Simulation Study of noise effects on cosmic ray air shower events in LHAASO-KM2A

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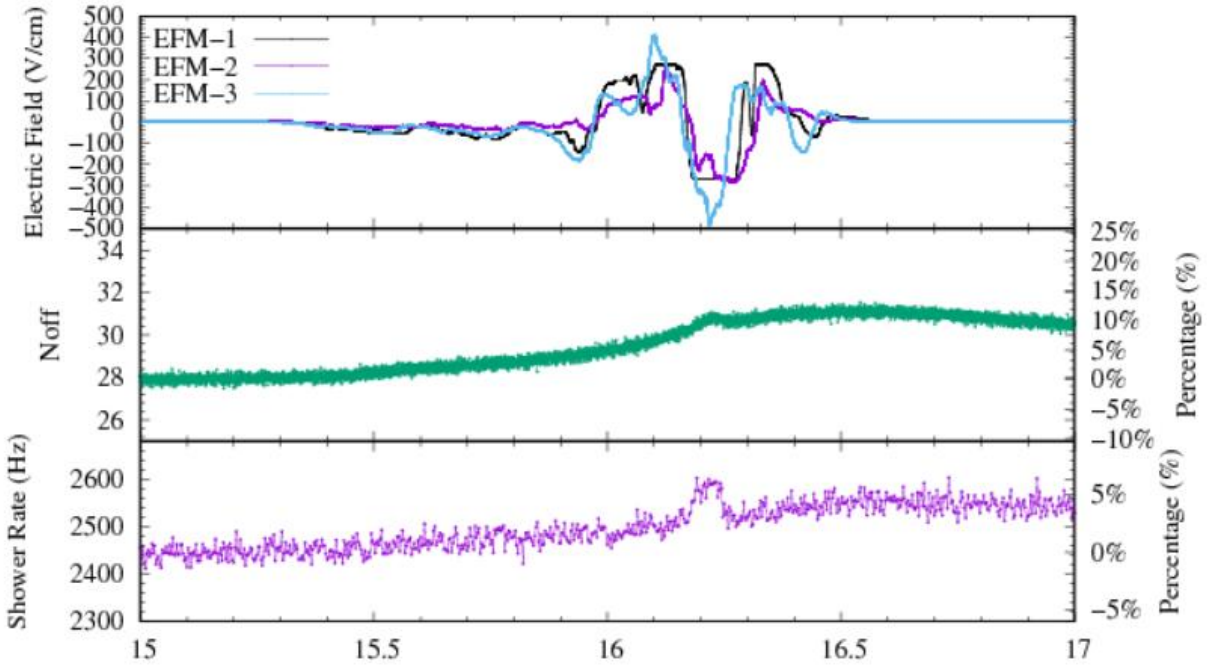
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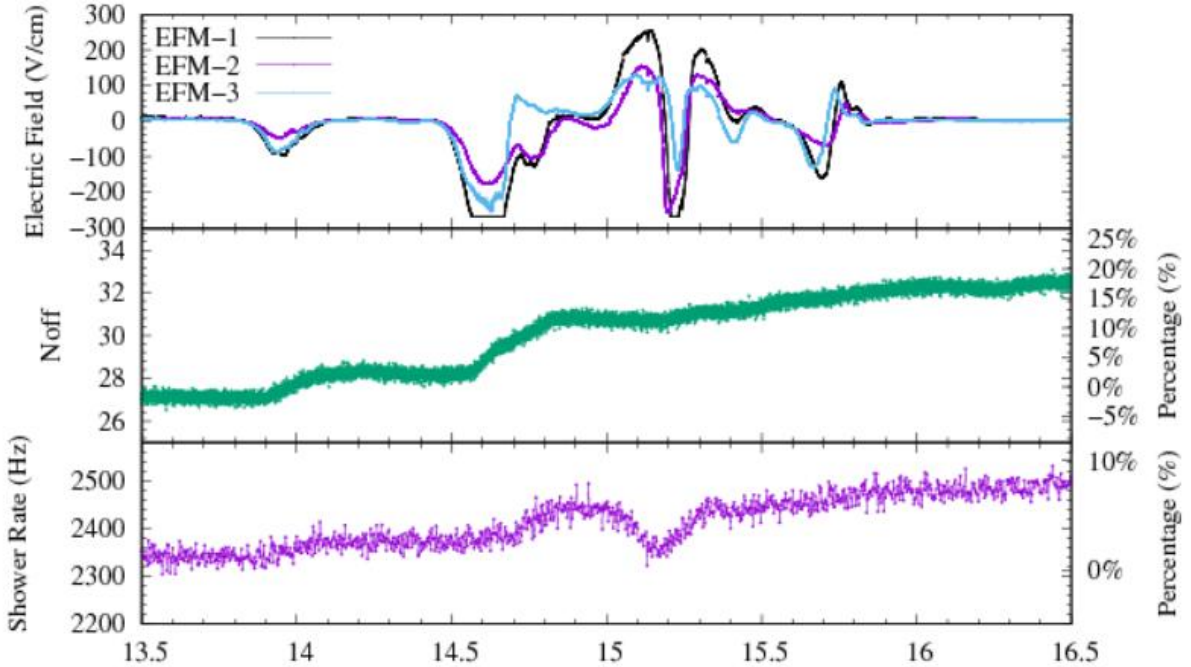
Outline

1. Simulation Parameters
2. Noise effects on cosmic ray shower rate in LHAASO-KM2A
3. Re-triggering for noise subtraction
4. Summary

Relationship between Noise-level and Shower Rate detected by KM2A

- In the shower mode of the KM2A array, a shower event is recorded when the trigger condition is satisfied, i.e., at least 20 EDs or MDs are fired within a 400 ns time window.
- During thunderstorms, the noise trigger recorded by the detector will increase, which consequently elevates the shower rate in LHAASO-KM2A.





