R2M 'RADIATION TO MATERIALS': Summary of Service activities in 2021

Matteo Ferrari, SY-STI-TCD
For the R2M team
Acknowledgements:
Rubén Garcia Alia, Tim Giles, Marco Calviani (SY-STI)

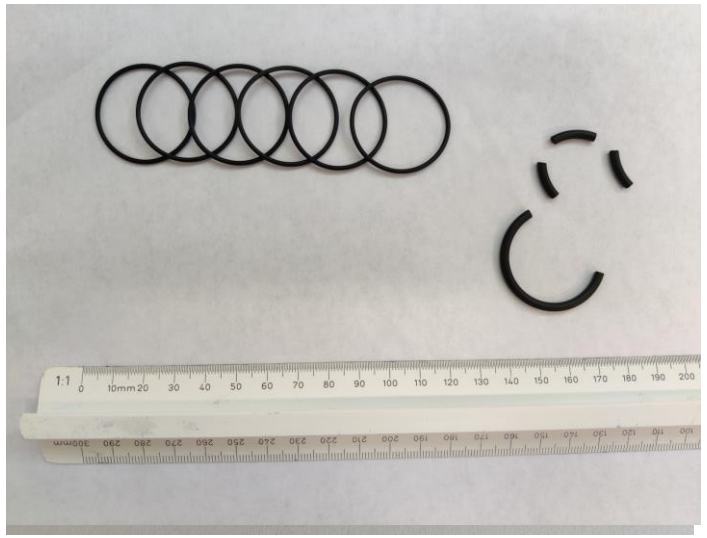
R2E Annual Meeting – 1-2 March, 2022
https://indico.cern.ch/event/1116677/

1 INTRODUCTION AND BACKGROUND

MATERIALS AT CERN IN HIGH-RADIATION AREAS

COMMERCIAL ITEMS:

- **Lubricants: oils & greases;**
- **Elastomeric O-rings;**
- Insulators/ cables;
- Optical components;
- Resins, glues…



➢ Specific radiation tolerance generally unknown

SENSITIVE TO RADIATION BUT NECESSARY FOR DESIGN/UPGRADE OF VARIOUS DEVICES

EXAMPLES OF RADIATION DAMAGE/1

Protective covers for magnets
10 MGy, used in CERN complex
Courtesy of C.L. Marraco Borderas (TE-MSC)

