G4DS Man Pages

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Contents

1 Short start up

To run g4ds you have first to set the proper environment. Depending on which shell you are using (bash or tcsh) you can look at the configuration files (.sh or .chs) present in the g4ds folder: configDarkSide.sh and configDarkSide.csh are done for the linux cluster (Lyon)

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in France and configDarkSide_argus.sh and configDarkSide_argus.csh for MacOS cluster (argus) at Princeton. configDarkside.sh also works for the ds50srv01 server at Fermilab. If you work in a different cluster, please edit and adapt the configuration file. Then, set the environment with:
source configDarkSidexxx.sh
and compile it with: *make*
If you work in a linux cluster, the executable *g4ds* will appear in *Linux-g++*, in MacOS in *Darwin-g++*. All the macro files (.mac) are in *Linux-g++*.
To run g4ds, goes to the executable directory and make:
./g4ds xxx.mac (Linux)
./g4ds ../Linux-g++/xxx.mac (MacOS)
The most general macro is *run.mac*. To modify the detector configuration, physics list, generator, and manager edit the macro file and use the commands listed in this manual.
The code is still in a development phase and must be debugged. Please, report any bug or strange behavior to the developers, in order to improve the code.

2 Convert binary to root file

To read the output binary file (.fil extension) and to generate the correspondent root file, compile (only the first time) the rooter generator with the command *compile_rooter* in the Linux-g++ folder (without ./); then, run *g4rooter filename.fil* (to print all the options run *g4rooter* without the filename).

3 Tips

- The use of hadronic physics implies a long time to construct the detector in the simulation. If you work at low enegies, de-activate it by using the command: /ds/physics/hadronic_list none .

- The amount of S2 light is huge with respect to S1. Tracking all the photons requires time. To give an idea, a 100 keV electron in the TPC is simulated in about 20 s. If S2 light is not needed, you can disable it using /ds/physics/killS2 1, or you can scale the light by a factor X, by using /ds/physics/scaleS2 X. A 100 keV electron, without S2 light, requires a fraction of a second.

- By default, g4ds stores in the binary file only information about the primary particle and the photoelectrons. There are 4 other options: saving daughters (secondary particles), energy depositions, generated photons, and thermal electrons. The 3 commands are:
  /ds/manager/writephotons 1
  /ds/manager/writedaughters 1
  /ds/manager/writedeposits 1
  /ds/manager/writethermalelectrons 1
  Be careful: the number of photons can exceed the maximum number of photons storable by g4rooter. Use /ds/manager/writephotons 1 only when you generate single photons or you work with a very low number of generated photons.

4 The Mac-File

The macro file (mac-file) is an ASCII-file, containing user-frendly instructions for running g4ds.
Mac file properties include:

- The MC is fully configurable with macro commands.

- Running different simulations simultaneously, one per each mac file, is possible without interference (output names are automatically changed).

- Modifying the mac file, you do not need to recompile the program.

Be careful. The mac file is structured into 2 parts, divided by the command: /run/initialize. Before this command, set the detector, manager, run and physics properties. After, everything concerns the generator and the number of events.
All commands are listed, with a short description, in the next sections.

5 Run

- **/run/filename xxx**
  type: optional

default: output
description: set the output filename (without extension!). G4ds will produce two output files: xxx.log and xxx.fil. The first is the log file (with both input and output information); the latter is the binary. If xxx.log already exists, G4ds will change xxx in xxx_vN (N = 1,2,3,...). Be careful: the re-naming does not depend on the binary file!

- **/run/autoSeed xxx**
  type: optional
  default: true
  description: set the random seed from the systime
  options: true or false

- **/run/heprandomseed xxx**
  type: optional
  default: no default
  description: set the user-defined random seed. It turns off autoSeed.

6 Manager

- **/ds/manager/log xxx**
  type: optional
  default: routine
  description: set the message priority
  options: debugging, trace, routine, warning, error, fatal.

- **/ds/manager/checkoverlap xxx**
  type: optional mandatory
  default: 0
  description: check if there exists any detector overlap
  candidates:

- **/ds/manager/GDML xxx**
  type: optional
  default: 0
  description: Switch ON (1) or OFF (0) GDML to export geometry in a .gdml file
  candidates: 0, 1

- **/ds/manager/writephotons xxx**
  type: optional
  default: 0
  description: store photons

- **/ds/manager/writedaughters xxx**
  type: optional
  default: 0
  description: store deposits

- **/ds/manager/writedeposits xxx**
  type: optional
  default: 0
  description: store daughters

- **/ds/manager/writedethermalelectrons xxx**
  type: optional
  defult: 0
  description: store thermal electrons number and drift time (dep_pdg set to -1)

