INFN PADOVA

Development & Innovation on Additive Manufacturing

DIAM for High Energy Particle Physics

- Detectors for HEP
- Parts for HEP accelerating machines

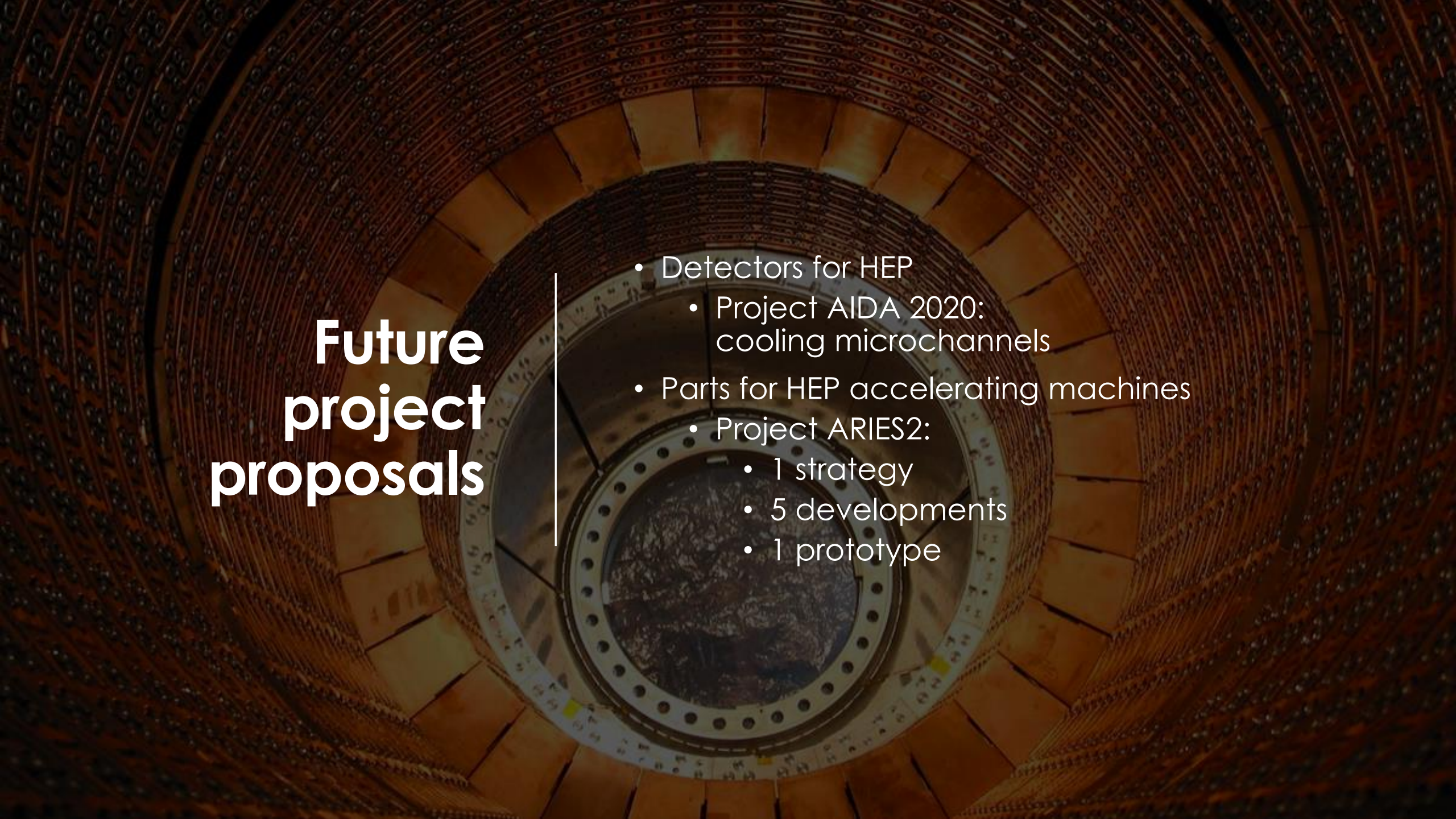
Ing. Adriano Pepato – INFN PD

http://diam.pd.infn.it

UNIONE EUROPEA
Fondi strutturali e di investimento europei

REPVBBLICA ITALIANA

POR FSE 2014-2020
REGIONE DEL VENETO



Future project proposals

- Detectors for HEP
  - Project AIDA 2020: cooling microchannels
- Parts for HEP accelerating machines
  - Project ARIES2:
    - 1 strategy
    - 5 developments
    - 1 prototype

ARIES 2

ARIES2 Strategy

Additive Manufacturing for the Accelerator community (prof. M. Vedani – PoliMi)

The uptake of AM in the accelerator sector implies deep expertise in fields such as

- ultra-high vaccum
- radiofrequency
- magnetism
- cryogenic behaviour of materials
- materials science
- manufacturing engineering
- ecc.

