JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-III, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-5-6. The Momentum Spectrum of Cosmic Ray Muons at a Zenith Angle of 80°*

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Introduction

It was pointed out by Jakeman (1956) that the sea level flux of muons of energy above 400 Gev at zenith angles approaching 90° should be considerably greater than the vertical flux of such particles. This is because at large zenith angles the atmosphere is more tenuous where interactions of the primary cosmic rays take place than in the vertical direction, with the result that there is an increased probability of π-μ decay rather than interaction. Thus if one wishes to study high energy muon interactions it would appear to be better to use muons arriving at large zenith angles.

A further point of interest is that information can also be obtained on the production of particles other pions in high energy collisions (>100 Gev) produced by the primary cosmic ray particles near the top of the atmosphere from a knowledge of the vertical spectrum at sea-level and the spectrum at a large zenith angle. Such an analysis has been carried out by Pak *et al* (1960) and Allen and Apastolakis (1961) who find that in the range of muon energies at sea-level of 1 Gev to 100 Gev the results are not inconsistent with a pion origin of the sea-level muons.

Experimental Arrangement

The apparatus (Fig. 1) consists of 3 trays of geiger counters *A*, *B* and *C* at the detecting levels, and a solid iron magnet. The magnet is that described by O'Connor and Wolfendale (1960). Each tray contains 8 counters of sensitive length 60 cm. Using 3 fold coincidence circuits the rate of events A_1, B_1, C_1 (8 channels), A_1, B_1, C_2 (7 channels), A_1, B_1, C_3 (6 channels) and A_1, B_1, C_4 (5 channels) were measured separately for both directions of the magnetic induction (14 K-gauss in the iron). Particles are accepted with zenith angles between 81°48′ and 78°28′, the axis of the apparatus pointing in a direction 55°36′ east of north. The opening angle of the telescopes in this plane is ±14°30′.

Extensive air showers which triggered the apparatus were rejected by requiring that only one counter in each of the trays, *A*, *B* and *C* was discharged for an event to be accepted. This also rejects a small percentage of muons which produce knock-on electrons in the iron and hence give rise to two particles traversing tray *C*.

Results

The observed rates of events have been converted into an approximate differential

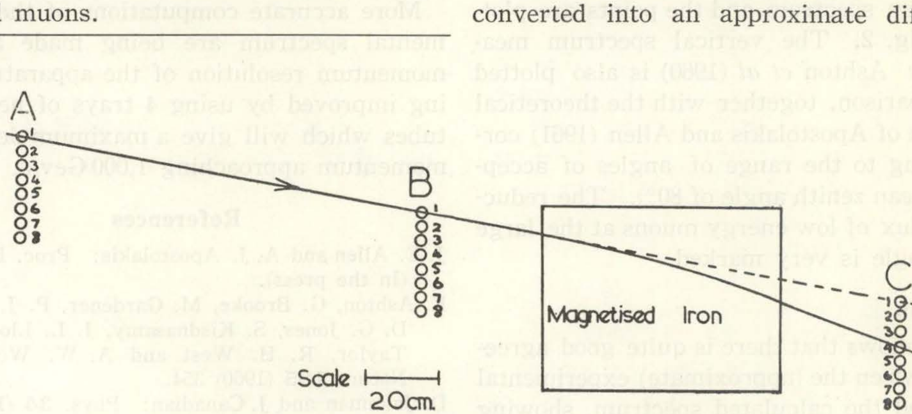

Fig. 1.

* This paper was combined with III-5-21 and presented by A.W. Wolfendale.

