Gamma Spectrometry at the Accredited Laboratory of STUK

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Radionuclide Analytics

Research and Environmental Surveillance

STUK - Radiation and Nuclear Safety Authority

Finland

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Accreditation

- Since 1999 the method of gamma spectrometric sample measurements at STUK has been accredited according to the standard EN ISO/IEC 17025 by

- Accreditation renewed in 2003 and 2007

- Two-grade scope of gammaspectrometric analysis in environmental samples, biological samples and foodstuffs

    - Gammaspectrometric measurements of Cs-137, Cs-134, I-131, K-40, U- and Th-decay series

    - Advanced analysis, all radionuclides emitting gamma-rays in the energy range of 30-2700 keV

- Since the reorganisation of the Department in 2007 all measurements in Helsinki have been performed at the Radionuclide Analytics Laboratory (NAL)

Gamma Laboratory

Counting rooms:

- Special concrete and mortar with low abundance of natural radionuclides
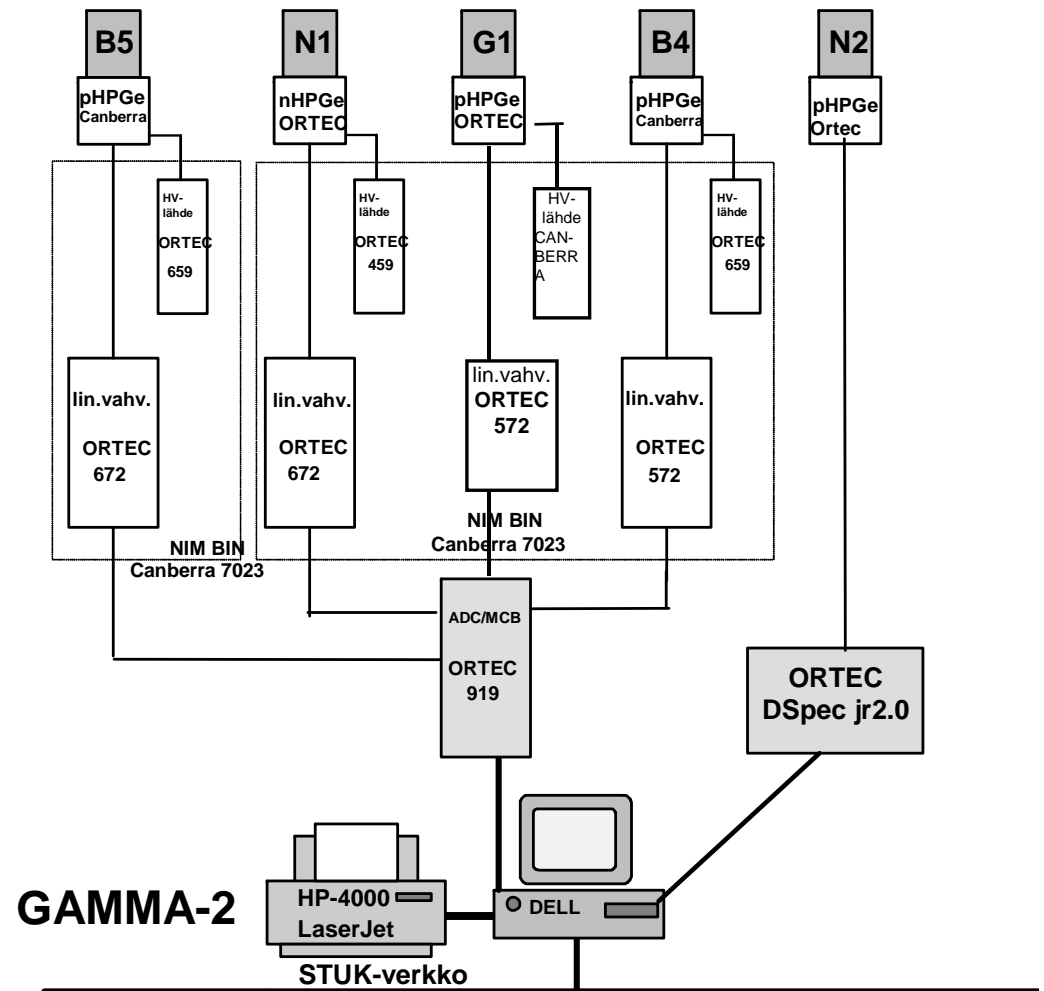
  Ra-226 6.2 Bq/kg

