



NMDB Meeting 2025: Cosmic Ray studies with Neutron Detectors

Athens, 19 – 21 March 2025

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

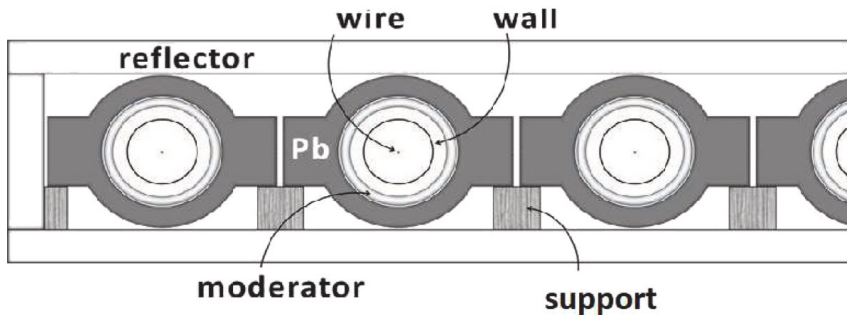
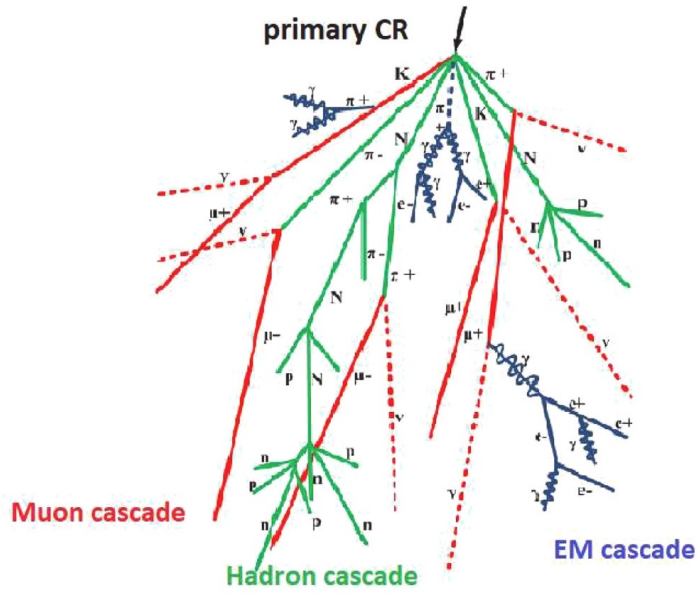
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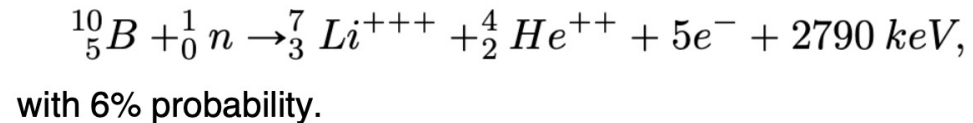
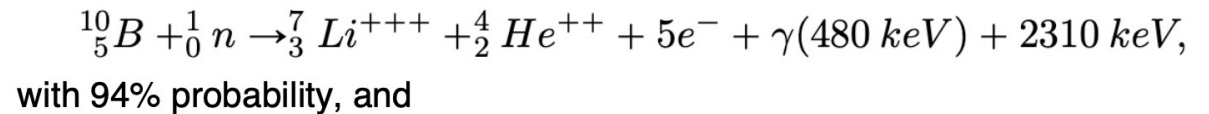
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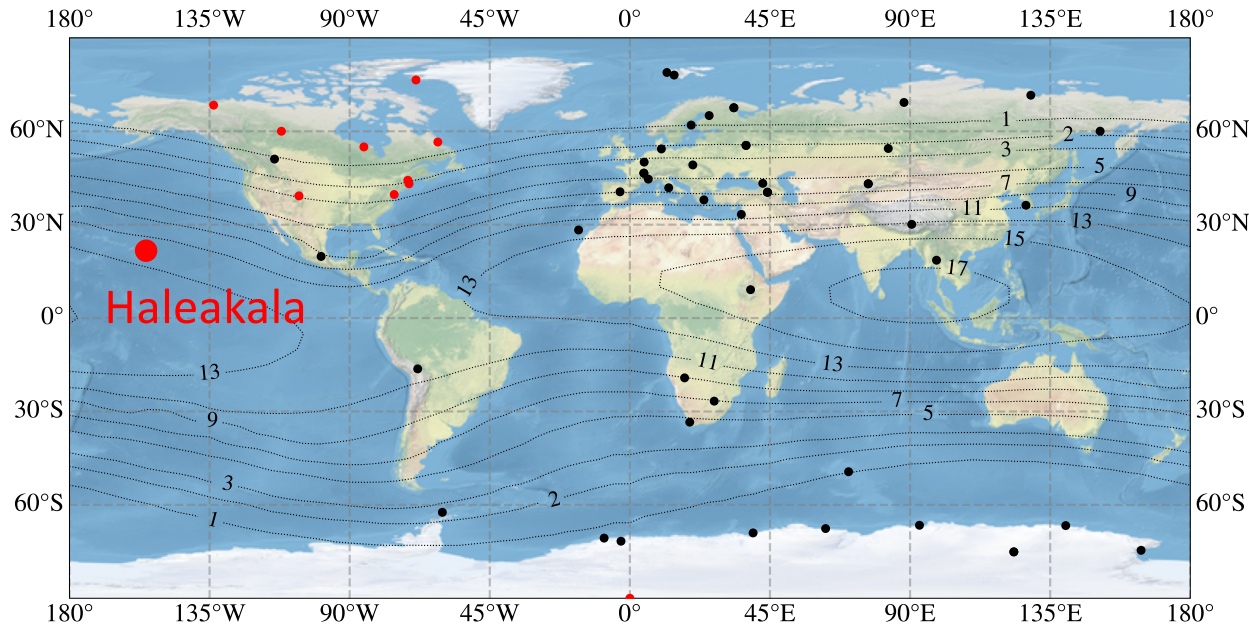
Neutron monitors in a nutshell



