The true coincidence summing correction method at STUK, Finland

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STUK gamma spectrum analysing program including summing correction

- Original STUK analysing program GAMMA-81: coincidence summing correction subroutine CSUM based on the general equations presented by Andreev et al. (1972) and McCallum and Coote (1975)
- In 1985 CSCOR program: the effect of X-rays (following internal conversion or decay by EC) by Debertin and Schötzig (1979)
- CSCOR can be run also separately

Input data

- Full-energy peak efficiency
- Total efficiency
- Detailed/modified decay scheme data including conversion coefficient data

line 1: symbol, half-life, type of decay (β, EC)
line 2: energy of KX-ray, fluorescence yield, numbers of energies (n), excitation levels, protons and neutrons
line 3-n: initial and final excitation **levels**, **energy** of the transition, gamma-ray **intensity**, **total** internal conversion coefficient, **K-conversion** coefficient, intensity of decay to the initial level

```
Cs-134     2.0648     Y        B-
32.9       0.877      9          5          55          79
4  2       475.35     1.465      1.00E-2    1.00E-2     0.0248
2  1       563.227    8.38       5.7E-3     5.7E-3      0.0045
5  3       569.315    15.43      7.8E-3     7.8E-3      0.274
1  0       604.699    97.56      5.03E-3    5.03E-3     0.00008
3  1       795.845    85.44      2.63E-3    2.63E-3     0.7011
5  2       801.932    8.73       2.69E-3    2.69E-3     0.274
4  1       1038.571   1.00       1.73E-3    1.73E-3     0.0248
2  0       1167.938   1.805      1.18E-3    1.18E-3     0.0045
5  1       1365.152   3.04       8.2E-4     8.2E-4      0.274
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Output

