Development of a TPC readout system based on the SALTRO ASIC

A status report
12.1.2021

Leif Jönsson
Representing the Lund Group

The Lund group:

Björn Lundberg: previous electronics engineer at the division. He moved to a private company in 2010 but has recently started his own private enterprise.
Ulf Mjörnmark: previous research engineer at the division. Since mid 2018 retired.
Anders Oskarsson: since the end of 2018 retired.
Lennart Österman: electronics engineer at the division. Is instructed to work mostly on the ATLAS experiment.
Leif Jönsson: since the end of 2010 retired.

We have financial support to finalize the present work but we have no chance to improve the manpower situation. It means that all personal is working part time.
The work pace has also been slowed down by the COVID-19 disease.

Normal project layout:

Several groups and experts in each WP.
Each WP has user teams for evaluation

WP1: ASIC design, fabrication, packaging.

WP2: Front end boards

WP3: Data collection HW and FW

WP4: Data to computer, performance monitoring

WP5: Integration with detector, LV distribution, services, cooling, slow control

This project:

WP1: CERN design and fab: Lund die packaging

WP2: Lund. Packaging intergrated with the board design

WP3: HW, SRU from RD51. FW partly done by master student in Lund.

WP4. Lund responsible for all evaluation

WP5: Cooling PISA. Slow control DESY? The rest is Lund work in progress

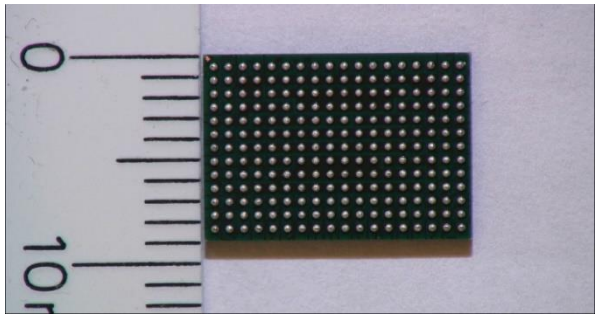
Retrospect:

The packaging of the SALTRO-dies was started at the end of 2017.

Top side ← 12 mm →

9 mm

Bottom side with soldering balls in BGA pattern



- Prior to the full production two pre-samples including in total 89 chips were packaged and tested.

- The packaging of the full number of dies was completed at the end of 2018 after careful tests of the pre-samples. Out of the initial number of 794 dies sent to the company, 748 were successfully packaged and delivered to Lund.

Test of the first MCM-version

- The first two boards were mounted at the end of 2019 by the DESY electronic workshop. the first version was intended for testing the design and because of this only two chips were mounted on one board and seven on the second.

- The test revealed the need for a few corrections to the circuit board design. These were implemented and a new version was manufactured.

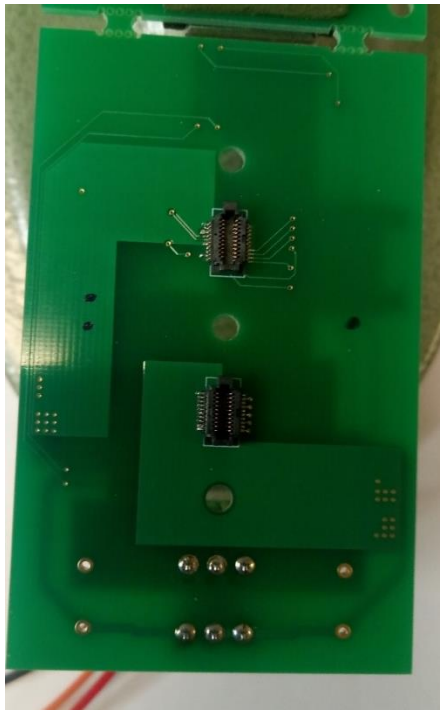
- The miniature MCM circuit board is very complicated to manufacture. Only a limited number of companies are able to carry out the work. The cost is high (about 6000 Euro) per order and the delivery time is about 2 months

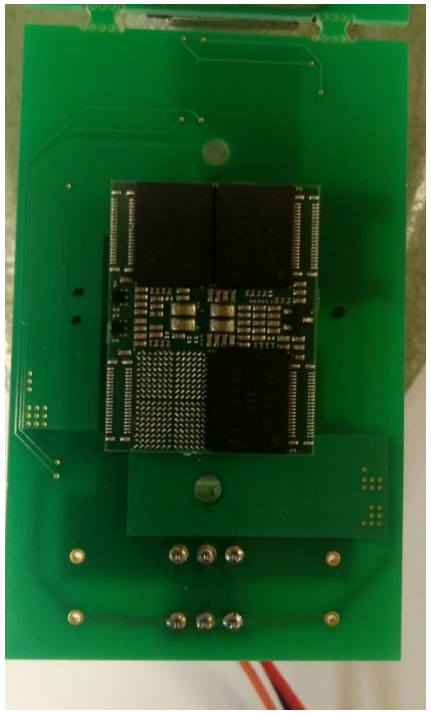
The LV prototype board

- For the tests of single MCM-boards a prototype LV-board was designed. The final LV-board will supply voltages for 5 MCM-boards.

- Due to the small size of the MCM-board the voltage regulators have to be placed on the LV-board.

- The MCM has seven different power domains. The R&D work has proven that these can be reduced to two, requiring the power supplies 1.5 and 2.5 volts.





Readout problems known so far:

- With the present DAQ-system we are limited to either perform a full readout of 2 channels out of 16, or to read out all channels but limited to 135 samples per chip and per MCM.

- The SRU: A re-arrangement of the memory management is necessary for full readout of all 16 channels.

- A bug which occasionally causes the system to hang has to be solved.

- These problems have caused us months and months of delay

All this needs an FPGA programmer.

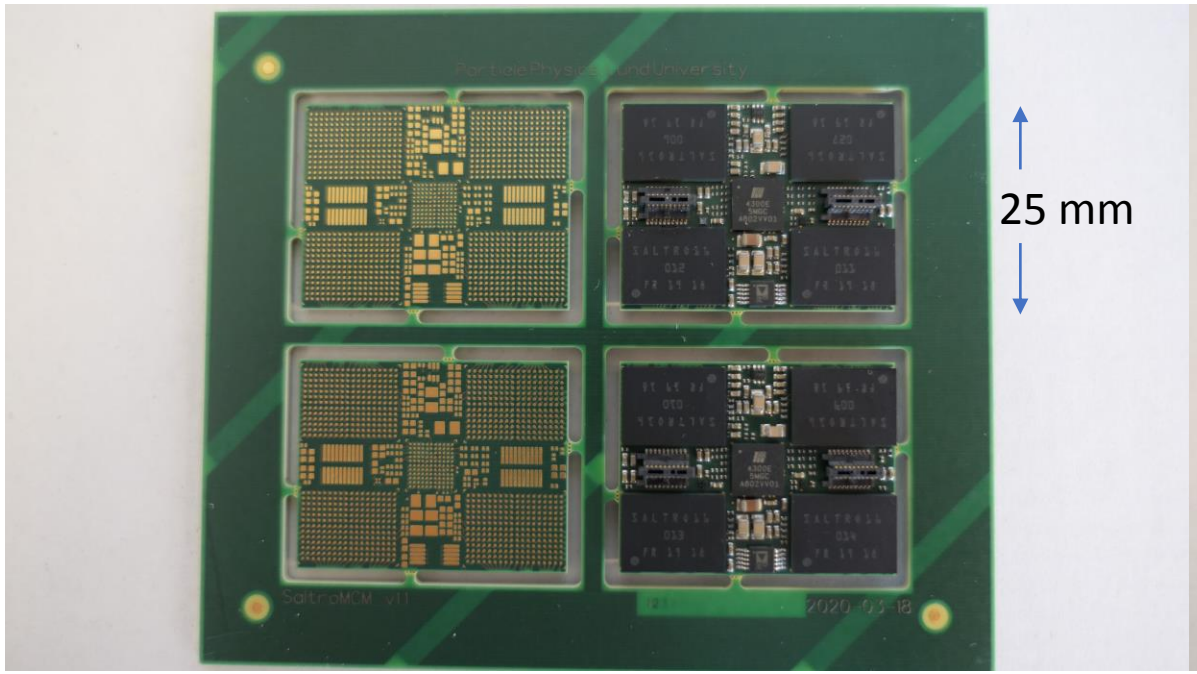
Until this has been solved no further chips will be tested.

