CDF/DOC/TRIGGER/CDFR/xxxx
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Specifications for a Level 1 $\phi \to K^+K^-$ Trigger

authors

1 Introduction

The p_T thresholds imposed on individual tracks and the scalar sum-p_T requirement imposed on pairs of tracks limits the acceptance with which B_s^0 decays satisfy the level 1 two-track trigger. An increased acceptance can be achieved by reducing these thresholds but this would result in high level 1 trigger rates. However, studies have indicated that the decay $\phi \to K^+K^-$ can be identified using low p_T thresholds while maintaining a reasonable level 1 trigger rate. Since many B decays to final states that include $\phi \to K^+K^-$ are of interest in Run-II, this would provide a way to retain a useful subset of hadronic B decay triggers at high luminosity.

2 Overview

The following criteria have been used to select $\phi \to K^+K^-$ decays based on quantities that approximate the information that could be made available for level 1 trigger decisions:

- Two axial XFT tracks with $1.5 < p_T < 5$ GeV/c
- opposite charge
- confirmed by the presence of track segments in the stereo superlayers
- $2.5° < \Delta\phi_6 < 25°$
- $\Delta\phi_0 < 10°$
- $m_T(\pi^+\pi^-) < 0.3$
- $|\Delta z_7| \lesssim 37$ cm

where ϕ_0 and ϕ_6 are the azimuthal angles of the track as it passes through the origin and super-layer 6, respectively, $m_T(\pi^+\pi^-)$ is the transverse mass of the pair, calculated assuming each track is a pion, and Δz_7 is the difference in z-position of the tracks as they pass through super-layer 7 of the tracking chamber, which is the outermost set of stereo wires. These criteria are efficient for $\phi \rightarrow K^+K^-$ decays because the two kaons are nearly parallel when they are produced. Although the magnetic field bends the tracks in the r-ϕ plane, the z-component of their momentum is unchanged and they emerge from the tracking chamber at approximately the same z-position.

The input to the proposed trigger hardware will be XFT track data provided by the SLAM modules. This will include both the list of axial XFT tracks and additional information provided by their association with stereo track segments. Phi candidates will be identified among the pairs of input tracks and will be used to form the following types of trigger decisions:

- at least n phi candidates
- ϕ + track within a given azimuthal angle ($< 90°$)
- high track multiplicity

The 90° requirement should be efficient for B decays in which a higher p_T threshold will be imposed on the additional track to control trigger rates. The angular coverage needed to trigger on these ϕ-track correlations will be provided by four Pulsar modules, each of which accepts tracks over 180° in azimuth, with each SLAM module sending identical track data to two Pulsar modules.

3 Hardware

Figure 1 shows the connections from the SLAM modules to the proposed phi trigger hardware. This configuration naturally allows trigger decisions to be made on pairs of tracks that are within 90° in ϕ. Each finder transmits an identical list of tracks to two Pulsar modules. On each fiber, a total of 24 16-bit words are transferred in 396 ns which is sufficient to send all axial XFT tracks at at least 16 bits of stereo information per track.

3.1 Track list data format

The axial and stereo track information may not necessarily need to be transferred at the same time. It may be more efficient to transfer all axial track data followed by all stereo track data when the axial tracks are available immediately and the stereo information follows after the SLAM processing is complete. One possible data format is listed in Table 2.

3.2 Interfaces

3.2.1 Fiber inputs

Each phi trigger Pulsar will receive data on 12 fibers using three 4-channel daughter boards.

