HSE

Occupational Health & Safety
and Environmental Protection unit

# CARE

# Cable Ageing Research project

## HSE Seminar

19th May 2022

J. Gascon

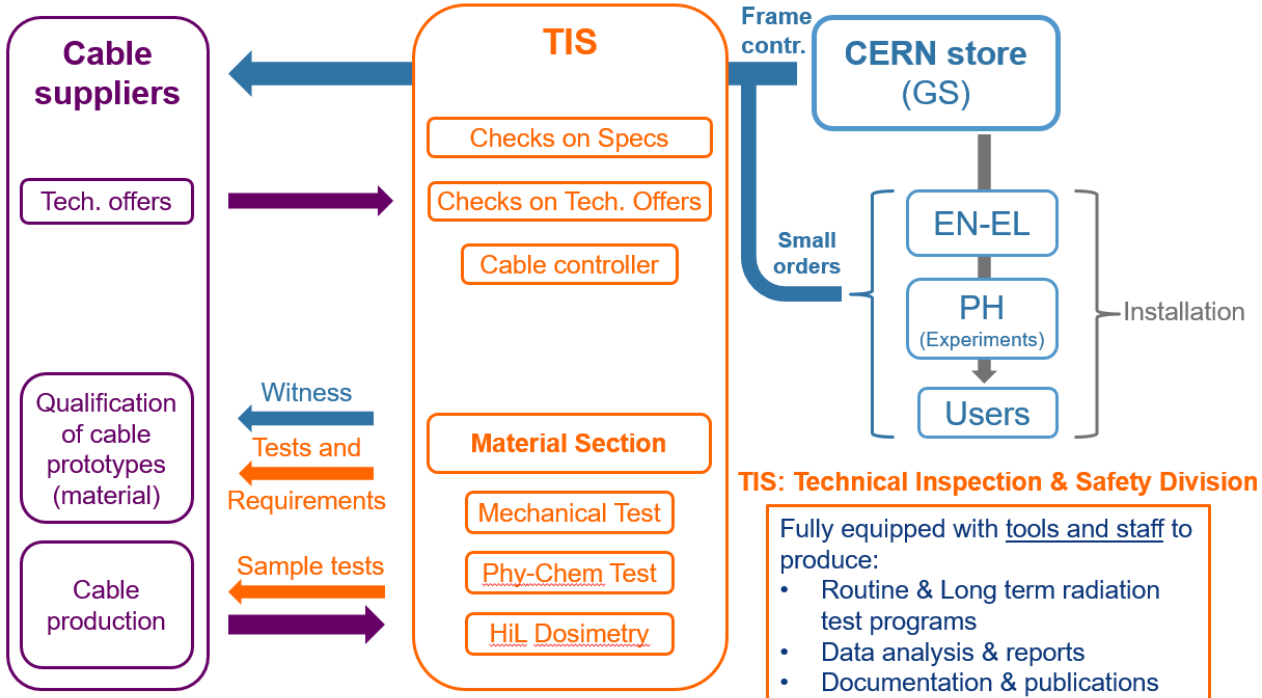
*on behalf of CARE project team*

# Introduction

# History

*Source: RIACWG*

## Historical perspective (until 1997)



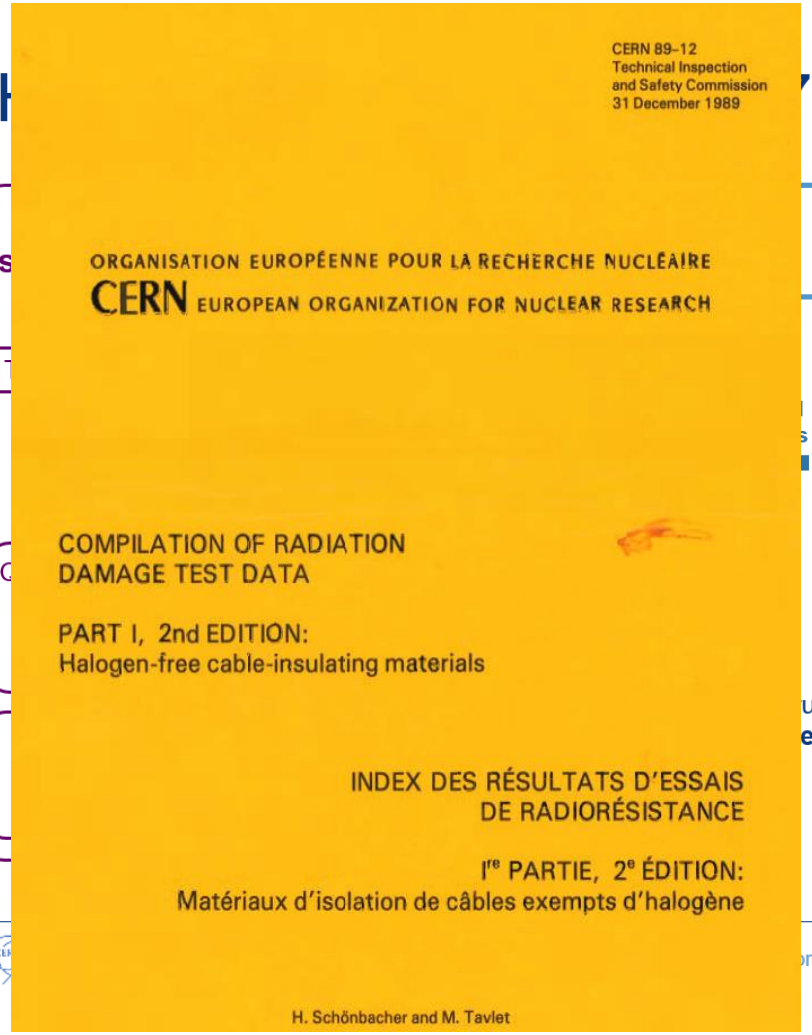

**TIS: Technical Inspection & Safety Division**

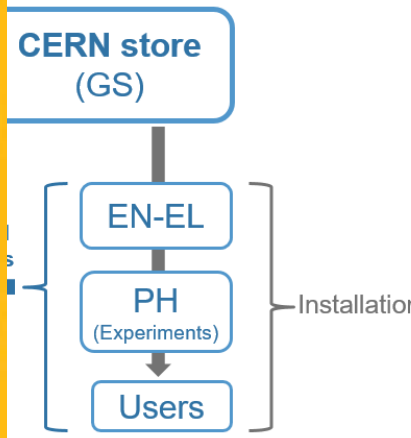
Fully equipped with tools and staff to produce:

- Routine & Long term radiation test programs
- Data analysis & reports
- Documentation & publications (eg. the "yellow" book)



## H -2002)



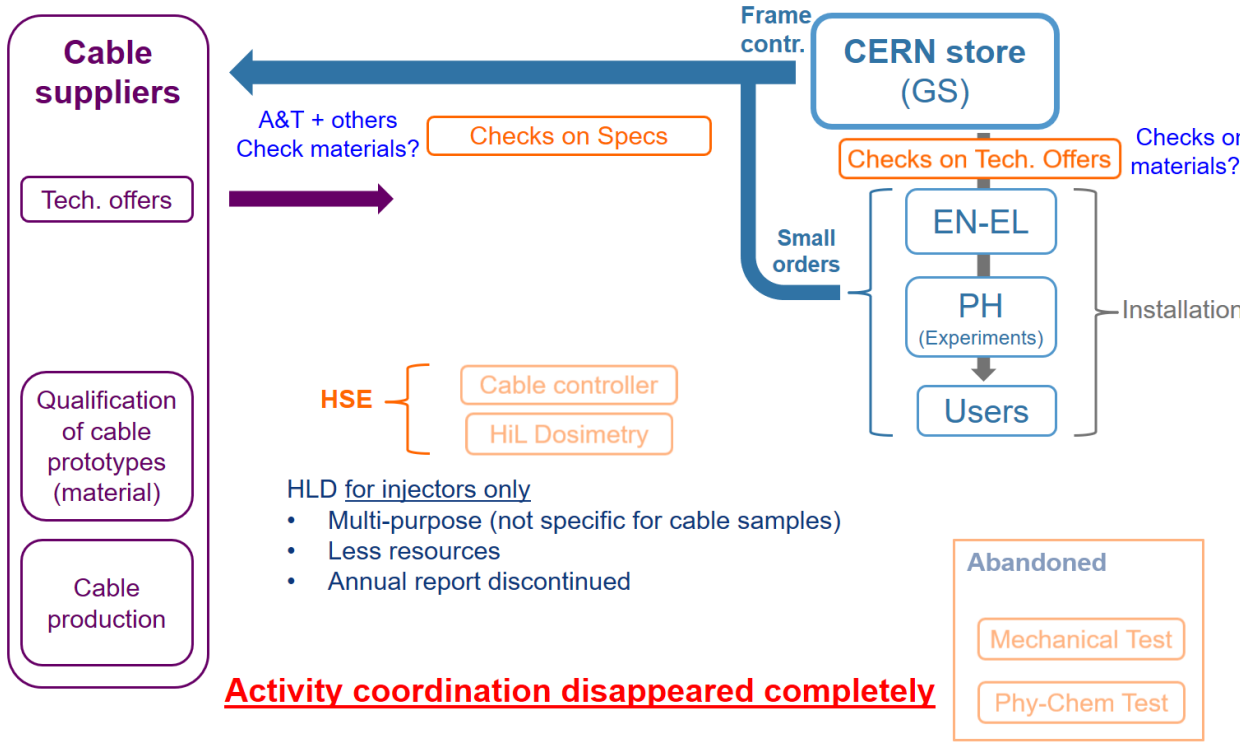




ucturing of material section
essive reduction of resources

# History

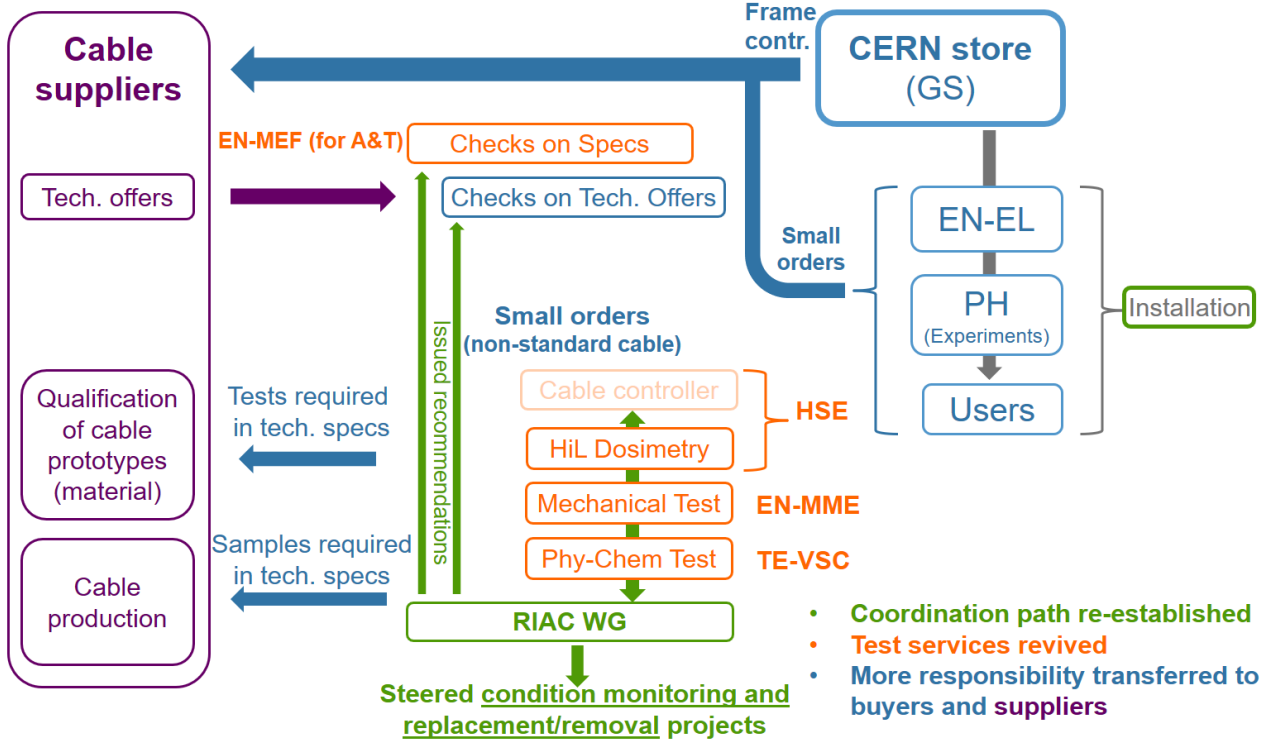
*Source: RIACWG*

## Historical perspective (after 2002)






## Historical perspective (Today: 2015)



# History

## CARE Working Group 2016-2019

- Mandated by S. Baird
- **Leader:** F. Szoncso
- **Members:** T. Wijnands, I. Petrova, D. Ternova, R. Kerschner

