Development Status of Electronics and Cooling for ILC TPC

Takahiro Fusayasu (Saga U.)

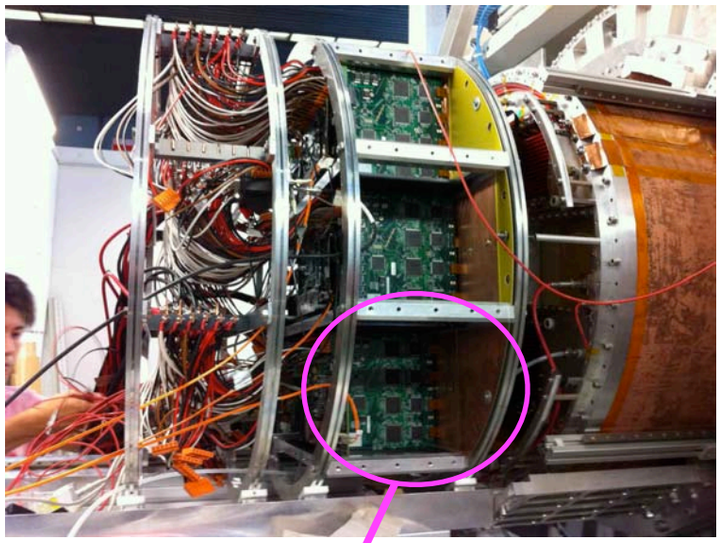
2014.12.17 ILC Tokusui Workshop @ KEK

1. Introduction

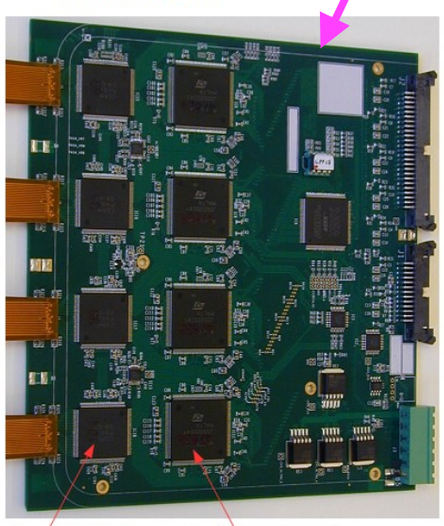
Introduction:

LCTPC Electronics Development for Pad Readout

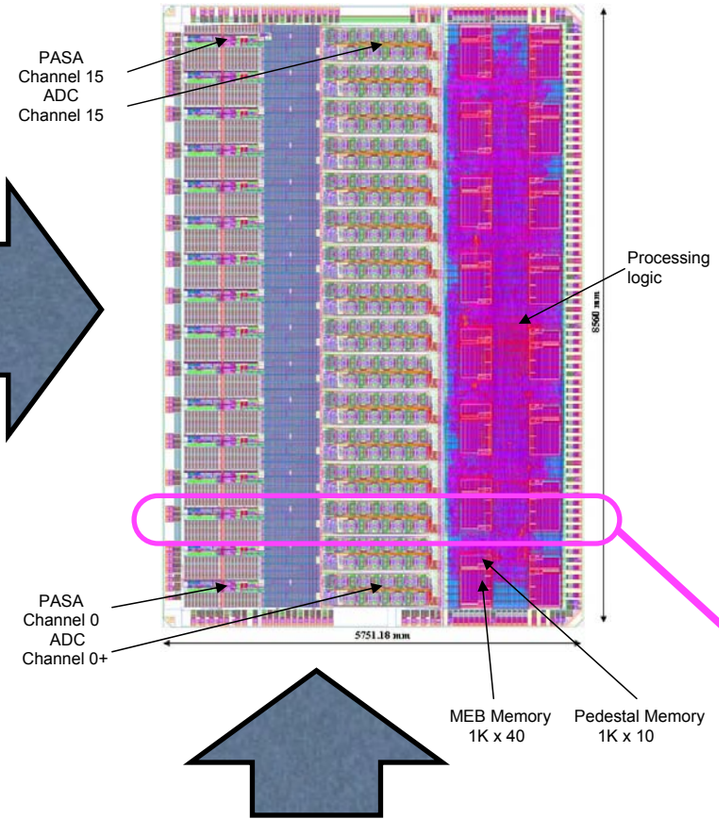
Large Prototype
test so far



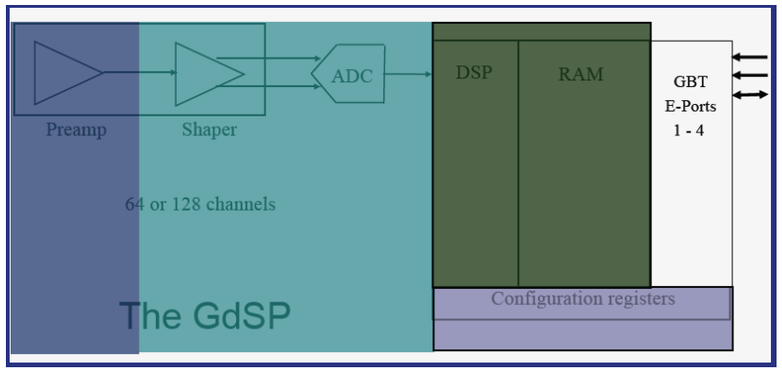
Front End Card



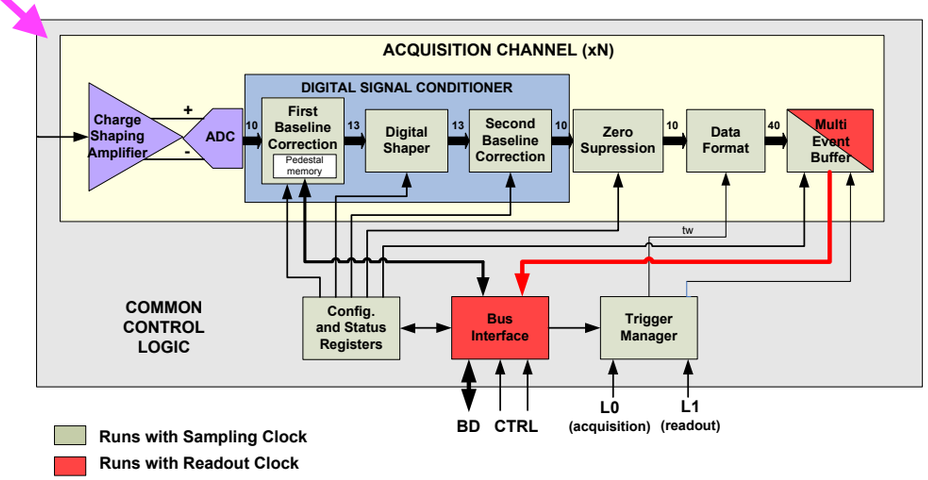
Next step
S-ALTRO16 (fabricated)



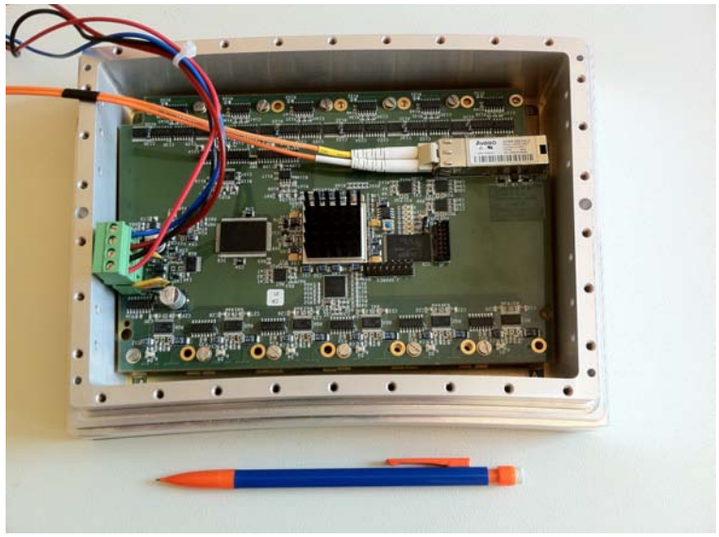
Future GdSP



- 64 or 128 channels in a chip.
- Low power consumption (7-8mW/ch).



- 16 channels in a chip.
- 59(42)mW per channel @ 40(20)Msps.



