Sources of Uncertainty in Gamma Spectrometry

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Nordic GammaSem Seminar
17. Sept. 2009

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Sources of Uncertainty

Presentation Overview

- **Uncertainties contributing to the total measurement uncertainty**
- **Cascade Summing Effect**
- **Unknown sample characteristics**

Sources of Uncertainty

- **Uncertainties contributing to the total measurement uncertainty (TMU)**
  - **Statistical measurement uncertainty**
    - Value may be very different depending on
      - Activity of sample (Count Rate)
      - Counting Time
      - Environmental Background / Other nuclides in sample
    - Range:
      - Few percent to 100%

Sources of Uncertainty

- **Uncertainties contributing to the TMU**
  - **Calibration (Efficiency) Uncertainty**
    - 2 different ways of determining the efficiency

      - Calibration source

      - Mathematical calculation, f. ex. by ISOCS / LabSOCS (Canberra)

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Sources of Uncertainty

- **Calibration source**
  - **Depending on the price of the calibration source, the inherent source uncertainty is in the range of 1 – 5 %**
  - **Additional: statistical uncertainty of the calibration source measurement**
  - **The statistical uncertainty mostly can be reduced to a level of 1 – 2 %**
  - **Summary: The calibration uncertainty is in the range of 2 – 5 or 6%**

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Sources of Uncertainty

- **Mathematical Efficiency Calculation**
  - **Based on Monte Carlo Simulations**
  - **Range:**
    - 4 to 10 % depending on γ- Energy
  - **Summary: it looks, as if the uncertainty from mathematical calibrations is higher than the uncertainty from Source calibrations – see later**

Sources of Uncertainty

- **Nuclear Parameters**
  - **Uncertainty in half live**
  - **Uncertainty in emission rate**
  - **Neglegible**

- **Uncertainty in Counting time**
  - **Neglegible**

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Sources of Uncertainty

- **Systematic Uncertainty**
- **Random Uncertainty**
  - **Sample Preparation**
  - **Sample Quantity**

Sources of Uncertainty

- All the listed uncertainties are mathematically propagated and result in a Total Measurement Uncertainty (TMU)
- A TMU of 3 to 5% (or even lower) can be achieved
- In environmental samples, the TMU is mostly higher: >10%

Sources of Uncertainty

- **All the previous topics ignore the Cascade Summing Effect (True Coincidence Summing)**
- **This effect comes from the fact that many nuclides emit 2 or more gammas within a very short period of time, which are not separated in the detector. This results in the fact, that too few gammas of a specific energy are seen. So, an activity is calculated, which is too low.**
- **The Cascade Summing Effect depends on**
  - **The nuclide decay scheme**
  - **The sample geometry**

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Sources of Uncertainty

- **Genie-2000 can correct for the effects of Cascade Summing (Cascade Summing Correction: CSC)**
- **Prerequisites:**
  - **Knowledge of the detector characteristics, especially of the 'Total Efficiency'**
  - **Description of the sample geometry**
  - **Knowledge of the nuclide decay scheme (internally stored in a CSC Library)**

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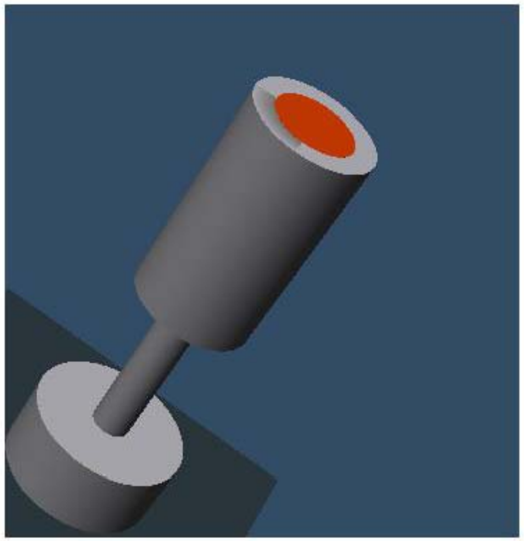
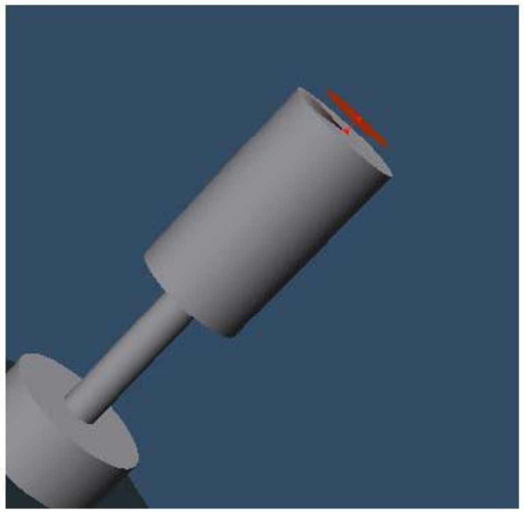
Sources of Uncertainty

