Portable Neutron Radiography to Track Fissile Material Transfers

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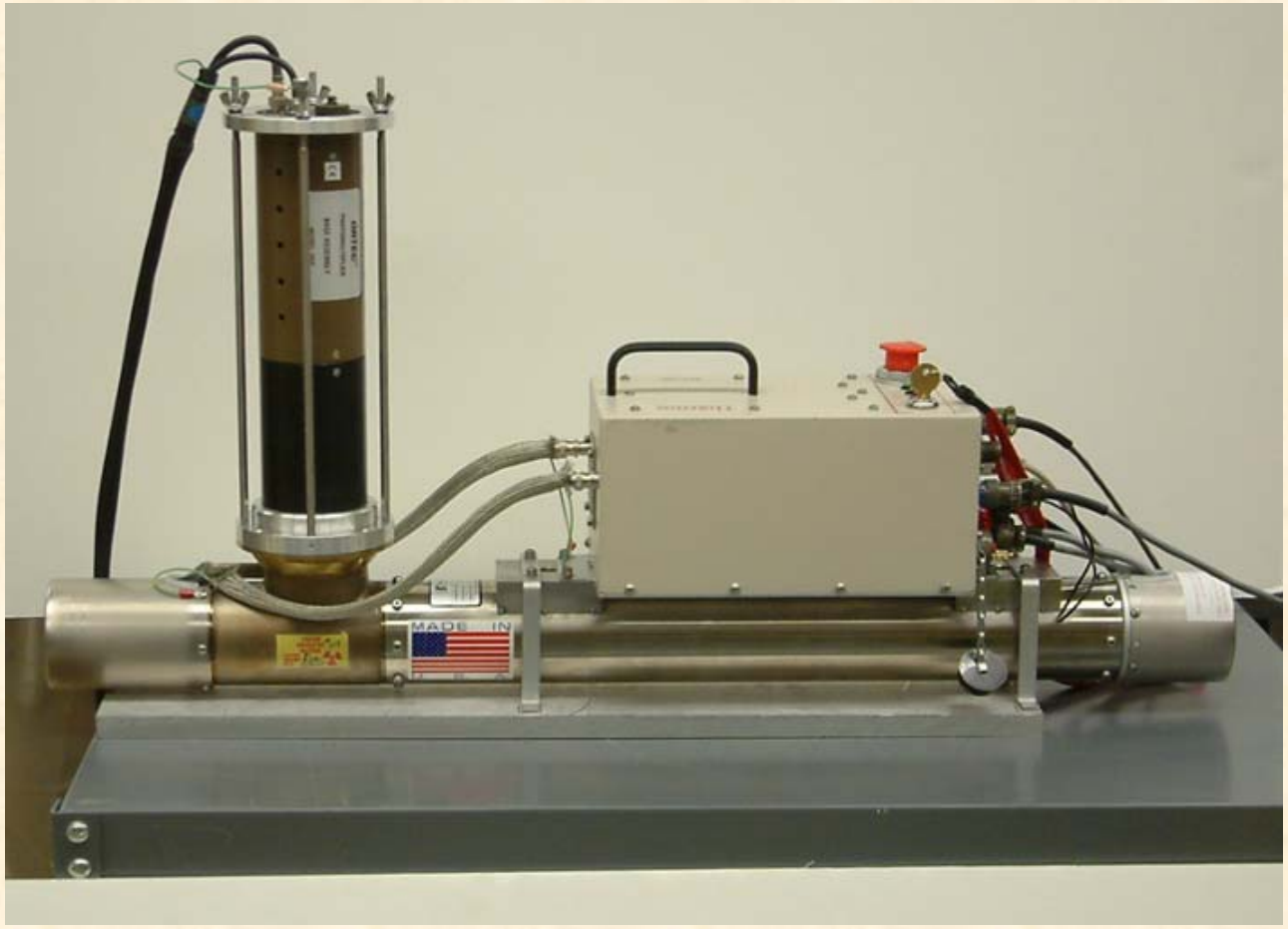
Contents

- Introduction
- DT Generator
- Feasibility Measurements
  - Uranium Casting
  - Polyethylene/Iron Pipe Assembly
- Conclusions

