RBX Cooling

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for the

HCAL RBX Group

Outline

- Introduction
- General Routing of RBX Services
- System Specifics
- RBX Power Consumption
- RBX Cooling Scheme
- Test Data
- Cooling in HE and HO
- Conclusions

Introduction

- Scheme to cool the HCAL readout system
  - electronics generate heat
  - heat affects the lifetime of the cards
  - cooling prolongs the card lifetime
  - reduces frequency of failure and access
- This is necessarily HB centric
  - other subsystems are not as far advanced
  - HE and HO will be discussed briefly at the end

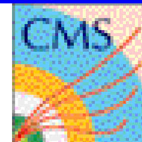
Introduction Continued

- Discuss general scheme for cooling RBX
- What kind of power dissipation is expected
  - along with safety factors
- The specifics of the RBX cooling
  - for the box in general
  - for the electronics in the box
- Show results of testing this method

Routing of Water Services

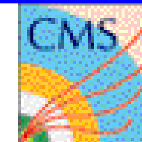
- Graphic shows general routing of the lines
  - each HB RBX gets an inlet and outlet
- Detail shows a connection to a single RBX

Water Services



- Flow Rate
  - a flow rate of 1.5 L/min should be sufficient
  - translates to an inlet pressure of <calculate>
- We intend to use copper cooling pipe
  - for all subsystems
- No special water chemistry is required
  - beyond experiments standard to prevent corrosion etc.
- Inlet temperature of 16 – 20 °C is sufficient

RBX Power Dissipation



- Power Dissipation
  - 1W/channel
  - Calib, CCM, QIE ≈ 6W/card
  - HB RBX
    - 23 QIE
    - 3 CCM
    - 2 Calibration
    - HV/LV
    - ≈ 200 W/RBX
- Safety Factor of 2x

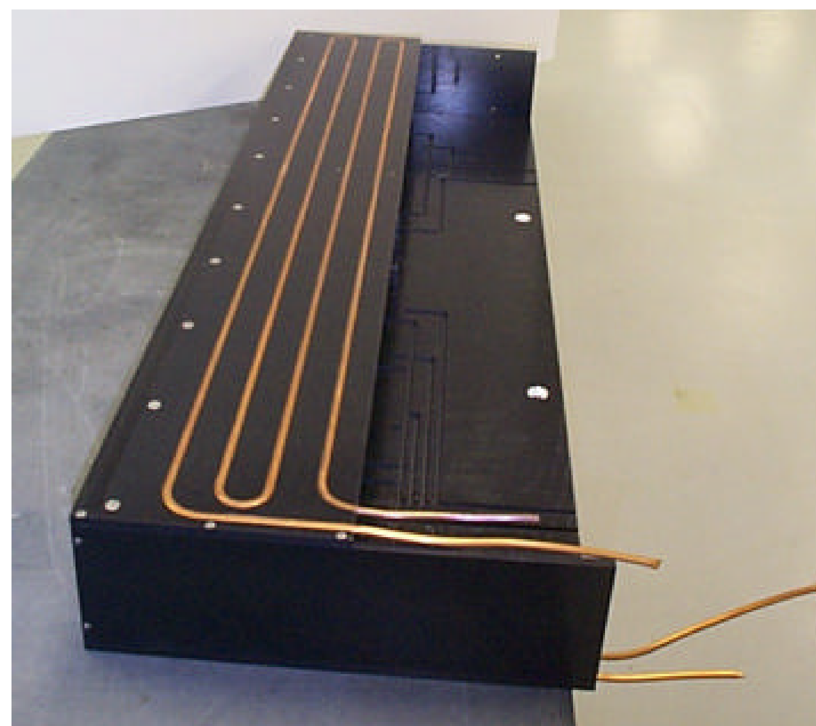
HB RBX	Number of Cards	W/Card	Total (W)
QIE	23	6	138
Cal	2	6	12
CCM	3	6	18
HV/LV	N/A	N/A	≈30
Total			198

