# BACKGROUND READING PRESENTATION

**TEAM 3**
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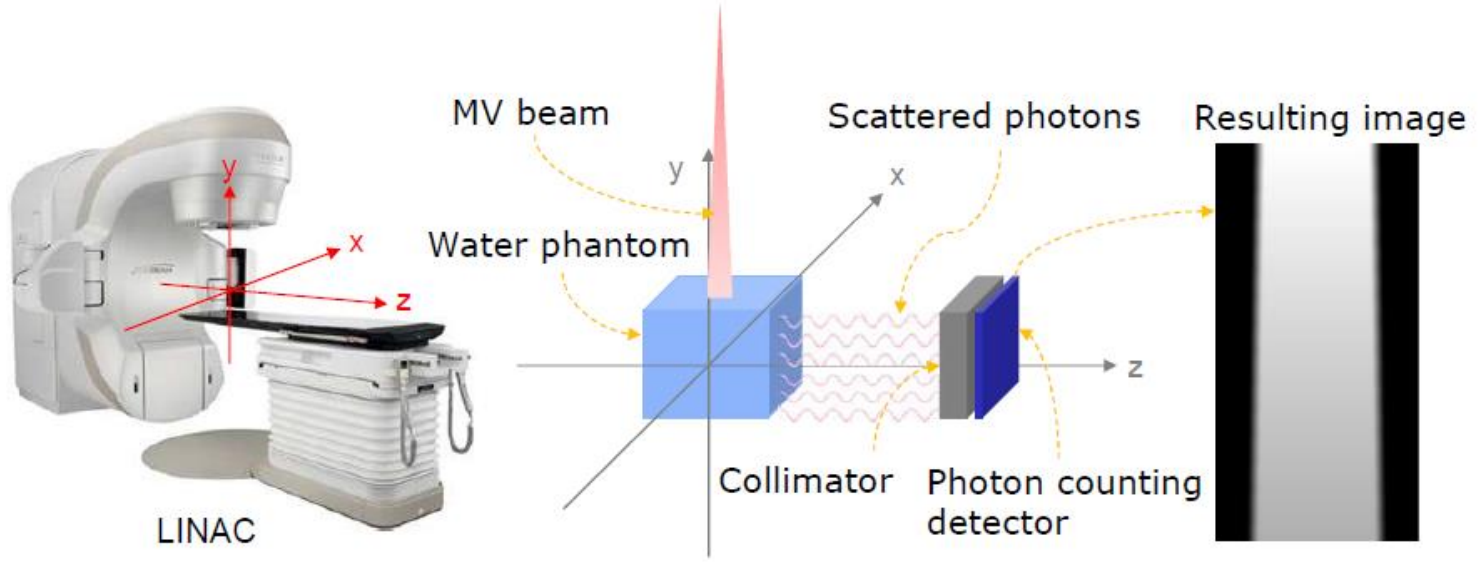
# PROJECT SUMMARY

**TITLE:** Quality assurance of radiotherapy using scattered x-ray

**GOAL:** To implement a new quality assurance method for radiation therapy (RT) using scattered x-ray registration




The diagram of the RT QA method using scattered x-ray registration

Source: Jia, X. (2023). Quality assurance of radiotherapy treatment using scattered x-ray. Presentation slides for CIS II

# PAPER #1

**TITLE:** Dose-Free Monitoring of Radiotherapy Treatments With Scattered Photons: Concept and Simulation Study

**AUTHORS:** Micaela Cunha, Marco Pinto, Hugo Simões, Brígida Ferreira, Maria do Carmo Lopes, Paulo Fonte, and Paulo Crespo

**JOURNAL:** IEEE Transactions on Nuclear Science, vol. 60, No. 4, 2013

**RELEVANCE:** Same QA method but in Geant4 and with more complex phantoms

# PAPER #1. Introduction

**RT:** maximum dose to the tumor, minimum dose to the normal tissue

**Challenges:**
- Patient mispositioning
- Organ movements
- Anatomical morphological changes

→

**Consequences:**
- Underdose
- Overdose

→

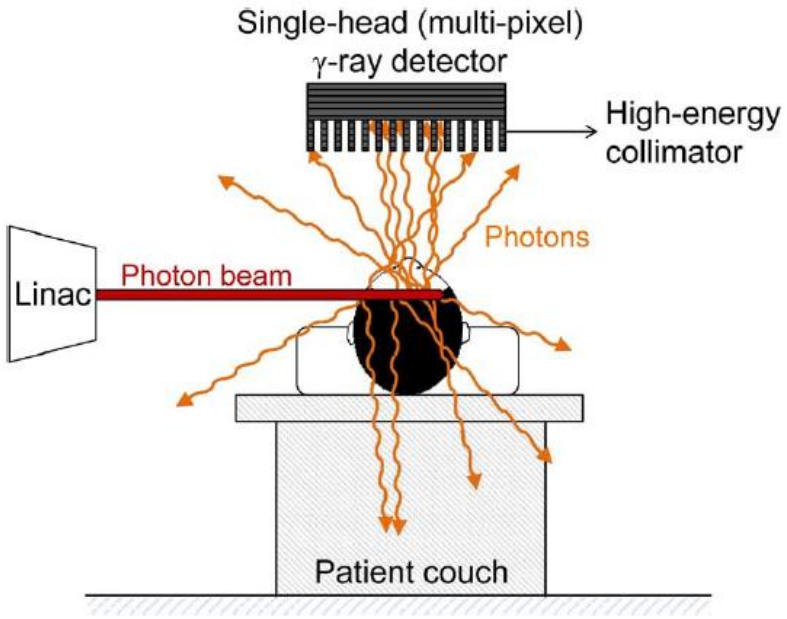
**Current solutions:**
- IGRT
- ART

**Side effects:**
Extra-dosage

**Proposed solution:**

A gamma-camera-like system for real time depth-dose verification without extra-dosage using scattered photons registration

