LIMS at LRM Laboratory: activity measurements

Leen Verheyen – 18/01/2024

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Contents

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- What is a LIMS and why using it
- γ-analysis process flow and management by LIMS
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  - Analysis operations
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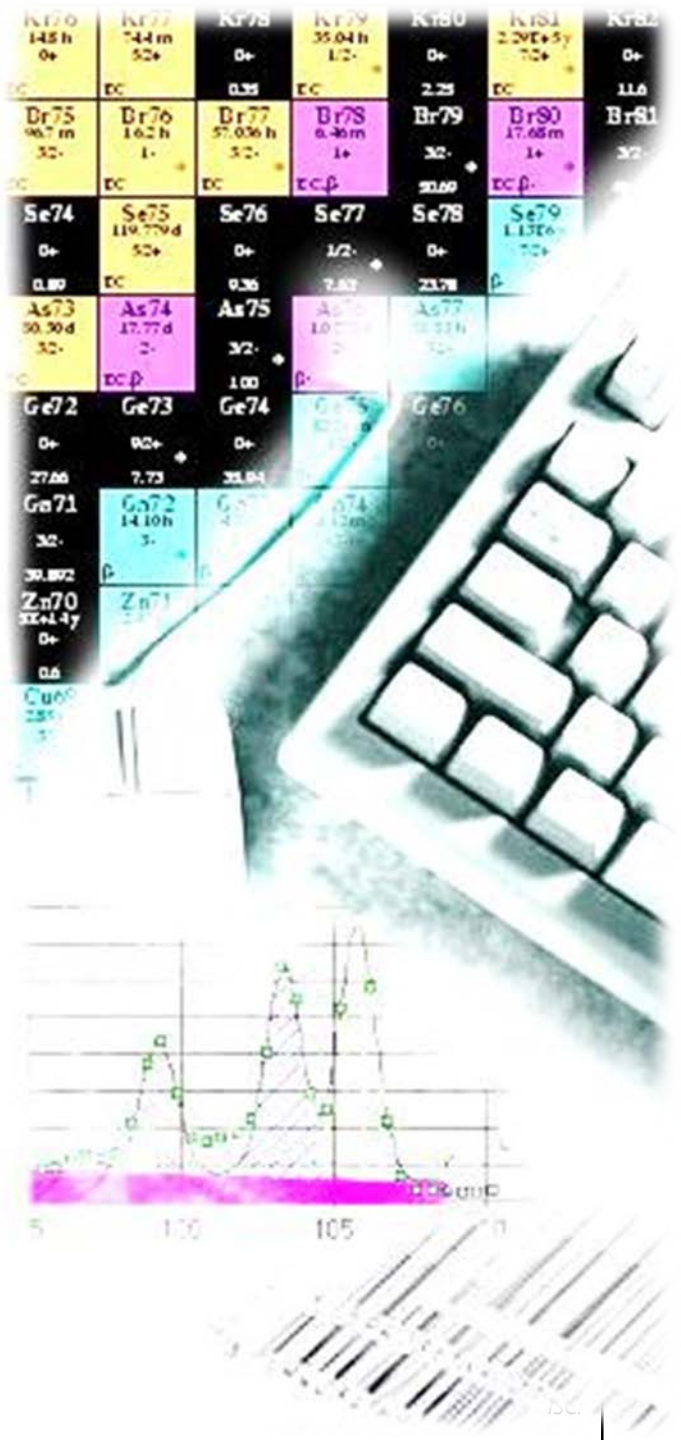
    - Efficiency transfer
    - Summing correction
    - Uncertainty budget
  - Reporting
  - Quality assurance: QC-QB- PTE's
  - Nuclide libraries
- Conclusions



Gamma ray spectroscopy

20 HPGe detectors:

- BeGe >> Rel. eff. 38%
- ReGe >> Rel eff. 28 %
- Extended Range >> Rel eff. 50%
- Coaxial HPGe
- Ge(Li)
- LeGE
- Well HPGe

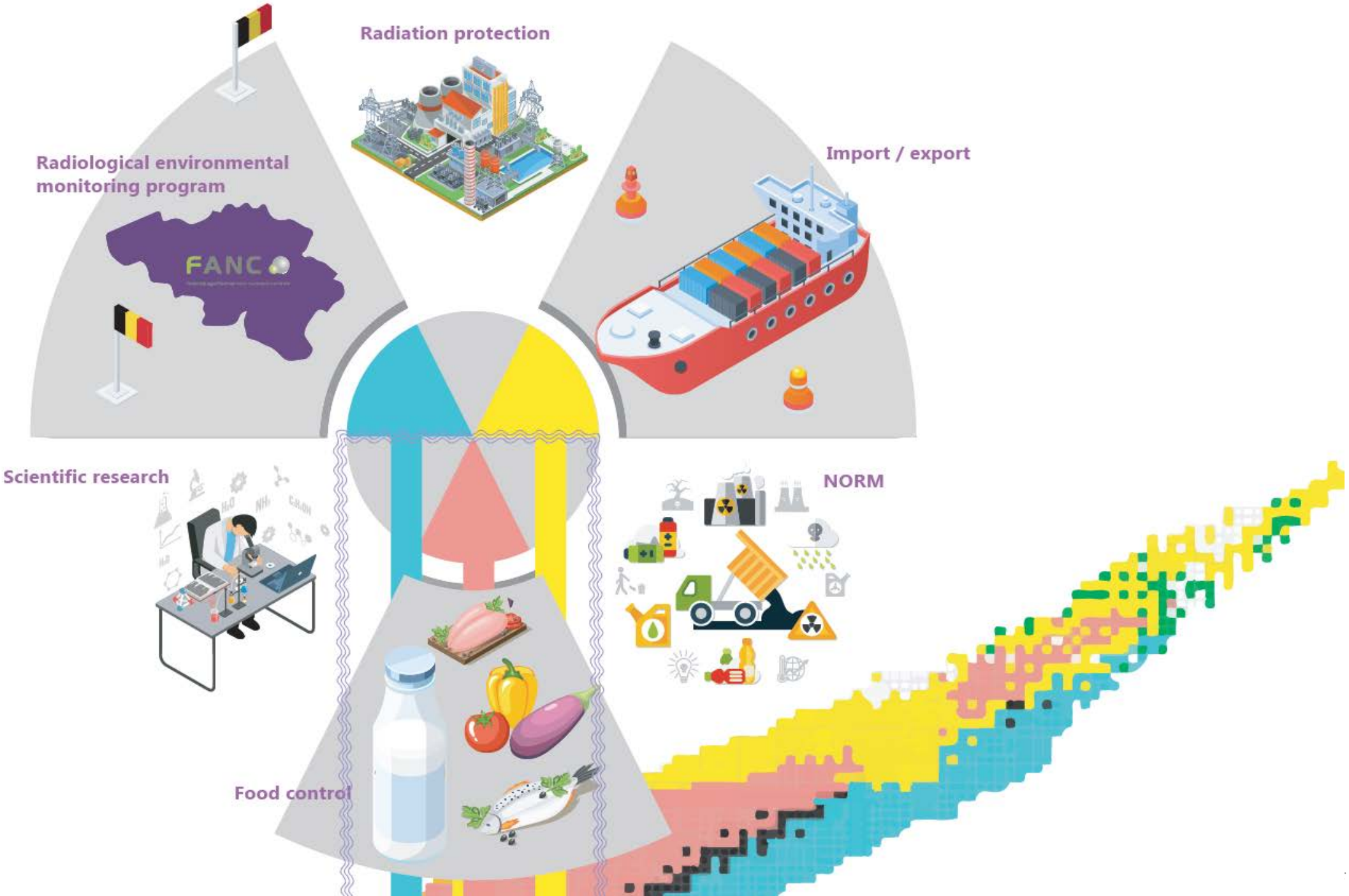
Rel. Eff. : 10-80 %

Digital signal analyzer LYNX (Mirion)

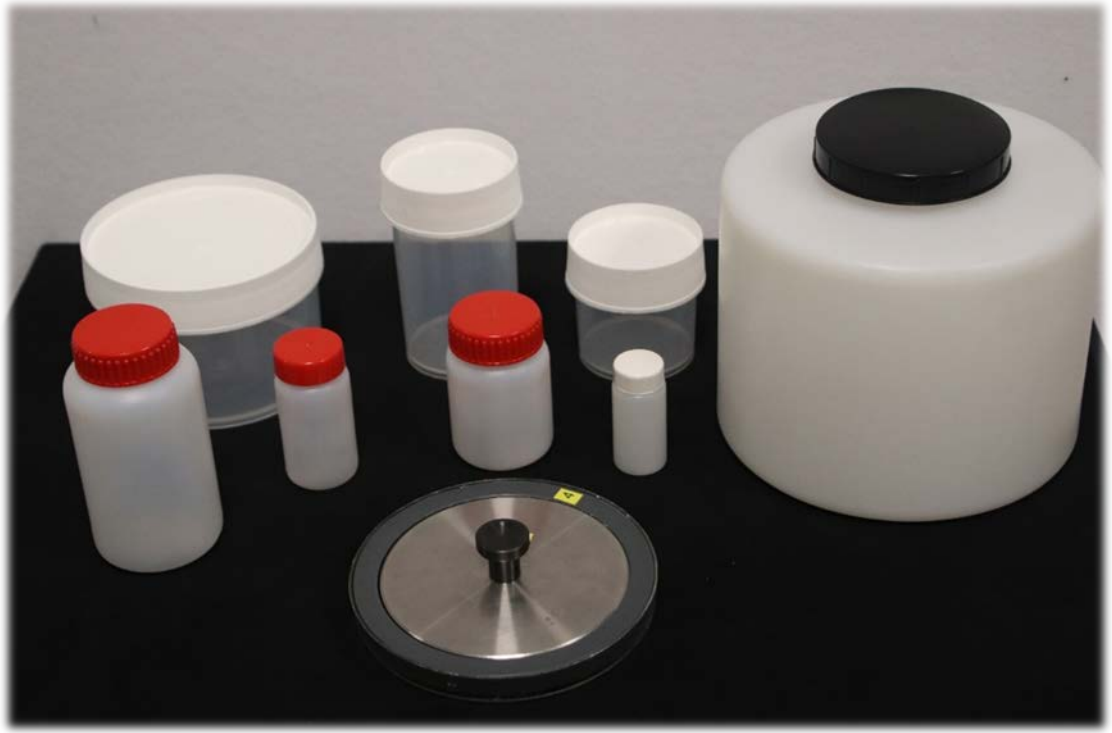
Liquid nitrogen:

Automated filling system

Weighing system under detector


Radiation protection
Radiological environmental monitoring program
FANC
Import / export
Scientific research
NORM
Food control

Gamma ray spectroscopy @ LRM



- 3000-3500 samples/year
- Different geometries:
  - volumetrical, marinelli, cardriges, filters
- Weekly QA measurement
- Monthly background check
- ISO/IEC 17025 and ISO14001

Calculations:

- GENIE2K
- EFFTRAN
  - Efficiency transfer
  - Summing correction

What is a LIMS and why using it ?

Laboratory Information and Management System

Is software-based laboratory and information management system that offers a set of key features that support a modern laboratory's operations. Those key features include:

- workflow;
- data tracking support;
- flexible architecture;
- smart data exchange interfaces;

That fully "support its use in regulated environments."

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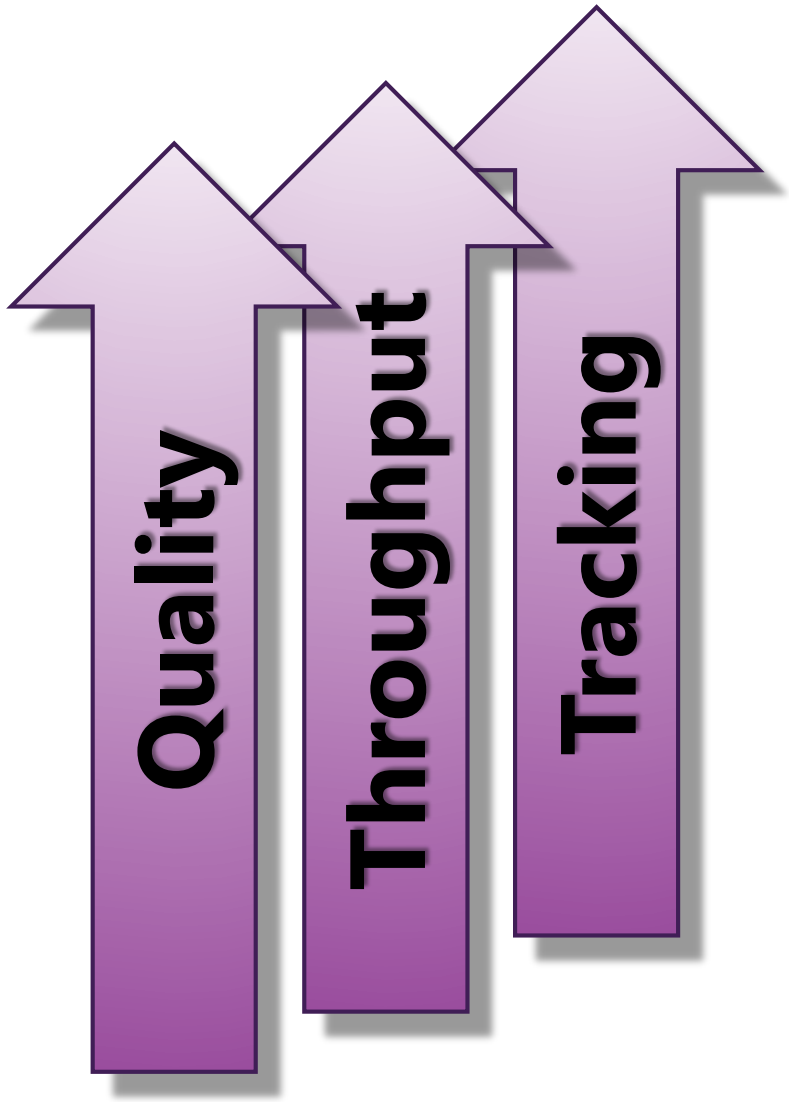
Why using a LIMS ?

