# Evaluating the Flux Misestimation in LST Due to Zenith Distance/ Azimuth Mismatch between Data and Analysis


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**Abstract**

CTAO (Cherenkov Telescope Array Observatory) is a new-generation gamma-ray observatory, and LST (Large-Sized Telescope) is one of its telescopes. The telescope response depends on its pointing direction. Therefore, accurate matching between the pointing direction of observed data and that of the Instrument Response Function (IRF) is essential. In practice, however, a perfect match is not achievable. In this study, we investigate the impact of such pointing mismatches through simulation-based analysis.


## Lorentz Invariance Violation (LIV) with Multi-Messenger

LIV: Some quantum gravitational theories predict that the speed of light in vacuum is not constant[1]. Numerous experiments seek to test LIV by searching for LIV-induced energy-dependent time delays in the arrival times of different messengers from **transient sources**, e.g. GRB, blazar.

Messenger combinations used to test LIV include:

◇ Gamma rays[2]

◇ Gamma rays and neutrinos[3]

◇ Gamma rays and gravitational waves[4]

The LST works as a gamma-ray observatory.

Since transient sources can be observed at any pointing direction, **understanding the LST response to pointing direction broadens the possibility for analyzing these sources.**

## Analytical Concerns in This Study

◇ LST observes Cherenkov light from gamma-ray.

◇ Real data and corresponding IRF are combined for further analysis.

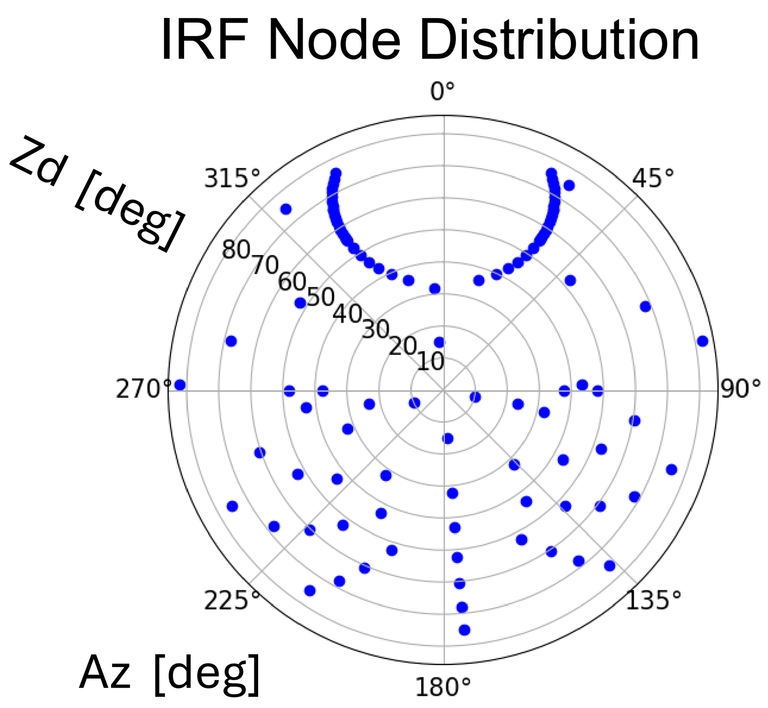
**Inevitable pointing mismatch between data and the IRF.**