# PAPER #1. Concept



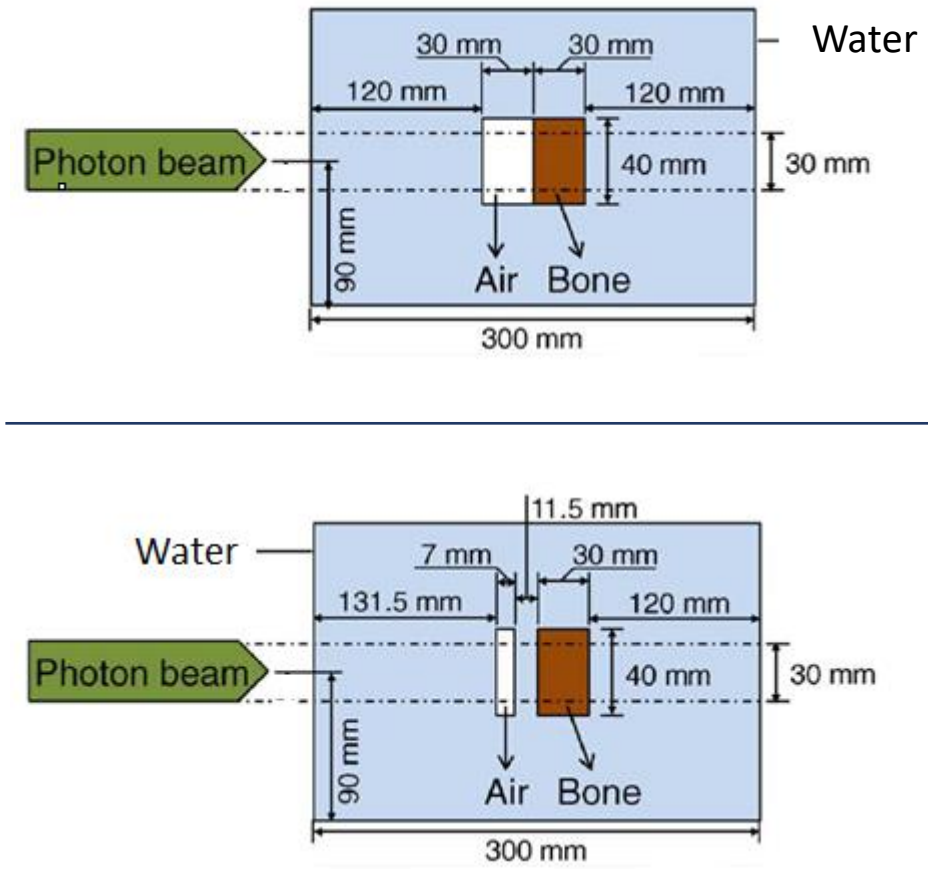

Monitoring system in a clinical RT environment

Source: Cunha, M., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: Concept and simulation study. *IEEE Transactions on Nuclear Science, 60*(4), p. 3119-3126

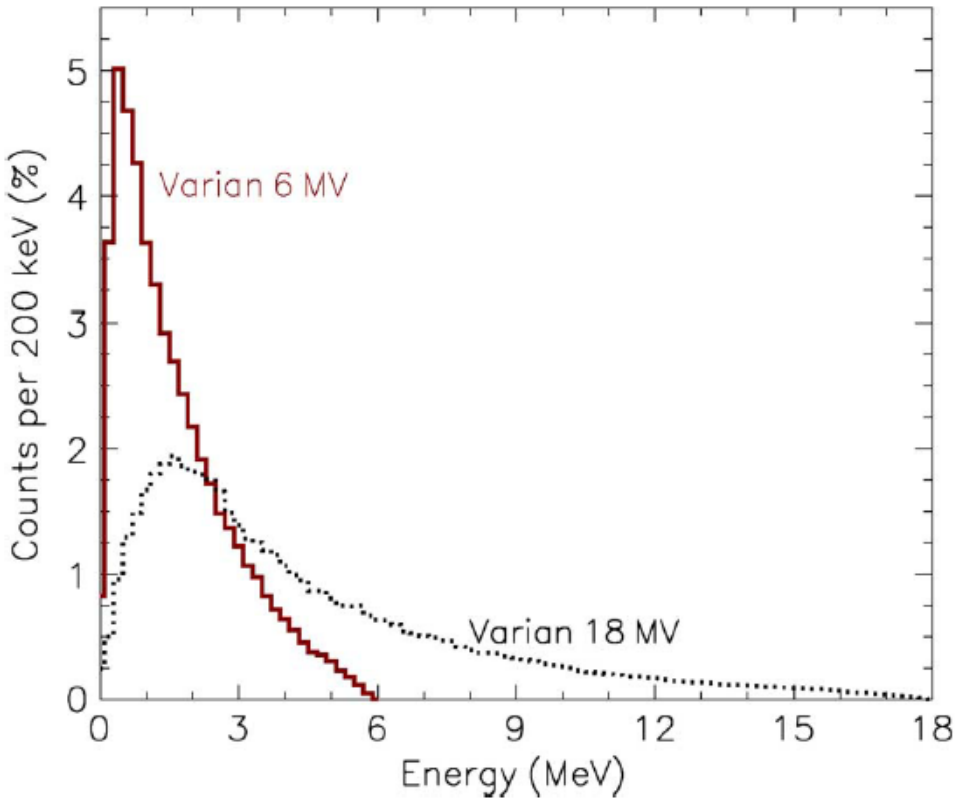
- Do photons escaping at 90° from the phantom correlate with the deposited dose?
- Can edema be detected with this system?

# PAPER #1. Materials and Methods

**Environment:** Geant4, v. 9.4, emstandard_opt3 physics list (electromagnetic processes)




Simulated phantoms

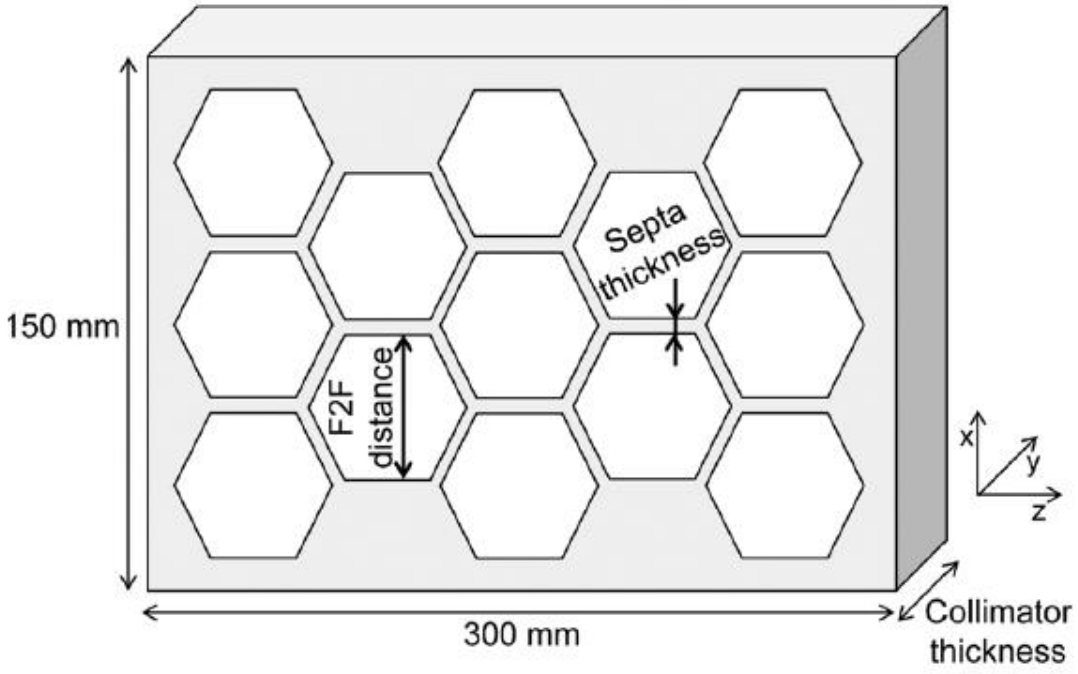



Simulated beam spectra

Source: Cunha, M., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: Concept and simulation study. *IEEE Transactions on Nuclear Science, 60*(4), p. 3119-3126

# PAPER #1. Materials and Methods (continued)

- Photons collected on the detector surface at $89.3° \leq \Theta \leq 90.7°$
- Collimator front face: 280 mm from the beam central axis



