# GEANT4 Simulation of Irradiation Facilities and Neutron Sources at University of Utah TRIGA for Nuclear Forensics and Detection

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## BACKGROUND

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Major: Chemical Engineering
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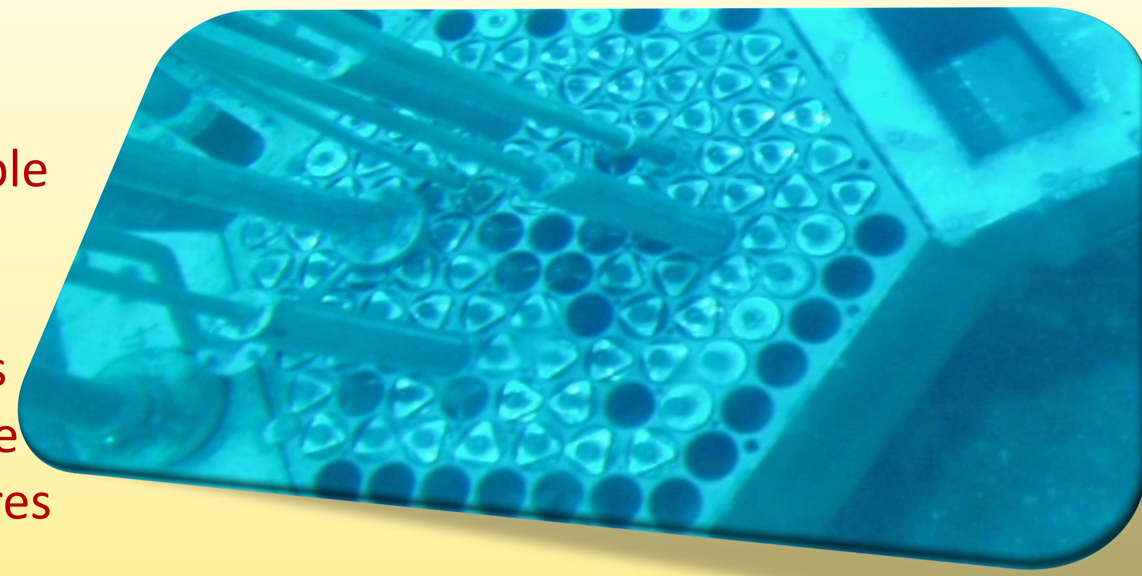
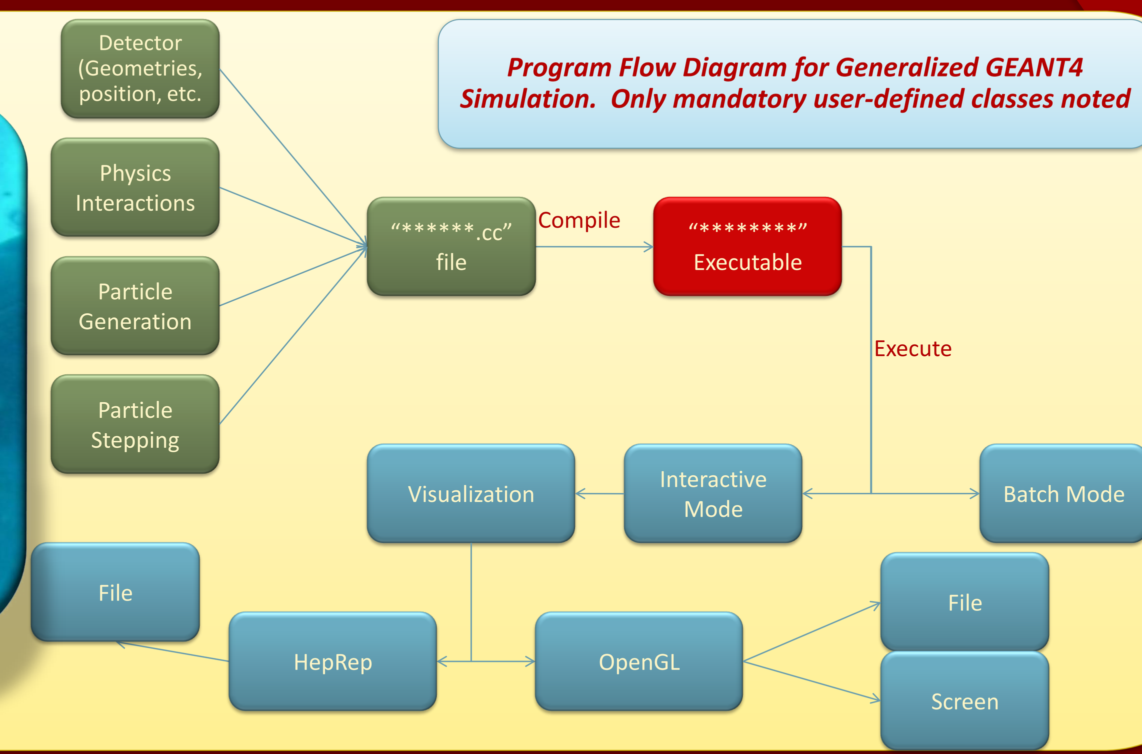
As a young child, my only wish for my future was to someday be in a history textbook. Now, I have the opportunity to be able to actually succeed in this effort: I want to be able to improve the world through nuclear technologies, and my current dream is to be able to help develop sustainable fusion as a viable power source for the future.

