

Description of the Data Structure for the Pulsar Trigger System

(To be included in CDFNote 4152)

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0.1 TP2D - Level-2 PULSAR Trigger Bank

The TP2D bank contains the diagnostic information for the Pulsar based Global Level-2 trigger decision crate. The main function of the Level-2 decision crate is to merge data from the various upstream L1 trigger system (Muon, XFT, Global Level-1, ShowerMax, SVT, and Cluster) and then forward the data to a LINUX based PC. The LINUX based PC runs the L2 trigger algorithm and returns the global L2 decision back to the Pulsar crate. One of the Pulsar boards in the crate is configured to receive the global L2 decision from the PC and handshake with the Trigger Supervisor.

The structure of the TP2D_StorableBank is given in Table 1. The Pulsar crate readout scheme is designed to be very flexible. When there are multiple crates reading out Pulsar boards, data from each crate is stored in a separate block in the TP2D_StorableBank. The DAQ buffer layout is identical for all the Pulsar boards. Each Pulsar board contains 6 unique DAQ buffers, which can be readout independently. Each DAQ buffer could either contain input data (data going into the Pulsar from upstream) or output data (data going out of the Pulsar board after internal processing). For each Pulsar board in the readout chain, there are 6 card pointers created in the block, which corresponds to the 6 DAQ buffers. In Table 1, the 6 DAQ buffer card pointers are labeled either as CONTROL or DATAIO.

The readout sequence of the Pulsar boards in a given crate follows the slot number (start from the lowest slot number). If a board is chosen not be readout (by setting online flag to 0 in the cardEditor database), then that board is skipped in the readout chain and no card pointers are created for that board. The Pulsar readout scheme also has a unique feature that each Pulsar board to be readout can be assigned to a different Readout-List (ROL). In addition, each of the 6 DAQ buffers within a Pulsar board could be removed from the readout by marking that particular Pulsar board DAQ buffer offline. The above features allow us the

possibility of reading out a subset of Pulsar boards for every event while the remaining boards are selectively readout (based on ROL). Furthermore, when a board is readout, we can also select to readout only a subset of the DAQ buffers for that particular Pulsar board. Note that as long as the ONLINE flag is set to 1 (active) for a given board, 6 card pointers will always be created in the TP2D bank for that board, even if the board is not readout due to the board-level ROL or some of the DAQ buffers were marked offline. However, the card pointers in this case will indicate that the contents of those cards are empty. The Pulsar readout configuration for a given run is stored in the hardware database, which can be retrieved offline.

In the current configuration, there are a total of 9 double-width Pulsar boards installed in the Level-2 decision crate. The board layout in the crate is: Muon board (slot 5), ShowerMax 0 (slot 7), ShowerMax 1 (slot 9), ShowerMax 2 (slot 11), SVT board (slot 13), Cluster board (slot 15), L2TS board (slot 17), ShowerMax Merger (slot 19), and Global SLINK Merger board (slot 21).

In the following sections, we will describe the content of the individual cards for the Pulsar boards in detail.

0.1.1 Pulsar Muon Board

The Pulsar Muon board is configured to merge data from the L1 muon trigger (12 matchbox fibers and 4 pre-match fibers). The Muon board also receives a copy of the XFT tracks from the XTRP and the L1 trigger bits from FRED. The Pulsar Muon board performs zero-suppression on the raw muon trigger data and sends the results downstream to the Global SLINK Merger along with the XTRP track-list and L1 trigger bits.

Pulsar Muon Board (CONTROL1 Card)

The Pulsar Muon board CONTROL1 card contains the output data for the Pulsar Muon Board. Aside from the header differences, it is essentially a copy of the data sent to the Global SLINK Merger board. The structure of the card is described in Table 2. The format of the XTRP word is defined in Tabel 4. Table 5 describes the format of the muon data words. Each non-zero muon word (24-bit long) is stored in two parts: part I contains the lower 12 bits (0..11) and part II contains the upper 12 bits (12..23). The bit definition for the muon word is identical to the Central Muon Matchbox Trigger Bank, TCMD (section ??¹). The data source (prematch or matchbox) and the fiber number could be translated from the Pulsar FPGA, mezzanine card, and channel numbers. The prematch fiber is always channel # 3. The prematch fiber number is given by the expression: $(2 \times \text{FPGA}\#) + (\text{mezzanine card}\#)$. The matchbox fibers are channels 0 to 2. The matchbox fiber number is given by the expression: $[(6 \times \text{FPGA}\#) + (3 \times \text{mezzanine card}\#) + \text{channel}\#]$. The Muon word # is defined in a similar way as the TCMD bank. For the matchbox, word #0 corresponds to “CMU East - High Pt Bits”, and the last word (#29) is the “IMP West Diagnostic Bits”. For the prematch, word #0 corresponds to “CMP Primitives for Stacks 00-23”, and the last word (#15) corresponds to “CMP/CSP West Matches for Stacks 72-95”.

¹All the references to the master CdfNote-4152 tex file are not properly shown in this stand-alone chapter

“TP2D”
Bank Number
Bank Version
Bank Length (variable)
Bank Type (I*4)
Number of Blocks (=2)
Pointer to Block 0
Pointer to Block 1
Pointer to End of Data
Block 0: Number of Cards (= $i \times 6$)
Pointer to Pulsar Board 1 (CONTROL1) Card
Pointer to Pulsar Board 1 (CONTROL2) Card
Pointer to Pulsar Board 1 (DATAIO1.1) Card
Pointer to Pulsar Board 1 (DATAIO1.2) Card
Pointer to Pulsar Board 1 (DATAIO2.1) Card
Pointer to Pulsar Board 1 (DATAIO2.2) Card
...
Pointer to Pulsar Board i (CONTROL1) Card
Pointer to Pulsar Board i (CONTROL2) Card
Pointer to Pulsar Board i (DATAIO1.1) Card
Pointer to Pulsar Board i (DATAIO1.2) Card
Pointer to Pulsar Board i (DATAIO2.1) Card
Pointer to Pulsar Board i (DATAIO2.2) Card
Block 1: Number of Cards (= $j \times 6$)
Pointer to Pulsar Board $i+1$ (CONTROL1) Card
Pointer to Pulsar Board $i+1$ (CONTROL2) Card
Pointer to Pulsar Board $i+1$ (DATAIO1.1) Card
Pointer to Pulsar Board $i+1$ (DATAIO1.2) Card
Pointer to Pulsar Board $i+1$ (DATAIO2.1) Card
Pointer to Pulsar Board $i+1$ (DATAIO2.2) Card
...
Pointer to Pulsar Board $i+j$ (CONTROL1) Card
Pointer to Pulsar Board $i+j$ (CONTROL2) Card
Pointer to Pulsar Board $i+j$ (DATAIO1.1) Card
Pointer to Pulsar Board $i+j$ (DATAIO1.2) Card
Pointer to Pulsar Board $i+j$ (DATAIO2.1) Card
Pointer to Pulsar Board $i+j$ (DATAIO2.2) Card