- Automation of analysis process (Interfacing)
  - Reducing user input
    - Spectrum management
    - Selection of Efficiency calibration
    - Selection of Background file
    - Selection of analysis parameters
- Increased throughput
- Improved quality
  - Same process for all analysis
- Data management (Tracking)
  - Calibrations
  - Spectra - analysis
  - QA data
  - Hardware Inventory
  - Reports & certificates
  - …



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γLIMS architecture

homemade based on MS Access – interfacing

Spectroscopy hardware

Backend database

Barcode reader

Front end database

Front end database

Front end database

Front end database

Application Software (VBA)

Local network, Operational in case of emergency

Global network

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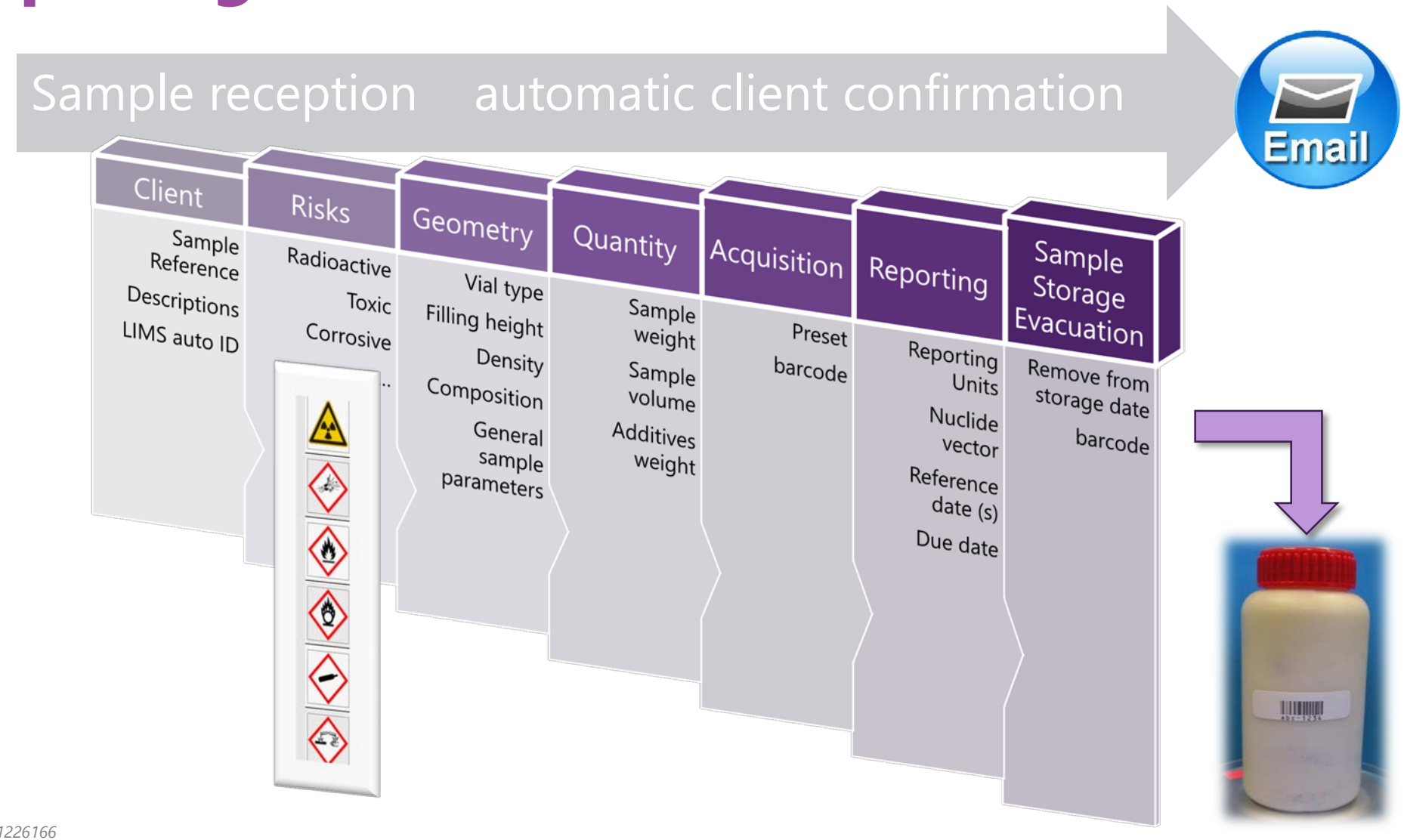
Sample registration



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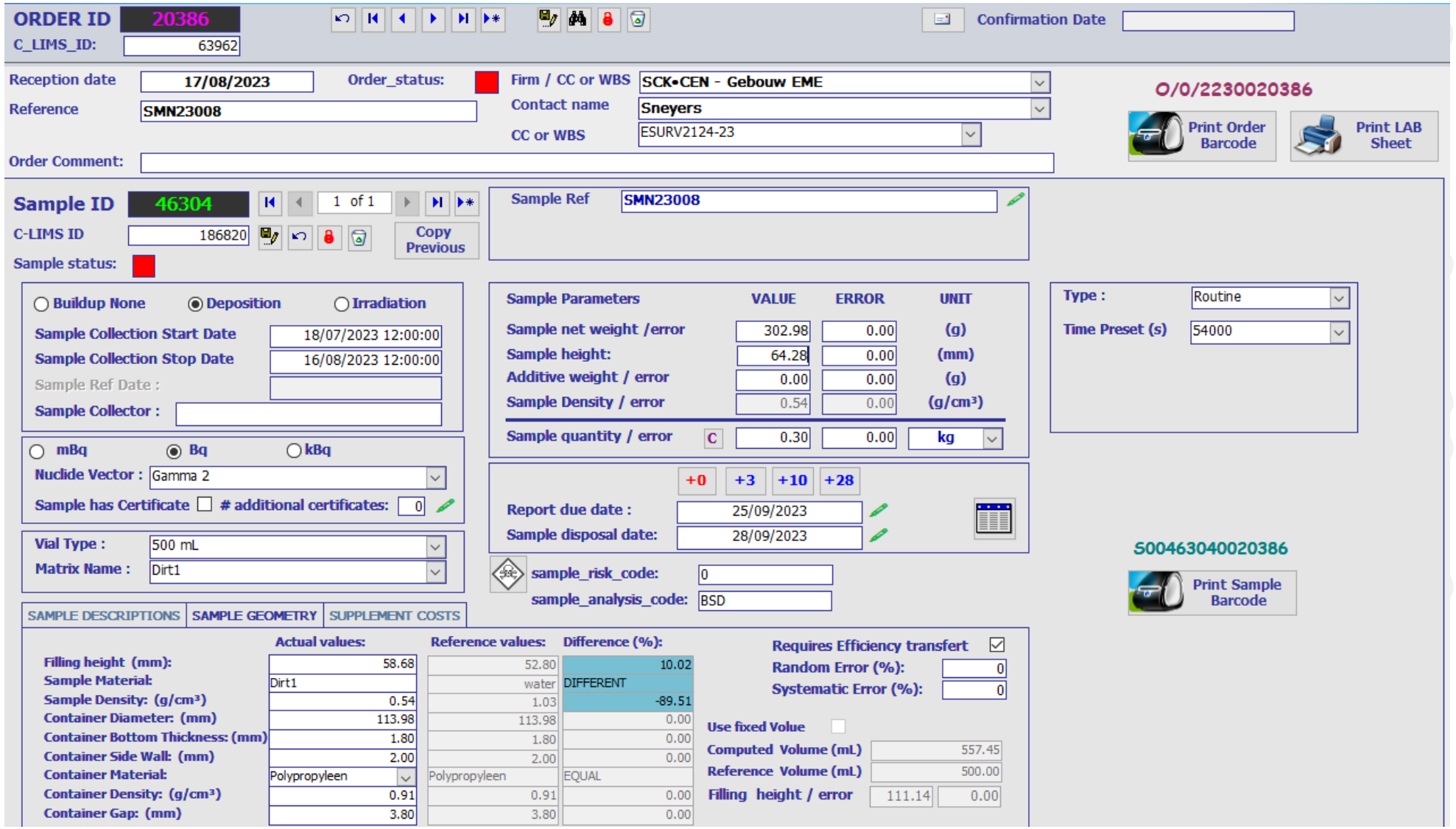
Sample registration

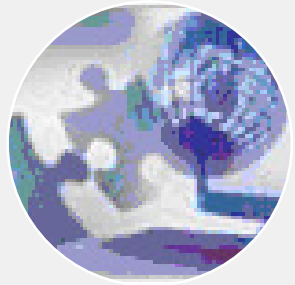


Automated acquisition via barcode

Acquisition

Detector

Sample



LIMS data

(Sample,Detector) couple
Start – Stop commands
Via barcode reader

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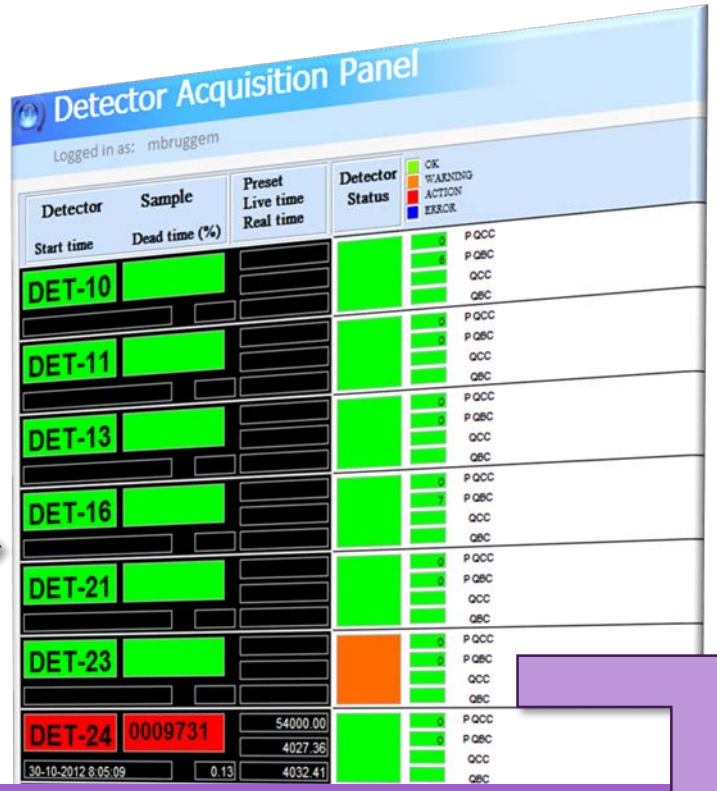
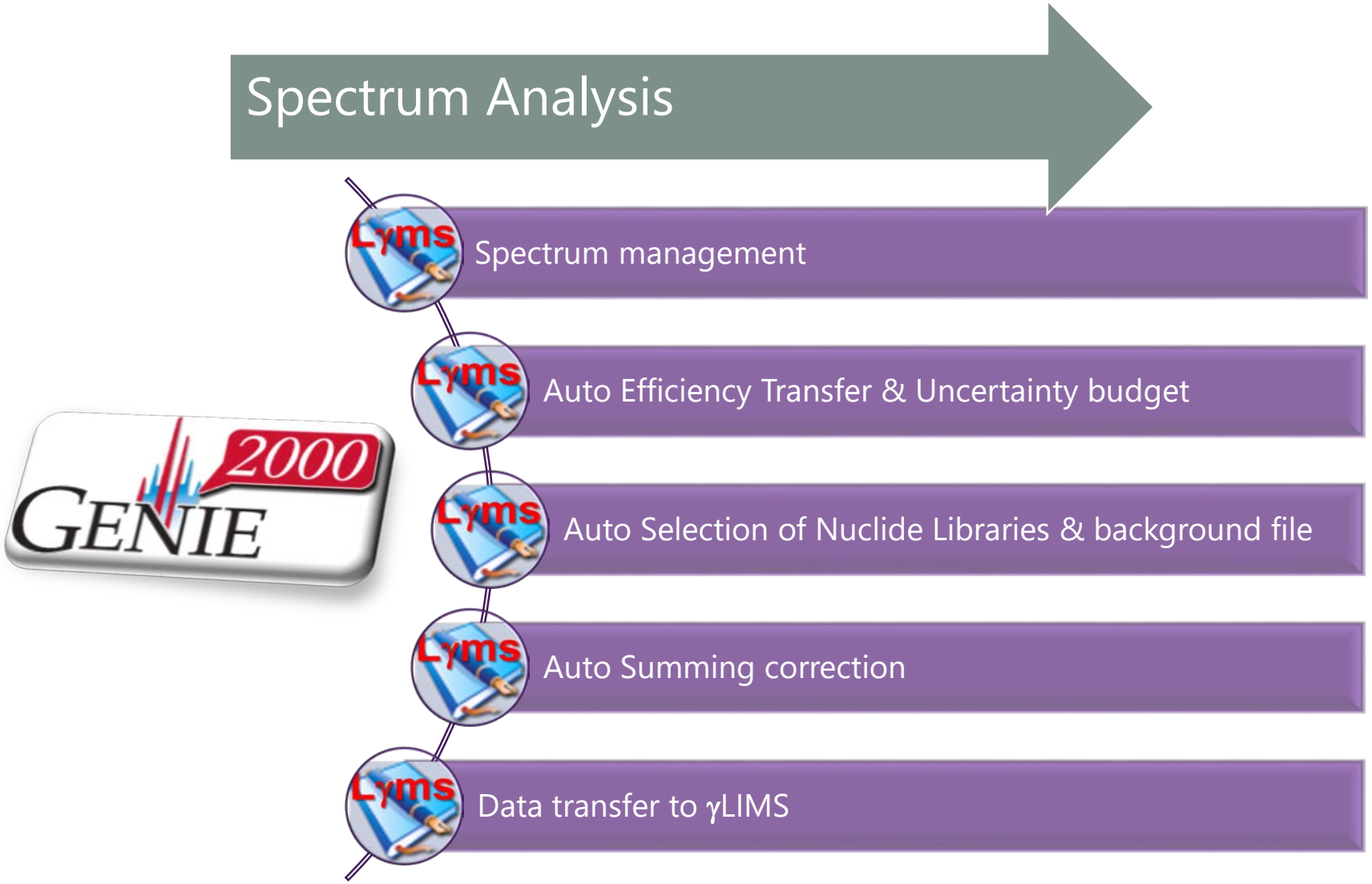
ISC:

Acquisition dashboard with QC functions visible on all PCs

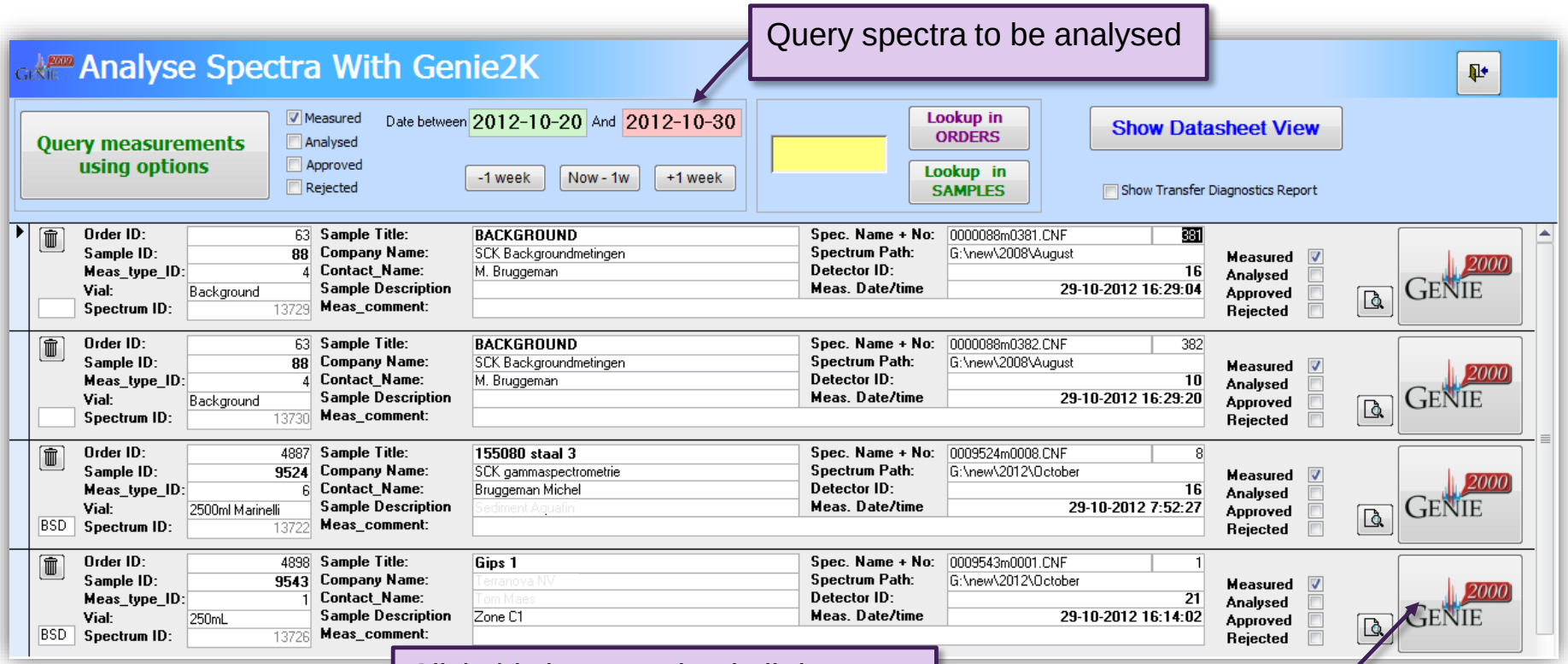


QA diagnostics indicators
QC frequency & period indicators
Status (OK, Warning, Action)

γ-LIMS control of Analyses



γ-LIMS management of spectra



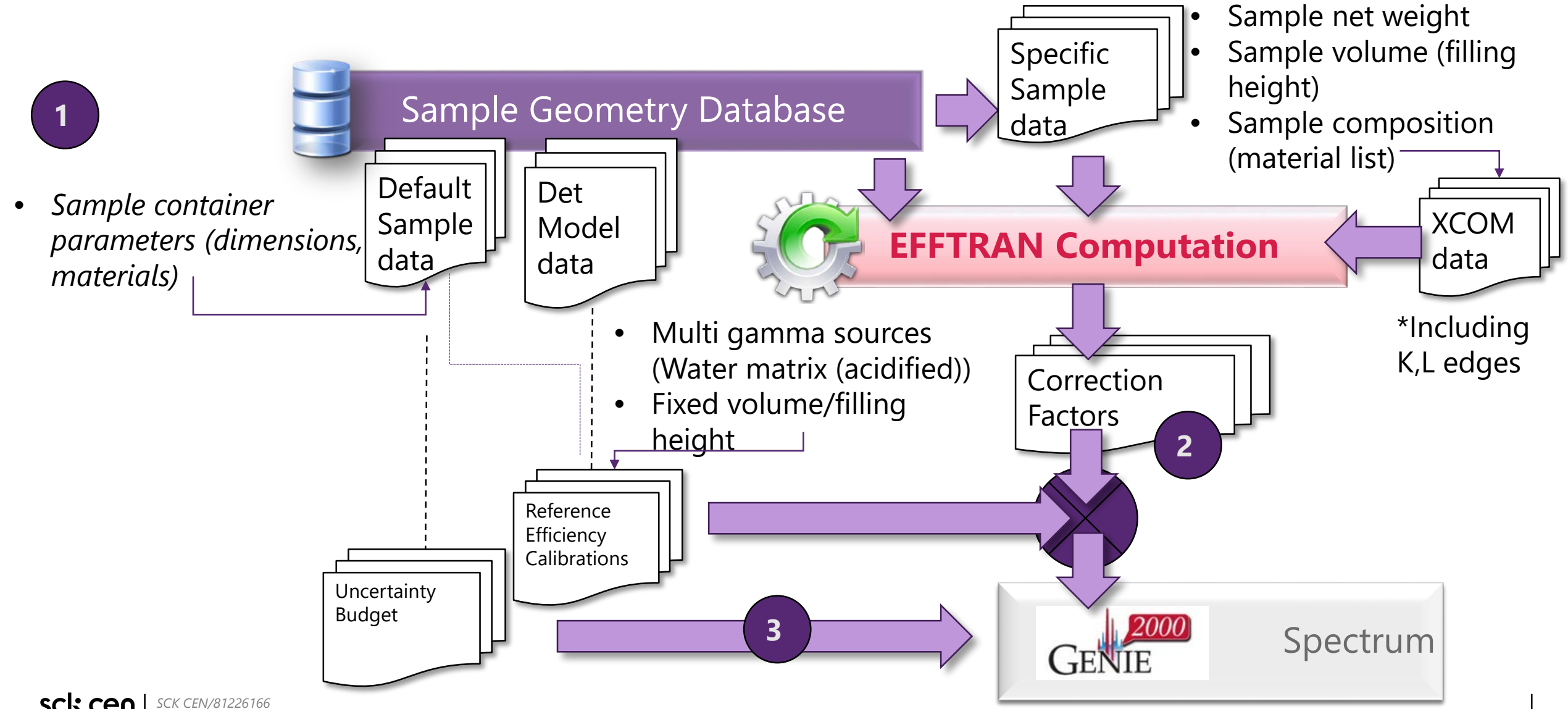
Click this button to load all data to the spectrum

