# Stability and Radiation Hardness of Plastic Scintillation Detectors for Ultra-High Dose Rate Electron Beam Dosimetry

Thibault Bernelin[1,2,3], Benjamin Coté[4], Simon Lambert-Girard[4], Boby Lessard[4], Louis Archambault[1,2], Arthur Lalonde[3,5]

[1] Département de Physique, de Génie Physique et d'Optique et Centre de Recherche sur le Cancer, Université Laval, Québec, Canada
[2] Département de Radio-Oncologie et Axe Oncologie du CRCHU de Québec, CHU de Québec, Université Laval, Québec, Canada
[3] Centre De Recherche du CHUM, Montréal, Québec, Canada
[4] Medscint, Quebec, Canada
[5] Université de Montréal, Montréal,, Québec, Canada

## INTRODUCTION

- FLASH radiotherapy delivers radiation at Ultra-High Dose Rates (UHDR)
- Accurate dosimetry is essential for clinical implementation and quality assurance
- Need for active point detector for daily output check
- Plastic scintillation detectors (PSDs) are promising candidates for UHDR dosimetry because of :
  - Water equivalence
  - Real-time response
  - High spatial resolution
  - Minimal beam perturbation
- Long-term detector stability and radiation hardness must be characterized before routine clinical use
- **Goal: Evaluate the stability & radiation hardness of PSDs configurations, and identify a detector suitable for routine UHDR electron beam dosimetry**

## MATERIAL & METHODS

### Detector configurations

- Four probes :
  - Scint01 (Medscint) + plastic fiber
  - BCF10 + plastic fiber
  - BCF60 + plastic fiber
  - Scint01 (Medscint) + silica fiber

### Stability assessment

- Daily irradiations of 16 Gy using a Mobetron (9 MV UHDR electrons) (IntraOp)
- Measurements performed over a two-week period
- Response variability used as a stability metric

### Radiation Hardness Assessment

- Successive UHDR irradiations of 500 Gy
- Total accumulated dose up to 3 kGy
- Dose response measured after each irradiation step
- Radiation-induced damage quantified from signal loss relative to baseline.

## RESULTS

### ➢ Dose Tracking (Fig 1 & 2)

- Scint01-based Probes (Ch1 & Ch4):
  - Ch1 (plastic stem) showed the highest stability, remaining tightly bound within 1610 – 1640 cGy
  - Ch4 (silica stem) closely mirrored Ch1 (1580 – 1640 cGy) but exhibited slightly larger day-to-day fluctuations
- BCF Probes (Ch2 & Ch3):
  - Ch2 (BCF-10) exhibited a continuous positive drift, climbing to 1755 cGy
  - Ch3 (BCF-60) experienced a critical drift followed by a strict horizontal plateau in 1900 cGy (Days 13–16), indicating a clear signal saturation/clipping effect

### ➢ Radiation Hardness (Fig 3)

- Scint01-based Probes (Ch1 & Ch4):
  - Ch1 (plastic stem) suffered severe degradation, reaching ~18% signal loss at 3 kGy
  - Ch4 (silica stem) exhibited vastly superior radiation hardness, limiting total signal loss to only ~5% at 3 kGy
- BCF Probes (Ch2 & Ch3):
  - Ch2 (BCF-10) was the most vulnerable configuration, showing a steep, linear decline that culminated in >26% signal loss
  - Ch3 (BCF-60) showed outstanding and anomalous radiation hardness, remaining virtually unaffected with < 1.5% signal loss across the entire 3 kGy range

