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SSC GEM Detector Muon Subsystem**

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December 15, 1993

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SSC GEM Detector Muon Subsystem**

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Abstract

The "48/48/48" ϕ -segmentation design for the Cathode Strip Chambers in the GEM Detector produces a number of coverage "gaps" in ϕ and θ . A revised "24/36/48" ϕ -segmentation layout provides increased geometric coverage and a significant reduction in the number of chambers in the detector. This will increase physics performance while reducing the labor costs associated with building and installing chambers in the GEM Detector. This paper documents the physical layout of the proposed change to the baseline chamber arrangement.

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Introduction

The "48/48/48" ϕ -segmentation for the Cathode Strip Chambers (CSC's), described in the GEM Technical Design Report¹ (TDR), produces a number of coverage "gaps" in ϕ and θ . The coverage gaps in the muon detector are caused mainly by physical separation between the ends of chambers (to accommodate cathode electronics and projective alignment) in the barrel assembly and between the barrel and endcap assemblies at the $\theta \approx 30^\circ$ interface.

TDR Baseline Chamber Arrangement

The so-called "48/48/48" chamber arrangement in the TDR Baseline Design has 48 CSC's in the ϕ -coordinate direction in each of the three superlayers for both the barrel and endcap assemblies. Also, the chambers are arranged in an "alternating-overlap" configuration in that direction.

In the barrel assembly Z-coordinate direction, there are two chambers positioned end-to-end in Superlayer #1 (inner), with four each in Superlayers #2 (middle) and #3 (outer). Cathode electronics mounted on the end of each chamber along with projective lines-of-site between chambers produce coverage gaps at these locations. Eight different size chamber designs are required for a barrel assembly.

Chambers in the endcap assembly superlayers are positioned with the long dimension aligned in the R-coordinate direction instead of the Z-coordinate direction as with the barrel chambers. Two chambers overlap radially in each of the three superlayers. Along with the alternating-overlap in the ϕ -coordinate direction, complete coverage is achieved except at the $\theta \approx 30^\circ$ interface with the barrel assembly. Six different size chamber designs are required for an endcap assembly.

Further details can be found in section 4 of Reference 1.

"24/36/48" Chamber Arrangement

The primary difference with the TDR Baseline Design is the number and arrangement of chambers in the ϕ - and θ -coordinate directions for the barrel assembly. In addition, a "tiled-overlap" configuration has been adopted which simplifies the chamber interface with the support structure. The number of chambers in the endcap assembly superlayers has also been changed to reflect the new arrangement in the barrel assembly. However, the alternating-overlap configuration has been maintained there.

Figure 1 depicts a cutaway view of a muon detector assembly using the proposed chamber arrangement. The CSC's for both the barrel and endcap regions are supported by a monolithic support structure instead of separate barrel and endcap structures as with the TDR Baseline Design. Alignment is to be implemented within a repeated 30° sector as shown in Figure 2. The overall chamber arrangement (without support structure) for one sector and the naming convention used for the endcap chambers is illustrated in Figure 3.

The support structure shown in Figure 4 is a modification of the MIC2 monolithic design proposed by Simpson Gumpertz and Heger² as a replacement for the TDR Baseline Design. A 4-point "partial" kinematic mounting design³ (not shown) will be used to

Figure 1: Cutaway View of Monolithic Barrel-Endcap Assembly

Figure 2: 30° Alignment Sector, Barrel and Endcap

Figure 3: Cathode Strip Chamber Layout (30° Alignment Sector)

Figure 4: Support Structure (30° Alignment Sector)

support each chamber in the support structure. The "tiled" chamber arrangement in the barrel region also simplifies the chamber supports by replacing two different geometric support designs (required for the alternating-overlap configuration in the TDR Baseline Design) with a single, repeated design for each superlayer.

The monolithic assembly concept produces a lighter structure, when truss element dimensions are optimized for the imposed loading, and improves access to the interior of the assembly. For the first iteration however, 4 inch diameter truss elements were used throughout. Larger members may prove necessary to meet other performance criteria and as future optimization of diameter and wall thickness of members are performed to reduce total mass.

The barrel region chamber parameters, sizes, and locations within a sector are listed in Tables 1, 2, and 3 respectively. Note that only three different size chamber designs are required.

Barrel Chamber Parameters - "24/36/48" Tiled Layout			
	SL1 (inner)	SL2 (middle)	SL3 (outer)
Chamber segmentation in ϕ	24	36	48
Chambers per alignment sector in ϕ	2	3	4
Chamber segmentation in z	2	3	4
Detection layers per chamber	6	6	6
Anode-cathode gap, m	0.00254	0.004	0.005
Lorentz angle, degrees	12.0	12.0	12.0
Inner radius: 3.9m (minimum limit)			
Outer radius: 8.9m (maximum limit)			
Lever Arm: 4.569m (center of SL1 to center of SL3)			
696 Total Barrel Chambers in 2 Monolithic Assemblies			

Table 1

Barrel Chamber Dimensions			
Superlayer	Length[a,b], m	Width[b], m	Thickness, m
SL1	2.950 (2.842)	1.275 (1.167)	0.17048
SL2	3.560 (3.452)	1.330 (1.222)	0.188
SL3	3.680 (3.572)	1.350 (1.242)	0.200

Notes: a) Gap between ends of chambers = 0.025 m

b) "Active" region in parentheses; 0.054 m inactive region around perimeter.

