This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

ARIES-WP 17

Materials for extreme thermal management (PowerMat)

CERN, 5th of May 2017

M. Tomut and A. Bertarelli for PowerMat

PowerMat WP Objectives

- *Optimization of carbide-graphite composite materials with respect to radiation hardness for LHC collimator system upgrade, exploring properties with new doping.*
- *Development of a carbon-based composite solutions for high power targets and beam dumps with improved resistance to short, intense pulse ion beam-driven shock waves.*
- *Testing and optimization and of diamond-metal matrix composites for applications as luminescence screens for high intensity beams (optimization will be performed as a function of beam-induced luminescence signal by changing diamond doping, to beam-induced shock resistance by using special light alloys and to diamond-matrix interface by using special additions).*

ARIES

PowerMat WP Description

Comprehensive and integrated R&D activity, including:

- *Investigation, development, manufacturing, characterization, testing and integration of novel Ceramic Matrix and Metal Matrix Composites based on graphite and diamond reinforcements.*
- *Development of new experimental methods to test materials at energy density conditions relevant for accelerators beyond LHC (e.g.FCC) in more accessible experimental areas and producing less activation.*
- *Development of new monitoring techniques for online tests of radiation-induced material degradation.*
- *Simulating behavior of novel composites at very high strain rates.*
- *Exploring challenging and/or unconventional applications of such materials for high power accelerators and society.*

ARIES

PowerMat WP Innovations

- *Online thermomechanical dynamic testing under high intensity beams.*
- *Study of ion-induced color centers in diamond for quantum computing applications.*
- *Prediction of radiation-induced microstructural damage and studies of methods to mitigate and cure such effects.*
- *Application to particle accelerator devices beyond collimators (e.g. novel luminescence screens for high intensity beams, beam windows, high power targets and beam catchers...).*
- *Exploration of demanding thermal management applications such high-end electronics, avionics, gas turbines, aerospace, advanced braking systems.*

ARIES

PowerMat WP Organisation

The WP is organized in the following tasks:

1. *Communication & Coordination*
   (A. Bertarelli – CERN, M. Tomut – GSI)
2. *Materials development and characterization*
   (A. Bertarelli – CERN)
3. *Dynamic testing and online monitoring (L. Peroni – POLITO)*
4. *Simulation of irradiation effects and mitigation methods*
   (A. Lechner – CERN)
5. *Broader accelerator and societal applications (M. Tomut – GSI)*

- *Within WP1 (Task 1.4) – Industries for resistant materials*
  (F. Carra– CERN)

PowerMat Participants

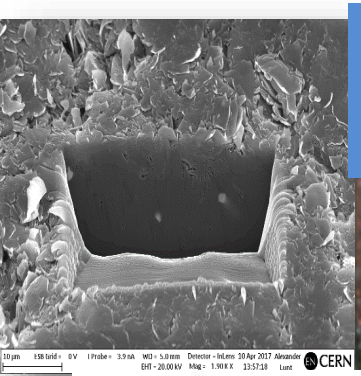
	Laboratories	
1	CERN	Geneva, Switzerland
2	***ELI-NP*** *(Extreme Light Infrastructure – Nuclear Physics)*	Bucharest-Magurele, Romania
3	GSI	Darmstadt, Germany
4	***POLIMI***	Milan, Italy
5	POLITO	Turin, Italy
6	UM	Malta
X	***NIMP (National Institute of Materials Physics)****	Bucharest, Romania
	Industries (in WP1 Innovation)	
X	Brevetti Bizz	Verona, Italy
X	RHP Technology	Seibersdorf, Austria

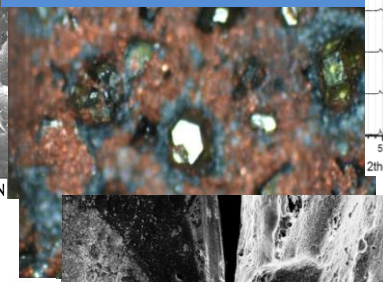
* Participating as associated (subcontractor)

