LG
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Update to Thermal Testing of a HFT Ladder Mechanical Mockup

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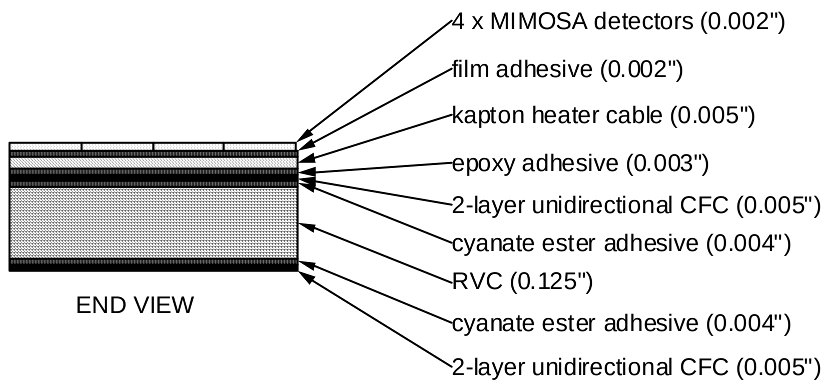
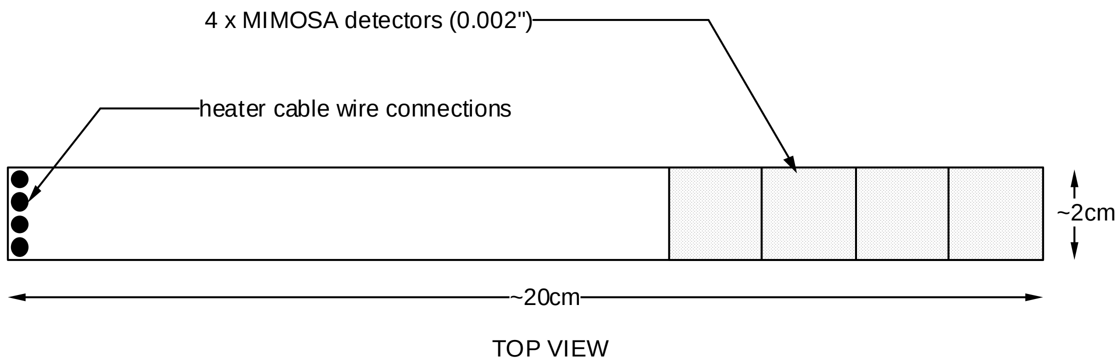
Thermal pixel analysis by Devis Contrato.

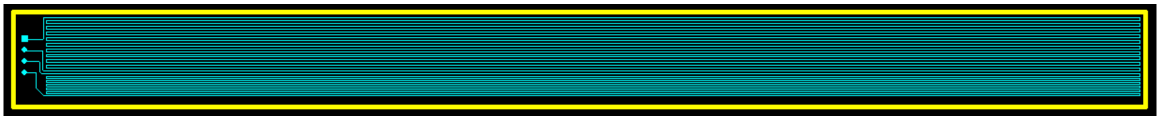
In 2004 some initial testing was done to measure the heat that could be dissipated by air cooling in a pixel vertex detector. These initial results are reported here, http://www.lbnl.leog.org/ir_prelim_writeup.htm.
We have done additional testing with much more representative mechanical mockups and report the results.

Mechanical Mockup – We have developed the models that we are using for measuring the mechanical and heat transfer properties since the last set of tests. We now have mechanical models that closely approximate what we expect to deploy as ladders in the HFT. The current mechanical mockup is shown schematically below;



