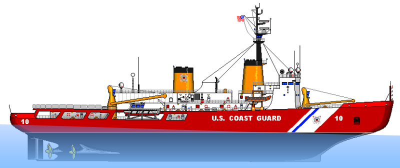

COSMIC RAYS AND CHANGVAN NEUTRON MONITOR

PRESENTED BY

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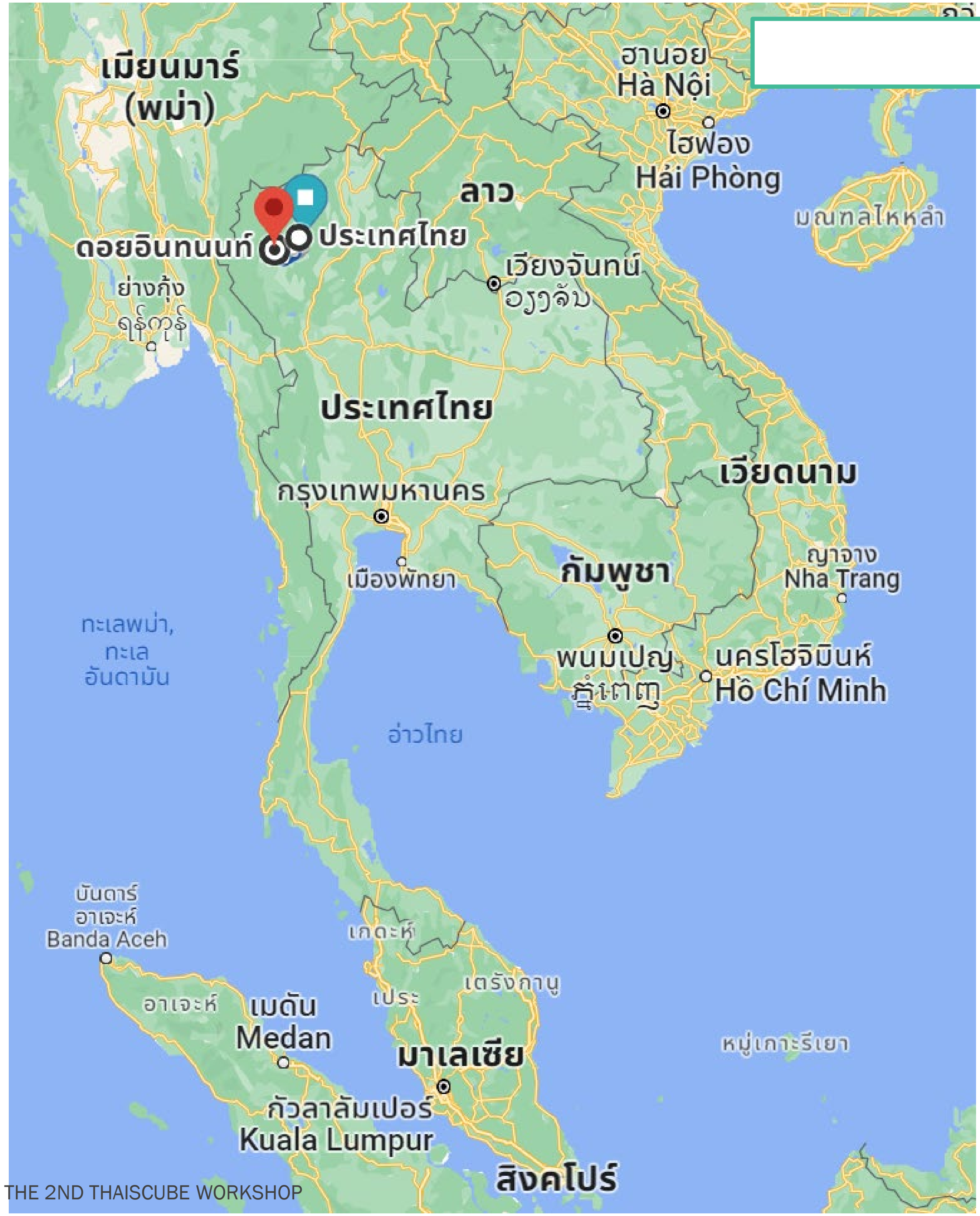
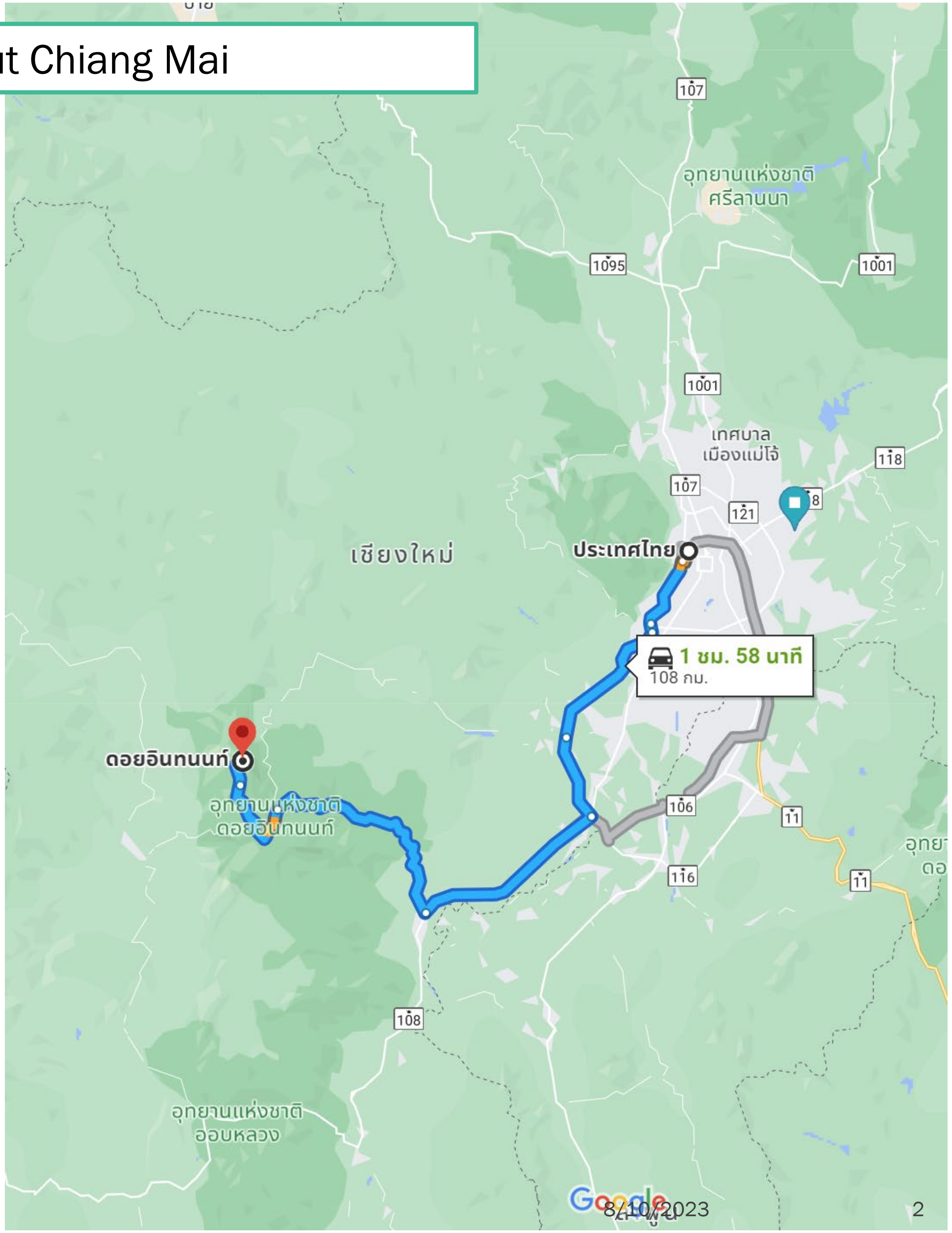
About Chiang Mai





