Neutron Monitor Response Functions from the 2023–24 Latitude Survey aboard the Araon Icebreaker

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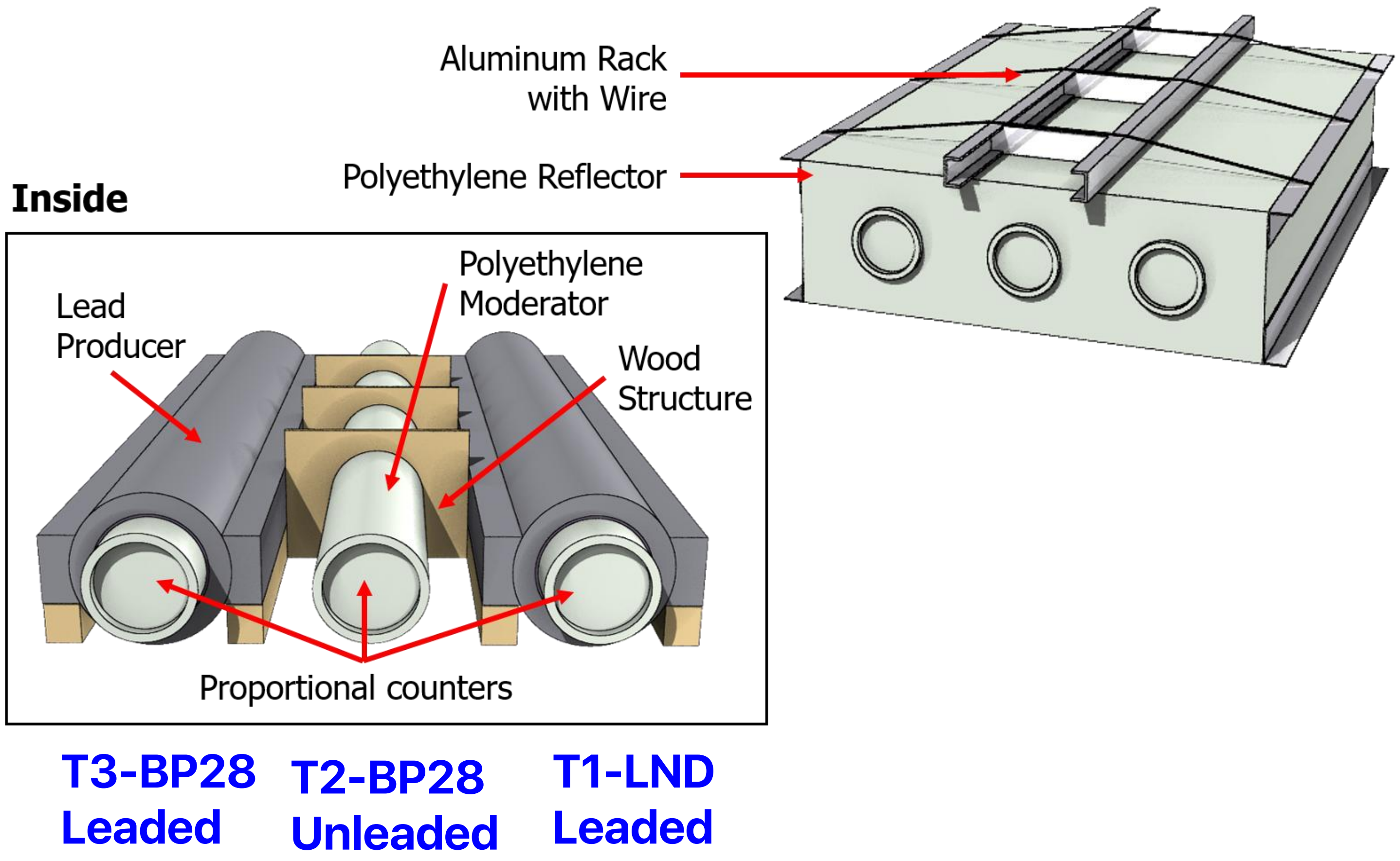
Motivation & Background

- Ground-based NMs are widely used to monitor GCRs, but their response depends on rigidity and shielding
- **Latitude surveys** aboard ships enable coverage across a broad range of geomagnetic cutoff rigidities
- The **semi-leaded setup** includes both leaded and unleaded BF_3 tubes for shielding comparisons
- The **LND 2061** is a newer tube model with limited response function data

DETECTOR SETUP: SEMI-LEADED NEUTRON MONITOR



Detector configuration highlighting the semi-leaded design with a central unleaded tube.

