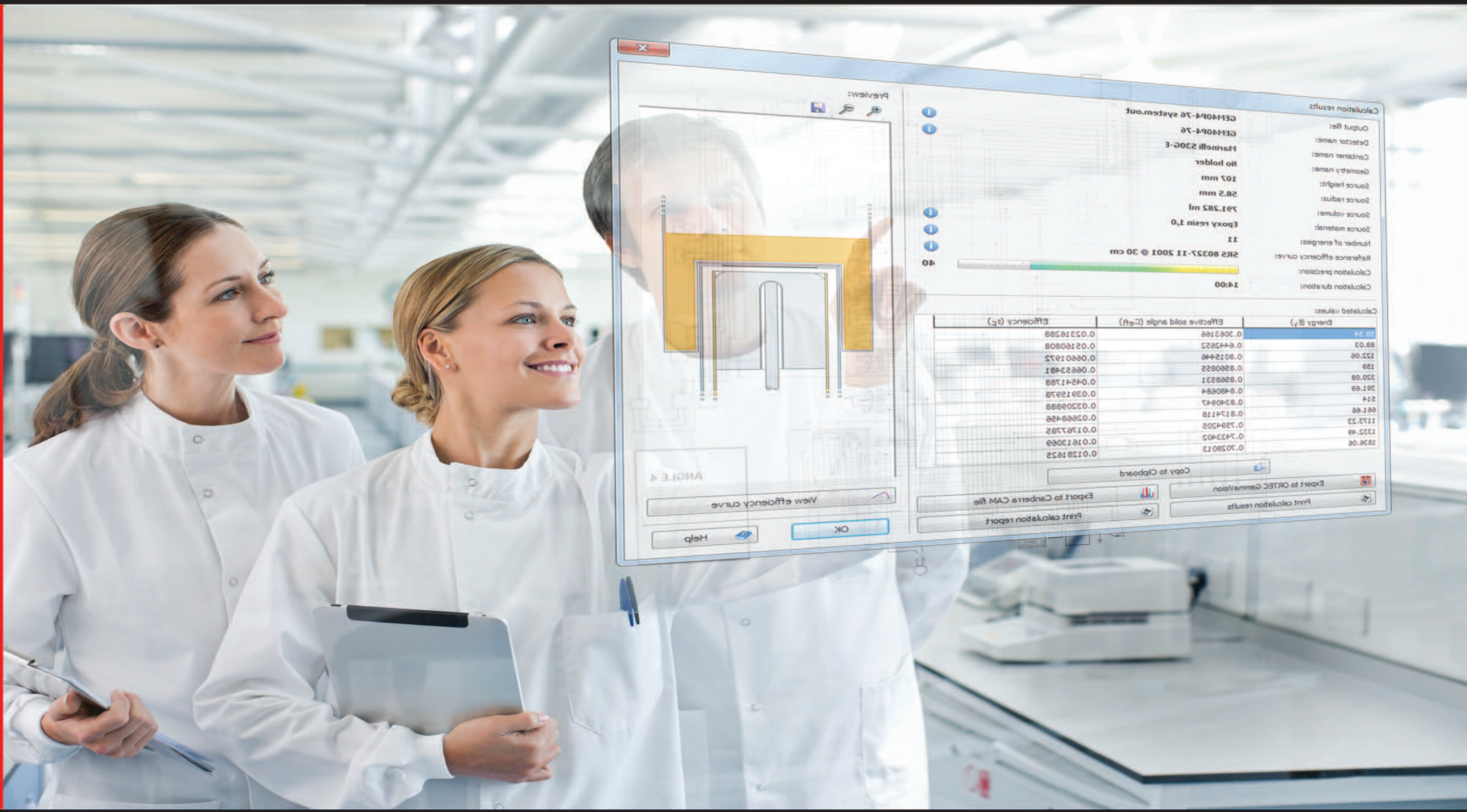
# ANGLE 5

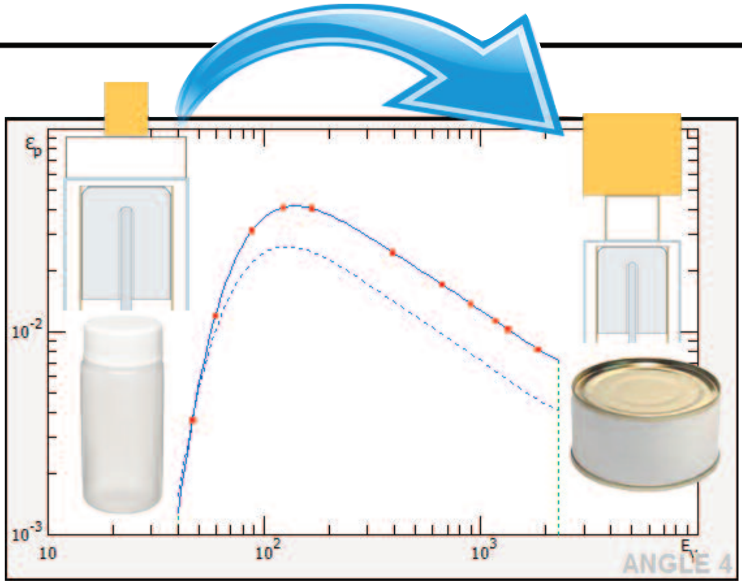
## Advanced Gamma Spectroscopy Efficiency Calibration Software



"Compatible, Efficient, and Defendable Calibrations for Gamma Spectroscopy Applications."