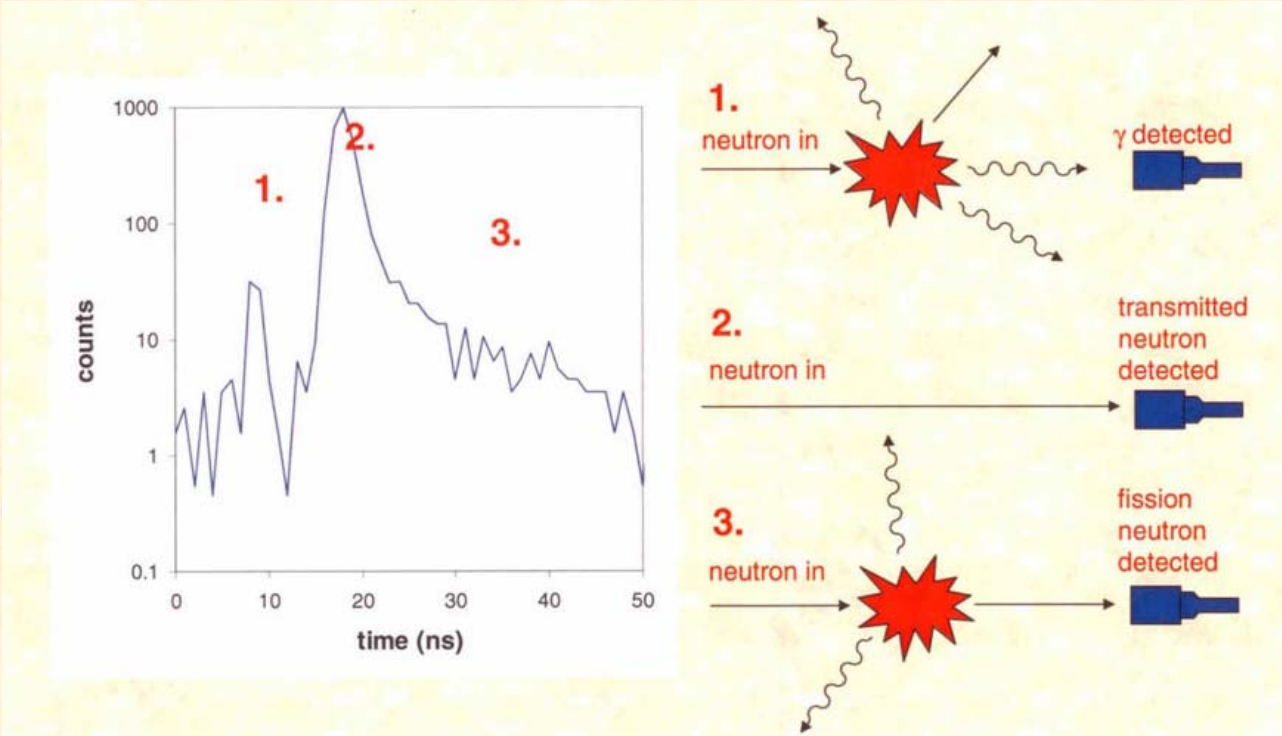
Introduction

- Time of flight transmission measurements with Cf using the NMIS fast (1 Ghz) processor successfully imaged a large deposit at the K-29 diffusion plant in 1999
- DOE supporting this imaging work to test the feasibility of imaging HEU metal parts and nuclear components with a small DT generator
- Applications are: NMC&A (inventory and fissile materials transfers), arms control and nonproliferation (traceability in dismantlement and warhead authentication), counter terrorism

DT Neutron Generator from MF Physics with ORNL Alpha detector (10^8 n/sec, 35 lbs, 40-in.-long)



