

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

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For the R2M team

Acknowledgements:

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A.Zenoni, S.Pandini (University of Brescia, Italy)

R2E Annual Meeting – 1-2 March, 2022

<https://indico.cern.ch/event/1116677/>



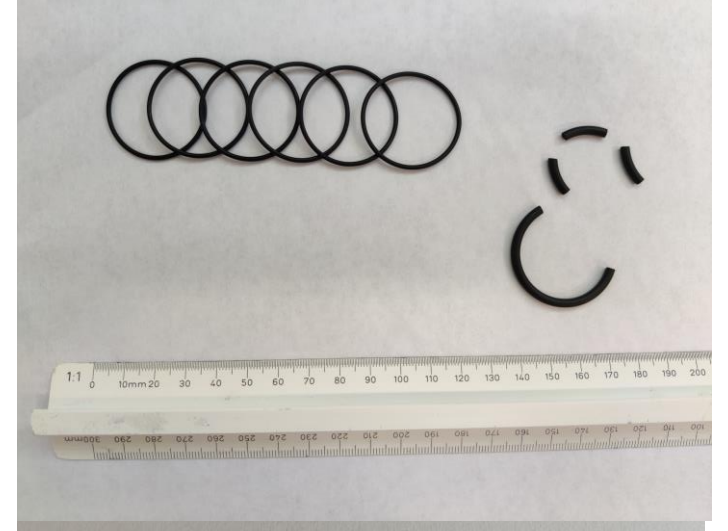


1 INTRODUCTION AND BACKGROUND

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 BEAM INTERCEPTING DEVICES

COMMON RADIATION EFFECTS/1

MACRO

- Softening
- Hardening

MICRO

- Chain cleavage
- Cross-link



**FOLLOWING TALK
AT 14.00**

D.Senajova

➤ [Radiation damage studies on lubricants](#)

Ordinary grease present in CERN STORES

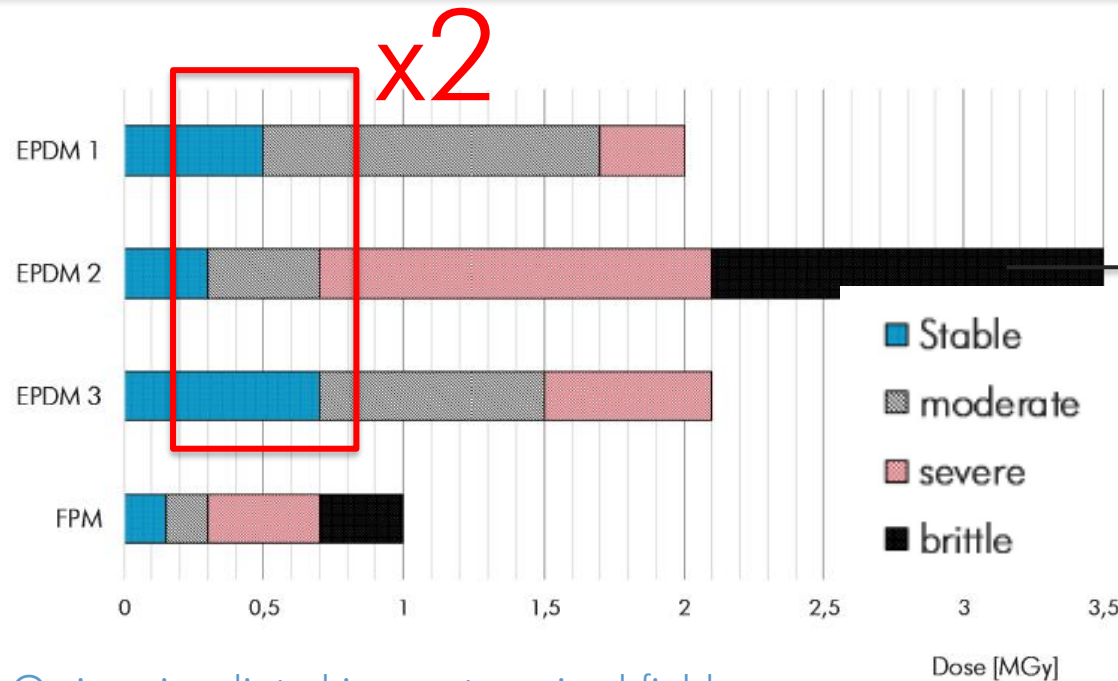
➤ [M.Ferrari et al., Heliyon 5 \(2019\) e02489](#)



EPDM O-rings – 3 MGy
M.Ferrari, PhD Thesis
[EDMS 2412825](#)

2 RESEARCH STUDIES: EPDM O-RINGS

EPDM BASED O-RINGS: LARGE DIFFERENCES!



