

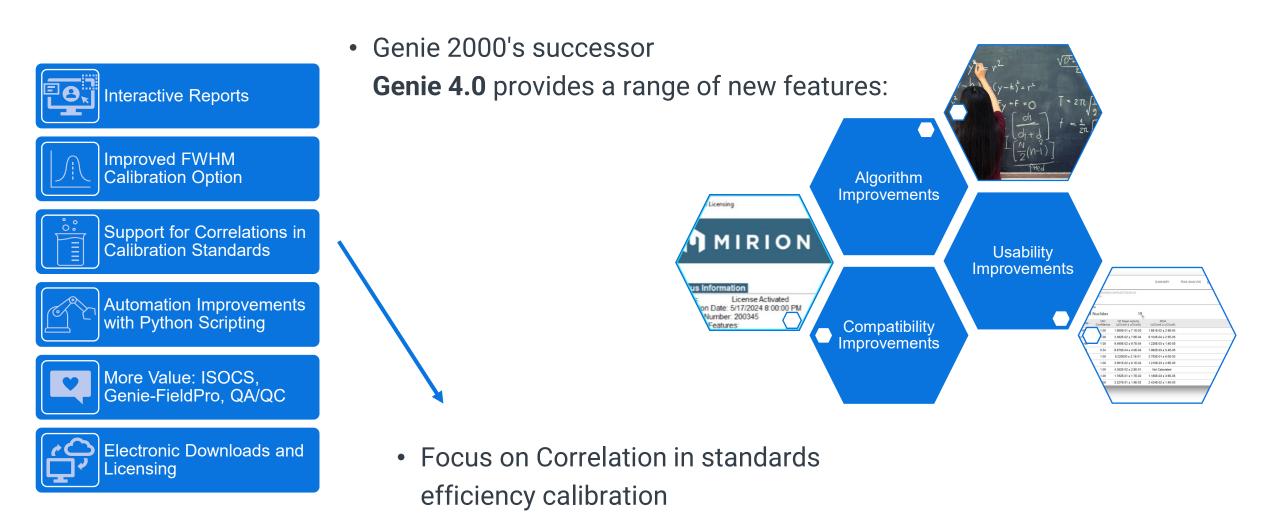
# Improving the accuracy of uncertainty calculations with Genie 4.0

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28 September 2023 Helsinki



# **Genie 4.0 Introduction**



### Genie 2000 / Genie 4.0

### Uncertainty management

- Efficiency calibration Uncertainty
  - Certificate used
    - Rate uncertainty •

(combine Abundance uncertainty and Nuclide Activity Uncertainty)

