Density Corrections for the Detection of Radioactive Contamination in Food with Gamma Spectrometry

Council on Ionizing Radiation Measurements and Standards
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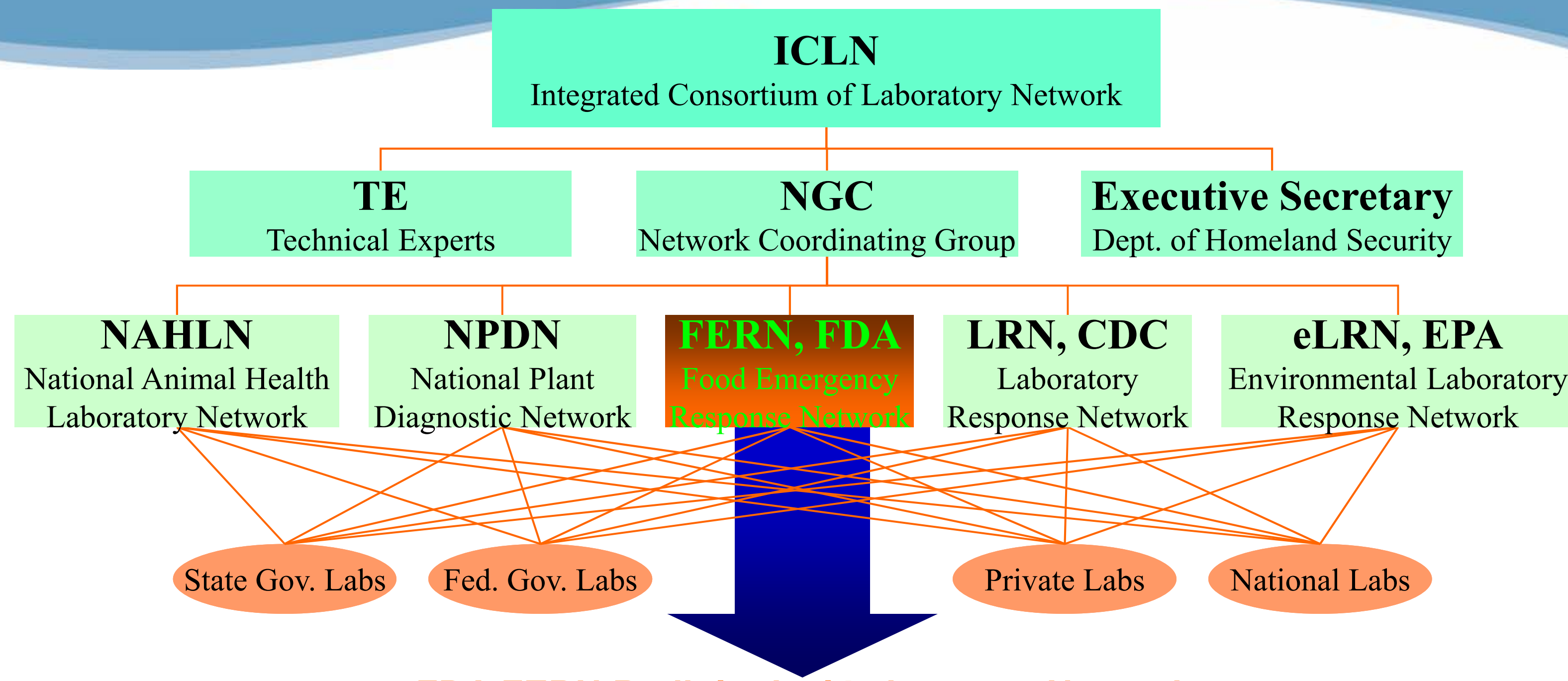
Clarence Rolle, Stephanie Healey, Zhichao Lin

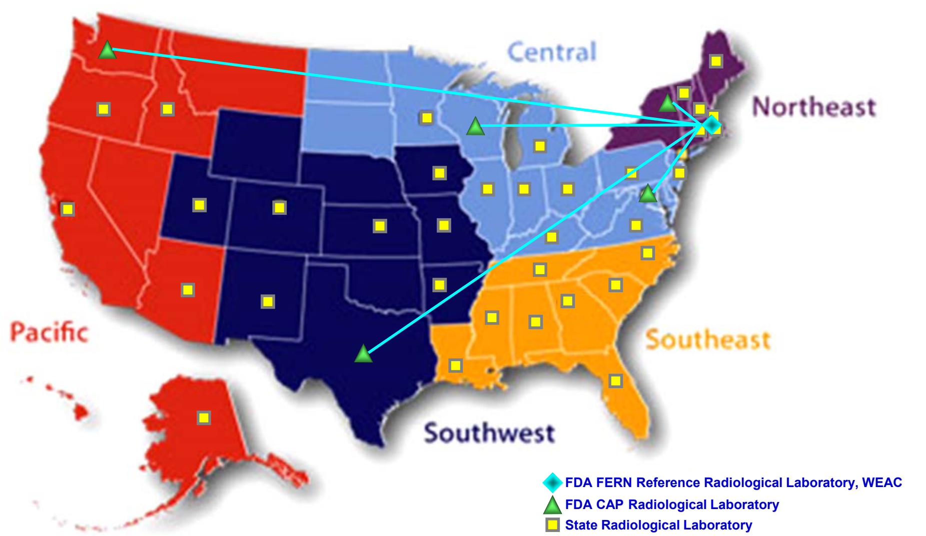
Winchester Engineering and Analytical Center
Food and Drug Administration

Rapid response, confident risk assessment, and coherent interagency action require:

- **A broad analytical capabilities with sufficient surge capacity**
- **Proficient laboratory analysis with assured data quality**
- **Data comparability with demonstrated measurement traceability**
- **Use of analytical methods developed with a harmonized approach**



FDA FERN Radiological Laboratory Network



The current limiting factors in food gamma-ray spectrometry analysis are:

- **Precise matrix effects and extent of measurement corrections for analyzing gamma-emitting radionuclides in foods are largely vague**

- **Greater than 50% of mostly concerned gamma-emitting radionuclides show significant coincidence-summing effects**

