PCB Testing and Cu pipe bending techniques

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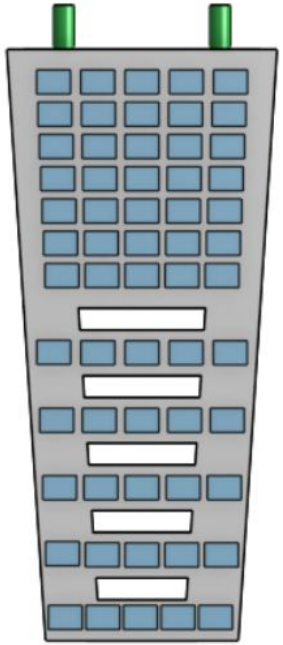
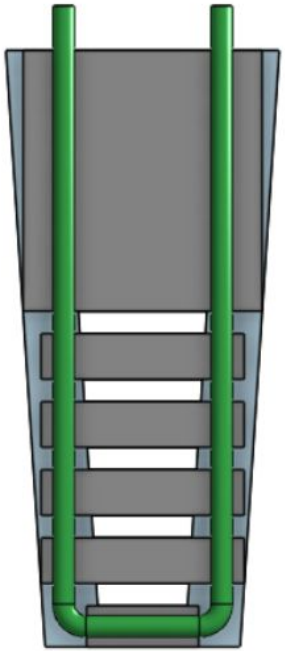
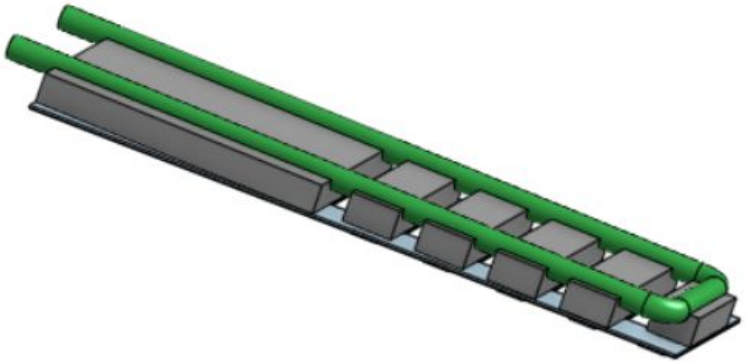
Design



