Distributed Optical Fiber Radiation and Temperature Sensing

D. Di Francesca, G. Li Vecchi, K. Kandemir and Y. Kadi

With contributions from EN-SMM, EN-STI, EN-EL
and the MOPERE group of the University of St Etienne

European Organization for Nuclear Research, Geneva, Switzerland

Outline

I.   **Motivations and Key Features**

II. **Working principle of the DOFRS**

III. **Implementation of DOFRS at CERN**

IV. **Real case scenario**

V.   **Conclusions and future prospects**

DOFRS: Motivations and Key Features

Providing radiation maps of the accelerators and online monitoring
Estimating equipment lifetime and preventing R2E-related failures

➢ **Well adapted large facilities**
➢ **Distributed 1D maps of the radiation dose**
➢ **Online monitoring**
➢ **All electronics installed in remote and radiation-free locations**
➢ **Cost effectiveness**
➢ **Easy replacement of OF sensors via cable blowing**
➢ **One cable -> multiple OFs -> multiple radiation sensitivities**
➢ **Information of the cumulated dose stored in the OF itself**
➢ **It also allows to perform distributed temperature measurement**

How does it work?

Radiation effects on silica-based OFs

Three main _macroscopic effects_ induced by radiation in OF:

➤ **Radiation Induced Attenuation (RIA)**
Due to the generation of point defects and related absorption bands

➤ **Radiation Induced Emission (RIE)**
Due to Cherenkov radiation as well as luminescence from excited color centers

➤ **Radiation Induced Refractive Index Change (RIRIC)**
Due to compaction phenomenon and appearance of defect related absorption bands (via the Kramers-Kronig relations)

Radiation effects on silica-based OFs

Three main _macroscopic effects_ induced by radiation in OF:

➢ **Radiation Induced Attenuation (RIA)**
Due to the generation of point defects and related absorption bands

➢ **Radiation Induced Emission (RIE)**
Due to Cherenkov radiation as well as luminescence from excited color centers

➢ **Radiation Induced Refractive Index Change (RIRIC)**
Due to compaction phenomenon and appearance of defect related absorption bands (via the Kramers-Kronig relations)

Working principle of the DOFRS

The **Radiation Induced Attenuation** (RIA) is the phenomenon used in the DOFRS

Optical Time Domain Reflectometer

Sensor calibration

RIA (dB/km)

Dose (Gy)

Dose (Gy)

