INL/MIS-24-79189-Revision-1

Intern Sized Poster for Dosimetry Research

July 2024

Derek Tian Lewis, Connor Cronin Williams

Changing the World's Energy Future

Idaho National Laboratory

INL/MIS-24-79189-Revision-1

Intern Sized Poster for Dosimetry Research

Derek Tian Lewis, Connor Cronin Williams

July 2024

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

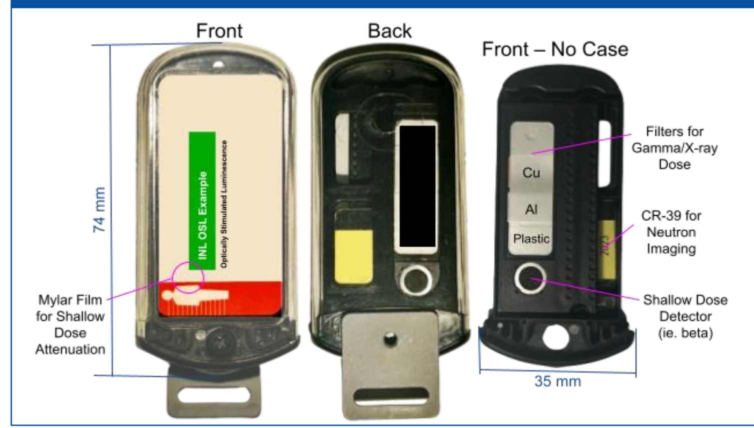
Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

X-ray Security Imaging on Personal Dosimetry

Derek Lewis[1,2,*], Connor Williams[1,*], Seth Kanter[1]

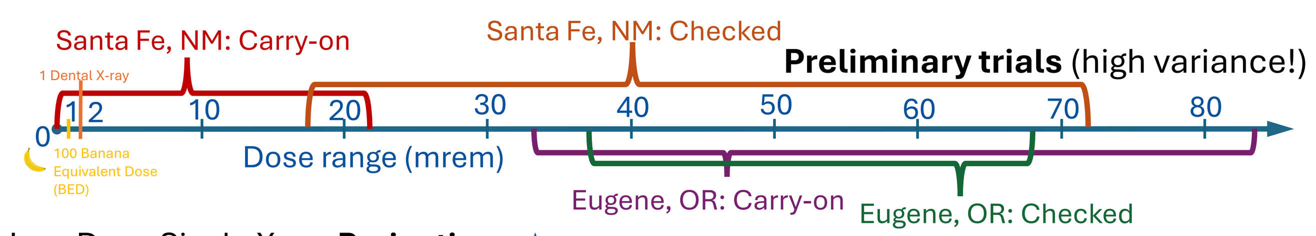
[1]Idaho National Laboratory, Radiological Engineering, Radiological Controls & Emergency Management, Idaho Falls, ID, 83415;
[2]Georgia Institute of Technology, Department of Nuclear & Radiological Engineering and Medical Physics, Atlanta, GA, 30318

Abstract

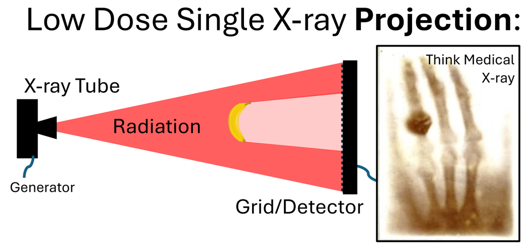


Federal regulations mandate that **personal dosimetry devices — like optically stimulated luminescence (OSLs) — must be worn** by all US Department of Energy (DOE) and associated radiation workers to track their occupational dose. Unfortunately, the inadvertent passage of **OSLs through x-ray security scanners can compromise their validity**. With the advent of high energy, advanced resolution security technology used in airports, this once insignificant issue now requires that Radiological Control (RadCon) be able to accurately discern non-occupational dose to effected OSLs. This presentation will discuss the principles, methods, and, rather interesting, models for **establishing the corrective dose estimates at the Idaho National Laboratory (INL), and its implication across the DOE.**