- **The Total efficiency can be introduced in one of 2 ways:**
  - **Perform a P/T- Calibration and calculate it from this relationship and the known Peak- Efficiency**
  - **Calculate it directly based on the so-called detector characterization (Canberra) or on the known detector data (size, etc.) – This method is more precise than the calibration – It is available since version 3.2 (now)**
- **The nuclide data can be imported directly from internationally approved nuclide library (ENSDF)**

Sources of Uncertainty

- **Example:**
  - **Measurement of a filter sample (5cm dia.) , measured directly on top of the end cap and at 10 mm distance**
  - **Detector: about 30%**





Sources of Uncertainty

- **Example:**

direct

Nuclide Name	Energy (keV)	Coinc. corr.	Coinc. Corr.
NA-22	1274.54*	0.684	0.811
K-40	1460.81*	miss	
SC-46	889.25*	0.852	0.911
	1120.51*	0.844	0.906
MN-54	834.83*	miss	
CO-58	810.76*	0.999	0.999
FE-59	142.65		
	192.34*	0.851	0.911
	1099.22*	miss	
	1291.56*	1.011	1.007
CO-60	1173.22*	0.859	0.915
	1332.49*	0.854	0.913
ZN-69M	438.63*	free	
SE-75	96.73		
	121.11*	0.809	0.885
	136.00*	0.811	0.886
	198.60*	miss	
	264.65*	miss	
	279.53		
	303.91*	0.635	0.762
	400.65		
Y-93	266.90*	miss	
	947.10		
	1917.80		
NB-95	765.79*	free	

Nuclide Name	Energy (keV)	Coinc. corr.	Coinc. Corr.
ZR-95	724.18*	free	
	756.72*	free	
TC-96	778.22*	miss	
	812.54*	miss	
	849.86		
	1126.85*	miss	
ZR-97	254.15*	miss	
	355.39*	0.788	0.870
	507.63*	miss	
	602.52		
	743.36*	0.987	0.992
	1021.30		
	1147.00*	0.781	0.865
	1362.66		
	1750.46		
MO-99	140.51*	0.940	0.964
	181.06*	0.750	0.851
	366.43		
	739.58*	0.828	0.895
	778.00*	free	
RU-103	497.08*	free	
	610.33*	free	
RH-105	306.10*	free	
	318.90*	free	
RU-106	621.84*	miss	
	1050.47*	miss	

Nuclide Name	Energy (keV)	Coinc. corr.	Coinc. Corr.
AG-110M	446.80*	0.594	0.740
	620.35*	0.590	0.737
	657.75*	0.686	0.803
	677.61*	0.589	0.737
	686.99		
	706.67*	0.611	0.752
	744.26*	0.637	0.769
	763.93		
	818.02*	0.591	0.738
	884.67*	0.681	0.801
	937.48*	0.690	0.807
	1384.27*	0.742	0.843
	1475.76		
	1505.00*	0.726	0.832
	1562.27		

1 cm from end cap

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Sources of Uncertainty

- **Estimation of Uncertainties for Calibration**
  - **Eff calibration with calibration source: Uncertainty: few percent**
  - **Mathematical eff calibration: Uncertainty: 4 to 10 percent**
- **For calibration sources:**
  - **Size of uncertainty only valid, if physical characteristics of the calibration source are identical to those of the real sample**
- **For mathematical calibration:**
  - **This value only applies for the statistical simulation process**
- **Additional uncertainties arise from differences in the source properties**

Sources of Uncertainty

- The source calibration cannot take these differences into account
- The mathematical calibration can do so, if the characteristics are known

