Analysis Functionalities

SLAC Geant4 Tutorial 2014

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A. Dotti (adotti@slac.stanford,edu)

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Acknowledgment and Notes

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Material from Ivana Hrivnacova, IPN Orsay

- New module in Geant4 Version 10.0
- Fixed in Patch 01: solved performance issue with ntuples with large number of columns

Geant4 Examples available in: **<g4src>/examples/extended/analysis**

Overview

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- Analysis of simulation data in Geant4
- New histogramming and ntuples tool
- UI Commands for analysis

Introduction

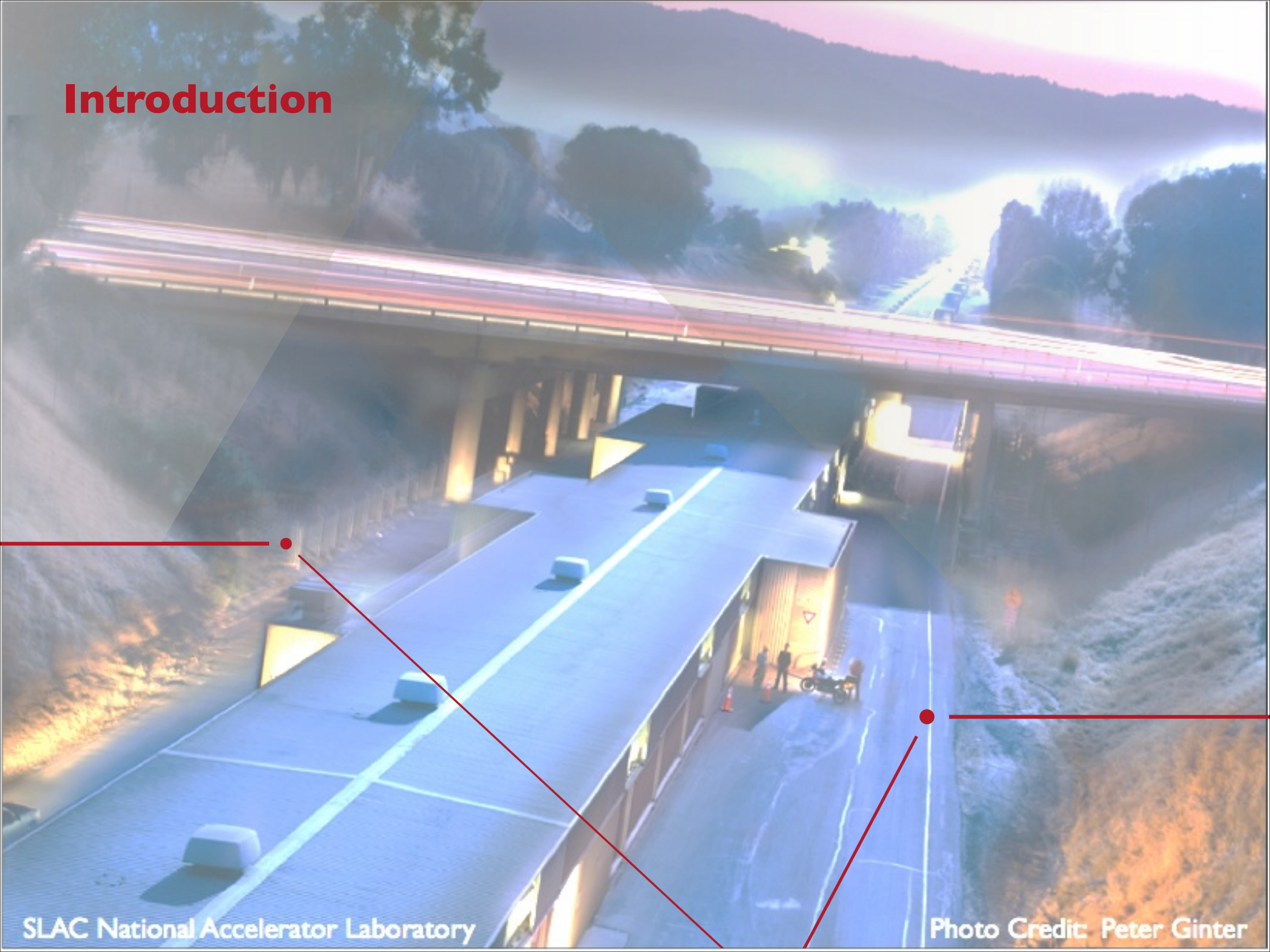

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Photo Credit: Peter Ginter

Introduction

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- Geant4 does not provide an complete analysis sub-system
  - Our user community is **too heterogeneous**
  - Each user group has its own requirements and a favorite tool(e.g. ROOT in HEP, what is yours?)
- Typical simulation output consists of: **ntuples-like** tables (row: event, column: quantity), **histograms**

Information for past version users

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Historically (up to 9.5) was discussed in Geant4 examples:

