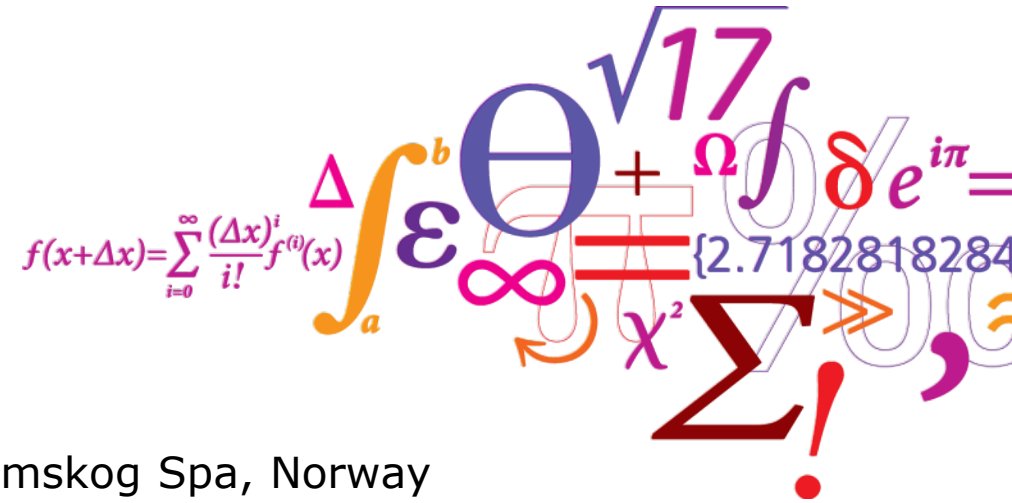
Gamma Spectrometry at DTU Nutech

Sven Nielsen



NKS GammaSpec 2016 Seminar, Rømskog Spa, Norway

DTU Nutech
Center for Nuclear Technologies

Status of gamma lab for routine analyses

- Nutech's laboratories including the gamma laboratory for routine measurements were renovated during 2015-2016 requiring temporary movement of gamma detector systems to other labs
- Renovation comprised painting of walls and ceiling, new light, shelves and door, aluminium sheet on floor, and a ventilation system that was later removed
- Renovation work was significantly delayed
- Liquid nitrogen is now piped into the lab which has reduced the time needed to fill dewars considerably by enabling several dewars to be filled simultaneously and avoiding use of 120-L transport containers
- Oxygen sensor in the gamma lab is connected to valves for nitrogen flow which stop automatically when concentration drops below limit
- Dehumidifying unit reduces humidity in lab air and thus formation of ice around detector cold fingers without collar in dewars, problem during summer with high levels of moisture in air
- Additional detectors acquired and all recalibrated during June-August 2016 with mixed-nuclide standard preparing for change of spectrum analysis procedure from old in-house method to Genie2000 combined with EFFTRAN

