GEM IN-92-7

Tile Hadron Calorimeter Design Cost Review

Oak Ridge National Laboratory

April 22, 1992

Abstract:

Presentations of the Tile Hadron Calorimeter Design Cost Review. Presented at the GEM Calorimeter Cost Review Meeting held at the SSC Laboratory on April 22, 1992.

GEM Calorimeter Cost Review

April 21, 1992

Action Items & Unresolved Issues

Barium Fluoride EM

1. BaF2 advocates should define what is included in $2.50/cc price and should write a model contract specifying Chinese deliverables. This will answer the following questions: Does $2.50/cc include dimensional QA? Rad-hardness QA? Other post-processing labor? What are the risks and who assumes them? Who wraps or coats the crystals?

2. Tracker support details are not worked out, nor tracker interface costs included.

3. Finite element analysis costs have been included in the estimate, but analysis has not been completed.

4. Titanium aluminide is a backup structural material which might reduce cost. Estimate is based on carbon composite.

5. Crystals are assumed to be shipped directly from China ready for assembly into structure. Onsite acceptance testing should be performed.

6. Crystal glueing and wrapping or coating costs should be included.

7. Schedule should be incorporated in near future.

Scintillating Fiber Hadronic

1. Simulate the effect of energy leaking out the back of the scintillating fiber hadron calorimeter with all of the scintillating fibers coming together at the light mixer. There can be rare events which have a small amount of energy deposited in the fibers but due to the ~100% sampling fraction plus proximity to the PMT appear as a very large energy. This can produce a small but significant systematic tail on the high side of the energy

distribution. Quantify this effect compared to the missing energy background. Prove whether or not the back longitudinal sample has any correlation with this effect and whether the copper shot improves the situation or makes it worse.

2. Stress analysis has not been performed on the structure.

3. Hourly craftsman costs should be verified.

4. Channel count should be corrected.

5. Describe the calibration scheme.

Scintillating Liquid Forward

1. Investigate muon chamber interface parameters.

Copper Tile Hadronic

1. Fiber-to-tile attachment method is a source of concern for some collaborators.

2. Tile manufacturing processes for uniformity, if required, may be very expensive.

GEM Detector

Tile Hadron Calorimeter Design/Costing Update

Oak Ridge National Laboratory

April 22, 1992

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1.0

Comment on Design/Costing Status

March 31, 1992

Plastic Tile Hadron Calorimeter
Signifcant Design and Costing Considerations

1. The plastic tile calorimeter has over 300,000 tiles. If the tiles need to be individually "tuned" the additional cost is approximately one million dollars for each 5 minutes of tile processing.

An understanding of the tile readout uniformity will be based on the test work underway at the University of Missippippi, Fermi Lab and CERN.

2. The costed design concept does not assume that the copper plates are solder or brazed together, consequently the structure is a conservative, exosketal design. If the bonding can be accomplished a significant cost reduction can be realized.

Vendors with experience in the processing of large copper components will be contacted to understand the design and manufacturing requirements for the tile calorimeter modules.

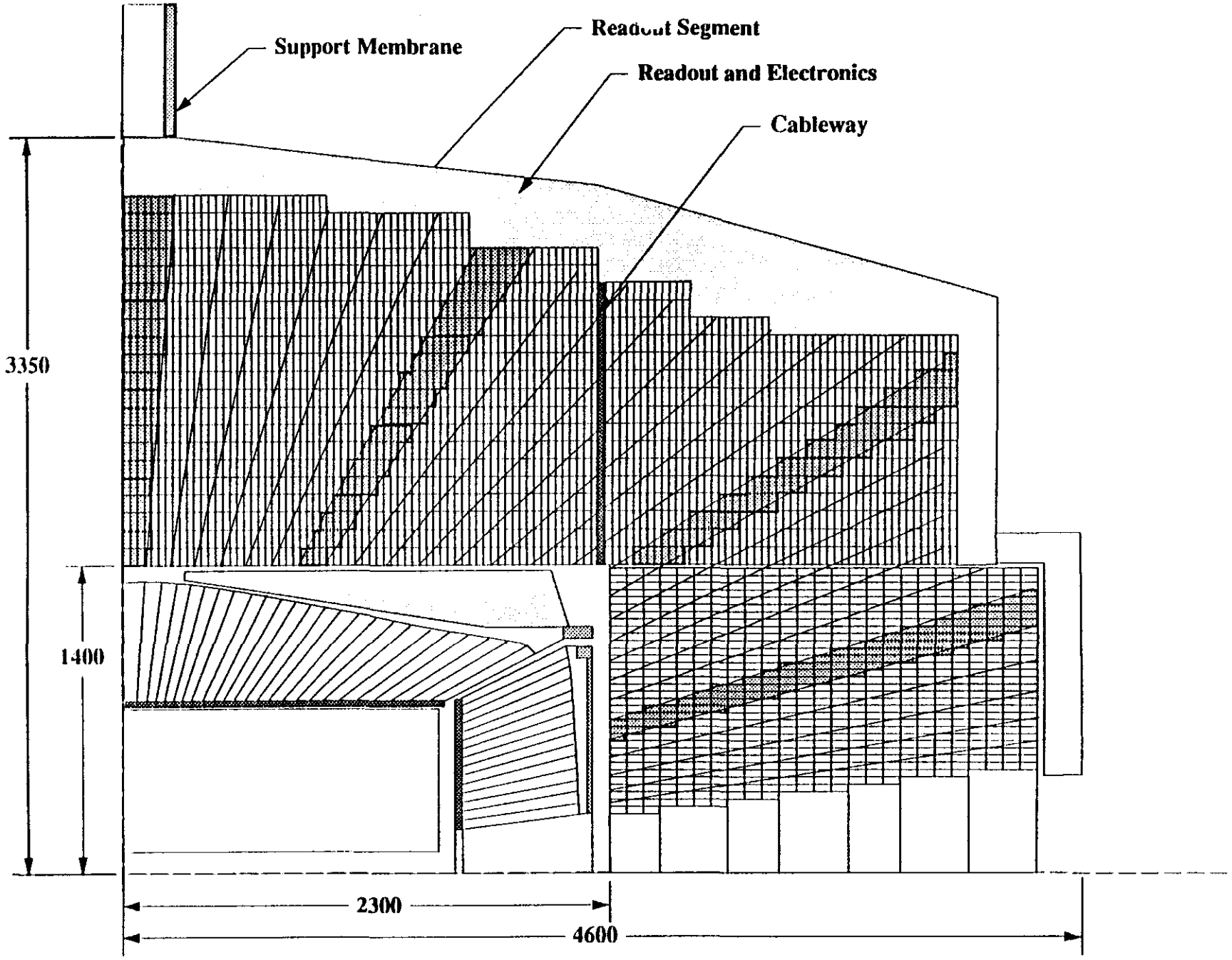
3. The overall tile calorimeter structure has not been fully analyzed. The analysis required can be accomplished when funding for engineering support is available.

4. A plastic tile calorimeter collaboration is currently being formed. Significant physics and engineering understanding of the concept is expected to the derived form this group in the next few months.

2.0

Technical Description

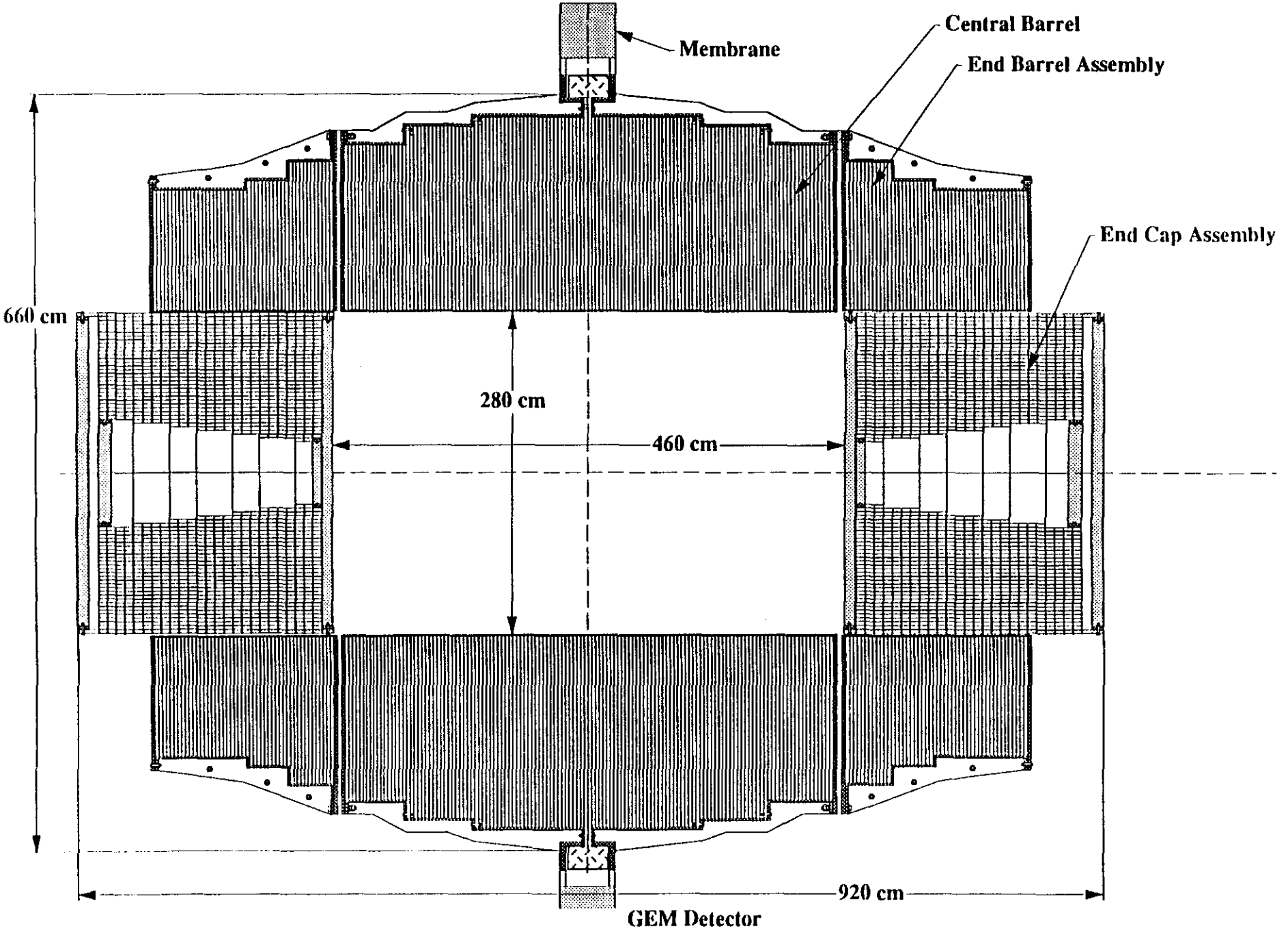
2.1. Parameters
2.2. Configuration Drawing



GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
(Theta Segmentation)

G.03.T.001

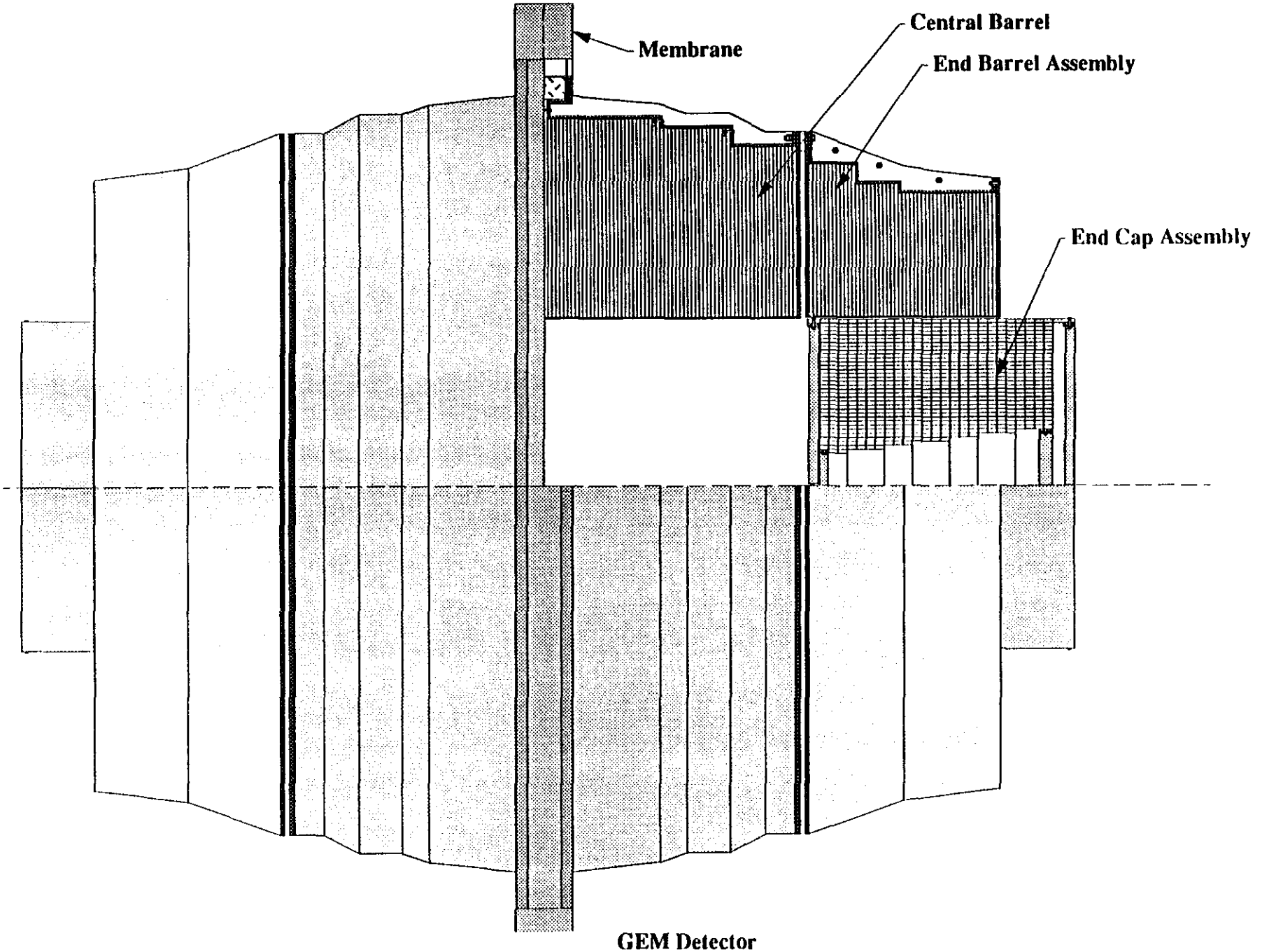
Rennich



GEM Detector
Plastic Tile Hadron Calorimeter

G.03.T.031

Rennich



GEM Detector
Plastic Tile Hadron Calorimeter
General Arrangement

G.03.T.032

Rennich

3.0

Design Calculations and Comments

Calculation of effective interaction length

Sense Material: Plastic Tile

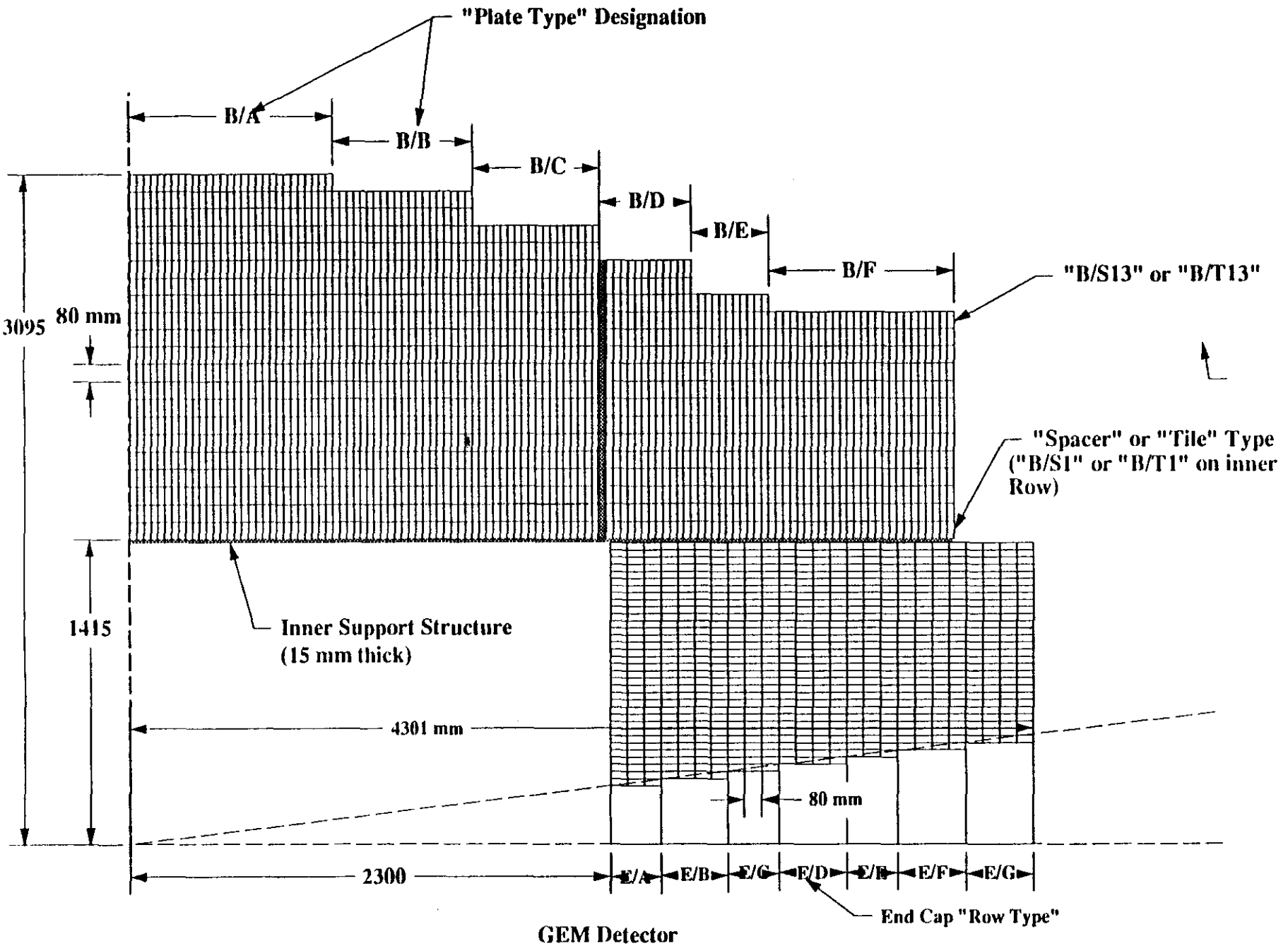
Absorber Material: Copper Plate

Material	Density	Int Lenght	Fraction	Inter. Lgh	Effect. IL
	g/cm^3	g/cm^2	% Vol	cm/L	cm/L
Absorber Composition					
Copper	8.96	134.9	88.24%	15.06	17.06
Sense Material Composition					
Plastic	1.03	83.7	8.82%	81.10	919.19
Gaps					
Air	0.00		2.94%		
Totals	8.00		100%		16.75

Hadron Make-up:

Material	Layers	Thickness	Total	Units	Total Perc
Copper	1	30.0	30.0	mm	88.24%
Air	1	1.0	1.0	mm	2.94%
Plastic	1	3.0	3.0	mm	8.82%
			34.0	mm	100%

Note: Air gap includes tile and fiber clearances



GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
Component Designations for Parameters Worksheet

G.03.T.004

Rennich

Plastic Tile Calorimeter Parameters

Calculation of the size and number of all the principle components in the GEM plastic tile calorimter
See Drawing number G.03.CU.024 for component designations

Calculated Numbers		
Number of SubAss	5	ea
Absorb. Thickness	3	cm
Wgh of Absorber	1,344	Mt
Wgh of Plastic	15	Mt
Wgh of Fib Shields	27	Mt
Wgh of Structure	35	Mt
Total Weight	1,421	Mt
Area of Plastic	4758	M^2
Number of Tiles	322,048	ea
Length of Fiber	120,392	M
Number of Fibers	110,720	ea
Number of Channels	11541	ea

Determined by Separate Structural Analysis

	Average Fiber Length	1.087	M
	Average Tile Area	147.76	cm^2
	Largest Tile	220.31	cm^2

Density of Copper	0.00896	Kg/cm^3
Density of Plastic	0.00103	Kg/cm^3

Input Central Barrel Parameters			
Number of Phi Modules	64	(0.1 Segmentation)	
Gap Between Modules	0.25	cm	
Fiber Guard Thickness	0.1	cm	
Absorber Plate Thickness	1.325	cm	
Spacer PLate thickness	0.35	cm	
Tile Thickness	0.3	cm	
Stack Thickness	3.35	cm	
Top/Bottom Plate Clearance	0.1	cm	
Tile Height	7.7	cm	
Fiber Channel Width	0.35	cm	