- **/ds/manager/eventcounter xxx**
  type: optional
  default: 100
  description: print info each xxx events
  candidates:

- **/ds/manager/verbosity xxx**
  type: optional
  default: -1
  description: set the level of information you want to print out (0: event; 1: daughter; 2: deposit; 3: photoelectrons; 4: photons)
  candidates: 0, 1, 2, 3, 4

- **/ds/manager/daughterdepth xxx**
  type: optional
  default: 1

description: set max parent id correspondent to the daughter to store

- **/ds/manager/TMB_fraction xxx**
  type: optional
  default: 0.5
  description: set the TMB/PC ratio for the neutron veto scintillator
- **/ds/manager/fast_simulation xxx**
  type: optional
  default: 0
  description: scale the TPC PMTs QE to 1.0 and generate less photons
- **/ds/manager/storecherenkov xxx**
  type: optional
  default: 0
  description: store the number of emitted Cherenkov photons (without tracking them) in the PhotonStructure
- **/run/beamOn xxx**
  type: mandatory
  default: Varies
  description: set the number of events to be generated
  candidates: Any integer [0, 100000000]

7 Detector

- **/ds/detector/configuration xxx**
  type: optional
  default: 0
  description:
  - 0: DS50 TPC+NW+WT
  - 1: DS50 TPC+NW
  - 2: DS50 NV+WT
  - 4: LAr test setup
  - 5: DS10 TPC
  - 6: Scintillator small setup
  - 7: DSG2 (first version) TPC + NV + WT
  - 8: DSG3 (ARGO-like) TPC + NV
  - 9: DS5k (second version) TPC
  - 10: DS20k (final version) TPC + WT (the WT can be filled with water, Gd-water, B-scintillator) or TPC + NV + WT
  - 100: Licorne
- **/ds/detector/wt_material xxx**
  type: optional
  default: Water
  description: define the water tank material candidates: BoronScintillator Water GdWater
- **/ds/detector/wt_radius xxx**
  type: optional
  default: 5 m
  description: define the water tank radius
  units: m, cm
- **/ds/detector/wt_height xxx**
  type: optional
  default: 9 m
  description: define the water tank height
  units: m cm
- **/ds/detector/ExtLarScintillating xxx**
  type: optional
  default: 0
  description: If 1, add scintillation to argon between cryostat and TPC in DS50. If you set it to 0, the simulation for external gammas is speeded up. candidates: 0, 1
- **/ds/detector/scintillator xxx**
  type: optional
  default: BoronScintillator
  description: Choose the scintillator in the neutron veto
  candidates: BoronScintillator GdScintillator
- **/ds/detector/vetoyieldfactor xxx**
  type: optional
  default: 1.0

description: Set the scaling factor for the veto scintillation yield (0 = no light emitted but visible energy stored)
candidates:

- **/ds/detector/holderRadius xxx**
type: optional
default: 70.0 cm
description: Set the distance of bottom of the source holder from the center of the TPC (units: mm, cm, m). The source holder constructor is automatically activated.
candidates:

- **/ds/detector/holderPhi xxx**
type: optional
default: 0.0
description: Set the angle with respect to the x axis in the LSV frame (units: rad, deg, degree). The source holder constructor is automatically activated.
candidates:

- **/ds/detector/holderZ xxx**
type: optional
default: 0.0
description: Set the vertical position of the source holder in the LSV frame (units: mm, cm, m). The source holder constructor is automatically activated.
candidates:

7.1 specific for ds20k design study

- **/ds/detector/ds20cryo_tpcHeight xxx**
type: optional
default: 240 cm
description: set the height of the octagonal TPC
units: mm cm m

- **/ds/detector/ds20cryo_tpcEdge xxx**
type: optional
default: 120 cm
description: set the edge of the octagonal TPC
units : mm cm m

- **/ds/detector/ds20_AcrylicWalls_Thick xxx**
type: optional
default: 5 cm
description: set the thickness of the TPC walls and anode and cathode
units : mm cm

- **/ds/detector/ds20_LArBuffers_Thick xxx**
type: optional
default: 40 cm
description: set the thickness of the LAr veto buffers
units : cm m

- **/ds/detector/ds20_VetoShell_Thick xxx**
type: optional
default: 40 cm
description: set the thickness of the passive Gd-loaded (2%) plastic
units : cm m

Old design version

- **/ds/detector/ds20lsv_detector xxx**
type: optional
default: 1
description: choose to build the LSV detector inside the water tank
candidates:

- **/ds/detector/ds20lsv_pmt xxx**
type: optional
default: 1
description: choose the LSV PMT type (1 means 8 inches, 2 means 20 inches)
candidates: 1, 2

