The University of Texas at Austin
Cockrell School of Engineering

JUNE 2021

# MCNP MODELLING OF A $^{10}B/ZnS(Ag)$ SCINTILLATION DETECTOR

A. Macris[1], K. Mckay[1], C. Brabec[2] W. S. Charlton[1] and S. Landsberger[1]

[1] Nuclear Engineering Teaching Lab

[2]Los Alamos National Laboratory

# PURPOSE

- A $^{10}B/ZnS(Ag)$ detector will be inserted into a shield and attached to a robot so that it can be sent into areas to perform radiological surveys that could pose radiological harm to humans.
- The shielding must be able to limit the counting contributions from sources outside the area of interest so that the measurements accurately represent the radiation levels of individual containers.
- In order to assess the effectiveness of different shielding designs, an accurate model of the inner workings of the detector needed to be developed.

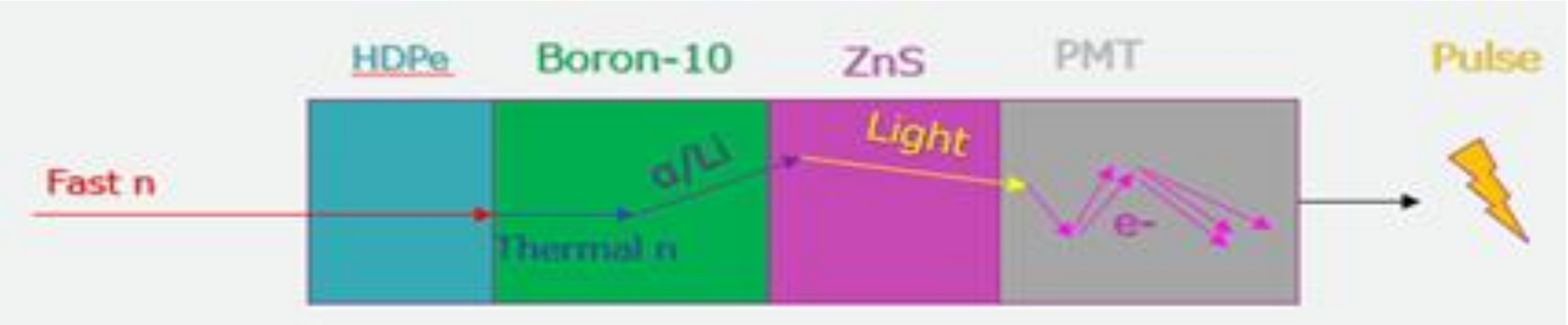
# The $^{10}$B/ZnS(Ag) DETECTOR

- Neutrons do not ionize atoms directly, so detectors rely on secondary particles emitted from interactions within a converter material.
- Our detector relies on the alpha particles emitted from the absorption reaction:
    - $^{10}B + n \rightarrow {}^{7}Li + \alpha + \gamma$

