# RESPONSE FUNCTIONS OF A SEMI-LEADED NEUTRON MONITOR FROM LATITUDE SURVEYS DURING 2018 – 2020

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# OUTLINE

- Introduction
  - Cosmic Rays
  - Neutron Monitor
- Latitude Survey Project
- Data and Simulation from Changvan
- Future Plan

# INTRODUCTION: COSMIC RAYS

- Energetic particles or $\gamma$-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 $\gamma$, $e^{+}$, $e^{-}$, $\mu$, $\nu$, …
- Key sources of cosmic rays 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

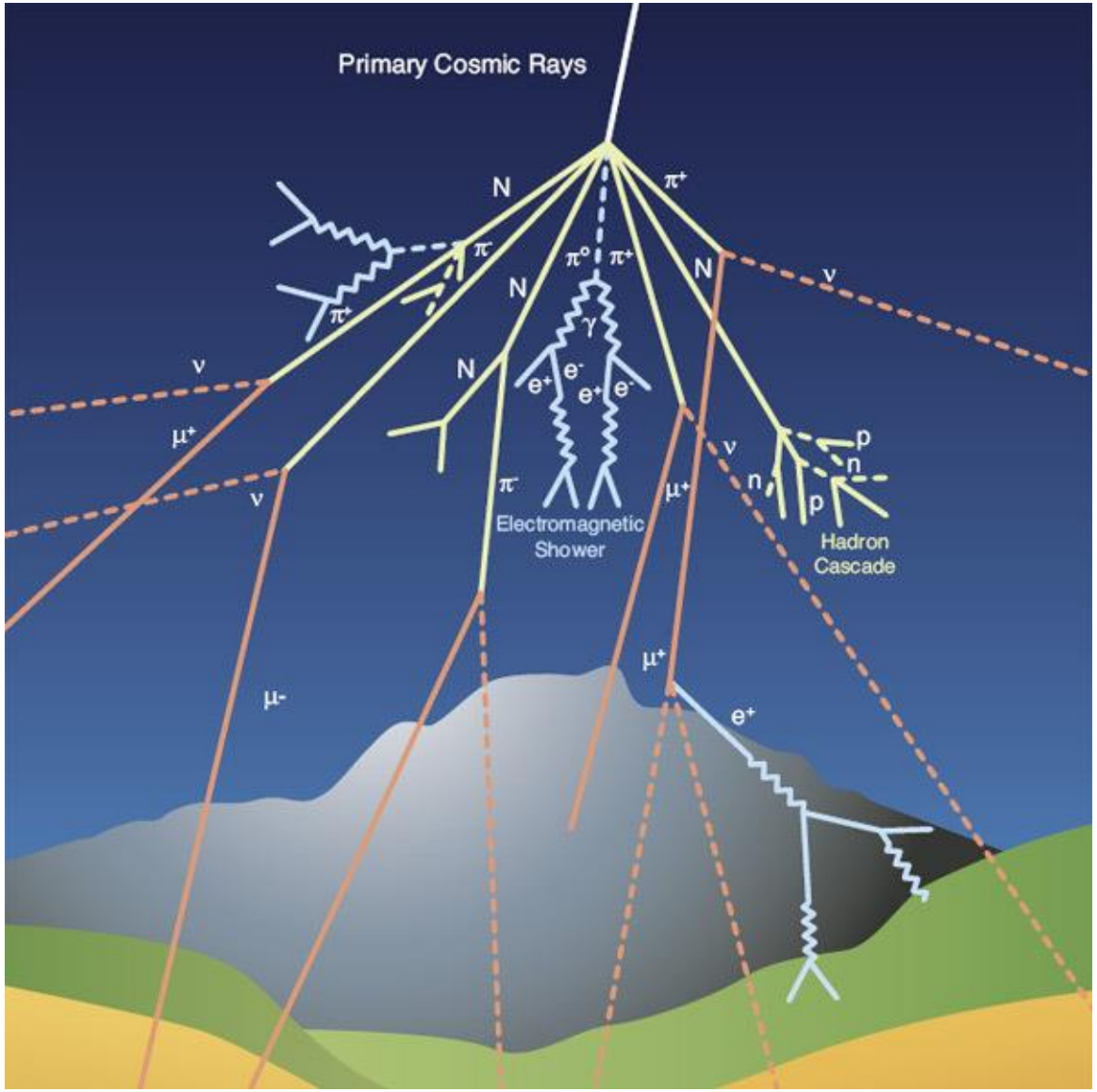



Image Credit: CERN

# INTRODUCTION: STANDARD NEUTRON MONITOR (NM64)

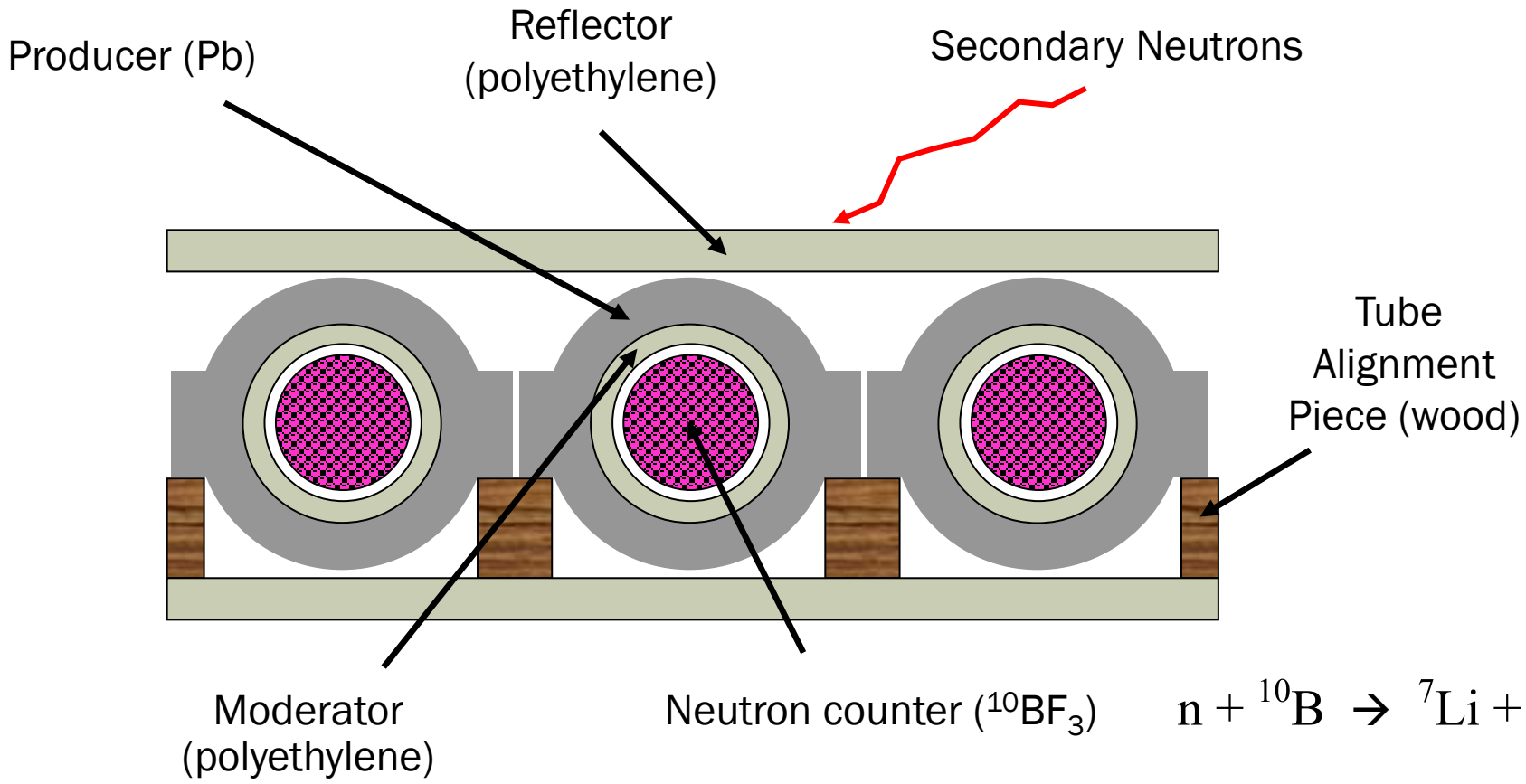



FIGURE 1 3NM64

# INTRODUCTION: BARE NEUTRON DETECTOR

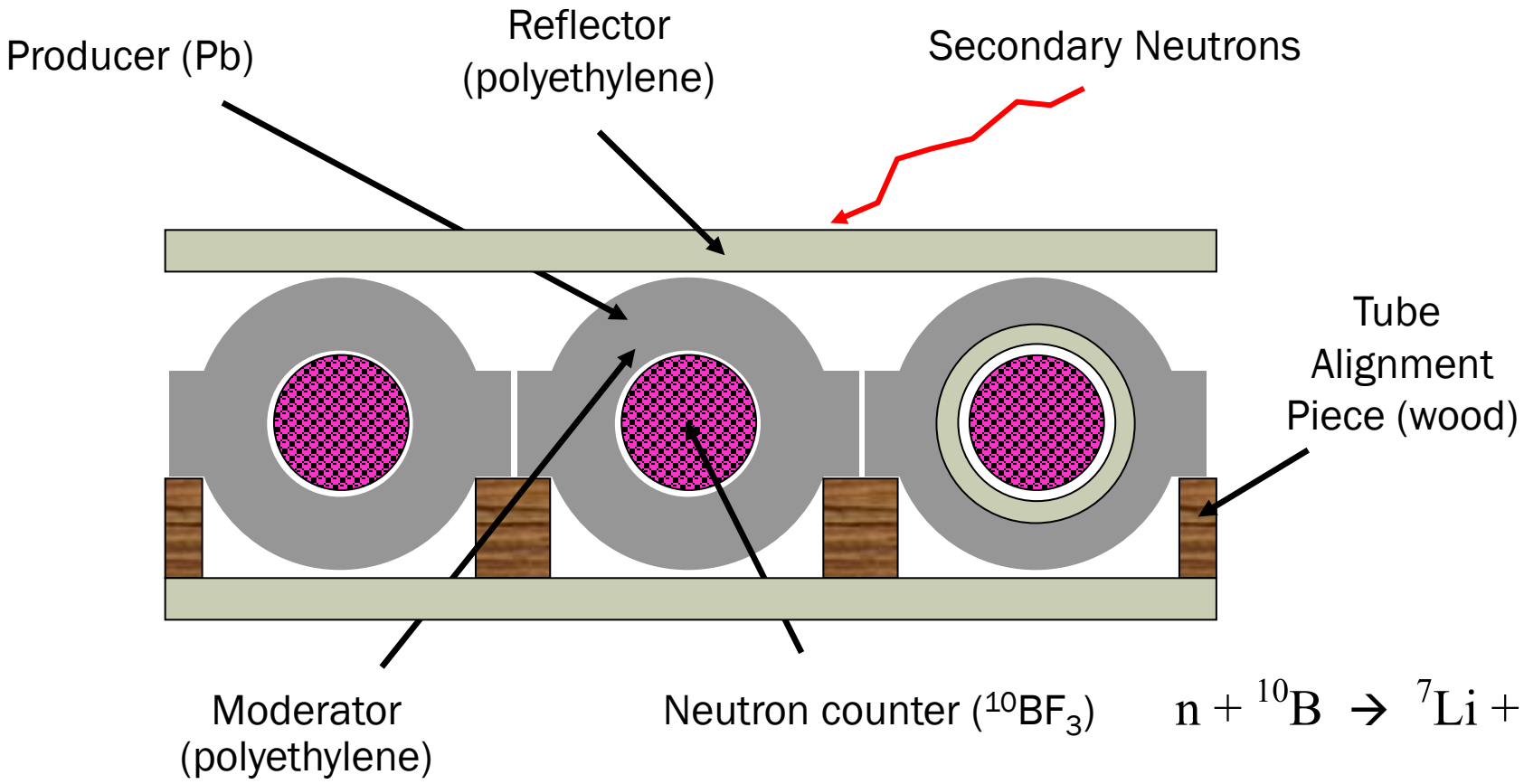



FIGURE 1 3NM64

# INTRODUCTION: SEMI-LEADED NEUTRON MONITOR

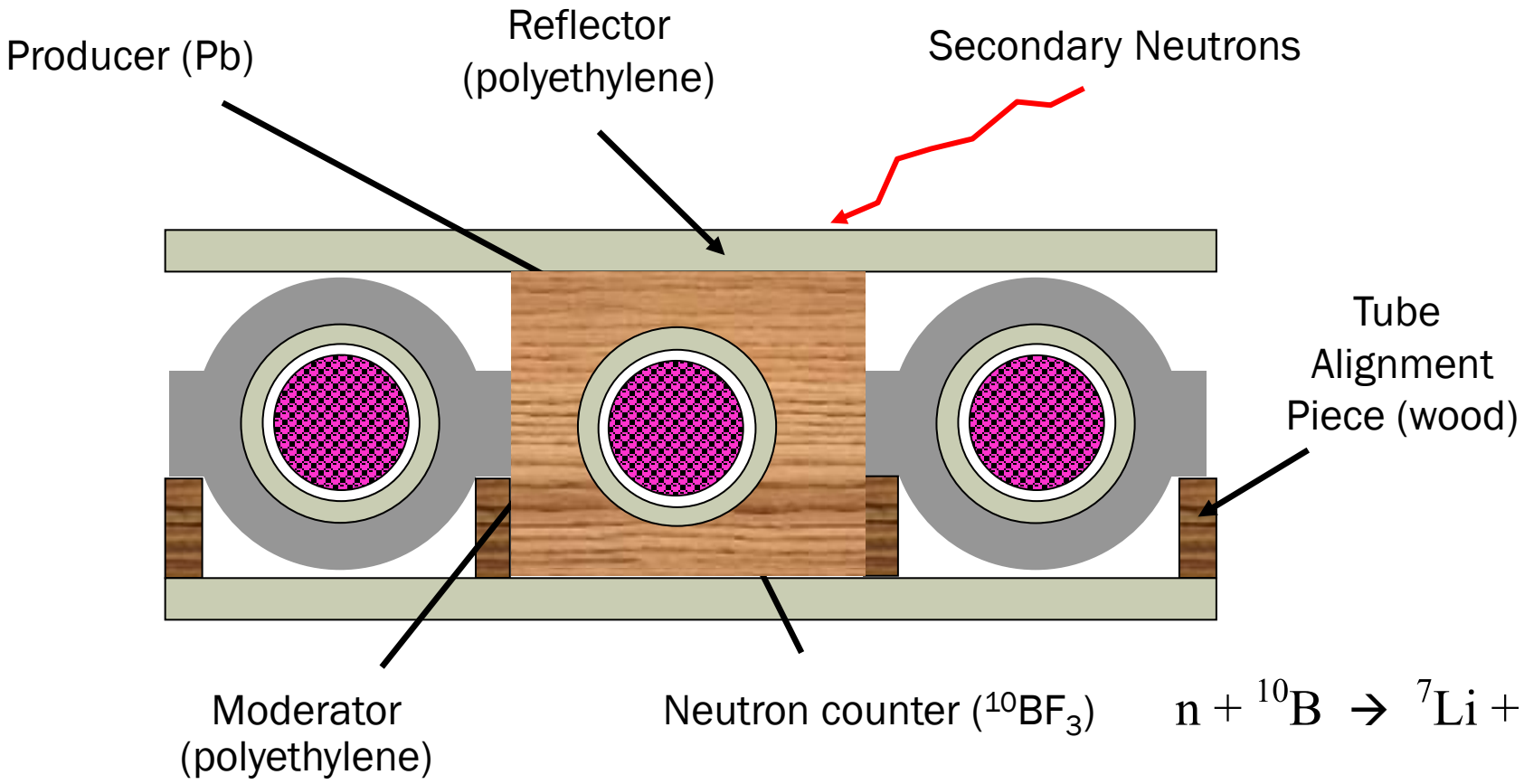



FIGURE 1 3NM64

# Latitude Survey Project



## Chinese Icebreaker Xue Long

**survey years**:

- 2018-2019
- 2019-2020


GCR spectrum — heliospheric Modulation — Yield function — geomagnetic Transmission

Count Rate

$$N(\Theta,\Phi,h,t)=\int_0^{\infty}\left[\sum_i G_i(P)M_i(P,t)Y_i(P,h)\right]T(P,\Theta,\Phi,t)\mathrm{d}P \quad \text{---------(1)}$$

$$N(P_c,h,t)=\int_{P_c}^{P_L}\sum_i G_i(P)M_i(P,t)Y_i(P,h)\mathrm{d}P \quad \text{---------(2)}$$

Differential Response function

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


FIGURE 2 Chanvan & Thimon monitors


FIGURE 3 The placement of the semi-leaded neutron monitor inside the shipping containter

