NE697: Introduction to Geant4

C++ Geant4 Intro

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Today's Agenda

- Administrative items

- Compile Geant4 and run exampleB1

- Geant4 basics

Last Time, On NE697…

- Assignment 3
  - Due tonight at midnight, Pacific time
  - Need more time?

- Class inheritance – any follow-up questions?

Geant4 Introduction

- **GE**ometry **AN**d **T**racking
- Developed by CERN for their high energy physics experiments
- Initial release as GEANT in 1974, written in FORTRAN
- GEANT4, C++, released in 1998
- Also does optical photon transport
- Not frequently used for fission beyond spontaneous fission for common sources

Geant4 Introduction

- Also includes tools for geometry/materials definition, run management, visualization, and some analysis

- Visualization is useful for verifying what you're running

- Analysis is less useful (you'll want to do this yourself)

- Once developed and tested, run in batch mode (.mac) on a beefy computer

- Sequential vs multi-threaded
  - We'll be using the latter

Geant4 Resources

- Application Developer's Guide
  - https://geant4-userdoc.web.cern.ch/UsersGuides/ForApplicationDeveloper/html/index.html
  - **Read this!!!**
- Doxygen documentation (source code browsing)
  - https://geant4.kek.jp/Reference/
- Examples
  - https://geant4-userdoc.web.cern.ch/Doxygen/examples_doc/html/index.html
- [DEMO]
  - Compiling Geant4

Geant4 Introduction

- [DEMO]
  - Geant4 exampleB1
  - Directory structure and build system
  - Macros/scripts (.mac files)
  - Run interactively
    - Components of visualization configuration (vis.mac)
    - Run1.mac, run2.mac
  - Run in batch mode
  - Changing the verbosity level (control, tracking)
  - Changing the number of particles to run

Example B1
- Simple geometry with a few solids
- Geometry with simple placements (G4PVPlacement)
- Scoring total dose in a selected volume user action classes
- Using G4Accumulable for automatic merging of scored values in multi-threading mode
- Geant4 physics list (QBBC)

Geant4 Introduction

- Anatomy of a basic Geant4 program
  - Set up the **G4RunManager**
  - Register actions with **ActionInitialization**
    - **RunAction**
    - **EventAction**
    - **PrimaryGeneratorAction** (particle source)
  - Create geometry with inherited **G4VUserDetectorConstruction**
  - Define physics with a **physics list**

- In main() we handle command-line args and deal with visualization

Geant4: RunManager

- G4RunManager (G4MTRunManager)
- Initialize() (/run/initialize)
- Remember run() from our MC1D assignment?
  – BeamOn() (/run/beamOn)
- SetUserAction() is deprecated
- SetUserInitialization() -> ActionInitialization

Public Member Functions

	G4RunManager ()
virtual	~G4RunManager ()
virtual void	BeamOn (G4int n_event, const char *macroFile=0, G4int n_select=-1)
virtual void	Initialize ()
virtual void	DefineWorldVolume (G4VPhysicalVolume *worldVol, G4bool topologyIsChanged=true)
virtual void	AbortRun (G4bool softAbort=false)
virtual void	AbortEvent ()
virtual void	InitializeGeometry ()
virtual void	InitializePhysics ()
virtual G4bool	ConfirmBeamOnCondition ()
virtual void	RunInitialization ()
virtual void	DoEventLoop (G4int n_event, const char *macroFile=0, G4int n_select=-1)
virtual void	RunTermination ()
virtual void	InitializeEventLoop (G4int n_event, const char *macroFile=0, G4int n_select=-1)
virtual void	ProcessOneEvent (G4int i_event)
virtual void	TerminateOneEvent ()
virtual void	TerminateEventLoop ()
virtual G4Event *	GenerateEvent (G4int i_event)
virtual void	AnalyzeEvent (G4Event *anEvent)
void	DumpRegion (const G4String &name) const
void	DumpRegion (G4Region *region=0) const
virtual void	rndmSaveThisRun ()
virtual void	rndmSaveThisEvent ()
virtual void	RestoreRandomNumberStatus (const G4String &fileN)
void	SetUserInitialization (G4VUserDetectorConstruction *userInit)
void	SetUserInitialization (G4VUserPhysicsList *userInit)
void	SetUserAction (G4UserRunAction *userAction)
void	SetUserAction (G4VUserPrimaryGeneratorAction *userAction)
void	SetUserAction (G4UserEventAction *userAction)
void	SetUserAction (G4UserStackingAction *userAction)
void	SetUserAction (G4UserTrackingAction *userAction)
void	SetUserAction (G4UserSteppingAction *userAction)
const G4VUserDetectorConstruction *	GetUserDetectorConstruction () const
const G4VUserPhysicsList *	GetUserPhysicsList () const
const G4UserRunAction *	GetUserRunAction () const
const G4VUserPrimaryGeneratorAction *	GetUserPrimaryGeneratorAction () const
const G4UserEventAction *	GetUserEventAction () const
const G4UserStackingAction *	GetUserStackingAction () const
const G4UserTrackingAction *	GetUserTrackingAction () const
const G4UserSteppingAction *	GetUserSteppingAction () const
void	SetNumberOfAdditionalWaitingStacks (G4int iAdd)
const G4String &	GetVersionString () const
void	SetPrimaryTransformer (G4PrimaryTransformer *pt)
void	StoreRandomNumberStatusToG4Event (G4int vl)
G4int	GetFlagRandomNumberStatusToG4Event () const
void	SetRandomNumberStore (G4bool flag)
G4bool	GetRandomNumberStore () const
void	SetRandomNumberStoreDir (const G4String &dir)
const G4String &	GetRandomNumberStoreDir () const
const G4String &	GetRandomNumberStatusForThisRun () const
const G4String &	GetRandomNumberStatusForThisEvent () const
void	GeometryHasBeenModified ()
void	PhysicsHasBeenModified ()
void	CutOffHasBeenModified ()
void	ReOptimizeMotherOf (G4VPhysicalVolume *)
void	ReOptimize (G4LogicalVolume *)
void	SetVerboseLevel (G4int vl)
G4int	GetVerboseLevel () const
void	SetGeometryToBeOptimized (G4bool vl)
G4bool	GetGeometryToBeOptimized ()
void	SetNumberOfEventsToBeStored (G4int val)
const G4Run *	GetCurrentRun () const
const G4Event *	GetCurrentEvent () const
const G4Event *	GetPreviousEvent (G4int i) const
void	SetRunIDCounter (G4int i)
G4int	GetNumberOfParallelWorld () const
void	SetNumberOfEventsToBeProcessed (G4int val)
void	SetDCtable (G4DCtable *DCtbl)
void	ConstructScoringWorlds ()