Table 1: Structure of the TP2D bank. This example shows the bank format when there are two crates reading out Pulsar boards. Block 0 contains the data from the i number of Pulsar boards to be readout in the first crate. Block 1 contains the data from the j number of Pulsar boards to be readout in the second crate. For each Pulsar board in the readout chain, 6 card pointers are created, which corresponds to the 6 onboard DAQ buffers.

Displacement	Data Description
P_{card}	Header Word
$P_{card}+1$	SLINK BOF
$P_{card}+2$	SLINK Header 1
$P_{card}+3$	SLINK Header 2
$P_{card}+4$	L1 Trigger Bits (bits 0 to 31)
$P_{card}+5$	L1 Trigger Bits (bits 32 to 63)
$P_{card}+6$	Track 1 XTRP Data
...	...
$P_{card}+5+N_{TRK}$	Track N_{TRK} XTRP Data
$P_{card}+6+N_{TRK}$	Muon Word 1 Data (Part I)
$P_{card}+7+N_{TRK}$	Muon Word 1 Data (Part II)
...	...
$P_{card}+4+N_{TRK}+2\times N_{\mu}$	Muon Word N_{μ} Data (Part I)
$P_{card}+5+N_{TRK}+2\times N_{\mu}$	Muon Word N_{μ} Data (Part II)
$P_{card}+6+N_{TRK}+2\times N_{\mu}$	End of Event Word
$P_{card}+7+N_{TRK}+2\times N_{\mu}$	SLINK Trailer
$P_{card}+8+N_{TRK}+2\times N_{\mu}$	SLINK EOF

Table 2: Structure of Pulsar Muon board CONTROL1 card. P_{card} is the card pointer for the Pulsar Muon board CONTROL1 card. Header word and various SLINK control word definitions are given in Table 3. The bit assignments for Part I and II of the Muon word are given in Table 5.

Data Word	Bit Definition
Header Word	Board Type(31:23), Serial Number(22:13), Reserved (12:8), Bunch Counter(7:0)
SLINK BOF	SLINK Beginning of Fragment Control Word
SLINK Header 1	Format (31:24), Source (23:20), Region ID (19:18), Reserved (17:10), Bunch Counter (9:2), Buffer (1:0)
SLINK Header 2	Reserved for future use
SLINK Trailer	Data Size (31:16), Error Flags (15:0)
SLINK EOF	SLINK End of Fragment Control Word

Table 3: Header word and SLINK control words definitions for the Pulsar Muon board CONTROL1 card.

Bit	Definition
11:0	Track ϕ
18:12	Track Curvature Bin
19	Not Used
20	SL6/SL8 Bit (Short Track Bit)
21	EP Bit (always 1)
22	EE Bit (always 0)
31..23	Not Used

Table 4: Bit assignments for the XTRP Data Word in the Pulsar Muon board CONTROL1 card.

Bit	Definition for Part I	Definition for Part II
11..0	Muon Data	Muon Data
16..12	Muon word # (0-29 for matchbox data, 0-15 for pre-matchbox data)	(Same as Part I)
18..17	Pulsar Channel # (0-3)	(Same as Part I)
19	Pulsar Mezzanine card # (0-1)	(Same as Part I)
20	Pulsar FPGA # (0-1)	(Same as Part I)
21	EP Bit (always 0)	EP Bit (always 0)
22	EE bit (always 0)	EE bit (always 0)
31..23	Not Used	Not Used

Table 5: Bit assignments for the zero-suppressed Muon Data Word in the Pulsar Muon board CONTROL1 card.

Bit	Definition
18:0	Reserved for Error Flags and Event ID Tag
20:19	Level-2 Buffer Number
21	EP Bit = 1
22	EE Bit = 1
31..23	Not Used

Table 6: Bit assignments for the End of Event Word in the Pulsar Muon board CONTROL1 card.

Pulsar Muon Board (CONTROL2 Card)

Pulsar Muon board CONTROL2 card contains a copy of the XFT track data sent to the Pulsar board from the Level-1 XTRP trigger. The format is described in Table 7.

Displacement	Data Description
P_{card}	Track 1 XTRP Data
P_{card+1}	...
$P_{card+N_{TRK}}$	Track N_{TRK} XTRP Data
$P_{card+1+N_{TRK}}$	End of Event Word

Table 7: Structure of Pulsar Muon board CONTROL2 card. P_{card} is the card pointer for the Pulsar Muon board CONTROL2 card. The bit assignments for the XTRP Data Word and the End of Event Word are described in Tables 4 and 6.

Pulsar Muon Board (DATAIO1.1 Card)

Reserved for future use.

Pulsar Muon Board (DATAIO1.2 Card)

Muon Board DATAIO1.2 card contains the muon trigger data sent to the Pulsar board from the Level-1 muon trigger. For each muon word, the Level-1 muon sends 24 data bits and 8 control bits. The 8 control bits, which are used for checking transmission errors, are bit 7, 15, 23, 27, 28, 29, 30, and 31 (counting from 0). The data content of this card is essentially a copy of the TCMD bank block 0 and 1. The main difference is that the muon words in the TCMD bank does not contain control bits, the data is given in the first 24 bits of each word in TCMD. DATAIO1.2 card contains fiber data from the L1 Muon MatchBox 0 to 5 and PrematchBox 0 and 1. The remaining fiber data are stored in DATAIO2.2 card.

