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The HiRadMat Facility and the EURO-LABS Initiative

HiRadMat
High-Radiation to Materials

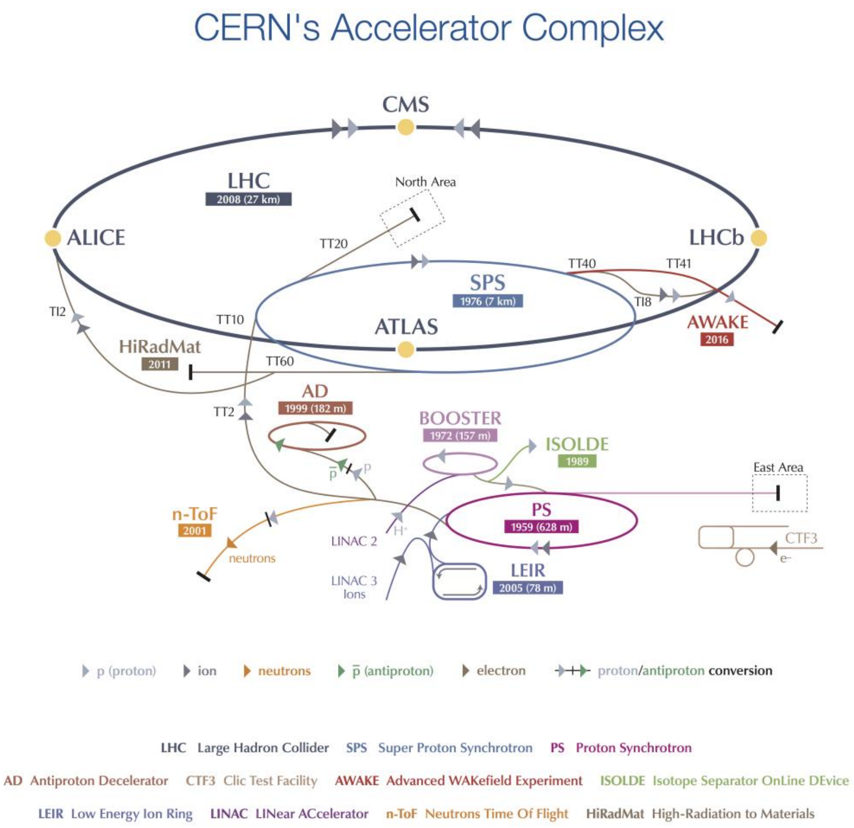
The raison d'etre

Envisioned in 2010 to "Test LHC collimators in conditions that are equivalent to accident scenarios in the LHC"

- Same spill **size** and **structure**

Over 10 years more than 41 completed experiments

- High-power targetry
- Instrumentation
- Detectors
- Beam-intercepting devices
- Machine protection



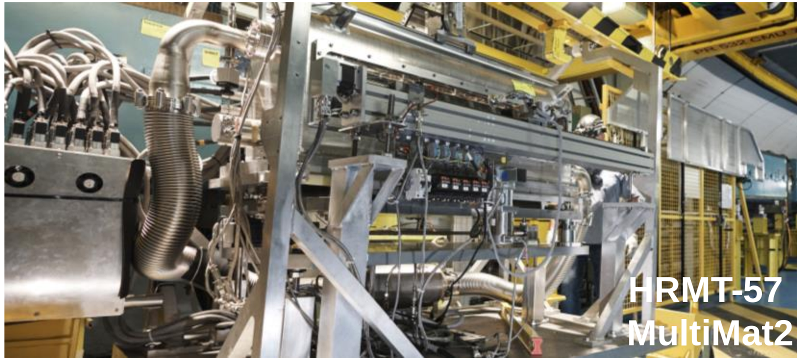
Why HiRadMat?

