SIMULATIONS OF SEMI-LEADED NEUTRON MONITOR RESPONSE FUNCTIONS FROM LATITUDE SURVEYS

A. SERIPIENLERT AND W. NUNTIYAKUL

On behalf of Thailand research group

OUTLINE

- Introduction
  - Cosmic Rays
  - Neutron Monitor
- Latitude Survey Project
- Atmospheric Simulations
- Detector Simulations
- Results
- Future work

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 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

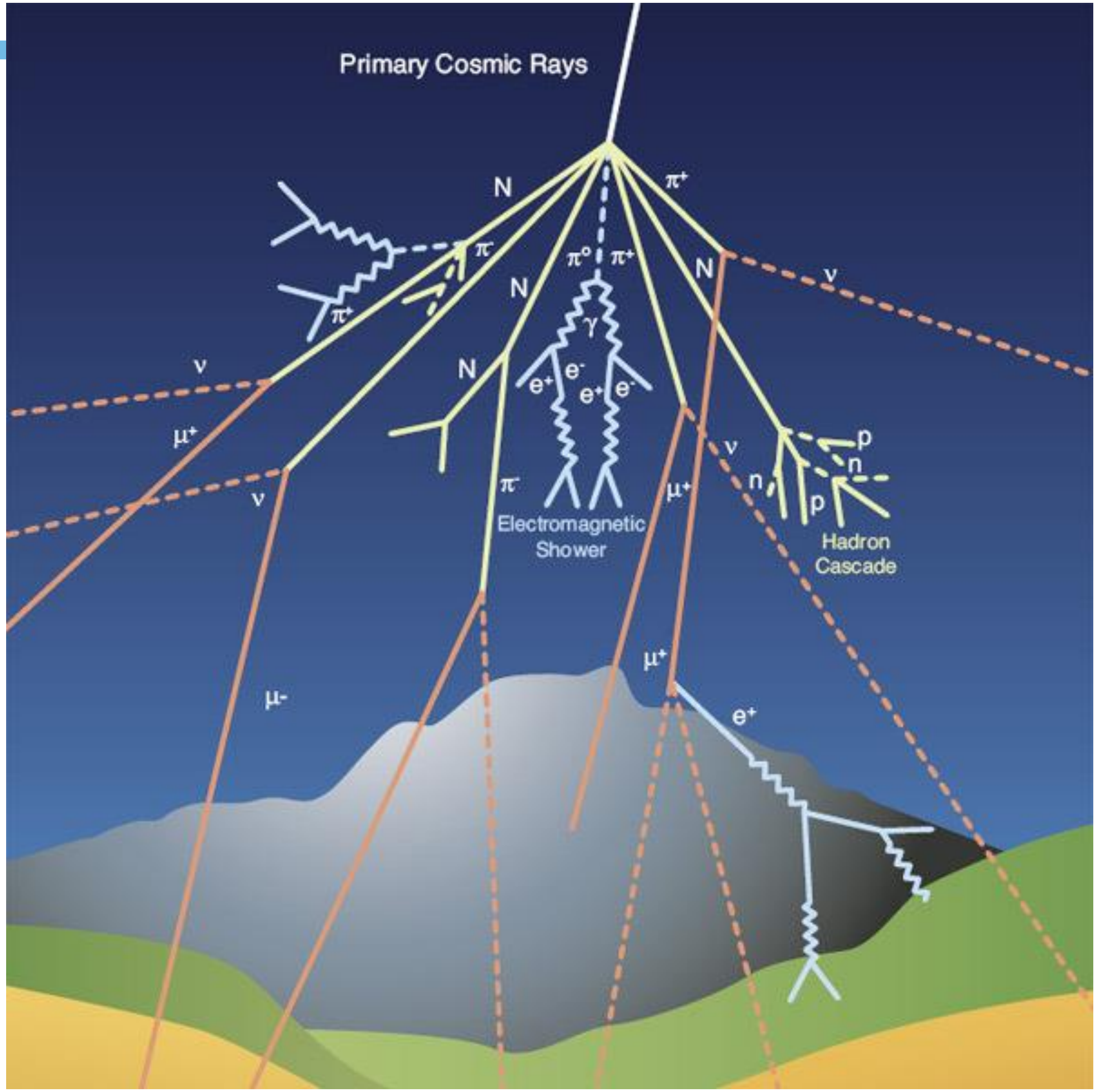
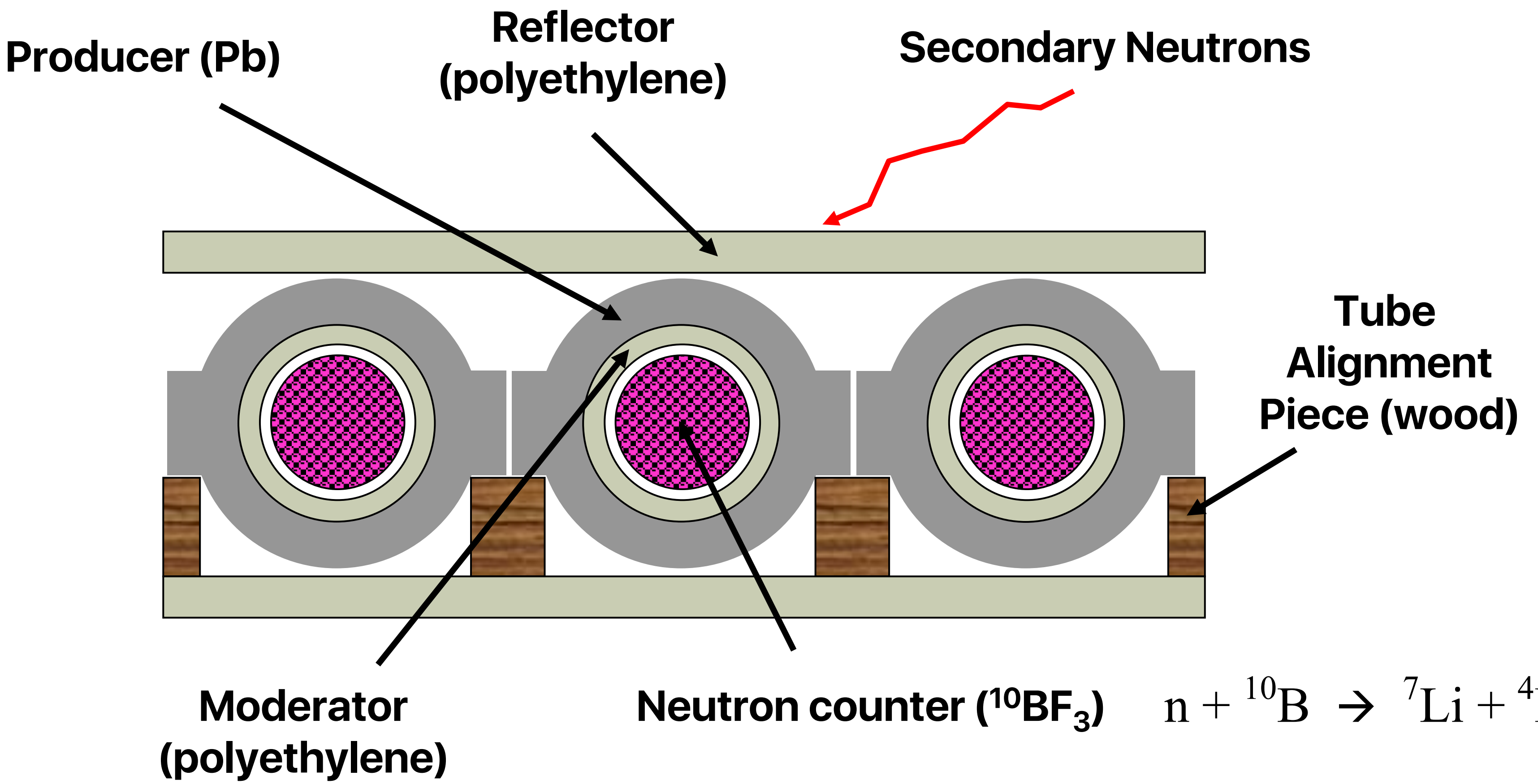


