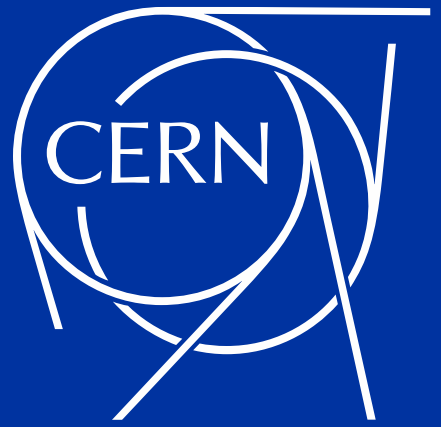


Overview of ARIES experiments at HiRadMat

P. Simon, N. Charitonidis, A. Ebn Rahmoun on behalf of the HiRadMat Users

6th December 2021

HiRadMat Facility

Short-pulse high-energy proton irradiation facility

Not to accumulate high doses, but to investigate pulsed beam effects

- **LHC-like beam structure:**

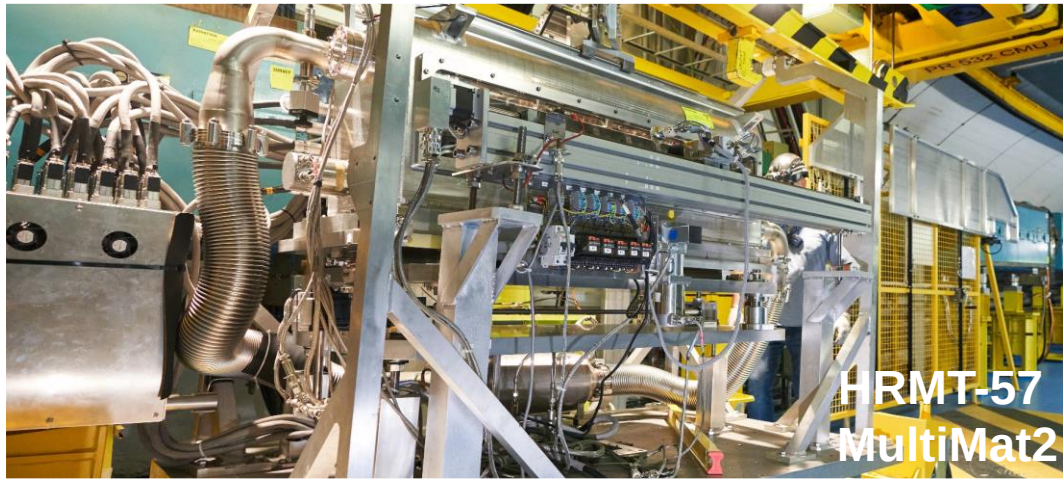
  1.5 ns bunch length (4 σ)

  25 ns bunch spacing

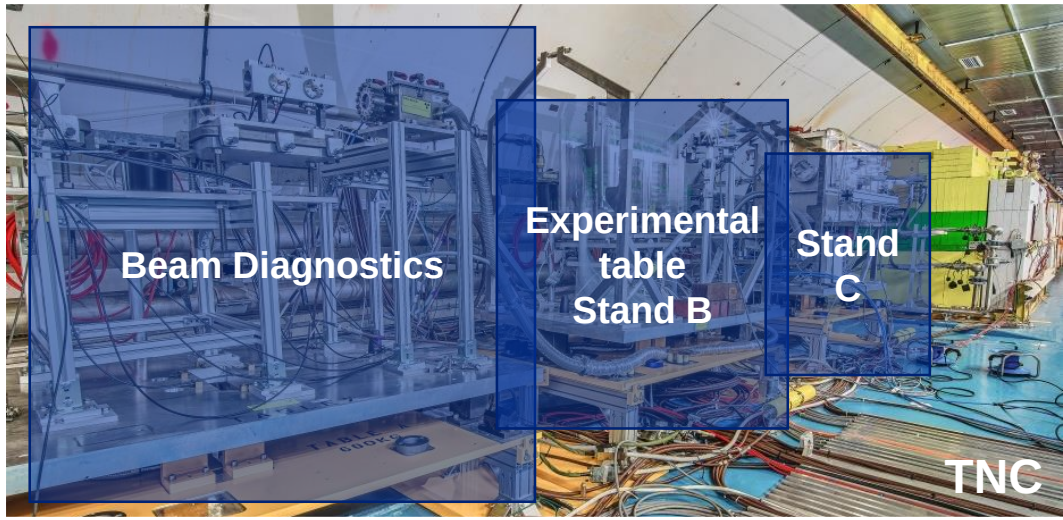
  Up to **288 bunches** with up to **$1.2 \cdot 10^{11}$** protons **per bunch**

