Matteo Ferrari EN/STI/TCD

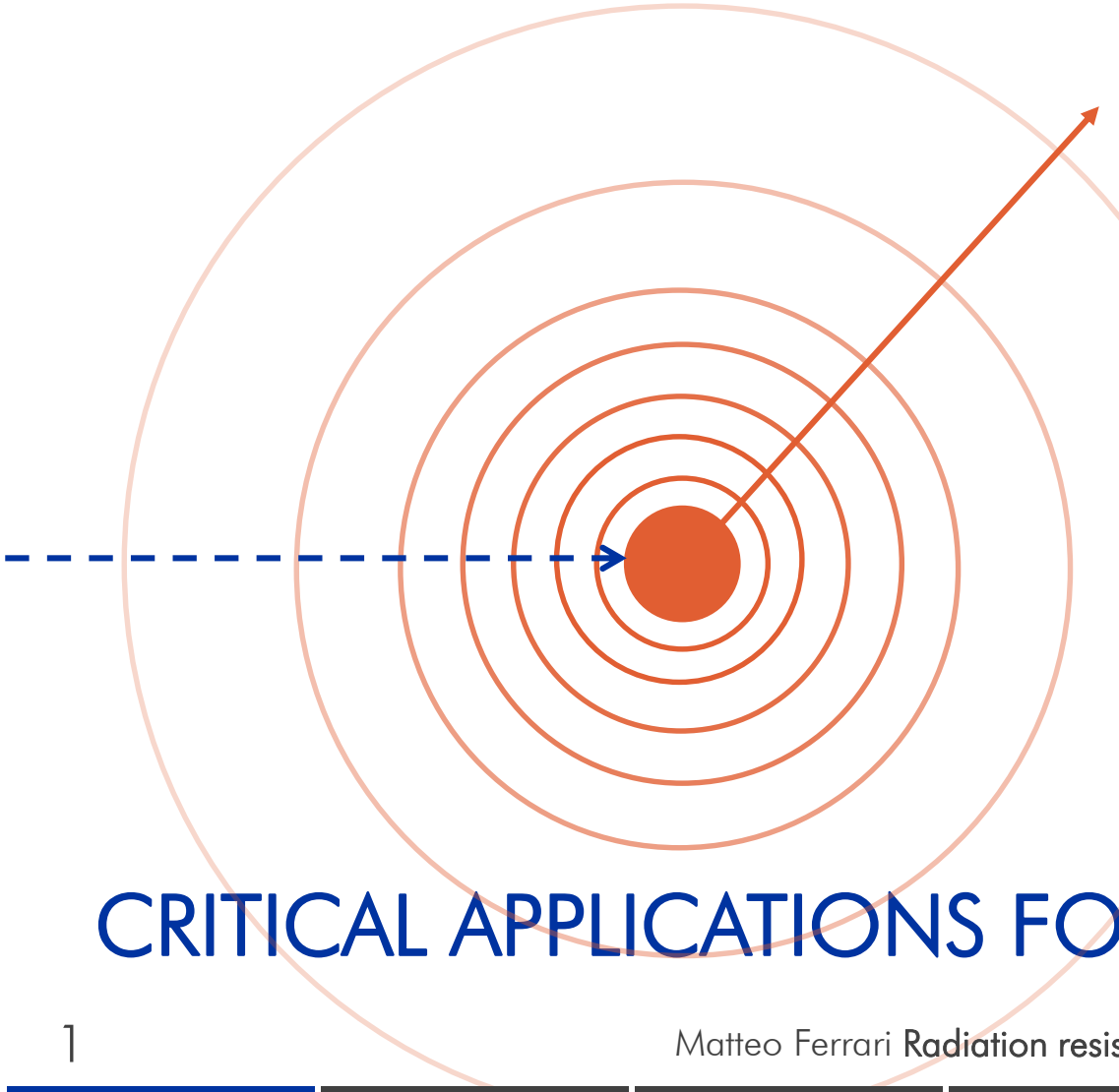
Radiation resistant lubricants Meeting • CERN • Oct 22st, 2019

NEUTRON AND GAMMA IRRADIATION TEST CAMPAIGNS ON GREASES AND OILS

Recent results

INTRODUCTION

HIGH-POWER FACILITIES

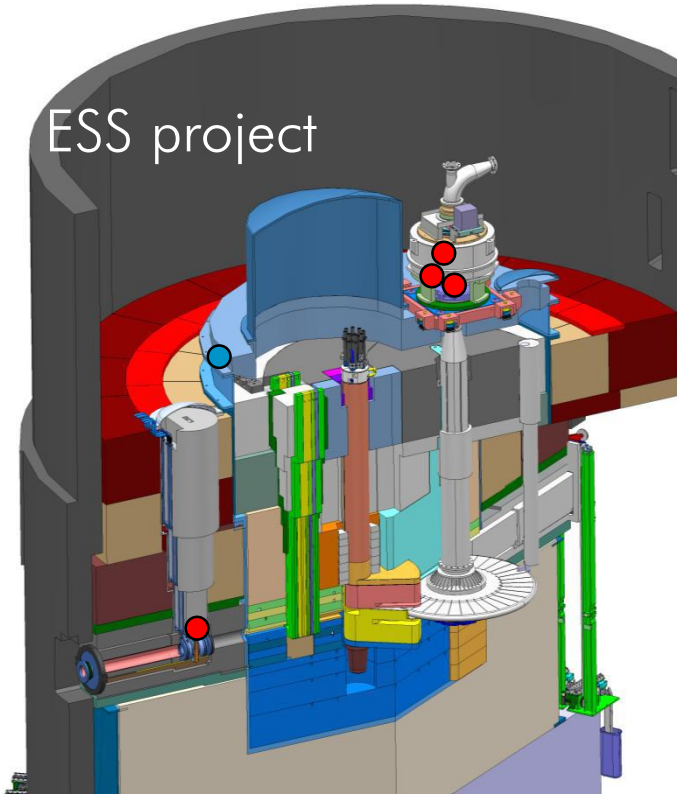


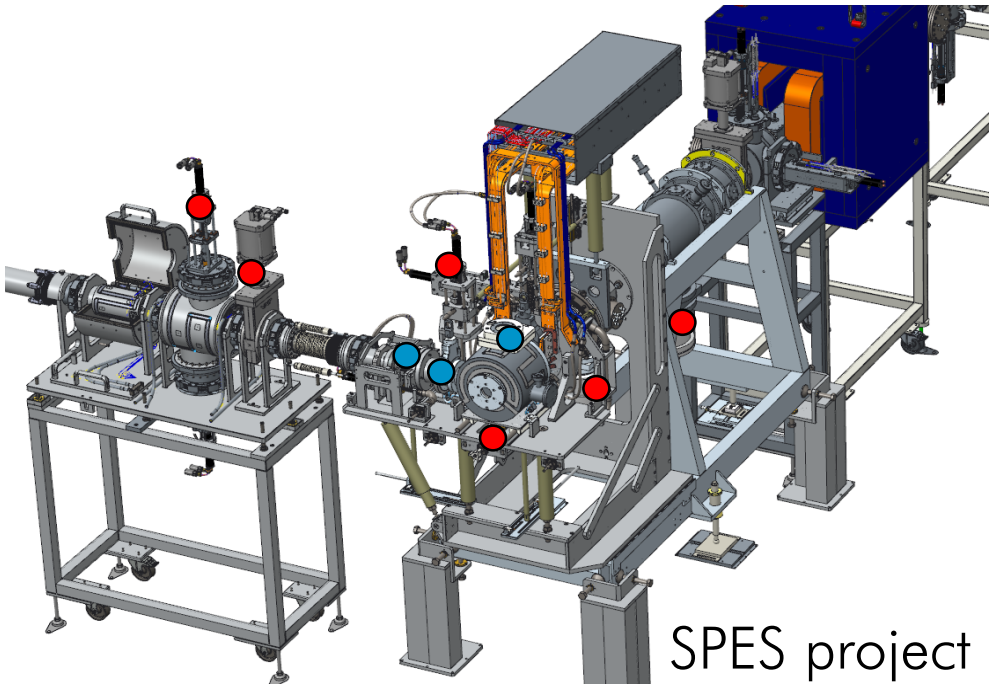
- **RADIATION DAMAGE** in MIXED FIELDS
- RESIDUAL ACTIVATION
  Radiation protection
  Maintenance
  Waste disposal