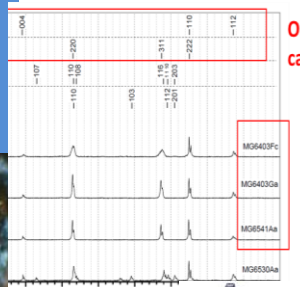
ARIES

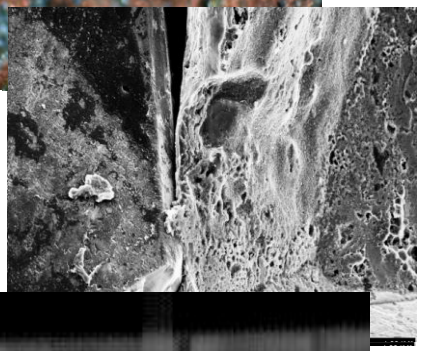
CERN in WP17 and WP14

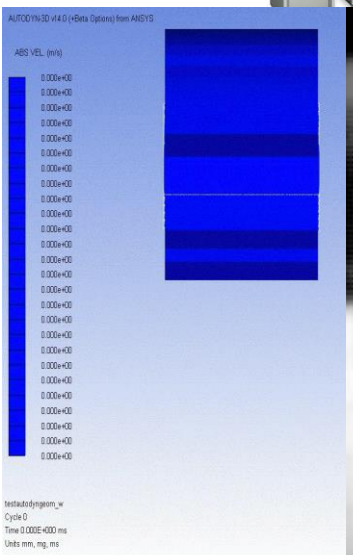
Material micro and macro characterization