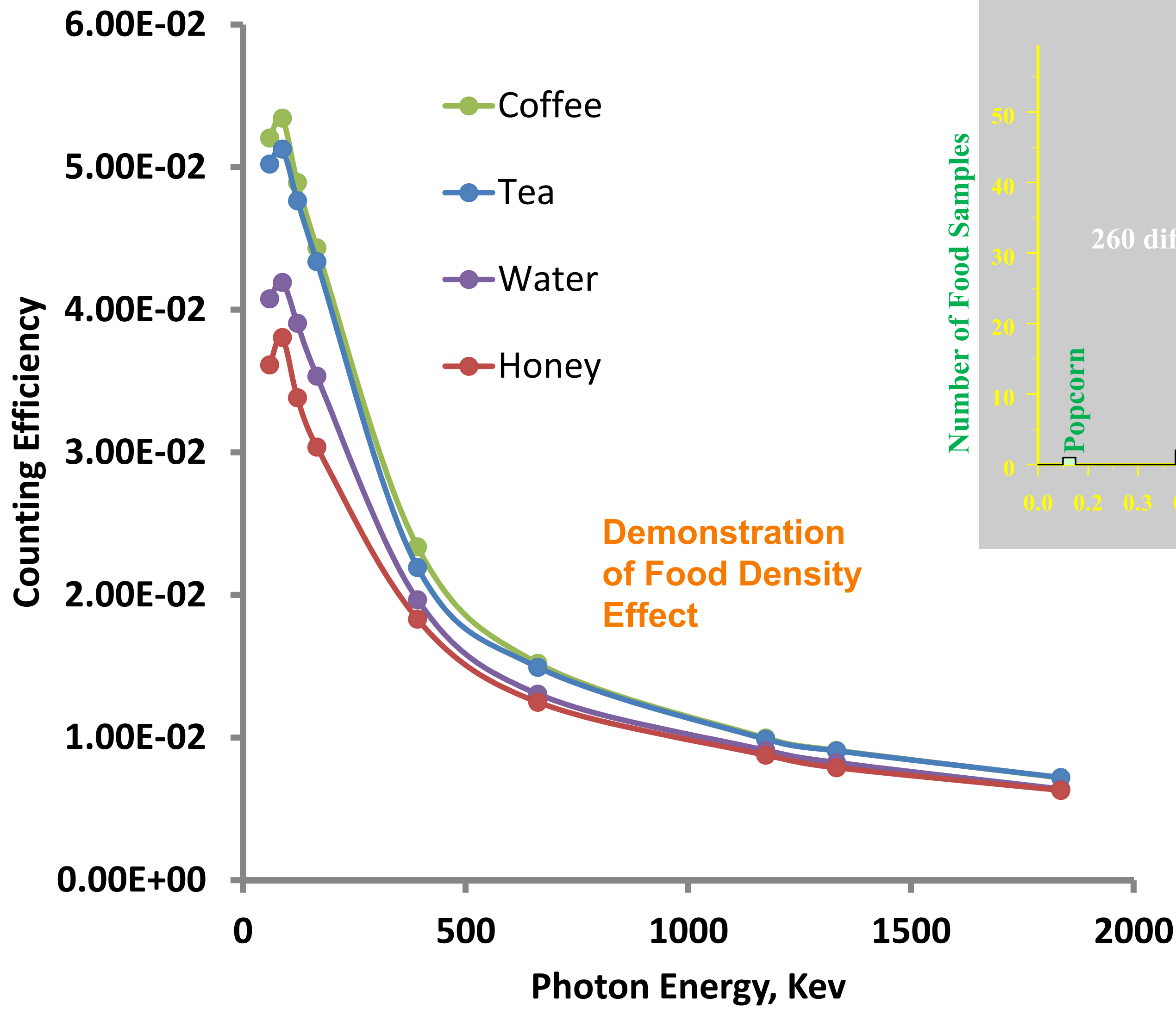
- **High cost and limited availability of food-based standards force most of FERN network laboratories to practice "one-standard-fit-all" calibration**

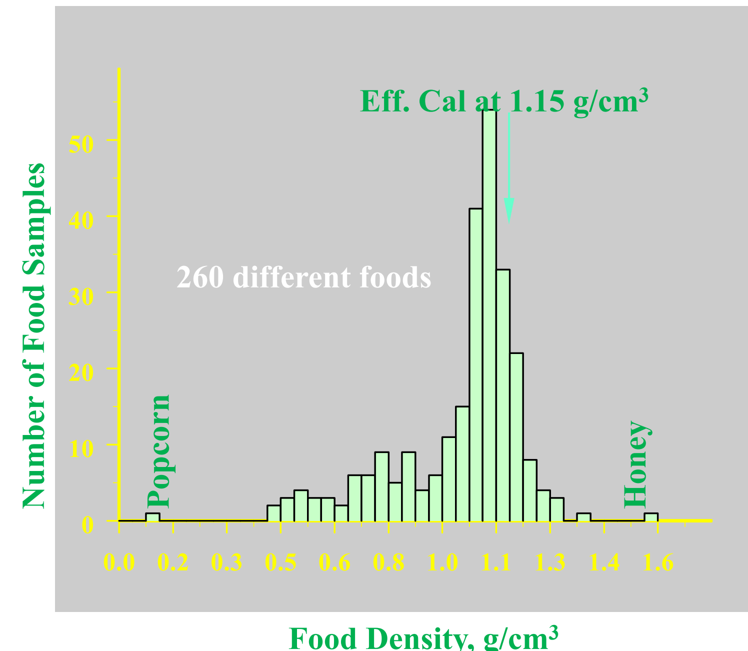
- **Significant self-attenuation and coincidence-summing effects are either generally ignored or corrected using different methods**

- **Measurement accuracy and data comparability are compromised due to method discrepancies and generalization**

- **Lack of a simple and practical efficiency correction technique applicable to a broad range of food matrices, counting geometries, and summing radionuclides**

Counting Efficiencies Measured with Different Mixed-Gamma Food Standards





Sample density effect in food analysis is real and significant, and self-attenuation effect increases with decrease in photon energy.

Applying one-standard-fit-all calibration will bias measurement results considerably.

Sourceless Efficiency Calibrations

General-purpose Monte Carlo N-Particle code (MCNP) will be used for calculations

Advantages of using calculations

Lower Cost than Source-based Calibration
Purchase of Sources
Replacement of Sources
Disposal of Sources

Easier to match the sample for calibration
Not enough material
Unusual material composition

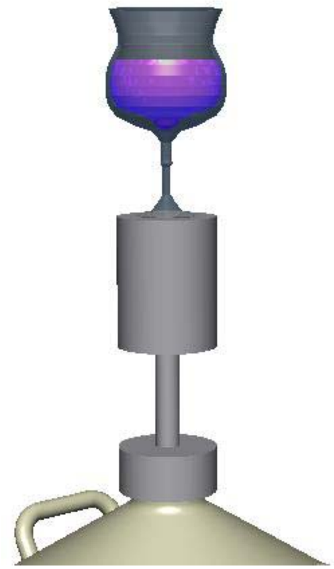
Each of the three software in this study is comprised of the Monte Carlo N-Particle code, but they all differ by having unique user interfaces and adjustable parameters that provide distinct advantages and disadvantages in comparison to each other.

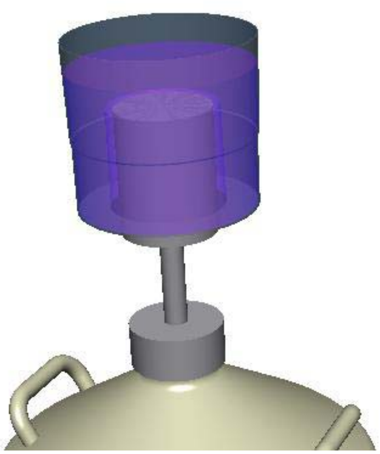
Sourceless Efficiency Calibrations

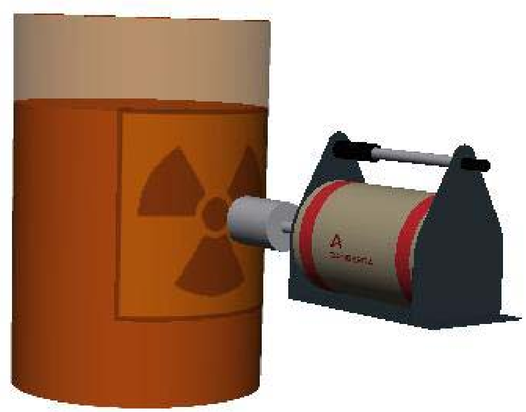
LABSOCS/ISOCS The LabSOCS (Laboratory SOurceless Calibration Software) mathematical efficiency calibration developed by Canberra.