Image Credit: Cosmic rays_ particles from outer space _ CERN.html

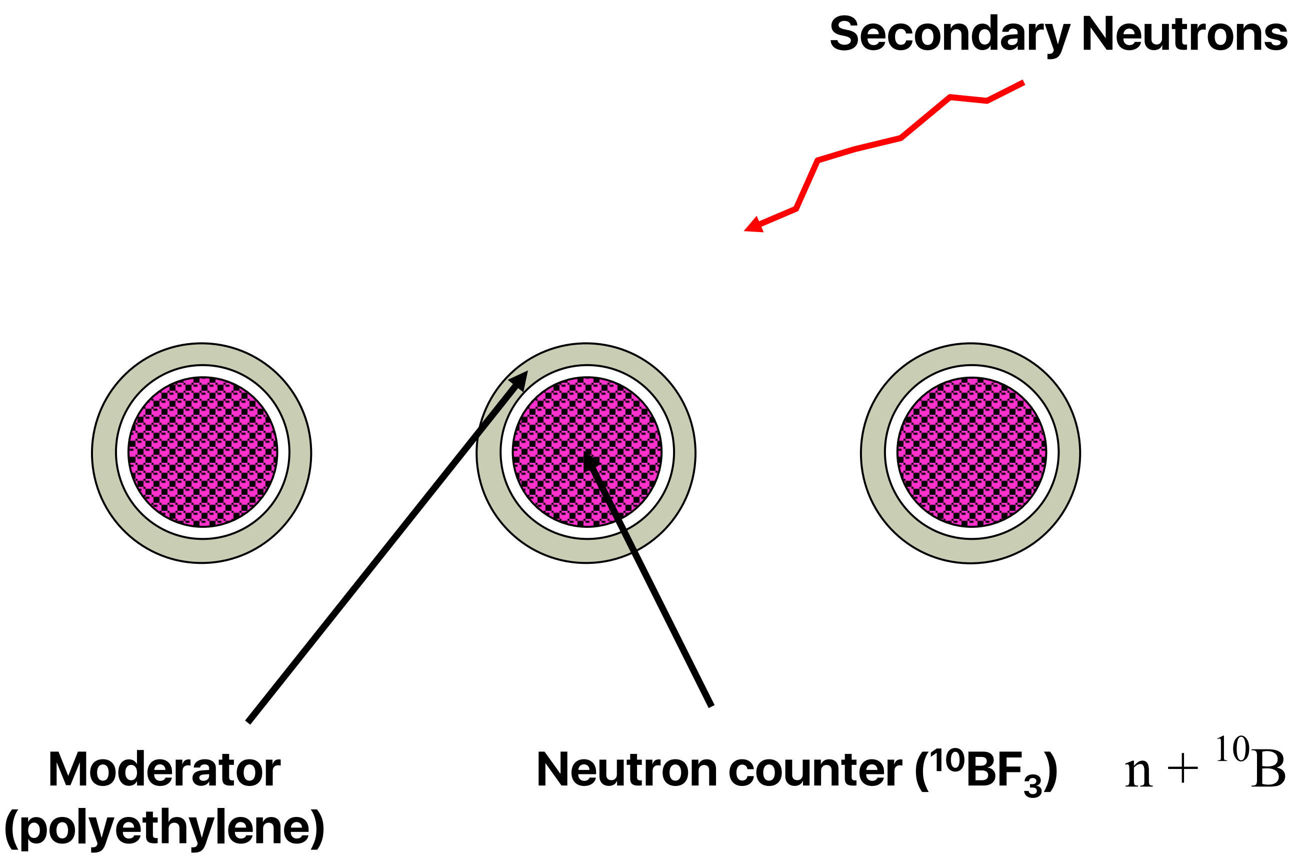
INTRODUCTION: STANDARD NEUTRON MONITOR (NM64)



