AIDAInnova 2nd Annual meeting

Work Package 10: Advanced mechanics for tracking and vertex detectors

Valencia 24-27 April 2023

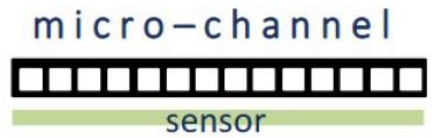
Massimo Angeletti

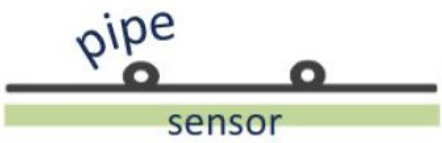
On behalf of WP10 group

https://indico.cern.ch/event/1191719/sessions/454933/#20230427

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

Outline



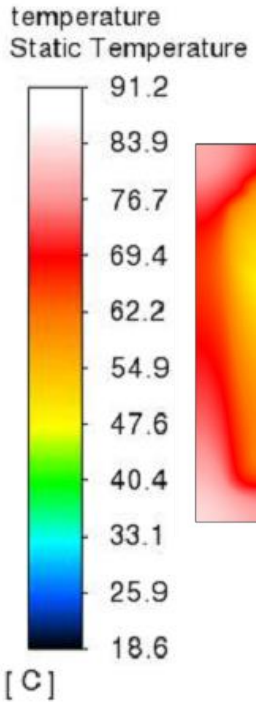


- **Task10.2a Silicon microchannel cooling technology :**
  - **Prototypes, analysis, experimental tests:**
    - **CoolFPGA project** (INFN Perugia, Pisa, Genova, FBK)
    - **Thin multi-CMOS-chip structures** (CSIC-Valencia)
    - **Single-Phase SOI-Based Microchannel Coolers** (MPG-HLL)
  - **Fabrication development:**
    - **Bonding technics, CMOS compatible** (IMB-CNM, MPG-HLL)
- **Task10.2b AM (micro)-channel cooling technology:**
  - **Materials and AM:**
    - **Ceramics by LCM technology** (Lithoz)
    - **Metals by LPBF technology** (CSEM)
  - **Analysis, experimental tests:**
    - Metrology, mechanical characterization tests (CERN)
- **Task10.2c Ultralight carbon cooling technology**
    - Compatibility with boiling fluids (CERN)
- **Task10.3 Hydraulic connections and interconnections:**
    - Low-mass PEEK 3D PEEK connectors (CNRS-LPNHE)
- **Task10.4 New coolants for warm and cold applications:**
    - **Supercritical-coolants (CO2, krypton)** (CERN, NTNTU)
- **Task10.5 Accurate measurement of ultralight structures:**
    - Vibrational setup, FSI based (UNIOXF)

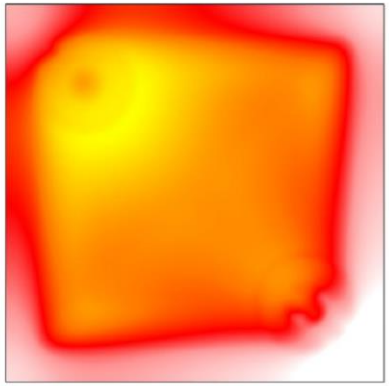
Task10.2a Silicon microchannel cooling technology

- **Prototypes, analyses, experimental tests:**
  - **Prototype: CoolFPGA project** (INFN Perugia, Pisa, Genova, FBK)

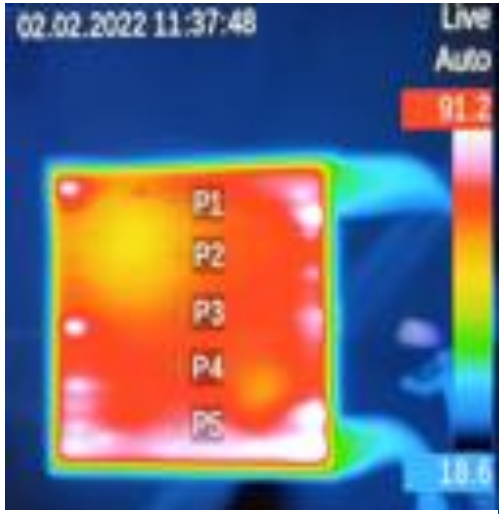
Thermal analysis:



Simulation



Experimental analysis

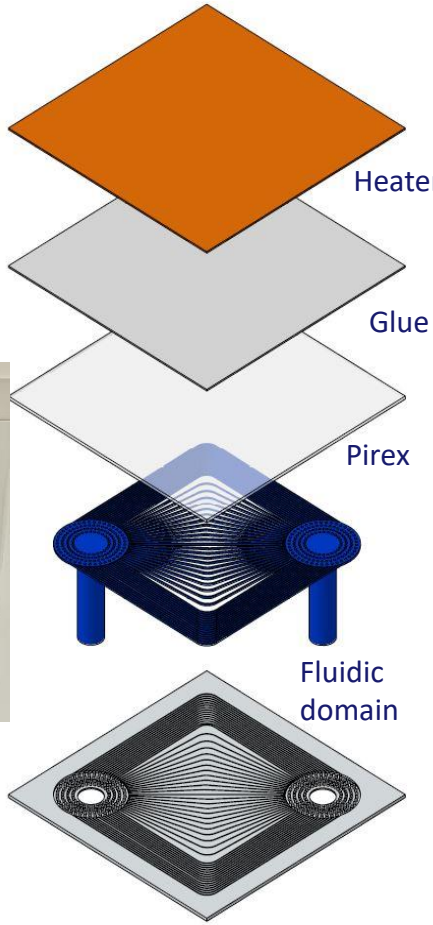


Cooling liquid (Novec 7100) at 5°C,
mass flow rate = 0.33 kg/min;
6 W/cm^2; theoretical: 96 W

