LHAASO
高海拔宇宙线观测站

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Measurement of muon contents in cosmic ray shower with LHAASO-KM2A

Hengying Zhang, Cunfeng Feng, Xiaoting Feng, Lingling Ma, Huihai He

Songzhan Chen, Cong Li (on behalf of the LHAASO collaboration)

Institute of Frontier and Interdisciplinary Science, Shandong University

Institute of High Energy Physics, Chinese Academy of Sciences

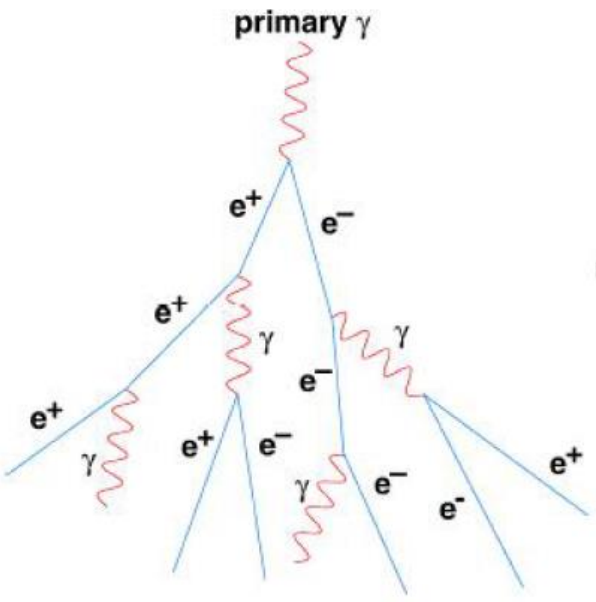
Outline

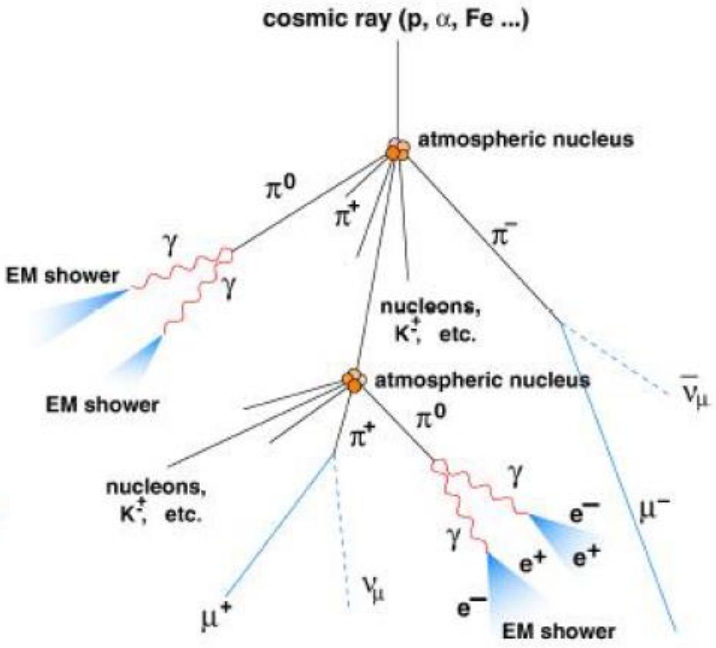
- Motivation
- Experimental set-up and MC simulation
- The comparison of experimental and simulation data
- Conclusion

Motivation

The muon in extensive air showers (EAS) play an important role for understanding air shower physics.

- Muon carry information about their parent particle, pions and kaons, production in hadronic interaction. Studying muons becomes therefore a sensitive and direct way to probe the hadronic physics and to identify possible deficiencies of hadronic interaction models.
- The muon number in an EAS is also sensitive to the cosmic ray mass composition.





$$\pi^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu}) \text{ and } K^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu})$$