Typical Time Distribution



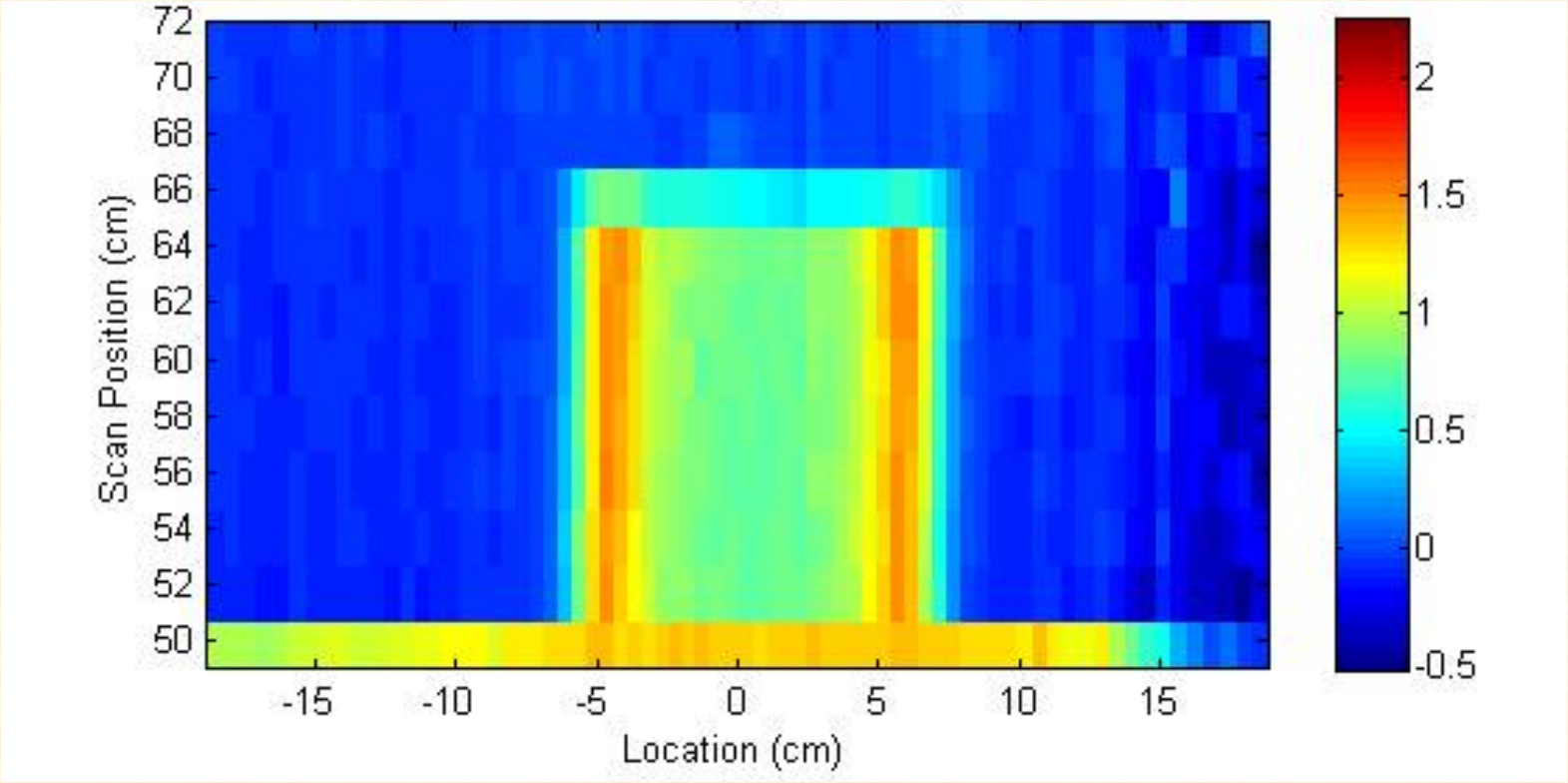
Typical time distribution of counts in a plastic scintillator after the DT reaction in a transmission measurement through a highly enriched uranium metal casting.

Imaging a Uranium Metal Casting

Source **Casting** **Detector Array**

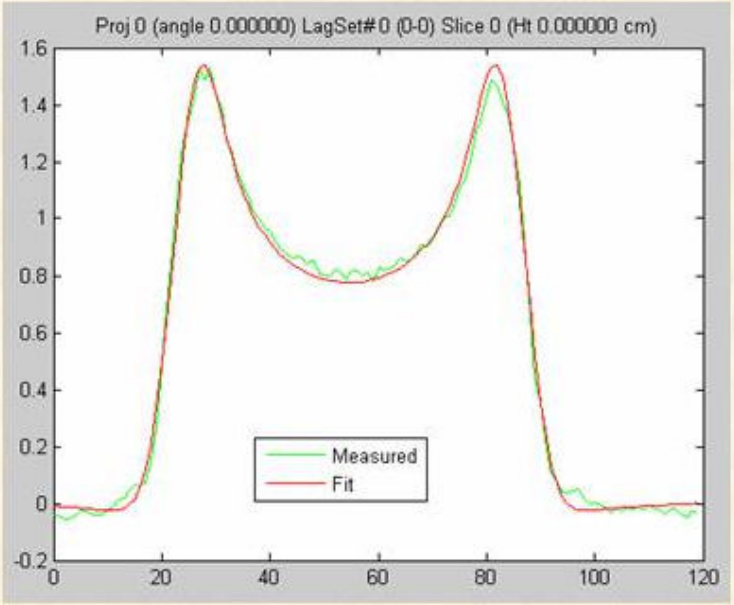
Source-Uranium Metal Casting-Detector Configuration for Imaging