CRITICAL APPLICATIONS FOR POLYMERS

POLYMERS IN FACILITIES UNDER CONSTRUCTION

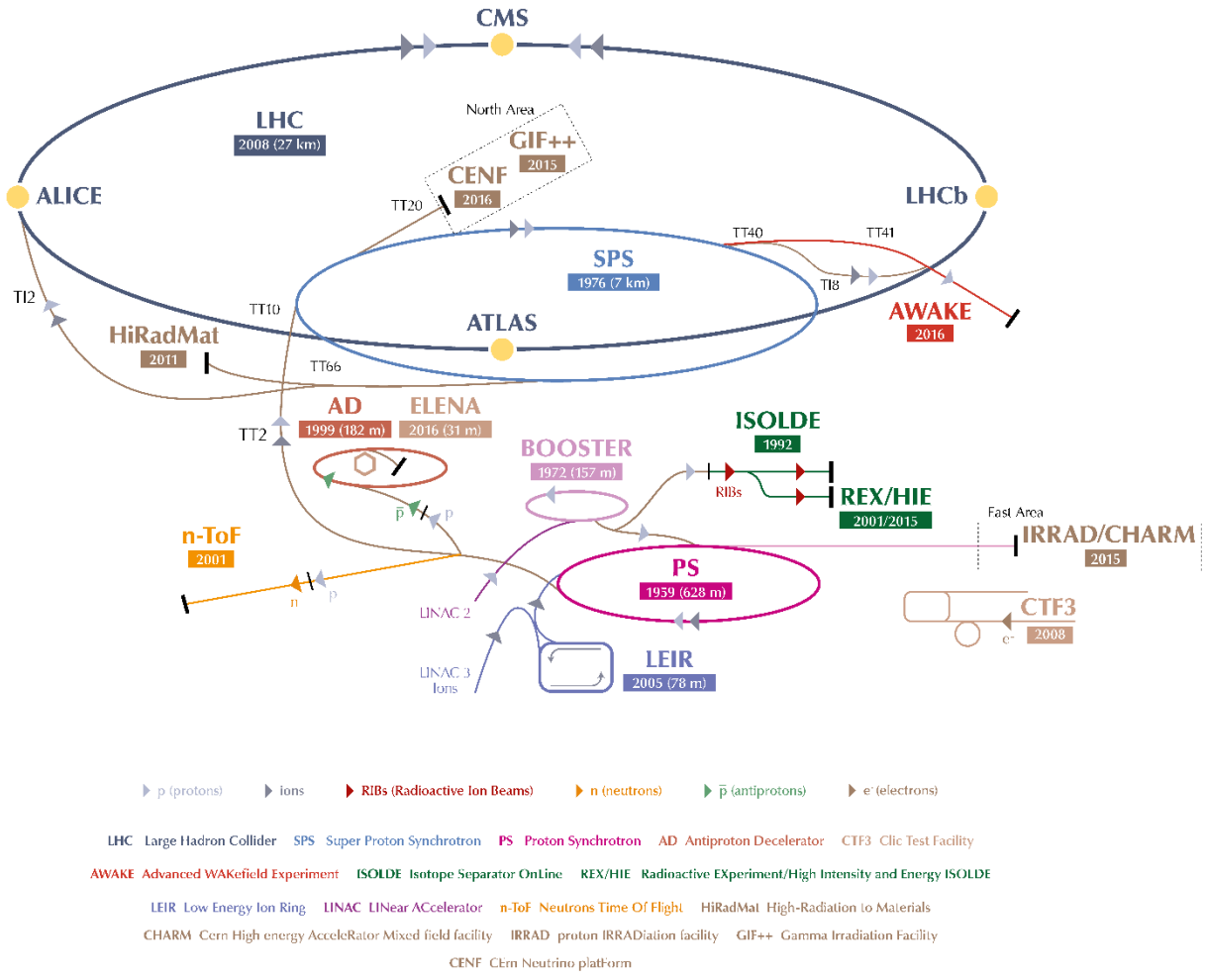
- O-rings
- Lubricants





NECESSARY BUT RADIATION-SENSITIVE

CERN ACCELERATOR COMPLEX



MAIN CONCERNS

BEST PRODUCTS FOR SPECIFIC APPLICATIONS

Design

UNDERSTANDING OF RAD MECHANISMS

Science

PREDICITON OF REAL-LIFE DEGRADATION

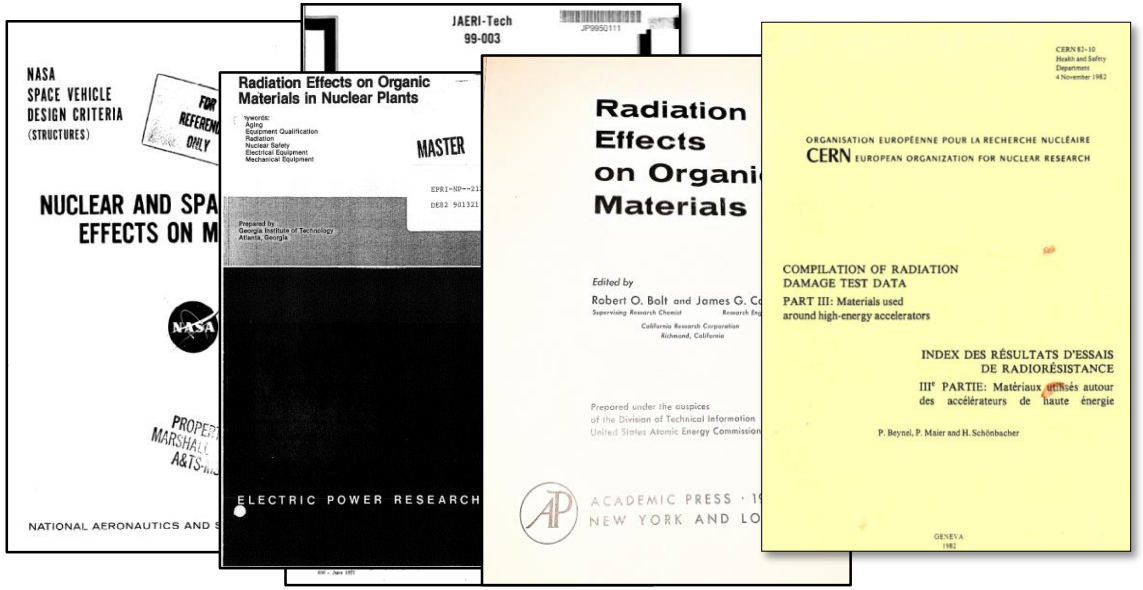
Maintenance

Prevent failure

FOLLOW-UP ON USED PRODUCTS

Know-how

LIMITS OF THE LITERATURE



- Mostly gamma
- Old data, obsolete products
- Very general tests
- Assumptions
- Lack of understanding
- Lack of thresholds
- More challenging conditions

'Equal dose – equal damage' ?

FEW NEUTRON/MIXED FIELD DATA

SELECTION OF COMMERCIAL PRODUCTS

MORESCO Corporation

LUBCON

KLÜBER LUBRICATION

M&I MATERIALS

Chemours

SANTOLUBES

THK

Castrol

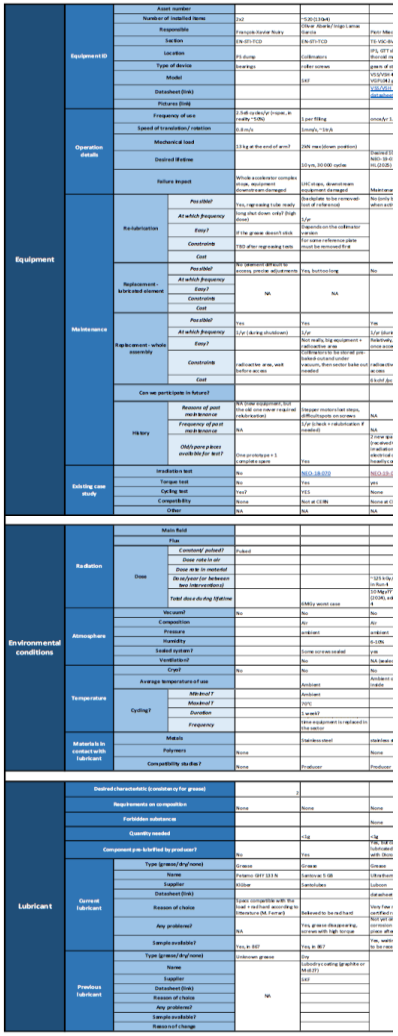
SCHAEFFLER

technical requirements

- Composition
- Temperature
- Atmosphere
- Extreme Pressure
- Compatibility
- Vacuum
- Mechanical features
- Radiation tolerance
- Product availability
- Price
- Producer reliability