Component Overview:

- Neutron Counters (BP28 and LND)
  Detect thermal neutrons via the ^{10}B(n,α) reaction.
- Moderator (Polyethylene): Slows down fast neutrons to thermal energies for efficient detection.
- Producer (Pb): Generates secondary neutrons through spallation when struck by high-energy cosmic rays.
- Reflector (Polyethylene): Reflects scattered neutrons back toward the detectors to enhance counting efficiency.
- Tube Alignment Piece (Wood): Provides mechanical support and maintains proper detector positioning.

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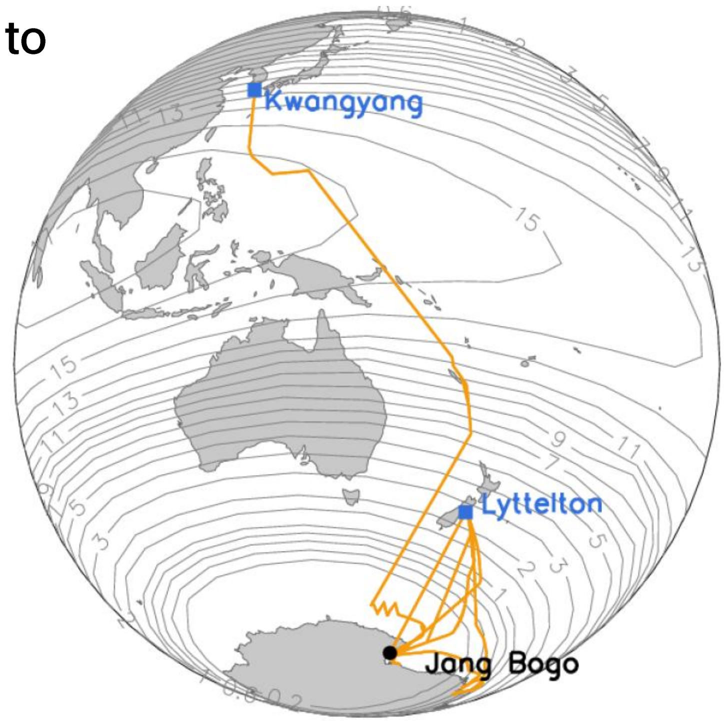
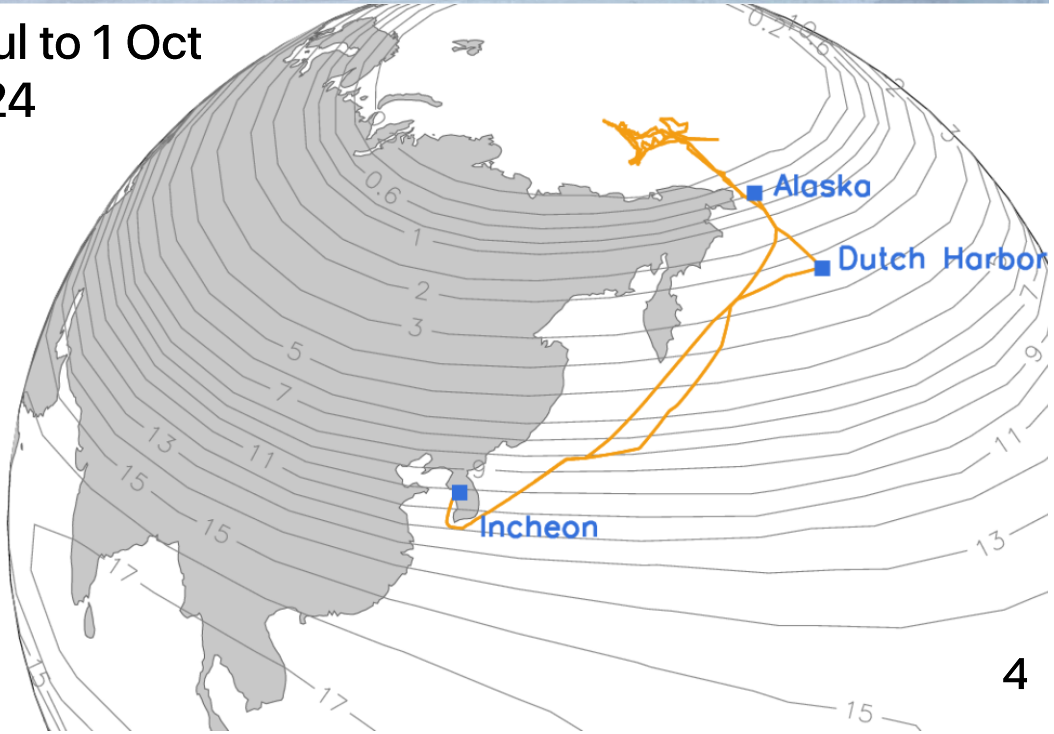
Latitude Survey
Antarctic Voyage in 2023

