

**Summer School of Applications of Radiation Physics on Cultural Heritage (SARP-CH),  
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**Statistical uncertainty in radiation emission: an intrinsic, or random, error that  
affects the precision of any measurement**

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Quantum mechanical processes are fundamentally random in nature. A clear example of this randomness is atomic decay: it is not possible to predict the exact moment when an atom in an excited state will return to its ground state. Instead, quantum mechanics allows only the calculation of the probability that this transition will occur within a certain time interval. Because excited atomic states typically have very short lifetimes, this randomness is not easily observed directly. However, it still plays an important role in experimental observations.

Measurements that rely on detecting radiation emitted during atomic decay are therefore subject to statistical fluctuations. These fluctuations arise from the random nature of the decay process and represent an unavoidable source of uncertainty in radiation measurements. The study of these uncertainties is known as *counting statistics*. Counting statistics provides the tools needed to analyze radiation counting data and to estimate the expected uncertainty associated with such measurements.

**Intended audience**

This lecture addresses the needs of young professionals and academics who employ x-ray analytical characterization techniques quantitatively in the development, production, and quality control of advanced materials, with applications spanning advanced manufacturing, environmental sciences, and cultural heritage.

**Learning outcomes**

By the end of the lecture, participants will understand that, in X-ray spectroscopy, unavoidable uncertainties arise both from the inherent instrument limitations and from the intrinsic nature of the observed phenomena. They will be introduced to analytical methods used to quantify measurement errors and to achieve instrument calibration and measurement validation in order to meet the requirements for reliable characterization of different materials.