Detection of Induced Fission in Sealand Containers

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Outline

- **Detection Possibilities**
- **Coincidence Measurements**
  - **Between Detector**
  - **With Source**
- **Detectors**
- **Matrix of Sources and Potential Measurements**

Detection Possibility from Fission

- **Prompt Neutrons**
- **Prompt Gamma Rays**
- **Delayed Neutrons**
- **Delayed Gamma Rays**

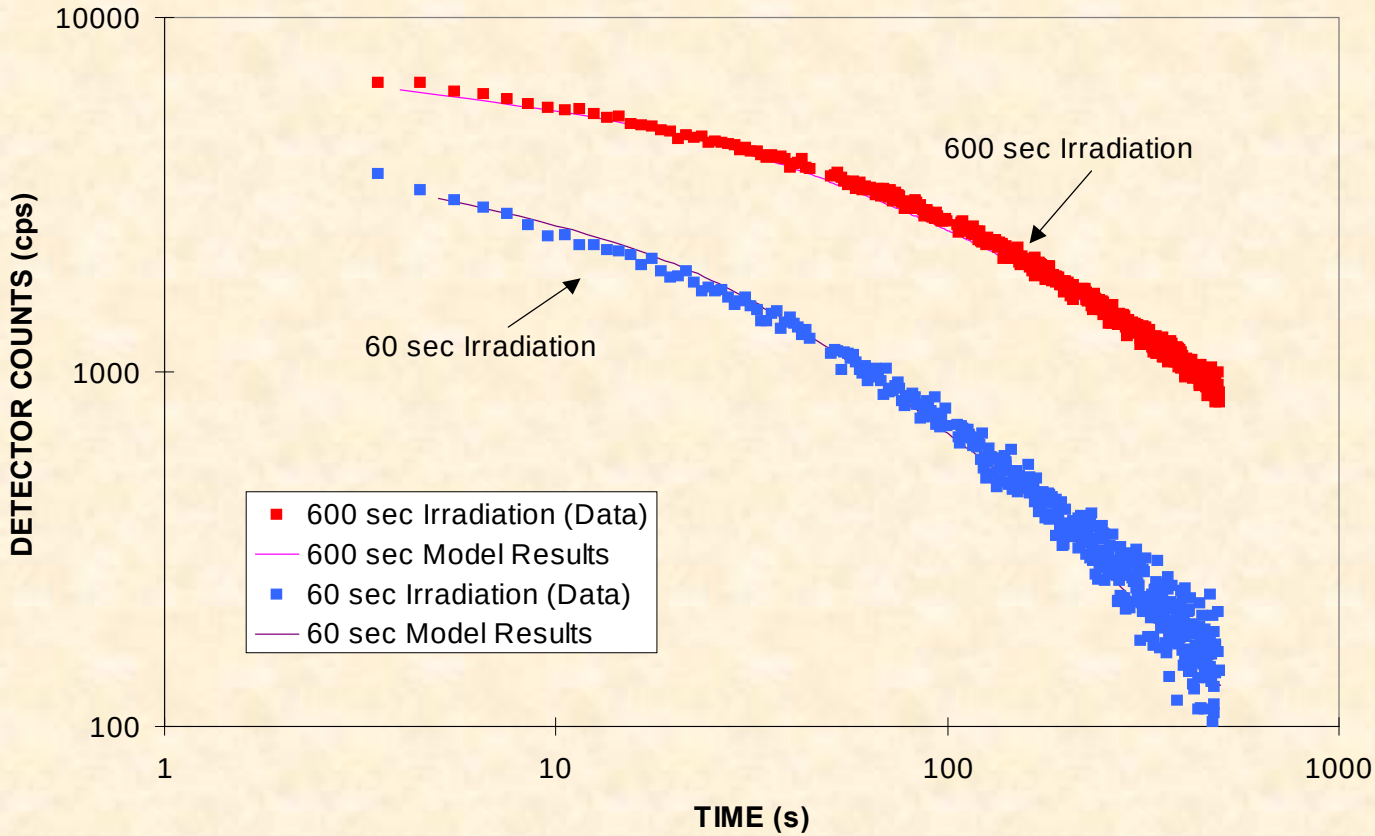
Delayed Neutron Data of Keepin, Wimmett, and Zeigler for ^{235}U

Group	Relative Yield	Decay constant (sec^{-1})
1	0.038	0.0127
2	0.213	0.0317
3	0.188	0.115
4	0.407	0.311
5	0.128	1.40
6	0.026	3.87

Delayed Gamma Data for ^{235}U

Group #	α_i (γ/s per fission)	λ_i (s^{-1})
1	0.35	0.4
2	0.06	0.04
3	0.015	0.008
4	0.0015	0.0008
5	0.0002	0.00005

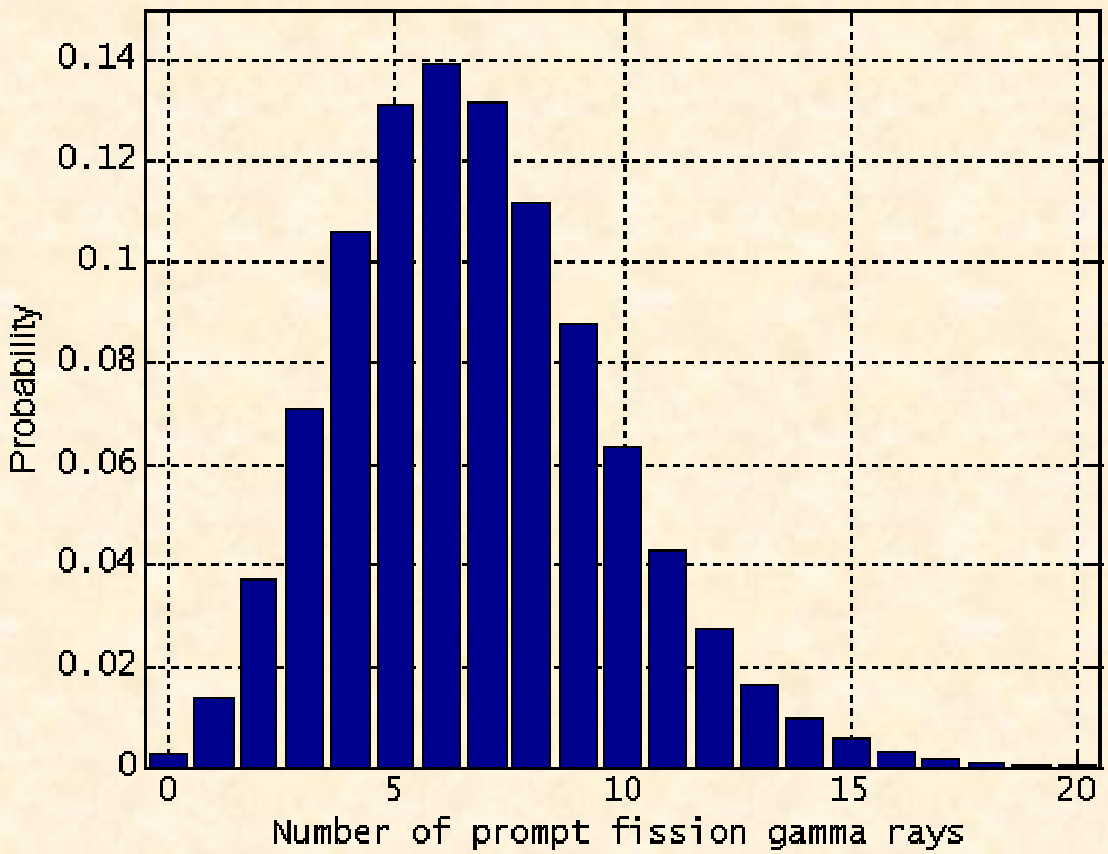
Comparison Between ORNL Irradiation Measurements and ^{235}U Delayed Gamma Decay Model Predictions



