Plastic Scintillator under Ultra-High Dose Rate Electron Beam: Long Term Damages and Changes in Optical Response

Boby Lessard[1,2], Alexandra Bourgouin[3], Luc Beaulieu[1,2], Andreas Schüller[3] et Louis Archambault[1,2]

1 Département de physique, génie physique et optique, et Centre de recherche sur le cancer, Université Laval

2 CHU de Québec – Université Laval et CRCHU de Québec, Québec, Canada

3 Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Lower Saxony, DE

Disclosure statement

Nothing to disclose

Context: Scintillation Dosimetry

- What is a scintillation detector?
- Advantages of scintillation detectors:
  - ✓Water-equivalent
  - ✓Real-time measurements
  - ✓Excellent spatial (mm) and temporal (ns) resolution

Context: Scintillation Dosimetry

- What is a scintillation detector?
- Advantages of scintillation detectors:
  - ✓Water-equivalent
  - ✓Real-time measurements
  - ✓Excellent spatial (mm) and temporal (ns) resolution

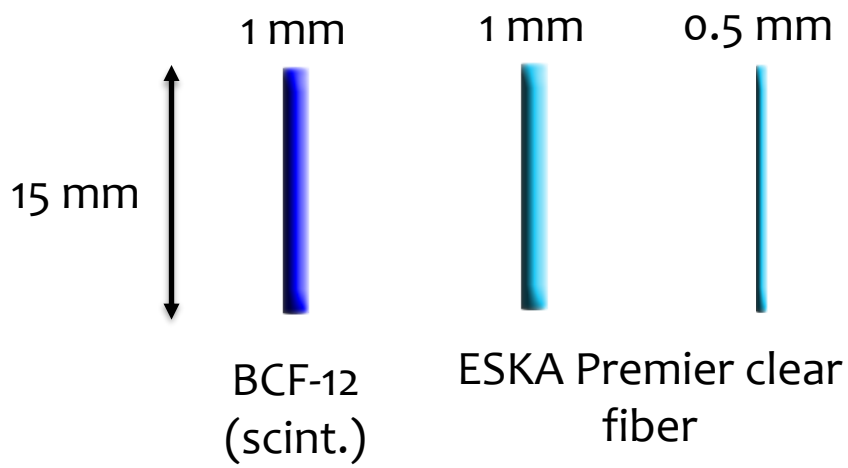
… but, are their properties altered by radiation damages?

Goal of the Project

- **What are the long term effects of ultra-high dose rate (UHDR) electron radiation on scintillation dosimeters?**
  - **Effects on light transmission efficiency?**
  - **Effects on scintillation efficiency?**

Irradiated Samples

- Small samples of clear and scintillating fibers irradiated under UHDR electron beam



- Three similar trials performed for each irradiation dose
- BCF-12 → Polystyrene core; ESKA Premier → PMMA core

Irradiation Conditions

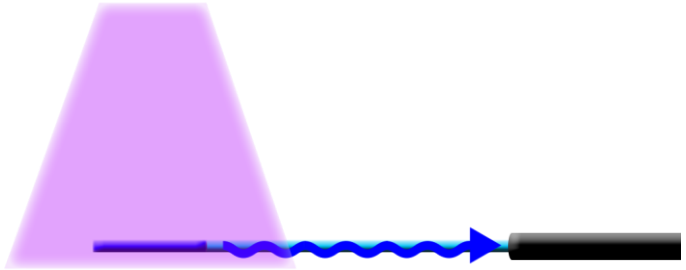
- Metrological Electron Accelerator Facility (MELAF) at PTB, Germany

- Irradiation doses: 0 kGy, 20 kGy, 50 kGy, 100 kGy
- Tests carried out at 20 MeV, 5 Hz PRF, pulse width of 2.5 µs
- Dose around 6 Gy per pulse

Experimental Measurements

- Scintillation and light transmission measurements were performed before and after the UHDR irradiation.