The difference between LabSOCS and other available mathematical calibration packages is that the detector used to perform activity measurements is initially characterized by the manufacturer.

The software also contains a variety of geometry templates of commercially available containers.





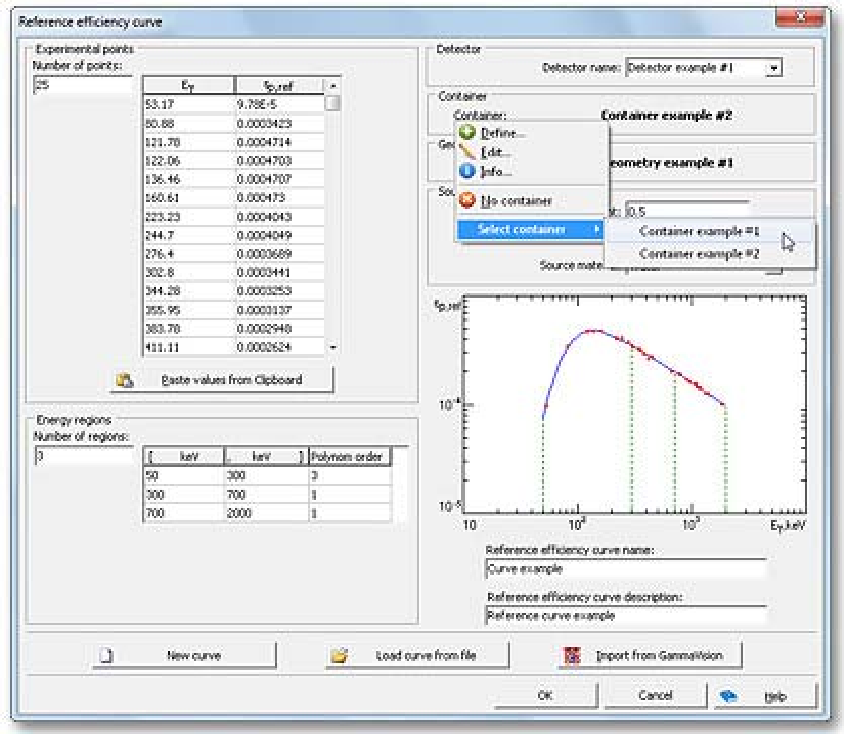


Sourceless Efficiency Calibrations

ANGLE 3 is developed by Ametek and combines advantages of both Monte Carlo calculations and calibrated-source-based methods.

By using both methods, the potential for systematic errors is significantly reduced in the calculations and while the practical limitations of source base corrections is mitigated.

Angle can be used with any HPGE detector, which is advantageous in applying the methods in this study across a range of detectors.

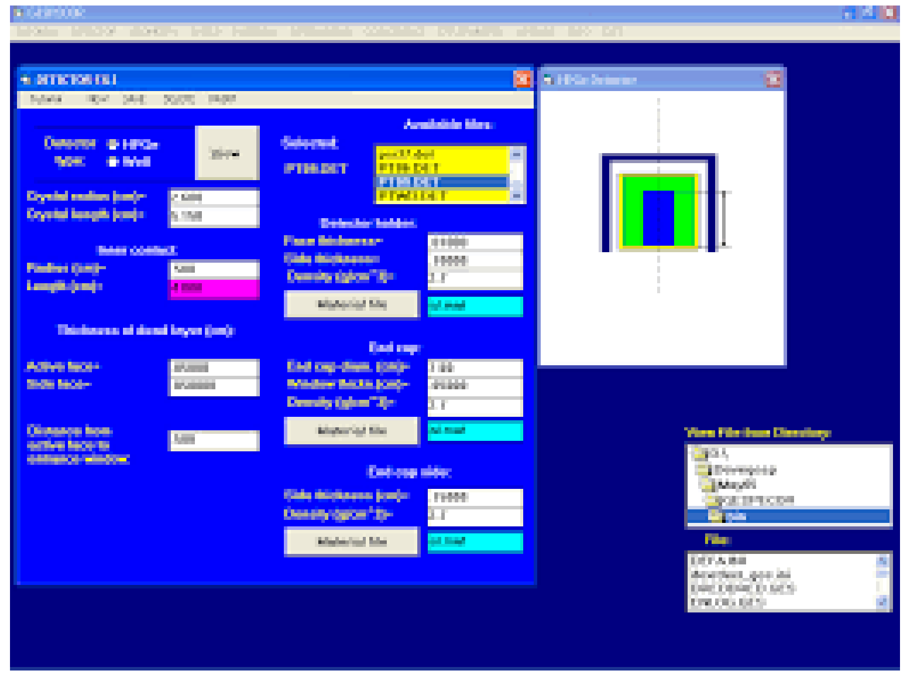


Sourceless Efficiency Calibrations

GESPECOR Germanium Spectroscopy Correction factors is a Monte Carlo based code specially developed by Sima for solving problems in gamma-ray spectrometry measurements.

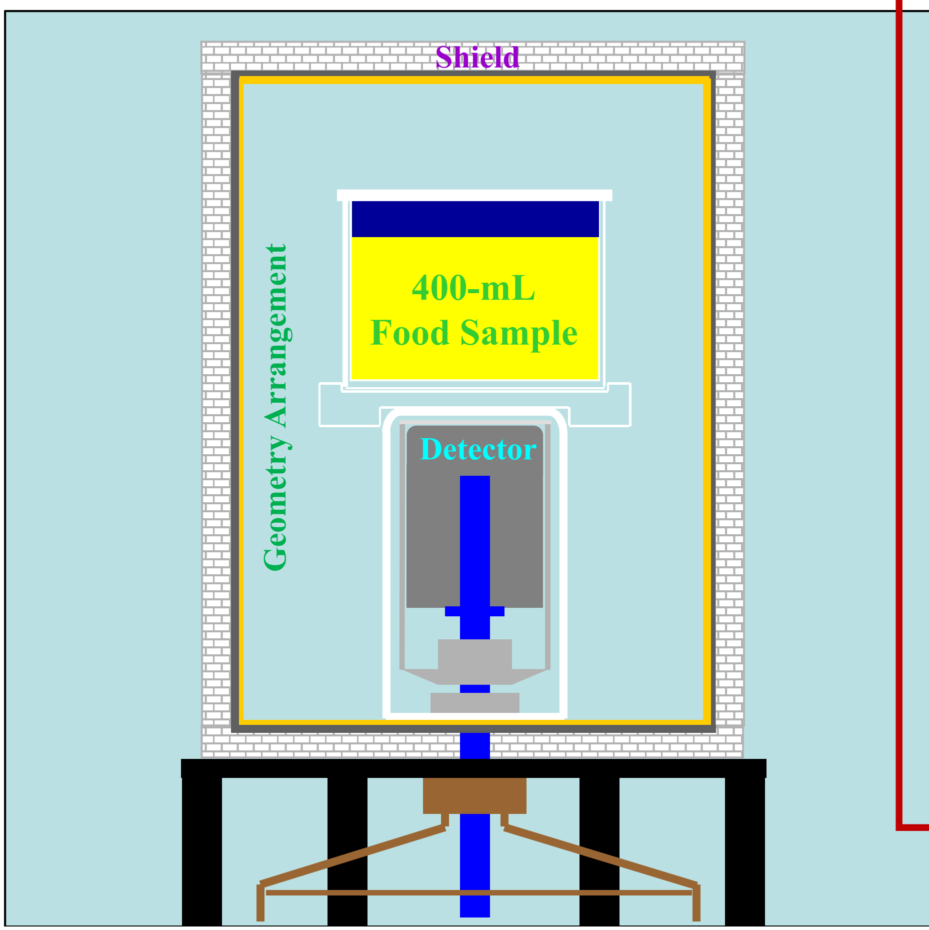
GESPECOR is able to provide a set of procedures for the efficiency calibration of high resolution gamma ray spectrometers based on hyper pure Ge detectors.

