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CMS Internal Note

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CSC Strip, Wire, Chamber, and Electronics Conventions

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Abstract

We present a labeling scheme for the endcap muon cathode strip chambers, including the order of strips, wire groups and layers within a chamber, as well as chambers within a trigger sector and sectors within a station. Information is also included about the

configuration of the peripheral crates of electronics. Care is taken to ensure consistent labeling between the two endcaps.

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Introduction

This note serves a number of purposes:

- A consistent labeling scheme is given for the CSC muon stations (ME1/1, ME1/2, etc.).
- A finer-grained numbering scheme is given for CSC strips, wires, chambers positions in ϕ, etc.
- Trigger sectors are described.
- Peripheral crate positions and numbering are described.
- Slots within the peripheral crates are described.

The note also contains other important information about the correspondence between chambers, on-chamber electronics, and the position of readout and trigger electronics within "peripheral crates" mounted around the endcap iron disks.

Layout of CSC Chambers in CMS

The CMS detector lies on the North side of the LHC ring. The LHC x-axis (ϕ=0°) points toward the center of the ring (South), while the y-axis is vertical and to complete the right-handed coordinate system, the z-axis points West. Therefore, the West (Jura direction) endcap is at $+z$ and $+\eta$ (rapidity), while the East (Saleve direction) endcap is at $-z$ and $-\eta$, as shown in Figure 1. In the surface hall SX5, the side of CMS that sits closest to the access shaft is the $+z$ detector end.

As viewed from the interaction region, ϕ increases in the conventional way of drawing, i.e. counterclockwise for the $-z$ endcap only, but ϕ increases *clockwise* for the $+z$ endcap.

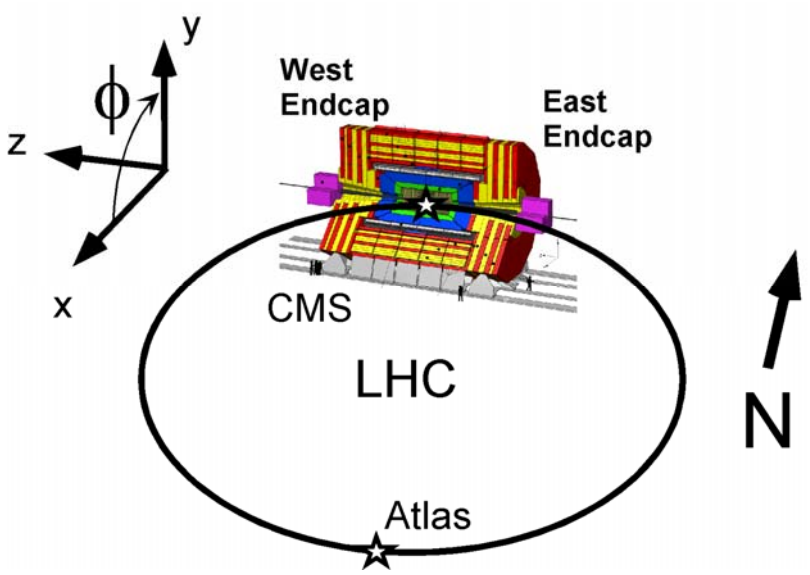


Figure 1. Overall CMS coordinate system

Stations 1 and 2 CSC chambers are mounted on the endcap iron disks on the sides closest to the interaction point. Conversely, in stations 3 and 4, chambers are mounted on the iron disks on the sides away from the interaction point. This is shown in Figure 2, which is similar to Figure 4.6.3 in the CMS Muon TDR.

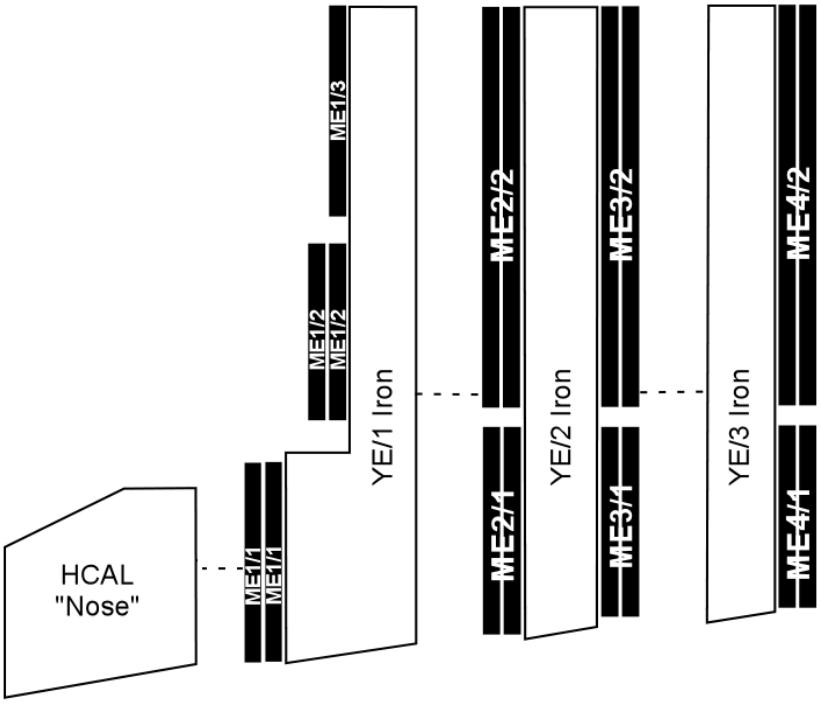


Figure 2. An r-z cross-section of the endcap muon system, showing the sides of the iron disks on which the various types of CSC chambers are mounted. (N.B. ME4/2 does not at present exist but might be built in a CMS upgrade.)

The chambers are numbered as ME<+->/<station>/<ring>/<phi index> :

- <+-> refers to + z or –z endcap.
- The station index (1-4) refers to the depth of muon penetration.
- The ring index refers to the inner→outer radius, running 1-3 in station 1 and running 1-2 in stations 2, 3, and 4. In software, "ring 4" often refers to the tiny inner section of ME1/1 that has strips split from the ME1/1 outer section and covers roughly $2.1<|\eta|<2.5$.
- The phi index obviously runs from 1-18 for 20^o chambers and 1-36 for 10^o chambers.

For example ME+2/1/1…ME+2/1/18 represent labels for all of the ME2/1 type chambers in the +z (Jura direction) endcap.

Note that chamber phi index=1 does not mean that the chamber is centered on the ϕ=0° i.e. x-axis. In the endcap muon system, there are 10° and 20° chambers. Every ring of chambers starts in ϕ with a chamber that has an edge at approximately -5°. For 10° chamber types such as those in ME1, the first chamber spans approximately $-5°<\phi<5°$. In 20° chamber types such as ME2/1, ME3/1, and ME4/1, the first chamber spans approximately $-5°<\phi<15°$.

Starting at ϕ = -5°, each chamber is numbered from 1 to 18 (for the 20° chambers) and 1 to 36 (for the 10° chambers) with increasing ϕ. In the positive η endcap, the chamber phi number increases *clockwise* as viewed from the interaction point; in the negative η endcap the chamber phi number increases *counterclockwise*.

There are other ways to refer to particular CSC chambers; such as (described below) by trigger sector and chamber number within a trigger sector, or CSCID within a particular peripheral crate of electronics.

