

ICRM GS WG : ACTION TO FACILITATE THE USE OF GEANT4 IN GAMMA-SPECTROMETRY



ICRM GS WG meeting | 29-30 Oct 2020 | Cheick THIAM

- **Geant4 is a toolkit:**
 - for simulating the passage of particles through matter and interacting with it
 - toolkit i.e. there is no main program
 - provides all the necessary components needed to describe and to solve particle transport simulation problems
 - tools to define/describe: geometry, materials and properties, particles and physical processes governing particles interactions, scoring, etc.
 - problem solution: step-by-step particle transport computation
 - while providing interaction points for the user
- **Build and implement simulation:**
 - user must build his own application by selecting the Geant4 components
 - either selecting ready to use tools in form of interfaces (called actions in Geant4 terminology)
 - or building his own from the base abstract classes
 - need a minimal knowledge of the Geant4 structure and base classes
 - need a basic knowledge in Linux and C++ programming
 - several examples are available within the code

GAMMA-RAY SPECTROMETRY BENCHMARK

« G4/GammaRaySpec » : gamma-ray spectrometry benchmark

The screenshot displays the GammaRaySpec application window. The main view shows a 3D visualization of a detector setup, with a red rectangular component and a yellow square component with a blue horizontal line. The text "Geant4" is overlaid in orange at the bottom left, and "GammaRaySpec" is overlaid in green at the bottom right. The date and time "Fri Oct 30 03:53:15 2020" are shown in cyan at the top right of the visualization area.

The interface includes a menu bar (File, Source Geometry, Particle, Energy, Detector, Run, View), a toolbar, and a scene tree on the left. The scene tree is expanded to show the following structure:

- material
 - nist
 - g4
 - verbose
- GRS
 - detector
 - Verbose
 - GeCristalDeadZone
 - AddGermaniumDeadZone
 - AddShielding
 - GeometryForceSolid
 - GeometrySpaceAngle
 - SourceParticlePosition
 - SourceType
 - SourceParticleName
 - IonAtomicMass
 - IonAtomicNumber
 - SourceParticleEnergy
 - PeakEnergySigma
 - DetectionEnergyThreshold
 - AddOutputFile
 - OutputFileName
 - update
 - physics
 - addPhysics
 - GammaCut
 - ElectronCut
 - PositronCut
 - Cuts
 - gun
 - List
 - particle
 - direction
 - energy

The Output window at the bottom shows the following commands and their matching commands:

```

/gui/addButton View "Update scene" "/vis/scene/notifyHandlers"
/gui/addButton View "Draw coordinate axes" "/vis/scene/add/axes 0 0 0 0.5 m"
Matching commands :
/vis/viewer/set/viewpointThetaPhi
/vis/viewer/set/viewpointVector
Matching commands :
/vis/viewer/set/viewpointThetaPhi
/vis/viewer/set/viewpointVector
/vis/viewer/set/viewpointVector 1 0 0
/vis/viewer/refresh
  
