Calibration of High Temperature Thermal Conductivity System

New Algorithm to Measure Heat Capacity using Flash Thermal Diffusivity in Thermoelectric Materials

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Presentation Map

- **Introduction**
  - Thermoelectric Materials Background
  - Research Goal & Heat Capacity Measurements
- **Process**
  - Flash Thermal Diffusivity
- **Experiments**
  - Stainless Steel Comparison
  - Pulse Max Integral Fit
  - Graphite Comparison Algorithm
- **Conclusion**

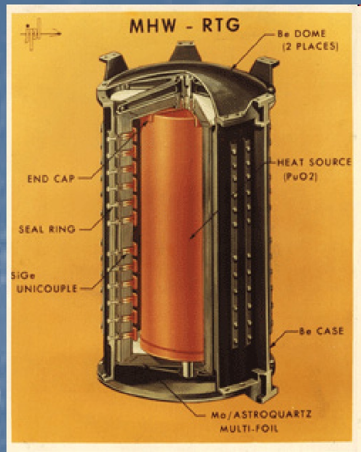
What are Thermoelectrics?

- Materials that are power generators or coolers depending on their use
- Case 1:

  Heat gradient → electron flow = current
- Case 2:

  Current flows → reverse heat gradient = refrigerator

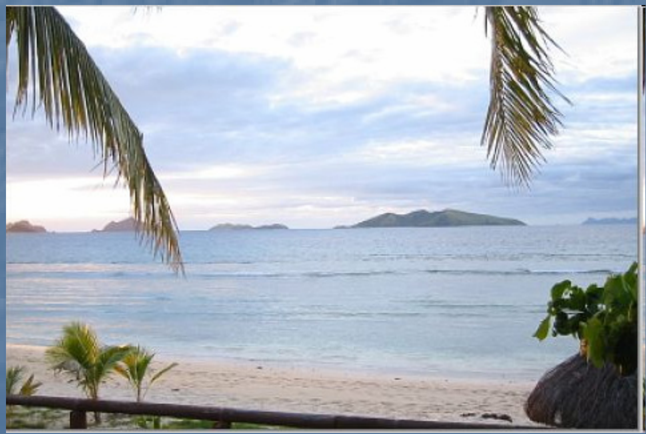
Thermoelectric Applications



RTGs in Space Missions

Peltier Coolers

Waste Heat Automobiles



Direct Power Source

Improving Thermoelectrics

- Limiting use factor: only 4-6% efficiency
- 2 ways to improve thermoelectrics:

  Develop more efficient materials

  Improve Measurement Systems

Research Goal

- Improve the figure of merit calculation for thermoelectrics by improving the accuracy of heat capacity measurements

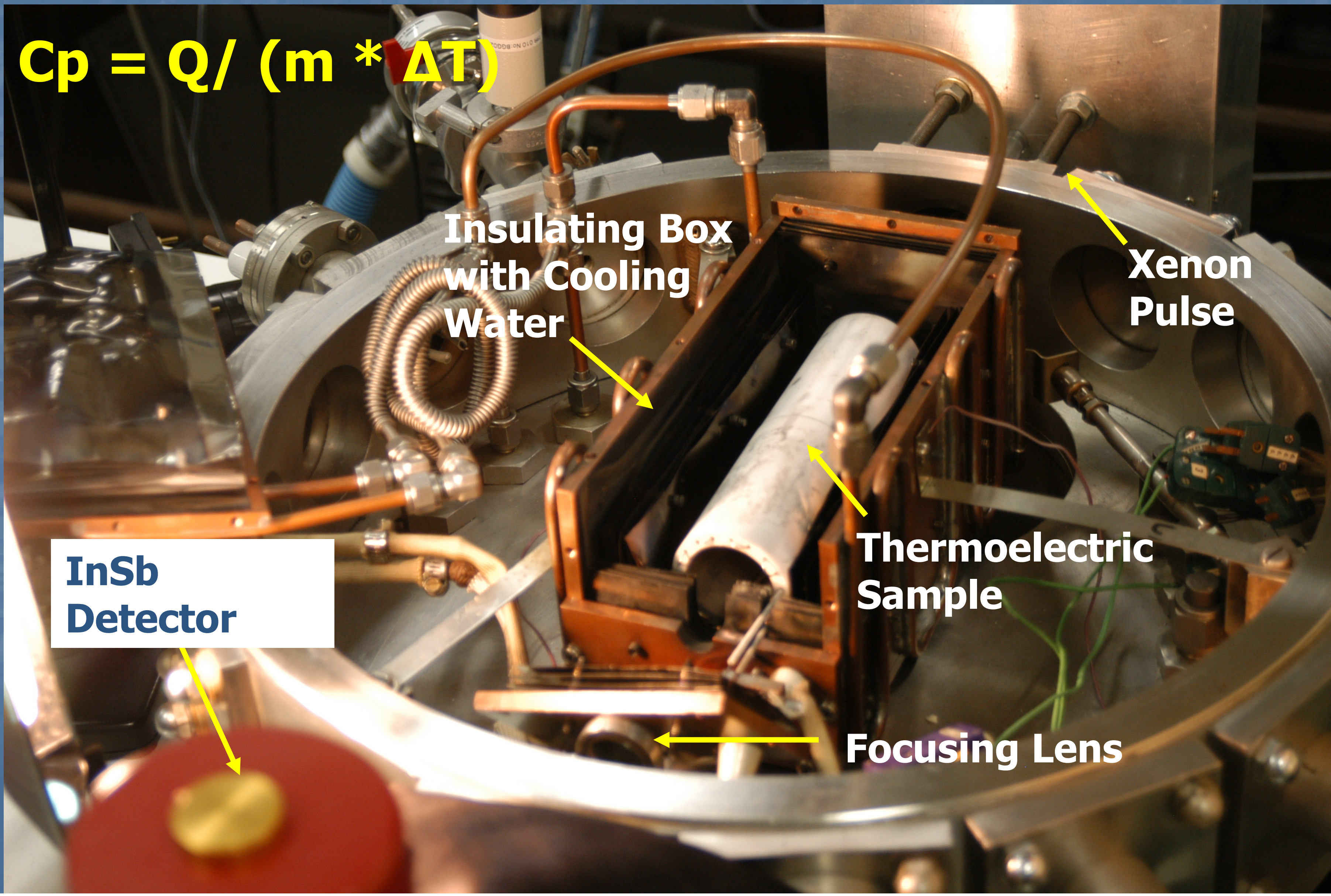
- $$zT = \frac{\alpha^2}{\rho\, \alpha'\, C_p\, d}$$