Strips, Wires, and Layers for Single Chambers

Non-ME1/1 Case

The CSC chambers are constructed as trapezoidal objects, and during assembly they lay on tables so that electronics can be mounted on top. In this configuration, the top plane of wires and strips (*i.e.* those closest to the electronics) is layer 1, and the bottom plane is layer 6, as shown in Figure 3. ME1/1 is a special case in this respect and is described in detail below. Wires are strung between the sides of the trapezoidal chambers, and wire group number always increases from inner radius to outer radius (1:*n*). Strips run from inner radius to outer radius at constant ϕ, and strip number increases from left to right (1:*n*) when one looks from the small "inner" end toward the large "outer" end of the chamber,

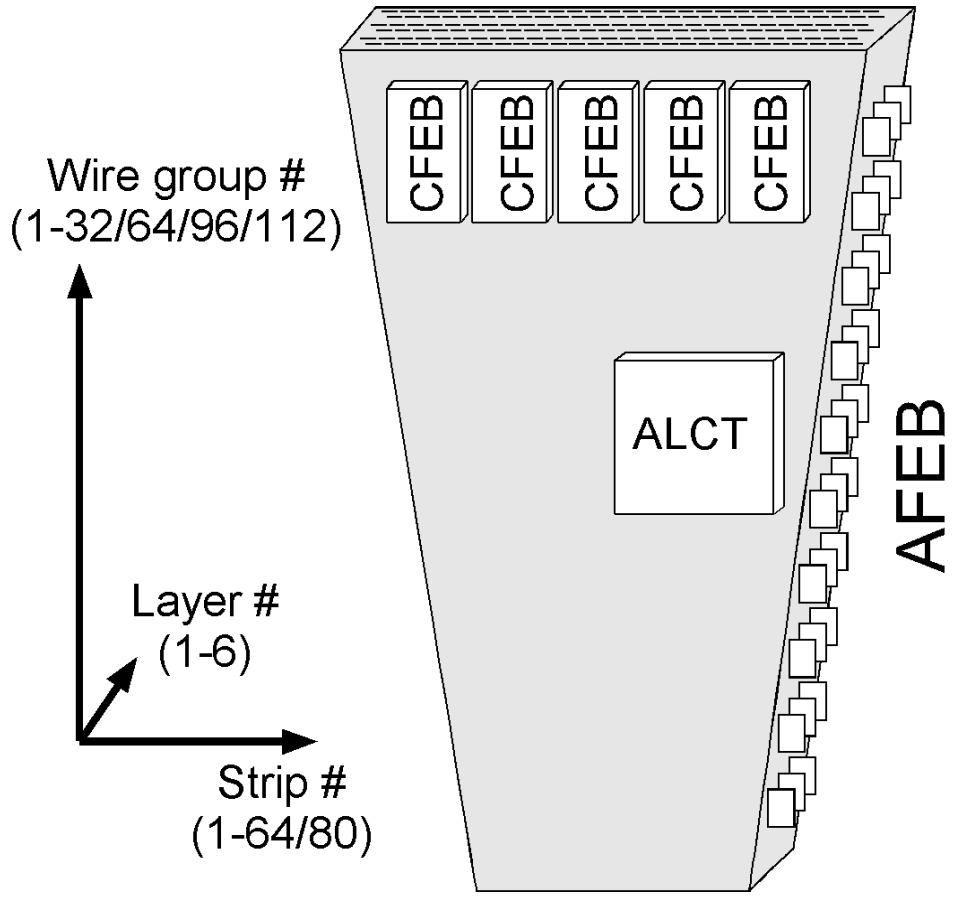


Figure 3. A view of a (non-ME1/1) CSC chamber with electronics on top and the corresponding definition of local CSC coordinates. (* Note that the number of wire groups is 1-32/48/64/96/112. Awaiting figure update using Canvas software)**

We can conclude that in the West (positive z, positive η) endcap, strip numbers in stations 1 and 2 are in increasing ϕ order, and strip numbers in stations 3 and 4 are in decreasing ϕ order. In the East (negative z, negative η) endcap, strip numbers in stations 1 and 2 are in decreasing ϕ order, while strip numbers in stations 3 and 4 are in increasing ϕ order. These statements are also true in ME1/1, although the reasons are different. This is summarized in Table 1.

Endcap	Station	Φ direction of strips ($1 \rightarrow n$)
$+z$ (West)	1	↑ (increasing)
"	2	↑
"	3	↓
"	4	↓
$-z$ (East)	1	↓
"	2	↓
"	3	↑
"	4	↑

Table 1. Direction in ϕ of increasing CSC strip number.

ME1/1 Case Only

The ME1/1 chambers differ from all other chambers in that within a single station the electronics are mounted facing alternately toward and away from the interaction region. For the chambers centered at ϕ=0°, 10°, 20°, etc.; the electronics face towards, away, towards etc. the interaction region, respectively.

ME1/1 is divided into two chambers in η, labeled ME1/1a inner part (by radius) and ME1/1b outer part. ME1/1b has 64 strips while ME1/1a has 48 strips. The 48 strips of ME1/1a are ganged 3:1 into 16 readout channels in a fashion that retains fine-grained position information, e.g. strips 1, 17, and 33 are ganged together into the first readout channel, and strips 16, 32, and 48 are ganged together into the last, 16th readout channel.

Also, the cabling has been arranged so that the firmware in ALCT, TMB, etc electronics does not depend on the ϕ position of the chamber. To summarize, the local coordinate definitions in the $+z$ (West) ME1/1 chambers are as follows:

- Wire numbers increase from inner to outer radius (same as other chambers)
- Strip numbers increase from 1-64 in increasing ϕ direction for ME1/1b.
- Strip numbers increase from 1-48 in increasing ϕ direction for ME1/1a.
- Layer numbers increase going away from the interaction region.

In the –z (East) endcap ME1/1 chambers:

- Wire numbers increase from inner to outer radius (same as other chambers)
- Strip numbers increase from 1-64 in *decreasing* ϕ direction for ME1/1b.
- Strip numbers increase from 1-48 in *decreasing* ϕ direction for ME1/1a.
- Layer numbers increase going away from the interaction region.

These points are illustrated in Figure 4.