# LATITUDE SURVEY: VOYAGE IN 2019 & 2020 SURVEY YEARS

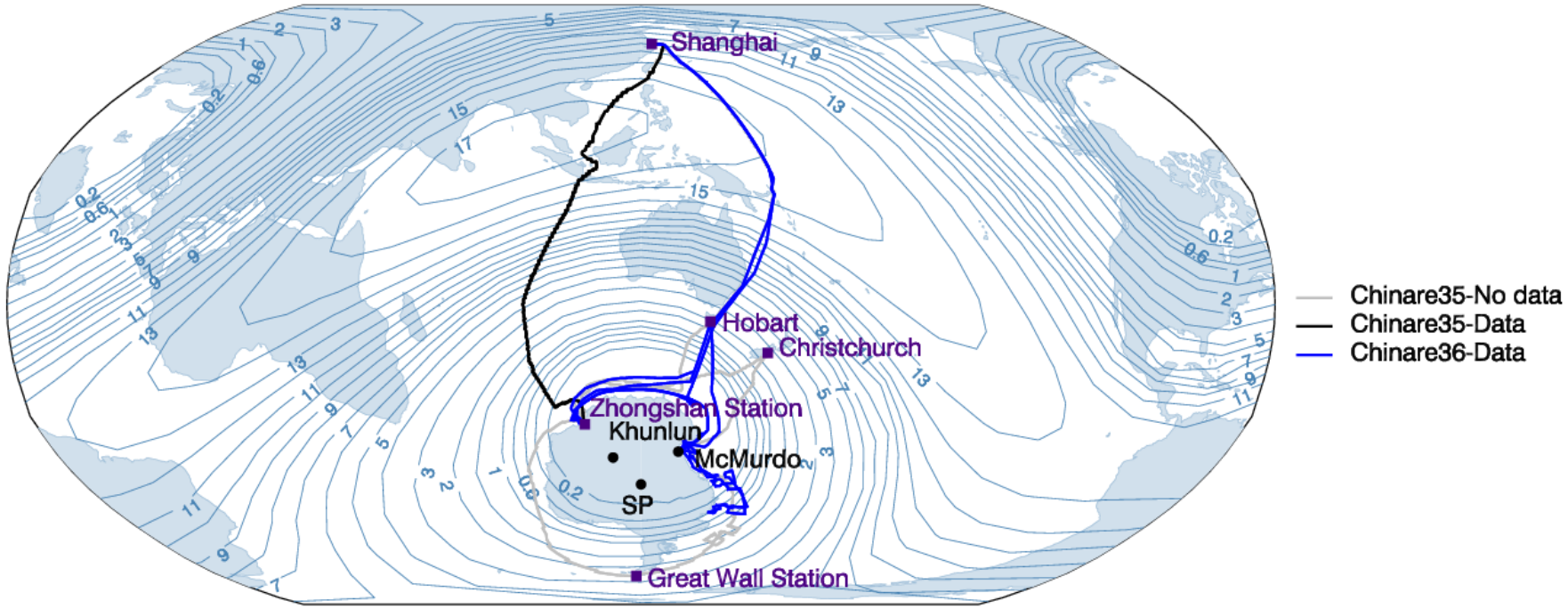



FIGURE 4 Path of Changvan neutron monitor in the 2019 (CN35: grey line) and 2020 (CN36: blue line) survey years. The contours with numbers indicate vertical cutoff rigidity (in the units of GV), calculated for February 11, 2019, at 12:00 UT