## CARE Project 2019-

- Mandated by D. Forkel-Wirth – Endorsed by B. Delille
- **Leader:** J. Gascon
- **Team members:**

Artem DANYLIUK

Chemical Eng.
*Senior fellow*

Berta RUIZ PALENZUELA

Materials Eng.
*PJAS*

Federica BORTOLETTO

Materials Eng.
*Junior fellow*

Dr. Marija KRANJCEVIC

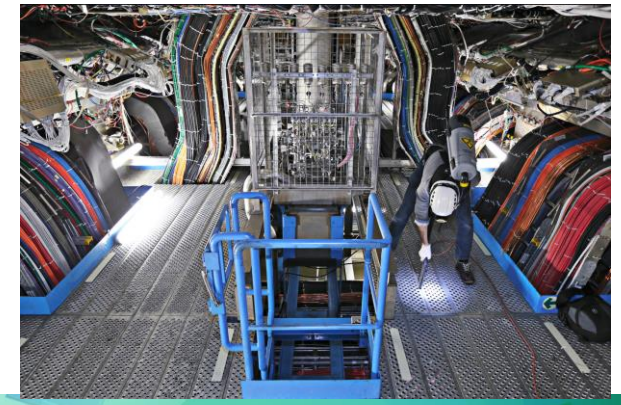
PhD in CS
*Senior fellow*

# Basics

# Cable design

## Cable applications at CERN

- HV power
- LV power
- DC power *(Power converters & magnets)*
- Instrumentation & Control
- Speciality *(RF, experimental areas, others)*
- Safety *(lighting, monitoring, safety systems)*
- *IT & office (IEC/EU compliant)*
- *Grounding*



# Cable design

## Cable Stressors

- **Temperature**
- Humidity
- **Chemicals** (oxygen, ozone, lubricants,…)
- **Ionising radiation** *(UV included)*
- **Electrical** *(ohmic heating)*
- **Mechanical** *(bending, squeezing, vibration)*

## Cable degradation is a combination of stressors effects !!!!

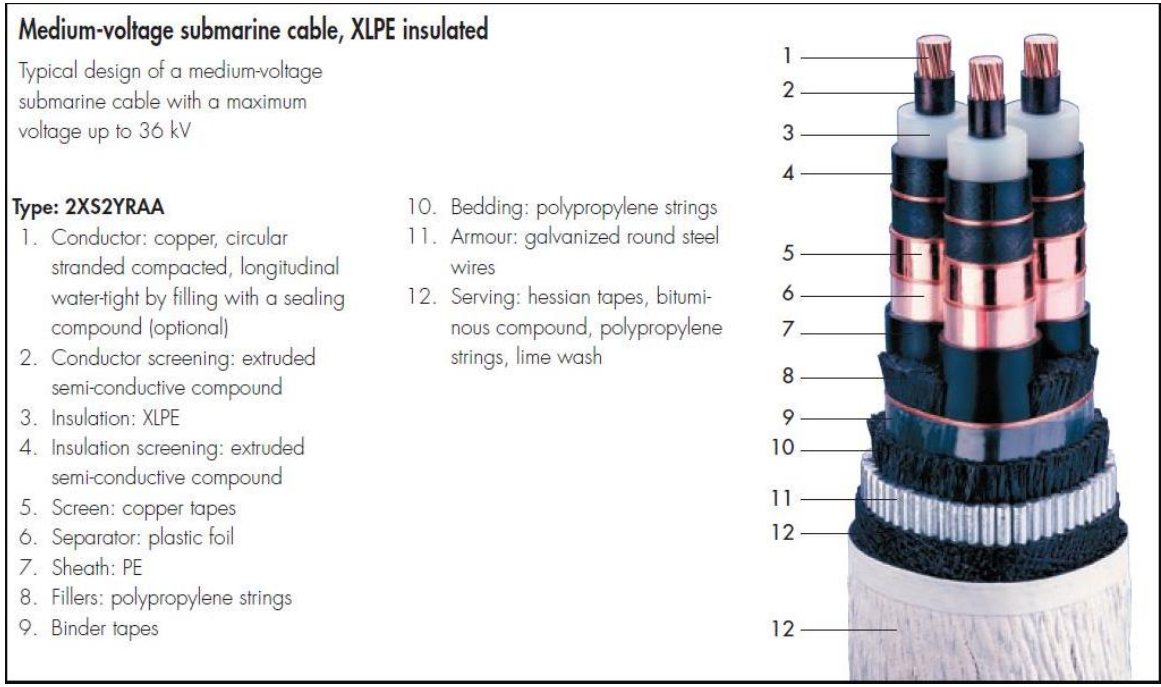
# Cable design

## Cable main components

- Conductors (electrical): *copper, aluminium*
- Insulation (electrical): *polymers (XLPE, XLPO, EPR,…)*
- Shielding (electrical): *foil (Al) or braided (Cu, Al)*
- Jacket (mechanical, chemical, fire): *polymers (PP, PUR, PE,...)*

## Structural components

- Fillers, binder or bedding: *mechanical stability*
- Tapes or semiconductors: *electrical, mechanical, fire or identification*
- Armouring: *mechanical protection*



# Cable design

**Polymer types used in cable manufacturing** *(halogen free)*

- Ethylene vinyl acetate (EVA)
- Cross-linked polyethylene/polyolefin (XLPE / XLPO)
- Low and High density polyethylene (LDPE / HDPE)
- Ethylene propylene based elastomers (EPR / EPDM)
- Polypropylene (PP)
- Polyphenylene oxide (PPO)
- Polyphenylene ether (PPE)
- Butyl rubber (BR)
- Polyimide (Kapton®)
- Silicone rubber (SiR)
- Polyether ether ketone (PEEK)
- Polyurethane rubber (PUR)

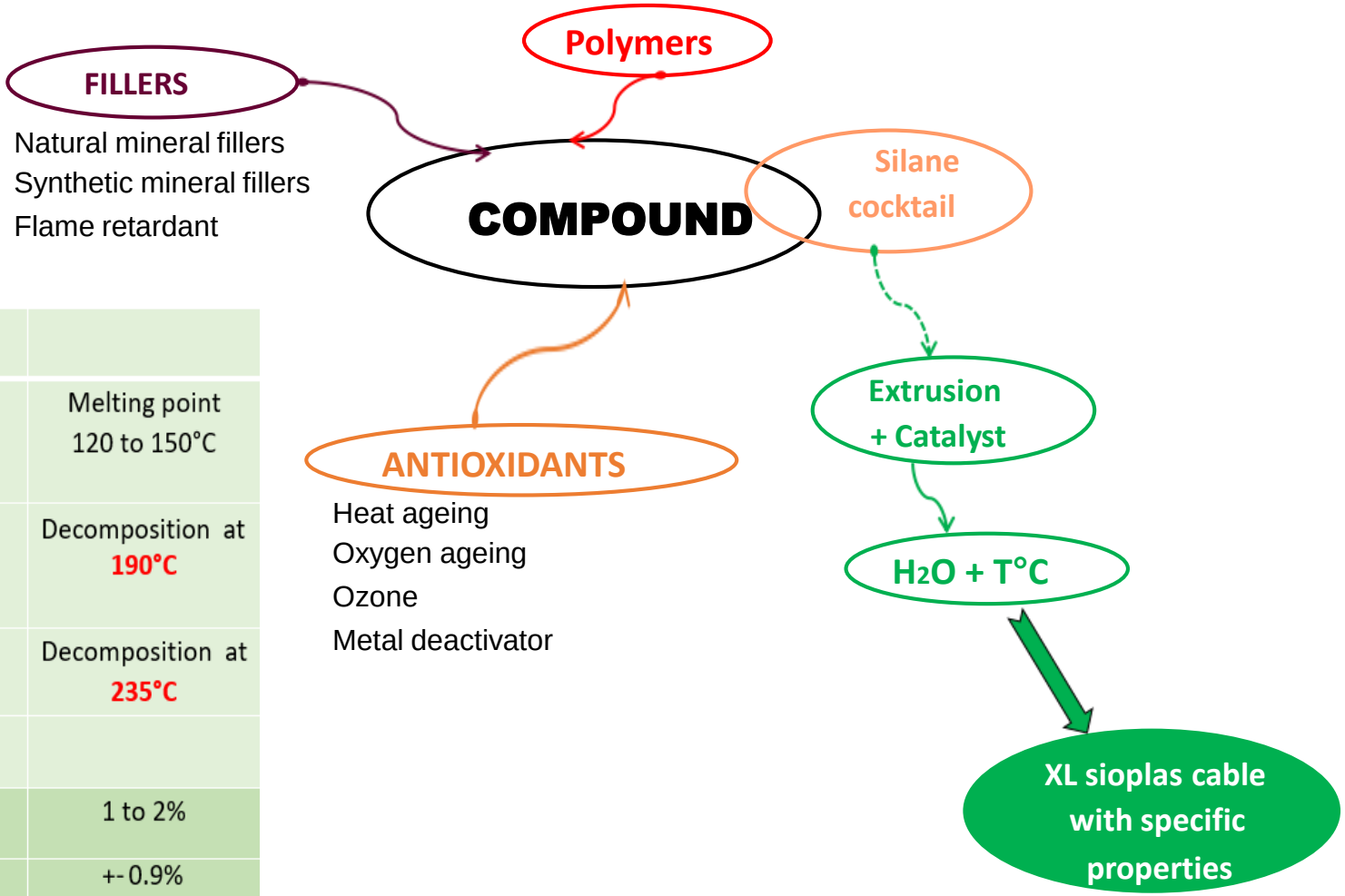
**Additives *(antioxidants, flame retardants, stabilizers)*: know-how of cable manufacturers !!!**

# Cable manufacturing

## Typical cable formulation recipe

| | Insulation | | Sheath | |
|---|---|---|---|---|
| Polymers | PE type | Melting point 140 to 170°C | EVA type | Melting point 120 to 150°C |
| Fillers | ATH | Decomposition at 190°C | ATH | Decomposition at 190°C |
| Fillers | MDH | Decomposition at 235°C | MDH | Decomposition at 235°C |
| Additifs | Ao + ACu | | Ao (Acu) | |
| Catalyst | S2000 | 1 to 2 % | S2000 | 1 to 2% |
| Self XI Masterbatch | No | | MBatch Viba | +-0.9% |
| Color masterbatch | Base PE | | Base EVA or PE | |

