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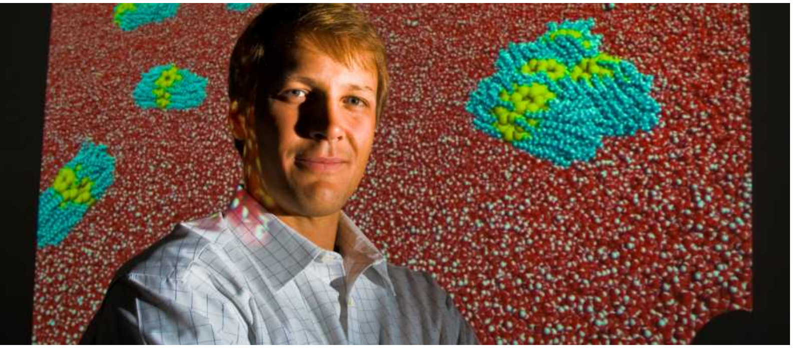
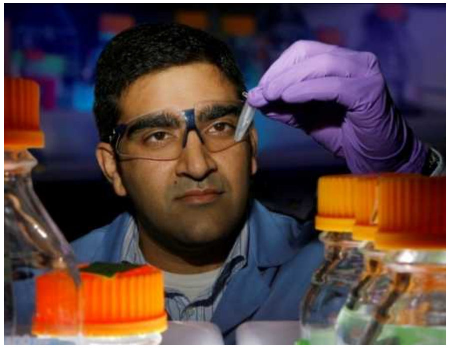
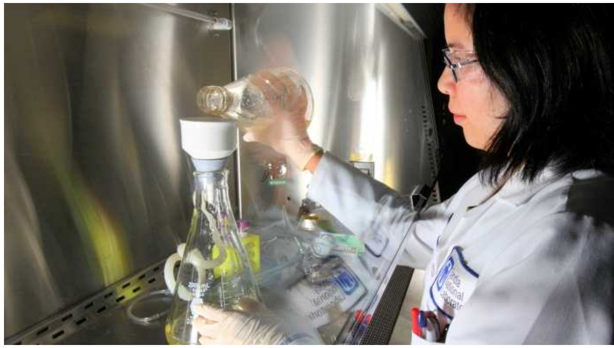

Development of a Rapid Field Response Sensor for Characterizing Nuclear Detonation Debris

S.S. Mitra, O. Doron, A.X. Chen, A.J. Antolak

U.S. DEPARTMENT OF ENERGY · NNSA National Nuclear Security Administration · LDRD Laboratory Directed Research & Development

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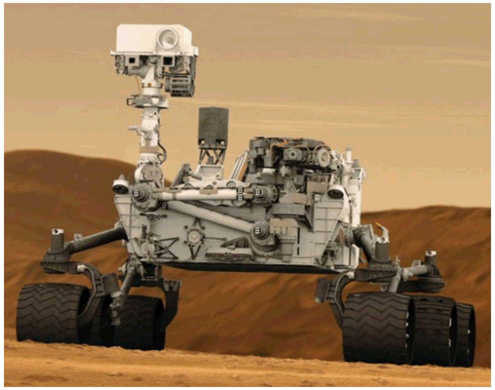
Motivation