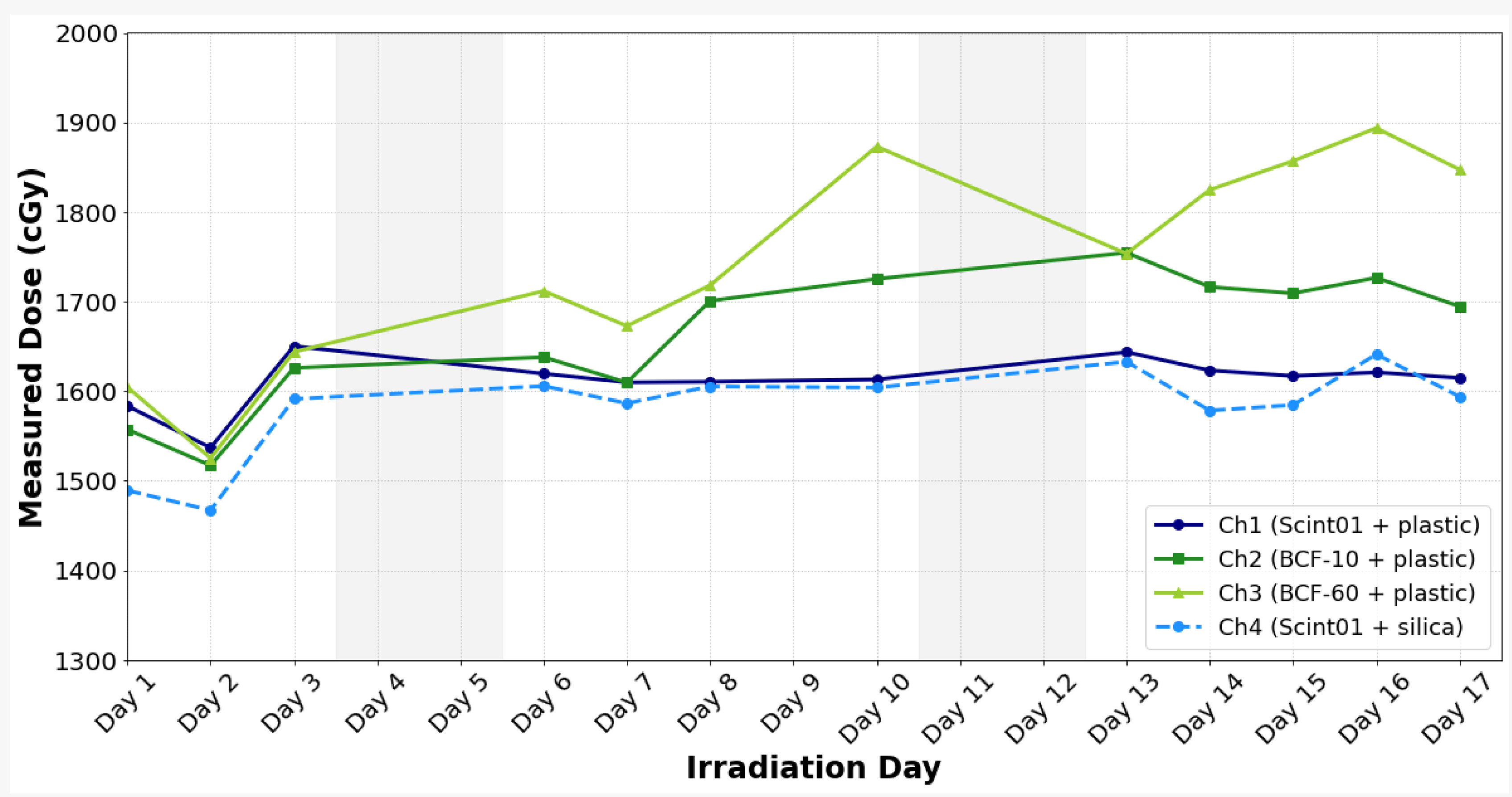


FIG. 1 – Absolute dose tracking of the 4 probes with a UHDR electron beams

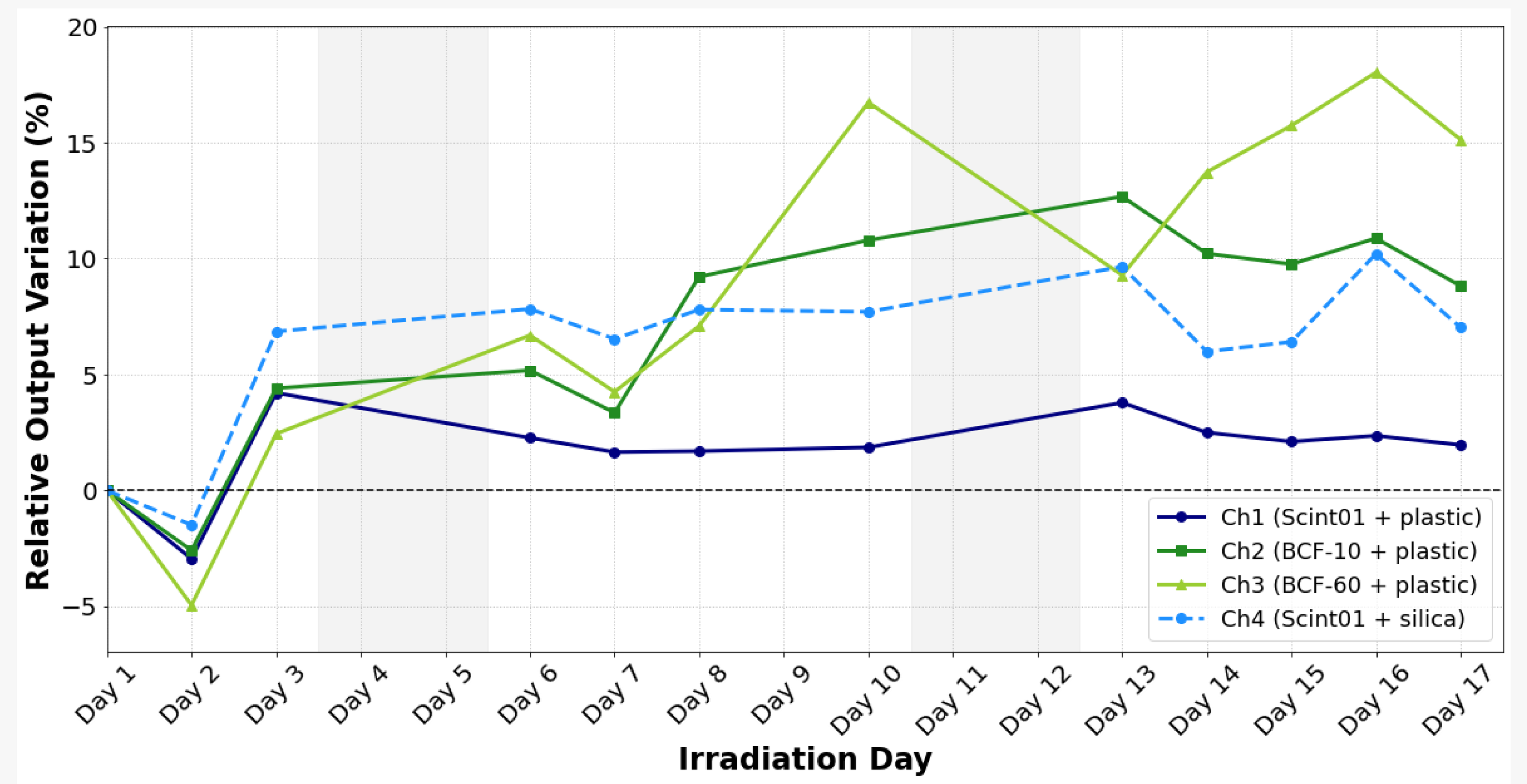


FIG. 2 – Relative dose tracking of the 4 probes with a UHDR electron beams

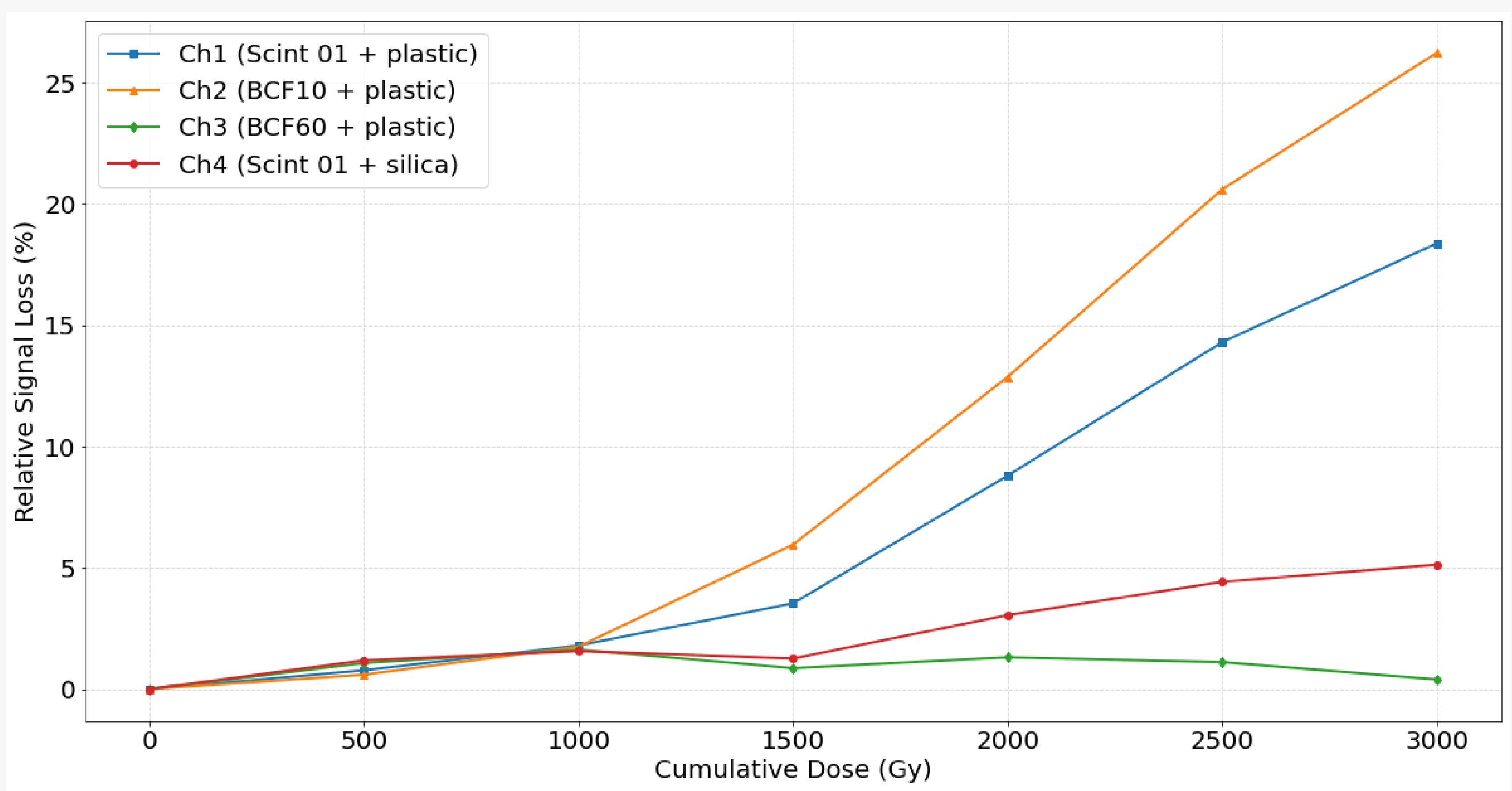


FIG. 3 – radiation damage as a function of accumulated dose

## CONCLUSIONS

- **Optimal Candidate Identified:** The Scint01 + silica fiber configuration (Ch4) emerges as the most suitable candidate for routine UHDR electron beam dosimetry, providing the best compromise between superior baseline reproducibility and high radiation hardness
- **Stem Material is Critical:** Substituting the plastic stem with a silica stem successfully mitigates radiation-induced attenuation (RIA), preventing a ~13% additional signal loss
- **Limitation of BCF Probes**: Despite the outstanding radiation hardness of BCF-60 (Ch3, <1.5% loss), the signal drift observed during daily tracking make BCF-based probes unreliable for routine quality assurance