```
 ------ CSCOR -----   13-JAN-09

LIBRARY : CS134.dat  EFFICIENCY DATA : c2a.dat    SAMPLE HEIGHT :  0.0      RHO : 1.0


Cs-134

EKX=32.90  OMK= 0.877  EPX=8.7888E-02  ETX=1.2595E-01
```

TRANSIT. I-K	ENERGY	INTENSITY	CONVERSION COEFFICIENT	BRANCHING	PEAK EFF.	TOTAL EFF.	DECAY TO LEVEL I
1-0	604.69	9.7630E-01	5.9000E-03	4.9400E-03	1.6834E-02	7.7784E-02	8.0000E-05
2-0	1167.92	1.7920E-02	1.3100E-03	1.1200E-03	9.0999E-03	5.1719E-02	4.5000E-03
2-1	563.23	8.3800E-02	7.3000E-03	6.1000E-03	1.7963E-02	8.0605E-02	4.5000E-03
3-1	795.84	8.5520E-01	3.0000E-03	2.5800E-03	1.3036E-02	6.6271E-02	7.0110E-01
4-1	1038.56	1.0000E-02	1.8000E-03	1.5700E-03	1.0151E-02	5.5795E-02	2.4800E-02
4-2	475.34	1.5000E-02	1.1400E-02	9.5000E-03	2.0925E-02	8.6706E-02	2.4800E-02
4-3	242.80	2.1000E-04	8.7000E-02	7.2200E-02	4.5845E-02	1.0335E-01	2.4800E-02
5-1	1365.16	3.0150E-02	9.6000E-04	8.2000E-04	7.8759E-03	4.6210E-02	2.7400E-01
5-2	801.93	8.7000E-02	3.0000E-03	2.5400E-03	1.2943E-02	6.5952E-02	2.7400E-01
5-3	569.32	1.5390E-01	9.6000E-03	8.2000E-03	1.7788E-02	8.0186E-02	2.7400E-01
5-4	326.50	1.4000E-04	3.6700E-02	3.1000E-02	3.0935E-02	9.6918E-02	2.7400E-01

TRANSITION ENERGY I-K		**CORRECTION COEFFICIENT**				
1-0	604.69	**1.092**	S(I,K)=1.5106E-02	N(I)=9.0267E-01	D(I,K)=1.6735E-02	M(K)=1.0000E+00
2-0	1167.92	**0.928**	S(I,K)=1.8374E-04	N(I)=9.9898E-02	D(I,K)=1.8393E-03	M(K)=1.0000E+00
2-1	563.23	**1.161**	S(I,K)=1.3548E-03	N(I)=9.9898E-02	D(I,K)=1.4707E-02	M(K)=9.2213E-01
3-1	795.84	**1.101**	S(I,K)=1.0124E-02	N(I)=8.4474E-01	D(I,K)=1.2997E-02	M(K)=9.2213E-01
4-1	1038.56	**1.037**	S(I,K)=9.6104E-05	N(I)=2.4932E-02	D(I,K)=4.1802E-03	M(K)=9.2213E-01
4-2	475.34	**1.156**	S(I,K)=2.6641E-04	N(I)=2.4932E-02	D(I,K)=1.2349E-02	M(K)=8.6534E-01
