Advanced European Infrastructures for Detectors at Accelerators

WP9 (NA8) New support structures and micro-channel cooling: STATUS

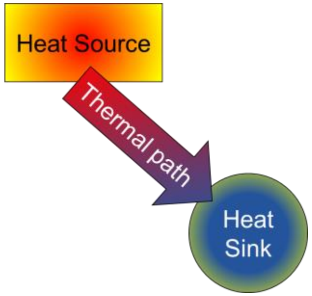
2nd Annual Meeting, Paris, Apr 7th 2017

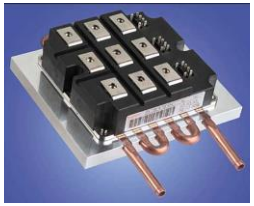
Paolo Petagna (CERN) on behalf of WP9 Network

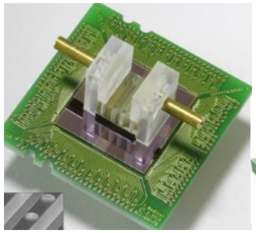
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168.

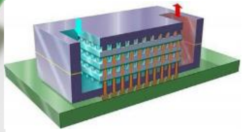
WHY WP9?
Electronics thermal management

High power microelectronics

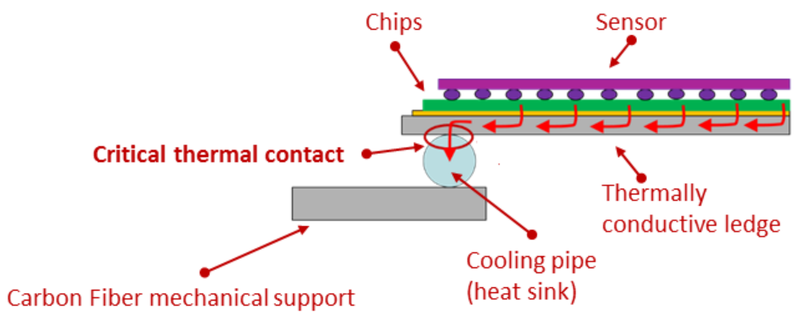




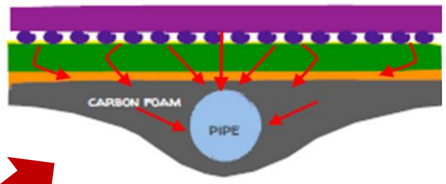




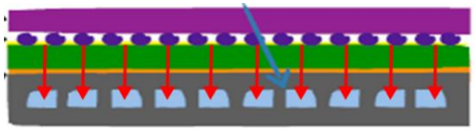
1st generation LHC Pixel detectors



Trends for next generation Pixel detectors



Main focus: X/X_0

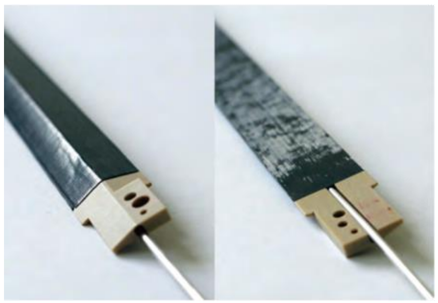


Main focus: TFM(*)
Δ CTE

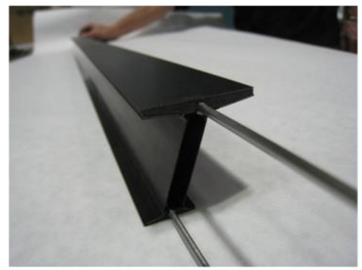
(*) TFM = $\Delta T_{sensor\text{-}fluid}$ / Power Density
useful parameter to compare cumulative thermal resistances of configurations

WHY WP9?
Trends

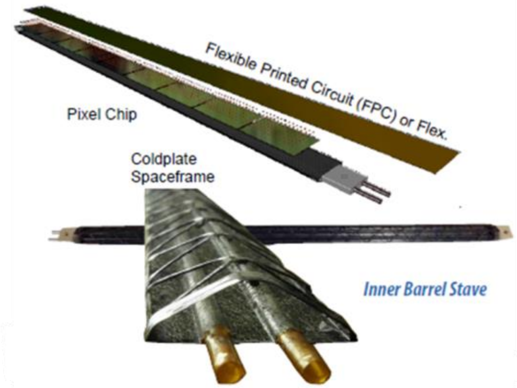
- Great attention to early design and integration of optimized support structures and thermal management solutions is mandatory for the present and the coming generation of Vertex detectors: **not surprisingly all “classes of approach” are represented!**



ATLAS IBL

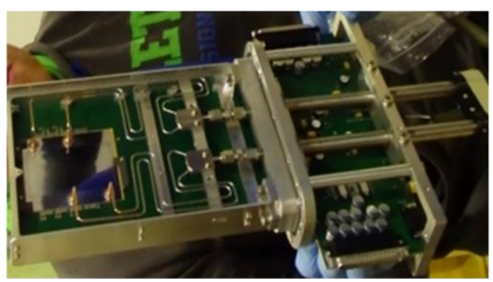


ATLAS PIXEL upgrade (study)

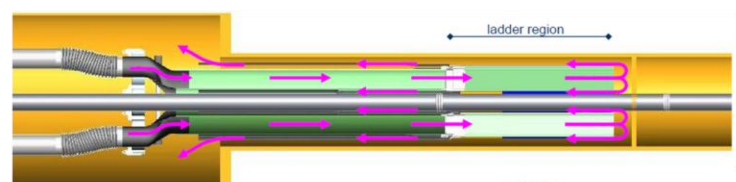


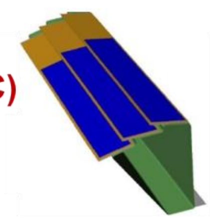
ALICE ITS upgrade

CMS PIX upgrade



NA62 GTK





STAR PXL (@ BNL RHIC)

WHY WP9? Objectives

From AIDA-2020 website:

- Improve the **integration of ultra-light support structures and cooling devices** in the design of future detectors
- Develop the missing **building blocks** for a generalized implementation of **micro-channel cooling devices**
- Provide **common standards for the fabrication and testing** of micro-channel cooling devices

→ **T9.2: R&D targeting new technologies**

- Develop a **facility for low-mass support structure testing**, with adequate standards for characterization and validation
- Provide and validate **test structures and libraries for FEA simulations**

→ **T9.3: Setup of a distributed facility for future access**

WP9 Beneficiaries (and friends...)

- **CERN**
  INFN-Milano (INFN beneficiary in WP 4, 6, 7, 13, 14, 15)
  UNIMAN (beneficiary in WP 3, 7)
  University of Twente (external)
- **CNRS-LPNHE**
  FBK (beneficiary in WP 7)
  University of Goettingen (external)
  CNRS-LAL Orsay (CNRS beneficiary in WP 1, 2, 3, 4, 6, 8, 9, 13, 14)
  MPG-MPP Munich (MPG-MPP beneficiary in WP 4, 7, 13, 14)
  INFN-Pisa (INFN beneficiary in WP 4, 6, 7, 13, 14, 15)
  University of Padova (external)
- **CSIC-IFIC**
  MPG-HLL Munich (external, although MPG-MPP beneficiary in WP 4, 7, 13, 14)
  UBONN (beneficiary in WP 4, 6)
- **UOXF:**
  STFC-RAL (STFC beneficiary in WP 6)
  UNIBRIS (beneficiary in WP 5)
  UNILIV (beneficiary in WP 2, 6)

