

# Application of the TDCR method in radioluminescence studies

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## ABSTRACT

The TDCR method is based on the triple to double coincidence ratio in order to determine the activity of a radionuclide. In this technique, the TDCR counter detects scintillation photons generated by alpha or beta particles interacting within a scintillator, typically a liquid cocktail. Radioluminescence in air has been investigated as an indirect approach for the imaging and remote detection of alpha particles. Several radioluminescence scanning systems have been developed and successfully applied in environmental studies for alpha particle detection. In the present work, the TDCR counter from the Ionizing Radiation Metrology Laboratory (LMRI) from Horia Hulubei National Institute for Research and Development in Physics and Nuclear Engineering (IFIN-HH) was employed to detect radioluminescence photons produced in air. For validation of the method under air conditions, radioactive standard sources of Am-241 were used.

## MOTIVATION

- Detection of alpha-emitting radionuclides in air is important for environmental monitoring, nuclear safety, and contamination control.
- Radioluminescence produced in air by alpha particles (Fig. 1, Fig. 2) represents a promising indirect detection method because it enables remote and stand-off measurements [1].
- The Triple-to-Double Coincidence Ratio (TDCR) method is widely used in radionuclide metrology as an absolute method for activity standardization in liquid scintillation counting.
- In this work, the TDCR technique was investigated for the detection of radioluminescence photons generated directly in air by alpha particles emitted from Am-241 standard sources.

