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The CSC Track Finder Installation

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Abstract

This note describes the installation of the CSC Track Finder in the CMS Underground Service Cavern. Specific details of the location and type of electronics boards, fiber and cable connections pertaining to the crate are given.

1 Overview of the Crate

The CMS CSC Track Finder Crate is described in [1] and its functionality within the scope of the CMS Level-1 (L1) trigger in [2] and [3].

The basic function of the Track Finder is to receive CSC trigger primitives originating from individual CSC chambers and to try to extrapolate combinations of them into candidate muon tracks. When a candidate muon track is found, the Track Finder assigns a "rank" to it, based on the likelihood of it being a collision muon and a coarse calculation of its $P_{\perp}$. This information is then passed on to the CMS Global Muon Trigger (GMT) which serves to combine inputs from all three CMS muon subsystems. The task of receiving trigger primitives and ranking potential muon tracks must be done within a strict latency budget of around half a microsecond.

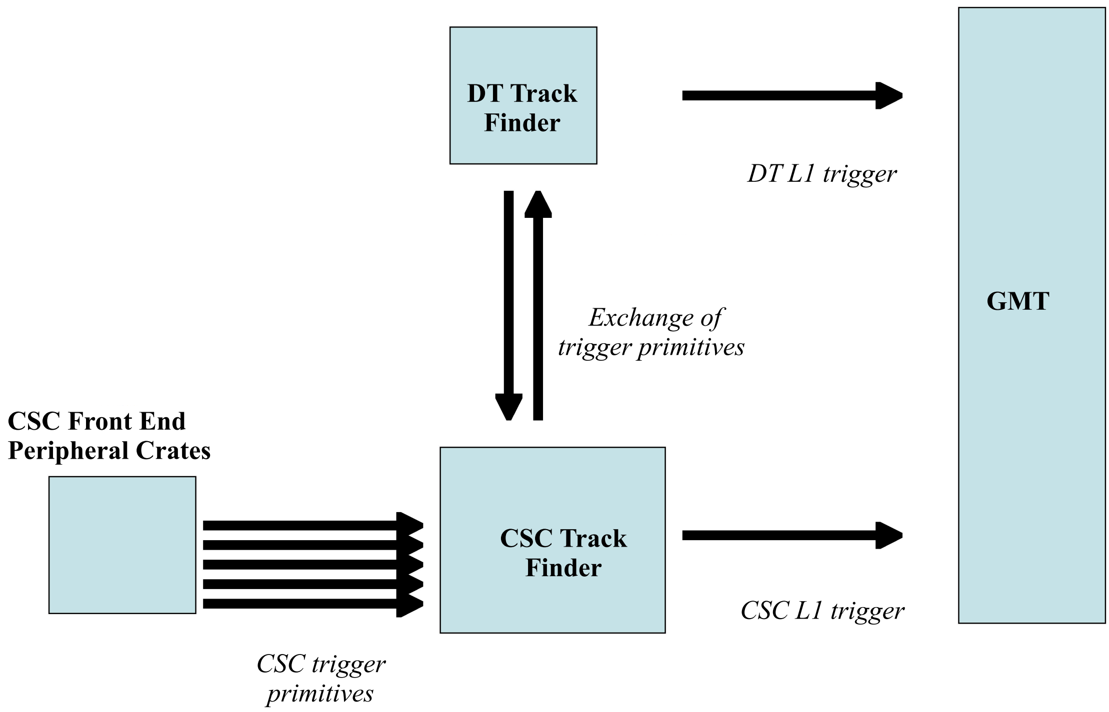

Figure 1. An overview of the CSC Track Finder within the CMS L1 Trigger Path.

The CSC Track Finder consists of a single crate filled with custom FPGA based electronics. The guts of the work is done by 12 Sector Processor (SP) boards. Each of the SPs receives CSC trigger primitives from chambers in a single end cap, within a region subtended by a 60^{o} slice in phi and produces up to three corresponding candidate muon tracks during each 25 ns bunch crossing. Six of the SPs cover one CSC end cap and six cover the other. All 12 of the SPs pass their candidate muon tracks on to the single Muon Sorter (MS) board. The MS then filters the (up to 36) incoming candidate tracks down to a maximum of 4 candidates per bunch crossing and passes these on to the GMT which resides in the Global Trigger (GT) crate. The optical fiber connections responsible for bringing the CSC trigger primitives from the CSC Peripheral Crates to the Track Finder are described in Section 2 and the output links from the Track Finder to the GMT are described in Section 6.

All Sector processors are connected via optical fiber to a single Device Dependent Unit (DDU) board. This board receives data associated with the L1 trigger decisions made by the SPs and passes it on to CMS Global Data Acquisition (DAQ) and also the CSC local DAQ. The DDU is a 9-U high board but unlike the rest of the boards in the crate is only 220 mm deep[1]. In order to fit it into the Track Finder crate, it is mounted on a custom backplane extender card. The DDU connections are described in Section 4.

The Track Finder Crate contains a Clock and Control Board (CCB) which is responsible for receiving and redistributing CMS fast control and clock signals to the crate. It also provides a "local" trigger output to the CSC Trigger Timing and

[1] The Track Finder Crate is built to take 9-U high, 400 mm deep boards.

Control (TTC) crate. Communication to the boards within the crate is done via a CAEN VME controller which is linked to the control computer via optical fiber. These two links are described in Section 8.

The CSC Track Finder Crate passes on CSC trigger primitives to the DT Track Finder originating from (ME 1/3) chambers designated to be in the region that overlaps the DT subsystem. Similarly the CSC Track Finder receives DT trigger primitives from the (DT MB2/1) overlap region. This prevents a loss of trigger efficiency at the boundary between the two subsystems. The actual connections to the DT Track Finder are made at the rear of the CSC Track Finder and incorporate custom "DT Transition" link boards. Further details of the connection are given in Section 3.

The VME crate itself is a standard 9-U 6023 series Wiener Crate[7]. The lower 6-U part of the backplane is built to interconnect to the custom electronics. Further details of the backplane are given in Section 3 and of the crate itself in Section 9.

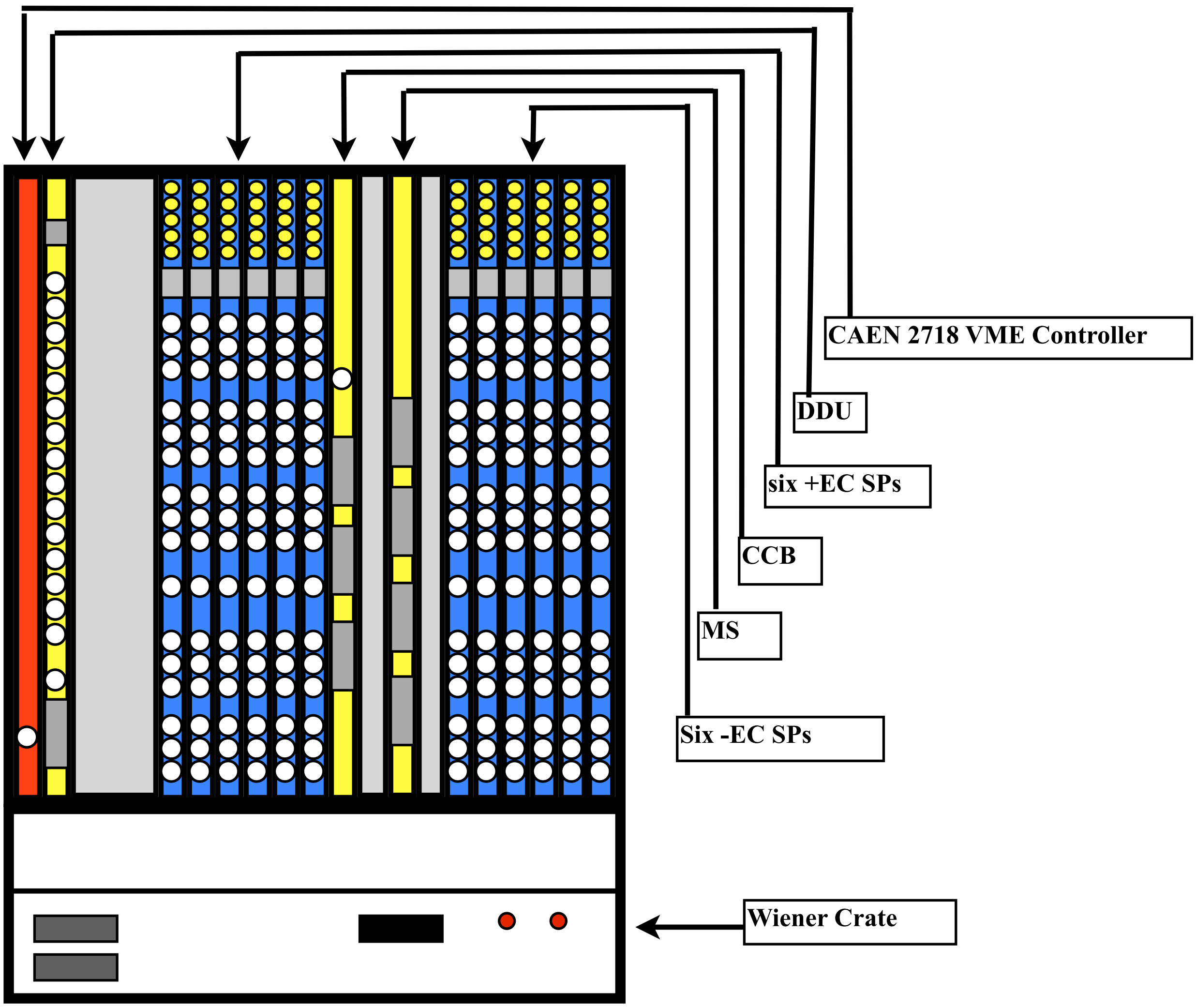

Figure 2. A diagram of the boards as viewed from the front of the Track Finder Crate.