Prototype

40x40 mm^2

Layout

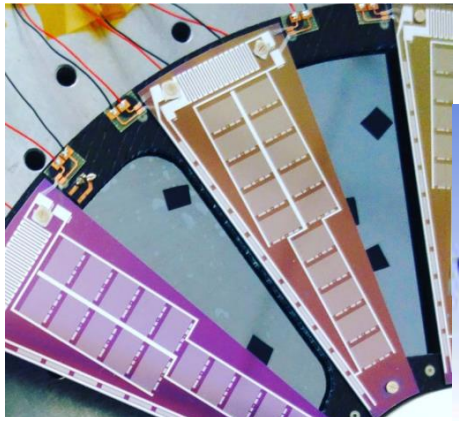


Silicon microchannel plate

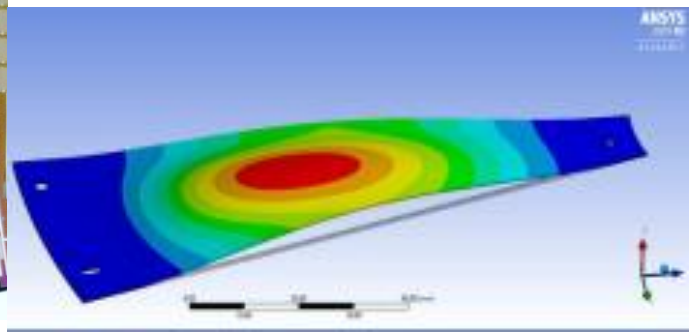
Outcomes: reasonable good agreement

Task10.2a Silicon microchannel cooling technology

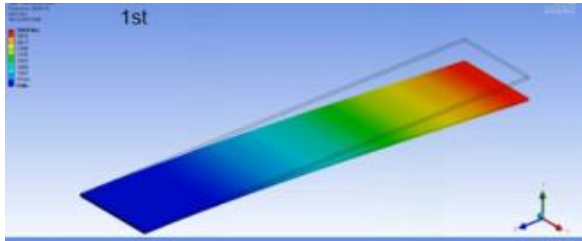
- **Prototypes, analyses, experimental tests:**
  - **Prototype: Thin multi-CMOS-chip structures** (CSIC-Valencia)