Distribution of Prompt Neutron Numbers for Thermal Fission of ^{235}U

Number of neutrons	Fraction of emissions
0	0.0313
1	0.1729
2	0.3336
3	0.3078
4	0.1232
5	0.0275
6	0.0038

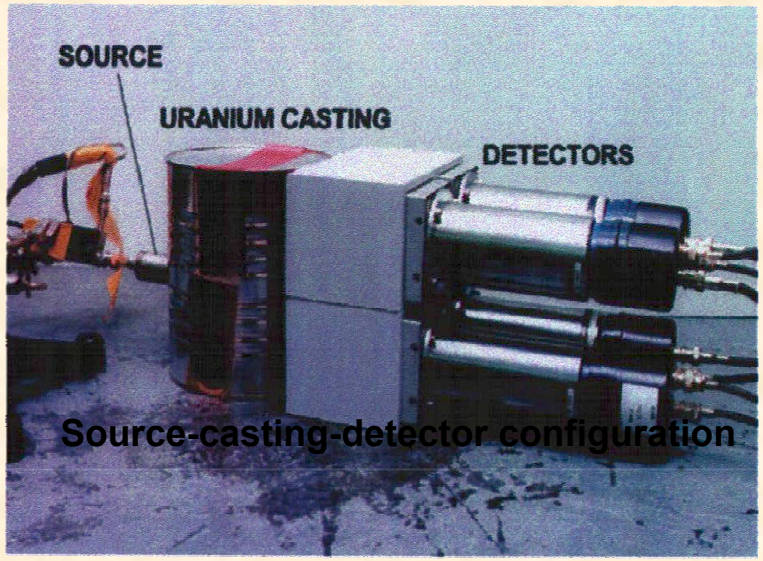
Thermal Neutron Induced ^{235}U Multiplicity of Prompt Gamma Rays from the Negative Binomial Distribution of Valentine

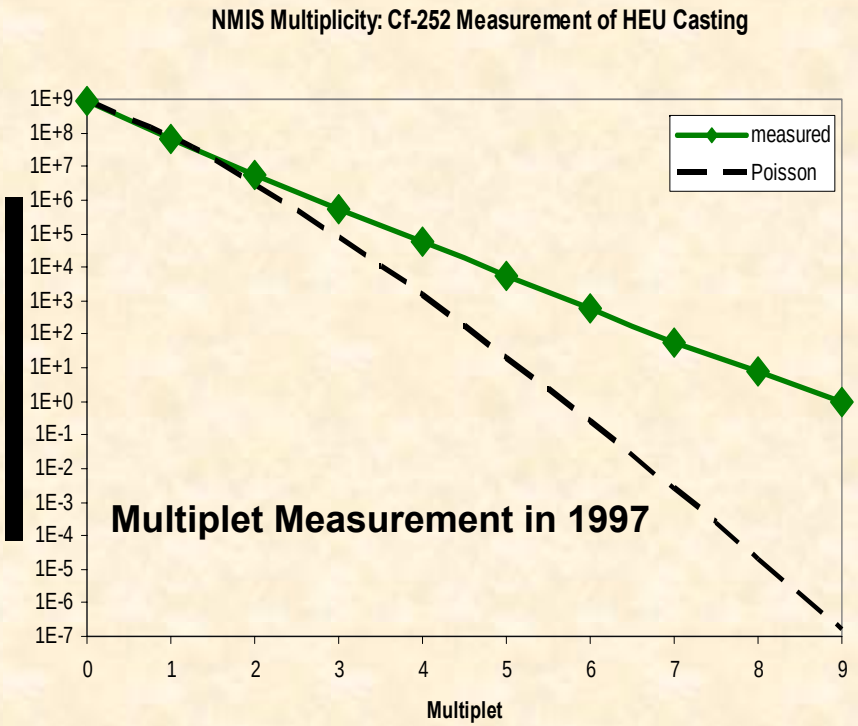


Sources of Coincidence Counts

- **Prompt Fission Chains Induced by the Source**
  - **During or Immediately After the Pulse**
- **Delayed Neutron induced Fission Chains from Previous Prompt Fission Neutrons**
  - **Between Pulses**

