CO_2 Cooling Test with TPG mockup

LCTPC Collaboration MTG @ DESY, 13/Jan/2020

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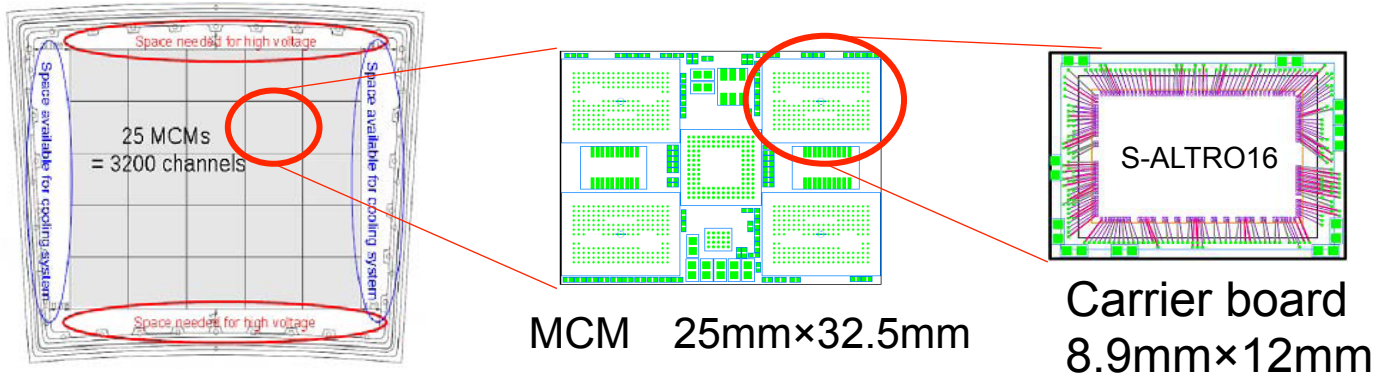
Next prototype readout electronics



MCM 25mm×32.5mm

Carrier board
8.9mm×12mm

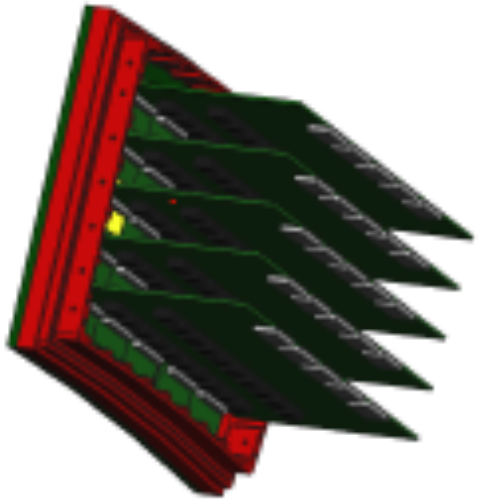
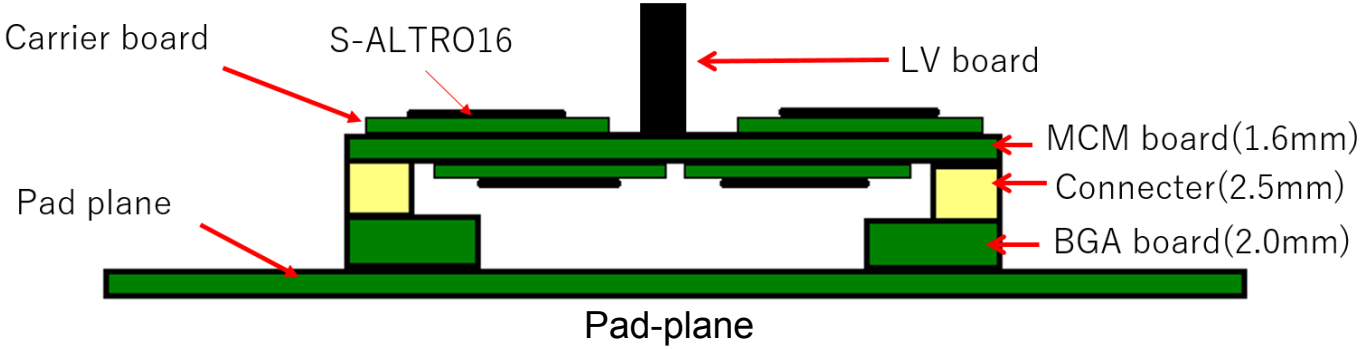


Figure by Lund group



MCMs (Multi-Chip Module with S-ALTRO16) are placed in parallel to the pad-plane via connectors.

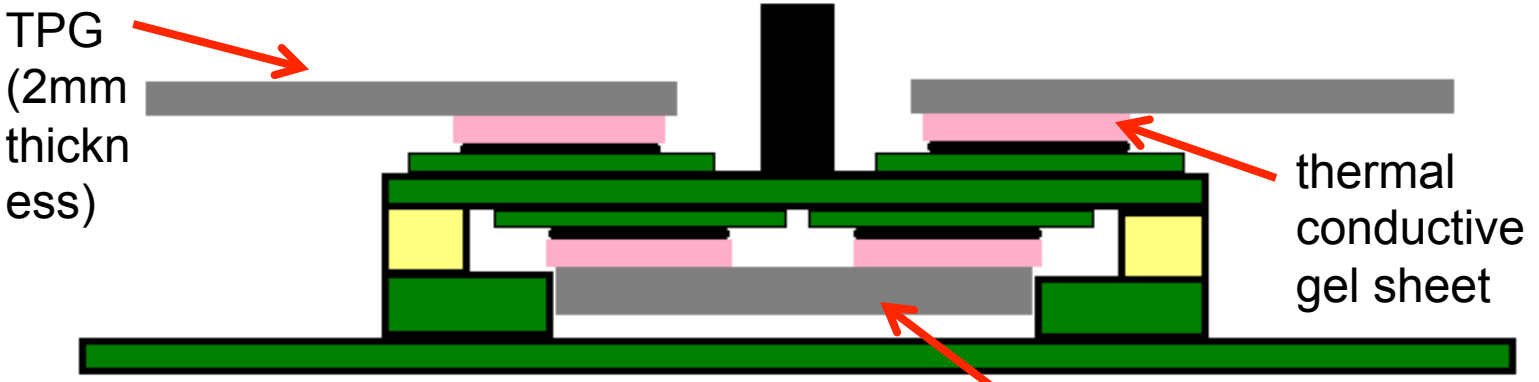
- S-ALTRO16 （@40MHz）

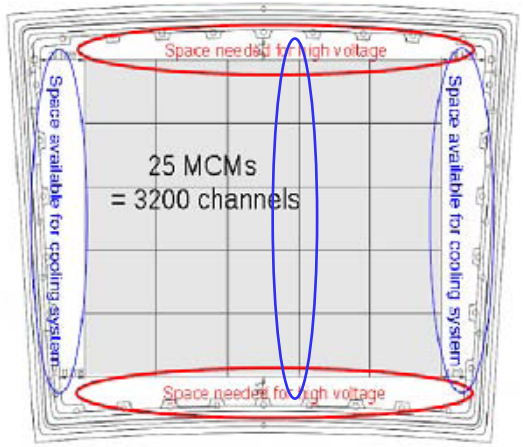
  chip power = 0.94W → 188W / module

→ heat flow from chip to pad-plane can affect the TPC resolution.

