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Title: Design and Characterization of a Neutron Detector for the Confinement Vessel Disposition Project

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Design and Characterization of a Neutron Detector for the Confinement Vessel Disposition Project

Sy Stange, Louise Evans, Katherine C. Frame, Mark M. Bourne, Douglas R. Mayo, and William J. Crooks

Los Alamos National Laboratory has a number of spherical confinement vessels remaining from tests involving nuclear materials. The Confinement Vessel Disposition (CVD) project will be removing debris and contamination from these vessels, with the current goal of reducing the amount of radioactive material present to below ~100 g ^{239}Pu-equivalent, and the eventual goal of reducing the activity to below 100 nCi/g (~ 2g ^{239}Pu), the low-level radioactive waste cut-off. We have designed and are implementing a neutron assay system to quantify the plutonium content of the vessels during cleanout. Designing a system capable of measuring the activity of these large (6-foot diameter) and thick steel vessels presents a number of challenges. Our neutron assay system design is based upon polyethylene moderated ^{3}He tubes. The system must be modular, able to perform safeguards-quality assays before and after the cleanout process, and able to measure holdup in the glovebox that will be used during the cleanout process. We will report on the results of the detector modeling and optimization, characterization measurements, and preliminary instrument calibration.

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Waste will be removed from confinement vessels remaining from 1970s-era experiments

- Los Alamos has 9+ spherical confinement vessels remaining from experiments
- Each vessel contains ~ 500 lbs of radioactive debris
  - Actinide metals and oxides
  - Metal
  - Powdered silica
  - Graphite
  - Wires and hardware

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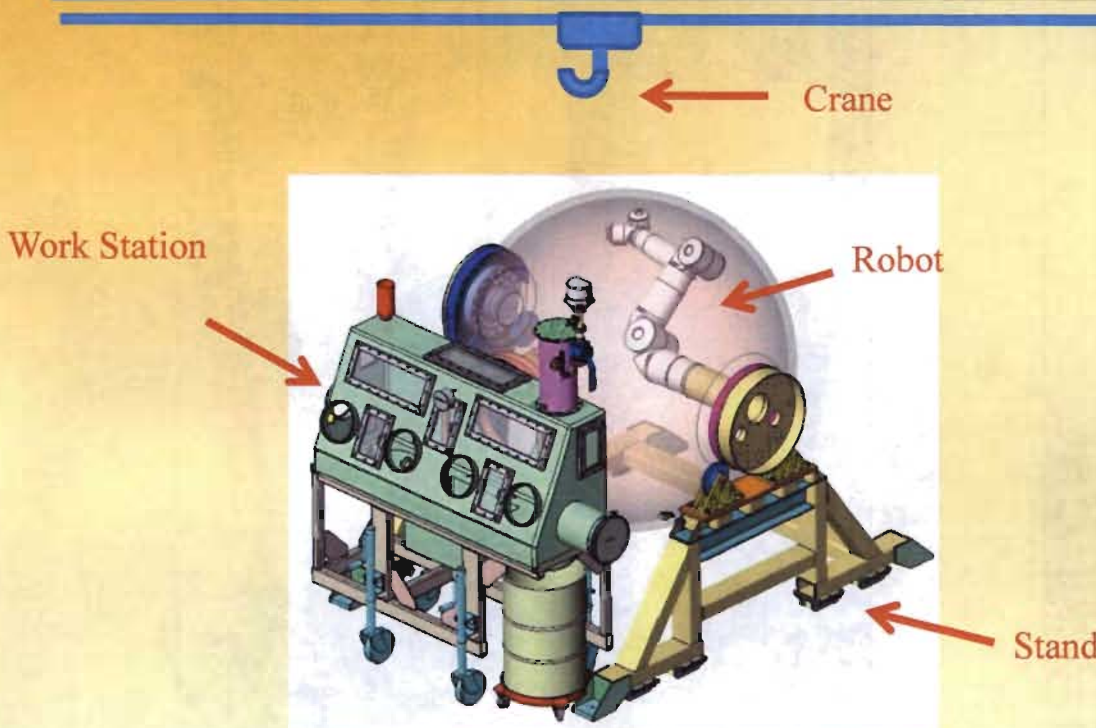
In order to dispose of the vessels, debris and contamination must be removed



Confinement Vessel Disposition (CVD) project has designed a system to safely remove debris and contamination

Activity must be reduced to <~ 100 g ^{239}Pu-equiv. for vessels to be removed from radioactive waste list

