Detection of Small Scale Components in Power Law Spectra

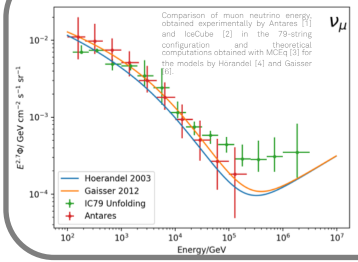
e5 experimentelle physik 5
astroteilchenphysik teilchenphysik medizinphysik

SFB 876 Providing Information by Resource-Constrained Data Analysis

Tim Ruhe*, Wolfgang Rhode*

tim.ruhe@tu-dortmund.de

technische universität dortmund



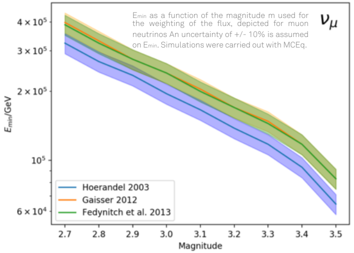
Comparison of muon neutrino energy, obtained experimentally by Antares [1] and IceCube [2] in the 79-string configuration and theoretical computations obtained with MCEq [3] for the models by Hörandel [4] and Gaisser [6].

Introduction

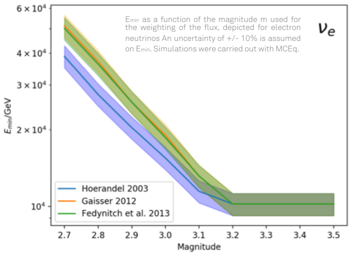
Although, atmospheric lepton spectra are routinely detected by large scale neutrino telescopes, inferring physics parameters from these spectra remains a challenging task. Moreover, the spectra do not allow to discriminate between different models, due to their large uncertainties. On this poster we present a method that circumvents these challenges by considering the minima of the spectra.

Discriminating between cosmic ray model

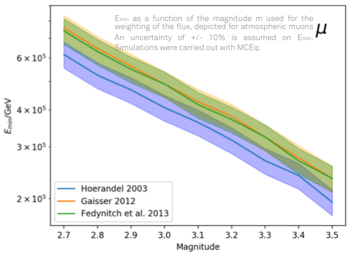
In unweighted lepton spectra small scale structures are often invisible as all components of the fluxes can be modelled by steeply falling power laws. Therefore, energy weighted spectra $E^m \frac{d\Phi}{dE}$ of atmospheric leptons are often used for visualisation purposes. As the minimum of these energy weighted spectra depends on m as well as on the underlying cosmic ray model, the positions of the minima can be utilised to discriminate between different models.



E_{min} as a function of the magnitude m used for the weighting of the flux, depicted for muon neutrinos An uncertainty of +/- 10% is assumed on E_{min}. Simulations were carried out with MCEq.



E_{min} as a function of the magnitude m used for the weighting of the flux, depicted for electron neutrinos An uncertainty of +/- 10% is assumed on E_{min}. Simulations were carried out with MCEq.

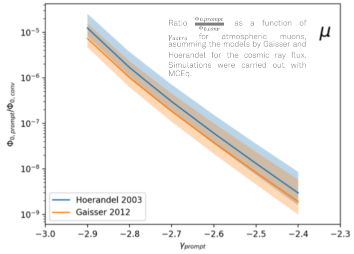


E_{min} as a function of the magnitude m used for the weighting of the flux, depicted for atmospheric muons An uncertainty of +/- 10% is assumed on E_{min}. Simulations were carried out with MCEq.

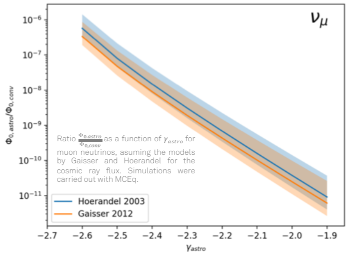
Extracting physics parameters

In case all spectral components can be modelled as power laws, the minima of energy weighted lepton spectra be used for the extraction of physics parameters. The ratio of the normalisations of a component of interest and the conventional components can then be expressed as a function of E_{min} and γ_{int}. $\Phi_{0,conv}$ and γ_{conv} are extracted by a power law fit to simulated fluxes.