3.2.2 Trigger output

The trigger output will be made via a special cable that attaches to

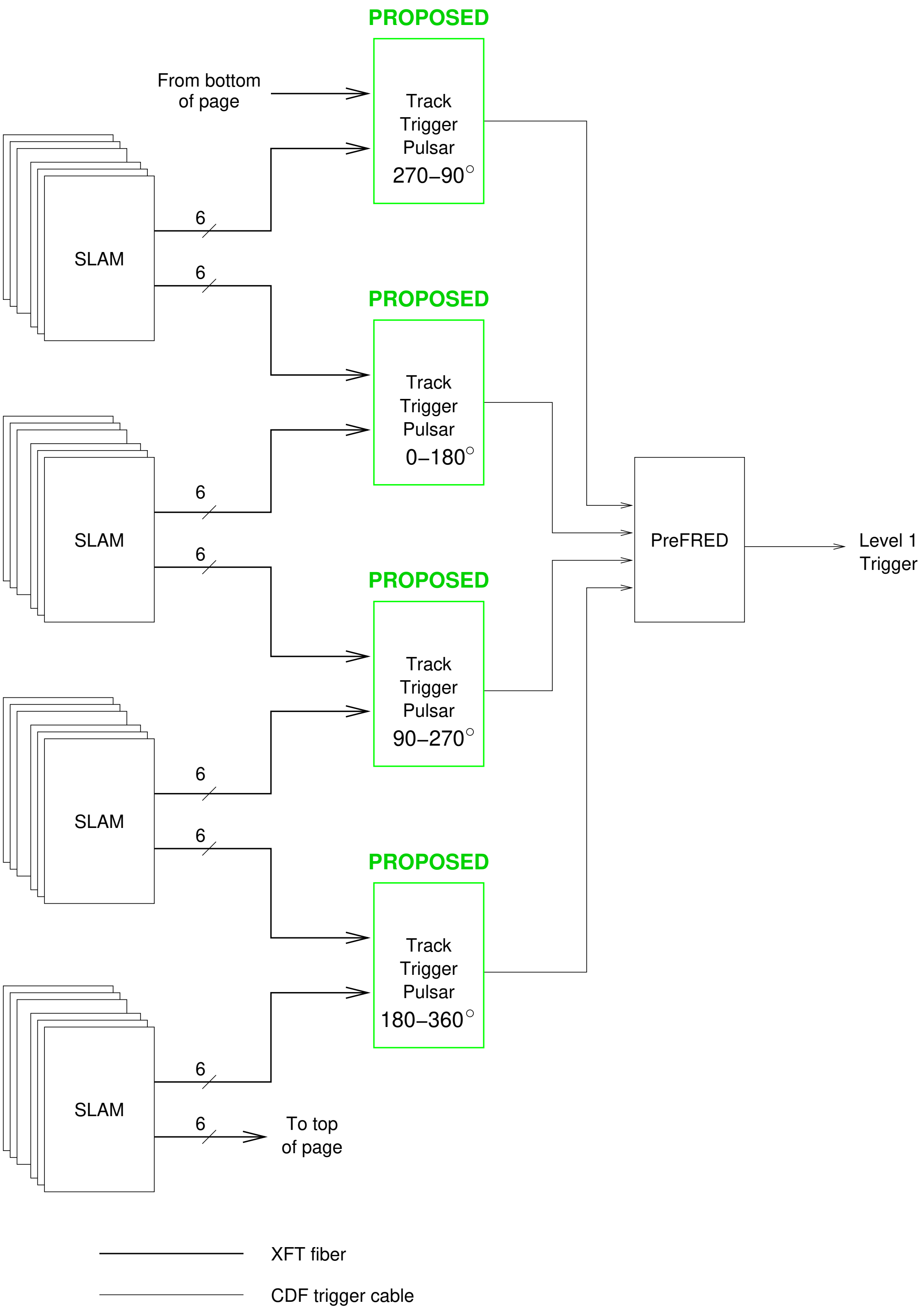

Figure 1: Components and interconnections of the proposed trigger upgrades.

