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Specification for Upgraded Track Trigger Interfaces to Level 2

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1 Overview

Figure 1 shows the components of the proposed trigger upgrades and their interconnection. The proposed upgrades described here serve two main functions. The first, referred to as the Track List, provides the SVT and Level 2 with a list of tracks with lower latency than the current path, by way of the XTRP system. Second, the hardware that provides the functionality referred to as the Segment List, concatenates a list of track segments found by the stereo finder modules and passes them to Level 2. As shown in Figure 1, the Track List and Segment List hardware are each implemented using three Pulsar modules. The details of data input and output to each of these modules, and to other parts of the trigger system, are described in the following sections.

2 Functionality

This section describes the functions that the proposed upgrades will perorm. This is not necessarily a complete list and much of this functionality can be implemented in a staged fashion.

2.1 Track List Hardware

The primary function of the Track List hardware is to provide lists of tracks to other compoents of the trigger system. The axial track data used as input to the SLAM modules will be concatenated and sent to other trigger components after possibly applying sparsification algorithms. The following sections describe the three components of the trigger that could benefit from these lists of tracks. Possible sparsification algorithms that could be applied to each type of track list are described in section 2.3.

2.1.1 Output to SVT Mergers

The Track List hardware will provide a list of tracks to the SVT system with a lower latency than is currently possible by way of the XTRP system. Sparsification applied at this stage will reduce the number of track fits performed in the SVT, reducing the overall level 2

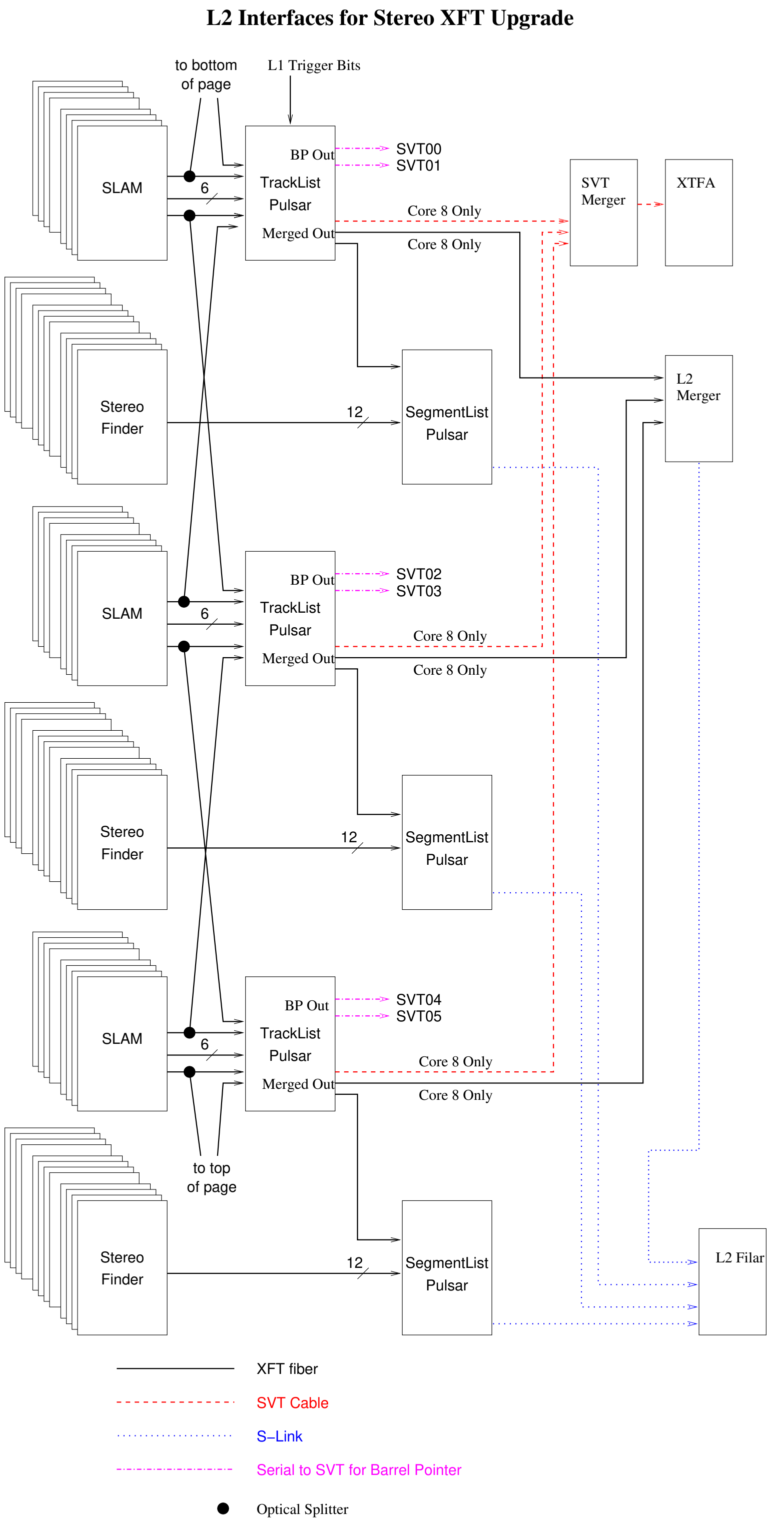

Figure 1: Components and interconnections of the proposed trigger upgrades.

processing time. The track lists will be sent to the SVT merger by the same type of SVT cable and with data in the same format as is currently used.

