



Optical Fibre Dosimetry

R2E Annual Meeting

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1-3-2022



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

Agenda

1. Optical Fibre Dosimetry Work Package

2. Distributed Optical Fibre Radiation Sensors (DOFRS)

3. DOFRS O&M

4. R&D activities

5. Conclusions and Outlook

Optical Fibre Dosimetry Work Package

WP holder - EN-EL-FO

Mandate and main objectives

The mandate of the Optical Fibre Dosimetry Work Package (OFD WP) is to develop, deploy, operate and maintain the optical fibre radiation sensors that are employed in the monitoring of the radiation dose levels in CERN's accelerators and transfer lines.

As of today, **the main deployed system is the Distributed Optical Fibre Radiation and temperature Sensor (DOFRS).**

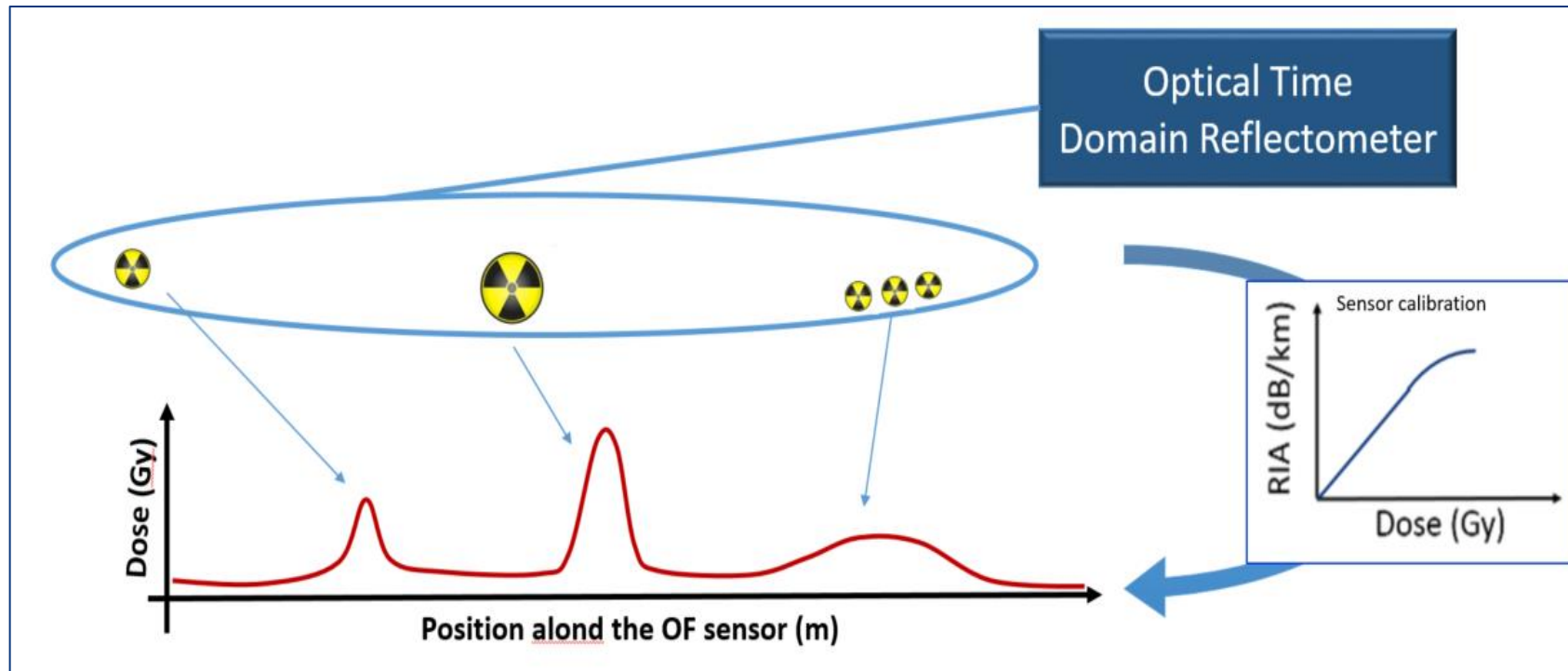
The OFD WP is instrumental to the *Monitoring & Calculation Working Group (MCWG)* as it contributes to its main tasks: addressing specific requests from equipment groups; the general reporting activities; the comparison and cross-validation of radiation field simulations; the comparison and cross-validation of radiation measurements from other monitors and detectors.