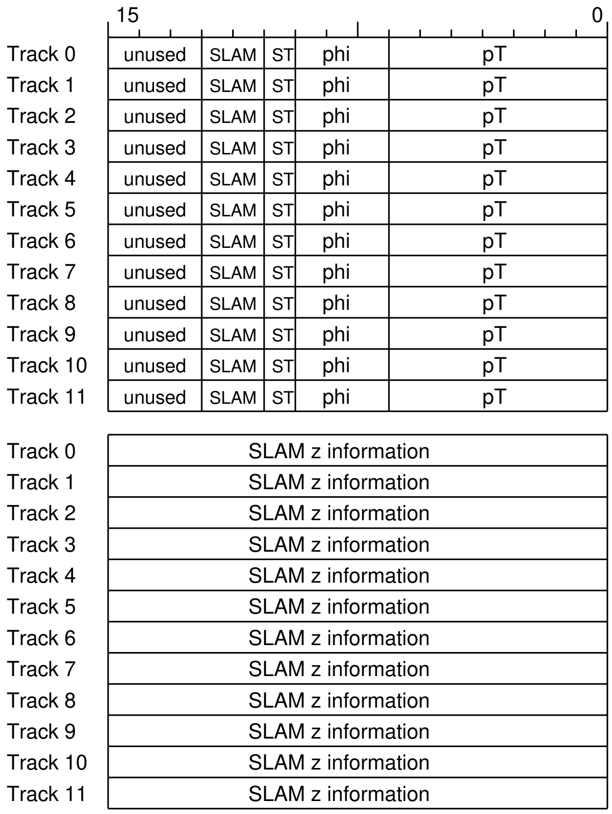

Figure 2: A possible representation of track data transmitted from the SLAM modules. The two SLAM bits may not necessarily be available at the earliest possible time that the axial track data is available. The short track bit (ST) may be redefined.

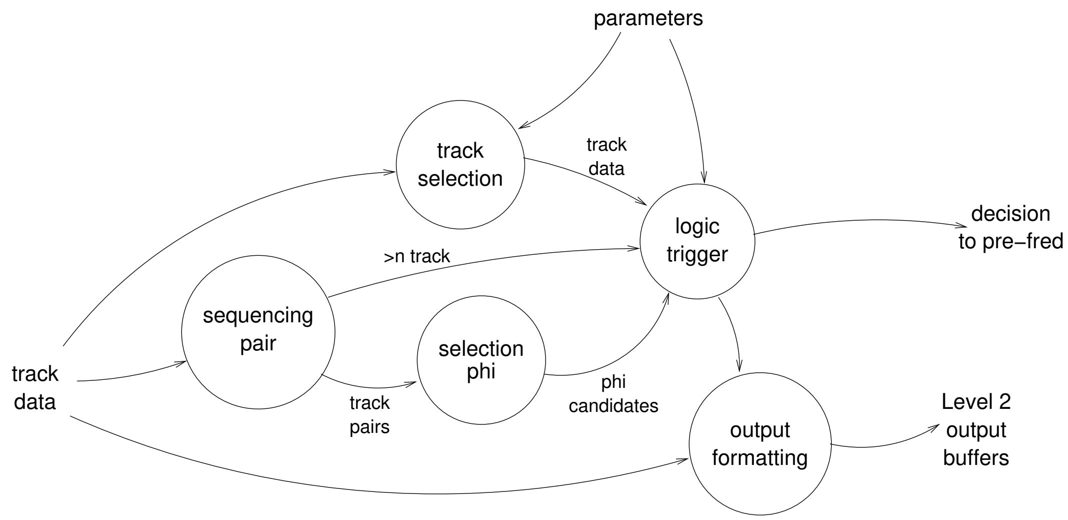

Figure 3: Data flow through the firmware elements.

4 Firmware

The proposed flow of data through the firmware is shown in Figure 3. "Pair sequencing" refers to the operation of forming pairs of tracks which are to be tested for consistency with being a phi candidate in the "phi selection" logic. The "track selection" logic will apply criteria to the list of input tracks before ϕ-track correlations are formed in the trigger logic. The "trigger logic" considers the phi candidate multiplicities and their spatial correlation with other tracks to form the trigger decision that is sent to pre-fred. The "output formatting" section maintains the address space occupied by the level 2 buffers that will (optionally) contatin the input track data, the trigger candidates identified as well as any intermediate lists of data or triggerable objects.

4.1 Pair sequencing

As track data is received from the fibers it can be formed into pairs to be analysed by the phi selection logic. The requirements on $\Delta\phi_6$ impose restrictions on which track words from which fibers are paired with others. To some extent, the design of the pair sequencing logic and the global implementation of the phi selection logic are coupled, in the sense that a massively parallel, a pipelined architecture or a combination of the two dictate how pairs are presented to the phi selection logic elements.

If it is the pair sequencing logic that determines when there are too many tracks to process, then this must be communicated to the trigger logic section.