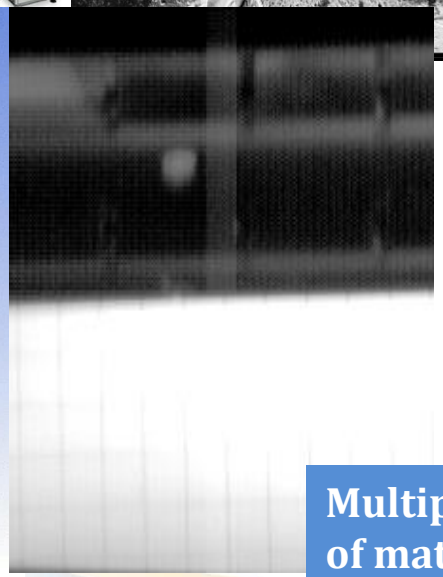




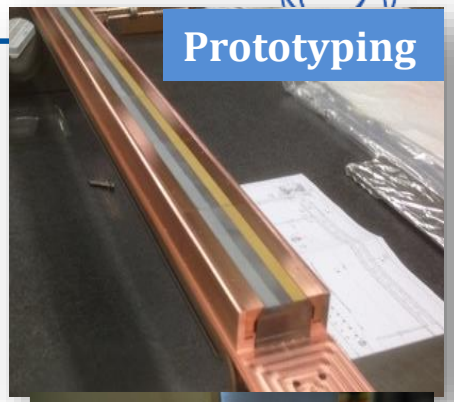


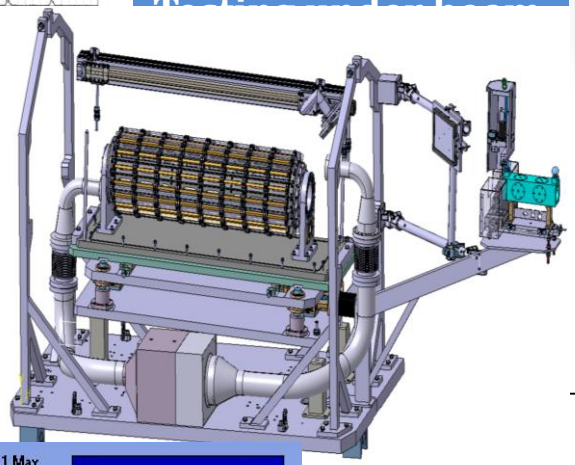


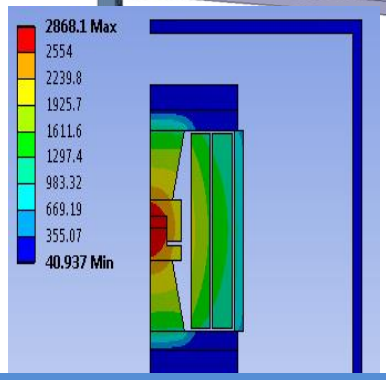


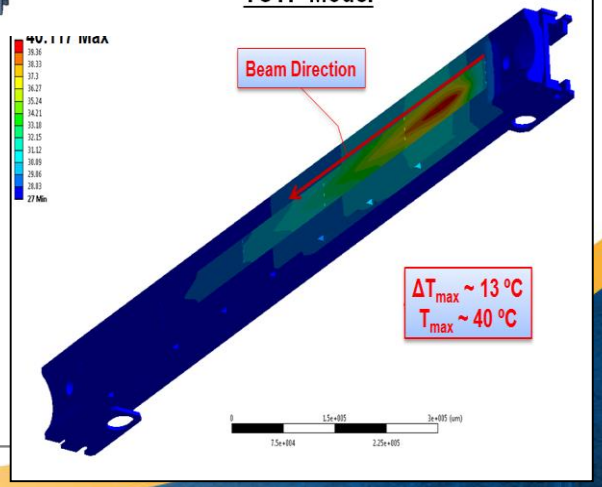


Prototyping





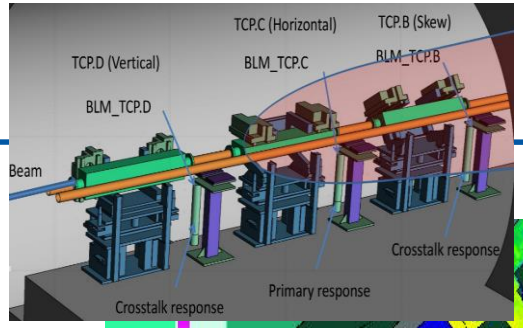


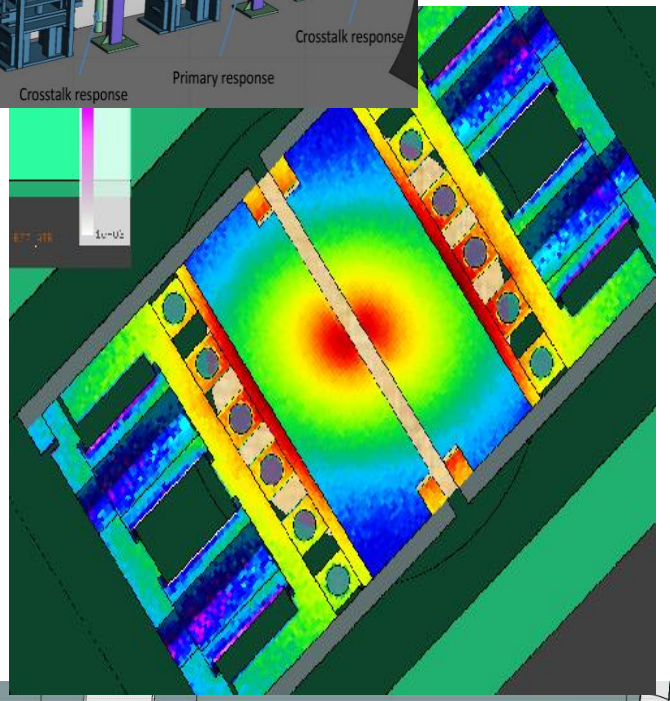


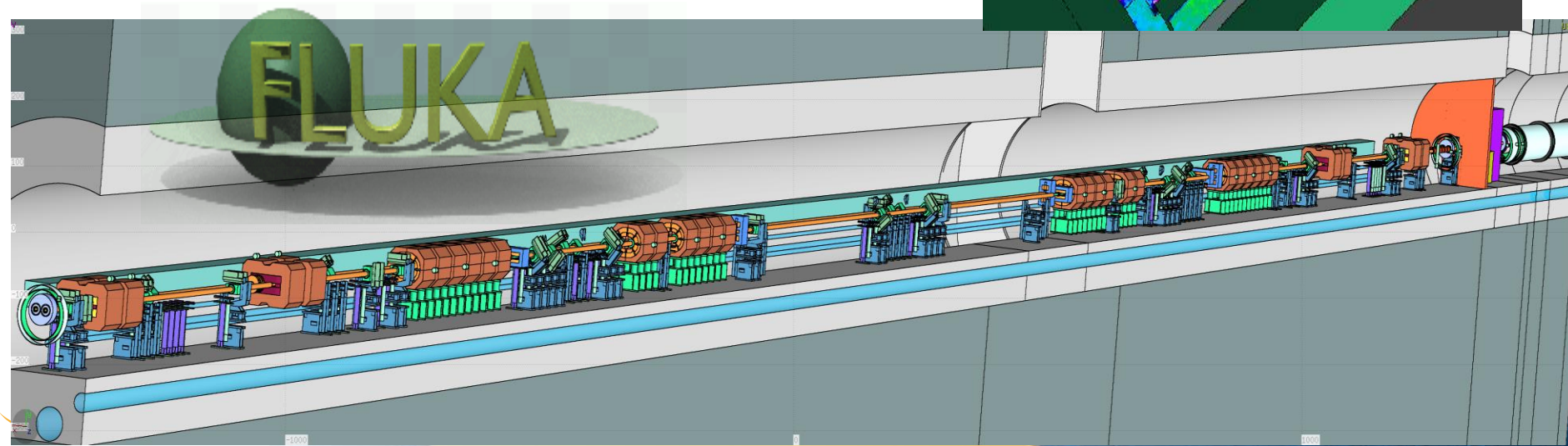
Multiphysics simulation of material response and technology processes

