# Distribution of Sea Level Muons at Zenith Angles below 10 TeV Energy

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**Abstract**

The moderate energy primary cosmic ray nucleon spectrum has been constructed fro the direct measurements of Webber et al., Seo et al., Menn et al. along with the other results surveyed by Swordy. The sea leve muon energy spectra at different zenith angles have been derived from the decay of non-prompt mesons by adopting standard diffusion equation of hadronic cascades. The contribution of charmed mesons to muon spectrum has also been accounted following standard procedure. Our estimated tota muon energy spectra have been found comparable with the global spectrograph muon flux results of MARS, DEIS, MSU and other groups.

## 1. Introduction

Investigation on the muon astronomy has immense importance i astroparticle research to understand their energy spectrum, mass composition and to confirm their arrival direction from astronomical sources. The atmosphere may be treated as target for the study o astroparticle interactions with low Z nuclei like nitrogen and oxygen present in the atmosphere to estimate the spectral characteristics of the secondary components produced through extensive air showers. Among the shower components high energy muons are unique which can give some idea about the hadronic stage of the nucleon cascade. Muon energy spectrum is directly related to the primary cosmic ray nuclei spectrum and such spectrum yields information about the amount of energy transferred t muons by nucleons. The precise derivation of muon energy spectrum is necessary for the estimation of diffuse background muon flux estimation in the isolation of diffuse muons emitted from the astronomical sources.Due to the scarcity of high energy A-A collision accelerator data and limitation of the nucleon cascade formulation till date the derivation of precise spectra of the secondary components emitted by primary cosmic rays is an interesting topic of astroparticle research.

## 2. Nuclear Physics and Kinematics

The priary nucleon spectrum has been constructed fitting the different available data to power law [Mitra et al. (1999a)].

In a similar way the muon flux at an atmospheric depth y emitted from the N generation of pions and kaons produced from the inelastic collisions with the atmospheric nuclei can be estimated by using the relations as described i Mitra et al. (1999a).

The contribution of promp muon has been estimated using the procedure described in Pal et al. (1994).

## 3. Results and Discussion:

The primary elemental energy spectra available from direc meaurements by using balloon and satellite borne active and passive detectors by different groups have been duly fitted to power law and the conventional superposition model has been used to convert the primary nuclei spectrum to the nucleon spectrum using standard procedure and found to follow the form: $N(E)dE = 1.42\ E^{-2.66}\ dE\ [cm^2\ .s.sr.GeV/n]^{-1}$

The Lorentz invariant cross-section CERN LEBC EHS data [ Benitez et al. (1991)] initiated by pp collisions and FNAL data [Brenner et al. (1982)] for $\pi \pm p$ can be calculated and duly corrected for pA and AA collisions.The adopted inelastic cross-sections for pp and $\pi$ p interactions are 35 mb and 22 mb, respectively. The Q-G plasma correction of Z-factors have also been made.

The muon flux at an atmospheric depth y emitted from the N generation of pions produced from the inelastic collisions with the atmospheric nuclei can be estimated by using the formulation described eatlier in Mitra et al. (1999a).

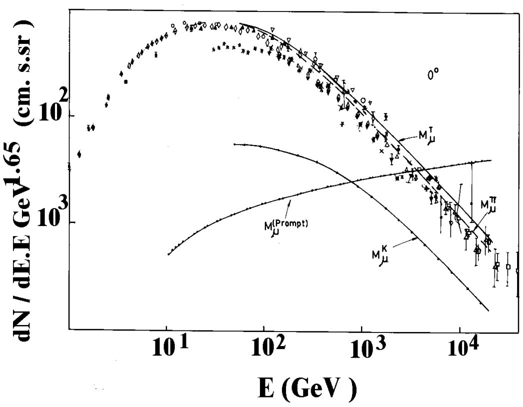


**Fig. 1**. *A comparison of the derived muon energy spectrum in the vertical direction with the experimental data of different authors considered from the survey of Mitra et al. (1999b):*

The contribution of direct muons from D mesons and $\lambda_c$ hyperons have been estimated from the primary nucleon spectrum with spectral amplitude K and index $\gamma$ following the recen procedure of Pal et al. (1994). which has been added to the spectrum o muons from the atmospheric $\pi$ and K meson decays to obtain the total zenith angular muon energy spectra a sea level below 10 TeV energies.The directly measured magnetic spectrograph data and indirectly measured range spectrometer data of different authors [ Mitra et al. (1999b)] have been displayed in the Fig.1 and found comparable to our derived vertica muon energ spectrum obtained from the latest all nucleon spectrum through non-prompt and prompt meson production.