2.1.2 Output for SVT Barrel Pointer

A reduction in the number of track fits performed by the SVT will be achieved if hits are not read out from SVX-II half-barrels to which no XFT tracks are found to be pointing. To achieve this, the SLAM modules identify which half-barrels are likely to contain hits from a given track, and the Track List modules OR these masks to obtain a mask corresponding to an entire wedge. These masks are then sent to the appropriate SVT crates that process individual wedges.

2.1.3 Output Level 2

In addition to providing a list of tracks to the SVT system, the Track List hardware will provide a similar, but not necessarily identical list, to the Level 2 processor. This path will provide reduced latency, possible sparsification of tracks and the associated stereo information provided by the SLAM modules.

2.1.4 Output to the Segement List hardware

The Segment List hardware, described in Section 2.2, provides Level 2 with a list of stereo track segments identified by the Stereo Finder modules. Because of the possibly large data volume, it may be necessary to sparsify this list. One way that this can be achieved is by sending only those segments found in roads around the axial XFT tracks. The Track List hardware can be used to provide this list of tracks using algorithms that are similar, but not necessarily identical to the algorithms used to construct the lists sent to the SVT and Level 2.

2.2 Segment List Hardware

A list of track segments identified by the stereo finder modules will be concatenated and sent to Level 2 by a set of Segment List pulsar boards. Because of the large volume of data, it may be necessary to sparsify this list based on level 1 trigger bits, or based on roads around a list of axial tracks provided by the Track List Pulsar modules.

2.3 Track List sparsification algorithms

2.3.1 Level 1 trigger masks

The track lists sent to other trigger components can be sparsified based on the level 1 trigger mask. In this way, for example, only XFT tracks with $p_T > 2.0$ GeV/c, need to be sent to the SVT in events that satisfy the `L1_MET15_&_JET5_&_TWO_TRK2` trigger to drive the `L2_TWO_TRK2_D100_&_BJET15_&_MET15_DPS` trigger path.

from	to	medium	$n \times \ell$	format	driver	receiver	desc.
SLAM	TL	fiber	24×60 ft	XFT	on-board	RX mezz.	3.2.1
L1	TL	cable	$1\times?$ ft	L1	FRED fanout	Pulsar L1	3.2.2
TL	SVT AMS	cable	$6\times?$ ft	serial	Pulsar ?	Pulsar ?	3.2.4
TL	SVT Merger	cable	$3\times?$ ft	SVT	Pulsar SVT	Pulsar SVT	3.2.3
TL	SL	fiber	$3\times?$ ft	XFT	TX mezz.	RX mezz.	3.2.5
TL	L2 Merger	fiber	$3\times?$ ft	XFT	TX mezz.	RX mezz.	3.2.6
L2 Merger	L2	fiber	$1\times?$ ft	S-Link	S-Link mezz.	FILAR	3.2.7
SF	SL	fiber	36×60 ft	XFT	TX mezz.	RX mezz.	3.2.8
SL	L2	fiber	$3\times?$ ft	S-Link	S-Link mezz.	FILAR	3.2.9

Table 1: Interconnects throughout the proposed trigger upgrade hardware. TL = Track List, SL = Segment List, SF = Stereo Finder.

2.3.2 Barrel pointer algorithms

The limited track z_0 resolution provided by the SLAM modules may be used to identify SVX-II half barrels that are unlikely to contain hits associated with an XFT track. This information could be used to reduce the number of combinations of tracks and SVX hits analysed by the track fitter, reducing slightly the SVT processing time.

2.3.3 SLAM track quality

Any additional information that the SLAM module could provide that might be used as a basis for providing a smaller, higher purity list of tracks to the Level 2 and the SVT system, could be made available by the Track List hardware.

3 Interconnects

Table 1 describes the interconnects used to pass data between components in the trigger upgrades.

3.1 Driver and Receiver hardware

3.1.1 Pulsar connectors

The Pulsar has connectors that transmit and receive the 64-bit L1 trigger word[1]. The Pulsare also has the ability to transmit and receive data in the format used by the SVT system[2] via front-pannel connectors. Each Pulsar also accommodates up to four mezzanine cards that will be used to drive and receive data in other formats.