O-rings irradiated in reactor mixed field

- [A.Zenoni et al., Review of Scientific Instruments 88, 113304 \(2017\);](#)
- [M.Ferrari, Ph.D. Thesis \(2020\); EDMS 2412825](#)

POOR CHOICE OF EPDM: LIFETIME REDUCTION
EPDM 3 (JAMES WALKER): BEST PRODUCT

RECENT STUDIES: IRRADIATION CAMPAIGNS

GAMMA IRRADIATIONS

External gamma sources (ref)

- ✓ **Test 20-06 (1-2 MGy)**
- Test 21-04 (0.1, 0.5 MGy)
- New test in 2022

➤ [EDMS CERN-0000216221](#)

Radtest Ltd

NEUTRON AND GAMMA MIXED FIELD

In-house at n_TOF irradiation station:

- NEAR 2021 (0.4-0.8 MGy)
- NEAR 2022 (1.2-2.4 MGy)
- New RABBIT irradiation in 2022

FOLLOWING TALK at 14.15

➤ [New NEAR irradiation station at n_TOF: design, implementation and first results](#)

SAME DOSE - DIFFERENT IRRADIATION CONDITIONS



NEAR Irradiation station

Telex carrying samples

M.Ferrari et al., [arXiv:2202.12809](https://arxiv.org/abs/2202.12809) (2022)

COMPARISON: 2 EPDM-BASED ELASTOMERS

Shieldseal 663 by James Walker

SPECIAL RAD-HARD FORMULATION

- 1.6 M Gy gamma by producer;
- 2 M Gy in reactor mixed field;
- Best EPDM for high-rad areas
- Used in BIDs (LHC dump)
- Very high cost

James Walker[®]

EPDM 70.10-02 by Angst+Pfister

GENERIC PRODUCT

- Declared as rad-hard but no tests
- Standard at CERN: available in stores and widely used at CERN.

AP Angst+Pfister

RADIATION HARD EPDM vs GENERIC ONE

POST-IRRADIATION CHARACTERIZATION

MECHANICAL

- ✓ Tensile Test

STRUCTURAL

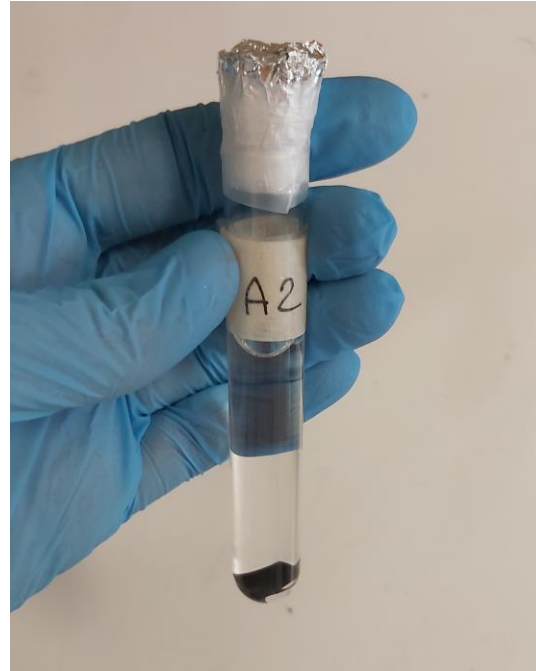
- ✓ Swelling test
- ✓ DSC Test

GAMMA DOSE STEPS:

- ✓ 0, 2, 3 MGy

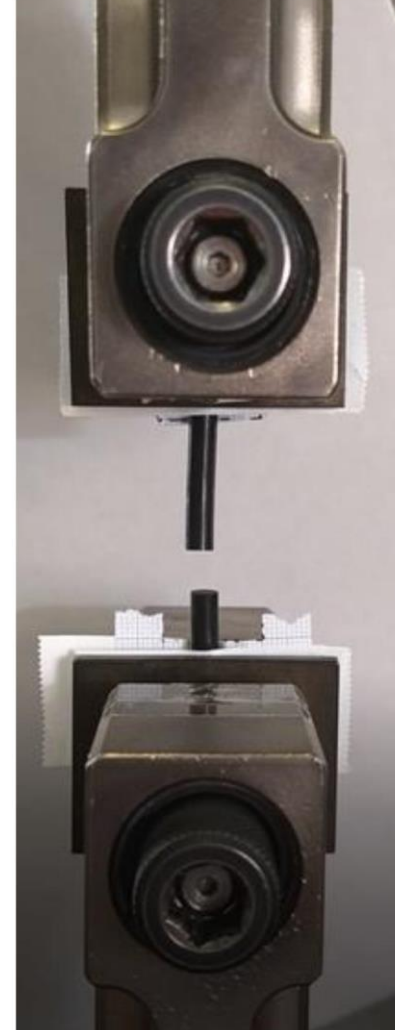


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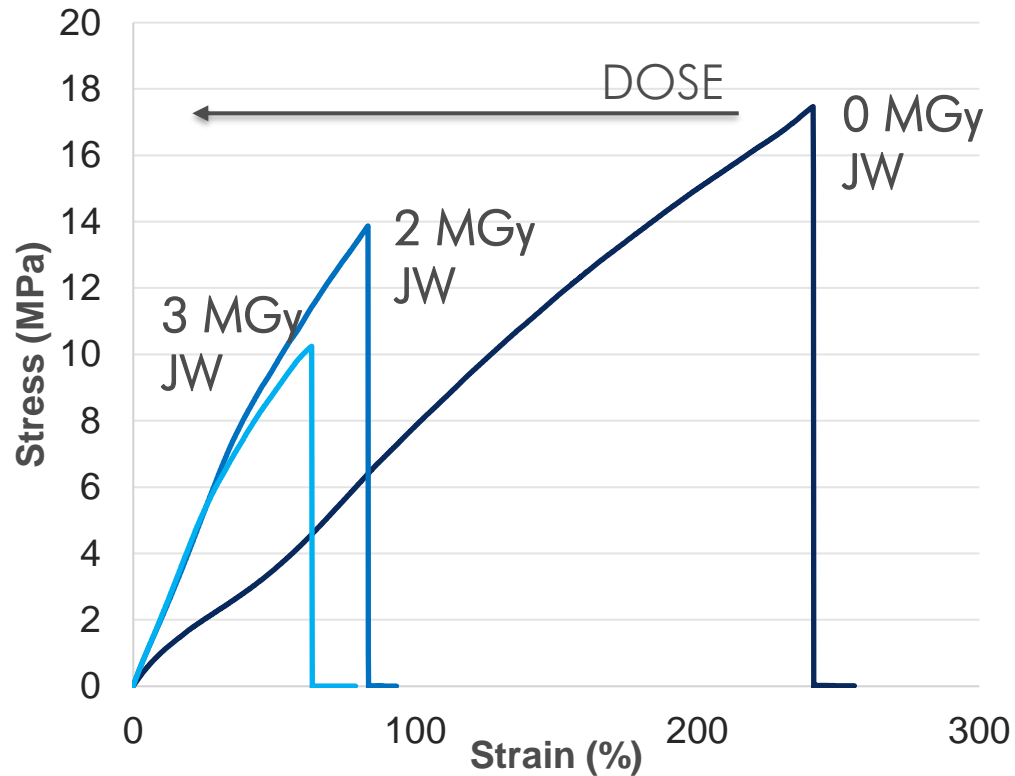


Swelling test and tensile tests
➤ [M.Ferrari, Ph.D. Thesis \(2020\)](#)