Position alond the OF sensor (m)
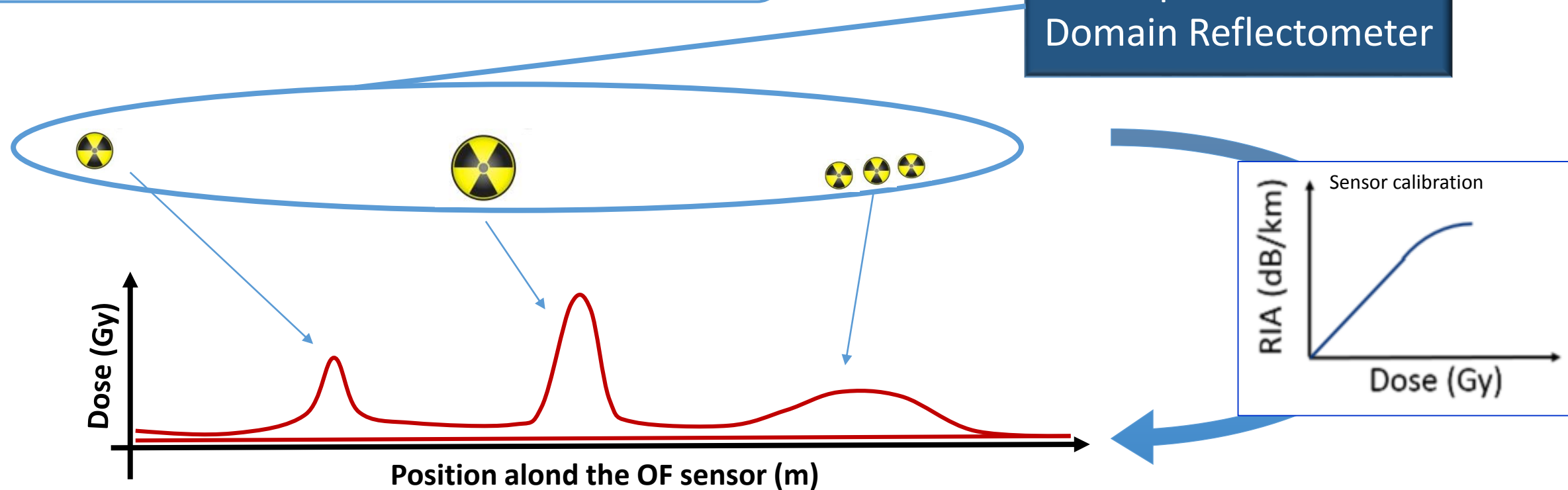
H. Henschel et al., *Nucl. Instrum. Methods Phys. Res. B*, 69, 307, 1992.
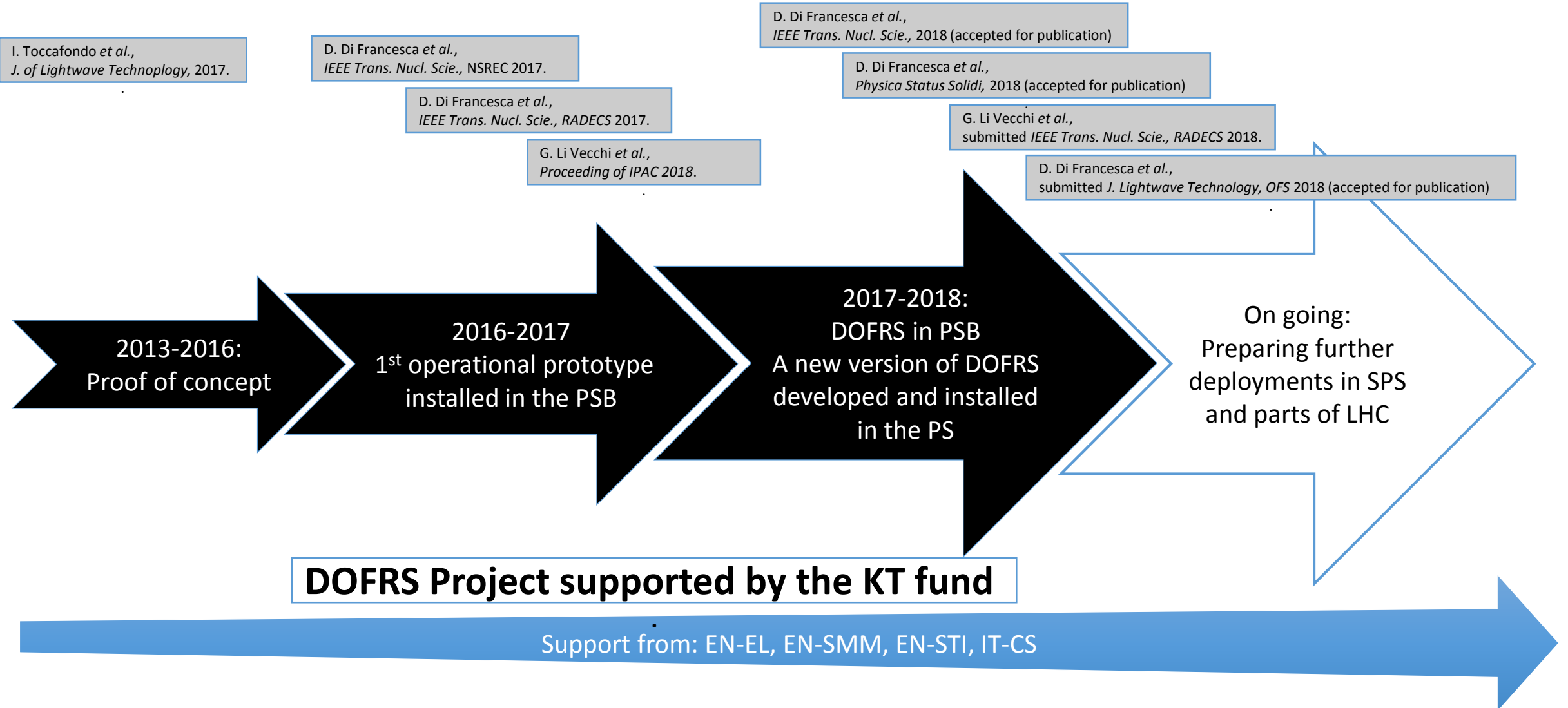
Selection of the OF radiation sensor

➢ **Properties of a P-doped OF in the NIR:**
  - **Monotone dose dependence**
  - **No dependence on the dose rate**
  - **No dependence on the irradiation temperature**
  - **No recovery processes: thermal-bleaching, photo-bleaching**
  - **Absence of complicated effects related to successive irradiations**