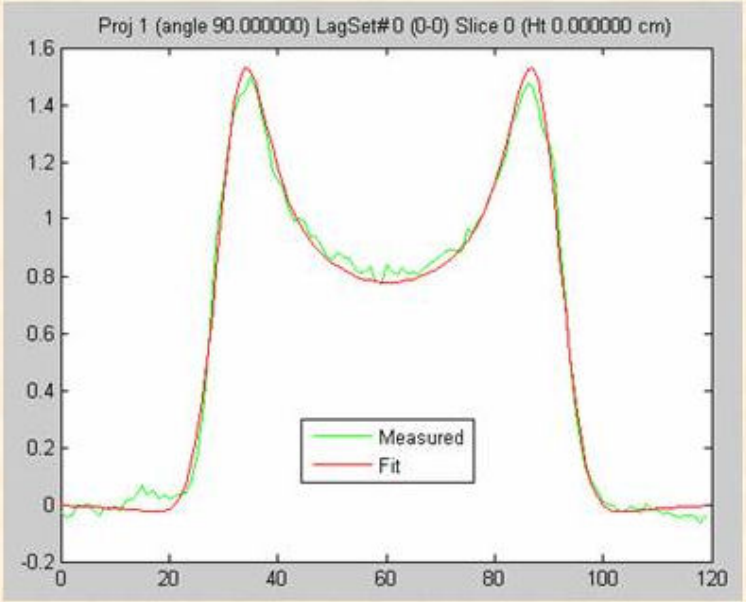
Full Scan of DU Casting



Attenuation versus lateral location and height above the floor.

Interpretation with Ray-tracing and Scattering



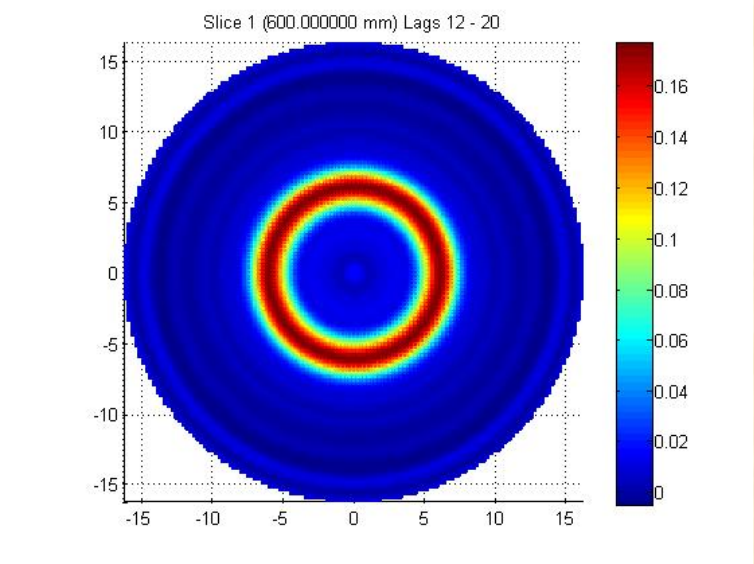


- **Ray-tracing model, which includes actual U cross section and small-angle scattering, reproduces casting measurement with correct dimensions**
- **Enables interpretation of ensemble of basic shapes with few views (as long as number of shapes is not large)**

Dimensions From Fit of Casting Dataset

Parameter	Initial Guess	Final Fit	Actual Dimensions
Inner Diameter (cm)	10.00	8.56	8.89
Outer Diameter (cm)	11.00	12.93	12.81
Attenuation Coefficient (cm^{-1})	0.280	0.202	0.280