Output Cent. Barrel Parameters		
Wgh of Copper	775	Mt
Wgh of Plastic	8,145	Kg
Area of Plastic	2636	M^2
Number of Tiles	168,192	ea
Length of Fiber	41,226	M
No. of Fibers	33,792	ea
Number of Channels	2816	ea

Calculation of Central Barrel Module Absorber Plates

Plate Type	Number	Long Seg	Seg	Thickness	Bottom	Top	Plt Area	Plt Vol	Plt Wgh	Total Wgh
			cm	cm	cm	cm	cm^2	cm^3	Kg	Kg
A	120	21	8	1.325	141.5	309.50	3,688	4,887	43.79	5,254
B	72	20	8	1.325	141.5	301.50	3,450	4,571	40.95	2,949
C	72	18	8	1.325	141.5	285.50	2,991	3,964	35.51	2,557
Totals	264						10,129	13,421	120.25	10,760

Calculation of Central Barrel Module Copper Spacer Plates

Calculations are for one barrel module only

Spacer Type	Number Spacers	Thickness cm	Bottom cm	Top cm	Plt Area cm^2	Plt Vol cm^3	Plt Wgh Kg	Total Wgh Kg
S1	132	0.35	141.5	149.50	103	36	0.324	42.71
S2	132	0.35	149.5	157.50	109	38	0.343	45.31
S3	132	0.35	157.5	165.50	116	41	0.363	47.91
S4	132	0.35	165.5	173.50	122	43	0.383	50.52
S5	132	0.35	173.5	181.50	128	45	0.402	53.12
S6	132	0.35	181.5	189.50	135	47	0.422	55.72
S7	132	0.35	189.5	197.50	141	49	0.442	58.32
S8	132	0.35	197.5	205.50	147	52	0.462	60.93
S9	132	0.35	205.5	213.50	153	54	0.481	63.53
S10	132	0.35	213.5	221.50	160	56	0.501	66.13
S11	132	0.35	221.5	229.50	166	58	0.521	68.74
S12	132	0.35	229.5	237.50	172	60	0.540	71.34
S13	132	0.35	237.5	245.50	179	63	0.560	73.94
S14	132	0.35	245.5	253.50	185	65	0.580	76.55
S15	132	0.35	253.5	261.50	191	67	0.600	79.15
S16	132	0.35	261.5	269.50	197	69	0.619	81.75
S17	132	0.35	269.5	277.50	204	71	0.639	84.35
S18	132	0.35	277.5	285.50	210	74	0.659	86.96
S19	96	0.35	285.5	293.50	216	76	0.678	65.14
S20	96	0.35	293.5	301.50	223	78	0.698	67.03
S21	132	0.35	301.5	309.50	229	80	0.718	94.77
Totals	2700							1393.91

Calculation of Central Barrel Module Plastic Tile Plates
Calculations are for one barrel module only

								Module Totals	
Tile Type	Number	Thickness	Bottom	Top	Tile Area	Tile Vol	Tile Wgh	Weight	Tiles
		cm	cm	cm	cm^2	cm^3	Kg	Kg	cm^2
T1	132	0.3	141.6	149.30	99	30	0.031	4.05	13,102
T2	132	0.3	149.6	157.30	105	32	0.033	4.30	13,901
T3	132	0.3	157.6	165.30	111	33	0.034	4.54	14,700
T4	132	0.3	165.6	173.30	117	35	0.036	4.79	15,499
T5	132	0.3	173.6	181.30	123	37	0.038	5.04	16,298
T6	132	0.3	181.6	189.30	130	39	0.040	5.28	17,097
T7	132	0.3	189.6	197.30	136	41	0.042	5.53	17,896
T8	132	0.3	197.6	205.30	142	42	0.044	5.78	18,695
T9	132	0.3	205.6	213.30	148	44	0.046	6.02	19,494
T10	132	0.3	213.6	221.30	154	46	0.048	6.27	20,293
T11	132	0.3	221.6	229.30	160	48	0.049	6.52	21,092
T12	132	0.3	229.6	237.30	166	50	0.051	6.76	21,891
T13	132	0.3	237.6	245.30	172	52	0.053	7.01	22,689
T14	132	0.3	245.6	253.30	178	53	0.055	7.26	23,488
T15	132	0.3	253.6	261.30	184	55	0.057	7.50	24,287
T16	132	0.3	261.6	269.30	190	57	0.059	7.75	25,086
T17	132	0.3	269.6	277.30	196	59	0.061	8.00	25,885
T18	132	0.3	277.6	285.30	202	61	0.062	8.25	26,684
T19	96	0.3	285.6	293.30	208	62	0.064	6.18	19,988
T20	96	0.3	293.6	301.30	214	64	0.066	6.36	20,569
T21	60	0.3	301.6	309.30	220	66	0.068	4.08	13,219
Totals	2628							127.26	411,853

Central Barrel Module Descriptions-continued

Calculation of Approximate Fiber count and lenghts

Readout Tower	No. of Type	Segment	Layers Longitud.	Layers Axial	Plates	Fibers	Fiber Length	Fiber Lgh/Seg	Tot Fib Lenght	No of Tiles	No. of Channe	No. of Fibers
			each	each	each	each	cm	M	m	ea	ea	ea
A	5	1	5	6	30	12	188	22.56	307	630	20	240
		2	5	6	30	12	148	17.76				
		3	5	6	30	12	108	12.96				
		4	6	6	36	12	68	8.16				
B	3	1	5	6	30	12	180	21.60	173	360	12	144
		2	5	6	30	12	140	16.80				
		3	5	6	30	12	100	12.00				
		4	5	6	30	12	60	7.20				
C	3	1	4	6	24	12	164	19.68	164	324	12	144
		2	4	6	24	12	132	15.84				
		3	5	6	30	12	100	12.00				
		4	5	6	30	12	60	7.20				
Totals for One Central Barrel Module									644.16	1314	44	528

Input End Barrel Parameters			
Number of Phi Modules	64	(0.1 Segmentation)	
Gap Between Modules	0.25	cm	
Fiber Guard Thickness	0.1	cm	
Absorber Plate Thickness	1.325	cm	
Spacer PLate thickness	0.35	cm	
Tile Thickness	0.3	cm	
Stack Thickness	3.35	cm	
Top/Bottom Plate Clearance	0.1	cm	
Tile Height	7.7	cm	
Fiber Channel Width	0.35	cm	

Output End Barrel Parameters		
One Side Only		
Wgh of Copper	199	Mt
Wgh of Plastic	2,296	Kg
Area of Plastic	743	M^2
Number of Tiles	52,224	ea
Length of Fiber	22,733	M
No. of Fibers	24,576	ea
Number of Channels	2048	ea

Output End Barrel Parameters		
Two Sides		
Wgh of Copper	398	Mt
Wgh of Plastic	4,591	Kg
Area of Plastic	1,486	M^2
Number of Tiles	104,448	ea
Length of Fiber	45,466	M
No. of Fibers	49,152	ea
Number of Channels	4,096	ea

Calculation of End Barrel Module Absorber Plates

Plate Type	Number	Long Seg	Seg	Thickness	Bottom	Top	Plt Area	Plt Vol	Plt Wgh	Total Wgh
			cm	cm	cm	cm	cm^2	cm^3	Kg	Kg
D	24	16	8	1.325	141.5	269.50	2,558	3,390	30.37	729
E	24	14	8	1.325	141.5	253.50	2,150	2,849	25.53	613
F	60	13	8	1.325	141.5	245.50	1,956	2,592	23.22	1,393
Totals	108						6,665	8,831	79.12	2,735

Calculation of End Barrel Module Copper Spacer Plates

Calculations are for one barrel module only

Spacer Type	Number Spacers	Thickness cm	Bottom cm	Top cm	Plt Area cm^2	Plt Vol cm^3	Plt Wgh Kg	Total Wgh Kg
S1	54	0.35	141.5	149.50	103	36	0.324	17.47
S2	54	0.35	149.5	157.50	109	38	0.343	18.54
S3	54	0.35	157.5	165.50	116	41	0.363	19.60
S4	54	0.35	165.5	173.50	122	43	0.383	20.67
S5	54	0.35	173.5	181.50	128	45	0.402	21.73
S6	54	0.35	181.5	189.50	135	47	0.422	22.80
S7	54	0.35	189.5	197.50	141	49	0.442	23.86
S8	54	0.35	197.5	205.50	147	52	0.462	24.92
S9	54	0.35	205.5	213.50	153	54	0.481	25.99
S10	54	0.35	213.5	221.50	160	56	0.501	27.05
S11	54	0.35	221.5	229.50	166	58	0.521	28.12
S12	54	0.35	229.5	237.50	172	60	0.540	29.18
S13	54	0.35	237.5	245.50	179	63	0.560	30.25
S14	42	0.35	245.5	253.50	185	65	0.580	24.36
S15	42	0.35	253.5	261.50	191	67	0.600	25.18
S16	30	0.35	261.5	269.50	197	69	0.619	18.58
Totals	816							378.30

Calculation of End Barrel Module Plastic Tile Plates
Calculations are for one barrel module only

								Module Totals	
Tile Type	Number	Thickness	Bottom	Top	Tile Area	Tile Vol	Tile Wgh	Weight	Tiles
		cm	cm	cm	cm^2	cm^3	Kg	Kg	cm^2
T1	54	0.3	141.6	149.30	99	30	0.031	1.66	5,360
T2	54	0.3	149.6	157.30	105	32	0.033	1.76	5,687
T3	54	0.3	157.6	165.30	111	33	0.034	1.86	6,014
T4	54	0.3	165.6	173.30	117	35	0.036	1.96	6,341
T5	54	0.3	173.6	181.30	123	37	0.038	2.06	6,667
T6	54	0.3	181.6	189.30	130	39	0.040	2.16	6,994
T7	54	0.3	189.6	197.30	136	41	0.042	2.26	7,321
T8	54	0.3	197.6	205.30	142	42	0.044	2.36	7,648
T9	54	0.3	205.6	213.30	148	44	0.046	2.46	7,975
T10	54	0.3	213.6	221.30	154	46	0.048	2.57	8,302
T11	54	0.3	221.6	229.30	160	48	0.049	2.67	8,628
T12	54	0.3	229.6	237.30	166	50	0.051	2.77	8,955
T13	54	0.3	237.6	245.30	172	52	0.053	2.87	9,282
T14	42	0.3	245.6	253.30	178	53	0.055	2.31	7,474
T15	42	0.3	253.6	261.30	184	55	0.057	2.39	7,728
T16	30	0.3	261.6	269.30	190	57	0.059	1.76	5,701
Totals	816							35.87	116,077

End Barrel Module Descriptions-continued

Calculation of Approximate Fiber count and lenghts

Readout Tower	No. of Type	Segment	Layers Longitud. each	Layers Axial each	Plates each	Fibers each	Fiber Length cm	Fiber Lgh/Seg M	Tot Fib Lenght m	No of Tiles ea	No. of Channe ea	No. of Fibers ea
D	2	1	4	6	24	12	148	17.76	96	192	8	96
		2	4	6	24	12	116	13.92				
		3	4	6	24	12	84	10.08				
		4	4	6	24	12	52	6.24				
E	2	1	3	6	18	12	132	15.84	90	168	8	96
		2	3	6	18	12	108	12.96				
		3	4	6	24	12	84	10.08				
		4	4	6	24	12	52	6.24				
F	4	1	3	6	18	12	124	14.88	169	312	16	192
		2	3	6	18	12	100	12.00				
		3	3	6	18	12	76	9.12				
		4	4	6	24	12	52	6.24				
Totals for One End Barrel Module									355.2	672	32	384

Parameters for End Caps

Input Parameters		
Number of Modules	32	ea
Gaps Between Modu	0.025	cm
Fiber Guard Thick	0.1	cm
Absorb. Plt Thick	1.325	cm
Spacer Thickness	0.35	cm
Tile Thickness	0.3	cm
Tile Lenght	8	cm
Dist. to Layer One	230	cm
Inner Radius	3	eta
Stack Thickness	3.35	cm

Output Parameters, One End Cap		
Wgh of Copper	86	MT
Wgh of Plastic	984	KG
Area of Plastic	318.40	M^2
Number of Tiles	24,704	ea
Length of Fiber	16,850	M
Number of Fibers	13,888	ea
Number of Channels	2315	ea

Output Parameters Two End Caps		
Wgh of Copper	171	MT
Wgh of Plastic	1968	Kg
Area of Plastic	637	M^2
Number of Tiles	49408	ea
Length of Fiber	33,700	M
Number of Fibers	27,776	ea
Number of Channels	4629	ea

Calculation of End Cap Module Component Dimensions
Calculations are for one Module only

Parameters for Layer E/A

Number Rows	Inner Radius	Outer Radius	Number Layers	Inner Width	Outer Width
each	cm	cm	each	cm	cm
3	21.10	135	34	3.91	26.34

	Absorber Plates	Spacer Plates	Tile Plates	
Average Area	121.00	121.00	121.00	cm^2
Total Area	24,683	12,342	12,342	cm^2
Total Volume	32,705	4,320	3,702	cm^3
Total Weight	293.04	38.70	3.81	Kg
Total Number			102	Each

Parameters for Layer E/B

Number Rows	Inner Radius	Outer Radius	Number Layers	Inner Width	Outer Width
each	cm	cm	each	cm	cm
4	24.45	135	33	4.57	26.34

	Absorber Plates	Spacer Plates	Tile Plates	
Average Area	123.64	123.64	123.64	cm^2
Total Area	32,640	16,320	16,320	cm^2
Total Volume	43,248	5,712	4,896	cm^3
Total Weight	387.50	51.18	5.04	Kg
Total Number			132	Each

Parameters for Layer E/C						
	Number Rows each	Inner Radius cm	Outer Radius cm	Number Layers each	Inner Width cm	Outer Width cm
	3	27.80	135	32	5.23	26.34

	Absorber Plates	Spacer Plates	Tile Plates	
Average Area	126.28	126.28	126.28	cm^2
Total Area	24,245	12,122	12,122	cm^2
Total Volume	32,124	4,243	3,637	cm^3
Total Weight	287.83	38.02	3.75	Kg
Total Number			96	Each

Parameters for Layer E/D						
	Number Rows each	Inner Radius cm	Outer Radius cm	Number Layers each	Inner Width cm	Outer Width cm
	4	31.15	135	31	5.89	26.34

	Absorber Plates	Spacer Plates	Tile Plates	
Average Area	128.91	128.91	128.91	cm^2
Total Area	31,971	15,985	15,985	cm^2
Total Volume	42,361	5,595	4,796	cm^3
Total Weight	379.56	50.13	4.94	Kg
Total Number			124	Each

Parameters for Layer E/E						
	Number Rows each	Inner Radius cm	Outer Radius cm	Number Layers each	Inner Width cm	Outer Width cm
	3	34.50	135	30	6.55	26.34

	Absorber Plates	Spacer Plates	Tile Plates	
Average Area	131.55	131.55	131.55	cm^2
Total Area	23,680	11,840	11,840	cm^2
Total Volume	31,376	4,144	3,552	cm^3
Total Weight	281.13	37.13	3.66	Kg
Total Number			90	Each

Parameters for Layer E/F						
	Number Rows each	Inner Radius cm	Outer Radius cm	Number Layers each	Inner Width cm	Outer Width cm
	4	37.85	135	29	7.21	26.34

	Absorber Plates	Spacer Plates	Tile Plates	
Average Area	134.19	134.19	134.19	cm^2
Total Area	31,133	15,566	15,566	cm^2
Total Volume	41,251	5,448	4,670	cm^3
Total Weight	369.61	48.82	4.81	Kg
Total Number			116	Each

Parameters for Layer E/G

Number Rows	Inner Radius	Outer Radius	Number Layers	Inner Width	Outer Width
each	cm	cm	each	cm	cm
4	41.20	135	28	7.87	26.34

	Absorber Plates	Spacer Plates	Tile Plates	
Average Area	136.83	136.83	136.83	cm^2
Total Area	30,651	15,325	15,325	cm^2
Total Volume	40,612	5,364	4,598	cm^3
Total Weight	363.89	48.06	4.74	Kg
Total Number			112	Each

End Cap Module Descriptions-continued
Calculation of Approximate Fiber count and lenghts

Calculated Total Fiber Lenght for one end cap= 16,850 Meters
Calculated total number of fiber for one end cap= 13,888 Each
Calculated total number of channels for one end cap= 2,315 Each

Layer Type	No. of Layers	Segments Per Layer each	Fiber Lenght cm	Fibers/ Layer each	Total Fiber Length Meters	Channels
E/A	3	34	200	68	136	11
E/B	4	33	176	66	116	11
E/C	3	32	144	64	92	11
E/D	4	31	120	62	74	10
E/E	3	30	88	60	53	10
E/F	4	29	64	58	37	10
E/G	4	28	32	56	18	9
				434	527	72
Totals for One End Cap Module						

Calculation of Barrel Module Fiber Guard Plates

Input Parameters

Guard Plate Thickness	0.1	cm
Number of Plates	128	each

Calculated Parameters

Total Area	283	M^2
Total Weight	25.38	Mt

Area	Height	Length	Pt Area	Plt Wgh
	cm	cm	cm^2	Kg
A	168	402	6,754	60.51
B	160	241.2	3,859	34.58
C	144	241.2	3,473	31.12
D	128	160.8	2,058	18.44
E	112	160.8	1,801	16.14
F	104	402	4,181	37.46
Totals	816		22,126	198.25

Calculation of End Cap Module Fiber Guard Plates

Input Parameters

Guard Plate Thickness	0.1	cm
Number of Plates	64	each

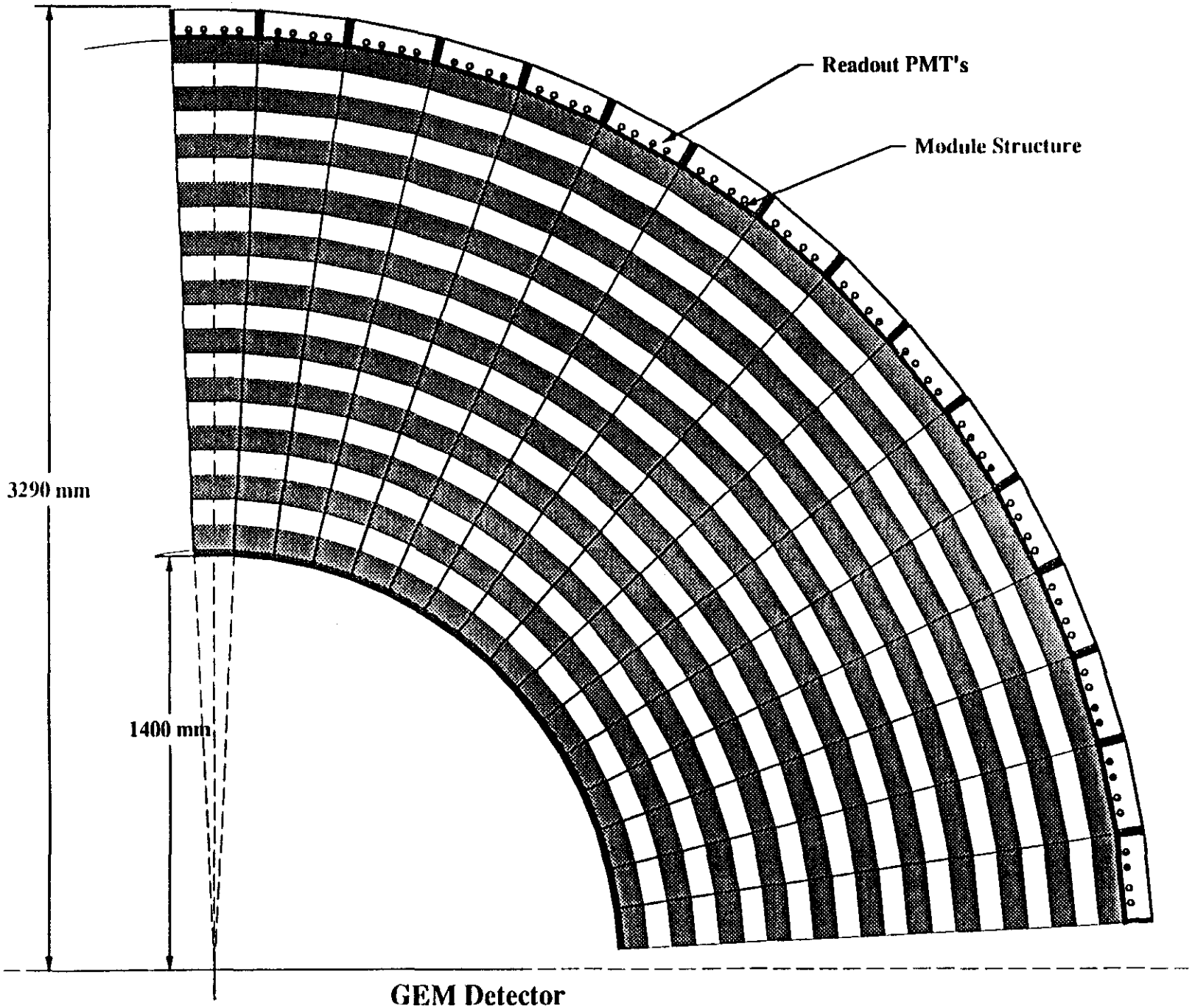
Calculated Parameters

Total Area	11	M^2
Total Weight	1.01	Mt

Area	Height	Length	Pt Area	Plt Wgh
	cm	cm	cm^2	Kg
E/A	113.9	24	273	2.45
E/B	110.55	32	354	3.17
E/C	107.2	24	257	2.31
E/D	103.85	32	332	2.98
E/E	100.5	24	241	2.16
E/F	97.15	32	311	2.79
E/G	93.8	32	300	2.69
Totals	633.15		1,769	15.85

