INTERNAL REPORT 78

CROSSTALK PROBLEMS IN THE IMP-H AND J EIS*

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Gordon Hurford
September 1974

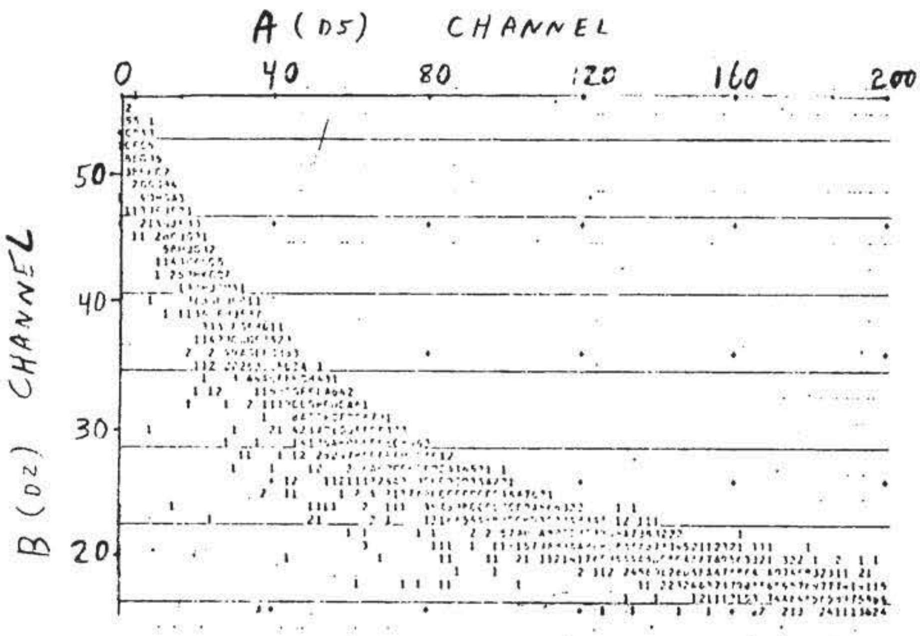
D25 → D6 Crosstalk on IMP-7 EIS

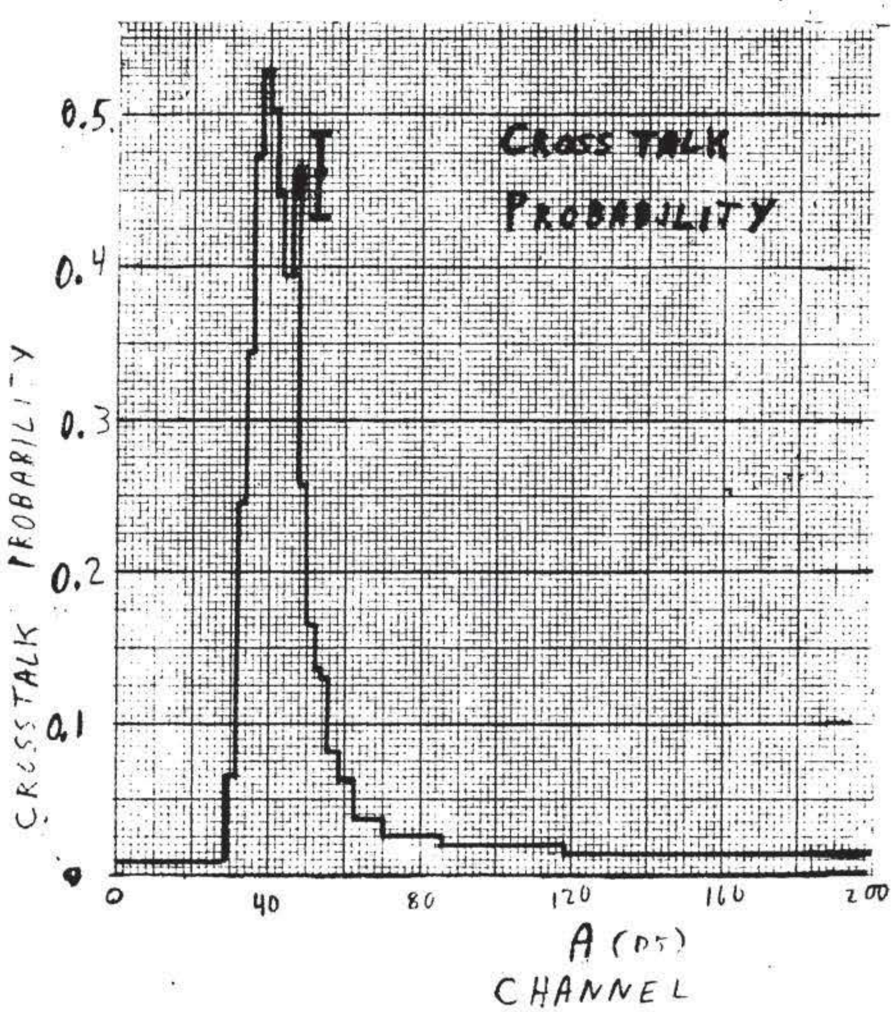
1. Introduction

This addendum describes an anomaly in the operation of the IMP-7 EIS and suggests a way by which the data can be corrected for its effect. The reader is assumed to be familiar with the normal operation of the EIS.

The anomaly consists of otherwise normal D2-D5 coincidence events which occasionally 'crosstalk' into the D6 ADC chain. This has three consequences. First the D25(H) event appears in the telemetry as a D25(H)6 event. Second the B register, instead of containing the D2 pulse height as required by arithmetic type I, contains a zero (or occasionally 1023) representing a small D6 pulse height. This change from arithmetic type I to type II causes the D2 energy loss information to be lost. Third, the PHI rate accumulator is not incremented. For typical flare data, about 10-15% of the D25(H) events are affected, but because the crosstalk is strongly dependent on the D2 and D5 pulse heights, more than 50% of the events in some cases may trigger D6. Thus the effect can be important.

Figure 1A shows a typical flare D25(H) scatter plot, with the D5 pulse height plotted horizontally and the D2 pulse height vertically. Figure 1B shows the fraction of crosstalk events for this flare as a function of the D5 pulse height. Comparison shows that the probability of crosstalk is not independent of D5 pulse height, but is strongly enhanced when the D2 and D5 pulse heights are approximately equal as shown by the light diagonal line in Figure 1A. The problem, then, is to determine the probability of crosstalk, P(A,B) as a function of the D2 and D5 pulse heights, so that a quantitative correction or evaluation of the error can be made.





