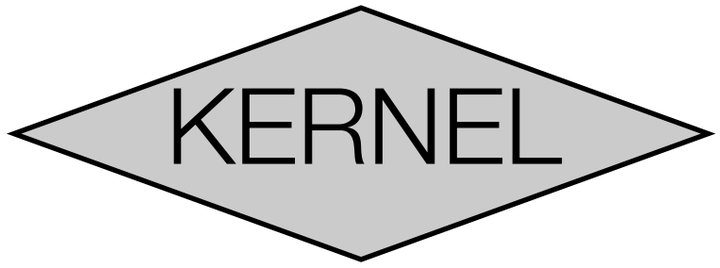
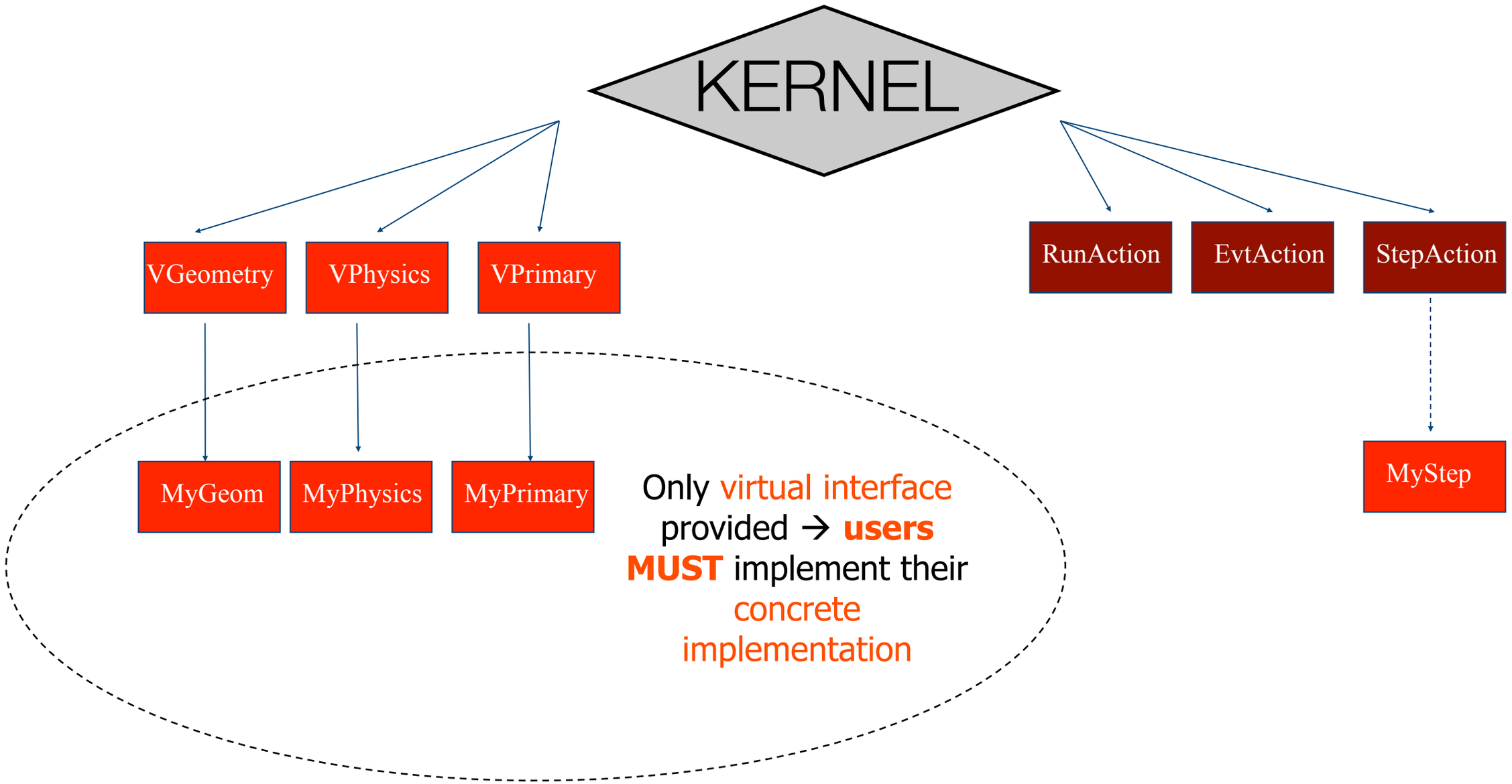
Generation of a primary event

