Materials for extreme thermal management (PowerMat)

A. Rossi, M. Tomut, A. Bertarelli, L. Peroni,
A. Lechner

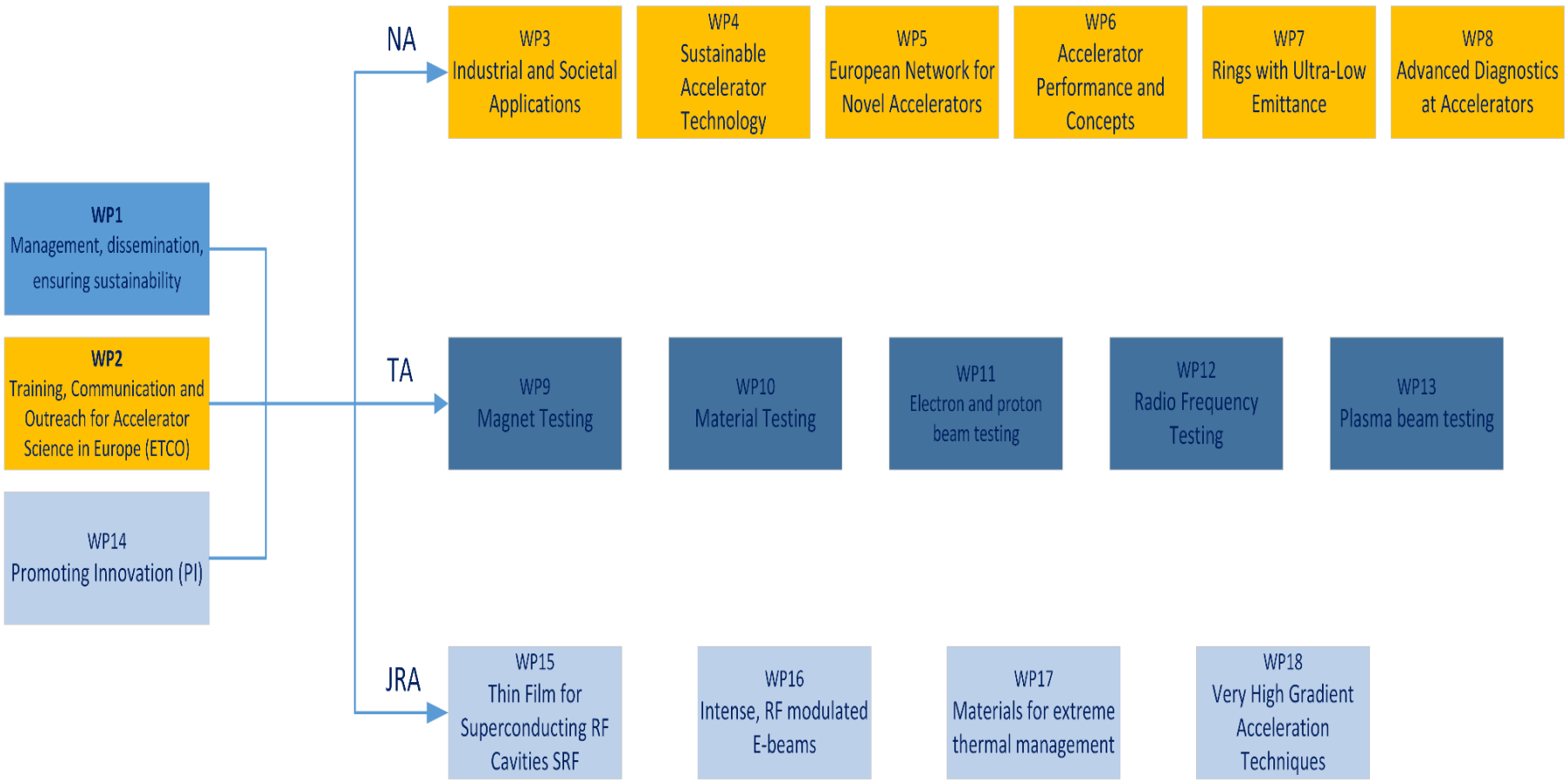
with thanks to F. Carra and S. Redaelli

From EuCARD-2 to ARIES

Accelerator
Research and
Innovation for
European
Science and Society

- New proposal for the call H2020 INFRAIA-01-2016-2017 **submitted on 30 March 2016**
- Continuation of some EuCARD-2 activities, start of new ones.
- Requested EC funding **10 M€**, total budget 24.8 M€ (42% funding rate).
- **18 Workpackages** (MGT, 7 Network Activities, 5 Transnational Access Workpackages, 5 Joint Research Activities).
- **42** partners from **18** EU countries (+CERN and ESS); coordination by CERN.