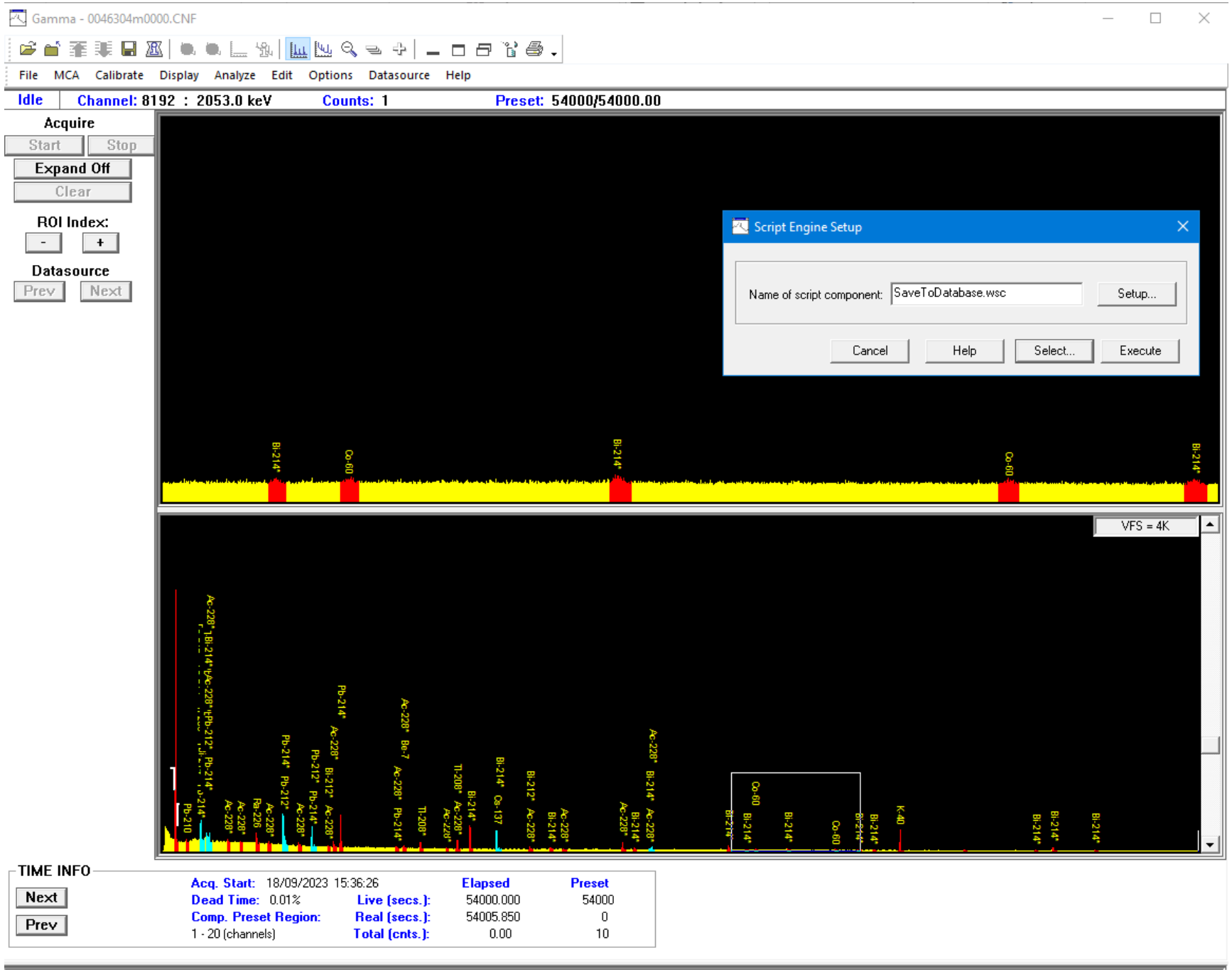
Ref. efficiency + transfer

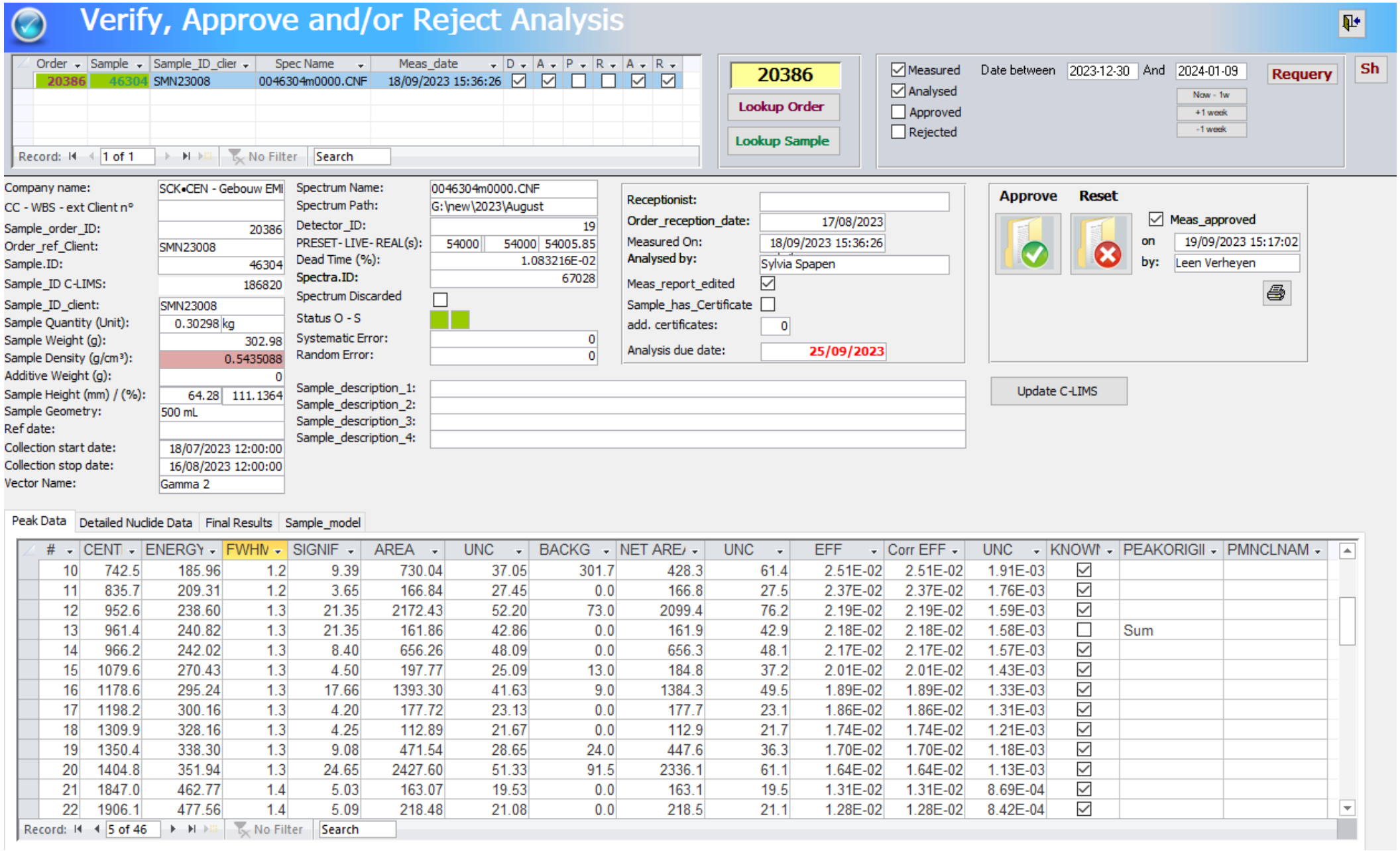
Background

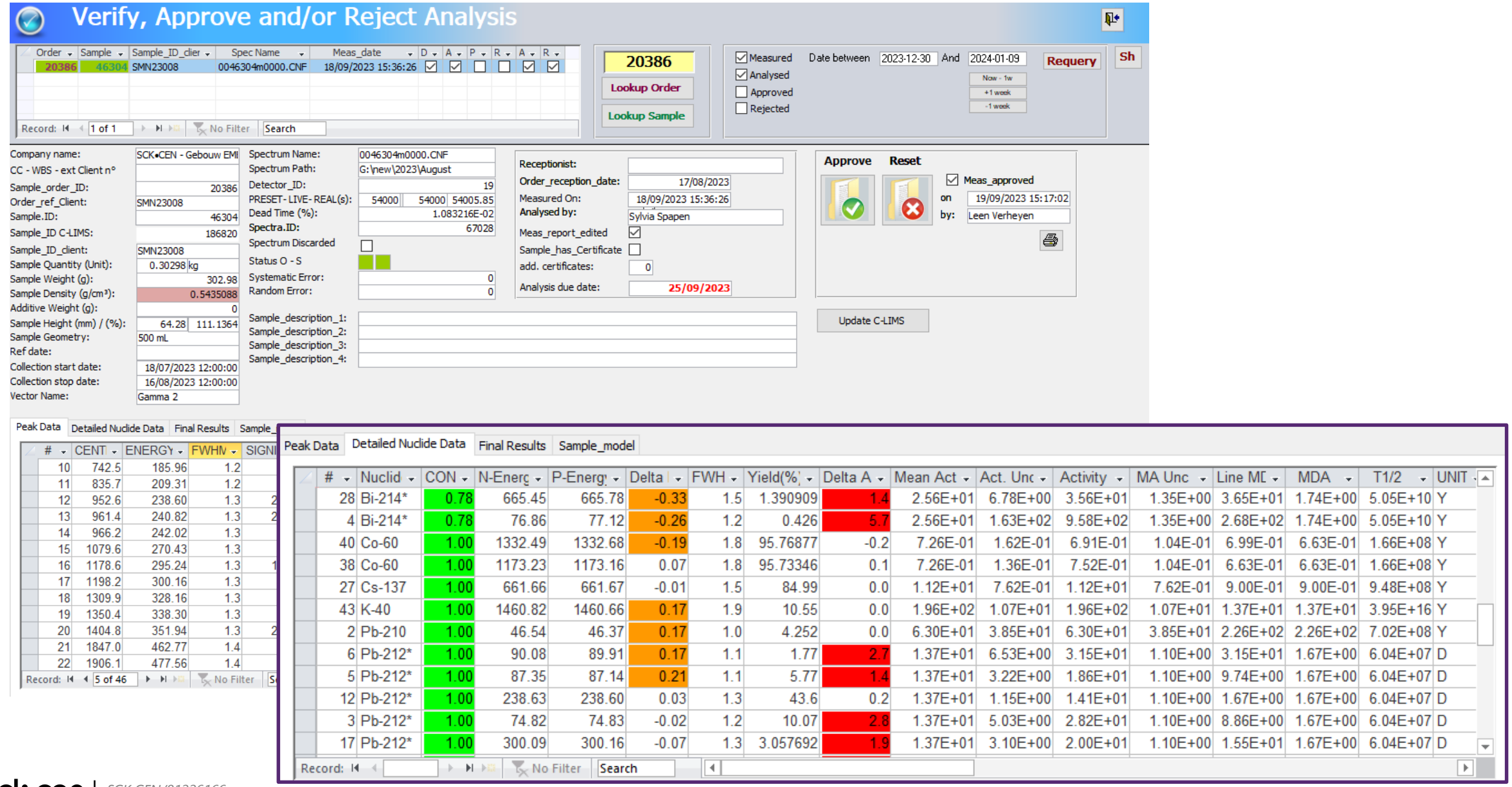
Nuclide libraries

Efficiency Transfer and Uncertainty Budget *imported in Genie 2000*




Gamma - 0046304m0000.CNF
File MCA Calibrate Display Analyze Edit Options Datasource Help
Idle
Channel: 8192 : 2053.0 keV
Counts: 1
Preset: 54000/54000.00
Acquire
Start
Stop
Expand Off
Clear
ROI Index:
-
+
Datasource
Prev
Next
Script Engine Setup
Name of script component:
SaveToDatabase.wsc
Setup...
Cancel
Help
Select...
Execute
VFS = 4K
TIME INFO
Next
Prev
Acq. Start: 18/09/2023 15:36:26
Dead Time: 0.01%
Comp. Preset Region:
1 - 20 (channels)
Live (secs.):
Real (secs.):
Total (cnts.):
Elapsed
54000.000
54005.850
0.00
Preset
54000
0
10


Verify, Approve and/or Reject Analysis
Order Sample Sample_ID_clier Spec Name Meas_date D A P R A R
20386 46304 SMN23008 0046304m0000.CNF 18/09/2023 15:36:26
Record: 1 of 1 No Filter Search
20386
Lookup Order
Lookup Sample
Measured
Analysed
Approved
Rejected
Date between 2023-12-30 And 2024-01-09
Now - 1w
+1 week
-1 week
Requery
Sh
Company name: SCK•CEN - Gebouw EMI
CC - WBS - ext Client n°
Sample_order_ID: 20386
Order_ref_Client: SMN23008
Sample.ID: 46304
Sample_ID C-LIMS: 186820
Sample_ID_client: SMN23008
Sample Quantity (Unit): 0.30298 kg
Sample Weight (g): 302.98
Sample Density (g/cm³): 0.5435088
Additive Weight (g): 0
Sample Height (mm) / (%): 64.28 111.1364
Sample Geometry: 500 mL
Ref date:
Collection start date: 18/07/2023 12:00:00
Collection stop date: 16/08/2023 12:00:00
Vector Name: Gamma 2
Spectrum Name: 0046304m0000.CNF
Spectrum Path: G:\new\2023\August
Detector_ID: 19
PRESET- LIVE- REAL(s): 54000 54000 54005.85
Dead Time (%): 1.083216E-02
Spectra.ID: 67028
Spectrum Discarded
Status O - S
Systematic Error: 0
Random Error: 0
Receptionist:
Order_reception_date: 17/08/2023
Measured On: 18/09/2023 15:36:26
Analysed by: Sylvia Spapen
Meas_report_edited
Sample_has_Certificate
add. certificates: 0
Analysis due date: 25/09/2023
Approve
Reset
Meas_approved
on 19/09/2023 15:17:02
by: Leen Verheyen
Sample_description_1:
Sample_description_2:
Sample_description_3:
Sample_description_4:
Update C-LIMS
Peak Data
Detailed Nuclide Data
Final Results
Sample_model
CENT ENERGY FWHM SIGNIF AREA UNC BACKG NET ARE UNC EFF Corr EFF UNC KNOWI PEAKORIGII PMNCLNAM
10 742.5 185.96 1.2 9.39 730.04 37.05 301.7 428.3 61.4 2.51E-02 2.51E-02 1.91E-03
11 835.7 209.31 1.2 3.65 166.84 27.45 0.0 166.8 27.5 2.37E-02 2.37E-02 1.76E-03
12 952.6 238.60 1.3 21.35 2172.43 52.20 73.0 2099.4 76.2 2.19E-02 2.19E-02 1.59E-03
13 961.4 240.82 1.3 21.35 161.86 42.86 0.0 161.9 42.9 2.18E-02 2.18E-02 1.58E-03 Sum
14 966.2 242.02 1.3 8.40 656.26 48.09 0.0 656.3 48.1 2.17E-02 2.17E-02 1.57E-03
15 1079.6 270.43 1.3 4.50 197.77 25.09 13.0 184.8 37.2 2.01E-02 2.01E-02 1.43E-03
16 1178.6 295.24 1.3 17.66 1393.30 41.63 9.0 1384.3 49.5 1.89E-02 1.89E-02 1.33E-03
17 1198.2 300.16 1.3 4.20 177.72 23.13 0.0 177.7 23.1 1.86E-02 1.86E-02 1.31E-03
18 1309.9 328.16 1.3 4.25 112.89 21.67 0.0 112.9 21.7 1.74E-02 1.74E-02 1.21E-03
19 1350.4 338.30 1.3 9.08 471.54 28.65 24.0 447.6 36.3 1.70E-02 1.70E-02 1.18E-03
20 1404.8 351.94 1.3 24.65 2427.60 51.33 91.5 2336.1 61.1 1.64E-02 1.64E-02 1.13E-03
21 1847.0 462.77 1.4 5.03 163.07 19.53 0.0 163.1 19.5 1.31E-02 1.31E-02 8.69E-04
22 1906.1 477.56 1.4 5.09 218.48 21.08 0.0 218.5 21.1 1.28E-02 1.28E-02 8.42E-04
Record: 5 of 46 No Filter Search