The software is very flexible and allows the user to change many variables, including the detector, shield and geometry all from a friendly user interface.



Computational approach requires descriptive inputs with regard to:

- Detector Characteristics
- Sample Properties
- Shielding Material
- Counting Geometry Arrangement



List of Input Variables

Crystal Radius
Crystal Length
Crystal Inner Contact Radius
Crystal Inner Contact Length
Crystal Holder Face Thickness
Crystal Holder Side Thickness
Crystal Holder Material Density
Face Dead Layer Thickness
Side Dead Layer Thickness
End Cap Diameter
End Cap Window Thickness
End Cap Side Thickness
End Cap Material Density

Container Radius
Container Height
Container Wall Thickness
Container Material Density
Sample Composition
Sample Density

Shield Inner Radius
Shield Inner Height
Shield Outer Radius
Shield Outer Height
Shielding Material Density

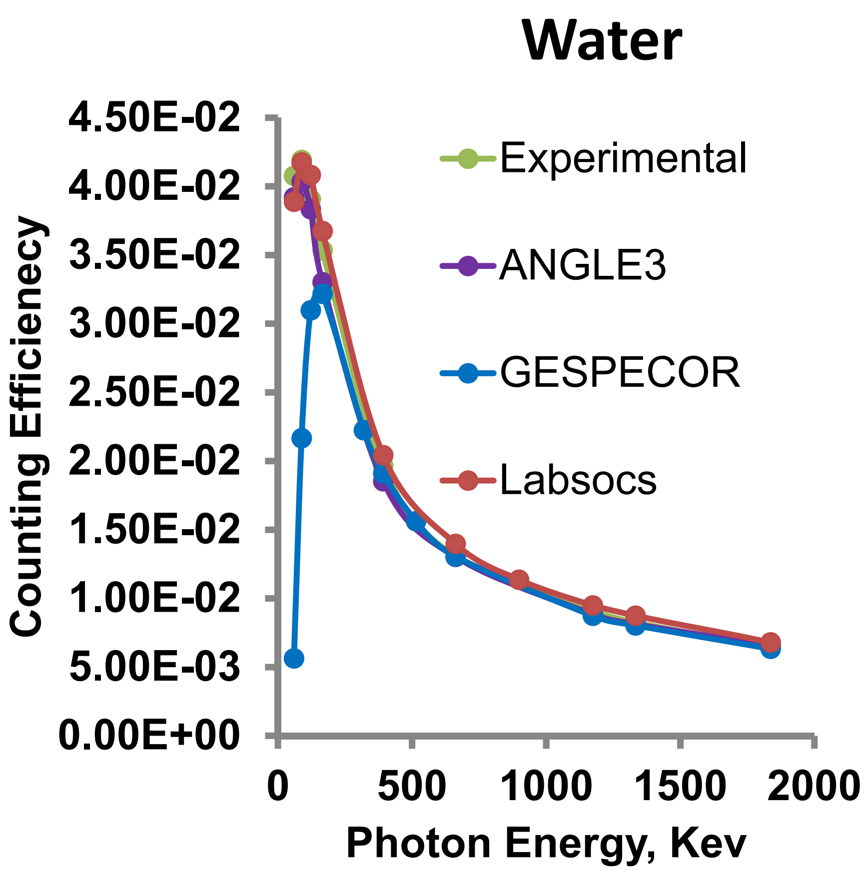
End Cap-to-Inner Shield Top Distance
Active Face-to-Entrance Window Distance

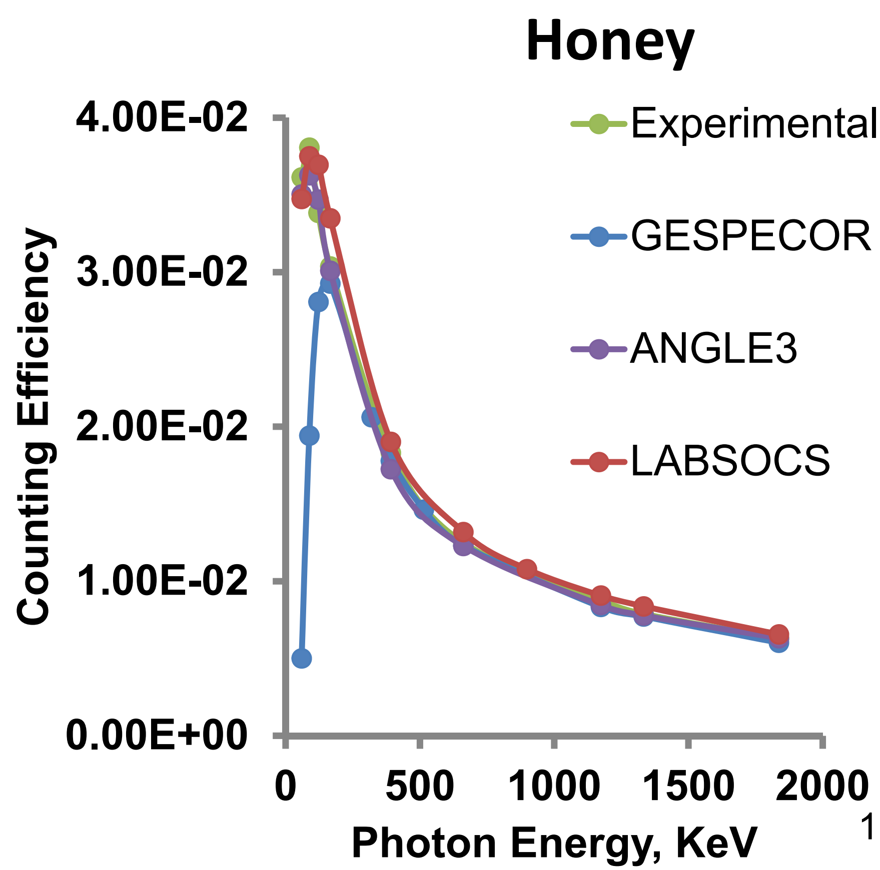
Comparison of Measured Efficiencies with Computed Efficiencies

