COMPARISON OF THE ENERGY RESPONSE OF AN IONIZATION SPECTROMETER FOR PIONS AND PROTONS*

W.V. Jones and S.D. Verma

Department of Physics and Astronomy,
Louisiana State University,
Baton Rouge, Louisiana 70803 USA

An ionization spectrometer consisting of a sandwich of iron absorbers and plastic scintillation counters was used to measure the energy of pions and protons in the interval 10-1000 GeV. For the limited energy interval of 10 to 40 GeV, pions and protons were identified by an air cerenkov counter. Interactions in carbon were studied in a multiplate cloud chamber placed between the cerenkov counter and the spectrometer. Knowledge of these interactions has been used in conjunction with a Monte Carlo simulation of the cascade process to study differences in the response of the spectrometer to pions and protons.

1. Introduction. Pioneer work was done by Grigorov, et al. (1959) and Ramana Murthy, et al. (1960, 1963) on determining of the energies of hadrons by measuring the nuclear-electromagnetic cascades in a total absorption spectrometer (calorimeter). The first total absorption spectrometer (TAS) designed and operated by Ramana Murthy, et al. (1963) consisted of alternate layers of iron (as absorber) and plastic scintillator. The energies of nearly vertical incident hadrons were measured in the spectrometer in the energy range of a few GeV to a few hundred GeV. Pions and protons were identified by an air cerenkov counter. This identification depended upon the accuracy of the energy measurement for pions and protons in the spectrometer. Since only a small fraction of the primary energy E of the particle was deposited in the scintillator material and observed, some method was needed to correlate the observed energy (E_o) to the primary energy (E). Ramana Murthy, et al. (1963) and Raghavan, et al. (1962) used the threshold property of the cerenkov counter to obtain E for each value of E_o. A comparison of the integral energy spectrum of nuclear active particles measured by the spectrometer and by a magnetic spectrograph provided the conversion of E_o to E in the 20 to 100 GeV energy interval.

Here we wish to obtain the relation between E_o and E using a model of nuclear-electromagnetic cascade utilizing Monte Carlo calculations (Jones 1969). The response of the spectrometer to primary pions and protons has been obtained using the Monte Carlo simulation of the cascade. This calculated response is compared with the observed response.

2. Experiment. The data utilized were obtained in an experiment consisting of an air cerenkov counter (Subramanian and Verma 1960, 1966) a multiplate cloud chamber and a total absorption spectrometer (Lal et al. 1962; Raghavan et al. 1962). In this experiment interactions of pions and protons in carbon (located inside a multiplate cloud chamber) were studied. For each interaction

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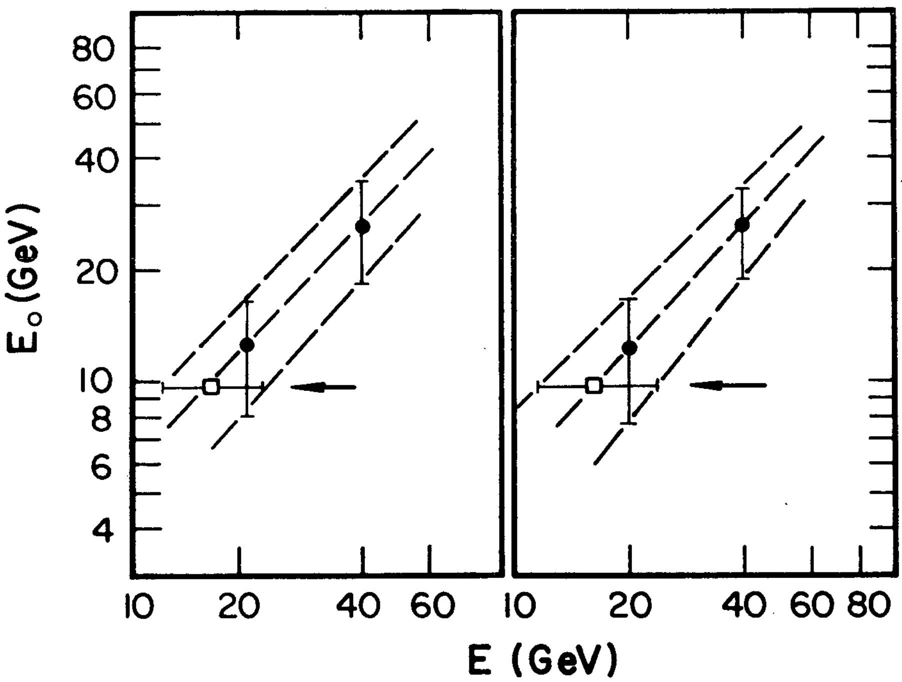

Fig. 1

angular distributions of the charged secondaries and the gamma rays produced in the decay of neutral pions were observed. The energy of each gamma ray was also measured by observing the electromagnetic cascades produced in the chamber. The energy E_0 observed in the spectrometer was obtained by summing the signals from all the scintillation detectors. The energy range of E_0 for the 13 proton and 10 pion events considered here is from 9 to 20 GeV.