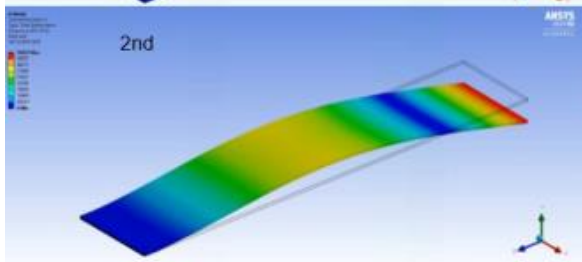


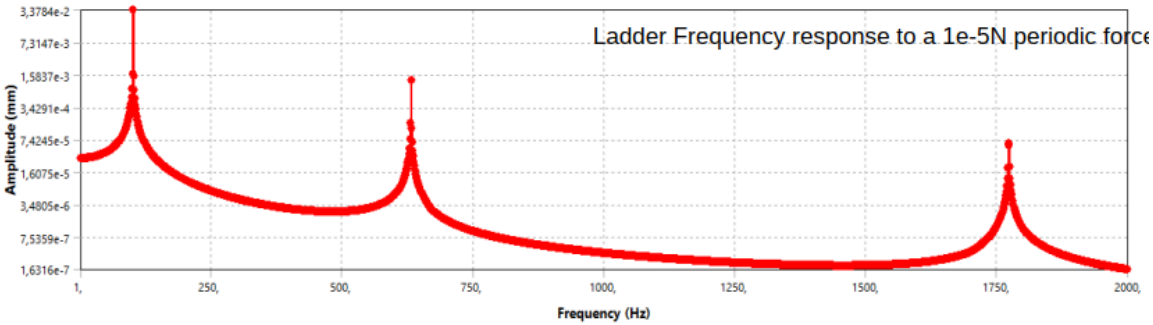
Vibration: FEA analysis



Vibration:
experimental and FEA analysis

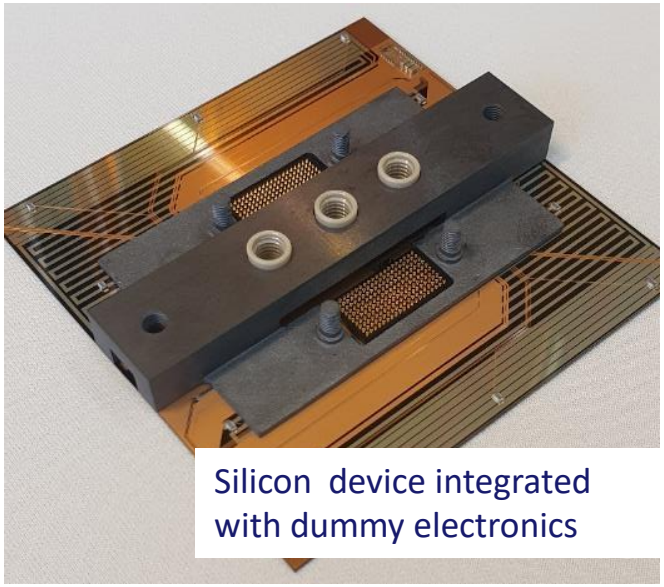




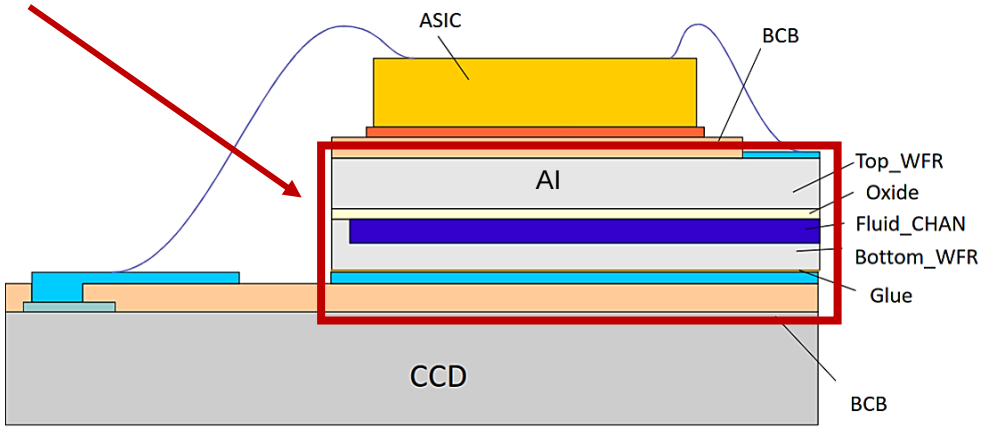


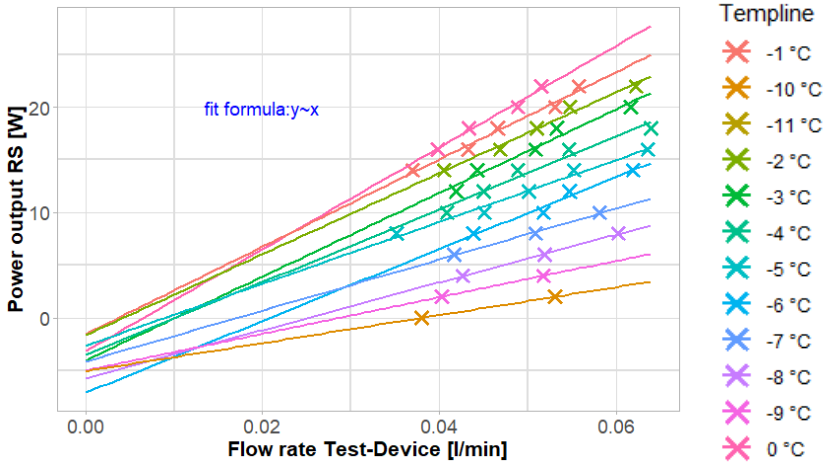
Task10.2a Silicon microchannel cooling technology

- **Prototypes, analyses, experimental tests:**
  - **Prototype: Single-Phase SOI-Based Microchannel Coolers** (MPG-HLL)



Silicon device integrated with dummy electronics

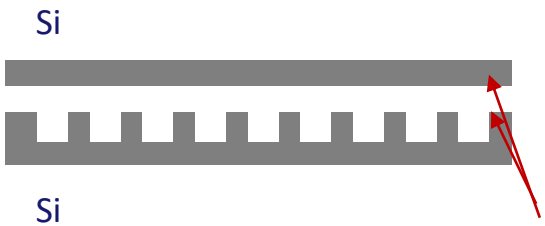




- **Experimental results:**
- 2.5 W/l/h heat removal at -10°C constant device temperature
- Additional heat input of -7W to -2W by radiation and conduction

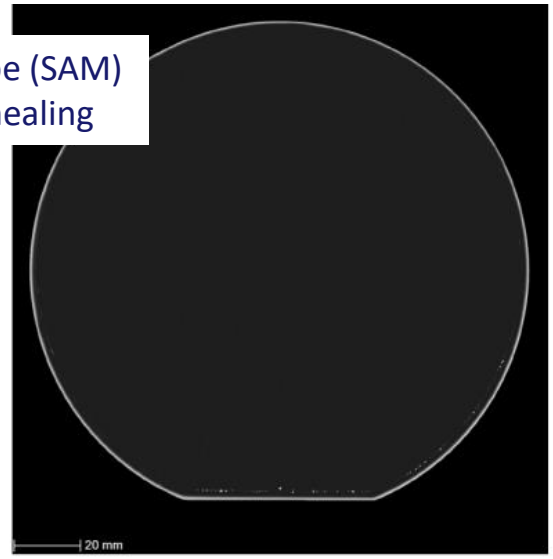
Task10.2a Silicon microchannel cooling technology

- **Fabrication development:**
  - **Bonding technics, CMOS compatible** (MPG-HLL)
    - Acquiring know-how on fabrication of silicon microchannel device
    - **Highlights: Si-Si direct bonding low temperature,** HLL is establishing a 200 mm post-processing line for integration of fluidic channels in sensor wafers, CMOS wafers or active interposers
  - Qualification runs with **low temperature** bonds at the equipment **manufacturer EVG** showed very promising results.
    - Bond energies of plasma activated bonds after low temperature annealing (below 350 °C) are around 2 J/cm2, comparable to high-temperature annealed bonds.