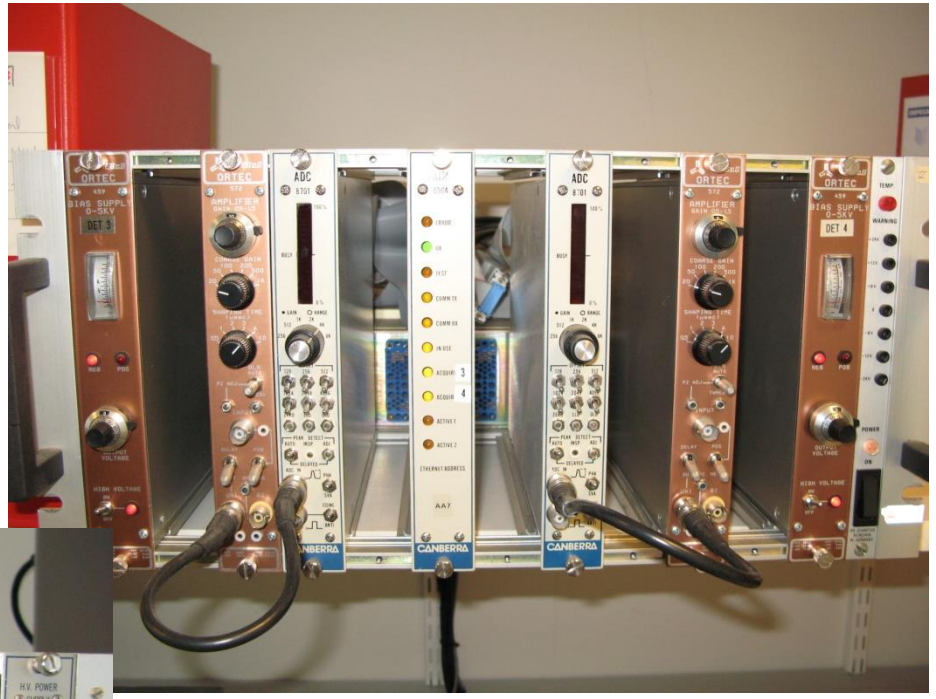
Gamma laboratory before renovation

Lead Shields

Ge Detector Specifications

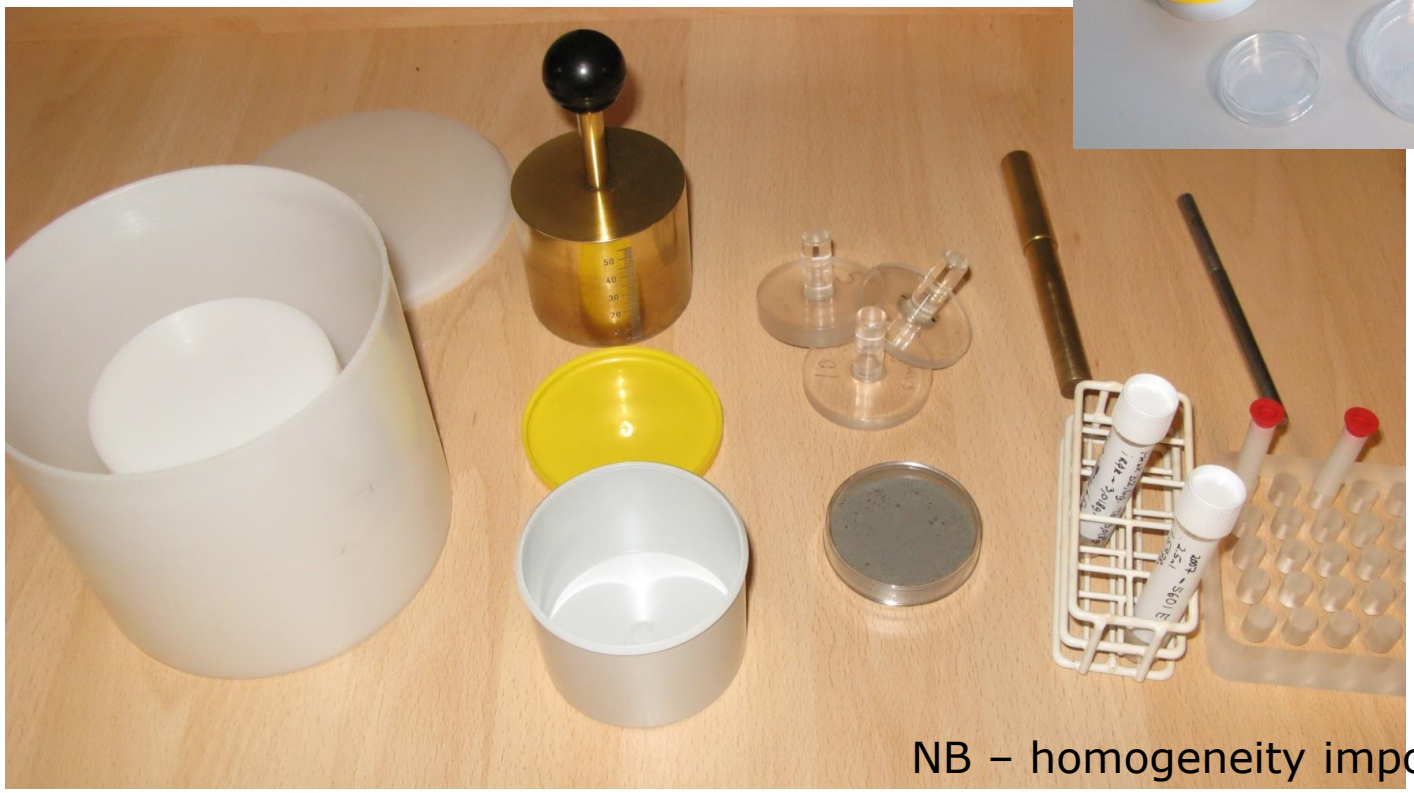
Risø id.	Producer	Year	Efficiency	Fwhm (keV)	Other
1	Ortec	1986	38%	1.8	1.3 mm Al window
2	Ortec	1986	35%	1.8	1.3 mm Al window
3	Ortec	1986	33%	1.9	Low energy, 0.5 mm Be window
4	Ortec	1986	33%	1.9	Low energy, 0.5 mm Be window
5	Canberra	1987	35%/180 cm^3	2.0	Low energy, Mg well, low background
6	Canberra	1998	118 cm^3	1.8	Low energy, 0.5 mm carbon epoxy, low background
7	Canberra	2001	260 cm^3	2.3	Low energy, Al well, low background
414	PGT	1979	25%	1.8	Ge(Li)
423	PGT	1978	27%	2.0	Ge(Li)
952	Ortec	1995	37%	1.8	Low energy, 0.5 mm Be window, low background

Electronics



Sample Geometries

- 1-L Marinelli beaker (0.6-1 L)
- 210 mL cylindrical beaker (range 20-200 mL)
- 400 mL cylindrical beaker (range 20-390 mL)
- 25 mL Petri dish (5, 10 and 15 mL)
- 70 mL Petri dish (20-65 mL)
- 10 mL vial (range 1-8 mL)
- 2 mL vial (range 0.2-2 mL)



NB – homogeneity important

Software for Spectrum Analysis

- Home-made software, developed since 1970's, implemented first in Algol programming language on main-frame computer, later in C on personal computer
- Peak search based on values of second derivative of smoothed spectrum
- Peak-area calculation based on simple summation of smoothed spectrum counts over peak channels minus background, fitting of doublets
- Accuracy of peak-area calculation method compared with other procedures (1998)

