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A.C. Odian(+) and T. Yamagata(°): THE COLLECTION OF LIGHT FROM THIN LARGE AREA SCINTILLATORS(x).

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Abstract.

General rules for the efficient collection of light from thin large area scintillators are stated. Curves are shown for the experimental resolution of various counter designs.

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The present article is the outgrowth of finding that in many laboratories, the design of the optics for light collection from thin, large area scintillators can be considerably improved.

The development of the light collection system described here was done early in 1956 in preparation for the experiment on the Compton Effect on the proton(1). In that experiment, a two counters telescope was used behind a magnet to separate the recoil protons of the Compton effect from the background. These protons ranged in energy from 15-60 MeV in the various runs.

The development of the light collection system was made for the counter which was to give information on the dE/dx of the protons. This counter was 3/16" thick by 9" by 6.5". In order to get good uniformity, and collect as much light as possible from this counter, it was decided in the beginning to use two phototubes. The first design of the counter was as shown in fig. 1 with aluminium foil which was used as a reflector touching the scintillator and the lucite light pipes.

To test the resolution and the uniformity of this counter using hard cosmic rays, a 517 A oscilloscope was triggered by a coincidence between two small scintillators, one above and the other below the dE/dx counter. The pulses from the two phototubes of the dE/dx counter were sum

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(1) - Auerbach, Bernardini, Filosofo, Hanson, Odian, Yamagata, CERN Symposium 1956, 291 (1956)- T. Yamagata, Univ. of Illinois, Ph.D. Thesis (1956).

med and displayed on the sweep of the scope. Photographs were taken, and the films were analyzed for pulse height. The spectrum obtained is shown in Fig. 2. Since this spectrum had a non zero number of counts at zero pulse height, the efficiency for counting would be certainly less than 100%. It was therefore decided to try to improve on the light collection system.

The first change made is shwon in Fig. 3. Here, the aluminum foil reflectors which were in physical, but not optical contact with the scintillator and light pipes were moved apart to a separation equal to the 2" diameter of the phototubes used (5819'S).

Under the same conditions as before, the pulse height spectrum shown in Fig. 4 was obtained. This represented a considerable improvement. To push things even futher, a new counter was constructed as shown in fig. 5. The scintillator in this counter was thinner than before, namely 1/8" thick. To compensate for this loss of light, four phototubes were used. Also the design of the light pipe was modified. The pulse height spectrum from this counter is shown in Fig. 6. This was the counter used in the actual experiment.

All three of these pulse height spectra are fit, but somewhat poorly, by curves. The first two are fit by Poisson curves representing the production of 8 and 20 photoelectrons respectively. The curve for the final counter is the result of a conbination of Landau statistics with the fluctuations produced by 60 photoelectrons. In this case the experimental points lie above the curve at large pulse heights. This is probably due to the passage of two particles through the counter.

Two other counters with scintillators 5" x 7" by 1/32" thick were constructed with a geometry similar to Fig. 5. When 37 MeV protons passed through these counters, the pulse height spectrum of the sum of the 4 phototubes had about the same width at half maximum as that obtained by Gooding and Eisberg(2) for 37 MeV protons from a small scintillator 0.025" thick placed at the focus of a paraboloid of revolution and viewed by a phototube.

Physically the reason for the improvement in response resulting from the movement of the aluminum foil is that the fraction of light which is not total internally reflected is usually almost completely lost when the aluminum foil is close to the scintillator. This is due to the large number of reflections from the aluminum foil, and also to the long path length in the scintillator necessary for this light to get to the phototubes. On the other hand, when the aluminum foils are separated by a distance equal to the diameter of the phototubes used the number of reflections on the aluminum foil are greatly reduced, and the path of the light is mostly in air. Making the separation of the foils greater than the phototube diameter would make matters worse.

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(2) - T.J. Gooding and R.M. Eisberg, Phys. Rev. 105, 357 (1957)

Other counters with no lucite at all have been constructed when there was concern about Cerenkov light from relativistic particles traversing the lucite. These counters with air light pipes have pulse height maxima somewat less than those with lucite light pipes.

In summary we find that the following considerations help in the collection of light from thin large area scintillators.