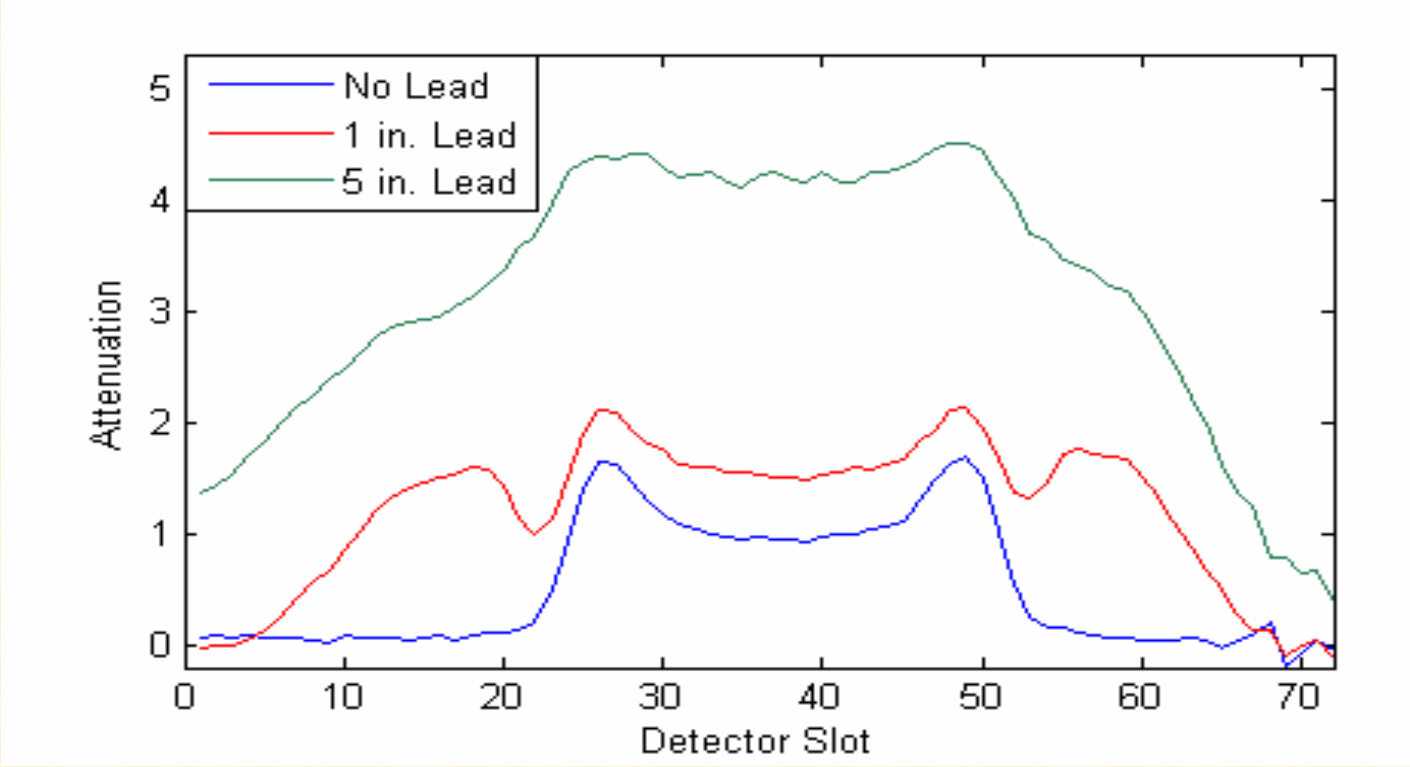
- **Initial guess determined from filtered back projection shown at right**
- **Dimensions in centimeters from fit of casting dataset containing two projections 90 degrees apart**