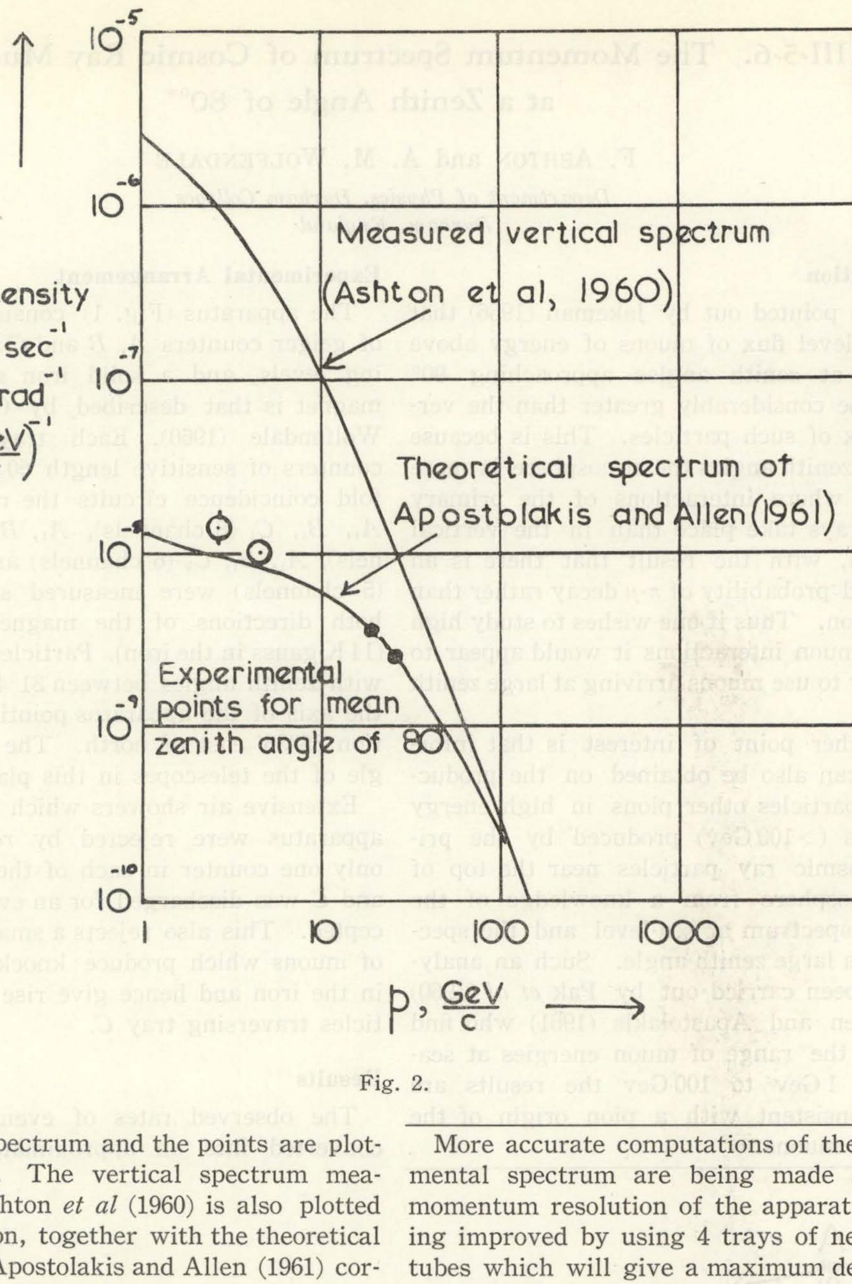

Fig. 2.

momentum spectrum and the points are plotted in Fig. 2. The vertical spectrum measured by Ashton *et al* (1960) is also plotted for comparison, together with the theoretical spectrum of Apostolakis and Allen (1961) corresponding to the range of angles of acceptance (mean zenith angle of 80°). The reduction in flux of low energy muons at the large zenith angle is very marked.

Conclusion

Fig. 2 shows that there is quite good agreement between the (approximate) experimental points and the calculated spectrum, showing that the interpretation of the mechanism of propagation of the particles through the atmosphere is essentially correct.

More accurate computations of the experimental spectrum are being made and the momentum resolution of the apparatus is being improved by using 4 trays of neon flash tubes which will give a maximum detectable momentum approaching 1,000 Gev/c.

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