Simulation Parameters

➢CORSIKA-77410

Parameters:

- ✓ The primary particle: protons

  The primary energy range: 1-10^5 TeV

  The primary zenith angle range: 0-60°
- ✓ Energy spectrum index : -2.7
- ✓ The energy cutoff: 0.05 MeV
- ✓ The detector level: 4410m
- ✓ The magnetic field: B_x =34.8μT, B_y =34.8μT

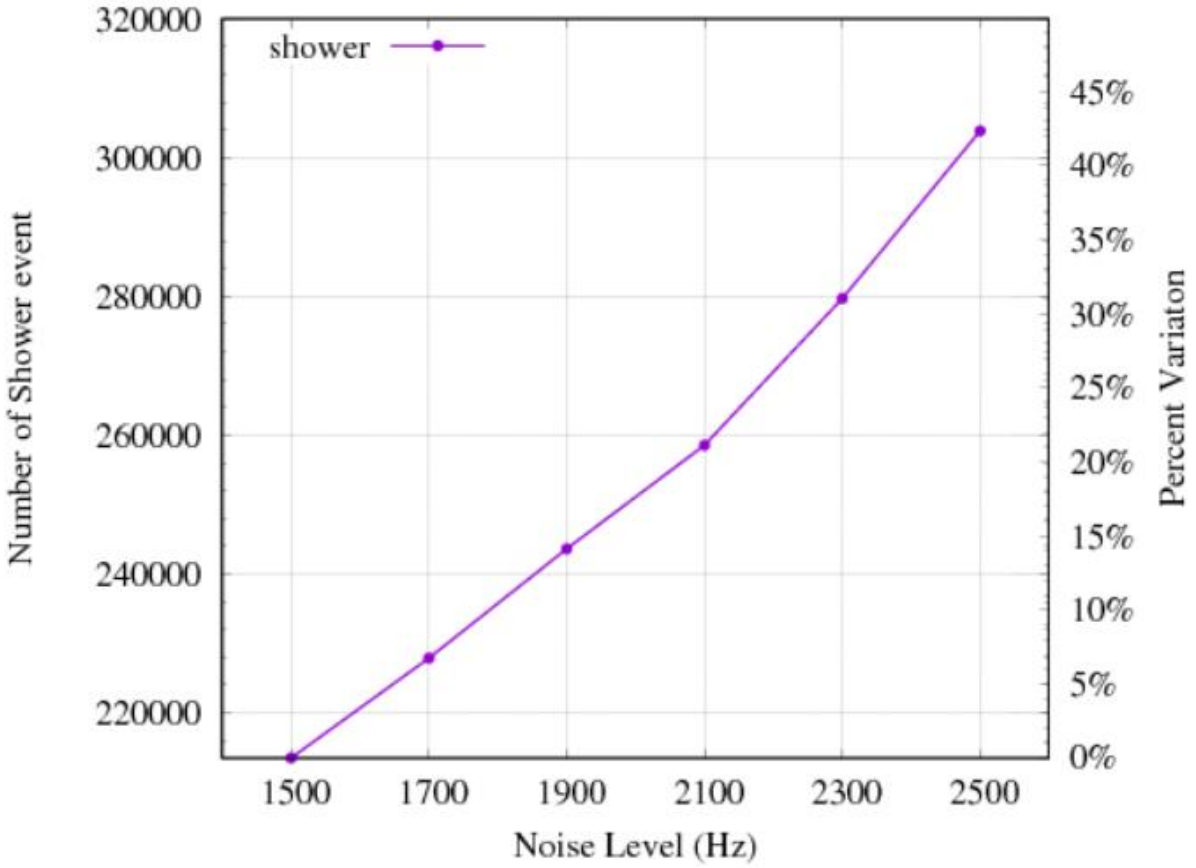
➢G4KM2A

Parameters:

- ✓ Full KM2A array
- ✓ Noise Level: 1500Hz, 1700Hz, 1900Hz, 2100Hz, 2300Hz, 2500Hz
- ✓ Trigger condition:

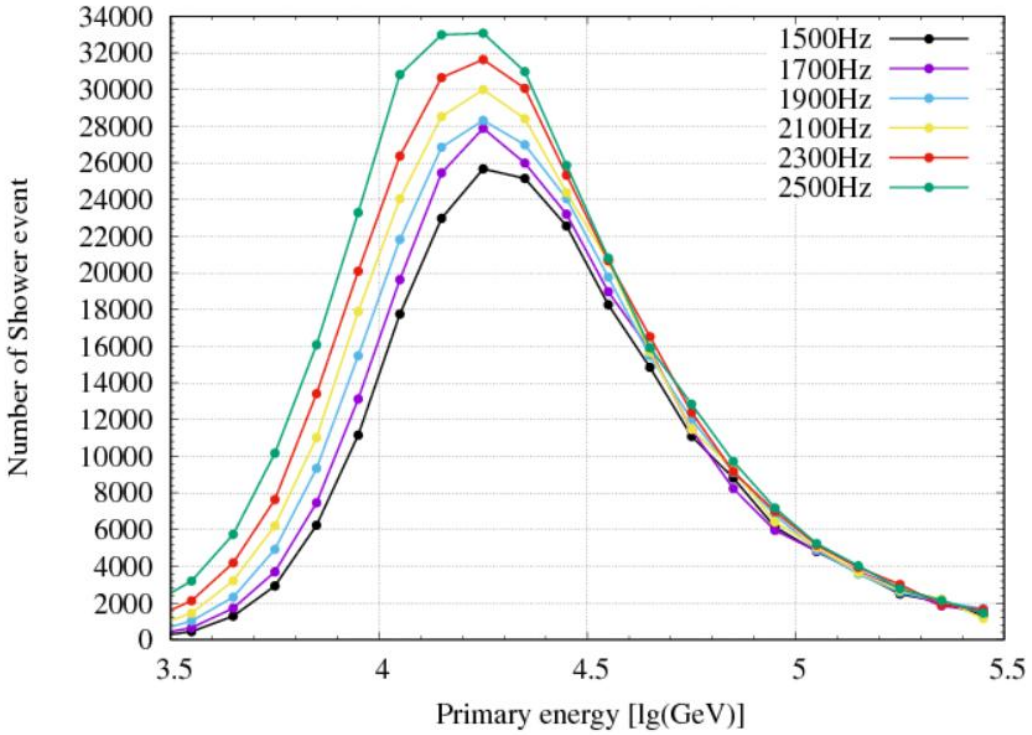
  >=20 EDs fired within 400 ns

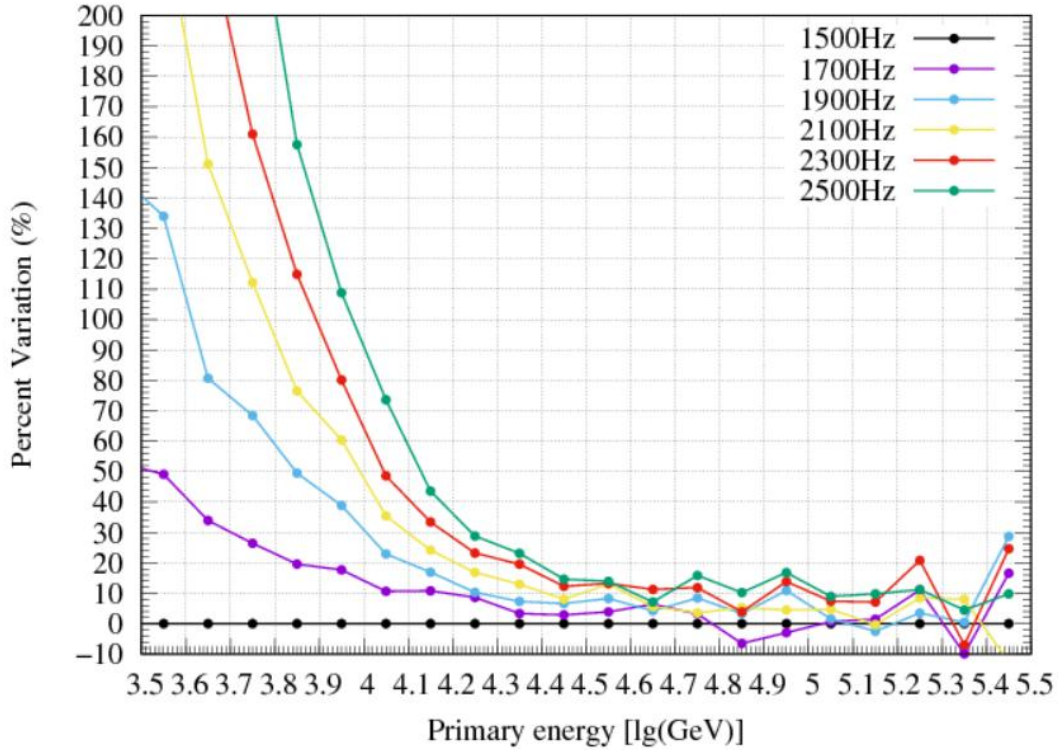
Shower Rate as a function of Noise-level



- For noise levels of 1500Hz–2100 Hz, the number of shower event increases by approximately 3.5% per 100 Hz on average.
- For noise levels of 2100Hz–2500 Hz, the number of shower event increases by approximately 5% per 100 Hz on average.

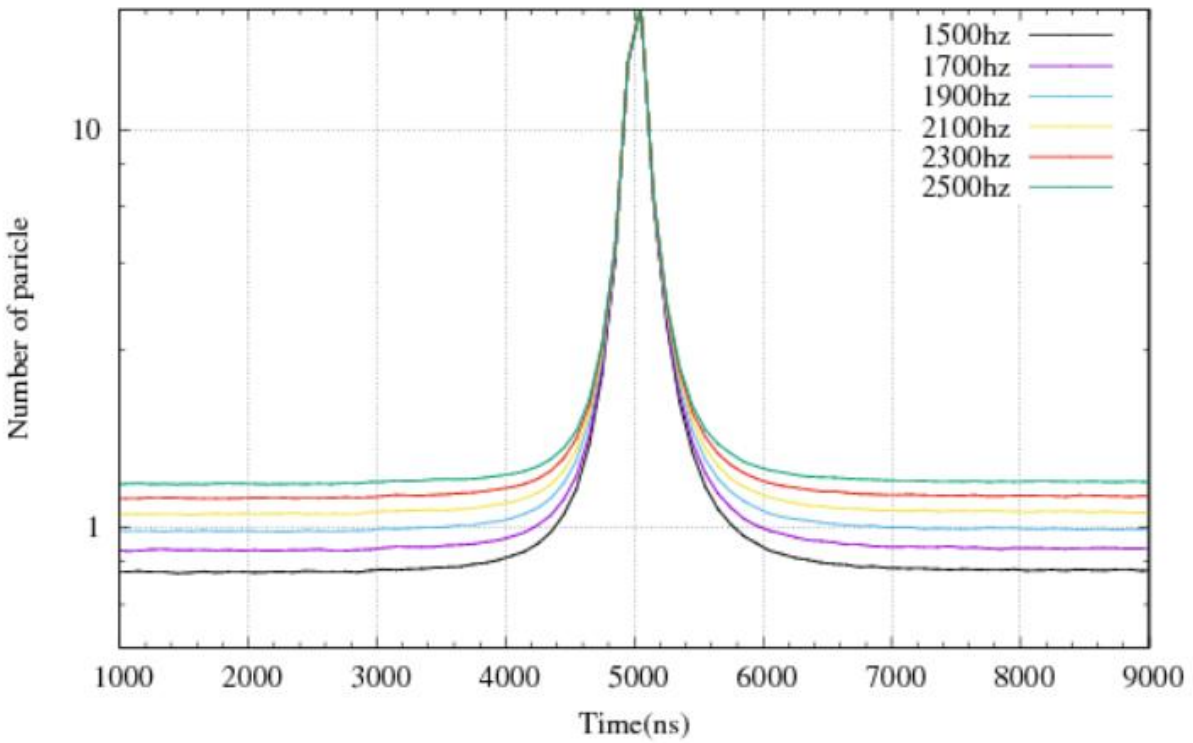
Shower Rate as a function of primary energy with different noise levels