The robotic system is a significant upgrade over the old clean-out technique

Hand tools for removing debris

Old hand-held brush

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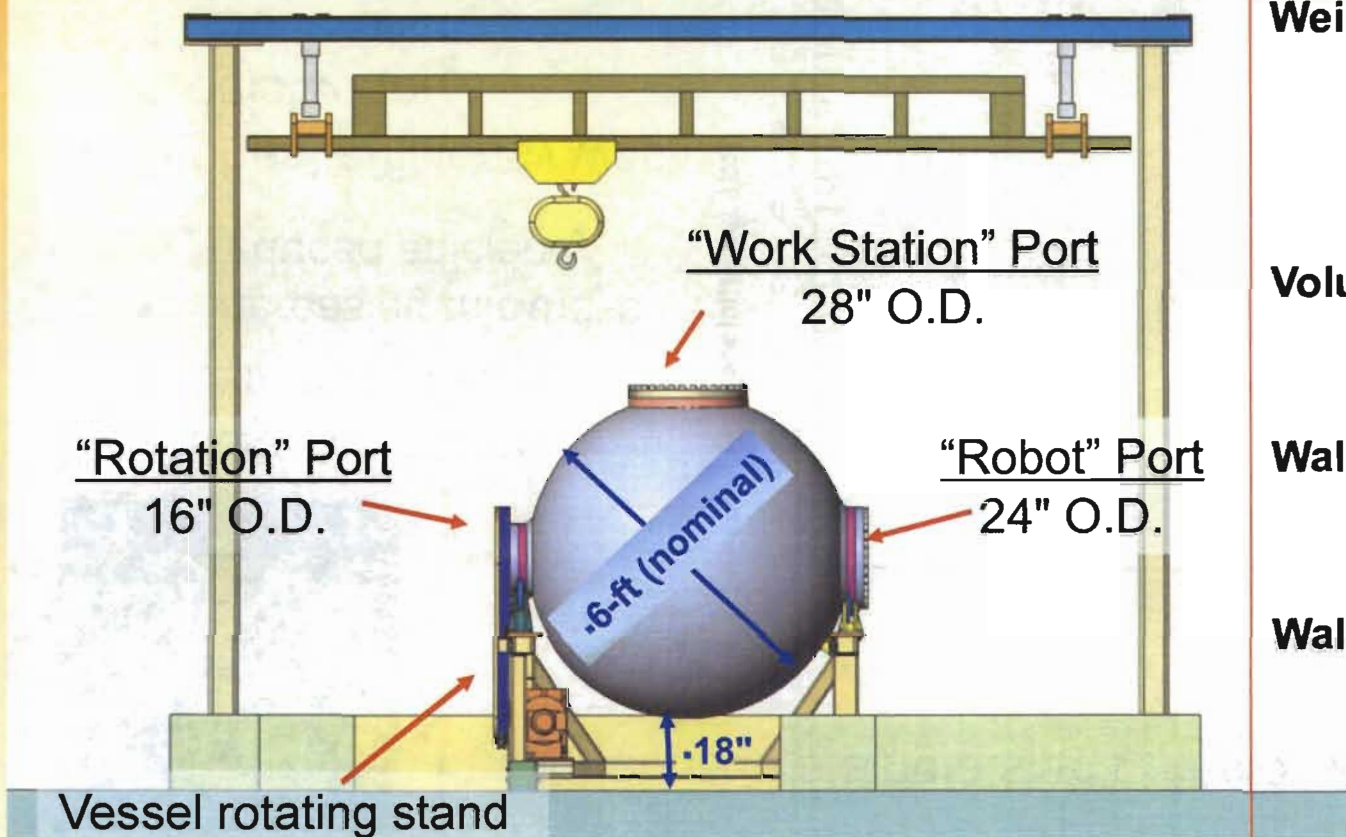
Gamma-ray and neutron detectors will be used to characterize the waste removed

- Gamma-ray measurements will be performed on:
  - the port covers, to determine their levels of contamination
  - the first drum of waste collected from each vessel, to establish its isotopic composition
  - each waste drum, to determine the DU content and report a drum total DU value
- Neutrons measurements will be performed on:
  - the workstation prior to and after the completion of removal of debris from each vessel, to determine beginning and final hold-up values
  - each vessel, prior to the removal of debris, in order to determine and fully document the beginning material inventory
  - each vessel upon completion of the cleanup operation, to verify the residual content of SNM,
  - each CVD debris container, using a shuffler, to determine the Pu content in each drum,

Neutron assay will be used to determine the vessel activity before and after clean-out

- System requirements:
  - Modular
  - Capable of detecting 2g ^{239}Pu equivalent in a 2"-thick steel sphere with 6' OD
  - Able to measure holdup in glovebox
  - Capable of safeguards-quality assays
  - Moveable
- Initial design parameters:
  - Use of 4-atm ^{3}He tubes with length 6'
  - ^{3}He tubes will be embedded in polyethelene for moderation
- Questions for model:
  - What is the optimum moderator thickness?
  - What is the detector efficiency at locations where debris is likely to be located?
  - Where is detector most and least efficient? – What is the variation in its response?