Further specific information on each of the CSC Track Finder Crate electronics boards can be found in [7]

2 Trigger Fibers

Each peripheral crate outputs three trigger fibers which are connected to the Sector Processors in the Track Finder Crate. On the detector side, 2-m-long fibers lead from the Muon Port Card (MPC) to a patch panel mounted above the peripheral crate. These fibers are then permanently blown from this patch panel on the end cap disk all the way to another patch panel in the counting house, in the same rack as the Track Finder Crate. The length of these fibers is of the order of 100 m (given accurately in Appendix 2). The final connection is between the counting house patch panel mounted at the top of rack S1D04 (Track Finder Crate rack) and the Track finder Crate itself and is again done by 2-m-long lc-lc fibers.

Tables 1 to 3 below show the layout of the trigger fiber connections to the patch panels in rack S1D04 in USC. Table 4 below that then shows the corresponding Track Finder Crate inputs. The two are connected together by 2-m-long lc-lc simplex fibers.

In the tables below, “o” denotes positions on the fiber cassettes to which spare fibers have been blown while “x” denotes unused spaces in the cassettes. See Appendix 1 for details of CSC and DT “Trigger Sector” numbering and conversion between the two.

Table 1 . The layout of the ME4 fibers in the upper patch panel.

TS1		TS2		TS3		TS4		TS5		TS6		TS-1		TS-2		TS-3		TS-4		TS-5		TS-6	
m1	o	m1	o	o	m1	o	m1	m1	o	m1	o	m1	o	m1	o	o	m1	o	m1	m1	o	m1	o
m2	o	m2	o	o	m2	o	m2	m2	o	m2	o	m2	o	m2	o	o	m2	o	m2	m2	o	m2	o
m3	o	m3	o	o	m3	o	m3	m3	o	m3	o	m3	o	m3	o	o	m3	o	m3	m3	o	m3	o
o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 2. The layout of the ME2 and ME3 fibers in the middle patch panel.

TS1		TS2		TS3		TS4		TS5		TS6		TS-1		TS-2		TS-3		TS-4		TS-5		TS-6	
ME3	ME2	ME3	ME2	ME3	ME2	ME2	ME3	ME3	ME2	ME2	ME3	ME3	ME2	ME3	ME2	ME3	ME2	ME2	ME3	ME3	ME2	ME2	ME3
m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1
m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2
m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3
o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 3. The layout of the ME1 fibers in the lower patch panel. Trigger sector numbering used in this panel is DT type trigger sector numbering.

TS 2	TS 3	TS 5	TS 4	TS 7	TS 6	TS 9	TS 8	TS 10	TS 11	TS 12	TS 1	TS -2	TS -3	TS -5	TS -4	TS -7	TS -6	TS -9	TS -8	TS -10	TS -11	TS -12	TS -1
m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1
m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	x-x	m2	m2	m2	m2	m2	m2	m2	m2
m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3
o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	m2	o	o	o	o	o	o	o	o
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

During Commissioning, the ME1, TS-4, m2 link was never seen alive and so the spare link was employed immediately. The broken connection is denoted x-x on the table above. Over time one would expect potential further degradation of the blown fibers and hence more of the spares to be employed. While this note may not be updated, the label attached to the patch panel itself should be.

Table 4. The layout of trigger fiber inputs to the 12 SPs.

SP #1	SP #2	SP #3	SP #4	SP #5	SP #6	SP #7	SP #8	SP #9	SP #10	SP #11	SP #12	
TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS -1	TS -2	TS -3	TS -4	TS -5	TS -6	
m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	ME 4
m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	
m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	
m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	ME 3
m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	
m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	
m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	ME 2
m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	
m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	m1	
TS 3, m3	TS 5, m3	TS 7, m3	TS 9, m3	TS 11, m3	TS 1, m3	TS -3, m3	TS -5, m3	TS -7, m3	TS -9, m3	TS -11, m3	TS -1, m3	ME 1b
TS 3, m2	TS 5, m2	TS 7, m2	TS 9, m2	TS 11, m2	TS 1, m2	TS -3, m2	TS -5, m2	TS -7, m2	TS -9, m2	TS -11, m2	TS -1, m2	
TS 3, m1	TS 5, m1	TS 7, m1	TS 9, m1	TS 11, m1	TS 1, m1	TS -3, m1	TS -5, m1	TS -7, m1	TS -9, m1	TS -11, m1	TS -1, m1	
TS 2, m3	TS 4, m3	TS 6, m3	TS 8, m3	TS 10, m3	TS 12, m3	TS -2, m3	TS -4, m3	TS -6, m3	TS -8, m3	TS -10, m3	TS -12, m3	ME 1a
TS 2, m2	TS 4, m2	TS 6, m2	TS 8, m2	TS 10, m2	TS 12, m2	TS -2, m2	TS -4, m2	TS -6, m2	TS -8, m2	TS -10, m2	TS -12, m2	
TS 2, m1	TS 4, m1	TS 6, m1	TS 8, m1	TS 10, m1	TS 12, m1	,TS -2 m1	TS -4, m1	TS -6, m1	TS -8, m1	TS -10, m1	TS -12, m1	

In Table 4, each of the columns represents a Sector Processor. Sector Processors count from 1 to 12, left to right as they would do if you were standing in front of the crate. Each white cell in the table above within a given Sector Processor represents a trigger fiber input. Each Sector Processor has 15 trigger inputs, coming in 5 groups of 3 fibers. From bottom to top, the 5 groups represent inputs from 2 sets of 30^{o} ME 1 chambers and single sets of 60^{o} ME2, ME3 and ME4 chambers. For the ME1 inputs, the DT trigger sector number is shown within the cell. The 15 trigger fiber inputs to an SP are shown in the Figure 3, below.

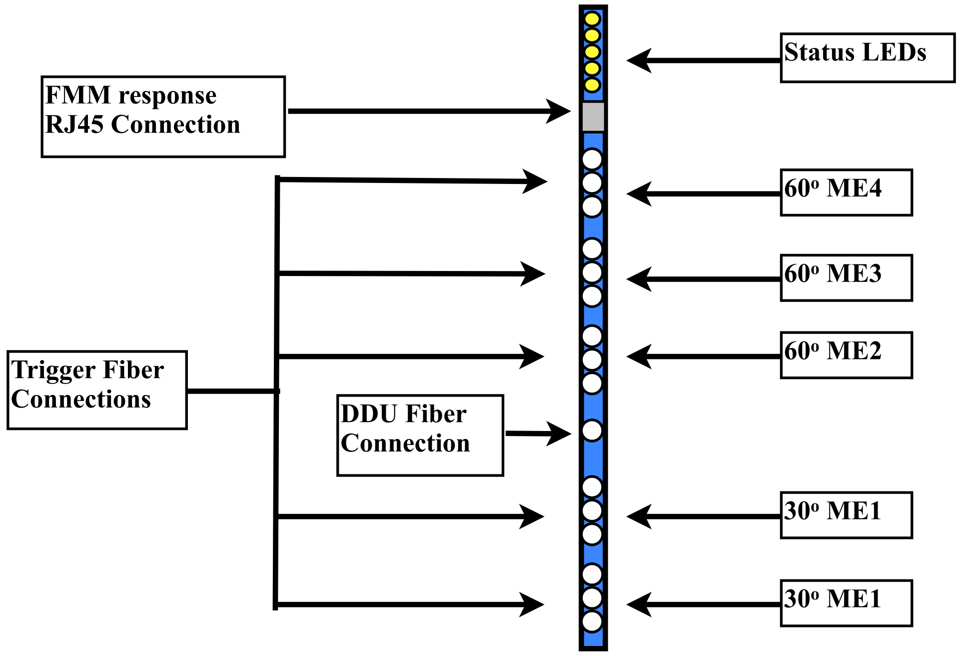

Figure 3. The connections to an SP front panel. The fiber connections are all of "lc" type.

The lengths of the blown fibers can be found in Appendix 2 and a description of the SP LEDs in Appendix 5.

3 Cable Links to the DT Track Finder

The CSC and DT Track Finders link together via 72 eight-meter-long SCSI II cables[2] which pass under the S1 D row between the CSC Track Finder in S1 D04 and the adjacent DT Track Finder in racks S1D01, D02 and D03. This allows trigger primitives found by the two systems to be exchanged between them so that they might make triggers upon the basis of combinations of the two types of hits. This prevents the trigger efficiency from dropping away at the boundary between the two systems. The DT, CSC interface is further described in [4].

