Cooling*

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ePIC Collaboration Meeting

January 21, 2025

*disc focused

Sensor Power Regions

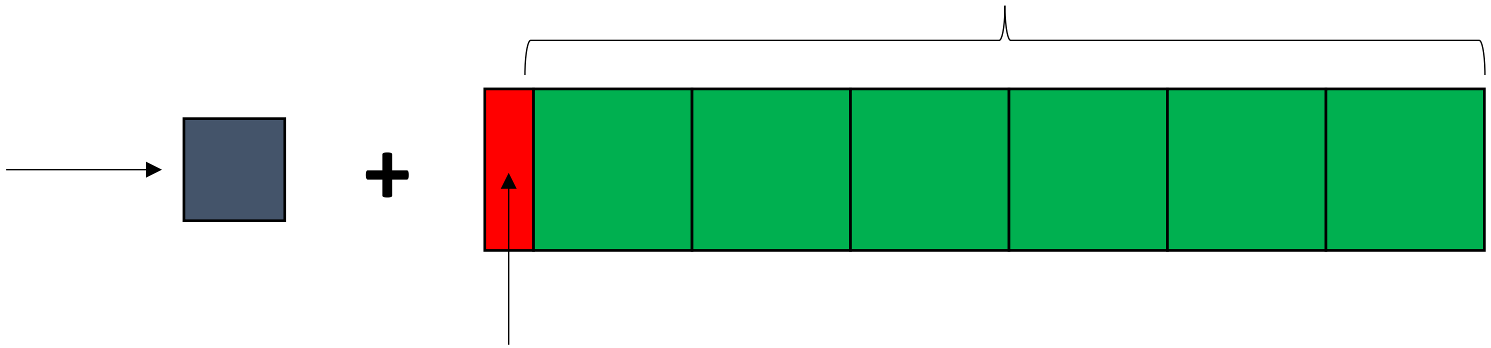
*Snapshot → new numbers shown today

Information from Iain and Georg's presentations at previous SVT meetings*

EIC-LAS

5-6 RSUs
Max: 0.05 W/cm2
Min: 0.03 W/cm2

AncASIC:
Max: 45% of LAS
Min: 35% of LAS



LEC
Max: 0.72 W/cm2
Min: 0.48 W/cm2

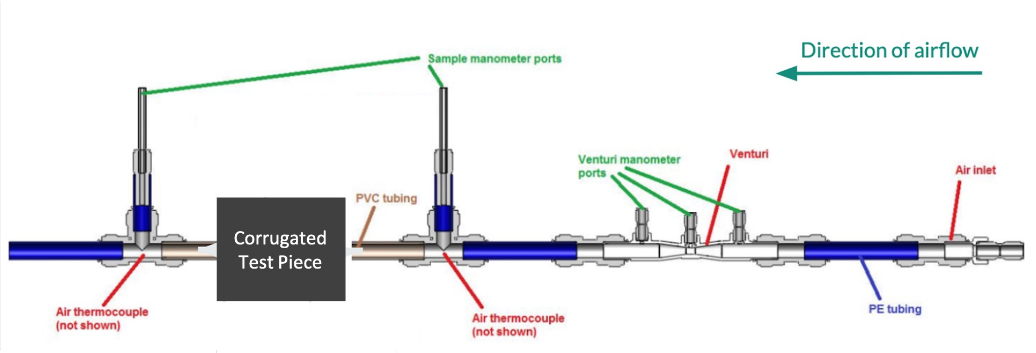
Total power (6 RSUs)
Max: 1.89 W
Min: 1.21 W

MOSAIX: same power densities as EIC-LAS

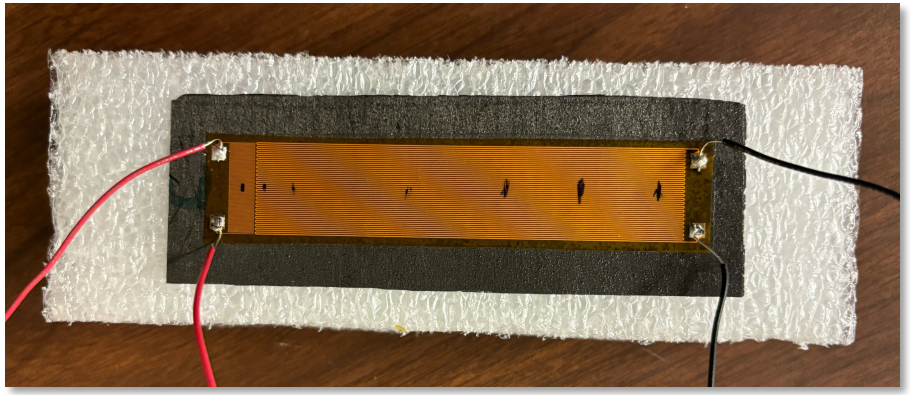
Thermal needs

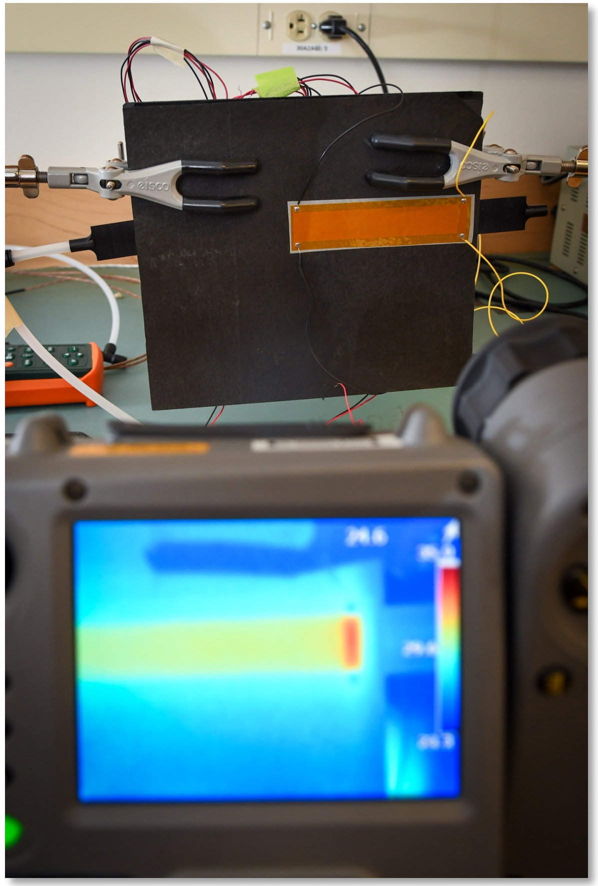
- End goal is operation of sensor at/near ***room temperature*** (25 – 30°C)
- $\Delta T = T_{Heater} - T_{Inlet\ Air}$
- **“Reasonable”** ΔT is one that achieves room temperature operation with sensible air inlet temperature
  - Aiming for $\Delta T < 20$°C (which would require 5-10 °C air)
- **“Reasonable”** also has to take total air volume into account
  - E.g. if we can achieve room temperature with 30 m/s air, this is not reasonable

Discs: previous results

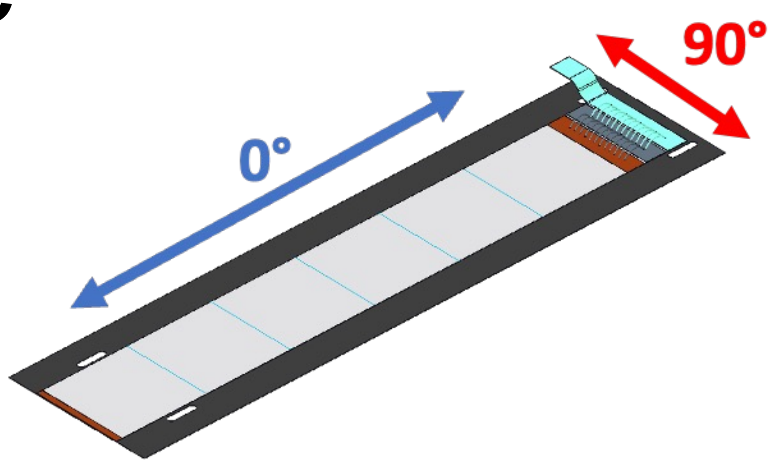


- [Cooling through corrugated carbon veil (first prototype)]()
- [Thermal studies using PGS (graphite) & unidirectional carbon fiber (K13C2U)]()