*ATH: Alumina Trihydrate*
*MDH: Magnesium Hydroxide*

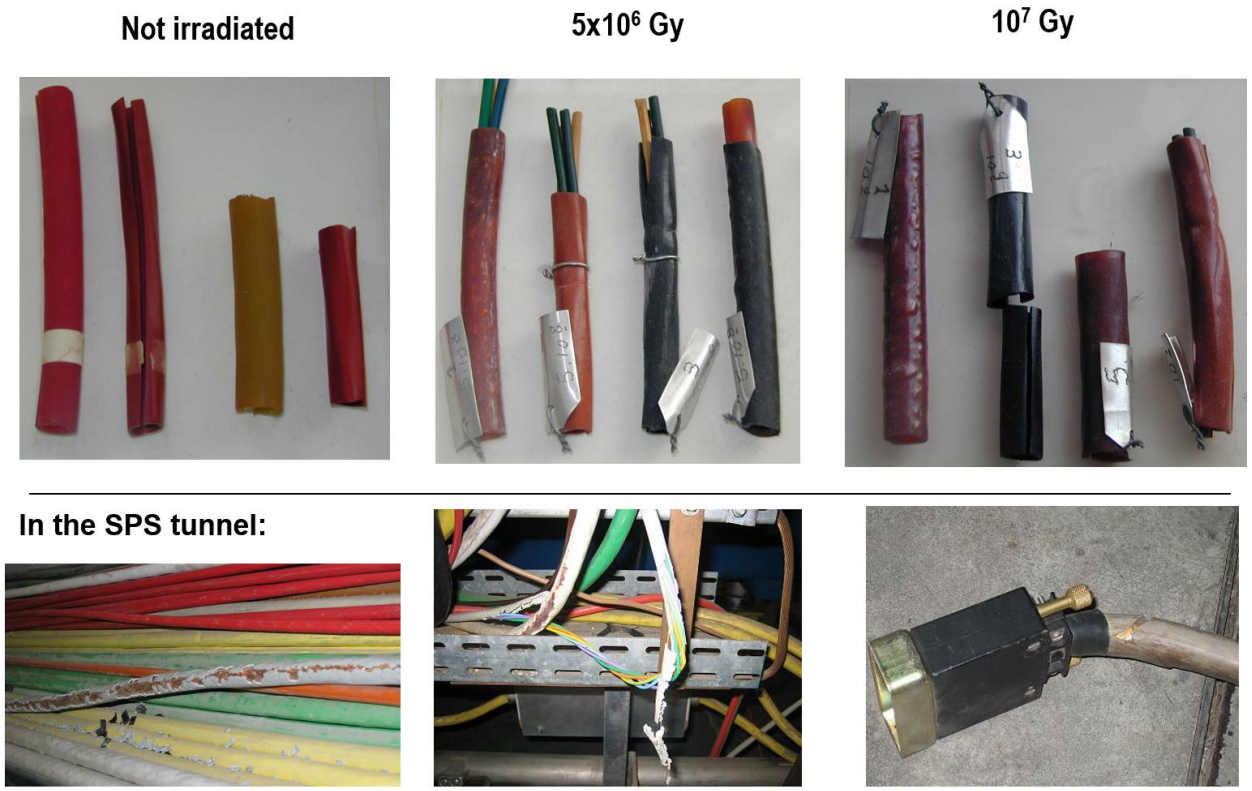



* Source: NEXANS Cables

# Radiation effects

## Ionizing radiation effects on Polymers

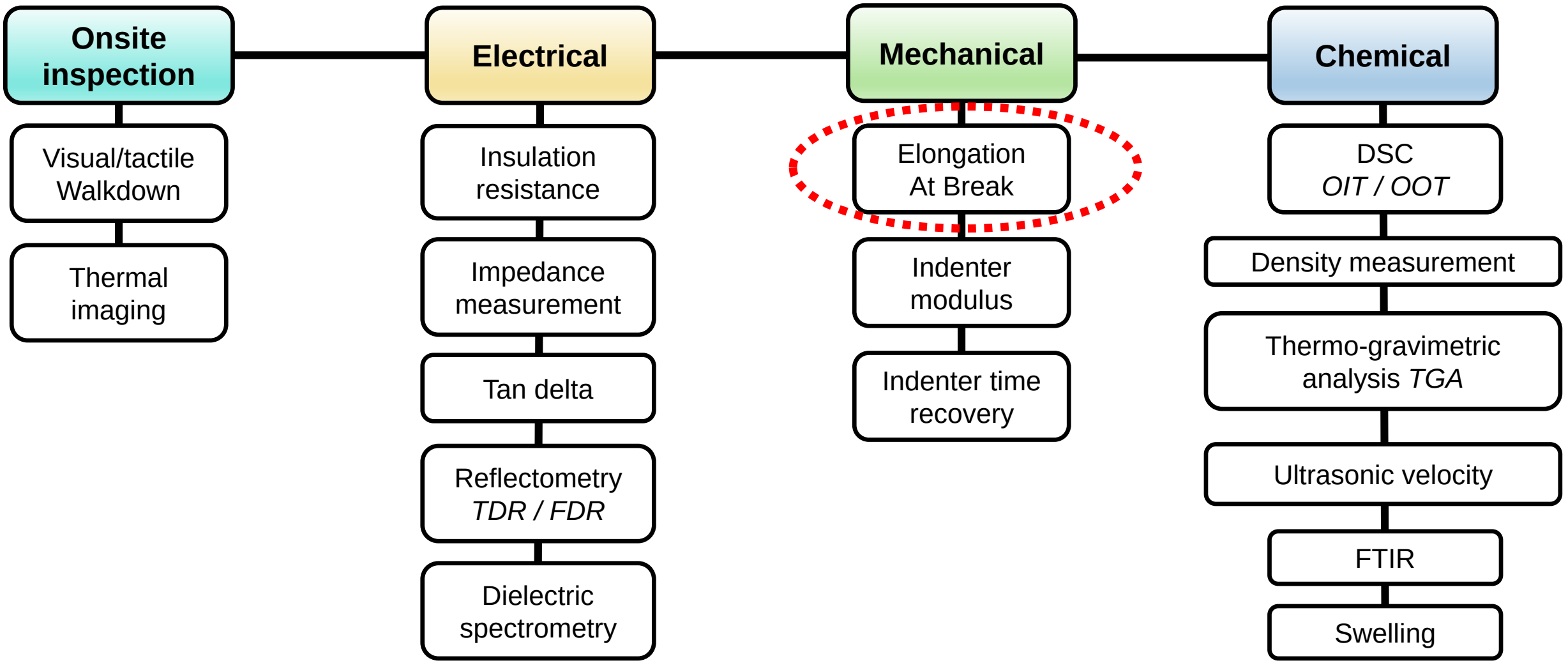
- Formation of free radicals: chemical structure, crystallinity, dose rate, solvent content, additives, plasticizer, stabilizers, temperature, oxygen levels, humidity.
- Formation of hydrogen & light hydrocarbon
- Formation of C-C bonds between molecules (crosslinking)
- Rupture of C-C bond (chain scission)
- Increase in unsaturation
- Breakdown of crystalline structure
- Discoloration
- Oxidation




## Synergistic effect

Collective stressors effects higher than stressors effects separately (e.g. temperature + radiation)

# Testing techniques on cable ageing



# CARE Project

# What is CARE

- Long-lead Research programme on cable ageing
- Oriented to Rad-Hard cables
- Focussing mainly on new cables procurement
- Predictive maintenance oriented to reduce cable replacements
- Enhancing decision making process in terms of expected cables lifetime

**Main Objective**: extend cable lifetime procuring the most appropriate cables for CERN operations

- Determining cable “weathering” conditions *(cable stressors)*
- Defining appropriate technical requirements and tests procedures
- Providing Quality control & acceptance criteria
- Assessing cable degradation during beam operation i.e. condition monitoring
- Tracking logbook during all cable lifecycle i.e. complete cable life data over years
- Establishing lifetime models for cable from cable life data analysis

# CARE Structure

- **WP1 Project Management**
  - **Project management documentation**
    - ✓ Minutes, presentations, collaboration
    - ✓ Management reports, deliverables
- **WP2 Cable procurement**
  - **Technical requirements for cable procurement**
    - ✓ Tests procedures
    - ✓ Qualification criteria
    - ✓ Acceptance criteria
- **WP3 Data management**
  - **Database documentation**
    - ✓ Cable samples and specimen codification
    - ✓ Managing Tests records, data sheets, TS, etc
    - ✓ Information storage & tracking in CERN tools
  - **Data analysis**
    - ✓ Correlations, statistics
    - ✓ lifetime models
- **WP4 Condition monitoring**
  - **Radiation calculations**
    - ✓ FLUKA simulations
    - ✓ Interactions R2E
  - **Artificial irradiation**
    - ✓ Technical specifications, R2M interactions
    - ✓ Preparation of samples
  - **Natural irradiation**
    - ✓ Management of samples in tunnels
    - ✓ Preparation of samples
- **WP5 Testing**
  - **Tests activities**
    - ✓ Sample conditioning
    - ✓ Testing: TT, DSC, FTIR, Thermal ageing, etc
    - ✓ Test records in database
  - **Tests techniques**
    - ✓ Exploring new techniques
    - ✓ Developing Procedures for procurement

# CARE Stakeholders

- **EN-MME:** expertise in mechanical tests;
- **TE-VSC:** expertise in chemical tests;
- **EN-EL:** cable procurer (machine);
- **BE-EA:** cable procurer (experiments);
- **TE-ABT:** special cable user;
- **SCE-SCC:** cable procurer (CERN stores);
- **SY-STI:** Radiation machine (R2E, R2M);
- **ATS-DO:** CERN Projects (HL-LHC);
- **HSE-RP:** radioactive waste management

- **Steering committee** EDMS 2594070
  - **B. Delille,** head of the HSE unit (chair);
  - **D. Ricci,** representing all cable users;
  - **S. Sgobba,** mechanical expert EN-MME;
  - **M. Taborelli,** chemical expert TE-VSC;
  - **C. Garino,** CERN stores SCE-SCC;
  - **J. Borburgh,** electrical testing expert SY-ABT;
  - **R. Garcia,** electrical testing expert SY-STI;
  - **J. Gascon,** CARE project leader;
  - **A. Danyliuk,** CARE member (sci. secretary);
  - **Y. Donjoux,** DPO HSE Unit

# CARE Activities

## Fields of work

- **Qualification process for cable procurement within HL-LHC project** (High priority)
  - ✓ Preparing detailed test procedures
  - ✓ Establishing qualification criteria and acceptance criteria for cables on ageing (radiation)
  - ✓ Preparation of MS for Rad-hard cable (new 3.5MGy cable category)
- **CERN Standardisation Technical Sub-Committee for cables & connectors**
  - ✓ Part of the subcommittee
  - ✓ Contribution on technical requirements for radiation hardness & quality assurance
- **Support on Cable Quality control**
  - ✓ Supporting SCE-SSC on quality control for cables delivered at CERN (on best effort approach)
  - ✓ Some cables delivered from India manufacturer within framework contract signed by CERN to be tested (1st CPR Class Cca)
  - ✓ Technical advice to SCE-SCC on tests to be outsourced (external labs)
- **Cable assessment**
  - ✓ Expertise on requests from CERN users tests on old cables installed in high radiation areas
  - ✓ Cable Assessment Request (CAR) is prepared including technical report and tests results performed.
  - ✓ Started in 2020, we have already dealt with 10 requests.