Distributed Optical Fibre Radiation Sensors (DOFRS)

Distributed Optical Fibre Radiation Sensors

DOFRS is based on:

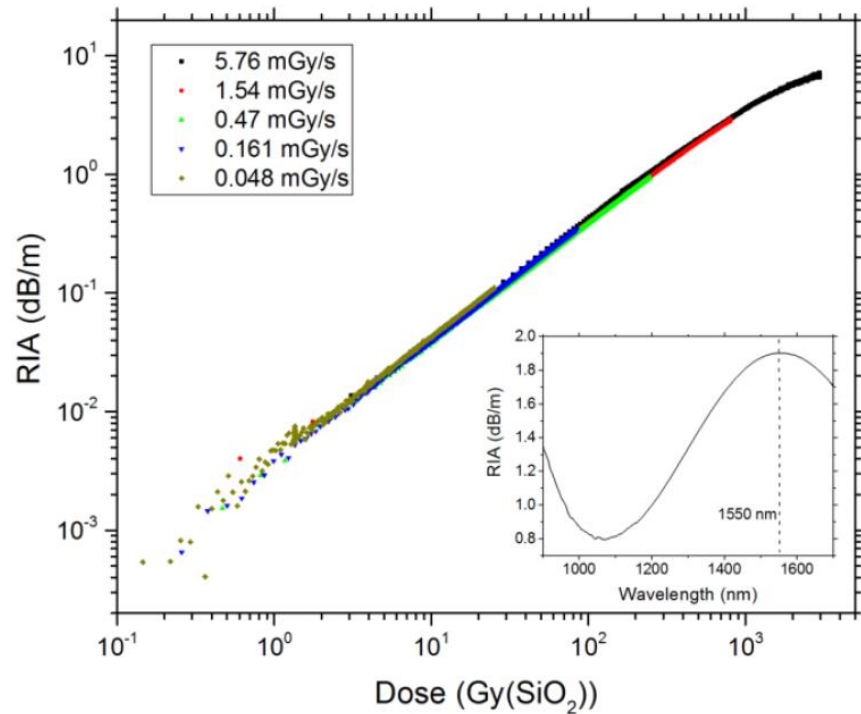
- **Radiation Induced Attenuation (RIA)** in suitable specialty OFs (*not any optical fibre*)
- **Optical Time Domain Reflectometry**