- Based on **AIDA** = Abstract Interfaces for Data Analysis
- List of AIDA compliant tools (linked in the Geant4 Guide for Application Developers):
  - JAS, iAIDA, Open Scientist Lab, rAIDA
  - Not all kept maintained, not all implement the AIDA interfaces completely
    Not always easy to be installed & used
- Feedback and help: Geant4 user forum, Analysis category
- Still supported in Geant4 Version 9.6.
- From Geant4 Version 10.0: focus only on new g4analysis

Current status

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- New **analysis category** introduced
- Based on g4tools from inlib/exlib developed by G. Barrand (LAL):
  - http://inexlib.lal.in2p3.fr/
  - "Pure header code" - all code is inlined (*a la* Boost)
    Can be installed on iOS, Android, UNIXes, Windows
- Provides code to write **histograms** and **"flat ntuples"** in several formats: ROOT, XML AIDA format, CSV for ntuples, HBOOK (needs CERNLIB)
  - Since it is pure header: you do not need ROOT/AIDA compliant tool to produce output files (very useful for production, no need to install code on worker nodes)
  - But you need a tool to read/visualize output

g4analysis

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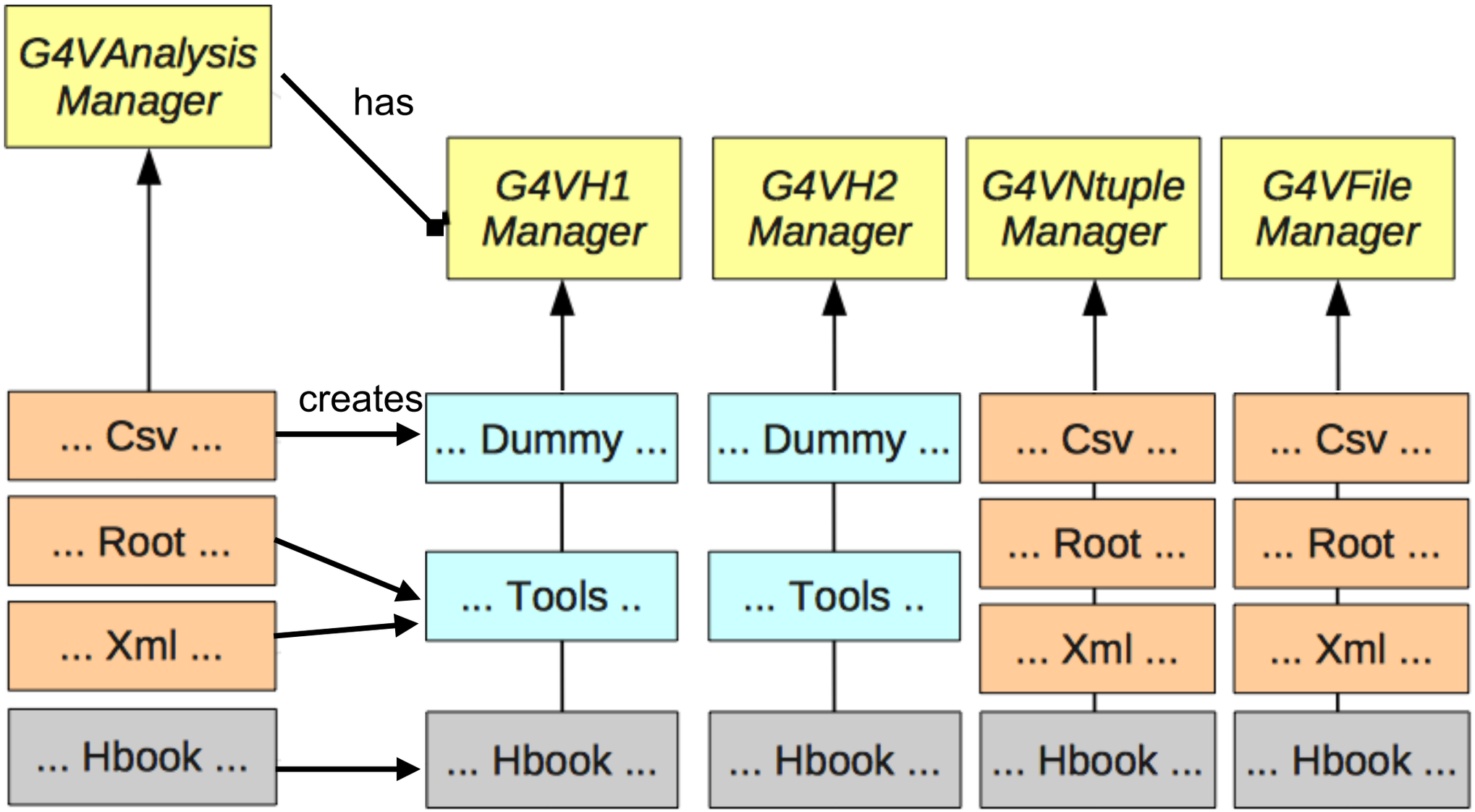
It includes a **manager** (G4AnalysisManager):