Front View



Back View



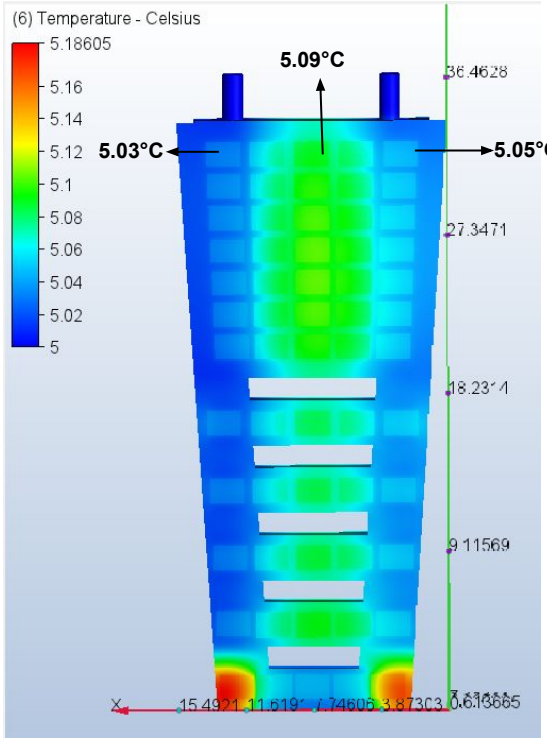
Isometric View

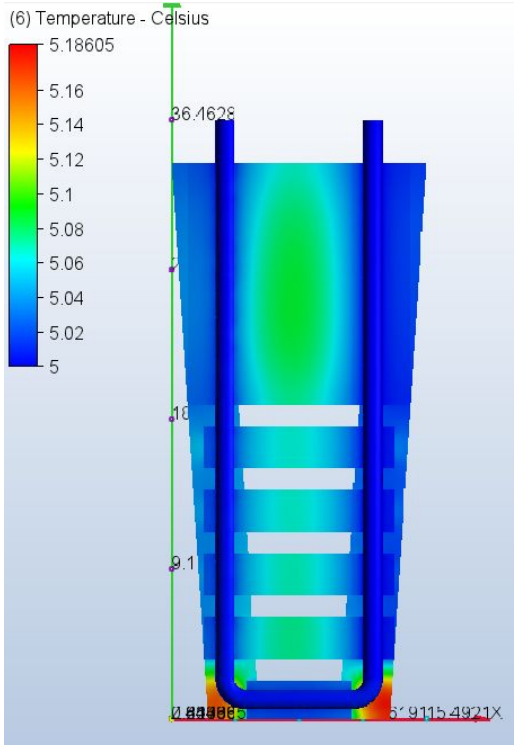
Boundary Conditions

1.) **Inlet Boundary Conditions**:
   a) Water is introduced at **5 °C**, as suggested in the **Mechanics and Sectors Meeting**.
   b) **Volume flow rate** is set to **2 gal/min** at the inlet.

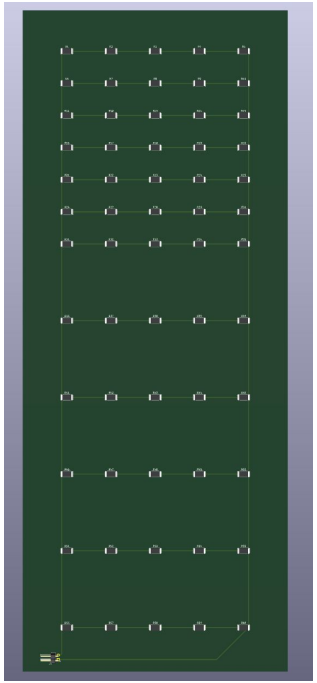
2.) **Outlet Boundary Condition**: **Pressure** is fixed at **0 Pa**.

Thermal Simulation results





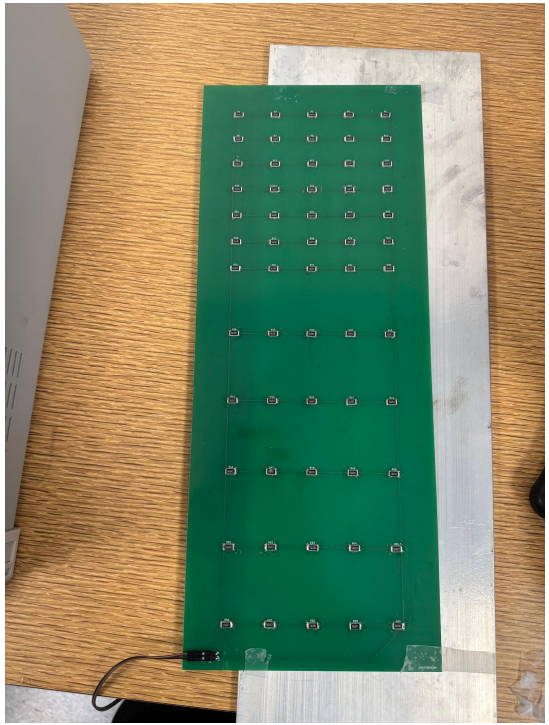
PCB Design



Design of the PCB

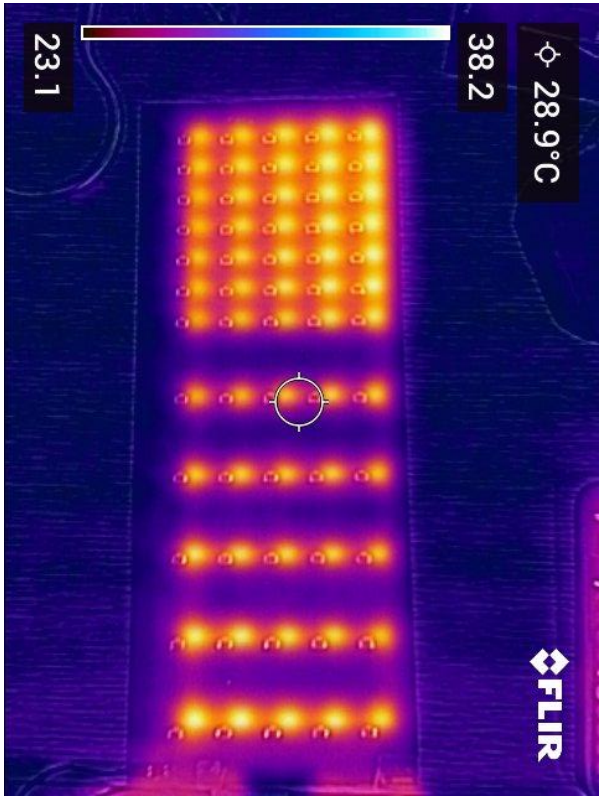
- Resistance of each resistor = 56 Ohm.
- I_i = 0.05 A
- V_i = 2.6 V
- $P_i \approx 0.14$ W, $P_t \approx 8.4$ W
- Dimensions of PCB: Length = 381 mm (15 in), Width = 152.40 mm (6 in), Thickness= 1.6mm or 0.06 in (FR4 = 0.3 mm, Cu base: 1.3 mm).
- Resistance = 23.33 Ohm