Pulsar Muon Board (DATAIO2.1 Card)

Reserved for future use.

Pulsar Muon Board (DATAIO2.2 Card)

Same as Pulsar Muon board DATAIO1.2 card. This card contains fiber data from the Muon MatchBox 6 to 11 and Prematchbox 2 and 3.

Displacement	Data Description
$P_{card}+(30\times n)$	CMU East - High Pt Bits
$P_{card}+(30\times n)+1$	CMU East - Low Pt Bits
$P_{card}+(30\times n)+2$	CMU West - High Pt Bits
$P_{card}+(30\times n)+3$	CMU West - Low Pt Bits
$P_{card}+(30\times n)+4$	CMX East - High Pt Bits
$P_{card}+(30\times n)+5$	CMX East - Low Pt Bits
$P_{card}+(30\times n)+6$	CMX West - High Pt Bits
$P_{card}+(30\times n)+7$	CMX West - Low Pt Bits
$P_{card}+(30\times n)+8$	CSX and HAD East Bits
$P_{card}+(30\times n)+9$	CSX and HAD West Bits
$P_{card}+(30\times n)+10$	BMU East - High Pt Bits
$P_{card}+(30\times n)+11$	BMU East - Low Pt Bits
$P_{card}+(30\times n)+12$	BMU West - High Pt Bits
$P_{card}+(30\times n)+13$	BMU West - Low Pt Bits
$P_{card}+(30\times n)+14$	BSU East Bits
$P_{card}+(30\times n)+15$	BSU West Bits
$P_{card}+(30\times n)+16$	TSU and HAD East Bits
$P_{card}+(30\times n)+17$	TSU and HAD West Bits
$P_{card}+(30\times n)+18$	Spare Word A
$P_{card}+(30\times n)+19$	Spare Word B
$P_{card}+(30\times n)+20$	TOF Bits
$P_{card}+(30\times n)+21$	CMU East Diagnostic Bits
$P_{card}+(30\times n)+22$	CMU West Diagnostic Bits
$P_{card}+(30\times n)+23$	Eta Gap Diagnostic Bits
$P_{card}+(30\times n)+24$	CMX East Diagnostic Bits
$P_{card}+(30\times n)+25$	CMX West Diagnostic Bits
$P_{card}+(30\times n)+26$	IMA East Diagnostic Bits
$P_{card}+(30\times n)+27$	IMA West Diagnostic Bits
$P_{card}+(30\times n)+28$	IMB East Diagnostic Bits
$P_{card}+(30\times n)+29$	IMB West Diagnostic Bits

Table 8: Structure of Pulsar Muon board DATAIO[1,2]-2 for fiber n ($n=0,1,2,4,5,6,8,9,10,12,13,14$). The data for the 12 fibers are coming from the 12 L1 Muon matchbox. There are 24 significant bits for each muon matchbox data word. The remaining bits are control bits. The control bits are bit # 7, 15, 23, 27, 28, 29, 30, and 31 (counting from 0).

Displacement	Data Description
$P_{card+(30 \times n)}$	CMP Primitives for Stacks 00-23
$P_{card+(30 \times n)+1}$	CMP Primitives for Stacks 24-47
$P_{card+(30 \times n)+2}$	CMP Primitives for Stacks 47-71
$P_{card+(30 \times n)+3}$	CMP Primitives for Stacks 72-95
$P_{card+(30 \times n)+4}$	CSP East Bits for counters 00-23
$P_{card+(30 \times n)+5}$	CSP East Bits for counters 24-47
$P_{card+(30 \times n)+6}$	CSP West Bits for counters 00-23
$P_{card+(30 \times n)+7}$	CSP West Bits for counters 24-47
$P_{card+(30 \times n)+8}$	CMP/CSP East Matches for Stacks 00-23
$P_{card+(30 \times n)+9}$	CMP/CSP East Matches for Stacks 24-47
$P_{card+(30 \times n)+10}$	CMP/CSP East Matches for Stacks 48-71
$P_{card+(30 \times n)+11}$	CMP/CSP East Matches for Stacks 72-95
$P_{card+(30 \times n)+12}$	CMP/CSP West Matches for Stacks 00-23
$P_{card+(30 \times n)+13}$	CMP/CSP West Matches for Stacks 24-47
$P_{card+(30 \times n)+14}$	CMP/CSP West Matches for Stacks 48-71
$P_{card+(30 \times n)+15}$	CMP/CSP West Matches for Stacks 72-95
$P_{card+(30 \times n)+16}$	Reserved
...	...
$P_{card+(30 \times n)+30}$	Reserved

Table 9: Structure of Pular Muon board DATAIO[1,2]₂ cards for fiber n ($n=3,7,11,15$). The data for the 4 fibers are coming from the 4 L1 Muon prematchbox. There are 24 significant bits for each muon pre-match card data word. The remaining bits are control bits. The control bits are bit # 15, 23, 27, 28, 29, 30, and 31 (counting from 0).

0.1.2 Pulsar ShowerMax Board

Like the other Pulsar boards in the L2 upgrade, there are 6 DAQ buffers on each ShowerMax board. The ShowerMax input path is unique however in that in full system running there are multiple Pulsar boards participating in the data fan-in. The 48 CES channels require 3 fully driven Pulsar boards to accept data from the entire system. Each of the boards has its own independent readout range in the TP2D bank.

There will be instances however (for example, during commissioning, test runs, *etc.*) when less than three of the Pulsar ShowerMax could be read out. There could also be instances in the future in which *more than* three Pulsar ShowerMax boards will be read out (for example, if we eventually have hot spare electronics constantly receiving parasitic data for testing purposes). To accommodate such cases, the construction of the TP2D bank keys off the ONLINE FLAG value for each Pulsar board in the hardware database; only boards that are active in the readout (ONLINE FLAG == 1) have corresponding entries in the TP2D bank. Boards that are not participating in the readout have card-pointers (those of Table ??) that point to the first non-null Pulsar card of any type downstream in the readout chain.