Verify, Approve and/or Reject Analysis
Order Sample Sample_ID_clier Spec Name Meas_date D A P R A R
20386 46304 SMN23008 0046304m0000.CNF 18/09/2023 15:36:26
Record: 1 of 1 No Filter Search
20386
Lookup Order
Lookup Sample
Measured
Analysed
Approved
Rejected
Date between 2023-12-30 And 2024-01-09
Now - 1w
+1 week
-1 week
Requery
Sh
Company name: SCK•CEN - Gebouw EMI
CC - WBS - ext Client n°
Sample_order_ID: 20386
Order_ref_Client: SMN23008
Sample.ID: 46304
Sample_ID C-LIMS: 186820
Sample_ID_client: SMN23008
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Sample Density (g/cm³): 0.5435088
Additive Weight (g): 0
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Sample Geometry: 500 mL
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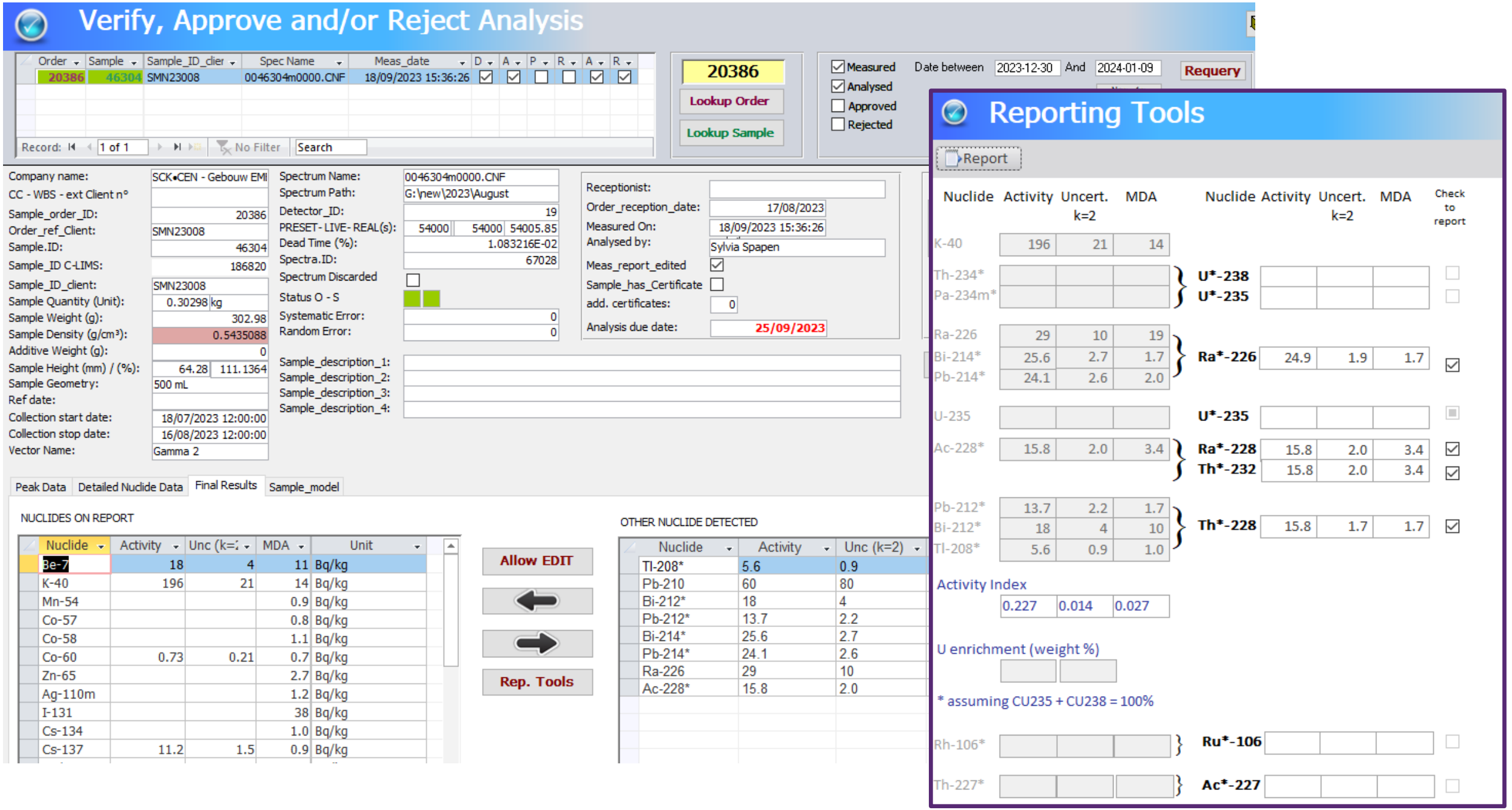
Collection stop date: 16/08/2023 12:00:00
Vector Name: Gamma 2
Spectrum Name: 0046304m0000.CNF
Spectrum Path: G:\new\2023\August
Detector_ID: 19
PRESET- LIVE- REAL(s): 54000 54000 54005.85
Dead Time (%): 1.083216E-02
Spectra.ID: 67028
Spectrum Discarded
Status O - S
Systematic Error: 0
Random Error: 0
Receptionist:
Order_reception_date: 17/08/2023
Measured On: 18/09/2023 15:36:26
Analysed by: Sylvia Spapen
Meas_report_edited
Sample_has_Certificate
add. certificates: 0
Analysis due date: 25/09/2023
Approve
Reset
Meas_approved
on 19/09/2023 15:17:02
by: Leen Verheyen
Sample_description_1:
Sample_description_2:
Sample_description_3:
Sample_description_4:
Update C-LIMS
Peak Data
Detailed Nuclide Data
Final Results
Sample_
CENT ENERGY FWHM SIGNI
10 742.5 185.96 1.2
11 835.7 209.31 1.2
12 952.6 238.60 1.3 2
13 961.4 240.82 1.3 2
14 966.2 242.02 1.3
15 1079.6 270.43 1.3
16 1178.6 295.24 1.3 1
17 1198.2 300.16 1.3
18 1309.9 328.16 1.3
19 1350.4 338.30 1.3
20 1404.8 351.94 1.3 2
21 1847.0 462.77 1.4
22 1906.1 477.56 1.4
Record: 5 of 46 No Filter
Peak Data
Detailed Nuclide Data
Final Results
Sample_model
Nuclid CON N-Energ P-Energy Delta FWH Yield(%) Delta A Mean Act Act. Unc Activity MA Unc Line MI MDA T1/2 UNIT
28 Bi-214* 0.78 665.45 665.78 -0.33 1.5 1.390909 1.4 2.56E+01 6.78E+00 3.56E+01 1.35E+00 3.65E+01 1.74E+00 5.05E+10 Y
4 Bi-214* 0.78 76.86 77.12 -0.26 1.2 0.426 5.7 2.56E+01 1.63E+02 9.58E+02 1.35E+00 2.68E+02 1.74E+00 5.05E+10 Y
40 Co-60 1.00 1332.49 1332.68 -0.19 1.8 95.76877 -0.2 7.26E-01 1.62E-01 6.91E-01 1.04E-01 6.99E-01 6.63E-01 1.66E+08 Y
38 Co-60 1.00 1173.23 1173.16 0.07 1.8 95.73346 0.1 7.26E-01 1.36E-01 7.52E-01 1.04E-01 6.63E-01 6.63E-01 1.66E+08 Y
27 Cs-137 1.00 661.66 661.67 -0.01 1.5 84.99 0.0 1.12E+01 7.62E-01 1.12E+01 7.62E-01 9.00E-01 9.00E-01 9.48E+08 Y
43 K-40 1.00 1460.82 1460.66 0.17 1.9 10.55 0.0 1.96E+02 1.07E+01 1.96E+02 1.07E+01 1.37E+01 1.37E+01 3.95E+16 Y
2 Pb-210 1.00 46.54 46.37 0.17 1.0 4.252 0.0 6.30E+01 3.85E+01 6.30E+01 3.85E+01 2.26E+02 2.26E+02 7.02E+08 Y
6 Pb-212* 1.00 90.08 89.91 0.17 1.1 1.77 2.7 1.37E+01 6.53E+00 3.15E+01 1.10E+00 3.15E+01 1.67E+00 6.04E+07 D
5 Pb-212* 1.00 87.35 87.14 0.21 1.1 5.77 1.4 1.37E+01 3.22E+00 1.86E+01 1.10E+00 9.74E+00 1.67E+00 6.04E+07 D
12 Pb-212* 1.00 238.63 238.60 0.03 1.3 43.6 0.2 1.37E+01 1.15E+00 1.41E+01 1.10E+00 1.67E+00 1.67E+00 6.04E+07 D
3 Pb-212* 1.00 74.82 74.83 -0.02 1.2 10.07 2.8 1.37E+01 5.03E+00 2.82E+01 1.10E+00 8.86E+00 1.67E+00 6.04E+07 D
17 Pb-212* 1.00 300.09 300.16 -0.07 1.3 3.057692 1.9 1.37E+01 3.10E+00 2.00E+01 1.10E+00 1.55E+01 1.67E+00 6.04E+07 D
Record: No Filter Search


