A New Method for Analyzing Special Nuclear Material in the Differential Die-Away Device

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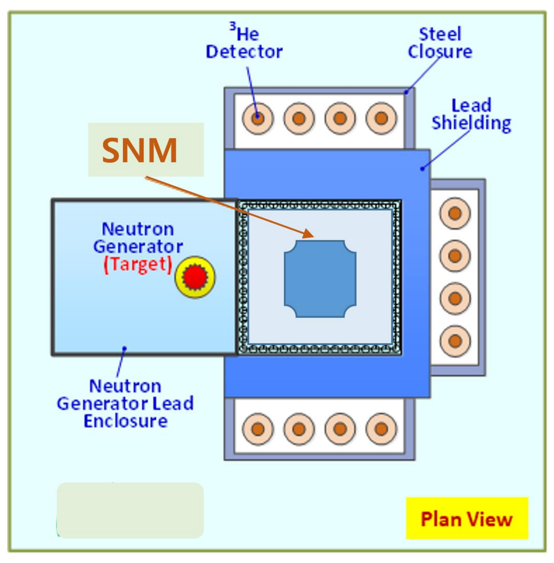
INTRODUCTION: Recently, with the increase of serious conflicts between races, religions, and boundaries around the world, even nuclear terror in anywhere becomes a feasible scenario. To prevent the possibility of terrors, SNM (Special Nuclear Material) should be controlled and handled in a recommended procedure by IAEA, and detection and analysis of SNM are one of the important mission in this process. SNM is hidden or kept in a container using various methods such as solid state, liquid state, powder, or mixture with others. Several passive and/or active techniques are used in detecting SNM depending on different situation. DDA (Differential Die-Away) technique [1] is one of the active method that uses neutron source as a probing tool, and this is applied to detect and analyze SNM, nuclear waste drum and nuclear spent fuel assembly by counting fission neutrons in a short time bin. A schematic diagram of a DDA equipment for SNM is shown in Fig. 1. Usually DDA technique is powerful in detecting SNM, but to analyze the nuclides in it other methods should be introduced such as gamma ray spectroscopy or others. Here a new method to analyze SNM with a DDA equipment is suggested.

Motivation of this Research

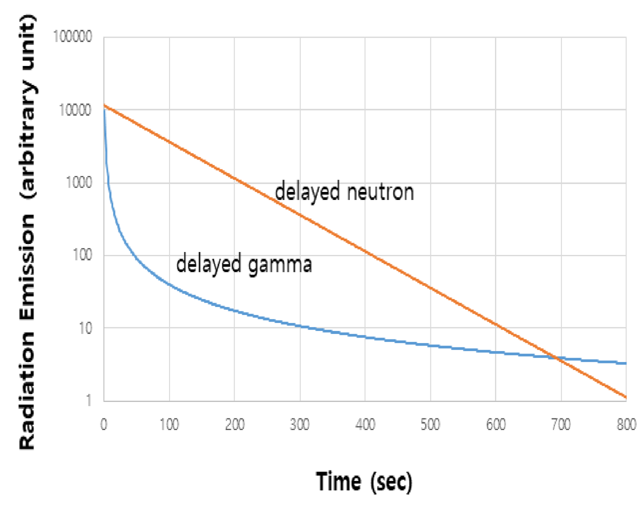
Fig. 1 Schematic diagram of a SNM detector based on DDA technology (active method)



- 현재 개발된 DDA 기법기반 특정핵물질 탐지장비(Fig. 1)의 문제점
  - 중성자발생장치 중성자에 의한 핵물질 탐지 능력 매우 우수하지만
  - 독자적으로는 핵물질 종류를 분석하는 능력이 없기 때문에
  - 핵물질 종류를 분석하기 위해서 추가로 delayed neutron spectrum 분석시스템을 사용하고 있음
  - 그러나 이 방법은 **delayed neutron 발생률이 fission 사건 발생직후 시간에 따라 급속히 감소**(Fig. 2)**하기 때문에**
  - spectrum 분석에 필요한 데이터를 얻는데 시간이 많이 소요되고,
  - 또한 주변 구조물에 의해 감마선 에너지 변화가 많이 발생하면서
  - 정확한 핵종평가가 어려운 것이 현실임

