ARIES Final Review Meeting

Material Testing with Extreme Beams,

Report from TNA WP10

V. Stergiou, P. Simon & **N. Charitonidis** (CERN, BE-EA)
Daniel Severin (GSI)

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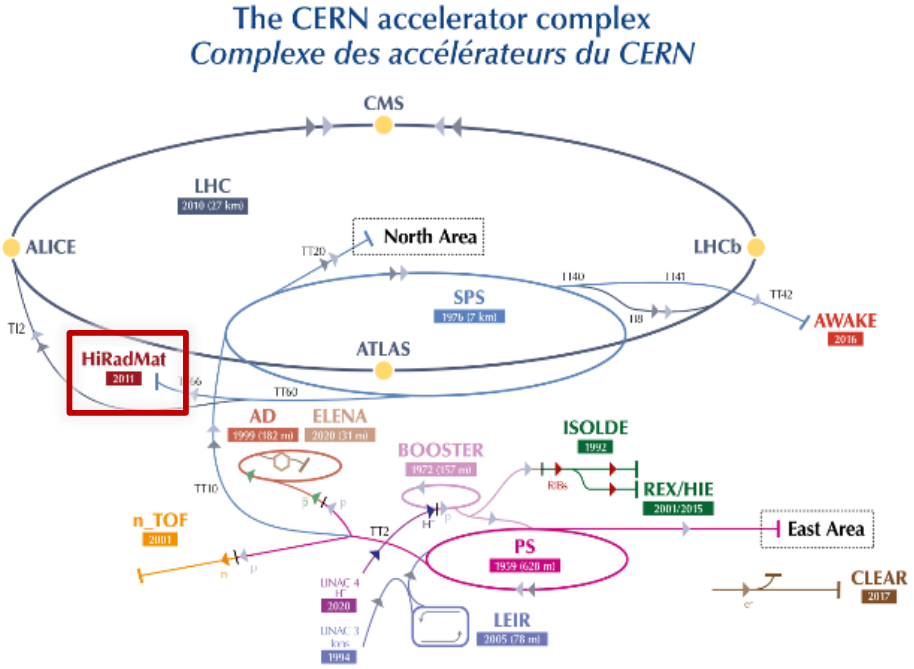
A “flash” reminder of HiRadMat

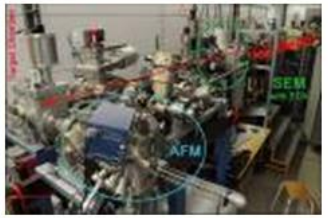
- HiRadMat (High-Radiation to Materials) is a user facility for **high-energy, high-intensity pulsed beams**
  - The facility **was commissioned in 2011** and **located in SPS Point 7**
  - **40 successful experiments** since the commissioning with the support of Eucard/Eucard2/ARIES



GSI-UNILAC M-Branch

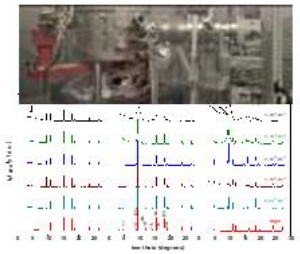
M-Branch
In-situ and On-line Analysis of Irradiated Material

M1
Microscopy



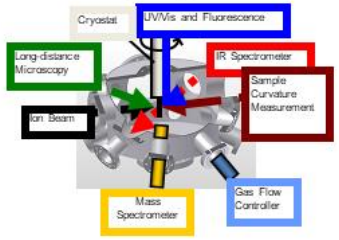
University of Stuttgart
University of Duisburg Essen

M2
X-Ray Diffraction

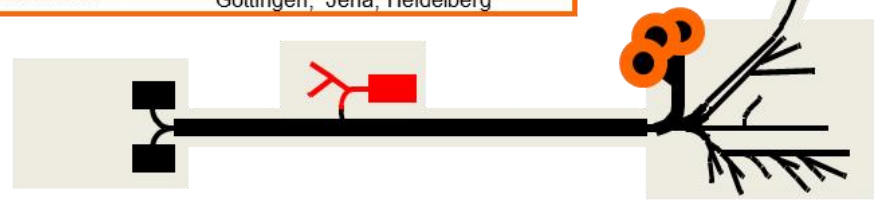


Helmholzzentrum Berlin / GSI

M3
Multi-Analysing Chamber



Universities of Darmstadt, Dresden
Göttingen, Jena, Heidelberg



UNILAC:

Ions: proton - Uranium
Energy: 3.6-11.4 MeV/u
Range: ~ 100µm

Highlights of HiRadMat experiments conducted during and supported by **ARIES**

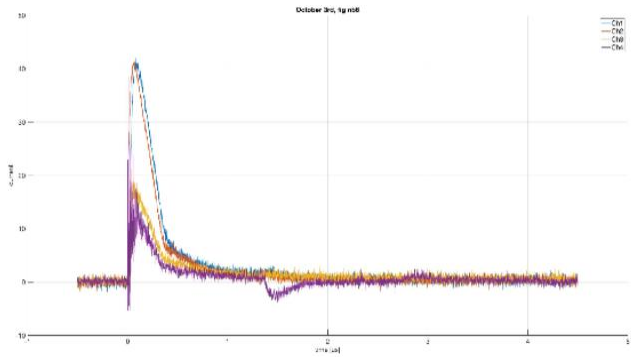
WP10.1 HiRadMat

2017-2022

HRMT-19 BLM2 (CERN-ESS/ERIC)