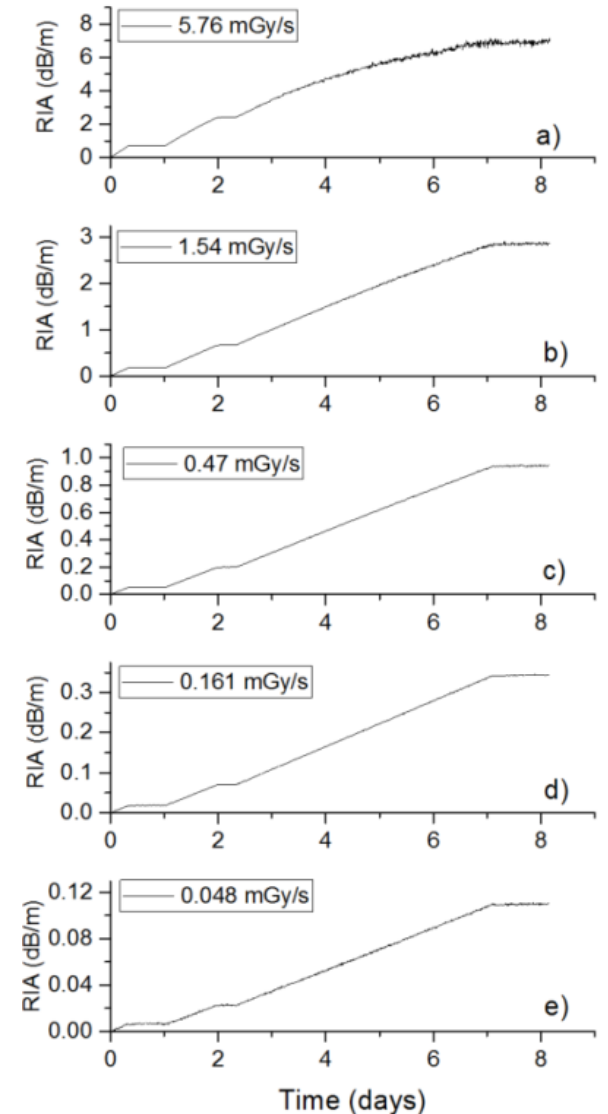
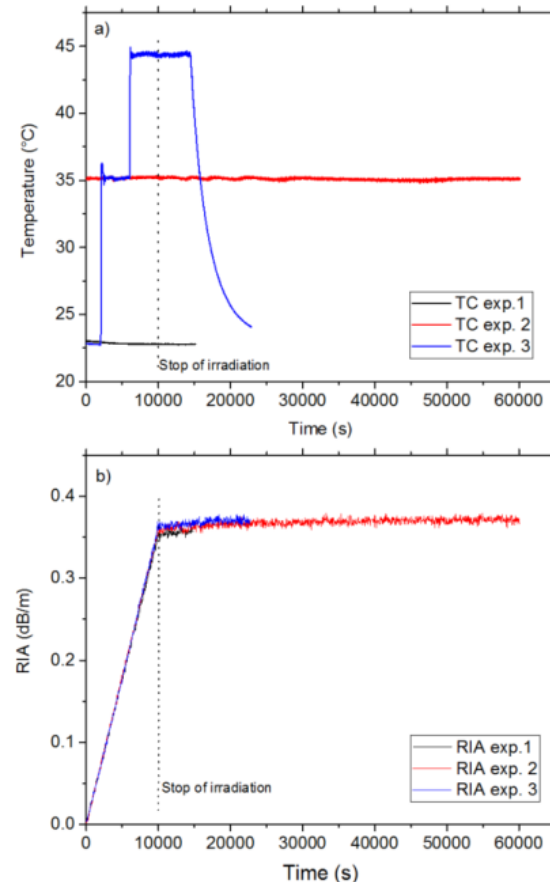
First implementation reported by *H. Henschel et al., Nucl. Instr. & Meth. in Phys. Res. A, vol. 526, no. 3, pp. 537–550, 2004*

Qualification and calibration of optical fibres for dosimetry

Most optical fibres are not suitable for dosimetry applications



D. Di Francesca *et al.*, *J. Lightwave Technol.*, 2019, doi: [10.1109/JLT.2019.2915510](https://doi.org/10.1109/JLT.2019.2915510).

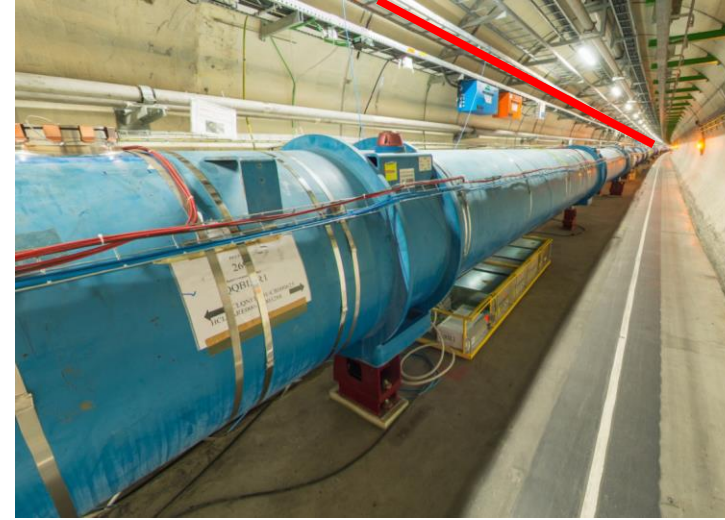


Key Features of DOFRS

- Well adapted for large facilities - several hundreds of meters up to 1 km
- Distributed 1D maps of the radiation dose - spatial resolution down to 1 m
- Online monitoring - temporal resolution of a few minutes
- All electronics installed in remote and radiation-free locations – measurement can be deported over km distances
- One cable -> multiple OFs -> multiple radiation sensitivities
- Information of the cumulated dose stored in the OF itself
- Cost Efficient
- Need to replace the OF sensors: cable blowing
- Possibility to reset and reuse some OF dosimeters by photobleaching (R&D phase)

