Manual of a GEANT4 Simulation Code for γ-Ray Detectors used in the RIKEN-RIBF Facility

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Contents

Chapter 1

Introduction

This manual describes briefly the GEANT4 [1] simulation code of the γ-ray spectrometers Dali2 [2] and SHOGUN, which are or will be employed at the Radioactive Ion Beam Factory (RIBF). The aim of the simulation code is to obtain reliable values for the γ-ray detection efficiency and energy resolution of a chosen detector geometry under realistic expererimental conditions for the secondary beams. Also effects on the γ-ray lineshape from the target thickness and lifetimes of the excited states can be studied. In the following description the necessary steps to perform a simulation and the options are discussed.

A typical simulation is divided into three steps, namely:

- The *Event Generator*, in which a heavy ion beam strikes on a target and emits γ-rays. Incoming beam and outgoing beam may be different, i.e. fragmentation reactions are covered in the simulation.

- The *Event Builder* simulates the γ-ray detection response and uses the first step as input values.

- The *Reconstructor* performs the necessary Doppler correction of the detected γ-rays. Here, the analysis of the observed γ-rays can be performed by the user.

The motiviation for partitioning the simulation into these three steps is that they are in principle independent from each other. Thus, when changing for instance the detector geometry, the first step does not have to be re-simulated

and can be used again. Since the first step is very time consuming (especially with thick targets), the whole simulation process is thereby accelerated.

Prior to explaining the three steps in detail, a few notes on the software necessary to run the simulation need to be mentioned. The following software is required to be installed on your computer:

- The Geant4 framework. The simulation code was tested only for g4.9.4. It can be downloaded from:
  `http://geant4.cern.ch/`.
  An installation guide for Linux and Windows machines is given in:
  `http://geant4.slac.stanford.edu/installation/`.

- The CLHEP class library. Details are given in the previously mentioned installation guide and under:
  `http://proj-clhep.web.cern.ch/proj-clhep/`.

- The ROOT [3] framework. It can be downloaded from:
  `http://root.cern.ch/`.
  The simulation code was tested succesfully with ROOT version 5.27/04.

The simulation package has to be unpacked with the command:

```
tar -zxf Geant4Shogun.1.0.1.tar.gz.
```

This will create the subfolders `EventGenerator`, `EventBuilder`, and `Reconstructor`. These subfolders contain the the Event Generator, the Event Builder, and the Reconstructor, respectively, and are now covered in detail. The manual will close with remarks on things that need improvement and/or need to be implemented. Note that the simulation package uses a left-handed system with the positive z-axis being the beam direction.

Chapter 2

The Event Generator

Go the the subfolder `EventGenerator`. Open the file `GNUMakefile` and make sure that the variables `G4INSTALL` and `CLHEP_BASE_DIR` are set according to the installation location on your computer. Compile the Event Generator with:

```
make all
```

It will create the Event Generator. Please ignore all the warning messages.

2.1 The Input File(s)

To change the parameters of the Event Generator, open the file `./input/EventGenerator.in`. The file contains keywords, which can be used in free format and change the default values of the simulation. The available keywords and their parameters are listed in Tab.2.1. In this table, s, i, and f are used for input string, integer, and floating point values, respectively. Note that in the current version the simulation code is very restrictive, that is, comments and not existing input keywords in this file will cause the programm to terminate.
The parameters are now discussed subsequently (if not specified differently, the units are cm and degrees, respectively):

- BEAMISOTOPE A_P Z_P Q_P
  Contains the information on the type of the projectile P in the order mass A_P, the element number Z_P and thecharge state Q_P.

Keyword	Parameters
BEAMISOTOPE	$i\ i\ i$
BEAMENERGY	$f\ f$
BEAMPOSITION	$f\ f\ f\ f$
BEAMANGLE	$f\ f\ f\ f$
TARGET	$i\ f\ f\ f$
TARGETANGULARBROADENING	$i\ f$
MASSCHANGE	$i\ i$
BORREL	$i\ f$
GOLDHABER	$i\ f$
GAMMAINPUT	s
THETARANGE	$f\ f$
NUMBEROFEVENTS	i
DEFAULTCUTVALUE	f
OUTPUTFILE	s
DEDXTABLE	$i\ s\ s$
ATOMICBG	$s\ s\ f\ f$
END	

- BEAMENERGY E_P $\Delta E(FWHM)_P$
  gives the total energy of the projectile (E_P before striking on the target) and the width of the energy distribution ($\Delta E(FWHM)_P$) in MeV/u.

