Application of ^{4}He Fast Neutron Scintillation Detectors to Nuclear Materials and Radiation Detection

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Introduction

The ^{4}He fast neutron scintillation detectors

- Neutrons undergo elastic scattering with ^{4}He nuclei
- Scintillation photons are produced by the decay of ^{4}He excimers to the ground state
- Two Hamamatsu-R580 photomultipliers (PMTs) on each end of the detector, 150 bar high pressure ^{4}He gas is filled inside the gas chamber

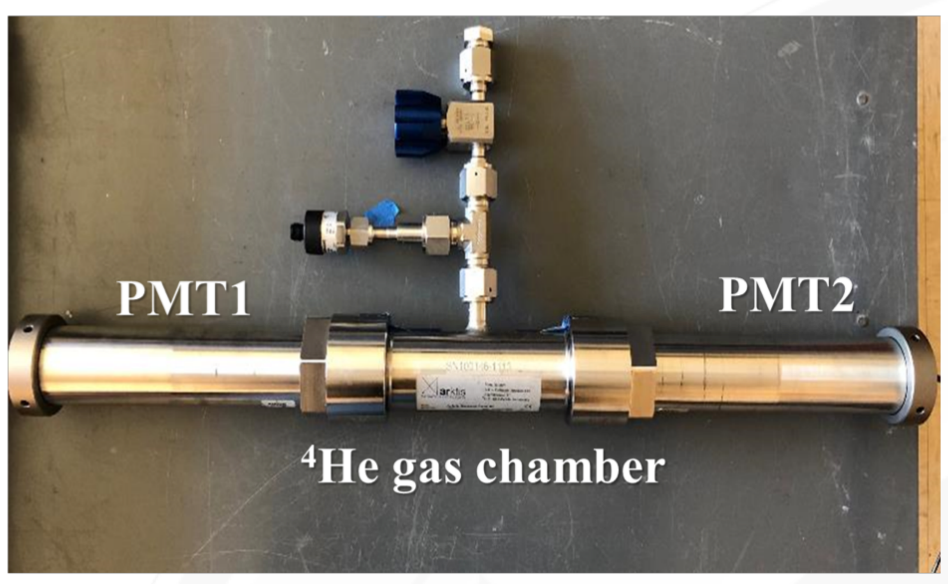

Figure 1: The PMT-based ^{4}He detector

Characteristics

- High ^{4}He elastic scattering cross-section around 1 MeV
- Neutron spectroscopy
- Good gamma-ray rejection and pulse shape discrimination (PSD) capability