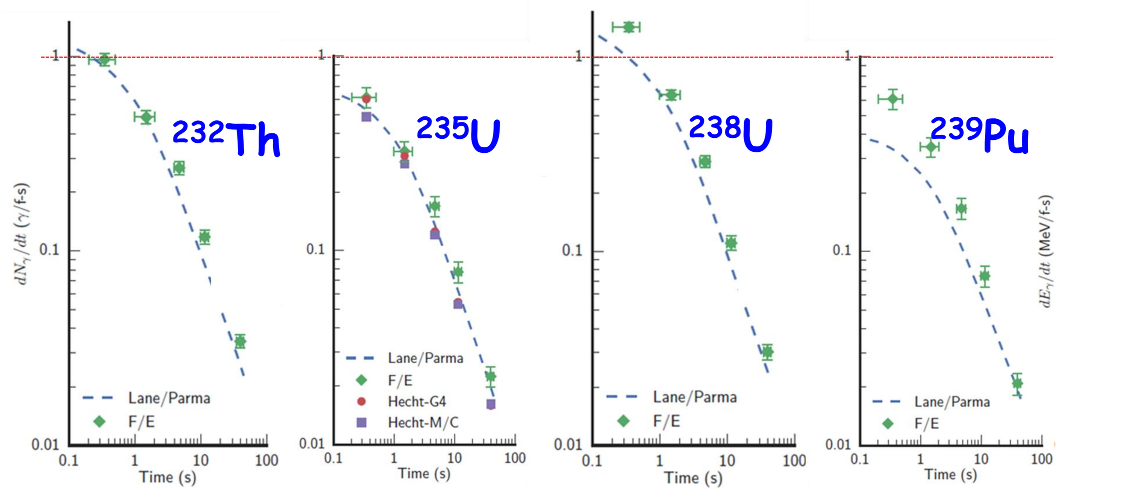
➡ **본 연구에서는 delayed gamma 발생률이 급격히 변화하는 구간에서 delayed gamma 선의 강도변화를 빠르게 추적해서 서로 다른 핵종을 구별할 수 있는 새로운 방법을 제시하고 있음**

Fig. 2 핵분열물질에서 fission 발생직후 delayed gamma 선과 delayed neutron 의 시간에 따른 발생확률 변화 그래프



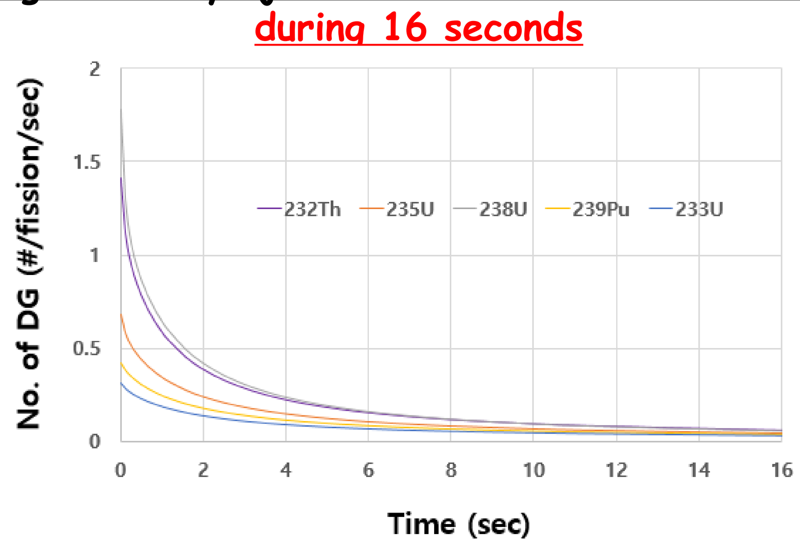
Time Characteristics of Delayed Gamma Ray Generation after Fission

Fig. 3 Long time characteristics of differential number of delayed neutron generation just from a fission event for SNMs



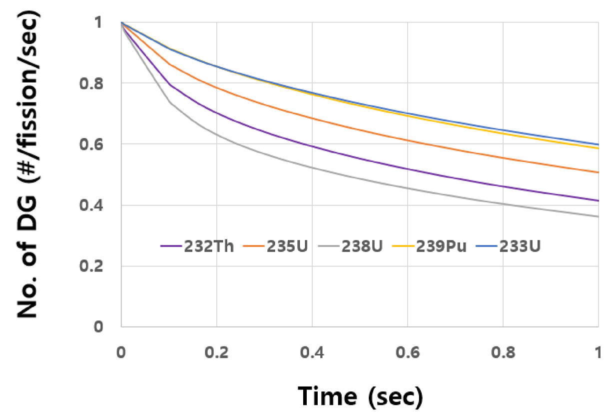
- **Fig. 3** 은 특정핵물질들의 핵분열 직후 시간에 따른 지발감마선 발생강도 특성을 핵종별로 정리한 결과로,
- 핵분열에 의해 만들어지는 지발중성자에 대한 정보는 **2015년 발행된 SANDIA 보고서[5]**에 상세하게 정리되어 있음
- 특히 이 결과는 **분열성 핵물질들의 시간에 따른 지발감마선의 발생특성이 서로 다름을 보여주고 있음**