C_p - heat capacity α - Seebeck coefficient

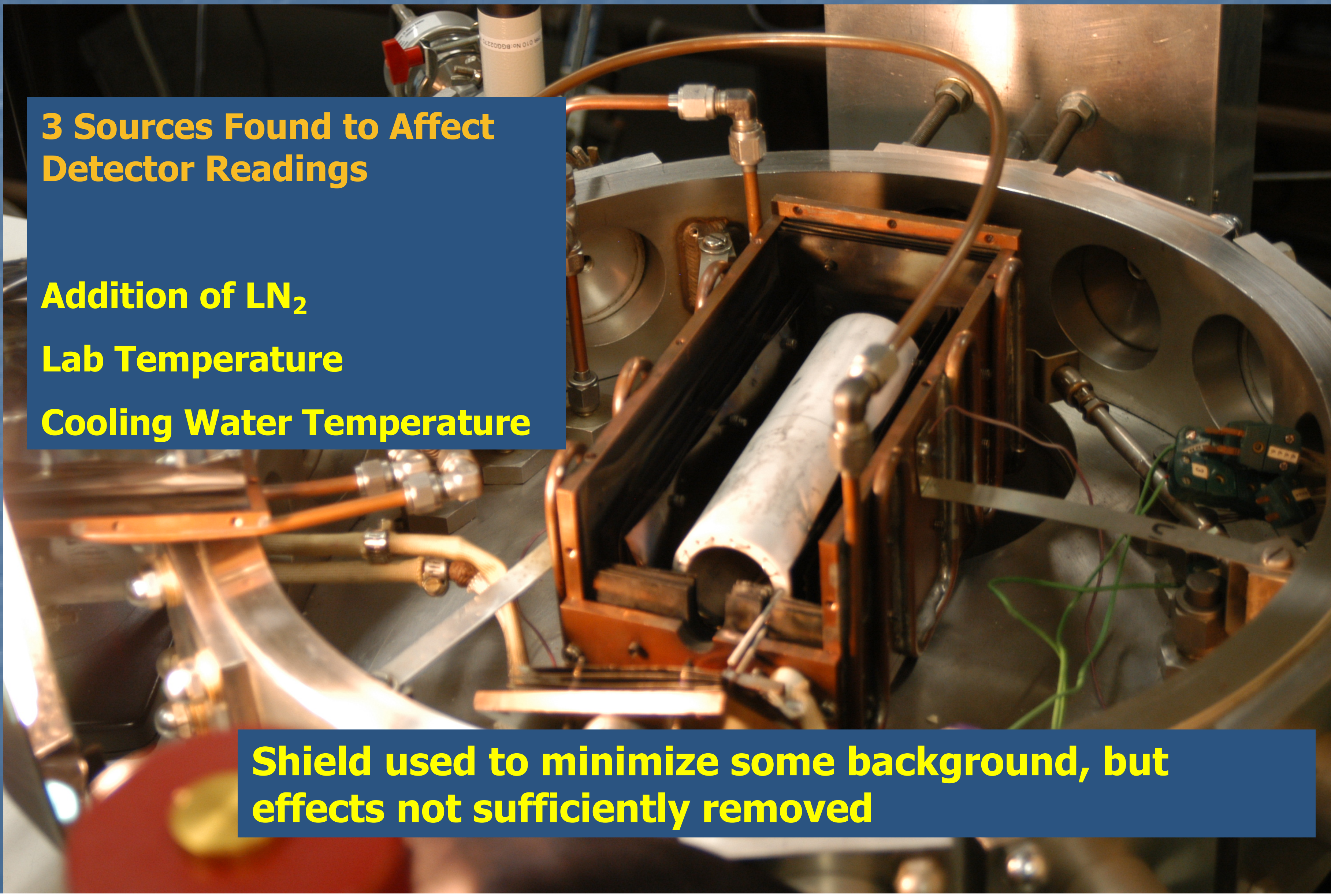
ρ - electrical resistivity α'- thermal diffusivity d - density

- **Improved heat capacity, Cp, measurements will directly improve the thermoelectric figure of merit**