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

FIGURE 1 3NM64

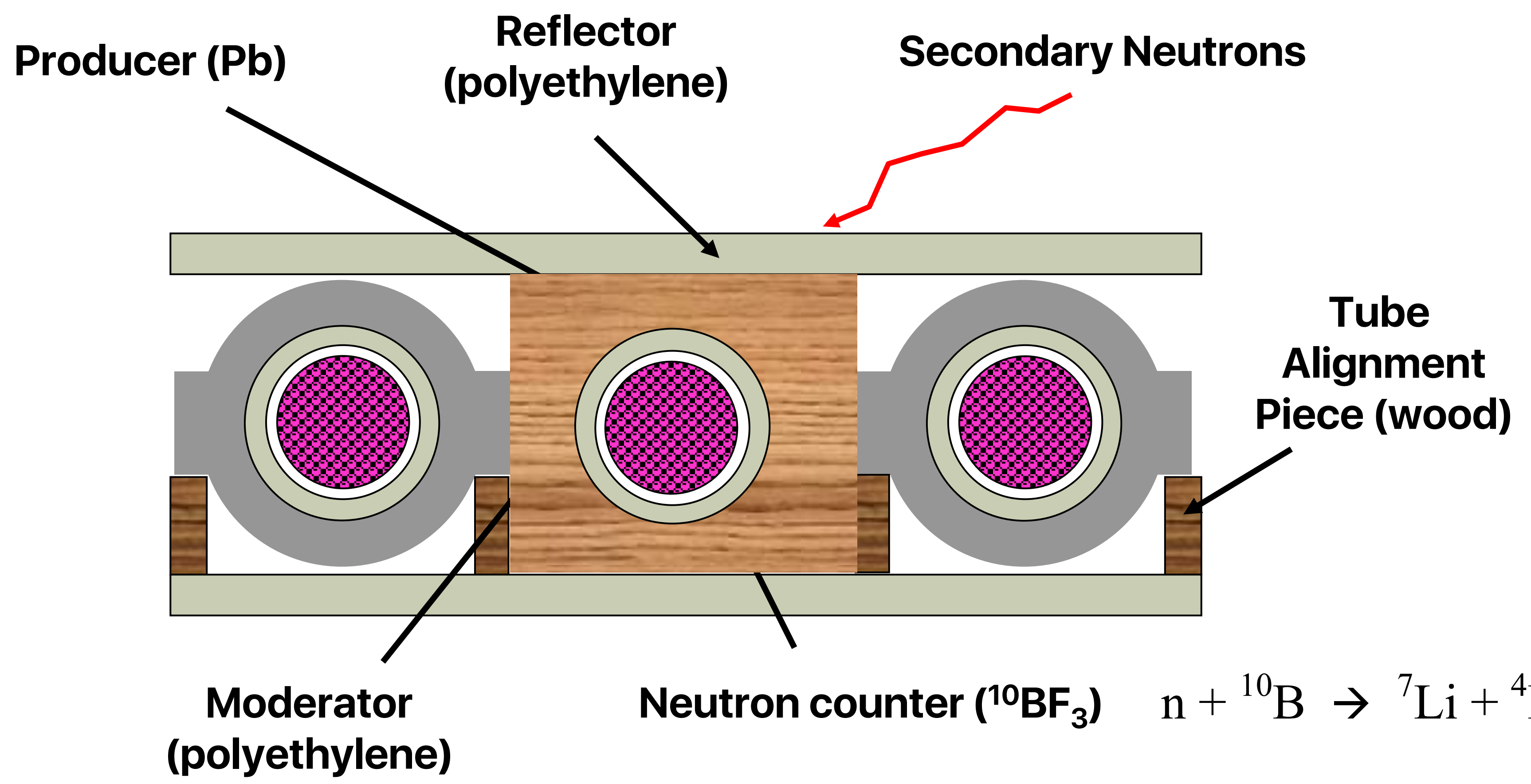
INTRODUCTION: BARE NEUTRON DETECTOR



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

FIGURE 1 3NM64

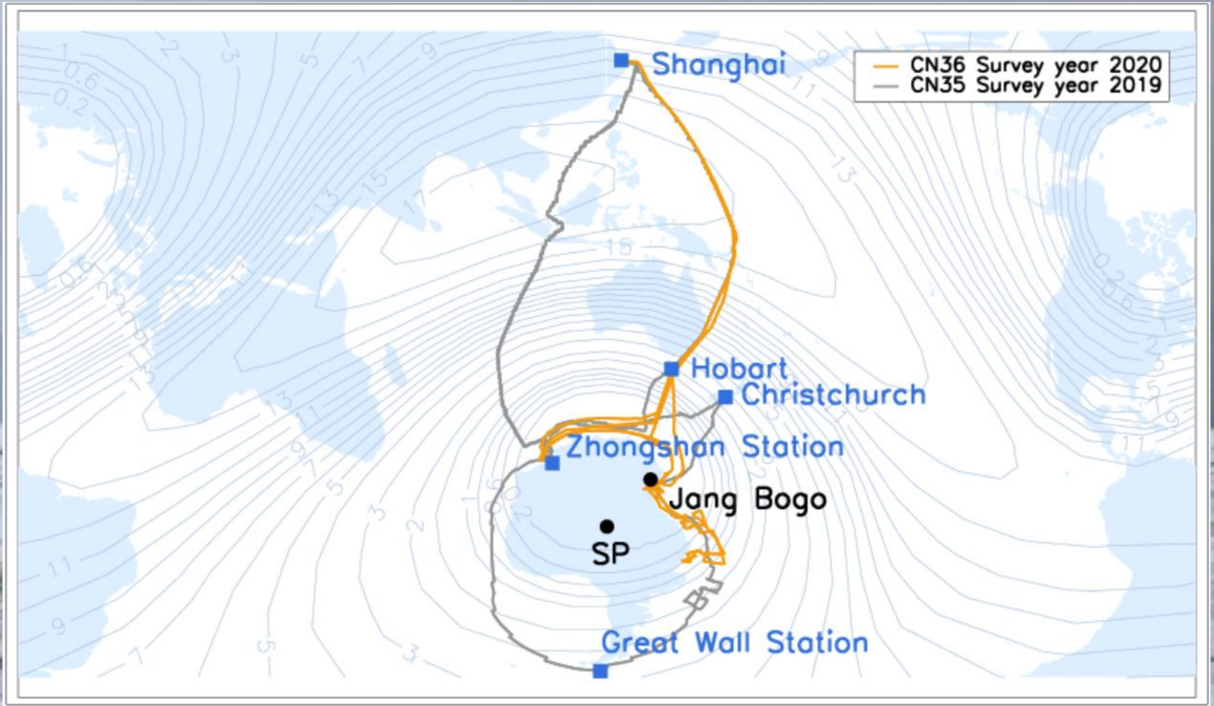
INTRODUCTION: SEMI-LEADED NEUTRON MONITOR