# CARE for HL-LHC Project

# CARE for HL-LHC Project

## ❑ HL-LHC project discussions

- **Benchmarking in similar labs** (EDMS 2520530)
  - ✓ ESS, ESRF, DESY (XFEL), ITER were contacted
  - ✓ Labs are not same radiation requirements (radiation levels, availability & accessibility)
  - ✓ Qualification cables samples seems to be appropriate for qualification purposes
  - ✓ Use of cables from Vendor's catalogue best option
- **New radiation resistant cable category**
  - ✓ SSI establishes 500kGy (100kGy operation) & 10MGy (2MGy operation) categories
  - ✓ After R2E simulations few cables will be irradiated beyond 700kGy
  - ✓ Create cable radiation category around 3.5MGy (700kGy operation) following benchmarking
- **Cable Procurement strategy**
  - ✓ Pre-survey among cable manufacturers on price factor for 3.5MGy & 10MGy cables
  - ✓ Endorsed by CERN management and project management
  - ✓ MS by June 2022 to qualify cable manufacturer according turnover, production capabilities, radiation resistant experience
  - ✓ Before tendering, manufacturers (reduced number) to provide cable samples for radiation qualification (November 2022)
  - ✓ 16 weeks for ageing (radiation) qualification by July 2022
  - ✓ Cables for general purposes (500kGy) not scoped to be qualified

**Cables in Radiation Environment**
Air (standard atmosphere)

Some typical numbers from suppliers:

| | |
|---|---|
| Lapp-Kabel (PU) | 0.5 MGy |
| Lapp-Kabel (EPR) | 1 MGy |
| Helukabel (PU, HM2, TM7) | 1 MGy |
| Huber+Suhner RADOX® (RX125-XLPolyolefin Copolymer) | 1 - 3 MGy |
| Marmon (XLPE + CSPE, certified to Class 1E, IEEE-323) | 2 MGy |
| Habiatron (XLPolyolefin, certified IEEE-323 + 383) | 2.3 MGy |
| Axon (Poliax®-PEI) | 3 MGy |
| Huber+Suhner RADOX® (TPU) | 5 MGy |
| Axon (Neutrax®-PEEK) | 5 MGy |
| Axon (Kapton®-Polyimide) | 10 - 20 MGy |

Source: ESS

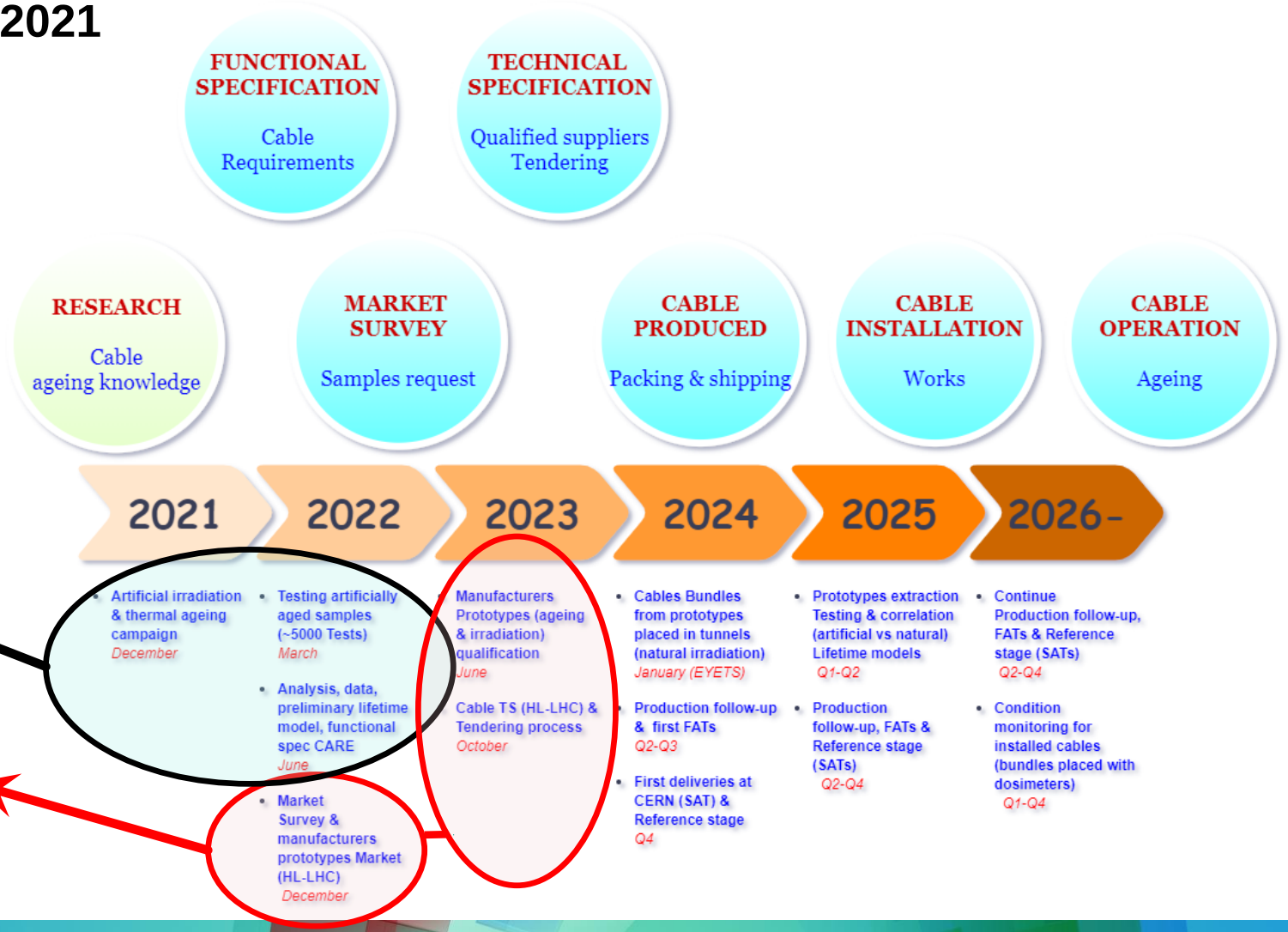
# CARE vs HL-LHC Project

- **CARE plan schedule in September 2021**

CARE Schedule delayed of 3 months by 2nd irradiation campaign

HL-LHC delayed on MS expected in June 2022

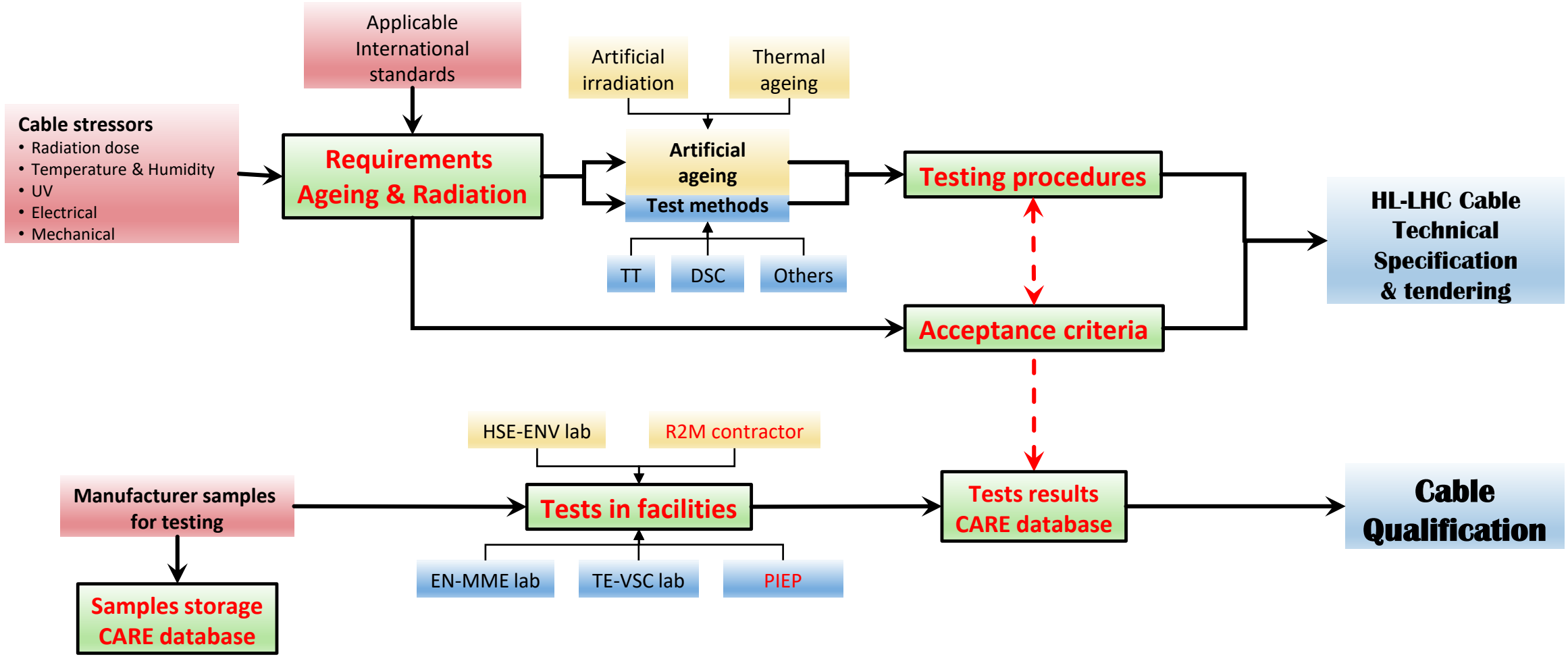
HL-LHC cables needs in LS3 (delayed)




- **Samples expected for qualification from manufacturers by November 2022**
- **CARE Qualification by June 2023 (IT)**

# CARE for HL-LHC Project

- **CARE Qualification process**



# CARE for HL-LHC Project

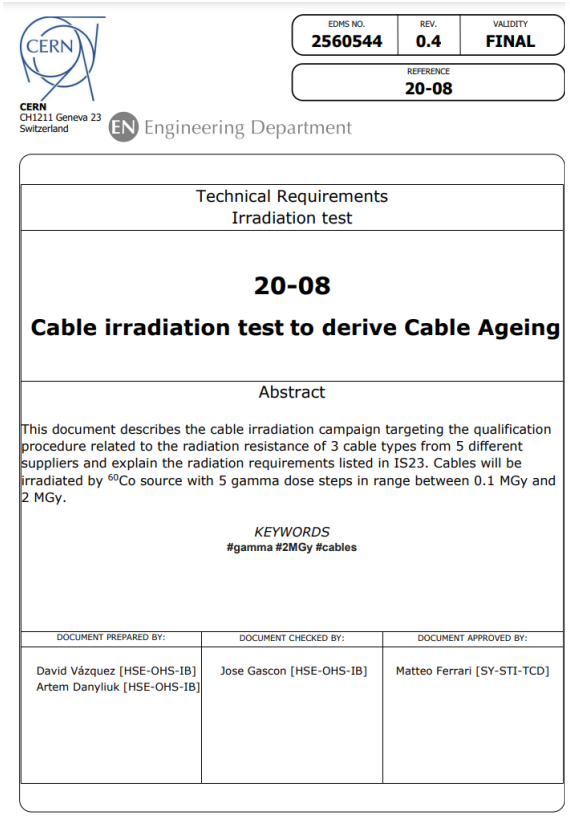
## ❑ Qualification readiness

- **Team experience on tests at CERN**
  - ✓ Performed around 3000 Tensile Tests (TT)
  - ✓ Performed around 200 Differential Scanning Calorimetry tests
  - ✓ Microscopy on defectives samples (MME lab)
  - ✓ Thermal ageing (BE-EA & HSE-ENV oven)
  - ✓ FTIR on old artificial irradiated cable and tunnels (TS1+ & TDC2)
- **Tests externally**
  - ✓ Thermal ageing & TT in PIEP (Portugal collaboration) to converge on tests procedure & results
  - ✓ Swelling tests in University of Brescia (EDMS no 2310744)
- **Test Facilities**
  - ✓ MME lab: TT,  Microscopy
  - ✓ VSC lab: DSC, TGA
  - ✓ ENV lab: FTIR & oven
  - ✓ PIEP (till 2023): TT, DSC, TGA , FTIR

# CARE for HL-LHC Project

## Qualification readiness

- **Artificial irradiation campaigns with cable bundles**
  - ✓ R2M framework contract used for 2 campaigns
  - ✓ Facility for 1st campaign Germany
  - ✓ Facility for 2nd campaign France
  - ✓ Difficulties due to COVID (facilities overbooked for medical)
  - ✓ 1st campaign sent out in May 2021- Cable bundles received in September 2021
  - ✓ 2nd campaign sent out in October 2021- Cable bundles received in May 2022
  - ✓ Finalising technical report on 1st campaign
  - ✓ Starting sample preparation for tests on 2nd campaign



