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The analysis of muon component of extensive air showers from the SUGAR data

Introduction and motimation

1 How does an muons excess depend on EAS parameters?

- primary energy
- primary composition
- distance to the shower core (the LDF shape)
- zenith angle
- muon energy threshold

To study the dependence of the muon excess on the EAS parameters, an installation with a muon detector is required

SUGAR array

• operated between 1968 and 1979

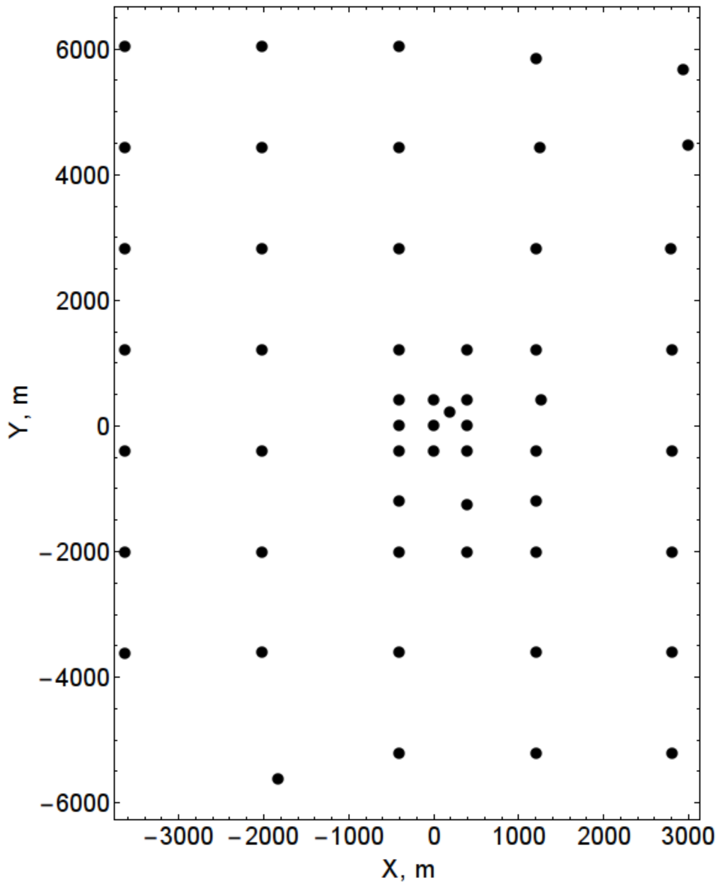
• located near the town of Narrabri in New South Wales, Australia, and altitude~250 m above sea level

• area of about 70 km^2 and consisted of 54 underground detector stations

• each detector station had two liquid-scintillator tanks 50 m apart in the North-South direction, buried at the depth varying within 1.5±0.3 m

