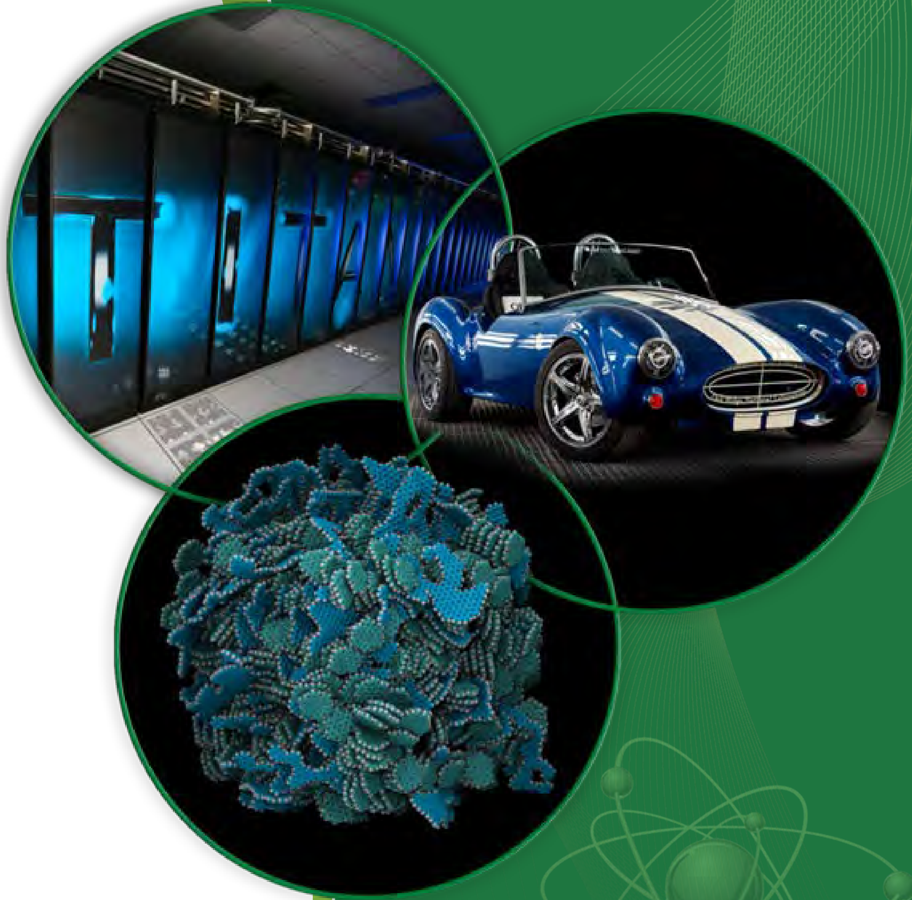
Initial Modeling of Urban Search Measurements



Douglas E. Peplow, Mathew W. Swinney, Gregory G. Davidson, Andrew D. Nicholson, and Bruce W. Patton

Oak Ridge National Laboratory

ANS Annual Meeting

June 11-15, 2017, San Francisco

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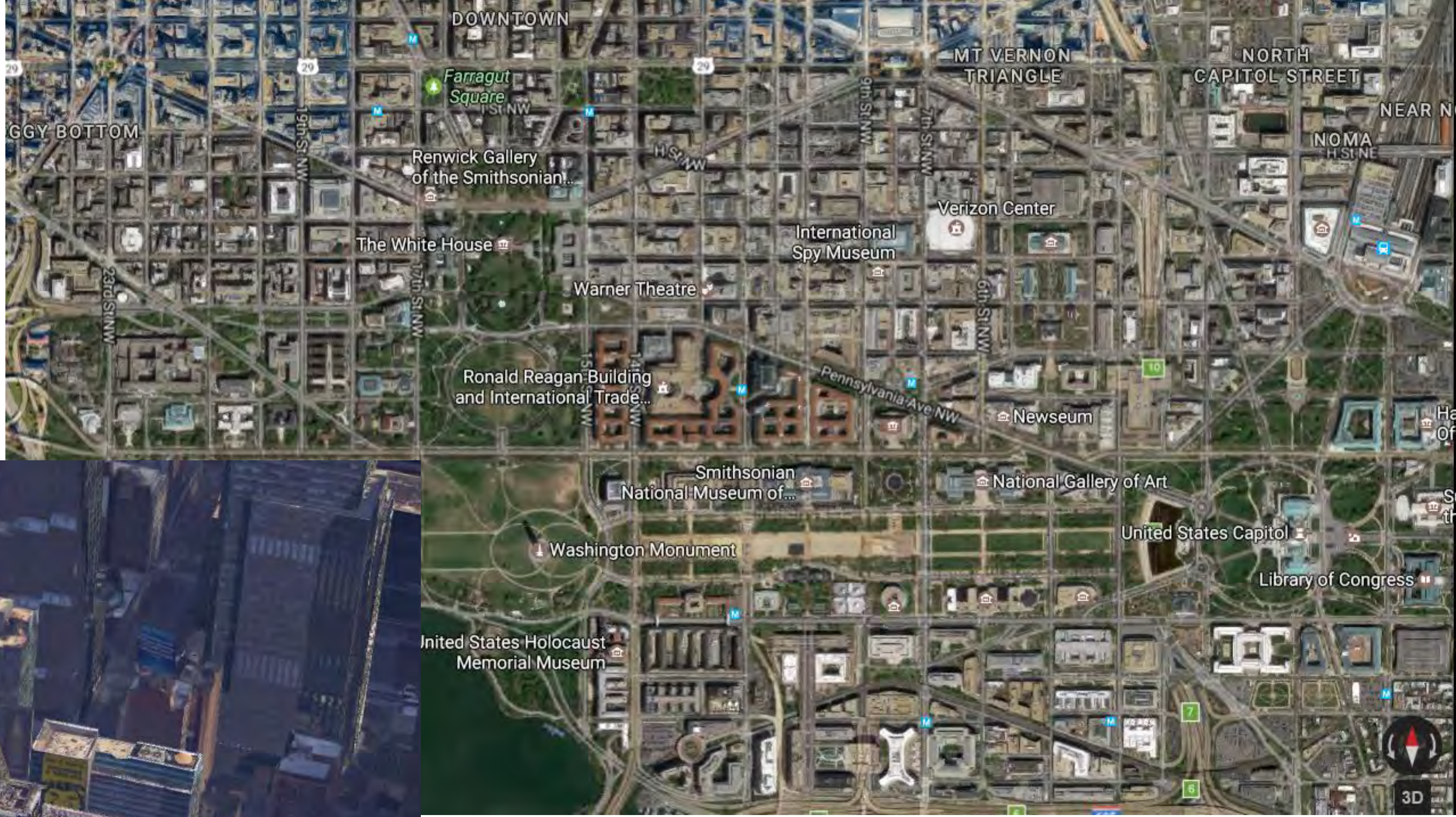
www.politico.com/gallery/2017/01/2017-trump-inauguration-day-photos-002396

Search Mission

Times Square Area maps.google.com



National Mall Area maps.google.com

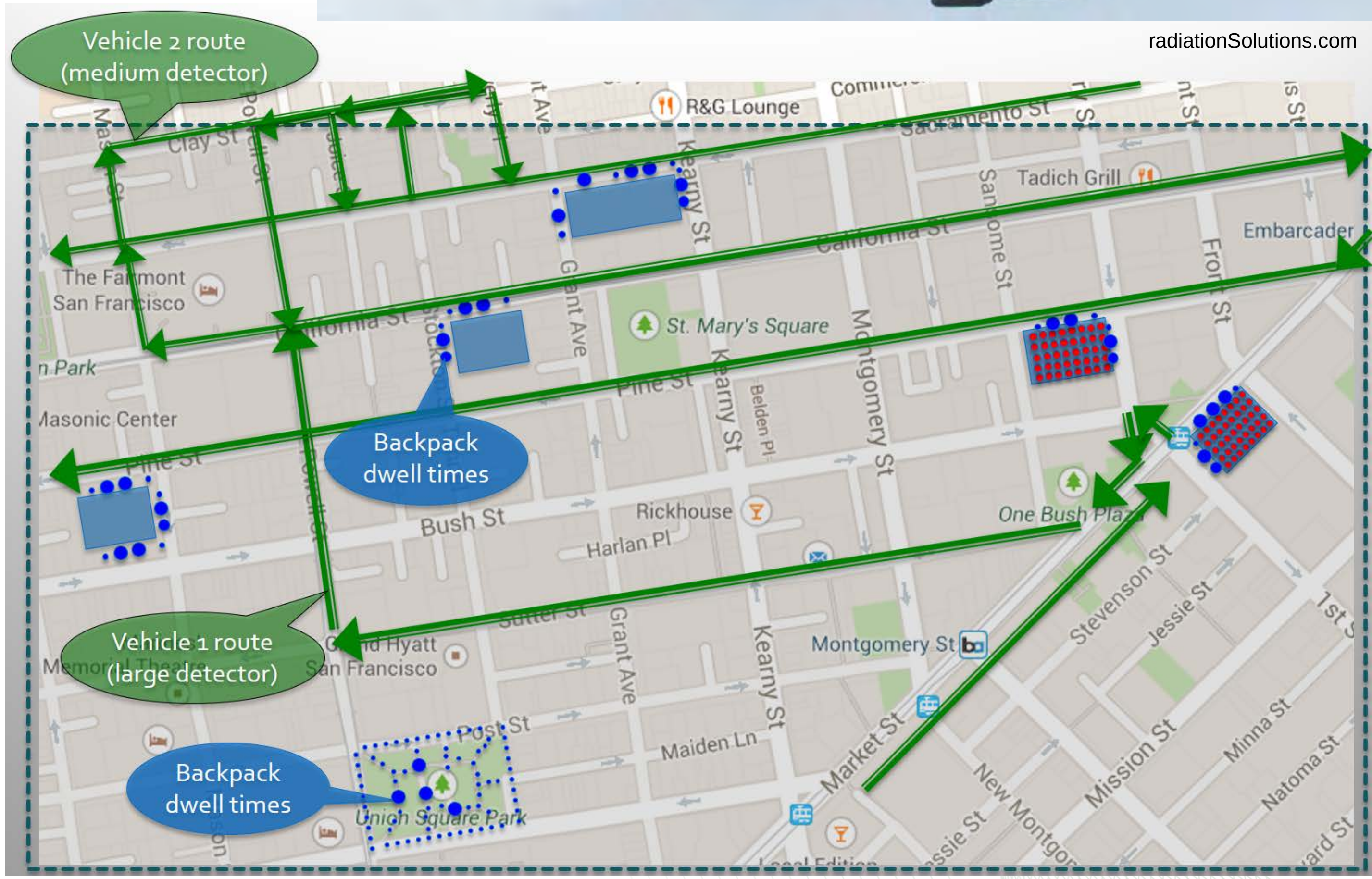
OPTUS Tool

- LLNL’s Optimization Planning Tool for Urban Search (OPTUS)
- Goal is to develop a tool to aid searchers in clearing an area quickly with a higher confidence that no radiological/nuclear threat is present
- Requires estimates of background and threat source
- DNN R&D Venture Project
  - LLNL, LBNL, RSL-Andrews, ORNL