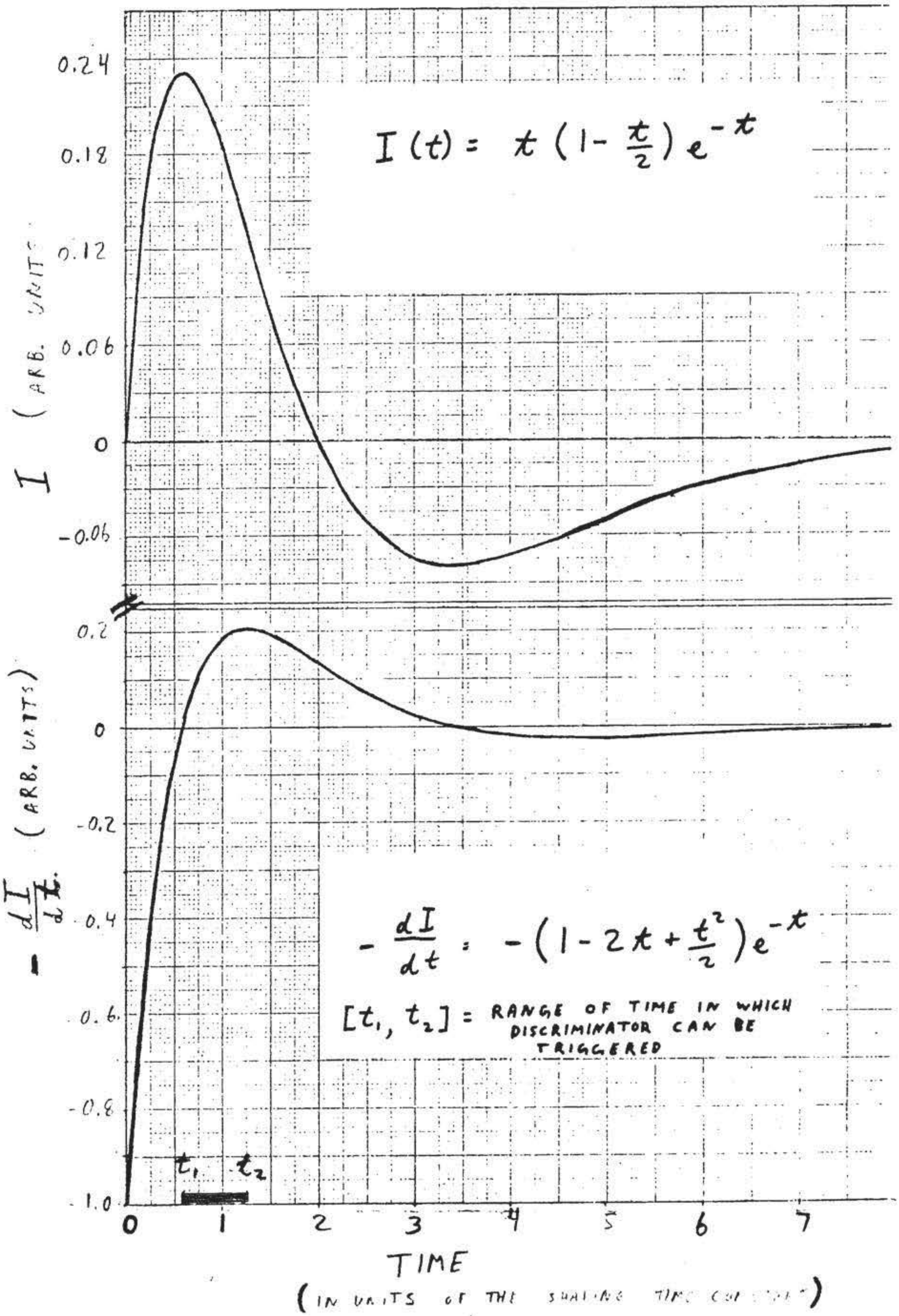
Figures 1A & 1B

The approach taken here is to assume a plausible model for the crosstalk mechanism, and then adopt a functional form for P(A,B) with three adjustable parameters. Given the pulse height distribution for D25(H) events in a statistically significant data set, the function P(A,B) is used to predict the D5 spectrum of D25(H)6 crosstalk events. The 3 parameters are varied to optimize the fit between the predicted and observed D5 spectrum. In this way a quantitative model of the process is obtained. In section 2 the model is discussed. Section 3 considers the values for the numerical parameters and discusses the resulting A and B dependence of P(A,B). Section 4 outlines one method of correcting an arbitrary set of data.

2. Crosstalk Model

The basic assumption is that the probability of crosstalk is determined by the interval between the times at which D2 and D5 discriminators trigger, such that the shorter the time interval, the more likely D6 is to be triggered. Figure 2A shows the shape of the current pulse at the preamp output. This shape is independent of signal amplitude. Figure 2B shows the time dependence of the negative slope. The discriminator is triggered when the negative slope first exceeds a fixed threshold value. For large pulses this occurs near t_1; for small pulses this occurs near t_2. From the functional form of the current shape, it can easily be shown that this time can be expressed as

$$t = 0.5858 + \frac{0.2616}{R} + \frac{0.0927}{R^2} + 0\left(\frac{1}{R^3}\right) \qquad (1)$$



Figures 2A & 2B

where t = the time at which the negative slope is first larger than the value corresponding to the ADC discriminator threshold, in units of the shaping time constant.

R = ratio of energy loss to the ADC discriminator threshold energy.

For a given channel, R can be calculated from the ADC calibration data so that t can easily be determined. Figure 3 shows a plot of

$$T \doteq t - 0.5858 = \frac{0.2616}{R} - \frac{0.0927}{R^2} \qquad (2)$$

as a function of the D2 and D5 channel numbers. It is clear that a good approximation to the predicted time interval between the D2 and D5 ADC firing times, δt (arbitrary units), can be given by

$$\delta t = \frac{(1+\alpha)}{A} - \frac{1}{B} \qquad (3)$$

where $\alpha \ll 1$, is a small parameter to allow for differences in the ADC thresholds and gains and differences in the preamp shaping time constants.

The possibility of crosstalk, P(A,B) is then given by

$$P(A,B) = f\,(|\delta t|) \qquad (4)$$

where $f\,(|\delta t|)$ is small for large values of $|\delta t|$ and is ~ 0.5 for small values of $|\delta t|$.