## OBJECTIVES

- Model UUTR irradiation facilities, using GEANT4 simulation toolkit
- Calculate dose from irradiated sample at various distances
- Provide method of benchmarking experiments at irradiation facilities
- Simulate shielding of neutron source
- THEREFORE, create nuclear signatures for nuclear forensics involving UUTR

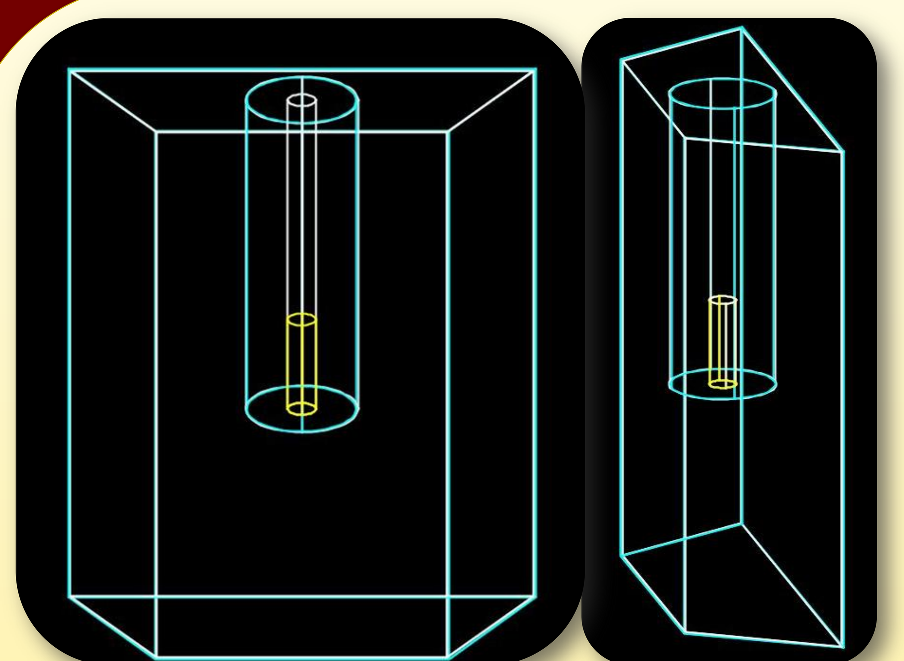


University of Utah TRIGA

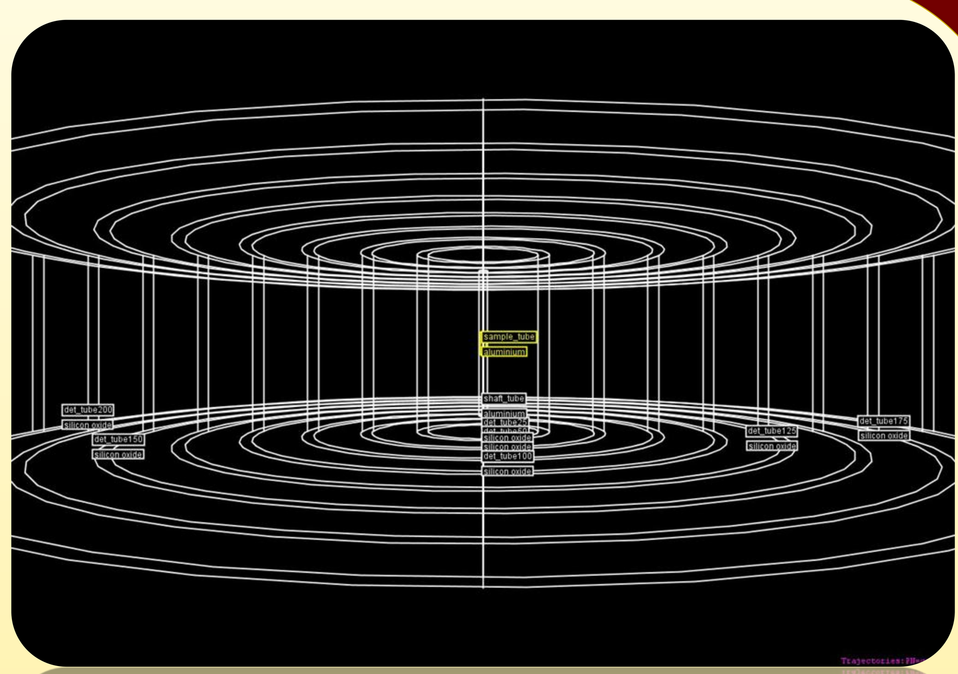