IEEE mfi16 Baden-Baden

R. WHEELER, D. FAISSOL, C. SANTIAGO, T. BAGINSKI, and K. NELSON, “Physics and Optimal Routing for Urban Radiation Source Search,” 2016 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems, Special Session on Multisensor Fusion Methods for Radiation Source Localization, Baden-Baden, Germany (September 19–21, 2016).

radiationSolutions.com



Courtesy of LLNL

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Validation of OPTUS Radiation Transport Estimates

- Benchmark measurements
  - in urban environments for
    - background and
    - threat sources
  - FTIG CACTF in Pennsylvania
- Full 3D radiation transport
  - with SCALE/MAVRIC
- This work
  - Comparisons of measurement to simulation for Nov. 2015 campaign
    - Static NaI measurements of background and ^{137}Cs

Fort Indiantown Gap, Combined Arms Collective Training Facility

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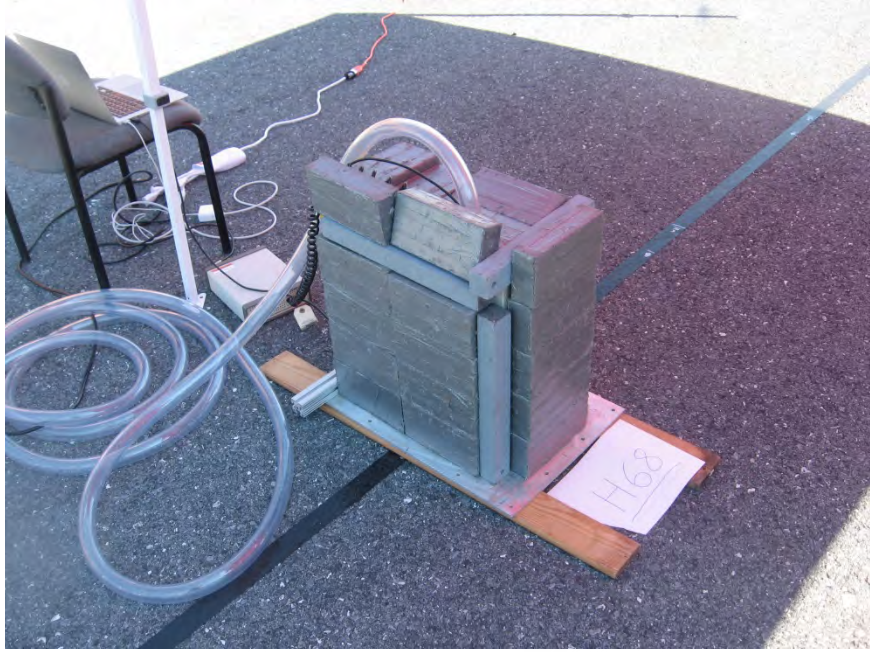
Measurements

OPTUS-1: May 2015
OPTUS-2: Aug 2015



- Measured surface emissions with HPGe to determine NORM concentrations (K/U/Th) and Cs
  - *Swinney's Talk!*
- Static NaI measurements
  - Background
  - 81 µCi ^{137}Cs source
- Dynamic measurement
  - Human-pulled cart
  - NaI in vehicle

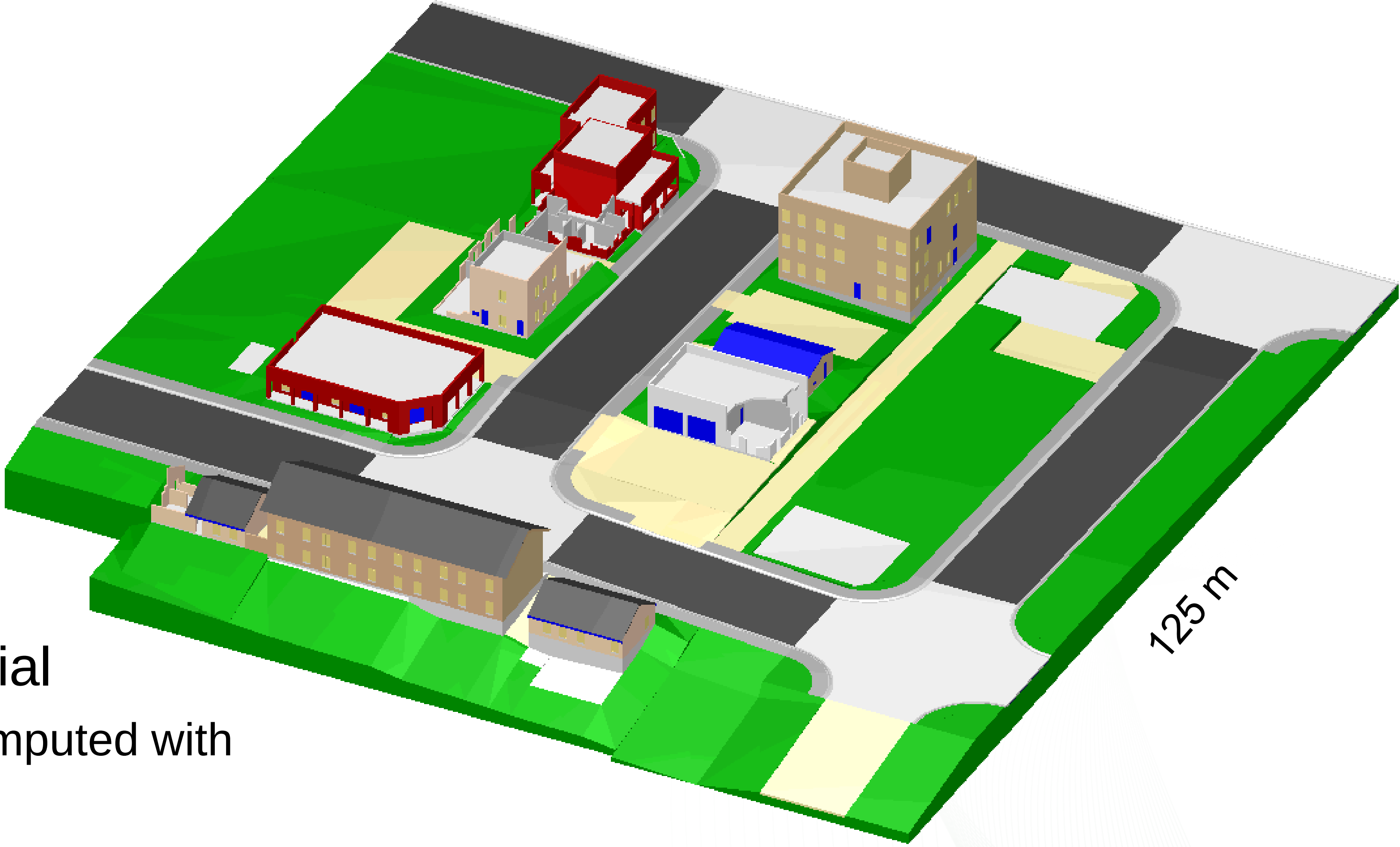
Measurements

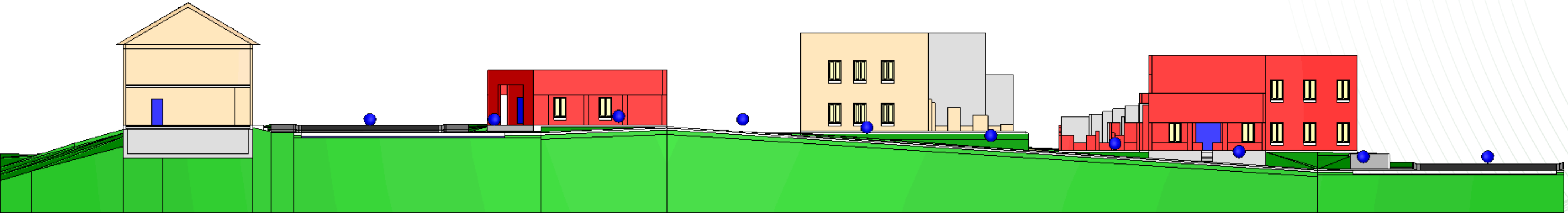
OPTUS-3: Nov 2015

- Wide-area exterior (WAE)
- High-interest location (HIL)

Modeling

- Focus on the main street
  - Nine buildings (outer shells)
  - Interior walls in three-story hotel
  - Asphalt streets (black)
  - Concrete intersections (white)
  - Concrete sidewalks (gray)
  - Gravel parking (tan)
  - Soil (green)
- Sources K/U/Th/Cs by material
  - Source energy distributions computed with SCALE/ORIGEN (equilibrium)
- Computed flux above main street
  - Detector not in the model