DOFRS O&M

Status of DOFRS after LS2



Most important LS2 activities:

- Large procurement of OFs (sensors and auxiliary OFs)
- Qualification and calibration of all OF sensors
- Procurement of optical interrogators and control units
- Installations of rack and mini-racks
- Installations of the OF infrastructure
- Software development for automatic data acquisition and analysis (with BE-CEM-EPR)
- Commissioning of the systems

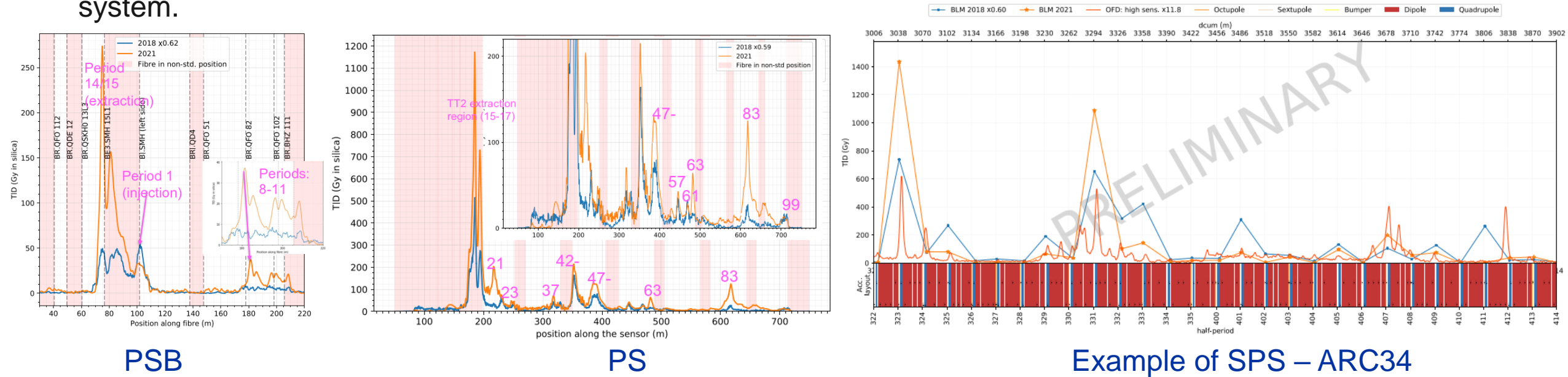
Four DOFRS systems installed:

- PSB, PS, SPS + TT20, 6 DS regions of Large Hadron collider
- More than **9 km of monitored area**
- **4 control units**
- **8 optical interrogators**
- 48*2 optical links (probed in both direction)
- about **97 km of total OF length** for the full **DOFRS infrastructure**
- OFs procured from three different OF manufacturers

DOFRS operation in 2021

Most important activities:

- Commissioning of all deployed systems and data acquisition in PSB, PS and SPS for the full operational year
- Commissioning of the systems and data acquisition in LHC (5 weeks)
- Development of the data visualization tools in collaboration with MCWG (K. BILKO)
- First (partial) hardware failure registered in PSB-DOFRS. No loss of information thanks to redundancy in the system.



Figures extracted from Overview of 2021 prompt radiation levels in the injector chain - K. BILKO *et al.* - IPP meeting 13th January 2022

DOFRS maintenance activities in 2021/2022

- Manufacturing of 15 km of new optical fibre cables for radiation sensing.
- Installation of new version of the LabVIEW control software for data acquisition and analysis in collaboration with BE-CEM-EPR (Rudy FERRARO)
- Preparation of all YETS maintenance activities
- Replacement of irradiated sensors in the PSB (230 m – 1 cable)
- Replacement of irradiated sensors in the PS (860 m – 2 cables)
- Replacement of irradiated sensors in the SPS (7 km – 13 cables)
- Re-commissioning of all systems before start of 2022 operation
- Repair of the PSB-OTDR

