**A METHOD OF EVALUATING SCANNING EFFICIENCY
FOR QUARK-LIKE (PSEUDO) TRACKS IN A
FLAT-GEOMETRY CLOUD CHAMBER**

R. D. Ernst

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Abstract

This paper is a supplement to "Pseudo Cloud Chamber Tracks and Their Uses" published April 13, 1972 (UCRL-51214), and deals with further uses of artificially produced cloud-chamber tracks used in

the quark quest. These tracks were used to train scanners to look for $1/9$ normal-density tracks, and to measure a scanner's efficiencies for finding $1/9$ and lower ($1/12$, $1/18$, and $1/36$) normal-density tracks.

Introduction

The work reported herein is a continuation of an earlier study employing artificial cloud chamber tracks¹ which was a part of the quark quest.^{2,3} To make it easier to find low-density tracks the cloud chambers were turned over on their sides, making the thin dimension of the photographed volume vertical, a configuration which we called "flat geometry."

The pseudo tracks for the flat-geometry chambers were developed in April 1971; first, as a feasibility study to determine the ability of the scanners to see $1/9$ quark tracks in this geometry; second, to educate the scanners in finding $1/9$ quark tracks; and third, to determine the efficiency of

the scanners for finding such tracks.

Following the feasibility studies, the scanner's education and efficiency studies were begun. The determination of the scanner's efficiencies was a long-term project extending from April 1971 to December 1972.

After the efficiency program had been running for about a year, an interest developed in how light a density track the scanners could see. Therefore, pseudo tracks having densities lower than $1/9$ were developed ($1/12$, $1/18$, $1/36$). This program started in July 1972 and was completed in December 1972. This report summarizes the results of these programs.

Flat-Geometry Cloud Chambers

The flat-geometry chambers had their unique problems since the apparent density and length of the tracks depend on the angle in which the particles go through the chambers. The scanners looked at

projected images of foreshortened tracks. Therefore, they had to be aware of the length-to-density ratio; the shorter the track, the higher the density (Fig. 1). Table 1 shows the pseudo tracks needed

Fig. 1. Various light density pseudo tracks that were picked up by our scanners in normal scanning. (a) 1/9 at 40°, (b) 4/9 at 20°, (c) 1/9 at 15° and a normal track at ~20°, and (d) 1/12 at 10°. Note the length-to-density ratio of the 1/9 tracks.

Table 1. Template guide for superimposing pseudo tracks.

Zenith angle (deg)	Density of projected pseudo track	Drops/cm needed	Drops/cm in template used	Total track length (cm)	In-Focus length (cm)
10°	4/9	191	—	1.6	1.3
	1/9	47	48	1.6	1.3
	1/18	24	20	1.6	1.3
20°	4/9	97	110	3.3	2.8
	1/9	25	20	3.3	2.8
	1/18	12	12	3.3	2.8
30°	4/9	67	65	5.3	4.4
	1/9	16	20	5.3	4.4
	1/18	8	7	5.3	4.4

to be placed on the top glass of the cloud chamber, such that the density is correct for the projection of quark tracks going through the chambers in the flat geometry. The first column is the zenith angle, the second column is the type of track needed. The third column is the drops/cm that should be placed on the

top glass to represent that type of track, the fourth column is the template that was chosen that matched the best. The fifth and sixth columns are the two different lengths used to make the tracks appear as if they were going through the regions of good focus and illumination and poor focus and illumination.

Scanner's Training

The technique used for training the scanners for finding $1/9$ quark tracks was as follows: First, a number of tracks with zenith angles ranging from 10° to 40° were superimposed on cloud chamber pictures and scanned. The scanners would mark all the light-density tracks they found. Next, the tracks that were missed were shown to the scanners. This would show the scanners that there were light-density tracks to be found and what they looked like in the chamber. After this was done, more light-density tracks were put on chambers at random for monitoring the scanner's abilities to find such tracks.

Any problems the scanners had were brought to their attention. It was noticed

while the scanners were being trained to see light-density tracks that once they understood what to look for, the scanning efficiency increased considerably. Most of the time during "production" scanning, the scanners were not made aware of the tracks they missed. Figure 2(a) plots the efficiency of two consecutive scanners in finding $1/9$ normal tracks (and $1/12$, $1/18$ and $1/36$ normal tracks) plotted versus time, and Fig. 2(b) plots chamber weeks^{*} scanned versus time. A total of 305 chamber weeks was scanned. When the curve in Fig. 2(a) is multiplied by the percent of film scanned in Fig. 2(b), the net "effective efficiency" is obtained. This is described later in the text.