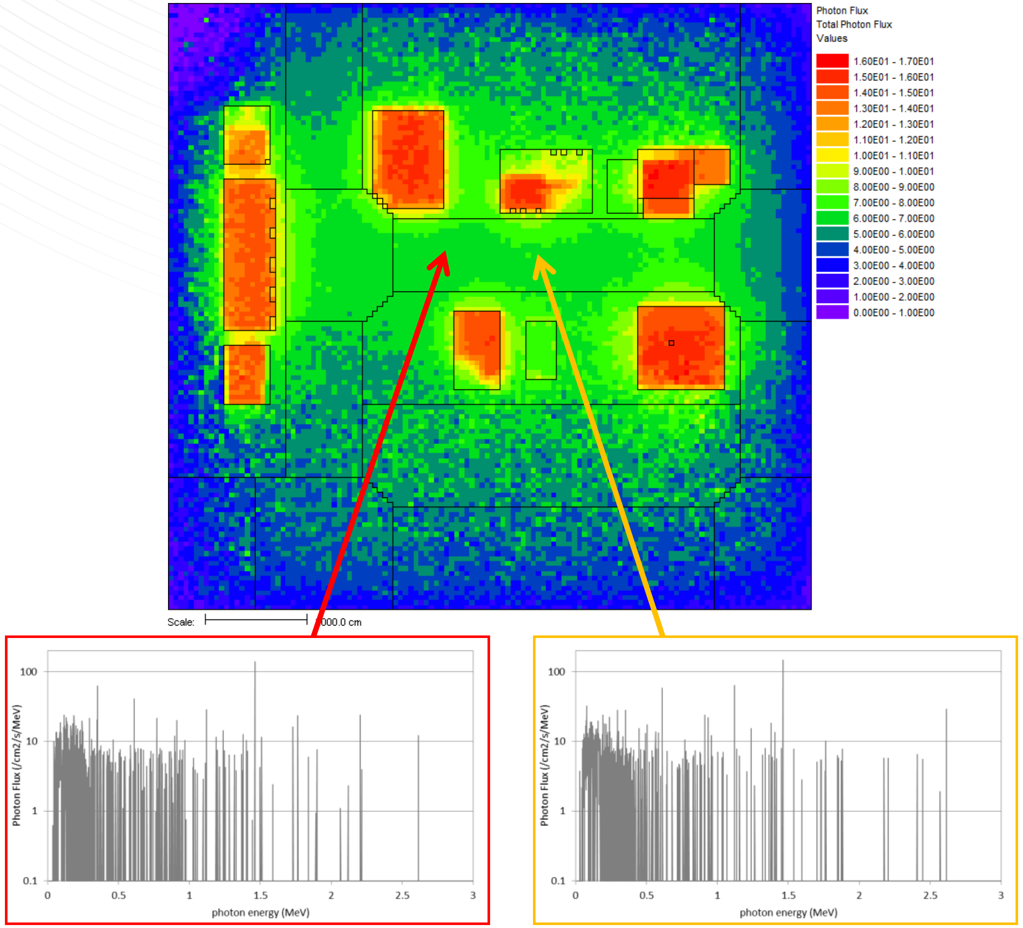




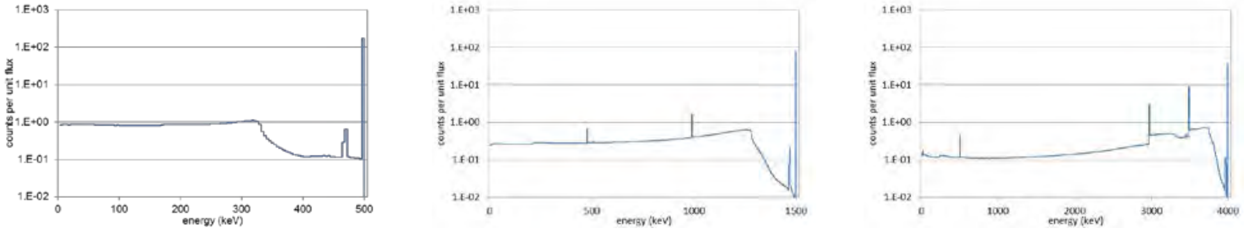
Model Validation – Split Transport and Response

1. Transport calculation – SCALE/MAVRIC

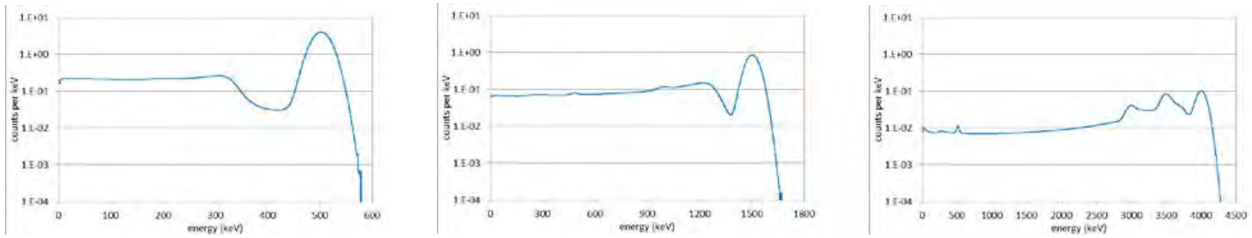
Compute energy-dependent flux anywhere
Specific regions or a mesh tally
Automated variance reduction



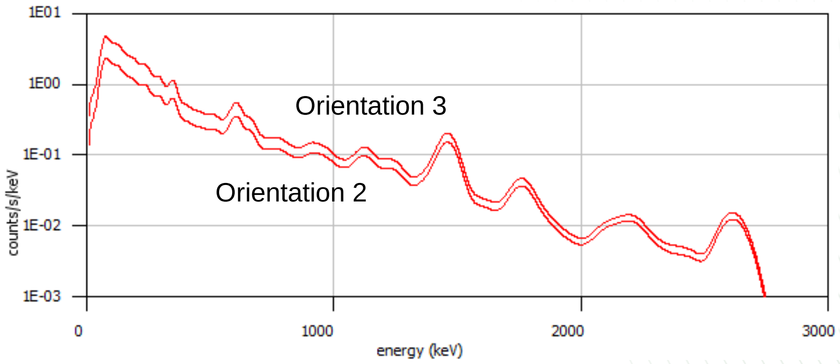
2. Energy deposited per unit flux (response function, MCNP)

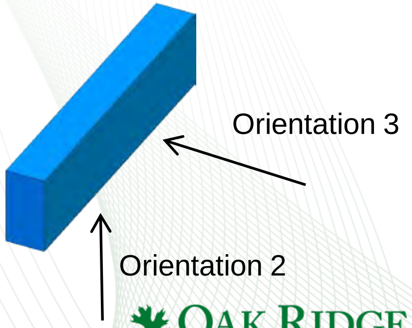


3. Convolve and apply resolution function (like GADRAS)



Note: For non-isotropic detector, steps 2 and 3 are directionally dependent





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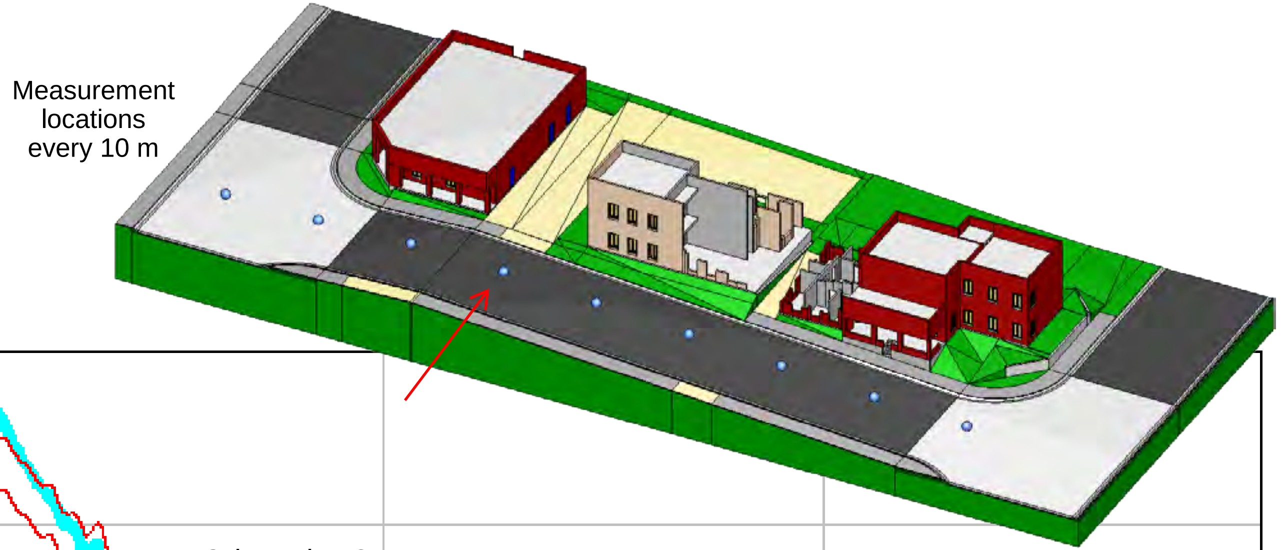
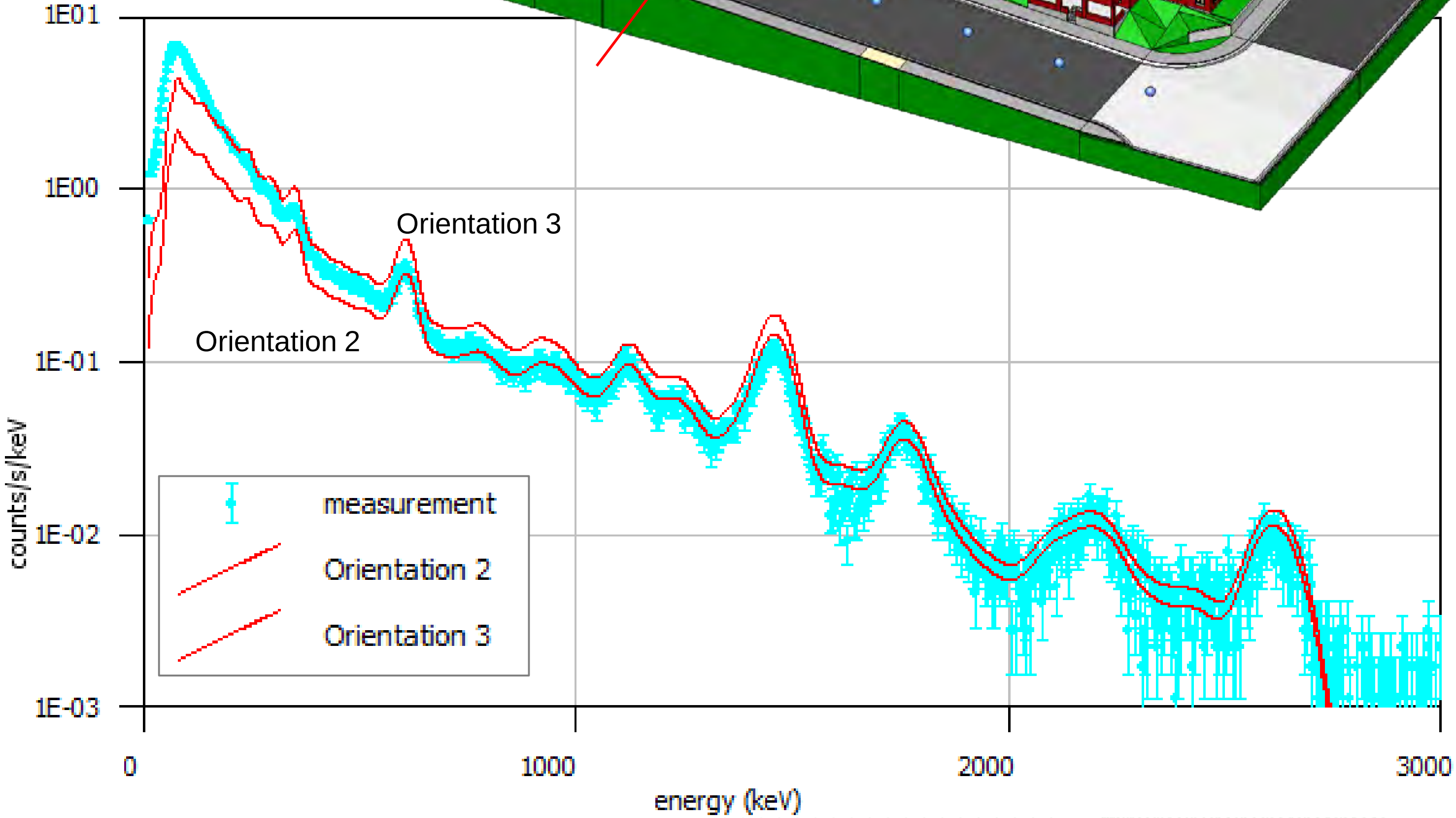
Model Validation – Background with NaI