Experimental set-up

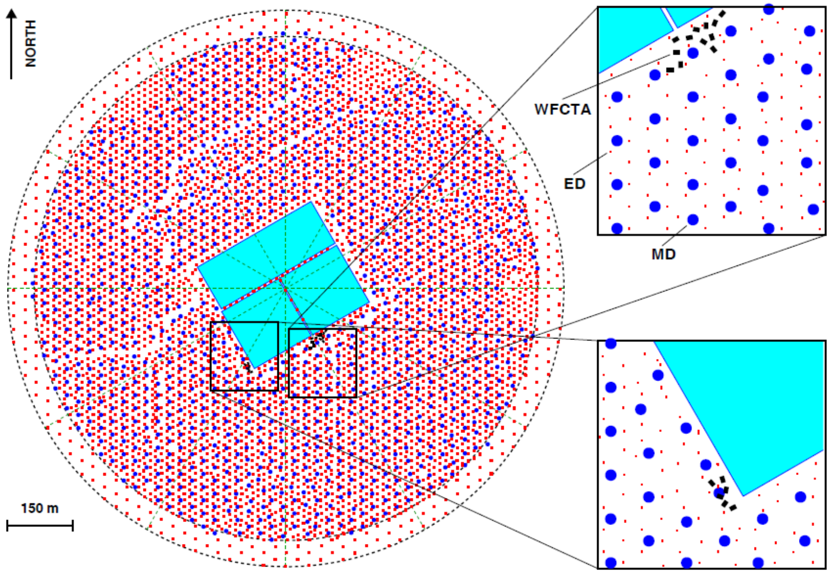
Large High Altitude Air Shower Observatory, LHAASO at 4410 m a.s.l. ($600 g/cm^2$) in Daocheng, China

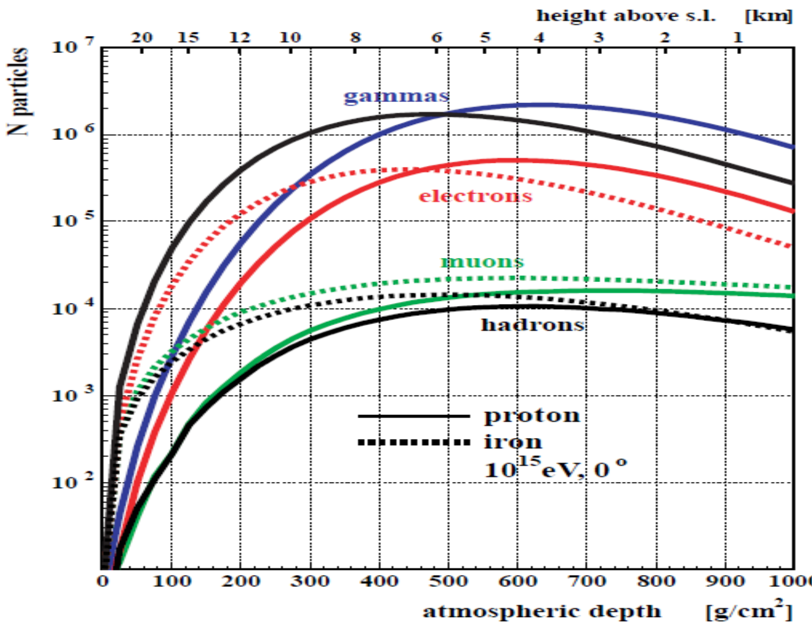
- 1 km^2 array (KM2A)

  electromagnetic particle detectors (5195 EDs)

  muon detector (1188 MDs)

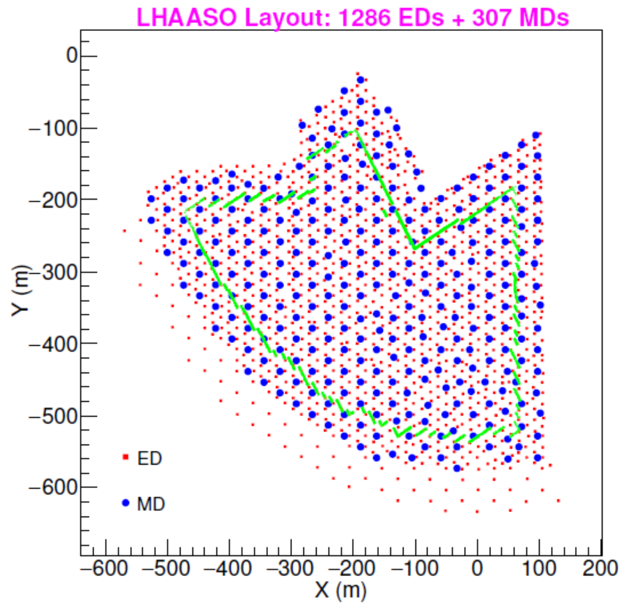
- water Cherenkov detector array(WCDA)
- wide-field-of-view Cherenkov/fluorescence telescope array (WFCTA)