- Handles output file(s) creation
- Owns and handles histograms and ntuples

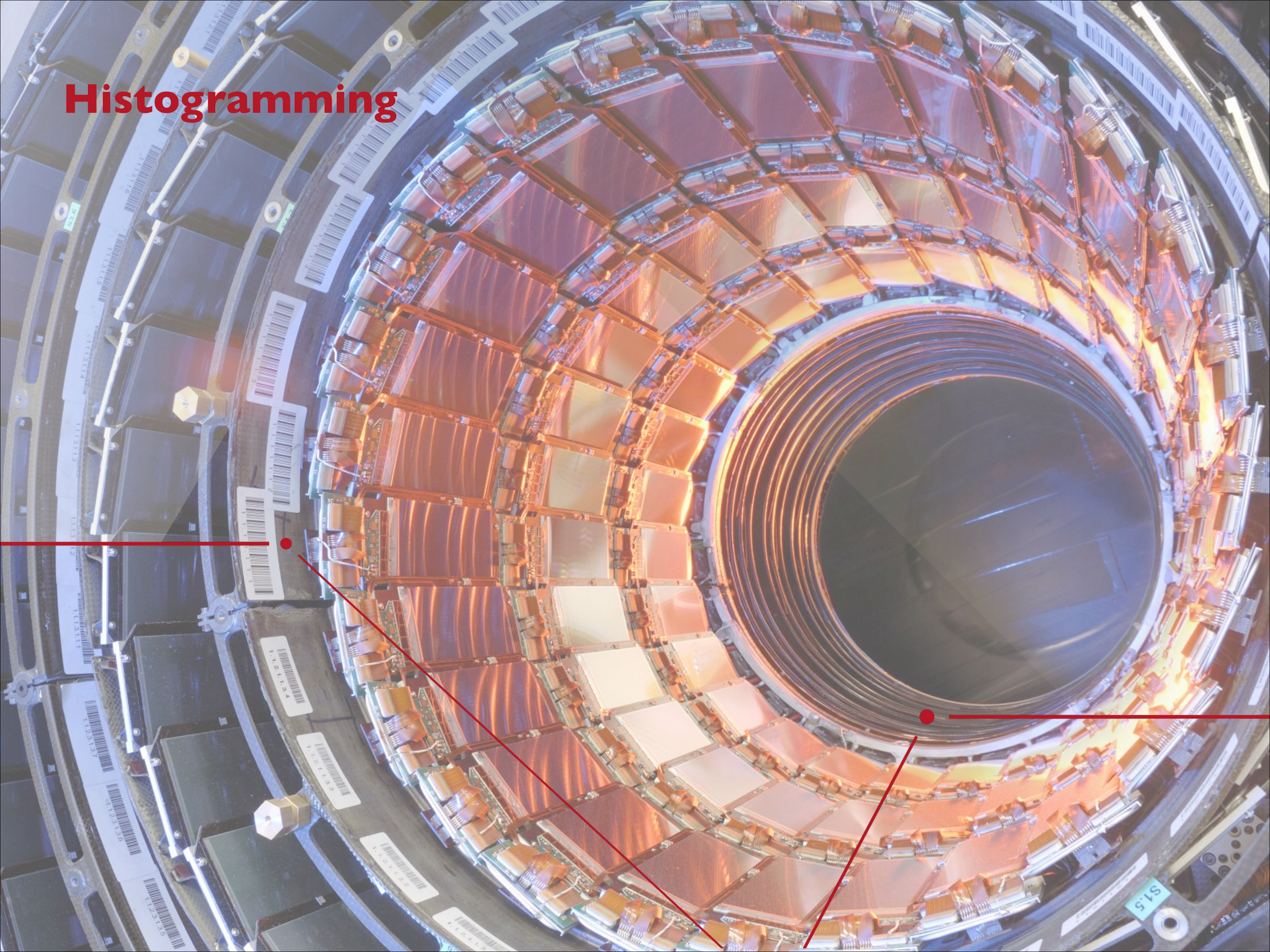
It provides:

- **Uniform interface**
  - Hide the differences according to a selected technology (root, XML, HBOOK) from the user
- **Higher level management** of g4tools objects (file, histograms, ntuples)
  - Memory management
  - Access to histograms, ntuple columns via indexes
- Integration in the Geant4 framework
  - Interactive commands, Units
- It is thread-safe and provides **automatic summing of histograms**

General Design



Histogramming



Histogram creation

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B4RunAction.cc

```
#include "B4Analysis.hh"

void B4RunAction::BeginOfRunAction(const G4Run* run)
{
  // Get analysis manager
  G4AnalysisManager* man = G4AnalysisManager::Instance();

  // Open an output file
  man->OpenFile("exampleB4");

  // Create histogram(s)
  man->CreateH1("0","Edep in absorber", 100, 0., 800*MeV);
  man->CreateH1("1","Edep in gap", 100, 0., 100*MeV);
}

void B4RunAction::EndOfRunAction(const G4Run* aRun)
{
  G4AnalysisManager* man = G4AnalysisManager::Instance();
  man->Write();
  man->CloseFile();
}
```

B4Analysis.hh

```
#ifndef B4Analysis_h
#define B4Analysis_h 1

#include "g4root.hh"
//#include "g4xml.hh"
//#include "g4hbook.hh"

#endif
```

Selection of the output format at a single place

B4EventAction.cc

```
#include "B4Analysis.hh"

void N4EventAction::EndOfEventAction(const G4Run* aRun)
{
  G4AnalysisManager* man = G4AnalysisManager::Instance();
  man->FillH1(0, fEnergyAbs);
  man->FillH1(1, fEnergyGap);
}
```

Histogram IDs are attributed Automatically

More on Histograms

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- 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 in filling.
  - The default start value 0 can be changed with: `G4AnalysisManager::SetFirstHistoId(G4int)`
    - The 1D and 2D histigrams IDs are defined independently
- Histogram objects:
  - It is also possible to access directly the histogram by `G4AnalysisManager::GetH1(G4int id)` / `G4AnalysisManager::GetH1Id( G4String name)` (remember no histos with CSV)
- **Note:** working on support for profiles

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

Histogram activation

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- The activation option allows the user to switch on/off selected histograms.
  - Set activation option, then only the histograms marked as activated are returned, filled or saved in a file.
  - Note: by default this all histograms are always active

```
G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();
 analysisManager->SetActivation(true);
  // define histogram parameters name, title, nbins, vmin, vmax
  G4int id = analysisManager->CreateH1(name, title, nbins, vmin, vmax);
  analysisManager->SetActivation(G4VAnalysisManager::kH1, id, false);
```