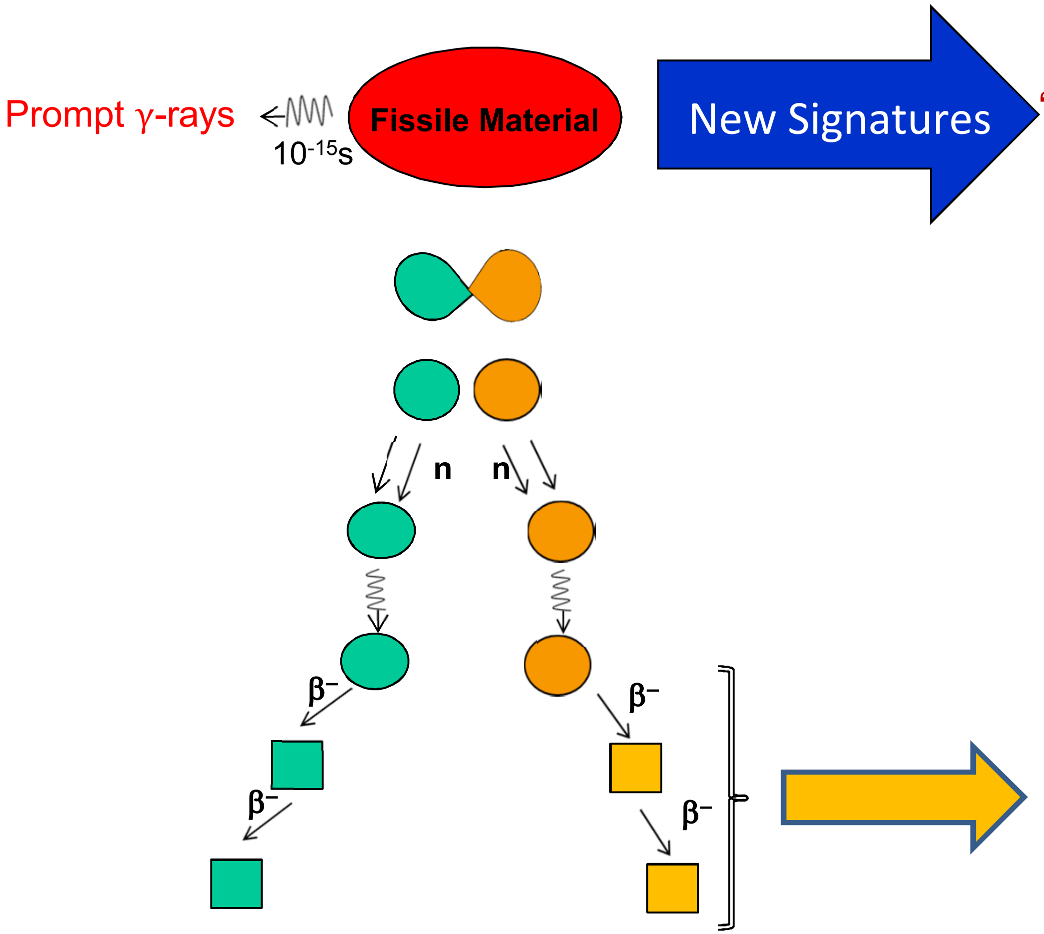
- Potential technologies are required to rapidly determine nuclear or radiochemical composition and isotopics on post-NUDET debris samples.
- Nuclear Forensics would greatly benefit from remotely controlled *in situ* techniques



Approach

Active probing with neutrons will produce

- ❑ pre-fission "inelastic" gamma-rays
- ❑ fission products



Detect characteristic pre-fission "Inelastic" γ-rays on-line (within 10^{-15}s) following active probing

Probing will generate neutron induced fission products

Detect early time fission product gamma-rays

Approach

Energy of neutron source

(D+D) 2.45 MeV

1) Enables to attain only a few of the nuclear excited states and simplifies the structure of the resulting gamma-ray spectrum
2) Neutron thermalization will be more effectively accomplished in the subsurface
3) Low velocity of neutrons (2.2 cm/ns) will produce less background signals from surrounding material if time-of-flight is used