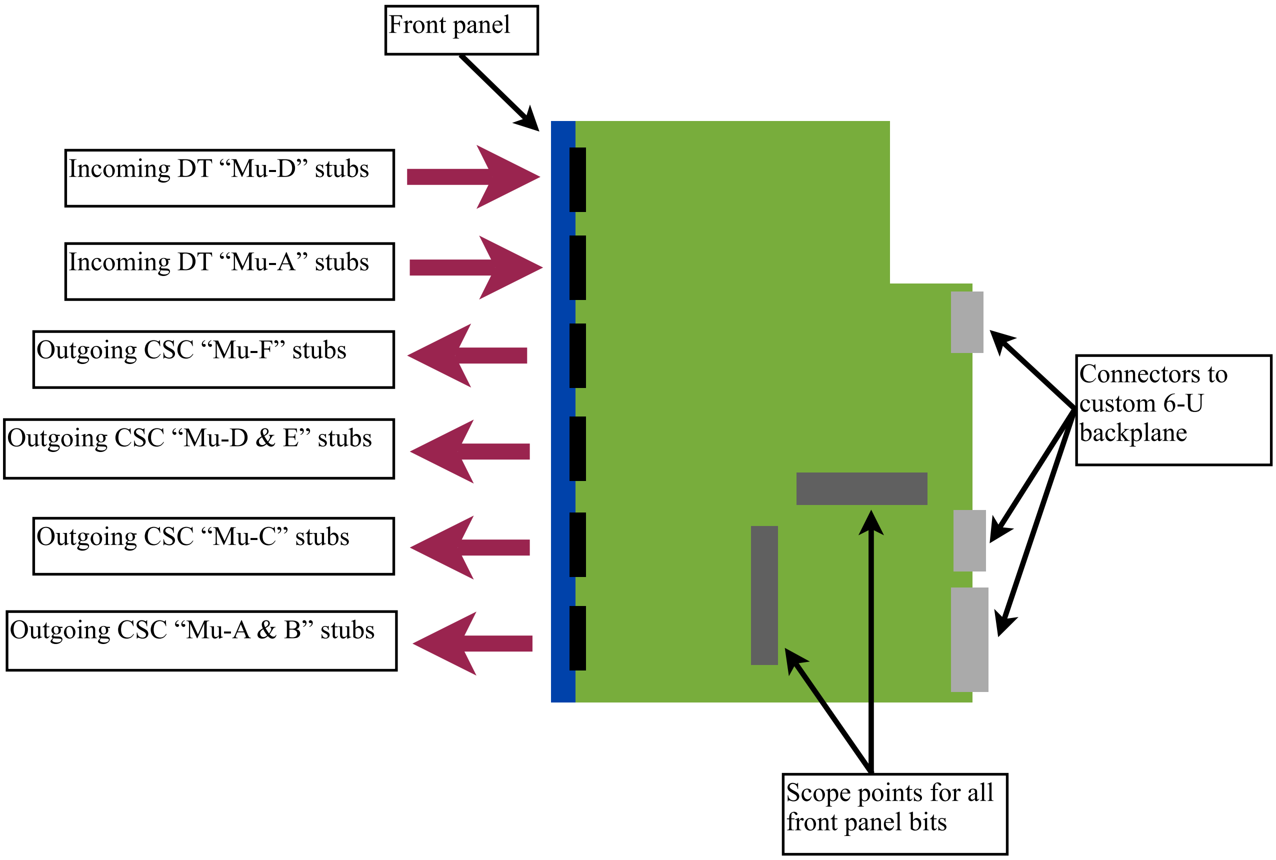

Figure 4. A side view of a DT Transition Board. Six SCSI cables linking to the DT Track Finder connect to the connectors on the front panel (left side in the above figure). There are multiple scope points in the centre of the board where all transferred bits (incoming and outgoing) can be spied upon and there are 3 connectors that slot into the 6-U custom part of the crate backplane (right side of above figure).

[2] The cables are halogen free VHDCI-HD68. Part 496868-315HF-M from Technical Cable Concepts.

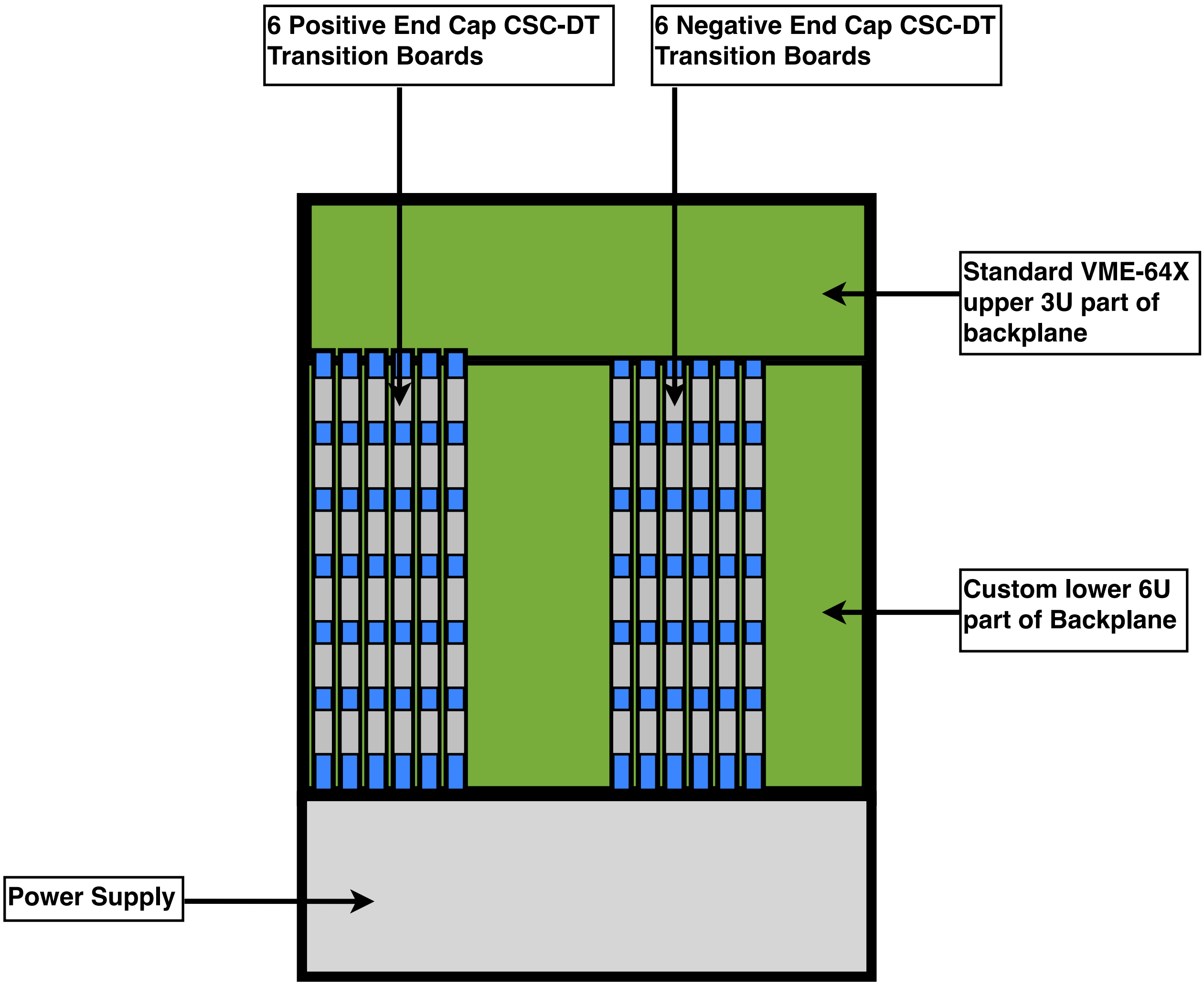

Figure 5. A diagram of the rear view of the Track Finder Crate. The standard VME-64X 3-U part of the backplane and the lower 6-U custom built backplane are shown as well as the 12 DT Transition boards, each with their 6 SCSI cable connectors.

The CSC Track Finder Crate backplane has connectors on the back side of the crate, linking the lower 6-U connections of each sector processor to a corresponding "DT Transition" board. This allows the insertion of 12 "DT Transition" boards, one corresponding to each SP into the back side of the crate. The CSC trigger primitives coming from ME 1/3 are parsed out from the SP, through the Transition Board to the DT Track Finder and in the opposite direction, primitives from the DT MB 2/1 are passed from the DT Track Finder, through the Transition Board to the SP. Each Transition Board links to the DT Track Finder via 6 SCSI-II cables. Figure 5 (above) shows the Track Finder Crate as viewed from the rear side, with the twelve DT-CSC Transition boards, each with six SCSI connectors[3]. Table 5 (below) shows the corresponding cable mapping of those connectors from a similar view point.

[3] The connectors are MOLEX 71430-0009 => 0.80 mm Pitch Ultra+T VHDCI Receptacles.

Table 5. The connections made to the DT-TF at back of the CSC-TF crate. Details on “trigger sector” nomenclature can be found in Appendix 1. Each of the columns represent a single transition board and its 6 SCSI connections, the order (left-right and top-bottom) of the connection is the same as in the diagram in Figure 5.

SP #12, CSC TS -6	**SP #11, CSC TS -5**	**SP #10, CSC TS -4**	**SP #9, CSC TS -3**	**SP #8, CSC TS -2**	**SP #7, CSC TS -1**	**SP #6, CSC TS 6**	**SP #5, CSC TS 5**	**SP #4, CSC TS 4**	**SP #3, CSC TS 3**	**SP #2, CSC TS 2**	**SP #1, CSC TS 1**	
DT TS -1	DT TS -11	DT TS -9	DT TS -7	DT TS -5	DT TS -3	DT TS 1	DT TS 11	DT TS 9	DT TS 7	DT TS 5	DT TS 3	**DT ---> CSC**
DT TS -12	DT TS -10	DT TS -8	DT TS -7	DT TS -4	DT TS -2	DT TS 12	DT TS 10	DT TS 8	DT TS 7	DT TS 4	DT TS 2	**DT ---> CSC**
CSC TS -1 ‘f’	CSC TS -11 ‘f’	CSC TS -9 ‘f’	CSC TS -3 ‘f’	CSC TS -5 ‘f’	CSC TS -3 ‘f’	CSC TS 1 ‘f’	CSC TS 11 ‘f’	CSC TS 9 ‘f’	CSC TS 3 ‘f’	CSC TS 5 ‘f’	CSC TS 3 ‘f’	**CSC --> DT**
CSC TS -1 ‘de’	CSC TS -11 ‘de’	CSC TS -9 ‘de’	CSC TS -7 ‘de’	CSC TS -5 ‘de’	CSC TS -3 ‘de’	CSC TS 1 ‘de’	CSC TS 11 ‘de’	CSC TS 9 ‘de’	CSC TS 7 ‘de’	CSC TS 5 ‘de’	CSC TS 3 ‘de’	**CSC --> DT ***
CSC TS -12 ‘c’	CSC TS -10 ‘c’	CSC TS -8 ‘c’	CSC TS -6 ‘c’	CSC TS -4 ‘c’	CSC TS -2 ‘c’	CSC TS 12 ‘c’	CSC TS 10 ‘c’	CSC TS 8 ‘c’	CSC TS 6 ‘c’	CSC TS 4 ‘c’	CSC TS 2 ‘c’	**CSC --> DT**
CSC TS -12 ‘ab’	CSC TS -10 ‘ab’	CSC TS -8 ‘ab’	CSC TS -6 ‘ab’	CSC TS -4 ‘ab’	CSC TS -2 ‘ab’	CSC TS 12 ‘ab’	CSC TS 10 ‘ab’	CSC TS 8 ‘ab’	CSC TS 6 ‘ab’	CSC TS 4 ‘ab’	CSC TS 2 ‘ab’	**CSC --> DT***

Each column represents the connections made to one of the “DT-transition” boards connected to the back side of the DT-TF crate. The table has the same left to right consecutive order of boards as you would see if you were standing looking at the back of the crate, i.e., the left most board is connected to the back of SP #12 which deals with CSC trigger sector -6. Each white cell represents a cable connection. The “DT” or “CSC” label denotes whether the cable carries a DT or CSC generated trigger primitive and the “TS” (trigger sector) given is the DT-30^{o} type.