Courtesy of Viatcheslav Grishin et al. (ESS-ERIC)

- **Study of the signal linearity and response, saturation, calibration, comparison of different types of BLMs**
- Started in 2015, received dedicated and parasitic time
- TNA support throughout 2017-2018
- **New** and **LHC installed** monitors were tested, calibrated and compared:
  - Ionization Chambers (**IC**)
  - Little Ionization Chambers (**LIC**) with IC and SEM ceramics
  - Flat Ionization Chambers (**FIC**)



Courtesy of E. Nebot

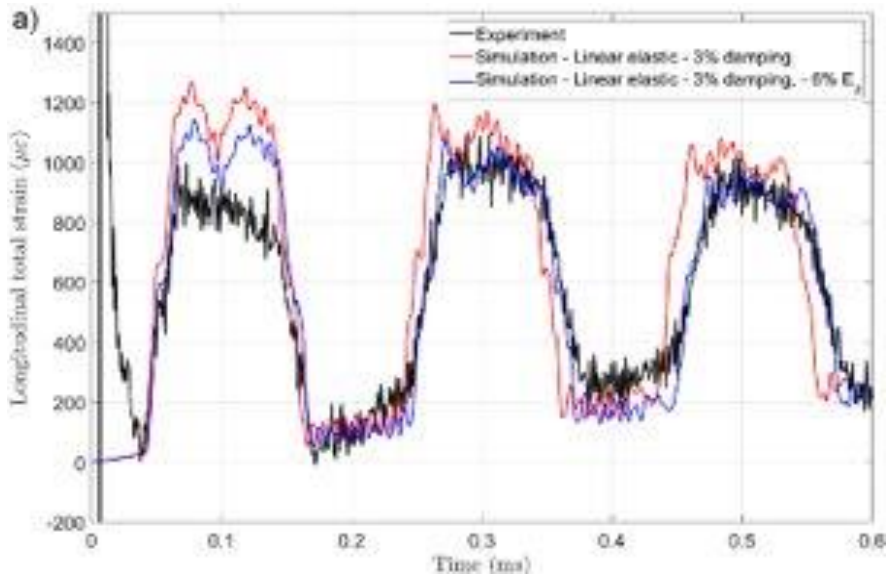
- **Tests confirmed the necessary design for future installations**
- Results published in **2 publications**

HRMT-36 MultiMat (U.Malta, Brevetti-Bizz SME Italy)

- **Study of multiple currently used and novel material samples for Beam Intercepting Devices of HL-LHC (and beyond e.g. FCC)**

- Performed in 2017
- Acquire material dynamic responses and **benchmark numerical simulations**

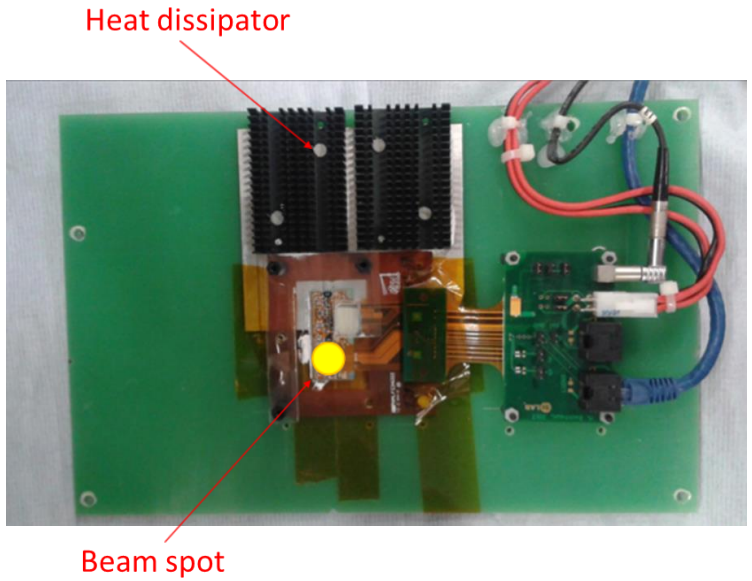
- **16 target stations - 18 different materials** (graphitic materials, carbides, carbon composites, metal alloys)
- **Results assisted the material qualification** for the HL-LHC collimators
- **6 peer reviewed publications**



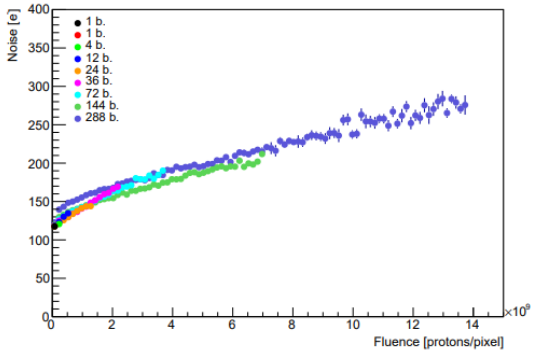
Courtesy of A. Bertarelli, F. Carra. M. Pasquali

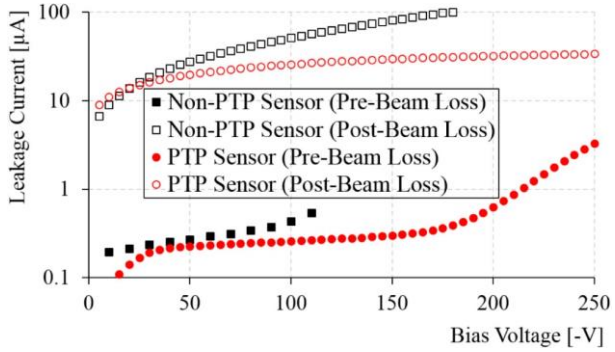
HRMT-47 ATLASPixRad (ATLAS Coll.)