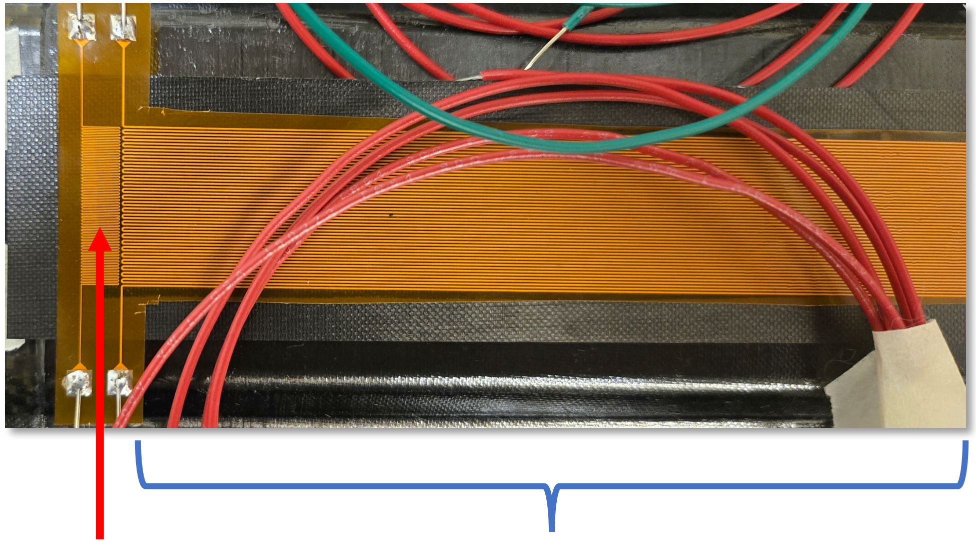


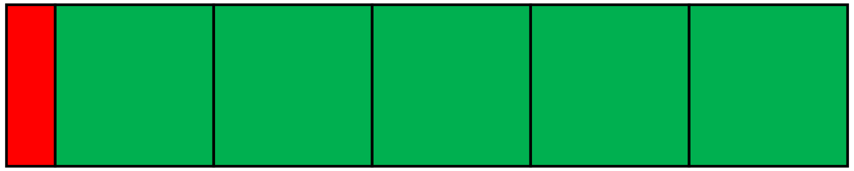


Modules: thermal performance



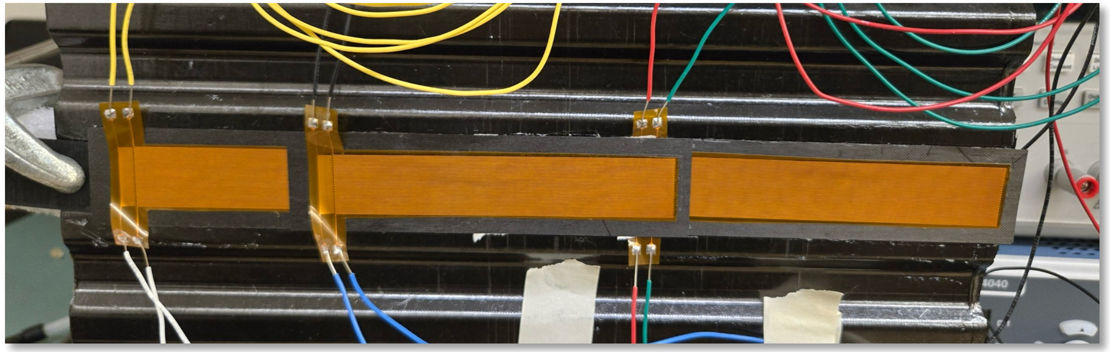
Heaters: 2 power regions





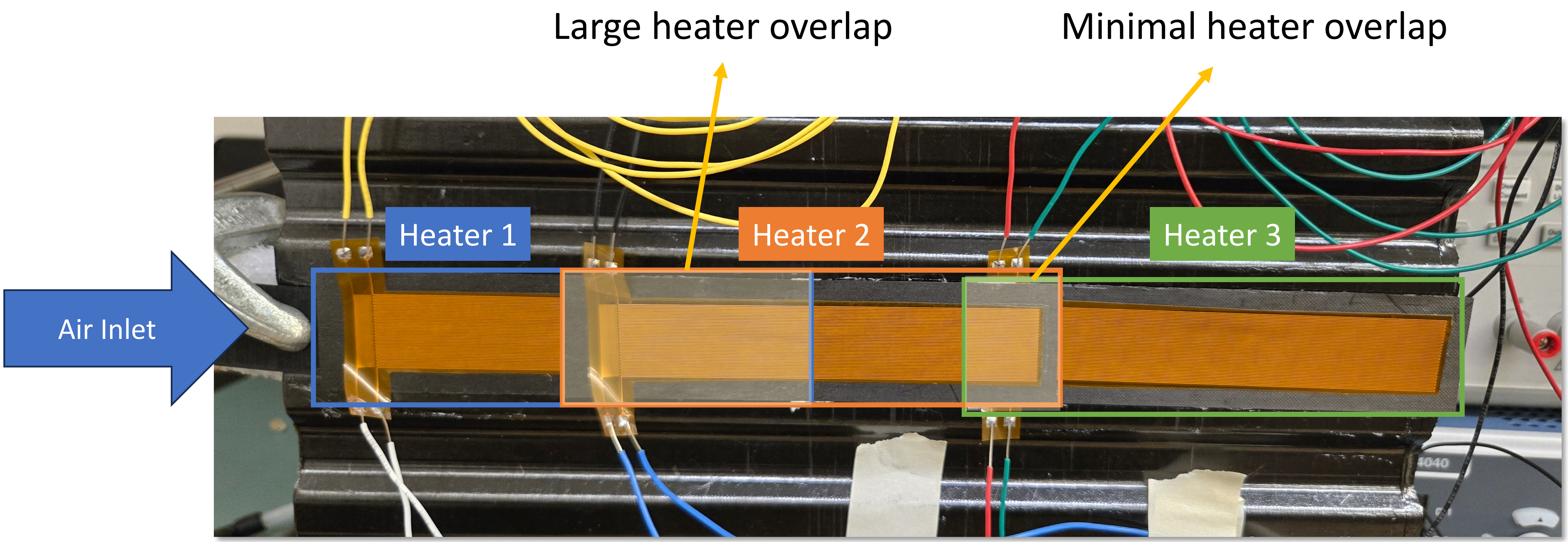
Each power region powered separately
Capable of a range of power densities

Thermal prototype



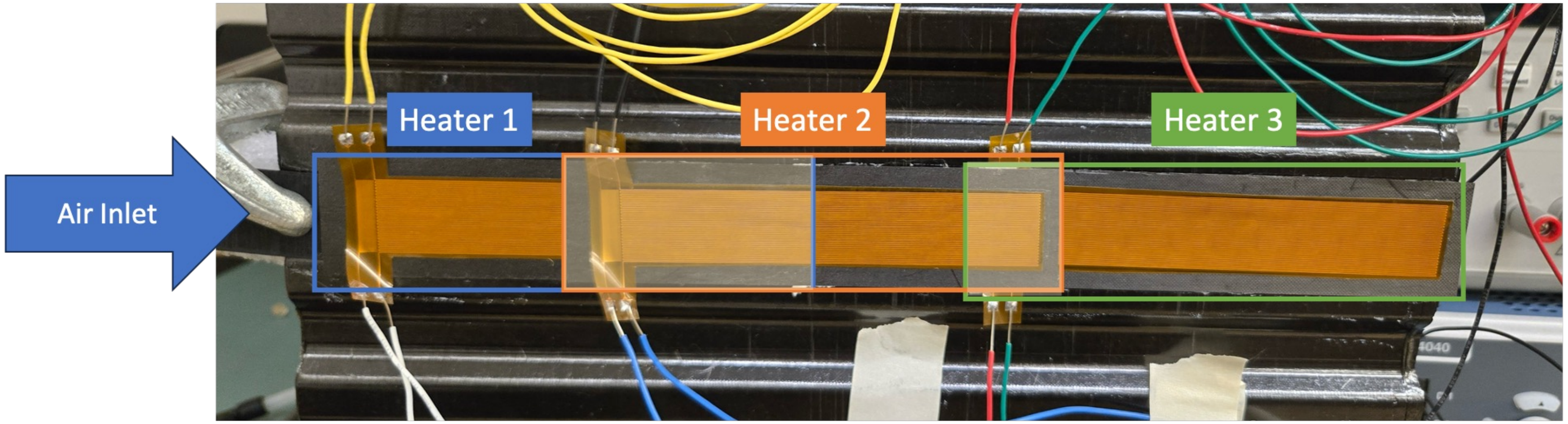
- Three heaters placed on one corrugated channel
- Two overlap regions
  - Large (~1/2 the heater length)
  - Minimal (~LEC length)
- Configuration: outward facing only
- Tested at two different powers, MAX and MIN (based on numbers shown in previous slide)
- Held in same orientation as planned in ePIC