**This can lead to systematic biases in the derived scientific results**

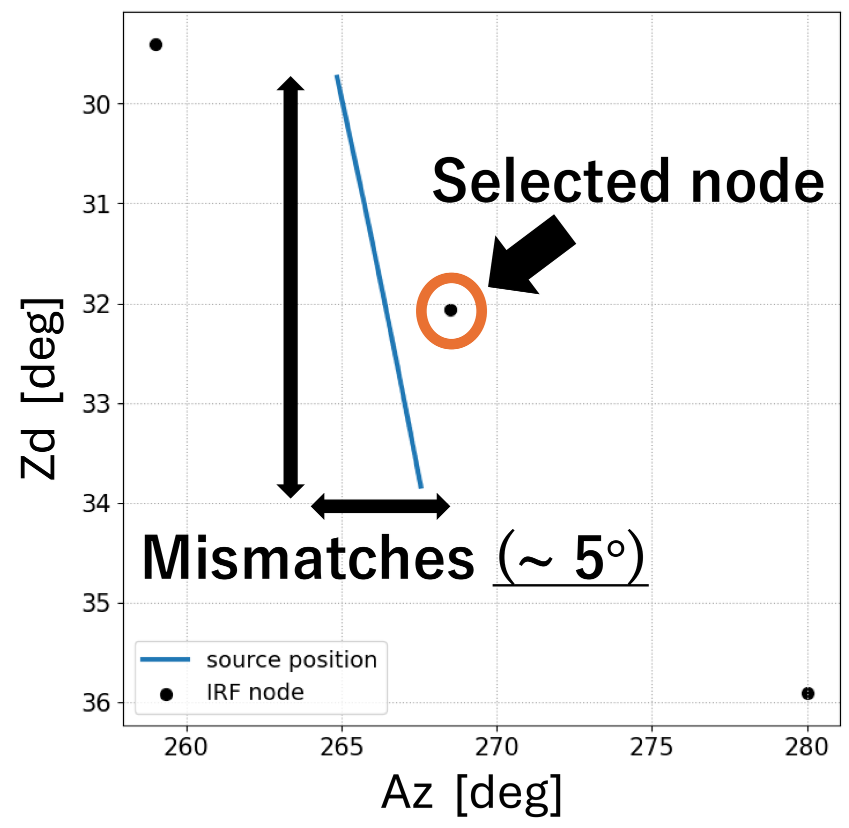
## IRF(Instrument Response Function)

◇ The IRF is generated at discrete grid points defined by zenith distance (zd) and azimuth (az), and these points are referred to as nodes.

◇ The components of (point-like) IRF are effective area, energy dispersion, GH cuts, RAD MAX.