Logical structure of a Geant4 application



Logical structure of a Geant4 application



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

ExG4PrimaryGeneratorAction01.cc

```
#include "ExG4PrimaryGeneratorAction01.hh"

#include "G4Event.hh"
#include "G4ParticleGun.hh"
#include "G4ParticleTable.hh"
#include "G4ParticleDefinition.hh"

//....oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo......
ExG4PrimaryGeneratorAction01::ExG4PrimaryGeneratorAction01(
                              const G4String& particleName,
                              G4double energy,
                              G4ThreeVector position,
                              G4ThreeVector momentumDirection)

{
  G4int nofParticles = 1;
  fParticleGun  = new G4ParticleGun(nofParticles);

  // default particle kinematic
  G4ParticleTable* particleTable = G4ParticleTable::GetParticleTable();
  G4ParticleDefinition* particle
    = particleTable->FindParticle(particleName);
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(energy);
  fParticleGun->SetParticlePosition(position);
  fParticleGun->SetParticleMomentumDirection(momentumDirection);
}

//....oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo......

ExG4PrimaryGeneratorAction01::~ExG4PrimaryGeneratorAction01()
{
  delete fParticleGun;
}

//....oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo......

void ExG4PrimaryGeneratorAction01::GeneratePrimaries(G4Event* anEvent)
{
  // this function is called at the begining of event

  fParticleGun->GeneratePrimaryVertex(anEvent);
}

//....oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo......
```

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

Outline

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- G4VPrimaryGenerator instantiated via the GeneratePrimaryVertex()
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  - Interfaces to HEPEVT and HEPMC
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- Particle gun or GPS?

G4VPrimaryGenerator

- *G4VPrimaryGenerator* is instantiated via the **GeneratePrimaries(G4Event* aEvent)**
  - You can invoke more than one generator and/or invoke one generator more than once
  - The logical steps are: In G4VUserPrimaryGeneratorAction the GeneratePrimaryVertex() is invoked inside the GeneratePrimaries(G4Event* anEvent);
    GeneratePrimaryVertex() is a public method of G4ParticleGun
- Geant4 provides three *G4VPrimaryGenerators*
  - G4ParticleGun
  - G4HEPEvtInterface
  - G4GeneralParticleSource

Selection of the generator

.... its concrete implementation

ExG4PrimaryGeneratorAction01.cc

```
#include "ExG4PrimaryGeneratorAction01.hh"

#include "G4Event.hh"
#include "G4ParticleGun.hh"
#include "G4ParticleTable.hh"
#include "G4ParticleDefinition.hh"

//....oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo......
ExG4PrimaryGeneratorAction01::ExG4PrimaryGeneratorAction01(
                              const G4String& particleName,
                              G4double energy,
                              G4ThreeVector position,
                              G4ThreeVector momentumDirection)

{
  G4int nofParticles = 1;
  fParticleGun  = new G4ParticleGun(nofParticles);

  // default particle kinematic
  G4ParticleTable* particleTable = G4ParticleTable::GetParticleTable();
  G4ParticleDefinition* particle
    = particleTable->FindParticle(particleName);
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(energy);
  fParticleGun->SetParticlePosition(position);
  fParticleGun->SetParticleMomentumDirection(momentumDirection);
}

//....oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo......

ExG4PrimaryGeneratorAction01::~ExG4PrimaryGeneratorAction01()
{
  delete fParticleGun;
}

//....oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo......

void ExG4PrimaryGeneratorAction01::GeneratePrimaries(G4Event* anEvent)
{
  // this function is called at the begining of event

  fParticleGun->GeneratePrimaryVertex(anEvent);
}

//....oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo.......oooOOOOOooo......
```

Class constructor

The needed generator is instatiated here

Class distruction

you have to invoke the *G4VPrimaryGenerator* concrete class you instantiated via the **`GeneratePrimaryVertex()`** method

G4ParticleGun()

- Concrete implementation of G4VPrimaryGenerator
- Is provided by Geant4
- It does not provide any sort of randomisation
- Such randomisation can be achieved by invoking various 'Set' methods provided by G4ParticleGun
  - 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)
- The methods must be invoked inside GeneratePrimaries() of G4VUserPrimarygeneratorActions before invoking GeneratePrimaryVertex()