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--------- Måling nr. 405486 ---------
1: Sample type: Milk
2: Date       : 2009-Aug
3: Location   : W-Jutland 3
6: Sample ID  : 20090327
Res.el.vægt:             2.0000  kg dry
1: Detektor   :        4,       4
2: Måleperiode: 20090812.1138,20090817.0847
3: Fyldning   :            -0.4000
4: Vægtfylde  :             0.6100
5: Energikal. :   2.0606,  0.6687
6: Måletid    :            421797
Spektrum: 4000 kanaler
TOPAREAL fil A -> B, t = 1.5, max.eta = 40 %
 41 - 5979 kan., delta = 2.5 keV
  br. fra kalib.  w1: 5, w2: 13, udglat = 3
 Isotoptabel indeholder 140 isotoper
Milk from Videbæk august 2009
Spektrum nr. 405486, detektor 4, kalibrering 4
Kan: KeV:   w:(w0) b: Bagg: Eta: cps*1000: Eta: Bq(100%)  Vfk.: Bq(vf):
438 761  510.6  7295.0  6( 6) 1.2 1.81  9.9     -0.22 100.0
439 ( 7) 2.525.41  1.0   5.25  11.2     0.303 0.932     0.283 ( 3)
 907  608.9  7( 7) 1.9 2.96  5.5     -0.09 100.0
 986  661.2  7( 7) 1.6               10.14   4.4     0.739 0.940     0.695 ( 4)
2180 1459.8  9( 9) 2.2 2.81  3.7    655.66   0.2    92.579 0.958    88.733 ( 6)
2634 1763.0 10(10) 2.9 0.87  9.6     -0.13 100.0
3905 2613.4 13(13) 3.1 1.69  4.5      0.00 100.0
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Sample output

Tests of accuracy versus that of data set no. 4

Data no.	Software	Type	DF	T	χ^2-Reduced	Sign.
1	CompAct	Simple	21	15.9	0.76	ns
2	GammaVision	Simple	21	202	9.62	***
3	GammaVision	Simple	21	195	9.29	***
4	GammaVision	Simple	21	21.9	1.04	ns
5	Genie-PC	Simple	21	40.0	1.90	*
6	Genie-PC	Simple	21	38.5	1.83	*
7	C-Base	Simple	21	38.2	1.82	*
8	Genie-PC	Fitting	21	18.4	0.88	ns
9	GAMANAL	Fitting	20	32.1	1.61	ns
10	GRILS	Fitting	20	269	13.5	***
11	EMCAPLUS	Fitting	21	11.0	0.52	ns
12	ANSP	Fitting	21	9.8	0.47	*
13	GammaTrac	Fitting	21	21.0	1.00	ns
14	GammaTrac	Fitting	21	53.9	2.57	***
15	GAMMA-96	Other	21	19.1	0.91	ns

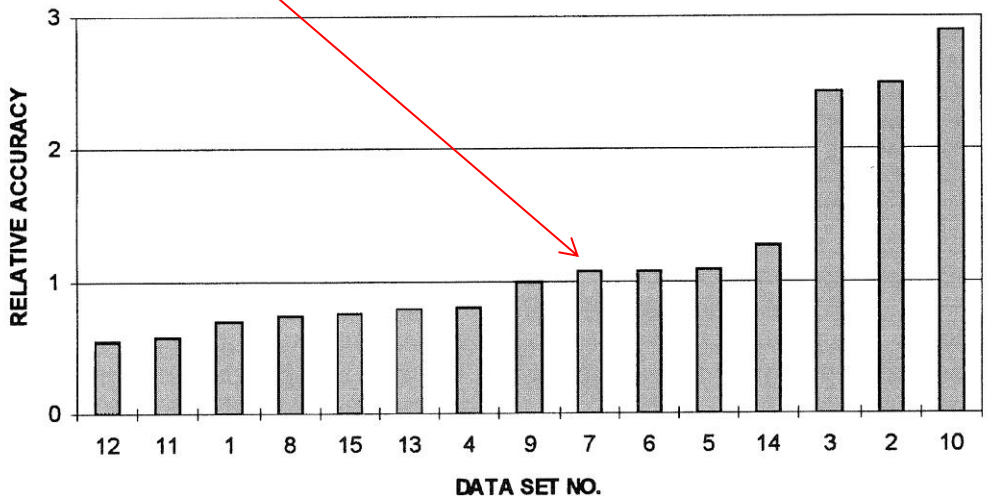
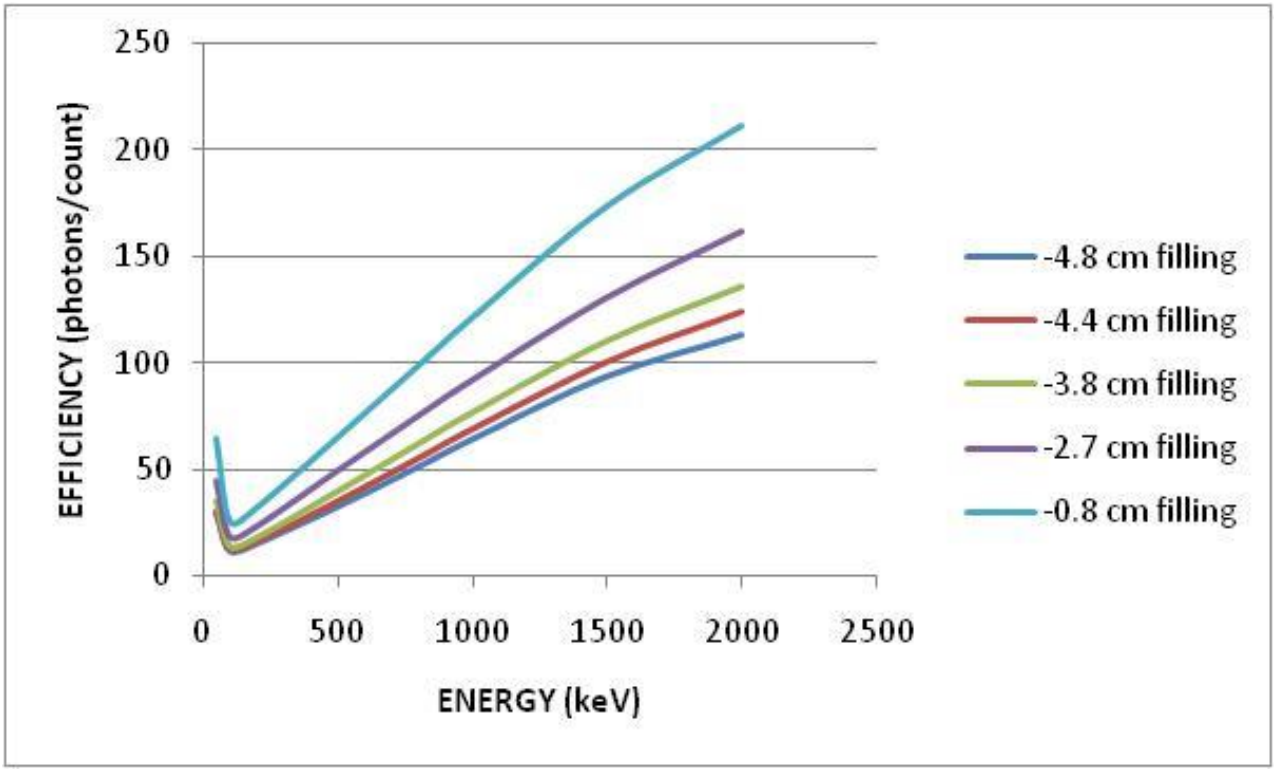