## Pointing Mismatch between Data and an IRF Node




◇ A source moves by **about 5° in both az and zd** in an observation and **this is the cause of pointing mismatch**.

◇ In the standard LST data analysis, interpolation between nodes is performed to create a virtual node that is even closer to the data[5].

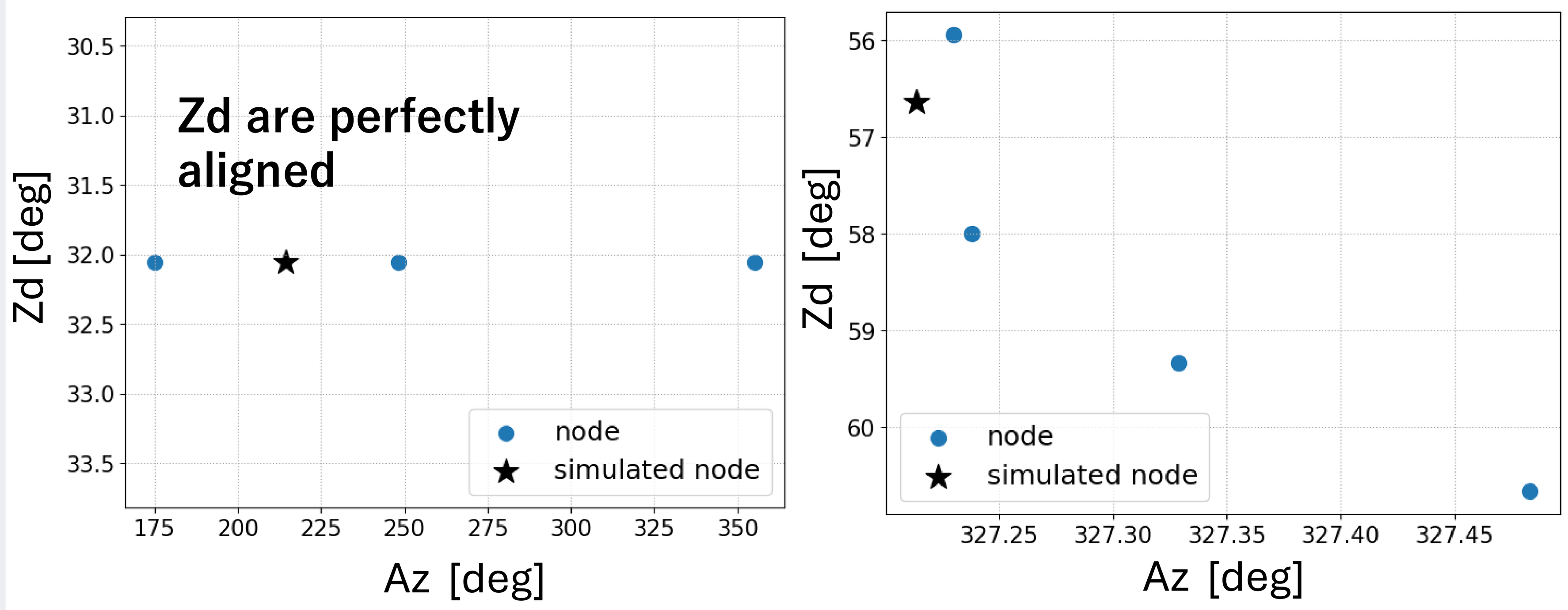
◇ In this analysis, we evaluated the effect solely due to the pointing mismatch, without considering interpolation.