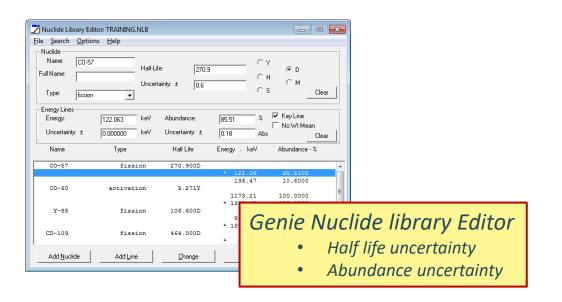
Net peak area 



| Quantity:         1         unit(s)         Assay date:         1/1/2011         at         120000           Disjinal Certificate         Bit  |      |
|--|------|
| Driginal Centricate:         Etric           Unignal Centricate:         Image: CD-103         HalkLife:         463.9         C Y         C           Image: State         State         Gardine         Gardine         Gardine         C <th></th>  |      |
| Original Centricate         Entre           Line         Nuclide:         CD-109         HalkLife:         463.9         C Y         C           Energy:         98.037         key         Uncertainly: +/-         0.1         C S           Add         Charge         Delete         Clear         Delete         Clear           Nuclide         Energy (keV)         Rate         2Uncert         HalkLife:         C - 139           C - 159         122.0         0.63         265.0000         4.1000         272.400         272.401           C - 159         122.0         0.63         2.9000         4.1000         2.9000         272.401           C - 159         126.635         365.0000         4.0000         272.401         2.900         2.900         2.900         2.900         2.9000  | I PM |
| Image         Image <th< th=""><th></th></th<> |      |
| Nuclide         CD-109         Hal-Lite         4633         C Y         C           Energy         88.037         keV         Uncertainty +/-         0.1         C H         C           Energy         980.037         keV         Uncertainty +/-         0.1         C H         C           Hot         4930000         geo daps per unit quantity         F         E         C         H         C           Add         Charge         Delete         Delete         Delet         Delet         C         C         S         C         C         S         C         C         C         S         C         C         S         C         C         C         S         C         C         H         C         C         C         C         S         C         C         S         C  | owse |
| Induce         CD/L03         marticle         ws.3         CH         OI         C           Emission Rate:         4933.0000         gps or aps per unit quantity         F         OI         C         C           Emission Rate:         4933.0000         gps or aps per unit quantity         F         Use for Cably/NIT ?           Add         Change         Delete         Clear         C           Nucide         Emergy (NeV)         Rate         3.0000         4.3000         222.401           C0=57         122.663         2563.0000         4.3000         222.401         277.701           EST=133         156.583         505.0000         3.0000         115.00         22.001         130.001         127.701           EST=133         156.583         505.0000         4.0000         130.001         127.701         158.713         30.001         177.701         158.713         30.001         177.701         158.713         30.001         177.701         158.713         30.001         177.701         158.713         30.001         177.701         177.711         177.711         177.711         177.711         177.711         177.711         177.711         177.711         177.711         177.711         177.711 <th></th>                    |      |
| Energy         88.037         keV         Uncertainly         +/-         U1         C           Emission Rate:         4933.0000         gps or aps per unit quantity         Rate Uncertainly: +/-         430000         gps or aps per unit quantity           Rate Uncertainly: +/-         430000         gp         Delete         Clear           Nuclide         Energy (keV)         Rate         2Uncert         HalfLife           CD-57         222.055         2555.0000         4.0000         272.401           CD-57         227.518         5655.0000         3.9000         137.701           RH-203         279.188         5101.0000         3.9000         146.621           SN+13         931.688         5205.0000         3.9000         146.621           CS-137         165.635         3565.0000         3.9000         166.621           SN+13         931.688         5205.0000         3.9000         166.621           CS-137         161.639         2526.0000         3.9000         166.621           CP-60         177.212         124.303         3.9000         106.652           CO-60         177.3120         6505.0000         4.0000         5.27   | M I  |
| Charte Uncertainty: +/-         4 5000         %         Use for Cabb/NIT ?           Add         Charge         Delete         Clear           Nucide         Energy (lev?)         Rate         XUncent         HalkLife           CD-50         58.007         4539.0000         4.0000         727.401           CD-19         165.655         5665.0000         3.9000         137.701           HP-203         279.188         5101.0000         3.9000         146.201           SN-113         991.668         5205.0000         3.9000         16.001           CS-137         661.639         2526.0000         3.9000         16.001           CS-149         161.621         12.430         3.9000         16.621           CS-137         1261.633         5205.0000         3.9000         16.621           CS-137         1261.633         500.0000         106.621         17.71           Y=88         950.021         12.430         3.9000         106.621           CO-60         173.210         6309.0000         5.271         12.430         3.9000         106.621  | m    |
| Add         Charge         Delete         Clear           Nucide         Energy (keV)         Rate         2Uncert         Half-Life           CD-57         122, 065         555, 0000         4, 1000         127, 401           CD-57         122, 065         5658, 0000         3, 1000         137, 701           CF-139         155, 853         3658, 0000         3, 1000         137, 701           HF-203         279, 188         8101, 0000         3, 1000         137, 701           SN-133         391, 688         5205, 0000         3, 5000         16, 621           CS-137         661, 689         5265, 0000         3, 5000         10, 600           Y=88         998, 021         12430         3, 5000         106, 621           CO-60         173, 210         6503, 0000         4, 0000         5, 277  |      |
| Add         Charge         Delete         Clear           Nucide         Energy (keV)         Rate         XUncett         Hal-Life           CD=19         43.9.35         45.95.000         4.9000         155.952           CD=19         122.055         2558.0000         4.9000         137.901           CT=139         165.853         3655.0000         3.9000         137.701           HF=203         279.188         B101.0000         3.9000         146.621           SN=13         391.688         5205.0000         3.9000         160.000           CC=137         661.639         32563.0000         4.0000         30.000           Y=88         998.021         12430         3.9000         106.621           CO=60         177.210         6505.0000         4.0000         5.27   |      |
| Nuclide         Energy (keV)         False         2Urcert         Helf-Life           C0-50         63.037         4999.0000         4.000         427.40           C0-57         122.063         258.000         4.000         272.40           C1-130         156.153         565.000         3.000         17.70           CF-131         156.153         505.000         3.000         115.00           CF-137         154.638         505.000         3.000         115.00           CF-137         154.163         5265.0000         3.000         155.00           CF-137         121.263.000         4.0000         3.000         155.00           CF-137         121.263.000         4.0000         3.000         155.00           CF-137         121.063.000         4.0000         5.27         121.17   |      |
| CD-109         48.037         4993.0000         4.5000         465.90           CD-57         122.063         2563.0000         4.1000         272.401           CT-139         165.853         3664.0000         3.0000         177.701           CT-137         165.853         3654.0000         3.0000         146.600           CT-137         165.853         3624.0000         3.0000         146.600           CT-137         166.1638         3263.0000         4.0000         30.000           CT-137         166.1638         3263.0000         4.0000         30.000           Y=88         198.021         12430         3.0000         106.62           CO-60         173.210         6303.0000         4.0000         5.27  |      |
| CD-57         122         058         2563         0000         4         1000         272.400           CZ=139         165         585         3656.0000         3.900         137.70           HG=203         279.188         8101.0000         3.900         146.62           SN=113         391.688         5205.0000         3.9000         115.00           CS=137         661.688         5205.0000         4.0000         30.000           Y=88         998.021         12430         3.9000         106.62           CO-60         1173.110         633.0000         4.0000         3.27  |      |
| CE-139         165.853         5665.0000         3.3000         137.70           HR-203         279.188         8101.0000         3.9000         46.62           SN-113         391.668         5205.0000         3.9000         116.00           CS-137         661.639         5205.0000         4.0000         30.00           Y=88         995.021         12430         3.9000         106.62           CO-60         177.210         6505.0000         4.0000         5.27   |      |
| HE-203 279.188 E101.0000 3.9000 4.6.62<br>SM-113 391.688 5205.0000 3.9000 115.00<br>CS-137 661.639 3252.0000 4.0000 30.00<br>Y-88 998.021 12430 3.9000 10.6.67<br>CO-60 1173.210 6530.0000 4.0000 5.27   |      |
| SN-113         391.688         5205.000         3.900         115.00           CE-137         661.688         5265.000         4.0000         50.00           Y-88         695.021         12430         3.9000         106.66           CO-60         1173.210         6530.0000         4.0000         5.27  |      |
| CS-137 661.638 3263.0000 4.0000 30.00<br>Y-B8 996.021 12430 3.9000 106.66<br>CO-60 1173.210 6303.0000 4.0000 5.27  |      |
| Y-88 898.021 12430 3.9000 106.66<br>CO-60 1173.210 6303.0000 4.0000 5.27   |      |
| CO-60 1173.210 6303.0000 4.0000 5.27   |      |
|  |      |
|  |      |
| 106.66   |      |
| 106.66   | 0    |
|  | -    |
| Conio Cortificato Editor   |      |
| Genie Certificate Editor   |      |
|  |      |
| Activity uncertainty for k=1   |      |
| $V_{CT}$   |      |