- In order to perform the full chip tests in a reasable time we plan to use parts of the automatic system that was used in the tests of the SAMPA chip.

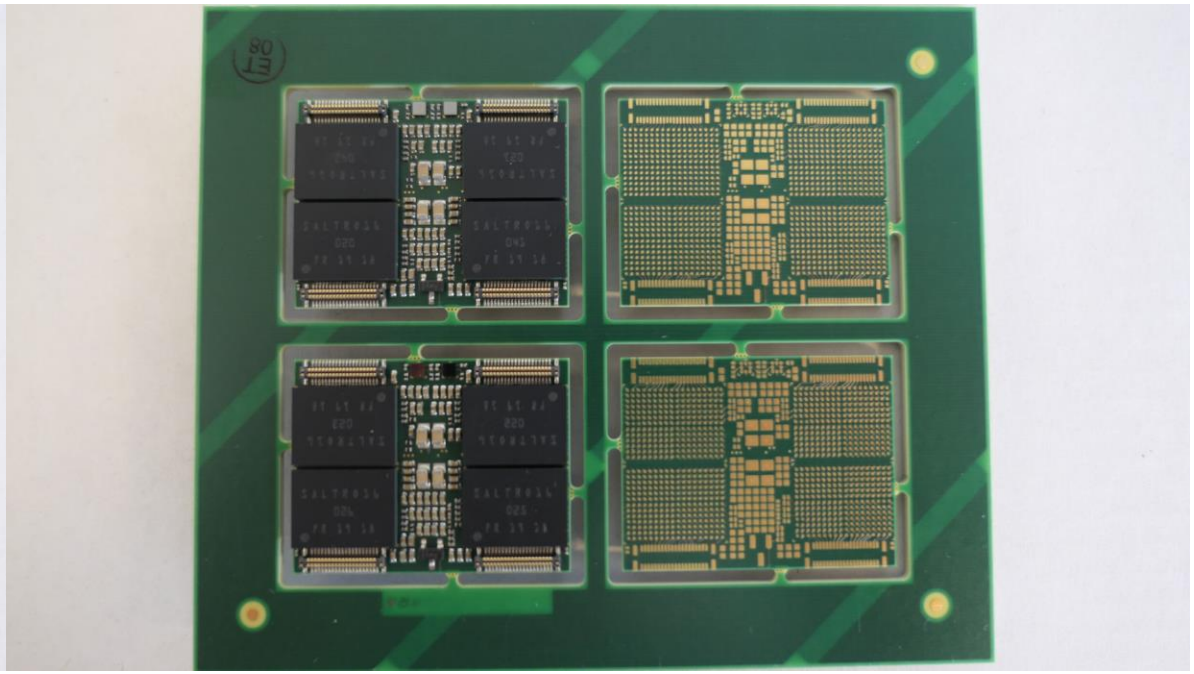
The present status

- The second version of the MCM-board was prepared and mounted in the middle of June 2020. Two MCM-boards were mounted with eight SALTRO-chips each.
- One PCB panel contains 4 MCM-boards. Due to the small size of the soldering pads, the solder mask has to be positioned very accurately.
- The soldering balls of the chips are 0.3 mm in diameter.
- In spite of the small and tight dimensions the challenging surface mounting of components by the DESY electronics workshop was faultless for the two boards fully assembled.

Top side



Bottom side



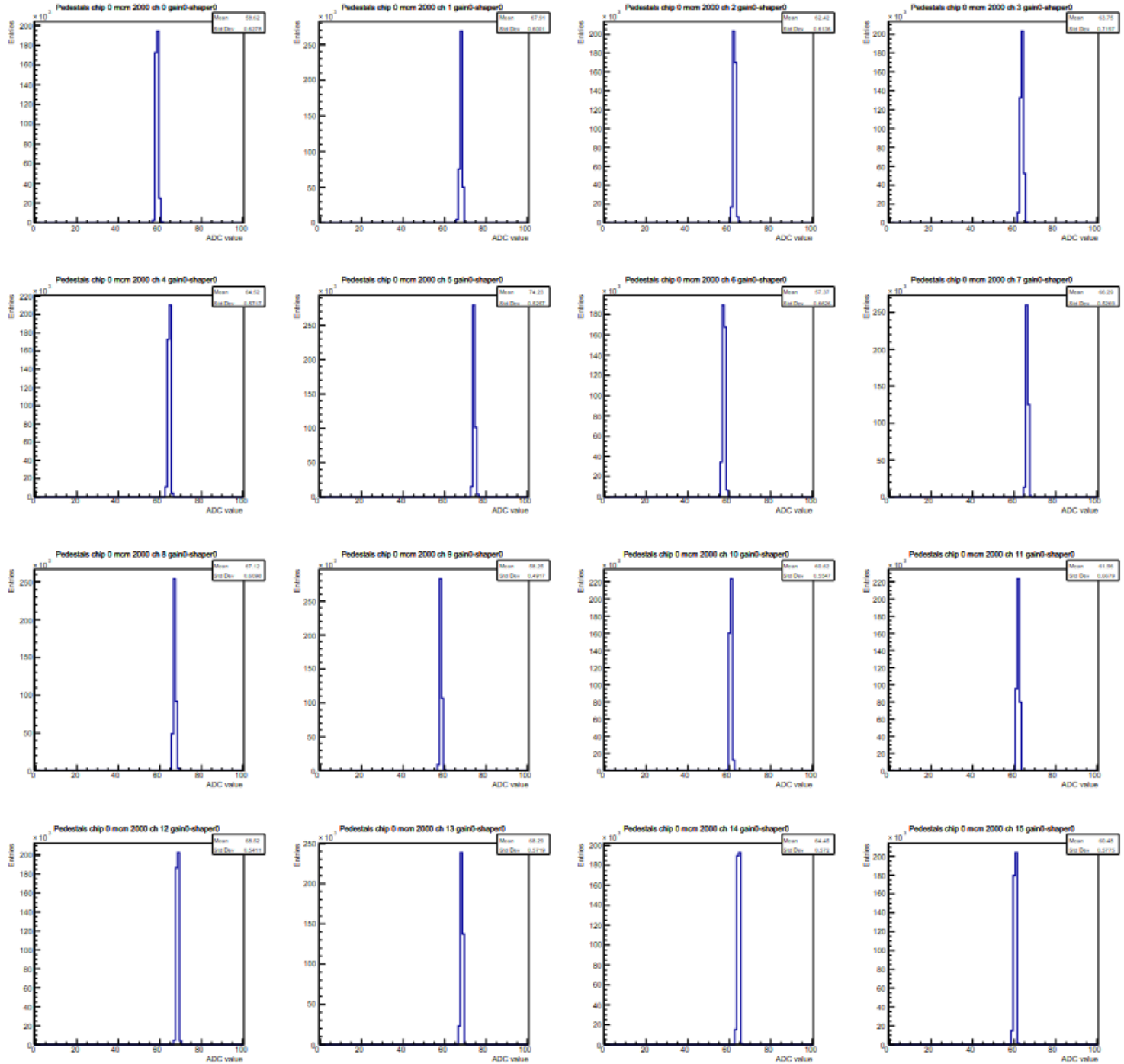
Tests performed so far

Shaping Time (ns) \ Gain (mV/fC)	12	15	19	27
30	P, TS			
60	P, TS			
90	P, TS			
120	P, TS	P, TS	P, TS	P, TS