Public methods of G4ParticleGun

- `void SetParticleDefinition(G4ParticleDefinition*)`
- `void SetParticleMomentum(G4ParticleMomentum)`
- `void SetParticleMomentumDirection(G4ThreeVector)`
- `void SetParticleEnergy(G4double)`
- `void SetParticleTime(G4double)`
- `void SetParticlePosition(G4ThreeVector)`
- `void SetParticlePolarization(G4ThreeVector)`
- `void SetNumberOfParticles(G4int)`

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

Randomisation

- Geant4 provides various random number generator methods with various distributions

- See the Section 3.2 of the manual where the 'Global Usage Classes' are described

3.2.2.1. *HEPRandom* engines

The class *HepRandomEngine* is the abstract class defining the interface for each random engine. It implements the `getSeed()` and `getSeeds()` methods which return the `initial seed' value and the initial array of seeds (if any) respectively. Many concrete random engines can be defined and added to the structure, simply making them inheriting from *HepRandomEngine*. Several different engines are currently implemented in *HepRandom*, we describe here five of them:

- *HepJamesRandom*

  It implements the algorithm described in ``F.James, Comp. Phys. Comm. 60 (1990) 329" for pseudo-random number generation. This is the default random engine for the static generator; it will be invoked by each distribution class unless the user sets a different one.

- *DRand48Engine*

  Random engine using the `drand48()` and `srand48()` system functions from C standard library to implement the `flat()` basic distribution and for setting seeds respectively. *DRand48Engine* uses the `seed48()` function from C standard library to retrieve the current internal status of the generator, which is represented by 3 short values. *DRand48Engine* is the only engine defined in *HEPRandom* which intrinsically works in 32 bits precision. Copies of an object of this kind are not allowed.

- *RandEngine*

  Simple random engine using the `rand()` and `srand()` system functions from the C standard library to implement the `flat()` basic distribution and for setting seeds respectively. Please note that it's well known that the spectral properties of `rand()` leave a great deal to be desired, therefore the usage of this engine is not recommended if a good randomness quality or a long period is required in your code. Copies of an object of this kind are not allowed.

Outline

- Primary vertex and primary particle
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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

G4HEPEvtInterface

```
#include "ExN04PrimaryGeneratorAction.hh"

#include "G4Event.hh"
#include "G4HEPEvtInterface.hh"

ExN04PrimaryGeneratorAction::ExN04PrimaryGeneratorAction()
{
  HEPEvt = new G4HEPEvtInterface("pythia_event.data");
}

ExN04PrimaryGeneratorAction::~ExN04PrimaryGeneratorAction()
{
  delete HEPEvt;
}

void ExN04PrimaryGeneratorAction::GeneratePrimaries(G4Event* anEvent)
{
  HEPEvt->SetParticlePosition(G4ThreeVector(0.*cm,0.*cm,0.*cm));
  HEPEvt->GeneratePrimaryVertex(anEvent);
}
```

Outline

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  - General Particle Source (or GPS)
- Particle gun or GPS?

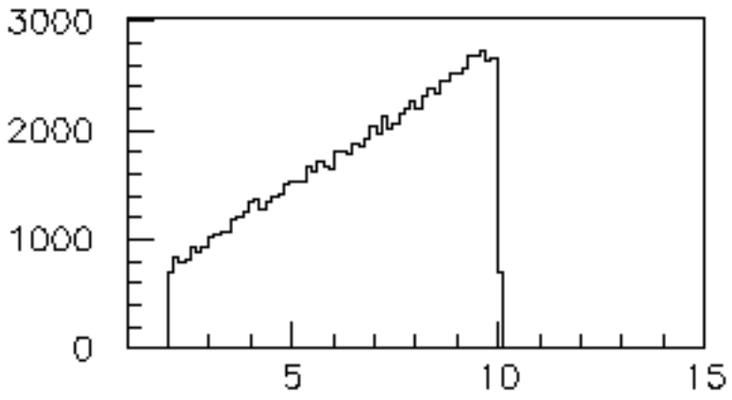
G4GeneralParticleSource()

- ../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**

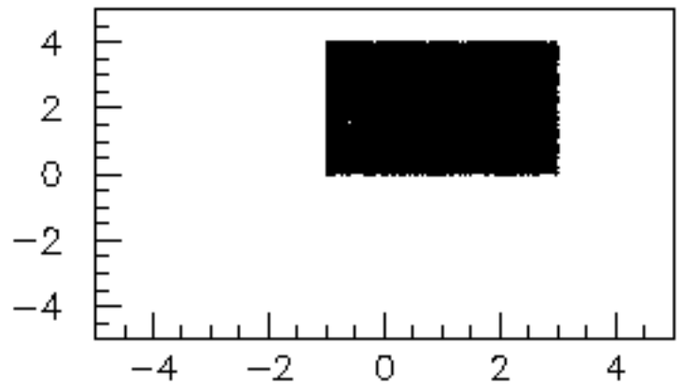
G4GeneralParticleSource

- 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)
  - .....

