Thermo-mechanical measurements on thin ladders under air-cooling or micro-channel cooling

(work performed within the DEPFET collaboration)

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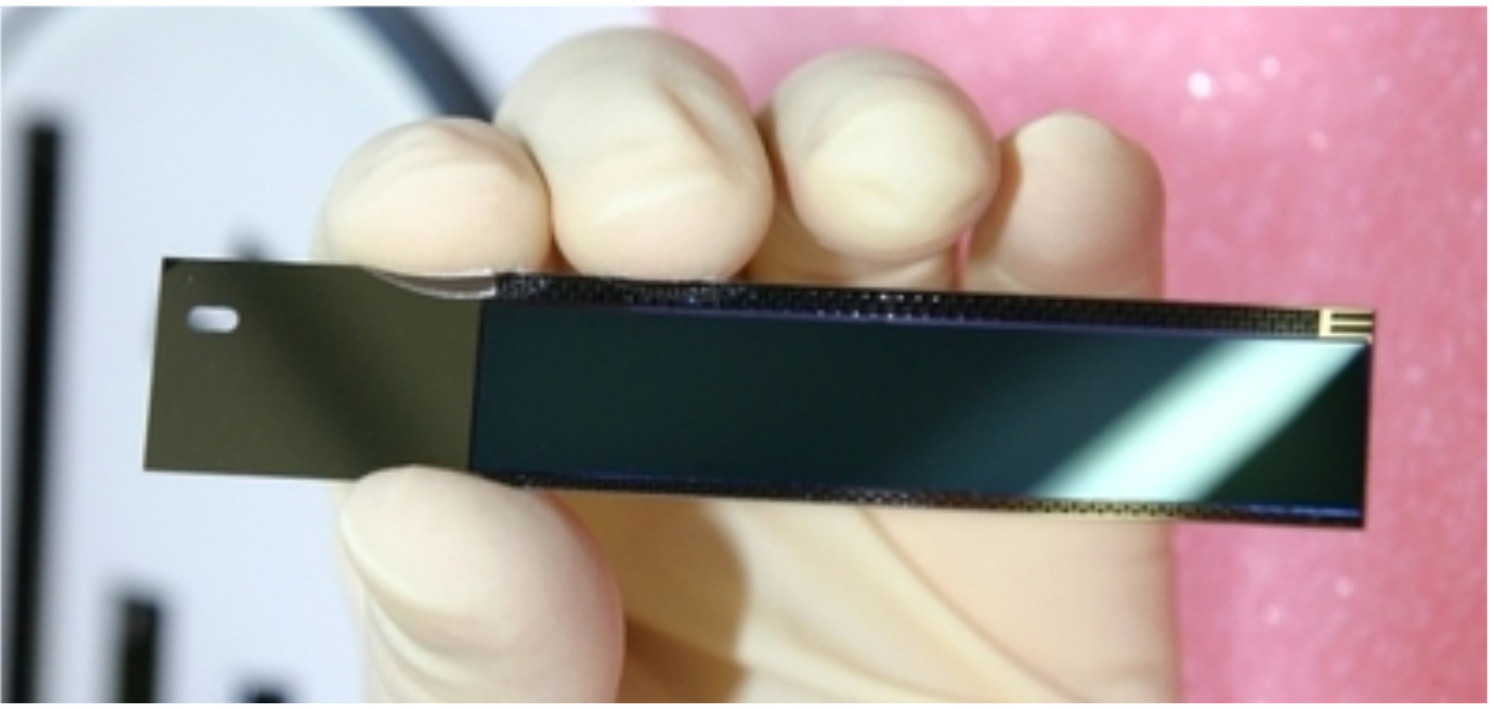
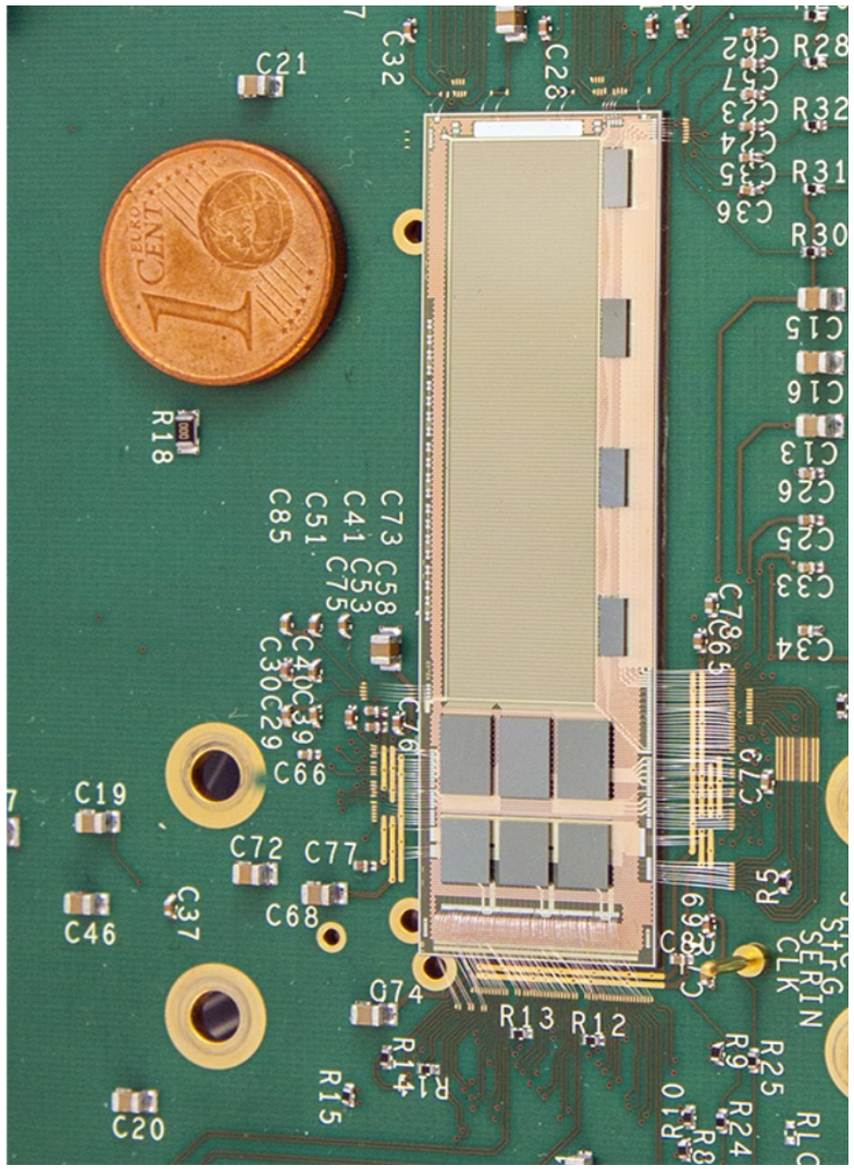
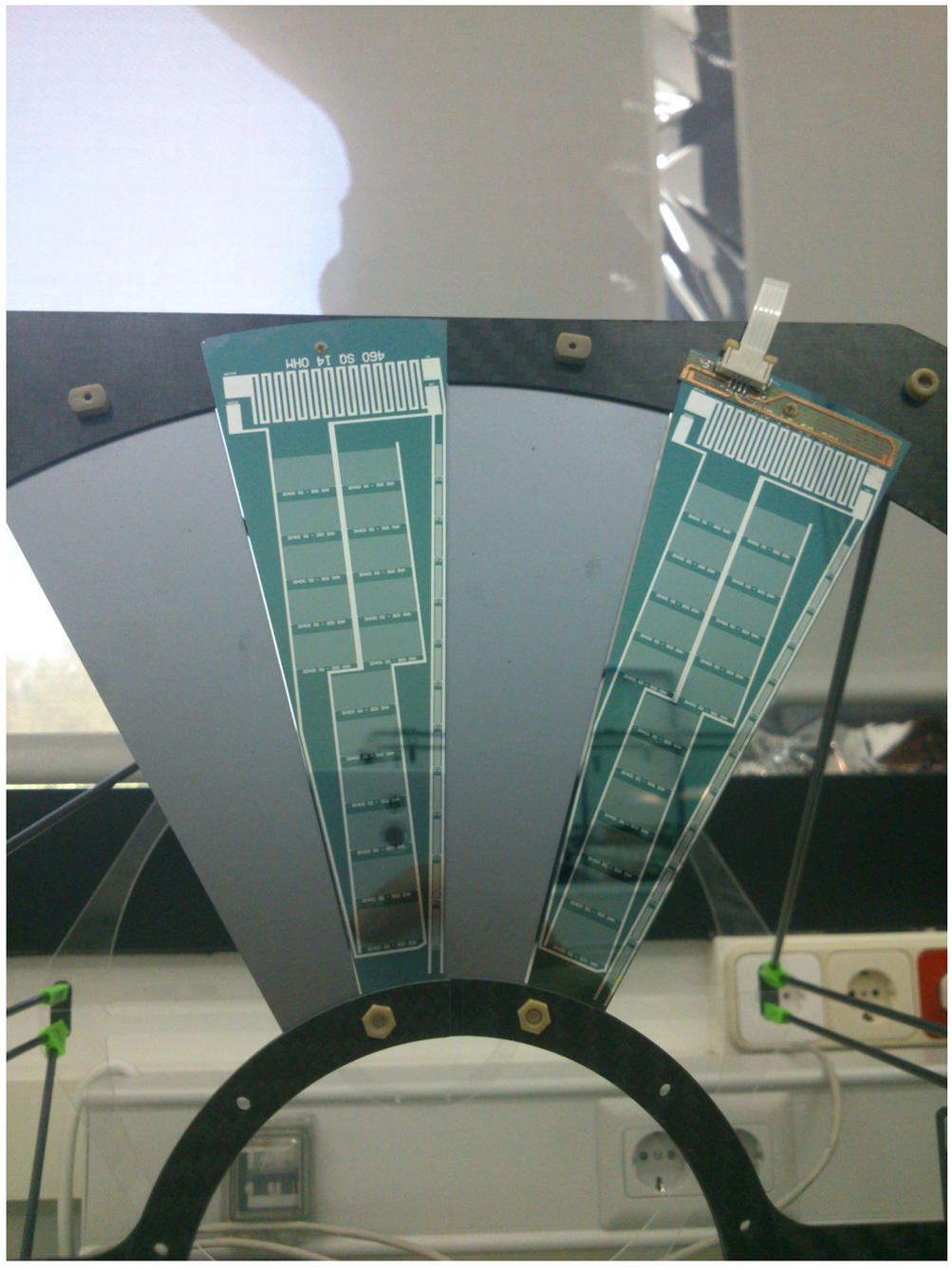
DEPFET