The per-event data content for ShowerMax in L2 is constant: every channel on every event transmits 32 bits of CES data followed by the event's L2 buffer number, which for now is coded into its own separate 32-bit hex word. Since the per-channel data content flowing into the board is fixed, the per-event readout is fixed as well. Note that this could change in the near future in the event that zero-suppression is employed in the Pulsar ShowerMax board to reduce the overhead incurred from readout. This is expected to have a significant impact, given that the logic-high occupancy in the 32-bit data words is small, and there is much wasted bandwidth on the 32-bit word dedicated to the L2 buffer number (which by virtue of always being in the range 0 to 3 could be encoded on just 2 bits per channel.)

The total readout per board is 54 32-bit words per event. Three of the DAQ buffers are presently not used, but are held in reserve to be exploited in some way down the road.

Pulsar ShowerMax Board (CONTROL1 Card)

This DAQ buffer (or “card” in the nomenclature of DAQ readout) contains 22 32-bit words (Table 10). Four header words and two trailer words contain organizational information; besides a beginning-of-data and an end-of-data word for SLINK and other header and trailer words for SLINK, there is a Pulsar header word that contains a code for the type of board (in this case Pulsar ShowerMax) we are reading out. See Table ?? for more information on the content of these words.

The remaining 16 words correspond to the per-event data words that are transmitted via SLINK to the ShowerMax Merger for the ShowerMax Pulsar in question. The content of these 32-bit words are described in detail in the Table below. Each ShowerMax module has 32 wires readout in two eta regions. ADC sums are performed on 4-wire groups for both the low-eta and high-eta regions, and these ADC sums are compared to a low and high trigger threshold. If the ADC sum of the 4 CES wires exceeds the threshold (high and low) the bit is set to 1. See Eqn. 1 for a description of the bit allotment per wedge.

Displacement	Data Description
P_{card}	Header Word
$P_{card}+1$	SLINK BOF
$P_{card}+2$	SLINK Header 1
$P_{card}+3$	SLINK Header 2
$P_{card}+4$	XCES data channel 0
...	...
$P_{card}+19$	XCES data channel 15
$P_{card}+20$	SLINK Trailer
$P_{card}+21$	SLINK EOF

Table 10: Structure of Pulsar ShowerMax board CONTROL1 card. P_{card} is the card pointer to the Pulsar ShowerMax board CONTROL1 card. Header word and various SLINK control word definitions are given in Table ??.

$$\frac{32 \text{ wires}}{4 \frac{\text{wires}}{\text{group}}} * (2 \frac{\text{regions}}{\text{wedge}}) * (2 \text{ trigger thresholds}) * (1 \frac{\text{bit}}{\text{threshold}}) = 32 \frac{\text{trigger bits}}{\text{wedge}} \quad (1)$$

NB: In the bit scheme described herein, zero-suppression is not yet implemented.

high η module $ z > 121$ cm			low η module $ z < 121$ cm		
Bit	wire	threshold	Bit	wire	threshold
0	0-3	low	16	0-3	low
1	0-3	high	17	0-3	high
2	4-7	low	18	4-7	low
3	4-7	high	19	4-7	high
4	8-11	low	20	8-11	low
5	8-11	high	21	8-11	high
6	12-15	low	22	12-15	low
7	12-15	high	23	12-15	high
8	16-19	low	24	16-19	low
9	16-19	high	25	16-19	high
10	20-23	low	26	20-23	low
11	20-23	high	27	20-23	high
12	24-27	low	28	24-27	low
13	24-27	high	29	24-27	high
14	28-31	low	30	28-31	low
15	28-31	high	31	28-31	high

Pulsar ShowerMax Board (CONTROL2 Card)

Reserved for future use.

Pulsar ShowerMax Board (DATAIO1_1 Card)

This card contains input data from channels 0 through 7. Unlike the data readout of the CONTROL card, here in the DATAIO cards there are no header or trailer words along with the data. Recall that there are two 32-bit words per input channel per event. That implies that the data size for this card's readout is 16 32-bit words, the length of which is fixed (until zero-suppression is implemented).

Displacement	Data Description
$P_{card+0+0}$	Input Channel 0 Data
$P_{card+0+1}$	Input Channel 0 Buffer Number
...	...
$P_{card+7+0}$	Input Channel 7 Data
$P_{card+7+1}$	Input Channel 7 Buffer Number

Table 11: Data readout format for Pulsar ShowerMax DATAIO DAQ buffers.

The bit-map for the data is word is given in the Table above.

Pulsar ShowerMax Board (DATAIO1_2 Card)

Reserved for future use.

Pulsar ShowerMax Board (DATAIO2_1 Card)

This card contains input data form channels 8 through 15. The data content is essentially the same as Table 11, but we reproduce another here for completeness. The data size for this card's readout is 16 32-bit words as in DATAIO1_1 Card.

Displacement	Data Description
$P_{card+0+0}$	Input Channel 8 Data
$P_{card+0+1}$	Input Channel 8 Buffer Number
...	...
$P_{card+7+0}$	Input Channel 15 Data
$P_{card+7+1}$	Input Channel 15 Buffer Number

Table 12: Data readout format for Pulsar ShowerMax DATAIO DAQ buffers.

The bit-map for the data is word is given in the Table above.

Pulsar ShowerMax Board (DATAIO2_2 Card)

Reserved for future use.

0.1.3 Pulsar SVT Board

The Pulsar SVT list board is used to transmit SVT data from the upstream SVT system to the downstream L2 decision PC. The Pulsar SVT board receives 7 words per SVT track at the input stage. After internal processing (stripping unneeded information), the Pulsar board outputs 2 32-bit SLINK words per SVT track.

