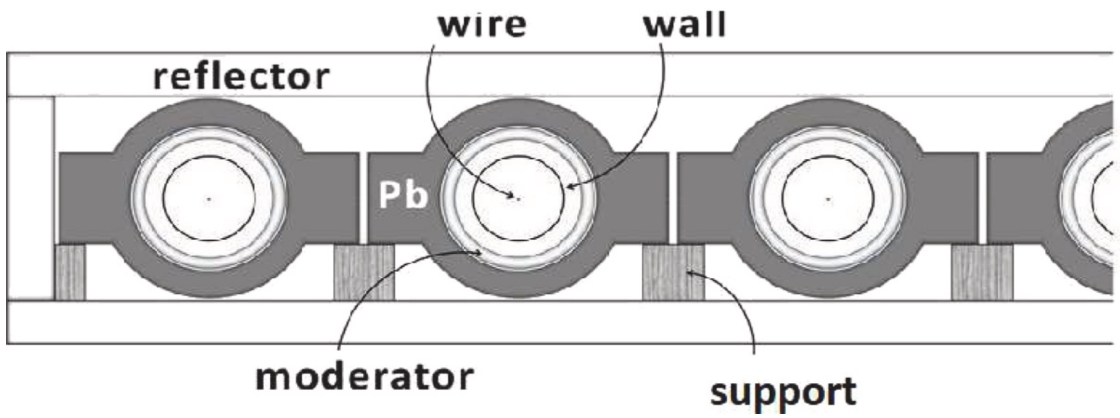
- The original Haleakala (HLEA) NM station was constructed by the University of Chicago in 1991 and decommissioned in 2006.

- The Pacific Ocean represents a large gap in the global NM network over equatorial latitudes for GCR measurements. This gap spans ~162 degrees from Thailand to Mexico City.



# Neutron monitors in a nutshell




- Catches hadronic component of Extensive Air Shower (EAS), produced by primary cosmic ray.
- Consist of:
  - polyethylene reflector – moderate and reflect back n
  - lead producer – increase detection probability with evaporated n (few MeV energy)
  - polyethylene moderator – decrease energy of neutrons to thermal (~0.1 eV)
  - gas – filled counter tube, $^3$He or $BF_3$ are commonly used

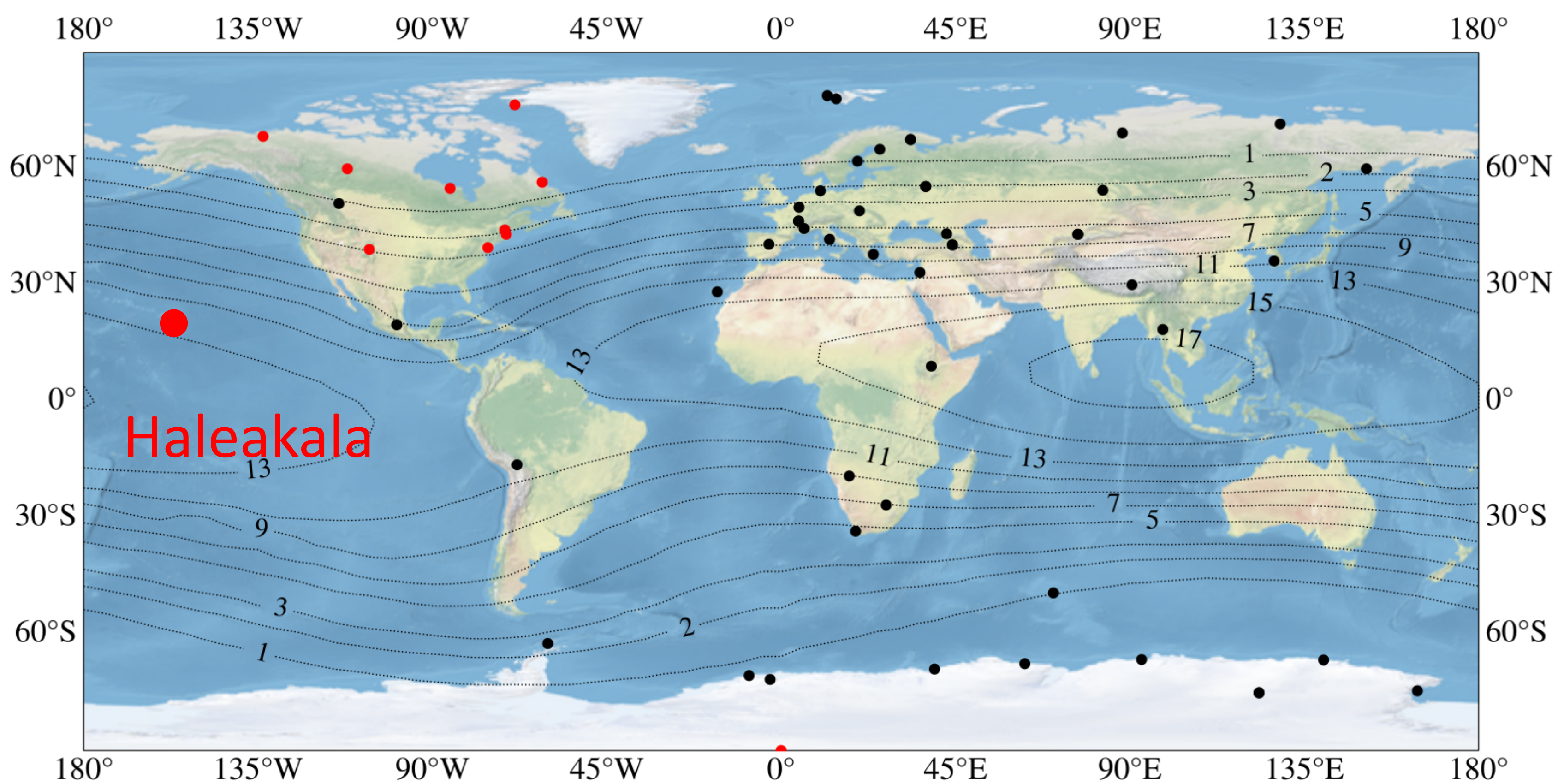
$$^{10}_{5}B + ^{1}_{0}n \rightarrow ^{7}_{3}Li^{+++} + ^{4}_{2}He^{++} + 5e^{-} + \gamma(480\,keV) + 2310\,keV,$$