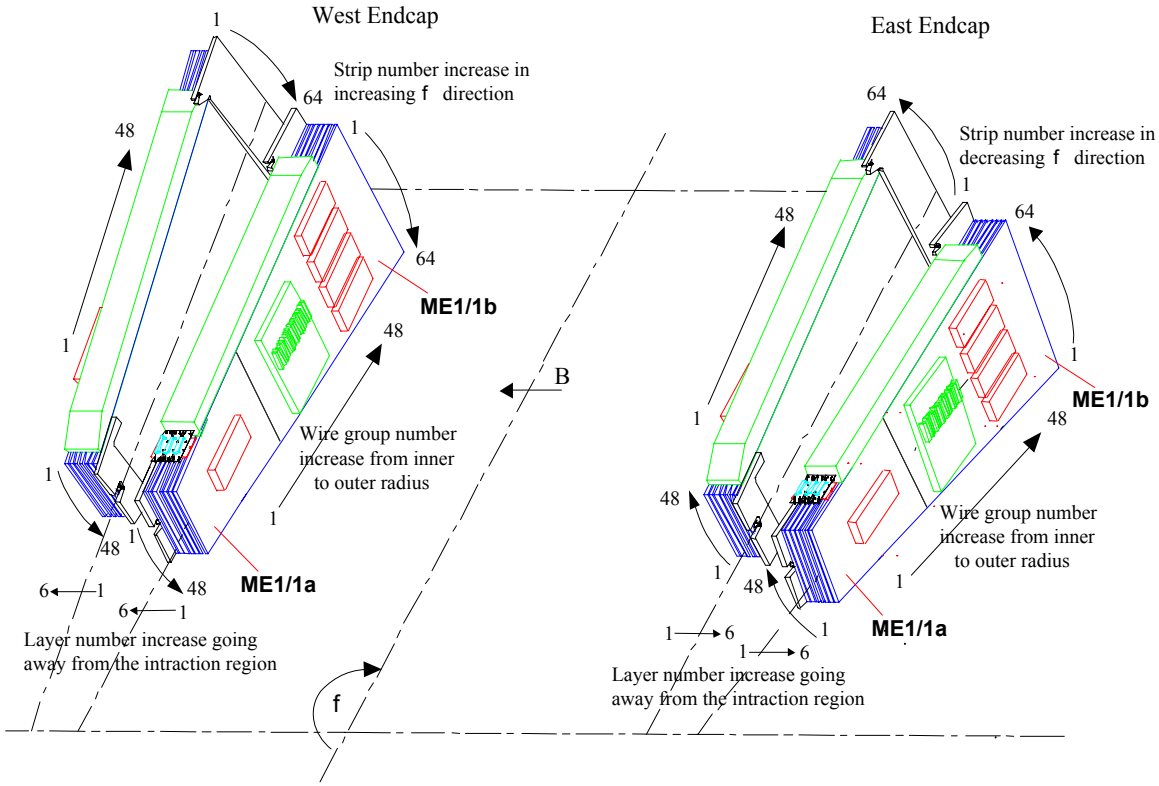


Figure 4. Orientation of layers and strips in the specific case of ME1/1 chambers (font problems: f=ϕ).

The Orientation of Strip Staggering

The CSC chambers contain strips milled on every cathode panel. In all types of chambers except ME1/1, strip 1 is indented by ½-strip in layers 1 (top), 3, and 5; with respect to strip 1 in layers 2, 4, and 6 (bottom), as shown in Figure 5. In ME1/1, there is no strip staggering.

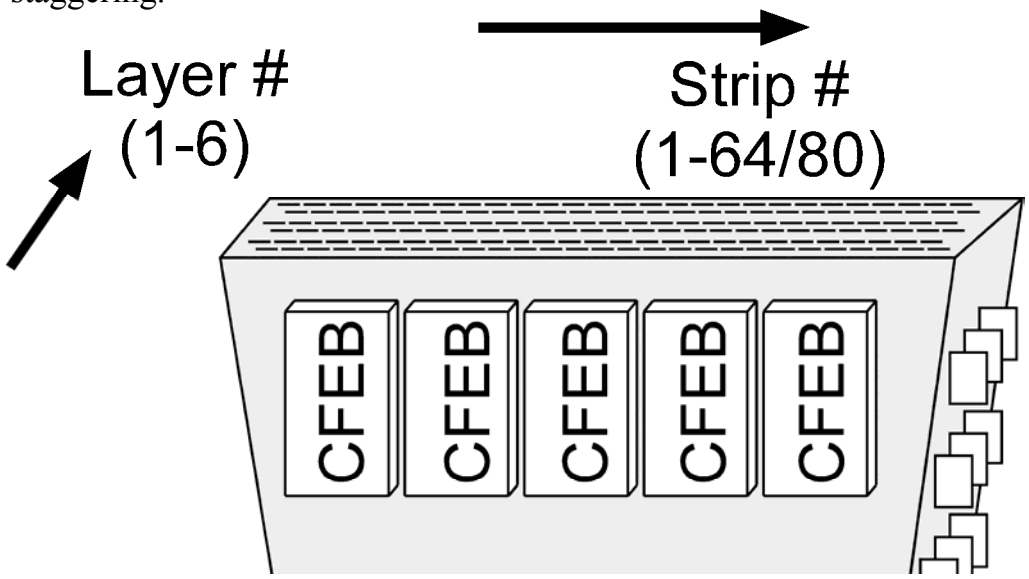


Figure 5. Staggering of strips in (non-ME1/1) CSC chambers. The first strip is indented by ½ strip in layers 1, 3, and 5 with respect to layers 2, 4, and 6.

The Direction of Muon Bending

The magnetic field points along the +z-axis. The bending direction of endcap muons reverses along the muon trajectory: initially, the muon crosses the +z solenoidal field lines, but around station 1 the magnetic field lines diverge in the +r direction and the muon crosses the field lines in the opposite direction. From Figure 1, one can therefore tell that the positive muons traveling in either direction (East or West) will first bend in the -ϕ direction and then reverse at some point toward the +ϕ direction in traveling through the return flux of the muon system.

CSC Trigger Sectors

CSC Trigger Sector Numbers

For purposes of triggering, the first chamber of the first 60^{o} muon sector starts at ϕ=15°. This location is determined by the first ϕ value at which chamber edges in the endcap line up with chamber edges in the barrel muon system (see Figure 6).

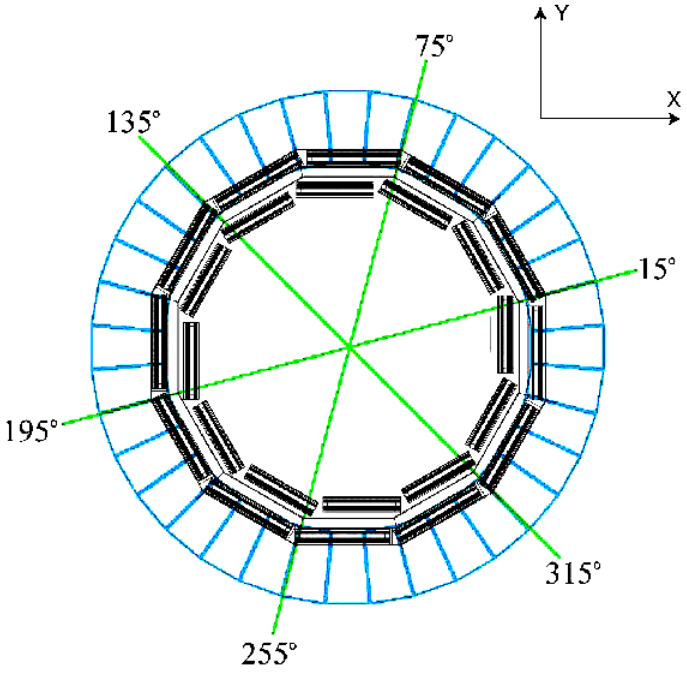
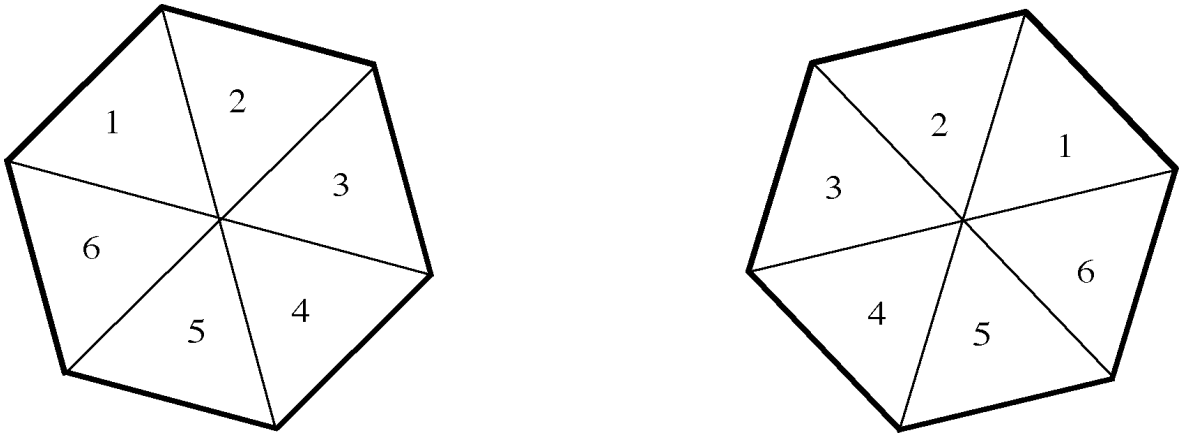


Figure 6. An *r*-ϕ cross-section view of the barrel muon system, with the positions of the outer ring of endcap muon chambers superimposed (looking East, or towards the –*z* endcap). This diagram shows the edges of the 60^{o} trigger sectors (ME2, ME3, and ME4) and the position of the outer (large) chambers.

