CERN
CH1211 Geneva 23
Switzerland

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] Artem Danyliuk [HSE-OHS-IB]	Jose Gascon [HSE-OHS-IB]	Matteo Ferrari [SY-STI-TCD]

HISTORY OF CHANGES

REV. NO.	DATE	PAGES	DESCRIPTIONS OF THE CHANGES
0.1	18/08/2021		First draft version of the document
0.2	19/08/2021		Comments by R2M and minor editing
0.3	20/08/2021		Editing with the comments by R2M
1.0	20/08/2021		Version shared with the Contractor
2.0	21/09/2021		Minor editing

Contents

1. Introduction

The aim of this irradiation campaign is to make progress towards the establishment of a cable radiation resistance procedure and explain the radiation requirements included

in IS23. Cables used in areas where the total absorbed dose exceeds 100 Gy, have to be subjected to mechanical tests before and after irradiation. Radiation resistance is measured by the determination of the Radiation Index that corresponds to the end-point where the mechanical properties of the polymeric materials are severely compromised. Such point can be characterised by a 50% decrease of the elongation at break value in respect to the unirradiated value or below 100% absolute value.

In order to apply results and conclusions in current projects, the most used cables types are chosen among all cables used at CERN. Therefore, the campaign will involve, if possible, the same cable types but from 3 different manufacturers. As well 3 other cables of 2 different suppliers are added to some bundles to check if cable can stand certain dose.

As radiation testing conditions listed in IS23 are not completely clear, it is expected to use the results to validate the test procedure concerning radiation index (RI) and establish a more accurate correlation between radiation ageing achieved in testing condition (gamma irradiation) and in operation conditions (typically mixed fields).

This irradiation test aims at providing complementary information to previously performed **irradiation test 20-08** (**EDMS** node: **CERN-0000217473**, Test Specification document available at **EDMS** reference **2560544**). In the present irradiation test, the same cable samples already used in 20-08 are irradiated at the same dose values previously explored, but using a lower dose rate, closer to the expected irradiation conditions in operation at CERN. Aim of the test is the assessment of the dose rate effect in the selected irradiation conditions.

2. Material/device information

2.1 Description of materials/devices, drawings and pictures

Samples for irradiation are presented in the form of 5 cable bundles, each including 3 to 5 cables with capped ends. Each bundle is fixed with 3 cable binders and 3 RPL dosimeters are attached to each bundle (see Figure 1 and Figure 2). The binders grouping the whole bundle are metallic.

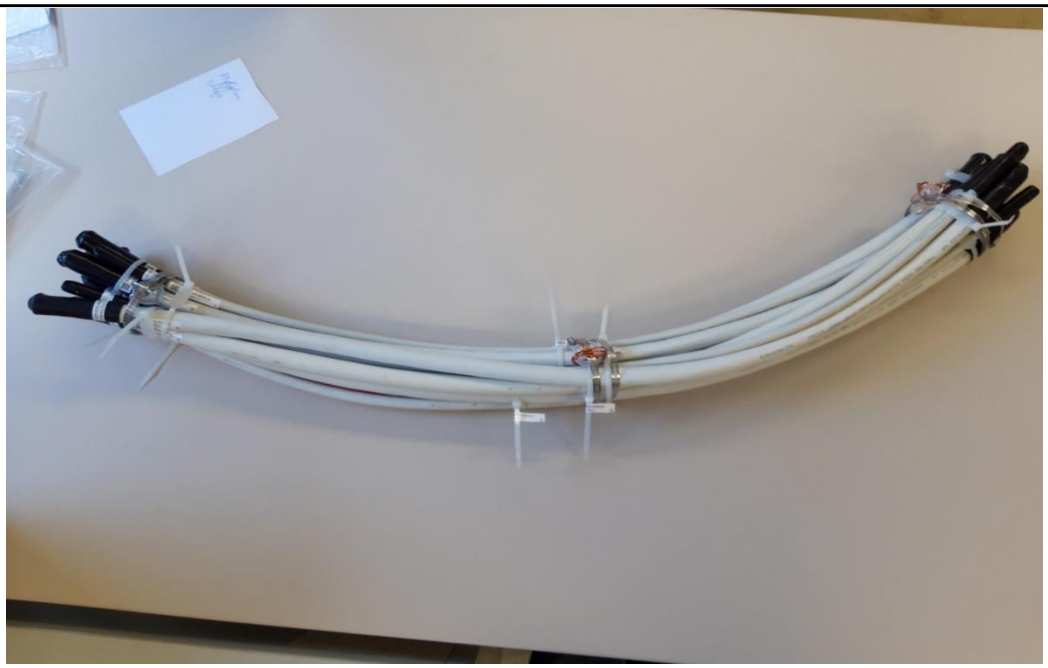

Figure 1: a cable bundle to be irradiated (1m long).