Expect 7.2 kW of power in HB

Cooling aims to handle 400W for each RBX

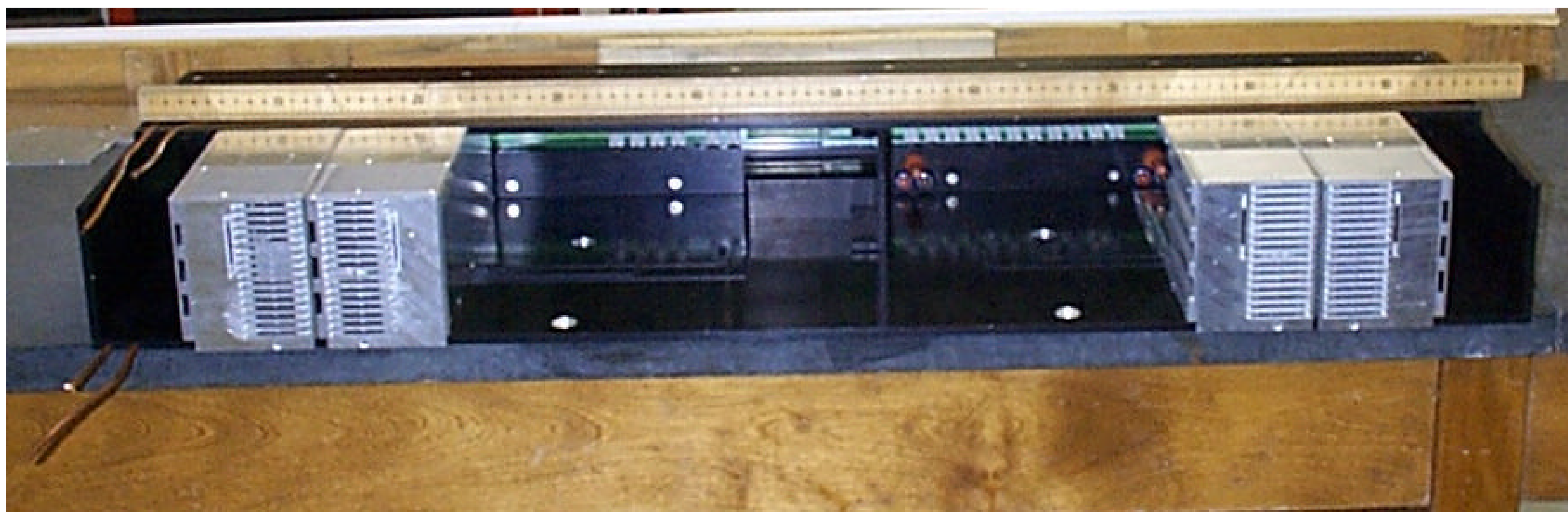
RBX Cooling Scheme

- Water flow through
  - 3/16 in. ID copper pipe
  - pressed into Al shell
  - top and bottom serially connected
    - pipes are soldered together with a sleeve
    - flex hose connection into system
- Pipes are only over electronics regions



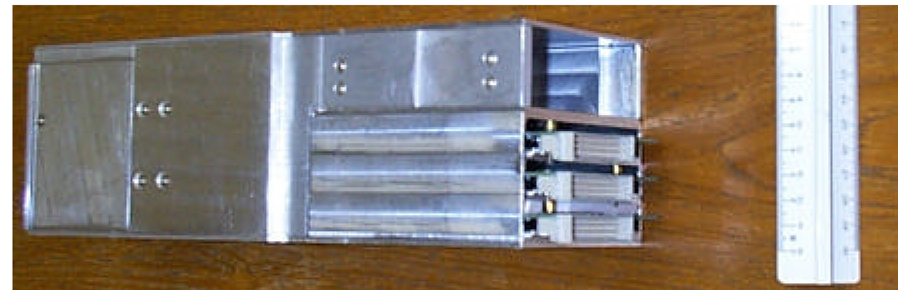
Thermal Coupling

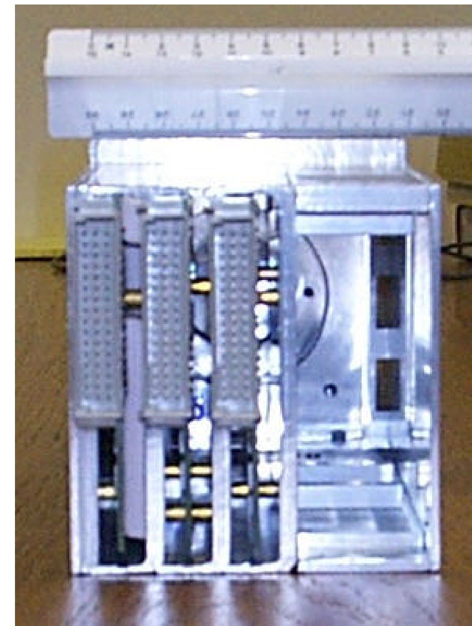
- Cooling by conduction
  - good thermal contact
  - tight fit is necessary
    - manufacturing tolerances
- Cards placed in Al channels and packed with thermal foam
  - provides a thermal path from the card to cooling