Activity Uncertainty

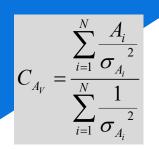
- Net peak area •
- Efficiency
- Energy line Abundance
- Nuclide Half life •
- Sample quantity
- Random (facultative) ۰
- Systematic (facultative) ۲



Genie 2000 /Genie 4.0

Uncertainty management

Activity



Formula used for Weighted mean Activity Multi-line nuclide

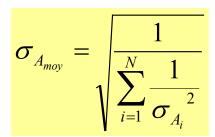
• The calculation of the uncertainty on the activity is given by the following formula

$$\sigma_{C} = C \cdot \sqrt{\left(\frac{\sigma_{R}}{100}\right)^{2} + \left(\frac{\sigma_{S}}{S}\right)^{2} + \left(\frac{\sigma_{V}}{V}\right)^{2} + \left(\frac{\sigma_{\varepsilon}}{\varepsilon}\right)^{2} + \left(\frac{\sigma_{y}}{y}\right)^{2} + \left(\frac{\sigma_{K}}{K}\right)^{2}}$$

Where 
$$C = \frac{S}{V.\varepsilon.y.T_1.K_C.K_W}$$

$$\sigma_R$$
: Random uncertainty

- $\sigma_s$ : Net peak area uncertainty
- $\sigma_V$ : Sample quantity uncertainty
- $\sigma_{\varepsilon}$  : Efficiency uncertainty
- $\sigma_y$ : peak Abundance Uncertainty
- $\sigma_{\scriptscriptstyle K}\,$ : Nuclide Half life Uncertainty
- The uncertainty calculated for the nuclide average activity will be given by the formula



#### Genie 2000 / Genie 4.0

#### **Uncertainty management**

### **ISO 11929 MDA**

#### ISO11929 MDA formula, where measurement Uncertainty

is part of MDA calculation

#### ISO11929 formula for decision threshold

$$c_A^* = k_{1-\alpha} \cdot \frac{w}{t_g} \sqrt{n_{b, E} + u^2_{(nb, E)}}$$

**ISO11929 MDA formula** 

 $c_{A}^{\#} = \frac{2.c_{A}^{*} + (k^{2}.w) / t_{g}}{1 - k^{2}.u_{rel}^{2}(w)}$ 

Detection Limit (MDA)

