High-Level Dosimetry (HLD)

Ygor Aguiar, Rubén García Alía, Giuseppe Lerner / SY-STI-BMI

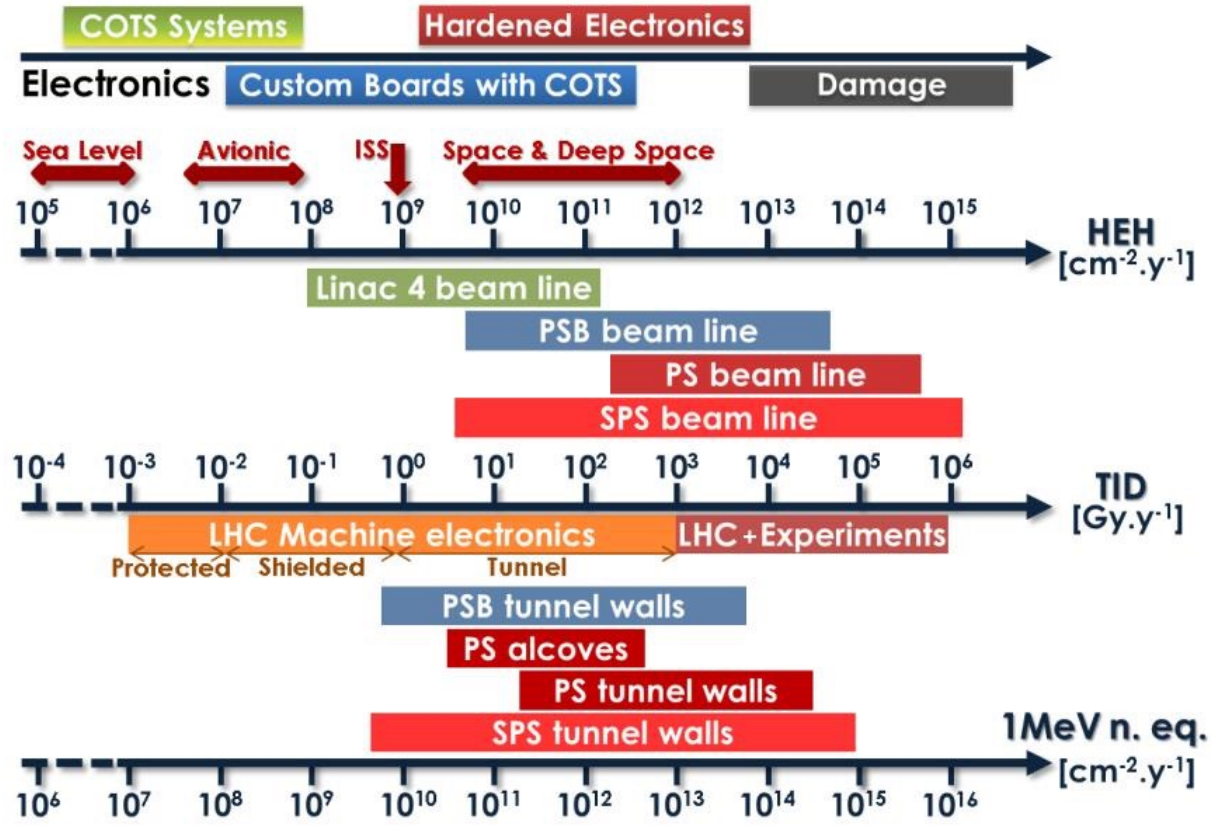
R2E Annual Meeting – 1-2 March, 2022
https://indico.cern.ch/event/1116677/

CERN radiation environment

Accelerator complex presents a mixed radiation field in the tunnels and adjacent caverns