```

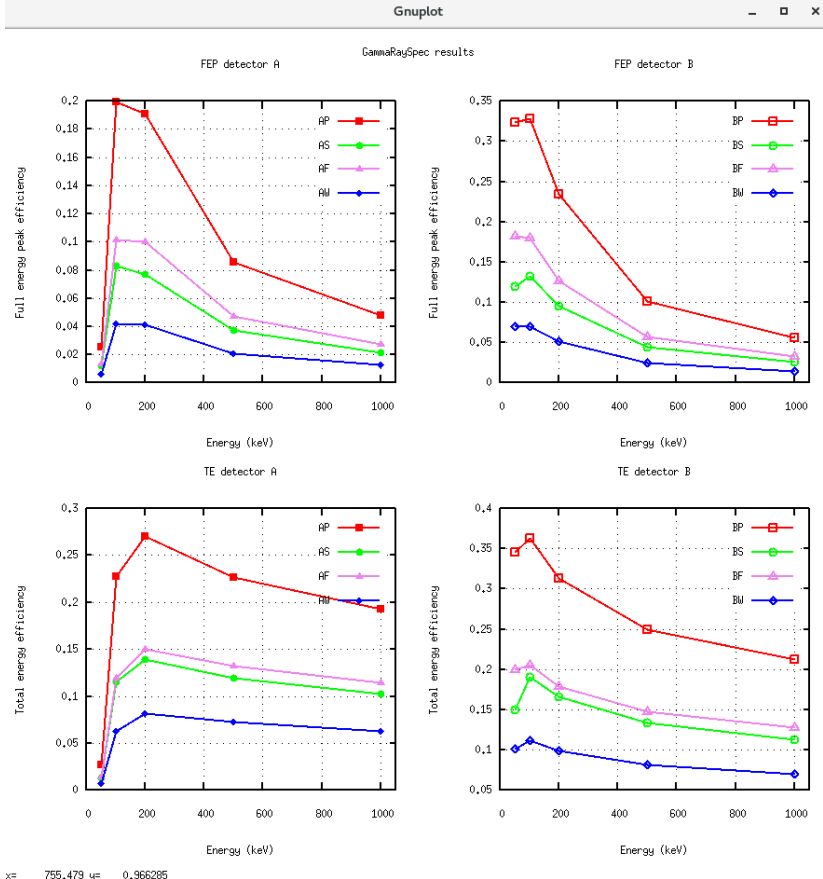
The Session field at the bottom is empty.

« G4/GammaRaySpec » : γ -ray spectrometry dedicated benchmark

Clone of ICRM GRS USERS (Scientific Linux 7) [En fonction] - Oracle VM VirtualBox

Fichier Machine Entrée Périphériques

Applications Places GnuPlot



x= 755,473 y= 0,966285

```
grs_user@localhost:~/GammaRaySpec/results
```

File Edit View Search Terminal Help

Detector B

Point source

Full energy peak efficiency Total energy efficiency

E(keV)	Events	Counts	FEP	U(%)	E(keV)	Events	Counts	TE	U(%)
0050.000	010000000	003235281	0.323528	0.055596	0050.000	010000000	003453322	0.345332	0.053812
0100.000	010000000	003283304	0.328330	0.055188	0100.000	010000000	003630534	0.363053	0.052483
0200.000	010000000	002340399	0.234040	0.065366	0200.000	010000000	003129380	0.312938	0.056529
0500.000	010000000	001015338	0.101534	0.099242	0500.000	010000000	002499002	0.249900	0.063258
1000.000	010000000	000565382	0.056538	0.132993	1000.000	010000000	002122524	0.212252	0.068639

Water source

Full energy peak efficiency Total energy efficiency

E(keV)	Events	Counts	FEP	U(%)	E(keV)	Events	Counts	TE	U(%)
0050.000	010000000	000703065	0.070306	0.119262	0050.000	010000000	001016555	0.101655	0.099182
0100.000	010000000	000695178	0.069518	0.119937	0100.000	010000000	001119930	0.111993	0.094404
0200.000	010000000	000513869	0.051387	0.139500	0200.000	010000000	000991666	0.099167	0.100419
0500.000	010000000	000249588	0.024959	0.200165	0500.000	010000000	000813437	0.081344	0.110876
1000.000	010000000	000148882	0.014888	0.259167	1000.000	010000000	000698058	0.069806	0.119689

Filter source

Full energy peak efficiency Total energy efficiency

E(keV)	Events	Counts	FEP	U(%)	E(keV)	Events	Counts	TE	U(%)
0050.000	010000000	001824958	0.182496	0.074024	0050.000	010000000	001999399	0.199940	0.070721
0100.000	010000000	001803304	0.180330	0.074467	0100.000	010000000	002062089	0.206209	0.069638
0200.000	010000000	001273505	0.127351	0.088613	0200.000	010000000	001793335	0.179334	0.074674
0500.000	010000000	000569975	0.056997	0.132456	0500.000	010000000	001479049	0.147905	0.082226
1000.000	010000000	000325465	0.032546	0.175286	1000.000	010000000	001282881	0.128288	0.088289