Geant4: ActionInitialization

Public Member Functions

	G4VUserActionInitialization ()
virtual	~**G4VUserActionInitialization** ()
virtual void	**Build** () const =0
virtual void	**BuildForMaster** () const
virtual **G4VSteppingVerbose** *	**InitializeSteppingVerbose** () const

- Used for "registering" user-defined action classes with Geant4
  - Register: give Geant4 a pointer to an instance of the object
    - Using inheritance; Geant4 keeps a **G4VUserActionInitialization***
- Build() is called by each thread
- BuildForMaster() is called by the master thread (often just RunAction)

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Geant4: RunAction

- Used for Run management

- Functions called at the start and stop of a Run

- Allows us to provide a custom Run object (inherits from G4Run)

- Note "const G4Run*": cannot change Run objects in these functions!
  - Reminder, same as G4Run const*

- We'll revisit the Run objects later

Public Member Functions

	G4UserRunAction ()	
virtual	**~G4UserRunAction** ()	
virtual **G4Run ***	**GenerateRun** ()	
virtual void	**BeginOfRunAction** (const G4Run *aRun)	
virtual void	**EndOfRunAction** (const G4Run *aRun)	
virtual void	**SetMaster** (G4bool val=true)	
G4bool	**IsMaster** () const	

Protected Attributes

G4bool	**isMaster**

Geant4: EventAction

- Used for Event management

- Functions called at the start and stop of an Event

- Often used for printing periodic updates (event number)

- EndOfEventAction() historically used for getting Event hit information (now done in Run::RecordEvent())

Public Member Functions

	G4UserEventAction ()
virtual	~G4UserEventAction ()
virtual void	SetEventManager (G4EventManager *value)
virtual void	BeginOfEventAction (const G4Event *anEvent)
virtual void	EndOfEventAction (const G4Event *anEvent)

Geant4: PrimaryGeneratorAction

- Sets the primary particle properties for the G4Event
  - Which, how many, position, direction, energy, etc
- GeneratePrimaries() is usually a pass-through to a particle gun's GeneratePrimaryVertex()
- G4GeneralParticleSource (GPS) built-in option

Public Member Functions

	G4VUserPrimaryGeneratorAction ()
virtual	~G4VUserPrimaryGeneratorAction ()
virtual void	GeneratePrimaries (G4Event *anEvent)=0

Geant4: DetectorConstruction

Public Member Functions

	G4VUserDetectorConstruction ()	
virtual	~G4VUserDetectorConstruction ()	
virtual G4VPhysicalVolume *	Construct ()=0	
virtual void	ConstructSDandField ()	
virtual void	CloneSD ()	
virtual void	CloneF ()	
void	RegisterParallelWorld (G4VUserParallelWorld *)	
G4int	ConstructParallelGeometries ()	
void	ConstructParallelSD ()	
G4int	GetNumberOfParallelWorld () const	
G4VUserParallelWorld *	GetParallelWorld (G4int i) const	

- Interface for providing geometry to Geant4
- Also handles SensitiveDetectors (more on this later)
- Parallel geometries (I've never used these)
- Construct() returns your top level simulation physical volume ("world")

Geant4: Physics Lists

- We can define what physics we want, how we want

- We usually want to use the physics we all know* and love

- Most people 1) copy from a similar example and then modify or 2) use a built-in

- Completely dependent on details of the use case

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Geant4 Example B1 Revisited

- [DEMO]
  - Look at the code anatomy of exampleB1
  - We'll be doing things a little bit cleaner, more best practices
    - Namespace instead of B1 prefix
    - No need for virtual prefix on inheriting functions
    - **override** keyword usage
    - All .cpp files in src/
    - Scripts in scripts/