# The 10B/ZnS(Ag) DETECTOR

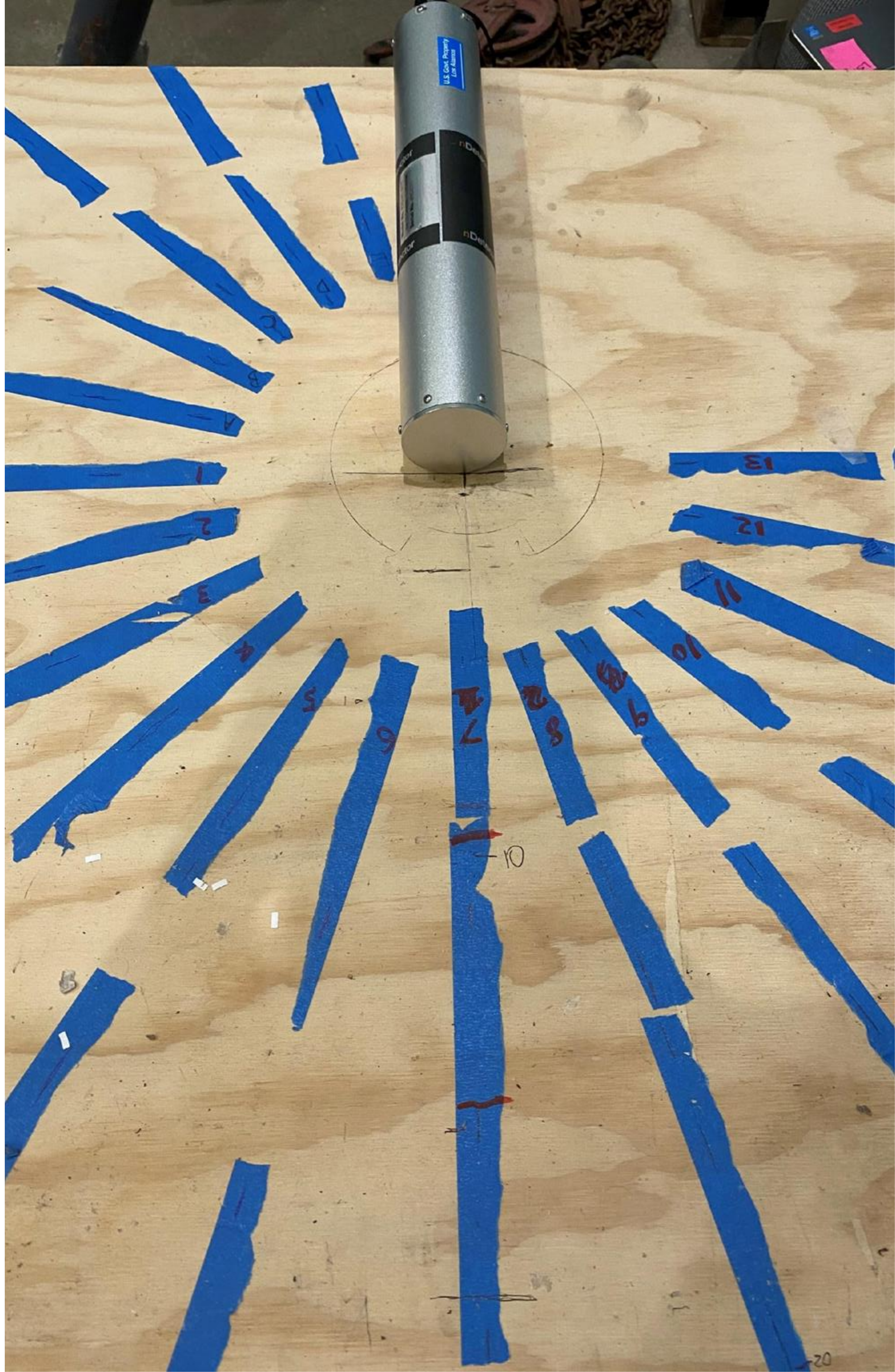
$^{10}B + n \rightarrow {}^{7}Li + \alpha + \gamma$

- This reaction is more probable with thermal neutrons, so the detector includes an internal lucite light guide and likely an internal HDPE moderator to slow down incident neutrons.
- The emitted alpha particles then deposit their energy in the ZnS scintillator to produce light, which is converted into electronic pulses via a photomultiplier tube (PMT).



# EXPERIMENTAL WORK

- The experimental work involved recording counts without any shielding around the detector.
- Counts were recorded with two plutonium-beryllium (PuBe) neutron sources (whose strengths are both known) placed at different angles with respect to the detector's face.
- The recorded counts were compared to results tallied in MCNP in order to refine the detector model.



# MODELING WORK


Sideway view of the detector

- First, external measurements of the neutron detector used in the experiments were taken.
- Further measurements for the detector could be found on Bridgeport Instruments' website—there, the diameter and length of the active portion of the detector are listed.
- From this information, we can determine that the cylindrical, aluminum case of the detector contains another cylinder of given length and radius that is used as the active area.

# MODELING WORK

- It was also determined from Bridgeport Instruments' website that the detector contains a photomultiplier tube (PMT) at its tail end.
- Most Boron-10 neutron detectors also have an internal moderator, as mentioned, and this was chosen to be HDPE in the model as it is commonly used for this purpose in other detectors.
- Bridgeport was able to provide us with the surface density of the Boron-10 that coats the outside of the active cylinder within the detector, as well. This number proved extremely valuable and confirmed the geometry of the detecting element.