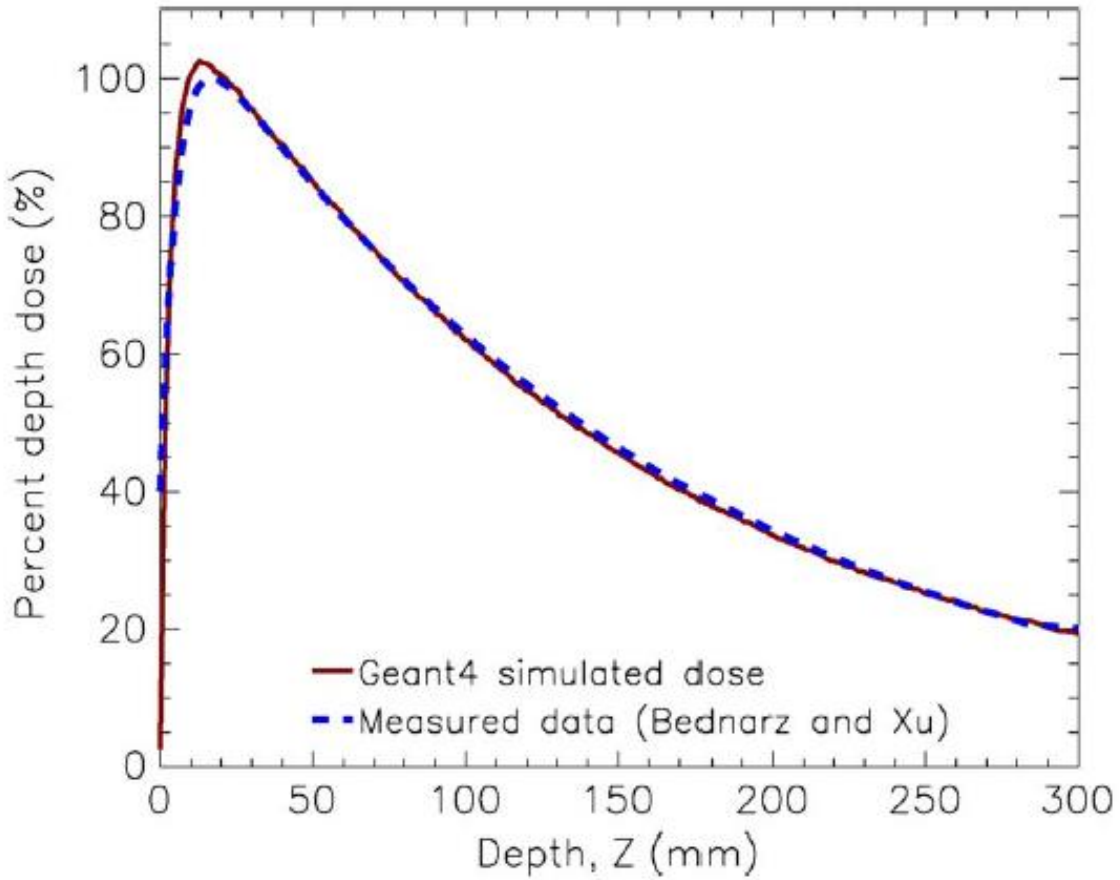

Simulated multi-hole collimator

Collimator geometrical parameters

| Energy (keV) | Collimator thickness (mm) | Septa thickness (mm) | Face-to-face distance (mm) |
|---|---|---|---|
| 200 | 45.912 | 0.12763 | 0.96548 |
| 300 | 80.811 | 0.31217 | 1.5349 |
| 400 | 116.99 | 0.52669 | 2.0196 |
| 500 | 151.40 | 0.73275 | 2.4051 |
| 600 | 182.93 | 0.91566 | 2.7080 |
| 800 | 237.43 | 1.2104 | 3.1445 |

Source: Cunha, M., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: Concept and simulation study. *IEEE Transactions on Nuclear Science, 60*(4), p. 3119-3126

# PAPER #1. Results

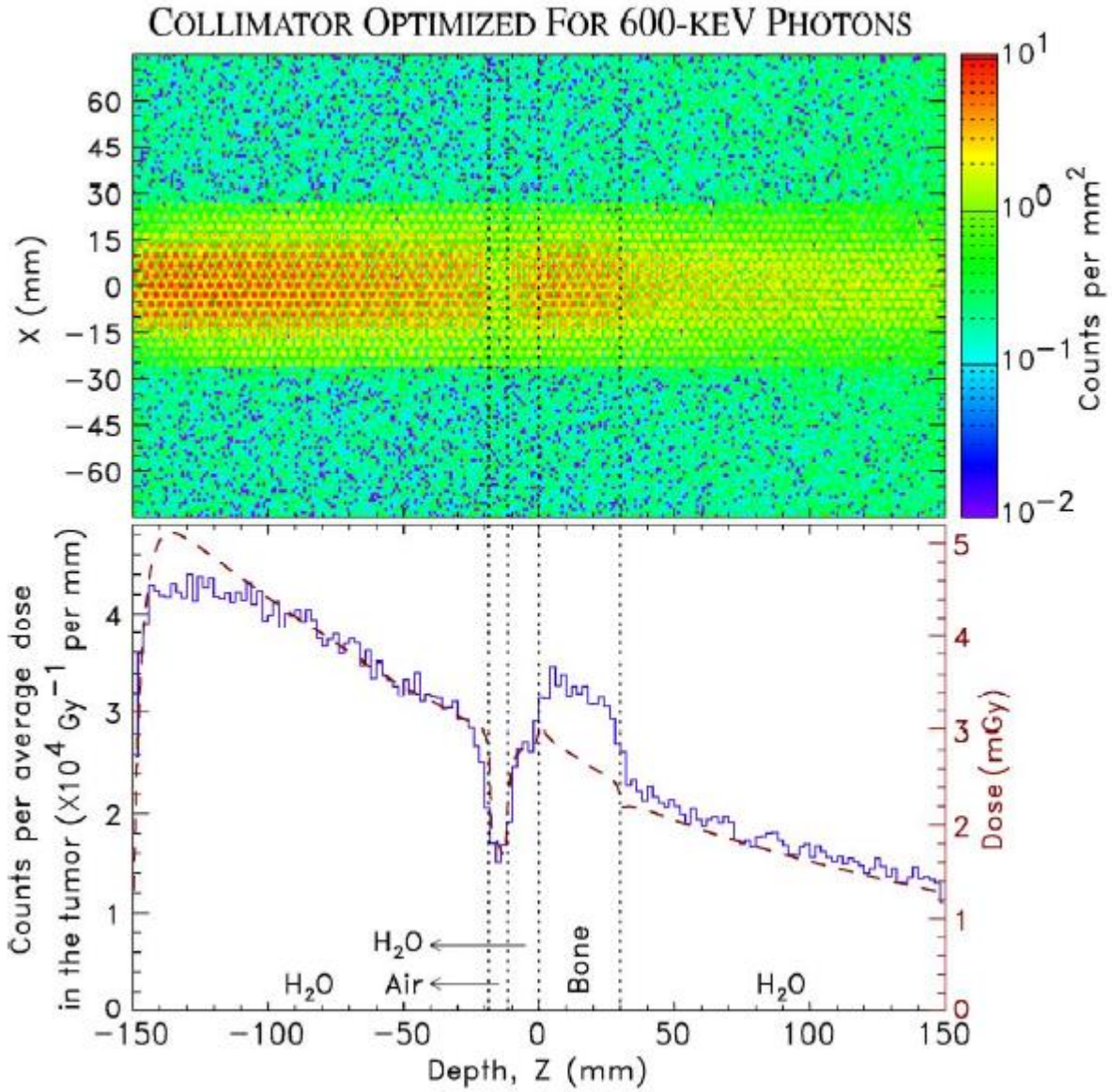



Physics list validation

- A cylindrical homogeneous water phantom (radius 90 mm, length 300 mm)
- A divergent beam (cross-section at the isocenter 40 mm x 40 mm, endpoint energy 6 MV)

