Design of radiation hard thermal interface material for CMS Phase II Inner Tracker

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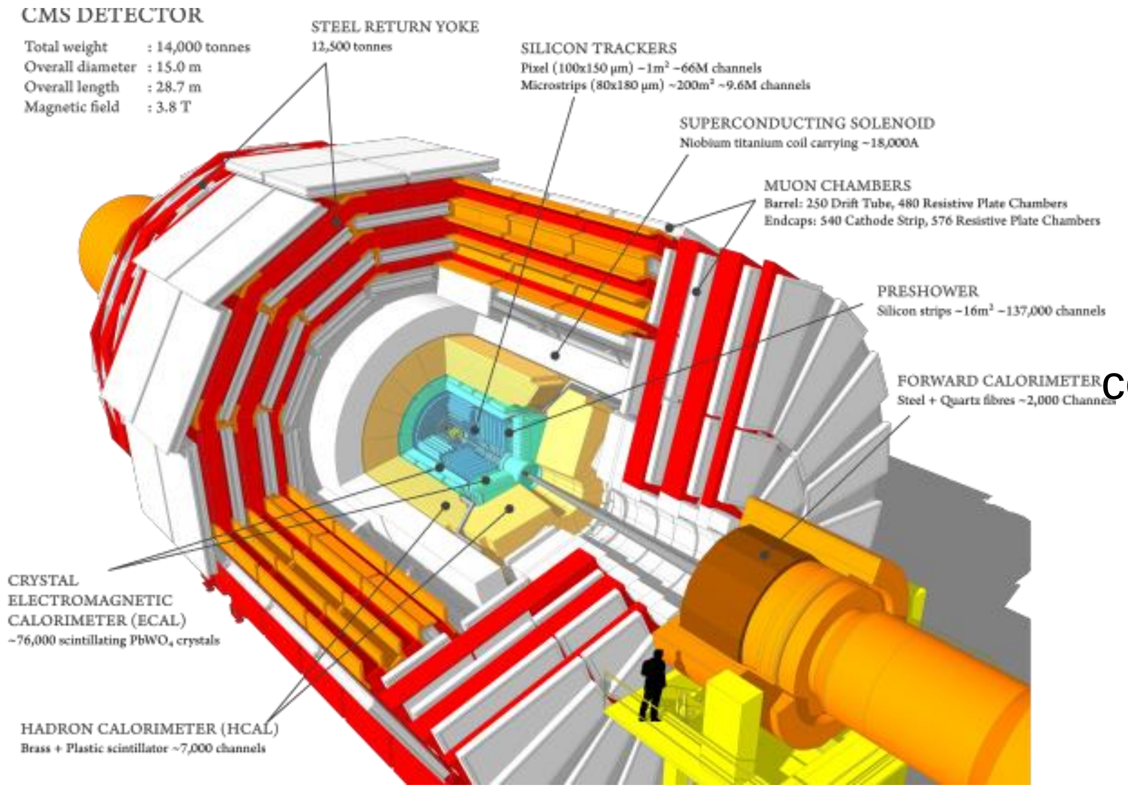
Overview

1. LHC
2. CMS Detector
3. Phase II Pixel Detector Upgrade
4. Thermal Interface Material (TIM)
5. Progress already Done
6. Simulation of two-size mixture of spheres
7. SAND33 Materials
8. Making SAND33 samples
9. Experimental Apparatus at Purdue
10. Testing SAND33 and Collecting Data
11. Data Analysis of SAND33_5 samples
12. Data Analysis of SAND33 samples

Large Hadron Collider

- Hadron – subatomic particle
- Switzerland & France
- Protons collide with each other at 13.6 TeV
- 27 km long

