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SOLENOIDAL DETECTOR NOTES

TILE CALORIMETER MODULE COST ESTIMATE

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July 11, 1990

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11-JUL-1990

Doucment File Location:

CSA::DISK$PHYSICS03:[SDCUSER.DOCS]SDC-90-00050.TXT (THIS FILE)
SDC-90-00050.IGESFLD (2-D IGES FILE)

This note is an attempt to estimate the cost of a SINGLE 'fake' calorimeter module, to be used as a costing example for the calorimeter sub-groups of the SDC collaboration. The cost estimates should provide at least 2-D mechanical drawings indicating the major dimensions, and drawings of each module type, indicating internal structure. The preferred format for text is ASCII text files, graphs in TOPDRAWER or HPLOT and mechanical drawings in IGES 2D format. If all text and graphics are 'digitized', it will make it simpler to transfer drawings, and they can be stored in a library with immediate access for all.

In what follows, I have created a mechanical design for a single module, and attached some costs to various components, providing the source of information where possible. In the best of worlds, all costs are documented, and it would be nice if the various calorimeter groups could relate their cost estimates to actual prototype costs, engineering cost estimates or manufacturer's quoted prices. Some caution must be exercised when using information from prototypes in order to correctly account for indirect charge backs (ie salaries or standing blanket orders). Labor estimates are easiest to understand when they include both the estimate of man hours as well as labor cost (a well known way of making things look cheaper is to use minimum wage for labor). While the calorimeter is agreed (via the EOI) to begin at r = 2250 mm for the barrel and z = 4700 mm at the endcaps, the outer dimensions are dependent on the technology, absorber, pre-radiator, and shower max detector (assuming of these items are needed for the calorimeter you are contemplating).

Therefore, every calorimeter group needs to calculate it's own estimate for the outer dimension. For this model I have chosen a lead/scintillator design, 9 interaction lengths thick at theta = 90 deg, using the dimensions from the EOI_Type_S design. For the purposes of this exercise, I have CONSTRAINED the total thickness of the Electromagnetic and Hadron Calorimeter to 2115 mm. (ie the EOI dimension) It is clear that this forced me into some unpleasant choices. Hence, it is very important that each calorimeter proposal calculate the thickness appropriate for their calorimeter. The thickness of the calorimeter is not independent of the resolution, and I would suggest that the thickness at least be estimated assuming 25%/sqrt(e) for the EM section and 70%/sqrt(e) for the hadronic section and lead radiators. The depth of the calorimeter is probably also dependent on the constant term as well, but I don't know how to specify this. Do your best.
The careful reader will realize that the hadronic section of the calorimeter listed below does not have a stochastic term of 70%/sqrt(e). This is a consequence of constraining the total depth of the calorimeter to 2115 mm. If you would like use a different set of resolutions or radiator, feel free to do so, but it would be nice to compare every one with the same resolutions. Choosing the same radiator helps reduce the uncertainty in the cost comparison, and I think everyone can use lead.

The Fake Design:

The calorimeter is divided in to 5 bays, three cental bays and two endcap bays. The tower structure of the calorimeter is shown the accompanying drawing and Table I-III (The program for generating Table I- III is available; contact KADEL@LBL. A mechanical drawing of the overall

calorimeter segmentation may be found in the File

CSA::DISK$PHYSICS03:[SDCUSER.DOCS]SDC-90-00050.IGESFLD

This is a 2D IGES file, which looks like the likely candidate format for transferring mechanical drawings around the collaboration and the world. Please try to learn how to read this file.
You may need help from you local CAD jockey. You can have access to the CSA cluster via the User id SDCUSER (password :SDC_GENERAL).

The approximate segmentation is (0.05 x 0.05) in (eta x phi).
In the barrel, the delta(phi) has been chosen as 2 * pi/128.
The delta (eta) segmentation was approximated by making towers with constant delta(z) at a given radius. I have assumed one EM section and two hadronic sections. This is consistent with dividing the calorimeter into central and endcap bays, where in the overlap region between the central and endcap the hadron towers are split in half for mechanical reasons. Each longitudinal section is read by two phototubes for redundancy. Hence, there are 6 PMT's per logical hadron tower. There is also a pre-radiator and shower max detector. The total number of logical hadron towers is 10,816.

The pre-radiator in this model is just a single scintillator tile with the same granularity as the hadron calorimeter. We assume it to be read out with a single fiber per tower to one channel of a multi-channel (256) PMT. We will need one such PMT per calorimeter module for this purpose.

The shower max detector consists of an orthogonal(z-phi) set of scintillator strips, each scintillator strip read out via a single fiber to a multi channel PMT. The strip dimensions have been adjusted to cover roughly the same area per strip with a segmentation of about 1 cm in either coordinate. As I show below I ended up with 256 strips in z and 256 in phi, each strip covering about 90 cm**2.