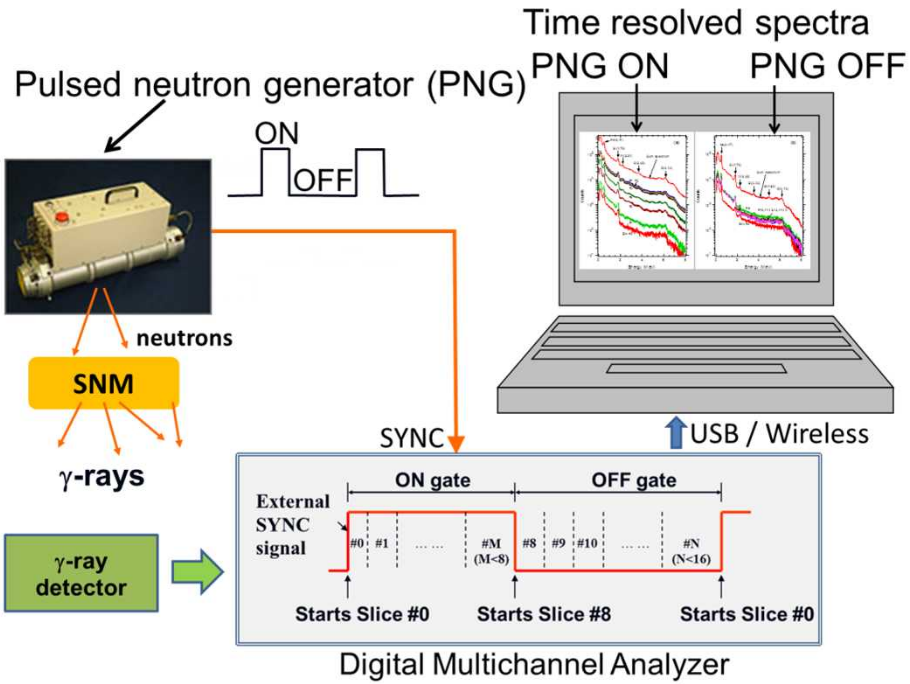
(D+T) 14 MeV

Signals from oxygen of soil will dominate the spectrum from 2-7 MeV

5 cm /ns

Approach

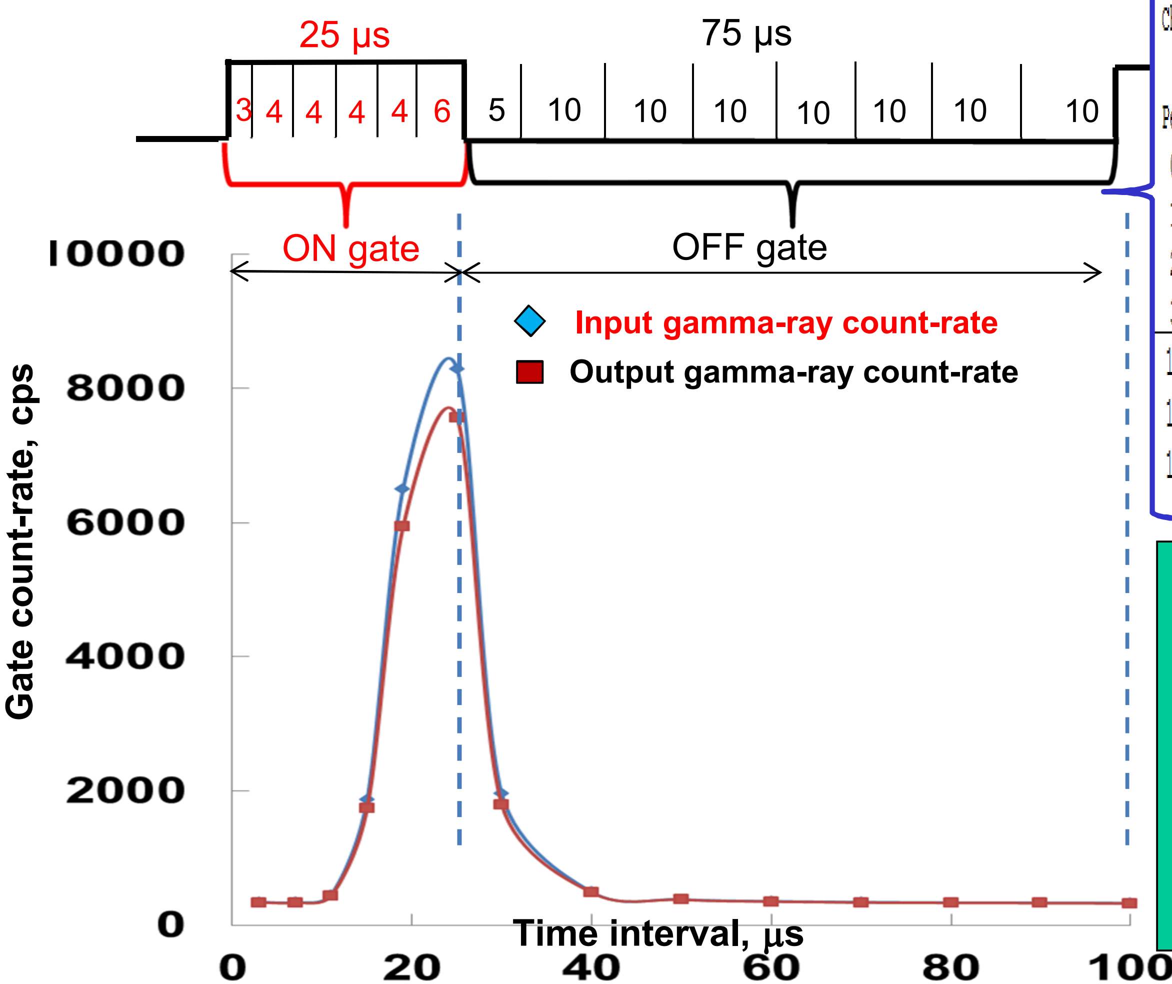
Pulsed interrogation



- Use a portable pulsed neutron generator (250 Hz-20kHz repetition rate)
- Implement time sequenced data acquisition to operate synchronously with the pulsing of the neutron generator
- Customize a digital system for multiple time resolved spectra to resolve the temporal signatures