4-3	242.80	**1.162**	S(I,K)=8.1302E-06	N(I)=2.4932E-02	D(I,K)=3.7877E-04	M(K)=8.6094E-01
5-1	1365.16	**0.889**	S(I,K)=2.6808E-04	N(I)=2.7400E-01	D(I,K)=1.0610E-03	M(K)=9.2213E-01
5-2	801.93	**1.156**	S(I,K)=9.7818E-04	N(I)=2.7400E-01	D(I,K)=4.1256E-03	M(K)=8.6534E-01
5-3	569.32	**1.162**	S(I,K)=2.3659E-03	N(I)=2.7400E-01	D(I,K)=1.0029E-02	M(K)=8.6094E-01
5-4	326.50	**1.217**	S(I,K)=3.5725E-06	N(I)=2.7400E-01	D(I,K)=1.5866E-05	M(K)=8.2177E-01

References

- Sinkko K., Aaltonen H., Calculation of the True Coincidence Summing Correction for Different Sample Geometries in Gamma-Ray Spectroscopy, Report STUK-B-VALO 40, Finnish Centre for Radiation and Nuclear Safety, Helsinki, 1985.
- Sinkko K. Computer analysis for gamma-ray spectra in sample measurements. Licentiate Thesis, Department of Physics. Helsinki: University of Helsinki, 1981. (In Finnish).
- Andreev D.S., Erokhina K.I., Zvonov V.S., Lemberg I.Kh., Consideration of Cascade Transitions in Determining the Absolute Yield of Gamma Rays. Translated from Pribory i Tekhnika Éksperimenta, No. 5, 63-65, 1972.
- G.J. McCallum, G.E. Coote, Influence of source-detector distance on relative intensity and angular correlation measurements with Ge(Li) spectrometers, Nucl. Instrum. and Methods 130 (1975) 189-197
- Debertin K., Schötzig U. Coincidence Summing Corrections in Ge(Li)-Spectrometry at Low Source-to-Detector Distances Nuclear Instruments and Methods 158 (1979), 471-477.

Gamma Laboratories

3 counting rooms:

2 in Helsinki, 1 in Rovaniemi

- Special concrete and mortar with low abundance of natural radionuclides

  Ra-226 6.2 Bq/kg

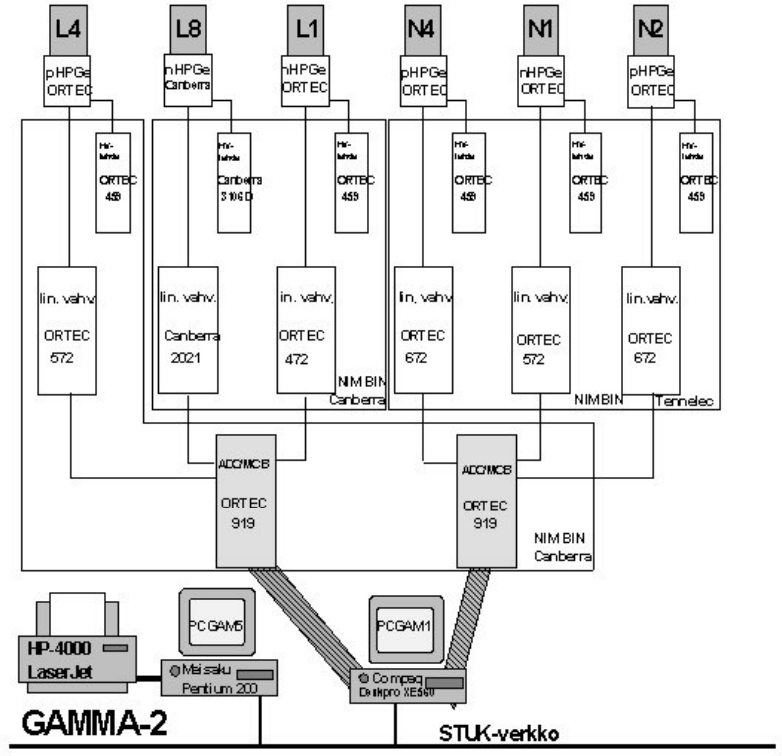
  Th-232 4.3 Bq/kg

  K-40 70.0 Bq/kg

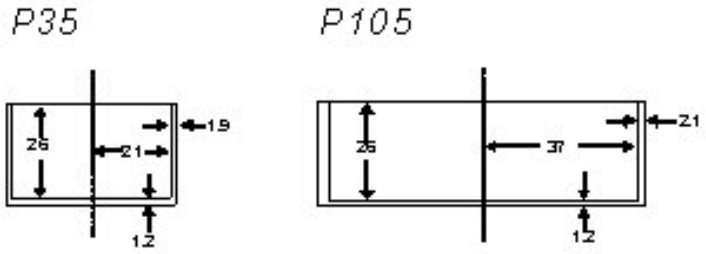
- Controlled access