Fig. 3. Plot of relative average accuracies of peak-area ratios for the data sets.

Efficiency Calibration for gamma spec

- Calibration based on measurements in standardized geometries of mixed radionuclide gamma-ray reference solutions and K_2CO_3 standard, e.g. ^{241}Am, ^{109}Cd, ^{57}Co, ^{139}Ce, ^{51}Cr, ^{113}Sn, ^{85}Sr, ^{137}Cs, ^{88}Y and ^{60}Co
- Calibration curves fitted to measured efficiencies (photons/count) using polynomial expressions



Detector 423
efficiency calibration

True Coincidence Summing Correction

- True coincidence summing correction factors for gamma spectrometry determined experimentally as deviations between observed efficiencies and calibration curves

Nuclide	Energy (keV)	-4.8 cm filling	-4.4 cm filling	-3.8 cm filling	-2.7 cm filling	-0.8 cm filling
57Co	122	0.98	0.99	0.99	0.99	1.00
57Co	136	0.93	0.89	0.93	0.96	0.95
60Co	1173	1.00	1.00	1.00	1.00	1.00
60Co	1332	0.99	0.99	1.00	1.00	0.99
134Cs	605	1.18	1.17	1.15	1.14	1.15
134Cs	796	1.13	1.13	1.11	1.10	1.11
134Cs	802	1.22	1.23	1.21	1.18	1.18
226Ra	186	0.47	0.47	0.49	0.48	0.46
226Ra	352	1.05	1.04	1.07	1.04	1.04
226Ra	609	1.17	1.16	1.16	1.15	1.14
226Ra	1765	0.95	0.95	1.00	0.99	0.99

Excerpt of coincidence summing correction factor table for five different fillings of the 210 mL geometry for detector 423

Density Correction

- Density correction based on a mathematical model of Ge detector, sample geometry and density (Lippert 1983)
- Correction factor CF calculated as

$$CF = e^{\rho - 1} \cdot xabs \cdot e^{m_0 - m_1 lnE_\gamma}$$

- Where ρ is sample density, xabs characteristic length for sample geometry, m_0 and m_1 constants, and E_γ gamma energy.
- Example correction factors

Gamma energy (keV)	210 mL cylinder 178 mL	210 mL cylinder 59 mL
100	1.33	1.13
500	1.14	1.06
1000	1.10	1.04
1500	1.08	1.03

- Furthermore, for measurements of ^{210}Pb at 47 keV, correction for self absorption is applied by experimental determination using a ^{210}Pb point source (Cutshall et al, 1983)