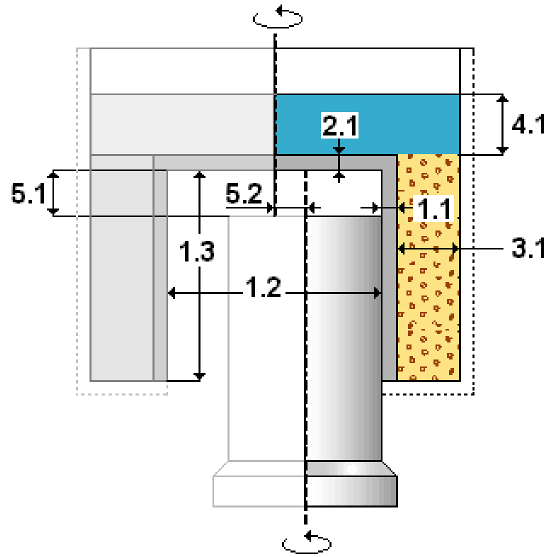
Sources of Uncertainty

- **If this is not the case, uncertainties can be determined by**
  - **ISOCS**
  - **Uncertainty**
  - **Estimator**
- **IUE is based on the ISOCS sample model**
- **It varies the not well known information and calculates statistical variations of the efficiency curve**

Sources of Uncertainty

- **Example:**
  - **Detector: 30%**
  - **Sample:**
    - Marinelli Beaker filled with 1.6 kg of soil
    - Wall thickness of beaker: between 1.3 and 3.0 mm
    - Density of material between 1.4 and 1.7 g/cm3
    - Filling height between 110.9 and 127.7 mm (depending on density of material)

General Purpose Marinelli Beaker



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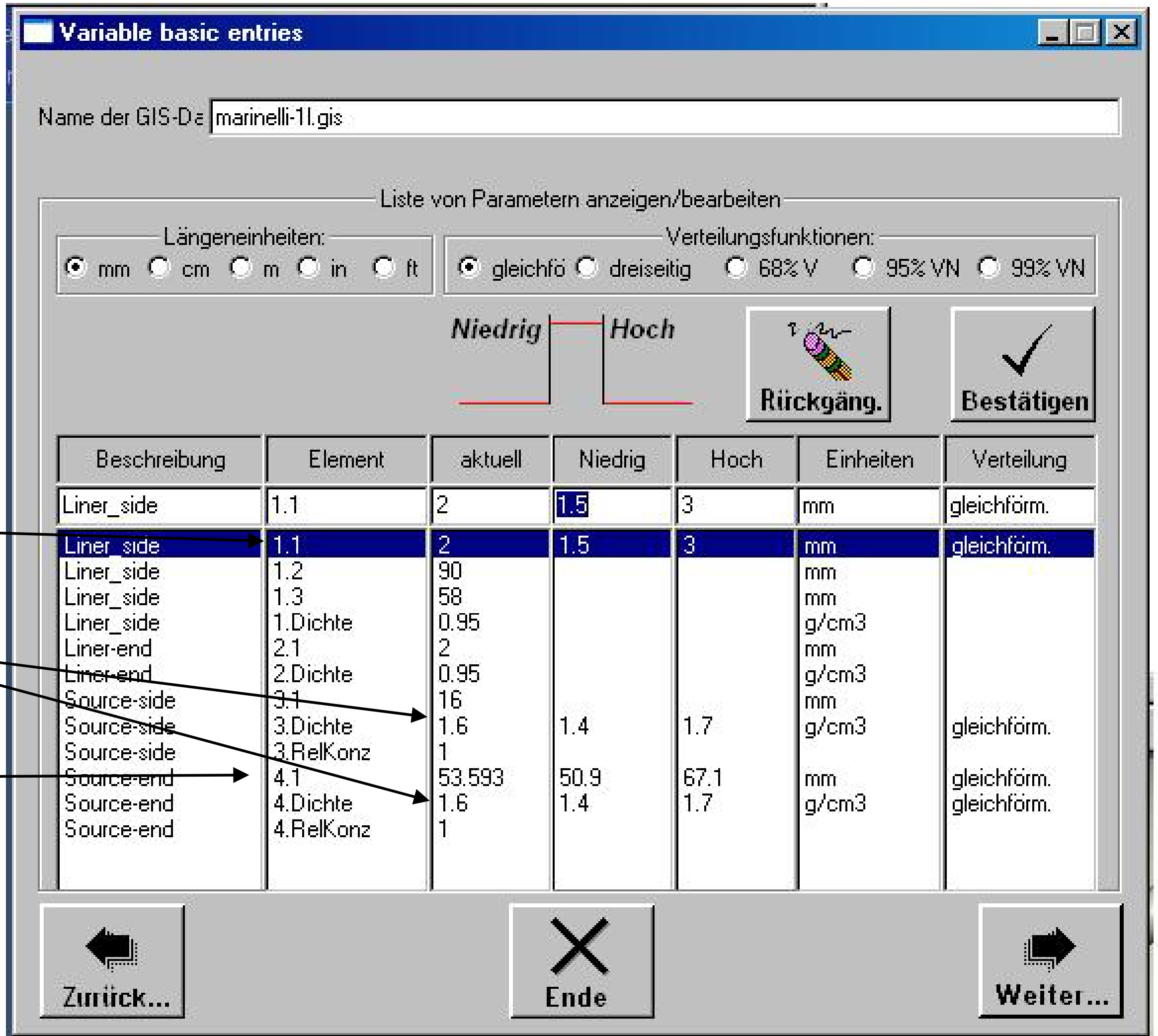
Sources of Uncertainty