DEPFET all-silicon ladder integrates sensor, flex and support structure





Full mock-up for ILC end-cap



Subject thinned petals to ILC environment:

- low-mass CF support structure
- pulsed power in heater circuits
- forced air flow for cooling (no liquid!)

And monitor thermo-mechanical properties:

- thin petals are very rigid when subject to perp. force
  - Deformations are 3x larger than solid 450 μm thick petal
  - Deformations are 23x smaller than solid 113 μm thick petal (same material)
- pulsed power with ILC duty cycle (1 ms on, 200 ms off)
  - No sign of fast temperature excursions (τ~3 s)
  - No sign of vibrations induced by power pulsing (for B=0)
- small temperature increase for nom. power and 1/25 duty cycle
  - ΔT ~ 3 degrees for single petal
- cooled very effectively by air flow of 1 m/s
  - ΔT ~ 3 degrees even for ¼ duty cycle
- air flow induces measurable vibrations
  - Frequency varies with clamping: 60 Hz (1-point support) to 300 Hz (3-point)
  - Amplitude controlled to few microns if correctly clamped

Thin petal thermo-mechanical performance reproduced by Finite Element simulation

DEPFET and MCC

Generates > 80% of heat on the end-of-ladder area → MCC is natural solution

Aggressive in some respects:

integrate cooling in all-silicon ladder

Conservative in others:

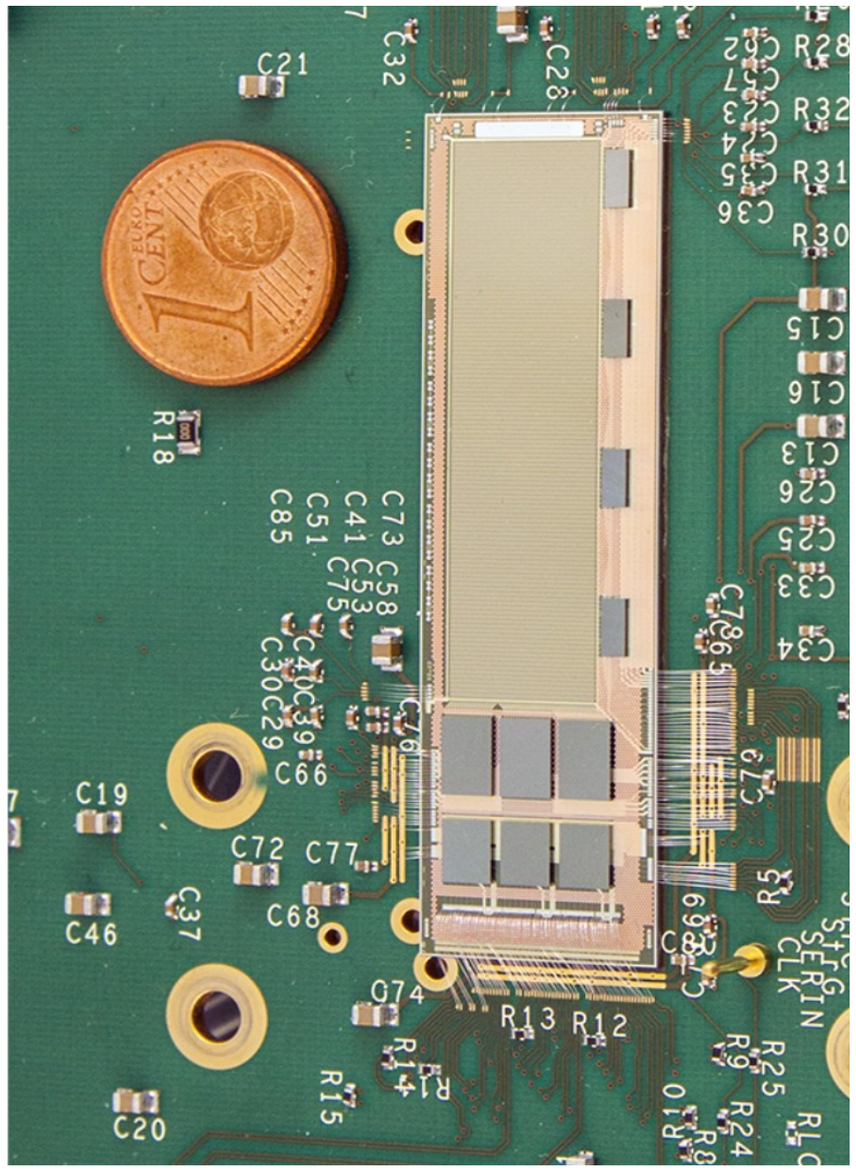
low-pressure, mono-phase cooling

intended for room temperature operation

(e+e- machines)