  Th-232 4.3 Bq/kg

  K-40   70.0 Bg/kg

- Controlled access

- Special air ventilation to decrease background radiation due to 1) ambient radon, 2) severe fallout

- Monitoring of temperature and humidity

- Separate counting and operator/computer rooms

- Pipelines for liquid nitrogen supply

- UPS + reserve power generator

10 Spectrometers

- coaxial HPGe

- vertical cryostat

- 9 p-type, 1 n-type

- rel. eff. 20-100%

- 12-14 cm Pb BG-shielding
  Cu+Cd lined

- DSP or NIM electronics, MCB

- meas. control & analysis:
  local PC or LAN workstations
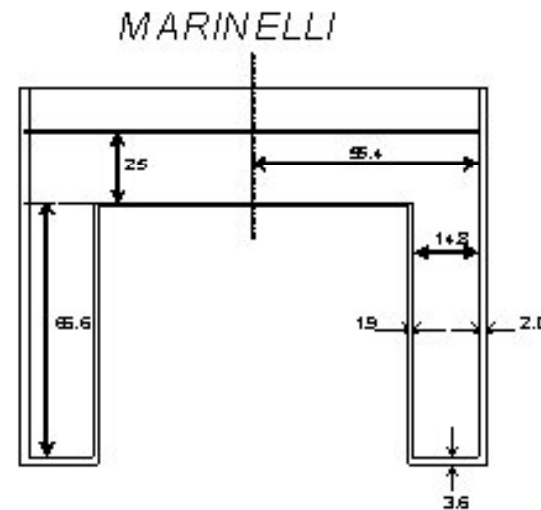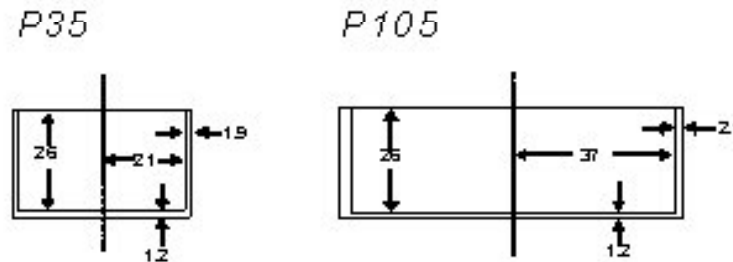
Standard measurement geometries

simple cylindrical:

- P35: 0-30 ml, free sample height

- P105: 0-100 ml, free sample height

Marinelli:

- 0.5 l, fixed sample height

Measured on top of a detector end-cap

New measuring geometries can be calibrated using semi-empirical DECCA-programme
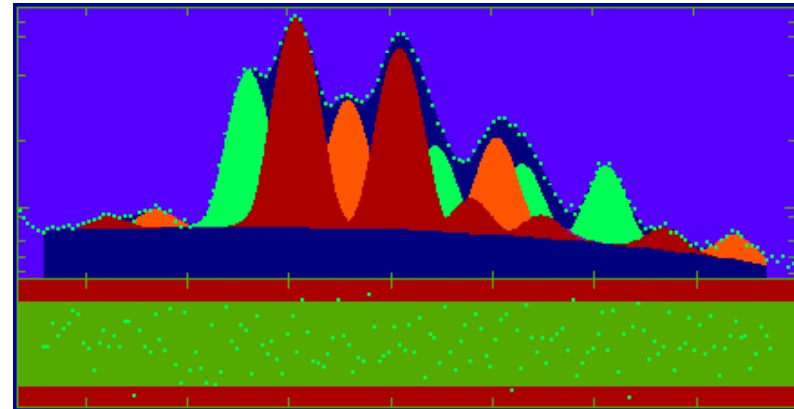
Software

- Measurement control
  - **MAESTRO** from ORTEC and **UniSampo**
- Spectrum analysis
  - **GAMMA-99** from STUK
    - Windows-version 1997
    - cascade summing correction since 1983 ! (Andreev, 1981)
    - sample height and density corrections
    - automatic and interactive operation modes
  - **UniSampo + Shaman**
- Efficiency calibration calculation
  - **DECCA**
    - efficiency transfer method (Moens et al, 1981)
    - developed in co-operation w. NRPA Norway in 1990
    - validated in ICRM and Euromet projects
  - **VGSL** Monte Carlo -method from CTBTO - not validated