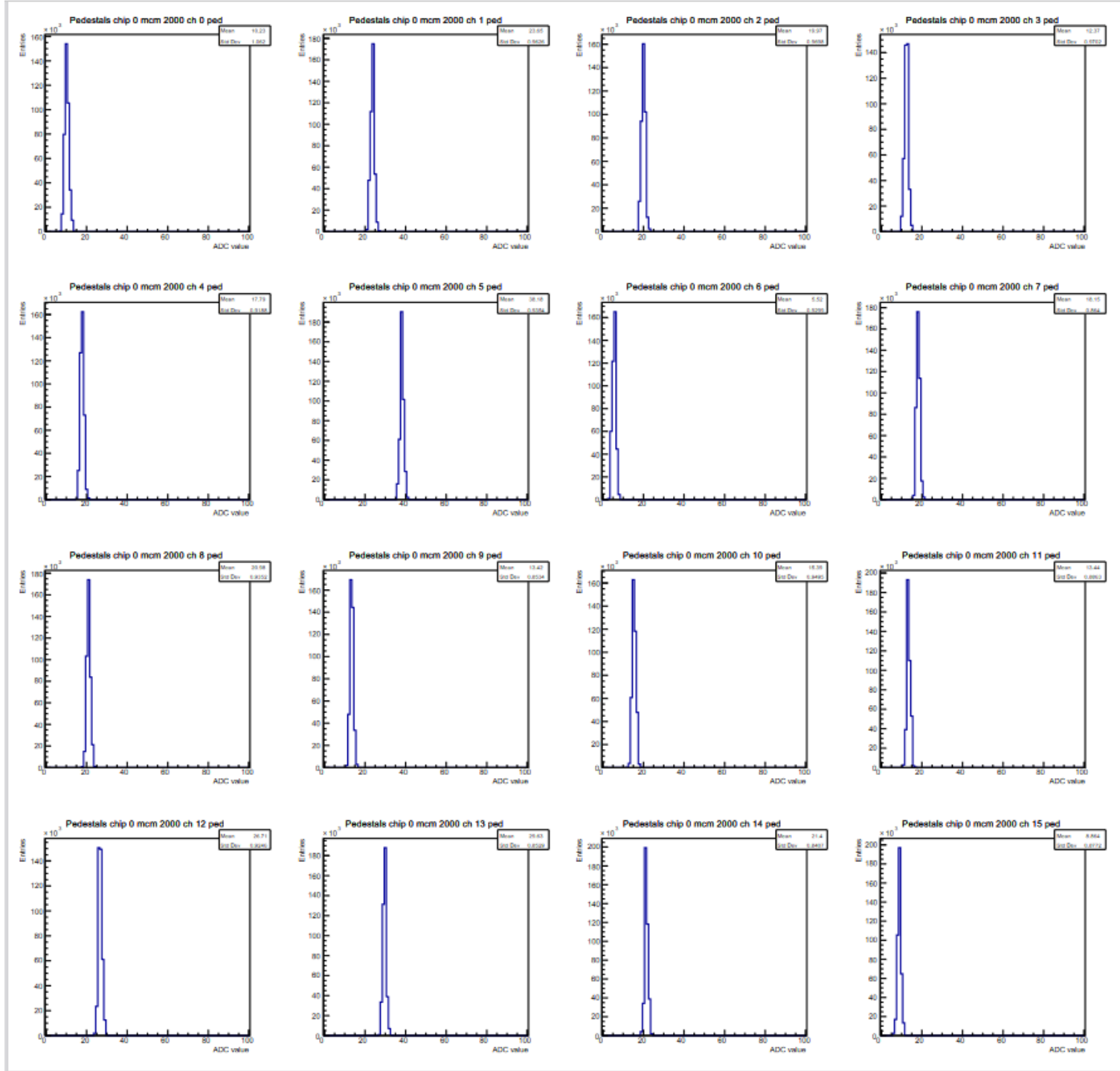
P = pedestal runs
TS = time sweep

Preamp decay time: 500 ns
Polarity: positive

Pedestals
MCM 2
Chip 1
Channel 0 – 15
Gain 12 mV/fC
Shaper 120 ns



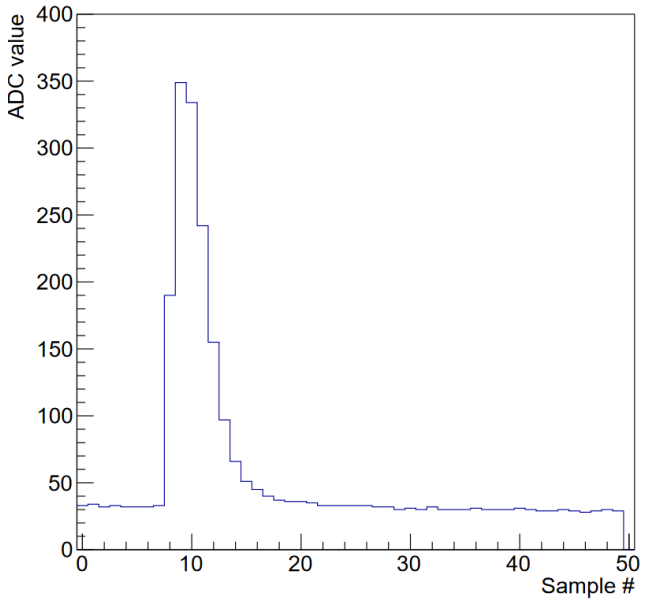
Pedestals
MCM 2
Chip 1
Channel 0 – 15
Gain 27 mV/fC
Shaper 120 ns