The partners of the project were selected so as to form a multidisciplinary team showing high qualification for the proposed task

ARIES2 - Strategy

Components

Component	Ref.	Application	Material	Estimated TRL	Location	Description	Requirements	Image
Fast beam wire scanner fork	[1]	CERN Beam Instrumentation Group	Al; Cu; Ti6Al4V	7	Beam Wire Scanners	This component the measures size of the proton beam. This component is part of the so called "fork" of BWS that senses the wire that passes the electron beam.	UHV of 10^{-12} mbar V: 20 ms^{-1} A: 15600 $rad\,s^{-2}$ Radiation: 20 kGy	
RF Filter	[6]	CLIC	Cu plated Al; Cu plated polymer SLA	3	X band production team	The filter has two functions, let pass the desired frequency and reject as much of the undesired frequencies as possible.	filter out the 24 GHz	
CLIC RF charge and inner filter	[2]	X-band technology to test CLIC accelerating structure prototypes	Ti6Al4V	7	Xbox3	This component acts as a "cable" for super high frequency. It is designed to work in the microwave region of the electromagnetic spectrum in the X-band frequency.	Vacuum of $5 \cdot 10^{-8}$ mbar τ_p: 50 – 200 ns f: 200 Hz P: 2,1 KW	
Quadrupole	[3]	the EuroCirCol (ECC) Project, the 16 T Magnet Technology Program and the USMag-net Development Program	Nb_3Sn	3	FCC design study	The quadrupoles guide the magnet field. One of their uses correct horizontally and vertically the bema by inducing a magnetic dipole moment on it.	T: 2 K Cu/nonCu: 0,8 T hot spot: 350 K Vacuum of $5 \cdot 10^{-8}$ mabr	
Spiral load	[2]	X-band technology to test CLIC accelerating structure prototypes	Ti6Al4V	7	Xbox3	This component acts as a "cable" for super high frequency. It is designed to work in the microwave region of the electromagnetic spectrum in the X-band frequency.	τ_p: 50 – 200 ns f: 200 Hz P: 2,1 KW Vacuum of 5·10-8 mbar	
HOM coupler for crab cavity DQW	[7]	Part of the High Luminosity Large Hadron Collider project	Nb	3	LHC 2025	The function is to provide a transverse electromagnetic kick to a proton bunch, allowing bunch rotation which leads to an increase in luminosity.	Bandwidth: 16.8MHz at 100 dB Ra: 0,07 µm RRR<300	
15 T dipoles	[3]	the EuroCirCol (ECC) Project, the 16 T Magnet Technology Program and the USMag-net Development Program	Nb_3Sn	3	FCC design study	The dipoles guide the magnet field. One of their uses correct horizontally and vertically the bema by inducing a magnetic dipole moment on it.	T: 2 K Void%: 0,2- 0,4 Cu/nonCu: 0,8 T hot spot: 350 K	
Beam screen Stability Springs	[8]	The EuroCirCol (ECC) project	Ti6Al4V	7		The spring support a series of zirconium oxide (ZrO_2) spheres. These spheres are the only point of contact between the beam screen and the cold bore.	Compression 7,5 – 15 N Base temperature: 75 – 90 K	
Solenoids	[4]				Storage ring KARA (Karlsruhe Research Accelerator) light source	The solenoid controls the magnetic field. The controlled magnetic fields help to focus and accelerate the electron beam.	T: 2,7 – 3 K Induction: 5,9 T Coil current: 141 A Heat load: 280 – 560mW	
Beam position monitor	[5]	PHIL Photoinjector (3 MeV electrons) at LAL	316L stainless steel	7	ThomX project	This component is used to determinate the deviation of the beam under vacuum condition.	Ultra-high vacuum of 10^{-9} Pa	