CERN FLUKA team

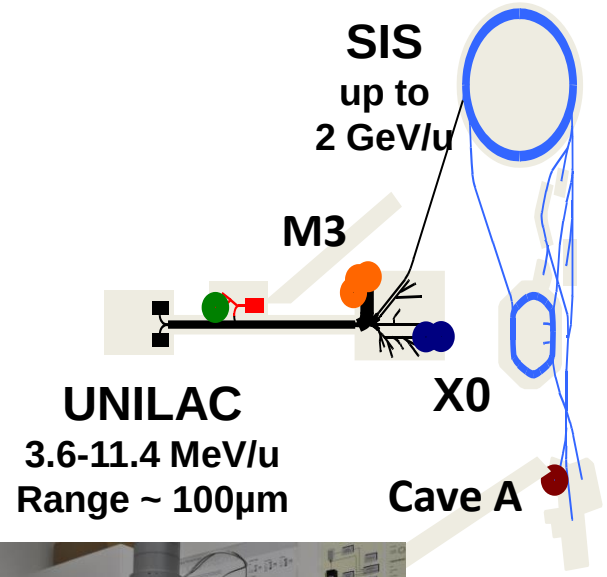
- Expertise in simulating particle-matter interactions and radiation effects
- Responsible for beam-induced shower studies for all CERN accelerators and future upgrades (e.g. HL-LHC)
- Coordination of ARIES Task 17.4





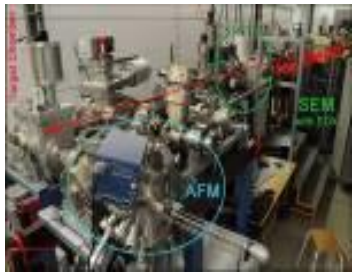


Acceleration of p to U^{28+} from 1.4 to 11.6 MeV/u..



