MULTISTAGE IONIZATION AND CHERENKOV SYSTEM

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ABSTRACT

In order to observe chemical composition and energy spectra of cosmic ray particles ($6 \leq Z \leq 30$) in the energy range of 4 to 200 GeV/nuc and the mean isotopic compostion near the geomagnetic cut off of 10GV, Multistage Ionization and Cerenkov System (MICS) is designed. MICS consists of : (1) Cerenkov detectors with different refractive indices (CRD), (2) Parallel plate pulse ionization chambers, (PIC) and (3) multiwire proportional chambers, (PRC). A prototype model of MICS with a geometric factor of 1300cm^2 str was flown for 20 hrs at an altitude of 10g/cm^2 in May, 1980. Characteristics of these detectors were checked from the analysis of observed events and found to be enough for our objectives. Based on the results two types of MICS are under constraction. First one, 6300 cm^{2}str, is to measure mean isotopic compostion at 10 GV rigidity. Second one with 7300 cm^{2}str has a low pressure gas Cerenkov detector to get information about energy spectrum shape above 70 GeV/n.

1. Introduction

Study of cosmic ray energy spectrum and chemical compostion in the energy range of 10 to 1000 GeV/n will give us important clue relating to the source mechanism and the propagation in the galactic space.

In order to get more accurate information, development of Multistage Ionization and Cerenkov Spectrometer (MICS) has been in progress by our group since 1976. A prototype of MICS with 1300 cm^{2}str was flown for 20 hours at atmospheric depth of 10 g/cm^2 at geomagnetic cut off of 10 GV in May, 1980. The characteristics of the detectors are examined using the data taken during this flight, and proved to be enough for our objective.

Based on the results, two types of MICS are under construction. First one consists of two Cerenkov detectors (liquid and solid), a scintillation counter and four layers of position detectors having 6300 cm^{2}str will be flown in September, 1981. Main aim of this experiment is to observe mean isotopic composition of cosmic ray heavy nuclei with $6 \leq Z \leq 30$ above 10 GV rigidity. Second one is equipped with a low pressure gas Cerenkov detector instead of liquid Cerenkov detector in the first model. The system will be used to get information about the shape of the energy spectrum of heavy nuclei above 70 GeV/n.

In this report, the results of the MICS prototype experiment will be described in order to show the expected resolution in the future experiment. Also brief explanation of the design of two MICS detectors will be given.

2. MICS-Prototype

The MICS-prototype consists of two diffusion type Cerenkov detectors with different refractive indices (CRD), five parallel plate pulse ionization chambers (PIC) and four multiwire proportional counters (PRC) as shown in Fig 1. Lower Cerenkov radiator is acrylate plate of 50 cm diameter and 2 cm thick containing 10^{-4} Bis-MSB by weight as wavelength shifter (n=1.49). Upper Cerenkov radiator is liquid of n=1.27 put into an aluminum container of 50 cm diameter and 1.5 cm depth with teflon window of 190 μm. Each radiator is enclosed in a white light integration box, the Cerenkov light emitted out of which is detected by four 5" phototubes. The pulse ionization chamber consists of eleven parallel plates of 120 μm aluminized mylar of 50 cm diameter with 3.5 cm gaps. Output from five collecting electrodes are taken from the chamber and their pulse heights are analysed respectively. One layer of PRC is 25 multi anode proportional counter of 50 cm diameter and 1.5 cm thickness. The position resolution for particle track is ± 1 cm in the X and Y coordinates, respecively. The PIC and PRC are enclosed together in a pressurized container which is filled with 95 % argon and 5 % methane gas mixture at one atmos.

The charge spectra obtained by two Cerenkov detectors are shown in Fig 2. (details are given in OG1.1-5). Correction for the path length of particles through the CRD could not be made because of troubles in high voltage supply system for PRC. Charge resolution of Cerenkov detector was found to be consistent with the expected value (σ_Z = 0.23 at Z=10) taking account of the path length distribution.

Average (PICAV) and standard deviation (σ_5) of output pulse heights from five PIC's were derived for each event. Average values $\overline{\text{PICAV}}$ and $\overline{\sigma_5}$ are derived for groups of events identified as same Z by Cerenkov detector. As shown in Fig 3, $\overline{\text{PICAV}}$ and $\overline{\sigma_5}$ are found to be proportional to Z^2 and Z, respectively for $Z \geq 8$ at $E \geq 5$GeV/n. This fact clearly shows that the number of ion pairs generated in the gas of PIC's obey Gaussian statistics for $Z \geq 8$. Deviations from this dependence in Z<8 may be due to gradual increase of fluctuation by Landau effect.