The **measured** *efficiency* values are determined using calibration standards

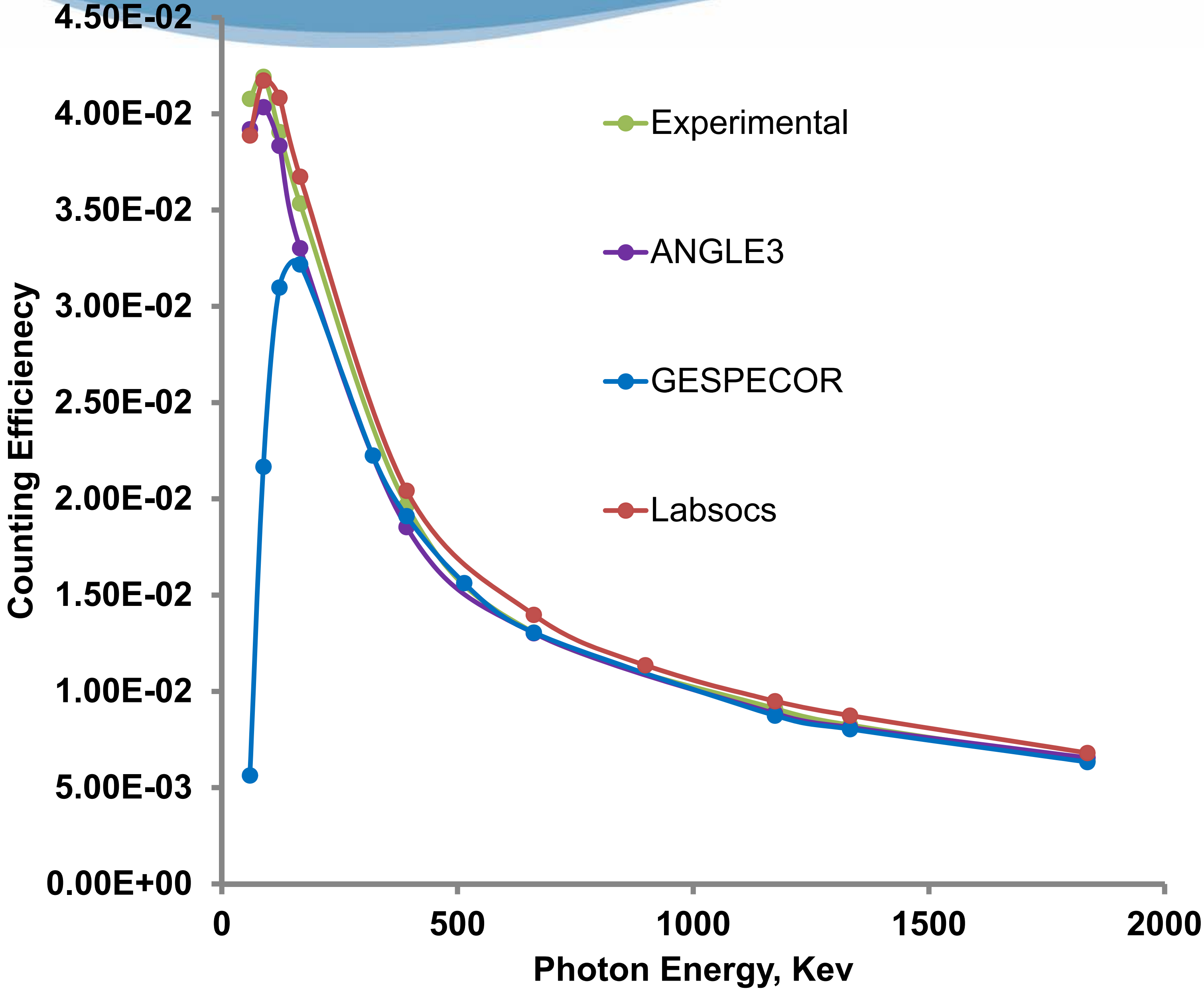
The **LabSOCS** *efficiency* values are calculated with precise detector parameters

The **GESPECOR** *and* ***ANGLE3*** are calculated with generic detector parameters