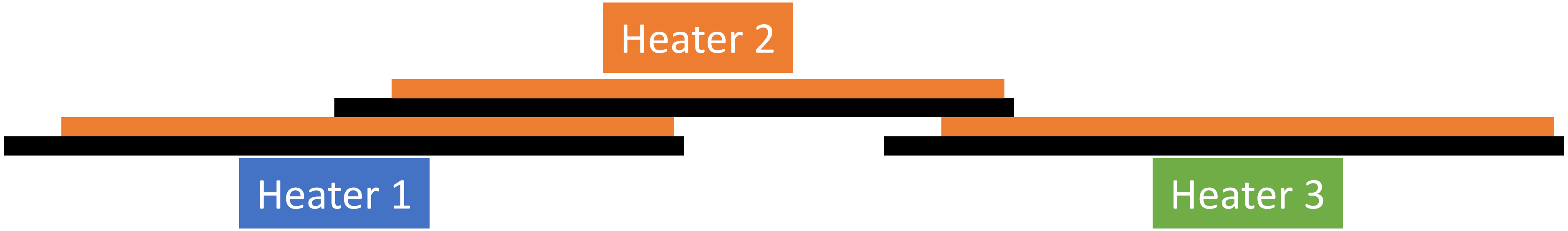
Test setup

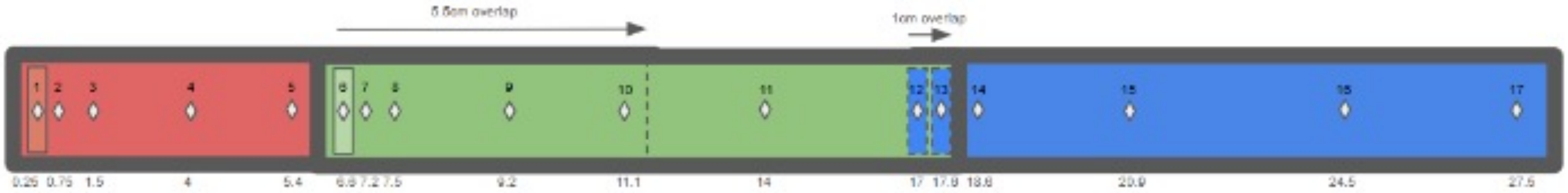


Large heater overlap
Minimal heater overlap
Heater 1
Heater 2
Heater 3
Air Inlet

From the side

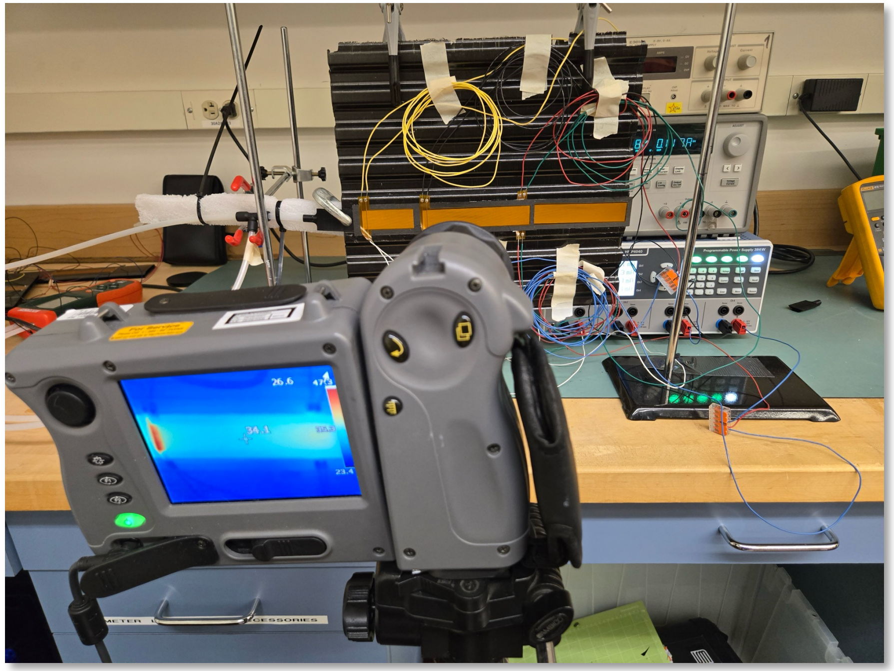




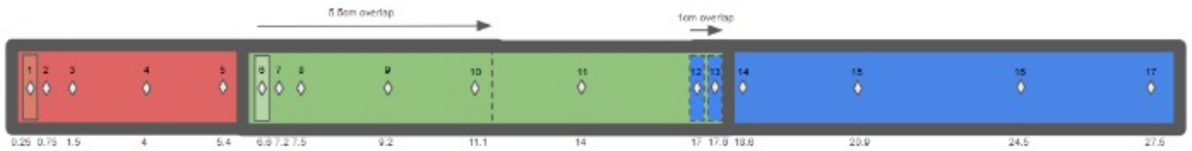


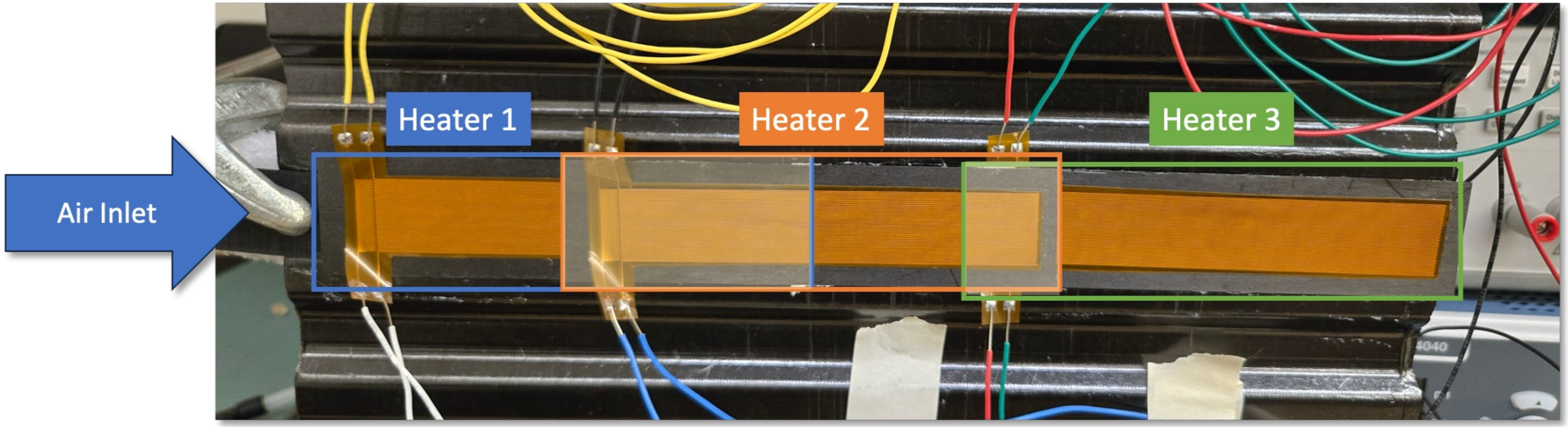
Test setup & caveats

- Using thermal camera → ~0.5°C fluctuations
- $\Delta T = T_{BrightTemp} - T_{DarkTemp}$
  - Dark temp taken with air flowing, but no power
  - Bright temp taken with air flowing and power on
- Cannot measure ΔT of sections we cannot see, i.e. hidden behind overlap
- Potential air leaks for large air velocity
  - Modules glued to each other ***ONLY*** via the carbon fiber → will not be the case for inward & outward alternation



