Proposed Method for Obtaining Amplitude Data in Multiple Muon Events.

The module data collection scheme proposed by Learned for multiple muon events is shown in Fig. 1. It uses a discriminator set as close to threshold as possible, and provides an output pulse whose length is proportional to the logarithm of the signal amplitude, for single pulses. For multiple pulses, the system is provided with either a zero-crossing discriminator or a differentiating circuit, to detect the minima A and B that signify additional muon pulses. A notching circuit - a one-shot MV - is provided to give an output signal like that shown in Fig. 2. The information in this output is the time of all three counts, but not their individual amplitudes.

Since Monte Carlo results indicate that the amplitude of the pulses is important if one is to have any chance of reconstructing the three tracks, it is worth while inquiring whether some simple modification of this scheme can supply the required additional data. Such a modification is described below; it requires three (possibly two) additional discriminators, each provided with a fixed delay. It also implies changes in the way the data are handled in the SBC.

Referring to Fig. 3, we now add three more discriminators just like the original time-over-threshold one, but with thresholds set at progressively (logarithmically spaced) higher levels. If we call the original discriminator A, the new ones can be denominated B,C, and D. Discriminator A is left unchanged; discriminators B, C, and D, are respectively delayed with respect to A by multiples of 100 nsec, so that four consecutive 100-nsec intervals contain their outputs. Small pulses may trigger three, two or even one discriminator; in such cases less time is required to store the data. A start-of-event signal may be desirable -- e.g. a notch at the beginning of the A output.

Fig. 4 shows pulse shapes and signal outputs for several possible cases. We note that the measurement of the signal at four different levels gives four conditions on the sums of pulse heights, and thus can determine the amplitudes of up to four signals; or it can overdetermine the levels of fewer than four. If less than four discriminators fire the number of amplitudes measurable decreases correspondingly.

A start-of-event signal - e.g. a notch - can unambiguously distinguish a closely spaced pair of single muons from the multiple outputs from a large pulse or a multiple pulse.

We are now taking up to 400 nsec to transmit the data to the SBC. In the original Learned scheme, the SBC converts the 50-nsec analogue pulse into a pulse whose length is a digital multiple of the time unit 5.6 nsec. With 8-bit coding, the maximum length of the output pulse can as long as 1.4 microseconds. I propose that we switch from a linear encoding to a logarithmic code, in which we use 20 values per decade. Successive values then differ by the factor 1.12, or 6% error. This then allows 6% accuracy over three decades of pulse height, using only 6 bits. The use of 6 bits shortens the time required for the encoded signal by a factor of four, allowing the four discriminator outputs to be transmitted in the same time previously allotted for one.

Noise pulses will in general be small, and the output pulses therefore short. It may perhaps be desirable to have an end-of-event signal for those cases in which only the first discriminator is fired; or perhaps this can be automatically sensed from its short duration.

There is a deadtime problem with both methods, since the data occupy 1.4 microseconds in both cases. However, in the original Learned scheme there is no serious deadtime problem in the module, where the signal is 50 nsec or less; and overlaps can be handled by buffer storage in the SBC. In the proposed scheme, the module output can last as long as 400 nsec, so that with an average interval of 10 microseconds between events a loss rate of 4% in the worst cases can be encountered -- less for smaller pulses. The only way to eliminate such a loss, if it is felt to be serious, is to add buffer storage in the module. A shift register could double both as delay and as storage.