Measurement uncertainty

**Decision thresold** 

 $c_A^{\#}$ 

 $c^*_A$ 

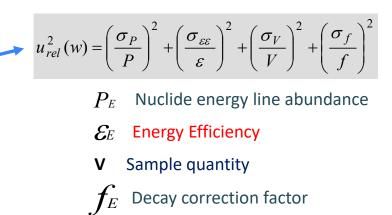
 $u_{rel}^2(w)$ 

$$w = \frac{1}{P_{E}.\varepsilon_{E}.V.f_{E}}$$

#### Where:

| *                    |                               |
|----------------------|-------------------------------|
| $\mathcal{C}_A$      | Decision threshold            |
| $k_{1-lpha}$         | Confidence factor             |
|                      | 1.645 for 95%, 1.96 for 97.5% |
| $n_{b, E}$           | Integral of the region        |
| $u^{2}_{(n_{b}, E)}$ | Integral Uncertainty          |
| $t_{g}$              | Active count time             |

Where:



## **Correlations in Calibration Standards**

∫\_\_\_\_ Imp Cal



Support for Correlations in Calibration Standards



Automation Improvements w Python Scripting

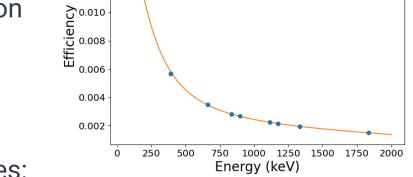


More Value: ISOCS Genie-Fieldpro, QA



Electronic Download and Licensing

- The uncertainty in an efficiency calibration is propagated to the uncertainty of the unknown sample activity.
- Uncertainty propagation is different for correlated values than independent values:



0.016

0.014

0.012

Efficiency calibration

Fit Tit Data

- Generally additional independent measurements improve the knowledge of the detector efficiency response, driving down the final activity uncertainty.
- Additional fully-correlated measurements *do not* improve the knowledge of the detector efficiency response, and the final activity uncertainty may be higher than with values treated independently.
- Uncertainty propagation and management is a topic of focus by regulators and the scientific community

## **Correlations in Calibration Standards**



Improved FW/HM

Calibration Optio



Support for Correlations in Calibration Standards

mprovements wi Python Scripting

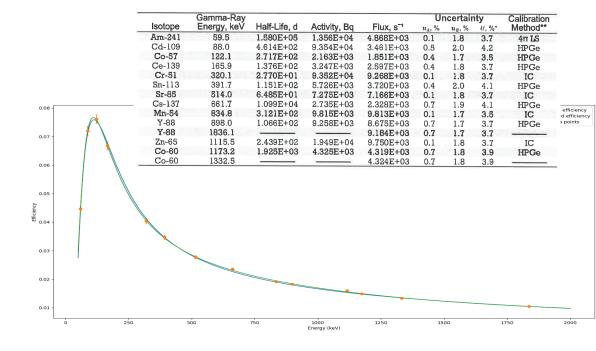
More Value: ISOCS, Genie-Fieldpro, QA/0



Electronic Download and Licensing

#### **Definitions:**

- Two vales are "correlated" if there is a relationship between the measurements
- Two values are independent if there is no information gained



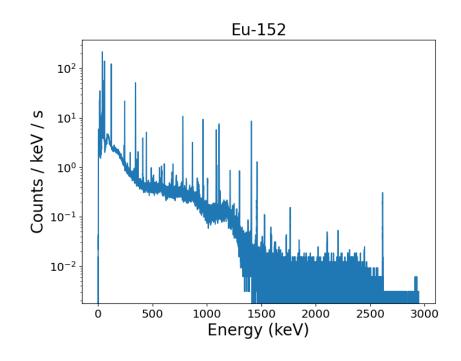
about one measurement from the other measurement

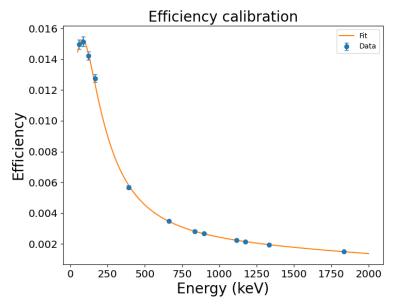
#### In our application:

- In Gamma Spectroscopy and Efficiency Calibrations, the item being "measured" is the true efficiency of the detector at various energies.
- The measurement values are the calculated "efficiency triplets" from the emission lines of the calibration standard.