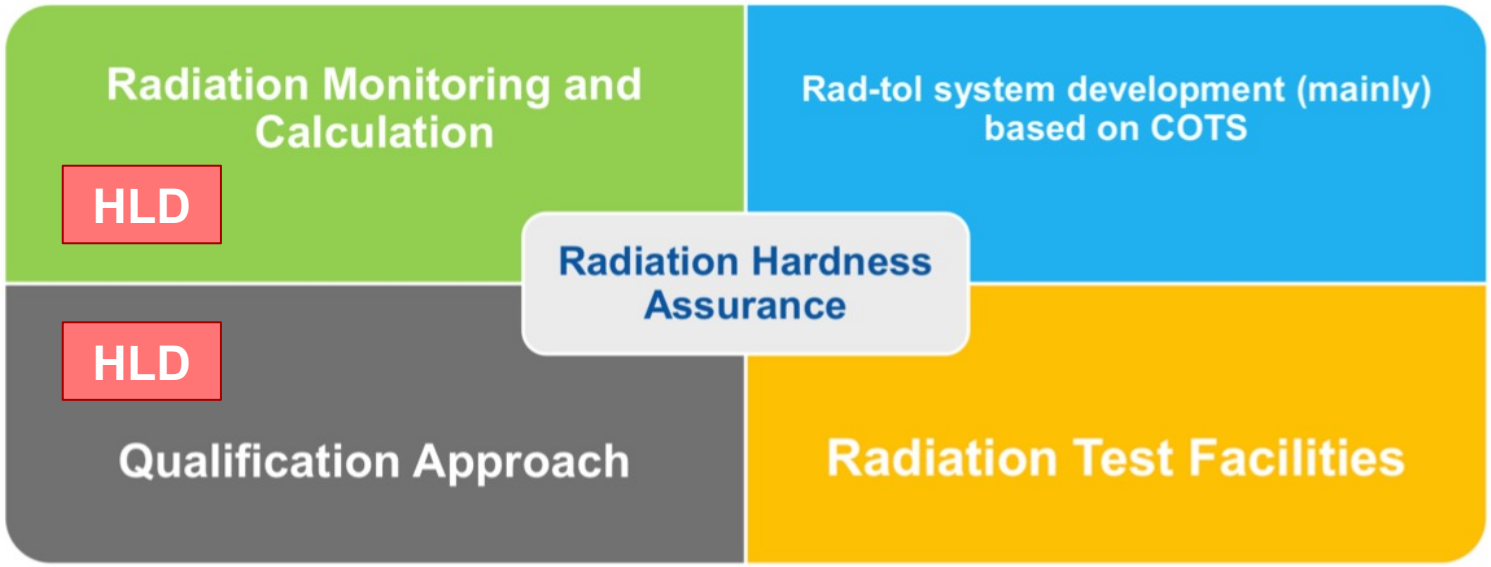
Radiation damage

Impact on the lifetime of the equipment and it can lead to **machine downtime**



CERN-ACC-NOTE-2015-0042

Radiation Hardness Assurance (RHA)



- Systematic application of RHA methodologies to **prevent radiation damages and meet expected equipment lifetime constraints**.
- HLD is present in two key elements in a RHA procedure:
  - Monitoring and calculation of radiation levels
  - Equipment qualification process.

Monitoring and Calculation Working Group (MCWG)

Analysis of the distribution and evolution of the radiation fields along the CERN's accelerator complex

- Radiation data based mainly on:
  - **Active dosimeters:** Beam Loss Monitor (BLM), RadMon, optical fibers;
    - New monitor installations are constrained to some infrastructure requirements
    - Large coverage but typically limited to dose levels up to 10kGy.
  - **Passive dosimeters:** RadFET, High-Level Dosimeters (HLD)
    - Easy of deployment → no infrastructure requirements
    - Small dimensions → can be placed next to equipment
    - Higher dose range → RPLs can reach up the MGy
- Fluka simulations → benchmark studies

Applicability of the HLD service

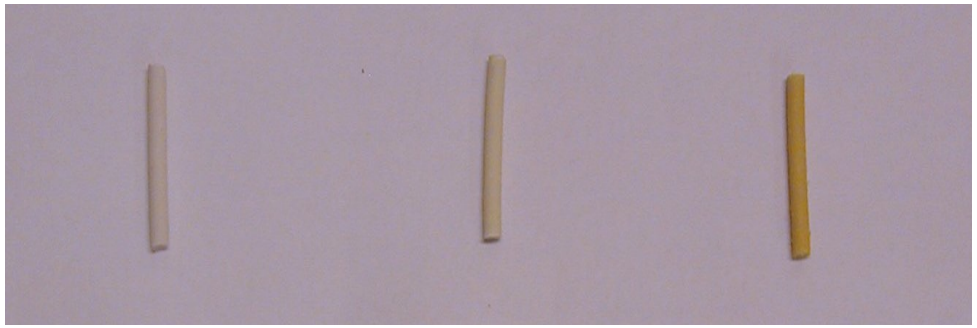
- Synergy with several activities at CERN
  - provides supplementary radiation level measurements where active dosimeters are not suitable.

- Assessment of irradiation testing conditions
  - Only option for high-dose requirements in Radiation to Materials (R2M) experiments which irradiations can reach up to several MGy, for example.