Advanced histogram functionalities

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- Advanced options are available (via `G4AnalysisManager`):
  - **Unit**: if a histogram is defined with a unit, all filled values are automatically converted to it
  - **Function**: if a histogram is defined with an associated function, this is used to transform the filling
    - Currently available functions: log, log10, exp .
    - When a histogram is defined with both unit and function the unit is applied first.
  - **User-defined binning scheme** supported (passing 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 command

Analysis category UI commands: output file handling

- Handling of files and general options:

```
/analysis/setFileName name        # Set name for the histograms and ntuple file
/analysis/setHistoDirName name    # Set name for the histograms directory
/analysis/setNtupleDirName name   # Set name for the histograms directory
/analysis/setActivation true|false # Set activation option
/analysis/verbose level           # Set verbose level
```

UI Commands for histograms

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- Basic UI commands for 1D histograms

```
/analysis/h1/create name title [nbin min max] [unit] [fcn] [binscheme] #Create 1D histo
/analysis/h1/set id nbin min max [unit] [fcn] [fcn] [binscheme] #Change parameters
```

- 2D commands

```
/analysis/h2/create                                    # Create 2D histogram
   name title [nxbin xmin xmax xunit xfcn nybin ymin ymax yunit yfcn]
/analysis/h2/set                                       # Set parameters
   id nbin xmin xmax xunit xfcn nybin ymin ymax yunit yfcn
```