MicroMegas module
with AFTER-based electronics

Outline

1. Introduction
2. Next module development
    - Evaluation of heat conducting plate
    - Evaluation of module cooling
3. Towards the final electronics
    - Readout chip specification
4. Summary

2. Next Module Development

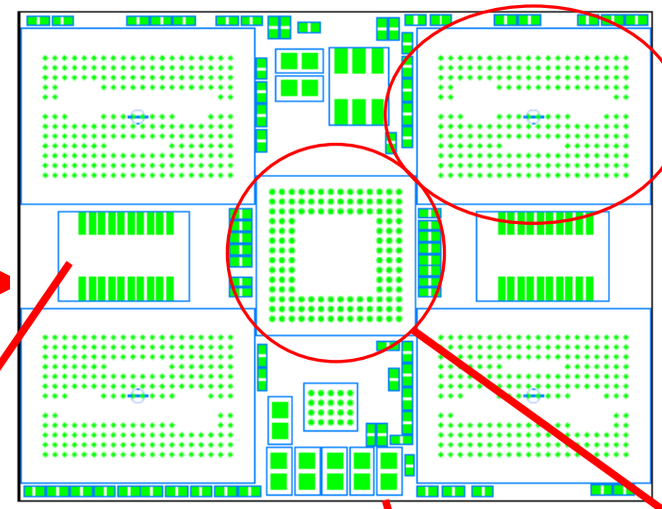
From ALTRO to SALTRO16
A decrease in size by a factor 40 of the front end electronics