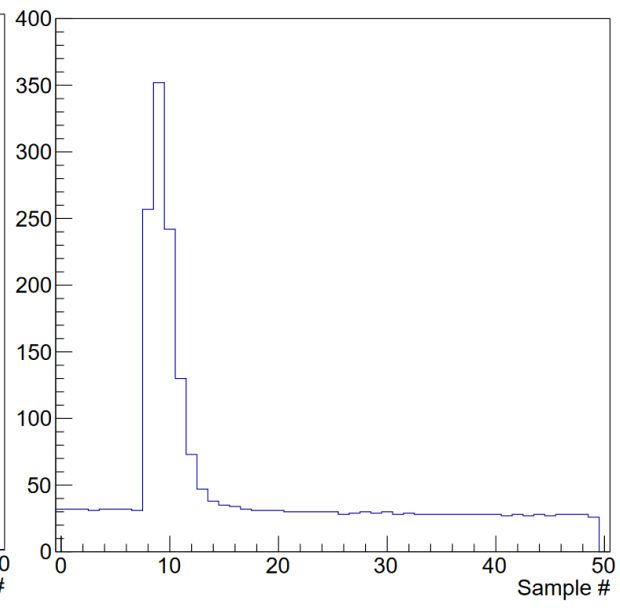
Pulse dependence on the shaping time

Gain 12 mV/fC

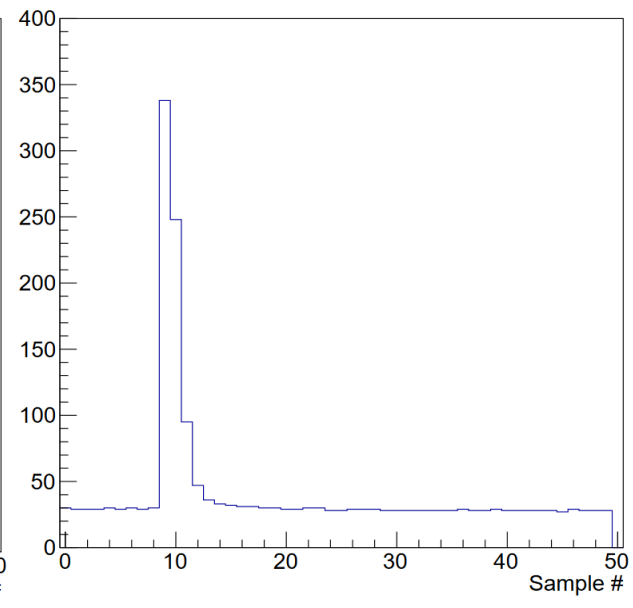
Shaper 120 ns



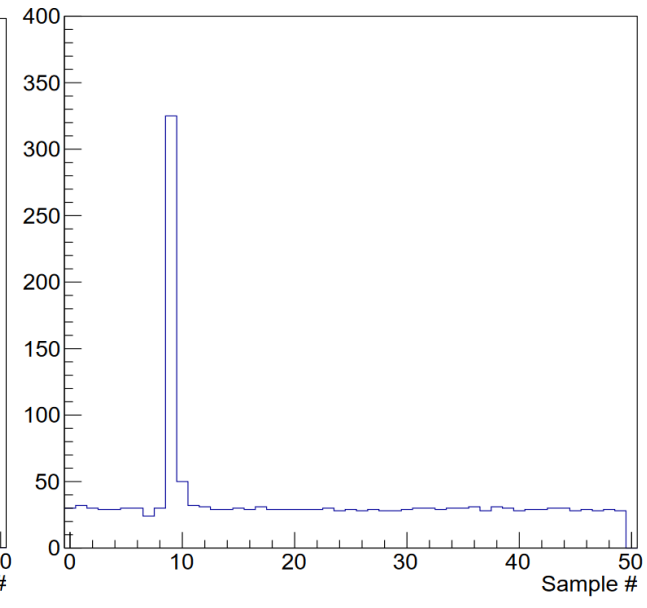
Shaper 90 ns



Shaper 60 ns



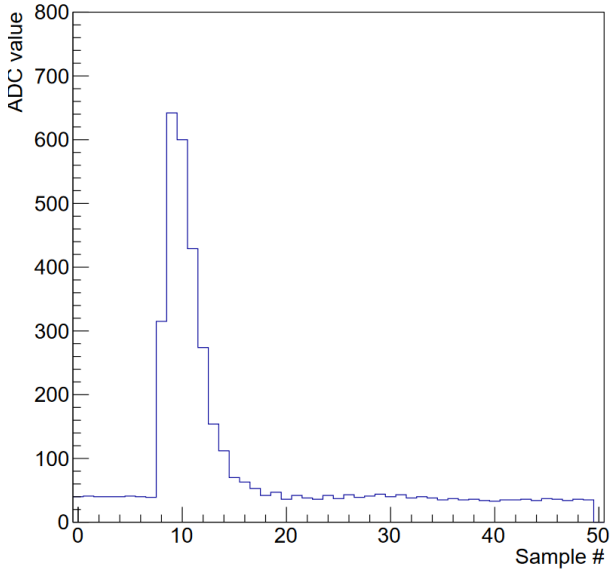
Shaper 30 ns



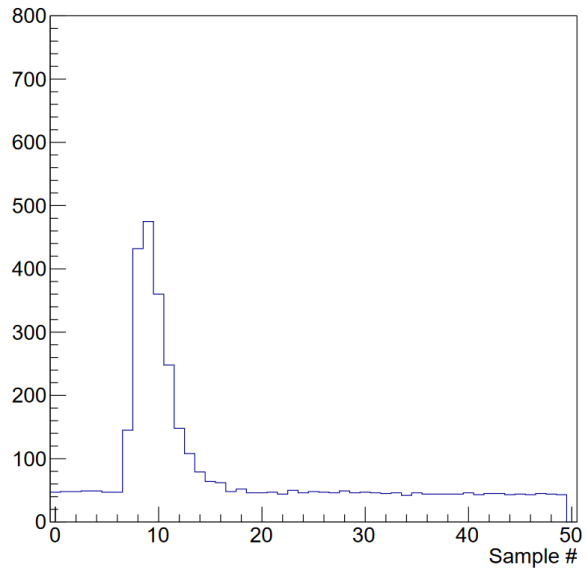
Pulse dependence on the gain

Shaping time 120 ns

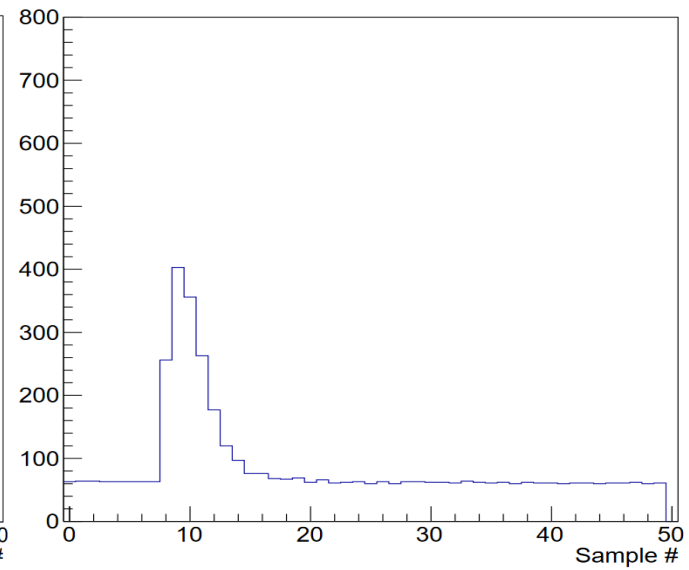
Gain 27 mV/fC



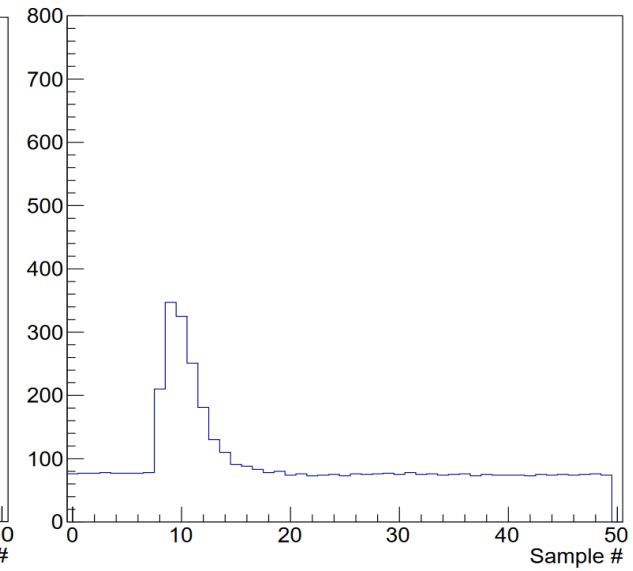
Gain 19 mV/fC



Gain 15 mV/fC

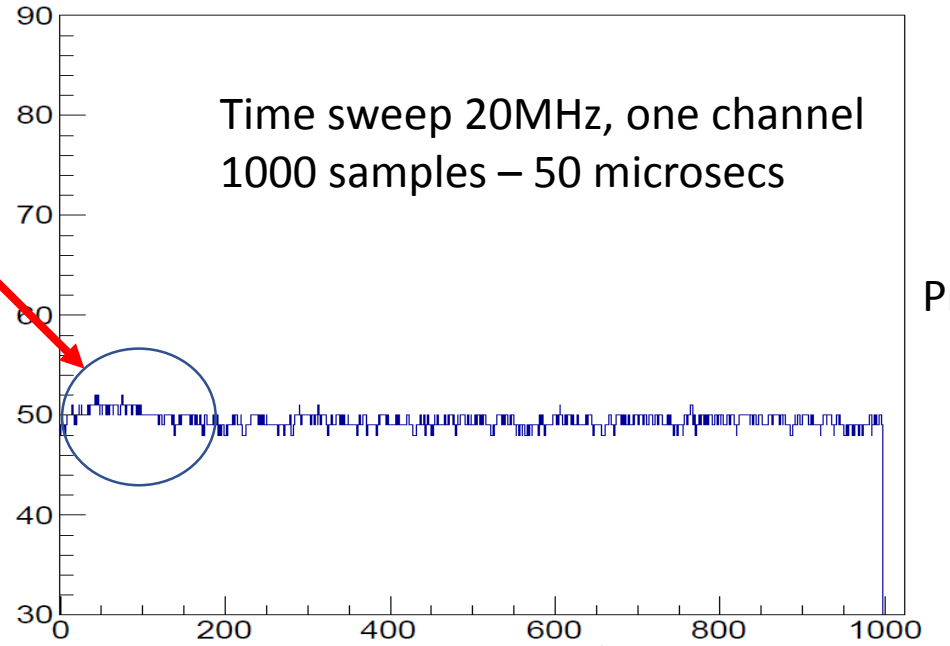


Gain 12 mV/fC

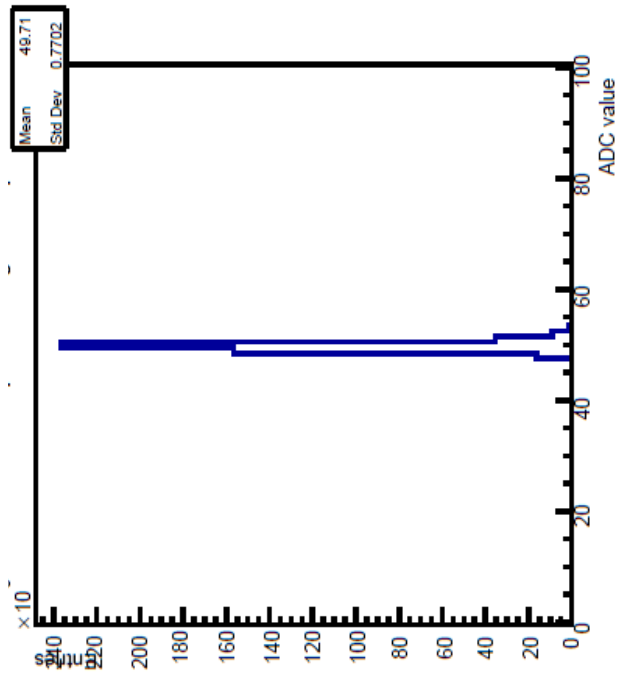


Noise full MCM, 128 channels, gain 12mV/fC and shaping time 120ns

Small dynamic effect
1-2 adc ticks when digital activity starts.
If not solved- subtract individual channel and sample pedestals