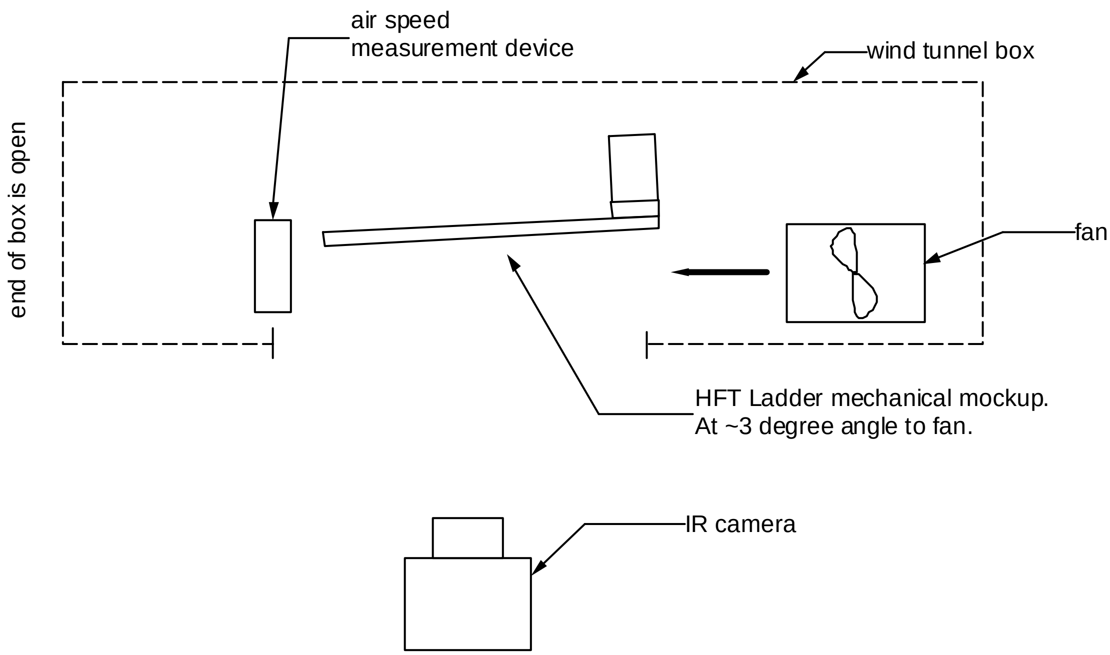


The heater cable consists of two areas of serpentines PCB traces on 0.005” Kapton. The two areas allow us to inject heat from the heating traces into different area of the silicon to more closely mock up different heat loads from pixel and digital processing parts of the sensor chips. This is shown below;



As one can see, the upper 75% of the cable is one independent heater trace and the lower 25% of the cable is another.

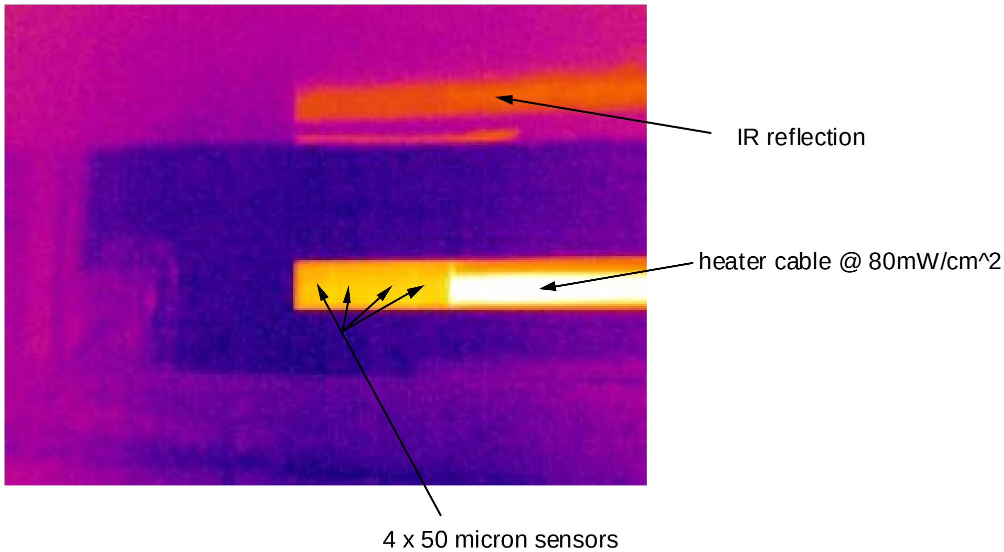
Test Setup – We used the same basic setup as in the previous test with the exception that the IR camera was a much improved device with a clean firewire connection to a laptop PC. The setup is shown below. We used some shielding around the camera to limit the IR reflections from the surface of the sensors.