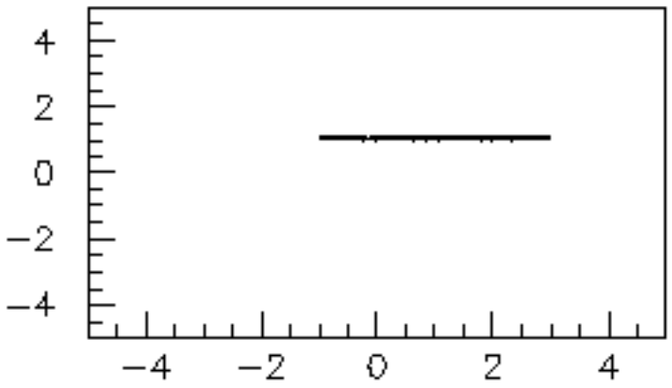
Square plane, cosine-law direction, linear energy



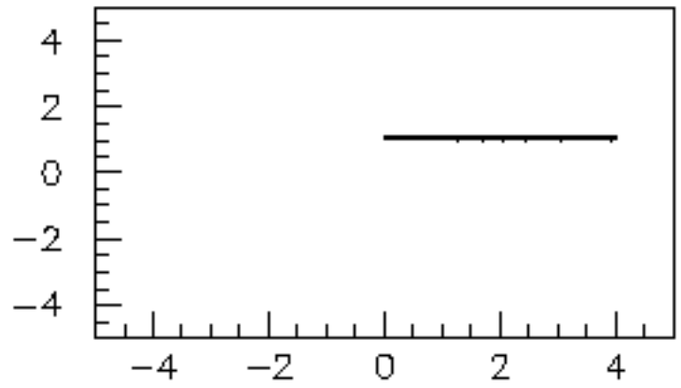
Source Energy Spectrum



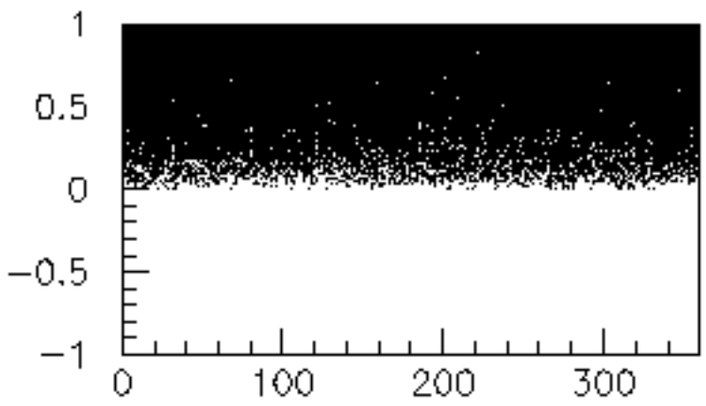
Source X−Y distribution



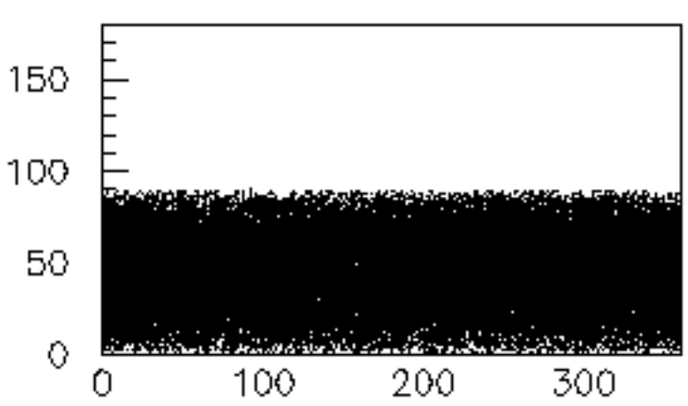
Source X−Z distribution



Source Y−Z distribution

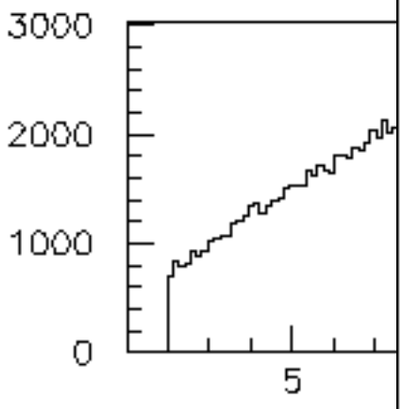