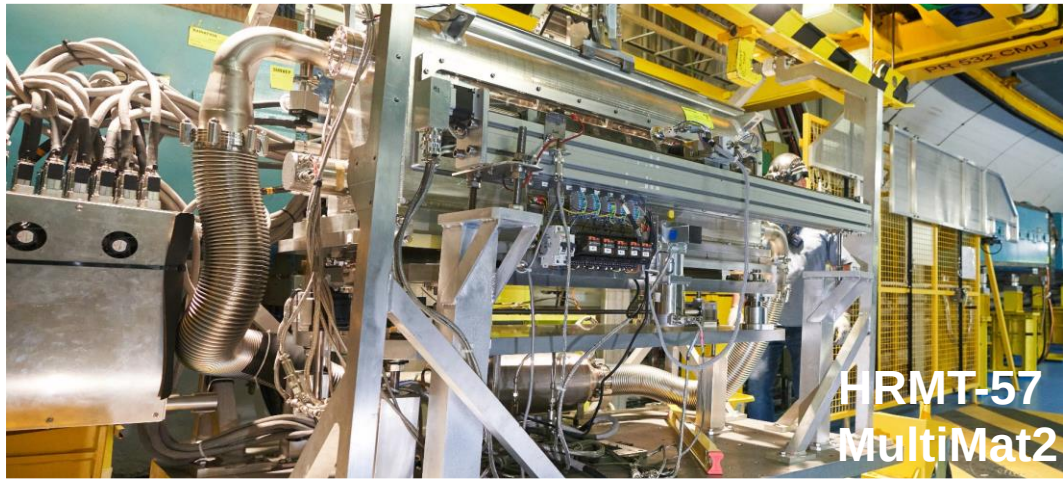
  $3.4 \cdot 10^{13}$ protons per pulse at **440 GeV/c (2.4 MJ)**

  Variable beam size at target: **<1 mm** (1 σ)



HiRadMat Facility





Designed for maximum flexibility

- **Assembly, alignment and dry-running at the surface in BA7 in supervised RP area**
- **Target Area with remote plug'n'play connectivity**

  More than 300 signal connections per experiment
- **Pulse-to-pulse beam diagnostics**

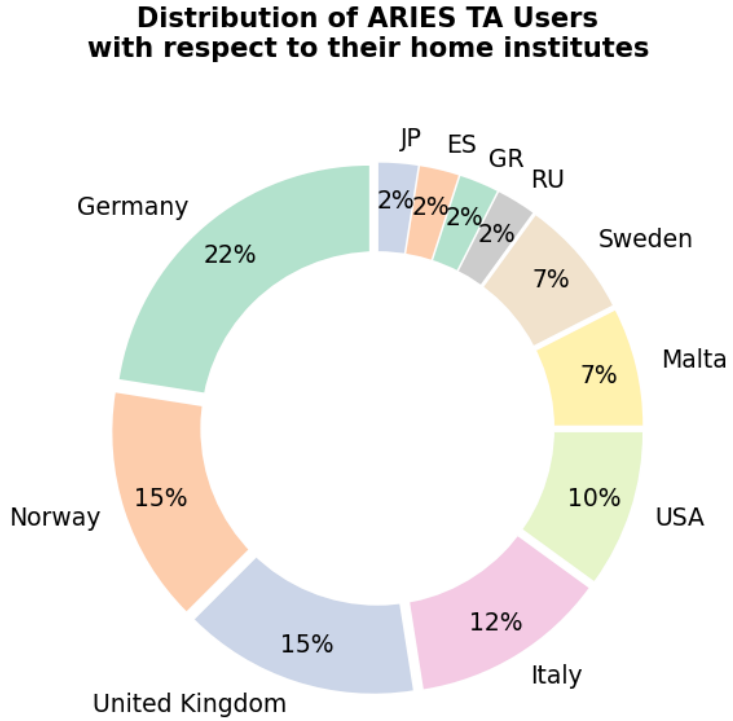
  Allows grazing incident impacts with <100 µm precision
- **Shielded locations in auxiliary tunnel and upstream 'bunker'**

  High speed cameras, laser diagnostics, short cabling length

HiRadMat Experiments during ARIES

2017		2018		2021	
HRMT42	TaScat	**HRMT47**	**ATLASPixRad**	**HRMT54**	EO-BPM
HRMT18	CRY2	**HRMT38**	**FlexMat**	HRMT53	CHEFT
HRMT28	TCDI	HRMT44	TCDIL	**HRMT55**	**BLM3**
HRMT41	**ATLASpixel**	HRMT37	SextSc	**HRMT57**	**MultiMat2**
HRMT21	**RotCol**	HRMT45	TDIS	**HRMT56**	**HED**
HRMT19	**BLM2**	HRMT48	PROTAD		
HRMT35	TDIcoat	HRMT49	TIDVG		
HRMT36	**MultiMat**	**HRMT43**	**BeGrid2**		
		HRMT46	n-ToF		

50% **33%** **80%**



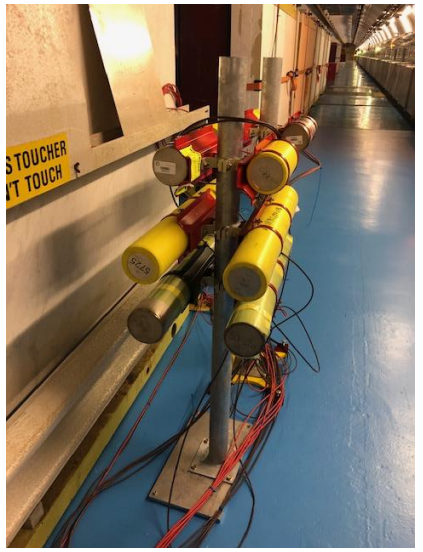
~50% of all experiments supported by ARIES-TA!