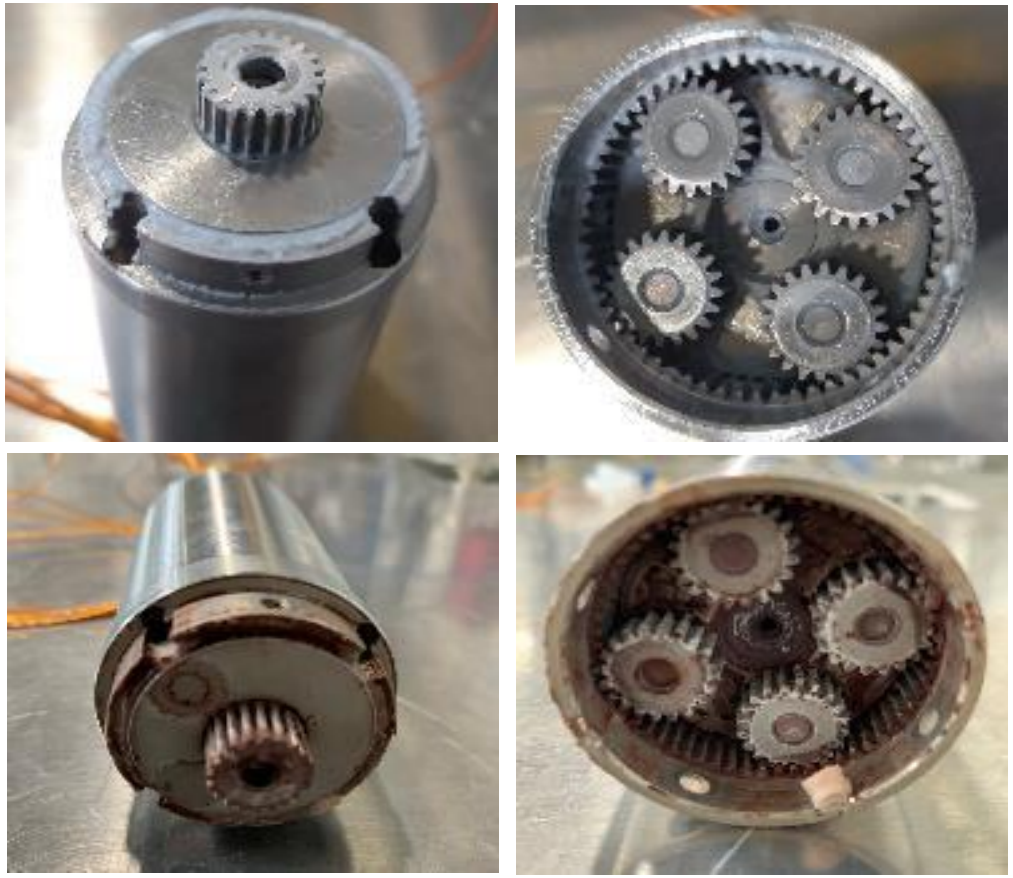
STRUCTURAL FAILURE: SWELLING

EXAMPLES OF RADIATION DAMAGE/2

Glass balls, precision components HL-LHC alignment system
Non-irr vs 5 MGy
Courtesy of M. Sosin (EN-SMM)

FUNCTIONAL FAILURE: DARKENING

EXAMPLES OF RADIATION DAMAGE/3



Lubricated motor and gearbox
Atlas
0.5 MGy and 3.0 MGy
Courtesy V.Rieker, P.Gebolis (TE-VSC)