Note that a trigger sector has the same sense of ϕ in both endcaps. Therefore, in the $+\eta$ endcap the sector number increases clockwise as viewed from the interaction point, while in the $-\eta$ endcap the sector number increases counterclockwise, as shown in Figure 7. Likewise, the numbering of the chambers within a sector (the next section of this note) increases in the opposite ϕ direction (within a ring) in the $-\eta$ endcap.



Positive η endcap *Negative η endcap*

Figure 7. Endcap trigger sector numbering, as viewed from the interaction region.

Numbering of Chambers Within a CSC Trigger Sector

Each trigger sector in stations ME2, ME3, and ME4 consists of three 20° chambers and six 10° chambers. They are numbered as shown in Figure 8, as seen from the interaction point.

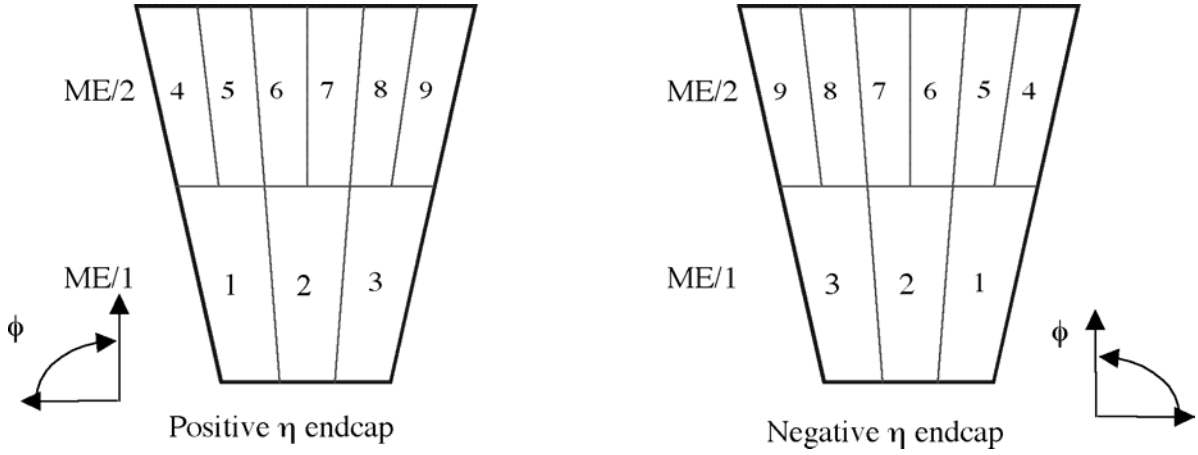


Figure 8. CSC chamber numbering in ME2, ME3, and ME4 within a 60-degree trigger sector, as seen from the interaction point. (ME4/2 chambers are a potential future upgrade.)

In station ME1 we have two 30° subsectors in each 60° sector. Each 30° subsector consists of nine 10° chambers. Note that cathode strips in ME1/1 are divided into inner-radius ME1/1a and outer-radius ME1/1b regions. As previously described, ME1/1a is read out, but it is not included in the CSC trigger. We number the chambers and sub-chambers in each 30° ME1 subsector from 1 to 12 (again, viewing from the interaction point) as shown in Figure 9.

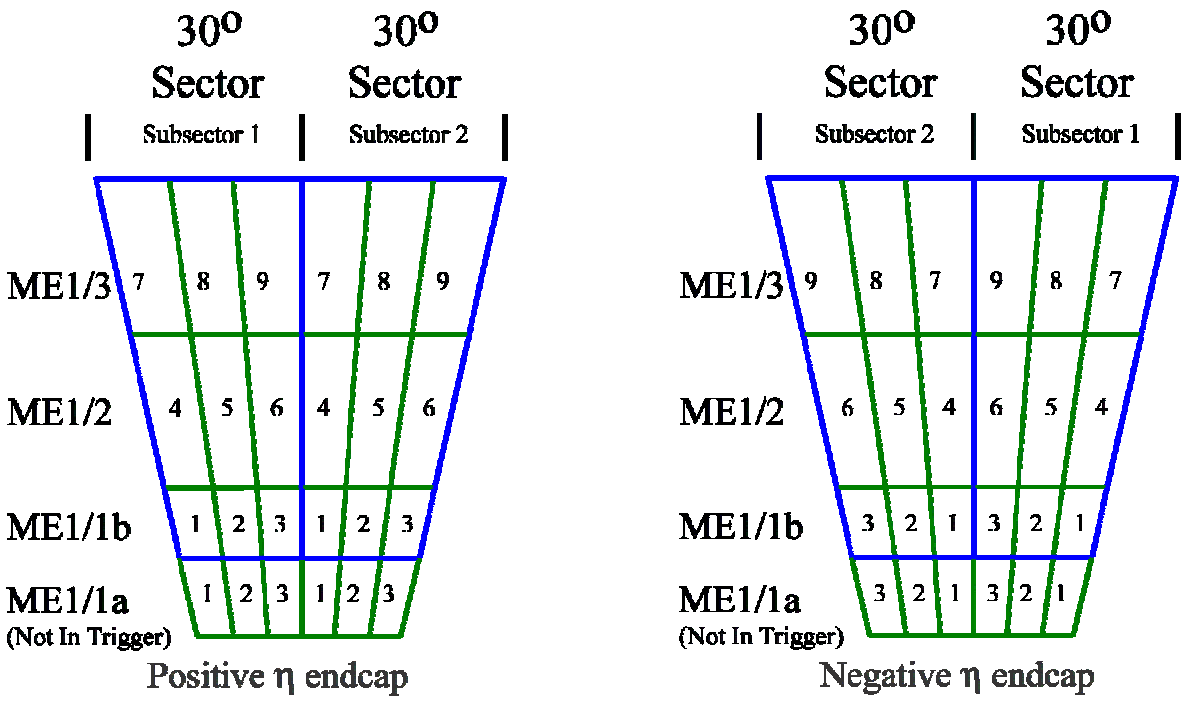


Figure 9. Numbering of CSC chambers within ME1 trigger sectors, as viewed from the interaction point.

Definitions for Peripheral Crate Electronics

Peripheral Crate Numbers

One peripheral crates of electronics contains one 60° trigger sector of electronics in ME2, ME3, and ME4. However, in ME1, one peripheral crate contains one 30° trigger subsector of electronics. The peripheral crates are in racks placed as close as possible to the chambers they are connected to.

Peripheral crates are identified as Crate (or VME) <station>/<ϕ index>. The peripheral crates ϕ indexes are the same as the trigger sectors in CSC stations ME2, ME3, and ME4, i.e. the crate with ϕ index 1 covers 15°<ϕ<75°, crate 2 covers 75°<ϕ<135°, and so on. This is shown in `Figure 10` below. To give an example, peripheral crates in ME2 (+ endcap) are denoted VME+2/1,…, VME+2/6.

