Generation of a primary event

XIII Seminar on software for Nuclear, Subnuclear and Applied physics,
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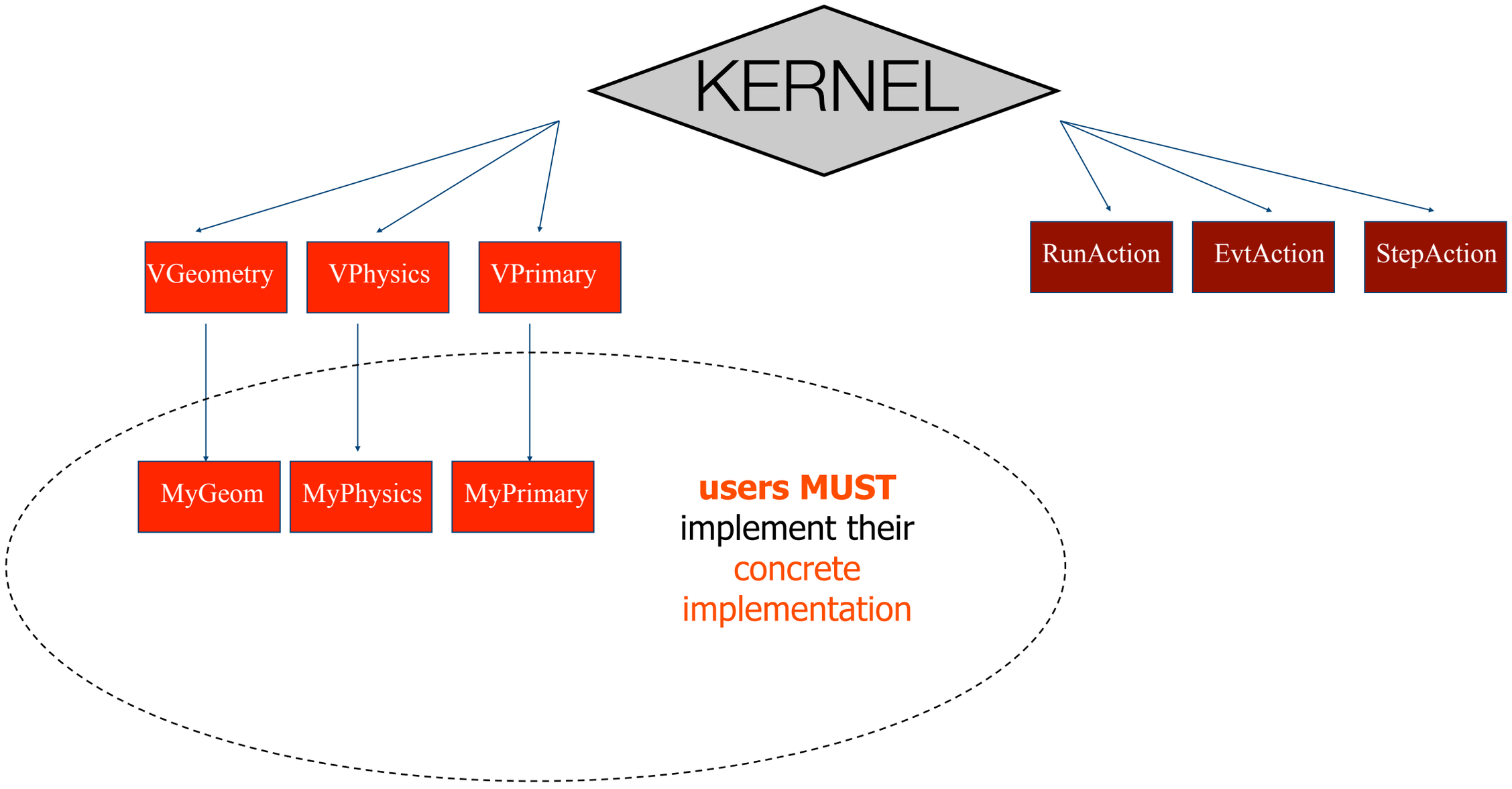
Logical structure of a Geant4 application



The Primary is a mandatory action class

- **The PrimaryGeneratorAction.cc class file is an 'Action' that must be defined**
- **The initialisation classes**

  -Use:
  `G4RunManager::SetUserInitialization()`
  to define;

  - Invoked at the initialisation:
  G4VUserDetectorConstruction
  G4VUserPhysicsList

- **Action classes**

  -`G4RunManager::SetUserAction()` to define;