Polymer Alanine Dosimeter (PAD)

Dosimeter composed of **alanine ($C_3H_7NO_2$)** and a polymer mixture

Cylinder (length: 2 cm, diameter: 0.4 cm)



Low dose **Mid dose** **High dose**

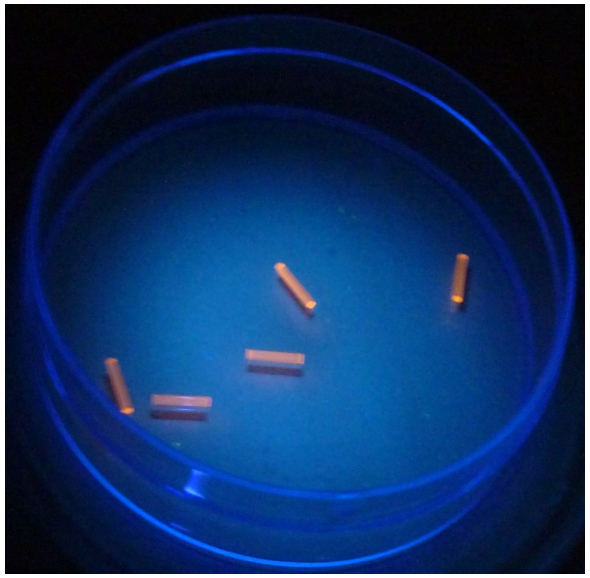
Irradiation of alanine creates free radicals → proportional to absorbed dose

Readout measurement based on the **Electro Spin Resonance (ESR)**

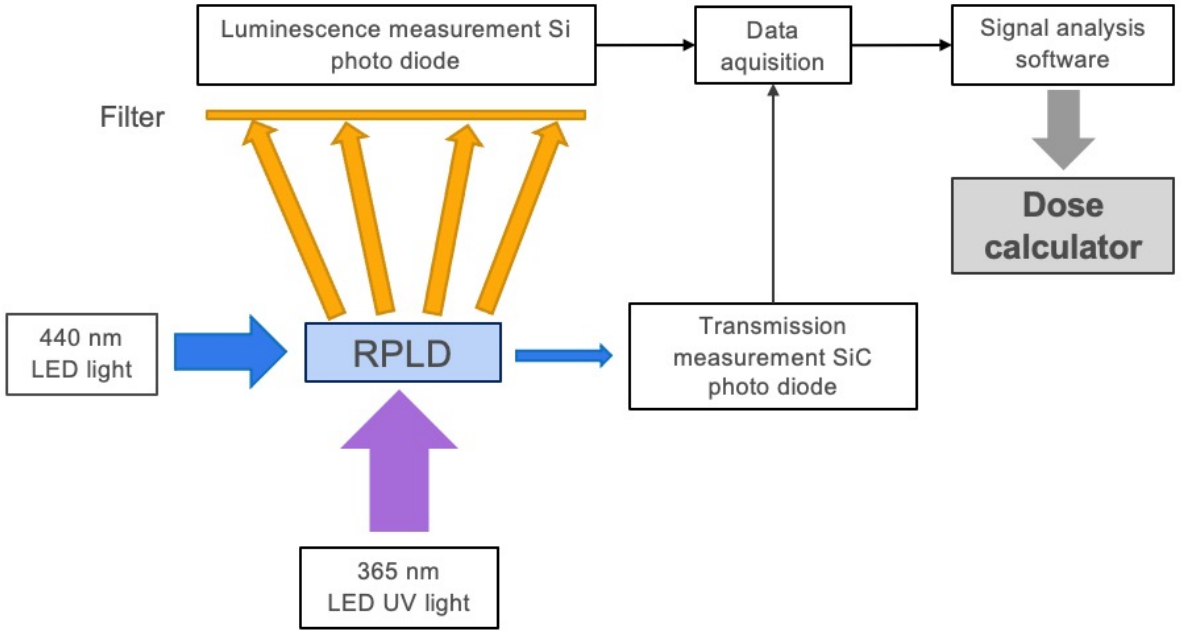
Dose range: 1 Gy – 100kGy

Radio-Photo-Luminescence Dosimeter (RPL)

- Cylinder: **Ag-activated metaphosphate glass** (length: 8.5mm, diameter: 1.5mm)
- Irradiation creates Radio-Photo-Luminescence (RPL) and colour centres
- Readout measurement based on an in-house setup
  - **Dose range: 1 Gy - MGy**