# ANGLE 5

ANGLE is an advanced efficiency calculation application for High Purity Germanium and Sodium Iodide detectors based on the concept of Efficiency Transfer. This method combines the measured efficiency of a known reference configuration and solid angle models to derive the efficiency for different containers, sample materials, and sample positions. This semi-empirical approach is more accurate than pure mathematical models due to large errors that can be imposed by detector characteristics that are not precisely known – such as crystal defects, contact thickness, and dead layers – as these errors largely cancel out in the reference efficiency measurement. And, since the Reference Efficiency can be determined from any standard source, there is no need for complex and costly factory characterization of the detector!



## WHY ANGLE?

| | |
|---|---|
| **Compatibility** | • All 32-bit and 64-bit versions of Windows from Windows XP to Windows 11<br>• Multiple Language: English, French, Spanish, Russian, Chinese, and Japanese<br>• High Purity Germanium and Sodium Iodide Detector Types<br>• Monte Carlo Modeling methodology for most common laboratory measurement containers |
| **Process Efficiency** | • No Factory Detector Characterization Necessary<br>• Import and Export GammaVision and Genie file formats<br>• Command line scripting and XML Data files for automation and application integration<br>• Rapid modeling using Container, Geometry, and Source Matrix configurations |
| **Defendable Results** | • Comprehensive Reporting of Efficiency Calculation Model<br>• Actual and Relative Efficiency Method provides Calibration Standard Traceability<br>• Graphical Display of model<br>• High Accuracy with Extensive Comparison Testing |

## New Features in ANGLE 5!

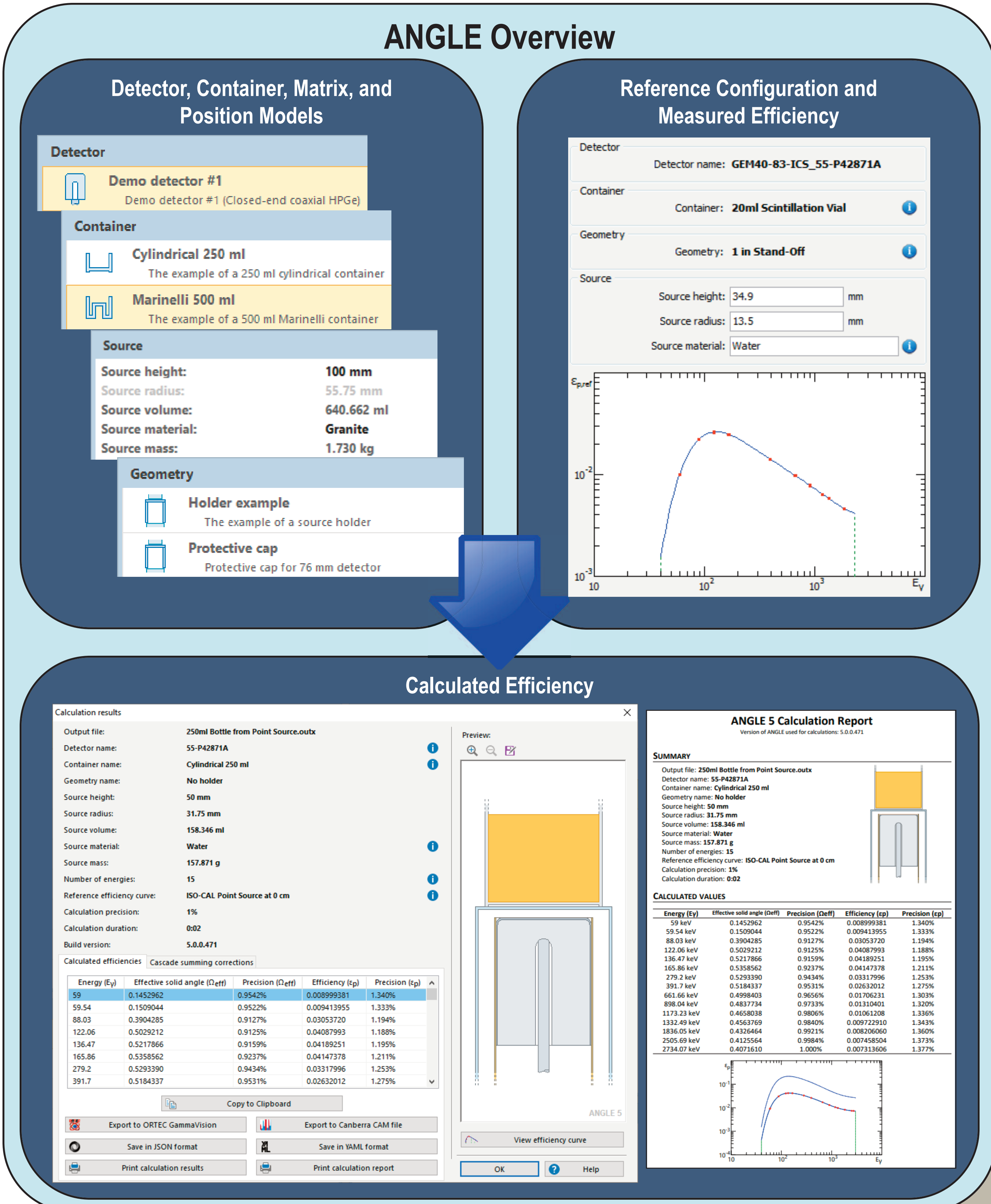
***New!*** Monte Carlo Calculation Methodology