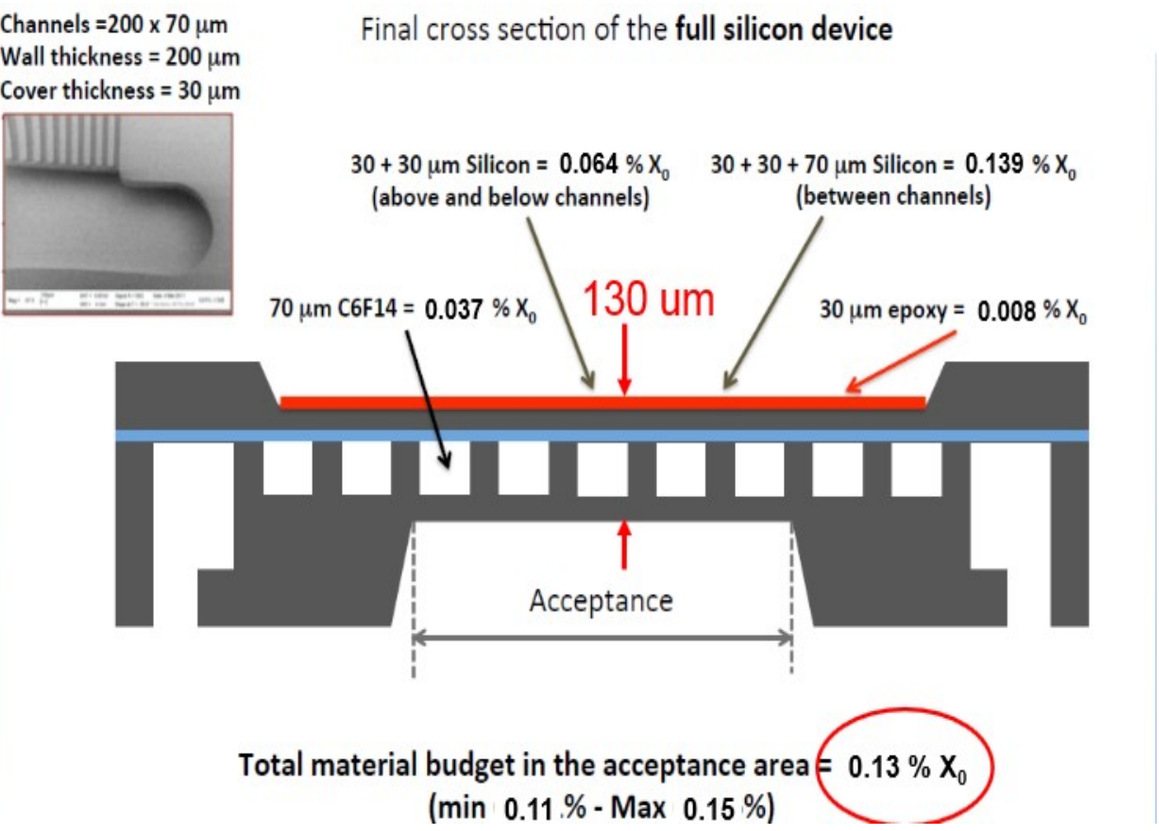
relatively large (300x300 μm^2) channels

in-plane connectors

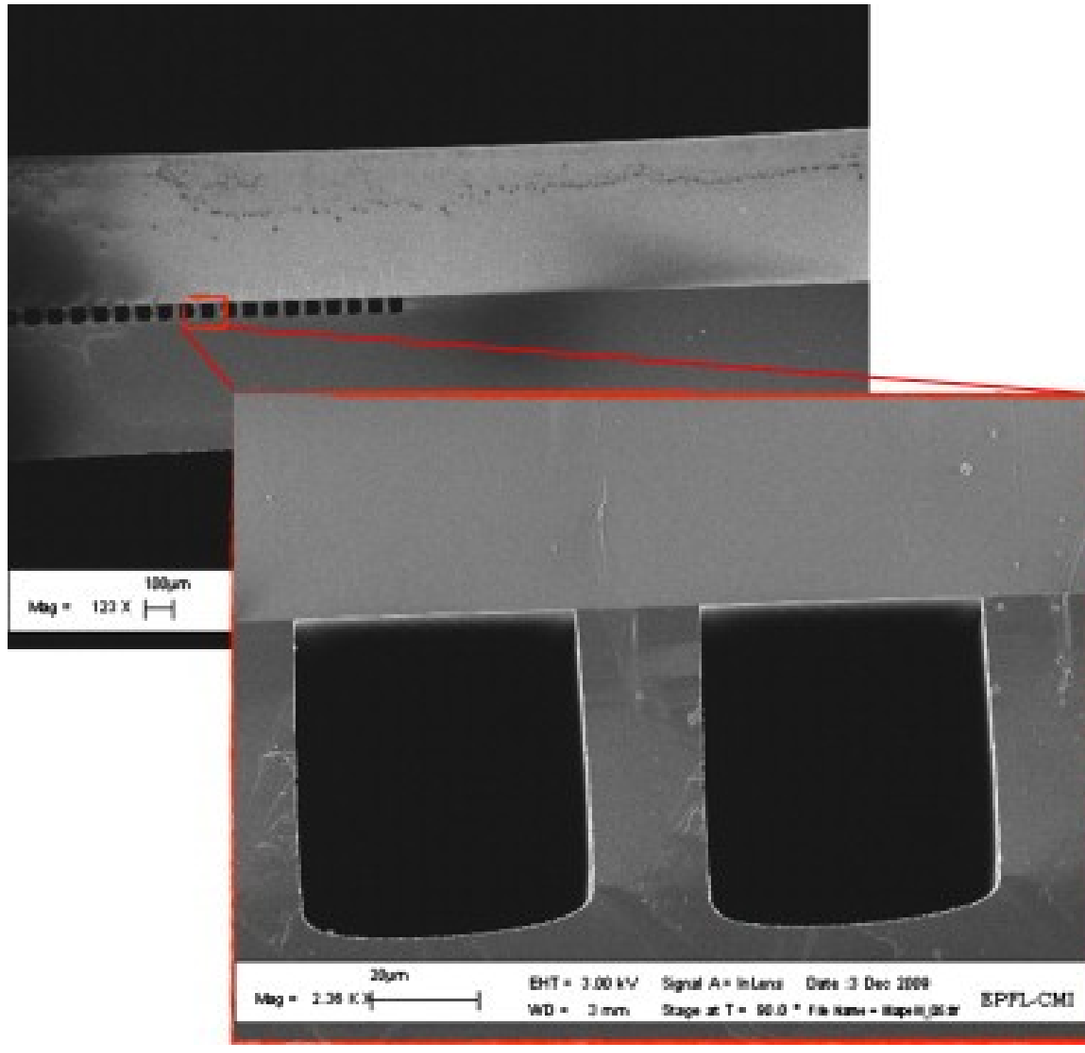


Introduction

Current MCC R&D in HEP:
LHCb, NA62 GTK*, SuperB/CMS



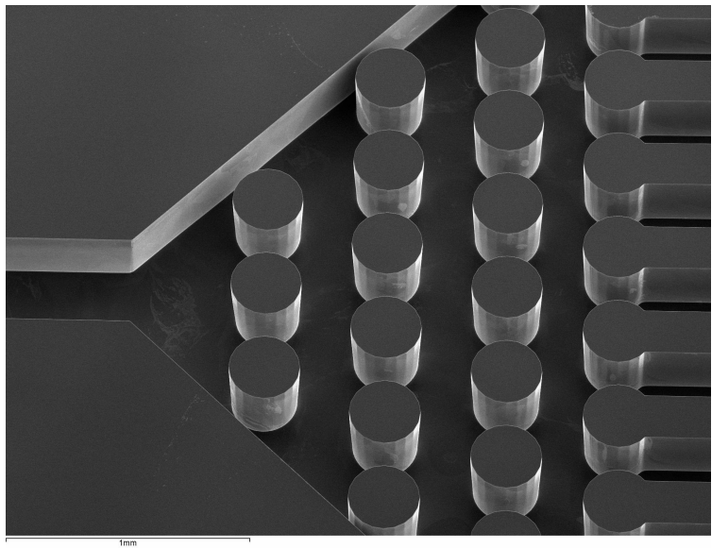
NA62 Single phase coolant C6F14 T<-20ºC



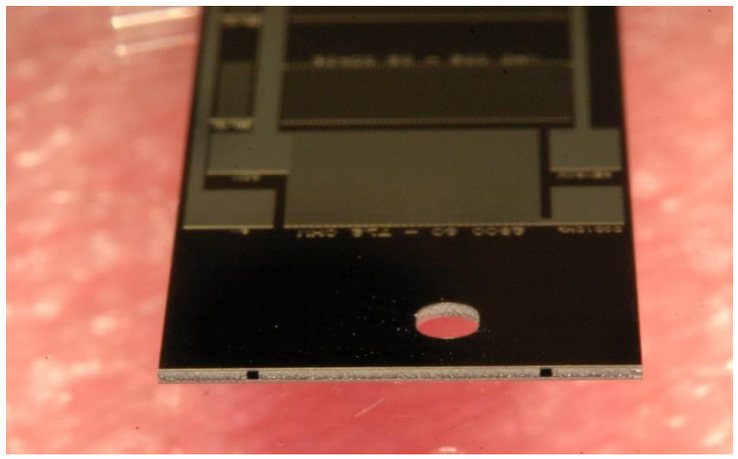
LHCb, silicon + pyrex cooling plate, bi-phase CO2