# MODELING WORK

- The information that is not known for certain is:
  - The size and specifications of the PMT
  - The thickness of the Boron-10 layer
  - The thickness of the aluminum casing
  - The existence and thickness of the internal HDPE moderator

# MODELING WORK

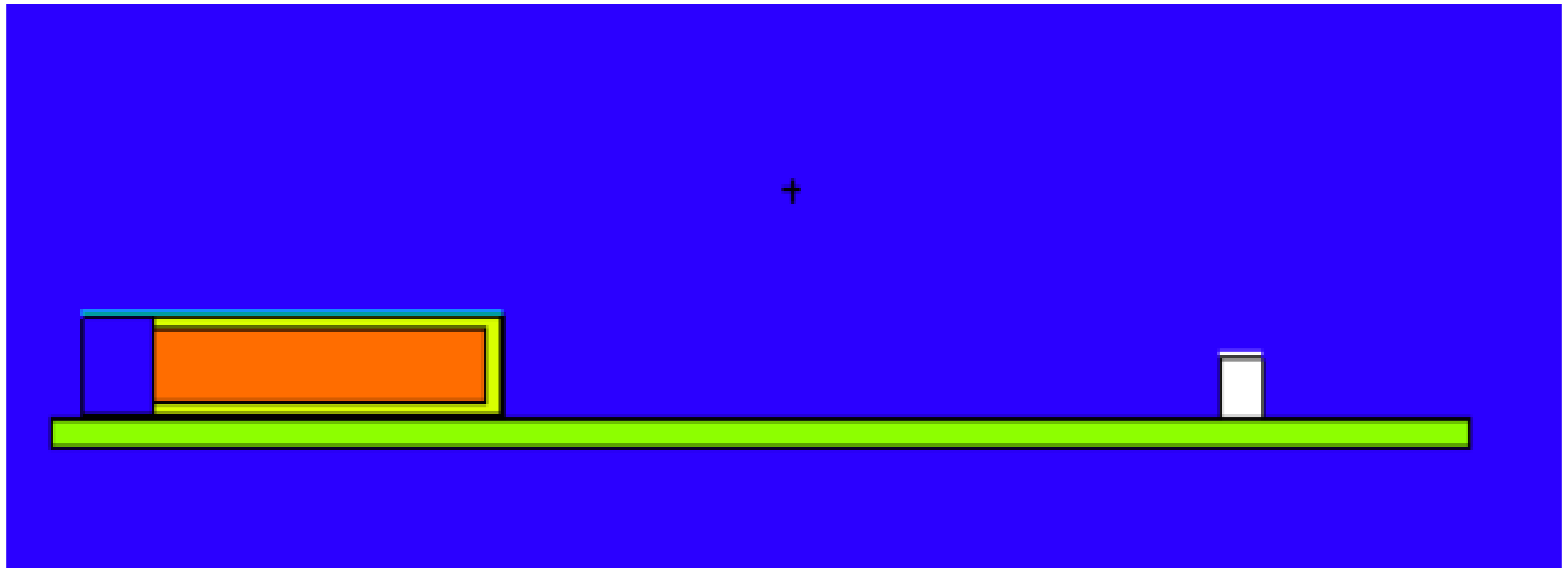
- The detector being used in this project is not the same as the standard model detectors that Bridgeport has information about on their website.
- This caused some of the measurements that were available for other detector models to be unusable for our case.
- A thickness of .017cm was chosen for the Boron-10 layer, as it was found in another paper that this is the thickness used by some Boron-10 portal monitors (Guzman-Garcia et al.).