3. Calculations. Monte Carlo simulations have been carried out for each observed event being considered, whether pions or protons, for a fixed incident energy of 20 GeV. The calculations required that each incident particle undergo its first interaction in the carbon. The observed number and angles of each charged secondaries and gamma rays, and the energies of the gamma rays were used in simulating the first interaction. The subsequent development of the cascade in the spectrometer was simulated by a Monte Carlo cascade model (Jones 1969). In these calculations the observed energy E_0, the energy lost by heavily-ionizing fragments from nuclear disintegrations, and the energy lost through the sides, bottom and top of the apparatus were recorded. The sum of these energy modes was checked to be equal to the primary energy E of the incident particle. The standard deviation σ of E_0 was also obtained from statistics of 250 calculated events for each observed event. These calculations were repeated for 40 GeV incident energy. The values of E_0 and its standard deviation σ were plotted against E for two events in Fig. 1. Circles are calculated values and squares the observed. The primary energy E and the corresponding σ for the observed events were obtained as illustrated in the figure using necessary interpolations and/or extrapolations. The calculation errors are about 20%.

In Fig. 2 are plotted E_0 vs. E for pions and for protons. Within the calculation errors there seems to be little difference between the E_0 vs. E relationship for pions and for protons. However, the slopes of the lines seem to be clearly different. These slopes are 1.5 ± 0.1 and 1.7 ± 0.2, respectively. The value of the slope (conversion factor) used by Ramana Murthy et al. was 2 for both pions and protons, and the error in energy estimation was about 30%.

4. Summary. The present calculations indicate that the conversion factor to obtain the primary energy from the energy observed in the spectrometer is somewhat lower than that used by Ramana Murthy, et al. (1963). There is some indication that this factor on the average is different for pions and for protons. However, within the calculation errors this difference may not be very significant.

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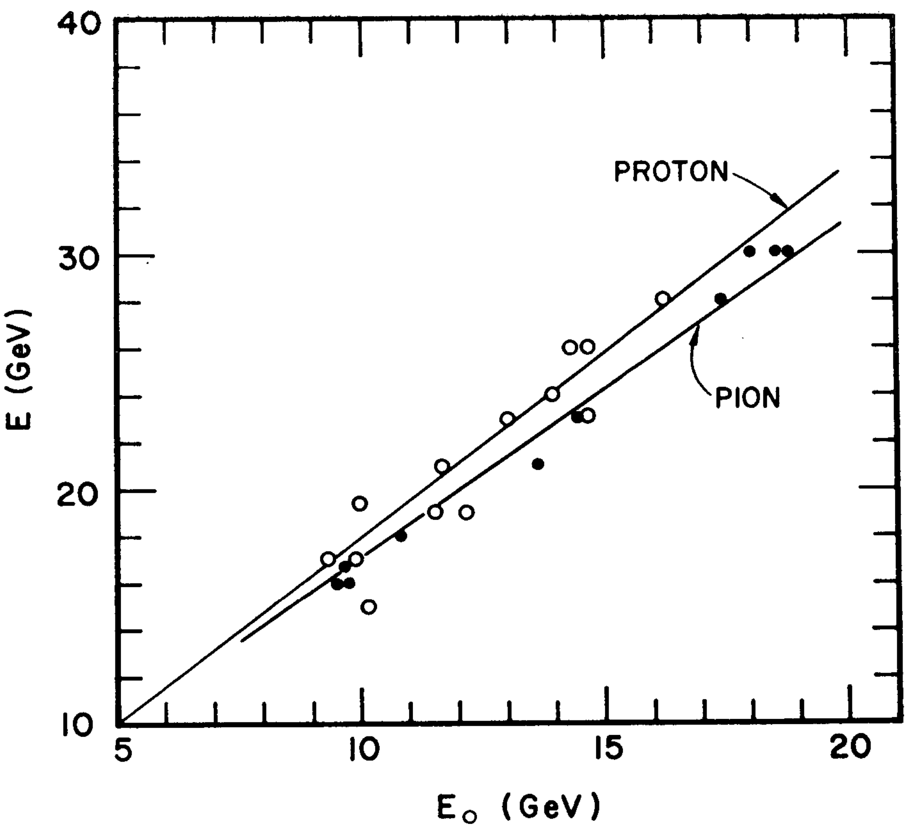

Fig. 2

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