RIKEN NiSHiNA CENTER

Small Tutorial on the Usage of my RIKEN GEANT4 Package

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Outline

Introduction

Introductive Remarks

- The Simulation package is intended to simulate the γ-ray detection response for different arrays employed presently or in the future at the RIBF.

- Why are simulations necessary?
  - Intensity and energy resolution estimations prior to an experiment
  - Optimize the geometry for present and future arrays
  - Understand lineshapes of observed spectra (lifetime, doublets, Compton-scattering, escape peaks, etc.)
  - Intensity determinations for observed peaks in in-beam experiments

Installation Requirements

- ROOT, preferably the newest version
- GEANT4 (version>=g4.9.0.p01)
- CLHEP (Class Library with High Energy Physics)
- DAWN (Drawer for Academic WritiNgs)
- Visit

  `http://geant4.slac.stanford.edu/installation/`

  for an installation guide.

Installing the Simulation Package

- Copy `Geant4Riken.0.5.7.tar.gz` from `/rarf/u/pieter/`
  (Starting from next week)

- Unpack the file with:
  `tar -zxf Geant4Riken.0.5.7.tar.gz`

Installing the Simulation Package

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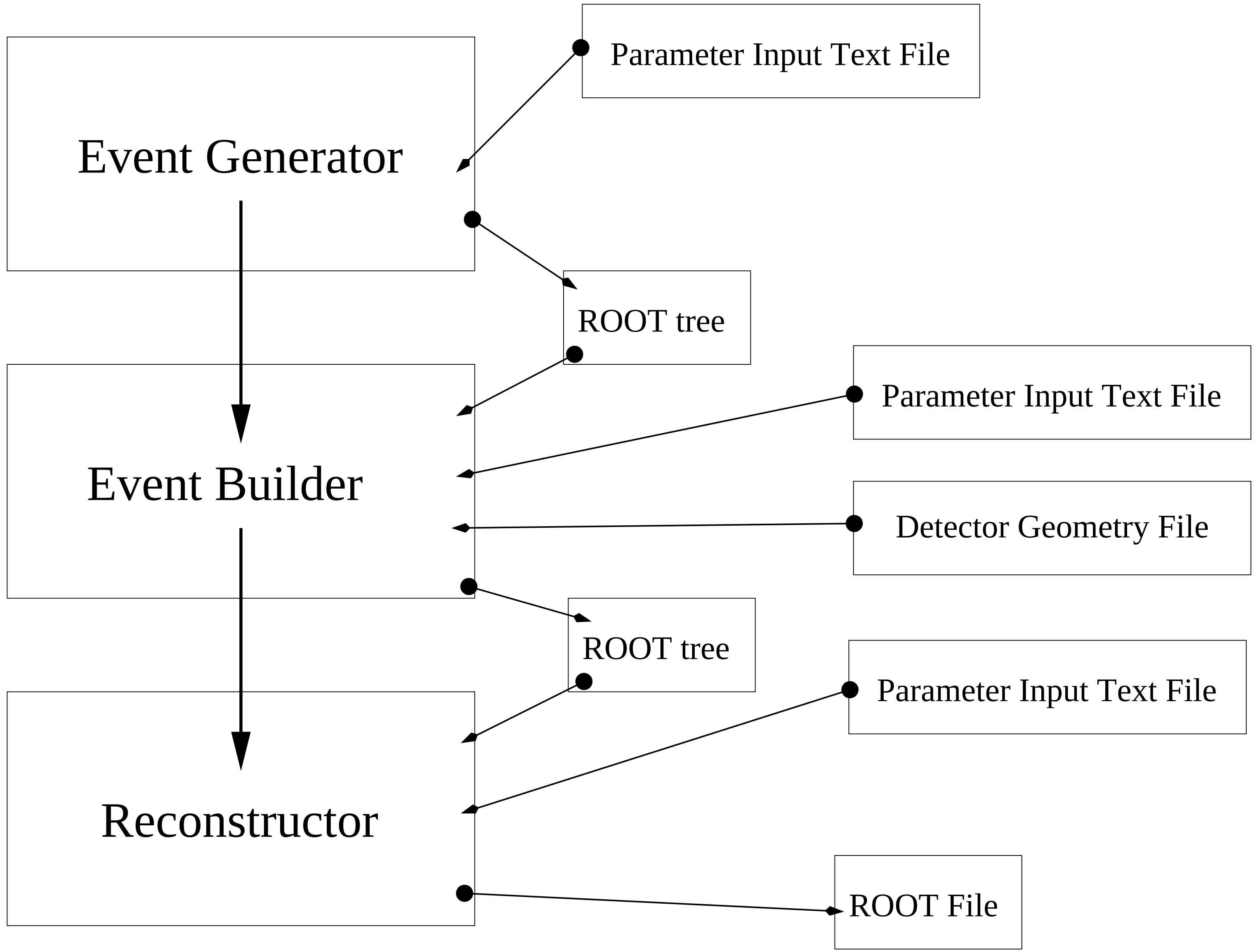
- Five subdirectories will be created, namely:
  `EventGenerator`
  `EventBuilderRIKEN`
  `Reconstructor`
  `tutorial` (Empty dummy folder)
  `manual` (Not finished, also these transparancies.)