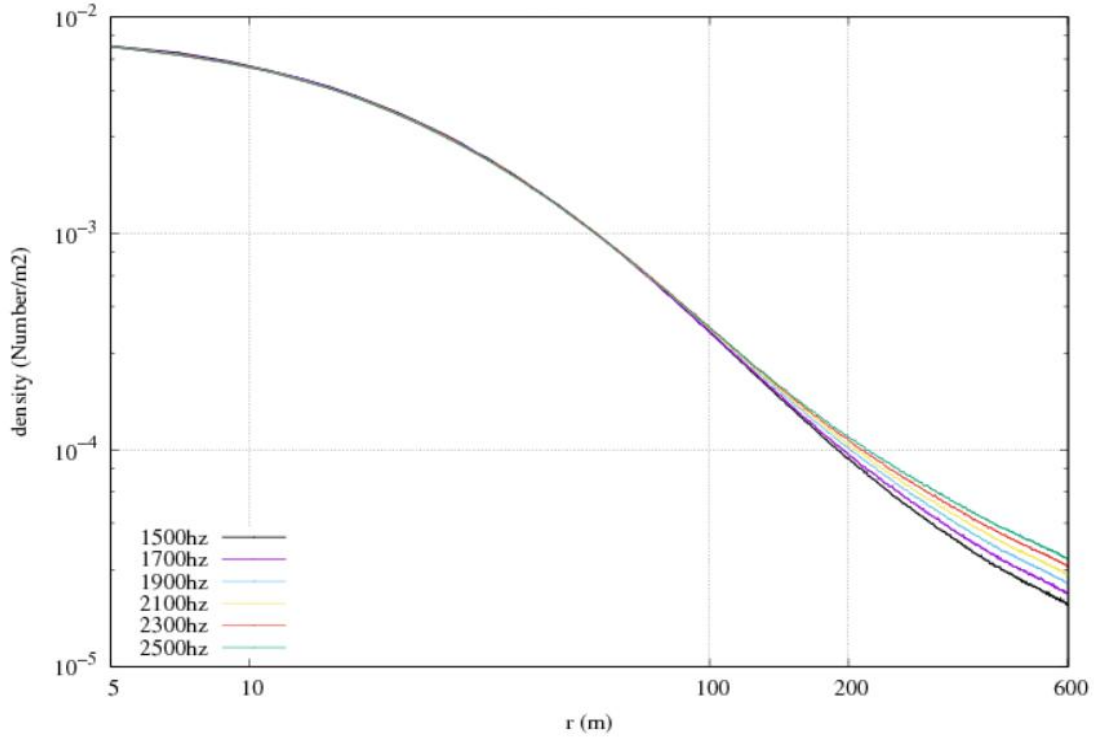




- The larger the noise level, the more pronounced the enhancement of shower number at lower primary energies.

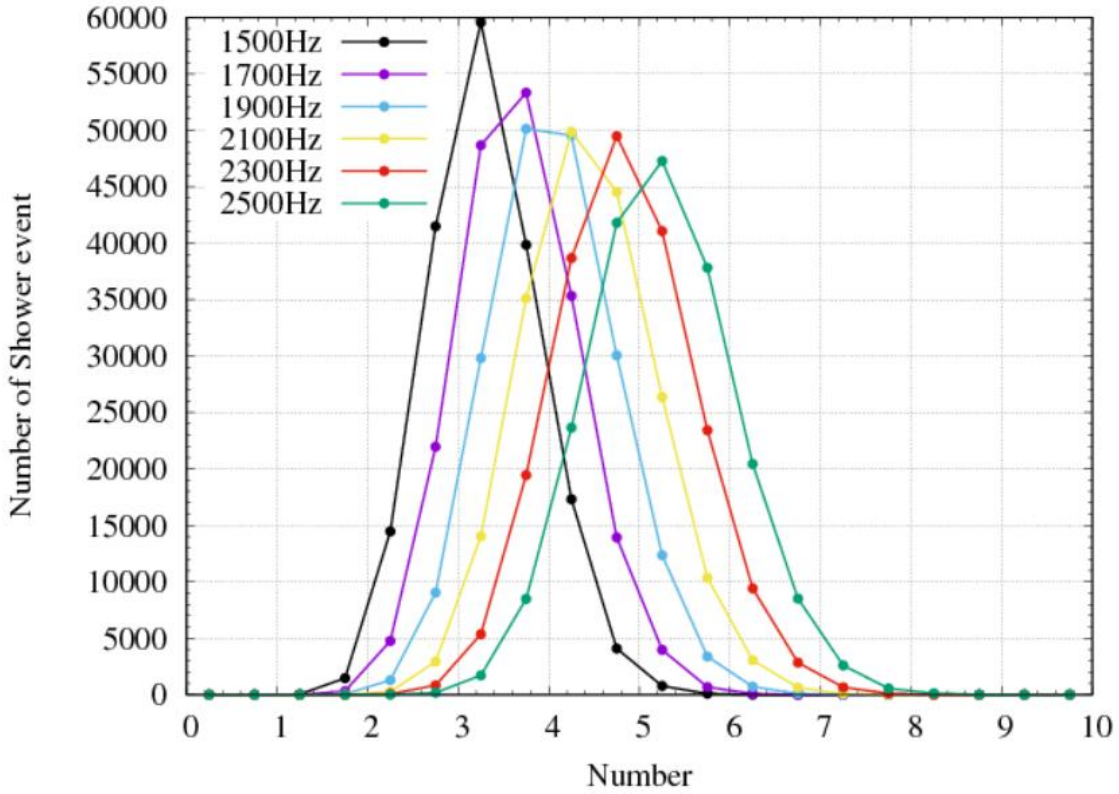
Spatiotemporal Distribution varies with Noise-level