NA62 GigaTracKer Cooling with Silicon Micro Channels, DOI: 10.1142/9789814603164_0081
Micro channel evaporative CO2 cooling for the upgrade of the LHCb vertex detector Nucl.Instrum.Meth. A731 (2013) 189-193
Light prototype support using micro-channel technology as high efficiency system for silicon pixel detector cooling, Nucl.Instrum.Meth. A650 (2011) 213-217

Micro-channel cooling



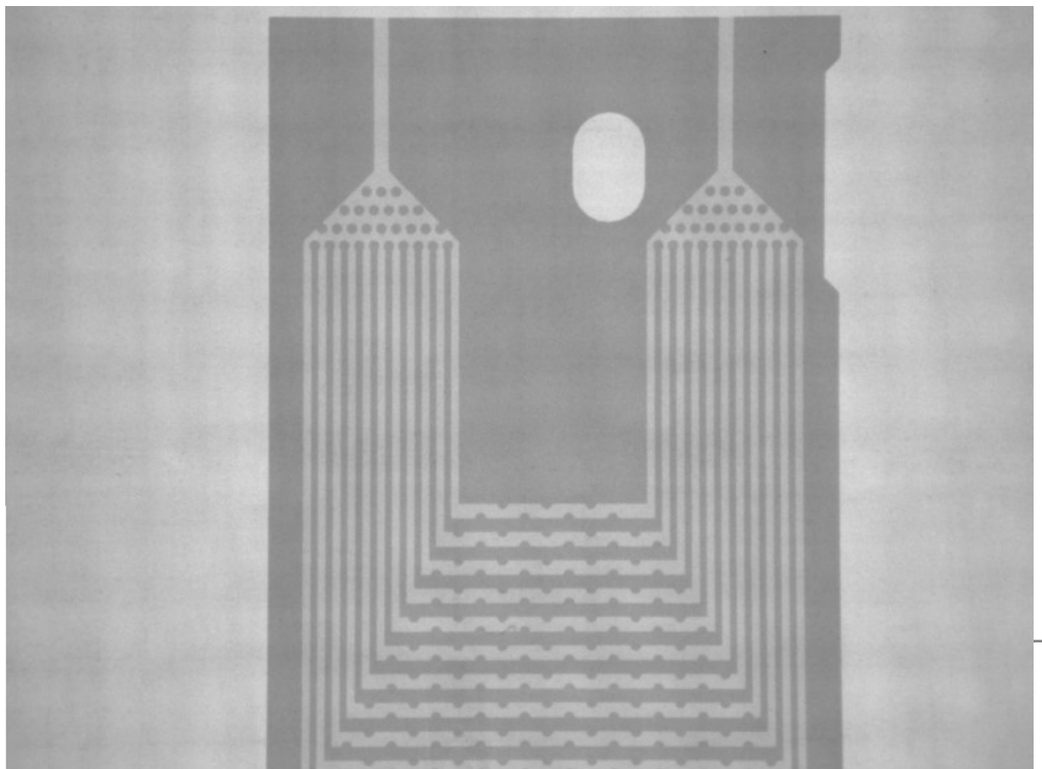
Micro-channel etched in handle wafer, sealed with sensor wafer

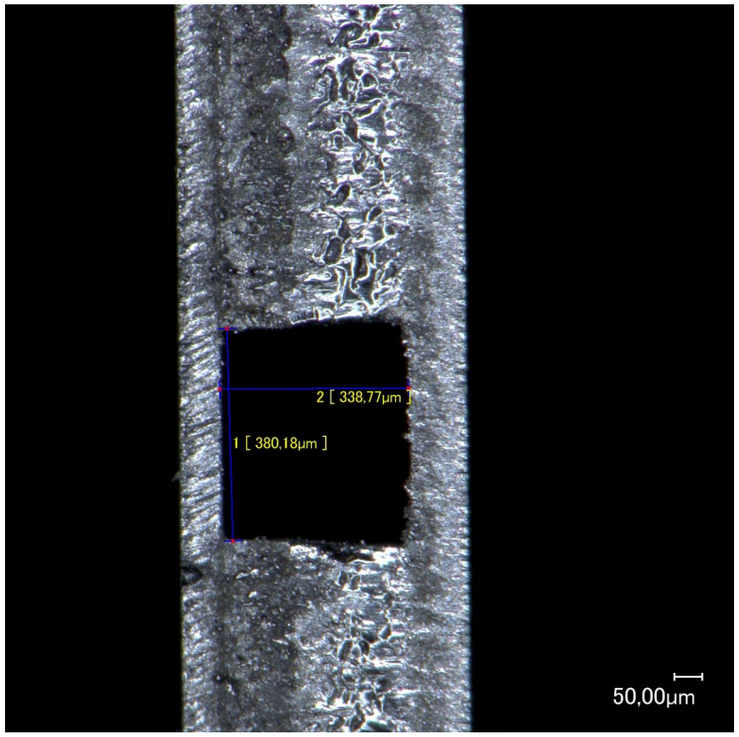


Detail of manifold before wafer bonding

Integrate in DEPFET all-silicon ladder concept; micro-manifold etched in handle wafer, sealed when active wafer is bonded on top

Inlet and outlet (340 x 380 μm^2) accessible in-plane

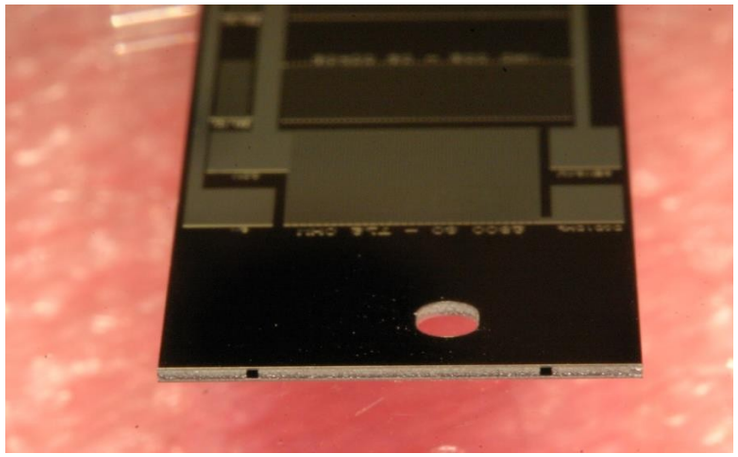




Several samples produced at HLL
Heater circuits in Al metal layer to mimic heat loads