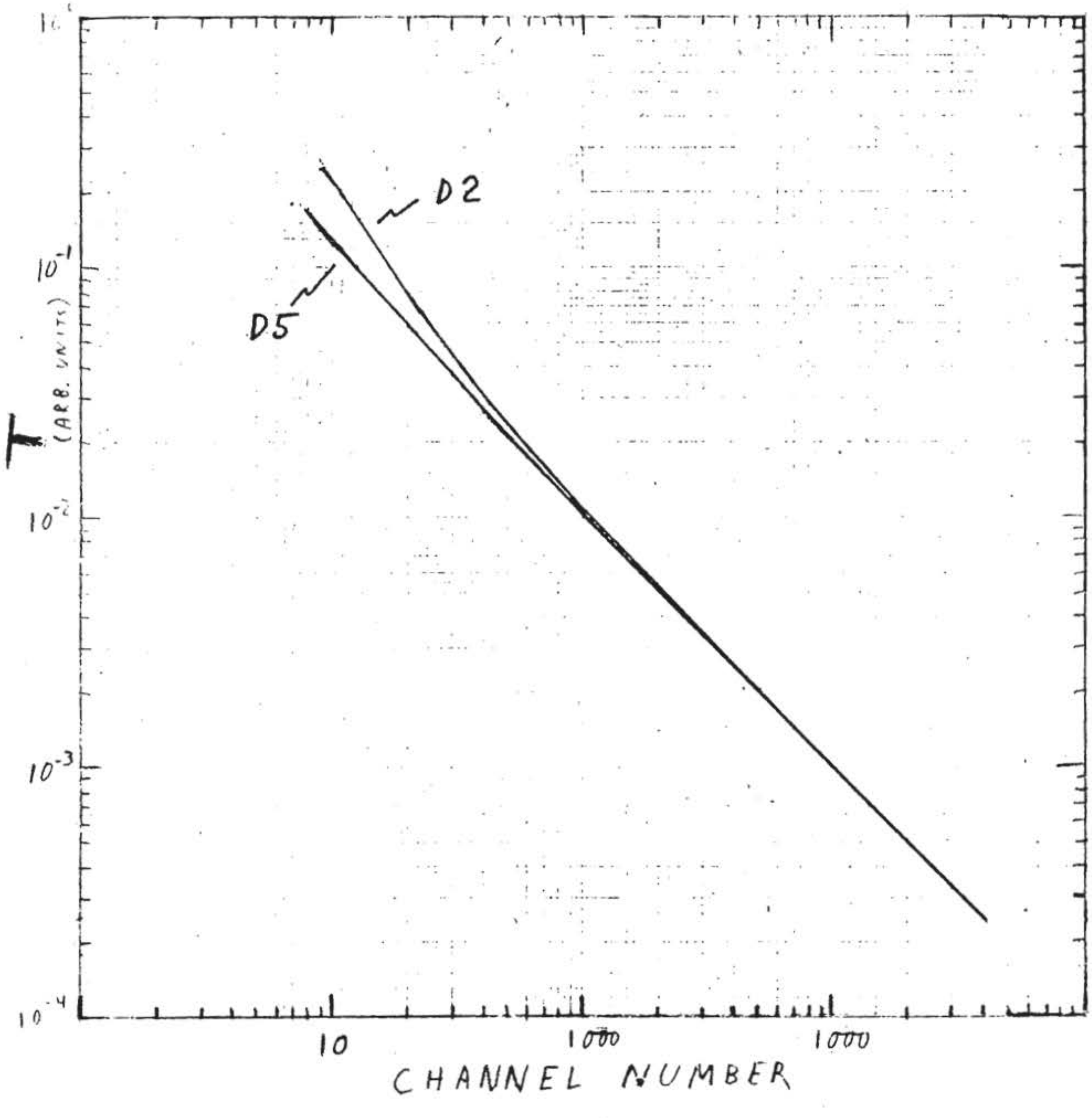


Figure 3

3. Numerical Fits to the Flight Data

In the absence of further clues to the functional form of f ($|\delta t|$), several functional forms were tried, with arbitrary parameters. In addition, two minor modifications to the A&B dependence of δt were also tested. The procedure used to distinguish between the various functional forms and to choose the optimum values of the numerical parameters can be described as follows:

1. A functional form was chosen for P(A,B) with 3 arbitrary parameters, reasonable starting values for the parameters and a representative data set (in this case the October 29, 1973 flare, excluding the peak ("Flare 1Y")).
2. The data set was divided into as many statistically significant D5 (A) pulse height groups as possible.
3. For each D5 group, the expected number of cross talk events was calculated and compared to the observed number.
4. χ^2 was calculated for the set of parameter values used in P(A,B).
5. The parameter values were varied and steps 3 & 4 repeated until no further improvement in the fit (as measured by χ^2) was obtained.
6. Steps 1 - 5 were repeated using different functional forms. Table 1 shows six functional forms for which this procedure was performed using program, BAKTOK.