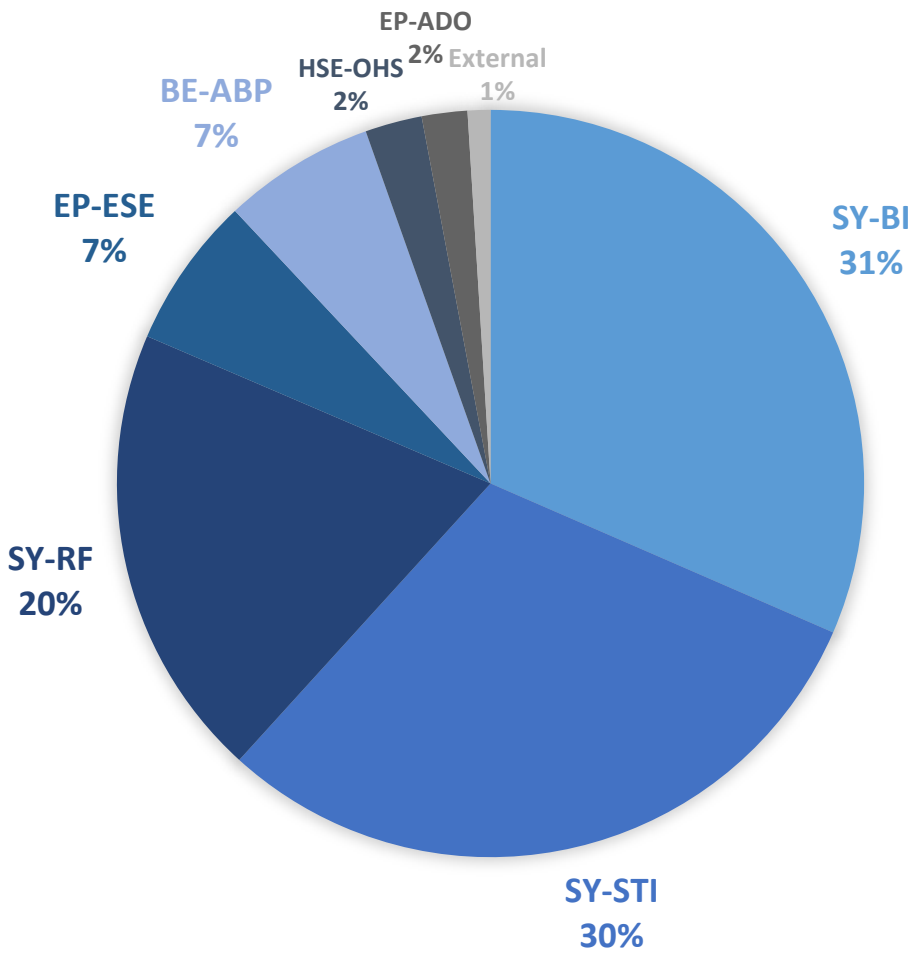
Irradiated RPL dosimeters when being illuminated with UV light