Source: Cunha, M., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: Concept and simulation study. *IEEE Transactions on Nuclear Science, 60*(4), p. 3119-3126

# PAPER #1. Results (continued)




2D distribution of photon counts; Comparison between depth-dose and collimated for 600-keV photon profiles

Statistical tests on the relation between dose data and counted photons

| Energy (keV) | RMSE | Correlation ($R$) between dose and detected photons profiles |
|---|---|---|
| 200 | 10813.15 | -0.9430 |
| 300 | 2143.04 | -0.9029 |
| 400 | 319.24 | -0.4749 |
| 500 | 119.91 | 0.9308 |
| 600 | 110.78 | 0.9442 |
| 800 | 94.03 | 0.9324 |

95%CI, $p < 0.001$

Source: Cunha, M., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: Concept and simulation study. *IEEE Transactions on Nuclear Science, 60*(4), p. 3119-3126

# PAPER #1. Critical Review

**Pros:**

- Great implementation of our CIS II project (minimum and ½ expected deliverables)
- Considered complex heterogenous phantoms
- Performed physics list validation
- Explored different detector energy thresholds

**Cons/suggestions:**

- The dimensions of the plane detector/sensor area are not mentioned
- ~1mGy difference in the dose to the bone is not discussed/analyzed
- Used only 6-MV photon spectrum in the discussed experiment
- Comparison with physical measurements would be beneficial

**Takeaways:**

- Our QA method is not novel
- Heterogenous phantoms (+real CT scans?) should be considered
- Different energy thresholds must be explored
- No complicated math might be needed to relate the detector signal to the deposited dose

# PAPER #2

**TITLE:** Dose-Free Monitoring of Radiotherapy Treatments with Scattered Photons: First Experimental Results at a 6-MV Linac

**AUTHORS:** Hugo Simoes, Marco Pinto, Micaela Cunha, Joana Goncalves, Liliana Sampaio, Ricardo J. Ferreira, Henrique M. Saraiva, Ana Rita Barbeiro, Miguel Capela, Brigida Ferreira, Paulo Fonte, Sharif Ghithan, Antonio Leal Plaza, Maria do Carmo Lopes, Paulo Martins, and Paulo Crespo

**JOURNAL:** IEEE Transactions on Nuclear Science, vol. 60, No. 4, 2013

**RELEVANCE:** Same QA method but with a different detector and phantoms

# PAPER #2. Introduction

**Simulation:**

A gamma-camera-like system for real time depth-dose verification without extra-dosage

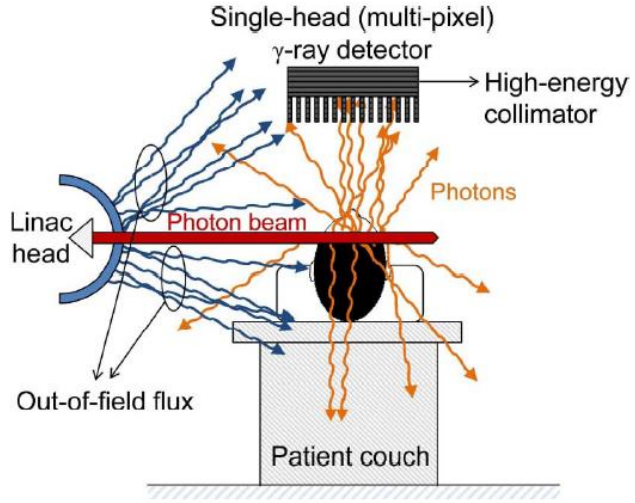
**Physical implementation challenge:**

Out-of-field LINAC flux

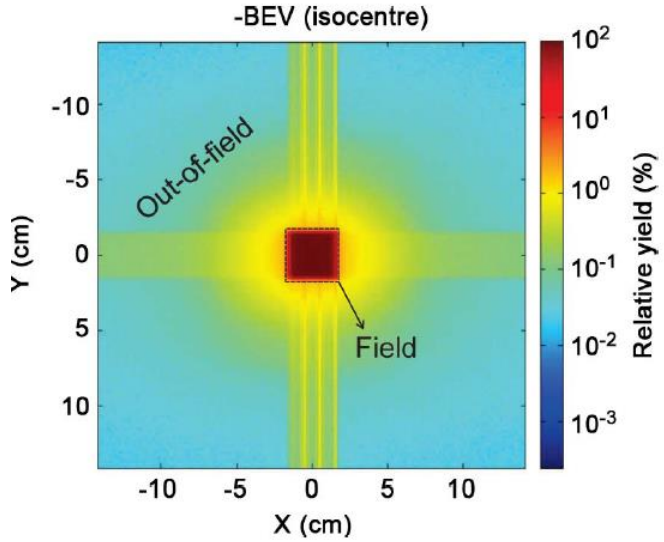
**Proposed physical system:**

RTmon

- Cerrobend shielding between the detector and the LINAC head to reduce noise
- Optimized detector geometrical orientation
- A differential signal readout implementation