Only area which receives LHC-like beams:

- 1.5 ns bunch **length**
- 25 ns bunch **spacing**
- Up **to 288 bunches** with **1.2·10^{11} protons** per spill
- 3.4·10^{13} protons per pulse at 440 GeV/c (2.4 MJ)

Other facilities at CERN are served by **slowly extracted** beams

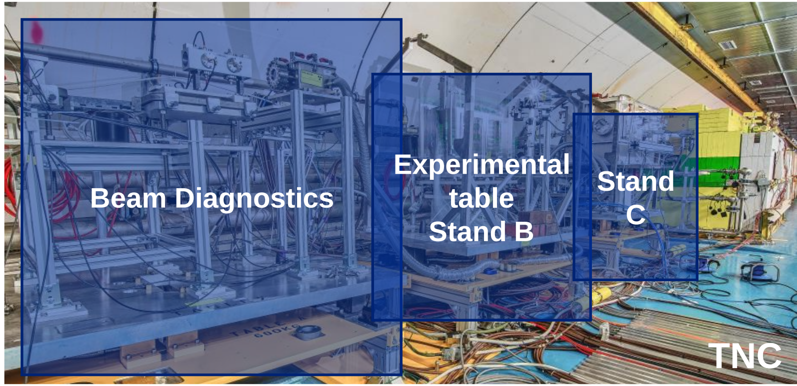
HiRadMat is **not** an irradiation facility where high doses are being accumulated, rather a single pulse facility for the instantaneous effects of the beams on the materials

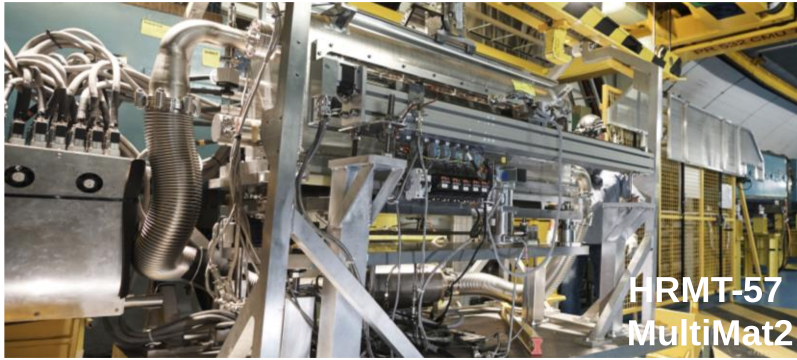


HiRadMat Facility

Designed for maximum flexibility:

- Assembly, alignment and dry-running **at the surface**
- Target area with remote **plug&play connectivity** with more than **300 signal connections** per experiment
- **Pulse-to-pulse beam diagnostics** enable grazing impacts with <100 µm precision
- **Shielded environments** for sensitive equipment along high speed cameras and laser diagnostics
- **Short cabling** length





HiRadMat Experiments Since LS2 and beyond

Facility upgrade for LIU intensities at HiRadMat
(up to 2.4×10^{11} protons per bunch)

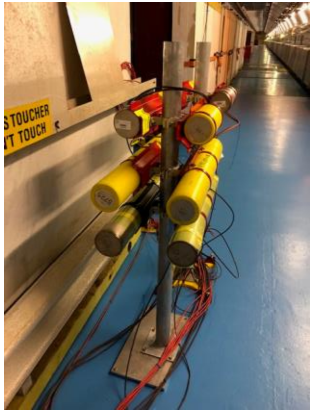
2021		2022		2023		2024	
HRMT54	EO-BPM	HRMT58	ATLAS-ITk	HRMT62	FIREBALL		DPA (KEK)
HRMT53	CHEFT	HRMT55	BLM3	HRMT58	ATLAS-ITk		**HED-2 (CERN)**
HRMT55	BLM3	HRMT59	SMAUG	--	SMAUG-2		**CRY3 (CERN)**
HRMT57	MultiMat2	HRMT60	RaDIATE2022	HRMT26	TPSG4-2		
HRMT56	HED	HRMT61	SCcoils				

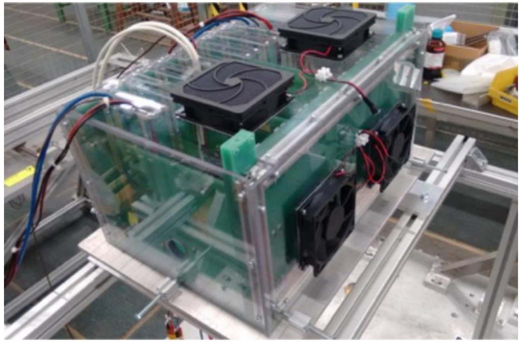
$\geq1.6\times10^{11}$ protons per bunch