3. HEIC (MICS-1981)

Two models of MICS were designed for experiments in near future based on the results of MICS -prototype experiment. In order to get enough statistics with minimum weight, simplification of the system was made. The first one to be flown in Sep. 1981 is called HEIC (High Energy Isotopic Composition detector) as shown in Fig 4. Two Cerenkov detectors in the center container are almost identical to those used in MICS-prototype except the diameter of 81 cm. To define the solid angle (± 60°), a plastic scintillation counter (SCI) of 100 cm diameter is added as third detector. Four layers of PRC's are placed above and below the center container to get informations about the incident direction of particles. Each layer of PRC consists of 96 proportional counters of 1 $cm^2 \times 100$ cm aluminum pipe filled with PR gas.

The effective geometrical factor of this system is 6300 cm^2str, so that $\sim$ 3 coincidence events / sec is expected for $Z \geq 4$ heavy nuclei at geomagnetic cut off rigidity of 10 GV. Pulse height data of CRD and SCI position information from PRC together with attitude data of the gondola will be telemetered to the ground for each coincidence event. By analysing these informations the mean isotopic composition for $Z \geq 6$ particles at 10 GV rigidity will be obtained with high accuracy.

4. HECO (MICS-1982)

The observation of the chemical composition and the energy spectra in the high energy region requests us a large area, large solid angle and light spectrometer with a threshold energy near 100 GeV/n. A low pressure gas Cerenkov detector fulfills this condition, since a gas Cerenkov detector filled with CO_2 at 0.25 atms has a threshold energy of 70 GeV/n. HECO consists of a solid Cerenkov detector (CRD), a gas Cerenkov detector (GCD), a plastic scintillation counter (SCI) and four layers, of PRC's is designed for this purpose as shown in Fig 5. The upper Cerenkov radiator is an acrylate plate of 150 cm diameter with 2 cm thick and is viewed with eight phototubes. The gas Cerenkov detector is a 0.5 mm thick aluminum container with a diameter of 150 cm and a length of 150 cm. The emitted Cerenkov light is viewed with 50 phototubes. CO_2 gas filled with an atmospheric pressure at the ground will be controled to leak out of the container keeping the pressure difference of less than 0.25 atmos. as the balloon acends. SCI and PRC's are similar to those used in HEIC but with larger dimension of 180cm $\times$ 180cm.

Expected integral flux of Fe nuclei relative to that at 5 GeV/n is plotted as the function of total number of photoelectrons detected by GCD phototubes in Fig 6. 10 % correction efficiency of Cerenkov light

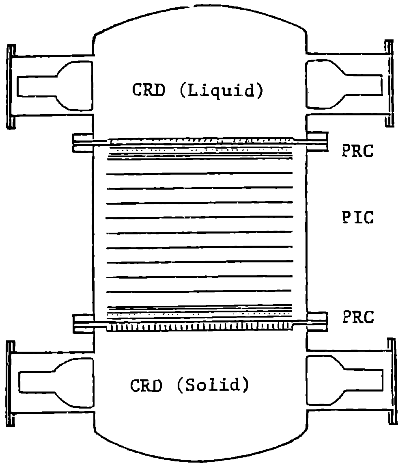

Fig. 1. MICS-Prototype
1300cm^2str 200kg

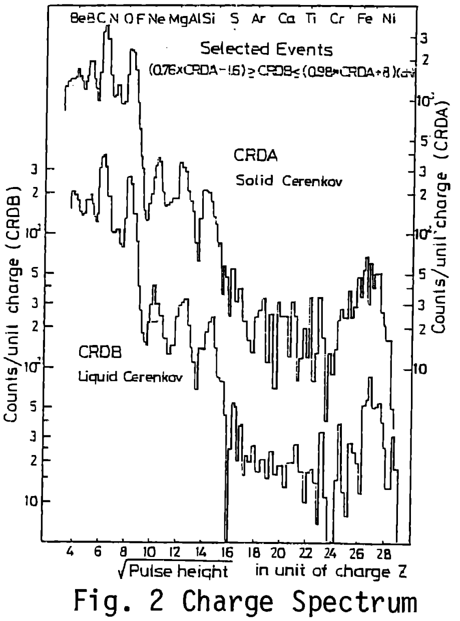

Fig. 2 Charge Spectrum

emitted in a path length of 1.5 m (0.25 atms CO_2 gas), together with 20% quantum efficiency of photocathode are assumed. The value of spectral index γ at $\sim$ 100 GeV/n can be determined with accuracy of ± 0.03 by 48 hours flight of this spectrometer.