Plasma activation of the surfaces (increase hydrophilicity)
➔ Bonding temperature <350C

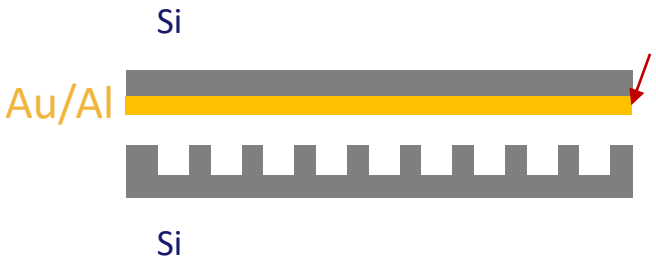
Scanning acoustic microscope (SAM) inspection after thermal annealing



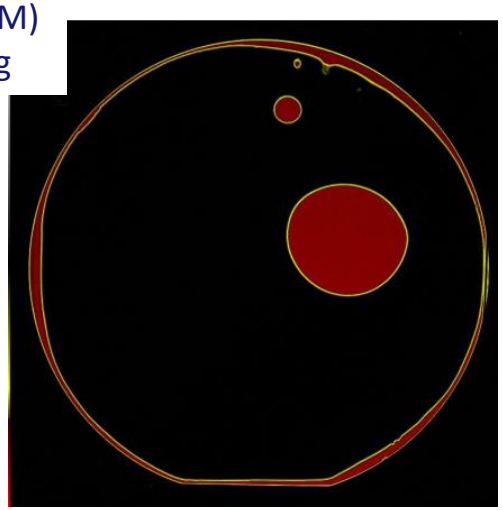
Task10.2a Silicon microchannel cooling technology

- **Fabrication development:**
  - **Bonding technics, CMOS compatible** (IMB-CNM)
    - Acquiring know-how on fabrication of silicon microchannel device
    - **Highlights: Eutectic bonding, low temperature ,** strong and hermetic bonds.
    - Wafer bonding technique with an intermediate metal layer that can produce a eutectic system.
  - Qualification runs with **low temperature** bonds on going

Scanning acoustic microscope (SAM) inspection after thermal annealing



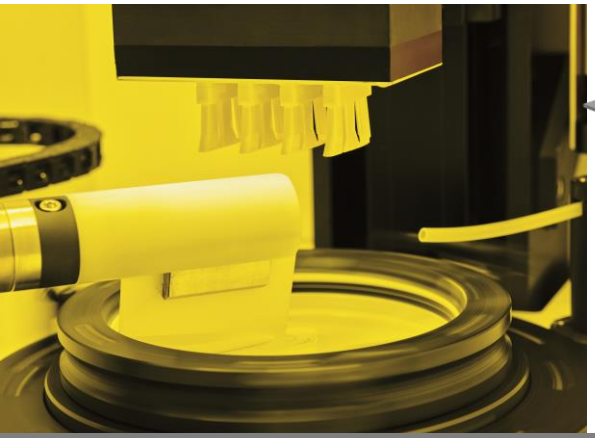
Eutectic system, low melting point

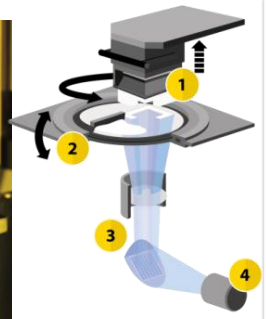


Task10.2b AM (micro)-channel cooling technology:

3D envelopment of integrated cooling circuits in the structure

- **Materials and AM:**
  - **AM:** Lithography-based Ceramic Manufacturing (LCM) technology.
  - **Ceramics:** Aluminum oxide (Al2O3),Aluminum nitride (AlN), **NEXT** Polymer-Ceramic composites.
  - **Target:** Define the optimal geometrical features attainable
    - Minimum achievable wall thickness of pipes/plates
    - Flatness optimization (Firing step, 1500-2000 C, warping effect).



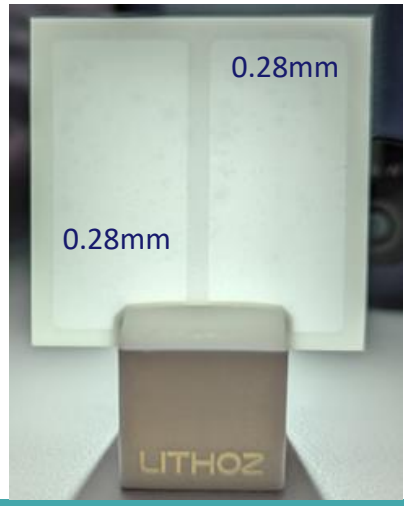


1 BUILDING PLATFORM
2 VAT
3 OPTICAL SYSTEM
4 LED

Blue light cures the photosensitive formulation

Click to watch a video about the LCM technology

30*30 mm2

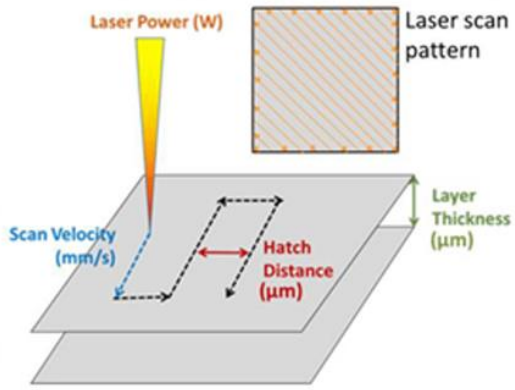


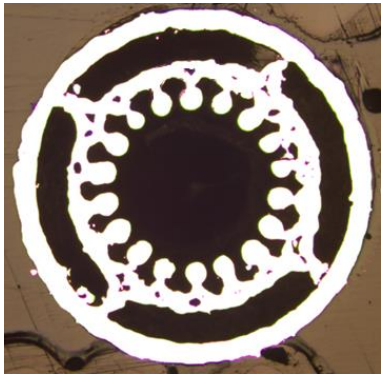
Task10.2b AM (micro)-channel cooling technology:

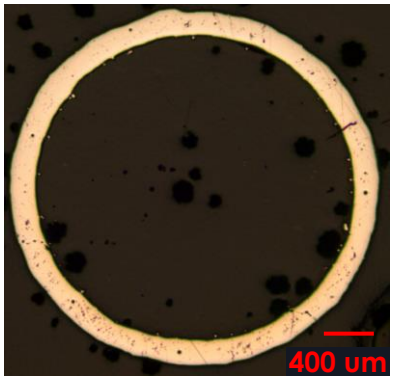
3D envelopment of integrated cooling circuits in the structure

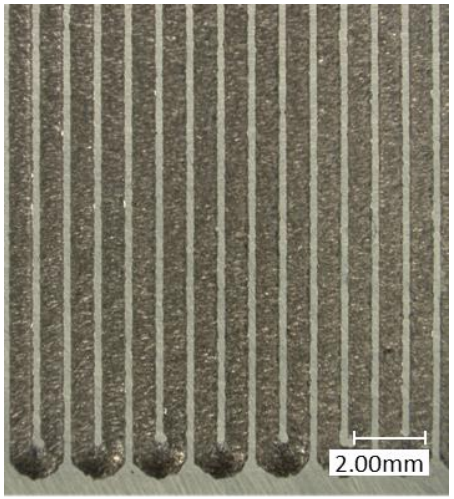
csem

- **Materials and AM:**
  - **AM:** Laser powder bed fusion (LPBF) technology.
  - **Metals:** Aluminum alloy (AlSi12), **NEXT** INVAR/COVAR (Si CTE matching)
  - **Target:** Define the optimal geometrical features attainable (e.g. min wall thickness of pipes/plates)
  - **ONGOING:**
    - Laser Power Tuning, Hot Isostatic Pressing (HIP) post-process
    - Different roughness in the same part (fluid dynamics)
    - Internal pipe structurization (induce phase transition)
    - internal porous pipe and external tight pipe (improve phase transition)







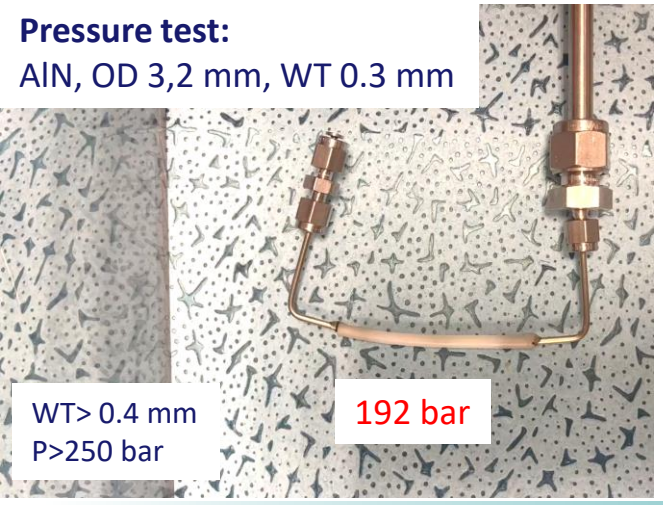


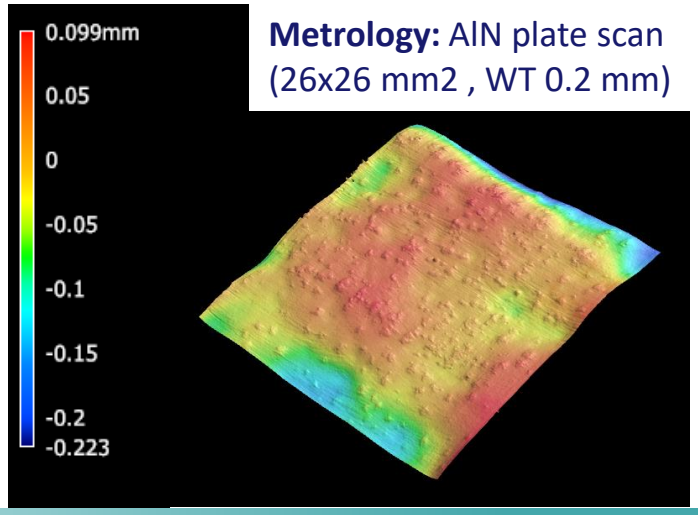
Task10.2b AM (micro)-channel cooling technology:

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

Leak-tightness:
Metal AlSi12,OD= 1.6 mm,
WT = 0.167mm, 1 line

Pressure test:
AlN, OD 3,2 mm, WT 0.3 mm

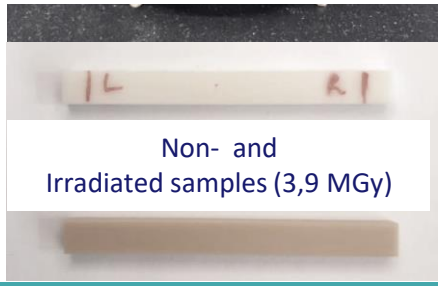




Metrology: AlN plate scan (26x26 mm2 , WT 0.2 mm)

Material properties investigation:

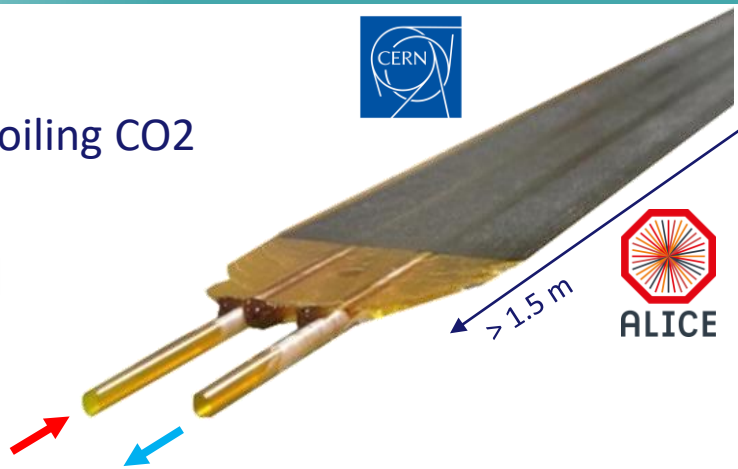
Aluminium cradle for
Irradiation test campaign