Gamma lab after renovation

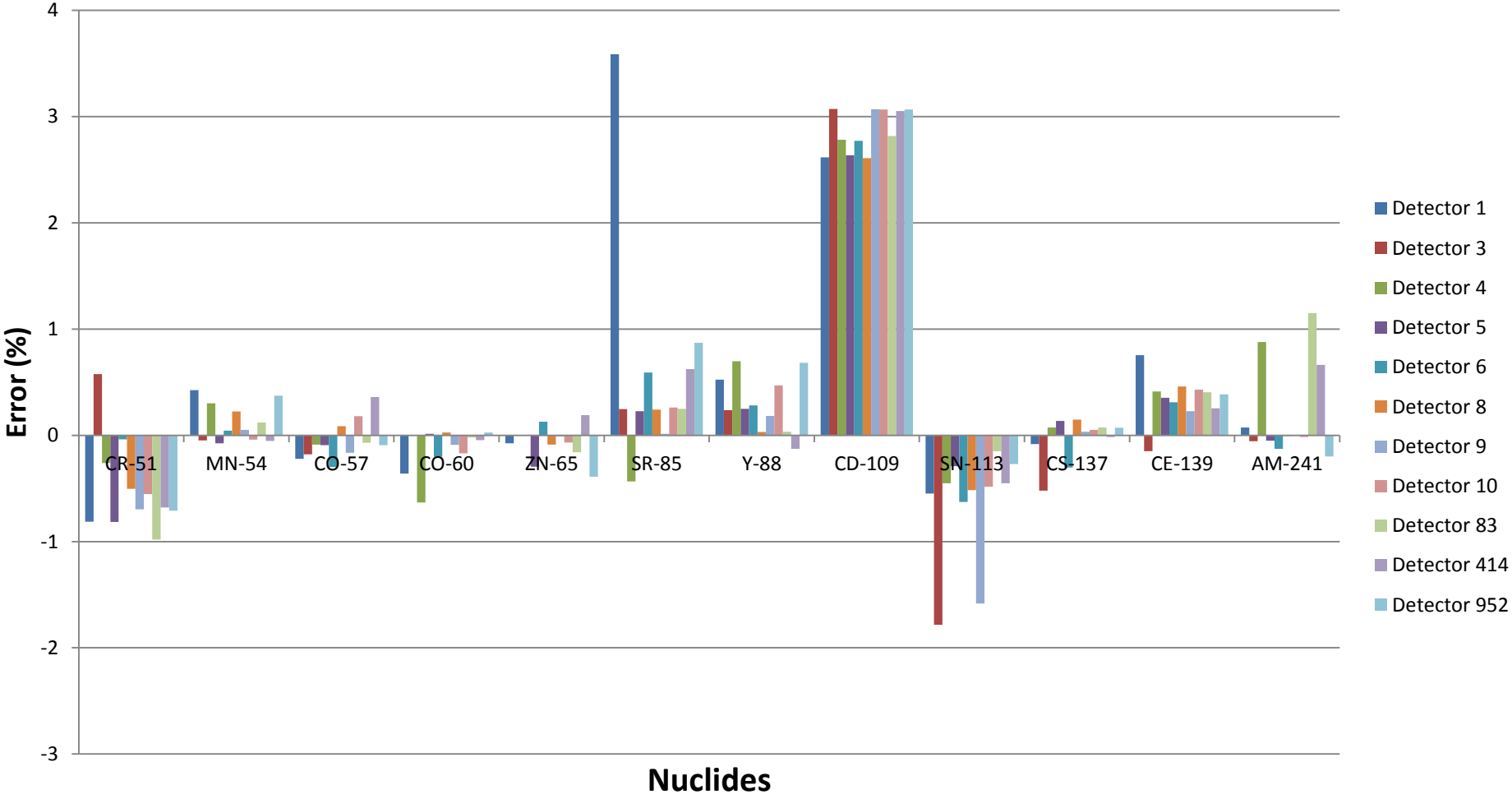
Calibration 2016

- 11 Ge detectors
- 7 standard sample containers, 3-5 fillings each
- About 250 calibration spectra
- AREVA calibration solution containing ^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{51}Cr, ^{137}Cs, ^{54}Mn, ^{113}Sn, ^{85}Sr, ^{88}Y, ^{65}Zn (range 60 – 1836 keV)
- Using Genie2000 and EFFTRAN to generate certificate files and nuclide libraries free from coincidence summing effects
- Checking quality of calibration by analysing calibration solutions as samples and comparing results with reference values