Neutron induced gamma-ray count rate profile within each gate

- (D+D) neutron generator (10 kHz, 25% DC)
- Co-axial HPGe gamma detector (35% efficiency)
- Iron sample



Module MTRS Run Statistics   Total run time:1h

Channel Number = 0

Period#	Live Time [s]	ICR [cps]	OCR [cps]
0	108.35532929	341.856743389719	336.467068476388
1	144.35376637	339.381515508427	332.627275390432
2	144.35373934	453.31004447259	434.585209131584
3	144.35370365	1873.21137707436	1740.4402772315
13	360.34467724	334.332675378358	329.881381655121
14	360.34453685	330.861128191959	326.631842483003
15	356.39664627	326.911044813071	322.604045810512

Observations from count rate measurements

- Fast neutrons are produced only after 10 µs from the beginning of the ON gate
- Fast neutrons are present 5 µs in to the OFF gate
- Thermalized neutrons in the OFF gate reach steady state ➡ implications for fission product measurements

Capture spectra from some gates between pulses

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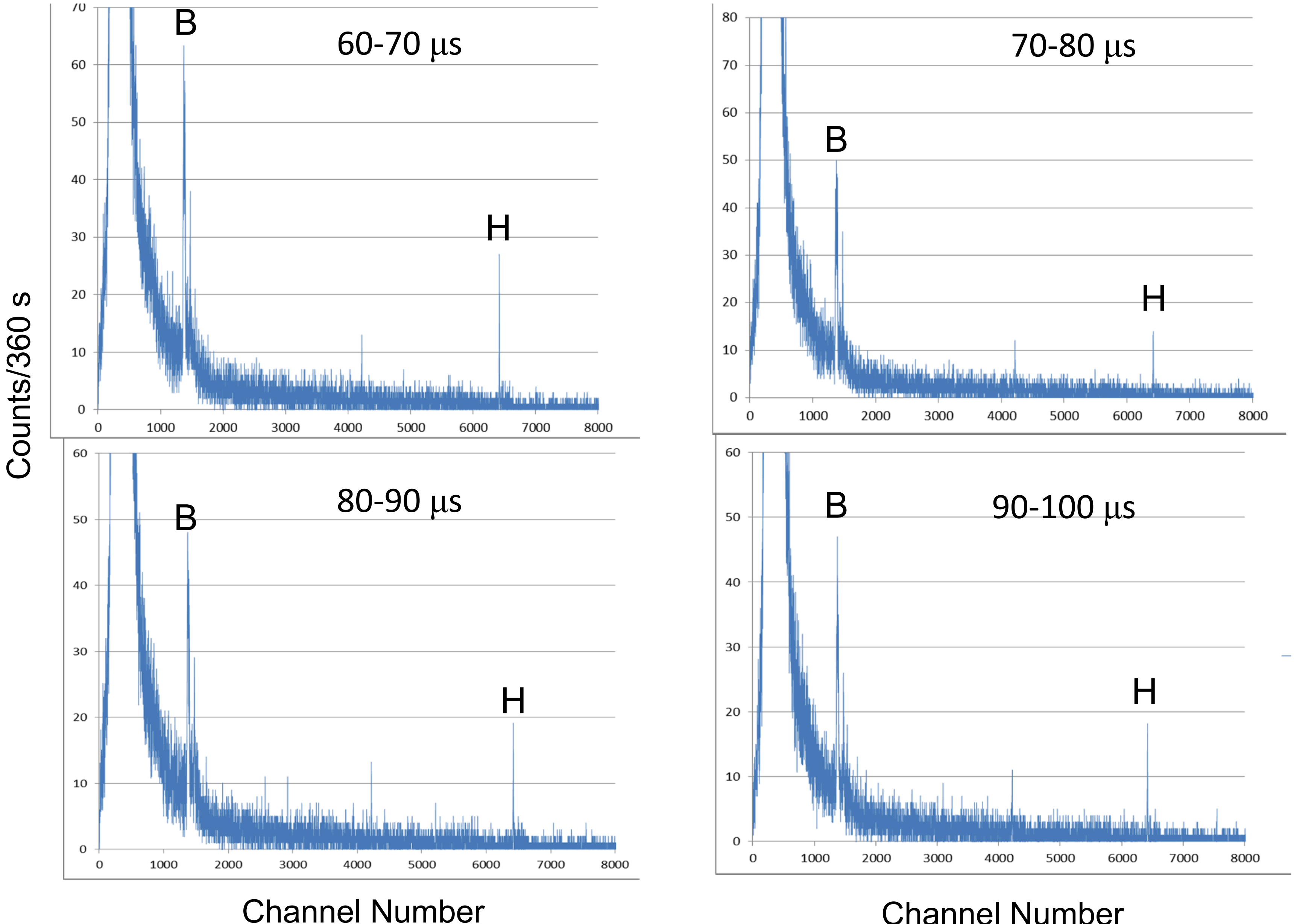
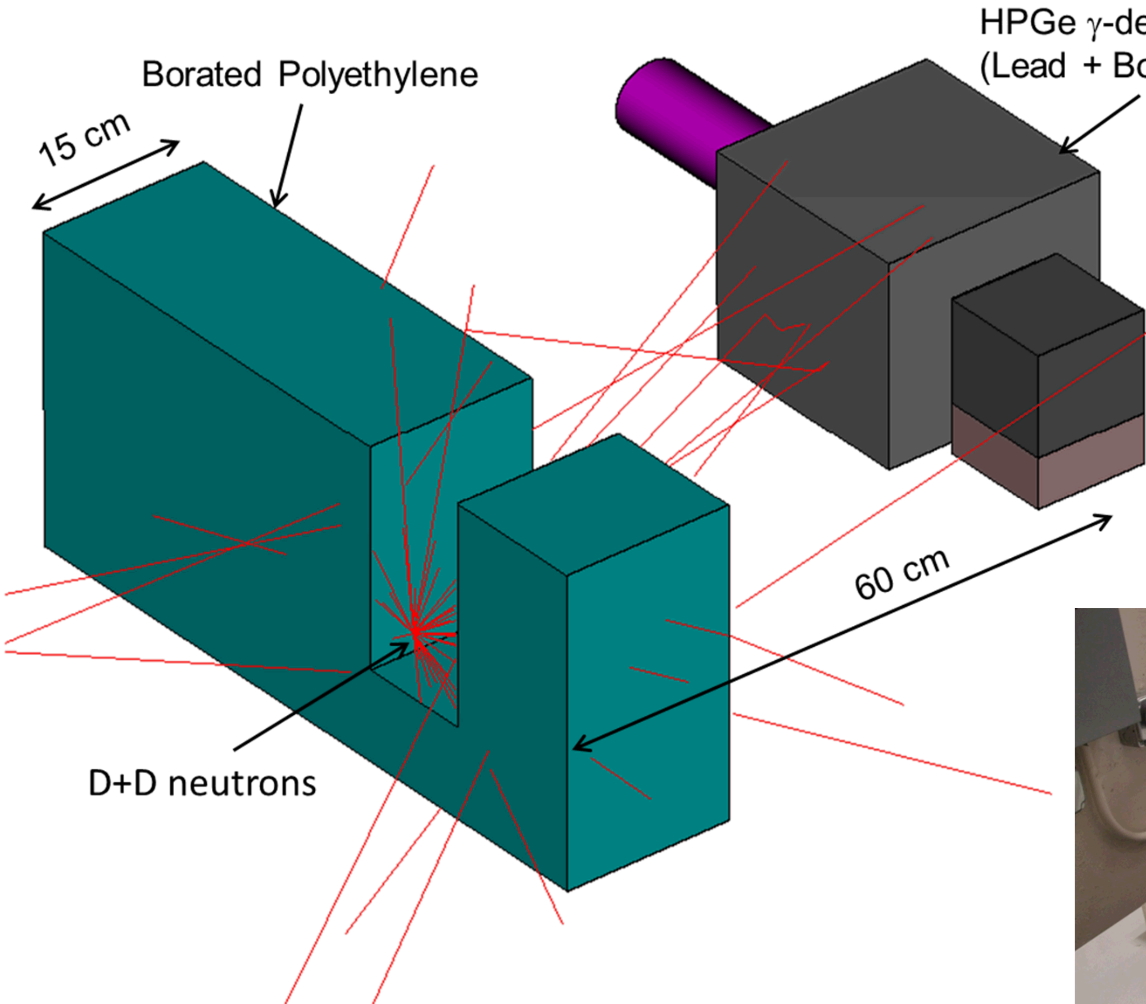
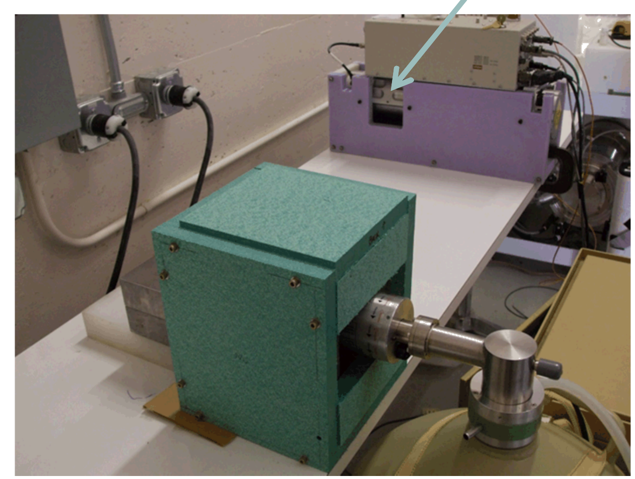