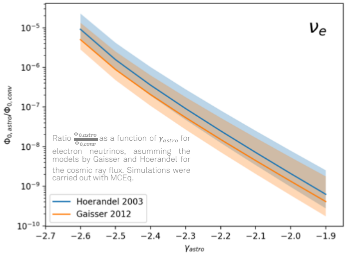
$$\frac{\Phi_{0,int}}{\Phi_{0,conv}} = E_{min}^{\gamma_{conv}-\gamma_{unkn.}} \frac{(\gamma_{conv}+m)}{-(\gamma_{int}+m)}$$



Ratio $\frac{\Phi_{0,prompt}}{\Phi_{0,conv}}$ as a function of γ_{astro} for atmospheric muons, assuming the models by Gaisser and Hoerandel for the cosmic ray flux. Simulations were carried out with MCEq.



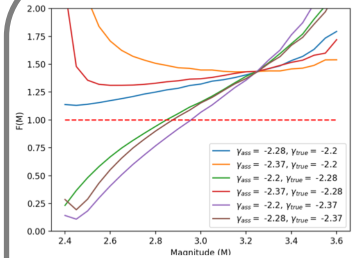
Ratio $\frac{\Phi_{0,astro}}{\Phi_{0,conv}}$ as a function of γ_{astro} for muon neutrinos, asuming the models by Gaisser and Hoerandel for the cosmic ray flux. Simulations were carried out with MCEq.

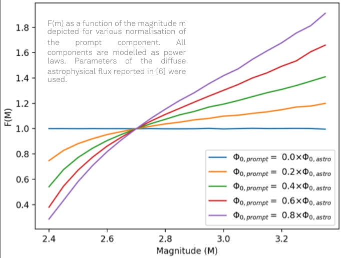


Ratio $\frac{\Phi_{0,astro}}{\Phi_{0,conv}}$ as a function of γ_{astro} for electron neutrinos, assuming the models by Gaisser and Hoerandel for the cosmic ray flux. Simulations were carried out with MCEq.

Conclusion

1. Studying E_{min} as a function of m allows for to discriminate between cosmic ray models.
2. Modelling all components as power laws allows for the estimation of physics parameters.
3. The derived quantity $F(m)$ can be used for the detection of additional spectral components.





F(m) as a function of the magnitude m depicted for various normalisation of the prompt component. All components are modelled as power laws. Parameters of the diffuse astrophysical flux reported in [6] were used.

Detection of small scale components

The minima can be used for the detection of small scale components. Assuming a contribution of two components to the spectrum, and modelling these components as power laws, a quantity $F(m)$ can be derived. For the case of only two components, one finds $F(m) = 1$. In case a third component is present $F(m)$ is altered, and the size of the alteration depends on the normalisation of the additional component.

$$F(m) = \frac{-\Phi_{0,conv}(m-\gamma_{conv})}{\Phi_{0,astro}(m-\gamma_{astro})} E^{\gamma_{conv}-\gamma_{astro}} = 1$$

References:

[1] S. Adrian-Martinez et al. [Antares Collaboration], Eur. Phys. J. C 73, 2606 (2013).
[2] M. G. Aartsen et al. [IceCube Collaboration], Eur. Phys. J. C. 77, 692 (2017).
[3] A. Fedynitch et al., PoS ICRC 2015 34, 1129 (2016).
[4] J. R. Hoerandel, Astropart. Phys. 19, 193 (2003).
[5] T. K. Gaisser, Astropart. Phys. 35, 801 (2012).
[6] J. Stettner, PoS ICRC 2019 36, 1017 (2019).