1) The aluminum foils used as reflectors should have a spacing about equal to the diameter of the phototubes used.
2) As many tubes as will fit along an edge should be used.
3) If it is possible to view only one edge of the scintillator, the separation of the aluminum foils should taper from a bit more than the thickness of the scintillator at the far end, to the diameter of the phototube on the near end.

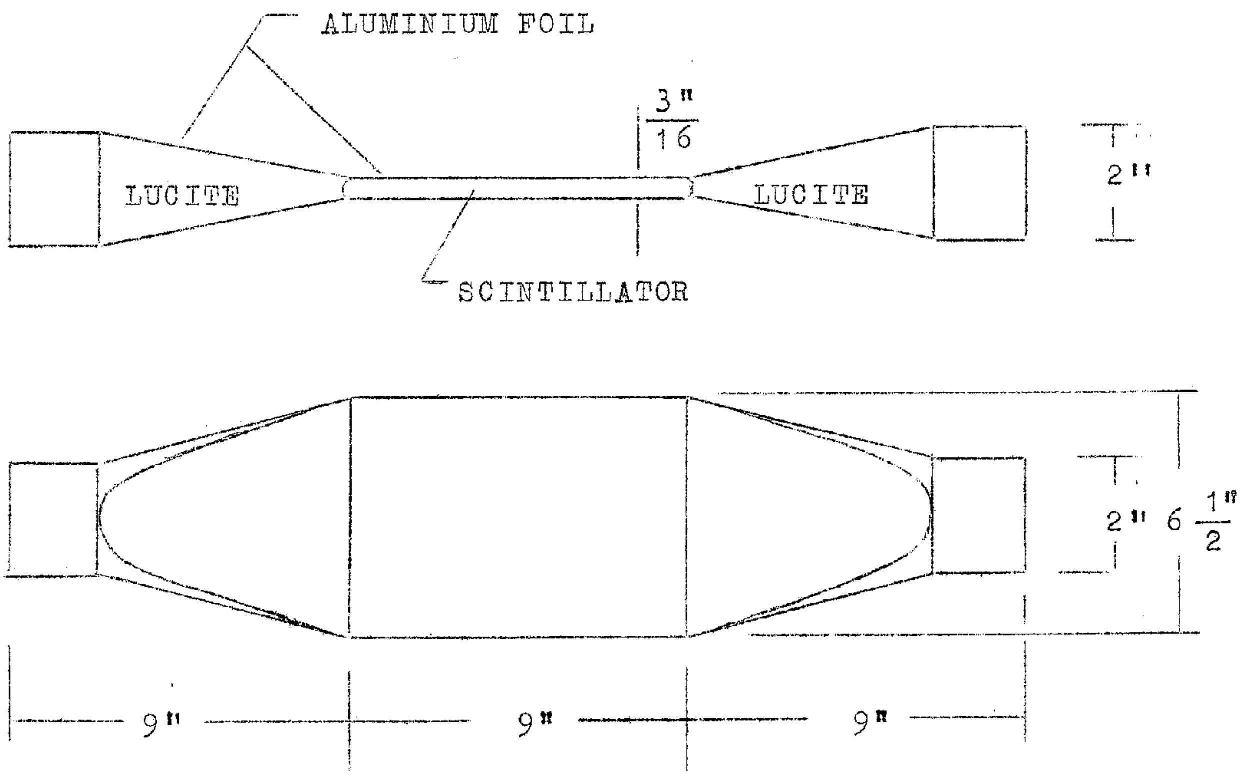

FIG. 1 - DESIGN OF THE FIRST PROTON COUNTER. THE ALUMINUM FOIL REFLECTORS WERE PHYSICALLY (NOT OPTICALLY) IN CONTACT WITH SCINTILLATOR AND LIGHT PIPES.

