SUBJECT: EFFICIENCY ANALYSIS FOR LIQUID-FILLED HIGH-RESOLUTION MULTI-STRIP IONIZATION-MODE CHAMBERS.

NAME: S. Derenzo & P. Eberhard

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This note describes the method used to estimate the detection efficiency of the liquid argon multi-strip ionization chambers tested in a 1.7 GeV/c pion beam at the Bevatron.[1] The test was conducted late in 1973. Two factors made the efficiency estimation non-trivial:

(1) The electron diffusion transverse to the electric field was ~30μ rms while the strip spacing was 20μ. Thus a single particle could be detected on more than one strip.

(2) Only a very limited number of strips were read out independently (1 in one chamber and 1 or 2 in the other chamber).

Two chambers (called X1 and X2) were used in the test. In order to study the spatial resolution and efficiency of the chambers, the particles were counted only if they triggered the coincidence of two scintillators S1 and S2 and a discriminator connected to one strip of X1, thus defining a very narrow beam of particles. At times a third scintillator S3 was used to further restrict the angular spread. The chamber X2 was moven horizontally across that beam and the ratio r(y) of the rate of coincidences S1 S2 X1 X2 to the rate of S1 S2 X1 coincidences was recorded for each displacement y of the chamber X2. Different curves of this type (called resolution curves) were drawn, corresponding to different values of the relevant parameters, i.e., different numbers of strips of X2 connected together, and the discriminator level on X1 or X2. The resolution curve for two adjacent strips in coincidence is designated by r'(y). (See Figs. 1 and 2 for examples.)

In order to interpret the data in terms of the parameters of the single Chamber X2 we introduce the parameter L, the effective width of a strip in X2, which is just the integral of the measured resolution curve r(y). We show here that L depends on the parameters of X2 but is independent of the distribution of beam particles defined by counters in coincidence with Chamber X1. Let x be the horizontal position of a particle traversing Chamber X2 and $p_o(x)$ its probability of triggering the discriminator connected to a strip centered at x = 0. Let b(x) be the distribution of such particles defined by the S1 S2 X1 coincidence. b(x) is normalized to 1. When a strip in Chamber X2 is set off-center by a distance x = y, the ratio of S1 S2 X1 X2 coincidences to S1 S2 X2 coincidences is

$$r(y) = \int b(x)\, p_o(x-y)\, dx. \qquad (1)$$

The effective width of a strip is defined by

$$L = \int r(y)dy = \int p_o(x)\, dx. \qquad (2)$$

L' is a similar effective width for two adjacent strips in X2 in coincidence. We We now relate the measured quantities L and L' to the efficiency.

For a particle passing through the chamber at position x, let $p_i(x)$ be the probability that it will be counted on the i th strip, and $p_i'(x)$ be the probability that it will be detected simultaneously on the i th and (i+1)th strips. If we define $g_i(x)$ as the probability that <u>only</u> the i th strip counts and $g_i'(x)$ as the probability that <u>only</u> the i th and (i+1)th strips simultaneously count,and $g_i''(x)$ as the probability that <u>only</u> the i th, (i+1)th, and (i+2)th strips simultaneously count,etc., then:

$$\begin{aligned} p_i(x) = {} & g_i(x) + g_i'(x) + g_i''(x) + g_i'''(x) + \ldots\ldots \\ & + g_{i-1}'(x) + g_{i-1}''(x) + g_{i-1}'''(x) + \ldots\ldots \\ & + g_{i-2}''(x) + g_{i-2}'''(x) + \ldots\ldots \\ & g_{i-3}'''(x) + \ldots\ldots \end{aligned}$$

and

$$\begin{aligned} p_i'(x) = {} & g_i'(x) + g_i''(x) + g_i'''(x) + \ldots\ldots \\ & + g_{i-1}''(x) + g_{i-1}'''(x) + \ldots\ldots \\ & + g_{i-2}'''(x) + \ldots\ldots \end{aligned}$$

Note that by ignoring the other possibilities (e.g., that the ith and (i+2)th strips count but not the (i+1)th) we have assumed that two strips cannot count unless all those between count also.

The efficiency $e(x)$ is the probability that any strip will count:

$$e(x) = \sum_{i=-\infty}^{\infty} g_i(x) + g_i'(x) + g_i''(x) + \ldots..$$

$$= \sum_{i=-\infty}^{\infty} p_i(x) - p_i'(x)$$

$e(x)$ is a periodic function with the same periodicity as the strips (strip spacing = d) and has an average value

$$E = \langle e(x) \rangle = \frac{1}{d} \int_o^d e(x)\, dx$$

$$= \frac{1}{d} \int_o^d \left[\sum_{i=-\infty}^{\infty} p_i(x) - p_i(x) \right] dx$$

$$= \frac{1}{d} \int_{-\infty}^{\infty} \left[p_o(x) - p_o'(x) \right] dx$$

$$= \frac{L-L'}{d}$$

where we have used the relationship $p_i(x) = p_o(x+id)$.