OFTEN UNKNOWN
NO GENERAL VALIDITY

TECHNICAL SPECIFICATIONS AT CERN



By Dominika Senajova

EQUIPMENT

- Equipment ID
- Operation details
- Maintenance
- Existing components/follow up

ENVIRONMENT

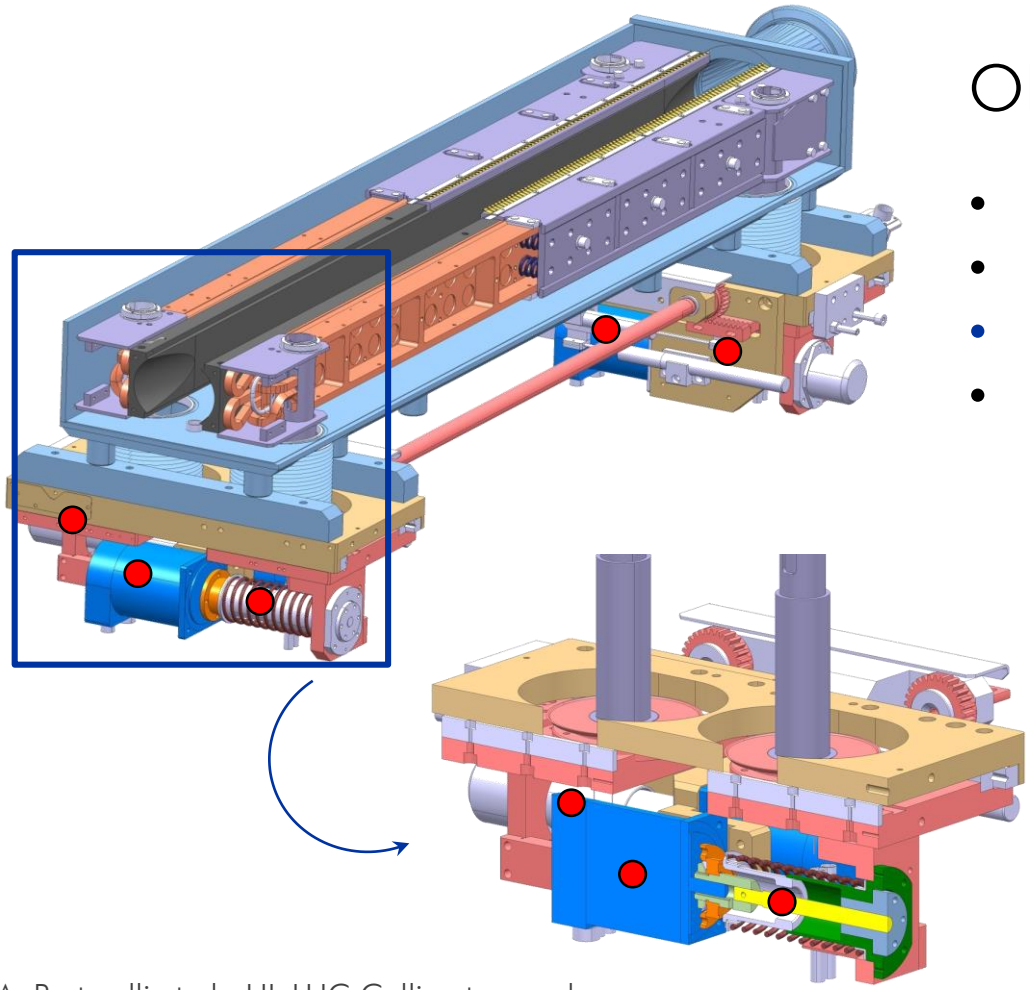
- Radiation field/rate
- Atmosphere
- Temperature
- Materials

LUBRICANT

- Consistency/viscosity
- Requirements on composition
- Quantity needed
- Previous products?

NEW ONGOING STUDY

COLLIMATORS LUBRICATION



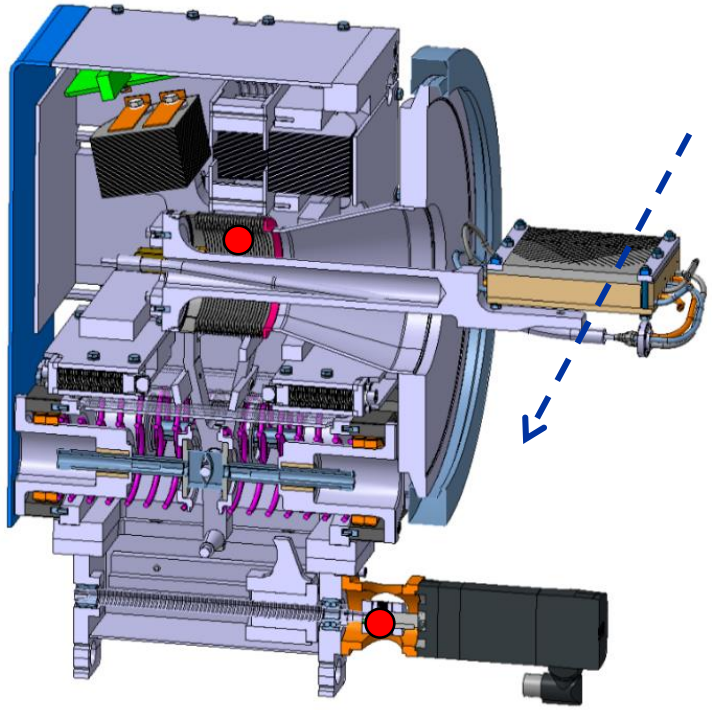
OPERATION CONDITONS

- ~130 collimators - LHC
- 4 roller screws per collimator
- ~10 MGy dose
- limited possible maintenance

CRITICAL DOSE LEVEL

A. Bertarelli et al., HL-LHC Collimators and High Temperature Materials, HiLumi LHC Goes To Industry Workshop (2015)

PS DUMP LUBRICATION



F-X. Nuiry et al., Designing and prototyping of the CERN Proton Synchrotron Internal Dump in the Framework of the LHC Injectors Upgrade Project, 7° High Power Targetry Workshop (2018)

OPERATION CONDITONS

- High energy protons
- ±6° rotation
- 250 000 cycles/yr
- 1 MGy dose

CASE STUDIES

- Grease evolution
- Endpoint
- Monitoring
- Failure scenarios
- Maintenance
- Follow up

IRRADIATION AND TESTING METHODOLOGIES

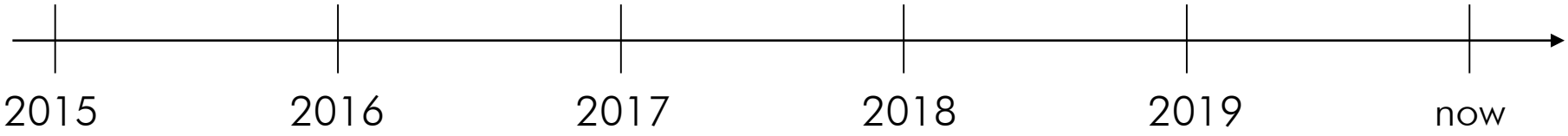
RADIATION DAMAGE STUDIES: A TIMELINE

RDS Radiation Damage Study - **polymers**

Phd - radiation damage on **lubricants**

case study - MORESCO grease/oil

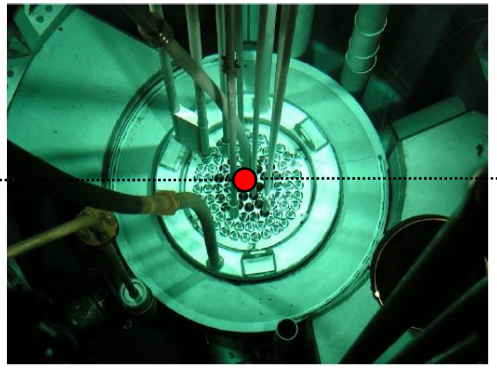
R2M



ELASTOMERIC O-RINGS

SAMPLES

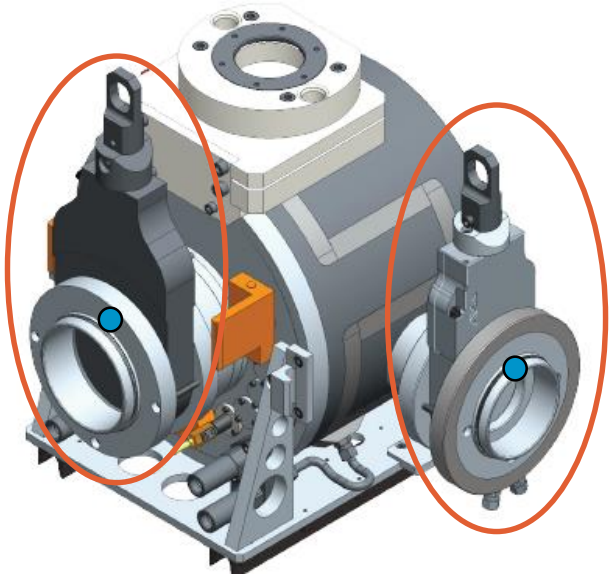
IRRADIATION FACILITY

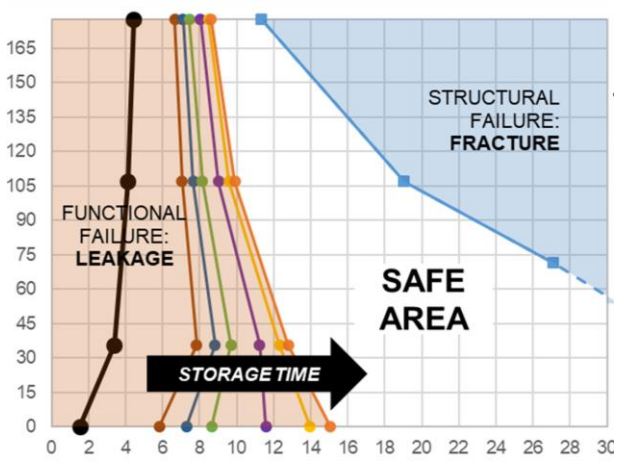


PIE

- A. Zenoni et al., **Radiation resistance of elastomeric O-rings in mixed neutron and gamma fields: Testing methodology and experimental results**, Review *of Scientific Instruments 88*, 113304 (2017) https://doi.org/10.1063/1.5011035
- M. Ferrari et al., **Degradation of EPDM and FPM elastomers irradiated at very high dose rates in mixed gamma and neutron fields**, Polymer Engineering and Science (2019) https://doi.org/10.1002/pen.25249