- **/ds/detector/ds20lsv_diameter xxx**
type: optional
default: 736.6 cm
description: define the LSV radius

units: cm m

- **/ds/detector/ds20cryo_thickness xxx**
  type: optional
  default: 1 cm
  description: set the thickness of the minimal cryostat
  units: mm cm

- **/ds/detector/ds20cryo_material xxx**
  type: optional
  default: 0
  description: set the material for the minimal cryostat
  candidates: 0, steel ; 1, titanium ; 2, copper

- **/ds/detector/ds20cryo_distance xxx**
  type: optional
  default: 5 cm
  description: set the distance between the cryostat and the TPC corner
  units: mm cm

8 Physics

- **/ds/physics/hadronic_list xxx**
  type: optional
  default: Shielding
  description: define the hadronic physics list
  candidates: none HP Shielding QGSP_BERT_HP QSGP_BIC_HP FTF_BIC_HP FTFP_BERT_HP

- **/ds/physics/em_list xxx**
  type: optional
  default: livermore
  description: define the electromagnetic physics list
  candidates: standard livermore

- **/ds/physics/optics xxx**
  type: optional
  default: 1
  description: 1 corresponds to the NEST scintillation model; 2 to the DSLight model, still based on the merging of Thomas-Imel and Doke-Birks; 3 to the model based on the effective recombination probability extracted from DS10 data

- **/ds/physics/LSoptics xxx**
  type: optional
  default: 2
  description: 1 corresponds to the quenching model using EMSaturation ; 2 to the quenching model using SRIM or analytical (Bethe-like) formula, validated in Borexino;

- **/ds/physics/tuned200V xxx**
  type: optional
  default: true
  description: use the calibrated recombination probability at 200 V/cm. If drift field is specified (/ds/physics/DriftField xxx), the tuned S1 option is switched automatically to false, and the old calibrations are used.

- **/ds/physics/cherenkov xxx**
  type: optional
  default: false
  description: activate the cherenkov process

- **/ds/physics/killS1S2 xxx**
  type: optional
  default: false
  description: kill S1 and S2 light pulses, after storing the equivalent energies

- **/ds/physics/killS2 xxx**
  type: optional
  default: false
  description: kill S2 light

- **/ds/physics/scaleS2 xxx**
  type: optional
  default: 1

description: scale S2 light by factor xxx

- **/ds/physics/DriftField xxx**
type: optional
default: 0 V/cm
description: set the drift field to xxx.
units: V/cm kV/cm

- **/ds/physics/ExtractionField xxx**
type: optional
default: 0 kV/cm
description: set the extraction field to xxx.
units: V/cm kV/cm

- **/ds/physics/HPRangeCuts xxx**
type: optional
default: true
description: by default, the range cuts are set to 1 mm in all the volumes but the active LAr, where they are set to 1 μm instead. If xxx = false, the 1 mm range cuts are extended also to the active LAr.

- **/ds/physics/DepositCuts xxx**
type: optional
default: false
description: to use with DSGeneratorEnergyDeposit; it sets the physics cut to 10 cm

9 Generators

- G4Gun: is the most general and flexible generator; it provies the ability to shoot single particles (e-, gamma, alpha, etc.) in pointlike positions or with spatial distributions; moreover, you can generate energy distributions;

- Multi: is similar to G4Gun, with the possibility to create a "multi" event (more particles in the same vertex), specifying the pdg code, energy and probability for each particle;

- RDM: radioactive decay module generates single isotope decay, exploiting the ENSDF tables;

- CosmicRayMuons: generate cosmic muons from measured distributions;

- NeutronsAtGS: generate neutrons from the rock from measured distributions;

- SCS: it allows generating special cross sections. So far, just the ^{39}Ar cross section from literature is implemented.

- AmBeSource: generates neutrons and gammas from AmBe decay.

- Licorne: neutron beam.

- HEPevt: read events in the HEPEVT format generated with an external program (p.e. *Marley*).

- **/ds/generator/select xxx**
type: optional mandatory
default:
description:
candidates: G4Gun, CosmicRayMuons, NeutronsAtGS, MultiEvent, RDM, SCS, AmBeSource, HEPevt.

9.1 General commands

- **/ds/generator/particle xxx**
type: mandatory with G4Gun
default: no default
description: define the particle type. Select Ar40 to generate Nuclear Recoils.
candidates: e-, e+, mu-, mu+, gamma, Ar40, etc.