Multiplet Measurement For an 18.75 kg HEU Uranium Metal Annular Cylinder



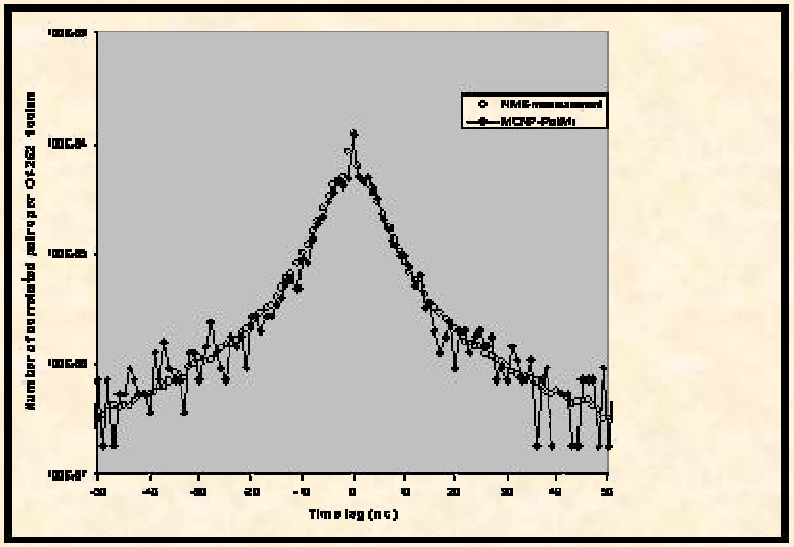


Deviation from Poisson distribution is an indication of fissile presence and mass

Second Order Correlations Between Detectors for 18.75 Kg HEU Annular Castings

Measurement Original

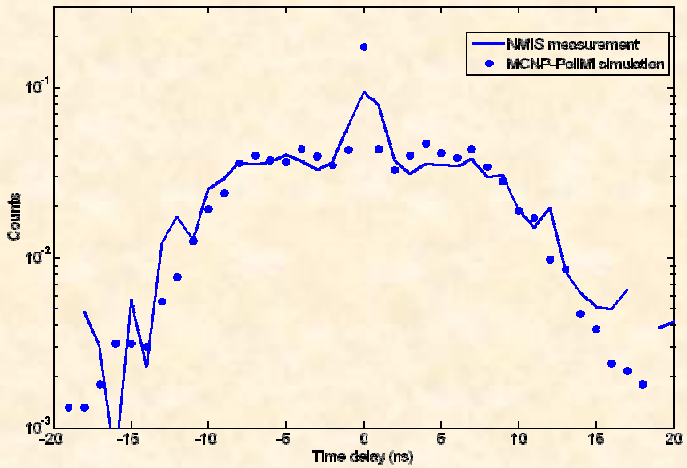
- **Cross Correlation Function Consists of 4 Components**
  - **γ-γ Coincidences at Time Lag = 0**
  - **γ-n Coincidences Between 5→50 nsec**
  - **n-γ Coincidences between -50→-5 nsec**
  - **M-n Coincidences spread Broadly about Time lag 0 Fm -50 to +50 nsec not Distinguishable**
- **Predominance of Various Components Depends on Shielding in Sealed Container**
  - **Very Thick Hydrocarbon — All γ-γ Coincidence**
  - **Very Thick Metal — All n-n Coincidence**



Time distribution of coincidences between two plastic scintillation detectors with comparison to Monte Carlo neutron-gamma transport calculation.

Time Distribution of Coincidences Between The Detectors for a 4 Kg Pu Metal (1.77 wt % ^{240}Pu) Spherical Shell at VNIIEF

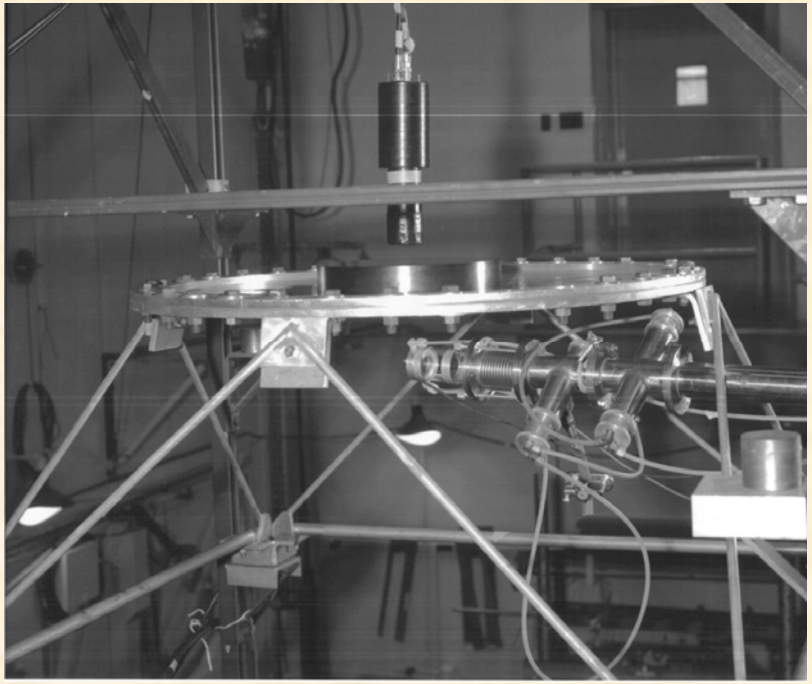
Detector –Pu Metal Shell Configuration with One Detector Removed



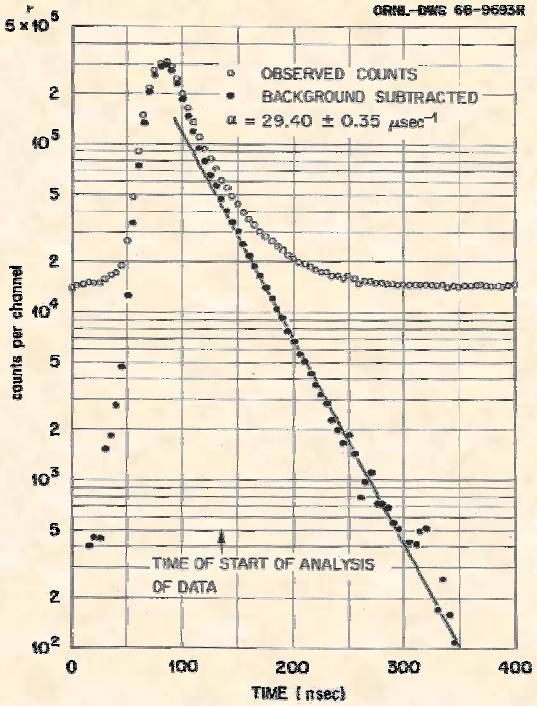
Time Distribution of Coincidence Between Two Plastic Scintillators

Delayed Neutron Induced Fission Between Accelerator Pulses Acts Like an Inherent Source in the Same Way as Spontaneous Fission of ^{240}Pu is an Inherent Source Pu Measurements