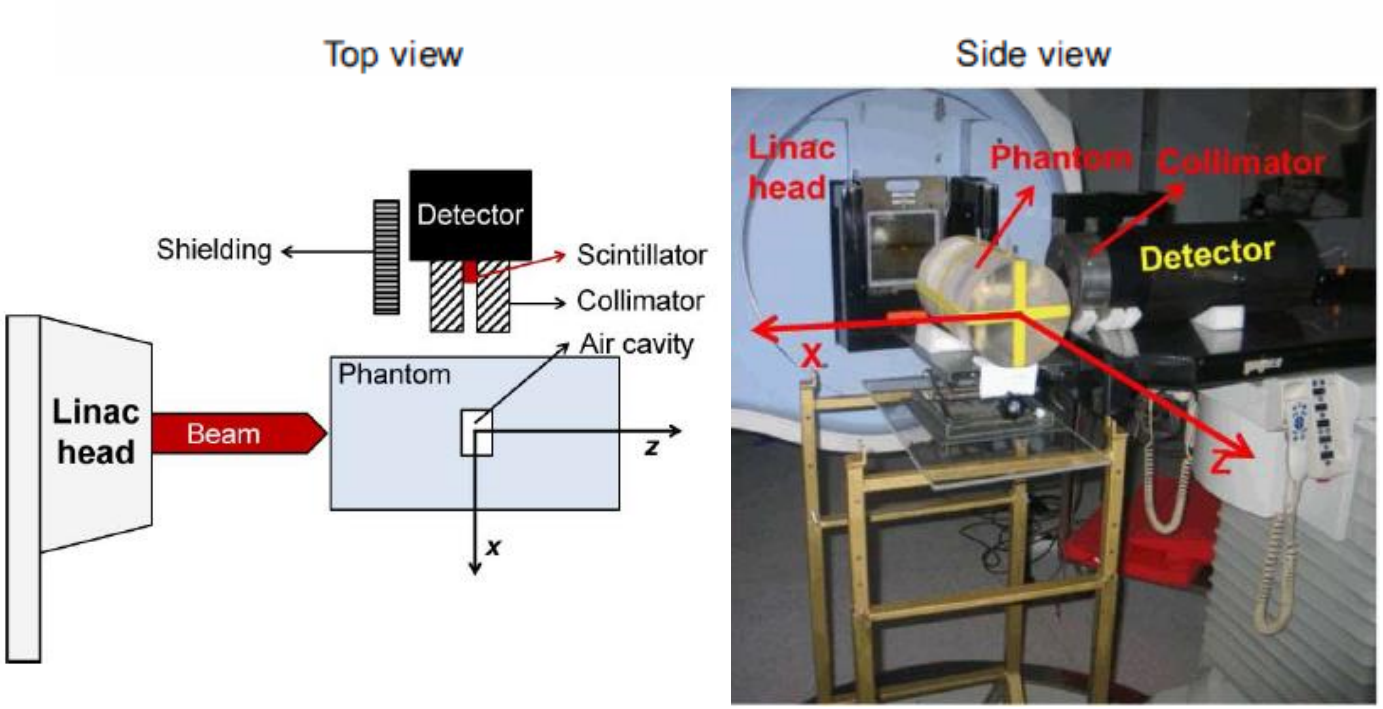

RTmon detector concept




Beam eye's view of the simulated particle flux

Source: Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118

# PAPER #2. Materials and Methods




Experimental setup

**Phantom:**

- Cylindrical shape: 30 cm (l) x 18 cm (d)
- PMMA plastic exterior
- Cylindrical air cavity: 2 cm (l) x 3 cm (d)

**Radiation:**

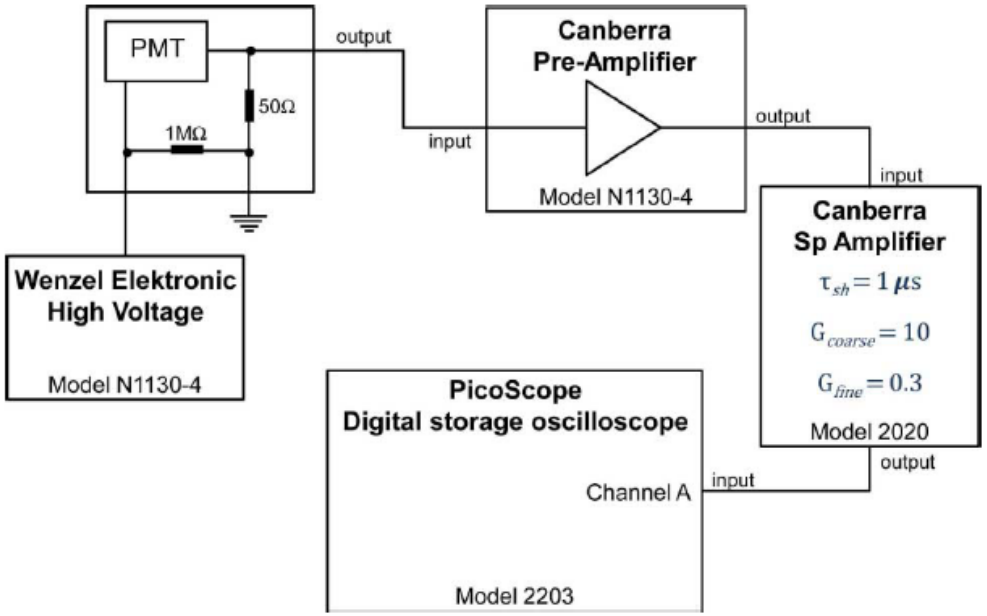
- X-ray beam, 3 cm x 3 cm field
- Siemens ONCORTM Avant-Garde LINAC, 6 MV

**Detector:**

- Single-pixel PMT

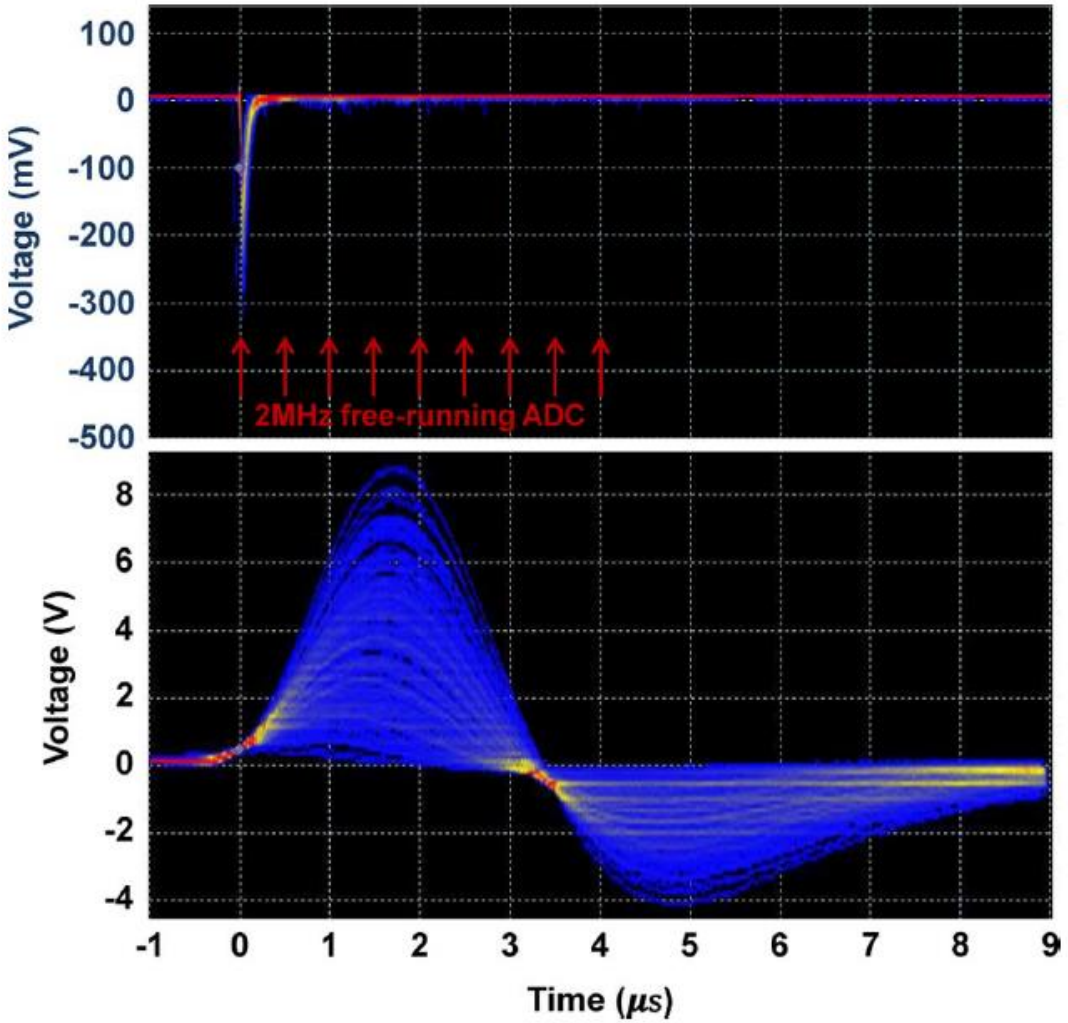
Source: Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118