- **/ds/generator/position xxx**
type: optional
default: no default
description: define the particle three vector position (with unit)
units: mm, cm, m

- **/ds/generator/direction xxx**
type: optional
default: no default
description: define the particle direction; to be used only with G4Gun position

- **/ds/generator/energy xxx**
  type: mandatory with G4Gun
  default: no default
  description: define the particle energy (with unit)
  units: eV, keV, MeV, GeV

- **/ds/generator/numberofparticles xxx**
  type: optional
  default:1
  description: define the number of particles to be generated in the same position with random direction. Currently working only with G4Gun.

- **/ds/generator/sphere_radius xxx**
  type: optional
  default: no default
  description: activate and set the radius of a spherical isotropic distribution centered on (0,0,0)
  units: mm cm m

- **/ds/generator/sphere_radius_min xxx**
  type: optional
  default: no default
  description: set the minimum radius of the spherical distribution defined by /ds/generator/g4gun/sphere_radius
  units: mm cm m

- **/ds/generator/surface_radius xxx**
  type: optional
  default: no default
  description: activate and set the radius of spherical surface isotropic distribution
  units: mm cm m

- **/ds/generator/set_center xxx**
  type: optional
  default: (0,0,0)
  description: shift the center of the spherical distributions
  units: nm um mm cm m

- **/ds/generator/postype xxx**
  type: optional
  description: set the position distribution type
  candidates: Point Plane Surface Volume

- **/ds/generator/posshape xxx**
  type: optional
  description: set the position distribution shape
  candidates: Square Circle Ellipse Rectangle Sphere Ellipsoid Cylinder Parallelepiped

- **/ds/generator/sethalfX xxx**
  type: optional
  description: set half X
  units: mm cm m

- **/ds/generator/sethalfY xxx**
  type: optional
  description: set half Y
  units: mm cm m

- **/ds/generator/sethalfZ xxx**
  type: optional
  description: set half Z
  units: mm cm m

- **/ds/generator/setradius xxx**
  type: optional
  description: set max radius
  units: mm cm m

- **/ds/generator/setradius0 xxx**
  type: optional
  description: set min radius
  units: mm cm m

- **/ds/generator/tpcdistribution xxx**
  type: optional
  description: automatically define a uniform spatial distribution in the TPC
  units: boolean

- **/ds/generator/gaspocketdistribution xxx**
type: optional
description: automatically define a uniform spatial distribution in the Gas Pocket
units: boolean

- **/ds/generator/tpccenter xxx**
type: optional
description: set the particle position or the the center of a spatial distribution in the center of theTPC
units: boolean

- **/ds/generator/dist_energy xxx**
type: optional
default: is off
description: set the energy distribution; candidates are: Lin (linear), Pow (power-law), Exp (exponential), Gauss (gaussian), Brem (bremsstrahlung), BBody (black-body), Cdg (cosmic diffuse gamma-ray)
candidates = Lin Pow Exp Gauss Brem BBody Cdg

- **/ds/generator/emin xxx**
type: optional
default: 0 MeV
description: set the minimum energy in the distribution
candidate units: eV keV MeV GeV

- **/ds/generator/emax xxx**
type: optional
default: 0 MeV
description: set the maximum energy in the distribution
candidate units: eV keV MeV GeV

- **/ds/generator/alpha xxx**
type: optional
default: no default
description: set alpha for a power-law distribution

- **/ds/generator/temp xxx**
type: optional
default: no default
description: set temperature for a Brem or BBody distributions (in kelvin)

- **/ds/generator/ezero xxx**
type: optional
default: 0 MeV
description: set Ezero for an exponential distribution
candidate units: eV keV MeV GeV

- **/ds/generator/gradient xxx**
type: optional
description: set gradient for a linear distribution

- **/ds/generator/intercept xxx**
type: optional
description: set intercept for a linear distribution

- **/ds/generator/confine xxx**
type: optional
default: no default
description: generates only inside a defined volume. The final distribution is an intersection between the spatial generator and the volume defined.
options: not yet implemented

- **/ds/generator/energyfile xxx**
type: optional
default: no default
description: reads a user defined file (xxx), formatted with 2 columns: the kinetic energy in keV and the number of events. It generates particles with random kinetic energy taken from the so-defined distribution.

  Files for neutron background from TALYS are already present in the data folder. To run neutron background simulations for individual material and decay chain use the following commands:

  - /ds/generator/energyfile
    ../data/physics/U238BoroSilicate.dat

- /ds/generator/energyfile ../data/physics/Th232Teflon.dat
- /ds/generator/energyfile ../data/physics/Th232StainlessSteel.dat
- /ds/generator/energyfile ../data/physics/Th232FusedSilica.dat
- /ds/generator/energyfile ../data/physics/Th232BoroSilicate.dat
- /ds/generator/energyfile ../data/physics/U238U235Th232StainlessSteel.dat
- /ds/generator/energyfile ../data/physics/U238Teflon.dat
- /ds/generator/energyfile ../data/physics/U238StainlessSteel.dat
- /ds/generator/energyfile ../data/physics/U238FusedSilica.dat

- **/ds/generator/holderSource_on xxx**
type: optional
description: events are simulated randomly inside the source placed in the source holder. The source holder constructor is not automatically activated: to construct it use one of the three holder position commands.

