Study of Muon-Based Mass-Sensitive Parameter for the IceTop Surface Array

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Motivation: Air showers induced by heavier primary particles develop earlier in the atmosphere and produce more muons observable at ground level than lighter cosmic rays with the same primary energy. Therefore, the fraction of muons to all charged particles measured by IceTop can characterize the mass of primary particles.

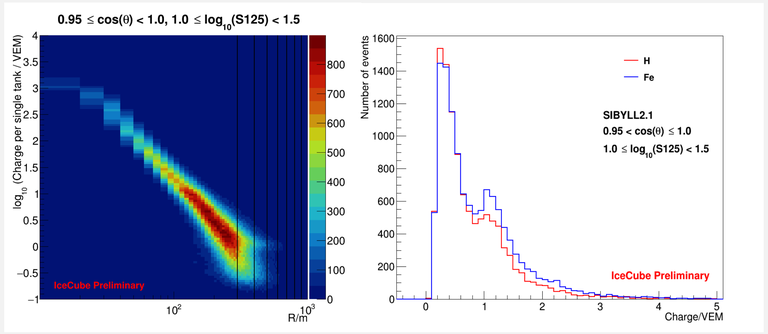

Figure 1: *Left*: The 2-dimensional charge distribution for 10% of 2012 IceTop data. *Right*: The charge distribution for a fixed distance from 350 to 450 m. The peak at 1 VEM is mainly caused by muons.

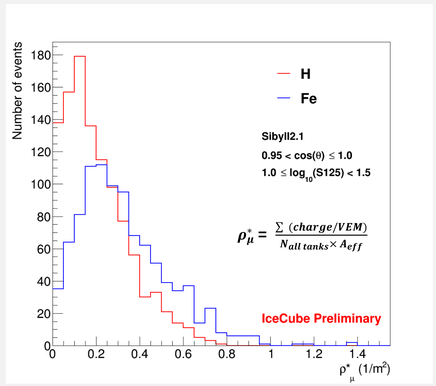

Figure 2: Estimated muon-based parameter (ρ^*_μ) per individual showers. ρ^*_μ is contaminated by the electromagnetic background, so that the correction has to be done to the true muon density

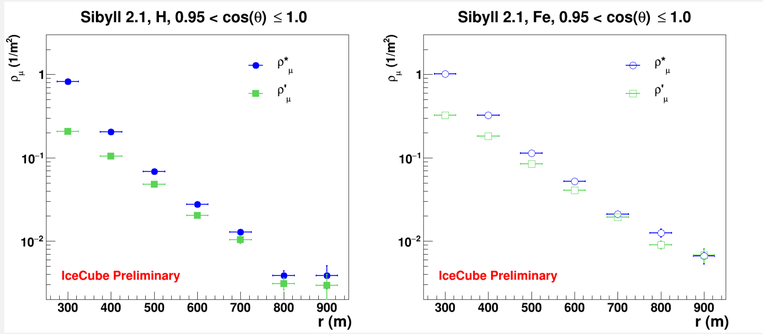

Figure 3: The muon parameter before and after the muon selection as a function of distances for proton (left) and iron (right) assumptions. ρ^*_μ (blue) and ρ'_μ (green) are the muon parameters before and after the muon selection, respectively.

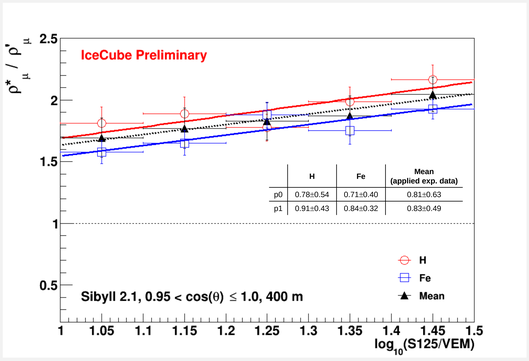

Figure 4: Energy-dependent muon correction factor (CF), the ratio between ρ^*_μ and ρ'_μ, for proton and iron primaries, showing the lines of best fit. ρ^*_μ is corrected by CF per individual showers to obtain the μ-based parameter.

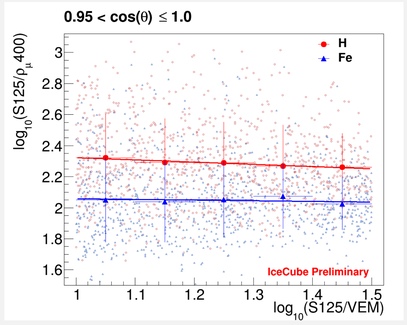

Figure 5: The ratio between shower size S125 and muon-based parameter $\rho_\mu 400$ for proton and iron assumptions.

$$k = \frac{\log10\left(\frac{S125}{\rho_{\mu,400,data}}\right) - \log10\left(\frac{S125}{\rho_{\mu,400}}\right)_H}{\log10\left(\frac{S125}{\rho_{\mu,400}}\right)_{Fe} - \log10\left(\frac{S125}{\rho_{\mu,400}}\right)_H}$$

$$\log10\left(\frac{S125}{\rho_{\mu,400}}\right)_{H,Fe} = c_{H,Fe} \cdot \log10(s125) + d_{H,Fe}$$

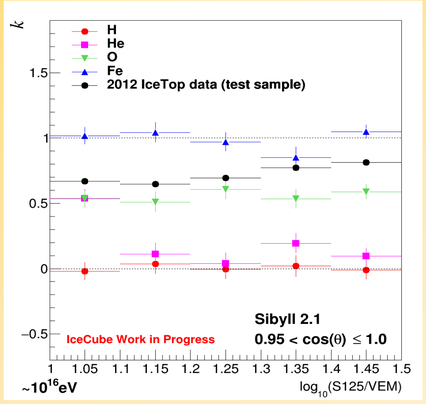

Figure 6: Muon-based mass sensitive parameter k as a function of the energy estimator (S125) for experimental data compared with simulations of four different primary masses based on the hadronic interaction model of Sibyll 2.1.

Conclusion

- Considering the charge signal distribution, a muon parameter per individual shower was defined and estimated. Using the shower size S125 and the estimated muon parameter at a reference distance, the mass sensitive ratio is estimated event by event.
- This ratio can be applied for energy spectrum and mass composition reconstruction of primary cosmic rays → **Work in progress**

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