- **Irradiation of ATLAS silicon detectors** to study the effects of **accidental beam loss** for HL-LHC
- Investigated **degradation and damage limit** of **new generation of pixel modules**



- **Experiment was conducted in 2018**, continuation of HRMT-41 that also benefited from ARIES TNA support
- The damage threshold of the ATLAS pixel detector determined to **approximately 10^{13} MIPs/cm^2**
  - Old generation of pixel modules: 10^{10} MIPs/cm^2
- Results published in **4 peer-reviewed articles**





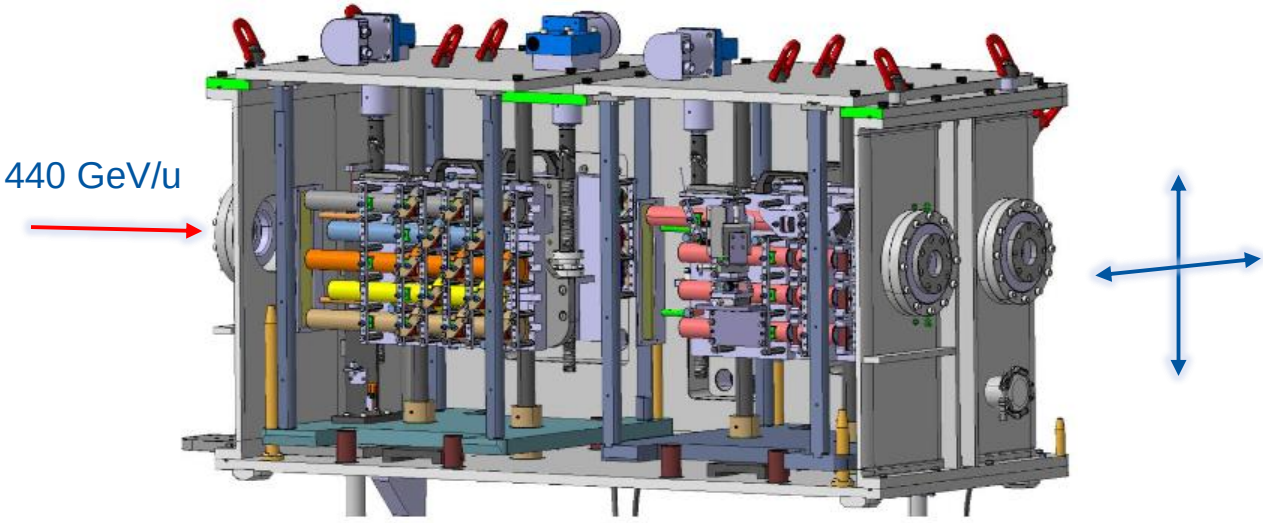
Courtesy of A. Sbrizzi (INFN-Bologna) & Simon P. (CERN)

HRMT-56 HED (NTNU, SINTEF)

- Studies on the **impact of high energy beams on currently used and novel material samples for use in high energy dump cores (HED)**

  - Experiment performed in 2021
  - **Tests on current LHC beam dump materials under HL-LHC operational conditions**
  - **Tests on a new design of the dump beam diluter** for the FCC-ee

- Important input for the **qualification of low-density graphite materials for present and future beam dumps** (present LHC dump, future HL-LHC, FCC-ee diluter…)



