WP10 – status report

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With inputs from all WP10 groups

AIDAinnova 3rd annual meeting, Catania, March 21st

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004761.

WP10 parallel session, with reports from all groups:

https://indico.cern.ch/event/1307202/sessions/502041/#20240320

Thanks to all speakers for their contributions, and for providing summary slides

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Advancement and Innovation for Detectors at Accelerators

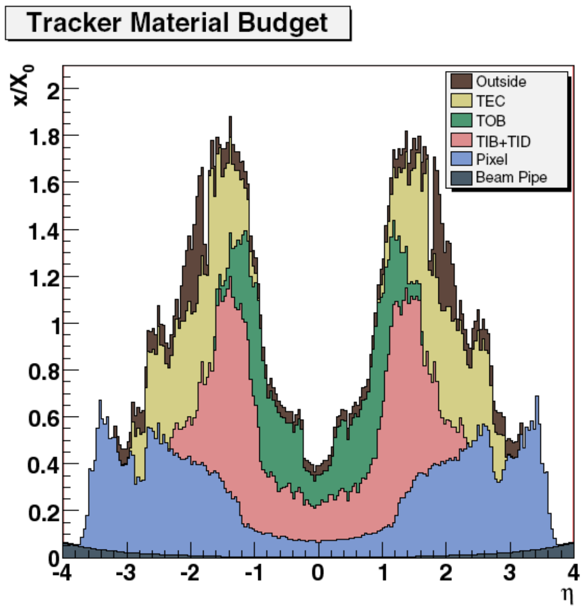
WP10 goal: make sure that support, cooling and services do not limit the material budget of the next generation of vertex detectors and silicon trackers

20 years ago:

Full rad-hard, high-rate pixel+strip system ~0.4-1.8 X_0
Note: Silicon contributes: 10 x 2 x 300 µm ~ 0.06 X_0

Today:

WP5&6: active Silicon reduced to < 50 µm/layer
Can we reduce all non-active material too?



The answer has to be yes, but this requires work on:
- new coolants and new cooling concepts
- novel materials/techniques
- further integration of active material, support, cooling and services
- more precise characterization of thermo-mechanical performance

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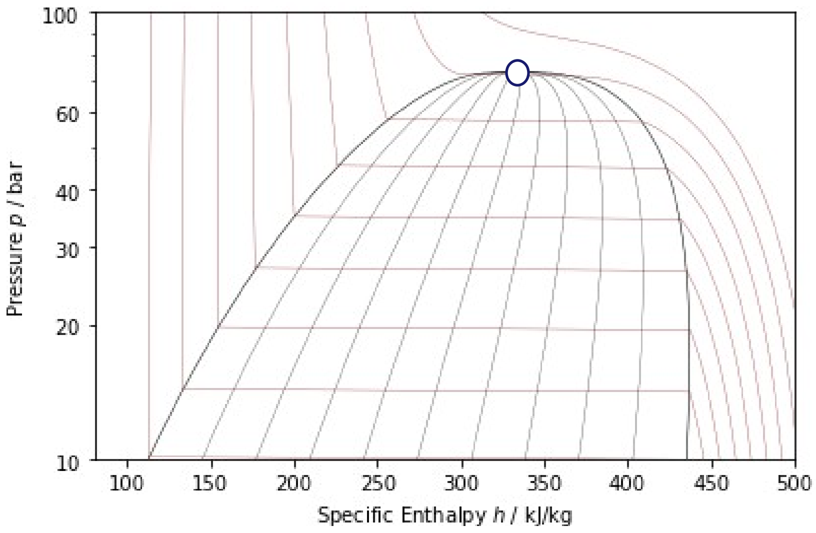
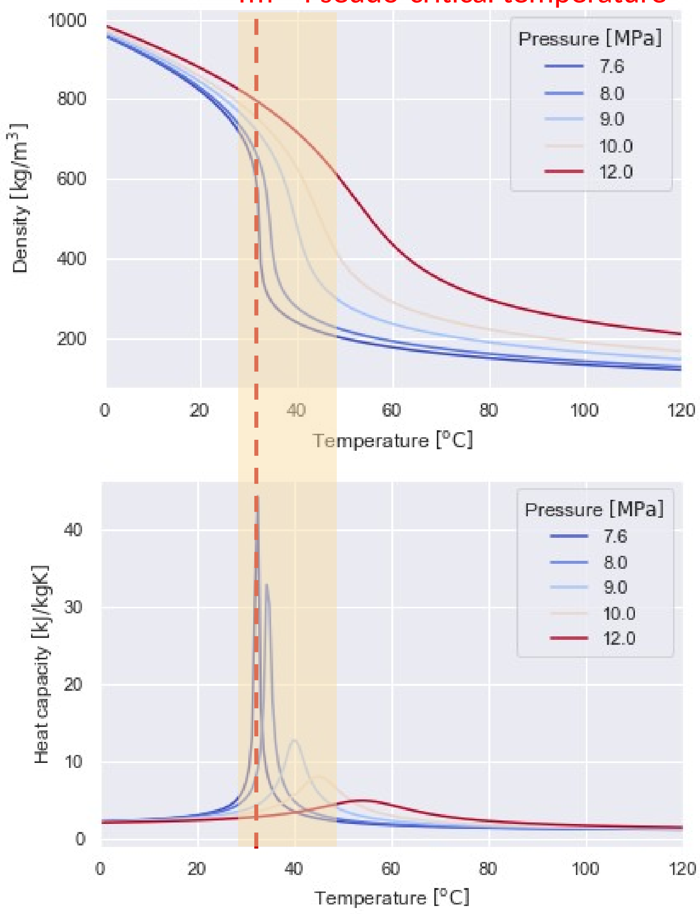
Super-critical coolants (CERN)

- Above critical value: change is continuous
  - T<Tc liquid-like fluid
  - T>Tc vapor-like fluid
- Critical point of carbon dioxide: 74 bar, 31 °C
- Super-critical Krypton possible ultra-cold solution

