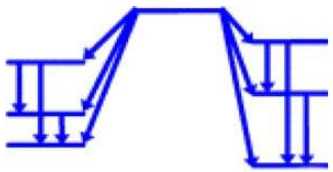
BENCHMARK FOR MONTE CARLO SIMULATION IN GAMMA-RAY SPECTROMETRY

- Monte Carlo simulation in gamma-ray spectrometry
  - Efficiency calibration
  - Efficiency transfer
  - Coincidence summing corrections
  - Optimisation of experimental conditions
  - Etc.

- Goal
  - Provide case studies for new users : input files and results
  - Validation by different codes/users

- Two types of codes
  - Dedicated: DETEFF, EFFTRAN, GESPECOR: specific user-friendly interface
  - General purpose: EGSnrc, GEANT4, MCNP, PENELOPE
    but training required to prepare the input files – description of geometries



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BENCHMARK FOR MONTE CARLO SIMULATION IN GAMMA-RAY SPECTROMETRY

Part 1 : Efficiency calculation

- 11 participants
- 19 data sets
- 5 codes (EGSnrc, GEANT4, GESPECOR, MCNP, PENELOPE)

- Presentation at ICRM 2019

ICRM SALAMANCA 2019
22nd International Conference on

- Publication in ARI

Applied Radiation and Isotopes 154 (2019) 108850

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

A benchmark for Monte Carlo simulation in gamma-ray spectrometry

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- Full report (nearly completed)

- Material available on the ICRM GSWG web page

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BENCHMARK FOR MONTE CARLO SIMULATION IN GAMMA-RAY SPECTROMETRY

Set of data available

The Gamma-Ray Spectrometry Working Group is devoted to the development of the metrological aspects of gamma-ray spectrometry and its applications. This includes, but is not restricted to: measurement techniques and equipment, determination of photon emission intensities, detector efficiency calibrations (including Monte Carlo methods), coincidence-summing corrections, uncertainties, correlations, new instrumentation, and X-ray spectrometry.

Meetings & Workshops

WG actions (Past & on-going)

Monte Carlo benchmarks

Past exercises & Publications

Events & Courses

Practical info & Useful links

http://www.lnhb.fr/icrm_gs_wg/

ICRM GSWG

http://www.lnhb.fr/icrm_gs_wg/icrm_gs_wg_benchmarks/

Monte Carlo benchmarks

A benchmark for Monte Carlo simulation applied to gamma-ray spectrometry

The use of Monte Carlo (MC) simulation in gamma-ray spectrometry is getting more and more interest since it can be run on PCs. Such approach is useful to perform different kinds of calculation, such as efficiency calibration, efficiency transfer or coincidence summing corrections.

In the frame of the Gamma Spectrometry Working Group (GSWG) of the International Committee for Radionuclide Metrology (ICRM), a benchmark has been prepared, as a learning tool for the use of Monte Carlo codes applied to gamma-ray spectrometry.

There are two kinds of software which can be used for these. The dedicated codes (GESPECOR, DETEFF, etc.) are conceived with a user-friendly interface and can be directly applied to derive the calculation results from input data. On the contrary, the use of generalist codes (GEANT4, MCNP, PENELOPE, etc.) need some training in order to derive the information of interest. One of the typical difficulties is the preparation of the input files which describe the geometrical conditions, since these must be written according to a specific format. To facilitate the use of generalist MC simulation software, the ICRM GSWG participants prepared geometrical files for a selection of high-purity germanium detectors (HPGe) and measurement conditions, and computed the total and full-energy peak efficiency for five energies. For each code, a specific information form, the input files and the results are available in the archives: GEANT4, MCNP, PENELOPE.

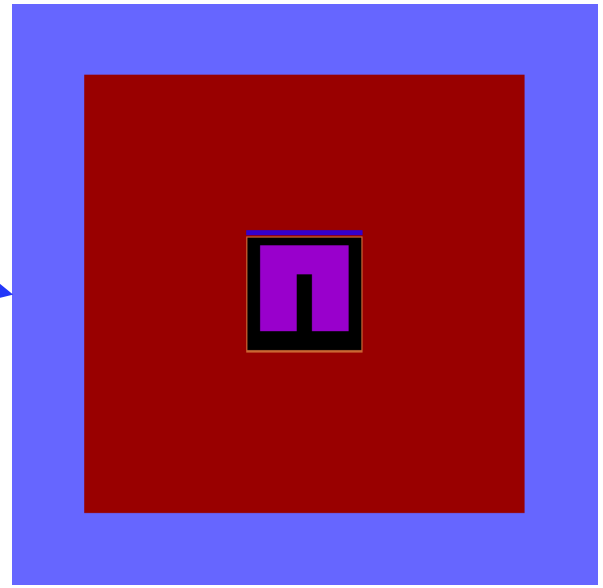
Download the files

Part 2 : Coincidence summing corrective factors calculation

- Geometries used in a previous exercises (Vidmar *et al*., 2014 and Benchmark 1)

- Cylindrical geometries
  - 2 detectors (A – B)
  - 4 types of sources (P, W, F, S)
  - Sample-to-window distance = 1 mm
  - Lead shielding

  - Materials composition and density provided



- Computation of the coincidence summing corrective factors

  8 case studies: AP, AW, AF, AS, BP, BW, BS, BF

  4 radionuclides (^{60}Co, ^{133}Ba, ^{134}Cs, ^{22}Na)