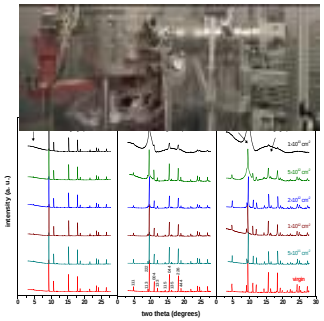
M-Branch
In-situ and On-line Analysis of Irradiated Material

M1
Microscopy



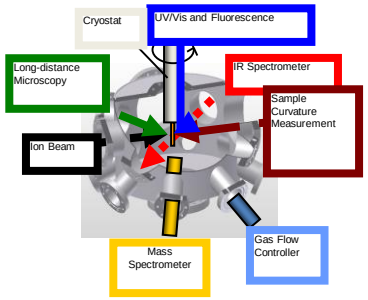
University of Stuttgart
University of Duisburg Essen

M2
X-Ray Diffraction

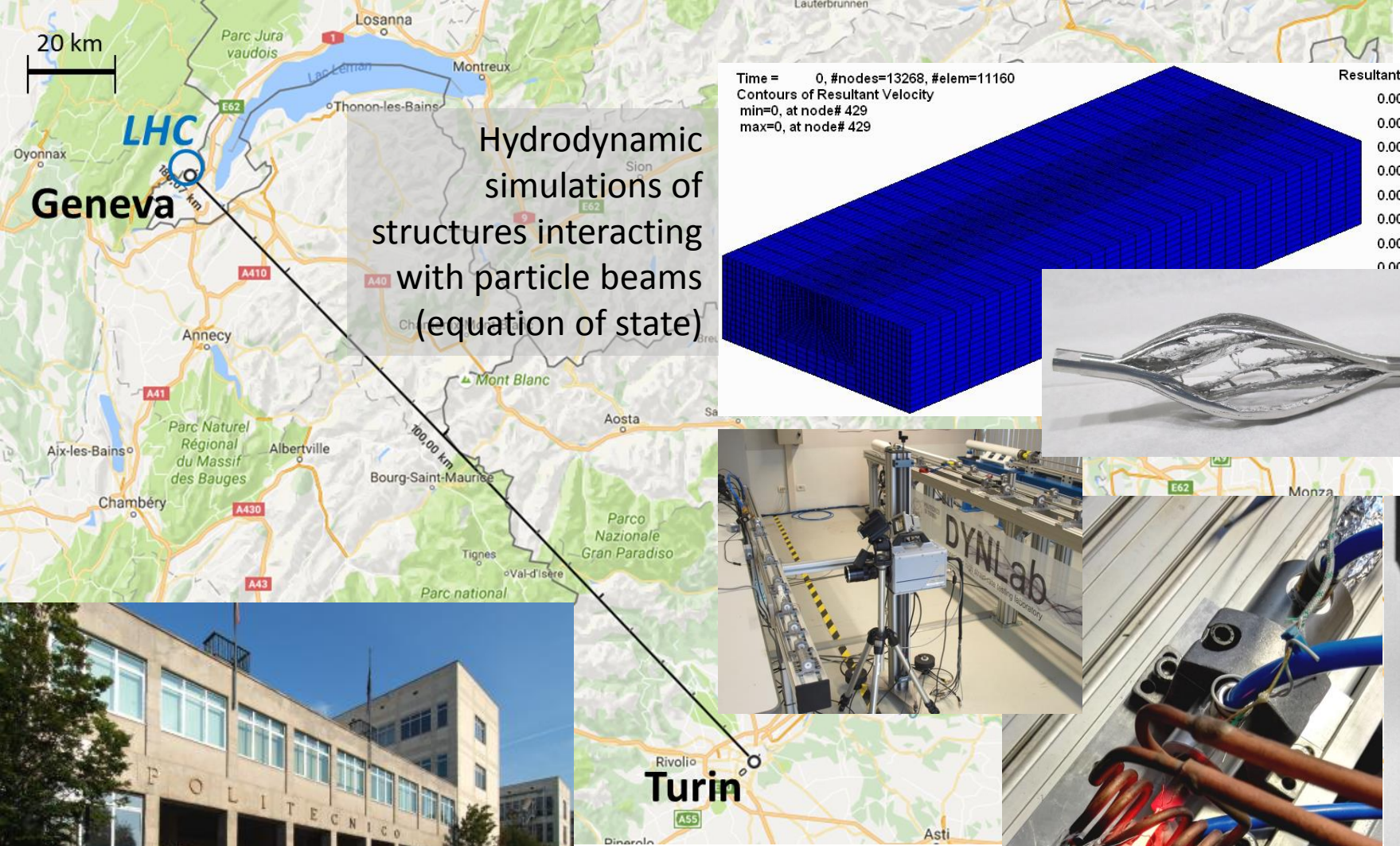


Helmholzzentrum Berlin / GSI

M3
Multi-Analysing Chamber



Universities of Darmstadt, Dresden
Göttingen, Jena, Heidelberg



Hydrodynamic simulations of structures interacting with particle beams (equation of state)