FUNCTIONAL FAILURE: CORROSION

COMMON RADIATION EFFECTS

MACRO

- Softening
- Hardening

MICRO

- Chain cleavage
- Cross-link

Ordinary grease present in CERN STORES

➢ M.Ferrari et al., Heliyon 5 (2019) e02489

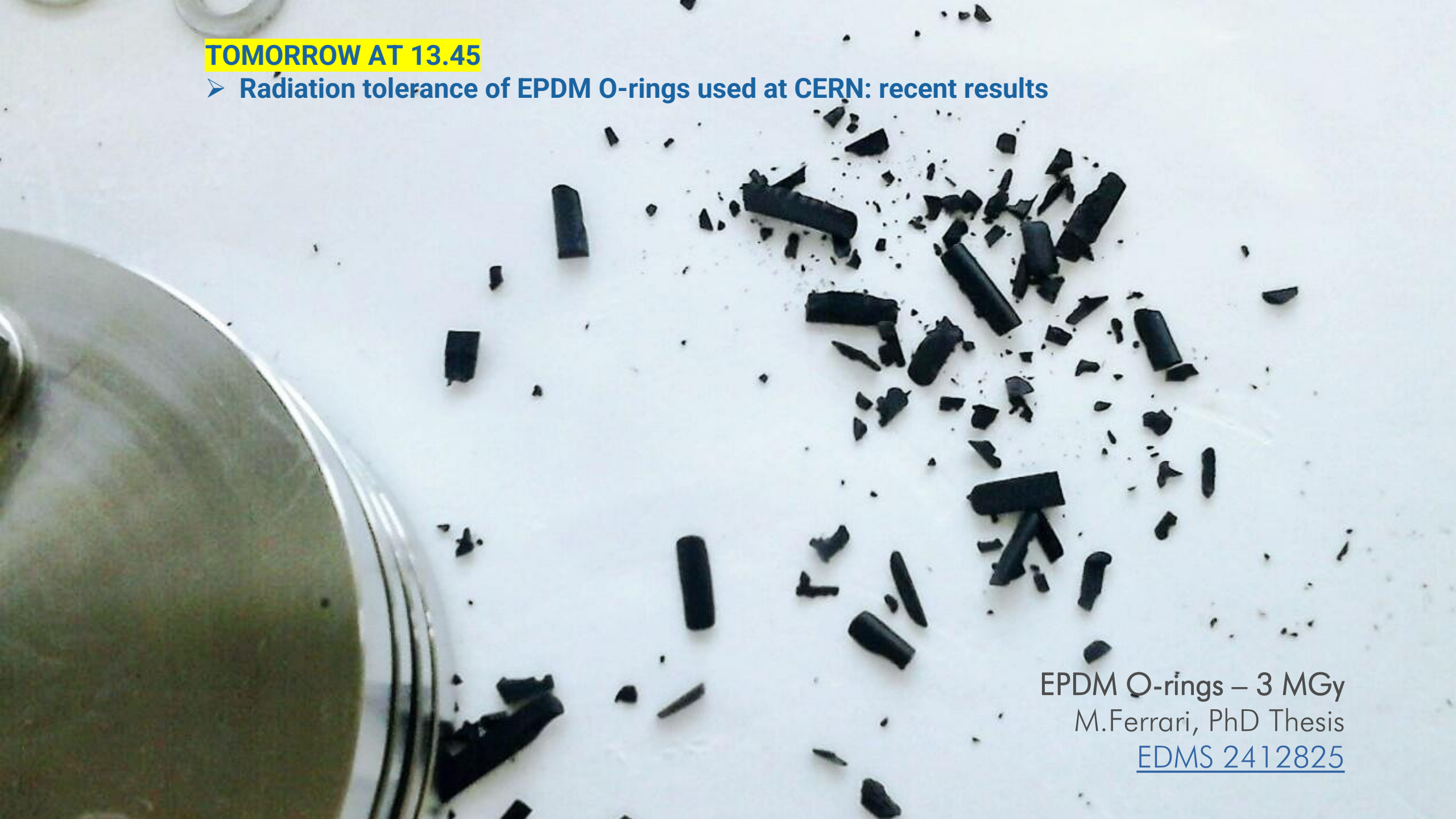
TOMORROW AT 14.00

D.Senajova

➢ **Radiation damage studies on lubricants**

TOMORROW AT 13.45

- **Radiation tolerance of EPDM O-rings used at CERN: recent results**



EPDM O-rings – 3 MGy
M.Ferrari, PhD Thesis
EDMS 2412825

2 R2M: MANDATE AND APPROACH

R2M WORK PACKAGE WITHIN R2E PROJECT

Synergies:

- CHALLENGE: minimize failures, increase equipment lifetime, comply with RP;
- IMPACT: successful operation of accelerator complex and its equipment;
- APPROACH: testing, qualification activities, support design making, increase of a structured knowledge on the topic via scientific activities, organize information
- INFRASTRUCTURES/INTERFACES: irradiation facilities, dosimetry simulations and measurements
- SOLUTIONS: selection of radiation tolerant products, increase reliability, DB

MINIMIZE RADIATION INDUCED FAILURES AT CERN IRRADIATION TESTS ARE CONTINUOUSLY NEEDED

R2M MAIN ACTIVITIES AND MANDATE

CERN Yellow Reports
1960's-2000's


ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

COMPILATION OF RADIATION DAMAGE TEST DATA
PART III: Materials used around high-energy accelerators

INDEX DES RÉSULTATS D'ESSAIS DE RADIORÉSISTANCE
III' PARTIE: Matériaux utilisés autour des accélérateurs de haute énergie

P. Beynel, P. Maier and H. Schönbacher

GENEVA

Limitations:

- Incomplete info
- New products missing
- Mostly gamma data

KNOWLEDGE TO BE UPDATED

MAIN AREAS:

1. SERVICE – organization of irradiation tests in external facilities
2. SUPPORT/ADVICE concerning the selection of rad hard materials
3. RESEARCH on radiation effects for a better product selection/failure anticipation. 3 talks tomorrow 13.45

SUCCESSFULL ACCELERATOR OPERATION/UPGRADE: RADIATION RESISTANT COMPONENTS ARE NEEDED

SUPPORT ACTIVITY AND SPECIFIC EXPERTISE

SY-STI	HL-LHC
EP-CMX	CMS
EP-UCM	LHC/b
TE-VSC	SPS
SY-ABT	ISOLDE FE
BE-EA	Collimators
TE-MPE	Dumps
TE-MSC	…
TE-VSC	
EP-LBO	
…	

MAIN TOPICS:

- Selection of rad-hard materials (O-rings, lubricants, cables, resins, other plastics…
- Radiation damage estimation
- Qualification of new products
- Radiation damage research studies
- Expertise for post-irradiation analysis
- Access to information/data/literature
- Any other R2M business

LARGE VOLUME OF SAMPLES TO BE IRRADIATED

3 IRRADIATION TESTS IN EXTERNAL FACILITIES

B1642/EN CONTRACT: OVERVIEW

CONTRACT TIMELINE

- July 2020: contract signature
- Jul 2020- Dec 2020: clarifications (COVID)
- Dec 2020 - **now: tests being organized**