Detector design is constrained by vessel and enclosure geometry



Weight (contents + stand):

Max: 15,000 lbs

Min: 7,200 lbs

Volume:

846 gallons (empty)

Wall composition:

Carbon Steel

Wall thickness:

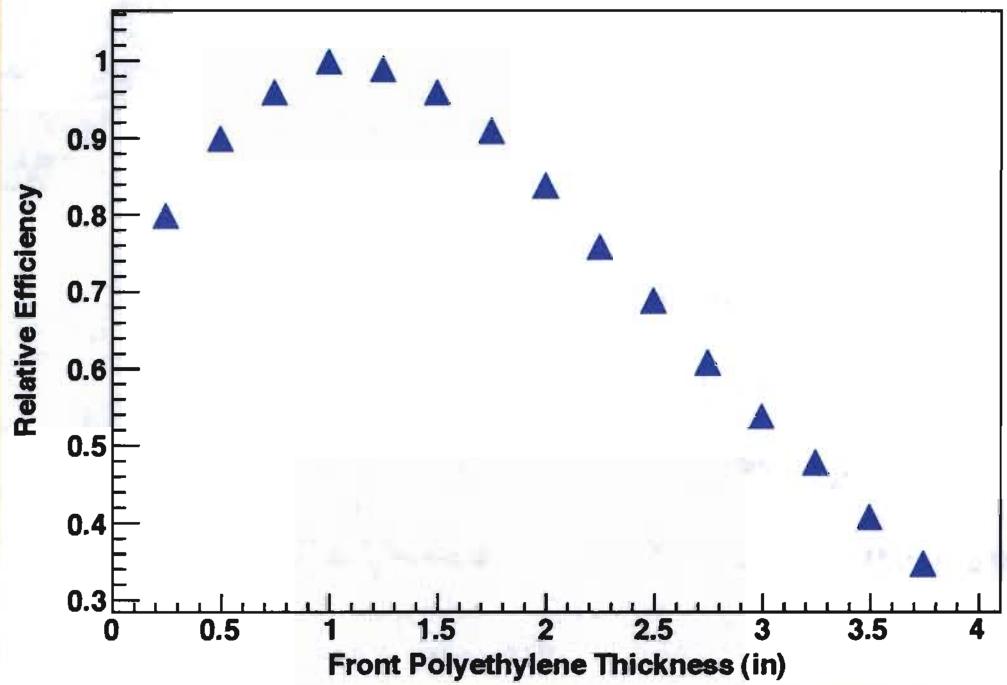
Max: 2 in.

Min: 1 in.

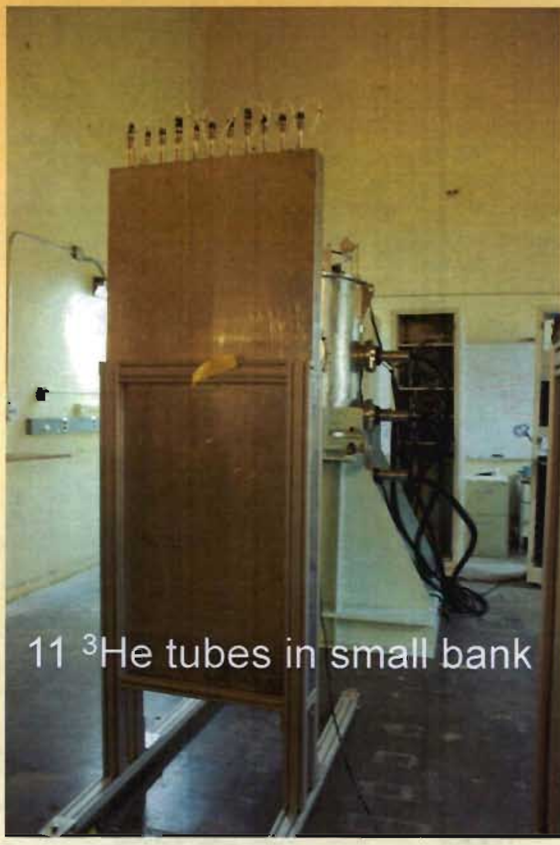
MCNPX model was used to determine optimum thickness of polyethylene moderators

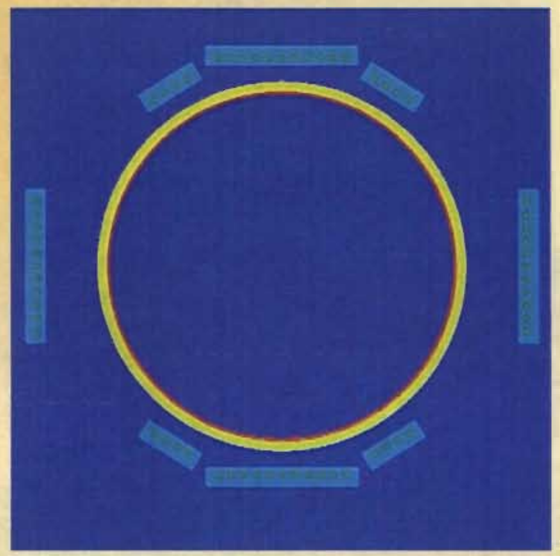
- Model used a single slab detector with 15 ^{3}He tubes

- Thickness behind tubes was fixed at 2”
  - Increasing thickness reduced efficiency
- Highest efficiency was predicted for 1” moderation between ^{3}He tubes and source