Verify, Approve and/or Reject Analysis
Order | Sample | Sample_ID_clier | Spec Name | Meas_date | D | A | P | R | A | R
20386 | 46304 | SMN23008 | 0046304m0000.CNF | 18/09/2023 15:36:26
Record: 1 of 1 No Filter Search
20386
Lookup Order
Lookup Sample
Measured
Analysed
Approved
Rejected
Date between 2023-12-30 And 2024-01-09
Requery
Company name: SCK•CEN - Gebouw EMI
CC - WBS - ext Client n°
Sample_order_ID: 20386
Order_ref_Client: SMN23008
Sample.ID: 46304
Sample_ID C-LIMS: 186820
Sample_ID_client: SMN23008
Sample Quantity (Unit): 0.30298 kg
Sample Weight (g): 302.98
Sample Density (g/cm³): 0.5435088
Additive Weight (g): 0
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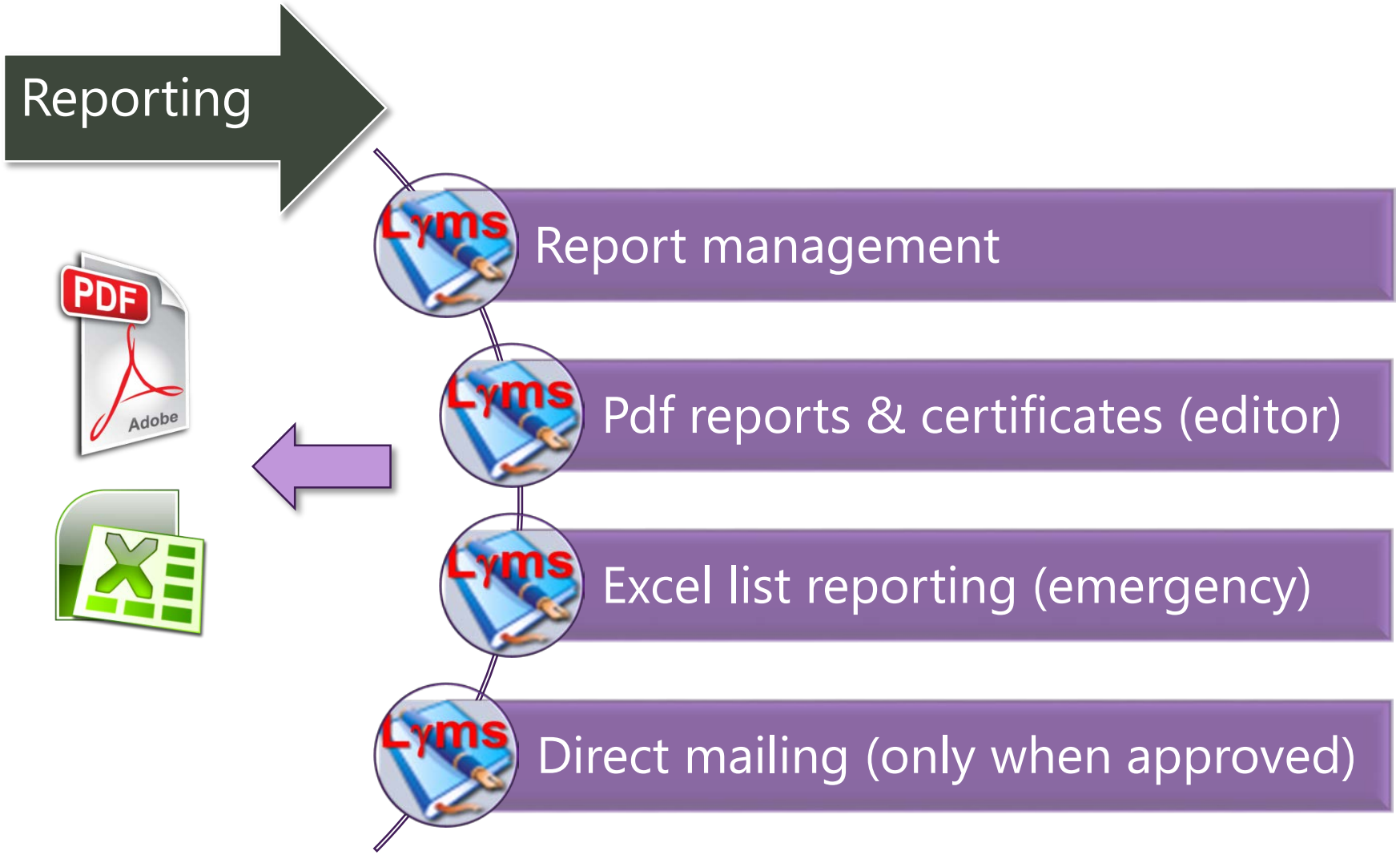
Detector_ID: 19
PRESET- LIVE- REAL(s): 54000 54000 54005.85
Dead Time (%): 1.083216E-02
Spectra.ID: 67028
Spectrum Discarded
Status O - S
Systematic Error: 0
Random Error: 0
Sample_description_1:
Sample_description_2:
Sample_description_3:
Sample_description_4:
Receptionist:
Order_reception_date: 17/08/2023
Measured On: 18/09/2023 15:36:26
Analysed by: Sylvia Spapen
Meas_report_edited
Sample_has_Certificate
add. certificates: 0
Analysis due date: 25/09/2023
Peak Data
Detailed Nuclide Data
Final Results
Sample_model
NUCLIDES ON REPORT
Nuclide | Activity | Unc (k=2) | MDA | Unit
3e-7 | 18 | 4 | 11 | Bq/kg
K-40 | 196 | 21 | 14 | Bq/kg
Mn-54 | | | 0.9 | Bq/kg
Co-57 | | | 0.8 | Bq/kg
Co-58 | | | 1.1 | Bq/kg
Co-60 | 0.73 | 0.21 | 0.7 | Bq/kg
Zn-65 | | | 2.7 | Bq/kg
Ag-110m | | | 1.2 | Bq/kg
I-131 | | | 38 | Bq/kg
Cs-134 | | | 1.0 | Bq/kg
Cs-137 | 11.2 | 1.5 | 0.9 | Bq/kg
Allow EDIT
Rep. Tools
OTHER NUCLIDE DETECTED
Nuclide | Activity | Unc (k=2)
Tl-208* | 5.6 | 0.9
Pb-210 | 60 | 80
Bi-212* | 18 | 4
Pb-212* | 13.7 | 2.2
Bi-214* | 25.6 | 2.7
Pb-214* | 24.1 | 2.6
Ra-226 | 29 | 10
Ac-228* | 15.8 | 2.0
Reporting Tools
Report
Nuclide | Activity | Uncert. k=2 | MDA | Nuclide | Activity | Uncert. k=2 | MDA | Check to report
K-40 196 21 14
Th-234* Pa-234m* U*-238 U*-235
Ra-226 29 10 19
Bi-214* 25.6 2.7 1.7
Pb-214* 24.1 2.6 2.0 Ra*-226 24.9 1.9 1.7
U-235 U*-235
Ac-228* 15.8 2.0 3.4 Ra*-228 15.8 2.0 3.4
Th*-232 15.8 2.0 3.4
Pb-212* 13.7 2.2 1.7
Bi-212* 18 4 10
Tl-208* 5.6 0.9 1.0 Th*-228 15.8 1.7 1.7
Activity Index
0.227 0.014 0.027
U enrichment (weight %)
* assuming CU235 + CU238 = 100%
Rh-106* Ru*-106
Th-227* Ac*-227

Reporting



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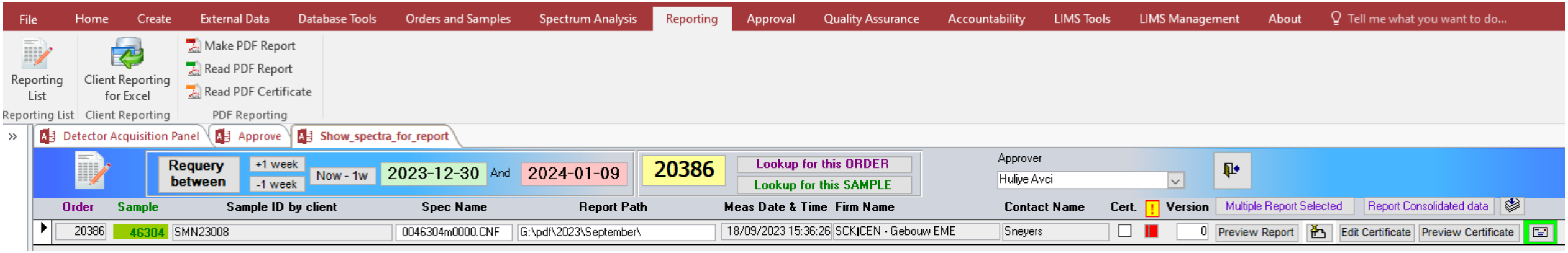
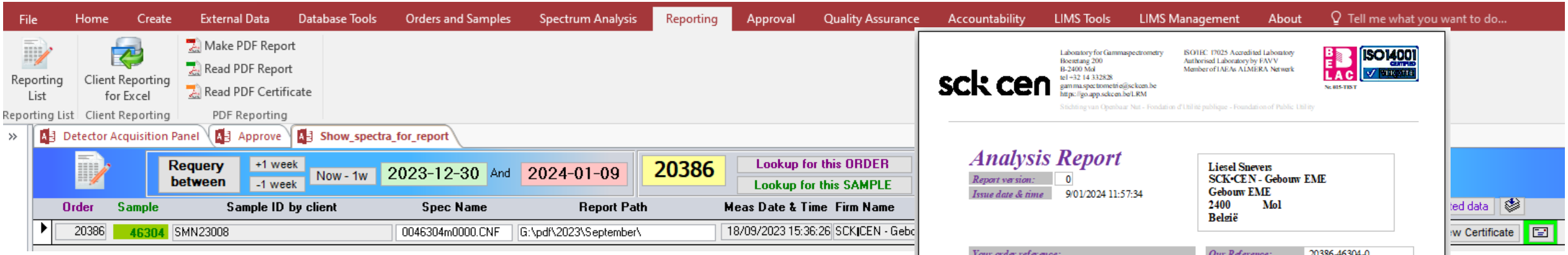
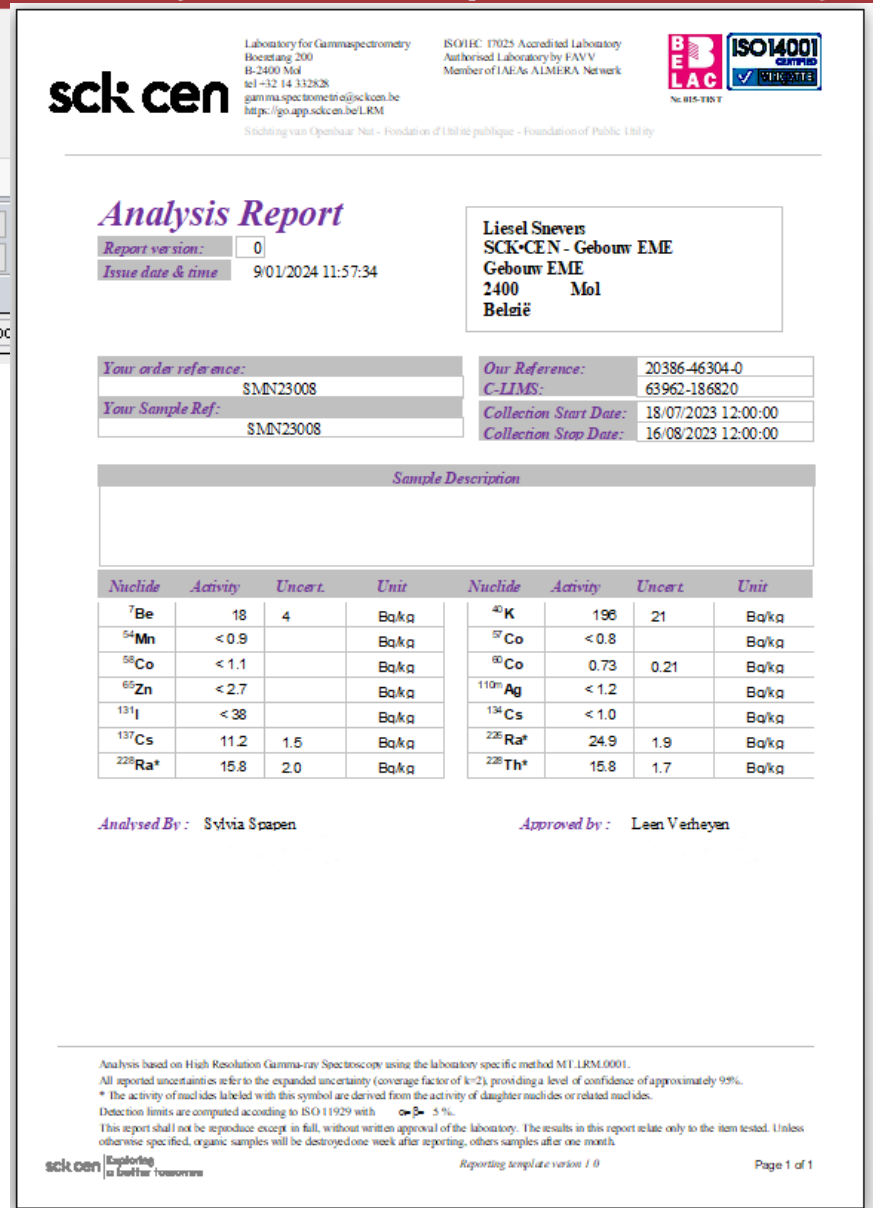


Reporting

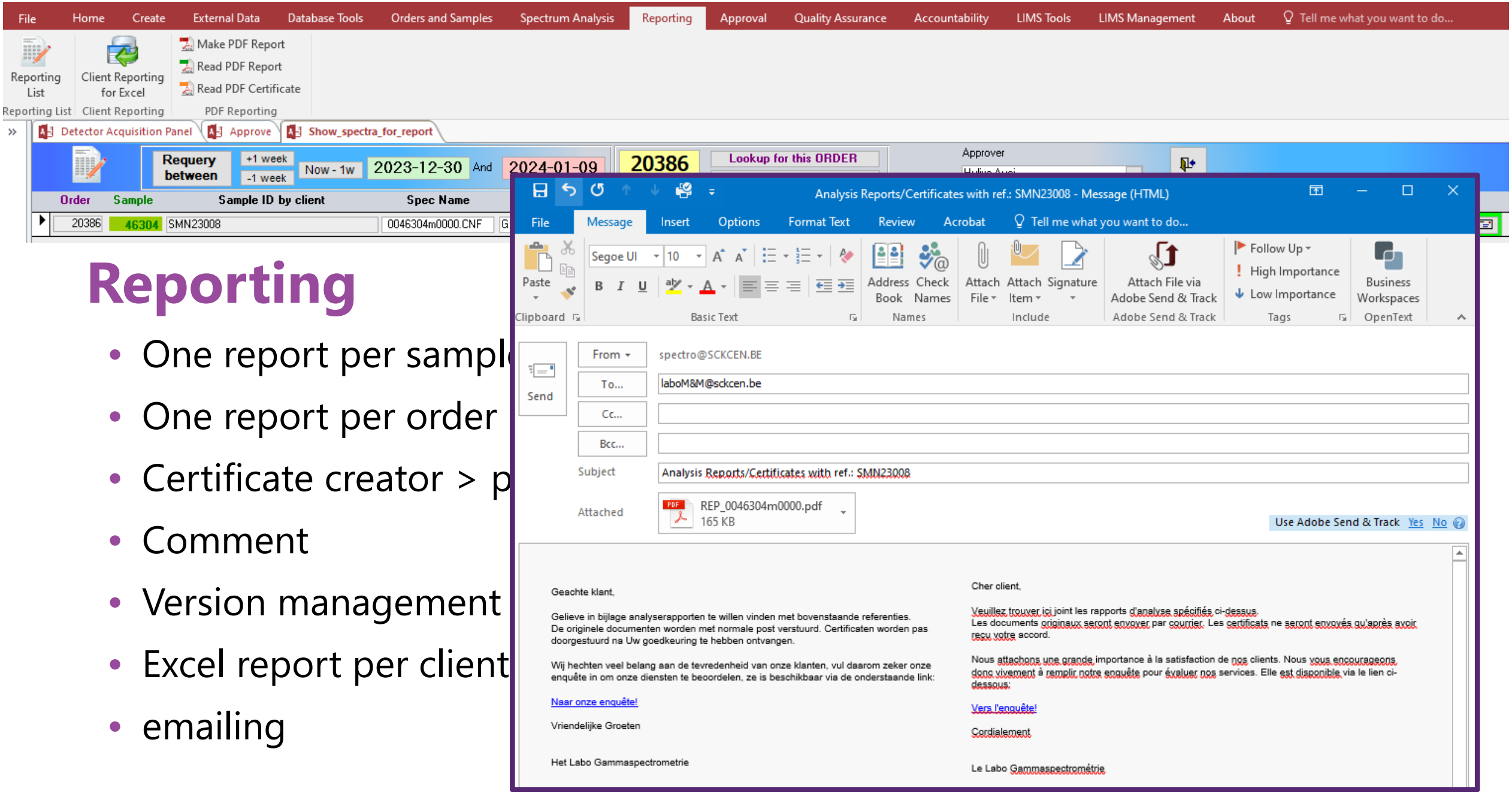
- One report per sample > pdf
- One report per order > pdf
- Certificate creator > pdf
- Comment
- Version management
- Excel report per client per period
- emailing





