Estimations of the muon content of cosmic ray air showers between 10 PeV and 1 EeV from KASCADE-Grande data

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Description of the analysis

- We measured N_μ vs the primary energy from 10 PeV to 1 EeV using KASCADE-Grande EAS data for zenith angles < 40° and compared the results with QGSJET-II-04, EPOS-LHC, SIBYLL 2.3 and SIBYLL 2.3c predictions.
- Due to the lack of a model independent energy estimator, we used the method proposed by NEVOD-DECOR (2010) and SUGAR (2018) to get $N_\mu(E)$:
  - Compare the experimental N_μ histogram against predictions with a reference cosmic ray model based on the spectrum from the PAO observatory (2019) and abundances from GSF model.
  - By a minimun Chi² procedure

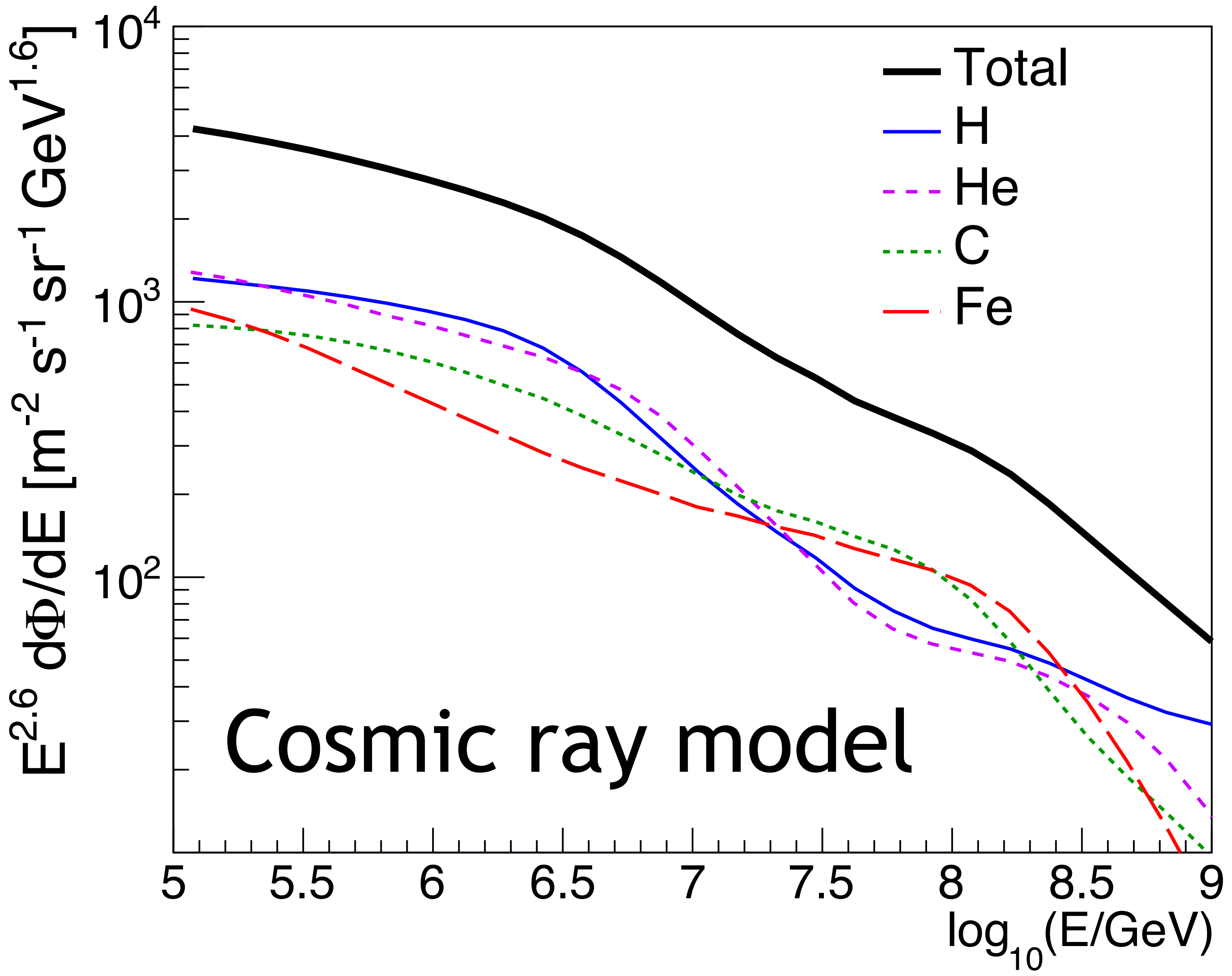
$$\chi^2 = \sum_{i=1}^{m} \left(\frac{n_{exp,i} - n_{MC,i}}{\sigma_{i,MC}} \right)^2$$