Measurements

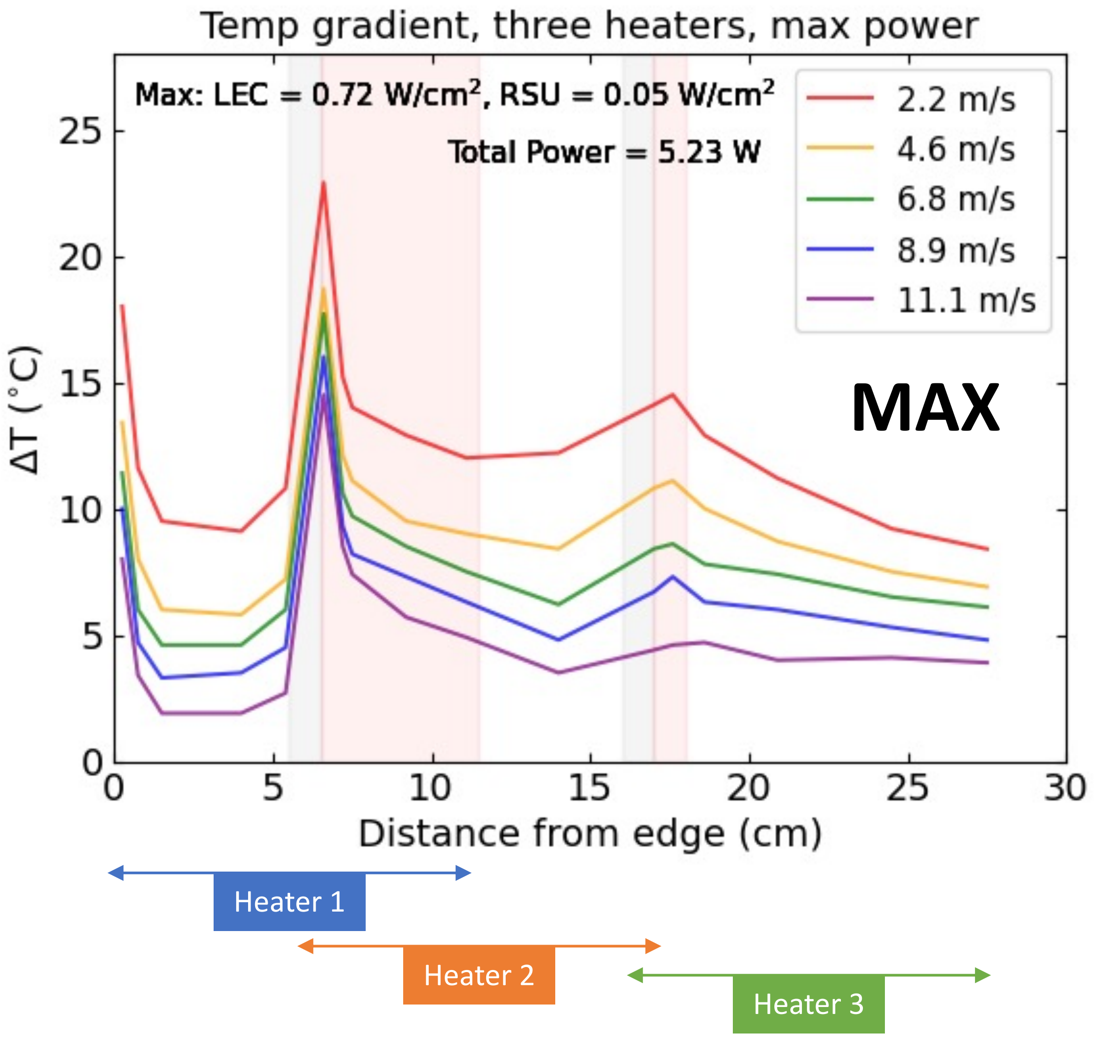


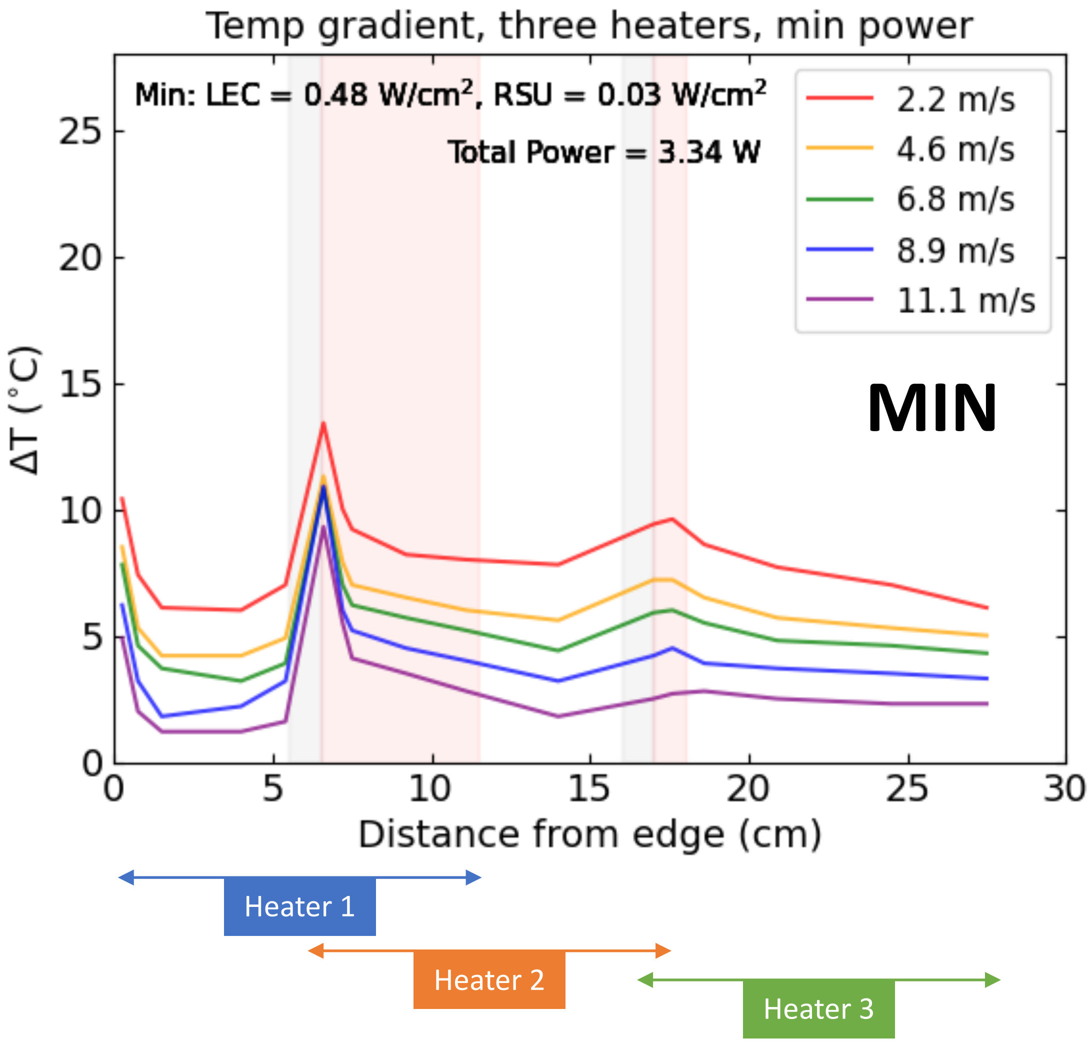


x = 0 cm → x = 28 cm

- Bright Temp measured at 17 different x values along corrugation (0 – 28 cm)
  - One point taken at each LEC position
- Data taken at 4-5 different air velocity values
- Taken at MAX and MIN powers
- Data taken with all three heaters on and then each heater powered individually

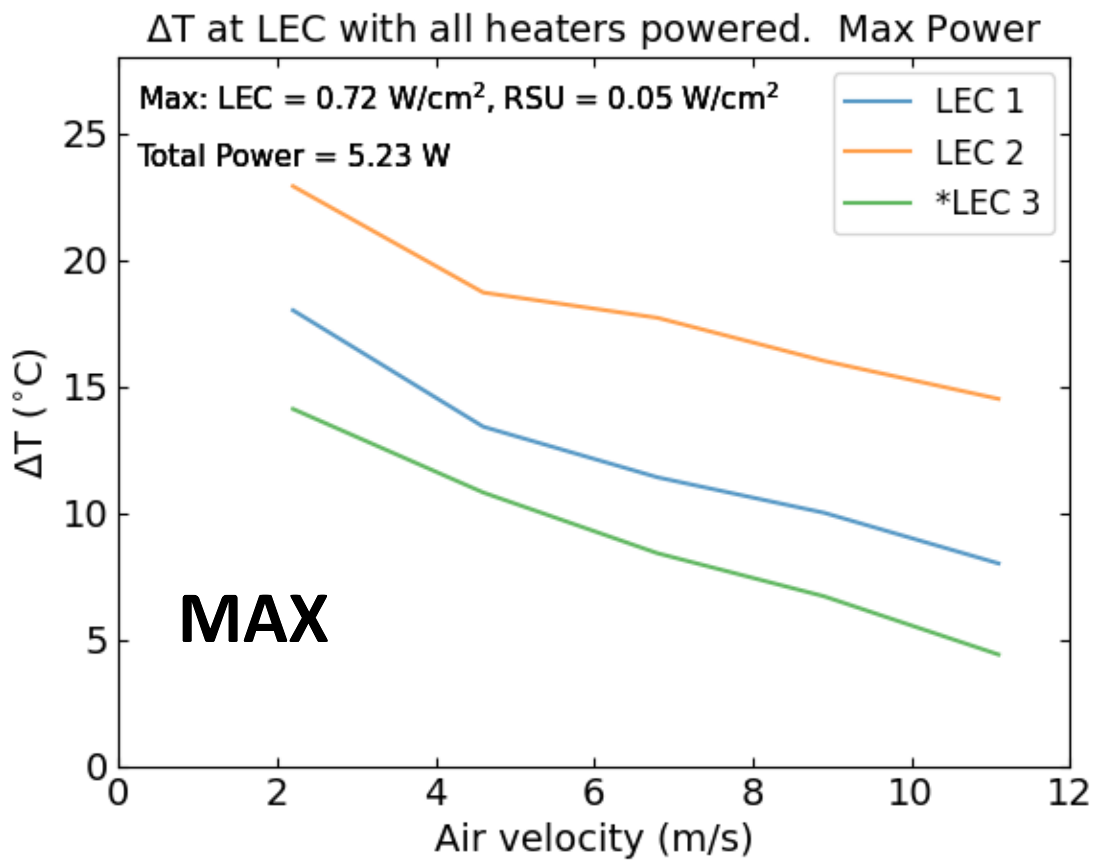
All heaters powered

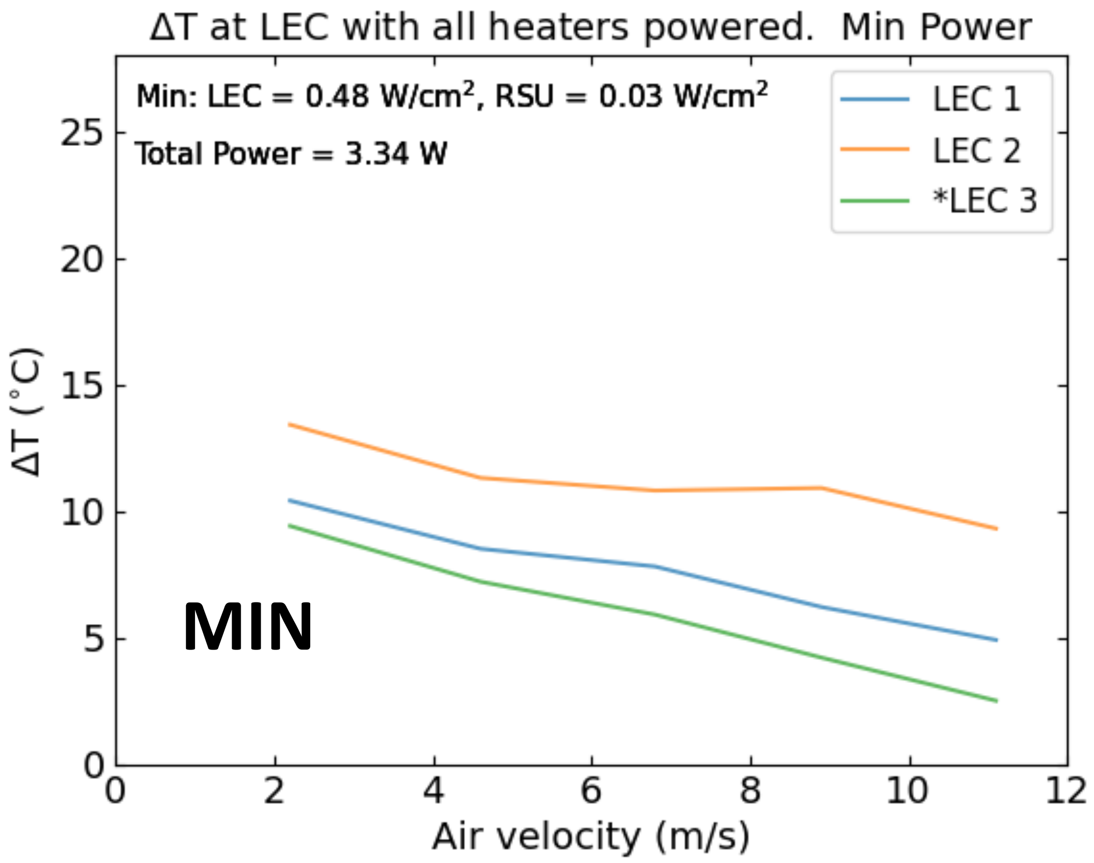




Isolated LEC

*LEC 3 → cannot be directly measured and is therefore a measurement of the RSU with the LEC on behind it