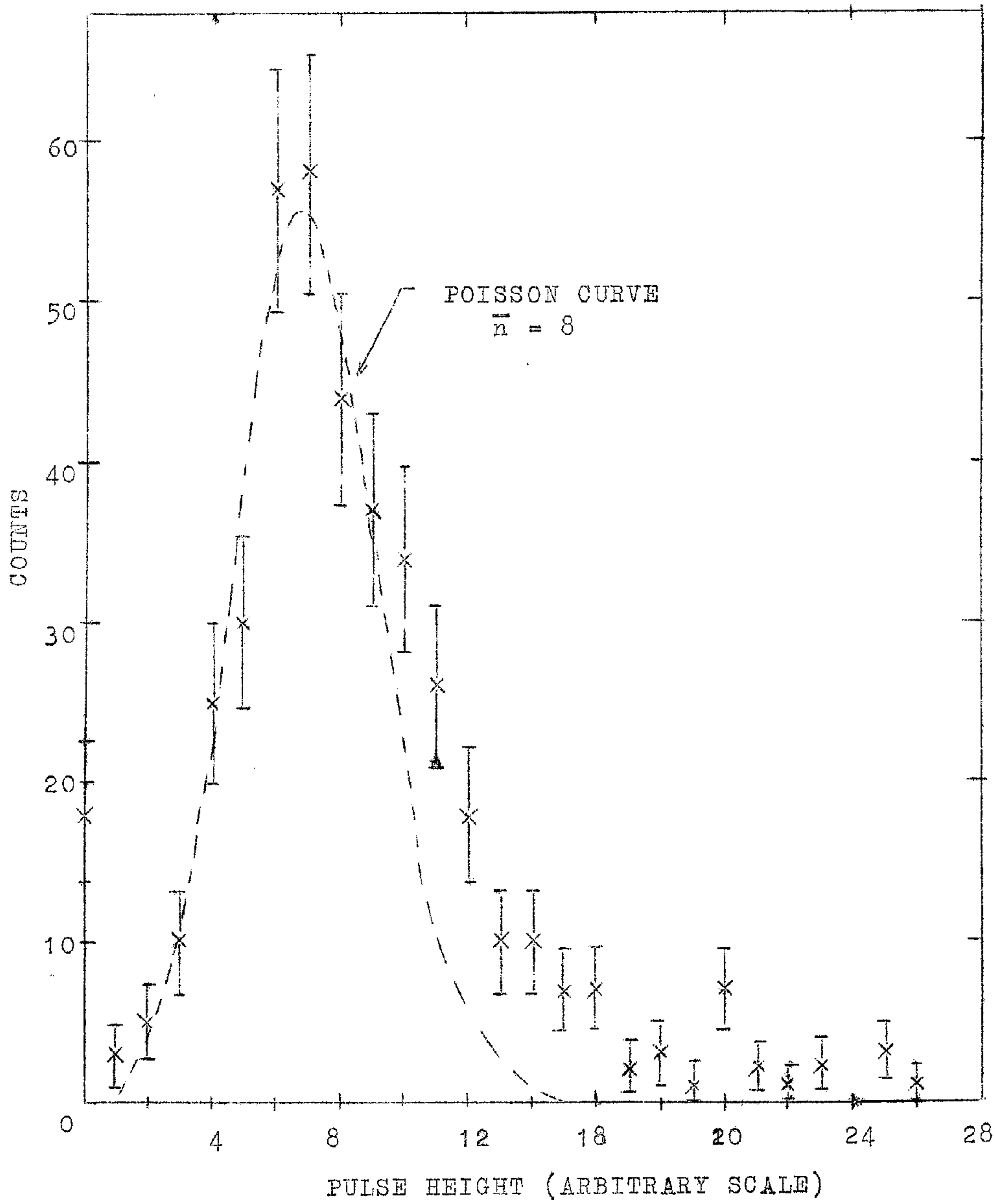

FIG. 2 - COSMIC RAY PULSE HEIGHT SPECTRUM OBTAINED BY THE COUNTER SHOWN IN FIG. 1. FIT WAS MADE WITH POISSON DISTRIBUTION. THE BEST FIT WAS OBTAINED WITH $\bar{n}$ = 8 AND SHOWN AS DOTTED LINE IN THE GRAPH.

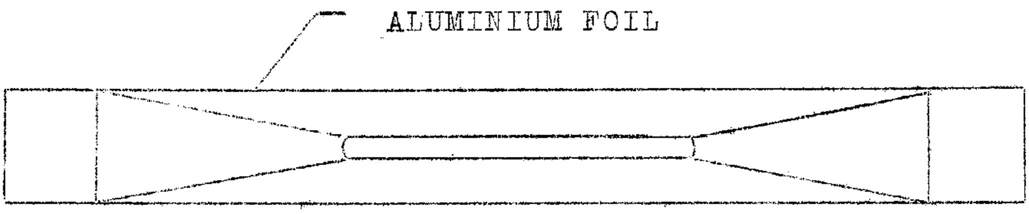

FIG. 3 - IMPROVEMENT ON THE FIRST PROTON COUNTER. ALUMINUM FOIL REFLECTORS WERE MOVED APART FROM THE SURFACE OF SCINTILLATORS GIVING AIR SPACE.