In station 1, however, in order to match the RPC system, the first peripheral crate is defined as the one covering the ϕ range of -15° to 15°. Therefore, in ME1 the first 30° trigger sector corresponds to peripheral crates 2 and 3, and the last 30° trigger sector corresponds to peripheral crates 12 and 1. This is shown in `Figure 11` below. To give an example, the ME1 crates in the + endcap are denoted VME+1/1, VME+1/2,…, VME+1/12.

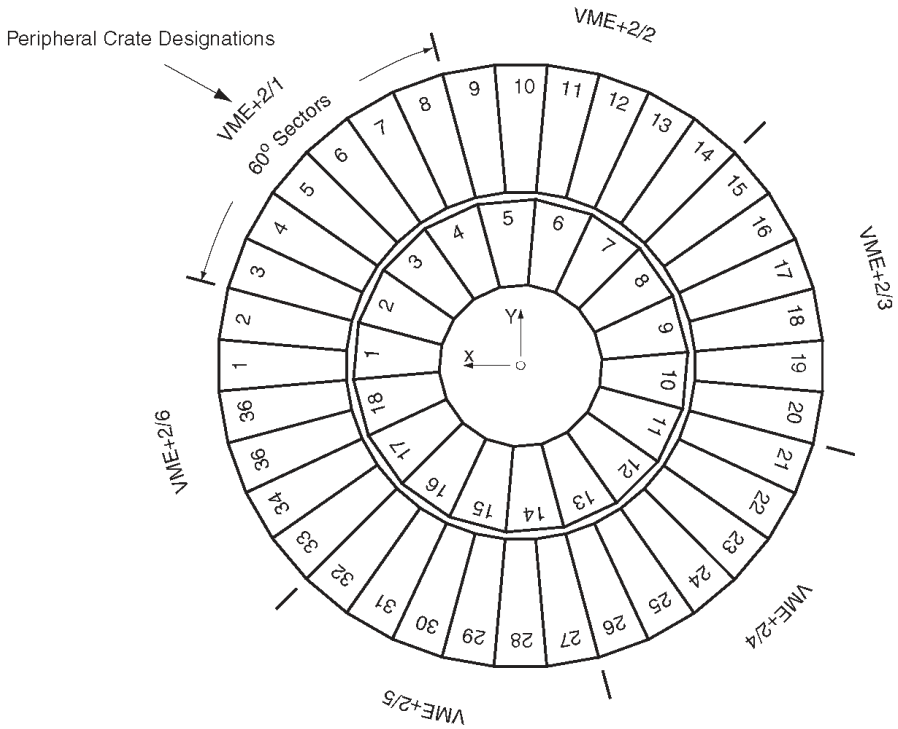


Figure 10. An *r*-ϕ cross-section of the ME2, ME3, and ME4 endcap muon stations on the +*z* side, showing the positions of chambers, trigger sectors, and correspondence to peripheral crates, denoted as VME<station><phi index>. (Slight bug: one of the outer chamber 36's should be a 35.)

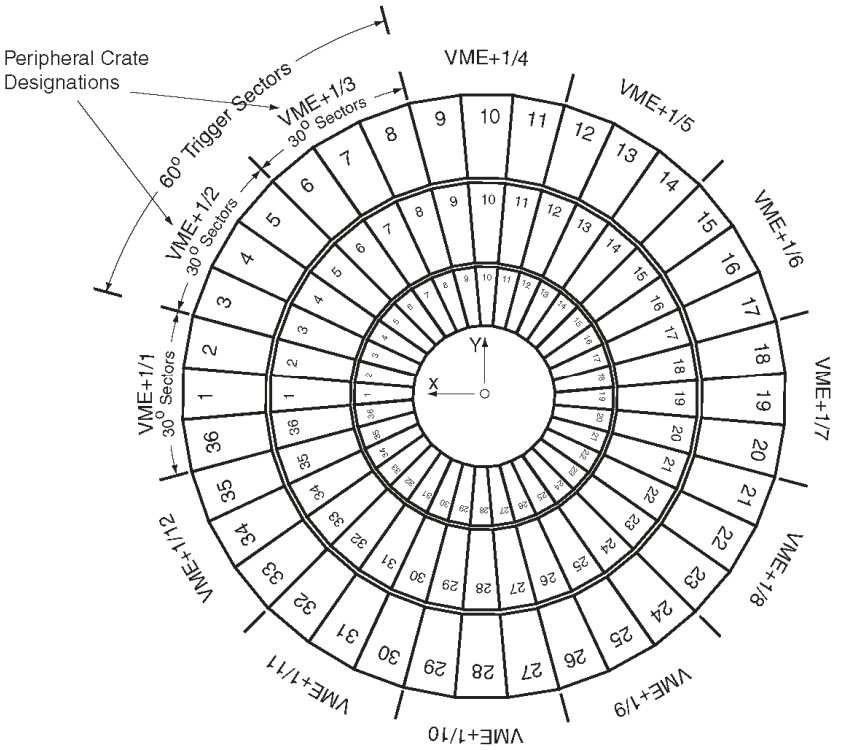


Figure 11. An *r-ϕ* cross-section of the ME1 endcap muon station on the +*z* side, showing the positions of chambers, trigger sectors, and correspondence to peripheral crates.

Two other well-defined notations for peripheral crates are also used:

- The 1:1 correspondance of MPCs to Sector Processors allows a 6-bit or [5..0] crate number. For this purpose, crates in the –*z* endcap are numbered 1-30, and crates in the +*z* endcap are numbered 33-62 (thus bit <5> can be used to identify which endcap). Crates 1-12 (33-44) are used for ME1, crates 13-18 (45-50) are ME2, crates 19-24 (51-56) are ME3, and crates 25-30 (57-62) are ME4 for the –*z* (+*z*) endcap. The crate numbers increase with phi exactly as in the VME+1/1 scheme.
- There is an 8-bit DMB_CRATE word sent in HEADER2 of the DMB data format, thus allowing numbers 1-255. For ease of decimal interpretation, the crates are numbered on the –*z* side (in the same phi order) 1-12 in station 1, 21-26 for station 2, 31-36 for station 3, and 41-46. On the +*z* side, they are just 100 higher, i.e. numbered 101-112 for ME1, 121-126 for ME2, 131-136 for ME3, and 141-146 for ME4.

Peripheral Crate Racks

In stations ME2-4, "mini-racks" holding 2 peripheral crates are stationed at approximately 60^{o} intervals. Station 4 peripheral crates are located in mini-racks holding only one crate. The positions of the peripheral crates within the racks are described in Table 2.