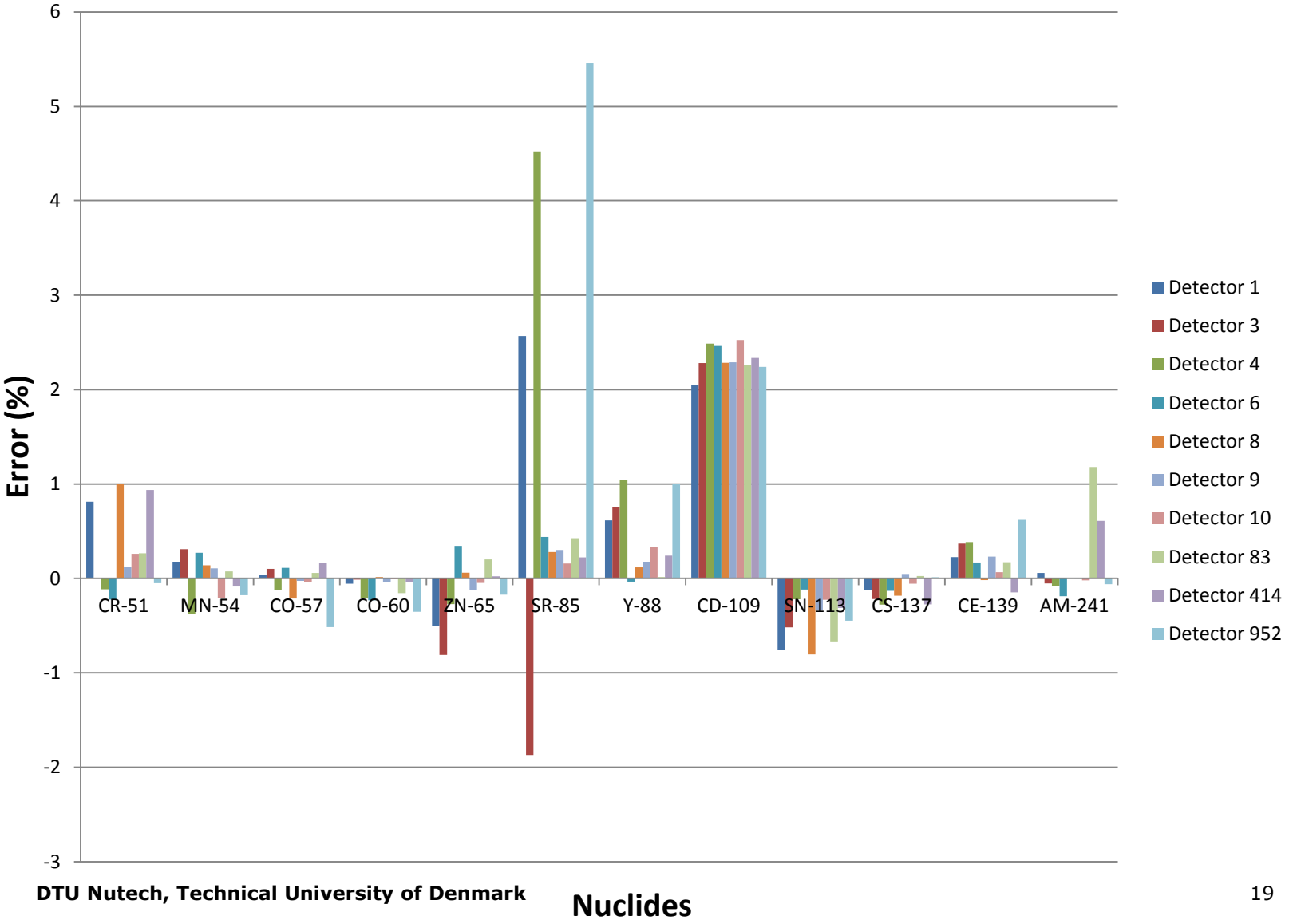
EFFTRAN coincidence summing corrections 210 mL geometry, 20 mL filling

Nuclide	E (keV)	Correction factors										
		det001	det003	det004	det005	det006	det008	det009	det010	det083	det414	det952
AM-241	59.5	1.000	1.010	1.010	1.001	1.011	1.012	1.012	1.012	1.000	1.000	1.010
CD-109	88.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CO-57	122.1	1.000	1.024	1.024	1.001	1.027	1.028	1.028	1.028	1.000	1.000	1.024
CO-57	136.5	1.000	0.920	0.921	0.996	0.907	0.899	0.899	0.899	1.000	1.000	0.921
CE-139	165.9	1.002	1.169	1.166	1.093	1.210	1.239	1.239	1.239	1.001	1.001	1.164
CR-51	320.1	1.000	1.002	1.002	1.000	1.002	1.002	1.002	1.002	1.000	1.000	1.002
SN-113	391.7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SR-85	514.0	1.000	1.069	1.068	1.002	1.083	1.091	1.091	1.091	1.000	1.000	1.068
CS-137	661.7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MN-54	834.8	1.000	1.003	1.003	1.000	1.003	1.003	1.003	1.003	1.000	1.000	1.003
Y-88	898.0	1.117	1.209	1.206	1.092	1.245	1.287	1.287	1.286	1.141	1.091	1.205
ZN-65	1115.5	1.000	1.013	1.013	1.000	1.014	1.014	1.014	1.015	1.000	1.000	1.013
CO-60	1173.2	1.128	1.132	1.130	1.097	1.152	1.183	1.183	1.182	1.153	1.100	1.130
CO-60	1332.5	1.133	1.138	1.135	1.101	1.160	1.192	1.192	1.191	1.158	1.104	1.135
Y-88	1836.1	1.135	1.229	1.226	1.107	1.276	1.324	1.324	1.323	1.160	1.107	1.225