In the Bevatron test where $d = 20\mu m$, we found $L = 31 \pm 2\mu m$, $L' = 13 \pm 2\mu m$. (The corresponding resolution curves $r(y)$ and $r'(y)$ are shown in Fig. 2)

Thus $E = 0.90 \pm 0.15$, compatible with 100%.

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1. S.E. Derenzo, A.R. Kirschbaum, P.H. Eberhard, R.R. Ross, and F.T. Solmitz, Test of a Liquid Argon Chamber with 20-μm RMS Resolution, Lawrence Berkeley Laboratory Report No. LBL-3058 (July 1974), to be published in Nuclear Instruments and Methods.

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FIGURE CAPTIONS

Fig. 1 Measured values of r for single strips in X1 and X2 vs. the horizontal position of chamber X2 relative to X1. r is the ratio of S1 S2 S3 X1 X2 coincidences to S1 S2 S3 X1 coincidences. X1 threshold ∿0.4 fC. (1 fC = 10^{-15} Coulombs)

Fig. 2 As Fig. 1, but r is the ratio of S1 S2 X1 X2 coincidences to S1 S2 X1 coincidences for single strips in X1 and X2. r' is same ratio for a single strip in X1 and two strips in coincidence in X2. All thresholds ∿.0.5 fC.

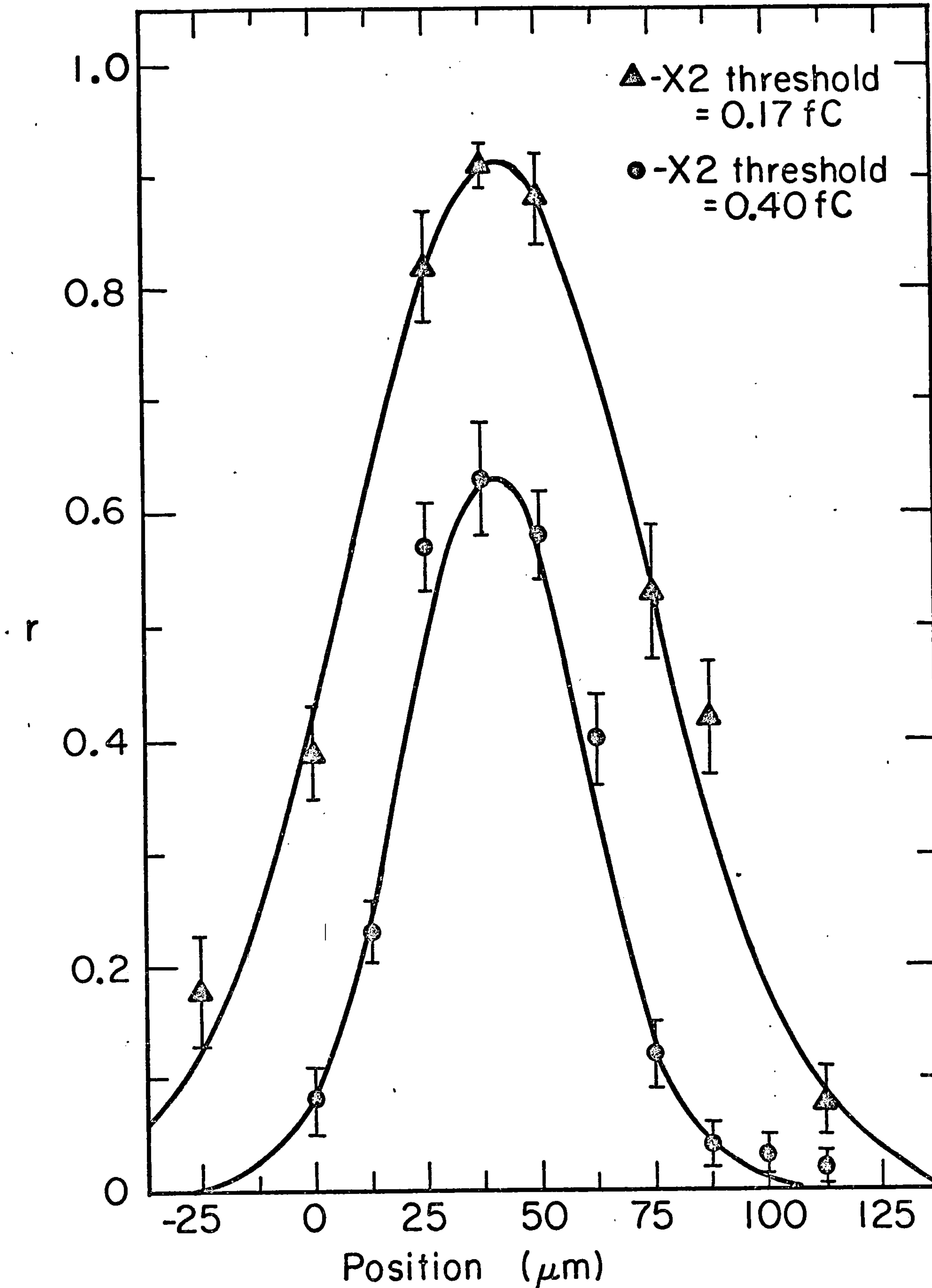

Fig. 1

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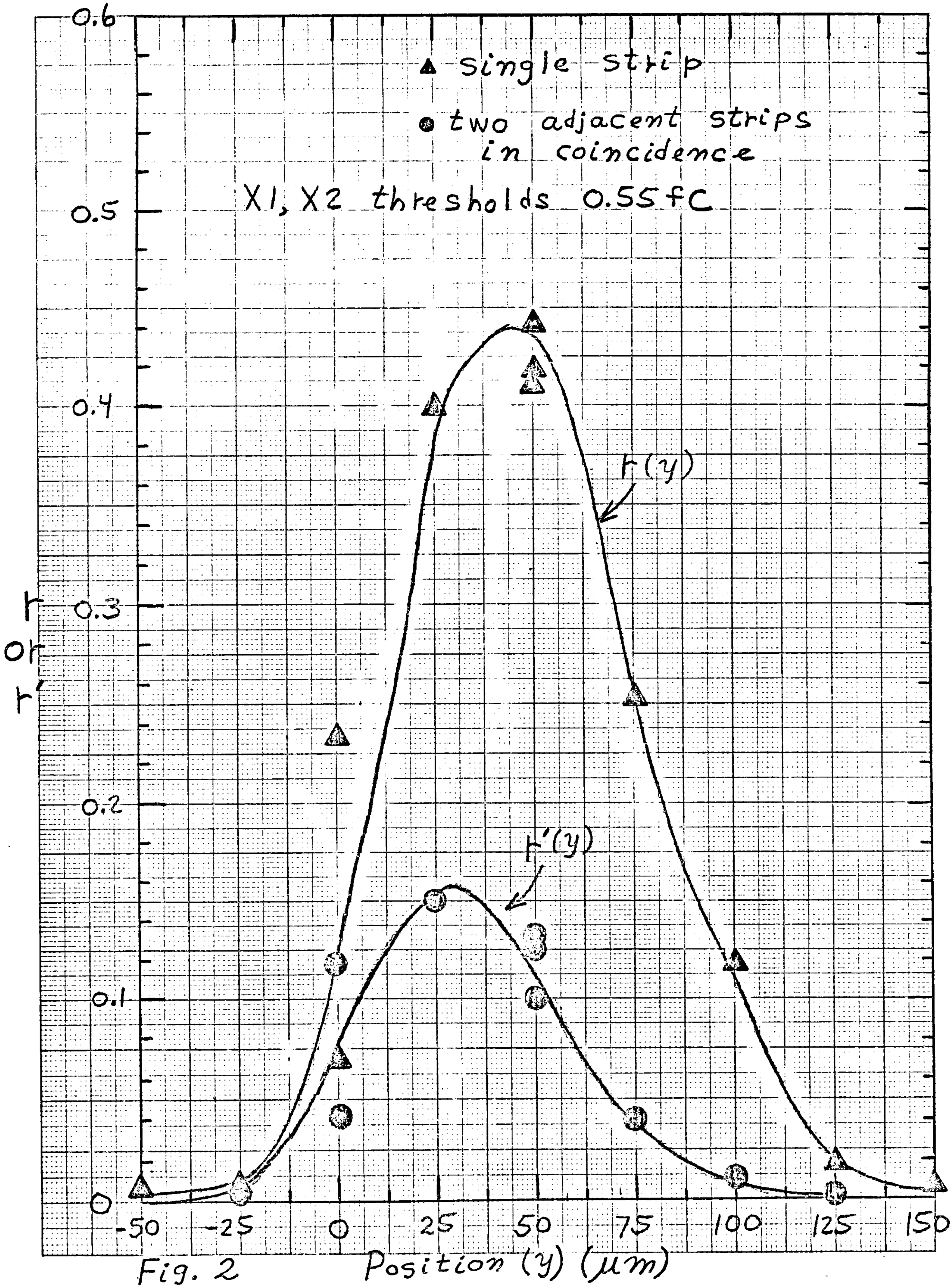

single strip
two adjacent strips in coincidence
X1, X2 thresholds 0.55fC
r(y)
r'(y)
r or r'
0
0.1
0.2
0.3
0.4
0.5
0.6
-50
-25
0
25
50
75
100
125
150
Position (y) (μm)

Fig. 2