- 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, ^3He or BF_3 are commonly used



Global NM network and US Simpson NM network (SNMNM)



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

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

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

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



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



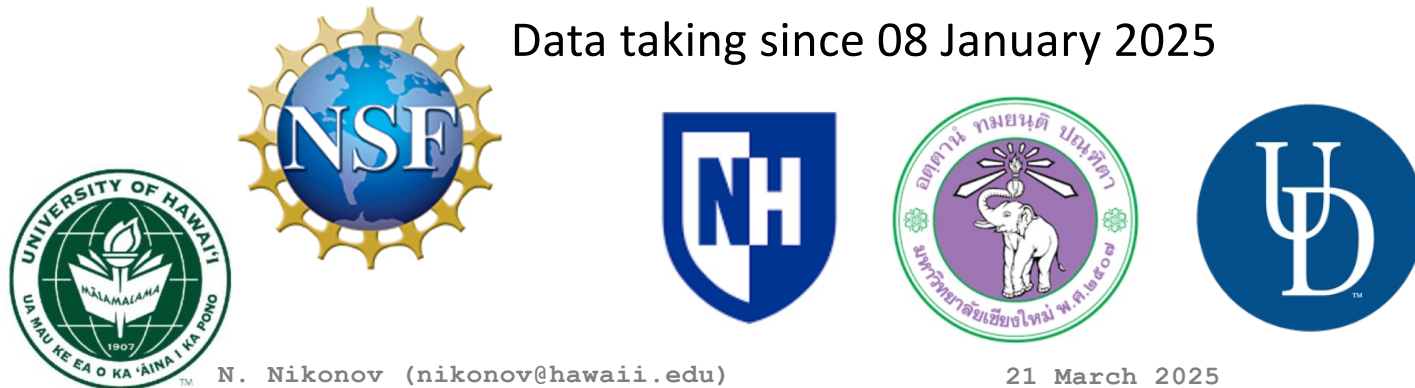
THIMON interior



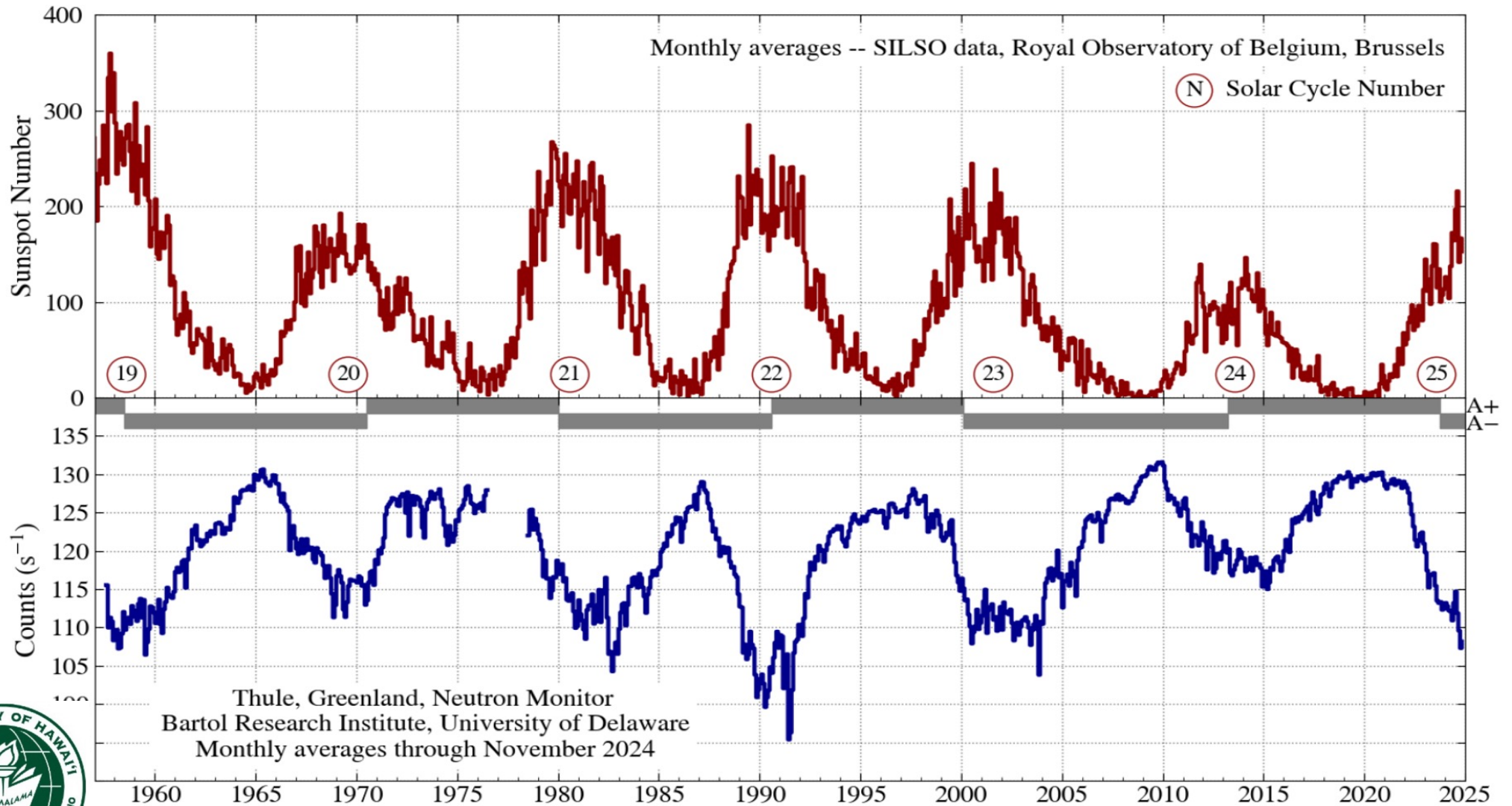
Data taking since 08 January 2025

Altitude: 3052 m
Vertical atmospheric density: 700 g/cm²
Cutoff Rigidity: 12.9 GV