Thermal Extrusions

- Al extrusions provide
  - thermal conduction
  - solid mounting for card
  - tight fit to RBX
  - rigidity for the module
- Foam provides
  - electrical isolation
  - thermal conduction
    - from the card surface to the Al Extrusions
- Modularity as a bonus





RBX Thermal Tests

Flow Rate = 0.83 L/min

Inlet on Bottom plate, outlet on top

Average EquilibriumTemperatures (11:00 - 16:42)

$\langle T_{in} \rangle$ = 15.5c $\langle T_{out} \rangle$ = 16.2c $\langle T_{ambient} \rangle$ = 16.3c

$\langle T_{top} \rangle$ = 18.4c $\langle T_{bottom} \rangle$ = 17.0c $\langle T_{side1} \rangle$ = 19.8c

$\langle T_{side2} \rangle$ = 28.5c $\langle T_3 \rangle$ = 38.5c $\langle T_7 \rangle$ = 45.2c

T_7

T_3

T_{side2}

T_{top}

T_{bottom}

T_{side1}

T_{out}

$T_{ambient}$

T_{in}

Temperature (c)

50

45

40

35

30

25

20

15

10

9:52

11:57

14:02

16:07

Time of Day (08/28/00)

T_12

T_9

T_6

T_3

T_11

T_8

T_5

T_2

T_10

T_7

T_4

T_1

Amb

S_1

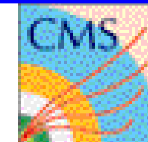
S_2

Top

Bot

T_in

T_out



Card Temperature Gradient

Ambient temperature = 16.3 Flow Rate = 0.83 L/min

18.4

41.2 45.0 43.4

41.9 41.6 45.2

40.9 44.0 42.9

38.5 41.5 40.4

Readout

Power

19.8

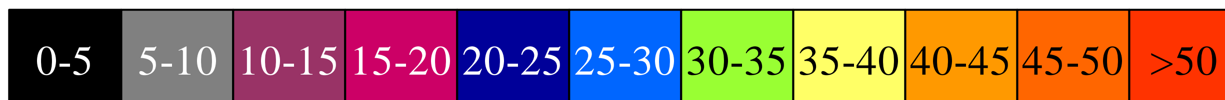
28.5

17.0

15.5

16.2

Legend



RBX Thermal Tests

Flow Rate = 0.83 L/min

Inlet on Bottom plate, outlet on top

Average EquilibriumTemperatures (11:00 - 16:42)

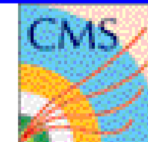
$\langle T_{in} \rangle$ = 15.4c	$\langle T_{out} \rangle$ = 16.1c	$\langle T_{ambient} \rangle$ = 16.4c
$\langle T_{top} \rangle$ = 18.4c	$\langle T_{bottom} \rangle$ = 16.9c	$\langle T_{side1} \rangle$ = 19.7c
$\langle T_{side2} \rangle$ = 28.5c	$\langle T_3 \rangle$ = 38.4c	$\langle T_7 \rangle$ = 45.1c

Curve labels: T_7, T_3, T_{side2}, T_{top}, T_{bottom}, T_{side1}, T_{out}, $T_{ambient}$, T_{in}

Temperature (c): 10, 15, 20, 25, 30, 35, 40, 45, 50

Time of Day (08/29/00): 10:55, 12:18, 13:42, 15:05, 16:29

Legend: T_12, T_9, T_6, T_3, T_11, T_8, T_5, T_2, T_10, T_7, T_4, T_1, Amb, S_1, S_2, Top, Bot, T_in, T_out