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CH1211 Geneva 23
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EN Engineering Department

| EDMS NO. | REV. | VALIDITY |
|---|---|---|
| 2560544 | 0.4 | FINAL |

REFERENCE: 20-08

Technical Requirements
Irradiation test

**20-08**

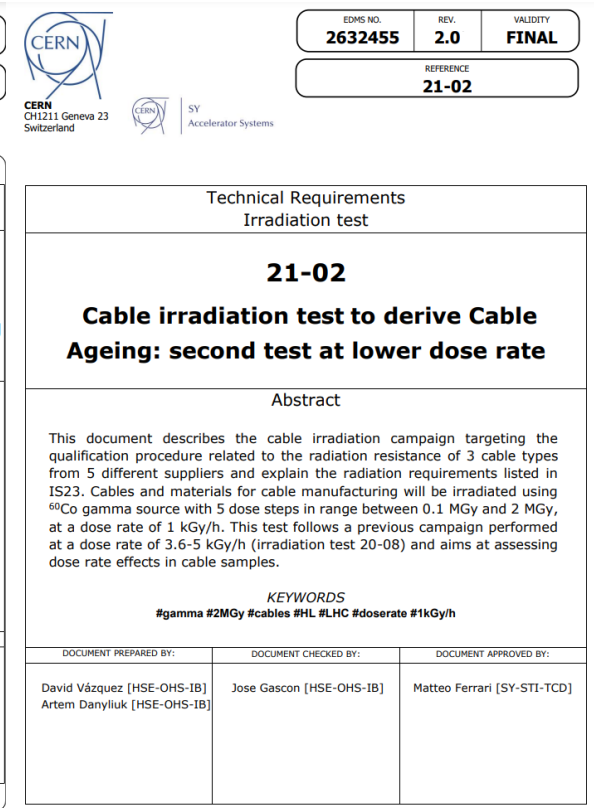
**Cable irradiation test to derive Cable Ageing**

Abstract

This document describes the cable irradiation campaign targeting the qualification procedure related to the radiation resistance of 3 cable types from 5 different suppliers and explain the radiation requirements listed in IS23. Cables will be irradiated by $^{60}$Co source with 5 gamma dose steps in range between 0.1 MGy and 2 MGy.

*KEYWORDS*
**#gamma #2MGy #cables**

| DOCUMENT PREPARED BY: | DOCUMENT CHECKED BY: | DOCUMENT APPROVED BY: |
|---|---|---|
| David Vázquez [HSE-OHS-IB]<br>Artem Danyliuk [HSE-OHS-IB] | Jose Gascon [HSE-OHS-IB] | Matteo Ferrari [SY-STI-TCD] |



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SY
Accelerator Systems

| EDMS NO. | REV. | VALIDITY |
|---|---|---|
| 2632455 | 2.0 | FINAL |

REFERENCE: 21-02

Technical Requirements
Irradiation test

**21-02**

**Cable irradiation test to derive Cable Ageing: second test at lower dose rate**

Abstract

This document describes the cable irradiation campaign targeting the qualification procedure related to the radiation resistance of 3 cable types from 5 different suppliers and explain the radiation requirements listed in IS23. Cables and materials for cable manufacturing will be irradiated using $^{60}$Co gamma source with 5 dose steps in range between 0.1 MGy and 2 MGy, at a dose rate of 1 kGy/h. This test follows a previous campaign performed at a dose rate of 3.6-5 kGy/h (irradiation test 20-08) and aims at assessing dose rate effects in cable samples.

*KEYWORDS*
**#gamma #2MGy #cables #HL #LHC #doserate #1kGy/h**

| DOCUMENT PREPARED BY: | DOCUMENT CHECKED BY: | DOCUMENT APPROVED BY: |
|---|---|---|
| David Vázquez [HSE-OHS-IB]<br>Artem Danyliuk [HSE-OHS-IB] | Jose Gascon [HSE-OHS-IB] | Matteo Ferrari [SY-STI-TCD] |

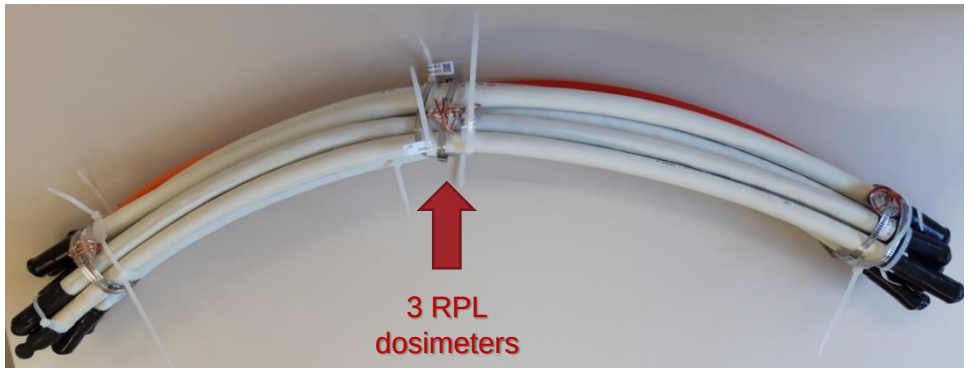
# CARE for HL-LHC Project

- **1st Irradiation campaign objectives** *(bundles received in September 2021)*
  - **Type of cables & manufacturers**
    - ✓ NE8 & NE48 types selected as most used type in HL-LHC project *(source EN-EL Group)* & cables available in CERN stores
    - ✓ NE48 type includes 2 different manufacturers to assess influence of manufacturer
    - ✓ PH3SJ type from Polycab manufacturer (contract signed by CERN stores) to assess radiation hardness
    - ✓ CGN50 type produced with popular Megolon S304 (radiation resistant)

  - **Dose rate influence 1Gy/s** *(~3.6kGy/h)*
    - ✓ 5 Dose steps 0.1 - 0.2 - 0.5 - 1 - 2 MGy increase data
    - ✓ Confirm degradation trend of each cable type & manufacturer
    - ✓ Confirm cable degradation around 500kGy
  - **Ageing methods**
    - ✓ 3 Combinations: Radiation only , Thermal ageing & radiation later, Radiation & thermal ageing later
    - ✓ Thermal ageing 168h as requested in IEC-60502
    - ✓ Assess influence of cable stressors and combination of them
  - **Pilot campaign**
    - ✓ Bundles dosimetry (3 dosimeters per bundle) & dose from facility
    - ✓ Get experience for cable qualification campaign in future


# CARE for HL-LHC Project

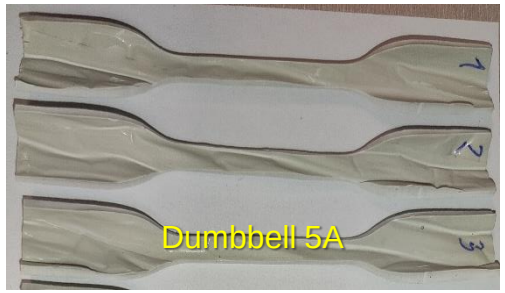
- **2nd irradiation campaign objectives** *(bundles received in May 2022)*
  - **Type of cables & manufacturers**
    - ✓ NE8 & NE48 types from same batch than 1st campaign
    - ✓ NF12, SVA3 & TFA3 type included as samples irradiated naturally in TS1+ & TDC2 tunnels
  - **Dose rate lower ~1kGy/h**
    - ✓ Same dose steps 0.1 - 0.2 - 0.5 - 1 - 2 MGy
    - ✓ Confirm cable degradation around 500kGy is independently of dose rate
  - **ageing methods**
    - ✓ Same as 1st campaign
  - **Dosimetry**
    - ✓ 2 extra RPL dosimeters per bundle + 2 RPLs for facility measurement
  - **Pilot campaign 2**
    - ✓ Dose rate effect
    - ✓ Fix parameters to be retained for HL-LHC qualification
    - ✓ Confirm shielding effect and dosimetry
    - ✓ Correlate all results with 1st campaign ones



# CARE for HL-LHC Project

## ❑ Tensile Tests (TT)

- **Procedure**
  - ✓ CARE procedure (EDMS no 2705496) for specimens preparation and test
  - ✓ Dumbbell specimens type 5A & 5B from jackets





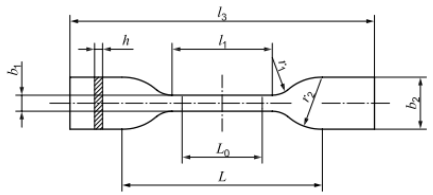
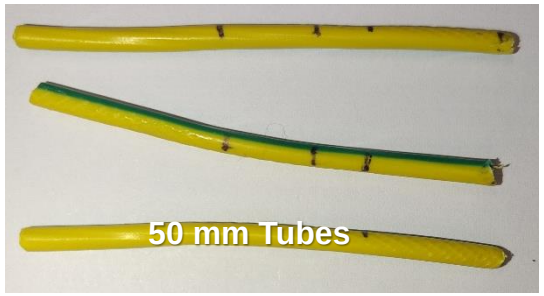



Figure A.2 — Type 5A and 5B test specimens

| | Specimen type | 5A | 5B |
|---|---|---|---|
| $l_3$ | Overall length | ≥75 | ≥35 |
| $b_2$ | Width at ends | 12,5 ± 1 | 6 ± 0,5 |
| $l_1$ | Length of narrow parallel-sided portion | 25 ± 1 | 12 ± 0,5 |
| $b_1$ | Width at narrow portion | 4 ± 0,1 | 2 ± 0,1 |
| $r_1$ | Small radius | 8 ± 0,5 | 3 ± 0,1 |
| $r_2$ | Large radius | 12,5 ± 1 | 3 ± 0,1 |
| $L$ | Initial distance between grips | 50 ± 2 | 20 ± 2 |
| $L_0$ | Gauge length | 20 ± 0,5 | 10 ± 0,2 |
| $h$ | Thickness | 2 ± 0,2 | 1 ± 0,1 |

  - ✓ 50 mm tubes from insulation (L0=10 mm)




CERN

| EDMS | Vers. | Status |
|---|---|---|
| 2705496 | 1.0 | See EDMS |

Visibility : CERN Internal

**OCCUPATIONAL HEALTH & SAFETY AND ENVIRONMENTAL PROTECTION UNIT**

Choose an item.

**PROCEDURE**

Testing procedure for the tensile testing of polymeric components of the cables

| Prepared by: | Checked by: | Approved by: |
|---|---|---|
| Artem Danyliuk | Berta Ruiz Palenzuela<br>Federica Bortoletto<br>Marija Kranjcevic | Jose Gascon |

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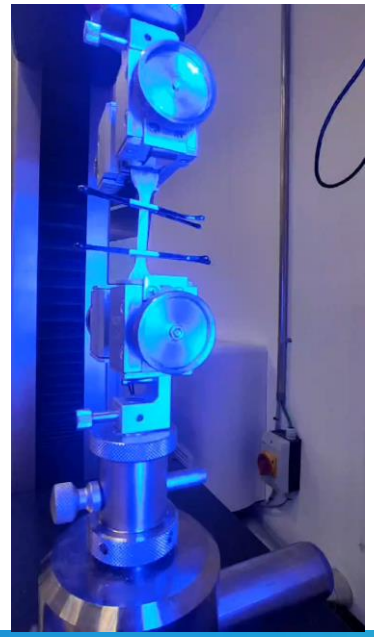
# CARE for HL-LHC Project