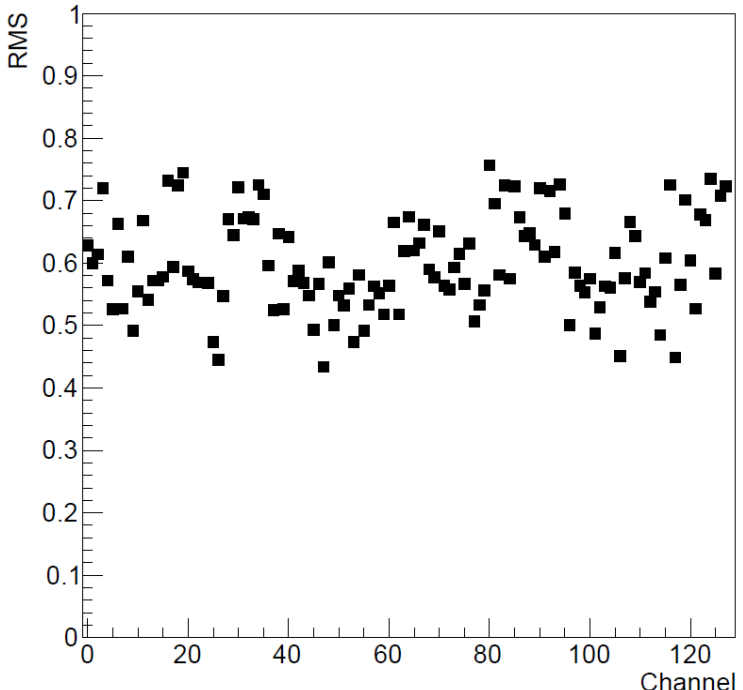
Project on ADC axis



Calculate RMS
Mesured noise

Repeat for all 128 Channels on MCM

Very low input capacitance
MPGD have very low input capacitance (but a few pF higher than bare MCM)



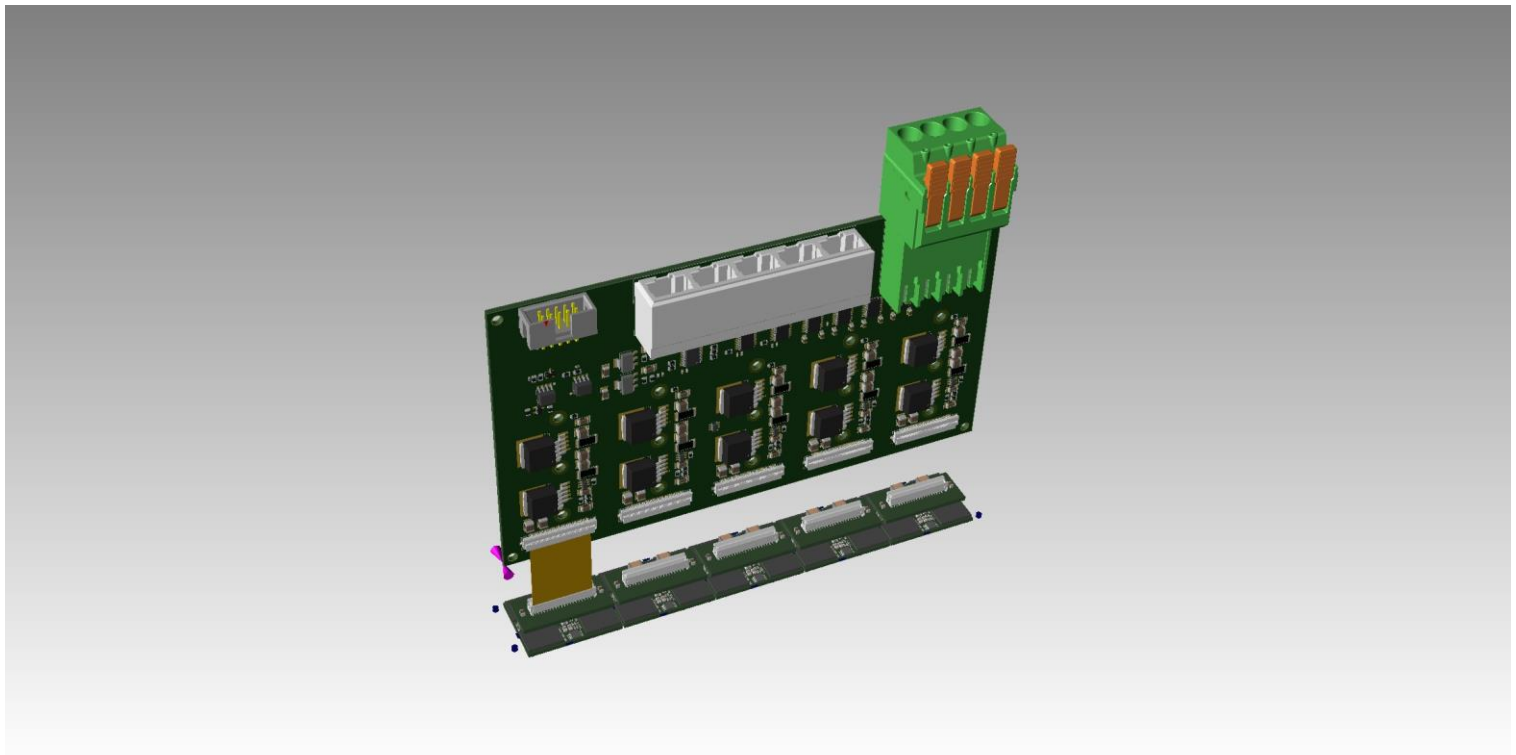
Measured noise includes:

- Amplifier random noise
- Noise due to digital activity
- Discrete ADC scale
- Baseline variations from nanosecs to seconds

Result
Noise average 0.6 ADC ticks
2mV/ADCtick and 12mV/fC gain - 625 electrons for full operation MCM of 128 channels.

The LV-board

- The LV-board is connected via short flat cables to the MCM board. Since there was no contact for the flat cable to directly connect to the Samtec connectors on the MCM-board, it was necessary to introduce a small adaptor board in between. The use of a flat cable has the advantage that the precision of the connector positioning on the adaptor board is not critical. The other advantage is that the connectors on the pad plane must only be very accurately positioned to fit the connectors on individual MCM board and not for a complete ladder of 5 MCM boards
- The LV-board also contain an LVDS (Low Voltage Differential Signaling) repeater (tranciever) for the communication with the SRU.



Summary of the electronics development

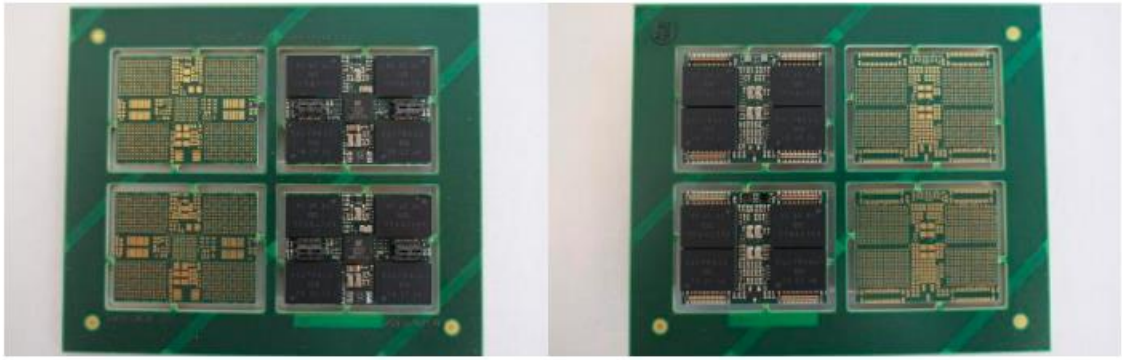
- The MCM-board is working up to specifications
- We are struggling with getting rid of a small bump in the beginning of the sweep
- The design of the LV- board is ready
- The design of the adaptor board is ready
- Quotes for the LV-board and the adaptor board is in the pipe line
- The flat cables connecting the LV-board and the MCM-board are ordered with expected delivery on the 18th of January
- Further chip testing is waiting for the FPGA-programming to be solved
- Before the final version of the MCM-board can be produced we need to test the chips