UniSampo

- Member of the SAMPO family of gamma-spectrum analysis programs
- Run under Linux
- The graphical user interface (X window can be redirected to another computer using suitable software), interactive menu and cursor controls
- Flexible batch language for automated spectrum analysis
- Both **linear and nonlinear peak fitting** using precalibrated peak shapes
- Optional **step function under each peak of a multiplet**
- Automated energy and shape calibration features
- Able to analyze 32K spectra with up to 2500 peaks, and **32 peaks in a single multiplet** extending over a fitting interval of 1024 channels
- An **interface to the expert system SHAMAN**
- Support for MCA hardware: measurement control
- The first phase of the gamma-ray spectrum analysis: determination of the peak positions, energies, areas, and intensities with the corresponding uncertainty estimates
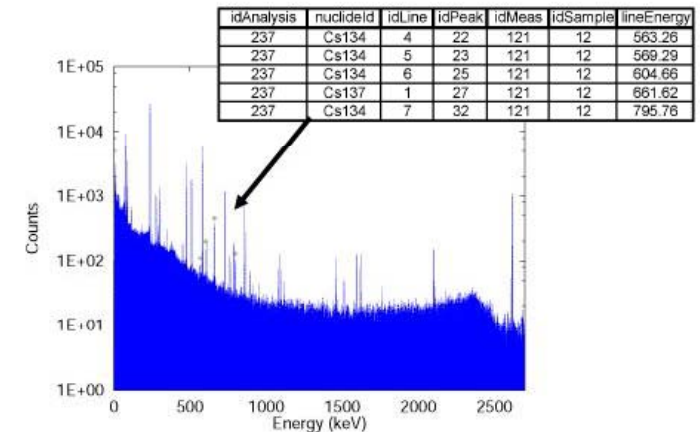
Shaman

- Expert system for radionuclide identification of gamma-ray spectra by Baryon Oy, Finland
- Rule-based expert system
  - mimics a human analyst: well-defined rules to discard false candidates and finds the final solution iteratively
  - knowledge base consists of about 60 rules
- Mathematical algorithms to qualitatively identify the radionuclides and to determine:
  - nuclide activities and concentrations taking into account e.g. <u>TCS corrections</u>
  - <u>MDA/MDC's</u>
  - associations between the nuclide's gamma lines and spectrum peaks
- Able to identify also most special peaks, incl. <u>escape</u> peaks, <u>sum</u> peaks, and <u>X-ray</u> peaks
- Utilizes a reference library with 3 648 radionuclides and 80 062 gamma lines
  - extracted from the ENSDF and NUDAT
- In batch mode both input and output is file-oriented, enabling fully automated operation: analysis pipeline
- Options to store data to a database (Linssi)

LINSSI

- SQL database for gamma-ray spectrometry:
  LINux System for Spectral Information

- Open source software (MySQL)
  developed in collaboration with
  - STUK
  - Baryon Ltd
  - Helsinki University of Technology
  - Health Canada

- Storing of all the relevant data starting from the
  collection of (air) sample to the final analysis results

- Enough information to enable a review of an analysis

- Emphasis on the analysis results and data directly
  affecting the quality of the results

LINSSI

- LINSSI 1.1 (2005)
  - 32 tables
  - 556 fields
- 2009: LINSSI 2.1
- Freely available
- Not dependent on UniSampo/Shaman
- Data in structured text files