- **/ds/generator/bgd_cryostats xxx**
type: optional
description: events are simulated with random direction and random position inside the stainless steel of the two cryostats

- **/ds/generator/is_G2_cryostat xxx**
type: optional
description: to be used in association with the previous command. If xxx = true, the background is simulated in the G2 cryostats rather than in the DS50 ones. Beware, this command does not automatically set the G2 detector configuration (configuration 7: G2 + NV + WT): the user has to set it.

- **/ds/generator/bgd_teflon xxx**
type: optional
description: events are simulated with random direction and random position inside the teflon present in the TPC

- **/ds/generator/bgd_fused_silica xxx**
type: optional
description: events are simulated with random direction and random position inside the fused silica of TPC cathode window and of diving bell

- **/ds/generator/bgd_pmt_photocathode xxx**
type: optional
description: events are simulated with random direction and random position inside the glass window of the pmts in the TPC

- **/ds/generator/liquidargon xxx**
type: optional
description: events are simulated randomly inside the liquid argon volume

- **/ds/generator/bgd_cryostats xxx**
type: optional
description: events are simulated randomly inside the cryostats

- **/ds/generator/bgd_sipm xxx**
type: optional
description: events are simulated randomly inside the SiPMs

- **/ds/generator/bgd_pmt_stem xxx**
type: optional
description: events are simulated randomly inside the PMT stems

- **/ds/generator/bgd_rings xxx**
type: optional
description: events are simulated randomly inside the rings

- **/ds/generator/bgd_grid xxx**
type: optional
description: events are simulated randomly inside the grid

- **/ds/generator/liquidscintillator xxx**
type: optional
description: events are simulated randomly inside the liquid scintillator veto volume

9.2 G4Gun

- **/ds/generator/g4gun/ion xxx**
  type: optional
  default: no default
  Set properties of ion to be generated. [usage] /ds/generator/g4gun/ion Z A Q E

  - Z:(int) AtomicNumber
  - A:(int) AtomicMass
  - Q:(int) Charge of Ion (in unit of e)
  - E:(double) Excitation energy (in keV)

- **/ds/generator/g4gun/ionL xxx**
  type: optional
  default: no default
  Set properties of ion to be generated. [usage] /ds/generator/g4gun/ionL Z A Q I

  - Z:(int) AtomicNumber
  - A:(int) AtomicMass
  - Q:(int) Charge of Ion (in unit of e)
  - I:(int) Level number of metastable state (0 = ground)

9.3 RDM

The Radioactive Decay Module is the geant4 internal radiaoctive decay generator. It exploits the ENSDF tables. It can generate only a single isotope per time.
It is mandatory to use with this generator the correspondent stacking actions **/ds/stack/select RDM** or, **/ds/stack/select RDMChain**, if you want to generate a decay chain segment starting from the source isotope.

- **ds/generator/rdm/ion xxx**
  type: mandatory
  default: no default
  description: set the ion A, Z and energy in keV (e. g. for C14 at rest: /ds/generator/rdm/ion 14 6 0)

9.4 CosmicRayMuons

- **/ds/generator/cosmicray/height xxx**
  type: optional
  default: 8.1 m
  description: Set the z position of the muon shower

- **/ds/generator/cosmicray/radius xxx**
  type: optional
  default: 8 m
  description: Set the radius of the muon shower

- **/ds/generator/cosmicray/depth xxx**
  type: optional
  default: 3700 m
  description: Set the depth of the Laboratory
  candidates: Depths between 1 and 10 km

- **/ds/generator/cosmicray/index xxx**
  type: optional
  default: 3.7
  description: Set the spectral index of muons
  candidates: 2.0 = Exotic sources, 2.7 = Prompt sources (e.g. charm decay), 3.7 = Standard spectrum

- **/ds/generator/cosmicray/energyLow xxx**
  type: optional
  default: 1GeV
  description: Set the lower edge of the energy spectrum
  candidates: Energies between 100 MeV and 10 GeV

- **/ds/generator/cosmicray/energyUp xxx**
  type: optional
  default: 10 TeV
  description: Set the upper edge of the energy spectrum
  candidates: Energies between 100 GeV and 50 TeV

- **/ds/generator/cosmicray/filename xxx**
  type: optional
  default: zenith_azimuth.dat

description: Name of the file containing the angular spectrum
candidates: File in the format cosθ, ϕ, pdf, evenly spaced in cosθ, located in the DSDATA directory