We took initial data under the following conditions;

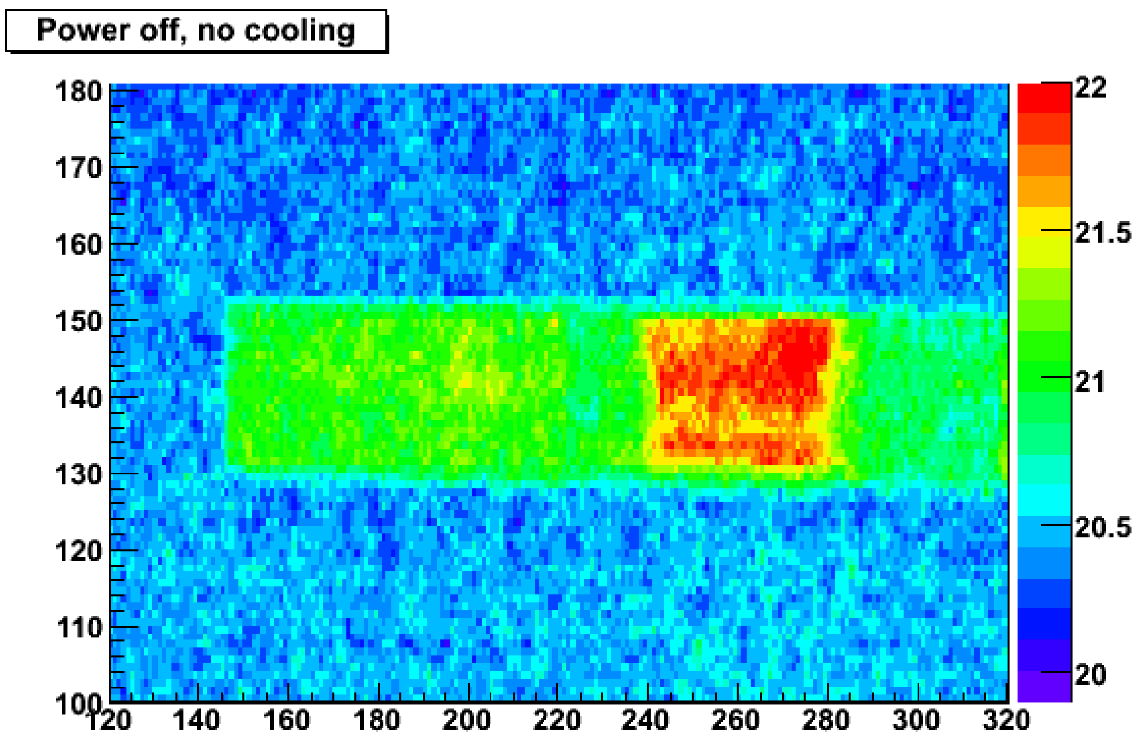
Heater cable – set to 80 mW / cm^2 (for the whole ladder surface) with only the larger area section of the heater cable energized.
Fan Speed – 0, 0.65, 1.1, 2.0, 3.5, 4.5, 0 m/s