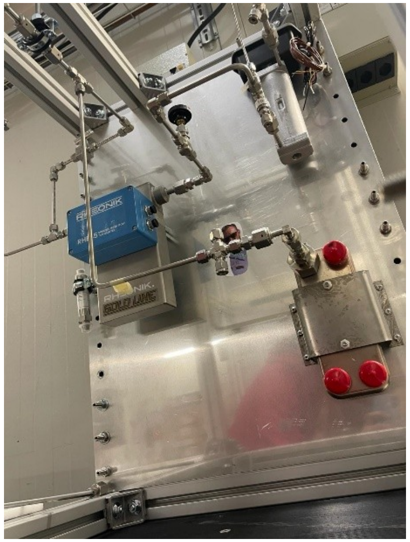


Temperature of interest for room temperature detector cooling (+31 to +45 °C)

Tm = Pseudo-critical temperature

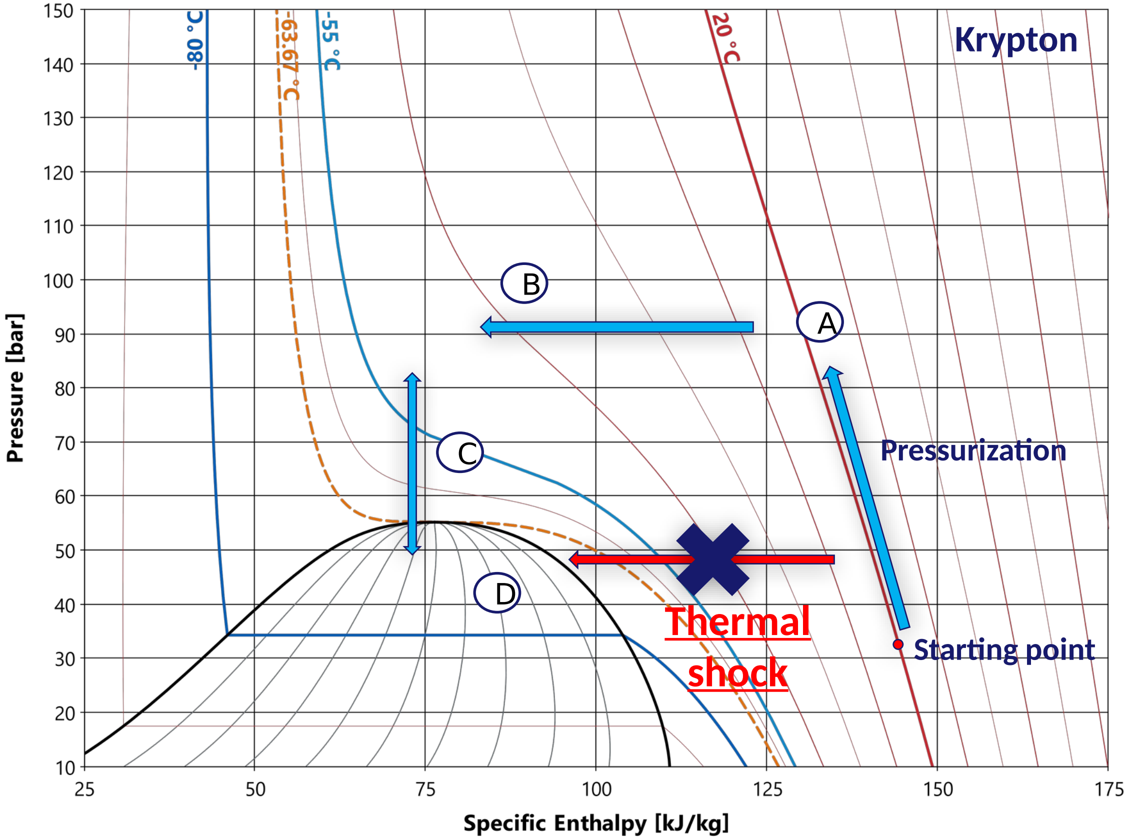


Status of CERN test rig



Super-critical Krypton (L. Contiero)

- Challenges with Krypton cooling: start cooling cycle without thermal shock
- Conceptual solution developed, tests foreseen



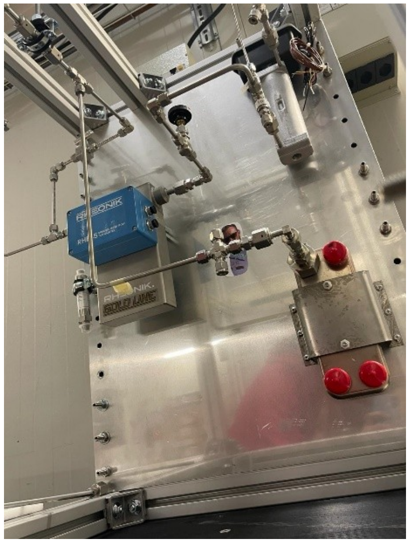
- Starting temperature (20 degC) in gas/supercritical phase

↓

Four different scenarios to be investigated:

- Startup (A)
- Supercritical cooldown (B)
- Supercritical operation (C)
- Transcritical operation (D)

Status of test rig (C. Pedano, CERN)



Task	CO2 Timeline	Krypton Timeline
April-May 2024	Setup construction Development of DAQ	Tests at NTNU
June 2024	Commissioning	
Summer 2024	Measurement campaign	Tests at CERN

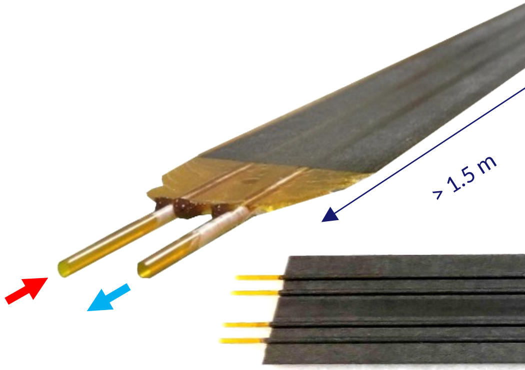
Answer essential questions in AIDAinnova:
Stable operation at super-critical CO_2?
Viable operation cycle for super-critical Krypton?