Reporting

- One report per sample > pdf
- One report per order > pdf
- Certificate creator > pdf
- Comment
- Version management
- Tranfer results to: .xlsx, .xml formats
- emailing



Reporting

- One report per sampl
- One report per order
- Certificate creator > p
- Comment
- Version management
- Excel report per client
- emailing

Detector Acquisition Panel | Approve | Show_spectra_for_report | Show_client_results

Query Client Specific Results

Export to excel

From 2023-12-01 Till 2024-1-01

Firm_SCK_number ESURV2124-23

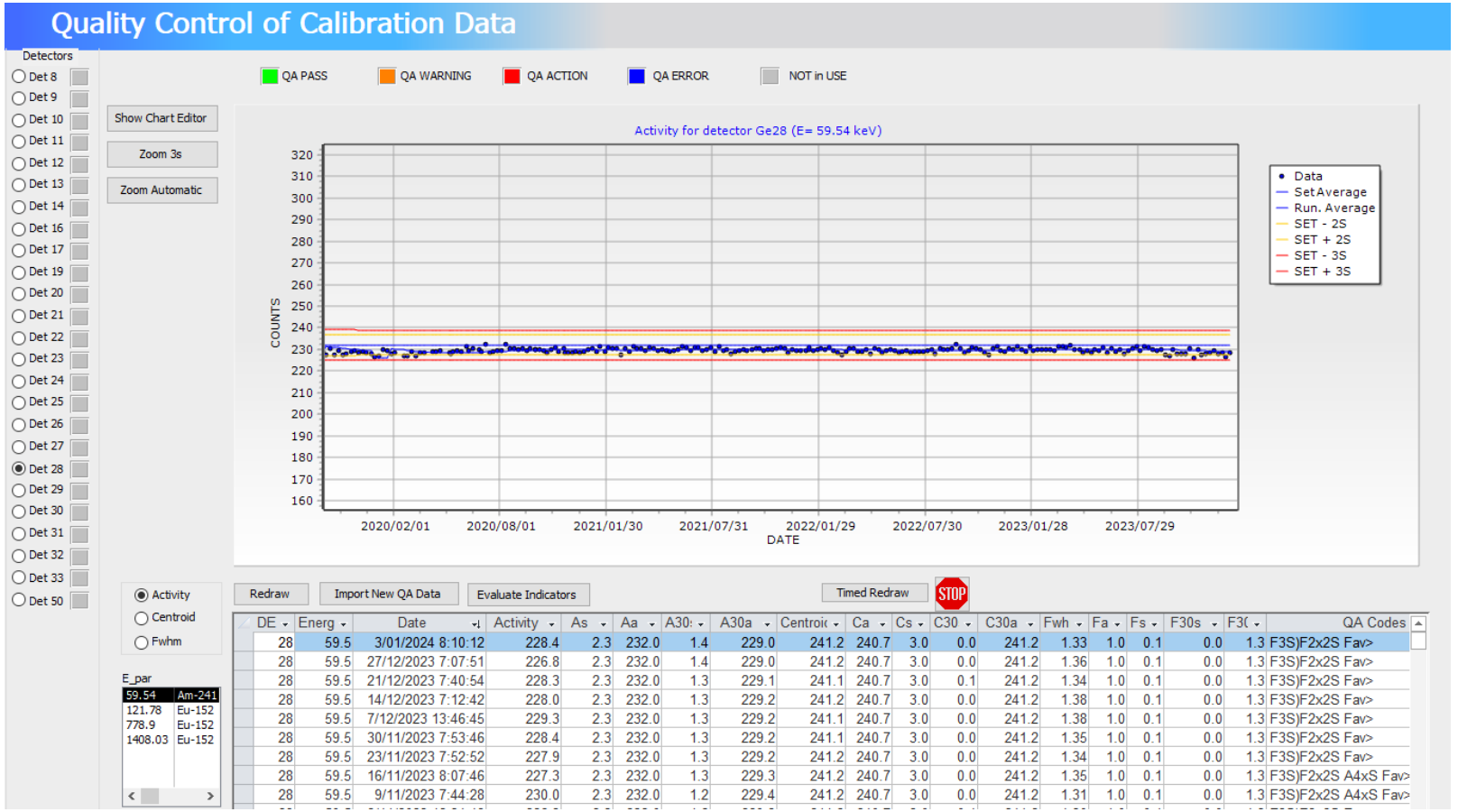
INTERNAL | Query | Export to Excel

Order_WBS_	Lab ID	Sample ID clie	coll. start date	coll. stop date	ref date	NUCLIDE	Less Tha	ACTIVITY	UNC(k=2	Unit	Approval Date	S
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Be-7	<	0.6		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		K-40	<	1.1		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Se-75	<	0.09		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Nb-95	<	0.08		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Zr-95	<	0.13		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Ru-103	<	0.08		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		I-131	<	0.16		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Cs-134	<	0.07		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Cs-137	<	0.08		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Ce-141	<	0.14		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Ce-144	<	0.5		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47682	WMN23351364	18/12/2023 12:00:00	31/12/2023 12:00:00		Ru*-106	<	0.6		Bq/L	8/01/2024 12:21:15	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Be-7	<	1.6		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		K-40	<	2.8		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Se-75	<	0.21		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Nb-95	<	0.19		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Zr-95	<	0.34		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Ru-103	<	0.20		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		I-131	<	0.39		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Cs-134	<	0.16		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Cs-137	<	0.18		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Ce-141	<	0.28		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Ce-144	<	1.1		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Ra*-228	<	0.6		Bq/L	8/01/2024 12:27:37	
ESURV2124-23	47683	WDS23351364	19/12/2023 12:00:00	1/01/2024 12:00:00		Th*-232	<	0.6		Bq/L	8/01/2024 12:27:37	

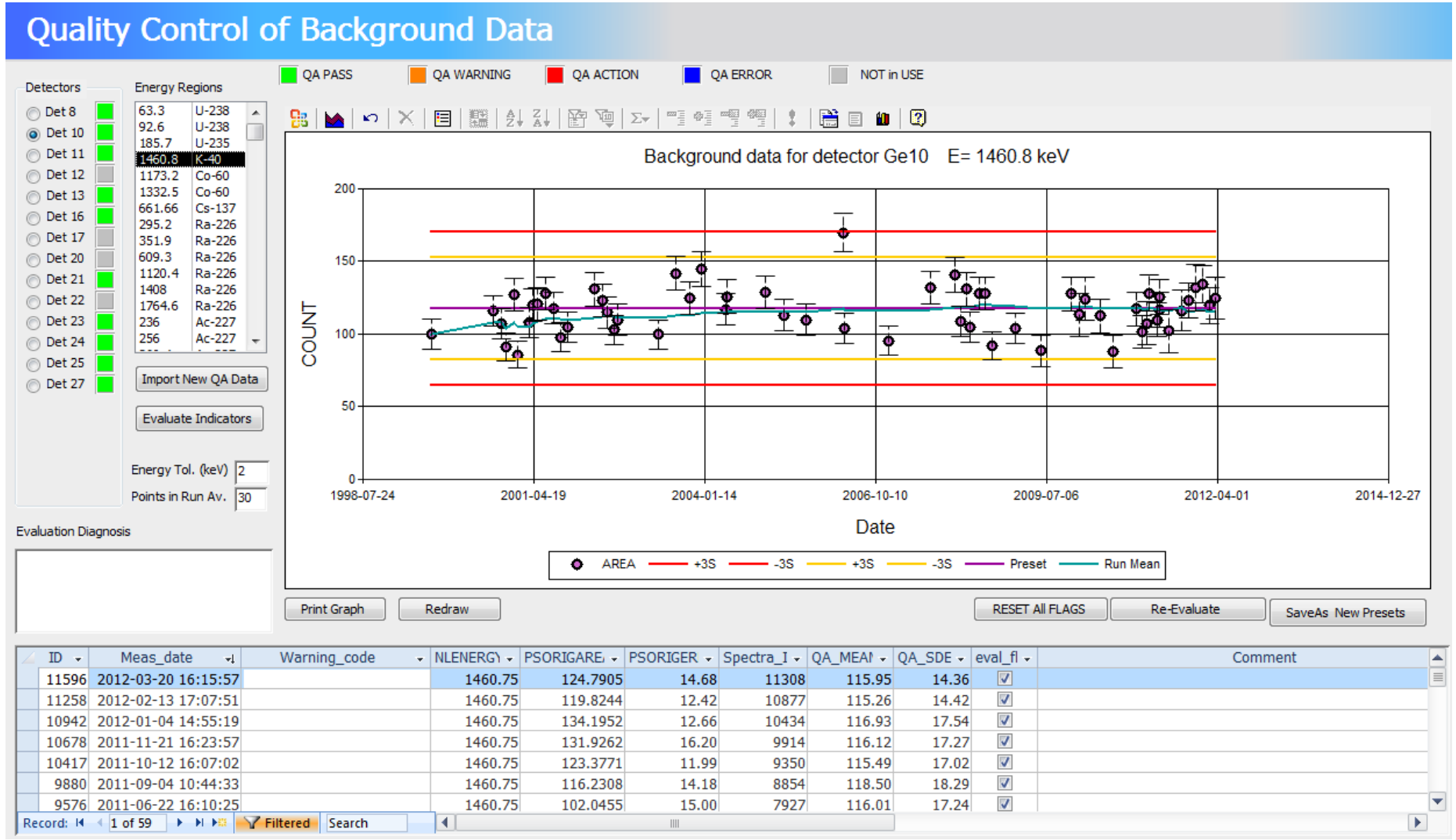
Record: 1 of 1051 | Filtered | Search

Quality assurance

- Quality control check
  > QCC
- Quality Background check
  > QBC
- Proficiency Testing



Background correction (ex. K-40)



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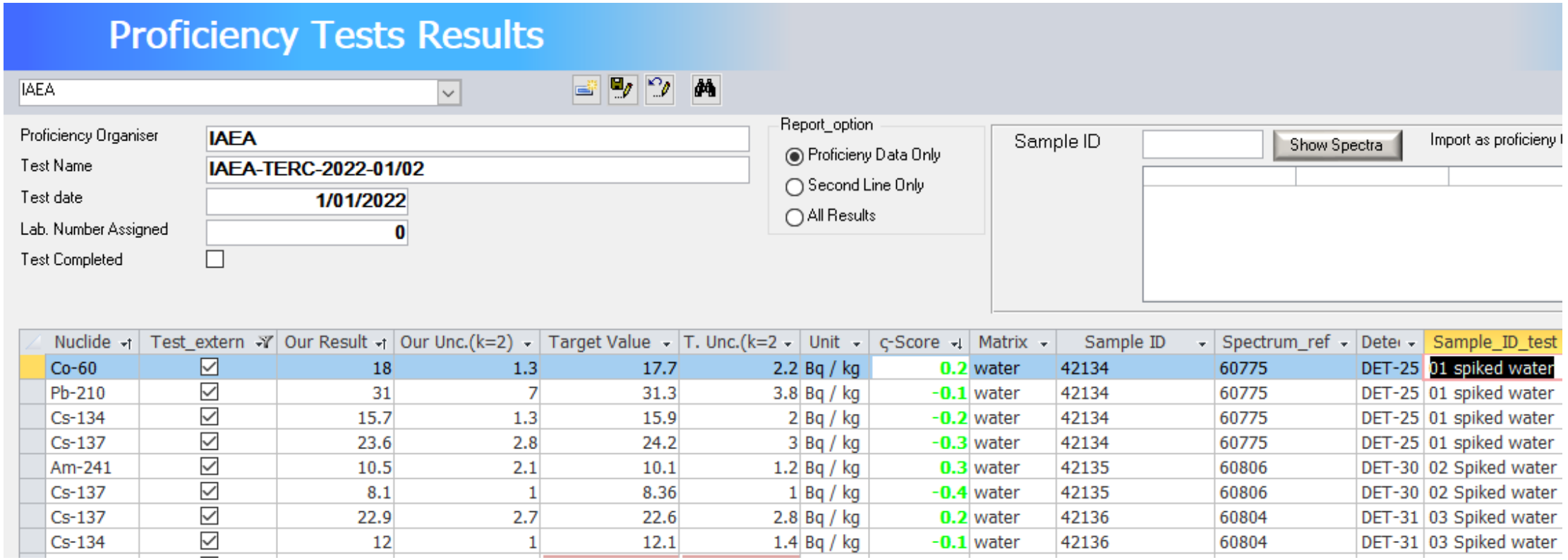
Registration and evalution of Proficiency tests