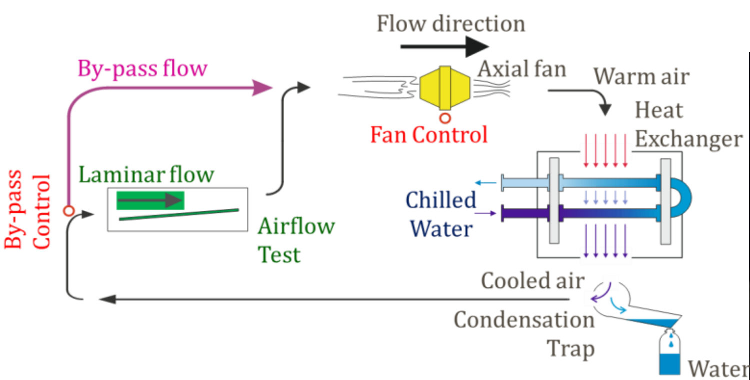
FROM AIDA-2020 KICK-OFF MEETING

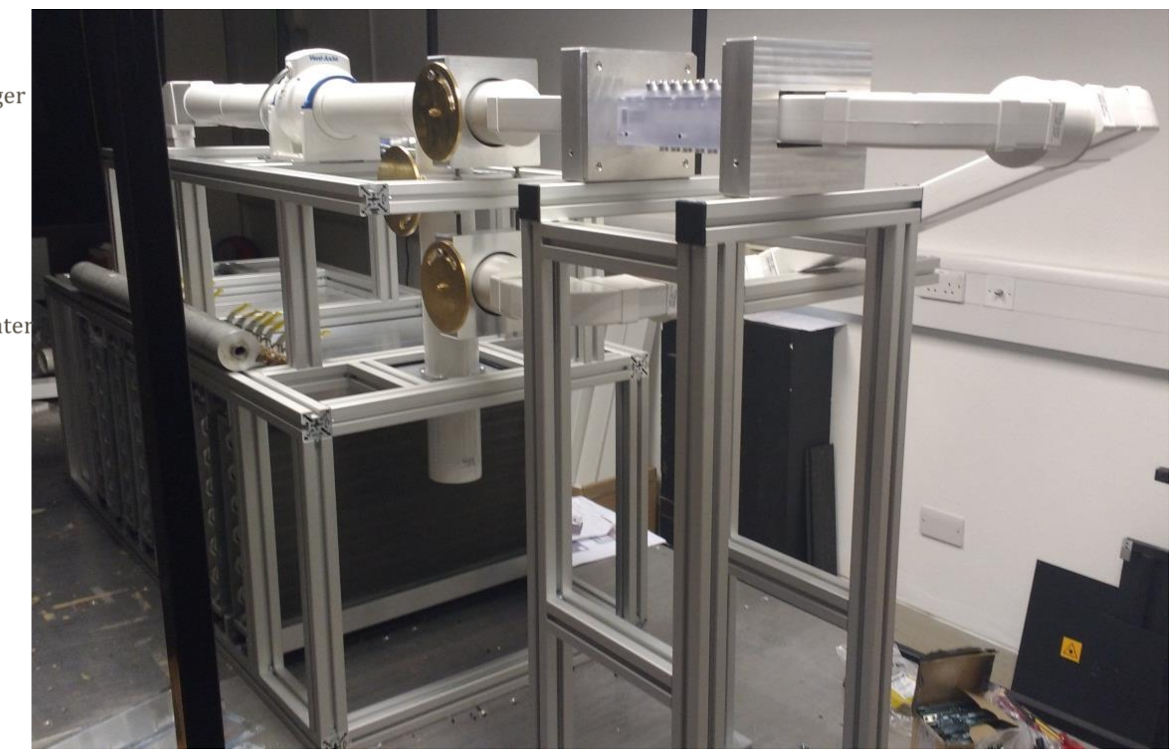
WP9 1st YEAR FOCUSES

- **First year activity: details in the talk by G. Calderini at the Plenary Session of the 1st Annual Meeting**
  https://indico.cern.ch/event/468478/contributions/2171478/
- Setting up a previously non existing community, losing some collaborators, gaining others…
- T9.2 Main focus on μ-channel prototype fabrication and fabrication procedure for both devices and connectors
- T9.2 Secondary focus on discussions between heat and mass transfer experts on existing models, setting-up basic simulation codes, defining needs to get to new reliable models
- T9.3 Focus on the definition of the specifications for a common testing facility in UK based on answers from potential “customers” to a questionnaire (+ hiring dedicated postdoc with the correct profile… not easy!)

T9.3 SECOND YEAR: Air flow cooling setup

Priority given to the facility getting higher consensus from questionnaire
Good progress with air cooling rig: fully assembled, commissioning to start in April



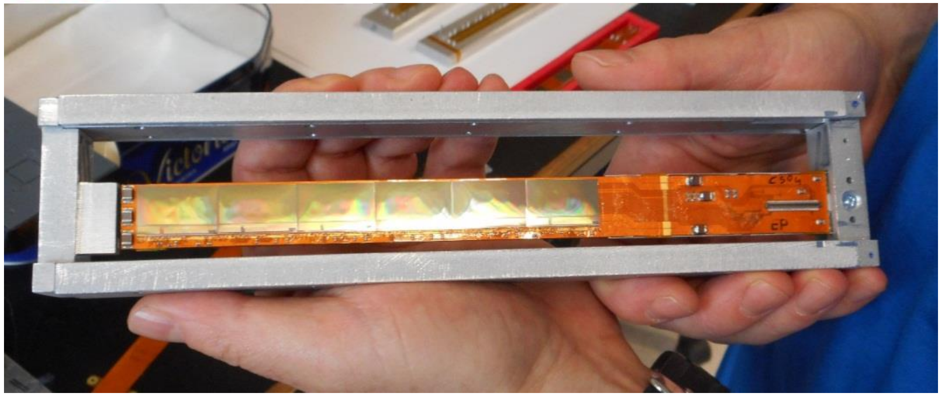


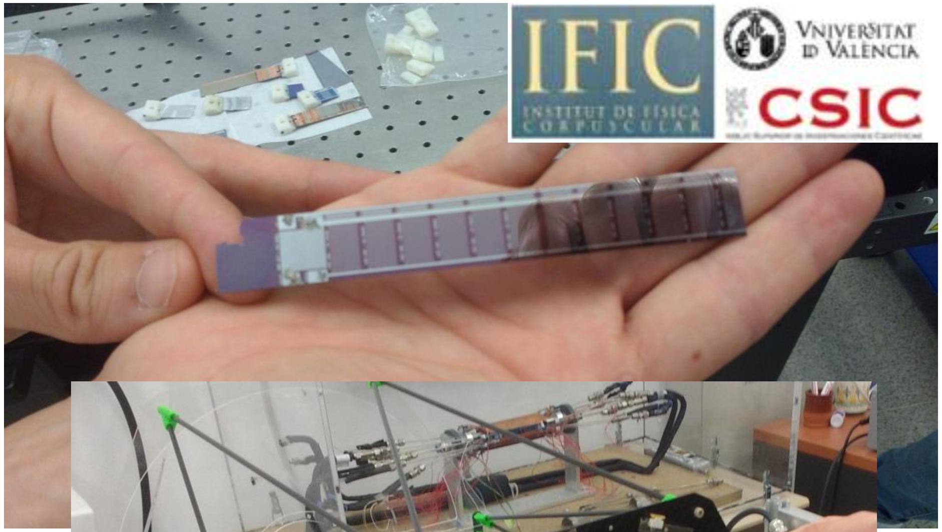
UNIVERSITY OF OXFORD

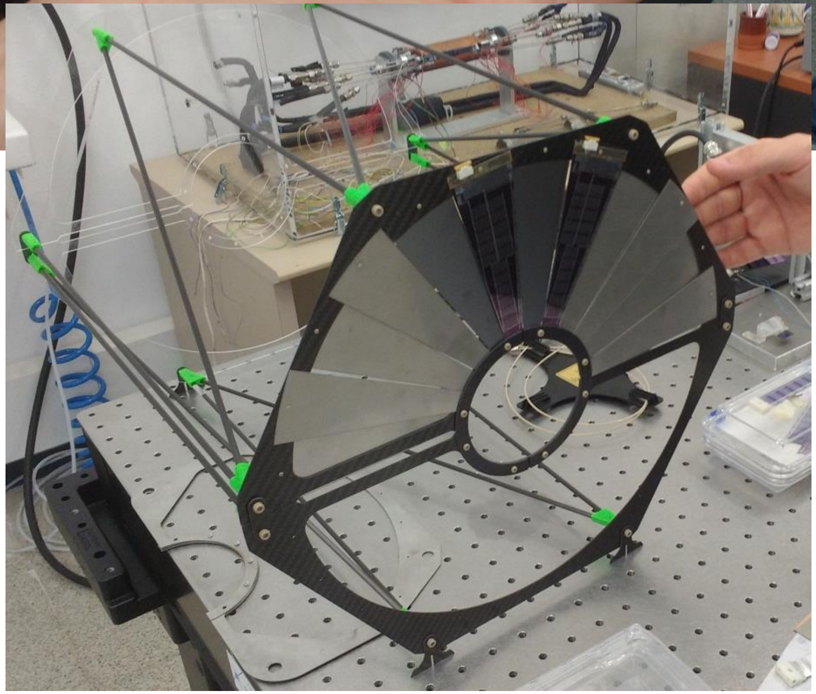
AIDA 2020

T9.3 SECOND YEAR: Common test structures

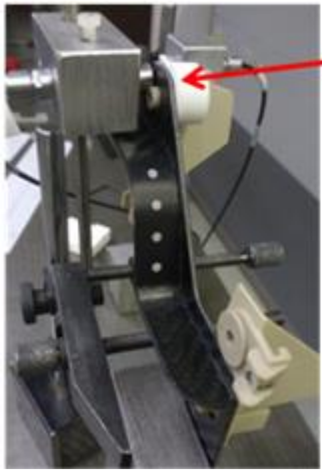
University of BRISTOL

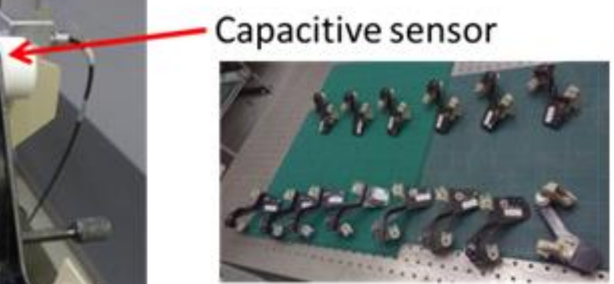






T9.3 SECOND YEAR
Additional instrumentation





Vibration shaker table and impact measurement instrumentation available to extract resonance frequencies of structures