Table 1. Functional Forms used to Fit Crosstalk Data

Optimum Parameter Values				
α	β	γ	χ^2	Functional form of P(A,B)*
0.11	0.1293	81.36	30.2	$\text{terf}\,(\beta-\gamma\cdot\lvert t\rvert),\ t = \frac{1+\alpha}{A} - \frac{1}{B}$
0.12	0.6617	155.3	49.7	$\beta\, e^{-\gamma\lvert t\rvert},\ t = \frac{1+\alpha}{A} - \frac{1}{B}$
0.272	0.5011	6552	49.0	$\beta\, e^{-\gamma t^2},\ t = \frac{1+\alpha}{A-A_o} - \frac{1}{B-B_o}$
0.00754	0.484	8636	85.8	$\beta\, e^{-\gamma t^2},\ t = \alpha + \frac{1}{A-A_o} - \frac{1}{B-B_o}$
0.00711	0.644	138	84.6	$\beta\, e^{-\gamma\lvert t\rvert},\ t = \alpha + \frac{1}{A-A_o} - \frac{1}{B-B_o}$
0.00747	0.116	73.43	66.9	$\text{terf}\,(\beta-\gamma\cdot\lvert t\rvert),\ t = \alpha + \frac{1}{A-A_o} - \frac{1}{B-B_o}$

$^*A_o = -1.6$, $B_o = -5.8$ } fixed by calibration data

$$\text{terf}\,(\chi) = \tfrac{1}{2}\,(1 - \text{erf}(\chi)) \quad \chi \le 0$$
$$= \tfrac{1}{2}\,(1 + \text{erf}(\chi)) \quad \chi \ge 0$$

While none of the forms was completely satisfactory*, indicating that the problem is by no means completely resolved, the best of the forms tried was quite good over all of the D5 values except around channel 100 where the crosstalk probability was small in any case. The resulting fit was

$$P(A,B) = \text{terf}^{+} \left(0.1293 - 81.36\left|\frac{1.11}{A} - \frac{1}{B}\right|\right). \qquad (5)$$

According to (5), the maximum crosstalk probability is 57% for events with a D2 energy loss ≈ 0.9 the D5 energy loss. Note that for similar energy spectra, heavier particles will have larger values of P(A.B) since A&B will tend to be proportionately larger.

4. Correction of Flight Data

Using equation (5) for P(A,B), an arbitrary set of flight data can be corrected as follows, using program BAKTOK.

1. The D25(H)6 data is separated into crosstalk and normal events depending on whether the B pulse height is or is not 0 (1023 counts as 0).
2. The D25(H)6 crosstalk events are divided into statistically significant groups on the basis of their D5 (A) pulse height. Usually D5 channels are grouped so that there is a minimum of 25 crosstalk events in each group.

*The best χ^2 was 30.2 with 28 degrees of freedom ⇒ 35% confidence.

+terf (χ) is defined in Table 1.

3. The D25(H) events are placed in corresponding D5 groups.
4. The crosstalk probability for each D25(H) event is calculated.
5. The sum of the predicted crosstalk total is compared to the observed total for each group and the predictions are scaled up or down to match the observed totals within each group. The result is a predicted number of crosstalk events associated with each observed event.
6. Since the predicted numbers are in general, non-integral, a random algorithm is used to digitize the predicted crosstalk events so as to maintain the normalization already established.

The output of the BAKTOK program includes a detailed outline of the crosstalk predictions, normalization and digitization, along with optional punched output of the corrected D25(H) and D25(H)6 data.

(Originally issued as Addendum to Internal Report #50)

R. A. Mewaldt
November, 1974

Crosstalk Problems in the IMP-H and J EIS

An extensive study of H and He isotope data from the IMP-H and J EIS instruments has revealed several crosstalk problems that affect the interpretation of data from range signatures involving particular combinations of detectors.