Flash Thermal Diffusivity



Background Effects



3 Sources Found to Affect Detector Readings

Addition of LN_2

Lab Temperature

Cooling Water Temperature

Shield used to minimize some background, but effects not sufficiently removed

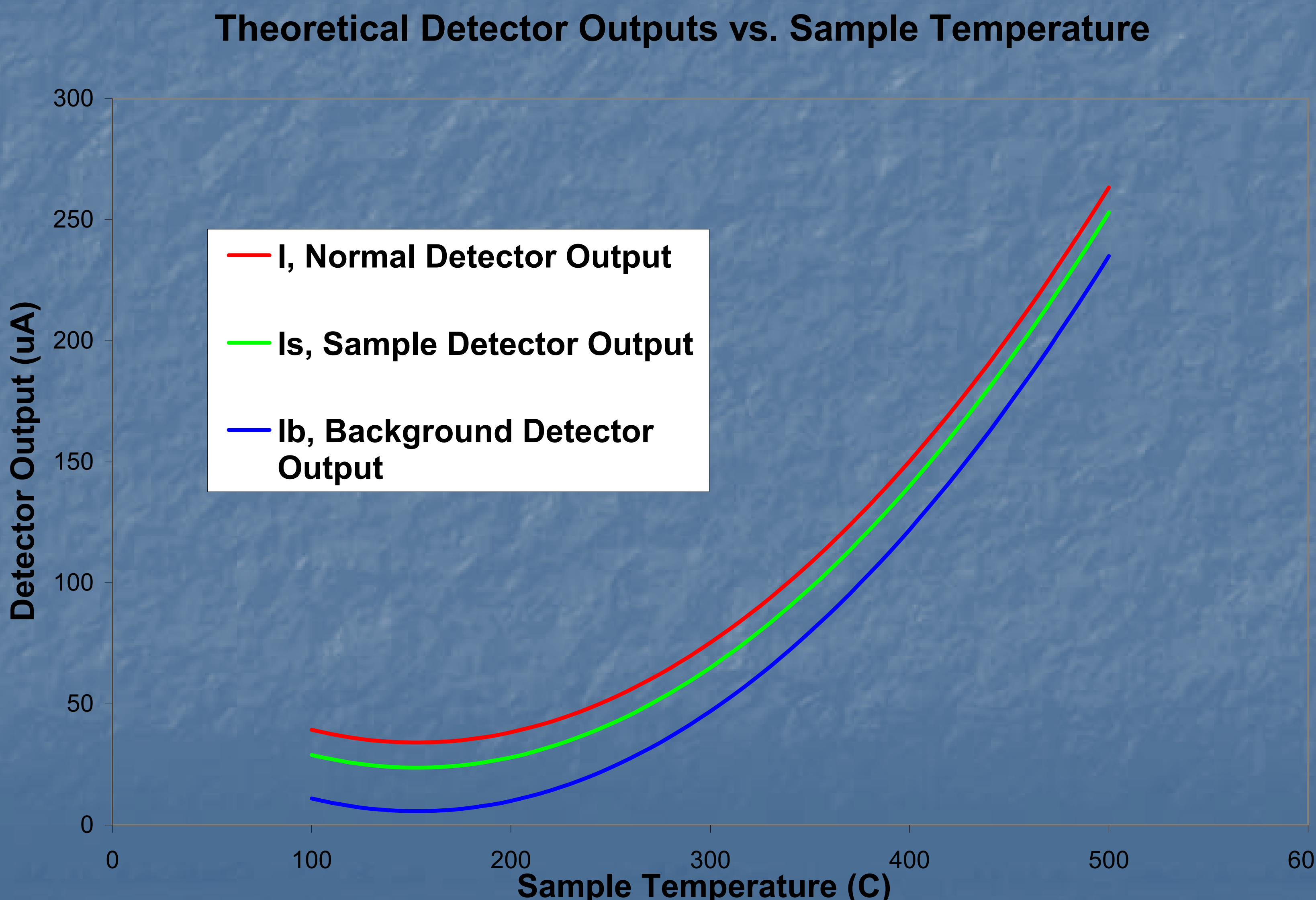
Stainless Steel Comparison

Experiment 1

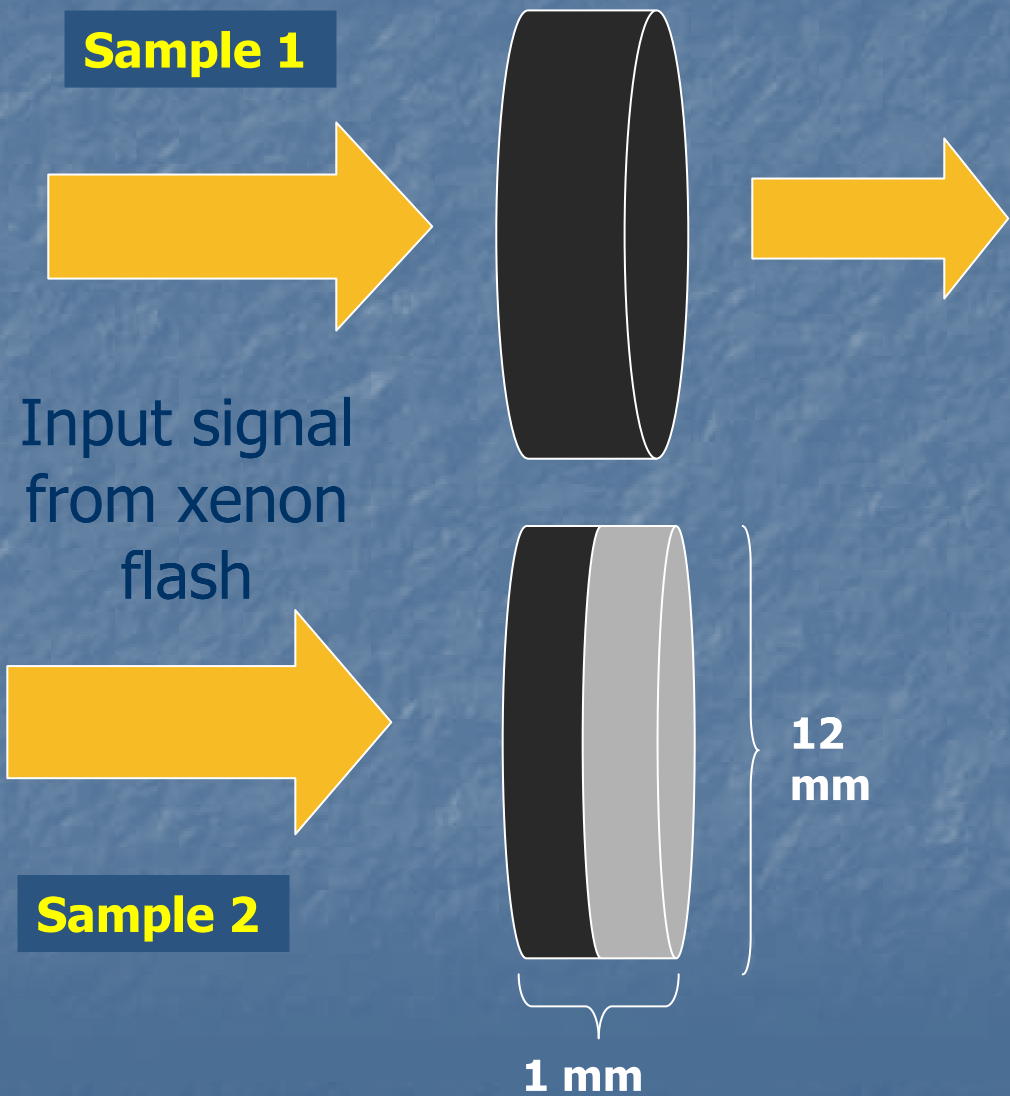
- Measurement: I_D - Detector Output
- Hypothesis: $I_D = I_B + I_S$

- If I_B removed, just have sample temperature ➡ eliminates background effects seen earlier