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

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

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

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

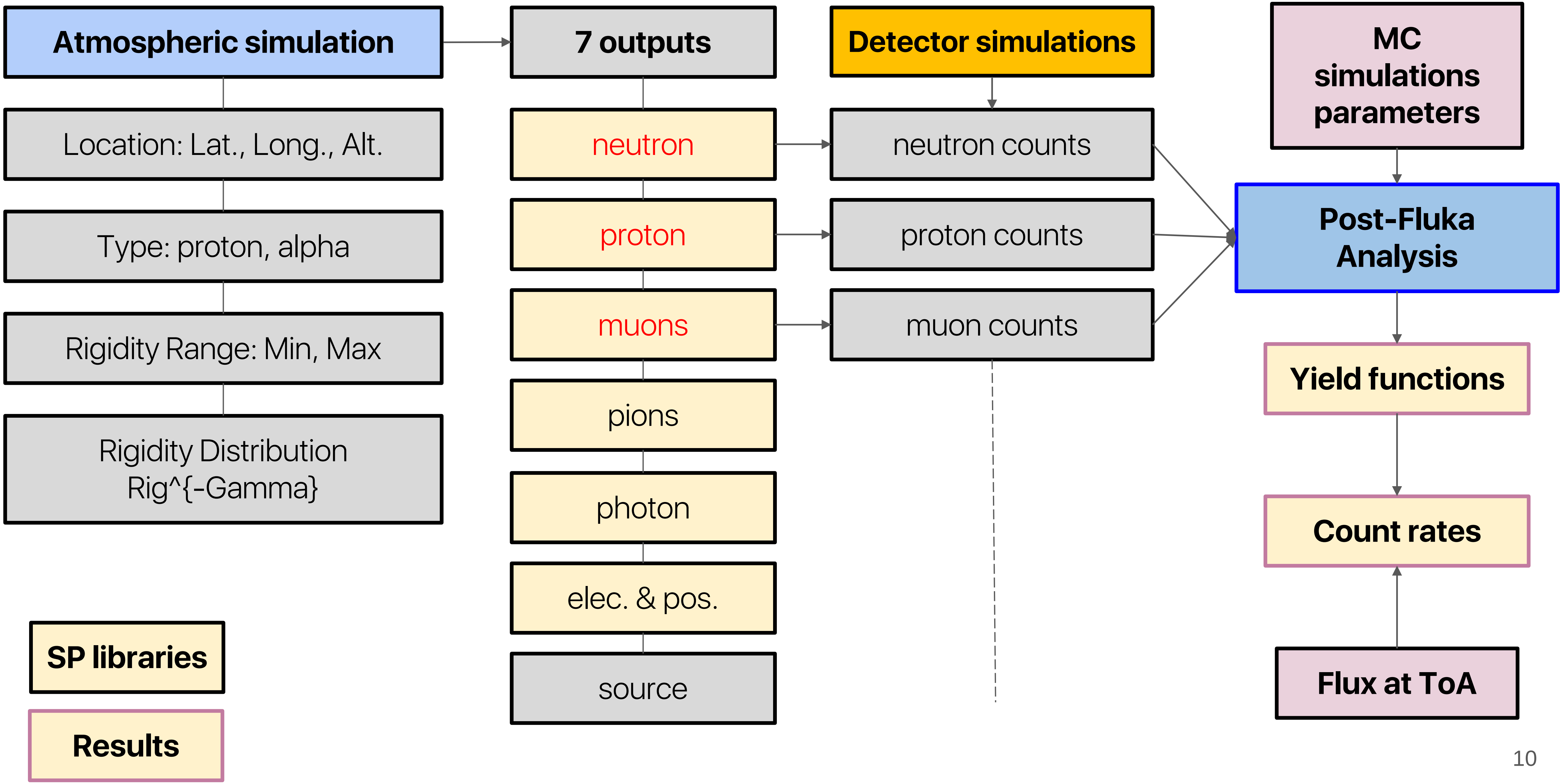
Differential Response function

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

Monte Carlo Simulations

FLUKA

Post FLUKA Analysis


Atmospheric simulation
Location: Lat., Long., Alt.
Type: proton, alpha
Rigidity Range: Min, Max
Rigidity Distribution
Rig^{-Gamma}
7 outputs
neutron
proton
muons
pions
photon
elec. & pos.
source
Detector simulations
neutron counts
proton counts
muon counts
MC simulations parameters
Post-Fluka Analysis
Yield functions
Count rates
Flux at ToA
SP libraries
Results

Atmospheric Simulations

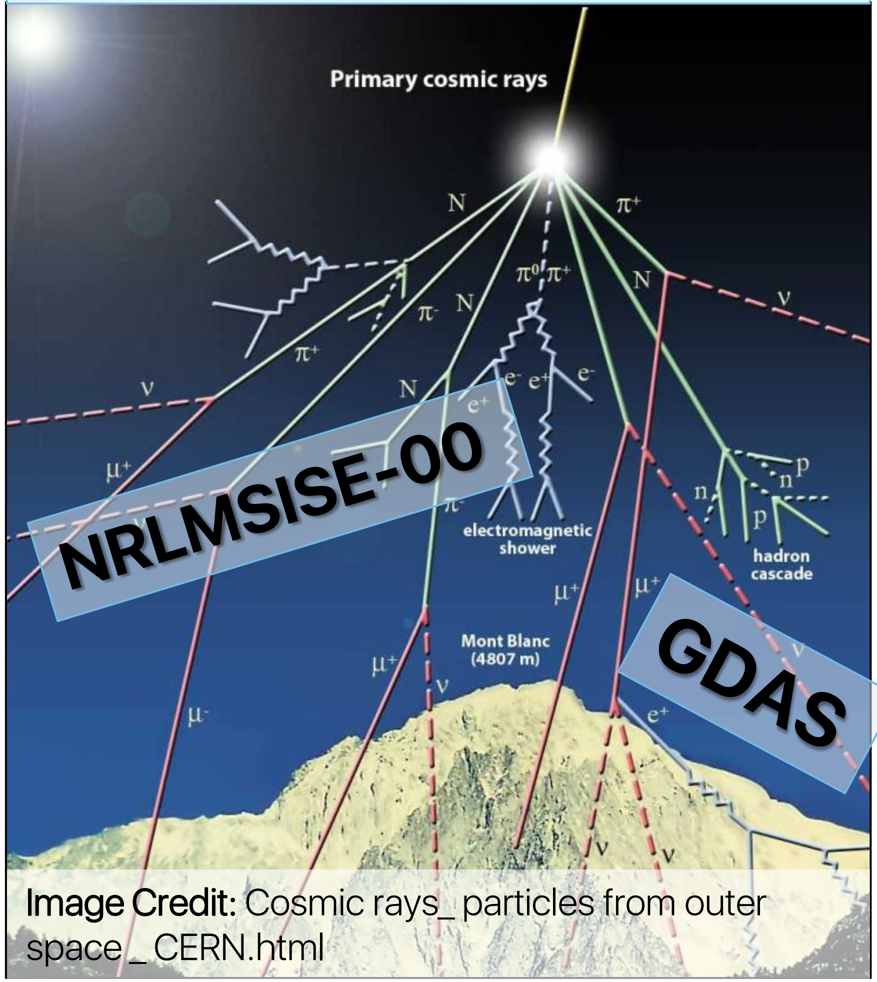


Image Credit: Cosmic rays_ particles from outer space _ CERN.html

- Generate atmospheric layer as spherical shell with different properties.
- Here we select 3 atmospheric locations: Hobart, Shanghai and Zhongshan