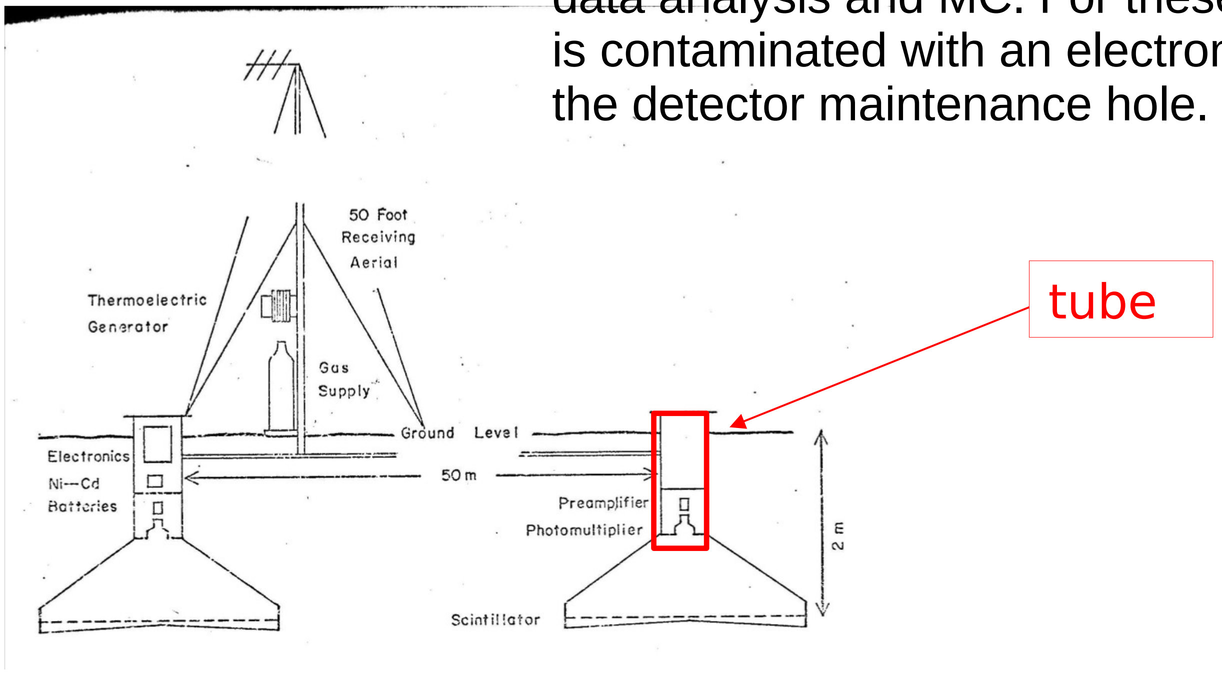
• The effective area of each scintillator tank was 6.0 m^2

• threshold energy for detected muons was (0.75±0.15) sec(θμ) GeV



Schematic of a muon scintillation detector

Discard showers with zenith angles less than 17 degrees from data analysis and MC. For these zenith angles, the muon data is contaminated with an electromagnetic component through the detector maintenance hole.



SUGAR muon LDF and vertical muon number

- muon lateral distribution function (LDF)

$$\rho_\mu = N_\mu k(\theta) \left(\frac{r}{r_0}\right)^{-a} \left(1 + \frac{r}{r_0}\right)^{-b}$$

where r_0=320m, a=0.75, b =1.5+1.86*cos(θ),
k(θ) =Γ(b)/(2*Pi*r_0^2Γ(2-a)Γ(a+b-2)), **N_μ - muon number**