Pulsed Neutron Measurement With a DT Generator For a 11-in-diam, 2.5-in-high A HEU Metal Cylinder (1963-ORNL)

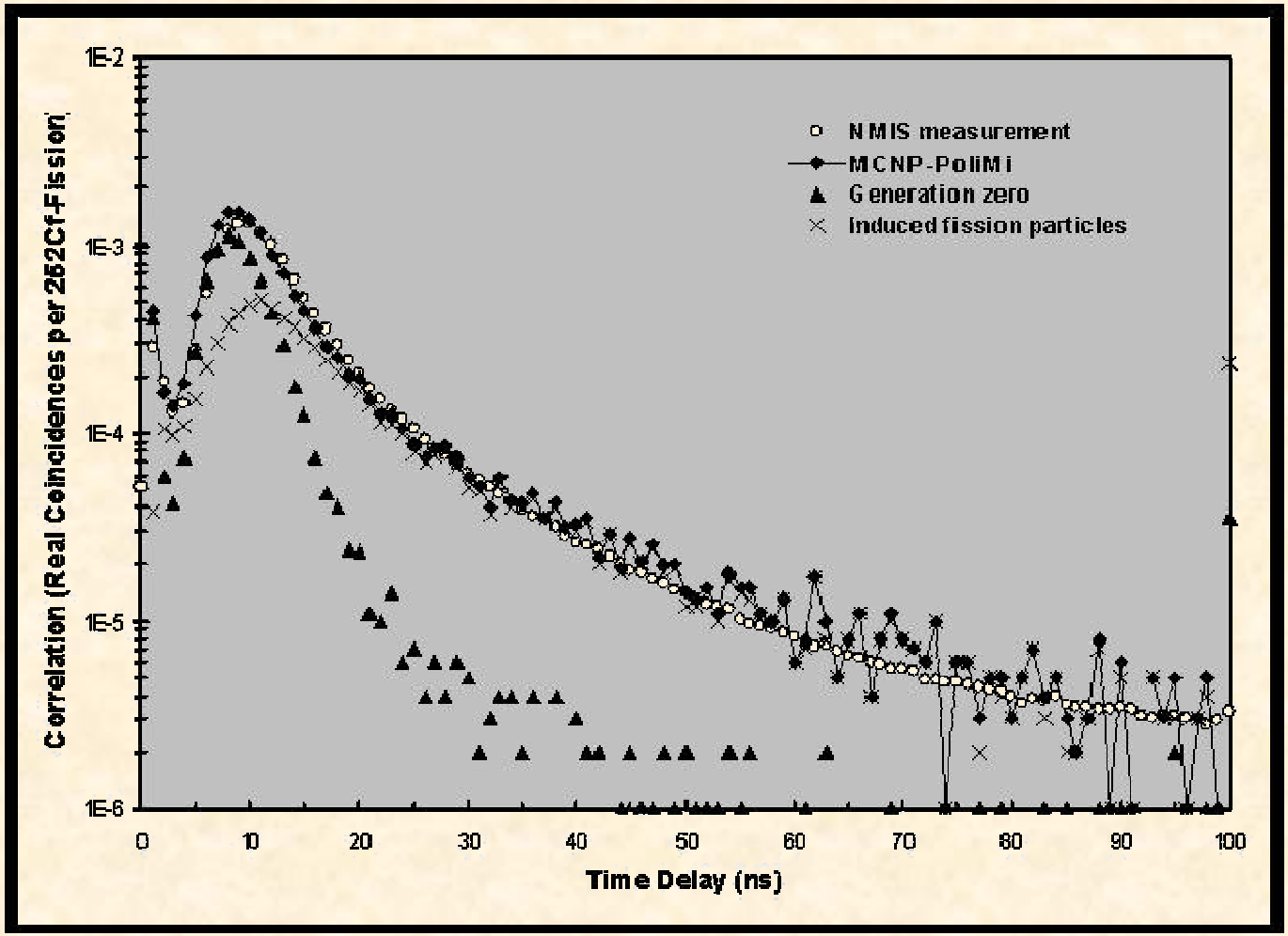


Source-HEU-Detector Configuration

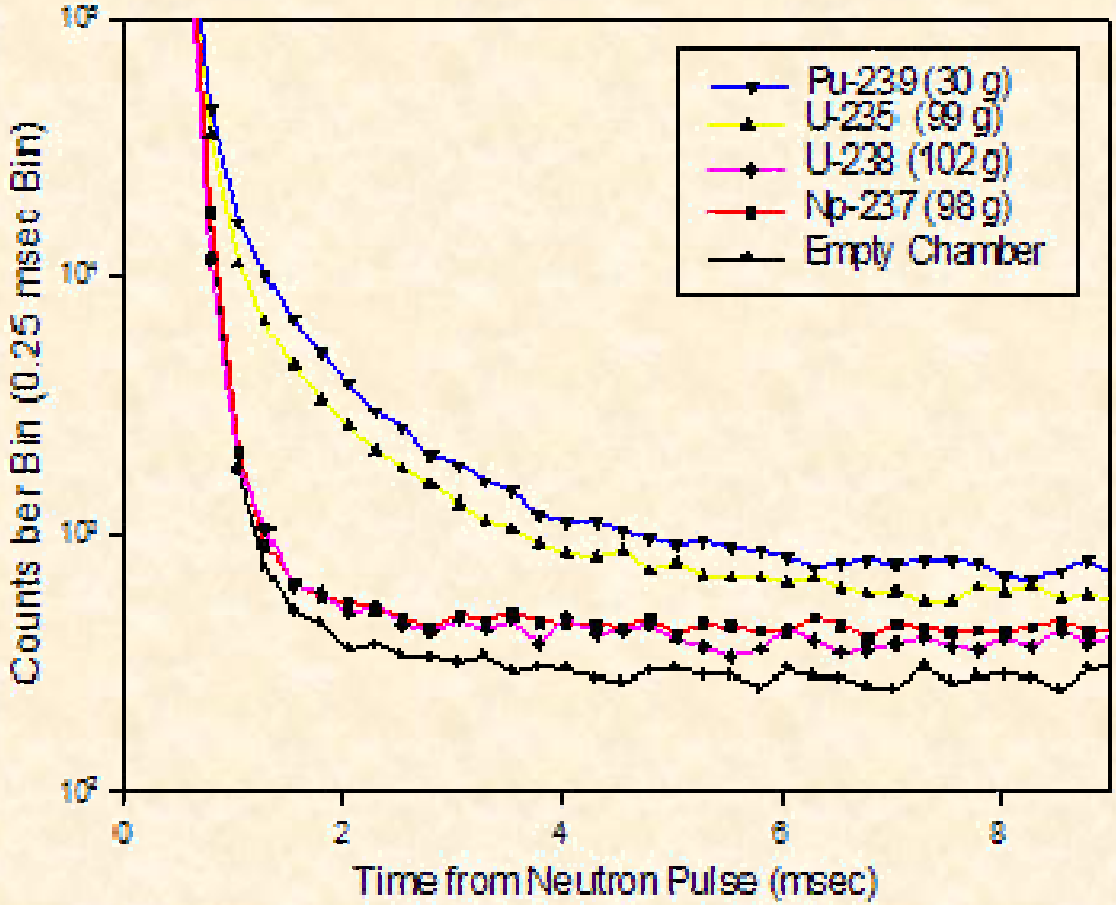


Time Distribution of Count after 30 nsec Accelerator Pulse