***New!*** Cascade Photon Emission Coincidence Summing Corrections

***New!*** Example Sample Materials composed of editable Compounds and Mixtures

***New!*** Calculation File results in YAML and JSON formats

***New!*** Save model graphics to PNG and SVG image formats


ANGLE Overview
Detector, Container, Matrix, and Position Models
Detector
Demo detector #1
Demo detector #1 (Closed-end coaxial HPGe)
Container
Cylindrical 250 ml
The example of a 250 ml cylindrical container
Marinelli 500 ml
The example of a 500 ml Marinelli container
Source
Source height: 100 mm
Source radius: 55.75 mm
Source volume: 640.662 ml
Source material: Granite
Source mass: 1.730 kg
Geometry
Holder example
The example of a source holder
Protective cap
Protective cap for 76 mm detector
Reference Configuration and Measured Efficiency
Detector
Detector name: GEM40-83-ICS_55-P42871A
Container
Container: 20ml Scintillation Vial
Geometry
Geometry: 1 in Stand-Off
Source
Source height: 34.9 mm
Source radius: 13.5 mm
Source material: Water
Calculated Efficiency
Calculation results
Output file: 250ml Bottle from Point Source.outx
Detector name: 55-P42871A
Container name: Cylindrical 250 ml
Geometry name: No holder
Source height: 50 mm
Source radius: 31.75 mm
Source volume: 158.346 ml
Source material: Water
Source mass: 157.871 g
Number of energies: 15
Reference efficiency curve: ISO-CAL Point Source at 0 cm
Calculation precision: 1%
Calculation duration: 0:02
Build version: 5.0.0.471
Calculated efficiencies
Cascade summing corrections
Energy (Eγ) | Effective solid angle (Ωeff) | Precision (Ωeff) | Efficiency (εp) | Precision (εp)
59 | 0.1452962 | 0.9542% | 0.008999381 | 1.340%
59.54 | 0.1509044 | 0.9522% | 0.009413955 | 1.333%
88.03 | 0.3904285 | 0.9127% | 0.03053720 | 1.194%
122.06 | 0.5029212 | 0.9125% | 0.04087993 | 1.188%
136.47 | 0.5217866 | 0.9159% | 0.04189251 | 1.195%
165.86 | 0.5358562 | 0.9237% | 0.04147378 | 1.211%
279.2 | 0.5293390 | 0.9434% | 0.03317996 | 1.253%
391.7 | 0.5184337 | 0.9531% | 0.02632012 | 1.275%
Copy to Clipboard
Export to ORTEC GammaVision
Export to Canberra CAM file
Save in JSON format
Save in YAML format
Print calculation results
Print calculation report
Preview:
ANGLE 5
View efficiency curve
OK
Help
ANGLE 5 Calculation Report
Version of ANGLE used for calculations: 5.0.0.471
SUMMARY
Output file: 250ml Bottle from Point Source.outx
Detector name: 55-P42871A
Container name: Cylindrical 250 ml
Geometry name: No holder
Source height: 50 mm
Source radius: 31.75 mm
Source volume: 158.346 ml
Source material: Water
Source mass: 157.871 g
Number of energies: 15
Reference efficiency curve: ISO-CAL Point Source at 0 cm
Calculation precision: 1%
Calculation duration: 0:02
CALCULATED VALUES
Energy (Eγ) | Effective solid angle (Ωeff) | Precision (Ωeff) | Efficiency (εp) | Precision (εp)
59 keV | 0.1452962 | 0.9542% | 0.008999381 | 1.340%
59.54 keV | 0.1509044 | 0.9522% | 0.009413955 | 1.333%
88.03 keV | 0.3904285 | 0.9127% | 0.03053720 | 1.194%
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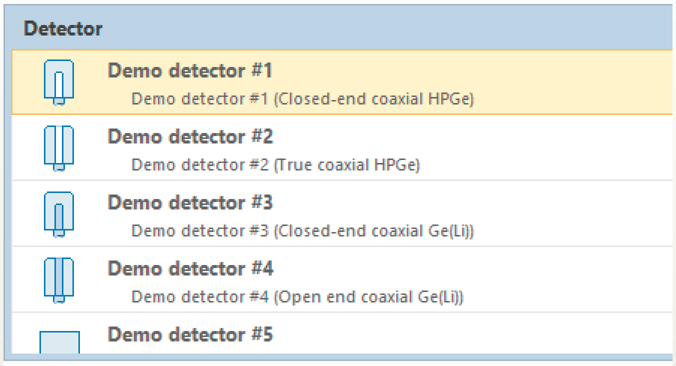
279.2 keV | 0.5293390 | 0.9434% | 0.03317996 | 1.253%
391.7 keV | 0.5184337 | 0.9531% | 0.02632012 | 1.275%
661.66 keV | 0.4998403 | 0.9656% | 0.01706231 | 1.303%
898.04 keV | 0.4837734 | 0.9733% | 0.01310401 | 1.320%
1173.23 keV | 0.4658038 | 0.9806% | 0.01061208 | 1.336%
1332.49 keV | 0.4563769 | 0.9840% | 0.009722910 | 1.343%
1836.05 keV | 0.4326464 | 0.9921% | 0.008206060 | 1.360%
2505.69 keV | 0.4125564 | 0.9984% | 0.007458504 | 1.373%
2734.07 keV | 0.4071610 | 1.000% | 0.007313606 | 1.377%