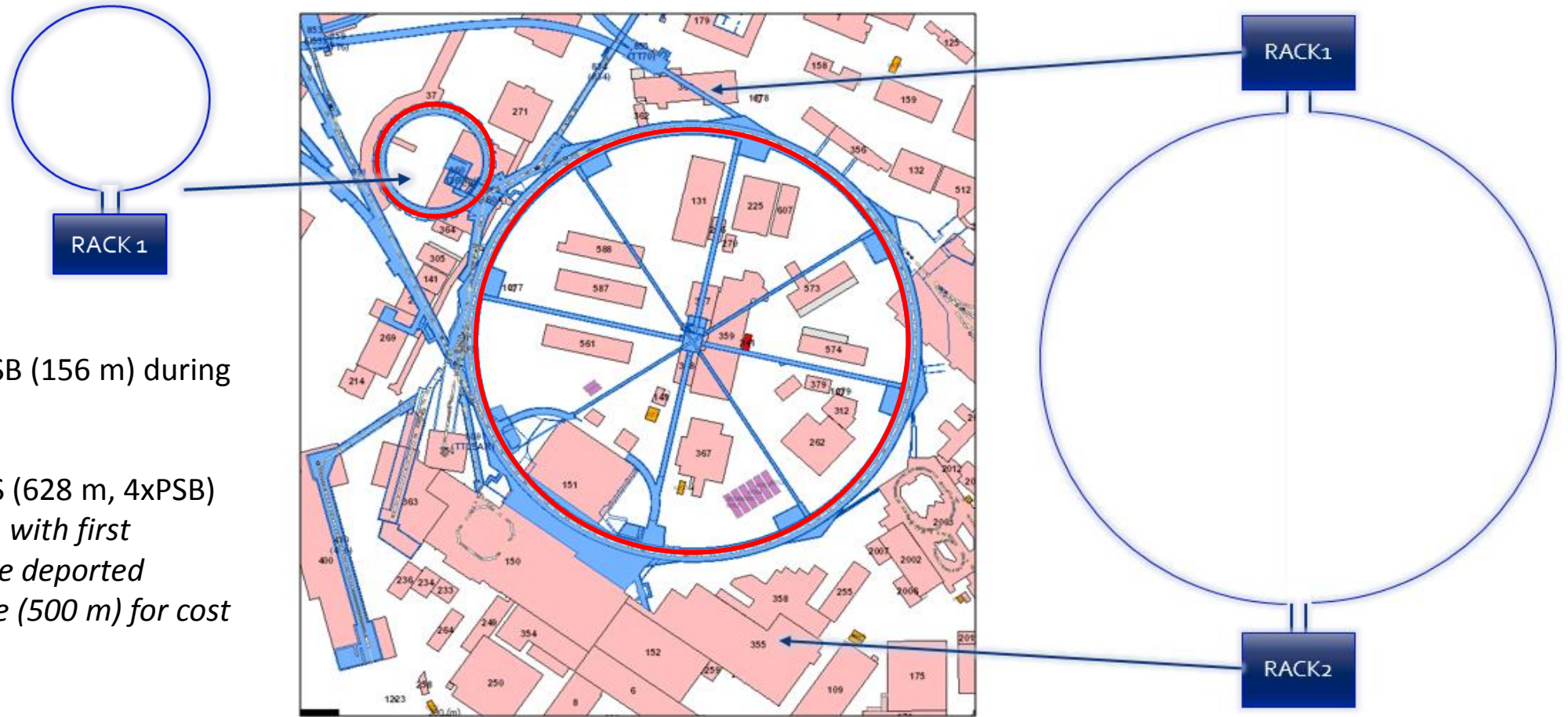➢ **Calibration of the sensor under ^{60}Co radiation source**

➢ **Qualification of the sensor for employment in <u>mixed field radiation environment</u>**