Cooling

AIDA 2020

Cooling of the multi chip module for a general-purpose readout system for MPGD's

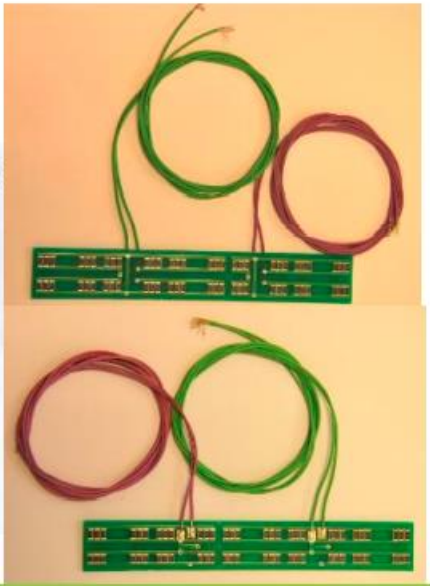
Contact person: Leif Jönsson, Lund University



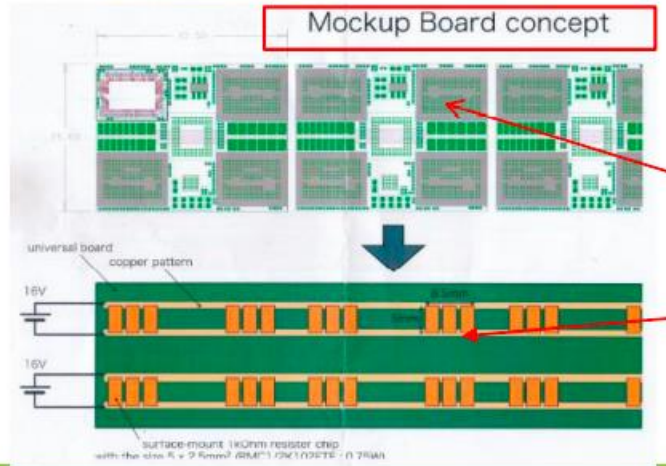
Last version of the panel with MCM Board top and bottom
The MCM Board works in principle but has some unwanted noise that the group is struggling.
When this will be solved ready for production

MCM Mockup

Top and bottom side

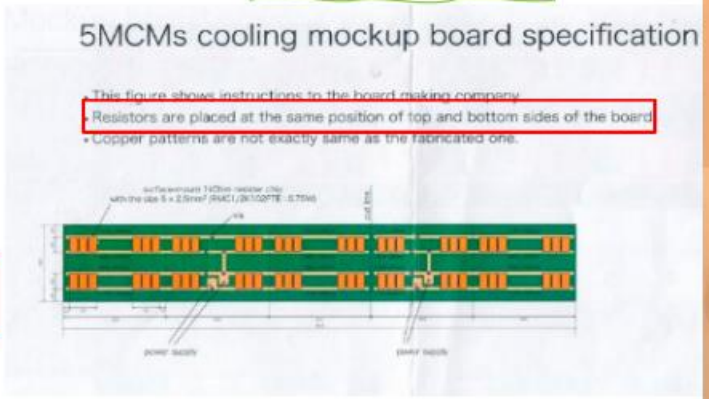


Thermal specifications



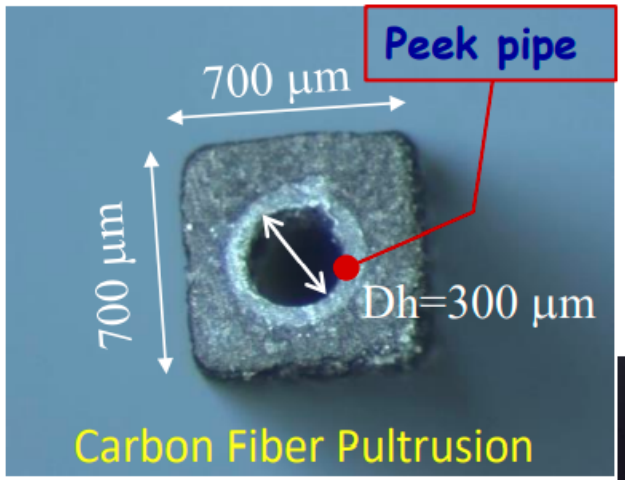
Max 1.0 W/cm^2

Board mockup



Our first cooling proposal: Microchannel Module Support

Obtained by pultrusion of C.F. TohoTenax HTS 40 , adding and gluing in special masks, side by side, single micro-tube. The inner diameter of the peek micro-tube is 300 μm, the thickness of the square composite profile is 700 μm .



Carbon Fiber Pultrusion

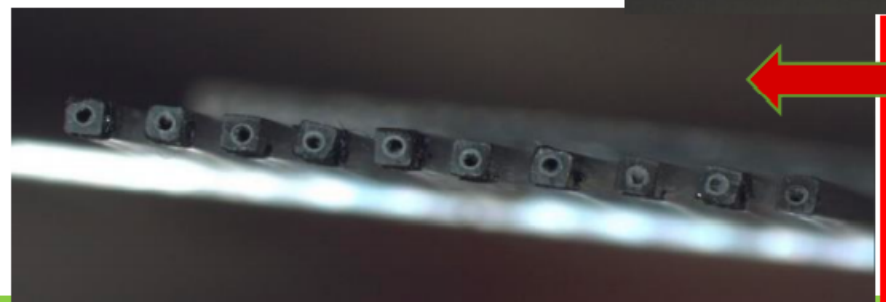
The single base microchannel unit

A square CF micro-tube with an internal peek tube 50 μm thick used to avoid moisture on carbon fiber

Support Cross Section

Full micro-channel module

The total radiation length (*) of this support is 0.28 %X_0



Net micro-channel module support

Alternated microtube structure with step of 700 micron

The total radiation length (*) is 0.15 %X_0

(*): Material of the support structure: (C.F. material + peek tube + Water)

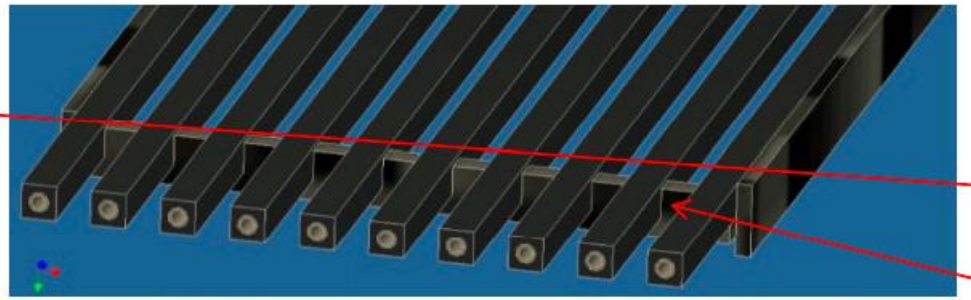
A possible improvement: Module Net Support

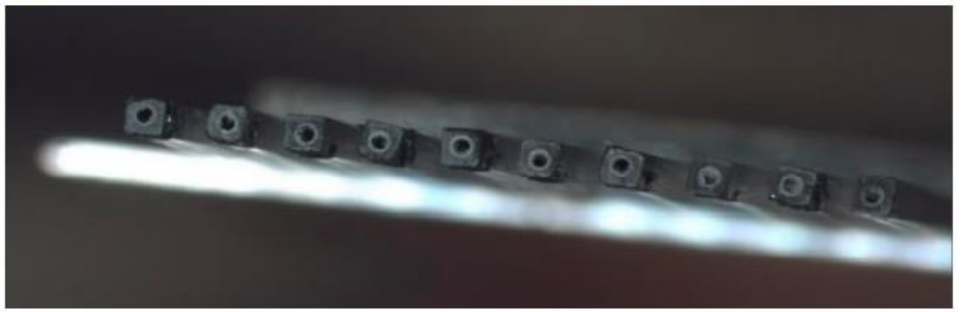
Assuming further progress in MAPS sensor design, and looking to actual hybrid pixel, the required Power (analog + digit), could step down to 1.5-1.0 W/cm^2.

We choose to design a lighter solution for the support structure .

The Net Module is a micro-channel support with vacancies of tubes with a step of 700 micron .