Scanner's Efficiency

The scanner's efficiency was checked using 24 different light-density tracks representing densities from $4/9$ to $1/25$ of normal, and at zenith angles from 10° to 35° (Fig. 3). The number of times a track of a given angle was used was determined by the likelihood that cosmic-ray tracks would come into the chambers at such angles.¹ The total number of tracks used was 163, and 7 was the average number of times any one track was used. But 3 was the average number of times the scanner found any one track. The tracks were superimposed on five different chambers, with three out of the five chambers having cameras set 24.5 in. from the center of the chamber and the other two chambers having cameras set 28.5 in. from the center. One of the

chambers was under 4 in. of lead; 7% of the $1/9$, 25% of the $1/12$, 20% of the $1/18$, and 12% of the $1/36$ tracks were superimposed on the lead-covered chamber.

The emphasis was put on the $1/9$ pseudo tracks. Nine different tracks were made up. The total number of $1/9$ tracks exposed on the chambers was 58.

To get the efficiency for finding light-density pseudo tracks normalized into a meaningful value that would show our ability for finding quark-like tracks in a cosmic-ray shower, we had to take into account the angle of the tracks and the amount of film scanned under a given efficiency.

^{*} Amount of film from one chamber operating for one week.

Fig. 2. (a) Scanner's efficiency versus time, and (b) chamber weeks scanned versus time. In (a), the slope of the line from $33\% \pm 17\%$ to 42% was assumed because there was no point at 42% ; also the scanner was still learning, as noted in later data. Also assumed were the slopes of the lines from the new scanner to $22\% \pm 14\%$ and from $57\% \pm 28\%$ to $67\% \pm 25\%$.

First, the angle at which the track came into the chamber versus efficiency

in finding these tracks was computed (Fig. 3). Thus, for example, in Fig. 3(b), the percentage of discovered 1/9 normal artificial tracks having a mocked-up foreshortening corresponding to zenith angles between 10° and 20° is 74%. The find-rates represented in each of the histograms of Figs. 3(a) through 3(e) are then multiplied by the percentage of cosmic-ray tracks having the corresponding zenith angles, as given in Fig. 3(f). In our example, the percentage of tracks having zenith angles between 10° and 20° is 30%. The efficiency thus derived is listed in the figures for each kind of track; for 1/9 normal tracks [Fig. 3(a)] the efficiency so derived is 59%. This type of analogy was done (with respect to time) for each data point on the graph in Fig. 2(a). Note in Fig. 3 that in the lower density tracks (1/18 and 1/36), data from both the low and the high angles were not taken. The reason for this was that the tracks that lay in these regions already approach

Fig. 3. (a-e) Efficiencies for tracks with droplet/cm counts ranging down from 4/9 normal (2e/3) to 1/36 normal (e/6) are presented as a function of the steepness of the tracks in the chambers. The total number of tracks present is the sum of the shaded and cross-hatched areas in the histograms. The number of tracks found, given in percent at the top of each bar, is indicated by the shaded area. (f) The distribution of extensive air showers versus zenith angle.

the limits of the experiment (efficiency ≈ 0); therefore, the lower angle, low-density tracks were too short and appeared as just a blob, and the high-angle, low-density tracks became too long and contained too few drops per centimeter and faded into the chamber background. Some tracks in these regions were superimposed on the chamber, but could not be located even when we knew which frame they were in; therefore, the assumption was a good one that the scanning efficiency at these points should be zero.

Second, the amount of film scanned by the scanner versus time was plotted [Fig. 2(b)]. With this information, one can now obtain a number that gives the effective scan time used to find 1/9, 1/12, 1/18, 1/36 normal density tracks in cosmic-ray showers. To get the efficiencies, one would multiply the efficiency each week by the amount of film scanned with various efficiencies. The relative

average efficiencies for finding 1/9, 1/12, 1/18, 1/36 densities are 45%, 6.5%, 5.4%, 1.2% respectively.

The efficiency for finding 1/36 density tracks must be multiplied by another factor (3%) because the only tracks at this low density that the scanner could find were those which had a blob of more than 30 droplets in view. The probability that a 1/36 density track would have such a blob is 3%. All tracks used in the efficiency number quoted above (for the 1%) had such a blob.

This technique has made it possible to push the limits³ on finding 1/9 quark-like tracks in cloud chambers to 2×10^{-11} particles $\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}$ and add new dimensions in the limits of finding light-density tracks in cloud chambers of 1/12, 1/18, and 1/36 of normal density with limits of 8×10^{-11} , 5×10^{-10} , 7×10^{-10} , and 1×10^{-7} particles $\text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}$ respectively.

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References

1. R. D. Ernst, Pseudo Cloud Chamber Tracks and Their Uses, Lawrence Livermore Laboratory, Rept. UCRL-51214 (1972).
2. A. F. Clark, R. D. Ernst, H. F. Finn, G. G. Griffin, N. E. Hansen, D. E. Smith, and W. Powell, Phys. Rev. Lett. **23**, 658 (1969).
3. A. F. Clark, R. D. Ernst, H. F. Finn, G. G. Griffin, N. E. Hansen, D. E. Smith, "On the Lack of Fractionally Charged Particles in Cosmic Radiation," Phys. Rev. Lett., submitted Feb. 22, 1973.