These cables actually carry up to 2 trigger primitives per bunch crossing. The net effect is that the DT track finder sends up to 2 muons per crossing per 30^{o} sector to the CSC track finder (incorporating a “muon belongs to last bunch crossing” flag) while the CSC track finder returns up to 3 of its own.

Figure 5 also shows the Track Finder crate backplane. The upper 3-U part is a standard VME-64X interface and was supplied as standard with the crate. The lower 6-U part is a custom design by the University of Florida. It allows specific routing to the SPs on the front side and links to the DT-Transition boards on the back side. On the back side of the custom backplane there resides a LV regulating mezzanine board which supplies +1.5V to the GTLP circuits. Nominal Voltages supplied to the crate by the supply are 3.3V and 5V.

Further specification of the “DT Transition” boards and the custom part of the backplane can be found in [7] and of the DT-CSC trigger primitive exchange in [4].

4 Optical Fiber Links between the Sector Processors and the DDU and from the DDU to the local DAQ machine in SCX

Each of the SPs has a single optical fiber output (just above the 2 lower sets of ME1 trigger fibers, see Figure 3) that carries its data to the DDU. The SP data consist of information about the trigger decision, i.e., information about the trigger primitives as input and the track parameters as output as well as counters and SP status monitors. The DDU serves to concatenate all of the data from all of the SPs for each event. That data are then pipelined off to both "local" and "global" DAQ. "Global" DAQ refers to the central CMS data collection while "local" DAQ refers to the CSC only farm of rack mount computers in the "Surface Control of the Experiment" (SCX) room. The DDU output to global DAQ is via an SLINK, a few more details of which can be found in Section 5 and the output to local DAQ is via optical fiber to the dedicated Track Finder local DAQ machine in the above ground SCX-D7 (further details in Appendix 6). This connection actually goes via a 25 m fiber run from the DDU in the Track Finder Crate, across the overhead cable trays inside a white plastic protective shell to a patch panel in rack S1G09. The connection in S1G09 is to the top slot in the 7th cassette from the left in the uppermost patch panel. This patch panel then connects via a set of blown fibers to one in the local DAQ rack in SCX.

The 12 optical fiber links from SP to DDU are made using 0.5-m-long lc-lc duplex fibers. Details of the connections are given below.

Table 6. The optical fiber connections made between each Sector Processor and the DDU.

SP & Slot Number	DDU Input Link
SP 1, slot 6	0
SP 2, slot 7	1
SP 3, slot 8	2
SP 4, slot 9	3
SP 5, slot 10	4
SP 6, slot 11	5
SP 7, slot 16	14
SP 8, slot 17	13
SP 9, slot 18	12
SP 10, slot 19	11
SP 11, slot 20	10
SP 12, slot 21	9

5 SLINK and FMM Responses and Links to DAQ

The status of each of the SPs and of the DDU are reported to CMS Central DAQ via Fast Merger Modules (FMM). There is an RJ45 link from each SP and the DDU to a FMM (see Figure 3). The communication is via simple levels over 4 LVDS pairs. The FMM responses and their meanings are given in Appendix 4. The mapping of the connections from the Track Finder Crate along with the allocated "FMM-ID" label is given in the table below.

The main stream of Track Finder data that are sent to Global DAQ goes via SLINK. The SLINK cable is connected to the DDU by a custom daughter board. The addition of this face-mounted daughter board (DDU serial numbers 1-3) is the only difference between Track Finder Crate and standard CSC DDUs. The actual DDU board hardware, the loaded firmware and controlling software are the same as that for CSC DDU. The Track Finder DDU identifies itself as such via the serial number contained in the on-board Flash memory.

The "FED-ID" number is a unique identifier assigned by DAQ to SLINK cables to denote from where the data originates (in this case CSCTF). For the DDU which has FED-ID 760, the corresponding FMM response is naturally assigned to be ID 760 as well.

Table 7. The mapping of SPs and DDUs to FMM response cables and allocated FED and FRL IDs.

Board	Trigger Sector	Cable Label	Bar Code	FMM ID
SP1, slot 6	+1	12MFMM4210	3DA 24831	890
SP2, slot 7	+2	12MFMM4211	3DA 24832	891
SP3, slot 8	+3	12MFMM4233	3DA 24833	892
SP4, slot 9	+4	12MFMM4232	3DA 24834	893
SP5, slot 10	+5	12MFMM4228	3DA 24835	894
SP6, slot 11	+6	12MFMM4229	3DA 24836	895
SP7, slot 16	-1	12MFMM4215	3DA 24837	896
SP8, slot 17	-2	12MFMM4214	3DA 24838	897
SP9, slot 18	-3	12MFMM4216	3DA 24839	898
SP10, slot 19	-4	12MFMM4217	3DA 24840	899
SP11, slot 20	-5	12MFMM4226	3DA 24841	900
SP12, slot 21	-6	12MFMM4227	3DA 24842	901
DDU FMM response	all	12MFMM2051	3DA 24538	760
DDU FMM response (spare)	all	12MFMM2053	3DA 24701	760
DDU SLINK (FED)	all		3DA 22538	FED ID = 760
DDU spare SLINK (FED)	all		3DA 22677	FED ID = 760

Further details of the FMM and FED IDs and of the FMM response levels are given in [8]

6 Global Trigger Connections from the Muon Sorter to the Global Muon Trigger

The Muon Sorter (MS) passes up to 4 CSC muon candidates per event to the Global Muon Trigger (GMT). The connection is made using four 8-m-long Universal SCSI Cables[4] containing shielded twisted pairs. The 4 connections count from "Muon 1" down to "Muon 4" as one reads down the MS front panel. These cables run up the side of the Track Finder rack, into the overhead cable tray and then down the opposite rack to the CSC part of the GMT input residing in the Global Trigger crate in S1E04. This is shown in figure 6 (below).

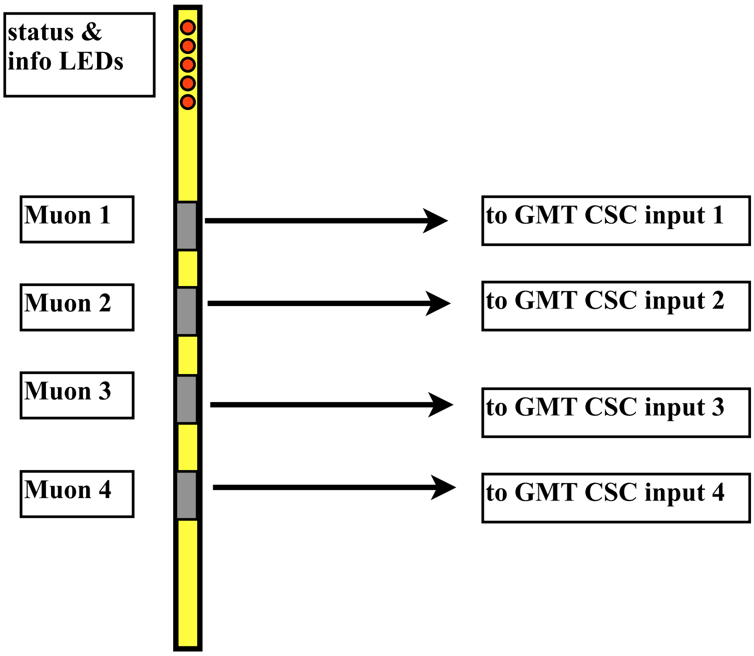

Figure 6. The SCSI Cable Connection from the Muon Sorter to the GMT.

Further details of the specific connections and the data transferred can be found in [5] and a description of the LEDs can be found in Appendix 4.

[4] The Cables are 36 Pair 30 AWG Non-Halogen Universal SCSI Cables

7 Local Trigger Connection from the Clock and Control Board to the CSC Local Trigger Controller

The CSC "local trigger" refers to the method by which the CSC subsystem can self-trigger without the need for the GMT or GT. This is essential for CSC debugging as well as allowing CSC running while the Global Systems are unavailable. A ribbon cable runs from the Clock and Control Board (CCB) central front panel connector, "LVDS-1", via the overhead cable tray to the Local Trigger Controller (LTC) in the CSC TTC crate in S1E03. It carries an LVDS trigger signal generated at the Track Finder Crate to be converted into a trigger signal and redistributed by the TTC Crate. It is configurable at the CCB as to exactly what the are the criteria for a local L1A. We currently choose an SP backplane trigger request.[5]

When the CSC TTC-CIs are configured to receive clock and triggers from the CSC LTC then they redistribute the trigger to the CSC subsystem. This allows CSC triggering without the need for the GMT or Global Trigger. Configurable settings at the CCB and the LTC allow selection between options of simple SP L1-requests, MS L1 requests or even 11KHz BC0 based or entirely randon requests as the generator for the local trigger pulse. The local trigger latency is tuned to match that of the Global Trigger and so switching between the two modes using the CSC TTC-CIs becomes seamless. In the TTC crate it is actually a pair of TTC-EX boards that do the optical distribution, one feeds from the positive and negative end cap TTC-CIs, via optical splitters to the FED and peripheral crates and one feeds from the Track Finder TTC-CI to the Track Finder Crate.