4.0

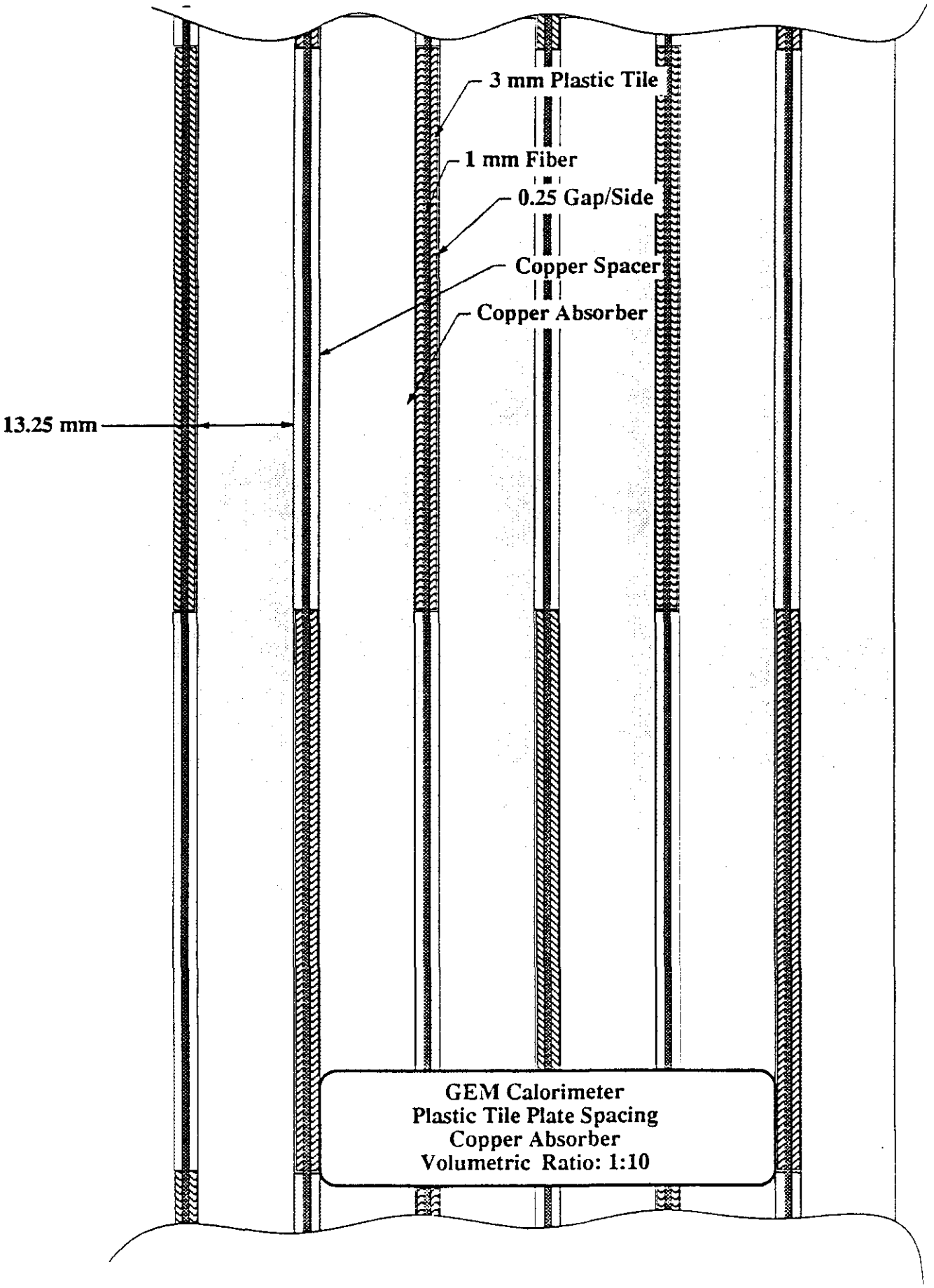
Design Sketches

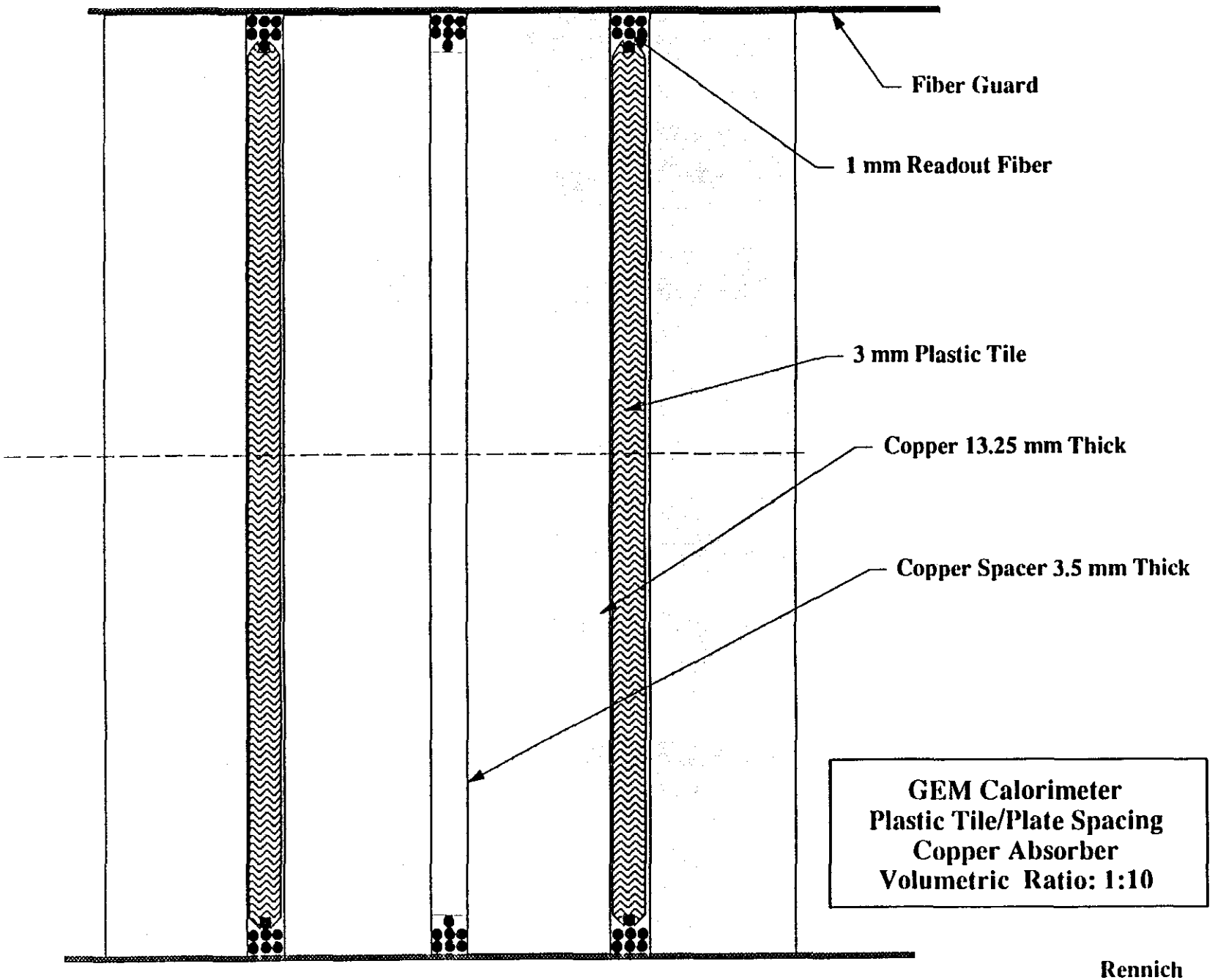


GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
Quarter Section View

G.03.T.003

Rennich

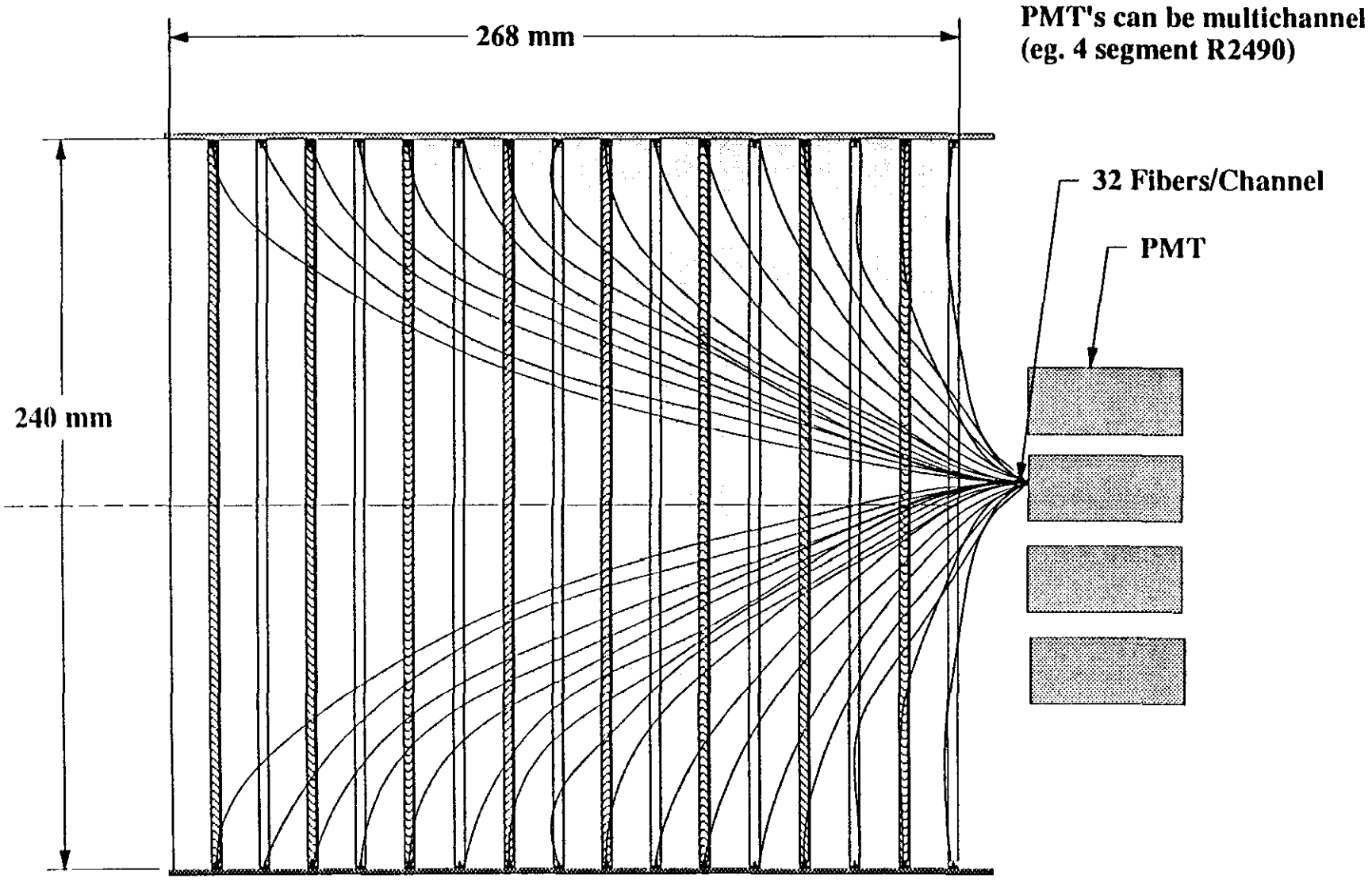

3 mm Plastic Tile
1 mm Fiber
0.25 Gap/Side
Copper Spacer
Copper Absorber
13.25 mm
GEM Calorimeter
Plastic Tile Plate Spacing
Copper Absorber
Volumetric Ratio: 1:10



Rennich

G.03.T.005

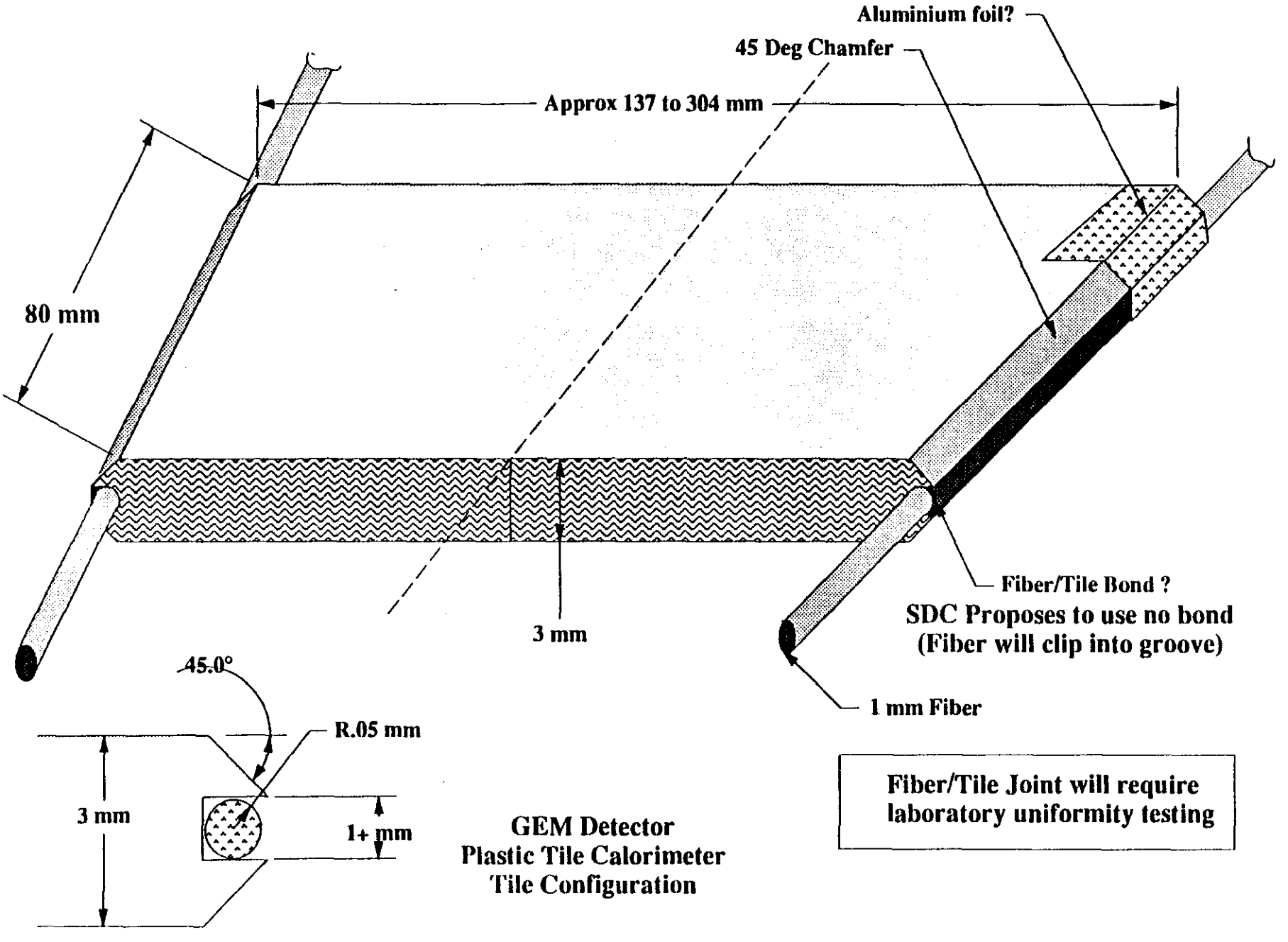
Top View of One Phi Segment



GEM Calorimeter
Plastic Tile Readout Configuration
Copper Absorber
View of Top of Tower Segment