FEC with 8 ALTRO

17 cm

19 cm

MCM with 8 SALTRO on carrier boards

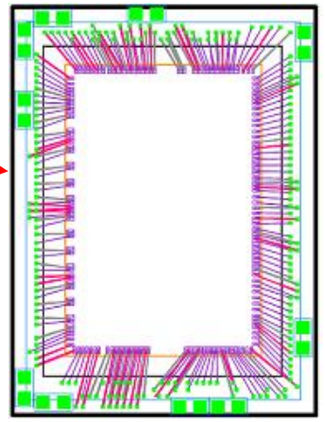


25 mm

32.5 mm

CPLD

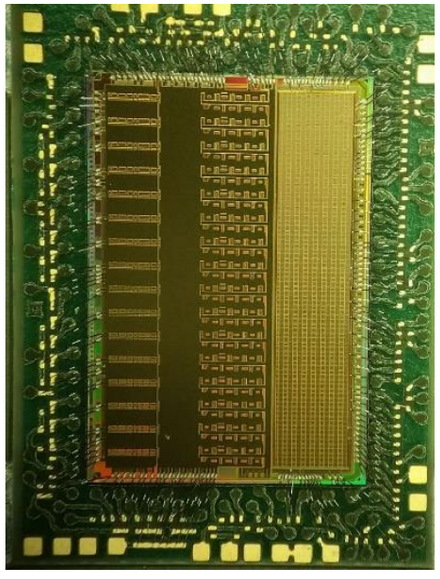
Carrier Board



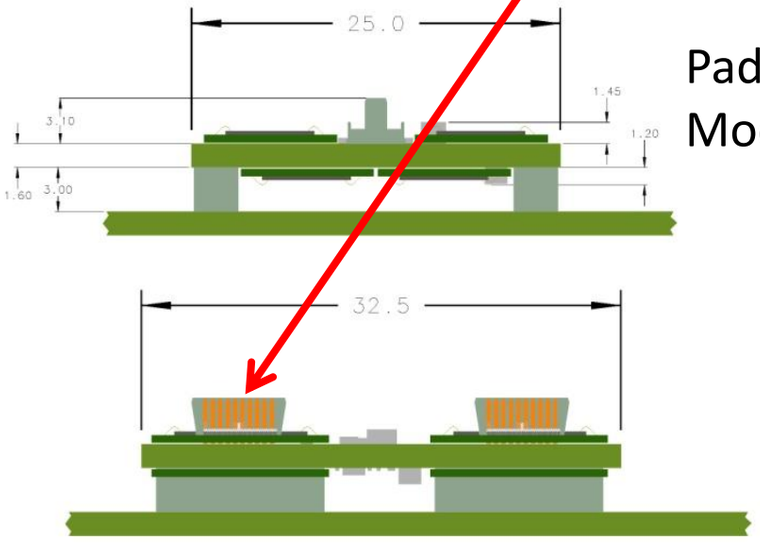
12 mm

8.9 mm

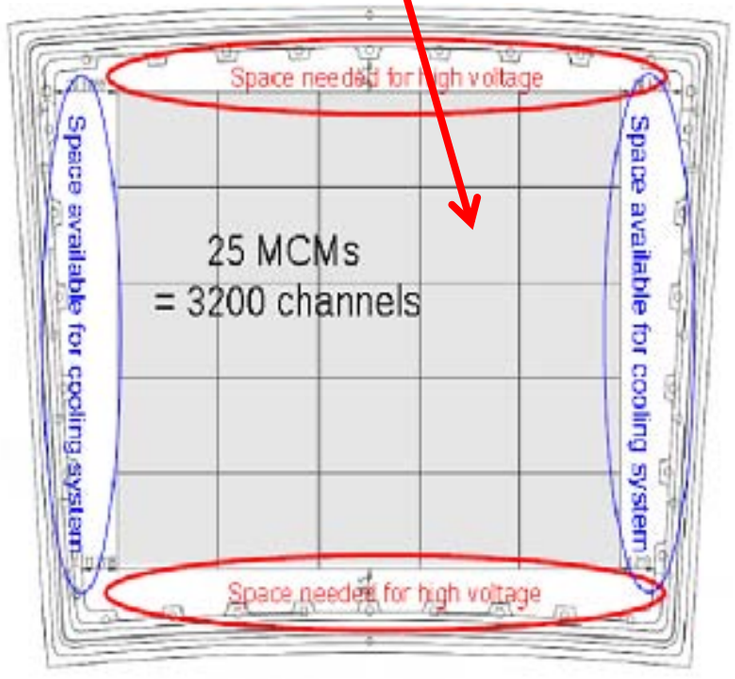
Carrier Board with SALTRO



Side views of an MCM



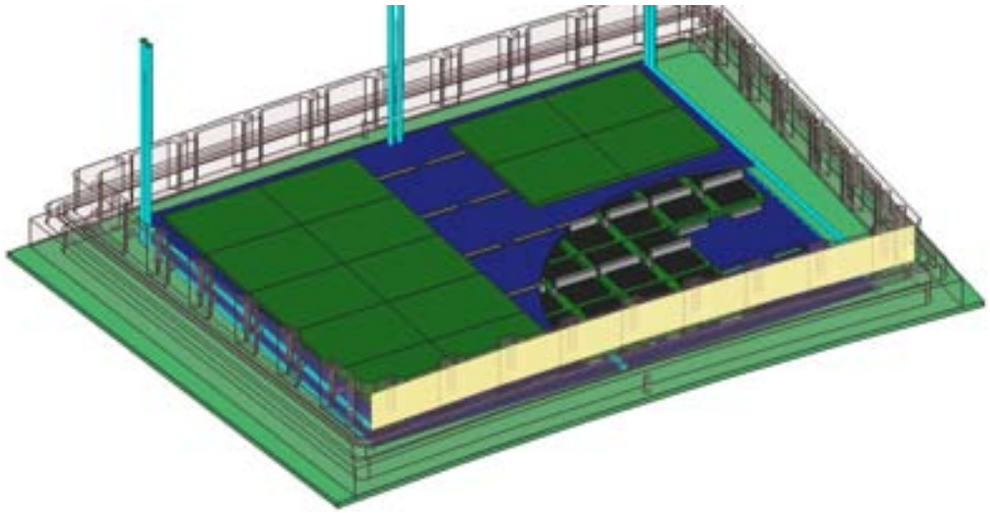
Pad Module

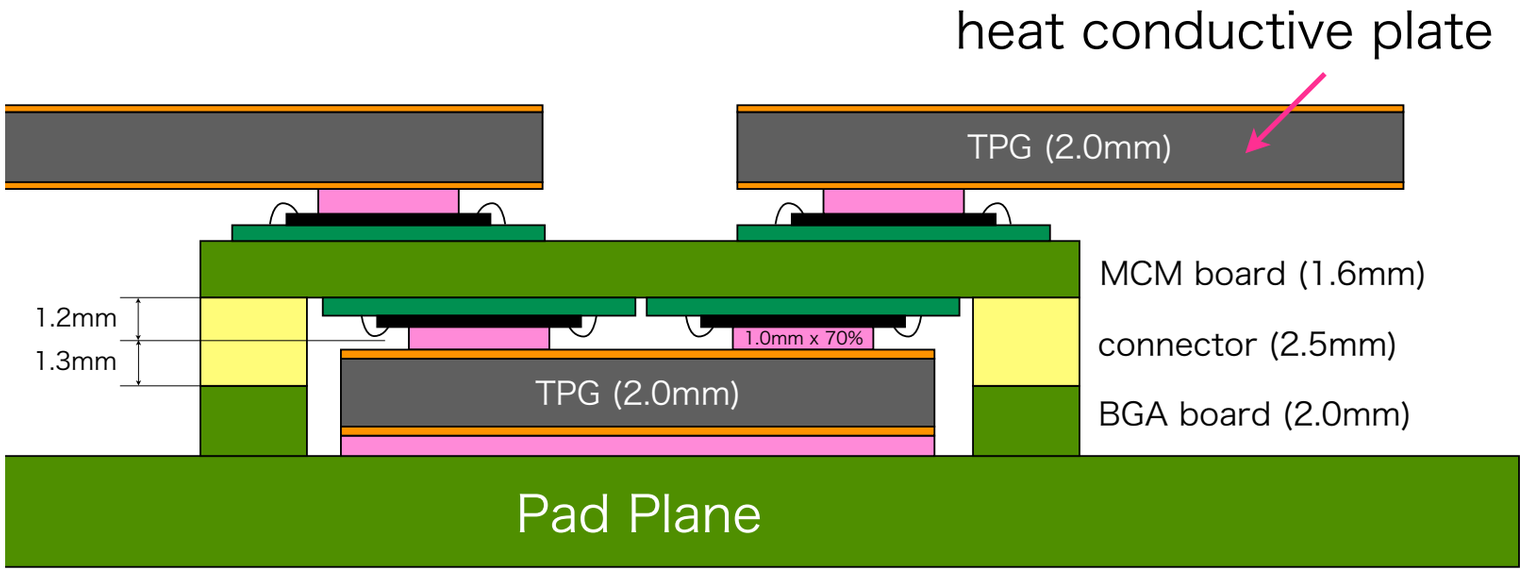


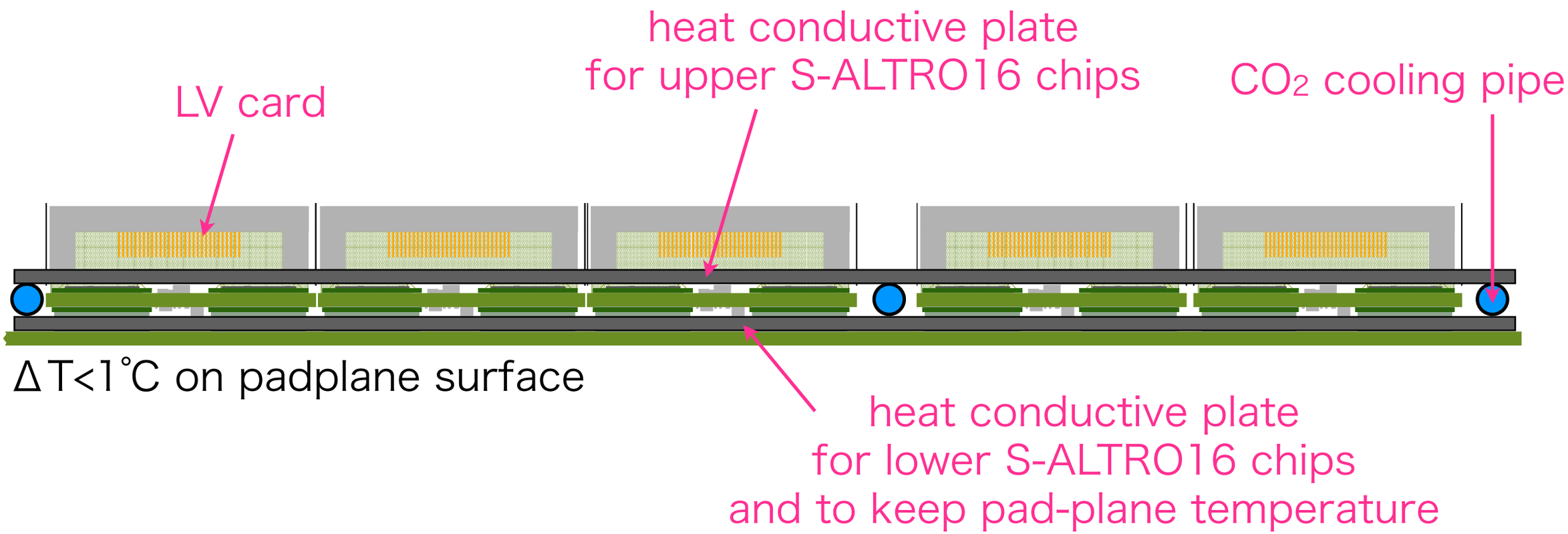
Slide by Leif Joensson

Proposed Cooling for our next module

CO_2 cooling pipe





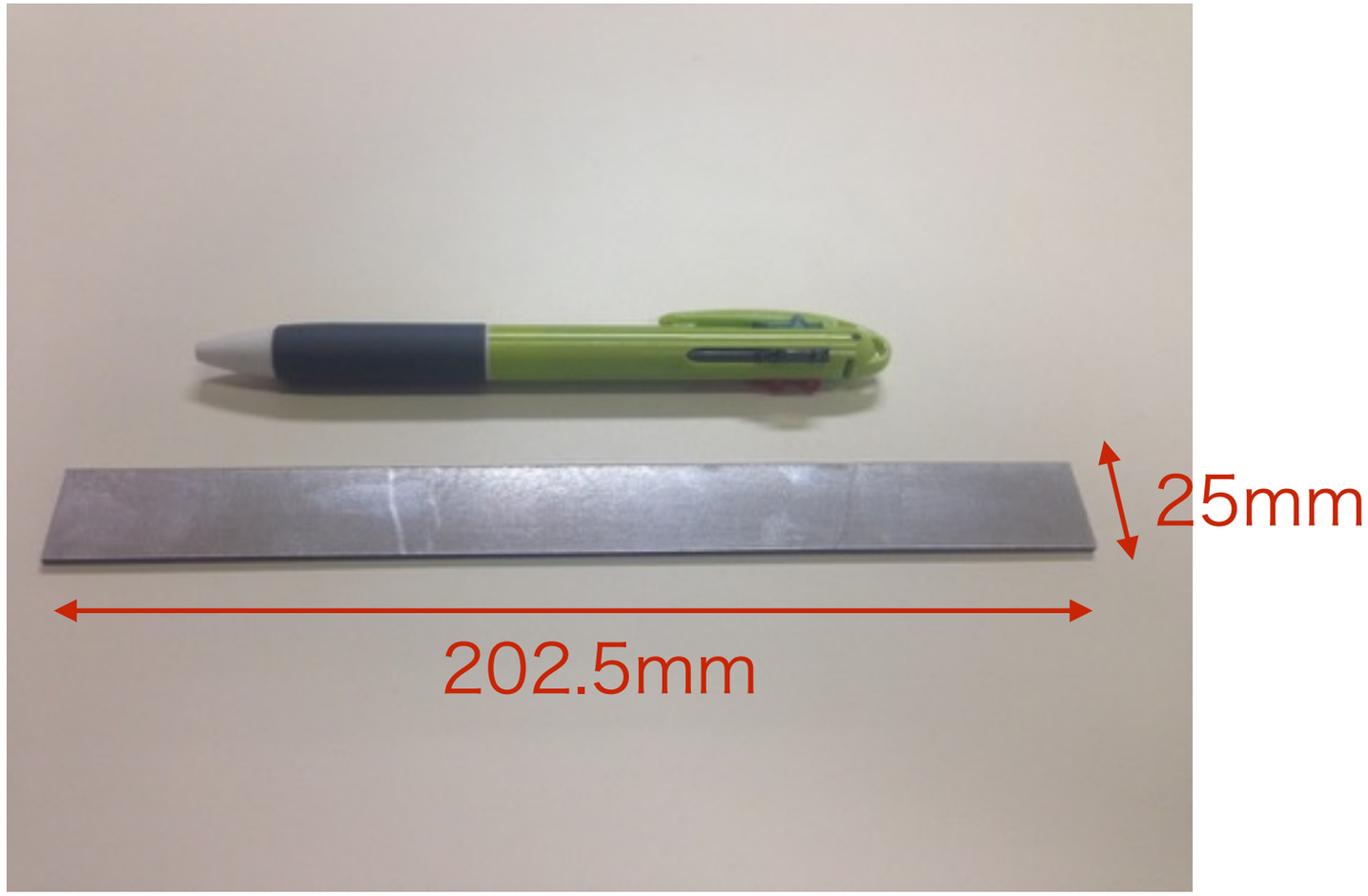


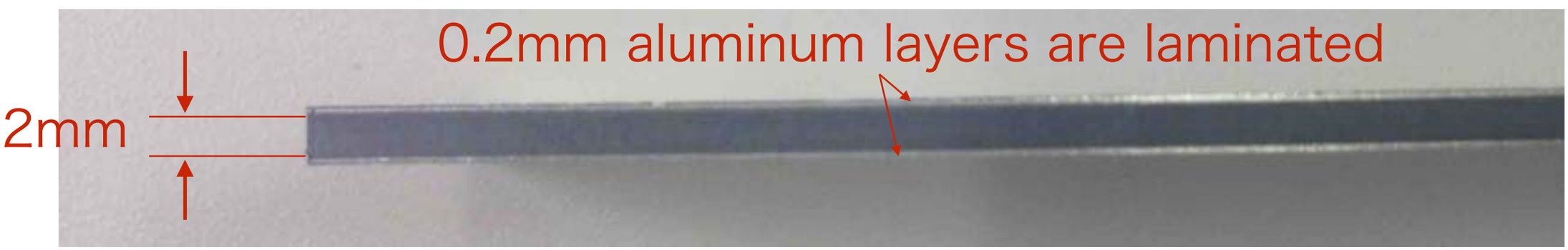
$\Delta T<1^{\circ}C$ on padplane surface