Source cos(theta)−phi distribution

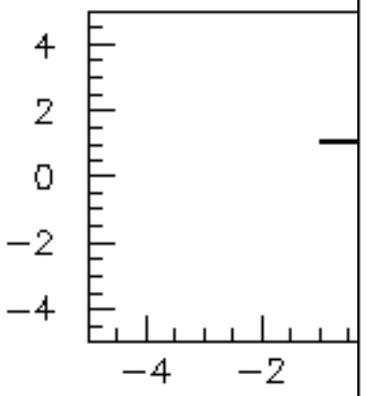


Source theta/phi distribution

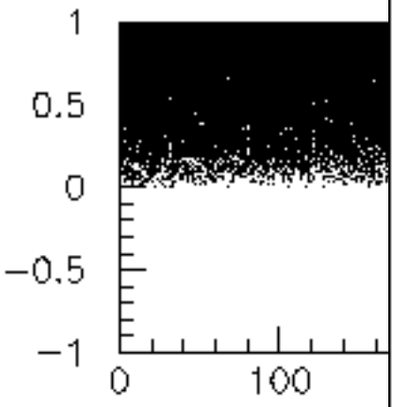
Square plane



Source Ene

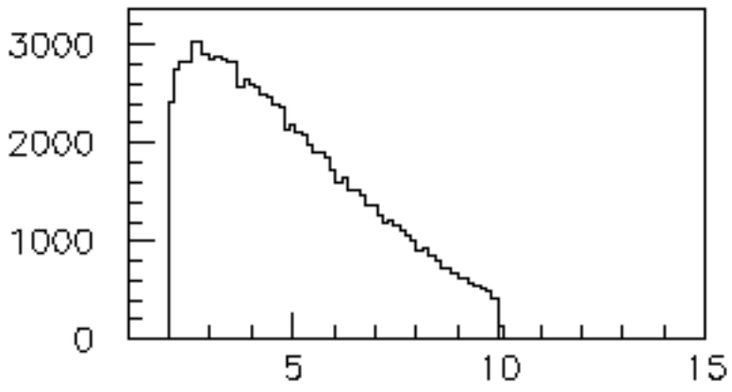


Source X−

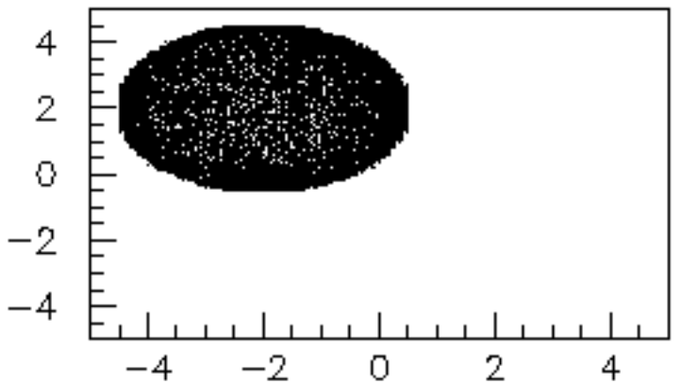


Source cos(thet

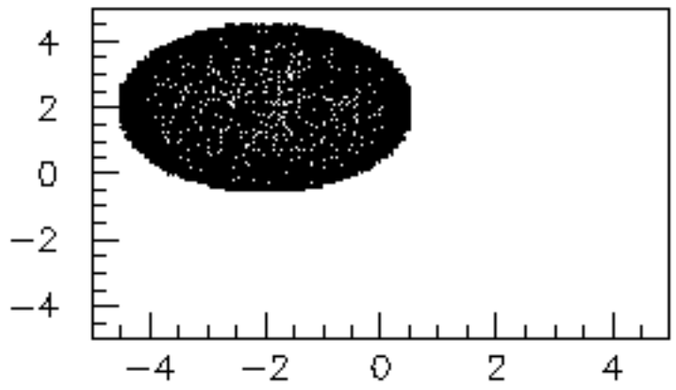
Spherical surface, isotropic radiation, black-body energy



