R2M – Radiation To Material
Material testing and external facilities

indico.cern.ch/event/760345/

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Why testing equipment and material ?

- Consequences of equipment radiation damage :
  - Machine unavailability
  - Unforeseen replacement costs

- Equipment qualification allows :
  - Selecting the most resistant equipment / materials
  - Meeting equipment lifetime constraints
  - Anticipate failures (prevention)
  - Avoiding ALARA issues (radiation protection)

Contents

- WP R2M scopes
  - Support in assessing radiation damage to CERN accelerators equipment
  - Coordination of CERN wide high doses irradiation tests in external facilities
  - Long-term know-how on material radiation damage effects

- Progress overview
- Outlook and prospects

Support in assessing radiation damage to CERN accelerators equipment

Which material(s)
- Which radiation is representative

(Gamma ? Particles ?)

- Materials = polymers, glass, etc
  - All equipment but electronics and beam intercepting devices (BID)
  - Materials damage due to
    - TID (Total Ionizing Dose)
    - DD (Displacement Damage)
    - Cumulative effects :
      - Long-term damage!
      - Accelerated ageing tests

- CERN environment = mixed particle field
  - Most of irradiation tests performed with gammas
    - TID damage depends on the dose (Gy), not the radiation type
    - Can reach high dose rate with large volume
    - Do not activate samples
  - Particles irradiation required in some cases, depending on material
    - Examples: crystals, ceramic, piezo (?)

Irradiation tests: Few examples

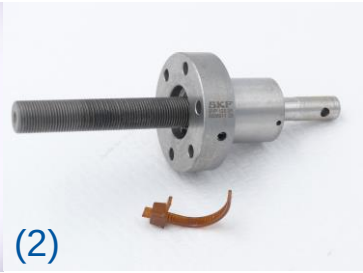

(1)


(2)


(3)

Test and drain valve (SPS fire safety upgrade): (1) not irradiated, (2) 500 kGy, and (3) 3 MGy Gamma irradiation in BGS facility conveyor, September / October 2018

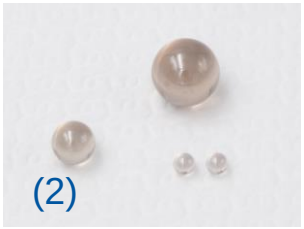

(1)

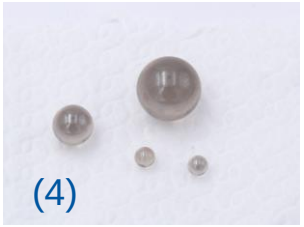

(2)

Lead screws for LHC collimators: (1) not irradiated, (2) 5 MGy Gamma irradiation in BGS facility conveyor, September / October 2018

Irradiation tests: Few examples

Vacuum bake out jacket:
(1) not irradiated, (2)10 MGy
Gamma irradiation in BGS facility conveyor,
May / June 2017

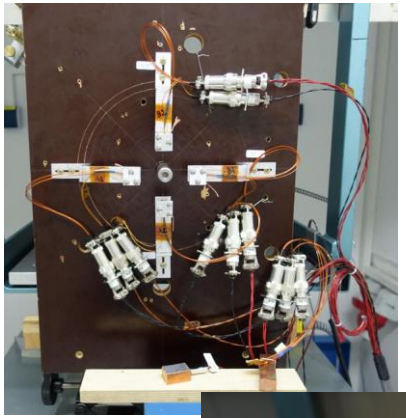


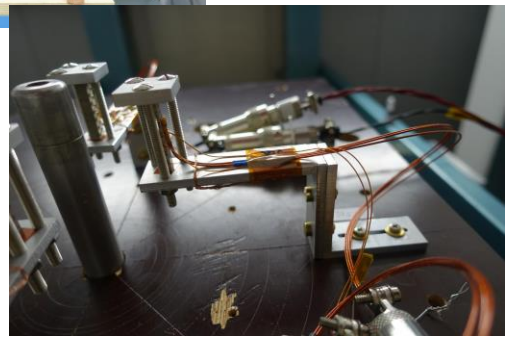


High index glass balls for high precision
alignment optical systems:
(1) not irradiated, (2) 300 kGy, (3) 1 MGy and (4) 5 MGy
Gamma irradiation in BGS facility conveyor,
September / October 2018