Monitoring Request - 2021

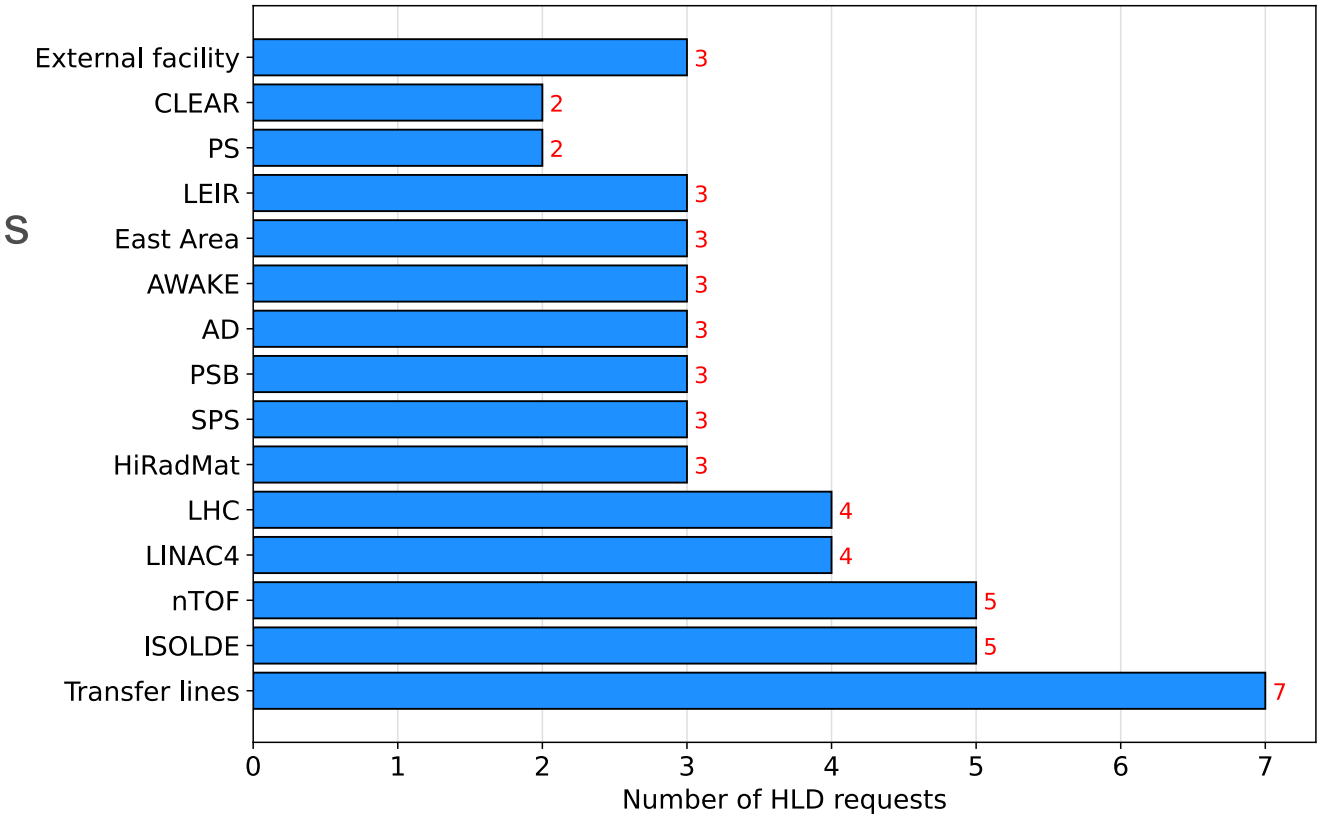
Overview

- Request form and measurement results are archived on EDMS.
  - Traceability and reusability
- 18 HLD requests
  - 40 PADs
  - 569 RPLs + 447 RPL readouts (2018/2020)
- Dosimeters per Users:
  - SY-BI: 192 RPLs
  - SY-STI: 184 RPLs
  - SY-RF: 120 RPLs



Requests per Machine/Facility

- The requests covered the complete accelerator complex from LINAC4 to LHC ring and experimental areas.
- Understand the radiation levels and component/system failures
- Anticipate upgrade/consolidation of systems due to end of radiation lifetime.
- Irradiation for qualification of components and materials.
  - Crucial step in RHA procedure
  - Support with dosimetry in external facility experiments.



