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Muon Trigger Sectors and CSC Layout

D. Acosta, S.M. Wang

University of Florida, Gainesville, USA

G. Wrochna[1)]

Soltan Institute for Nuclear Studies, Warsaw, Poland

for The Muon Trigger Group

Abstract

The muon chamber layout on the endcap iron disks affects the trigger regions for the Level-1 muon trigger. The solution which aligns the trigger region boundaries at each iron disk breaks the symmetry of the two endcaps, requiring different drawings for each endcap on the placement of the muon chambers.

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1 Introduction

The twelve-fold symmetry of the CMS magnet yoke naturally leads to the partitioning of the muon trigger into 30° sectors. This solution was adopted in the design of the Barrel Track-Finder [1]. The situation in the endcaps is more complicated because of the angular coverage of specific Cathode Strip Chambers (CSCs). An angular extent of 20° in azimuth was found to be a reasonable compromise between the cost, the dead space and the resolution for chambers ME/2/1, ME/3/1 and ME/4/1. The 10° size was chosen for the remaining CSCs.

One cannot match directly the 30° segmentation of the barrel with 20° chambers in the endcap. However, the 30° sectors can be restored with a redistribution of the CSC signals. This solution was presented in the Muon TDR [2] submitted in November 1997.

Shortly atfer that, the American funding agencies imposed higher contingency for the U.S. part of the budget. As a result, it was necessary to reduce the cost of the endcap muon trigger. This was achieved by limiting the number of sectors. A sector size of 60° was chosen as the smallest multiple of 20° and 30° to avoid the redistribution of signals. The phase of the edge was chosen to be $15^\circ + n \times 60^\circ$. This new design was presented in March 1998 to the Collaboration [3], and in May 1998 to the DOE/NFS [4]. Since then, it has become the new official baseline.

It became evident by the summer of 1998 that a unified Track-Finder for the barrel and endcaps is not an optimal solution [5]. A formal decision was taken at the TriDAS review (November 1998) to proceed with two different Track-Finders optimised separately for the barrel and endcaps [6]. This solution allows more freedom in choosing the trigger segmentation, but it was decided to preserve the baseline layout of 30° sectors in the barrel and 60°sectors in the endcaps, with edges at $15^\circ + m \times 30^\circ$ and $15^\circ + n \times 60^\circ$ respectively [7].

The described baseline was used to determine the chamber positions on the iron disks. Engineering drawings were made and sent to the iron manufacturer by the end of 1998. In February 1999, a mistake in the drawings was discovered. The Muon Trigger Group has been requested to revisit the requirements on the trigger segmentation in order to check whether possible changes could facilitate correction of the mistake. The present document is an outcome of this work.

2 Definition of the CMS coordinate system

The absolute CMS coordinate system is defined with respect to the LHC ring. The X axis points towards the center of the ring, the Y axis points up and the Z axis is defined as per a right handed coordinate system. The absolute azimuth ϕ runs from the X axis (at 0°) towards the Y axis.

The boundaries of trigger sectors are to be specified in the absolute azimuth (ϕ). They are to be specified separately for the $+Z$ and $-Z$ endcaps.

3 Symmetries of the Barrel Muon System

What can be seen from Fig. 1 is that

- The barrel is symmetric with respect to $Z = 0$ plane.
- There is no symmetry with respect to $Y = 0$.
- MB4 is symmetric with respect to $X = 0$.
- There is no exact $X = 0$ symmetry for MB1,2,3.
- MB1,2,3 obey a rotational symmetry modulo 30°.

This geometry requires trigger sectors to have 30° pitch, but to be wider than 30° (with about $\pm 5^\circ$ overlap). It was assumed that the middle of each sector is at $\phi = n \times 30^\circ$.

4 Symmetries of the Endcap Muon System

Since each endcap is composed of 10° and 20° chambers, it cannot follow the rotational 30° symmetry. Instead it obeys rotational symmetries of 20° and of any multiple of 20°.

Other symmetries depend on the choice of the ϕ position of chambers. In particular, each endcap is **not** necessarily identical. A more natural choice is to have one endcap being the mirror image of the other. In such case the absolute ϕ positions of the chambers in each endcap are identical.