Soil source

Full energy peak efficiency Total energy efficiency

E(keV)	Events	Counts	FEP	U(%)	E(keV)	Events	Counts	TE	U(%)
0050.000	010000000	001197041	0.119704	0.091400	0050.000	010000000	001503976	0.150398	0.081542
0100.000	010000000	001326530	0.132653	0.086824	0100.000	010000000	001902432	0.190243	0.072501
0200.000	010000000	000951370	0.095137	0.102524	0200.000	010000000	001661449	0.166145	0.077581
0500.000	010000000	000439256	0.043926	0.150883	0500.000	010000000	001335451	0.133545	0.086534
1000.000	010000000	000255478	0.025548	0.197844	1000.000	010000000	001135747	0.113575	0.093834

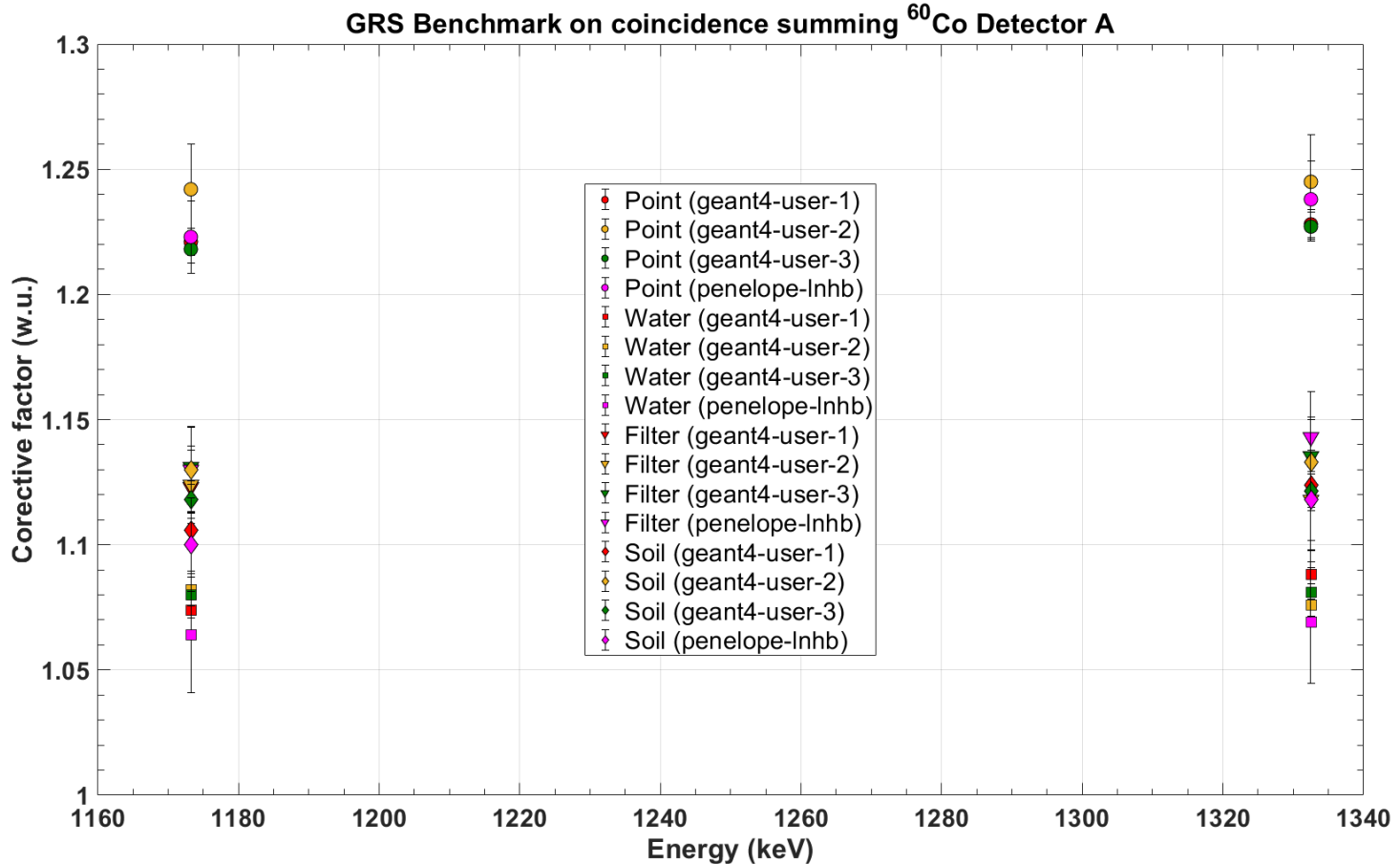
[grs_user@localhost results]\$

- « **G4/GammaRaySpec** » : γ -ray spectrometry dedicated benchmark
 - **On-going exercise:** Extension to coincidence-summing corrections