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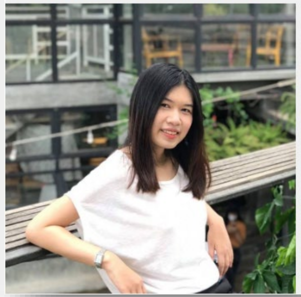
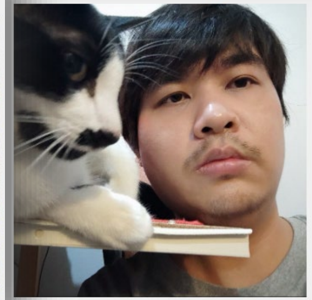


Ekawit Kittiya



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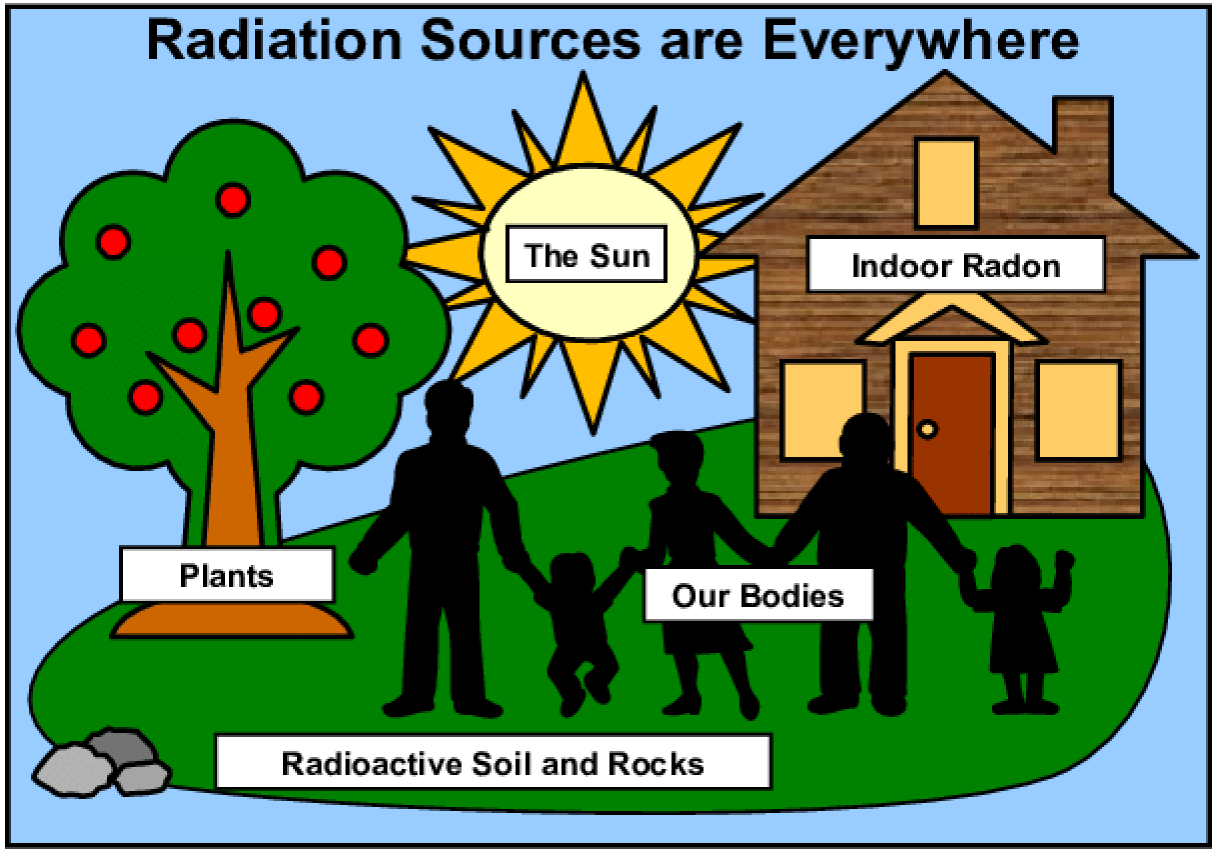
Kittinan Jomprasert

OUTLINE

- Introduction:
  - The Discovery of Cosmic Rays
  - Cosmic Rays
- Instrumentation
  - Standard Neutron Monitor (NM64)
  - Semi-Leaded Neutron Monitor Changvan
- Latitude Surveys
- Response Functions
- Conclusions

INTRODUCTION: THE DISCOVERY OF COSMIC RAYS



https://www.researchgate.net/figure/Natural-radiation-sources_fig4_255275007

Natural radioactivity from the ground

Does this imply that the expected trend is a decrease as we move higher?

H = D x W

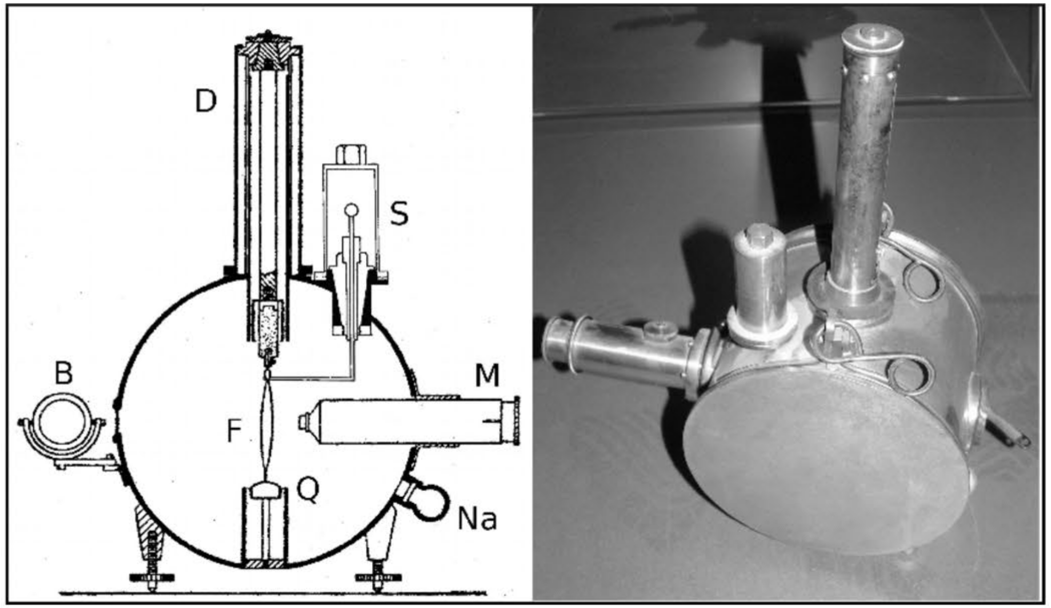
H = Equivalent Dose (Sv or J/kg)
D = Absorbed Dose (J/kg or Gy)
W = Relative Biological Effectiveness

~1 for photons and electrons
~2 for protons, neutrons
~20 for alphas

Dose (mSv)	Description
0.0001	A typical banana
0.0003	Airport security screening
0.1	Chest x-ray
2.4	1-year average for humans from natural (terrestrial + cosmic) background radiation (BR) at sea level
BR + 1.0	1-year limit recommended for public
BR + 1.5	Annual dose for flight attendants
250	6-month trip to Mars due to CRs
5000	Fatal dose if received over a short duration

INTRODUCTION: THE DISCOVERY OF COSMIC RAYS

Theodor Wulf (1868-1946)