  -Invoked during an event loop

  ✓G4VUserPrimaryGeneratorAction

  ✓G4UserRunAction

  ✓G4UserStackingAction

  ✓G4UserTrackingAction

  ✓G4UserSteppingAction

G4VUserPrimaryGeneratorAction

- Is one of the mandatory user classes and it controls the generation of primary particles
  - This class does not generate primaries but invokes the `GeneratePrimaryVertex()` method to make the primary
  - It sends the primary particles to the *G4Event* object
- Constructor
  - Instantiate primary generator (i.e. `G4ParticleGun()`)

```
particleGun = new G4ParticleGun(n_particle);
```

  - Set the default values

```
particleGun -> SetParticleEnergy(1.0*GeV);
```

- GeneratePrimaries() is a pure virtual method
  - Randomise particle-by-particle value
  - Set these values to primary generator
  - Invoke GeneratePrimaryVertex() method of primary generator

G4VUserPrimaryGeneratorAction

Where? ⟶ geant4.10.2.p01-install/include/Geant4

```
26 //
27 // $Id: G4VUserPrimaryGeneratorAction.hh,v 1.5 2006/06/29 21:13:38 gunter Exp $
28 // GEANT4 tag $Name: geant4-09-03-patch-02 $
29 //
30
31 #ifndef G4VUserPrimaryGeneratorAction_h
32 #define G4VUserPrimaryGeneratorAction_h 1
33
34 class G4Event;
35
36 // class description:
37 //
38 //  This is the abstract base class of the user's mandatory action class
39 // for primary vertex/particle generation. This class has only one pure
40 // virtual method GeneratePrimaries() which is invoked from G4RunManager
41 // during the event loop.
42 //  Note that this class is NOT intended for generating primary vertex/particle
43 // by itself. This class should
44 //  - have one or more G4VPrimaryGenerator concrete classes such as G4ParticleGun
45 //  - set/change properties of generator(s)
46 //  - pass G4Event object so that the generator(s) can generate primaries.
47 //
48
49 class G4VUserPrimaryGeneratorAction
50 {
51   public:
52     G4VUserPrimaryGeneratorAction();
53     virtual ~G4VUserPrimaryGeneratorAction();
54
55   public:
56     virtual void GeneratePrimaries(G4Event* anEvent) = 0;
57 };
58
59 #endif
```

.... its concrete implementation

Generate primaries

```
void ExN02PrimaryGeneratorAction::GeneratePrimaries(G4Event*
anEvent)
{
  G4double position = -0.5*(myDetector->GetWorldFullLength());
  particleGun->SetParticlePosition(G4ThreeVector(0.*cm,0.*cm,position));

  particleGun->GeneratePrimaryVertex(anEvent);
}
```

G4VPrimaryGenerator

- Geant4 provides three *G4VPrimaryGenerators concrete class:*

  - G4ParticleGun

  - G4HEPEvtInterface

  - G4GeneralParticleSource

G4ParticleGun()

```
particleGun = new G4ParticleGun ();
```

- Concrete implementation of G4VPrimaryGenerator
- It shoots one primary particle of a certain energy from a certain point at a certain time to a certain direction
- It does not provide any sort of randomizing ⟶ randomization can be achieved by invoking various set methods provided by ***G4ParticleGun**.
  - Various "Set" methods are available (see ../source/event/include/G4ParticleGun.hh) and all of them can be invoked from the **generatePrimaries()** method in your concrete **G4VUserPrimaryGeneratorAction** class.

```
void SetParticleEnergy(G4double aKineticEnergy);
void SetParticleMomentum(G4double aMomentum);
void SetParticlePosition(G4ThreeVector aPosition);
void SetNumberOfParticles(G4int aHistoryNumber);
```

G4ParticleGun()

```
void T01PrimaryGeneratorAction::GeneratePrimaries(G4Event* anEvent)
{ G4ParticleDefinition* particle;
  G4int i = (int)(5.*G4UniformRand());
  switch(i)
  { case 0: particle = positron; break; ... }
  particleGun->SetParticleDefinition(particle);
  G4double pp = momentum+(G4UniformRand()-0.5)*sigmaMomentum;
  G4double mass = particle->GetPDGMass();
  G4double Ekin = sqrt(pp*pp+mass*mass)-mass;
  particleGun->SetParticleEnergy(Ekin);
  G4double angle = (G4UniformRand()-0.5)*sigmaAngle;
  particleGun->SetParticleMomentumDirection
          (G4ThreeVector(sin(angle),0.,cos(angle)));
  particleGun->GeneratePrimaryVertex(anEvent);
}
```

