RELATIONSHIP OF SEA LEVEL MUON CHARGE RATIO TO PRIMARY COMPOSITION INCLUDING NUCLEAR TARGET EFFECTS

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ABSTRACT

The discrepancy between the muon charge ratio observed at low energies and that calculated using pp data is removed by including nuclear target effects. Calculations at high energies show that the primary iron spectrum is expected to change slope from 2-2.2 to 2.4-2.5 for energies $\geq 4\times10^3$ GeV/nucleon if scaling features continue to the highest energies.

1. Introduction

It is well known that there is a discrepancy between the observed muon charge ratio at low energies ($E_\mu \leq 100$ GeV) and calculations based on p-p data (e.g. Thompson and Whalley, 1977). At these energies, the nuclear physics and primary composition are thought to be fairly well known. A common procedure is to normalize the charge ratio at some energy (e.g. E_μ = 10 GeV).

In the present paper, it is shown that the inclusion of nuclear target effects removes the above discrepancy. Observations at high energies can then be used to derive reliable information on the primary mass composition up to about 10^5 GeV/nucleon.

2. Calculations Neglecting Nuclear Target Effects

Detailed calculations of the muon spectrum and charge ratio have been made assuming the continuance of scaling features to the highest energies. Initially, nuclear target effects were assumed to be negligible, and recent pp data have been used in the calculations.

From a comparison between calculations and spectrograph measurements of the muon spectrum, the primary nucleon spectrum has been derived in the form $I(E)dE = AE^{-\gamma}$, with A = 2.139 and γ = 2.7 ($70 < E < 10^4$ GeV). At this value of γ, the fractional energy moments for proton and neutron production in pp collisions were found to be Z_{pp}= 0.2622 and Z_{pn} = 0.0711 respectively, yielding an effective isospin retaining probability β_{pp} = 0.7867. Our analysis of pp data also gives δ_π= 0.225 and δ_K = 0.517 for the pion and Kaon positive excesses, repsectively, while for the primary proton excess, we take $\delta_0 = 0.74$ (Erlykin et al, 1974).

In the charge ratio calculations, we take for π and K production in neutron interactions :

$$Z_{n\pi^{\pm}} = Z_{p\pi^{\mp}} \quad , \quad Z_{nK^{+}} = Z_{nK^{-}} = \tfrac{1}{2}\,(Z_{pK^{+}} + Z_{pK^{-}})$$

The results of calculations are shown in Fig. (1). At E_μ = 10 GeV, the calculated charge ratio is R_μ = 1.3489 which is about 5.5% higher than the observed one. The difference is significant compared to the experimental error.

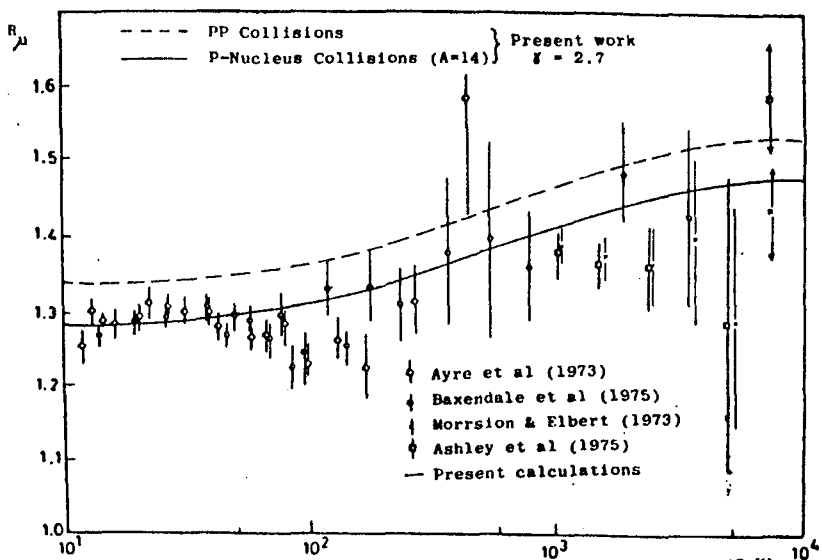

Fig. (1) Muon Charge Ratio at Sea level with and without Nuclear Target Effects (Scaling Model).

3. Calculations Including Nuclear Target Effects

The nuclear target effects have been included in the charge ratio calculations using a Glauber-Type model (Goned et al, 1985). For p-air we obtain Z_{pp} = 0.1094, Z_{pn} = 0.0347 and β_{pA} = 0.7591. We also take δ_π = 0.2025 and δ_K = 0.4653, which is 10% lower than the pp case. The results obtained for the charge ratio are also shown in Fig. (1). The calculated value at 10 GeV is R_μ=1.2794 which is in good agreement with the observed one (R_μ = 1.28).

4. Primary Mass Composition

Using charge ratio calculations with nuclear target effects, the neutron fraction in the primary beam (η)

has been derived from the data as shown in Fig. (2). The data below 100 GeV/nucleon correspond to direct measurements (Olejniczak et al, 1977). The curves correspond to the expected neutron fraction for different slopes γ_F of the primary iron component.

It can be seen that below about 4×10^3 GeV/nucleon, the charge ratio data are consistent with a slope γ_F = 2.0-2.2 compared to γ = 2.75 for protons and helium nuclei. If scaling continues above these energies then one should expect an increase to γ_F = 2.4-2.5. Other possibilities include significant scale breaking or a significant increase in the values of δ_π and δ_K in p-nucleus collisions.

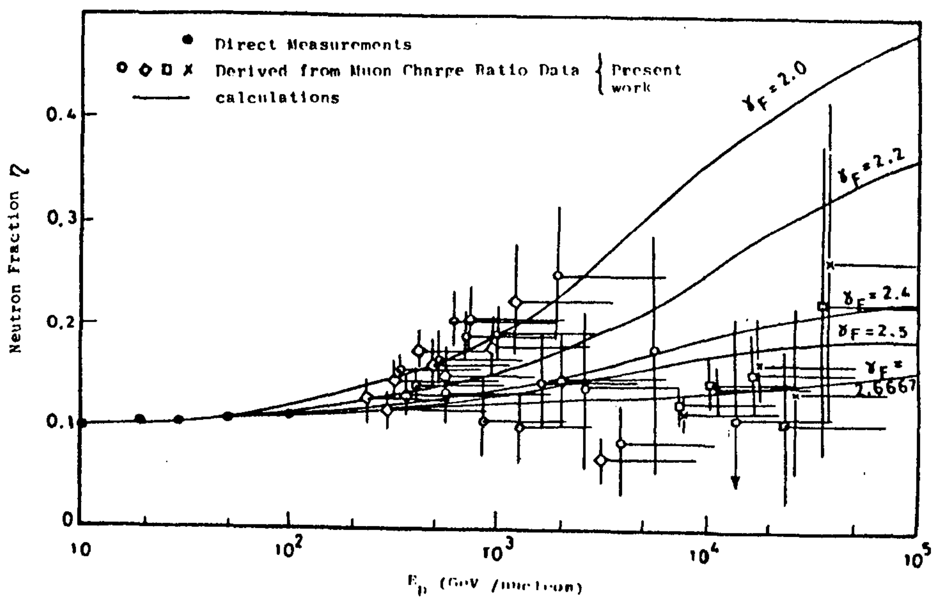

Fig. (2) The Neutron Fraction in the Primary Beam as a function of Primary Energy. γ_F is the differential exponent for the Fe group spectrum.

References

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