9.5 NeutronsAtGS

- **/ds/generator/neutrons/height xxx**
  type: optional
  default: 15.1 m
  description: Set the z position of the neutron shower

- **/ds/generator/neutrons/radius xxx**
  type: optional
  default: 15 m
  description: Set the radius of the neutron shower

- **/ds/generator/neutrons/direction xxx**
  type: optional
  default: roof
  description: Set the position of the neutron shower
  candidates: roof, walls, floor

- **/ds/generator/neutrons/fission xxx**
  type: optional
  default: false
  description: Set the fission and (α, n) neutron generation (TRUE) or the cosmogenic neutron generation (FALSE)
  candidates: TRUE, FALSE

9.6 MultiEvent

Similar to G4Gun, allows to simulate several complex vertexes, each one with several particles. There is no limit to the number of vertexes you intend to simulate, and to the number of particles in the same vertex. You have to specify the absolute weight of each vertex and the branching ratio of each particle within the same vertex. The direction of the particle is generated randomly.

- **/ds/generator/multi/event x1 x2 x3 x4 x5**
  type: mandatory
  default: no default
  description: specify the particle counter ID of the vertex (x1) starting from 1, weight of the vertex (x2), pdg code (x3), energy in MeV (x4) and branching ratio (x5); repeat this command for each particle you want to generate in the same vertex. For example, in Co57, for 89% of the cases there is a cascade of 2 gammas with 122 and 14 keV and for 11% of the cases there is a single gamma of 136 keV. Then you can write:
  /ds/generator/multi/event 1 0.89 22 0.122 1.
  /ds/generator/multi/event 1 0.89 22 0.014 1.
  /ds/generator/multi/event 2 0.11 22 0.136 1.

  For Ce139, a gamma of 166 keV is associated in 11% of the cases to a X-ray of 34 keV. Then:
  /ds/generator/multi/event 1 1 22 0.166 1.
  /ds/generator/multi/event 1 1 22 0.034 0.11

9.7 SCS

This generator allows the simulation of special cross sections, in addition to the ones already available in Geant4 and achievable through the RDM. For the moment, only the ^{39}Ar spectrum from literature is implemented.

- **/ds/generator/scs/isotope xxx**
  type: mandatory for this generator
  default: no default
  description: select the special cross section.
  candidates: Ar39

- **/ds/generator/scs/emin xxx**
  type: optional
  default: 0 MeV
  description: set the minimum energy in the distribution
  candidate units: eV keV MeV GeV

- **/ds/generator/scs/emax xxx**
  type: optional
  default: 0 MeV
  description: set the maximum energy in the distribution

candidate units: eV keV MeV GeV

9.8 AmBeSource

This generator produces neutrons and gammas from AmBe decay. It allows the user to simulate the full decay spectrum, or to generate a specific decay chain (either a lone neutron, a neutron with 1 gamma or a neutron with 2 gammas). See the macro ambe.mac for the list of commands.

- **/ds/generator/AmBe/source xxx**
  type: mandatory for this generator
  default: no default
  description: select the decay scheme
  candidates: all, neutron0G, neutron1G, neutron2G

- **/ds/generator/AmBe/disable xxx**
  type: optional
  default: no default
  description: allows to disable n or gammas. This is useful if you only want to study energy depositions of neutrons without contamination by the gammas (which are simulated in the same event). This option was used in collimator studies with AmBe, in which the collimation of neutrons was studied (Aug. 2014).
  candidates: n, gamma

9.9 HEPevt

This generator reads events from a text file in the HEP-EVT format, produced with an external program (p.e. *Marley*).

- **/ds/generator/hepevt/filename xxx**
  type: optional
  default: events.hepevt
  description: select the text file with the events information. The HEPEVT format is as follows:

```
For each event:
  int    nevhep - event number
  int    nhep   - number of entries in this event record

For each particle (j) in the event:
  int    isthep(j)    - status code
                          0 - null
                          1 - final state particle
                          2 - intermediate state
                          3 - documentation line
  int    idhep(j)     - particle ID, P.D.G. standard
  int    jmohep(0,j) - position of mother particle in list
  int    jmohep(1,j) - position of second mother particle in list
  int    jdahep(0,j) - position of first daughter in list
  int    jdahep(1,j) - position of last daughter in list
  double phep(0,j)   - x momentum in GeV/c
  double phep(1,j)   - y momentum in GeV/c
  double phep(2,j)   - z momentum in GeV/c
  double phep(3,j)   - energy in GeV
  double phep(4,j)   - mass in GeV/c**2
  double vhep(0,j)   - x vertex position in mm
  double vhep(1,j)   - y vertex position in mm
  double vhep(2,j)   - z vertex position in mm
  double vhep(3,j)   - production time in mm/c
```

10 Stacking Manager

The Stacking Action introduces a pre-selection of generated photons before their tracking. It is extremely useful if you need to speed up the simulation. Obviously, invoking the stack requires a large use of RAM memory. Each StackingAction has been thought for a proper kind of simulation.