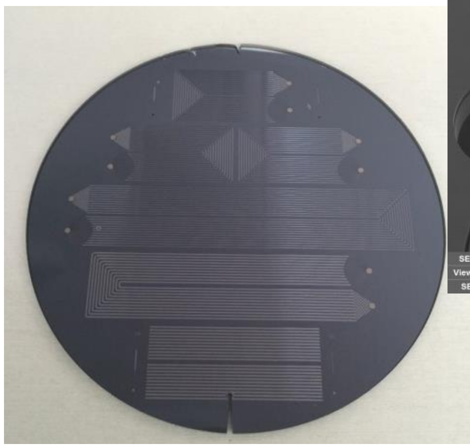
POSITIVE IMPACT OF AIDA-2020 FUND LEVERAGING

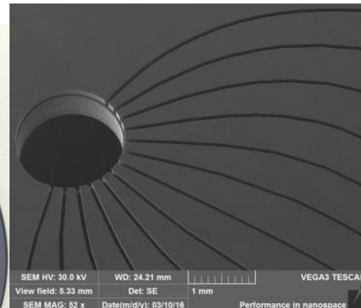
Additional funding from the University of Oxford has been secured to develop a 330 square metre instrumentation development and assembly area within the Department of Physics. This new refurbishment will house future activities within the framework of the Structure Characterisation Facility

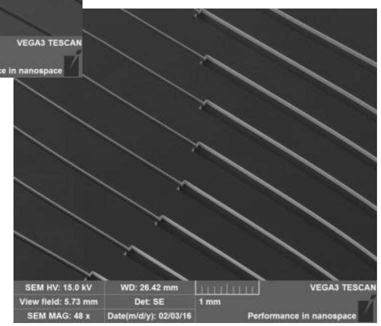
Confirmed funding from UK funding agencies (total 205k£) for:

- Medium sized (for up to 1.5m long objects) climate chamber
- 8-line Frequency Scanning Interferometer for precision distance measurements
- Large optical table

T9.2 SECOND YEAR
Fabrication process / Prototypes

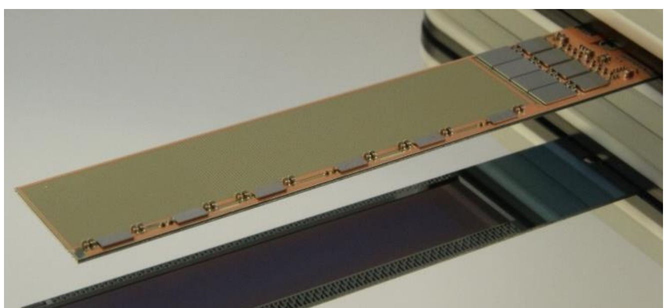


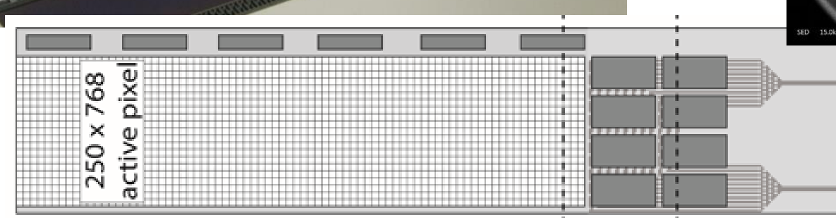


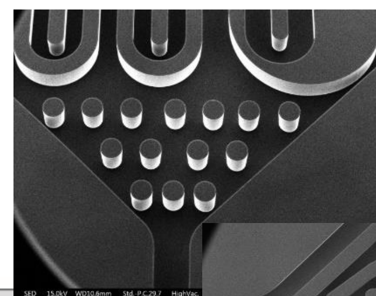


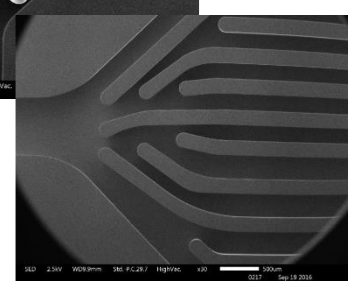
LPNHE Paris · Fondazione Bruno Kessler · CERN · Università degli Studi di Padova

Projects REFLECS and REFLECS2
Financed by CNRS through the call
"L'instrumentation aux limites"



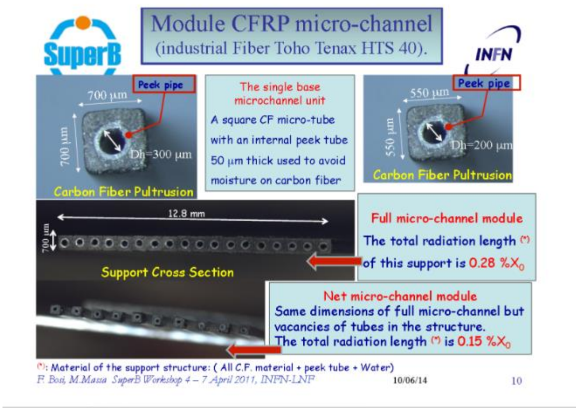


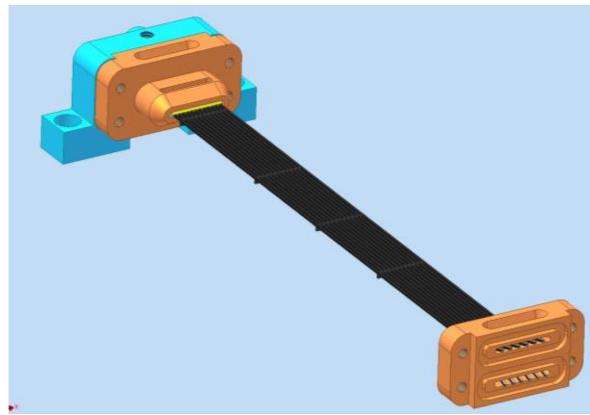




MPG HLL Halbleiterlabor der Max-Planck-Gesellschaft · universität bonn · IFIC Institut de Física Corpuscular · Vniversitat de València · CSIC

T9.2 SECOND YEAR
Alternative fabrication processes



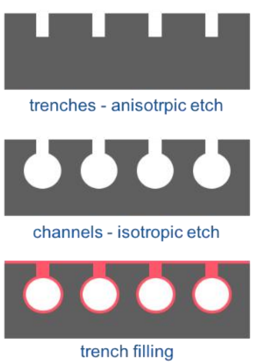


BURIED CHANNELS APPROACH

Silicon buried channels for pixel detector cooling

M. Boscardin [a,*], P. Conci [a], M. Crivellari [a], S. Ronchin [a], S. Bettarini [b,c], F. Bosi [c]

Nuclear Instruments and Methods in Physics Research A 718 (2013) 297–298



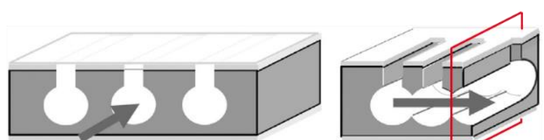
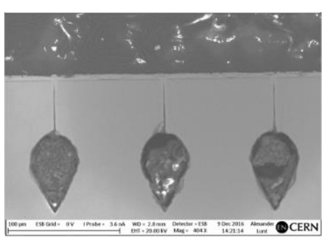
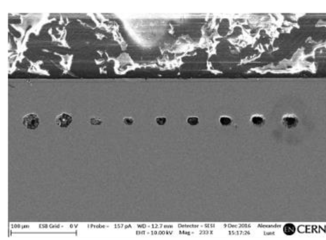
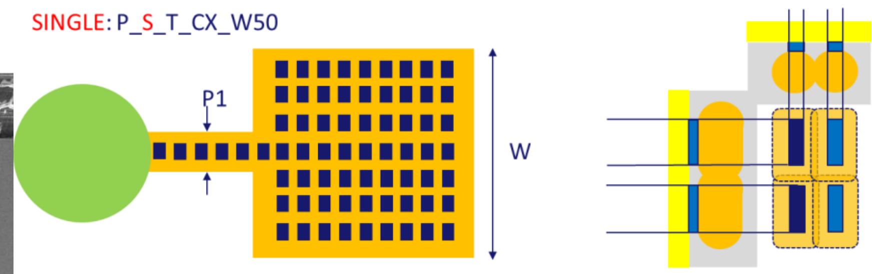


Fig. 1. Process sections for longitudinal and transverse channels.

