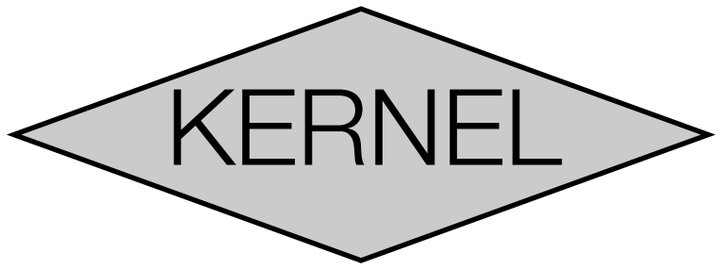
Generation of a primary event

IX Seminar on software for Nuclear, Subnuclear and Applied physics,
May 28 - June 2, 2012 - Porto Conte, Italy

Logical structure of a Geant4 application



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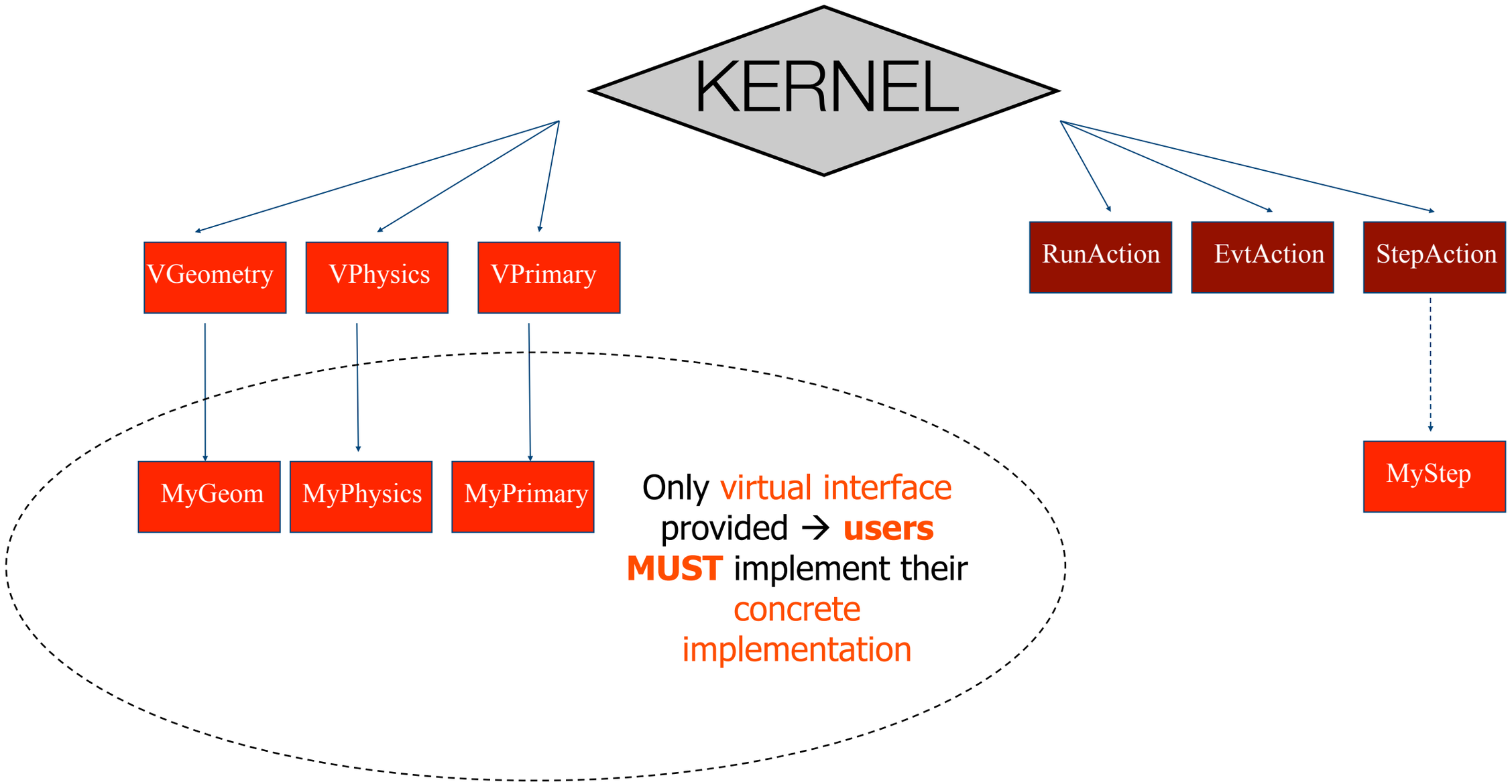

Outline

- Primary vertex and primary particle
- G4VPrimaryGenerator instantiated via the GeneratePrimaryVertex()
  - The particle gun
  - Interfaces to HEPEVT and HEPMC
  - General Particle Source (or GPS)
- Particle gun or GPS?