Brief list of the Partners

	Name	Short name	Country	Contact Person	Institution Type*
1	Politecnico di Milano, Dept. of Mechanical Engineering	PoliMi	Italy	Maurizio Vedani maurizio.vedani@polimi.it	University
2	Riga Technical University	RTU	Latvia	Toms Torims Toms.Torims@rtu.lv	University
3	Tallinn University of Technology	TalTech	Estonia	Tauno Otto tauno.otto@ttu.ee	University
4	Conseil Européen pour la Recherche Nucléaire	CERN	CH	**	Laboratory
5	Centre National de la Recherche Scientifique	CNRS	France	Nicolas Delerue delerue@lal.in2p3.fr	Laboratory
6	Fraunhofer Institute for Material and Beam Technology	IWS	Germany	Frank Brückner Frank.Brueckner@iws.fraunhofer.de	Research Centre
7	French Alternative Energies and Atomic Energy Commission, IRFU	CEA	France	**	Laboratory
8	Istituto Nazionale di Fisica Nucleare, Padova	INFN	Italy	Adriano Pepato pepato@pd.infn.it	Laboratory
9	H.C. Starck Tantalum and Niobium GmbH	HC	Germany	Markus Weinmann	Industry
10	Rösler – Surface Technology Srl (Italy), a company of the Rösler Holding GmbH	ROS	Italy	Maurizio Foppa Pedretti M.FoppaPedretti@rosler.com	Industry
11	Alsyom-Alcen	ALS	France	Eric Giguet egiguet@alsyom-alcen.com	Industry

The main role is summarized in the following table

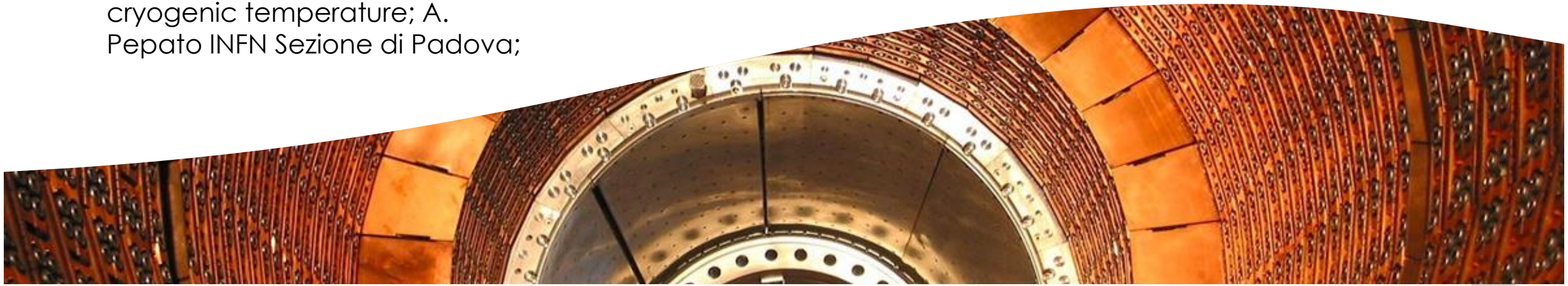
Short name	Description of main role / expertise
PoliMi	Project leader. Material science & AM Technology
RTU	AM system technology
TalTech	[illegible] solutions and networks, economical assessm[illegible]
CERN	[illegible] accelerator[illegible] solutions for [illegible] components
CNRS	[illegible] solutions for particle accelerators
IWS	AM technological solution development
CEA	[illegible] implementation of AM [illegible] accelerators
INFN	Development of AM components for particle accelerators
HC	Material supplier, development of new alloy powders
ROS	Surface finishing solutions for AM
ALS	Manufacturer of RF components based on Copper

ARIES2 Developments

Additive Manufacturing for the Accelerator community (prof. M. Vedani – PoliMi)

Five different Developments proposals have been formulated inside the Strategy

- **Dev2.1** - Validation of accelerators components built by additive manufacturing; N. Delerue CNRS/IN2P3;
- **Dev2.2** - Development of superconductive RF cavities, made by Nb or Cu coated thin film, to be tested at room and at cryogenic temperature; A. Pepato INFN Sezione di Padova;
- **Dev2.3** - Improvement of Additive Manufactured RF Components by Laser Radiation; A. Medvids, Riga Technical University;
- **Dev2.4** - Design of Magnet Poles by Additive Manufacturing; M. Vedani, Politecnico di Milano, DME;
- **Dev2.5** - Repair of damaged accelerator components by AM technologies; E. Lopez, Fraunhofer Institute for Material and Beam Technology.



