Tutorial on CEPCSW simulation

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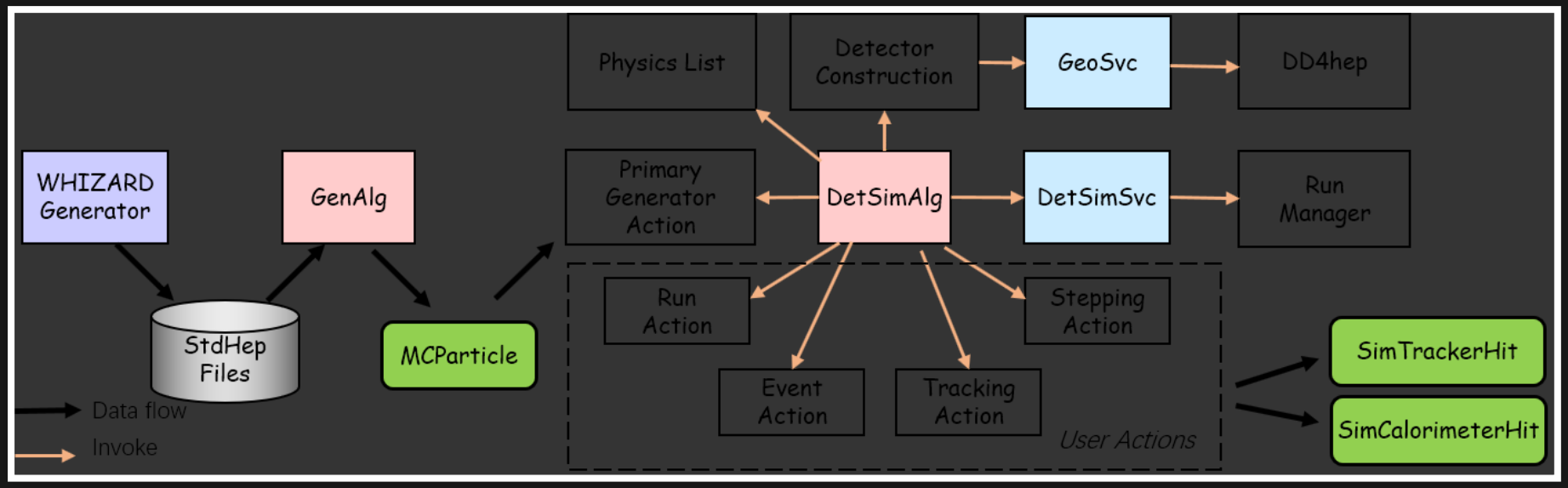
What will learn in this Tutorial?

- As Users
  - Run a simple simulation job in CEPCSW
  - Understand and Customize the simulation
  - Analyze the simulation output
- As Developers
  - Understand the simulation framework
  - Learn basics on Geant4 simulation
  - Simulate with different detector options
- Note: the emoji ✍️ means exercises

CEPCSW Simulation Framework



- The simulation chain is driven by Gaudi.
- Detector description is from DD4hep.
- Event Data Model is in EDM4hep format.
- Detector response is done by Geant4.

Code is on GitHub

- Detector description: See Detector
- Event generator interface: See Generator
- Detector simulation: See Simulation
  - DetSimInterface: Gaudi Tool interface
  - DetSimCore: integrate Gaudi and Geant4
  - DetSimGeom: integrate with DD4hep
  - DetSimAna: collect data from Geant4
  - DetSimSD: detector response
- Job options: See Examples/options

Run simulation in CEPCSW

- The simulation is run by following command:

```
$ ./run.sh Examples/options/tut_detsim.py
```

- The job option: `Examples/options/tut_detsim.py`.
- ✍️ copy the job option into your current directory. Edit your job option in the later exercises.

```
$ cp Examples/options/tut_detsim.py my_detsim.py
```

What's inside the job option?

- Random Number Service
  - Use `Seeds` option to control the random number sequences.
- Event Data Service and PODIO writer
- Geometry Service
  - Different detector options could be loaded here via `compact` option.
- Physics generator algorithm
- Detector simulation algorithm

Save detector response into ROOT file

```
from Configurables import PodioOutput
out = PodioOutput("outputalg")
out.filename = "test-detsim10-seed42.root"
out.outputCommands = ["keep *"]
```

- The EDM4hep format is used in the detector response.
- All the collections created in simulation will be saved.
- ✍️ modify the output file name.

Control how many events to be simulated

```
from Configurables import ApplicationMgr
ApplicationMgr( TopAlg = [genalg, detsimalg, out],
                EvtSel = 'NONE',
                EvtMax = 10,
                ExtSvc = [rndmengine, dsvc, geosvc],
)
```

- ✍️ modify the `EvtMax` property and check the entries in the output.

Random Number

```
from Configurables import RndmGenSvc, HepRndm__Engine_CLHEP__

# rndmengine = HepRndm__Engine_CLHEP__RanluxEngine_() # The d
rndmengine = HepRndm__Engine_CLHEP__HepJamesRandom_() # The d
rndmengine.SetSingleton = True
rndmengine.Seeds = [42]
```

- Seed is used to initialize the state of the random number engine.
- If two job set the same seed, the outputs will be same.
- ✍️ modify the seed and see the difference.