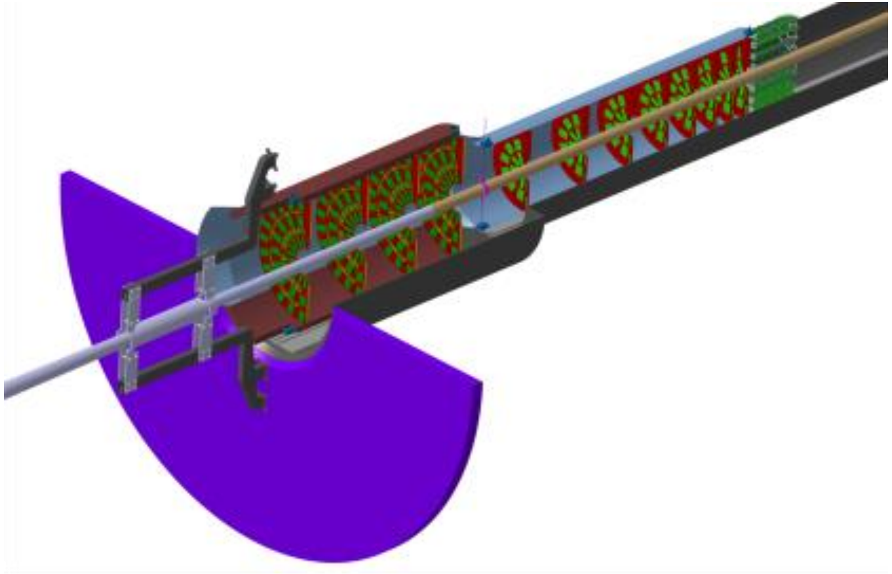
CMS Detector



The CMS Detectors is an complex apparatus with layers of sub-detectors

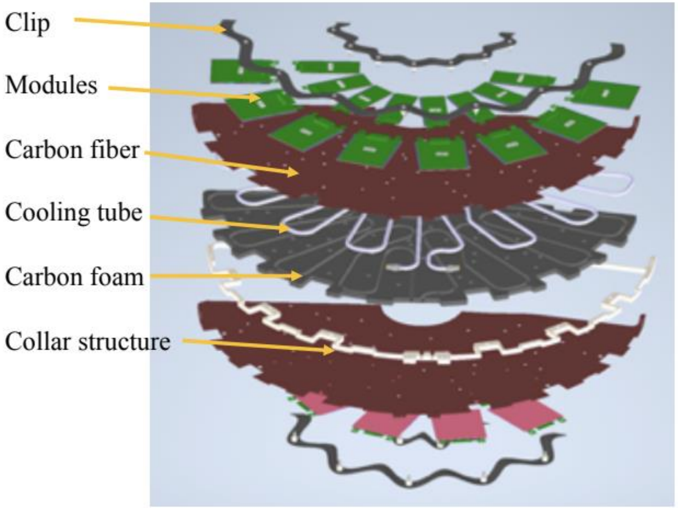
Phase II Pixel Detector Upgrade

Cross section of
Inner tracker

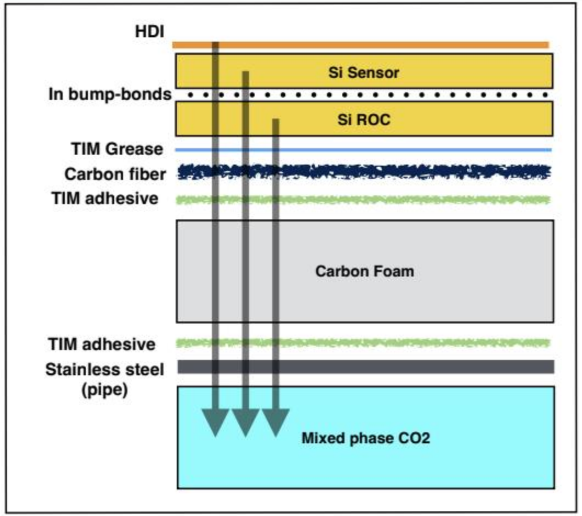


The CMS Phase II Pixel Detector made up of silicon detectors will emit 60 kW of heat

Thermal Interface Material (TIM)