The Three Simulations Steps

The simulation is divided into three steps because they are basically independent of each other.

- The Event Generator
  - γ-ray distribution and Doppler shift
  - Energy loss in the target
  - Velocity shift after fragmentation (Borrel *et al.*)
  - Parallel momentum distribution (Goldhaber *et al.*)
- The Event Builder
  - Inserting the detector geometry, target holder, beam pipe, etc.
  - γ-ray interaction with the material
- The Reconstructor
  - Doppler shift correction
  - γ-ray fold, energy resolution, lineshape, efficiency, etc.

The Simulation Procedure

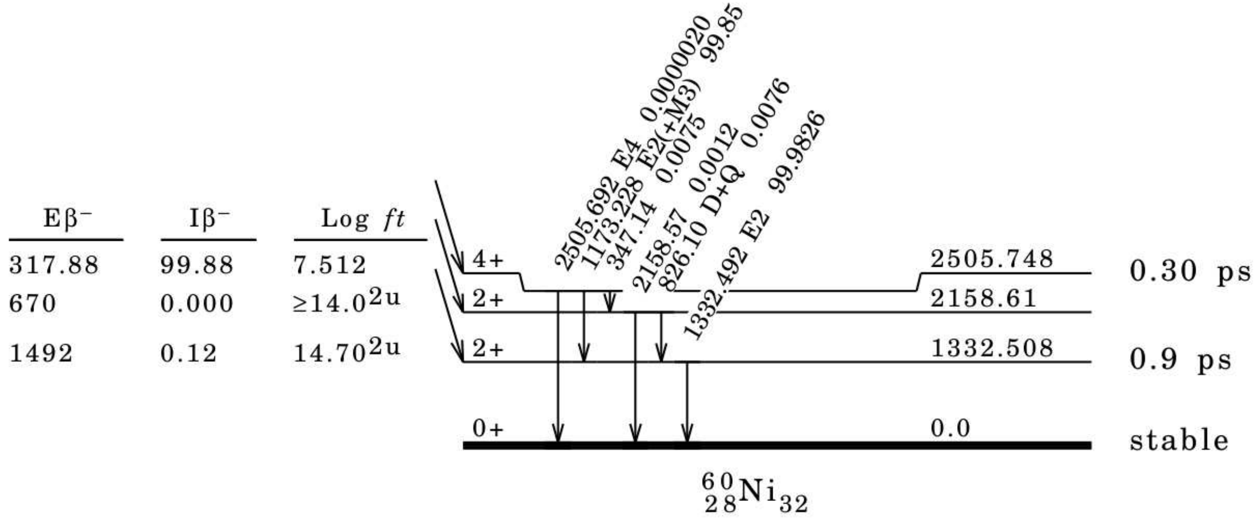


The Event Generator

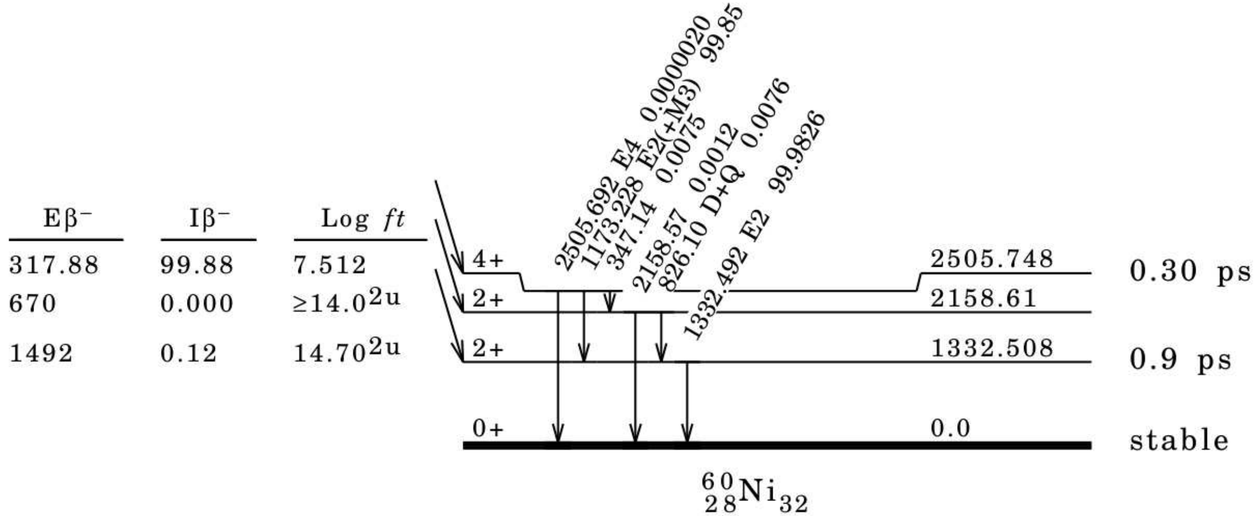
The Input File

- The Input File can be found under `./input/EventGenerator.in`
- Only the most important input keywords are listed. The manual, still under construction, will cover all.
  - `BEAMISOTOPE` A_P Z_P Q_P
  - `BEAMENERGY` E_P $\Delta E(FWHM)_P$
  - `BEAMPOSITION` X $FWHM_X$ Y $FWHM_Y$
  - `TARGET` $Type$ $Size_X$ $Size_Y$ $Thickness_Z$
  - `MASSCHANGE` ΔA ΔZ
  - `GAMMAINPUT` $File_{\gamma-in}$
  - `NUMBEROFEVENTS` N_{events}
  - `OUTPUFILENAME` $File_{out}$
  - `DEDXTABLE Option`$_{dEdX}$ $File_P$ $File_E$
  - `END`