- Change histogram properties via macro (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
```

Advanced UI commands

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- For 1D histograms:

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

- Similar commands for 2D histograms: "/analysis/h2/...."

MT support

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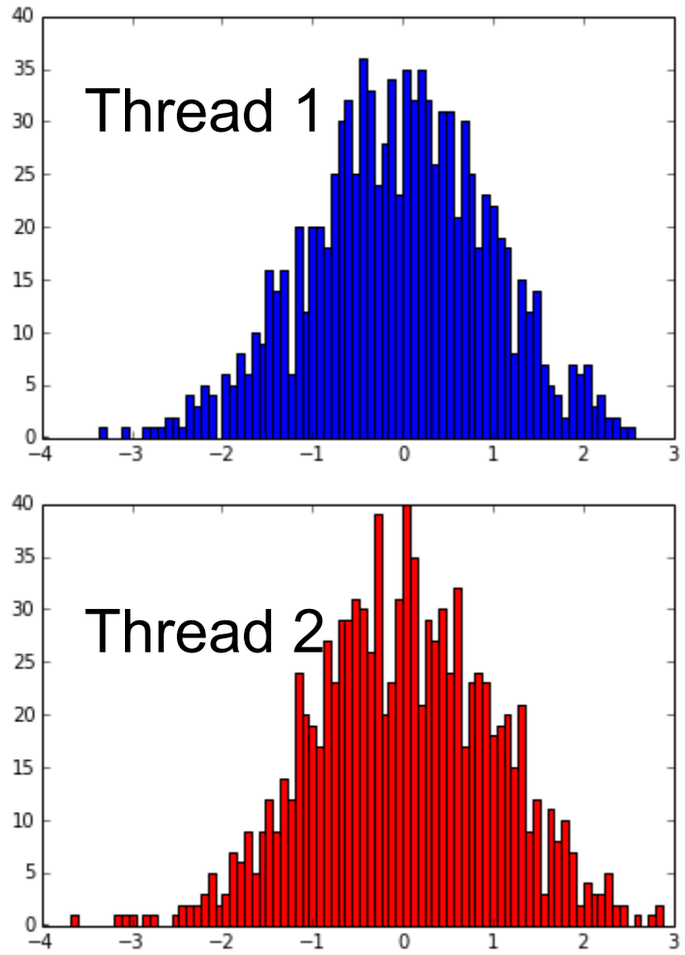
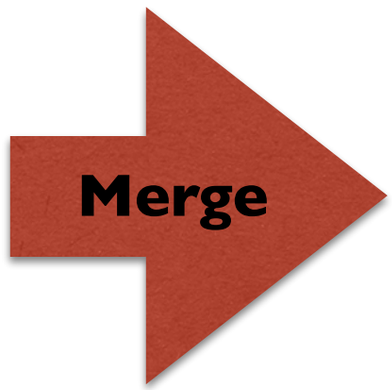
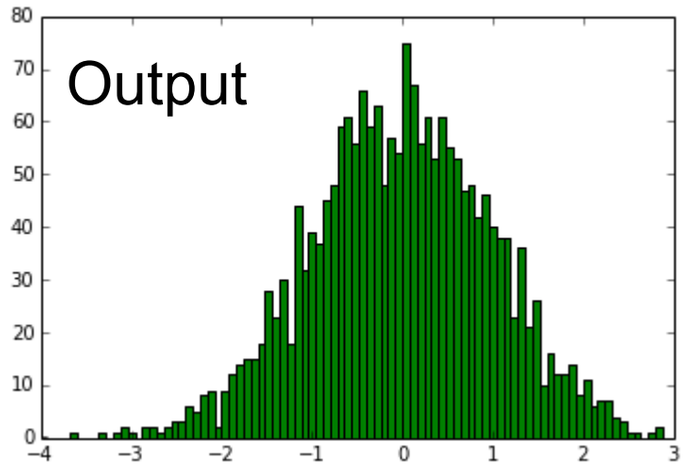
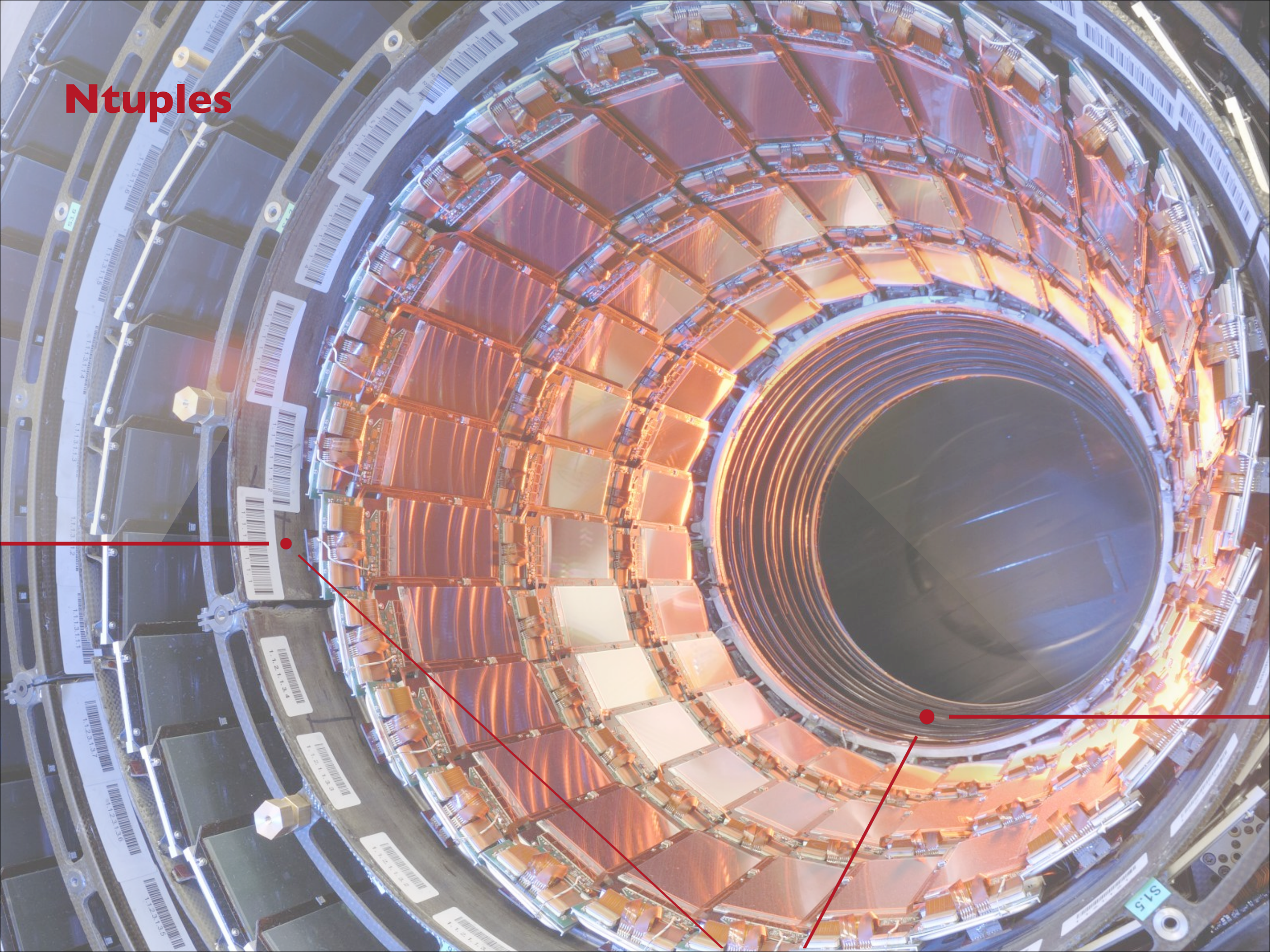
- Multi threading support for histograms:
  - Each thread owns its own copy of a given histograms
  - At the end of the run histograms are "merged" into single one
  - Single file with merged histograms will be produced







Ntuples



Ntuples creation

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B4RunAction.cc