Table 2

Barrel Chamber Locations (Center of Chamber)			
Superlayer	R, m	ϕ [a], degrees	Z[b], m
SL1	4.069	+7.50 (-7.50)	#1 1.975
			#2 4.950
SL2	6.400	+10.00 (0.00) (-10.00)	#1 2.355
			#2 5.940
			#3 9.525
SL3	8.638	+11.25 (+3.75) (-3.75) (-11.25)	#1 2.590
			#2 6.295
			#3 10.000
			#4 13.705

Notes: a) Repeated chambers within a 30° alignment sector are listed in parentheses.
b) All chambers listed within a particular superlayer have the same R and ϕ .

Table 3

A side view (R-Z plane) detailing the barrel chambers in the monolithic assembly is shown in Figure 5. In order to increase detector coverage by reducing the gap between barrel chamber ends to 25 mm, the cathode electronics must be moved from the chamber ends to some other location, i.e. the chamber face. Coverage was further increased by reducing the “inactive” width around the perimeter of each barrel chamber⁴ to 54 mm, particularly important at the chamber ends. End views (R- ϕ plane) of the barrel chambers from vantage points in each of the three endcap superlayers are shown in Figures 6, 7, and 8.

The endcap region chamber parameters, sizes, and locations within a sector are listed in Tables 4, 5, and 6 respectively.

Endcap Chamber Parameters - “24/36/48” Alternating-Overlap Layout			
	SL1 (inner)	SL2 (middle)	SL3 (outer)
Chamber segmentation in ϕ	24	36	48
Chambers per alignment sector in ϕ	TBD	TBD	TBD
Chamber segmentation in R	2	2	2
Detection layers per chamber	8	6	6
Anode-cathode gap, m	0.00254	0.004	0.005
Chamber thickness, m	0.22064	0.188	0.200
Lorentz angle, degrees[a]	12.0	12.0	12.0
432 Total Endcap Chambers in 2 Monolithic Assemblies			

Note: Implemented within the chamber by rotating the anode wires in the R- ϕ plane.

Table 4

Endcap Chamber Dimensions					
Superlayer Location		Width at Top[a], m	Width at Bottom[a], m	Length[a], m	Thickness, m
SL1	Lower, Inner	0.7458 (0.6378)	0.4500 (0.3420)	1.0553 (0.9461)	0.22064
	Lower, Outer	0.7954 (0.6874)	0.4750 (0.3670)	1.1400 (1.0308)	0.22064
	Upper, Inner	1.2305 (1.1225)	0.7000 (0.5920)	1.7682 (1.6590)	0.22064
	Upper, Outer	1.1658 (1.0578)	0.7400 (0.6320)	1.9662 (1.8570)	0.22064
SL2	Lower, Inner	0.8765 (0.7685)	0.4750 (0.3670)	1.9570 (1.8478)	0.188
	Lower, Outer	0.9268 (0.8188)	0.5000 (0.3920)	2.1267 (2.0175)	0.188
	Upper, Inner	1.2055 (1.0975)	0.8000 (0.6920)	2.2725 (2.1633)	0.188
	Upper, Outer	1.3037 (1.1957)	0.8500 (0.7420)	2.3218 (2.2126)	0.188
SL3	Lower, Inner	0.9720 (0.8640)	0.5000 (0.3920)	3.1974 (3.0882)	0.200
	Lower, Outer	0.9358 (0.8278)	0.5800 (0.4720)	3.3767 (3.2675)	0.200
	Upper, Inner	1.4351 (1.3271)	0.9150 (0.8070)	3.4286 (3.3194)	0.200
	Upper, Outer	1.4107 (1.3027)	0.9000 (0.7920)	3.5012 (3.3920)	0.200

Note: "Active" region in parentheses; 0.054 m inactive region around perimeter.

Table 5

Endcap Chamber Locations (Center of Chamber)				
Superlayer		R, m	ϕ [a], degrees	Z, m
SL1	Lower, Inner	1.525	+11.00	6.11032
	Lower, Outer	1.676	-4.00	6.75032
	Upper, Inner	2.810	+11.00	6.38032
	Upper, Outer	3.100	-4.00	7.02032
SL2	Lower, Inner	2.772	+10.00 (-10.00)	10.850
	Lower, Outer	2.950	0.00	11.420
	Upper, Inner	4.725	+10.00 (-10.00)	11.080
	Upper, Outer	5.000	0.00	11.650
SL3	Lower, Inner	4.253	+8.50 (-6.50)	16.050
	Lower, Outer	4.440	+1.00 (-14.00)	16.650
	Upper, Inner	7.400	+8.50 (-6.50)	16.300
	Upper, Outer	7.715	+1.00 (-14.00)	16.900

Note: Repeated chambers within a 30° sector are listed in parentheses.

