RECOVERY OF PLASTIC SCINTILLATORS AFTER RADIATION DAMAGE BY UHDR PROTONS

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INTRODUCTION

- Protons can reach deep-seated tumours: high potential for FLASH radiotherapy (RT)
- Safe clinical translation of FLASH-RT requires robust quality assurance
  → accurate dosimetry of ultra-high dose rates (UHDRs)
- Water equivalent and fast plastic scintillation detectors (PSDs)
- PSDs have radiation damage sensitivity
  → Characterize long-term recovery processes

METHODS

- 5-channel PSD (Fig. 1a) damaged by 10.4 kGy delivered with UHDR protons (~255 Gy/s)
- Tracking of response 3-256 days after radiation damage, with TrueBeam linac (Fig. 1b)
- Output recovery measured with 6 MV beam
- Spectral recovery measured with 90 kV tube, and quantified using spectral centroid (SC) and peak ratio (PR) metrics

$$SC = \frac{\sum_{n=0}^{N=136} I(n)\lambda(n)}{\sum_{n=0}^{N=136} I(n)}\ ;\ PR = \frac{I(n=1)}{I(n=2)}$$

$I(n)$: Intensity value of bin n,
$\lambda(n)$: wavelength of bin n.

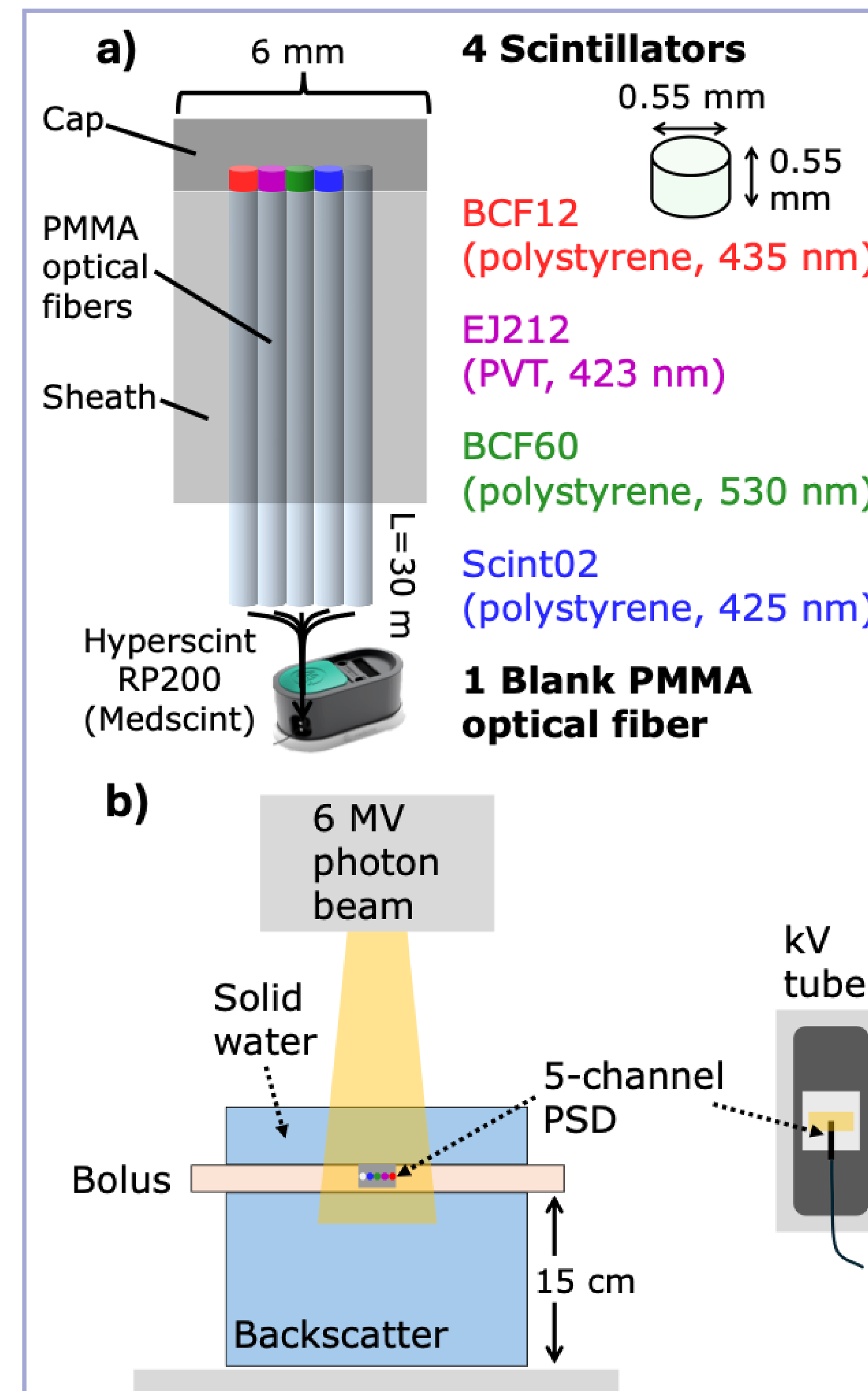

FIG. 1 – a) 5-channel PSD. b) Set-up in 6 MV and kV beam.