A REAL APPLICATION FOR AN EPDM O-RING





GATE VALVE - SPES facility

CONDITIONS

- Dynamic operation
- 0.7 MGy neutrons + gamma
- Vacuum
- About 85°C

SAFE USABILITY AREA

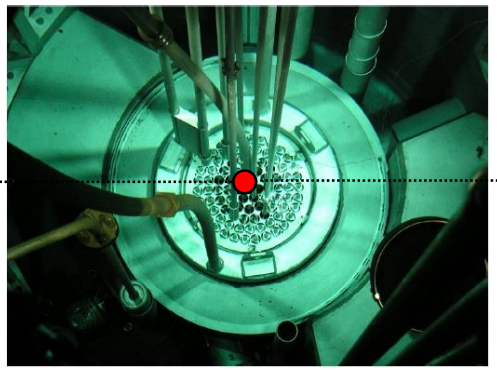
Battini, D. et al, Experimental testing and numerical simulations for life prediction of gate valve O-rings exposed to mixed neutron and gamma fields, Materials and Design vol. 156, 514-527 (2018) https://doi.org/10.1016/j.matdes.2018.07.020

LUBRICANTS

SAMPLES

IRRADIATION FACILITY

PIE



M.Ferrari et al., **Experimental study of consistency degradation of different greases in mixed neutron and gamma radiation**,
Heliyon, Vol 5 Issue 9 e02489 (2019)
https://doi.org/10.1016/j.heliyon.2019.e02489

IRRADIATION CAMPAIGNS

- O-RINGS
  4 products
- O-RINGS
  real application study
- O-RINGS
  Dose rate effect

2 experiments:

OAK RIDGE National Laboratory ISIS

+ proton irr. at IRRAD

- GREASES
  9 products
- LUBRICANT
  1 oil

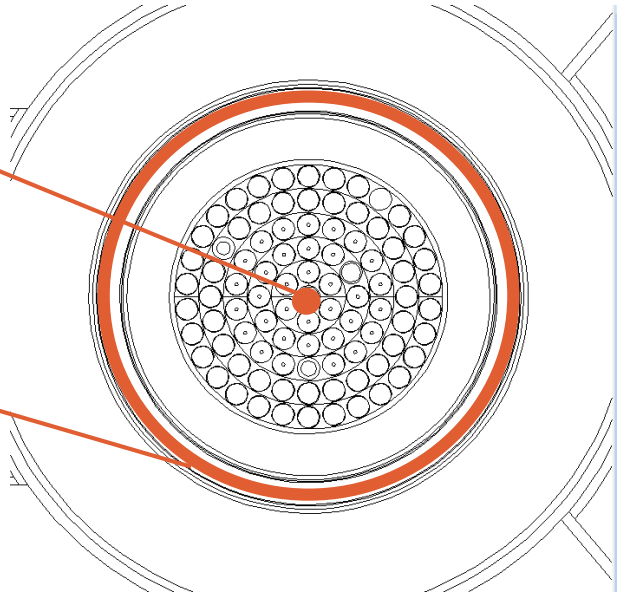
MORESCO Corporation

243 hours
83 samples
5 years

NEUTRON AND GAMMA REACTOR FACILITIES

In-core

Lateral



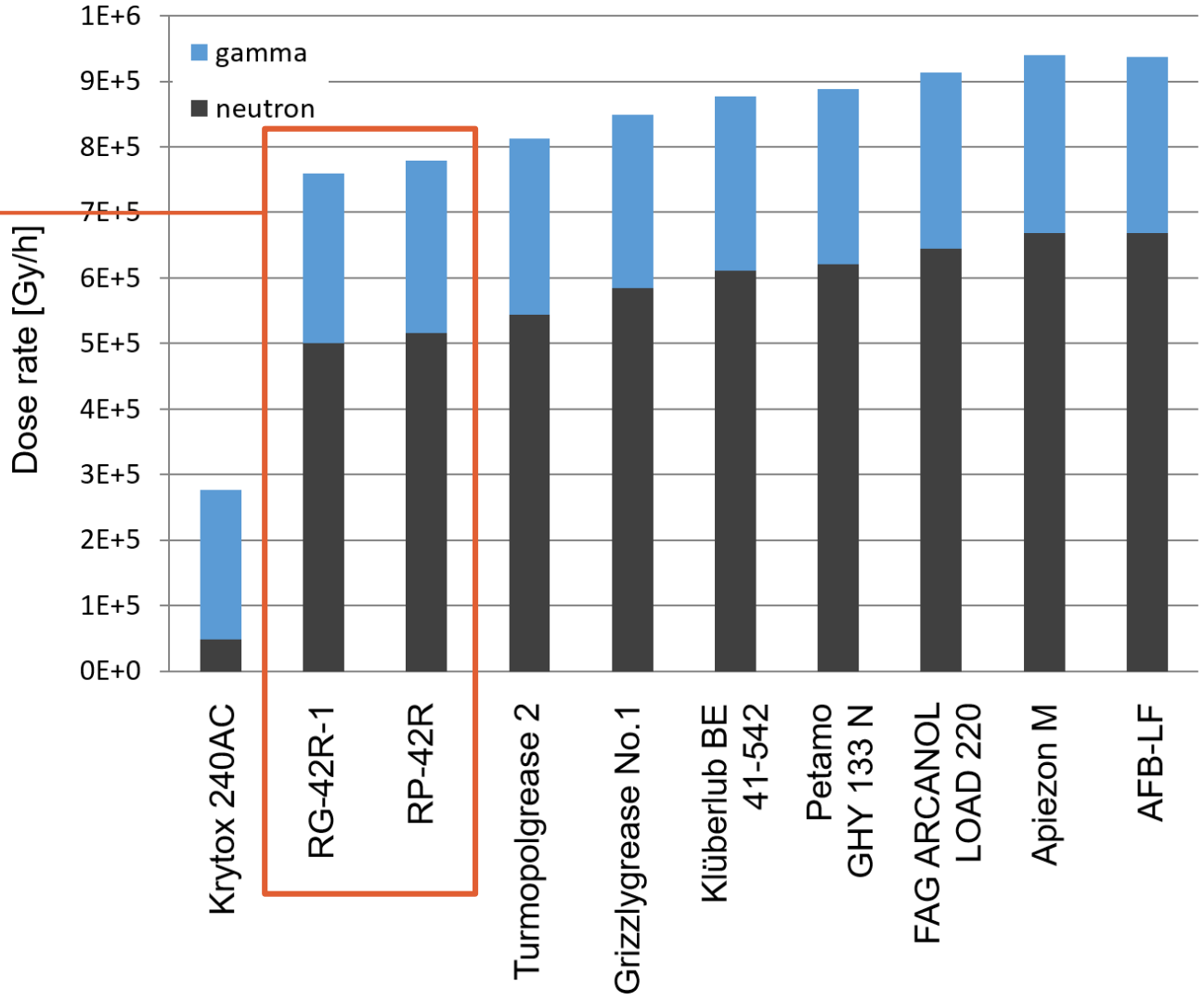
MIXED RAD FIELDS
HIGH FLEXIBILITY

Monte Carlo simulation
MCNPX reactor model

TRIGA Mark II
RESEARCH REACTOR
Pavia, Italy

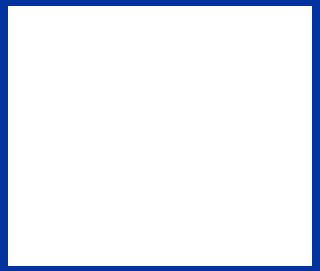
DOSIMETRY CALCULATIONS

MORESCO Corporation



COMPLEX DOSIMETRY

RADIATION STUDY ON GREASES



GREASE CONSISTENCY

MULTI-PHASE:

- Oil
- Thickener
- Additives

CONSISTENCY:

ASTM D217-02
Semi-fluid

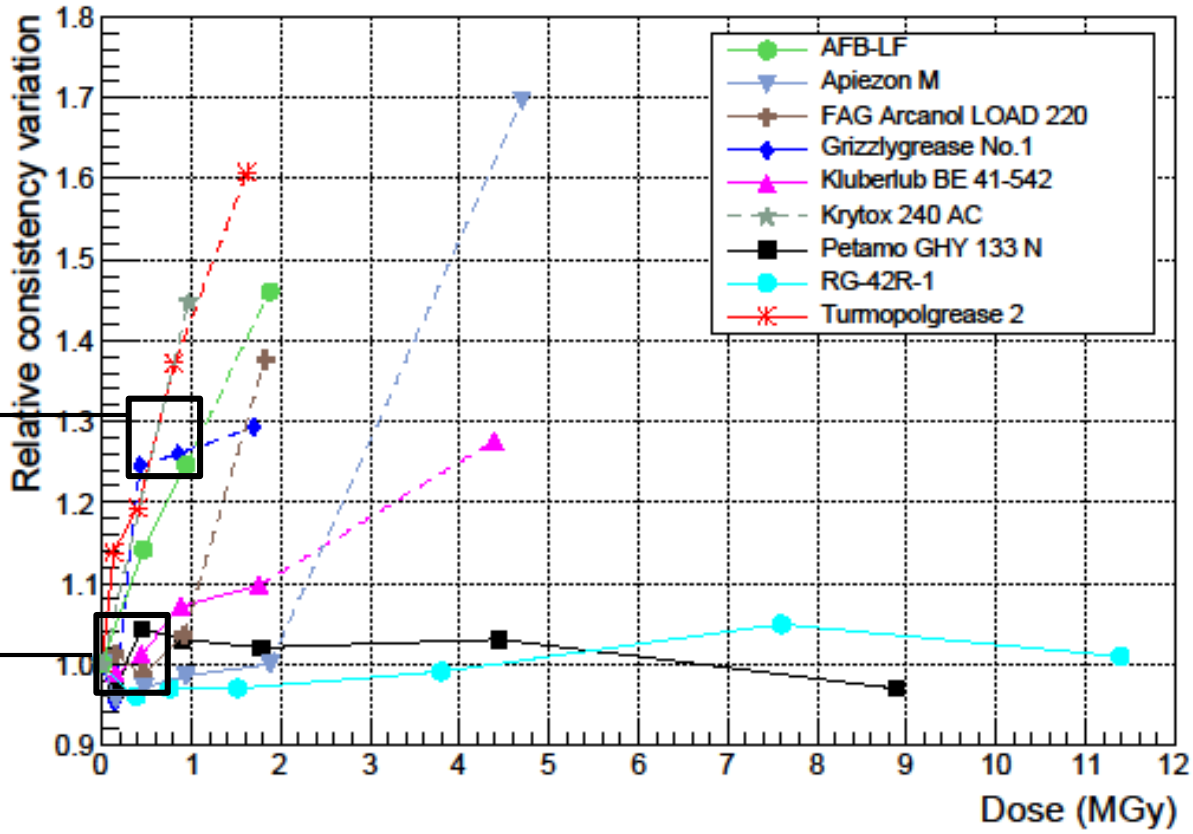
*'Grease is an exceptionally **complex** product incorporating a **high degree of technology** in chemistry, physics, rheology, tribology and the environmental sciences.'*

