# FIRST STEPS TOWARDS A DISTRIBUTED OPTICAL FIBRE RADIATION SENSING SYSTEM

I. Toccafondo[1,2], M. Brugger[1], F. Di Pasquale[2], E. Guillermain[1], J. Kuhnhenn[3]

[1]*European Organization for Nuclear Research (CERN), Switzerland.*

[2]*Scuola Superiore Sant'Anna (SSSA), Italy.*

[3]*Fraunhofer-Institut Naturwissenschaftlich-Technische Trendanalysen (INT), Germany.*

## Introduction and Motivations

In high energy accelerators or in physics experiments as well as space applications, ionizing radiation can:

- affect installed electronics
- limit equipment lifetime
- alter materials

In order to monitor radiation levels and being able to predict and mitigate these effects, an accurate radiation dosimetry is highly important but very challenging often due to two main reasons:

- monitoring of large areas
- extended dose range of interest

Distributed optical fiber sensors are:

- immune to EMI
- light weight and relatively small in size
- distributed with meter or sub-meter spatial resolutions
- highly accurate
- allowing for quasi-realtime measurements

**Promising for large space stations or long accelerator tunnels!**

## Requirements for a distributed optical fibre radiation sensor

For High Energy Physics Experiments

| Dose-rate range | Total absorbed dose | Total absorbed dose resolution | Spatial resolution | Temperature range |
|---|---|---|---|---|
| From a few µGy/s up to Gy/s | From a few 100 Gy up to 100 kGy | 10-100 Gy | < 1 m | 15°C – 35 °C Hot spots: 200°C |

For Space Applications:

- Very low doses inside space stations => 1 Gy over a few years
- 1 kGy over 15 years inside a GEO satellite
- Higher doses in space missions

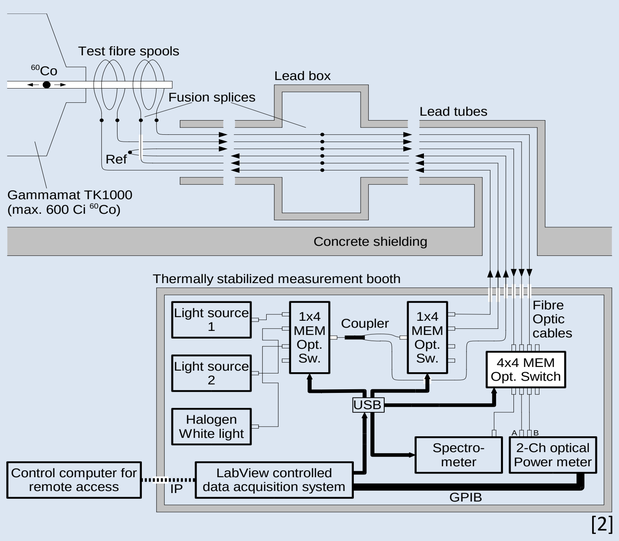
## Goals

- Investigating the response to ionizing radiation in terms of Radiation Induced Attenuation (RIA) of three selected P-doped optical fibres (1 MMF, 2 SMF) which could be suitable candidates for the radiation sensing system.
- Aiming for a first prototype test setup by carrying out distributed measurements with an OTDR.

## First Results and Discussion

The measurements have been carried out at Fraunhofer INT using the Gammamat TK1000 60Co as source of irradiation.

| Fiber Type | Total Dose (Gy) | Dose Rate (Gy/s) | λ (nm) |
|---|---|---|---|
| MMF J-Fiber | 60E3 | 0.5 - 1.7 | 830 1312 |
| SMF Sample A | 18E3 | 46.7E-3 | 1312 1570 |
| SMF Sample B | 60E3 | 153E-3 | 1312 1570 |

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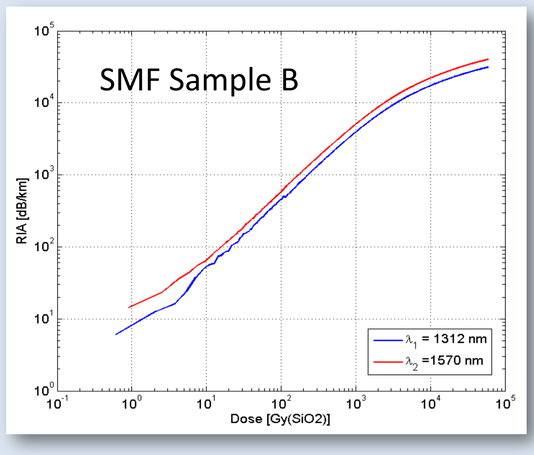
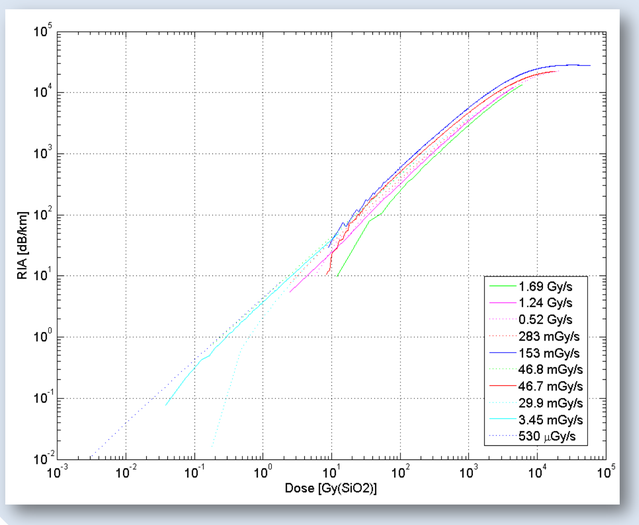