3.1.2 TX mezzanine board

The TX mezzanine board was developed as a Pulsar mezzanine card for use on the Stereo Finder transition boards to send pixel data to the Segment List Pulsar. These will also be used on the Track List Pulsars to drive data on fibers in XFT format to other components in the system. Each board drives four fibers, grouped into two pairs.

3.1.3 RX mezzanine board

The RX mezzanine board, used on the Stereo Finders to receive data from the TDC transition boards, will also be used on the Pulsars to receive fibers that carry data in XFT format. Each board receives four fibers.

3.1.4 FILAR board

This is the PCI interface card, used in the L2 decision PC, that receives up to 4 fibers carrying S-Link data.

3.2 Data format descriptions

This section specifies the format of the data transferred between the different components of the trigger upgrades. In several cases, the details are not yet fully specified. In some cases, constraints are imposed on the formats by the underlying hardware. Data sent on fibers in "XFT format" refers to the 8B/10B encoded serial optical bit stream transmitted at about 1.25 Gbps. Thus, 16 bits of data are clocked every 16.5 ns, allowing 24 16-bit words to be transferred in 396 ns. Data sent on the SVT cables[2]

3.2.1 SLAM → Track List

Each SLAM receives as input a total of 12 axial tracks from the backplane. On a Level 1 accept, the SLAM module will transmit this track data on one of three output fibers to the Track List module, along with information added to the axial tracks by their association with stereo segments. Table 2 shows a possible data transmission format in which the axial track information is sent first, including SLAM confirmation bits, followed by any additional stereo data associated with these tracks.

Note that the SLAM modules will need to transfer any r-z track information, for example, z and SL7, as well as information needed to drive the barrel pointer algorithms, such as a bit mask to specify z at the origin.

3.2.2 Level 1 trigger bits

The Level 1 trigger bits are brought into one of the Track List Pulsars on two front panel connectors[1]. This Pulsar then determines the level of sparsification needed for the other components in the system and broadcasts the sparsification level to the other Pulsars in the crate over the backplane.

3.2.3 Track List → SVT Merger

The track list sent to the SVT merger will be provided on one of the front panel SVT connectors on the Pulsar. The format will be identical to the copy currently received from XTRP[2].

data word	description
0	Track 0: 7-bits p_T, 3-bits ϕ, 1 short-track bit, 2-bits SLAM, 3-bits unused
1	Track 1: 7-bits p_T, 3-bits ϕ, 1 short-track bit, 2-bits SLAM, 3-bits unused
2	Track 2: 7-bits p_T, 3-bits ϕ, 1 short-track bit, 2-bits SLAM, 3-bits unused
...	
11	Track 11: 7-bits p_T, 3-bits ϕ, 1 short-track bit, 2-bits SLAM, 3-bits unused
12	stereo confirmation data (to be determined)
...	
23	

Table 2: Format of data driven by the SLAM to the Track List module.

3.2.4 Barrel Pointer → SVT

The small volume of data needed to identify which SVX-II half-barrels in a pair of wedges are expected to contain hits can be sent to the SVT crates using one of several types of cables already used in the system. The format needs to be specified, but will presumably consist of no more than 8-bits per SVX wedge on each L1 accept. The data could be sent to an AMS module and broadcast over the backplane of the SVT crate.

3.2.5 Track List → Segment List

It is not yet clear what the content of this data should be. It could be a list of tracks, sparsified according to some algorithm, that the Segment List Pulsar uses to construct roads around which it looks for stereo segments. Alternatively, the Track List Pulsar could simply identify which pixel positions might contain valid data based on where the axial tracks pass through superlayers 3, 5 and 7. In this case, the data could be a bit stream indicating which cells are masked and would then contain a maximum of 420 bits in total, which could be transferred in as little as 433 ns after receiving a L1 accept.

3.2.6 Track List → L2 Merger

To provide a list of tracks to Level 2, the lists received by each Track List Pulsar will be sent to a Level 2 Merger (which is another Pulsar), via a fiber in XFT format. A possible format would be to send 32 bits of data per track in two 16-bit XFT words.

3.2.7 L2 Merger → L2 decision

Track data sent to the L2 decision PC would consist of 32-bits of data per track sent over S-Link.

3.2.8 Stereo Finder → Segment List

The format of the pixel data sent from the Stereo Finder to the Segment List Pulsars has been specified[3] in a format that includes optional zero suppression. For now, this description will not be repeated here.

3.2.9 Segment List → Level 2

The Segment List Pulsars need to drive the sparsified list of segments to the L2 decision PC via S-Link. The format needs to be specified.