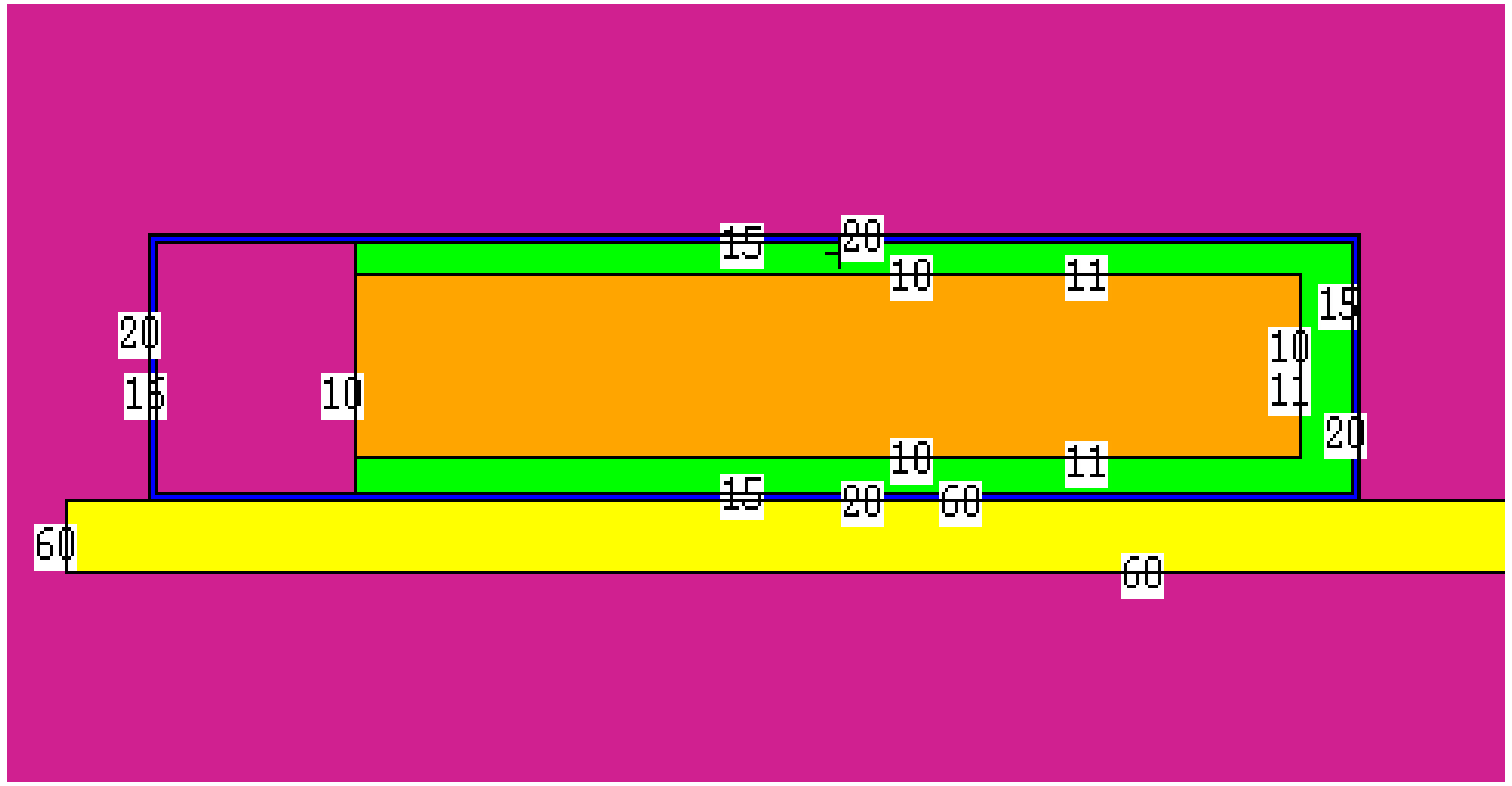
# MODELING WORK

- After many trials of different thicknesses of the casing and moderator, some values were settled on that gave the most accurate results.
- The PMT was simulated by simply having air in place of where the actual PMT would be in the detector, as its exact composition is not known.
- The MCNP simulation created contained the detector, the source, the wooden table upon which the setup was placed, and the room in which the experiments were conducted with accurate dimensions and wall thicknesses.

# MODELING WORK

- The experimental setup (left) and the finalized detector model (right) are shown below