Highlights of M-Branch experiments conducted during and supported by **ARIES**

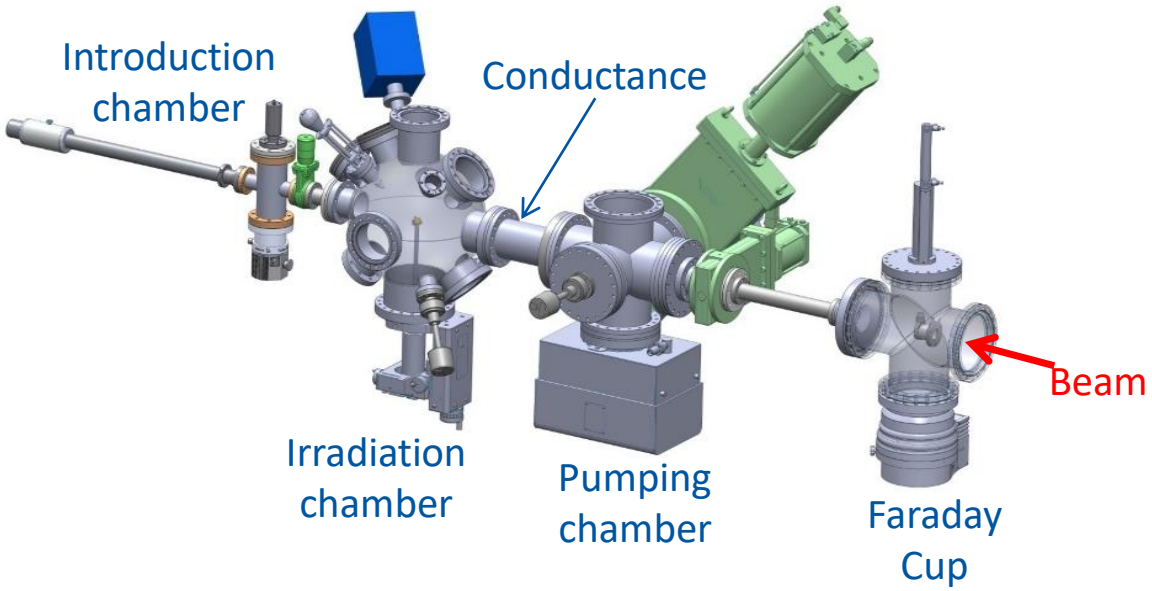
WP10.2 UNILAC M-Branch

2017-2022

Ion-induced outgassing and sputtering of volatile and frozen gasses

- Find the **best surface treatment** of Cu, W and Stainless Steel samples in order **to limit the released gas after impact**

- Ion-induced outgassing can be a severe limitation in modern accelerator developments
- Calibrated Residual Gas Analyser was used to determine **the nature of released gas**
- Ion Beam : Ca19+ or Ca10+ at 4.8 MeV/u
- Future publication is expected

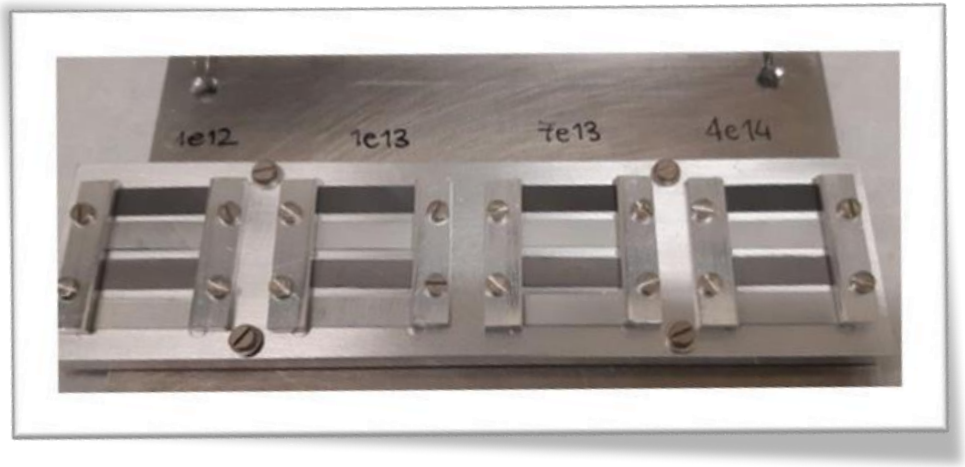


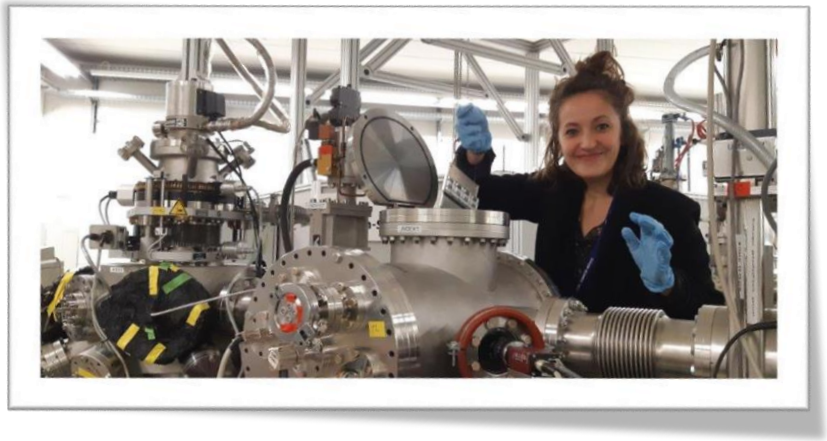
Courtesy of L.Kirsch / M.Bender (GSI)

Radiation damage scaling in accelerator materials for beam intercepting devices from high-flux light ions to high-energy protons

- Irradiation with Ca ions on **currently used and novel material samples for use in HL-LHC collimators and beam intercepting devices**
  - Graphite-based ceramic composites and diamond-reinforced materials

- Ca ions radiation comparable to radiation induced by high-energy protons





Courtesy of A. Bertarelli

- Results provided valuable information regarding the **assessment of long-term radiation damage** induced in materials for **beam intercepting devices.**