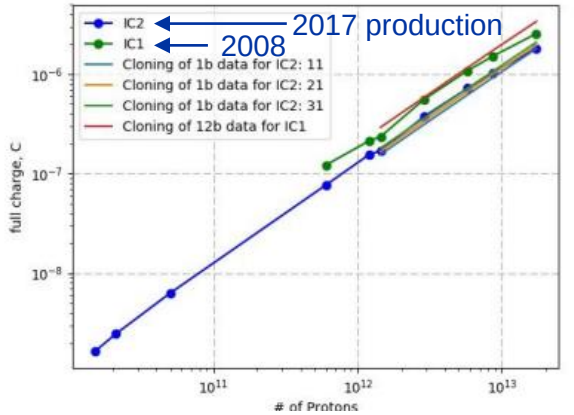
(Additionally, one experiment supported during preparation)

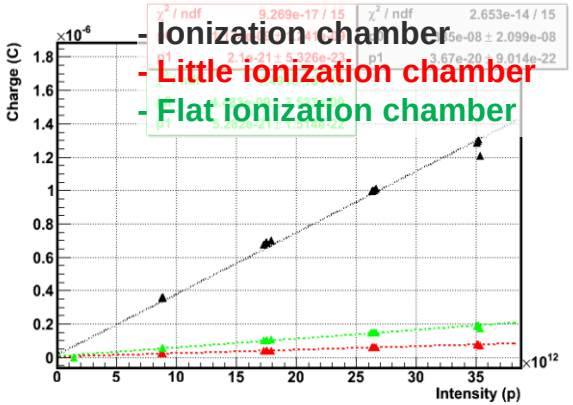
HRMT19 BLM2, HRMT55 BLM3 ESS

- **Validate and calibrate various beam loss monitors (BLMs) under real beam conditions**
  - New series production of ionization chamber BLMs
  - R&D on ‘little ionization chamber’ for injection regions of (HL-)LHC
- **Critical infrastructure for beam diagnostics at CERN, ESS and GSI**
  - Close to a thousand BLMs in the LHC alone

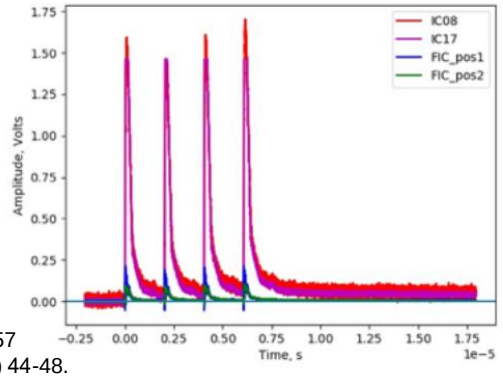
  “*After LS3, literally every 10 meters in the whole accelerator complex, from LINAC4 to LHC, there will be a bright yellow tube.*”
- **On-going measurement campaign in 2022**







