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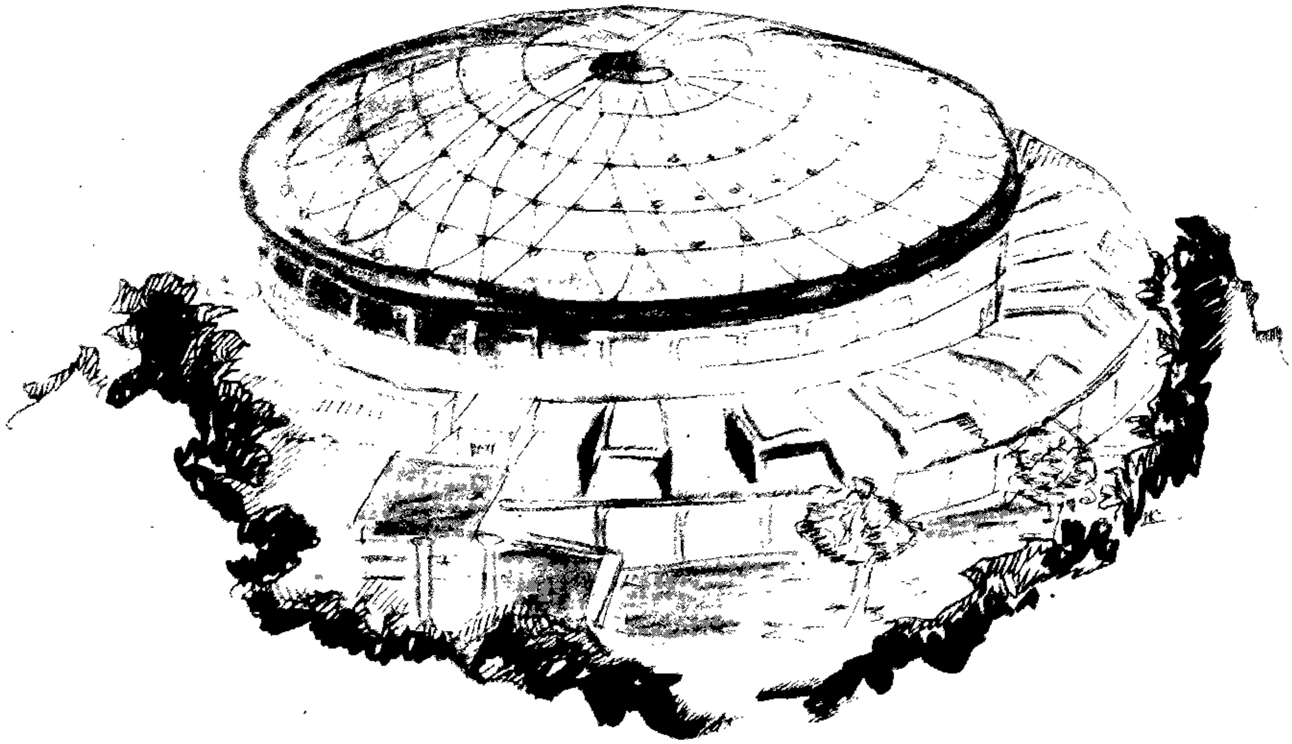

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Ground Level Observation Of Electrons, Positrons and Protons

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ABSTRACT

Analysis of the energy spectra of electrons and protons was carried out using ground data recorded in Prince Albert, Canada by the MASS experiment. We present the preliminary results on the energy spectra at an atmospheric depth of 945 g/cm^2 in the momentum interval 0.125 to 2.5 GeV/c for electrons and 3.7 to 20.0 GeV/c for protons.

1. INTRODUCTION

The observed cosmic ray spectra at ground level result from the propagation of primary cosmic rays in the atmosphere. This radiation consists mainly of weakly interacting muons. Most of the protons at ground level are the surviving fraction of the primary nucleons after ~ 11 interaction mean free paths; the electrons result from cascade processes in the atmosphere. An accurate determination of the spectra of these components gives information on the physical processes involved in the propagation and on the composition of the primary component. It also provides a standard source for the calibration of detector systems. Only a few attempts have been made in the past to measure their spectra at sea level. In the experiment described here, we used a superconducting magnet spectrometer, which was also deployed to study the primary and secondary cosmic rays at the top of the atmosphere (Basini et al, 1991 & 1993; Grimani et al, 1993) and muon component during the ascend of the balloon (Circella et al, 1993). We compare our observed spectra on proton and electron components with other experimental results and with theoretical calculations.