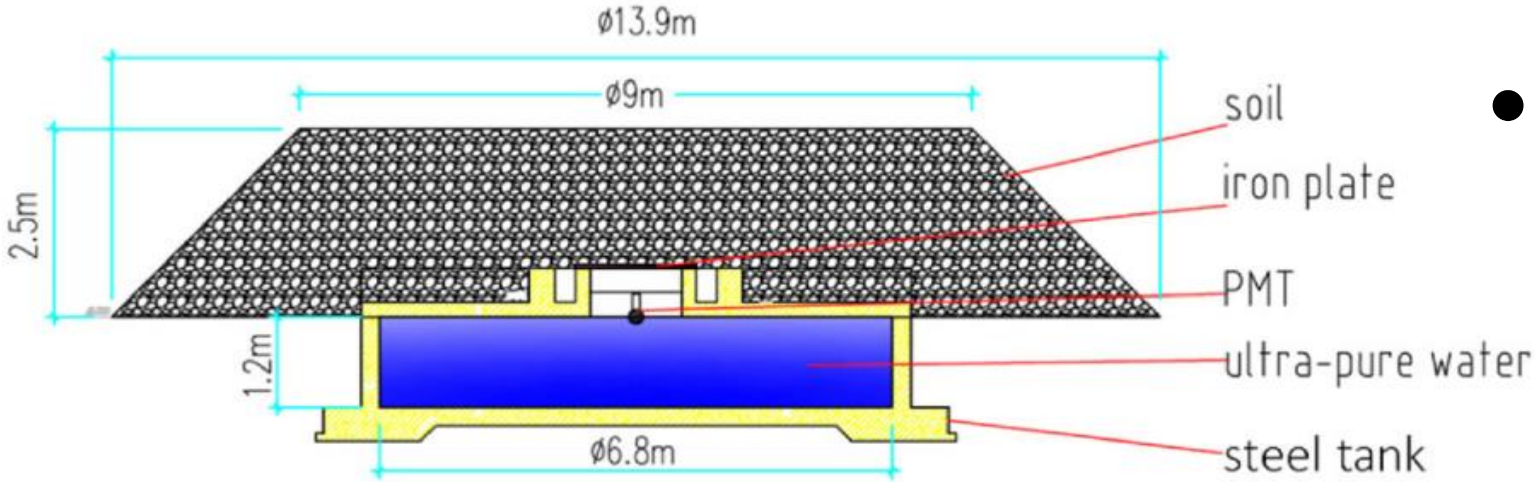




Andreas Haungs. Journal of Physics G: Nuclear and Particle Physics, 29(5):809–820, apr 2003.

KM2A quarter-array





Schematic diagram of muon detector

- A layer of 2.5 m thick soil is overburdened on the MD tank to absorb the secondary electrons/positrons and gamma-rays in air showers.

Monte Carlo Simulation

- CORSIKA (Cosmic Ray Simulations for KAscade)

  primary cosmic ray： Proton, He, CNO, MgAlSi, Fe

  high energy hadronic interaction model: EPOS-LHC

  low energy hadronic interaction model: FLUKA

Table 1: Corsika simulation: EPOS-Fluka.

Component	A	Energy range(eV)	γ	θ(deg)	φ (deg)
Proton	1	$10^{13} \sim 10^{17}$	-2	0-70	0-360
He	4	$10^{13} \sim 10^{17}$	-2	0-70	0-360
CNO	14	$10^{13} \sim 10^{17}$	-2	0-70	0-360
MgAlSi	27	$10^{13} \sim 10^{17}$	-2	0-70	0-360
Fe	56	$10^{13} \sim 10^{17}$	-2	0-70	0-360