- BEAMPOSITION X FWHM$_X$ Y FWHM$_Y$
  Position of the projectile before impinging on the target.

- BEAMANGLE ϑ_P $\Delta(FWHM)\vartheta_P$ $\varphi_{P_{min}}$ $\varphi_{P_{max}}$
  Angle of the incoming projectile. The distribution for $\Delta(FWHM)\vartheta_P$ is Gaussian, while the distribution between $\varphi_{P_{min}}$ and $\varphi_{P_{max}}$ is flat.

- TARGET Type Size$_X$ Size$_Y$ Thickness$_Z$
  This line specifies the target material and its dimensions. The Type is 1 for Au, 2 for Be, 3 for C, 4 for Fe, 5 for Pb, and 6 for LH_2. As density always the "standard" value for a solid state is given. The value for Thickness$_Z$ is given in mg/cm^2.

- TARGETANGULARBROADENING Option$_{ang.}$ $\Delta(FWHM)\vartheta_{target}$
  Angular Broadening caused by the reaction in the target. If

Option$_{ang.}$=1, this option is considered and the broadening is a Gaussian distribution defined by $\Delta(FWHM)\vartheta_{target}$.

- MASSCHANGE ΔA ΔZ

- BORREL: Option$_{Borrel}$ B_n
  Velocity shift for a fragmentation process. If Option$_{Borrel}$=1, the velocity shift is calculated according to the formula from Ref. [4]:

$$\frac{v_f}{v_p} = \sqrt{1 - \frac{B_n(A_P - A_F)}{A_P E_F}}, \tag{2.1}$$

  where the index F stands for the fragment, v is the velocity, and B_n the binding energy (in MeV) per ablated nucleon.

- GOLDHABER Option$_{Goldhaber}$ σ_0
  Parallel momentum distribution produced in a fragmentation process. If Option$_{Goldhaber}$=1, the momentum distribution is calculated according to:

$$\sigma_{||} = \sigma_0^2 \frac{A_F(A_P - A_F)}{A_P - 1}, \tag{2.2}$$

  where σ_0 is given in MeV/c.

- GAMMAINPUT $File_{\gamma-in}$
  The Filename specifies the location of the level and decay scheme to be simulated.

- THETARANGE $\vartheta_{\gamma_{min}}$ $\vartheta_{\gamma_{max}}$
  Polar angular range in the moving frame of the γ-rays that should be included in the simulation. If your detectors cover only extreme forward angles, $\vartheta_{\gamma_{min}}$ can be set to 0 and $\vartheta_{\gamma_{max}}$ to 90, thereby reducing the simulation time and filesize by a factor of two.

- NUMBEROFEVENTS N_{events}
  N_{events} gives the number of reactions to be simulated.

- DEFAULTCUTVALUE L_{cut}
  L_{cut} specifies the default cut value in mm used in the simulation. Visit the GEANT4 web pages for more information.

- OUTPUFILENAME $File_{out}$
  Specifies the location of the output file name.

- DEDXTABLE $Option_{dEdX}$ $File_P$ $File_E$
  Instead of letting GEANT4 calculate the energy loss of projectile and ejectile (the fragment), if Option$_{dEdX}$=1 the energy loss can be calculated much faster (for thick targets) according to energy loss tables. $File_P$ and $File_E$ specify the location of these tables for projectile and ejectile, respecitively.

- ATOMICBG $Option_{ATOMICBG}$ $FileName$ $Spectrumname$ σ_{bg} N_γ
  Option to include atomic background from a 2D ROOT histogram. The total cross section of the atomic background has to be specified in σ_{bg} in mbarn and the total number of γ-rays produced per incident particle, N_γ, has to be specified. A separate program to calculate the anticipated atomic background, abkg, is provided. More details are given in a Sec. 2.1.3.