# Genie 4.0 Correlation improvement Introduction

- For high precision gamma spectrometry, the uncertainty from efficiency calibration is often dominating
- Quantities in gamma spectrometry can be determined using multiple measurements
  - Efficiency as a function of Energy, weighted mean activity of radionuclides
- When these measurements are independent the uncertainty is reduced when more measurements are added
- This leads to uncertainties from the efficiency fit to be lower than the uncertainty of the individual points unless correlations between data points are accounted for



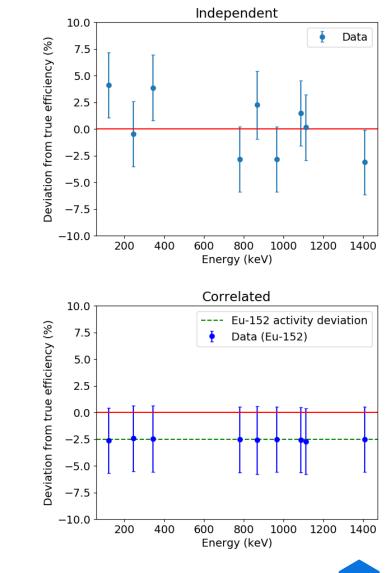


# Genie 4.0 Correlation

- Correlations are relations in data that varies together in a way not expected from chance alone
- The emission rate for lines from a multiline radionuclide
- Changes the least squares fit

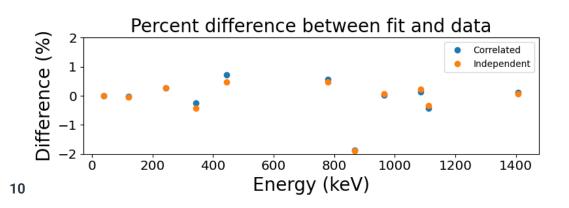
$$\chi^{2} = \sum_{i=1}^{n} \frac{(y_{i} - f(x))^{2}}{\sigma_{y_{i}}^{2}} \to \chi^{2} = (y - f(x))^{T} V^{-1} (y - f(x))$$

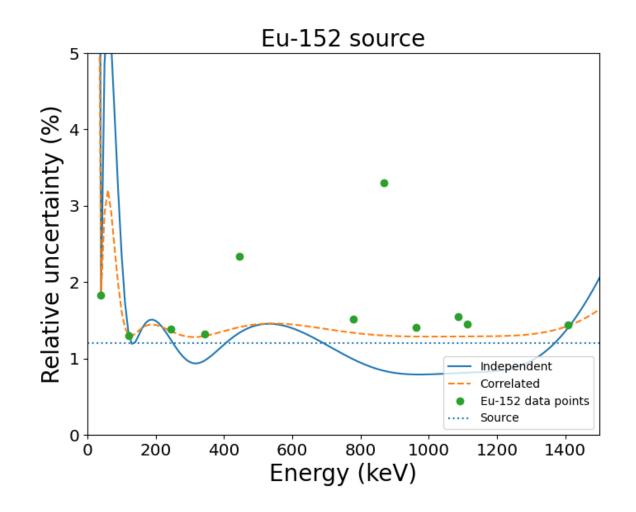
- This has consequences for efficiency calibration, weighted mean activity and interference correction of activities\*
- But also for MDA ISO11929 calculation



### **Example 1 - Single radionuclide calibration**

- Eu-152 calibration
  - Point source at 30 cm
  - 20% rel eff p-type detector
  - Multiple emission lines with correlation from the radionuclide activity
- Activity has a relative uncertainty of 3.1% at 99% CL

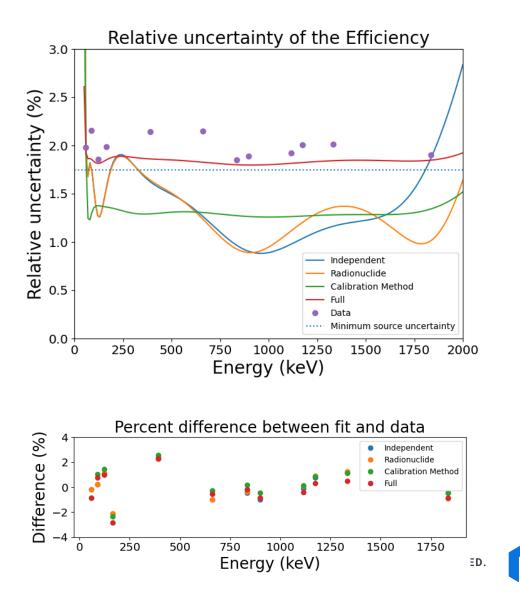




# Example 2 - Mixed gamma source

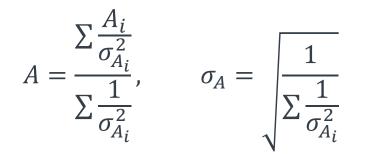
- Multi-radionuclide calibration source
- The level of correlation depends on the assumptions
  - All points independent
  - · Points from same radionuclide correlated
  - Points using the same calibration method correlated
  - All points correlated
- For the most conservative assumption the relative uncertainty will be slightly above the lowest relative uncertainty from the certificate.