Scintillation measurements: Scintillators excited via UV light (~400 nm)

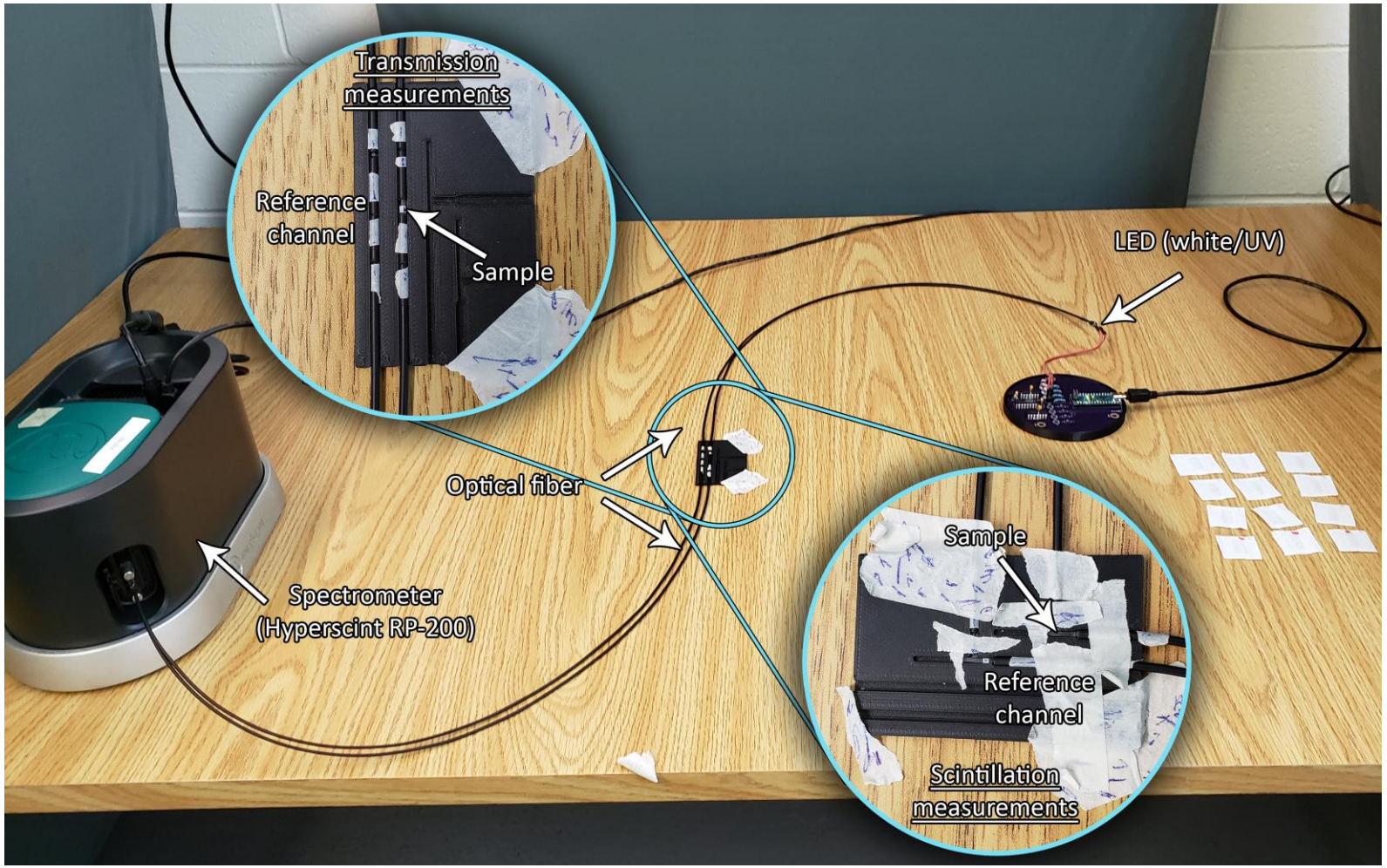


Transmission measurements: White light injected into the sample

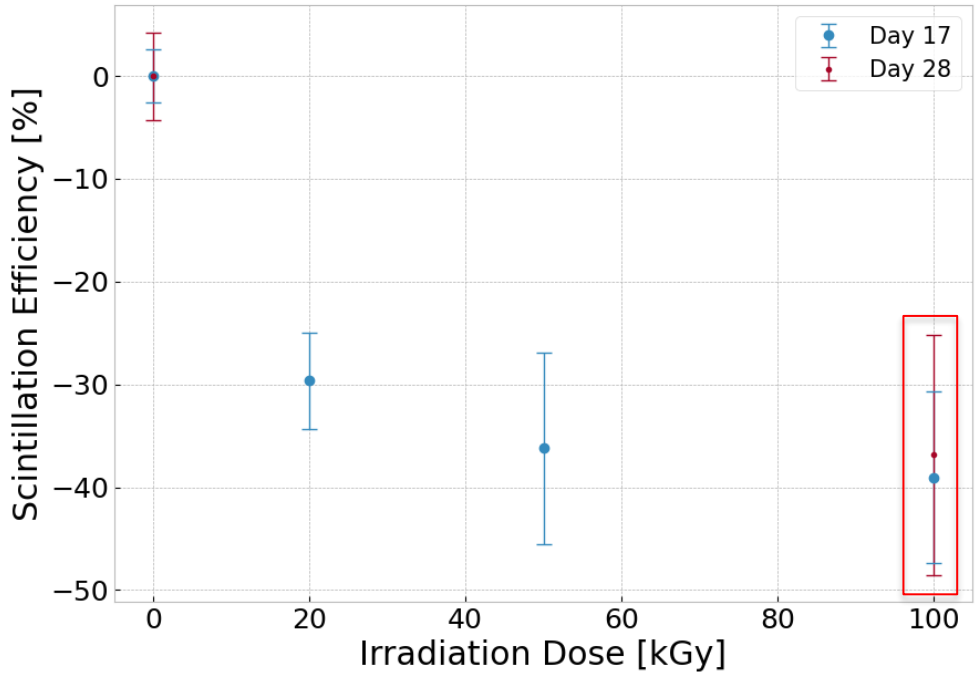
- Measurements done using the Hyperscint RP200 platform (*Medscint inc.*, Canada), 17 days and 28 days after the irradiation