The radial dimensions for a tower in the middle calorimeter bay are as follows:

```
r = 2250 mm      _______________
                |               |
                |    EM         |
                |   (265mm)     |
                |               |
                |               |
r = 2515 mm      _______________
                |               |
                |               |
                |    Had        |
                |               |
                |   (1850 mm)   |
                        .
                        .
                        .
                |               |
                |               |
                |               |
                |               |
                |               |
r= 4365 mm       _______________
                |               |
                |     Fe        |
                |   (300mm)     |
                |(flux return)  |
r= 4665 mm       _______________
```

Details of the EM Section (25 X0 thick):

A single 'radiator-detector' layer consists of

5.25 mm Pb radiator
2.50 mm Scintillator
0.75 mm Wrapping plus tolerance.

8.50 mm (= 1.0 radiation length exactly, incl scint and wrapping)

weighted average area of EM cal scintillator plate = 185 cm **2

(Note that to 2nd order the weighted average area of the scintillator tile is equal to the area of the Pb radiator plate. We will use this fact to calculate the total volume of lead).

Internal EM Mechanical Structure:

```
r = 2250 mm                                  (0.0)
                 |  Mech    (15.0)|
                                             (15.0)
                 |Pre rad   (10.0)|
                                             (25.0)
                 |                 |
                 | 7 X0     (59.5)|
                 |                 |
r = 2334.5 mm                                (84.5)
                 |Shwr max (12.5)|
                                             (97.0)
                 |                 |
                 |                 |
                 |                 |
                 | 18 X0   (153.0)|
                 |                 |
                 |                 |
                 |                 |
                 |                 |
                 |                 |
                                             (250.0)
                 | Mech     (15.0)|
r= 2515 mm                                   (265.0)
```

Strip chamber at shower max (r = 2334.5mm):

```
|<----------------- del(z) = 2490mm------------->|
 ____________________________________________________   ______
|                        |                          |     |
|                        |                          |     |
|                        |                          |  del(r-phi) = 916mm
|                        |                          |     |
|                        |                          |     |
 ____________________________________________________   ____
```

use 256 strips in z each strip 916mm x 9.7mm, 2.5 mm thick, incl wrapping + tol

use 2 x 128 strips in phi, each strip 1245mm x 7.1 mm , 2.5 mm thick, incl wrapping + tol

Hadron Calorimeter:

The hadron calorimeter is assumed to be a cast monolithic structure equivalent to:

Pb radiator plate thickness	14.0 mm
Scintillator plate thickness	3.5 mm
wrap + tolerance	1.0 mm
total	18.5 mm per layer

weighted average area of hadron tower scintillator plate = 395 cm**2

Depth: 100 layers x 18.5 mm = 1850 mm total.

The back bone of each module is 30cm of steel. Outside dimensions 1831 mm x 3730mm x 300mm, equivalent to 16.2 T.

Summary:

Total scint depth of calorimeter = (100 x 3.5 mm + 25 * 2.5 mm)
= 412.5 mm Scint
= 1 radiation length!
= .5 interaction lengths!

Total Pb depth of calorimeter = (100 x 14.0mm + 25 * 5.25mm)
= 1531.25 mm
= 9.0 interaction lengths

Materials and costs For Middle Calorimeter bay:

Assume that middle bay is divided into 16 phi modules (at 100 T/ module, this is a little to heavy; see below)

According to the IGES drawing, there are 16 x 8 EM towers, 12 x 8 full hadron towers and 4 x 8 half- hadron towers in a central module.

EM Section:

		Source of estimate
PMT:		
1 multi channel for Pre radiator	10.0K	(est phillips)
2 multi channel for shwr max	20.0K	"
2 x 16 x 8 = 256 PMT @ $116 incl base	29.7K	(Zeus)
256 shield+ mechanical structure @ $199	50.9K	(Zeus)
256 Laser Calibration @ $61	15.6K	(Zeus)
sub-total	126.2K	
shipping @ 15 %	18.9K	(Zeus)
Total	$145.1K	
Scintillator		
Cal		
16 x 8 x 25 = 3,200 plates		
3,200 x 185 cm**2 x 0.25 cm x $0.08	11.8K	(Zeus)
labor 1 hr/plate, $25/ hr	80.0K	(Sulak)
3,200 wrapping material, etc @ $1.5 ea	4.8K	(Zeus)
256 light guide @ $100	25.0K	(Guess)

sub-total	121.6	
shipping @ 5%	6.1K	(Zeus)
Total	$127.7K	

Pre- rad

16 x 8 = 128 plates

128 x 165 cm**2 x 0.25 x $0.08	0.4K	(Zeus)
labor 1 hr/plate $25/hr	3.2K	(Sulak)
128 wrapping material @ $1.50 ea	0.2K	(Zeus)
1 light guide @ 100	0.1K	(Guess)
sub total	3.9K	
shipping @ 5 %	.2K	(Zeus)
Total	$4.1K	

