leak out of the assembly. Die-away measurements are frequently used as the basis for studies of how to develop instruments to detect shielded special nuclear material.[5,9,12-15,24,26] Measurement approaches based upon the detection of die-away signatures alone can be problematic, however, due to possible complications arising from the presence of neutron absorbers in the test assembly being interrogated.[9]

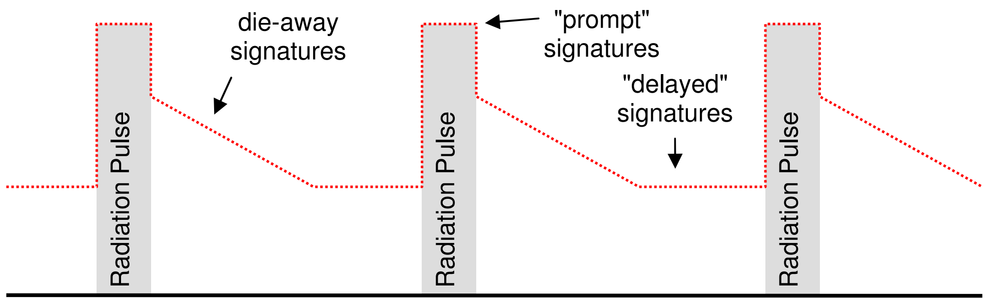

Figure 1 Representative active interrogation timing sequence. The dotted line (red) indicates the measured values that would be observed using a gamma-ray or neutron detector near an SNM-bearing assembly being irradiated.

Following the nomenclature of the prompt and delayed signature labels shown in Figure 1 many researchers have written of measurements that detect "prompt" emissions or "delayed" emissions, according to the timing structure of their detection apparatus. Unfortunately, in some cases though these general terms do not correctly reflect the signatures actually being measured. To understand this difference it is useful to consider traditional nuclear reactor physics concepts for subcritical reactors, including the effective multiplication factor $\boldsymbol{k_{eff}}$ and the subcritical multiplication, $\boldsymbol{M}$.[37] The effective multiplication factor is a ratio indicating the average fraction of new neutrons that will be produced within a multiplying nuclear assembly (accounting for absorption, capture, and fission) following the introduction of an initial neutron into the assembly, such as from a nearby ENG. For example, if a particular assembly has an effective multiplication factor of 0.8 then if 100 neutrons enter the assembly (the zeroth generation of neutrons), while most will escape or be captured, some will cause fission (yielding on average ~2.6 neutrons per fission) to create a so-called "first" generation of 80 new neutrons. These 80 neutrons will again be subjected to the effects of the assembly with $\boldsymbol{k_{eff}}$ = 0.8 to yield a second generation of 64 neutrons, followed by 51, and so on. Summing the zeroth generation plus all of the daughter generations a total of 500 neutrons will have been in the system including those initially from the ENG and then those subsequently produced in the system from fission. Subcritical multiplication is defined as the ratio of the total number of new fission neutrons produced within an assembly to the original number of neutrons injected into the system, Eq. 1.

$$\boldsymbol{M} = \frac{\mathbf{1}}{\mathbf{1} - \boldsymbol{k_{eff}}} \qquad \text{Eq. 1}$$

With this background now consider a pulsed active neutron interrogation measurement with a 25-kg assembly of highly enriched uranium (HEU) enriched to 93% ^{235}U, without any external neutron reflecting materials present, that has an effective multiplication factor of 0.8 and a subcritical multiplication $\boldsymbol{M}$ of 5.[37] During each neutron pulse many neutrons will injected into the systems, some of these will cause fission in the uranium. At the end of each interrogation pulse the neutron population in the assembly from the pulse will quickly die-away, at that time the only sources of neutrons emanating from the assembly will be neutrons produced from the decay of delayed-neutron emitting fission products created earlier and neutrons produced from new fission events in the assembly initiated by these delayed neutrons. For the assembly described here 80% of all the