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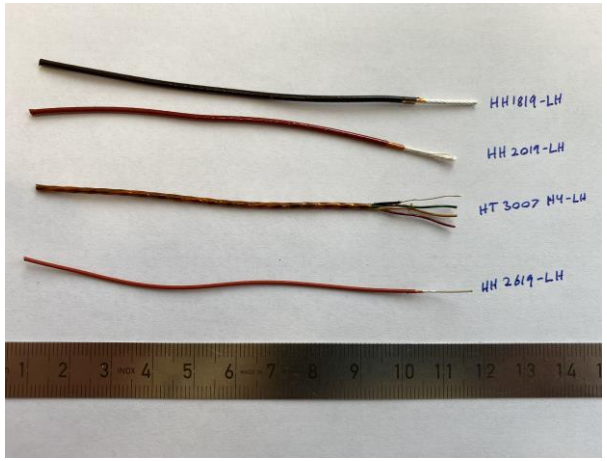
- ✓ **12 Tests organized since July 2020**
- ✓ **10** Test Specification docs finalized (EDMS FOLDER: **CERN-0000215827**)
- ✓ **9** Orders placed (1 in approval)
- ✓ **+2** tests currently being discussed/in preparation

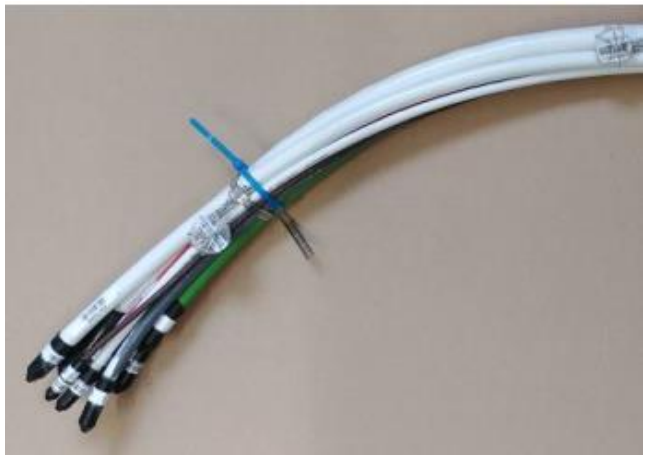
5 IRRADIATION TESTS COMPLETED

EXAMPLES OF IRRADIATION TESTS: SAMPLES

GROUT SAMPLES
LHC spacers for magnets
P.Schwarz (TE-MSC)



INSTRUMENTATION WIRES
HL-LHC magnets
C. Scheuerlein (TE-MSC)



SAMPLES OF CABLES
Various applications
J. Gascon (HSE-OHS)

VACUUM ASSEMBLIES
LHC dipole cryostats
V.Rieker (TE-VSC)

CONTRACT B1642/EN: ACCESS EXTERNAL FACILITIES

- **EDMS CERN-0000215827**
- Collaboration of MCWG, HLD, **R2E PROJECT** within SY-STI

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EXAMPLES OF ONGOING TESTS: GAMMA DOSE/2

HEATERS
HL LHC cryogenic
N.Trikoupis (TE-CRG)

CONNECTOR
HL-LHC
N.Trikoupis (TE-CRG)

ELASTOMERIC O-RINGS
LHC dump – various
M.Ferrari (SY-STI)

GREASES
BIDs – various
D.Senajova (SY-STI)

CONTRACT B1642/EN: ACCESS EXTERNAL FACILITIES

- **EDMS CERN-0000215827**
- Collaboration of MCWG, HLD, **R2E PROJECT** within SY-STI

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TEST OVERVIEW: REQUIREMENTS AND SAMPLES

TESTS IN NUMBERS:

- 10 tests/year (on demand)
- Contract frame: 5 years
- 100-200 k CHF / year irradiation service
- 10-20 kCHF/ test

➢ Full documentation: EDMS **CERN-0000215827**

SAMPLES (per year):

- Few cm^3 to 1m long;
- Tens/hundred samples / year
- **Total dose: 0.1-20 MGy**
- Dose rate: 1 kGy/h - 30 kGy/h
- Duration: several months