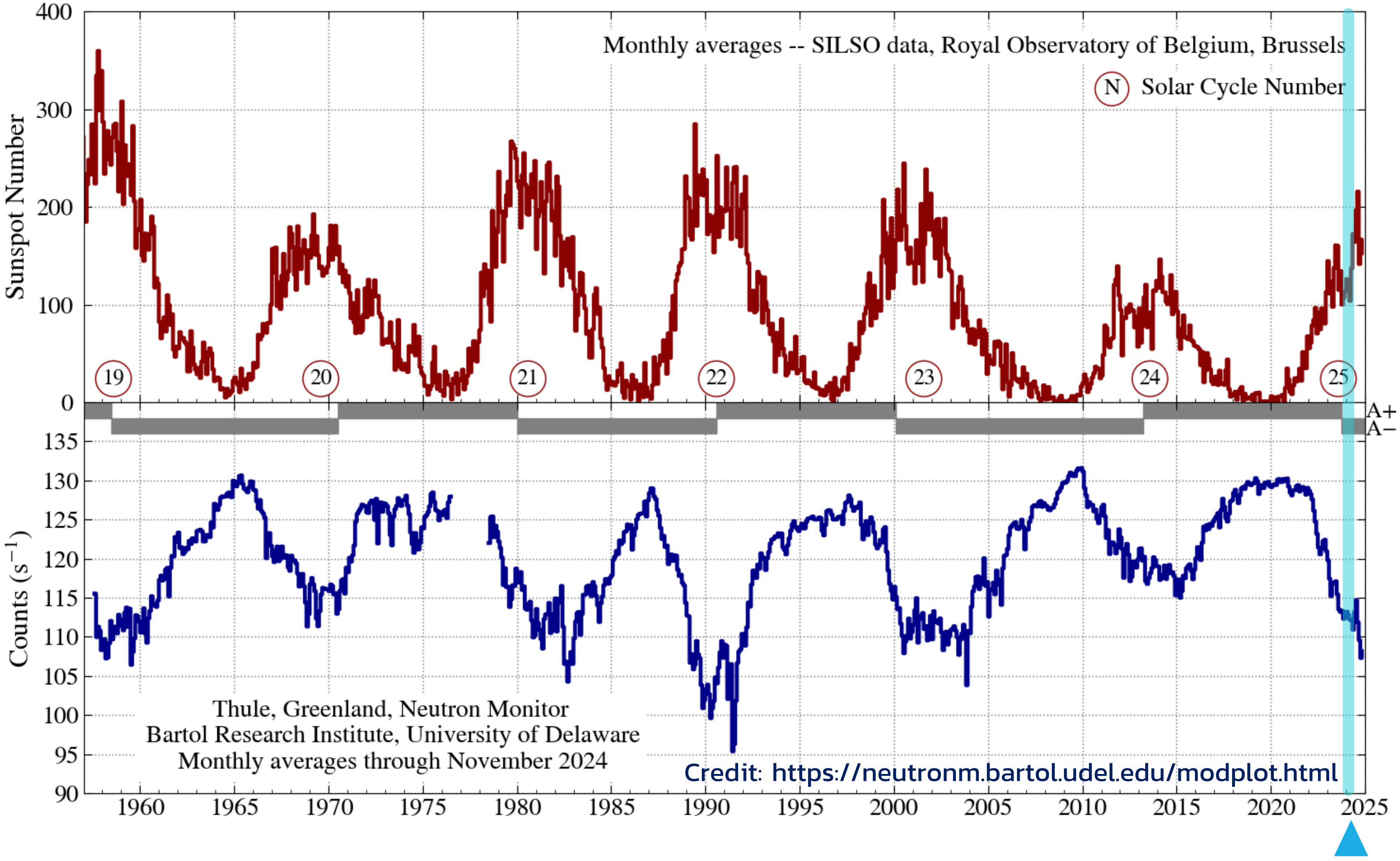
28-Dec-2023 to
1-May-2024



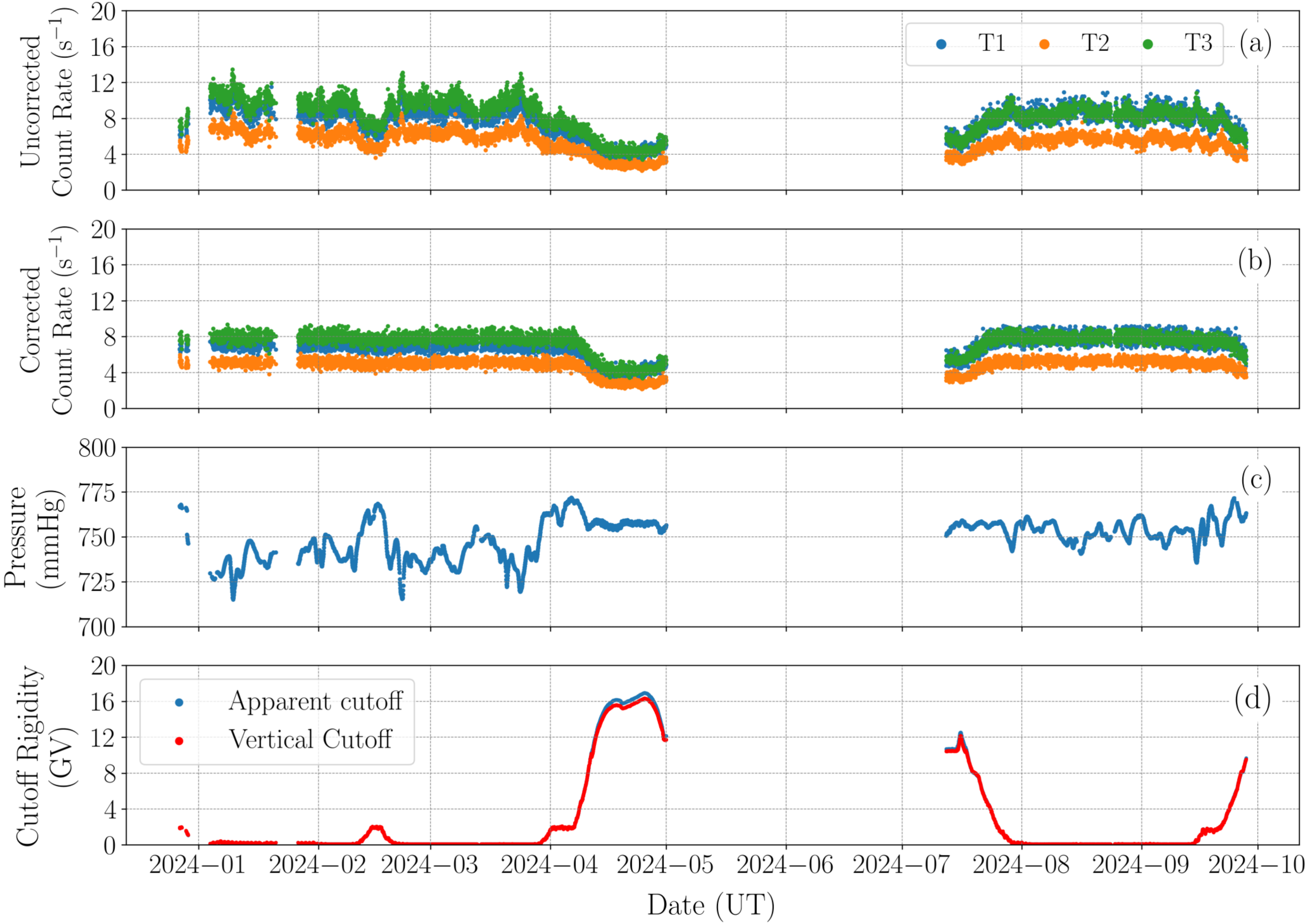
Latitude Survey
Arctic Voyage in 2024

1-Jul to 1 Oct
2024





Monthly sunspot number (top) and neutron count rate from the Thule Neutron Monitor (bottom) from 1955 to 2024. The ARAON latitude survey (cyan vertical bar) occurred during the rising phase of Solar Cycle 25, coinciding with the reversal of the solar magnetic field polarity from A+ to A−.