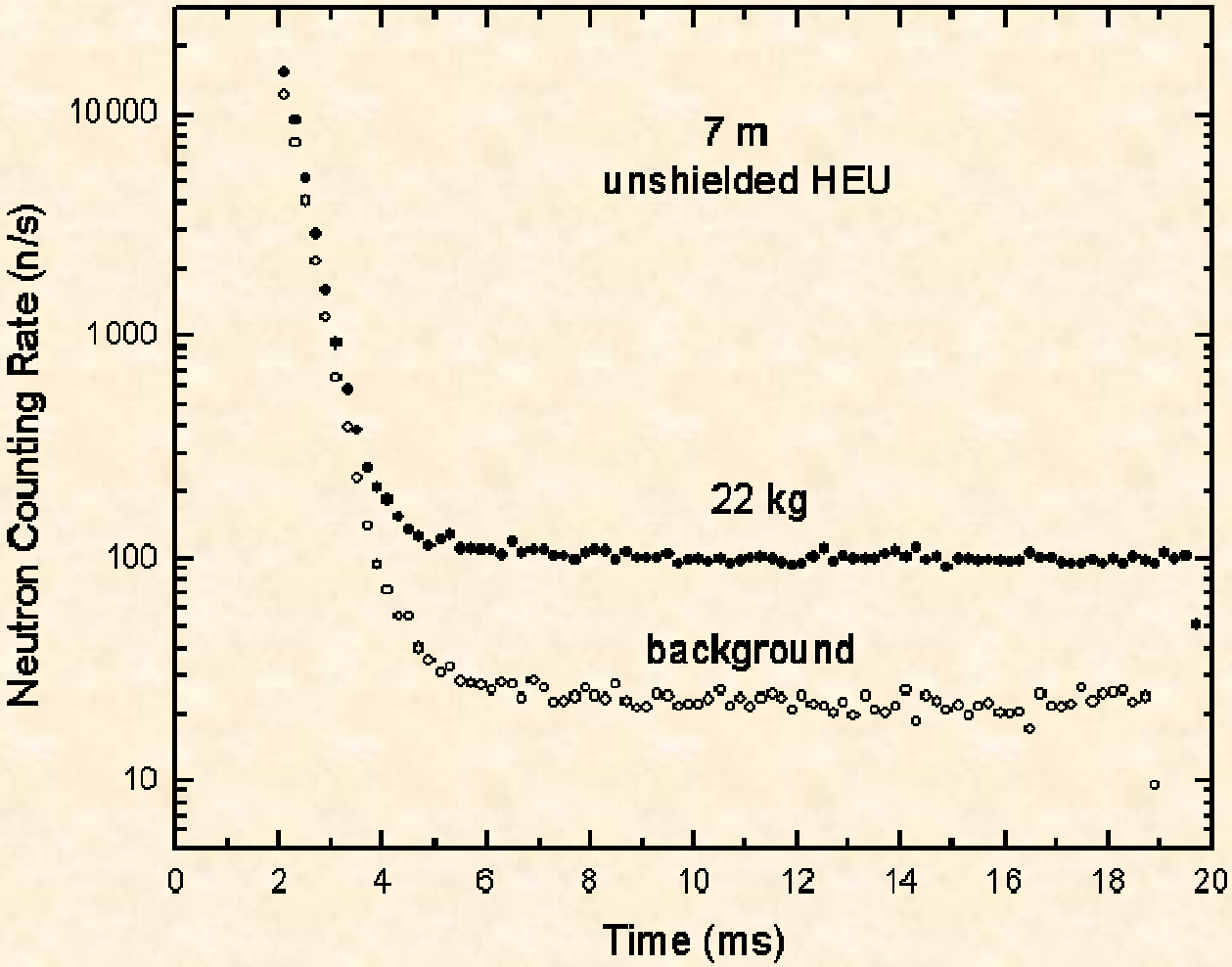
Time Distribution of Counts in a Plastic Scintillator after Cf Fission for an Annular 18.75 kg HEU Metal Casting



Typical Differential Dieaway Data from a Package Monitor at LANL (courtesy of C. Moss)



Response with Linac (INL) and Large-area Detector (LANL)