Evaluation of Heat Conductive Plate, TPG

TPG (Thermal pyrolytic graphite) — high heat conductive plate by MOMENTIVE

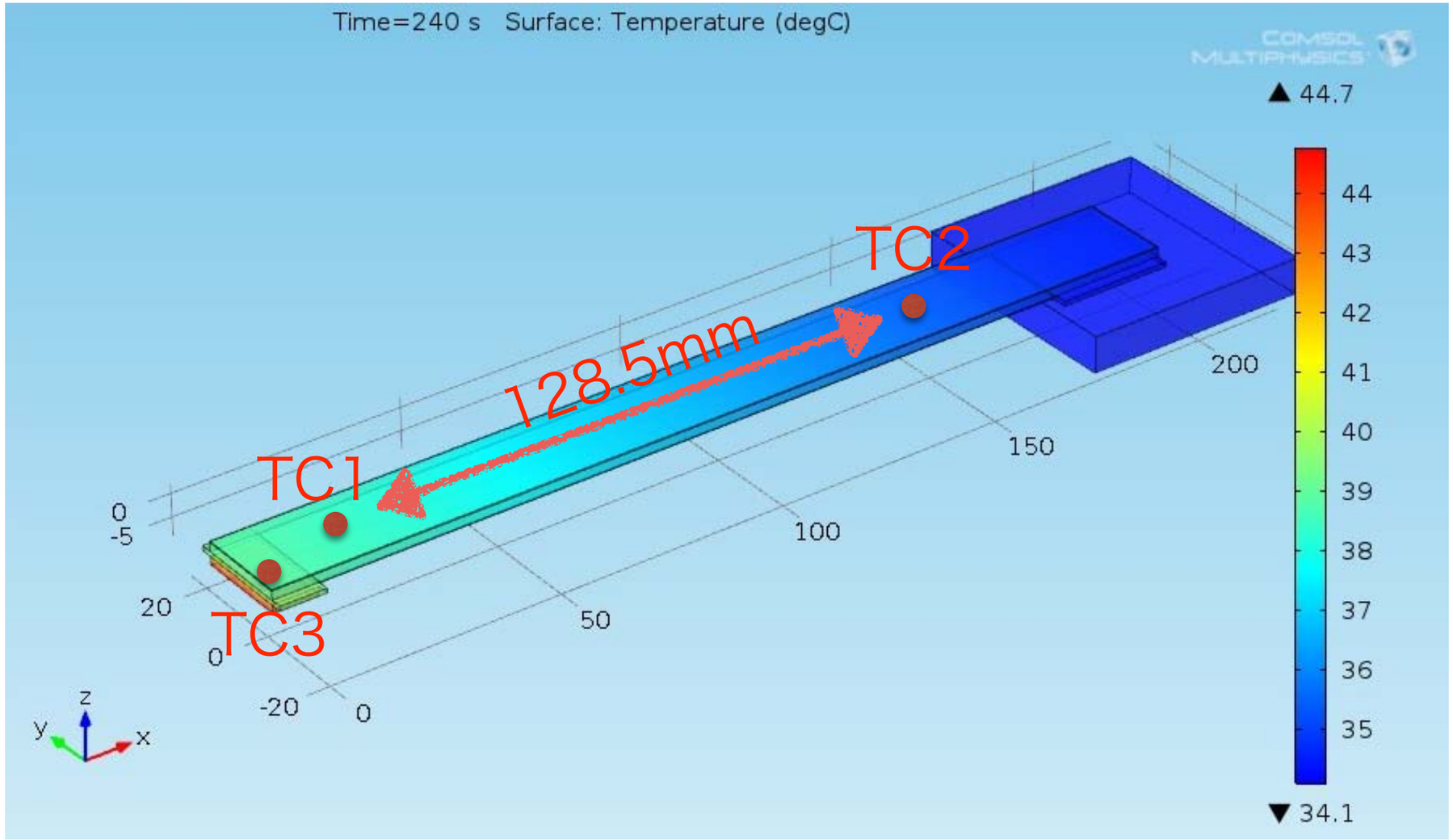
$\lambda \sim 1500$ W/(m・K) in plane and 20 W/(m・K) vertically

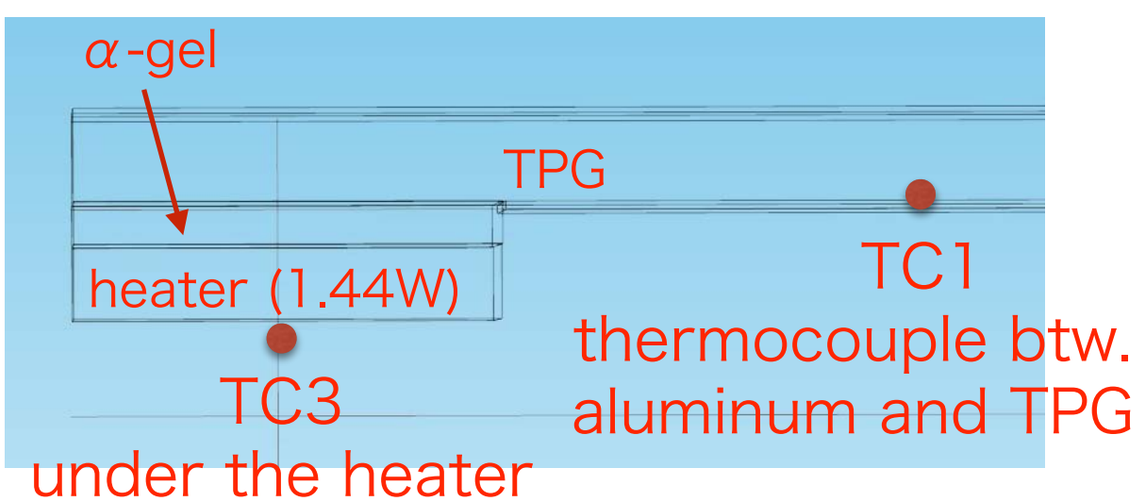


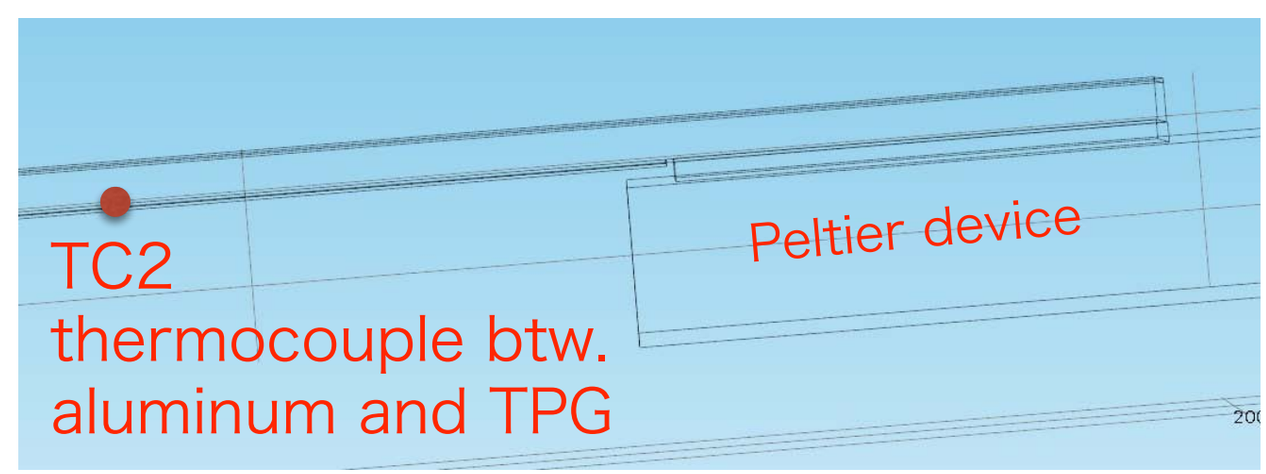


TPG Measurement Setup

A ceramic heater as a heat source, a Peltier device as a heat sink.