Non- and
Irradiated samples (3,9 MGy)

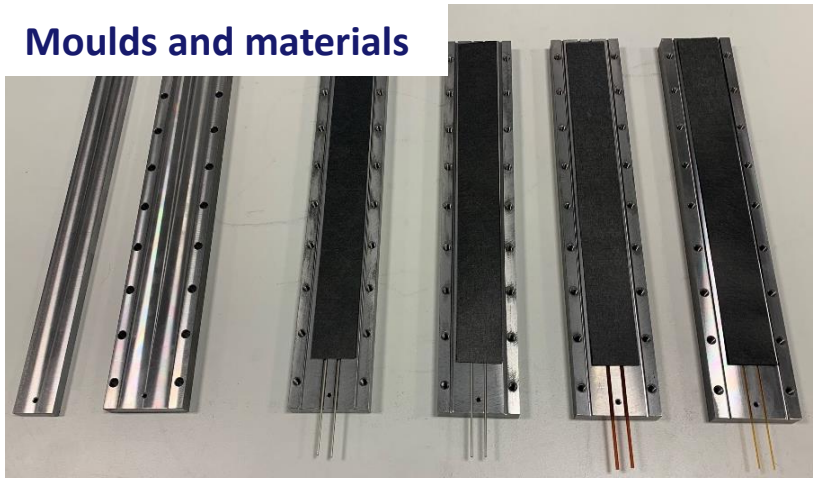
Task10.2c Ultralight carbon cooling technology

- Compatibility with boiling fluids
  - **Main outcomes:** Revised layout can operate with boiling CO2 (See B. Schmidt presentation, EP R&D).



- **ONGOING:** Cold plates production in series at Workshape industry partner.

Moulds and materials

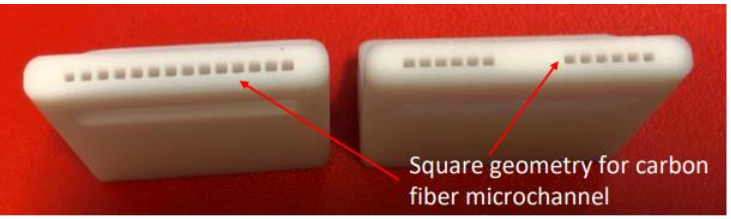


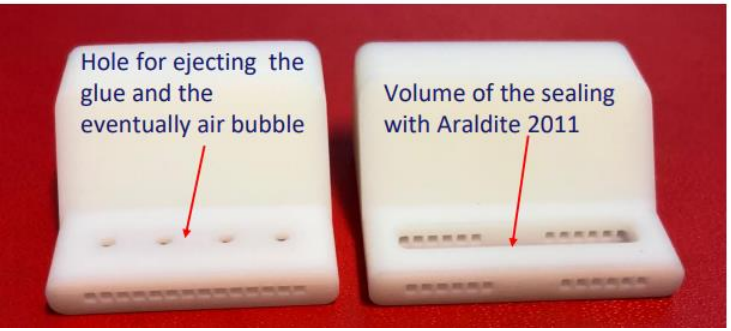
WORK | SHAPE
CONCEPTION . PROTOTYPAGE . COMPOSITES

CERN EP R&D WP4

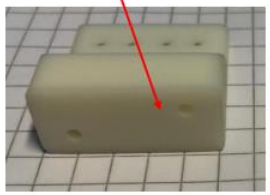
Task10.3 Hydraulic connections and interconnections

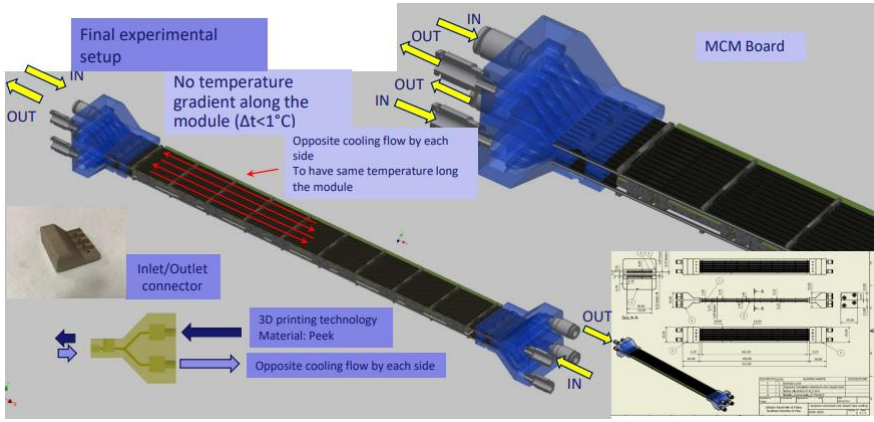
- Low-mass 3D printed PEEK connectors (CNRS-LPNHE)
  - Complex geometry manifold in rad-hard polymer ➔ PEEK
  - New leak-tight prototypes high pressure (>50 bar), new company: Bond 3D
  - **NEXT:** irradiation campaign
    New postdoc position will follow the task.