## EXPERIMENTAL SETUP

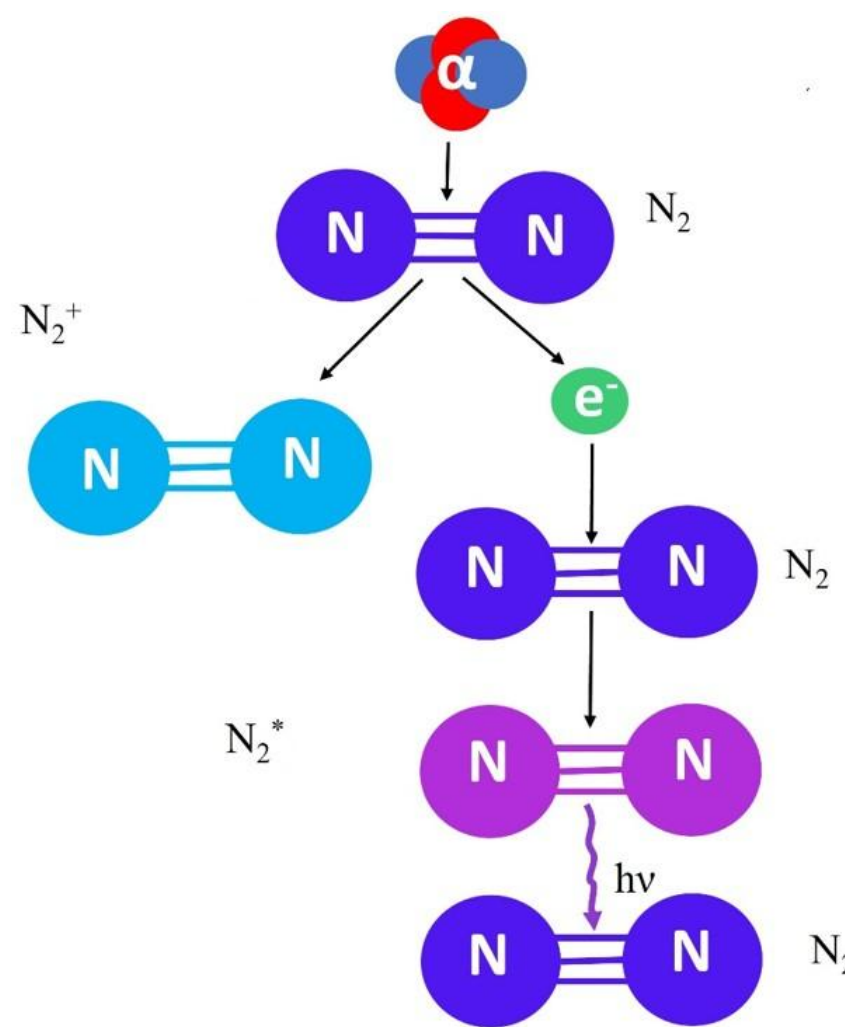


Fig. 1 Air Radioluminescence Induced by Alpha Particles

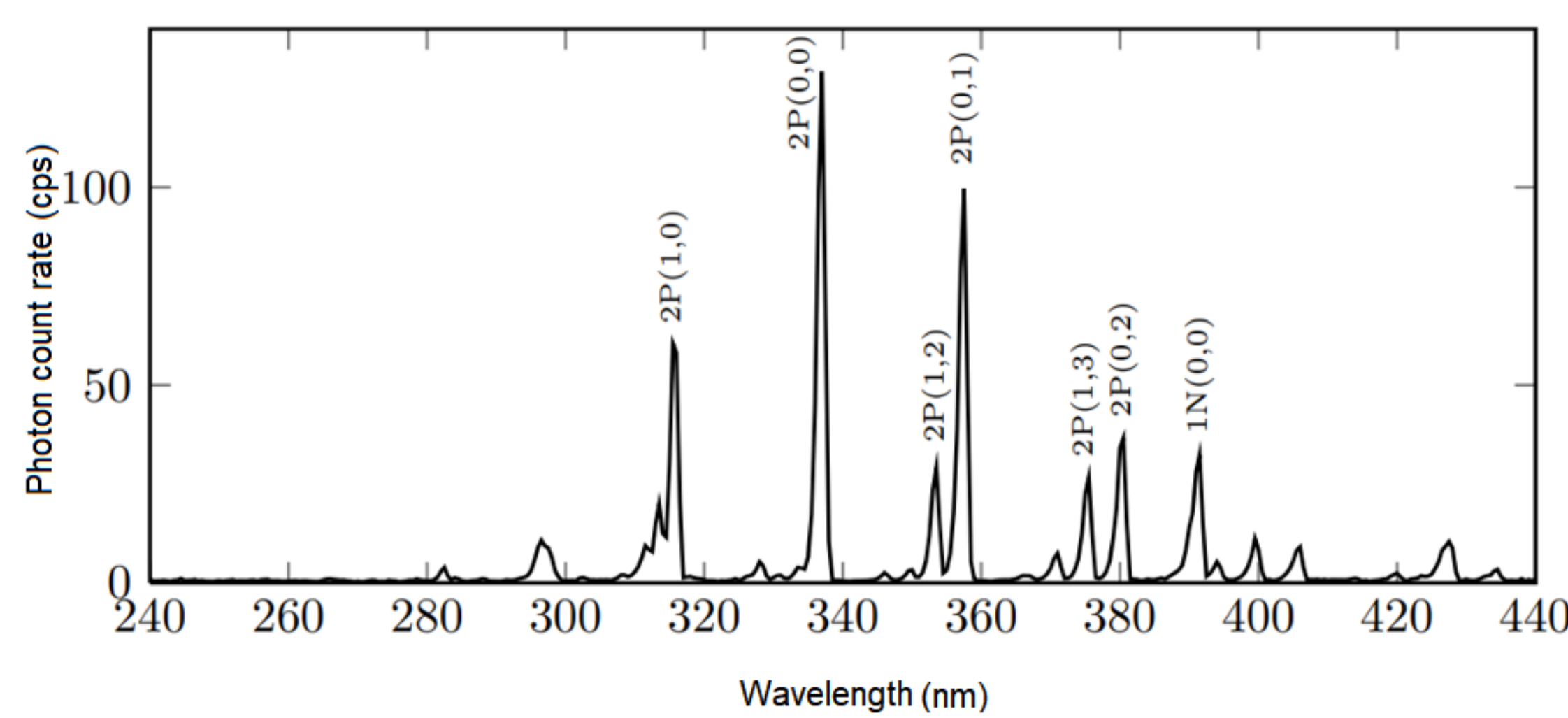


Fig. 2 Air Radioluminescence Emission Spectrum Induced by Am-241 Alpha Particles [2]