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()`** method
  - Randomise particle-by-particle value
  - Set these values to primary generator
  - Invoke **`GeneratePrimaryVertex()`** method of primary generator

G4VUserPrimaryGeneratorAction

```
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

```
ExN02PrimaryGeneratorAction::ExN02PrimaryGeneratorAction(
                                ExN02DetectorConstruction* myDC)
:myDetector(myDC)
{
  G4int n_particle = 1;
  particleGun = new G4ParticleGun(n_particle);
// default particle
  G4ParticleTable* particleTable = G4ParticleTable::GetParticleTable();
  G4ParticleDefinition* particle = particleTable->FindParticle("proton");

  particleGun->SetParticleDefinition(particle);
  particleGun->SetParticleMomentumDirection(G4ThreeVector(0.,0.,1.));
  particleGun->SetParticleEnergy(3.0*GeV);
}

ExN02PrimaryGeneratorAction::~ExN02PrimaryGeneratorAction()
{
  delete particleGun;
}
```

Class constructor

Class distruction

.... its concrete implementation

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

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

The unique native method

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G4VPrimaryGenerator

- *G4VPrimaryGenerator* is instantiated via the **GeneratePrimaries(G4Event* aEvent)**

- Geant4 provides three *G4VPrimaryGenerators*
  - G4ParticleGun
  - G4HEPEvtInterface
  - G4GeneralParticleSource

G4ParticleGun()

- Concrete implementation of G4VPrimaryGenerator
  - It can be used for experiment specific primary generator implementation
- It shoots one primary particle of a certain energy from a certain point at a certain time to a certain direction
  - Various "Set" methods are available (see ../source/event/include/G4ParticleGun.hh)

```
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

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G4HEPEvtInterface

- Concrete implementation of ***G4VPrimaryGenerator***
- Almost 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 particular it reads the /HEPEVT/ fortran block used by almost all event generators
- It does not give a place for the primary particle so the interaction point must be still set by the User

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G4GeneralParticleSource()

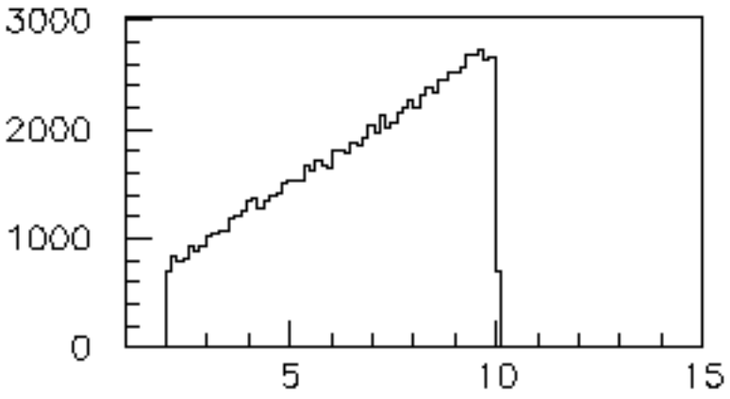
- ../source/event/include/G4GeneralParticleSource.hh
- Concrete implementation of G4VPrimaryGenerator

  `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**

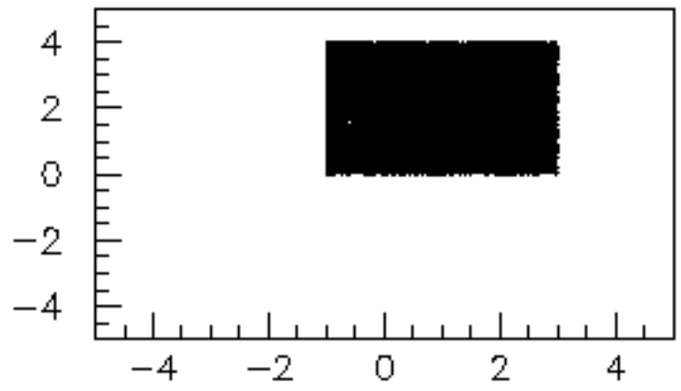
G4GeneralParticleSource

- 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)
  - .....