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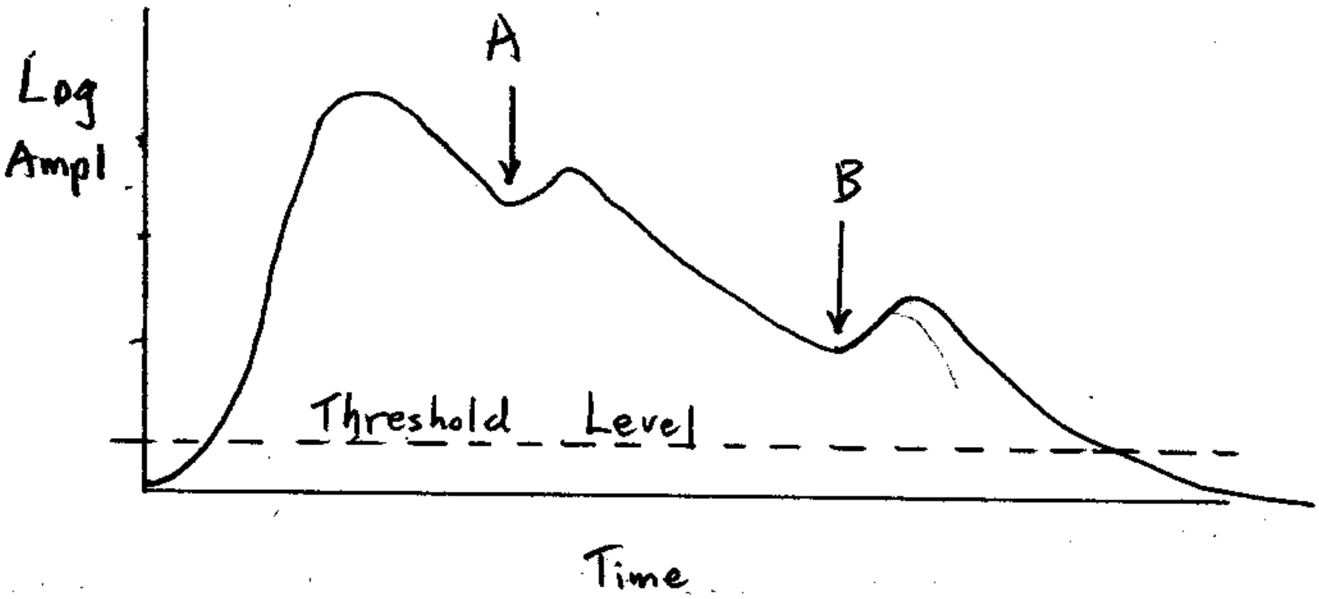

Fig. 1. PMT signal from a three-muon event; A, B indicate arrival times of second and third muons.

Fig. 2. Discriminator outpput for three-muon event, in Learned scheme. Note notches at A, B, that provide timing information.

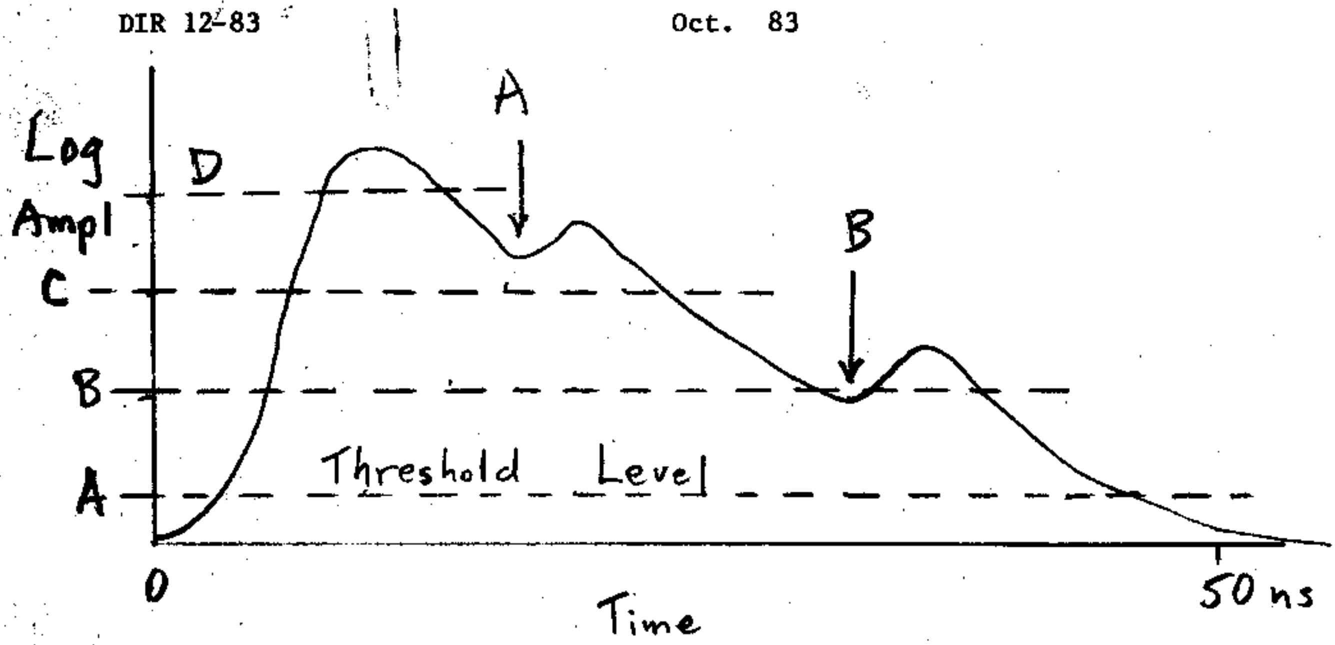

Fig. 3. The same three-muon event, with multiple discriminator thresholds.