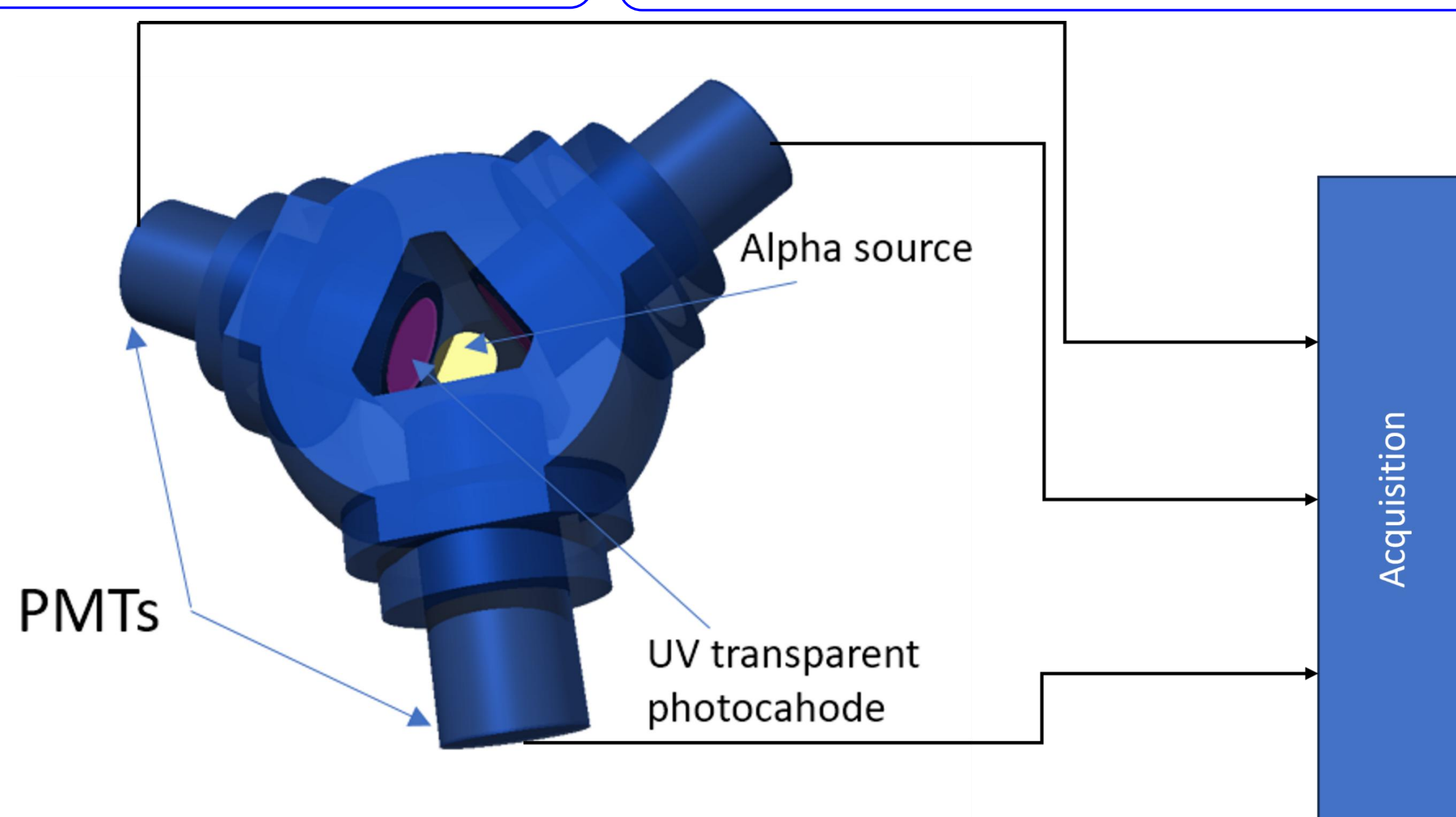


Fig. 3 Simplified Diagram of the TDCR Counter Simulated by FLUKA [3]



Am-241 Standard Sources Used for TDCR Measurements Based on Air Radioluminescence Induced by Alpha Particles