NEED FOR EXTERNAL COMMERCIAL 60Co FACILITIES

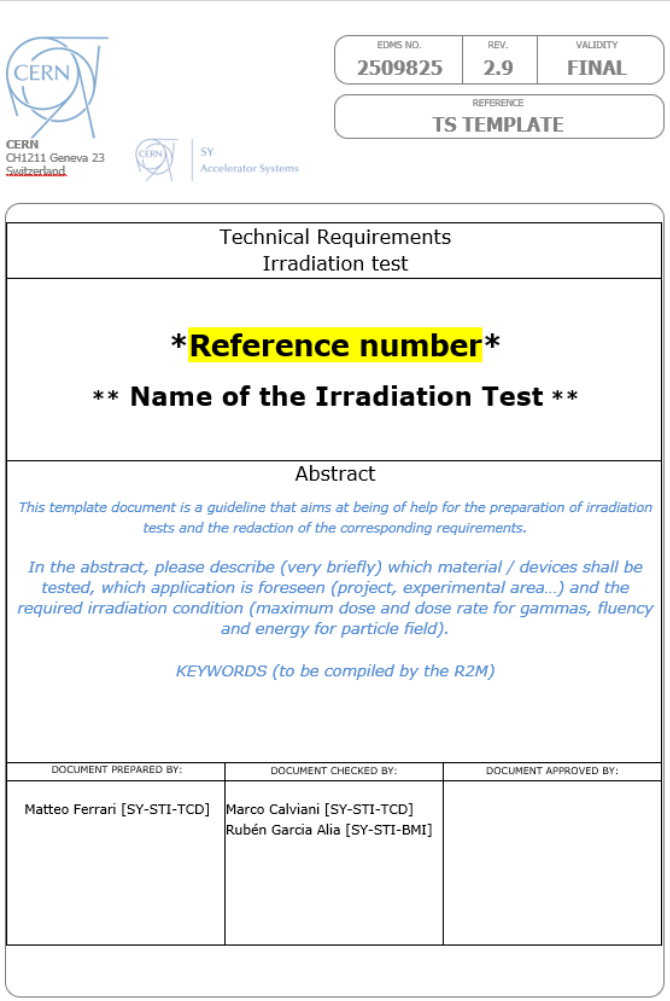
R2M: COORDINATION (TECHNICAL + ADMIN), EXPERTISE FOR TEST DESIGN AND INTERPRETATION

R2M SUPPORT ACTIVITIES

R2M MAIN EXPERTISE:

- Design of irradiation/post-irradiation tests
- Selection of samples and irradiation conditions
- Technical documents: template, approval and archive
- Administration documents: quote, order, invoice
- Communications with Contractor/facilities.
- Interpretation of test results

RADIATION LEVELS IN BOTH OPERATION AND TEST



CERN
CH1211 Geneva 23
Switzerland

SY
Accelerator Systems

EDMS NO.	REV.	VALIDITY
2509825	2.9	FINAL

REFERENCE: TS TEMPLATE

Technical Requirements
Irradiation test

Reference number

** **Name of the Irradiation Test** **

Abstract

This template document is a guideline that aims at being of help for the preparation of irradiation tests and the redaction of the corresponding requirements.

In the abstract, please describe (very briefly) which material / devices shall be tested, which application is foreseen (project, experimental area…) and the required irradiation condition (maximum dose and dose rate for gammas, fluency and energy for particle field).

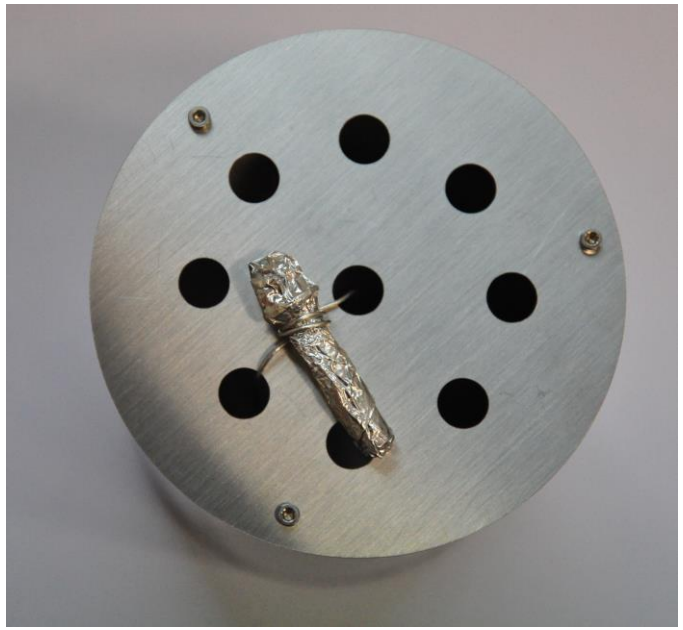
KEYWORDS (to be compiled by the R2M)