*Program Flow Diagram for Generalized GEANT4 Simulation. Only mandatory user-defined classes noted*

## GEANT4 MODELS

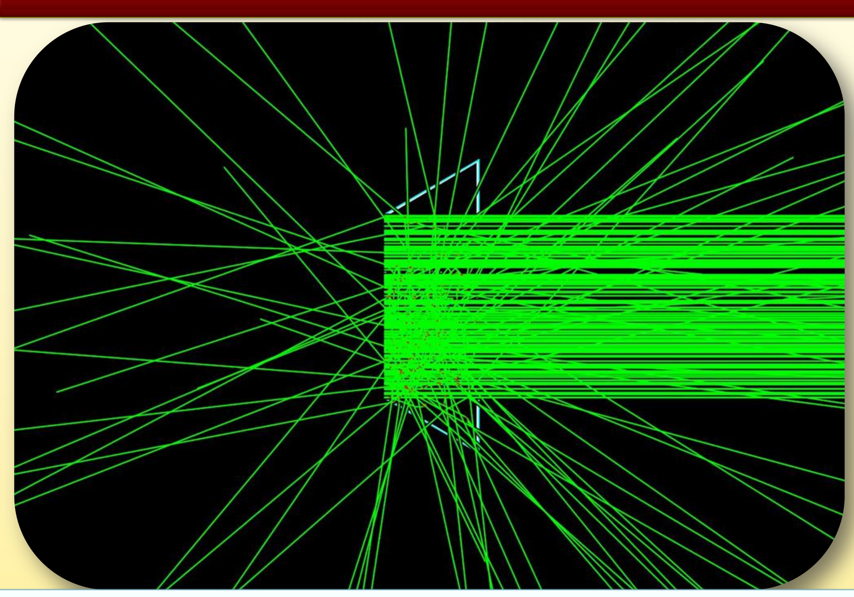


- HepRApp-rendered model of thermal TRIGA irradiator facility
- Air shaft nested at the center shaft of heavy water.
- Shafts embedded in aluminum trapezoidal prism filled with heavy water.
- Sample is subjected to a planar flux of 3.6 $*10^{11}$ $^{neutrons}/_{cm^2*sec}$

