Overview of EuCARD2-WP11 study and plans for "EuCARD3"

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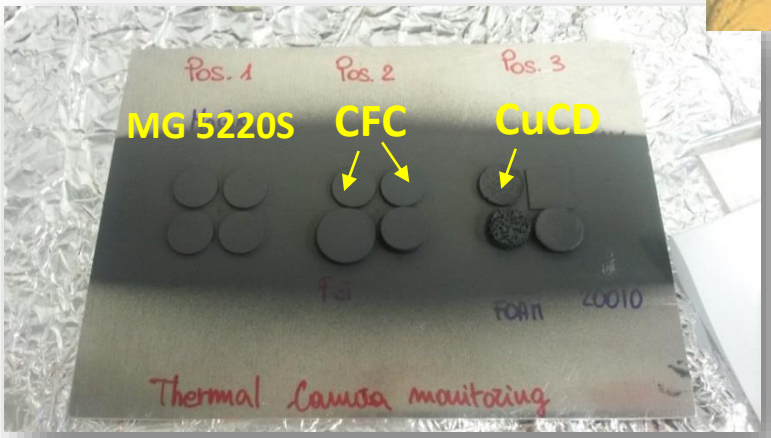
Outline:

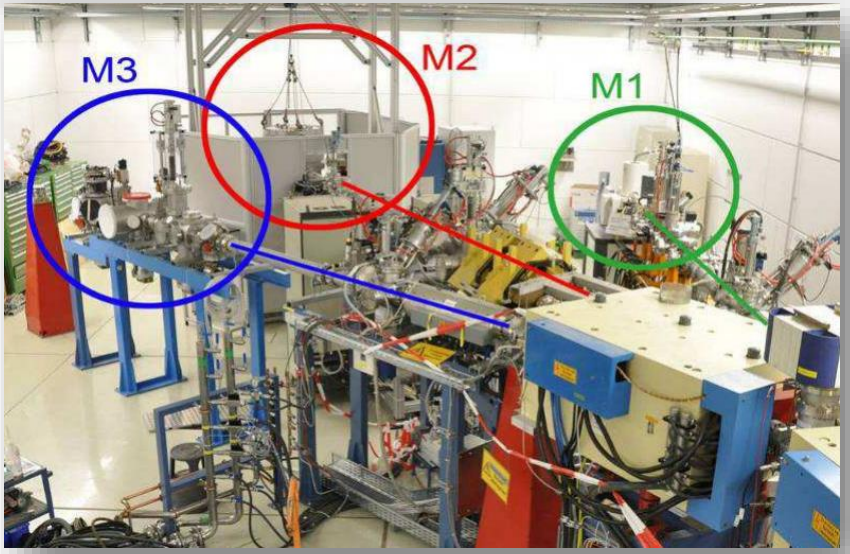
- Some recent results from GSI irradiation tests on MoGr
- Plans for Material studies within H2020

11.2. Material testing for fast energy density deposition and high irradiation doses Results

Irradiation Tests with Swift Heavy Ions

- *M-branch irradiation facility at **GSI UNILAC***
- ***In-situ online and offline monitoring**: camera, fast IR camera, SEM, XRD, LFA, nano-indentation and Raman spectroscopy*
- *3 irradiation campaigns completed with **U**, **Bi**, **Au**, **C**, **Sm ions***
- *Doses 1e11 to 5e13 ions/cm^2* (or higher)
- *Available results indicate good behavior of CuCD*
- *At high accumulated doses MoGr transversal samples deform, no change for in-plane samples.*
- *Damage threshold dose identified*
- *Substantial improvement in performance after post-processing annealing*





Au 5.9 MeV/u test

- MoGR samples were bombarded with Au 5.9 MeV/u:
  - MG6400 : latest MoGr grade **without** C fibers,
  - MG6530 : " + C fibers long {Ø10µm, 3mm length}
  - MG6541 : " + C fibers short {Ø10µm, 300µm length}