Holes for hydraulic connection





Task10.4 New coolants for warm and cold applications

- Supercritical-coolants: (CERN, NTNTU)

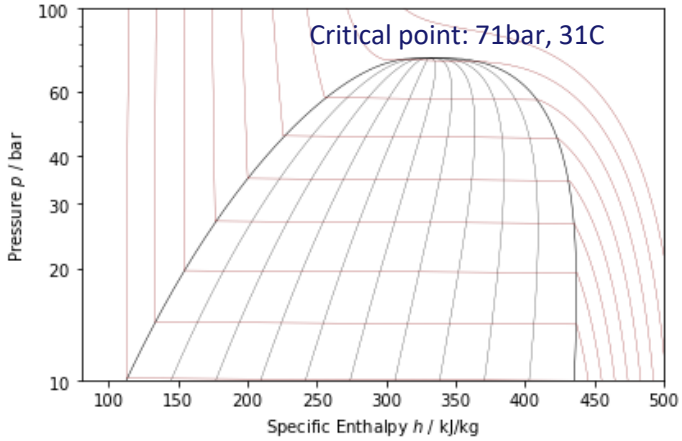
Tracking systems operating at

warm temperature

(Low radiation)

Supercritical CO2 (sCO2)

- In the range +32 C to + 40 C
- **Simplicity** of a single-phase cooling-like
  - Hydraulic pressure drop, gas-like
- Better heat and mass transfer properties than water.
- Dielectric fluid, **Natural refrigerant**
- Drawback: high-pressure fluid.

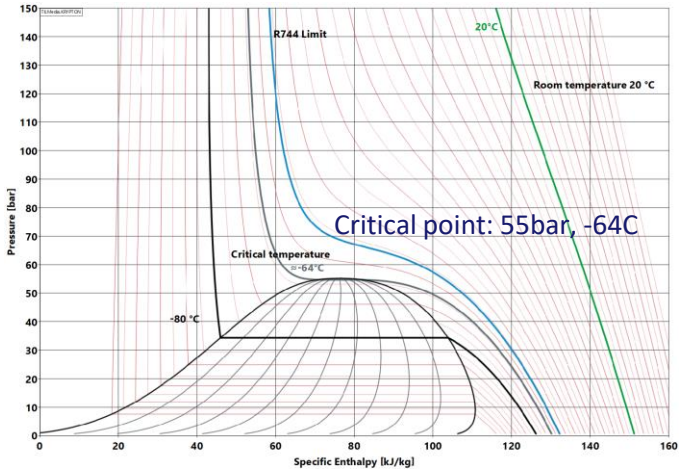


cold temperature (<-45 C)

(High radiation)

Supercritical Krypton (sKr)

- As low as **-60C**
- **Simplicity** of a single-phase cooling-like
  - Hydraulic pressure drop, gas-like
- Dielectric fluid, **Natural refrigerant**



Task10.4 New coolants for warm and cold applications

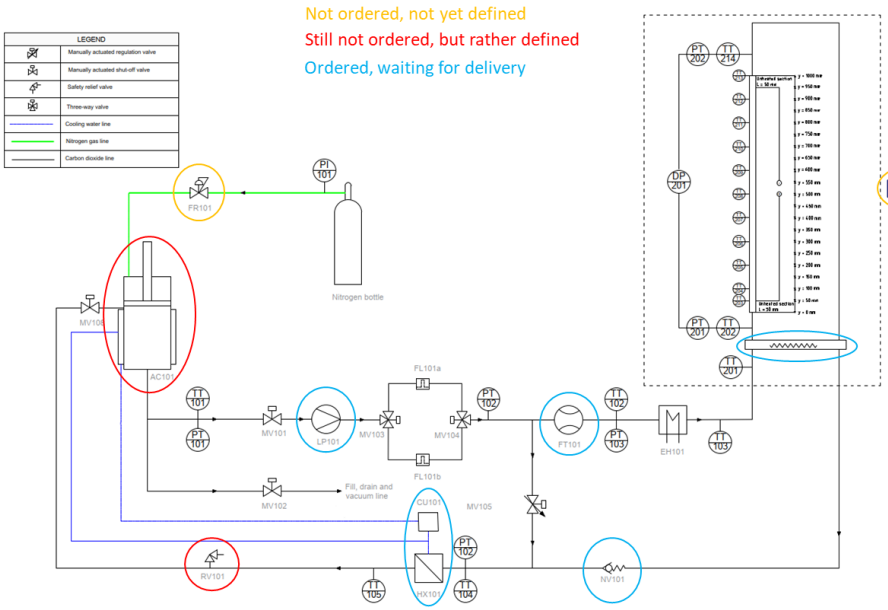
- Supercritical-coolants: (CERN, NTNTU)

Tracking systems operating at

warm temperature
(Low radiation)
Supercritical CO2 (sCO2)

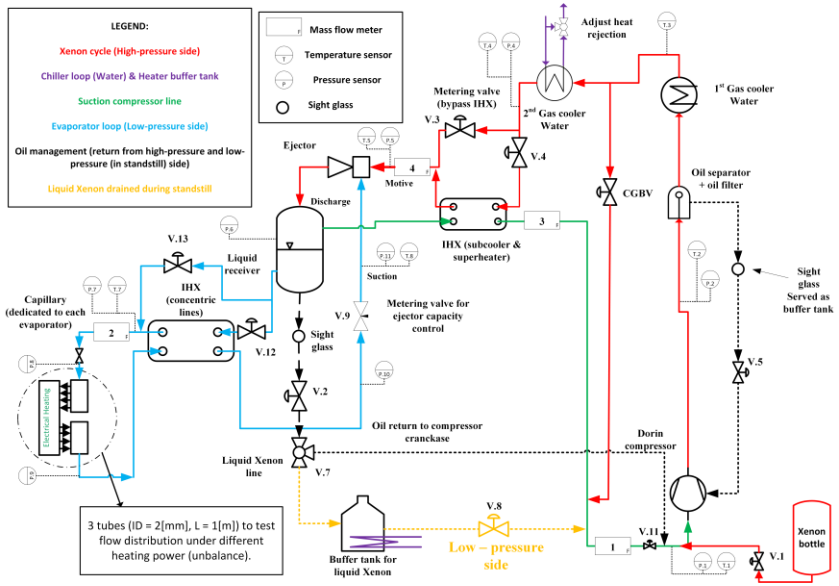
cold temperature (<-45 C)
(High radiation)
Supercritical Krypton (sKr)

- Test setup being build at CERN (within 2023).