Participant name	Santiago Hurtado-Bermúdez (CIEMAT)	Stefan Röttger (PTB)	Cheick Thiam (LNHB)
Code	Geant4	Geant4	Geant 4
Version	10.6	10.6.p02	10.6.p02
Radionuclide database	ENSDF	ENSDF	DDEP
Number of channels	8192	8192	1024
Detection threshold	1 keV		1 keV
E cut for secondary particles (photons)	250 eV	0.1 eV	250 eV
E cut for secondary particles (electrons)	250 eV	0.1 eV	250 eV
E cut for secondary particles (positrons)	250 eV	0.1 eV	250 eV
Number of generated events	1E7 to 3E7	1.00E+07	1.E+07
Peak energy sigma (if applicable)	2 keV		2 keV

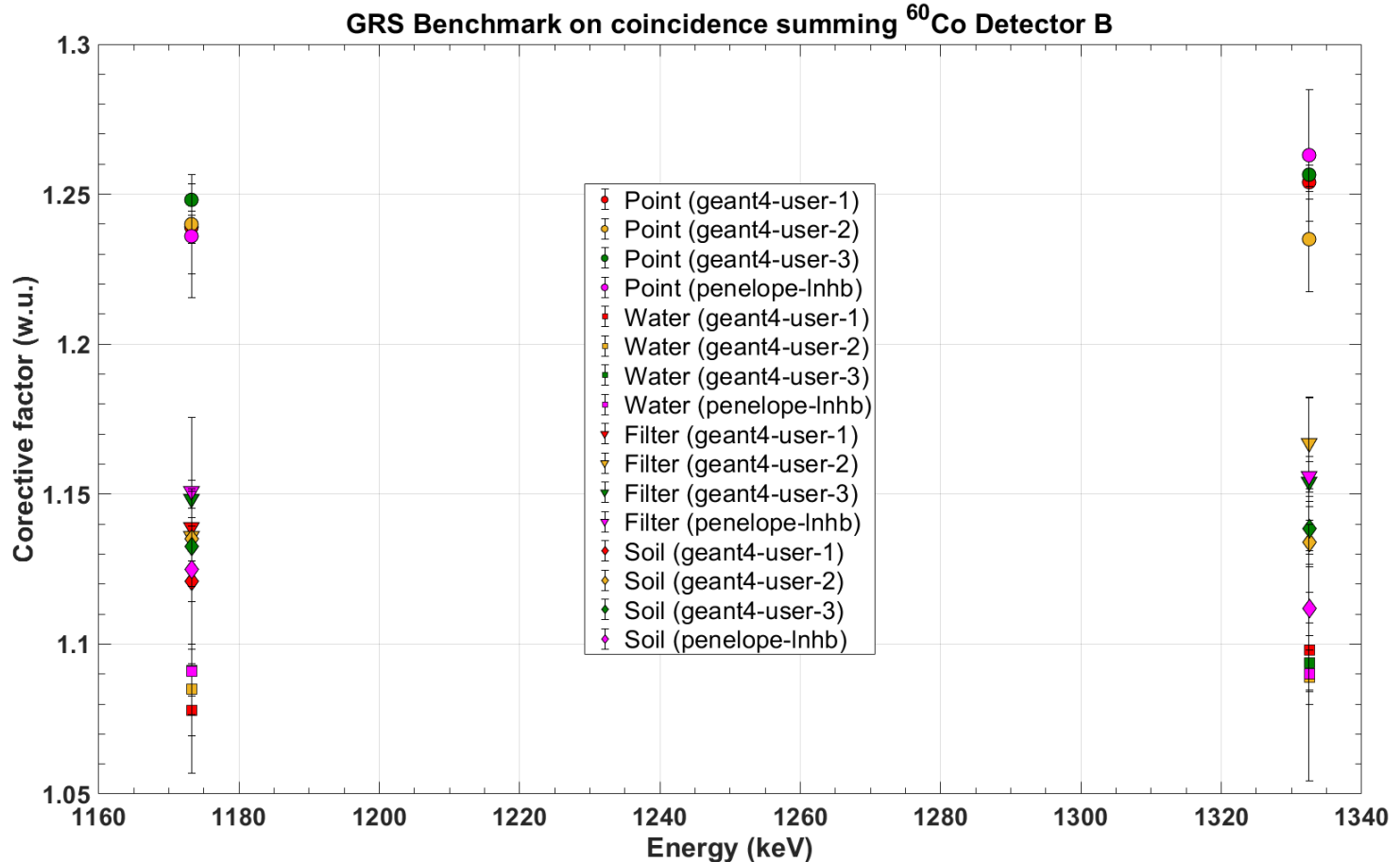
GAMMA-RAY SPECTROMETRY BENCHMARK

- Determination of corrective factors: comparisons between users
- Co-60, detector A