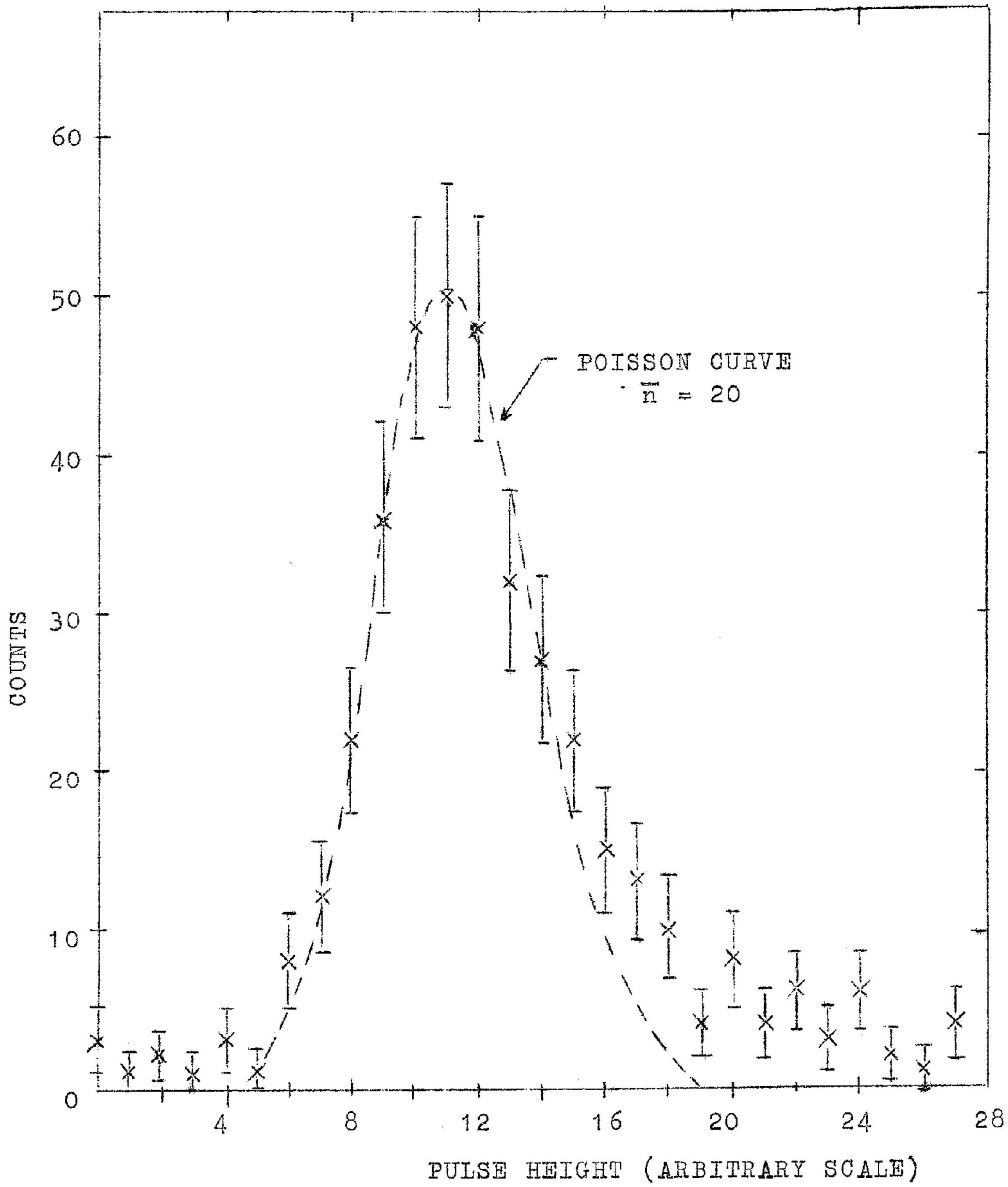

FIG. 4 - COSMIC RAY PULSE HEIGHT SPECTRUM OBTAINED BY THE COUNTER SHOWN IN FIG. 3. LIGHT COLLECTION HAS IMPROVED SUBSTANTIALLY COMPARED WITH FIG. 2. DOTTED LINE SHOWS POISSON DISTRIBUTION WITH $\bar{n}$ = 20.