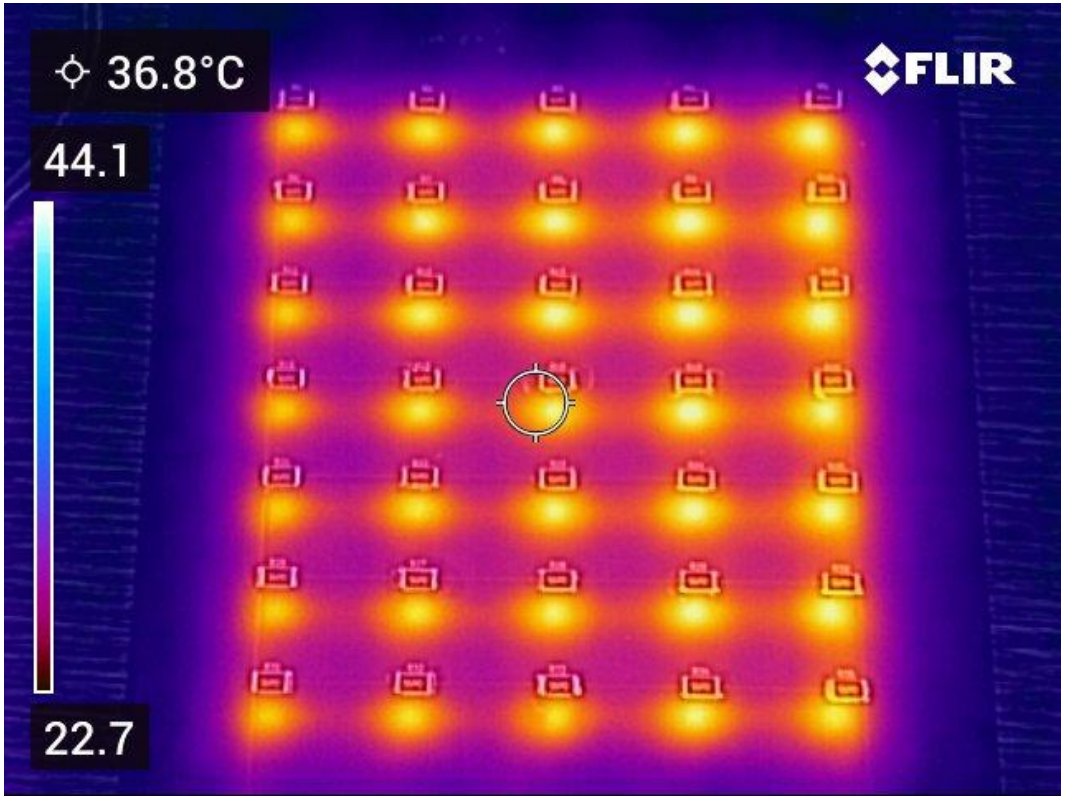
PCB Testing



- Size of the Resistors = (6.3 X 3.15) mm (smd__6332_2512).
- PCB has one layer, FR4 = 1.6 mm.
- Resistance measured = 26.1 Ohm.
- We will deposit 8.4 W of power.

PCB Testing





Copper Pipe Bending Specification

Pipe Details:

- Type: **K**
- Inner Diameter (ID): **0.222 in**
- Outer Diameter (OD): **0.25 in**
- Wall Thickness: **0.014 in**
- Standard: **ASTM B251**
- Temper: Hard

Bending Goal: 90° bend — Determine safe minimum bend radius (**R□ᵢ□**).

