H2020-INFRAINNOV-2019-2020: Demonstrating the role of Research Infrastructures in the translation of Open Science into Open Innovation

INFRAINNOV-04-2020: Innovation pilots

Type of Action: Research and Innovation action

Title of proposal: **Advancement and Innovation for Detectors at Accelerators**

Short name: **AIDAinnova**

WP10: Advanced Mechanics for Tracking and Vertex detectors

Work Package number	10		**Lead beneficiary**		CERN - CSIC	
Work Package title	**Advanced Mechanics for Tracking and Vertex Detectors**					
Participant number	1	31	36	22	2	15
Short name of participant	CERN	CSIC	CSEM	INFN	LIT	MPG-HLL
Person months per participant:	9.2 (36.8)	11 (24.5)	4 (8.5)	4 (8)	6.7 (6.8)	2.8 (6.2)
Participant number	11	8	26	43	13	
Short name of participant	WORK SHAPE	CNRS	NTNU	UOXF	ETALON	
Person months per participant:	2.5 (2.5)	35 (0)	4.9 (10.1)	9 (23.8)	6.7 (4.3)	
Start month - End month	M1- M48					

Objectives

Task 10.1. Coordination and Communication

See introductory section on page 29.

Task 10.2. Engineering of optimised cooling substrates

- Develop the process of cooling channel integration in CMOS structures into scalable solutions
- Define the optimal geometrical features attainable for 3D printed ultra-thin cold plates in metal alloys and ceramic composites
- Implement the full integration of cooling features into ultra-light carbon composite structures

Task 10.3. Micro-connectivity

- Define advanced engineered solutions for the hydraulic interconnection of multiple micro-structured silicon cold plates

Task 10.4. Supercritical CO2 as refrigerant

- Characterise Supercritical CO2 (sCO2) as a possible ultra-effective single-phase refrigerant for "warm" detector cooling
- Study the design of new supercritical heat exchangers for optimal energy recovery at higher temperatures in transcritical CO2 cycles

Task 10.5. Characterisation of ultra-light structures

- Evaluate the feasibility of a new version of the existing Frequency Scanning Interferometry (FSI) instrumentation suited for use as an accurate survey of ultra-light and small detector structures

- Refine and standardize the methodology for vibration and distortion measurements in view of new and more precise specifications for future detectors

Description of work

Task 10.1. Coordination and Communication (CERN, CSIC-IFIC)

See introductory section

Task 10.2. Engineering of optimised cooling substrates (CSIC-IFIC, CSIC-CNM, CERN, CSEM, INFN-PI, INFN-PG, *LIT*, MPG-MPP, *WORKSHAPE*)

The groups involved in this task will develop several new approaches to integrate active cooling solutions in silicon detector systems. The innovative solutions improve the cooling performance while minimising the contribution to the material budget and provide a promising testbed for applications in other areas.

Sculpting in silicon: Integrated micro-channels in silicon sensors (CSIC-IFIC, CSIC-CNM, CERN, INFN-PI, INFN-PG, MPG-HLL)

Modern semiconductor processes allow for the integration of the cooling system in the silicon sensor itself, thus ensuring direct thermal contact, perfectly matched thermal expansion coefficients, and minimal impact on the material budget. This Task builds on two complementary processes demonstrated in AIDA-2020 and will develop these into a scalable and mature solution, compatible with the requirements of advanced CMOS sensors. A realistic demonstrator ladder will be produced in collaboration with WP5.

Ultra-light 3D-printed cold plates (CERN, CSEM, *LIT*)

Leveraging on the recent progresses in Additive Manufacturing technologies ("3D-printing"), the task will target standardised and reliable approaches to produce 3D-printed high precision micro-channel cold plates. Different metallic alloys and ceramic composites will be studied and experimentally characterised. The minimum channel cross section attainable for a fixed channel length will be investigated, thus providing clear guidelines for the engineering of the future advanced detector cooling solutions.