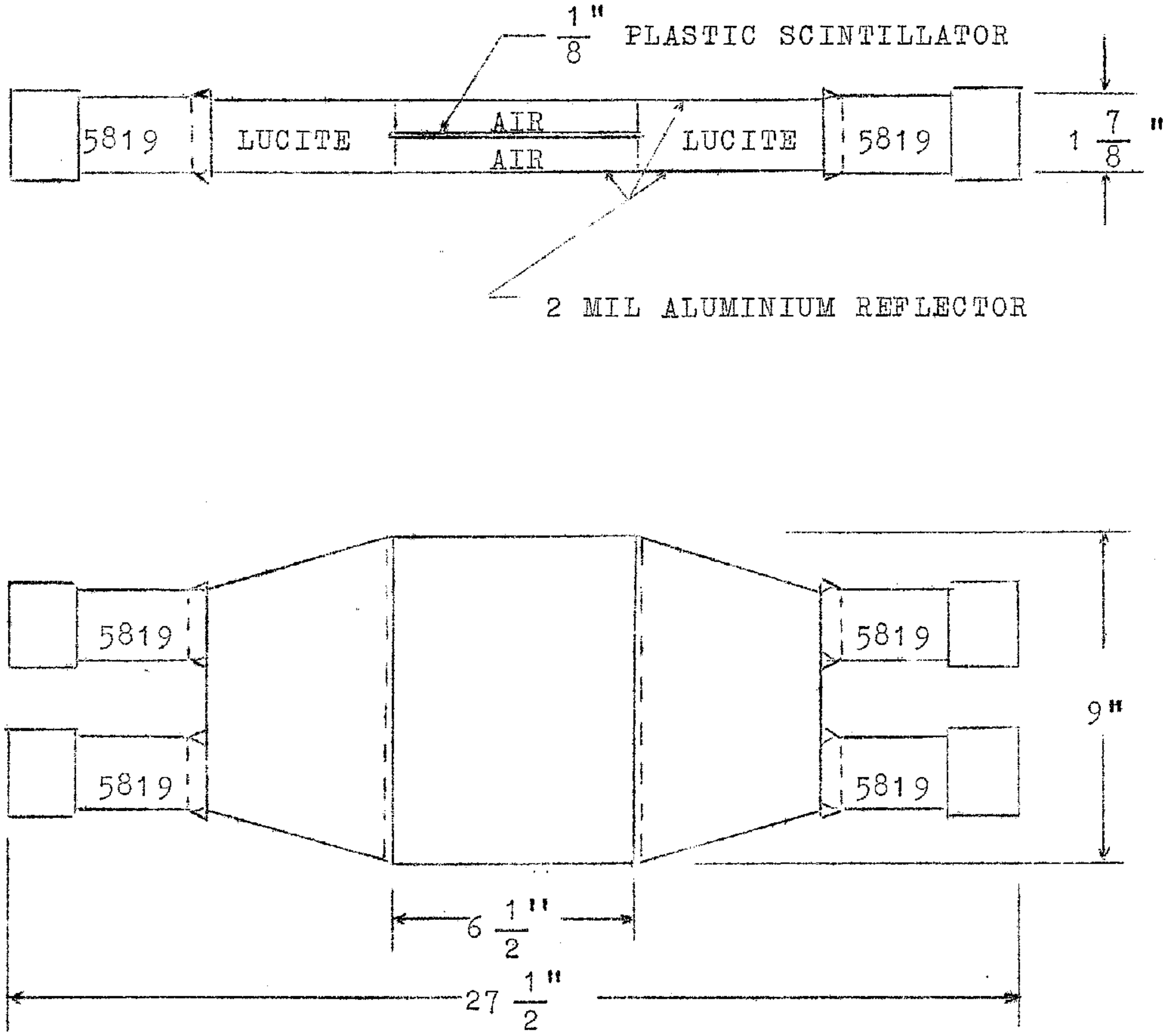

FIG. 5 - FINAL DESIGN OF THE PROTON COUNTER. THE ALUMINUM REFLECTORS ARE AIR-SPACED.