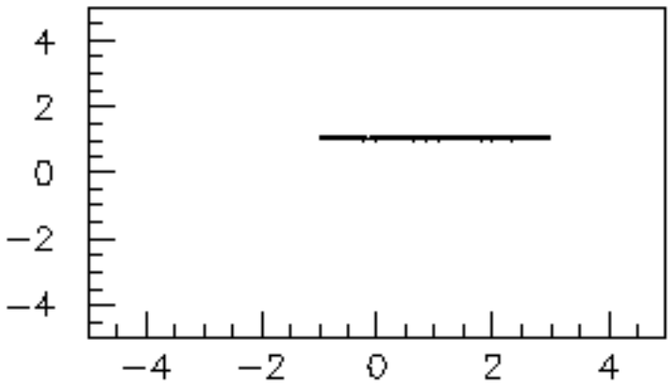
Square plane, cosine-law direction, linear energy



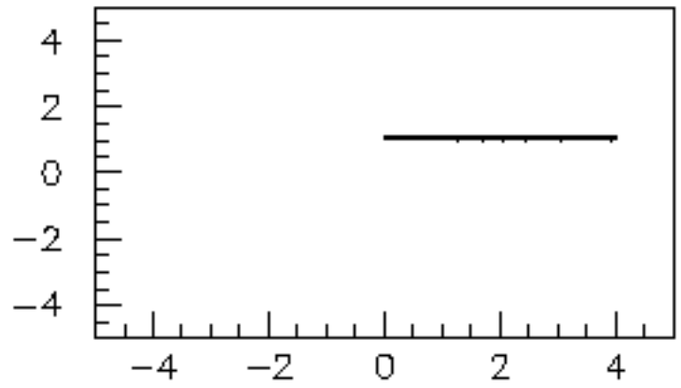
Source Energy Spectrum



Source X−Y distribution



Source X−Z distribution



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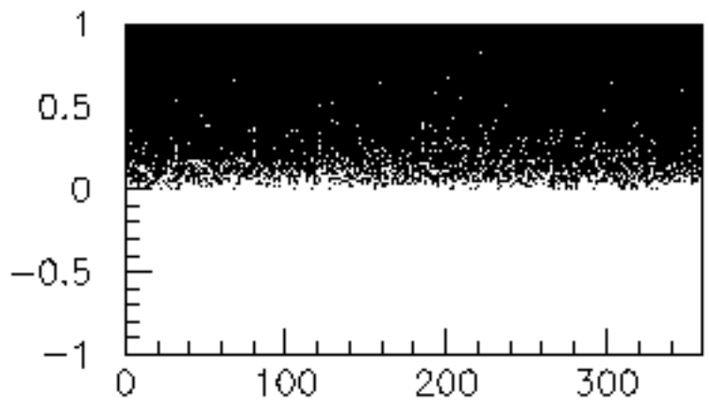
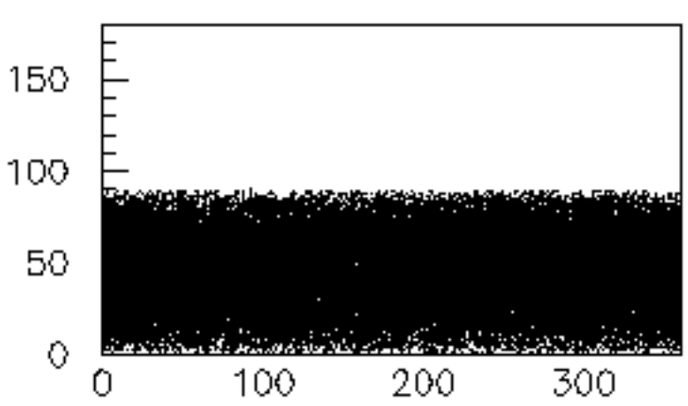
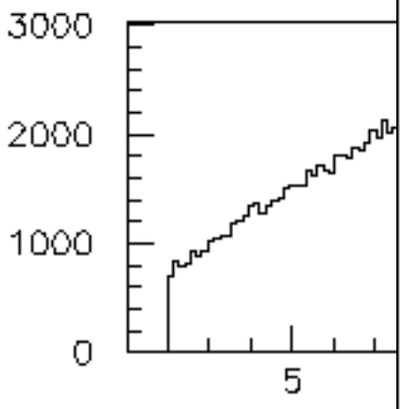