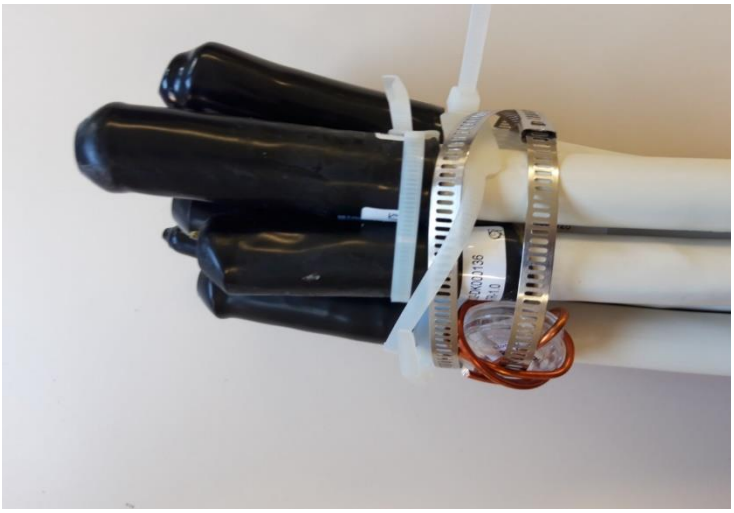

Figure 2: a detail of the cable bundle and of the binders.

A detailed description of the cables included in the 5 bundles is listed in the Table 1. Each cable has unique name that contains information about ageing procedure, dose step and cable type. Cable unique name can be decoded by the following scheme:

Cable name contains following digits R2 X-Y-A-Z where:

X is Cable type

X code	Cable type
NE8	NE8
NE48	NE48

SVA3	SVA3
TFA3	TFA3
NF12	NF12
CLP50	CLP50
EcoWire6716	EcoWire6716

Y is Manufacturer code

Y code	Manufacturer
N	Novacavi
D	Draka
K	2M Kablo

A is code is corresponding to ageing procedure:

A code	Ageing procedure
R	Irradiation without thermal ageing
TR	168 h of thermal ageing at 100°C in oven that comes before irradiation
RT	168 h of thermal ageing at 100°C in the oven that comes after irradiation

Z is code corresponding to dose step

Z CODE	DOSE STEP
0	REF
0.1	0.1 MGy
0.2	0.2 MGy
0.5	0.5 MGy
1	1 MGy
2	2 MGy

List of the description of cables are tested can be found in Table 1.

Table 1: Cables description

Cable type	SCEM	Producer	Drum number	production date	Jacket Material	Insulation material	Cable colour	Cable diameter, mm
NE8	04.21.52.115.0	Nova Cavi	0813413	40/2019	LSZH FR rad. resist. compound	Radiation resistant LDPE	Grey	10.5
NE48	04.21.52.150.2	2M Kablo	3733547	07/220	LSZH compound Megolon S536	PE LE 6006	Grey	21
NE48	04.21.52.150.2	Draka		19/2020	FRNC	PE	Grey	21
SVA3	-	Draka	J12-4591	n/a	LSZH	PE	Red	10
TFA3	-	Draka	J13-7579	n/a	LSZH	PE	Orange	10
NF12	-	Draka	J12-6754	n/a	LSZH	PE	White	14

CLP50	-	Draka	71100008	11/2017	LSFRZH	PE	RED	31
EcoWire6716	-	Alpha Wire Corp. USA	131710-08	09/2020	-	MPPE	Violet	2.06

Aside the cables, one bundle additionally contains samples of materials that are going to be used for cable manufacturing (See Figure 3). Materials are presented by sheets 15x18 cm with thickness ~2 mm. Detailed information on materials is reported in Table 2.