4 x 72 bunches

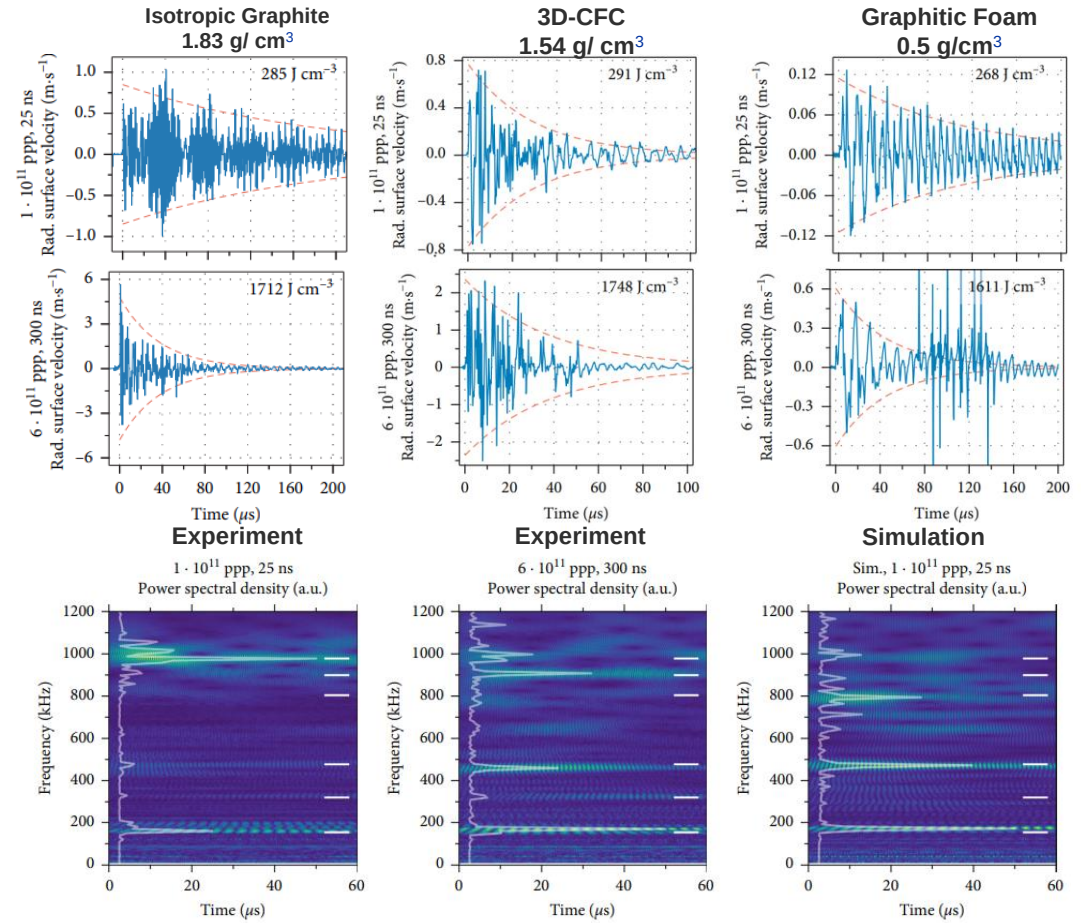


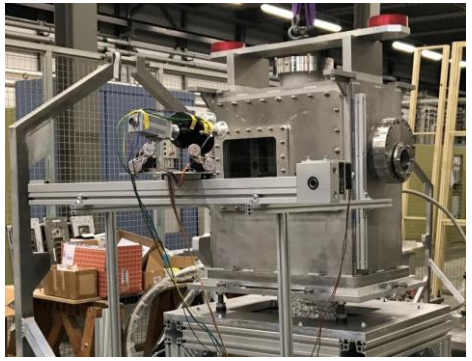
V. Grishin et al. 2017 Proc. 6th Int. Beam. Instrumentation Conf. (IBIC’17) 454-57
V. Grishin et al. 2018 Proc. 26th Russian Particle Accelerator Conf. (RuPAC’18) 44-48.

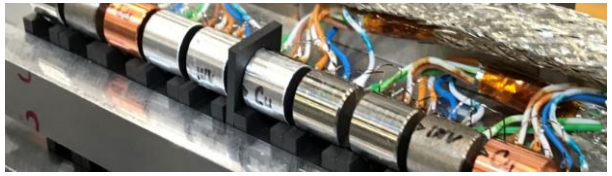
HRMT38 FlexMat GSI/FAIR

- **Test dynamic response of graphitic materials for beam-intercepting devices**
  - Large density range: 0.5 – 2.2 g/cm^3
  - 35 samples of 12 different grades
- **Systematically investigate influence of:**
  - Micro-structure, porosity, pyrolization treatment
  - Degree of graphitization
  - Anisotropy

  Benchmark for advanced numerical simulations
- **R&D on FAIR p-bar target material:**
  - 10 samples of Invar, Inconel, Copper
  - p-bar mock-up target





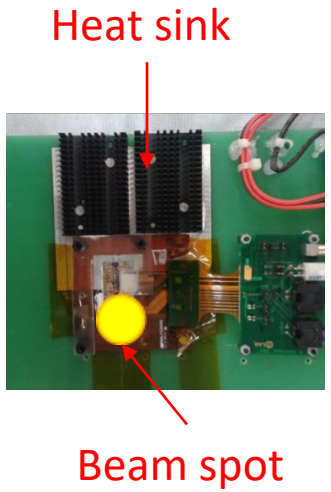


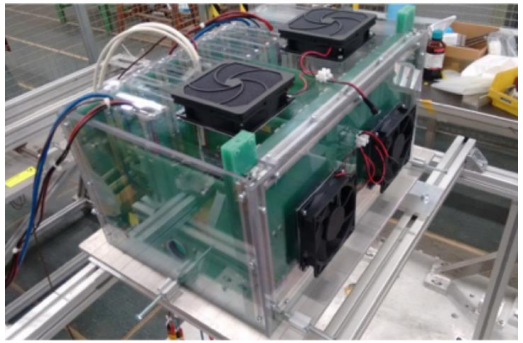
P. Simon et al. 2021 Shock and Vibration, vol. 2021, Article ID 8884447