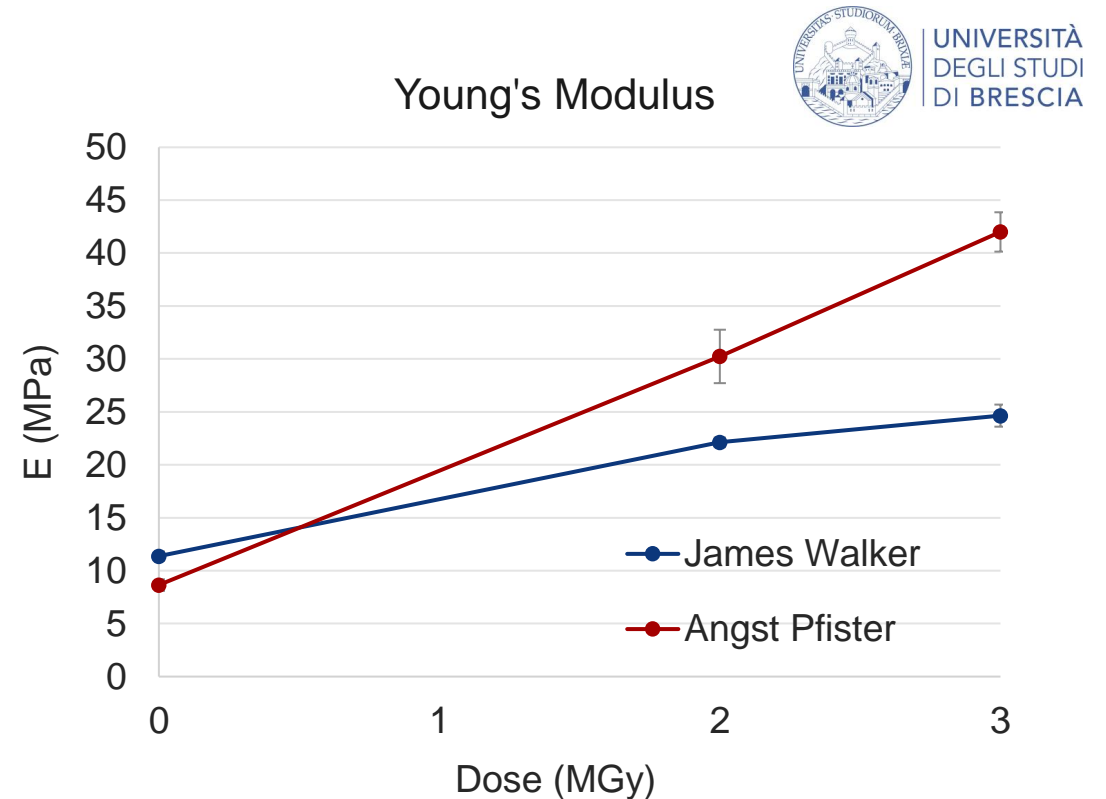
Thanks to (EN-MME):
M.Crouvizier, I.Aviles