X-ray image of end-of-ladder with integrated micro-manifold

Test setup



Thermometer

Fluid storage

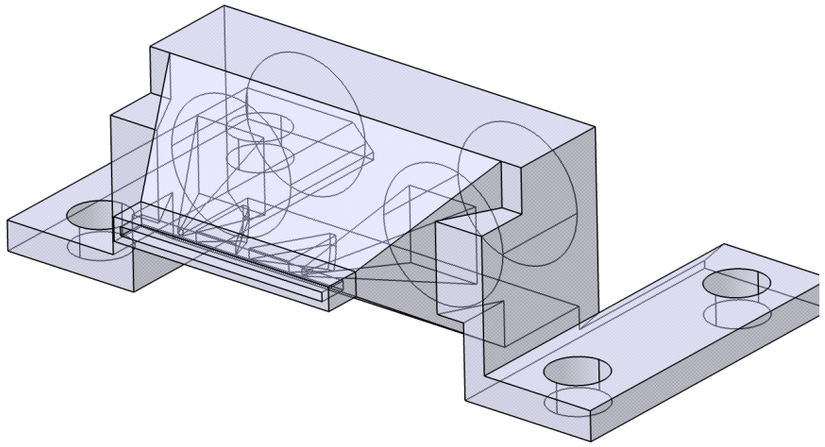
Digital pump

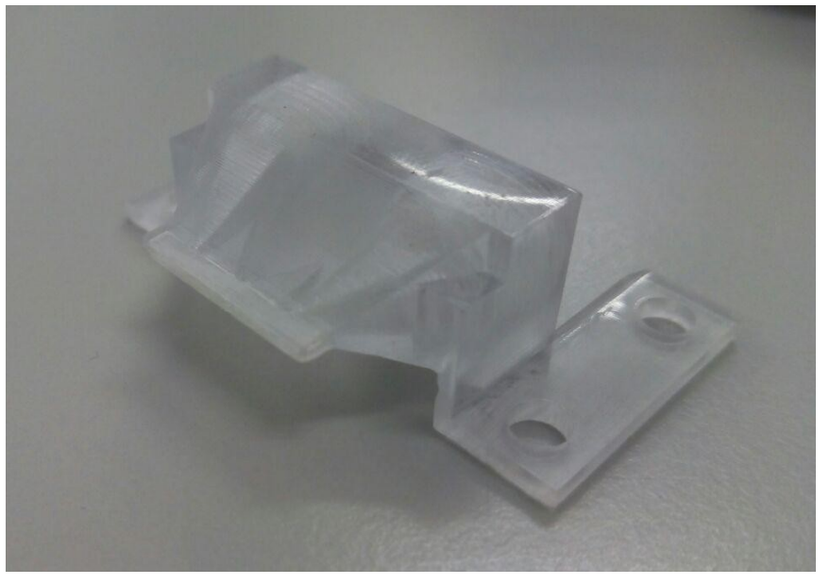
High purity filter

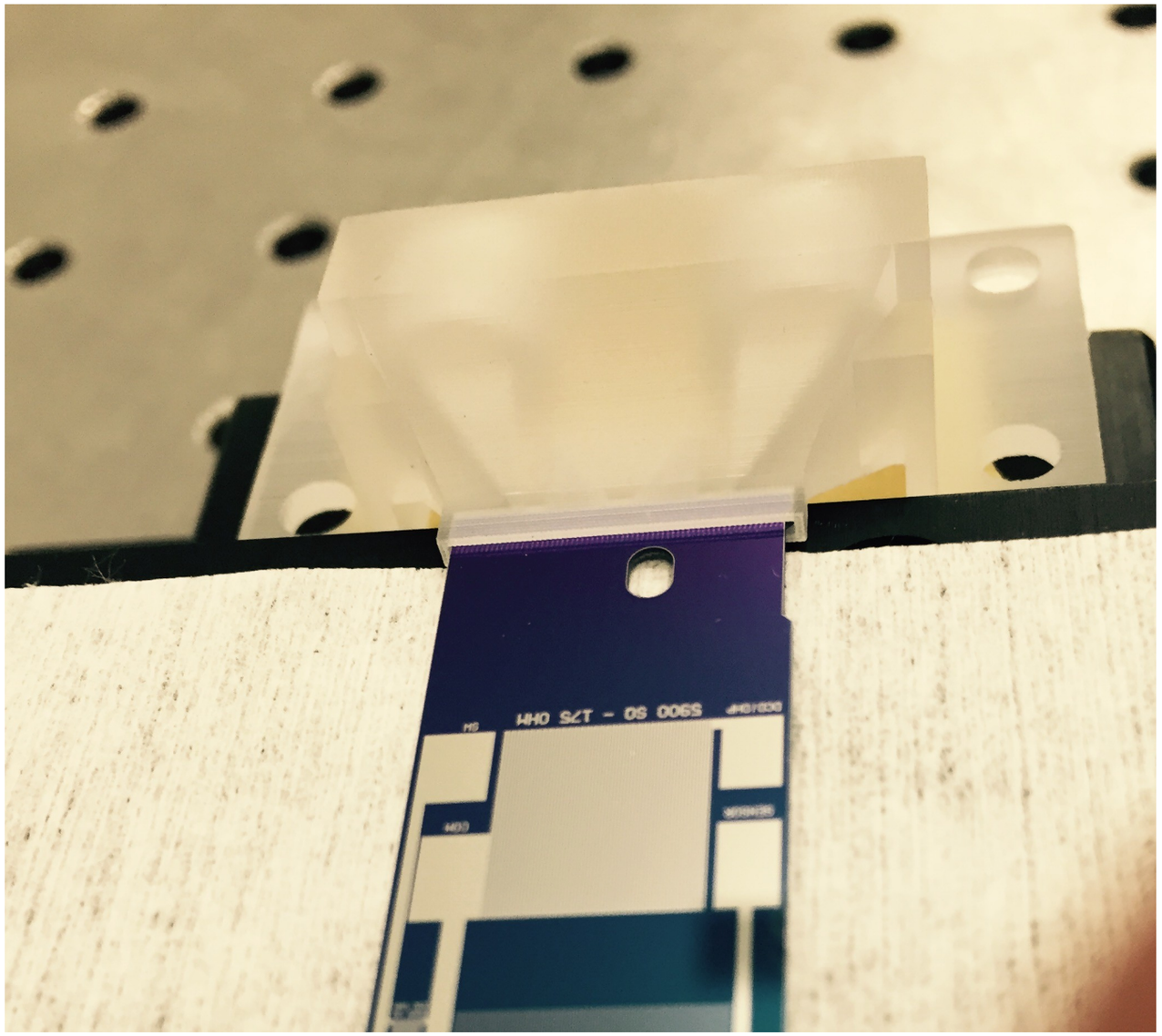
Flow meter

Thermometer

Connectors



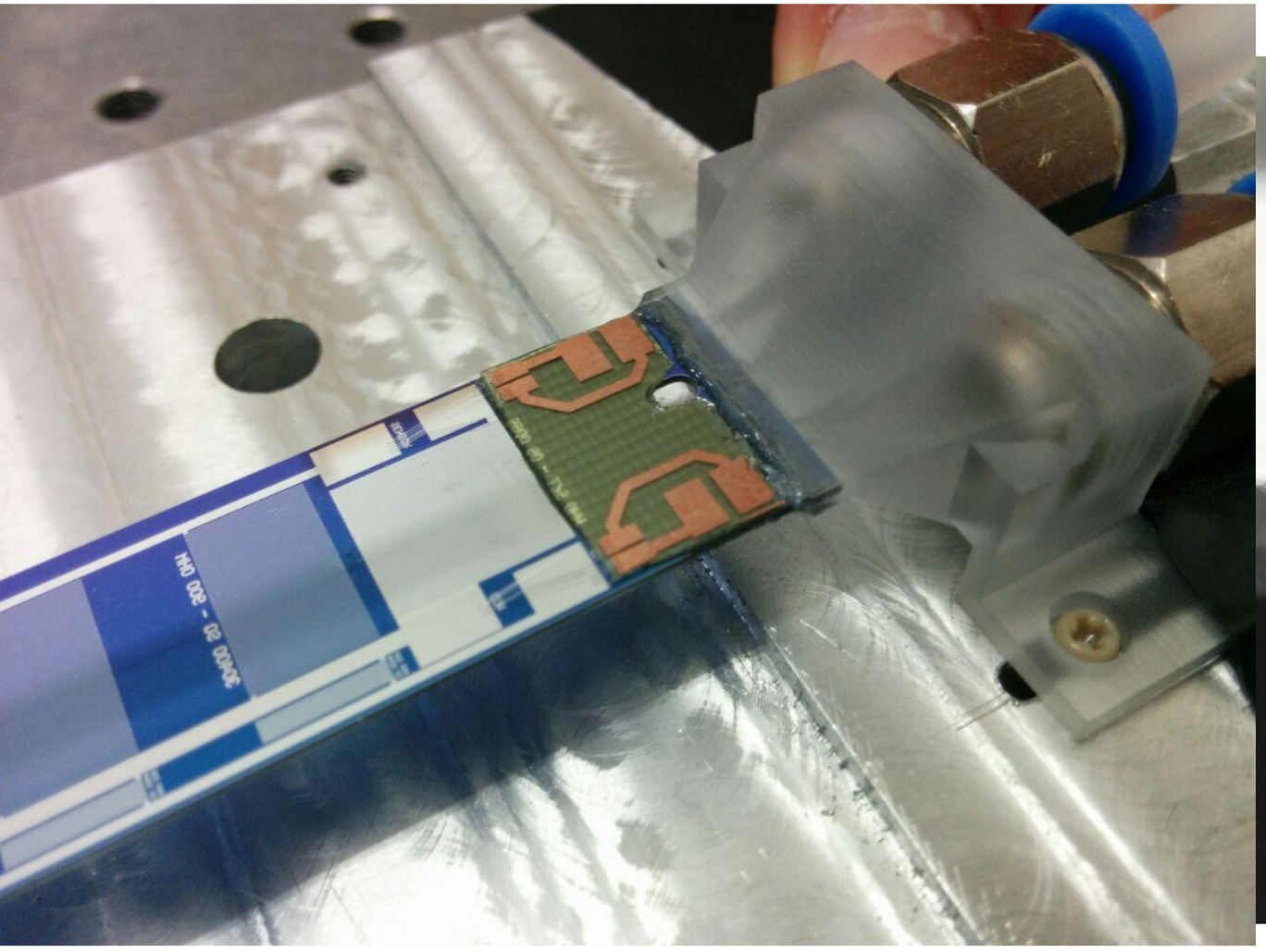


