Definition of geometries from external files in MaGe

Luciano Pandola

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1 Introduction

The possibility to define a simple geometry by an external text file has been recently introduced in the MaGe framework. The requirement for such a capability mainly comes from the need to roughly evaluate the detection efficiency in simple configurations. One instance is the probability that a γ-ray from a background source dissolved in liquid argon gives a full-energy deposition in a naked detector. While the precise evaluation of the efficiency requires a precise description of the whole experimental setup, that must be coded in C++ and included in the directories `gerdageometry`, `mjgeometry` or `munichteststand`, a first order-of-magnitude estimate can be performed using the new feature, without editing or re-compiling the MaGe code. This is particularly useful for non MC experts wishing to get a feeling of the efficiency of a given setup.
The results have been compared with those obtained using the Teff code, developed by V. Tretyak.

2 Material definition

The MaGe program already contains a list of commonly-used materials, that are coded in a local file, or read from a remote database. An arbitrary number of new materials can be defined using external files. The complete list of the materials defined in MaGe can be obtained interactively using the command
`/MG/geometry/dumpG4materials`
given after the run initialization. A new material read from file is registered using the command

```
/MG/geometry/addMaterial myfile.def
```

where `myfile.def` is the external file containing the material definition. The command can be repeated several times, changing the file name, in order to define an arbitrary number of new materials.
An example of material definition file is the following:

```
SodiumIodide 3.67 2
Sodium Na 11.0 22.989 0.153
Iodine I 53.0 126.904 0.847
```

In the first line, it must be specified:

- the name of the new material (string). It must be different from the names of the materials already defined in the MaGe databases. If the user tries to re-define an existing material, the command is ignored, and a warning message is printed.
- material density, expressed in g/cm^3 (double).
- number of elemental components (int).

The first line must be followed by the definition of the single elemental components. Their number must be equal to the one declared in the first line. Each of the element lines is specified as follows:

- name of the element (string).
- symbol of the element (string).
- atomic number Z (double).
- average atomic mass A (double)
- mass fraction in the compound (double).

If an element with the same name is already defined in the MaGe internal database, the re-definition from the file is ignored, and only the mass fraction is taken into account. A warning message is printed. The user must take care that the sum of the mass fractions is actually 1.0.

3 Geometry definition

To switch on the geometry definition from an external file, the messenger command

`/MG/geometry/detector GeometryFile`
has to be given. The name of the file containing the geometry to be read is set using the command
`/MG/geometry/geometryFileName mygeometry.def`
If the command `/MG/geometry/geometryFileName` is issued more than once, the file name is overwritten, and the last one is taken into account. If the general geometry has not been set with the command `/MG/geometry/detector GeometryFile`, the file name is anyway accepted but it is not used. If the file name is not given explicitly, the default `geometry.def` is looked for in the current directory.
It is possible to define an arbitrary number of boxes, cylinders and spheres. Volumes can be daughters of the world or of an other volume. In the latter case, it is possible to define "holes" in a given volume.
An example of geometry definition file is the following:

```
1 Crystal 2 1 0 SodiumIodide
0.  0.  2.55
2.55 5.10 0.
0.  0.  0.
2 Hole 2 0 1 Air
0.  0.  0.65
1.43 3.80 0.
0.  0.  0.
```

Each volume is defined in four lines.
(1) The entries for the first line are:

- ordering number (int).
- volume name (string). This is the name of the physical volume defined in the geometry. It can be used, for instance, for the uniform sampling routine. The names of the volumes should be different, though there is no specific control in the program.
- shape of the volume (int). The code is 1 for boxes, 2 for cylinders and 3 for spheres. If the code is different from the values listed above, the volume is ignored.
- sensitive detector flag (int). If the flag is 1, the volume is registered as a sensitive detector for the subsequent analysis.
- mother flag (int). If the flag is set to 0, the volume is placed inside the world volume. If the flag is a non-zero integer n, the volume is

considered to be a daughter of the volume n. The mother volume must be defined *before* the daughter one (namely, the ordering number of the Daugherty must be larger than n). It is possible to nest daughter volumes one inside the other.

- material name. The material has to be included in the MaGe database or defined using an external file, as described in Sect. 2.