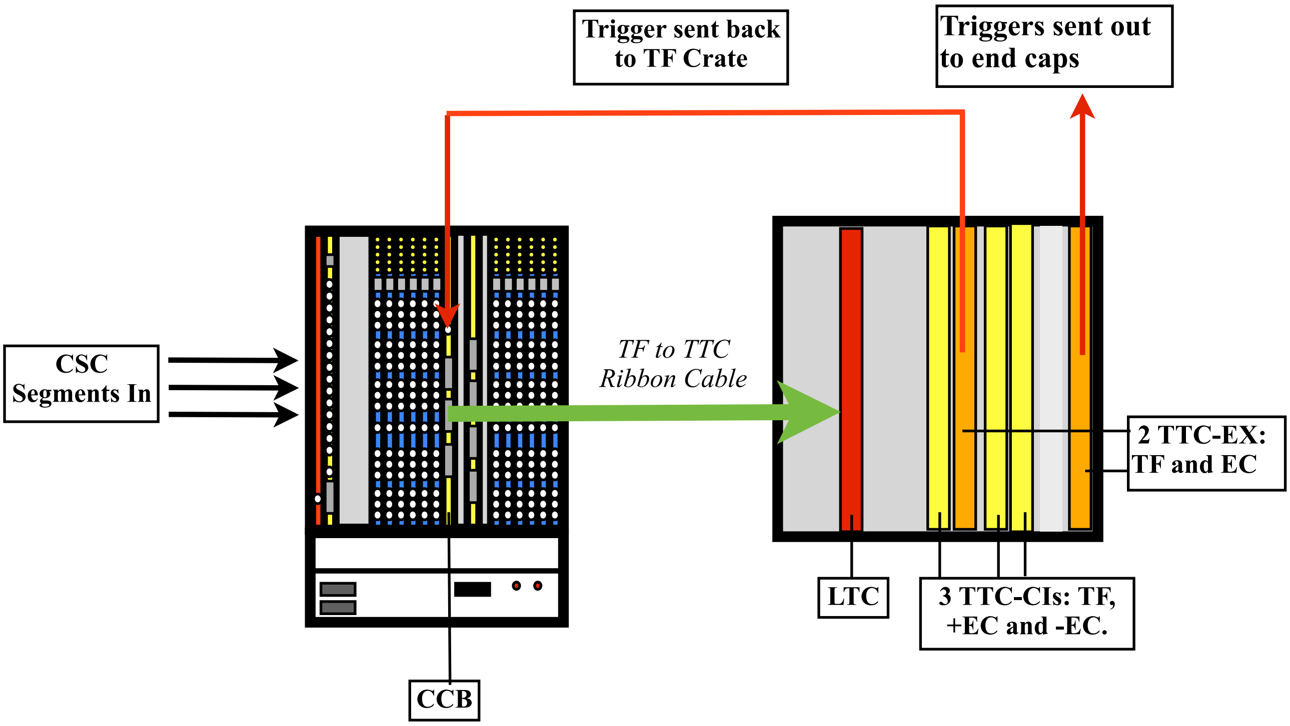

Figure 7. The CSC Local Trigger path.

[5] The CCB P4 connector 23/24 lines form the LVDS pair carrying the CCB generated L1A signal via the ribbon cable to the LTC. Which pair is to be interpreted at the LTC as the trigger pair is configurable. We currently set the 23/24 pair as "TF-SP". For now we have no other configured options at the LTC.

8 TTC and VME Control.

Clock, fast control and trigger signals are brought into the Track Finder Crate via the CCB front panel. The Track Finder TTC signals come either from the Global Trigger (global mode) or the LTC (local mode) via the Track Finder TTC-CI in the CSC TTC Crate. It is the TTC-CI module that is responsible for switching between local and global running modes. An (ST-ST connector) optical fiber runs from the output of the Track Finder TTC-EX (paired with the Track Finder TTC-CI) to the front panel input of the CCB.

Control of the Track Finder crate is done via a rack mounted computer (csc-tf.cms) in rack S2G18 which is on the floor above the with the crate itself. Communication with the crate control is done using a CAEN 2718 VME controller. More information on this module is in [7].

An overview of the 2 .cms machines (CSCTF control and local DAQ), the accounts and the online infrastructure is given in Appendix 6.

9 Basic Set up of the Crate

The Track Finder Crate itself has monitoring tools and cut off limits that can be checked and set manually using the front panel and remotely via the Detector Control System (DCS). The manual interface comes via the "power" and "mode" switches on the front of the fan tray. For expert tasks, one also uses the 2 little variable resistors on the back of the power supply, on the top left hand corner as you look at it from behind. The DCS interface comes via a CAN bus link to the front of the fan tray.

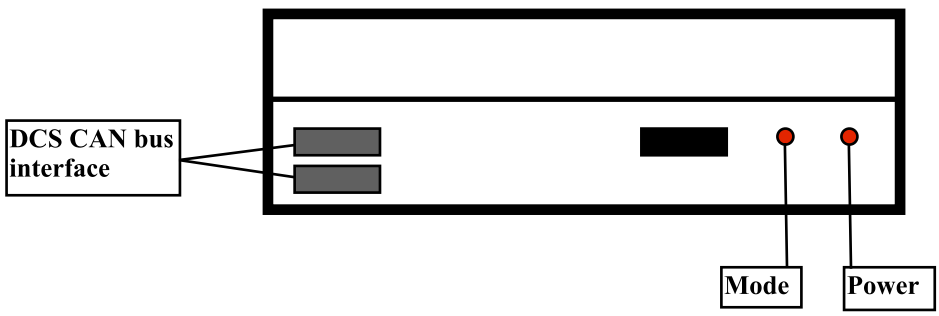

Figure 8. A view of the fan tray with the control interfaces as seen from the front of the crate.

Simple on/off functionality of the crate comes from the "power" switch. When the crate is in off mode, it is switched on by pushing the power button up for a second or so.

While the crate is running, one can use the "mode" button to scroll through various monitored quantities such as the supplied potential and current on the 3.3V and 5V lines as well as the crate power output, fan speeds etc. A few of the basic items for a running but non-triggering crate are shown in Table 8, below.

Table 8. A few basic quantities read out from a full but non-triggering crate.

Item	Reading
5V supply line	• 5.00 V supplied • 29 A; full crate, not triggering • Current limit is 100 A max • Voltage limits: 4.75 V < V < 5.25 V
3.3V supply line	• 3.40 V supplied • 82 A; full crate, not triggering • Current limit is 200 A max • Voltage limits 3.13 V < V < 3.60 V
Crate Power Output	• 82 A; Full crate, no triggers.
CANBUS (DCS)	• Address = 42 • 500 KBaud • limit on temperature read over DCS = 30^{o}C
Fans	• speed = 2880 RpM • Temperature = 19^{o}C

In order to adjust basic presets (such as current or voltage cutoffs), one first selects the relevant mode and then enters the adjust mode by holding the "power" and "mode" buttons up for five seconds. One then selects the specific adjustable quantity using the mode button (up and down) and then pushes up on the power button to select it and make it flash. Once flashing, the quantity is adjusted by the mode button (up and down). To select the new preset, press the power button down. Press the power button down once again to leave the adjust menu.

The crate monitors temperature both internally in the fan tray and also via a small white thermocouple attachment that is connected to 2 pins on the front side of the backplane close to the top of the DDU extender card top connector in "temperature sensor position 8".

The specific expert case of raising or lowering the actual supplied voltages is discussed in Appendix 3. This method can be readily adapted to change various other settings. For more extended information on the Wiener Crate, consult the manual referenced in [7].

10 Situation and Layout of the CSC Track Finder Racks.

The Track Finder Crate is installed in 56-U high rack S2D04 in the CMS Underground Service Cavern (USC). The rack is cooled by four water circulating heat exchangers on a parallel network which can be isolated via taps under the rack and a single air turbine at the top of the rack. Power distribution comes from four 220 V supplies on the bottom of the turbine. Two of these are routed to power strips mounted on the inside-back of the rack, one powers the Track Finder Crate and one is free.

The 180 trigger fibers coming from the 60 MPCs come into the rack via 3 patch panels. Fibers from these patch panels are then routed to the front of the Track Finder Crate as detailed in Section 2.

The back of the rack is sealed by a locking aluminium door and the front is sealed with either crates or blank panels except for a 2-U gap at the bottom of the rack allowing FMM, SLINK and VME control distribution to the Track Finder Crate. The front of the rack is protected by an extended transparent door.

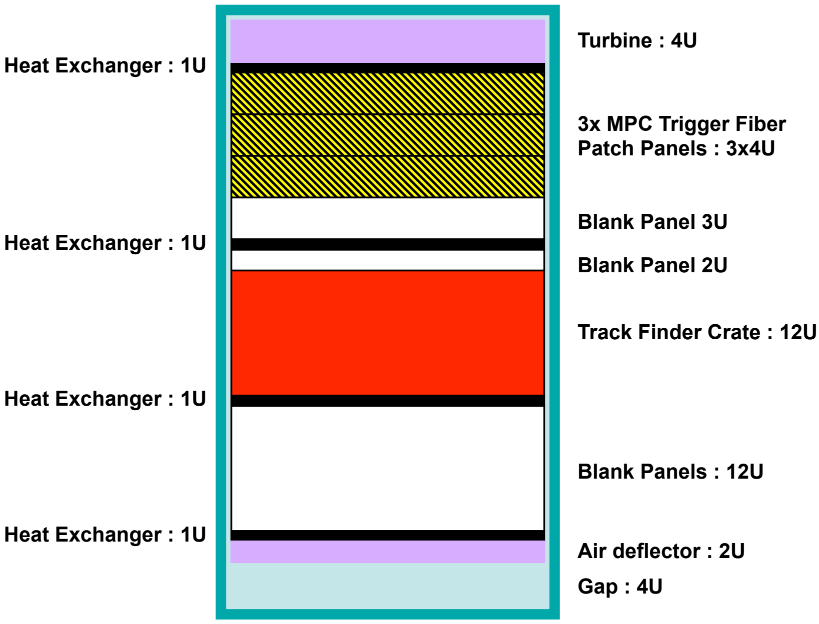

Figure 9. A Diagram of the layout of Rack S1D04 in USC housing the CSC Track Finder Crate.