Shower max

512 x 22 cm**3 x $0.08	0.9K	(Zeus)
labor 1 hr/plate $ 25/hr	12.4K	(Sulak)
512 wrapping material @ $1.5	0.8K	(Zeus)
2 light guide @ $100	0.2K	(Guess)
sub-total	14.3	
shipping @ 5%	.7	
Total	$15.0	

Radiator + Mech

3,200 x 0.525 x 185 cm**2 x 11.4
= 3.54 T @ $5k/T

	17.7K	(Westinghouse)
Misc Mech	5.0K	(Guess)
sub total	22.7K	
shipping $ 0.54K/ Ton	1.9K	(Zeus)
Total	$24.6K	

Hadron Section

PMT:

(pmt)x phi * (2 sec * twr + 1 sec x twr)
2 x 8 * (2 * 12 + 1 * 4)
= 448 PMt

448 PMT @ $116 incl base	52.0K	(Zeus)
448 shield+ mechanical structure @ $199	89.2K	(Zeus)
448 Laser Calibration @ $61	27.3K	(Zeus)
sub-total	168.5K	
shipping @ 15 %	25.3K	(Zeus)
Total	$193.8K	

Scintillator

Cal

phi x eta x depth + phi x eta x depth
8 x 12 x 100 + 8 x 4 x 50
= 11,200 plates

11,200 x 395 cm**2 x 0.35 cm x $0.08	123.8K	(Zeus)
labor 1 hr/plate, $25/ hr	280.0K	(Sulak)
448 light guide @ $100	44.8K	(Guess)

11,200 wrapping material @ $1.50	16.8K	(Zeus)
sub total	465.4K	
shipping 5%	23.3K	(zeus)
Total	$488.7K	

Radiator + Mech

11,200 x 1.4 x 395 cm**2 x 11.4 = 70.6 T @ $5k/T	353.0K	(Westinghouse)
Misc Mech	50.0K	(Guess)
total	403.0k	
shipping @ 0.54/T	38.1	(Zeus)
Total	$441.1K	

Iron Backing (flux return)

30 cm x 373 x 183 cm = 2.05 m**3		
weight = 2.05 x 7.9 =16.2 T		
16.2 T @ $2.5K/ton =	40.5K	(RTK)
shipping @ $0.54/T	8.8	(Zeus)
Total	$49.3K	

Shipping of completed module to SSCL

Total Weight
70.6T + 16.2T + 3.5 T = 90.3 T
+ stand = 100T

@ $0.54K/Ton $54.0K (Zeus)

Grand Total/ module (approx 100 T) $1,543.4K

Not yet included (and should be done for all calorimeter types):

Module design for the 2 other cental bays
Module design for 2 endcap bays
Mechanical support for Bays
Facilities support for calorimeter
Test Beam hardware and fixtures
Assembly at SSCL
Quality control
Readout Electronics
Cabling @ SSCL
Checkout at SSCL
EDIA
Assembly Areas for modules
Assy Fixtures and Tooling for modules.

TABLE I: CALORIMETER ASSUMPTIONS:

ASSUMES EQUAL DELTA(Z) FOR CENTRAL CAL

Inner radius of central elec cal (cm) 225.00
Half length of coil(cm) 450.00
distance to face of endcap calorimeter (cm) 470.00
eta min of endcap calorimeter 1.35
eta max of endcap calorimeter 3.00
typical length of tower edge (cm) 10.00
maximum number of cells in phi at outer radius 128
min symmetry of calorimeter in phi 16
min eta bin size 0.05
Total Hadron towers 10816
pi 3.141593