An outlook in the future

Status of proposals for 2023++

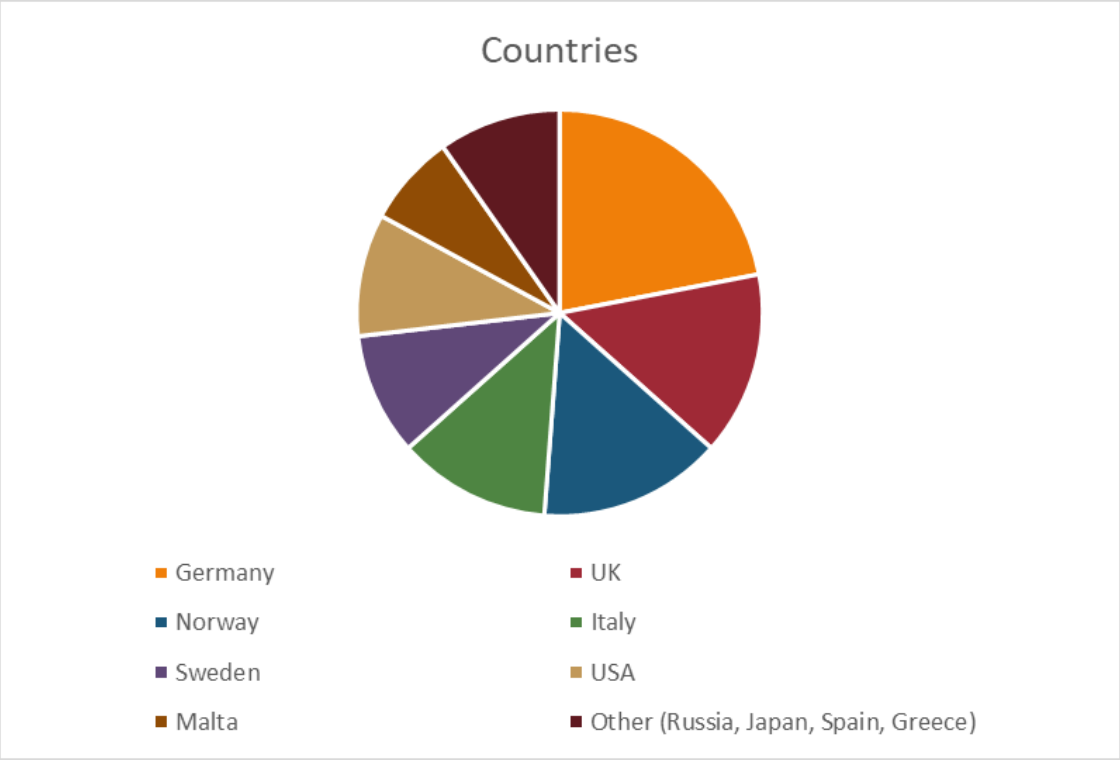
Proposal	Identifier	Experiment Name	Scientific Board	TB#1	IEFC	TB#2	Beam Time (tentative)	Safety Folder EDMS#	Requested integrated intensity (p)	Maximum Pulse Intensity	# requested Shifts
p-2003		CRY3 UA9 Coll.	Cond. Rec.#				2023	2421042	0.2 x 10^{15}	288 x 1.2·10^{11}	2
p-2005		DPA J-PARC, JP	Recommended				2023	2421044	0.2 x 10^{15}	24 x 1.2·10^{11}	2
p-2101		FIREBALL Uni. of Oxford, UK	Recommended				2023	2644127	<0.1 x 10^{15}	1 x 3·10^{11}	6
p-2001-4		ScintOF CERN / BE-BI	Pending				2023 ?	2421040			
p-1402	HRMT-25	TPSG4-2 CERN / SY-ABT	Recommended				*LIU-beams*	2421049			
…	…	*HED-2 CERN / SY-STI*	*Pending*				*LIU-beams*				
…	…	*MultiMat++ CERN/ EN-MME*	*Pending*				*LIU-beams*				

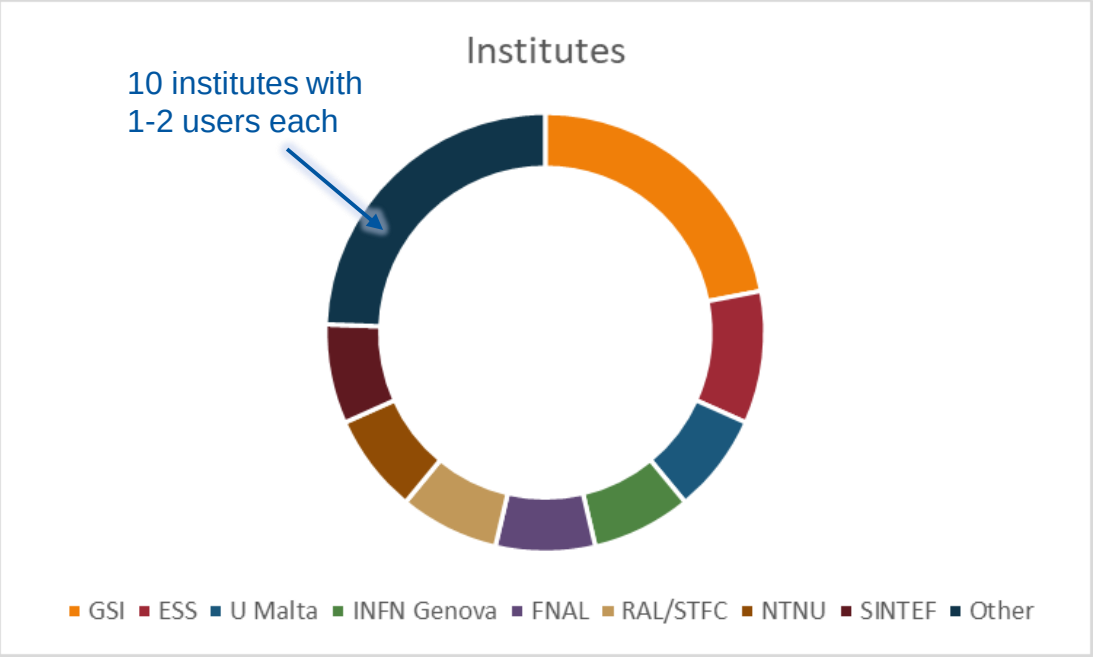
HiRadMat upgrade study group mandated and studies ongoing