The following picture key illustrates what is seen in the thermal images

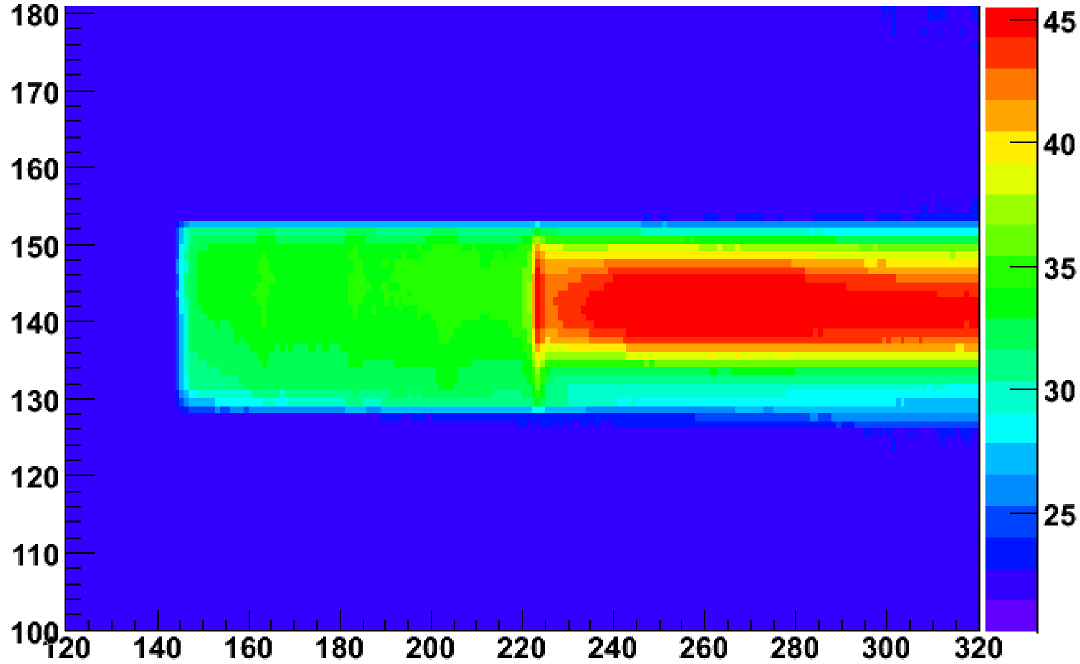


Later images have been cropped to remove the IR reflection and to show only the ladder area.

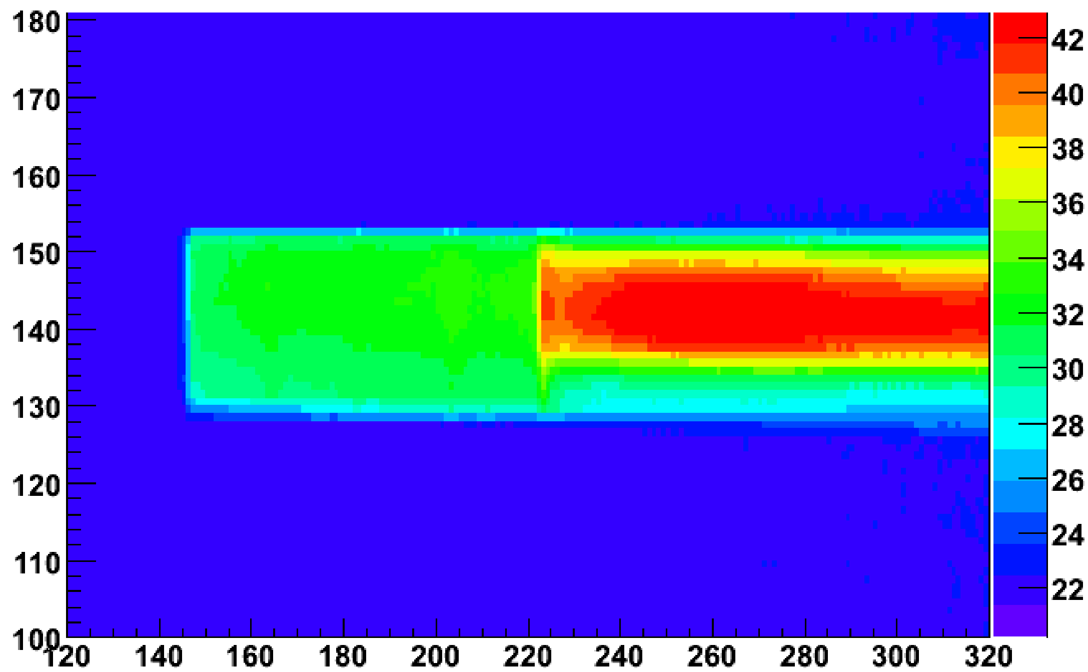
Thermal image for the various air speeds are shown below. Note the changing temperature/color scale.