- END
  This keyword will end the scan of the input file and can be set at any line within the input file.

2.1.1 Input of the Level Scheme

The variable $File_{\gamma-in}$ specifies the location of the decay scheme to be simulated. It contains two keywords, `LEVEL` and `DECAY`. They are defined as follows:

- LEVEL N_{Level} P_i E_{Level} $T_{1/2}$
  N_{Level} is the identifier of the level, P_i is the relative initial probability of the ejectile (fragment) to end in that state after the initial reaction, E_{Level} is the energy of the level above the ground state in keV, and $T_{1/2}$ is the halflife of the level given in ps.

- DECAY L_i L_f P_γ
  This keyword controls the decay scheme of a initial level L_i into the level L_f via the relative probability P_γ. Note that any given level may possess up to a maximum five levels thats it decays into.

A possible level scheme with two excited levels at $L_1 = 1000$ keV and $L_2 = 1500$ keV and an initial level probability of $P_1 = 67$ and $P_2 = 33$ would look as:

```
LEVEL 0 0.  0.  0.
LEVEL 1 67.  1000.  10.
LEVEL 2 33.  1500.  20.
DECAY 1 0 100.
DECAY 2 1 100.
DECAY 2 0 1.
```

In the above example, L_1 has a halflife of $T_{1/2} = 10$ ps, while L_2 has 20 ps. Furthermore, L_2 decays into the groundstate (LEVEL 0) with a relative probability of 1/100 compared to the decay to the first excited state (LEVEL 1).

2.1.2 Input of the $dEdX$ Tables

The energy loss tables have the structure:

```
dEdX Energy SpecificEnergyLoss.
```

The energy is given in MeV/u and the specific energy loss is given in MeV/(mg/cm^2).

2.1.3 Including atomic background into the simulation

The program abkg can be used to inlcude atomic backgroung into the simulation. It can be found under abkg/abkg and requires one input file. Examples input files are given under abkg/exampleFiles. As this program produces an hbk-file, you will have to use h2root to convert it to a root-file.
For the input keyword ATOMICBG the spectrum name to be specified is h1. The total cross-section is given in the title of the spectrum. The total number of *gamma*-rays per incident event has to be calculated according to the chosen target thickness.
Without ATOMICBG option, it is assumed that the reaction probability per incident particle is always 100 %. Now, with ATOMICBG option, the initial

level probabilities of the input level schem are given in mbarn.

2.2 Starting the Simulation

To start the simulation in the batch mode, type:

```
Eventgenerator run_noting.mac
```

Omitting a filename will bring the Event Generator into the "standard" GEANT4 interactive session, which is not intended to be used for this step.

Chapter 3

The Event Builder

The Event Builder is located in the directory `EventBuilderRIKEN`. As mentioned already for the Event Generator, make sure that the variables `G4INSTALL` and `CLHEP_BASE_DIR` are set correctly in the file `GNUMakefile`. Compile the Event Builder with:

```
make all
```

3.1 The Input File(s)

To change the parameters of the Event Builder, open the file `./input/EventBuilder.in`. The parameters of this file are listed in Tab.3.1. The restriction for the Event Generator input file is valid here, too, causing the program to terminate if comments and not existing input keywords are written in this file (before the END statement).
The parameters are now discussed subsequently (if not specified differently, the units are cm and degrees, respectively):

- INPUTFILE FILE$_{in}$
  Gives the location of the input root file generated by the Event Generator.

- OUTPUTFILE FILE$_{out}$
  Gives the location of the output root file generated in this step.