Rennich

G.03.T.006

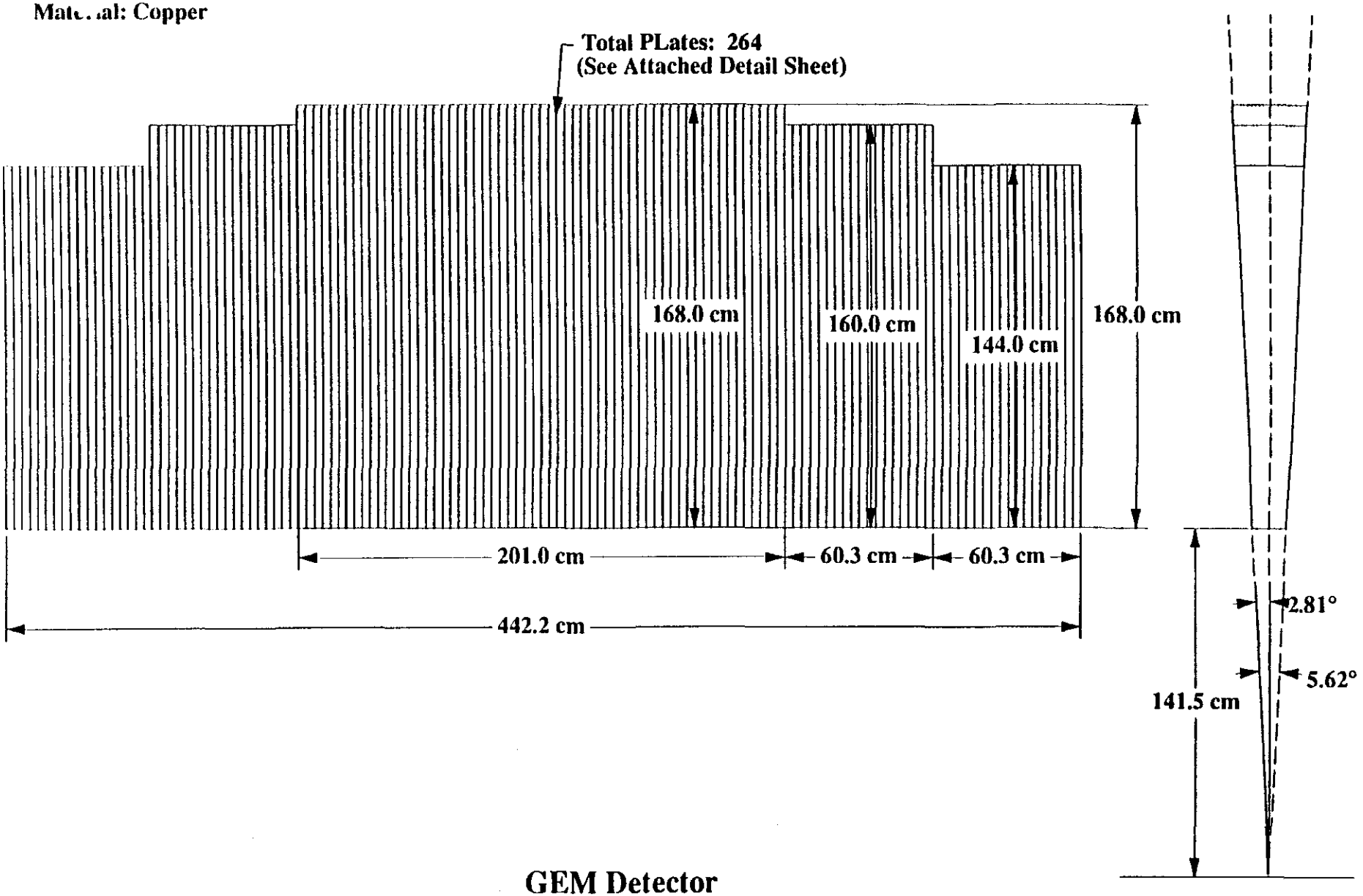


Fiber/Tile Joint will require laboratory uniformity testing

GEM Detector
Plastic Tile Calorimeter
Tile Configuration

Rennich

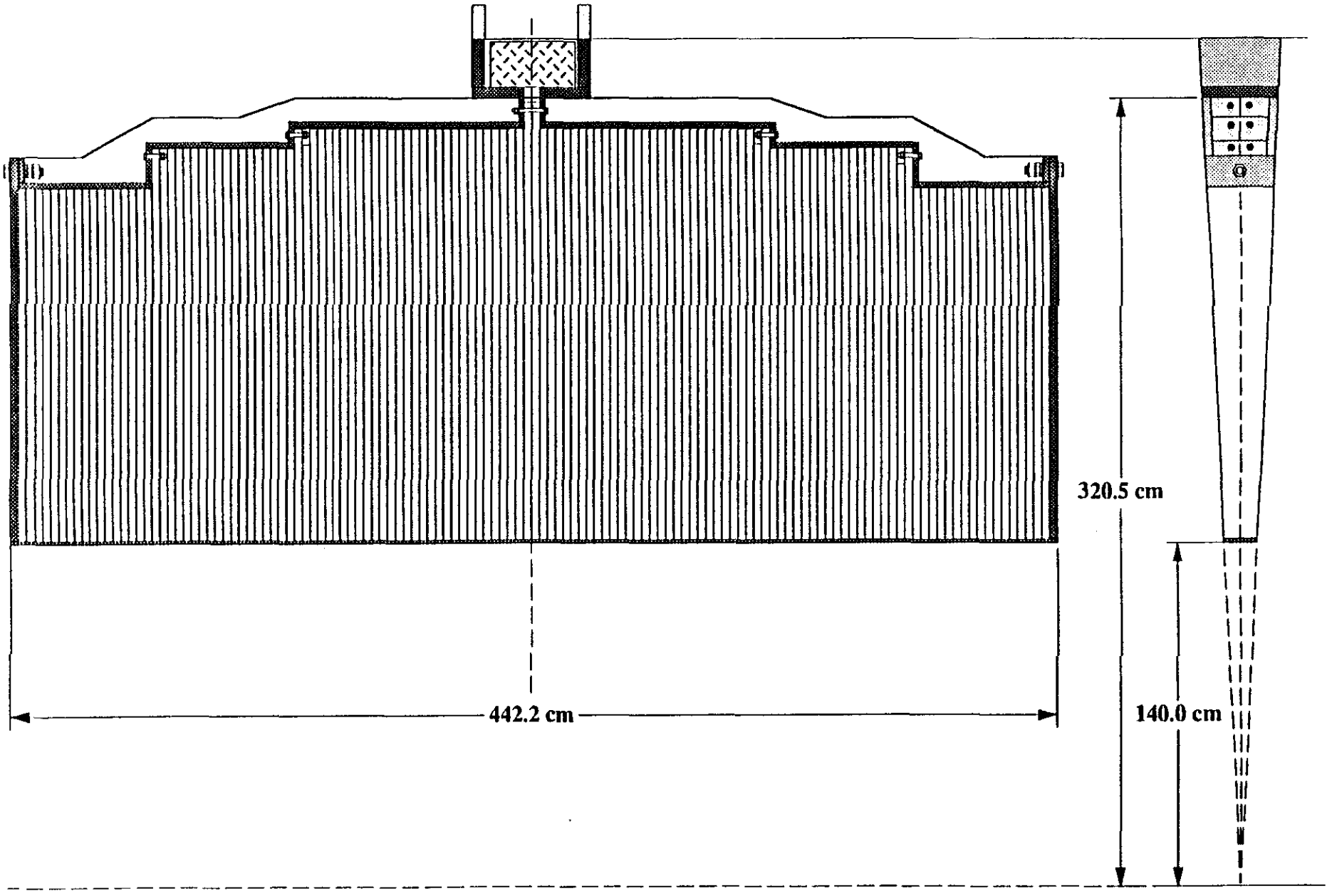
Material: Copper



GEM Detector
Plastic Tile Hadron Calorimeter
Copper Barrel Module

G.03.T.011

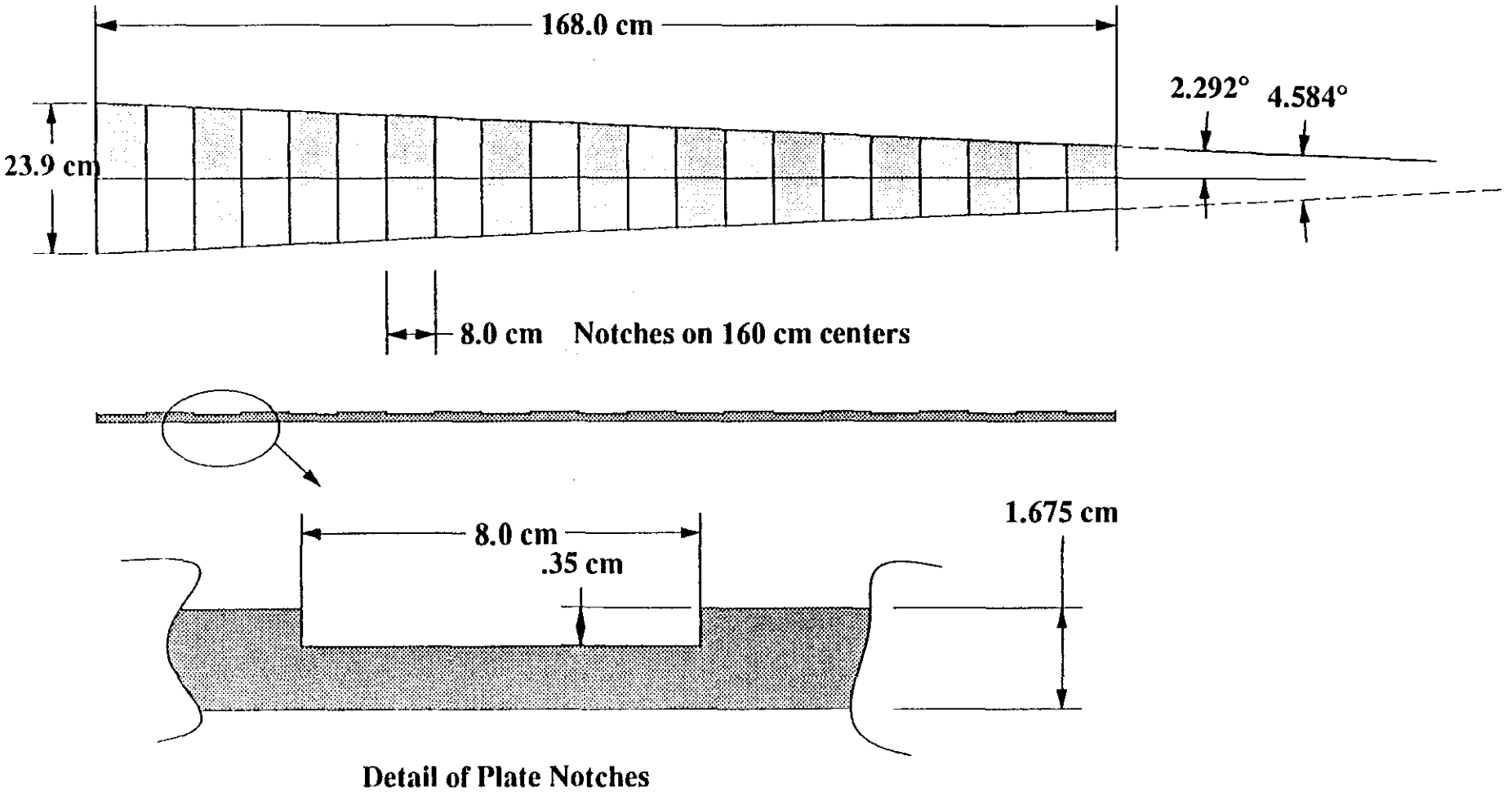
Rennich



GEM Detector
Plastic Tile Hadron Calorimeter
Copper Barrel Module

G.03.T.011

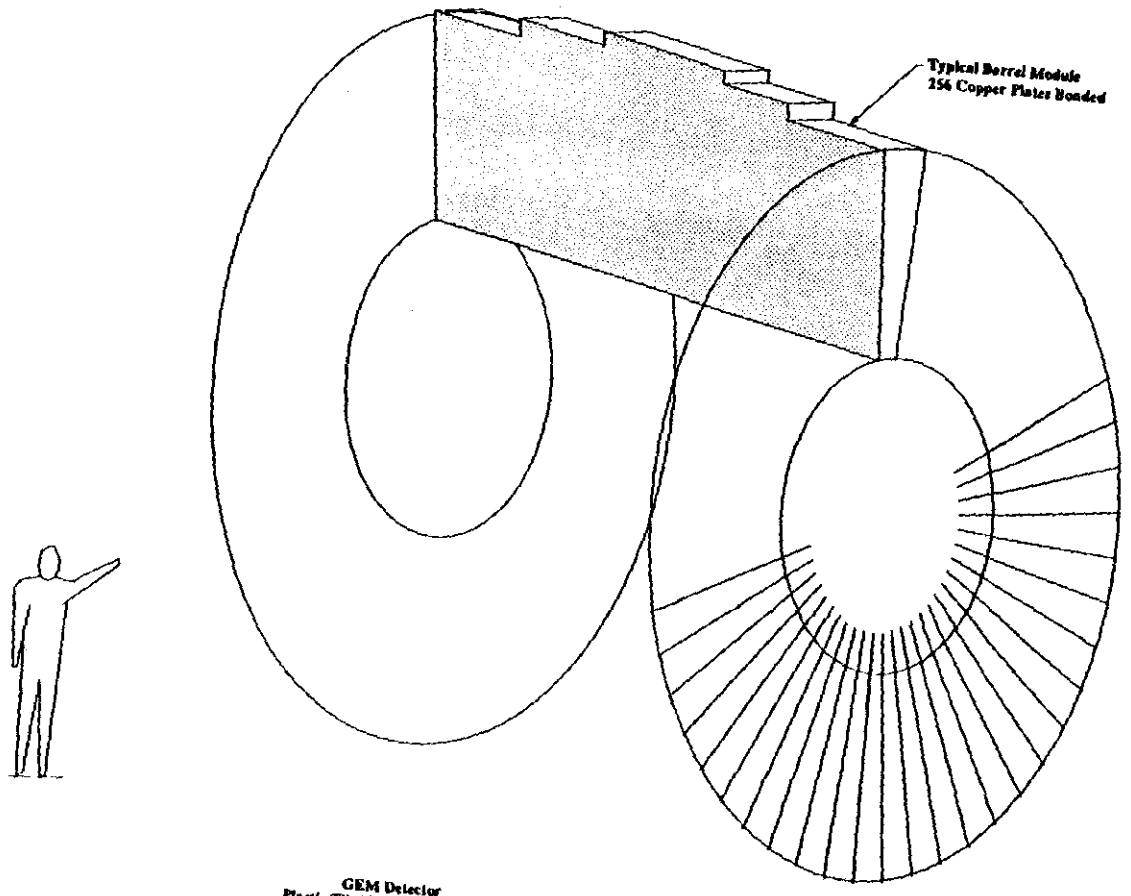
Rennich



GEM Detector
Plastic Tile Calorimeter
Typical Absorber Plate

G.03.T.012

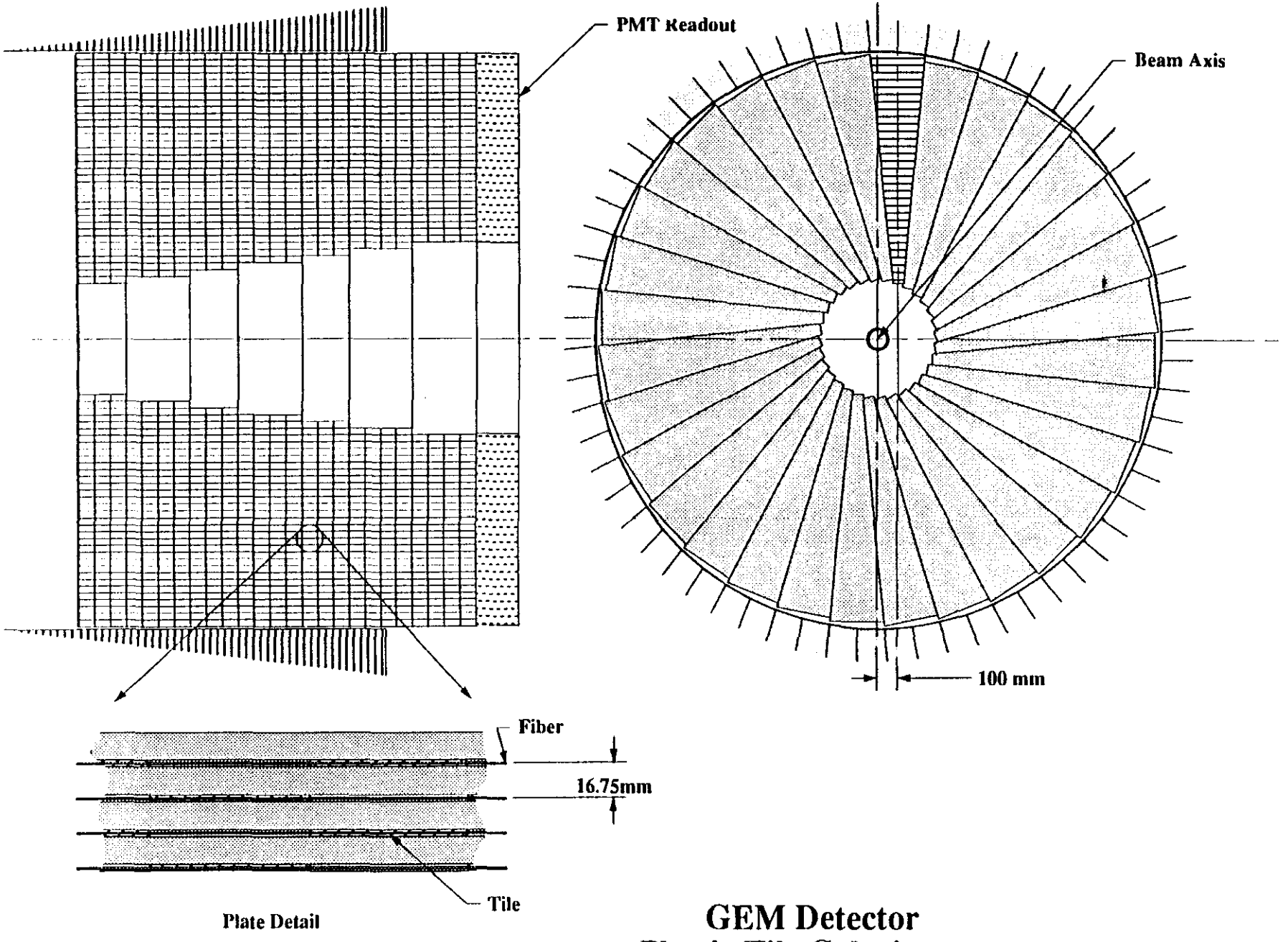
Rennich



GEM Detector
Plastic Tile Hadron Calorimeter
Copper Barrel Module
Tile Assembly Configuration

G 03 7-013

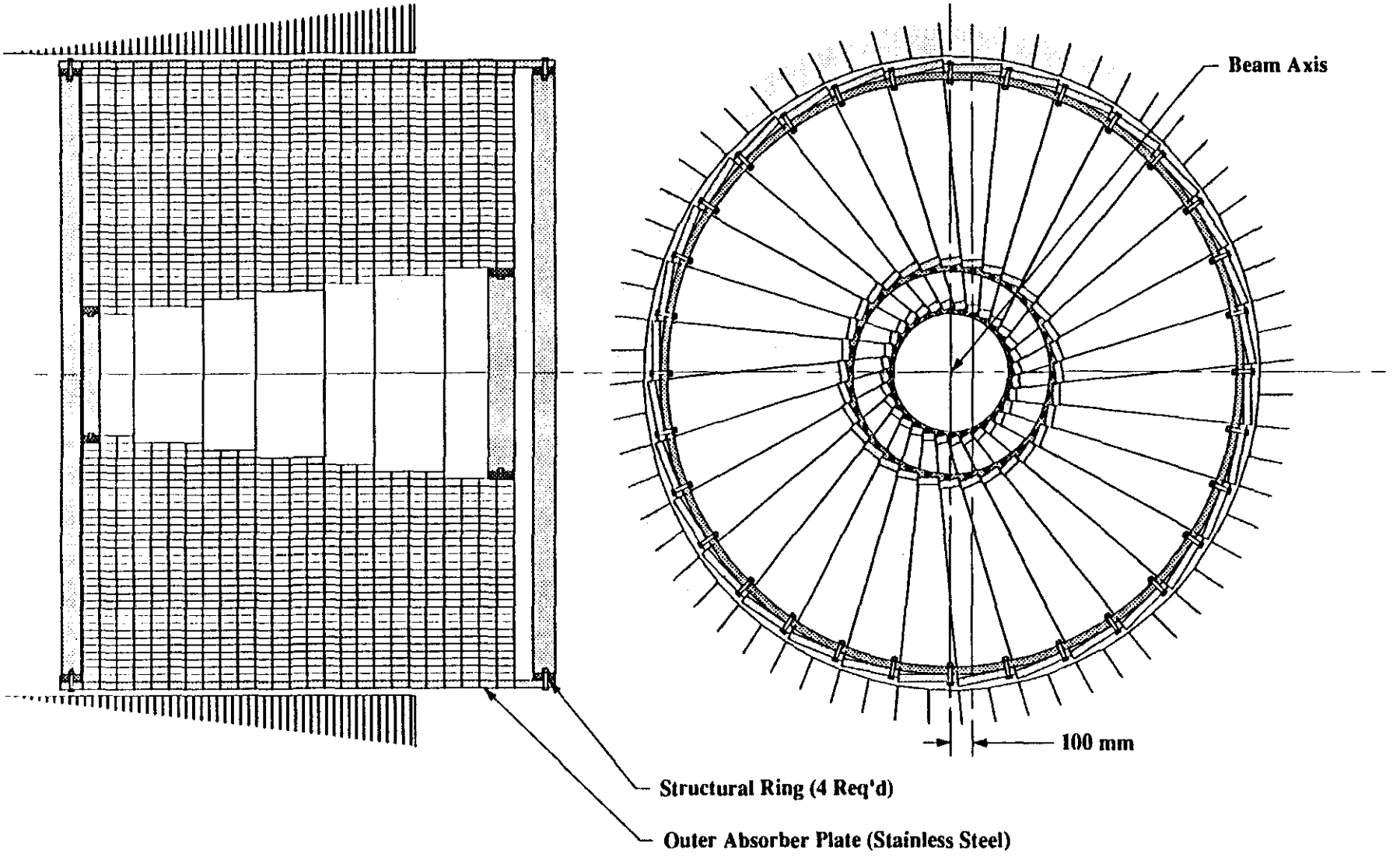
Rosnick



GEM Detector
Plastic Tile Calorimeter
End Cap Structure

G.03.T.025

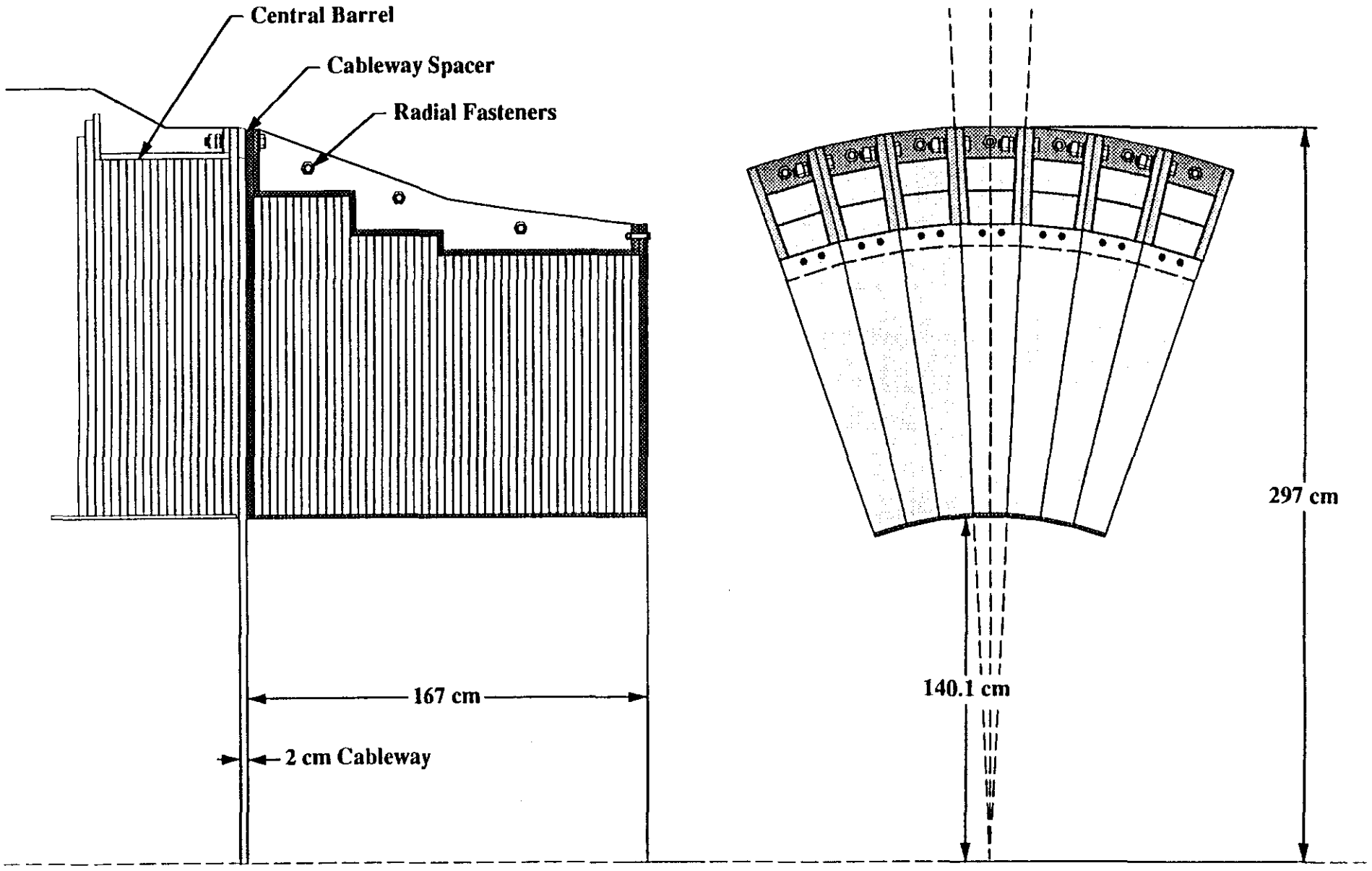
Rennich



GEM Detector
Plastic Tile Calorimeter
End Cap Structure

G.03.T.027

Rennich



GEM Detector
Plastic Tile Hadron Calorimeter
End Barrel Module Structure

G.03.T.030

Rennich

5.0

Manfacturing and Assembly

Plastic Tile Hadron Calorimeter

	STATION ONE						
1.00	Barrel Module Assembly						
Task	Task Descript.	Hrs/Unit	Personload	Tot PHRS/Unit	Units	Tot. PHRS	Run. Time
1.01	Receive Module Block	4	3	12	1	12	4
1.02	Dimensional Inspection	2	2	4	1	4	2
1.03	Install Readout Frames	2	2	4	1	4	2
1.04	Clean Block	6	2	12	1	12	6
1.05	Insert Plastic Tiles	0.01	1	0.01	2628	26.28	26.28
1.06	Inspect Tile Fitup	0.005	1	0.005	2628	13.14	13.14
1.07	Cut and Sort Fibers	0.02	1	0.02	528	10.56	10.56
1.08	Install Fibers	0.05	1	0.05	528	26.4	26.4
1.09	Group and Route Fiber Bundles	0.5	1	0.5	44	22	22
1.10	Install Fibers in Readout Frame	0.25	1	0.25	44	11	11
1.11	Inspect Fiber Installation	0.12	1	0.12	44	5.28	5.28
1.12	Install Fiber Shields	4	2	8	2	16	8
1.13	Finish Bundle Ends	1	1	1	44	44	44
1.14	Complete Closure and Inspections	2	2	4	1	4	2
1.15	Move Module to Barrel Assembly	2	3	6	1	6	2
	Totals for One Barrel Module	23.955		51.955		216.66	184.66
	Personnel Efficiency					1.25	1.25
	Estimated Personhours/Module					271	231
	Modules/Assembly					64	64
	Total Personhours for Station One					17333	14773
	Person Years	1770	Hr/Yr			9.79	
	Station One Machine Years	3540	Hr/Yr				4.17