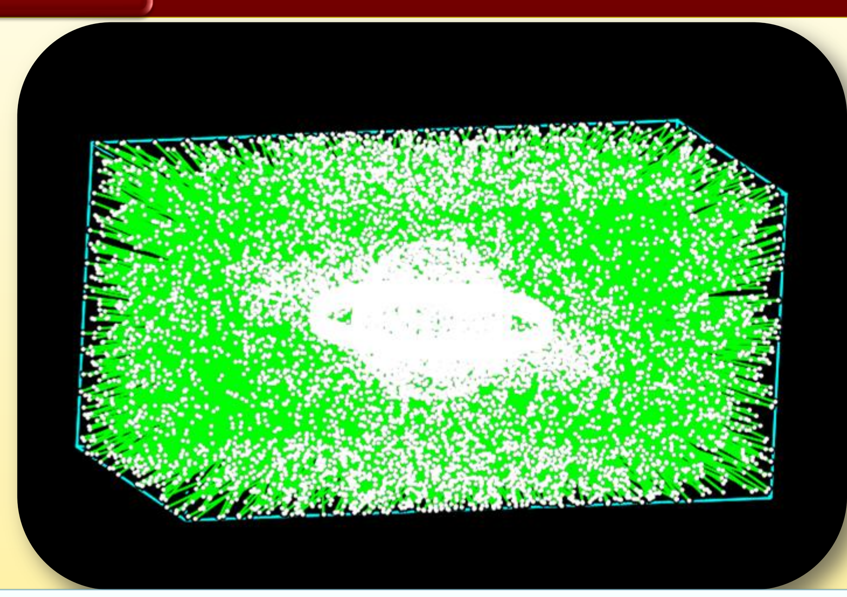


- HepRApp-rendered model of central TRIGA irradiator facility
- 1"-diameter, 5"-tall aluminum cylinder in the center of aluminum air shaft
- Subjected to a homogeneous cylindrical flux of 3.9 $*10^{12}$ $^{neutrons}/_{cm^2*sec}$.
- MCNP5 used to simulate geometry, to calculate neutron flux-per-source-particle, to calculate the number of neutrons necessary to be generated in order to simulate a desired flux.
- Same concentric tube detector assembly for thermal model shown

## GEANT4 PARTICLE MODELS

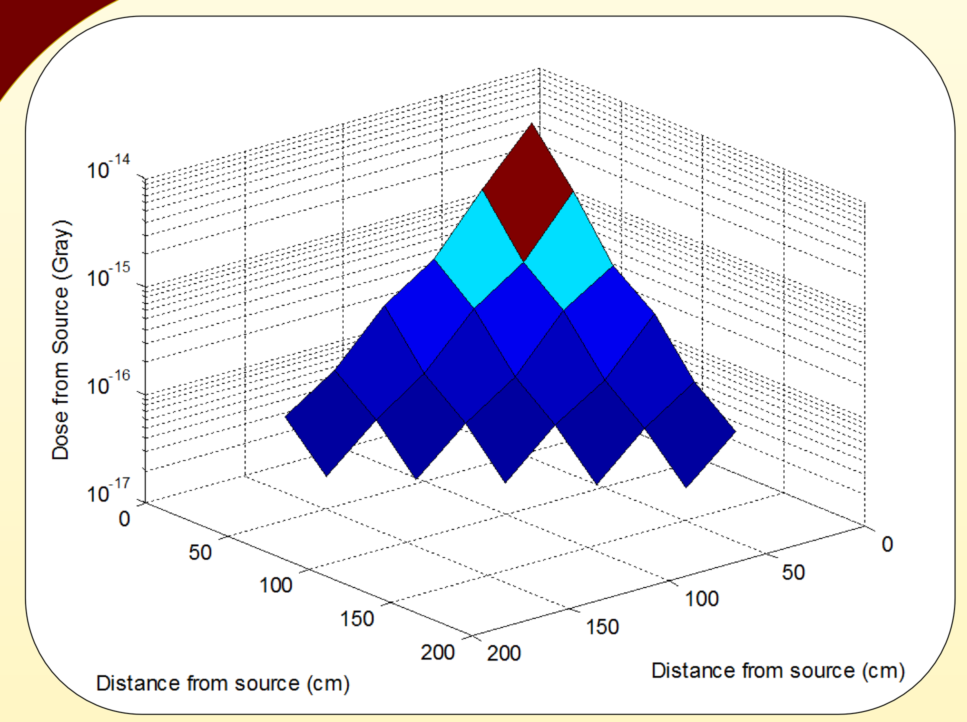


*GEANT4 simulation of thermal irradiator planar flux irradiation of aluminum sample. Green rays indicate neutron tracks; red tracks indicate negatively-charged particles; blue tracks indicate positively-charged particles; white points mark stepping points for particles.*

