Contribution ID: **20**

Type: **Oral Presentation**

#6-20 A Compact Solution for Detecting and Identifying Radioactive Gases Through Coincidence Quenching

Wednesday, June 11, 2025 3:40 PM (20 minutes)

The measurement of pure β-emitting radioactive gases, such as tritium (^{3}H) and krypton-85 (^{85}Kr), is critically important for nuclear safety authorities, particularly for environmental and safety assessments of nuclear facilities. The demand for these measurements is expected to increase with the global expansion of nuclear energy production and the growing need for radioactive waste management. Due to the limited penetration depth of β particles in air, direct detection of gaseous β emitters requires their interaction with radiosensitive materials. Traditionally, these gases are detected through gas-gas mixtures in ionization chambers or gas-liquid mixtures in liquid scintillation systems. However, these methods are often destructive, especially in primary measurement techniques such as triple-differential proportional counters. Moreover, they are typically used to measure high concentrations—on the order of hundreds of $Bq \cdot cm^{-3}$—which are much higher by about 6 orders of magnitude than the concentrations found in the environment, often around hundreds of $Bq \cdot m^{-3}$. This leaves a gap in accurate and non-destructive methods for detecting lower concentrations in everyday environmental scenarios.

In this study, we introduce a novel concept and set of methods designed for non-destructive, direct measurement of radioactive gases at concentrations as low as $kBq \cdot m^{-3}$, with measurement times as short as 100 seconds. This new approach is based on a gas-solid mixture using highly porous inorganic aerogels as scintillators, that act as the detection medium. These aerogels are specifically designed to emit light when they interact with ionizing radiation from radioactive gases. The light emitted by the aerogels is detected by a system incorporating double or triple photomultiplier tubes (PMTs), providing efficient real-time measurement of β-emitting gases at low concentrations.

The device we developed is compact and designed to be integrated into routine monitoring systems at nuclear facilities or environmental sites. The measurement method relies on a simple yet effective coincidence quenching technique, which we developed within the scope of this study. This technique allows for the accurate detection of low-energy β particles by improving signal clarity through coincidence counting between multiple PMTs. Additionally, this method supports the measurement of gas mixtures (even pure beta emitters), which is a significant advance over traditional techniques that often struggle with complex mixtures of multiple radioactive isotopes. We will present the unmixing method developed to separate the signals from different gases, allowing individual radionuclide identification in mixed samples.

Experimental results from tests performed in a unique radioactive gas mixture chamber will be presented, showcasing the device's performance in detecting both ^{3}H and ^{85}Kr gases. These tests include a full characterization of the system's linearity and detection efficiency for each gas, both individually and when combined in mixtures. The system was found to provide accurate measurements over a wide range of concentrations, demonstrating its robustness and flexibility in various applications. The ability to efficiently and non-destructively measure low concentrations of β-emitting gases in real-time represents a significant step forward for nuclear safety monitoring and environmental protection.

In terms of future applications, this technology has the potential to be scaled and adapted to a wide range of radioactive gases beyond ^{3}H and ^{85}Kr. Its use in conjunction with portable or stationary monitoring systems could provide valuable insights into atmospheric or industrial contamination, ensuring safer working conditions and improving compliance with safety regulations.

The authors acknowledge support from the European Community through grant n° 899293, HORIZON 2020

–SPARTE and the support of Laboratoire National de Métrologie et d'Essais (LNE) in the framework of SCINTIPLUS project.

Primary author: Dr SABOT, Benoit (Université Paris Saclay, CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), 91192 Palaiseau, France)

Co-authors: Prof. DUJARDIN, Christophe (Université Claude Bernard Lyon 1, CNRS, ILM UMR 5306, Villeurbanne, France); Dr CHAPUT, Fréderic (Laboratoire de Chimie, Ecole Normale Supérieure de Lyon, Université Claude Bernard Lyon 1, CNRS, UMR 5182, Lyon, France); Dr LEROUGE, Fréderic (3Laboratoire de Chimie, Ecole Normale Supérieure de Lyon, Université Claude Bernard Lyon 1, CNRS, UMR 5182, Lyon, France); Dr RODRIGUES, Matias (Université Paris Saclay, CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), 91192 Palaiseau, France); Mrs PIERRE, Sylvie (Université Paris Saclay, CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), 91192 Palaiseau, France); Dr CHEREF, Yannis (Université Claude Bernard Lyon 1, CNRS, ILM UMR 5306, Villeurbanne, France)

Presenter: Dr SABOT, Benoit (Université Paris Saclay, CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), 91192 Palaiseau, France)

Session Classification: #06 - Nuclear Safeguards, Homeland Security and CBRN

Track Classification: 06 Nuclear Safeguards, Homeland Security and CBRN