MUR - BANDO 2022

UNIVERSITÀ
DEGLI STUDI
DI PADOVA

PRIN Ultra-low vibration thermal switch for Pulse Tube cryocoolers (Cool Vibes)

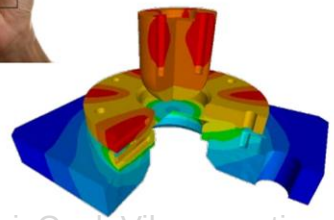
Irene Calliari, UNIPD-Department of Industrial Engineering (DII)
https://research.dii.unipd.it/grimp/

DEPARTMENT OF INDUSTRIAL ENGINEERING

Staff

- over **100** faculty members
- over **100** research assistants and postdoctoral research fellows
- ~**80** administrative & technical staff
- **48** research labs

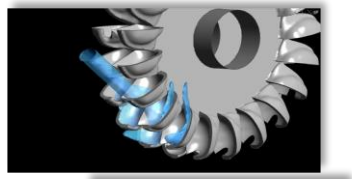
The Department clusters together all the main expertise in industrial engineering promoting innovation through **excellence** and **competitiveness** in research



Mission

The **Department promotes and manages teaching and research**, as well as **technology transfer** in all fields of Industrial Engineering:

- **Aerospace Engineering**
- **Chemical and Environmental Engineering**
- **Electrical Engineering**
- **Mechanical Engineering**
- **Material Engineering**
- **Thermomechanical Energy Engineering**



An **interdisciplinary approach** and **constant co-operation** with leading foreign Universities and Research Centres grant high international standards in its activities.

Research - 2

bioengineering, biotechnology and health technologies

energy

management and entrepreneurship

materials

industrial products and processes

The **9** research fields at DII

industrial and civil safety

aerospatial systems

electrical systems

mechanical systems

DII metallurgy group (GRIMP) : People and Expertise

….From the PRIN form:

The University will take part to the project through the Department of Industrial Engineering (DII), where competences are **available in metallurgy and mechanical engineering necessary to the aim of the project.**
In particular DII metallurgy group has facilities and expertise to perform proper **chemical analysis of the metals….. optical (OM)and electron microscopes (SEM,TEM) for the materials characterization, facilities for metallographic preparation, hardness, tensile and fatigue resistance machine testers in order to measure the mechanical properties and XRD….**

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DII- GRIMP and Cool_Vibes
A.Benato (ex-L.Pezzato) P.I
M.Pigato, A.Zambon and I.Calliari

b

GRIMP Facilities

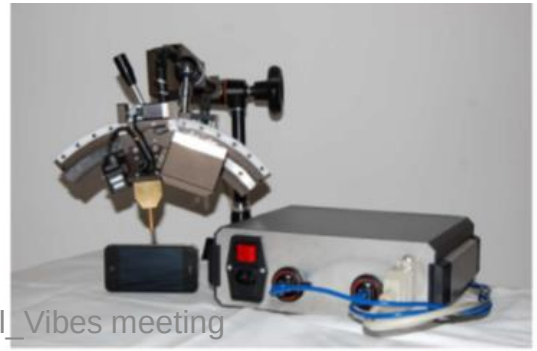
Metallography
Samples preparation (cut-off machines, mounting, grinding, polishing, electropolishing)
Optical microscopy (Stereomicroscopes, Metallographic microscopes, microhardbess tester)

Microstructural Characterization
Scanning Electron Microscope (SEM equipped with EDS and WDS)
Transmission Electron Microscopy (JEOL TEM 200kV)
Siemens X-ray Difractometer (4 axes) also for stress measurements
Spectro X-ray Fluorescence Spectrometer
Leco Glow Discharge Spectrometer

GRIMP Facilities

Corrosion measurements
Potentiostats - Galvanostats
Electrochemical Impedance Spectroscopy
Treatments
Heat treatments in furnaces in air and in controlled atmosp
Surface treatments by atmospheric plasma
Ultrasound
US generators for leaching of ores.
Residual Stresses characterization
STRESS-X - Portable Residual Stress Diffractometer