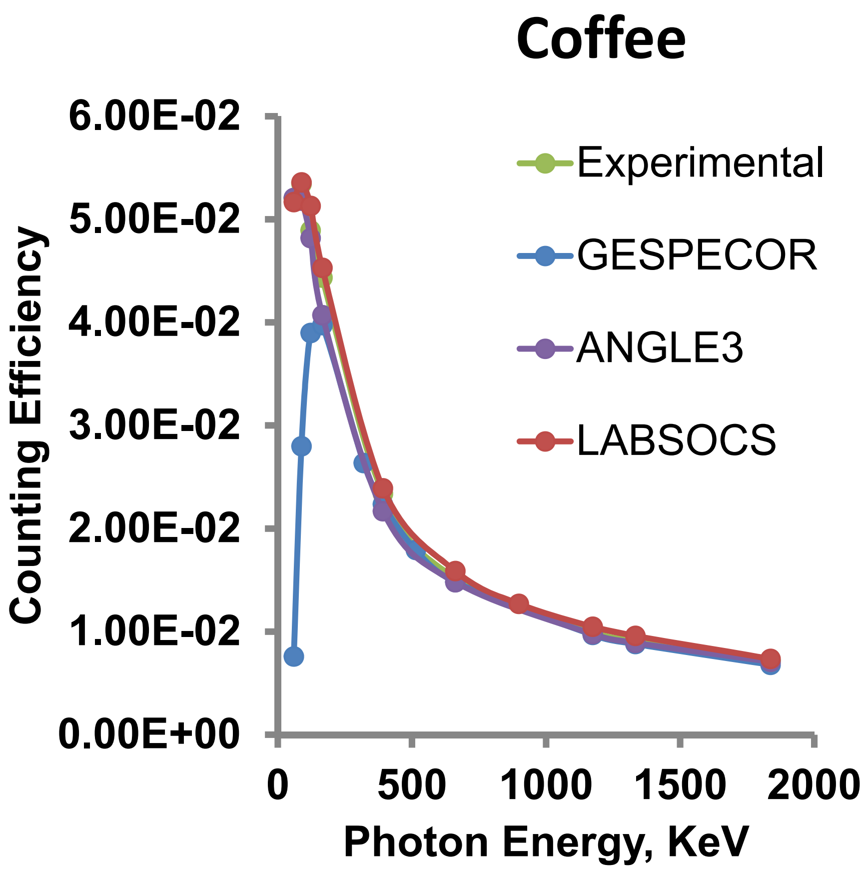


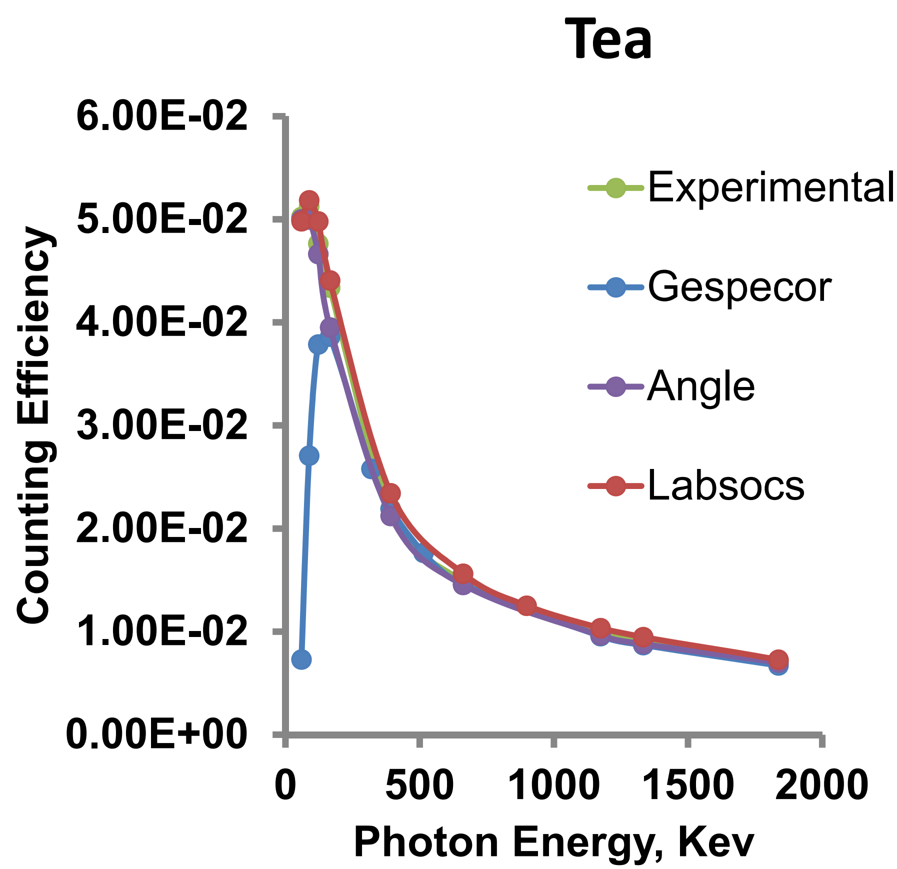


Water


4.50E-02
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Counting Efficienecy
0
500
1000
1500
2000
Photon Energy, Kev
Experimental
ANGLE3
GESPECOR
Labsocs

Comparison of Measured Efficiencies with Computed Efficiencies

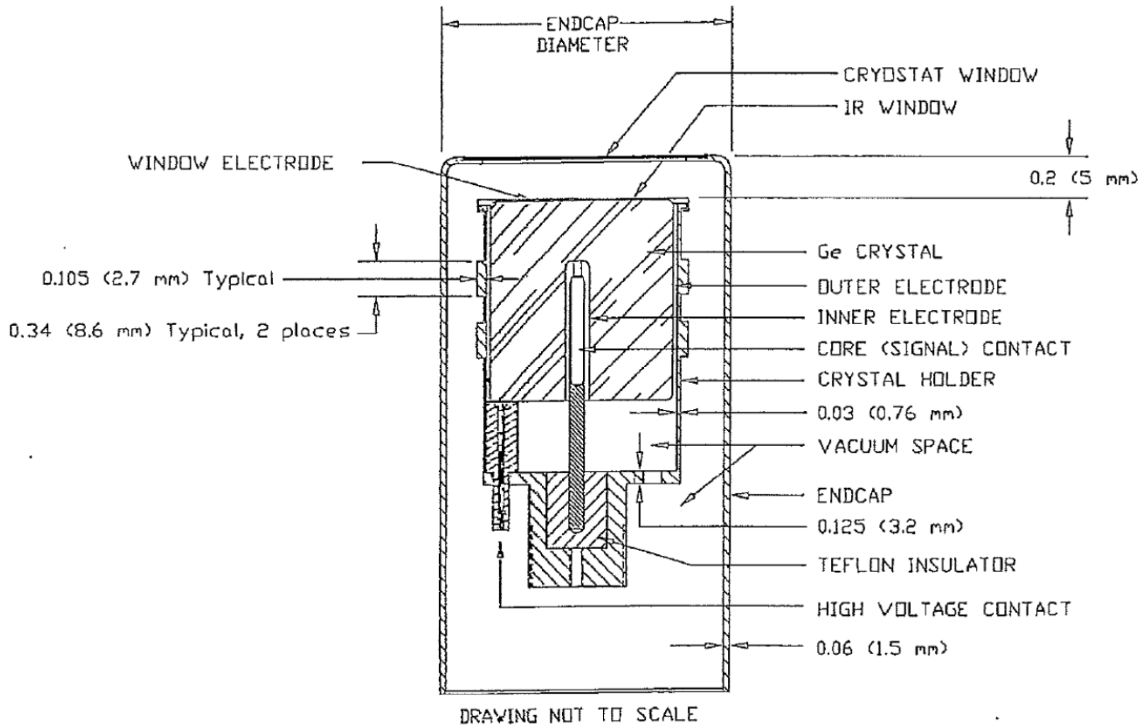




Comparison of Measured Efficiencies with Computed Efficiencies

LABSOCS is the best at predicting measured efficiencies

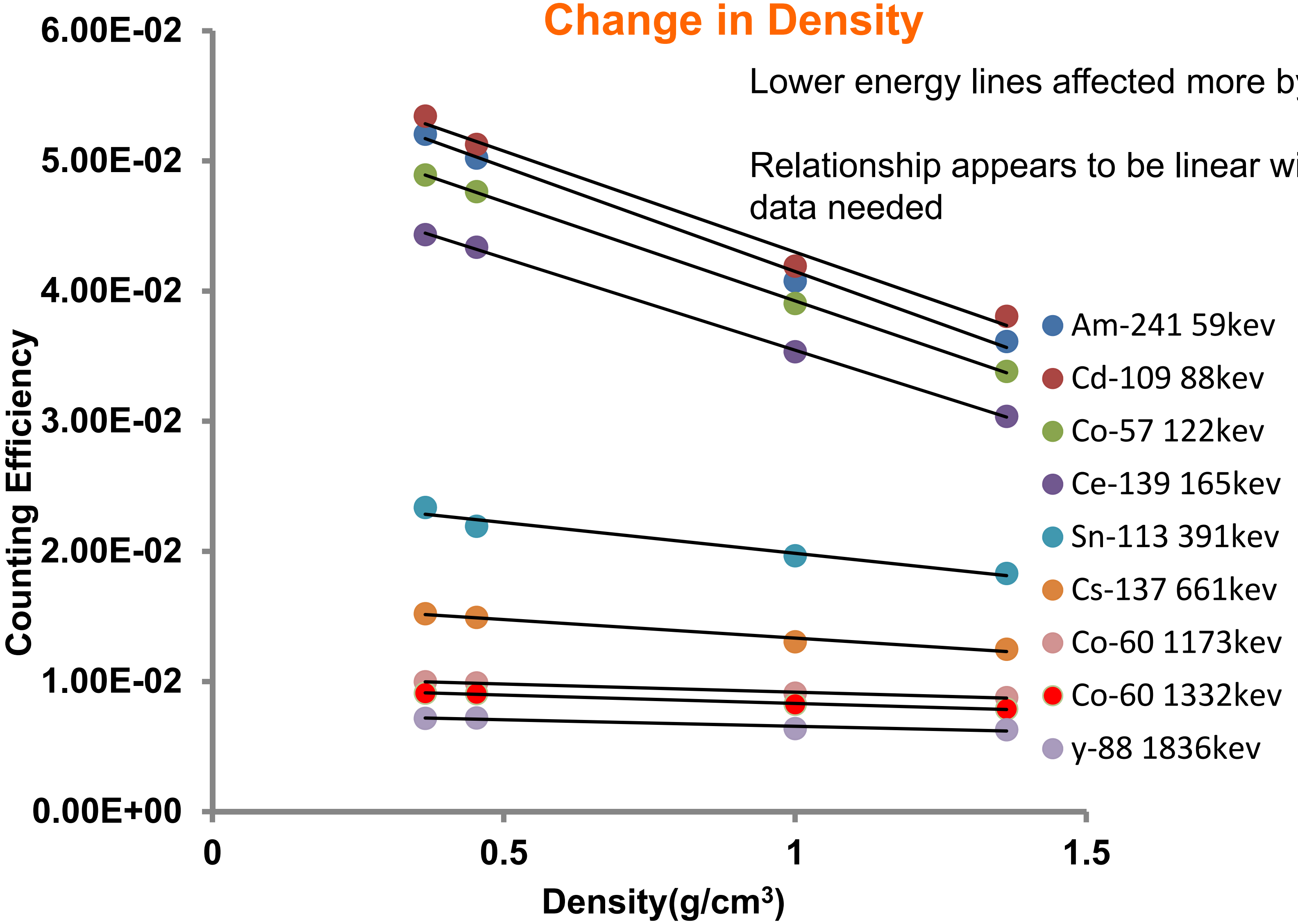
Can detector characterization have unique parameters to improve accuracy?