Model results were used to design 8 panels with a total of 60 ^{3}He tubes





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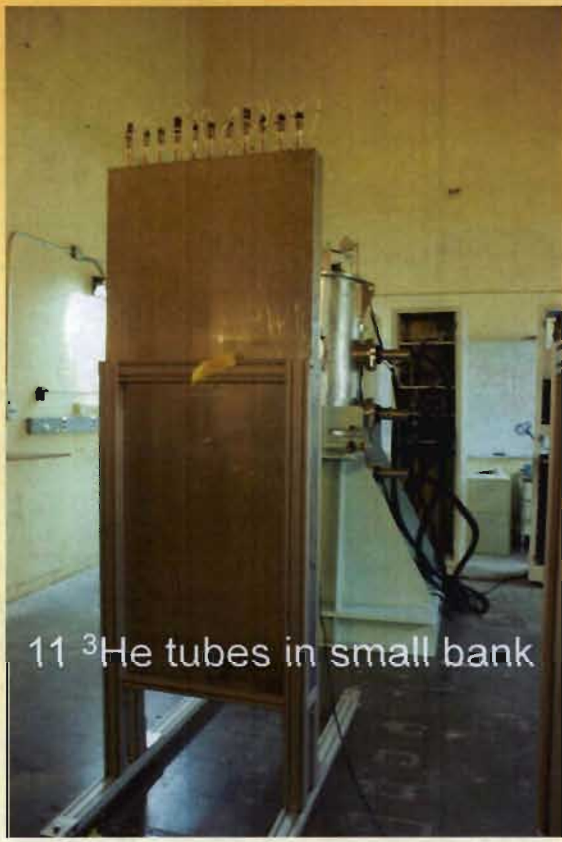
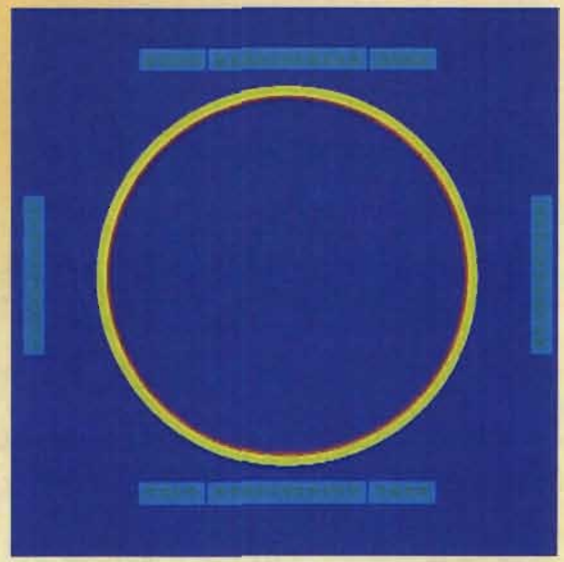
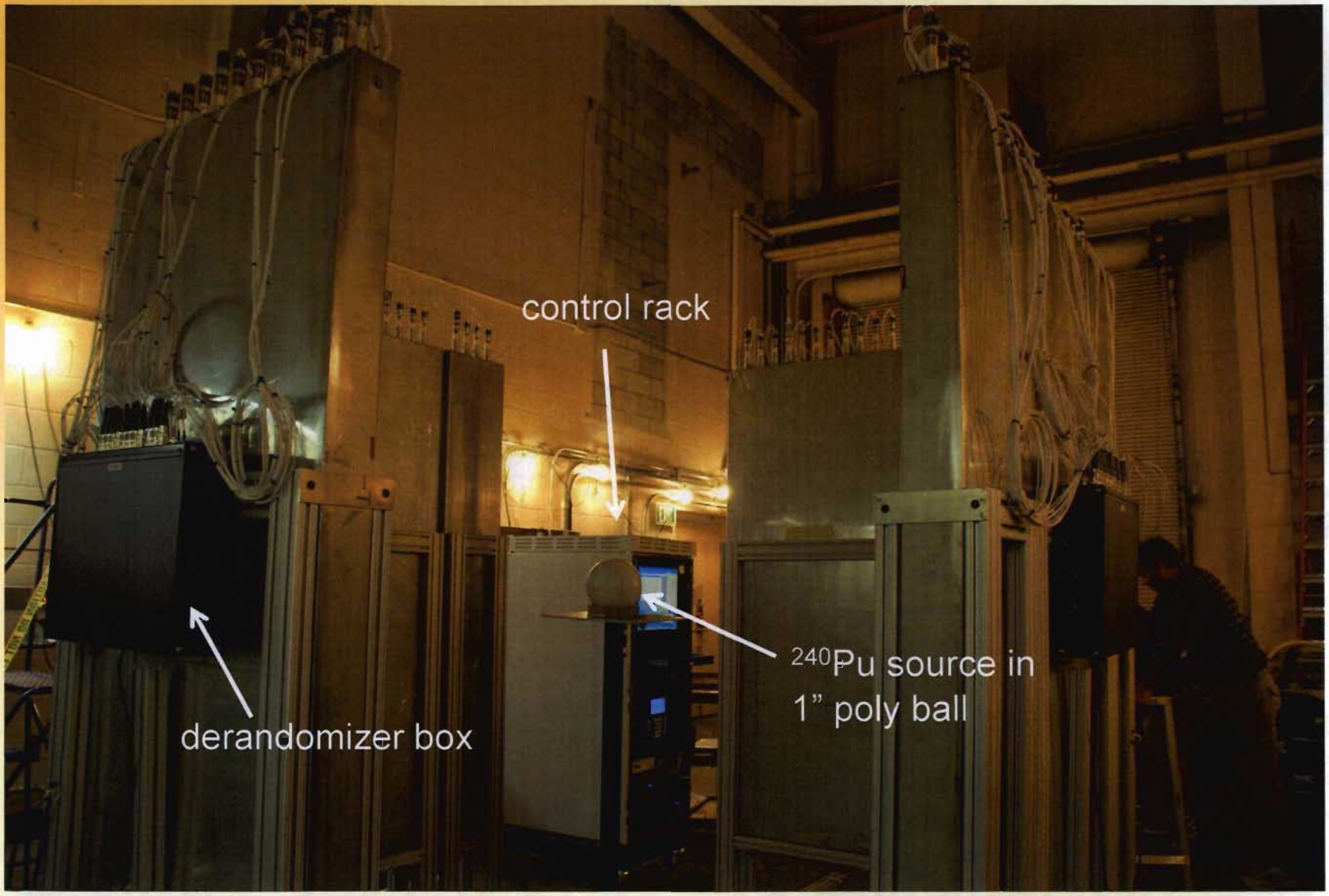