- HiRadMat facility **strongly looking forward for EUROLABS** – Absolutely critical in order to support the experimental efforts that are already preparing their beam time in the facility.
- Potential new targets for TNA (2022-2026) : ~**4800 Access Units (h)**

Some statistics - HiRadMat

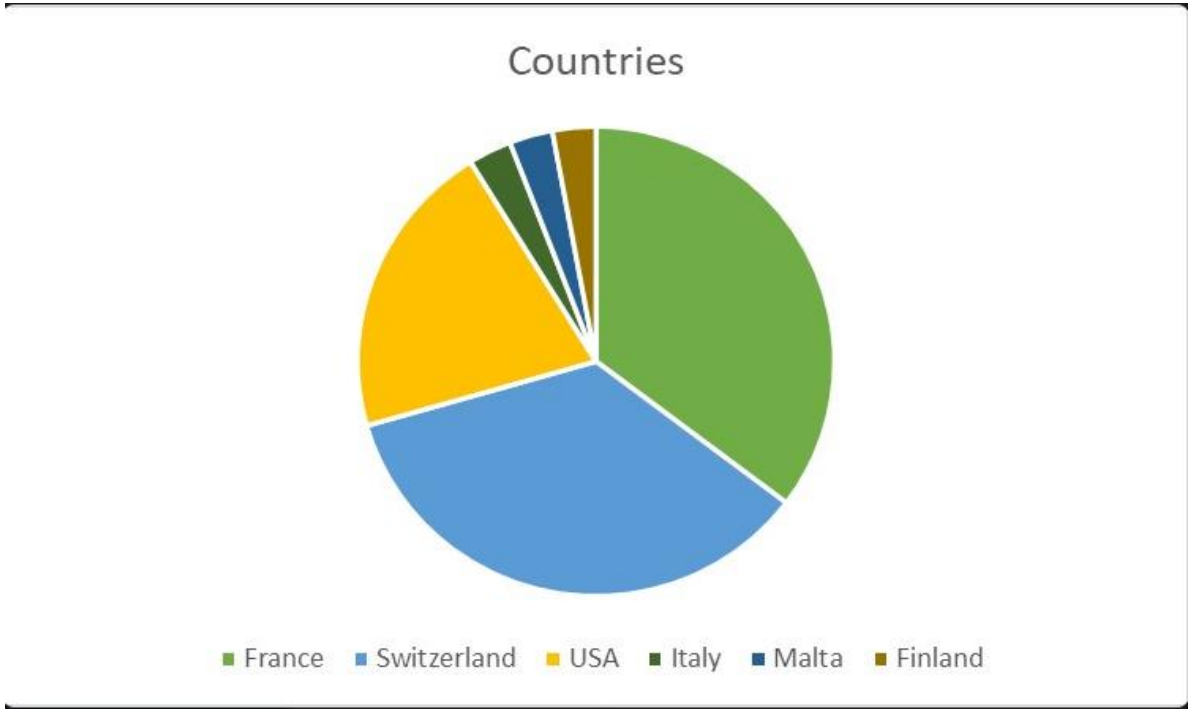
- 40 different users from 18 institutes, from 11 countries

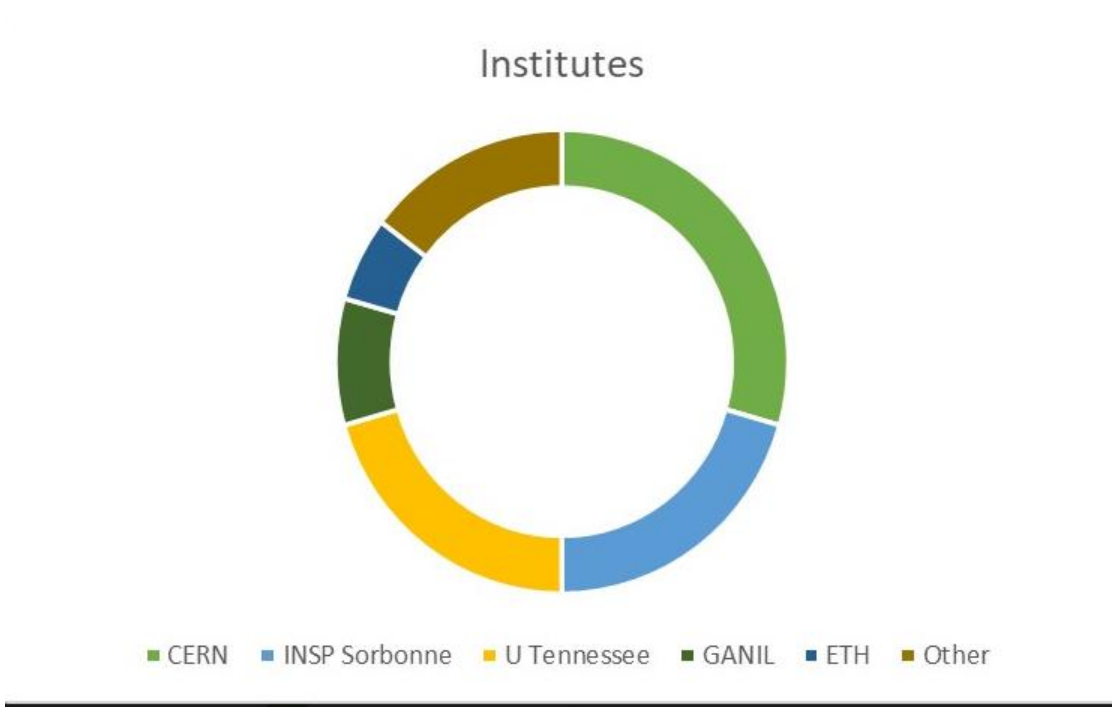




Some statistics – M-Branch

- 34 users from 10 institutes, from 6 countries





Summary of ARIES for WP10

- **WP10 has fulfilled by far the promised targets** (requested: 200 (664) HiRadMat and 480 (768) UNILAC) AU, delivered **2426 at HiRadMat and 900 at UNILAC**.