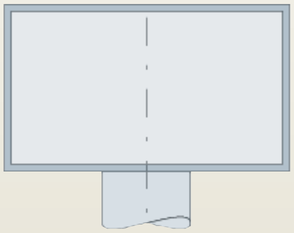
# Detector Model

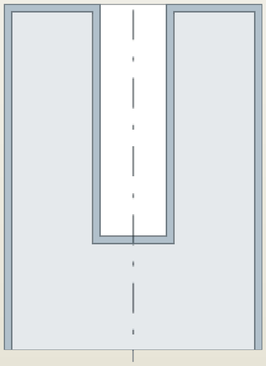
The Detector Model defines the physical construction of the detector. The input parameters are dependent on the detector type which may be Germanium or Sodium Iodide in Coaxial, Planar, or Well configurations. A graphic display of each model helps validate the appropriate detector type in the configuration process. Some parameters, such as the Inactive material thickness and the Contact thickness, are usually not precisely known for each detector so nominal values are typically used. These minor deviations are typically inconsequential with the Efficiency Transfer calculation method implemented in ANGLE because the minor error in transmission cancels out in the Reference and Target solid angle models. This is one of the significant advantages of Efficiency Transfer over modeling alone. And, if the detector response is affected by changes to any of these parameters, then a new Reference calibration can be generated with standard sources in the lab instead of having to return the detector to the factory for an expensive and time consuming characterization.

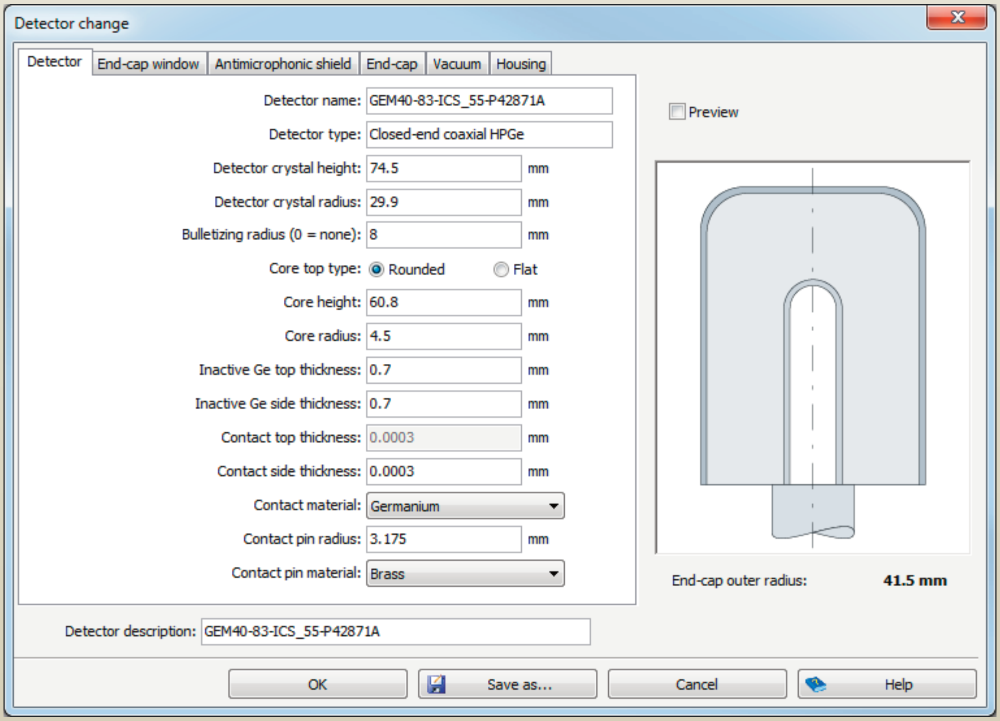


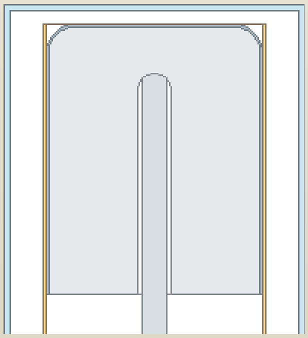

Detector Types:

- γ HPGe: Closed or open end coaxial, Planar, and Well
- γ Ge(Li): Closed or open end coaxial
- γ NaI: Cylinder and Well


NaI Cylinder


NaI Well



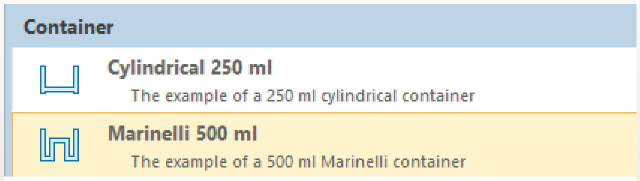


HPGe Closed End Coaxial

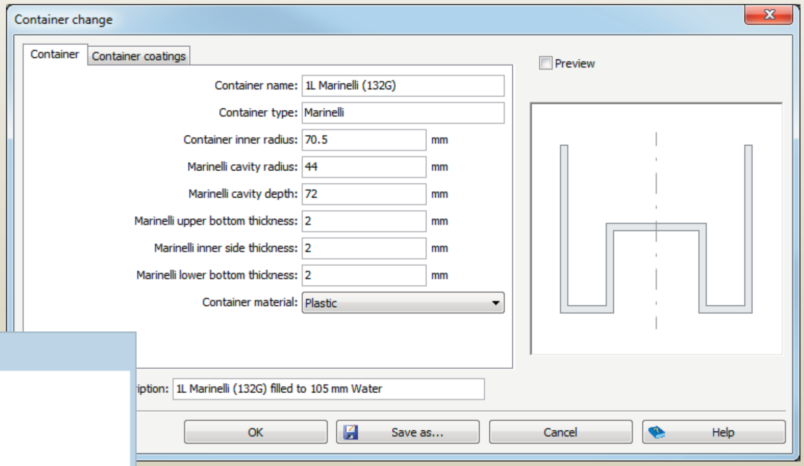
# Container and Source Model

Containers define the physical holders of source or sample material, and Sources define the actual material within the container. Containers and Sources are defined independently in ANGLE to simplify the process of establishing different combinations of material and volume in each container. Common materials are pre-defined for Containers and Sources, and additional materials can easily be added based on user-defined compounds or mixtures.

Container Types:

- γ Marinelli
- γ Cylinder to define Point Source, Filter Paper, Disk, Charcoal Cartridge, and Bottles

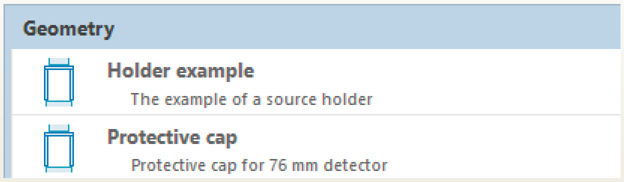


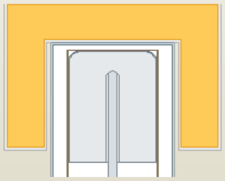





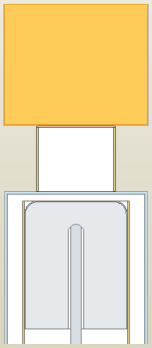
# Geometry Model

The Geometry defines the relative position of the Container to the Detector including any sample holders that may be used and up to five additional absorbing layers between the detector and the container. Common materials for sample holders and absorbers are pre-defined, and additional materials are easily added by the user.