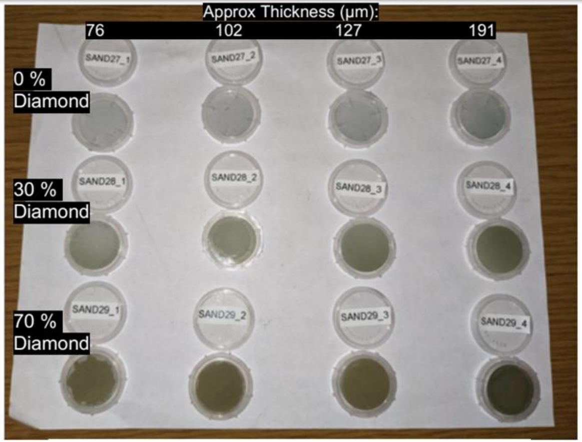
Exploded Dee

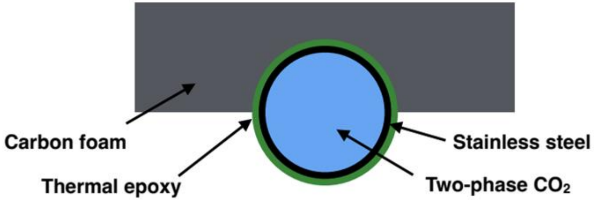


Materials that heat encounters

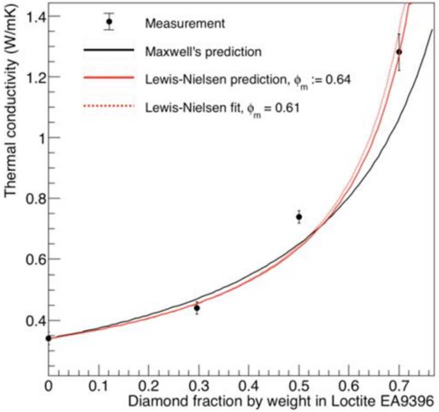
TIM adhesive is an important step in heat extraction to Stay away from thermal Runaway. We Want to see if we can make it better with a bimodal distribution of diamond!

Progress already Done





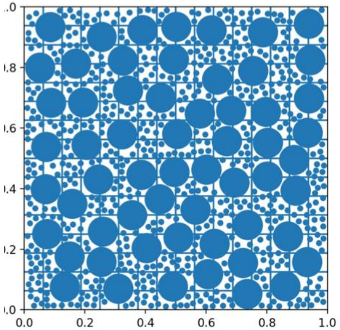
- Loctite EA9396 also survives radiation according to CERN's maxrad database
- It has low viscosity and is used for aerospace applications



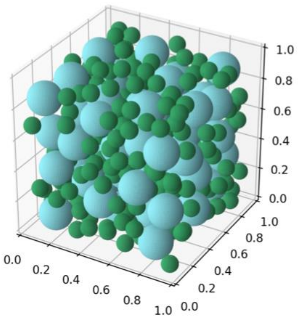
Material	Thermal Conductivity	Thermal Conductivity after 1.5 Grad
Loctite EA9396	0.34 ± 0.02 W/mK	
Loctite EA9396 + 30% 20 um	0.44 ± 0.02 W/mK	
Loctite EA9396 + 50% 20 um	0.74 ± 0.02 W/mK	
Loctite EA9396 + 70% 20 um	**1.28 ± 0.06 W/mK**	**1.14 ± 0.09 W/mK**

Simulation of two-size mixture of spheres

Georgia Nissen, REU student



2D random loose packing

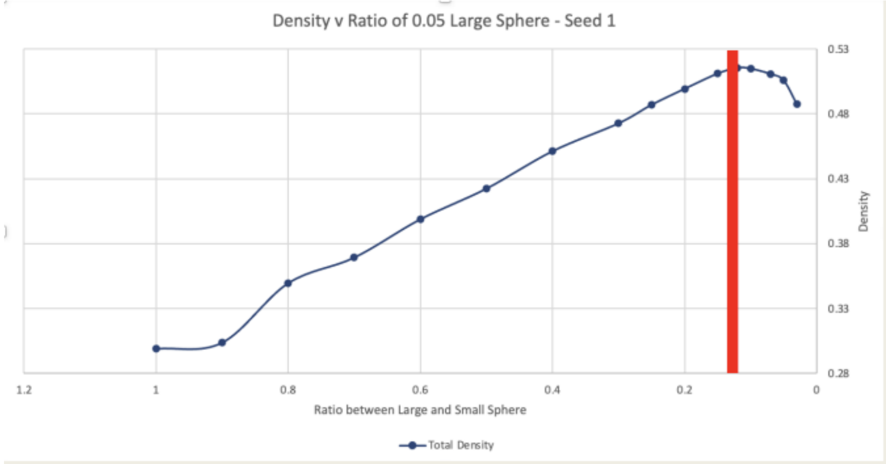


3D random loose packing

- Georgia Nissen and Souvik found through computer simulations that random loose packing of spheres maximizes when radius of small sphere is ~ 12% the radius of the large sphere