- The measurements were performed using the TDCR counting system available in the Ionizing Radiation Metrology Laboratory (LMRI) at IFIN-HH (Fig. 3).
- The detection system consists of three photomultiplier tubes (PMTs) arranged symmetrically at  $120^\circ$  around the optical chamber. Instead of using a liquid scintillation cocktail, the alpha-particle emitting standard sources were positioned in air in front of the PMTs in order to detect the radioluminescence photons produced by alpha-particle interactions with air molecules.
- Several Am-241 standard sources with certified activities in the range (19 - 12150) Bq, were measured under the same geometrical conditions.
- Triple and double coincidence counting rates were recorded and analyzed as a function of alpha-particle emission rate (Fig. 4).
- The counting rate as a function of the active area diameter  $\phi$  expressed in cm and as a function of the distance were measured (Fig. 5, Fig. 6).
- Monte Carlo simulations using the FLUKA code were also performed in order to model the geometry of the TDCR system and to better understand the photon generation and transport processes.

## RESULTS

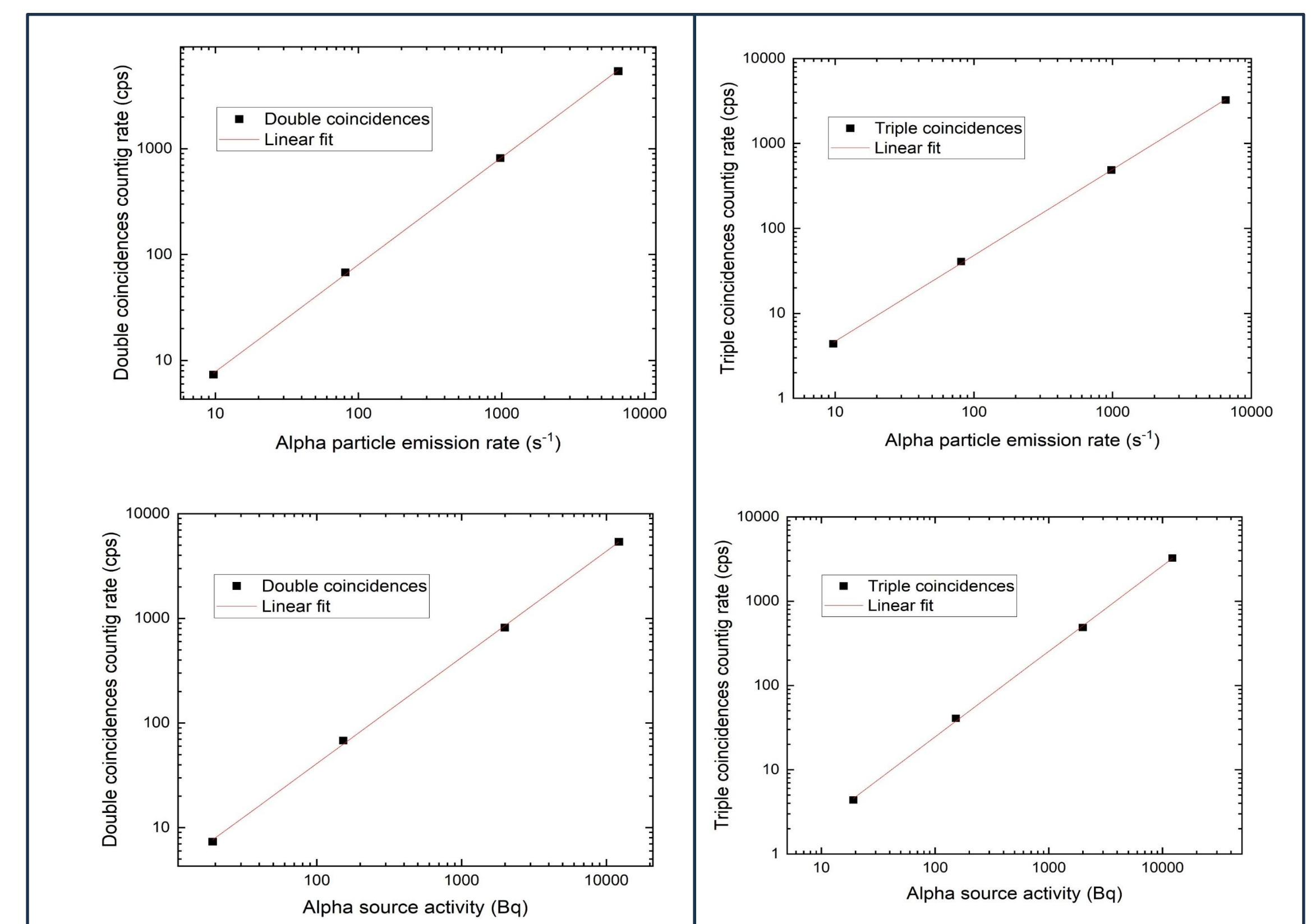


Fig. 4 Linearity Tests of the TDCR System Using Standard Sources

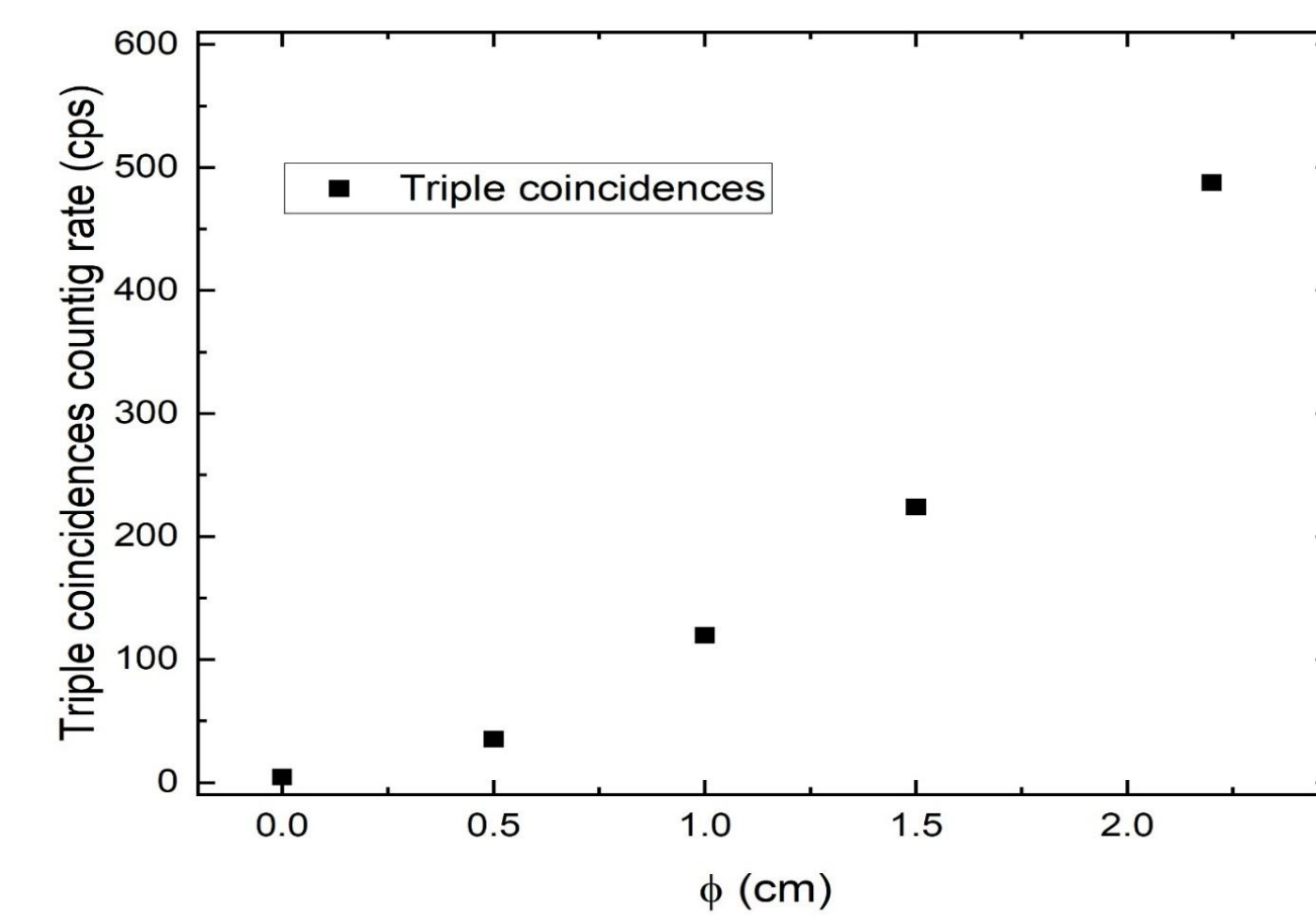


Fig. 5 Counting Rate as a Function of Source Active Area

✓ An increase in counting rate was observed with increasing the source active area.