STATION TWO

2.00 End Barrel Module Assembly

Task	Task Descript.	Hrs/Unit	Personload	Tot PHRS/Unit	Units	Tot. PHRS	Run. Time
2.01	Receive Module Block	4	3	12	1	12	4
2.02	Dimensional Inspection	2	2	4	1	4	2
2.03	Install Readout Frames	2	2	4	1	4	2
2.04	Clean Block	6	2	12	1	12	6
2.05	Insert Plastic Tiles	0.01	1	0.01	816	8.16	8.16
2.06	Inspect Tile Fitup	0.005	1	0.005	816	4.08	4.08
2.07	Cut and Sort Fibers	0.02	1	0.02	384	7.68	7.68
2.08	Install Fibers	0.05	1	0.05	384	19.2	19.2
2.09	Group and Route Fiber Bundles	0.5	1	0.5	32	16	16
2.10	Install Fibers in Readout Frame	0.25	1	0.25	32	8	8
2.11	Inspect Fiber Installation	0.12	1	0.12	32	3.84	3.84
2.12	Install Fiber Shields	4	2	8	2	16	8
2.13	Finish Bundle Ends	1	1	1	32	32	32
2.14	Complete Closure and Inspections	2	2	4	1	4	2
2.15	Move Module to Barrel Assembly	2	3	6	1	6	2
	Totals for One End Barrel Module	23.955		51.955		156.96	124.96
	Personnel Efficiency					1.25	1.25
	Estimated Personhours/Module					196	156
	Modules/Two Assemblies					128	128
	Total Personhours for Station Two					25114	19994
	Person Years	1770	Hr/Yr			14.19	
	Station Two Machine Years	3540	Hr/Yr				5.65

STATION THREE

3.00 End Plug Module Assembly

Task	Task Descript.	Hrs/Unit	Personload	Tot PHRS/Unit	Units	Tot. PHRS	Run. Time
3.01	Receive Module Block	4	3	12	1	12.0	4.0
3.02	Dimensional Inspection	2	2	4	1	4.0	2.0
3.03	Install Readout Frames	2	2	4	1	4.0	2.0
3.04	Clean Block	6	2	12	1	12.0	6.0
3.05	Insert Plastic Tiles	0.01	1	0.01	772	7.7	7.7
3.06	Inspect Tile Fitup	0.005	1	0.005	772	3.9	3.9
3.07	Cut and Sort Fibers	0.02	1	0.02	434	8.7	8.7
3.08	Install Fibers	0.05	1	0.05	434	21.7	21.7
3.09	Group and Route Fiber Bundles	0.5	1	0.5	72	36.2	36.2
3.10	Install Fibers in Readout Frame	0.5	1	0.5	72	36.2	36.2
3.11	Inspect Fiber Installation	0.25	1	0.25	72	18.1	18.1
3.12	Install Fiber Shields	4	2	8	2	16.0	8.0
3.13	Finish Bundle Ends	1	1	1	72	72.3	72.3
3.14	Complete Closure and Inspections	2	2	4	1	4.0	2.0
3.15	Move Module to Barrel Assembly	2	3	6	1	6.0	2.0
	Totals for One End Barrel Module	24.335		52.335		262.7	230.7
	Personnel Efficiency					1.25	1.25
	Estimated Personhours/Module					328	288
	Modules/Two Assemblies					64	64
	Total Personhours for Station Three					21016	18456
	Person Years	1770	Hr/Yr			11.87	
	Station Three Machine Years	3540	Hr/Yr				5.21

STATION FOUR

4.00 Central Barrel Assembly

Task	Task Descript.	Hours	Personload	Unit Tot PHRS	Quantity	Tot. PHRS	Run. Time
4.01	Adjust Barrel Assembly Stand	8	2	16	1	16	8
4.02	Inspect Barrel Assembly Stand	8	2	16	1	16	8
4.03	Receive Barrel Modules	4	2	8	64	512	256
4.04	Install Barrel Modules	4	1	4	64	256	256
4.05	Install Cables and Piping	24	2	48	1	48	24
4.06	Inspect Barrel Subassembly	4	2	8	1	8	4
4.07	Secure and Store Subassembly	4	2	8	1	8	4
	Total for Station Four	56		108		864	560
	Personnel Efficiency					1.25	1.25
	Estimated Personhours					1080	700
	Person Years	1770	Hr/Yr			0.61	
	Station Four Machine Years	1770	Hr/Yr				0.40

STATION FIVE

5.00 End Barrel Assembly

Task	Task Descript.	Hours	Personload	Unit Tot PHRS	Quantity	Tot. PHRS	Run. Time
5.01	Adjust Barrel Assembly Stand	8	2	16	1	16	8
5.02	Inspect Barrel Assembly Stand	8	2	16	1	16	8
5.03	Receive Barrel Modules	4	2	8	64	512	256
5.04	Install Barrel Modules	4	1	4	64	256	256
.05	Install Cables and Piping	24	2	48	1	48	24
5.06	Inspect Barrel Subassembly	4	2	8	1	8	4
5.07	Secure and Store Subassembly	4	2	8	1	8	4
	Total for Station Four	56		108		864	560
	Personnel Efficiency					1.25	1.25
	Estimated Personhours					1080	700
	Number of Subassemblies					2	2
	Total Personhours/Station Five					2160	
	Person Years	1770	Hr/Yr			1.22	
	Station Five Machine Years	1770	Hr/Yr				0.79

Station Six

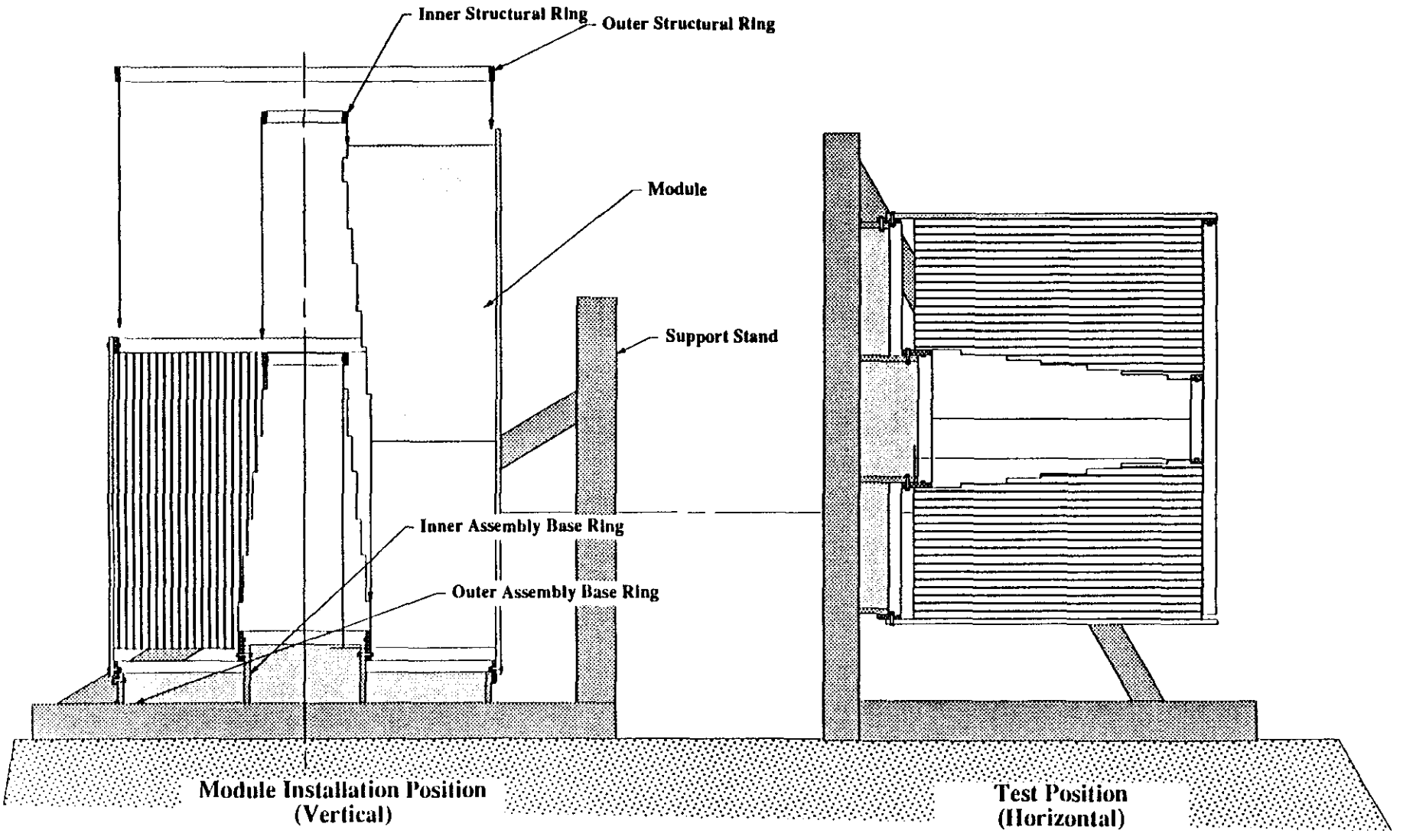
6.00 End Plug Assembly

Task	Task Descript.	Hours	Personload	Unit Tot PHRS	Quantity	Tot. PHRS	Run. Time
6.01	Adjust End Plug Assembly Stand	6	2	12	1	12	6
6.02	Receive End Plug Abs. Plate	1	2	2	32	64	32
6.03	Receive End Plug Tile Plate	1	2	2	32	64	32
6.04	Install Spacers	0.5	2	1	32	32	16
6.05	Install Readout Frames	4	2	8	1	8	4
6.06	Group Fiber Bundles	12	2	24	1	24	12
6.07	Terminate Fiber Bundles	4	2	8	1	8	4
6.08	Finish Fiber Bundle Ends	24	2	48	1	48	24
6.09	Install Readout Mixer/PMT	8	2	16	1	16	8
6.10	Install Cabling and Piping	48	2	96	1	96	48
6.11	Install Shielding	12	2	24	1	24	12
6.12	Inspect End Plug Subassembly	4	2	8	1	8	4
6.13	Secure and Store Subassembly	4	2	8	1	8	4
	Total for Station Six	128.5		257		412	104
	Personnel Efficiency					1.25	1.25
	Estimated Personhours/Subassembly					515	130
	Number of Subassemblies					2	2
	Total Personhours/Station Six					1030	
	Person Years	1770	Hr/Yr			0.58	
	Station Six Machine Years	1770	Hr/Yr				0.15

Schedule Requirements

2 Year (50 week) Production Schedule Assumed

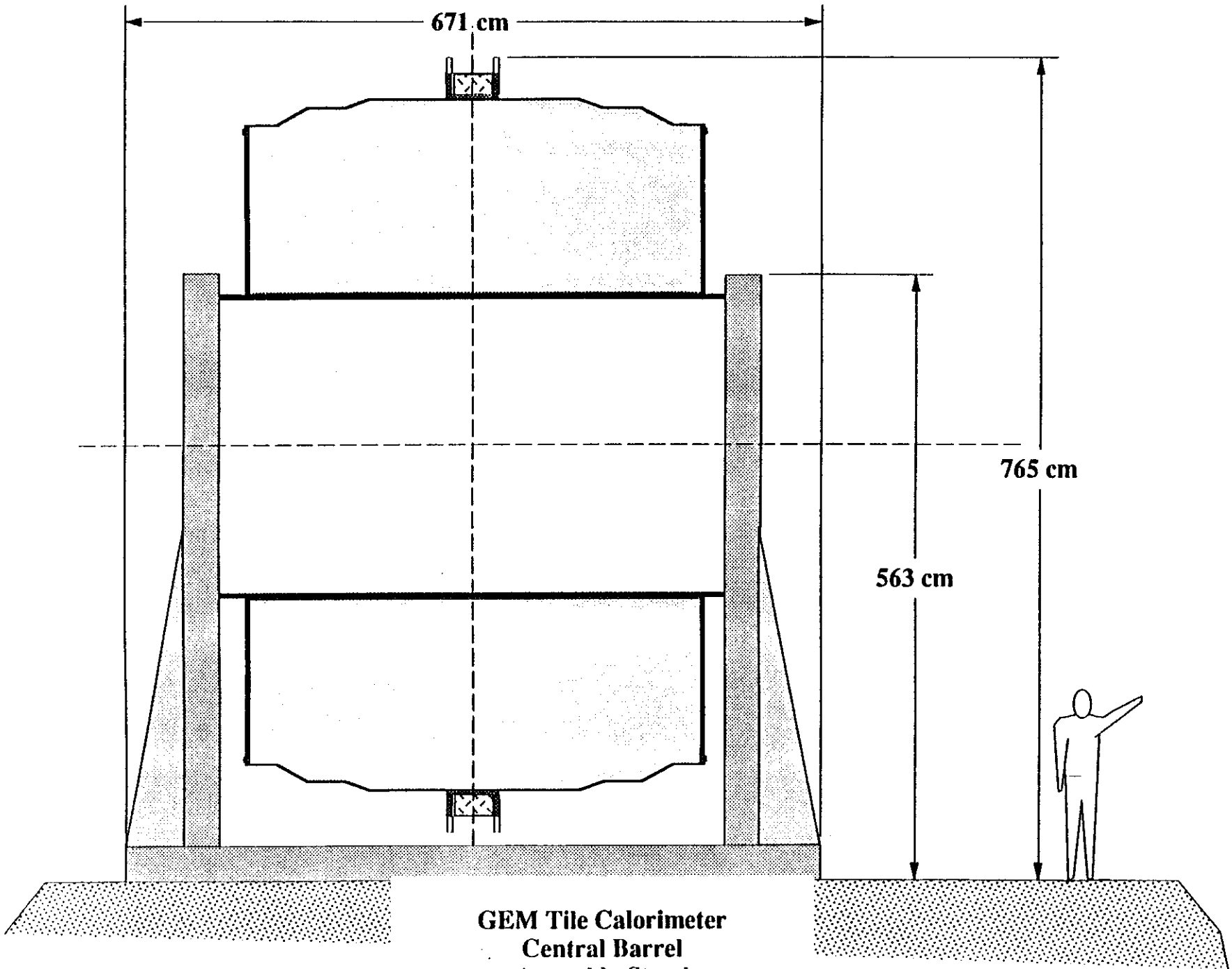
All Assembly Work To Be Performed At the SSCL	
Total Estimated Personhours	67,732
Total Person Years@1770 Hr/Yr	38.27



GEM Detector
Plastic Tile Calorimeter
End Cap Assembly Stand

G.03.T.028

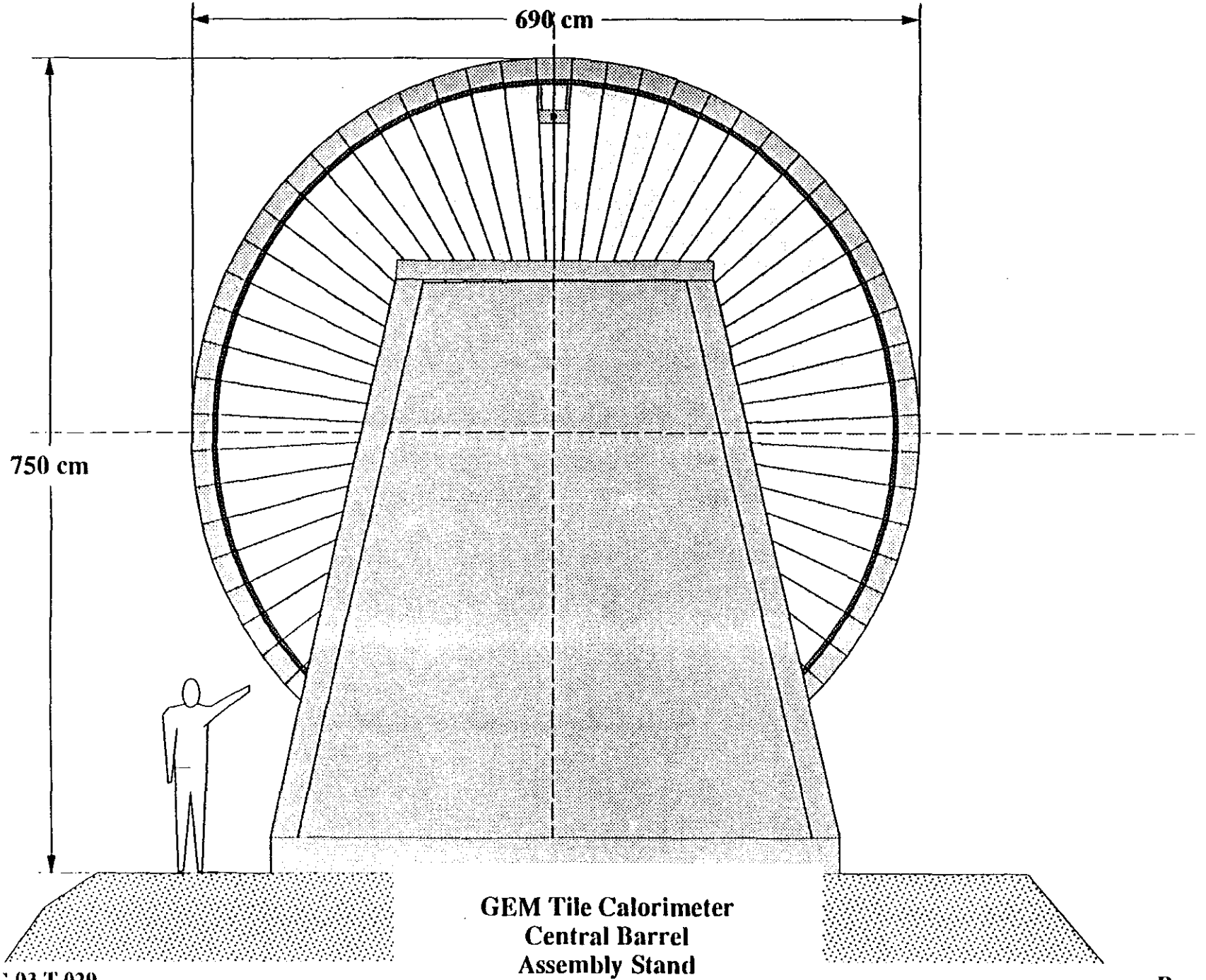
Rennich



GEM Tile Calorimeter
Central Barrel
Assembly Stand

G.03.T.029
Sheet 1/2

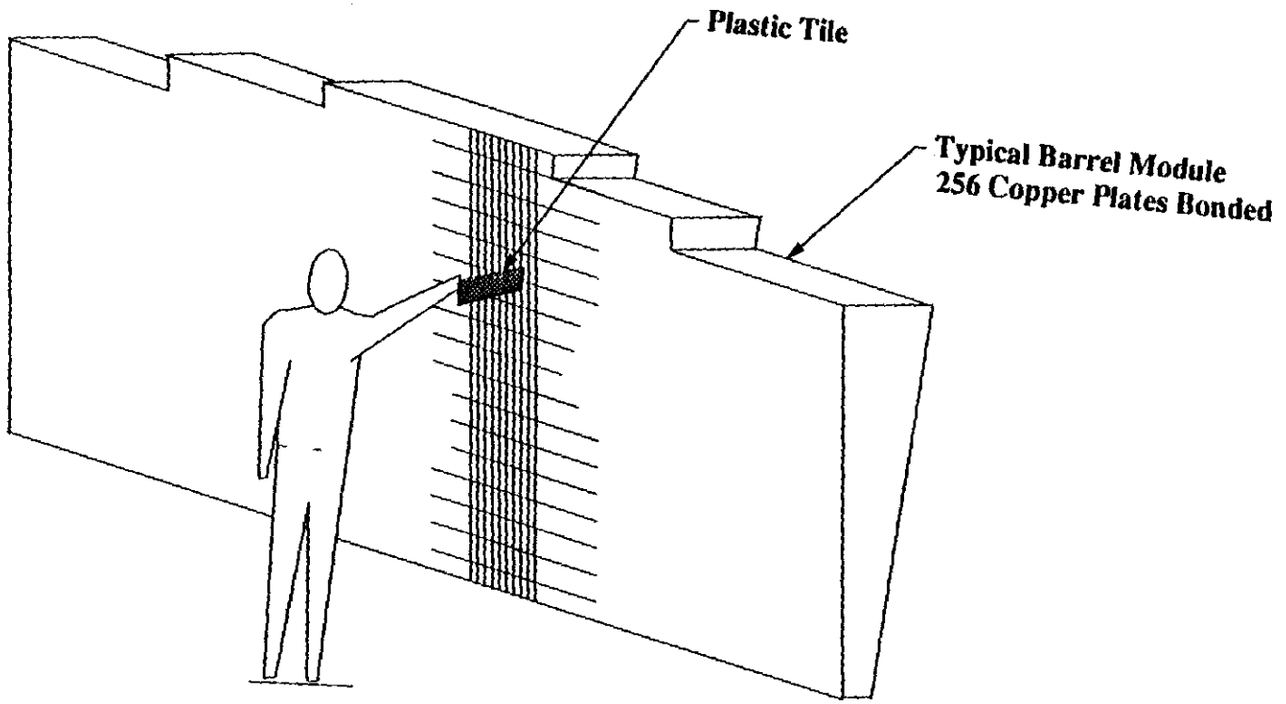
Rennich



GEM Tile Calorimeter
Central Barrel
Assembly Stand

G.03.T.029
Sheet 2/2

Rennich



G.03.T.013

GEM Detector
Plastic Tile Hadron Calorimeter
Copper Barrel Module
Tile Assembly Configuration