Pulsar SVT Board (CONTROL1 Card)

The CONTROL1 card contains the output data for the Pulsar SVT board. The structure of the card is shown in Table 13:

Displacement	Data Description
P_{card}	Header Word
$P_{card}+1$	SLINK BOF
$P_{card}+2$	SLINK Header 1
$P_{card}+3$	SLINK Header 2
$P_{card}+4$	Track 1, Word 1
$P_{card}+5$	Track 1, Word 2
$P_{card}+6$	Track 2, Word 1
...	...
$P_{card}+2 \times N_{SVT}+2$	Track N_{SVT} , Word 1
$P_{card}+2 \times N_{SVT}+3$	Track N_{SVT} , Word 2
$P_{card}+2 \times N_{SVT}+4$	SVT Error Word (see table ??)
$P_{card}+2 \times N_{SVT}+5$	SLINK Trailer
$P_{card}+2 \times N_{SVT}+6$	SLINK EOF

Table 13: Structure of Pulsar SVT board CONTROL1 Card. The variable, N_{SVT} , is the total number of SVT tracks. The Header word and SLINK control words are defined in Table 3.

Each track has two associated words. These word are reduced version of the SVTD data and are defined in Table 14:

Pulsar SVT Board (CONTROL2 Card)

The Pulsar SVT board CONTROL2 card is a copy of the SVTD bank. Each SVT track is described with seven words. The structure of the card is shown in Table 15:

Word	Bit	Function
1	12:0	ϕ
	15:13	z_{in}
	18:16	z_{out}
	27:19	Absolute Value of Impact Parameter
	28	Sign of Impact Parameter
	31:29	Not assigned
2	7:0	Absolute Value of Curvature (Pt) Bin
	8	Sign of Curvature (Pt) bin
	19:9	χ^2 of fit
	28:20	XFT Linker ID
	29	Track-fitter error summary
	31:30	Not assigned

Table 14: Description of each SVT track. See Section ?? and Table ?? for a more detailed description.

Displacement	Data Description
P_{card}	Track 1, Word 1
$P_{card}+1$	Track 1, Word 2
$P_{card}+2$	Track 1, Word 3
...	...
$P_{card}+6$	Track 1, Word 7
...	...
$P_{card}+7 \times (N_{SVT} - 1)$	Track N_{SVT} , Word 1
$P_{card}+7 \times (N_{SVT} - 1)+1$	Track N_{SVT} , Word 2
$P_{card}+7 \times (N_{SVT} - 1)+2$	Track N_{SVT} , Word 3
...	...
$P_{card}+7 \times (N_{SVT} - 1)+6$	Track N_{SVT} , Word 7
$P_{card}+7 \times N_{SVT}$	SVT Error Word (see table ??)

Table 15: Structure of Pulsar SVT board CONTROL2 Card.

Each of the seven SVT track words are further defined in Table 16. For more information see Section ?? and Table ??

Pulsar SVT Board (DATAIO1.1 Card)

Reserved for future use.

Pulsar SVT Board (DATAIO1_2 Card)

Reserved for future use.

Pulsar SVT Board (DATAIO2_1 Card)

Reserved for future use.

Pulsar SVT Board (DATAIO2_2 Card)

Reserved for future use.

0.1.4 Pulsar Cluster Board

The Pulsar Cluster board takes the cluster and iso-cluster fragments from the L2 calorimeter crates, sums up the cluster and iso-cluster energy, converts the ϕ position of the seed from local to global coordinates and computes the total number of trigger towers in the cluster. In addition, the PreFred EtSum bits are merged together with the calorimetry data as part of the SLINK output. In what follows we define N_{ISO} to be the number of iso-clusters in the event and N_{CLU} the number of clusters.

Pulsar Cluster Board (CONTROL1 card)

A copy of the SLINK package sent to the the Global Merger Board could be read in the CONTROL1 card. The firmware associated with this card acts very similar to the Merger firmware, therefore, the Cluster, Iso-cluster and PreFred data are merged together as separate SLINK packages. Consequently, we will have separate SLINK headers and trailers for individual data as well as general Slink headers and trailers for the merged package. The detailed structure of the data appears in Table 17².

Pulsar Cluster Board (CONTROL2 Card)

Reserved for future use.

Pulsar Cluster Board (DATAIO1_1 Card)

This card is effectively split into 8 readout sections. The first 6 contain a replica of the data coming from the 6 ISOPICK boards. The 7'th section is empty and the 8'th section contains a replica of the data coming from ISOCLIQUE. The ISOPICK data is logged as presented in Table 21 while the ISOCLIQUE data is shown in Table 22.

In the case of an empty event, each one of the 8 sections will read 1, except for the 7'th one which will read 0.

²In the case of an empty event, the SLINK package will contain a single word (aside from the SLINK control words) which will be End of Event word, for Iso-Cluster part and 0XEFFFFFFF, for Cluster part

Pulsar Cluster Board (DATAIO1_2 Card)

This card contains the SLINK packed data for the Iso-clusters. Table 24 details the format for this data³. This is practically identical to the Iso-Cluster part of the CONTROL1 data.

Pulsar Cluster Board (DATAIO2_1 Card)

As in the case of DATAIO1_1, there are effectively 8 readout sections. The first 6 contain a replica of the data coming from the 6 LOCOS boards. The 7'th section is empty and the 8'th section contains a replica of the data coming from CLIQUE. The LOCOS data is logged as presented in Table 25.

In the case of an empty event, each one of the eight sections will read 0.

Pulsar Cluster Board (DATAIO2_2 Card)

This card contains the SLINK packed data for the Iso-clusters. Table 26 details the format for this data⁴.

0.1.5 Pulsar L2TS Board

The function of the Pulsar L2TS board is to receive the global Level-2 trigger decision from the PC and transmit the decision to the Trigger Supervisor. The content of the TL2D bank from the PC is also stored in one of the DATAIO DAQ buffer to be readout by the VME crate processor.

Pulsar L2TS Board (CONTROL1 Card)

The CONTROL1 DAQ buffer is not used in the L2TS board. However, to conform to the CDF DAQ standard, a header word is stored in this buffer.