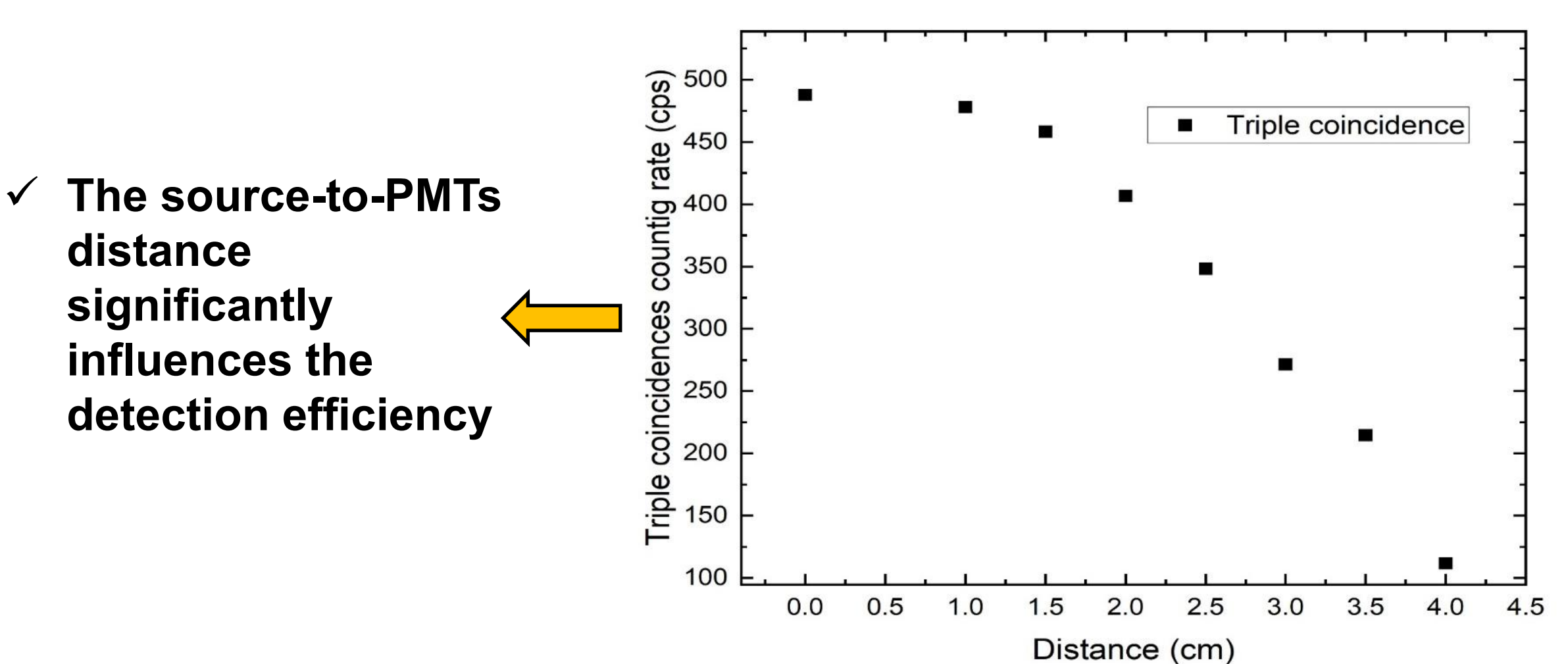


Fig. 6 Counting Rate as a Function of Source-to-Detector Distance

✓ The source-to-PMTs distance significantly influences the detection efficiency

## CONCLUSIONS

- ✓ The TDCR system successfully detected alpha-particle-induced radioluminescence in air.
- ✓ A linear relationship between counting rate and source activity was demonstrated.
- ✓ Detection efficiency strongly depends on source geometry and source-to-detector distance.
- ✓ The method shows potential for future radon (Rn-222) detection and alpha-particle contamination monitoring applications.

## ACKNOWLEDGEMENTS

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