ME1 Crate #	Trigger Sector	Rack (+z,-z end)	Position in Rack
VME(+,-)1/1	6	X3(J,V)31	top
VME(+,-)1/2	1	X5(U,E)31	bottom
VME(+,-)1/3		X5(U,E)31	top
VME(+,-)1/4	2	X5(R,L)31	top
VME(+,-)1/5		X5(R,L)31	bottom
VME(+,-)1/6	3	X3(A,S)31	top
VME(+,-)1/7		X3(A,S)31	bottom
VME(+,-)1/8	4	X1(R,L)31	top
VME(+,-)1/9		X1(R,L)31	bottom
VME(+,-)1/10	5	X1(U,E)31	bottom
VME(+,-)1/11		X1(U,E)31	top
VME(+,-)1/12	6	X3(J,V)31	bottom

ME(2,3,4) Crate #	Trigger Sector	Rack (+z,-z)(2,3,4)	Position in Rack
VME(+,-)(2,3,4)/1	1	X5(U,E)(41,41,51)	(top,bot,bot)
VME(+,-)(2,3,4)/2	2	X5(R,L)(41,41,51)	(top,bot,bot)
VME(+,-)(2,3,4)/3	3	X3(A,S)(41,41,51)	(top,bot,bot)
VME(+,-)(2,3,4)/4	4	X1(R,L)(41,41,51)	(bot,top,top)
VME(+,-)(2,3,4)/5	5	X1(U,E)(41,41,51)	(top,bot,bot)
VME(+,-)(2,3,4)/6	6	X3(J,V)(41,41,51)	(bot,top,top)

Table 2. Peripheral crate locations in racks. The rack notation, e.g. X3J31, follows CMS-wide convention. The X refers to "on-detector", the 3 labels the height, and so on. This may be viewed using a convenient "Rack Wizard", see https://oraweb.cern.ch/pls/cmsintegration/docs/EMDH.html

Peripheral Crate Slots, CSCIDs, and DMBIDs:

The 9U VME peripheral crates contain slots 1-21, with slot 1 on the left. Within each peripheral crate, slot 1 is always used for the VME Crate Controller, Slot 12 is for the MPC (Muon Port Card), and Slot 13 for the CCB (Clock and Control Board). All of the remaining slots are used by TMB/DMB (Trigger MotherBoard/Data-acquisition MotherBoard) pairs.

There is one TMB/DMB board pair occupying two slots for each chamber. The order of the TMB/DMB pairs in each peripheral crate from left (slot 1) to right is in order of chamber number within a trigger sector, i.e. from 1 to 9, also known as CSCID. The slot positions also correspond to "DMBIDs" that appear in the offline data stream, which are simply the crate slot of TMB/DMB board pairs divided by 2. The correspondence between CSCIDs, DMBIDs and the trigger sector chamber numbers is listed below:

TMB/DMB Slots	CSCID = Chamber Number in Trigger Sector	DMBID
2/3	1	1
4/5	2	2
6/7	3	3
8/9	4	4
10/11	5	5
14/15	6	7
16/17	7	8
18/19	8	9
20/21	9	10

Table 3. CSC peripheral crate cross-reference between TMB/DMB board slots, CSCIDs, and DMBIDs.

In ME2, ME3, and ME4, the TMB/DMB order corresponds to the ϕ order of chambers, with the TMB/DMB board pairs corresponding to inner-radius chambers (MEn/1) occupying the lower-numbered slots (2/3, 4/5, and 6/7), followed by the TMB/DMB pairs for outer-radius (MEn/2) chambers occupying the higher-numbered slots (8/9, 10/11, 14/15, 16/17, 18/19, 20/21). An example is shown in Figure 12.

In ME1, the same pattern is followed for TMB/DMB board pairs in a peripheral crate: ME1/1 chambers occupy the lower-numbered slots (2/3, 4/5, 6/7), ME1/2 chamber occupy the middle-numbered slots (8/9, 10/11, 14/15), and ME1/3 TMB/DMB board pairs occupy the higher-numbered slots (16/17, 18/19, 20/21). An example is shown in Figure 13.

ME1/1 is a special case in that the chamber is divided into inner-radius ME1/1a strips and outer-radius ME1/1b strips. In each ME1/1 chamber, there are 64 ME1/1a strips and 48 ME1/1b strips per layer. As previously described, the ME1/1a strips are ganged 3:1 so that there are only 16 readout strips per layer. The ME1/1a and ME1/1b strips are connected to the same TMB/DMB board pair, with the information from ME1/1b strips going to the top 4 front-panel connectors, and the ganged information from ME1/1a strips going to the bottom-most front-panel connector.

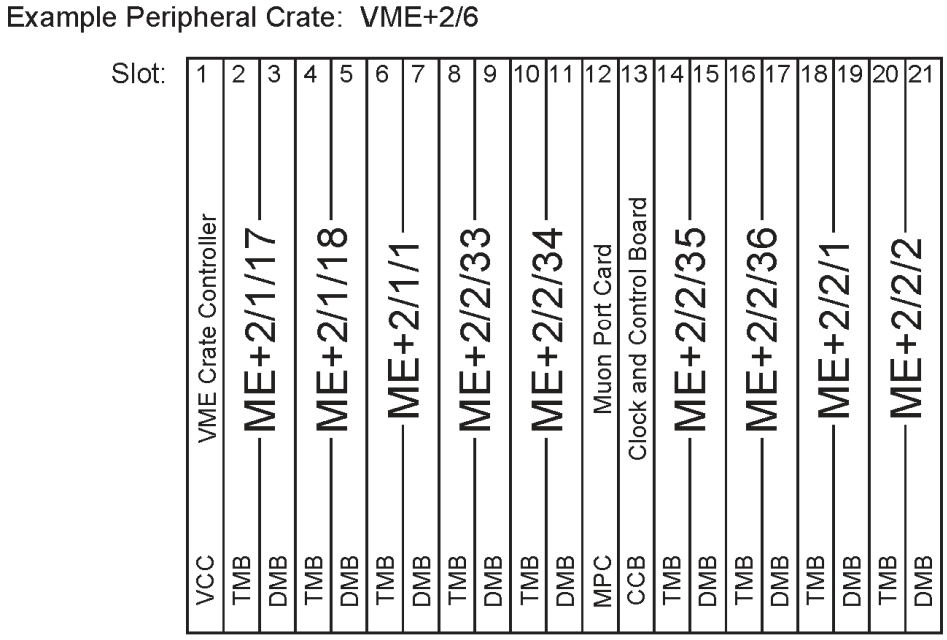


Figure 12. An example of the arrangement of slots in peripheral crates to TMB/DMB board pairs and other modules (CCB, MPC, Controller) in ME2, ME3, and ME4.

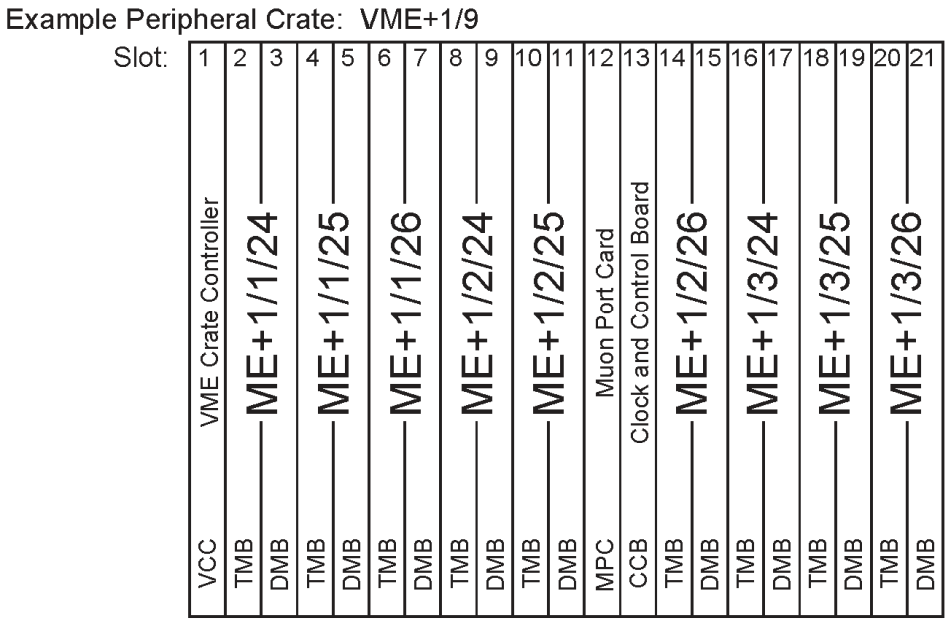


Figure 13. An example of the arrangement of slots in peripheral crates to TMB/DMB board pairs and other modules (CCB, MPC, Controller) in ME1.

