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COSMIC RAY COMPOSITION MEASUREMENTS AT HIGH ENERGIES

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An ionization spectrometer consisting of a lead-scintillator sandwich was used to detect primary cosmic rays at balloon altitudes. Added to the ionization spectrometer were a five gap spark chamber for trajectory determination together with a Čerenkov counter and a scintillator for charge measurement. The instrument was flown in October, 1972, from Palestine, Texas. Preliminary results of that flight are presented here.

1. Introduction. The study of primary cosmic rays has long been confined to rigidities below ~15 GV, where the earth's magnetic field can be used as a rigidity analyser. Only for protons and alpha particles had results been reported for energies well beyond this point (1,2). However, recently first results for higher energy cosmic rays with charge $Z > 2$ have been obtained, (3,4,5,6); and there is evidence that flux ratios for different charge groups change with energy. In this paper we report the preliminary analysis of data obtained during a balloon exposure of a large-area cosmic ray detector. The balloon flight was made on October 12/13, 1972, from Palestine, Texas. The detector floated at 6.3 mb residual atmosphere for 14 hours. A second exposure had been planned, but was not carried out due to catastrophic failure of the recovery parachute at the termination of this flight.

2. Apparatus. A detailed description of the instrument will be given elsewhere. However, Figure 1 shows a schematic cross section of the detector. It consists basically of the following sections: first a Čerenkov counter and plastic scintillator, used for charge determination. The Čerenkov counter consisted of a 3/4" thick piece of "Pilot 425", which contains a wavelength shifter. This results in an increase in photomultiplier signal by 80% over UV transmitting plexiglass in the selected viewing mode. The scintillator was a 3/4" thick layer of "Pilot B". Underneath these detectors was a five-gap spark chamber with magnetostrictive readout for trajectory determination. Following the spark chamber was a target region (marked "C" in figure 1). During the flight this was occupied by alternating layers of styrofoam, lead, styrofoam and scin-

tillator. The lead layers (1 or 1.5 mm thick; total = 1 electron radiation length) were used to initiate electromagnetic cascades. It was planned that the styrofoam and lead would be replaced by carbon slabs during the second flight. Finally, below the target was located the spectrometer itself, consisting of alternating 2 radiation length thick lead slabs and scintillators. The electromagnetic cascades were enhanced and measured in this section.

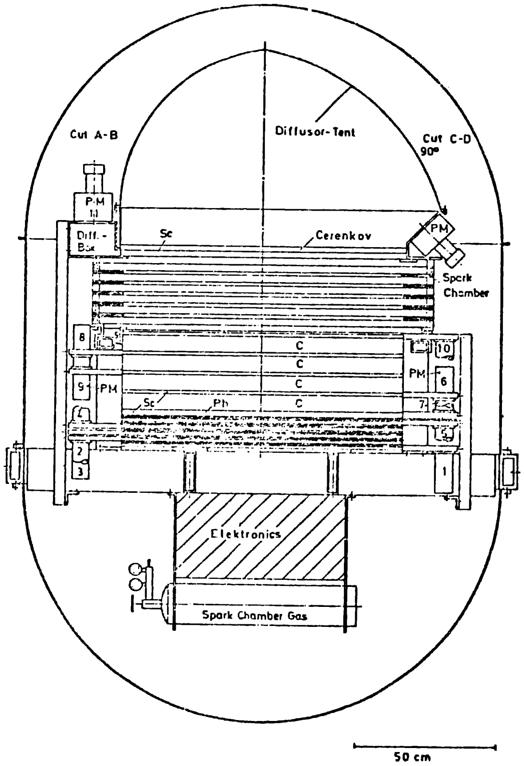


Figure 1: Schematic cross section drawing of the cosmic ray detector. The "egg" around the apparatus indicates the pressure vessel used during the balloon flight. For other explanations see text.

The sensitive area of the apparatus was 1 m^2, and at a depth of 65 cm this yielded a geometry factor of 1.0 m^2sr. The basic philosophy was to build a cosmic ray detector with the largest possible aperture. This was done at the expense of some energy resolution. Previous experience (2,7) showed that in order to obtain really good energy resolution one needs a very deep ionization spectrometer. One of medium depth will not yield significantly better energy resolution than a very shallow one. Therefore we built a very shallow one with the intent to determine only that part of the energy of an incident particle that is transferred to the π^o-electron-photon cascade in the first nuclear interaction. In this way the geometry factor was maximized with respect to the restricted weight capabilities of stratospheric balloons.

A small (30cm x 30cm) functional unit with the same absorber configuration was exposed at CERN to 10, 15, and 24 GeV/c protons, and at DESY to 1, 2, 4, 7 GeV/c electrons. This allowed the flight instrument to be calibrated at the lower end of the cosmic ray energy range.

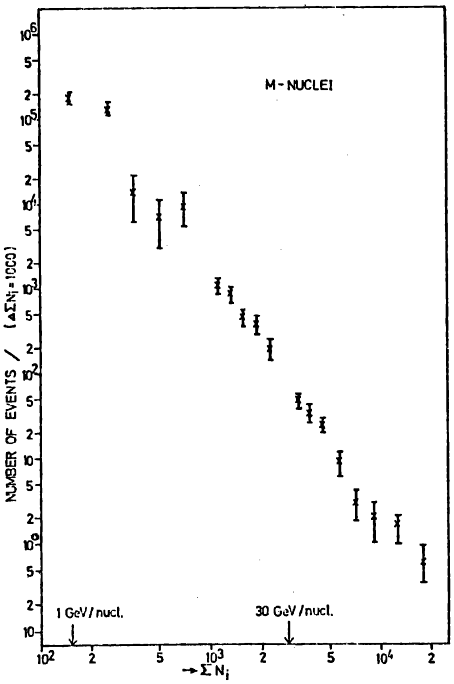
3. <u>Analysis and Results</u>. Cosmic ray charge groups are defined as follows in this paper: M: $6 \leq Z \leq 9$; LH: $10 \leq Z \leq 14$; VH: $23 \leq Z \leq 28$. A preliminary analysis of the data obtained during the flight gives spectral indices for the M, LH, and VH nuclei, assuming power law intensities. The first step in this analysis

