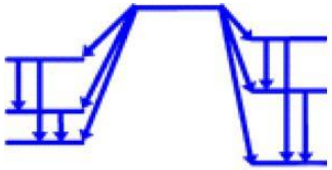

Meeting of the ICRM Gamma Spectrometry Working Group
Monte Carlo benchmark on coincidence summing corrections
October 29-30, 2020

GESPECOR results

Participants:

1. Aurelian Luca & Ciprian Cosar, IFIN-HH, Romania: GESPECOR 4.2
2. Larisa Ganea & Ana Pantelica, IFIN-HH , Romania : GESPECOR 4.2
3. Hasan Dikmen, Nucl. Energy Res. Institute, Turkey: GESPECOR 4.2
4. Octavian Sima, Univ. of Bucharest & IFIN-HH, Romania: GESPECOR 5.0

Presenter:
Octavian Sima

General features of FC computations with GESPECOR:

- **Detectors**: Closed End Coaxial, Planar, Well-type HPGe (Sima, Arnold & Dovlete, JRNC 248 (2001) 359);
- **Source geometries**: cylinder, point source, Marinelli beaker;
- **Source matrix**: any matrix with given composition and density
  - For self-attenuation calculations: composition and density not required if the linear attenuation coefficient is known (Sima & Dovlete, ARI 48 (1997) 59; Sima & Arnold, 56 (2002) 71) – efficient algorithm
- **User friendly interfaces**; extensions beyond interfaces

Coincidence summing:

- **Peak oriented** => fast; easy evaluation also for photons with low emission probability;
  - all peaks included, normal, pure sum peaks [common, with non-linked transitions, sum peaks with X-rays (Arnold & Sima, ARI 64 (2006), 1297)]
- **Decoupling** of decay scheme analysis from radiation transport (Sima & Arnold, ARI 53(2000)51)
  - exactly balanced decay scheme is initially constructed
- **Analytical calculation** of joint emission probabilities for all groups of photons

  => done before simulation; faster than Monte Carlo simulation of the decay scheme; better statistical uncertainty of the results; flexibility in coupling decay scheme data with photon transport (Sima & Arnold, ARI 66 (2008) 705)
- **Nuclide Data Base**: KORDATEN (ASCII file, easily editable); **Source of data**: http://www.nucleide.org/DDEP_WG/DDEPdata.htm or ENSDF

General features of FC computations with GESPECOR (cont.):

- Extensions:
  - Detailed information on groups of photons (DED files), on results (DSC files)
  - Angular correlations**:** easily included by adapting the Decay Data Files
  - Structure of the dead layer (Arnold & Sima, ARI 60 (2004) 167)
  - Compton Suppressed Spectrometers (Sima & Osvath, ARI 81 (2013) 109)
  - Additional geometries (point source placed anywhere, tilted of axis cylinder, attenuators)
  - Non-homogeneous sources (Sima, JRNC 244 (2000) 669; Suvaila, Sima & Osvath, ARI 87 (2014) 384; Sima ARI 134 (2018) 137)

Known issues:

- Decay electrons and positrons and Auger electrons not transported in the source
- LX rays not transported (except the case when KX rays are not emitted)
- Geometry limits (10 μm) in GUI (can be avoided by editing the geometry file)
- Bug in geslib.dll version from 2007 – affects total efficiency below 100 keV – corrected in later versions

Comment:

- In the case of detector B, especially in the case of point source, **significant contribution of the decay electrons and positrons, LX rays and Auger electrons** to coincidence summing corrections is expected, because **there is no attenuation between the emitting nuclide and the sensitive volume** of the detector => bias in GESPECOR results
- In typical measurement conditions, smaller or negligible contributions => much lower bias

Details of the participants' simulations:

- Number of events: 10^6 (participants 1-3), $2*10^7$, for evaluation of the distribution of FC values between sets of results (participant 4)
- Angular correlations not included
- KORDATEN version: last edition (participants 1 and 4); an earlier version (participants 2 and 3).
- Point source: standard procedure (small cylindrical source), or a true point source
- Uncertainty of FC: approximated by the uncertainty of the ideal peak efficiency or evaluated from the dispersion of repeated simulations