RESULTS & DISCUSSION

- Radiation damage caused light output decrease (1.30-4.04 %/kGy), 2.7-12.4 nm SC shift and preferential quenching of scintillation emission in the 380 to 500 nm range (Fig. 2)
- Minimal light output recovery after 299 days rest

	BCF-12	EJ-212	BCF-60	Scint02
Output recovery (%)	-0.6	6.5	-3.8	7.3
Residual damage (%)	14.4	8.9	12.2	7.9

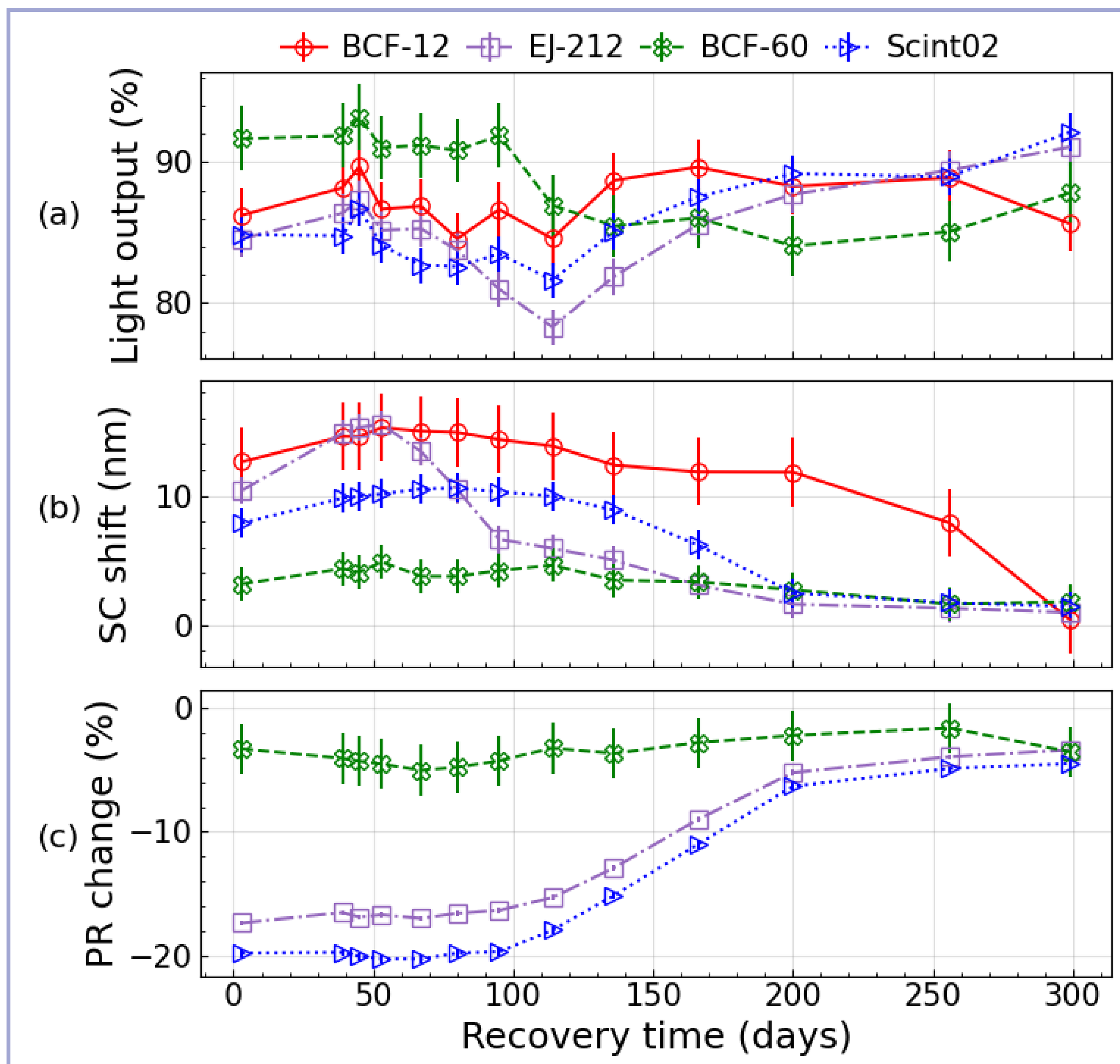

FIG. 2 – (a) Light output, (b) SC shift and (c) PR change of 5-channel PSD over long-term rest, compared to initial undamaged response.