Mechanical Properties
Universal testing machines
Thermo-mechanical simulator Gleeble 3800
Hardness tester



Field of Research and Funds program

1. Steels : physical metallurgy, heat treatment, metal matrix, new grades for demanding applications
2. Production of metallic nanoparticles
3. Surface coatings on steels and light alloys
4. Hydrometallurgy
5. Welding and brazing process
6. Precious metal and rare earths Recycling and re-use
7. Blast furnace monitoring by muons scattering
8. Electroplasticity
9. Metal Additive Manufacturing

2 RFCS projects

FSE, LNL,TECH-FPA Phd

Long dated

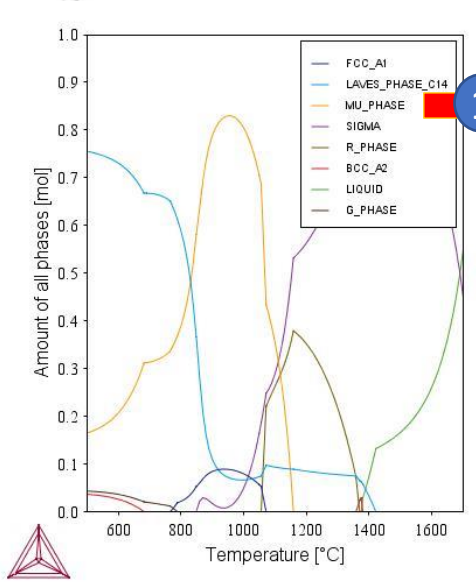
H2020, RFCS (Research for Coal and Steel) , eit-Raw Material, MAECI(Ministre of International cooperation),National and Regional Programs, INFN (National Institute of Nuclear Physics) , Private companies

Interface analysis of additively manufactured pure Mo and AISI 304 building plate

BD

dilution with Mo

element	*AISI 304*	*AISI 304 + Mo*
Si	0,87	0,43
Cr	18,81	9,41
Mn	1,80	0,90
Fe	68,37	34,19
Ni	10,15	5,08
Mo	0,00	50,00
tot	100,00	100,00



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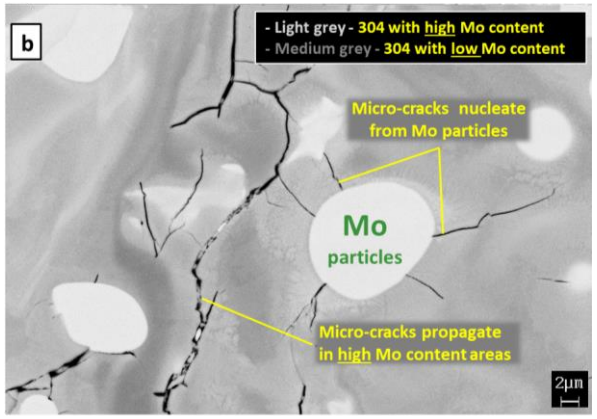