Table 6

Figure 5: Side View of Barrel-Endcap Assembly
(Barrel Chamber Locations & Lengths)

Figure 6: View from Endcap at SL1 (30° Alignment Sector)

Figure 7: View from Endcap at SL2 (30° Alignment Sector)

Figure 8: View from Endcap at SL3 (30° Alignment Sector)

Figure 9 shows a typical trapezoidal-shaped endcap chamber (refer to Table 5). Although twelve different endcap chamber sizes are required in this arrangement, it should be possible to reduce this to six. A single, optimized design should be developed to replace the lower inner and lower outer chambers and similarly another design to replace the upper inner and upper outer chambers in each superlayer.

Figure 9: Typical Endcap Chamber

The forward field shaper (FFS) interface with the endcap region is illustrated in Figure 10. Also shown is the "clear zone" at the barrel-endcap interface reserved for alignment lines-of-site. It is assumed that the inner and outer superlayer interfaces can accommodate an alignment system while preserving chamber overlap at the interface.

The minimum overlap of chamber "active" regions is listed in Table 7. This needs further optimization during the next iteration of chamber arrangement and sizes. Preferably, a single value should be selected.

Minimum Overlap of "Active" Chamber Regions		
Superlayer Location	Barrel, mm	Endcap, mm
SL1	34.8	69
SL2	36.6	67
SL3	41.0	72

Table 7

Figure 10: Location of Endcap Chambers and Forward Field Shaper (FFS)

Comparison with the TDR Baseline Design

Material costs and assembly labor (barrel chambers only) for various chamber arrangements is compiled in Table 8. The "24/36/48" proposal is highlighted and the "48/48/48" TDR Baseline design (last row) is also included for comparison.

Summary Cost Estimates^[a]: Barrel Chambers					
Chamber Arrangement		3.7 m Inner Radius		3.9 m Inner Radius	
SL1/SL2/SL3 (Superlayer Totals)	Total Chambers	Material k\$	Labor man-years	Material k\$	Labor man-years
32/32/32 ^[b] (128/192/256)	576	\$13,846	56.16	\$13,910	56.24
32/32/48 (128/192/384)	704	\$14,340	68.64	\$14,404	68.74
24/36/48 (96/216/384)	696	\$14,573	67.82	\$14,691	68.00
48/48/48 ^[c] (192/384/384)	960			\$14,994	148.09

Notes: a) Provided by F. Nimblett and P. Sebelius (Charles Stark Draper Laboratory), 21 September 1993.

b) Requires extra-wide chambers for SL3.

c) TDR Baseline Design.

Table 8

There is very little difference in material costs among the various alternatives because of the "fixed" detector area to be covered. However, significant savings may be realized in assembly labor by using fewer, larger chambers compared to the TDR Baseline Design. This should also hold true for the endcap chambers, although an estimate is needed.

Ultimately, all the "3.7 m Inner Radius" options were eliminated because a smaller radius would likely create a very tight dimensional interface problem with the existing calorimeter design. Of the "3.9 m Inner Radius" options, the "32/32/32" arrangement was eliminated because it required a SL3 chamber design that exceeds current manufacturing size capability. Of the remaining two options, the costs and labor differences were negligible.

The "24/36/48" arrangement was selected because it is probably more compatible with proposed (axial-projective hybrid) revisions to the baseline alignment system. This chamber arrangement is not compatible with the projective alignment system defined in the TDR Baseline Design; there is not enough room for the lines-of-site between the ends of the chambers.

Summary

The proposed "24/36/48" ϕ -segmentation layout opens the possibility for increased coverage. Monte Carlo analysis is required to verify an expected increase in physics performance. In addition, the proposed revision to the TDR Baseline Design requires significantly fewer chambers in the detector assembly. Estimates indicate a significant reduction in the labor costs associated with building and installing chambers in the GEM

Detector. However, interface issues with proposed revisions to the CSC alignment system must be resolved.

In fine-tuning the final chamber arrangement, the chamber alignment system must be an integral part of the chamber layout process. Furthermore, it may be possible to reduce chamber dimensions slightly by optimizing "active region" overlap from one chamber to the next. This may also lead to a reduction of 50% in the number of different endcap chamber designs.

References

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2. GEM TN-93-519, *Monolithic Integrated Concepts for Muon Subsystem Structures*, June 8, 1993
3. GEM TN-93-510, *Cathode Strip Chamber Interface with Support Structure for SSC GEM Detector Muon Subsystem*, December 8, 1993
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