with 94% probability, and

$$^{10}_{5}B + ^{1}_{0}n \rightarrow ^{7}_{3}Li^{+++} + ^{4}_{2}He^{++} + 5e^{-} + 2790\,keV,$$

with 6% probability.

# Global NM network and US Simpson NM network (SNMN)



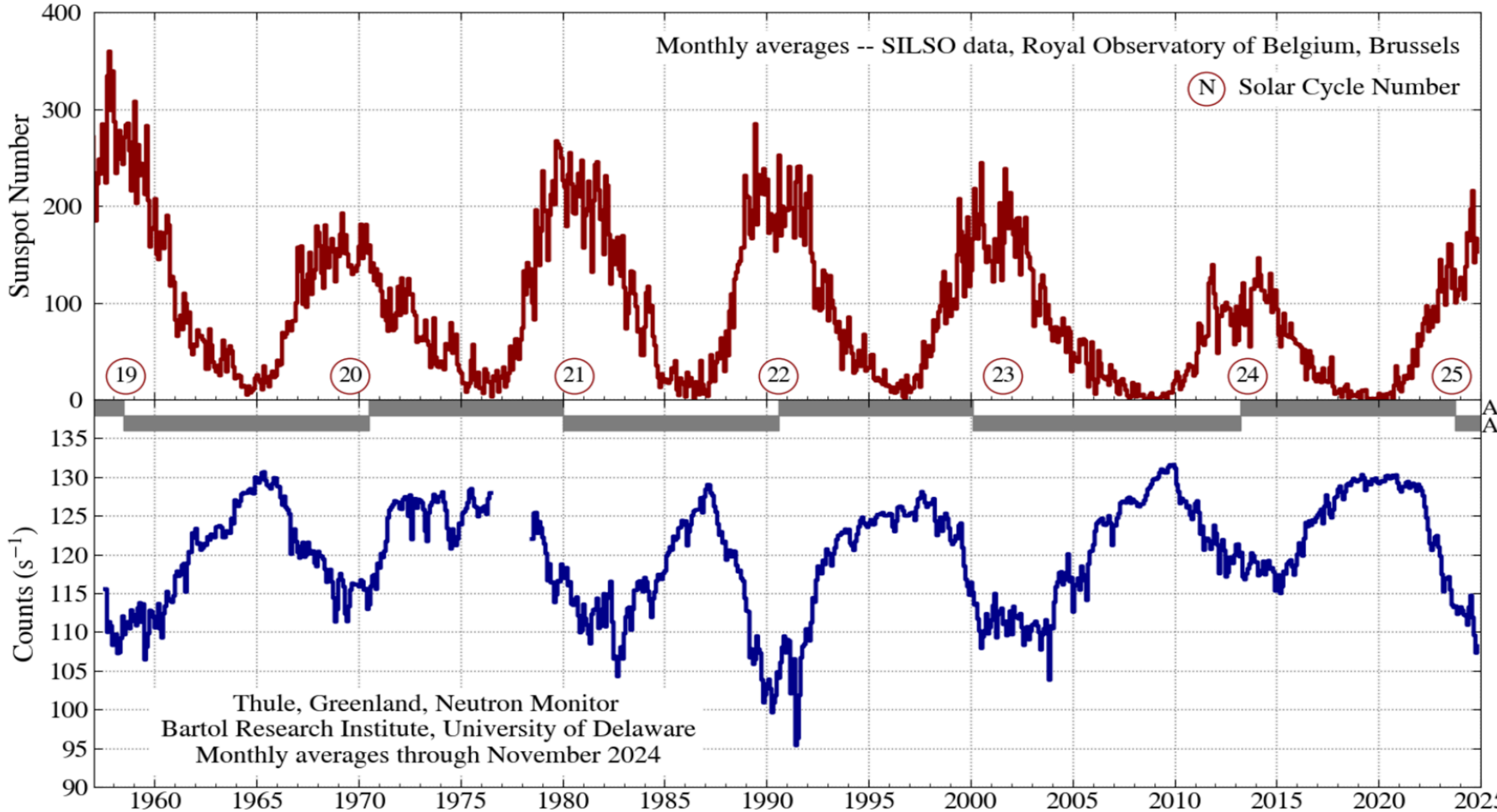

- 50+ operating stations
- ~25 stations provide real-time 1-min data to NMDB
- 11 US operated stations

$$N(t) = \frac{1}{k} \sum_{i=p,He,\cdots} \int_{R_c}^{\infty} J_i(R,t) Y_i(R) dR$$