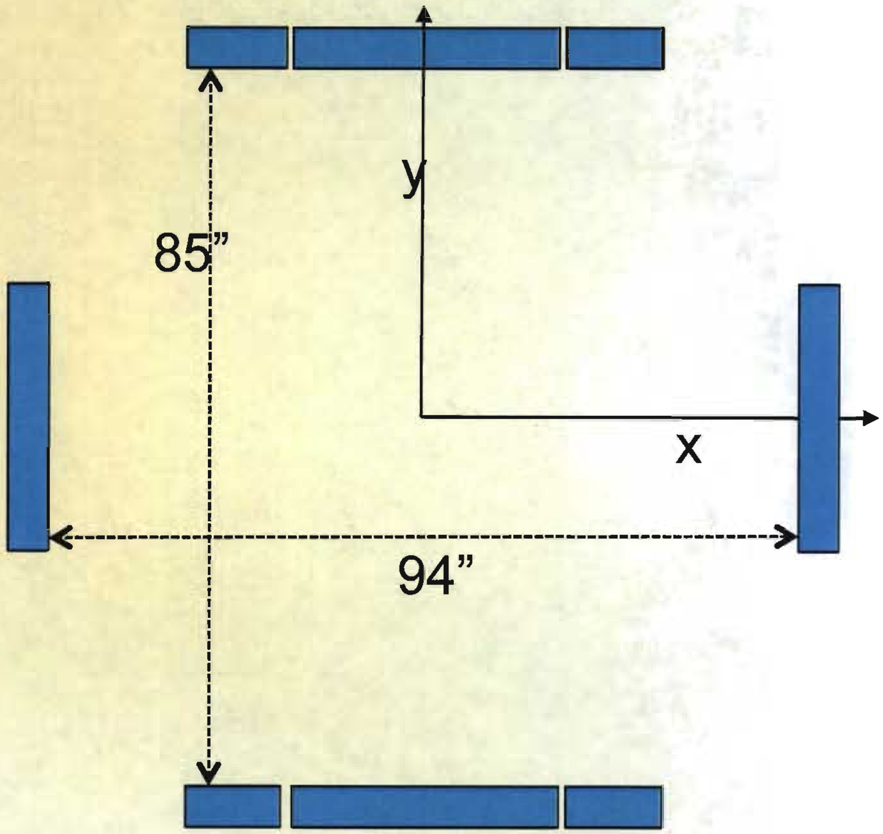


- Corner panels were placed in line with central panel to accommodate support stands