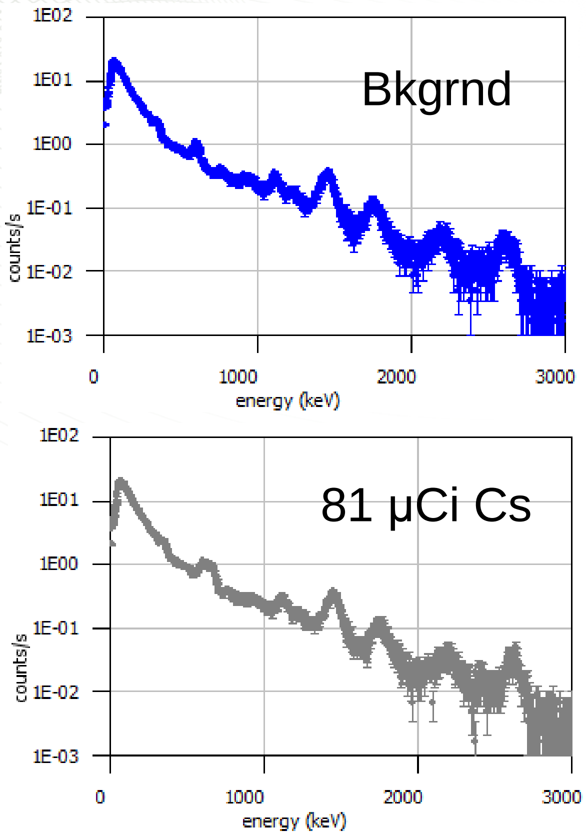
Measurements: Along centerline of main street
Used standard issue 2”×4”×16” NaI detector

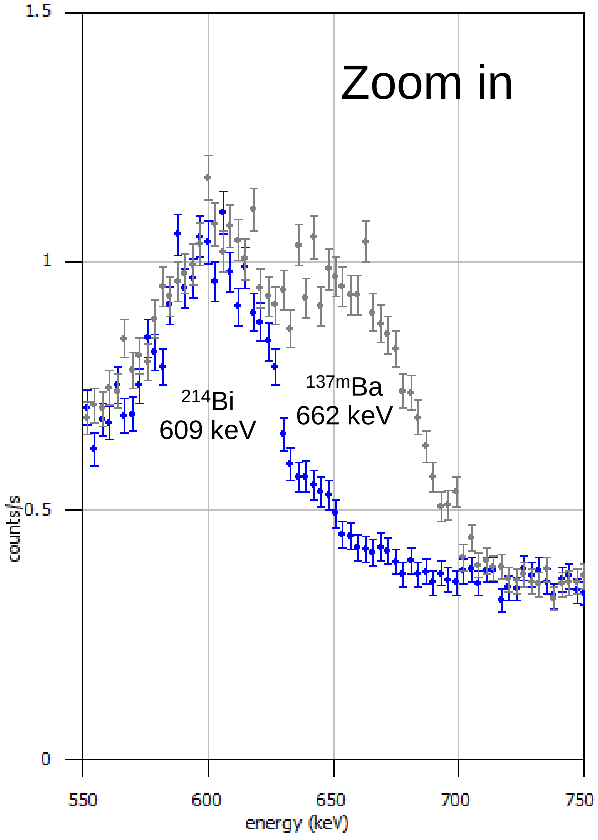




1. Flux computed by SCALE/MAVRIC
2. Flux-to-pulse height computed with MCNP
3. Energy response applied for two orientations

Model Validation – Threat Source (81 μCi ^{137}Cs)

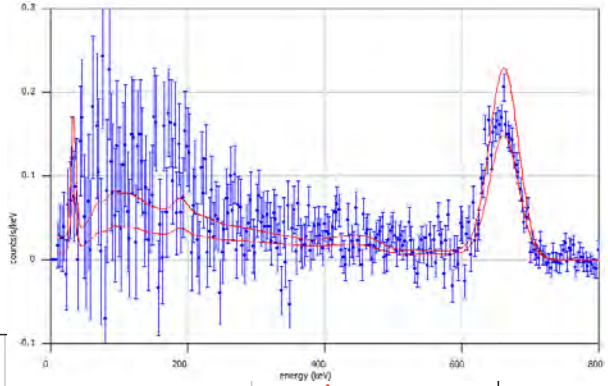


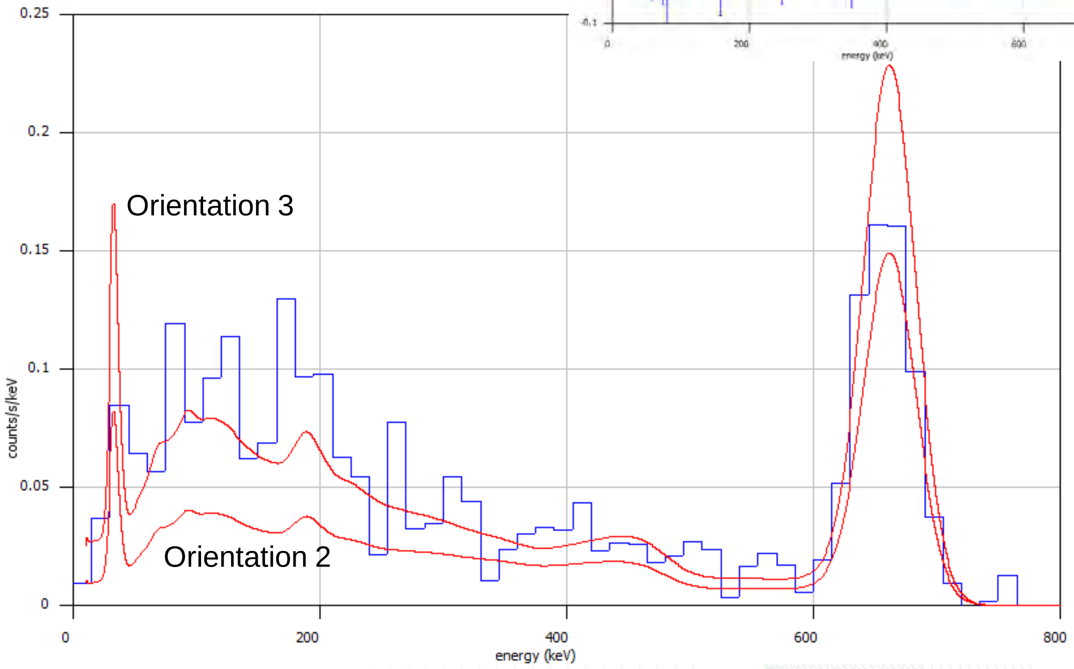


Measurements (2”×4”×16” NaI detector)

Measurements: 30 minutes, 3 keV bins

Compare MC simulation of threat source (two detector responses) to background-subtracted measured values





Use coarser bins in background-subtracted measured values to show scattered contribution

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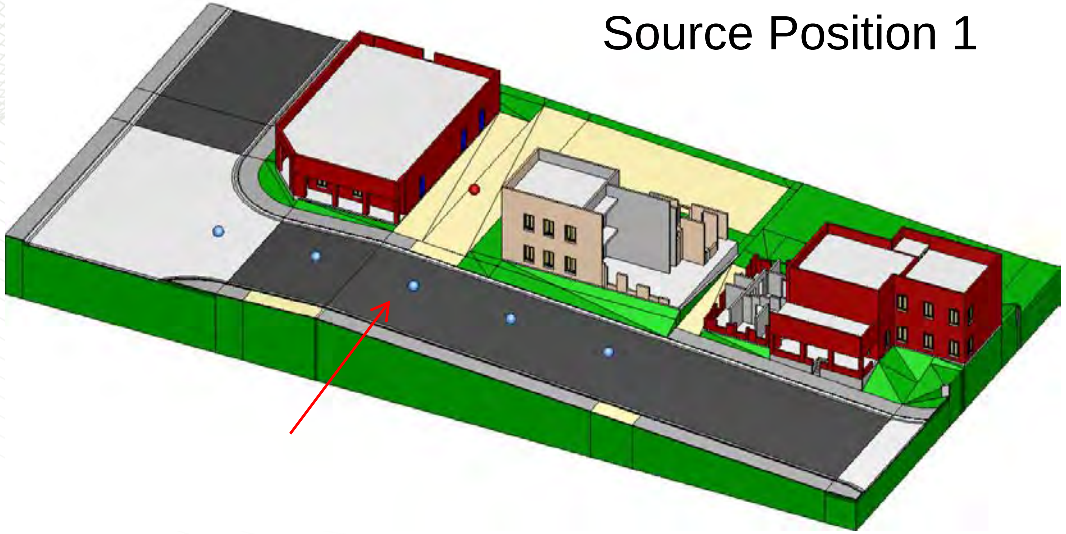
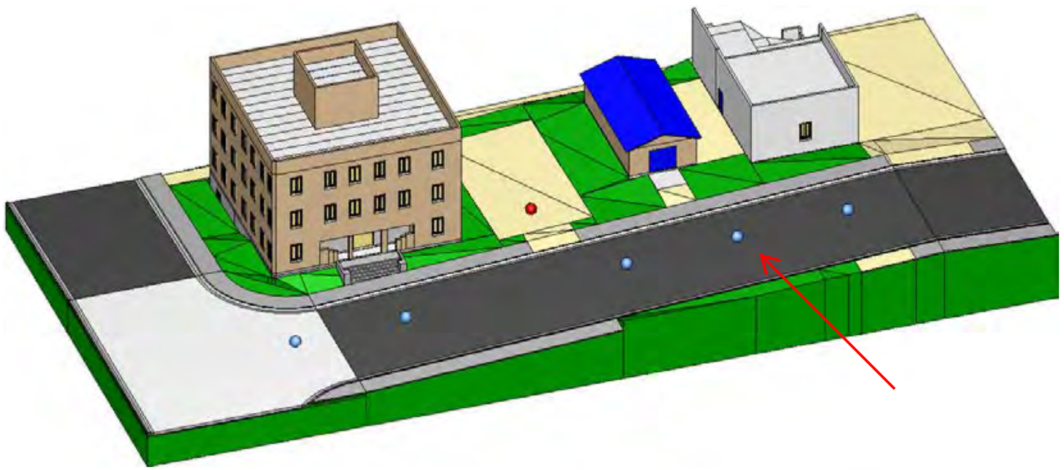
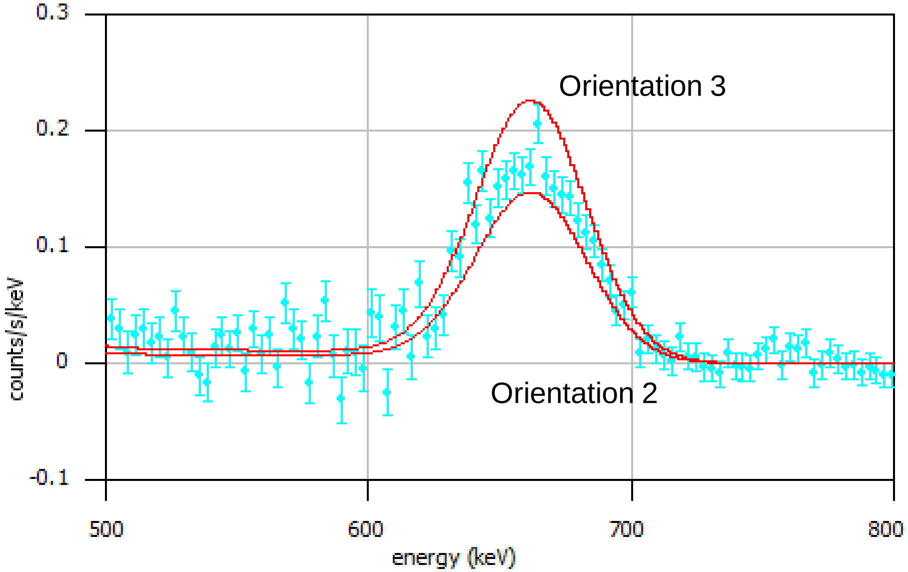
Model Validation – Simulation of ^{137}Cs Measurements

