Muon content in horizontal air showers

1973 J. Phys. A: Math. Nucl. Gen. 6 L148

(http://iopscience.iop.org/0301-0015/6/10/004)

J. Phys. A: Math., Nucl. Gen., Vol. 6, October 1973. Printed in Great Britain. © 1973

LETTER TO THE EDITOR

Muon content in horizontal air showers

J P Hochart

Laboratoire de Physique Cosmique, Centre National de la Recherche Scientifique, Route des Gâtines, 91370 Verrières le Buisson, France

Received 15 August 1973

Abstract. The muon content in horizontal air showers is calculated for various assumptions about the origin of these showers. It is shown that the experimentally observed relatively high muon densities are not in clear contradiction with a conventional origin of the horizontal showers.

The problem of the origin of the horizontal air showers is one of the basic questions in the investigation of these showers. At least three possibilities have been considered so far. The showers may be due either to the photons produced via bremsstrahlung of high energy muons or may occur as a result of nuclear interactions of these muons. The second case would require a relatively fast increase of the photonuclear cross section; if that cross section remained constant, the showers produced by muon bremsstrahlung would dominate. The third possibility often discussed is that the showers are due to some sort of interaction (probably nuclear interaction) of certain hypothetical particles.

One of the interesting features of the horizontal showers is the fact that their muon content is relatively high (see for instance Böhm and Nagano 1973). The fact has often been quoted as an argument against a conventional bremsstrahlung origin of those showers. The validity of that argument is however far from obvious since, in any model, the showers should be initiated in two steps (the primary shower and the secondary shower produced deep in the atmosphere) and the so-called remnant muons from the primary shower can be detected together with the secondary shower.

In the present letter, results of calculations of the muon intensities due to both the muons from the primary showers and those from the secondary showers are given, assuming that the latter are produced as a result of nuclear interactions. The calculations were performed using the so-called standard model of EAS (see de Beer *et al* 1966). That model was applied to both the primary and the secondary showers. It should be pointed out that the density of the remnant muons is dependent on the assumed multiplicity law in the production of secondaries. The moderate increase of the multiplicity with energy assumed in the standard model ($n_s \propto E^{1/4}$) and consequently in the present considerations seems to be reasonable. A faster increase, recently suggested by Wdowczyk and Wolfendale (1973) would not essentially change our conclusions.

Results of the calculations performed are given in figure 1, where the ratio of the remnant muon density to electron density in the horizontal showers is presented for two zenith angles. The same ratio for the locally produced muons is also marked in the figure.

The energy threshold in both cases was taken at 3 GeV. The practical constancy of the latter ratio follows from the fact that the lateral distribution of the locally produced muons has, for the assumed threshold, approximately the same width as the

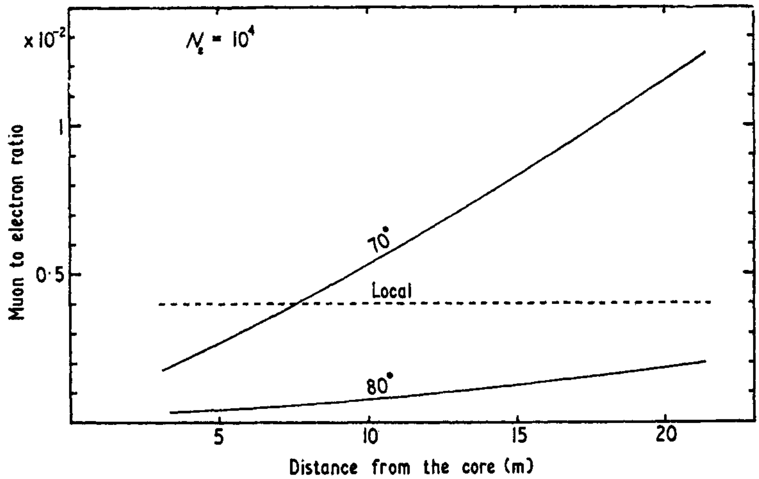

Figure 1. Remnant and local muon densities in horizontal air showers

distribution of electrons in the showers with age parameter close to unity. The lateral distribution of the remnant muons has been calculated taking into account the divergences due to the angle of emission at production, magnetic deflection and Coulomb scattering. The fast change of the remnant muon densities with the zenith angle is due to the rapid increase of the muon lateral distribution radius. It can be seen from the figure that the remnant muon densities at angles of the order of 70° even exceed the densities of the muons produced locally.

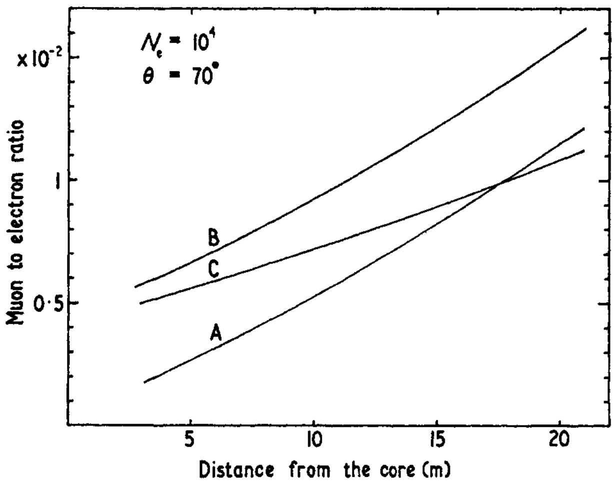

Figure 2. Expected muon densities in horizontal air showers for various mechanisms of the shower origin: A, Bremsstrahlung of a high energy muon; B, nuclear interaction of a high energy muon; C, 'X process'.

The data presented in figure 1 can be used in order to predict the density of muons in the horizontal showers for the three above quoted possible origins. The predictions for the case of bremsstrahlung and nuclear interactions of muons are straightforward, but those for the case of hypothetical particles have to be based on some arbitrary assumptions about the properties of the particles. For the purpose of the present work, the properties were taken according to the hypotheses of regenerated showers discussed by Wdowczyk and Zujewska (1972). The results are given in figure 2. From this figure it can be seen that a distinction between the three possible origins of the horizontal showers on the basis of their muon content is not possible in practice. Measurements of the muon lateral distribution and of the muon content as a function of zenith angle are necessary.

These conclusions tend to support the bremsstrahlung origin of the horizontal air showers since they remove the encountered difficulty of the apparently high muon content in those showers. The frequency of the horizontal showers, as was shown earlier by Kiraly *et al* (1971), can be explained by using an acceptable energy spectrum of muons.

The author is grateful to Dr J Wdowczyk for pointing out the interest of the problem and for his advice and to Professor R Maze and Professor A Zawadzki for many helpful conversations regarding this work. He wishes to thank Professor A W Wolfendale for his comments.

References

Böhm E and Nagano M 1973 *J. Phys.* A: *Math., Nucl. Gen.* **6** 1262–84
De Beer J, Holyoak B, Wdowczyk J and Wolfendale A W 1966 *Proc. Phys. Soc.* **89** 567–85
Kiraly P, Thompson M G and Wolfendale A W 1971 *J. Phys.* A: *Gen. Phys.* **4** 367–76
Wdowczyk J and Wolfendale A W 1973 *J. Phys.* A: *Math. Nucl. Gen.* **6** 1594–611
Wdowczyk J and Zujewska E 1972 *J. Phys.* A: *Gen Phys.* **5** 1514–23