Source cos(theta)−phi distribution



Source theta/phi distribution

Square plane



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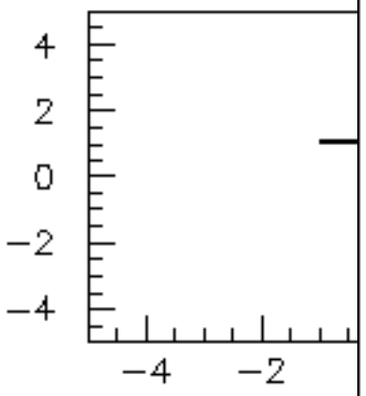
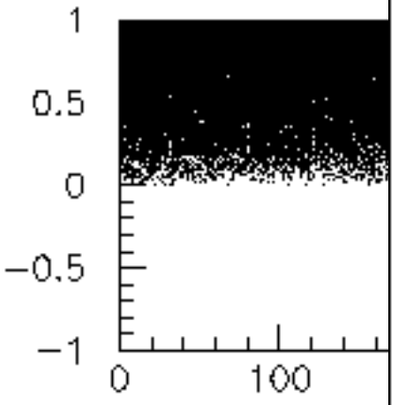
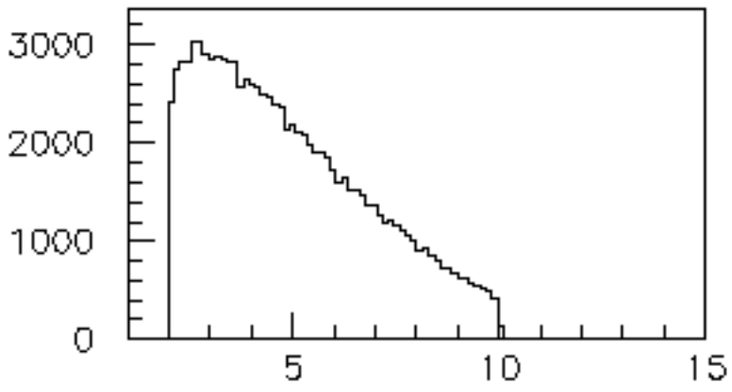


Source X−

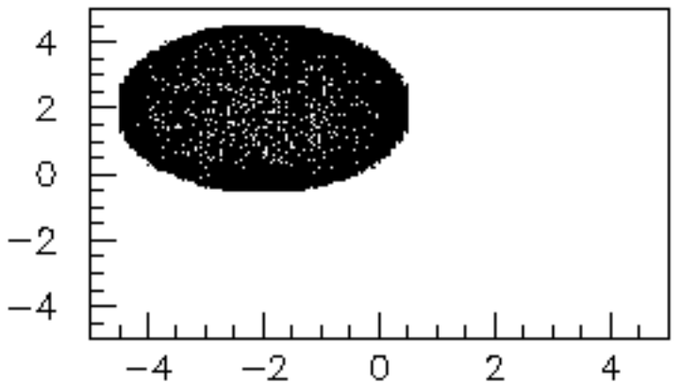


Source cos(thet

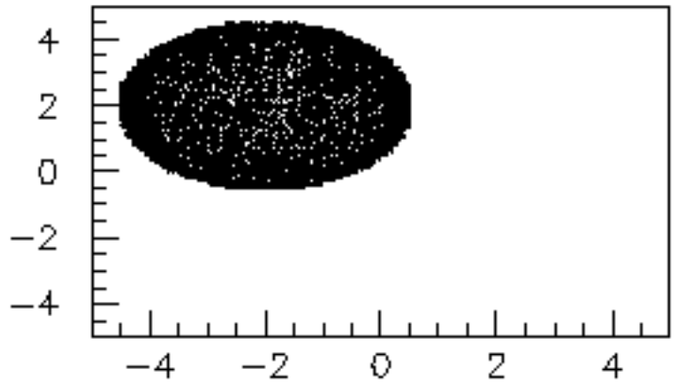
Spherical surface, isotropic radiation, black-body energy