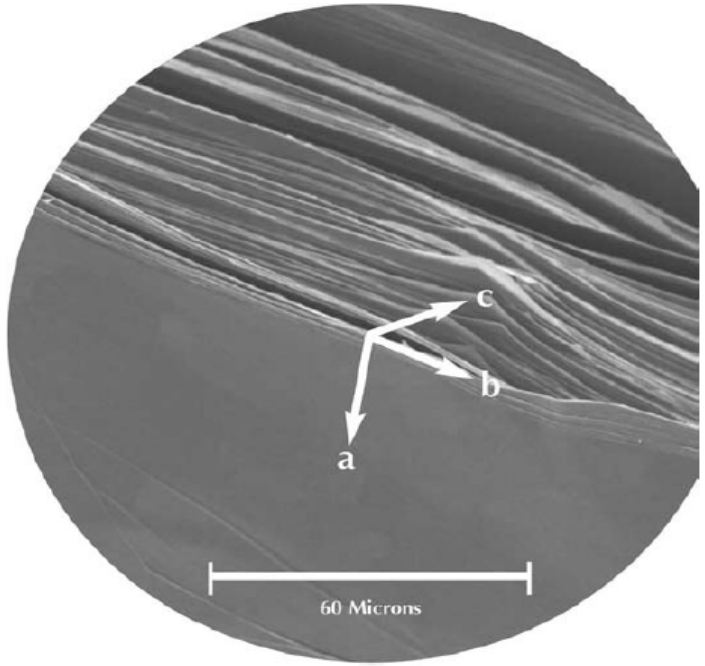
Must remove heat efficiently

Idea: Next prototype with TPG cooling





MOMENTIVE
performance materials



TPG (thermal pyrolytic graphite)

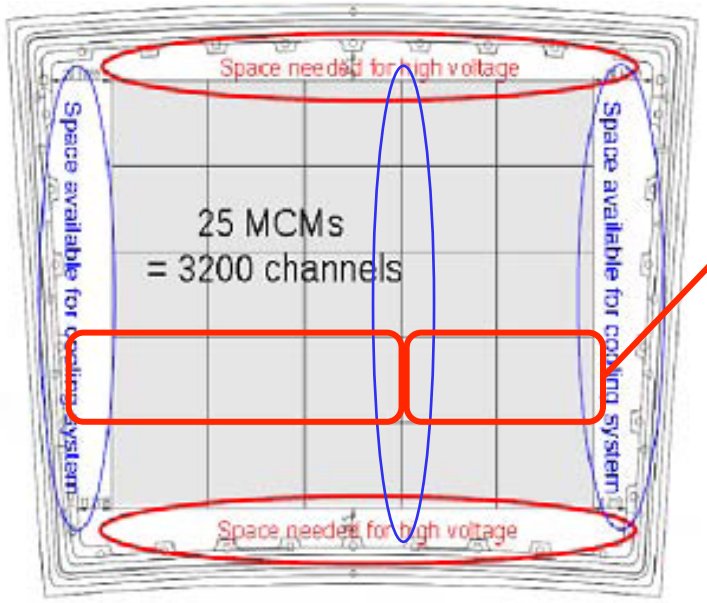
・heat conductivity
λ～1500W/(m・K) a-b direction

20W/(m・K) c direction

compare w. Cu 386~402W/(m・K)

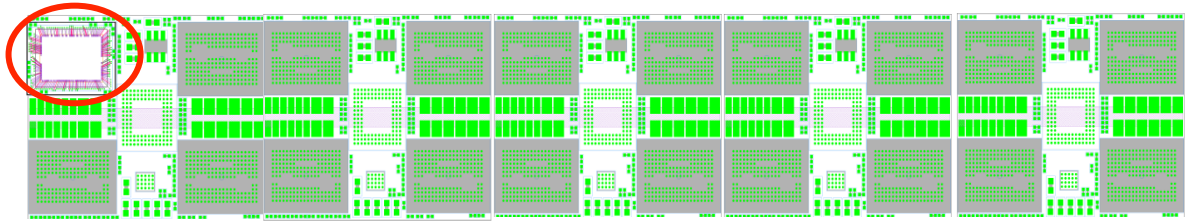
Temperature gradient on the pad-plane
Target: < 1 ℃