5 Alignment with other detectors

Recently it was suggested [8] that some RPC information be delivered to the CSC chambers to provide a possibility of matching muons seen by both systems at the chamber level. This can be done effectively only if RPC and CSC are properly aligned. The RPC design presented in the TDR does not provide this possibility. However the new design which is being worked out now assumes the same shape and positions of all RPC and CSC. In such case the RPC layout does not impose any additional constraints on the partitioning of the CSC trigger.

Muons found by the First Level Trigger will be associated with calorimeter regions in order to distinguish isolated muons from those accompanied by jets. A *quiet bit* is set for each calorimeter region of $\Delta\eta \times \Delta\phi = 0.35 \times 20°$ if the energy deposited in this region is below a threshold. The ϕ and η coordinates of the muon defined by the Track-Finder are used to find an area of 2×2 calorimeter regions (i.e. $\Delta\eta \times \Delta\phi = 0.7 \times 40°$) centered as much as possible on the muon. The muon is called *isolated* if the quiet bits in all 4 regions are set. This algorithm does not make use of the Muon Trigger sectors, therefore the choice of Calorimeter Trigger segmentation does not have any impact on the Muon Trigger.

6 Choosing the Muon Trigger Segmentation

The three independent Track-Finder regions (one barrel + two endcaps) do not need to have the same sector geometry, in principle. Communication between them is not absolutely necessary, and the Global Muon Trigger processes track parameters, not sectors. The only constraint comes from the sharing of information in the region of overlap between the two muon systems in order to improve the trigger efficiency: information from ME1/3 and ME2/2 is used by the barrel Track-Finder, and information from MB1 and MB2 is used by the endcap Track-Finder [9].

The barrel TF is an easy case, because ME1/3 and ME2/2 are 10° wide. Thus, the only requirement is to center the CSC chambers at $\phi = n \times 10°$ to align with the 30° barrel segmentation, which is already foreseen.

The endcap track finder case is more complicated. The overlap processors have to receive signals from MB1 and MB2. MB1 chambers are separated by I-beams located approximately at $20° + n \times 30°$, whereas MB2 - at roughly $15° + n \times 30°$. Hence it is not possible to contain fully 2 MB1 and 2 MB2 in a single 60° sector of any orientation.

From the barrel drawing (Fig. 2), one can draw the following conclusions:

- The gaps between the MB1 chambers are rotated $+5°$ with respect to the nominal 30° trigger boundaries at $\phi = 15° + n \times 30°$.
- The gaps between the MB2 chambers are rotated $-2°$ with respect to the nominal trigger boundaries.
- The gaps between the MB3 chambers are rotated $+1.5°$ with respect to the nominal trigger boundaries.

Those conditions are true for all azimuth. On the contrary, MB4 has several different sized chambers and is not symmetric in azimuth. Fortunately this does not cause any serious problem, because MB4 does not participate in the region of overlap between the two muon systems.

Choosing 60° sector boundaries at $15° + n \times 60°$ or $45° + n \times 60°$ matches closely ($< 0.5°$) to the average MB2 and MB3 boundaries. MB1 is rotated $+5°$. It seems it is not worthwhile to align the CSC system to MB1, though it is an important sagitta measurement station. The small increase in coverage does not justify the complication.

The gaps between MB1 chambers are about 4° in ϕ (13% dead area). Thus, if MB1 is rotated $+5°$ with respect to the 60° CSC sectors, one edge of the sector loses this 4° plus 5° of the chamber not included in the sector, or 9° total. This, together with the 4° of dead space in the middle of the sector gives $13/60 = 22\%$ dead area in ϕ. One can reduce it down to $5/60 = 8\%$ rotating the CSC sector 5° in ϕ, but then one loses more of MB2 coverage. In any case one cannot avoid the acceptance loss in MB1 or MB2 by simple redefinition of trigger sectors. If we consider it important the only way to improve it is by sharing the MB1 or MB2 signals between sectors.