## Methods and Details of Selected Nodes

1. Simulate* the gamma-ray counts of Crab nebula.
2. Calculate spectra using the simulated counts and different IRF nodes.
3. Check az/zd dependence of spectra at certain energies.

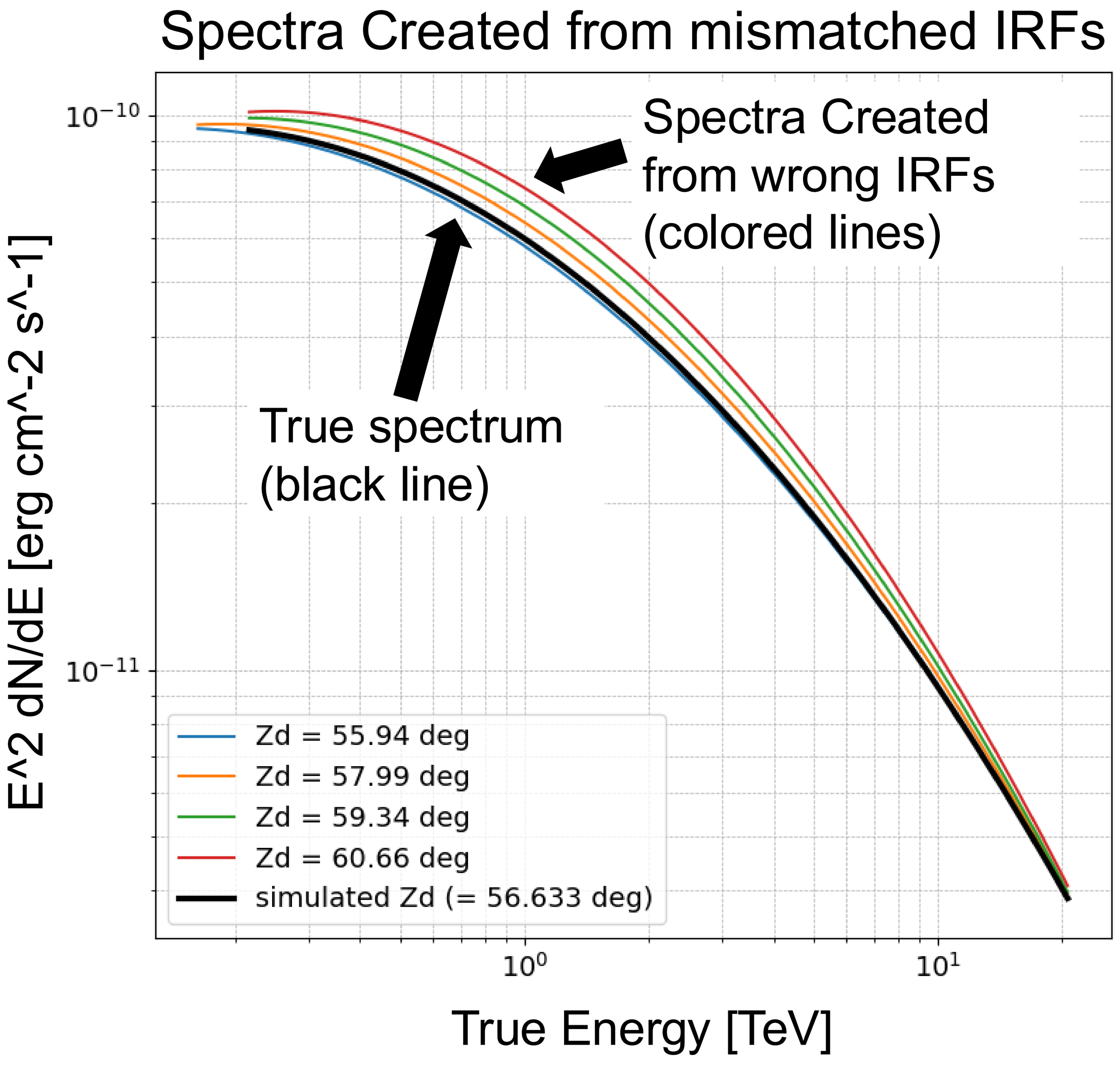
* Poisson fluctuations in the counts and the background events are neglected in the simulation.