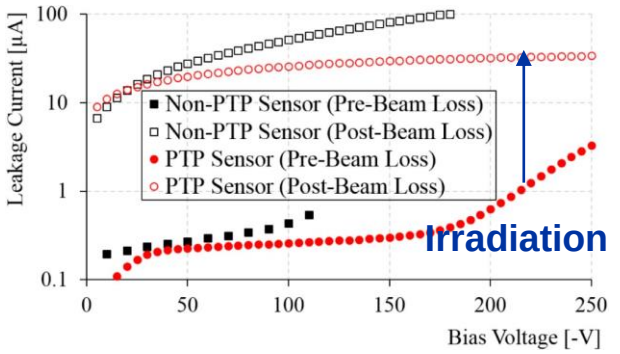
HRMT41/47 ATLASPixRad INFN Genova

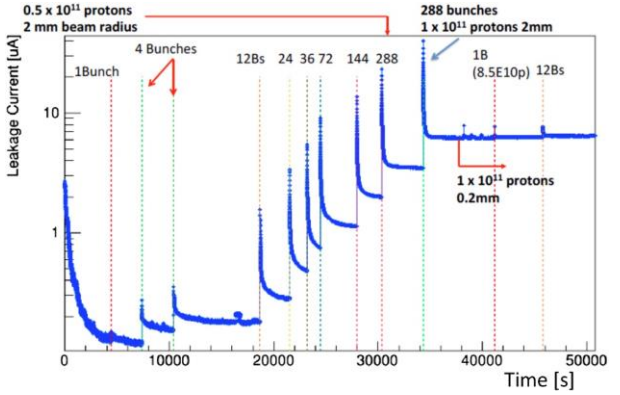
C. Bertella et al. 2019 IL NUOVO CIMENTO 42 C 205
C. Bertella et al. 2019 JINST 14 C05024
J. Fernandez-Tejero et al 2019 NIMA 958 162838
C. Bertella et al. 2019 NIMA 924 236

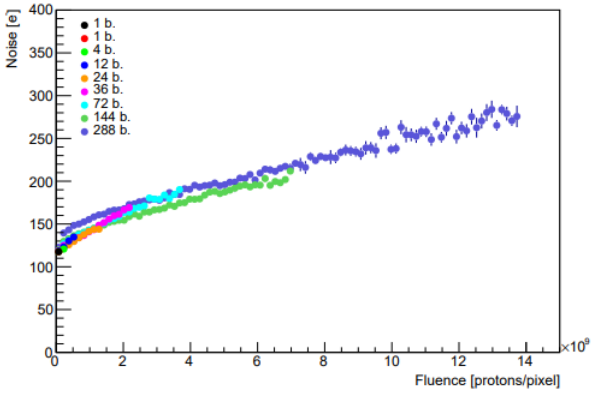
- **Investigate detector degradation and damage limit of new generation of pixel modules**
  - Innermost layer (IBL) of the ATLAS Pixel detector
- **Direct irradiation of pixel and strip modules at HiRadMat**
  - Simulate beam loss conditions expected at HL-LHC
- **Experiment established a damage limit of 10^{13} MIPs/cm^2**
  - Old generation: 10^{10} MIPs/cm^2
- **Punch trough protection (PTP) effective**
  - 99% survival vs. 40% strip survival, but damaged readout electronics





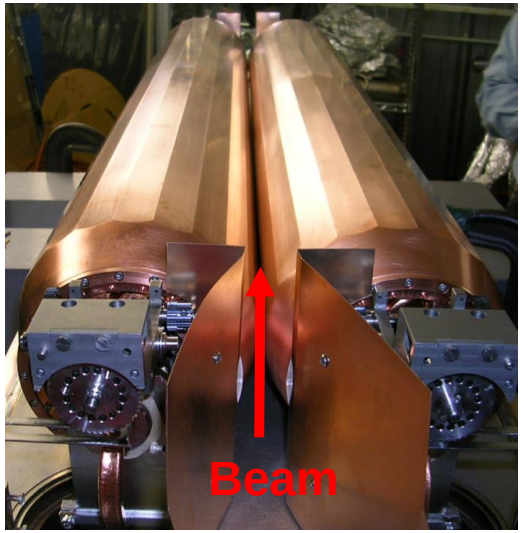


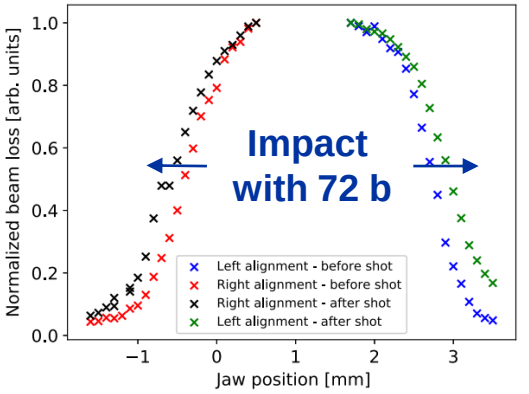


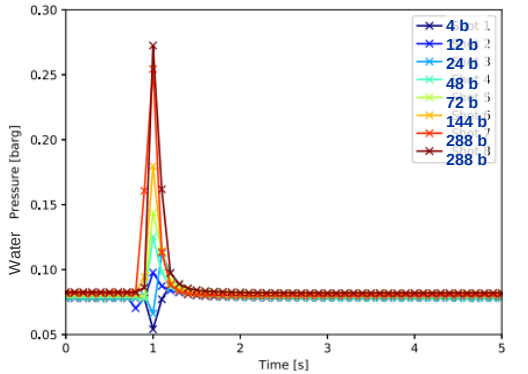


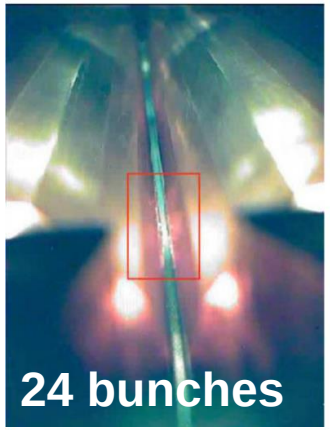
HRMT21 RotColl
SLAC, University of Malta