Implementation of DOFRS at CERN

DOFRS project at CERN

I. Toccafondo *et al.*,
J. of Lightwave Technoplogy, 2017.

D. Di Francesca *et al.*,
IEEE Trans. Nucl. Scie., NSREC 2017.

D. Di Francesca *et al.*,
IEEE Trans. Nucl. Scie., RADECS 2017.

G. Li Vecchi *et al.*,
Proceeding of IPAC 2018.

D. Di Francesca *et al.*,
IEEE Trans. Nucl. Scie., 2018 (accepted for publication)

D. Di Francesca *et al.*,
Physica Status Solidi, 2018 (accepted for publication)

G. Li Vecchi *et al.*,
submitted *IEEE Trans. Nucl. Scie., RADECS* 2018.

D. Di Francesca *et al.*,
submitted *J. Lightwave Technology,* OFS 2018 (accepted for publication)

2013-2016:
Proof of concept

2016-2017
1st operational prototype
installed in the PSB

2017-2018:
DOFRS in PSB
A new version of DOFRS
developed and installed
in the PS

On going:
Preparing further
deployments in SPS
and parts of LHC

DOFRS Project supported by the KT fund

Support from: EN-EL, EN-SMM, EN-STI, IT-CS

Distributed Optical fiber sensor installed in the PSB and PS

- Deployment in the PSB (156 m) during EYETS 2016/17

- Deployment in the PS (628 m, 4xPSB) during YETS 2017/18, *with first implementation of the deported measurement scheme (500 m) for cost effectiveness*
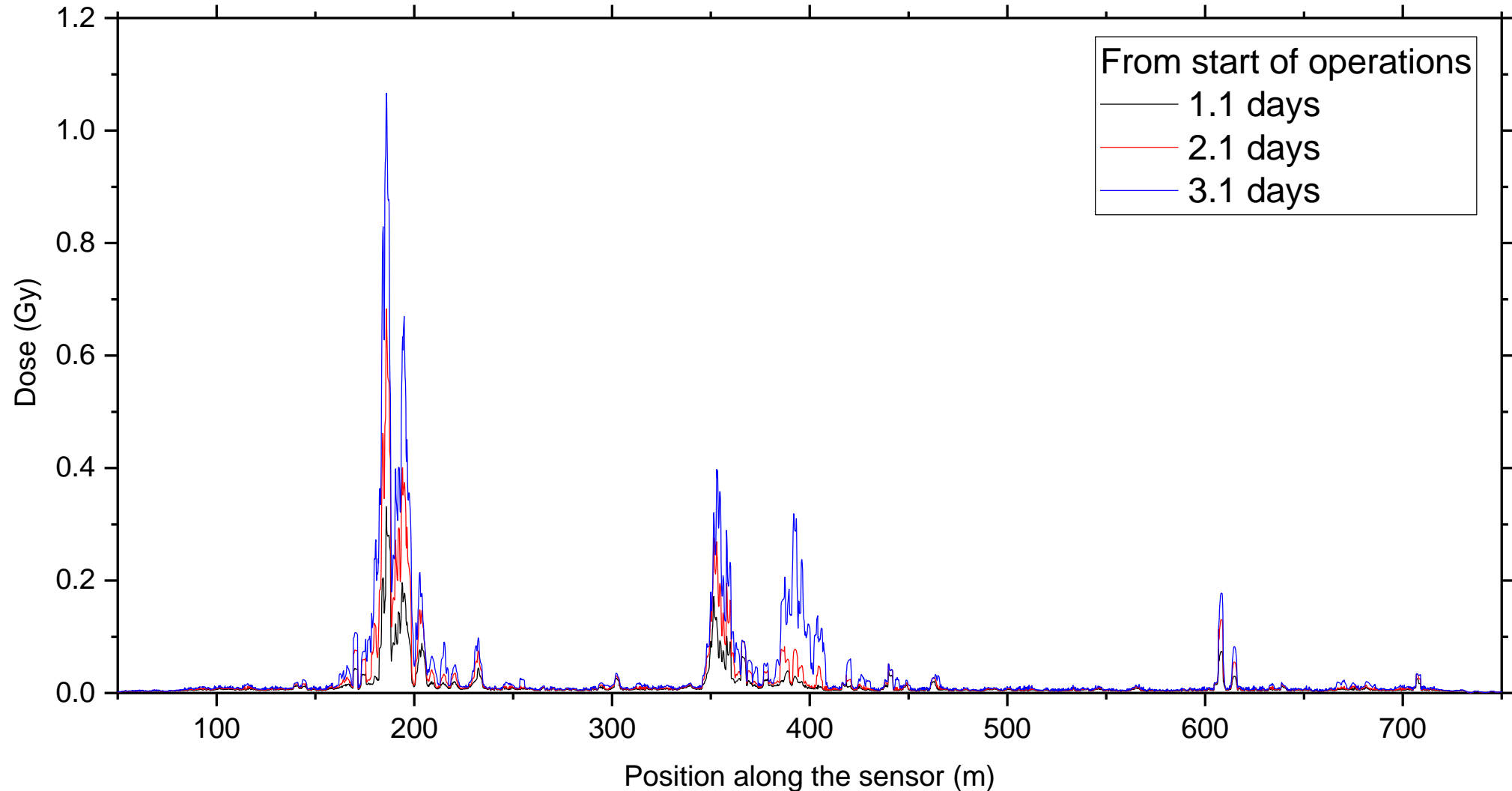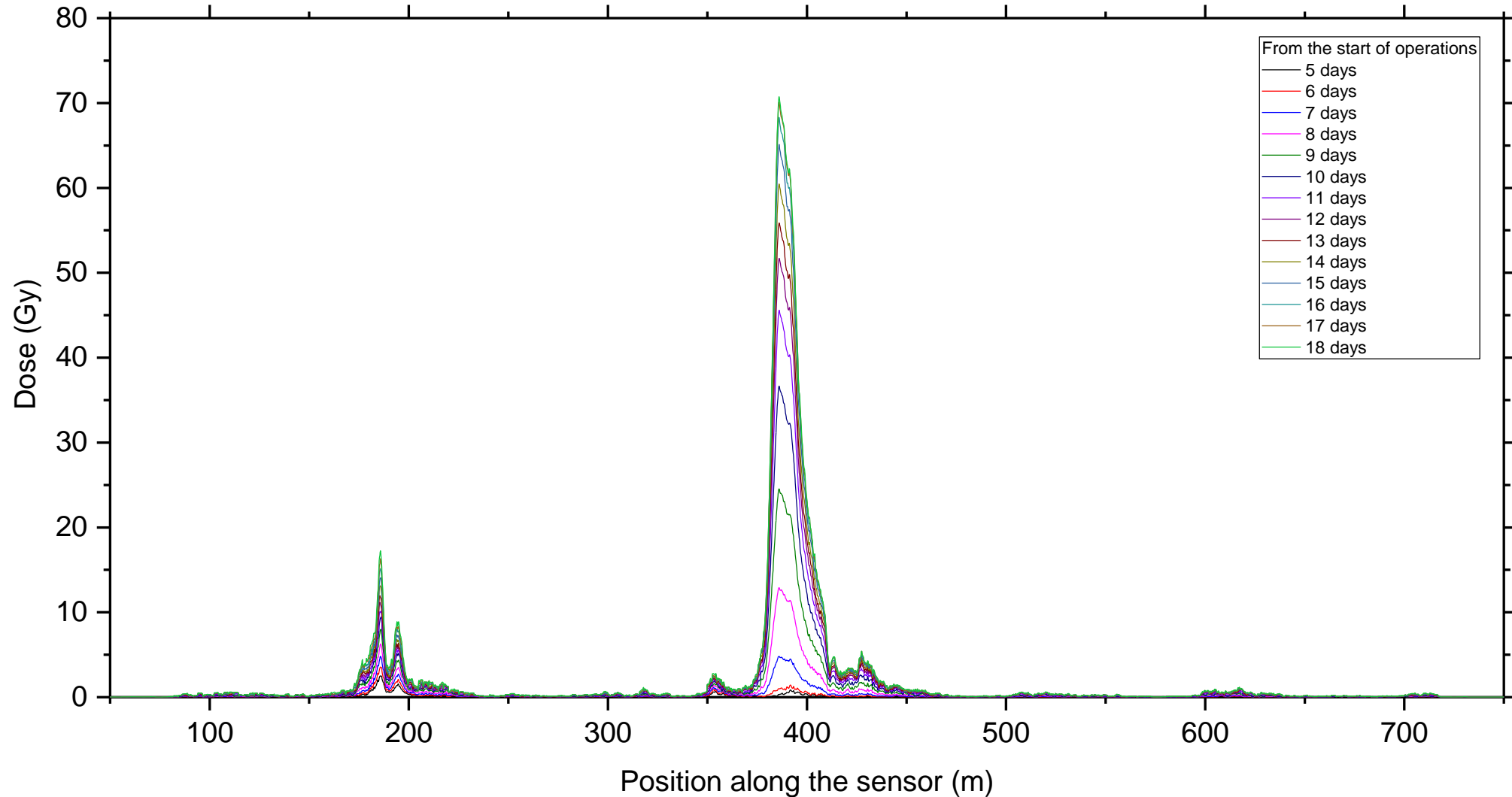
Real case scenario:
Deployment of DOFRS in the PS