|         | Gamma-Ray   |              |              |           | Ur        | certair   | nty   | Calibration |
|---------|-------------|--------------|--------------|-----------|-----------|-----------|-------|-------------|
| Isotope | Energy, keV | Half-Life, d | Activity, Bq | Flux, s⁻¹ | $u_A, \%$ | $u_B, \%$ | U, %* | Method**    |
| Am-241  | 59.5        | 1.580E+05    | 1.358E+04    | 4.875E+03 | 0.1       | 1.8       | 3.7   | 4π LS       |
| Cd-109  | 88.0        | 4.614E+02    | 9.367E+04    | 3.466E+03 | 0.5       | 2.0       | 4.2   | HPGe        |
| Co-57   | 122.1       | 2.717E+02    | 2.165E+03    | 1.854E+03 | 0.4       | 1.7       | 3.5   | HPGe        |
| Ce-139  | 165.9       | 1.376E+02    | 3.251E+03    | 2.601E+03 | 0.4       | 1.8       | 3.7   | HPGe        |
| Cr-51   | 320.1       | 2.770E+01    | 9.365E+04    | 9.281E+03 | 0.1       | 1.8       | 3.7   | IC          |
| Sn-113  | 391.7       | 1.151E+02    | 5.733E+03    | 3.725E+03 | 0.4       | 2.0       | 4.1   | HPGe        |
| Sr-85   | 514.0       | 6.485E+01    | 7.285E+03    | 7.175E+03 | 0.1       | 1.8       | 3.7   | IC          |
| Cs-137  | 661.7       | 1.099E+04    | 2.739E+03    | 2.331E+03 | 0.7       | 1.9       | 4.1   | HPGe        |
| Mn-54   | 834.8       | 3.121E+02    | 9.828E+03    | 9.826E+03 | 0.1       | 1.7       | 3.5   | IC          |
| Y-88    | 898.0       | 1.066E+02    | 9.270E+03    | 8.686E+03 | 0.7       | 1.7       | 3.7   | HPGe        |
| Y-88    | 1836.1      |              |              | 9.196E+03 | 0.7       | 1.7       | 3.7   | -           |
| Zn-65   | 1115.5      | 2.439E+02    | 1.951E+04    | 9.763E+03 | 0.1       | 1.8       | 3.7   | IC          |
| Co-60   | 1173.2      | 1.925E+03    | 4.331E+03    | 4.324E+03 | 0.7       | 1.8       | 3.9   | HPGe        |
| Co-60   | 1332.5      | <u> </u>     |              | 4.330E+03 | 0.7       | 1.8       | 3.9   |             |



# Weighted mean activity

• Independent weighted mean



• New Correlated weighted mean algo

$$A = \frac{\sum_{i,j} V_{ij}^{-1} A_j}{\sum_{i,j} V_{ij}^{-1}}, \qquad \sigma_A = \sqrt{\frac{1}{\sum_{i,j} V_{ij}^{-1}}}$$

From covariance matrix 
$$V = \begin{pmatrix} \frac{\sigma_{\varepsilon_1}^2}{\varepsilon_1^2} & \dots & V_{1n} \\ \dots & \dots & \dots \\ V_{n1} & \dots & \frac{\sigma_{\varepsilon_n}^2}{\varepsilon_n^2} \end{pmatrix}$$

| Energy<br>(keV) | Eff:Corr<br>WtM:Corr | Eff:Corr<br>WtM:Indep | Eff:Indep<br>WtM:Corr | Eff:Indep<br>WtM:Indep |
|-----------------|----------------------|-----------------------|-----------------------|------------------------|
| 121.8           | 1.39 %               | 1.39 %                | 1.39 %                | 1.39 %                 |
| 244.7           | 1.52 %               | 1.52 %                | 1.42 %                | 1.42 %                 |
| 344.3           | 1.41 %               | 1.41 %                | 1.12 %                | 1.12 %                 |
| 444.0           | 2.47 %               | 2.47 %                | 2.43 %                | 2.43 %                 |
| 778.9           | 1.62 %               | 1.62 %                | 1.35 %                | 1.35 %                 |
| 867.4           | 3.33 %               | 3.33 %                | 3.18 %                | 3.18 %                 |
| 964.1           | 1.48 %               | 1.48 %                | 1.08 %                | 1.08 %                 |
| 1085.9          | 1.62 %               | 1.62 %                | 1.27 %                | 1.27 %                 |
| 1112.1          | 1.52 %               | 1.52 %                | 1.15 %                | 1.15 %                 |
| 1408.0          | 1.63 %               | 1.63 %                | 1.61 %                | 1.61 %                 |
| Wt Mean         | 1.25 %               | 0.52 %                | 0.55 %                | 0.44 %                 |

Relative uncertainty of Eu-152 source 1.20 %

# **Correlations are supported in Genie 4.0**

• Primary User Focus: Updated

Certificate File Editor (see right).

This is where the user defines how the calibration source standard emission lines are correlated.