ARIES

POLITECNICO DI TORINO

Mechanical characterization of advanced materials at high temperature and strain-rate

University of Malta

UNIVERSITY OF MALTA
L-Università ta' Malta

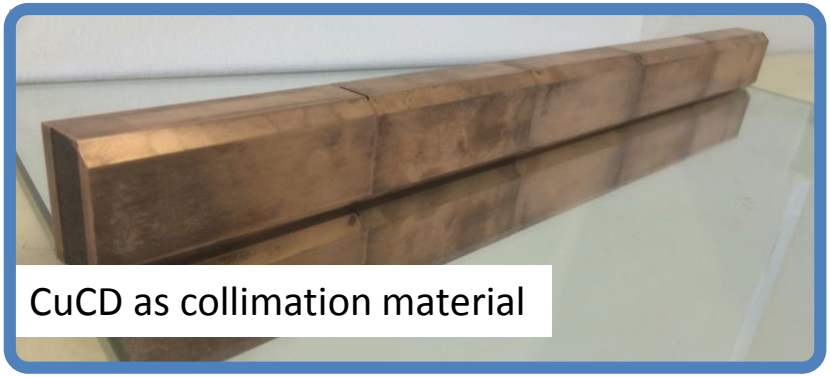
- **Highest research and teaching institution in Malta**
- **Track record of collaboration with CERN (EuCard2)**:
  - PhD, Marija Cauchi: '*Thermo-Mechanical Studies of Large Hadron Collider Collimators in Accident Scenarios*', inermet blocks, collimator
  - MSc, Miryea Borg: '*Numerical Modelling and Experimental Testing of Novel Materials for LHC Collimators*', new candidate materials Molybdenum Graphite, Copper Diamond, Carbon composites
  - MSc, Marcus Portelli (on-going): '*Preliminary Thermo-mechanical Design of a high-power absorber for HL-LHC Crystal Collimation*', investigation on new crystal collimation designs
- **Expertise:**
  - Thermo-mechanical finite element analysis (FEA) simulations (ANSYS)
  - Analysis of high temperature (e.g. welding) induced stresses through full and reduced (computationally efficient) methods
  - Residual stresses hole drilling equipment
  - Sensor technology
- **WP 17 Task 17.2**

Main foreseen contribution: support for analysis for assessment of components performance, testing planning and validation

RHP-Technology @ ARIES

2 Technologies &
many material compositions

3 different topics to work on

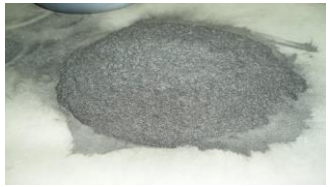


Metal-Diamond composite applications like novel **luminescence screens** for particle beams, quantum computing, florescence imaging,....

Demonstrate **Additive Manufacturing of MgB2 for large dimensions** (applications: novel beam pipes, RF cavities, …)

ARIES

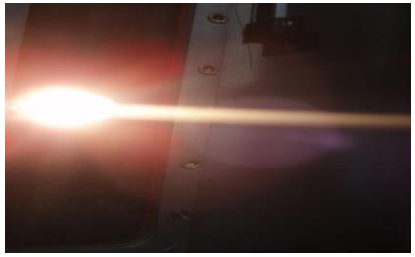
Spark Plasma Sintering (SPS)



