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A Quick Overview of the Extended Feynman Project

L. F. Nakae

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PI: Leslie F. Nakae, Lawrence Livermore National Laboratory

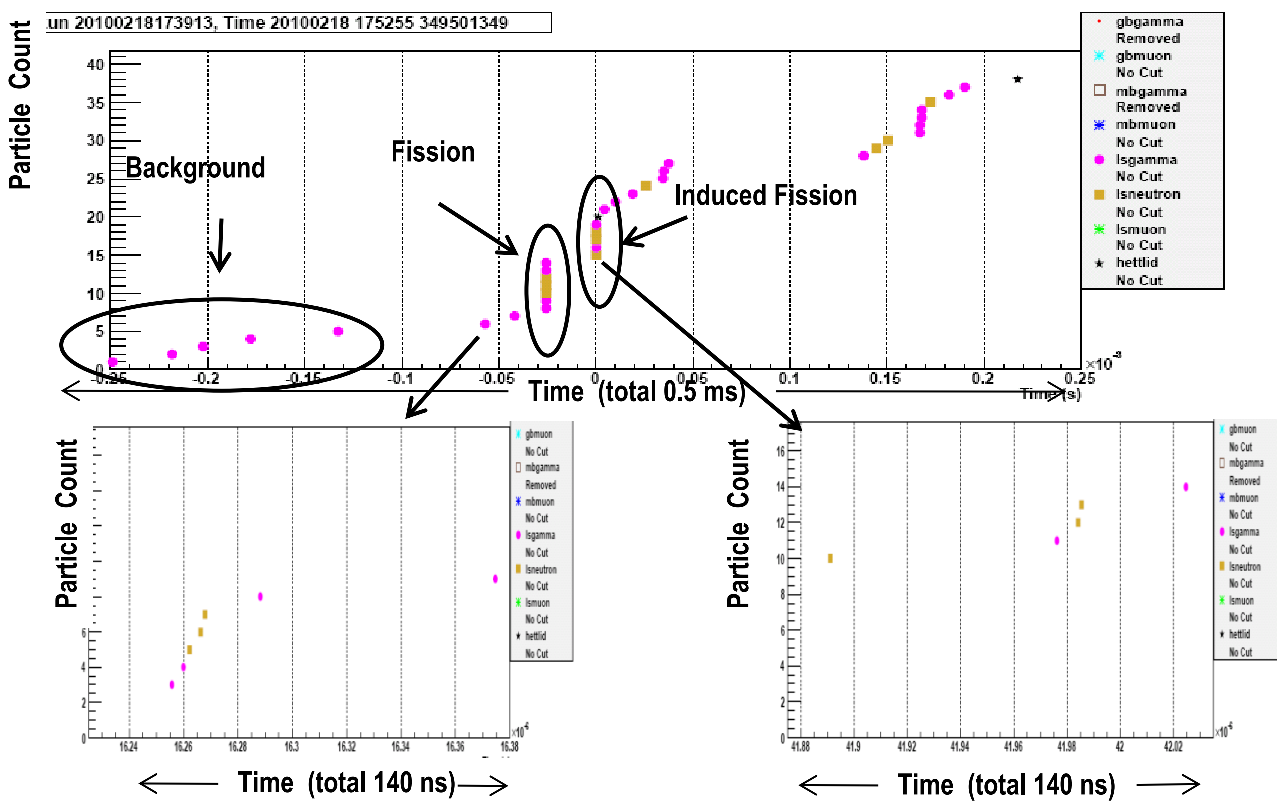
Introduction:

The low natural background rates and the penetrating nature of neutron radiation makes neutron detection a good method for quantifying and accounting for large amounts of special nuclear material capable of neutron induced fission and fission chains. Fission is one of the few natural processes that produces time-correlated neutrons, the others are spallation-type processes (*e.g*. (n,Xn), cosmic induced background, *etc*) which have low but measurable rates in common terrestrial material. The high rates of most transuranic spontaneous fission sources of even a gram or less usually swamp any cosmic induced background rate but even Kilogram quantities of natural uranium produce neutrons only on the same order as that of the cosmic generated background flux. However the primary characteristic of special nuclear material is its ability to fission and to support fission chains through neutron induced fission. This means that neutrons produced from fission are not produced randomly singly but rather in time-correlated bursts. Almost from the beginning of the atomic age, the measurement of time-correlated neutrons has been used to detect and quantify fission and fission processes. Feynman himself proposed a method, the grandfather of what is used today, to compare correlation rates of neutron flux in a fixed time to that which would be expected of a random neutron source. The larger variance (broader distribution) as compared to a random distribution is a tell-tale sign of correlated production and commonly used as signature of fission and more importantly fission chains, the broader the distribution (and its departure from a random distribution) the higher the multiplication. Feynman's original method was used to determine the criticality of the first reactor and other critical or near critical systems. We at LLNL have been developing this concept over the past decade and a half and have employed it for the detection and assessment of nuclear materials. Our method for doing this involved generating a theoretical prediction of what we might expect to see, given a neutron source (spontaneous fission with a nubar, or alpha-n) and a possibly multiplying material (Plutonium or Uranium) and comparing it to a measured result and deducing from this what it is we are measuring. We first developed these methods for portable (low efficiency) thermal neutron detectors that were used predominantly for emergency response situations and we have applied some of these techniques with thermal neutron detectors to arms control verification and authentication, for example verifying that there are multiplying quantities of plutonium in an unknown object. In recent years we have been exploring the use of fast neutrons using liquid scintillator cells with Pulse Shape Discrimination (PSD) and in this project we developing both the theory of fast particle production from fission and fission chains and the use of fast particle detection methods primarily for arms control verification and authentication, but for other uses. We have found that fast detection has many advantages, primarily because the speed of the detection (nanoseconds) preserves the original time scale of the particles produced by fission (and more importantly from induced fission) but also because the fast time scales allow for considering much shorter measurement times (binning) that greatly reduce the pollution of random correlations.

Project Description:

We found that the implementation of fast counting (gamma-rays as well as neutrons) has yielded great dividends. For FY12-13 our plan has been to naturally extend the time correlated analysis to include gamma-rays and fast neutrons while leveraging our fast neutron and gamma ray detector development from NA-22 and our existing thermal neutron detection technology with the analysis and algorithm development in this project. The idea is to develop robust algorithms that exploit time-correlation measurements for verification purposes. These algorithms are intended to verify meaningful characteristics of nuclear weapons systems. From our technology this will mean specifically SNM characteristics: multiplication, material form, quantities, geometry of system (including numbers of sources), and more, all determined from the neutron and gamma ray time signatures of an object in question. We use both thermal and fast neutrons as well as data collected with both NaI and within our LSA at LLNL and other sites and also at the Warhead Measurement Campaign (ongoing) to develop and test these algorithms. Work completed that will be shown in the review.

1) Theoretical Developments: Past work includes the theoretical formulation of fission chains and the use of theoretical predictions in the evaluation and assay of SNM. Supported by this project, the inclusion of gamma rays as well as neutrons into the formulations. Theoretical effects of thermal vs. fast detection.
2) Thermal and Fast Neutron Assay – Development of quantitative assay methods for determining source mass and multiplication (and form) from measurement of correlated neutrons from fission.
3) Neutron Momentum Spectral Methods – Using measured neutron momentum distributions for determining form and better quantitative methodology.
4) Imaging with Fast Neutrons and Gamma Rays – use of time correlated neutrons and gamma rays for imaging fissioning sources.
5) Other verification methods from detailed time structure of SNM objects – This bullet describes our current ongoing work where we will describe the methods we are developing time correlation signatures that are markers for material characteristics necessary for verification. Many of these methods are simple, very robust and impossible to spoof.



Fission chain burst from HEU (data) - X-Axis running time (0.5ms in upper figure) Y-Axis number of particle in sequence. Left group of Gamma rays show background gamma rate, middle group is a fission right group is fission group induced by a thermal neutron. Lower plots are blown up time scale of bursts in circles. Individual fission bursts occur at 10ns time scale, induced fission at 0.1 μs time scale