The choice between sector boundaries at $15° + n \times 60°$ and $45° + n \times 60°$ is arbitrary from the trigger point of view. One can even think of one endcap being $15° + n \times 60°$, whereas the other one being $45 + n \times 60°$. However, for simplicity it was chosen to have the same definition in both endcaps. This implies that **each endcap is different**. As far as chamber boundaries are concerned, one endcap is the mirror image of the other.

Finally, the sector boundaries were chosen to be at $\phi = \mathbf{15° + n \times 60°}$ in each endcap.

7 Implications for the CSC layout

Since ME2 and ME3 chambers are mounted on the same iron disk, the definition of sectors described above implies that the mounting of one station is the mirror image of the other. Unfortunately, in the engineering drawings delivered to the producer the layout looks the same if one faces the front or the back of the disk, but not if one looks through the disk (which is what particles do). The $\phi = 15^\circ$ edge is at the boundary between chambers of ME3/1 and ME3/2, but not for ME2/1. In other words, a twenty-degree chamber in each sector is cut in half. Since the ϕ neighbors are not considered in the Track-Finder, there is a 10° hole in each sector.

This can be seen from the plots (Fig. 3). They are all drawn in an absolute coordinate system with $+X$ to the right and $+Y$ vertical (so ϕ starts from the right and goes counter-clockwise). Although it says "Geant" on the top of each figure, the endcap views were generated from a separate program taking the geometry from the recent engineering drawings (10-28-98). Looking at the plots one can conclude that the 60° endcap trigger sectors which start at $\phi = 15^\circ$ are not internally consistent within the endcap stations:

- ME1/1, ME1/2, ME1/3 are correct for both $+Z$ and $-Z$ endcaps. This is because $\phi = 0^\circ$ and $\phi = 90^\circ$ bisect 10° chambers, so everything is symmetric.
- ME2/1 and ME2/2 are correct for the $+Z$ endcap. The $\phi = 15^\circ$ edge (and all other edges which are separated by 60° multiples) lines up from ME2/1 (a 20° chamber) to ME2/2.
- ME3/1 is **not** correct (but ME3/2 is correct) for the $+Z$ endcap. The $\phi = 15^\circ$ boundary bisects a 20° chamber.
- ME2/1 is **not** correct (but ME2/2 is correct) for the $-Z$ endcap. The $\phi = 15^\circ$ boundary bisects a 20° chamber.
- ME3/1 and ME3/2 are correct for the $-Z$ endcap.

Thus, the problem switches from ME3/1 for the $+Z$ endcap to ME2/1 for the $-Z$ endcap, where a 10° rotation should be taken out.

8 Possible modifications of the trigger sectors

Is it possible to facilitate correction of the mistake by changing trigger partitioning? Discussion in Section 6 concluded with the statement that the optimal alignment with the barrel can be obtained for one of the following choices of the initial phase:

- $+Z$ endcap at 15°, $-Z$ endcap at 15° (current baseline)
- $+Z$ endcap at 45°, $-Z$ endcap at 45°
- $+Z$ endcap at 15°, $-Z$ endcap at 45°
- $+Z$ endcap at 45°, $-Z$ endcap at 15°

In any of these 4 cases one needs to move half of the 20° chambers in ME2 and ME3. The holes foreseen for the possible upgrade with ME4 are identical to those for ME3. Thus the last option ($+Z$ at 45°, $-Z$ at 15°) requires least changes, because one needs to move 20°chambers in +ME2 and –ME2, leaving untouched +ME3, –ME3, +ME4 and –ME4.

However, since the holes are not yet done and one has to change only the drawings we recommend to stay with the current baseline ($+Z$ at 15°, $-Z$ at 15°) and to move 20° chambers in –ME2, +ME3 and +ME4.

9 Conclusions

There is no way to correct the mistake in the CSC layout by changing the trigger partitioning. No compelling reason has been found to go away from a nominal definition of sectors starting at $\phi = 15^\circ + n \times 60^\circ$ (it is assumed that each sector edge goes through the middle of the overlap of two chambers). Engineering drawings should be corrected to conform to this definition.