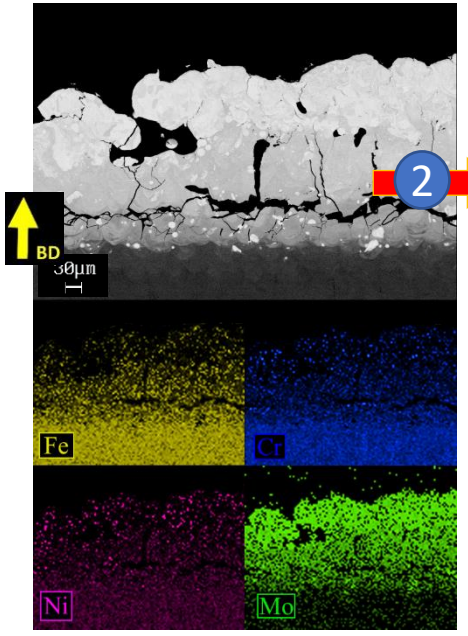

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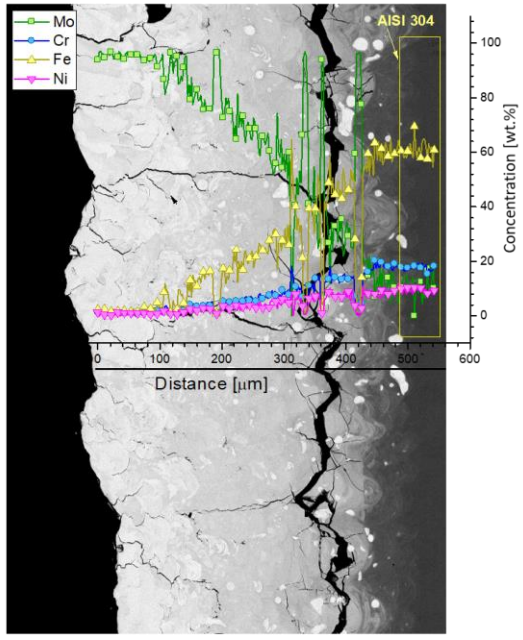

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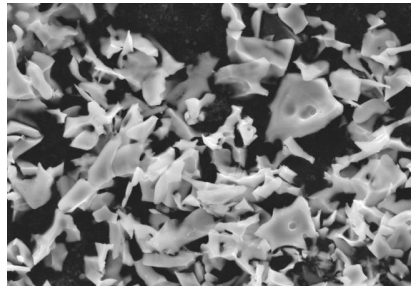
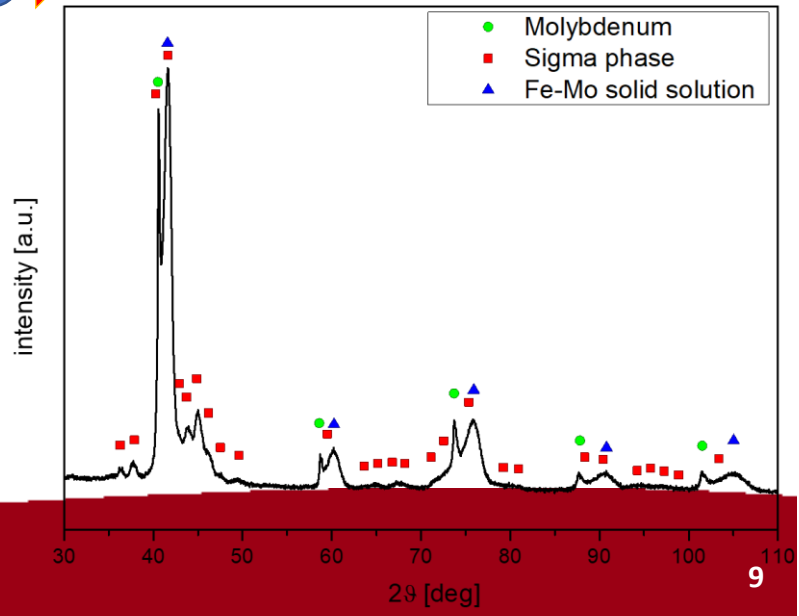
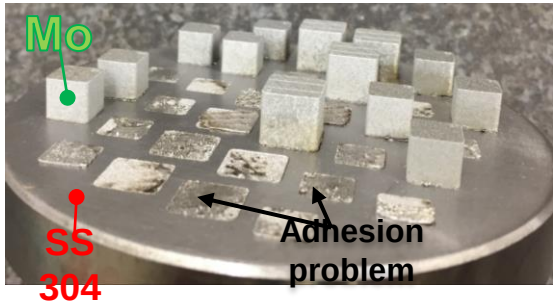




BD

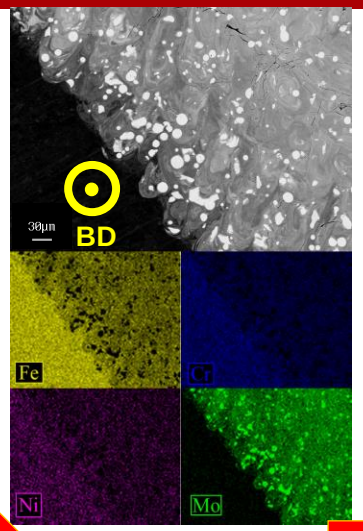
Adhesion Issues and main Substrate Solutions