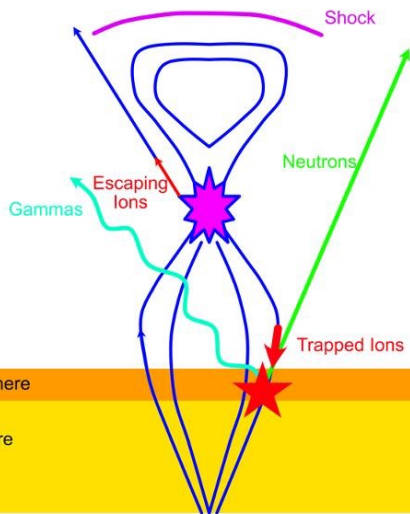
Covers gap between PSNM and MXCO
Good for GCR modulation, SNPs



Long term solar modulation, GCR flux variation and sunspot number



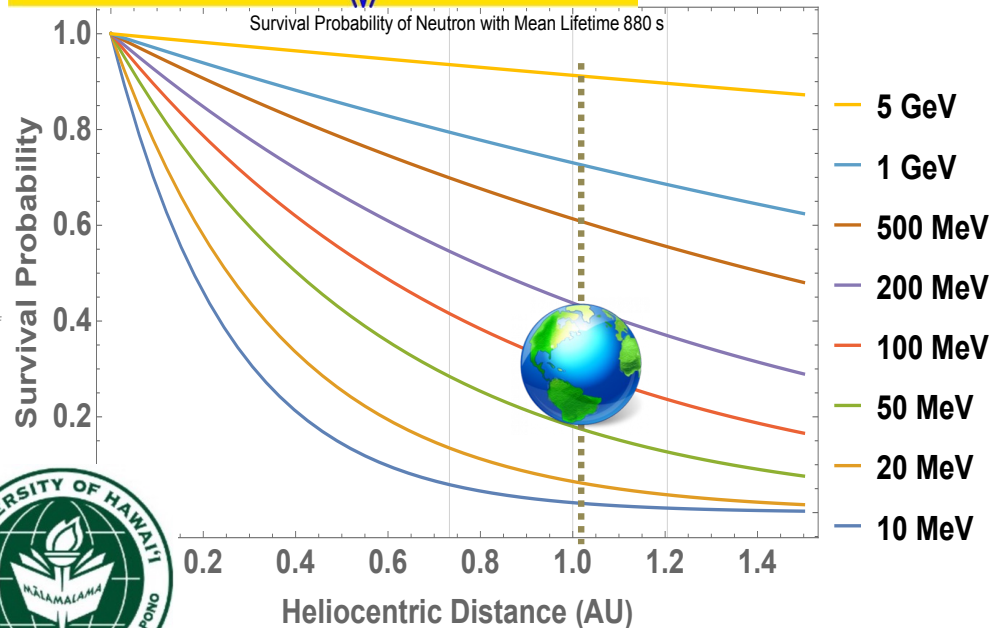
HLEA: Solar Neutron Particles (SNPs) Detector



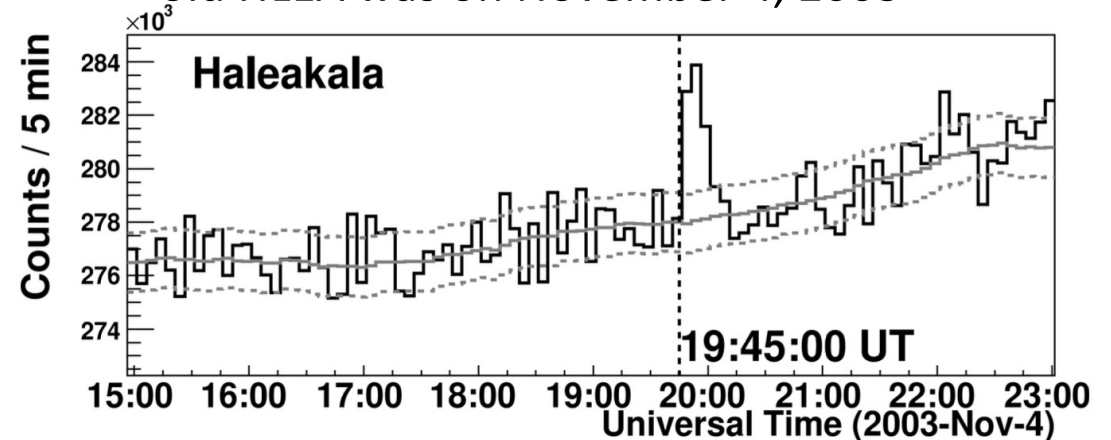
- SNPs are produced in large solar eruptive events from the interactions of accelerated protons deep in the solar atmosphere
- SNPs carry valuable direct about nuclear interactions, happening near SEP acceleration site.

Only < 20 SNP events observed from the Sun due to

- Lifetime of free neutrons
- Challenge of measuring neutrons



The most recent SNP event observed by the old HLEA was on November 4, 2003



At 19:45 UT, HLEA measured a ~ 2% increase over the background due to SNPs with a significance of 7.5σ .