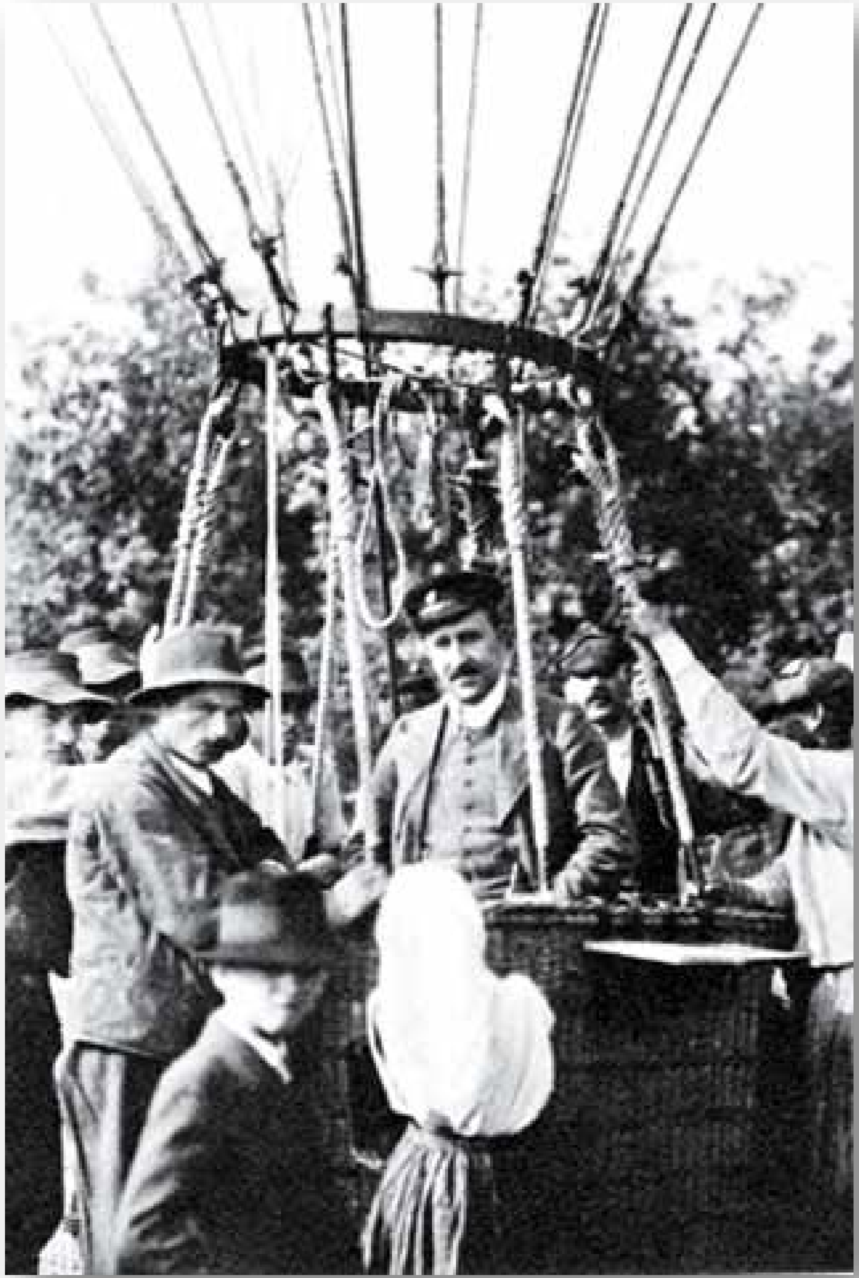
electrometer to measure ionization currents from gamma rays

air ionization measurements on the ground and on top of **Eiffel Tower**

@300m - **15.7** ions/cm³ sec

expected - **6** ions/cm³ sec

@ground - **17.5** ions/cm³ sec



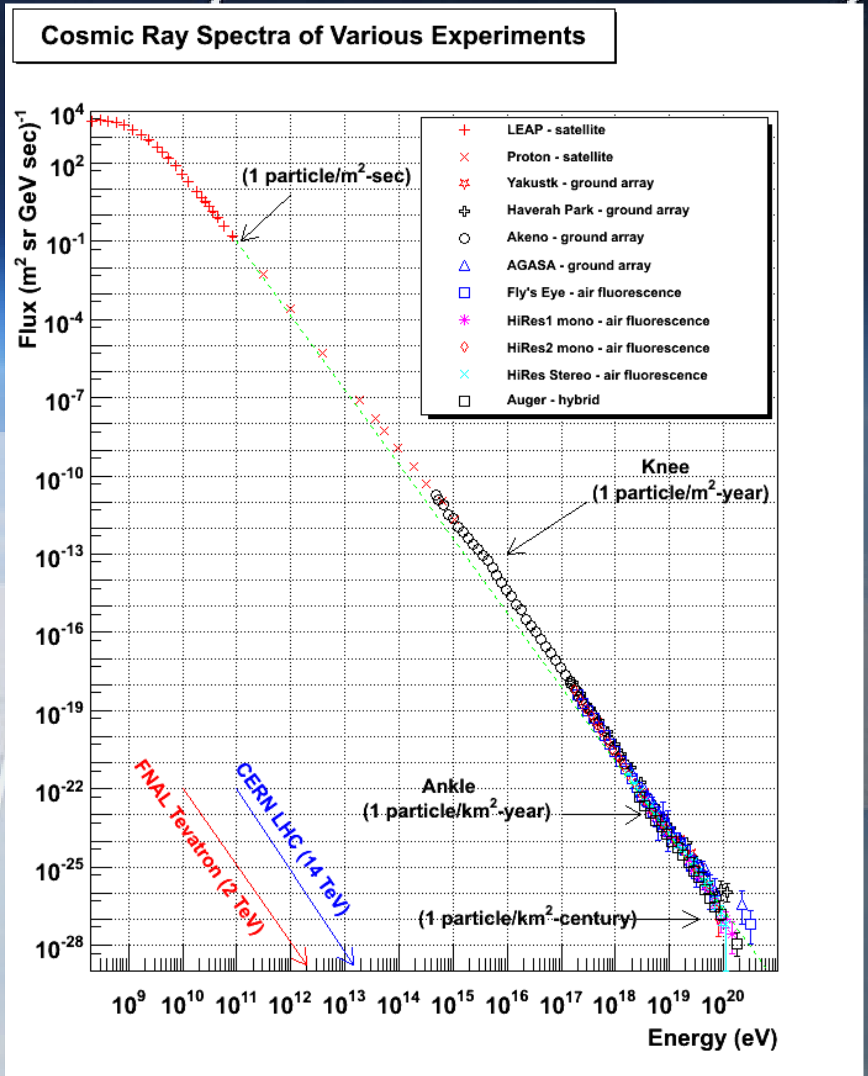
Victor Hess is credited with the discovery of cosmic rays (1912)

- Ionization of air was known to be due to “radiation” (particles + gamma rays).
- Due to radioactive minerals in Earth? Yes, 1–2 km above land.
- Hess’s balloon flight showed 4-fold increase at 5-km altitude, inferring what was later called “cosmic radiation” (or “rays”); later received Nobel Prize.

Victor Francis Hess

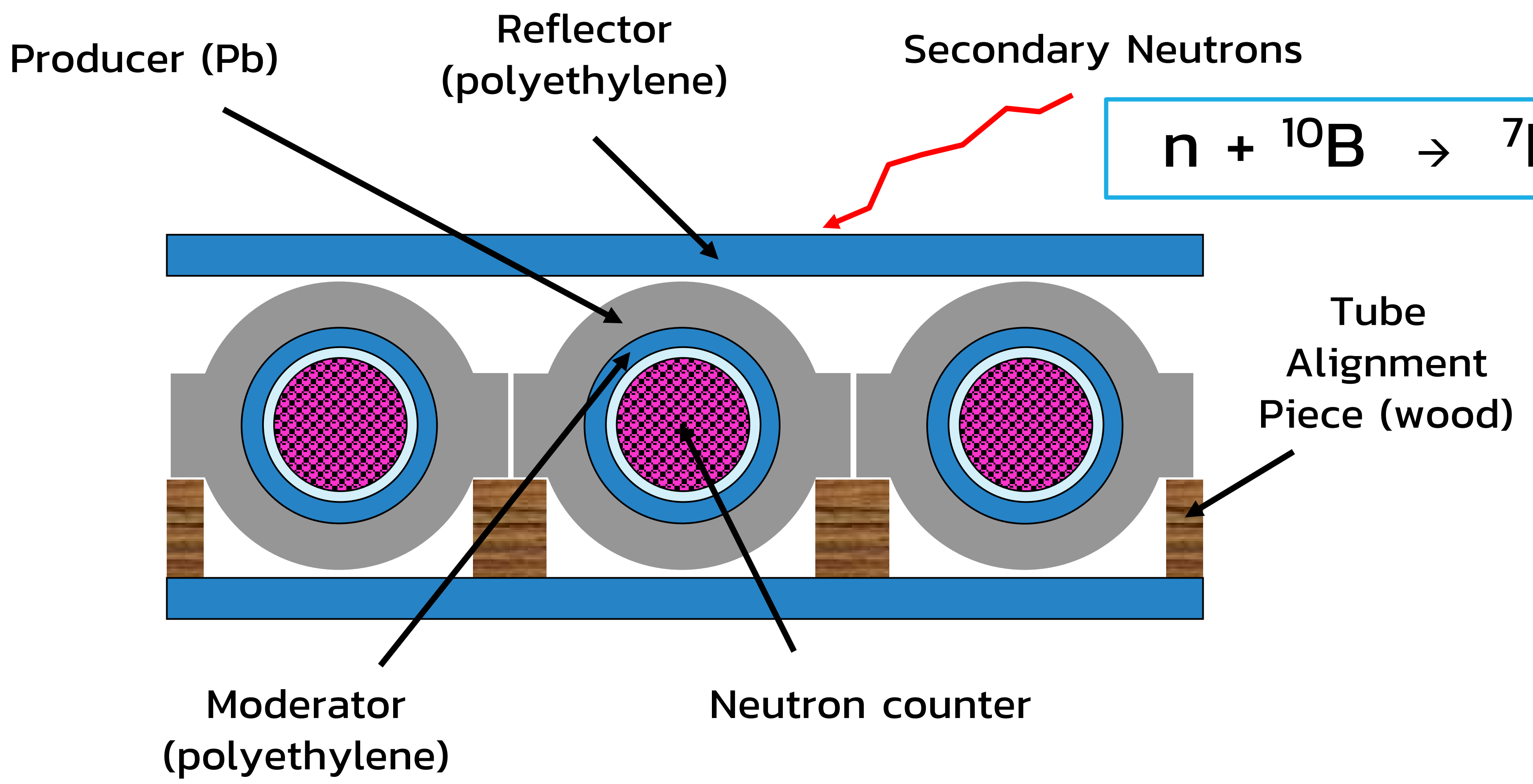
Nobel Prize in Physics in 1936 for the Discovery of Cosmic Rays

