Triggers at a Tau/Charm Factory

Jon J. Thaler
University of Illinois

Data rates and pattern recognition are considered for a general purpose detector at a tau/charm factory operating at 10^{33} luminosity. The conclusion is that the primary concern must be to control the understanding of efficiencies and systematic errors at the 0.1% level. Data rates are manageable even at the highest luminosity.

This paper considers some general features of data acquisition and trigger pattern recognition at a tau/charm factory (τcF). While reading it, one must keep in mind the needs of off-line analysis as well, because the trend is to blur the distinction between the on-line and off-line environments. The increasing use of general purpose processors in the data acquisition environment, especially those with standard compilers and operating systems, makes the migration of software from one environment to the other straightforward. Although data acquisition and the trigger at a τcF do not require the level of analysis integration that are needed at Fermilab or the SSC, by the time the factory is built such integration will be routine, and we assume that the τcF will conform to this norm. There will be little cost and much benefit to such an approach. We will not discuss the integrated approach here, but its existence should underlie any discussion. The reader should also be aware that I am not going to propose any specific trigger or DACQ schemes. This paper can be considered as containing some general purpose wisdom (*i.e.*, platitudes) concerning the τcF environment.

Trigger:

The trigger has two simple goals:

- Take all e+e- annihilation events,
- Understand systematic errors to 0.1%.

The first goal is not difficult to meet. For example, at the Ψ the data rate is:

$$\text{Rate} = 2200\ \text{nb} \times 0.5\,\frac{\text{evt}}{\text{nb}\cdot\text{s}} \times 10^4\,\frac{\text{byte}}{\text{evt}} = 10^7\ \text{bps}.$$

I have assumed a luminosity of 5×10^{32} which yields an 1 kHz event rate, and I have assumed that the event size will be about the same as at the Mark-III detector at SPEAR. The data rate is about 10× what the CDF now takes, and is comparable to the expected rates after the Tevatron upgrade (1992). Thus, by the time the τcF is running, these rates will be handled by existing technology.

Background data rates are not a problem. Consider, for example, beam-gas. The Mark-III saw about 2 Hz of beam related junk @5 ma beam current, with a 50 MeV $p_\perp$ cut. Thus, at the τcF the 500 ma beam current will give a 200 Hz rate. This can be reduced if improved z-resolution can be obtained. The Mark-3 had ±60 cm, the size of the inner drift chamber. No other z-information was used in the trigger. If the background does need to be reduced, the beam-gas background decreases rapidly with the $p_\perp$ cut, proportional to $(p_\perp \text{ cut})^{-2}$. I would prefer the use of an improved z-requirement to a tighter $p_\perp$ cut, because it affects the acceptance less.

The second goal (understand systematic errors to 0.1% accuracy) will provide the major challenge for the trigger and data acquisition. This goal will stress several aspects of both the on-line and off-line analyses, such as efficiency and acceptance calculations and detector calibration. I will only discuss those aspects relevant to the trigger.

The first commandment in the religion of precision measurement is:

Thou shalt keep the trigger loose & redundant.

This commandment has several corollaries, the most important of which is: **Don't let missing or extra hits kill events.** It cannot be stressed too much that if one is going to keep systematics under control, the trigger must not be sensitive to aberrations in the behavior of either the detector or the storage ring.

In the absence of a specific proposal, the rest of this discussion will assume a detector that looks more-or-less like the Mark-III at Spear. There are obvious improvements that one will want to make, but it turns out that even the Mark-III could survive the tcF environment (from the point of view of trigger rates, but *not* of systematics), so realistic extrapolation is possible.

Mark-III style triggers:

The Mark-III planned two kinds of triggers, a charged particle trigger and a neutral energy trigger. The latter trigger was never implemented.