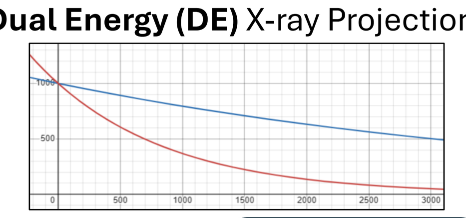
Introduction



Low Dose Single X-ray **Projection:**



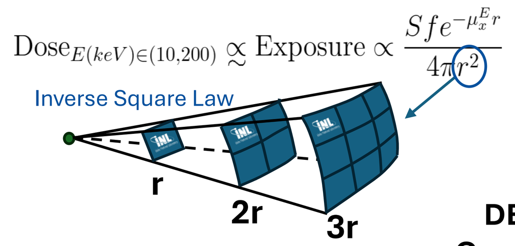
Explosive Detection System (EDS) **Dual Energy (DE)** X-ray Projection:



Attenuation is dependent on photon **energy** and the medium's Z_{eff} (atomic number)

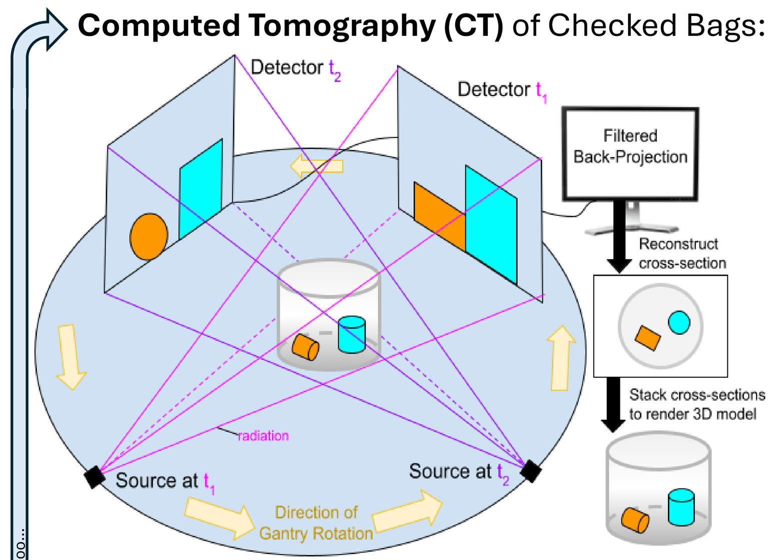
We can **characterize** materials by solving for their Z_{eff} (Unfortunately, water and explosives' Z_{eff} are very close)

$$\text{Dose}_{E(keV)\in(10,200)} \underset{\sim}{\propto} \text{Exposure} \propto \frac{Sfe^{-\mu_\rho^E r}}{4\pi r^2}$$

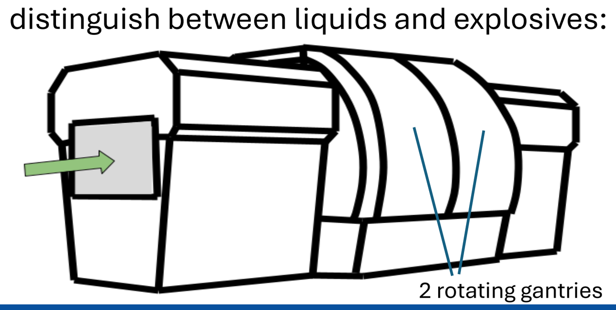


1974

Computed Tomography (CT) of Checked Bags:



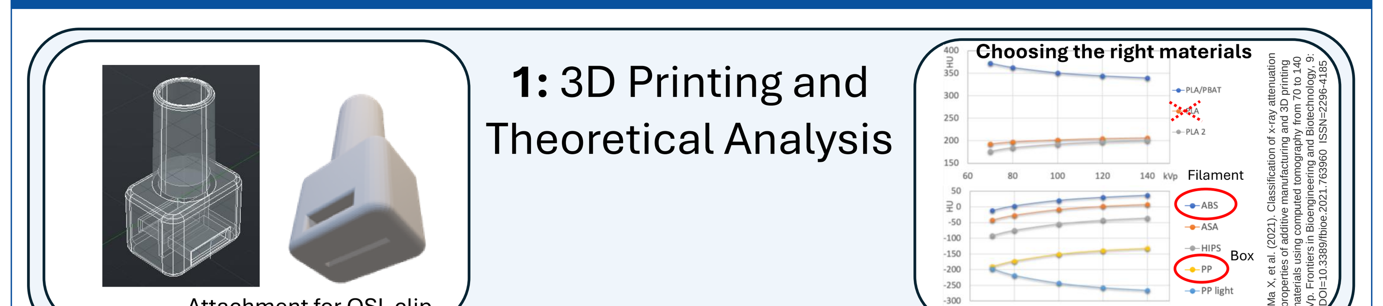
DE CT uses the Z_{eff} and **volume-density** to distinguish between liquids and explosives:



2024
DE CT Carry-ons

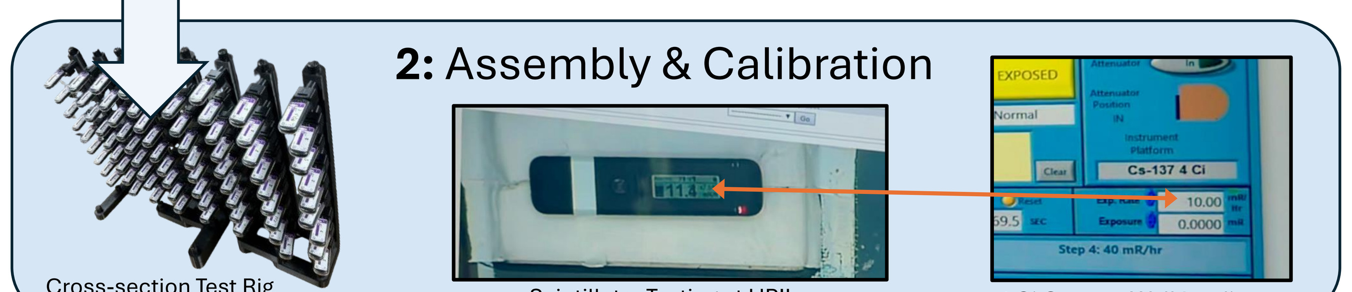
**All figures are original or public domain