Secondary Particle libraries from Atmospheric Simulations

neutron

proton

muons

Detector Simulations

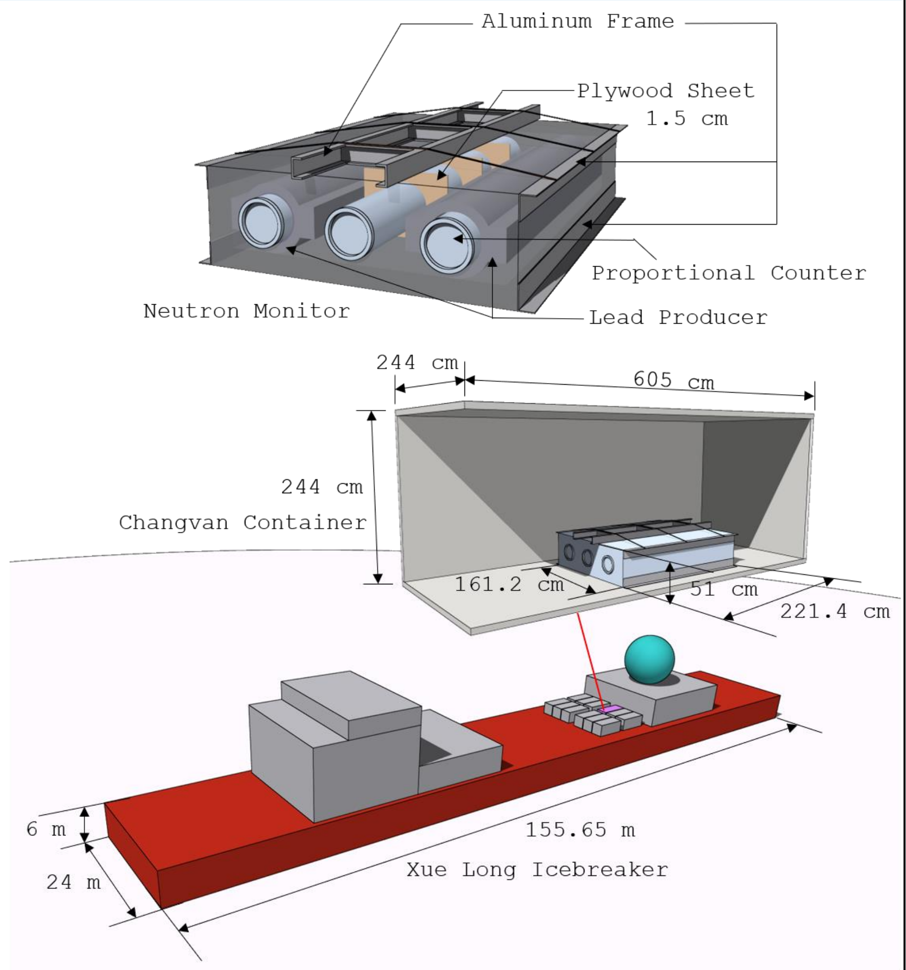
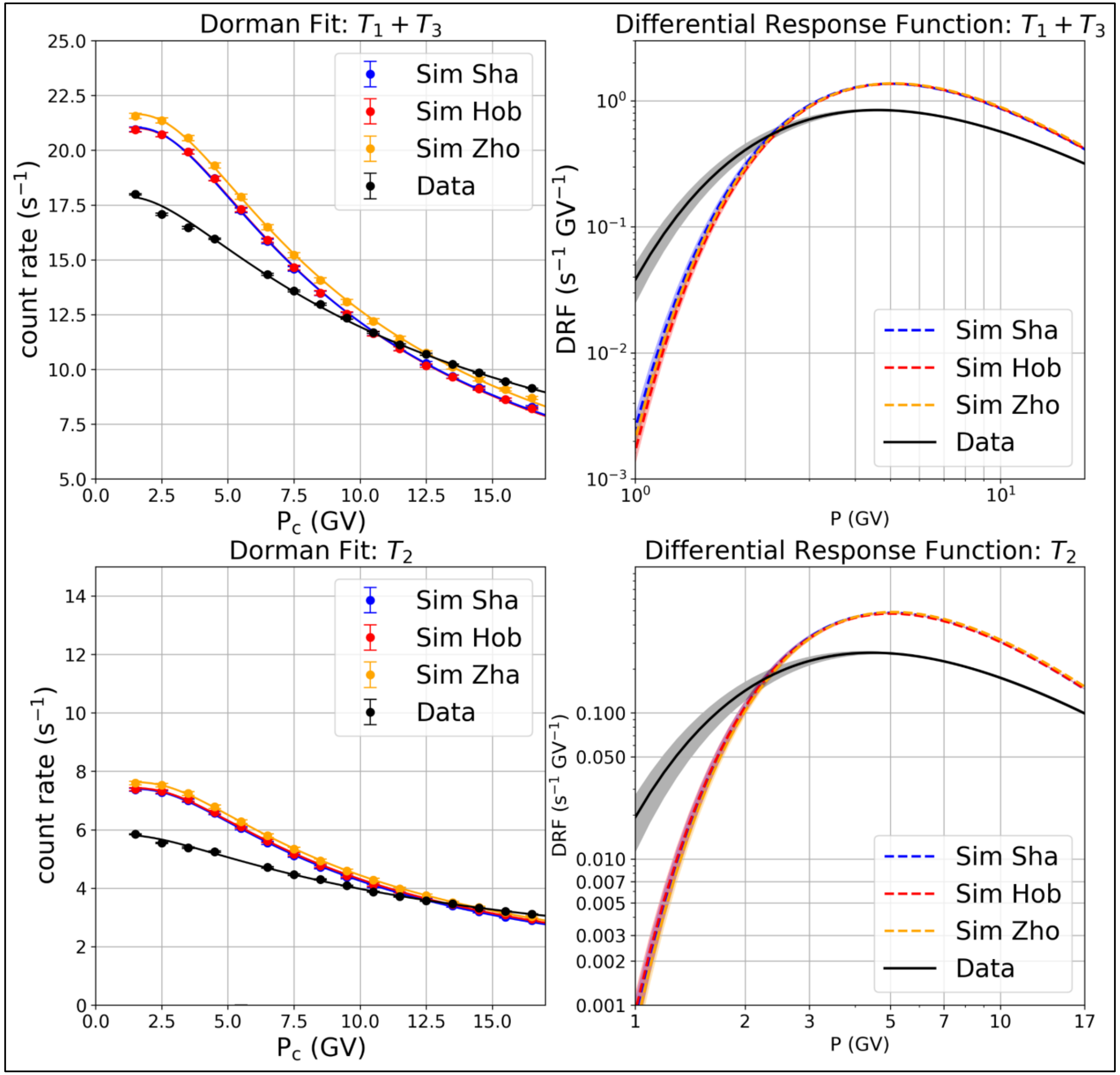