References

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[9] *Issues Related to the Separation of the Barrel and Endcap Muon Trigger Track-Finder*, G.M. Dallavalle *et al.*, **CMS IN-1999/015**.

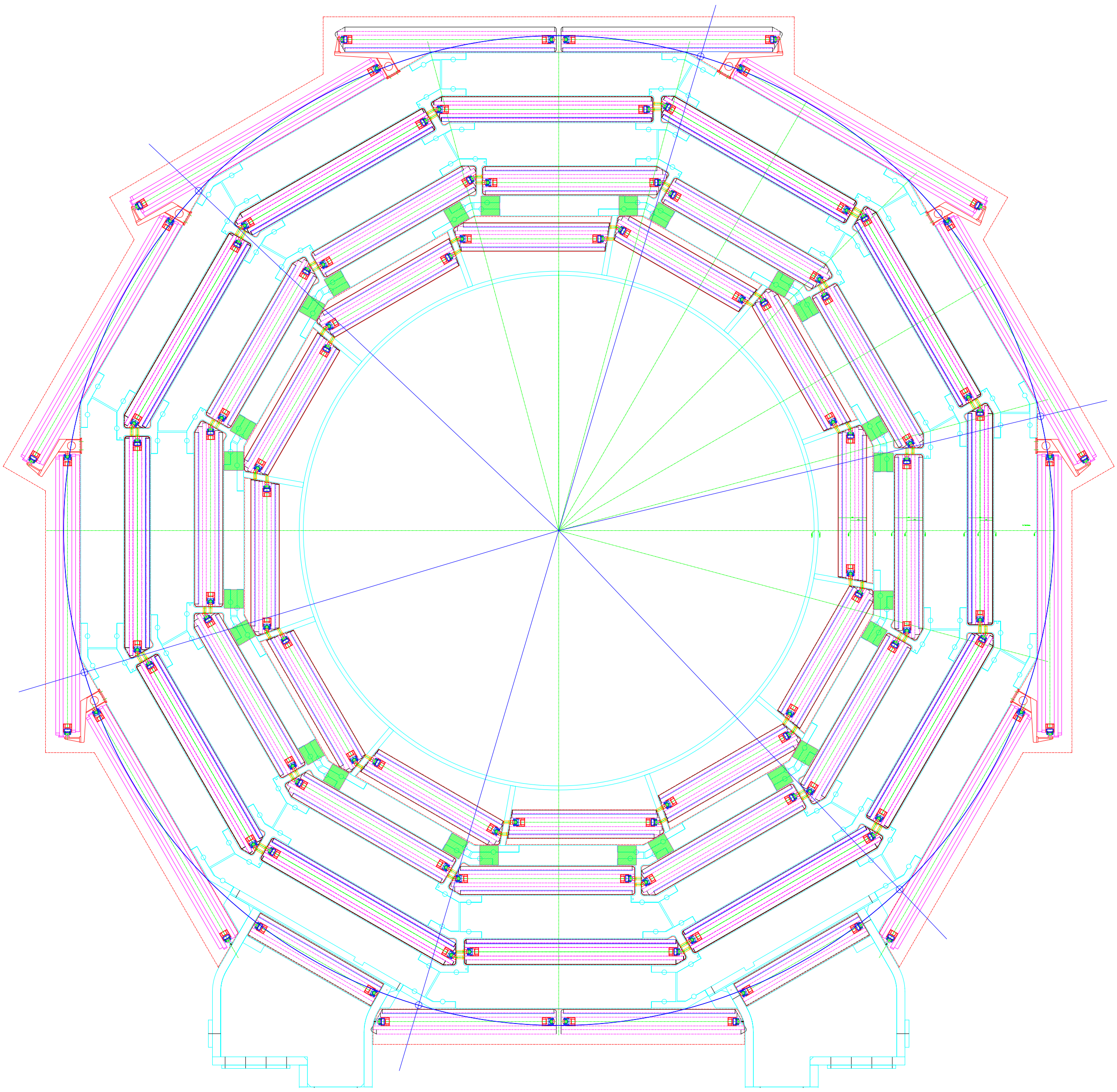

Figure 1: CMS Barrel cross section.