BP-28 counters qualification tests at IfA Waiakoa Laboratory, Maui



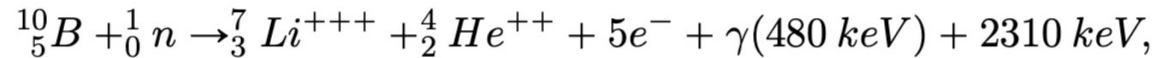
- The original Haleakalā (HLEA) NM station was constructed at the summit by the University of Chicago in 1991
 - HLEA has been continuously taking data until its decommission in 2006, due to lack of funds
- We reused BP-28 counters and polyethylene for new HLEA and THIMON construction

Before, several qualification tests have been taken to select the best counters

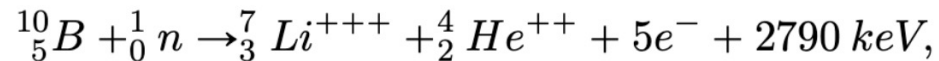


BP-28 counters qualification tests: amplitude distributions

A thermal neutron event triggers reactions:

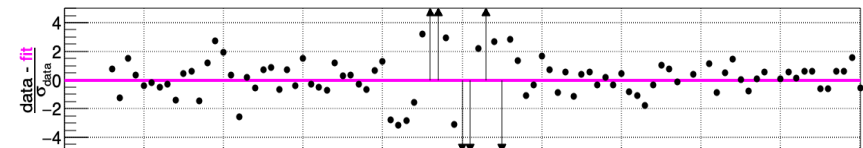
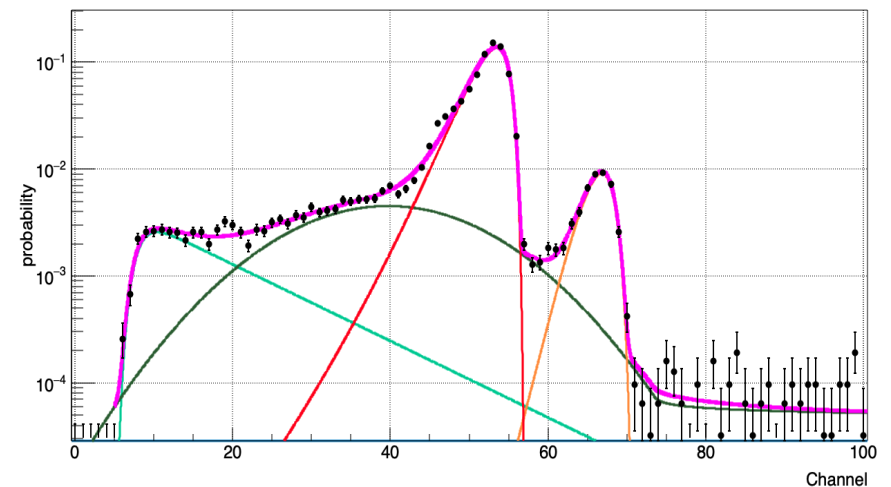
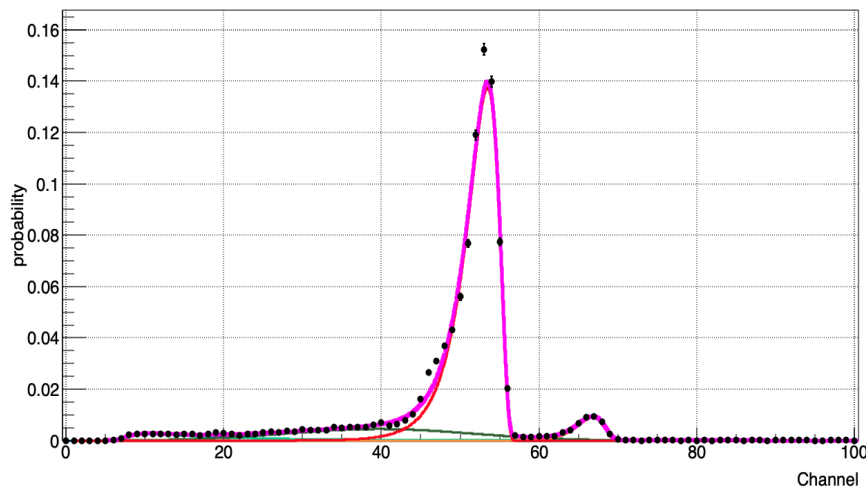


with 94% probability, and



with 6% probability.

The spectra were fitted to measure the width of the primary peak, which enables the qualification of the uniformity of the tube response along with the level of noise used to estimate the counter quality.



$$E_1 = 53.48 \pm 0.02$$

$$\sigma_1 = 2.08 \pm 0.01$$

$$E_2 = 66.84 \pm 0.07$$

$$\sigma_2 = 1.76 \pm 0.05$$



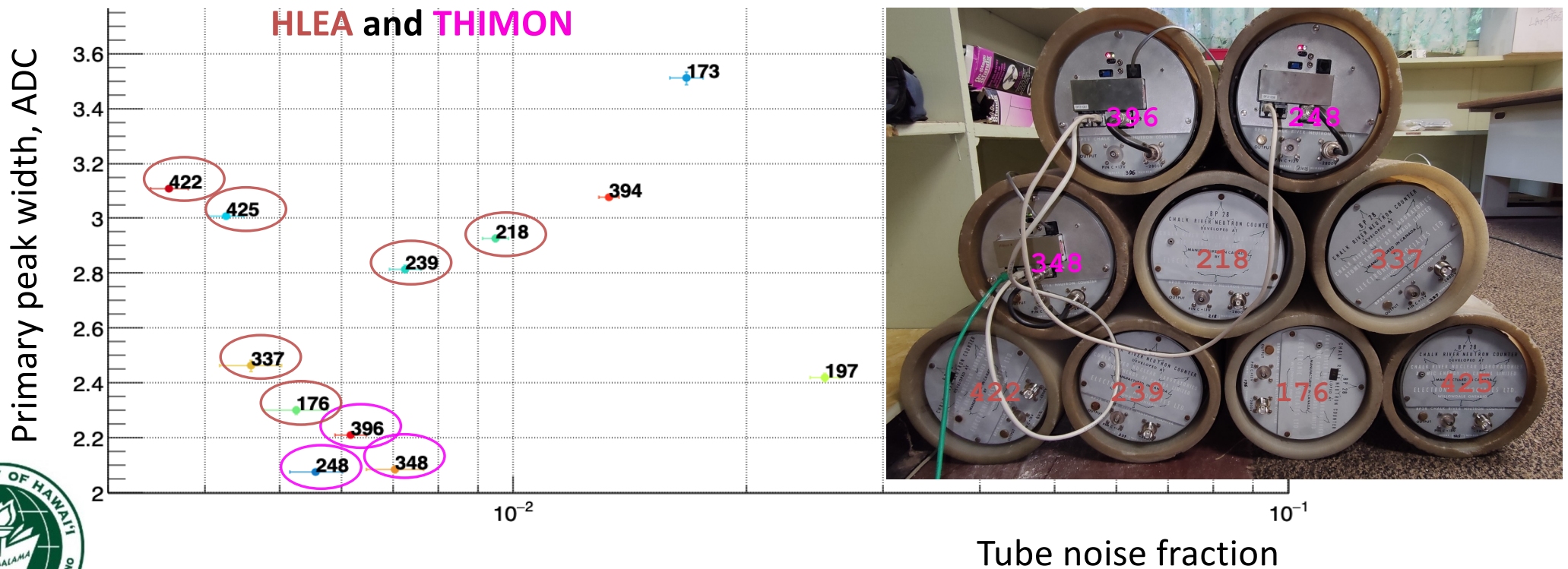
BP-28 counters qualification tests: primary peak width vs noise