Methods



1: 3D Printing and Theoretical Analysis

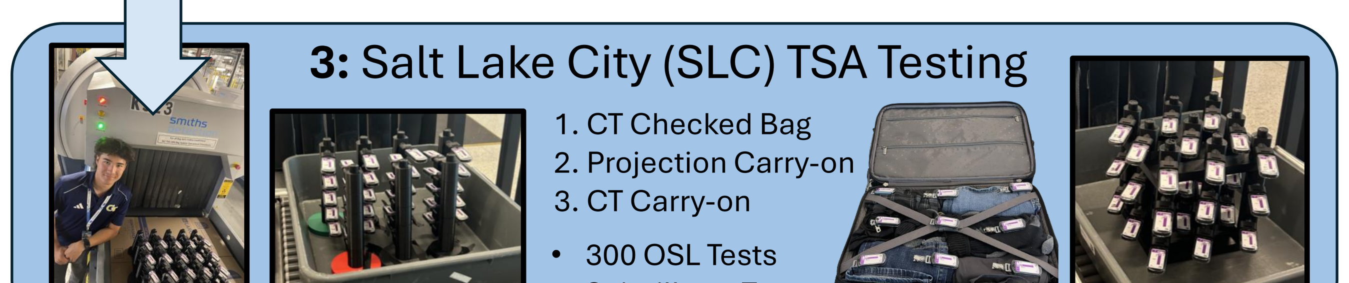
2: Assembly & Calibration



3: Salt Lake City (SLC) TSA Testing

1. CT Checked Bag
2. Projection Carry-on
3. CT Carry-on

- 300 OSL Tests
- Scintillator Tests



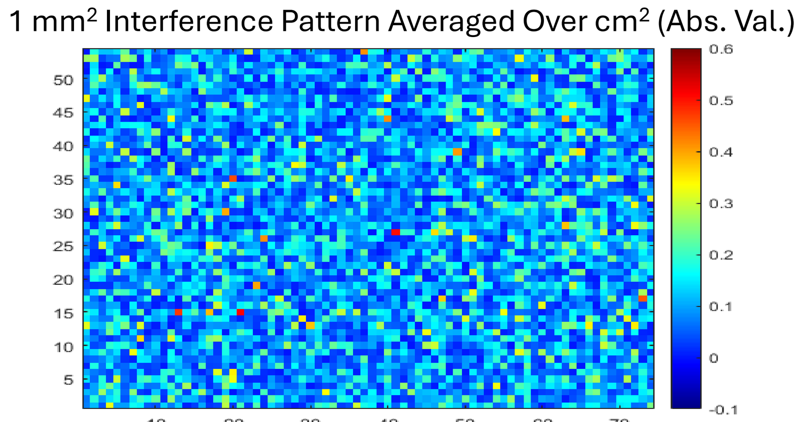
Acknowledgements

U.S. Department of Energy; Transportation Security Administration; SLC International

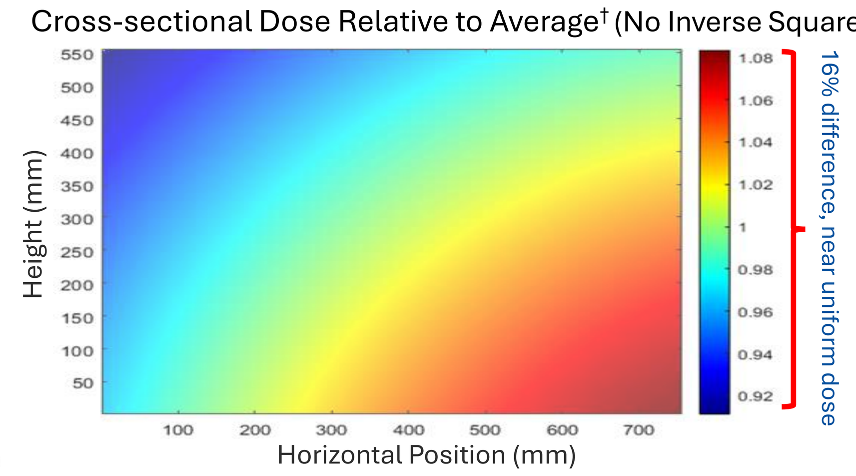
Theoretical Predictions

Resonance and Projection Imaging

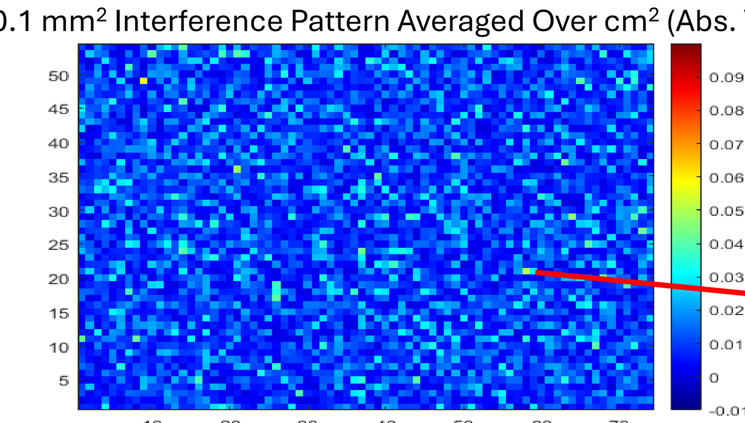
1 mm² Interference Pattern Averaged Over cm² (Abs. Val.)