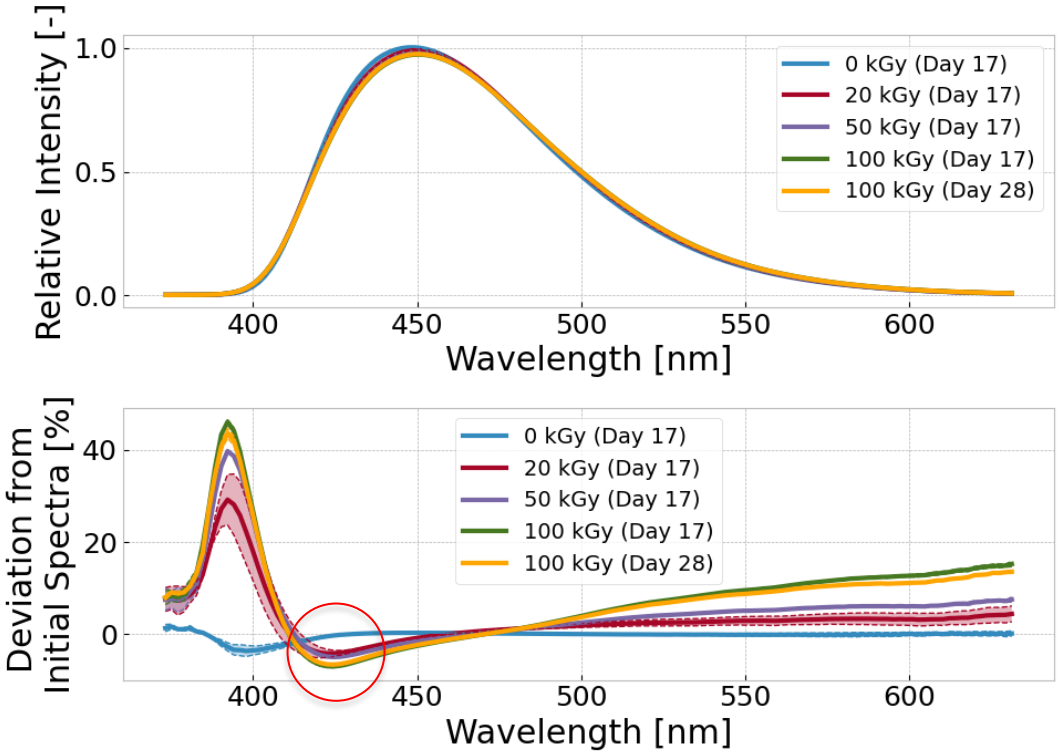
Experimental Setup

- 2-channel measurements
  - Reference channel
  - Measurement channel, with the sample of interest
- Samples always placed in jackets with the same orientation
- Each measurement repeated 5 times
- 4 doses, 3 trials, 3 different samples → 36 samples



