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MEASUREMENT OF THE ATMOSPHERIC MUON SPECTRUM FROM 20 TO 2000 GeV

Michael Unger
DESY Zeuthen, Germany
for the L3 Collaboration

ABSTRACT

The atmospheric muon spectrum between 20 and 2000 GeV was measured with the L3 magnetic muon spectrometer for zenith angles ranging from 0 to 58 degrees. Due to the large data set and the good detector resolution, a precision of 2.6% at 100 GeV was achieved for the absolute normalization of the vertical muon flux. The momentum dependence of the ratio of positive to negative muons was obtained between 20 and 630 GeV.

1 Introduction

Atmospheric muons are amongst the final products of primary cosmic ray induced air shower cascades. A precise measurement of the ground level muon flux can therefore be used to test the understanding of the primary cosmic ray flux and the hadronic interactions involved in the production of the muons' parent mesons. Moreover, it provides a crucial test for theoretical neutrino flux calculations, because each muon is produced with an accompanying muon neutrino.

Here a new measurement of the atmospheric muon flux is presented using the precise muon spectrometer of the L3 detector [1] located at the LEP accelerator at CERN, Geneva. During the analysis special attention was given to the precise determination of all relevant detector and environmental parameters needed to convert the raw data distributions to an absolute surface level flux. Due to the large amount of available statistics, extensive studies of the residual systematic uncertainties were possible.

2 Experimental Setup

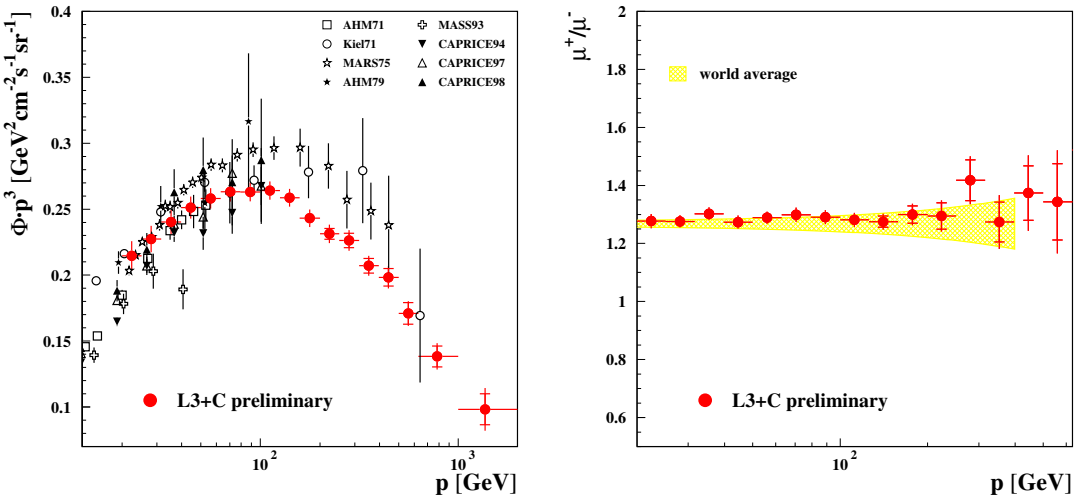
The momentum distribution of atmospheric muons is measured with the extended L3 setup known as L3+C [2]. It is located 450 m above sea level and shielded from the hadronic and electromagnetic air shower components by a 30 m thick molasse overburden. The muon momentum is measured with the L3 muon spectrometer, which is situated inside a large magnetic volume of 1000 m^3 at a field of 0.5 T. A 202 m^2 scintillator array was installed on top of the detector to record the arrival time of the muons. With this arrangement a relative momentum resolution ranging from 2.2% at 20 GeV to 52% at 2000 GeV is achieved. Being equipped with a trigger and data acquisition system independent of the normal L3 data taking, L3+C recorded $1.2 \cdot 10^{10}$ atmospheric muon triggers during its operation in the years 1999 and 2000.

3 Analysis

In total $2 \cdot 10^7$ high quality events are used in the muon spectrum analysis. The geometrical acceptance of the detector as well as the energy loss in the molasse overburden is calculated with a simulation of the L3+C setup and its surroundings. The detector efficiencies are determined from the data itself as a function of time, charge, momentum and zenith angle. The raw event distributions at the detector level are deconvoluted taking into account the detector resolution and the stochastic energy loss in the molasse. The systematic uncertainties of the muon flux and charge ratio measurement are studied by investigating the stability of the results with time and azimuth angle and under the variation of the selection cuts.

4 Results

The L3+C vertical muon spectrum is shown in figure 1(a) along with previous measurements [4] providing an independent absolute normalization. The best precision is achieved around 100 GeV, where the total error amounts to 2.6%. At lower energies uncertainties of the molasse overburden get important, whereas at high energies the statistical error dominates. The measured vertical charge ratio is compared to an average [3] of previous measurements in figure 1(b). It is worthwhile pointing out, that the total error of one zenith angle bin from this experiment is compatible with the error from the average of all previous experiments. Both, muon flux and charge ratio were measured as function of the zenith angle from 0 to 58 degrees. Their relative angular dependence is found in good agreement with the prediction from an air shower simulation [5] of atmospheric muons.



(a) *Muon flux* (b) *Charge ratio*

Figure 1: *The L3+C vertical muon flux and charge ratio compared to previous measurements [3, 4]. The inner error bar denotes the statistical error, the full error bar is the total error.*

References

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