Fig. 4 Time characteristics of differential number of gamma-rays just after an ENDF fission event during 16 seconds



- **Fig. 4** 는 **SANDIA 보고서[5]**의 핵종별로 시간에 따른 delayed gamma ray 의 시간에 따른 발생률 Table 들을 정리해서 같은 그래프에 정리한 내용으로,
- 특히 10초 이내의 delayed gamma ray 발생율에서 뚜렷하게 서로 다른 핵종을 구별할 수 있는 수준의 차이가 만들어짐을 볼 수 있음

Fig. 5 Time characteristics of the normalized differential number of gamma-rays just after fission event during 1 second



- **Fig. 5** 는 **Fig. 4** 그래프의 시작점들을 일치 시켜고 이에 맞게 발생률들을 표준화 시켜서 fission 직후 1초 동안 비교한 결과로
- **다음과 같은 측정 및 평가에 의해 SNM 핵종들의 구별이 가능**
  - ➤ SNM 에 펄스 중성자를 조사.
  - ➤ 중성자 조사 종료와 거의 동시에,
  - ➤ 수백 μsec 간격으로 delayed gamma 선의 counting 수를
  - ➤ 수백 msec 동안 지속적으로 계측함으로써,
  - ➤ 수백 msec 동안의 delayed gamma 선 발생감소율을 측정.
  - ➤ 측정된 변화율의 분석을 통해 SNM 핵종 평가.

The Suggested DDA System and Detection Scenario

Fig. 6 Schematics of the suggested system for detection and analysis of SNM in a same machine

