Geant4 release 10.5

ANALYSIS

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Introduction

Introduction

- Geant4 does not provide a complete analysis sub-system
  - Our user community is too heterogeneous
  - Each user group has its own requirements and a favourite tool
    - e.g. Python, ROOT in HEP, what is yours ?

- Typical simulation output consists of
  - n-tuple like tables (row: event, column: quantity)
  - histograms

Status of g4analysis

- Analysis category in Geant4 since December 2011
  - Before the analysis code in Geant4 examples used external tools (based on AIDA = Abstract Interfaces for Data Analysis) that had to be linked with the Geant4 application to produce histograms or ntuples

- Area of new developments and improvements: more features are added in each release
  - Example: better MPI (Message Passing Interface) support

- Based on g4tools from inlib/exlib developed by Guy Barrand (LAL, France)
  - http://inexlib.lal.in2p3.fr
  - "Pure header code" - all code is inlined : can be installed on iOS, Android, UNIXes, Windows…

- Provides unique interface to write histograms and "flat n-tuples" (i.e. with primitive types) in several formats:
  ROOT, XML AIDA, CSV, HBOOK

Status of g4analysis

- It includes a manager G4AnalysisManager (singleton):
  - Handles output file(s) creation
  - Owns and handles histograms and n-tuples
- It provides
  - Uniform interface
    - Hides the differences according to a selected technology (root, XML, HBOOK, CSV) from the user
  - Higher level management of g4tools objects (file, histograms, n-tuples)
    - Memory management
    - Access to histograms, n-tuple columns via indexes
- Integration in the Geant4 framework
  - Interactive commands, units
- It is thread-safe and provides automatic merging of histograms

Histograms

Using Geant4 Analysis

- 3 basic steps
  1. - Create/get the G4AnalysisManager
     - Book (create) your histograms, n-tuples
     - Open a file
  2. Fill values in histograms, n-tuples
  3. Write & close file

Using Geant4 Analysis

- The few basic steps in detail…

1.	Create G4AnalysisManager	in RunAction::BeginOfRunAction()
	Open an output file	in RunAction::BeginOfRunAction()
	Book (create) your histograms, n-tuples	in RunAction::BeginOfRunAction()
2.	Fill values in histograms, n-tuples	anywhere during event processing, e.g. in EventAction::EndOfEventAction()
3.	Write & close file	in RunAction::EndOfRunAction()

Note: performing the steps in the suggested classes & methods is not mandatory, but it guarantees correct functioning in multi-threaded mode

Selection of output type

- For simplicity of use, G4AnalysisManager provides a complete access to all interfaced methods for all output formats: ROOT, CSV, AIDA XML
  - though it is implemented via a more complex design
  - the real type is different for each output type: G4RootAnalysisManager, G4CsvAnalysisManager, G4XmlAnalysisManager
- The generic types are defined in dedicated header files for each output type:
  - g4root.hh, g4csv.hh, g4xml.hh
  - using **namespaces** and **typedefs**
- It is recommended to add the selected include in an extra header file MyAnalysis.hh and include this header file in all classes which use g4analysis
- Changing the format requires only one line change in this MyAnalysis.hh header

MyAnalysis.hh

```
#ifndef MyAnalysis_h
#define MyAnalysis_h 1

#include "g4root.hh"
//#include "g4csv.hh"
//#include "g4xml.hh"
#endif
```

1) Step 1: creation

MyRunAction.cc

```
#include "MyAnalysis.hh"

void MyRunAction::BeginOfRunAction(const G4Run* run)
{
  // Create/get analysis manager
  G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();
  analysisManager->SetVerboseLevel(1);

 // Open an output file
  analysisManager->OpenFile("MyApplication");

 // Create histograms
  analysisManager→CreateH1("Edep","Energy deposit", 100, 0., 800*MeV);
  analysisManager→CreateH1("Tlen","Track length", 100, 0., 100*mm);
}
```

2) Step 2: filling

□ Example of filling 2 one-dimensional histograms

MyEventAction.cc

```
#include "MyAnalysis.hh"

void MyEventAction::EndOfEventAction(const G4Event* event)
{
  // Get analysis manager
  G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();

  // Fill histograms
  analysisManager→FillH1(0, fEdep);
  analysisManager→FillH1(1, fTrackLength);
}
```