- In SUGAR data **N_μ** was determined by fitting individual detector readings

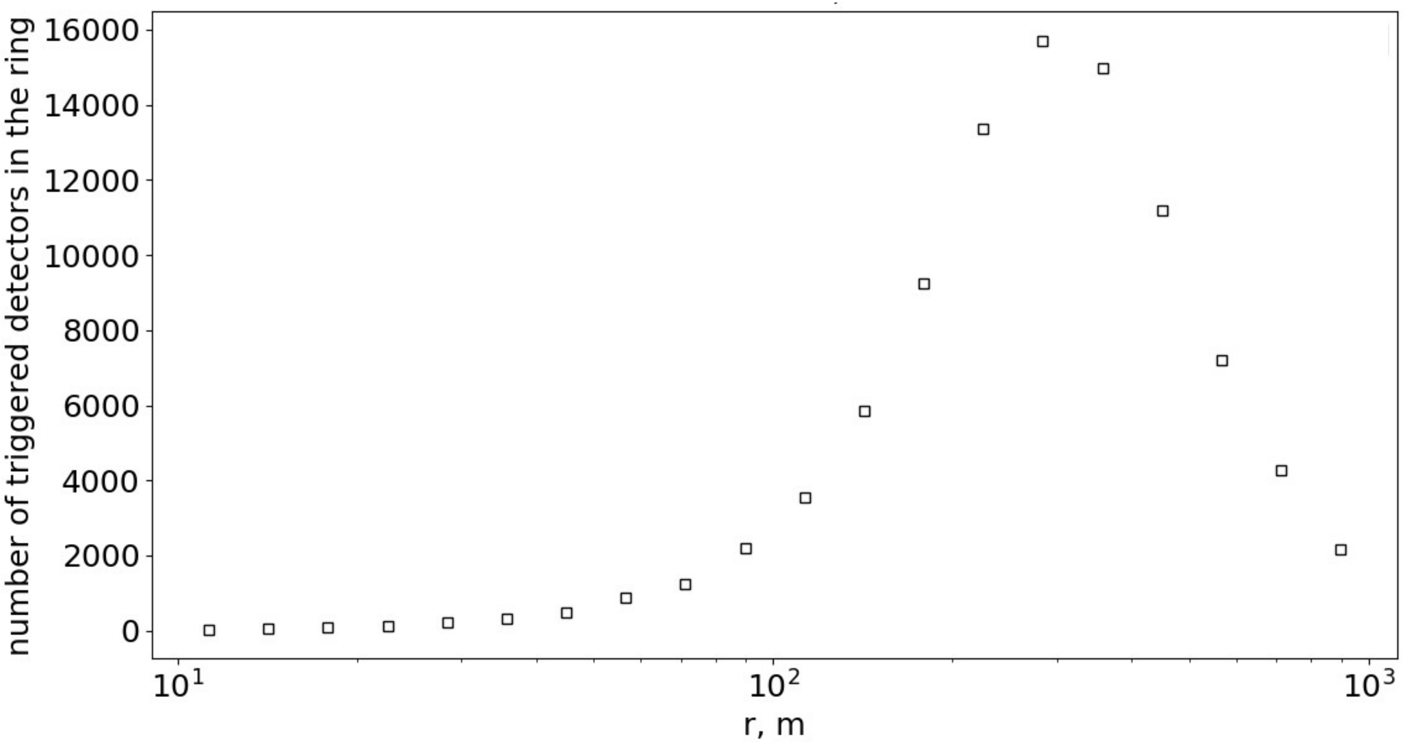
- for each observed EAS with a reconstructed **N_μ** and **θ**, the number of vertical muons **N_v** was determined by the expression

$$\log\left(\frac{N_v}{N_r}\right) = \frac{(1-\gamma_v - A(\cos(\theta)-1))\log\left(\frac{N_\mu}{N_r}\right) + B(\cos(\theta)-1) + \log\frac{1-\gamma_v}{1-\gamma_v - A(\cos(\theta)-1)}}{1-\gamma_v}$$

where the coefficients are A= 0.47, B= 2.33, γv= 3.35, N_r=10^7

Distribution of triggered detectors by distance from the EAS axis

We will use this distribution to determine the Nmu of events in Moente Carlo.