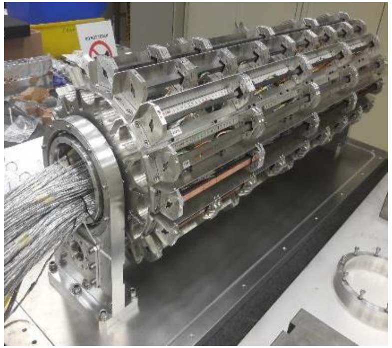
- An upgrade study group is already working towards proposing upgrades to the facility for LIU-type beams
- **Deliver LIU beam intensity with identical beam spot sizes**
  - Up to 2.4×10^{11} protons per bunch
  - ~Factor of 2 in beam density!
- **Experiments eagerly waiting for these kinds of beams**

More about the upgrades tomorrow in **N. Solieri**'s talk

Highlights of some previous HiRadMat experiments



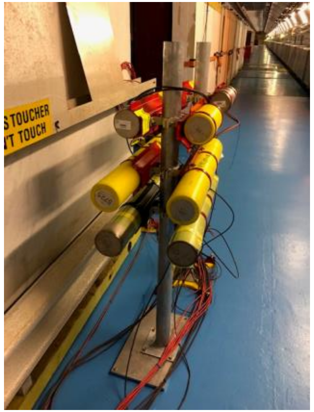


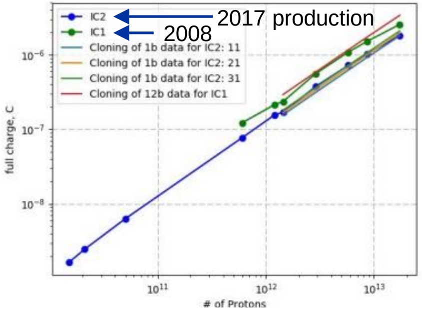


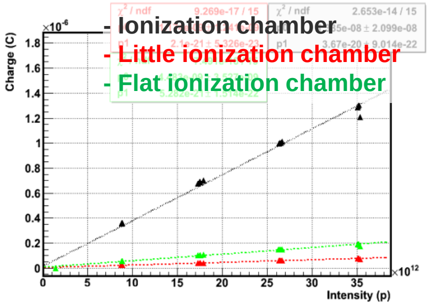
HRMT19 BLM2, HRMT55 BLM3 ESS

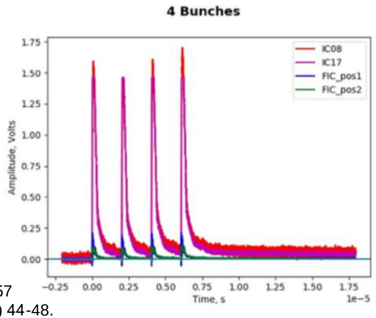
- **Validate and calibrate various beam loss monitors (BLMs) under real beam conditions**
  - New series production of ionization chamber BLMs
  - R&D on 'little ionization chamber' for injection regions of (HL-)LHC
- **Critical infrastructure for beam diagnostics at ESS, GSI and CERN**
  - Close to 1000 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**







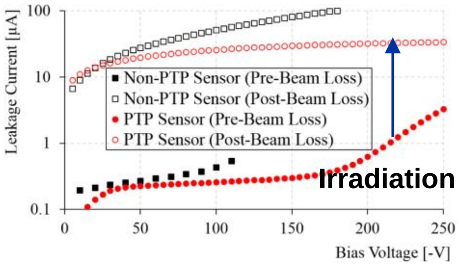


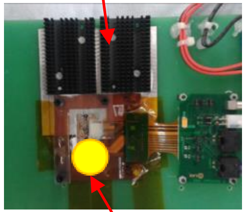
V. Grishin et al. 2017 Proc. 6th Int. Beam. Instrumentation Conf. (IBIC'17) 454-57
V. Grishin et al. 2018 Proc. 26th Russian Particle Accelerator Conf. (RuPAC'18) 44-48.

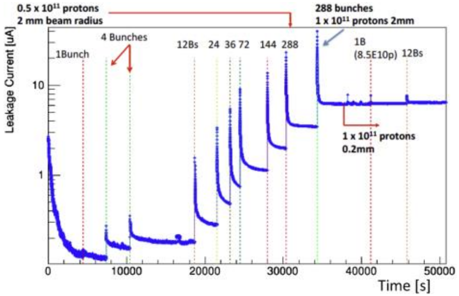
HRMT41/47 ATLASPixRad ATLAS Collaboration

