CSC Strip, Wire, and Chamber Orientation

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Abstract
We present a labeling scheme for the endcap muon cathode strip chambers, including the strips, wire groups and layers within a chamber, chambers within a sector and sectors within a station. Care is taken to ensure consistent labeling between the two endcaps.

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Introduction

It took several years to come up with a consistent labeling scheme for the CSC muon stations (ME1/1, ME1/2, etc.). However, there has been no generally accepted finer-grain labeling scheme for strips, wires, and chambers positions in φ. The reason for this is that for most purposes, e.g. the DAQ readout of the CSC system, the relative orientation and labeling of CSC strips, wires, and chambers does not much matter - they can always be re-oriented or re-labeled in software. For the trigger, on the other hand, we must be able to form stubs from multi-layer coincidences, and derive space coordinates and vector directions easily for track finding and for correlation with the calorimetry. These matters lead us to propose a scheme by which any strip or wire in the system can be uniquely identified and its position in various coordinate systems understood. There also seems to be a need to explain the various coordinates in one self-consistent place.

Single-Chamber, Standalone Layout

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. The wire group number increases from inner radius to outer radius (1:n). 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, as shown in below:

Layout of CSC Chambers in CMS

The CMS detector lies on the North side of the LHC ring. The 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:
As shown in the following figure, stations 1 and 2 chambers are mounted on iron disks on the sides closest to the interaction point. Conversely, in stations 3 and 4, chambers are mounted on iron disks on the sides away from the interaction point. This is shown in the figure below, which is similar to figure 4.6.3 in the CMS Muon TDR. Therefore, in the West (positive $z$, positive $\eta$) endcap, strip numbers in stations 1 and 2 are in increasing $\phi$ order, and strip numbers in stations 3 and 4 are in decreasing $\phi$ order. In the East (negative $z$, negative $\eta$) endcap, strip numbers in stations 1 and 2 are in decreasing $\phi$ order, while strip numbers in stations 3 and 4 are in increasing $\phi$ order. Note that ME1/1 is mounted to the iron rather differently than the other chambers.
We use the CMS convention of defining $\phi = 0^\circ$ at the positive x-axis. The first chamber is at $\phi = 15^\circ$. 
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 looking at the picture above, one can tell that the positive muons travelling in either direction (East or West) will first bend in the -φ direction and then reverse toward the +φ direction in travelling through the muon system.

The Orientation of Strip Staggering

The CSC chambers contain strips milled on every anode and cathode panel. Except for ME1/1 (which is not staggered), strip 1 is indented by 1/2-strip in layers 1 (top), 3, and 5; with respect to strip 1 in layers 2, 4, and 6 (bottom), as shown:
Global labeling of chambers

Starting at $\phi = 15^\circ$, each chamber is numbered from 1 to 18 (for the 20° chambers) and 1 to 36 (for the 10° chambers). In the positive $\eta$ endcap, the chamber number increases clockwise; in the negative $\eta$ endcap the chamber number increases counterclockwise.

Labeling of sectors and chambers within a sector (trigger)

Each sector starts at +15°. Note that once a sector is defined, it has the same sense of $\phi$ in both endcaps. In the $+\eta$ endcap the sector number increases clockwise. In the $-\eta$ endcap the sector number increases counterclockwise. Likewise, the numbering of the chambers within a sector goes in the opposite direction (within a ring) in the $-\eta$ endcap.

Sector labeling

Each sector in stations 2, 3, 4 consist of three 20° chambers and six 10° chambers. They are numbered as shown below, as seen from the interaction point:
In station 1 we have two 30° subsectors in each 60° sector. Each 30° subsector consists of nine 10° chambers. Note that ME1/1 is divided into two chambers in η, labeled ME1/1 and ME1/A. We number them from 1 to 12 (again, viewing from the interaction point):

**Decoding Channel IDs into η and φ (Trigger)**

The Sector Receiver card in the Muon Track Finder electronics must decode a precise φ and η position from the hit wire and strip numbers. In the η coordinate there is a straightforward lookup table, but in the West endcap (+η) the η value decreases as wire number increases from inner to outer radii. In the East endcap,
$\eta$ increases with increasing wire number, since it is a negative number. The lookup table is also somewhat non-linear.

In the $\phi$ position coordinate, one takes the 15° offset ($2\pi/24$) in any case. Then there are two cases, depending on whether the strips are in increasing or decreasing $\phi$ order within a chamber (as discussed above):

1. Increasing $\phi$ order: $\phi = 2\pi/24 + [k+(m/N\text{strip})]*d\phi$
2. Decreasing $\phi$ order: $\phi = 2\pi/24 + [k+1-(m/N\text{strip})]*d\phi$

**Summary**

Internal to a chamber, laying on a table with cathode electronics on top, narrow end towards viewer:
- Strip numbers increase from left to right
- Wire group numbers increase from small end to large end
- Layers run from top to bottom

This then has the following implications:
- For ME1 and ME2 in the positive $\eta$ endcap, the strip number increases with $\phi$
- For ME3 and ME4 in the positive $\eta$ endcap, the strip number decreases with $\phi$
- In the negative $\eta$ endcap, the opposite happens
- In all stations the wire group number increases with decreasing $|\eta|$ in both endcaps

Viewing the positive $\eta$ endcap from the interaction point,
- $\phi = 0^\circ$ at the positive $x$-axis, increasing clockwise
- 60° sectors begin at $\phi = 15^\circ$, increase clockwise, and are numbered from 1-6
- In the negative $\eta$ endcap, all numbering (and $\phi$) increase counterclockwise

Within a sector in the positive $\eta$ endcap
- For station ME1 the numbering runs from 1-12, where chambers 1-3 are ME1/A, chambers 4-6 are ME1/1, chambers 7-9 are ME1/2 and chambers 10-12 are ME1/3. Only chambers 4-12 are in the trigger baseline. The numbering increases clockwise
- For all other stations, 1-3 are the inner ring, 20° chambers and 4-9 are the outer ring, 10° chambers. All are in the trigger and the numbering increase clockwise.
- In the negative $\eta$ endcap all numbering increases counterclockwise.

*Document history:*
19 November 1999. Modified by Benn Tannenbaum for distribution as a CMS note and to include information about labeling within a sector.