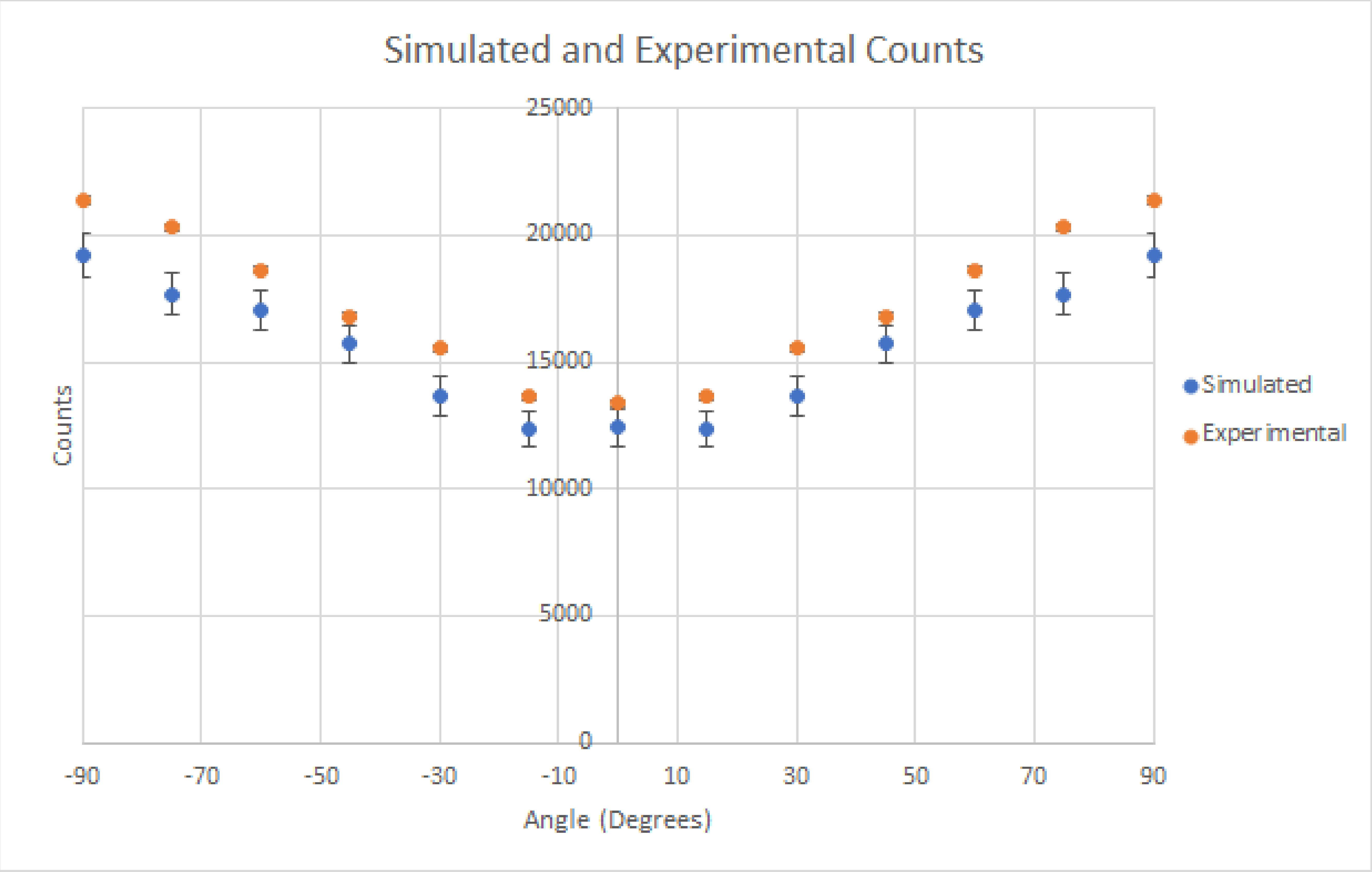
# MODELING RESULTS

- The simulated results differed from the experimental data by no more than 13% at its most, and by as close as 7% at its best.

| Angle | Experimental Cts | Uncertainty (Cts) | Simulated Cts | Uncertainty (Cts) | Percent Difference |
|---|---|---|---|---|---|
| 0 | 13382 | 115.68 | 12421.8 | 746.55 | 7.172% |
| 15 | 13629 | 116.74 | 12360.8 | 684.79 | 9.305% |
| 30 | 15539 | 124.66 | 13657.9 | 748.45 | 12.1% |
| 45 | 16813 | 129.66 | 15699.1 | 769.26 | 6.625% |
| 60 | 18625 | 136.47 | 17024.8 | 804.24 | 8.195% |
| 75 | 20297 | 142.47 | 17683.6 | 820.52 | 12.87% |
| 90 | 21366 | 146.171 | 19190.6 | 857.820 | 10.18% |