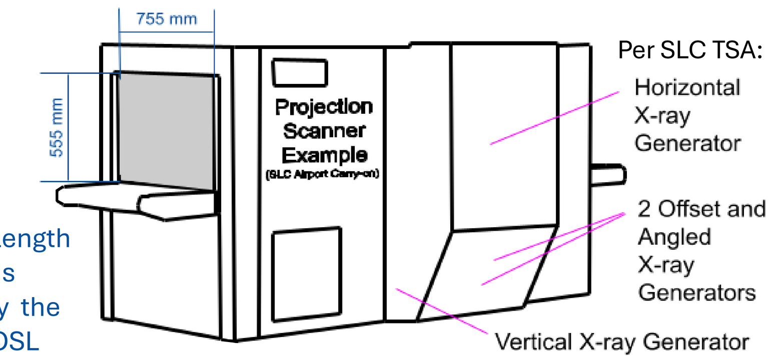


Cross-sectional Dose Relative to Average† (No Inverse Square)



0.1 mm² Interference Pattern Averaged Over cm² (Abs. Val.)



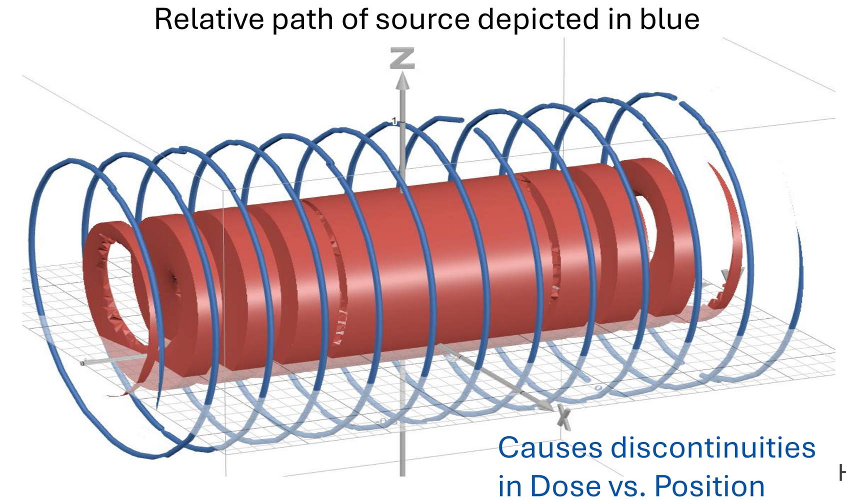


†Estimated variable values used in model, time = 0

CT Imaging

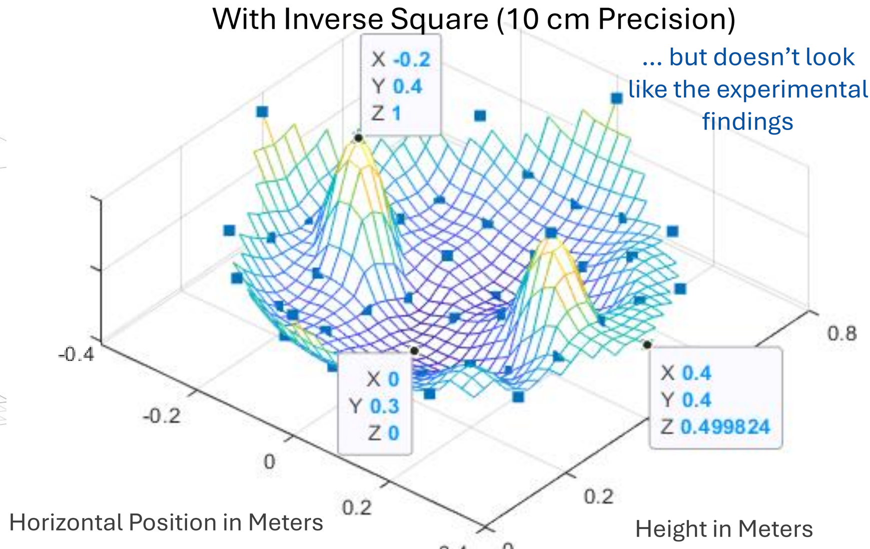
Time (*y*-axis) Dependence of X-rays Incident on Cross-section (*xz*-plane)†††

