Low mass carbon based support structures for the HL-LHC ATLAS pixel forward disks

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Introduction

- Large Hadron Collider (LHC) at CERN luminosity will increase
  by an order of magnitude
  around 2020 to the high luminosity HL-LHC
- The ATLAS experiment will require a new tracker
  radiation damage and event density & rate
- This tracker will consist of
  pixel and strip devices
  both as barrel and endcap disks.

The new pixel detector

Smaller pixels -> to minimize occupancy & increase spatial resolution

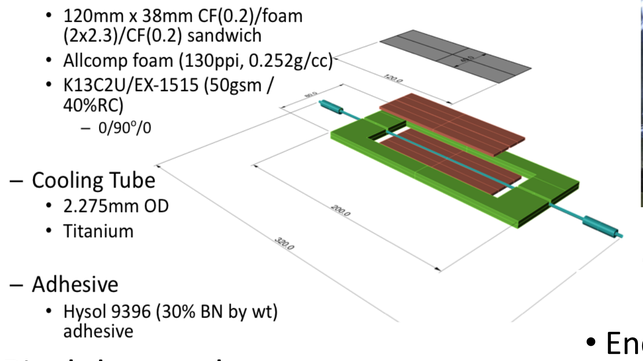
Extremely radiation hard silicon detectors.

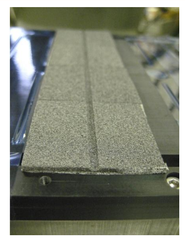
New front-end electronics to cope with the higher data rates.

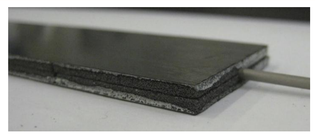
These devices will be supported by low mass thermal-mechanical structures.

Pixel mechanical test structure

- Sandwich
  - 120mm x 38mm CF(0.2)/foam (2x2.3)/CF(0.2) sandwich
  - Allcomp foam (130ppi, 0.252g/cc)
  - K13C2U/EX-1515 (50gsm / 40%RC)
    - 0/90°/0
- Cooling Tube
  - 2.275mm OD
  - Titanium
- Adhesive
  - Hysol 9396 (30% BN by wt) adhesive

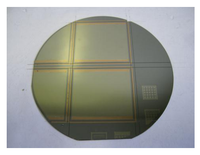






Pixel dummy heaters

- 500um thick Silicon
- 1um Tungsten with Cu solderable strip
  - Thermal simulation verification
  - Disk loading

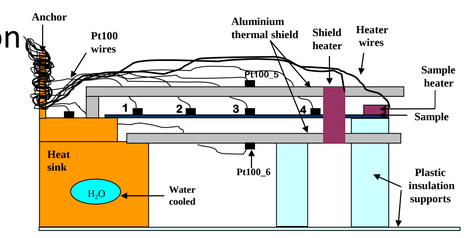


Test box / Cooling system

- Enclosure at 20C flushed with N2
- CO2 from gas bottle
  - via chiller
  - & needle valve
- Evaporation T = -33C
- Measure with IR camera

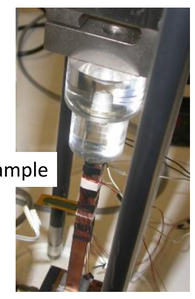
Thermal measurement test apparatus

All measurements are steady state
Systems are verified against copper and silicon
Temperatures measured with 4 wire PT100s
Heat from 4 wire electrical heaters



Through-thickness measurements for glues and thin films

Sample between Cu rods
Pressure and DC340 at interfaces
Measured at RT

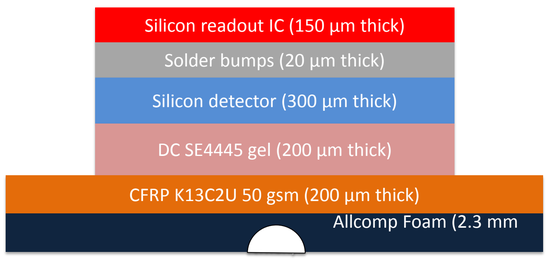


In-plane measurements for thin sheets

Sample surrounded by radiation shield
Under vacuum (10^{-5} mbar)
Measurements from -30C to +20C

Thermal testing and Simulations

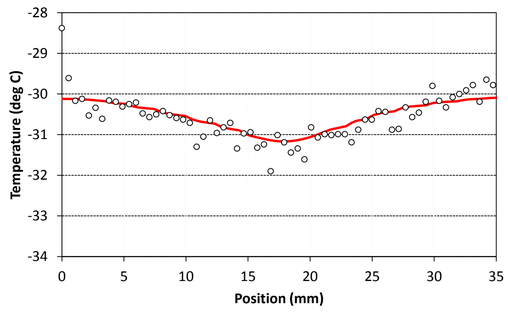
Cross-section of loaded cooling structure



- Solder bumps at 5.3% fill factor
- DC SE4445 100% coverage
- No glue between foam and pipe

Test object simulated and measured in dry air

- Input data from measurements
- No glue between foam and pipe
- HTC CO2 = 10k $Wm^{-2}K^{-1}$
- HTC still air = 5 $Wm^{-2}K^{-1}$
- Good agreement with data