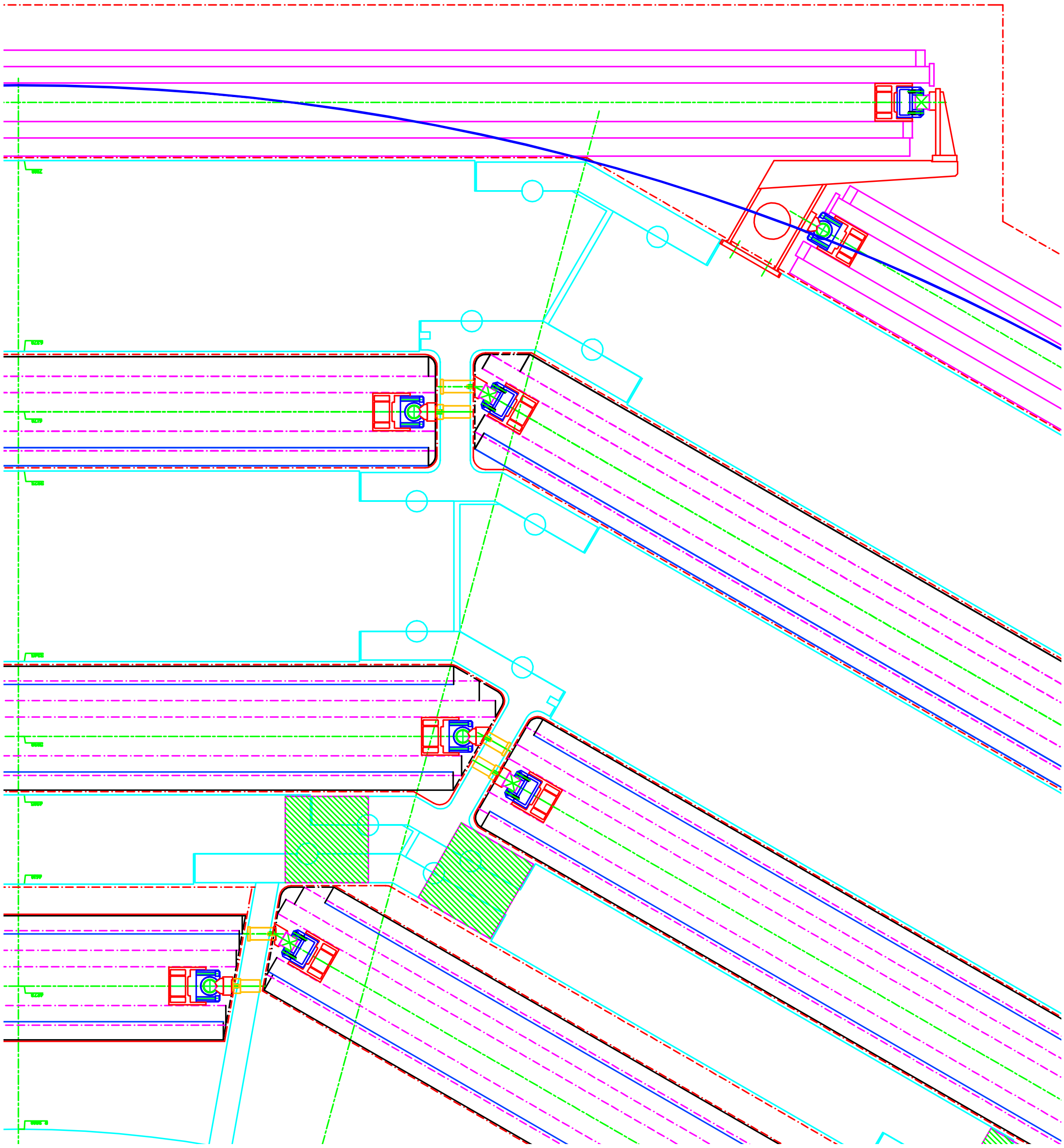

Figure 2: Zoom of the CMS Barrel cross section. The nominal sector boundary is drawn.