Nodes Used to See Az (left) and Zd (right) Dependence

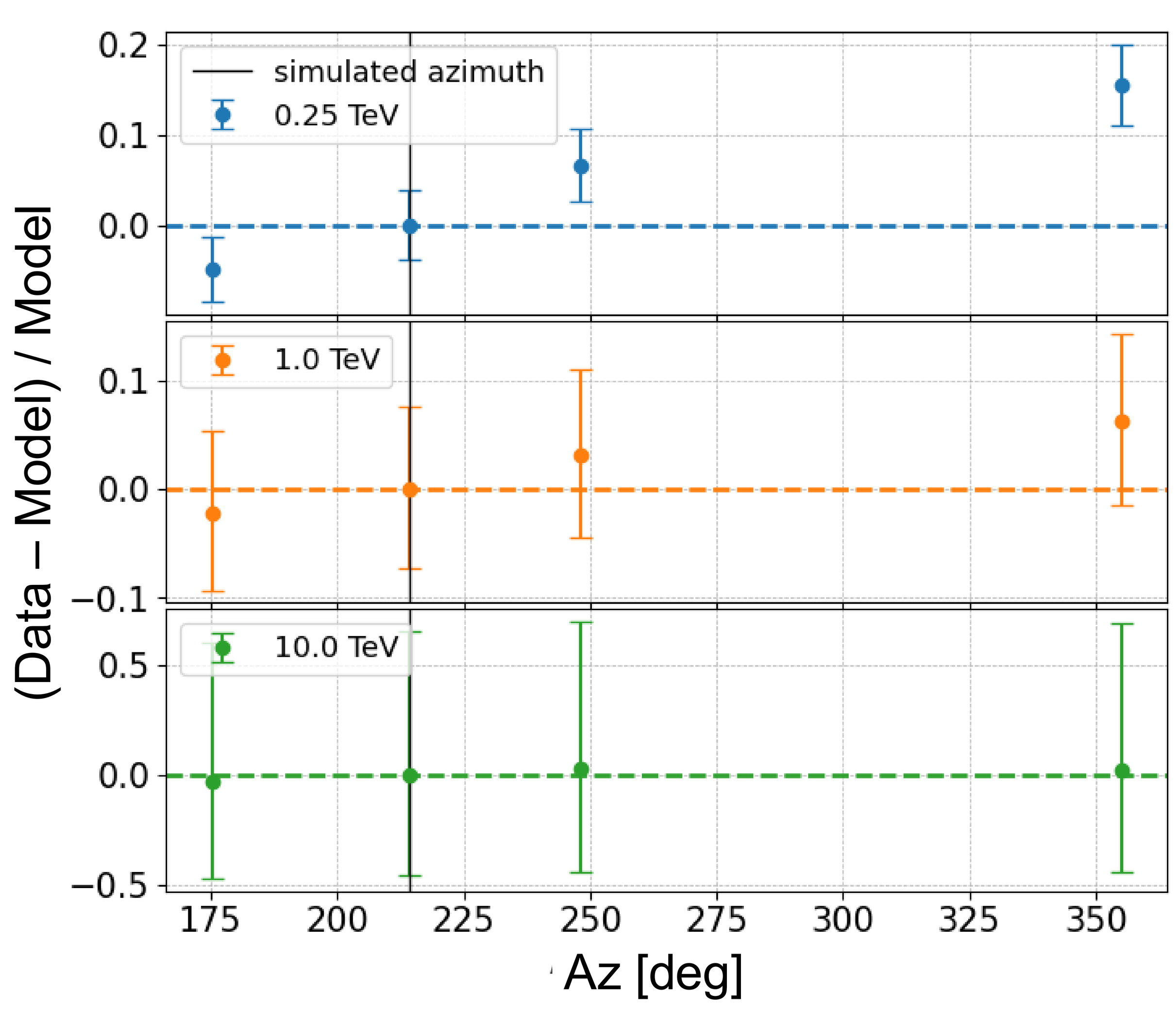



## Results

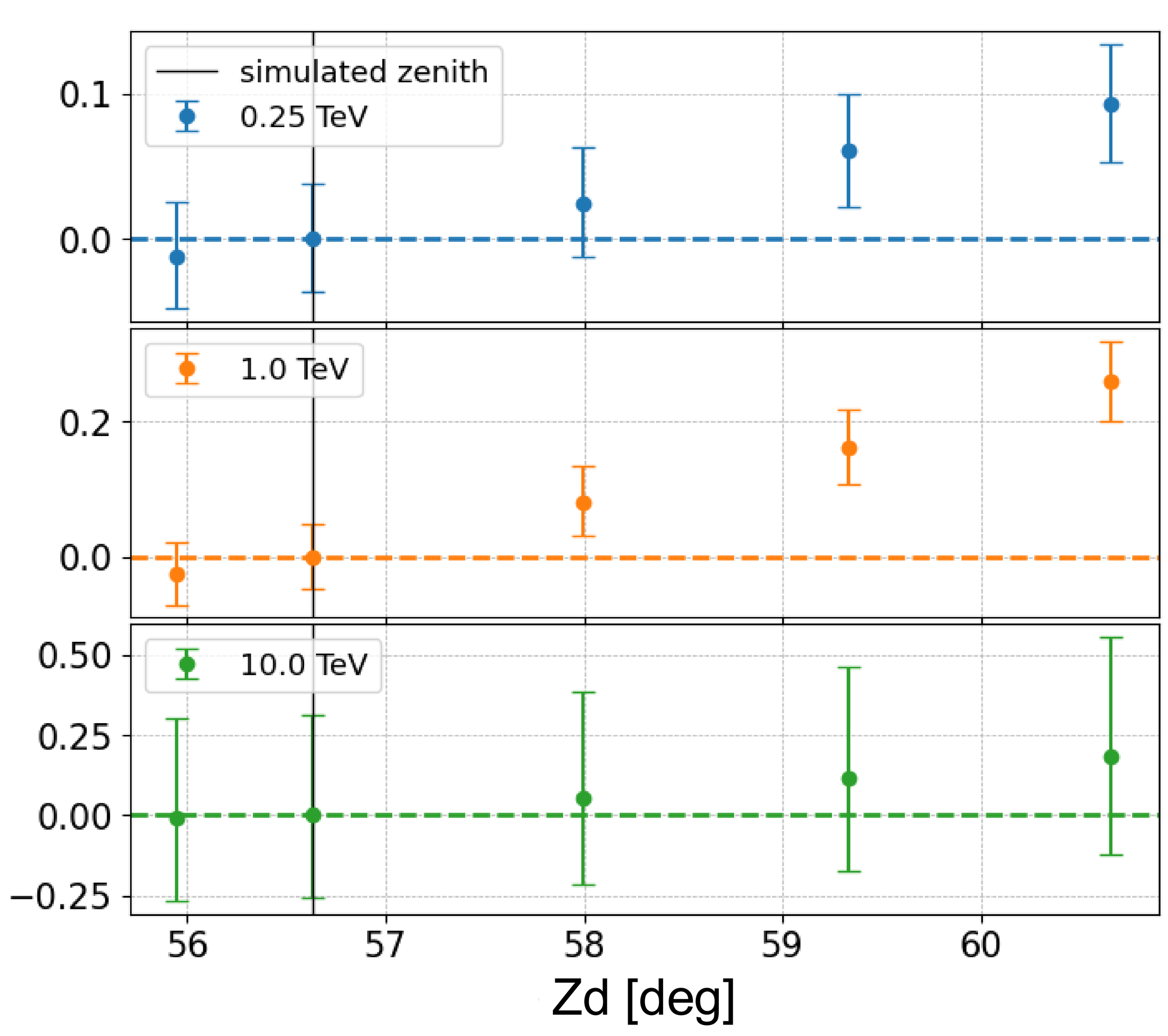
Spectra Created from mismatched IRFs




Az Mismatch Effect




Zd Mismatch Effect




◇ Less than 10% deviation in spectrum at 0.25 TeV due to the 30 degrees az discrepancy (**expected deviation by 5° az is 1.6%** with linear calculation).

◇ At **large zd, even a few degrees of zd mismatch can introduce ~10% deviation** in the spectrum.

## Conclusion

◇ Zd mismatches can significantly affect the analysis, particularly at large zd (zd ≳ 55°) and low energies (E ≲ 1 TeV).

◇ These results are expected to improve the precision of transient-source analysis conducted at high zd, potentially leading to tighter constraints on LIV.


Reference

[1] Mavromatos, N. E. (2007). Lorentz invariance violation from string theory. *arXiv preprint arXiv:0708.2250.*[2] Plard, C., & Caroff, S. (2025). Lorentz invariance violation search with the Cherenkov Telescope Array Observatory Large-Sized Telescope. [3] Abbott, B. P., Abbott, R., Abbott, T. D., Acernese, F., Ackley, K., Adams, C., ... & Callister, T. A. (2017). Gravitational waves and gamma-rays from a binary neutron star merger: GW170817 and GRB 170817A. *The Astrophysical Journal Letters*, *848*(2), L13. [4] Ellis, J., Mavromatos, N. E., Sakharov, A. S., & Sarkisyan-Grinbaum, E. K. (2019). Limits on neutrino Lorentz violation from multimessenger observations of TXS 0506+ 056. *Physics Letters B*, *789*, 352-355. [5]Priyadarshi, C. S. (2024). Observation of Active Galactic Nuclei in the gamma-ray band using the first telescope of the CTA North. [6] Abe, H., Abe, K., Abe, S., Aguasca-Cabot, A., Agudo, I., Crespo, N. A., ... & Majumdar, P. (2023). Observations of the Crab Nebula and Pulsar with the Large-sized Telescope Prototype of the Cherenkov Telescope Array. *The Astrophysical Journal*, *956*(2), 80.



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