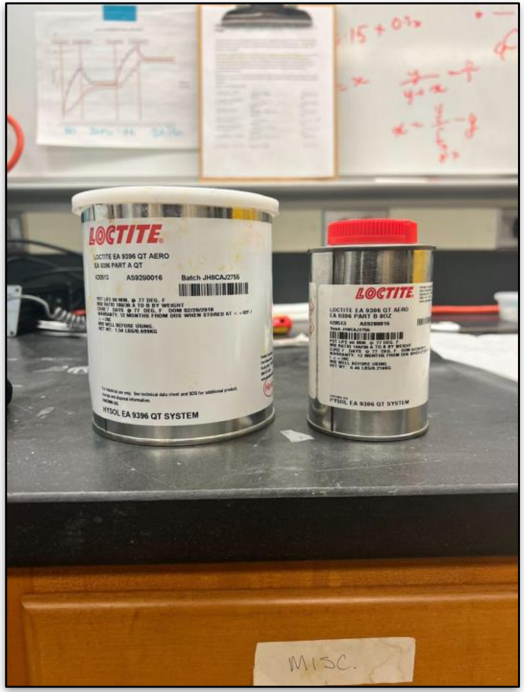
- Therefore, I began preparing such samples for experimental measurements of thermal conductivity

R	Radius(S)	Radius(L)	Num(S)	Num(L)	Density(S)	Density(L)	Density(T)		Change
1	0.05	0.05	48	523	0.0251327	0.273842	0.2989747		
0.9	0.045	0.05	78	523	0.0297729	0.273842	0.3036149		0.004640
0.8	0.04	0.05	282	523	0.0755993	0.273842	0.3494413		0.045826
0.7	0.035	0.05	531	523	0.0953646	0.273842	0.3692066		0.019765
0.6	0.03	0.05	1104	523	0.124859	0.273842	0.398701		0.029494
0.5	0.025	0.05	2269	523	0.148506	0.273842	0.422348		0.023647
0.4	0.02	0.05	5292	523	0.177337	0.273842	0.451179		0.028831
0.3	0.015	0.05	14067	523	0.198868	0.273842	0.47271		0.021531
0.25	0.0125	0.05	26052	523	0.213137	0.273842	0.486979		0.014269
0.2	0.01	0.05	53824	523	0.22545725	0.273842	0.49929925		0.012320
0.15	0.0075	0.05	134248	523	0.237236	0.273842	0.511078		0.011779
0.12	0.006	0.05	267171	523	0.241731	0.273842	0.515573		0.004495
0.1	0.005	0.05	460556	523	0.24114635	0.273842	0.51498835		-0.000585
0.07	0.0035	0.05	1319885	523	0.237044	0.273842	0.510886		-0.004102
0.05	0.0025	0.05	3547133	523	0.232159	0.273842	0.506001		-0.004885
0.03	0.0015	0.05	15133857	523	0.21395	0.273842	0.487792		-0.018209