(2) The second line contains the three coordinates of the volume center, given in cm (double). Coordinates are always expressed with respect to the mother volume reference system.
(3) The third line contains the three physical dimensions of the volume (double), given in cm. For boxes, the numbers are the sizes along the x, y and z axes, respectively. For cylinders, the first parameter is the radius, and the second the height (the third parameter is unused). For spheres, the first parameter is the radius, the other two are unused.
(4) The fourth line contains the three Euler angles (degrees) defining the volume rotation. The angles are always referred to the mother volume reference system.
The volumes defined in the external file are placed in a world volume made of air. The world volume is a cube of 5 m size. Therefore, the dimensions of the volumes in the file cannot exceed 5 m.
The geometry file presented above represents: a cylindrical sodium iodide detector (radius 2.55 cm, height 5.10 cm) with a cylindrical hole (radius 1.43 cm, height 3.8 cm) displaced of 0.65 cm along the z-coordinate of the detector. The coordinates of the center of the detector are (0,0,2.55 cm) with respect to the world reference frame. The sketch of the geometry is displayed in Fig. 1.

4 Analysis

The analysis of the Monte Carlo data can be performed using an output scheme of MaGe, and depends on the information that the user wants to extract. A specific output scheme is available in MaGe for the evaluation of the efficiency of the detectors that are registered as sensitive. The general-purpose output scheme for the efficiency is instantiated with the command:
`/MG/eventaction/rootschema DetectorEfficiency`
It gives in output a single ASCII file, whose name is set with the command:
`/MG/eventaction/rootfilename myoutput.dat`
If the output file name is not set explicitly, the default `output_eff.dat` is

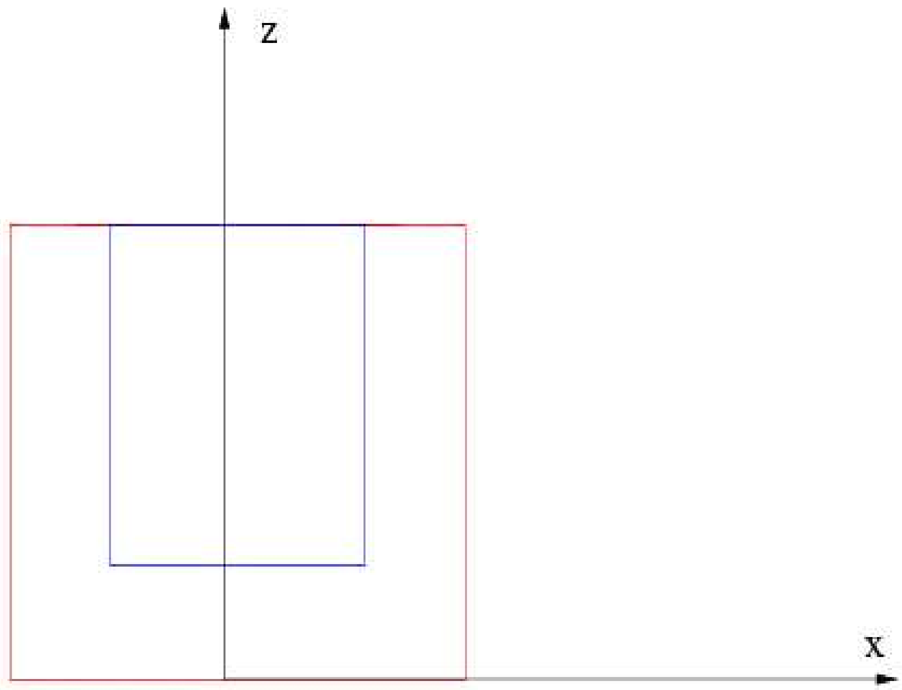

Figure 1: Sketch of the setup geometry defined in MaGe with the external data files used as example in the text.

created.
The output ASCII file is a 4-column table. The columns contain:

1. the energy of the primary particles;

2. the total number of generated primary tracks;

3. the number of events having an energy deposition in the sensitive detector;

4. the number of events having full energy deposition in the sensitive detector.

An event is considered as a full-energy deposition if the energy deposited in the sensitive detector is equal to the primary energy, within 1 keV tolerance.