You can repeat this for generating more than one primary particles

G4HEPEvtInterface

- **Unfortunately *a*lmost all event generators in use are written in FORTRAN but Geant4 does not link with any external FORTRAN code**

- **Geant4 provides an ASCII file interface for such event generators**

- **G4HEPEvtInterface reads an ASCII file produced by an Event generator and reproduce the G4PrimaryParticle objects.**

- **In other words, `G4HEPEvtInterface` converts information stored in the `/HEPEVT/` common block to an object-oriented data structure.**

  Because the `/HEPEVT/` common block is commonly used by almost all event generators written in FORTRAN, `G4HEPEvtInterface` can interface to almost all event generators currently used in the HEP community

- **It does not give a place for the primary particle so the interaction point must be still set by the User**

G4GeneralParticleSource()

```
fGenerateParticleSource = new G4GenerateParticleSoure ();
```

- ../source/event/include/G4GeneralParticleSource.hh
- Concrete implementation of G4VPrimaryGenerator

```
class G4GeneralParticleSource : public G4VPrimaryGenerator
```

- Is designed to replace the G4ParticleGun class
- It is designed to allow specification of multiple particle sources each with independent definition of particle type, position, direction and energy distribution
- Primary vertex can be randomly chosen on the surface of a certain volume
- Momentum direction and kinetic energy of the primary particle can also be randomised
- Distribution defined by UI commands

G4GeneralParticleSource()

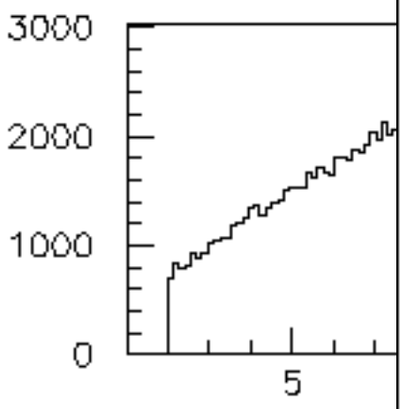
GPS allows the user to control the following characteristics of primary particles:

- **Spatial sampling:** on simple 2D or 3D surfaces such as discs, spheres, and boxes.
- **Angular distribution:** unidirectional, isotropic, cosine-law, beam or arbitrary (user defined).
- **Spectrum:** linear, exponential, power-law, Gaussian, blackbody, or piece-wise fits to data.
- **Multiple sources:** multiple independent sources can be used in the same run.

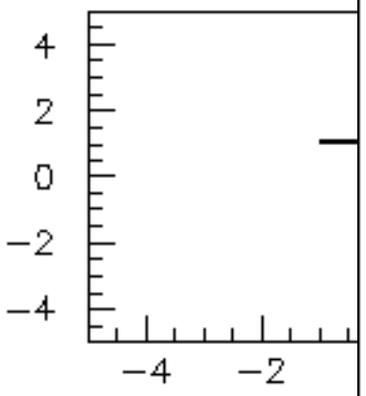
G4GeneralParticleSource

- On line manual: http://reat.space.qinetiq.com/gps/
- /gps main command
  - -/gps/pos/type (planar, point, etc.)
  - -gps/ang/type (iso, planar wave, etc.)
  - -gps/energy/type (monoenergetic, linear, User defined)
  - -.....

Square plane, cosine-law direction, linear energy



Source Ene



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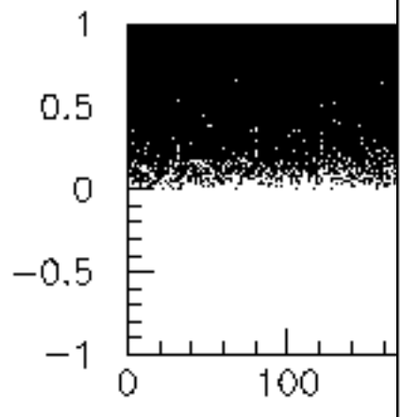
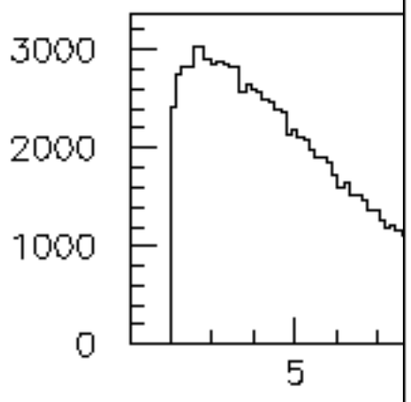