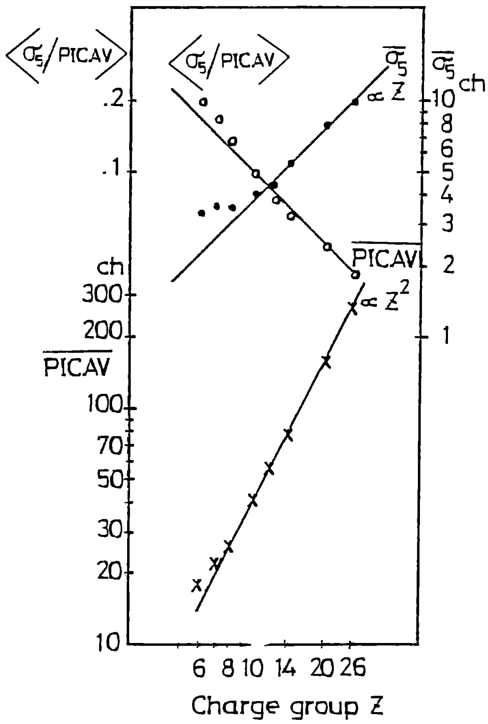

Fig. 3

HEIC(1981 Flight)

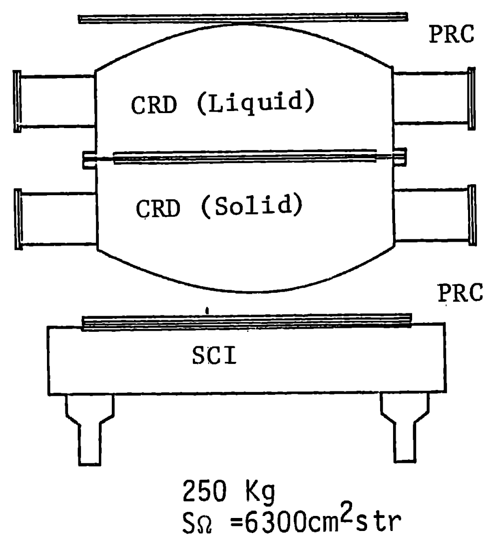

Fig. 4

HECO(1982 Flight)

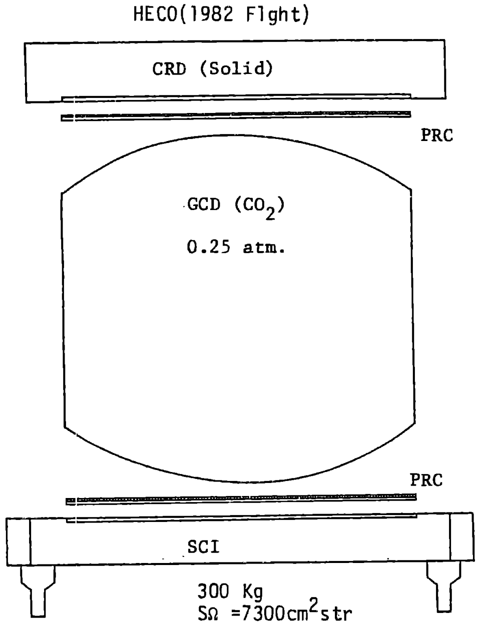

Fig. 5

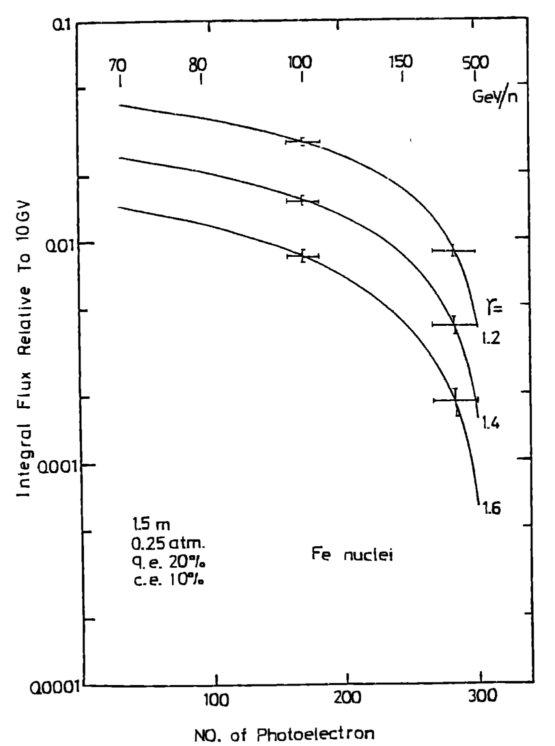

Fig. 6