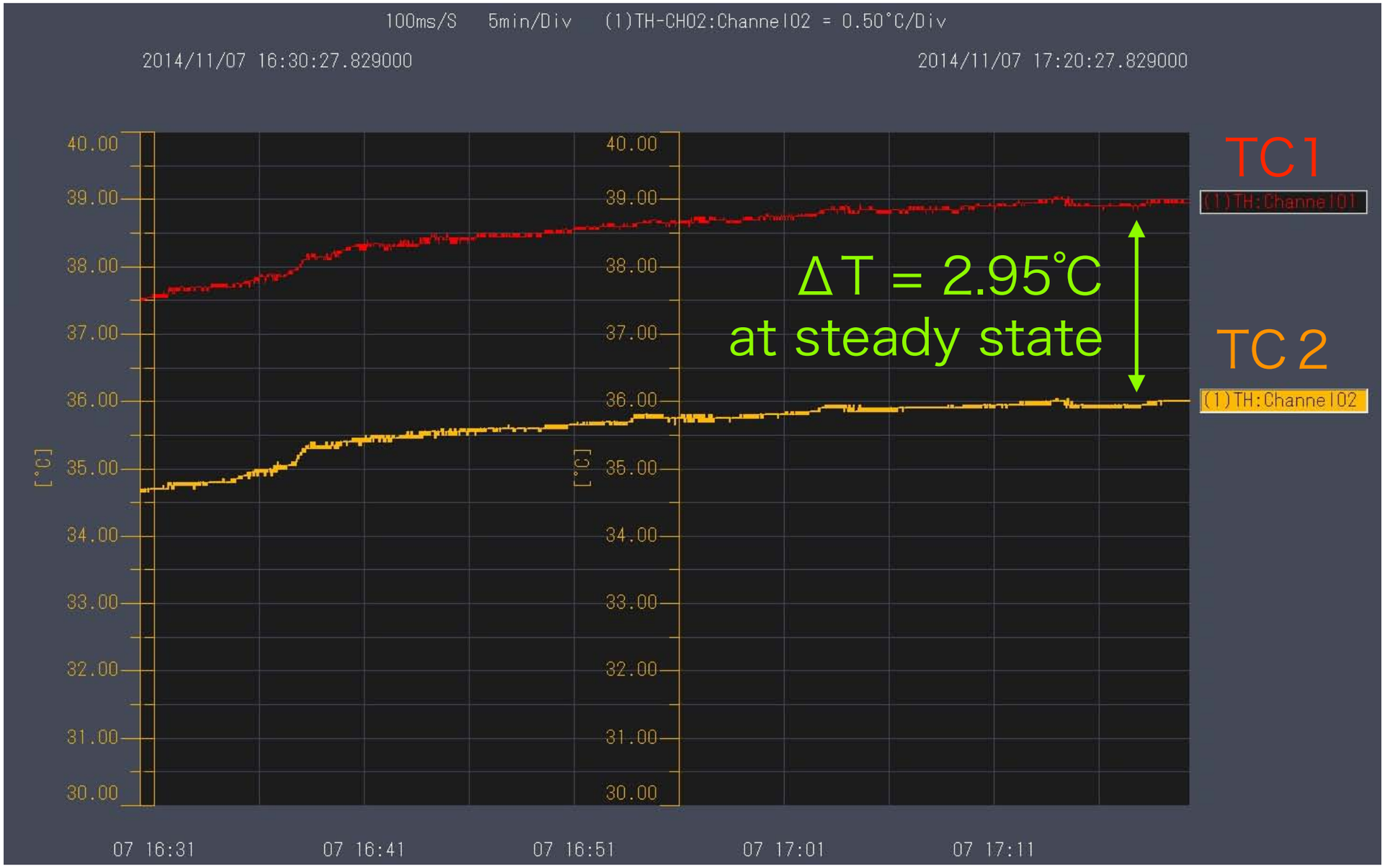






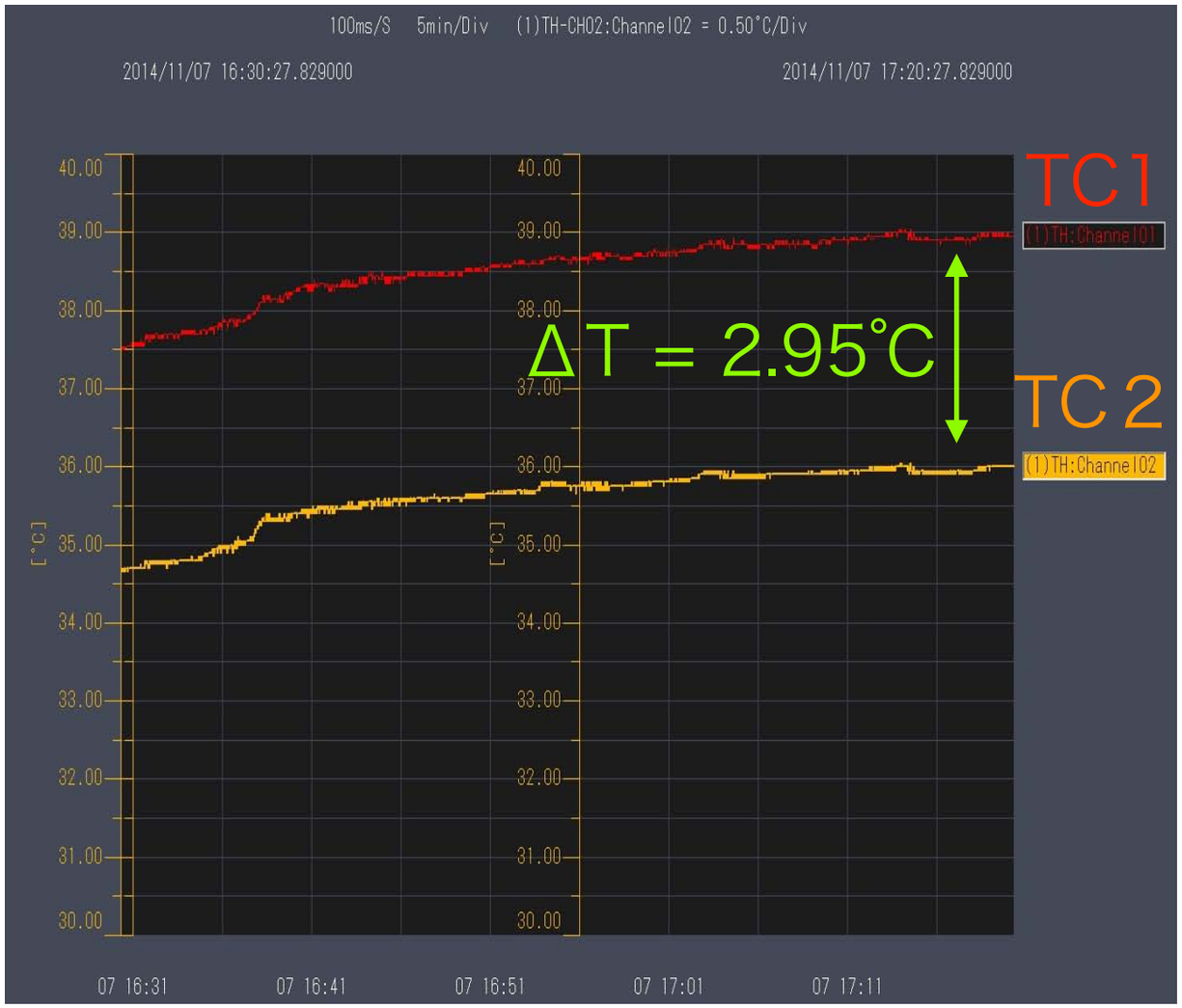
Measurement performed by Kenji Ishida @ Dept. of Mechanical Engineering, Saga-U.