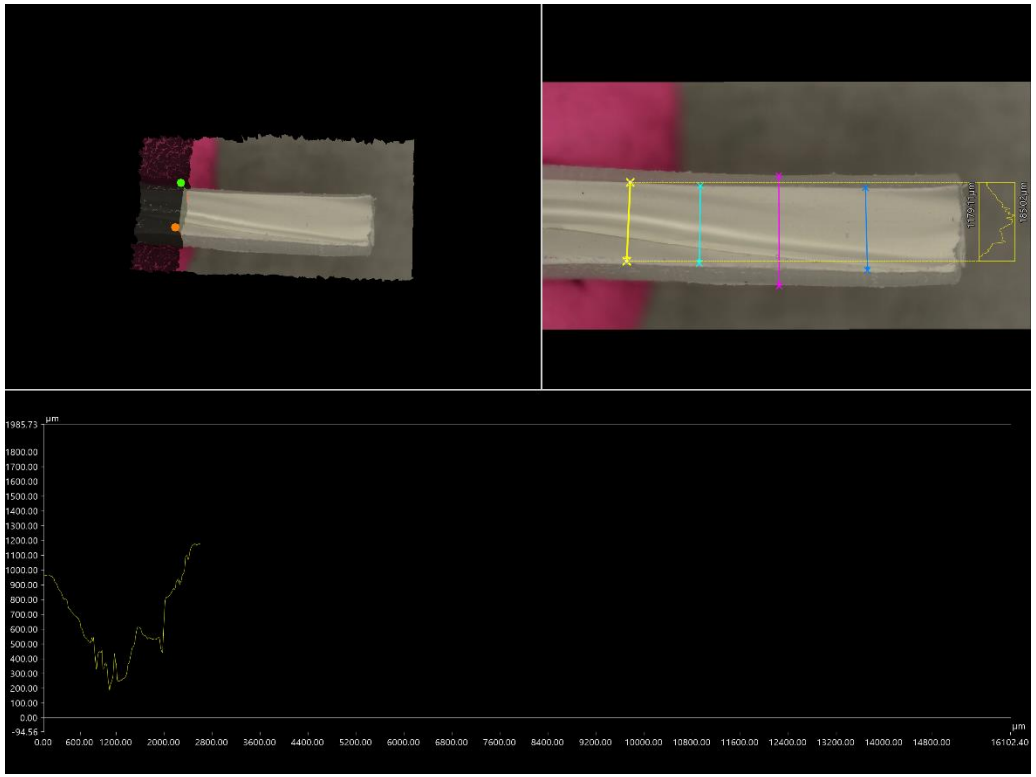
- **Tensile Tests (TT)**
  - **Equipment (MME lab)**
    - ✓ Machine Zwick/Roell Z010
    - ✓ Grips 8106 500N
    - ✓ 2 different jaws
    - ✓ Limmes video-extensometer
  - **Tests**

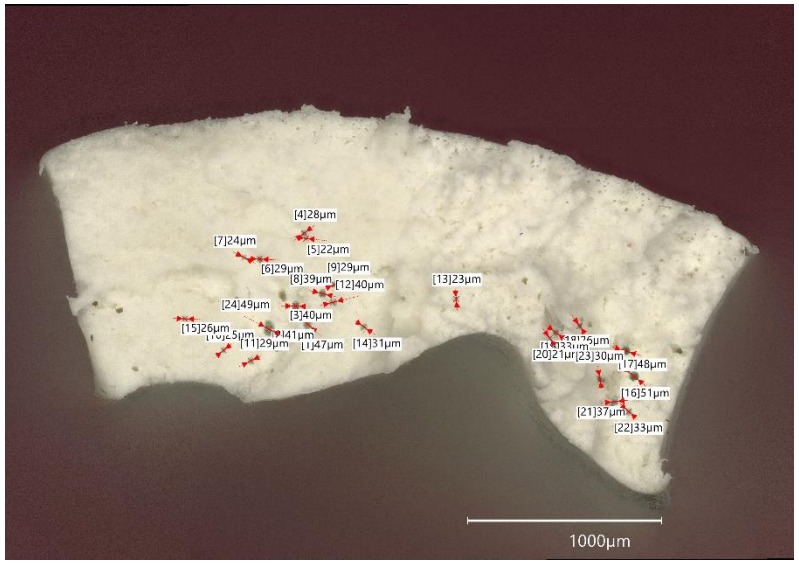


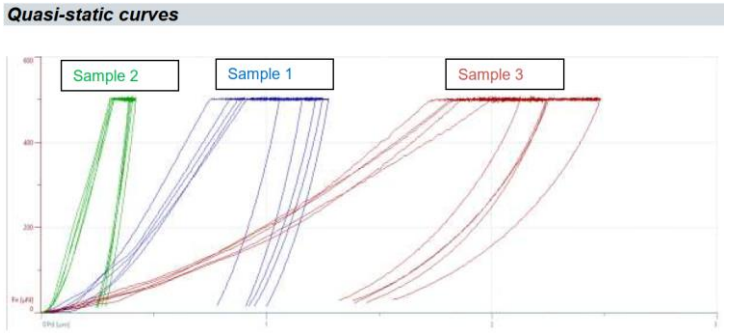


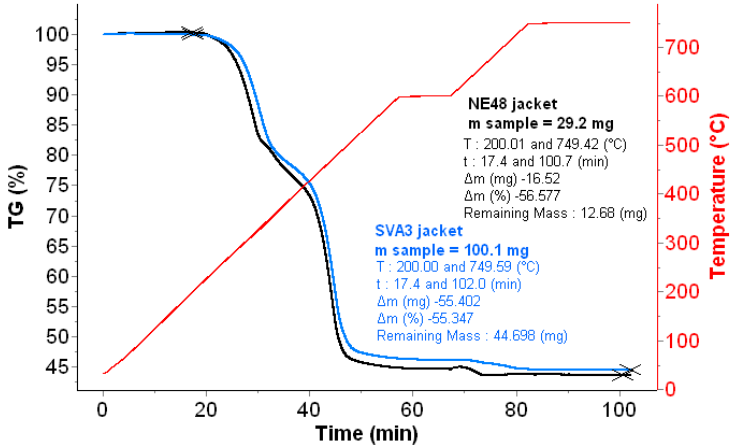
# CARE for HL-LHC Project

- **Illustration tests related**





# CARE for HL-LHC Project

## ❑ Testing methods & acceptance criteria EDMS 2447411

| | ageing Method | Source ageing method | Acceptance criteria | International standards |
|---|---|---|---|---|
| **Reference Stage** | | | • EaB ≥ 200% (jacket)<br>• EaB ≥ 300 % (insulation)<br>• Tensile strength ≥ 8MPa | According to IEC 60502<br>**jacket LSZH**<br>• EaB ≥ 125%<br>• Tensile strength ≥ 9MPa<br>**insulation XLPE**<br>• EaB ≥ 200%<br>• Tensile strength ≥ 12MPa |
| **Thermal Ageing Stage** | Thermal ageing<br>42 days at 100°C | Temperature, time and oven requirements are taken from IEC 60811-408 | • Residual EaB ≥ 70%<br>• OIT > 2 minutes | According to IEC 60811-408<br>Applicable for wires, materials to be rolled into coils, no cracks to be obtained after the thermal ageing |
| **Radiation Resistance Stage** | Gamma Irradiation<br>Dose 500 kGy<br>(dose rate >1Gy/s) | Values from SSI-FS-2-1 | • EaB ≥ 100 % (jacket)<br>• Residual EaB ≥ 50% (insulation)<br>• Residual Tensile strength ≥ 50% Jacket | According to IEC 60544-2<br>• Residual EaB ≥ 50%<br>• Residual Tensile strength ≥ 50% |

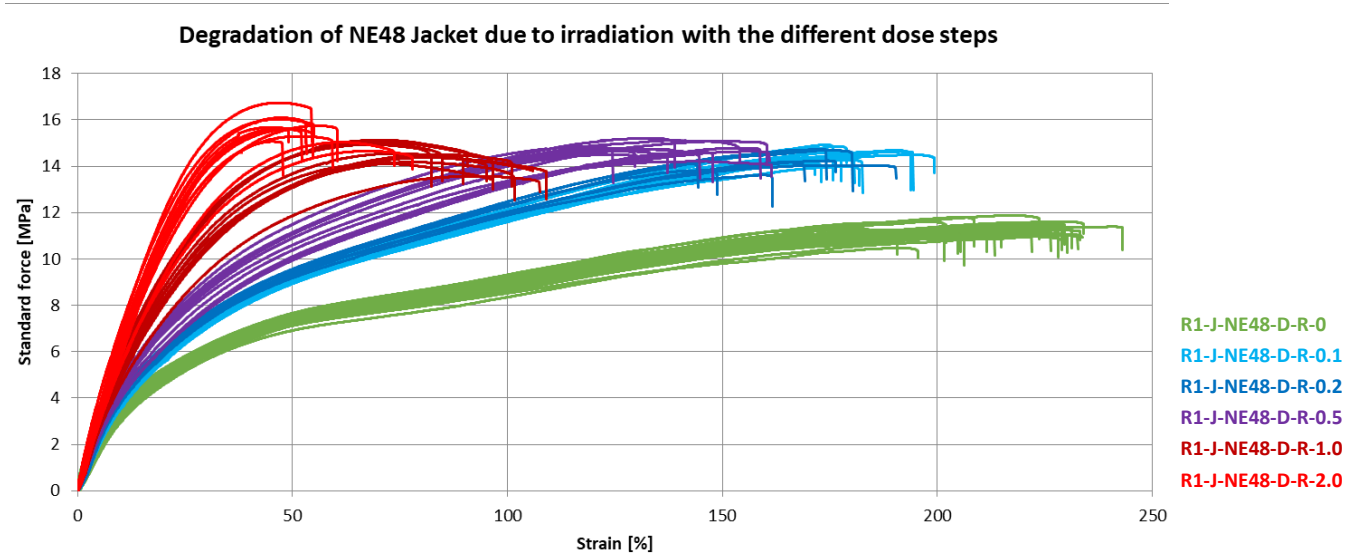
# CARE for HL-LHC Project

- **Tensile tests performed on 1st irradiation samples**

Most used cable types (33%) in HL-LHC Project

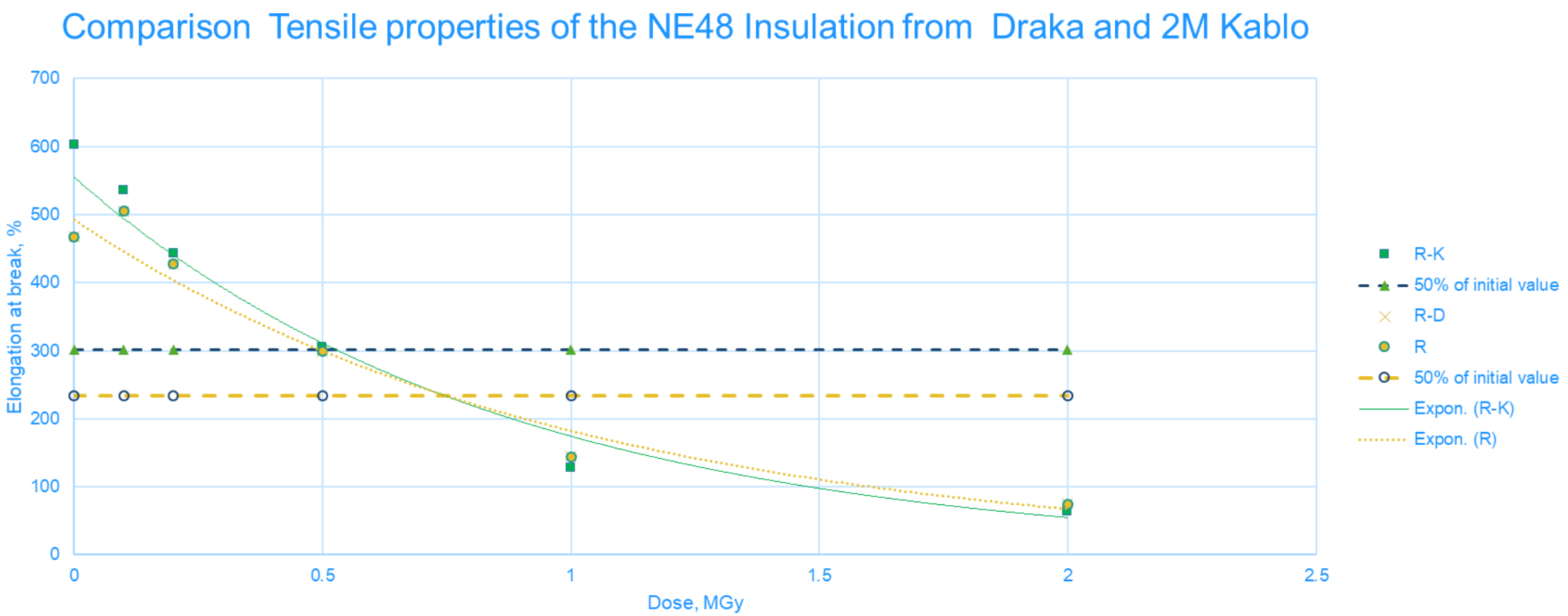
| Cable Type | Manufacturer | Number of tested specimens | | | | | |
|---|---|---|---|---|---|---|---|
| | | Jackets | | | Insulation | | |
| | | Total | Valid | Share of valid [%] | Total | Valid | Share of valid [%] |
| NE8 | NOVACAVI | 275 | 184 | 67 | 22 | 15 | 68 |
| NE48 | DRAKA | 463 | 337 | 73 | 114 | 67 | 59 |
| NE48 | 2M KABLO | 492 | 408 | 83 | 341 | 225 | 66 |
| CGN50 | RFS | 37 | 32 | 86 | - | - | - |
| HCA78 | RFS | 36 | 33 | 92 | - | - | - |
| PH3SJ | POLYCAB | 41 | 38 | 93 | 112 | 65 | 58 |