DOCUMENT PREPARED BY:	DOCUMENT CHECKED BY:	DOCUMENT APPROVED BY:
Matteo Ferrari [SY-STI-TCD]	Marco Calviani [SY-STI-TCD] Rubén Garcia Alia [SY-STI-BMI]	

Specification template
EDMS 2509825
Regularly updated

DOSIMETRY CALCULATIONS AND MEASUREMENTS

- ✓ Definition of radiation levels in operation
- ✓ Dose measurements



RPL dosimeters attached to irradiated samples

COLLABORATION WITH MCWG, HLD WITHIN SY-STI

IRRADIATION TEST SCHEDULE

TEST DURATION
12-17 months

IRRADIATION:
4-8 months

LONG TESTS:

- Test design and sample preparation
- Compilation/discussion of technical documentation
- Inquiry to facilities and wait for available slot
- Administration: order approval
- Sample shipment
- Report review and approval

COVID-19 PANDEMIC: IMPACT ON GENERAL FACILITY AVAILABILITY AND SCHEDULE

IRRADIATION FACILITIES

GAMMA FACILITIES IN EUROPE:

- Commercial 60Co plants
- Huge volumes – routine activities
- Extremely busy during covid
- Few slots for research activities
- Negotiation/compromise

STERIS® IONISOS

IN-HOUSE Irradiation Station

Installed in July 2021

Tomorrow at 14.15

- **New NEAR irradiation station at n_TOF: design, implementation and first results**

NEW NEUTRON DOMINATED IRRADIATION STATION FOR R2M/R2E AT THE n_TOF FACILITY

NEAR Irradiation station
Telemax carrying samples
M.Ferrari et al., arXiv:2202.12809 (2022)