List of HLD requests in 2021

* No dosimeter was provided in 2021

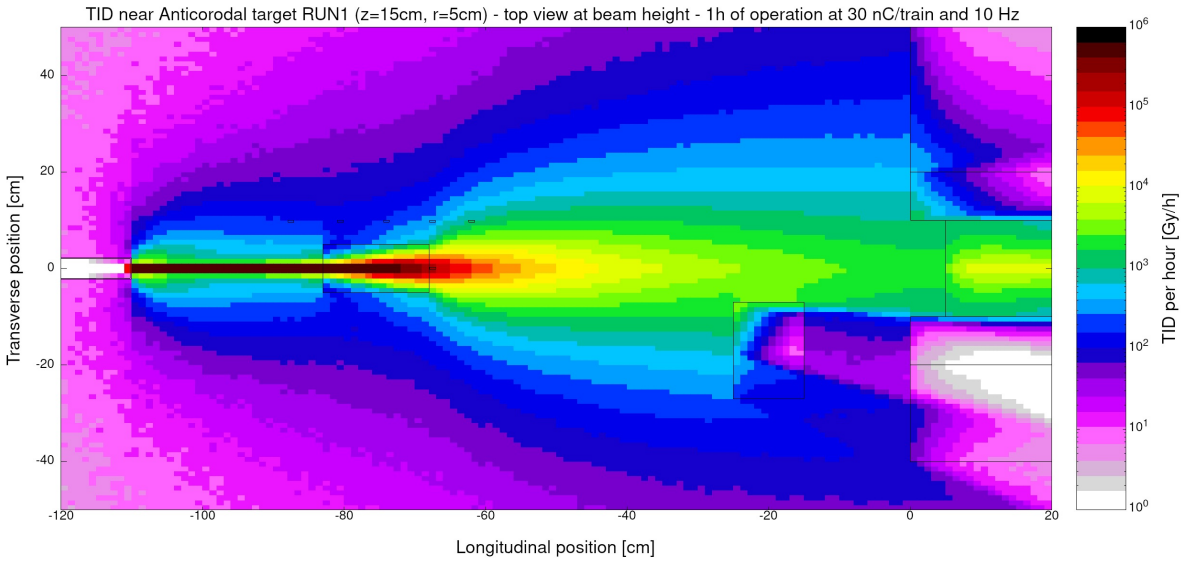
EDMS	Request title	User	Machine/ Facility	Dosimeter Number/Type	Status
2599448	Alanine pellets for Neutrons dosimetry at UCL on May 2021	S. Detraz (EP-ESE-BE)	External	40 PADs	Dosimeters provided
2606649	Radiation level request for 20-08 Cable irradiation test to derive Cable Ageing	A. Danyliuk, J. Gascon (HSE-OHS-IB)	External	15 RPLs	Done
2599441	HLD dosimeters for the 2021 irradiation campaign at n_TOF NEAR	D. Senajova, M. Ferrari (SY-STI-TCD)	n_TOF	16 RPLs	Done
2599445	Use of high radiation dosimeters to measure irradiated optical materials at the HIFR gamma facility	W. Blokland (ORNL)	External	6 RPLs	Dosimeters provided
2599450	BTV radiation survey (RPL dosimeters) run 2018. *	S. Burger (SY-BI-PM)	LINAC4 to LHC	137 RPLs	Done
2621775	ALPS BPM Frontend in TT2 & TT10 *	T. Bogey, M. Marin (SY-BI-BP)	TT2 and TT10	-	Done
2647945	Dosimetry cross-check with EBT3-HD films for medical applications - CLEAR	W. Farabolini, L. Dyks (BE-ABP-LAF)	CLEAR	40 RPLs	Done
2651888	Readout of RPL dosimeters for radiofrequency equipment in PS - Run 2018 *	V. Desquiens, C. Gagliardi (SY-RF-LIS)	PS	110 RPLs	Done
2655812	Measurement of RPL dosimeters for BTV radiation survey for 2021 run *	S. Burger (SY-BI-PM)	LINAC4 to LHC	~ 200 RPLs	Waiting for dosimeters
2708292	Radiation to Electronics (R2E) CLEAR test campaign in 2021	Y. Aguiar, G. Lerner (SY-STI-BMI)	CLEAR	32 RPLs	Done

List of HLD requests in YETS2021-2022

EDMS	Request title	User	Machine/ Facility	Dosimeter Number/Type	Status
2651162	RPL dosimeters for radiofrequency equipment in LINAC4 and PS - Run 2022	V. Desquiens, C. Gagliardi (SY-RF-LIS)	LINAC4, PS	120 RPLs	Dosimeters provided
2655780	Request for RPL dosimeters for BTV radiation survey for 2022 run.	S. Burger (SY-BI-PM)	LINAC4 to LHC	192 RPLs	Dosimeters provided
2648761	RPL measurements around the LUCID detector in ATLAS	V. Hedberg (EP-ADO)	ATLAS	12 RPLs	Dosimeters provided
2659976	Monitoring of TT2 and TT10 using RPLs in the BLM and BPM positions.	Y. Aguiar, K. Bilko (SY-STI-BMI)	TT2 and TT10	95 RPLs	Dosimeters provided
2683546	Monitoring the radiation levels in the Beam Intercepting Devices (TED, TBSE and TCSC)	J.-L. Grenard (SY-STI-TCD)	TI2, TI8, TT20,TT40, TT41, TT60	16 RPLs	Dosimeters provided
2688094	RPL for the Beam Dump in TT2 - F16.TDU394	J.-L. Grenard (SY-STI-TCD)	TT2	4 RPLs	Dosimeters provided
2688187	ISOLDE target area visualisation cameras and robots	J.-L. Grenard (SY-STI-TCD), J. Vollaire (SY-STI-RBS)	ISOLDE	8 RPLs	Dosimeters provided
2698775	HLD dosimeters for the 2022 irradiation campaigns at n_TOF NEAR	D. Senajova, M. Ferrari (SY-STI-TCD)	n_TOF	13 RPLs	Dosimeters provided

