Rare Neutral Particle Detection in Fundamental and Applied Physics

Course Number: NE 290D
Course Control Number: 64180
Course Units: 3
Course Instructor: Bernstein

Catalog Description

In both fundamental and applied nuclear physics, researchers and users of radiation detection equipment are often confronted with the need to extract a weak signal from a strong, fluctuating, or uncertain background. This area of research is sometimes referred to as rare event detection, where the rareness is defined not in an absolute sense, but as a rate relative to background. In this course we further restrict the topic to neutral particles, in part because these are the penetrating radiations of greatest interest for nuclear security applications, and in part because some of the most interesting topics in modern fundamental physics involve neutral particle detection. Students will learn about the unifying concept of rare neutral particle detection as applied to topics as disparate as dark matter detection, fundamental and applied reactor antineutrino physics, and identification of shielded highly enriched uranium in nonproliferation contexts. While rare event detection is pervasive throughout experimental physics, from accelerator-based particle physics to astrophysics, emphasis in this course will be on detection of keV-MeV scale interactions of neutral particles, including gamma-rays, neutrons, neutrinos and dark matter. The lectures will introduce the technologies and techniques used for rare neutral particle detection, illustrated by examples from ongoing fundamental and applied nuclear physics experiments. Presentations by representatives of these experiments will make up approximately one half of the lectures.

Course Prerequisites

- Graduate standing or consent of the instructor
- NE 104 or similar course strongly recommended (see instructor otherwise)

Textbook(s) and/or other required material
• Journal articles distributed in advance of lectures
• Recommended: G. Knoll, Radiation Detection and Measurement, 4th Ed.

Course Objectives

• Explore the unifying concept of rare event detection as applied to fundamental and applied nuclear physics
• Introduce students to advanced methods for measuring MeV-scale neutral particle interactions.
• Introduce students to cutting-edge research into the limits of rare event detection, as illustrated by ongoing experiments and deployments.

Topics covered

• Basic concepts in MeV-scale neutral particle detection
• Noble liquid and noble gas detectors
• Time Projection chambers
• Scintillator and water based detectors
• Analysis techniques specific to rare event detection
• Gamma-ray detection and imaging, imaging modalities, basic concepts in image reconstruction.
• Neutron detection and imaging.
• Examples of fundamental and applied rare event detection experiments and deployments

Class schedule

• 3 hours of lecture per week

Assessment of student progress toward course objectives

• Homework: 50%
• Technical presentation or paper: 50% Student are expected to choose a topic from the course and do research into some aspect of that topic in the style of a review article. The students will work with the Instructor and guest lecturers to define the paper topic.