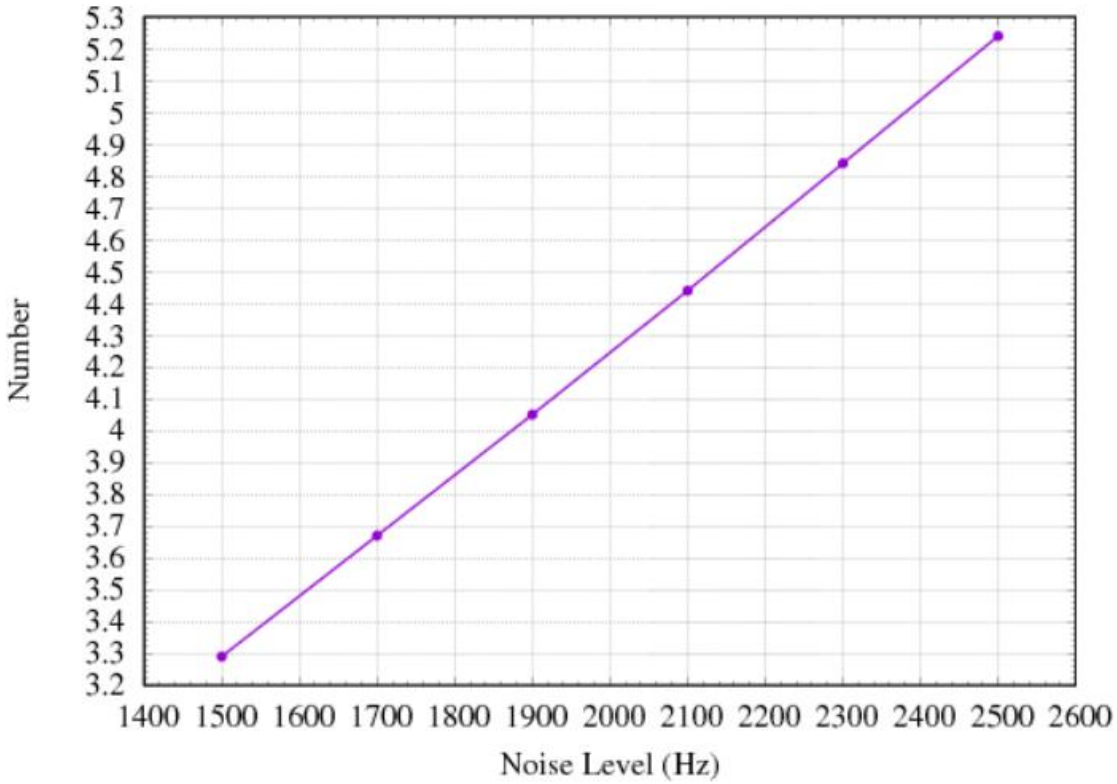




- When the noise level increases, the spatiotemporal distribution of secondary particles becomes broader.

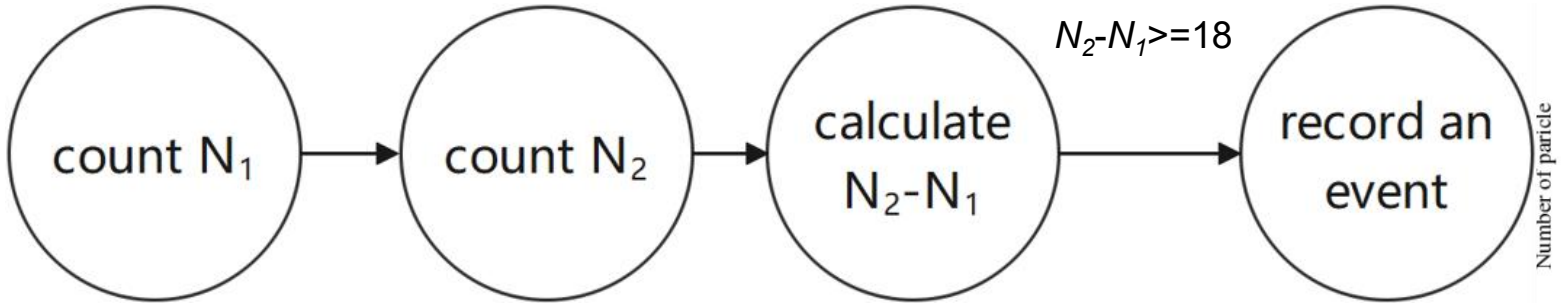
Number of EDs fired within 400 ns at different noise levels

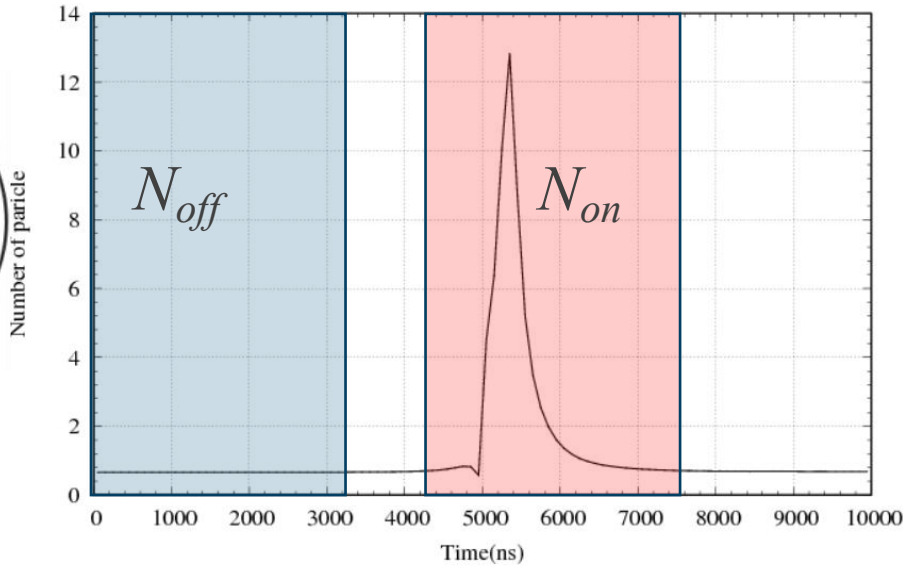




- As the noise level increases, the number of EDs fired by noise within the 400 ns time window increase.
- Increasing noise triggers make shower events more likely to satisfy the trigger condition, resulting in a higher recorded shower rate.

