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 it, 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

```cpp
#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

ROOT

https://root.cern.ch

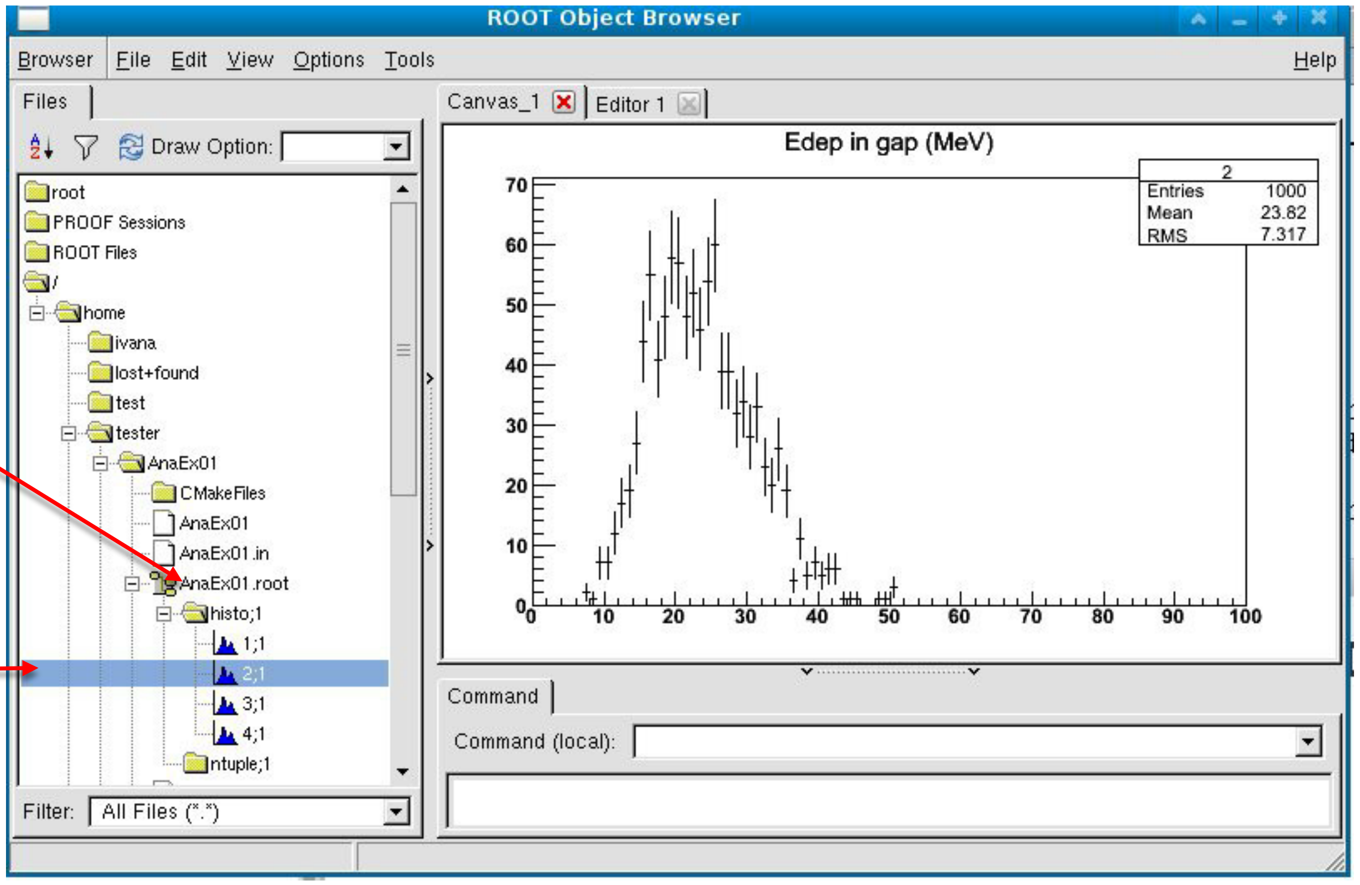
A data analysis tool from CERN

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