Experimental Measurement of K^{40} True Coincidence Rate

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It is important to measure the rate at which the K^{40} in the ocean will cause true coincidences in the DUMAND sensors. A calculation of that quantity has been made[1], but an experimental verification of the result is highly desirable. Pending the possibility of ocean measurement, which may materialize next spring, it is worth considering a laboratory experiment from which the desired result can be obtained. Such an experiment was started some time ago, but never completed.

Consider a concentrated solution of a potassium source in water, contained in a glass bottle so that the Cerenkov light produced within the solution can escape. The emitted light is isotropic, and the average disintegration produces 43 Cerenkov quanta in the appropriate wavelength range[2]. How can we design a coincidence experiment, in which two PMT's independently view the source, and measure the probability of a single disintegration giving a true coincidence?

Let the number of disintegrations/sec in the source be N. Let Ω be the fractional solid angle subtended at the source by the photocathode of a PMT, and n be the number of Cerenkov photons emitted in a single disintegration. Then the probability that a single K^{40} disintegration in the source produce a count in the PMT – which we denominate its efficiency E – is given by $E=P(n,\Omega,\varepsilon)$, in which ε is the photocathode efficiency, and $P(n,\Omega,\varepsilon)$ is given by

$$P(n,\Omega,\varepsilon) = 1 - \exp(-n\Omega\varepsilon). \qquad (1)$$

The exponential is the probability of obtaining zero photoelectrons when $n\Omega$ photons strike a cathode of efficiency ε.

The probability of a coincidence from a single disintegration is given by

$$P_c = P_1P_2,$$

where the subscripts refer to the two PMT's. The net true coincidence rate N_c is then

$$N_c = NP_1P_2$$

where N is the number of disintegrations/sec in the source; we expect N to be about 2400/sec.

With n = 40 (assuming some losses within the source), and $\varepsilon = 0.25$, Eq. 1 becomes

$$P(n,\Omega,\varepsilon) = 1 - \exp(-10\Omega) \qquad (2)$$

In addition to the true K^{40} coincidences, the apparatus will also record cosmic-ray coincidences and random coincidences. The random coincidence background rate N_R is

$$N_R = 2R_1R_2\tau \qquad (3)$$

where R_1, R_2 are the individual counting rates and τ is the coincidence resolving time, which we take as 10^{-8}sec. If we use 8" EMI hemispherical-cathode PMT's, we estimate an individual background noise rate of about 3000/sec, since we must set the threshold to accept single-photoelectron counts.

The individual K^{40} counting rate is $N_s = NP_i$, and for the proposed source $N = 2400$/sec. At the solid angles we expect to use, not exceeding $\Omega = 0.01$, $P_i \sim 10\Omega$, so that $N_s < 240$/sec. The cosmic ray singles rates are small compared to these numbers; thus the total singles rates will probably not exceed about 3300/sec. The random coincidence rate is then

$$N_R < 2 \times 3300^2 \times 10^{-8} \cong 0.2/\text{sec}$$

The cosmic-ray background rate is likely to be of the order of 0.2/sec, and will vary as the separation of the PMT's changes. To keep it from dominating the coincidence rate, the solid angle should at least be equal to .005; this implies the distance from source to PMT should not exceed about four times the PMT diameter. With 5-8" PMT's, this is a convenient distance.

Fig. 1 illustrates the various rates to be expected.