The CSC Track Finder actually owns but does not currently extend into a second rack next to the first on the left as you face the front of the electronics. The second rack is S1D05 and currently only holds panels for CSC TTC optical fiber distribution and offers space for potential upgrade projects. The current layout of rack S1D05 is show below.

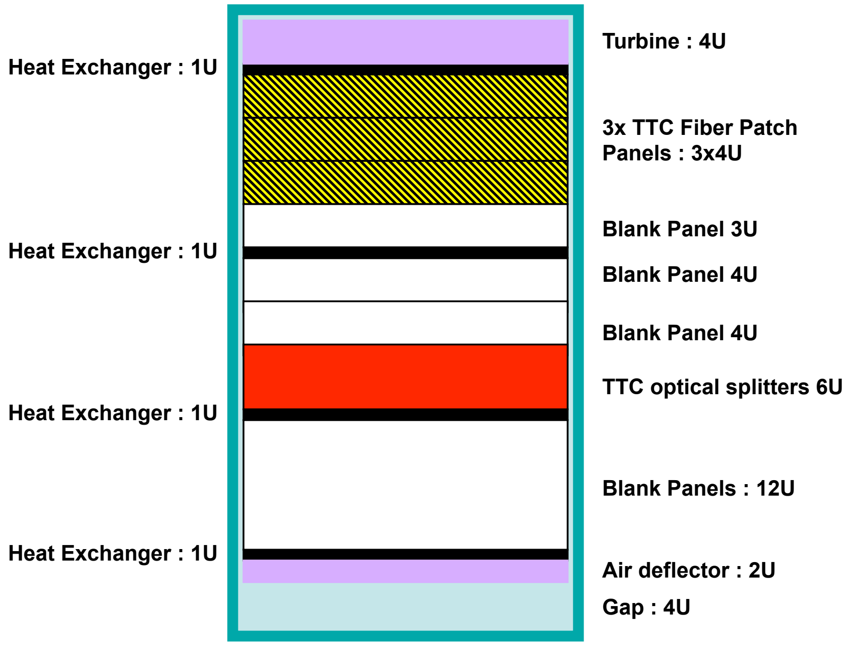

Figure 10. A diagram of the layout of Rack S1D05 in USC.

Appendix 1. Trigger Sector Nomenclature.

“Trigger sectors” are labels denoting discreet regions in phi within which the CSC and DT L1 trigger systems search for candidate primitives that may result in a L1 trigger request. There is no linking at L1 of candidates across trigger sector boundaries. Resulting inefficiency at the sector boundaries is reduced by the overlapping of chambers in ME 1/1, 1/2 (not 1/3), 2, 3 and 4 to the order of a degree. The DT subsystem splits into twelve 30^{o} trigger sectors while the CSCs split into six 60^{o} ones. Table A.1 shows the translation between the two systems.

Table A.1 Translation between DT and CSC trigger sector labeling.

30^{o} DT Trigger Sectors	60^{o} CSC Trigger Sectors	Phi range*
2	1	15^{o} --> 45^{o}
3		45^{o} --> 75^{o}
4	2	75^{o} --> 105^{o}
5		105^{o} --> 135^{o}
6	3	135^{o} --> 165^{o}
7		165^{o} --> 195^{o}
8	4	195^{o} --> 225^{o}
9		225^{o} --> 255^{o}
10	5	255^{o} --> 285^{o}
11		285^{o} --> 315^{o}
12	6	315^{o} --> 345^{o}
1		345^{o} --> 15^{o}

* Phi = 0 corresponds to the “X-direction”, pointing from CMS towards the centre of the LHC ring. Viewed from the interaction point, it increases as you look towards the positive end cap and rotate clockwise around the disc. Phi (and trigger sector number) is constant across the join of the two end caps and hence if you view the negative end cap from the interaction point then phi increases as you rotate counter clockwise. If standing in UXC then the phi=0 line points horizontally towards the counting house (USC).

When the nomenclature “-TS xyz” is used, we are simply referring to trigger sector xyz in the negative end cap. Further details can be found on CSC numbering and nomenclature in [6].

Appendix 2. Lengths of the Blown Trigger Fibers.

Table A.2. Lengths in meters of the blown trigger fibers of stations ME2 to ME4 for both end caps. The lengths shown are those from the on-detector patch panel to the counting house patch panel. The true lengths of the corresponding links between the MPC and SP are 4 m longer due to 2 m link fibers at either end. The trigger sector numbering is CSC type.

	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6
ME +2	90.9	100.9	97.3	93.0	83.4	87.0
ME +3	90.9	100.9	97.3	93.0	83.4	89.0
ME +4	95.2	104.6	112.1	102.6	90.1	88.2
ME -2	94.9	103.8	102.1	96.5	85.7	86.4
ME -3	94.9	103.8	102.1	96.5	85.7	86.4
ME -4	96.2	106.7	112.7	107.6	95.8	90.2

Table A.3. Lengths in meters of the blown trigger fibers of station ME1 for both end caps. The lengths shown are those from the on-detector patch panel to the counting house patch panel. The true lengths of the corresponding links between the MPC and SP are 4 m longer due to 2 m link fibers at either end. The trigger sector nomenclature shown is of DT type. See Appendix 1 for conversion to CSC sectors.

	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS 7	TS 8	TS 9	TS 10	TS 11	TS 12
ME +1	68.0	74.7	74.7	82.2	82.3	81.3	81.3	71.7	71.7	59.1	59.1	68.0
ME -1	70.7	78.2	78.2	88.4	88.4	85.4	85.4	76.6	76.6	65.6	65.6	70.7

These numbers were measured by S. Casenove, 25 June 2008. They are kept on the CSC Commissioning web page[9].

Appendix 3. Adjustment of Supplied Crate Voltages.

Adjusting the potential difference applied across the 3.3 V and 5 V lines in the crate is clearly an expert-only task and requires express permission from the CSC Track Finder project manager. Incorrect application of the procedure below can damage electronics boards.

Table A.4. An example method for changing the Track Finder Crate Supplied Potentials.

• (1) Turn the crate off and remove the boards.

• (2) Set the crate voltage limits to a wider range to prevent accidental trips:
  - Toggle "Mode Select" until the crate display shows the "+3V3" reading.
  - Push UP on "POWER" & "Mode Select" simultaneously & hold for 5-10 sec.
  - To begin CONFIG mode:

    - Release both switches, then use the "Mode Select" to get to "UMIN"
    - Push UP on "POWER" for ~1 sec to enable changes (displayed value should now blink) , then use "Mode Select" to set the value.
    - Lower it by 100 mV or set it to 3.1 V, whichever is lowest.
    - n.b. Please record the values before you change them.
    - Push DOWN on "POWER" for ~1 sec to save the setting.

    - Use the "Mode Select" to get to "UMAX".
    - Push UP on "POWER" for ~1 sec to enable changes (displayed value should now blink) , then use "Mode Select" to set the value.
    - Raise it by 100 mV or set it to 3.6 V, whichever is the highest.
    - Push DOWN on "POWER" for ~1 sec to save the settings.

•(3) Set the Supplied Voltage with 2 rotary switches:
  - Turn on the Crate.
  - Identify the two rotary switches on the back of the power supply. The “Channel Selection” switch is the one nearest the corner while the “Adjustment Switch” is the one next to it and further from the corner.
  - Set the “Channel Selection” rotary switch to "0x3" to select the 3.3 V line.
  - The ‘Adjustment Switch’ is now the voltage control for 3.3 V supply.
    - Measure the backplane 3 V & 5 V potential lines with a meter (record the values).
    - Raise the 3 V level by turning the “Adjustment Switch” clockwise slowly and measure the potential frequently (each click counts for 1 mV). You may see some LEDs blinking as the supply changes. Anti-clockwise to decrease the voltage. Keep track of the approximate number of turns in case you go too far.
    - Once the desired new potential has been reached, push DOWN on “POWER” for ~1 sec to save the setting.
  - Set the “Channel Selection” switch back to something benign such as “0xf”.

• (4) Set the Crate voltage limits back to a suitable (narrow) range around the new potential settings.
  - Follow the procedure as in (2) above.

Appendix 4. The FMM levels and interface.

The connection from each of the SPs and the DDU to the FMM module employs RJ45 connectors and uses the eight wires as four LVDS pairs. There are only 6 valid states, either none of the 4 lines turned on, all of them or any one of them individually. Combinations of states are not allowed.

Table A.5. The FMM levels and their meanings.

Code	Meaning	Note
0x0 or 0xf	"disconnected"	Hardware is disconnected (or has a problem)
0x1	"warning of overflow"	Buffers are in imminent danger of overflow. Request that trigger rate should be throttled.
0x2	"out of synch"	Hardware is in error state or the cable is disconnected. Request "resynch"
0x4	"busy"	Hardware cannot accept triggers.
0x8	"ready"	Hardware is running and is ready to accept triggers
0xc	"error"	Hardware is transmitting an error state, technically the combination of states also signifies error.

Table A.5. The Pin Assignment in the FMM RJ45 Connection.

RJ45 pin	Line Meaning	RJ45 pin	Line Meaning
1	- busy	5	- overflow warning
2	+ busy	6	+ ready
3	- ready	7	- out of synch
4	+ overflow warning	8	+ out of synch

Information for these tables comes from [8].

Appendix 5. A Description of the Front Panel LEDs seen on the Track Finder Crate Boards.

Table A.6. The Sector Processor Front Panels.