```
#include "B4Analysis.hh"

void B4RunAction::BeginOfRunAction(const G4Run* run)
{
  // Get analysis manager
  G4AnalysisManager* man = G4AnalysisManager::Instance();

  // Open an output file
  man->OpenFile("exampleB4");

  // Create ntuple
  man->CreateNtuple("B4", "Edep and TrackL");
  man->CreateNtupleDColumn("Eabs");
  man->CreateNtupleDColumn("Egap");
  man->FinishNtuple();
}
```

B4EventAction.cc

```
#include "B4Analysis.hh"

void B4EventAction::EndOfEventAction(const G4Run* aRun)
{
  G4AnalysisManager* man = G4AnalysisManager::Instance();
  man->FillNtupleDColumn(0, fEnergyAbs);
  man->FillNtupleDColumn(1, fEnergyGap);
  man->AddNtupleRow();
}
```

More on Ntuples

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- Ntuple and Ntuple Column Identifiers
  - Automatically generated when the ntuple or ntuple column is created by `G4AnalysisManager::CreateNtuple()` or `G4AnalysisManager::CreateNtupleTColumn()` and its value is returned from this function.
  - The default start value 0 can be changed with the `G4AnalysisManager::SetFirstNtupleId(G4int)` method.
- The ntuple column ID is not specific to the column type

Supported file formats

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ROOT:

- Can be view/processed with ROOT: http://root.cern.ch; which is able to process also the HBOOK and CSV formats

XML (AIDA):

- JAS, iAIDA, Open Scientist Lab, rAIDA – see more details in the Appendix 2, in Geant4 Application Developer's Guide And "new" inlib/exlib: http://inexlib.lal.in2p3.fr/

CSV (comma-separated values):

- The simplest possible output format, can be analyzed by many tools Gnuplot, Excel, OpenOffice, ROOT

HBOOK (legacy support):

- Requires Geant4 to be compiled with this support, requires external CERNLIB package (fortran)

Additional notes

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- New in Version 10.0: support for more than a single NTuple
  - Notes:
    - With ROOT file format, supports more than one ntuple in final file, in other cases multiple files will be produced
    - Histograms file are written to separate file
- Multi-threading note:
  - Each thread owns copy of ntuple
  - **Not** merged at the end of the run (concatenate in analysis!)
  - Each thread will write out a separate file: `fileName[_ntupleName]_tID.[xml|root|hbook]` (where `ID =` thread Identifier 0,1,2…)

Exercise

Hands On 4 (Thursday Morning):

Exercise 2: Introduce a simple NTuple and few histograms