From fitted amplitude histograms we derived 2 quantities:

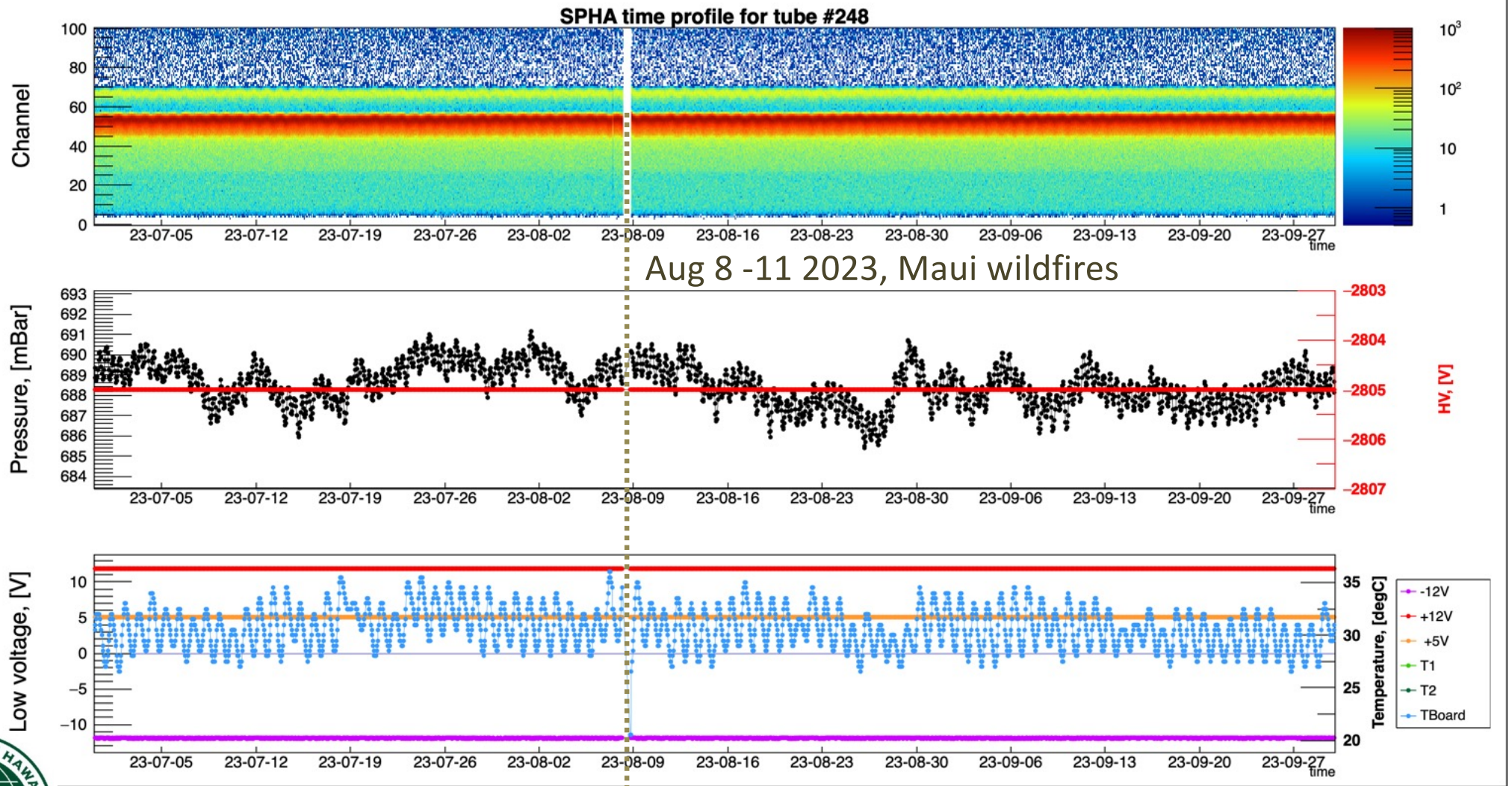
- width of the primary peak (proxy to anode uniformity)
- noise fraction - fraction of the counts above 3σ from the secondary peak

Finally, we selected best tubes: 3 for THIMON and 6 for HLEA out of 21 tubes for long term test