Table 4 shows the chamber ϕ number for each type of chamber, trigger sector or 30° sector (in ME1) number, and for each TMB and DMB pair of crate slots.

Peripheral Crate		Chamber Type and Chamber Number								
	30° Sector	ME(+,-)(1)/1			ME(+,-)(1)/2			ME(+,-)(1)/3		
VME(+,-)(1)/	1	36	1	2	36	1	2	36	1	2
	2	3	4	5	3	4	5	3	4	5
	3	6	7	8	6	7	8	6	7	8
	4	9	10	11	9	10	11	9	10	11
	5	12	13	14	12	13	14	12	13	14
	6	15	16	17	15	16	17	15	16	17
	7	18	19	20	18	19	20	18	19	20
	8	21	22	23	21	22	23	21	22	23
	9	24	25	26	24	25	26	24	25	26
	10	27	28	29	27	28	29	27	28	29
	11	30	31	32	30	31	32	30	31	32
	12	33	34	35	33	34	35	33	34	35
Crate Slot Numbers	TMB	2	4	6	8	10	14	16	18	20
	DMB	3	5	7	9	11	15	17	19	21
	Trigger Sector	ME(+,-)(2,3,4)/1			ME(+,-)(2,3,4)/2					
VME(+,-)(2,3,4)/	1	2	3	4	3	4	5	6	7	8
	2	5	6	7	9	10	11	12	13	14
	3	8	9	10	15	16	17	18	19	20
	4	11	12	13	21	22	23	24	25	26
	5	14	15	16	27	28	29	30	31	32
	6	17	18	1	33	34	35	36	1	2
Crate Slot Numbers	TMB	2	4	6	8	10	14	16	18	20
	DMB	3	5	7	9	11	15	17	19	21

Table 4. Correspondances between CSC chambers, peripheral crates, and slots for electronics boards. (N.B. ME4/2 chambers do not currently exist but might be built in the future as part of a CMS detector upgrade).

Appendix A: CSC System Connection Diagrams shows explicitly the DAQ and Trigger cable connections for three types of chambers:

1. Figure 14 shows connections for all types of chambers except for ME1/3 and ME1/1.
2. Figure 15 shows connections for ME1/3 chambers.
3. Figure 16 shows connections for ME1/1 (a and b sub-chambers).

Appendix A: CSC System Connection Diagrams

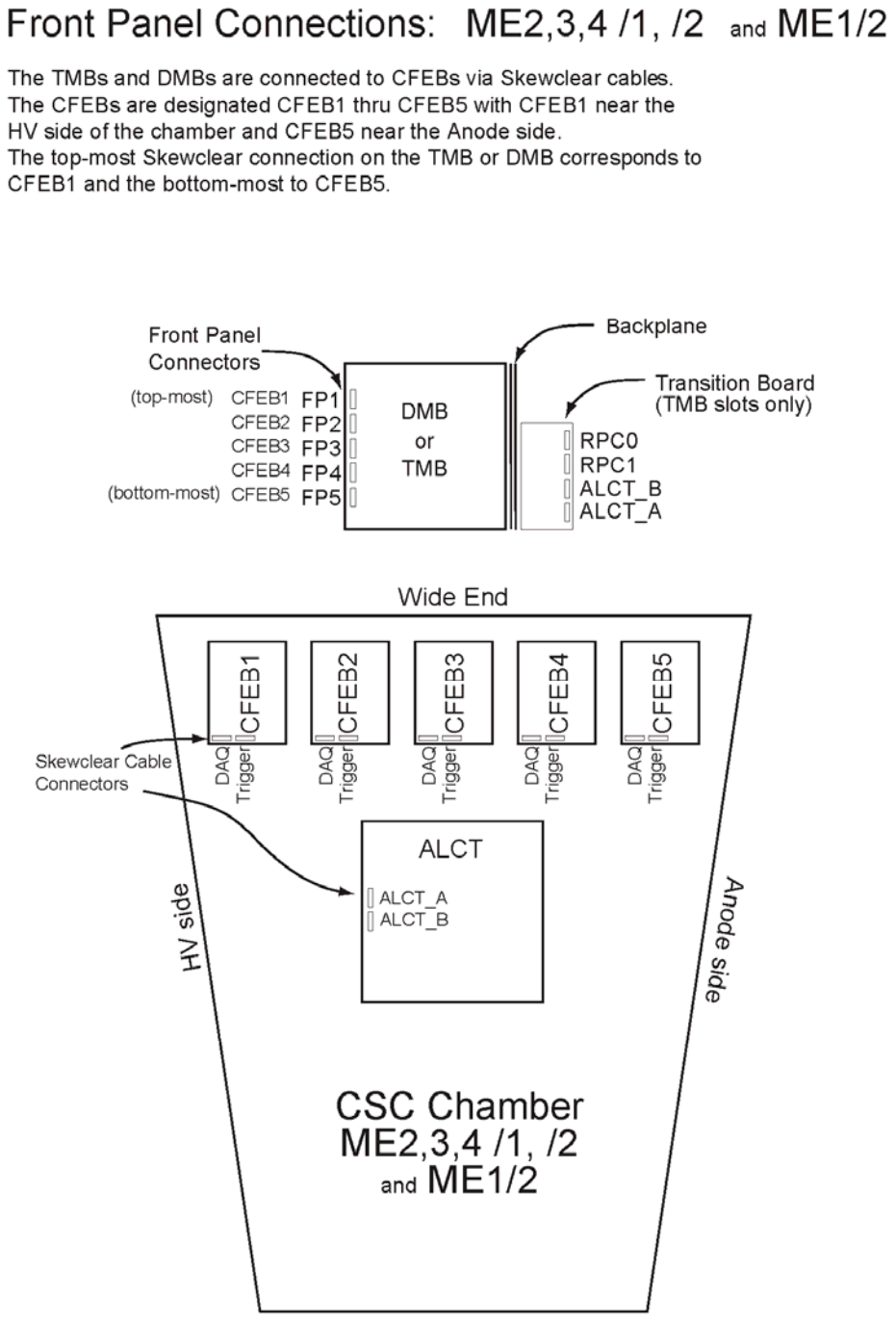


Figure 14. Cable connections for all types of chambers *except* ME1/3 and ME1/1. Explicitly, these are ME1/2, ME2/1, ME2/2, ME3/1, ME3/2, and ME4/1

Front Panel Connections: ME1/3

The TMBs and DMBs are connected to CFEBs via Skewclear cables.
The CFEBs are designated CFEB1 thru CFEB4 with CFEB1 near the HV side of the chamber and CFEB4 near the Anode side.
The top-most Skewclear connection on the TMB or DMB corresponds to CFEB1 and the next to bottom-most to CFEB4.
The bottom-most connector is left unused.