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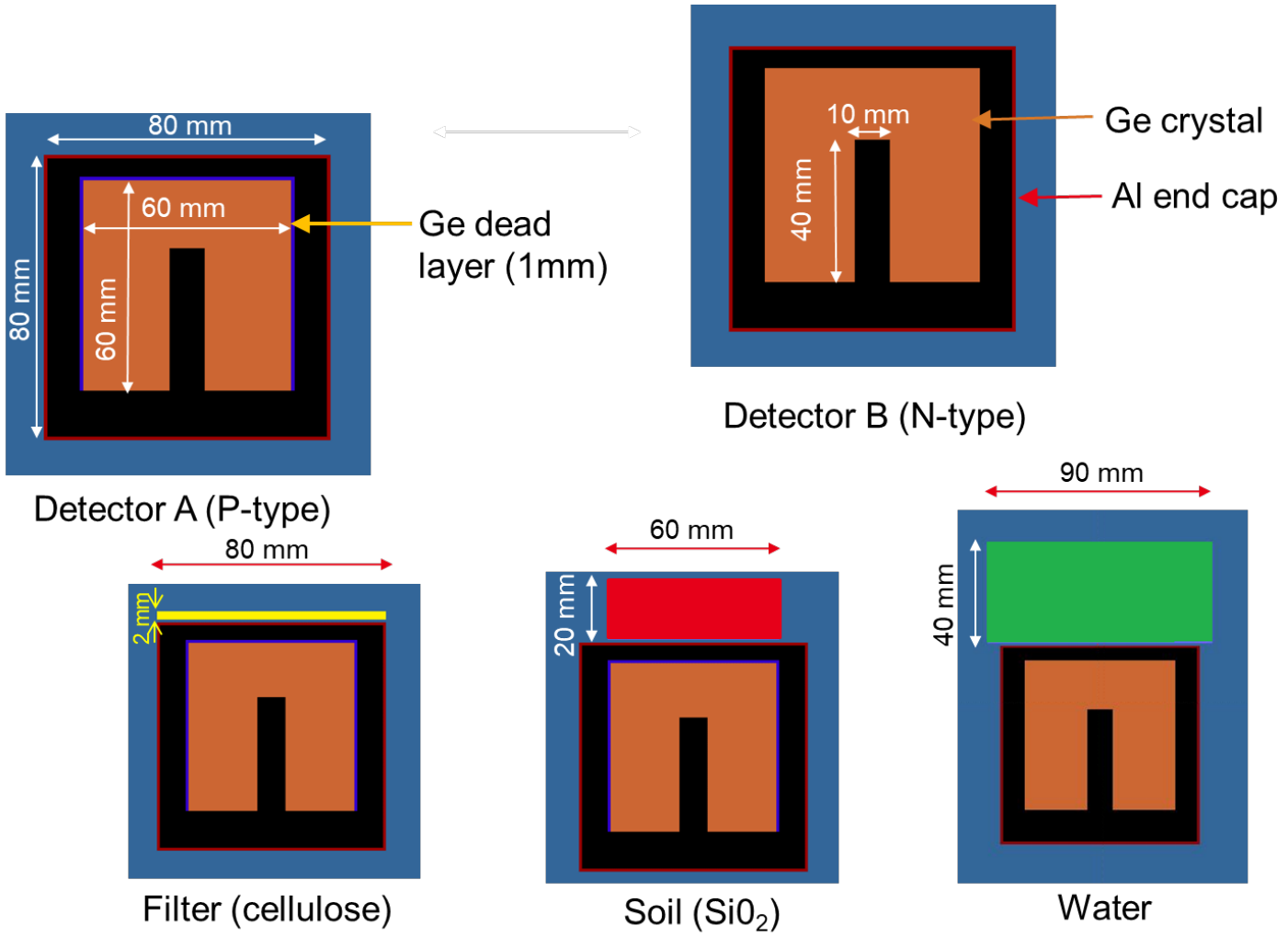
GEOMETRIES



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RESULTS : Part 2 : Coincidence summing corrective factors

16 participating institutes: Marios Anagnostakis, Ciprian Cosar, Alfredo de Blas del Hoyo, Hasan Dikmen, Maria-Larisa Ganea, Santiago Hurtado, Konstantinos Karfopoulos, Marie-Christine Lépy, Aurelian Luca, Guillaume Lutter, Iason Mitsios, Ana Pantelica, Constantinos Potiriadis, Stefan Roettger, Nikolaos Salpadimos, Marilia Savva, Octavian Sima, Cheick Thiam, Tran Thien Than, Theodora Vasilopoulou, Leen Verheyen, Tim Vidmar

22 data sets
6 codes (EFFTRAN (2), EGSnrc (2), GEANT4 (5), GESPECOR (4), MCNP (2), PENELOPE (7))

Presentation at ICRM 2021 ?

Publication in ARI (+ detailed report) ?

Material will be available on the ICRM GSWG web page

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RESULTS : Part 2 : Coincidence summing corrective factors

Small problem : definition of the corrective factor:

Activity measurement : $I(E) = \frac{N(E)}{A\,\varepsilon(E)t}\prod_i C_i$

Either we apply the corrective factor
- to the net peak area (numerator) or
- to the efficiency (denominator)

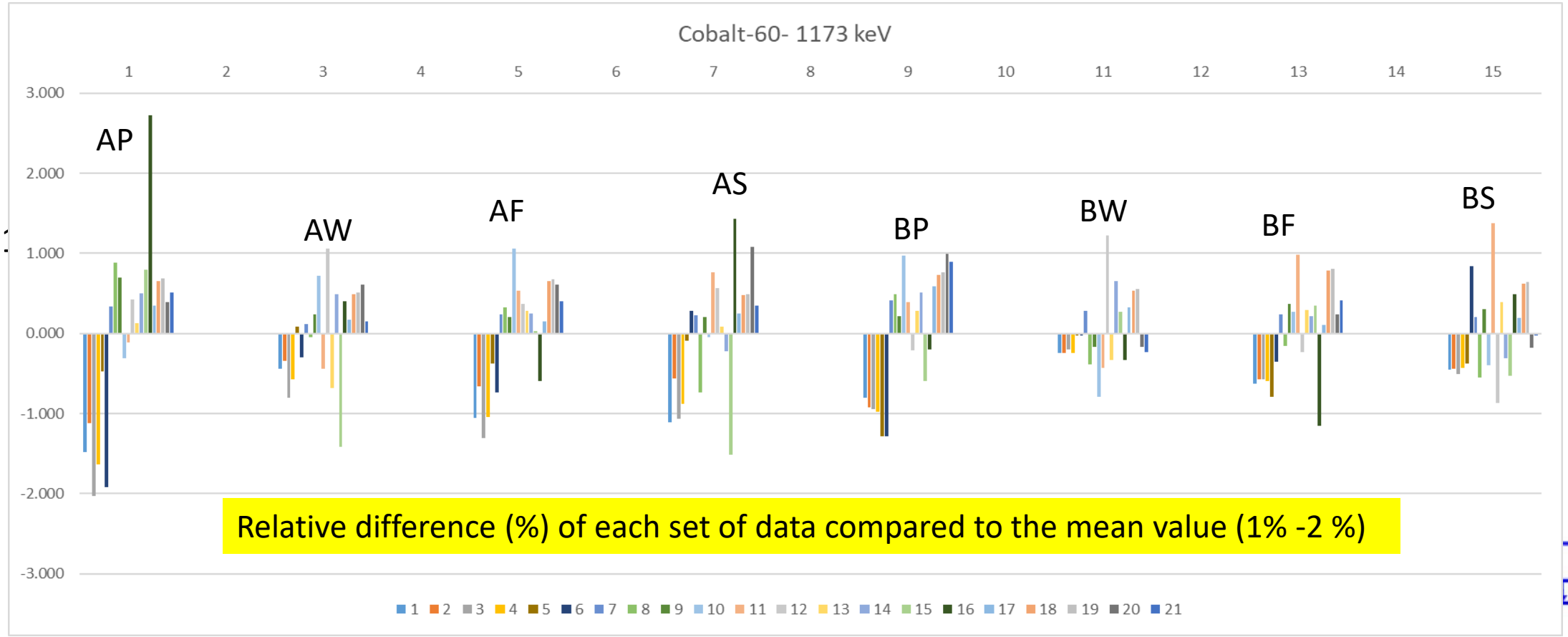
Thus according to the participants we got F_C or $1/F_C$!