There are still 5 good tubes to be used in next detector

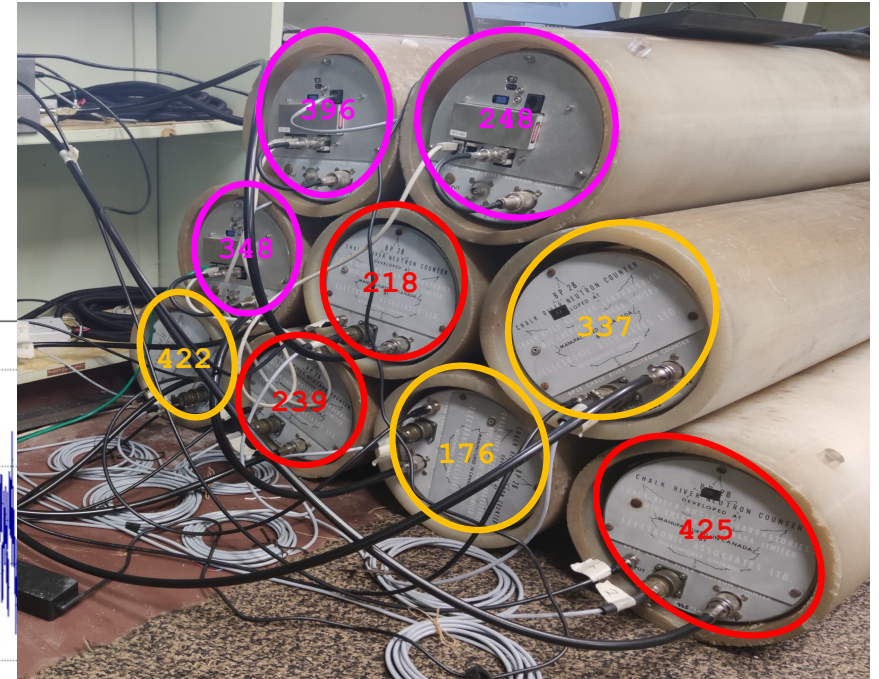
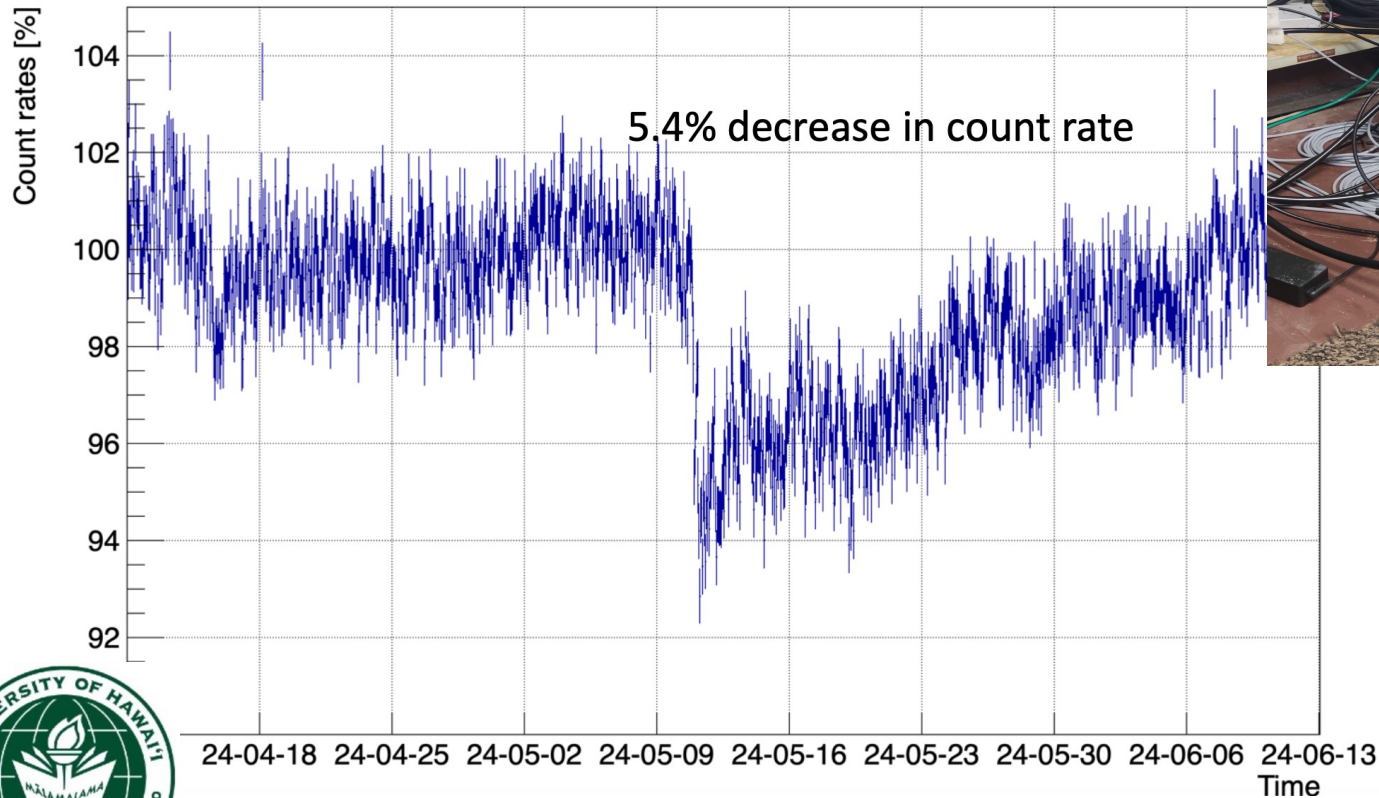


BP-28 counters qualification tests: long term stability



Forbush decrease by bare BP-28 counters during Solar Event on May 11, 2024

THIMON + HLEA, 9 Bare BP-28 at MAUI IfA, (Rc=13GV)