R. M. Mortier et al., Chemistry and Technology of Lubricants, 3rd edn., Springer (2010).

CONSISTENCY TEST: GRIZZLYGREASE No.1

0.45 MGy

0.15 MGy



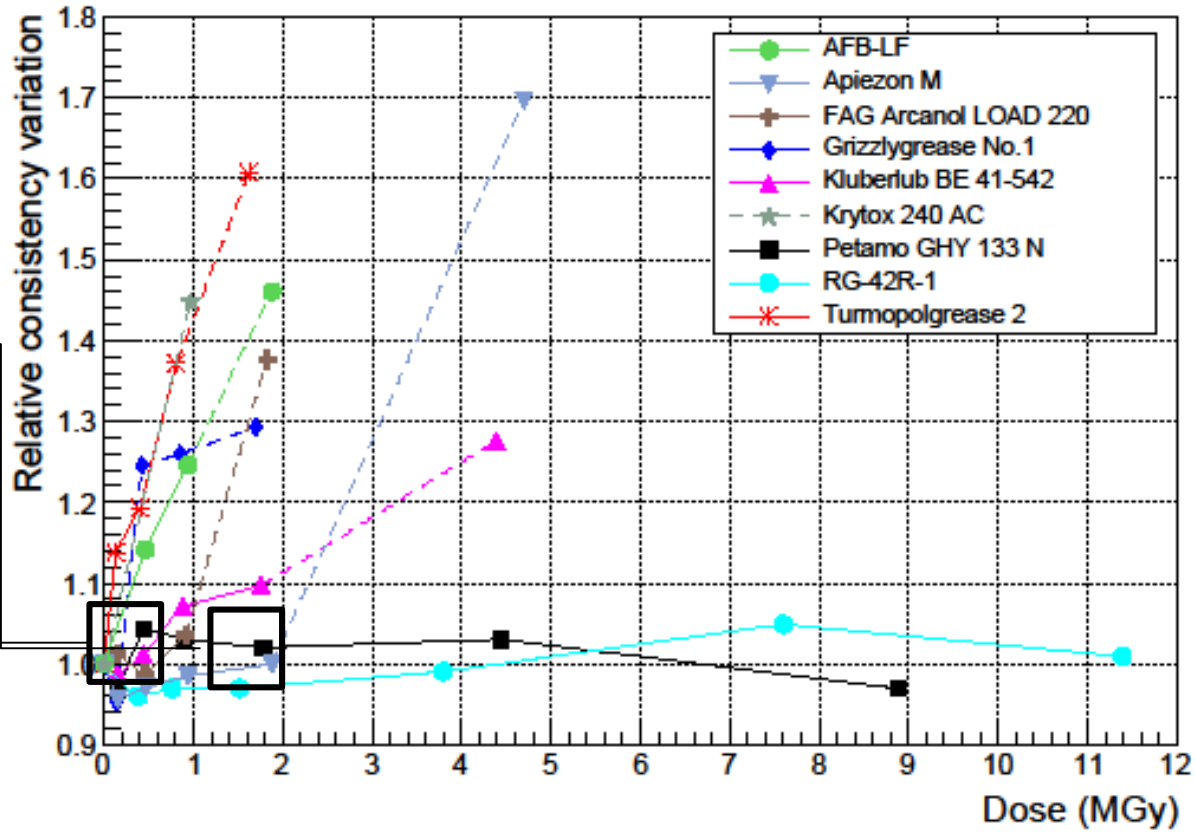
RADIATION-INDUCED FLUIDIZATION


DRIPPING
GREASE

CONSISTENCY TEST: PETAMO GHY 133 N

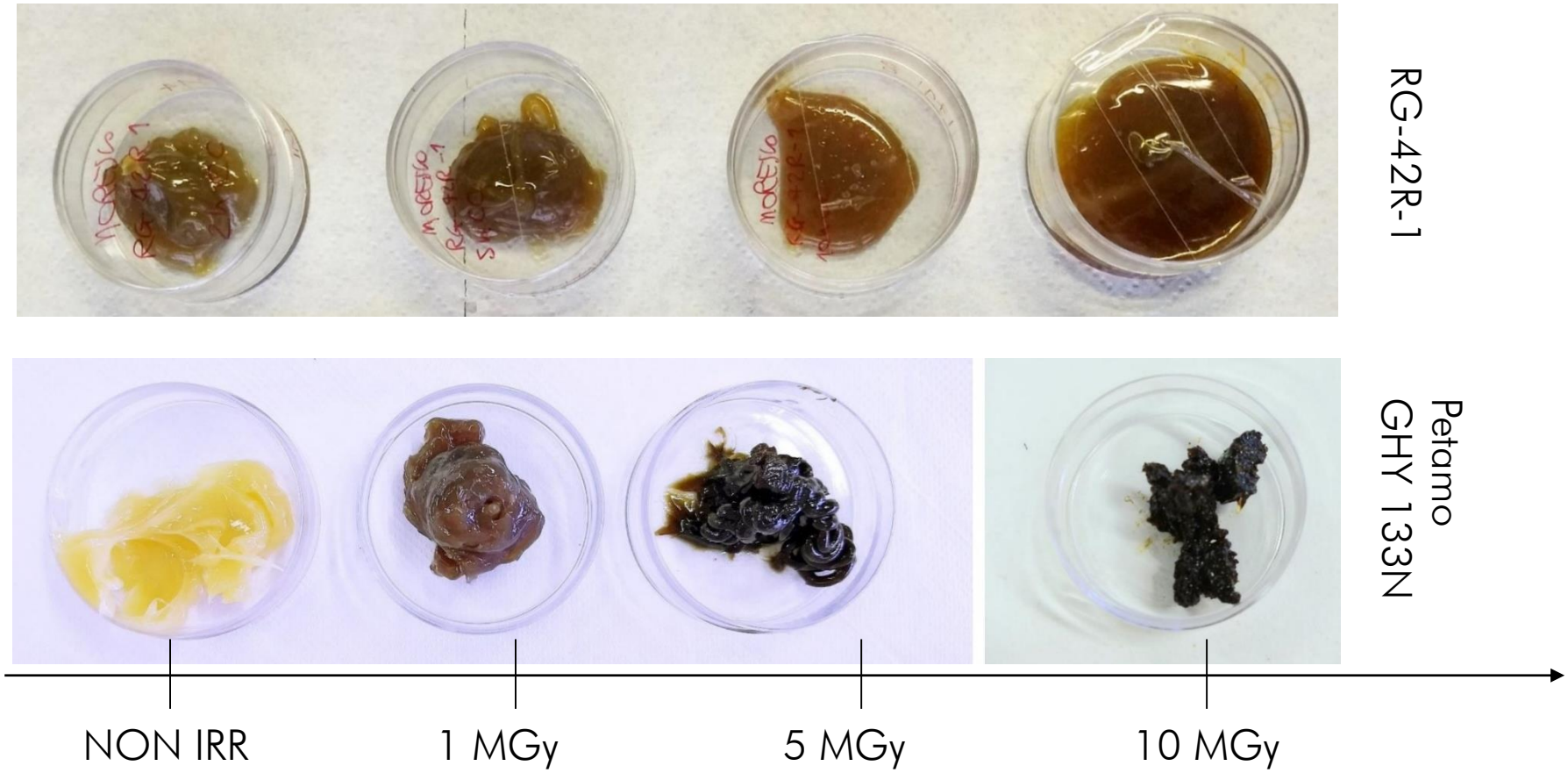
0.40 MGy

0 MGy



COLOR CHANGE BUT STABLE

DIFFERENT BEHAVIOURS AT HIGH DOSES

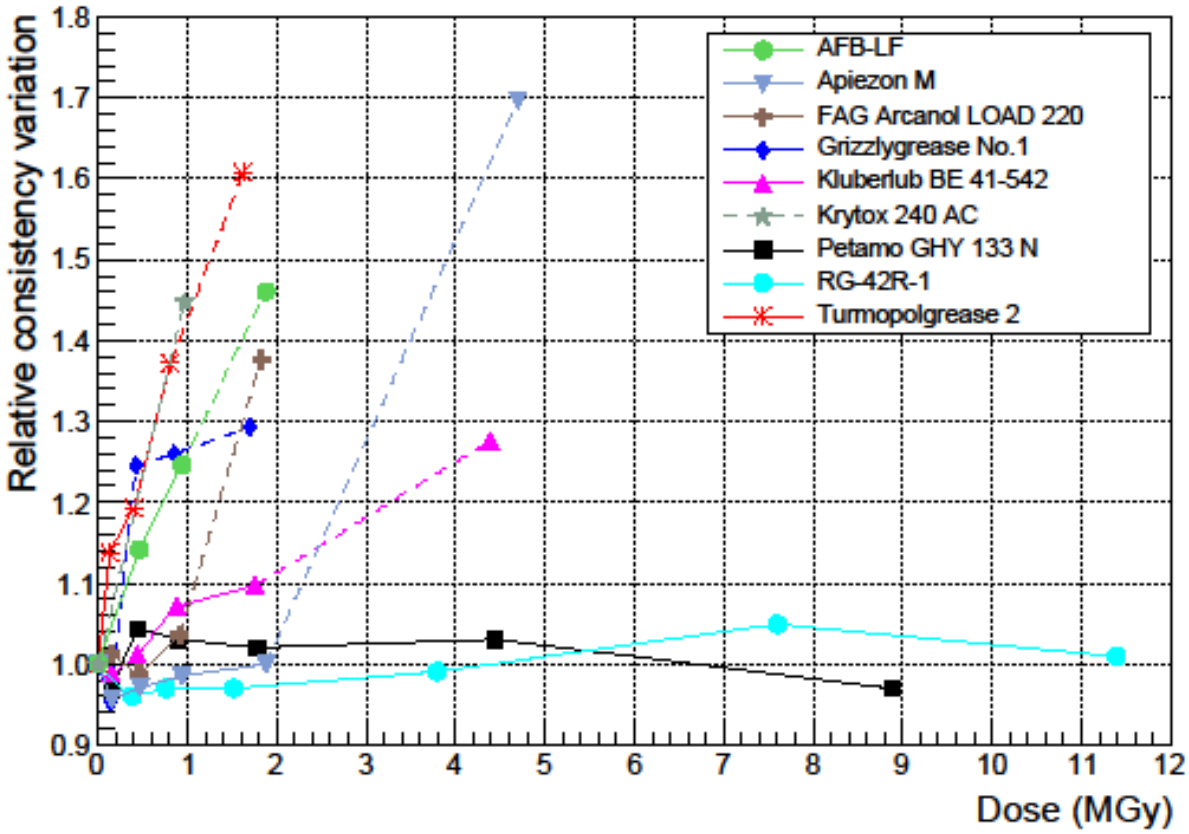


SOFTENING VS HARDENING

USABILITY ENDPOINTS FOR GREASES (1)

FLUID

Structural endpoint

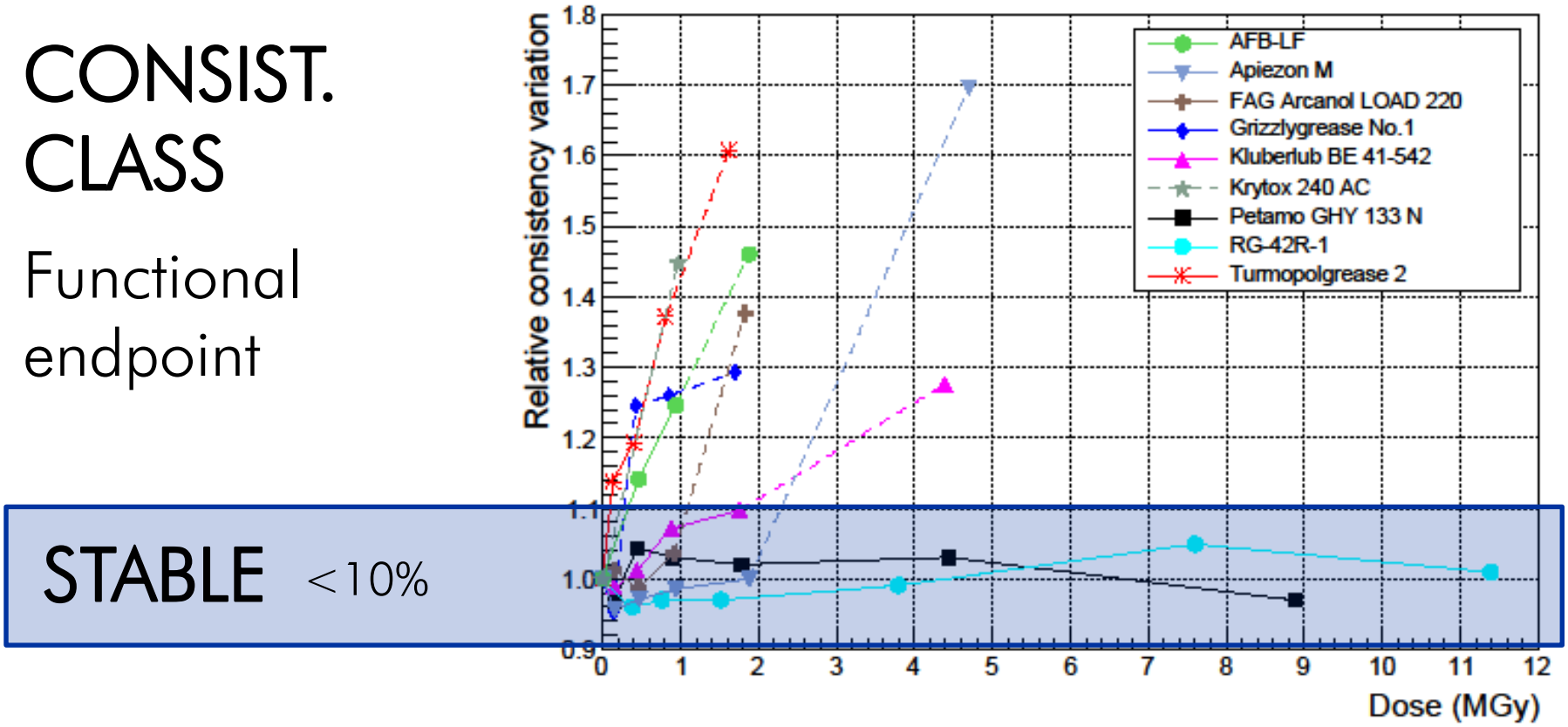


SEVERE MATERIAL MODIFICATION

USABILITY ENDPOINTS FOR GREASES (2)

CONSIST. CLASS

Functional endpoint



DOSE THRESHOLDS FOR USERS

RP-42R OIL: A CASE STUDY

A RESEARCH COLLABORATION

ESS project
Lund, Sweden

UniBs DIMI
Brescia, Italy

MORESCO
Kobe, Japan

OIL CHARACTERIZATION

PERFORMED TESTS:

- Kinetic viscosity
- Total acid number
- NMR spectra
- GPC gel permeation
- GC gas chromatography
- FT-IR spectroscopy