Irradiation tests: Few examples

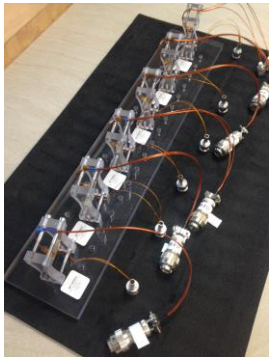
Test of piezoelectric actuators
For the UA9 Si crystal
collimation goniometer





Test in Fraunhofer
Gammas from ^{60}Co
Dose of 1MGy
Active Test
(Also 10MGy as passive)

Test in IRRAD
24 GeV protons from PS
Fluence of approx. 10^{16} p/cm^2,
Dose of approx. 2MGy
Active Test



Support in assessing radiation damage to CERN accelerators equipment

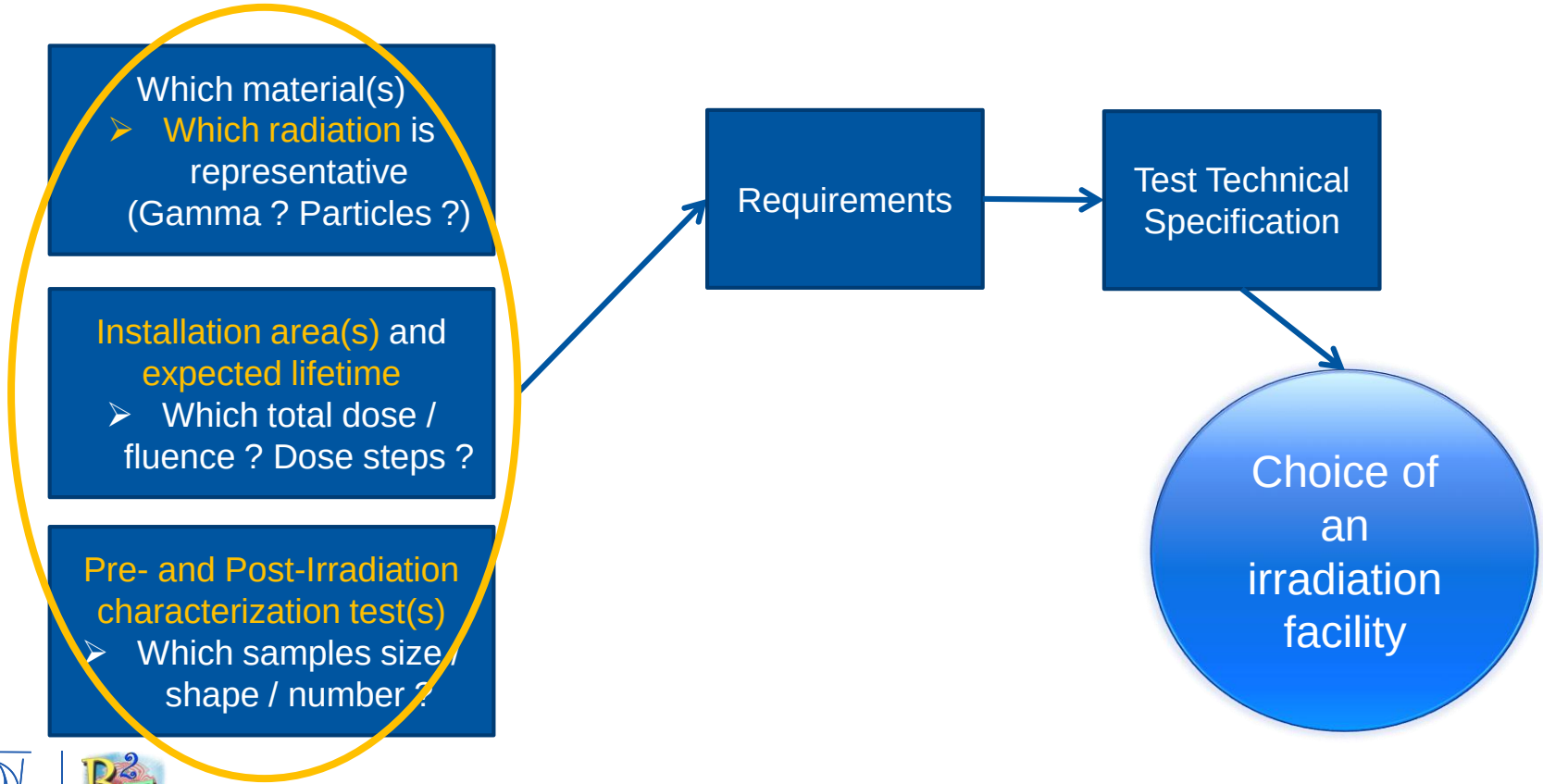
Which material(s)
- Which radiation is representative (Gamma ? Particles ?)