Here, I am summarizing the F_C values

RESULTS : Part 2 : Coincidence summing corrective factors

^{60}Co

1173 keV:



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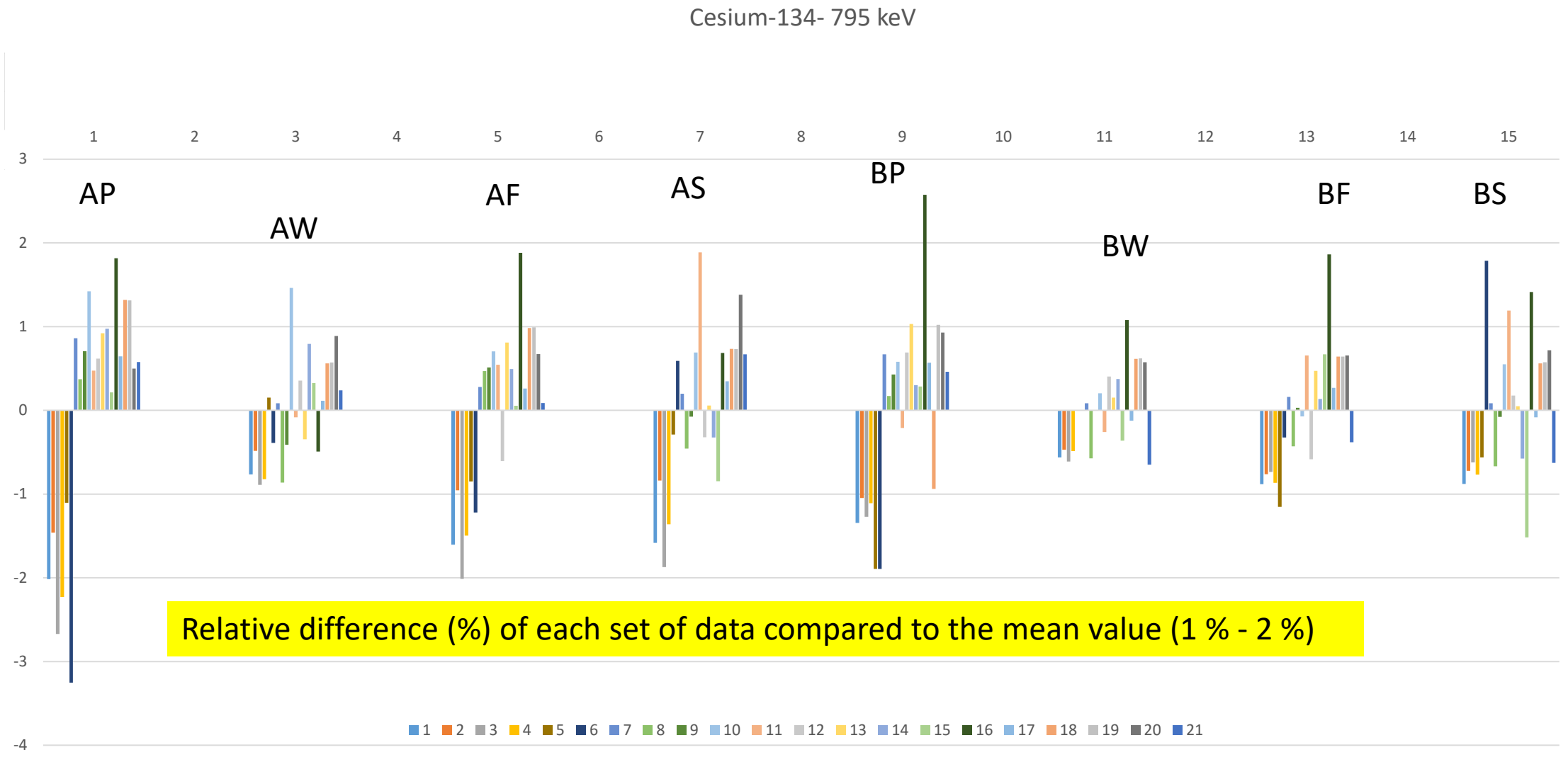
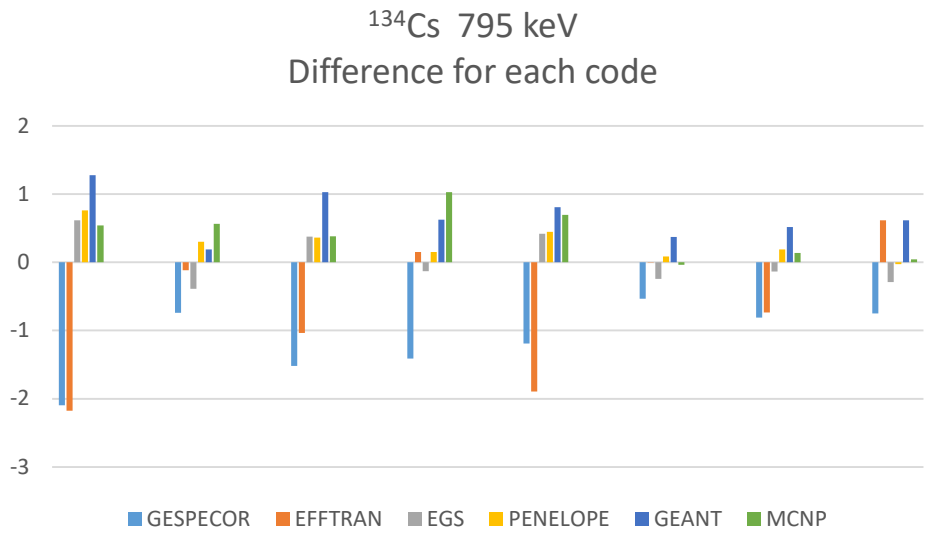
^{134}Cs