Pulsar L2TS Board (CONTROL2 Card)

The CONTROL2 DAQ buffer contains the timing information for the Level-2 trigger system. The three timer words are shown in Table 27 and the bit definitions are given in Table 28. The Timer Word 1 gives the arrival time interval between L1A signal and the L2A/R decision on the VME backplane (issued by the Trigger Supervisor). The Timer Word 2 gives the time difference between when the L1A signal arrives at the board and when the L2A/R decision is sent to the Trigger Supervisor from Pulsar L2TS board. The Timer Word 3 gives the time interval between L1A signal and the GL2A/R signal received by the Pulsar L2TS board from the Trigger Supervisor. For all 3 Timer Words, the first 16 bits (0..15) gives the

³In the case of an empty event, the SLINK package will contain a single word (aside from the SLINK control words) which will be the ISOCLIQUE End of Event word

⁴In the case of an empty event, the SLINK package will contain a single word (aside from the SLINK control words) which will be 0XEEEEEEEE

timing information for the current L1A event and the higher 16 bits (16..31) give the timing information for the previous L1A event (which is unbiased w.r.t Level-2 decision).

Pulsar L2TS Board (DATAIO1_1 Card)

The DATAIO1.1 card contains the data sent to the L2TS board from the Level-2 decision PC. The data contains the Level-2 trigger decision as well as the TL2D bank. The TL2D bank of the Pulsar based system is identical to the RunIIa TL2D bank to ensure backward compatibility with the existing software infrastructure. The format of this card is given in Table 29.

Pulsar L2TS Board (DATAIO1_2 Card)

Reserved for input timing information.

Pulsar L2TS Board (DATAIO2_1 Card)

Reserved for future use.

Pulsar L2TS Board (DATAIO2_2 Card)

Reserved for future use.

0.1.6 Pulsar Merger Boards

Each Pulsar Merger board receives its inputs through up to 4 SLINK Mezzanine cards. All inputs are recoded in the DATAIO DAQ Buffers. The arrival times of the first and last data word for the current and the previous event are recorded in the last two words of each DATAIO DAQ buffer. The board only merges the inputs which are selected for merging by configuring the Control FPGA control register. During the pre summer shutdown 2004 commissioning runs two Pulsar merger boards were installed in the Level-2 Pulsar crate, a Pulsar ShowerMax Merger (slot 19) combining the SLINK messages of the three Pulsar ShowerMax receiver (RX) boards and a so-called Pulsar Global SLINK Merger (slot 21). The later combines the SLINK messages of the Pulsar Muon Rx, Reces Merger and input from a SLINK transmitter (TX) which provided Pulsar Cluster RX test pattern.

Pulsar Merger Board (CONTROL1 Card)

same structure for ShowerMax merger and SLINK Merger, SLINK message 1 stands for the Reces Rx 0 or Muon Rx, SLINK message 2 stands for Reces Rx 1 or Reces Merger, SLINK message 3 stands for Reces Rx 2 or Pulsar Cluster Rx pattern. Note that the the SLINK EOF word is carried on for the 3rd SLINK message only. This is a known firmware feature and may be corrected in future.

Pulsar Merger Board (CONTROL2 Card)

Reserved for future use.

Pulsar Merger Board (DATAIO_{i,j} Card)

The SLINK messages are recoded in the DataIO cards ($i,j=1,2$). N_{SLINK} is the wordcount as found in the SLINK trailer word.

Word	Bit	Function
0	12:0	ϕ
	15:13	z_{in}
	18:16	z_{out}
	19	0
	20	1
	22:21	0
	31:23	Not assigned
1	8:0	Absolute value of Impact parameter
	9	Sign of impact parameter
	17:10	Absolute value of Curvature (Pt) Bin
	18	Sign of Curvature
	22:19	0
	31:23	Not assigned
2	14:0	Road ID
	16:15	0
	20:17	ϕ sector
	22:21	0
	31:23	Not assigned
3	9:0	x_0 – Hit coordinates in layer 0
	19:10	x_1 – Hit coordinates in layer 1
	20	Spare
	22:21	0
	31:23	Not assigned
4	9:0	x_2 – Hit coordinates in layer 2
	19:10	x_3 – Hit coordinates in layer 3
	20	Spare
	22:21	0
	31:23	Not assigned
5	9:0	x_4 – Hit coordinates in layer 4
	20:10	χ^2 of fit
	22:21	0
	31:23	Not assigned
6	8:0	XFT linker ID
	20:9	Track-fitter status
	21	1 (End of Packet)
	22	0
	31:23	Not assigned

Table 16: Description of a single SVT track in the CONTROL2 Card. For a detailed description, see section ??.

Displacement	Data Description
P_{card}	Header Word
$P_{card}+1$	SLINK BOF
$P_{card}+2$	Combined SLINK Header 1
$P_{card}+3$	Combined SLINK Header 2
$P_{card}+4$	PreFred Et Sum data (bits 0 to 31)
$P_{card}+5$	SLINK BOF
$P_{card}+6$	Iso-Cluster SLINK Header 1
$P_{card}+7$	Iso-Cluster SLINK Header 2
$P_{card}+8$	Iso-Cluster 0 Word 1
$P_{card}+9$	Iso-Cluster 0 Word 2
$P_{card}+10$	Iso-Cluster 0 Word 3
$P_{card}+11$	Iso-Cluster 0 Word 4
...	...
$P_{card}+8+4 \times N_{ISO}$	Iso-Cluster N_{ISO} Word 1
$P_{card}+9+4 \times N_{ISO}$	Iso-Cluster N_{ISO} Word 2
$P_{card}+10+4 \times N_{ISO}$	Iso-Cluster N_{ISO} Word 3
$P_{card}+11+4 \times N_{ISO}$	Iso-Cluster N_{ISO} Word 4
$P_{card}+12+4 \times N_{ISO}$	Iso-Cluster End of Event Word
$P_{card}+13+4 \times N_{ISO}$	Iso-Cluster SLINK Trailer
$P_{card}+14+4 \times N_{ISO}$	SLINK EOF
$P_{card}+15+4 \times N_{ISO}$	SLINK BOF
$P_{card}+16+4 \times N_{ISO}$	Cluster SLINK Header 1
$P_{card}+17+4 \times N_{ISO}$	Cluster SLINK Header 2
$P_{card}+18+4 \times N_{ISO}$	Cluster 0 Word 1
$P_{card}+19+4 \times N_{ISO}$	Cluster 0 Word 2
...	...
$P_{card}+18+2 \times N_{CLU}+4 \times N_{ISO}$	Cluster N_{CLU} Word 1
$P_{card}+19+2 \times N_{CLU}+4 \times N_{ISO}$	Cluster N_{CLU} Word 2
$P_{card}+20+2 \times N_{CLU}+4 \times N_{ISO}$	Cluster SLINK Trailer
$P_{card}+21+2 \times N_{CLU}+4 \times N_{ISO}$	SLINK EOF
$P_{card}+22+2 \times N_{CLU}+4 \times N_{ISO}$	Combined SLINK Trailer
$P_{card}+23+2 \times N_{CLU}+4 \times N_{ISO}$	SLINK EOF