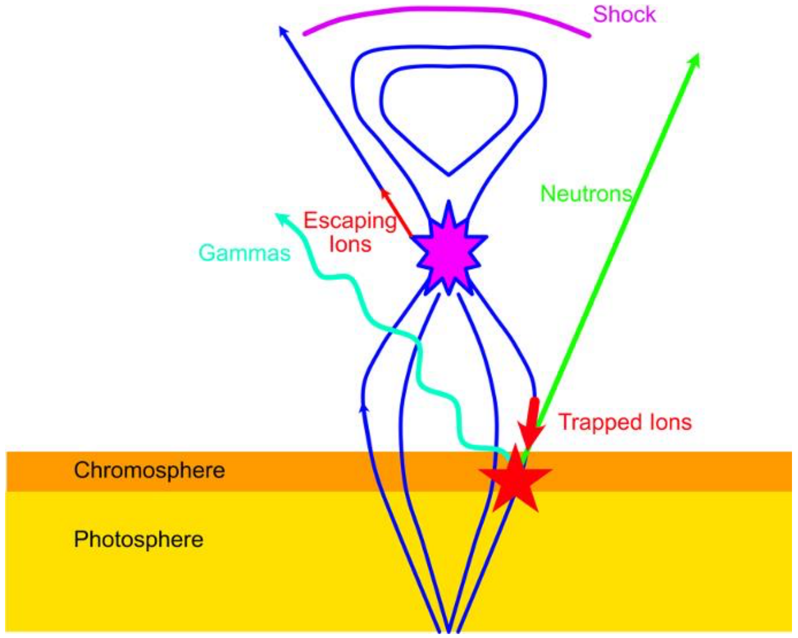
- Geomagnetic rigidities varies up to 17 GV
- Polar regions: SEPs
- Equatorial regions: SNPs
- Altogether: SEP and GCR spectrum over time

**NM stations are located all over the world, employing Earth’s magnetosphere and atmosphere as giant spectrocalorimeter,  recovering primary spectra from count rates**