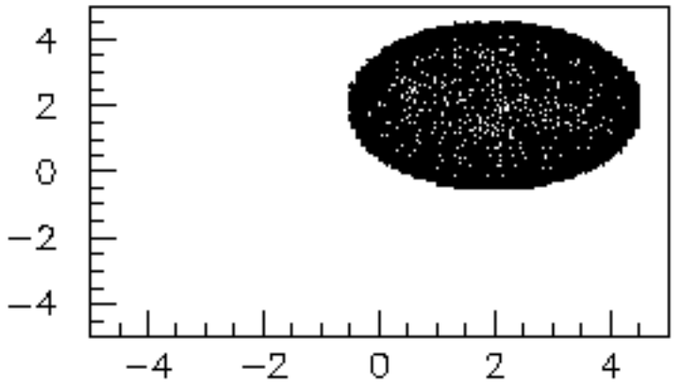
Source Energy Spectrum



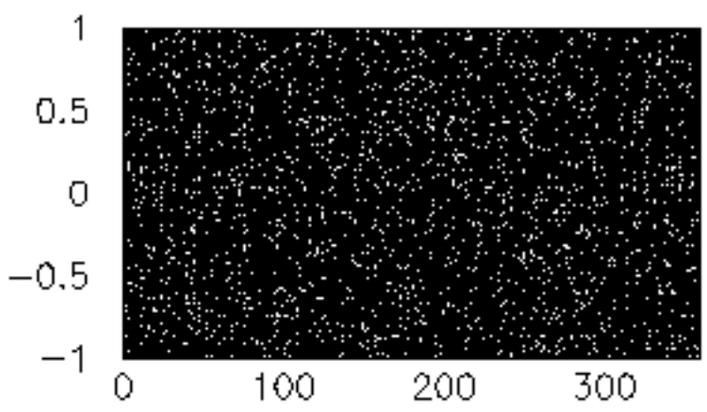
Source X−Y distribution



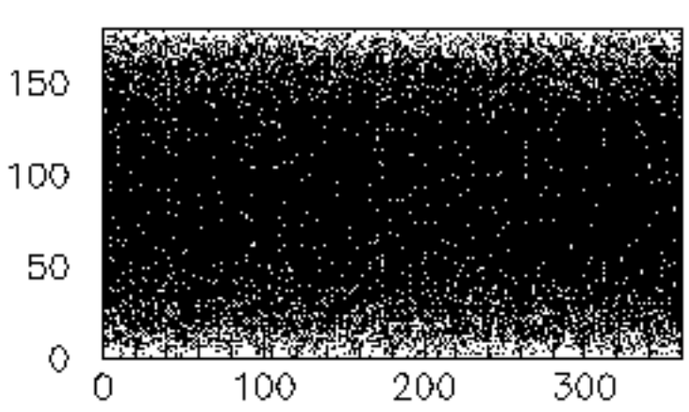
Source X−Z distribution



Source Y−Z distribution

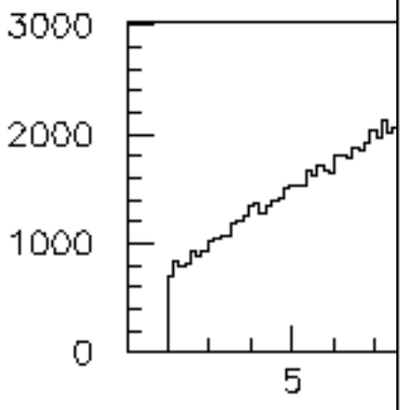


Source cos(theta)−phi distribution



Source theta/phi distribution

Square plane



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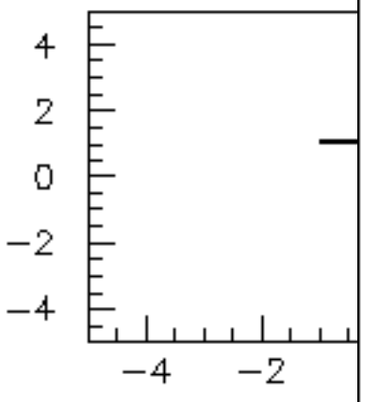
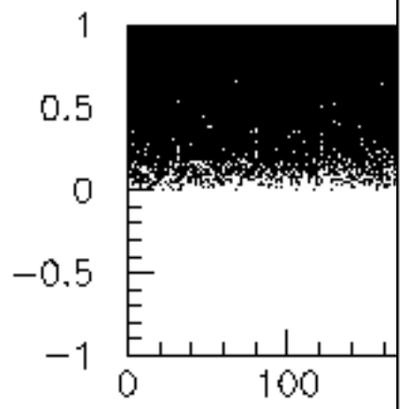
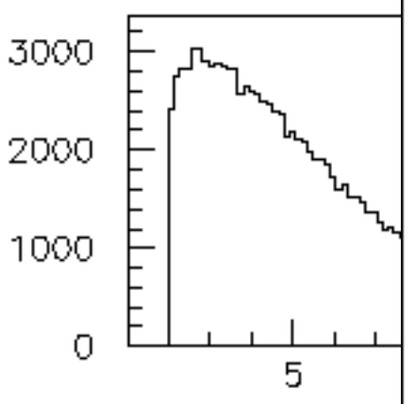