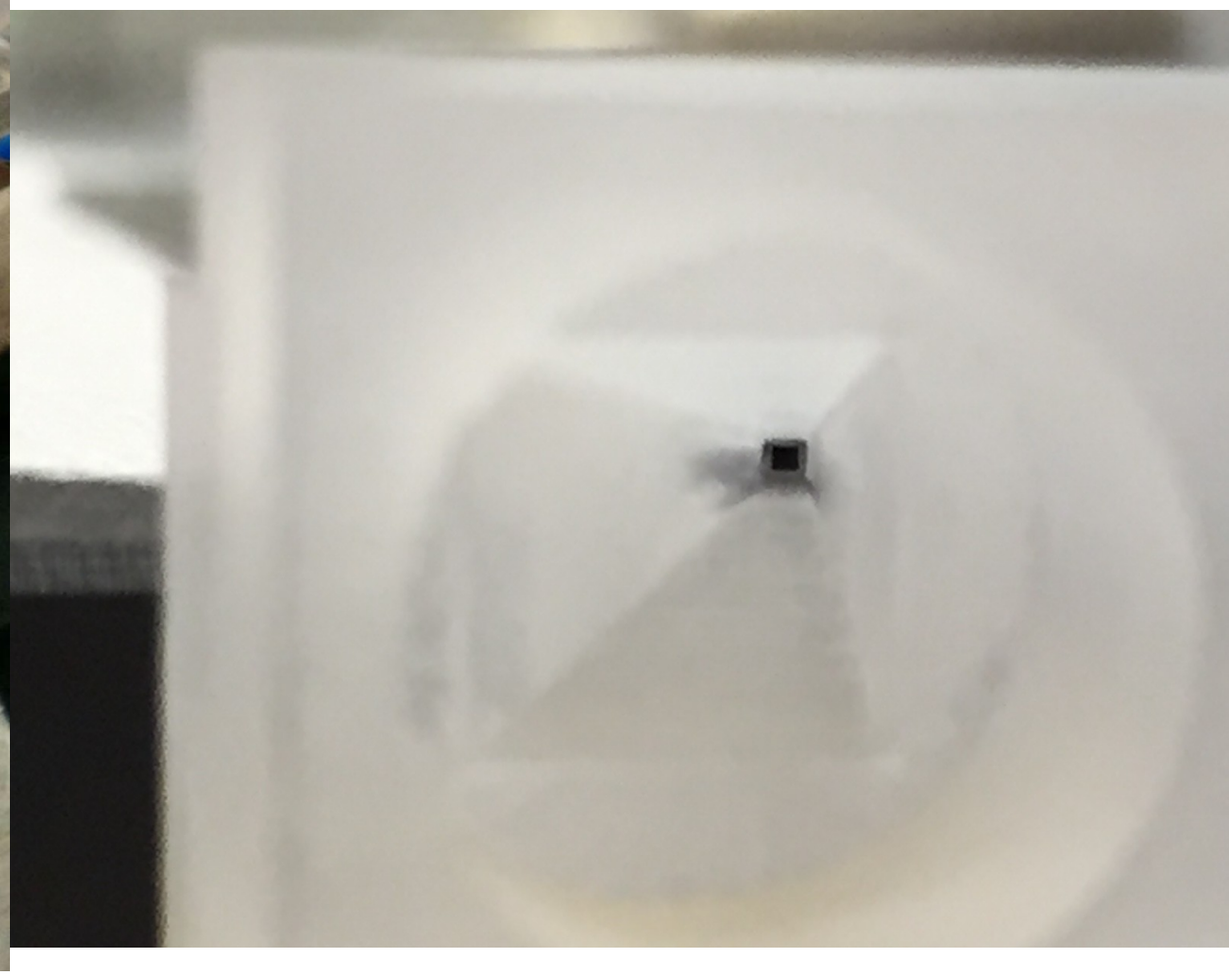


- Stereolithography technology:
  - 15µm precision
  - 300 µm per layer

– Low pressure → standard plastic

Test setup

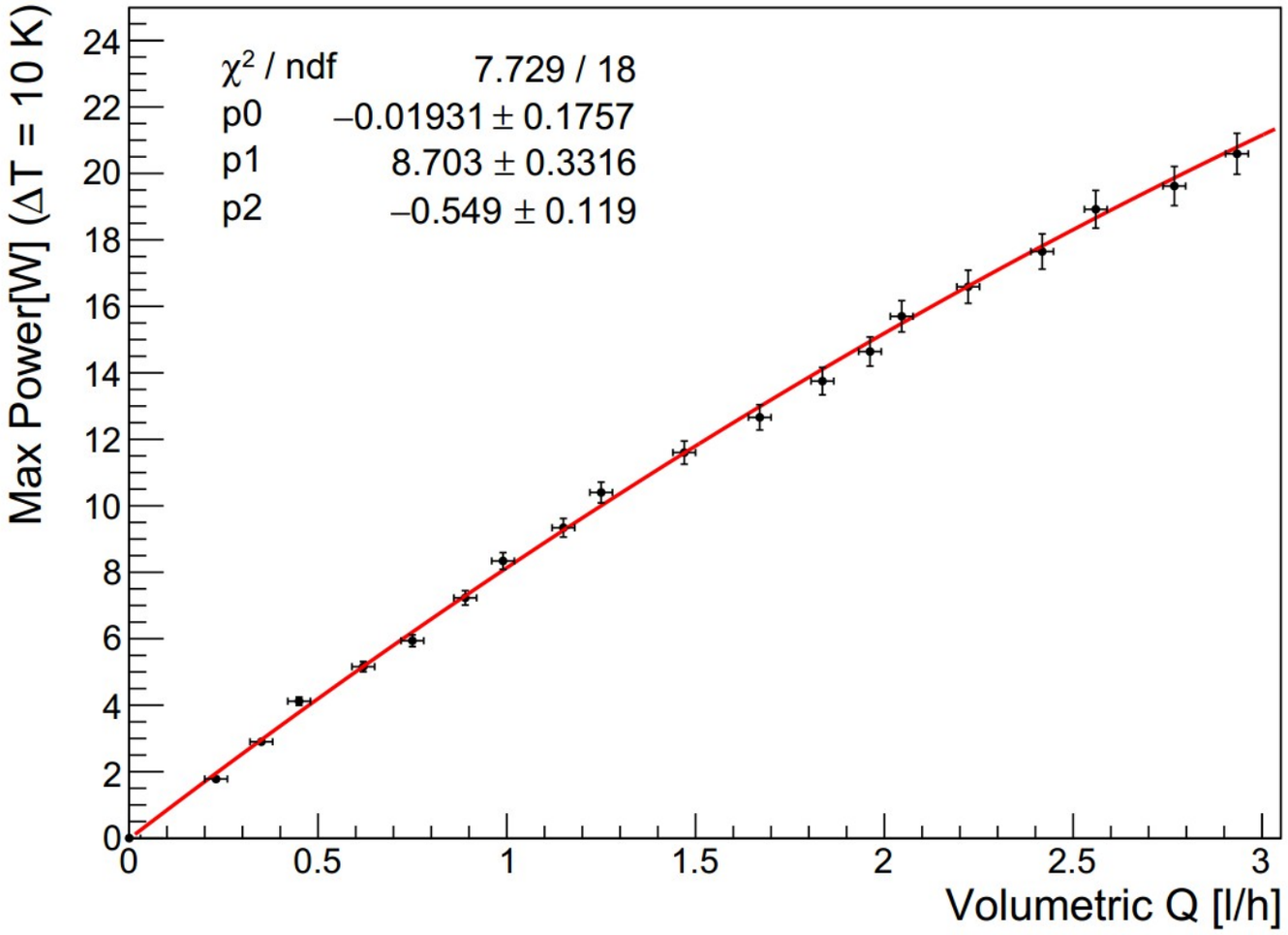




- Self-aligning, sealed with glue
- Success rate so far: 3/3
- Operated non-stop weeks; no leaks, no clogging