# Long term solar modulation, GCR flux variation and sunspot number



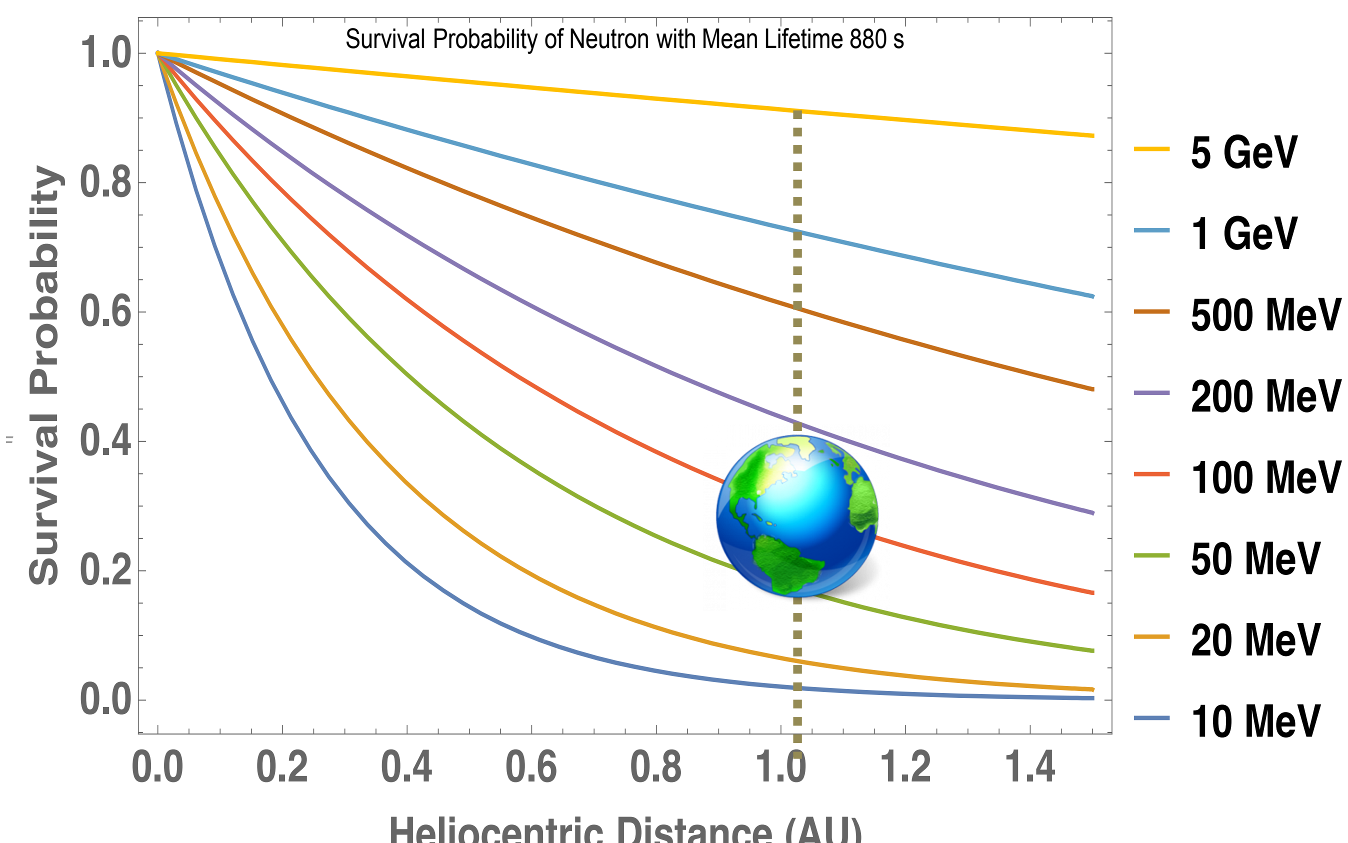
# HLEA: Solar Neutron Particles (SNPs) Detector