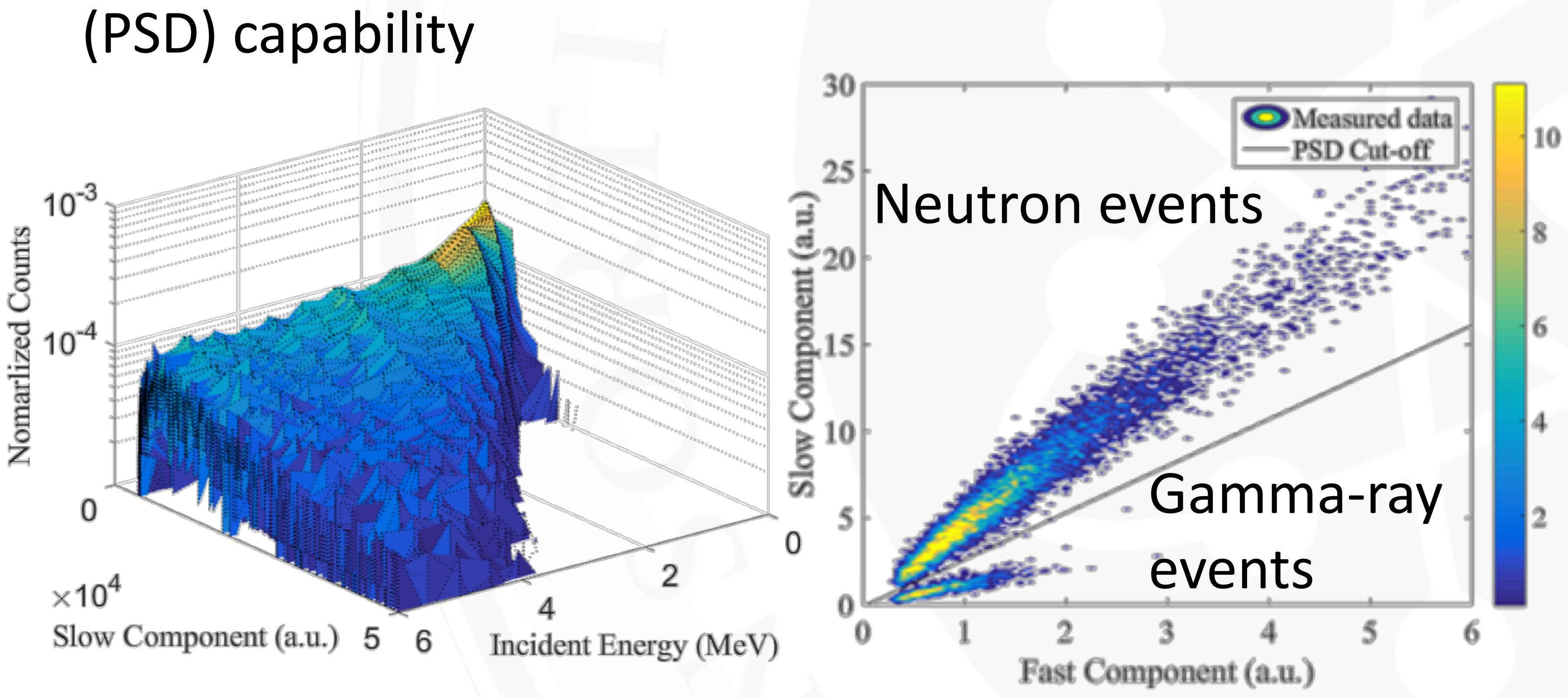

Figure 2: The ^{4}He detector's response matrix (left) and the PSD plot (right)

Technical Work and Results

Measurement of neutron and gamma-ray cross-correlation functions

- Two sources (a 73.7 μCi ^{252}Cf and a 1 Ci Pu-Be) are placed at three source-detector distances during the measurement

