Bursts in NaI(Tl) near Sea Level*

S. STANDIL
Department of Physics, University of Manitoba, Winnipeg, Canada
(Received June 29, 1954)

The spectrum of cosmic-ray events induced in a NaI(Tl) scintillation spectrometer has been observed near sea level. The high-energy bursts so observed are interpreted as due mainly to nuclear interactions in the crystal with an energy distribution given by the power law $N(E)dE \propto E^{-3.6}dE$. The attenuation length for the star-producing component in concrete is found to be 200 ± 25 g/cm^2.

THE differential distribution of energy releases or bursts due to cosmic radiation in an unshielded NaI(Tl) crystal near sea level (elevation 775 feet) has been observed during a period of 3000 hours. The experiment is similar to burst studies with ionization chambers,[1] differing in that a medium-Z solid detector is employed. The use of NaI has an advantage in that its density and constituent atomic numbers are close to that of photographic emulsions, hence comparison of results by the two methods is made easier.

Two scintaillation spectrometers were employed, each consisting of NaI crystals (diameter $3\frac{1}{2}$ inches, thickness 2 inches) mounted on DuMont K1198 photomultipliers. The amplified spectrometer pulses were lengthened and displayed by pen recorders. Energy calibration was in terms of a 2.6-Mev gamma ray, assuming linearity.

The observed distribution is given in Fig. 1. The feature A is due to singly charged relativistic particles, mainly μ mesons, passing right through the crystal.[2] Beyond about 100 Mev the distribution can be represented by a power law $N(E)dE \propto E^{-\gamma}dE$, with $\gamma = 3.6 \pm 0.2$. There is some deviation from this at very high energies, possibly due to extensive air showers. For reasons outlined below it is thought that almost all of the events >100 Mev are due to stars or nuclear interactions initiated in the crystal by the N component.

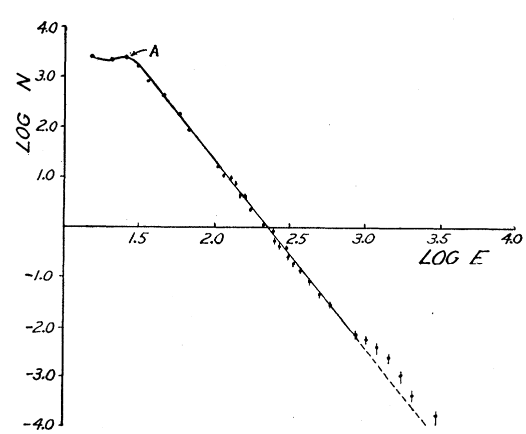

FIG. 1. N represents the hourly rate per 10-Mev interval and E is the energy in Mev. Standard deviations are indicated where they are appreciable.

Preliminary coincidence measurements indicate that less than 3 percent of the events greater than 100 Mev in one counter are accompanied by events of at least 20 Mev in the second counter when they are placed close together. Thus the contribution of events >100 Mev by showers originating outside the detectors is small. Further, charged cosmic ray particles just coming to rest in this size of crystal would not liberate sufficient energy to seriously alter the above interpretation. For example, protons just coming to rest in this detector would give pulses of energy from about 120 to 150 Mev.

George and Evans[3] give the frequency of stars with 3 or more prongs in emulsion to be 1.46 ± 0.07/cc day. For such 3-pronged stars Tidman and Hodgson[4] determined the mean total energy of the low- and medium-energy particles (ionization >1.5 minimum ionization) as 196 ± 18 Mev of which about 55 percent is taken by neutrons. Translating the above frequency figure to the NaI detector used here, one would then expect about 23 such events per hour. A frequency of this magnitude is found for events >140 Mev, indicating that this detector captures a large fraction of the energy liberated in such stars.

With the assumption that over a limited energy range the NaI detector captures a fixed fraction of the total star energy the distribution of star energies is then given by the power law above. This is not in agreement with the results of Barton *et al.*[5] who, using emulsions, also find a power law distribution with $\gamma = 2.6 \pm 0.1$. The reason for this discrepancy is not clear. It should be noted, however, that the present method gives a direct measurement of energy loss in the detector. The results of Barton *et al.* are obtained indirectly by determining the prong number distribution and using corrected data for total star energy *vs* prong number.

The above experiment has also been performed in a basement laboratory, the total thickness of concrete above the detectors being about 3 feet. The distribution is attenuated but similar to that in Fig. 1. Comparison of integral counting rates above 100 Mev gives an attenuation length of 200 ± 25 g/cm^2 for the star-producing component in concrete.

* Supported by the National Research Council of Canada.
[1] See for example, C. N. Chou, Phys. Rev. **74**, 1659 (1948); H. Carmichael and J. F. Steltjes, Phys. Rev. **93**, 913 (1954).
[2] A. Hudson and R. Hofstadter, Phys. Rev. **88**, 589 (1952).
[3] E. P. George and J. Evans, Proc. Roy. Soc. (London) **A63**, 1248 (1950).
[4] D. A. Tidman and P. E. Hodgson, Phil. Mag. **43**, 992 (1952).
[5] Barton, George, and Jason, Proc. Roy. Soc. (London) **A64**, 175 (1951).