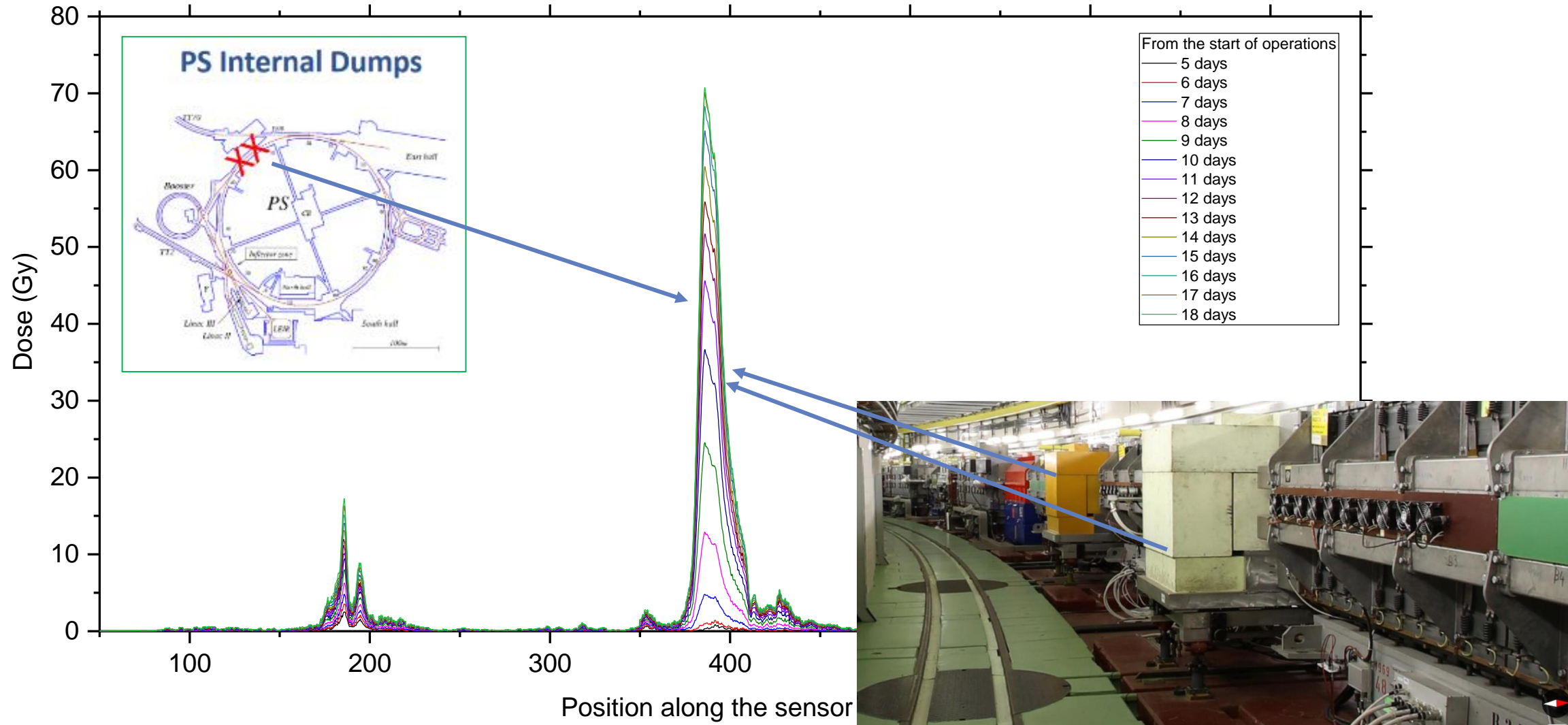# The sensor is placed on a cable tray on the inner side wall of PS tunnel