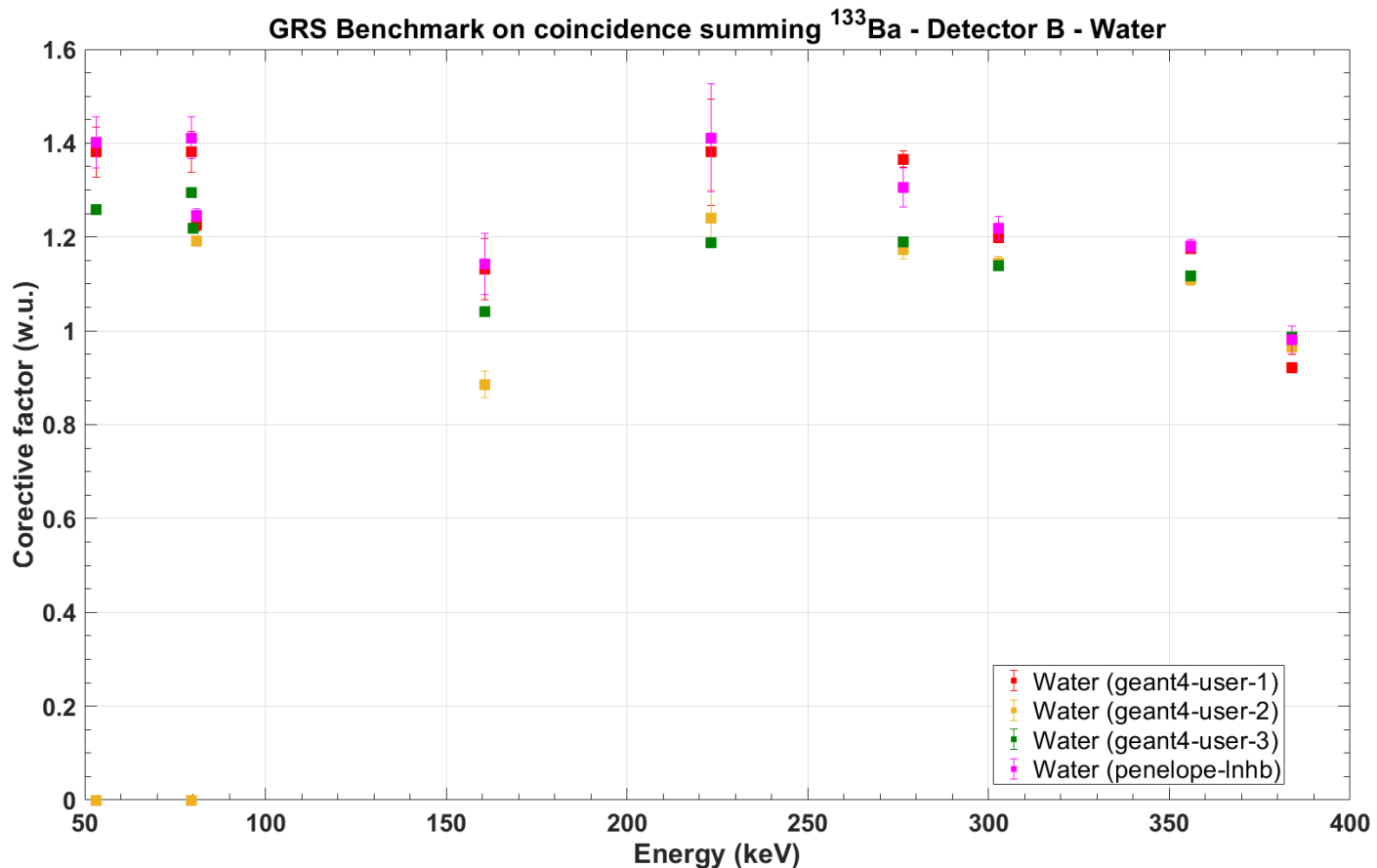
GAMMA-RAY SPECTROMETRY BENCHMARK

- Determination of corrective factors: comparisons between users
- Co-60, detector B