Table II: CENTRAL CALORIMETER TOWER SEGMENTATION

Dimensions evaluated at r = 225.000 cm

Total Barrel Hadron towers = 3456

	Z(0) (cm)	Z(I) (cm)	The(O) (deg)	The(I) (deg)	Eta(O)	Eta(I)	d_eta	del_Z (cm)	del(R_phi) (cm)	phi bins
1	0.000	14.992	90.000	86.188	0.000	0.067	0.067	14.992	11.045	128
2	14.992	29.985	86.188	82.409	0.067	0.133	0.066	14.992	11.045	128
3	29.985	44.977	82.409	78.696	0.133	0.199	0.066	14.992	11.045	128
4	44.977	59.970	78.696	75.076	0.199	0.263	0.065	14.992	11.045	128
5	59.970	74.962	75.076	71.574	0.263	0.327	0.064	14.992	11.045	128
6	74.962	89.955	71.574	68.209	0.327	0.390	0.063	14.992	11.045	128
7	89.955	104.947	68.209	64.994	0.390	0.451	0.061	14.992	11.045	128
8	104.947	119.940	64.994	61.939	0.451	0.511	0.060	14.992	11.045	128
9	119.940	134.932	61.939	59.049	0.511	0.569	0.058	14.992	11.045	128
10	134.932	149.924	59.049	56.323	0.569	0.625	0.056	14.992	11.045	128
11	149.924	164.917	56.323	53.760	0.625	0.679	0.055	14.992	11.045	128
12	164.917	179.909	53.760	51.354	0.679	0.732	0.053	14.992	11.045	128
13	179.909	194.902	51.354	49.100	0.732	0.784	0.051	14.992	11.045	128
14	194.902	209.894	49.100	46.989	0.784	0.833	0.050	14.992	11.045	128
15	209.894	224.887	46.989	45.014	0.833	0.881	0.048	14.992	11.045	128
16	224.887	239.879	45.014	43.167	0.881	0.927	0.046	14.992	11.045	128
17	239.879	254.871	43.167	41.438	0.927	0.972	0.045	14.992	11.045	128
18	254.871	269.864	41.438	39.820	0.972	1.016	0.043	14.992	11.045	128
19	269.864	284.856	39.820	38.304	1.016	1.058	0.042	14.992	11.045	128
20	284.856	299.849	38.304	36.884	1.058	1.098	0.041	14.992	11.045	128
21	299.849	314.841	36.884	35.551	1.098	1.138	0.039	14.992	11.045	128
22	314.841	329.834	35.551	34.300	1.138	1.176	0.038	14.992	11.045	128
23	329.834	344.826	34.300	33.125	1.176	1.213	0.037	14.992	11.045	128
24	344.826	359.819	33.125	32.018	1.213	1.249	0.036	14.992	11.045	128
25	359.819	374.811	32.018	30.976	1.249	1.283	0.035	14.992	11.045	128
26	374.811	389.803	30.976	29.994	1.283	1.317	0.034	14.992	11.045	128
27	389.803	404.796	29.994	29.067	1.317	1.350	0.033	14.992	11.045	128

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TABLE III: ENDCAP CALORIMETER TOWER SEGMENTATION

Dimensions evaluated at z = 470.000 cm

Endcap Hadron towers (one end)= 3680

	Rad(0) (cm)	Rad(I) (cm)	The(O) (deg)	The(I) (deg)	Eta(O)	Eta(I)	d_eta	del_phi (deg)	del(R_phi) (cm)	phi bins
28	261.243	246.810	29.067	27.705	1.350	1.400	0.050	2.813	12.824	128
29	246.810	233.335	27.705	26.402	1.400	1.450	0.050	2.813	12.115	128
30	233.335	220.732	26.402	25.157	1.450	1.500	0.050	2.813	11.454	128
31	220.732	208.925	25.157	23.966	1.500	1.550	0.050	2.813	10.835	128
32	208.925	197.847	23.966	22.829	1.550	1.600	0.050	2.813	10.256	128

33	197.847	187.440	22.829	21.743	1.600	1.650	0.050	2.813	9.712	128
34	187.440	177.651	21.743	20.706	1.650	1.700	0.050	3.214	10.515	112
35	177.651	167.595	20.706	19.625	1.700	1.755	0.055	3.214	9.966	112
36	167.595	157.538	19.625	18.531	1.755	1.813	0.058	3.214	9.402	112
37	157.538	147.482	18.531	17.421	1.813	1.876	0.063	3.750	10.311	96
38	147.482	137.425	17.421	16.299	1.876	1.944	0.068	3.750	9.653	96
39	137.425	127.369	16.299	15.163	1.944	2.017	0.073	4.500	10.793	80
40	127.369	117.312	15.163	14.015	2.017	2.096	0.080	4.500	10.004	80
41	117.312	107.255	14.015	12.855	2.096	2.183	0.087	4.500	9.214	80
42	107.255	97.199	12.855	11.684	2.183	2.280	0.096	5.625	10.530	64
43	97.199	87.142	11.684	10.504	2.280	2.387	0.107	5.625	9.542	64
44	87.142	77.086	10.504	9.314	2.387	2.508	0.121	7.500	11.407	48
45	77.086	67.029	9.314	8.117	2.508	2.646	0.138	7.500	10.091	48
46	67.029	56.973	8.117	6.912	2.646	2.807	0.161	7.500	8.774	48
47	56.973	46.916	6.912	5.700	2.807	3.000	0.193	11.250	11.187	32