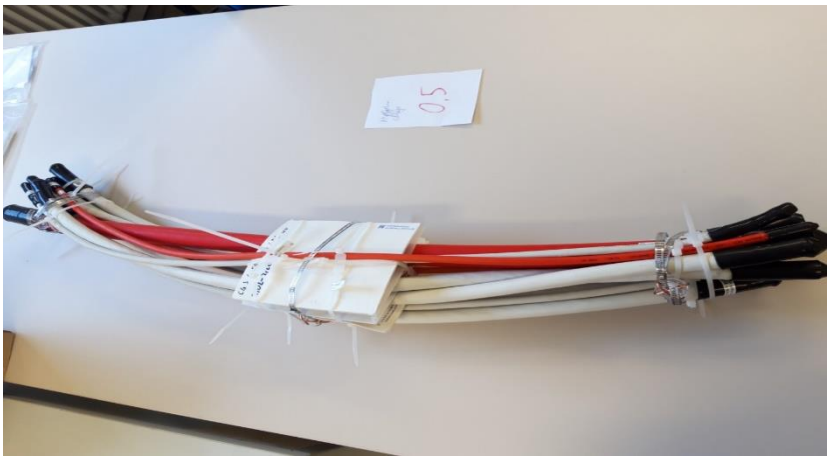

Figure 3: the bundle that includes additional samples.

Table 2 Materials for cable manufacturing: description of the samples.

Material name	Material code	Producer	Material	material colour	Dimensions, mm
ECCOH RP 5549	A2-ECCOH_RP_5549-T-42	PolyOne	LSZH	White	180x150x2
MEGOLON S534	A2-MEGOLON_S534-T-42	AlphaGary	LSZH	White	180x150x2
DHF 9740	A2-DHF_9740-T-42	Prysmian Group	LSZH	White	180x150x2
CONGuard S 6650	A2-CONGuard_S_6650-T-42	CONDOR COMPOUNDS GmbH	HFFR	White	180x150x2
LE 6006	A2-LE_6006-T-42	Borealis A/S	PE	Transparent	180x150x2

2.2 List of material/device types and their quantities

Table 2: description of the bundles.

Bundle number	NE8	NE48 2M	NE48 Draka	SVA3	TFA3	NF12	CLP50	EcoWire6716	TOTAL number of cables per bundle
R2-Bundle-R-0.1	1	1	1	1	1	1			6

R2-Bundle-R-0.2	1	1	1	1	1	1			6
R2-Bundle-R-0.5*	1	1	1	1	1	1	1		7
R2-Bundle-R-1.0	1	1	1	1	1	1			6
R2-Bundle-R-2.0	1	1	1	1	1	1		1	7
R2-Bundle-TR-0.1	1	1	1						3
R2-Bundle-TR-0.2	1	1	1						3
R2-Bundle-TR-0.5	1	1	1						3
R2-Bundle-TR-1.0	1	1	1						3
R2-Bundle-TR-2.0	1	1	1						3
R2-Bundle-RT-0.1	1	1	1						3
R2-Bundle-RT-0.2	1	1	1						3
R2-Bundle-RT-0.5	1	1	1						3
R2-Bundle-RT-1.0	1	1	1						3
R2-Bundle-RT-2.0	1	1	1						3
TOTAL number of cables	15	15	15	5	5	5	1	1	62

*- R2-Bundle-R-0.5 contains 5 samples of materials for cable manufacturing according to table 2.

Experiment is split in 3 parts: irradiation campaign with 5 dose steps (R), irradiation of thermally aged samples with 5 dose steps (TR, TTRO, TRO) and irradiation with 5 dose steps of samples with post irradiation thermal ageing (RT). Bundles description is listed in Table 2.

2.3 Dimension, shape and weight of the devices/materials

Irradiation with each dose step should be held with big cable bundles (referred to as macrobundles) containing 3 bundles each, grouped by irradiation step. The bundles are made of different number of cable samples as specified in Table 2. The macrobundles are grouped together by metal binders and protected by black plastic foil. The diameter of each macrobundle ranges between 10-18 cm.

3. Normal operational conditions of the material/device at CERN

Cables are installed in CERN accelerators mostly on the cable trays with no mechanical stress, no influence of aggressive environment at room temperature.