Thermal conductivity results Foam & CFRP

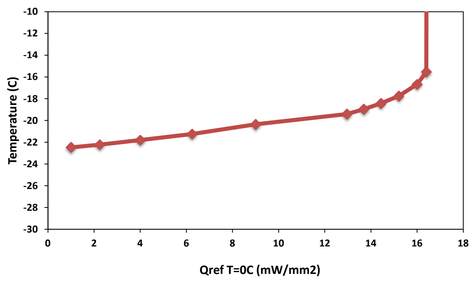
Allcomp foam

Direction	Conductivity (W/mK)	
	ρ=0.22g/cm³	ρ=0.36g/cm³
X	34	74
Y	38	62
Z	34	64

CFRP	K13D2U 0-90-0 100 gsm	K13C2U 0-90-0 100 gsm
Thickness (um)	230	254
0 - Predicted	318	229 ± 7
0 - measured	294 ± 20	285 ± 12
90 - predicted	159	114 ± 6
90 - measured	144 ± 20	
Through thickness	1.20 & 0.96	1.3 & 1.1

K13D2U kf = 800 W/mK: K13C2U kf = 620 W/mK. Density = 2.19 gcm^{-3}

Thermal run-away on the test structure

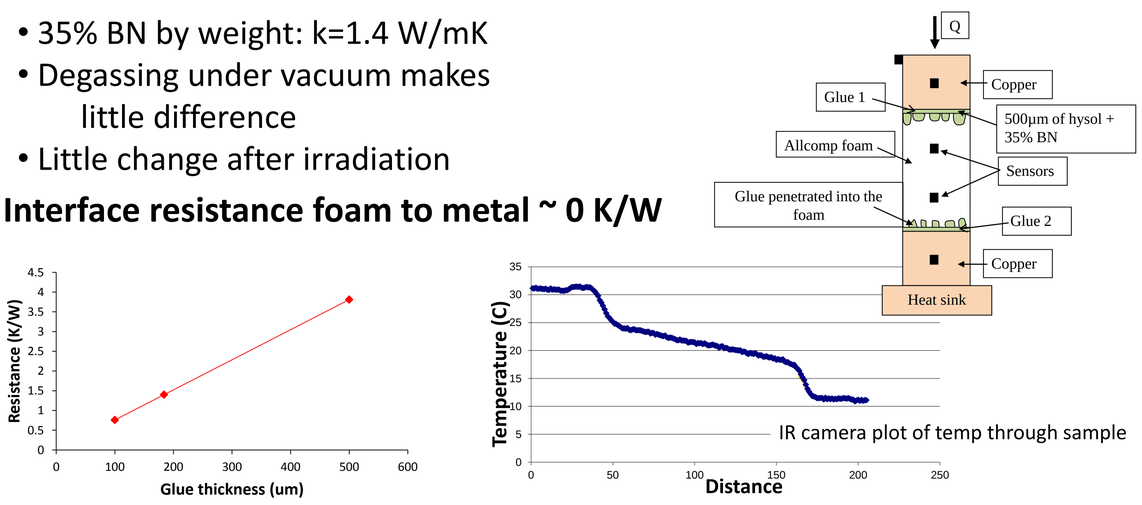


- ASIC power set to 1.56 W/chip (0.41 Wcm^{-2})
- Nominal detector power ~ 3 $mWmm^{-2}$ at 0C
- Exact power depends on sensor thickness and desired collected charge
- Factor of 4 in safety

Conductivity of BN filled Hysol 9396 epoxy

- 35% BN by weight: k=1.4 W/mK
- Degassing under vacuum makes little difference
- Little change after irradiation

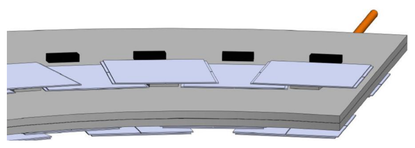
Interface resistance foam to metal ~ 0 K/W

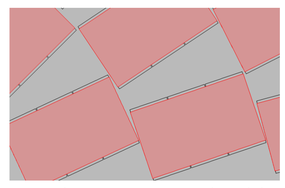


IR camera plot of temp through sample

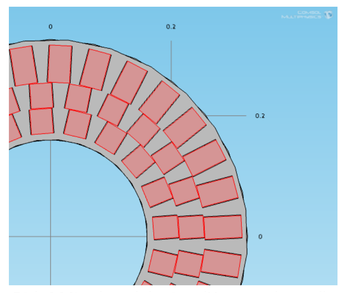
Proposed design

Disks with have an inner radius of 130 mm and outer radius of 315 mm
3 rings of quad(hex) modules required.
Services for middle ring will be a challenge





Zoom showing space around modules



Disk 4 Mixed module sizes (Hex, quad, quad)

Phi overlap on modules

all disks on in ring to be placed on the same side
gives simpler tape design
- Lower contact area to high modules => Detailed FEA to take place

Pixel 2012: International Workshop on Semiconductor Pixel Detectors for Particles and Imaging , September 2012, Japan