ARIES2 Developments

Dev2.1 - Validation of accelerators components built by additive manufacturing

N. Delerue CNRS/IN2P3

This development aims at

- validation
- long-term test

of Accelerator components in real operation conditions.

During this development we will build on previous achievements to design and build accelerators components suitable to installation in accelerators. These components will then be installed in accelerators and their performances monitored during the project. This will allow to demonstrate that

- AM components can be used in accelerator
- there is no effect on their performances

during long service in the hostile accelerator environment.

ARIES2 Developments

Dev2.1 - Validation of accelerators components built by additive manufacturing

N. Delerue CNRS/IN2P3

Short name	Contact Person	Institution Type*
CNRS	Nicolas Delerue	Research Center
TalTech	Tauno Otto	University
IWS	Elena Lopez	Research Center
PoLiMi	Maurizio Vedani	University
IP		Industry

ARIES2 Developments

Dev2.2 - Superconductive RF cavities, made of Nb/Cu-coated thin film. To be tested at room and at cryogenic temperature

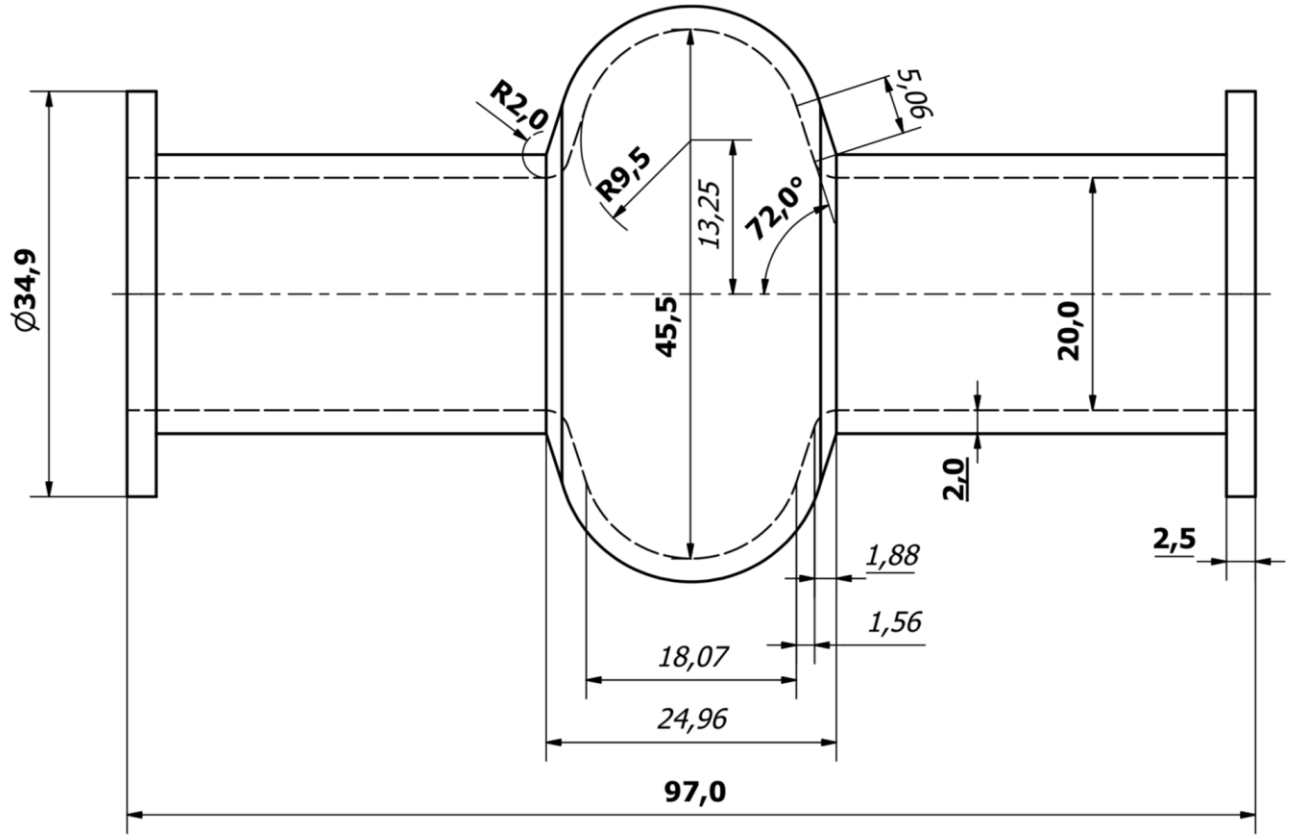
A. Pepato INFN Sezione di Padova

This development aims at

- design & test

the relevant properties of AM Nb-made RF cavities in room&cryogenic temperature conditions.

The relevant cost of the Nb powders induces also in investigate the feasibility of a partial or full replacement of it, with alternative materials (e.g. pure Cu / Cu alloys), for the realization of the RF cavity body, while providing the realization of a thin layer of Nb at the inner surface, to guarantee the superconducting performances of RF cavities.



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1	Istituto Nazionale di Fisica Nucleare (INFN PD and LNL)	INFN	Italy	Adriano Pepato	Laboratory
2	Centre National de la Recherche Scientifique CNRS	CNRS	France	Nicolas Delerue	Labortory
3	Fraunhofer Institute for Material and Beam Technology, IWS	IWS	Germany	Frank Brueckner	AM Technological solution development
4	Roesler – Surface Technology srl (Italy) a company of Roesler Holding Gmbh	ROS	Italy	Maurizio Foppa Pedretti M.FoppaPedretti@rosler.com	Industry
5	H.C. Starck Tantalum and Niobium GmbH	HC	Germany	Markus Weinmann	Industry

ARIES2 Developments

Dev2.5 - Repair of damaged accelerator components by AM technologies

E. Lopez, Fraunhofer Institute for Material and Beam Technology

The improvement of crystallinity and stoichiometry od thN superconducting compounds is proposed using laser radiation. These compounds belong to the most promising superconducting coating materials for RF cavities of the next gen. Laser radiation allows also to increase the grain size of the material and to improve its adhesion to Cu substrate allowing a better coupling on a curved inner surface of a cavity.