Courtesy *Khamphakdee et al., 2021*

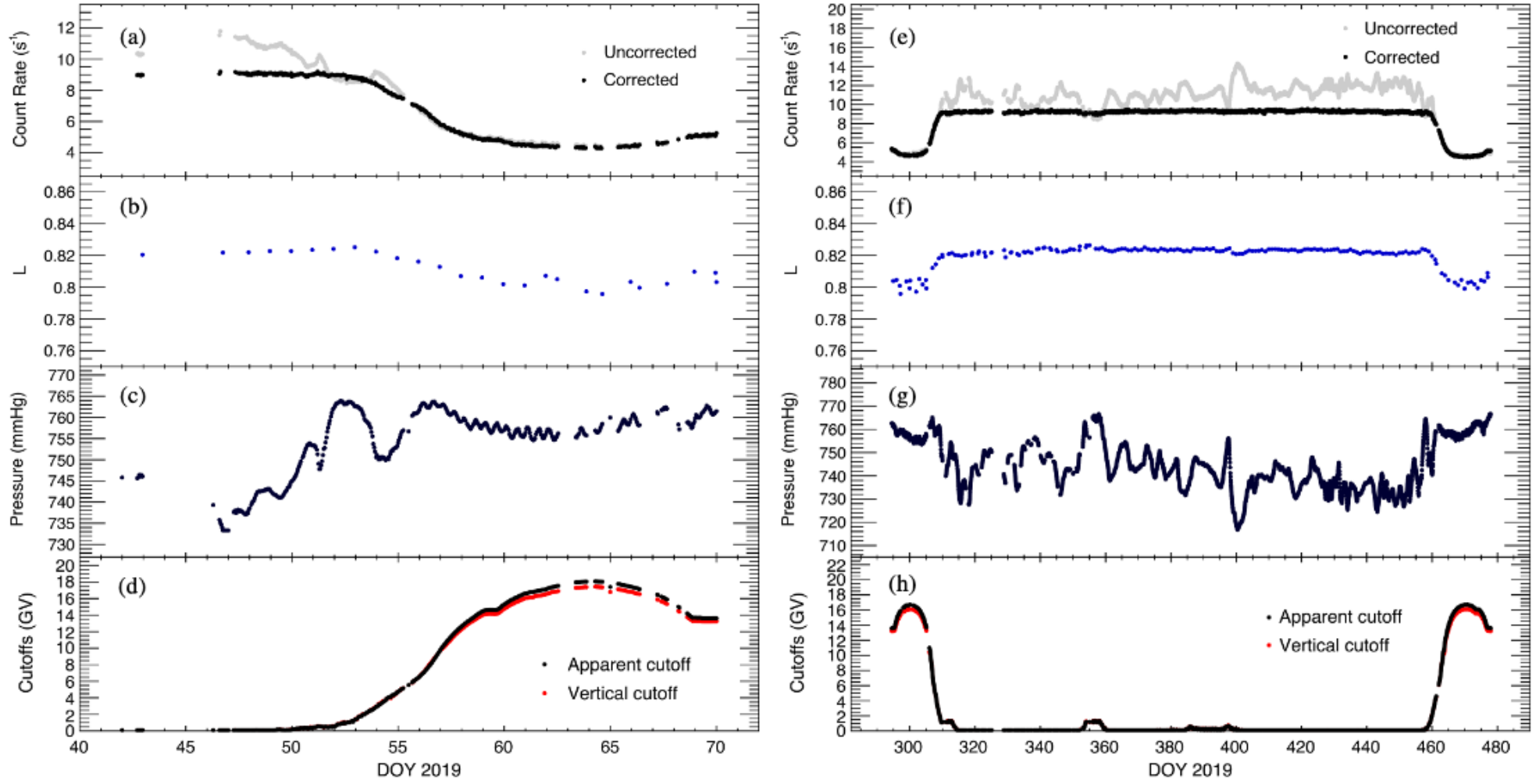



FIGURE 5 (a)-(d) Data set of the survey year 2019 and (e)- (h) of the survey year 2020, as a function of time. (a) and (e) Hourly averaged count rates for two counter tubes (T1 & T3). (b) and (f) display daily uncorrected $L$ for pressure. More detail of calculating $L$ is explained in the text. (c) and (g) The barometric pressure was recorded by GPS on the *Xue Long* icebreaker. (d) and (h) show geomagnetic cutoff rigidity, where the black line shows the apparent cutoff rigidity, and the red line shows the vertical cutoff rigidity. Courtesy *Yakum et al., 2021*

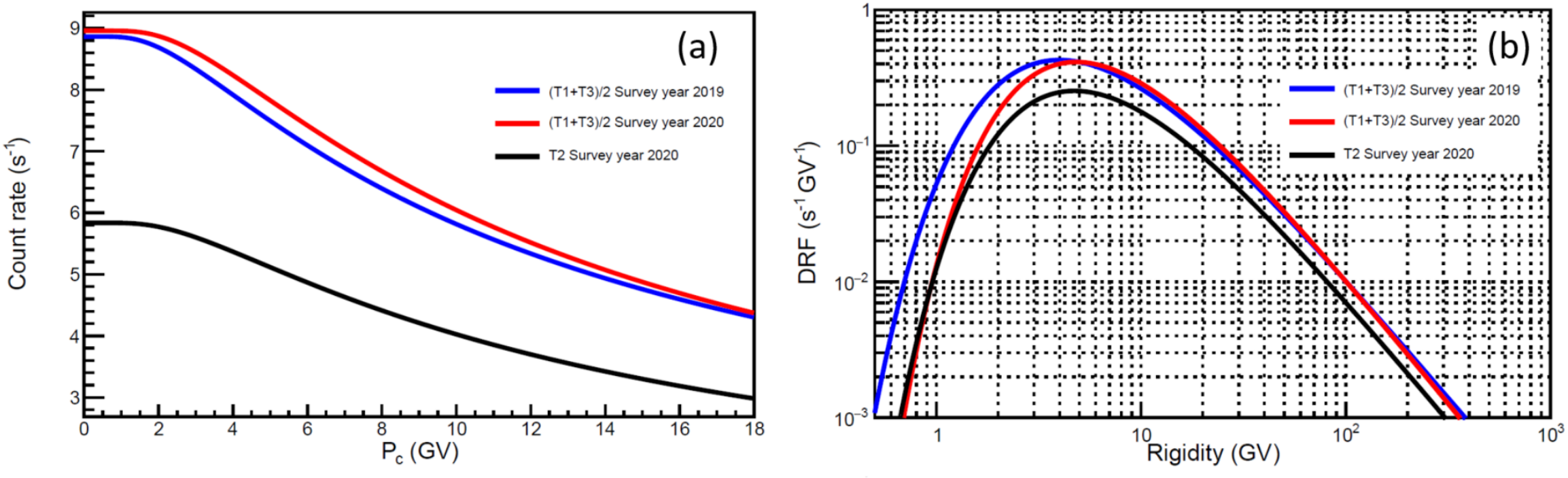



FIGURE 6 Dorman function fits Vs $P_c$ for 2019 and 2020 survey years. (a)-(b) Integral and differential count rate response functions.