Stainless Steel Comparison



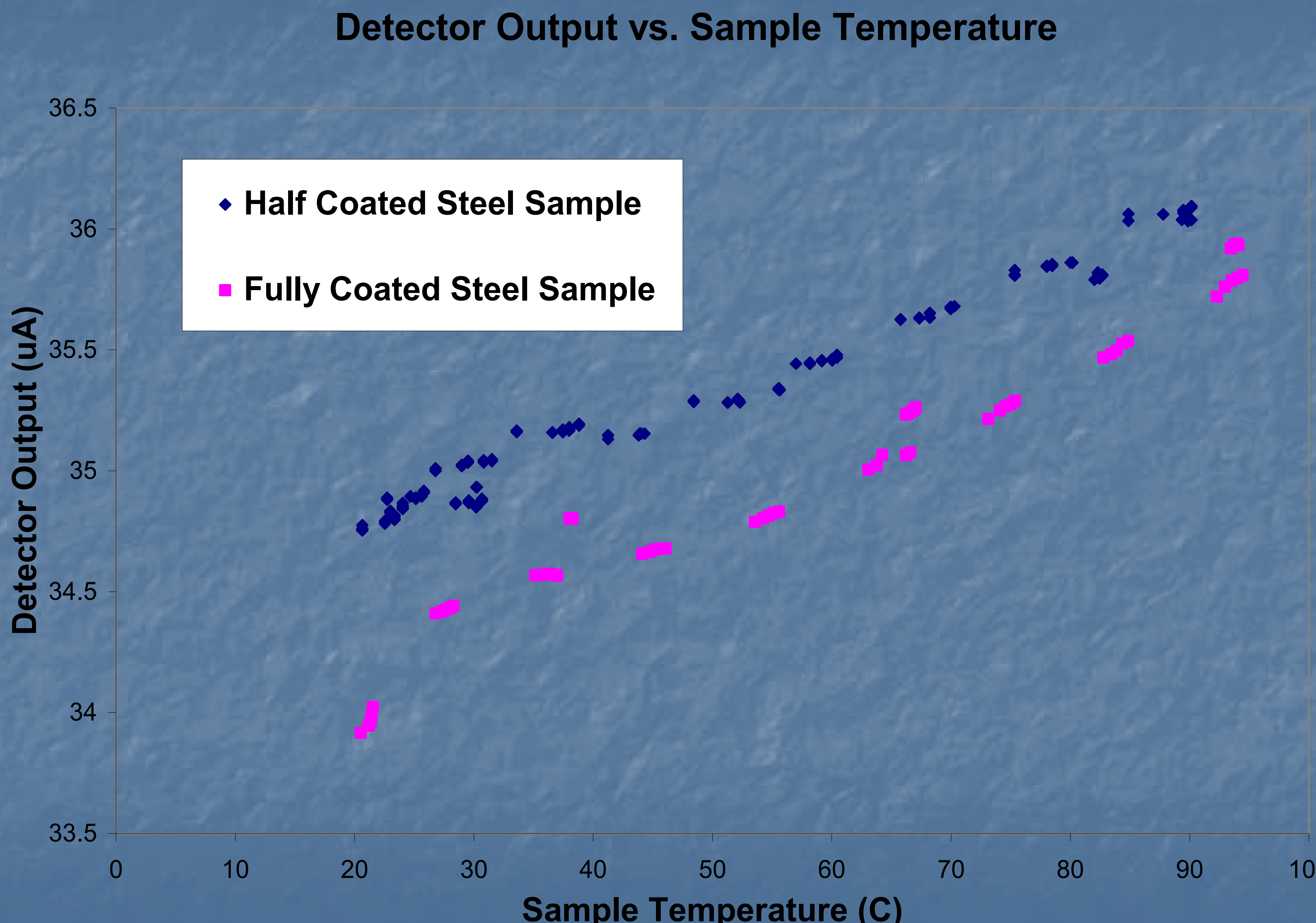
Stainless Steel Comparison



Sample 1 fully coated in graphite, emissivity is 1, Detector should pick up normal output, I_D

Sample 2 was left uncoated on one half, the emissivity is 0, so no output signal. Any signal detector picks up should be background, I_B