Installation area(s) and expected lifetime
- Which total dose / fluence ? Dose steps ?

Support in assessing radiation damage to CERN accelerators equipment

- Radiation levels
  - Radiation levels will increase to the point where material radiation physical “damage” will become (again) an issue
    - More and more location and equipment concerned
    - Increasing demand for high dose irradiation tests
  - In the LHC -> HL-LHC
  - In the injectors
- At which total dose to perform the irradiation tests ?
  - Depends on equipment location + wished equipment lifetime
  - Support from MCWG
  - Support from the FLUKA team
  - See previous talk, and Wednesday 09:00 – 12:00

Support in assessing radiation damage to CERN accelerators equipment



Some irradiation facility examples

Cumulative effect :
Need for high dose (or, high fluence)
Accelerated tests :
Need for high dose rate

CERN facilities do not reach all CERN requirements… (even for electronics..)
➢ Need for external facilities

Displacement Damage (DD)
→ Particle irradiation

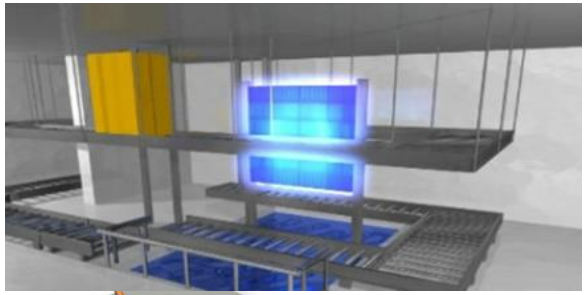
- CERN in-house
  - Protons : IRRAD
  - Mixed field : CHARM
  - Tunnels (TDC2), target areas (AD)
  - New irradiation platforms under study :
    nTof target, ISOLDE dump
- External facilities

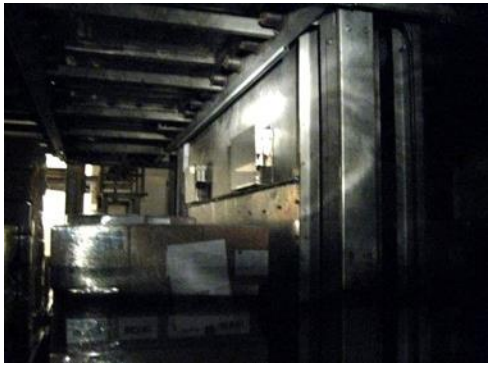
Total Ionizing Dose (TID)
→ Gamma irradiation - ^{60}Co

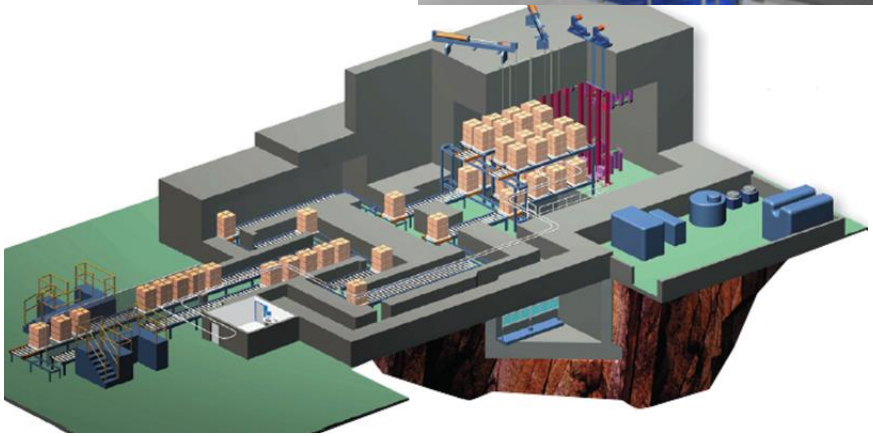
- CERN gamma source (CC60)
  - Activity is too low for assessing material resistance
  - 20 kGy in 45 days (x10 increase in the near future)
- External gamma facilities
  - BGS (Wiehl in Germany)
    - through Fraunhofer INT
    - Since 2012 with R2E/R2M activities
    - 10 MGy in 45 days for large volumes
    - 30 MGy in 45 days for small volumes
  - Ionisos (Dagneux near Lyon)
    - For a long time with EP dpt
    - Since 2015 with R2E/R2M activities
    - 500 kGy in 45 days