- Ultra-light structures with integrated cooling

Carbon cold plate with embedded Kapton pipe

Purpose:

- Technology compatibility with high-pressure boiling coolants.
- Produce large surfaces cold plate (CP) for high-pressure boiling coolants.
    - i.e. evaporative CO_2 and new coolants (Krypton, …)

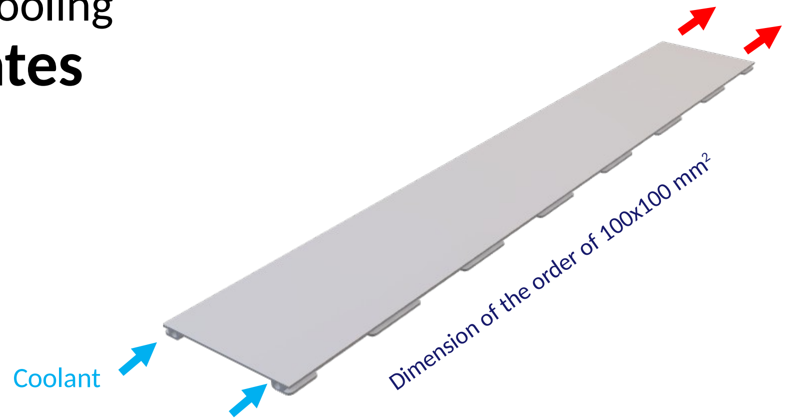


- 3D-printed structures with integrated cooling

AM Ceramic & Metal cold plates

Purpose:

- Generation of new standards to produce micro-structured cold plates produced by additive manufacturing, (ultra-thin wall).



Carbon cold plate with polyimide pipes

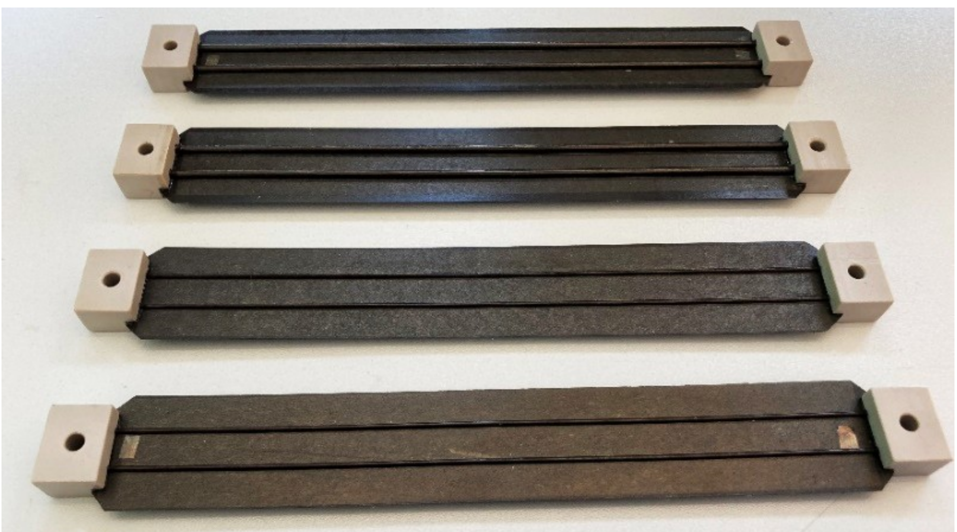
AIDA innova

CERN EP R&D WP4

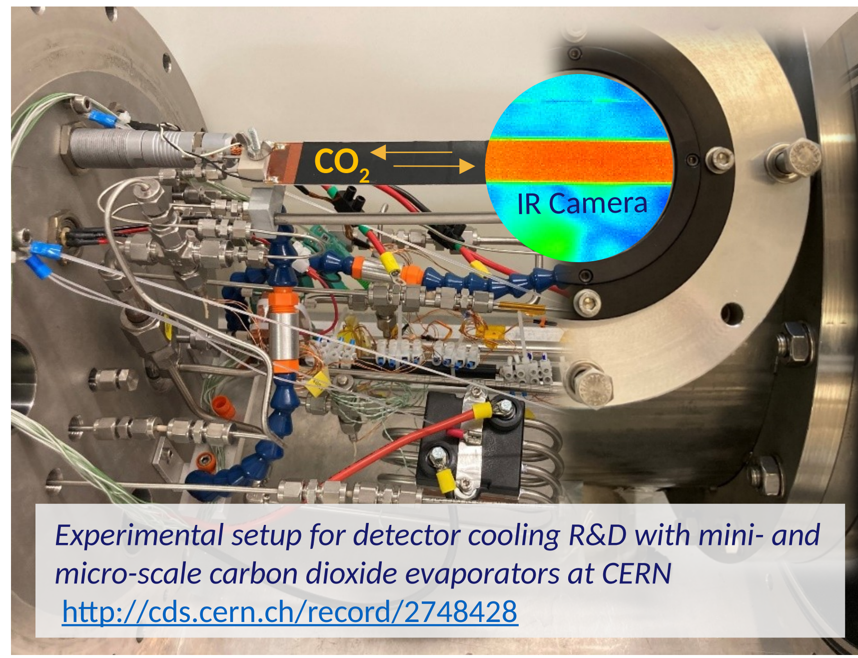
D. Hellenschmidt
M. Angeletti

- **Achievement:** Established low-mass cold plate design with embedded Kapton pipes adapted and tested successfully **with evaporative CO_2**

Article under internal review: *On-detector cooling systems based on low-mass carbon dioxide evaporators: cold plates with embedded Kapton tubes* (D. Hellenschmidt, …)



Experimental setup



Experimental setup for detector cooling R&D with mini- and micro-scale carbon dioxide evaporators at CERN
http://cds.cern.ch/record/2748428

Carbon cold plate with polyimide pipes

- Know-how transferred to Workshape industrial partner

ONGOING: 1.5m cold plate production (ITS2 like)