- G4KM2A(detector response)

  array： ED and MD

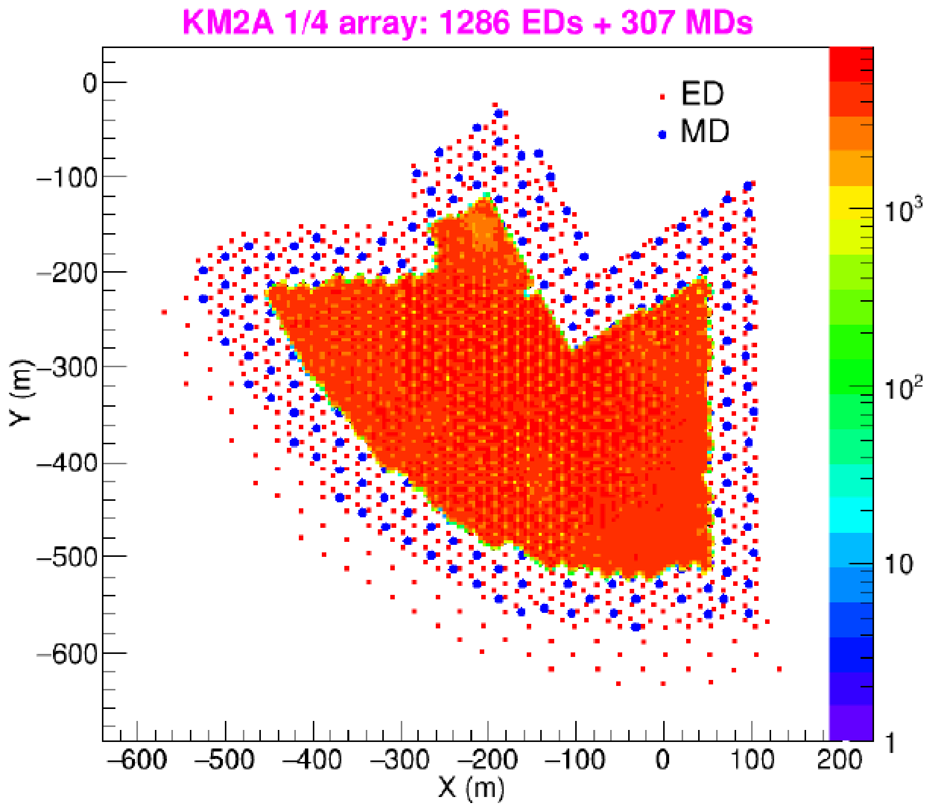
  simple radius： 1000m

Table 2: G4KM2A simulation: the number of cosmic ray shower.

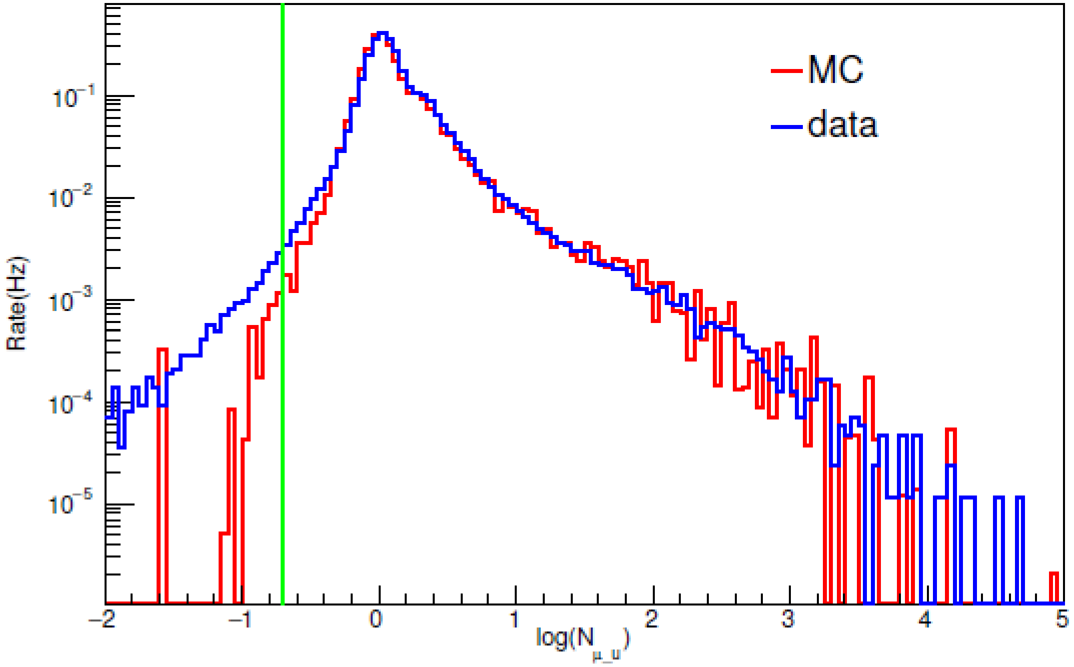
Component	$10^{13} \sim 10^{14}$ eV	$10^{14} \sim 10^{15}$ eV	$10^{15} \sim 10^{16}$ eV	$10^{16} \sim 10^{17}$ eV
Proton	4×10^{7}	4×10^{6}	6×10^{5}	10^{5}
He	10^{7}	10^{6}	10^{5}	2.5×10^{4}
CNO	10^{7}	10^{6}	10^{5}	2.5×10^{4}
MgAlSi	10^{7}	10^{6}	10^{5}	2.5×10^{4}
Fe	4×10^{7}	4×10^{6}	6×10^{5}	10^{5}