### SMF Sample A

- Linear behavior up to around 1 kGy
- Sensitivity of about 80 µdB/m/Gy and 175 µdB/m/Gy at 1312 nm and 1570 nm
- Low dynamic range

### SMF Sample B

- Linear behavior up to around 850 Gy
- Sensitivity of about 3.5 mdB/m/Gy and 4.5 mdB/m/Gy at 1312 nm and 1570 nm
- Not saturating at 60 kGy

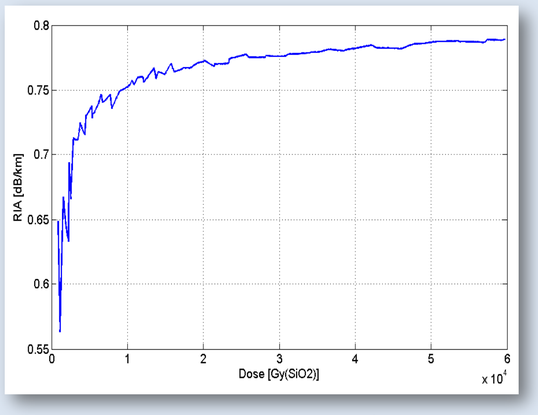


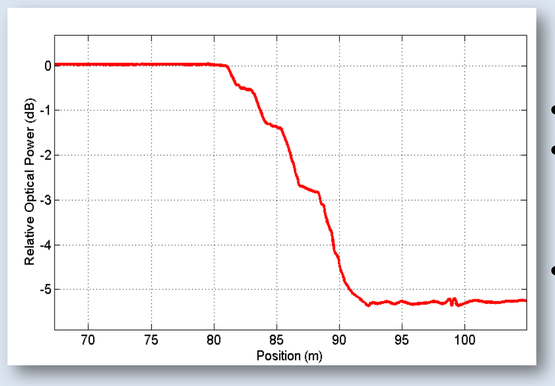

### MMF J-Fiber

- RIA as function of dose shows: linearity up to ~2 kGy
- A couple of mdB/m/Gy of sensitivity
- A moderate dose rate dependency

The dose rate dependency can be overcome by estimating the RIA variation which is sufficient to correlate to the dose variation with a 15% uncertainty.

- The ratio between the attenuation values shows a good agreement between the measurements carried out at SCK-CEN and those at Fraunhofer INT for SMF Sample B => good reproducibility




- Slope of the steps => RIA in dB/m
- 5-20% uncertainty on the event localization due to noise and limited spatial resolution
- OTDR measurements promising allowing to estimate the dose with 10%-30% uncertainty.

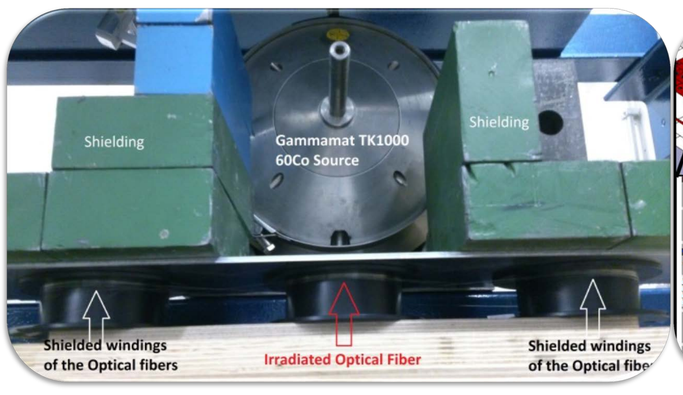
## Conclusions

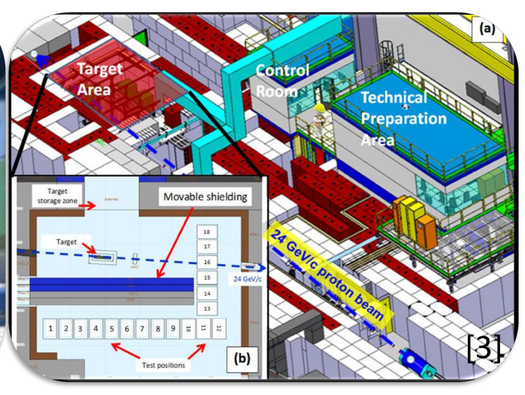
P-doped fiber suitable for radiation sensing:

- SMF Sample A and MMF J-Fiber are suitable for radiation sensing up to 1-2 kGy => too low for our scope
- SMF Sample B should be further investigated as it shows a high sensitivity to radiation and didn't saturate yet at 60 kGy
- Promising OTDR results allowing to estimate the dose with 10%-30% uncertainty

## Further Work

- Seeking for the optimum fiber for a specific application (i.e. high energy accelerators)
  - different concentration of P-dopant
  - different dopants
  - Prototype in the new mixed field facility CHARM
  - variety of particle spectra representative of several radiation environments
  - dose rate ranging from a few µGy/s up to a few tens of Gy/s

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## References

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