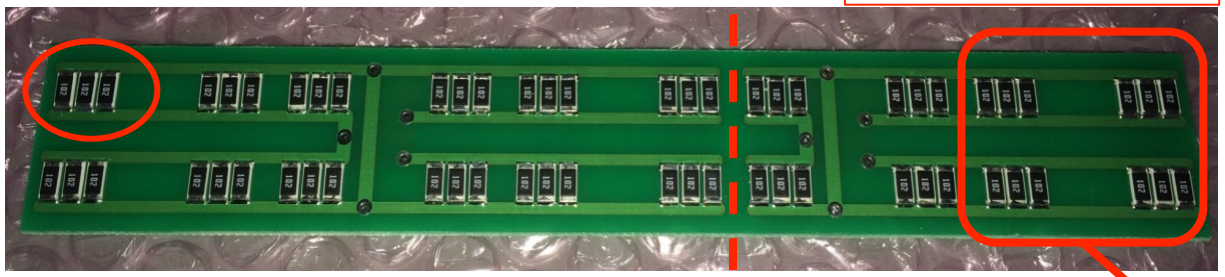
Mockup for cooling consideration



S-ALTRO16

5MCMs





Mockup board

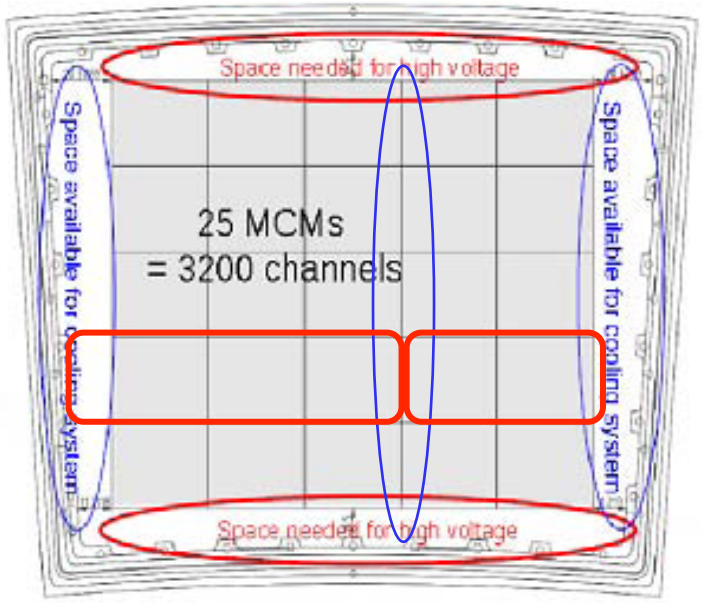
Cut line

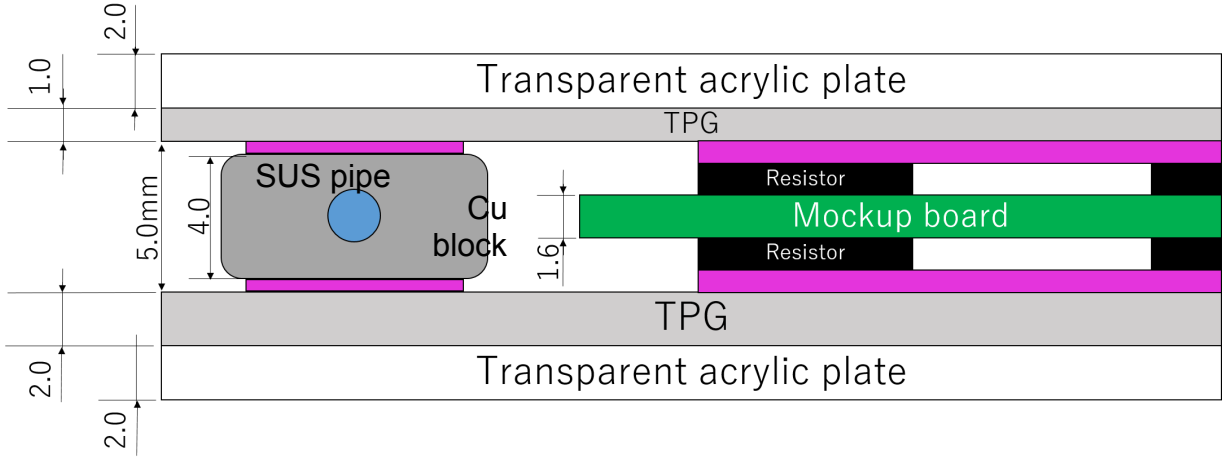
corresponds to 1 MCM

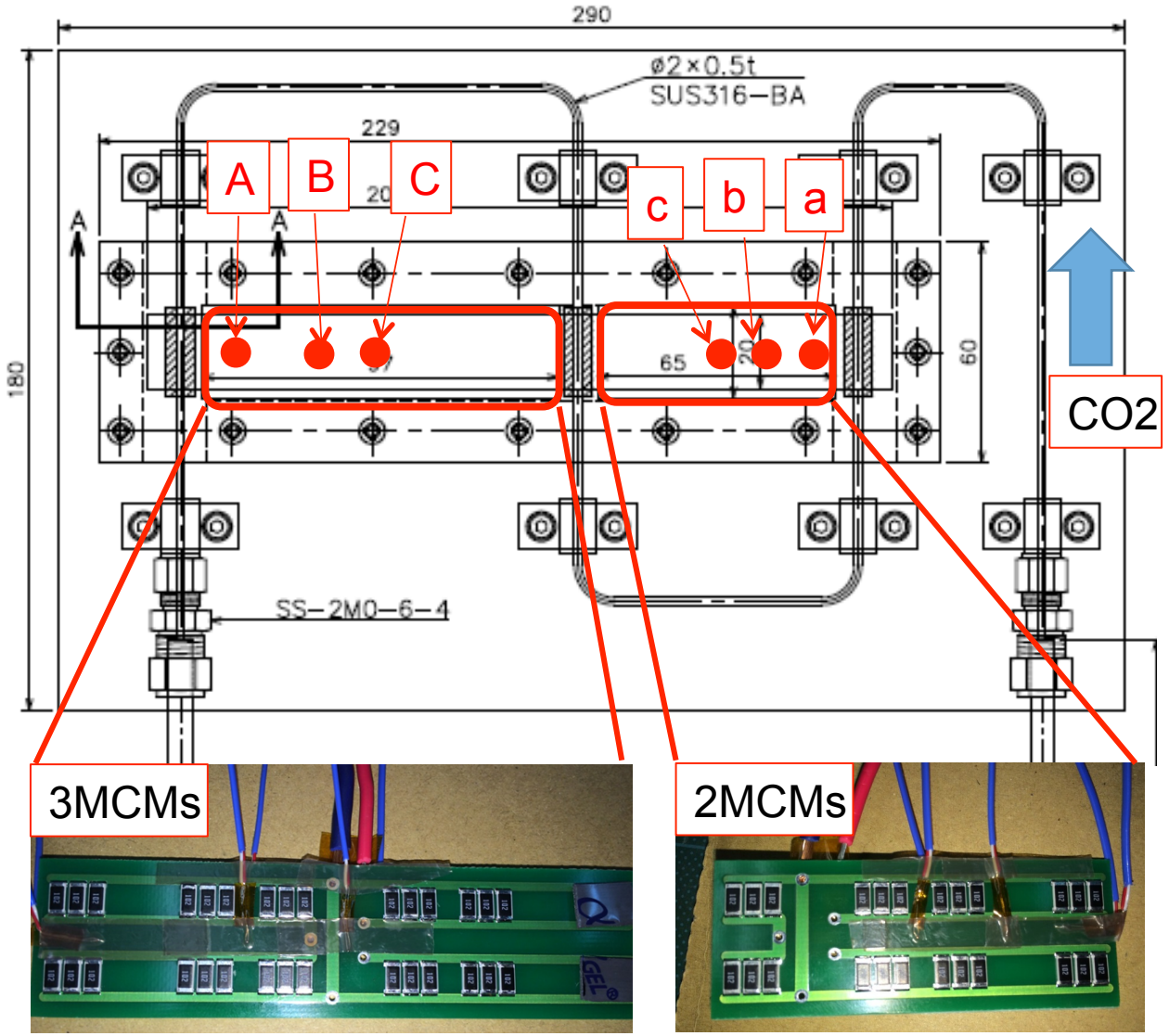
Mockup board -- 162.5 x 25.0mm x 1.6mm (thick)

with 1kΩ, 0.75W chip resisters (size 5×2.5mm)

Simple mockup design for CO_2 cooling test







In this presentation, only 3 points (A, B, C) on the 1mm-TPG side of the 3MCMs because these will have highest temp.

Heat source condition for mockup cooling test

	Estimation for 1MCM		Mockup test under CO2 cooling (Mar/2016)		
	Top side	Bottom side	Top side	Bottom side	Power Supply Voltage
MCM continuous operation	3203 mW	3028 mW	3203 mW	3203 mW	16.34 V
Test beam bench at DESY	343 mW	168 mW	343 mW	343 mW	5.35 V
ILC power pulsing	223 mW	48 mW	223 mW	223 mW	4.31 V

- The power estimation is based on Leif's information.
- Instead of power pulsing, we just decrease the DC voltage in the mockup test.
- In our mockup tests, we apply the same voltage to the top and bottom side registers, which results in overestimation.