# PAPER #2. Materials and Methods (continued)



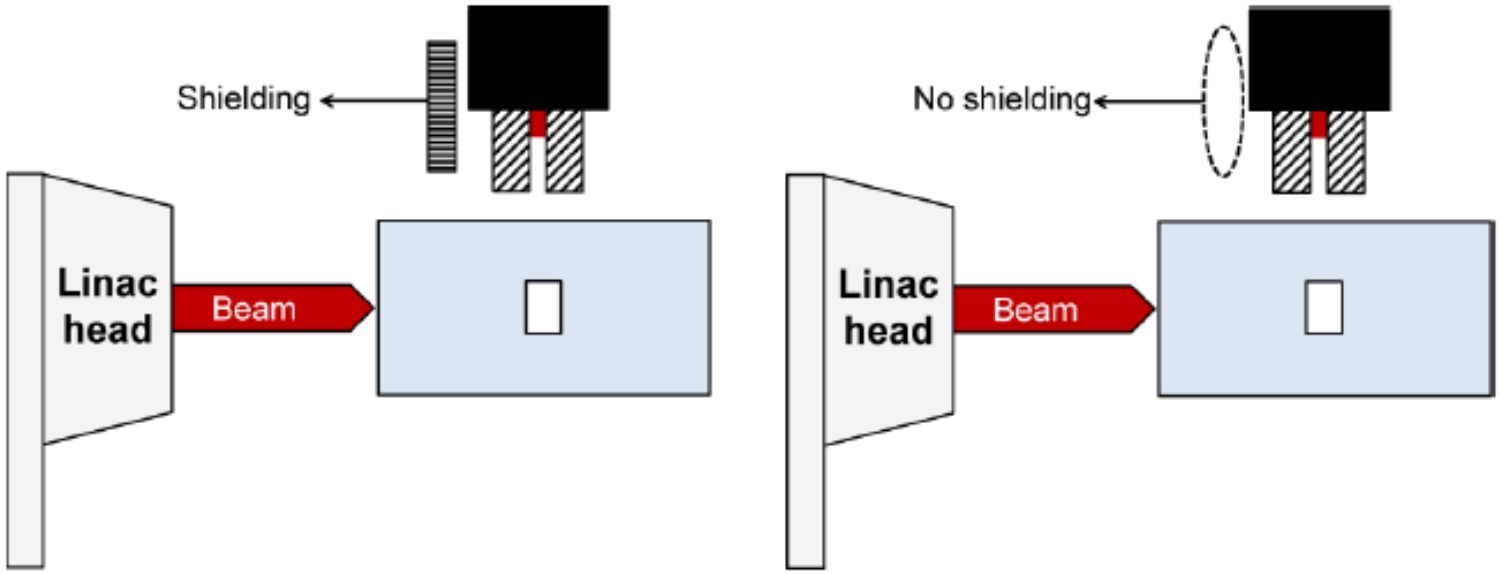

Readout electronics

Source: Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118




Signals acquired directly at the PMT (top) and after signal shaping (bottom)