- **/ds/stack/select xxx**
  type: optional
  default: no stacking action
  candidates: RDM RDMChain

10.1 RDM

- **/ds/stack/rdm/kill xxx**
  type: optional
  description: kill particles by selecting the PDG code. It can be useful if you want to study, e. g. only gammas in a beta + gammas decay. This command must be repeated for each particle type you want to kill.

- **/ds/stack/rdm/killLE xxx yyy**
  type: optional
  description: kill low energy particles by selecting the PDG code (xxx) and the energy threshold (yyy) in keV. This command must be repeated for each particle type you want to kill.

10.2 RDMChain

- **/ds/stack/rdmchain/maxlifetime xxx**
  type: optional

default: 1.e30 ms
description: Generate the radioactive chain segment until the isotope with $\tau >$ xxx.
units: ps ns mus ms s

11 Licorne

11.1 Licorne Setup

- **/ds/detector/licorne/distance xxx**
type: optional
default:
description:
units: m cm

- **/ds/detector/licorn/theta xxx**
type: optional
default:
description:
units: degree rad

- **/ds/detector/licorn/theta xxx**
type: optional
default:
description:
units: degree rad

- **/ds/detector/licorne/phi1 xxx**
type: optional
default:
description:
units: degree rad

- **/ds/detector/licorne/phi2 xxx**
type: optional
default:
description:
units: degree rad

- **/ds/detector/licorne/nuclear_energy xxx**
type: optional
default:
description:
units: keV MeV

- **/ds/detector/licorne/neutron_energy xxx**
type: optional
default:
description:
units: keV MeV

11.2 Licorne Generator

- **/ds/generator/licorne/position xxx**
type: optional
default:
description:
units: m cm

- **/ds/generator/licorne/pulse_mode xxx**
type: optional
default: activate the pulse mode run, otherwise it shoots a single neutron each time
description:

- **/ds/generator/licorne/run_time xxx**
type: optional
default: 100 microsecond
description: mandatory in pulse mode or activating the gamma background
units: ns s microsecond

- **/ds/generator/licorne/neutron_rate xxx**
type: optional
default: neutron rate in pulse mode
description:
units: hertz kilohertz

- **/ds/generator/licorne/gamma_neutron_ratio xxx**
type: optional
default: 0
description: fraction of 478 keV gamma's per

emitted neutron

- **/ds/generator/licorne/pulse_period xxx**
  type: optional
  default: 800 ns
  description: time interlapsing between two pulses
  units: ns s microsecond

- **/ds/generator/licorne/pulse_width xxx**
  type: optional
  default: 1.5 ns
  description: pulse time width
  units: ns s microsecond

12 g4rooter variables

When applicable, the variable units are keV, ns or cm.

12.1 Primary particle

- **ev**: event id
- **pdg**: pdg
- **ene0**: initial kinetic energy
- **s1ene**: s1 equivalent energy (number of photons divided by the working function)
- **s2ene**: s1 equivalent energy (number of electrons divided by the working function)
- **veto_visene**: visible energy in the NV.
- **mu_visene**: visible energy in the OV (not yet implemented)
- **tpcene**: true energy deposited in LAr
- **vetoene**: true energy deposited in scintillator.
- **muene**: true energy deposited in water (not yet implemented)
- **x, y, z**: primary vertex position
- **radius**: primary vertex radius
- **px, py, pz**: primary direction
- **bx,by,bz**: coordinates of the center of mass of the light (not yet implemented)
- **npe**: number of detected photoelectrons in the TPC
- **vnpe**: number of detected photoelectrons in the Neutron Veto
- **munpe**: number of detected photoelectrons in the Muon Veto
- **nph**: number of generated photons
- **ndaughters**: number of secondary particles
- **ndeposits**: number of deposits
- **nusers**: number of user variables

12.2 Secondary (daughter) particles

- **Did[ndaughters]**: id
- **Dpdg[ndaughters]**: pdg
- **Dpid[ndaughters]**: father pdg
- **Dprocess[ndaughters]**: creation process number (to be compared with the list printed in the log file)
- **Dtime[ndaughters]**: time w.r.t. the starting time of the primary particle
- **Dene[ndaughters]**: deposited energy
- **Dx, Dy, Dz[ndaughters]**: position
- **Dpx, Dpy, Dpz[ndaughters]**: direction