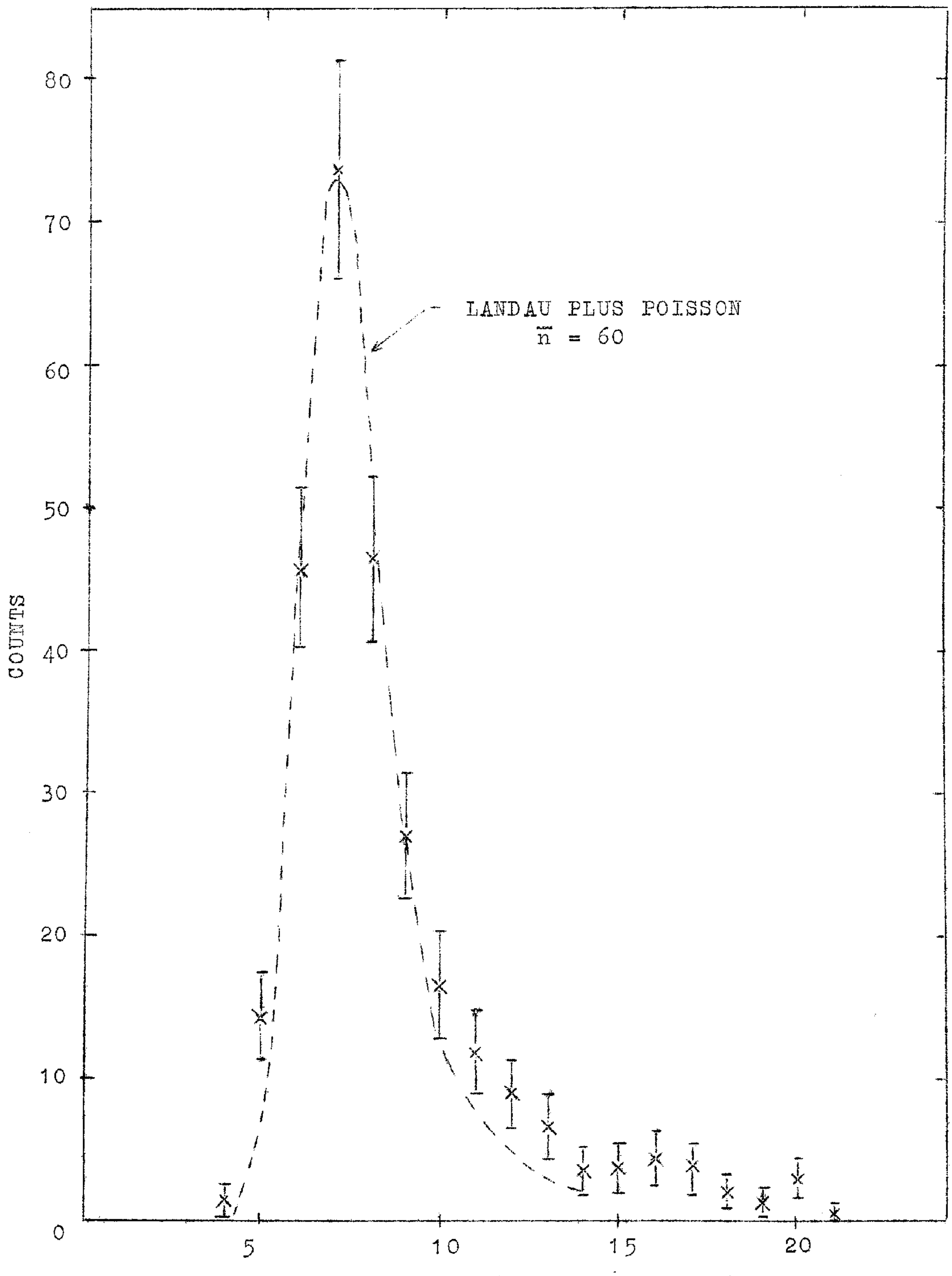

FIG. 6 - COSMIC RAY PULSE HEIGHT SPECTRUM OBTAINED BY THE COUNTER SHOWN IN FIG. 5. THE BEST FIT SHOWN AS A DOTTED LINE WAS OBTAINED BY FOLDING THE LANDAU DISTRIBUTION WITH THE POISSON CURVE FOR $\bar{n}$ = 60.