#### • Transparent for the user

Genie algorithms updated for efficiency calibration fits and nuclide identification with interference correction engine (now called w/ Correlations") "NID

| 🖉 Certificat  | te File Editor - N   | BSNEW.CTF   |  |   |  |   |   |  | _  |  | > |
|---|--|---|--|---|--|---|---|--|--|--|---|
| ile Option  | s Help   |   |  |   |  |   |   |  |  |  |   |
| Title:  | NBS Standard   |   |  |   |  |   |   |  |  |  |   |
| Quantity:   | 1  | unit(s)   | Assay date:  | 9/ 1/1978   |  |   | 00:00 AM  | -  |  |  |   |
|   |  |   |  | 1   |  |   |   | -  |  |  |   |
| Certificate In  | nage:  |   |  |   |  |   |   |  |  | Browse   | 1 |
| C-166-11-11   | n a artainte Canalal   | tion: 🔍 F   |  | Nuclide   | C None   | C Custo   | n Dofin   | e Custom Corre   | Jation                                   |  |   |
| Lertificate U   | ncertainty Correla   | uon: 🤊 r  | uii V  | Nuclide   | <ul> <li>None</li> </ul>   |   | Denn  | e custom cone  | siation                                  |  |   |
| luclide   |  |   |  |   |  |   |   |  |  |  | 1 |
| Name:   |  | CD-109  | ł  | Half-life:  |  | 462.9 🖸   |   |  |  | Add  |   |
| Activity:   |  | 14247.1 Ba  | 1  | Uncertainty:  |  | 2 0   |   |  |  |  | 1 |
| -   |  | 3.0227  | Ì  | ornoontainty.   | ,  | - ° °   | S   |  |  | Change   |   |
| % Uncertaint  | ty: I  | 3.0227  |  |   |  |   |   |  |  |  |   |
| ine   |  |   |  |   |  |   |   |  |  |  |   |
|   |  |   |  |   |  |   |   |  |  | Delete   |   |
|   | 00.0241  | half Intern   | -11-11   |   | 2.01   | Enciencies I  | Data (atturitt):  | E14  | 2202                                     | Delete   |   |
| nergy:  | 88.0341  | keV Inten   | sity:  |   | 3.61   | Emissin F   | Rate (s=1 unit=1):  | 514  | .3203                                    |  |   |
| Energy:<br>🔽 Use for C  | 1  |   | sity:<br>rtainty:  |   | 3.61   | Emissin F<br>% Uncert   |   |  | 1.3203                                   | Delete<br>Clear  |   |
|   | 1  |   |  |   |  |   |   |  |  |  |   |
| Use for C   | 1  |   |  | Intensity (per<br>100 decays)                                     |  |   |   |  |  |  | e |
| ✓ Use for C<br>Nuclide<br>CD-109  | alib/Init  | Unce<br>%Uncert<br>3.023                              | rtainty:   | 100 decays)<br>3.6100   | 0.1<br>Uncertainty   | % Uncert<br>Rate<br>(s⁻¹ unit⁻¹)<br>514.3203  | ainty:<br>%Uncert<br>4.1000   | 4<br>Half-life   | .1000                                    | Clear<br>Current Rate<br>(s 1 unit 1)<br>1.95e-08  |   |
| ✓ Use for C<br>Nuclide<br>CD-109<br>CO-57                               | alib/Init<br>Activity (Bq)<br>14247.100<br>1068.310                                    | Unce<br>%Uncert<br><u>3.023</u><br>1.700              | rtainty:<br>Energy (keV)<br>88.034<br>122.061                                  | 100 decays)<br>3.6100<br>85.9000                                  | 0.1<br>Uncertainty<br>(per 100)<br>0.1000<br>1.2000                      | % Uncert<br>Rate<br>(s <sup>-1</sup> unit <sup>-1</sup> )<br>514.3203<br>917.6783                           | ainty:<br>%Uncert<br><u>4.1000</u><br>2.2000                        | Half-life  | .1000<br>Uncertainty<br>2.0000<br>0.0500 | Clear<br>Current Rate<br>(s 1 unit 1)<br>1.95e-08<br>1.65e-15                                      |   |
| Vuclide   | alib/Init<br>Activity (Bq)<br>14247.100<br>1068.310<br>690.209                         | Unce<br>%Uncert<br>3.023<br>1.700<br>4.000            | rtainty:<br>Energy (keV)<br>88.034<br>122.061<br>165.853                       | 100 decays)<br>3.6100<br>85.9000<br>79.8860                       | 0.1<br>Uncertainty<br>(per 100)<br>0.1000<br>1.2000<br>0.0150            | % Uncert<br>Rate<br>(s <sup>-1</sup> unit <sup>-1</sup> )<br>514.3203<br>917.6783<br>551.3803               | ainty:<br>%Uncert<br>4.1000<br>2.2000<br>4.0000                     | Half-life<br>462.90 D<br>271.80 D<br>137.64 D                        | Uncertainty                              | Clear<br>Current Rate<br>(s 1 unit 1)<br>1.95e-08<br>1.65e-15<br>4.98e-33                          |   |