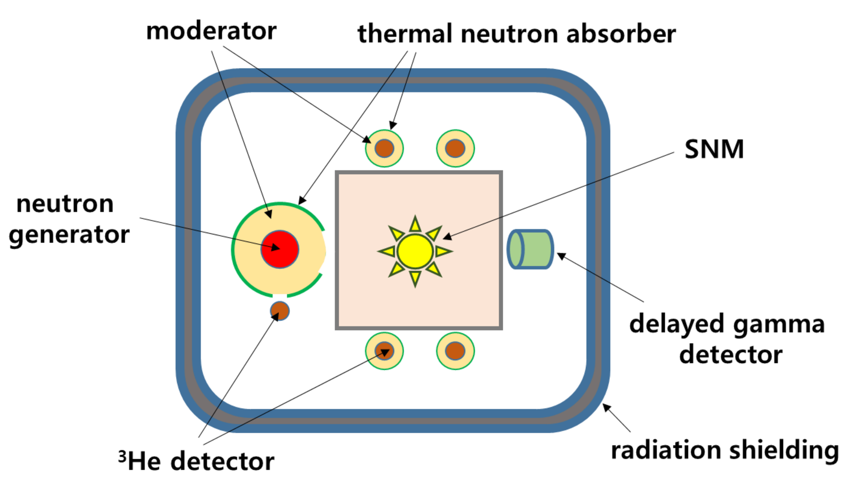


Fig. 7 Circuit diagram of the suggested DDA system

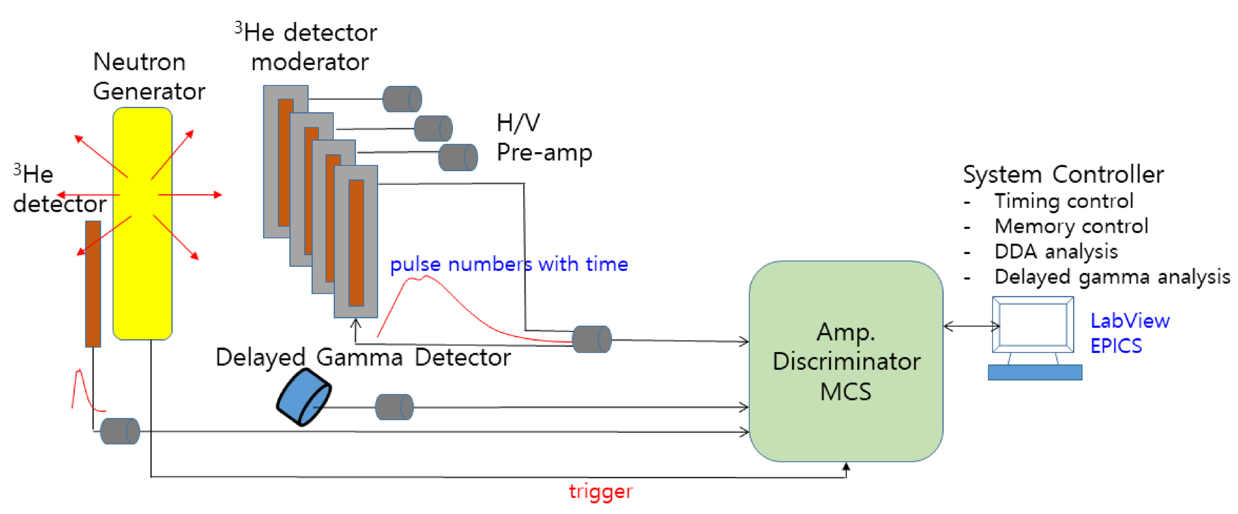
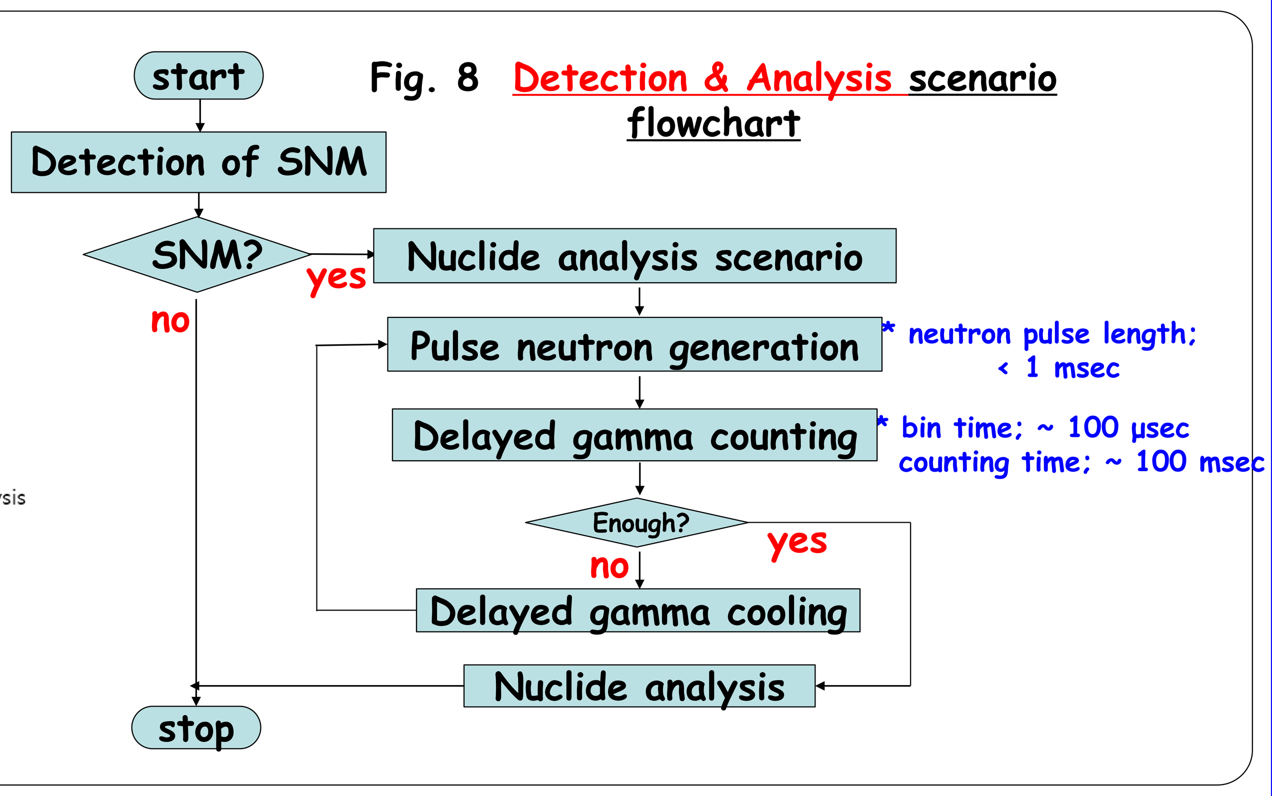


Fig. 8 Detection & Analysis scenario flowchart



FUTURE WORKS: To realize the SNM analysis scenario by counting the delayed gamma-ray in a short time bin with MCS, estimations of optimum operation conditions of neutron radiation time, delay time for counting from the stop of neutron generator, counting time of delayed gamma-rays, counting time bin, and radiation cooling time needed to start next neutron generation are essential to design and operate the system. Some simulation tool or MCNP code will be used for this estimation.

CONCLUSION: A new method to analyze SNM material such as ^{232}Th, ^{233}U, ^{235}U, ^{238}U and ^{239}Pu by counting delayed gamma-rays during the initial transient time of a fission is suggested. The new method could be realized by adding a fast photon detector system to a standard DDA equipment. Compared with the present one that is using gamma-ray spectrum analysis methods, the new system could make faster results with less efforts and money.

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