# ATMOSPHERIC SIMULATION

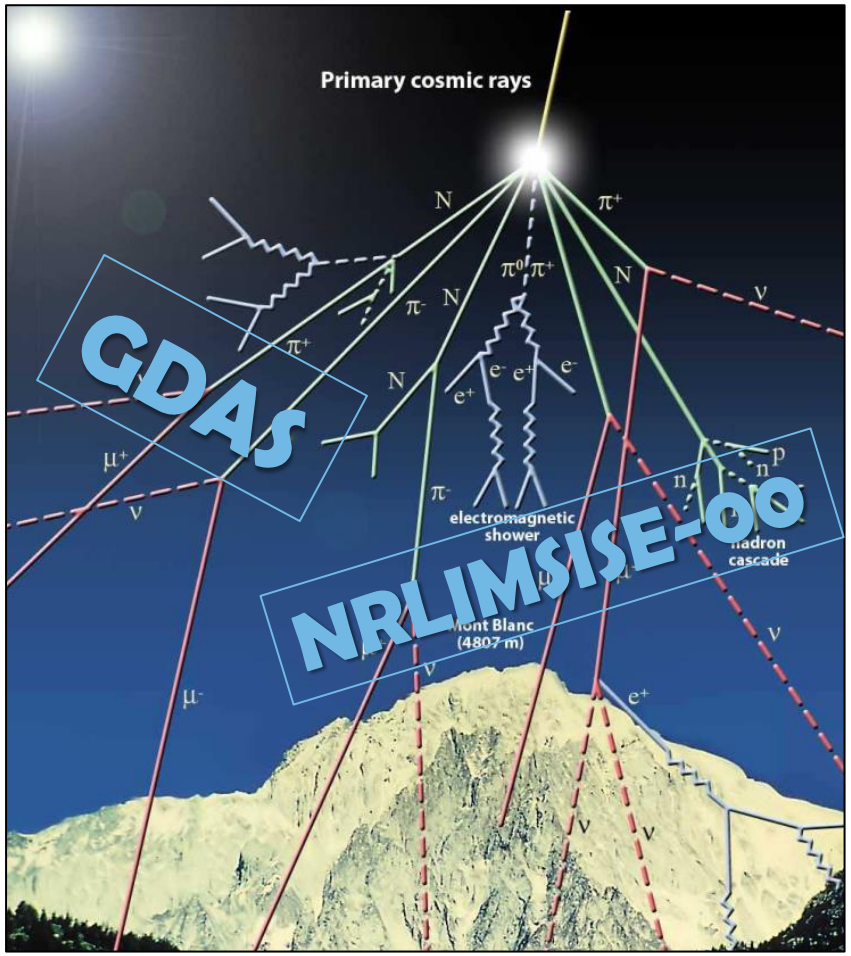
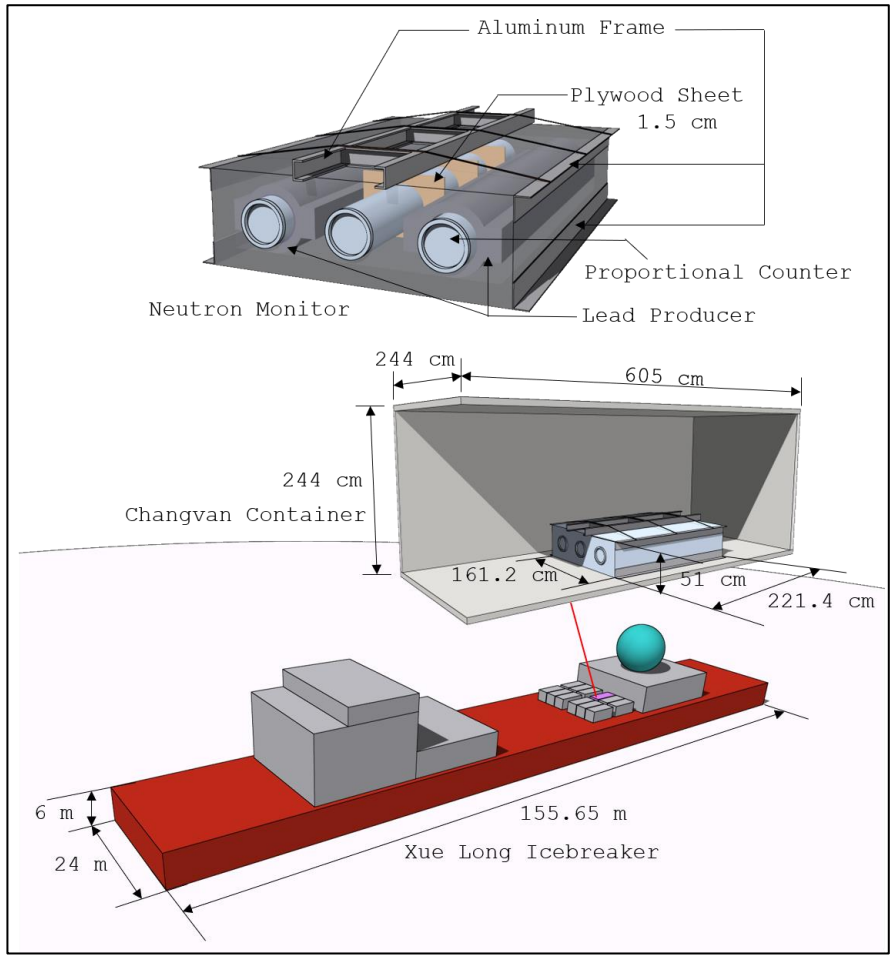



Image credit: http://scifun.ed.ac.uk/card/images/left/cosmic-rays.jpg

# DETECTOR SIMULATION



# SIMULATION INFORMATION

| | Type | No. of simulated particles |
|---|---|---|
| Atmospheric simulation | $p$ | 1,000,000 |
| | $\alpha$ | 1,000,000 |
| Library | $n$ | 136,508 |
| | $p$ | 13,486 |
| | $\mu$ | 1,149,070 |
| Detector simulation | $n$ | 100,000,000 |
| | $p$ | 100,000,000 |
| | $\mu$ | 75,000,000 |