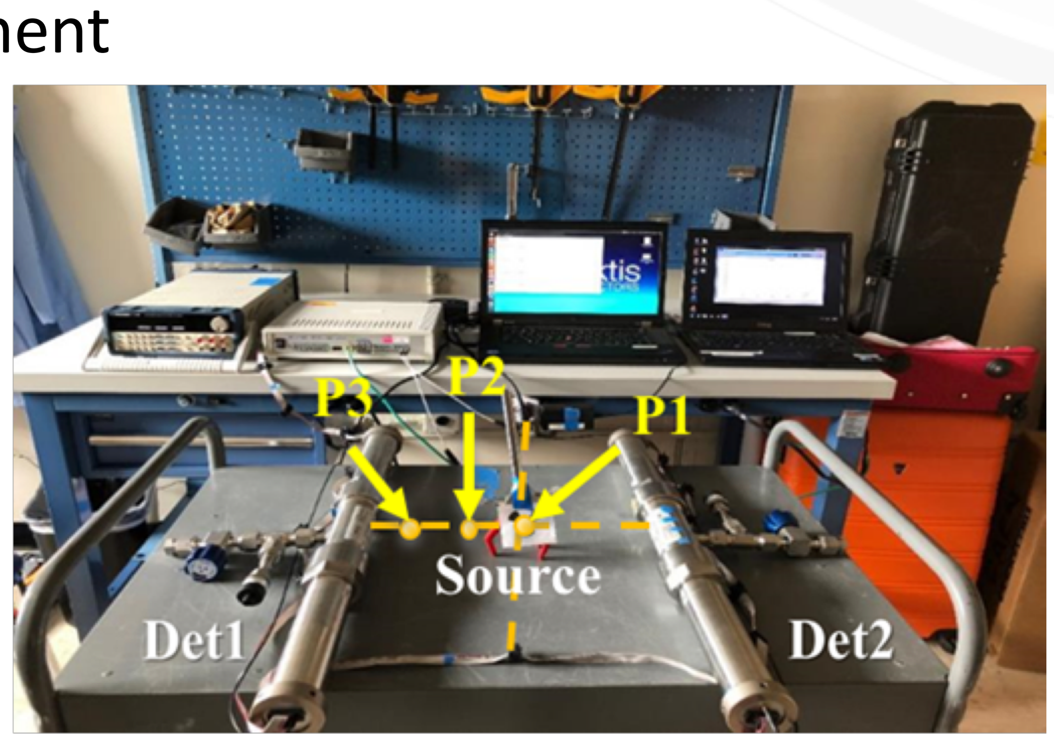

Figure 3: The experimental setup of the cross-correlation function measurement

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- Both separate ((γ, γ), (n, n), (γ, n), and (n, γ)) and total cross-correlation functions are measured

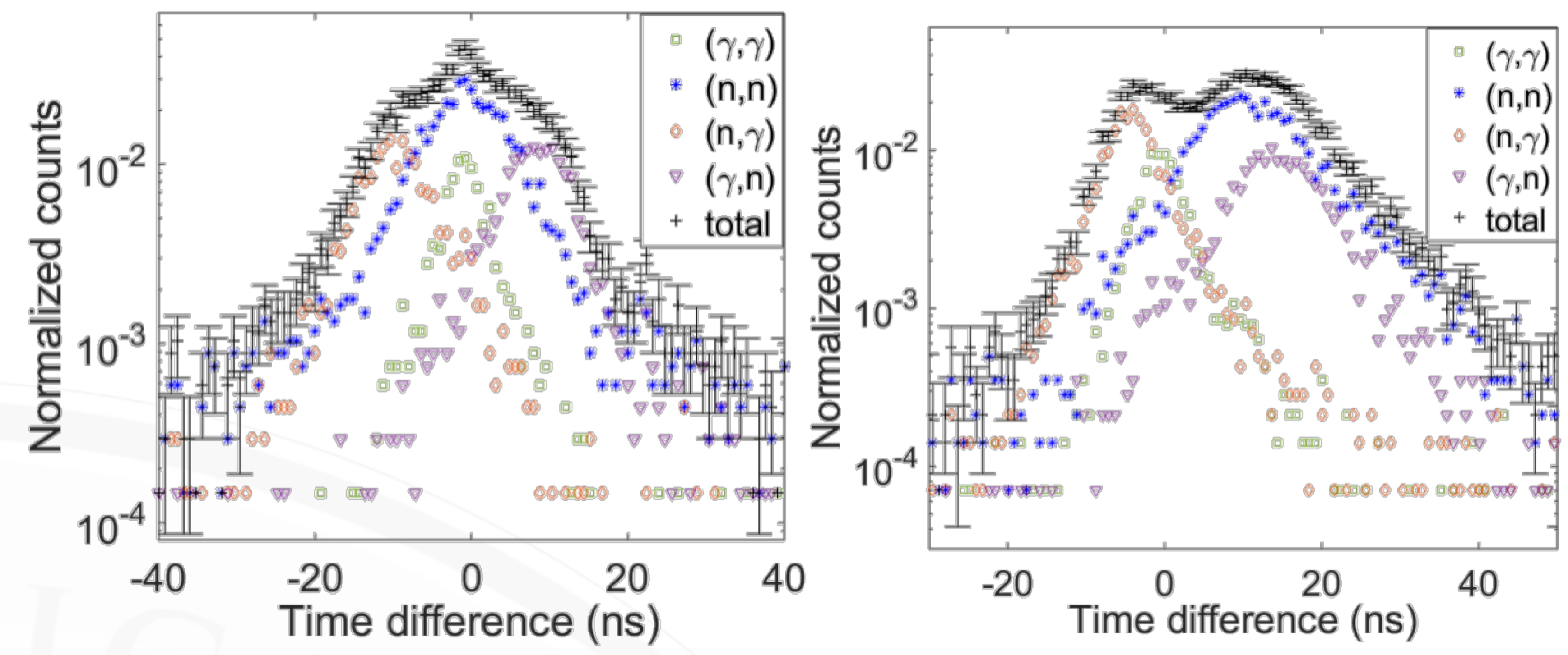

Figure 4: Measured cross-correlation functions at P1 (left) and P3 (right) by using ^{252}Cf source