PR - PR.SD.. Date captured: 2017-03-27
Please note that the situation may have changed since the picture was taken

Distributed Optical fiber sensor installed in the PS

Distributed Optical fiber sensor installed in the PS

Distributed Optical fiber sensor installed in the PS

Distributed Optical fiber sensor installed in PS
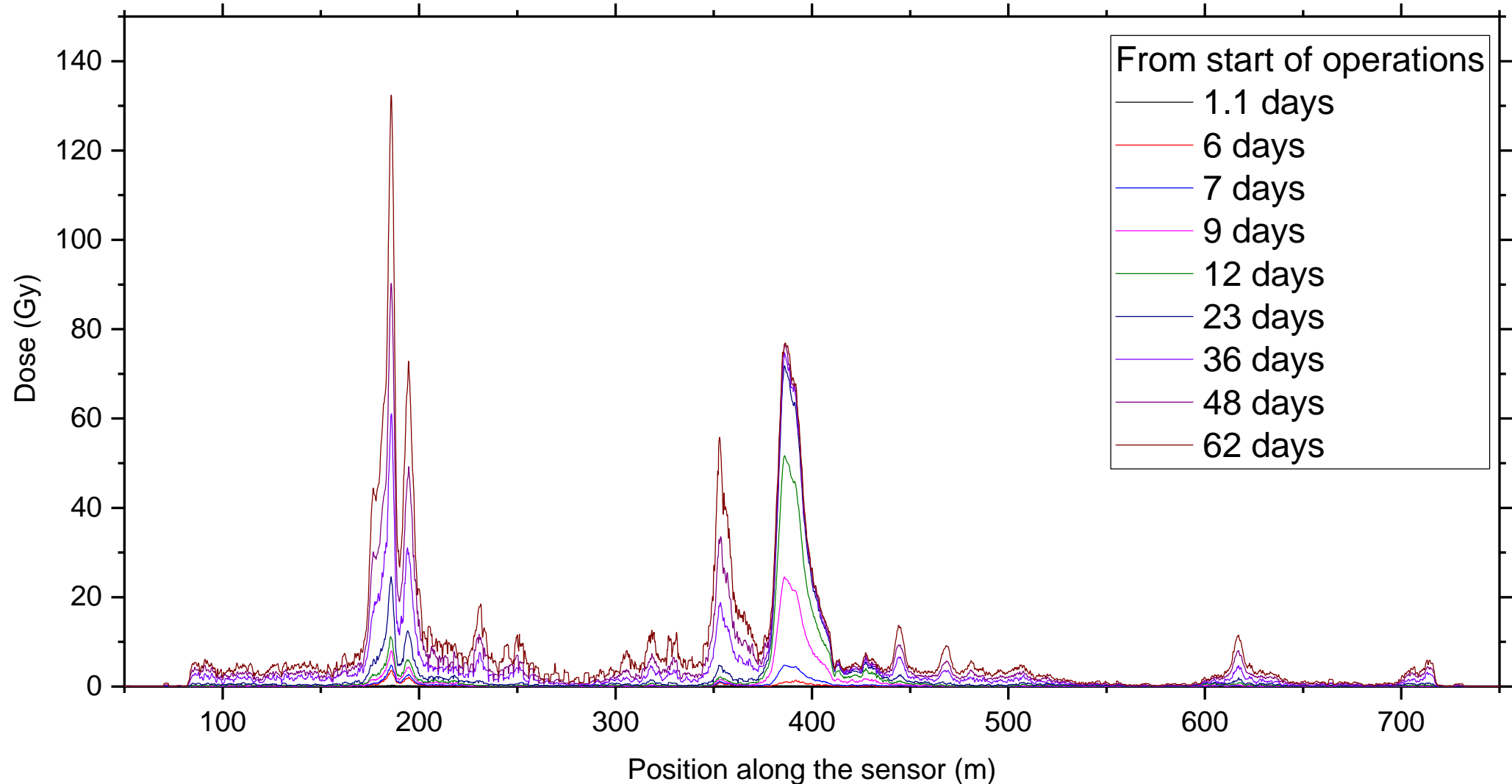
Conclusions and Future prospects

Conclusions

DOFRS allows to perform <u>online and distributed</u> measurements of the TID along hundreds of meters.

We can achieve a spatial resolution of ~1 m.

Dose measurement from few Gy to ten kGys, by using different radiation sensors.

DOFRS was successfully deployed in the first two circular accelerators of the injector chain and is currently acquiring data.
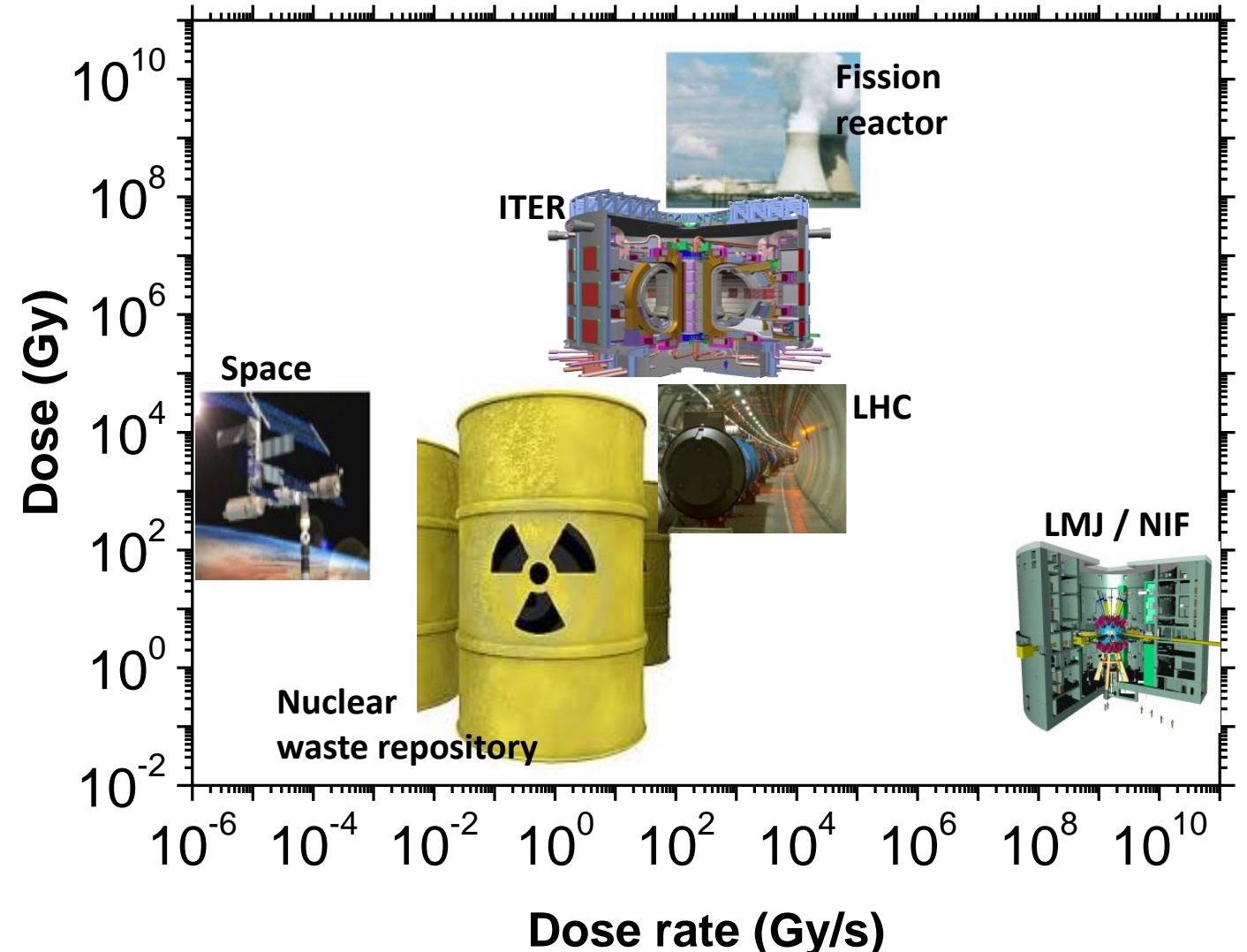
Future prospects at CERN