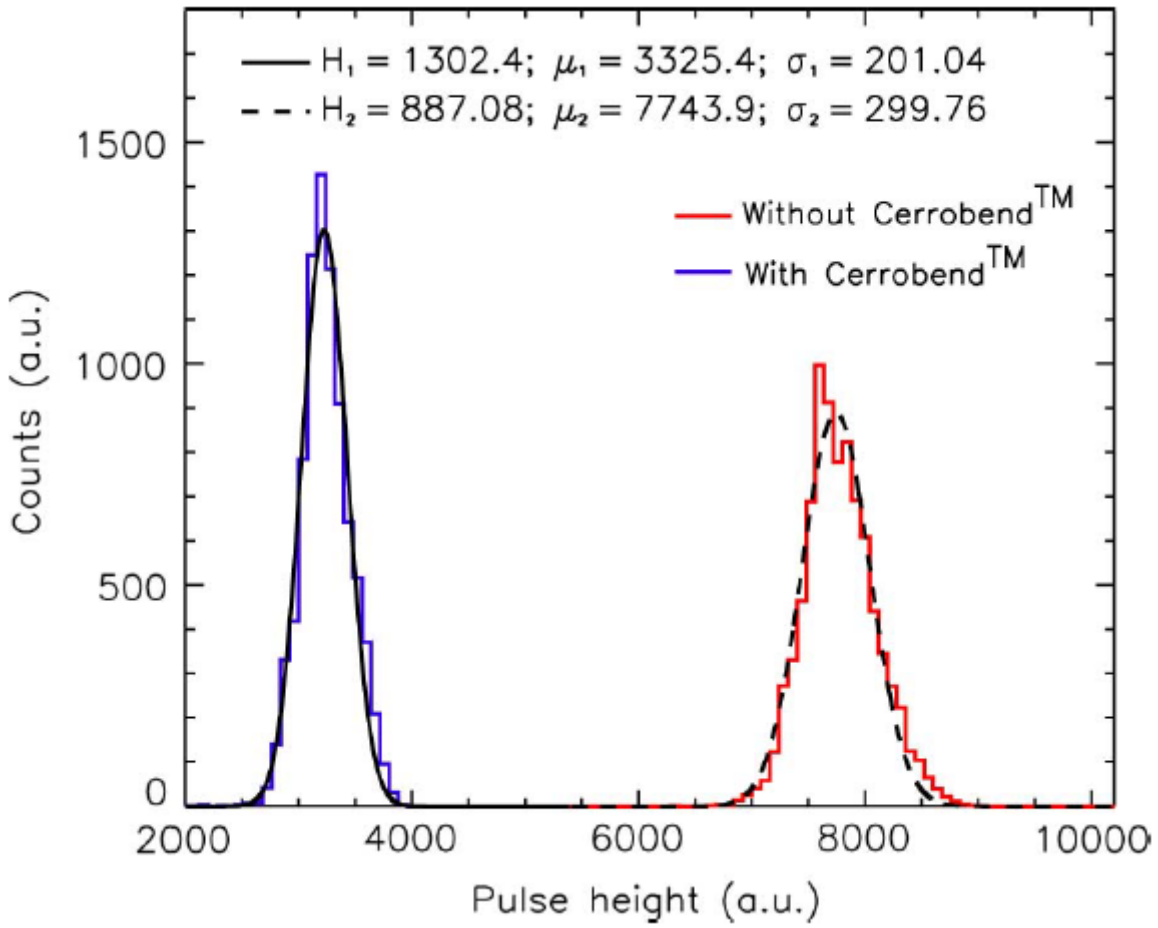
# PAPER #2. Study 1




Experimental setup to analyze the influence of Cerrobend™ shielding

Source: Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118

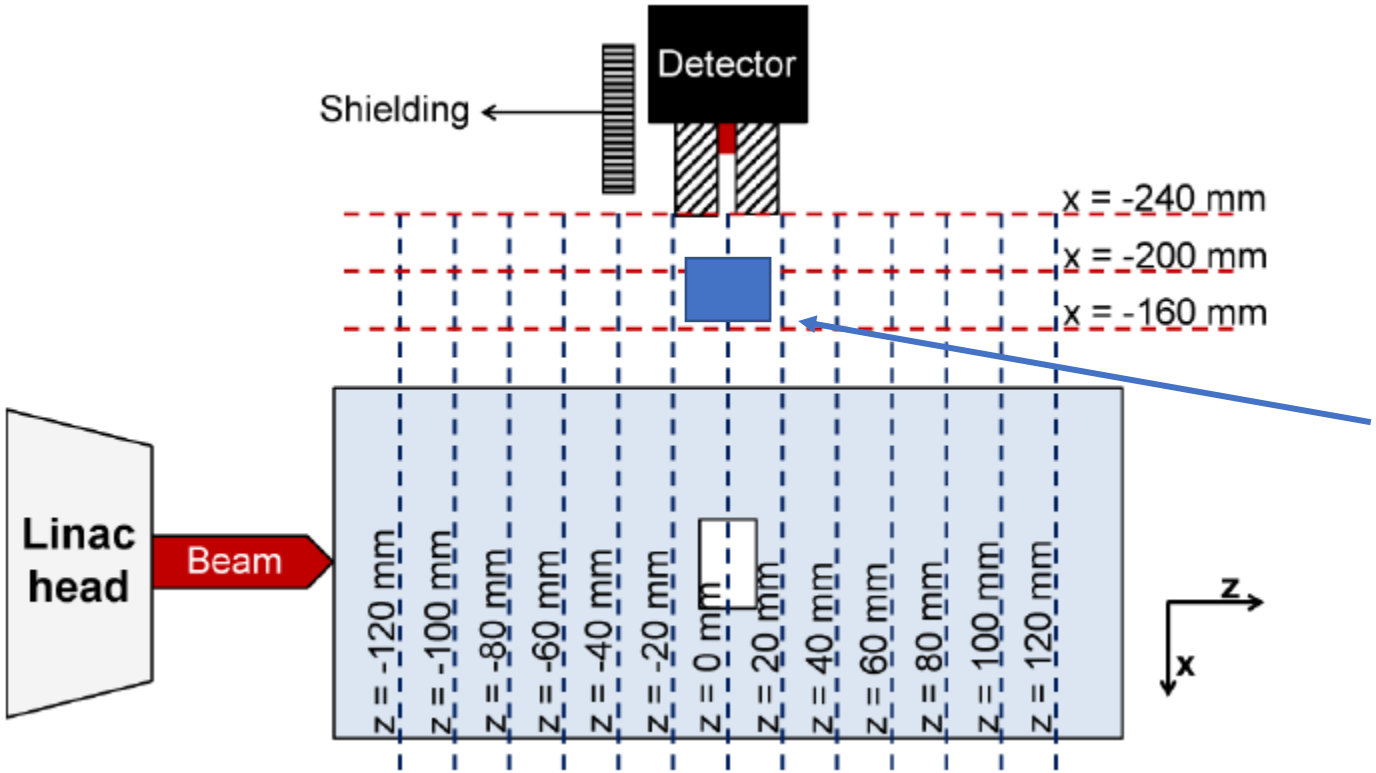
# PAPER #2. Study 1 Results




Pulse height spectra obtained with and without Cerrobend™ shielding

Source: Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118

# PAPER #2. Study 2

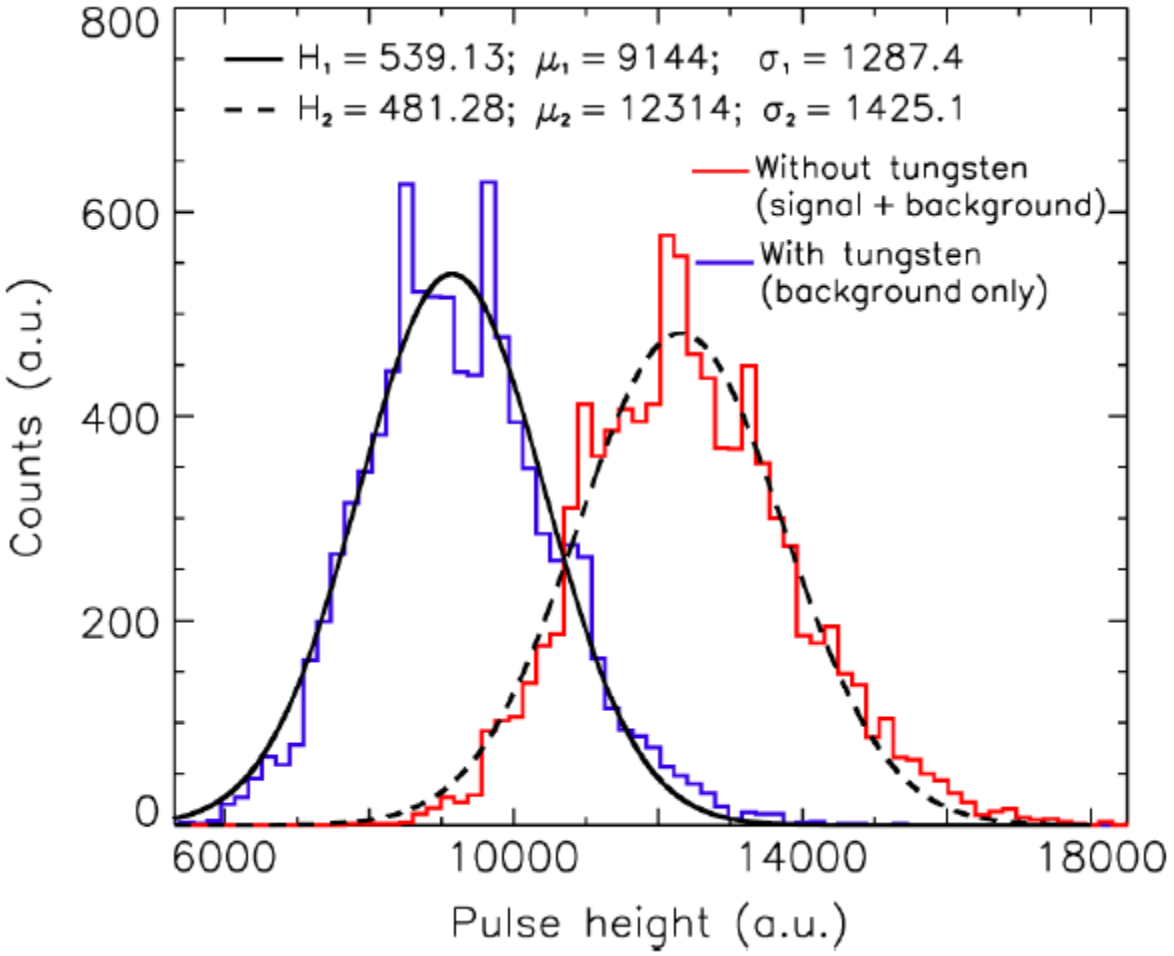



Grid used to test various x-depths

- A tungsten block in front of the detector center
- Detector positioning along x-axis