Maximum Packing Fraction achieved at radius ratio of 12%

SAND33 Materials

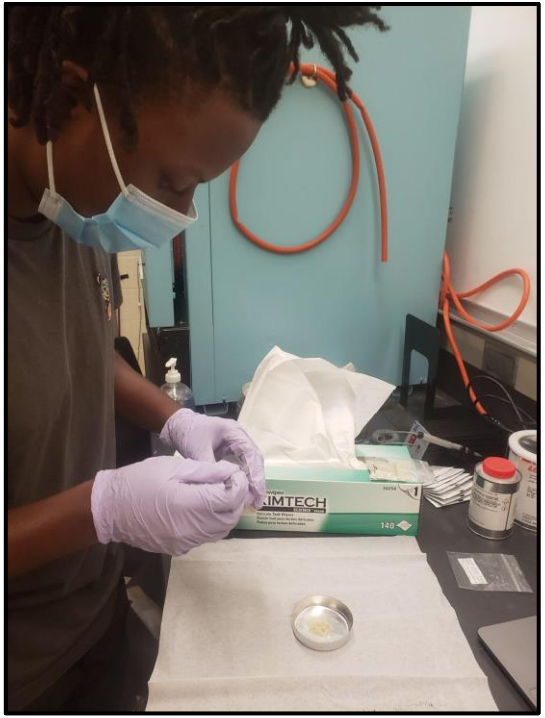


LOCTITE EA 9396 AERO Part A and B

Synthetic Diamond Powder Left 2.4 um right is 20 um

Making SAND33 samples Pt 1

Me mixing Part A and Part B of the Resin



Me Mixing the Resin with the 2.4 and 20 um Diamonds

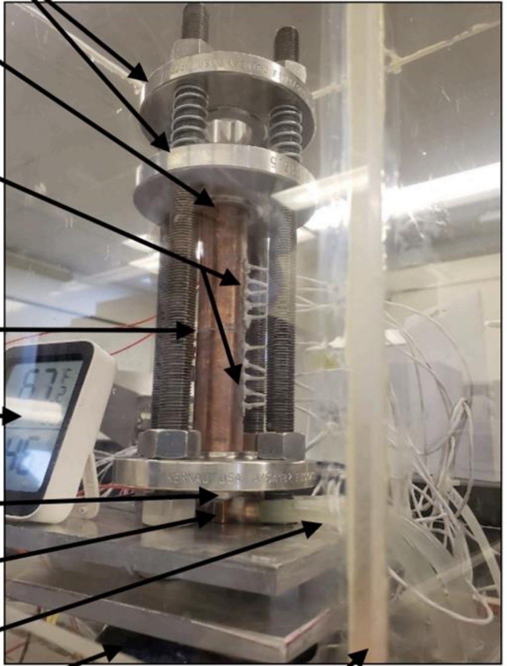
Making SAND33 Samples Pt 2

Result of Mixing the all of the Materials

Me putting the Newly made glue in between two sapphire dics to test the samples

The Finished Samples

Experimental Apparatus at Purdue



How do we **mitigate convective and radiative losses** from the sample?

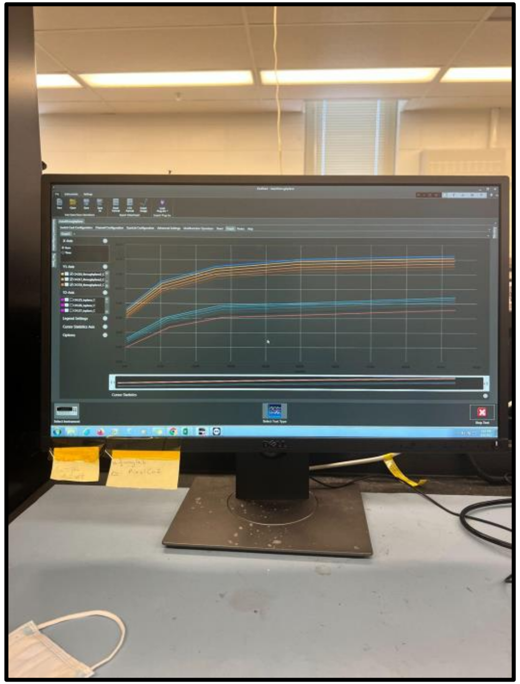
- Ensure heat flow entering sample is equal to heat flow exiting sample. Requires tweaking heater voltage and Peltier voltage with realtime estimation of the fluxes
  - Residual difference of ~ 5% is one of the dominant uncertainties

How do we **eliminate contact conductance** from our measurements?

- By carrying out four or more independent measurements with varying sample thicknesses
- By using the same amount of thermal grease between sample and flux-meters across all measurements
- By using the same force across all measurements