3) Step 3: write & close

- Example of writing & closing the output file

MyRunAction.cc

```
#include "MyAnalysis.hh"

void MyRunAction::EndOfRunAction(const G4Run* run)
{
  // Get analysis manager
  G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();

  // Write and close the output file
  analysisManager->Write();
  analysisManager->CloseFile();
}
```

More on histograms

- 1D, 2D, 3D histograms and 1D, 2D profile histograms available
- Histogram identifiers
  - The histogram ID is automatically generated (when a histogram is created by G4AnalysisManager::CreateH1()), and its value is returned from this function
    - Note: the histogram names have no relation to the histogram ID which is used at filling
  - The default start value 0 can be changed (eg. to 1) with:
    G4AnalysisManager::SetFirstHistoId(G4int)
    - The 1D, 2D and 3D histograms IDs are defined independently
- Histogram objects
  - It is also possible to access directly a histogram by
    G4AnalysisManager::GetH1(G4int id)
    The concrete histogram type is hidden behind a selected namespace (e.g. root, csv,…)

```
G4cout << "Print histograms statistic \n" << G4endl;
G4cout << " EAbs : mean = " << analysisManager->GetH1(1)->mean()
       << " rms = " << analysisManager->GetH1(1)->rms() << G4endl;
```

Histogram options

- Properties, additional to those defined in g4tools, can be added to histograms via G4AnalysisManager
  - Unit : if defined, all filled values are automatically converted to this defined unit
  - Function : if defined, the function is automatically executed on the filled values (can be log, log10, exp)
    - When a histogram is defined with both unit and function, then the unit is applied first
  - Binning scheme : users can define a non-equidistant binning scheme (passing a vector of bin edges)
    - UI command only for lin/log scheme
  - ASCII option : if activated the histogram is also printed in an ASCII file when G4AnalysisManager::Write() function is called
  - See /analysis/h1/set UI commands

Ntuples

1) Step 1: creation

- Example of creating an n-tuple

MyRunAction.cc

```
#include "MyAnalysis.hh"

void MyRunAction::BeginOfRunAction(const G4Run* run)
{
 // Create analysis manager
  G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();
  analysisManager->SetVerboseLevel(1);

 // Open an output file
   analysisManager->OpenFile("MyApplication");

 // Creation of ntuple
  analysisManager->CreateNtuple("MyNtuple", "Edep and TrackLength”);
 // X = D in CreateNtupleXColumn stands for G4double (I,F,D,S)
  analysisManager->CreateNtupleDColumn(“Eabs");
  analysisManager->CreateNtupleDColumn("Labs");
  analysisManager->FinishNtuple();
}
```

2) Step 2: filling

- Example of filling an ntuple

MyEventAction.cc

```
#include "MyAnalysis.hh"

void MyEventAction::EndOfEventAction(const G4Event* event)
{
  // Get analysis manager
  G4AnalysisManager* analysisManager =   G4AnalysisManager::Instance();

  // Fill ntuple
  analysisManager->FillNtupleDColumn(0, fEnergyAbs);
  analysisManager->FillNtupleDColumn(1, fTrackLAbs);
  analysisManager->AddNtupleRow();
}
```

3) Step 3: write & close

□ Example of writing & closing the output file

MyRunAction.cc

```
#include "MyAnalysis.hh"

void MyRunAction::EndOfRunAction(const G4Run* run)
{
  // Get analysis manager
  G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();

  // Write and close the output file
  analysisManager->Write();
  analysisManager->CloseFile();
}
```

More on ntuples

- N-tuple and N-tuple Column identifiers
  - Automatically generated when the n-tuple or n-tuple column is created by G4AnalysisManager::CreateNtuple() or G4AnalysisManager::CreateNtupleXColumn() and its value is returned from this function.
  - The default start value 0 can be changed with the G4AnalysisManager::SetFirstNtupleId(G4int) and G4AnalysisManager::SetFirstNtupleColumnId(G4int) methods.
  - In a similar way as for histogram ID