- The peak position of the cross-correlation functions (Gaussian-fitted) can indicate the source location; the shape of the cross-correlation functions can indicate the source type

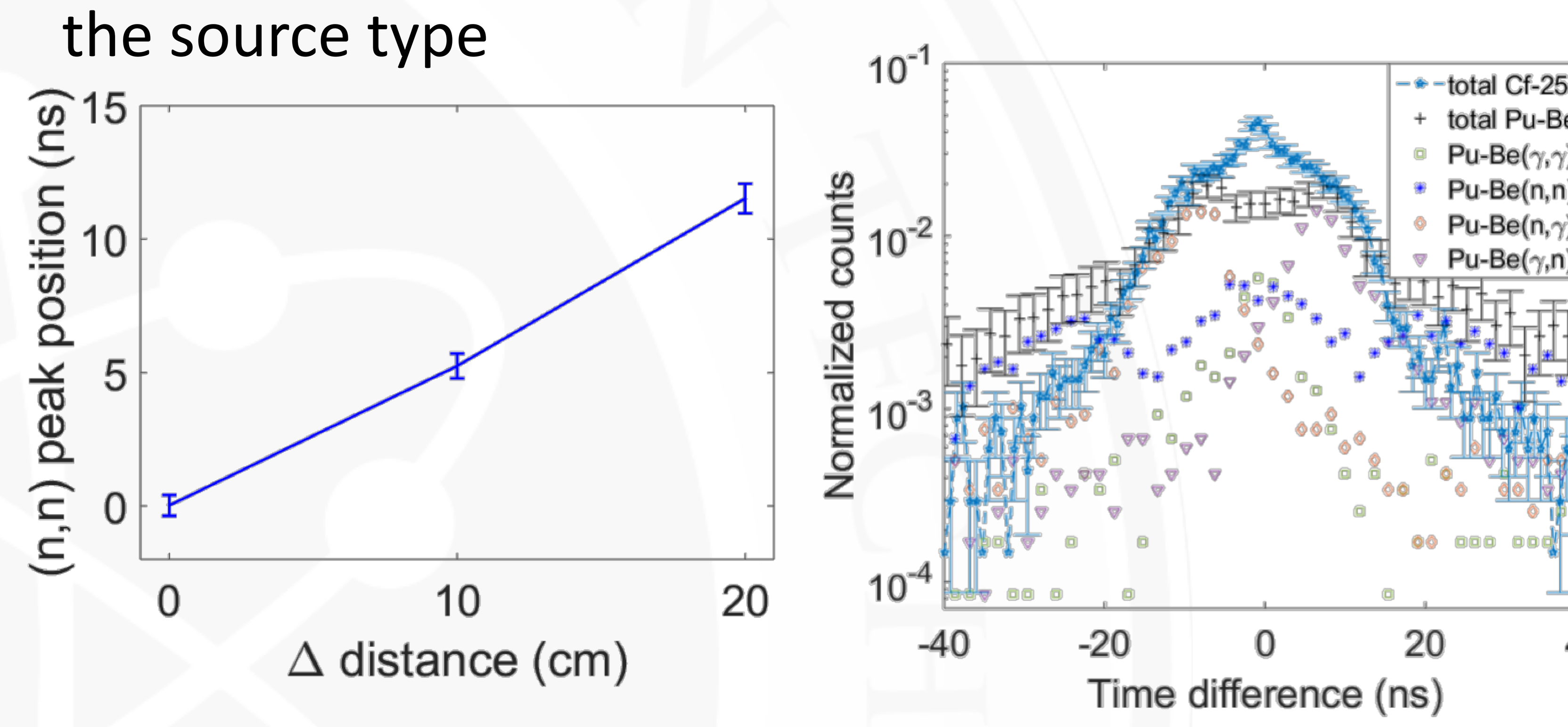

Figure 5: the (n, n) peak position as a function of the source location (left) after gamma peak correction from ^{252}Cf measurement, and the measured Pu-Be and ^{252}Cf cross-correlation functions at P1 (right).