2. EXPERIMENT

The MASS apparatus consisted of a magnet spectrometer with multiwire proportional chambers (MWPC), scintillators, a gas Cherenkov detector and a calorimeter, to measure respectively, the rigidity and sign of charge, charge and time of flight, velocity and shower profile. This magnetic spectrometer was described by Golden et al (1991) and the trigger criteria for recording events were given in De Pascale et al(1993). To briefly describe the detectors, the Cherenkov detector consisted of a segmented mirror to focus the Cherenkov light on four phototubes and was filled with a mixture of Freon 12 and Freon 22, having a threshold Lorentz factor of 23. The time flight device had 2 planes, each with 2 layers of scintillators separated by 2.4 m; an additional high resolution scintillator was used for charge measurement. The calorimeter consisted of 40 layers each with 64 brass streamer tubes; the alternate layers of tubes being perpendicular to each other. It had an effective depth of 0.75 interaction length for protons. This experiment was carried out in Prince Albert, which was located at 53N & 106E, and 600m above sea level. The data were recorded on August 30, 1989 for a period of about 17 hours. In the present analysis, we have restricted the energy interval for electrons from 0.125 to 2.5 GeV, and protons from 2.76 to 19.06 GeV.

3. SELECTION OF EVENTS

The selection criteria used for an event to have a good trajectory in the spectrometer were the same as those described in De Pascale et al (1993). The criteria used for selecting electron-positron events were similar to those in Basini et al (1991). After selecting singly ionizing particles, we applied signals from the Cherenkov detector and calorimeter for further analysis. Below 500 MeV, where the number of electromagnetic shower particle is small, we selected events accompanied by a Cherenkov signal corresponding to > 1 photoelectron; the accidental rate for such signal was only 5×10^{-4}. Between 500 MeV and 2.5 GeV we included additional calorimeter constraints as we were approaching the Cherenkov threshold for muons(2.4 GeV). We required that an event to show > 6 cells to be activated in the first nine planes of the calorimeter and that single cell activation should not be in more than 9 planes in a region of 5 cells around the particle trajectory projected from MWPCs. A total of 282 e^- and 199 e^+ were identified.

In the case of protons we selected singly ionizing events with positive curvature and with no Cherenkov signal. We also required that the calorimeter has multiple tracks in order to select proton interaction in the calorimeter. These events were examined visually for interaction vertex to confirm that the event is due to a proton. Proton selection was made in the restricted geometry as in the case of electrons (Basini et al, 1991). A total of 69 protons were identified. This number was corrected for non-interacting ones in the calorimeter. To look for any selection bias resulting from backward going secondary particles in to the MWPC, we divided the calorimeter into two sectors. We had 41 interactions in the upper half and on this basis we expected 28 in the in the lower half and we found 30 ± 5.5 which is in good agreement with the expectation.

4. RESULTS

The electron spectrum is shown in the lower part of Fig.

1. In computing the flux, the geometric factor was estimated to be 85.4 $cm^2.sr$ which decreases below 1 GV. The spectrometer efficiency for selecting good tracks was 0.69, which also decreases below 4GV, and we have taken care of selection efficiencies relating to Cherenkov, scintillator, tape reading and trigger (see De Pascale et al, 1993; Basini et al,1991).It appears that the spectrum below 0.3 GeV is steeper than it is above this energy. We are examining at this stage any bias due to the sharp decrease in the estimated geometric factor in these energy regions. For comparison, we have shown the measurements by Beuermann & Wibberenz (1968)corrected for the present altitude by the electron attenuation mean free path given by Daniel & Stephens (1974). We have also shown by solid curve, the theoretival estimate by Daniel & Stephens which falls in between the two experimental results. The e^+/e^- ratio is shown as a function of energy in the same figure and one can notice an excellent agreement with the theoretical expectation.

The estimated proton flux values are plotted in Figure 2. This spectrum can be represented by a powerlaw in momentum with a spectral slope of -3.0 ±.3 and in kinetic energy as

$$J(E) = 5.5\ E^{-2.7 \pm 0.25}$$

proton / (m^2.sr.s.GeV). This spectral slope is in good agreement with that of the primary spectrum. For a comparison we have shown the measured flux values at sea