The project aims at the development of strategies to repair damaged accelerator components by means of AM. Expensive and complex components that are damaged by thermal fatigue cracks or any other reason can be refurbished by removing the damaged volume and depositing the missing volume of material according to an AM approach. Critical parts for accelerators require well defined and validated procedures for surface preparation, filler material selection and deposition parameters. Evaluation of the refurbished part performance is also essential to raise confidence on this approach.

	Name	Short name	Country	Contact Person	Institution Type*
1	Riga Technical University	RTU	Latvia	Artur Medvids *medvids@latnet.lv*	University
2	Politecnico di Milano, Dept. of Mechanical Engineering	PoliMi	Italy	Maurizio Vedani maurizio.vedani@polimi.it	University
3	Science and Technology Facilities Council	STFC	UK	Oleg Malyshev oleg.malyshev@stfc.ac.uk	Laboratory
4	Rösler – Surface Technology Srl (Italy), a company of the Rösler Holding GmbH	ROS	Italy	Maurizio Foppa Pedretti M.FoppaPedretti@rosler.com	Industry

Dev2.4 - Design of Magnet Poles by Additive Manufacturing

M. Vedani, Politecnico di Milano DME

The project aims at the development of design approaches and at testing relevant properties of Additively Manufactured alloys for their use as magnet poles. Selection of suitable alloys with respect to magnetic behavior and mechanical strength, evaluation of their printability by AM, setting of design rules for poles having complex shape are the main objectives of this development project

	Name	Short name	Country	Contact Person	Institution Type*
1	Fraunhofer Institute for Material and Beam Technology	IWS	Germany	Elena Lopez Elena.lopez@iws.fraunhofer.de	Research Institution
2	Centre National de la Recherche Scientifique	CNRS	France	Nicolas Delerue delerue@lal.in2p3.fr	Laboratory
3	CEA	CEA	France	***	Laboratory
4	HC Starck	HC	Germany	Markus Weinmann	Industry
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3	Centre National de la Recherche Scientifique	CNRS	France	Nicolas Delerue delerue@lal.in2p3.fr	Laboratory
4	Fraunhofer Institute for Material and Beam Technology	IWS	Germany	Frank Brückner Frank.Brueckner@iws.fraunhofer.de	Research Centre
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5	Istituto Nazionale di Fisica Nucleare, Padova	INFN	Italy	Adriano Pepato pepato@lnl.infn.it	Laboratory
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ARIES2 Prototype