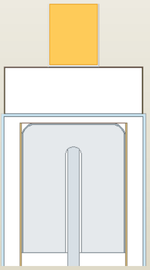


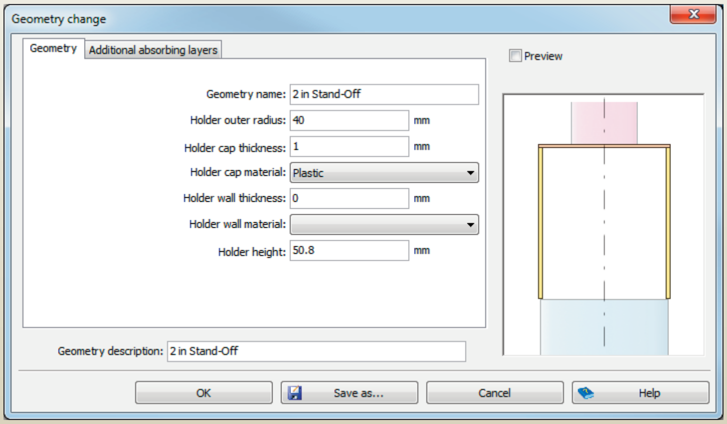
Marinelli Beaker on end cap



Large Bottle on narrow stand-off



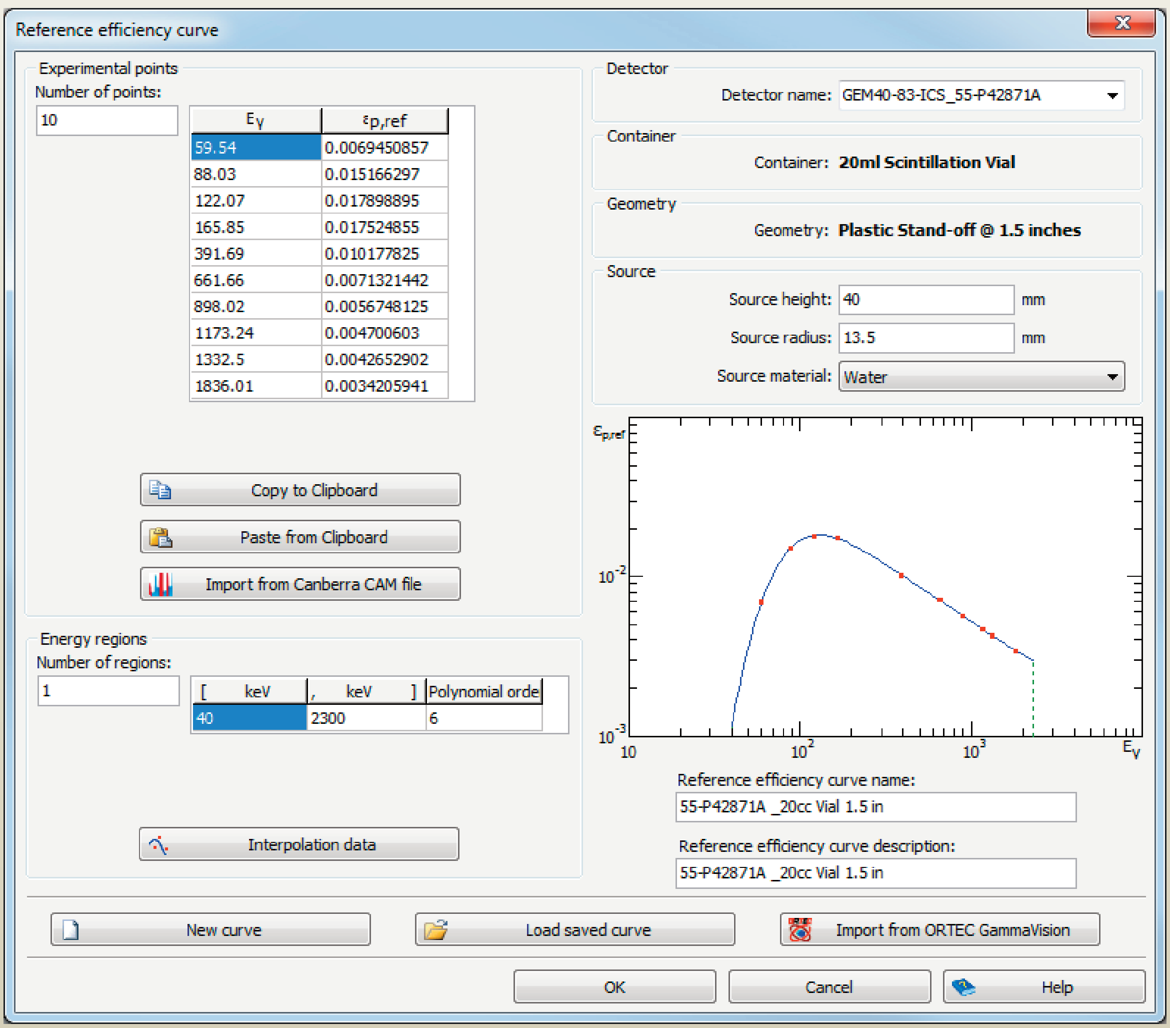
Small Bottle on wide stand-off



# Reference Efficiency Calibration

ANGLE eliminates complex, expensive, and time consuming detector characterization because the Reference Calibration can be determined by direct measurement of a known source within the lab. Optimally, the Reference Calibration is determined using a source/geometry that is similar to the one being modeled in order to minimize uncertainty in the modeled efficiency; however, any source/geometry can be used as the reference when modeling any other source/geometry with good results when all of the detector and source/geometry configuration parameters are well known.