# YIELD FUNCTION

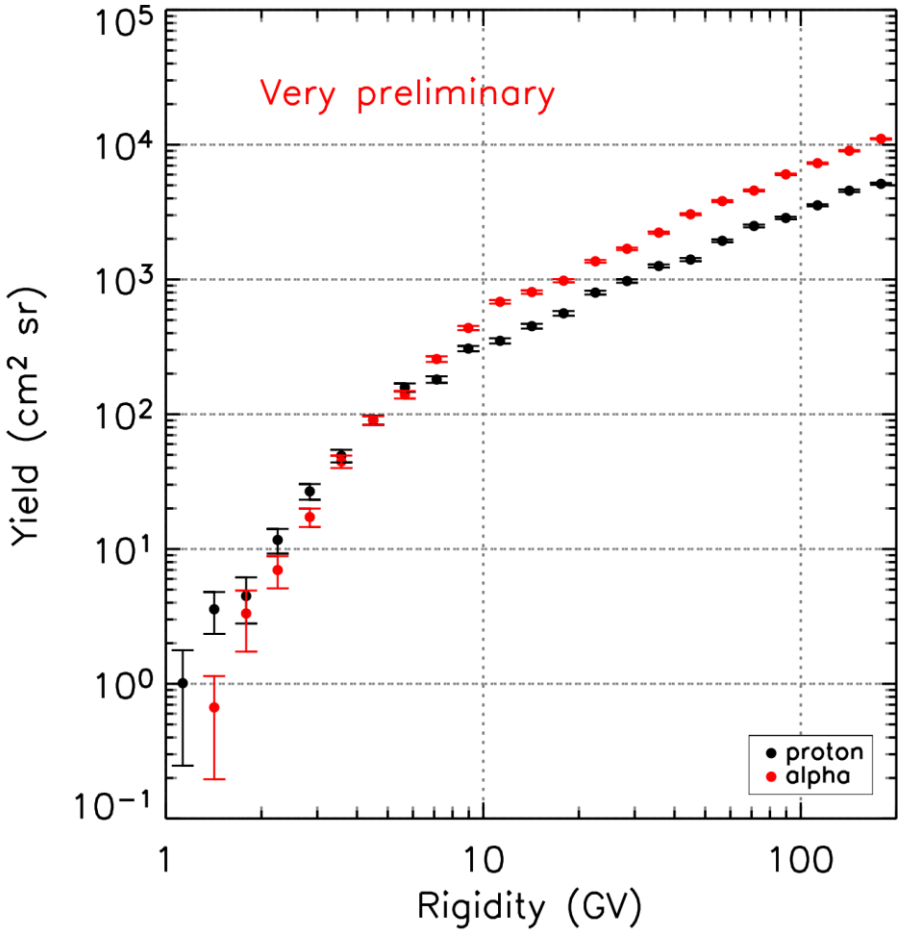



FIGURE 7 Yield functions for protons and alphas of Changvan neutron monitor.

# COUNT RATES VS CUTOFF RIGIDITY

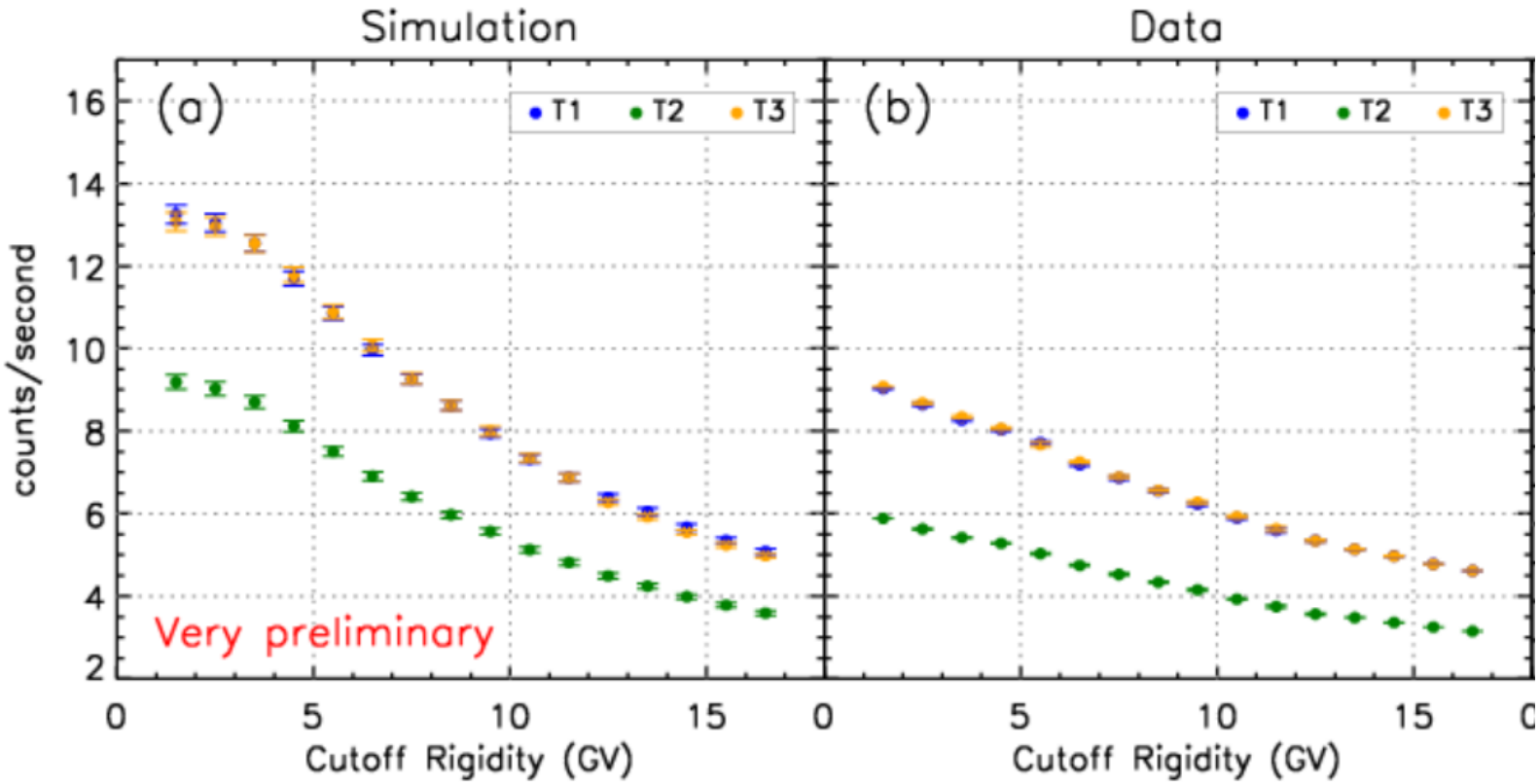



FIGURE 8 (a) Comparison between (a) Simulation count rate and (b) Data count rate. The simulation count rate is higher than the Data count rate.