5 Full application

Here is presented, as an example, a MaGe macro to evaluate the efficiency of the sodium iodide detector of Fig. 1 for point-like γ-ray sources of different energies placed in the hole.

```
/MG/manager/mglog trace
#
/MG/geometry/detector GeometryFile
/MG/geometry/database false
/MG/geometry/addMaterial sodiumiodide.def
/MG/geometry/geometryFileName geometry.def
#
/MG/eventaction/rootschema DetectorEfficiency
/MG/eventaction/rootfilename output.dat
#
/MG/processes/lowenergy true
/MG/processes/realm DarkMatter
#
/run/initialize
#
/MG/generator/select G4gun
/gun/particle gamma
/gun/position 0.  0.  1.4 cm
/MG/generator/g4gun/cone_on true
/MG/generator/g4gun/coneDirection 0 0 -1
/MG/generator/g4gun/thetaDelta 180 deg
#
/gun/energy 100 keV
/run/beamOn 10000
/gun/energy 200 keV
/run/beamOn 10000
/gun/energy 300 keV
/run/beamOn 10000
...
```

The first command, `/MG/manager/mglog trace` is used to set the verbosity level of MaGe (namely, the quantity of information that is given in the interactive output).
The block
`/MG/geometry/detector GeometryFile`

```
/MG/geometry/database false
/MG/geometry/addMaterial sodiumiodide.def
/MG/geometry/geometryFileName geometry.def
```

is used to define the geometry. The MaGe material database is read from the local file (rather than remotely from the Majorana database) and a new material is read from the file `sodiumiodide.def`. The geometry is read from the file `geometry.def`.

The block

```
/MG/eventaction/rootschema DetectorEfficiency
/MG/eventaction/rootfilename output.dat
```

sets the output scheme and the name of the output file. The physics of the simulation is set in the block

```
/MG/processes/lowenergy true
/MG/processes/realm DarkMatter
```

With the first line the user requires that the electromagnetic processes are treated according to the specific low-energy models of Geant4. The low-energy models, that include fluorescence and other atomic effects, are more precise than the standard Geant4 electromagnetic processes but typically slower. The second line sets the cut for the generation of δ-ray and of bremsstrahlung photons. With the `DarkMatter` option, the cuts are small, and the tracking is extremely accurate (and slow). More relaxed cuts can be set with the `DoubleBeta` and `CosmicRays` options. The command `/run/initialize` is then issued to initialize the MaGe run. After that, the block

```
/MG/generator/select G4gun
/gun/particle gamma
/gun/position 0.  0.  1.4 cm
/MG/generator/g4gun/cone_on true
/MG/generator/g4gun/coneDirection 0 0 -1
/MG/generator/g4gun/thetaDelta 180 deg
```

is used to define the primary particles. The generator is set to be `G4gun`, which is the default `G4ParticleGun` generator provided by Geant4. The second and third lines define the particle type (γ-ray) and position, respectively. The coordinates of the source are defined in the world reference system. It is possible to use the existing MaGe capabilities to generate primary particles uniformly from a given volume[1]. The sub-set

```
/MG/generator/g4gun/cone_on true
/MG/generator/g4gun/coneDirection 0 0 -1
```

[1]For instance, the commands

```
/MG/generator/confine volume
/MG/generator/volume Crystal
```

would generate primary particles uniformly distributed in the volume named Crystal.

```
/MG/generator/g4gun/thetaDelta 180 deg
```
defines the angular distribution of the primary γ-rays. The γ-rays are generated isotropically in a cone, whose axis is the z axis and the opening angle is 180 degrees. This is a way to generate an isotropic flux from the source.
```
/gun/energy 100 keV
/run/beamOn 10000
/gun/energy 200 keV
/run/beamOn 10000
```
Eventually, the user sets the particle energy to 100 keV and shoots 10 000 events, then to 200 keV and shoots 10 000 events, and so on. The procedure can be repeated for an arbitrary number of times, changing the primary energy (and possibly the particle type and position).

6 Comparison

The results obtained by MaGe for the simpled geometry sketched in Fig 1 running the macro discussed in Sect. 5 have been compared with those obtained using the code Teff by Vladimir Tretyak for the same setup. Fig. 2 (courtesy of V. Tretyak) shows the profile of the full efficiency (= any energy deposition in the detector) vs. energy obtained using MaGe and Teff. The results are in good agreement.