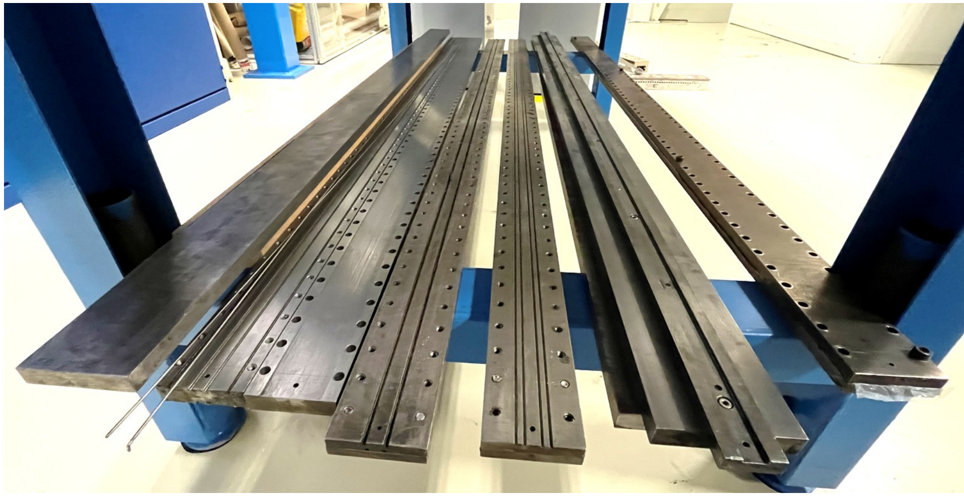
- Issues reproducing ALICE cold plates due to resin differences
- Cold plates manufacturing by end of April 2024.

CERN EP R&D WP4

CERN Knowledge Transfer

NEXT: 1.5m cold plate
(High-pressure resistance)

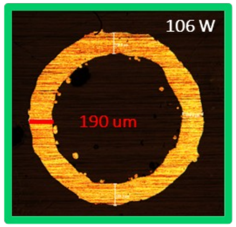
WORK SHAPE
CONCEPTION . PROTOTYPAGE . COMPOSITES

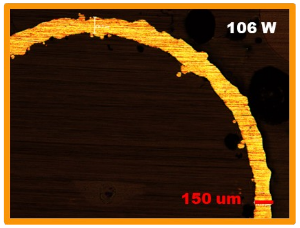


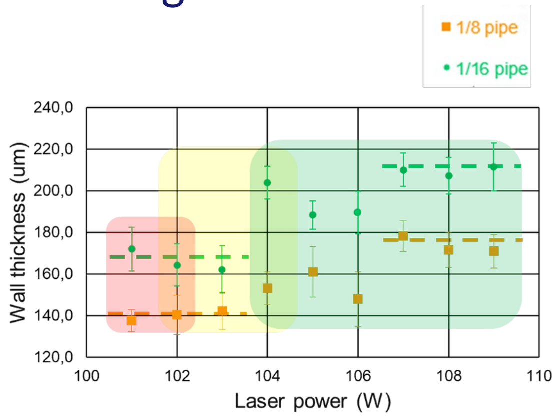
Task10.2b AM (micro)-channel cooling technology

3D integrated cooling circuits

- Investigation on the smallest leak-tight wall thickness for Al alloy
  - **160 um 1/8'' pipe**
  - **190 um 1/16'' pipe**



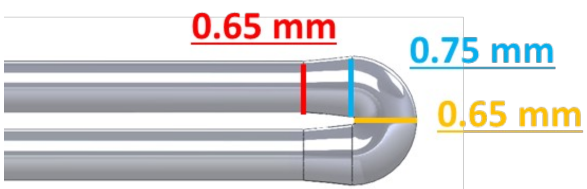




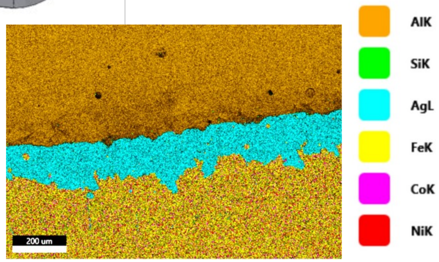
Updates: CSEM

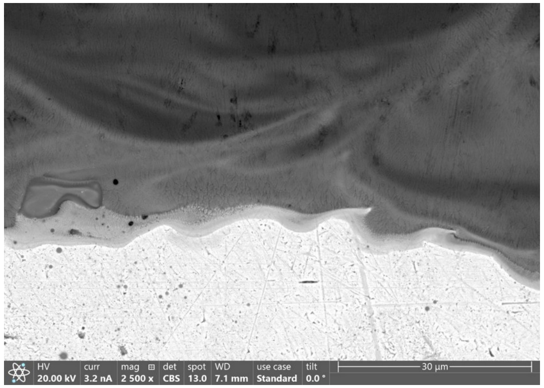
- The printing limits of AlSi12 material have been thoroughly understood.
- KOVAR powder has been purchased; and printing capabilities with KOVAR material is currently under study.

- Investigation on the smallest 180° curvature design size to remove powder
  - **Pipe length: 85 mm**
  - **Pipe hole: 0.44 mm**



- Multi-material printing
  - Aluminium-kovar with silver inter-layer
  - Thermal cycling to be tested





Task10.2b AM (micro)-channel cooling technology

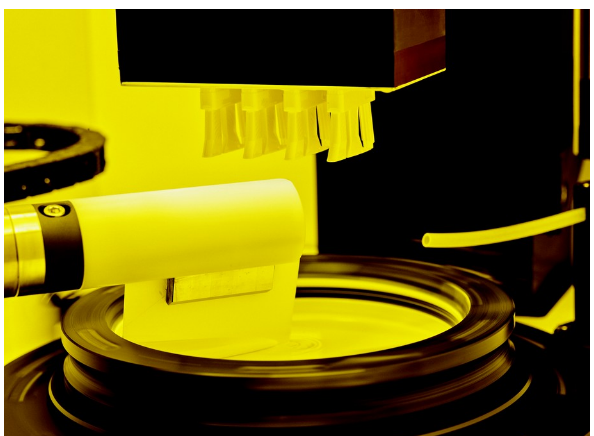
3D integrated cooling circuits in the structure