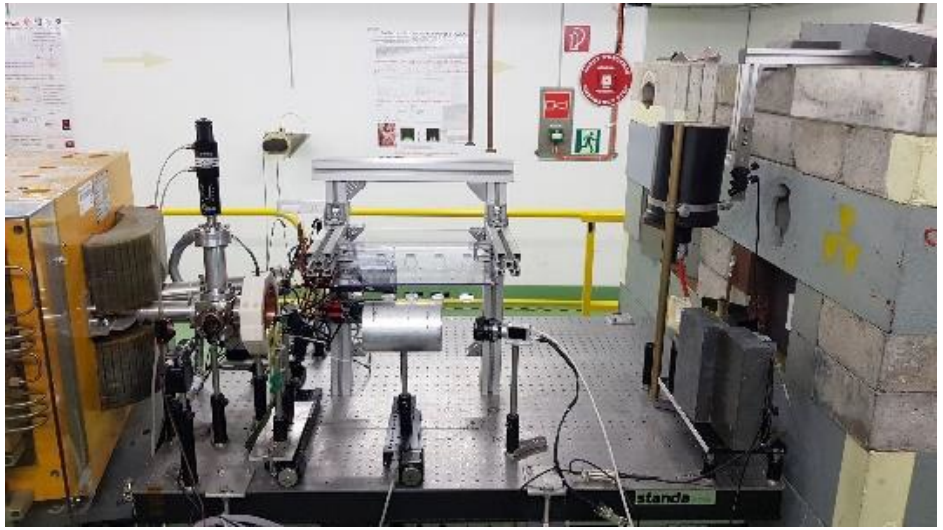
Radiation Effects study at CLEAR

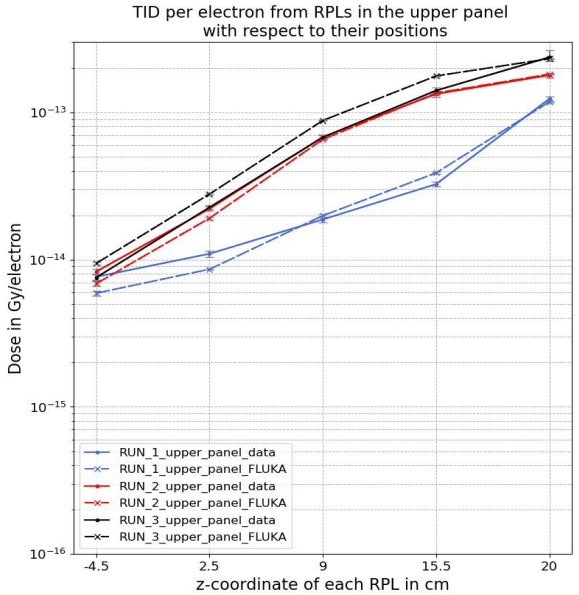
- Characterization of the radiation environment of the CLEAR facility using the interaction between the 200-MeV electron beam of CLEAR with two cylindrical Al-based alloy targets
  - SRAM memories are used to measure the HEH fluences through the SEU counts.
  - RPL are used to measure the absorbed dose important to the study of Total Ionizing Dose (TID) effects in components.
  - Several runs with different beam parameters



P. Pelissou et al. “First results on radiation level measurements near an Al target at the CLEAR electron accelerator”, 48th MCWG meeting, https://indico.cern.ch/event/1069803/

Radiation Effects study at CLEAR





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- Great agreement among FLUKA simulations and RPL measurements.
  - Max measured dose of 83kGy, behind the Al-based target.
  - Dose rate range from 0.27kGy/h to 237kGy/h.
  - More information will be discussed in the presentation “Photoneutron field analysis near an Al-based target at the CLEAR accelerator” by G. Lerner.