Source X−



Source cos(thet

Spherical surfa



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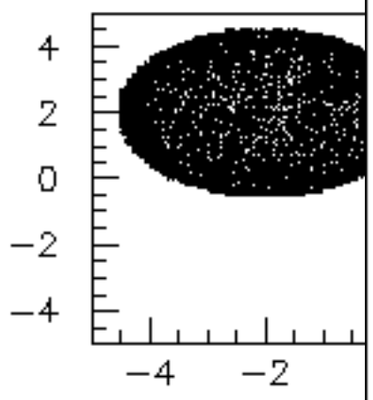
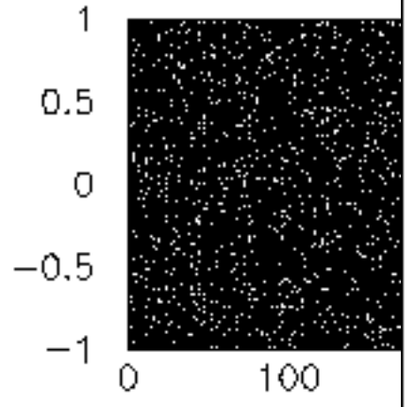
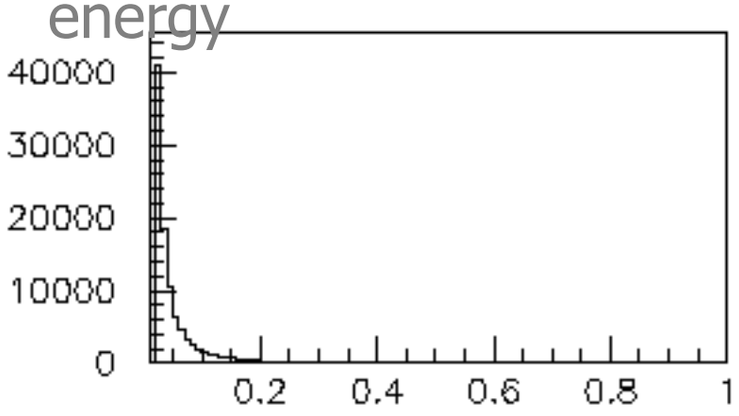


Source X−

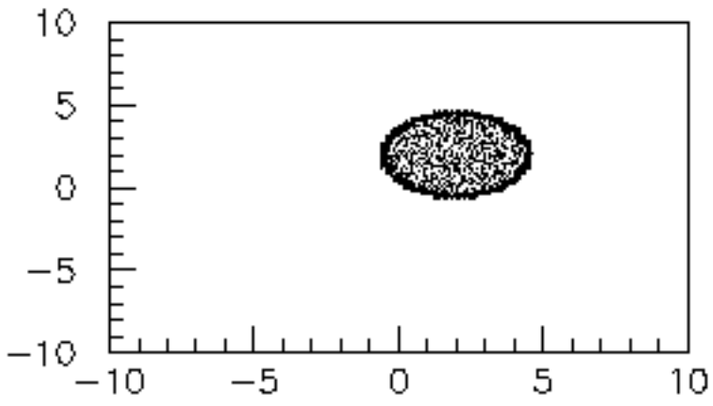


Source cos(thet

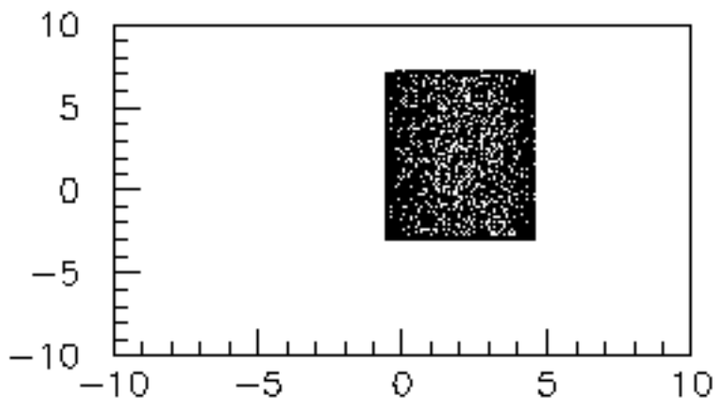
Cylindrical surface, cosine-law radiation, Cosmic diffuse energy