CO_2 Cooling Test Setup at KEK

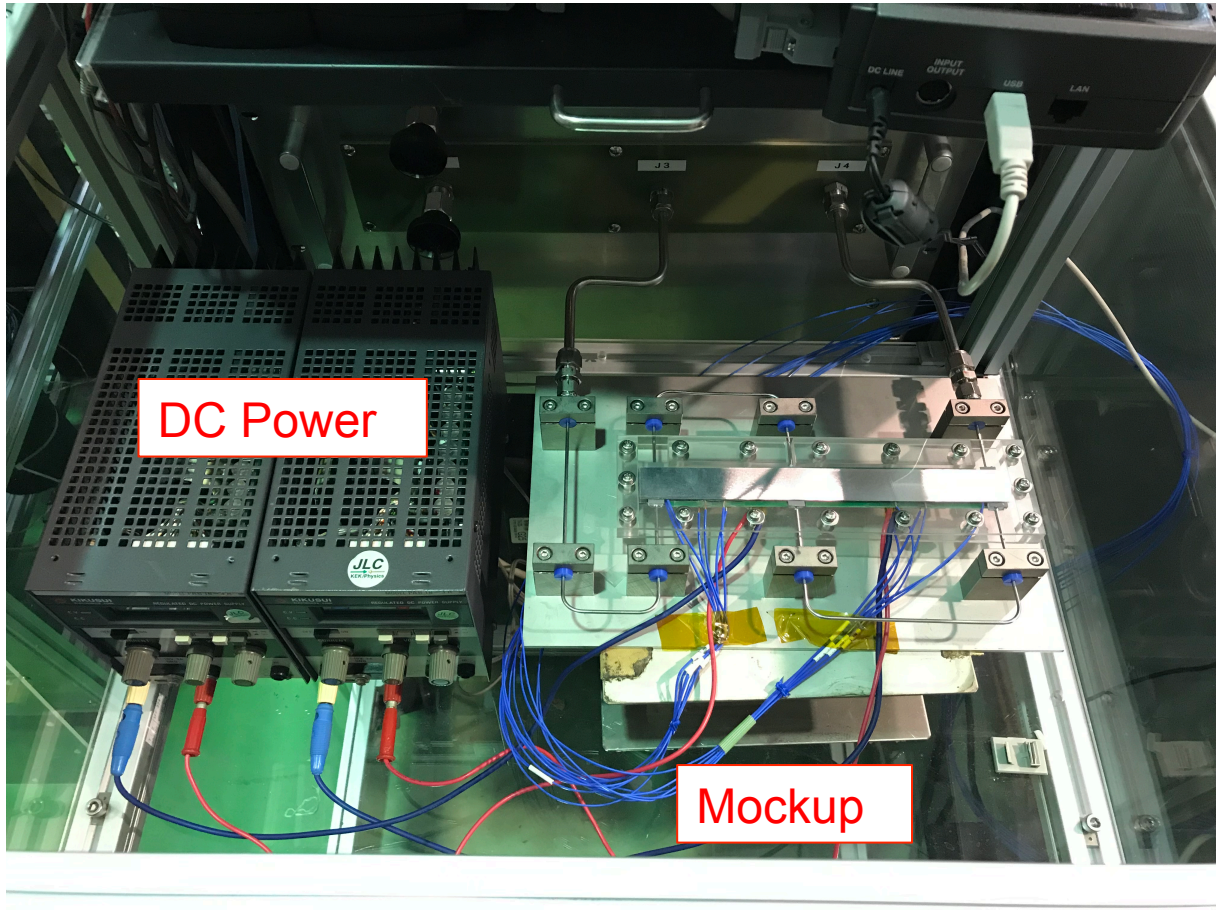
Liquefaction Unit

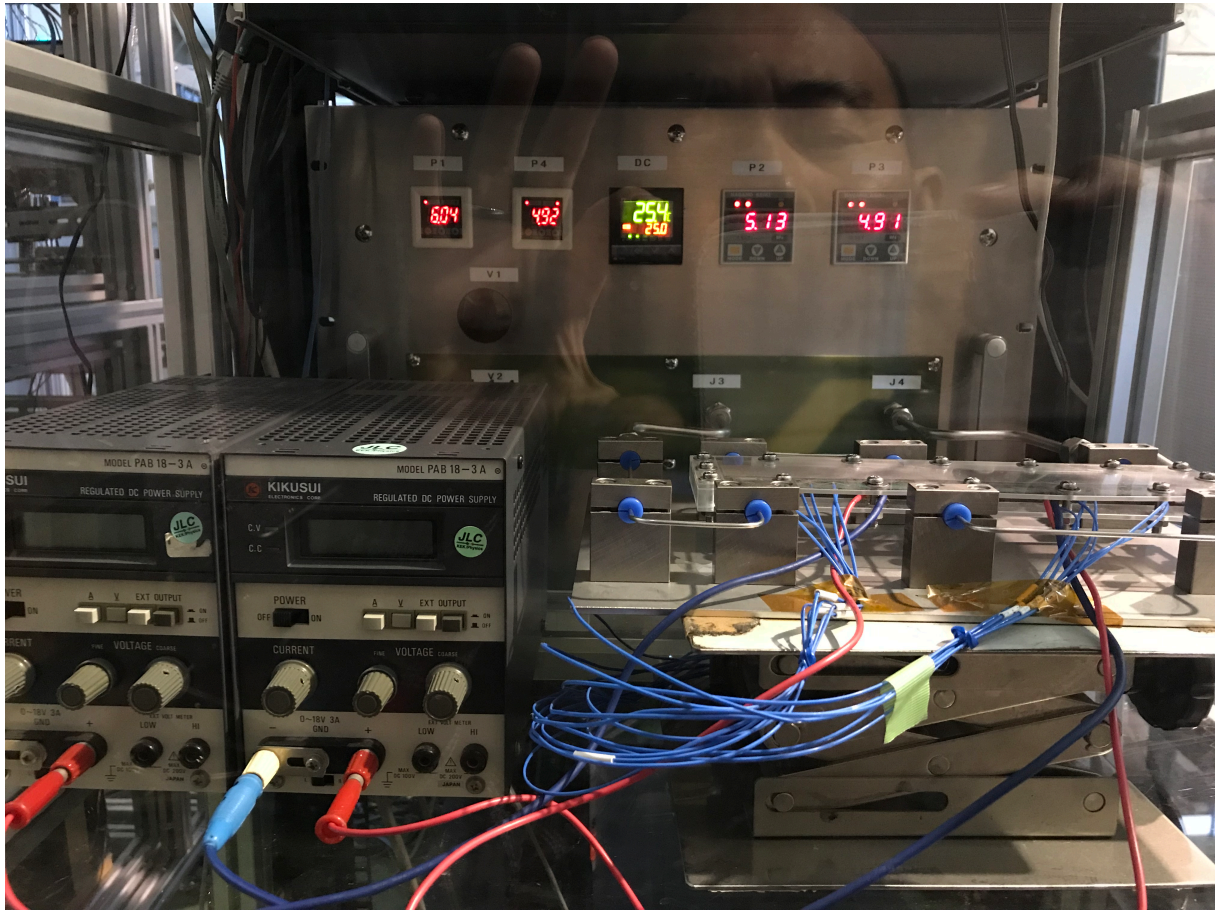
Cooling Unit

Our Mockup

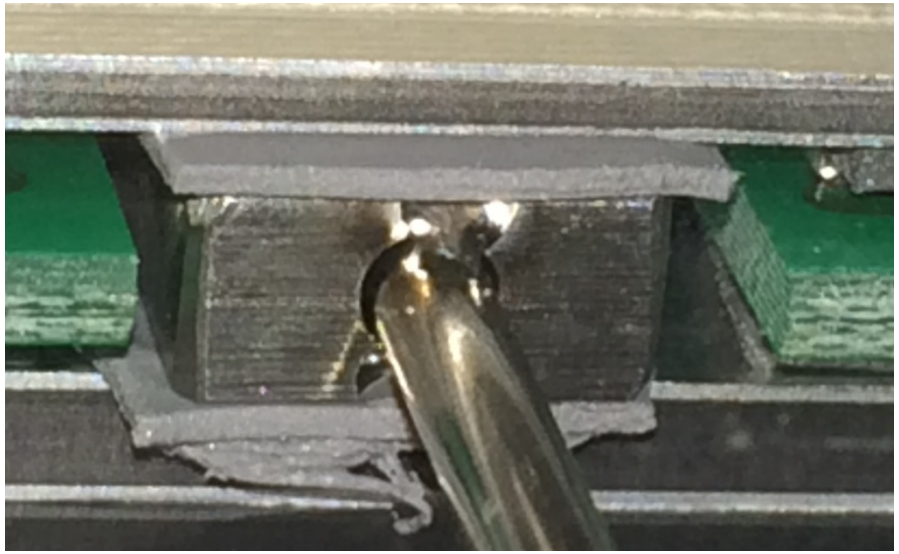
CO2 cooling system developed by Y. Sugimoto and his group

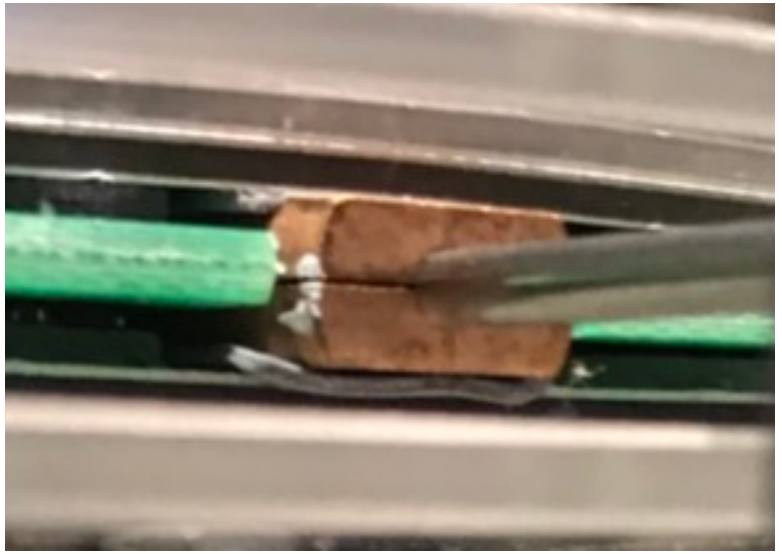
CO_2 Cooling Test Setup at KEK