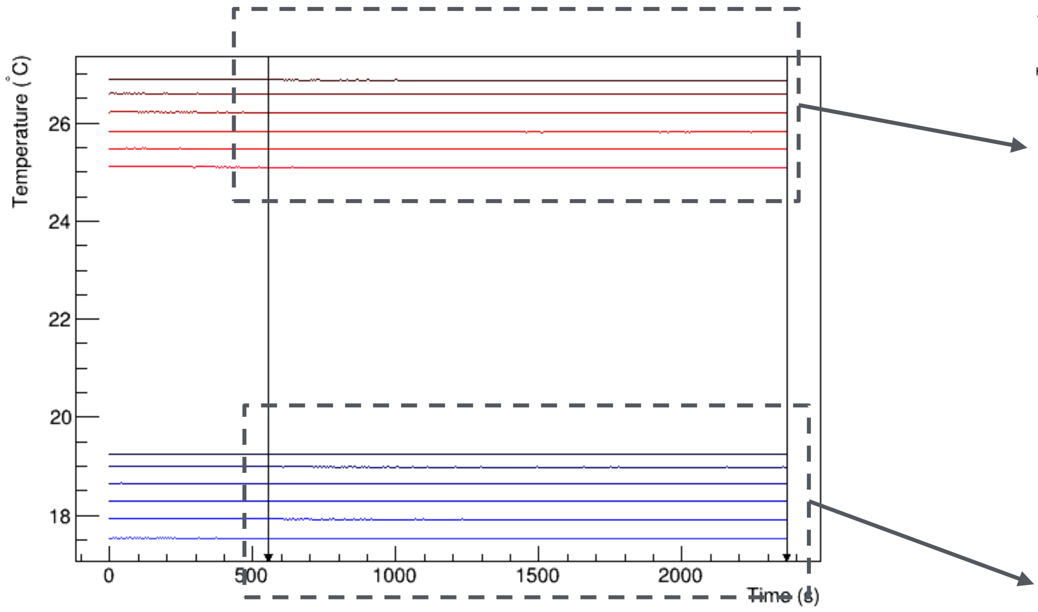
Testing SAND33 and Collecting Data

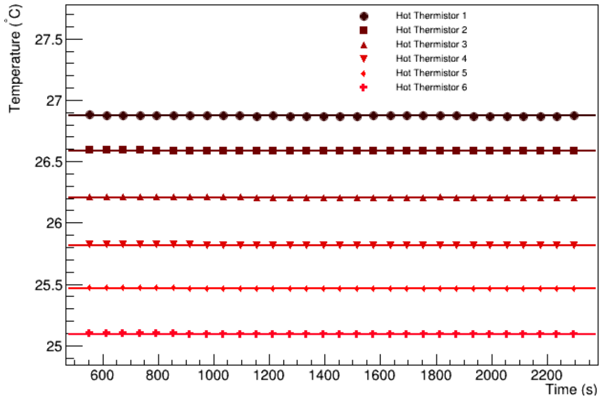
SAND33_3 being tested in Apparatus

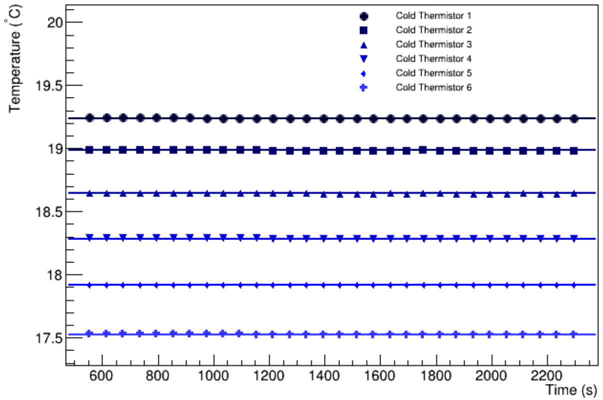


We are trying to get the slope of the hot and cold curves as even as possible

Data Analysis of SAND33_5 samples Pt 1



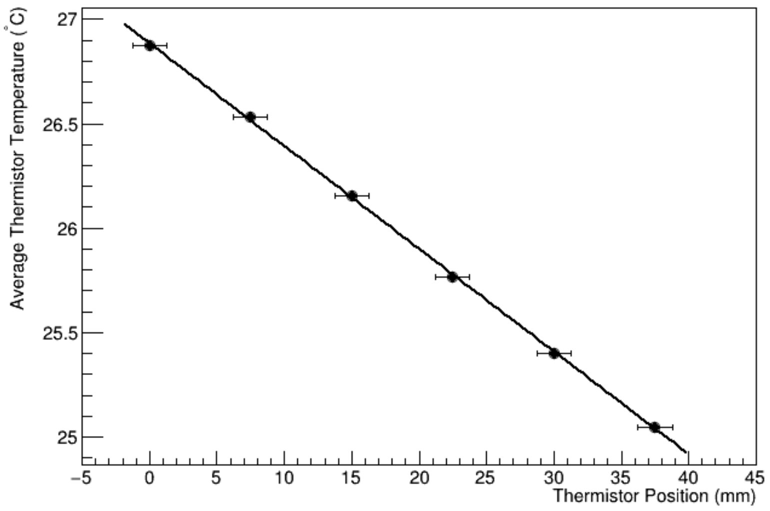




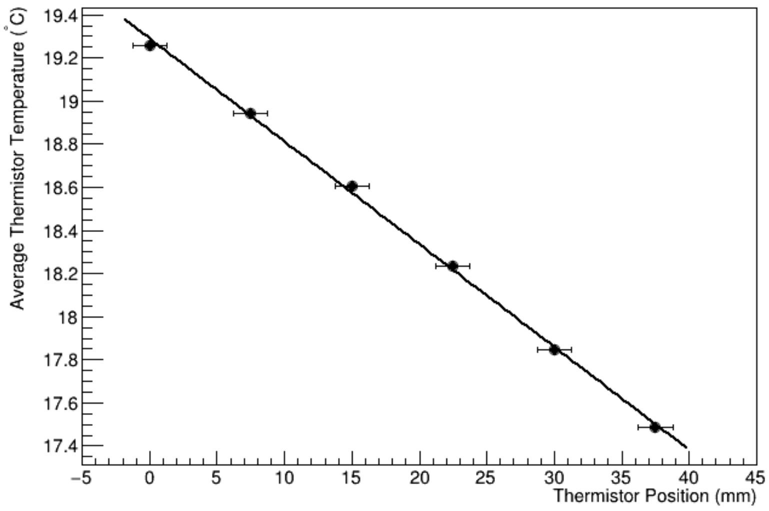
Temperatures measured at the flux meters for SAND33_5. Graphs to the right is an expanded graph of the stable window

SAND33_5 has a thickness of 253 ± 10 um of material