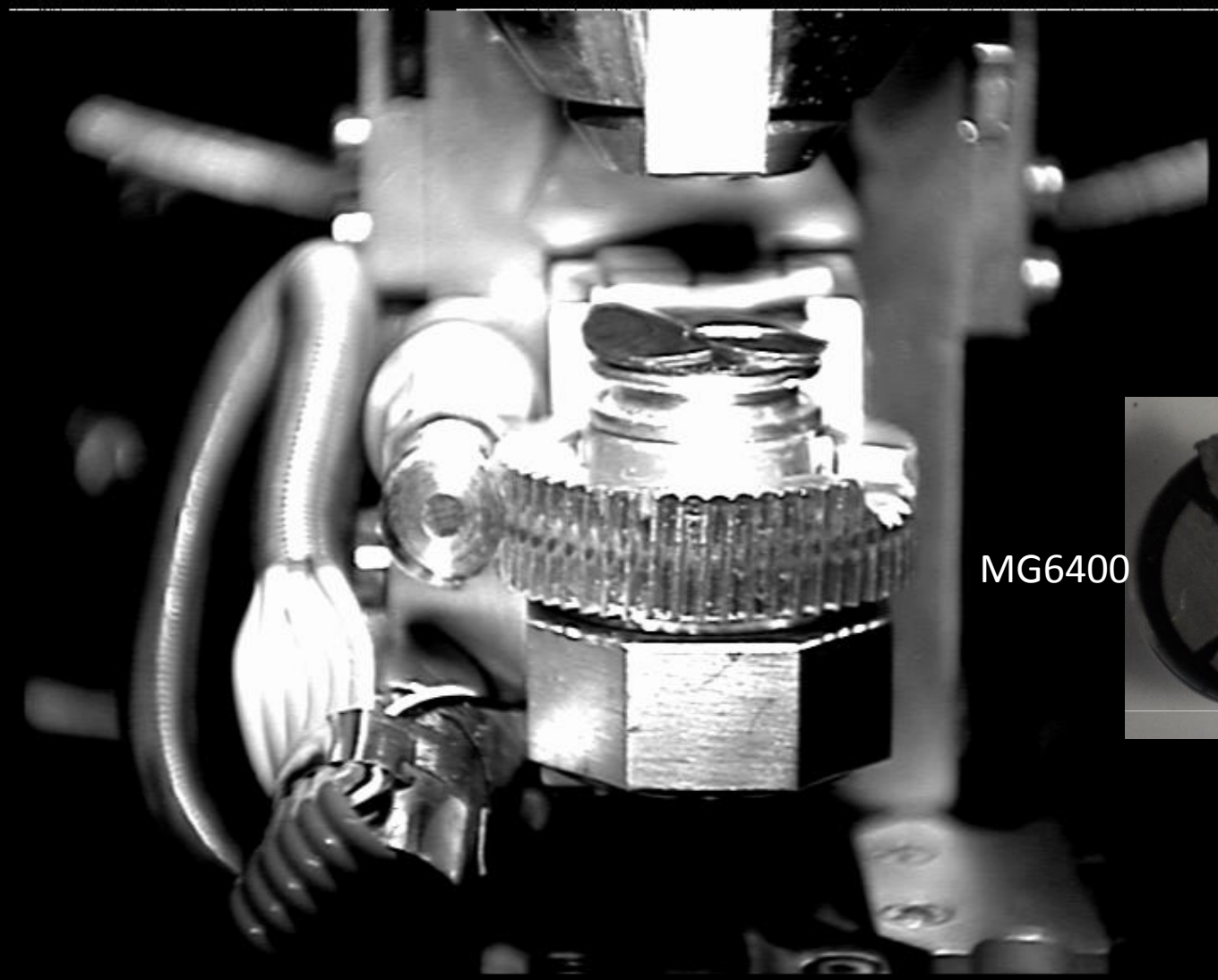
- The 10mm diameter samples were fixed with Al, and inter-mediate flexible graphite masks with a diameter of the opening of 8 mm.

After 5.10^{13} ions/cm^2 – Au 5.9 MeV/u Transverse cut

Courtesy of M. Tomut (GSI)

- All 3 grades exposed to 5.10^{13} Au ions/cm^2 broke due to beam induced deformation.
- At 2.10^{13} Au ions/cm^2 samples show different degree of deformation, depending on the C fiber content.
- Analysis is ongoing