Kinetic viscosity

GC

Acid number

MORESCO Corporation

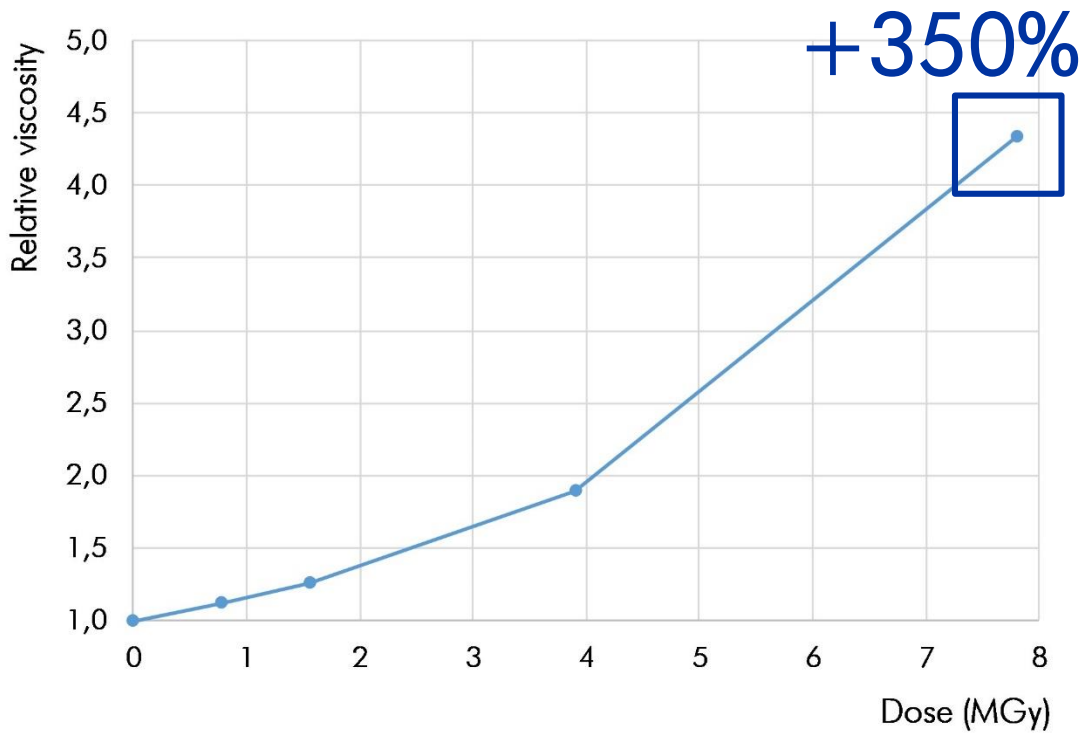
MORESCO RP-42R: VISCOSITY

NON IRR

0.78 MGy

1.55 MGy

7.78 MGy

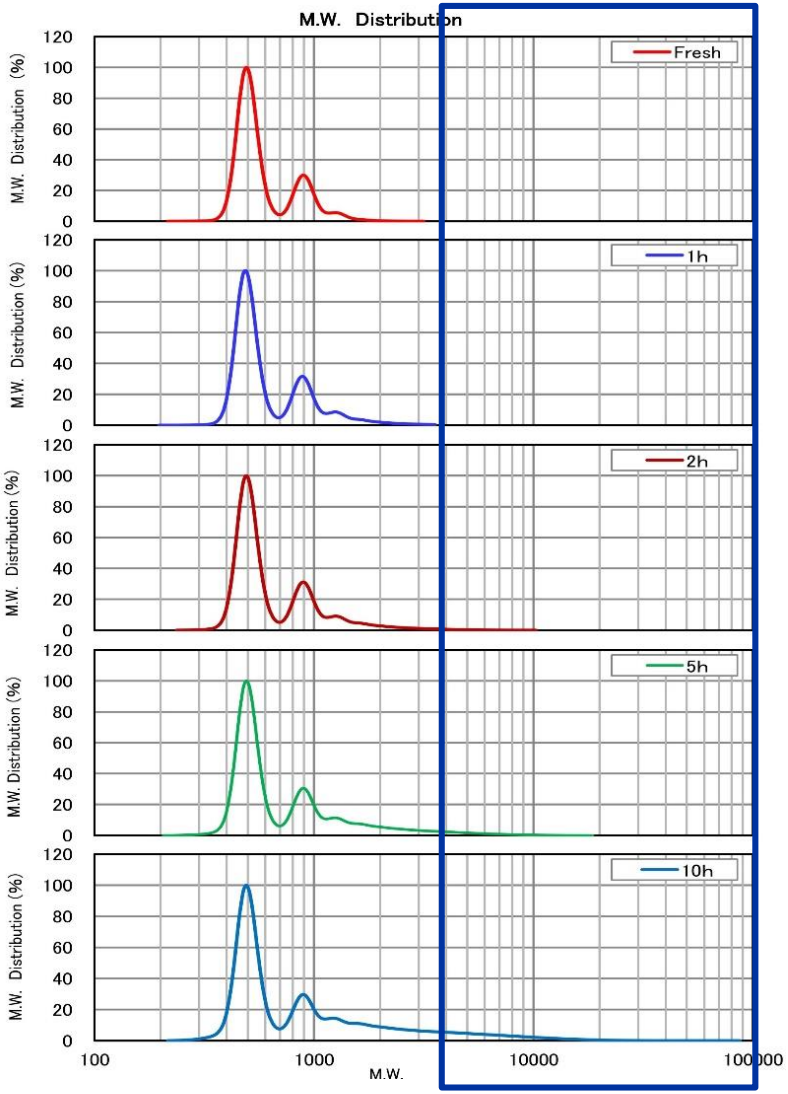


REMARKABLE MODIFICATIONS

RP-42R-1 grease: stable

GEL PERMEATION FRACTION ANALYSIS

DOSE



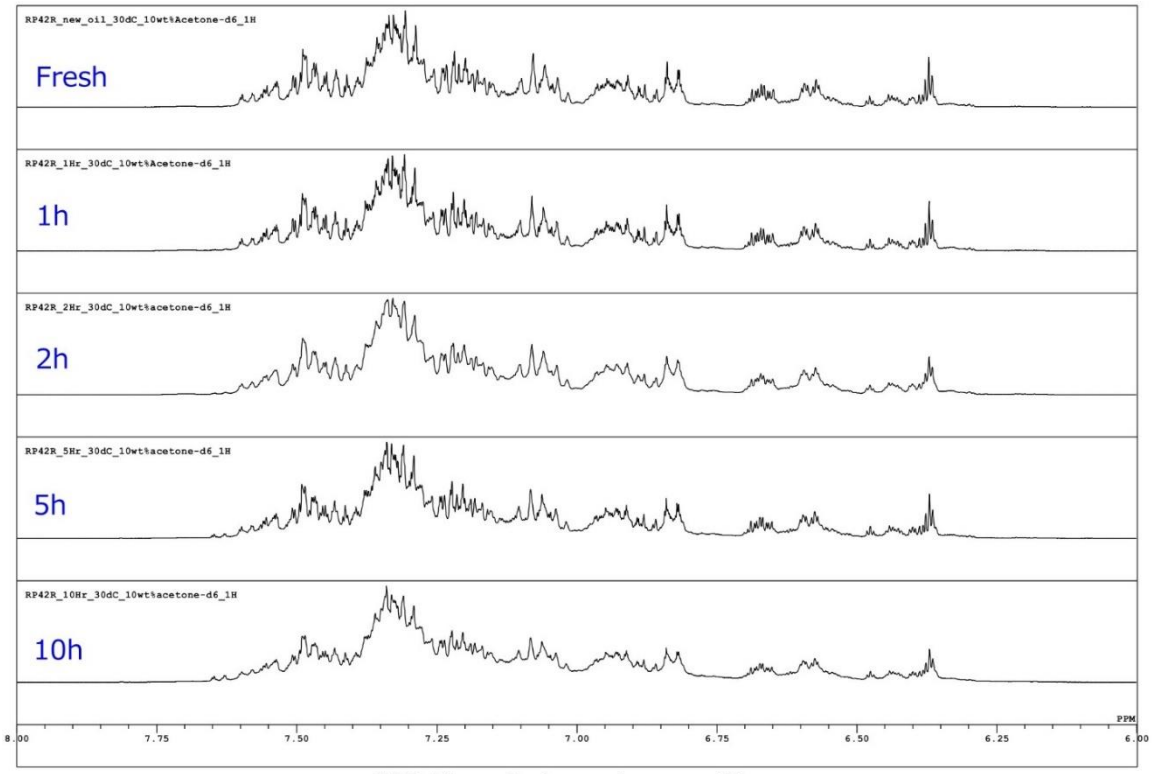
Molecular chains >2500

0% nonIRR
20% at 8 MGy

RAD-INDUCED POLYMERIZATION

NMR ANALYSIS

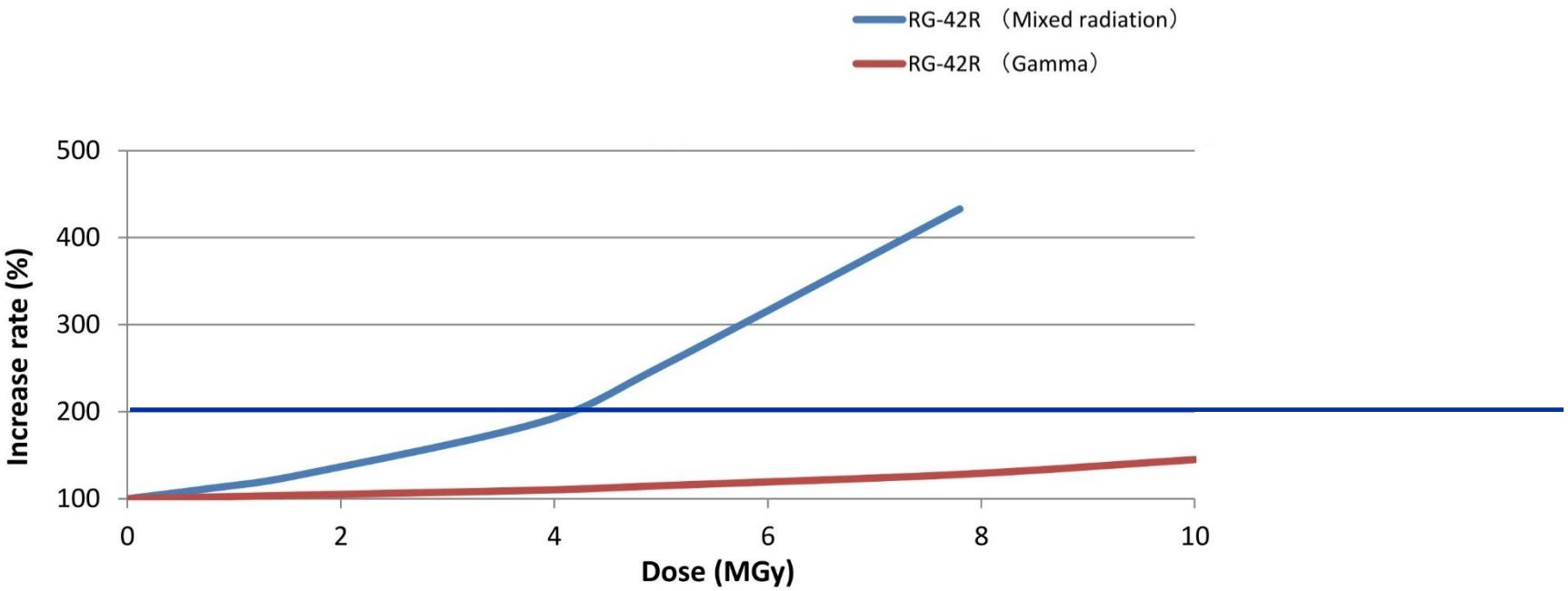
DOSE



CHEMICALLY STABLE

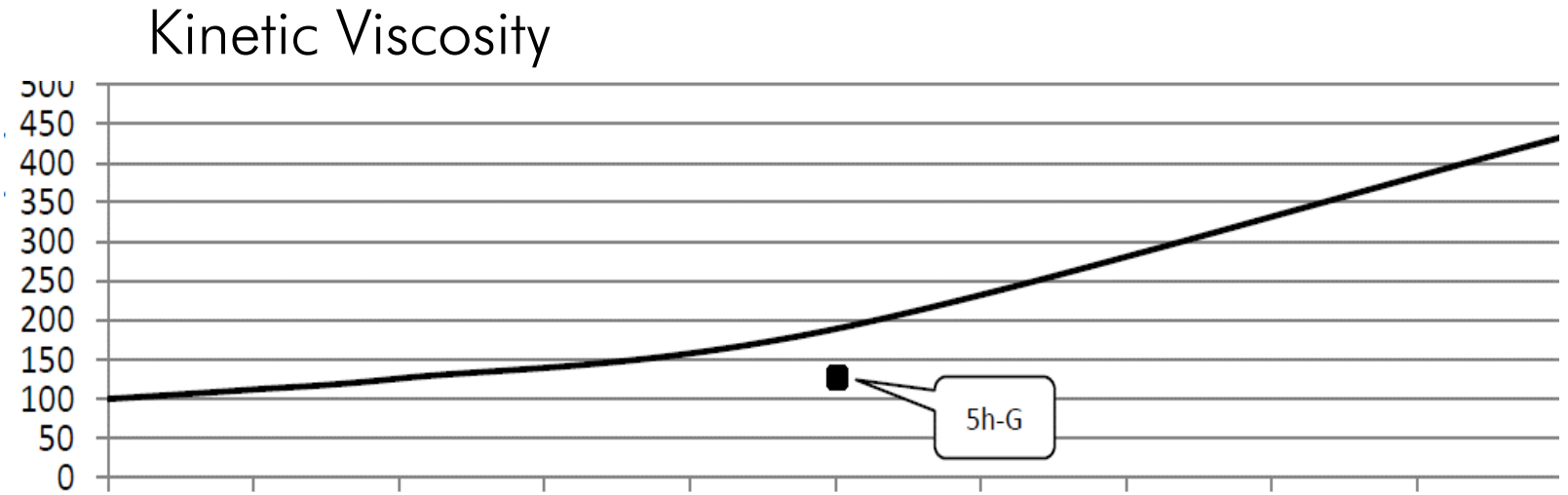
ONGOING STUDIES

GAMMA VS MIXED FIELD: VISCOSITY



DIFFERENT EFFECT AT EQUAL DOSE

OIL EXTRACTED FROM THE GREASE



BULK OIL vs OIL IN GREASE: DIFFERENT EFFECTS

CONCLUSIONS AND FURTHER DEVELOPMENTS

TAKE HOME MESSAGE

- Large sensitivity range: 0.1 MGy -10 MGy