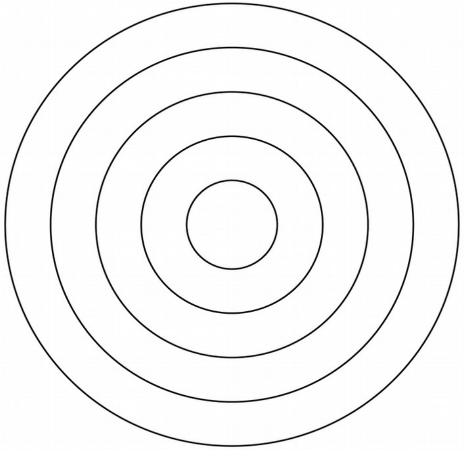


Monte Carlo simulation

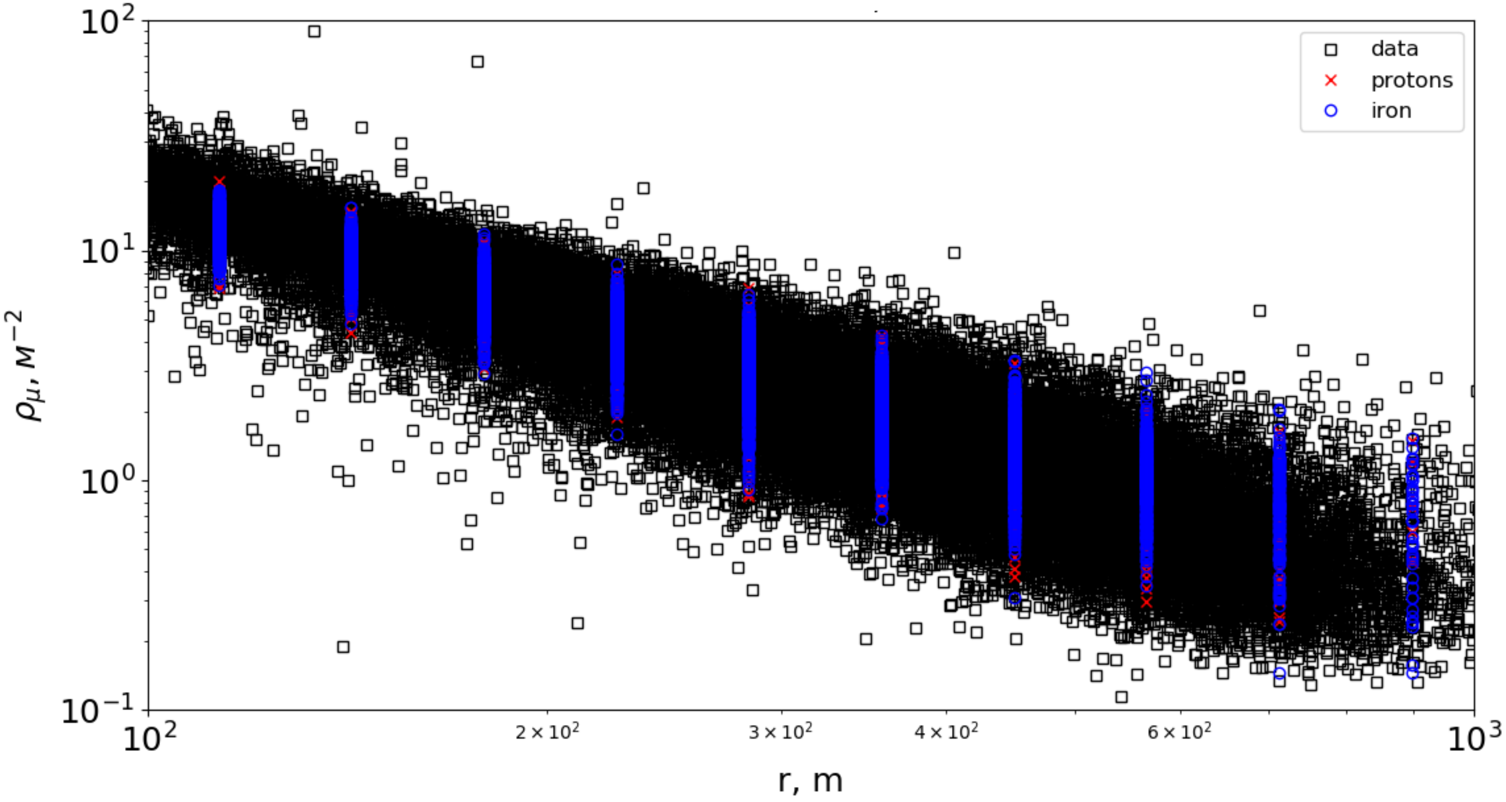
- CORSIKA7.4001
- QGSJET-II-04 high-energy hadronic interaction models
- FLUKA2011.2c as the low-energy hadronic interaction models
- primary energies following an $E^{-3.19}$ differential spectrum
- energy range 9×10^{16} eV< E <4×10^{18} eV.
- θ in the range between 0 and 75 degrees
- thinning parameter $\varepsilon = 10^{-5}$
- For each hadronic interaction models, we simulated 10000 showers for primary protons and the same number of showers for primary iron.