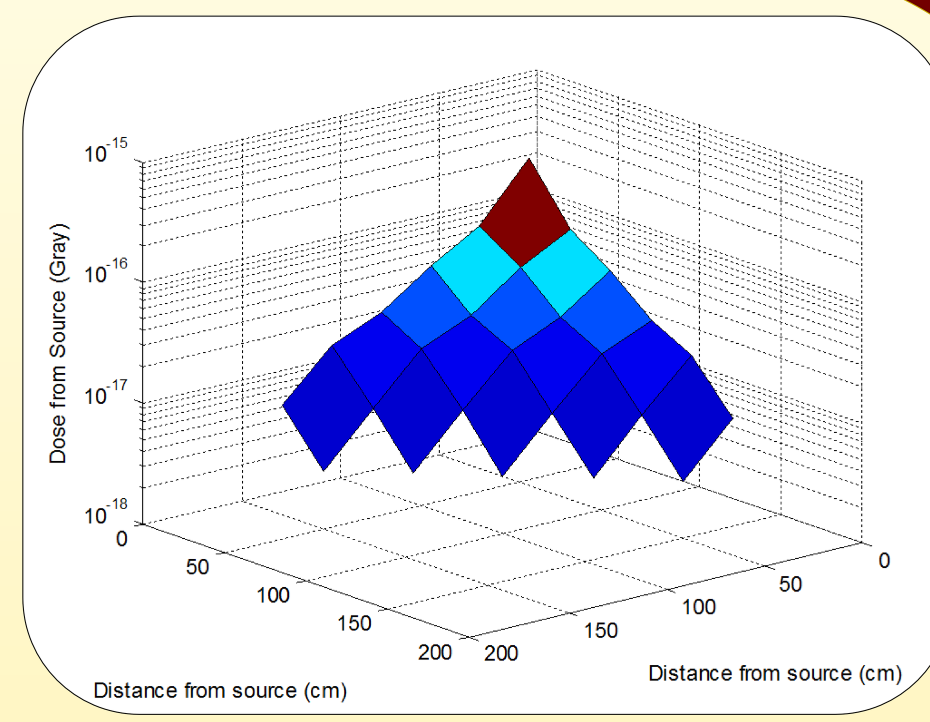


*GEANT4 simulation of central irradiator cylindrical flux irradiation of aluminum sample. Green rays indicate neutron tracks; red tracks indicate negatively-charged particles; blue tracks indicate positively-charged particles; white points mark stepping points for particles.*