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6.0

Costing Analysis

Equipment Required For Plastic Tile Calorimeter

Summary Listing

WBS	Equipment	Quantity	Unit Cost	Total Cost
.0.2.4.1.5.1.1	Cent. Barrel Module Ass. Stands	5	15	75
.0.2.4.1.5.2.2	End Barrel Module Ass Stands	7	15	105
.0.2.4.1.5.3.2	End Cap Module Assembly Stands	3	10	30
.0.2.4.1.5.4.2	Barrel Assembly Stand	1	450	450
.0.2.4.1.5.5.2	End Barrel Assembly Stand	2	75	150
.0.2.4.1.5.6.2	End Cap Assembly Stand	2	75	150
.0.2.4.1.5.7.2	Tile Milling Machine	1	250	250
.0.2.4.1.5.7.3	Tile Finishing Machine	2	250	500
.0.2.4.1.5.7.4	Cent. Barrel Module Lifting Fix.	1	50	50
.0.2.4.1.5.7.5	End Barrel Module Lift. Fixture	1	50	50
.0.2.4.1.5.7.6	End Cap Module Lifting Fixture	1	40	40
.0.2.4.1.5.7.7	Module Dimensional Insp. Fix.	1	100	100
.0.2.4.1.5.7.8	Fiber Cutting Machine	1	25	25
.0.2.4.1.5.7.9	Portable Readout Test Stand	2	100	200
.0.2.4.1.5.7.10	Temporary Wiring Harness	2	25	50
.0.2.4.1.5.7.11	Op Test Sources/Counters	2	25	50
	Total Equipment Cost			2275

WBS: 1.3.3.6.1

Installation Manpower-Plastic Tile Hadron Calorimeter

Personnel	No.	Duration	Service Time	Total Hours	Hourly Rate	Cost
		Months	MH/Month			
Millwrights	4	3	173	2076	23.00	$47,748
Electrician	4	6	173	4152	20.63	$85,656
Crane Operator	1	3	173	519	27.42	$14,231
Rigger	6	5	173	5190	24.99	$129,698
Pipe Fitter	4	2	173	1384	22.13	$30,628
Total	19			13321	118.17	$307,961
PersonYears				6.53		
Yearly Rate				$47.16K		

Plastic Tile Hadron Calorimeter

0.2.4.5 Beam Test Plan

WBS		Quantity	Test Cost	Total
.0.2.4.5.1	Individual Tests	50	$11,739	$586.94K

Test Duration: 100 Hrs

Item	Cost	Unit		
Installation Labor	$23.72	Hr	96	$2,277
Test Labor	$37.02	Hr	80	$2,962
Beam Cost	$50.00	Hr	120	$6,000
Material	$500.00	Each	1	$500

.0.2.4.5.2	Tower Test Fixture	$500.00K
.0.2.4.5.3	Test Electronics/Cabling	$750.00K
.0.2.4.5	Total Detector Testing Total	$1,836.94K

Notes:

Tests to be performed at the SSCL
Tests performed by SSCL employees

Test Team composed of: (Engineer/Physicists)	2	Pers/Shft
Duration of Average Test Will be:	120	Hrs
Installation of modules will require:	24	Hrs
Removal of Modules will require:	8	Hrs
Install/Removal Team composed of: (Senior Technicians)	3	Persons

Plastic Tile/Copper Material Costs

			Unit Costs				
WBS	Item	Description	Unit Cost	Units	Quantity	Cost	Total
.0.2.4.1.3.2/3	End Barrel Modules				128	$17,465	$2,235K
0.1	Module Blocks					$14,493	
	Copper Plate	90Cu/10Sn	$4.41	Kg	3,110	$13,715	
	Plate Sizing		$0.25	Kg	3,110	$778	
0.2	Module Bonding					$1,350	
		Labor	$25.00	Hr	30	$750	
		Furnace				$600	
0.3	Module Finishing					$600	
		Labor	$25.00	Hr	20	$500	
		Material				$100	
0.4	Shipping					$1,022	
		Labor	$25.00	Hr	6	$150	
		Container				$250	
		Freight	$0.20	Kg	3,110	$622	

Plastic Tile/Copper Material Costs

WBS	Item	Description	Unit Costs: Unit Cost	Units	Quantity	Cost	Total
.0.2.4.1.3.4/5	End Cap Modules				64	$15,272	$977K
0.1	Module Blocks					$12,582	
	Copper Plate	90Cu/10Sn	$4.41	Kg	2,700	$11,907	
	Plate Sizing		$0.25	Kg	2,700	$675	
0.2	Module Bonding					$1,000	
		Labor	$25.00	Hr	16	$400	
		Furnace				$600	
0.3	Module Finishing					$700	
		Labor	$25.00	Hr	24	$600	
		Material				$100	
0.4	Shipping					$990	
		Labor	$25.00	Hr	8	$200	
		Container				$250	
		Freight	$0.20	Kg	2,700	$540	
							$539K
.0.2.4.1.2	Plastic Tile		$100.00	M^2	4758	$475,800	
		Labor	$25.00	Hr	2000	$50,000	
		Containers	$250.00	Each	12	$3,000	
		Freight			1	$10,000	
.0.2.4.1.1	1.0 mm dia Fiber	SCI	$0.35	M	120400		$42K
.0.2.4.3.1	PMT's	Hama. R2490	$1,000	Each	2,885		$2,885K

Plastic Tile/Copper Material Costs

			Unit Costs				
WBS	Item	Description	Unit Cost	Units	Quantity	Cost	Total
.0.2.4.1.4	Readout				512	$1,156	$592K
	Base Plate	Stainless St	$16.00	Kgs	26.4	$422	
	PMT Frame	2 in Sch 80 Pipe	$10.00	Kgs	4.50	$45	
	Light Mixer	Molded Acrylic	$25.00	Each	23	$575	
	Fasteners	1/2 in	$0.50	Each	28	$14	
	Freight				1	$100	
.0.2.4.3.2	Local Electronics				11541	$50	$571K
		Labor	$25.00	Hr	0.5	$13	
		Preamp	$25.00	Each	1	$25	
		Conn./Wire				$12	

Plastic Tile/Copper Material Costs

WBS	Item	Description	Unit Costs: Unit Cost	Units	Quantity	Cost	Total
.0.2.4.2.1	Structural Components						
0.1	Cent. Barrel Struct.					$424,000	$424K
	Outer Ribs	St. St. Plate	$16.00	Kg	15000	$240,000	
	Inner Ribs	St. St. Plate	$16.00	Kg	4000	$64,000	
	Structural Rings	St. St. Plate	$16.00	Kg	7500	$120,000	
.2/.3	End Barrel Structure					$176,000	$176K
	Outer Ribs	St. St. Plate	$16.00	Kg	7500	$120,000	
	Inner Ribs	St. St. Plate	$16.00	Kg	1500	$24,000	
	Structural Rings	St. St. Plate	$16.00	Kg	2000	$32,000	
.4/.5	End Cap Structure					$72,000	$72K
	Face Plate	St. St. Plate	$16.00	Kg	1500	$24,000	
	End Frame	St. St. Plate	$16.00	Kg	2000	$32,000	
	Structural Rings	St. St. Plate	$16.00	Kg	1000	$16,000	
0.6	Assembly Equipment					$169,000	$169K
	Cent. Barrel Outriggers	Struct. Steel	$6.00	Kg	10000	$60,000	
	End Cap OneOut Riggers	Struct. Steel	$6.00	Kg	5000	$30,000	
	E.C. Two Outriggers	Struct. Steel	$6.00	Kg	5000	$30,000	
	Rollers		$2,000	Each	12	$24,000	
	Assembly Rails	Struct. Steel	$5.00	Kg	5000	$25,000	

Evaluation of Plastic Tile Cost Estimate

Strengths	Weaknesses
Accurate Component Count	Lack of Production Prototype
Complete Conceptual Design	Lack of Detail Equipment Designs
Preliminary Manufacturing Plan	Lack of Beam Test Results
Prelim. Assembly Equipment Layouts	Lack of Individual Tile Design
Mechanically Simple Configuration	

Plastic Tile Hadron Calorimeter Installation Equipment

WBS	Equipment	Quantity	Weight	Units	Unit Cost	Cost
1.1.1.1.1.0	Installation Rails	1	600000	Lbs	$1.50	$900K
1.1.1.1.1.0	Central Barrel Lift Fixture	1	50000	Lbs	$4.00	$200K
1.1.1.1.1.0	End Cap Lift Fixture	1	25000	Lbs	$4.00	$100K
1.1.1.1.1.0	Temporary Bracing	1	10000	Lbs	$2.00	$20K
1.1.1.1.1.0	Crane Rental	1		Ea	$250.00	$250K
1.1.1.1.1.0	Transport Pusher	2		Ea	$50.00	$100K
	Total					$1,570K

Plastic Tile/Copper Material Costs

WBS	Item	Description	Unit Costs: Unit Cost	Units	Quantity	Cost	Total
.0.2.4.1.3.1	Central Barrel Modules				64	$61,956	$3,965K
0.1	Module Blocks					$56,386	
	Copper Plate	90Cu/10Sn	$4.41	Kg	12,100	$53,361	
	Plate Sizing		$0.25	Kg	12,100	$3,025	
0.2	Module Bonding					$2,000	
		Labor	$25.00	Hr	36	$900	
		Furnace				$600	
		Material				$500	
0.3	Module Finishing					$700	
		Labor	$25.00	Hr	24	$600	
		Material				$100	
0.4	Shipping					$2,870	
		Labor	$25.00	Hr	8	$200	
		Container				$250	
		Freight	$0.20	Kg	12,100	$2,420	

Plastic Tile/Copper Material Costs

WBS	Item	Description	Unit Costs: Unit Cost	Units	Quantity	Cost	Total
.0.2.4.1.3.2/3	End Barrel Modules				128	$17,965	$2,299K
0.1	Module Blocks					$14,493	
	Copper Plate	90Cu/10Sn	$4.41	Kg	3,110	$13,715	
	Plate Sizing		$0.25	Kg	3,110	$778	
0.2	Module Bonding					$1,850	
		Labor	$25.00	Hr	30	$750	
		Furnace				$600	
		Material				$500	
0.3	Module Finishing					$600	
		Labor	$25.00	Hr	20	$500	
		Material				$100	
0.4	Shipping					$1,022	
		Labor	$25.00	Hr	6	$150	
		Container				$250	
		Freight	$0.20	Kg	3,110	$622	

Plastic Tile/Copper Material Costs

WBS	Item	Description	Unit Costs: Unit Cost	Units	Quantity	Cost	Total
.0.2.4.1.3.4/5	End Cap Modules				64	$15,772	$1,009K
0.1	Module Blocks					$12,582	
	Copper Plate	90Cu/10Sn	$4.41	Kg	2,700	$11,907	
	Plate Sizing		$0.25	Kg	2,700	$675	
0.2	Module Bonding					$1,500	
		Labor	$25.00	Hr	16	$400	
		Furnace				$600	
		Material				$500	
0.3	Module Finishing					$700	
		Labor	$25.00	Hr	24	$600	
		Material				$100	
0.4	Shipping					$990	
		Labor	$25.00	Hr	8	$200	
		Container				$250	
		Freight	$0.20	Kg	2,700	$540	
							$539K
.0.2.4.1.2	Plastic Tile		$100.00	M^2	4758	$475,800	
		Labor	$25.00	Hr	2000	$50,000	
		Containers	$250.00	Each	12	$3,000	
		Freight			1	$10,000	
.0.2.4.1.1	1.0 mm dia Fiber	SCI	$0.35	M	120400		$42K
.0.2.4.3.1	PMT's	Hama. R2490	$1,000	Each	2,885		$2,885K

Plastic Tile/Copper Material Costs

			Unit Costs				
WBS	Item	Description	Unit Cost	Units	Quantity	Cost	Total
.0.2.4.1.4	Readout				512	$1,156	$592K
	Base Plate	Stainless St	$16.00	Kgs	26.4	$422	
	PMT Frame	2 in Sch 80 Pipe	$10.00	Kgs	4.50	$45	
	Light Mixer	Molded Acrylic	$25.00	Each	23	$575	
	Fasteners	1/2 in	$0.50	Each	28	$14	
	Freight				1	$100	
.0.2.4.3.2	Local Electronics				11541	$50	$571K
		Labor	$25.00	Hr	0.5	$13	
		Preamp	$25.00	Each	1	$25	
		Conn./Wire				$12	

Plastic Tile/Copper Material Costs

WBS	Item	Description	Unit Costs: Unit Cost	Units	Quantity	Cost	Total
.0.2.4.2.1	Structural Components						
0.1	Cent. Barrel Struct.					$376,000	$376K
	Outer Ribs	St. St. Plate	$16.00	Kg	12000	$192,000	
	Inner Ribs	St. St. Plate	$16.00	Kg	4000	$64,000	
	Structural Rings	St. St. Plate	$16.00	Kg	7500	$120,000	
.2/.3	End Barrel Structure					$168,000	$168K
	Outer Ribs	St. St. Plate	$16.00	Kg	7000	$112,000	
	Inner Ribs	St. St. Plate	$16.00	Kg	1500	$24,000	
	Structural Rings	St. St. Plate	$16.00	Kg	2000	$32,000	
.4/.5	End Cap Structure					$72,000	$72K
	Face Plate	St. St. Plate	$16.00	Kg	1500	$24,000	
	End Frame	St. St. Plate	$16.00	Kg	2000	$32,000	
	Structural Rings	St. St. Plate	$16.00	Kg	1000	$16,000	
0.6	Assembly Equipment					$154,000	$154K
	Cent. Barrel Outriggers	Struct. Steel	$6.00	Kg	7500	$45,000	
	End Cap OneOut Riggers	Struct. Steel	$6.00	Kg	5000	$30,000	
	E.C. Two Outriggers	Struct. Steel	$6.00	Kg	5000	$30,000	
	Rollers		$2,000	Each	12	$24,000	
	Assembly Rails	Struct. Steel	$5.00	Kg	5000	$25,000	

Plastic Tile Calorimeter
Catagory Distribution

Catagory	Estimate	Fraction
Research & Devel.	$3,011K	10.9%
EDIA	$9,622K	25.1%
Construction	$27,527K	
Contingency	$11,620K	31.6%
Total	$51,780K	

Plastic Tile Calorimeter

Major Cost Items

Catagory		Estimate	Fraction
Module Hardware		$11,532K	31.39%
Assembly			
	Equipment	$2,982K	8.12%
	Labor	$3,112K	8.47%
Engineering		$7,311K	19.90%
Electronics		$5,275K	14.36%
Structure		$1,470K	4.00%
Installation			
	Equipment	$1,603K	4.36%
	Labor	$322K	0.88%
Beam Calibration		$2,429K	6.61%
SubSystem Management		$2,264K	6.16%
Subtotal		$36,739K	

Above Costs Do Not Include Contingency

Plastic Tile Hadron Calorimeter WBS Costs

	WBS	Item	Engineering/design Labor my	Engineering/design Rate k$/my	Engineering/design Total k$	M&S Material k$	Inspection/Admin Labor my	Inspection/Admin Rate k$/my	Inspection/Admin Total k$	Proc/Fab Material k$	Assembly Labor my	Assembly Rate k$/my	Assembly Subtotal k$	Assembly Material k$	Assembly Total k$
	5.2.2.5.														
		Total Sc Fiber Had Calor Cost	**69.4**		**8860.7**	**2274.3**	**15.0**		**1498.0**	**24066.8**	**55.6**		**3111.6**	**0.0**	**3111.6**
3	.0 .2.4 .0	**Hadron Calorimeter Const**	**58.9**	**124**	**7310.6**	**403.3**	**15.0**	**100**	**1498.0**	**24066.8**	**55.6**	**56**	**3111.6**	**0.0**	**3111.6**
4	.0 .2.4 .1	**Tower Modules**	20.5		2214.0	148.5	3.9		310.3	14823.9	46.3		2498.4	0.0	2498.4
5	.0 .2.4 .1 .1	**Fibers**	0.0	0	0	0	0.0	0	0	42					
5	.0 .2.4 .1 .2	**Plastic Tiles**	3.0	108	324	54	0.0	0	0	539					
5	.0 .2.4 .1 .3	**Absorber Modules**	3.5	108	378.0	18.9	0.0	0	0.0	10582.9					
5	.0 .2.4 .1 .3	**Central Barrel**	1.0	108	108	5	0.0	0	0	3965					
5	.0 .2.4 .1 .3	**End Barrel One**	0.5	108	54	3	0.0	0	0	2299					
5	.0 .2.4 .1 .3	**End Barrel Two**	0.5	108	54	3	0.0	0	0	2299					
5	.0 .2.4 .1 .3	**End Cap One**	1.0	108	108	5	0.0	0	0	1009					
5	.0 .2.4 .1 .3	**End Cap Two**	0.5	108	54	3	0.0	0	0	1009					
5	.0 .2.4 .1 .4	**Readout Assy**	3.0	108	324	16	1.0	0	0	592	0.0		0	0	0
5	.0 .2.4 .1 .5	**Assembly**	9.0	0	972.0	48.6	2.6	0	278.2	2508.0	46.3		2498.4	0.0	2498.4
6	.0 .2.4 .1 .5 .1	**Station one**	1.0		108.0	5.4	0.5		53.5	85.0	9.8		528.8	0	528.8
7	.0 .2.4 .1 .5 .1 .1	**Station One assy**	1.0	108	108	5	0.5	107	54		9.8	54	529		529
7	.0 .2.4 .1 .5 .1 .2	**Barrel Module Assem. Stand**								75					
7	.0 .2.4 .1 .5 .1 .3	**Personnel Platform**								10					
6	.0 .2.4 .1 .5 .2	**Station two**	1.5		162	8	0.3		27	113	14.2		766	0	766
7	.0 .2.4 .1 .5 .2 .1	**Station Two assy**	1.5	108	162	8	0.3	107	27		14.2	54	766		766
7	.0 .2.4 .1 .5 .2 .2	**End Barrel Module Ass. Stand**								105					
7	.0 .2.4 .1 .5 .2 .3	**Personnel Platform**								8					
6	.0 .2.4 .1 .5 .3	**Station three**	1.5		162	8	0.3		27	30	11.9		641	0	641
7	.0 .2.4 .1 .5 .3 .1	**Station Three assy**	1.5	108	162	8	0.3	107	27		11.9	54	641		641
7	.0 .2.4 .1 .5 .3 .2	**End Plug Module Ass. Stand**								30					
6	.0 .2.4 .1 .5 .4	**Station Four**	1.0		108	5	0.3		27	450	0.6		33	0	33
7	.0 .2.4 .1 .5 .4 .1	**Station Four assy**	1.0	108	108	5	0.3	107	27		0.6	54	33		33
7	.0 .2.4 .1 .5 .4 .2	**Barrel Ass. Stand**								450					
6	.0 .2.4 .1 .5 .5	**Station Five**	1.5		162	8	0.3		27	150	1.2		66	0	66
7	.0 .2.4 .1 .5 .5 .1	**Station Five assy**	1.5	108	162	8	0.3	107	27		1.2	54	66		66
7	.0 .2.4 .1 .5 .5 .2	**End Barrel Ass. Stand**								150					
6	.0 .2.4 .1 .5 .6	**Station Six**	1.0		108	5	0.3		27	150	0.6		31	0	31
7	.0 .2.4 .1 .5 .6 .1	**Station Six assy**	1.0	108	108	5	0.3	107	27		0.6	54	31		31