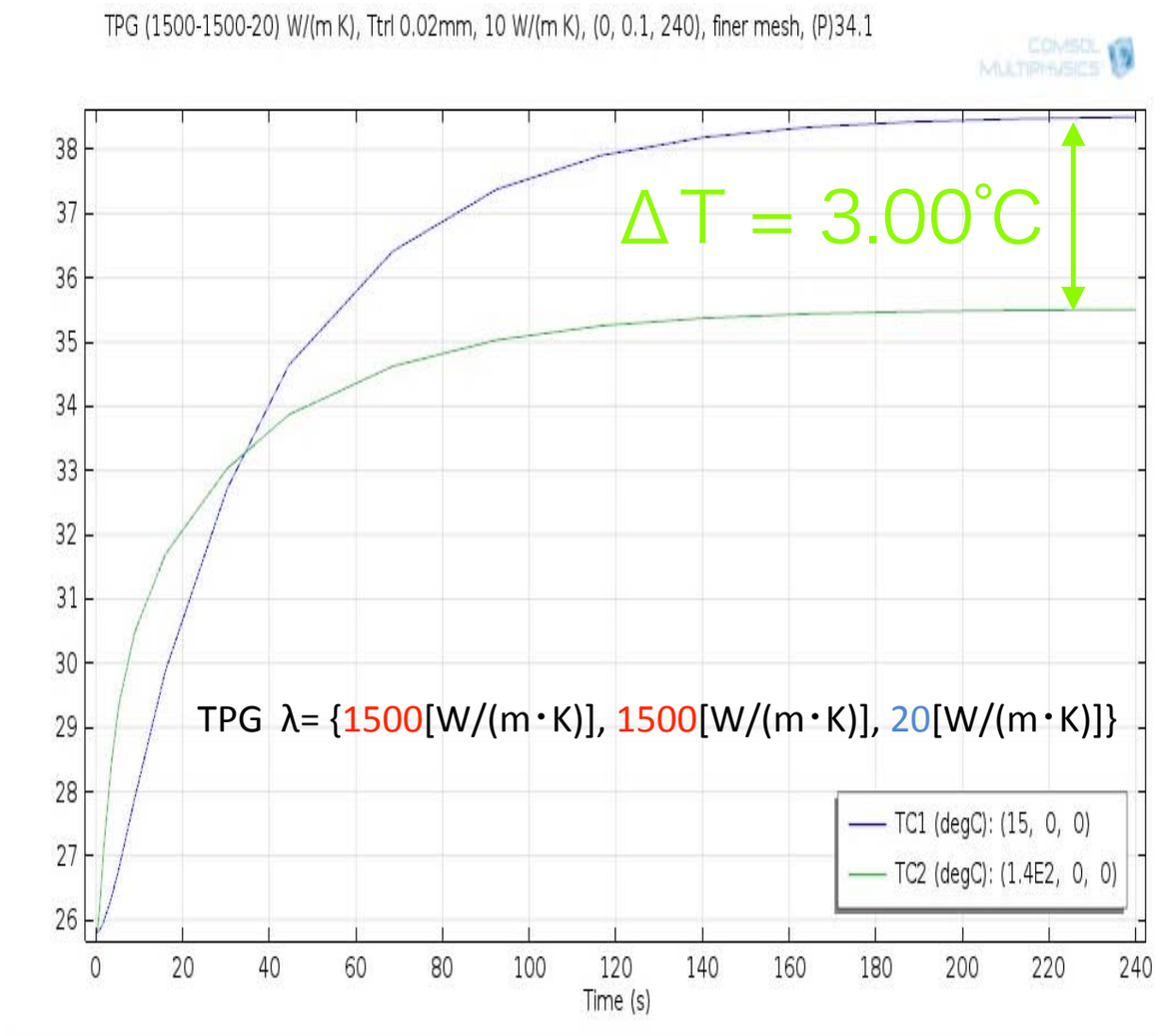
TPG Measurement Results



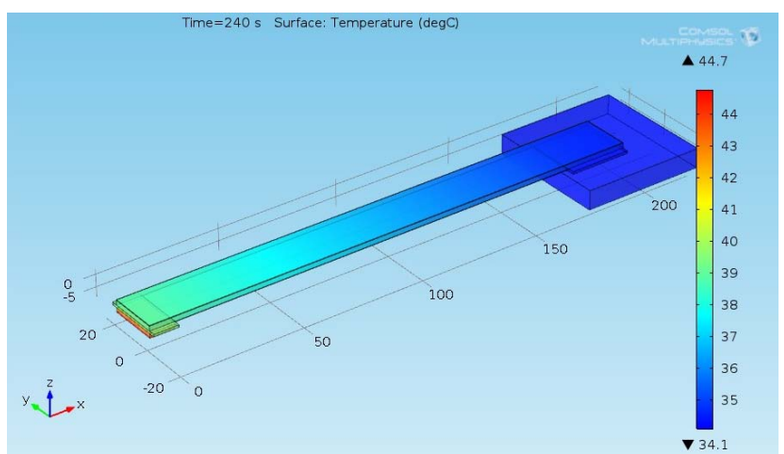
The steady state measurement gives thermal conductivity λ=1526W/(m・K), after subtracting the effect of aluminum laminate. The result is well consistent with the specification.

Comparison with Simulation





- Well explained by the simulation.

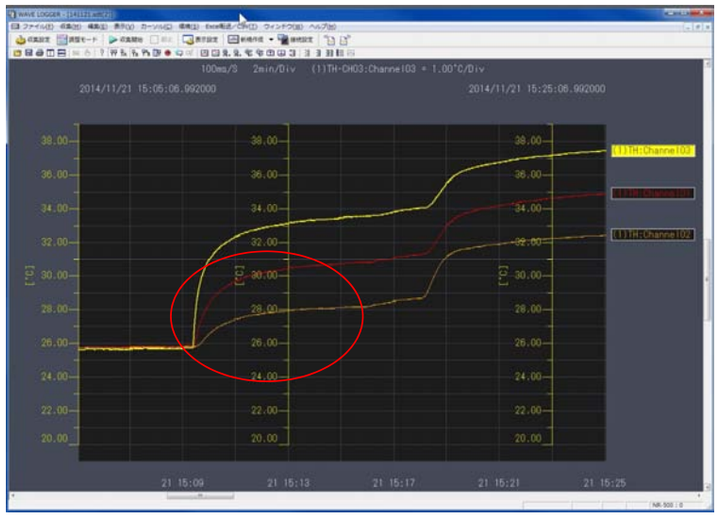


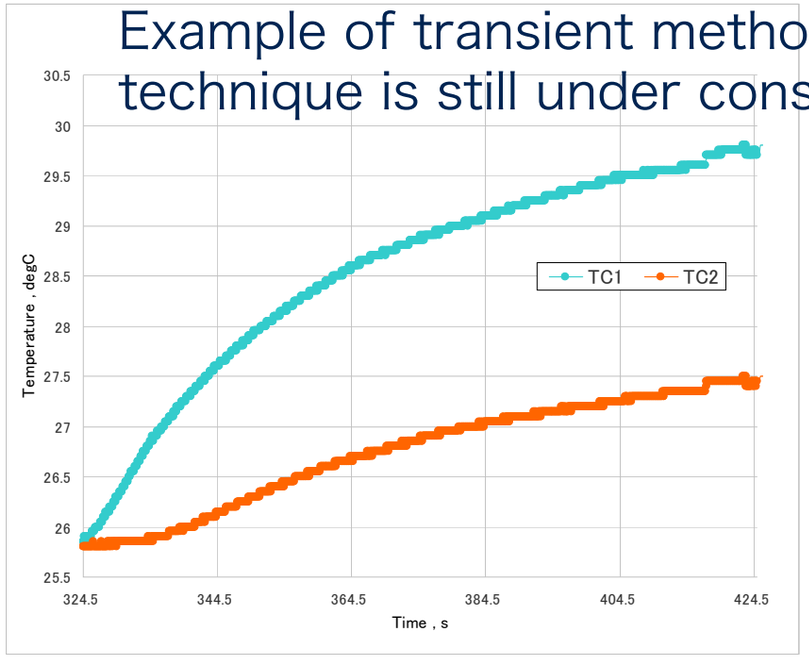
TPG Evaluation Summary and Plan

- Thermal conductivity of TPG was measured with the steady state method. The value can be an input to the module simulation.

- Heat conductivity through the Al, glue and TPG is also important but not given by the specification sheet. It will be measured next.