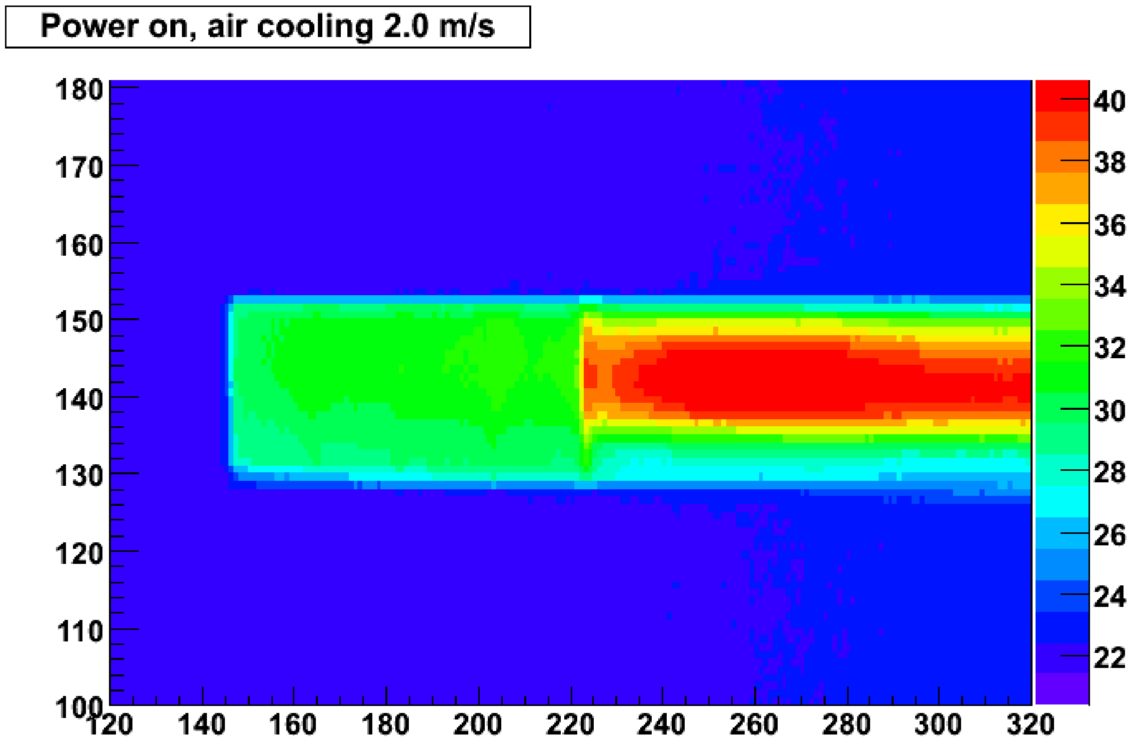


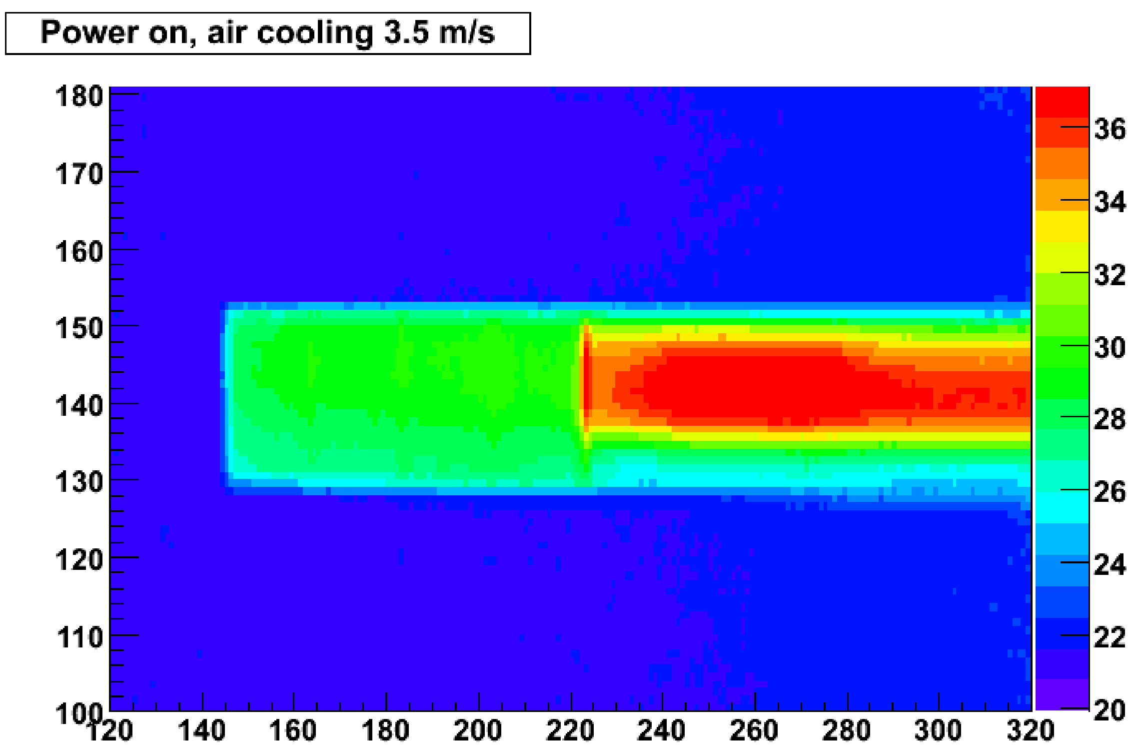
The red spot seen above is an IR reflection that is not over the area of the sensors and not used in the calculations, Power on, air cooling 0.65 m/s