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T1: LND 2061 leaded
T2: BP28 unleaded
T3: BP28 leaded)

Time series of

(a) Raw count rate
(b) Corrected count rates
(c) Atmospheric pressure
(d) Geomagnetic cutoff rigidities during the 2023–24 Araon voyages.

Survey Overview and Response Function Framework

South Korea (KOPRI):

Survey years

- Antarctic Voyage: 28-Dec-2023 to 1-May-2024
- Arctic Voyages: 1-Jul to 1 Oct 2024

Korea Polar Research Institute

GCR spectrum — Solar Modulation — Yield function

Integral Response Function

$$N(P_c, h, t) = \int_{P_c}^{P_L} G_i(P) M_i(P, t) Y_i(P, h) dP$$

Differential Response Function

$$DRF(P) = -\left[\frac{dN}{dP}\right]_p = \sum_i G_i(P) M_i(P, t) Y_i(P, h)$$

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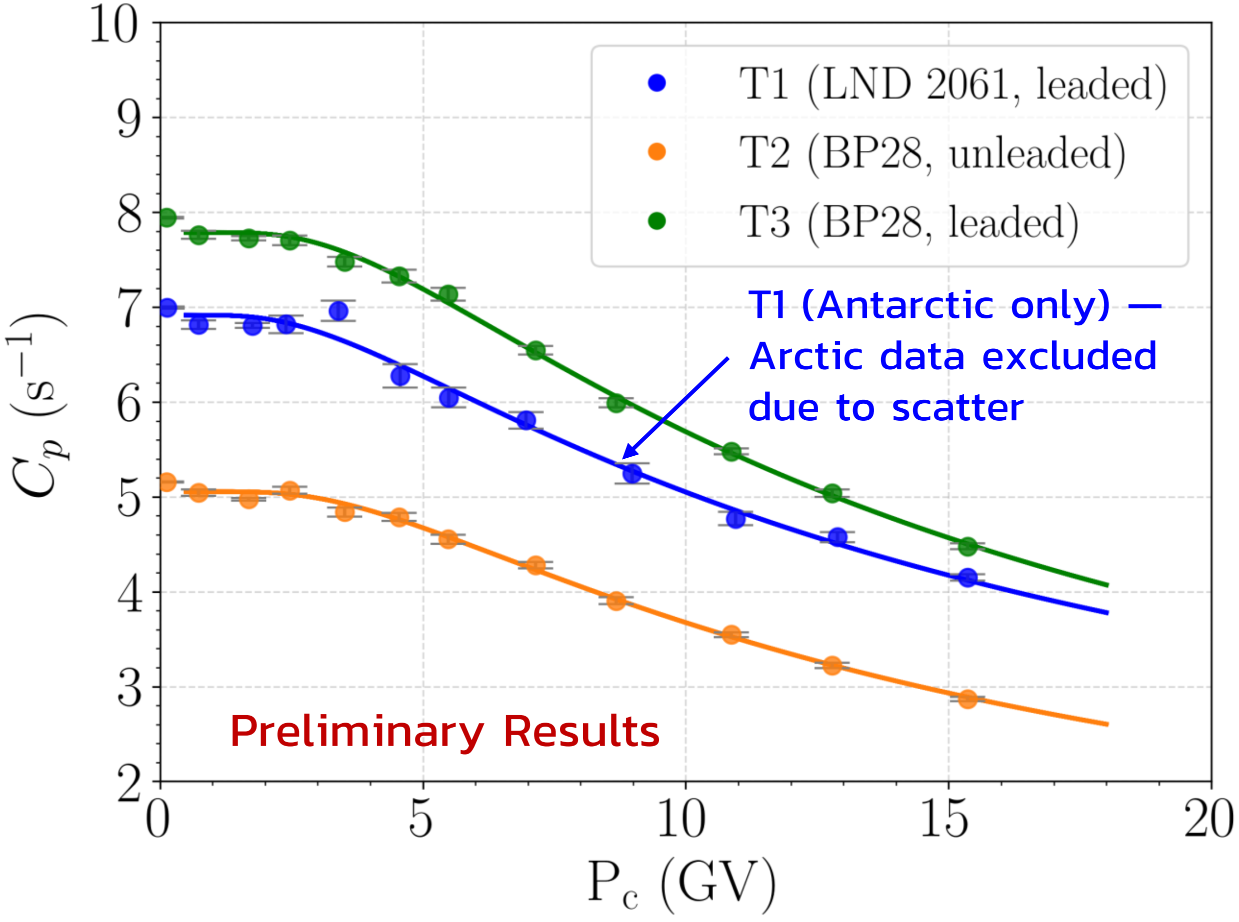
Response Functions