Co-60									
		Detector A				Detector B			
E (keV)	I(E)	Point	Water	Filter	Soil	Point	Water	Filter	Soil
1173.2	0.999	1.199	1.073	1.119	1.107	1.233	1.086	1.141	1.126
1332.5	1	1.208	1.076	1.123	1.111	1.243	1.088	1.147	1.130

Individual relative uncertainty: less than 0.7 % for all results

Relative standard deviation between the participants: less than 0.3%

Ba-133									
		Detector A				Detector B			
E (keV)	I(E)	Point	Water	Filter	Soil	Point	Water	Filter	Soil
30.85	0.979	1.335	1.135	1.220	1.196	1.618	1.236	1.360	1.349
35.1	0.230	1.336	1.132	1.217	1.189	1.619	1.230	1.359	1.331
53.16	0.021	1.360	1.135	1.222	1.191	1.961	1.307	1.529	1.394
79.61	0.027	1.391	1.142	1.230	1.205	2.250	1.362	1.653	1.454
81	0.329	1.300	1.113	1.180	1.160	1.694	1.232	1.397	1.289
160.61	0.006	1.113	1.053	1.062	1.067	1.007	1.023	0.973	0.986
223.24	0.005	1.167	1.060	1.097	1.088	2.375	1.358	1.702	1.408
276.4	0.072	1.159	1.057	1.093	1.085	2.083	1.295	1.567	1.345
302.85	0.183	1.080	1.029	1.048	1.042	1.811	1.233	1.447	1.252
356.01	0.621	1.067	1.025	1.040	1.036	1.556	1.171	1.317	1.186
383.85	0.089	0.883	0.962	0.927	0.940	1.028	1.021	1.018	0.971

Individual relative uncertainty: less than 0.7 % for all results
Relative standard deviation between the participants: 223 keV: 1.8 %, 276 keV: 1.4 %, 302 keV: 1.3 %, 79 keV: 1.2 % (detector A point source)
- Two versions of nuclear data: DDEP, 10.03.2016 (2 participants), Nucleide 2-2004 (2 participants) – slightly different decay data for Ba-133

Cs-134									
		Detector A				Detector B			
E (keV)	I(E)	Point	Water	Filter	Soil	Point	Water	Filter	Soil
32.1	0.007	1.347	1.140	1.230	1.202	1.414	1.168	1.251	1.254
36.6	0.002	1.347	1.137	1.227	1.196	1.413	1.165	1.250	1.245
475.3	0.015	1.497	1.169	1.280	1.253	1.602	1.204	1.339	1.306
563.2	0.084	1.554	1.184	1.307	1.278	1.676	1.221	1.375	1.335
569.3	0.154	1.546	1.182	1.304	1.274	1.663	1.218	1.370	1.331
604.7	0.976	1.298	1.107	1.175	1.158	1.355	1.128	1.210	1.190
795.8	0.855	1.302	1.107	1.174	1.158	1.360	1.127	1.210	1.191
801.9	0.087	1.495	1.166	1.278	1.250	1.599	1.200	1.337	1.303
1038.6	0.010	1.063	1.036	1.038	1.047	1.069	1.039	1.042	1.054
1167.9	0.018	0.778	0.923	0.846	0.885	0.745	0.905	0.816	0.861
1365.2	0.030	0.677	0.870	0.767	0.814	0.635	0.842	0.727	0.782

Individual relative uncertainty: less than 0.75 % for all results; some results were reported with an unrealistically low uncertainty
Relative standard deviation between the participants: less than 1 %

Na-22									
		Detector A				Detector B			
E (keV)	I(E)	Point	Water	Filter	Soil	Point	Water	Filter	Soil
511	1.798	1.202	1.085	1.123	1.120	1.237	1.100	1.145	1.143
1274	0.999	1.612	1.179	1.313	1.279	1.768	1.218	1.388	1.342

Individual relative uncertainty: less than 0.7 % for all results

Relative standard deviation between the participants: less than 0.9%

CONCLUSIONS

- Results of FC simulations with different versions of GESPECOR are consistent
- Discrepancies between the participants generally lower than 1 %
- Discrepancies up to 1.8 % due to different versions of the KORDATEN nuclide data base (i.e between BA-133 decay data from Nucleide 2004 and DDEP 2016)
- Expected bias in the case of detector B (especially in the case of point source) due to significant contribution to coincidence effects of decay electrons, positrons (whatever energy they have) and LX rays – no attenuation between the source and the sensitive volume of the detector