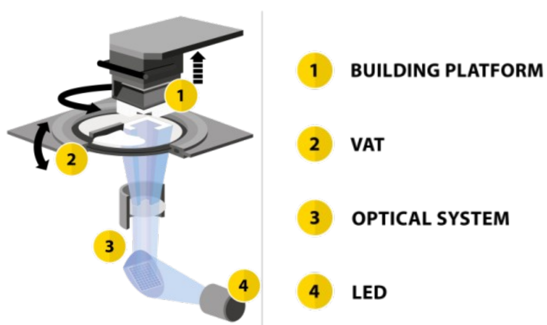
LITHOZ

- **Materials and technologies:**
  - **AM:** Lithography-based Ceramic Manufacturing (LCM) technology.
  - **Ceramics:** Aluminum oxide (Al_2O_3),
    ONGOING: Aluminum nitride (AlN),
    Polymer-Ceramic composites.
  - **Aim:** Define the optimal geometrical features attainable
    e.g. Minimum achievable wall thickness of pipes/plates,
    Flatness optimization (Firing step, 1500-2000 C, warping effect).

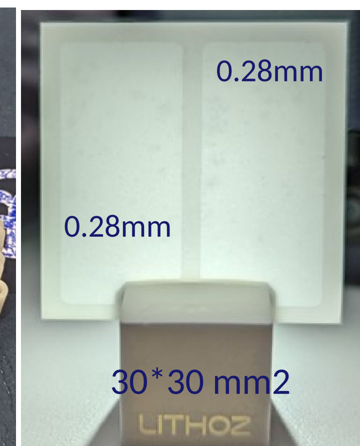
Updates: Lithoz

- The printing limits of Al2O3 material have been thoroughly understood.
- Additional samples in AlN are in production for future irradiation test campaign.
- Optimization of cold plate flatness investigation currently on going





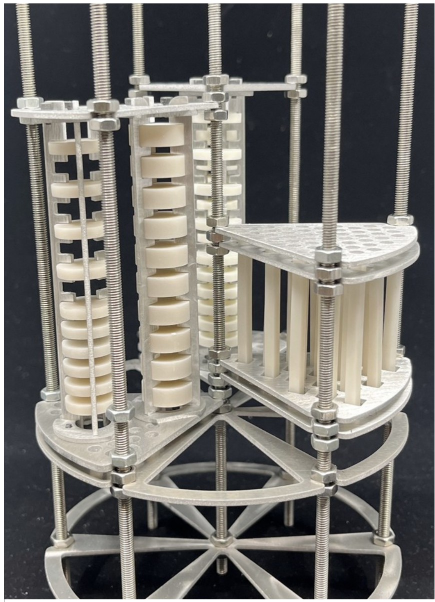
Blue light cures the photosensitive formulation



Task10.2b (micro)-channel cooling

- **Analysis, experimental tests:**
  - Metrology, mechanical characterization tests (CERN)

Material properties investigation



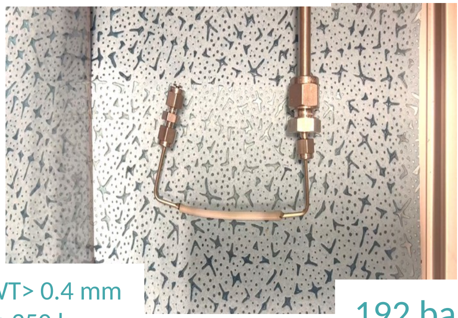
Aluminium cradle for
Irradiation test campaign

Non- and
Irradiated samples (3,9 MGy)

Updates: CERN

- Geometrical limits for AlSi12, Al2O3 and AlN have been identified.
- First irradiation campaign and characterization tests completed for Al2O3 and AlN. No relevant changing in material properties (thermal conductivity, Flexural modulus/strength) have been noticed.