- Installation of DOFRS in the whole SPS (~7 km) and TT20

- Installation of DOFRS in six parts of LHC (~ 3 x PS):
  - DS region left and right of IP1
  - DS region left and right of IP5
  - DS region left and right of IP7
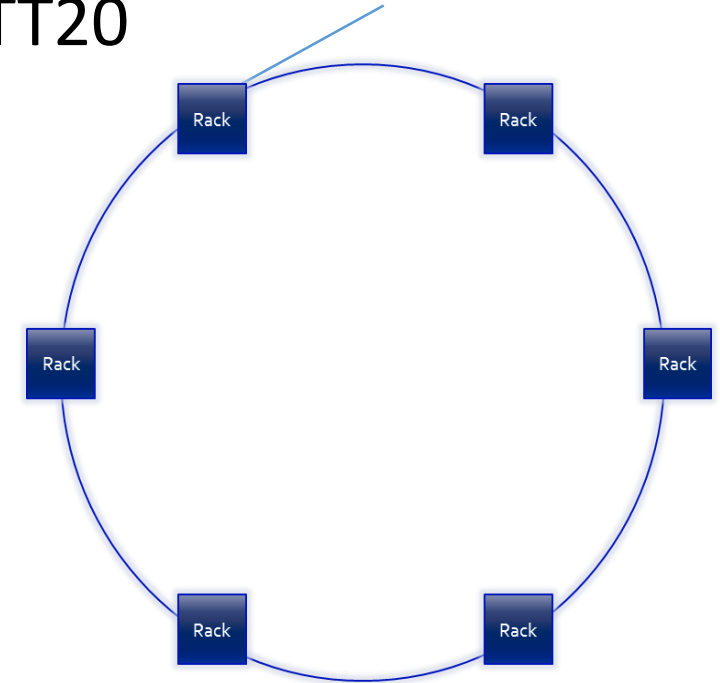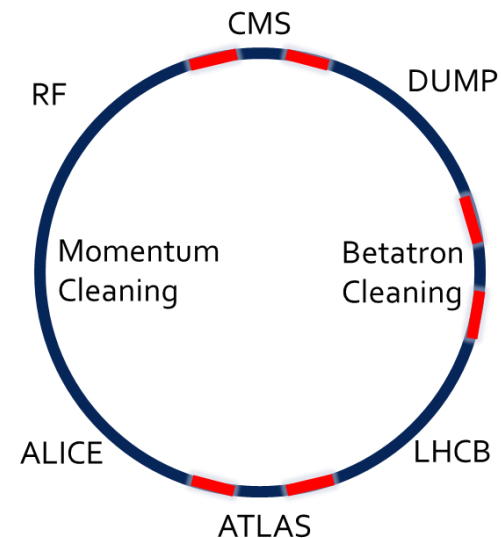
Technology of interest outside CERN

DOFRS project selected by
12 students during the
10th NTNU Screening Week

R&D and new ideas!

Thank you for your attention

Diego Di Francesca

CERN EN/EA

R2E Project

@ diego.di.francesca@cern.ch

www.cern.ch