R2M radiation station at nTOF

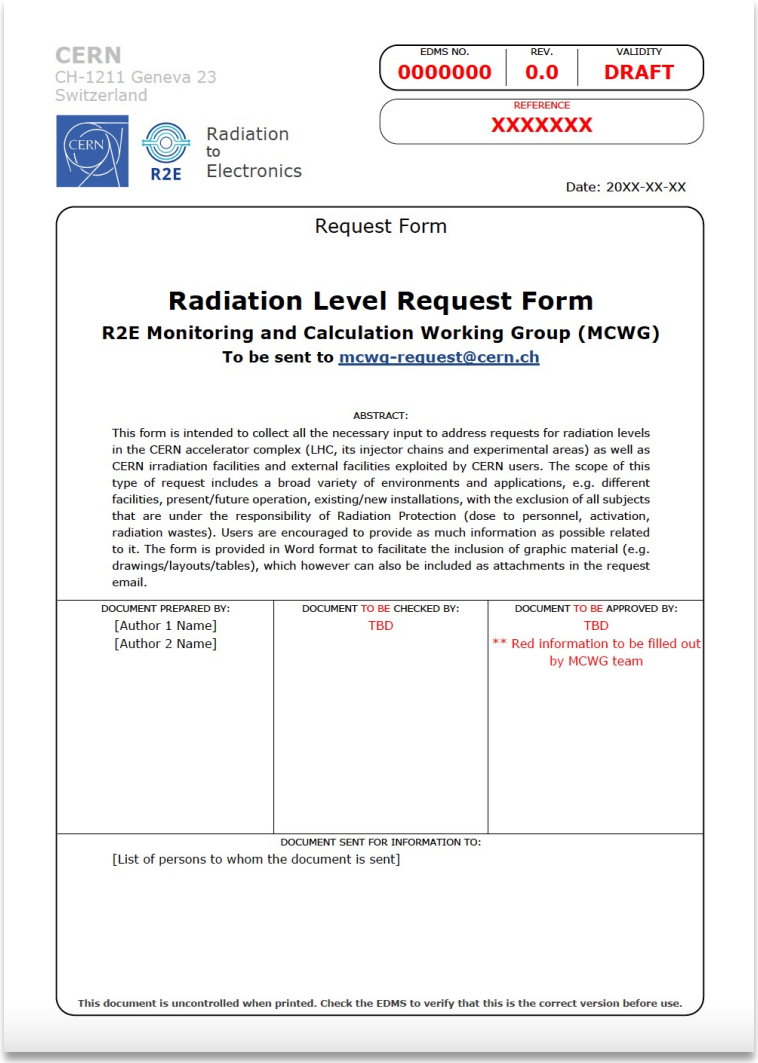
- Characterization of a radiation station for Radiation to Materials (R2M) activities at nTOF.
  - Elastomers and lubricants can have their lifetime shorted due to exposure to radiation.
  - "New NEAR irradiation station at n_TOF: design, implementation and first results" by D. Senajova and M. Ferrari
- Radiation levels can reach up to the MGy per year.
- Several RPLs were used during the run 2021 in different positions.
  - Measurement results in EDMS 2599441
  - Good agreement among data and FLUKA simulations.

"EPM O-rings, nuclear reactor irradiation", M. Ferrari, Ph.D. Thesis (2020)

"Characterization of a polyphenyl ether oil irradiated at high doses in a TRIGA Mark II nuclear reactor", M. Ferrari, et al. https://doi.org/10.1016/j.nimb.2021.03.021

Monitoring Request Procedure

- Standard MCWG Radiation Level Request: https://edms.cern.ch/document/2574855/
- MCWG email: mcwg-request@cern.ch
- Together with the user, the MCWG team will propose the monitor which best suits their needs



CERN
CH-1211 Geneva 23
Switzerland

Radiation to Electronics

EDMS NO.	REV.	VALIDITY
0000000	0.0	DRAFT

REFERENCE: XXXXXXX

Date: 20XX-XX-XX

Request Form

Radiation Level Request Form

R2E Monitoring and Calculation Working Group (MCWG)

To be sent to mcwg-request@cern.ch

ABSTRACT:

This form is intended to collect all the necessary input to address requests for radiation levels in the CERN accelerator complex (LHC, its injector chains and experimental areas) as well as CERN irradiation facilities and external facilities exploited by CERN users. The scope of this type of request includes a broad variety of environments and applications, e.g. different facilities, present/future operation, existing/new installations, with the exclusion of all subjects that are under the responsibility of Radiation Protection (dose to personnel, activation, radiation wastes). Users are encouraged to provide as much information as possible related to it. The form is provided in Word format to facilitate the inclusion of graphic material (e.g. drawings/layouts/tables), which however can also be included as attachments in the request email.

DOCUMENT PREPARED BY:	DOCUMENT TO BE CHECKED BY:	DOCUMENT TO BE APPROVED BY:
[Author 1 Name] [Author 2 Name]	TBD	TBD ** Red information to be filled out by MCWG team

DOCUMENT SENT FOR INFORMATION TO:

[List of persons to whom the document is sent]

This document is uncontrolled when printed. Check the EDMS to verify that this is the correct version before use.

Conclusions

- **Monitoring and Calculation of radiation levels** are essential to increase the performance and availability of systems
  - Support the implementation of RHA methodologies
  - Mitigation approaches
- **High-Level Dosimetry (HLD)** provides information on accumulated dose in a wide range → from Gy to MGy
- PAD/RPLs can be placed next to the machines where other dosimeters might not be suitable due to their size or to specific infrastructure requirements
- HLD service is entirely provided at CERN, including the readout measurement of the dosimeters.

Thank you for
your attention!

CERN SY STI R2E