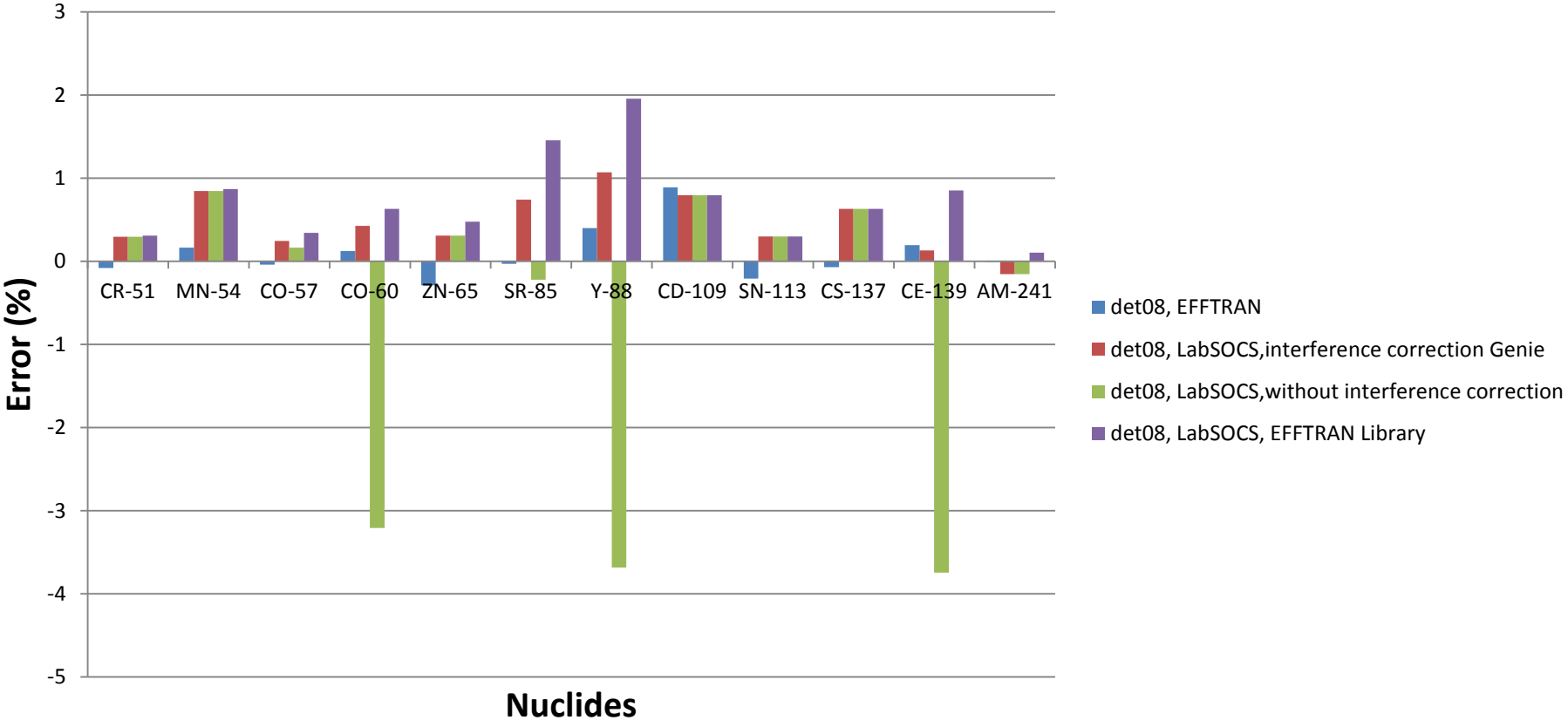
Percentage difference between reference and measured activities for 210 mL geometry, GY200_163



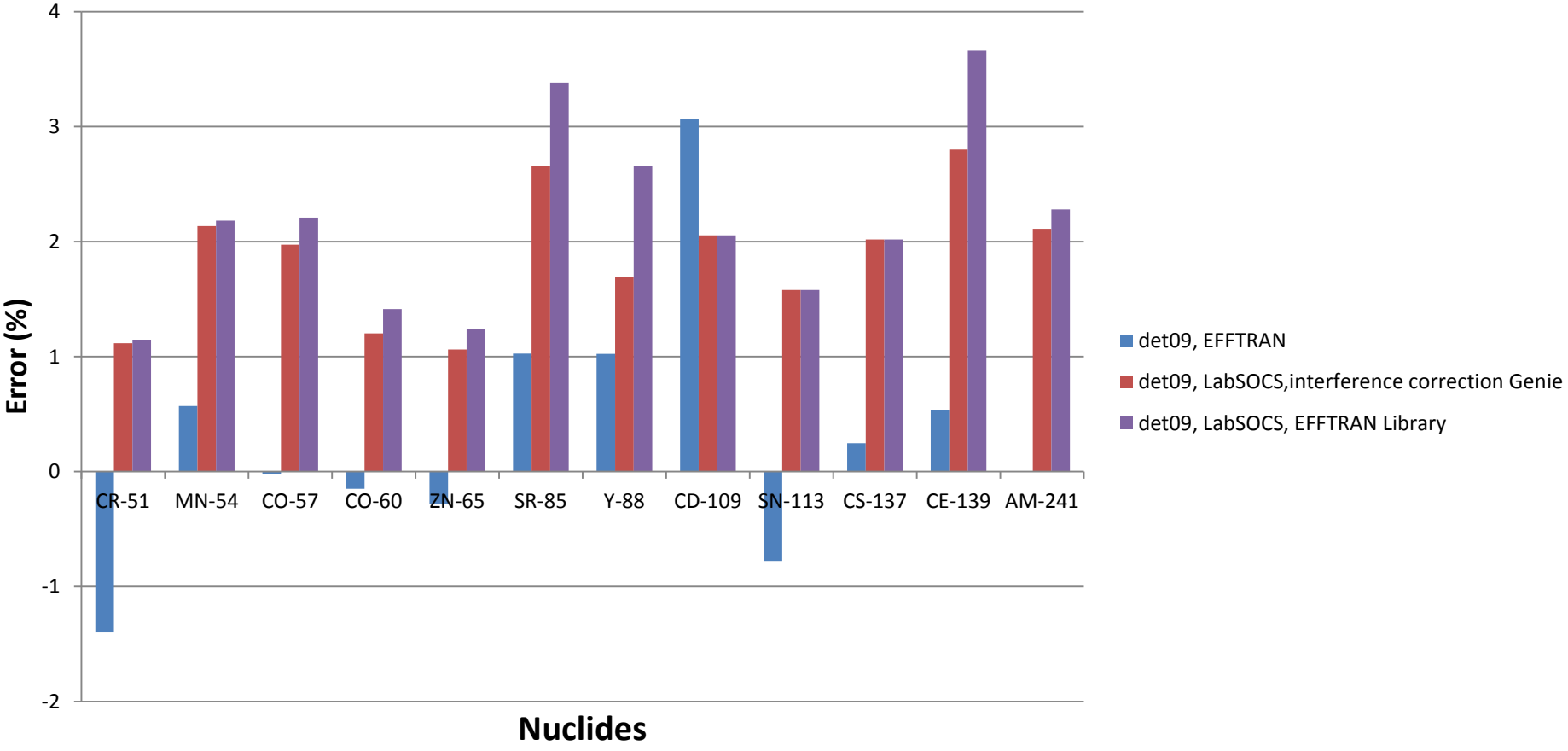
Percentage difference between reference and measured activities for Petri dish geometry PET25_15