Comparison of Measured Efficiencies with Change in Density

Lower energy lines affected more by density

Relationship appears to be linear with but more data needed



Comparison of Measured Efficiencies with Change in Density

Food Product	Density	Elemental Analysis
Coffee	0.365	**C%** 57.00 **H%** 7.00 **O%** 35.00 **N%** 1.00
Tea	0.453	**C%** 55.59 **H%** 6.10 **O%** 35.16 **N%** 3.02 **S%** 0.07 **P%** 0.07
Water	1	**H%** 11.19 **O%** 88.81
Honey	1.363	**C%** 40.00 **H%** 7.00 **O%** 53.00

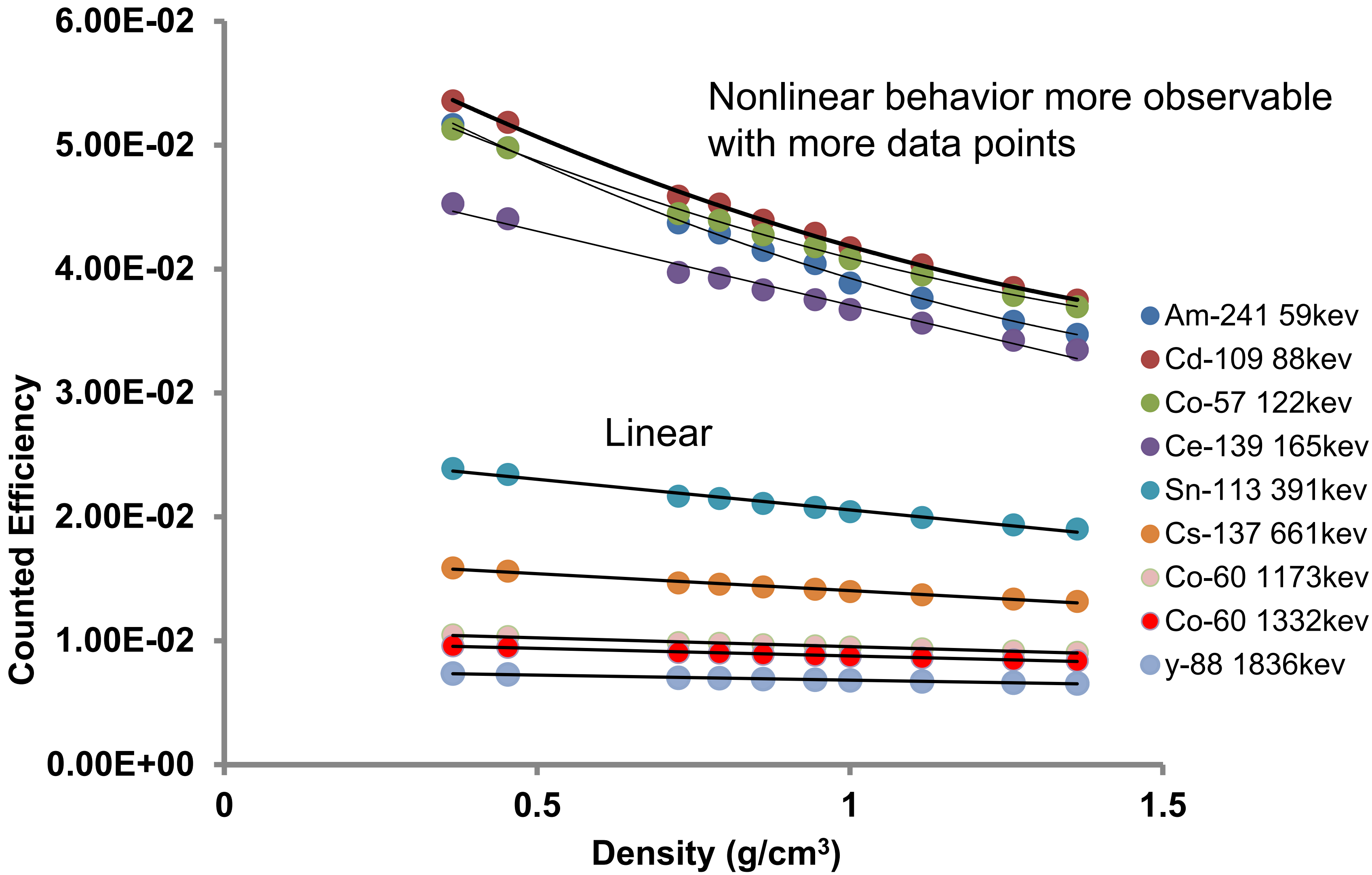
Organic Solvent	Density	Elemental Analysis
Triethylamine	0.7255	**C%** 71.22 **H%** 14.94 **N%** 13.84
Acetone	0.791	**C%** 62.04 **H%** 10.41 **O%** 27.55
DMF	0.944	**C%** 49.30 **H%** 9.65 **O%** 21.89 **N%**19.16
Glyme	0.9637	**C%** 53.31 **H%** 11.18 **O%** 35.50
Ethylene Glycol	1.115	**C%** 38.70 **H%** 9.74 **O%** 51.55
Glycerol	1.261	**C%** 39.13 **H%** 8.76 **O%** 52.12