Relative path of source depicted in blue



Range of Cross-sectional Dose††

With Inverse Square (10 cm Precision)

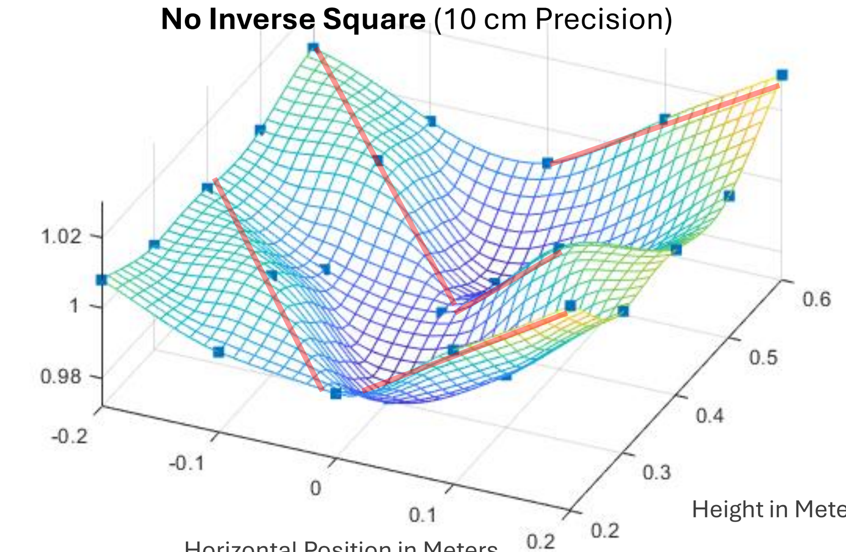


$$\pm vt\cot(\theta_A) \le \sqrt{(R\cos(\omega t)-x)^2+(R\sin(\omega t)-z)^2}$$
$$x^2+z^2 \le r_{in}^2$$

$$\text{Dose}(x,z) \underset{\sim}{\propto} \sum_{m=1}^{k/2}\int_{t_{2m-1}}^{t_{2m}} \left(\frac{e^{-\mu\sqrt{((R\cos(\omega t)-x)^2+(R\sin(\omega t)-z)^2+(vt)^2)}}}{(R\cos(\omega t)-x)^2+(R\sin(\omega t)-z)^2+(vt)^2}\right)dt$$
$$\text{when } \sin(\theta_A)\sqrt{-2Rx\cos(\omega t)-2Rz\sin(\omega t)+R^2+x^2+z^2} - vt\cos(\theta_A)=0$$

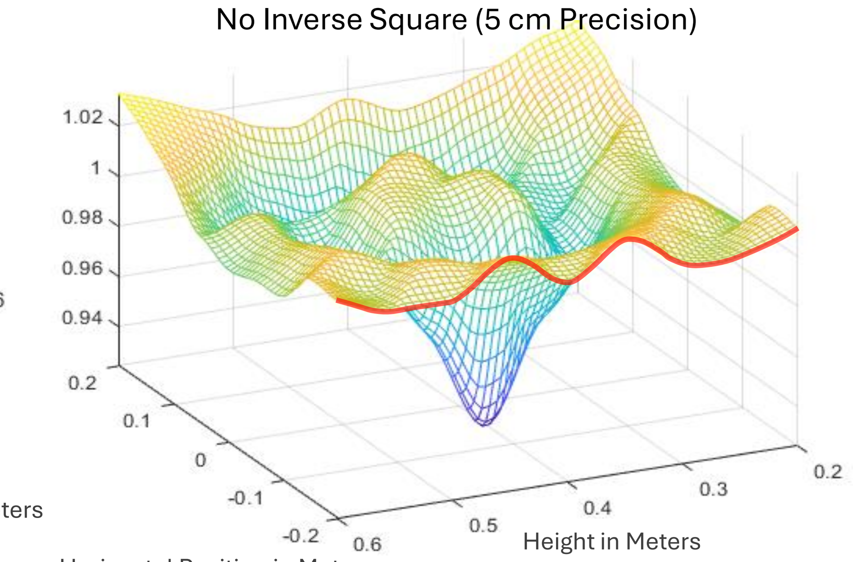
Cross-sectional Dose Relative to Average††