Re-triggering for noise subtraction



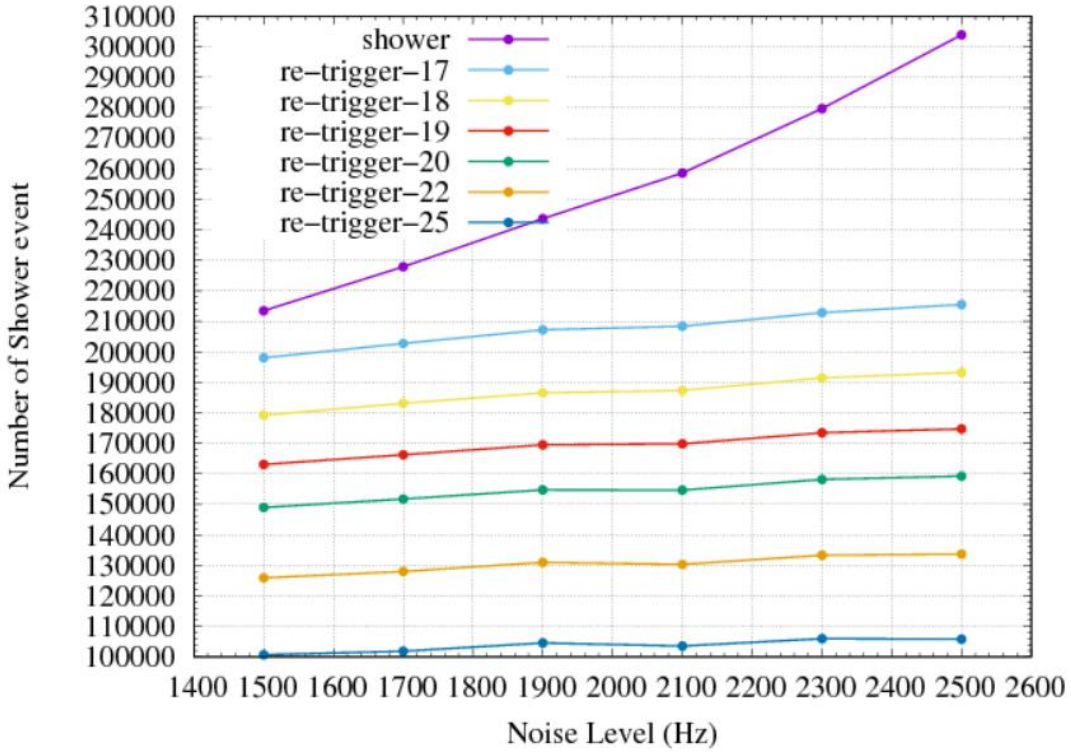


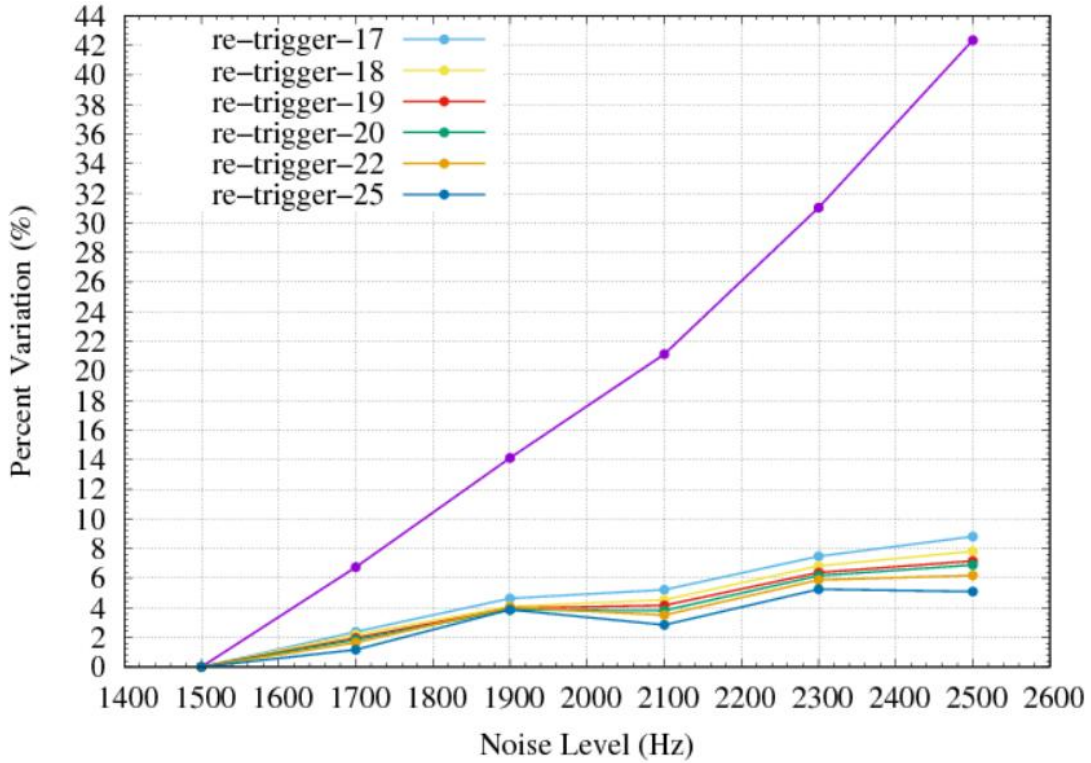
N_1:The average number of EDs fired per 400 ns time window within the range of 0–3200 ns

N_2:The maximum number of EDs fired within a 400 ns time window in the range of 5000–10000 ns