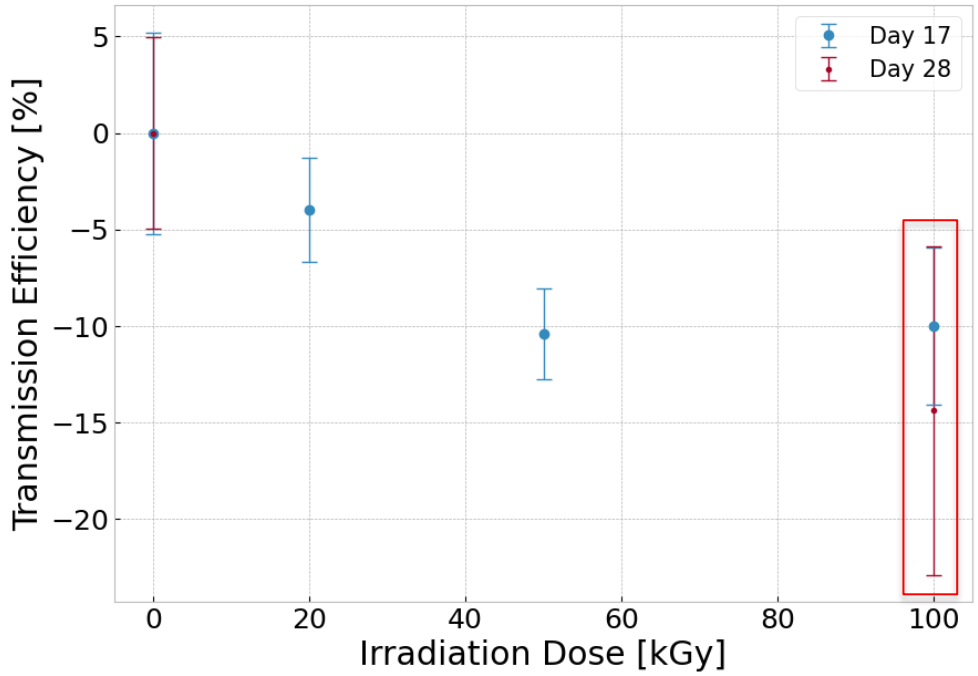
Results: Scintillation (BCF-12)