Test results: MCC for ΔT=10K

Maximum allowed power for 10 degree temperature increase



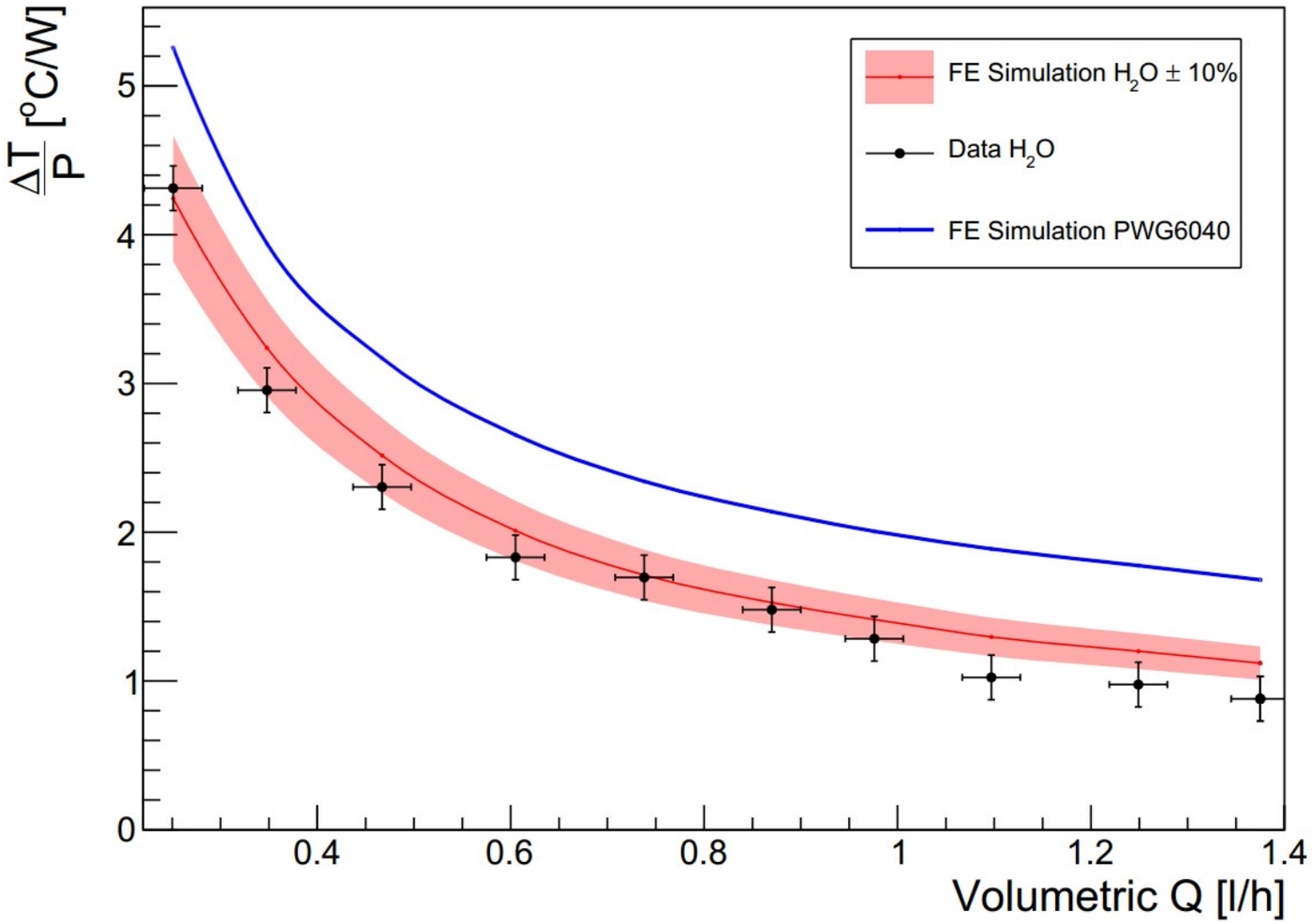
- T stability even with 22W

- ΔT/P vs liquid flow at max. pump power: limit not in sight

- Low pressure drop: about 1,5 bar

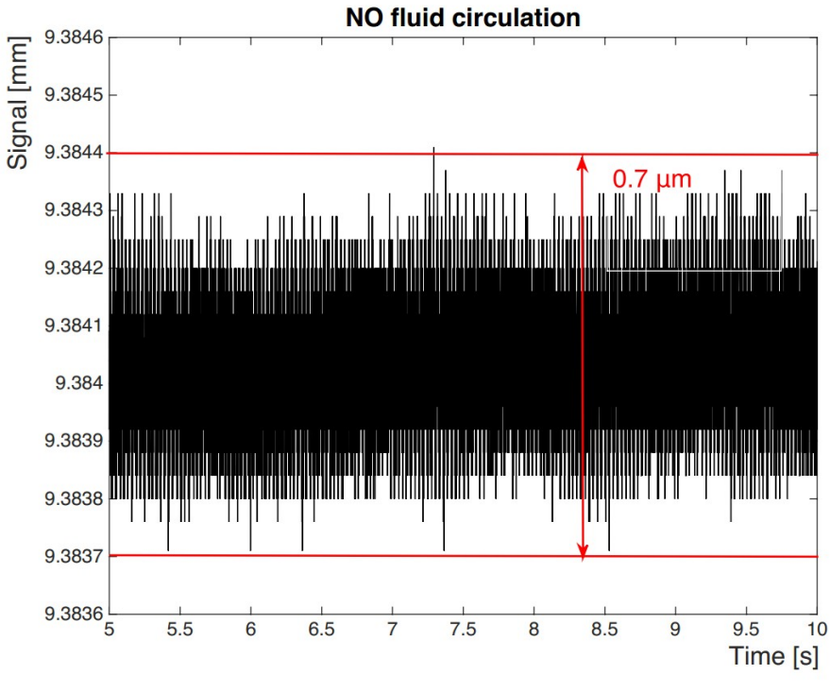
FE simulation vs. data

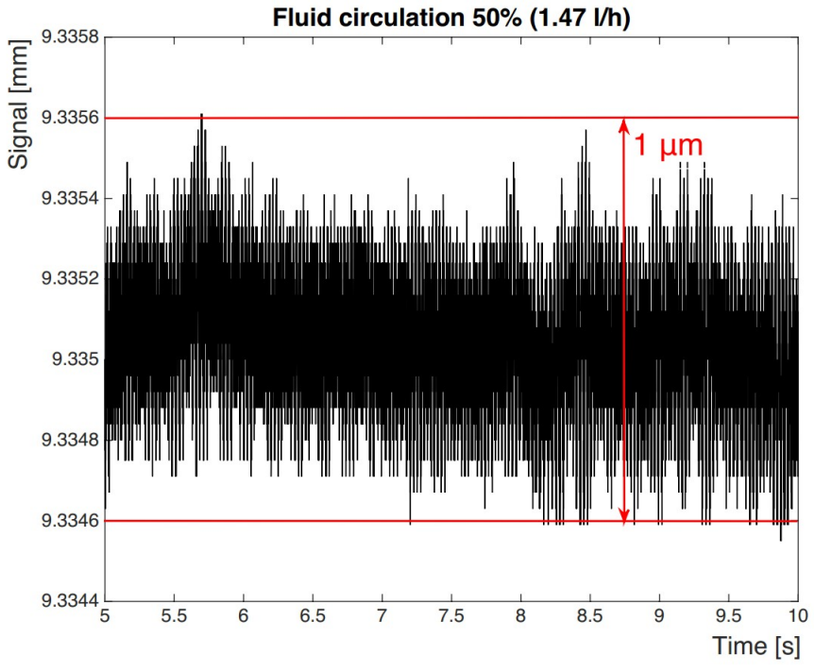
Good agreement with FE simulation

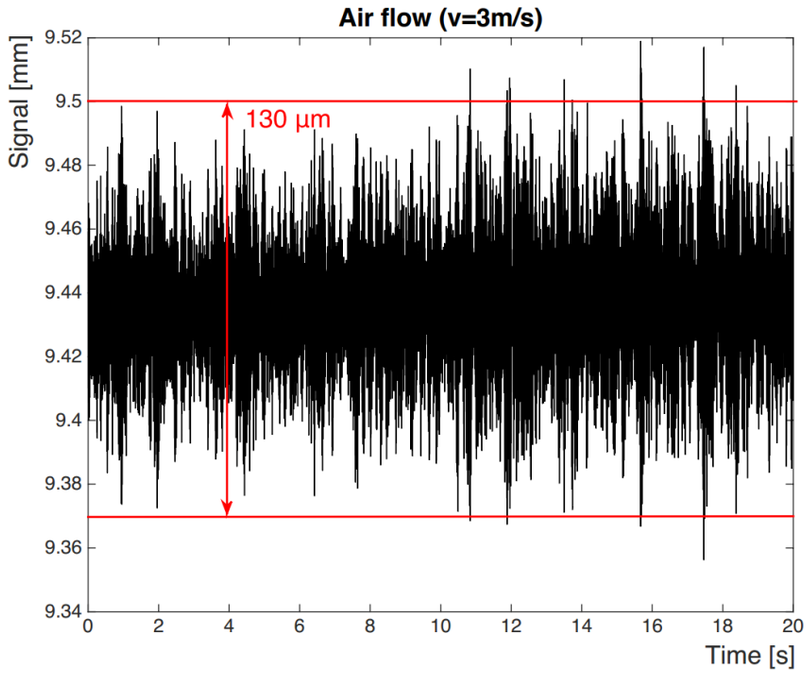


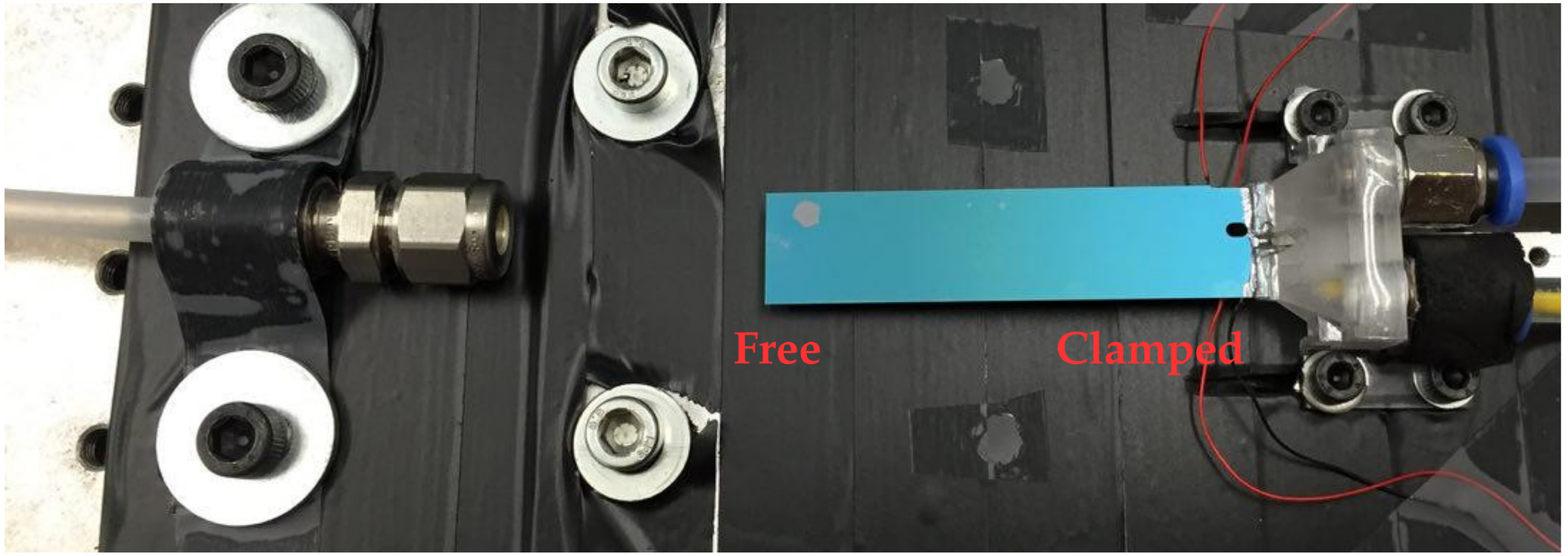