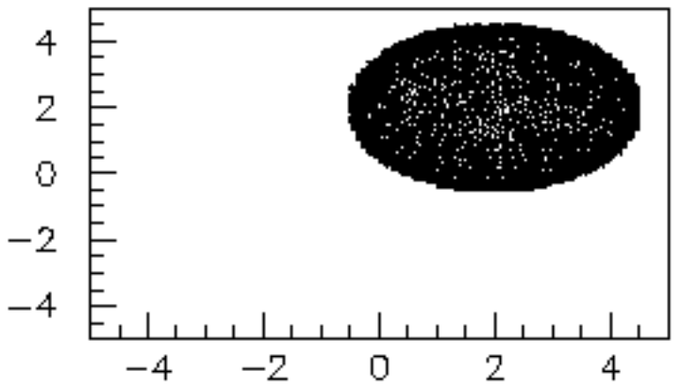
Source Energy Spectrum



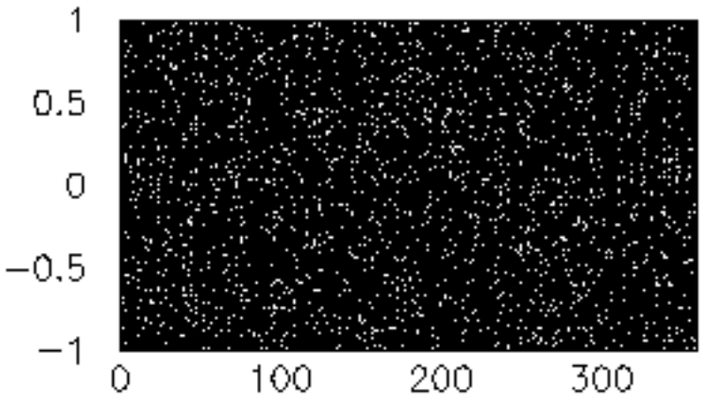
Source X−Y distribution



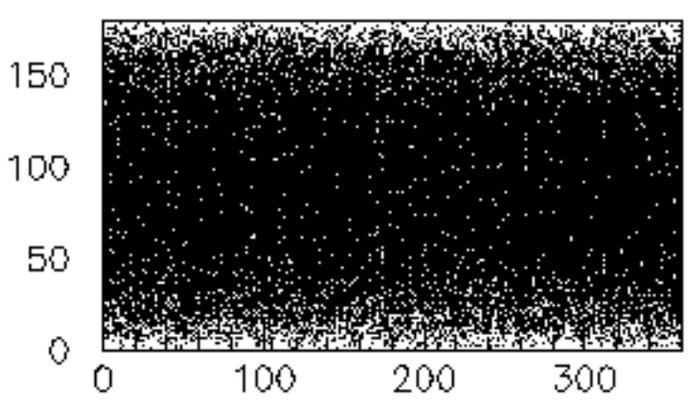
Source X−Z distribution



Source Y−Z distribution

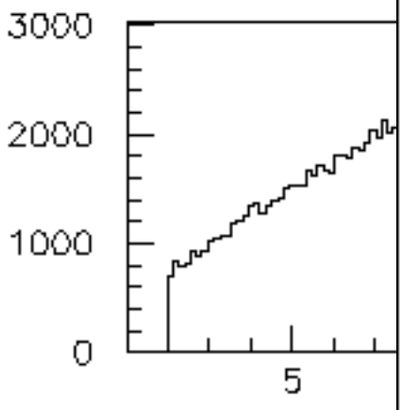


Source cos(theta)−phi distribution

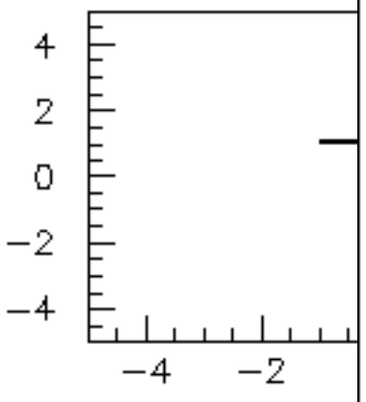


Source theta/phi distribution

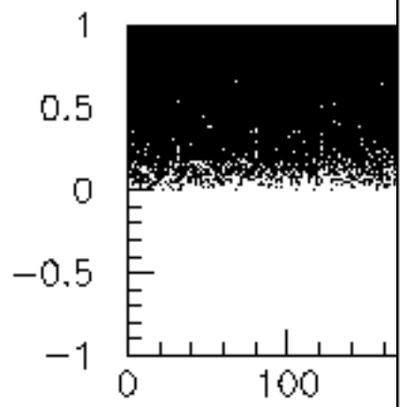
Square plane



Source Ene

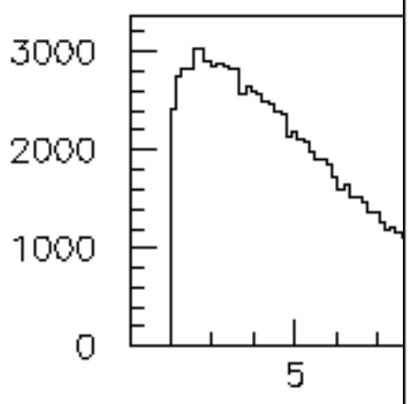


Source X−