STRESS vs STRAIN CURVES AND YOUNG'S MODULUS

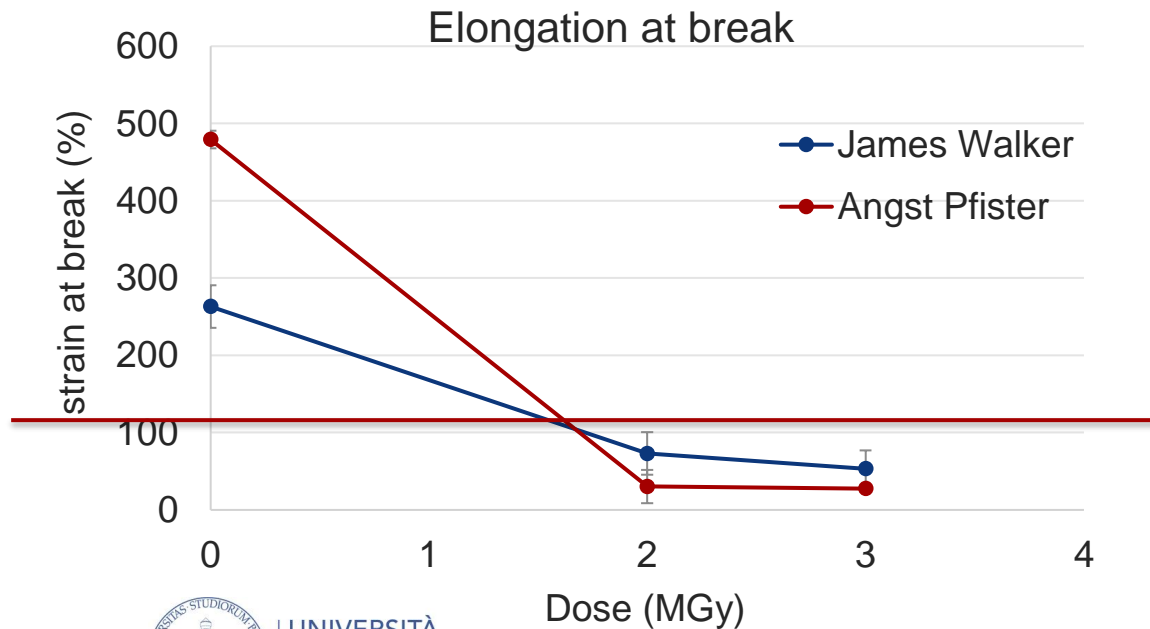


➤ Average of 5 tested samples



PROGRESSIVE HARDENING WITH DOSE

ELONGATION AT BREAK – SENSITIVE QUANTITY



➤ Average of 5 samples

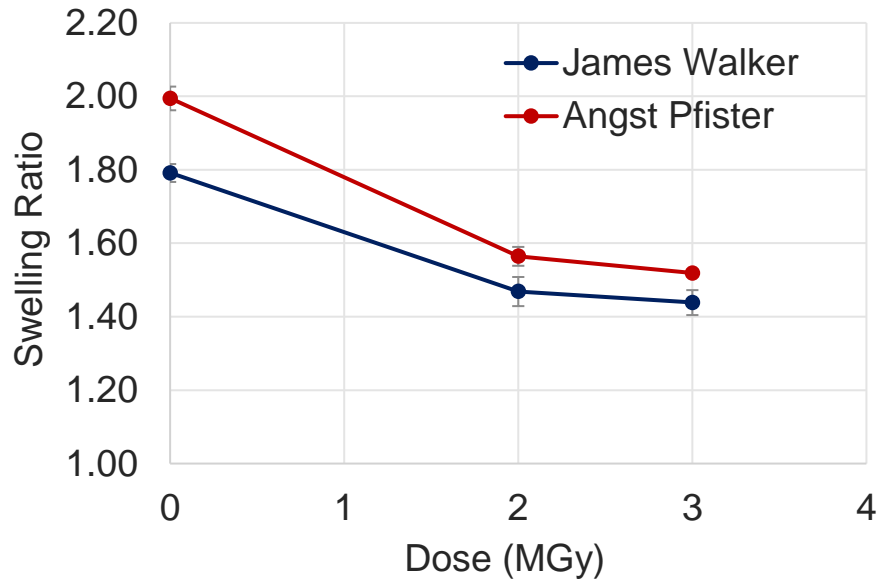
FIGURES OF MERIT - standard:

- **D50(EB)**: dose corresponding to a reduction of the E@B of 50% in comparison to initial value
- **D100%** : dose for residual 100% of the E@B
- Lower doses being explored

PROGRESSIVE EMBRITTLEMENT OF BOTH MATERIALS SEVERE DAMAGE FOR BOTH AT 2 MGy (gamma)

SWELLING & DSC: CROSS-LINKING MEASUREMENTS

SWELLING TEST



MASS LOSS:

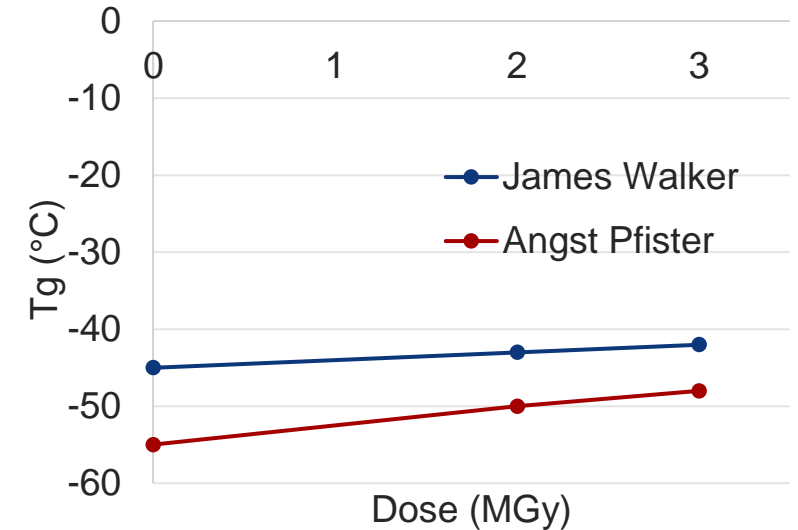
James Walker: 1-2%

Angst Pfister: 15%



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DIFFERENTIAL SCANNING CALORIMETRY



