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ABSTRACT

We describe here a Monte Carlo method of successively generating the grain coordinates of particle tracks in emulsion. For such a calculation one needs to know three parameters of the distribution functions of the grain variables. These are the parameters of multiple scattering, grain noise and grain spacing. To generate equivalent tracks, the parameters for the distributions of these three random variables may be experimentally determined from a fair sample of real tracks. The method was developed for an emulsion application, but it is readily adapted to other instruments such as the bubble chamber, and to problems of the spatial distribution of ionization in a beam of particles penetrating matter.

We also give a brief description of the IBM 7094 program for performing such Monte Carlo calculations of particle track grains.

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The three parameters[1] needed for a Monte Carlo calculation of the linear and transverse track structure are:

1) mean grain spacing, $\langle t \rangle$, the expectation value of the random spacing t, which has a Poisson distribution when the grain density is low;

2) a multiple scattering parameter $\langle \alpha^2 \rangle$. The variable α has a gaussian distribution, in the small angle approximation, and

3) the grain nois, $\langle \delta^2 \rangle$. The variable δ is assumed to have an approximate gaussian distribution.

To determine experimentally these parameters we pass a straight line throught the centers of the first and the last grains of track-segments each defined, for example, by seven grains.

From measurements of the distances between consecutive grains for all tracks, we determine the mean value $\langle t \rangle$ of t.

Next, we determine the parameter for grain noise $\langle \delta^2 \rangle$. One method is to measure the y-coordinate of the center of each grain which belongs to the track. The distribution of the squares of the second differences has a mean $\langle D''^2 \rangle$, and when the cell is so short that the grain-noise greatly exceeds the scattering:

$$\langle D''^2 \rangle \approx 6 \langle \delta^2 \rangle.$$

[1] W. H. Barkas, Nuclear Research Emulsions, Vol. I (Academic Press, Inc., New York, 1963). Chap. 8, Sect. 8.4.

In this case the cells are the grain spacings.

The parameter for scattering, $\langle \alpha^2 \rangle$, is determined as follows:

The center of the middle grain will be a measured distance y_4 from the straight line. The variance σ^2 of this distance derived from many observed track-segments will be

$$\sigma^2 = \frac{\langle \psi^2 \rangle_\tau}{12} + \frac{3}{2} \langle \delta^2 \rangle$$

where $\langle \psi^2 \rangle_\tau$ means $\langle \psi^2 \rangle$ for a track length τ and is related to $\langle \alpha^2 \rangle$ by

$$\langle \psi^2 \rangle_\tau = \langle \alpha^2 \rangle \langle \tau^3 \rangle.$$

The variable ψ was introduced by Barkas.[1] The particle scattering then was shown to be completely determined by it and another random variable χ.

The quantity $\langle \tau_i^3 \rangle$ for observed tracks of $(i + 1)$ grains is given by

$$\langle \tau_i^3 \rangle = i(i + 1)(i + 2)\langle t \rangle^3,$$

where $\langle t \rangle$ has been defined previously.

In the calculations of coordinates X_i, Y_i for each track, we pick the variables t_i, δ_i, and α_i at random from their respective distributions. For a track of k grains, i will run from 0 to k-1.

The coordinates of a certain point on the particle path where the particle comes closest to the first grain-center are taken to be $(0,0)$, with $\varphi_0 = \delta_0 = t_0 = 0$. Then

$$X_0 = 0 \text{ and } Y_0 = 0.$$

The formulae (as derived by Barkas[1]) for the coordinates of grain centers

(X_1, Y_1) are:

$$X_{j+1} = X_j + t_{j+1}$$

$$Y_{j+1} = Y_j + t_{j+1}\,\varphi_j + \psi_{j+1} + \chi_{j+1} + \delta_{j+1} - \delta_j$$

$$\varphi_{j+1} = \varphi_j + \frac{2\psi_{j+1}}{t_{j+1}}$$

$$\psi_{j+1} = t_{j+1}^{3/2}\,\alpha_{j+1}$$

$$\chi_{j+1} = \frac{1}{\sqrt{3}}\,t_{j+1}^{3/2}\,\alpha'_{j+1}$$

j runs from 0 to k-1, where k is the total number of pairs of grain-coordinates. The random numbers α and α' are picked independently from the same distribution of α. This is necessary because ψ and χ are <u>independent</u> random variables which together determine the scattering.

An IBM 7094 program (CARLO) has been written for the purpose of calculating any number of grains for each track. The only input needed for the program are the parameters $\langle t \rangle$, $\langle \delta^2 \rangle$, and $\langle \alpha^2 \rangle$. The subroutines in the program take care of the proper distributions for t, δ and α.

When t, δ and α do not have the simple distribution functions assumed here, their actual distributions, whatever they are, can be used in the same way. The parameters $\langle \alpha^2 \rangle$ and $\langle t \rangle$ also can be permitted to depend on i so as to allow for energy-loss of the particle.