- The n-tuple column ID is not specific to the column type: available column types:
  - integer (I), float (F), double (D), string (S)
  - std::vector of integer (I), float (F), double (D) types

UI commands

Analysis UI commands (1/3): options and output file handling

- General options

```
# Set verbose level
/analysis/verbose level
# Set activation option (one of the followings)
/analysis/setActivation id true|false
/analysis/setActivationToAll true|false
/analysis/h1/set 1 100 0   50 cm  #track length of prim.
```

- Handling output files and general options

```
# Set name for the histograms and n-tuple file
/analysis/setFileName name
# Set name for the histograms/n-tuple directory
/analysis/setHistoDirName name
/analysis/setNtupleDirName name
```

UI commands (2/3)

- Commands to create or define 1D histogram

```
# Create 1D histogram
/analysis/h1/create name title [nbin min max] [unit] [fcn] [binscheme]

# Set histogram parameters from UI command
/analysis/h1/set id nbin min max [unit] [fcn] [binscheme]
```

- Example of a macro gammaSpectrum.mac in TestEm5 example (examples/extended/electromagnetic/TestEm5/gammaSpectrum.mac)

```
/analysis/setFileName gammaSpectrum
/analysis/h1/set 3 200 0.01 10 MeV #gamma: energy at vertex
/analysis/h1/set 5 200 0.01 10 MeV log10 #gamma: energy at vertex (log10)
/analysis/h1/set 20 200 0 6 MeV #gamma: energy at exit
/analysis/h1/set 40 200 0 6 MeV #gamma: energy at back
```

- Analogous commands are available for 2D and 3D histograms and 1D and 2D profiles

UI commands (3/3)

- For 1D histograms control

```
# Activate printing 1D histogram on ASCII file
/analysis/h1/setAscii id true|false
# Set title for the 1D histogram
/analysis/h1/setTitle id title
# Set x-axis, y-axis title for the 1D histogram
/analysis/h1/setXaxis id title
/analysis/h1/setYaxis id title
# Set activation for the id 1D histogram
/analysis/h1/setActivation id true|false
# Set activation to all 1D histograms
/analysis/h1/setActivationToAll true|false
```

- The same sets of commands are available for 2D and 3D histograms and 1D and 2D profiles, under h2, h3, p1 and p2 directories

More: batch graphics (1/3)

- Since Version 10.2
- Users can activate plotting of selected histograms and profiles using G4AnalysisManager methods

```
// Activate plotting of 1D histogram
analysisManager->SetH1Plotting(id, true);
// etc for H2, H3, P1, P2
```

- Or via UI command

```
/analysis/h1/setPlotting id true|false
/analysis/h1/setPlottingToAll true|false
## etc for h2, h3, p1, p2
```

- The selected objects will be plotted in a single postscript (.ps) file with the page size fixed to A4 format

More: output files (2/3)

Depending on selected file format, multiple output files can be produced

- ROOT
  - All histograms, profiles and n-tuples are written in one file
- XML (AIDA)
  - The histograms and profiles are written in one file, and each n-tuple is written in a separate file
- CSV (comma-separated values)
  - Each histogram, profile and n-tuple are written in a separate file