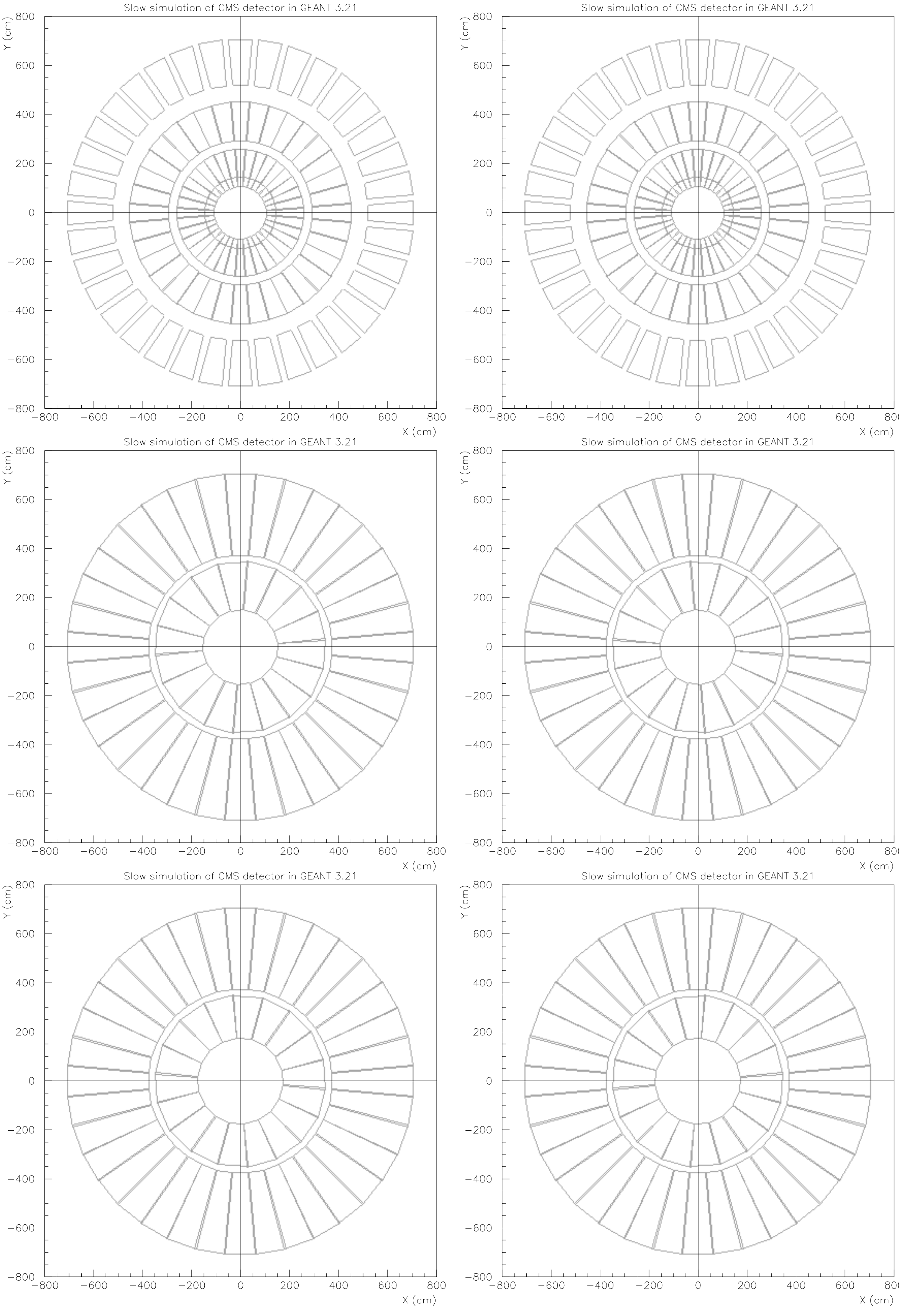

Figure 3: Original cross sectional layout of the CMS Endcap chambers before correction: –ME1, +ME1, –ME2, +ME2, –ME3, +ME3.