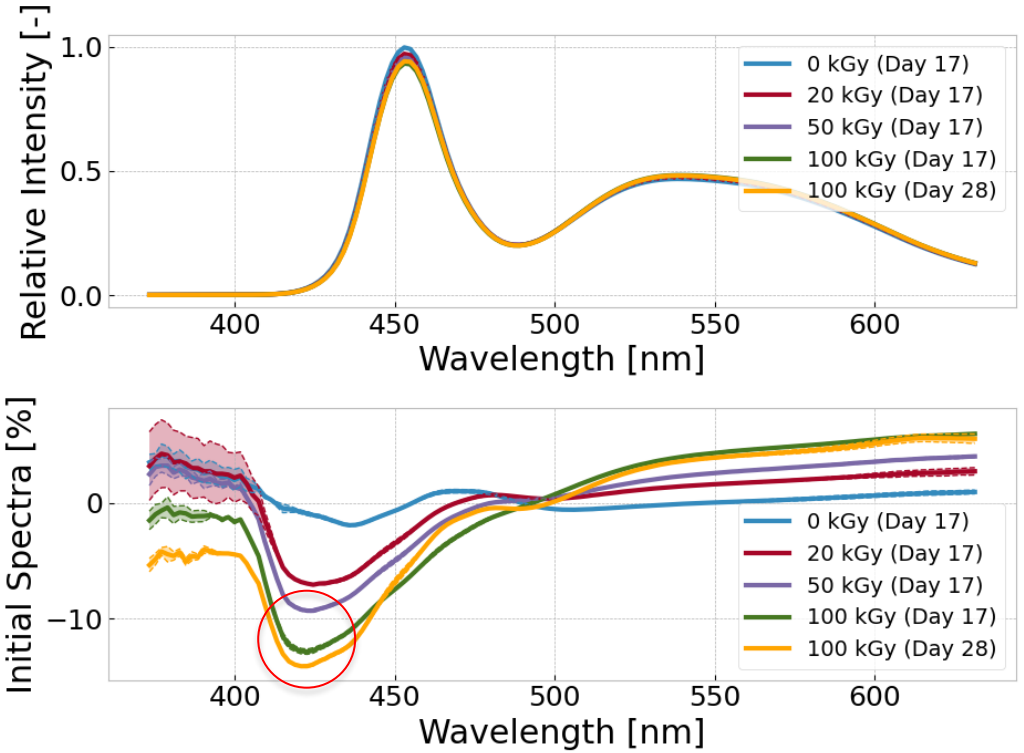




- At 100 kGy: Decrease of (39 ± 8) % at day 17
  - Decrease of (37 ± 12) % at day 28 → no increase/decrease with time
- Decrease more important around 425 nm

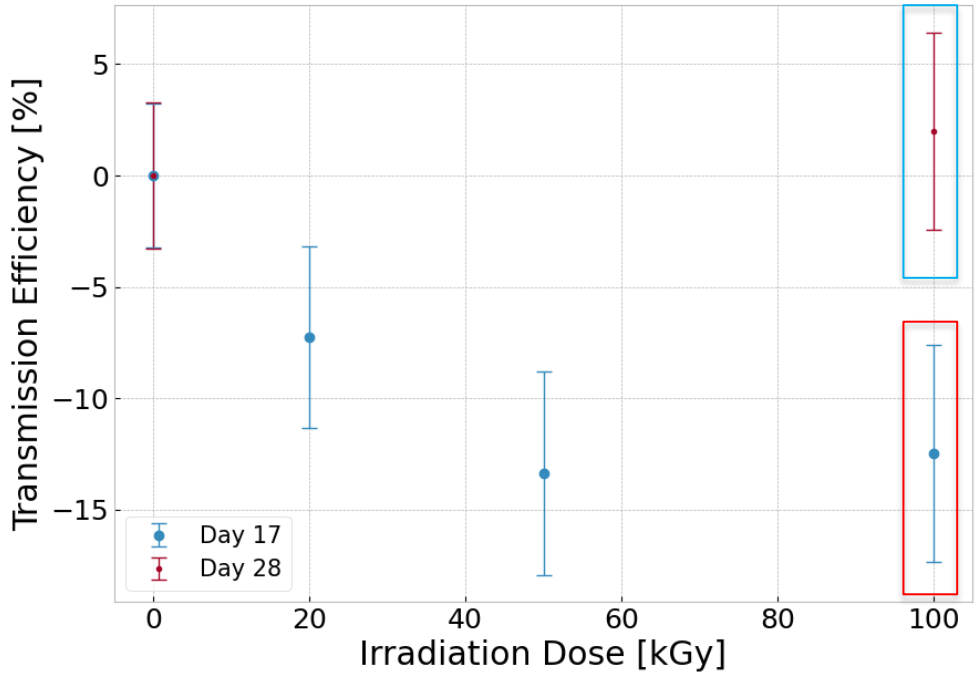
Results: Transmission (BCF-12)