No Inverse Square (10 cm Precision)



Cross-sectional Dose Relative to Average††

No Inverse Square (5 cm Precision)

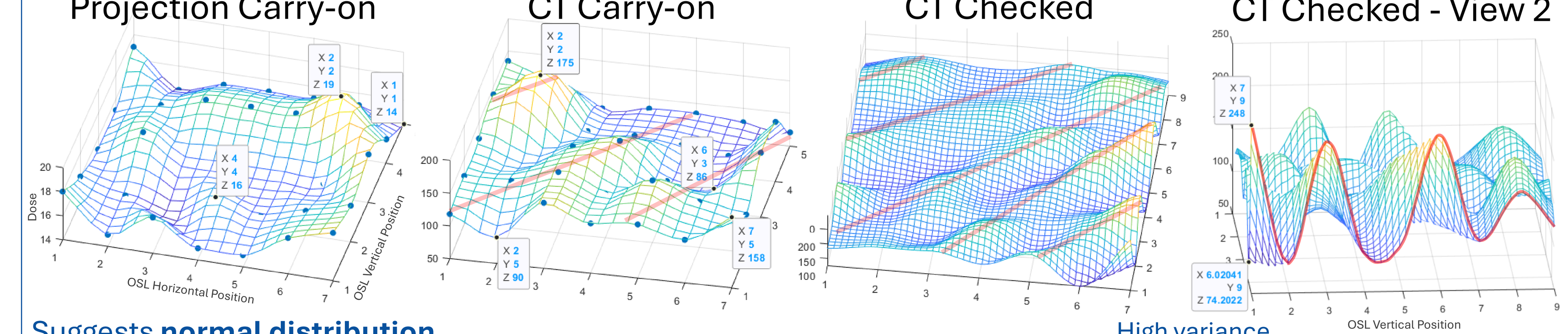


††Interpolated

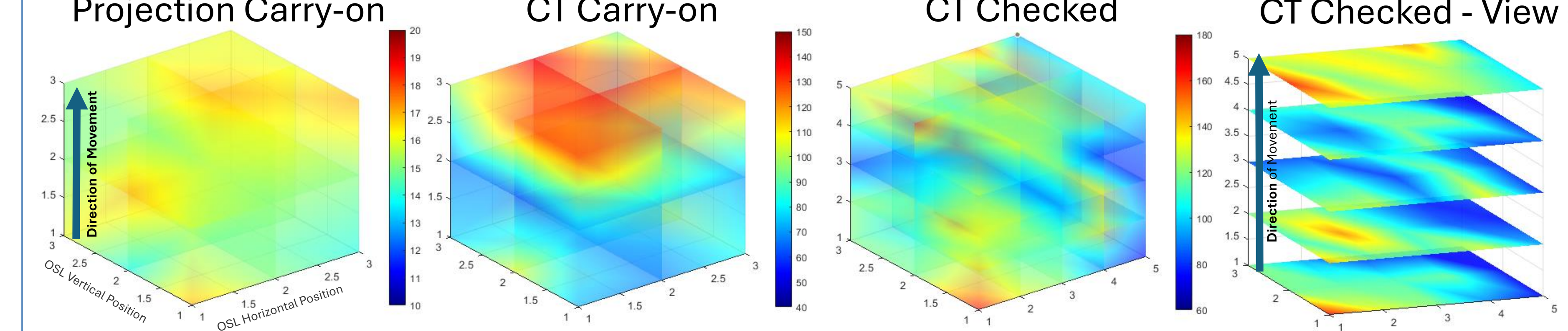
†††Estimated variable values used in model

Experimental Findings

Cross-sectional Dose†† (mrem)