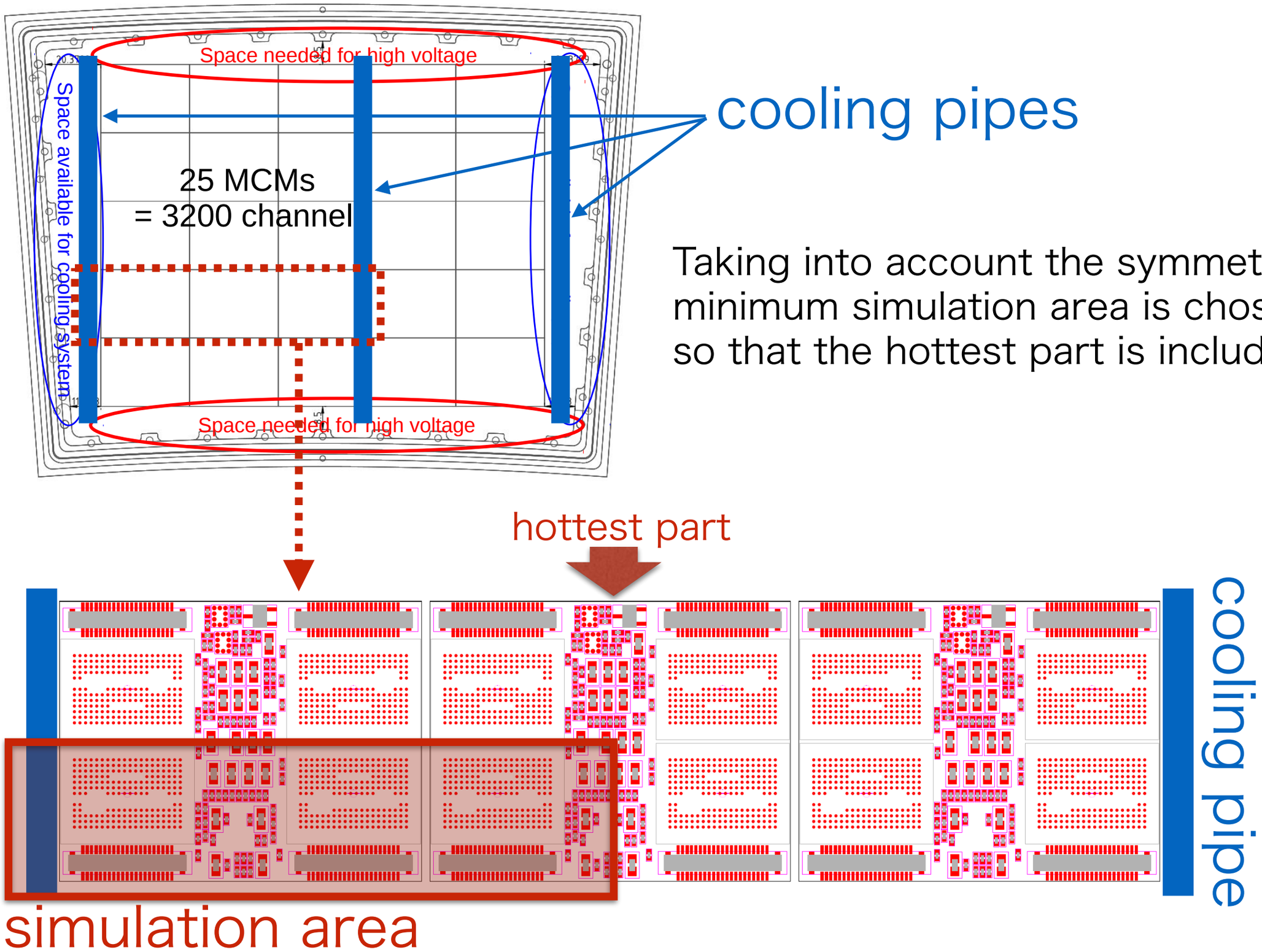
- Instead of the steady state method, the transient method is also being tried, which is faster to obtain measurement results. This will be valuable to evaluate various alternative materials.





3D Thermal Modeling of the Readout Module

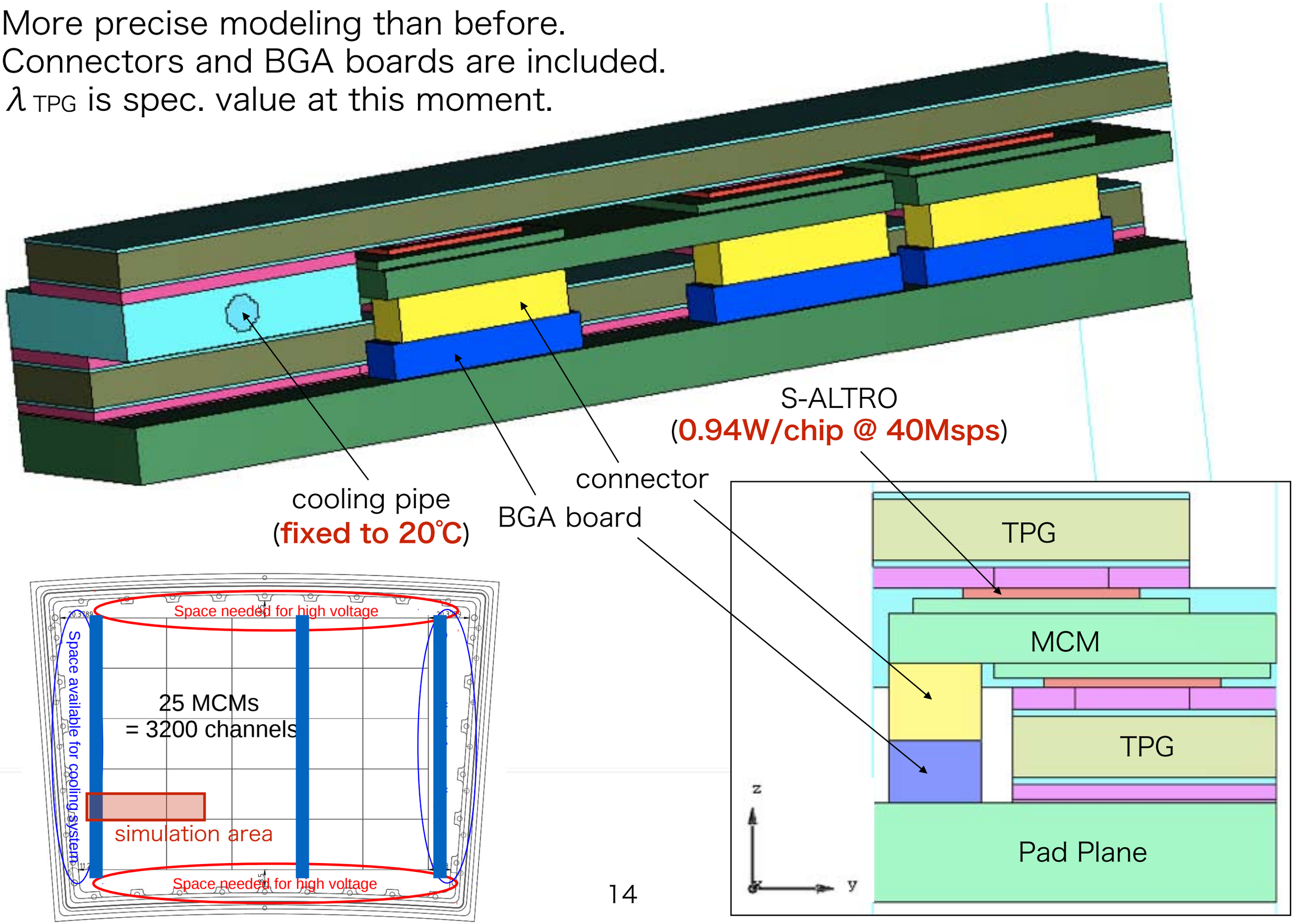
Two cooling pipes at the module sides and one near the middle.



Taking into account the symmetry, minimum simulation area is chosen so that the hottest part is included.

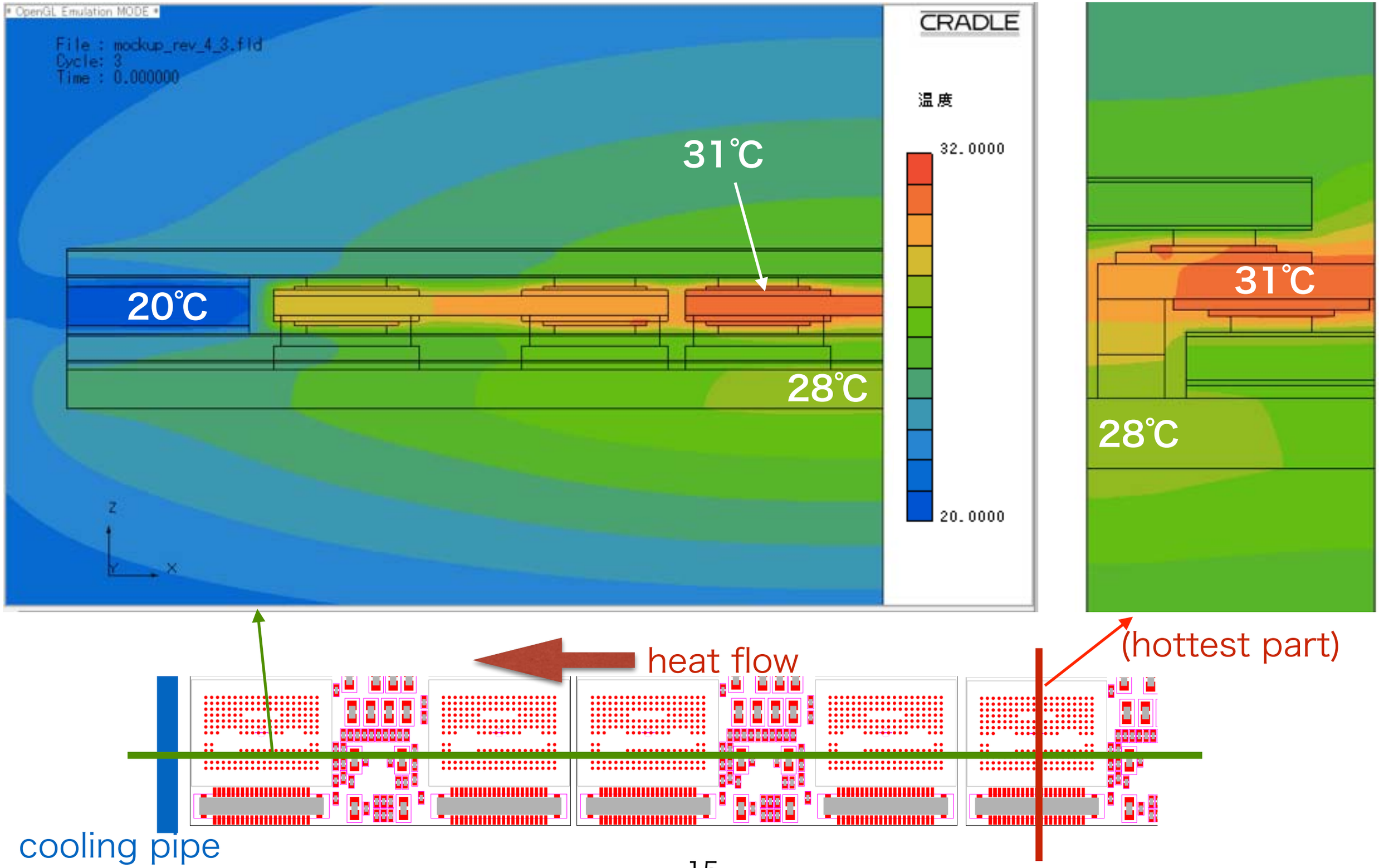
3D Thermal Modeling of the Readout Module