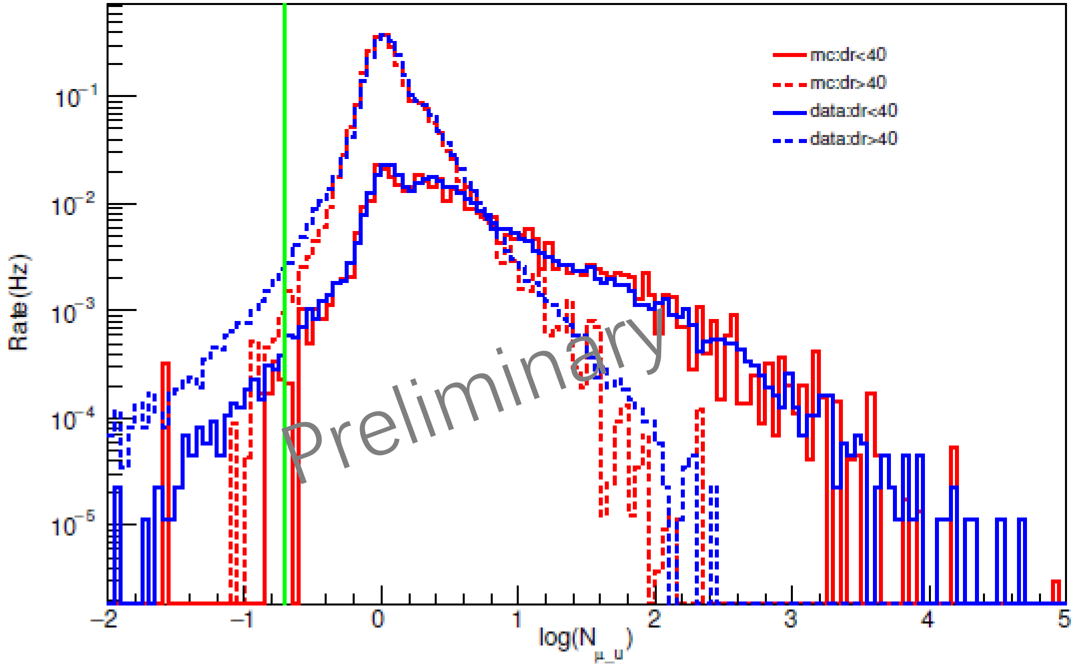
Data quality selection

- Theta: 0-30° ;
- NtrigE > 50: the number of fired EDs
- NpE2 > 20 (40-100m);
- NuM2> 10 (40-200m);
- NpE1/NpE2 > 2.2: the number of particles detected within 0-100 m from shower core is larger than that within 40-100 m;
- N_{size}>20000: the shower size is reconstructed using NKG function;
- Dr > 65m : distance from shower core to array edge