| Use for C<br>Nuclide<br>CD-109<br>CO-57<br>CE-139<br>HG-203             | alib/Init<br>Activity (Bq)<br>14247.100<br>1068.310<br>690.209<br>2134.180             | Unce<br>%Uncert<br>3.023<br>1.700<br>4.000<br>2.495   | rtainty:<br>Energy (keV)<br>88.034<br>122.061<br>165.853<br>279.197            | 100 decays)<br>3.6100<br>85.9000<br>79.8860<br>81.4600            | 0.1<br>Uncertainty<br>(per 100)<br>0.1000<br>1.2000<br>0.0150<br>0.1300  | & Uncert<br>Rate<br>(s <sup>-1</sup> unit <sup>-1</sup> )<br>514.3203<br>917.6783<br>551.3803<br>1738.5029  | *ainty:<br>%Uncert<br>4.1000<br>2.2000<br>4.0000<br>2.5000          | Half-life<br>462.90 D<br>271.80 D<br>137.64 D<br>46.61 D             | Uncertainty                              | Clear<br>Current Rate<br>(s <sup>-1</sup> unit <sup>1</sup> )<br>1.65e-15<br>4.98e-33<br>5.74e-101 |   |
| ✓ Use for C<br>Nuclide<br>CD-109<br>CO-57<br>CE-139<br>HG-203<br>SN-113 | alib/Init<br>Activity (Bq)<br>14247.100<br>1068.310<br>690.209<br>2134.180<br>2580.310 | Uncert<br>%Uncert<br>1.700<br>4.000<br>2.495<br>3.643 | rtainty:<br>Energy (keV)<br>88.034<br>122.061<br>165.853<br>279.197<br>391.688 | 100 decays)<br>3.6100<br>85.9000<br>79.8860<br>81.4600<br>64.0000 | 0.1<br>Uncertainty<br>(per 100)<br>0.12000<br>0.0150<br>0.1300<br>2.0000 | % Uncert<br>Rate<br>(s <sup>-1</sup> unit <sup>-1</sup> )<br>917.6783<br>551.3803<br>1738.5029<br>1651.3986 | Ainty:<br>XUncert<br>4.1000<br>2.2000<br>4.0000<br>2.5000<br>4.8000 | Half-life<br>462.90 D<br>271.80 D<br>137.64 D<br>46.61 D<br>115.09 D | Uncertainty                              | Clear<br>Current Rate<br>(s*1 unit*1)<br>1.95e-08<br>1.65e-15<br>4.98e-33<br>5.74e-101<br>2.03e-39 |   |
| ✓ Use for C<br>Nuclide<br>CD-109<br>CO-57<br>CE-139<br>HG-203           | alib/Init<br>Activity (Bq)<br>14247.100<br>1068.310<br>690.209<br>2134.180             | Unce<br>%Uncert<br>3.023<br>1.700<br>4.000<br>2.495   | rtainty:<br>Energy (keV)<br>88.034<br>122.061<br>165.853<br>279.197            | 100 decays)<br>3.6100<br>85.9000<br>79.8860<br>81.4600            | 0.1<br>Uncertainty<br>(per 100)<br>0.1000<br>1.2000<br>0.0150<br>0.1300  | & Uncert<br>Rate<br>(s <sup>-1</sup> unit <sup>-1</sup> )<br>514.3203<br>917.6783<br>551.3803<br>1738.5029  | *ainty:<br>%Uncert<br>4.1000<br>2.2000<br>4.0000<br>2.5000          | Half-life<br>462.90 D<br>271.80 D<br>137.64 D<br>46.61 D             | Uncertainty                              | Clear<br>Current Rate<br>(s <sup>-1</sup> unit <sup>1</sup> )<br>1.65e-15<br>4.98e-33<br>5.74e-101 |   |

# Conclusion

- Taking correlations into account for efficiency calibration and activity calculations in gamma spectrometry can increase the uncertainty of the radionuclide activities when the efficiency data points are correlated.
- Uncertainties in the independent variable, intensities, are necessary when performing interference correction when the relative uncertainty in the decay data is comparable or large compared to other uncertainties.
- Nuclide Activity Uncertainty Results <u>may</u> increase by 1-3%

# Included in Genie 4.0



# Genie 4.0 webinar presentation available on our website

Latest in Gamma Spectroscopy: New Genie<sup>™</sup> 4.0 Software (on24.com)

# Thank you

Special thank to our scientist team Henrik Persson, Troy Anderson, John M Kirkpatrick, Kara Phillips