DU Casting

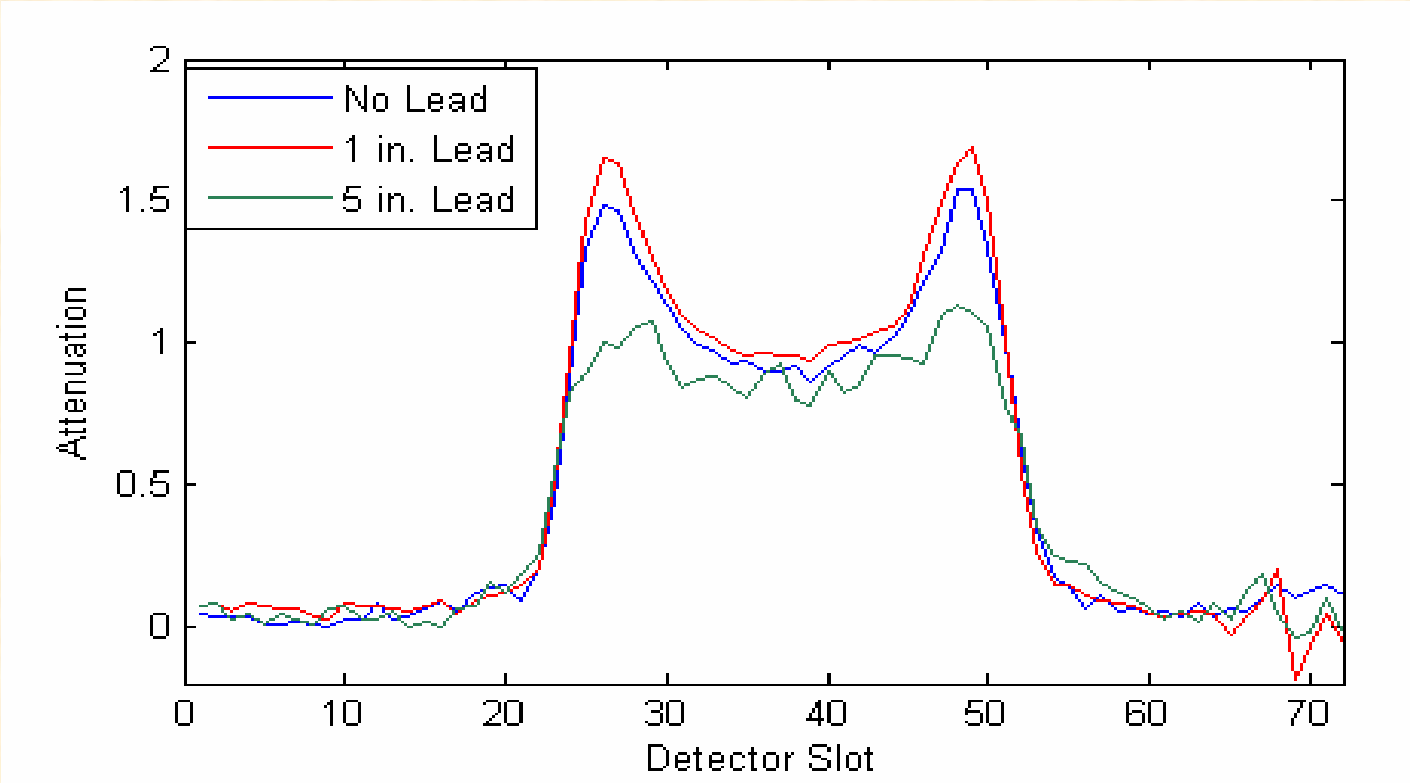
DU Casting with 2.5-cm-thick lead box surrounding and 10.2-cm-thick lead plates in front and back.

Projection of Casting – Varying Levels of Shielding



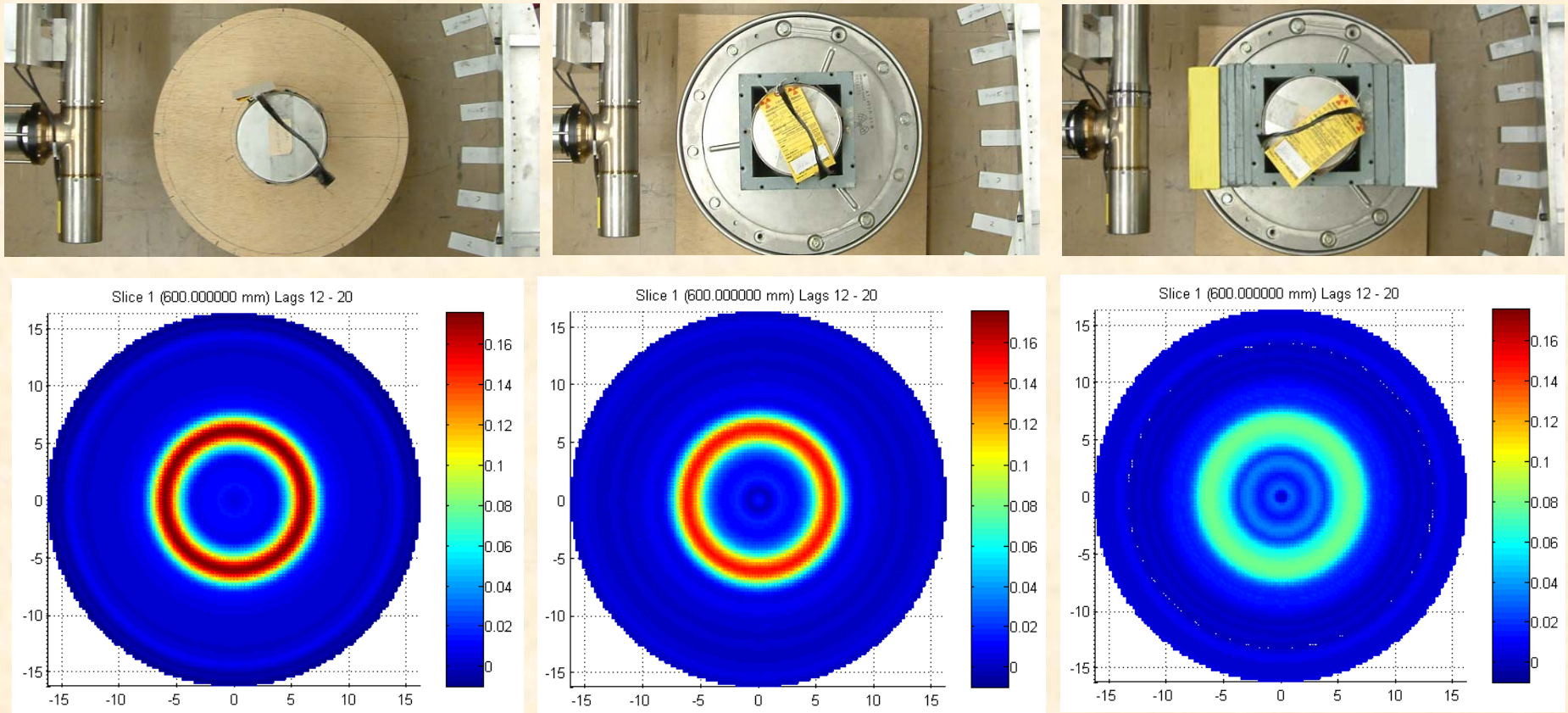
Projection of casting with varying levels of shielding. The 25-cm-thick lead shielding measurement was 10 minutes long and the other measurements were 2 minutes long.