Geometry for MCNP6 Simulations



Neutron generator



Pulsed D,D neutron profile

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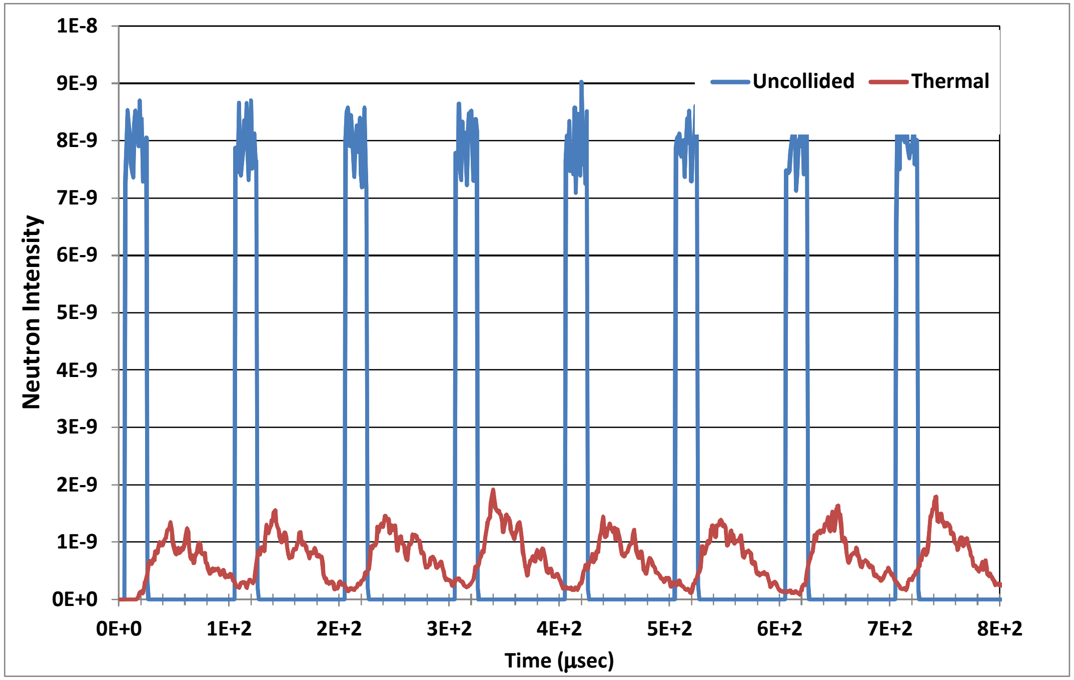
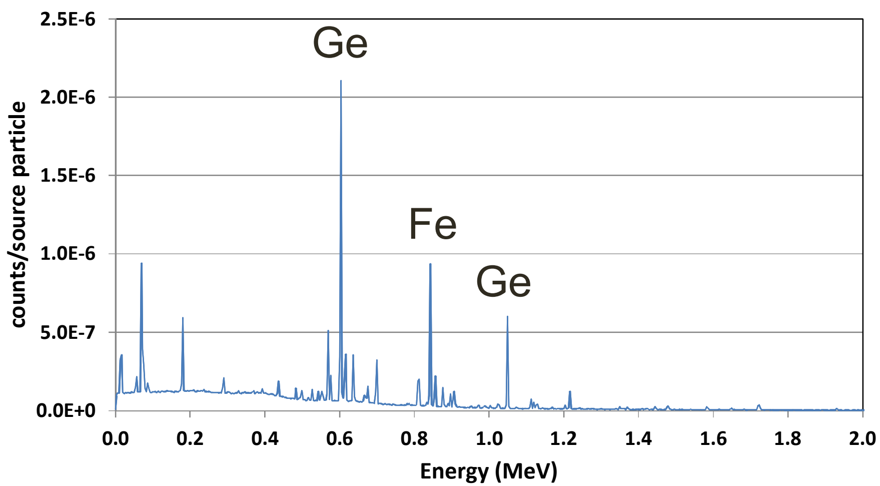
- Pulsed neutron generator simulated in MCNP6. 10 kHz repetition rate (25% duty cycle)
- Thermal neutron flux between NG pulses do not reflect experimentally observed profile.
- This is believed to be due to MCNP6s treatment of neutron transport.