High dose gamma irradiation facilities

- External commercial facilities for large scale irradiation
  - Aimed at sterilization, decontamination, cross linking
  - Allows for large volumes (pallet)
  - Normal facility operation = large volumes and moderate doses
    ≠ from CERN high dose irradiation
    - ➢ Planning to be done well in advance

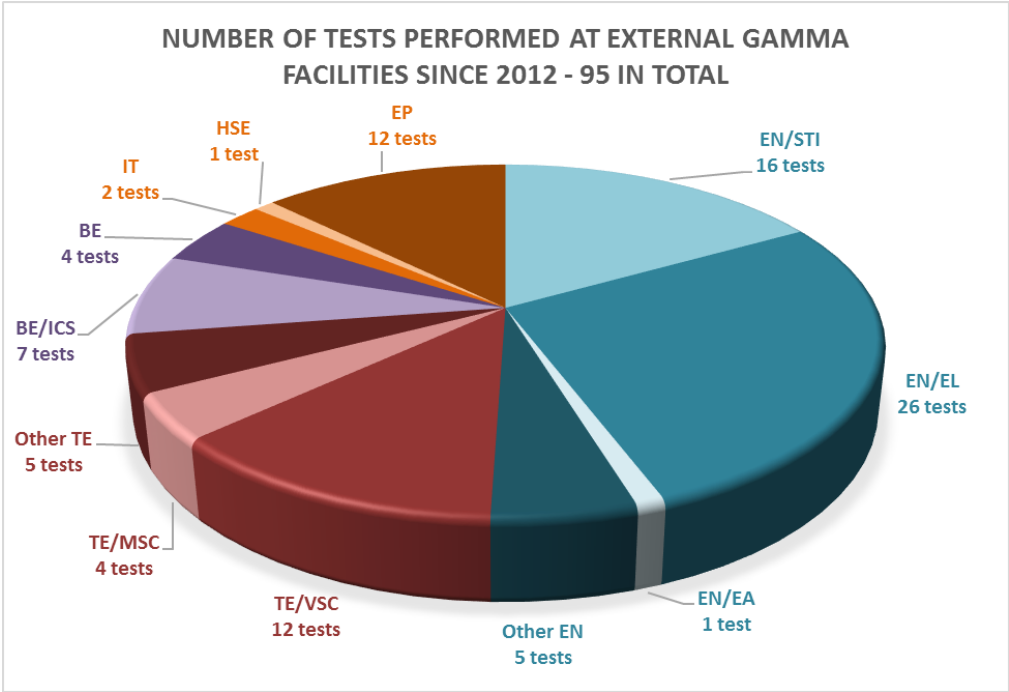






Coordination of CERN wide irradiation tests in external facilities

- Irradiation tests volume
  - Depends on upgrades, scheduled maintenance, long shutdowns
  - R2M to anticipate requests and preparing facilities access in case of needs
- Number of irradiation tests performed with commercial gamma facilities since 2012 = 95 tests
  - From 100 kGy up to 100 MGy



Coordination of CERN wide irradiation tests in external facilities

- R2M "team" aims at
  - Managing relationship with external facilities
    - Technical aspects
    - Administrative aspects
  - Follow-up of irradiation tests and corresponding documentation
  - Coordination of CERN material irradiation tests
    - Combination of irradiation campaigns
      - CERN wide coordination of irradiation campaigns
      - Shared irradiation time : Optimization of time and cost

Coordination of CERN wide irradiation tests in external facilities

- Commercial gamma facility
- Pallet irradiation
- Mean dose rate
  - 10 kGy/h

Combined [NEO-17-064]
5 MGy 8 steps
90 days
Irradiation time = **27kCHF**
Samples handling and associated costs = **45kCHF**

5 MGy						
HL tracker glues	**PICCA (cables)**	**New bake out jackets**	**Glued kapton n°2**	**Vacuum Pumps**	**Silicon Clamps**	**O'ring assemblies**
15 MGy 5 steps	5 MGy 6 steps	15 MGy 5 steps	15 MGy 7 steps	15 MGy 3 steps	1 MGy 2 steps	15 MGy 6 steps