Proficiency Tests Results

IAEA

Proficiency Organiser: IAEA
Test Name: IAEA-TERC-2022-01/02
Test date: 1/01/2022
Lab. Number Assigned: 0
Test Completed: ☐

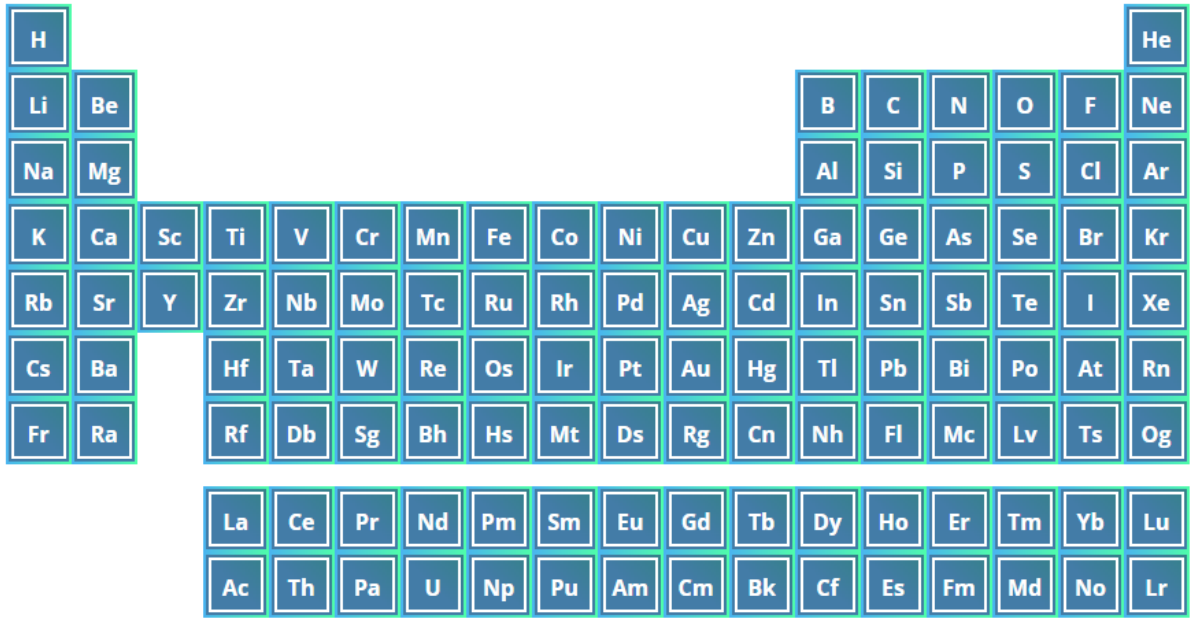
Report_option
- (•) Proficiency Data Only
- ( ) Second Line Only
- ( ) All Results

Sample ID | Show Spectra | Import as proficiency

Nuclide	Test_extern	Our Result	Our Unc.(k=2)	Target Value	T. Unc.(k=2	Unit	ç-Score	Matrix	Sample ID	Spectrum_ref	Dete	Sample_ID_test
Co-60	☑	18	1.3	17.7	2.2	Bq / kg	0.2	water	42134	60775	DET-25	01 spiked water
Pb-210	☑	31	7	31.3	3.8	Bq / kg	-0.1	water	42134	60775	DET-25	01 spiked water
Cs-134	☑	15.7	1.3	15.9	2	Bq / kg	-0.2	water	42134	60775	DET-25	01 spiked water
Cs-137	☑	23.6	2.8	24.2	3	Bq / kg	-0.3	water	42134	60775	DET-25	01 spiked water
Am-241	☑	10.5	2.1	10.1	1.2	Bq / kg	0.3	water	42135	60806	DET-30	02 Spiked water
Cs-137	☑	8.1	1	8.36	1	Bq / kg	-0.4	water	42135	60806	DET-30	02 Spiked water
Cs-137	☑	22.9	2.7	22.6	2.8	Bq / kg	0.2	water	42136	60804	DET-31	03 Spiked water
Cs-134	☑	12	1	12.1	1.4	Bq / kg	-0.1	water	42136	60804	DET-31	03 Spiked water

Use of recommended nuclear data www.nucleide.org

Données **atomiques** et **nucléaires**



Trier par :

Ordre alphabétique

Nuclide		Z	Vol. (?)	UpDate	Type (?)	Table (?)	Comments (?)	ASCII files (?)
Ac-225	^{225}Ac	89	9	20/12/2023	3	T	C	E P L
Ac-227	^{227}Ac	89	4	16/02/2009	2	T	C	E P L B
Ac-228	^{228}Ac	89	6	22/01/2010	3	T	C	E P L B
Ag-108	^{108}Ag	47	3	04/09/2006	2	T	C	E P L B

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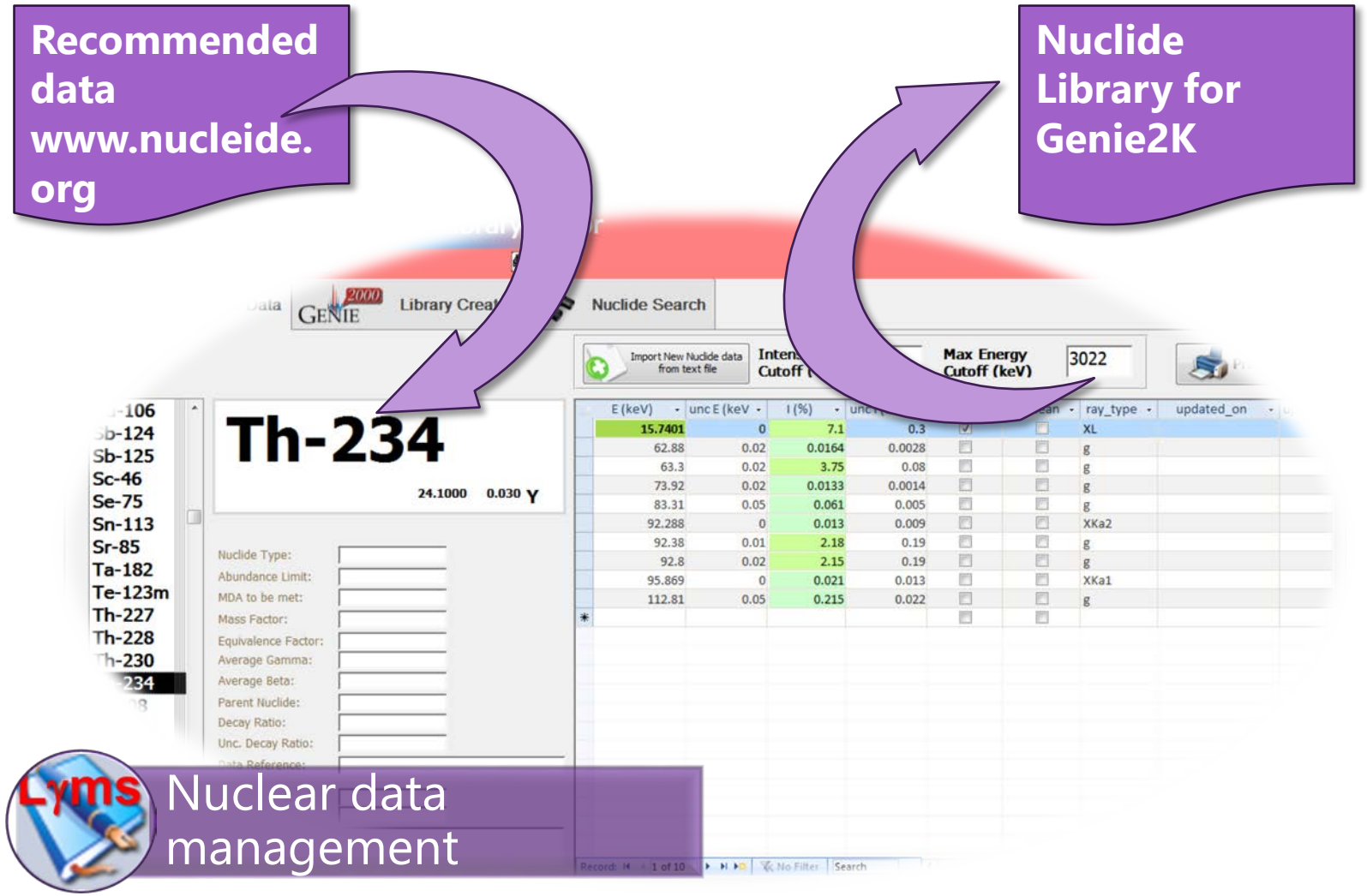

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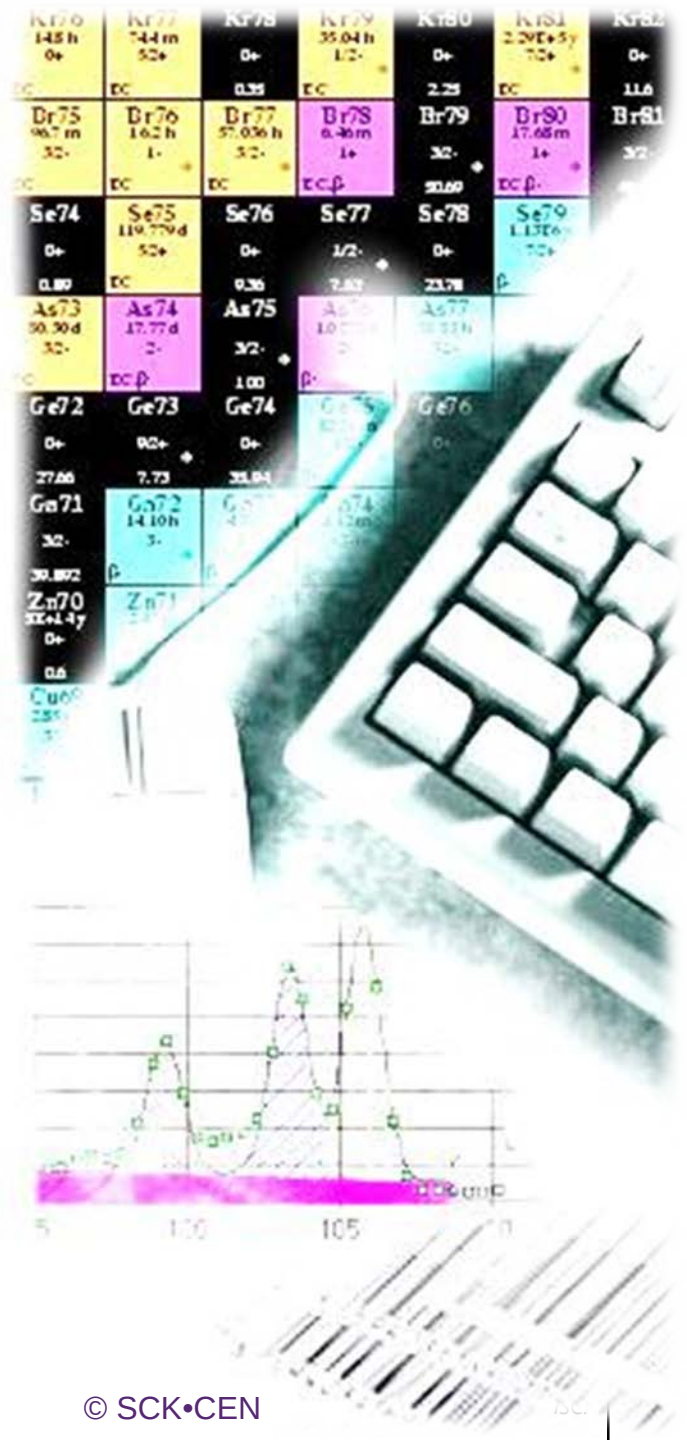
Conclusions

A LIMS will improve your analysis process and work efficiency

- Automation via dedicated interfacing
  - Minimises human blunders in data treatment
  - Assures a same level of quality for all samples treated
  - Contributes to confidence based on diagnostics

  and easy verification options
  - Increases throughput
  - Simplifies methods (instructions)
  - Easier training of new operators
  - Offers more flexibility (continuity in process by different operators)
- Easy data tracking options
- Communication with customers (ISO 17025)

All functionality needs to be validated



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Any questions, ideas, ...

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Belgian Nuclear Research Centre

Foundation of Public Utility

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