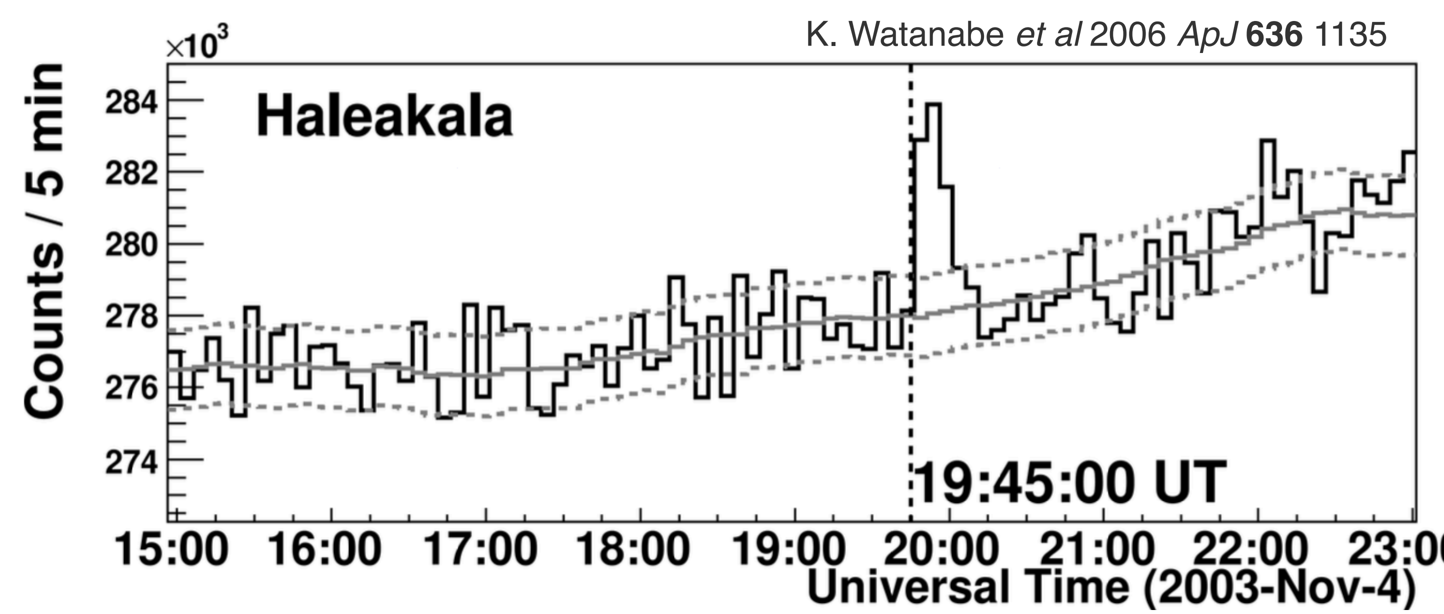

- ➢ SNPs are produced in large solar eruptive events from the Interactions of accelerated protons deep in the solar atmosphere
- ➢ SNPs carry valuable direct  about nuclear interactions, happening near SEP acceleration site.

Only  < 20 SNP events observed from the Sun due to

- Lifetime of free neutrons
- Challenge of measuring neutrons




SNP observed by HLEA on November 4, 2003




**~ 2% increase over background with significance of 7.5 σ**

# HLEA and THIMON neutron monitors at the summit of Haleakalā, Maui


THIMON interior

Data taking since 08 January 2025

Altitude: 3052 m
Vertical atmospheric density: 700 g/cm$^2$
Cutoff Rigidity: 12.9 GV

Covers gap between PSNM and MXCO
Good for GCR modulation, SNPs

# Space Weather - Mission Control Center (SW-MCC) at UH Mānoa



- ➢ Haleakalā NM: HLEA, THIMON
- ➢ AMS
- ➢ Simpson NM network (ground)
- ➢ Global NM network (NMDB)
- ➢ Space and ground instruments

**SWMCC operations** will include:

- ✓ running HLEA and THIMON instruments
- ✓ NM data quality check and analysis
- ✓ AMS data archiving

**SWMCC alerting**:

- ✓ Real time, daily / weekly and monthly reports of the radiation environment on a website
- ✓ AMS and global NM network alert system for SEPs and solar neutrons

# SW-MCC scientific program

- ✓ Cross-calibration of NM, AMS and other space instrument data
- ✓ Derivation of new AMS data products: GCRs variations, SEPs, secondary and trapped particles
- ✓ Derivation of new global NM data products: GCRs variations, GLEs, SNPs.
- ✓ Radiation environment studies in cis-lunar space and at aviation altitudes with NM and AMS
- ✓ Modeling and forecasting of GCR propagation in the heliosphere
- ✓ SW-MCC will be an educational hub

# Happy Birthday John!