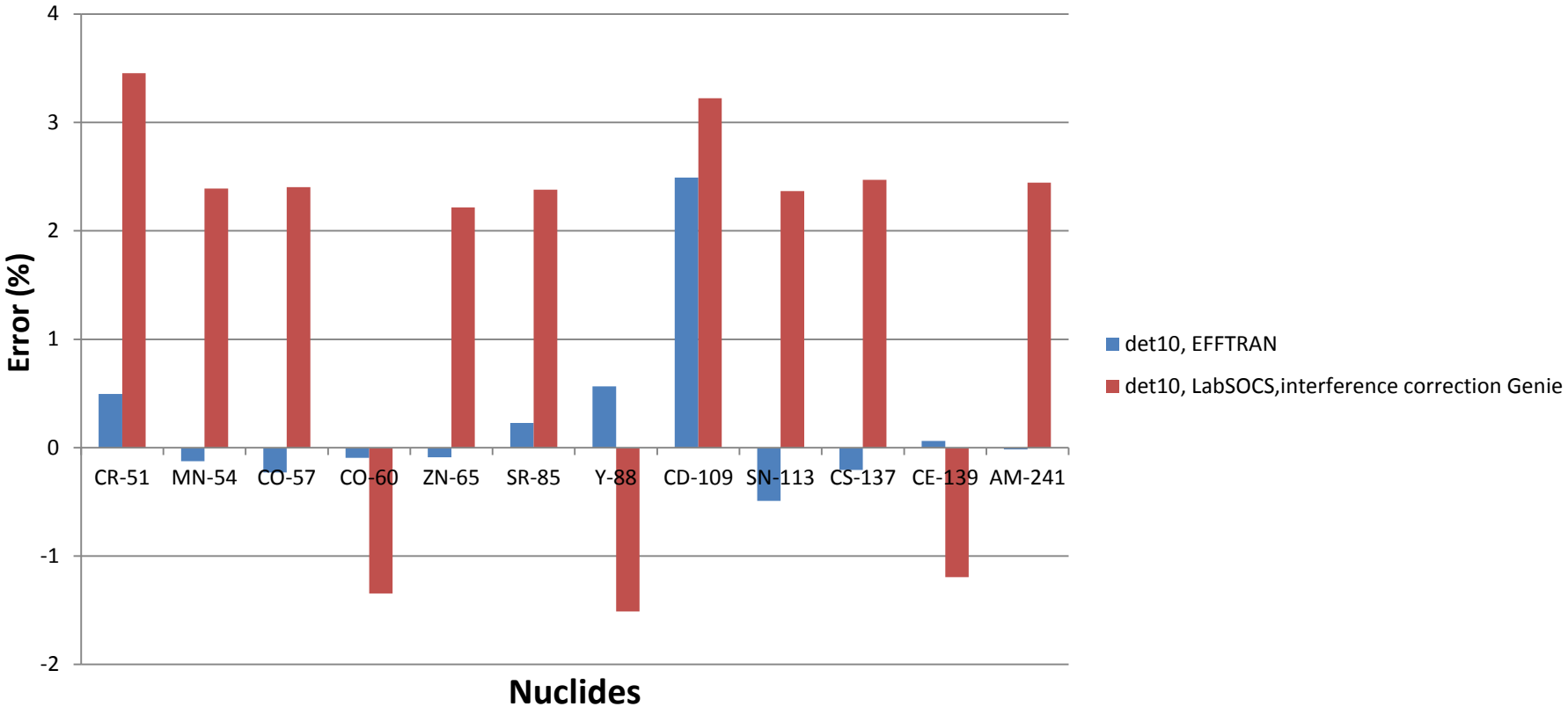
Percentage difference between reference and measured activities with EFFTRAN and LabSOCS for Detector 8, 210 mL geometry GY200_20



Percentage difference between reference and measured activities with EFFTRAN and LabSOCS for Detector 9, 400 mL geometry WH400_299



Percentage difference between reference and measured activities with EFFTRAN and LabSOCS for Detector 10, Petri dish geometry PET70_60



Future

- Complete and validate calibration of Ge detectors
- Establish user-friendly system for analysis based on Genie2000 and EFFTRAN/MEFFTRAN
- Expand accreditation to include gamma spectrum analysis