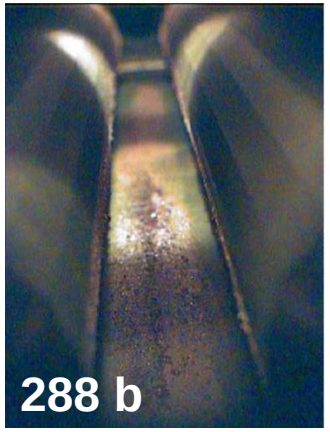
- **Rotatable collimator prototype by SLAC**
  - US-LARP collaboration
  - Offers up to 20 collimating surfaces in case of beam damage
- **Validation of the rotation mechanism and integrity of cooling circuit during the design failure scenario**
  - LHC asynchronous beam dump: 8 bunches @ 7 TeV
- **Investigate damage onset beyond design case**
  - LHC injection error: 288 bunches @ 450 GeV
- **Fully validated design concept together with installation in the SPS**
  - Damage onset at 24 bunches
  - Rotation mechanism and cooling circuit robust







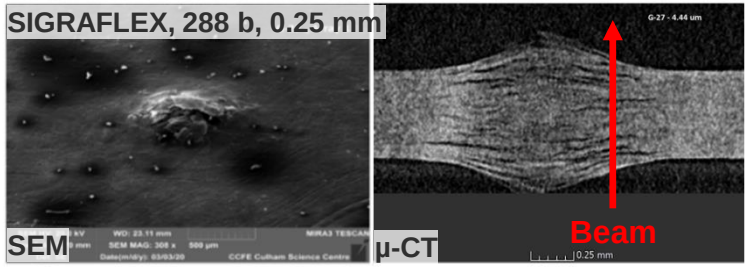


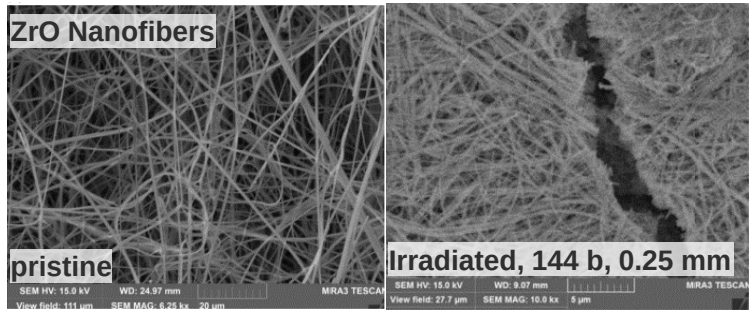


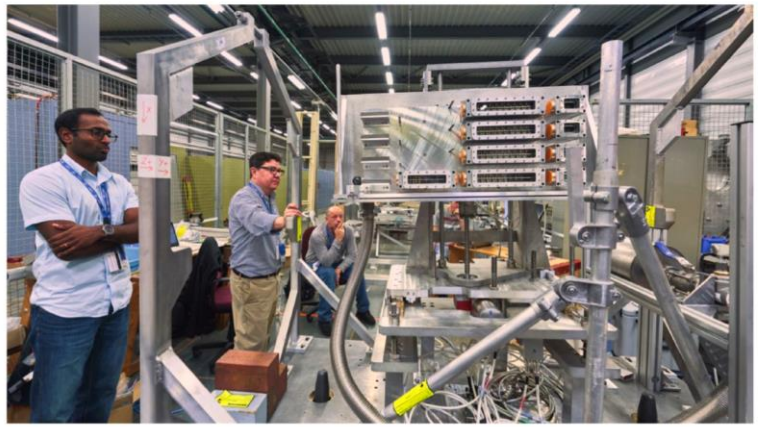
T. Markiewicz et al. 2019 PRAB 22 123002

HRMT43 BeGrid2
RaDIATE Collaboration

- **First test ever at HiRadMat with pre-irradiated samples**
  - 25 pre-irradiated material specimen from BNL BLIP (out of 89 in total)
  - Relevant for high power targetry applications
  - Complex coordination between BNL, FNAL, PNNL and CERN to handle and assemble highly radioactive samples
- **Goal to identify differences in thermal shock response**
  - Benchmark highly non-linear numerical simulations
- **Ambitious post-irradiation characterization campaign**
  - Hot cell measurements at Culham Centre for Fusion Energy, UK
- **Follow-up experiment in 2022**