7	.0 .2.4 .1 .5 .6 .2	End Plug Ass. Stand								150					
6	.0 .2.4 .1 .5 .7	Special Purpose Equipment	0.5		54	3	0.6		64	1055	8.0		432	0	432
7	.0 .2.4 .1 .5 .7 .1	Assembly Support Labor	0.5	108	54	3	0.6	107	64		8.0	54	432		432
7	.0 .2.4 .1 .5 .7 .2	Tile Milling Machine								250					
7	.0 .2.4 .1 .5 .7 .3	Tile Finishing Machine								250					
7	.0 .2.4 .1 .5 .7 .4	Barrel Mod. Lifting Fixture								50					
7	.0 .2.4 .1 .5 .7 .5	End Cap Mod. Lifting Fixture								40					
7	.0 .2.4 .1 .5 .7 .6	End Cap Mod. Lifting Fixture								40					
7	.0 .2.4 .1 .5 .7 .7	Dimensional Insp. Fixture								100					
7	.0 .2.4 .1 .5 .7 .8	Fiber Cutting Machine								25					
7	.0 .2.4 .1 .5 .7 .9	Portable Readout Test Stand								200					
7	.0 .2.4 .1 .5 .7 .10	Temporary Wiring Harnesses								50					
7	.0 .2.4 .1 .5 .7 .11	Op Test Sources/Counters								50					
6	.0 .2.4 .1 .5 .8	Assembly equipment	1.0		108	5	0.3		27	475	0.0		0	0	0
7	.0 .2.4 .1 .5 .8 .1	General Assembly Equipment	1.0	108	108	5	0.3	107	27		0.0	0	0		0
7	.0 .2.4 .1 .5 .8 .2	Clothing								50					
7	.0 .2.4 .1 .5 .8 .3	Cleaning Supplies								50					
7	.0 .2.4 .1 .5 .8 .4	Tools								100					
7	.0 .2.4 .1 .5 .8 .5	Temporary Use Items								200					
7	.0 .2.4 .1 .5 .8 .6	Handling Carts (10-100 T)								75					
5	.0 .2.4 .1 .6	Calibration Loops	2.0	108	216	11	0.3	107	32	560					
4	.0 .2.4 .2	System Assembly	6.5		702.0	35.1	2.1		224.7	1080.0	1.0		51.3		51.3
5	.0 .2.4 .2 .1	Central Barrel Structure	2.0	108	216	11	0.3	107	32	376					
5	.0 .2.4 .2 .2	End Barrel One Structure	1.0	108	108	5	0.3	107	32	168					
5	.0 .2.4 .2 .3	End Barrel Two Structure	0.0	108	0	0	0.3	107	32	168					
5	.0 .2.4 .2 .4	End Cap One Structure	1.0	108	108	5	0.3	107	32	72					
5	.0 .2.4 .2 .5	End Cap Two Structure	0.0	108	0	0	0.3	107	32	72					
5	.0 .2.4 .2 .6		2.5		270.0	13.5	0.6		64.2	224.0	1.0		51.3		51.3
6	.0 .2.4 .2 .6	Labor	2.5	108	270	14	0.6	107	64	0	0.95	54	51		51
6	.0 .2.4 .2 .6 .1	Cent Barrel Outriggers								75					
6	.0 .2.4 .2 .6 .2	End Cap One Outriggers								50					
6	.0 .2.4 .2 .6 .3	End Cap Two Outriggers								50					
6	.0 .2.4 .2 .6 .4	Rollers								24					
6	.0 .2.4 .2 .6 .5	Assembly Rails								25					
4	.0 .2.4 .3	Electronics	2.5		310	16	2.3		246	4703	0.0		0	0	0
5	.0 .2.4 .3 .1	Photomultiplier Tubes	0.5	124	62	3	0.3	107	32	2885					
5	.0 .2.4 .3 .2	Local Electronic Readout	2.0	124	248	12	2.0	107	214	571					
5	.0 .2.4 .3 .2	External Electronics								1246					
4	.0 .2.4 .4	Thermal Control	3.5		378	19	0.6		64	640	0.0		0	0	0
5	.0 .2.4 .4 .1	Heat Transfer System	2.5	108	270	14	0.3	107	32	440					
5	.0 .2.4 .4 .2	Heat Exchangers	1.0	108	108	5	0.3	107	32	200					

4	.0 .2.4 .5	Beam Test/Calibration	4.0		496.0	24.8	0.9		96.3	1250.0	8.4		562	0	562
5	.0 .2.4 .5 .1	Test Stands	3.0	124	372	19	0.3	107	32	500					
5	.0 .2.4 .5 .2	Manpower	0.0	0	0	0	0.3	107	32		8.4	67	562		562
5	.0 .2.4 .5 .3	Beam Calibration System	1.0	124	124	6	0.3	107	32	750					
4	.0 .2.4 .6	Hadron Installation	7.9		1054.6	52.7	5.2		556.4	1570.0	0.0		0.0		0.0
5	.0 .2.4 .6 .1	Manpower	2.5	154	385	19	2.0	107	214						
5	.0 .2.4 .7 .2	Equipment	5		670	33	3		342	1570					
6	.0 .2.4 .7 .2 .1	Installation Rails	2.7	124	335	17	1.0	107	107	900					
6	.0 .2.4 .7 .2 .2	Cent Barrel Lift Fix	1.2	124	149	7	1.0	107	107	200					
6	.0 .2.4 .7 .2 .3	End Cap Lift Fixture	0.8	124	93	5	0.5	107	54	100					
6	.0 .2.4 .7 .2 .4	Temporary Bracing	0.3	124	31	2	0.5	107	54	20					
6	.0 .2.4 .7 .2 .5	Crane Rental	0.3	124	31	2	0.1	107	11	250					
6	.0 .2.4 .7 .2 .6	Transport Pusher	0.3	124	31	2	0.1	107	11	100					
4	.0 .2.4 .7	Subsystem Management	14.0		2156.0	107.8									
5	.0 .2.4 .7 .1	Project Management	7.0	154	1078	54									
5	.0 .2.4 .7 .2	Resource Management	3.0	154	462	23									
5	.0 .2.4 .7 .3	ES&H	1.5	154	231	12									
5	.0 .2.4 .7 .4	Quality Assurance	1.5	154	231	12									
5	.0 .2.4 .7 .5	System Integration	1.0	154	154	8									

3	.1 .2.4 .0	Hadron Calorimeter R&D	7.4	0.0	1164.5	1647.0										
4	.1 .2.4 .1	Material Tests	1.5		237	353										
5	.1 .2.4 .1 .1	Fiber Testing	1.0	158	158	130										
5	.1 .2.4 .1 .2	Fiber/Tile Bond Testing/Devel.	0.5	158	79	223										
4	.1 .2.4 .2	Single Tower Prototype	2.0		316	664										
5	.1 .2.4 .2 .1	Tower Assembly	0.5	158	79	102										
5	.1 .2.4 .2 .2	Electronics	1.0	158	158	456										
5	.1 .2.4 .2 .3	Assembly/Test Frame	0.3	158	40	68										
5	.1 .2.4 .2 .4	Thermal Control	0.3	158	40	38										
4	.1 .2.4 .3	Sixteen Tower Prototype	1.9		295	674										
5	.1 .2.4 .3 .1	Tower Assembly	0.5	158	79	250										
5	.1 .2.4 .3 .2	Electronics	0.5	158	79	139										
5	.1 .2.4 .3 .3	Assembly/Test Frame	0.5	158	79	99										
5	.1 .2.4 .3 .4	Thermal Control	0.3	158	40	54										
5	.1 .2.4 .3 .5	Beam Testing	0.1	158	19	132										
4	.1 .2.4 .4	Manufacturing Development	2.0		316	156										
5	.1 .2.4 .4 .1	Fiber Cutting	1.0	158	158	50										
5	.1 .2.4 .4 .2	Copper Bonding	1.0	158	158	106										
3	.2 .2.4 .0	Had Cal Concep/Pre Design	3.1	124	386	24										
4	.2 .2.4 .1	Preparation of LoI	0.7		87	9										
5	.2 .2.4 .1 .1	Conceptual Design	0.3	124	31	4										
5	.2 .2.4 .1 .2	Costing Studies	0.3	124	41	4										
5	.2 .2.4 .1 .3	Document Preparation	0.1	124	15	1										
4	.2 .2.4 .2	Prep of Tech Prop.	2.4		299	15										
5	.2 .2.4 .2 .1	Conceptual Design	1.0	124	124	6										
5	.2 .2.4 .2 .2	Costing Studies	0.3	124	41	2										
5	.2 .2.4 .2 .3	Manufacturing Studies	0.5	124	62	3										
5	.2 .2.4 .2 .4	Installation Studies	0.3	124	31	2										
5	.2 .2.4 .2 .5	Prep of Tech Prop	0.3	124	41	2										

Plastic Tile Hadron Calorimeter WBS Costs

Installation/Assembly					Totals				
Labor	Rate	Subtotal	Material	Total	Labor	Material	Subtotal	Conting.	Total
my	k$/my	k$	k$	k$	k$	k$	k$	k$	k$
6.4		322.5	0.0	322.5	13792.8	26341.2	40134.0	11583.5	51717.4
6.4		322.5	0.0	322.5	12242.7	24470.2	36712.9	10559.6	47272.4
6.4		322.5	0.0	322.5	5022.7	14972.4	19995.1	5644.8	25639.9
					0	42	42	4	46
					324	593	917	83	999
					378.0	10601.8	10979.8	2964.6	13944.4
					108	3971	4079	1101	5180
					54	2302	2356	636	2992
					54	2302	2356	636	2992
					108	1015	1123	303	1426
					54	1012	1066	288	1354
					324	608	932	0	932
					3748.6	2556.6	6305.2	2159.9	8465.2
					690.3	90.4	780.7	252.4	1033.1
					690	5	696	223	918
					0	75	75	26	101
					0	10	10	4	14
					955	121	1076	341	1417
					955	8	963	308	1271
					0	105	105	30	135
					0	8	8	2	10
					830	38	868	277	1145
					830	8	838	268	1106
					0	30	30	9	39
					168	455	623	231	854
					168	5	173	55	228
					0	450	450	176	626
					255	158	413	143	555
					255	8	263	84	347
					0	150	150	59	209
					166	155	322	113	435
					166	5	172	55	226

					0	150	150	59	209
					550	1058	1608	583	2191
					550	3	553	171	724
					0	250	250	98	348
					0	250	250	98	348
					0	50	50	20	70
					0	40	40	16	56
					0	40	40	16	56
					0	100	100	39	139
					0	25	25	10	35
					0	200	200	78	278
					0	50	50	20	70
					0	50	50	20	70
					135	480	615	220	835
					135	5	140	50	191
					0	50	50	15	65
					0	50	50	15	65
					0	100	100	37	137
					0	200	200	76	276
					0	75	75	28	103
					248	571	819	434	1253
					978.0	1115.1	2093.1	731.1	2824.2
					248	387	635	235	870
					140	173	314	116	429
					32	168	200	74	274
					140	77	218	80	298
					32	72	104	49	153
					385.5	237.5	623.0	176.7	799.7
					386	14	399	124	523
					0	75	75	19	94
					0	50	50	12	62
					0	50	50	12	62
					0	24	24	6	30
					0	25	25	6	31
					556	4718	5275	1394	6669
					94	2888	2982	656	3639
					462	584	1046	376	1422
					0	1246	1246	361	1608
					442	659	1101	352	1453
					302	454	756	242	997
					140	205	346	111	456

					1154.2	1274.8	2429.0	658.4	3087.4
					404	519	923	231	1153
					594	0	594	172	766
					156	756	912	255	1168
6.4		322.5		322.5	1933.5	1622.7	3556.2	969.6	4525.8
6.4	50	322		322	921	19	941	263	1204
0		0	0	0	1012	1603	2615	706	3322
					442	917	1359	367	1725
					256	207	463	125	588
					147	105	251	68	319
					85	22	106	29	135
					42	252	293	79	372
					42	102	143	39	182
0.0		0	0	0	2156.0	107.8	2263.8	809.3	3073.1
					1078	54	1132	407	1539
					462	23	485	175	660
					231	12	243	85	327
					231	12	243	82	325
					154	8	162	60	222

					1164.5	1847.0	3011.5	1023.9	4035.4
					237	353	590	201	791
					158	130	288	98	386
					79	223	302	103	405
					316	664	980	333	1313
					79	102	181	62	243
					158	456	614	209	823
					40	68	108	37	144
					40	38	78	26	104
					295	674	969	330	1299
					79	250	329	112	441
					79	139	218	74	292
					79	99	178	61	239
					40	54	94	32	125
					19	132	151	51	202
					316	156	472	160	632
					158	50	208	71	279
					158	106	264	90	354
					386	24	410	0	410
					87	9	96	0	96
					31	4	35	0	35
					41	4	45	0	45
					15	1	16	0	16
					299	15	314	0	314
					124	6	130	0	130
					41	2	43	0	43
					62	3	65	0	65
					31	2	33	0	33
					41	2	43	0	43

MANUFACTURING SCIENCES CORPORATION

P.O. Box 5058 Oak Ridge, Tennessee 37831 (615) 481-0455 FAX (615) 481-3142

April 2, 1992

Dr. Howard Gordon
Physicist, GEM Collaboration
Brookhaven National Laboratory
FAX 516-282-5568

Subject : Availability of DOE Scrap Copper for Use with GEM

Dear Howard :

I have been trying to track the subject matter recently and the purpose of this letter is to share my findings to date.

I include with this FAX letter 2 pages from a DOE memorandum that reports that 45% of 23,100 metric tons of radioactively contaminated scrap metal at the DOE Fernald site is copper. This is apparently bad data. According to Dan Burns of Westinghouse, the current Fernald Contractor, there are only 1350 tons of scrap copper there. It comes from electric motors used in the gaseous diffusion process and much of it is still wrapped in insulation. He is willing to discuss the availability of this material for an SSC application (513-738-8439).

I am also including 3 pages from a report that describes how 112 metric tons of this scrap was shred, air-classified to remove the insulation, vacuum induction melted with 1% glass flux, and cast into 500 lb ingots in an effort to reduce the radioactive contamination level. My copy of these pages is hard to read so yours may be impossible. The conclusion was that they were able to reduce the U content to <2 ppm and the technicium content to < 20 ppb. Since there is no current standard for unrestricted release of bulk-contaminated metals, even this low contamination level does not allow release of the metal for commercial purposes. However it could be used in a DOE controlled application such as the SSC should you choose to do so.

I am dissappointed to have mislead you and have been mislead by the earlier report about the quantity of this scrap metal at Fernald. I am trying to reach my source within DOE to see if there is such an amount in some other inventory. I will keep you posted. Hans Cohn of ORNL contacted me about the possible use of this source of copper in the e/m section of the GEM detector. I am sending him a copy of this letter too.

Very Truly Yours,

Dennis

Dennis R. Floyd
Executive Vice President

CHAMBERLAIN MANUFACTURING CORPORATION, A DUCHOSSOIS ENTERPRISE

TABLE 1
RADIOACTIVE SCRAP METAL VOLUMES AT SELECTED DOE SITE OPEN STORAGE YARDS

Site		Scrap Metal In Storage (Tons)	Annual[1] Generation Rate (tons/yr)
Oak Ridge, TN, K-25		45,000	200
Oak Ridge, TN, Y-12		3,500	800
Oak Ridge, TN, X-10		500	-
Portsmouth, OH		24,600	200
Paducah, KY		32,400	200
Fernald, OH		23,100	-
	TOTAL	129,100[2]	1,400

Sources: Jugan, 1991; and Swindle, 1991.

[1]The annual generation rate has been highly variable in the past. Hence, these figures do not represent average current generation rate.

[2]Detailed information on RSM volumes at the Nevada Test Site (NTS) could not be obtained at this time. Further investigation will be conducted on the RSM volumes and composition at the NTS in future.

UNI-SA-204

Summary

Part of the Cascade Improvement/Cascade Upgrade Programs (CIP/CUP) operations resulted in the removal of large quantities of metallic components. These components were contaminated with uranium and very small amounts of fission products carried over from the nuclear reactor fuel reprocessing cycle associated with uranium feed material recovery. In 1979 the National Lead Company of Ohio was awarded a contract to demonstrate the feasibility of recovering purified copper from the CIP/CUP scrap copper. Two hundred forty-seven thousand pounds of insulated scrap copper was used for the demonstration. The objective of the demonstration was to produce copper ingots with a total uranium content of less than 17.5 ppm and a technetium content of less than 5000 ppb. The target specifications for the finished copper are shown in Table 4.

TABLE 4

TARGET SPECIFICATIONS

Item	Value				
Cu	99.7 Min. w/o				
Tc	5,000	Max. ppb	←	0.0005%	
U	17.5	Max. ppm	U ←	0.00175%	
O	500	Max. ppm	O	0.06%	0.2%
Si	100	Max. ppm	Si	0.01%	
As	25	Max. ppm	As	0.005%	
P	25	Max. ppm	P		
Fe	400	Max. ppm	Fe	0.04%	
Ni	200	Max. ppm	Ni	0.02%	
Cr	100	Max. ppm	Cr	0.01%	
Mg	100	Max. ppm	Mg	0.01%	
Al	100	Max. ppm	AL	0.01%	
Bi	100	Max. ppm	Bi	0.01%	
C	200	Max. ppm	C	0.02%	

The CIP/CUP scrap copper was hand fed into a feed chute to a hydraulic shredder; then conveyed to a granulator containing a 1/2-inch mesh screen. From the granulator, the material was conveyed to an air classifying unit. The cleaned copper was discharged at one drumming station and the insulating materials at another station. The entire system, under a negative pressure, discharged into a standard dust collector. The cleaned copper was packaged to provide about 500 to 550 pounds per charge to a graphite crucible. The charged crucible was placed into the remelt furnace. Pulverized glass was added as a flux. The scrap copper was heated to about 2500 F under vacuum and the melt cast into a graphite mold.

Originally ten pounds of glass was added as a decontamination flux to each 500 pounds of copper scrap. As the process progressed it became evident that the amount of glass could be reduced. Subsequent charges contained only five pounds of glass for flux and finally only three pounds.

The uranium content was determined for a number of slag samples. The uranium content ranged from 30 to 2000 ppm. This wide range was expected since the amount of contamination on the scrap copper varied as received for the demonstration.

A total of 498 ingots were produced as the product of the demonstration test. The cost per pound of copper to produce the ingots was $0.98 (1981 dollars). It was estimated that a production campaign would produce ingots at a cost of about $0.78 (1981 dollars) per pound.

The chemistry of the finished 498 ingots is shown in Table 5.

Overall, the quality of the copper ingots produced during this demonstration was equal to or exceeded copper produced commercially. The very smooth surface quality of the ingots is generally not found in commercially-produced ingots. The electrical conductivity of the copper is preserved provided the silicon level is low (silicon is from residual insulating material). It is concluded that a high-quality copper metal was produced as part of the demonstration campaign. In fact, the uranium content of 90% of the demonstration ingots is below that in copper presently used in industry.

10 lb glass powder to 500 lb Cu.
↓
3 lb

cost $0.98 '81 dollars → $0.78 ('81 dollars)/lb Cu.

NAT'L LEAD CO OF OHIO in 1979.

112 Tons into 498 ingots (each ~500 lb)

each ingot ≈ 2.8 Cu ft.