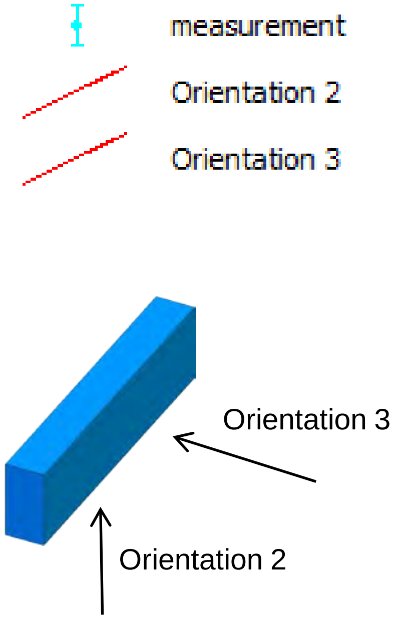
Source Position 1

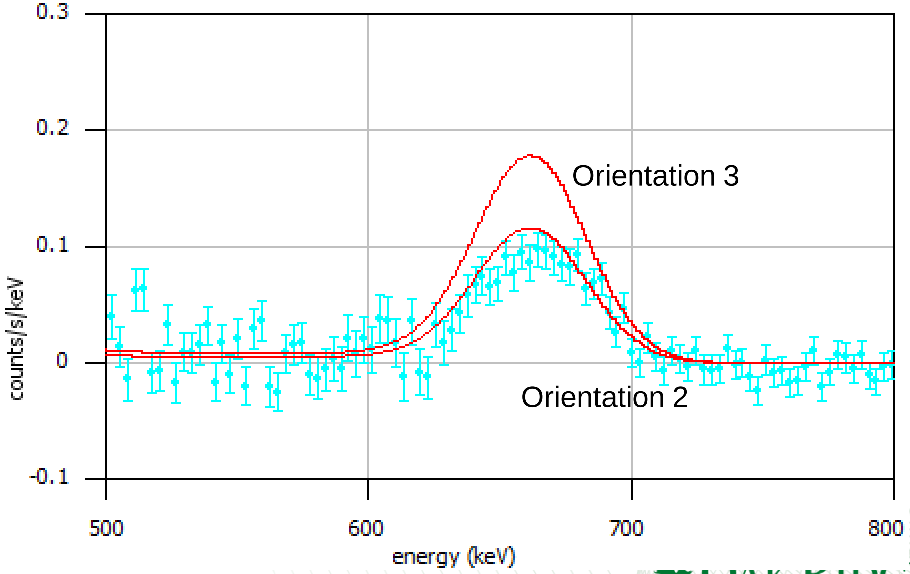


Source Position 3



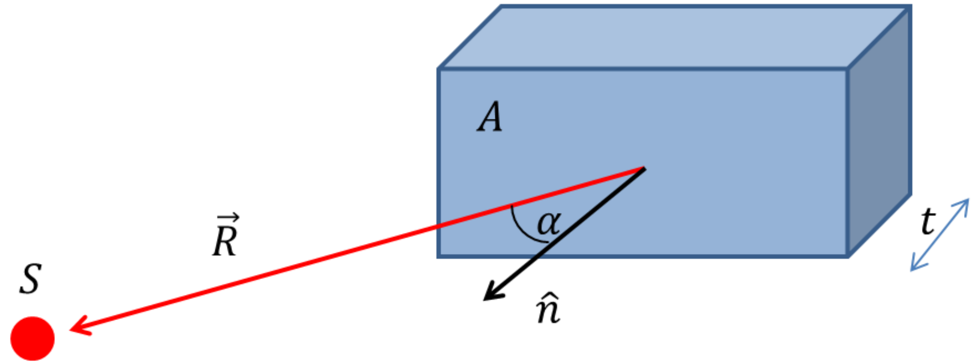






Model Validation – Overall Results

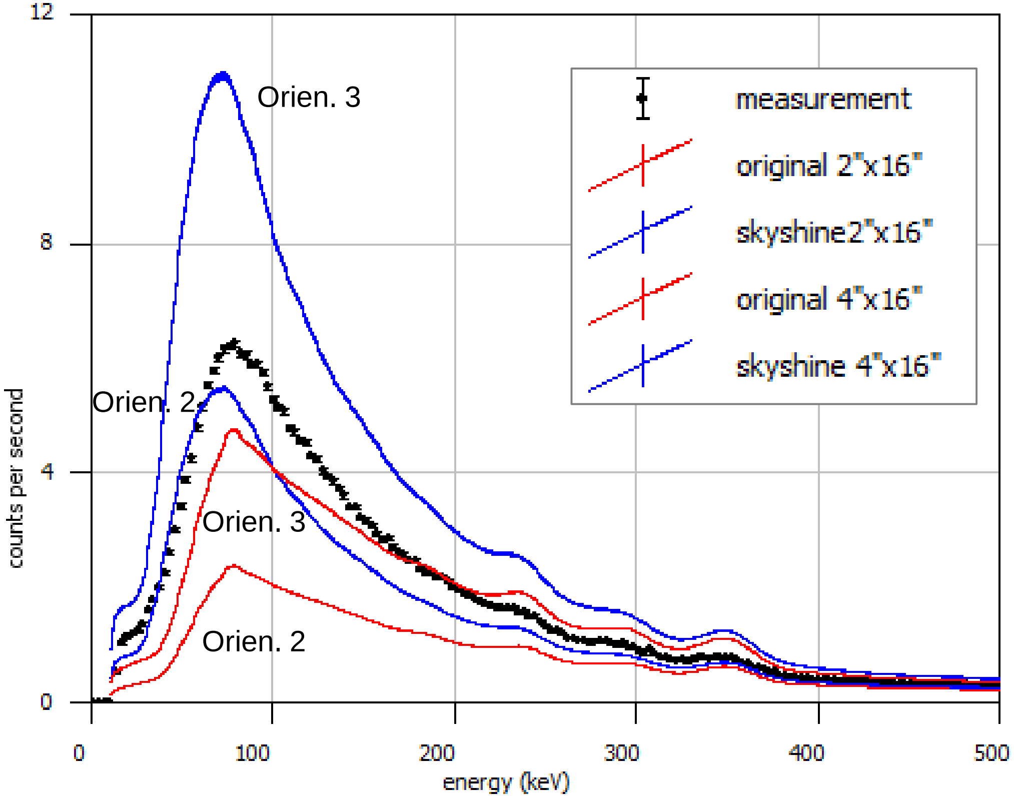
- Background
  - Good match overall
  - Predictions were high for ^{40}K 1460 keV
  - Predictions were low for <300 keV
- Threat sources
  - For three source locations – measurements are between predictions
  - Other source location, measurements are below both predictions
  - Angle of detector not taken into account

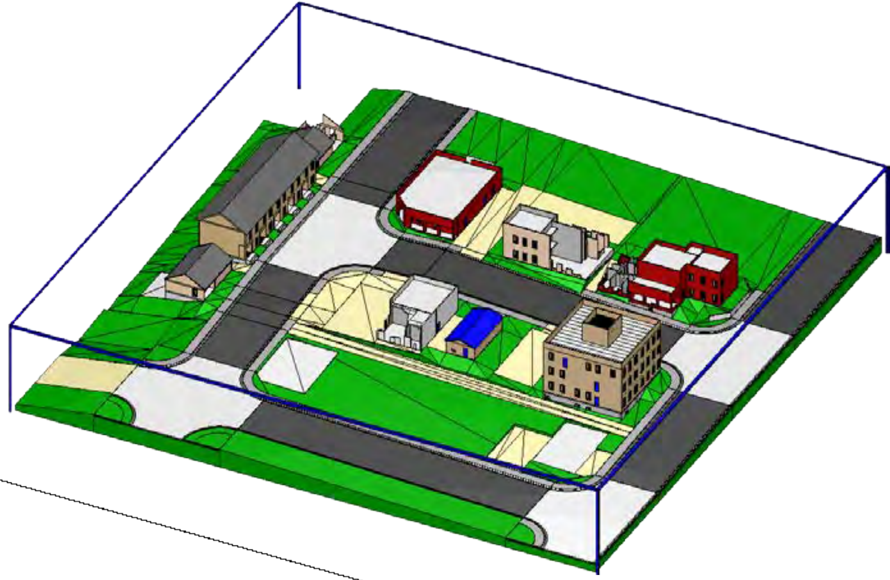


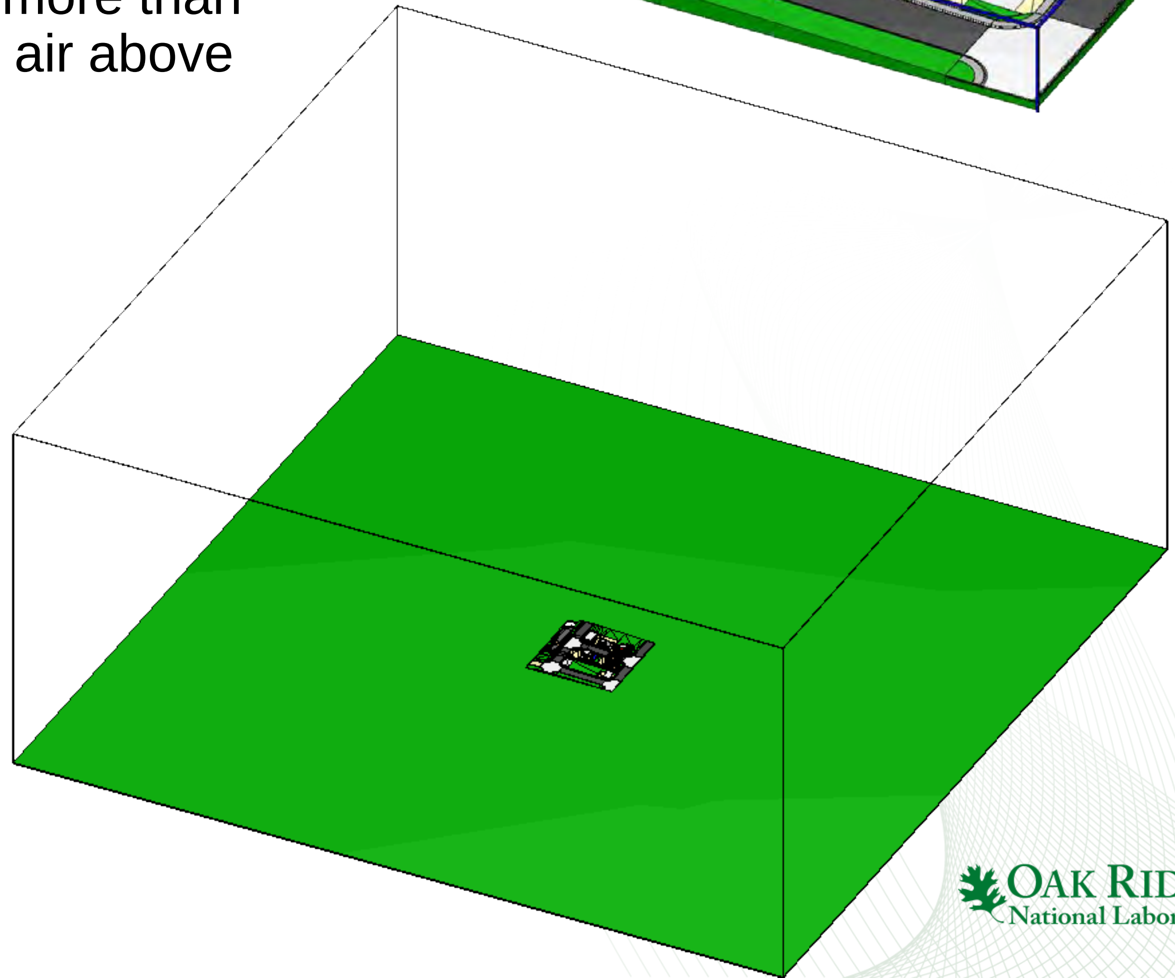
- Better background
  - Use latest ^{40}K concentration values
    - Brick decreased 20-45%
    - Concrete decreased 3-8%
    - Gravel almost tripled
  - Look at more air/soil for skyshine
  - Look at impact of materials near detector
- Response function (bkgd and src)
  - Need one response function that incorporates incident angle
  - Tally flux and flux moments