- Special designs for air conditioning to decrease background radiation due to 1) radon, 2) severe fallout
- Separate counting and operator/computer rooms
- Pipelines for LIN supply
- UPS + reserve power generator

14 Spectrometers

- coaxial HPGe
- vertical cryostat
- 13 p-type, 1 n-type
- rel. eff. 20-100%
- 12-14 cm Pb BG-shielding
  Cu+Cd lined
- DSP + NIM electronics, MCB
- control: local PC or LAN
  workstations



Beakers



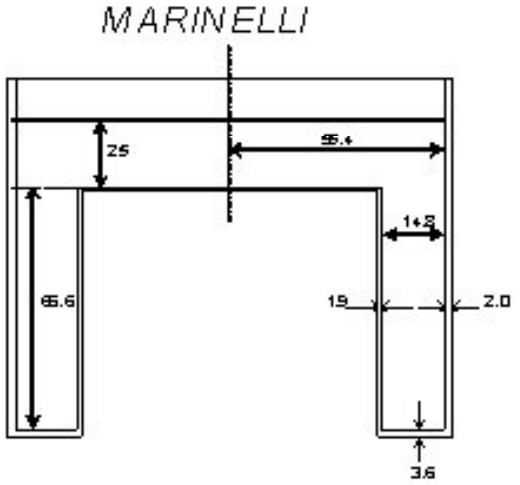
<u>cylindrical</u>:

0-30 ml, free sample height

0-100 ml, free sample height

<u>Marinelli</u>:

0.5 l, fixed sample height



New measuring geometries can be calibrated using DECCA-programme

Software

- Measurement control: **MAESTRO** from ORTEC
- Spectrum analysis: **GAMMA-99** from STUK
  - originally Gamma-81 (Fortran 5)
    - sample height and density correction
  - cascade summing correction since 1983 ! (Andreev, 1981)
  - DOS-version 1990 (Fortran 77)
  - Windows-version 1997
    - automatic and interactive operation modes
- Efficiency calibration calculation: **DECCA**
  - efficiency transfer method (Moens et al, 1981)
  - programmed in co-operation w. NRPA Norway in 1990
  - validated in ICRM and Euromet projects

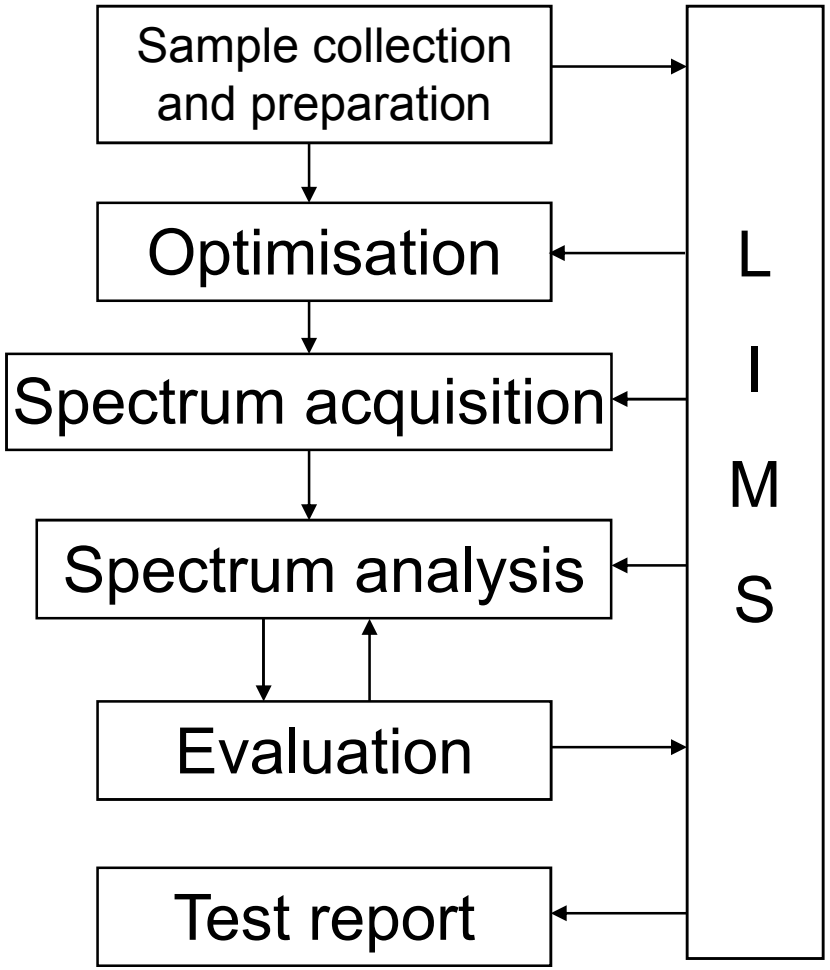
Accreditation

- 1995: Initial motivation: EC Council Directive 93/99
- 1996: Gamma spectrometry as a pilot project, 1st draft of quality manual
- 1997: STUK Quality system (TQM): basis for laboratory manuals
- 1998-1999: Preparation of the laboratory manuals
- 21.12.1998: Application for accreditation to FINAS
- Feb 1999: Main documentation to FINAS
- 17.12.1999: Accreditation certificate
- 2003: Renewed accreditation acc. ISO/IEC 17025

Fields and volume

- Surveillance of environmental radiation