Projection of Casting – Varying Levels of Shielding (Normalized)



Projections of castings with varying levels of shielding when normalized by the shielding attenuation.

Various Sheilded Casting Configurations



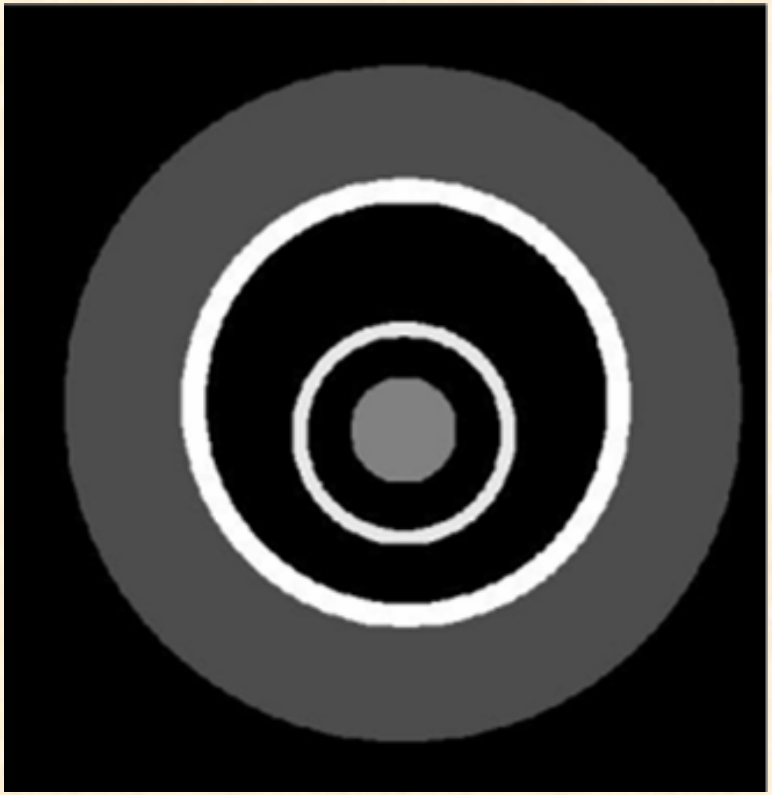
(a) Bare DU casting **(b) DU + 2-in. Pb** **(c) DU + 10-in. Pb**

Photographs of the shielding scenarios along with the measured pseudo-tomographs are shown for the D-T neutrons passing through, (a) the casting alone, (b) the casting and 5 cm of Pb, and (c) the casting and 25 cm of Pb. While the contrast is reduced for heavy shielding, the basic geometry is still apparent.