4 Algorithms

4.1 Track List Processor

Each of the four track lists prepared by the Track List Pulsars could, in principle, be constructed using separate algorithms running in parallel. One Track List Pulsar will receive the L1 trigger bits via the front panel connectors and determine which sparsification level to apply on each list. If we assume there are four different types of track lists to be constructed and allow for four different levels of sparsification, then a single 16 bit word transferred across the backplane will be sufficient.

4.1.1 SVT Track List

Construct a sparsified list of tracks based on axial XFT tracks, L1 trigger bits and possibly stereo information. The concatenated, ϕ-ordered list of tracks is then sent to the SVT Merger.

4.1.2 SVT Merger

The SVT Merger concatenates the lists of tracks, orders them in increasing ϕ, and transfers the list to XTFA.

4.1.3 L2 Merger

The Level 2 Merger concatenates the lists of tracks received from each Track List module, orders them in increasing ϕ and transferrs them by S-link to the L2 interface card.

4.1.4 Segment List

As described in Section 3.2.5, the Track List Pulsar could prepare a sparsified list of tracks for transmission to the Segment List Pulsar, or it could construct a bit mask to indicate which cells might contain track segments based on the axial tracks, possibly with SLAM confirmation or other sparsification.

4.2 Segment List Processor

The Segment List processor needs to format the list of segments received by the stereo finders, apply additional sparsification using Level 1 trigger bits and the data received from the Track List Pulsars, and transmit this list to the L2 decision PC.

5 L2 Buffer Address Space

To facilitate commissioning, the Track List and Segment List Pulsars need to implement Level 2 buffers that will allow validation of their input and output data. While the complete specification needs to be included in Note 4152[4], the following sections identify which information will need to be made available for readout. We shall assume that there is no need for zero suppression in any of the data sections described below. Since these buffers are only provided for commissioning and diagnostics, readout data volume will be controlled with readout lists.

5.1 Track List Pulsars

Data sections in the Track List Level 2 address space should provide the following information

- module header word
- input L1 bits
- input sparsification word
- input track data
- output sparsification word
- barrel pointer mask word
- track data to SVT merger
- track data to L2 merger
- track data/pixel masks sent to Segment List

5.2 Segment List Pulsars

Data sections in the Segment List Level 2 address space should provide the following information

- module header word
- input L1 bits
- input sparsification word
- input track segment pixels
- input track data/pixel masks from Track List
- output pixel data

6 Staged Implementation

As many of the possible improvements in trigger performance provided by the proposed upgrades are incremental, the extent to which all options are implemented can be based on ongoing performance studies using current data, or using data recorded with earlier stages of implementation.

6.1 Stage 0 - axial track pass through mode

The bulk of the firmware needed to operate the Track List Pulsars can be developed even if the SLAM modules operate in passthrough mode. The SLAM modules will still output the lists of axial XFT tracks which will allow the development of most of the algorithms described in Section 4 to begin. In this way, the track lists would initially be a concatenation of all axial tracks found by the linkers, but the use of stereo confirmation data would be almost completely transparent when it becomes available.

Lists of axial tracks would be sufficient for the Track List Pulsars to prepare masks of cells found to contain axial tracks which would be ANDed with the input pixels in the Segment List Pulsars to sparsify the list of pixels output to Level 2.

6.2 Stage 1 - availability of SLAM tracks

The confirmation of axial tracks by the SLAM module will be indicated by the re-use of bit fields already defined for the description of axial XFT tracks. Thus, as soon as the complete implementation of the SLAM firmware becomes available, using the lists of tracks confirmed by the presence of stereo pixels would require only very minor firmware changes to the Track List Pulsar firmware.

6.3 Stage 2 - sparsification based on trigger bits

Different classes of triggers may have different p_T thresholds on tracks. Suppose there are four classes of sparsification based on trigger bits. We need to write the L1 trigger bit masks to four sets of registers indicating which thresholds to apply in each case. A priority encoder then determines the threshold to be applied to each event. The same approach can be applied to the lists of segments prepared by the Segment List Pulsars.

6.4 Stage 3 - barrel pointer

Implementation of the barrel pointer algorithm requires that the SLAM modules identify candidate SVX half-barrels through which a track may have passed. It would then be relatively straight forward to OR these masks in the Track List pulsars and pass them to the SVT.

References

[1] Thurston Chandler, *et al.*, *Specification for the Global Level 1 $\leftrightarrow$ Level 2 Interface Board for Run II*, CDF Note 4971, July 8, 1999.

[2] S. Belforte, *et al.*, *Specification of the XTRP, SVT, and Level 2 Interfaces*, CDF Note 4578, February 25, 2000.

[3] R. Erbacher, *et al.*, *Specification of the Data Format from Level 1 to Level 2 of Stereo XFT*, CDF Note 7772, July 12, 2005.

[4] W. Badgett, *et al.*, *The CDF Run-II Event Structure*, CDF Note 4152.
`http://www-cdf.fnal.gov/internal/upgrades/computing/data_format/data_format.html`