Keyword	Parameters
INPUTFILE	s
OUTPUTFILE	s
SHIELD	$f\ f\ f$
DALI2INCLUDE	i
DALI2FIINCLUDE	i
SHOGUNINCLUDE	i
SHOGUNFIINCLUDE	i
SHOGUNHOUSINGTHICKNESSZYZ	$i\ f\ f\ f$
SHOGUNMGOTHICKNESSZYZ	$i\ f\ f\ f$
GRAPEINCLUDE	i
SGTINCLUDE	i
SPHEREINCLUDE	$i\ f\ f$
DALI2ENERGYRESOLUTION	$i\ f\ f$
DALI2ENERGYRESOLUTIONINDIVIDUAL	s
SHOGUNENERGYRESOLUTION	$i\ f\ f$
GRAPEENERGYRESOLUTION	$i\ f\ f$
SGTENERGYRESOLUTION	$i\ f\ f$
DALI2TIMERESOLUTION	$f\ f$
SHOGUNTIMERESOLUTION	$f\ f$
GRAPETIMERESOLUTION	$f\ f$
SGTTIMERESOLUTION	$f\ f$
POSDETECTORONTARGETRESOLUTION	f
ENERGYDETECTORAFTERTARGETINCLUDE	f
POSDETECTORAFTERTARGETDISTANCE	f
POSDETECTORAFTERTARGETRESOLUTION	f
BETARESOLUTION	f
BEAMPIPEINCLUDE	i
TARGETHOLDERINCLUDE	i
STQINCLUDE	i
COLLIMATORINCLUDE	i
END	

- SHIELD r D_{Pb} D_{Sn}

  Specifies the thickness of absorbermaterial placed along beam pipe. r is the inner radius of the absorber tube. D_{Pb} D_{Sn} the thickness in cm of the Pb and Sn.

- DALI2INCLUDE i
  SHOGUNINCLUDE i
  GRAPEINCLUDE i
  SGTINCLUDE i
  SPHEREINCLUDE i R_{out} R_{in}
  If i=1, these detector arrays are included in the simulation. They require an input file that specifies their postion and rotation relative to the target. These input files are covered in section 3.2. For the sphere, the center is (0,0,0) and thickness is determined by R_{out} - R_{in}.

- DALI2FIINCLUDE i
  If i=1, the first interaction point of a γ-ray is determined for every crystal of the DALI2 array. Note that for cascade decays, every γ-ray is treated independently. Therefore, if subsequent decays are registered in the same detector, also two first interaction points are determined.

- SHOGUNHOUSINGTHICKNESSXYZ i $SIZE_x$ $SIZE_y$ $SIZE_z$
  If i=1, the DALI3 detectors are surrounded by an Al-frame of the thickness $SIZE_x$ $SIZE_y$ $SIZE_z$.

- SHOGUNMGOTHICKNESSXYZ i $SIZE_x$ $SIZE_y$ $SIZE_z$
  Thickness of the material between housing and crystal, assumed to be MgO

- DALI2ENERGYRESOLUTION i a b
  SHOGUNENERGYRESOLUTION i a b
  GRAPEENERGYRESOLUTION i a b
  SGTENERGYRESOLUTION i a b
  If i=1, the energy resolution has the form: $\Delta E(FWHM) = a + bx$ keV. If i=2, the form is: $\Delta E(FWHM) = ax^b$ keV.

- DALI2TIMERESOLUTION a b
  SHOGUNTIMERESOLUTION a b

GRAPETIMERESOLUTION a b
SGTTIMERESOLUTION a b
The time resolution has the form: $\Delta T(FWHM) = a + bx$ ns, where x is the detected energy in keV.

- POSDETECTORONTARGETRESOLUTION x
  This keywords determines the precision of the tracking onto the target position from imaginary detectors. x is given in cm (FWHM).

- ENERGYDETECTORAFTERTARGETINCLUDE 0
  If i=1, energy detectors after the target will be inserted and included in the simulation. This option is, however, not really integrated into the simulation, yet.

- POSDETECTORAFTERTARGETDISTANCE a
  POSDETECTORAFTERTARGETRESOLUTION b
  The distance a (in cm) of a position sensitive detector after the secondary target and its resolution b in x and y.

- BETARESOLUTION a
  The β-resolution a = $\Delta\beta/\beta(FWHM)$ for the time-of-flight measurement before the target. This parameter is necessary for event-by-event Doppler correction of the emitted γ-rays based on the particles' velocities.

- BEAMPIPEINCLUDE i
  If i=1, the beam pipe will be included in the simulation.

- TARGETHOLDERINCLUDE i
  If i=1, the targetholder will be included in the simulation. This option requires to insert the target position, material and thickness in the file:

  `./input/TargetHolder.in`

  The file has the format:

  ```
  0 SetTargetPosition X
  P MATERIAL THICKNESS
  .
  .
  ```

.