Spontaneous fission and (α, n) neutrons differentiation

- Based on detector characterization (TOF technique), and iterative least square unfolding algorithm

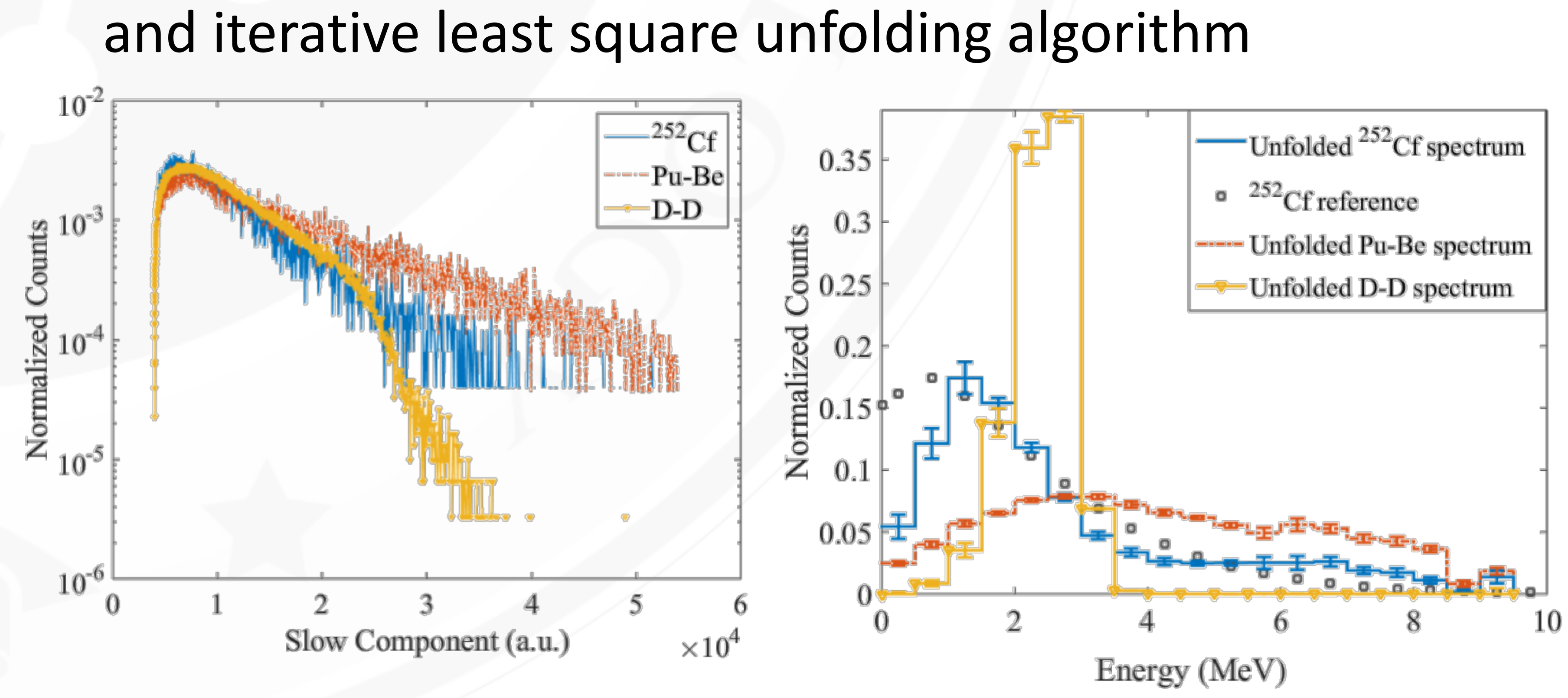

Figure 6: Measured scintillation light output from three types of neutron sources (left), and the corresponding unfolded spectra (right).

Mission Relevance

- Spent nuclear fuel dry casks monitoring
  - Primary neutron sources from the SNF: SF and (α, n) reactions
  - The emission neutron spectrum varies as a function of cooling time
- Nuclear safeguards
  - Source identification
  - Material-geometry configuration