EXAMPLE OF IRRADIATION REPORT: 20-06

In confidence
REP227

Radtest Ltd

20-06: Irradiation of vacuum assemblies with EPM- and EPDM-based O-rings

Date of issue: September 2021

In confidence

Fig. 24: vacuum assembly 2A, post-irradiation

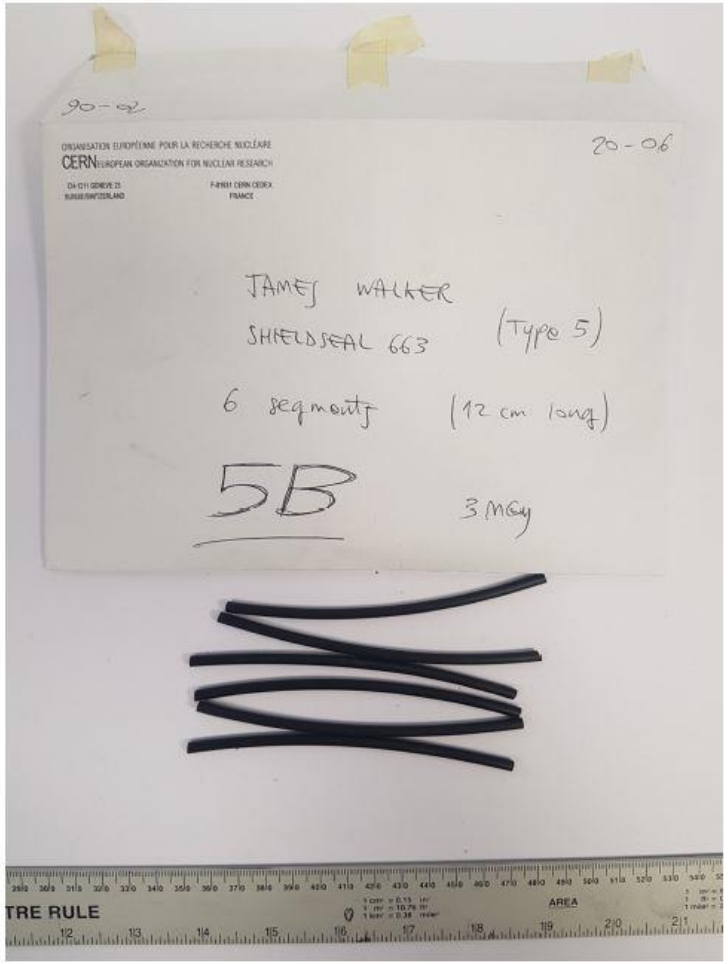


Fig. 38: O-ring cut samples type 5B, post-irradiation

20-03 test

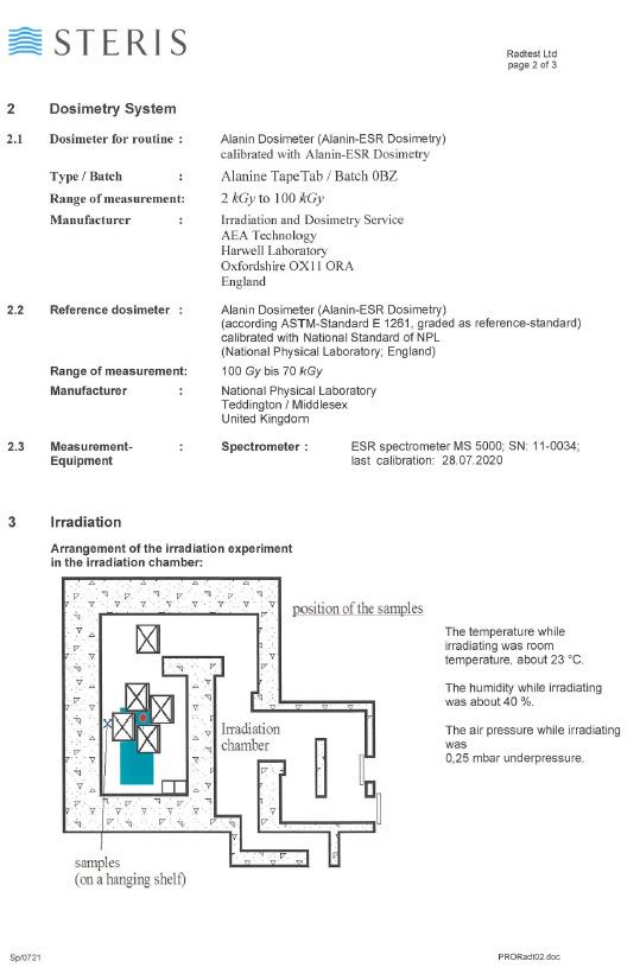
3 MGy irradiation

EXAMPLE OF DOSIMETRY REPORT

INFO ON:

- Irradiation time
- Facility stops
- Dosimetry measurements (in irradiation slots)

DEPENDS ON SPECIFIC FACILITY



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2 Dosimetry System

2.1 Dosimeter for routine : Alanin Dosimeter (Alanin-ESR Dosimetry) calibrated with Alanin-ESR Dosimetry

Type / Batch : Alanine TapeTab / Batch 0BZ

Range of measurement: 2 *kGy* to 100 *kGy*

Manufacturer : Irradiation and Dosimetry Service
AEA Technology
Harwell Laboratory
Oxfordshire OX11 ORA
England

2.2 Reference dosimeter : Alanin Dosimeter (Alanin-ESR Dosimetry) (according ASTM-Standard E 1261, graded as reference-standard) calibrated with National Standard of NPL (National Physical Laboratory; England)

Range of measurement: 100 *Gy* bis 70 *kGy*

Manufacturer : National Physical Laboratory
Teddington / Middlesex
United Kingdom

