Slope of the radial distribution of secondary muons and hadrons in EAS at PeV energy

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Introduction

The analytical methods in obtaining the radial distribution of Extensive Air Shower (EAS) muons and hadrons in air shower theory suffers from restricted applicability due to several simplifications or approximations adopted in the treatment. A Monte Carlo (MC) calculation of the radial distribution of muons and hadrons can of course avoid all these limitations and is in principle more accurate, even if it has normal dependencies upon hadronic interactions adopted in the simulation. A more judicious estimation of age or slope parameter has been made through local age or segmented slope parameter in the work. Using KASCADE data extracted from published papers we studied the details of the characteristics of the local age/slope for muons and hadrons.

The main parameters associated with the lateral distribution of EAS muons and hadrons at the given observation level are the muon size (N_μ), hadron size (N_h), and the lateral (or transverse) shower ages ($s_\perp(\mu/h)$). N_h is often related with the energy of the EAS initiating particle while N_μ is used for identifying the shower initiating particle.

Local age or segmented slope parameters

Several air shower groups have proposed mathematical expressions empirically to describe the lateral (radial) distribution of the muons from the EAS core, in analogy to the lateral density distribution (LDD) functions for electrons. These were basically constructed empirically or borrowed from the electromagnetic cascade theory. In the intermediate energy range and radial distances like the present case the Hillas function (eqn. 1) used by Haverah park experiment has been chosen for the parametrization to the lateral distribution of muons for defining segmented slope parameter (SSP), $\beta_{local}(x)$ [1].

$$\rho_\mu(r) \propto (r/r_m)^{-\beta} exp(\frac{-r}{r_m}) \quad (1)$$

For the reconstruction of experimental LDD of muons many EAS groups have used structure function proposed by Greisen with different Moliere radius and muon size in the formula (2) [2]. Sometimes exact NKG-type structure function with N_μ instead of N_e has been used.

$$f_\mu(r) = const.(r/r_G)^{-\beta}(1 + r/r_G)^{-2.5}, \quad (2)$$

with slope parameter $\beta = 0.75$ and Greisen radius $r_G = 320$ m.

For the reconstruction of an EAS with hadronic component the KASCADE experiment employed an NKG-type function as was used to describe the electron distribution and found a similar trend as the electron distribution with $r_0 = 10$ m [3]. However, an exponential type function employed by Leeds group in their data analysis for the reconstruction of hadronic part has also been used here for studying the radial dependence of the $\beta_{local}(x)$. The characteristic function of the LDD for the hadrons to obtain $\beta_{local}(x)$ brought from the Leeds group is the following:

$$\rho_\mu(r) = Aexp(\frac{-r}{r_m})^{\beta}, \quad (3)$$

where A is a constant.

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Results

To compute SSPs ($\beta_{local}(r)$) corresponding to muon and hadron lateral distributions we have used density profile functions employed in Haverah park and Leeds experiments respectively. The Greisen function given in equation 2 is also used for the purpose.

The LAP has also been estimated with muons using NKG-type lateral distribution function and the radial variation of LAP as obeyed by electrons still persists for muons as well. All these studies were performed by extracting KASCADE density data from published work and is given in the figure Fig. 1.

Since air shower measurements are subjected to large fluctuations, instead of LAP at a particular radial distance we consider for each event a mean LAP (s_{local}(mean)), which is the average of LAPs for several small distance bands (r_i, r_j) over the radial distance between 75 m to 150 m. The radial distance band from 75 m to 150 m is chosen because the positions of local minimum and maximum at 75 m and 150 m are nearly universal, independently of primary energy. Such average ages are shown in the top of figure Fig. 1 by straight lines parallel to X-axis. Secondary hadrons in an EAS are generally concentrated near the shower core and experience much fluctuations. In the present study of the radial variation of LAP for hadrons with NKG type profile function such inconsistent behaviour is exhibited clearly through the figure Fig. 2.

Conclusions

In case of muons the minimum of muon LAP is found at 75 m range while maximum occurs at around 150 m. The behaviour of the SSP with radial distance follows a reverse trend compared to LAP for muons. The radial dependence of the LAP for hadrons using KASCADE data seems very unreliable.The LAP takes higher value for Fe initiated showers in compared to that of p initiated showers.

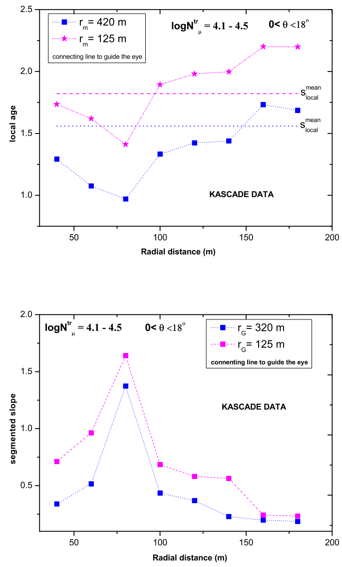

FIG. 1: Top: The radial variation of LAP estimated from the KASCADE observed lateral distribution data for muons using NKG function. Bottom:The radial variation of SSP estimated from the KASCADE observed lateral distribution data for muons using Greisen type function.

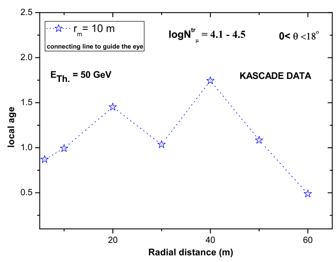

FIG. 2: The radial variation of LAP estimated from the KASCADE observed lateral distribution data for hadrons using NKG function.

References

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