Explore alternative cooling liquids, manifold geometries, etc. in simulation

Test results: deformation

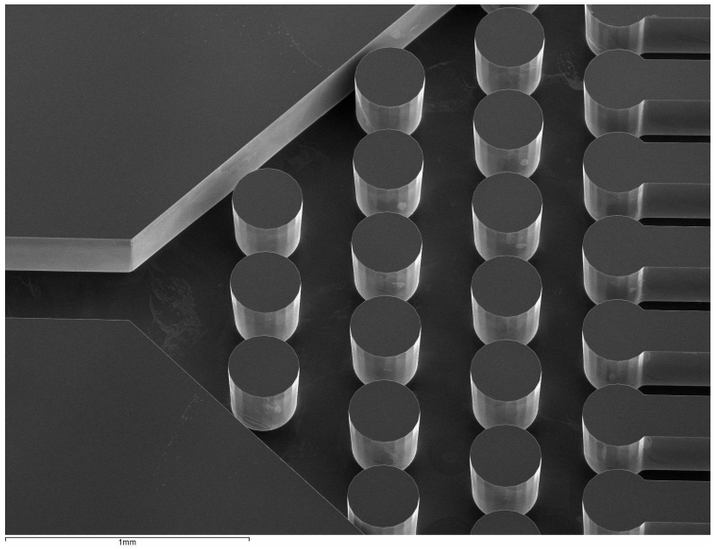
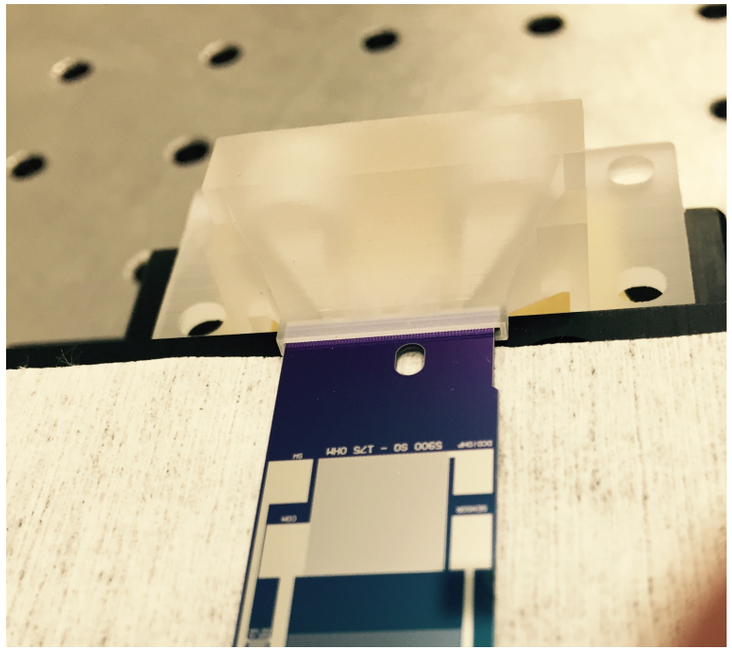
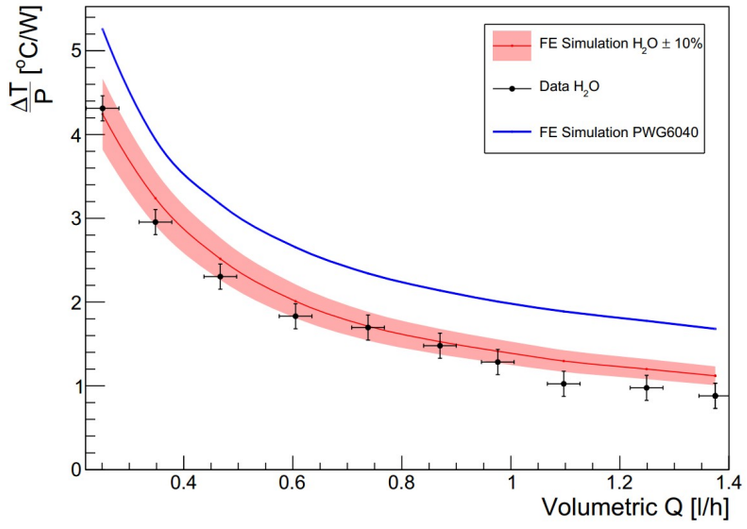








- MCC has no significant impact on mechanical stability

Contribution to AIDA deliverables

- Can provide standard samples
- Can help develop standard in-plane connectors
- Can develop/validate FE simulation