High resolution online SEM studies at M-branch beamline, GSI



MG6530

MG6400

MG6541

200 µm

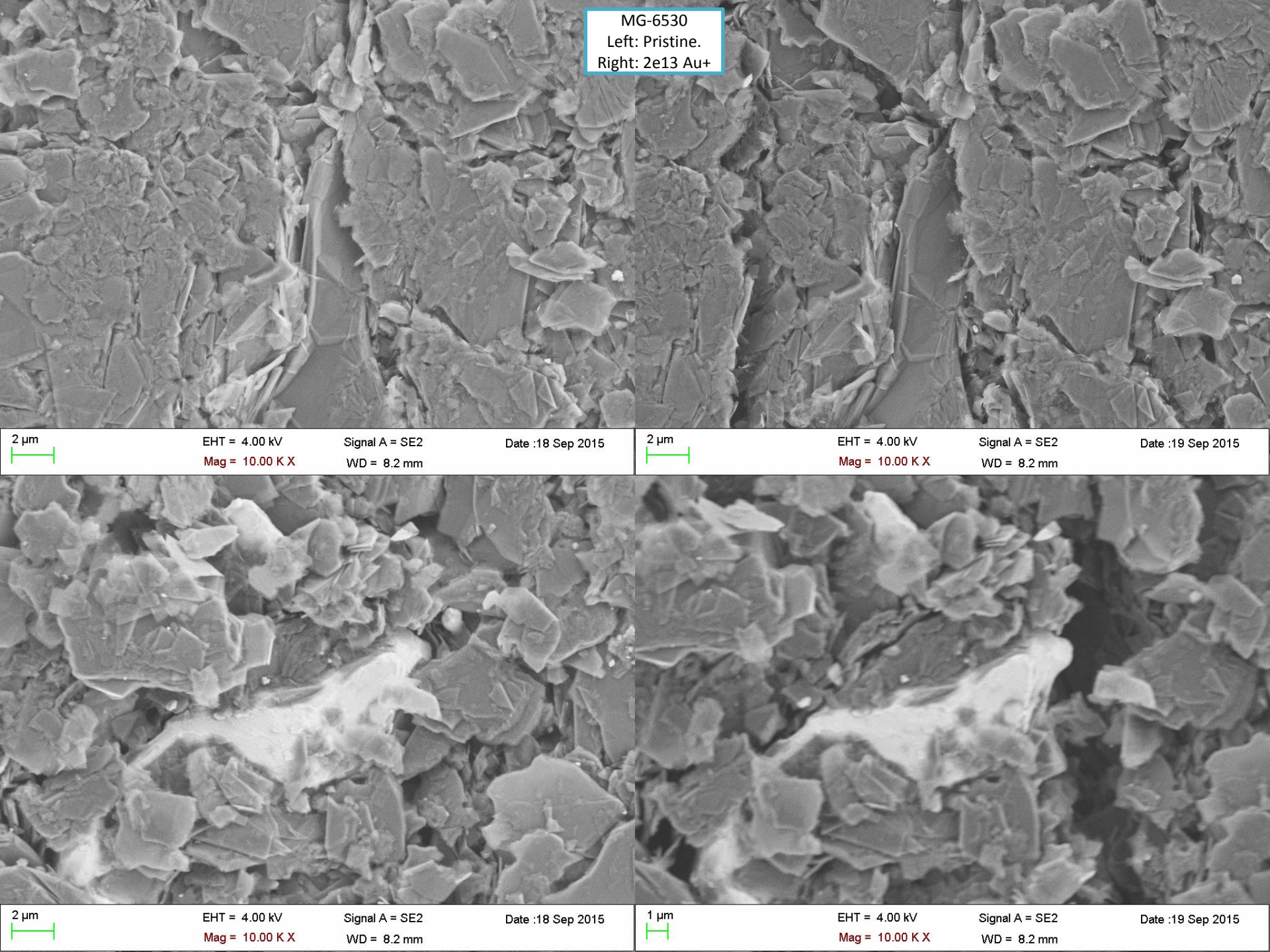
EHT = 0.00 kV

Mag = 77 X

Signal A = TV

WD = 2.8 mm

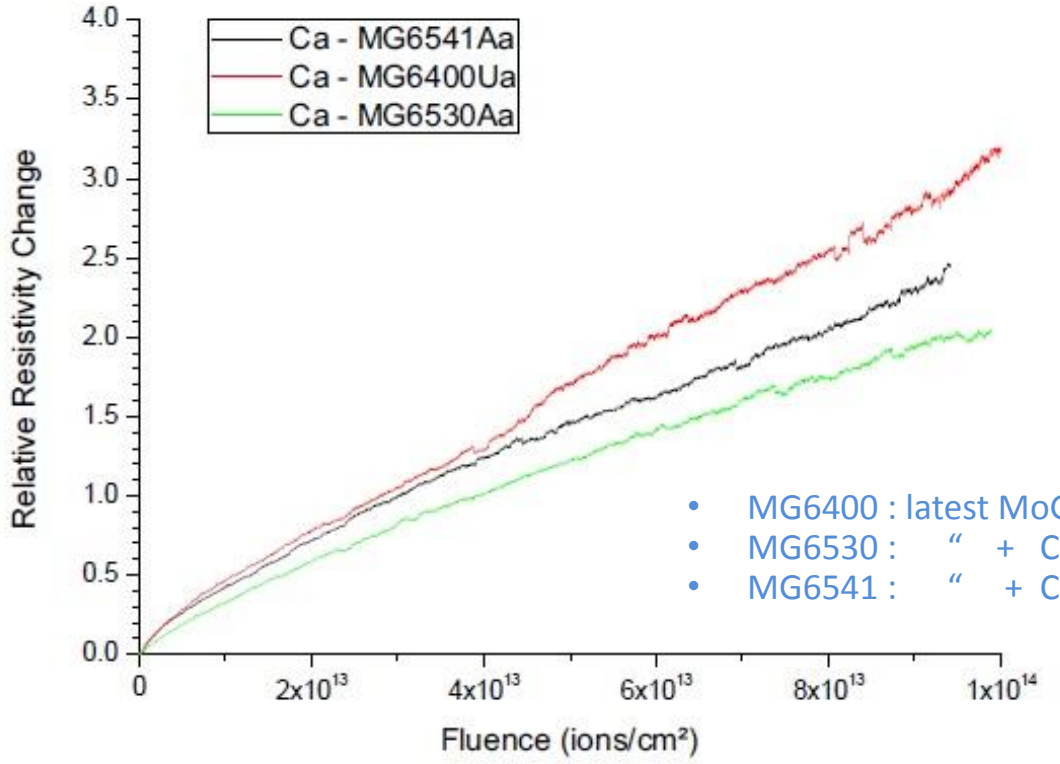
Date :19 Sep 2015


MG-6530
Left: Pristine.
Right: 2e13 Au+
2 µm
EHT = 4.00 kV
Mag = 10.00 K X
Signal A = SE2
WD = 8.2 mm
Date :18 Sep 2015
2 µm
EHT = 4.00 kV
Mag = 10.00 K X
Signal A = SE2
WD = 8.2 mm
Date :19 Sep 2015
2 µm
EHT = 4.00 kV
Mag = 10.00 K X
Signal A = SE2
WD = 8.2 mm
Date :18 Sep 2015
1 µm
EHT = 4.00 kV
Mag = 10.00 K X
Signal A = SE2
WD = 8.2 mm
Date :19 Sep 2015

Ca 4.8 MeV/u test: Resistivity

- Online resistivity measurements.
- For this light ion, the elastic collisions effects dominate, therefore DPA calculation would be meaningful.

Courtesy of M. Tomut (GSI)



Sample holder for R measurements

- MG6400 : latest MoGr grade without C fibers,
- MG6530 : " + C fibers long {Ø10µm, 3mm length}
- MG6541 : " + C fibers short {Ø10µm, 300µm length}

Comparison of relative resistivity changes for different MoGr samples as a function of the Ca ions fluence.

Materials for extreme thermal management (PowerMat)

- From FP7 to Horizon 2020

Main guidelines for Advanced Communities (from draft Work Programme):

- "Proposals from advanced communities will have to clearly demonstrate the added value and the progress beyond current achievements in terms of integration and services"
- "focusing on innovation aspects and widening trans-national access provision"
- "creation of strategic roadmaps for future research infrastructure developments as well as the long-term sustainability"
- "fostering the potential for innovation of research infrastructures by reinforcing the partnership with industry"

  - Politecnico di Milano,
  - National Institute of Materials Physics (Bucharest),
  - Extreme Light Infrastructure – Nuclear Physics (Bucharest)

PowerMat Participants

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

NIMP

The National Institute for Materials Physics (NIMP) Bucharest is devoted to fundamental and applied research and development, with particular emphasis in the fields of solid state physics and materials research.

- *Preparation, characterization and study of the physical properties of new materials connected to high technology products and devices.*
- *Development of analytical techniques and methods applied in materials science.*