I. IMP-H

1) D7 Crosstalk into D8

Events with signature 01345H67 with trigger D8 a substantial fraction of the time. Flight data analysis indicates that $\sim 30 \pm 4\%$ of protons and $\sim 49 \pm 5\%$ of alphas with range 01345H67 will trigger D8. To first approximation these crosstalk fractions are independent of the energy deposit in D7 for protons and ^{4}He individually. However a gradual dependence on the D7 signal may explain the differences between the proton and ^{4}He crosstalk fractions. It is not known whether this problem affects electron events.

The problem is most easily studied using "range" vs "mass" plots from the SRL programs MASH and PERMAB (G. Hurford). Examples are shown in Figure 1.

Note that this problem is <u>not</u> an example of the capacitive coupling crosstalk discussed in Section V.3.d of Internal Report #50, for several reasons. a) The signal sides of D7 and D8 are not adjacent. b) As a function of the D7 energy loss there is no sudden threshold to the effect. c) There is no crosstalk ($< 1\%$) of 25H67 events into D8 for narrow geometry ^{4}He events.

A workable method of correcting for this problem is to eliminate the crosstalk events from the analysis by placing a lower limit (~ 7 mm Si) on the "calculated range" of 01345H678 events , and to use an effective geometry factor for 01345H67 events that is smaller than the usual geometry factor by the crosstalk fraction.

D9 Crosstalk into D10?

The ^{4}He flux found from 25H6789 events is .65 ± .08 of that expected from an extrapolation of 25H6,25H67, and 25H678 events, which may indicate crosstalk into D10. The discrepancy appears to be independent of the D9 energy deposit. There is no noticeable deficiency of 01345H6789 events.

3) Range signatures free of crosstalk for Z=1, Z=2 events.

There is no evidence of substantial crosstalk ($\gtrsim$ 5%) between adjacent detectors for proton and ^{4}He events with the following range signatures.

25H6 → 25H67 25H67 → 25H678 25H678 → 25H6789	$\lesssim$ 1%
01 → 013 013 → 0134 0134 → 01345 01345H → 01345H6 01345H6 → 01345H67 01345H678 → 01345H6789	$\lesssim$ 5%

II. IMP-J

1) D3 crosstalk into D8

Alpha particles stopping in ranges 015H678 and 25678 will trigger D3 a signficant fraction of the time, depending on the energy loss in D8. This problem is due to capacitive coupling of the signal sides of D8 and D3, as discussed in Section V.3.d. of Internal Report #50. The threshold for crosstalk is $\sim$ 30 MeV energy loss in D8. Below $\sim$ 20 MeV energy loss there is no crosstalk; at $\gtrsim$ 40 MeV the crosstalk is $\sim$ 100%. This problem affects ^{3}He, ^{4}He, and $Z \geq 3$ measurements in these ranges, but has no effect on ^{1}H and ^{2}H measurements. Note that 25678 events that crosstalk into D3 are lost, since the narrow geometry logic requirements are no longer satisfied.

This relatively low crosstalk threshold is apparently due partly to the small spacing between D8 and D3 ($\sim$ .6 mm, see IMP-J detector log book) compared to a typical spacing of $\sim$ 1 mm between other detector combinations.

2) The following range signatures appear to be relatively crosstalk free for protons and ^{4}He.

25H6 → 25H67 (< 1%)	015H → 015H6	$\lesssim$ 5%
25H67 → 25H678 (< 1%)	015H6 → 015H67	
	015H67 → 015H678	
	015H6783 → 015H67834	
	015H67834 → 015H678349	

3) Crosstalk into D2

Long range alpha events in wide geometry may crosstalk into D2, making it necessary to consider two signatures for each range.

4) Examples of IMP-J range distributions are shown in Figure 2.