LEC 2 highest → expected since overlaps RSU

Expect *actual* LEC 3 to be similar to LEC 2

Isolated LEC

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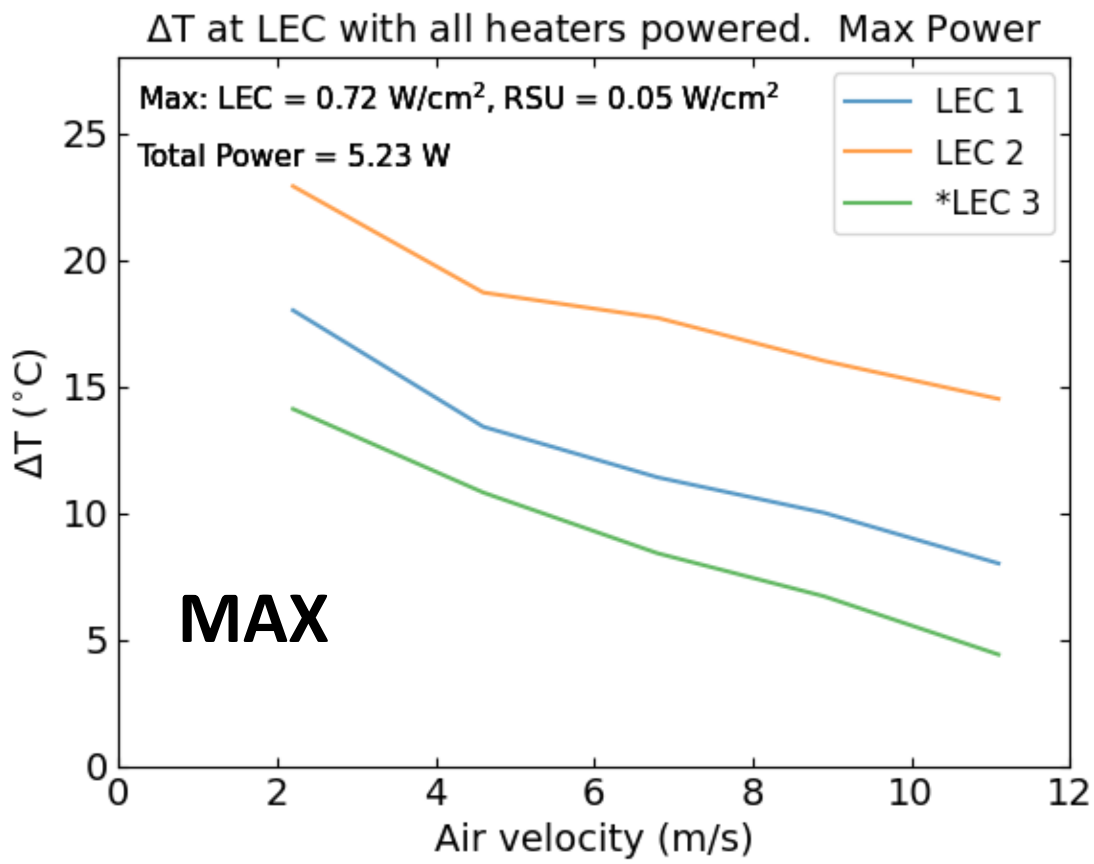
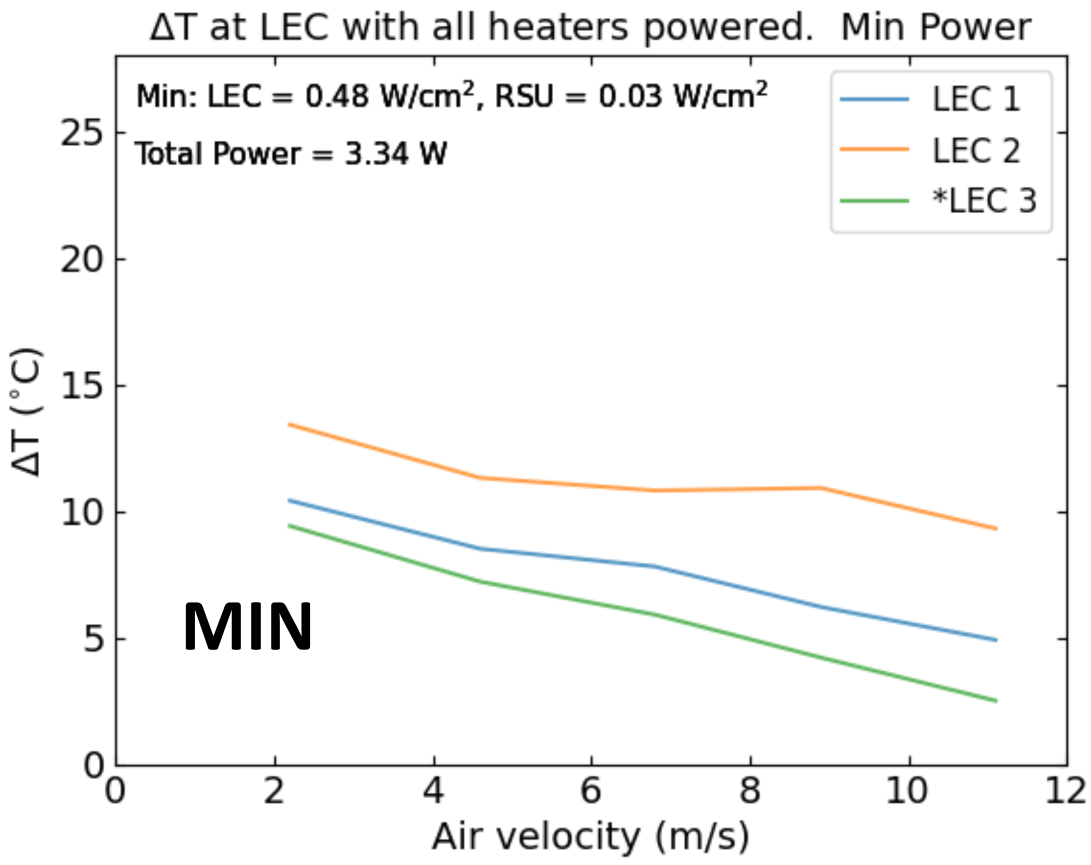
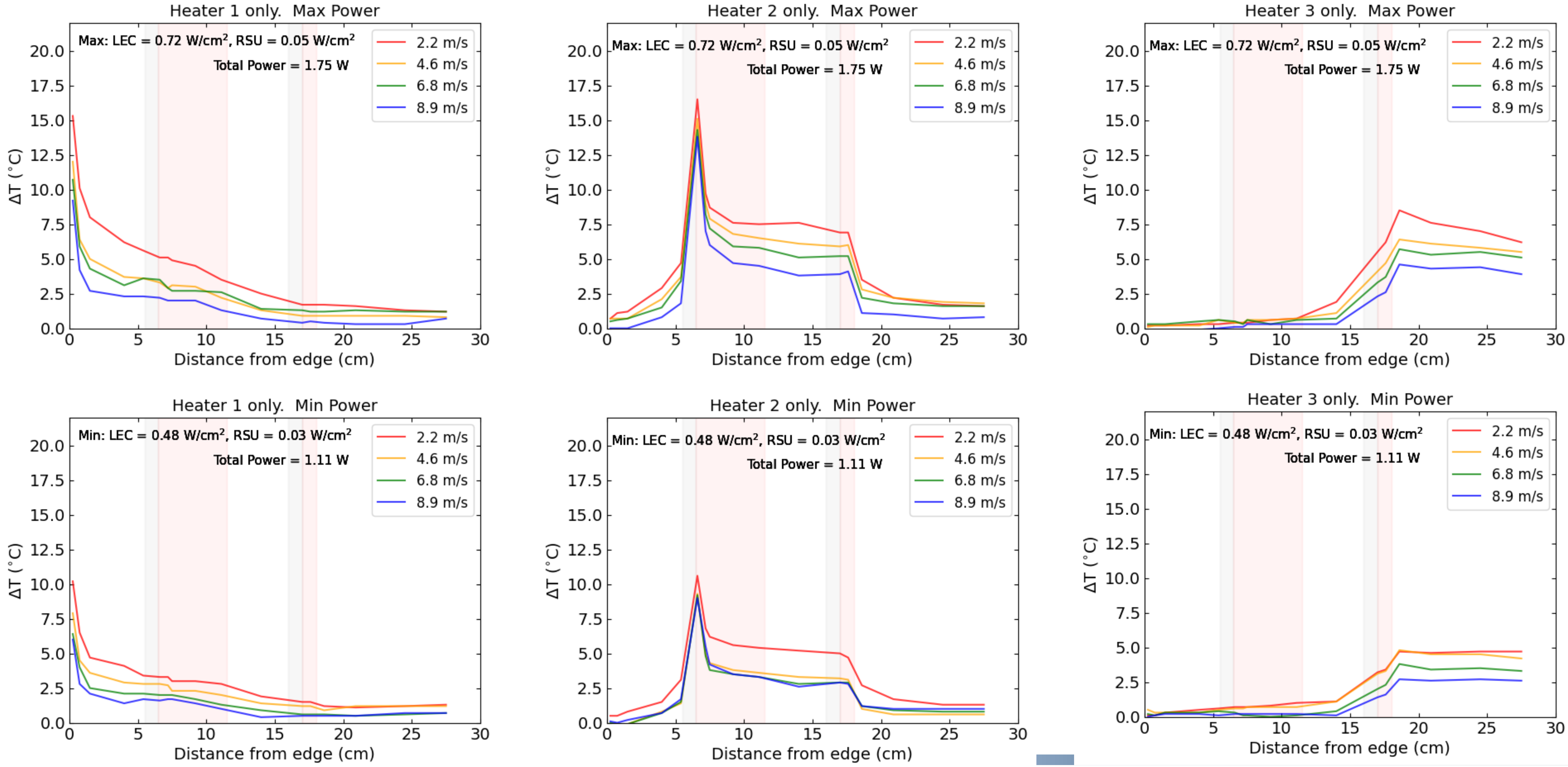