Geometry / Detector Description

```
geometry_option = "CepC_v4-onlyVXD.xml"

geometry_path = os.path.join(os.getenv("DETCEPCV4ROOT"),
                             "compact", geometry_option)

from Configurables import GeoSvc
geosvc = GeoSvc("GeoSvc")
geosvc.compact = geometry_path
```

- The compact file is in XML format, which describes the detector.
- ✍️ change the geometry path and run simulation again.

```
geometry_path = "Detector/DetEcalMatrix/compact/det.xml"
```

Customize primary particles

Particle Gun

```
gun = GtGunTool("GtGunTool")
gun.Particles =  ["pi+", "pi-"]
gun.EnergyMins = [100.,  100]  # GeV
gun.EnergyMaxs = [100.,  100]  # GeV

gun.ThetaMins =  [0,     0]    # deg
gun.ThetaMaxs =  [180.,  180]  # deg

gun.PhiMins =    [0.,    0.]   # deg
gun.PhiMaxs =    [360.,  360.] # deg
```

- Particle name can be found in `$ROOTSYS/etc/pdg_table.txt`
- ✍️ change the particles, energies and directions.

Event Generators

```
stdheprdr = StdHepRdr("StdHepRdr")
stdheprdr.Input = "/cefs/data/stdhep/CEPC250/2fermions/E250.P

genalg = GenAlgo("GenAlgo")
genalg.GenTools = ["StdHepRdr"]
```

- There are several readers to read the output of event generators in different formats
  - StdHep: `StdHepRdr`, lcio: `SLCIORdr`, HepMC: `HepMCRdr`.
- ✍️ use the different readers to load different samples.
- The existing samples could be found here.

Customize Geant4 using built-in commands

✍️ Turn on the verbose during tracking

```
detsimalg.RunCmds = [
    "/tracking/verbose 1",
]
# Or
detsimalg.RunMacs = [
    "run.mac",
]
```

```
# Below is the content of run.mac
/tracking/verbose 1
```

- Each step will be print out. Remeber to redirect the output to a file.

```
$ ./run.sh my_detsim.py >& mylog
```

Geant4 tracking output

```
*********************************************************************************************************
* G4Track Information:   Particle = gamma,   Track ID = 1,   Parent ID = 0
*********************************************************************************************************

Step#     X(mm)     Y(mm)     Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0         0         0         0     1e+05        0        0         0      pWorld initStep
    1 1.03e+03  1.8e+04  1.1e-12         0        0  1.8e+04   1.8e+04      pWorld conv

*********************************************************************************************************
* G4Track Information:   Particle = e+,   Track ID = 4,   Parent ID = 1
*********************************************************************************************************

Step#     X(mm)     Y(mm)     Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0 1.03e+03  1.8e+04  1.1e-12  2.91e+04        0        0         0      pWorld initStep
    1 1.04e+03  1.8e+04 -0.00523  2.91e+04   0.0117     54.9      54.9      pWorld eIoni
    2 1.04e+03 1.81e+04 -0.00912  2.91e+04  0.00604     38.7      93.6      pWorld eIoni
    3 1.06e+03 1.84e+04  -0.0404  2.91e+04   0.0634      321       415      pWorld eIoni
    4 1.06e+03 1.84e+04  -0.0416  2.91e+04  0.00234     13.1       428      pWorld eIoni
```

- From this output, you can see the current track and its stepping information.
- Particle name, current track ID, parent track ID
- Step position, deposit energy