Monte Carlo simulation

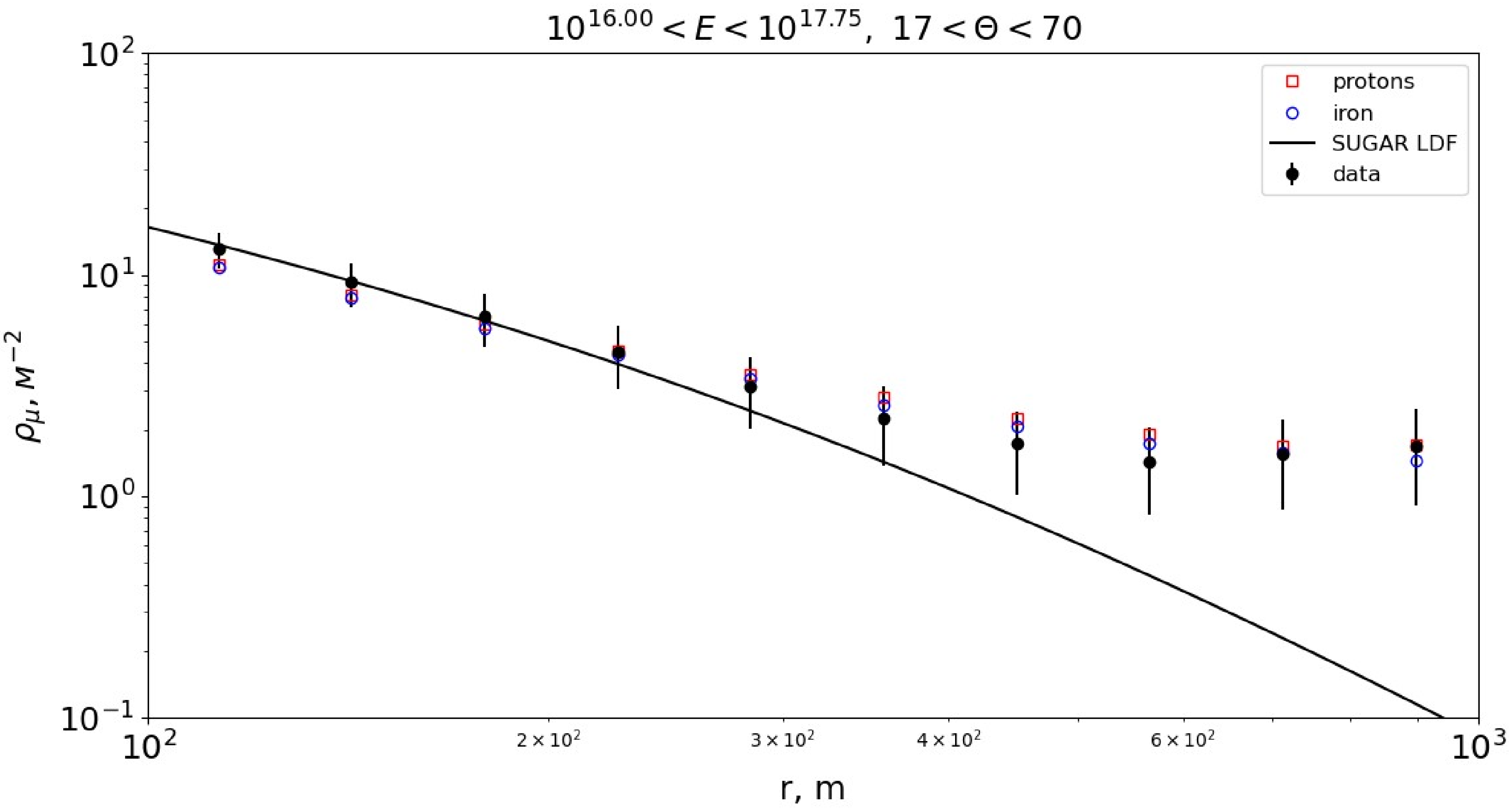
- calculate the mean muon density in concentric rings around the shower axis
- pass through Poisson, impose a threshold of 2.4 muons.
- "smear" the position of the axis with an error of 50 meters(errors of axis).
- For each muon density in the ring, a weight is assigned depending on the distribution of the triggered detectors (see slide 6)
- we use the experimental muon LDF and fit the muon density distribution in MC for obtaining **Nμ**
- The muon density of model and experimental showers is normalized to one number of muons



Muon LDF: data vs MC, (without averaging)