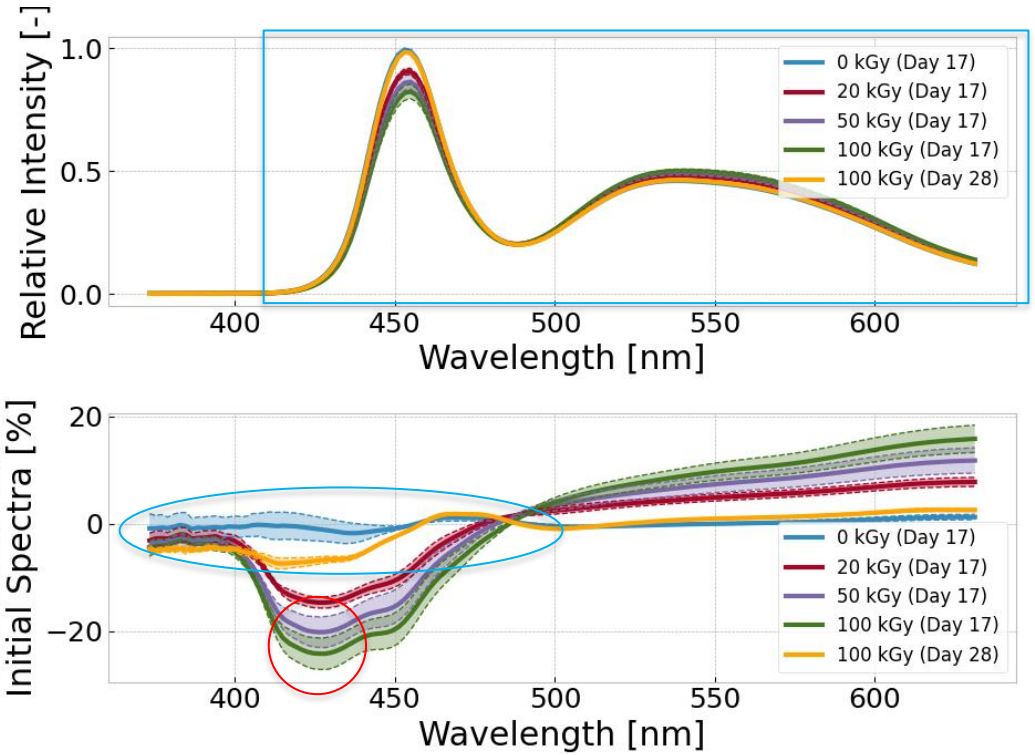




- At 100 kGy: Decrease of (10 ± 4) % at day 17
  - Decrease of (14 ± 8) % at day 28 → no increase/decrease with time
- Decrease more important around 420 nm

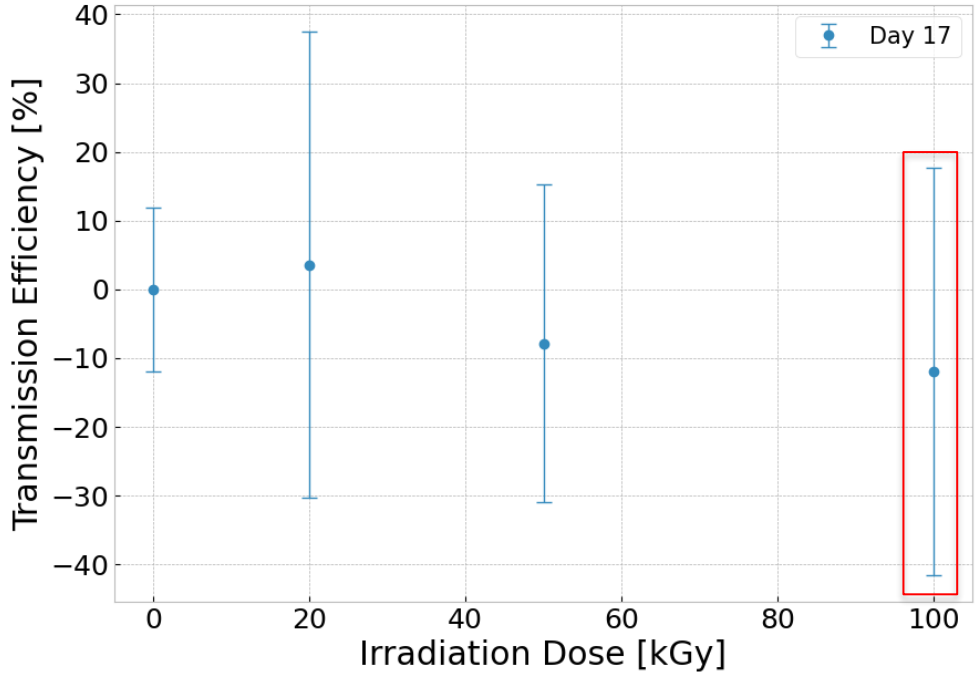
Results: Transmission (ESKA 1 mm)