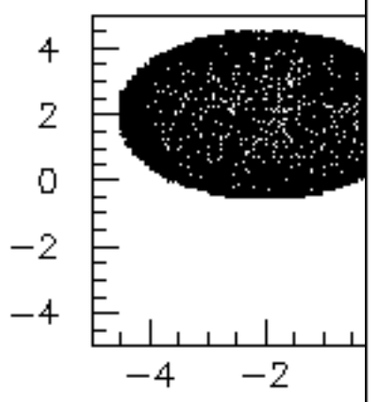


Source cos(thet

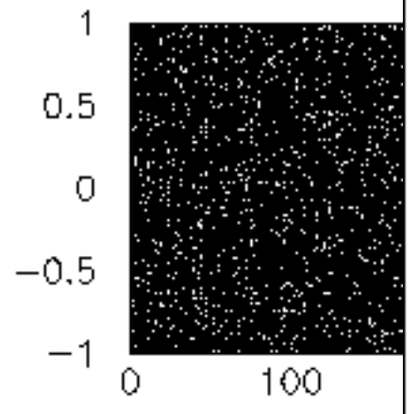
Spherical surfa



Source Ene

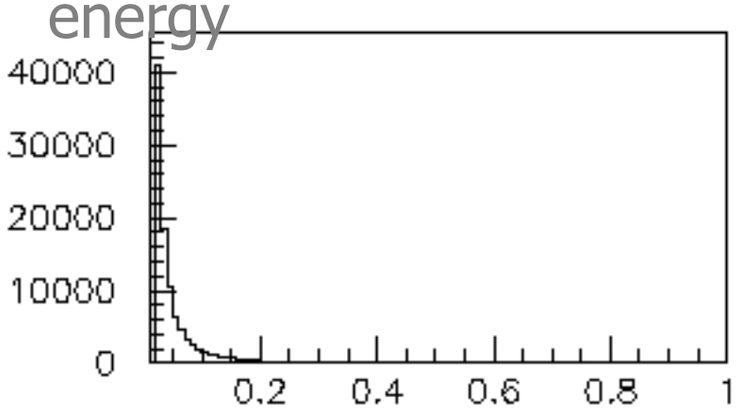


Source X−

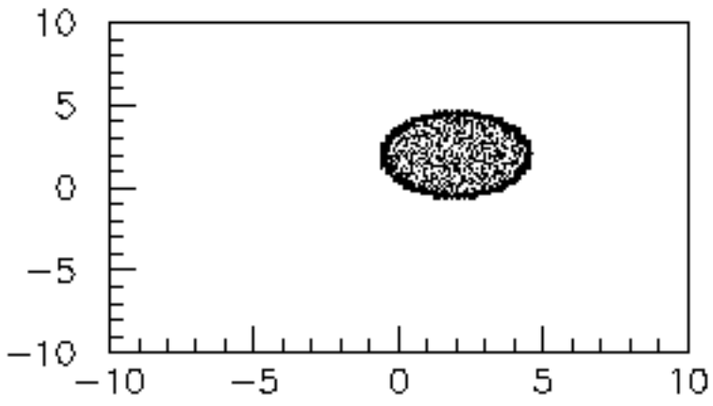


Source cos(thet

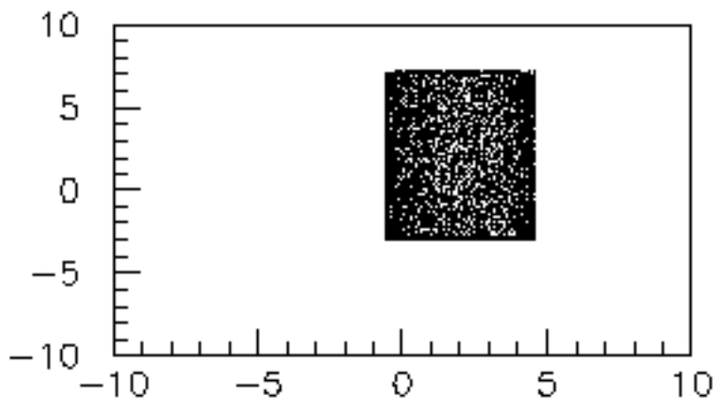
Cylindrical surface, cosine-law radiation, Cosmic diffuse energy



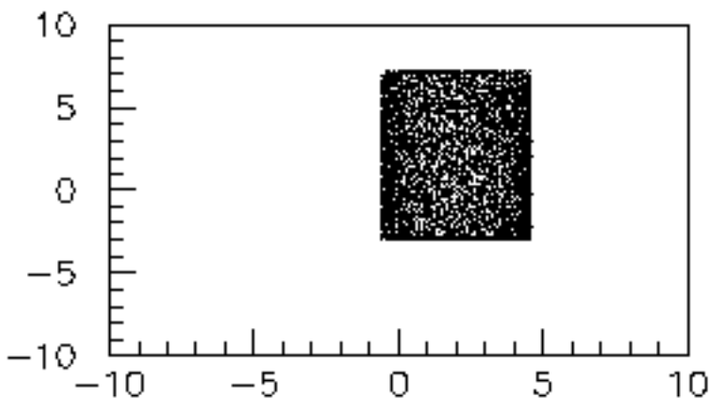
Source Energy Spectrum



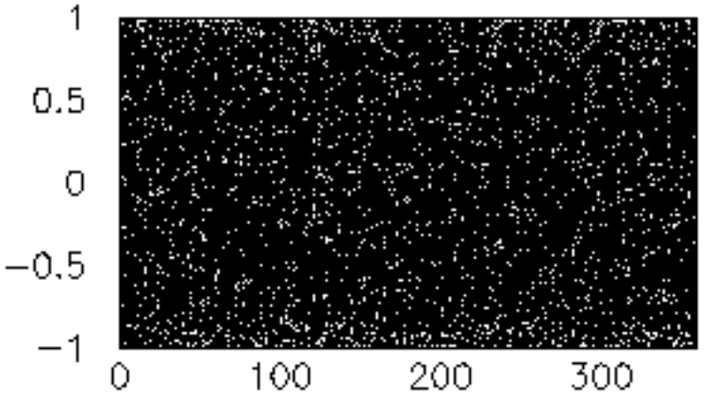
Source X−Y distribution



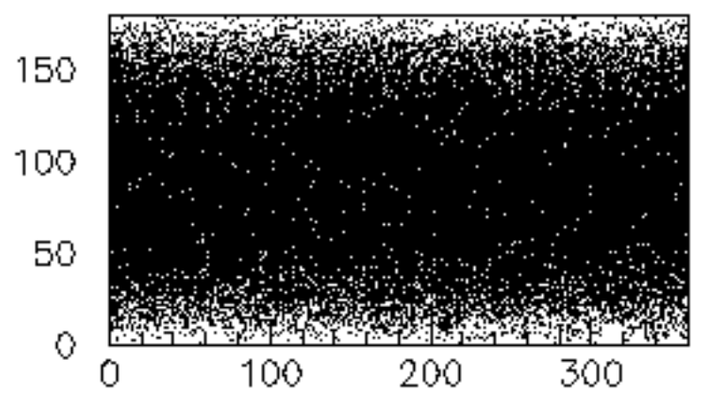
Source X−Z distribution



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
  - /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

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  - Shoot one track at a time
  - Easily to handle

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  - Controlled by UI commands `(G4GeneralParticleSourceMessenger.hh)`
    - ✓ Almost impossible to control with set methods
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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()