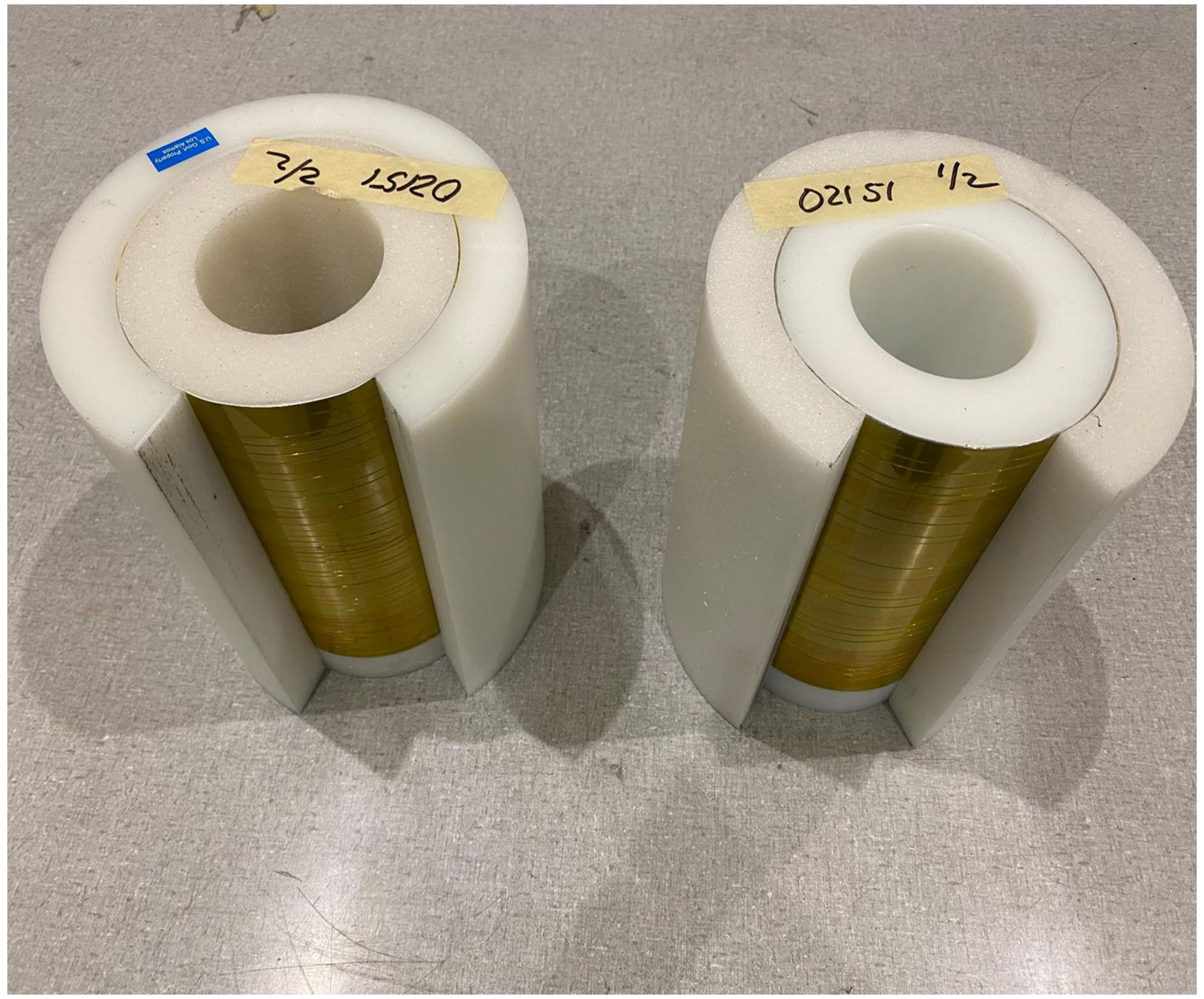
# MODELING RESULTS

- The results plotted against each other are shown with uncertainty measurements represented as error bars.
- The same shape can be seen for both, confirming the geometry and design of our model's interior is consistent with experimental measurements.



# NEXT STEPS

- Two shielding designs have been developed that include concentric layers of HDPE, cadmium, and borated polyethylene. The shields differ in the order of each layer.
- Both designs include a window cut into the outermost layer, which allows more neutrons to reach the detector from sources located in front of the opening.
- Work is currently being done to model both shielding designs. Counts have been recorded with the detector placed in both shields, which will help in refining the MCNP models.



# REFERENCES


- Bridgeport Instruments, “Neutron Detector Suitable for Second Line of Defense Program”, Data Sheet, Mar. 2020, http://bridgeportinstruments.com/products/neutron/ndet_2x24_r1.pdf.
- Shultis, J.K., and R.E. Faw. “AN MCNP PRIMER.” Kansas State University, Dec. 2011, www.mne.k-state.edu/~jks/MCNPprmr.pdf.
- Guzman-Garcia, Karen Arlet, Hector Rene Vega-Carrillo, Eduardo Gallego, Juan Antonio Gonzalez-Gonzalez, Alfredo Lorente, and Sviatoslav Ibañez-Fernandez. “10B+ZnS(Ag) as an Alternative to 3He-Based Detectors for Radiation Portal Monitors.” EPJ Web of Conferences 153 (2017): 07008. https://doi.org/10.1051/epjconf/201715307008.
- https://cdn.pixabay.com/photo/2017/10/18/14/31/box-2864328_960_720.png

The University of Texas at Austin
Cockrell School of Engineering