UNI-SA-204

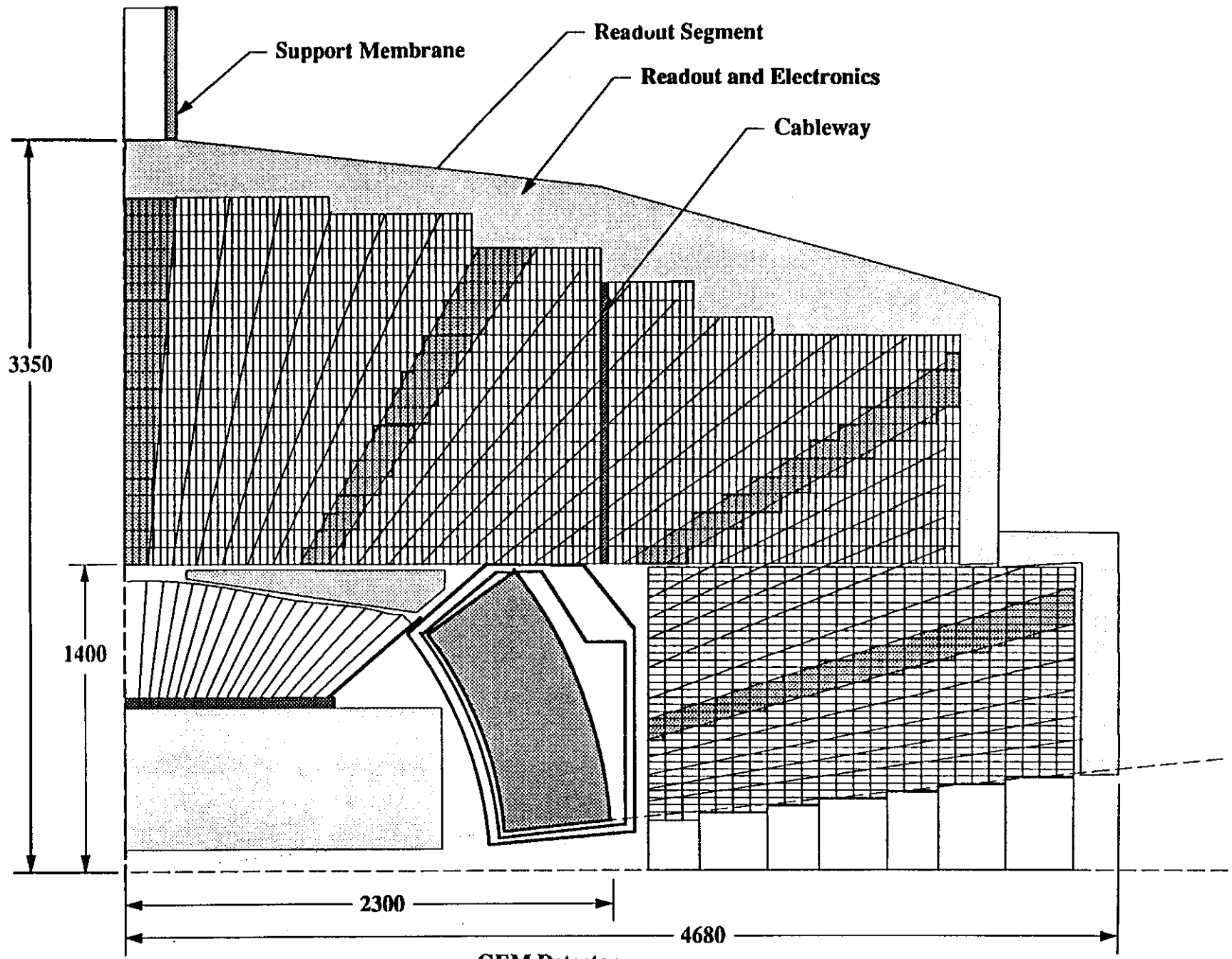
TABLE 5

CHEMISTRY OF FINISHED COPPER INGOTS

	ITEM	SPEC VALUE	INGOT VALUE	NO. OF INGOTS	% OF INGOTS
	Copper	99.7 w/o min.	Over 99.8	419	84.1
			99.7-99.79	73	14.7
			Below 99.7	6	1.2
	Tellurium-99	5000 ppb max.	less than 20	498	100
U	Uranium	17.8 ppm max.	less than 1	118	23.7
			1	259	52.0
			2	71	14.3
			3	27	5.4
			4	15	3.0
			5	3	0.6
			6	1	0.2
			8	1	0.2
			14	1	0.2
			27	1	0.2
			36	1	0.2
O	Oxygen	500 ppm max.	less than 50	296	59.5
			51-100	199	39.4
			over 100	8	1.6
Si	Silicon	100 ppm max.	less than 50	361	72.5
			51-99	115	23.1
			100-199	13	2.6
			over 200	9	1.8
As + Bi	Arsenic / Bismuth	As-25 ppm max. Bi-100 ppm max.	As less than 5 ppm Bi less than 1 ppm	498	100
P	Phosphorus	25 ppm max.	less than 10	426	85.5
			10-19	71	14.7
			23	1	0.2
Fe	Iron	400 ppm max.	less than 50	361	72.5
			51-99	97	19.5
			100-199	15	3.0
			200-300	4	0.8
			400	1	0.2
Ni	Nickel	200 ppm max.	less than 4	356	71.5
			5-10	124	24.9
			10-40	14	2.8
			over 40	2	0.4
Cr	Chromium	100 ppm max.	less than 5	482	96.7
			5-10	12	2.4
			over 10	4	0.8
Mg	Magnesium	100 ppm max.	less than 5	461	92.6
			5-10	23	4.6
			over 10	14	2.8
AL	Aluminum	100 ppm max.	less than 5	387	77.7
			5-10	90	18.1
			11-20	20	5.8
			over 20	2	0.4
C	Carbon	200 ppm max.	1-10	470	94.4
			11-40	22	4.4
			over 40	2	0.4

7.0

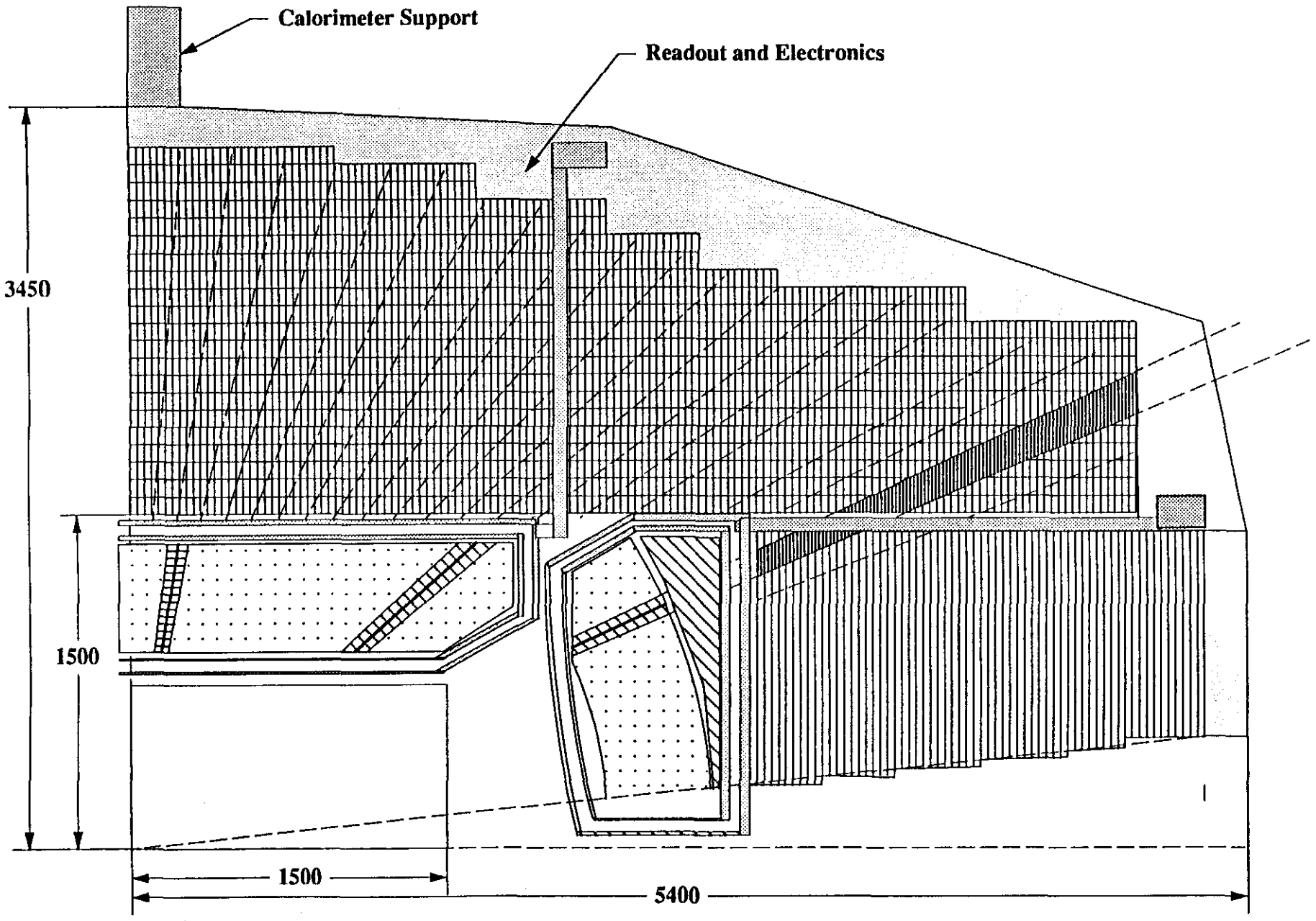
Alternative Configurations



GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
BaF2/Liquid Argon EM Calorimeter

G.03.T.001

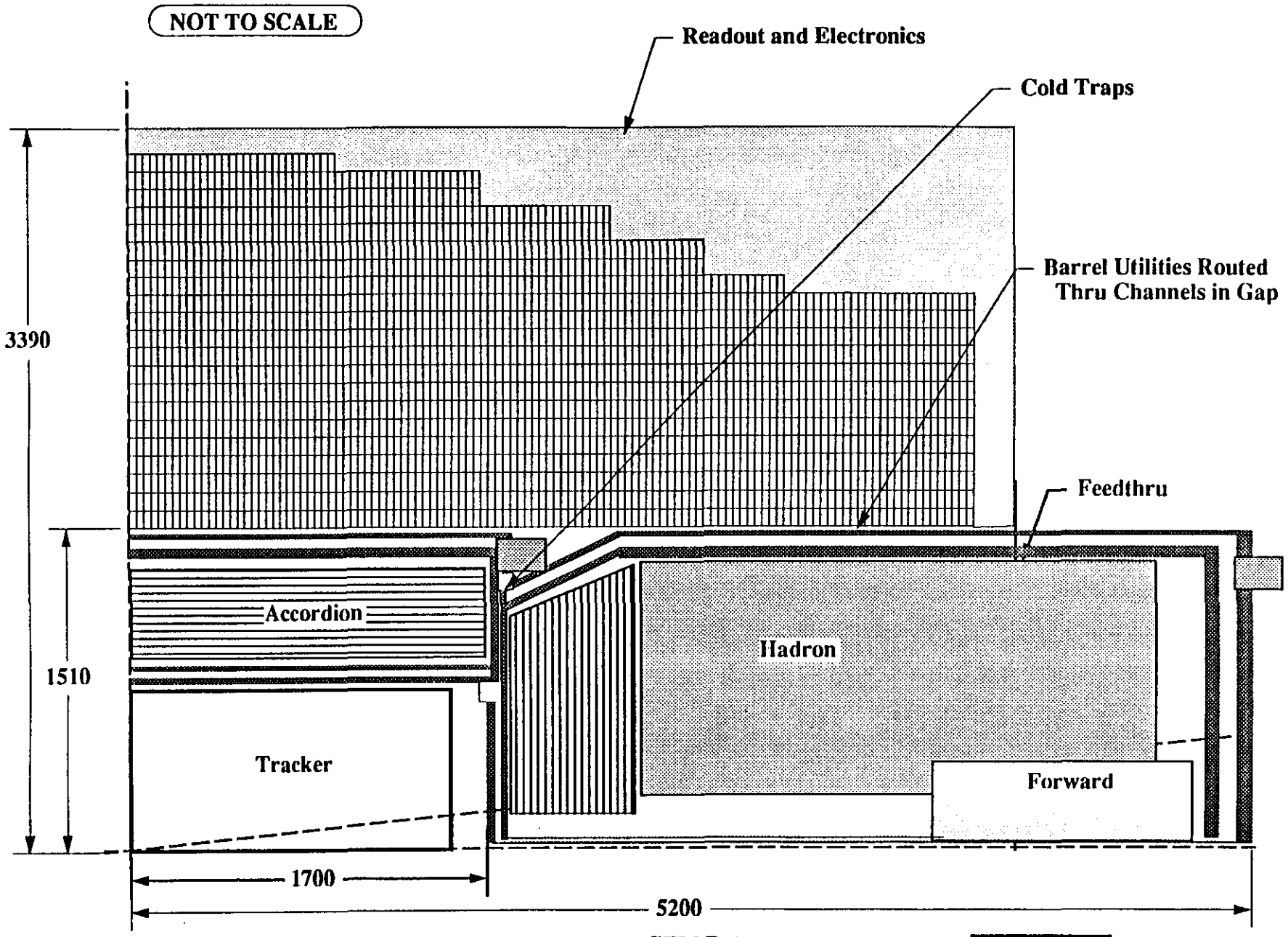
Rennich



GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
W/LKr EM Calorimeter

G.03.T.023

Rennich

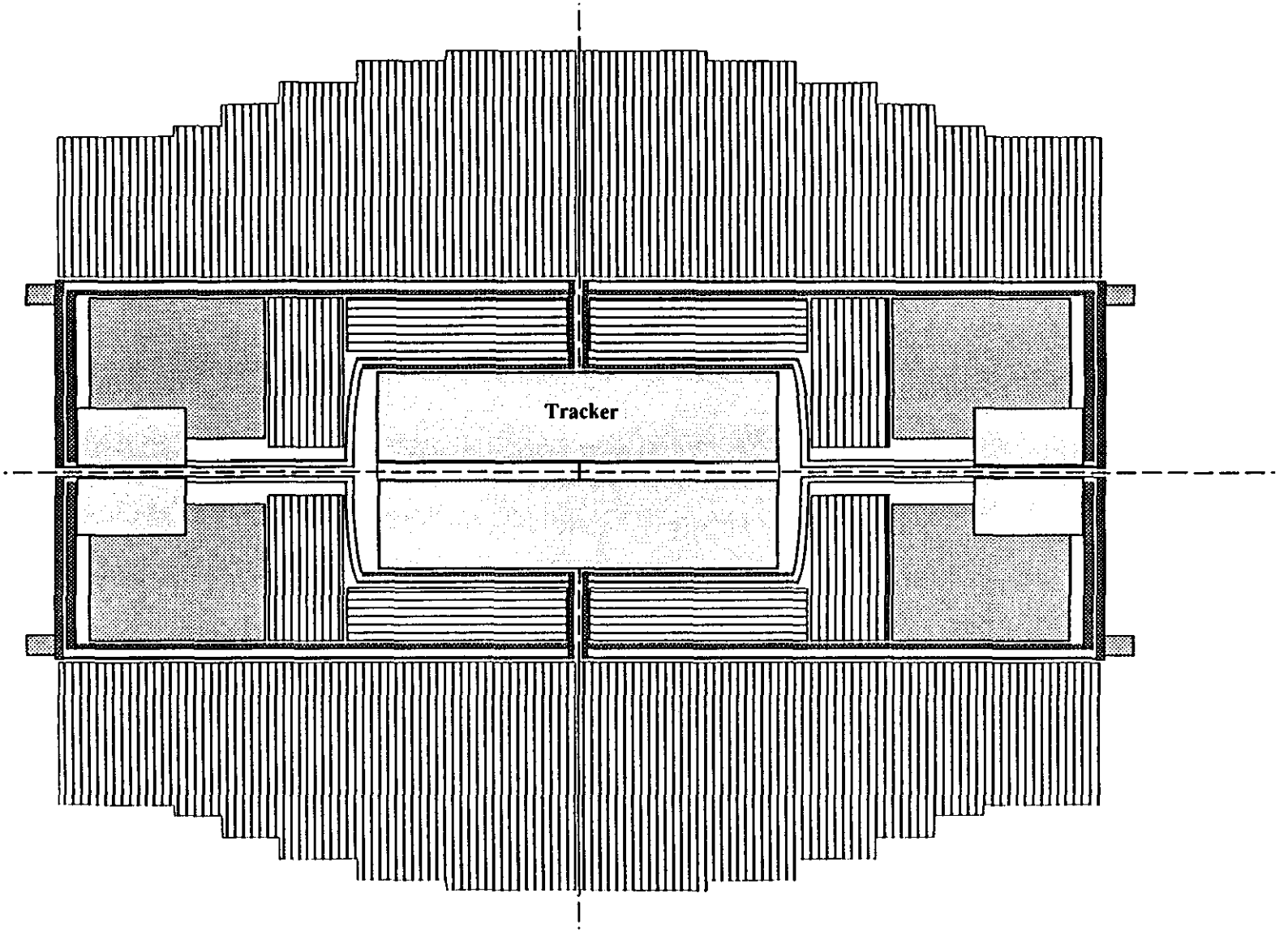


GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
W/LAr EM Calorimeter

Option IIIA

G.03.T.022

Rennich

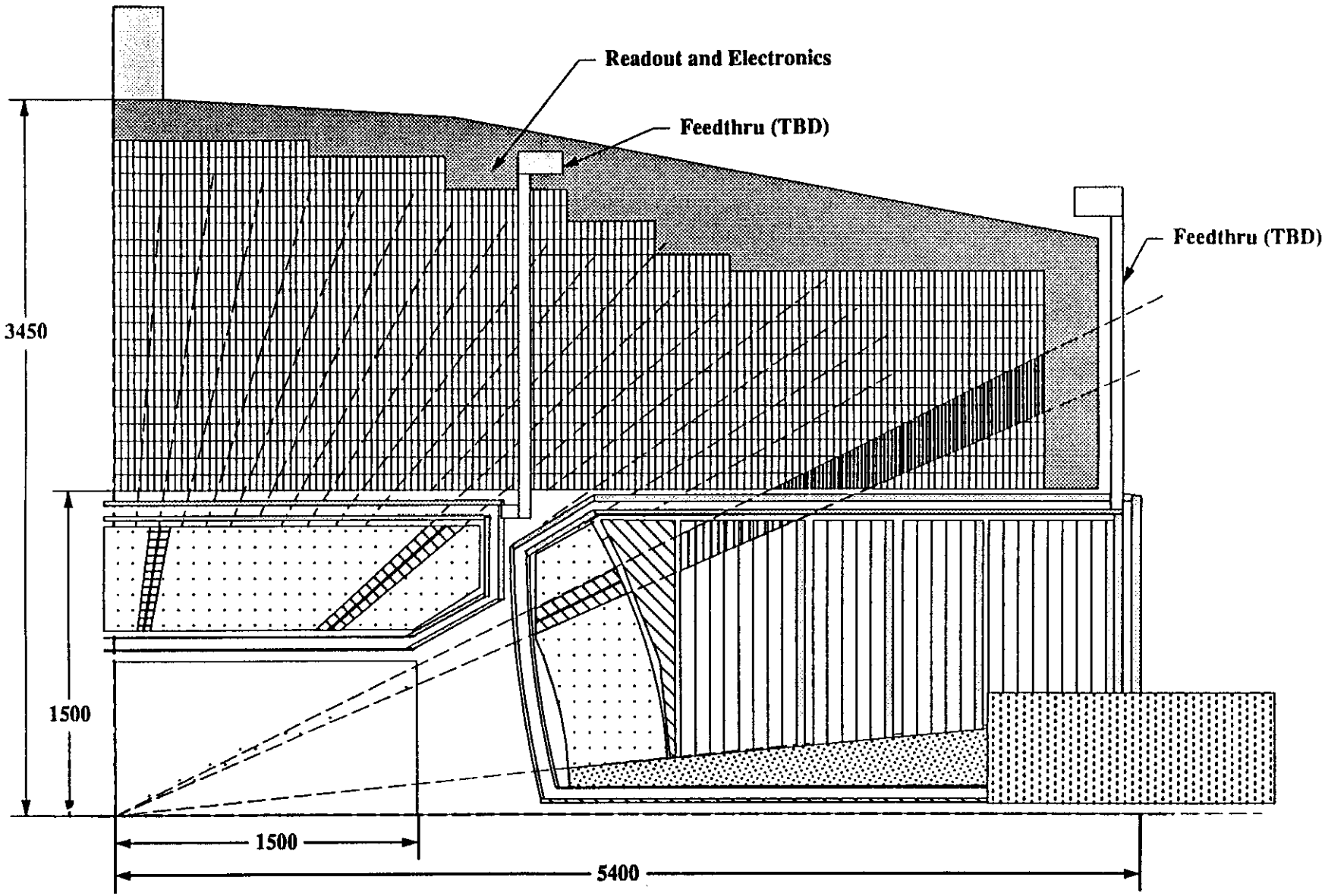


G.03.T.019

Option IA
(aka KM Option)

GEM Detector
Plastic Tile/Copper
Hadron Calorimeter
W/LAr EM Calorimeter

Rennich



GEM Detector
Plastic Tile/Copper
Hadron Barrel Calorimeter,
LAr EM - Hadron End Cap and
LKr EM Barrel Calorimeter

G.03.T.018

Rennich