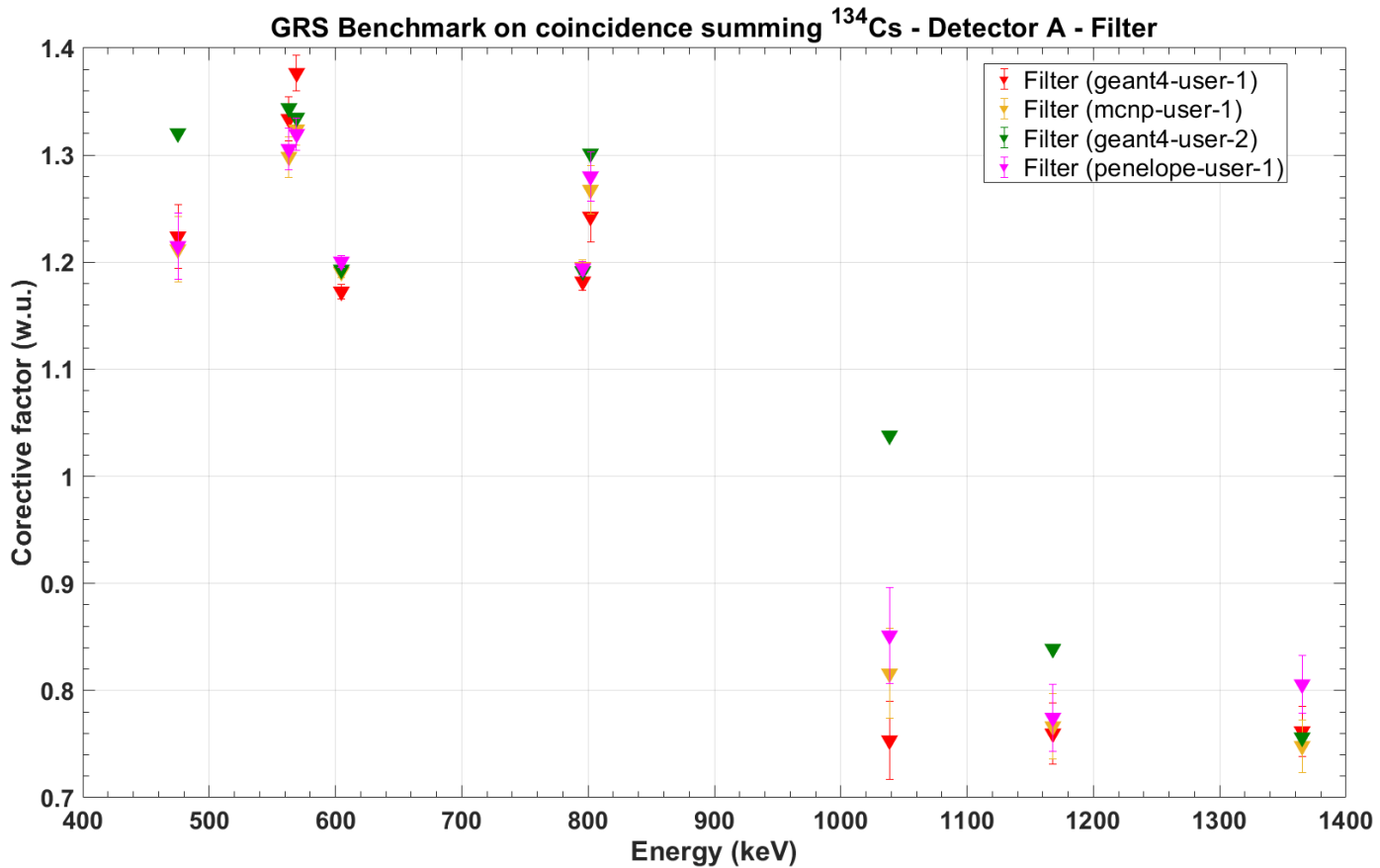
GAMMA-RAY SPECTROMETRY BENCHMARK

- Determination of corrective factors: comparisons between users
- Ba-133, detector B, Water



GAMMA-RAY SPECTROMETRY BENCHMARK

- Determination of corrective factors: comparisons between users
- Cs-134, detector A, Filter



- **Conclusion/Discussion on corrective factors calculation using MC tools**
 - Geant4 and other codes give good results if the problem is well described
 - Users have to pay attention to the radioactive decay simulation
 - The energy spectrum obtained in sensitive detector depend a lot on decay data used
 - Geant4: a specific module, Radioactive Decay Module (*G4RadioactiveDecay*), with associated classes, allows to simulate the decay of radioactive nuclei by alpha, beta plus and beta minus emission and electron capture
 - The simulation model is empirical and data-driven, and uses the ENSDF data for information on nuclear half-lives, nuclear level structure for the parent or daughter nuclide, decay branching ratios and the energy of the decay process
 - Data are not always complete and some emissions may not be considered in the decay process due to low intensity or low energy emitted, which can be problematic in simulation applications concerning in particular the metrology of the radionuclides
 - Alternative to Geant4 Radioactive Decay Module:
 - User can set his own radionuclide decay input (with N numbers of events)
 - Interface other decay module (ex. Nuclide++ is ongoing development at LNHB)

Commissariat à l'énergie atomique et aux énergies alternatives