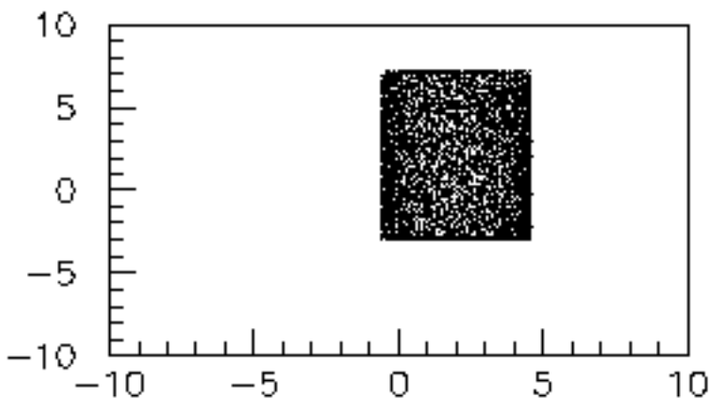
Source Energy Spectrum



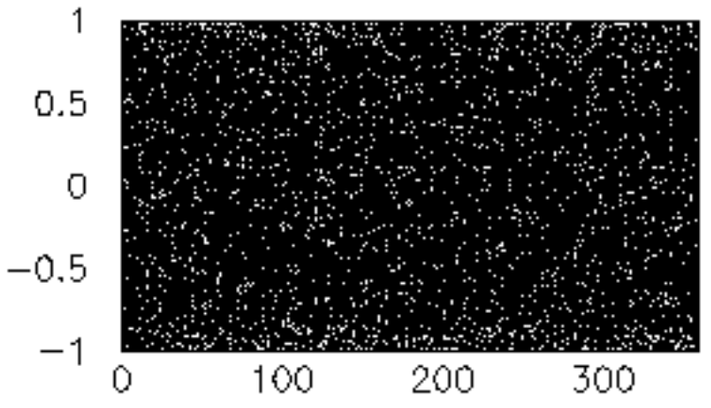
Source X−Y distribution



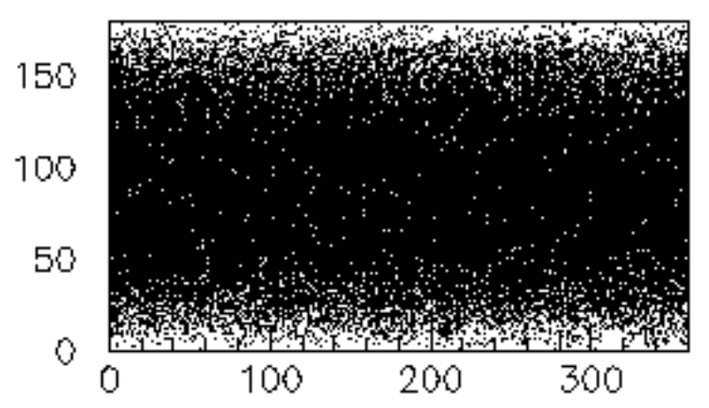
Source X−Z distribution



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
  - As above
- 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
  - /gps/pos/sigmay 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)

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- 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`

A summary: what to do and where to do

- **In the constructor of your UserPrimaryGeneratorAction**
  - Instantiate **G4ParticleGun**
  - Set default values by set methods of G4ParticleGun:
    - ✓ Particle type, kinetic energy, position and direction
- **In your macro file or from your interactive terminal session**
  - Set values for a run
- **In the GeneratePrimaries() method**
  - Shoot random numbers and prepare the values of
    - ✓ Kinetic energy, position, direction ....
  - Use set methods of G4ParticleGun to set such values
  - Then invoke **GeneratePrimaryVertex()** method of G4ParticleGun
  - If you need more than one primary tracks per event loop over randomisation and GeneratePrimaryVertex()