Mixed Powders

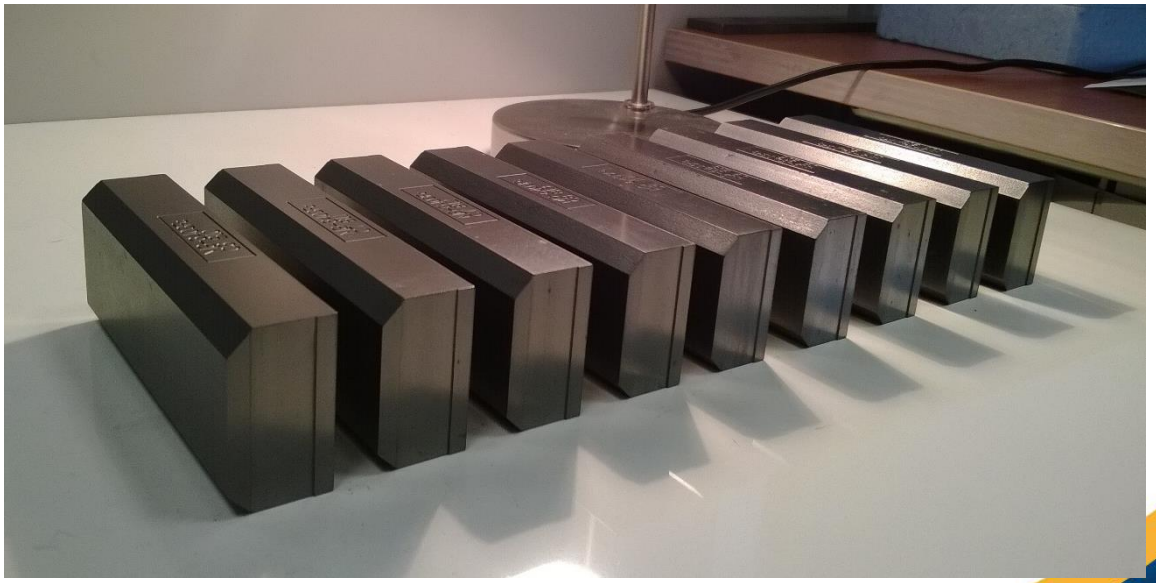
BREVETTI BIZZ

VACUUM SPS 1200°C



VACUUM SPS >2600°C

INDUCTION VACUUM HOT PRESSING 1500 C°



Molybdenum carbide - Graphite material. Produced by SPS at >2600°C.
Production of the absorber blocks for the HL-LHC TCSPM collimator prototype

Task 2 description

Task 2: Materials development and characterization
(A. Bertarelli – CERN)

- Research, investigation, development, manufacturing, characterization of novel CMC and MMC based on graphitic, carbide or diamond reinforcements. Continuous material optimization will be fostered by the feedbacks provided by tasks 3 and 4.
- Study and development of electrically conductive coatings, resisting the impact of high intensity particle beams.
- Characterization of thermophysical properties measurements, microstructural analysis (SEM, XRD, EDS ...), study of phases and of their change under various environments …

Participants: CERN, GSI, NIMP, POLIMI, POLITO, UM, Brevetti Bizz, RHP Technology

ARIES

Task 3 description

Task 3: Dynamic testing and online monitoring
(L. Peroni – POLITO)

Testing of material samples in a broad range of environments:

- Mechanical testing in quasi-static and dynamic conditions, at various temperatures
- Tests with high power beams (CERN,GSI, ELI-NP)
- Irradiation tests with online monitoring of properties evolution (GSI)
- Hydrodynamic simulations of experiments –constitutive models, spall strengths for new materials

Participants: CERN, ELI-NP, GSI, POLIMI, POLITO, UM

Task 4 description

Task 4: Simulation of irradiation effects and mitigation methods (A. Lechner – CERN)

- Simulations on the degradation due to irradiation, ions (with ion tracks) and protons bombardment.
- Understand effect of time of energy deposition on damage and property degradation, taking into account dose rate and dynamical annealing effects for high intensity beams.
- Include effects of nuclear transmutations and gas production.