Table 1: FLUKA simulation statistics: M denotes one million particles.

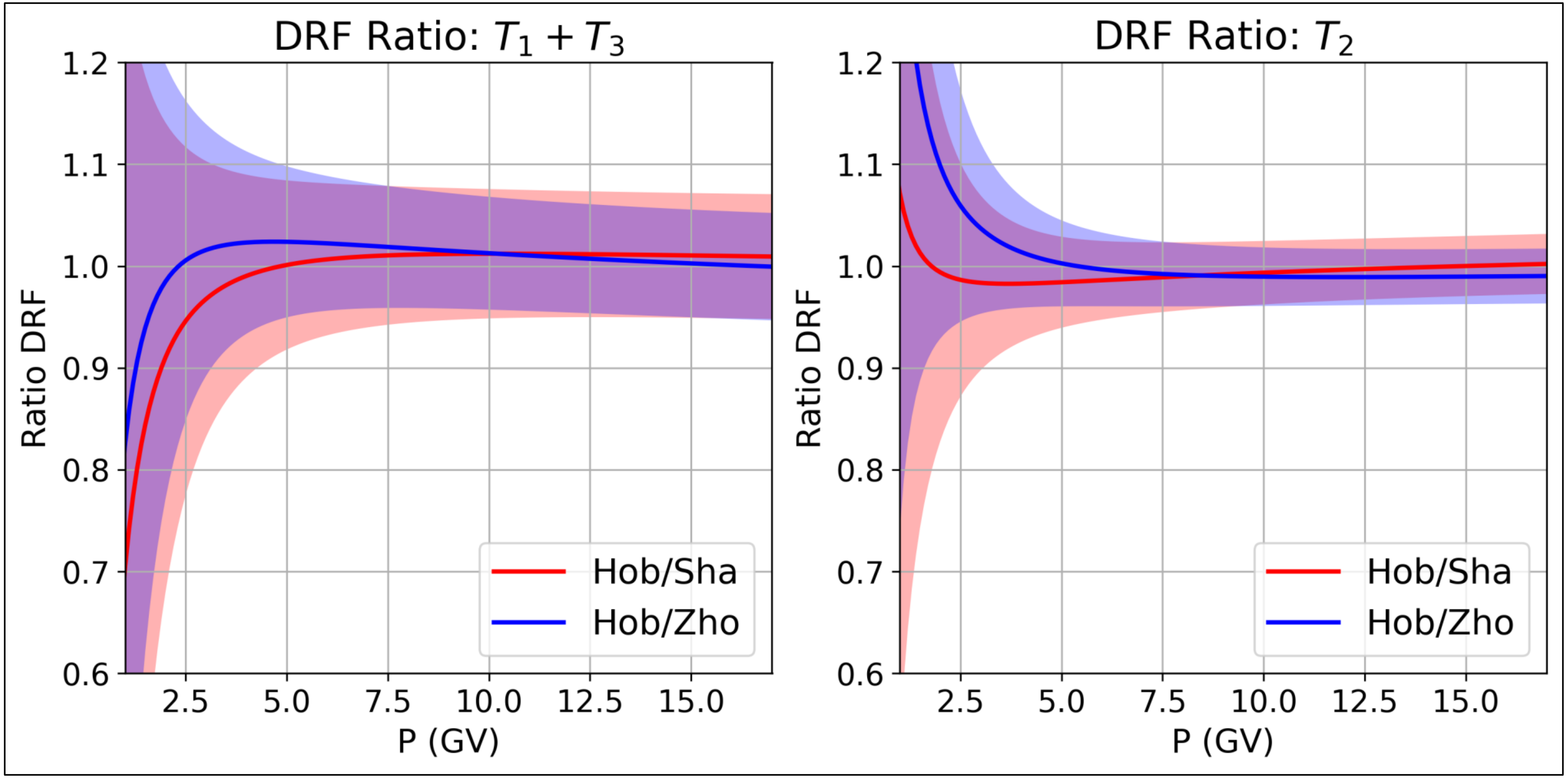
Type	No. of simulated particles								
	Rigidity 1-10 GV			Rigidity 10-200 GV			Rigidity 200-500 GV		
	Hob	Sha	Zho	Hob	Sha	Zho	Hob	Sha	Zho
Atmospheric simulations									
p	10M	10M	10M	1M	1M	1M	1M	1M	1M
α	10M	10M	10M	1M	1M	1M	1M	1M	1M
Library									
n	104441	93771	120957	136508	125494	155272	925016	853698	1029597
p	5163	4523	5955	13486	12147	15443	109524	99484	122149
$\mu^{\pm}$	16592	15304	18988	1149070	1126119	1200135	14247188	14023234	14697068
Detector simulations									
n	1000M	1000M	1000M	100M	100M	100M	100M	100M	100M
p	1000M	1000M	1000M	100M	100M	100M	100M	100M	100M
$\mu^{\pm}$	1000M	720M	743.5M	100M	100M	100M	88.5M	51M	51.5M

