TRIGGERING AT ISABELLE - THE FIRST 200 NANoseconds

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At full luminosity of ISABELLE and with an anticipated pp total cross section of 60 mb, there will be, on the average, one interaction every 70 ns. At the other end of the spectrum, it will probably take about 10 ms to store a complete event onto magnetic tape. In between these two extremes comes a triggering scheme which must select the one event out of 14,285,714 that is of interest to the experimenter.* In a typical experiment, a certain small number of signals will come into an electronics trailer on cables that are as short as possible and have propagation velocities as high as possible. With these signals a fast decision will be made as to whether the rest of the information coming in on the slower, longer cables should be further processed or not. The typical length of time for this decision is 200 ns. In this paper, we grapple with some of the problems arising during that first 200 ns, and we give some examples of attempts to solve those problems.

One of the first things to note about a fast triggering system is that it must be device and physics dependent. General multipurpose detectors can be built with very fancy hardware processors and very general on-line computing power, but the basic fast trigger for each experiment on the device will be different and will be mandated by the type of event the experimenter wants to see in the end. For this reason, no single fast trigger or even small set of fast triggers will be used at ISABELLE. There will be as many and as wide a variety of fast triggers as there are experimenters. Therefore, the solution to the problem of what to do for the first 200 ns cannot be given in a paper like this. Only a few ground rules can be stated. Within those rules the experimenters can roam at will.

Rule 1. The first 200 ns shall not be used up as system deadtime. It is not fair to the operators of the machine, who are constantly striving to deliver the greatest luminosity possible, or to others in the high energy community, who will be waiting for the use of an interaction region, for an experimenter to have to run twice as long because he designed a 50% deadtime into his system.

Rule 2. This is really a corollary of Rule 1: The fast trigger shall reduce the data rate sufficiently that the rest of the system can keep pace.

* Presumably the other 14,285,713 events are interesting to other experimenters. Given 6 interaction regions and 4 experiments per year per region, this gives ISABELLE an active life of 600 millennia.

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Rule 3. Extraneous events that are of no interest or that cannot be interpreted should not be accepted in lieu of a good event.

The overall message of these three rules is that as little deadtime is to be designed into the system as possible. Everyone will agree that this rule is quite reasonable, but in an ISABELLE environment it is a tough order to follow. A typical trigger for a large apparatus is shown in Fig. 1A. It is a five-stage trigger

Fig. 1. (A) Typical linear trigger. (B) Five parallel fast triggers plus two parallel microprocessors.

with each stage reducing the data rate by a factor of 30. If each stage had 10% deadtime, the overall system would be dead for 40% of the time, which is unacceptable. On the other hand, if the overall system is to have only 10% deadtime, each stage can be dead for 2.1% of the time. This means that the pretrigger must be able to resolve and act upon events 1.5 ns apart and that the trigger must do the same with events 40 ns apart. Clearly, this will be difficult for the big detectors.

One way to avoid the dilemma is to put the full 10% deadtime in the pretrigger and have essentially no deadtime in the rest of the system. This gives the pretrigger a leisurely 7 ns to make up its mind as to whether an event occurred or not. Now the rest of the system must be "deadtime free." One way to achieve this and still have reasonable lengths of time for making complicated decisions is by constructing parallel trigger paths, as illustrated in Fig. 1B. Here, a pretrigger detects an event and signals the switch to send the information from the fast cables to whichever trigger unit is free at the time; thus, an event is lost only when all five units are filled. Figure 2 answers the question of how many parallel units are needed. The abscissa is the average overall deadtime of the parallel system, and the ordinate is the number of units. The lines plotted are curves of constant $r\tau$ where r is the overall rate coming into the units and τ is the processing time of a single unit. As an example, for $r\tau = 3$ ($r = 1$ event per 70 ns;

Fig. 2. Number of parallel processors vs deadtime. The number with each curve is the value of $r\tau$; the dashed line is for $r\tau = 1$ unit selected at random.

$\tau \approx 210$ ns processing time), one would need 7 units to achieve an overall deadtime rate of 1.5%. The dashed line shows what happens if the switch picks a unit at random and tries to hand it an event. This demonstrates vividly that the switch must be smart enough to hand the event to a free unit. It is also worth noting that going from 1 to 2 units increases the amount of processing time available by a factor of 5 at the 10% deadtime level and 15 at the 1% level.

The parallel trigger method can be used anywhere in the trigger scheme. Several microprocessors might be available to process several events, or a few minicomputers might be working simultaneously. Though this system is expensive in electronics and cables, it serves as existence proof that a system with small overall deadtime can be built if a suitable pretrigger can be found. The rest of this paper is devoted to comments on and examples of the care necessary in designing a pretrigger.

An example of an apparatus that examines every interaction is that used in the elastic scattering experiment described by Edelstein and Zeller in the 1975 Summer Study (BNL 20550, p. 234). In this experiment, the trigger counters are 1 m long, which implies a time jitter from one end to the other of ~ 8 ns. This alone requires that photomultipliers be placed on both ends and the jitter be removed by some sort of mean timer circuit. Once the mean times have been formed, a pretrigger can be constructed along the lines shown in Fig. 3. The logic in this system is to limit the sample to events with only one hit in each of the right and left hodoscopes. Such a decision can be made with commercially available logic with resolution times of the order of 7 to 10 ns. Simple rate calculations indicate that this circuit should reduce

SCHEME FOR TRIGGERING:

Fig. 3. Elastic scattering experiment.

the rate by a factor of >100 and should therefore provide $\geq 1 \mu s$ for making the more complicated decision of whether the horizontal coordinate matches.

Another method of handling the high rate problem is to ignore it altogether, as the muon portion of the lepton detector does. In this experiment, the apparatus is blind to the major portion of the interactions and therefore should have no high rate elements in the triggering logic. Although lepton detection at ISABELLE will certainly have many problems, a fast pretrigger and large trigger electronic deadtime probably will not be among them.

An example of the insidious types of problems that creep in when dealing with fast pretriggering is found when examining p_1 triggers for hadron calorimeters. In the 1977 Summer Workshop, a group designed a calorimetry trigger that was supposed to separate showers 5 ns apart on 6-m counters (C. Akerlof et al., BNL 50721, p. 104). Although this followed the right approach from deadtime and accidental considerations, it would probably result in sufficiently degraded energy resolution and so violate Rule 3, above. As shown in Fig. 4, if the small integration time degrades the energy resolution of a uranium calorimeter by a factor of 3 (from $30\%/\sqrt{E}$ to $90\%/\sqrt{E}$), which is not unreasonable for a 5-ns integration time, then, at $p_1^{-8} = 25 \text{ GeV}/c$ and at 90° , the amount of usable data decreases from 93% of that taken to only 17% (usable data are defined as those having a correction factor for trigger efficiency of ≤ 10 ; production cross section is assumed to fall as

Fig. 4. Cross section $\times$ trigger efficiency for two choices of calorimeter resolution.

p_T -8). The only way to solve this problem and regain the resolution is to make the calorimeter modules smaller (and therefore less apt to see another interaction) or to form a pretrigger with other apparatus.

In conclusion, it seems that the deadtime problem can be solved on an experiment by experiment basis, but not without a lot of hard work. Special care must be taken at each level of triggering. The rewards are there, however, for the diligent experimenter, for in the end he will have greater sensitivity in his experiments.