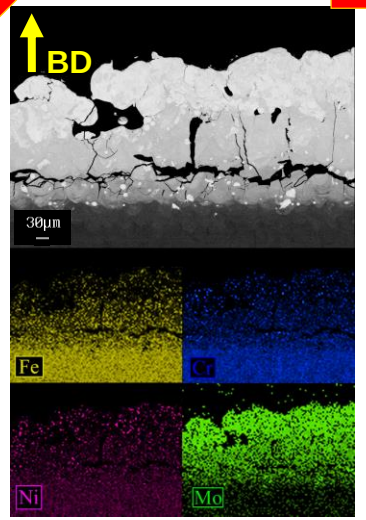


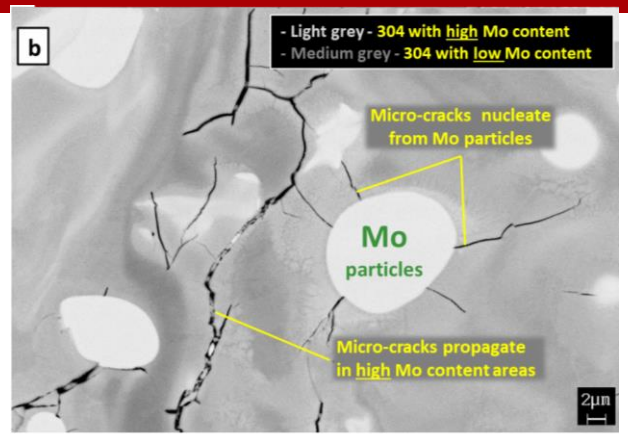
Bad melting in the first 50 l

The interaction of molten Mo with the platform materials could define the integrity of the whole production process