Institut List | CEA SACLAY NANO-INNOV | BAT. 861 – PC142
91191 Gif-sur-Yvette Cedex - FRANCE
www-list.cea.fr

Établissement public à caractère industriel et commercial | RCS Paris B 775 685 019



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Geant4

Overview

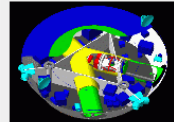
Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The three main reference papers for Geant4 are published in Nuclear Instruments and Methods in Physics Research A 506 (2003) 250-303, IEEE Transactions on Nuclear Science 53 No. 1 (2006) 270-278 and Nuclear Instruments and Methods in Physics Research A 835 (2016) 186-225.

Applications



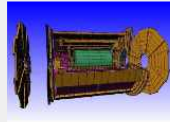
A sampling of applications, technology transfer and other uses of Geant4

User Support



Getting started, guides and information for users and developers

Publications



Validation of Geant4, results from experiments and publications

Collaboration



Who we are: collaborating institutions, members, organization and legal information

News

2020-06-26

Release 10.7-BETA is available from the [BETA Download](#) area.

2020-05-29

Patch-02 to release 10.6 is available from the [download area](#).

2020-03-13

[2020 planned developments](#).

Events

[Virtual] [4th LPCC Detector Simulation Workshop](#), CERN (Geneva), **2-3 November 2020**.

[Virtual] [2nd HSF/WLCG Virtual Workshop](#), **19-25 November 2020**.

[Virtual] [IN2P3 & PHENIX Geant4 School](#), Orsay (France), **23-27 November 2020**.

[Past events](#)

➔ <https://geant4.web.cern.ch>