12.3 Deposits

- **dep_pdg[ndeposits]**: pdg
- **dep_mat[ndeposits]**: material index number of the deposit (the list of the material indexes is written at each simulation in the log file)
- **dep_time[ndeposits]**: time w.r.t. the starting time of the primary particle

- **dep_ene[ndeposits]**: deposited energy
- **dep_step[ndeposits]**: step length
- **dep_x,dep_y, dep_z[ndeposits]**: position
- **dep_r[ndeposits]**: radius

12.4 User defined variables

- **int1[nusers]**:
- **int2[nusers]**:
- **float1[nusers]**:
- **float2[nusers]**:
- **double0[nusers]**:

12.5 TPC photoelectrons

- **pe_time[npe]**: time
- **pe_pmt[npe]**: pmt

12.6 Neutron veto photoelectrons

- **veto_pe_time[vnpe]**: time
- **veto_pe_pmt[vnpe]**: pmt

12.7 Muon veto photoelectrons

- **mu_pe_time[munpe]**: time
- **mu_pe_pmt[munpe]**: pmt

12.8 Photons

- **ph_volume[nph]**: volume id (to be implemented)
- **ph_pid[nph]**: father id
- **ph_wl[nph]**: wavelength
- **ph_x, ph_y, ph_z[nph]**: position
- **ph_time[nph]**: time

13 g4rooter_full additional variables

13.1 Clusters

The clusterization algorithm groups close deposits (within 2 mm in vertical direction and 2 μs in time, no x–y clusterization is applied.

- **nclus**: number of clusters.
- **cl_true_ene[nclus]**: true deposited energy in the cluster.
- **cl_ene[nclus]**: energy of the cluster (accounting for NR quenching -flat 0.25 assumed).
- **cl_nucl[nclus]**: cluster energy due to nuclear recoils (deposits by heavy particles). Assuming the recombination S1 quenching (200 V/cm).
- **cl_elec[nclus]**: cluster energy due to electronic recoils (deposits by gammas or electrons). Assuming the recombination S1 quenching (200 V/cm).
- **cl_npe[nclus]**: Poisson energy to photo–electrons conversion with constant LY of 7.1 pe/keV. Assuming the recombination S1 quenching (200 V/cm).
- **cl_ndep[nclus]**: number of clustered deposits.
- **cl_x, cl_y, cl_z[nclus]**: position (weighted by the deposit energy).
- **cl_t[nclus]**: time of the first deposit in the cluster.

13.2 Data comparison

- **tdrift**: conversion from the z coordinate of the first cluster to a drift time.

Only when the optics is activated:

- **s1_max_frac**: maximum fraction of npe on one PMT
- **f90like**: f90 computed integrating npe over 90 ns and 7 μs. A Gaussian sigma of $0.4\sqrt{\mathrm{npe}}$ is simulated to account for SPE resolution.
- **s1_corr**: npe corrected for tdrift (using the official analysis conversion function).

13.3 Veto Variables

The energy deposited in the veto is directly computed by GEANT4 (veto_visene). If the storing of the deposits, the following variables are also calculated (but using possibly different quenching models):

- **prompt_npeVeto**: number of pe's in a [-10,200] ns window
- **prompt_npeNoise**: to be implemented
- **prompt_timeVeto**: prompt singnal time
- **prompt_zVeto**: prompt singnal z
- **prompt_rVeto**: prompt singnal r
- **late_npeVeto**: number of pe's in a [200 ns, 140 μs] window
- **late_timeVeto**: late singnal time
- **prompt_depMat**: arrays with dimension equal to the number of constructed materials. The array index is the material index (eg 3 is Air, 7 is Acrylic, 8 is TPC UAr, 72 is LAr buffer). Each element of the list is given by the sum of the deposited energy in the index material. The prompt coincidence window is [-200, 200] ns around the time of the first interaction in the TPC.
- **prompt_qdepMat**: as the above, including basic model for quenching.
- **late_depMat**: as prompt, but integrated in the [200 ns, 2 ms] time window
- **late_qdepMat**: as the above, including basic model for quenching.

13.4 Specific for DS20k design studies

- **nphc**: number of Cerenkov photons produced in the water tank.

14 g4rooter_nDS2k additional variables

Capture variables (require writedaughters). These variables are filled when a set of secondaries is produced by process 4131 (nCapture).

- **pdgCap**: Z of the capturing nucleus
- **cap_time**: capture time in ns
- **cap_x,y,z**: capture coordinates
- **cap_gamma_ene**: total energy of the gamma cascade
- **cap_gamma_mult**: number of gammas in the cascade

Energy depositions in all the detector materials. Specific veto variables are not yet implemented.