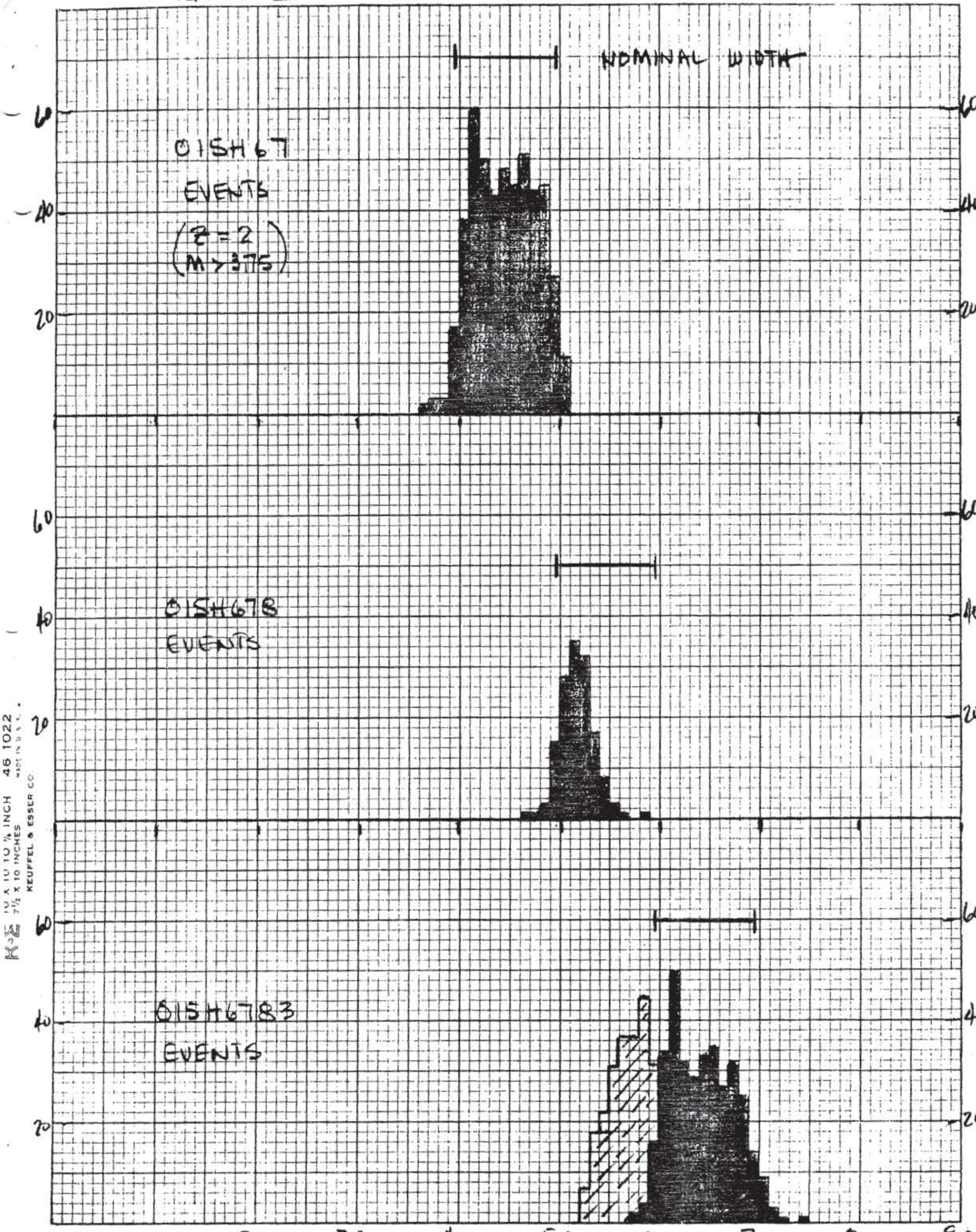
FIGURE CAPTIONS

1) Distributions of the "calculated range" for alpha particle (Z = 2, M > 3.75 amu) events from selected IMP-H range signatures. For each event a charge (Z) and mass (M) are calculated from the pulse-height data, and a "calculated range" found from range-energy relationships. The horizontal lines show the expected extent of the distributions for Z = 2, M = 4.0, and the assumed detector thicknesses. Note the events (shaded) with signature 01345H678 having calculated ranges between 6 - 7 mm of silicon. These are crosstalk events from range 01345H67. About 140 days of flight data are shown here. Distributions from other range signatures are similar to that from 01345H6 events.

2) IMP-J "calculated range" distributions. The shaded events with signature 015H6783 result from cross-talk from signature 015H678. Note that the distribution of IMP-J cross-talk events is unlike that in Figure 1 (IMP-H), indicating the different nature of the two problems.

Both figures show a small number of "background" events due to other causes.

FIGURE 2 IMP-J RANGE DISTRIBUTIONS



CALCULATED RANGE (mm of Silicon)