Source cos(thet

Spherical surfa



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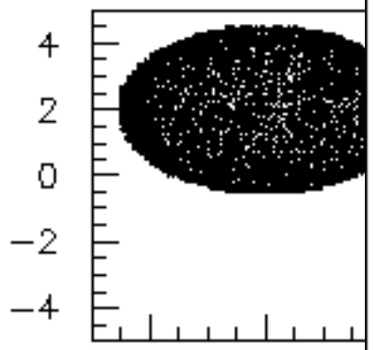

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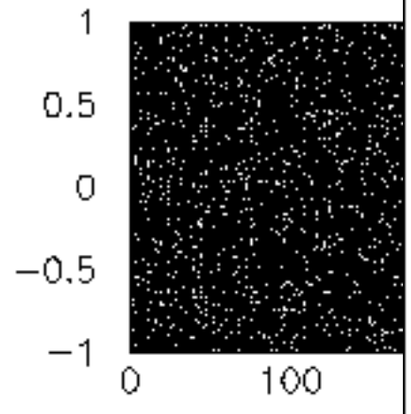
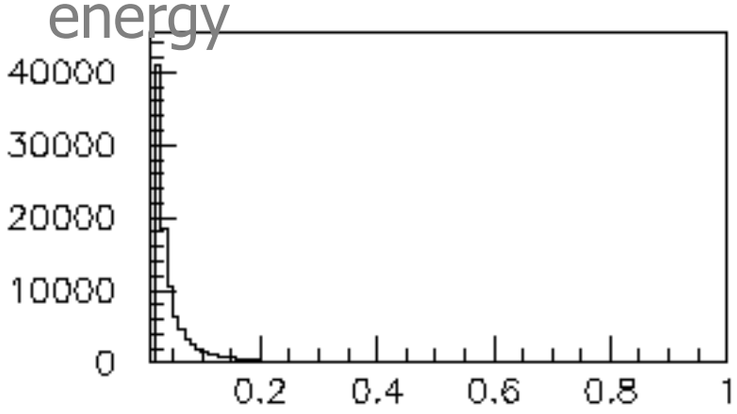
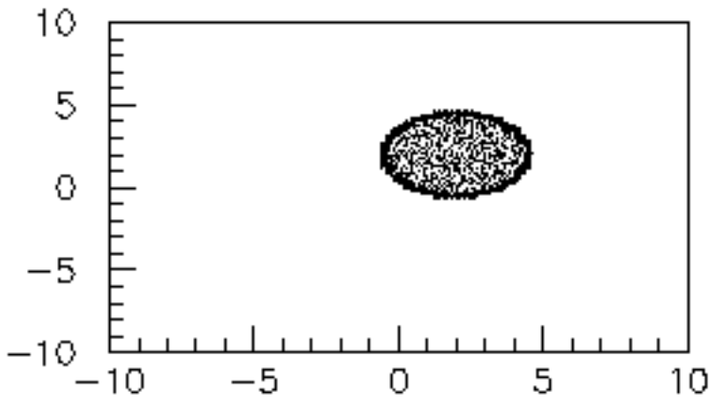


Source cos(thet

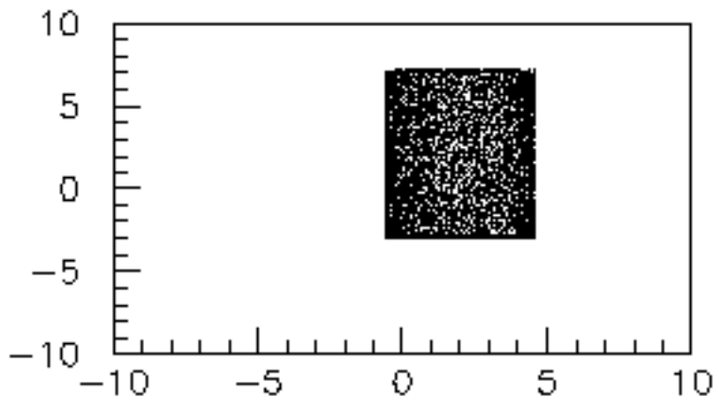
Cylindrical surface, cosine-law radiation, Cosmic diffuse energy