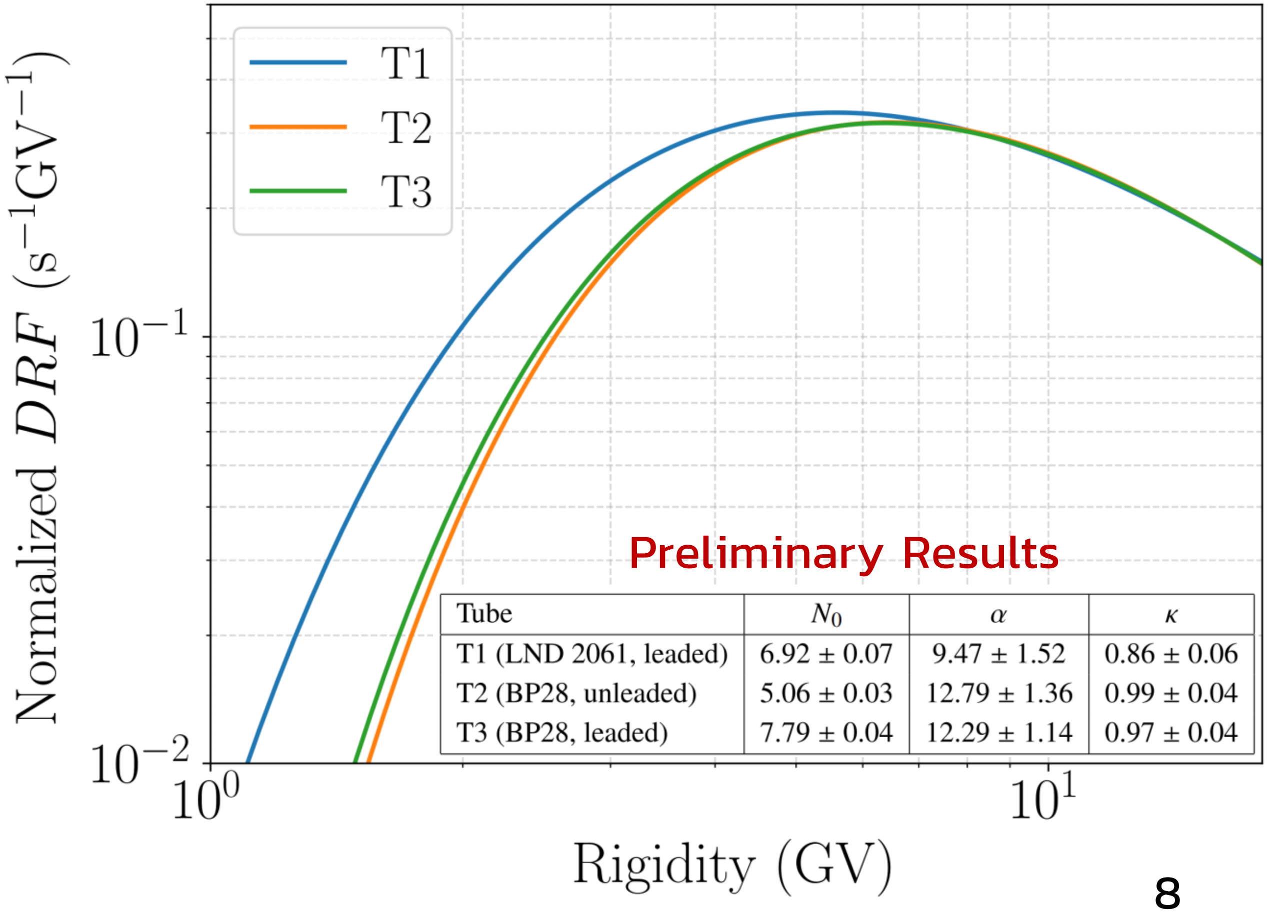
Integral Response Function

$$N = N_0\left(1 - e^{-\alpha P_c^{-\kappa}}\right)$$



Differential Response Function (DRF)

$$DRF = N_0 \alpha P^{-\kappa-1} \kappa\left(e^{-\alpha P^{-\kappa}}\right)$$



Tube	N_0	α	κ
T1 (LND 2061, leaded)	6.92 ± 0.07	9.47 ± 1.52	0.86 ± 0.06
T2 (BP28, unleaded)	5.06 ± 0.03	12.79 ± 1.36	0.99 ± 0.04
T3 (BP28, leaded)	7.79 ± 0.04	12.29 ± 1.14	0.97 ± 0.04

Summary and Next Directions

Key findings:

- The 2023–24 ARAON latitude survey enabled direct comparison of response functions among three BF_3 tube types: Leaded-LND, Unleaded-BP28, and Leaded-BP28 under dynamic geomagnetic and solar conditions during the rise of Solar Cycle 25 ($A^+ \rightarrow A^-$).
- Each tube in the semi-leaded setup exhibited a distinct response function.
- LND 2061 (T1) exhibited mechanical instability during the Arctic leg, resulting in large scatter and exclusion from DRF fitting for that segment.
- Preliminary DRF results reveal variation in Dorman parameters (N_0, α, κ) across tube types, suggesting sensitivity to both physical construction and environmental modulation.

Next steps:

- Reinforce tube mounting structure for future polar deployments
- Integrate short-term solar modulation corrections into DRF modeling.
- Expand Monte Carlo simulations to validate and refine yield functions for different tube types

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Thank you for your attention

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COMPARISON OF NEUTRON DETECTOR TUBES: LND 2061 VS. BP28

Property	LND 2061	BP28
Manufacturer	LND Inc. (USA)	Electronic Associates Ltd. (Canada)
Effective Length	1905 mm (75.0")	1908 mm (75.1")
Effective Diameter	127 mm (5.00")	149 mm (5.87")
Effective Volume	~24,100 cm^3	~33,200 cm^3
Gas Pressure (BF_3)	200 torr @ 21 °C	200 torr (20 cm Hg @ 20 °C)
Boron-10 Enrichment	Not specified (assumed enriched)	95% Boron-10
Recommended Operating Voltage	1200 V recommended (operated at 1300 V on Changvan; range: 1000–2000 V)	~2800 V
Cathode Material	Stainless steel	Stainless steel
Wall Thickness	2.1 mm	0.75–0.84 mm
Anode Wire Diameter	0.05 mm	0.2 mm
Cathode Wall Surface	Smooth / Non-corrugated	Corrugated
Weight	8000 g	~9000–9500 g
Relative Sensitivity	0.90–0.95 relative to BP28	1.00 (baseline)