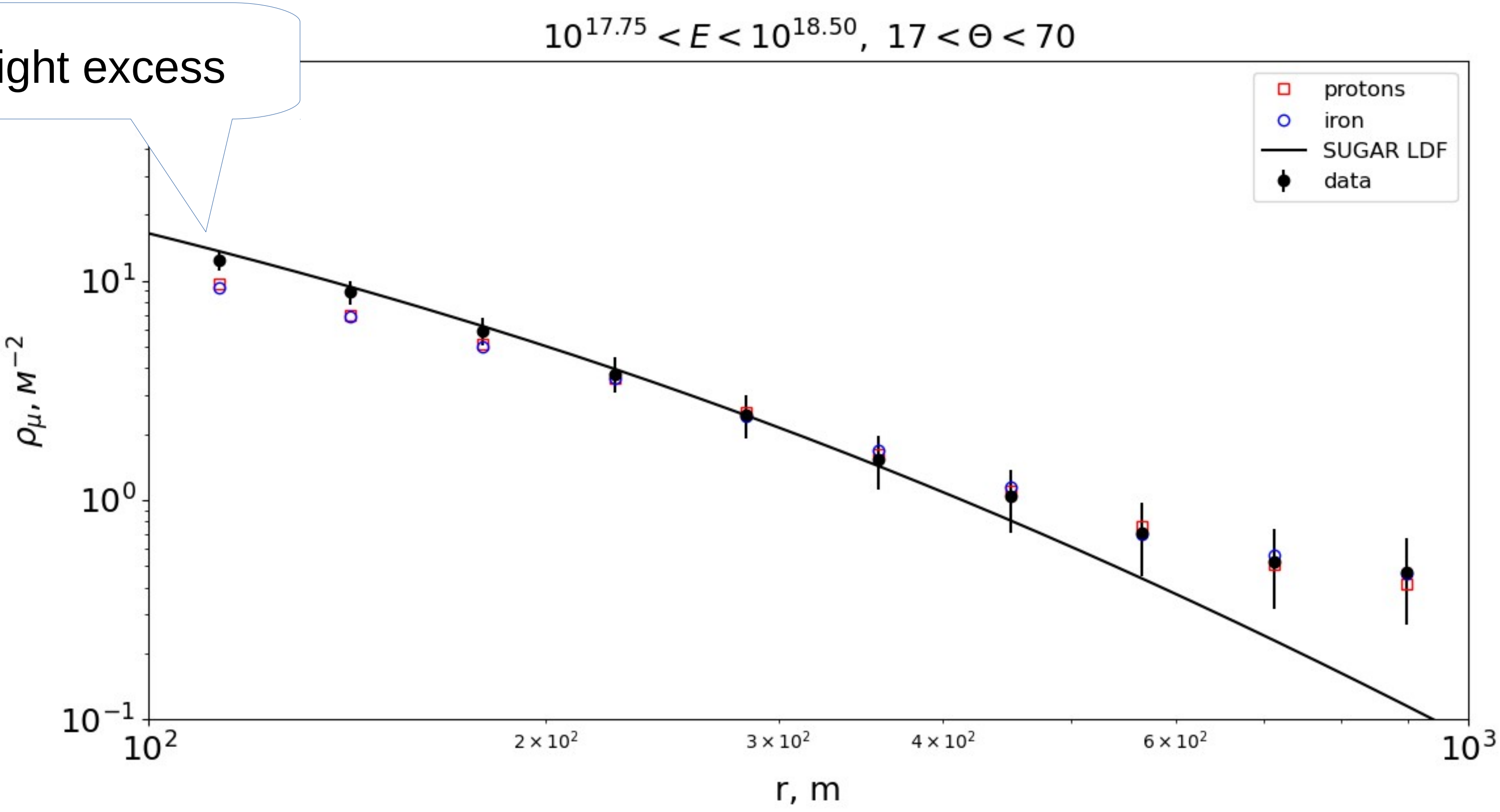


Muon LDF: data vs MC, low energy



Muon LDF: data vs MC, high energy

Slight excess



Conclusions and perspectives

- From the experimental data, an empirical muon lateral distribution function (LDF) was obtained
- A comparison was made between the obtained empirical muon LDF and the results of Monte Carlo simulation.
- In general, the model LDF describes the experimental data except for the area at close distance from the axis of the high-energy showers.

Thank you for your attention

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