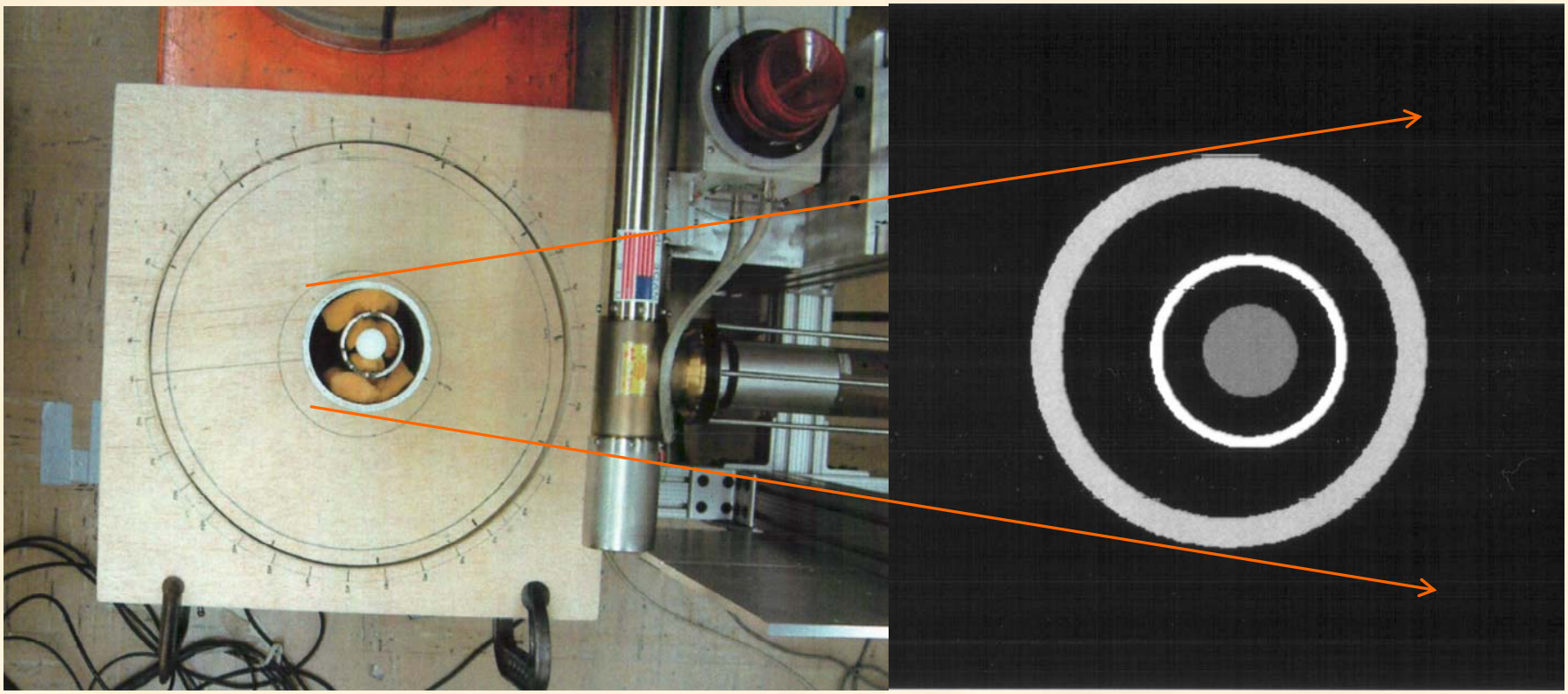
Iron Pipe-Polyethylene Object Image

Iron Pipe-Polyethylene object imaged in an AT 400 container between the DT source on the right and the array of detectors on the left.

Geometry from Imaging the Iron Pipe-Polyethylene Object



Algebraic Image Reconstruction of Polyethylene Rod and Steel Pipes



Tomographic Imaging of a HEU Metal Containers at Y-12

Conclusions

- NMIS with a small, lightweight, portable DT generator has successfully imaged a variety of configurations of non-fissile and fissile material.
- Although transmission was used for imaging, the induced fission portion (region 3 of earlier slide) of the signal can be used to determine HEU
- This type of imaging can enhance NMC&A by confirming the presence of all fissile material and can be used to verify the configurations of nuclear weapons / components shipped or received. Therefore, it is also useful for arms control and nonproliferation.
- This type of imaging can be used for warhead authentication for treaty applications and advanced template matching.
- This type of imaging can trace weapons components/parts both fissile and non fissile in dismantlement.
- This type of imaging is useful for counter-terrorism applications
- Imaging can determine unknown configurations of HEU for criticality safety and identification or to determine appropriate standards for other NMC&A methods.