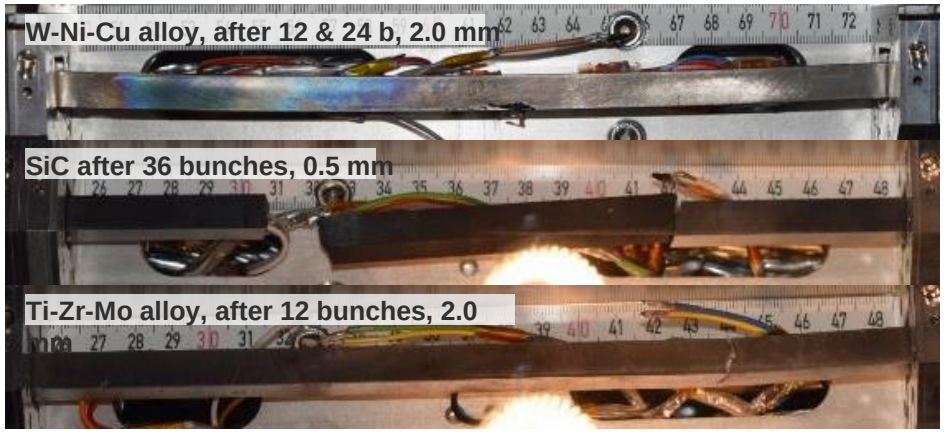
S. Bidhar et al. 2021 PRAB 24 123001
J. Heredia et al. 2021 IPAC2021 3571-3574
Courtesy K. Ammigan, FNAL

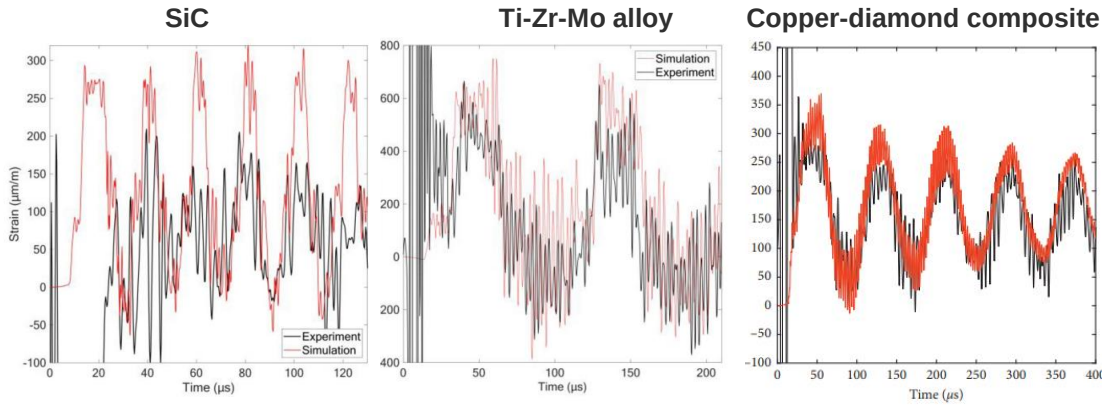
HRMT36 MultiMat
U. Malta, Brevetti-Bizz SME Italy

- **Investigate dynamic response of novel materials for HL-LHC collimator upgrade**
  - 16 target stations with 18 different materials ranging from ultra light C foams to heavy W alloys
  - MoGr, CFC and graphite coated with Mo, Cu, TiN
  - To derive & extend constitutive models and material properties as input for numerical simulations
- **Conditions exceeding maximum energy deposition density of LHC injection error**
- **Re-usable multi-purpose testbench**


'revolver barrel' target station


Experiment installation





F. Carra et al. 2017 Proceedings IPAC17 MOPAB005
A Bertarelli et al. 2018 J. Phys.: Conf. Ser. 1067 082021
F. Carra et al. 2019 J. Phys.: Conf. Ser. 1350 012083
M. Pasquali et al. 2019 Journal of Dynamic Behavior of Materials 5 266
M. Portelli et al. 2019 Mechanics of Materials 138 103169
M. Portelli et al. 2021 Shock and Vibration, vol. 2021, 8879400

2021 Experiments

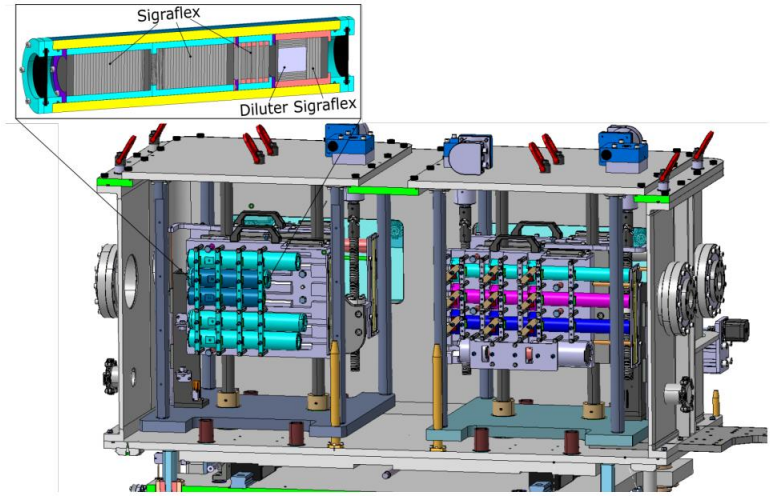
HRMT57 – MultiMat2
Sapienza University

Validation of industrial grades and coatings for HL-LHC collimator series production

J. Guardia “Results on HRM incl. status of CuCD” 11th HL-LHC Collaboration Meeting, 19-22 Oct 2021 https://indico.cern.ch/event/1079026/