- **A very big list of publications has been produced**, and the HiRadMat experiments supported by TNA **have revealed unique results on material limits**, **crucial for the new accelerator driven systems in the high-brightness era**.

- The TNA access units were **delivered via TNA selection panels, acheiving a transparent an even distribution of nationalities and institutes both for HiRadMat and UNILAC**.

Conclusions

- **HiRadMat is already running with 4 approved slots (5 experiments) for 2022**
  - Outlook for 2022-2026 ~4800 AU expected for TNA (EUROLABS).
  - ARIES has been essential for HiRadMat supporting 10 experiments that brought many novel and crucial results for CERN and other institutes worldwide.

- **GSI/M-branch Facility succesfully completed the supported projects exceeding the foreseen AU and thanks ARIES for the critical support.**

  - Delivered ~900 AU to 34 researchers conducting 4 different experimental projects.

List of publications

List of Publications

2.1. HiRadMat

The following list contains all HiRadMat-relevant publications from April 2017 until April 2022. Entries in bold have received support by ARIES-TA.

HiRadMat Facility

- F. Harden et al. (2019) "HiRadmat: A facility beyond the realms of materials testing" J. Phys. Conf. Series 1350 012162. 10.18429/JACoW-IPAC2019-THPRB085
- F. Harden et al. (2021) "Targetry Challenges & HiRadMat" Proceedings of the 3rd J-PARC Symposium (J-PARC2019). 10.7566/jpscp.33.011149

On-line instrumentation for HiRadMat Experiments

- F. Carra et al. (2021) "Design and Construction of an Instrumentation System to Capture the Response of Advanced Materials Impacted by Intense Proton Pulses" Shock and Vibration. 10.1155/2021/8855582

HRMT10 – WTHIMBLE / HRMT22 – PTarg

- T. Davenne et al. (2018) "Observed proton beam induced disruption of a tungsten powder sample at CERN" Phys. Rev. Accel. Beams 21 073002. 10.1103/PhysRevAccelBeams.21.073002
- O. Caretta et al. (2018) "Proton beam induced dynamics of tungsten granules" Phys. Rev. Accel. Beams 21 033401. 10.1103/PhysRevAccelBeams.21.033401

HRMT12 – LPROT

- Y. Nie et al. (2019) "Simulation of hydrodynamic tunneling induced by high-energy proton beam in copper by coupling computer codes" Phys. Rev. Accel. Beams 22 014501. 10.1103/PhysRevAccelBeams.22.014501

HRMT18 – CRY2

- W. Scandale et al. (2019) "Beam steering performance of bent silicon crystals irradiated with high-intensity and high-energy protons" Eur. Phys. J. C 79 933. 10.1140/epjc/s10052-019-7448-2

HRMT19 – BLM2

- V. Grishin et al. (2017) "Ionization Chambers as Beam Loss Monitors for ESS Linear Accelerator" Proc. 6th Int. Beam. Instrumentation Conf. (IBIC'17) 454-57. 10.18429/JACoW-IBIC2017-WEPWC03
- V. Grishin et al. (2018) "A Family of Gas Ionization Chambers and SEM for Beam Loss Monitoring of LHC and Other Accelerators" Proc. 26th Russian Particle Accelerator Conf. (RuPAC'18) 44-48. 10.18429/JACoW-RuPAC2018-TUZMH03

HRMT21 – RotColl

- T. Markiewicz et al. (2019) "Design, construction, and beam tests of a rotatable collimator prototype for high-intensity and high-energy hadron accelerators" Phys. Rev. Accel. Beams 22 123002. 10.1103/PhysRevAccelBeams.22.123002

HRMT23 – Jaws

- G. Gobbi et al. (2019) "Novel LHC collimator materials: High-energy Hadron beam impact tests and non-destructive post-irradiation examination" Mechanics of Advanced Materials and Structures. 10.1080/15376494.2018.1518501

HRMT24 – BeGrid

- K. Ammigan et al. (2019) "Thermal shock experiment of beryllium exposed to intense high energy proton beam pulses" Phys. Rev. Accel. Beams 22 044501. 10.1103/PhysRevAccelBeams.22.044501

HRMT27 – RodTarg / HRMT42 – TaScat

- C. Torregrosa et al. (2017) "Renovation of CERN antiproton production target area and associated design, testing and R&D activities" Proc. 8th Int. Particle Accelerator Conf. (IPAC'17) WEPVA103 3506-09. 10.18429/JACoW-IPAC2017-WEPVA103
- C. Torregrosa et al. (2018) "Prototyping Activities for a New Design of CERN's Antiproton Production Target" Proc. 9th Int. Particle Accelerator Conf. (IPAC'18) TUPAF038 772-75. 10.18429/JACoW-IPAC2018-TUPAF038
- C. Torregrosa et al. (2018) "Scaled prototype of a tantalum target embedded in expanded graphite for antiproton production: Design, manufacturing, and testing under proton beam impacts" Phys. Rev. Accel. Beams 21 073001. 10.1103/PhysRevAccelBeams.21.073001