✍️ Visualize using Geant4

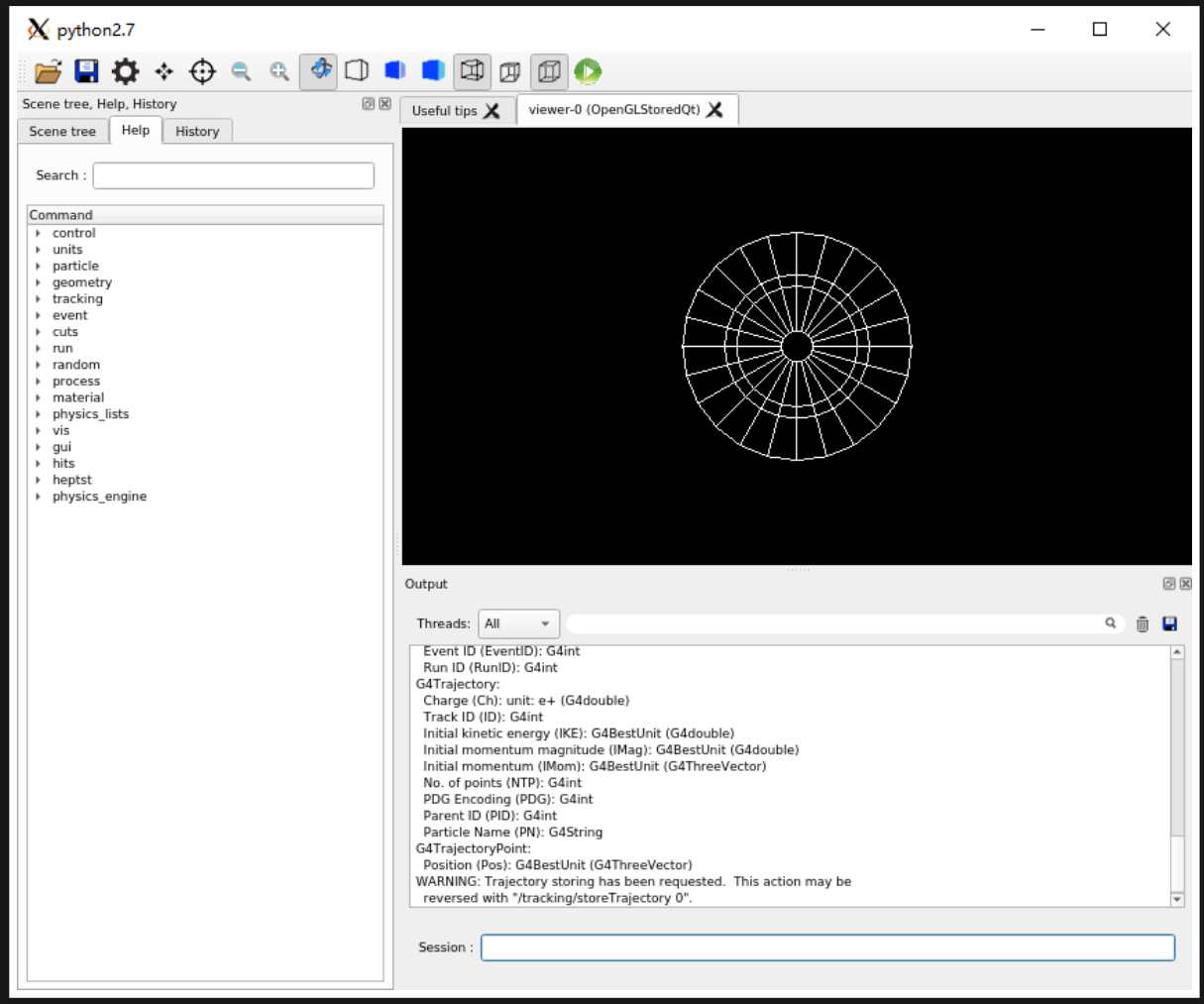
- Enable following command in your job option:

```
detsimalg.VisMacs = ["Examples/options/vis.mac"]
```

- ⚠️ If your X Server supports the G4 OpenGL, the detector will be shown.
  - Try Xming X Server in Windows.
- 📘 Visualization in Geant4 Documentation
  - G4 UI commands during visualization

```
/vis/scene/add/axes 0 0 0 3 m
/vis/scene/add/magneticField
```

Snapshot: The Qt based Geant4 visualization



Play with Geant4 Visualization

Analyze the simulation output

- ✍️ Modify the geometry option and run the simulation

```
geometry_option = "CepC_v4-onlyECAL.xml"
```

- ✍️ Plot the `EcalBarrelCollection` in ROOT

```
root [] events->Draw("EcalBarrelCollection.position.y:EcalBarrelCollection.position.x")
root [] events->Draw("EcalBarrelCollection.position.y:EcalBarrelCollection.position.x", "Entry$==0")
```

See the branches in the events tree

```
root [] events->Print()
*.....................................................................*
*Br  146 :EcalBarrelCollection.cellID :                               *
*         | ULong64_t cellID[EcalBarrelCollection_]                   *
*Entries :       10 : Total  Size=    1398779 bytes  File Size  =     420214 *
*Baskets :        4 : Basket Size=      32000 bytes  Compression=   3.33     *
*.....................................................................*
*Br  147 :EcalBarrelCollection.energy : Float_t energy[EcalBarrelCollection_]*
*Entries :       10 : Total  Size=     699855 bytes  File Size  =     163107 *
*Baskets :        3 : Basket Size=      32000 bytes  Compression=   4.29     *
*.....................................................................*
*Br  148 :EcalBarrelCollection.position.x : Float_t x[EcalBarrelCollection_] *
*Entries :       10 : Total  Size=     699865 bytes  File Size  =     466951 *
*Baskets :        3 : Basket Size=      32000 bytes  Compression=   1.50     *
*.....................................................................*
*Br  149 :EcalBarrelCollection.position.y : Float_t y[EcalBarrelCollection_] *
*Entries :       10 : Total  Size=     699865 bytes  File Size  =     469393 *
*Baskets :        3 : Basket Size=      32000 bytes  Compression=   1.49     *
*.....................................................................*
*Br  150 :EcalBarrelCollection.position.z : Float_t z[EcalBarrelCollection_] *
*Entries :       10 : Total  Size=     699865 bytes  File Size  =     560229 *
*Baskets :        3 : Basket Size=      32000 bytes  Compression=   1.25     *
*.....................................................................*
```

Thank you for your attention

- Create issue: Report a bug
- Pull Request: Fix a bug or Implement a feature

Your contributions are welcome!