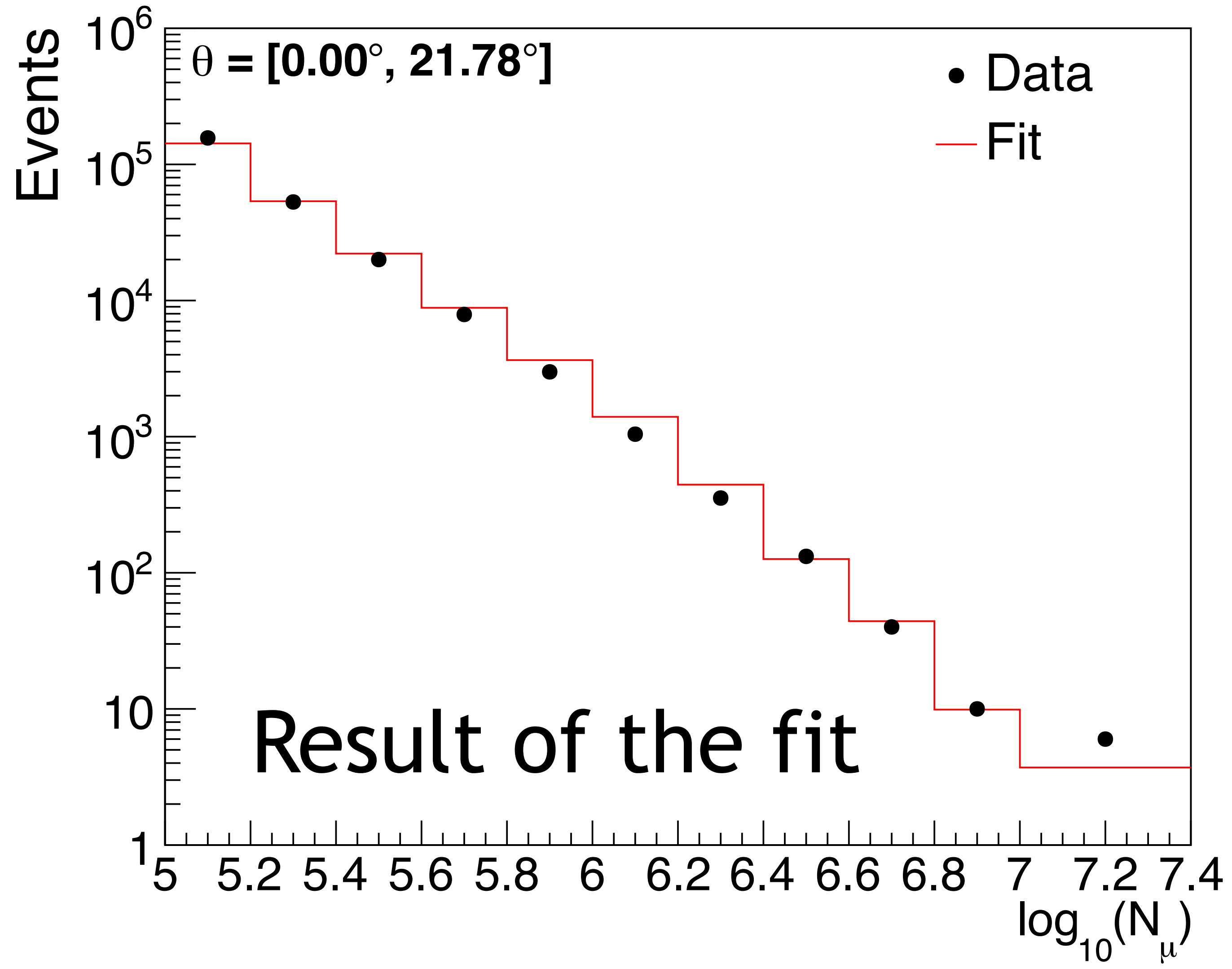
find the shift between MC and measured data that allows to describe the experimental N_μ distribution.

$$\delta_\mu = \Delta \log_{10}(N_\mu) = a_0 + a_1 \cdot \log_{10}(E/\mathrm{GeV}) + a_2 \cdot \log_{10}^2(E/\mathrm{GeV})$$

  - Apply the shift to MC simulations to estimate the actual muon content.

$$\log_{10}[N_\mu(E)] = \log_{10}[N_{\mu,\,MC}(E)] + \delta_\mu$$





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Results

- None of the high-energy hadronic interaction models studied here is able to describe consistently the KASCADE-Grande EAS data on N_μ for all zenith angles and energies.

- Predictions of EPOS-LHC, SIBYLL 2.3 and SIBYLL 2.3c on N_μ for primary energies between 100 PeV and 1 EeV are above the KASCADE-Grande data for vertical EAS.

- Attenuation of N_μ with the zenith angle is smaller in data than in MC simulations.

- Better agreement for inclined EAS close to 40º.

- Observed anomalies could imply that the energy spectrum of muons from real EAS at production site for a given primary energy is harder than the respective model predictions.