# COUNT RATES RATIOS VS CUTOFF RIGIDITY

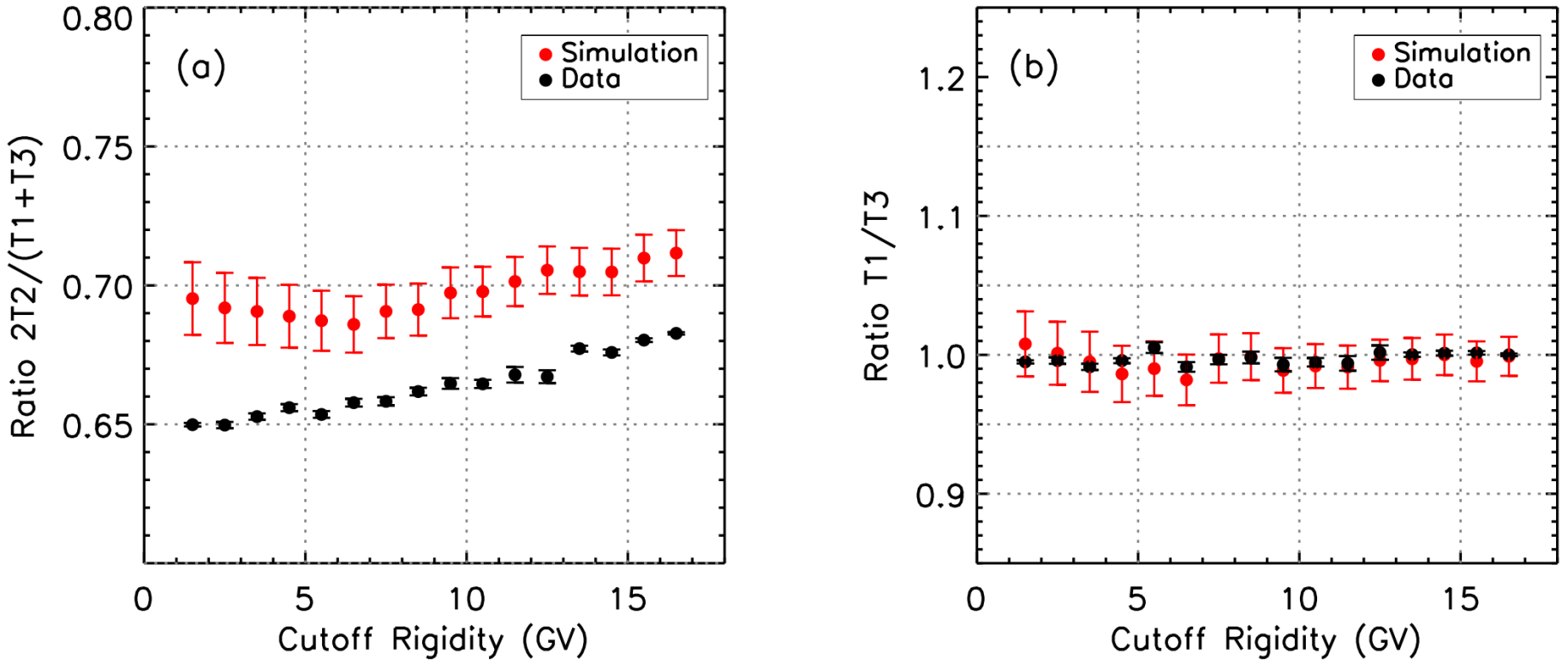



FIGURE 9 (a) The ratios of unleaded/leaded NM count rates. (b) The ratio of leaded/leaded NM rates.

Courtesy *Seripienlert et al., 2021*

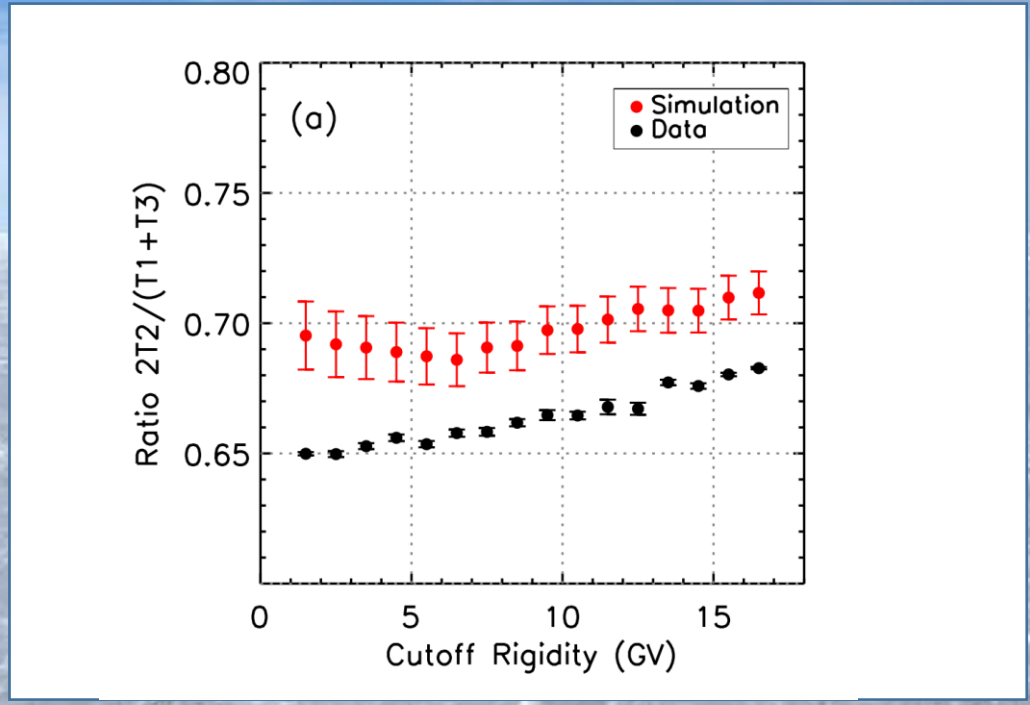
# FUTURE WORK

## Experiment

- Another mobile monitor “Thimon”


## Simulation

- Use more atmospheric data
- Run more simulation at lower rigidity







Thank you for your attention!