4. Desired lifetime

Desired lifetime of cables under radiation is around 40 years.

5. Material/device location in the beam facilities

Cables that are subjected to irradiation are going to be installed in CERN accelerators tunnels. Cables are mainly located on cable trays along the beam but the end side of some cables will be connected to equipment close to the beam.

5.1.1 Radiation level in the installation area

Cables are installed in several location in the accelerator complex, including both high-radiation areas and areas where radiation levels are lower or negligible. Typically, they are exposed to mixed fields of secondary radiation produced by interactions of the primary protons with beam intercepting devices.

5.1.2 Environmental conditions in the installation area

Cables are installed in areas that are generally not subjected to influence of low temperatures or humidity.

5.2 Total accumulated dose during material/device lifetime

The most critical cables or part of cables used in the LHC are expected to absorb a total dose in the MGy range during their lifetime.

6. Samples to be tested

6.1 Sample preparation by contractor

To protect each cable bundles from mechanical damage and influence of the sun light to dosimeters, cables bundles are wrapped in black foil that should be removed by contractor before the irradiation. Examples of bundles wrapped in black foils can be seen in Figures 4 and 5.

Figure 4: example of wrapped cable bundle.

Figure 5: bigger wrapped cable bundle including materials for cable manufacturing.

6.2 Sample preparation by CERN

Cable Samples are organised in 5 cable bundles, one per each dose step.

6.3 Special precautions

6.3.1 Specific handling requirements

The cable bundles should be covered again in a black foil after irradiation, to protect bundles and dosimeters. Extra black foil is provided by CERN to cover the samples after irradiation. The unused foil should be returned to CERN together with the samples.

6.4 Sample value

Total sample value is 415.4 CHF without taking into account price of dosimeters, packaging materials and shipment.

6.5 Table summarizing the samples to be tested.

The following Table summarizes the information on the samples to be irradiated.

Table 3: samples to be tested.

#	*SAMPLE TYPE*	*MATERIAL*	*TOTAL AMOUNT of samples*	*DIMENSION (per sample) (L=cm x D=cm)*	*WEIGHT (per sample) (g)*	*VALUE (CHF)*	*SPECIAL PRECAUTIONS*
R2-Bundle-R-0.1	*Cable bundle*	*Cables*	6	100x7	1600	32.7	none
R2-Bundle-R-0.2	*Cable bundle*	*Cables*	6	100x7	1600	32.7	none
R2-Bundle-R-0.5*	*Cable bundle*	*Cables*	7	100x7	1850	47.7	none
R2-Bundle-R-1.0	*Cable bundle*	*Cables*	6	100x5	1600	32.7	none
R2-Bundle-R-2.0	*Cable bundle*	*Cables*	7	100x5	1700	33.7	none
R2-Bundle-TR-0.1	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-TR-0.2	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-TR-0.5	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-TR-1.0	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-TR-2.0	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-RT-0.1	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-RT-0.2	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-RT-0.5	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-RT-1.0	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none
R2-Bundle-RT-2.0	*Cable bundle*	*Cables*	3	100x5	1109	16.7	none

TOTAL VOLUME: 156’058 cm3

TOTAL WEIGHT: 19’440 g

Table 4: description of the content of each bundle.

Bundle	Description
R2-MBundle-0.1	R2-Bundle-R-0.1, R2-Bundle-TR-0.1, R2-Bundle-RT-0.1
R2-MBundle-0.2	R2-Bundle-R-0.2, R2-Bundle-TR-0.2, R2-Bundle-RT-0.2
R2-MBundle-0.5	R2-Bundle-R-0.5, R2-Bundle-TR-0.5, R2-Bundle-RT-0.5
R2-MBundle-1.0	R2-Bundle-R-1.0, R2-Bundle-TR-1.0, R2-Bundle-RT-1.0

R2-MBundle-2.0	R2-Bundle-R-2.0, R2-Bundle-TR-2.0, R2-Bundle-RT-2.0

The samples are grouped in the following ways, to be irradiated at different dose steps:

1. Bundle 0.1: Dose 0.1 MGy
2. Bundle 0.2: Dose 0.2 MGy
3. Bundle 0.5: Dose 0.5 MGy
4. Bundle 1.0: Dose 1 MGy
5. Bundle 2.0: Dose 2 MGy