INTRODUCTION: COSMIC RAYS



- Energetic particles or γ-rays from space
- Discovered by Hess in 1912 (Nobel Prize in 1936)
- Ordinary matter accelerated to high energies
  - p, ^{4}He, ^{12}C, ^{16}O, heavy nuclei and γ, e^+, e^-, μ, ν, ...
- Key sources of CRs for Earth's radiation environment:
  - From solar storms (solar energetic particles)
  - From supernova explosions inside the Milky-Way Galaxy (Galactic cosmic rays)
  - From intense events/objects GRB, AGN outside the Galaxy (Extra Galactic cosmic rays)
- Key cause of biological mutation

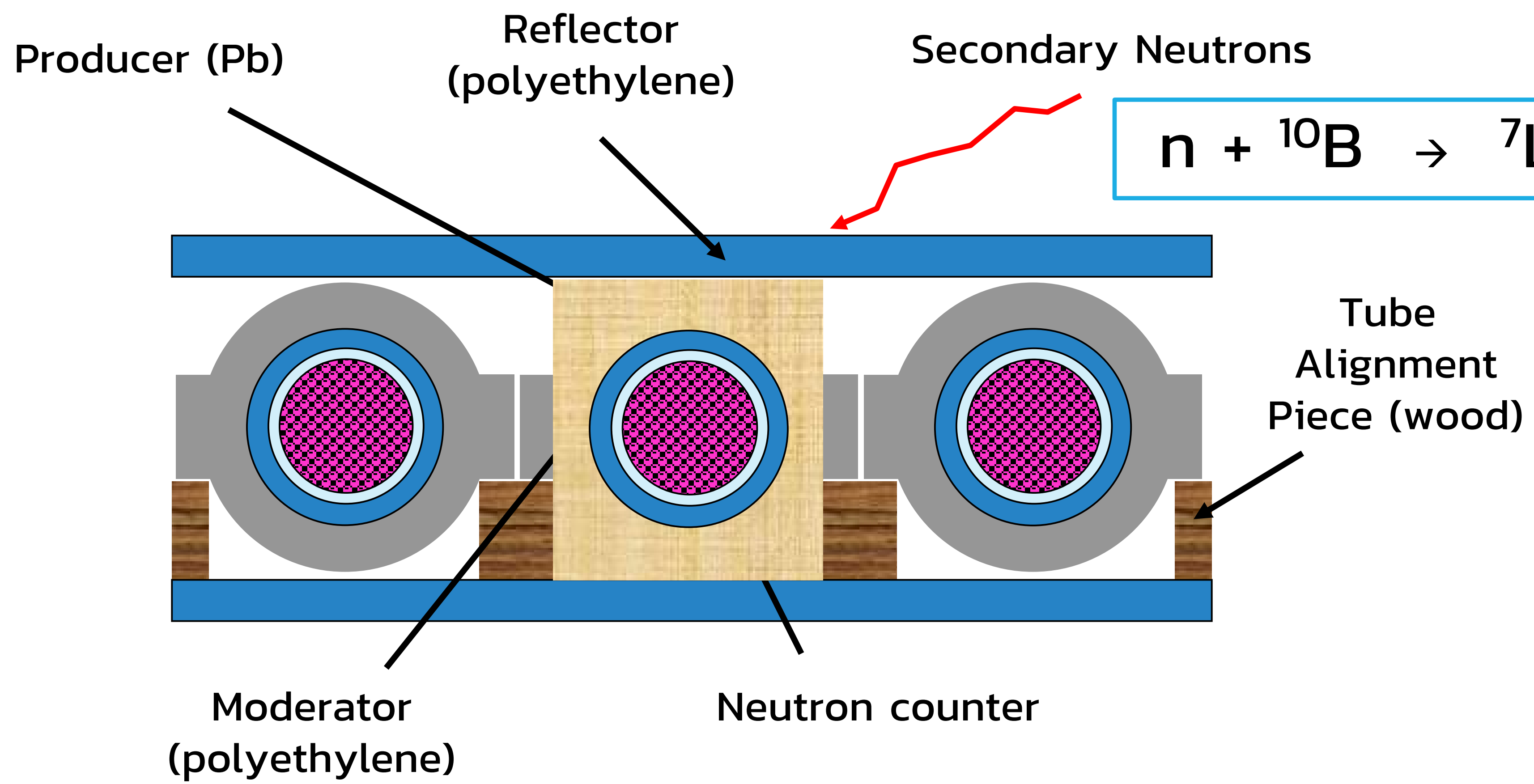
INSTRUMENTATION: STANDARD NEUTRON MONITOR (NM64)



$$n + {}^{10}B \rightarrow {}^{7}Li + {}^{4}He$$

Sketch of the standard neutron monitor (NM64)

INSTRUMENTATION: CHANGVAN SEMI-LEADED DETECTOR



$$n + {}^{10}B \rightarrow {}^{7}Li + {}^{4}He$$

Sketch of the semi-leaded neutron monitor Changvan

Current Collaborations:

South Korea (KOPRI):

Korea Polar Research Institute

- Survey year 2023-2024
- Survey year 2024-2025
- Survey year 2025-2026

There is a possibility of changes occurring.

University of Hawaii: Haleakala summit

Chinese Icebreaker Xue Long survey years:

- 2018-2019
- 2019-2020

GCR spectrum

Yield function

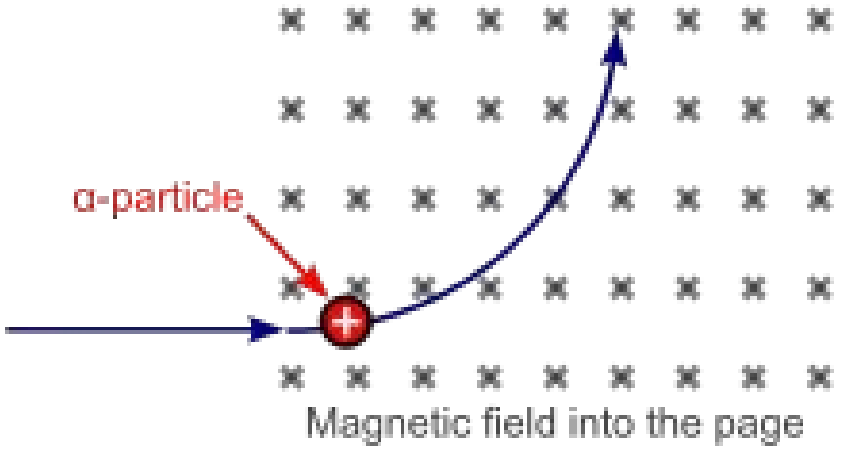
Count Rate

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

Differential Response function

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

RIGIDITY



- Rigidity (P) = momentum/charge = p/q
- Charge q is in proton unit
- Normal unit for P is “Gigavolt” (GV)
- P is a good quantity for describing a article's behavior in a magnetic field

$$qvB = mv^2/r$$
$$P = mv/qB = p\,/\,qB$$

RIGIDITY TO ENERGY

The total energy of a nucleon E_T is the sum of the kinetic energy E plus rest-mass energy m_0c^2

$$\boxed{E_T = E + m_0c^2 = mc^2} \quad (1)$$

Where m_0 is the rest mass, m is the relativistic mass, and c is the speed of light in vacuum.