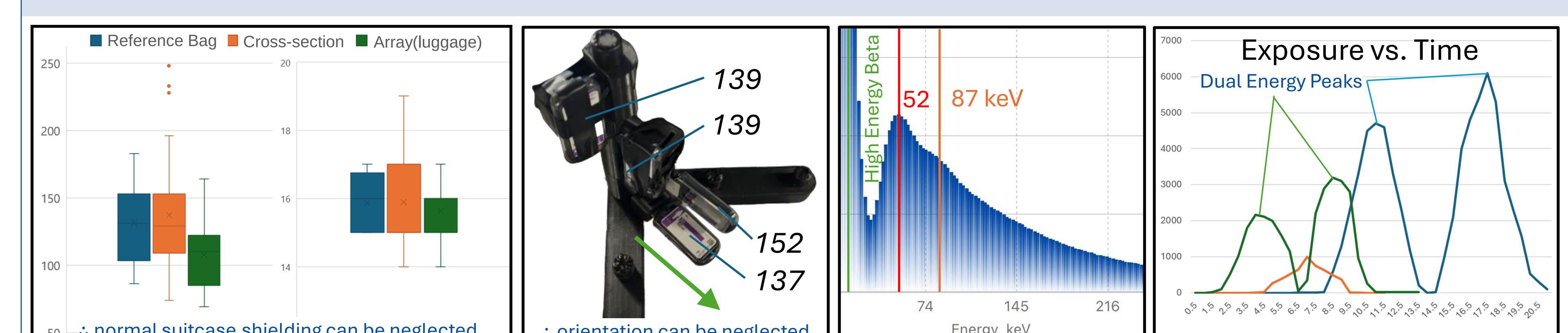


Luggage Dose†† (mrem)



Dose appears to be independent of position

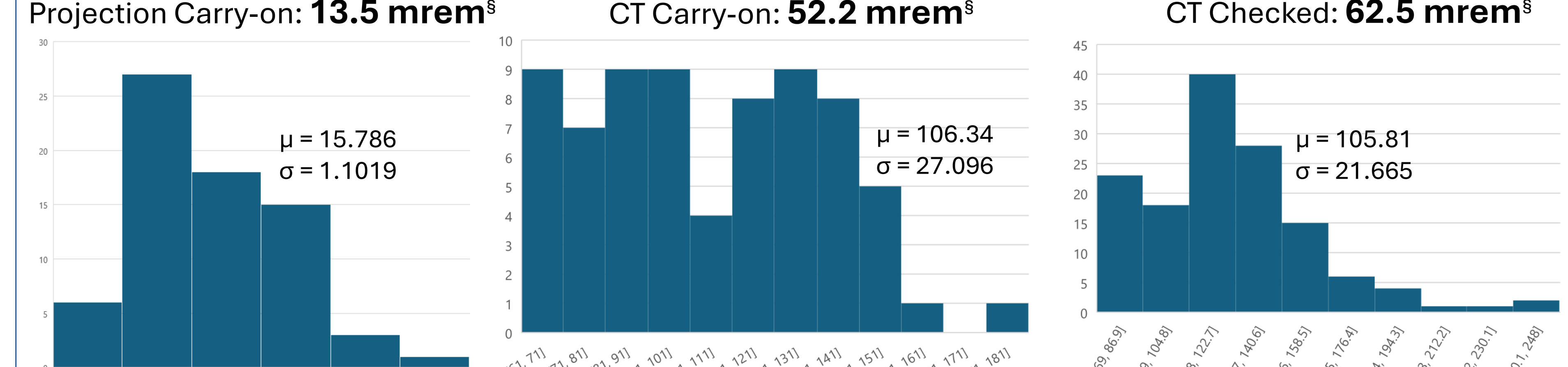
Attenuations, Orientations, Energy Spectra, & Exposures Tests



Conclusion

Recommendations for Radiological Control

Projection Carry-on: **13.5 mrem§** | CT Carry-on: **52.2 mrem§** | CT Checked: **62.5 mrem§**



§**With 97.5% confidence** that the true mean dose is greater than the recommendation

Limitations and Future Works

Additional Airports & Scanners | Proprietary and Security Concerns | **Shallow Dose Variance in CT**