Lower radiation length with net module support





Carbon fiber stiffer

Material of the support structure: (CFRP + peek tube + Water + CFRP Stiffeners)

Mockup Board Power Consumption

Mockup board power consumption compared to MCMs

	5MCMs top side	5MCMs bottom side
Mockup 17.7V	3760mW	3760mW
MCM continuous operation	3203mW	3028mW
MCMs with ILC power pulsing	223mW	48mW
MCMs with DESY test beam power pulse	343mW	168mW
	total 3769	Total 3244

} based on Leif's description in the Liason report.

There are two power supply points on the mockup (5MCMs) board.
The same voltage is applied to all resistors, as you can see from the board.
The resistor part no. is "RMC1/2K102FTE", which is 1kOhm, 0.75W resistor.
Max voltage we tried is 17.7V as shown above, with which the power per resistor will be 313mW.

Microchannel cooling top/bottom for mockup board

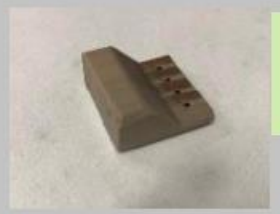
Final experimental setup

IN
OUT
OUT
IN

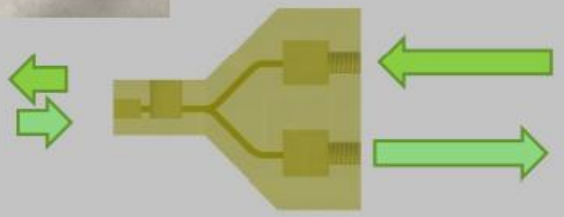
MCM Board

No temperature gradient along the module ($\Delta t<1°C$)