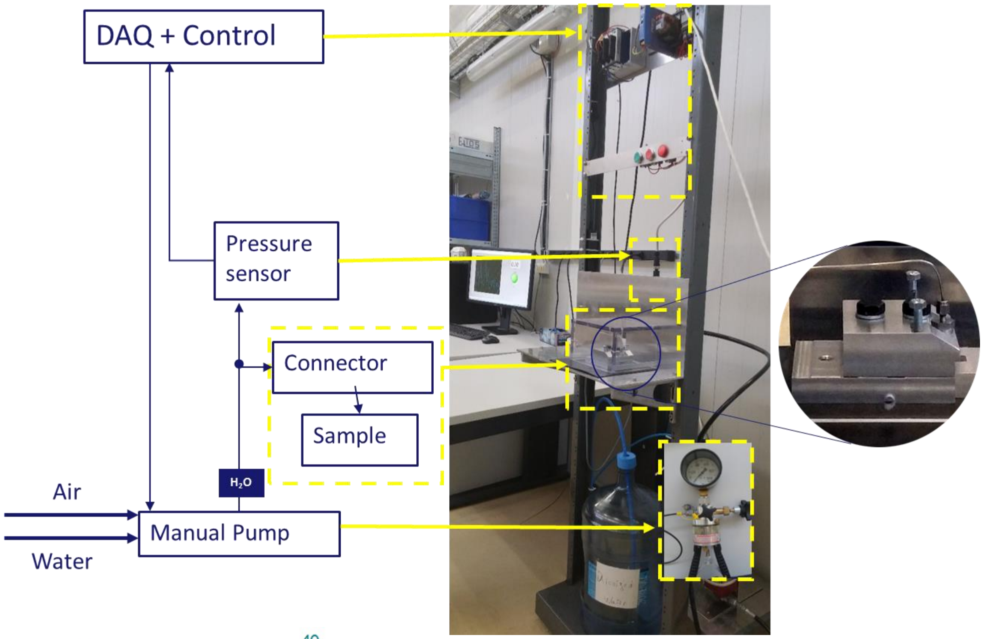


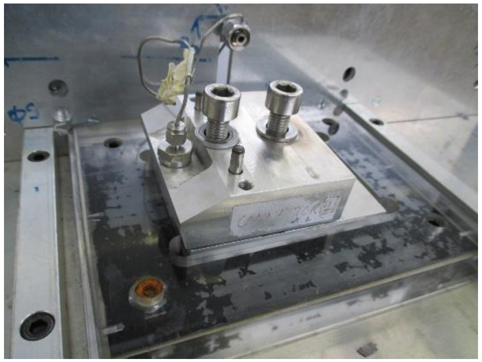




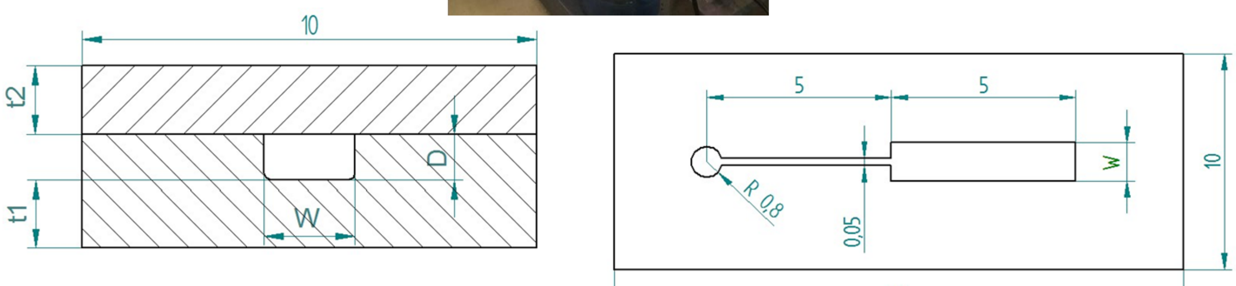
New standard for the characterization of limit pressure for silicon cannels

Test stand





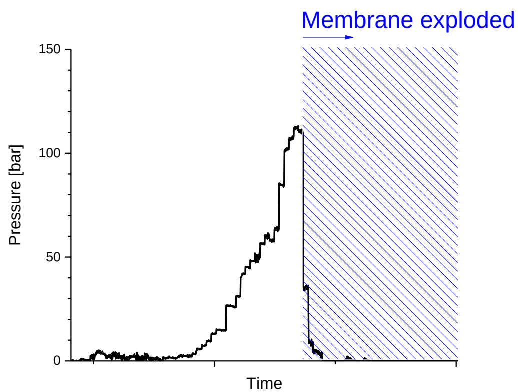
Sample holder

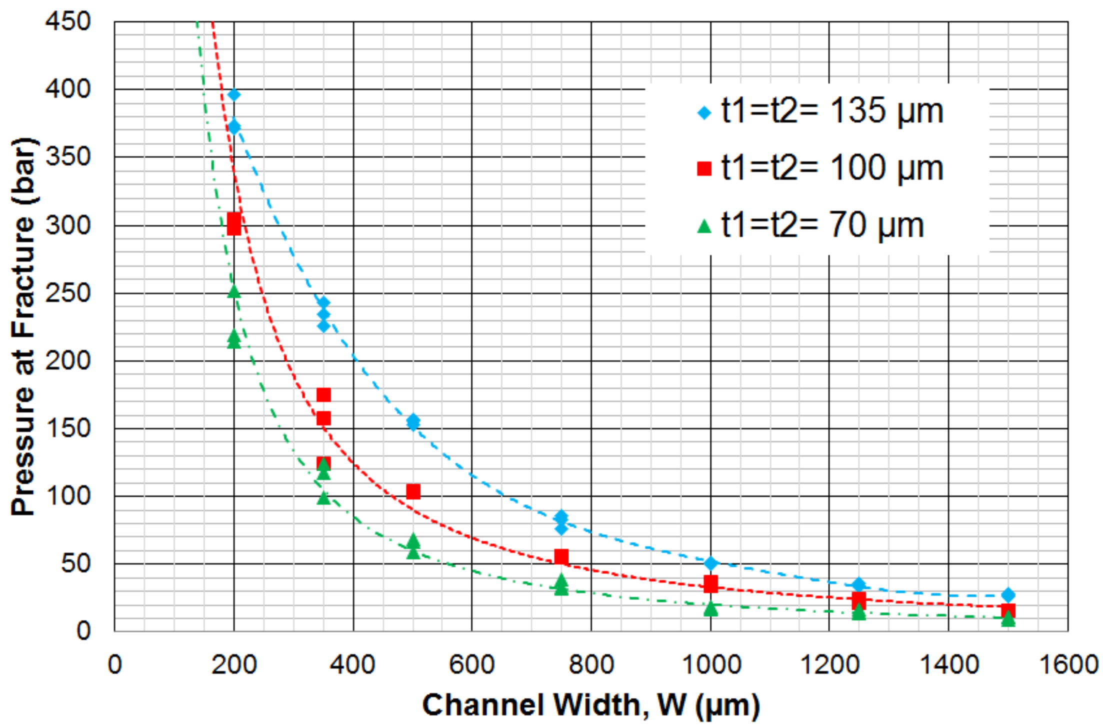


Standardized sample design

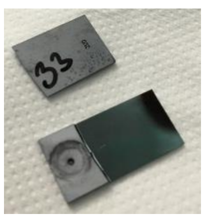
T9.2 SECOND YEAR
Silicon structural properties

First results from data analyses

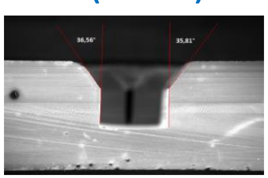




interfacial failure (not valid)

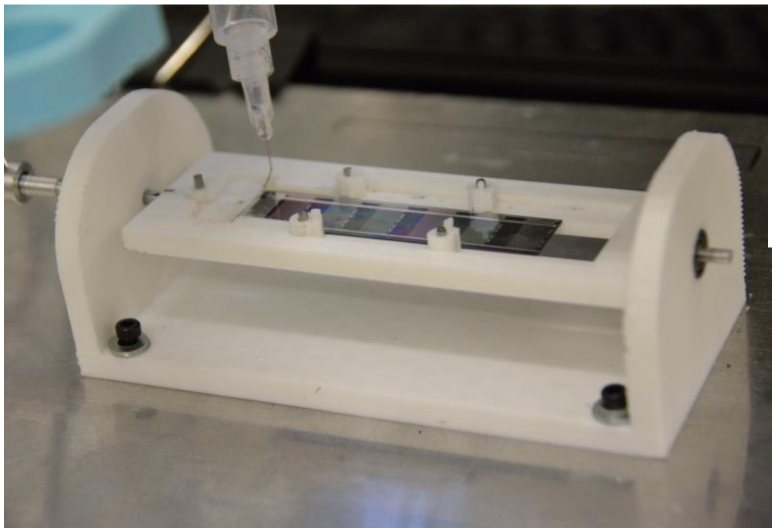


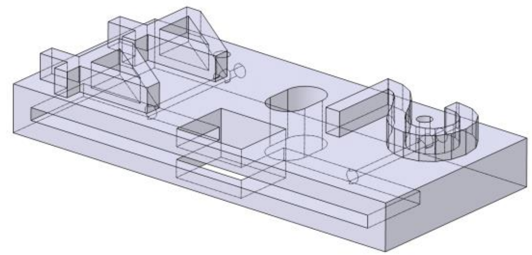
crystalline failure (valid)