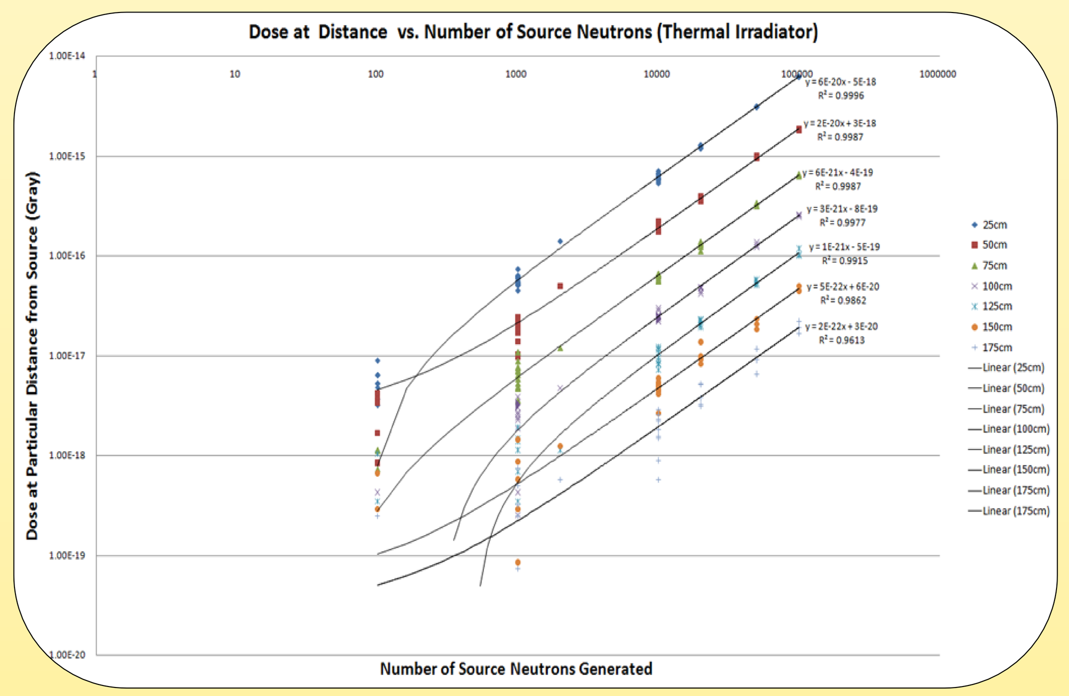
## GEANT4 DOSE CALCULATIONS

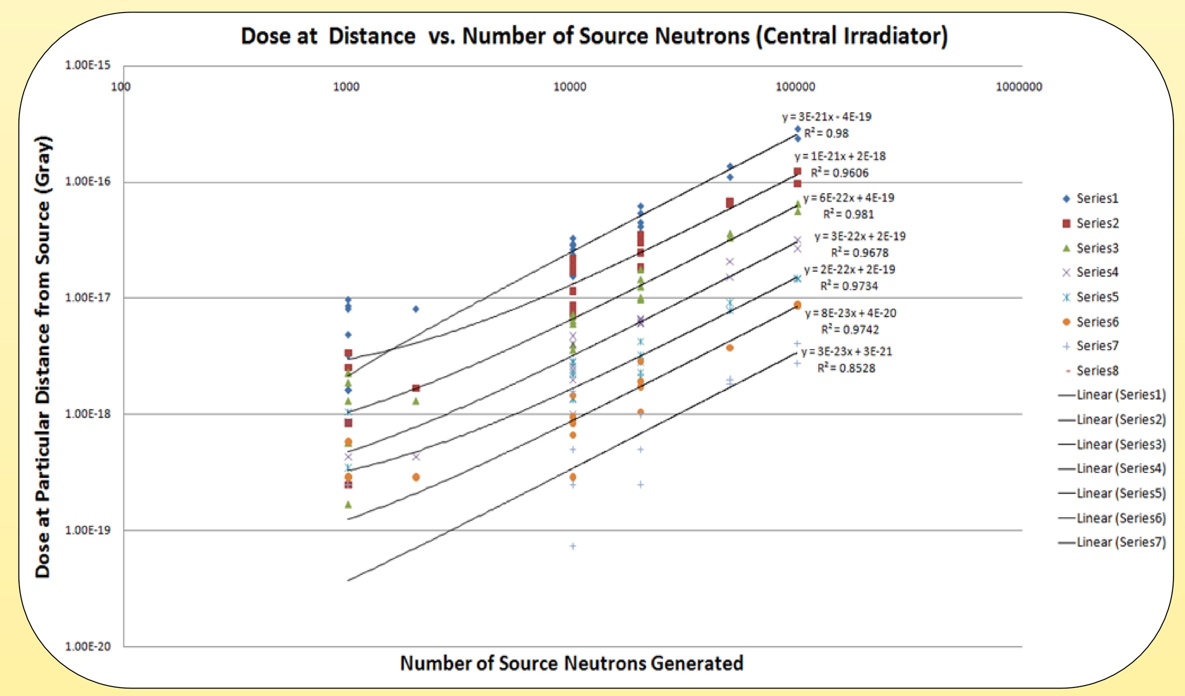



Dose plot for the thermal TRIGA irradiator model, as a function of distance from the source, for 0.154 µs irradiation time




Dose plot for the central UUTR irradiator model, as a function of distance from the source, for 0.0141 µs irradiation time