Skyshine

- Quick study using air-over-ground
  - Added more soil source and air in 100 m increments around a detector 1 m above ground
  - Showed that the spectra didn't change with more than 500 m of soil in each direction and 500 m of air above
- Shift Calculation

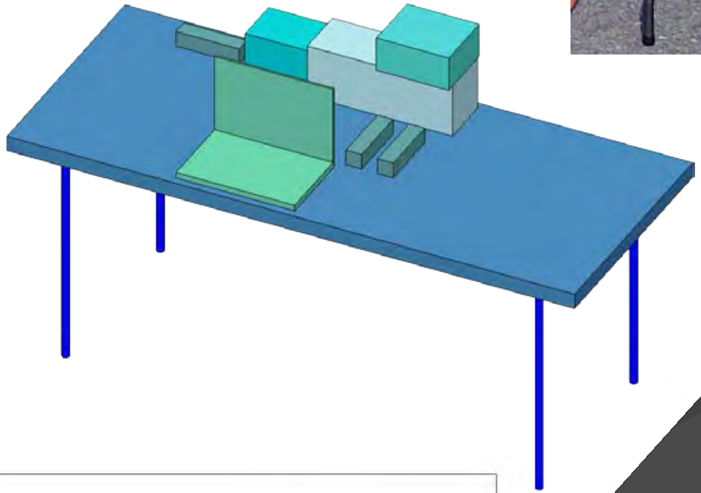


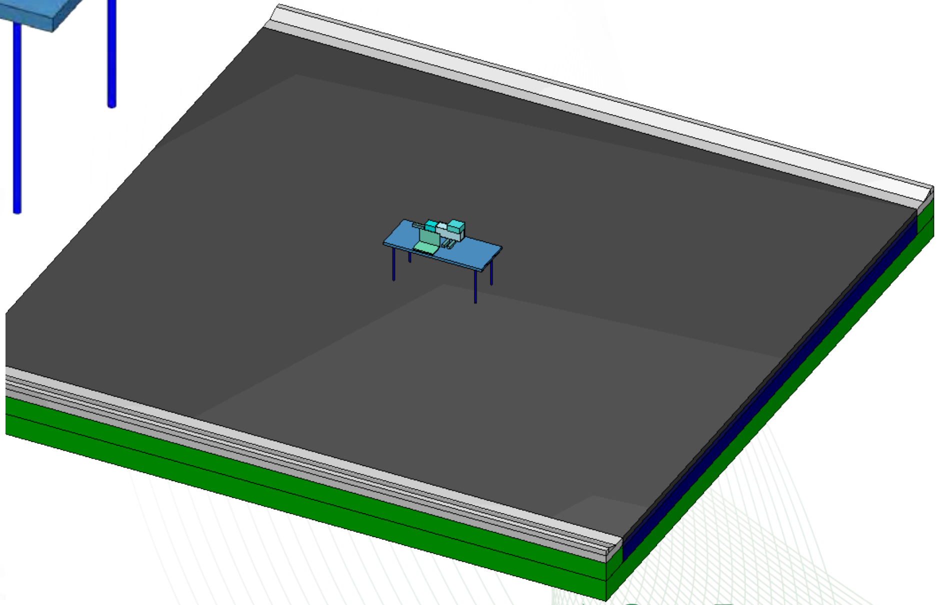


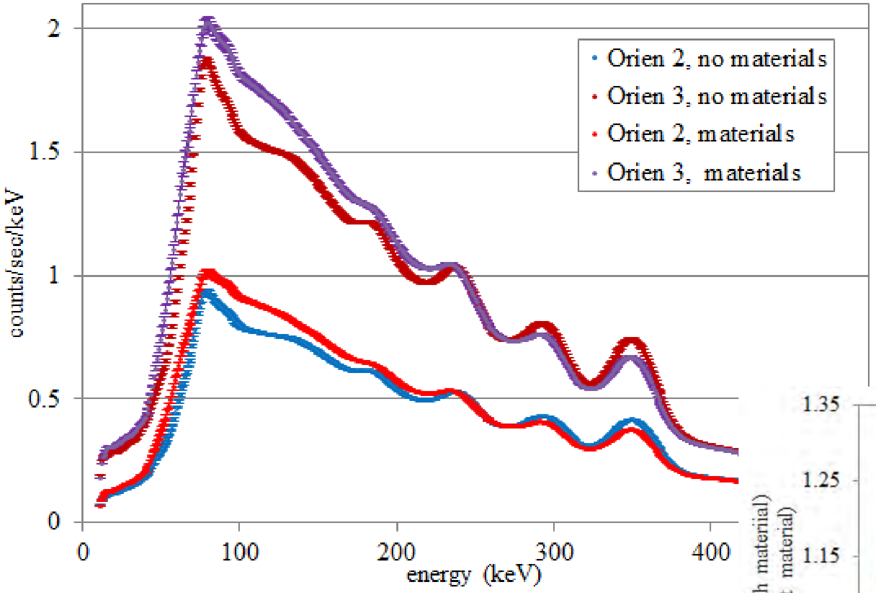


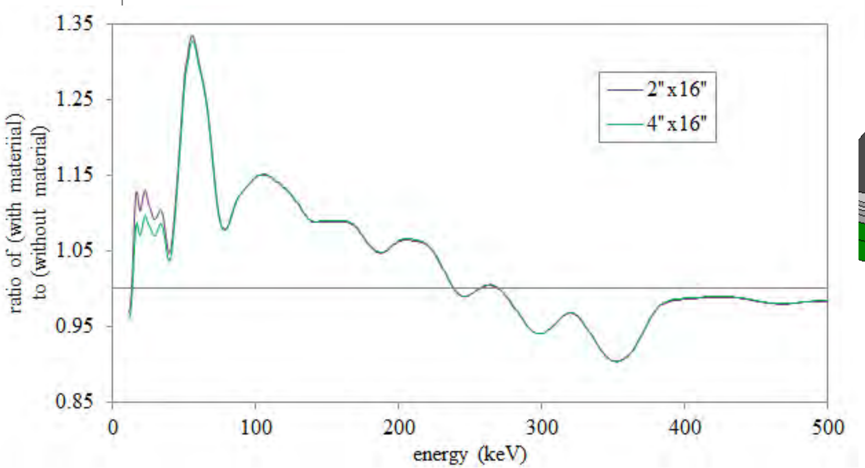
Materials Near Detector

- Materials near detector can
  - Absorb or deflect photons from detector
  - Scatter photons into detector









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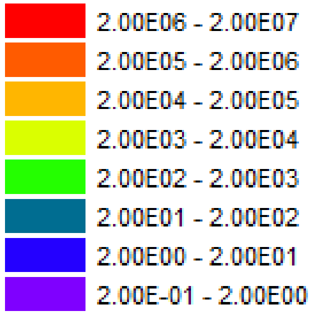
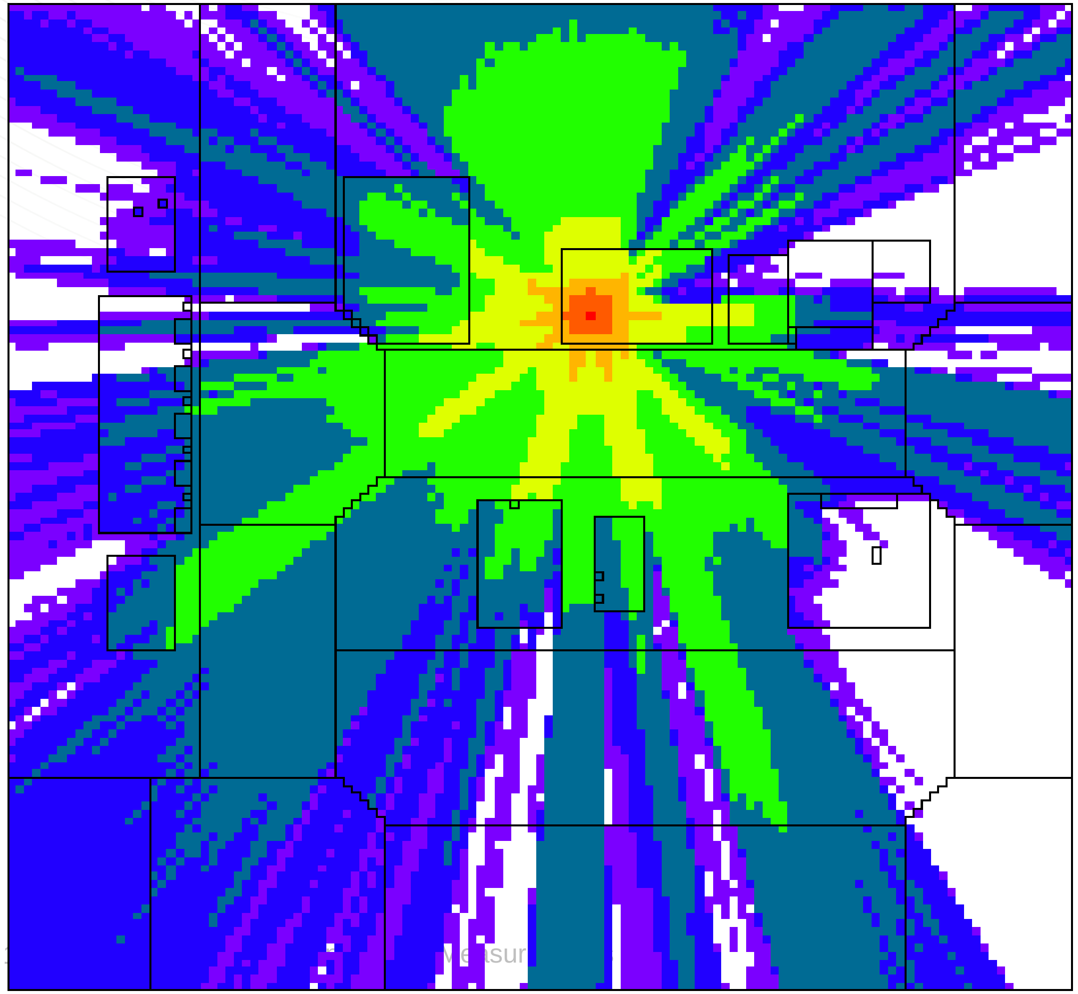
Model Predictions