Card Temperature Gradient

Ambient temperature = 16.4 Flow Rate = 0.83 L/min

18.4

41.1 44.8 43.2

41.8 41.5 45.1

40.8 43.9 42.8

38.4 41.4 40.3

Readout

Power

19.7

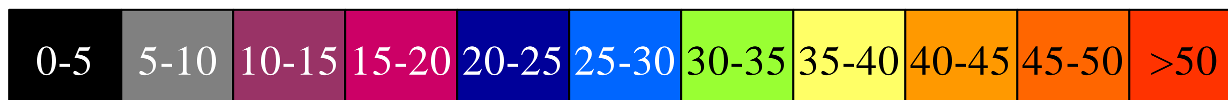
28.5

16.9

15.4

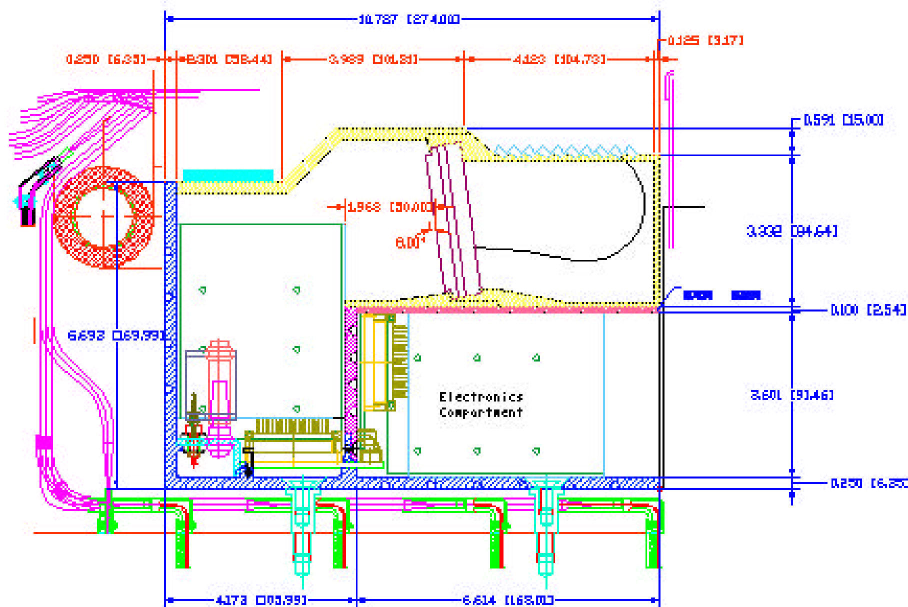
16.1

Legend

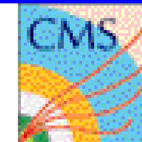


HE RBX Cooling

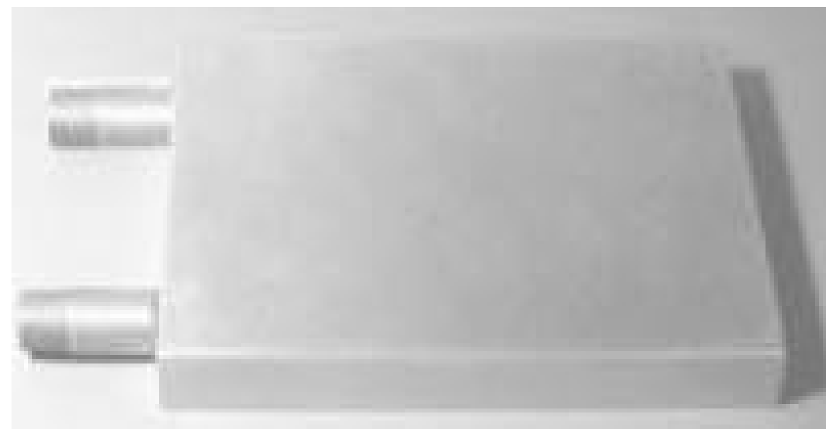
- HE is different than HB
  - 6 fewer QIE / RBX
  - 36W less power
- Geometry very different
  - cooling works the same
    - Cu pipes pressed into Al
  - pipe routing is messy
  - single – sided cooling of Calib/CCM components
- Not yet tested
  - should work as well as HB



HO RBX Cooling

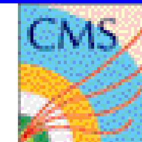


- HO RBX
  - less power than HE
  - not fully designed
  - very tight constraints
  - little vertical space
- Similar scheme to HE
  - use pipes pressed into walls between the RMs
- Commercially available parts



http://www.acktechnology.com/

Conclusions



- We can suitably cool the RBX electronics
  - cooling is sufficient even with a 2x safety factor
- No special requirements
- Monitoring by the slow control system (?)
- HB is tested and ready to go
  - HE and HO are not as far along
  - Design is similar and presents no special problems