Sector Processors: Looking at the front panel of a Sector Processor one sees, working from top to bottom; •9 SP status LEDS •"No Lock" (red): If this is on then the SP QPLL is not locked to a clock from the CCB. This is fatal. •"VME" (orange): This lights up as data are read or written over VME. •"DTRUN (yellow): This is on when the Overlap region is active in the trigger. •"L1ACC" (yellow): Flashes when the SP receives an L1A (accepted trigger) over the backplane. •"TRACK" (yellow): Flashes when the SP makes a trigger request to the backplane. •"BSY" (red): This indicates that the SP is in a "busy" state and is not capable of running. •"RDY" (green): This indicated that the SP is in a "ready" state and can be run. •"WOF" (red): This means "warning of overflow"; the DAQ FIFO is not being read out fast enough and will likely become full if the trigger rate is not throttled. •"OSY" (red): This means that a synch error has been raised. •If all of the bottom 4 status LEDs are on then the SP is in an unconfigured mode. •An RJ45 connector carrying the SP FMM response •3 ME4 Trigger Fiber Links •3 ME4 Link LEDs •Each LED flashes as its corresponding trigger link passes up a trigger primitive. •3 ME3 Trigger Fiber Links •3 ME3 Link LEDs •Each LED flashes as its corresponding trigger link passes up a trigger primitive. •3 ME2 Trigger Fiber Links •3 ME2 Link LEDs •Each LED flashes as its corresponding trigger link passes up a trigger primitive. •DDU FIber Link •3 ME1D Trigger Fiber Links •3 ME1D Link LEDs •Each LED flashes as its corresponding trigger link passes up a trigger primitive. •3 ME1A Trigger Fiber Links •3 ME1A Link LEDs •Each LED flashes as its corresponding trigger link passes up a trigger primitive.

On top of the front panel LEDs, the SP also has LEDs mounted on each of the FPGAs. When they are powered then they should show either red or green. The green signifies that the FPGA is on and data from the PROM has been loaded correctly into memory. Red signifies power but a problem has occurred.

Table A.7. The Clock and Control Board Front Panel.

Clock And Control Board:

Running from top to bottom down the CCB front panel, one sees the following LEDs and connections;

- "DISLOG" (green): The CCB is in "Discrete Logic" mode and TTC commands are passed directly to the backplane. This is the standard mode of operation and should always be on unless CCB FPGA functionality is specifically being used.
- "DACK" (yellow) indicates VME access to the CCB.
- "I2C" (yellow) shows access to the TTC-RX chip. Should only be on during configuration.
- "JTAG" (yellow) indicates JTAG access from VME to FPGA. Should only be on during firmware updates.
- "HRESET" (red) Hard Reset (has been sent via the TTC distribution)
- "CCBHR" (red) local Hard Reset
- "CMDSTR" (red) Command Strobe
- "DATSTR" (red) Data Strobe
- "L1A" (red) Level 1 Accept; The crate has received an L1 trigger. Should be in time with the SP "L1A" LED.
- "BC0" (red) BC0 Orbit marks are coming. They should be constant at 11KHz so this should always be on when the system is running.
- "L1RES" (red) L1 Reset or resynch. This should flash as a resynch is sent.
- "EVCRES" (red) Event Counter Reset. This flashes as an EC0 is sent. (Currently along with resynch)
- "BCRES" (red) Bunch Counter Reset. This flashes as a bunch counter reset is sent.
- "TTCRDY" (green) TTC-RX Ready; indicates that the TTC-RX is in normal operation mode and should be on during normal running
- "QLOCK" (green) CCB QPLL is locked. This should always be on during normal running.
- "DONE" The loading of the FPGA from the EEPROM was done successfully. This should be on during normal running
- "CRDONE" "Whole Crate Done" LED; All FPGA on all boards loaded from PROMS and QPLLs locked. Actually for the CCB in the Track Finder Crate this is not implemented so far and so you should expect it to be off.
- "CLK40" The clock is received and locked by the CCB. This should always be on during normal running.
-
- TTC input fiber (ST connector)
- 2 more LEDs, repeats of above; CLK40 and QLOCK
-
- LVDS input
- LVDS Output 1
    - This one has the ribbon cable output to the LTC, providing the Track Finder Crate output for the CSC local trigger. It is the 23/24 pair that give the local L1A signal.
- LVDS Output 2

- 4 voltage LEDs (green). These monitor the reception of the potential from the backplane and should always all be on.

Table A.8. The Muon Sorter Board Front Panel.

Muon Sorter:

Running from the top of the Muon Sorter Front Panel to the bottom, you will see the following connections and LEDs;

• “DONE” (green) indicates that FPGA configuration and initialization done properly and the board is locked. This should always be on during normal running
• “TEST” (yellow) Is on when the MS is in “test” mode. This should be off during normal running.
• “DACK” (yellow) Flashes when there is VME access.
• “JTAG” (yellow) Flashes when there is JTAG access. This should only happen during a firmware update.
• “FAEM” (red) All 12 FIFO-A buffers are empty. This is generally on during normal low rate running
• “FBEM” (red) All 4 FIFO-B buffers are empty. This is generally off during normal running
• “FAFL” At least one of the 12 FIFO-A buffers is full. This is generally off during normal running.
• “FBFL” (red) At least one out of 4 FIFO-B buffers is full. This is generally on during normal running.
• “CLK40” (green). This shows that the 40 MHz clock is provided to the main FPGA. This should always be on during running.
• “MUON[1..4] (4 red LEDs) These flash when a valid muon candidate is passed over the corresponding line to the GMT.
• 2 reserved red LEDs.
• 4 68-pin connectors with connected SCSI cables taking the Track Finder Crate output to the GMT.
    • The top cable is “Muon 1”, the bottom is “Muon 4”.
• 4 voltage LEDs (green). These monitor the reception of the potential from the backplane and should always all be on.

Table A.9. The Device Dependent Unit Board Front Panel.

Detector Dependent Unit:

Looking at the front panel of the DDU and running from top to bottom one sees;

• A little block of 4 LEDs at the top of the front panel;
• Yellow on the upper left, orange on the lower left, a red one in the upper right and a green one in the lower right
    •top left (yellow). This comes on once the FPGAs have been programmed correctly, it should stay on.
    •top right (red). This comes on during VME transfer.
    •bottom left (orange). This shows 3.3 V power is correctly supplied. It should be on.
    •bottom right (green). This shows 5 V power is correctly supplied. It should be on.
• An RJ45 connection taking the DDU FMM status to DAQ.
• Two LEDs on the RJ45 connector;
    •yellow : An FMM error state is raised.
    •green : There are no errors and the board is running fine. This one should be on during normal running.
    •If either are flashing then the board is in an intermediate state
• 15 connectors, 12 of which are connected to SPs
    •Each connector has a yellow and a green LED next to it.
    •The (upper) green one shows that the fiber is connected and synched to an SP. It should be on for all live SPs during normal running.
    •The yellow one flashes when data are sent over the link. It should be on when L1As are coming (or flashing for a low rate).
• An optical output taking local data over fiber to the GB Ethernet card in the Track Finder local DAQ PC.
• An SLINK output taking data to Global DAQ.

The front panel LEDs of the CAEN controller are described in the appropriate manual in [7].

Appendix 6. The CSCTF .cms network computers and the online systems layout

The CSC Track Finder group is responsible for two of the .cms network online systems rackmount PCs. One is used to control the Track Finder Crate via VME and the second is used to dump and perform basic analysis on local trigger data. One accesses the two machines via the .cms online systems nfs mounted accounts for which one has to request a personal user name. Once one has a personal account on the .cms network, one then has to apply for permissions to be able to switch from the local account into an account that is used to control or administrate certain machines.

The control PC is "vmepcS2G18-10.cms"[6] and is situated in rack G18 in the S2 level of USC, one floor above the crate itself. It has the local network alias "csc-tf.cms". This PC contains a CAEN "a2818" PCI card that is used to communicate with the VME control card in the Track Finder Crate. The VME controller, both 400 mm, 9-U PCB and the PCI card inside the machine were supplied through RICE University. The driver for the CAEN installation is the commercial CAEN one and provides a module (a2818.ko) that is inserted into the machine kernel modules at machine boot time. The CAEN installation itself comes as part of the XDAQ[10] package[7] that is installed locally on the machine. The XDAQ package is the responsibility of the online systems administration and is produced by the CMS DAQ group.

There is a "xdaqd" daemon that starts at boot time that controls services including job control, slow controls, the cell that is receptive to SOAP configurations and the link to the ORACLE databases. In order to start or stop machine services, one needs root access but one can monitor the status from a standard user account (example in Table A.10 below). The main .cms nfs user account for functional access to the control PC is "csctfts". It is within this network account that the Track Finder "TriDAS/trigger/csctf" crate control and monitoring software is installed. This includes the core libraries used to talk to the crate, load firmware, load lookup tables, perform local VME reads etc. and the trigger supervisor software that allows automatic parsing of keys to the configuration service. The CSC Track Finder DDU is controlled from the same machine via the same controller but the CSC FED crate software that controls it is installed under the network "cscpro" account.