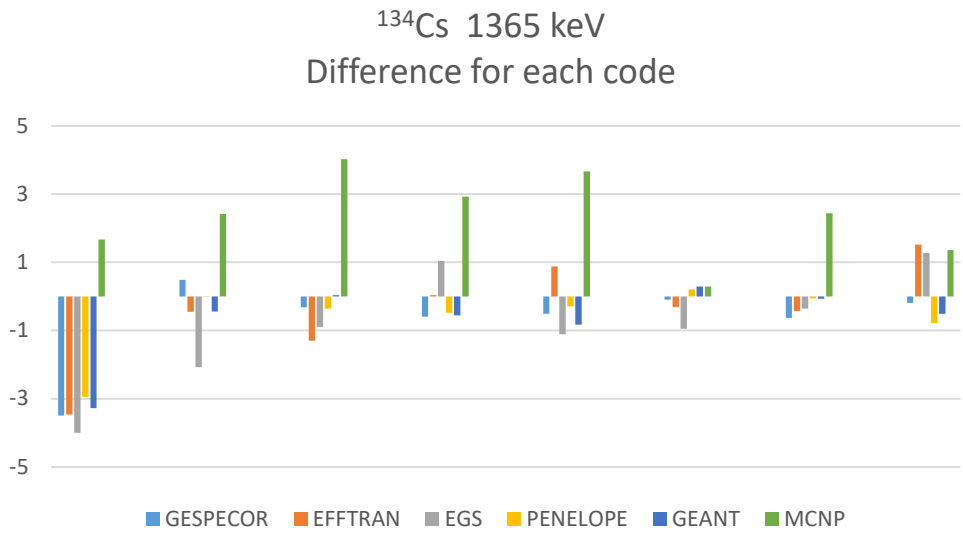
795 keV:



Relative difference (%) of each set of data compared to the mean value (1 % - 2 %)

BENCHMARK FOR MONTE CARLO SIMULATION IN GAMMA-RAY SPECTROMETRY





Relative difference (%) of the mean value from each code compared to the mean value (1 % - 2 %)

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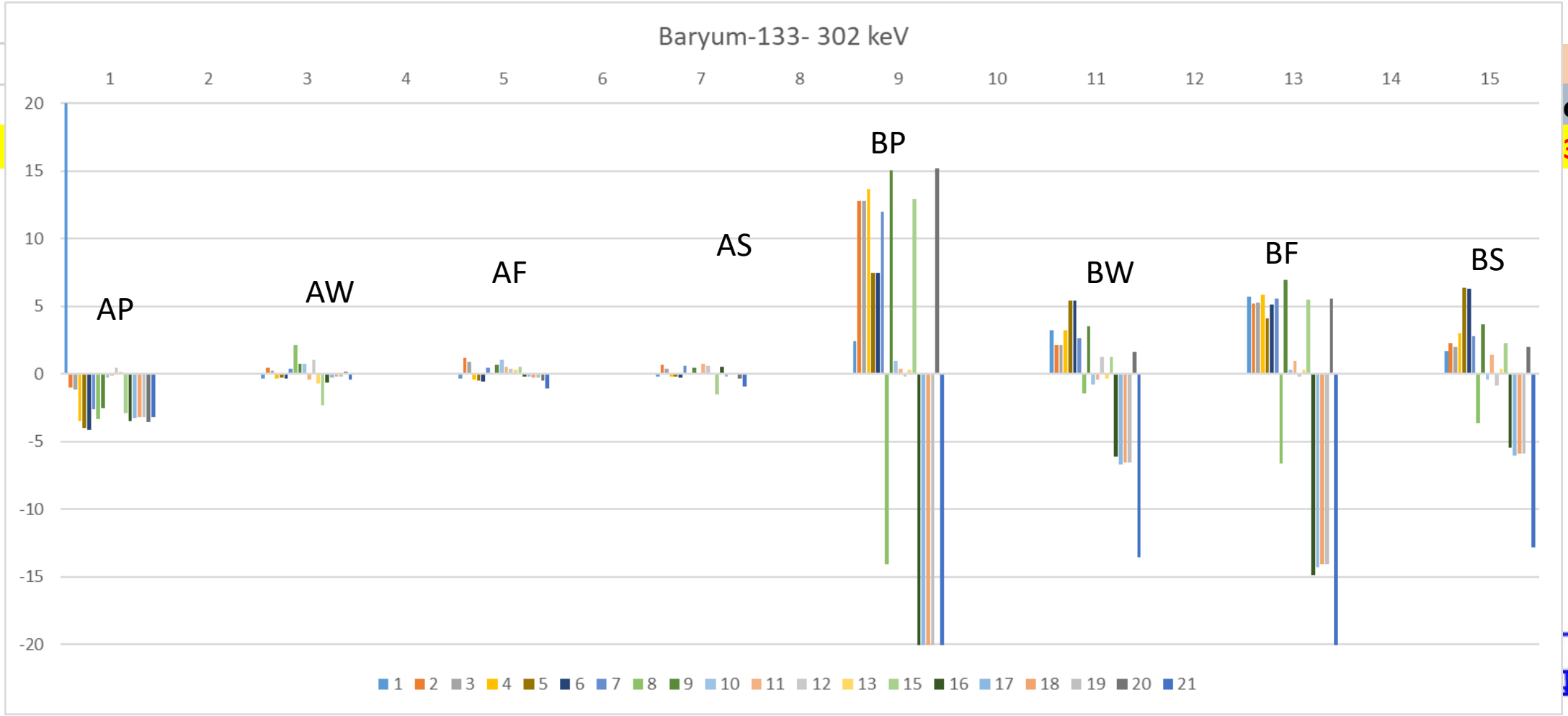
^{133}Ba
302 keV:

Relative difference (%) of each set of data compared to the mean value (5 % - 10 %)



oil

3 (5)

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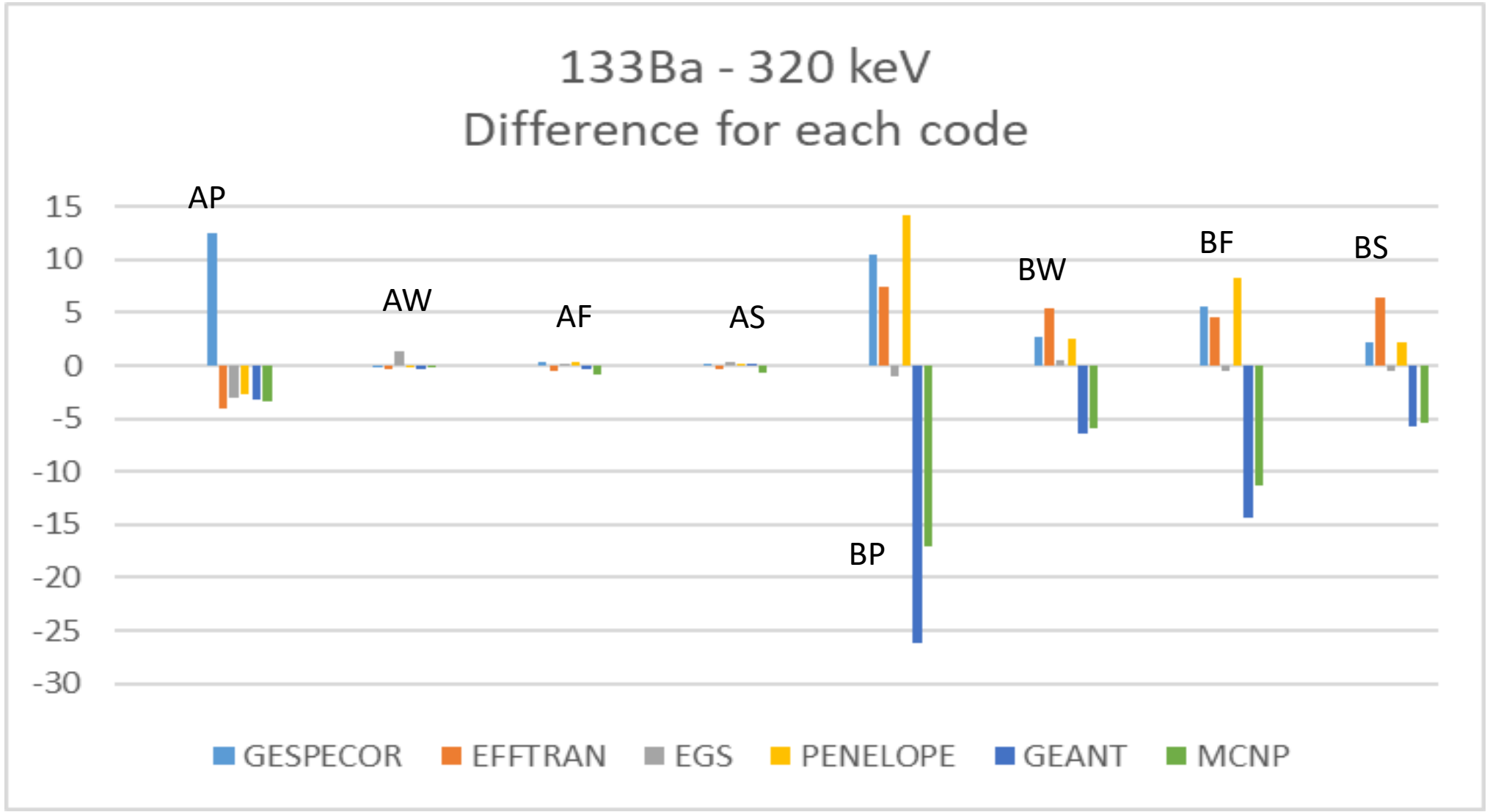
BENCHMARK FOR MONTE CARLO SIMULATION IN GAMMA-RAY SPECTROMETRY

^{133}Ba

302 keV:

Relative difference (%) of the mean value from each code compared to the mean value (15 % - 20 %)