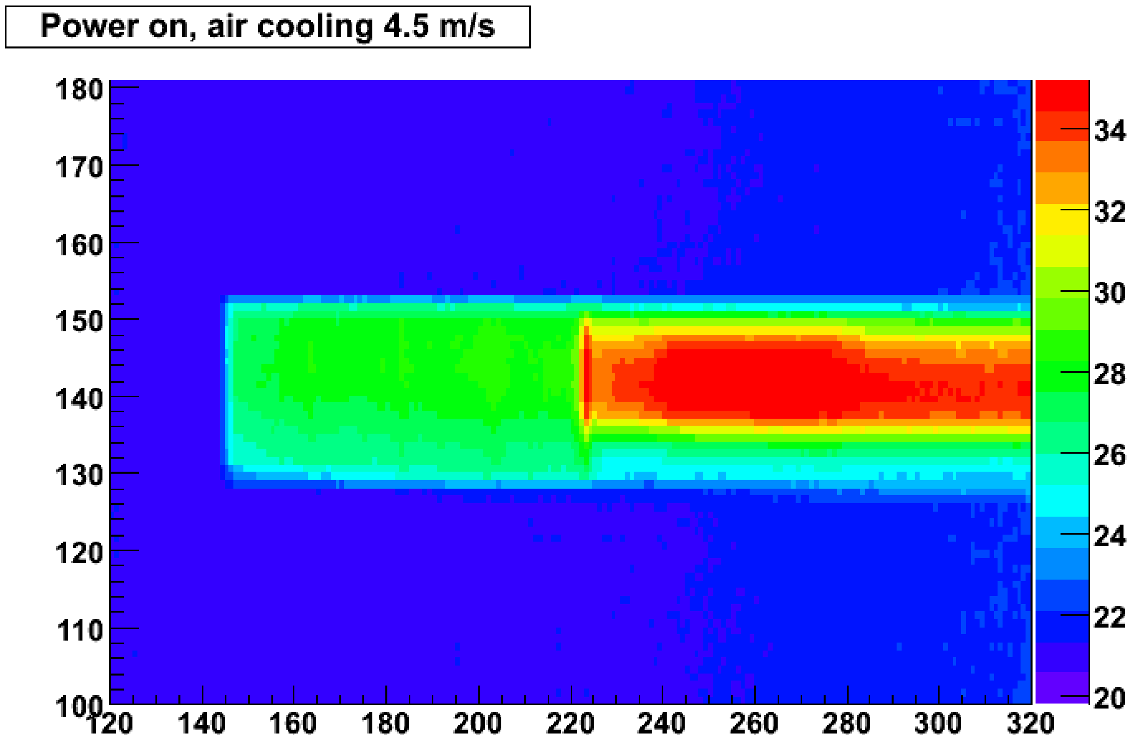


Power on, air cooling 1.1 m/s




Power on, air cooling 2.0 m/s
180
170
160
150
140
130
120
110
100
120
140
160
180
200
220
240
260
280
300
320
40
38
36
34
32
30
28
26
24
22


Power on, air cooling 3.5 m/s
180
170
160
150
140
130
120
110
100
120
140
160
180
200
220
240
260
280
300
320
36
34
32
30
28
26
24
22
20