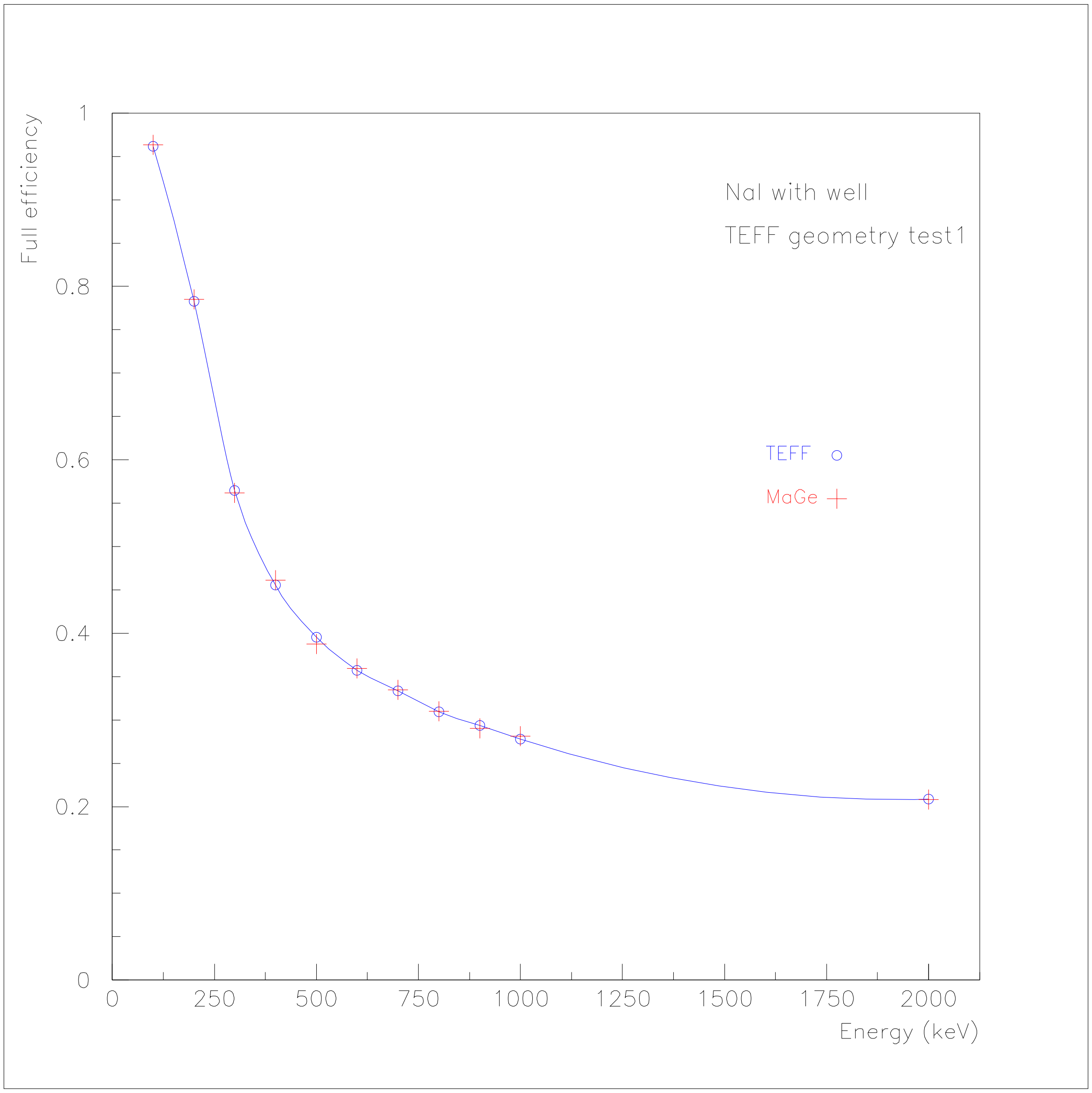

Figure 2: Total efficiency for a point-like γ-ray source in the setup shown in Fig. 1 using MaGe and Teff (courtesy of Vladimir Tretyak). The efficiency represents the probability that the γ-ray interacts in the NaI sensitive volume, with any energy release (full peak + Compton continuum).