- Complete description:
  http://www.tkk.fi/Units/AES/projects/radphys/linssi/index.htm
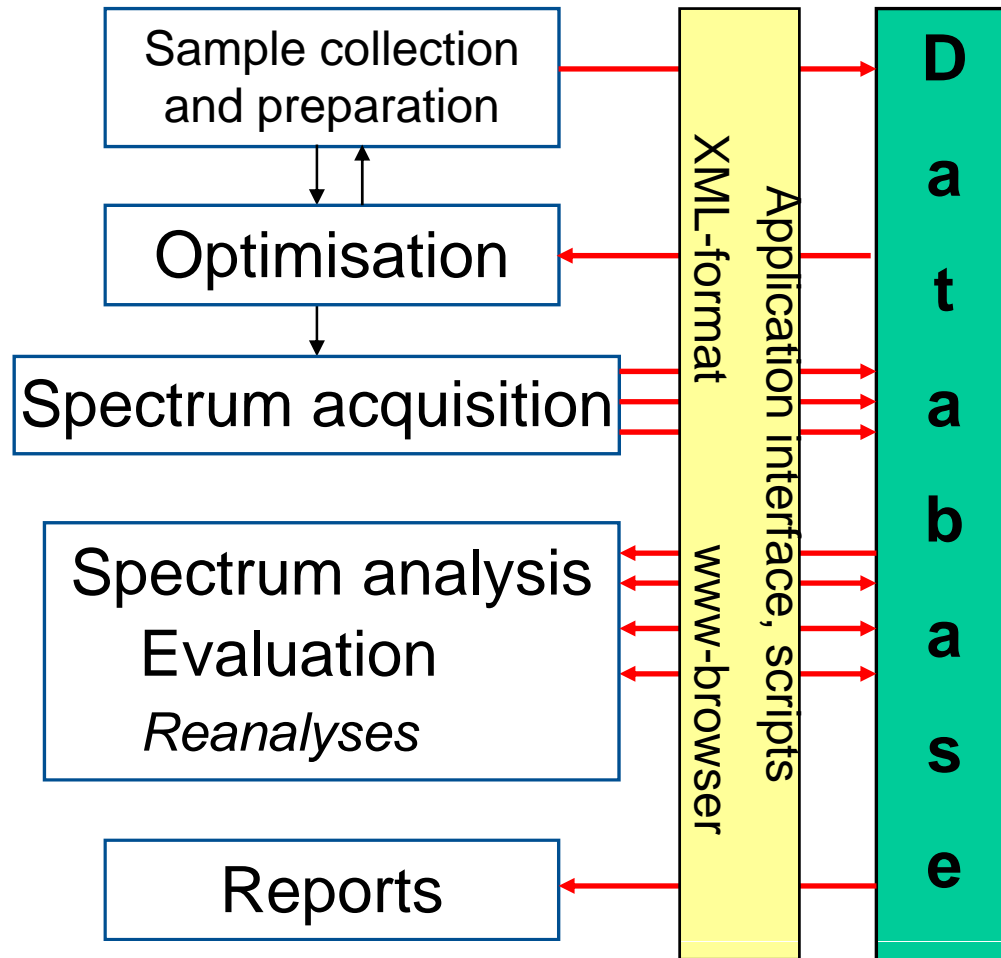
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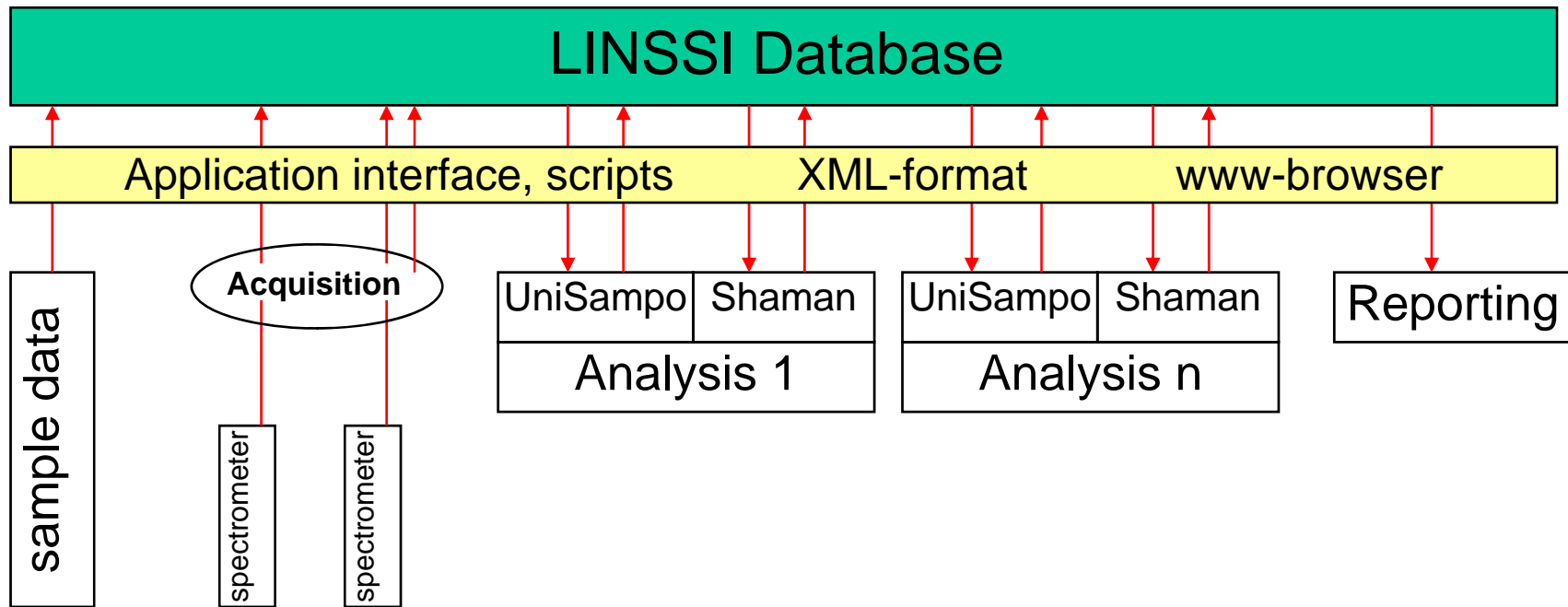idAnalysis
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Analysis Procedure with Database