7. Irradiation conditions

Table 5: summary of irradiation conditions

PARAMETER	*VALUE and UNIT*	*NOTES*
RADIATION TYPE	*Gamma radiation*	
DESIRED DOSE RATE (gamma irr)	*Minimum 0.9 kGy/h* *Maximum 1.2 kGy/h*	*In accordance with IS23 and IEC 60544-2*
TOTAL DOSE (gamma irr)	*2 MGy*	
Dose/irradiation steps	*0.1 MGy* *0.2 MGy* *0.5 MGy* *1 MGy* *2 MGy*	***All the irradiation steps should finish at the same time*** *to correctly perform following ageing tests at CERN.*
Temperature	*Room temperature °C (uncontrolled increase)*	*To be monitored (accuracy +- 5°C)*
Atmosphere	*Air (ventilation)*	*Sample wrapping to be removed before irradiation*

7.1 Irradiation plan

Table 6: irradiation plan.

GROUP REFERENCE	DESCRIPTION	DOSE STEP

R2-MBundle-0.1	*Bundle of cables*	*0.1 MGy*
R2-MBundle-0.2	*Bundle of cables*	*0.2 MGy*
R2-MBundle-0.5	*Bundle of cables and samples of material for cable manufacturing*	*0.5 MGy*
R2-MBundle-1.0	*Bundle of cables*	*1 MGy*
R2-MBundle-2.0	*Bundle of cables*	*2 MGy*

Please note that all the irradiation steps should finish at the same time, as this is necessary to standardize the following ageing tests performed at CERN.

8. Characterization and measurements by the contractor

8.1 Measurements during irradiation

Dosimetry.

Each cable bundle that will be irradiated is equipped with 3 RPL dosimeters, fixed in the middle of cable bundle and on the cable ends. Each dosimeter is marked in the way that its belonging can be easily determined. Dosimeter data to be read and reported as 3 values per Group of cable bundles. The dosimeters are provided by CERN and will be read at CERN after irradiation

Temperature to be monitored during the irradiation of the samples with accuracy +-5°C

8.2 Step or post irradiation measurements by the contractor

No measurement is required. The cable bundles should be wrapped in black foil after irradiation to protect bundles from mechanical damage and dosimeters from light exposure.

8.2.1 Pictures of irradiated samples to be provided by the contractor

Pictures of each bundle after irradiation are required.

9. Samples return to CERN

Samples should be shipped back to CERN as soon as possible after irradiation.

After irradiation samples to be shipped back to CERN for the following contact details:

CERN

Artem Danyliuk, Office: 570/R-024,

Site de Meyrin

Route de Meyrin

CH-1211 Geneve 23

Switzerland

10. Test schedule

10.1 Irradiation schedule

11. Test summary table

Table 7: summary

UPL ref.	*ITEM DESCRIPTION*	*ORDERED QUANTITY*
1	**TID Tests (^{60}Co gamma)**	
1.1	**Samples handling, characterisation and documentation**	
1.1_1	**Irradiation test without characterisation** (up to 400 samples)	
1.1_1a	pallet volume - heavy (120 cm x 80 cm x 190 cm, >25 kg)	
1.1_1b	standard volume - heavy (40 cm x 40 cm x 40 cm, >25kg)	
1.1_1c	standard volume - light (40 cm x 40 cm x 40 cm, <= 25 kg)	
1.1_1d	small volume - heavy (20 cm x 20 cm x 20 cm, >25 kg)	
1.1_1e	small volume - light (20 cm x 20 cm x 20 cm, <=25 kg)	
1.1_4	**Irradiation test with active electronical or optical characterisation**	
1.1_5a	**Manpower for passive characterisation (Scientist)**	
1.1_5b	**Manpower for passive characterisation (Technician)**	
1.1_6	**Special samples packaging for irradiation (airtight container with vacuum or filled with a specific gas)**	
1.1_6a	pallet volume (120 cm x 80 cm x 190 cm)	
1.1_6b	standard volume (40 cm x 40 cm x 40 cm)	