Data Analysis of SAND33_5 samples Pt 2



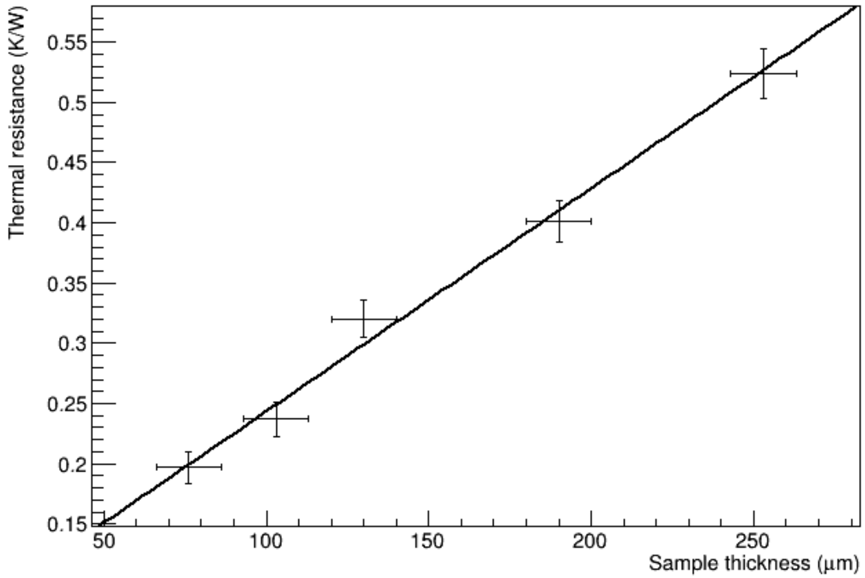
Gradient of temperature in hot flux meter



Gradient of temperature in cold flux meter

Heat flow through sample, I = 9.6 ± 0.3 W
Temperature difference across the sample, ΔT = 5.0 ± 0.1 C
Therefore, thermal resistance of the sample, R = ΔT/I = 0.52 ± 0.02 K/W

Data Analysis of SAND33 samples



Inferred thermal conductivity k = 1.06 ± 0.10 W/mK

No appreciable improvement detected. More careful studies may be needed!

Thank you for listening!!!