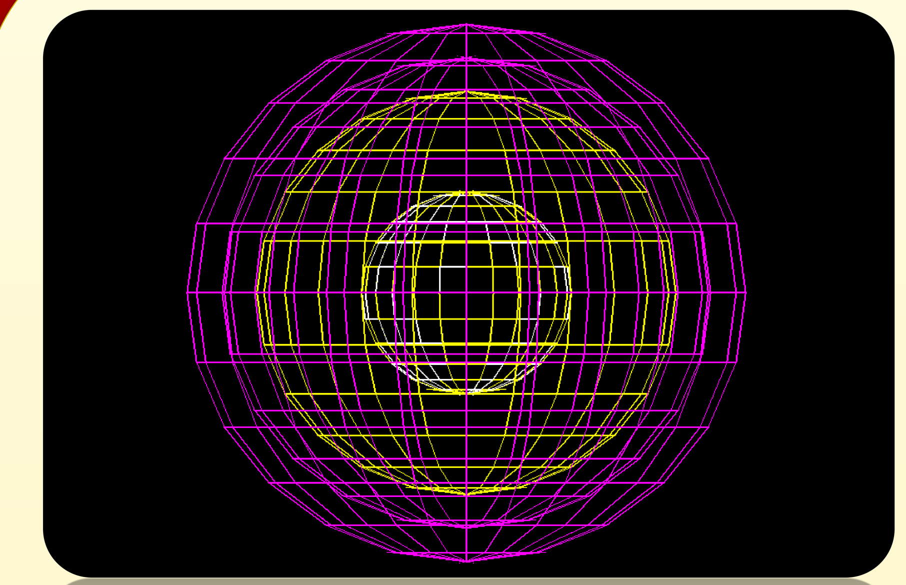


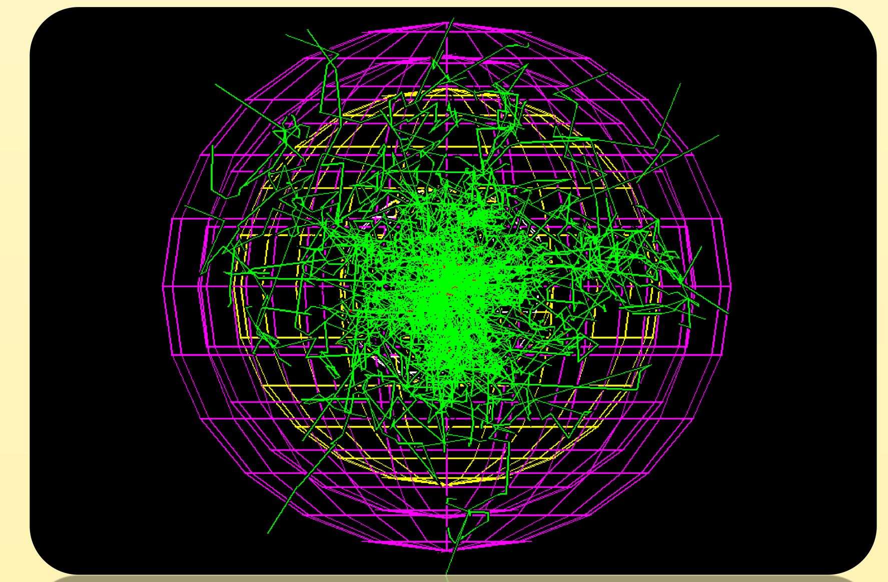

- At 25cm from sample, absorbed dose for 0.154 µs irradiation time of aluminum sample from thermal irradiator is $5.995 \cdot 10^{-15}$ Gray
- For 2 hour irradiation time common for NAA, this equals a dose rate of 0.139 $^{Sv}/_{hr}$ = $1.39 \cdot 10^{4}$ $^{mrem}/_{hr}$

- At University of Utah TRIGA, Area Radiation Monitors SCRAM reactor for detection of > 10 $^{mrem}/_{hr}$ dose rates
  - In this case, samples are suspended at half depth in reactor pool to cool until < 10 $^{mrem}/_{hr}$
  - For 1 $^{mrem}/_{hr}$ < dose rates < 10 $^{mrem}/_{hr}$, samples are cooled inside 4"-thick lead box until < 1 $^{mrem}/_{hr}$
  - Samples < 1 $^{mrem}/_{hr}$ are deemed safe

## NEUTRON SOURCE DETECTION



HepRApp rendered model of GEANT4 neutron source. Innermost shell (white) is paraffin shell, next outer shell (yellow) is lead shell, next outer shell (purple) is sensitive gamma and neutron detector. The neutron source is approximated as a point source.



- Top-down view of GEANT4 neutron source model for $6.700 \cdot 10^{6}$ neutrons /cm$^2$ *sec, with particle tracks. Green rays indicate neutron and gamma tracks; red tracks indicate negatively-charged particles; blue tracks indicate positively-charged particles; white points mark stepping points for particles.
- Note how vast majority of neutrons and gammas are contained within the paraffin shell, and nearly all within lead shell.

## Dose Estimates

| Neutron Flux ($^{neutrons}/_{cm^2*sec}$) | Thickness of Paraffin Shell (cm) | Thickness of Lead Shell (cm) | Absorbed dose at 30 cm ($^{mrem}/_{hr}$) |
|---|---|---|---|
| $6.700 \cdot 10^{6}$ | 15 | 15 | 0.00183 |
| $3.350 \cdot 10^{6}$ | 15 | 15 | 0.00091 |
| $1.675 \cdot 10^{6}$ | 15 | 15 | 0.00046 |