- Optimisation of sample flow
  - right sample (amount), right detector (type and efficiency), right counting time

- Spectrum acquisition

- Computer analysis

- Evaluation of analysis, reanalysis if needed

- All stages (to be) integrated to LIMS with advanced handling of uncertainties

Set-up & Procedures

Applications / 1

- Surveillance of environmental radioactivity in Finland
  - Radioactive substances in air, deposition, surface water, drinking water, milk, foodstuffs and in the Baltic Sea

- Research, radioecological studies
  - Artificial radionuclides: fallout, NPP discharges, ...
  - Natural radionuclides: wood, grain, vegetables, sediment, ...

- Contracted services
  - Industry: NPP environmental monitoring, swipe samples, building materials ...
  - Trade: radioactivity certificates e.g. for export of mushrooms ...
  - National and international organisations and institutes: municipalities, universities, Geological Survey of Finland, IAEA Safeguards, CTBTO...

FIL07 - CTBT radionuclide laboratory

CTBTO/IMS has 16 radionuclide laboratories of which 10 is certified

STUK laboratory certified in 2003

Reanalysis of filter samples:

- interesting (level 5)
- station QC
- 1-7 days measurement
- Low background, long measurement time -> possibly hundreds of relevant peaks

Requirements

- Performance better than the average station
  - Equipment
- Formal certification from the CTBTO
  - Quality Assurance
- Demanding internal QC program
  - Proficiency tests
- Data integrity

Applications / 2

- Support for radiation and nuclear safety authorities at STUK
  - Dosimetry, metrology, inspections, NPP radiation safety, safeguards, quality assurance
- Emergency preparedness
  - Maintenance and development of equipment and competence for rapid response
- Development of analytical methods
- Metrology of gamma-emitting radionuclides
  - Maintenance of measurement standards for activity
    - accurate spectrometers with traceable calibration and validated methods
    - traceable standard sources
- Total volume: **~3 000 anal./year**

Metrology and measurement standards

- Goal of the national metrological activities:

  Radiation measurements in Finland are adequately accurate and internationally comparable

- Task of the Laboratory: to maintain measurement standards to ensure the reliability of activity measurements of gamma-emitting radionuclides

- Standards are accurate spectrometers with traceable calibration, validated methods, or certified radioactive sources

- STUK is a member in a network for ionising radiation standard laboratories

- Participates in the activities of ICRM (International Committee for Radionuclide Metrology) and its Gamma-Ray Spectrometry Working Group

  - Intercomparison of methods for coincidence summing corrections in gamma-ray spectrometry

- Will formally apply for membership of ICRM

International Committee for Radionuclide Metrology (I.C.R.M.) Gamma-Ray Spectrometry Working Group

- Devoted to the development of the metrological aspects of gamma-ray spectrometry and its applications
  - measurement techniques and equipment
  - determination of photon emission intensities
  - detector efficiency calibrations (including Monte Carlo methods)
  - coincidence-summing corrections
  - uncertainties and correlations
  - new instrumentation
  - X-ray spectrometry
- 2006-07: Monte Carlo codes intercomparison exercise
- 2008-09: Coincidence summing correction exercise