- Green BCF-60 was ~twice more radiation-hard than other blue scintillators, but its output decreased with rest
  → Importance of long-term response stability
- Near-complete spectral recovery for all scintillators after 299 days (Fig. 3):
  → (99.7 ± 0.1) % for SC (Fig. 2b)
  → (96.5 ± 0.3) % for PR (Fig. 2c)

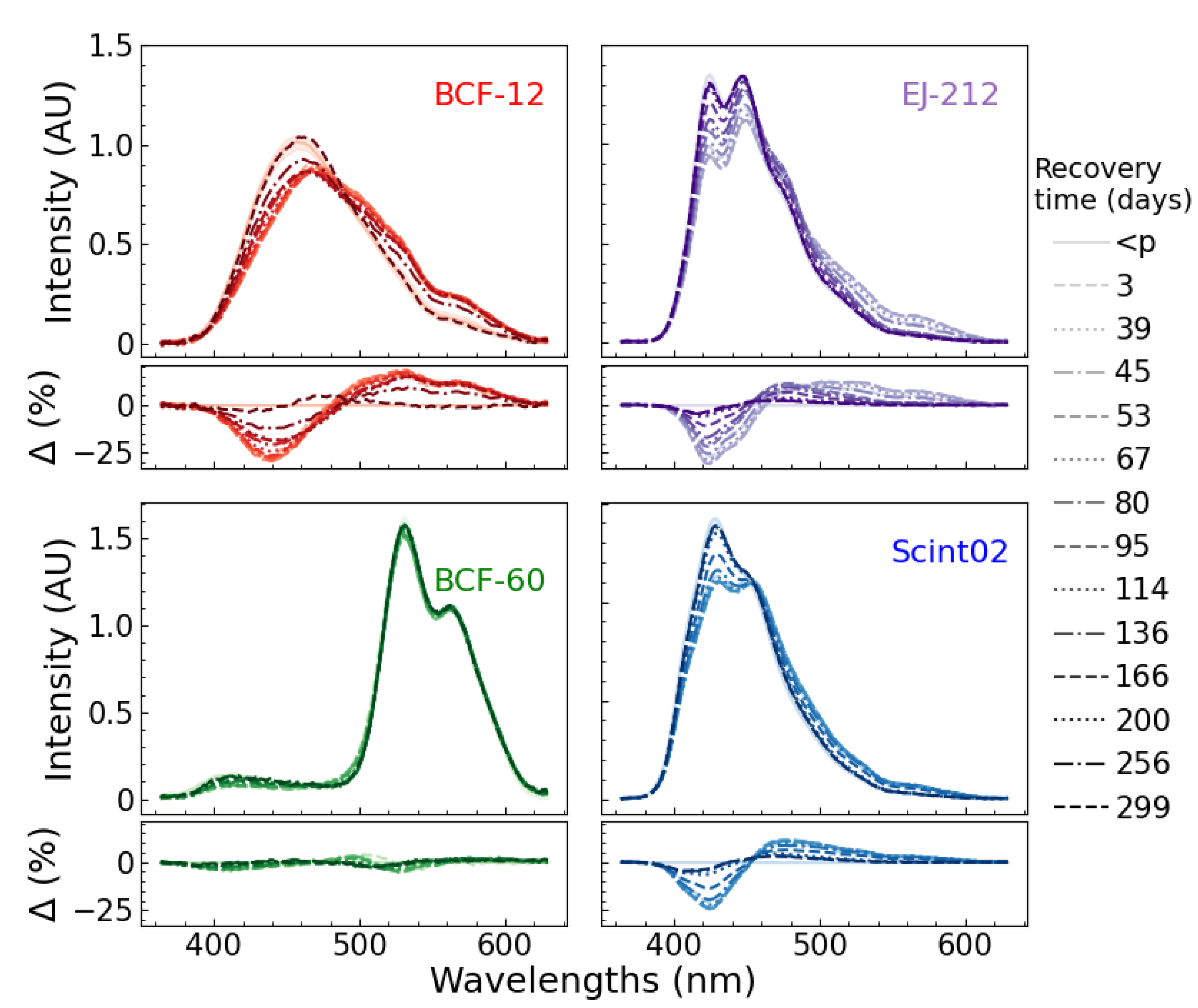

FIG. 3 – Scintillation spectra over long-term rest, normalized by their area under the curve. Δ plots show % difference between each spectrum and the undamaged spectra ('<p').

CONCLUSIONS

- First systematic investigation of recovery processes in PSDs after radiation damage by UHDRs
- Even with residual permanent damage, PSDs maintain their linear response to dose
  → Recalibration allows continuous use
- Recovery processes depend on cumulative dose, particle type (LET effect) and scintillator composition
- Considerations for selecting scintillators for FLASH applications:
  → Radiation hardness
  → Recovery capacity
  → Response stability

REFERENCES

[1] Bazalova-Carter M, Schüler E, et al. Nat Rev Phys. 2025.

[2] Kharzheev YN. Phys Part Nuclei. 2019.

[3] Bross AD, Pla-Dalmau A. IEEE Trans Nucl Sci. 1992.

[4] Zorn C. Nucl Phys B - Proc Suppl. 1993.