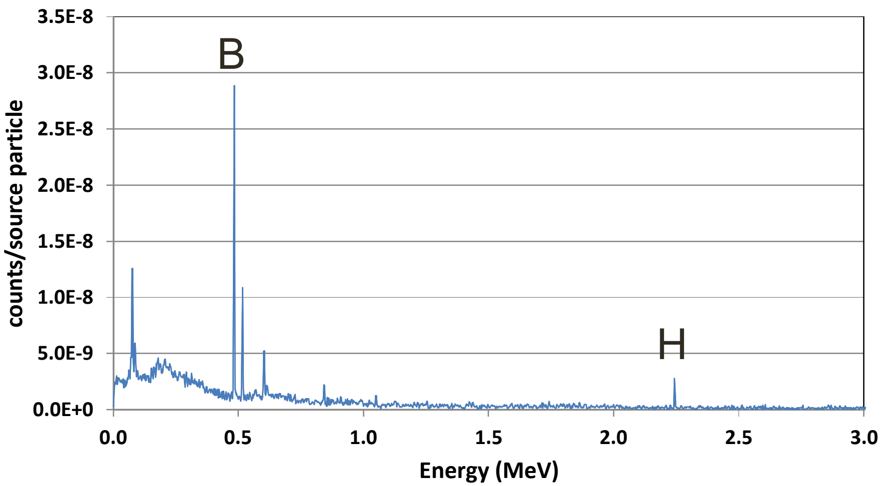
Simulated spectra of Iron

10 kHz (25%DC)

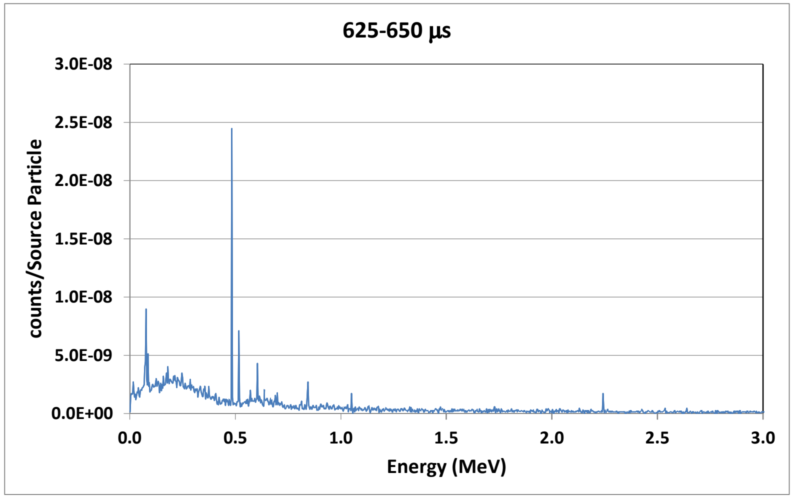
During Pulse (25 μs)