  - Radioactive substances in outdoor air, deposition, surface water, drinking water, milk, foodstuffs and in the Baltic Sea
- Research, radioecological studies
  - Artificial radionuclides: fallout, NPP discharges, ...
  - Natural radionuclides: eg. wood ash, sediment dating, ...
- Contracted service
  - Industry NPP environmental monitoring, national and international organisations and institutes
- Emergency preparedness, method development, QA
- Total volume of gammalaboratories : **5000 anal./year**

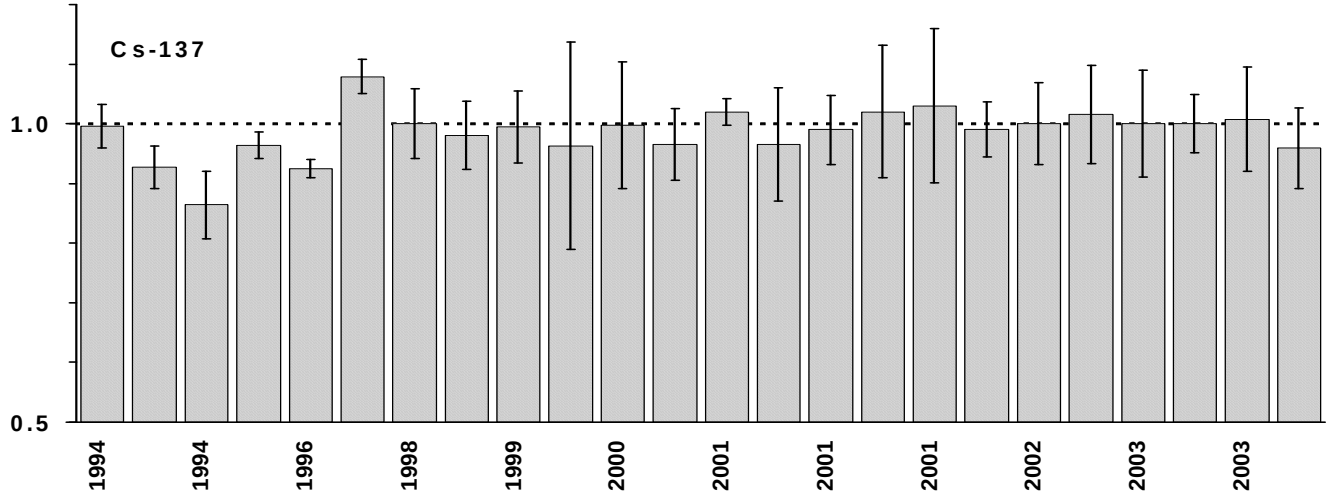
Procedure



- Sample collection & preparation not included in the method
- Optimisation of sample flow
  - right sample (amount), right detector (type and efficiency), right counting time
- Spectrum acquisition (counting', measurement')
- Computer analysis
- Evaluation of analysis report, re-analysis if needed
- All stages (to be) integrated to LIMS with advanced handling of uncertainties

Intercomparisons

+ Successful participation in intercomparisons: the best way of proving good quality
+ One of the ways to validate a new method
– The procedure → results not always comparable with routine work
– The results often only available after a long time, even years



Special Intercomparisons

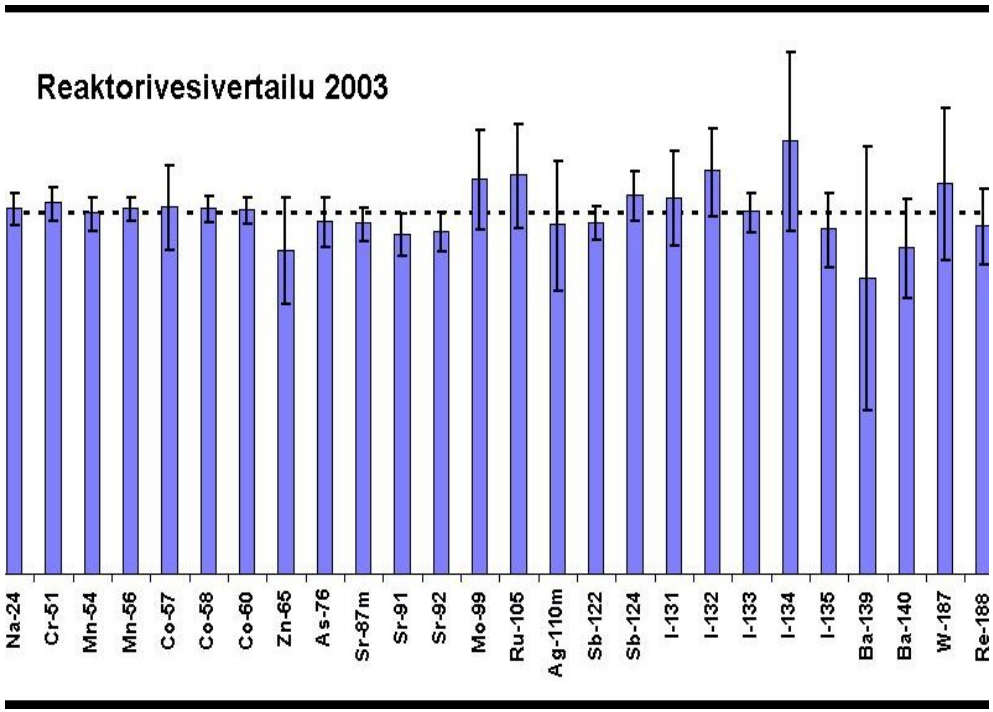
Fresh fission and activation products in NPP primary coolant water

- Inspection of power plant laboratory extended to intercomparison between 6 gamma spectrometry laboratories in Finland since 1994
- 'age' of the sample 3-5 h → possible to analyse nuclides with halv-lives < 1 h
- typically results of 30 nuclides

Use of Synthetic Spectra

to test and demostrate

- software capability and quality
- emergency preparedness
- personnel competence



The summing of gamma- and X-ray peaks + Ge-escape peaks

case : ^{111}In