The rest mass energy of a proton is 938.232 MeV, the rest mass of a neutron is 939.526 MeV, and the rest mass of an electron is 510.984 keV. The total energy is related to the particle momentum p by…

$$\boxed{E_T = [p^2c^2 + {m_0}^2c^4]^{1/2}} \quad (2)$$

The magnetic rigidity P, with units of momentum per unit charge, is defined as

$$\boxed{P = \frac{pc}{q}} \quad (3)$$

From equation (2), the conversion can be done conveniently by employing the relativistic parameter γ. We defined E_A is the kinetic energy per nucleon, and E_{0A} is the rest mass energy per nucleon.

$$\boxed{E_T = [p^2c^2 + {m_0}^2c^4]^{1/2} \qquad \text{where} \quad {m_0}^2c^4 = {E_0}^2}$$

Squaring both sides, $${E_T}^2 = p^2c^2 + {E_0}^2$$

$$p^2c^2 = {E_T}^2 - {E_0}^2$$

Take $\left(\frac{A}{eZ}\right)^2$ both sides, $$\left(\frac{A}{eZ}\right)^2 p^2c^2 = \left(\frac{A}{eZ}\right)^2 {E_T}^2 - \left(\frac{A}{eZ}\right)^2 {E_0}^2$$

$$\frac{\cancel{A^2}}{Z^2e^2}p^2c^2 = \frac{\cancel{A^2}}{Z^2e^2}({E_T}^2 - {E_0}^2)$$

$$P^2 = \frac{{E_T}^2 - {E_0}^2}{Z^2e^2}$$

$$P = \frac{\sqrt{{E_T}^2 - {E_0}^2}}{Ze}$$

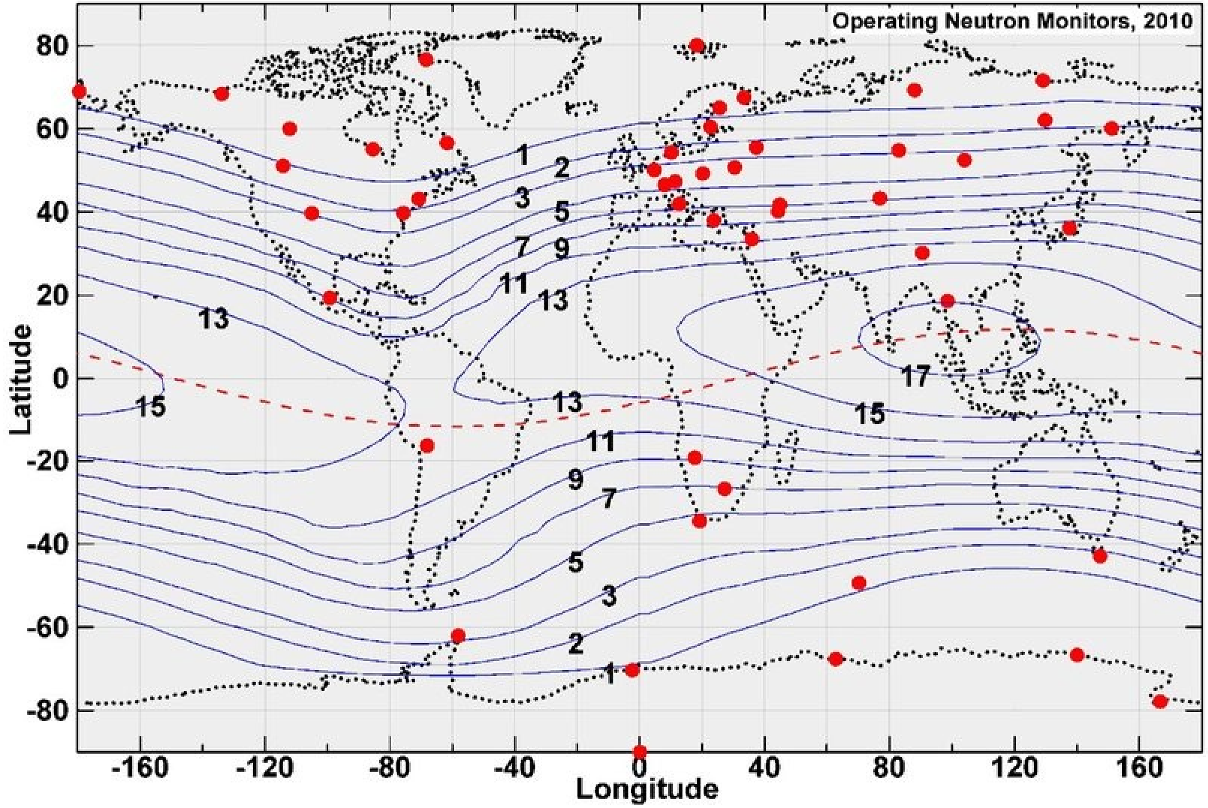
For $E_A \equiv E_T/A$ **("Total energy per nucleon"),** $E_T = E_A A$**, and** $E_0 = E_{0A}A$**.**

$$\boxed{P = \frac{A}{Ze}\sqrt{{E_A}^2 - {E_{0A}}^2}}$$

Exercises

Thailand has highest cutoff rigidity (minimum momentum per unit charge) with a value of approximately 17 GV.

a) How much energy in GeV for a proton?
b) How much energy in GeV for an alpha particle (Helium-4)?
c) What province in Thailand has the highest cutoff rigidity?