- Irradiation and testing methodologies
- Dose thresholds are not universal
- Scarce knowledge of radiation damage mechanisms
- Ingredients and final product: different resistance
- Prediction of damage in real application: a challenge

EXPERIMENTAL TEST OF PRODUCTS: MANDATORY FOR FACILITIES

FURTHER RESEARCH TOPICS

- Different rad fields
- Dose rate effect
- Oxygen effect
- Grease/bulk oil/extracted oil
- Radiation mechanisms: thickener vs oil
- Thresholds determination
- Specific case studies
- New products

TO BE INVESTIGATED

THANK YOU FOR YOUR ATTENTION!

Special thanks to Hayashi San (MORESCO)

R2M
Radiation to Materials
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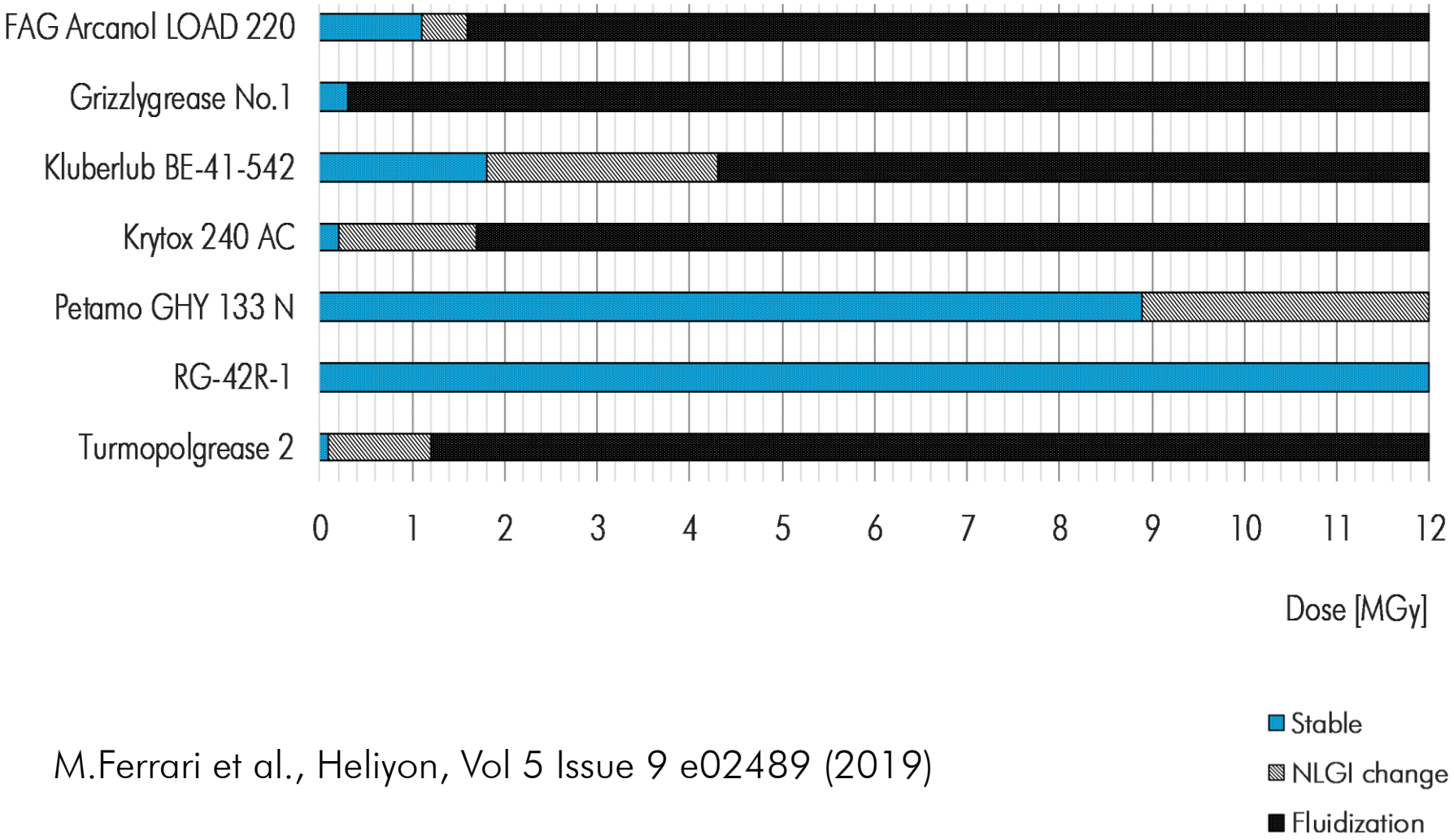
THRESHOLDS OF RADIATION DAMAGE: GREASES



M.Ferrari et al., Heliyon, Vol 5 Issue 9 e02489 (2019)