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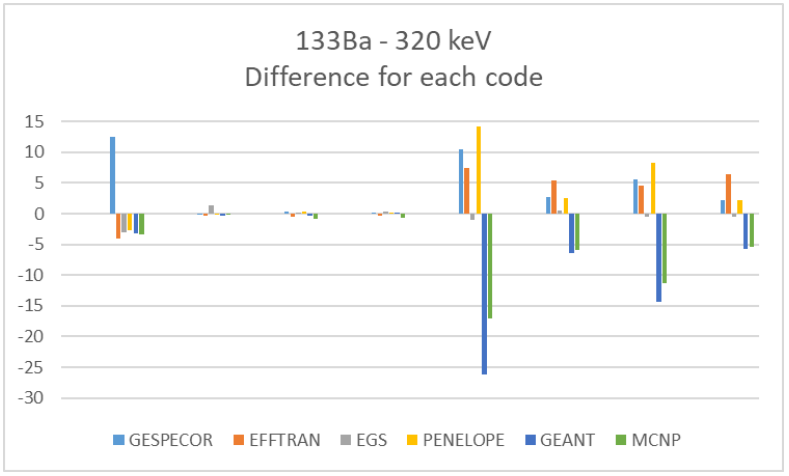
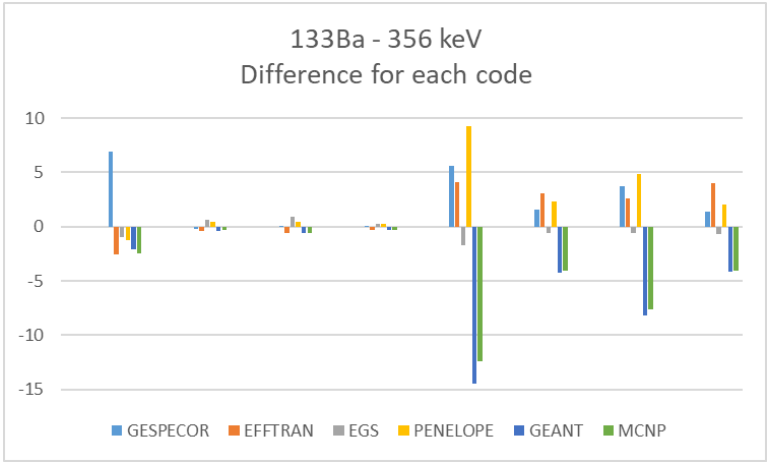
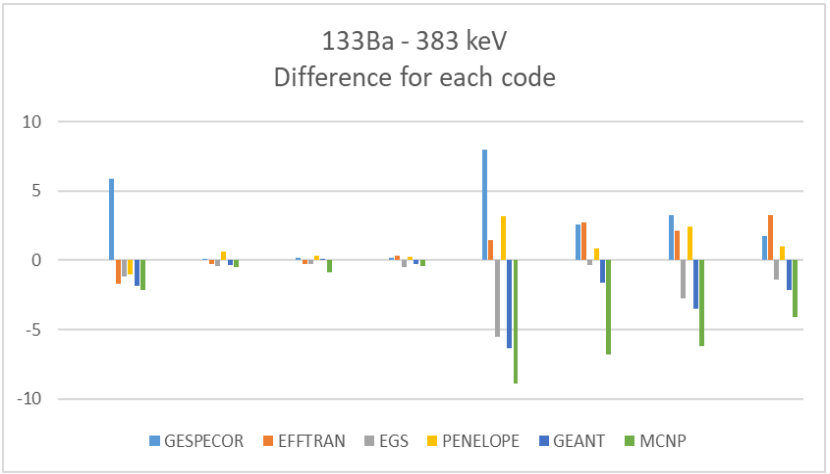
BENCHMARK FOR MONTE CARLO SIMULATION IN GAMMA-RAY SPECTROMETRY

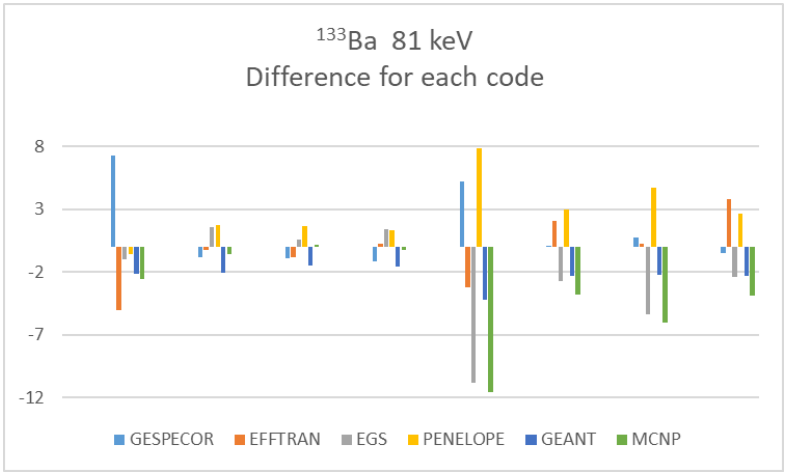
^{133}Ba

Relative difference (%) of the mean value from each code compared to the mean value









BP is the most critical case !