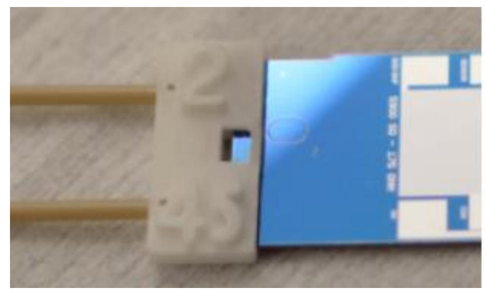


T9.2 SECOND YEAR
3D printed connectors

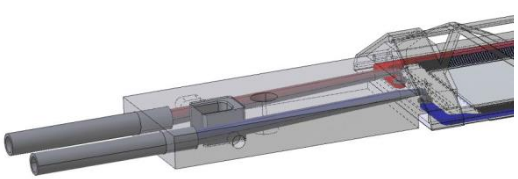
3D printed polymer and automated gluing

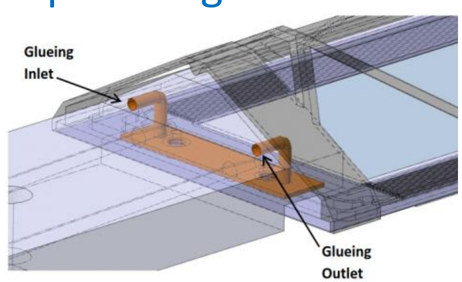


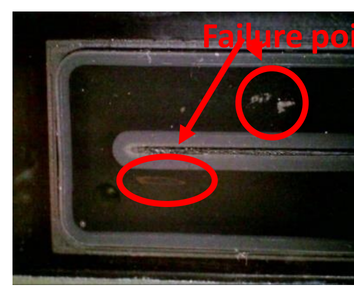




3D printed polymer with 3D printed gasket

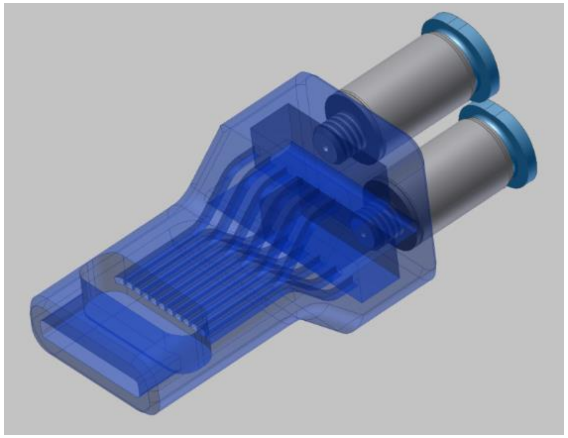






T9.2 SECOND YEAR
3D printed connectors (R&D)

3D printed PEEK with internal manifold



INFN Istituto Nazionale di Fisica Nucleare

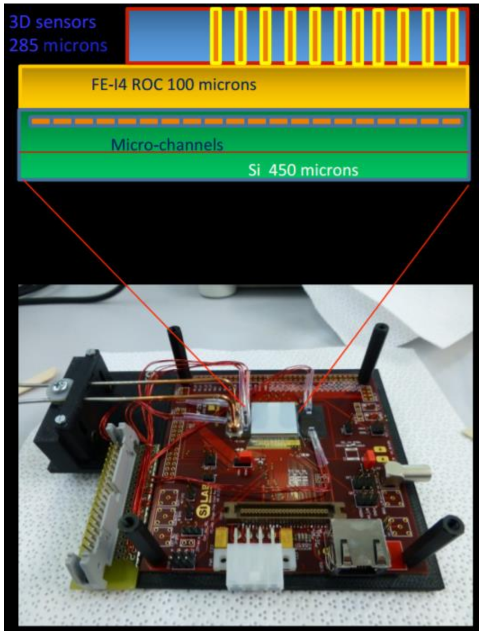
3D printed ceramics

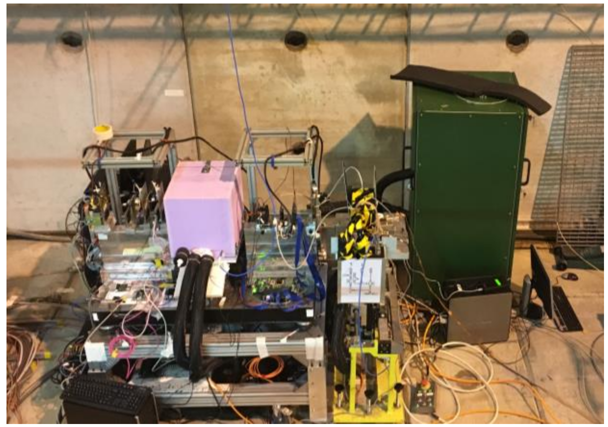
CERN

MANCHESTER 1824 The University of Manchester

LPNHE PARIS

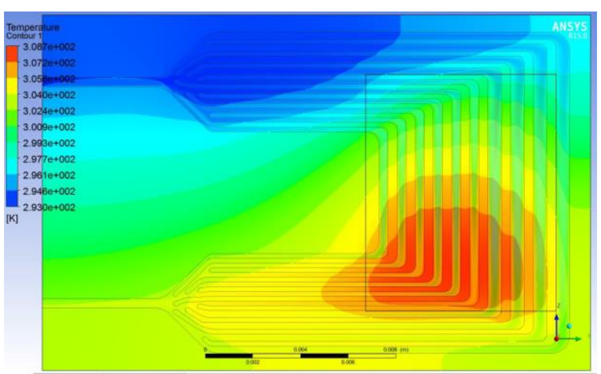
T9.2 SECOND YEAR
Operative tests with protos

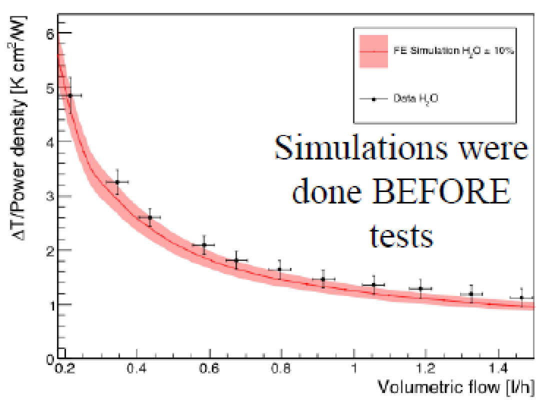




1st complete module (3d+FEI4) cooled by a CO_2 μ-channel device (T=-22 °C) in a test beam (TFM < 4 K·cm²/W)

WP7 – WP9 cross activity

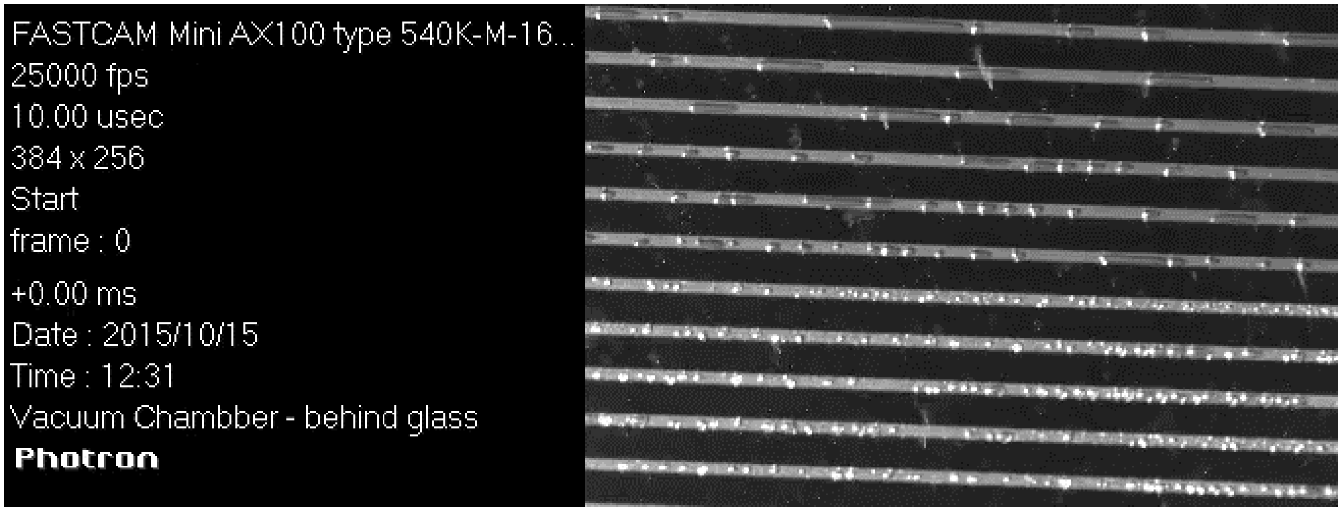




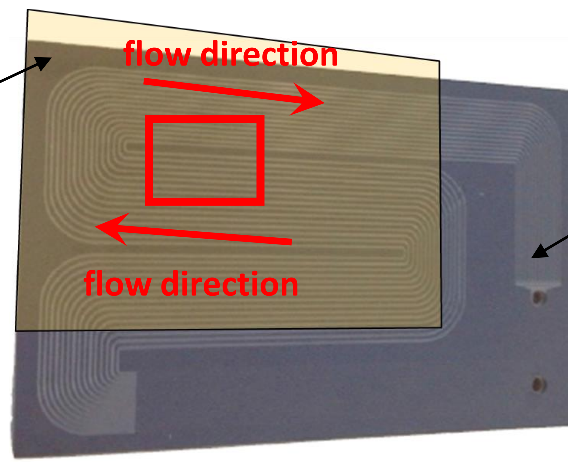
Successful simulation and measurement of DEPFET module cooled by μ-channel device with water (1-phase)

Why are 2-phase models needed?