Opposite cooling flow by each side
To have same temperature long the module



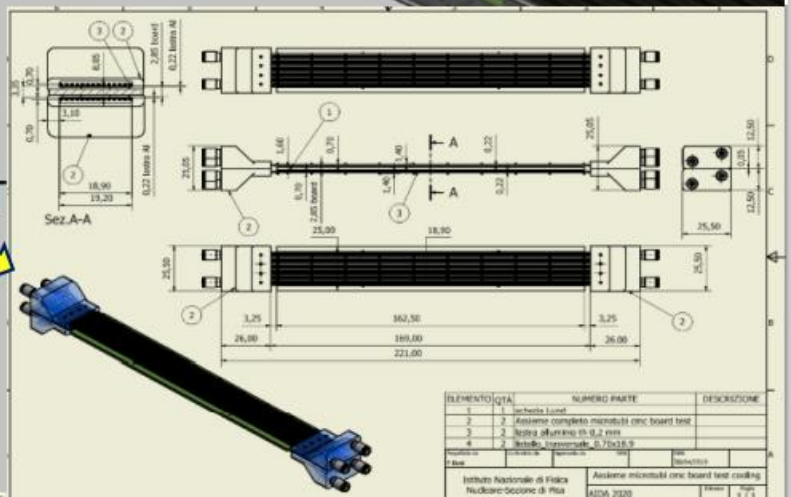
Inlet/Outlet connector



3D printing technology
Material: Peek

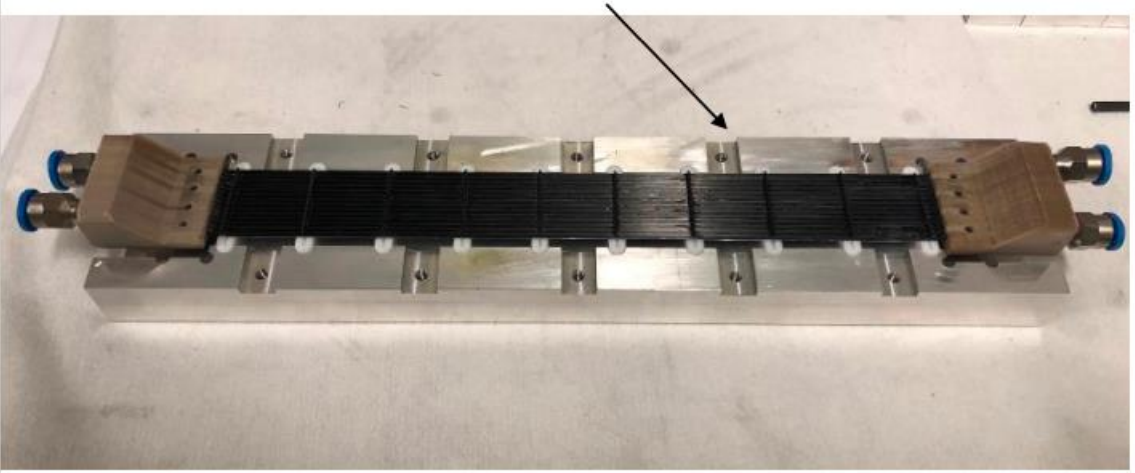
Opposite cooling flow by each side

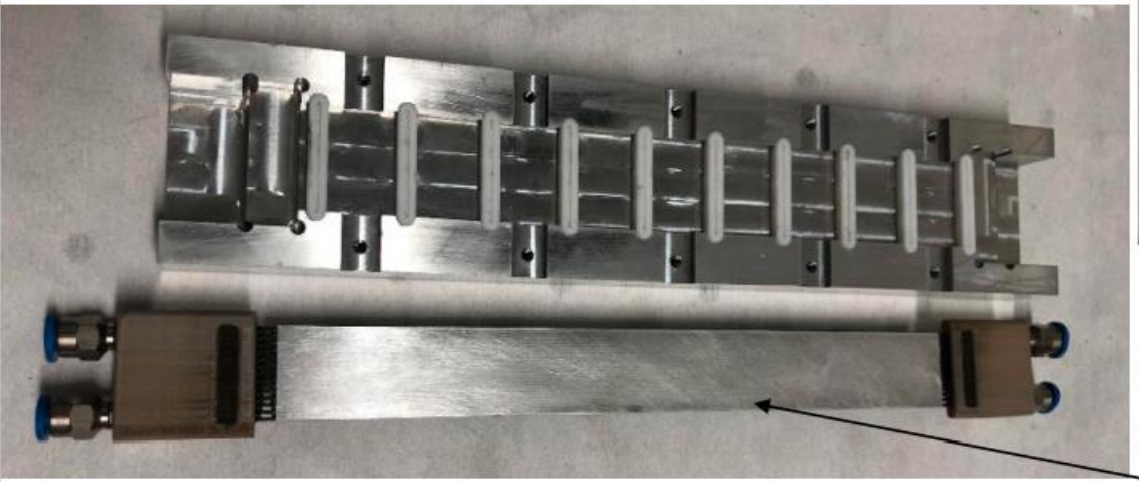
OUT
IN



First Module prototype

Top support prototype on the gluing mask





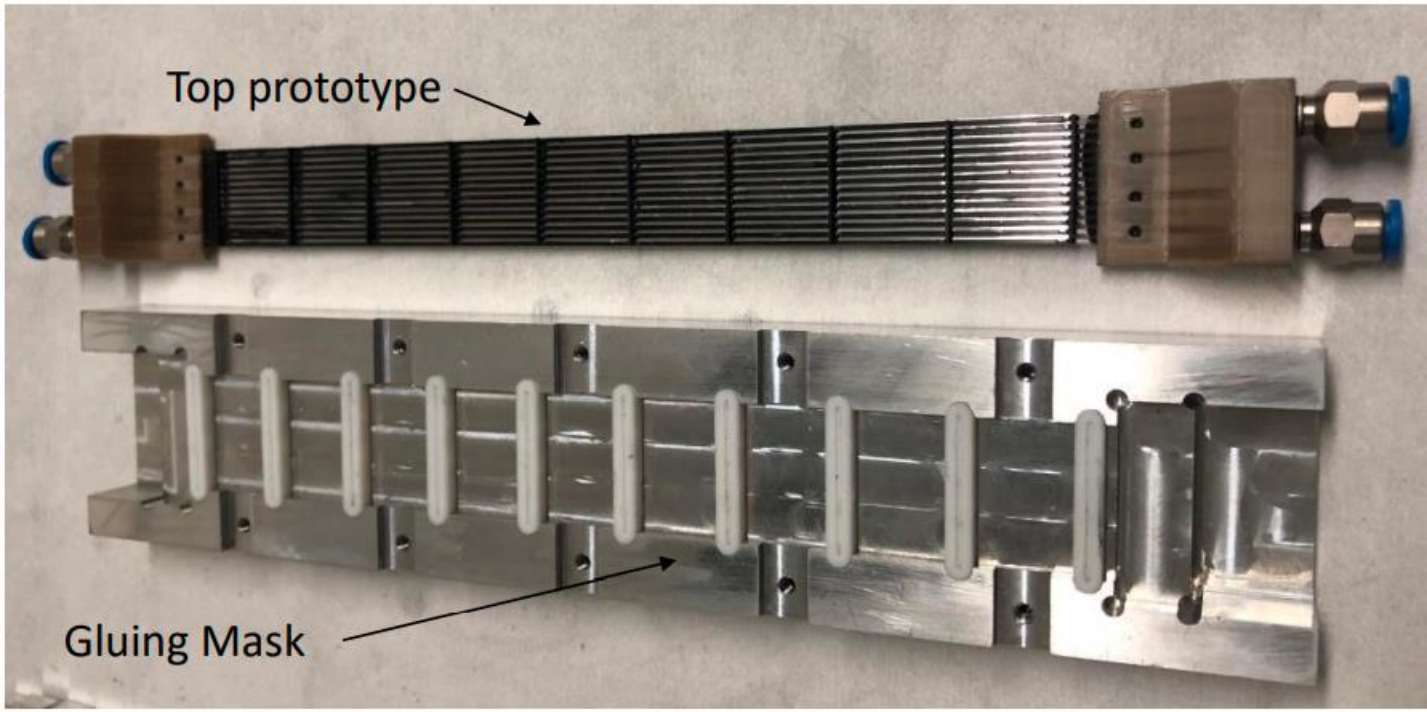
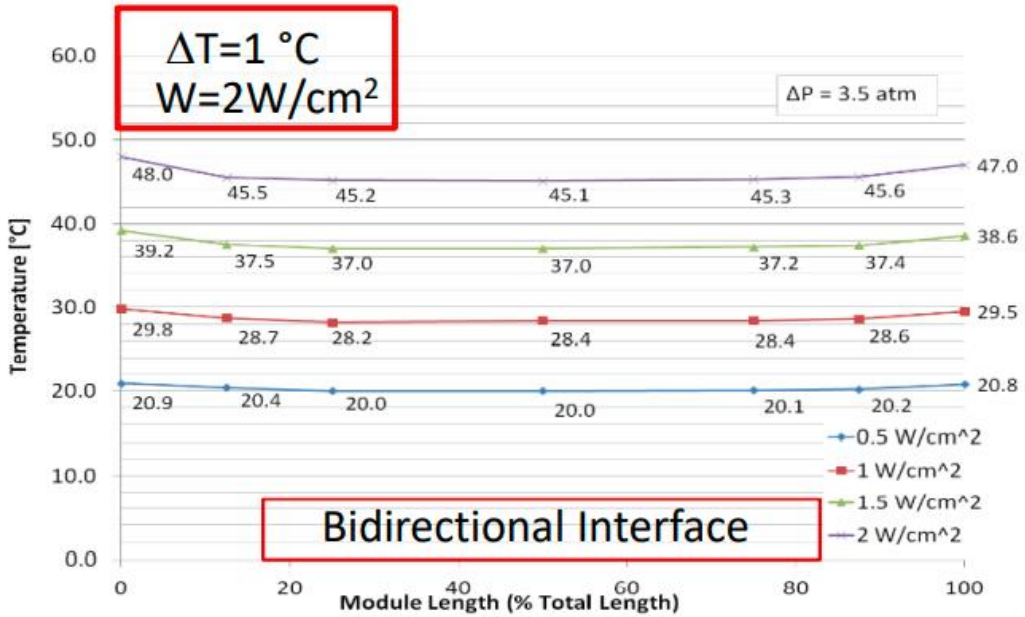
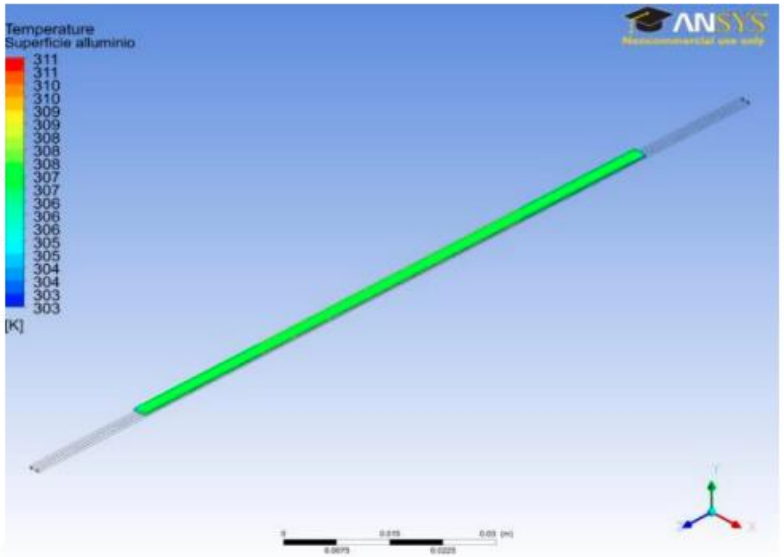
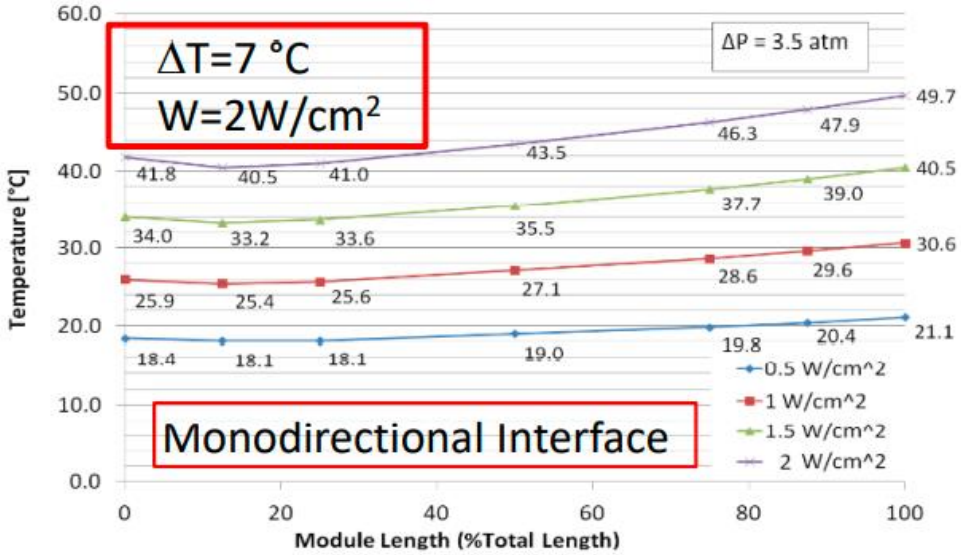


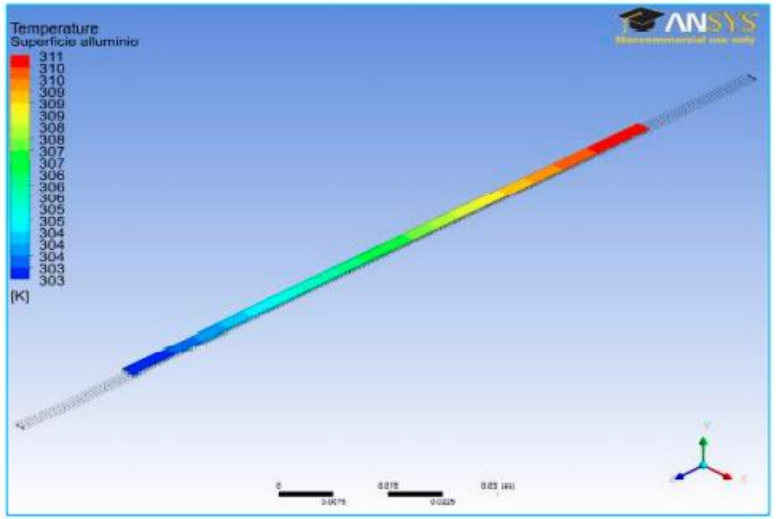
Plate in Aluminum for heath diffusion glued on the bottom side of the module support

Net Module sample (L= 120 mm - Dh=300 mm th= 700 mm) - coolant water-glycol @ 10 °C









Status of the AIDA Project

- First prototype of the microchannel support ready for cooling tests of the MCM board
- Second prototype in preparation
- TFD lab ready for testing
- MCM Mockup Board in our hand
- Final setup on the MCM Board will be ready at the end of October 2020
- First results of the thermo-hydraulic test on the MCM Mockup Board ready by the end of the year