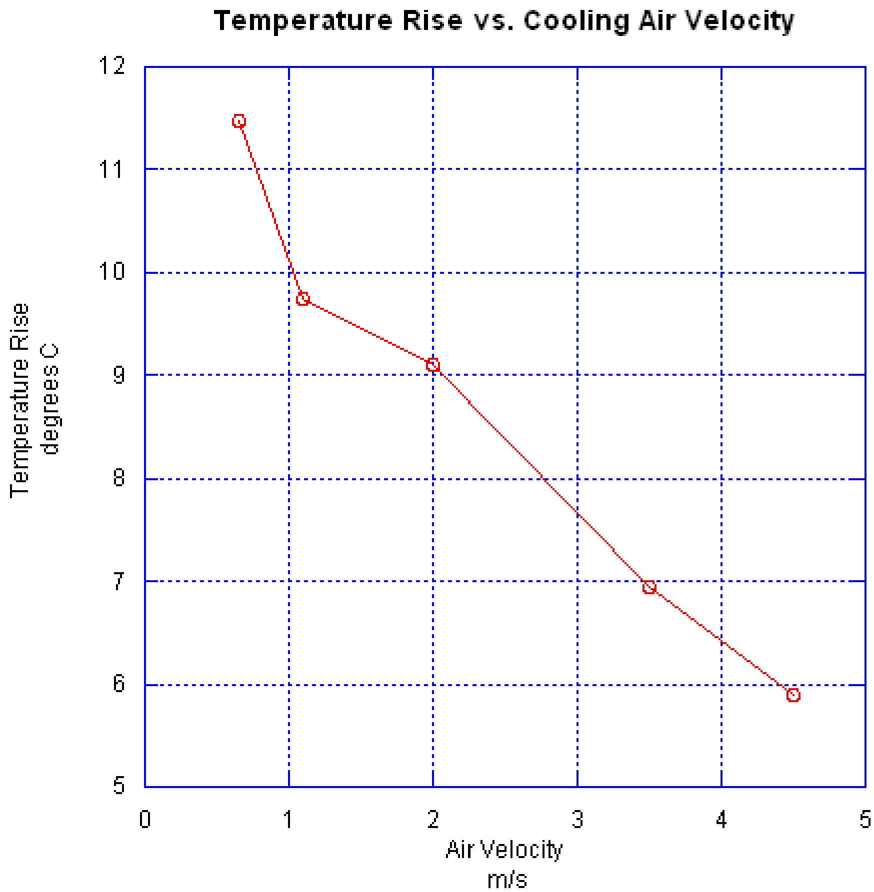
One can see from the above images that the silicon is an excellent heat conductor and despite the uneven heating profile, the silicon temperature remains within ~1 degree over the whole surface.

An average temperature was calculated for an area of the sensor in a 5x5 pixel spot on the chip (between 160 and 164 horizontally and between 140 and 144 vertically). The ambient temperature of the structure and surrounding area was measured before and after the test with the airflow and heaters off and found to be 21.06 and 21.34 degrees respectively. The cooling from simple convection was found by turning the airflow off and keeping the heater on at 80 mW/cm^2 (as in all previous cases). The temperature of the silicon in this case was 53 C, thus the cooling provided from the flow of air is quite significant. The data are shown below.

Data

Airspeed m/s	**Temperature**
off (pre-test)	21.016 C
0.65 m/s	32.828 C
1.1 m/s	31.092 C
2.0 m/s	30.44 C
3.5 m/s	28.288 C
4.5 m/s	27.24 C
off (after test)	21.344 C
0 (larger heater on at 80mW/cm^2)	53 C

From the ambient temperature level after, we calculate a temperature rise plotted below.



This thermal cooling test used a ladder mechanical prototype that is very similar to what we expect to deploy in the STAR HFT detector. The air cooling data gathered and presented above should be a fairly reliable representation of what we can expect in the final detector. The data here differ at the ~30 -40 % level from the previous testing (link given above) using platinum heaters and a single silicon sensor model. The most likely explanation is that the previous test measured the cooling air speed some distance from the ladder and thus was likely underreporting the true airspeed at the ladder. In this test, we measure the airspeed at the end of the ladder and are confident that we have an accurate measurement of the airflow over the ladder. In any case, given the different model types, the level of agreement is actually quite reasonable. We will follow this up with additional measurements and mechanical vibration and deflection measurements.