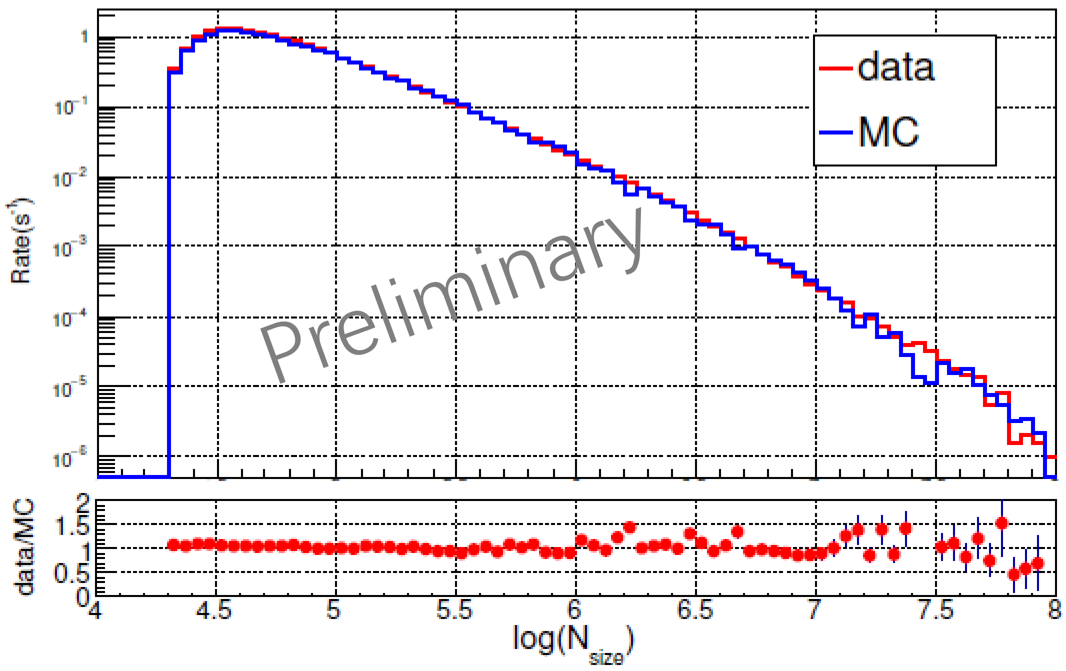
The comparison of unit muon detector

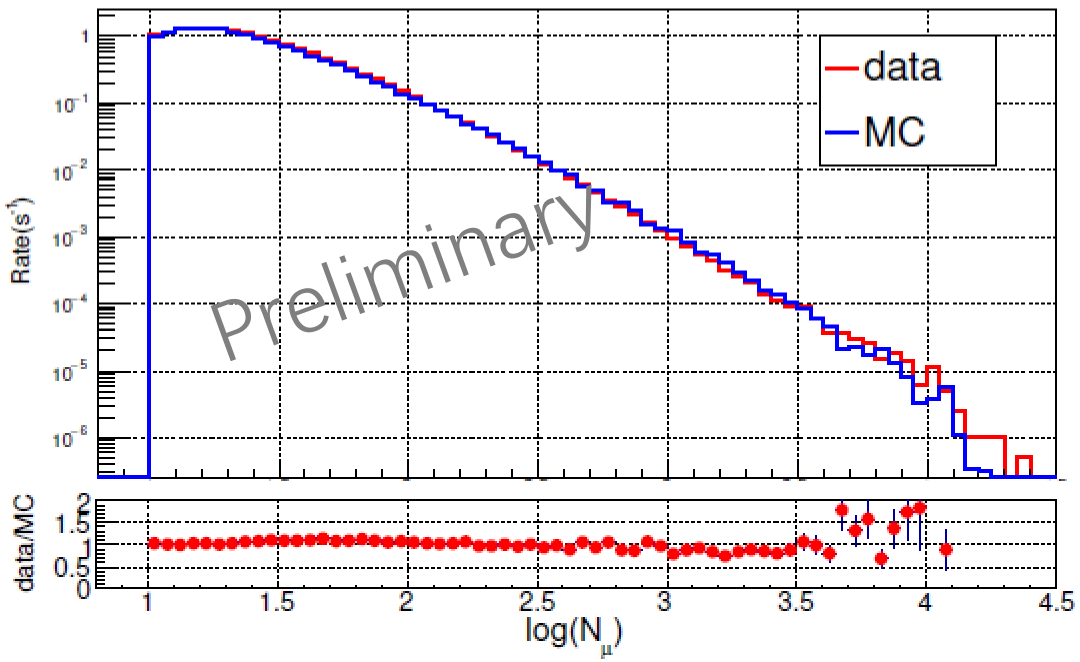




Comparison between MC simulation and experimental data of the daily averaged trigger rate distribution of a typical MD. The horizontal axes indicate the number of particles recorded by these detectors for the triggered events. Right: the muon spectrum of the distance of a typical MD to the shower core (r <40m and r >40m). The MC simulation (EPOS), with five components, is normalized to the cosmic ray model of Gaisser H3a .