HRMT56 – HED
SINTEF, NTNU, U. Granada

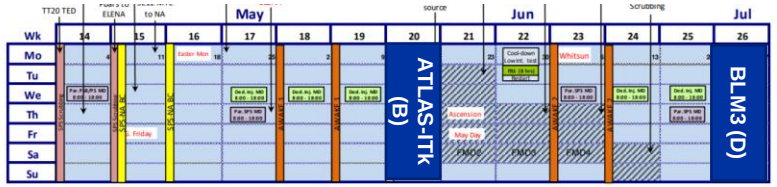
Performance assessment of graphite materials for the (HL-)LHC beam dump

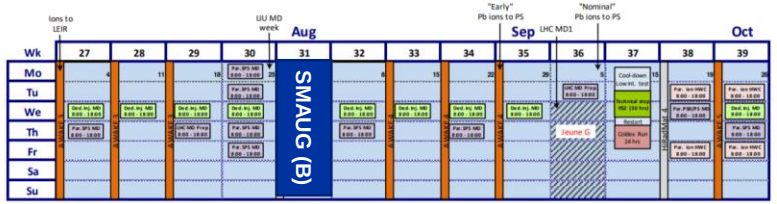


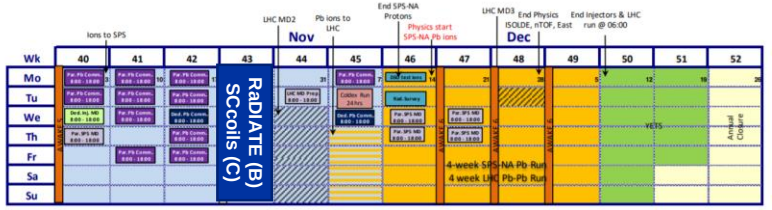
J. Heredia et al. 2021 IPAC2021 3571-3574

HiRadMat future after ARIES

- **2022: 4 slots with 5 experiments (3 external)**
- **2023: 3 experiments in the pipeline (2 external)**







HiRadMat Upgrade Study Group

Multiple experiment proposals calling for LIU beams already!

EURO-LABS

Transnational access support starting September 2022

EURO-LABS
EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

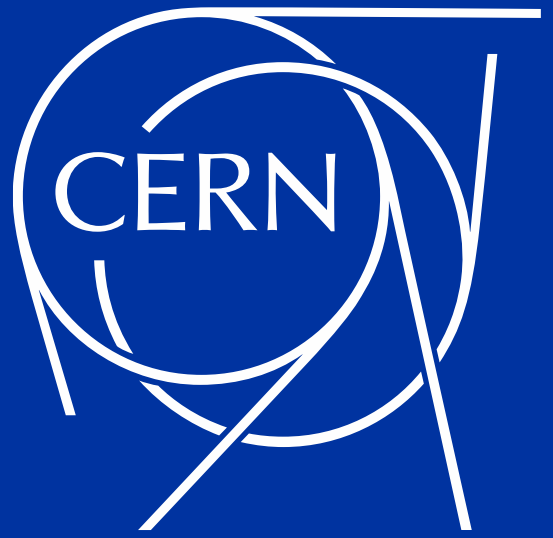
	Experiment	Context	POT	Max. Pulse Intensity	Beam Time (tentative)
HRMT58	**ATLAS-Itk** Jožef Stefan Inst., SI	Detector	**2.9 x 10^{15}**	**288 x 1.2·10^{11}**	**2022**
HRMT55	**BLM3** ESS, SE	Beam Instrumentation	**0.9 x 10^{15}**	**288 x 1.2·10^{11}**	**2022**
HRMT59	**SMAUG** CERN / TE-VSC	Beam Intercepting Devices	**2.6 x 10^{15}**	**288 x 1.2·10^{11}**	**2022**
HRMT60	**RaDIATE2022** FNAL, US	Targetry	**0.2 x 10^{15}**	**288 x 1.2·10^{11}**	**2022**
HRMT61	**SCcoils** CERN / TE-MPE	Machine Protection	**<0.1 x 10^{15}**	**24 x 1.2·10^{11}**	**2022**
p-2003	**CRY3** UA9 Coll.	Beam Intercepting Devices	**0.2 x 10^{15}**	**288 x 1.2·10^{11}**	**2023**
p-2005	**DPA** J-PARC, JP	Materials Science	**0.2 x 10^{15}**	**24 x 1.2·10^{11}**	**2023**
p-2101	**FIREBALL** Uni. of Oxford, UK	Plasma Physics	**<0.1 x 10^{15}**	**1 x 3·10^{11}**	**2023**
p-2001-4	**ScintOF** CERN / BE-BI	Beam Instrumentation			**2023?**
HRMT25	**TPSG4-2** CERN / SY-ABT	Beam Intercepting Devices			**LIU beams**
	HED-2 CERN / SY-STI	Beam Intercepting Devices			**LIU beams**
	MultiMat++ CERN, EN-MME	Beam Intercepting Devices			**LIU beams**

List of HiRadMat publications and references:

https://cern.ch/hiradmat

Thank you for your attention!

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


CERN