Stainless Steel Comparison

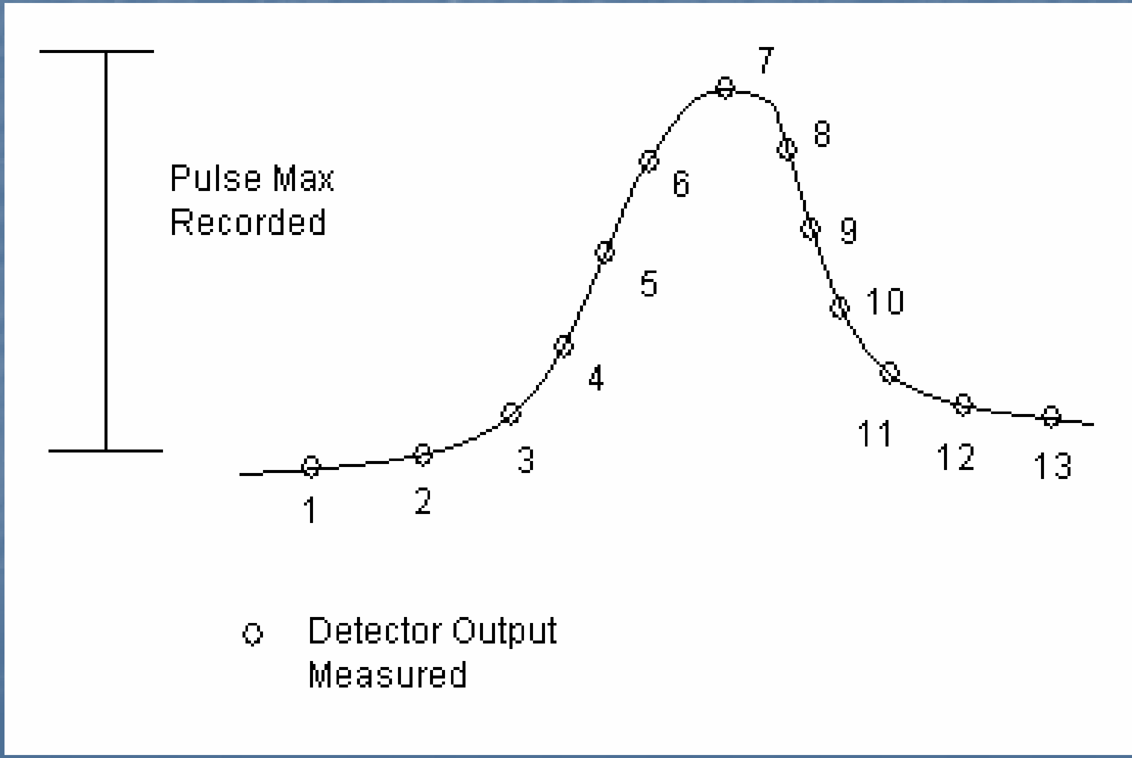


Results of this experiment did not match hypothesis

Pulse Max Integral

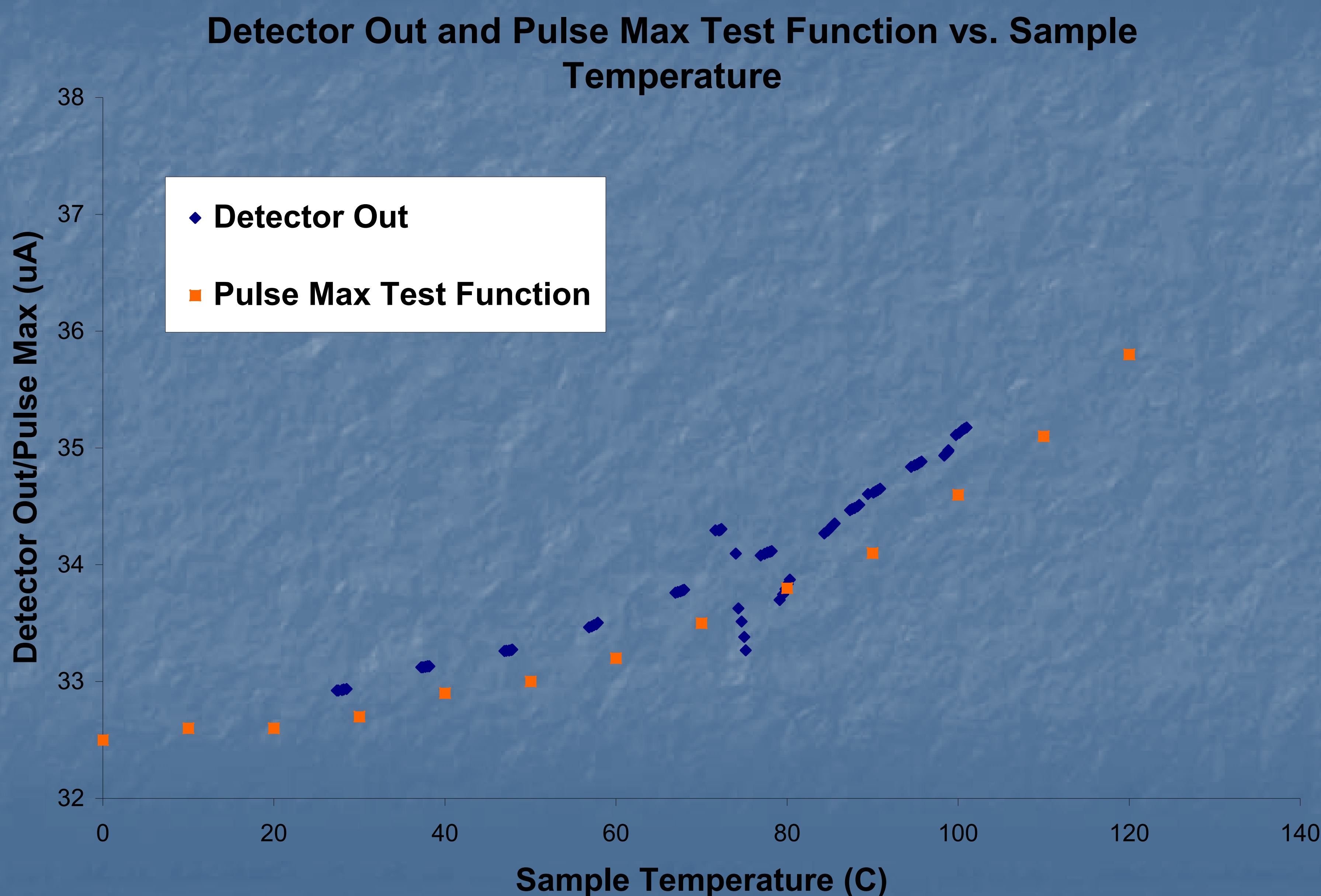
Experiment 2

- Measurement: P – Pulse Max
- $P = \Delta T * \dfrac{dIs}{dT}$

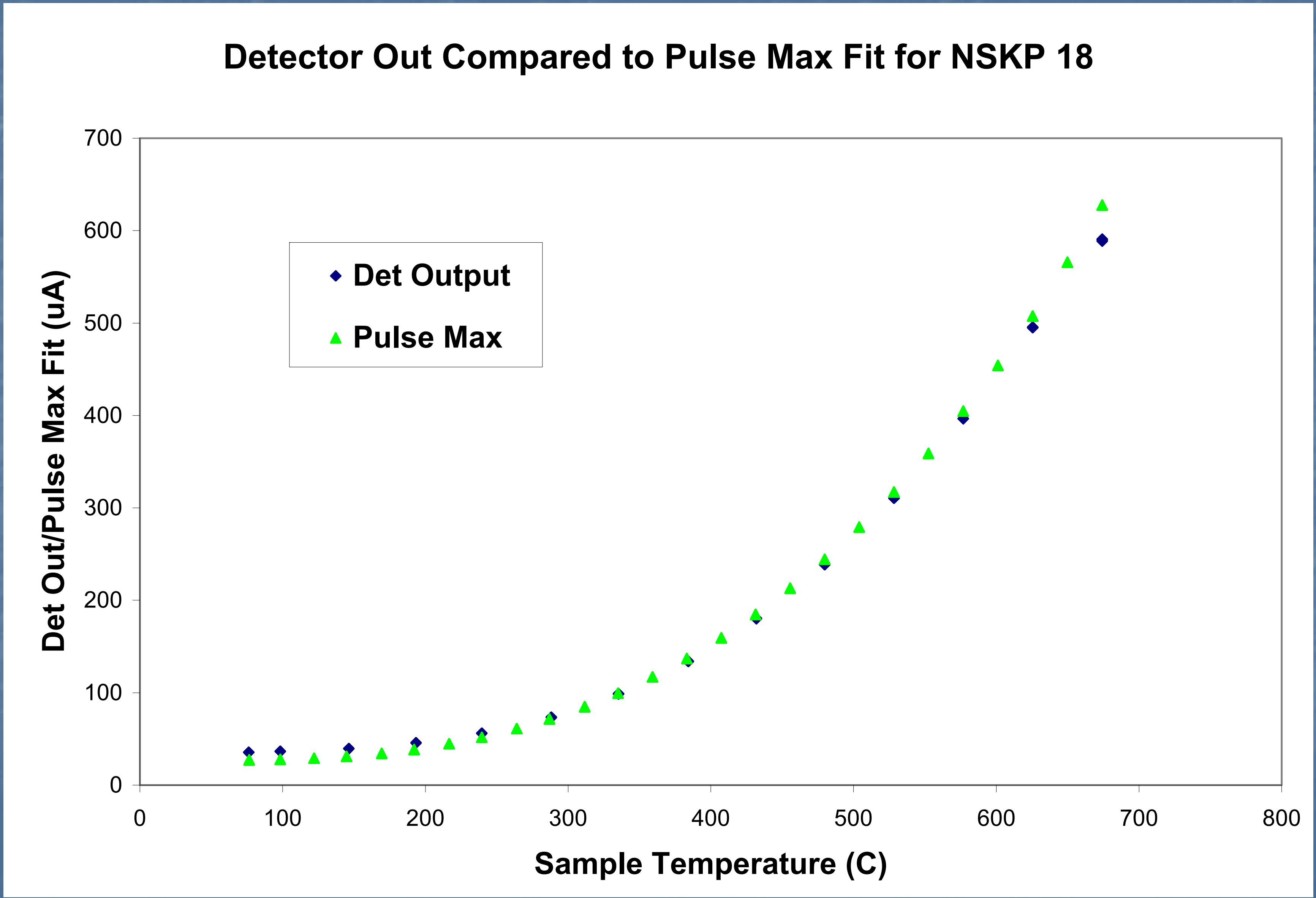


Pulse Max measured over greater time interval, so less prone to background effects