The Gamma Input File



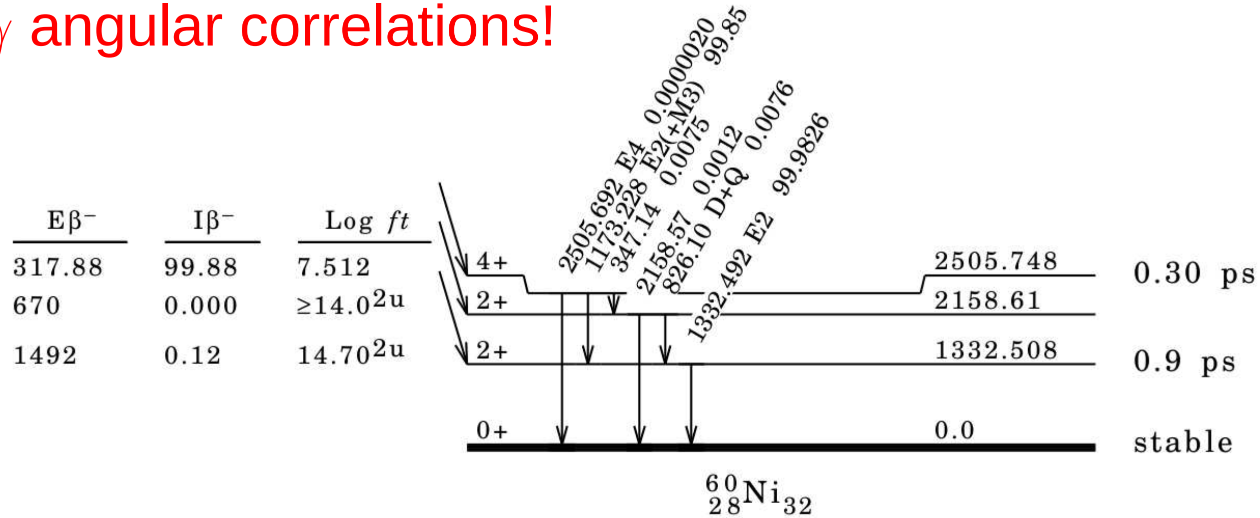
The Gamma Input File




```
LEVEL 0 00.00 0000.000 0.00
LEVEL 1 00.12 1332.510 0.90
LEVEL 2 00.00 2158.610 0.00
LEVEL 3 99.88 2505.748 0.30
DECAY 1 0 99.9826
DECAY 2 1 00.0076
DECAY 2 0 00.0012
DECAY 3 2 00.0075
DECAY 3 1 99.85
DECAY 2 0 00.0000020
```

The Gamma Input File

No γ-γ angular correlations!




```
LEVEL 0 00.00 0000.000 0.00
LEVEL 1 00.12 1332.510 0.90
LEVEL 2 00.00 2158.610 0.00
LEVEL 3 99.88 2505.748 0.30
DECAY 1 0 99.9826
DECAY 2 1 00.0076
DECAY 2 0 00.0012
DECAY 3 2 00.0075
DECAY 3 1 99.85
DECAY 2 0 00.0000020
```

Using dEdX Tables

Instead of letting GEANT4 calculate the energy loss in the target, dEdX tables can be used. For thick targets, this will speed up the simulation process. The input table has the following form:

```
dEdX 267.5 0.336315
dEdX 265.0 0.338156
.
.
.
END
```

- Up to 50 values can be inserted.
- Energy loss is given in MeV/(mg/cm^2).
- The First two point define the energy spacing for a linear interpolation.
- Use for example the goodies section in LISE++ (based on ATIMA1.2)

The Event Builder

The Input File

- The Input File can be found under `./input/EventBuilder.in`

- Only the most important input keywords are listed. The manual, still under construction, will cover all.
  - `INPUFILENAME` $File_{in}$
  - `OUTPUFILENAME` $File_{out}$
  - `DALI2INCLUDE` $Option_{DALI2}$
  - `DALI2ENERGYRESOLUTION` $i \quad a \quad b$
    If $i = 1$: $\Delta E(FWHM) = a + bx$ keV.
    If $i = 2$: $\Delta E(FWHM) = ax^b$ keV.
  - `BETARESOLUTION` a
    $a = \Delta\beta/\beta(FWHM)$
  - `TARGETHOLDERINCLUDE` $Option_{TargetHolder}$
  - `BEAMPIPEINCLUDE` $Option_{BeamPipe}$
  - `DALI2FIINCLUDE` $Option_{FI}$
  - `END`

The DALI2 Geometry Input File

- The Input File can be found under:
  `./geometry/dali2_geometry_in.txt`

- It has the following structure:
  `POSX POSY POSZ PSI THETA PHI ROTSIGN DETTYPE`
  `.`
  `.`

- Up to 182 detectors (check the global variable defined in `Globals.hh`)

- Three different NaI detector types can be chosen:
  - `DETTYPE = 0` Saint-Gobain
  - `DETTYPE = 1` Scionix
  - `DETTYPE = 2` DALI1

- The crystals are not centered with respect to their housing

- Take a look at **./src/Dali2.cc** and **./include/Dali2.hh** !