Brittle intermetallic phases ?
→ Compromise the interface

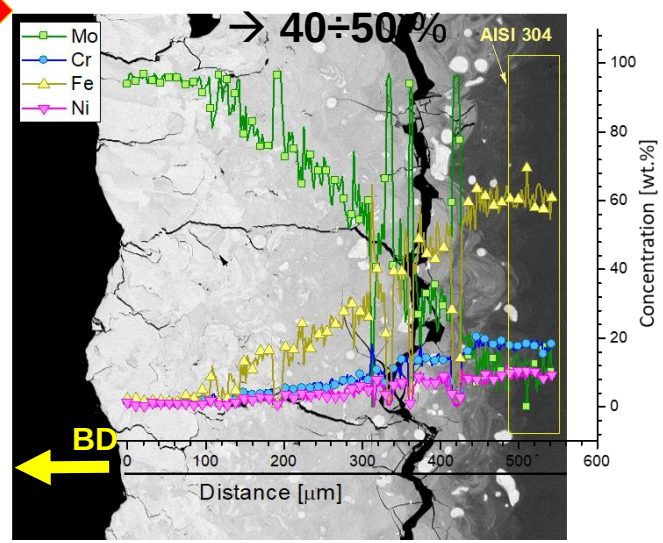




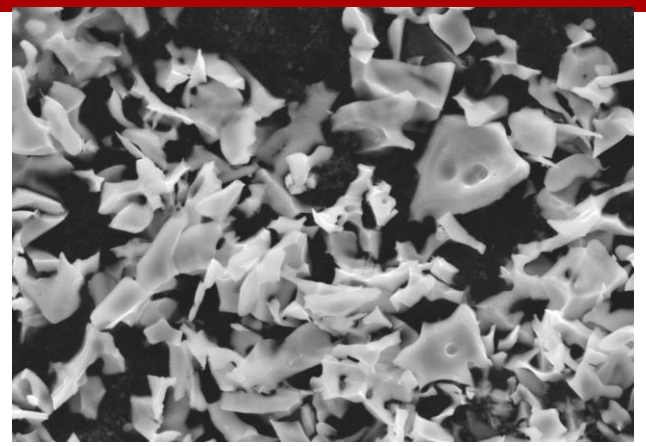


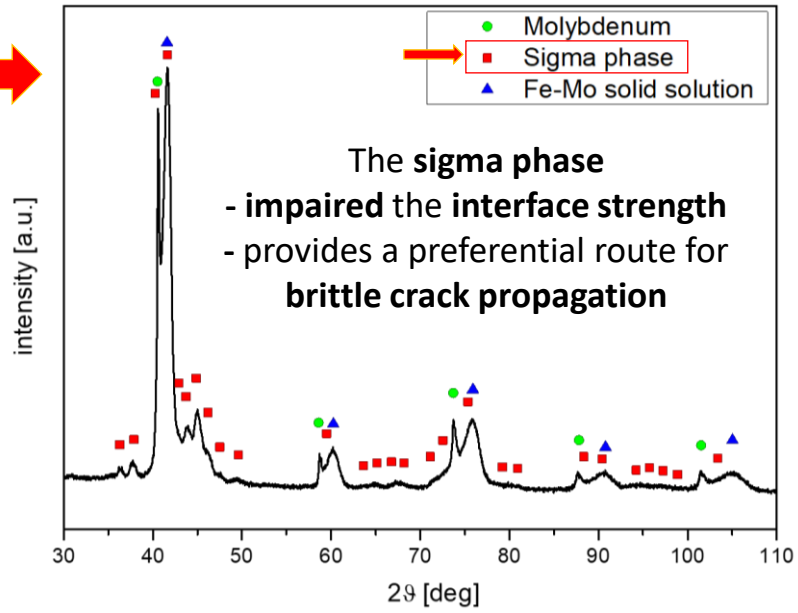
Large cracks could propagate when **dilution** of **Mo** on **SS304**

→ 40÷50%



Interface analysis was performed to investigate possible origins of the **failure**





European project – Research Funds for Coal and Steel program (RFCS-2019) – Grant Agreement n. 899263

BLEMAB

BLast furnace stack density Estimation through on-line Muons ABsorption measurements

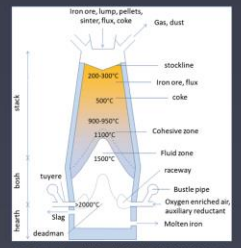
L. Bonechi[1,*], F. Ambrosino[2,3], P. Andreetto[4], G. Bonomi[5,6], D. Borselli[1,7], S. Bottai[1], T. Buhles[8], I. Calliari[9], P. Checchia[4], U. Chiarotti[10], C. Cialdai[1], R. Ciaranfi[1], L. Cimmino[2,3], V. Ciulli[11,1], R. D'Alessandro[11,1], M. D'Errico[2,3], R. Ferretti[12], F. Finke[8], A. Franzen[8], B. Glaser[13], S. Gonzi[11,1], Y. Liu[13], A. Lorenzon[14,4], V. Masone[3], O. Nechyporuk[15], L. Pezzato[9], B.V. Rangavittal[13], D. Ressegotti[16], G. Saracino[2,3], J. Sauerwald[8], O. Starodubtsev[1], L. Viliani[1]

Introduction

The BLEMAB project is conceived to establish a new methodology for the imaging of the inner volume of blast furnaces (BF).

The knowledge of the dependence of shape and extension of the so called cohesive zone on the BF operating parameters is a key point for the improvement of the steel production process.

BF are huge structures, some tens of meters in height. The temperature of material inside of them can exceed 2000° C. The direct study of the inner volume is anything but a trivial excercise.



P. Cavaliere, https://doi.org/10.1007/978-3-030-21209-4_4

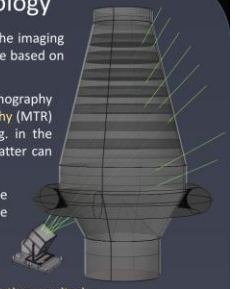
Radiographic techniques potentially represent a paradigm shift in this area.

Methodology

Currently the only techniques allowing the imaging of large size structures such as BF are those based on the detection of cosmic-ray muons [1].