Pulse Max Integral



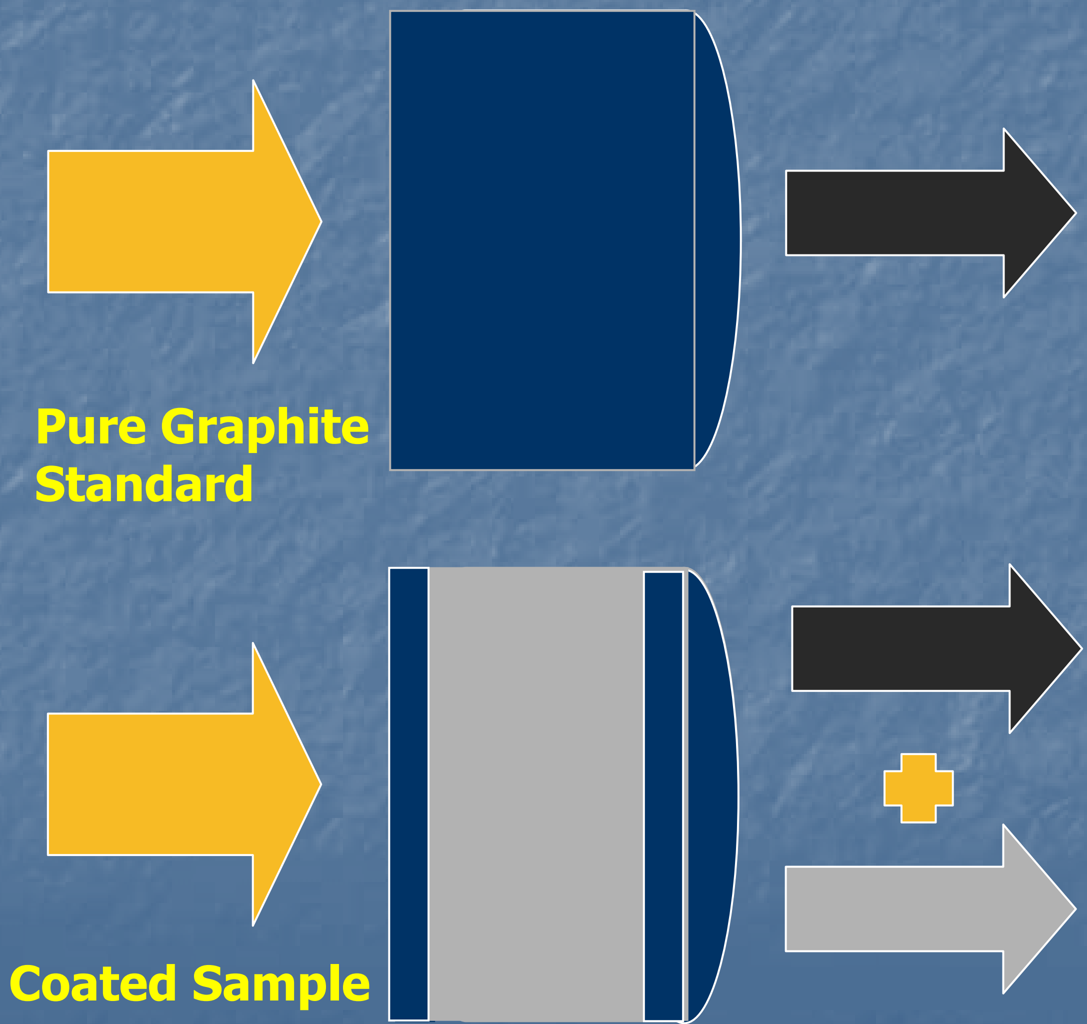
Pulse Max Integral



Graphite Comparison Algorithm

Experiment 3

Basis: **3D Cross Section**



Every coated sample should have some signal characteristics of pure graphite

Any other signal measured should be due to sample material

Graphite Comparison Algorithm

Need to develop formula to express the comparison technique

Pulse max: $P = \Delta T * \frac{dIs}{dT}$

Heat Capacity: $Cp = Q/\ (m * \Delta T)$ ⇨ $\Delta T = Q/\ Cp * m$

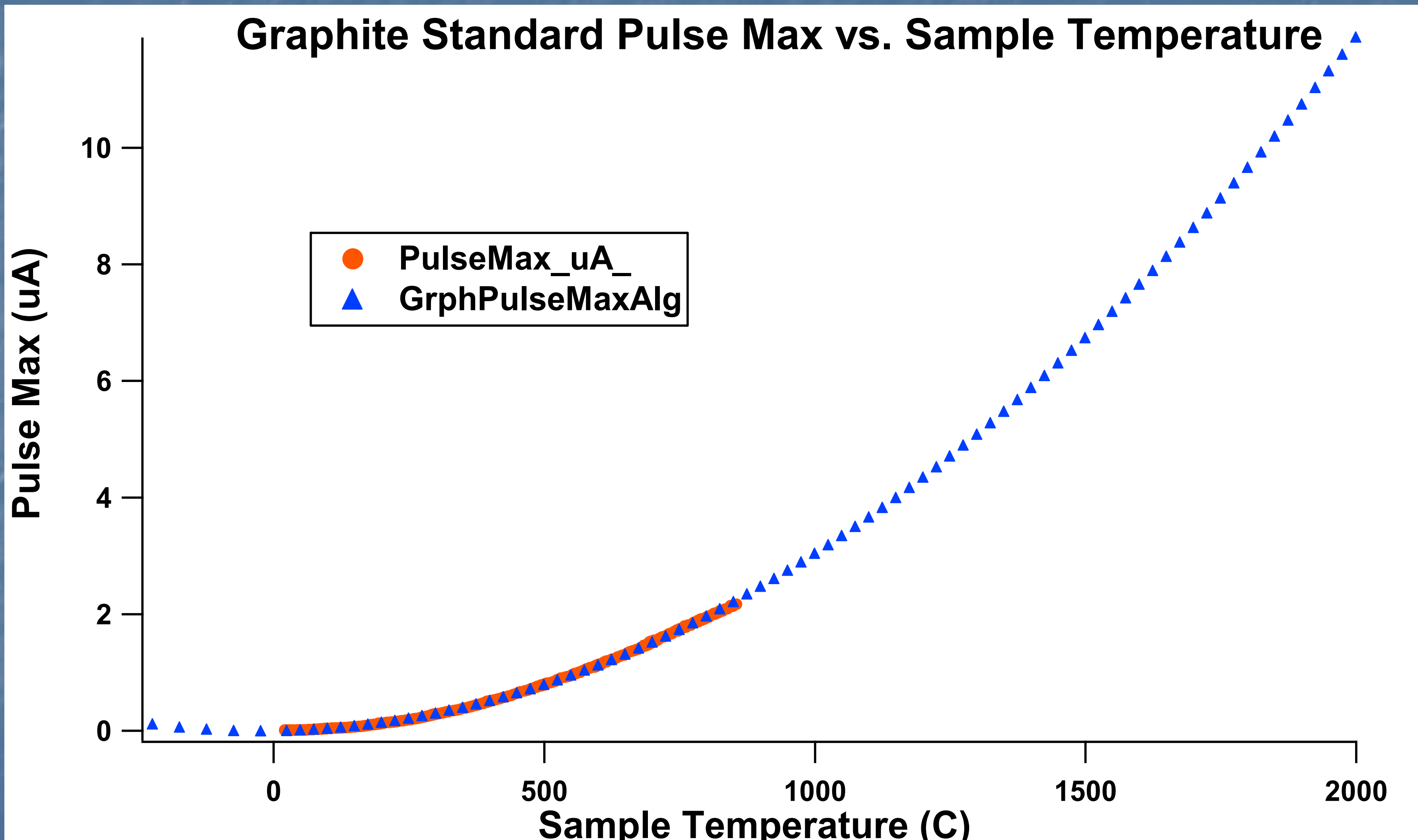
⇨ $P * Cp * m = Q * dIs/dT = Q'$ **Graphite Standard**