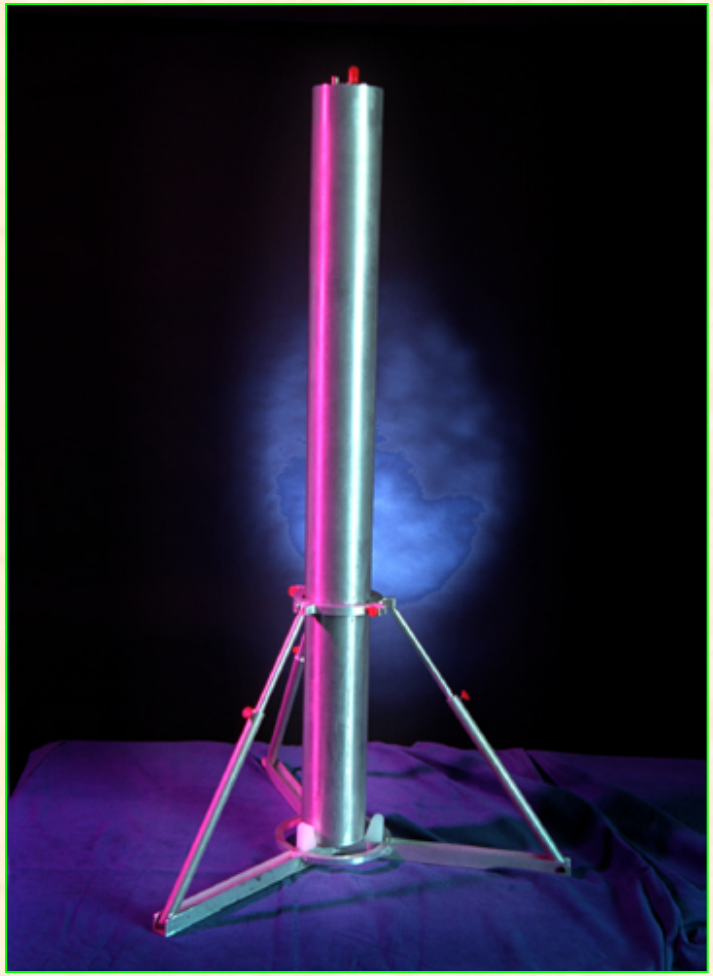
Coincidence Measurements Summary

- **A variety of Fast Time Coincidence Distribution Measurements are Possible with High Speed Data Sampling and Acquisition Systems for a Variety of Sources and Include Multiplet Distributions from which Multiplicities can be Obtained, Detector-Detector and Detector Source Correlations.**
- **Large Plastic Scintillators are Available for these Measurements.**
- **If the Detectors are Insensitive to Source Particles Measurements could be made with the Interrogating source on such as may be the case for a 60KeV Neutron source.**
- **Immediately after source pulses prompt decay could be measured.**
- **Between Pulses Delayed Neutrons act as an Inherent source for Time Correlation Measurements**
- **Which Measurements are Practical Depend on the Background which may Require Measurements to Quantify.**

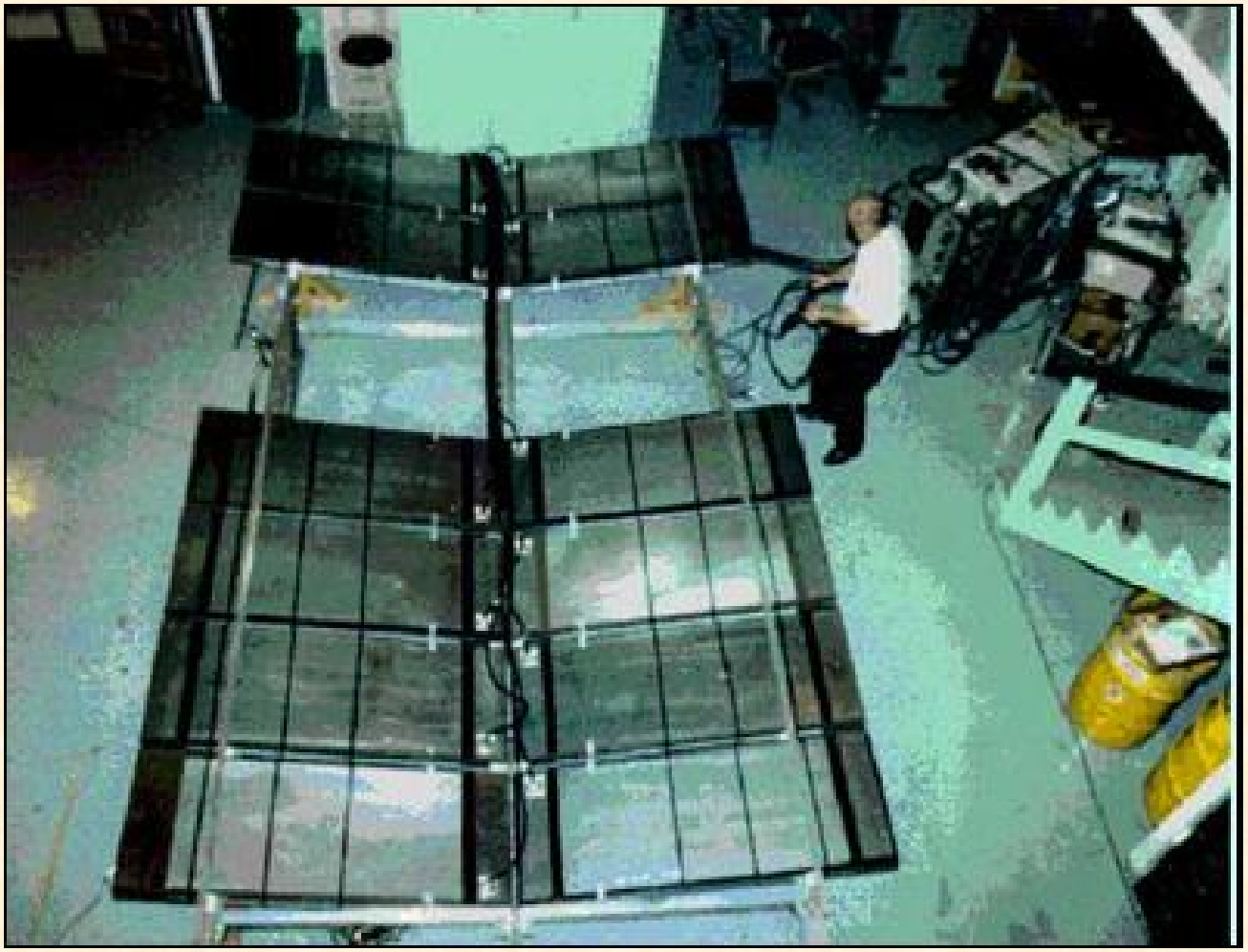
Large-area (4 × 8 ft), ^{3}He Neutron Detector Panel (LANL)

Portable ^{3}He Detector in Moderator (51 × 43 × 10 cm Dimensions-LANL)