- N_{off}: 0 ~ 3200 ns
- N_{on}: 4500 ns ~ 7700 ns
- $N_s = N_{on} - N_{off}$

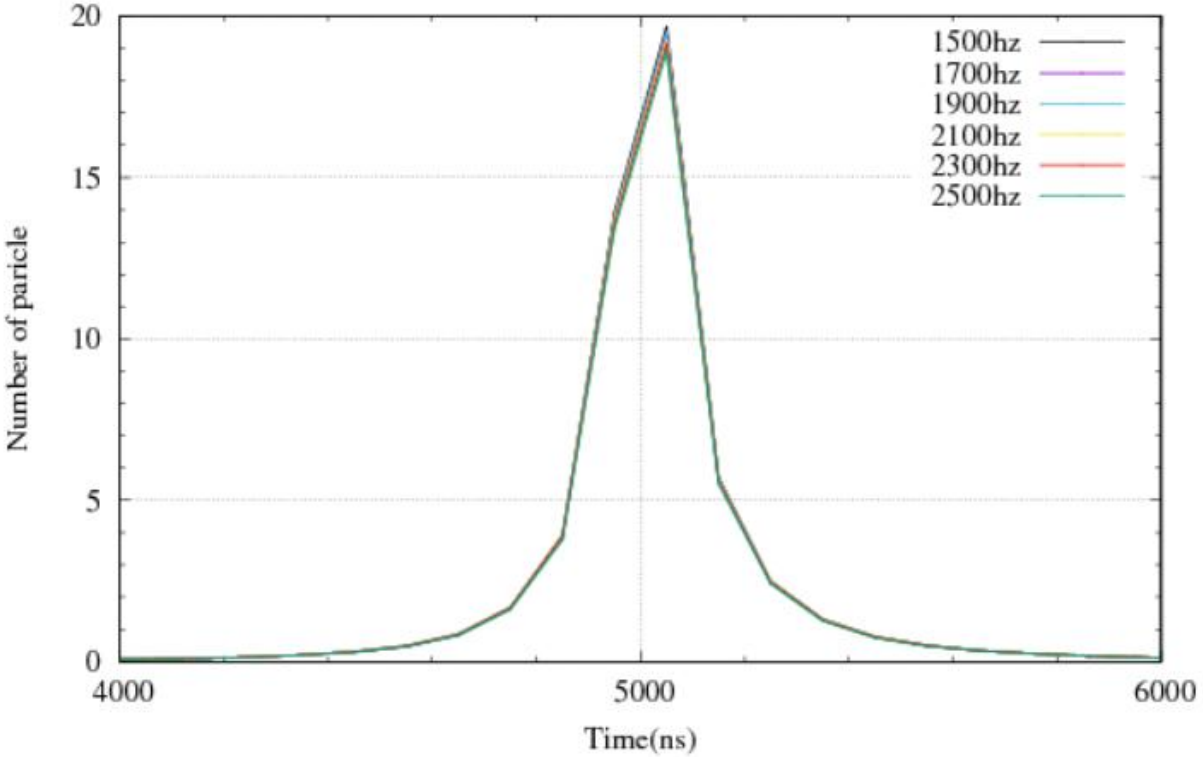
Shower Rates at different Noise Levels after Re-triggering

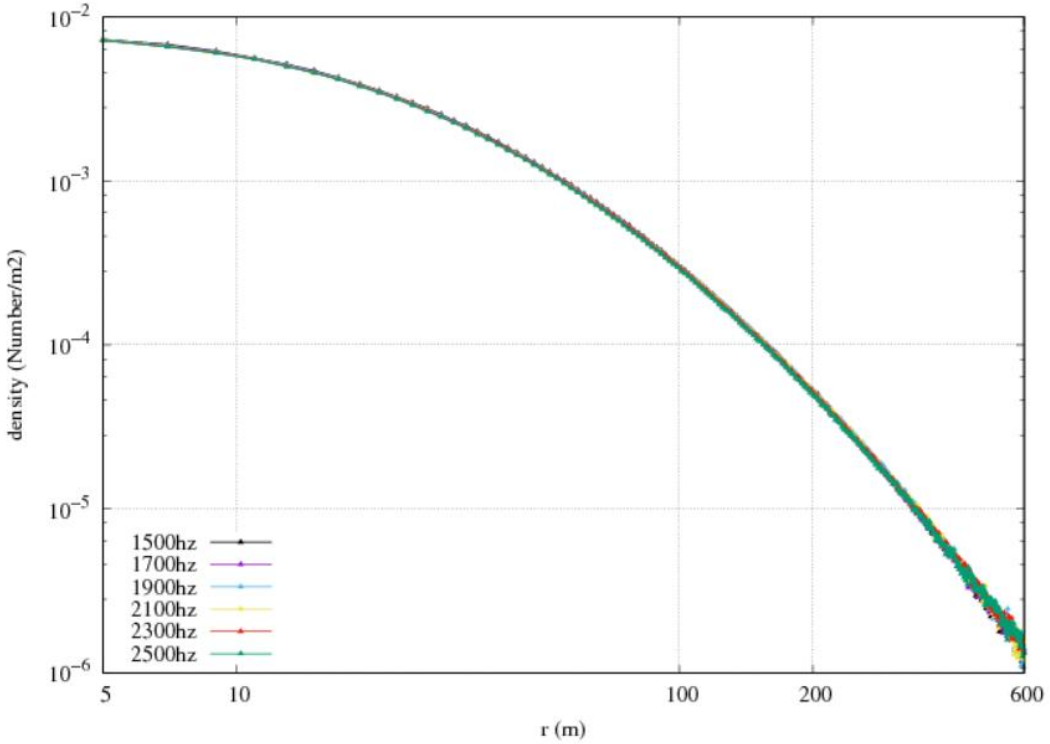




- After re-triggering filtering, the increase in shower events caused by noise is substantially reduced.
- The re-triggering method can reduce the impact of noise on cosmic ray shower events in LHAASO-KM2A.