control rack
^{240}Pu source in
1" poly ball
derandomizer box

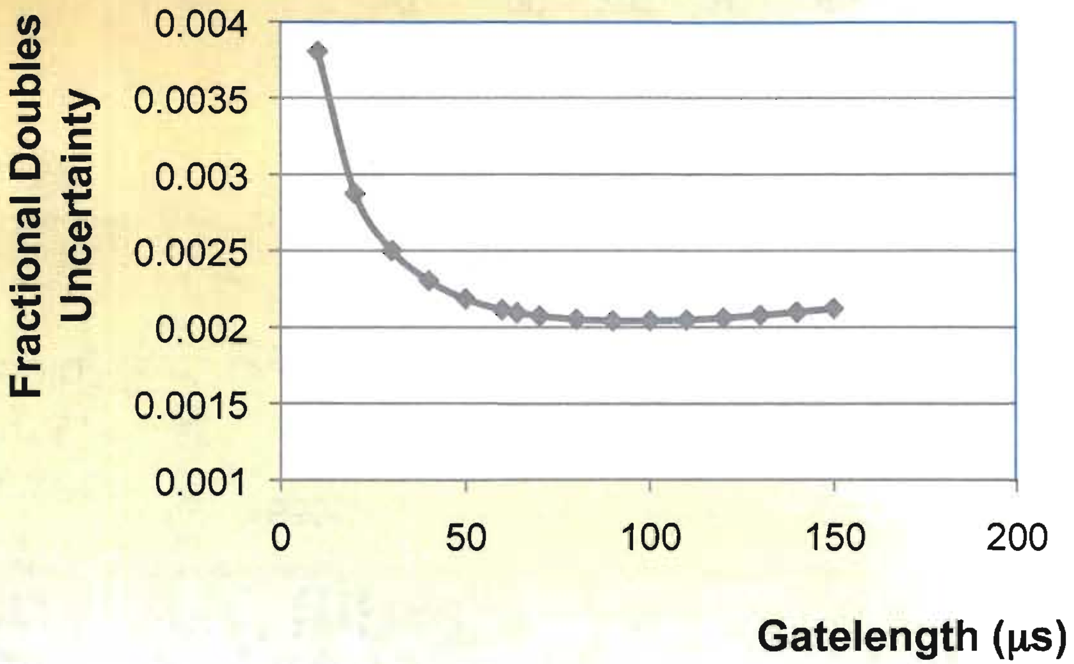
The system response to neutron sources was characterized and compared with simulations

- Characterization goals:
  - Optimize data acquisition parameters: gate length, predelay
  - Locate maximum and minimum efficiency locations
    - Material in minimally efficient areas will be most challenging to measure
  - Measure response to ^{252}Cf and ^{240}Pu in 1" and 2" poly and steel shells
  - Compare detector response and efficiency to MCNPX model
    - Establish confidence in model's predictions



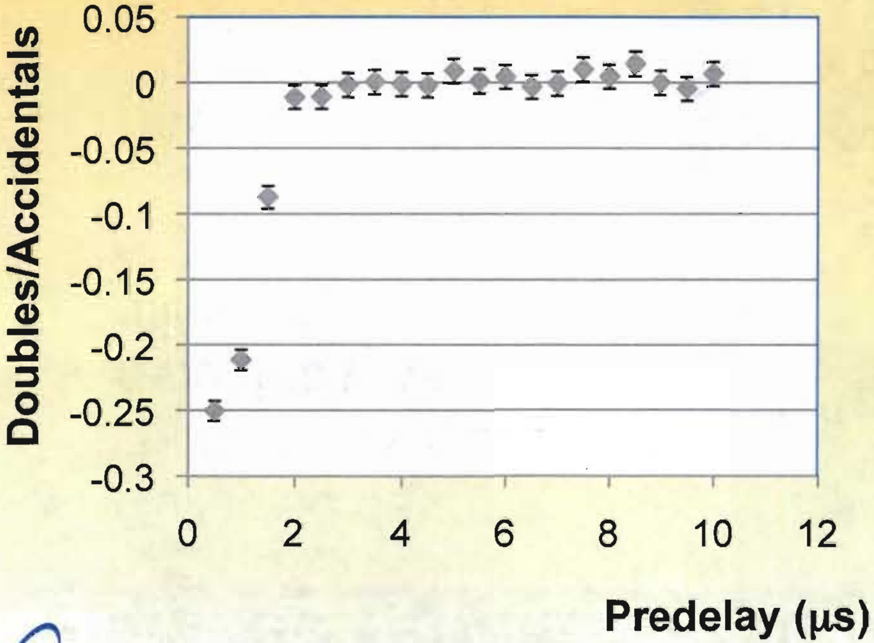
Use of List Mode Module enabled data to be analyzed repeatedly to optimize parameters