Table 17: Structure of Pulsar Cluster board CONTROL1 card. P_{card} is the card pointer to the Pulsar Cluster board CONTROL1 card. The Combined SLINK control words are defined in Table 3. Header word and various cluster/iso-cluster SLINK control word definitions are given in Table 18. The bit assignments for Cluster words are given in Table 20 and for Iso-Cluster words in Table 21.

Data Word	Bit Definition
Header Word	Board Type(31:23), Serial Number(22:13), Reserved (12:8), Bunch Counter(7:0)
SLINK BOF	SLINK Beginning of Fragment Control Word
SLINK Header 1	Format (31:24), Source (23:20), Region ID (19:18), Reserved (17:10), Bunch Counter (9:2), Buffer (1:0)
SLINK Header 2	Latency(31:16), Data Size(15:0)
SLINK Trailer	Data Size (31:16), Error Flags (15:0)
SLINK EOF	SLINK End of Fragment Control Word

Table 18: Header word and cluster/iso-cluster SLINK control words definitions for the Pulsar Cluster board CONTROL1 card.

Word number	Bit	Definition
1	1:0	Pass Number
1	6:2	Seed ϕ
1	8:7	Buffer Number
1	13:9	Seed η
1	31:14	Unused
2	15:9	EtSum1
2	31:16	EtSum2
3	15:9	EtSum3
3	31:16	EtSum4
4	15:9	EtSum5
4	31:16	Unused

Table 19: Bit assignments for the Iso-cluster words in the Pulsar Cluster board CONTROL1 card.

Word number	Bit	Definition
1	15:0	Cluster HAD Energy
1	31:16	Cluster EM Energy ϕ
2	1:0	Buffer Number
2	3:2	Pass Number
2	13:4	Number of towers
2	18:14	Seed η
2	23:19	Seed ϕ
2	31:24	Unused

Table 20: Bit assignments for the Cluster words in the Pulsar Cluster board CONTROL1 card.

Displacement	Data Description	Bit assignment
$P_{card+i} \times (3 \times N_{ISO} + 1) + 0$	$3 \times N_{ISO} + 1$	
$P_{card+i} \times (3 \times N_{ISO} + 1) + 1$	ISOPICK i , Iso-cluster 0, Word 0	$eta(4:0)$, $buffer(6:5)$, diagnostic bit(7), IsoSum1(31:15)
$P_{card+i} \times (3 \times N_{ISO} + 1) + 1$	ISOPICK i , Iso-cluster 0, Word 1	IsoSum2(15:0), IsoSum3(31:16)
$P_{card+i} \times (3 \times N_{ISO} + 1) + 1$	ISOPICK i , Iso-cluster 0, Word 2	IsoSum4(15:0), IsoSum5(31:16)

Table 21: ISOPICK i for iso-cluster 0 data, as logged in the Pulsar Cluster board DATAIO1_1 card.

Displacement	Data Description
$P_{card+7} \times (3 \times N_{ISO} + 1) + i$	ISOCLIQUE Word i

Table 22: ISOCLIQUE data as logged in the Pulsar Cluster board DATAIO1_1 card for iso-cluster number i . The bit assignment for an ISOCLIQUE word is defined in Table 23.

Bit assignment	Description
1:0	Seed ϕ (local)
6:2	Seed η (global)
7	Diagnostic bit
9:8	Pass number
11:10	Buffer number
14:12	Seed crate number
15	Done Bit
31:16	Unused

Table 23: The bit assignment for an ISOCLIQUE word.

Displacement	Data Description
$P_{card}+0$	SLINK BOF
$P_{card}+1$	Iso-Cluster SLINK Header 1
$P_{card}+2$	Iso-Cluster SLINK Header 2
$P_{card}+3$	Iso-Cluster 0 Word 1
$P_{card}+4$	Iso-Cluster 0 Word 2
$P_{card}+5$	Iso-Cluster 0 Word 3
$P_{card}+6$	Iso-Cluster 0 Word 4
...	...
$P_{card}+3+4 \times N_{ISO}$	Iso-Cluster N_{ISO} Word 1
$P_{card}+4+4 \times N_{ISO}$	Iso-Cluster N_{ISO} Word 2
$P_{card}+5+4 \times N_{ISO}$	Iso-Cluster N_{ISO} Word 3
$P_{card}+6+4 \times N_{ISO}$	Iso-Cluster N_{ISO} Word 4
$P_{card}+7+4 \times N_{ISO}$	Iso-Cluster End of Event Word
$P_{card}+8+4 \times N_{ISO}$	Iso-Cluster SLINK Trailer
$P_{card}+9+4 \times N_{ISO}$	SLINK EOF

Table 24: Format of the DATAIO1.2 Card for the Pulsar Cluster Board. The bit assignment of particular words is found in Table 18 and 19

Displacement	Data Description	Bit assignment
$P_{card}+i \times (2 \times N_{CLU} + 1)+0$	$2 \times N_{ISO} + 1$	
$P_{card}+i \times (2 \times N_{CLU} + 1)+1$	LOCOS i Word 1 Cluster 0	buffer(1:0), EM(16:2), pass(18:17),HAD(31:19)
$P_{card}+i \times (2 \times N_{CLU} + 1)+2$	LOCOS i Word 2 Cluster 0	seed phi(1:0),seed eta(7:2) , select(8), towers(15:8)
...

Table 25: LOCOS i data as logged in the Pulsar Cluster board DATAIO2.1 card.