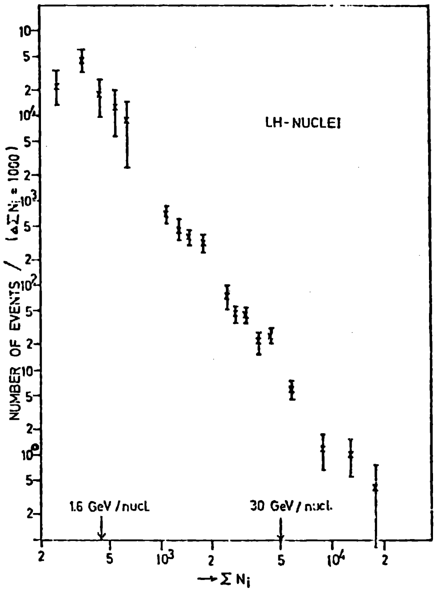
consisted of defining the charge groups using scatter plots of the Cerenkov counter vs. various scintillators. It was found that for the small signals, the scintillator directly beneath the Cerenkov counter gave the most consistant results, whereas for large signals the first scintillator beneath this was best. This was due apparently to the various responses when a nuclear interaction occurred within one of these counters. From these scatter plots, the various charge groups were identified. Due to a large primary electron contamination and the resulting spillover into the alpha particle region, no attempt has been made as yet to determine the spectra below that of Carbon. However, the position of the singly charged particle peak is fairly well defined, and has been used to determine the locations of the higher charge groups.

The energy of an individual event is determined by adding together the normalized signals from the five spectrometer scintillators. It was found in the accelerator calibrations and in previous work, (7), that this method gave the best indication of the primary particles energy. It has generally been assumed that this sum is proportional to the energy transferred to the instrument, however, it is not clear that this in turn is linear with respect to the primary particles' energy. In fact, for a shallow spectrometer the fraction of the primary energy detected decreases with increasing primary energy. This is obvious, because for sufficiently high primary energy, the cascade particles are able to escape from the bottom of the detector before they have deposited all of their energy. From Monte Carlo calculations, (8), extending up to 300 GeV/nucleon we have determined the approximately expected rate of change of deposited fractional energy. This was normalized at low energies using the accelerator measurements mentioned above. However, Monte Carlo calculations for heavy nuclei have not yet been carried out for this particular absorber configuration. Therefore, we have determined what we consider to be a lower limit for the energy corresponding to a particular measured signal. The real energy could be as much as a factor 2 higher.

Figure 2 shows examples of our data. The frequencies of events is plotted over an abscissa that shows units of measured signal in the instrument. Corresponding energies are indicated at a few places. Due to the nonlinear relationship between measured signals and primary energy, the spectra appear to be somewhat steeper than the primary spectra. The error bars represent only statistical errors. In order to avoid saturating the data with low energy events, these were taken at a reduced rate. Consequently the accuracy in this region is somewhat lower.

As of the deadline for papers for this conference we have not determined absolute fluxes of these various particle groups. However, assuming power law spectra at sufficiently high energies, spectral indices are obtained using a maximum





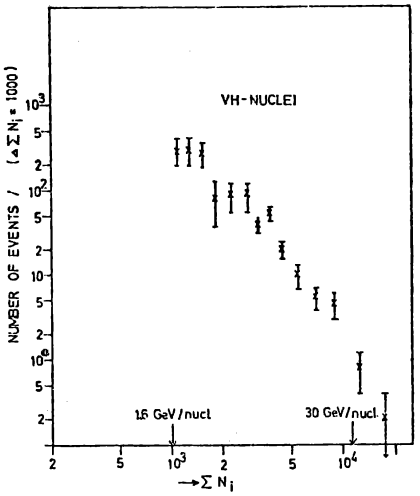


Figure 2: Differential Spectra for the M, LH and VH nuclei. The abscissas are given in terms of cascade particle numbers, and several corresponding energies are indicated.

likelihood procedure. These values are presented in Table 1, together with the associated statistical e errors, the number of events used for for determining the index, and the range of validity of the power law.

Table 1

Particle Group	No. of Events	Integral Spectral Index	above $\frac{GeV}{n}$
M	115	- 1.67 ± 0.14	29
LH	97	- 1.68 ± 0.17	14
VH	115	- 1.52 ± 0.15	5

Table 2 shows integral flux ratios above 29 GeV/nucleon for these same charge groups. For these ratios no correction for overlying matter has been attempted.

Table 2

Particle Groups	Ratio
M/VH	23 ± 10.5
M/LH	3.1 ± 0.6
LH/VH	7.4 ± 3.5

4. Conclusion:

At this stage in our data analysis we find flux ratios which are not completely consistant with those reported by other workers, (4,6). However, it should be noted that our results are preliminary, and we wish to substantiate these before drawing definite conclusions. We also find that the VH Spectrum is somewhat flatter than that for the M and LH nuclei, although not as flat as reported by some other workers (9).

The analysis is continuing, and additional results for other charge groups as well as improved statistical accuracy for the M, LH and VH nuclei will be published elsewhere.

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