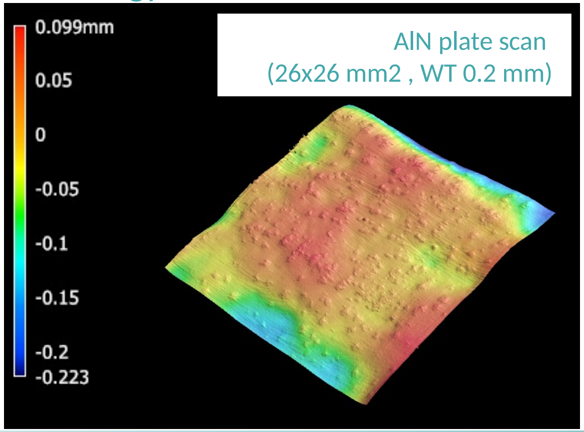
AlN, OD 3,2 mm, WT 0.3 mm



WT> 0.4 mm
P>250 bar

192 bar

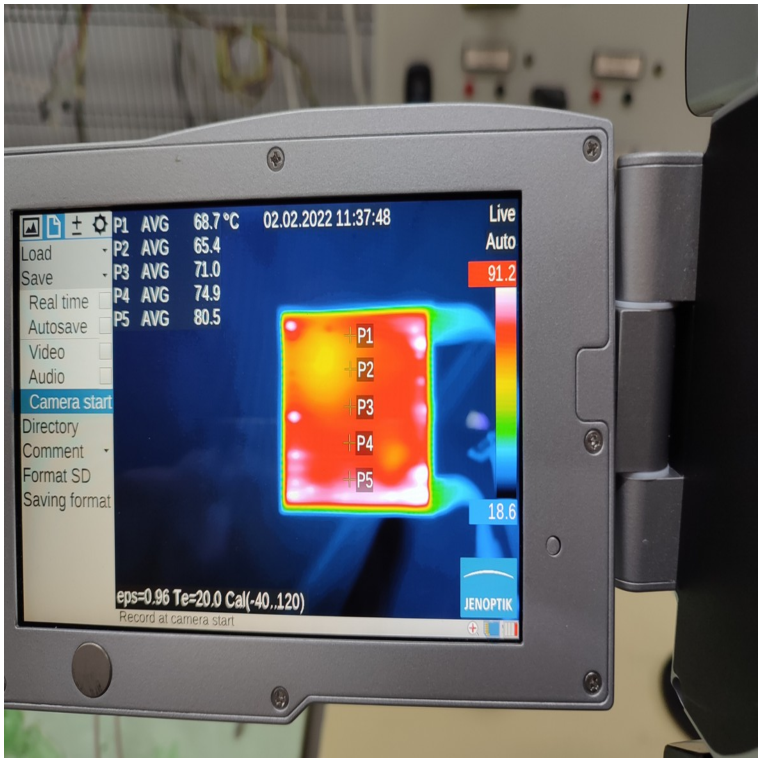
Metrology



NEXT:
5 MGy irradiation campaign

WP10 Activities at INFN
Cool FPGA (F. Palla, Pisa)

Pyrex (300 µm)+ Silicon sandwich, glue Masterbond EP30TC



Heaters to simulate power load up to 97 W

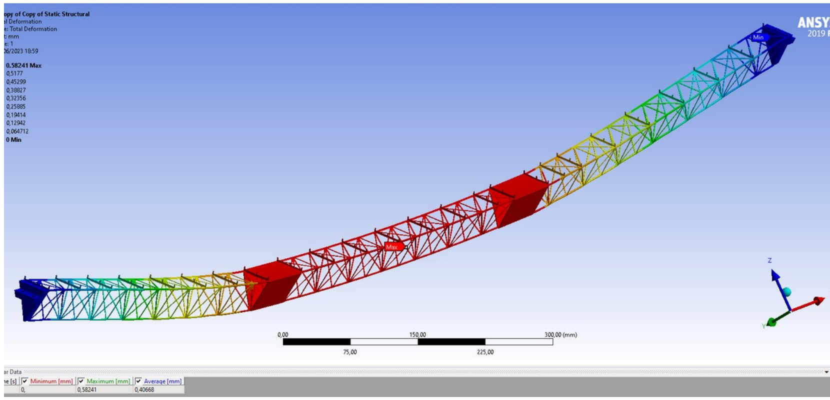
Cooling fluid at 5°C with 0.33 kg/min flow rate

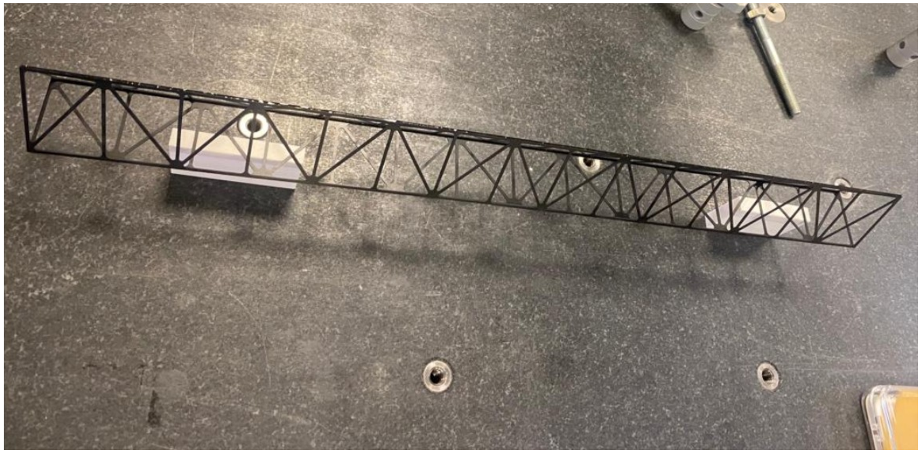
Calibrated infrared camera to monitor temperature: kept to 72°C

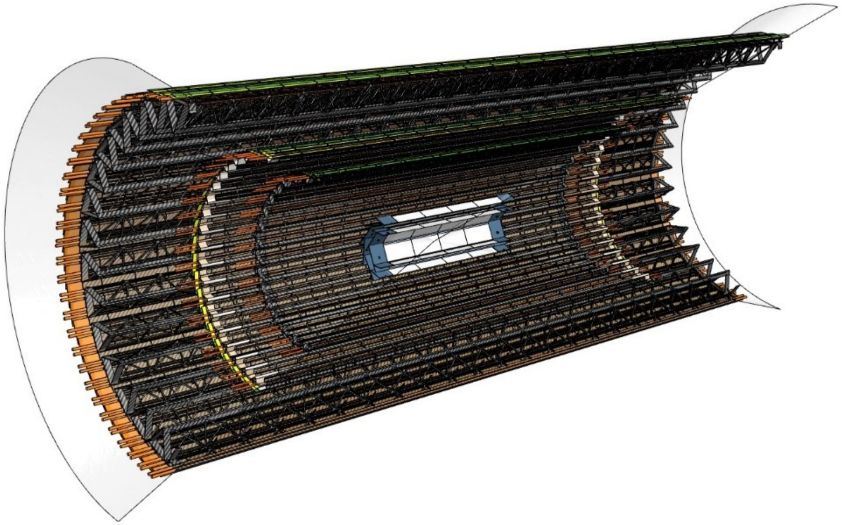
WP10 Activities at INFN
Cool FPGA (F. Bosi, F. Palla, Pisa)

Truss structure for outer layers of Belle 2 silicon tracker and future CEPC experiment

Measurements, simulations on prototypes and complete engineered design







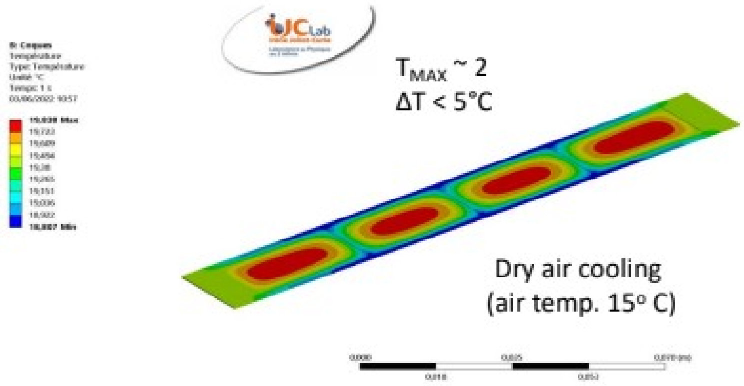
WP10 Activities at CSIC
(C. Mariñas, IFIC, M. Ullan CNM)