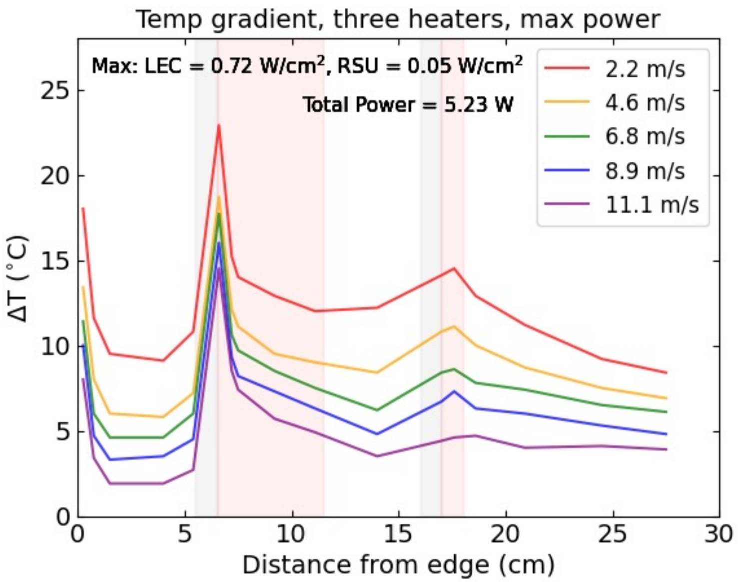
MAX: ΔT < 20°C for air > 8 m/s

MIN: ΔT < 15°C for all air speeds

Powering individual heaters



Comparing all powered to single



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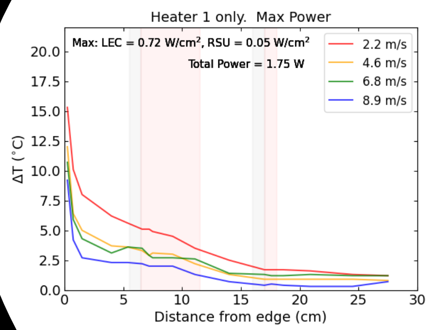

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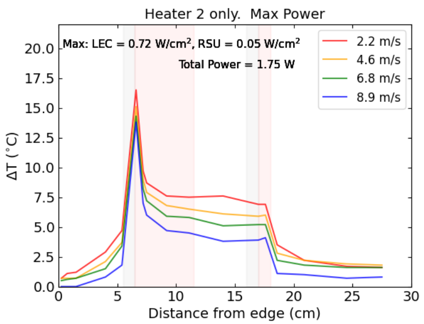

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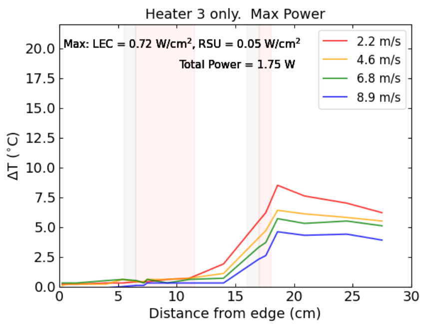

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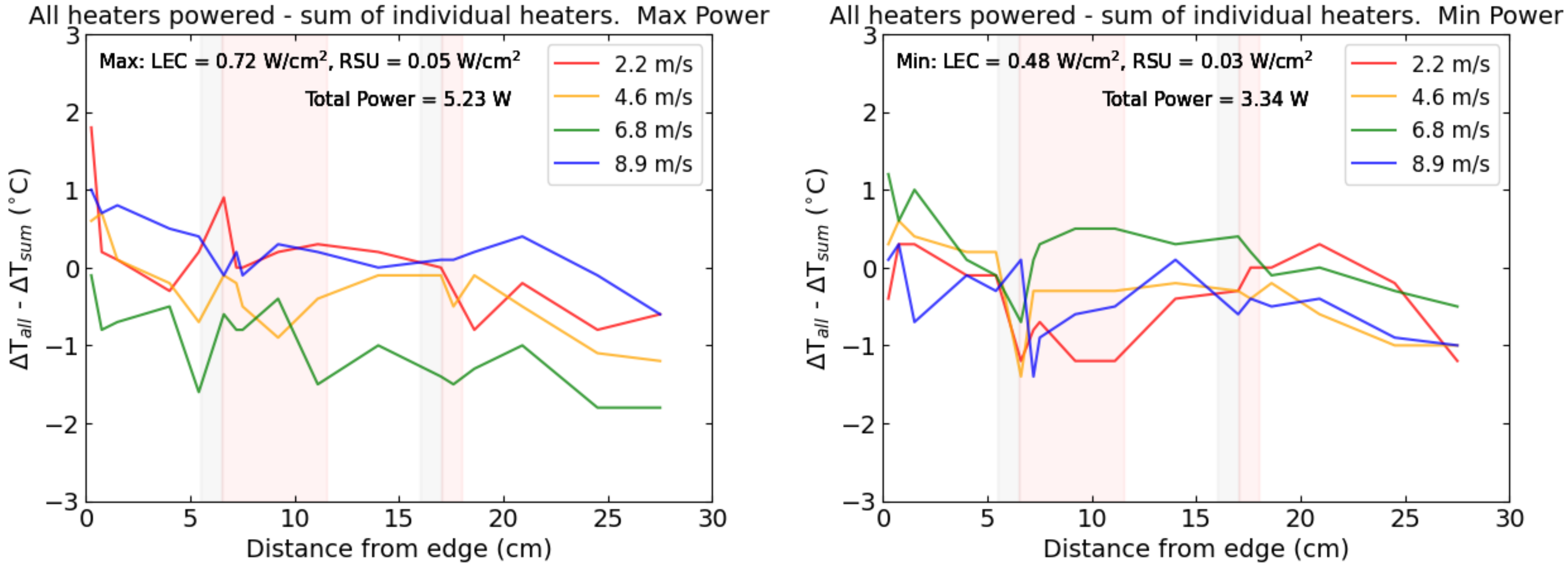
ΔT_{all}: all 3 powered

ΔT_{sum}: $\Delta T_1 + \Delta T_2 + \Delta T_3$

Comparing all powered to single



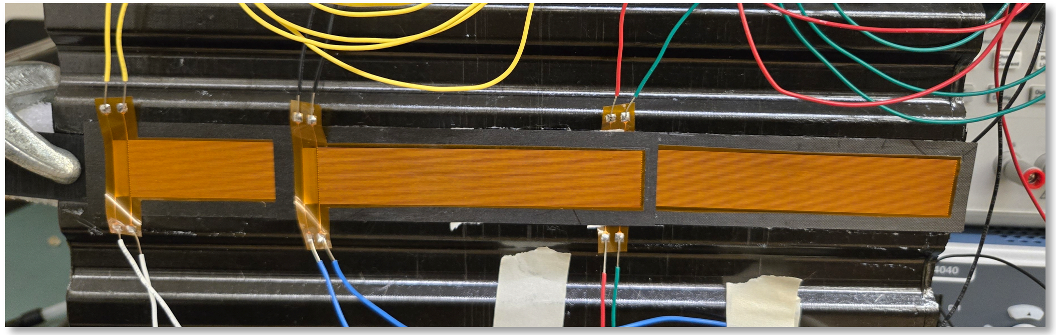
ΔT all powered – ΔT sum of individual results

Varies around 0 → confidence that we can predict ΔT if power changes

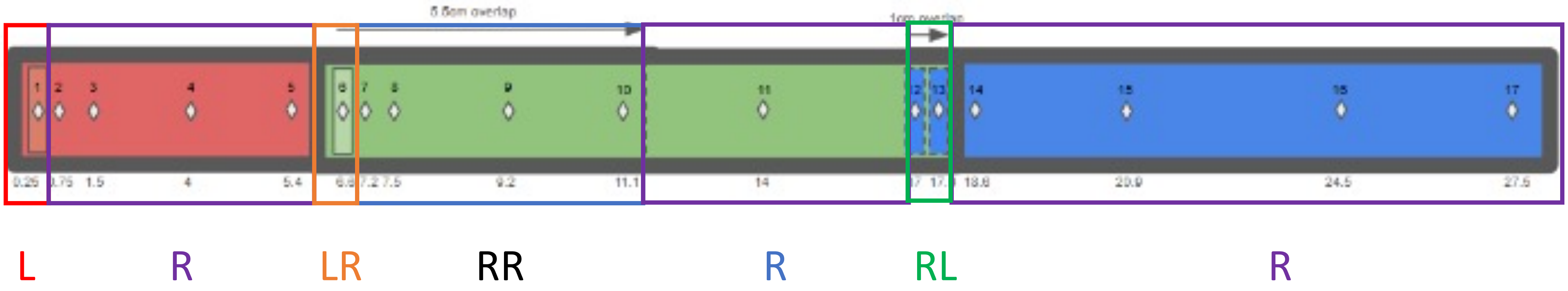
Determining heat transfer coefficient

- Heat transfer coefficient, *h:*
  - $h \sim \frac{q}{\Delta T}$, q is power density
- *h* is dependent on air properties, changes with velocity & temperature
- Can be calculated using Reynolds and Nusselt numbers
  - Based on laminar or turbulent flow, which is dependent on air speed, air temperature, tube (or channel) size
- Can also be measured based on q and ΔT