Here, `X` determines the set target position of the target holder, `P` the position of the to be specified next, `MATERIAL` the material name (see file `./src/MaterialList.cc` for the material definitions), and `THICKNESS` the thickness in cm.

- STQINCLUDE i
  If i=1, the STQXX triplet will be put after the target. Just for optical reasons at the moment.

- END
  This keyword will end the scan of the input file and can be set at any line within the input file.

3.2 The Geometry Input Files

The geometries of the γ-ray arrays are defined in the directory `./geometry`. These input files are slightly different for all the arrays. Therefore, they are covered independently. If not specified differently, the units are cm and degrees.
The geometry input files for the arrays are given under:

```
./geometry/dali2_geometry_in.txt
./geometry/shogun_geometry_in.txt
./geometry/grape_geometry_in.txt
./geometry/sgt_geometry_in.txt
```

All input files must end wit a -1 in the last line. To ensure that your detectors have been put to the correct position, you can check the respective `*out.txt` file in the same directory. It has the format

```
ID (TYPE) THETA PHY RADIUS
```

The parameter `TYPE` is printed only for the DALI2 array.

3.2.1 The DALI2 Geometry Input File

For the DALI2 array, the geometry input file has the form:

```
POSX POSY POSZ PSI THETA PHI ROTSIGN DETTYPE
.
.
.
```

The crystals' positions are not centered within their outer housing, but shifted by 0.535 cm and 0.7 cm, respectively, depending on their type. `ROTSIGN` defines in which direction they are shifted (+1,-1, 0 for no shift). Furthermore, three differet types of DALI2 crystals exist, which are covered in Ch. **??**ch:DALI2). Therefore, `DETTYPE` specifies the type of crystal at the given position is to be simulated.

3.2.2 The SHOGUN Geometry Input File

For the DALI3 array, the geometry input file has the form:

```
ID RING TYPE X Y Z RADIUS THETA PHI SIZEX2 SIZEX1 SIZEY2 SIZEY1
SIZEZ
.
.
.
```

The input values `ID, RING, TYPE,` and `RADIUS` stem from Heiko Scheit's script `det_place.gawk` and are not used for the placement of the detectors. The crystals are of trapezoidal shape and defined by the last 5 input values. Example configurations can be found under `./geometry/configurations/*.txt`.

3.2.3 `det_place.gawk`

The script `det_place.gawk` is used to calculate sample configurations. One can find some example commands under `det_place/ListOfCases.txt`. The input parameters are:

- -a
  Determines the starting angle of the array

- -3, -4, etc.
  The Doppler broadeing of the detectors at β=0.43.

- -g Number1 Number2
  Number1 is starting angle. Number2 defines how many crystal should be put into one common housing.

- -t Number
  Defines the detector geometry specified in the script.

- Number
  Defines how many crystals can be used at maximum.

- -w Number
  How much space has the scrip to leave between the different single-, double-, triple-detectors.

3.2.4 The Grape Geometry Input File

The Grape detectors are placed according to:

```
X Y Z PSI THETA PHI
.
.
.
```

No further explanation is necessary, I think.

3.2.5 The SGT Geometry Input File

The Grape detectors are placed according to:

```
X Y Z PHI
.
.
.
```

No further explanation is necessary, I think.

3.3 Starting the Simulation

To start the simulation in the batch mode, type:

```
EventBuilder run_noting.mac
```

Omitting a filename will bring the Event Builder into the "standard" GEANT4 interactive session. To get a view of your detector system, type:

```
/vis/viewer/flush
```

in this session. This will open up the DAWN GUI, from which you can select the viewing point, distance, light position, etc... Pressing the "OK" button will start the drawing.

Chapter 4

The Reconstructor

The Reconstructor performs the Doppler correction of the simulated γ-rays. It comprises of the single ROOT-macro `RikenFastBeamReconstructor.C` or `ShogunReconstructorSimple.C`. A shared library can be created with the command:

```
root [0] .L ShogunReconstructorSimple.C+
```

from the Root command prompt. Afterwards the Reconstructor can be run with the command:

```
root [1] ShogunReconstructorSimple()
```

Before running it, you must specify the parameters from the respective `*.in` input file, given in Tab. 4.