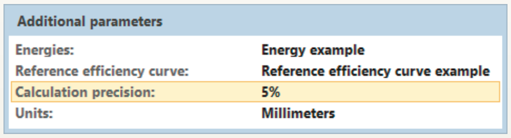
The Reference Energy/Efficiency pairs can be manually entered into ANGLE, or imported from either ORTEC GammaVision Efficiency Tables or Genie CAM files. A calibration curve is then generated using up to a 6-order logarithmic polynomial function over each of up to ten different energy regions to optimize the calibration fit. Alternatively, the reference Energy/Efficiency pairs can exclude the fit function in order to calculate the modeled efficiency for only the input energy points without any uncertainty imposed by using a fit function. The choice to use a fit function or discrete energy/efficiency pairs is largely determined by how the extrapolated efficiency calibration will be used. In many cases, the extensive calibration fit algorithms in ANGLE can achieve a much more precise calibration fit than is possible with other spectroscopy applications.



## Calculated Efficiency

$$\varepsilon_p = \varepsilon_{p,ref} \frac{\overline{\Omega}}{\overline{\Omega}_{ref}}$$

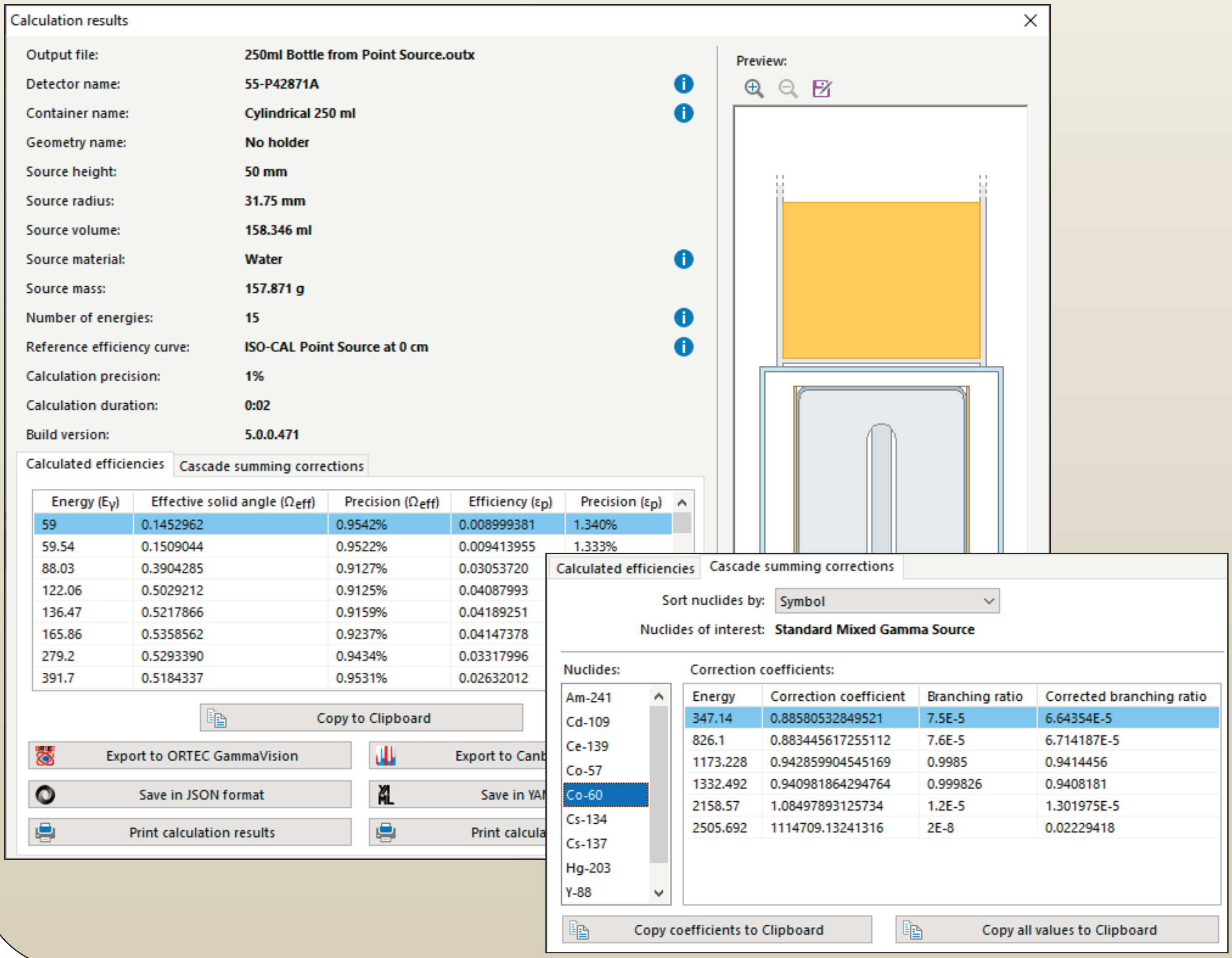
ANGLE uses an Efficiency Transfer method, which is a semi-empirical approach comprised of experimental evidence (i.e. measured efficiency of a known reference source) and mathematical comparison of effective solid angle modeling for the reference and target configurations. The effective solid angle is based on the Monte Carlo methodology with the precision of the calculations set from 0.1 to 5.0%.