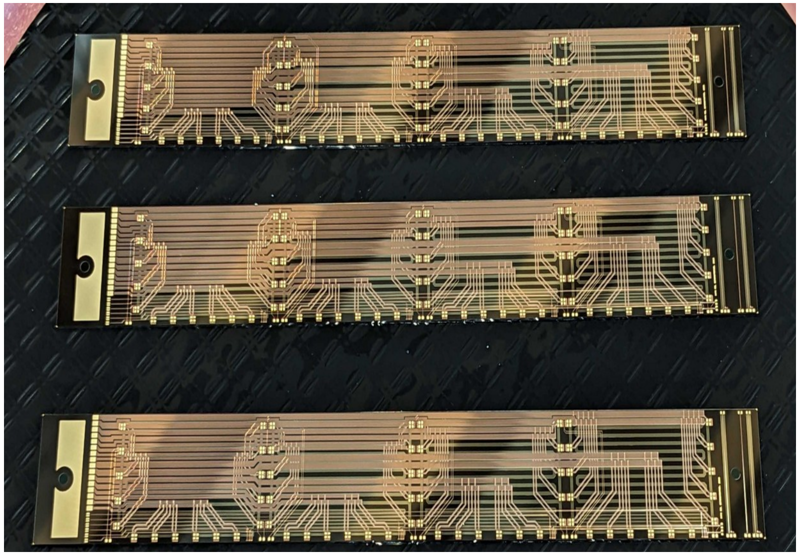
Thin multi-CMOS-chip Silicon structures for Belle 2 upgrade

Thermo-mechanical iVTX demonstrator delivered by IZM to Valencia/Bonn

Thermal simulations (IJCLab Paris)
to be validated against lab tests

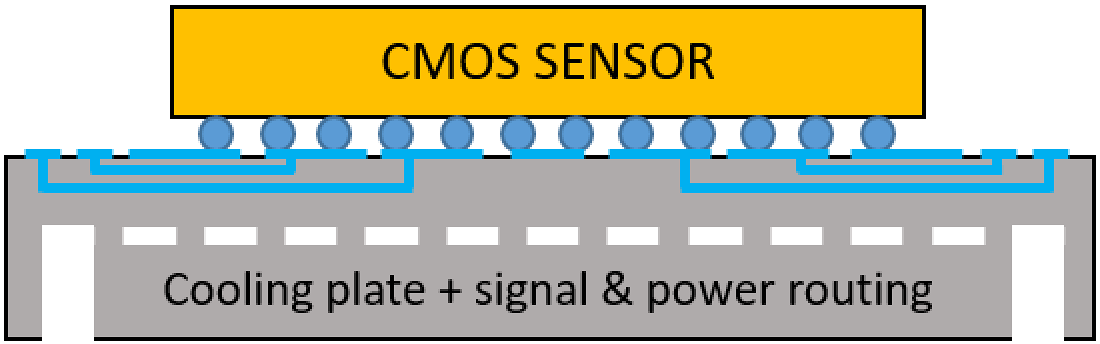
Basis for FE analysis of future
collider cooling strategies (C. Orero, IFIC)

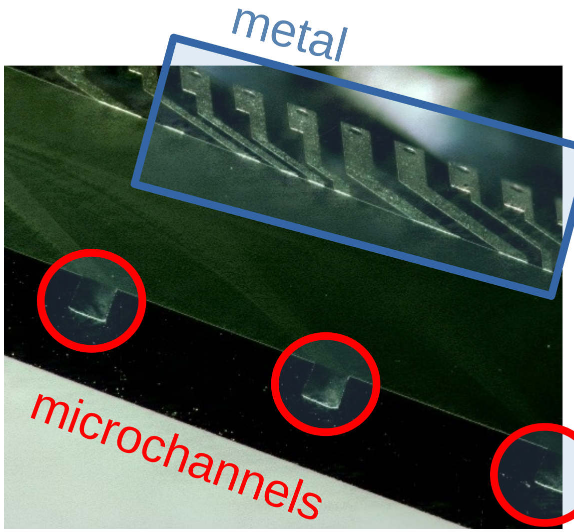




Micro-channel production capacity at CNM

- Integrated cooling channels and metal system with different bonding techniques
  - Pre-processing (i.e. micro-channels first, metal/CMOS last)
  - Anodic (glass-Silicon) bonding post-processing
  - Optimizing eutectic wafer bonding technique





Wire bonding tests show integrity of metal after wafer bonding

Steps on the way to CMOS-compatible integrated microchannels

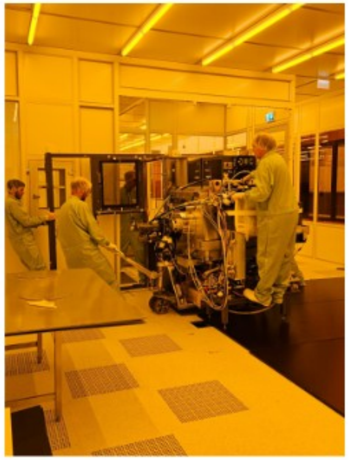
WP10 Activities at MPG-HLL (L. Andricek)

MPG HLL Status

▷ MPG HLL is working on the installation of a process line for
- Post processing of up to 200 mm CMOS wafers
- Fabrication of actively cooled interposers with micro-channels and TSVs
- Low temperature direct bonding
- Hybrid bonding of post-processed CMOS wafers or single CMOS chips to sensors wafers

▷ Current status
- The clean room of MPG HLL was relocated to a new and larger building
- Tests with equipment manufacturer finished, tool configuration done, purchasing in progress
- Relocated equipment currently in the hook-up phase, qualification to follow