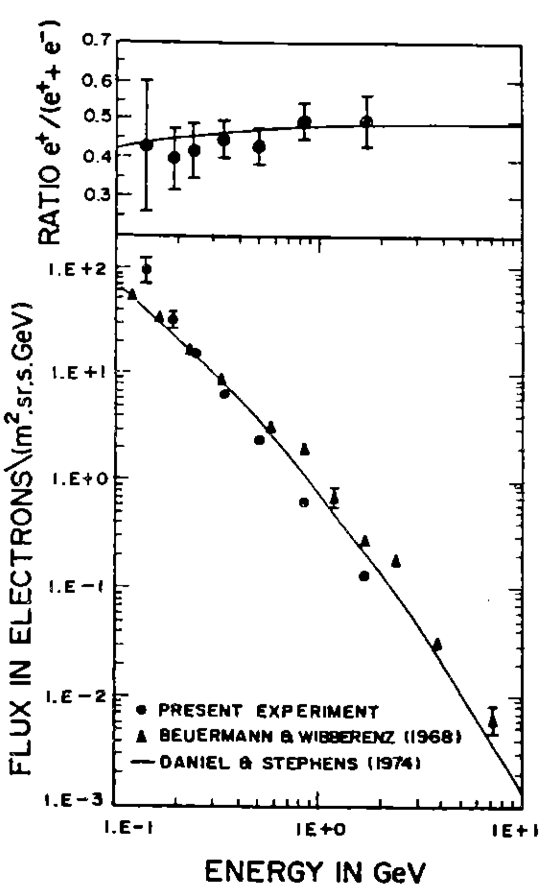

Fig.1 The energy spectra of e^+ $+e^-$ are shown in the lower part and the charge ratio in the upper part.

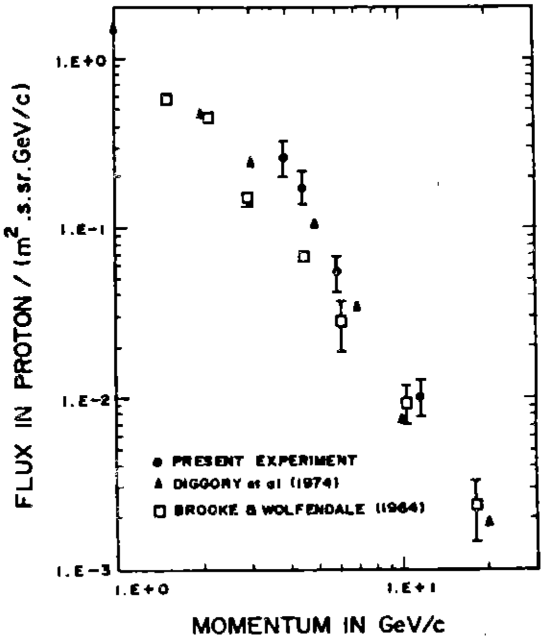

Fig.2 Proton spectrum is shown as afunction of momentum.

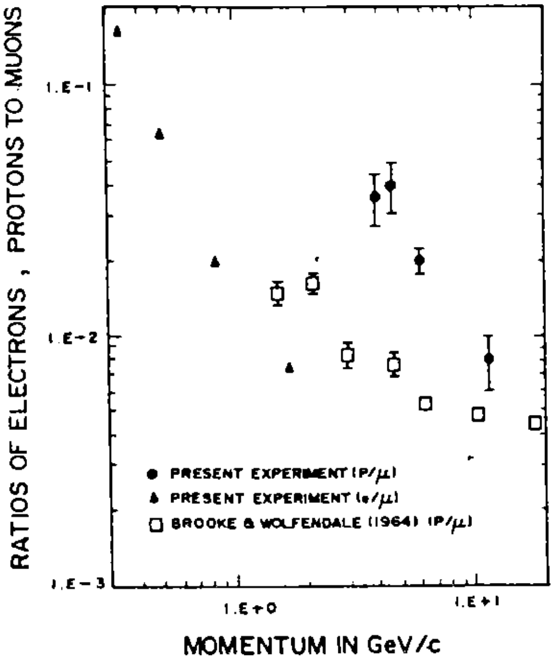

Fig.3 The ratios of electrons & prons to muons are plotted as a function of momentum.

level (Diggory et al, 1974; Brooke & Wolfendale, 1964) multiplied by exp (85/120) to elevate to the present depth of 945 g/cm**2. One can notice that our flux values are higher than the earlier measurements.It may be pointed out that in the earlier measurements, the flux values were obtained by normalizing the integral muon flux measured in the same experiment to some standard values, while we determined the absolute flux values. The ratios of protons to muons are plotted in Figure 3. It can be seen here that there is a noticeable difference between our results and those of Brooke & Wolfendale. Since our spectral slope is in agreement with the primary spectrum and that the measured muon spectral shape flattens below about 30 GeV/c, we believe that our proton measurements are reliable. It may be pointed out that the muon spectrum obtained by us is in excellent agreement with other measurements and with theoretical expectations (De Pascale et al, 1993). Therefore, we conclude that either the proton flux or the muon spectrum below 20 GeV/c, measured by Brooke & Wolfendale could be in error. It will be interesting to extend the proton spectrum to lower energies to look for the effect of ionization, which flattens the spectrum below 2 GeV/c. We also show the electron to muon ratio as a function of momentum in Figure 3 in the region from 0.3 to 2.5 GeV/c and it can be seen that the soft component at ground level contributes more than 10% of the radiation below 200 MeV/c, but decreases to < 1% above 1 GeV/c.

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