More precise modeling than before.
Connectors and BGA boards are included.
λ_{TPG} is spec. value at this moment.



Heat Simulation of the Next Module

T(S-ALTRO) ~ 31℃ → acceptable for the chip operation
Tmax(Pad Plane) ~ 28℃ = T(pipe) + 8℃ → NOT acceptable for the final LCTPC



What we know from the module simulation

- For the proposed design, temperature gradient will be about 8℃ in the case of 40Msps operation w/o power pulsing.
- If the operation is at 20Msps, P(chip) is 0.67W and the temperature gradient will be ~6℃.
- Heat flow through the connector is not small. Because of this, pad plane temperature is near the chip temperature. Therefore, the chip at the “operational” temperature is not enough and should be relatively near to the room temperature.
- Via of the BGA board should be as thin as possible. Thermal contact between TPG and chips and the one between TPG and pad plane should be better.
- (mockup test will be performed)

3. Towards the final electronics

Discussions on final ILC-TPC electronics

- Electronics meeting was held at Bonn on 18/Sep/2014.
  Materials can be obtained at
  https://agenda.linearcollider.org/event/6507/

- Exchanged information with ASIC experts.

- Options:
  ASIC process — keep IBM 130nm? move to TSMC 65nm?
  Digital filtering rather than analog shaping for baseline correction?
  Common Front End (CFE) project for analog part?
  Stack two or more different chips?

- Need to determine parameters by the physics aspects
  —> temporary values are listed in the next slide.
  —> These numbers have to be verified.

Parameters of final ILD TPC

1.) List: Parameters driven by physics

Preamplifier: input capacitance (5-20 pF)

shaping peaking time (60-200 ns) Martin Ljunggren MSc

sensitivity (1-10 mV/fC)

polarity (negative)

dynamic range (SALTRO: 150 fC, AFTER: 120, 240,?,600fC) dE/dx

linearity error <1% for full dynamic range dE/dx

noise (<600 electrons)

Shaper: restoring to baseline in units of counts

at least 1 µs for Micromegas (not to lose the signal on side pads)

ADC: number bits (8-10) Wenxin's thesis (Saclay), Liangliang's thesis (Lund) for spatial resolution

sampling frequency (20 - 40 MHz)

Time of continuous readout: ~800 µs (full bunch train)

2.) List system driven by other considerations

Input leakage current compensation (if too high -> noise, but may be necessary, e.g. for protection diodes)

pad density (1/4 of smallest pad size per channel)

Power consumption: 4 mW/channel (without power pulsing) -> 20 W per Module (5000 channels) -> 1 kW per endcap with power pulsing (+ at least a factor of 5 in power reduction by power pulsing)

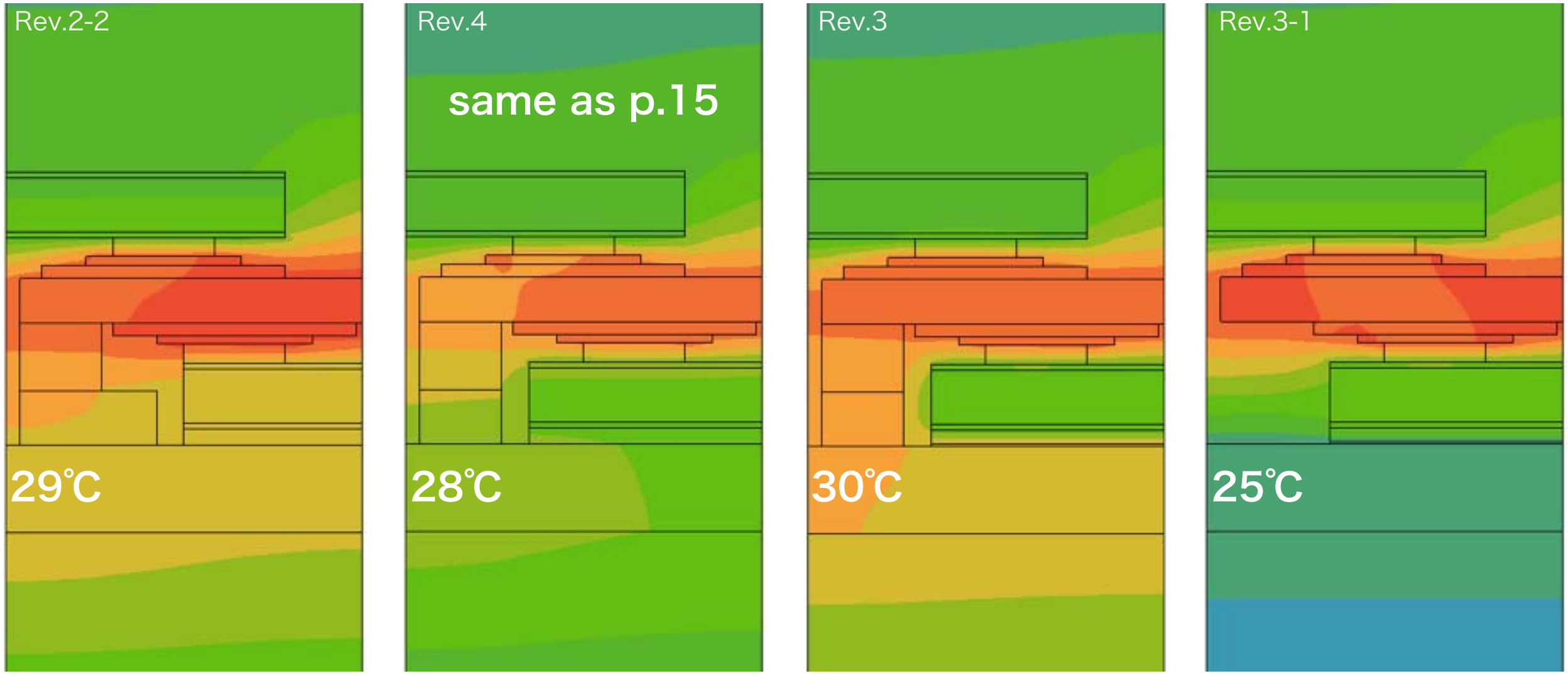
from https://agenda.linearcollider.org/event/6507/

Summary

- For the next module development,
  - thermal conductivity of the TPG was measured, which is consistent with specification and well explained by simulation. The result will be a good input to the module simulation. Further study will be performed for improved measurements and for various alternative devices.
  - Thermal simulation of the next module was performed. The result shows rather large temperature gradient. More detailed study and mockup test will be performed.
- For the future final electronics,
  - a discussion group was formed and the first meeting was held. We listed specifications of the readout chip. Verification of the given spec. numbers is the next step.

Backup Slides

Comparison btw. different cases



Wider BGA board, hence narrower TPG

Insulator to block heat from TPG to pad plane. This doesn't work at all because of heat flow through the connector.

Remove the connector to show that the insulator works well only when thermal contact btw. MCM and pad plane is small.