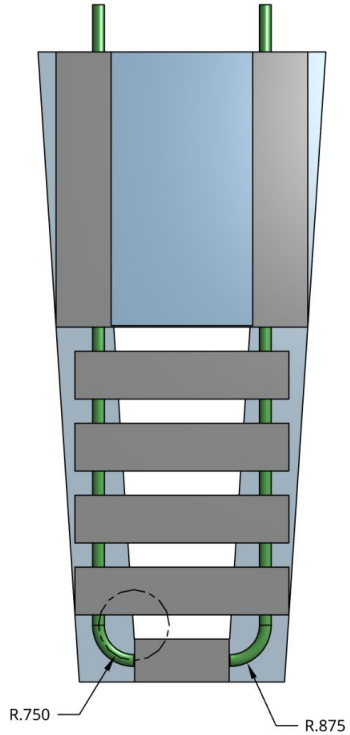
Table 4.1. Bending Guide for Copper Tube

Nominal Standard Size, in	Tube Type	Temper	Minimum Bend, Radius*, in
¼	K,L	Annealed	¾
⅜	K,L	Annealed	1½
	K,L,M	Drawn	1¾
½	K,L	Annealed	2¼
	K,L,M	Drawn	2½
¾	K,L	Annealed	3
	K,L	Drawn	3
1	K,L	Annealed	4
1¼	K,L	Annealed	9

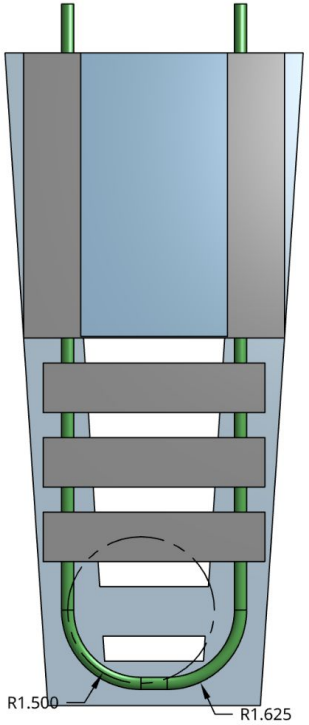
* The radii stated are the minimums for mechanical bending equipment only.

Cu Temper	k-factor	R_{min}	Our case (CLR)
Soft (Annealed)	2.5- 3	3 times OD	0.75 in
Hard (Drawn)	3-6	6 times OD	1.5 in

Comparing CLRs for soft and hard Cu pipe



Soft (Annealed): CLR = 3*OD



Hard (Drawn): CLR = 6*OD

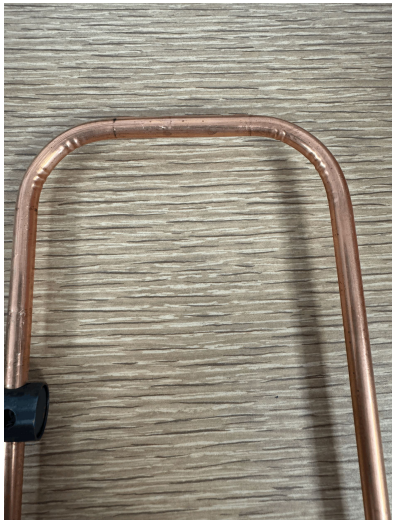
Bending Approaches

Using the bender:

Bending Issues: Vertex keeps moving/slipping even after clamping.

Solution: Use a **rubber cap** over the wire before inserting into the bending slot to **prevent slipping** *(yet to be tested)*

Current Focus: Find an **easier and repeatable bending method** for mass production



Center-to-center spacing (CLR as reference): **3.628 in**

Bending Approaches

Circular tool:

Radius = **3 in, Groove machined using a ¼-in ball-nose cutter.**

Center-to-center spacing (CLR as reference): **3.508 in**

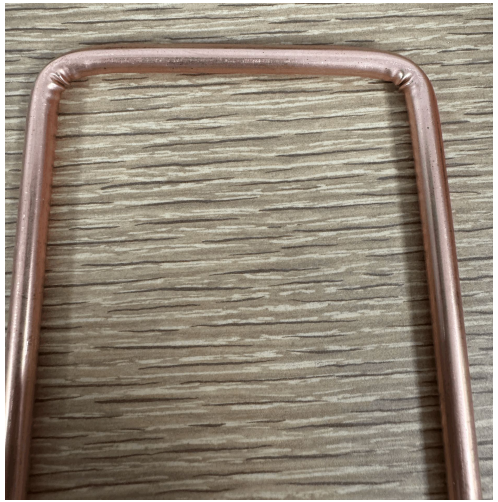
Problem: Circular pipe end needs a matching groove on the Al plate for proper fit. Straight grooves were preferred for easier fitting.