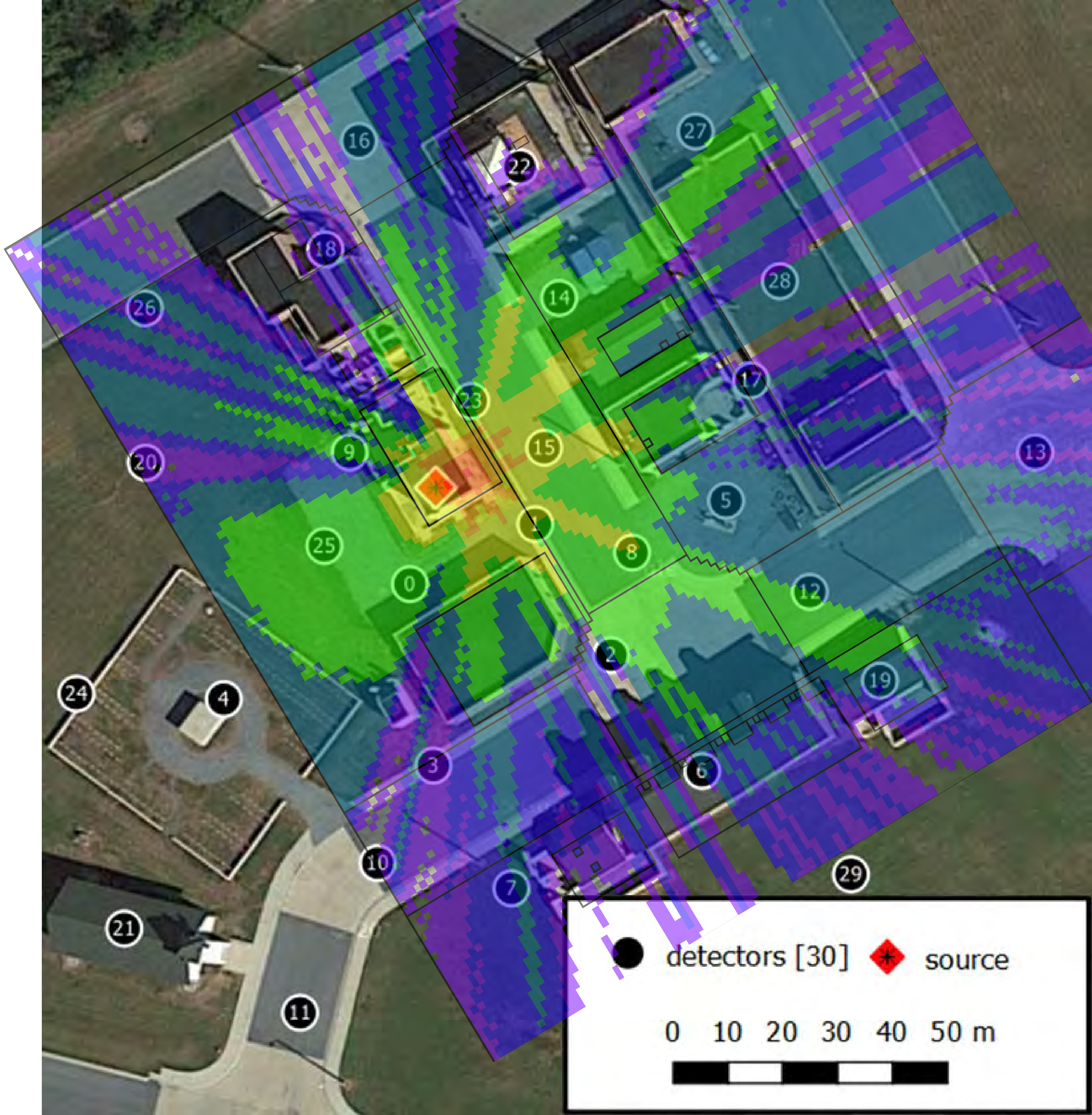
- NCSU (CNEC)
  - 40 mCi ^{137}Cs Source
  - 2”×4”×16” NaI, 30 locations
- Used for:
  - development, testing, and evaluation of algorithms for source localization
  - to validate low- and high-fidelity radiation transport models
- Can we predict with model?

Model Predictions

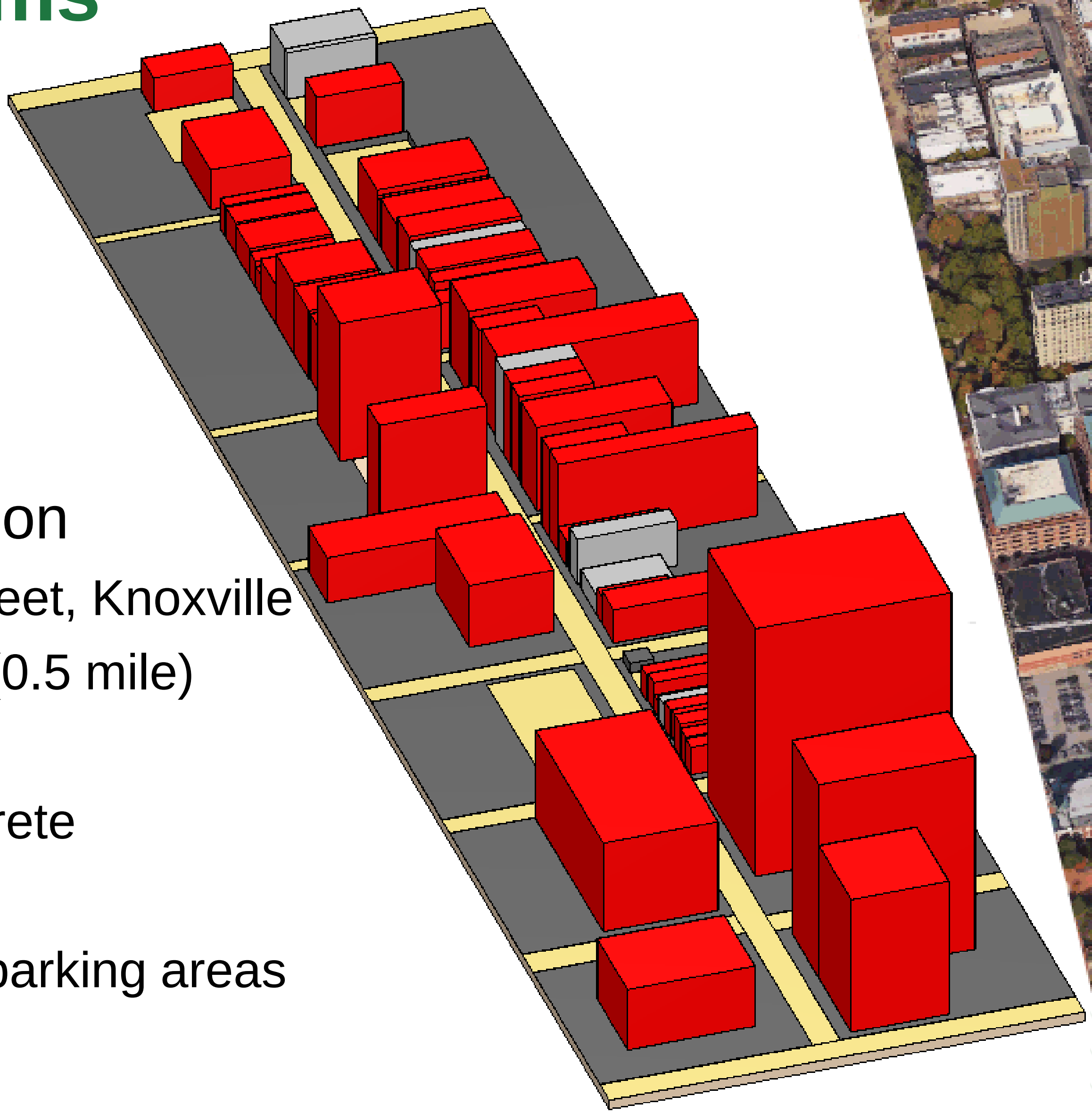
Full-energy count rate (/sec)







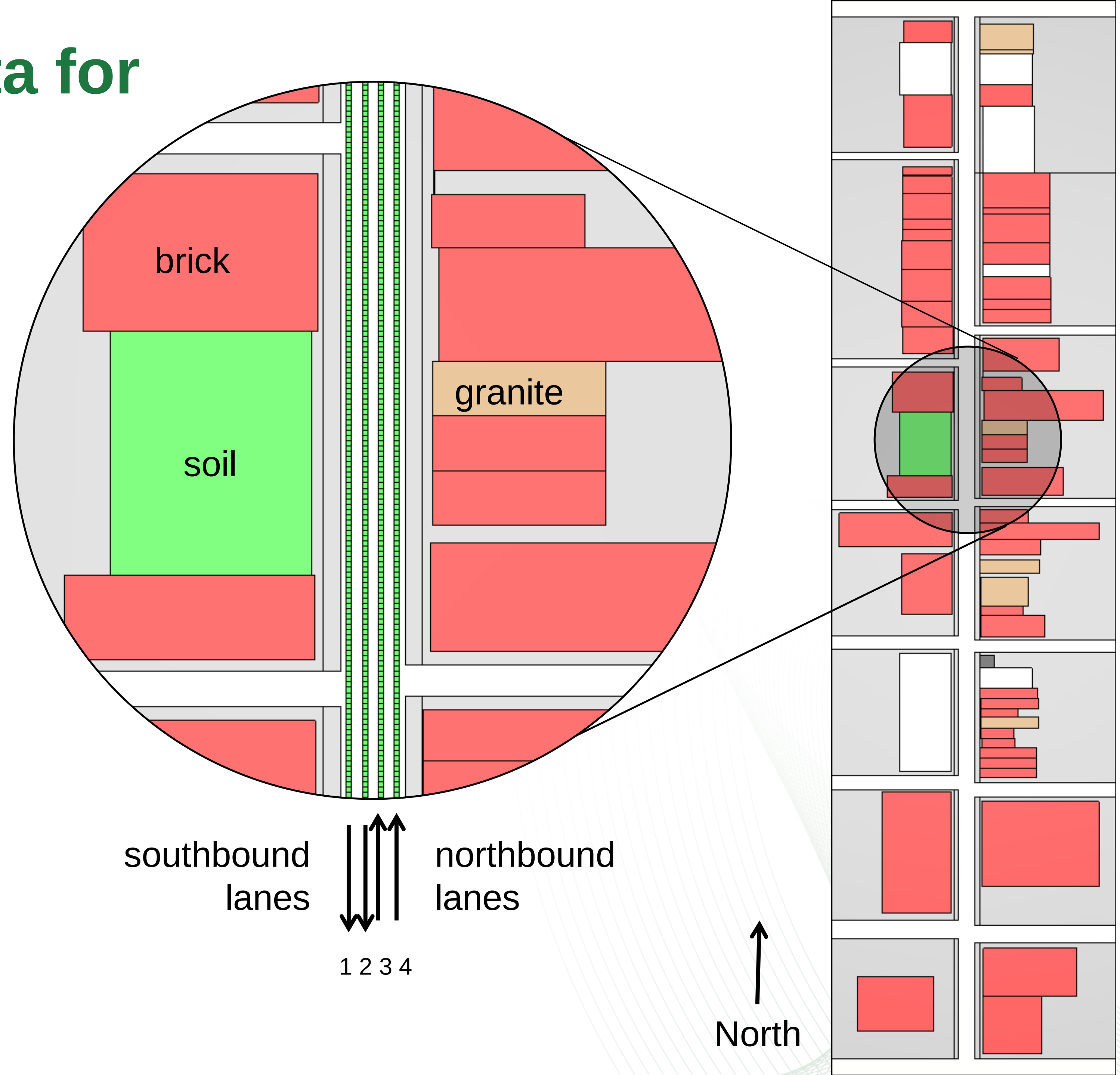
Model Predictions – Data for Detection Algorithms