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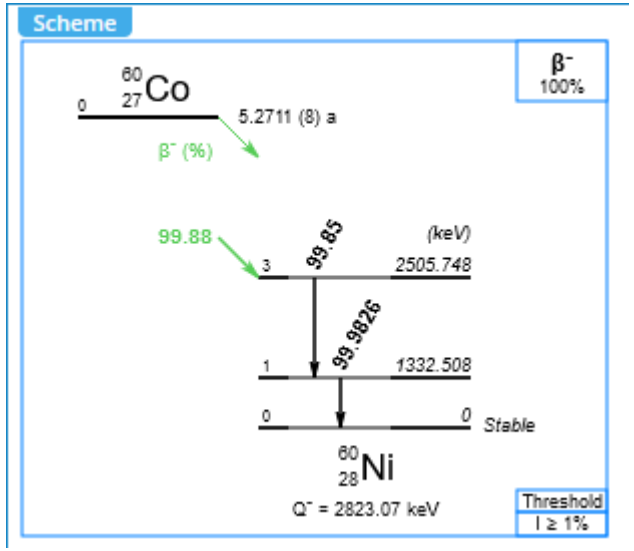
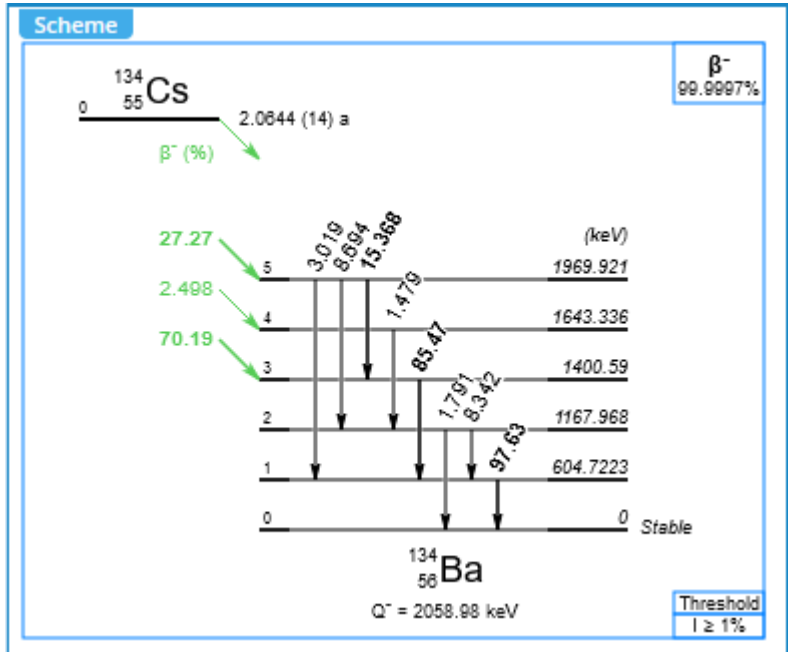
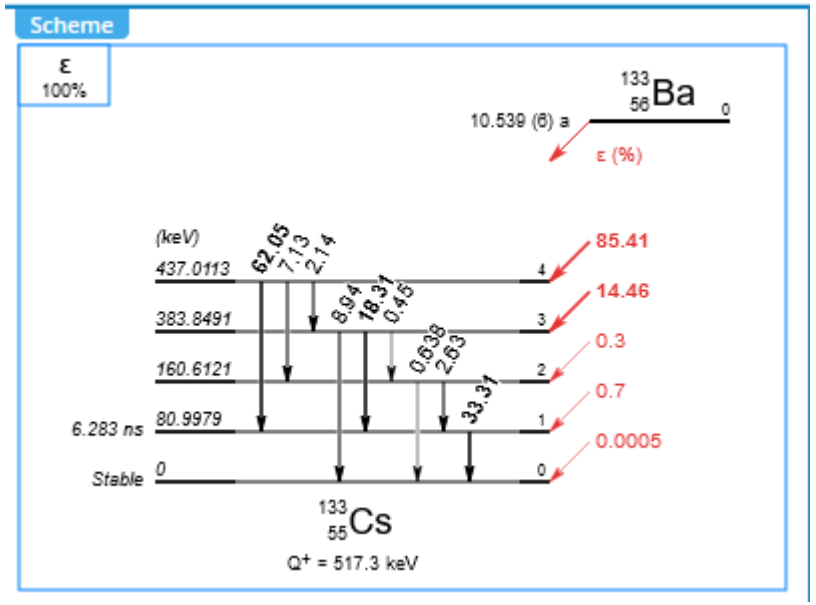
RADIONUCLIDES DECAY SCHEME