The Reconstructor

The Input File

- The Input File can be found under:
  `./Dali2Reconstructor.in`

  - `INPUFILENAME` $File_{in}$
  - `OUTPUFILENAME` $File_{out}$
  - `FIFIND` i
    If $i = 1$, the average first interaction point of a full energy peak γ-ray (with fold=1) is determined for every crystal.
  - `BETADOPPLERAVERAGE` a
    The average β-value used for the Doppler correction.
  - `BETATOFAVERAGE` a
    The average β-value in front of the target. This value is necessary for an event-by-event Doppler correction with different incoming velocities.
  - `DECAYPOSITION` z
  - `STATISTICSREDUCTIONFACTOR` a
  - `END`

Simulation Examples

DALI2 Efficiency with ^{60}Co Source

- Structure of the Event Generator Input File:

```
GAMMAINPUT ./input/60Co.in
NUMBEROFEVENTS 100000
OUTPUTFILE ../tutorial/60CoGenerator.root
END
```

- Structure of the Event Builder Input File:

```
INPUTFILE ../tutorial/60CoGenerator.root
OUTPUTFILE ../tutorial/60CoBuilder.root
DALI2INCLUDE 1
DALI2ENERGYRESOLUTION 2 2.2795 0.5
END
```

- Structure of the Reconstructor Input File:

```
INPUTFILE ../tutorial/60CoBuilder.root
OUTPUTFILE ../tutorial/60CoReconstructor.root
SPECTRABINANDRANGE 400 0.  4000.
END
```

DALI2 Efficiency with ^{60}Co Source

- Set the environment from my `.bashrc` or by typing `sh setup.sh`
- Run the Event Generator in the directory `EventGenerator` with:
  `EventGenerator run_nothing.mac`
- Run the Event Builder in the directory `EventBuilderRIKEN` with:
  `EventBuilder run_nothing.mac`
  Omitting `run_nothing.mac` will bring you into the interactive mode, from which you can take a look of the geometry by typing:
  `/vis/viewer/flush`
- Open a ROOT session in the directory `Reconstructor` and build the shared library using ACLIC by typing:
  `root[].L Dali2Reconstructor.C+`
  and run the script with
  `root[]Dali2Reconstructor()`

The First Excited State in ^{36}Ca from the 1n-Knockout Reaction

- Structure of the Event Generator Input File:

```
BEAMISOTOPE 37 20 20
BEAMENERGY 195.7 6.06
BEAMPOSITION 0.0 1.0 0.0 1.0
BEAMANGLE 0.0 0.65 0.0 360.0
TARGET 2 7.0 7.0 700
TARGETANGULARBROADENING 1 0.6
MASSCHANGE 1 0
BORREL 1 8.
GOLDHABER 1 90.
GAMMAINPUT ./input/36ca.in
NUMBEROFEVENTS 50000
DEFAULTCUTVALUE 0.001
OUTPUTFILE ../tutorial/36CaGenerator.root
DEDXTABLE 1 ./dEdXTables/CaOnBe.in
./dEdXTables/CaOnBe.in
```

The First Excited State in ^{36}Ca from the 1n-Knockout Reaction

- Structure of the Event Builder Input File:

```
INPUTFILE ../tutorial/36CaGenerator.root
OUTPUTFILE ../tutorial/36CaBuilder.root
DALI2INCLUDE 1
DALI2ENERGYRESOLUTION 2 2.2795 0.5
POSDETECTORONTARGETRESOLUTION .3
POSDETECTORAFTERTARGETDISTANCE 100.
POSDETECTORAFTERTARGETRESOLUTION .3
BETARESOLUTION 0.001
END
```

- Structure of the Reconstructor Input File:

```
INPUTFILE ../tutorial/36CaBuilder.root
OUTPUTFILE ../tutorial/36CaReconstructor.root
SPECTRABINANDRANGE 400 0.  8000.
BETADOPPLERAVERAGE 0.5459
BETATOFAVERAGE 0.5631
DECAYPOSITIONZ 0.0
END
```

THE END

Backup slides from now