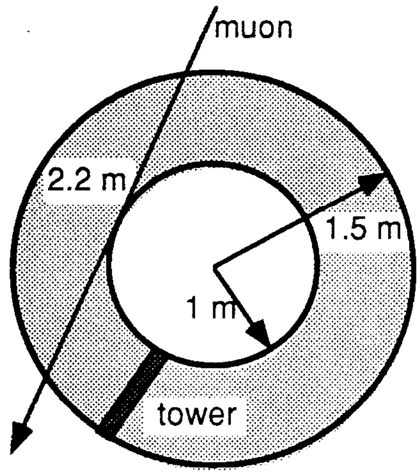
The charged particle trigger used the drift chamber to find tracks and the time of flight counters (and a beam line requirement) to suppress cosmic rays. As was discussed above, beam-gas was suppressed by a $p_\perp$ cut of 50 MeV. The track finding was sufficient for Mark-III purposes, but it would need to be made less sensitive to detector behavior at the tcF. In the Mark-III, only three DC layers were used in the tracking. There are three important differences for the trigger tracking between Spear and the tcF:

- Pursuant to the commandment, we shall not veto cosmic rays based on timing in the ToF counters, or else noise will be able to kill events. The cosmic ray rate of 2 Hz into a 100 cm^2 area is too small to worry about. This will be reduced by improved interaction point extrapolation.

- Some high luminosity tcF proposals have 3 ns beam collision repetition times. This will make on-line determination of the correct b.c. of an event too difficult to do reliably. ToF resolution is easily sufficient to determine this off-line, but we don't want to have to rely on calibration constants in the trigger.

- New machine designs present us with an unknown synchrotron radiation environment. This background is potentially quite hazardous, and it will be important to understand the effect of drift chamber occupancy on the trigger.

The energy trigger is more susceptible to cosmic rays than the tracking trigger, because the interaction point is less well measured. One must perform some pattern recognition, such as requiring localized energy deposits in radial towers. Otherwise, tangential cosmic rays can deposit as much as 3 GeV in a sampling calorimeter, and 600 MeV in a homogeneous one. With care, this requirement should not affect trigger systematics significantly. A simple Crystal Ball trigger should work:



$$E_{sum} = \Sigma(E_i > E_{th}) > 800 \text{ MeV},$$
$$\text{where } E_{th} = 50 \text{ MeV}.$$

Again, in accordance with our commandment, we don't want to veto on energy imbalance or other noise susceptible quantities.

Dead time:

At high rates, dead time becomes difficult to control. Nevertheless, we must do this, if branching ratios are to be measured accurately.

The dead time must be kept small, and independent of trigger rate.

The difficulty results from the fact that the beam crossing time is too short to make any decision in the interim. This means (I will not defend the merits of my suggestions):

- For the drift chamber, use a ring buffer similar to the SLD AMU for storing the wave form; freeze the pattern when a trigger is made.
- For the calorimeter, we must use a similar method, although coarser time granularity (one sample per beam crossing) is sufficient.

Although the short beam crossing time gives the trigger some similarities with high rate hadron machines (such as the SSC!), one important difference is the lack of event pile-up. Even at the peak of the Ψ, the accidental pile-up probability is less than 10^{-3}, as long as the event data collection time is less than 500 ns. This means that no special effort needs to be made to sort out the beam crossing for each detector component's data.

General platitudes:

My goal here has been to persuade the reader that tcF data rates do not stress the technology; the difficult part will be to understand the systematic errors to a level where they do not dominate the statistical errors. I close with a few platitudes:

- Pattern recognition must be robust. We must not be sensitive to dead channels, timing drifts, and calibration errors. The Mark-3 trigger efficiency was dominated by single-wire DC cells which were required in the trigger.

- Cracks and other sources of nonuniform detector response will complicate the acceptance calculation.

- The τcF detector will be Mark-4, not CDG or SLE. No new technology will be required for the trigger, just careful design.

- There may be serious data handling problems in the off-line environment. While 10^7 bytes per second is certainly feasible for the data acquisition, the management of 10^{14} bytes per year will not be trivial. This is an area where the tcF problems may be comparable to what will be encountered at the SSC.