Source: Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118

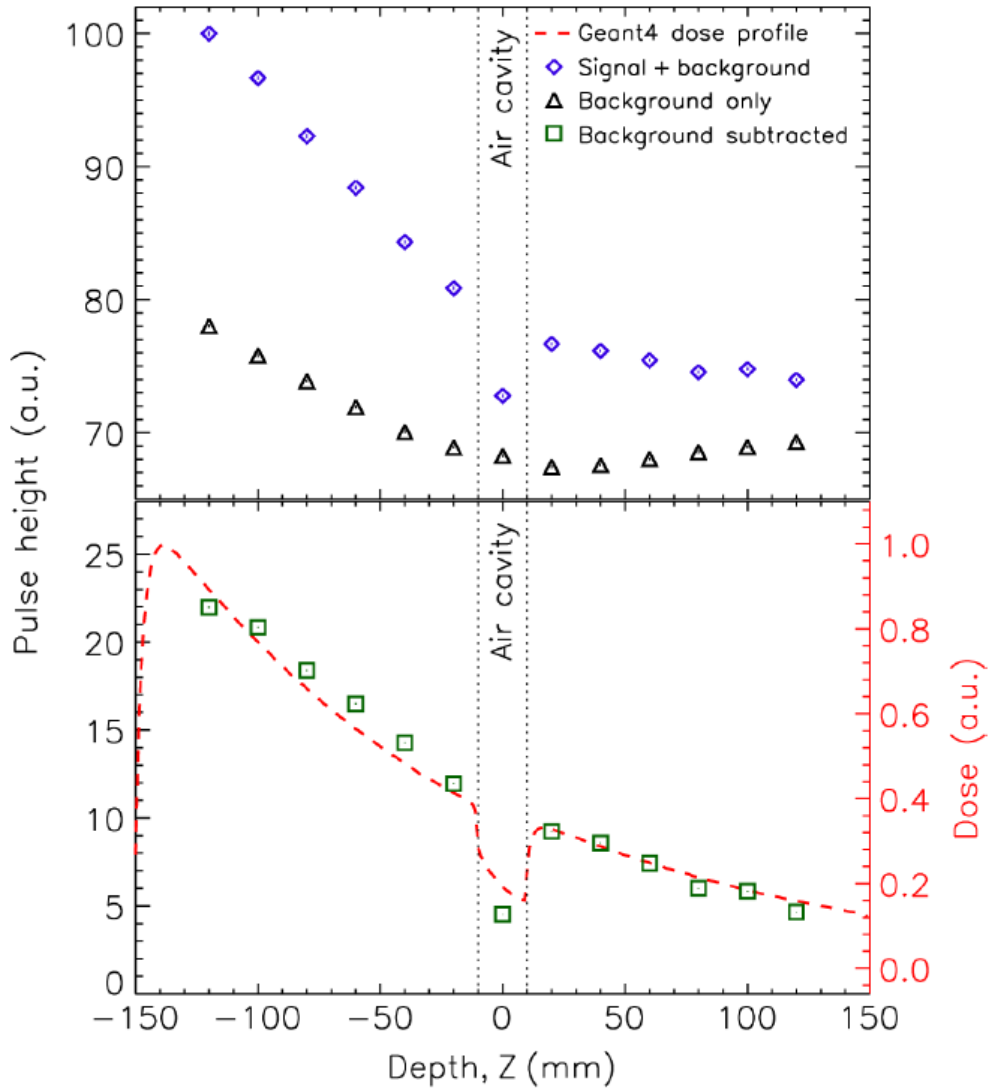
# PAPER #2. Study 2 Results



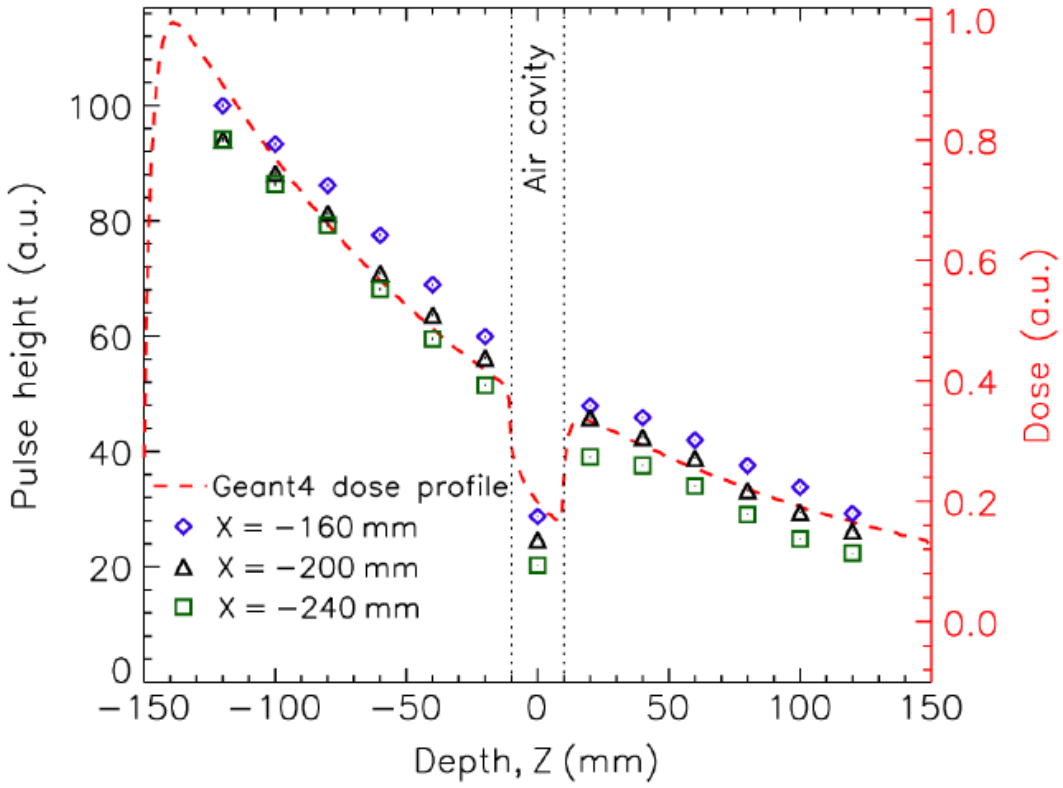

Pulse height spectra obtained with and without tungsten block

Source: Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118

# PAPER #2. Study 2 Results (continued)




Scan profiles along the phantom depth (X=-200 mm)




Depth-profiles obtained by scanning the detector along the phantom at different X distances from the isocenter

Source: Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118

# PAPER #2. Critical Review

**Pros:**

- Great implementation of our CIS II project (maximum deliverable)
- Built on previously presented paper
- Methods for dealing with out-of-field flux in physical experiments

**Cons/suggestions:**

- A single-pixel collimated detector has a poor resolution
- The comparison of the pulse height data with the simulated depth-dose profile in arbitrary units which is also somehow visually adjusted is not sufficient for inferring the exact delivered dose deposition

**Takeaways:**

- Physical measurement experiments might be more challenging than expected
- The research findings will assist us with
    - Detector positioning
    - Out-of-field flux management

# REFERENCES


1. Jia, X. (2023). Quality assurance of radiotherapy treatment using scattered x-ray. Presentation slides for CIS II
2. Cunha, M., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: Concept and simulation study. *IEEE Transactions on Nuclear Science, 60*(4), p. 3119-3126
3. Simões, H., et al. (2013). Dose-free monitoring of radiotherapy treatments with scattered photons: First experimental results at a 6-MV Linac. *IEEE Transactions on Nuclear Science, 60*(4), p. 3110-3118