Ultra-light composite structures with fully integrated cooling (*WORKSHAPE*, CERN)

This activity will optimise production of ultra-light composite support structures with integrated cooling. It will focus on heat exchangers made of carbon fibre composites with embedded ultra-thin polymeric micro-pipes compatible with high-pressure liquid coolants. The design and production of heat exchangers made of carbon foam radiator for forced air cooling will be studied, to be used for very low power applications.

Task 10.3. Micro-connectivity (CNRS-LPNHE)

The problematic of interconnectivity between different micro-channel devices still represents one of the most challenging aspects of micro-channel cooling and a fundamental limiting factor to a more generalised adoption of this high performing approach. This issue will be tackled by studying in particular the integration with silicon devices of 3D-printing techniques based on new materials. The work will aim at greatly simplifying the design of some of the parts, and at studying the integration of the connection in the interior part of the cooling element. Based on initial studies, prototypes of hydraulic interconnecting elements will be tested on samples produced in the AIDA-2020 project. A possible small *ad hoc* production of new devices optimised for interconnectivity is envisaged for the final phase of the activity.

Task 10.4. Supercritical CO2 as refrigerant (NTNU, CERN)

Supercritical CO_2 (sCO_2), a special status attained by CO_2 above 31 °C and 76 bar, can in principle provide extremely effective single-phase cooling in extremely small pipes and micro-heat exchangers, with values of the heat transfer coefficient comparable to those typical of two-phase flows, but with much lower pressure drops and much more controllable flow conditions.

The activity will target two different applications of sCO_2: on the one hand its use as ultra-effective single-phase refrigerant for detector cooling at temperature in the range +32 to +45°C; and on the other hand, the special design of new supercritical heat exchangers for optimal energy recovery at higher temperatures in trans-critical CO_2 cycles. In addition, the partners will launch detailed studies of the thermohydraulic phenomena in small pipes passing across the critical point, which are also useful as a base for other potentially interesting supercritical fluids at lower temperatures.

Task 10.5. Characterisation of ultra-light structures (UOXF, *ETALON*)

The central infrastructure for the characterisation of the mechanical performance of advanced and transparent silicon sensors at UOXF will be further developed and made available to groups inside and

outside AIDAinnova. The methodology for vibration and distortion measurements will be refined and a standardised interpretation and formulation of detector specifications will be developed. In particular, the partners will evaluate the feasibility of a new version of the existing Frequency Scanning Interferometry (FSI) instrumentation requiring substantially smaller reflectors – or even directly sensitive to material reflection properties – for a similar precision in absolute position determination. Such a new instrumentation would be potentially used for accurate survey of ultra-light and small structures. The infrastructure will be used to characterise advanced prototypes from several groups and a comprehensive set of measurements will be made available for use in the design of future detectors.

Deliverables related to WP10	
D10.1 Cooling Device Demonstrators *Set of at least three demonstrators, one per technology developed, accompanied by a report*	M46
D10.2 Hydraulic Interconnection Technologies *Report on validated technologies and their applications*	M43
D10.3 Supercritical CO_2 as a refrigerant *Publication (submitted) on the use and properties of sCO_2 as refrigerant*	M44
D10.4 Upgraded FSI *Feasibility study of new mirrorless FSI*	M45

Table 3.2: List of Deliverables (in Task order within a WP)

Deliverable No	Deliverable name	Work Package No	Lead partici-pant	Type	Dissemi-nation level	Delivery date
D10.1	Cooling device demonstrators	10.2	CSIC	R/ DEM	PU	M46
D10.2	Hydraulic interconnection technologies	10.3	CNRS	R	PU	M43
D10.3	Supercritical CO_2 as a refrigerant	10.4	NTNU	R	PU	M44
D10.4	Upgraded FSI	10.5	UOXF	R	PU	M45

Table 3.3: List of milestones

Milestone number	Milestone name	Related Work Package(s)	Due date	Means of verification
MS41	Combined work plan with objectives and test definition for all technologies	10.2	M11	Report
MS42	Work plan taking also into account the detailed programme announced in MS10.1	10.3	M12	Report
MS43	Plan of investigation and prototyping for development of mirrorless FSI	10.5	M15	Report
MS44	Mid-time report detailing the new experimental facility and results from the theoretical studies.	10.4	M22	Report