Participants: CERN, GSI, POLIMI

This task will contribute as well to an extra European collaboration (RaDIATE - Radiation Damage In Accelerator Target Environment), aimed at understanding the effects of radiation on material

Task 5 description

Task 5: Broader accelerator and societal applications (M. Tomut – GSI)

This task will follow broader applications of new developed materials for high-power accelerators, space, society (energy, medicine, computing)

- Irradiation induced defect centers in diamond for luminescent screens, medical imaging and quantum computing.
- Novel materials for high power targets, beam catchers, beam windows.
- Applications for advanced engineering solutions, efficient energy solutions, space.
- Applications for thermal management.

Participants: CERN, GSI, UM, Brevetti Bizz, RHP Technology

Deliverables

- Task 17.2) Comparative compendium of the developed materials [month 40]
- Task 17.4) Report on simulations on irradiation effects [month 44]
- Task 17.3) Irradiation test results: Beam impact on new material and composite [month 48]
- Task 1.4) Production of material samples (as large as possible for each industry to demonstrate workability) [month 24]

Milestones

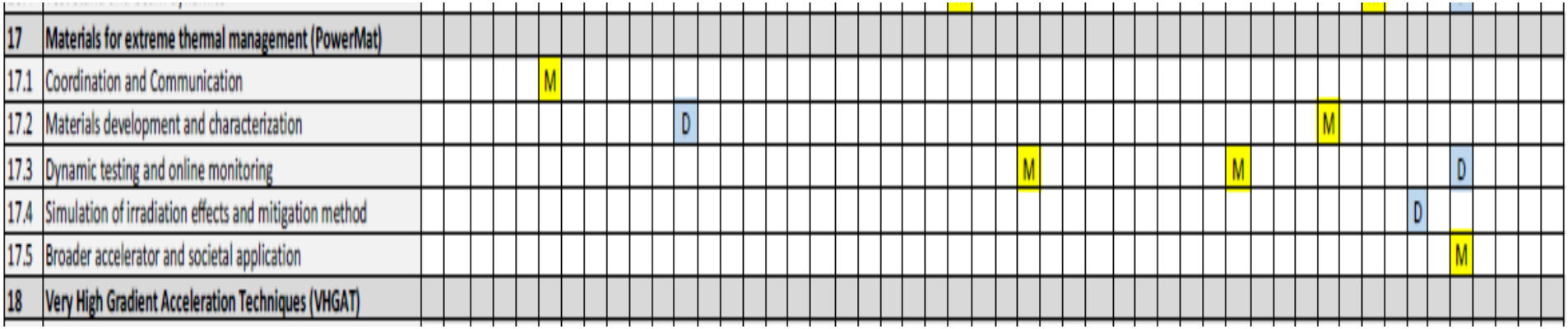
Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS58	Organisation of PowerMat kick-off meeting (Task 17.1)	WP17	1 - CERN	6	Agenda, summary report
MS59	Irradiation campaigns at GSI for radiation hardness studies (Task 17.3)	WP17	23 - POLITO	27	Report to StCom
MS60	Irradiation effects analysis (Task 17.3)	WP17	1 - CERN	36	Report to StCom
MS61	Comparative compendium of materials developed (Task 17.2)	WP17	1 - CERN	40	Report to StCom
MS62	Dissemination of R&D results on novel materials for accelerator and societal applications (Task 17.5)	WP17	12 - GSI	46	Report to StCom

Deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D17.1	Material characterization	1 - CERN	Report	Public	12
D17.2	Irradiation effect simulations	1 - CERN	Report	Public	44
D17.3	Irradiation test results	23 - POLITO	Report	Public	46

Deliverables and Milestones

Task	Year 1				Year 2				Year 3				Year 4			
	Q1	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*
17.1		M														
17.2				**D**										**M**		
17.3									M			**M**				D
17.4														D		
17.5																M
1.4								D								


17 Materials for extreme thermal management (PowerMat)
17.1 Coordination and Communication
17.2 Materials development and characterization
17.3 Dynamic testing and online monitoring
17.4 Simulation of irradiation effects and mitigation method
17.5 Broader accelerator and societal application
18 Very High Gradient Acceleration Techniques (VHGAT)
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obrigado
Dank U
Merci
mahalo
Köszi
спасибо
Grazie
Thank you
mauruuru
Takk
Gracias
Dziękuję
Děkuju
danke
Kiitos