- **Example:**
  - **Detector: 30%**
  - **Sample:**

Wall thickness

Density of material

Filling height



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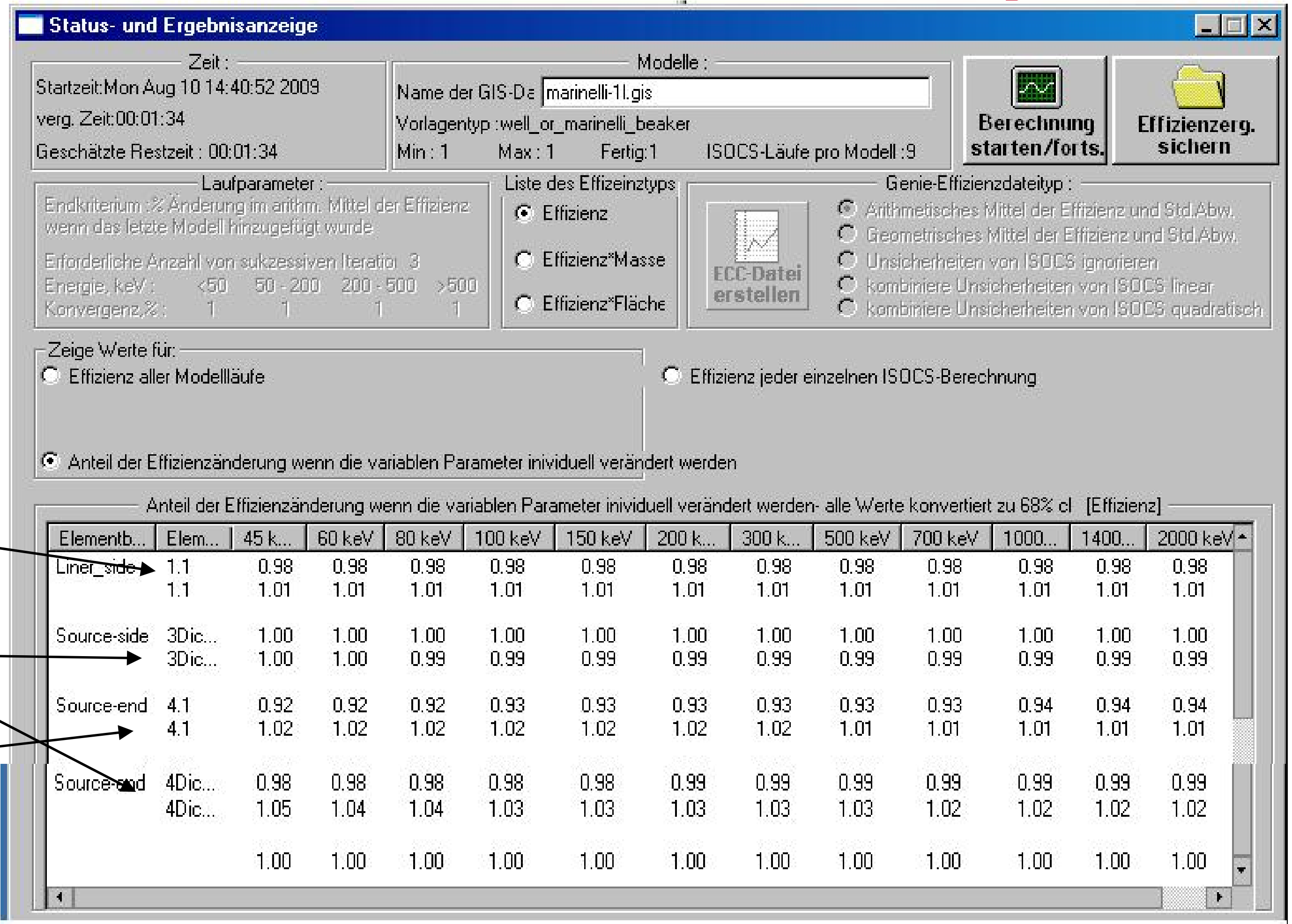
Sources of Uncertainty

- **Example:**
  - **Results:**

Wall thickness

Density of material

Filling height



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