So far, both multiple scattering muon tomography (MSMT) and muon transmission radiography (MTR) have been considered in simulations (e.g. in the previous Mu-Blast project), but only the latter can be actually deployed at an affordable cost.

BLEMAB will investigate in detail the performance of the MTR technique in the imaging of a blast furnace inner zone.



A muon detection apparatus will be installed at blast furnaces in the ArcelorMittal site in Bremen for a long duration monitoring.

Muographic results will be compared with measurements obtained through an enhanced multipoint probe and standard blast furnace models.

Apparatus

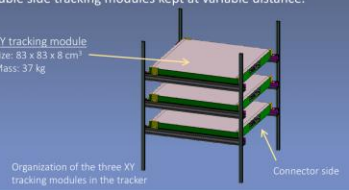
The BLEMAB apparatus, suitable for the installation in an industrial environment, will be composed by two independent state-of-the-art muon tracking systems allowing for redundancy and stereoscopic parallel measurements.

Muon tracking detector

Details

- Based on plastic scintillator technology
- Includes latest generation optical sensors
- Fully custom DAQ
- Rugged and low power consumption

- Design based on previous experience gained in the development of MU-RAY[2], MURAVES[3], MIMA[4] and other detectors developed for muon radiography and cosmic ray studies.
- Each independent muon tracker will be composed of three XY double side tracking modules kept at variable distance.



Electronics and data taking

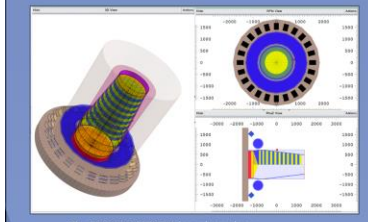
- Based on 32ch Omega EASIROC chip
- 4 slave boards for each tracking module (64 ch X-side + 64 ch Y-side)
- Single master board driving up to 16 slave boards and controllable through a Raspberry PI small computer

Slave board (12 per detector)

Master board (1 per detector)

Simulations

The software simulation, allowing predictions and comparisons with real data, is based on the CERN GEANT4 tool and includes a detailed representation of the BF structure and a realistic cosmic ray muon generator based on real measurements of the muon energy and angular distributions at ground level.



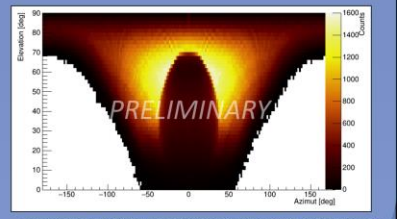
The BLEMAB GEANT4-based simulator

The structure of the BF is carefully reproduced using available data on geometries and construction materials.

Detector geometry and position relative to the BF is considered.

Muon event generation is optimized for the case study.

Preliminary estimation: some hundreds muons per day are expected from the cohesive zone in solid angle bins 1° in elevation and 1° in azimuth wide.



Estimated angular distribution of muons collected in 24h data taking with a single BLEMAB tracker.

REFERENCES

1. L. Bonechi et al., Rev.Phys. 5 (2020) 100038 2. F. Ambrosino et al., J.Geophys.Res.Solid Earth 120 (2015) 11, 7290-7307 3. G. Saracino et al., Ann.Geophys.Italy 60 (2017) 1, S0103 4. G. Baccani et al., JINST 13 (2018) 11, P11001