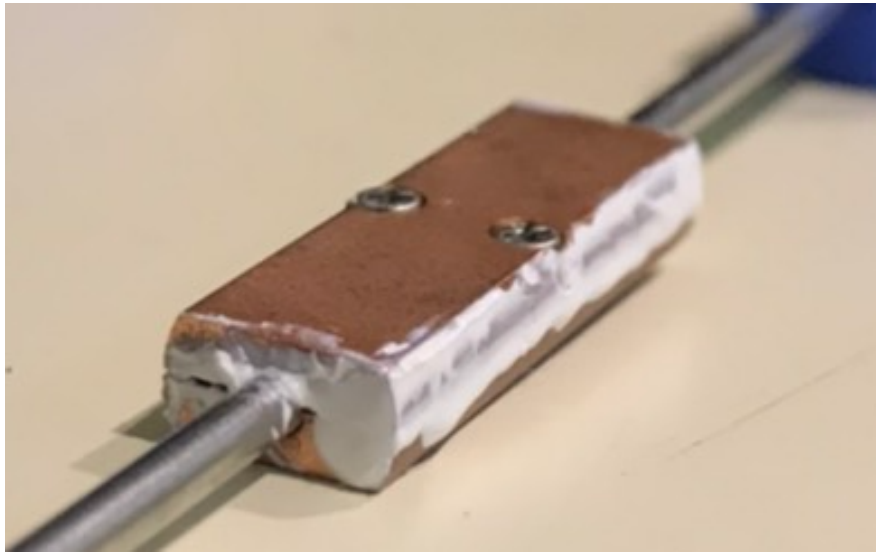


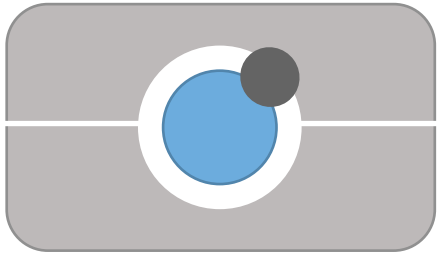


Tried 3 types of SUS or Cu block for connection btw. pipe and TPG, which could be the bottle neck of the heat flow

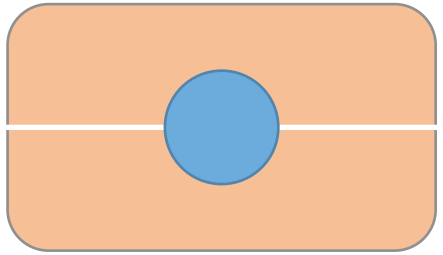




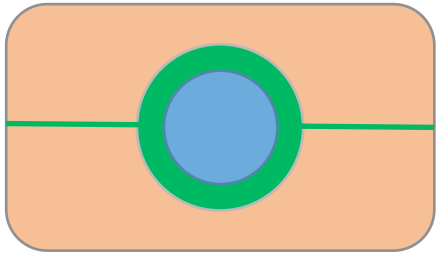




Type 1:
Point connection
(SUS block)