1.1_6c	small volume (20 cm x 20 cm x 20 cm)	
1.2	**Beam time and irradiation conditions**	
1.2_1a	**Beam time for TID tests for large volumes**	
1.2_1aa	pallet volume - high priority (120 cm x 80 cm x 190 cm)	
1.2_1ab	pallet volume - standard priority (120 cm x 80 cm x 190 cm)	
1.2_1ac	pallet volume - low priority (120 cm x 80 cm x 190 cm)	
1.2_1ad	standard volume - high priority (40 cm x 40 cm x 40 cm)	
1.2_1ae	standard volume - standard priority (40 cm x 40 cm x 40 cm)	
1.2_1af	standard volume - low priority (40 cm x 40 cm x 40 cm)	
1.2_1ag	small volume - high priority (20 cm x 20 cm x 20 cm)	
1.2_1ah	small volume - standard priority (20 cm x 20 cm x 20 cm)	
1.2_1ai	small volume - low priority (20 cm x 20 cm x 20 cm)	
1.2_1b	*Beam time interruption*	
1.2_1c	*Transport of samples for their installation in the irradiation facility*	
1.2_2a	**Beam time for TID tests at very high dose rates**	
1.2_2aa	high priority	
1.2_2ab	standard priority	
1.2_2ac	low priority	
1.2_2b	*Beam time interruption*	
1.2_2c	*Transport of samples for their installation in the irradiation facility*	
1.2_3a	**Beam time for TID tests with active characterisation** (square samples of 1cm^3, required homogeneity of 30%)	
1.2_3b	**Beam time for TID tests with active characterisation (s**quare samples of 4cm^3, required homogeneity of 10%)	
1.2_3c	*Beam time interruption*	
1.2_3d	*Transport of samples for their installation in the irradiation facility*	
1.2_3e	*Temperature control at cryogenic temperature*	
1.2_3f	*Temperature control at low temperature*	
1.2_3g	*Temperature control at room temperature*	
1.2_3ga	*Allowed temperature variation: +- 1°C*	
1.2_3gb	*Allowed temperature variation: +- 5°C*	

1.2_3h	*Temperature control at high temperature*	
2	**Accelerated Hadrons Tests (protons or neutrons)**	
2.1	**DD Tests**	
2.1_1	**Proton or neutron irradiation, active characterisation**	
2.2	**SEE Tests**	
2.2_1	**Proton or neutron irradiation, active characterisation**	

12. Annex

12.1 Test priority

The time required to the facility to complete an irradiation of 5 MGy is established in 10 weeks. This time is calculated from the moment CERN releases the order for the irradiation test and after samples receipt by the contractor.

This 10 weeks irradiation time can be adjusted based on the priority assigned to the project as reported in the following table:

TOTAL DOSE	HIGH PRIORITY	STANDARD PRIORITY	LOW PRIORITY
<= 5 MGy	5 weeks	10 weeks	15 weeks
5 MGy – 10 MGy	10 weeks	15 weeks	20 weeks
> 10 MGy	15 weeks	20 weeks	26 weeks

The expected duration of the whole test is presented in Section 10.2

12.2 Test indicative schedule

As a general reference, an example of typical schedule for irradiation test is reported in the following Table:

	Activities for an Individual Irradiation Test	Indicative Schedule
T0	CERN provides the test requirements, and the required schedule of the irradiation test.	

	Activities for an Individual Irradiation Test	Indicative Schedule
	The Contractor confirms the feasibility of the technical aspects and provides an offer in line with the test requirements and with the required schedule.	T0 + 2 weeks
T1	CERN sends the irradiation test release order (for the sample handling, characterization, technical documentation, beam time and irradiation conditions).	
	The Contractor carries out the irradiation of the samples, according to the test requirements (Irradiation beam time starts).	T1 + 10 weeks
T2	Irradiation beam time ends.	
	The Contractor carries out sample passive characterization, if requested by CERN.	T2 + 1 weeks
T3	Irradiation test ends, including sample characterization if applicable.	
	The Contractor proceeds with packing, prepares the post irradiation samples for pickup by CERN's carrier and provides the raw data associated with the characterization, if applicable.	T3 + 1 weeks
	The Contractor provides the technical documentation for the irradiation test, including the test report.	T3 + 4 weeks

Indicative Schedule for Individual Irradiation Tests