❑ Vertical Cutoff Rigidity

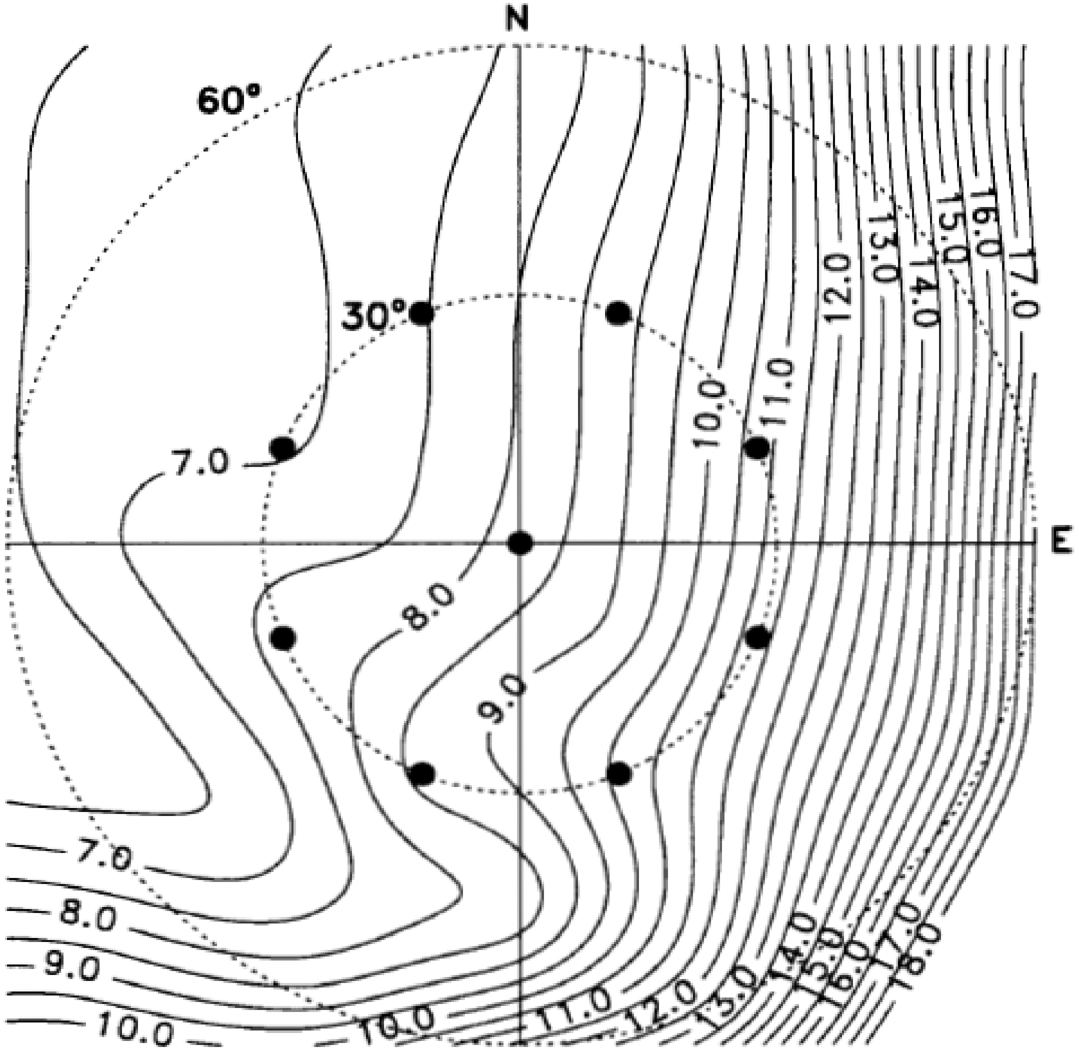
is the minimum rigidity for a vertically incident particle to enter the atmosphere at a particular location

❑ Apparent Cutoff Rigidity

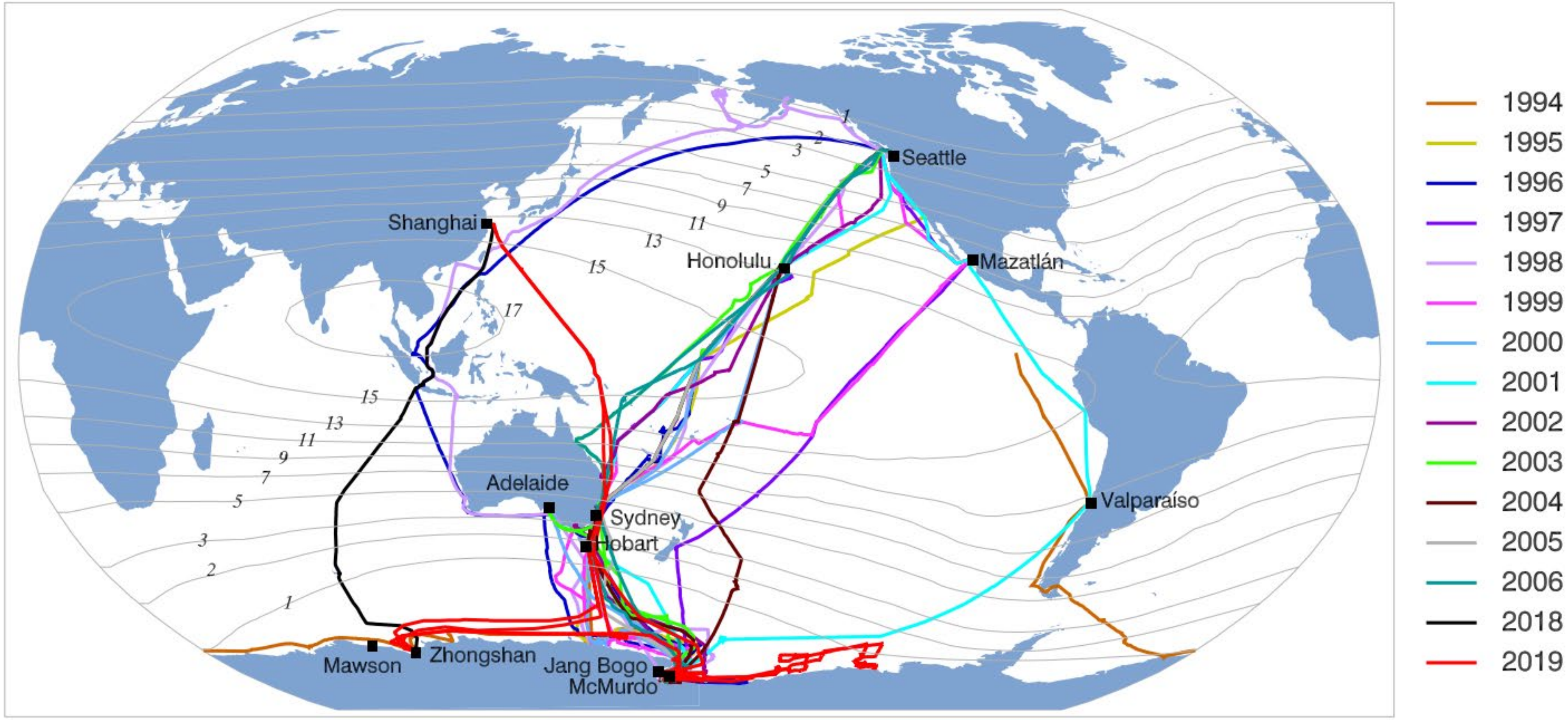
is an estimate taking into account the details of geomagnetic penumbra in each possible direction of incidence.

IGRF Magnetic Field Model : International Geomagnetic Reference Field **plus** Tsyganenko magnetosphere