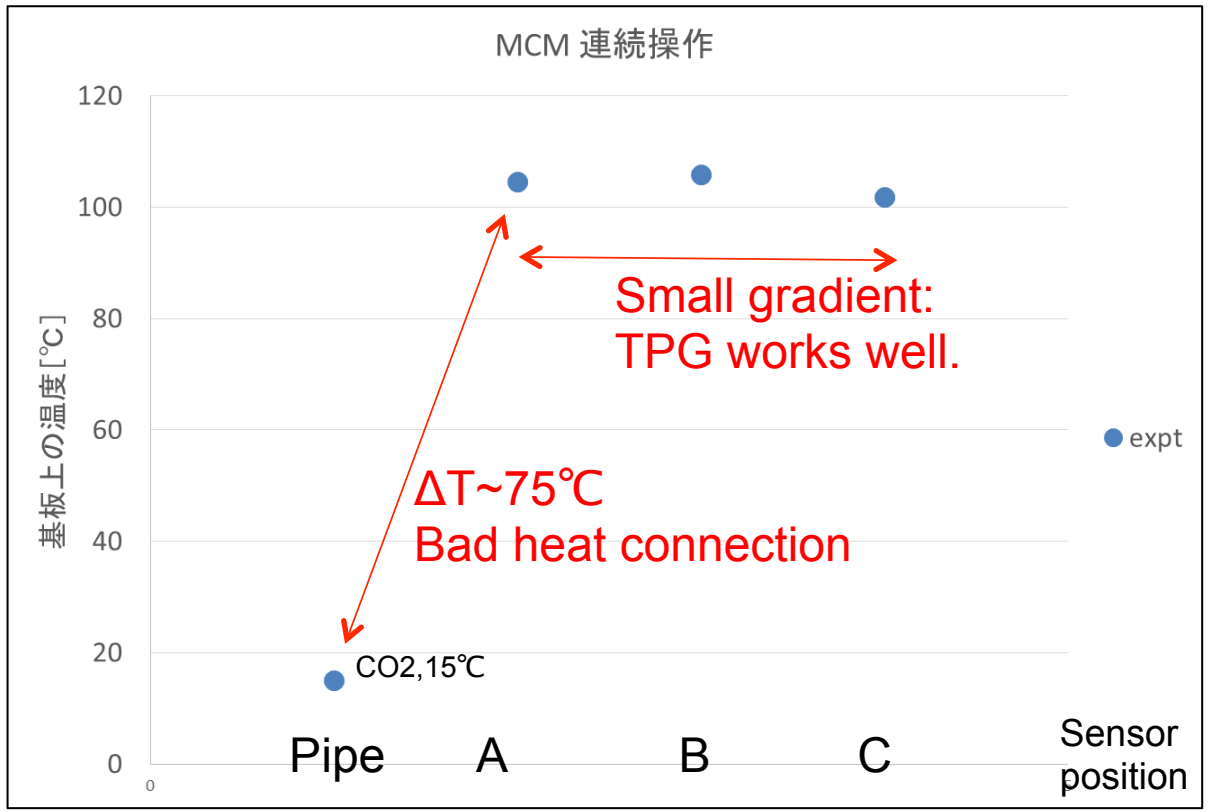
Type 2:
Complete touch
(Cu block)

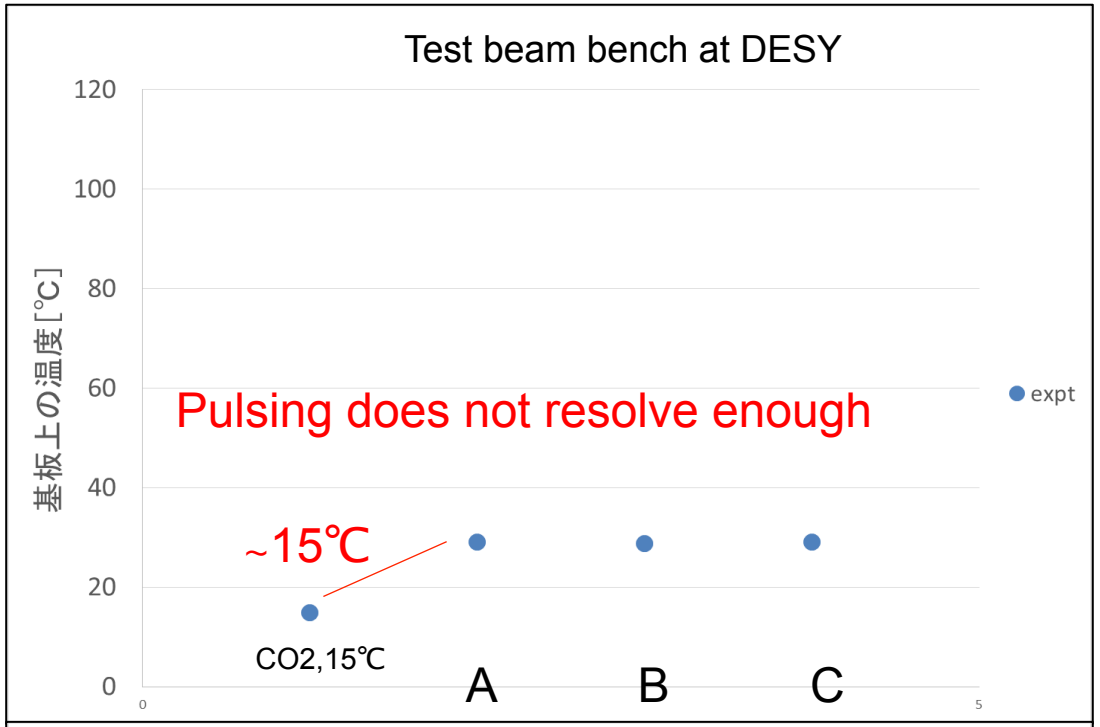


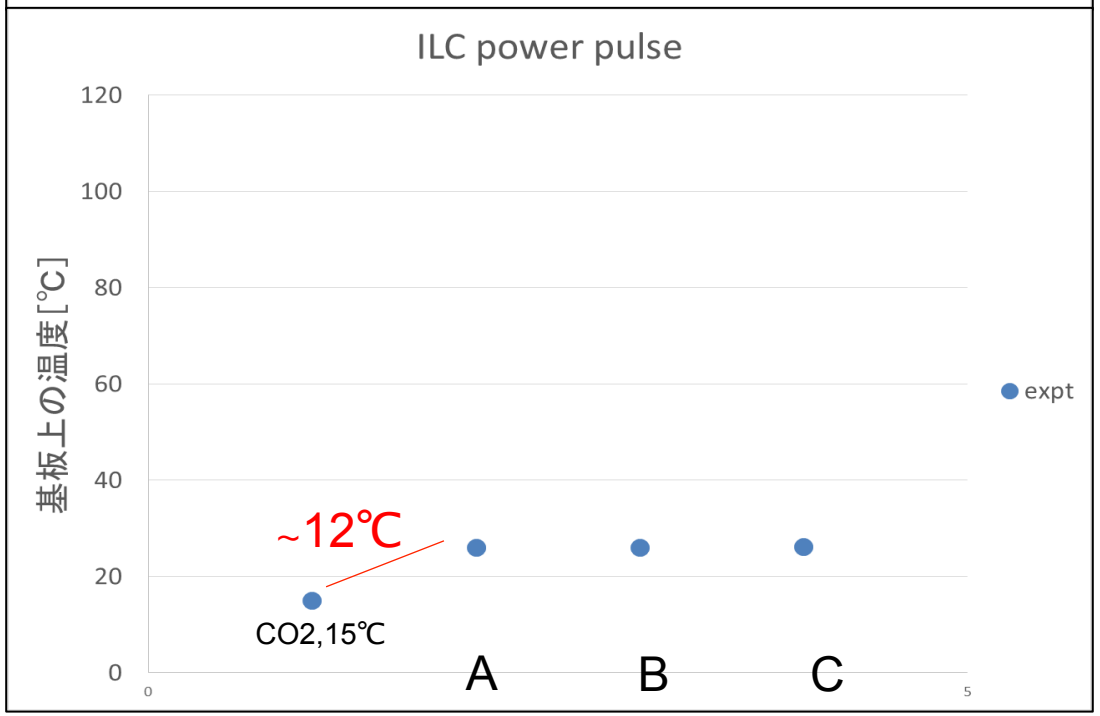
Type 3:
Filled with grease
(Cu block)