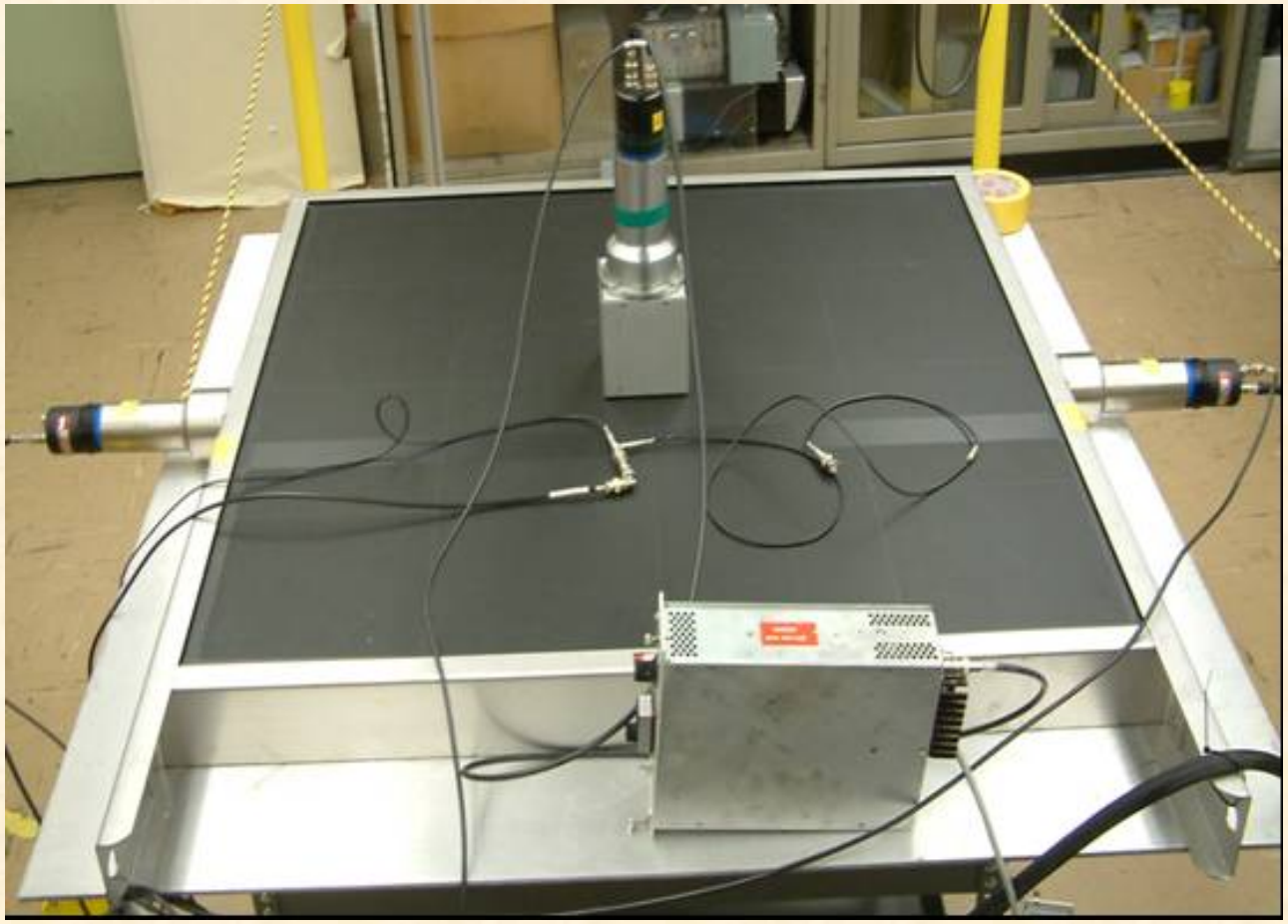
INL's ^{3}He Proportional Counter for Pulsed LINAC Photo Fission Measurements



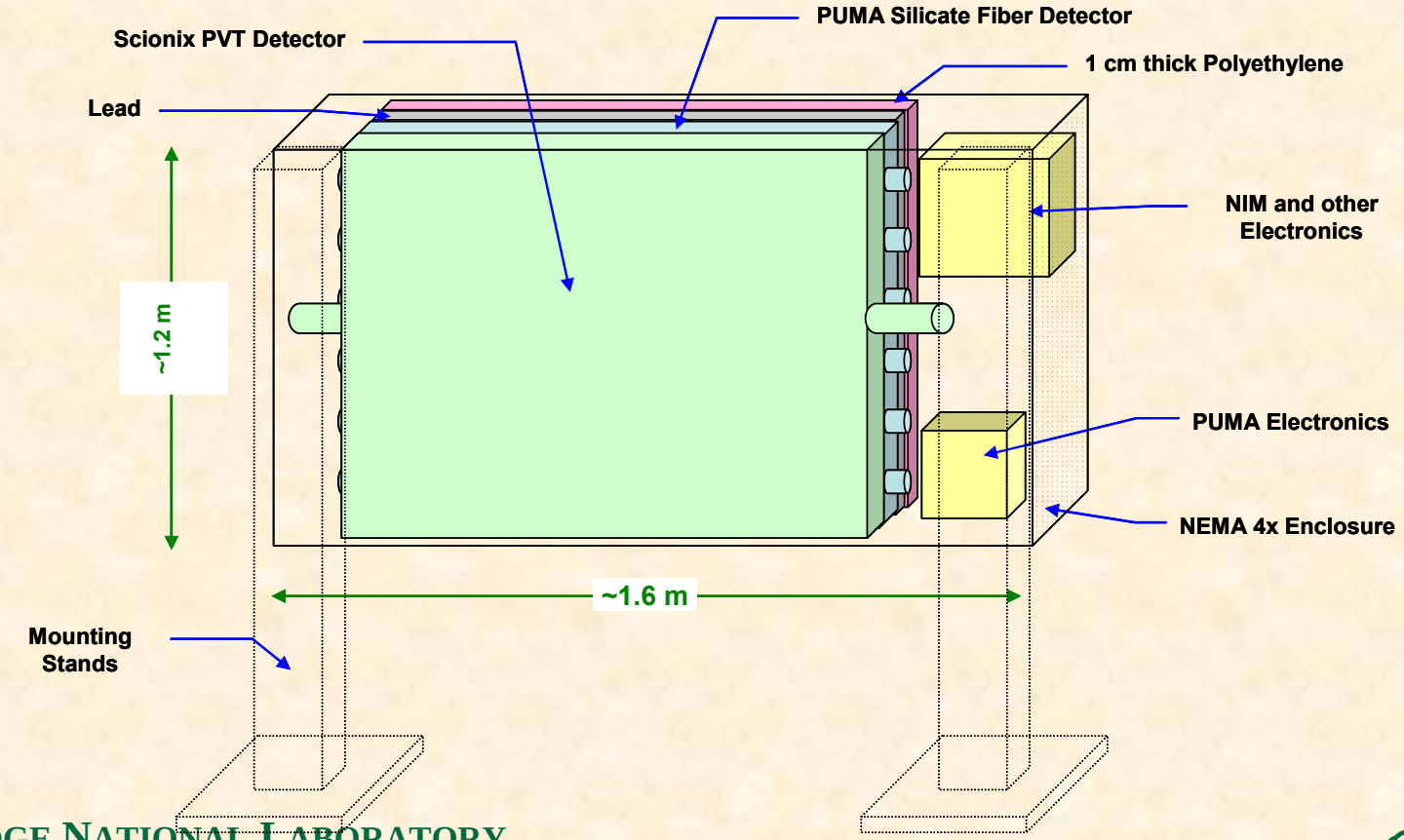
Large Panels of ^{6}Li Glass Fiber Thermal Neutron Detectors (PNNL)