Cutoff Sky Map



LATITUDE SURVEY: VOYAGES IN 2018 & 2019 SURVEY YEARS

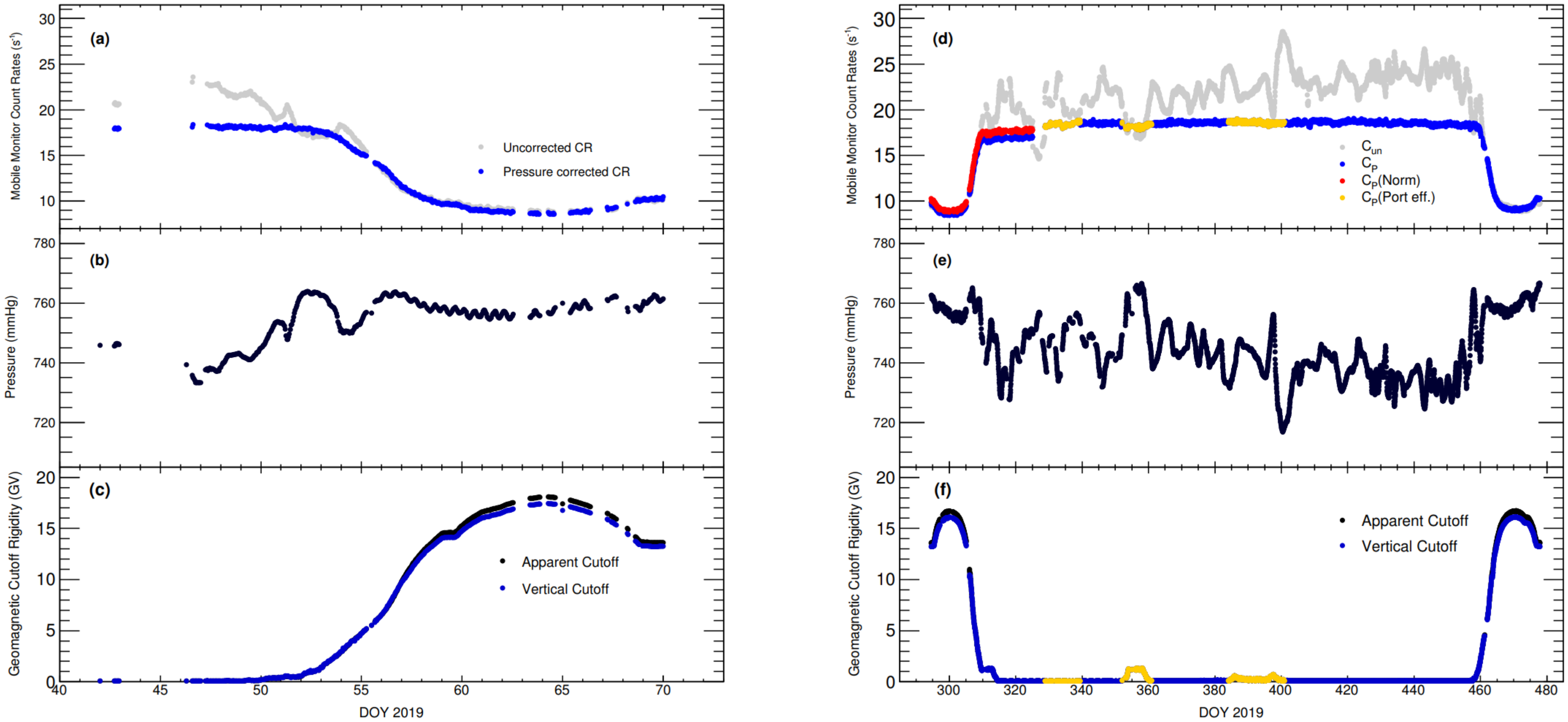


The tracks of the ship-borne neutron monitor latitude surveys are overlaid onto a contour map of the vertical cutoff rigidity (GV) calculated for February 11, 2019 at 12:00 UT.

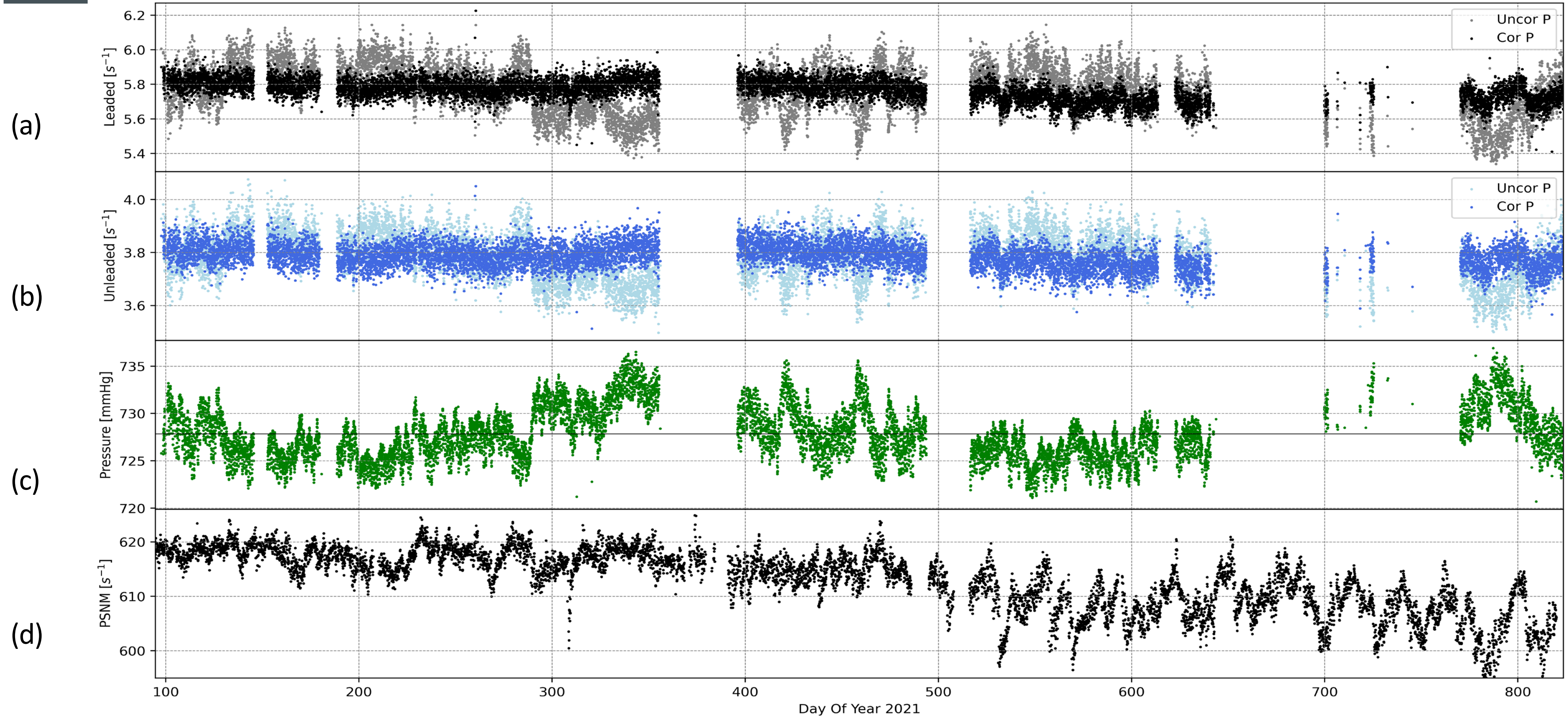
Image Credit: Poopakun et al., 2023

2018 Survey Year

2019 Survey Year



Comparative Overview of Changvan Data for the Survey Years: (LEFT) 2018 and (RIGHT) 2019. Categories: (a) Count Rate, (b) Pressure, and (c) Geomagnetic Cutoff Rigidity (GV). Image Credit: Poopakun EA 202x



(a) Changvan hourly rates for leaded counters, uncorrected (grey) and corrected (black) for pressure.
(b) Changvan hourly rates for unleaded counter, uncorrected (light blue) and corrected (blue) for pressure.
(c) The barometric pressure.
(d) PSNM count rate corrected for pressure. [downloaded from NMDB]
Image Credit: Khamphakdee EA 2020

DIFFERENTIAL RESPONSE FUNCTION (DRF)

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

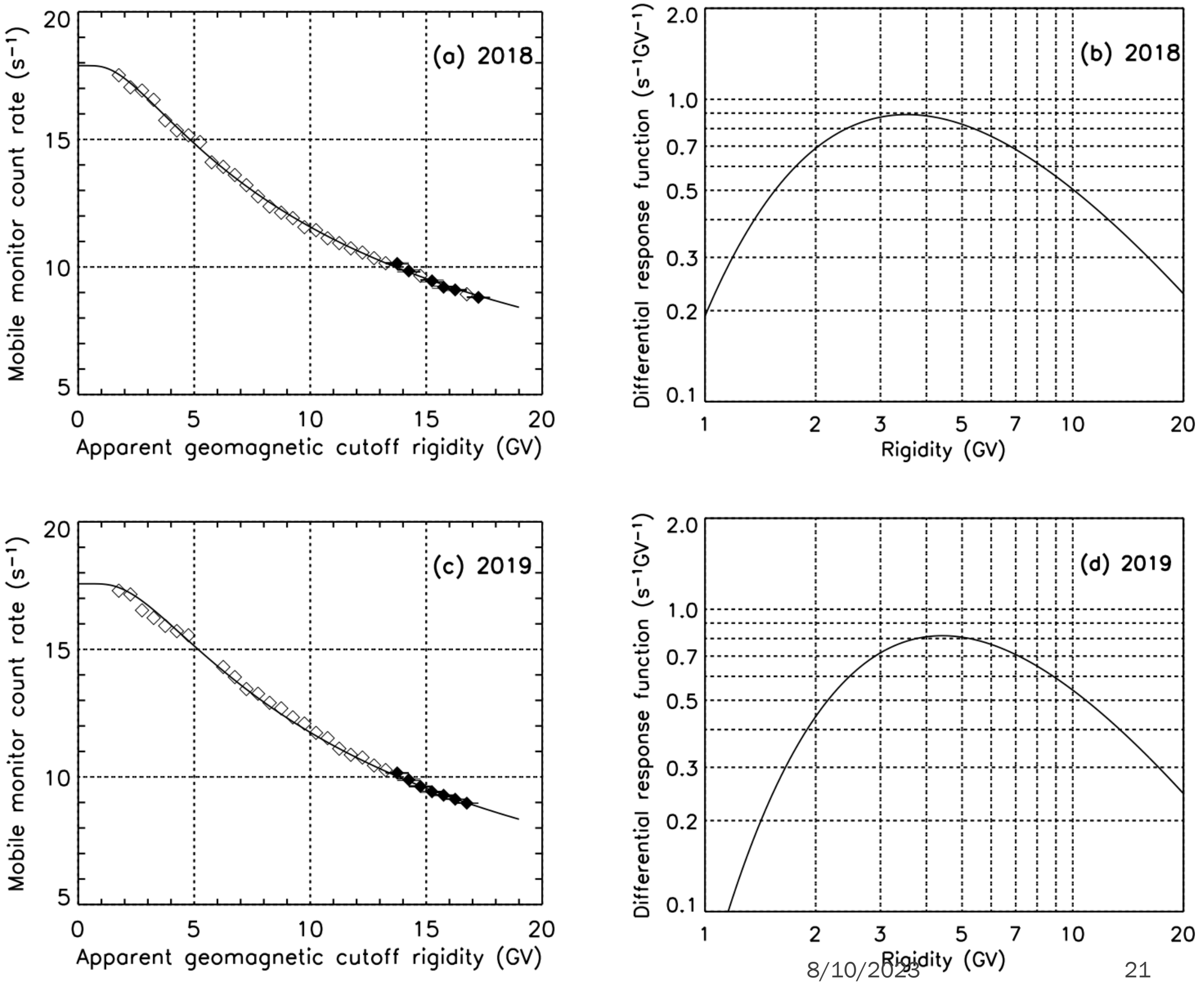
$$N(P_c) = \int_{P_c}^{\infty} DRF(P)dP,$$