CASE 1: "FLOW-MAPS"

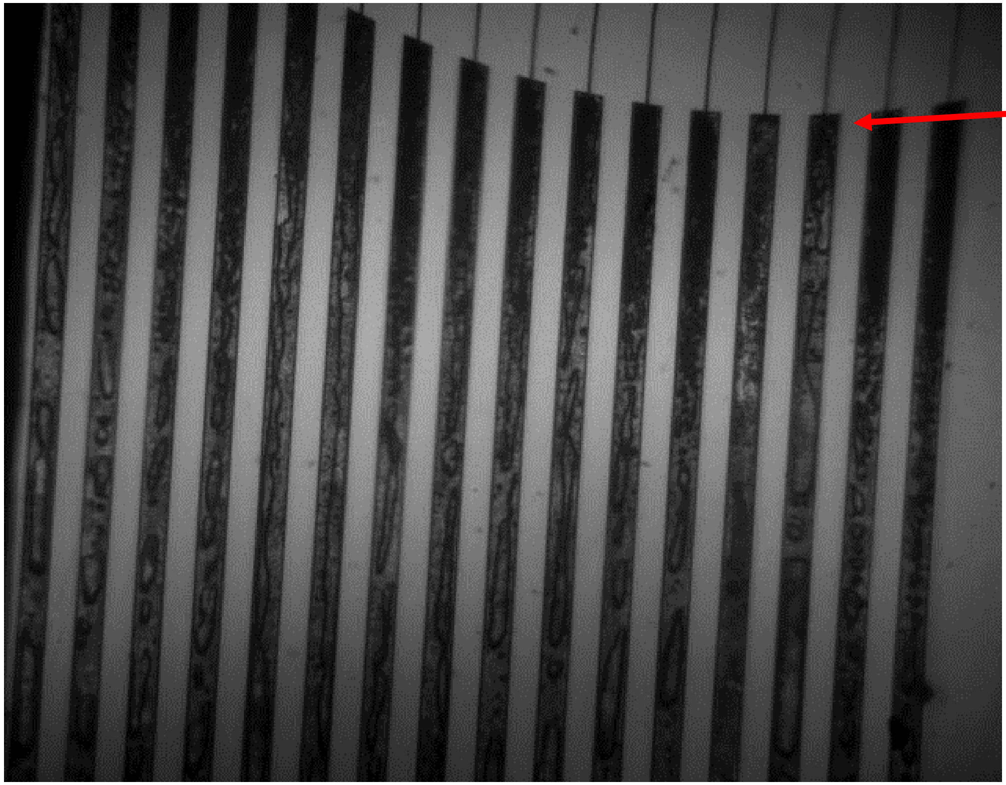


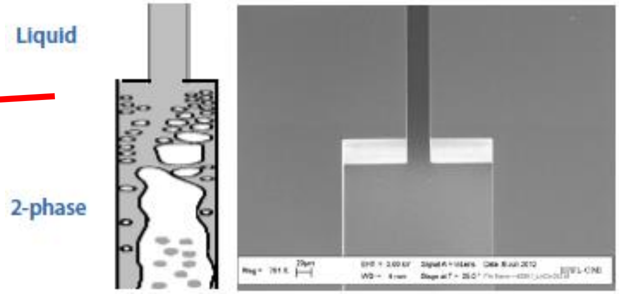
Heater



m-channel device with CO_2 boiling

CASE 2: "BOILING ONSET"

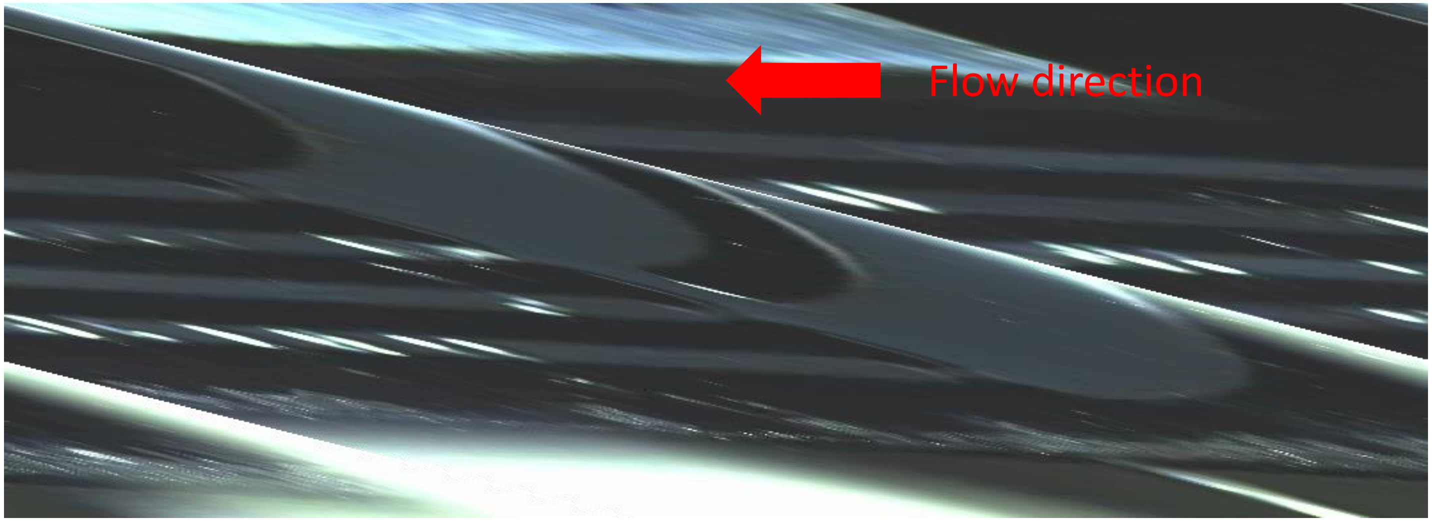




Transition from inlet restrictions to evaporative microchannels

University of Twente
The Netherlands

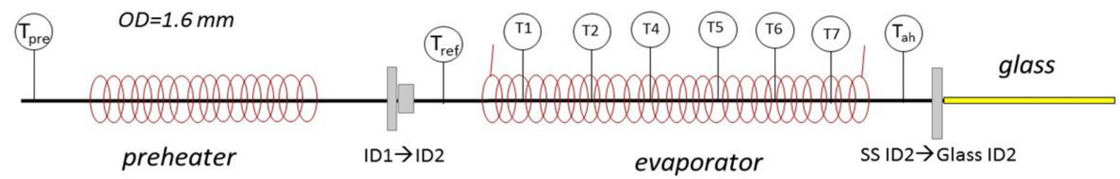
CASE 3: “INSTABILITY”