Principle components in food are C, H, O, N

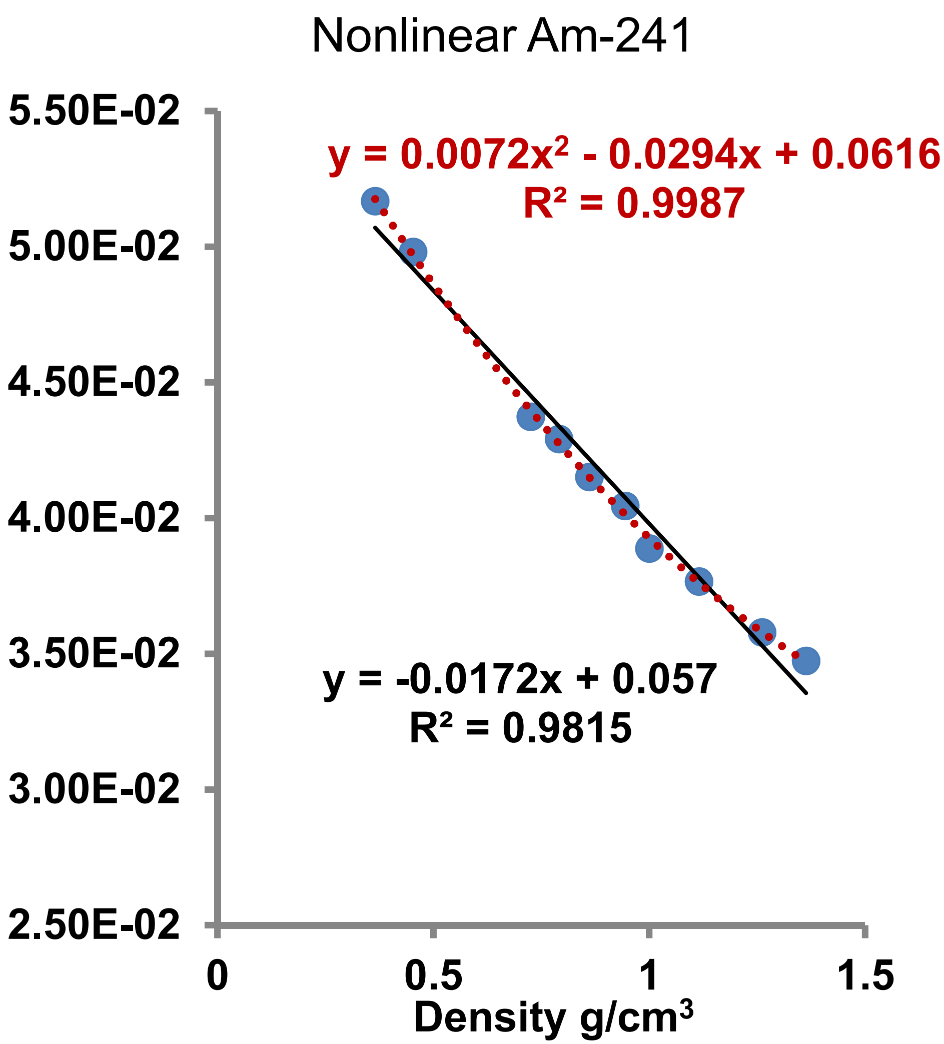
Using organic solutions to mimic food components, while improving range of densities that can be studied

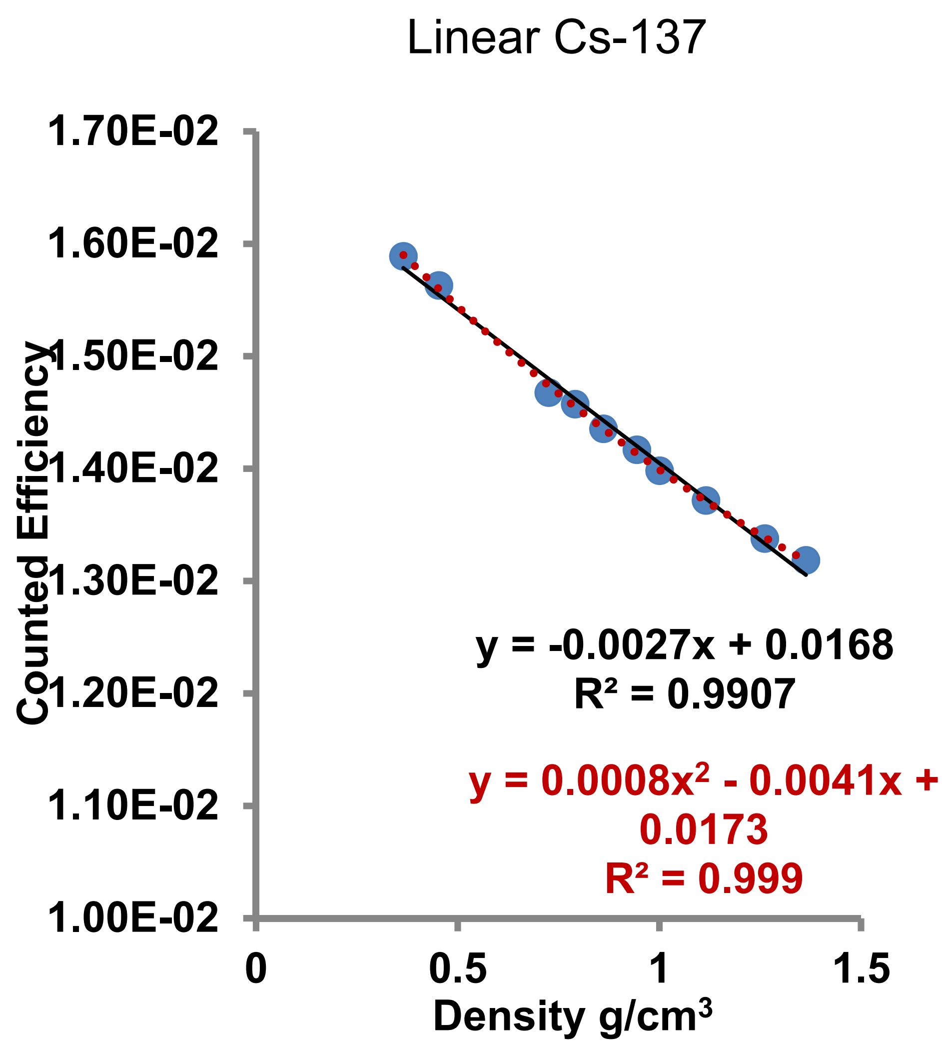
Simulate radioactive solutions to minimize generating waste.

Comparison of Computed Efficiencies with Change in Density



Comparison of Computed Efficiencies with Change in Density





Results of Food Spiked With ^{137}Cs and ^{60}Co

Spiked Activity – The amount of radioactive material added to the food sample.

Measured Activity – The activity determined by measurement of the sample using a water based efficiency

Corrected Activity – The activity determined in the sample using computed efficiencies with density corrections

Food Product	Density	Isotope	Spiked Activity (Bq/g)	Measured Activity (Bq/g)	%error	Corrected Activity (Bq/g)	%error
Water	1	^{137}Cs	0.64	0.66	3.29	0.62	2.93
		^{60}Co	1.03	0.96	6.98	0.98	5.41
			1.04	0.95	8.41	0.98	6.00
Coffee	0.365	^{137}Cs	4.09	4.76	16.45	3.94	3.55
		^{60}Co	6.61	6.87	3.99	6.32	4.33
			6.61	6.70	1.34	6.72	1.60
Tea	0.453	^{137}Cs	3.33	3.83	15.10	3.21	3.63
		^{60}Co	5.38	5.51	2.46	5.16	4.08
			5.38	5.41	0.65	5.08	5.47
Unknown Syrup	1.15	^{137}Cs	0.18	0.16	10.68	0.19	1.68
		^{60}Co	0.37	0.35	5.26	0.35	7.01
Honey	1.363	^{137}Cs	0.48	0.47	1.67	0.47	1.91
		^{60}Co	0.77	0.70	10.08	0.74	4.20
			0.78	0.70	9.42	0.74	3.94

Conclusions

Computational Methods effective at predicting efficiencies over a range of densities
-LABSOCS

Organic Solutions can mimic food components, and allows for variation in density

Simulating radioactive solutions can help minimize generating waste saving cost of preparing samples and improve response time in the case of an emergency.

Acknowledgements

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THANK YOU!

Questions?

The Need for Food Density Corrections

Self absorption of gammas from radionuclides in a sample can affect the efficiency curve used to quantify sample activity.

The amount of correction can be trivial for isotopes with high energy photons (e.g. Cs-137) and favorable geometries (MarinelliBeakers).

Alternately, isotopes with significant low energy photon emissions (e.g. Am-241), and unfavorable counting geometries, such as large buckets of the food product, can require significant corrections.