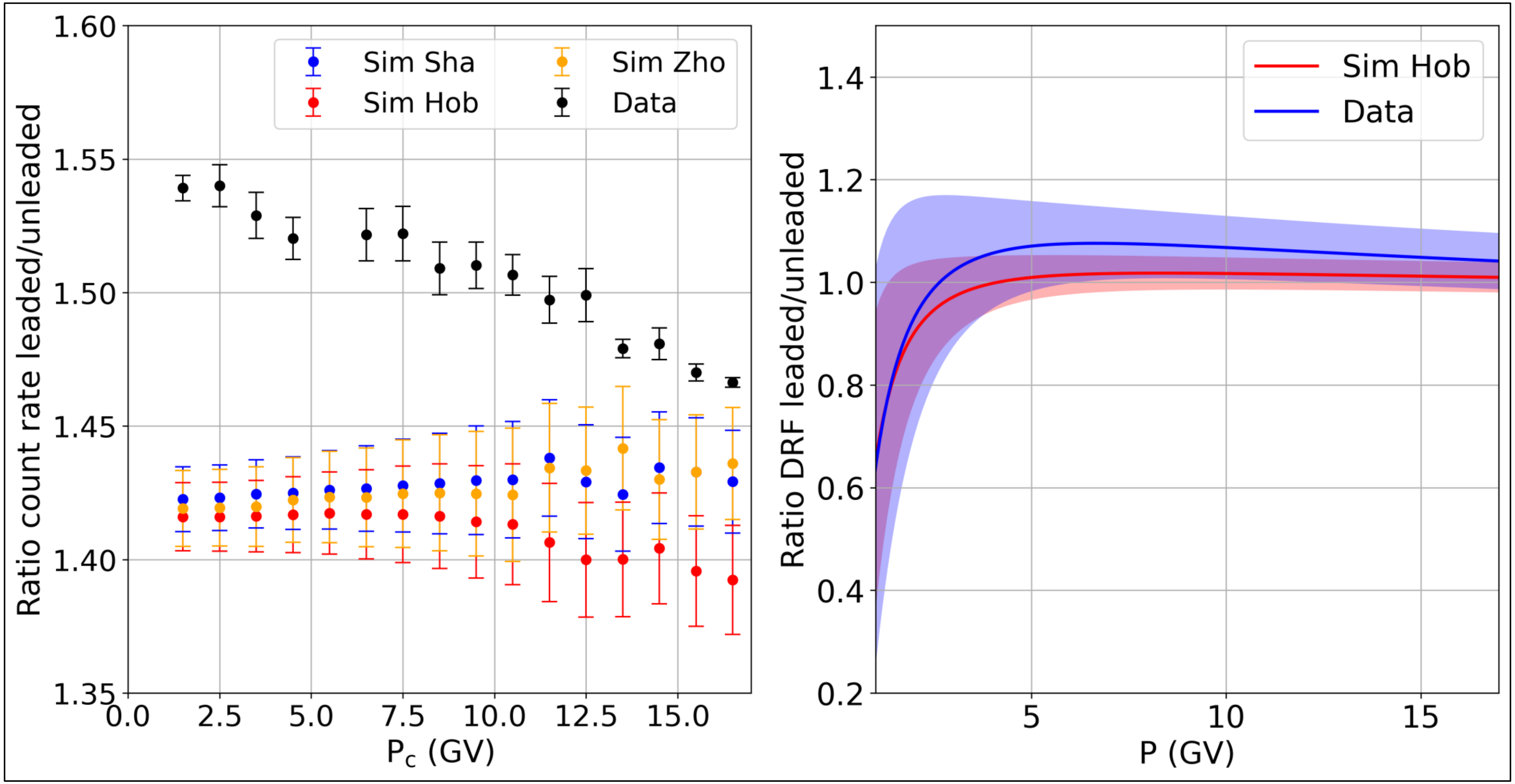
Integral Response Functions

Differential Response Functions



DRF Ratio, N_0 = 1





The ratios of the leaded to unleaded detectors, represented as $(T_1+T_3)/T_2$, were obtained as a function of cutoff rigidity (P_c).

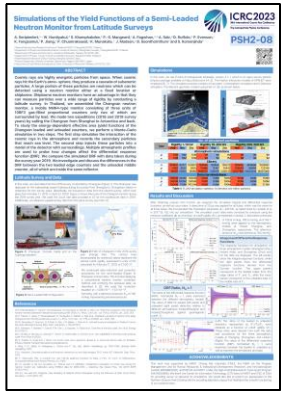
The ratios of the differential response function (DRF), normalized $N_0 = 1$.

FUTURE WORK

- Run simulation with new version of FLUKA
- Use more atmospheric profiles

More details of this work can be found in

PoS(ICRC2023)1334



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CHIANG MAI UNIVERSITY
NARIT
Changvan
A.A.A.R.T
SHINSHU UNIVERSITY
มหาวิทยาลัยมหิดล Mahidol University
UNIVERSITY OF WISCONSIN River Falls
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XUE LONG 2
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Thank you for your attention!