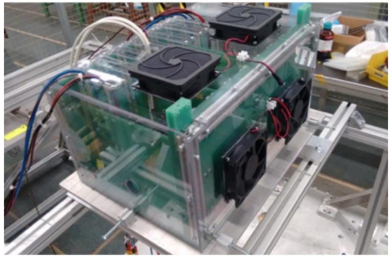
C. Bertella et al. 2019 IL NUOVO CIMENTO 42 C 205
C. Bertella et al. 2019 JINST 14 C05024
J. Fernandez-Tejero et al 2019 NIMA 958 162838
C. Bertella et al. 2019 NIMA 924 236

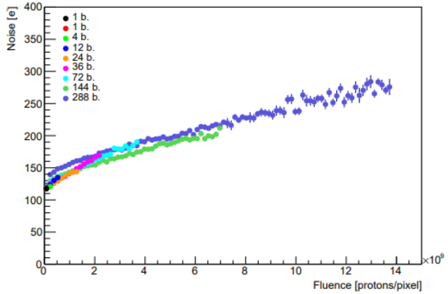
- **Direct irradiation of pixel and strip modules at HiRadMat**
  - Simulate beam loss conditions expected at HL-LHC
- **Investigate detector degradation and damage limit of new generation of pixel modules**
  - Innermost layer (IBL) of the ATLAS Pixel detector
- **Experiment established a damage limit 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









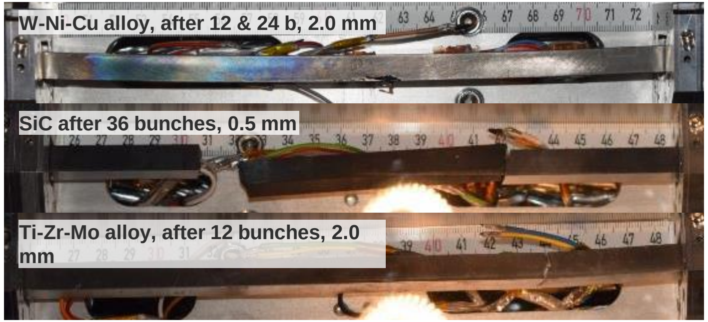


HRMT36 MultiMat
U. Malta, Brevetti-Bizz SME Italy

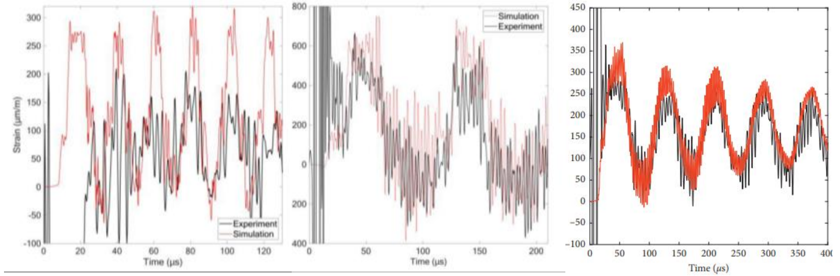
- **Investigate dynamic response of novel materials for HL-LHC collimator upgrade**
  - 16 target stations with 18 different materials ranging from ultra light C foams to heavy W alloys
  - MoGr, CFC and graphite coated with Mo, Cu, TiN
  - To derive & extend constitutive models and material properties 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



SiC | Ti-Zr-Mo alloy | Copper-diamond composite

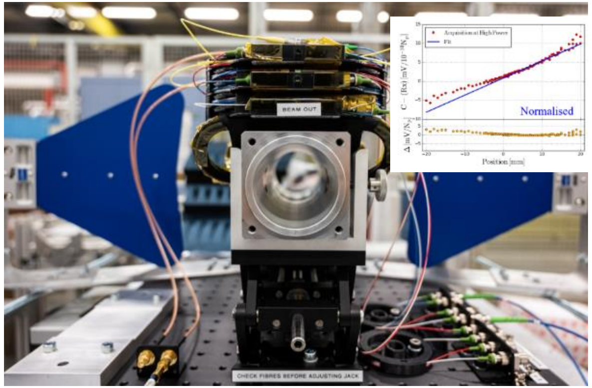


F. Carra et al. 2017 Proceedings IPAC17 MOPAB005
A Bertarelli et al. 2018 J. Phys.: Conf. Ser. 1067 082021
M. Pasquali et al. 2019 Journal of Dynamic Behavior of Materials 5 266
M. Portelli et al. 2019 Mechanics of Materials 138 103169
M. Portelli et al. 2021 Shock and Vibration, vol. 2021, 8879400