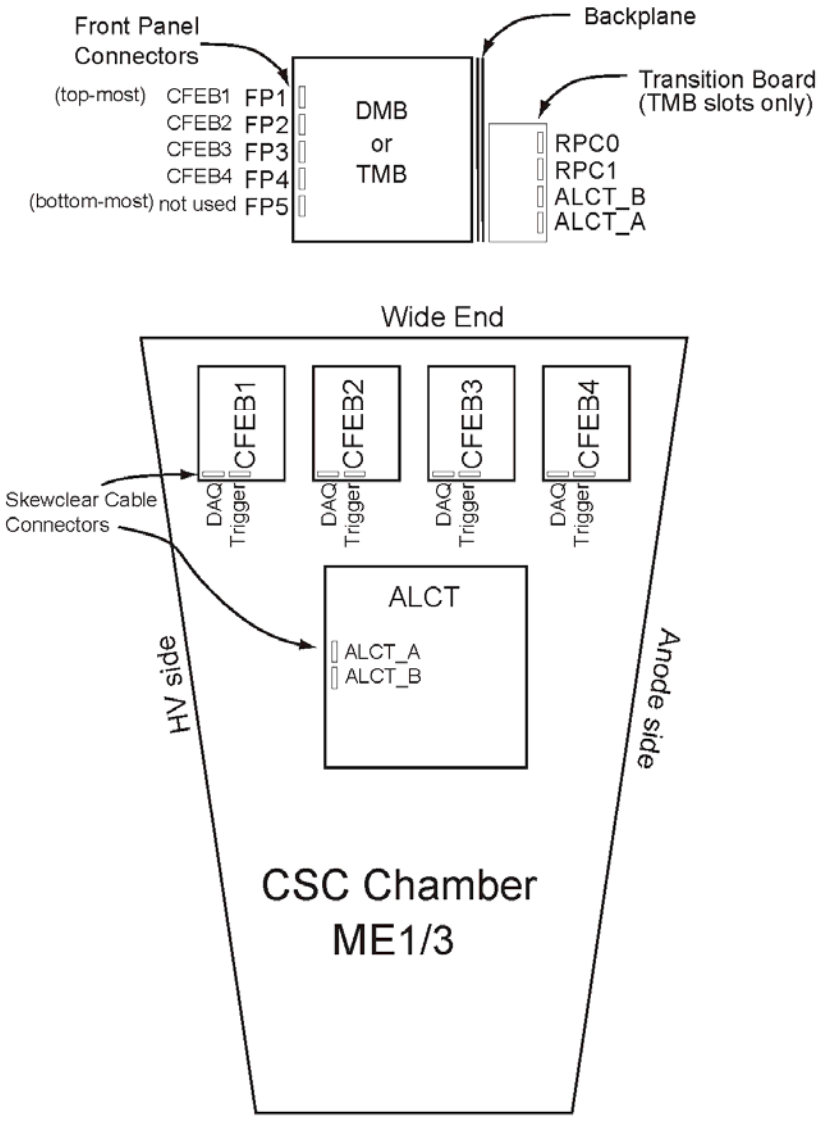


Figure 15. Cable connections for ME1/3 chambers.

Front Panel Connections: ME1/1a, and ME1/1b

The TMBs and DMBs are connected to CFEBs via Skewclear cables.
The CFEBs for ME1/1b are designated CFEB1 thru CFEB4 with CFEB1 near the HV side of the chamber and CFEB4 near the Anode side on the wide end.
There is only one CFEB for ME1/1a on the narrow end.
The top-most Skewclear connection on the TMB or DMB corresponds to CFEB1 on ME1/1b and the next to bottom connection to CFEB4 on ME1/1b.
The bottom-most connector corresponds to CFEB1 on ME1/1a.

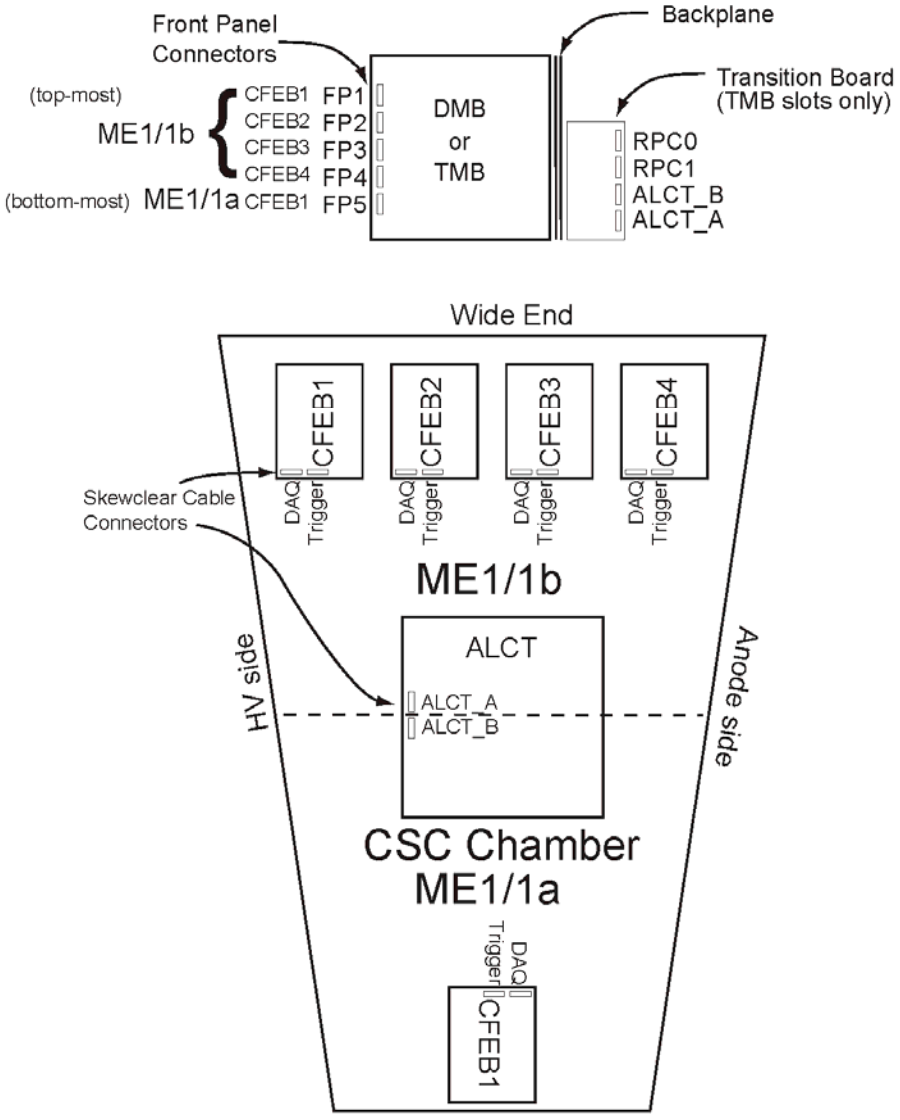


Figure 16. Cable connections for ME1/1 chambers (a and b sub-chambers).

Document Revision History:

1998 Feb.: original version written by Jay Hauser and posted on the Web only.
1999 Nov., CMS note version 1.0: modified by Benn Tannenbaum for distribution as a CMS note and to include information about labeling within a sector.
2002 Aug., CMS note version 2.0: Modified by Jay Hauser, Vladimir Karjavin, and Serguei Khabarov to include ME1/1 orientation and improve quality of figures, add captions.
2005 Nov., CMS note version 2.2 or 2.3 (JH). Text for peripheral crate and slot numbering added, and several figures from Ben Bylsma.
2006 Aug., CMS note version 2.4 (JH) Add table of contents, cleaned up and updated the text and figures. Peripheral crate numbering is clarified.