Displacement	Data Description
$P_{card}+0$	SLINK BOF
$P_{card}+1$	Cluster SLINK Header 1
$P_{card}+2$	Cluster SLINK Header 2
$P_{card}+3$	Cluster 0 Word 1
$P_{card}+4$	Cluster 0 Word 2
...	...
$P_{card}+3+2 \times N_{CLU}$	Cluster N_{CLU} Word 1
$P_{card}+4+2 \times N_{CLU}$	Cluster N_{CLU} Word 2
$P_{card}+5+2 \times N_{CLU}$	Cluster SLINK Trailer
$P_{card}+6+2 \times N_{CLU}$	SLINK EOF

Table 26: Format of the DATAIO2.2 Card for the Pulsar Cluster Board. The bit assignment of particular words is found in Table 20

Displacement	Data Description
P_{card}	TIMER WORD 1
$P_{card}+1$	TIMER WORD 2
$P_{card}+2$	TIMER WORD 3
$P_{card}+3$	Reserved for future use

Table 27: The CONTROL2 DAQ buffer for the L2TS Board.

Data	Bits	Definition
TIMER WORD 1	(15: 0)	arrival time counter of first word current event
TIMER WORD 1	(31:16)	arrival time counter of first word previous event
TIMER WORD 2	(15: 0)	arrival time counter of last word current event
TIMER WORD 2	(31:16)	arrival time counter of last word previous event
TIMER WORD 3	(15: 0)	arrival time counter of last word current event
TIMER WORD 3	(31:16)	arrival time counter of last word previous event
		1 counter unit = 0.100 μs

Table 28: TIMER WORD definitions.

Displacement	Data Description
$P_{card}+0$	SLINK BOF
$P_{card}+1$	PC Decision Word
$P_{card}+2$	SLINK Header 1
$P_{card}+3$	SLINK Header 2
$P_{card}+4$	Start of TL2D Bank
...	...
$P_{card}+n+1$	SLINK EOF

Table 29: Format of the DATAIO1.1 card for the Pulsar L2TS board. The index n indicates the total number of words in the TL2D bank. The format of the TL2D bank is given in Table ???. The SLINK control word definitions can be found in Table 3. The bit definition of the PC Decision word is given in Table 30.

Bit	Definition
1:0	Buffer Number
9:2	Bunch Counter
10	L2 Accept Bit
11	L2 Reject Bit
12	L2 Done-Time-Out Bit
15..13	ROL Bits
31..16	Not Used

Table 30: Bit assignments for the PC Decision Word.

Displacement	Data Description
P_{card}	Header Word
$P_{card}+1$	SLINK BOF
$P_{card}+2$	SLINK Header 1 (merger)
$P_{card}+3$	SLINK Header 2 (merger)
$P_{card}+4$	SLINK Header 1 (SLINK message 1)
$P_{card}+5$	SLINK Header 2 (SLINK message 1)
$P_{card}+5+1$	SLINK Data Content (SLINK message 1, first word)
...	SLINK Data Content (SLINK message 1)
$P_{card}+5+N_{SLINK1}$	SLINK Data Content (SLINK message 1, last word)
$P_{card}+5+N_{SLINK1}+1$	SLINK Trailer (SLINK message 1)
$P_{card}+5+N_{SLINK1}+2$	SLINK Header 1 (SLINK message 2)
$P_{card}+5+N_{SLINK1}+3$	SLINK Header 2 (SLINK message 2)
$P_{card}+5+N_{SLINK1}+4$	SLINK Data Content (SLINK message 2, first word)
...	SLINK Data Content (SLINK message 2)
$P_{card}+5+N_{SLINK1+2}$	SLINK Data Content (SLINK message 2, last word)
$P_{card}+5+N_{SLINK1+2}+1$	SLINK Trailer (SLINK message 2)
$P_{card}+5+N_{SLINK1+2}+2$	SLINK Header 1 (SLINK message 3)
$P_{card}+5+N_{SLINK1+2}+3$	SLINK Header 2 (SLINK message 3)
$P_{card}+5+N_{SLINK1+2}+4$	SLINK Data Content (SLINK message 3, first word)
...	SLINK Data Content (SLINK message 3)
$P_{card}+5+N_{SLINK1+2+3}$	SLINK Data Content (SLINK message 3, last word)
$P_{card}+5+N_{SLINK1+2+3}+1$	SLINK Trailer (SLINK message 3)
$P_{card}+5+N_{SLINK1+2+3}+2$	SLINK EOF (SLINK message 3)
$P_{card}+5+N_{SLINK1+2+3}+3$	SLINK Trailer (merger)
$P_{card}+5+N_{SLINK1+2+3}+4$	SLINK EOF (merger)

Table 31: Structure of Pulsar Merger CONTROL1 card. P_{card} is the card pointer to the Pulsar Muon board CONTROL1 card. Header word and various SLINK control word definitions are given in Table 3.

Displacement	Data Description
P_{card}	SLINK BOF
$P_{card}+1$	SLINK Header 1
$P_{card}+2$	SLINK Header 2
$P_{card}+3+1$	SLINK Data Content
...	SLINK Data Content
$P_{card}+3+N_{SLINK}$	SLINK Data Content
$P_{card}+3+N_{SLINK}+1$	SLINK Trailer
$P_{card}+3+N_{SLINK}+2$	SLINK EOF
$P_{card}+3+N_{SLINK}+3$	TIMER WORD 1
$P_{card}+3+N_{SLINK}+3$	TIMER WORD 2

Table 32: Structure of Pulsar Merger CONTROL1 card. P_{card} is the card pointer to the Pulsar Muon board CONTROL1 card. Header word and various SLINK control word definitions are given in Table 3. The TIMER WORD definitions are given in 33.

Data	Bits	Definition
TIMER WORD 1	(15: 0)	arrival time counter of first word current event
TIMER WORD 1	(31:16)	arrival time counter of first word previous event
TIMER WORD 2	(15: 0)	arrival time counter of last word current event
TIMER WORD 2	(31:16)	arrival time counter of last word previous event
		1 counter unit = $0.1 \mu s$

Table 33: TIMER WORD definitions.