Solution: Making a rectangular pipe bending tool.

Bending Approaches

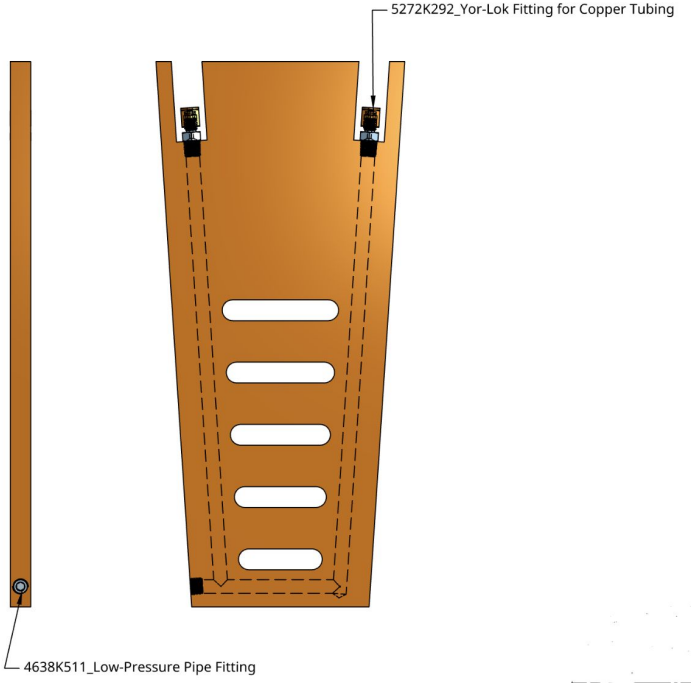
Rectangular tool:

Groove machined using a ¼-in ball-nose cutter, Bending radius **= 0.75 in**



Center-to-center spacing (CLR as reference): **3.258 in**

Another approach for the model

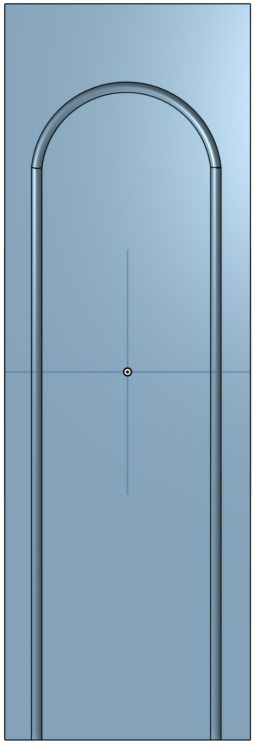


Another model approach without using cooling pipes. (Created by Dr. Deconinck)

Machined by Chad (Machinist at UoM)

Work in progress

- **Groove machining:**
  - Mill the groove on the aluminum plate as shown in the CAD model.
  - After milling, cut the plate into smaller cold plate sections.
- **Attachment to PCB:**
  - Exploring different methods to attach each cold plate piece to the PCB.
  - Current assumption: use thermal pads for attachment.
  - If required, a mechanical fastening (e.g., drilling and screwing through PCB) can be used, with a soft thermal pad layer in between.
- **Role of thermal pad:**
  - Provides thermal interface between the PCB and cold plate.
  - Acts as cushioning, reducing stress and potential vibrations from external sources.



Summary:

- In the last few slides, we compared different **Cu pipe bending methods**.
- The center-to-center distance in the CAD model is **3.533 in**, and the values from all three bending approaches are close to this target.

Observed Issues:

- **Pipe Bender:** Difficult to control the bend vertex due to pipe slipping.
- **Circular Bend (Hard Cu):**
  - Requires either removing the last cold plate or increasing pipe separation, increasing separation not feasible due to space constraints, as our pipelines already align closely with the last SiPM columns.
- **Rectangular Tool:**
  - Promising, but tight 90° bends cause wrinkling (inner side) and deflation (outer side).
  - Increasing bend radius could fix this, but would create the same spacing issue as the circular tool.
  - Also, we want to avoid semicircular milling of grooves on the Al plate for ease of fitting and manufacturing.

Suggestions Needed :

- Would using a soft (annealed) Cu tube help minimize these bending issues?
- Or, is there a better alternative material (stainless steel, Aluminum) or method to achieve the desired geometry?

Specifications (from GlueX)	values
OD	0.25 in
Thickness	0.035 in
ID	0.11 in