Design approach of new-ge

This prototyping project a
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3	Conseil Européen pour la Recherche Nucléaire	CERN	Switzerland	**	Laboratory
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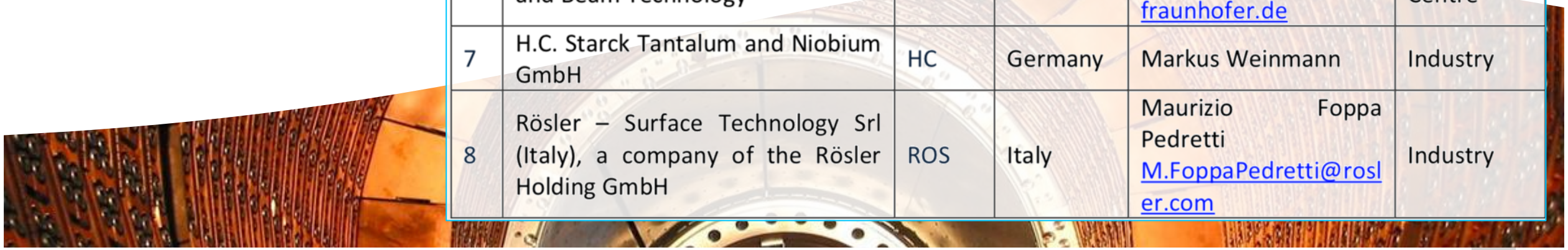


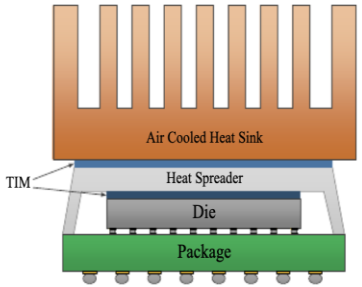
AIDA 2020

HEP detectors. Microchannels for cooling applications

AIDA 2020

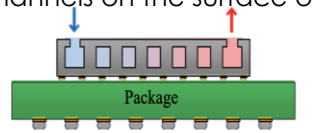
Microchannels on the surface of the die

Traditional, air based



(a)

Microchannels on the surface of the die



(b)

Fig. 1. (a) Traditional microelectronic system (b) Microelectronic system with monolithically integrated microfluidic heat sink

Sarvey, Zhang, Cheung, Gutala, Rahman, Dasu, Bakir (2017)
Monolithic Integration of a Micropin-Fin Heat Sink in a 28-nm FPGA.
IEEE Transactions on Components, Packaging and Manufacturing Technology. PP. 1-8.
10.1109/TCPMT.2017.2740721

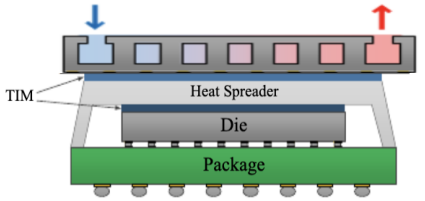
Pros compared to traditional heat-sinks:

- More efficient way to cool down the device (e.g. high surface/volume ratio, low thermal resistances between the fluid and the circuit dissipating power)
- Less obstruction for traditional air based cooling for other boards components
- It overcomes limitations on device density on PCB due to the limited air based cooling capability of crates

Cons compared to traditional heat-sinks:

- Risks due to manipulation of the bare die
- Probably less suitable for large scale systems (in case we need to manipulate O(1k) devices)

Microchannels on metallic plate with AM



Pro WRT channels on the surface of the die:

- No need to manipulate bare die
- Easier to use on commercial electronic devices
- Manufacturing capability of smaller metallic inlet and outlet

Cons WRT channels on the surface of the die:

- Maybe less efficient in cool down the device due to the presence of the heat spreader and of the TIM.