- INPUTFILE FILE$_{in}$
  Gives the location of the input root file generated by the Event Generator.
- OUTPUTFILE FILE$_{out}$
  Gives the location of the output root file generated in this step.
- DALI2INCLUDE i
  SHOGUNINCLUDE i
  GRAPEINCLUDE i

Keyword	Parameters
INPUTFILE	s
OUTPUTFILE	s
SPECTRABINANDRANGE	$i\ f\ f$
BETADOPPLERAVERAGE	f
BETATOFAVERAGE	f
DECAYPOSITIONZ	f
STATISTICSREDUCTIONFACTOR	f
FIFIND	i
DALI2INCLUDE	i
SHOGUNINCLUDE	i
GRAPEINCLUDE	i
SGTINCLUDE	i
END	

SGTINCLUDE i
SPHEREINCLUDE i
If i=1, these detector arrays are included in the simulation. In the present script, only the SHOGUN data are analyzed.

- FIFIND i
  If i=1, the average first interaction point of a full energy peak γ-ray (with fold=1) is determined. Not used in present script.

- 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
  The average z-positon along the beam-axis shifts as a function of the excited states' lifetimes. This value can be inserted to correct for this effect.

- STATISTICSREDUCTIONFACTOR a
  If you have simulated many events in the second step and want to see

how the Doppler corrected response might have looked like for limited statistics you can reduce your statistics by putting a value a ≥ 1.

- END
  This keyword will end the scan of the input file and can be set at any line within the input file.

The Doppler corrected spectra will be stored in a ROOT-file, which you can inspect using the TBrowser. Type:

```
root [2] TBrowser b;
```

and open the folder "ROOT Files". It will include the input as well as the output files you used for your event reconstruction.

Chapter 5

Simulation Examples

5.1 DALI2 Efficiency from a ^{60}Co source

5.1.1 Running the Event Generator

Your input file `./EventGenerator/input/EventGenerator.in` should have the following structure:

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

The γ-ray decay file should be `./EventGenerator/input/60Co.in` and have the following structure:

```
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
```

Go into the directory `EventGenerator` and type

```
EventGenerator run_nothing.mac
```

into the command line. This will start the Event Generator and create the root output file `./tutorial/60CoGenerator.root`.

5.1.2 Running the Event Builder

Your input file `./EventBuilderRIKEN/input/EventBuilder.in` should have the following structure:

```
INPUTFILE ../tutorial/60CoGenerator.root
OUTPUTFILE ../tutorial/60CoBuilder.root
SHOGUNINCLUDE 1
SHOGUNENERGYRESOLUTION 2 0.7 0.5
END
```

go into the directory `EventBuilderRIKEN` and type
`EventBuilder run_nothing.mac`

into the command line. This will run the Event Builder and create the root output file `./tutorial/60CoBuilder.root`.

5.1.3 Running the Reconstructor

Your input file `.Reconstructor/input/Dali2Reconstructor.in` should have the following structure:

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

Go into the directory `Reconstructor` and open a ROOT-session by typing `root` into the shell. Yuo have to load/compile the libray by typing:

```
root[].L ShogunReconstructorSimple.C+
```

The reconstruction process is started by typing:

```
root[]ShogunReconstructorSimple()
```

You can take a look into the created spectra with the TBrowser by typing:

```
root[]TBrowser b;
```

Chapter 6

To-Do List

It is understood that the simulation has room for improvements. The subsequent list enumarates objects and features that need to be worked on:

- The longitudinal momentum spread from the fragmentation is included (Goldhaber formula [5]), however, the perpendicular momentum spread is not. Instead, a ϑ-spread has to be given by the input file.
- The Angular straggling from the energy loss of the heavy ion in the target is not included.
- The γ-ray angular distribution is isotropic and there is no γ-γ correlation.
- An important issue for a precise Doppler correction is an accurate measurement of the heavy ion trajectory. It is desirable to improve the users options and to enable the placing of position detectors at different positions along the beam axis.
- A routine that checks if the detectors overlap has to be implemented.
- A realistic add-back routine has to be implemented.

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