It is found that the contribution of prompt mesons to muon flux is not appreciabl below 10 TeV muon energy and for that reason their contribution to moderate energy muon spectral shape is inadequate.

We have also derived sea leve muon energy spectra at zenith angles $45^0$, $72^0$, $75^0$, $83^0$ and $89^0$ from the primary nucleon spectrum using similar parameters and formulations as stated earlier in the case of vertica muon incidence and the results have been displayed with the experimental results of different authors [Mitra et al. (1999b)] in the Figs. 2-3. Those plot indicate that our estimated absolute muon energy spectra from the primary nucleon spectru (based on direct measurements) are well in accord with the observed data.

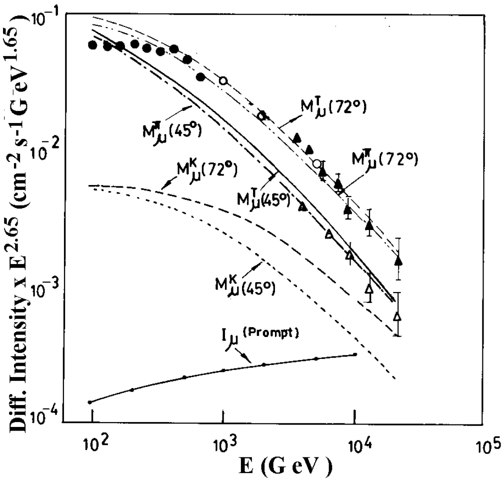

**Fig. 2.** *Muon spectra at zenith angles 45 $^0$ and 72 $^0$ Experimental data cited in Mitra et al. (1999b*

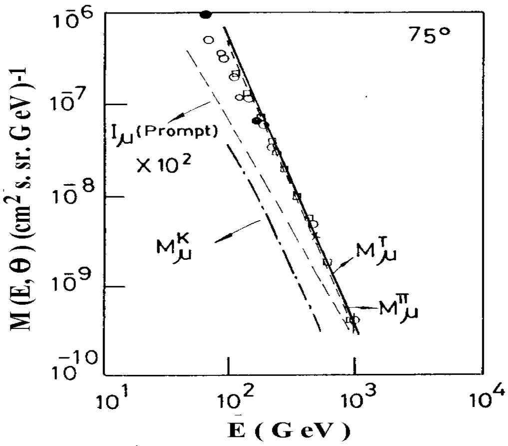

**Fig. 3**. *Sea level muon energy spectrum at zenith angle 75$^0$ Experimental data cited in Mitra et al. (1999b):*

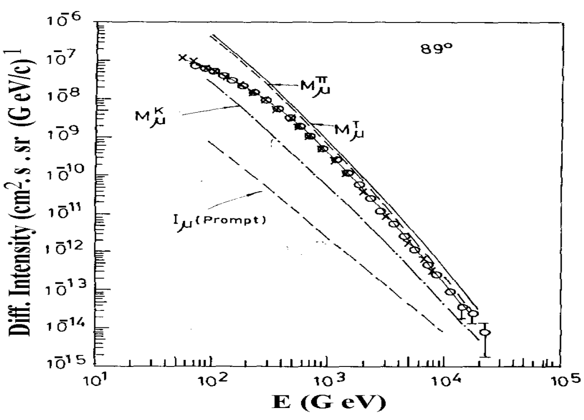

**Fig. 4**. *Sea level muon energy spectrum at large zenith angle 89$^{0}$ Magnetic spectrograph data cited in Mitra et al. (1999b):*

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Fig. 4. Muon spectrum at zenith angle 83\$^{o}\$: Experimental data: \$\Box\$ Asbury et al. [19],
\$\circ\$ Allkofer et al., \$\bigtriangledown\$ Ashton et al.,
\$\bigtriangleup\$ Palmer and Nash,
\$\Bigg \times\$ Flint and Nash, \$\Big {+}\$ Allkofer et al.
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