RINA (IT) 10. CSM, Rome 12. CSM, Terni 16. CSM, Dalmine
ArcelorMittal 8. Ironmaking Dept., Bremen (DE) 15. Maizieres Research SA (FR)
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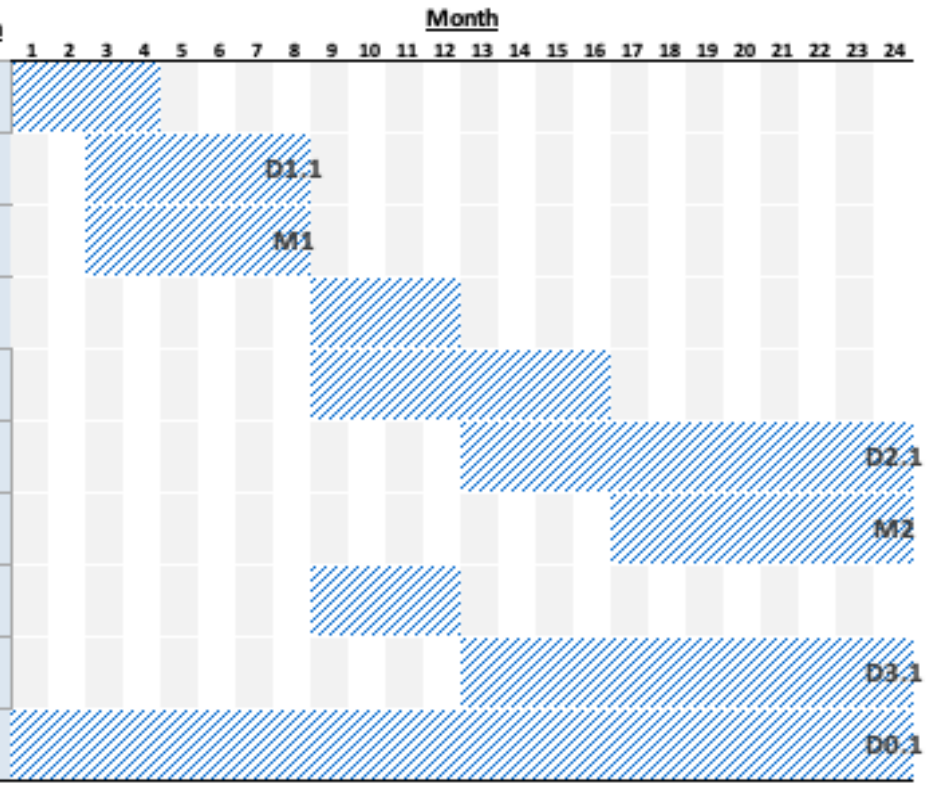
Univ. of Perugia (IT) 7. Dept. of Physics and Geology
13. Royal Institute of Technology (SE)
E.U.
BLEMAB Homepage https://www.blemab.eu/

GANNT

Activity	Start	Duration
Task 1.1: Selection of materials and analyisisof grade of purity (LNGS and UNIPD)	1	4
Task 1.2: Analyisis of the thermal properties of the selected metals at low temperature (LNGS)	3	6
Task 1.3: Analyisis of the mechanical properties of the selected metals at room temperature (UNIPD)	3	6
Task 2.1: Design of the prototype (LNGS)	9	4
Task 2.2: Joining process of the metals (UNIPD)	9	8
Task 2.3: Microstructural, mechanical and thermal characterization of the metals after joining (UNIPD and LNGS)	13	12
Task 2.4 Realization of the prototype and vibration tests (LNGS)	17	8
Task 3.1: Design of thermal switch architecture (LNGS)	9	4
Task 3.2: 3D-print of samples (LNGS)	13	12
WP0: Project Management and dissemination of the results (LNGS and UNIPD)	1	24



Milestones
M1: Definition of the best metals to realize ultra-low vibrations thermal link
M2: Realization and validation of the prototype of the thermal link

Deliverables:
D0.1: Report on the dissemination activity of the project
D1.1: Report on the study of metal samples properties
D2.1: Report on prototypation process and heat link prototype performance
D3.1: Report on the feasibility study for the thermal switch

WP0	Managment and Dissemination (LNGS and UNIPD)
WP1	Purchase and characterization of metal samples (UNIPD)
WP2	Realization, characterization and validation of prototype (LNGS)
WP3	Feasibilty study for thermal switch (LNGS)

UNIVERSITÀ DEGLI STUDI DI PADOVA

COOL_VIBES UNIPD-DII group:

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A.Zambon

UNIVERSITÀ
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PRIN Ultra-low vibration thermal switch for Pulse Tube cryocoolers (Cool Vibes)

Assegnista: Mirko Pigato

Coordinatore d'Unità: Prof. Alberto Benato