File names are generated automatically

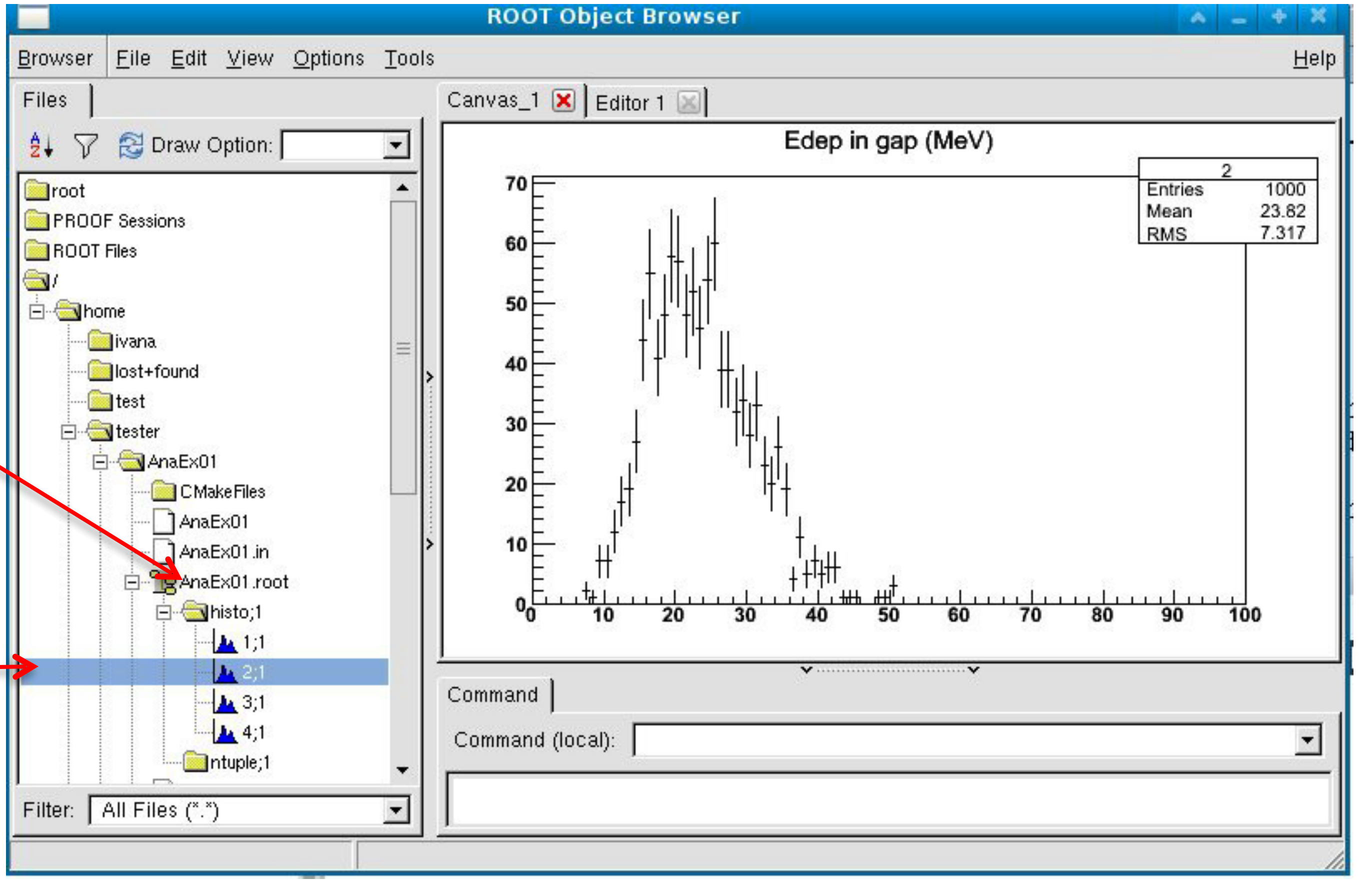
fileName[_objectName].ext where ext = xml, csv

ROOT

https://root.cern.ch

- A data analysis tool from CERN
- Start session with root, then open a browser with:

  root [0] new TBrowser



File generated In Geant4 simulation

Selected H1 is automatically drawn in the canvas

Geant4 examples

- In examples/extended/analysis, 3 examples to demonstrate how to make histograms and ntuples
  - AnaEx01 – use of Geant4 analysis tools
  - AnaEx02 – use of ROOT classes, requires linking with Root libraries
  - AnaEx03 – use of AIDA interface classes, requires linking with an AIDA compliant tool, eg. OpenScientist
- http://geant4.web.cern.ch/geant4/UserDocumentation/Doxygen/examples_doc/html/Examples_analysis.html
- Geant4 Analysis Documentation

Summary

- Geant4 provides a lightweight analysis tool as part of distribution
- Can handle histograms (1D, 2D, profiles) and ntuples
- Variety of UI commands
- Variety of output formats
- Compatible with MT
  - Histogram and ntuple merging
- The Geant4 analysis is now used in all basic, extended and most of advanced examples
- Users can also choose to use an external package and link their application against its libraries