- Model for Data Competition
  - Loosely based on Gay Street, Knoxville
  - 7 blocks, 796 m in length (0.5 mile)
  - 56 buildings
  - 48 brick, 7 granite, 1 concrete
  - Hollow shells
  - Sidestreets, sidewalks, 6 parking areas

Model Predictions – Data for Detection Algorithms

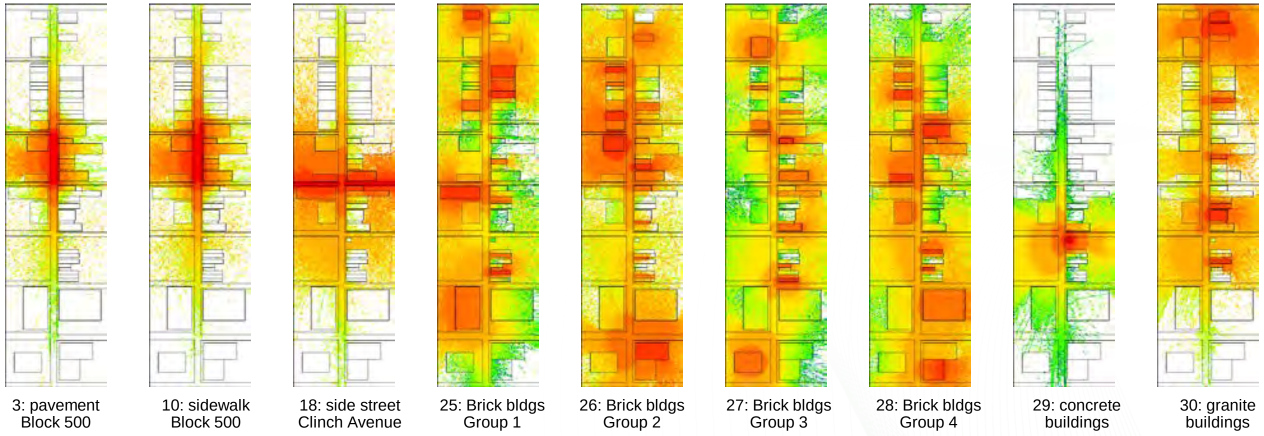
- Sources
  - Variety of isotopes and strengths
  - Variety of interesting places
- Tallies
  - 4 mesh tallies (1×796×1)
  - Correspond to traffic lanes
  - 1995 channels – 2 keV width
  - From 10 keV to 4 MeV

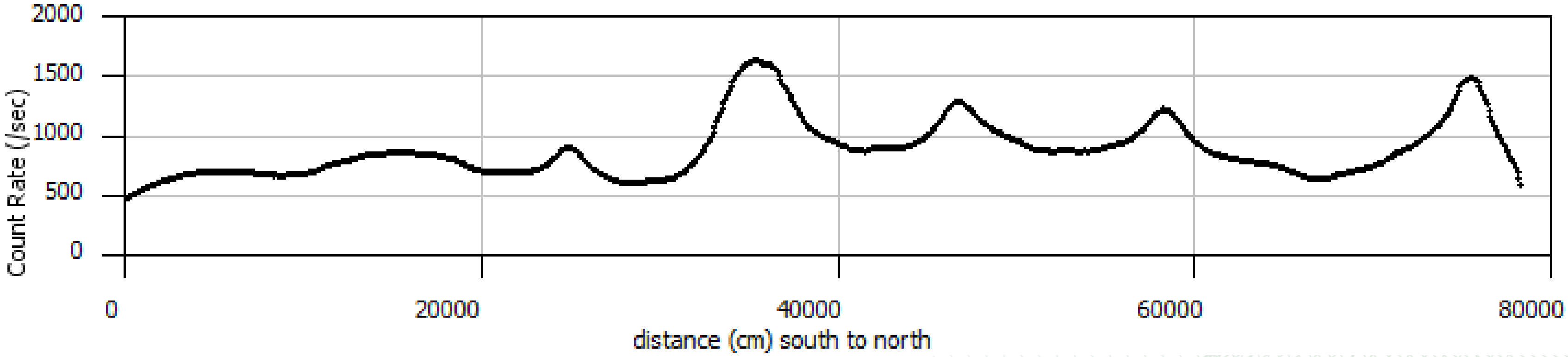


Model Predictions – Data for Detection Algorithms

- Background Components (30)
  - Asphalt pavement (by block)
    - each block of the main street (7)
    - cross streets (8)
  - Concrete sidewalks (by block)
    - each block of the main street (7)
  - Parking areas
    - Five asphalt lots (1)
    - soil (1)
  - Buildings
    - Twelve brick bldgs (4)
    - One concrete bldg (1)
    - Seven granite bldgs(1)
- 91 total components

- Isotopes
  - ^{40}K, ^{232}Th, $^{238}U/^{235}U$
  - ^{137}Cs only in soil
  - All computed at 1 Bq/kg

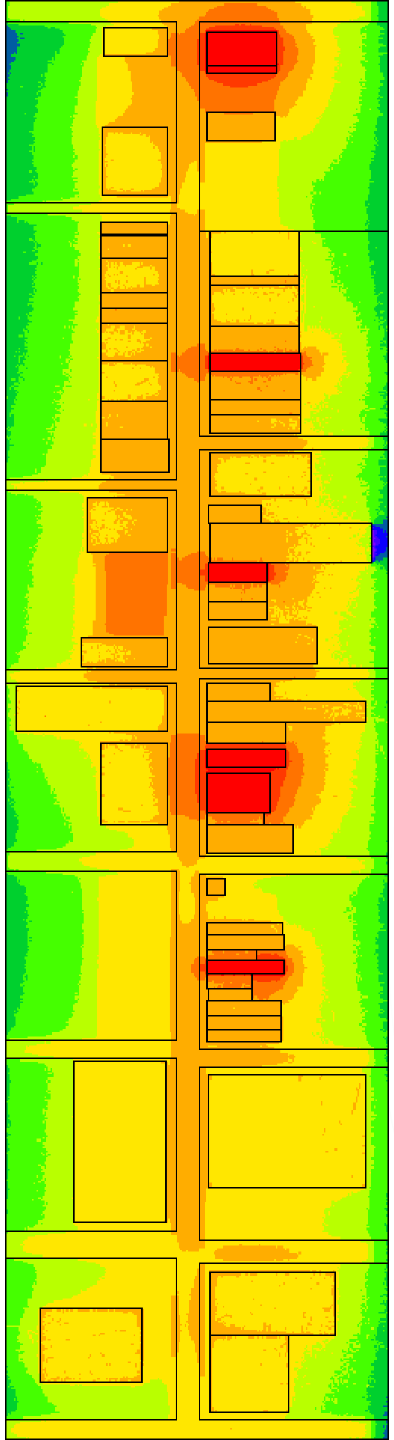


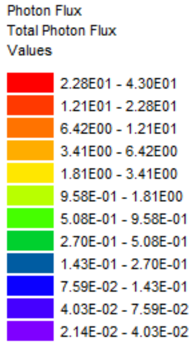


Data Competition

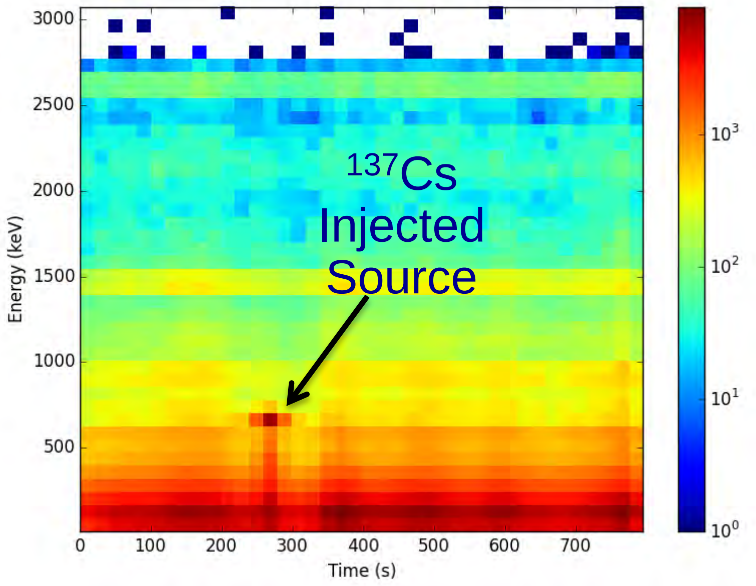
(Shameless Advertisement)

- **TBD 2017**: Data competition for radiation detection algorithms
- Synthetic data generated from a particle transport model
- We expect participants from the **national labs**, **universities,** and **data science** communities
- Contact: Donald Hornback Donald.Hornback@nnsa.doe.gov





- Left: Alpha version of total background flux along the x-y plane at z=1 m
- Bottom: Two-dimensional histogram of a synthetic dataset



Future

- Synthetic data for algorithm testing
  - We know exactly what was put in the model
- Improved response function
  - Account for angular distribution of flux at the detector location and orientation of detector
- More benchmark experiments
  - Clutter, motion
- Models based on LIDAR/CAD geometry

- Questions?

$$[\hat{\Omega}\cdot\vec{\nabla} + \sigma(\vec{r},E)]\psi(\vec{r},\hat{\Omega},E) =$$

$$\int dE \int d\Omega' \, \sigma_s(\vec{r},E' \longrightarrow E,\hat{\Omega}'\cdot\hat{\Omega}) \, \psi(\vec{r},\hat{\Omega}',E')$$

$$+ \, q_{ext}(\vec{r},\hat{\Omega},E)$$

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