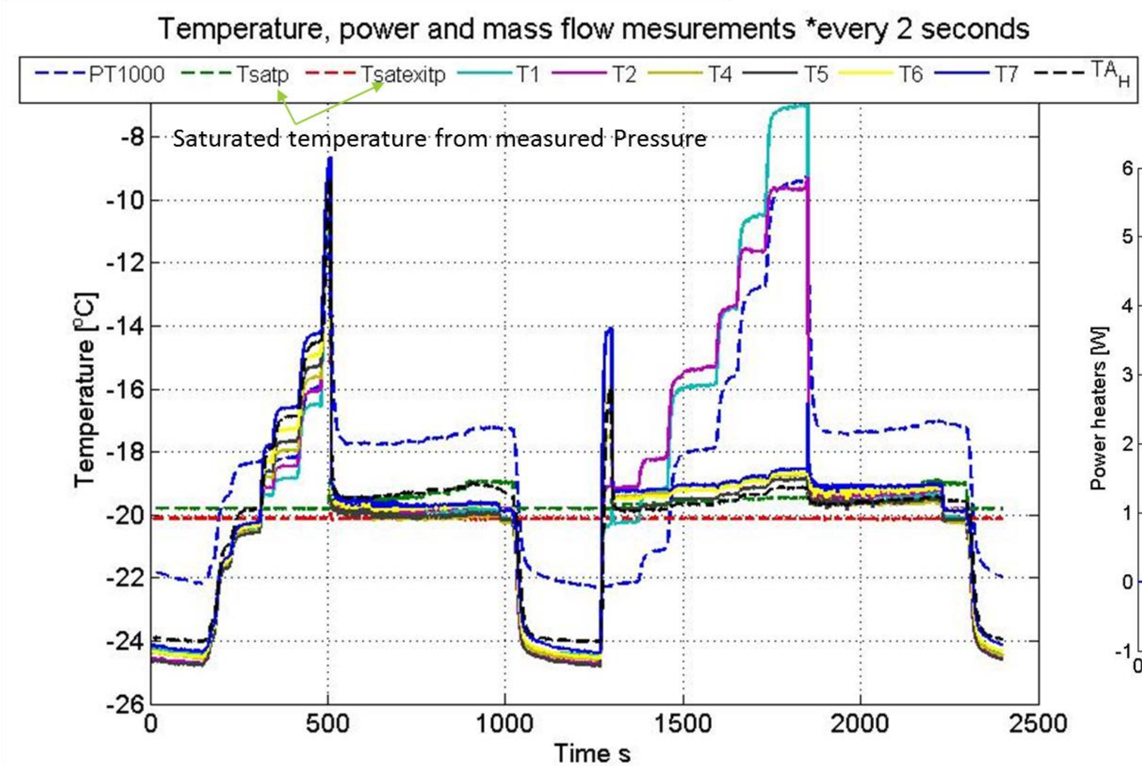


(Movie courtesy of A. Francescon, ALICE)

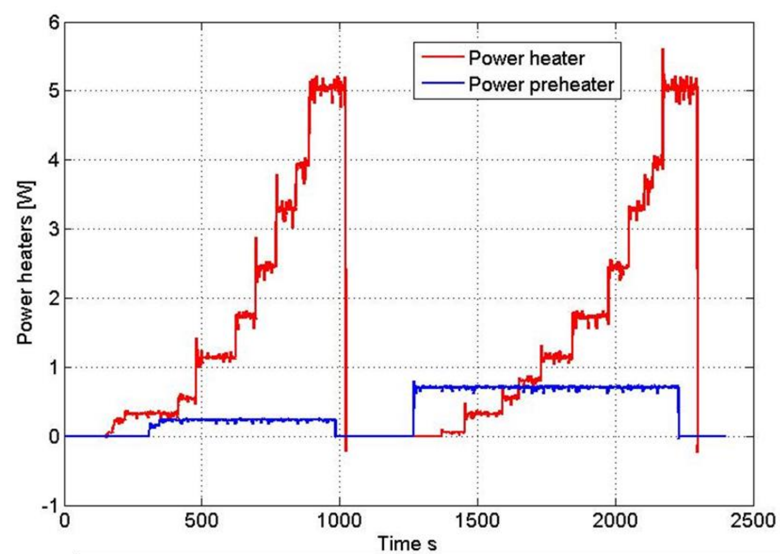
T9.2 SECOND YEAR
CO_2 measurements in μ-channel

Measurements single μ-channel





Raw data

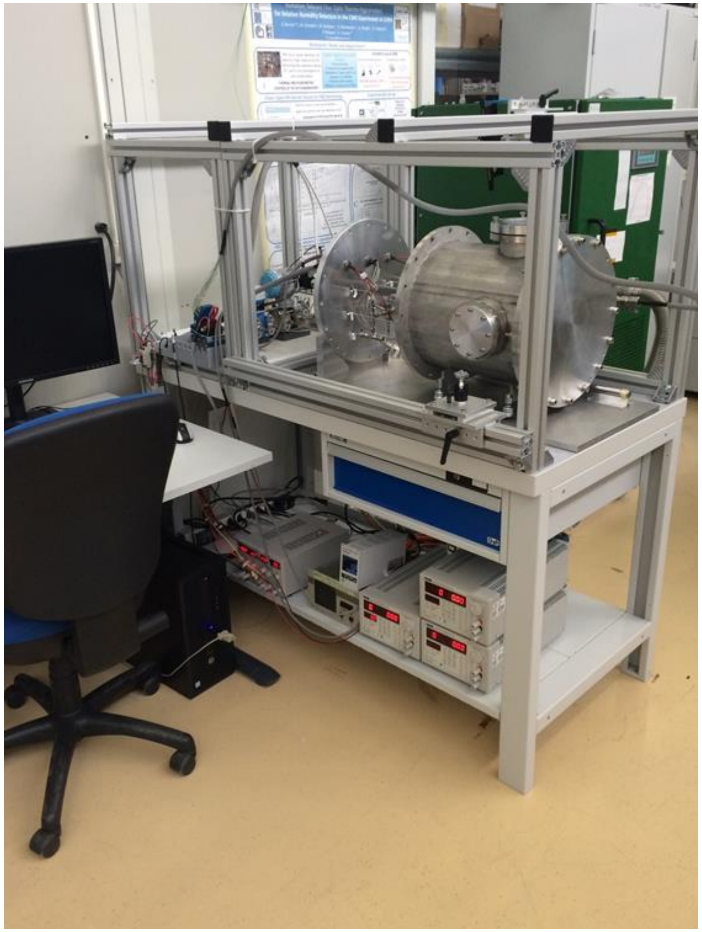


University of Twente
The Netherlands

T9.2 SECOND YEAR

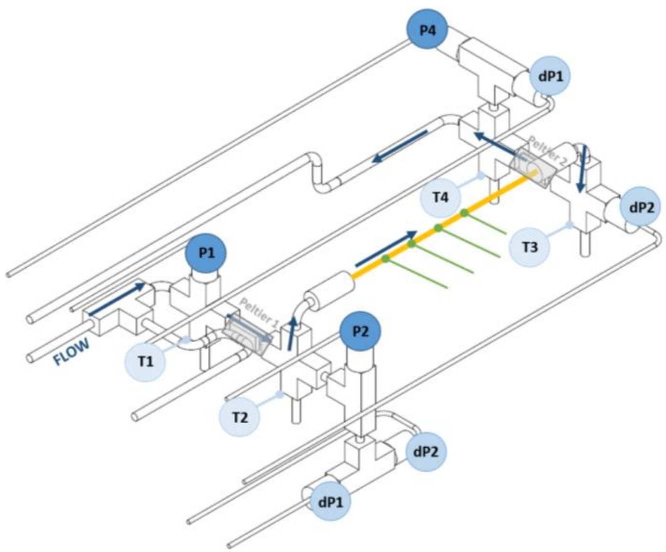
New CO_2 boiling test facility @CERN

New test facility for evaporative CO_2 flow measurements in mini- and micro-channels (I)



New test facility for evaporative CO_2 flow measurements in mini- and micro-channels (II)

T9.2 SECOND YEAR
New CO_2 boiling test facility @CERN



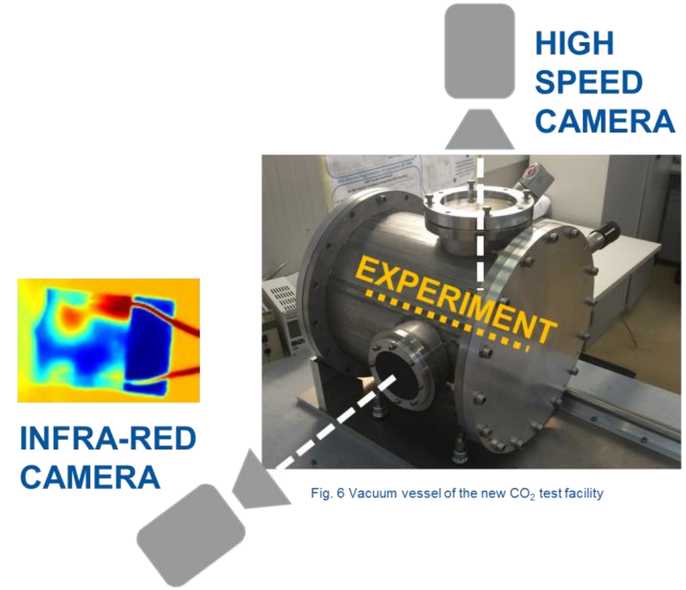
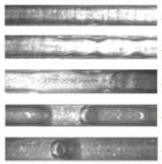
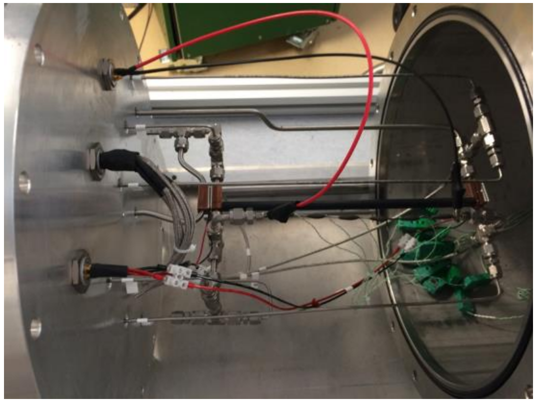