TRANSNATIONAL ACCESS TO MATERIAL TESTING FACILITIES
Deliverable: D10.1
Date: dd/mm/yyyy

- C. Torregrosa et al. (2019) "Experiment exposing refractory metals to impacts of 440 GeV/c proton beams for the future design of the CERN antiproton production target: Experiment design and online results" Phys. Rev. Accel. Beams 22 013401. 10.1103/PhysRevAccelBeams.22.013401
- C. Torregrosa et al. (2019) "First prototypes of the new design of the CERN's antiproton production target" Mat. Design Process Comm. 2019;1:e38. 10.1002/mdp2.38
- C. Torregrosa et al. (2021) "First observation of spalling in tantalum at high temperatures induced by high energy proton beam impacts" European Journal of Mechanics - A/Solids, 85, 104149. 10.1016/j.euromechsol.2020.104149

HRMT28 – TCDI

- F-X. Nuiry et al. (2019) "3D Carbon/Carbon composites for beam intercepting devices at CERN" Mat Design Process Comm. 2019;1:e33. 10.1002/mdp2.33

HRMT36 – MultiMat

- F. Carra et al. (2017) "The "Multimat" experiment at CERN HiRadMat facility: advanced testing of novel materials and instrumentation for HL-LHC collimators" IOP Conf. Series: Journal of Physics: Conf. Series 874 012001. 10.18429/JACoW-IPAC2017-MOPAB005
- A. Bertarelli et al. (2018) "Dynamic testing and characterization of advanced materials in a new experiment at CERN HiRadMat facility" IOP Conf. Series: Journal of Physics: Conf. Series 1067 082021. 10.1088/1742-6596/1067/8/082021
- M. Pasquali et al. (2019) "Dynamic Response of Advanced Materials Impacted by Particle Beams: The MultiMat Experiment" Journal of Dynamic Behavior of Materials 5 266–95. 10.1007/s40870-019-00210-1
- M. Portelli et al. (2019) "Numerical and experimental benchmarking of the dynamic response of SiC and TZM specimens in the MultiMat experiment" Mechanics of materials 138 103169. 10.1016/j.mechmat.2019.103169
- F. Carra et al. (2019) "Mechanical robustness of HL-LHC collimator designs" IOP Conf. Series: Journal of Physics: Conf. Series 1350 012083. 10.1088/1742-6596/1350/1/012083 [also linked to HRMT23]
- M Portelli et al. (2021) "Thermomechanical Characterisation of Copper Diamond and Benchmarking with the MultiMat Experiment" Shock and Vibration. 10.1155/2021/8879400

HRMT37 – SextSC

- A. Will et al. (2019) "Beam impact experiment of 440 GeV/p protons on superconducting wires and tapes in a cryogenic environment" Proc. 10th Int. Particle Accelerator Conf. (IPAC'19) THPTS066 4264-67. 10.18429/JACoW-IPAC2019-THPTS066

HRMT38 – FlexMat

- P. Simon et al. (2021) "Dynamic response of graphitic targets with tantalum cores impacted by pulsed 440-GeV proton beams" Shock and Vibration. 10.1155/2021/8884447

HRMT41 – ATLAS-PIXEL / HRMT47 – ATLASPixRad

- J. Fernandez-Tejero et al. (2019) "Beam-loss damage experiment on ATLAS-like silicon strip modules using an intense proton beam" Nuclear Inst. And Methods in Physics Research A 958 162838. 10.1016/j.nima.2019.162838
- C. Bertella et al. (2019) "Damages induced on ATLAS IBL modules by fast extracted and intense proton beam irradiation" J. Inst. 14 C05024. 10.1088/1748-0221/14/05/C05024
- C. Bertella et al. (2019) "Test with high-energy and high-intensity proton beam on ATLAS silicon detectors towards HL-LHC" Nuovo Cim. C42 205. 10.1393/ncc/i2019-19205-8
- C. Bertella et al. (2019) "Study of damages induced on ATLAS silicon by fast extracted and intense proton beam irradiation" Nucl Instrum Meth A 924 236-40. 10.1016/j.nima.2018.06.043

HRMT43 – BeGRID2

- S. Bidhar et al. (2021) "Design, prototyping activities and beam irradiation test for the new n_TOF neutron spallation target" Proc. 9th Int. Particle Accelerator Conf. (IPAC'18) WEPMF084 2582-85. 10.18429/JACoW-IPAC2018-WEPMF084

HRMT46 – n-ToF Target

- R. Esposito et al. (2018) "Design, prototyping activities and beam irradiation test for the new n_TOF neutron spallation target" Proc. 9th Int. Particle Accelerator Conf. (IPAC'18) WEPMF084 2582-85. 10.18429/JACoW-IPAC2018-WEPMF084

HRMT48 – PROTAD

- J. Busom Descarrega et al. (2020) "Development and Beam Irradiation of Ir/W/Ta/Ta-Alloys Refractory Metals and Cladding Via Hot Isostatic Pressing at CERN for Beam Intercepting Devices Applications", Proc. 14th Int. Workshop Spallation Materials Technology, JPS Conf. Proc. 28. 10.7566/JPSCP.28.041002

We thank ARIES for their important support on behalf of WP10 and our users !

Thank you for your attention !

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