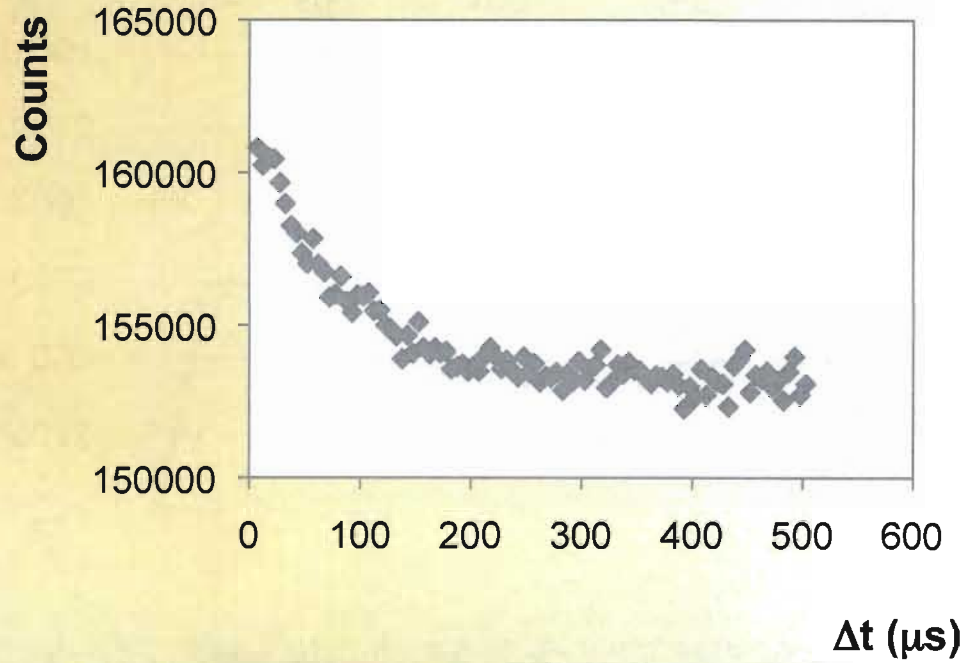
- Collected data could be analyzed repeatedly with different parameters
  - List Mode Module (LMM) was also useful for troubleshooting individual ^{3}He tube responses
- Error in doubles was relatively constant between 64 μs and 96 μs
  - 64 μs chosen as gate width for data acquisition



Analysis of coincidence distributions showed normal behavior from ^{3}He tubes

- Analysis of relationship between reals and accidentals for AmLi indicated that predelay should be set at 4.5 μs





- Rossi-alpha distribution for ^{252}Cf data did not display peaks indicative of double-pulsing
- Dieaway time was ~ 70 μs

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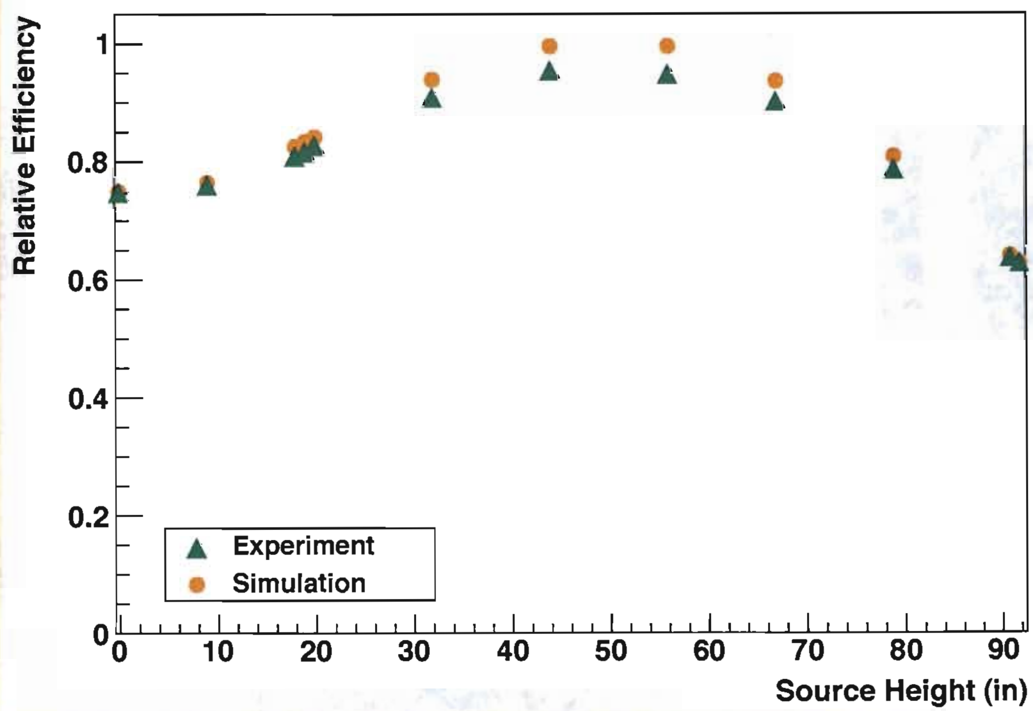
The system efficiency was highest near the panel centers

- Efficiency was uniform near center of panels
- Decrease in efficiency was more pronounced as source height increased
  - Concrete floor muted efficiency fall-off
- Predicted and actual absolute efficiencies are in good agreement