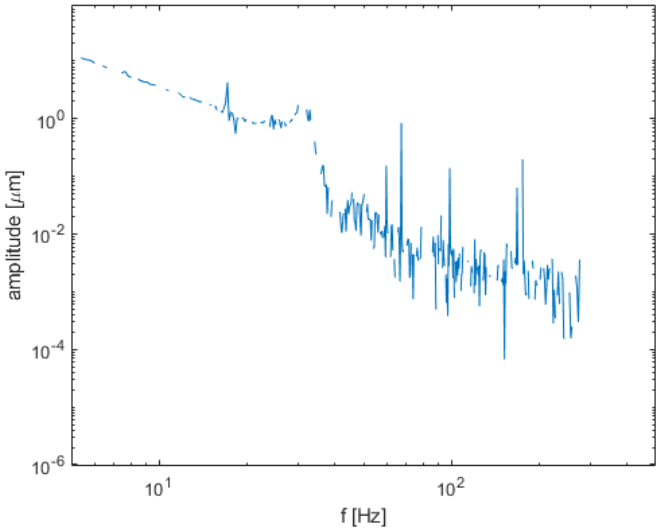
- Test set-up being built at NTNU (transferred at CERN after its completion)

(first phase, will use Xe instead of Kr, easier and less expensive)

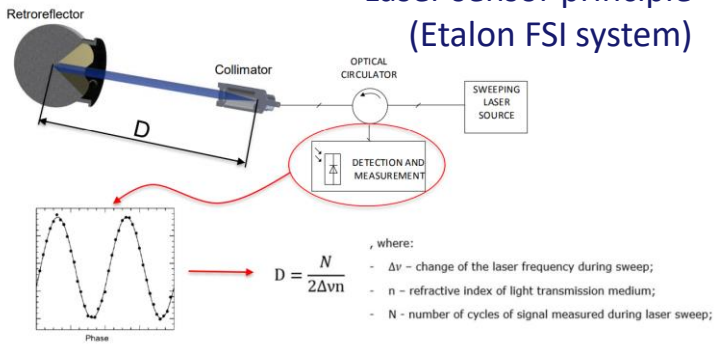


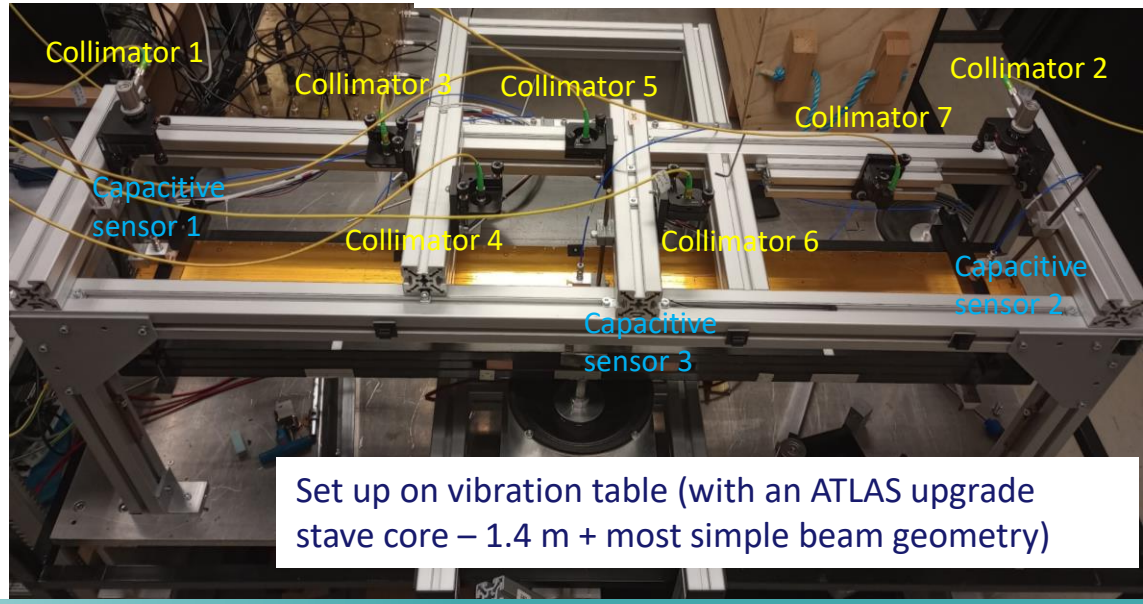
Task10.5 Accurate measurement of structures

- Frequency Scanning Interferometry (FSI) system (UNIOXF)
  - Non-contact displ. sensor, µm accuracy.
  - **Main updates:** First FSI Mirrorless measurement



Laser sensor principle (Etalon FSI system)





Set up on vibration table (with an ATLAS upgrade stave core – 1.4 m + most simple beam geometry)

THIS IS THE END…

Thank you
for your attention