Coordination of CERN wide irradiation tests in external facilities

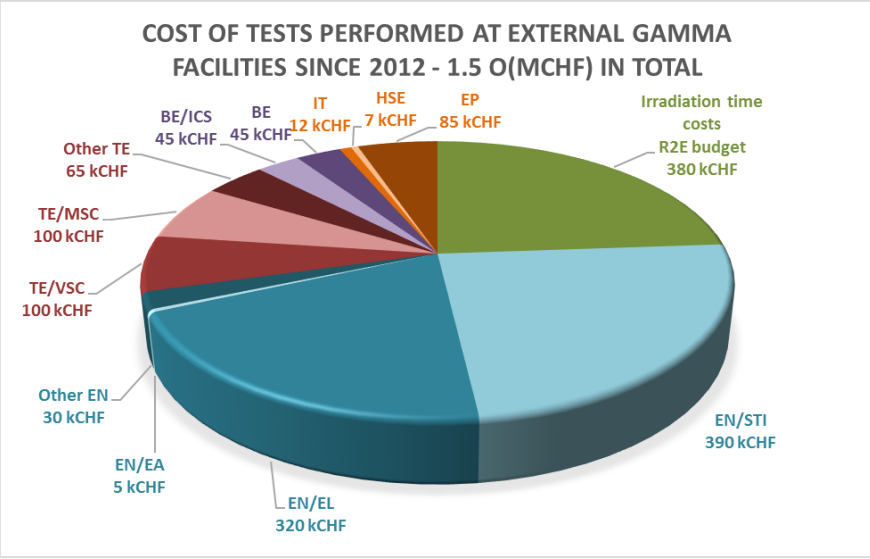
Combined [NEO-18-115]
5 MGy 8 steps
60 days
Foreseen **27kCHF**
Foreseen **3 x 6 kCHF**
3 new projects so far

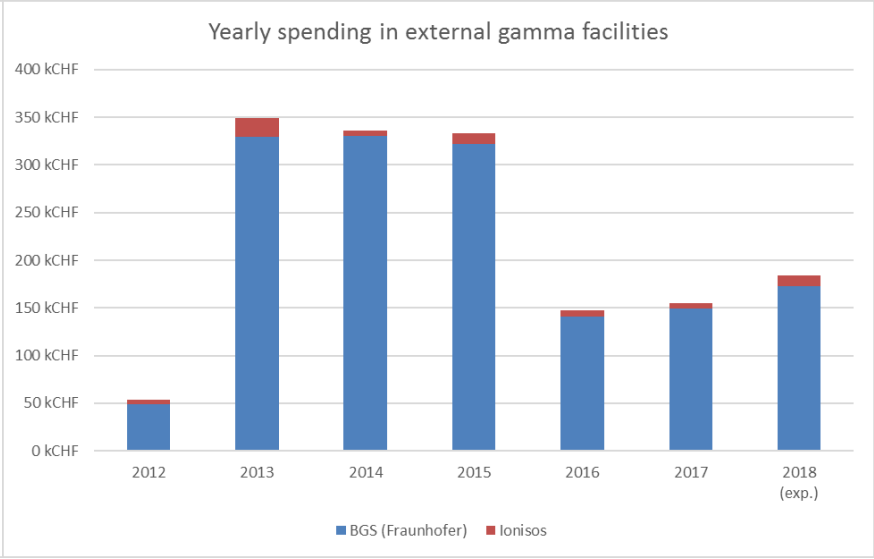
HL tracker glues	Optic fibre cables and microducts	New bake out jackets	Glued kapton n°2	Vacuum Pumps	O'ring assemblies	Small O'ring assemblies	HL-LHC alignement system	Glued HL lap joints	HL tracker material	Roller screws	S a
15 MGy 5 steps	10 MGy 5 steps	15 MGy 5 steps	15 MGy 7 steps	15 MGy 3 steps	15 MGy 6 steps	10 MGy 6 steps	10 MGy 6 steps	15 MGy 5 steps	10 MGy 6 steps	10 MGy 2 steps	

TOTAL With combination
200 days **200 kCHF**
TOTAL Without combination
+ 1000 days **645 kCHF**

Coordination of CERN wide irradiation tests in external facilities

- Shared irradiation time costs: R2E Budget Code
- "Samples handling" costs: Equipment group Budget Code
  - Samples procurement, characterization tests and related analysis also from Equipment groups