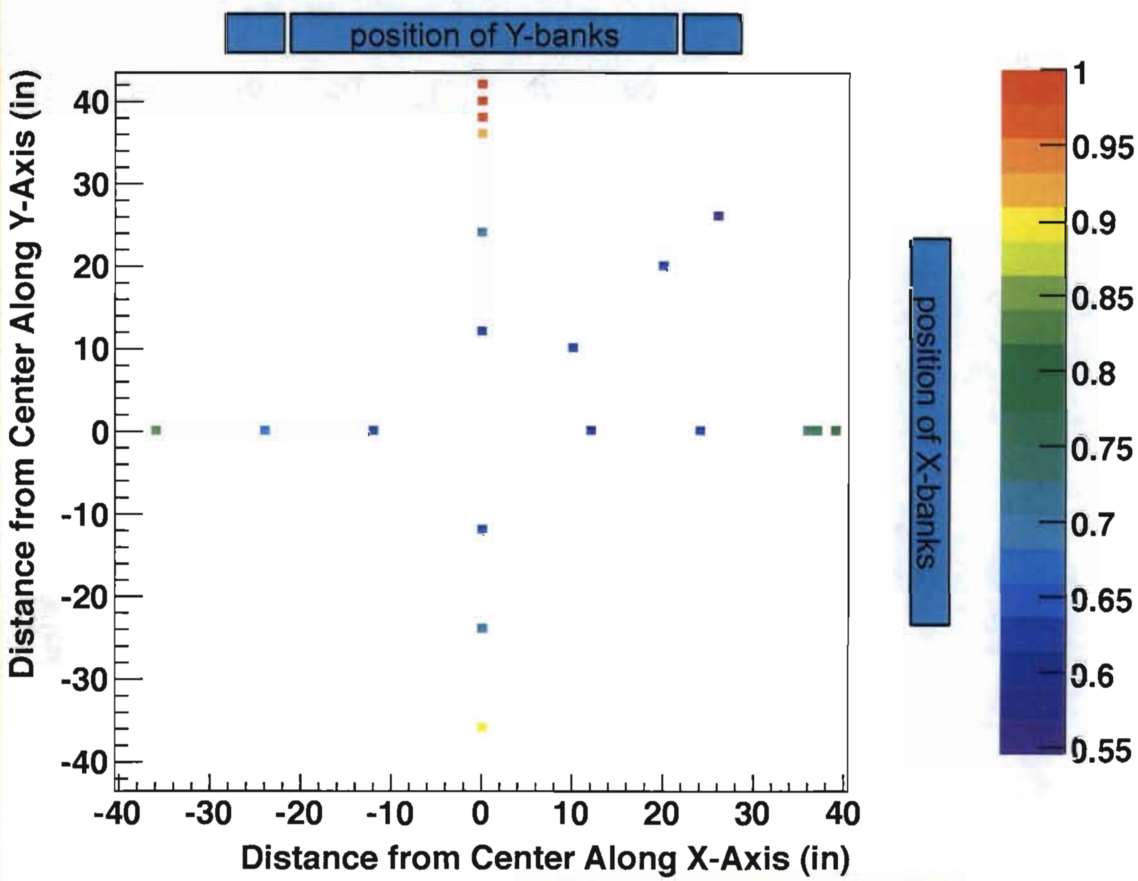


All measurements performed at center of x-y plane using a ^{252}Cf source

Efficiencies relative to simulation results at center (Z=56.5")

Spatial mapping showed that efficiency was highest near the large detector banks

- Banks along y-axis have more ^3He tubes and are closer to the sphere
  - Approach of x-axis banks to the sphere is limited by ports
- Minimum efficiency was found along the diagonal, between banks
  - Model predicts lowest efficiency at 35-40°



All measurements performed at Z = 56.5" (detector center)

Experiment and simulation were in agreement on the most and least efficient locations

- In Z-plane testing, highest efficiency was near the detector center
  - Highest experimental efficiency was 5.61% (at Z=44") and highest simulation efficiency was 5.85% (at Z=44" and Z=56.5")
- In Z-plane testing, lowest efficiency was at the top of the virtual sphere (Z=94")
  - Lowest experimental efficiency was 3.59%, lowest simulation efficiency was 3.53%
  - Efficiency was higher at the bottom of the virtual sphere (Z=18") and even under it (Z=0") because of reflection from the concrete floor
- In XY-plane testing, highest efficiency was at closest location to 3-panel detector banks
  - Experimental efficiency of 9.17% was higher than at closest location to single-panel bank (ε=7.38%) due to larger solid angle and closer approach
- In XY-plane testing, lowest efficiency was between detector banks
  - Least efficient measurement was at X=Y=26", with efficiency of 5.03%
- Least efficient location overall was at top of sphere

Summary and Conclusions

- Data acquisition parameters (gate width, predelay) have been thoroughly characterized and are in agreement with MCNPX predictions
- Absolute efficiency data for neutron assay system is in agreement with MCNPX simulations
- Measurements of ^{240}Pu in 1" and 2" poly and steel spheres are currently undergoing analysis and comparison with simulation results
- In the next few months, the detector's response to sources in an actual confinement vessel will be characterized

Future Work: Upgrades to improve the detector's capabilities

- Incorporation of a List Mode Module into the system would allow individual ^{3}He tube responses to be measured
  - Would permit imaging of radioactive material inside the confinement vessel
- Separate 4-tube system could be used for energy corrections for (α,n) on light elements
- Incorporation of triples measurements into analysis could lower minimum detectable limit of system
  - Further reduction of confinement vessel activity to < 100 nCi/g (~2 g. ^{239}Pu equivalent) would permit vessels to be treated as Low Level Waste