The derived efficiency data can be comprised of the same energy points used in the reference calibration or user-defined energy points derived by ANGLE's robust fitting algorithms. These Energy/Efficiency pairs can then be used to generate efficiency calibrations in standard gamma spectroscopy applications. A Geometry correction file can also be generated for use in ORTEC's GammaVision application so that the final analysis results retain traceability to the Reference calibration while applying the necessary efficiency corrections to the derived geometry configuration.

Cascade Summing Corrections are calculated with correction factors applied to the nuclide branching ratios to account for coincidence summing of photon emissions from a single atom. This correction is geometry dependent and more significant when the sample is closer to the detector.

Detailed and Summary reports of the reference and derived efficiency calibrations and their associated configurations are also available for verification and record retention.



# ANGLE 5

## Ordering Information

| Model | Description |
|---|---|
| ANGLE-BW | Advanced Gamma Spectroscopy Efficiency Calibration Software – Single PC License |
| ANGLE-UW | Update from ANGLE Version 4 to Version 5 |
| ANGLE-GW | Additional Hard Copy Documentation for ANGLE |

## References


1. ANGLE v2.1 — New version of the computer code for semiconductor detector gamma-efficiency calculations, S. Jovanovic, A. Dlabac and N. Mihaljevic, Nuclear Instruments and Methods in Physics Research Section A, doi:10.1016/j.nima.2010.02.058.
2. Testing efficiency transfer codes for equivalence, T. Vidmar, N. Çelik, N. Cornejo Díaz, A. Dlabac, I.O.B. Ewa, J.A. Carrazana González, M. Hult, S. Jovanovic, M.C. Lépy, N. Mihaljevic, O. Sima, F. Tzika, M. Jurado Vargas, T. Vasilopoulou and G. Vidmar, Applied Radiation and Isotopes, Volume 68, Issue 2, February 2010, Pages 355-359.
3. Reliability of two calculation codes for efficiency calibrations of HPGe detectors, K. Abbas, F. Simonelli, F. D'Alberti, M. Forte and M. F. Stroosnijder, Applied Radiation and Isotopes, Volume 56, Issue 5, May 2002, Pages 703-709.
4. Methods and software for predicting germanium detector absolute full-energy peak efficiencies, K. R. Jackman and S. R. Biegalski, Journal of Radioanalytical and Nuclear Chemistry, Volume 279, Number 1/January, 2009, Pages 355-360.
5. Calculation of the absolute peak efficiency of gamma-ray detectors for different counting geometries, L. Moens, J. De Donder, Lin Xi-lei, F. De Corte, A. De Wispelaere, A. Simonits and J. Hoste, Nuclear Instruments and Methods in Physics Research, Volume 187, Issues 2-3, 15 August 1981, Pages 451-472.
6. Calculation of the peak efficiency of high-purity germanium detectors, L. Moens and J. Hoste, The International Journal of Applied Radiation and Isotopes, Volume 34, Issue 8, August 1983, Pages 1085-1095.
7. ANGLE: A PC-code for semiconductor detector efficiency calculations, S. Jovanović, A. Dlabač, N. Mihaljevic and P. Vukotic, Journal of Radioanalytical and Nuclear Chemistry, Volume 218, Number 1/April, 1997, Pages 13-20.
8. On the applicability of the effective solid angle concept in activity determination of large cylindrical sources, P. Vukotic, N. Mihaljevic, S. Jovanovic, S. Dapcevic, and F. Boreli, Journal of Radioanalytical and Nuclear Chemistry, Volume 218, Number 1/April, 1997, Pages 21-26.
9. "EXTSANGLE" — An extension of the efficiency conversion program "SOLANG" to sources with a diameter larger than that of the Ge-detector, N. Mihaljevic, S. Jovanovic, F. De Corte, B. Smodiš, R. Jacimovic, G. Medin, A. De Wispelaere, P. Vukotić and P. Stegnar, Journal of Radioanalytical and Nuclear Chemistry, Volume 169, Number 1/March, 1993, Pages 209-218.
10. Introduction of Marinelli effective solid angles for correcting the calibration of NaI(Tl) field gamma-ray spectrometry in TL/OSL dating, F. De Corte, S. M. Hossain, S. Jovanovic, A. Dlabac, A. De Wispelaere, D. Vandenberghe and P. Van den Haute, Journal of Radioanalytical and Nuclear Chemistry, Volume 257, Number 3/September, 2003, Pages 551-555.
11. Contribution of 210Pb bremsstrahlung to the background of lead shielded gamma spectrometers, D. Mrda, I. Bikit, M. Veskovic and S. Forkapic, Nuclear Instruments and Methods in Physics Research Section A, Volume 572, Issue 2, 11 March 2007, Pages 739-744.
12. Production of X-rays by cosmic-ray muons in heavily shielded gamma-ray spectrometers, I. Bikit, D. Mrda, I. Anicin, M. Veskovic, J. Slivka, M. Krmar, N. Todorovic and S. Forkapic, Nuclear Instruments and Methods in Physics Research Section A, Volume 606, Issue 3, 21 July 2009, Pages 495-500.