$Q' = P(s) * Cp(s) * m(s)$ **Sample Properties**

$$Cp(s) = Q'/\ \{P(s) * m(s)\}$$

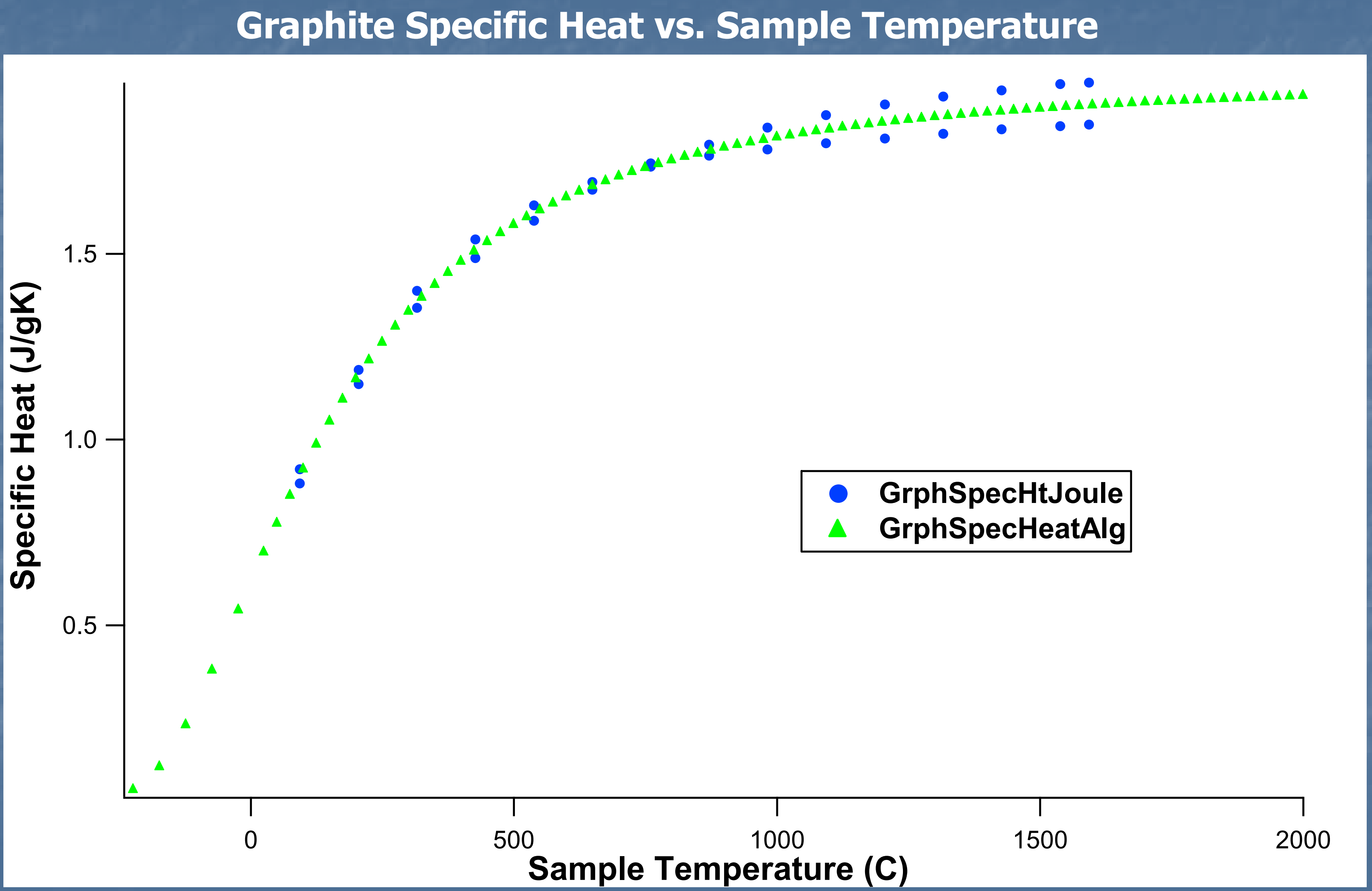
To make Q', need Cp and P data for graphite standard