Table A.10. An example showing how to get from the .cern network to the CSCTF control machine and query the state of the xdaqd services.

```
[dan@lxplus242]              >  ssh cmsusr1   Enter .cms gateway machine using personal account "dan"
[dan@srv-C2C05-07]           >  ssh csc-tf    Enter the csc-tf.cms control machine
[dan@vmepcS2G18-10]          >  xsudo -H -u csctfts bash -login  Change in to nfs mounted CSCTF control account
"csctfts"
[csctfts@vmepcS2G18-10] > cd TriDAS/trigger/csctf This is the base directory for the CSCTF software installation
[csctfts@vmepcS2G18-10] >  /sbin/service xdaqd status  List the status of the xdaqd services;
Status of XDAQ service 'csctf-tstore':              [  OK  ]
Status of XDAQ service 'csctf-ws-eventing':         [  OK  ]
Status of XDAQ service 'general-ws-eventing':       [  OK  ]
Status of XDAQ service 'csctf-pulser':              [  OK  ]
Status of XDAQ service 'csctf-sensor':              [  OK  ]
Status of XDAQ service 'general-dashboard':         [  OK  ]
Status of XDAQ service 'general-las':               [  OK  ]
Status of XDAQ service 'exception-ws-eventing':     [  OK  ]
Status of XDAQ service 'exception-dashboard':       [  OK  ]
Status of XDAQ service 'xdaq-jc':                   [  OK  ]
Status of XDAQ service 'csctf-cell':                [  OK  ]
[csctfts@vmepcS2G18-10] >  exit  Leave the "csctfts" user account
[dan@vmepcS2G18-10]          >  exit  Leave the csc-tf.cms machine
[dan@srv-C2C05-07]           >  exit  Leave the .cms network.
[dan@lxplus242]              >
```

[6] The hostnames of the .cms network machines tell you where they are physically situated. e.g. The CSCTF control PC "vmepcS2G18-10.cms" is situated on the USC S2 level, rack G18 and is in position 10 inside that rack.

[7] The XDAQ package currently installed is actually a very specific version containing patches necessary for operation of the Trigger Supervisor package. As such, administration of it is currently the responsibility of the Trigger Supervisor team.

The csc-tf.cms machine runs a QUATTOR service to ensure the local configuration is kept as expected. This means that periodically and when the machine boots, the local file system is checked to see that it agrees with what is backed up in the QUATTOR system. Any local changes will be removed and the default restored. This has the consequence that if any local file system changes are required then the QUATTOR system must be notified. The QUATTOR system only runs on the machine local file systems and not the nfs mounted .cms accounts.

The second .cms PC that comes under the auspices of the CSC Track Finder Group is “csc-daq10” (real hostname is csc-C2D07-02). This machine is in the above ground SCX computer center in the upstairs room and is positioned in rack D07 along with the rest of the CSC local DAQ machines. It is connected via optical fiber to the output of the Track Finder DDU and serves to store Track Finder local data as they are passed out. A commercial DLink gigabit ethernet card receives the data and fills a ring buffer while the data are saved. The software hooks into the ethernet card driver are custom and are developed by OSU. The CSC local DAQ machine specification was laid out by OSU and one was purchased by the University of Florida to represent the Track Finder DAQ machine. The data stored on this machine has RAID-5 redundancy.

References

[1] **CMS Internal Note 1999/060.** Acosta, Madorsky, Scurlock, Wang, Atamanchuk, Golovtsov, Razmyslovich. *"The Track-Finding Processor for the Level-1 Trigger of the CMS Endcap Muon System".*

[2]**Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. Volume 496, Issue 1, 1 January 2003, Pages 64-82**
Acosta, Adams, Atamanchouk, Cousins, Ferguson, Golovtsov, Hauser, Madorsky, Matveev, Mumford, Nussbaum, Padley, Razmyslovich, Sedovd, Smith, Tannenbaum. *"Development and test of a prototype regional track-finder for the Level-1 trigger of the cathode strip chamber muon system of CMS".*

[3] **CERN/LHCC 2000-38. CMS TDR 6.1 15 December 2000.**, The CMS Collaboration, *"The TriDAS Project. Technical Design Report, Volume 1: The Trigger Systems".*

[4] **CMS Internal Note 2002/040.** Acosta, Madorsky, Cousins, Hauser, Padley, Ero, Fierro, Wultz, SAkulin, Dallavalle, Wrochna. *"Specification Of The Interface Between The DT And CSC Level-1 Track-Finders".*
For further CSC and DT trigger primitive Exchange Specification, see the DT Transition Board Manual in [7] and the Trigger TDR in [3].

[5] **CMS Internal Note 2004/022.** Acosta, Dallavalle, Kudla, Matveev, Montanari, Padley,
Sakulin, Taurok. *"Specification of the Interface Between the Regional Muon Triggers and the Global Muon Trigger".*

[6] **CMS Internal Note 2007/024**. Breedon et al. *"CSC Strip, Wire, Chamber, and Electronics Conventions".*

[7] **Web links to detailed specification of the Track Finder Crate boards:**

Most of these boards have non-published manuals available from various HEP group web pages. Current web links are provided below. The links themselves are liable to change, the URL stems less so.

Sector Processor, DDU Extender Board and DT Transition Board. Built by the University of Florida CMS HEP group.
"SP Backplane Interfaces. Petersburg Nuclear Physics Institute / University of Florida. July 1, 2006, Version 8.3."
"CSC-DT Data Exchanging Transition Board Upgrade." L. Uvarov, V. Golovtsov. May 2004.
http://www.phys.ufl.edu/~uvarov/SP05/SP05.htm

Device Dependent Unit. Built by Ohio State University CMS HEP Group.
http://www.physics.ohio-state.edu/~cms/ddu/index.html

Clock and Control Board and Muon Sorter Board. Built by the CMS HEP Group at Rice University, Texas.
"Clock and Control Board for the CSC EMU Peripheral and Track Finder Electronics." CCB2004 Specification (Production Board). Rice University, Version 3.4, 27th June 2007
"The MS2005 Muon Sorter Specification." Rice University, Version 1.3, 26th June 2007.
"The CCB2004, MPC2004 and MS2005 User's Guide". Rice University. V1.4.4 October 1st 2008.
http://bonner-ntserver.rice.edu/cms/projects.html
http://lhc-workshop-2005.web.cern.ch/lhc%2Dworkshop%2D2005/Posters/80-MikeMatveev.pdf

CAEN 2718 VME Controller.
"Mod. V2718 VME PCI Optical Link Bridge. Technical Information Manual, Revision 4". CAEN S.p.A. February 2005.
http://www.caen.it

Wiener Crate.
"Series 6000 VME, VME 64x, VME64xP, VXI User's Manual". Wiener Plein & Baus GmbH. February 2005.

Track Finder Crate Backplane.
"CSC Track Finder Crate Specification".
http://www.phys.ufl.edu/~madorsky/TrackFinder

[8] **DAQ:: FMM response Levels and specification of connections:**
https://twiki.cern.ch/twiki/bin/view/CMS/DaqSetupMTCCFEDFRL
http://cmsdoc.cern.ch/cms/TRIDAS/horizontal/RUWG/DAQ_IF_guide/DAQ_IF_guide.html

[9]*https://twiki.cern.ch/twiki/bin/view/CMS/CSCTimingProgram*

[10] **CMS-CR 2003/007**, Gutleber et al., *"Using XDAQ in Application Scenarios of the CMS Experiment"*.

Glossary of Acronyms

CMS specific:
CMS: Compact Muon Solenoid. *One of two multi-purpose LHC detectors.*
YE: Yoke End Cap. *CMS large iron end cap disks.*
DAQ: Data AcQuisition. *The CMS sub-group responsible for receiving data from the subdetectors and then recording them.*
FRL: Front End Readout link. *The DAQ electronics into which subdetectors plug their s-links.*
FED: Front End Driver. *The bit of electronics that sends the data S-LINKs from each subdetector to DAQ.*
GT: Global Trigger. *The bit of electronics that receives muons and calorimeter primitives and then distributes level one triggers as well as clock and control commands.*
GMT: Global Muon Trigger. *Receives primitives from the three muon subdetectors and passes on requests to the GT.*
DT: Drift Tubes. *The barrel muon subdetector.*
CSC: Cathode Strip Chambers. *The end cap muon subdetector.*
DDU: Device or Detector Dependent Unit. *The boards used to serialise subdetector raw data into a stream to be passed on to DAQ.*
USC: Underground Service Cavern. *The area underground in the CMS experimental site that is accesible during beam running and houses the trigger electronics amongst other things.*
UXC: Underground Experimental Cavern. *The main CMS experiment hall where the detector is installed. This area is not accesible during running due to the level of radiation.*
SCX: Surface Control of the eXperiment. *The above ground control room. In SCX, the CSC subsystem has a rack filled with PCs which make up the "local DAQ farm".*
L1: Level-One. *Refers to the CMS "Level-One trigger" which consists of custom hardware that filters LHC events down from the 40 MHz nominal bunch crossing rate to the order of a hundred Hz.*

CSC subdetector specific:
LCT: Local Charged Track. *A CSC raw trigger primitive compirising a combination of wire and strip hits.*
SP: Sector Processor. *The board that analyses CSC primitives and makes level one trigger requests.*
BXA: Bunch Crossing Analyser. *The SP functionality allowing primitives from different bunch crossings to be combined in trigger logic.*
CCB: Clock and Control Board. *The board which receives and distributes TTC clock, fast control commands and triggers across CSC crates.*
MS: Muon Sorter. *The board in the Track Finder Crate which filters up to 36 SP trigger requests down to only the best four to be sent to the GMT.*
DMB: Data Acquisition Motherboard. *The boards in the peripheral crate that are responsible for holding data corresponding to a single chamber until a level one trigger decision can be made.*

TTC subsytem specific:
TTC: Trigger Timing and Control. *The electronics responsible for the distribution of clock, triggers and fast control commands to the CMS subdetectors.*
CTC: Central Trigger Crate. *An acronym used only in the MTCC to denote the TTC crate used to replace the Global Trigger crate and functionality.*
LTC: Local Trigger Controller. *The board used in each of the subsystems local TTC crates to send clock, fast control commands and triggers.*
TTC-CI: TTC CMS interface. *The board used to switch between local subsystem LTC control and GT or CTC control.*
TTC-EX: TTC Encoder and Transmitter. *The board outputting the optical bers carrying TTC information to the subsystems.*
TTC-RX:*The chip on the TTC "RQ" receiver board which has adjustable delays for the incoming TTC information to the subsystems.*

Generic Acronyms:
ECL: Emitter Coupled Logic.
NIM: Nuclear Instrumentation Module.
LED: Light Emitting Diode.
FIFO: First-in, First-out.
CRC: Cyclic Redundancy Check.30
CAN bus: Controller Area Network Bus.