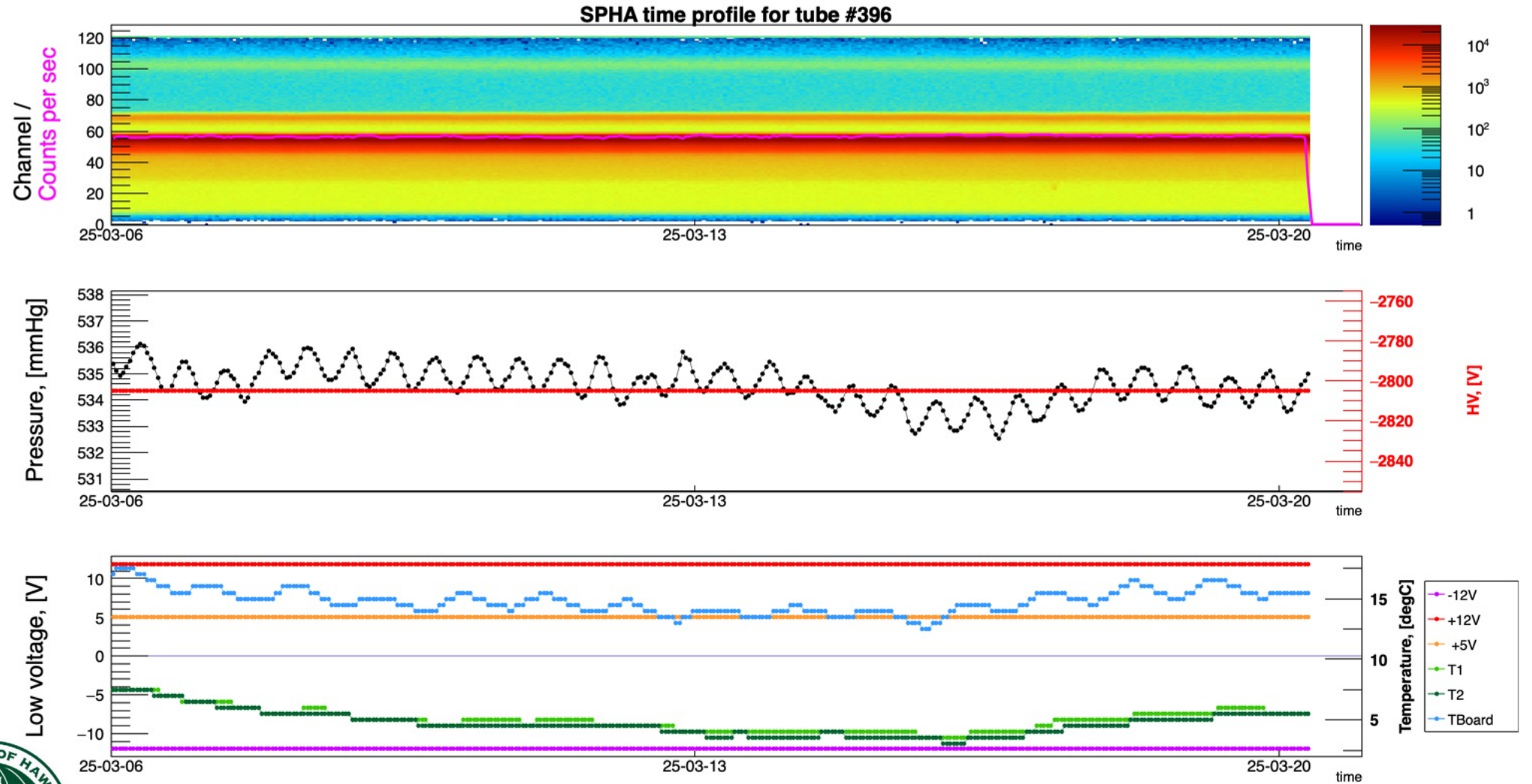
THIMON

HLEA bank A

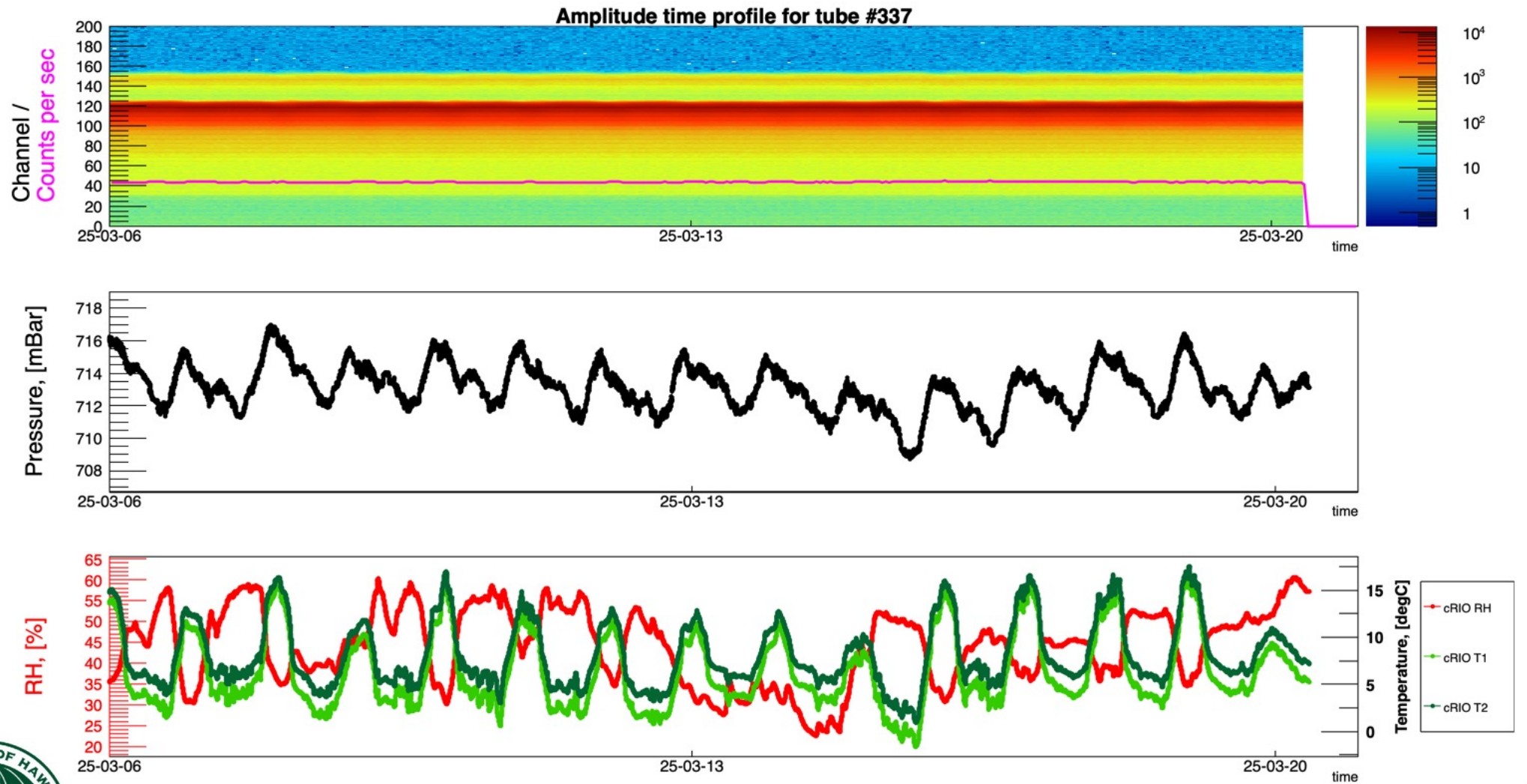
HLEA bank B



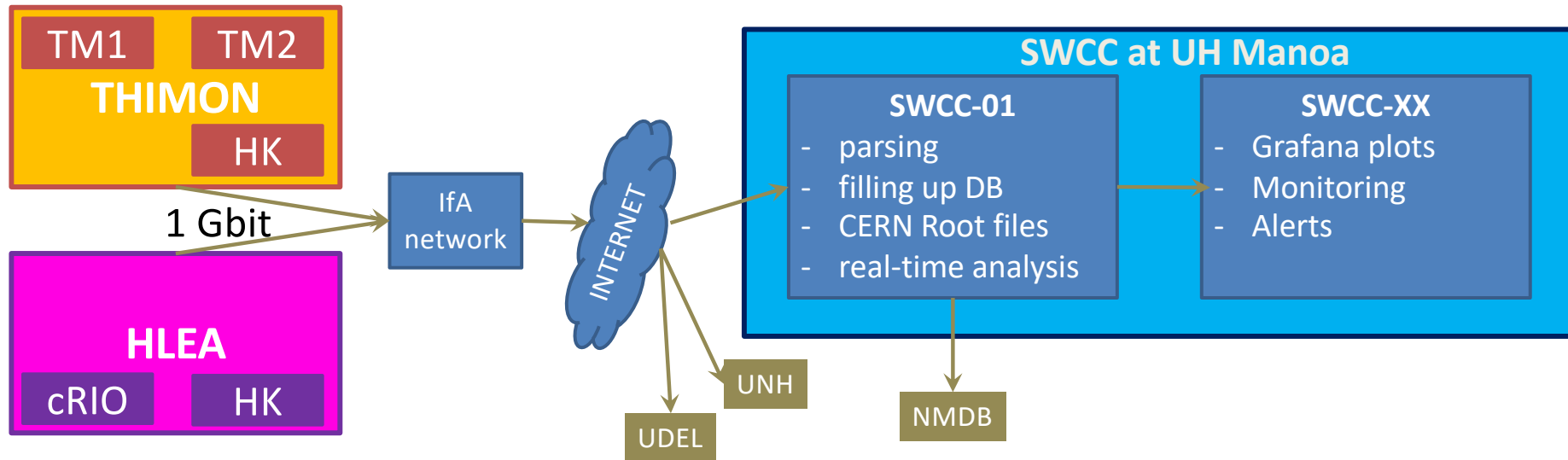
THIMON tube 396: Counts and housekeeping data



HLEA tube 337: Counts and housekeeping data



Haleakala NM data flow diagram



Data handling, analysis, presentation:

Remote access to HK and DAQ machines:



Real time data synchronization:

- > rsync
- > crontab



MariaDB



ROOT
Data Analysis Framework

Grafana



Space Weather Control Center (SWCC) at UH Mānoa



Having data from instruments:

- Haleakalā NM: HLEA, THIMON
- AMS, GOES, ACE (space-based)
- Simpson NM network (ground)
- Global NM network (NMDB)

SWCC operations will include:

- ✓ running HLEA and THIMON instruments
- ✓ NM data quality check and analysis
- ✓ pushing HLEA and THIMON data to NMDB

SWCC 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

SWCC scientific program, include but not limited to:

- ✓ 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
- ✓ Modelling of GCR propagation in heliosphere, SEP acceleration and propagation