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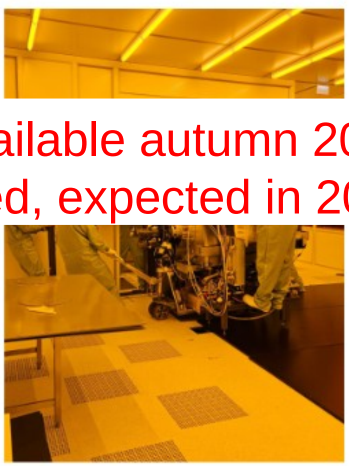
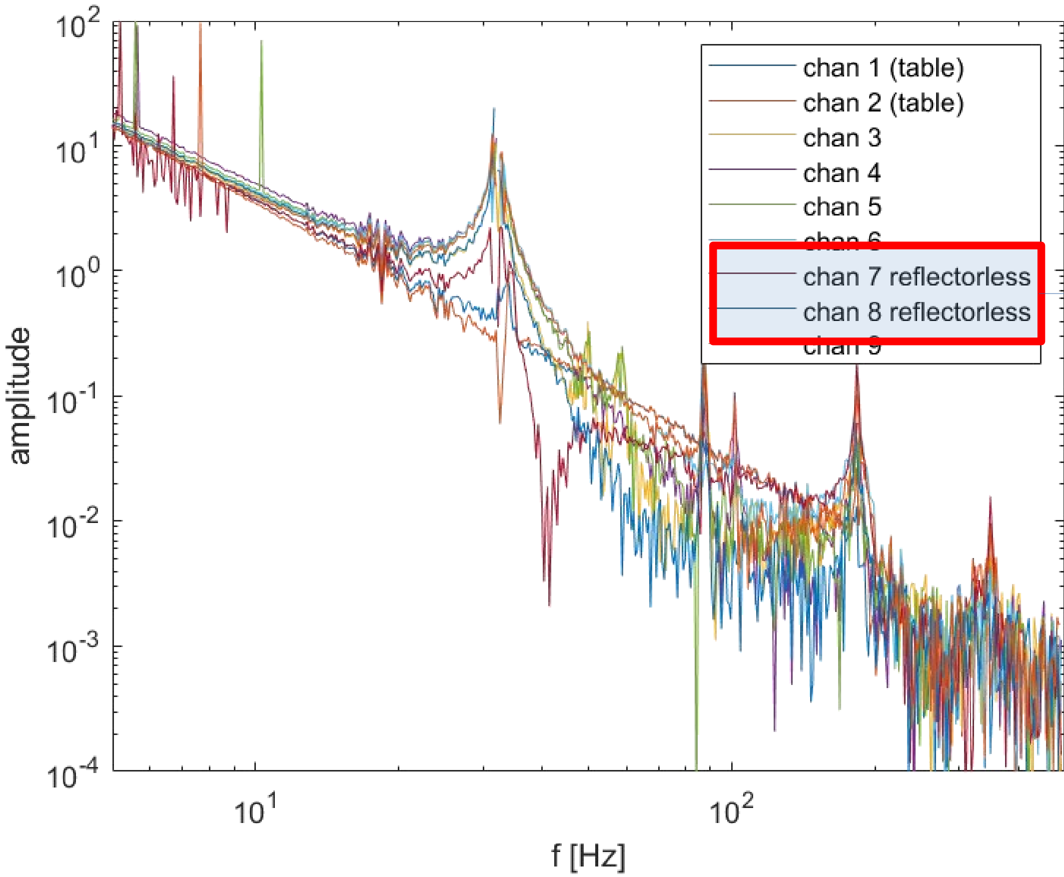


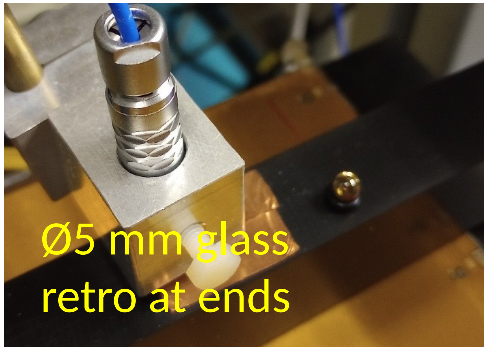

Time line: building ready, new equipment available autumn 2024.
Plasma-based direct bonding process defined, expected in 2025.

WP10 Activities at Oxford
(G. Viehhauser)

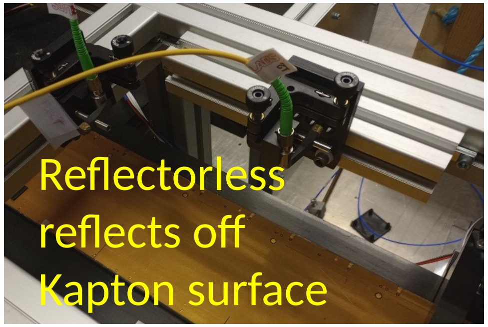
Detailed characterization of mechanical response of tracker elements



FSI system + actuator operational (despite loss of personpower)



Reflector-less operation works (AIDA-innova deliverable)



Tests on Kapton successful, other materials soon

Status of WP10: reporting

D #	Deliverable Name	Lead beneficiary	Type	Due Date (in months)
D10.1	Cooling device demonstrators	30 - CSIC	Report	46
D10.2	Hydraulic interconnection technologies	8 - CNRS	Report	43
D10.3	Supercritical CO2 as a refrigerant	25 - NTNU	Report	44
D10.4	Upgraded FSI	41 - UOXF	Report	45

Discussed also “lessons learnt” document on 3D printing with non-standard materials

Deliverables include reports on main tasks,
Due in months 43-46 (end ‘24, early ‘25)

WP10 – summary

Progress/results:
Work proceeding correctly in most nodes; a selection of results shown today
Important: industrial partners actively involved in developments

Practical/organizational:
- Some synergy with I.FAST on additive manufacturing
- Massimo Angeletti joined (busy) WP10 conveners
- An extension of AIDAinnova is likely helpful in several areas