REFERENCES

1. A. Roberts, DUMAND Note 81-20

2. A. Roberts, Proc. 1978 DUMAND Summer Study, Vol. 1, p. 139.

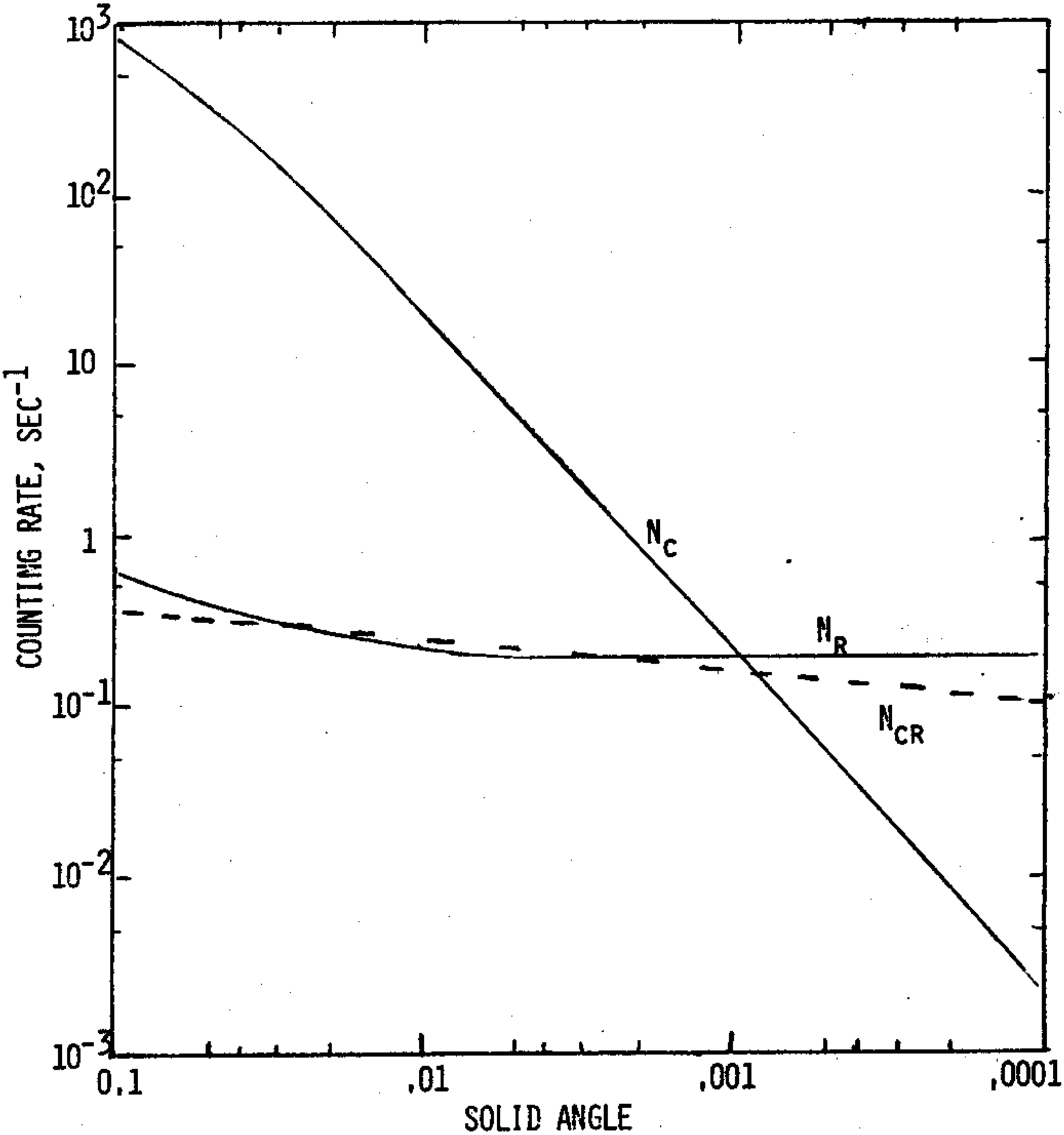

Fig. 1. Counting rates of true K^{40} Cerenkov coincidences, N_c, random coincidences N_r, and cosmic-ray coincidences, N_{cr}, as a function of the fractional solid angle subtended at the source by each of the PMT's. The variation of N_{cr} with solid angle is only a guess. Source strength is 2400 disintegrations/sec.