Measuring *h*

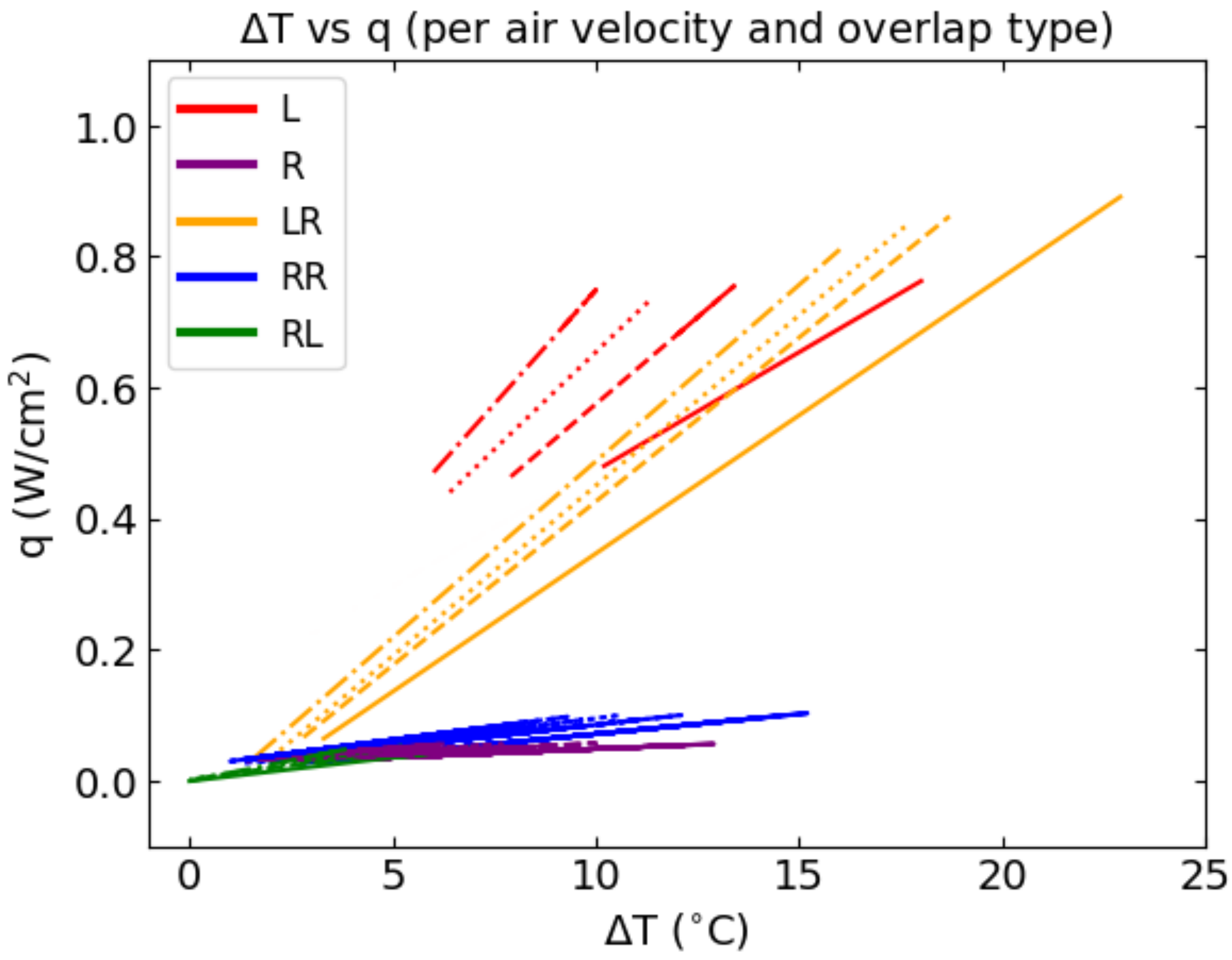


- Identify 5 regions: L, LR, RR, RL, R
  - Looking from front face in, represents the power domains in overlap, e.g. LR is LEC with RSU behind.
- q is sum of powers, e.g. LR is LEC power density + RSU power density
- Plot q vs DT separately for each region and each air velocity



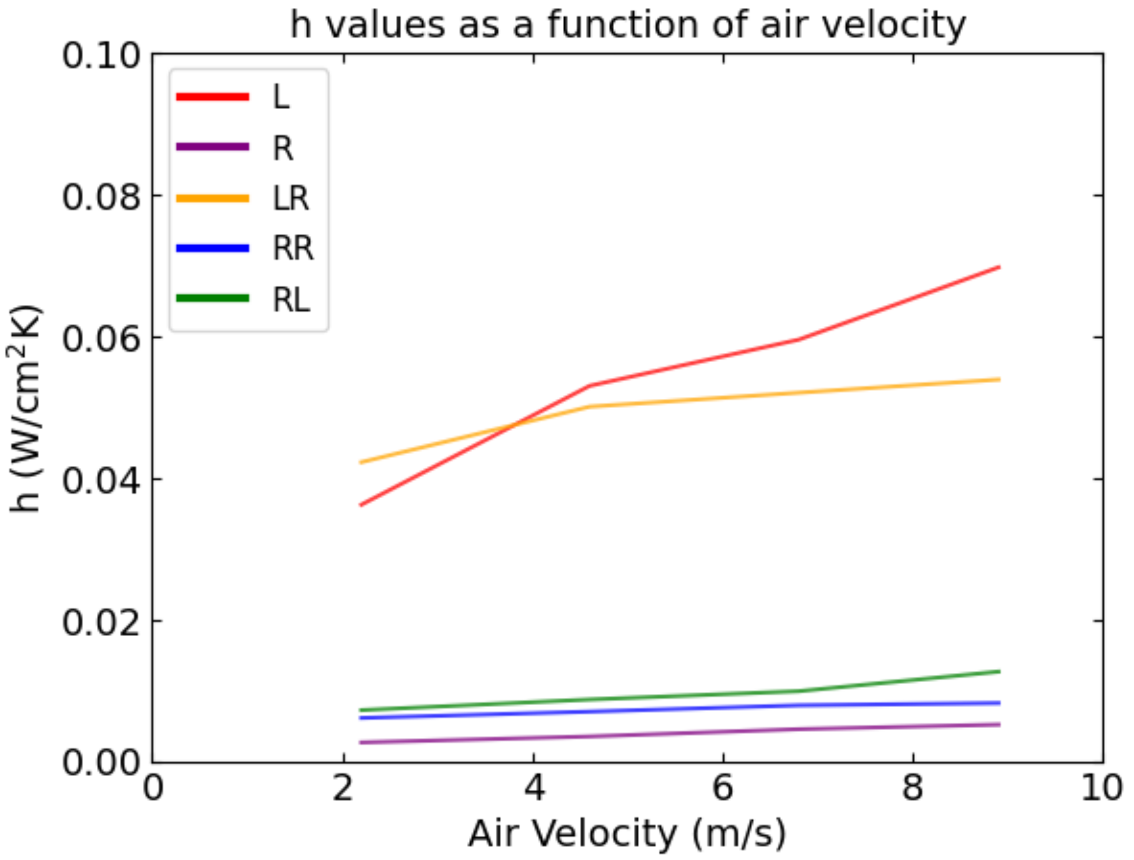
q vs ΔT

- Only consider data where the heater can be seen
  - E.g. do not include part of individual heater 1 measurements that are behind heater 2
- Plotted as best fit line to the data
- Shown for 4 difference air velocities per overlap configuration
- All RSU measurements are very similar
- Extract slope from line to get *h*