ARIES Workpackages



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.*
- *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.*

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 organized 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)*

- *Within WP1 (Task 1.4) – Industries for resistant materials (A. Rossi – 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)

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, NIMP, POLIMI, POLITO, UM, Brevetti Bizz, RHP Technology

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 very high power laser beams (GSI, ELI-NP)
- Irradiation tests with online monitoring of properties evolution (GSI)
- Hydrodynamic simulations of experiments - EOS, spall strengths for new materials

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

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 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

Budget

TASK	Lab-Ind	Person•month	From EU (k€)
1. Communication & Coordination	GSI	7	15
	CERN	7	15
2. Materials development and characterization	CERN	36	55 (Meas)
	GSI	16	70 (PhD +30 subc)
	POLITO	5	20 (studies - meas)
	UM	20	50 (studies, part PhD)
3. Dynamic testing and online monitoring	CERN	4	-
	GSI	16	100 (PhD+irradiation)
	POLITO	45	100 (analysis-meas)
	POLIMI	50	80 (PhD)
	ELI-NP	10	30 (laser: target/cons.)
4. Simulation of irradiation effects and mitigation methods	CERN	30	30 (studies)
	GSI	1	10 (studies)
	POLIMI	4	10
5. Broader accelerator and societal applications	CERN	1	5
	GSI	3	20 (subc.)
		255	**645**

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

- Task 17.1) Organisation of PowerMat kick-off meeting, with publication of talks on Web [month 6]
- Task 17.2) Material characterisation, with publication of results on Web [month 18-24]
- Task 17.3) Irradiation, with publication of report on web[month 27]
- Task 17.4) Irradiation effects analysis, with publication of report on web[month 36]
- Task 17.5) Report on studies, with publication of report on web, [month 46]
- Task 1.4) Prepare first samples [month 12]

Deliverables and Milestones Gannt-Chart

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							M						D			
17.3									M							D
17.4												M		D		
17.5																M
1.4				M				D								

PowerMat WP summary

Objectives:

Study and development of graphitic materials and electrically conductive coatings, resisting the impact of high intensity particle beams: aiming at electrical conductivity of 2.5MS/m (10 times normal graphite and 2.5 times what presently achieved), with robustness to beam impacts of the order of 3MJ, and resistance to radiation to at least a fraction of a DPA (displacement per atom).

Develop new diamond-metal matrix composites luminescence screens capable of operating at intensities 1 or 2 orders of magnitude larger than the actual Cr doped Al2O3 screens (10^9 – 10^{10} heavy ions/cm^2).

1.
2.
3.
4.
5.
6.

		Personnel (person • month)	Total costs (d.+ ind.) (k€)	Eu contribution (k€)	%
1	CERN	78	636	85	> 50
2	ELI-NP	10	86	50	50
3	GSI	43	447.5	200 (+50)	50
4	POLIMI	54	276	90	> 50
5	POLITO	50	298	120	50
6	UM	20	131	50	> 50
-	NIMP			(50)	(associate)
	total		255	645	

– CERN)

CERN)

Budget & Personnel by Participant

		Personnel (person • month)	Total costs (d.+ ind.) (k€)	Eu contribution (k€)	%
1	CERN	78	636	85	> 50
2	**ELI-NP**	10	86	50	50
3	GSI	43	447.5	200 (+50)	50
4	**POLIMI**	54	276	90	> 50
5	POLITO	50	298	120	50
6	UM	20	131	50	> 50
-	**NIMP (associate)**			(50)	
	total	**255**	**1895**	***645***	