Fig. 6 Vacuum vessel of the new CO_2 test facility





Experiment section within the vessel

Differential & absolute pressure sensors and flow meter outside the vacuum vessel

CERN

MANCHESTER 1824 The University of Manchester

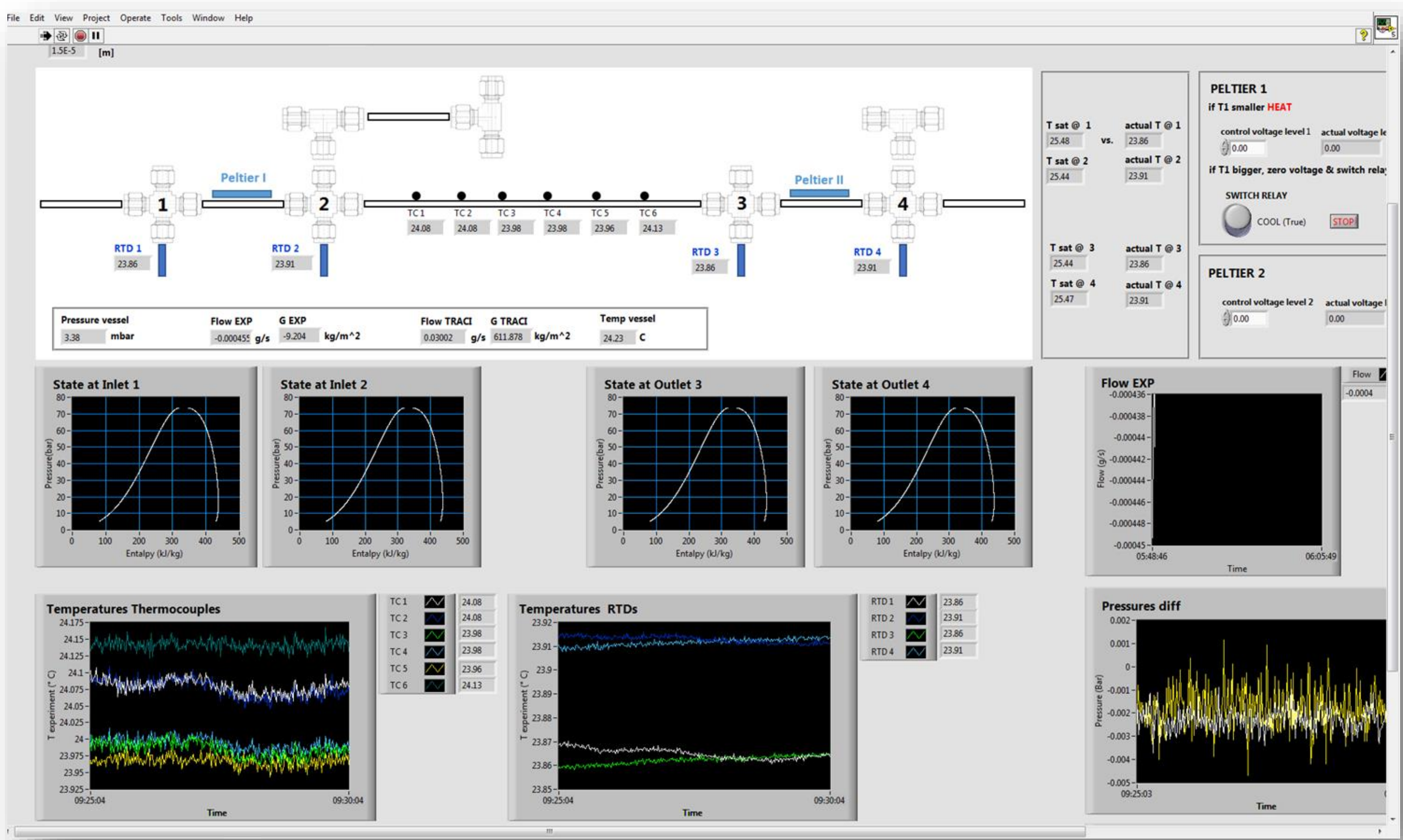
LPNHE PARIS

universität bonn

DATA AQUISITION with LabVIEW®

- experiment sensors
- flow meter
- vacuum level
- temperature inside vacuum vessel
- control of Peltier & Joule heater
- online-evaluation of fluid state
- acquisition in parallel with cameras possible

→ MATLAB® code for analysis



T9.2 SECOND YEAR

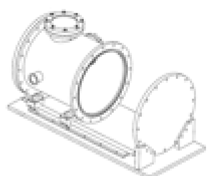
New CO_2 boiling test facility @CERN

Controlled and accurate measurements are ensured by following components:

2-phase CO_2

Transportable Refrigeration Apparatus for CO_2 Investigation

Vacuum vessel



Adiabatic test conditions for more accurate heat transfer measurements

P & T sensors

High precision measurements for pressure & heat transfer

Flow meter

Direct high precision measurement of the mass flow rate

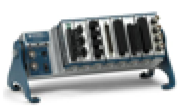
IR Camera

Heat transfer visualization

High speed cam

Visualization of details on bubble dynamics (100 000 fps)

+ Data acquisition



WP9: Status of Milestones and Deliverables

- T 9.2 Milestones

	Milestone Description	Beneficiary	Due Date	Verification
MS 24	CFD models available (Preliminary models to be used for thermofluidics simulations implemented in the available software and ready to launch comparison with experimental results)	CERN	Jun 2016 ✓	Agenda, attendance list on Indico
MS 77	Standard connectors available (Engineered design of a family of miniaturized connectors suited for both testing and final applications. Order for procurement submitted)	CERN	Mar 2018	Purchase order submitted
MS 82	Validated CFD models ready (Advanced models, based on subsequent improvements of the preliminary definition provided in MS24 , validated for use and ready for final phase of comparison with experimental results)	CERN	Apr 2018	Report to St Com

- T 9.2 Deliverables

Next deadlines coming

	Deliverable Description	Beneficiary	Due Date	Type
D 9.1	**Station for tests on μ-channel test devices** Fully engineered design of a test station available to partners, including detailed list of instruments and components, and manual of operation. One prototype test station built and in use for tests	CERN	Oct 2017	Other
D 9.2	**μ-channel prototypes** μ-channel cooling devices in Si-Si and Si-Glass available to the partners for execution of the agreed test programme, including final model validation. Specifications, geometries and features previously agreed by the partners	CSIC	Oct 2017	Demonstrator
D 9.3	**Technology recommendations for μ-channel cooling** Report detailing the state-of-the-art technologies selected for the production process of μ-channel cooling devices to be installed in future HEP experiments	CERN	Feb 2019	Report
D 9.4	**Qualification and characterisation of μ-channel cooling** Report detailing the standardized procedures endorsed to qualify and characterise μ-channel cooling devices to be installed in future HEP experiments	CNRS	Feb 2019	Report

WP9: Status of Milestones and Deliverables

- T 9.3 Milestones

	Milestone Description	Beneficiary	Due Date	Verification
MS 8	Advanced Mechanical Distributed facility requirements (Report outlining the range of measurement setups and their capabilities to be installed within the Advanced Mechanical Distributed Facility)	UOXF	Jan 2016 ✓	Agenda, attendance list on Indico
MS 99	Advanced Mechanical Distributed facility ready (Report listing experimental setups within the Facility, and their performance as demonstrated with realistic prototypes)	UOXF	Feb 2019	Report to St Com

- T 9.3 Deliverables

Report in preparation

	Deliverable Description	Beneficiary	Due Date	Type
D 9.5	**Advanced Mechanical facility** Definition of facility requirements: Identification of parameters characterizing the performance of support structures and identification of experimental techniques which make these parameters accessible, prioritization of the need by the international community for these measurements at a central facility	UOXF	Jun 2016 ✓	Other
D 9.6	**Common test structures** Identification of test structure designs which allow discriminating measurements of relevant structural performance parameter, prediction of performance by FEA, production of test structures and benchmarking results of these structures with the facility	CSIC	Apr 2017	Other
D 9.7	**Standard procedures for qualification and characterisation** Setup of measurement facilities, operation of the facility, evaluation of measurement hardware and procedures, development of definition of standard measurement procedures at the Advanced Mechanical facility	UOXF	Feb 2019	Report

CONCLUSION
(Mainly to quote myself…)

Conclusions

- The thermal management of the next generation of Tracking detectors (and Pixels in particular) requires careful design and early integration
- Recent spectacular technical advances make available several effective approaches to the detector designer
- No single thermal management scheme is by definition better suited than the others for any configuration: careful analysis of the design parameters and of priorities (the “engineer questions”) must guide towards the optimal choice
- The most relevant novelty in the approach to pixel thermal management in future detectors is indeed that there is a systematic approach and an early integration in the design concepts!

PH-DT
Detector Technologies
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THIS IS WHERE AIDA-2020 WP9 TARGETS ITS IMPACT ON THE DETECTOR COMMUNITY

QUESTIONS?