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

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

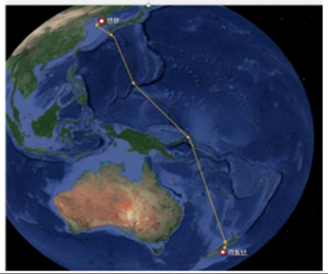
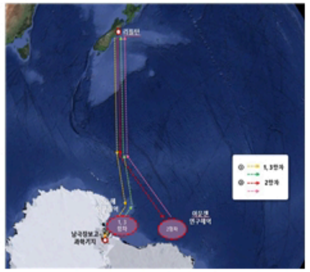
Integral Response Function

Differential Response Function



New Journeys (Araon Icebreaker)

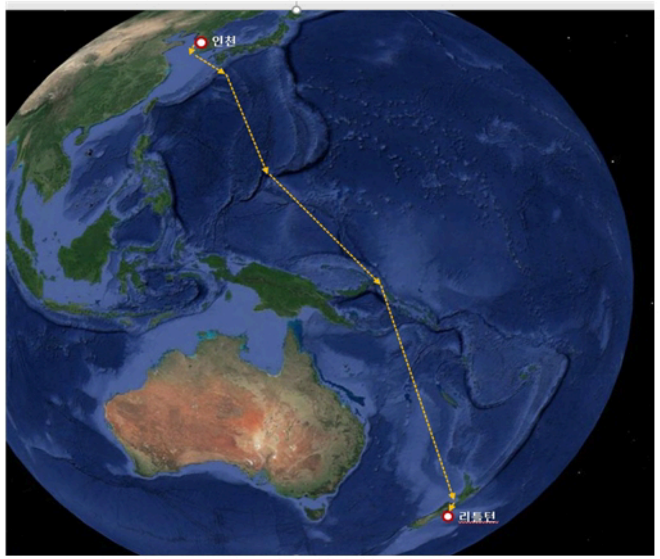
□ 아라온호 남극 항적도

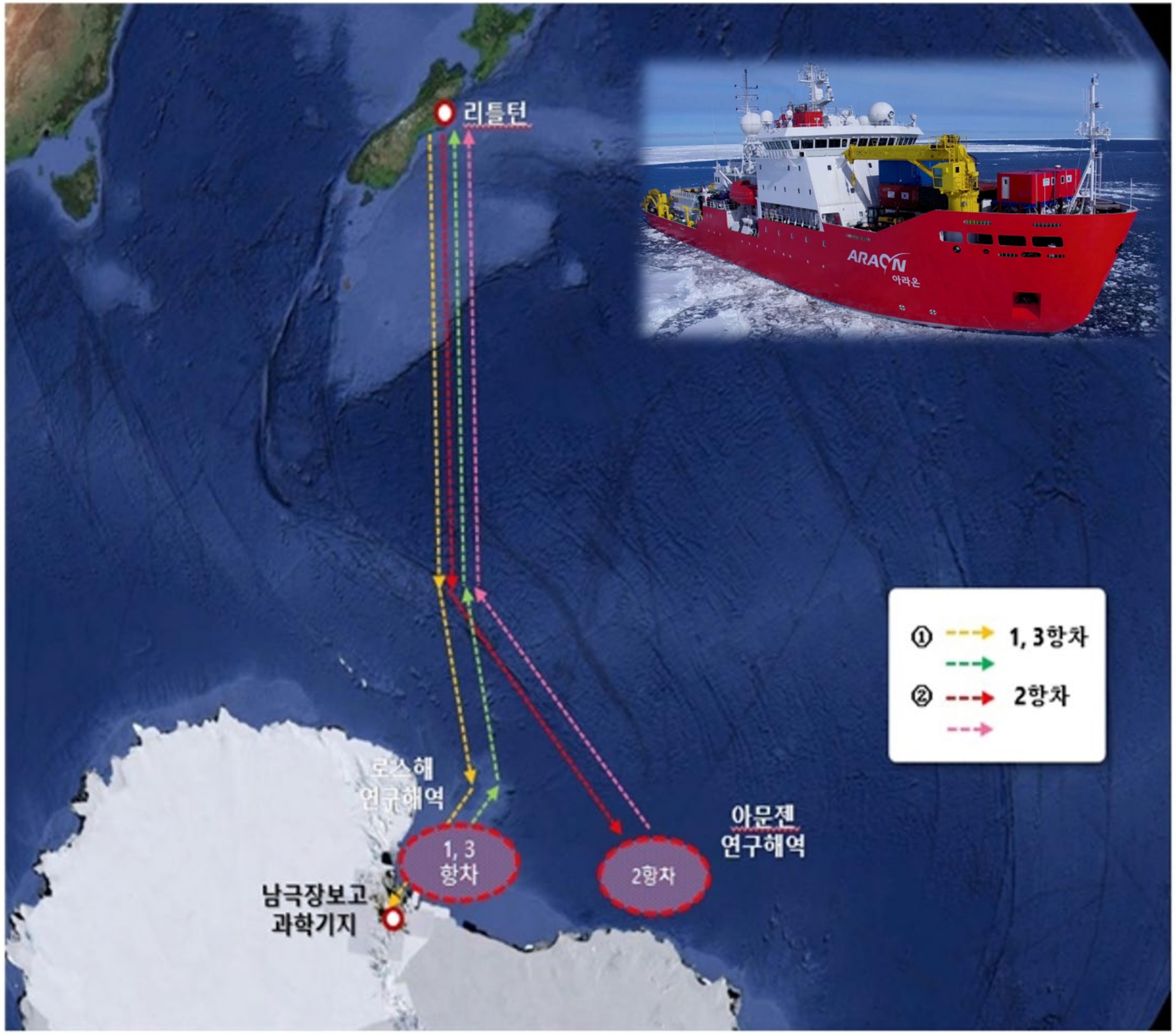
구분	항차별 이동경로	
아라온호 (남극)		
	이동항로	1,2,3 항차

① 아라온호(남극항해)

- 공동활용 가능기간 : '23.10.31~'24.4.22

구분 \ 항차		이동	1항차	2항차	3항차	이동
운항 일수	(전체)	20일	34일	45일	38일	20일
	단독 활용	0	1일	2일	2일	0





CONCLUSIONS

- The Changvan neutron monitor represents a portable solution for neutron detection.
- Pressure correction is required for neutron monitors globally.
- Neutron monitors are highly sensitive to environmental and surrounding influences.
- Utilizing this device, we have the capability to derive a differential response function, enabling the study of changes within the spectrum.
- Exciting new collaboration with South Korea (KOPRI).
- The upcoming Antarctic expedition is scheduled for December 20, 2023.

Q & A

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