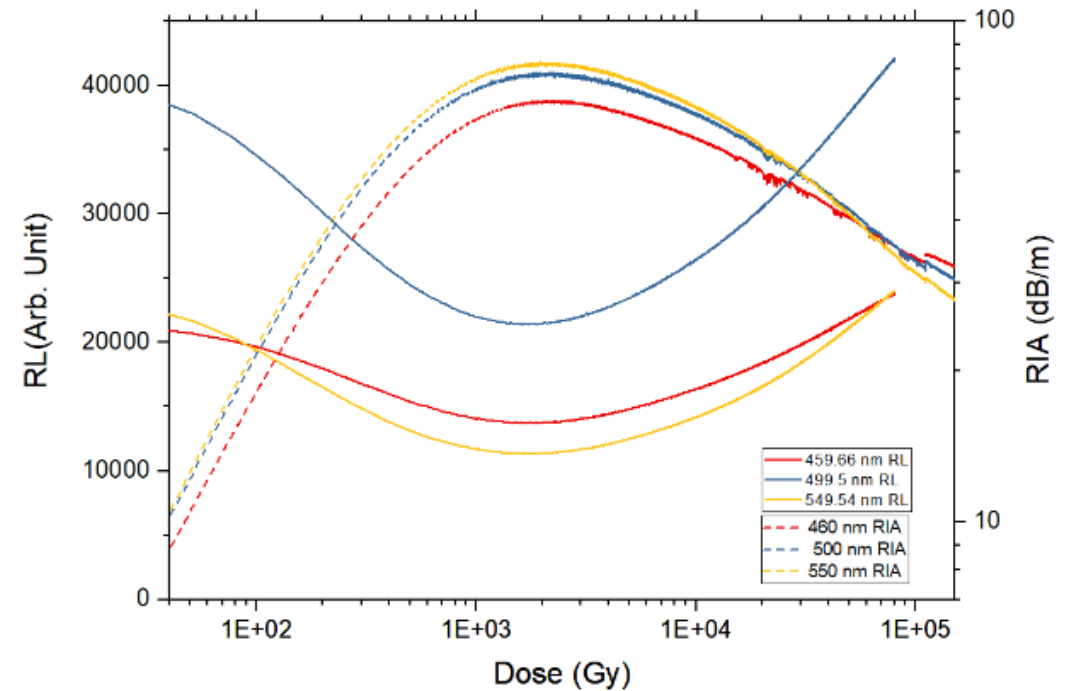
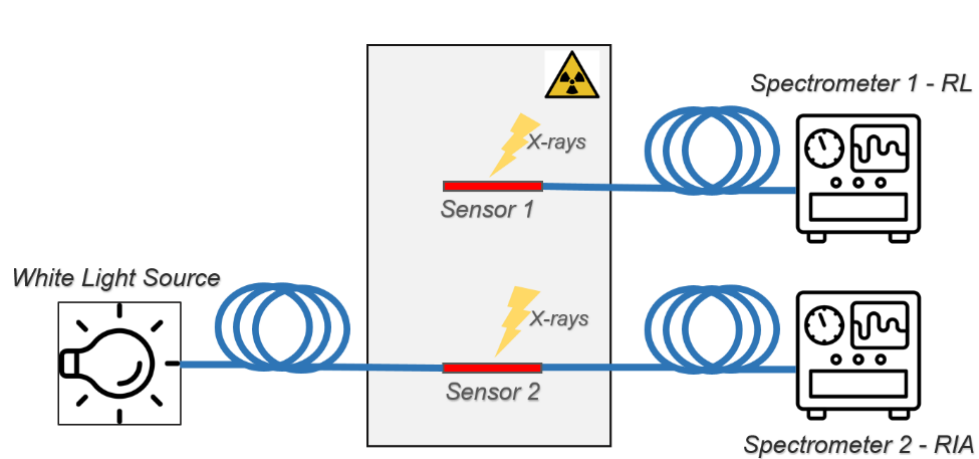
R&D activities

R&D activities

- Qualification, procurement and calibration of OFs for cable manufacturing (“yearly” activity).
- Design and qualification of new OFs for radiation sensing allowing targeting high radiation dose levels (> 10 kGy).
- Improvement of overall sensor performance by dedicated data analysis protocols.
- Passive point/distributed dose measurements: proof of feasibility in 2019.
- Feasibility study of reset and reuse of irradiated OF sensors to be completed by the end 2023 with first possible demonstration in the PSB booster during operational year 2024.
- Development and improvement of alternative OF radiation sensing techniques which are complementary to the ones used today.