SWCC will be an educational hub, provide university course and internship opportunities








Space Weather Control Center at UH Mānoa (HLEA page prototype)



Simpson NM network current status

UDEL electronics
UNH electronics

| | Station | Status | NMDB | Leader Fraction Capability |
|--|------------------|-----------|------|----------------------------|
|  | Fort Smith | Operating | FSMT | To be deployed |
| | Inuvik | Operating | INVK | To be deployed |
| | Nain | Operating | NAIN | To be deployed |
| | Newark | Operating | NEWK | Deployed |
| | Peawanuck | Operating | PWNK | Deployed |
| | Thule | Operating | THUL | Deployed |
|  | South Pole | Operating | SOPO | Deployed & Calibrated |
| | South Pole bares | Operating | SOPB | N/A |
|  | Haleakala THIMON | Operating | - | To be deployed |
| | Haleakala HLEA | Operating | - | N/A |
|   | Durham | Operating | DRHM | N/A |
| | Leadville | Offline | LDVL | N/A |
| | Mt Washington | Operating | MTWS | N/A |



Haleakala Workshop materials: <https://indico.cern.ch/event/1474973/>

Ribbon-cutting ceremony video: <https://youtu.be/VwjpmCd1Hmo>

How we build HLEA and THIMON: <https://youtu.be/-Hpuezva4hE>