Graphite Comparison Algorithm



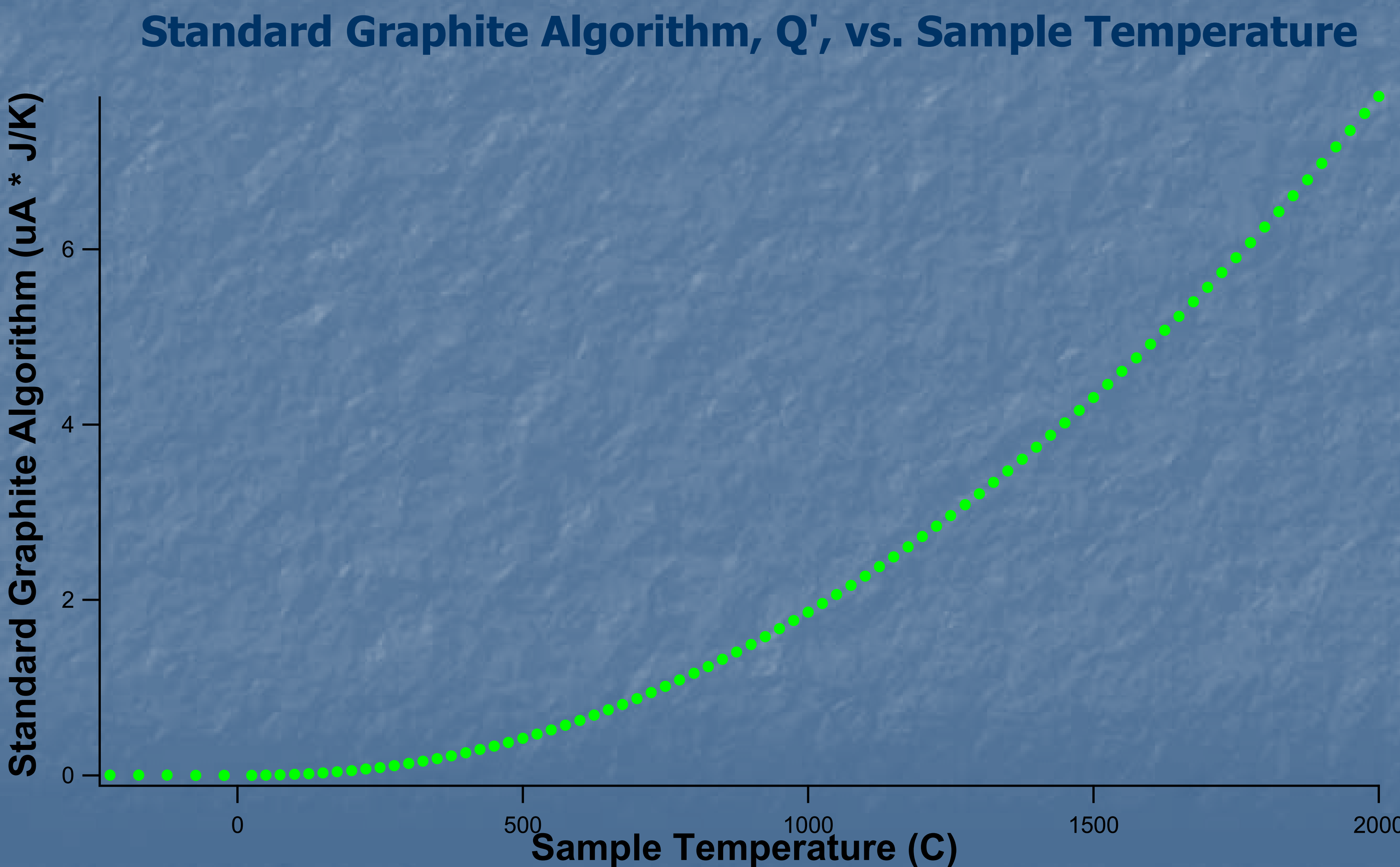
*From Lab measurements

Graphite Comparison Algorithm



*From Reference material

Graphite Comparison Algorithm



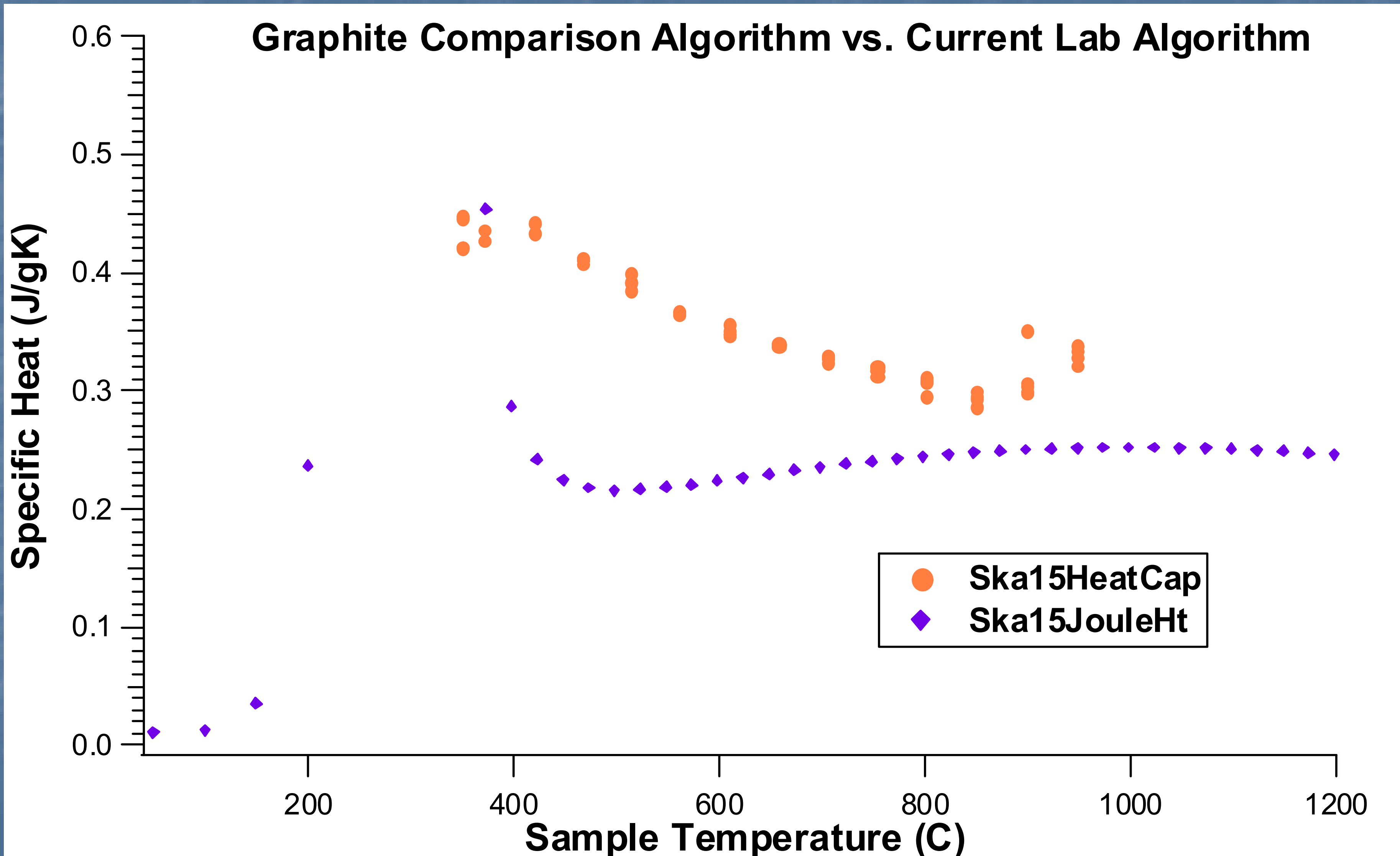
Graphite Comparison Algorithm

Q′(T) = -8.7124E-14 T^4 + 3.4188E-10 T^3 + 1.5829E-6 T^2 + 4.0911E-5 T – 0.02258

To test, used a skutterudite, a new thermoelectric material

Dulong-Petit law gave the specific heat of this sample as 0.23 Joules/gK at 430°C, with it increasing slightly as temperature increased

Graphite Comparison Algorithm



Conclusion

- Improved heat capacity algorithm achieved after testing multiple algorithms
- Gives specific heat measurements in real time, no additional calculations needed
- New materials can be measured more accurately
- Older materials can be remeasured to find new avenues to pursue in materials research
- Future work: Test graphite comparison algorithm using different types of materials, especially standards such as stainless steel, to ensure validity of new algorithm

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