ELI-NP

Extreme Light Infrastructure - Nuclear Physics facility (ELI-NP) will consist of two components:

- *A very high intensity laser, where the beams from two 10^{15}W lasers are coherently added to the high intensity of 10^{23}-10^{24}W/cm^2 or electrical fields of 10^{15}V/m.*
- *A very intense (10^{13}γ/s), brilliant γ beam, 0.1 % bandwidth, with E_γ > 19 MeV, which is obtained by incoherent Compton back scattering of a laser light off a very brilliant, intense, classical electron beam (E_e > 700 MeV) produced by a warm Linac.*

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 materials for high power target 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).

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.*
- *Simulate and understand behaviour of novel composites at very high strain rates.*
- *Explore challenging and/or unconventional applications of such materials for high power accelerators and society.*

PowerMat WP Innovations

- *Thermomechanical dynamic testing under very high intensity laser pulses and laser-driven particle beams, extending the energy density frontier of particle beam testing beyond facilities such as HiRadMat and avoiding problems such as activated debris.*
- *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.*

PowerMat WP Organisation

The WP is organised in the following tasks:

1. *Communication & Coordination (A. Rossi – 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)*

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 analyses (SEM, XRD, EDS ...), study of phases and of their change under various environments …

Participants: CERN, GSI, Brevetti Bizz, RHP Technology, POLITO, POLIMI, National Institute of Materials Physics, University of Malta

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 under particle pulses (HiRadMat) (not under EuCARD)
- Tests under very high power laser beams (GSI, ELI-NP)
- Irradiation tests with online monitoring of properties evolution (GSI)
  To be complemented with tests at BNL and NRC-KI
- Hydrodynamic simulations of experiments - EOS, spall strengths for new materials

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

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

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 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, Brevetti Bizz, RHP Technology

THANK YOU