Photograph of a 1 x 1 meter Plastic Scintillator in Testing at ORNL



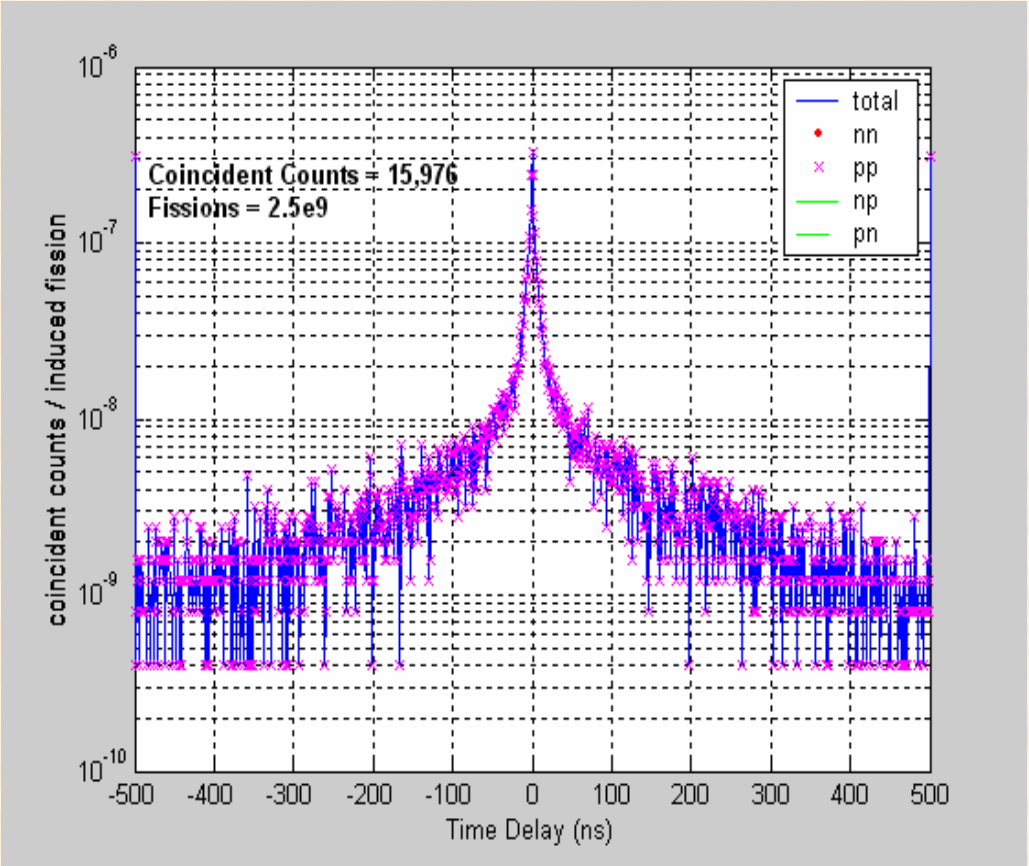
Combined Plastic Scintillator Li Glass Fiber Detector for Detection of Fast Neutrons Gamma Rays and Thermal Neutrons ORNL/NUCSAFE/DHS/DTRA



Calculated Time Distribution of Coincidence Counts between Detectors on Opposite Sides of Container of CH_2

Coincidence/Induced Fission

- **Total = 6.39e-6**
- **nn = 0**
- **pp = 6.39e-6**
- **np + pn = 0**



Matrix of Interrogating Sources and Potential Measurements

INTERROGATION SOURCE	PROMPT TIME CORRELATIONS			DELAYED TIME CORRELATIONS			COUNT RATE	GAMMA RAY SPECTROMETRY
	Multiplets	With Source	Detector-Detector	Multiplets	With Source	Detector - Detector		
Low enery stimulated multiplication (60KeVn)	DP*	BP	DP	BP	BP	BP	BP	–
High energy stimulated multiplication (14.1 MeVn)	SS**	SS**	SS**	BP	BP	BP	BP	–
PFNA (14.1MeVn)	–	–	–	BP	AP***	BP	BP	–
High energy monoenergetic photofission (4-14MeVp)	–	–	–	BP	BP	BP	BP	HPGe
Neutron induced fission from thermalized 2.5 MeVn	DP	–	DP	BP	AP	BP	BP	–

*BP means between pulses, DP means during source interrogation, and AP means immediately after pulsing.

**DT generator operated steady state with alpha detector to define a cone of neutrons.

***Differential dieaway

Matrix of Interrogating Sources and Potential Measurements (continued)

INTERROGATION SOURCE	PROMPT TIME CORRELATIONS			DELAYED TIME CORRELATIONS			COUNT RATE	GAMMA RAY SPECTROMETRY
	Multiplets	With Source	Detector	Multiplets	With Source	Detector		
Monoenergetic Photon induced fission (6-7MeVp)	SS	–	SS	BP*	AP	BP	BP	HPGe
Thermal neutron induced fission (14.1 McVn)	–	–	–	BP	–	BP	BP	–
Thermal neutron induced fission (14.1 McVn)	–	–	–	–	–	–	BP	>3NeV
Photon (bremstralung) induced fission, delayed neutron detection (7-9MeVp)	–	AP	–	BP	AP	BP	BP	–
Pulsed photonuclear assessment (PPA) bremstrahlung (10-20MeVp)	–	AP	–	BP	AP	BP	BP	HPGe

*BP means between pulses, DP means during source interrogation, and AP means immediately after pulsing.