2.3 Measurement-Equipment : Spectrometer : ESR spectrometer MS 5000; SN: 11-0034; last calibration: 28.07.2020

3 Irradiation

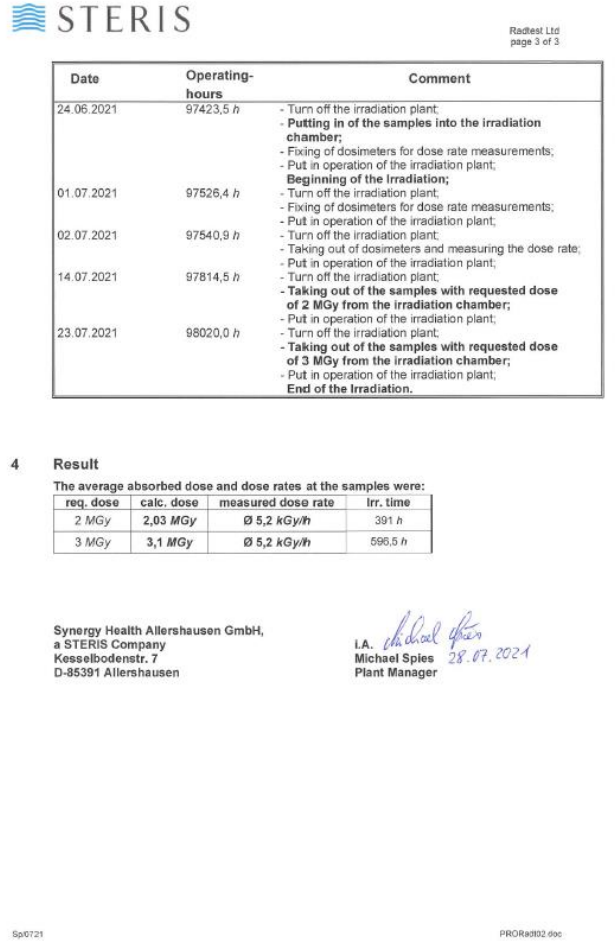
Arrangement of the irradiation experiment in the irradiation chamber:

The temperature while irradiating was room temperature, about 23 °C.

The humidity while irradiating was about 40 %.

The air pressure while irradiating was 0,25 mbar underpressure.

Sp/0721 PRORad02.doc



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Date	Operating-hours	Comment
24.06.2021	97423,5 *h*	- Turn off the irradiation plant; - **Putting in of the samples into the irradiation chamber;** - Fixing of dosimeters for dose rate measurements; - Put in operation of the irradiation plant; **Beginning of the Irradiation;**
01.07.2021	97526,4 *h*	- Turn off the irradiation plant; - Fixing of dosimeters for dose rate measurements; - Put in operation of the irradiation plant;
02.07.2021	97540,9 *h*	- Turn off the irradiation plant; - Taking out of dosimeters and measuring the dose rate; - Put in operation of the irradiation plant;
14.07.2021	97814,5 *h*	- Turn off the irradiation plant; - **Taking out of the samples with requested dose of 2 MGy from the irradiation chamber;** - Put in operation of the irradiation plant;
23.07.2021	98020,0 *h*	- Turn off the irradiation plant; - **Taking out of the samples with requested dose of 3 MGy from the irradiation chamber;** - Put in operation of the irradiation plant; **End of the Irradiation.**

4 Result

The average absorbed dose and dose rates at the samples were:

req. dose	calc. dose	measured dose rate	irr. time
2 *MGy*	**2,03 *MGy***	**Ø 5,2 *kGy/h***	391 *h*
3 *MGy*	**3,1 *MGy***	**Ø 5,2 *kGy/h***	596,5 *h*

Synergy Health Allershausen GmbH,
a STERIS Company
Kesselbodenstr. 7
D-85391 Allershausen

i.A. Michael Spies 28.07.2021
Plant Manager

Sp/0721 PRORad02.doc

DIFFERENT TYPES OF TEST AND OUTPUT

1. QUALIFICATION: standard test
2. QUALIFICATION with specific/special requirements
3. COMPARISON for design choices
4. RESEARCH STUDIES

WIDE APPLICABILITY OF RESULTS AT CERN

R2M AIMS AT BUILDING KNOWLEDGE
RESULTS OF THIS APPROACH ALREADY VISIBLE

TEST RESULTS AND THEIR CONSEQUENCES

Protective Covers for magnets:
10 MGy, **CERN complex**
C. L. Marraco Borderas (TE-MSC)

OUTPUT AND BENEFITS

- **Product selection:** design finalization
- **Increase reliability/equipment lifetime**
- **Qualification** of new materials
- **Minimize** failure risks and maintenance
- **Minimize** dose to personnel
- **Database** of data/**publications** for future use
- **Optimization** of processes

KNOWLEDGE INCREASED, DEVELOPED AND SHARED

TAKE HOME MESSAGE

- Commercial non-metallic components to be used in high-radiation areas require irradiation tests
- CERN has a Contract in place with Radtest concerning irradiation services
- The R2M can provide expertise to help you organize an irradiation test and for the results interpretation

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