2021 Experiments

HRMT54 – BPM
Royal Holloway University

Prototype electro-optical BPM for intra-bunch beam position measurements at HL-LHC



A. Arteche “High bandwidth PU using EO technologies”
11th HL-LHC Collaboration Meeting, 19-22 Oct 2021
https://indico.cern.ch/event/1079026/

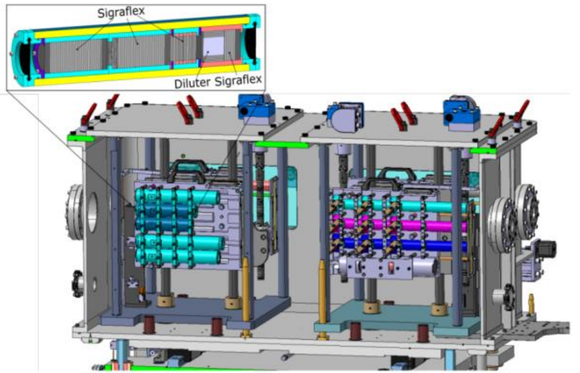
HRMT57 – MultiMat2
CERN, Sapienza University

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
CERN

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



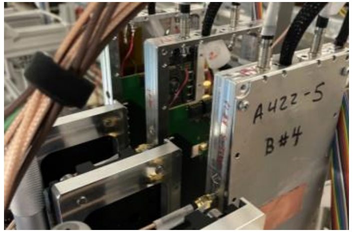
J. Heredia et al. 2021 IPAC2021 3571-3574
P. Andreu Muñoz et al. 2022 IPAC2022 2883-2886

2022 Experiments

ATLAS-ITk

CERN, JSI

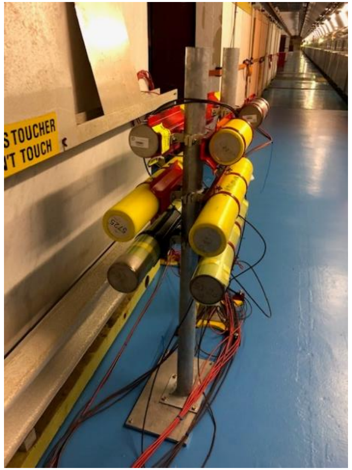
Prototype ATLAS beam condition monitor



BLM3

CERN, GSI, ESS

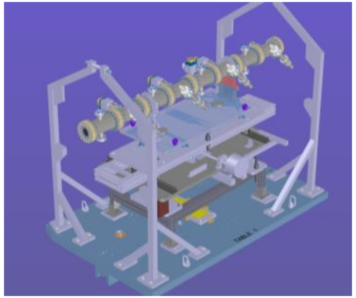
Validation of production BLMs for HL-LHC



SMAUG

CERN

Validation of beam windows for LIU intensities at HRMT

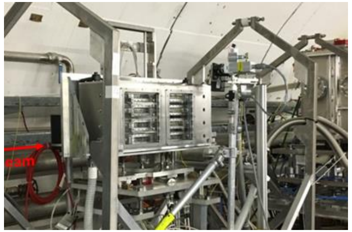


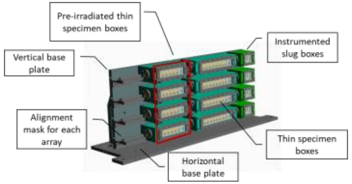
Talk by N. Solieri
Wednesday 14:30

RaDIATE2022

CERN, FNAL, KEK

Thermal shock in pre-irradiated materials





SCcoils

CERN, KIT

Damage limits in SC miniature HL-LHC dipoles (3 K)

EURO-LABS
Transnational Access at HiRadMat

- **Transnational Access by ARIES Project has been huge success for HiRadMat**
  - 50% of all experiments at HiRadMat supported from 2017 to 2021!
- **Since 1st September new Transnational Access Program until August 2026!**
  - https://web.infn.it/EURO-LABS/
- **Support external users with daily subsistence and (some) travel support**
  - Up to ~40 days/experiment*
  - Additional resources for user support:
    - CAD integration
    - Small workshop works
    - CERN support (Metrology, controls, DAQs, …)

EURO-LABS
EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

* depending on total no. of experiments requesting support

List of HiRadMat publications and references:

https://cern.ch/hiradmat

Thank you for your attention!

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