A HARDWARE PROCESSOR FOR ON-LINE EVENT RECONSTRUCTION

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Abstract: The measurement of CP violation using tagged \(K^0\) and \(\bar{K}^0\) would lead to a very high initial reaction rate if a useful CP violation rate were achieved, owing to a neutral kaon production probability of 0.4% and to the CP violation parameters being typically 0.2%. The trigger set-up, including the hardware processor, is able to cope with \(2 \times 10^6\) pp reactions per second. The initial rate is lowered to \(5 \times 10^5\) events per second, containing 60% of the desired \(K^0/\bar{K}^0\) events. The dead-time is of the order of 10%, neglecting further data processing. We describe the proposed trigger logic for our experiment.

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1. CONFIGURATION OF THE EXPERIMENT

The experiment intends to use the DM2 solenoidal magnet from Orsay which offers a field with 1 m radius, 2.5 m length, and a strength of 0.5 T. The equipment, from the target outwards, will be: two multiwire proportional chambers (MWPCs), six drift chambers, a double layer of streamer tubes, a liquid scintillator, twin Cherenkov counters, another scintillator, and an electromagnetic calorimeter. This allows us to distinguish charged kaons from charged pions fast enough for the trigger. A candidate kaon is defined as the configuration where both scintillators get a signal, but not the Cherenkovs in between. The refractive index of the Cherenkov detector is such that all charged kaons from p̅p annihilation are accepted by the trigger, but charged pions will be rejected with an efficiency of 75%.

2. REACTIONS OF INTEREST

The CP violation can be studied using tagged K^0 and K^-^0, respectively. Starting with a high-intensity, low-energy p̅ beam from LEAR, they are produced through the reactions

\[
\begin{align*}
p\bar{p} &\rightarrow K^+\pi^-K^0 \\
p\bar{p} &\rightarrow K^-\pi^+K^0
\end{align*}
\]

(0.4%)

The neutral kaon is uniquely identified through its companion charged kaon. Since the reaction occurs at rest, the neutral kaon momentum and its direction are defined by the K^+\pi^-/K^-\pi^+ kinematics, whilst its strangeness is defined by the sign of the charged kaon. A decent trigger scheme involves triggering on the K^0/\bar{K}^0 mass.

3. TRIGGER LEVELS

The triggering is done at several levels. At each level the event rate is reduced just enough to provide sufficient evaluation time for the next level. Figure 1 shows a survey of the evaluation delay and the reduction efficiency for each trigger level.

![Fig. 1 Delay and efficiency of the trigger levels](image)
We start with an input rate of $2 \times 10^6 \bar{p}$ per second. The raw pretrigger KT1 (kaon trigger 1) requires the presence of at least one candidate kaon, as defined by the Cherenkov detectors and the scintillation counters. Furthermore, it tests the multiplicity of charged-particle tracks, which must be an even number not higher than four. If these conditions are not met, an Internal Clear is generated within less than 50 ns. Considering the solid angle and the pion momentum distribution, 75% of the events are rejected at this early stage, leaving one event every 2 $\mu$s.

The KTA pretrigger, still on gate level, performs a crude transverse momentum evaluation for the candidate kaon tracks by using the fast inner MWPCs. The presence of a candidate kaon with a transverse momentum in excess of 250 MeV/c is indicated within 200 ns. We require that just one kaon be confirmed, in which case the gates of the ADCs etc. are opened. As was found in the Monte Carlo simulations, this trigger cuts 90% of the events, leaving us with one every 20 $\mu$s.

The trigger HW1 is a set of two hardware-wired processors, a track follower, and a kinematics processor. Each track is followed from chamber to chamber in order to remove ambiguities due to crossing tracks, and to give precise momentum and starting-angle information for each particle. The time required to follow four tracks through all the chambers is of the order of 1 $\mu$s; the attached kinematics processor uses approximately another 300 ns. Thus not only the missing mass of a hypothetical neutral kaon is known, but also the position of the production vertex. At least 80% of the events are rejected at this level, using a Fast Clear.

The HW2 performs a cross-check by using the scintillator and Cherenkov TDCs and flash ADCs. The remaining rate will be approximately $5 \times 10^3$ events per second. From the initial $8 \times 10^3 K^0/\bar{K}^0$ per second, we are left with approximately $3 \times 10^2$ per second owing to the solid angle and the detection efficiency. This means that the trigger increases the $K^0/\bar{K}^0$ content from 0.4% to 60%.

4. TRACK FOLLOWER

This processor follows the charged particles through all (or most of) the chambers. It assumes approximately circular tracks in the x-y plane and their starting point close to the origin. Since the MWPCs are the fastest devices, whilst the streamer tubes are quite slow, it is natural to start the operation from the inner MWPC as soon as it has fired.

Arcs starting at the origin transform to sine functions in r-φ coordinates. This is trivial on the hardware level—one has only to assign a discrete φ value for each wire of each chamber. It is sufficient to work with 256 discrete φ values. With the mechanical size and magnetic field chosen, the relevant line segment is virtually straight for a transverse momentum above 80 MeV/c. Below about 60 MeV/c, the particle will spiral and produce multiple hits. This case would be rejected by KT1.

A rather simple algorithm assuming a straight line through planes with known distance ratio is sufficient for the track follower, provided that it allows both for slight deviations in the slope due to multiple scattering and, of course, dead wires.

5. HARDWARE IMPLEMENTATION

The track follower has to use a pipe-line architecture with one processing element for each chamber. Any other approach would be slower, even if only two tracks had to be followed. The number of input lines is quite high. If every processing element has its direct link with the chamber, the whole event can in principle be loaded with a single strobe signal.
Fig. 2 One processing element of the track follower

Figure 2 shows the modules needed for each processing element. The range and start estimators are built with down-line loadable look-up tables rather than PROMs, since the former are both easier to modify and faster in operation. Of course, the devices can be tested via the computer whenever this is desirable, either by loading test patterns or sampling original data. The result of each stage can be read individually and verified. The operation delay of 80 ns per stage is not influenced by these test features. In order to match this speed, only 100K ECL logic is fast enough.

6. MONTE CARLO SIMULATIONS

In order to determine the efficiency of the track follower algorithm, Monte Carlo simulations have been done, assuming reactions with two or four charged particles emerging from the target. All the hardware, except the HWP2, has been emulated by the FORTRAN programs on a VAX. The momentum resolution to be expected is about 9.6% (FWHM), and the neutral kaon mass has 128 MeV/c (FWHM).

The initial event rate is cut by a factor of 400, whilst the loss of interesting events owing to solid angle and other inefficiencies is of the order of 65%.