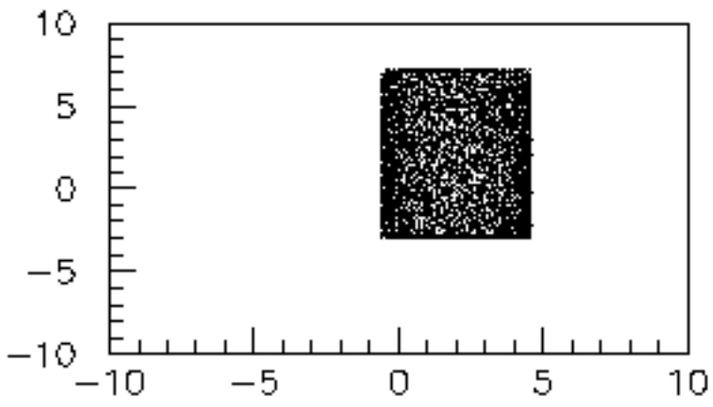
Source Energy Spectrum



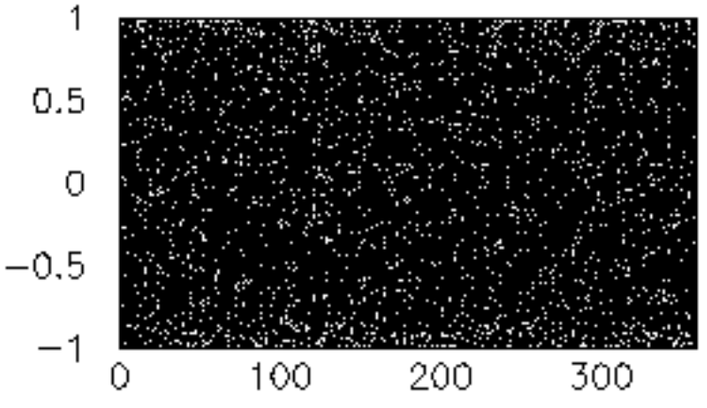
Source X−Y distribution



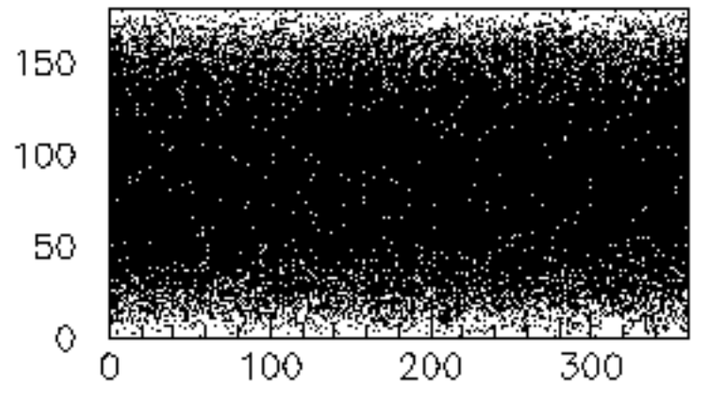
Source X−Z distribution



Source Y−Z distribution



Source cos(theta)−phi distribution



Source theta/phi distribution

Example of gps commands

•Source 1: point-like source, 100 MeV proton, along z

- /gps/pos/type point
- /gps/particle proton
- /gps/energy 100 MeV
- /gps/direction 0 0 1

•Source 2: plane source (2x2 cm), 100 MeV proton, along z

- /gps/pos/type plane
-/gps/pos/shape square
-/gps/pos/centre x y z
-/gps/pos/Halfx
-/gps/pos/Halfy

•Source 3: gaussian-like (sigmax and sigmay = 2cm), 100 MeV proton, along z

-/gps/pos/shape Circle
-/gps/pos/centre x y z
-/gps/pos/sigmax 2 cm

Particle Gun vs GPS

- **Particle Gun**
  - **Simple and native**
  - **Shoot one track at a time**
  - **Easily to handle**
- **General Particle Source**
  - **Powerful**
  - **Controlled by UI commands** `(G4GeneralParticleSourceMessenger.hh)`
    - ✓ Almost impossible to control with set methods
  - **Capability of shooting particles from a surface of a volume**
  - **Capability of randomizing kinetic energy, position, direction following a user-specified distribution (histogram)**

- If you need to shot primary particles from a surface of a complicated volume (outward or inward), GPS is the choice
- If you need a complicated distribution, GPS is the choice

Examples

- **`examples/extended/analysis/A01/src/`**
  A01PrimaryGeneratorAction.cc is a good example to start with

- Examples also exists for GPS
  `examples/extended/eventgenerator/exgps`

- And for HEPEvtInterface
  `example/extended/runAndEvent/RE01/src/RE01PrimaryGeneratorAction.cc`

Thanks for your attention

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