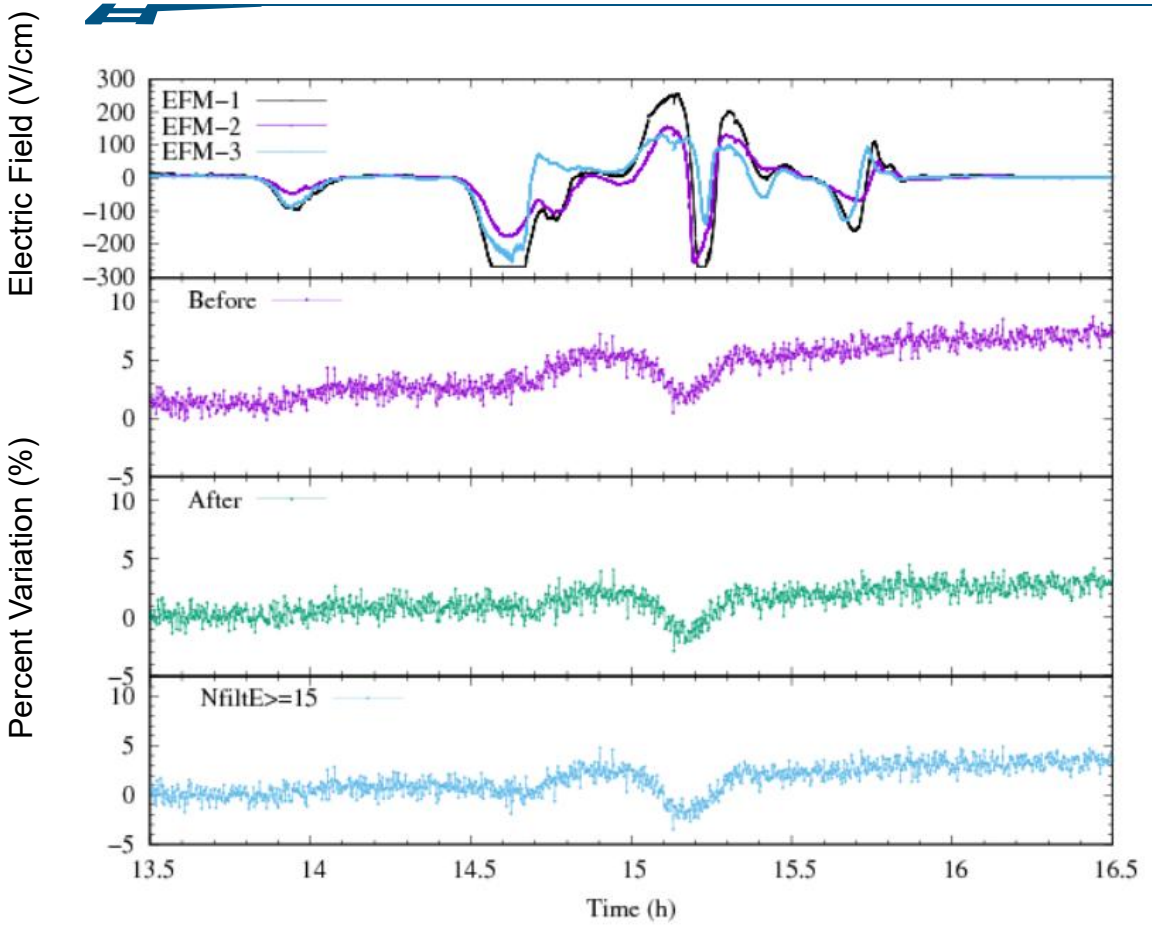
Spatiotemporal Distribution after Noise subtraction

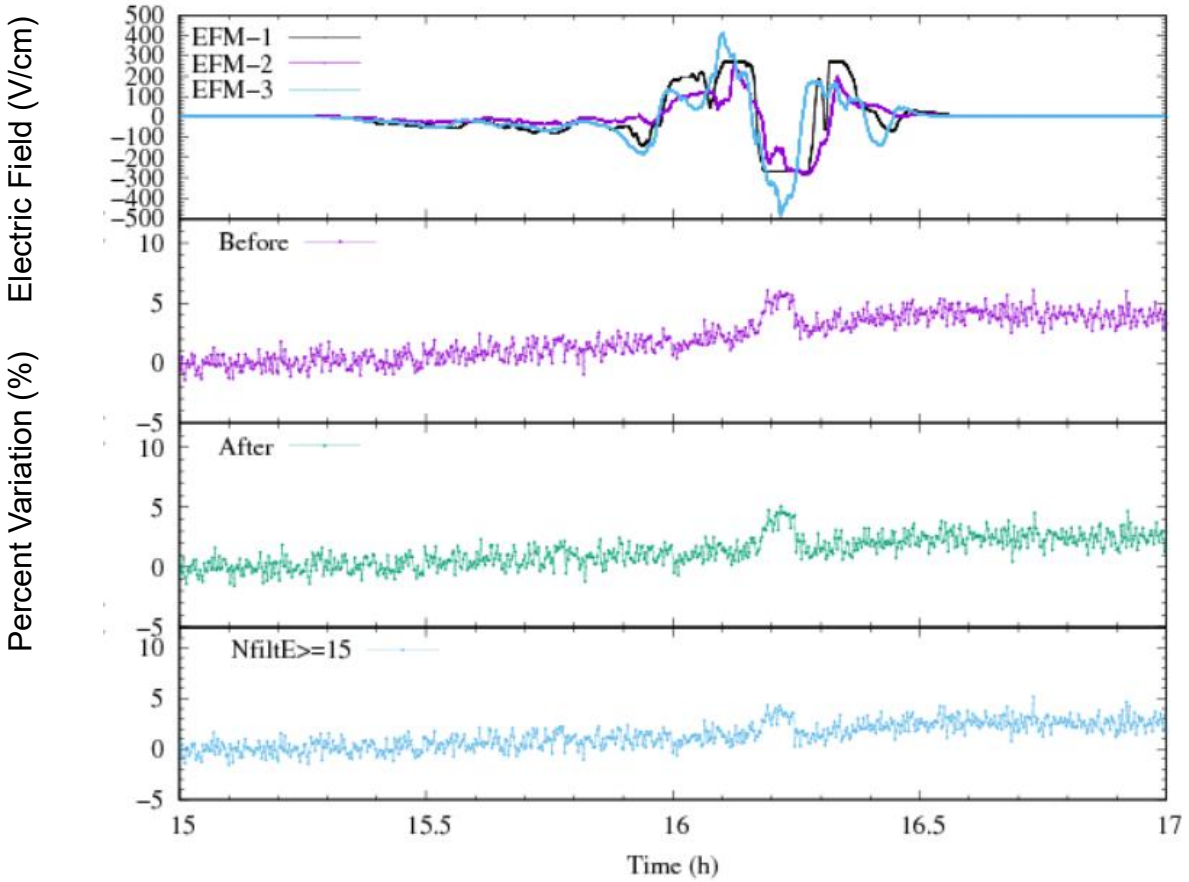




- After considering the effect of N_{off}(0-3200 ns), the spatiotemporal distribution of secondary particles hardly changes with different noise levels.

Comparison of Shower Rate before and after re-triggering detected by KM2A





- After re-triggering, the impact of higher noise levels on shower events is significantly reduced.
- These results are consistent with the NfiltE data.

Summary

- The shower rate of LHAASO-KM2A increases with noise level, with stronger enhancement at higher noise.

- Higher noise levels broaden the spatiotemporal distribution of shower events, while accounting for the effect of N_{off} can reduce the impact of noise.

- Re-triggering can effectively reduce the impact of increased noise on cosmic ray shower events in LHAASO-KM2A.