The comparison of KM2A quarter-array



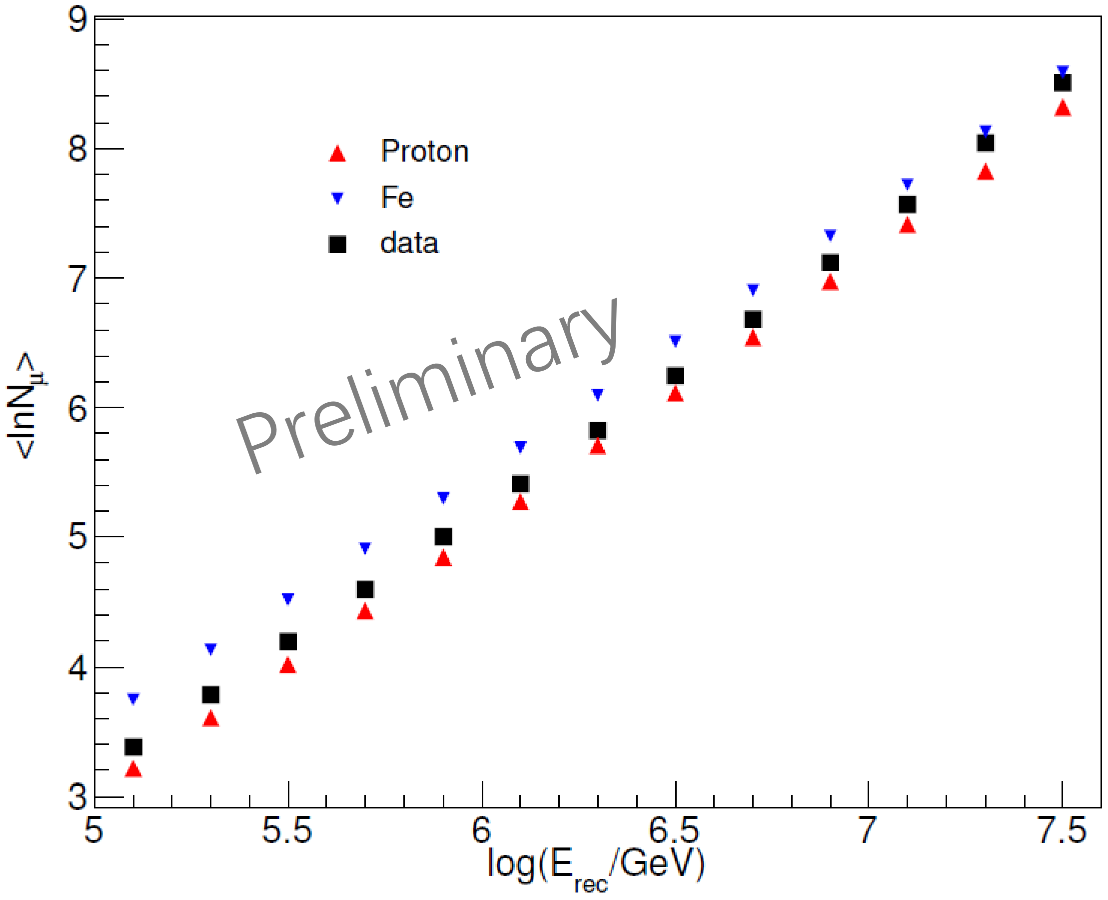


Simulation and experimental distributions of N_{size}(left), N_{μ} (right) of KM2A quarter-array.

- The event rate of experimental data is about 5% higher than that of simulated data.

Measurement of muon contents

Energy reconstruction: $log_{10}(E_{rec}) = a + b \times log_{10}(\sqrt{N_{size} \times N_{\mu}})$



- This method to reconstruct energy is weakly dependent on the composition;
- The mean logarithmic N_{μ} for the events in each energy interval is measured;
- simulation results for irons and protons for which used the EPOS-LHC interaction model;
- No obvious muon excess is found in this energy region;

Conclusion

- EPOS-LHC hadronic interaction model is used to describe the development of showers in the atmosphere, and the interactions in the detector are simulated by a G4KM2A procedure;
- The simulation results are fairly consistent with experimental data;
- No obvious muon excess is found in this energy region;

Outlook :

- Different hadronic interaction model, like QGSJETII-04 and EPOS-LHC
- Muon content will studied using the LHAASO full array data.


Thanks for your attention!