- **Results trend on cable degradation**




# CARE for HL-LHC Project

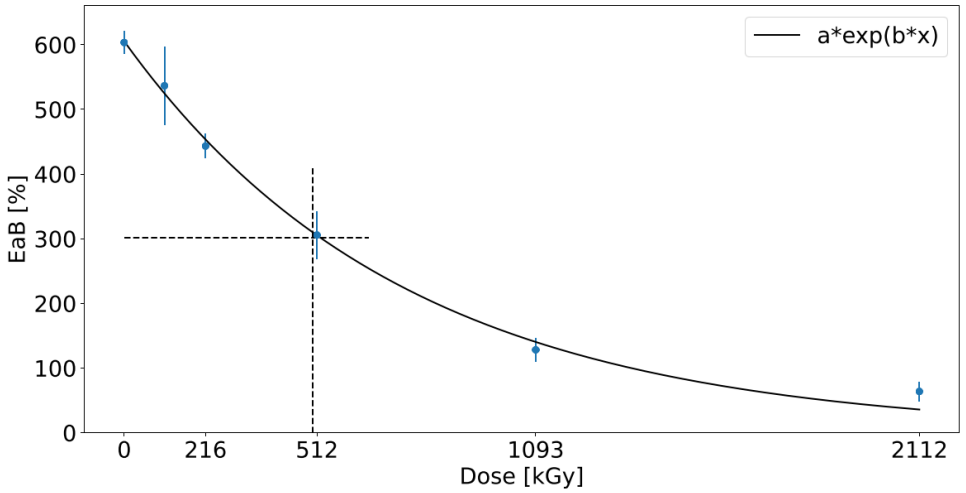
- **Results comparison per manufacturer**



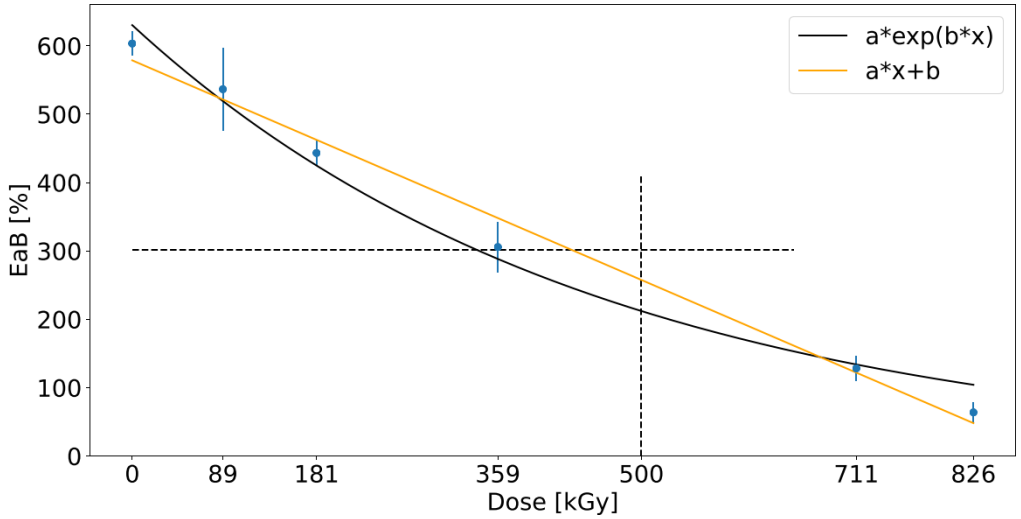
# CARE for HL-LHC Project

## ❑ Dosimetry issue on 1st irradiation campaign

**Facility dose Measurement**




**CERN measurement (RPL)**




| Target Dose [kGy] | Dose Facility [kGy][4] | R2E | | |
|---|---|---|---|---|
| | | Dosimeter | Dose [kGy][5] | Error |
| 100 | 107 | D1-0.1 | 78 | 27 % |
| | | D2-0.1 | 89 | 17 % |
| | | D3-0.1 | 88 | 18 % |
| 200 | 216 | D1-0.2 | 171 | 21 % |
| | | D2-0.2 | 181 | 16 % |
| | | D3-0.2 | 176 | 19 % |
| 500 | 512 | D1-0.5 | 270 | 47 % |
| | | D2-0.5 | 359 | 30 % |
| | | D3-0.5 | 359 | 30 % |
| 1000 | 1093 | D1-1 | 681 | 38 % |
| | | D2-1 | 711 | 35 % |
| | | D3-1 | 641 | 41 % |
| 2000 | 2112 | D1-2 | 754 | 64 % |
| | | D2-2 | 826 | 61 % |
| | | D3-2 | 730 | 65 % |

(4) Dose calculated by facility via 2 alanine dosimeters (2 positions)

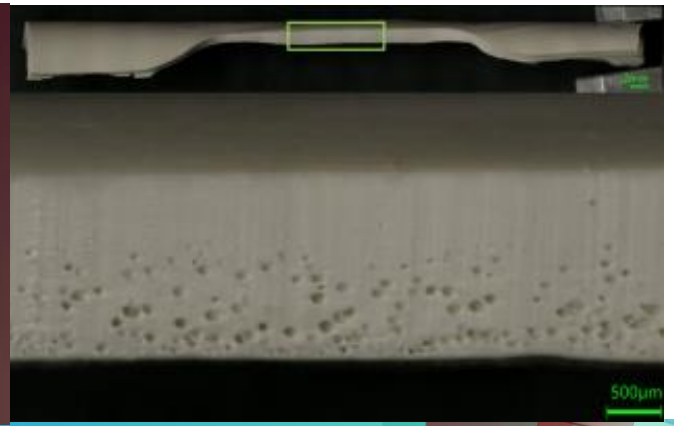
(5) Measured by R2E at CERN after an ultrasonic bath

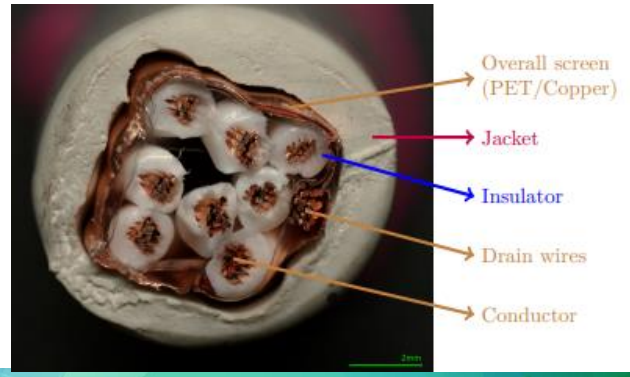
# CARE for HL-LHC Project

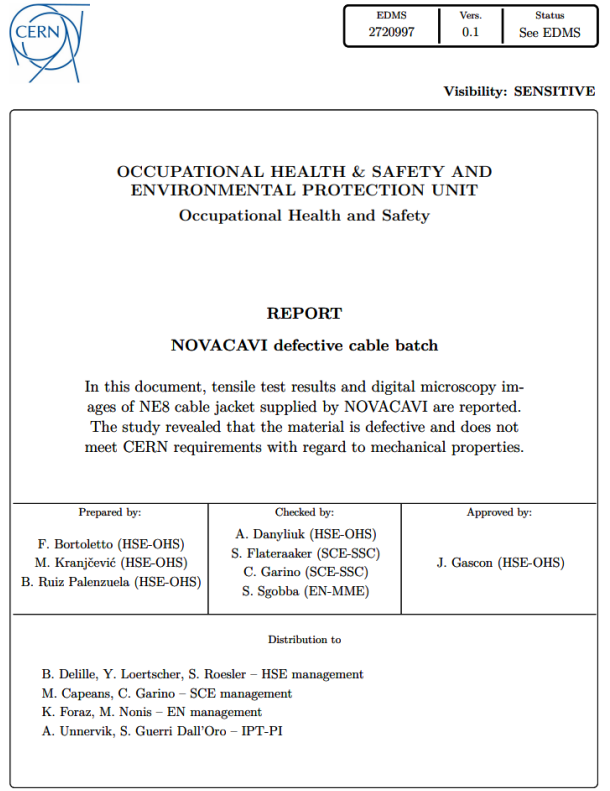
- **Results applying acceptance criteria**

| Cable | Cable component | 500kGy Facility | 500kGy CERN |
|---|---|---|---|
| NE8 NV | jacket | do not pass* | do not pass |
| NE48 DR | jacket | pass | pass |
| NE48 DR | insulation | pass | do not pass |
| NE48 2M | jacket | pass | pass |
| NE48 2M | insulation | pass | pass |
| PH3SJ Polycab | jacket | pass | n/a |
| PH3SJ Polycab | insulation | do not pass | n/a |

* Production defect discovered in the cable jacket



EDMS 2720997 | Vers. 0.1 | Status See EDMS

Visibility: SENSITIVE

OCCUPATIONAL HEALTH & SAFETY AND ENVIRONMENTAL PROTECTION UNIT
Occupational Health and Safety

**REPORT**

**NOVACAVI defective cable batch**

In this document, tensile test results and digital microscopy images of NE8 cable jacket supplied by NOVACAVI are reported. The study revealed that the material is defective and does not meet CERN requirements with regard to mechanical properties.

| Prepared by: | Checked by: | Approved by: |
|---|---|---|
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Distribution to

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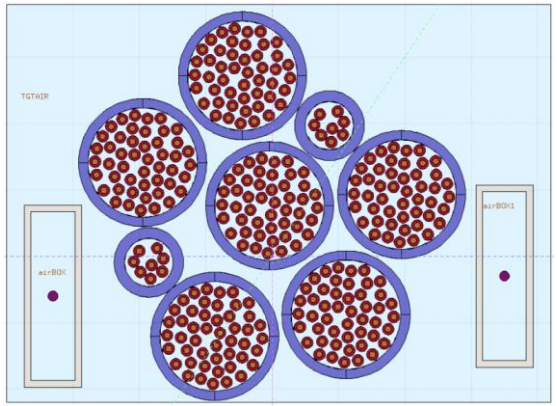
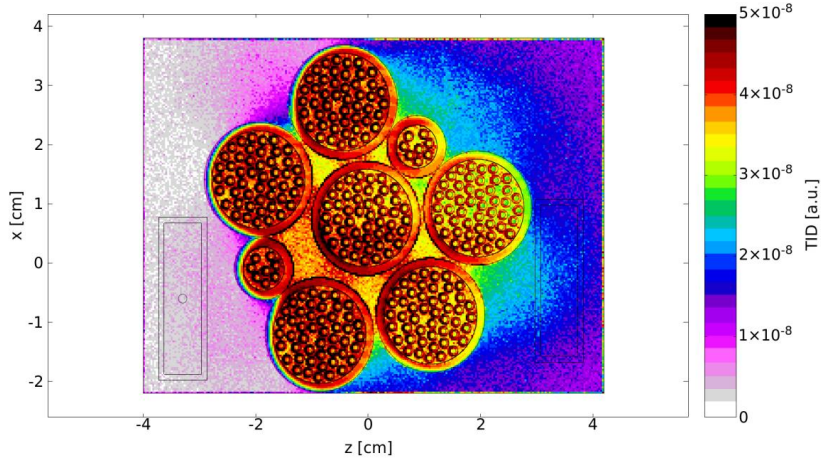
M. Capeans, C. Garino – SCE management
K. Foraz, M. Nonis – EN management
A. Unnervik, S. Guerri Dall'Oro – IPT-PI