Results from CO_2 cooling mockup test Type 1:

3MCMs 1mm-thick-TPG side





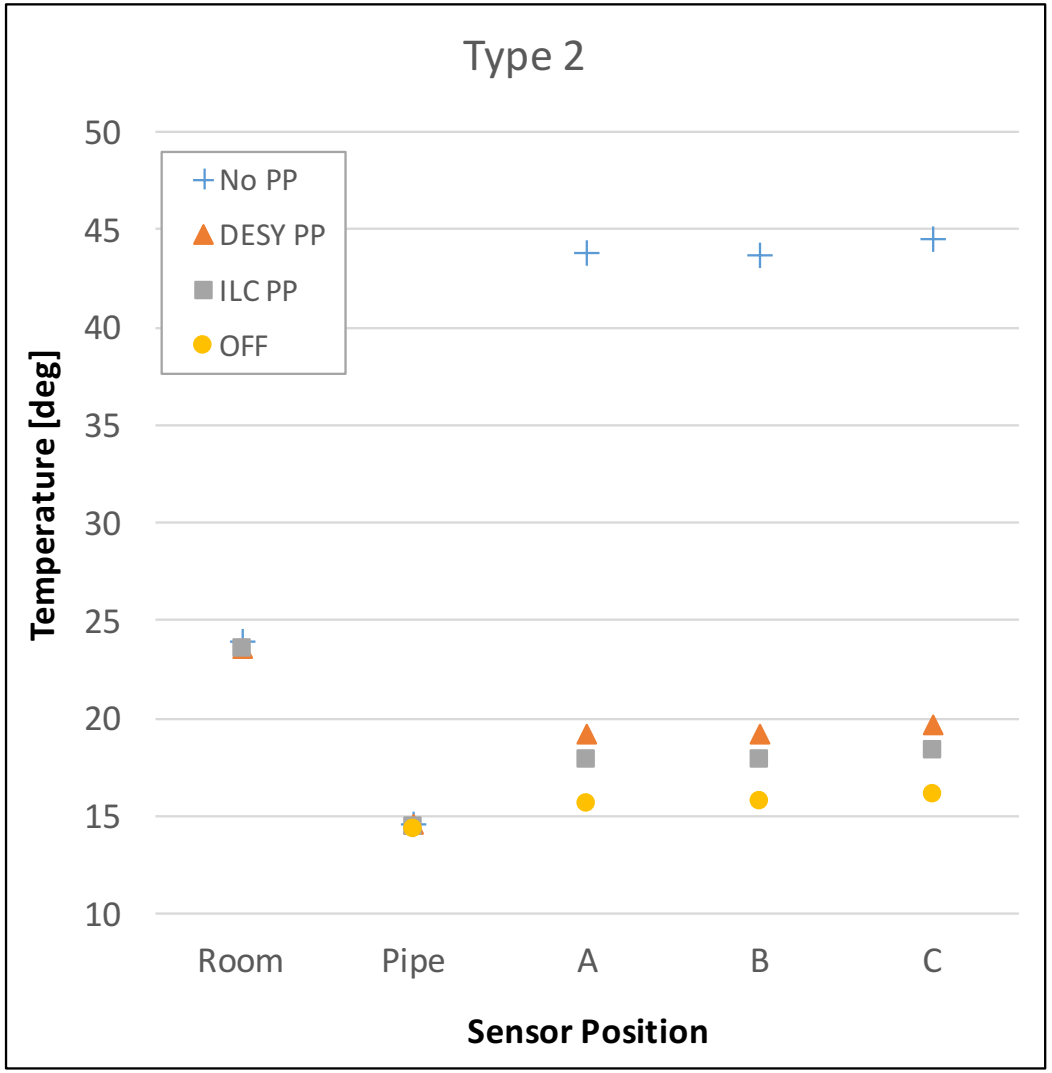


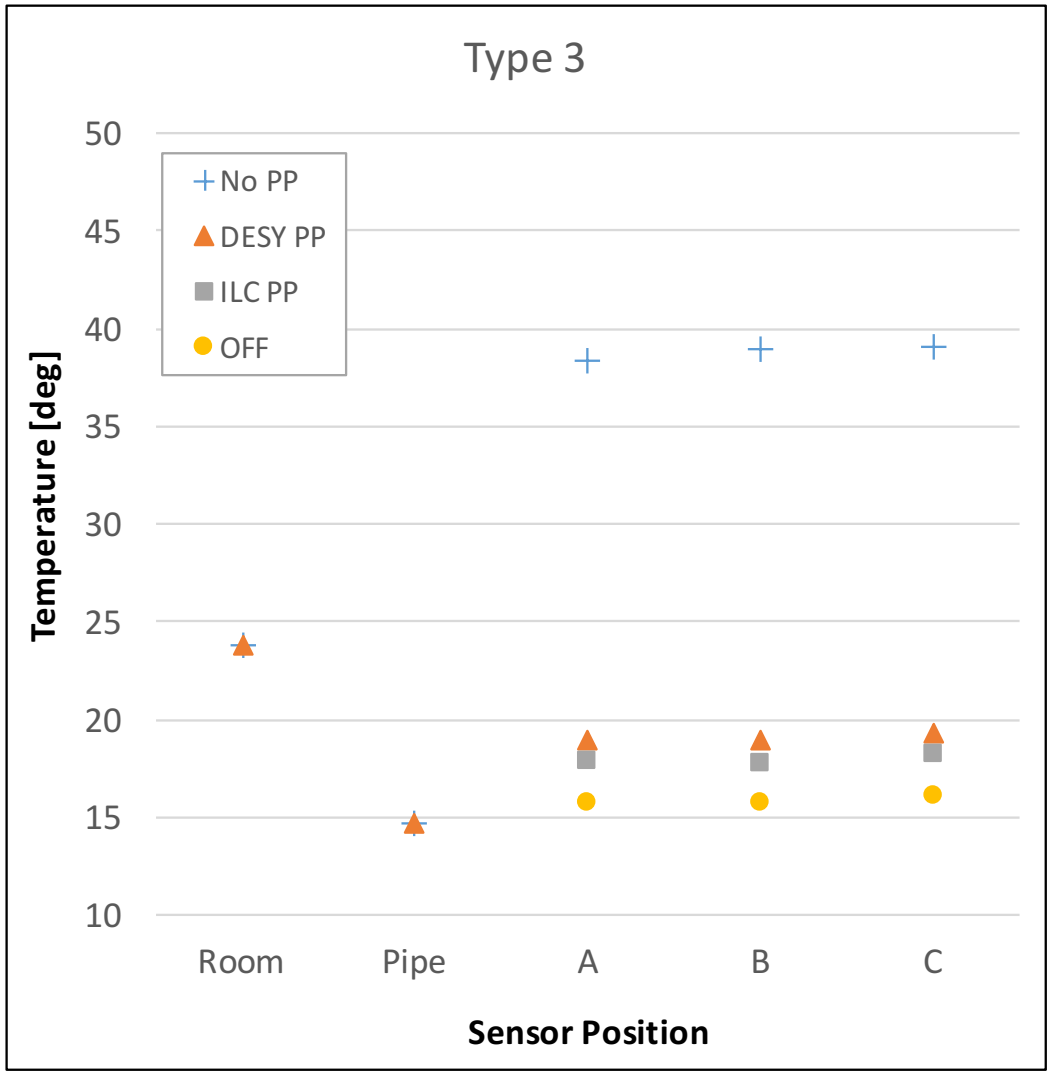
Type 2

	Room	Pipe	A	B	C
No PP	23.9	14.5	43.8	43.7	44.5
DESY PP	23.6	14.5	19.2	19.2	19.6
ILC PP	23.6	14.5	17.9	17.9	18.3
OFF		14.3	15.6	15.7	16.1

Type 3

	Room	Pipe	A	B	C
No PP	23.8	14.7	38.3	38.9	39.1
DESY PP	23.8	14.7	19.0	18.9	19.3
ILC PP			17.9	17.8	18.2
OFF			15.7	15.7	16.1



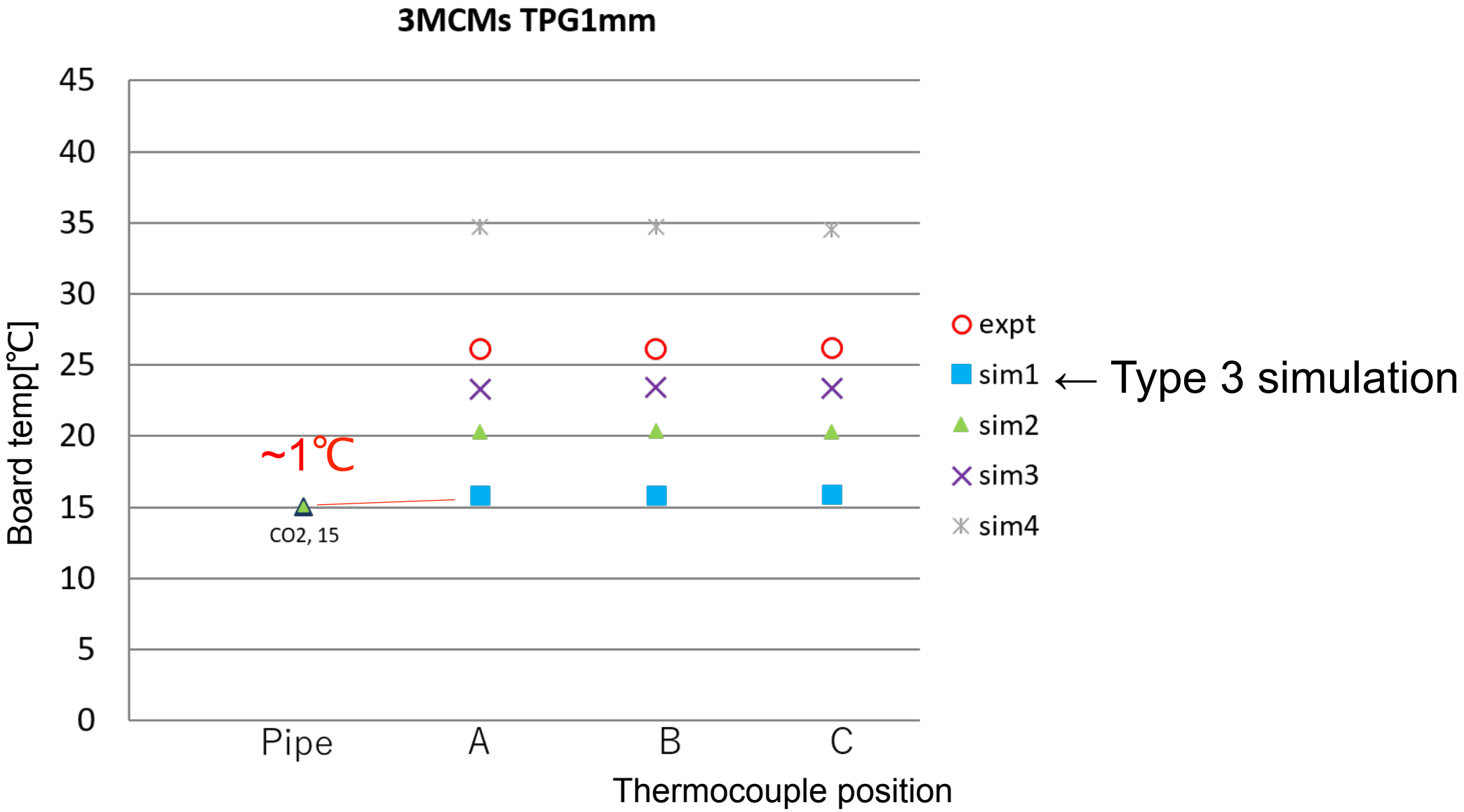


Results from CO_2 cooling mockup test

- Type 3 gives the best results.
- In the ILC PP condition,
  type 3 gives Temperature gradient ~0.3℃ on the board.
- In the ILC PP condition,
  type 3 gives Temperature gap of 3℃ against cooling pipe.
  → 1℃ is because of temperature gap btw. pipe and air.
  → Better grease (0.8W/mK → 6.5W/mK)
  can decrease temp. by ~1.5℃ from a rough calculation.
  → Expect ~0.5℃ remains.

Simulation

ILC power pulse: 223mW



Summary

- Simple mockup of MCM was made and
  CO_2 cooling test was performed.
- Experiments show ~0.3℃ gradient on the MCM board
  and 3℃ gap from the cooling pipe.
  (type 3 Cu block, 3MCMs board, 1mm-TPG side, ILC PP condition)
- The gas 3℃ is expected to decrease to <1℃
  by replacing the grease with better one
  and set the cooling pipe temperature near the room temperature.
  (latter was not able in the test because max. CO_2 temp. was 14℃)
- Simulation supports the expectation.
- Next, we should go to more realistic model
  with a pad-plane, connectors, etc.