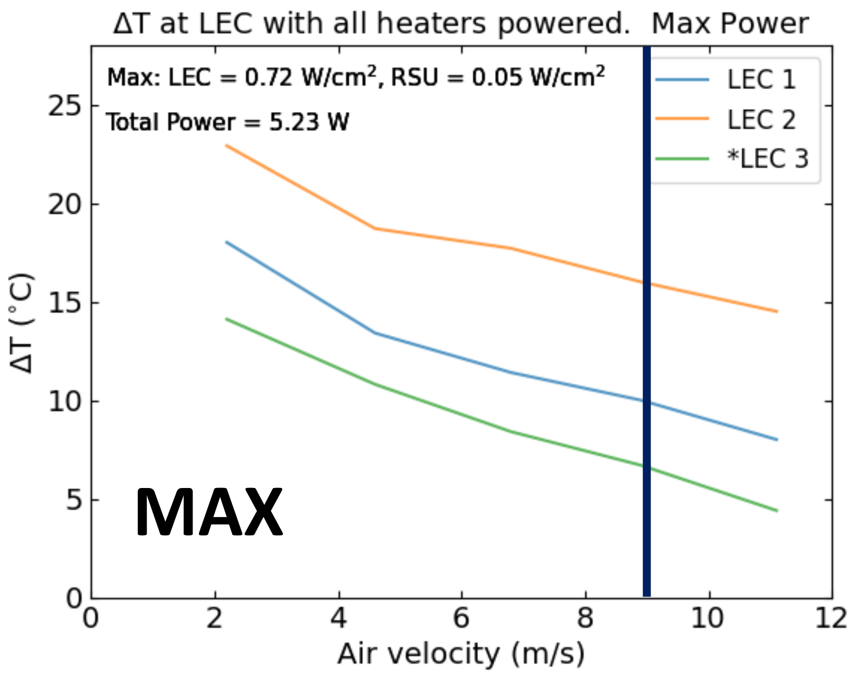
h as a function of air velocity

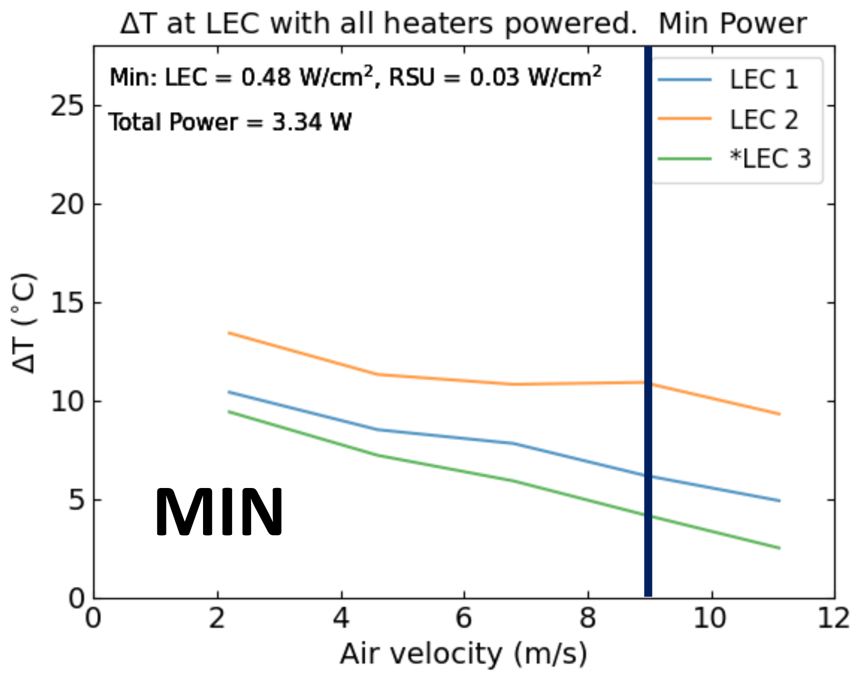
- Slope of q vs DT plotted as a function of air velocity, estimated as *h*
- Extract equation $h \propto v$ → determine ΔT based on q and air velocity
- PT100s would allow us to refine these measurements and calculations
  - Measure the ”hidden” sections



Caveat: not quite *h*, but a combination of conduction & convection

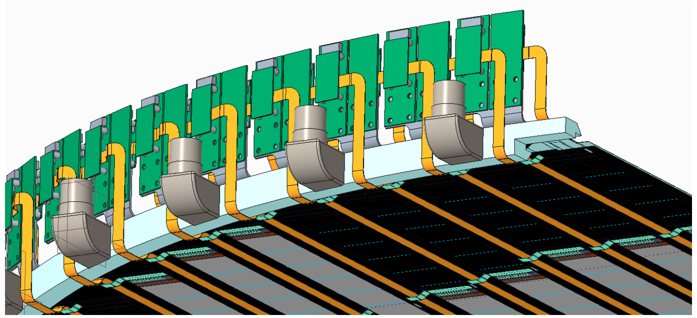
Summary





- At 9 m/s:
  - RSU ΔT < 10°C for MAX and < 5°C for MIN
  - LEC ΔT < 20°C for MAX and < 15°C for MIN
- ΔT dependent on overlap and proximity to air flow/edge of disc
- At 9 m/s through 2 corrugated channels, discs would need ~400 cfm

Next steps (not exhaustive)



- **Include the AncASIC ← priority**
    - Quick check is with current heaters, using the LEC section
- Comparison to ANSYS simulations
    - Started/ongoing for IB/OB/Discs
- Thermo-mechanical dummies → includes the silicon for a more realistic thermal performance
- ”Reasonable” ΔT determination
    - Understanding the total air volume necessary.
    - Infrastructure to cool the air
- Air inlets and outlets and pipe/tube routing
    - Preliminary designs for the discs based on air through multiple corrugated channels

Backups

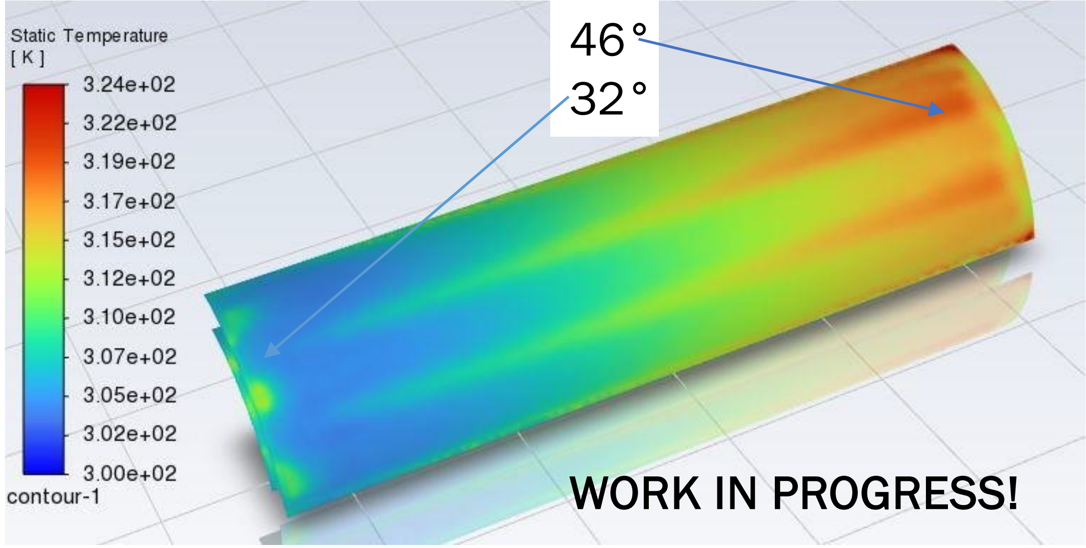
Inner Barrel

Thermal load simulation via Ansys Fluent @INFN

- Quarter-barrel simulation L0+L1
- Uniform 40 mW/cm^2 heat emission
- Results dependent on mesh granularity
- Turbolence (critical for proper cooling) not easily set

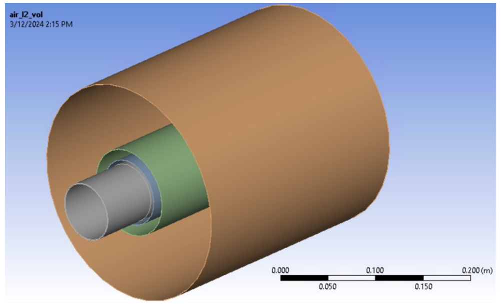
→ see details in the presentation by R. Turrisi within WP4 session @ SVT workfest this afternoon!

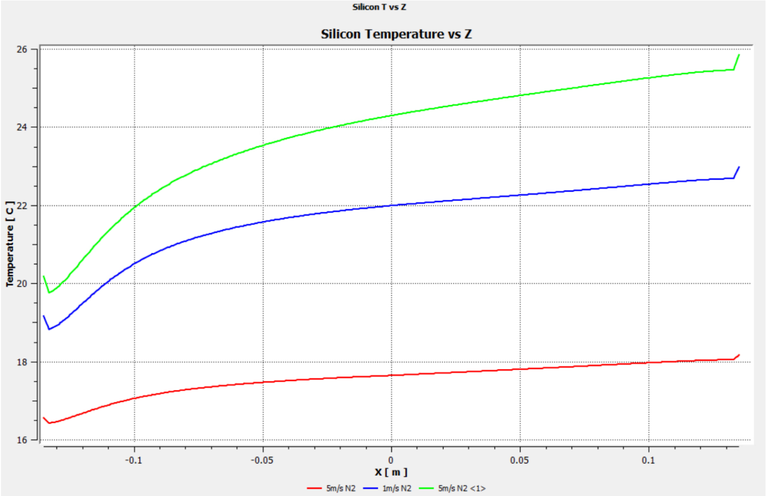
V_{IN}= 15 m/s = 54 kph

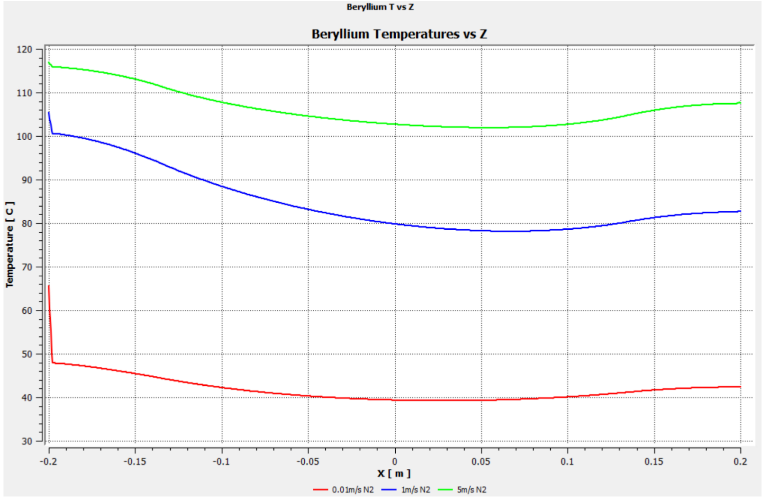


Beam-pipe Bake-out

- Beam-pipe bake-out with SVT installed
- Aiming for no additions to cooling
  - No extra material (e.g. insulators) or changes (i.e. liquid instead of air)
- ANSYS studies at JLab and LBNL
  - Flow N2 at 120°C at various speeds in beam-pipe to get inner wall >100°C
  - 15°C air between L0 and L1 to cool silicon







Towards a new disc prototype

- K13C2U
  - Unidirectional, high thermal conductivity
  - 3 layers
- Modules
  - Flat sheets in 0/90/0 orientation
  - For strength & thermal performance
- Corrugation
  - 90/0/90 orientation
  - For strength