# CARE for HL-LHC Project

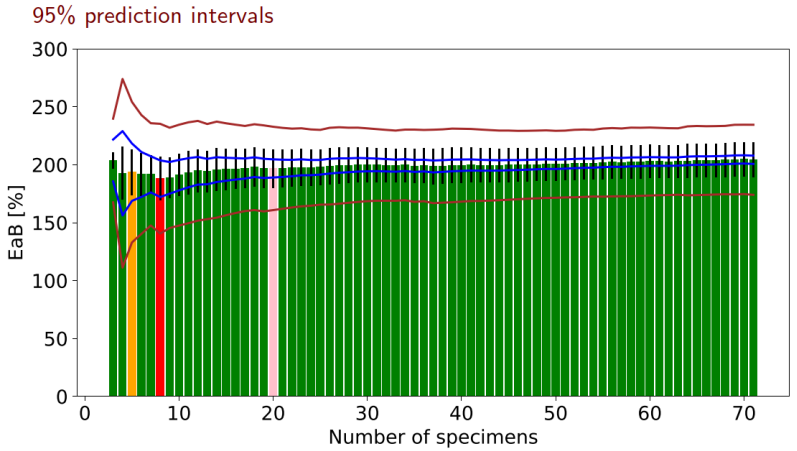
## Calculations

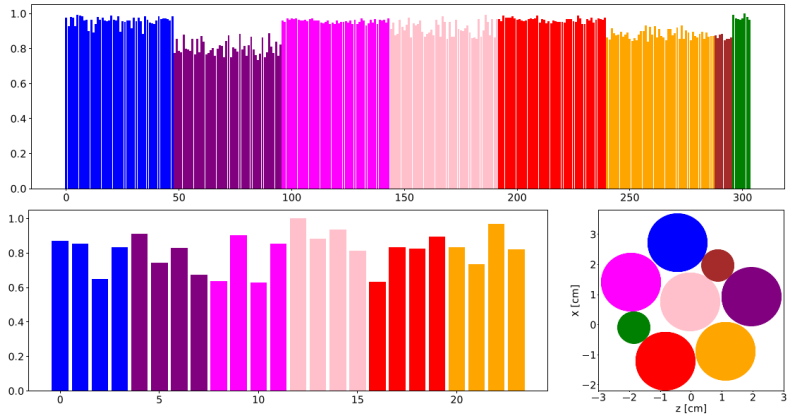
- **Working closely with R2E group on dosimetry & FLUKA for artificial irradiation**






- **Math analysis: statistics, data correlation, models**

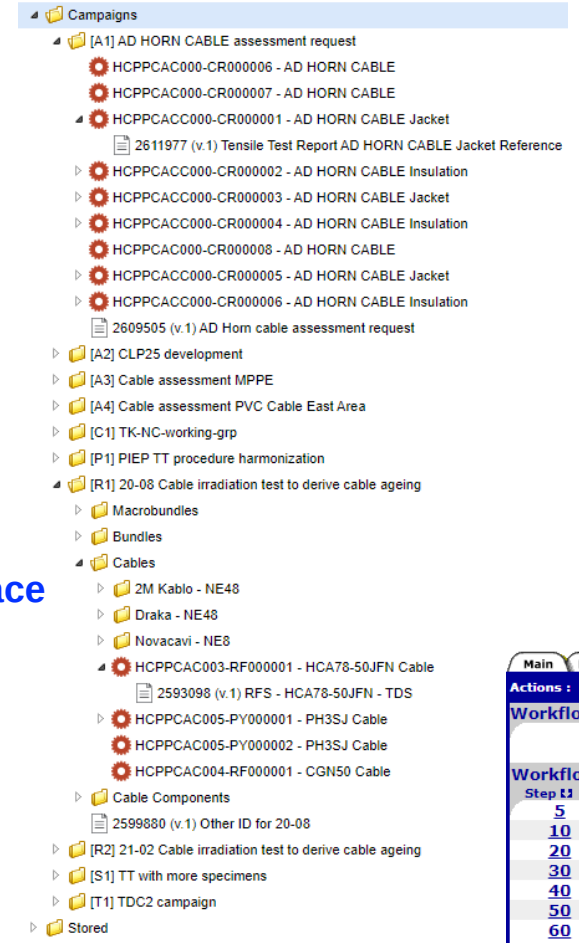


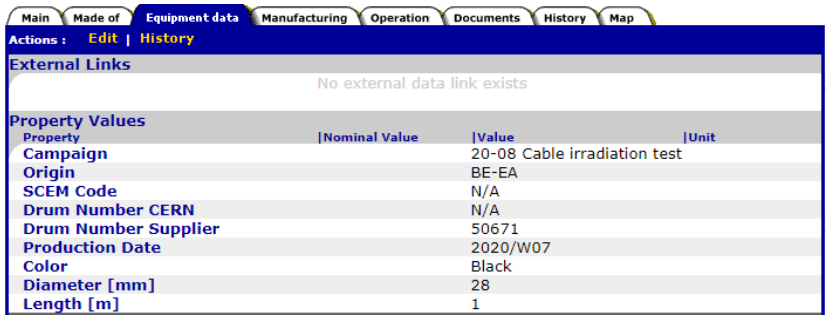



# CARE for HL-LHC Project

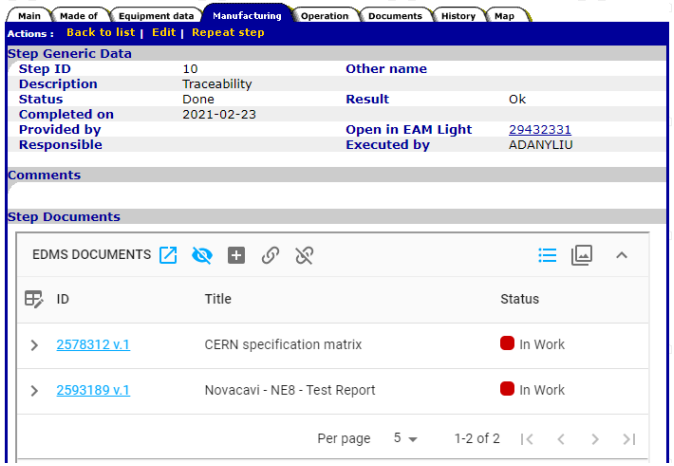
- **Database fully operational in CERN environment**
  - **Created with the guidance of the HL-LHC quality control group**
  - **Tracking CARE elements**
    - ✓ Cables and cable components (jacket & insulation)
    - ✓ Cable bundles
    - ✓ Dosimeters
    - ✓ Raw Materials
  - **EDMS Node**
    - ✓ Items & assets (cables, materials, etc.)
    - ✓ Documents (specifications, test reports, etc.)
    - ✓ Projects (campaigns, documentation, etc.)
  - **Infor, MTF, EAM Light**
    - ✓ Asset properties
    - ✓ Steps
  - **EAM store representing the physical storage space**
  - **Labels with a QR code**

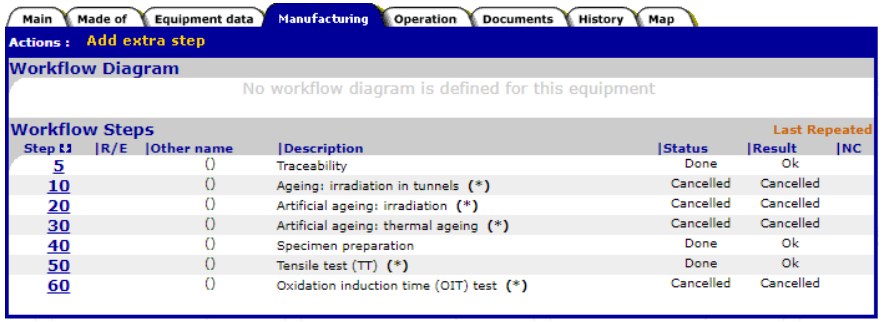





*Equipment Identifier:* **HCPPCAC001-N4000100**
*Other Identifier:* **00-NE8-N-drum**
*Description:* **NE8 Cable**



# Conclusions

# CARE roadmap

- **Deliverables *short term***
  - ✓ Technical report on 1st irradiation campaign
  - ✓ Tensile Tests & Technical reports on 2nd irradiation campaign
  - ✓ Correlation and technical analyses from results obtained in both campaigns
  - ✓ Technical report with cable requirements, tests methods and qualification acceptance criteria applicable for HL-LHC project (to be agreed)
  - ✓ Prepare qualification campaign from HL-LHC selected manufacturers
- **Deliverables *long term***
  - ✓ Prepare natural irradiation campaign in CERN facilities with similar doses as HL-LHC simulations
  - ✓ Extract and test placed samples from RIAC in SPS (TS1+ & TDC2 tunnels)
  - ✓ Research on the factor 5 used historically for artificial & natural irradiation
  - ✓ Establish first lifetime models from all data & experience obtained from irradiation campaigns and qualification processes
  - ✓ Prepare condition monitoring for HL-LHC operation

# CARE Benefits

- ✓ Extending cable lifetime
  - Reduction on cable consumption *(material & procurement)*
  - Decreasing works required for removal & installation
  - Lowering personnel stay in High Radiation Areas during works *(Personnel Dose)*
  - Optimizing resources *(material, manpower & duration)* required in LS & TS schedules
  - Reduction of radioactive waste *(treatment of activated cables)*
- ✓ Improvement in cable quality assurance
- ✓ Expertise on cable ageing testing techniques & ageing mechanisms
- ✓ Knowledge on polymers & additives behavior under radiation
- ✓ Experience on Qualification procedures
- ✓ Reference database for studied cables
  - TS, data sheet, tests records, FAT, SAT, control monitoring

# CARE challenges

- **Technical topics**
  - **CPR cables (Cca-s2,d1,a2)**
    - ✓ Higher amount of flame retardants and solids in polymers (ATH, M… …s) impacting other cable properties
    - ✓ Polymers qualified for radiation environment (Yellow Book) m… …e to pass CPR
    - ✓ CPR certified cables lower performance in terms of mec… …ues and/or radiation resistance
  - **Artificial irradiation**
    - ✓ Improve monitoring radiation on bundles in ext…
    - ✓ Improve shipping conditions (shipment du… …ing, time after radiation)
  - **Tensile Tests improvements**
    - ✓ Pneumatic grips, hair pins techn… …xtensometer, etc
    - ✓ Specimen insulation prepar…
- **Scientific topics**
  - **Develop other testi… …ues on cable ageing**
    - ✓ Indentation … …trometry, FTIR, TGA,…
    - ✓ For cor… …ng, non destructible
  - **Radiati…**
    - ✓ Accu… …simeters for high radiation doses above 1MGy
    - ✓ Research on applied safety factor 5 among artificial vs natural radiation
    - ✓ Natural and Artificial irradiation at CERN

All ideas/suggestions welcome!!!

# Acknowledgement

**CARE team**

S. Sgobba & EN-MME lab team

M. Tabourelli & TE- VSC lab team

HSE ENV lab team,

R. Garcia & G. Lerner, Y. Aguiar (R2E),

M. Ferrari (R2M)


# THANK YOU

# FOR YOUR ATTENTION