R&D activities in 2021

Characterization of radio-luminescent OFs to carry out dose measurements with higher temporal resolution (N. Kerboub's presentation tomorrow)



20cm 5Gy/s

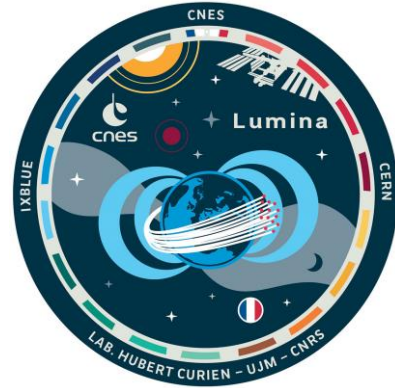
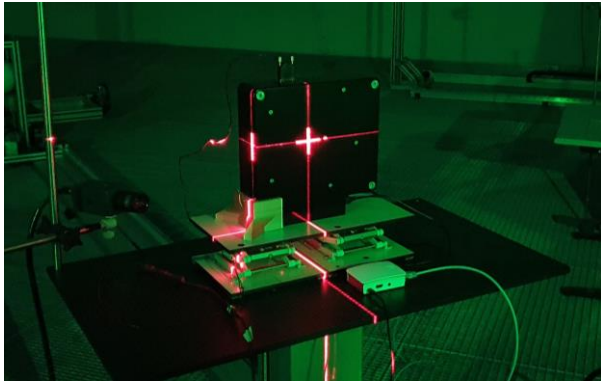
Example of combined RIA-RIE studies

R&D activities in 2021: LUMINA project

Our contribution:

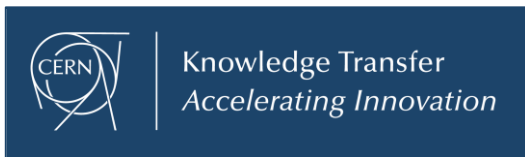
- Providing a **theoretical model** for the radiation response of the sensor
- Carrying out the **irradiation tests** to qualify and calibrate the LUMINA dosimeter.

Collaboration



DOFRS-like optical fibres dosimeters are now in operation on the International Space Station (ISS)

- Strong expertise developed in the domain thanks to the **R2E project** at CERN
- Key role of **Knowledge Transfer** group

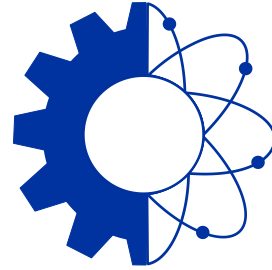
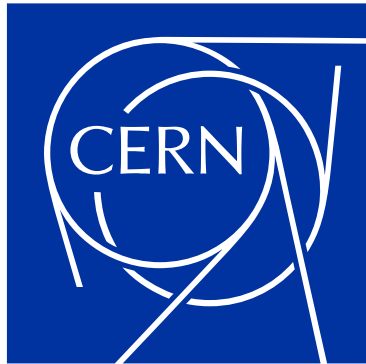


L'astronaute de l'ESA Thomas Pesquet avec l'expérience Lumina à bord de la Station spatiale internationale. (Crédit: ESA/NASA) (Image: CERN)

- <https://home.cern/fr/news/news/knowledge-sharing/cern-tested-optical-fibres-now-international-space-station>

Conclusions and Outlook

- In 2021, for the first time the DOFRS was operated in the SPS.
- PSB and PS were also monitored for the full year, as in 2018.
- All major maintenance/commissioning activities foreseen for the systems in PSB, PS, and SPS were carried out during YETS without issues and in reasonable time.
- In 2022, we will be measuring the dose levels with DOFRS systems deployed in the DS regions of LHC on the left and right of IP1, IP5 and IP7 for the first time.
- In parallel to DOFRS O&M, several R&D activities are carried out in the section in order to improve the performance of our systems as well as extending their capabilities.



**ENGINEERING
DEPARTMENT**

Thanks for you attention



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