4.1.1 Massively parallel implementation

A fully parallel implementation maps each possible pairing of tracks onto a dedicated phi selection logic element. As the track data is clocked in from the input fibers there are at most 228 pairs that need to be analysed in each 16 ns clock cycle. Although there may be

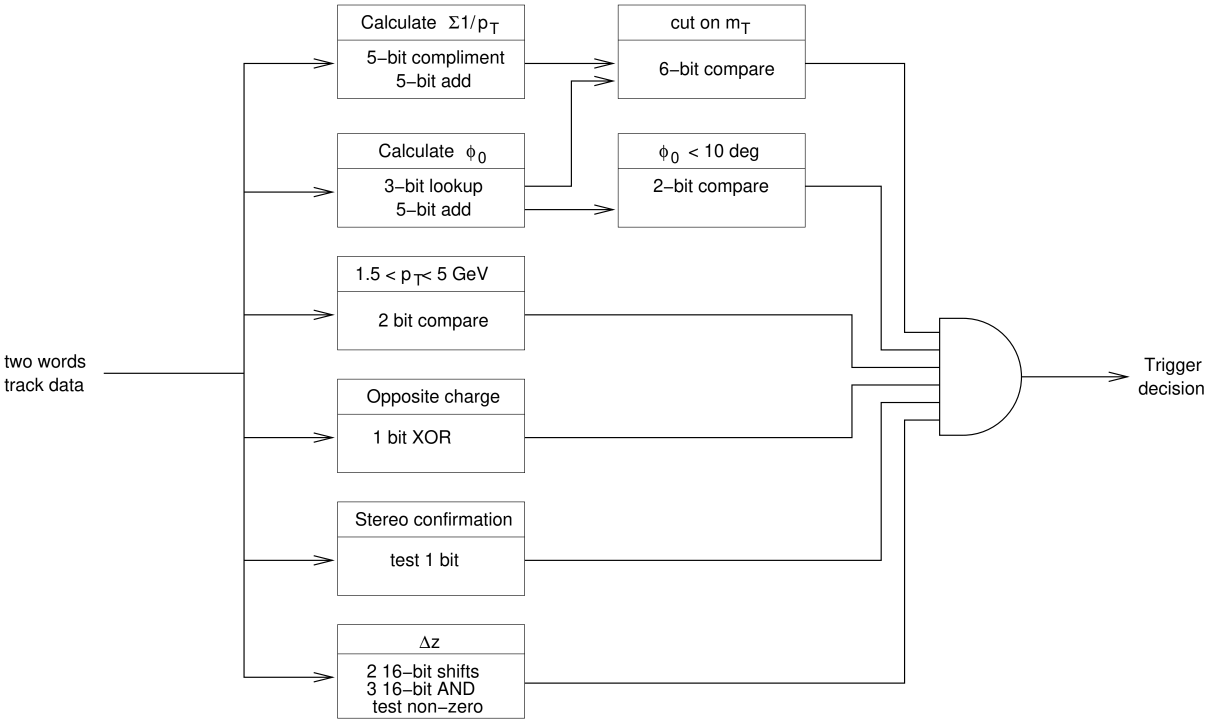

Figure 4: Logic operatons to apply selection criteria to track pair data.

enough resources available to implement this number of pairs, the routing of input tracks to phi selection logic elements may be problematic given the constraints imposed by the Pulsar architecture.

4.1.2 Pipelined architecture

Since it is unlikely that every SLAM module will identify the maximum of 12 tracks, a smaller number of phi selection logic elements could be used to process only pairs obtained from valid tracks. This would lend itself to easily generating triggers to accept high track multiplicity events. This approach would also be important if it took longer than 16 ns to process a single track pair.

4.2 Phi selection

Pairs of tracks to be tested for consistency with being a phi candidate can be represented by two data words that describe their transverse momentum, azimuthal angle and any associated stereo information. The logic operations that are needed to implement the list of selection criteria appear to be simple and should be fast to execute. One possible set is represented in Figure 4.

4.3 Track selection

We anticipate forming triggers that require the selection of a phi candidate in coincidence with a track with some minimum transverse momentum that is found within a given azimuthal angle. The track selection logic identifies candidate tracks before correlations are identified in the trigger logic section.

4.4 Trigger logic

The trigger logic will count the total number of phi candidates identified as well as the number identified within 15° ϕ-wedges. In addition, the number of tracks selected by the track selection logic will be counted in 15° wedges.

We need to write down Jonathan's algorithm here.

4.5 Output formatting

Some logic will be required to format the level 2 buffers to be read out for trigger validation. The two main types of data to be read out will be the data describing the phi candidates that are identified and an input data section from which trigger emulations can be driven. In addition, it will be important to optionally read out intermediate state data, particularly during commissioning.