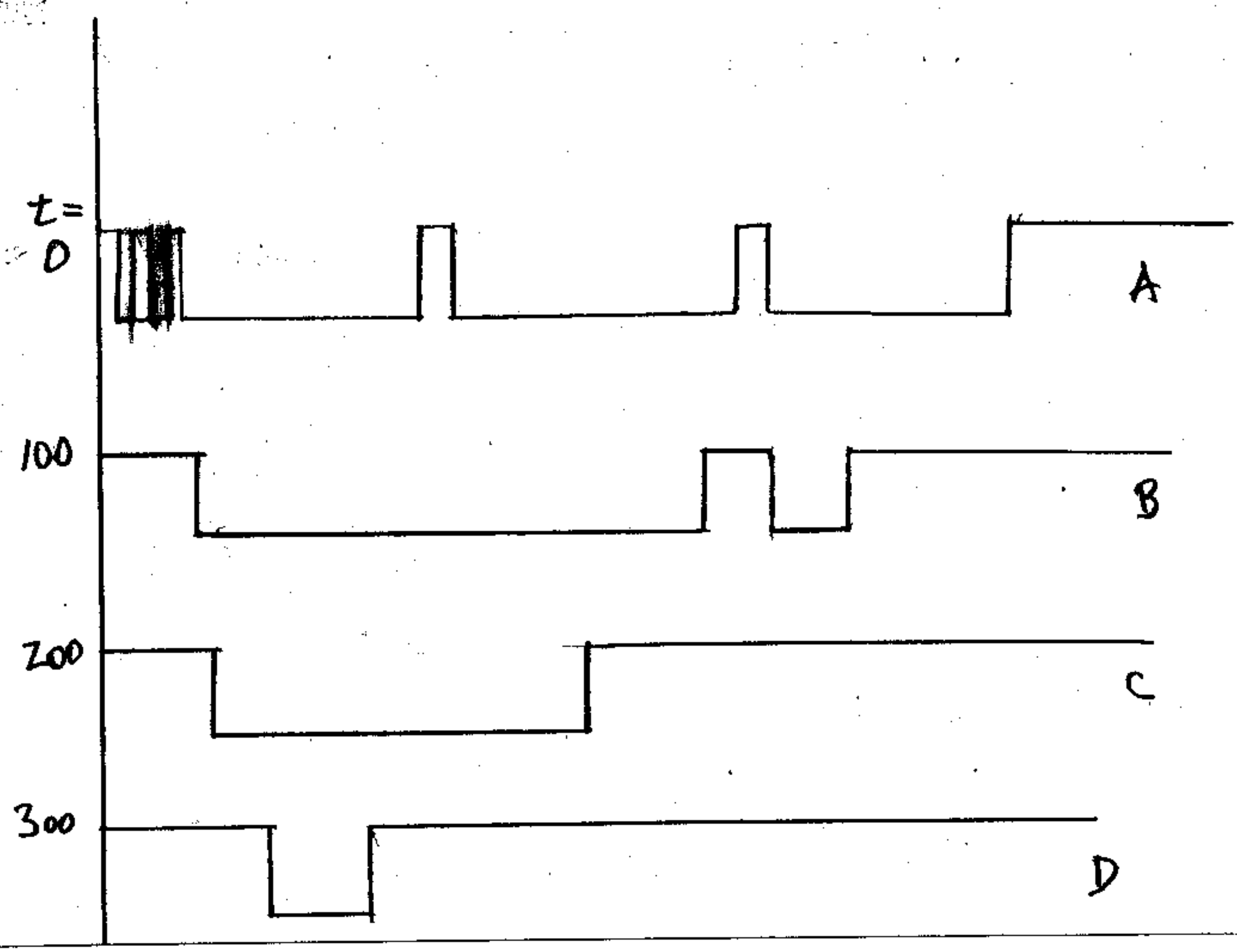

Fig. 4. Discriminator outputs and delays for multiple-discriminator set-up. Note start-of-event signal on A.