➤ Average of 3 tested samples

SR DECREASE (20%) = CROSSLINKING DOMINATES
CONFIRMED BY T_g INCREASE WITH DOSE

DISCUSSION

OBSERVED:

- Progressive degradation of properties with dose;
- Embrittlement and increased stiffness of both materials;
- Severe degradation for both at 2 MGy as expected – saturation of some effects;
- To quantify end-of-life conditions: data at lower doses (being collected)
- Agreement between mechanical and structural effects
- Further investigations at lower doses

JAMES WALKER OVERALL MORE STABLE THAN A+P

3 EXAMPLES OF APPLICATIONS

O-RINGS OF THE LHC DUMP – UPSTREAM WINDOW



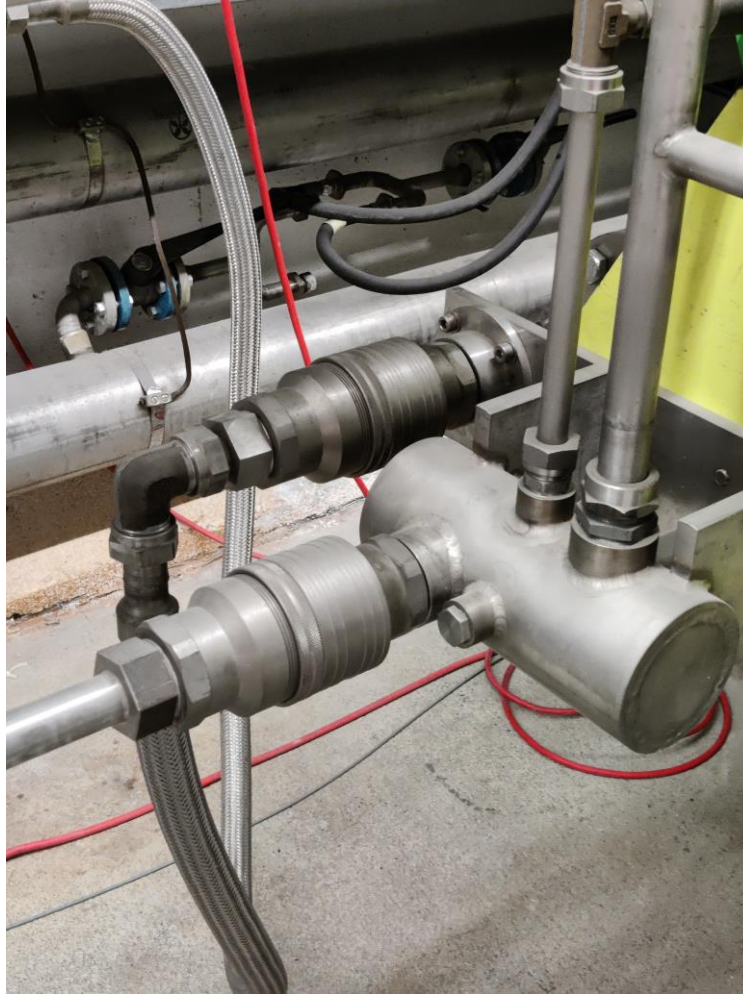
- 0.12 MGy expected
- **Maintenance:**
impossible/very difficult
- **Failure impact:**
accelerator shutdown

James Walker[®]

➤ [J. Maestre et al 2021 JINST 16 P11019](#)

SELECTION OF JAMES WALKER EPDM

O-RINGS REPLACEMENT FOR TED: END OF 2022



- Dose measurements in progress (thanks to HLD/R2E)
- James Walker EPDM O-ring selected

TAKE HOME MESSAGE

- Be careful with the selection of commercial EPDM materials! They are not all equally resistant to radiation
- High radiation areas require EPDMs, whose radiation tolerance is tested
- The R2M can help you selecting the best product for your application
- New studies are ongoing to better predict the lifetime of EPDMs in operation
- Centralized and coordinated studies on EPDMs would be beneficial for CERN

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