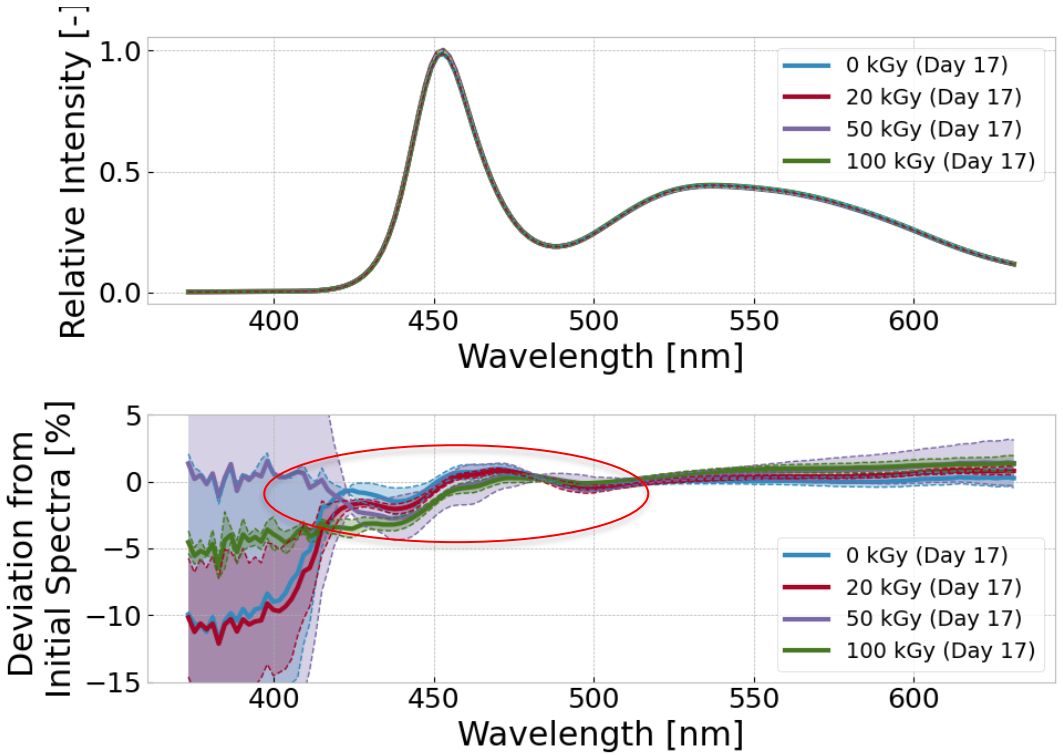




- At 100 kGy: Decrease of (12 ± 5) % at day 17
  - Increase of (2 ± 4) % at day 28 → Increase in efficiency with time! (Influence of oxygen?)
- Decrease more important around 425 nm
  - Around 425 nm: increase by ~20% for 100 kGy within 9 days!

Results: Transmission (ESKA 0.5 mm)





- At 100 kGy: Decrease of (12 ± 30) % at day 17 (same mean value as ESKA 1 mm, but large uncertainties)
- No apparent decrease as a function of the wavelength…

Conclusion

- Efficiency decrease always around 420-425 nm (blue region)
- Damages more important for scintillation
- Non-linear decrease with dose
- **Important drop in scintillation efficiency at high dose**
  - **No recovery in time (scintillation)**
  - **Must be accounted for when manufacturing/using scintillation detectors**

Summary of the behavior at 100 kGy

Sample	Efficiency Decrease at 100 kGy [%]	Change over 9 days
BCF-12 (Scint.*)	39 ± 8	Nothing
BCF-12 (Trans.)	10 ± 4	Nothing
ESKA 1 mm	12 ± 5	Potential full recovery
ESKA 0.5 mm	12 ± 30	Unknown

* Scintillation and transmission

Acknowledgements

Research group at Université Laval

Medscint Team

This project 18HLT04 UHDpulse has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

EMPIR EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Alexandra Bourgouin (PTB)

THANK YOU FOR LISTENING!

CENTRE DE RECHERCHE SUR LE CANCER

AXE ONCOLOGIE

CHU de Québec

NSERC CRSNG

UHDpulse

medscint

UNIVERSITÉ LAVAL

GRPM

PTB