Coordination of CERN wide irradiation tests in external facilities

European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

EDMS No. 1959184
The R2E Project

Group Code: EN-STI
MS-4440/EN/R2E

Market Survey

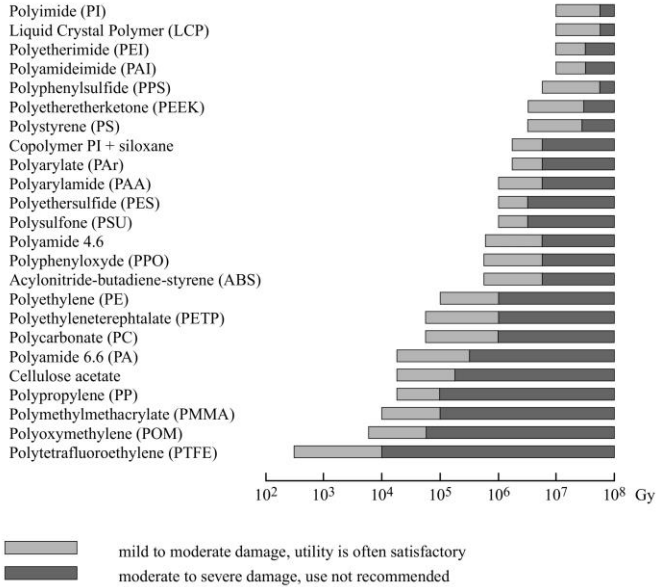
Technical Description
Irradiation Tests

Market survey launched mid-2018
MS-4440/EN/R2E

- 25 firms contacted
  - 16 gave no feedback
  - 5 declined
- 10 firms / group of firms replied
  - Qualification on-going
- IT foreseen for 1st quarter of 2019
  - 1 MCHF over 5 years
  - 200 kCHF/year
- TS describes norms to comply with, required documentation, etc

Long-term know-how on material radiation damage effects

- CERN History with materials under radiation :
  - Late 70's → Early 2000's :
    - Yellow books: Compilation of radiation damage test data
      → The bible(s) !
    - *Post irradiation characterization : mechanical tests*
  - In 1995
    - IS41 *"The use of plastic and other non-metallic materials at CERN with respect to fire safety and radiation resistance"*
  - In 2014 :
    - *"Demand for radiation test campaigns (TID, DD) is steadily increasing"*
    - *"Time and man-power constraints are a frequent issue for equipment groups"*
    - *"R2M" as an R2E spin-off*



Yellow book report CERN-98-01
Compilation of radiation damage test data
http://cds.cern.ch/record/357576

Long-term know-how on material radiation damage effects

- Documentation and Quality assurance
- ➢ Current situation
  - Technical Specification
    - Produced by the equipment group
    - Describing CERN requirements and shared with the irradiation facility staff
    - Template available in EDMS 1807333
  - Reporting
    - Irradiation report
    - Characterization report, including analysis and conclusions
    - If applicable, global report for multiple tests

- Archiving of relevant documentation
  - Share know how and results
  - Avoid redundant tests
  - Twiki – collaborative website
  - EDMS structure - centralized documentation to guarantee long-term documentation
- Radiation to material CERN guideline
  - Same purpose than EDMS 1740220 "Radiation Hardness Assurance Procedure"

Resources

- Resources
  - 2012-2015
    - Activity held by R2E project leader
  - 2016-2018
    - Activity held by TEMP (3 year)
  - 2019
    - TEMP extended for 6 months – until June 2019
    - Fellow expected as from July 2019

- In R2E C&S review (Indico 666689, 10.2017) "R2M Outlook and Strategy" talk by Marco Calviani :
  - Long-term management of R2M+R2BID know-how would require a dedicated staff
  - Similar level of resources should be made available in equipment groups requiring R2M-related test

Conclusion

Current situation for material irradiation tests

- Increasing demand for high dose irradiation tests
- Equipment group responsible for their equipment
  - Example of TE/VSC
- R2M for expertise and support
  - Support to equipment groups = efficient preparation of the tests
  - Optimization of time and cost when combining tests
  - Centralization of archives
  - Contract set-up with external gamma facilities

- Importance of centralizing the know-how in order to avoid wasted resources and budget
  - Know-how can be lost due to non-continuous support and no long-term strategy

➢ Material irradiation testing is a key activity for CERN operation

➢ Expertise on material radiation damage is essential for CERN

➢ Resources are presently limited – long-term management to be clarified