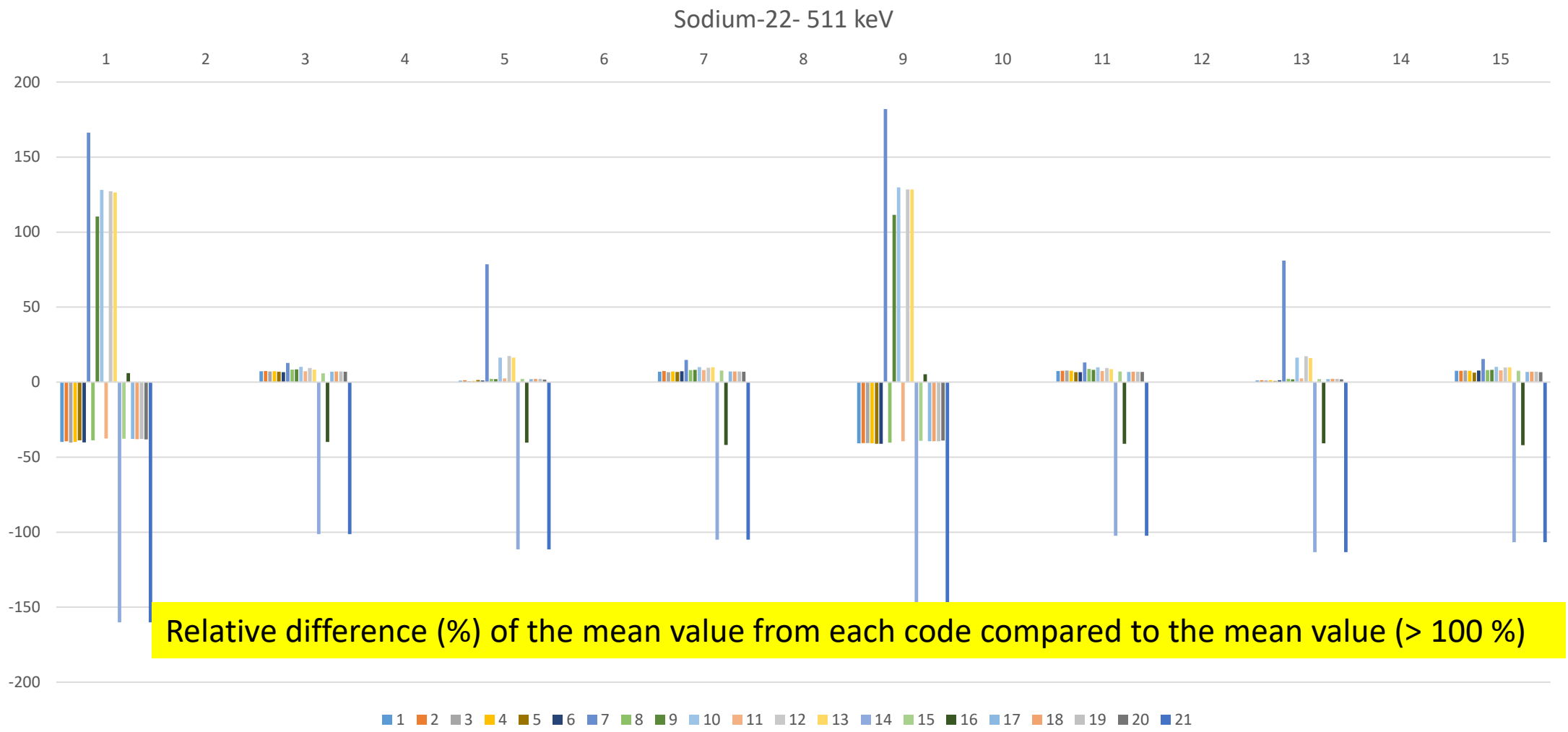
Beta minus decay



Electron capture : intense X-rays

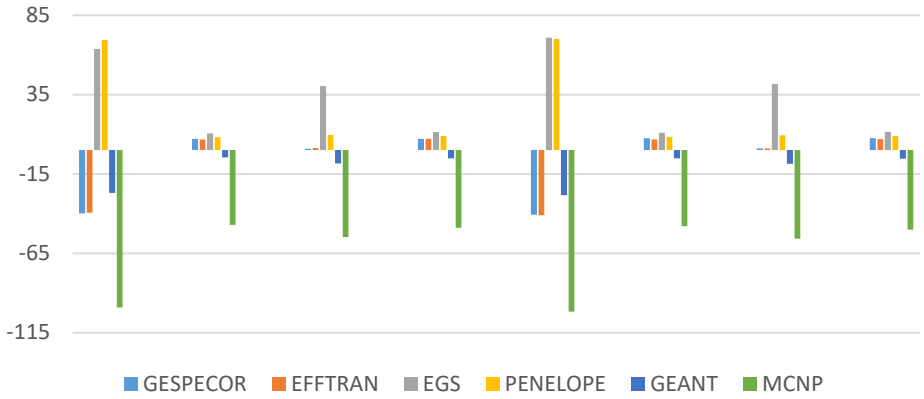
BENCHMARK FOR MONTE CARLO SIMULATION IN GAMMA-RAY SPECTROMETRY

^{22}Na

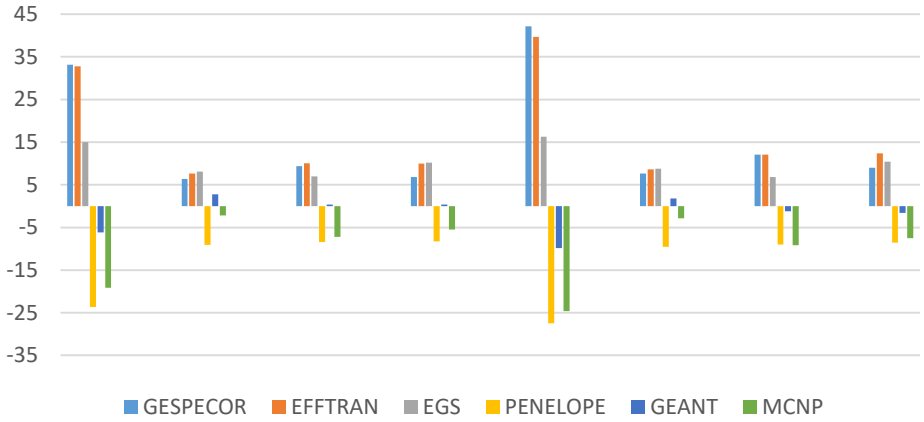


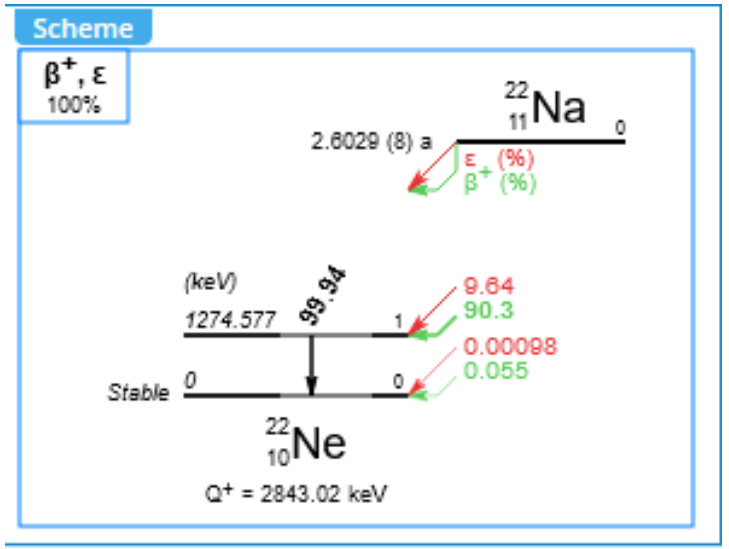
Relative difference (%) of the mean value from each code compared to the mean value (> 100 %)

22Na - 511 keV
Difference for each code



22Na - 1274 keV
Difference for each code





Electron capture and beta plus
(annihilation : 511 keV)

BENCHMARK FOR MONTE CARLO SIMULATION IN GAMMA-RAY SPECTROMETRY

Next steps:

1. Check report of data

2. Discussion/harmonisation between participants : dedicated meeting early december ?

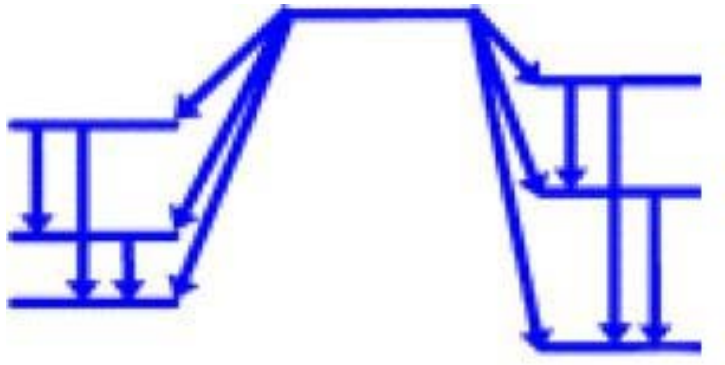
   Check data between groups – identify discrepant values : explanation ?

   Influence of X-rays on ^{133}Ba?

   Influence of decay data for beta+ emitters

3. Preparation of an article for the next ICRM meeting (and full report of results)

4. Make consolidated data (input files and results) available on the ICRM GSWG web page



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THANK YOU FOR

YOUR ATTENTION

Commissariat à l'énergie atomique et aux énergies alternatives
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