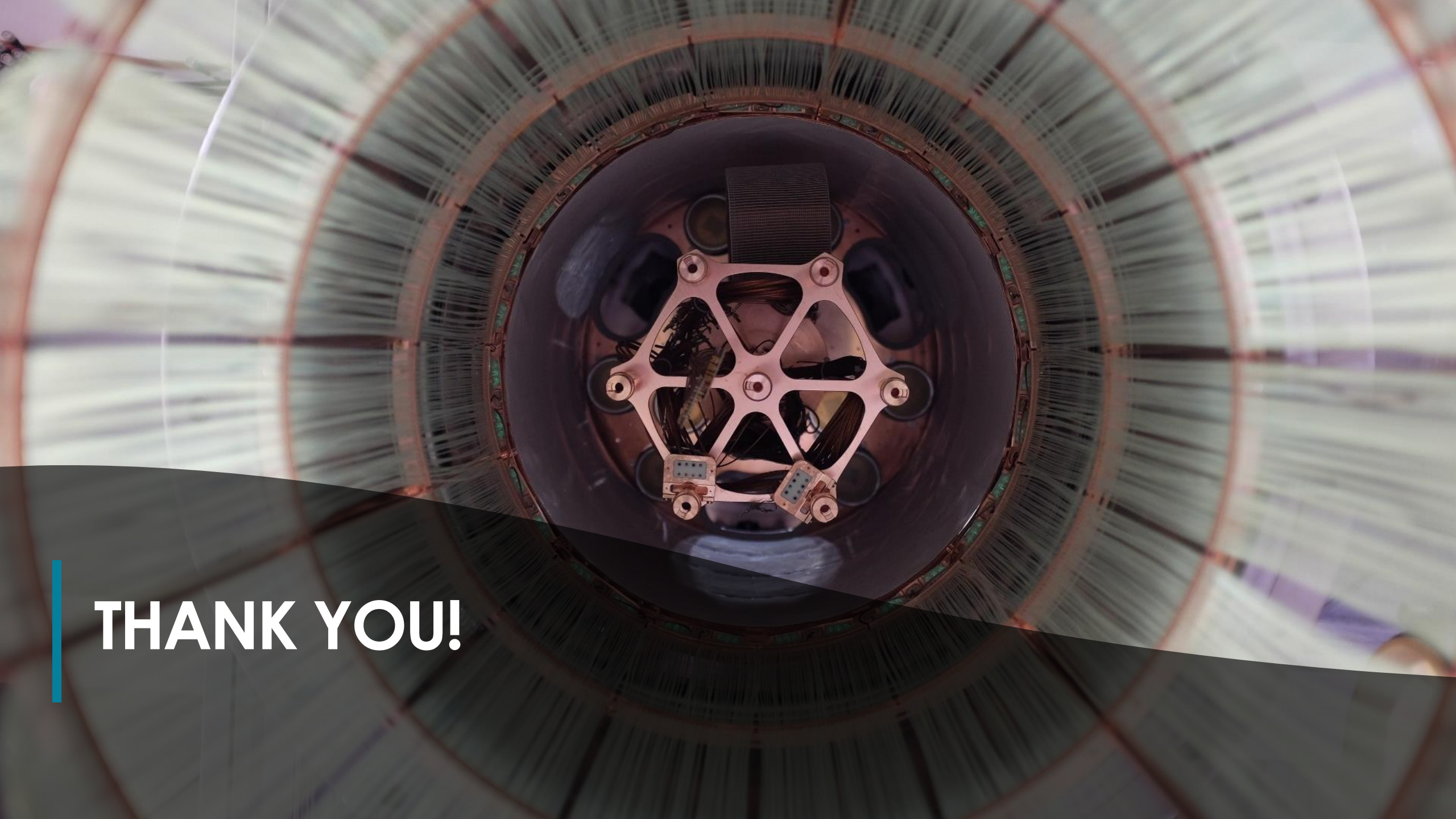
TO BE STUDIED

Studies ongoing on microchannel cooling for FPGAs

INFN Grant: CoolFPGA (2019-2021)

In collaboration with **FBK**

PI: A. Coccaro (INFN-Ge), P. Francavilla (INFN-Pi)
People involved: M. Boscardin (FBK), F. Bosi (INFN-Pi) M. Massa (INFN-Pi), F. Palla (INFN-Pi), R. Dell'Orso (INFN-Pi)
It could be very interesting to compare the two options.



THANK YOU!