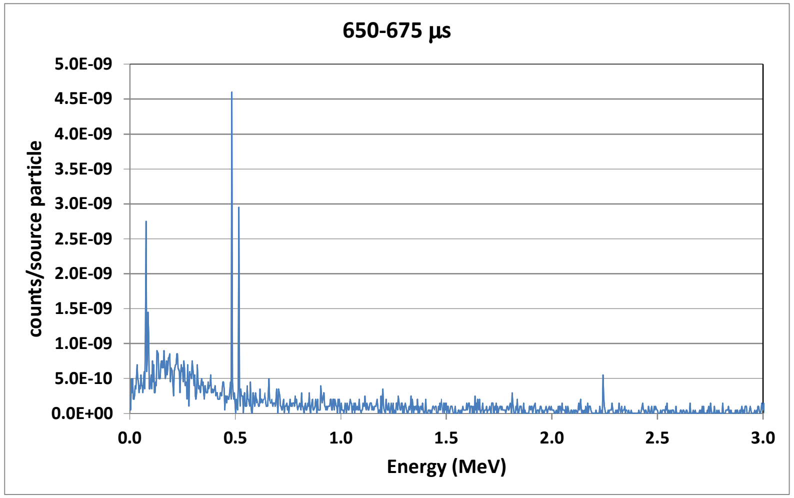


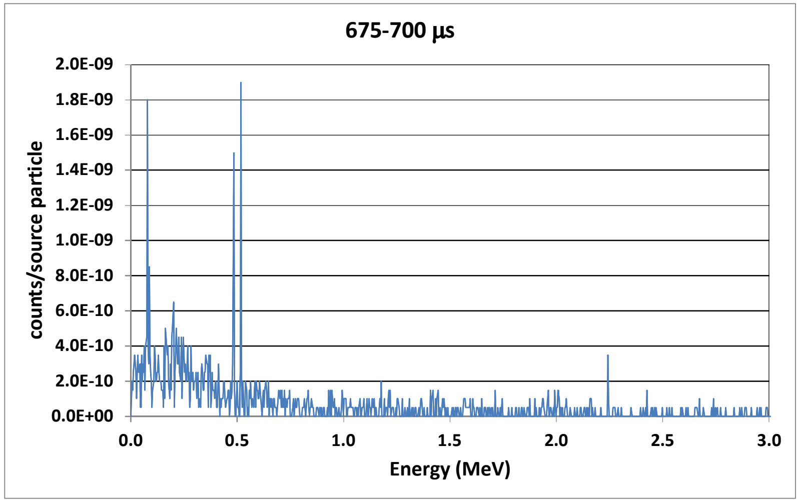
Between Pulse (75 μs)

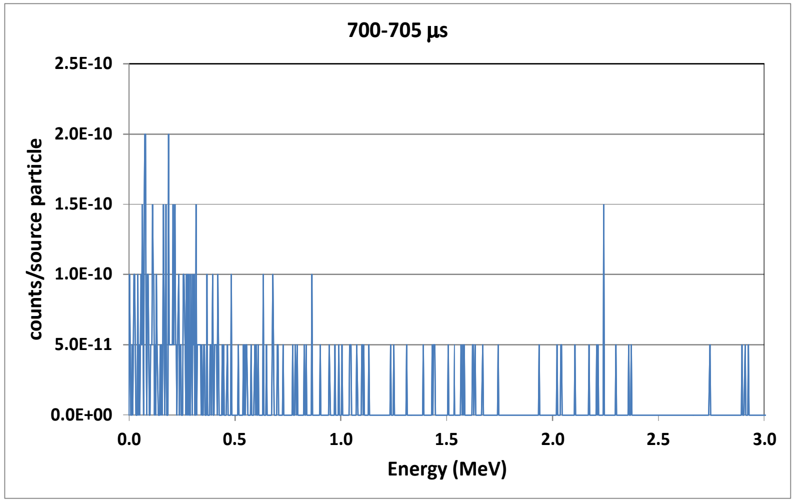


Simulated spectra between pulses follow neutron die-away









Potential New Signatures for Nuclear Forensics

DU Box used as sample

Inelastic gamma-rays observed for an ON gate

- ❖ **Gate Width - 4 μs**
- ❖ **Total run time - 1h**
- ❖ **Gate run time - 145s**

Energy, keV	S/N
680	1.4
885	3.2
1015	1.9

Future Work

- Investigate discrepancies between multi-gate modeling and experiment
- Incorporate pulse pile-up in simulations
- Interrogate DU and other actinides with improved geometry and shielding