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Outline

- 1 Introduction
- 2 ROOT Features
- 3 Applications
- 4 Summary

Disclaimer: most images are taken from official ROOT sources

Introduction

HEP (high energy physics) aside from scientific research pushes leading edge technology as its byproduct.

Main demands for data processing:

- for petabytes of data:
 - effective storage
 - fast analysis
- extensible framework

And so ROOT (ROOT Object Oriented Toolkit) was born in 1995 for NA49 experiment. PAW is its ancestor, Rene Brun is founder of both projects.

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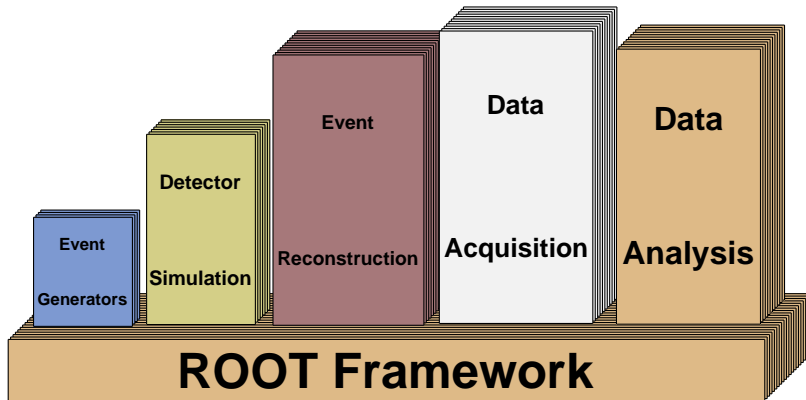
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ROOT framework



C++11 framework

Typically each experiment creates own classes and applications based on ROOT framework.

Key features

- Cross-platform: Linux, MacOS, Windows
- All major compilers: gcc, clang, icc
- LGPL-2.1 (+ other free licenses for aux components)

- C++11 framework for building applications
- Analysis tools

- Regular compilation/linking
- C++ interpreter: Cling (LLVM/Clang based)
- Automatic interface to compiler (ACLiC)

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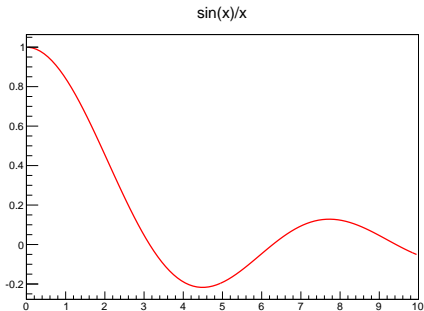
Advanced features

- ~ 2700 C++ classes
- Statistical analysis tools (fitting, minimizing)
- Multivariate analysis (MVA)
- Neural networks
- Visualisation tools (including OpenGL)
- Effective data queries in large data sets
- Client/server networking
- Parallel computing facilities (PROOF)
- Grid, AFS
- ...

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C++ Interpreter



```
$ root -l
root [0] TF1 f1("func","sin(x)/x",0,10);
root [1] f1.Draw();
Info in <TCanvas::MakeDefCanvas>: created default TCanvas with
name c1
root [2] c1->Print("sin.pdf");
Info in <TCanvas::Print>: pdf file sin.pdf has been created
root [3] .q
```

C++ Interpreter

- \leq ROOT-5.x CINT (C Interpreter)
- \geq ROOT-6.x Cling
- ACLiC support for fast compiling and linking
- Can be separated from ROOT!

Cling features:

- based on Clang and LLVM
- JIT
- stricter C++11 support

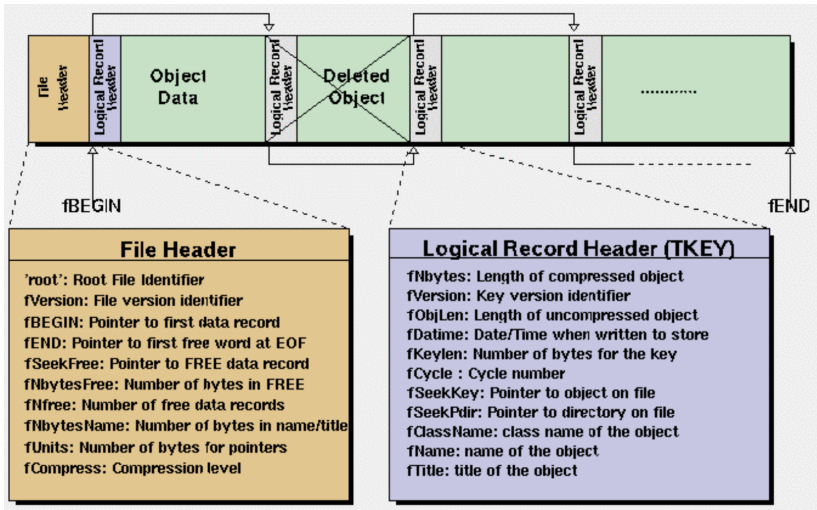
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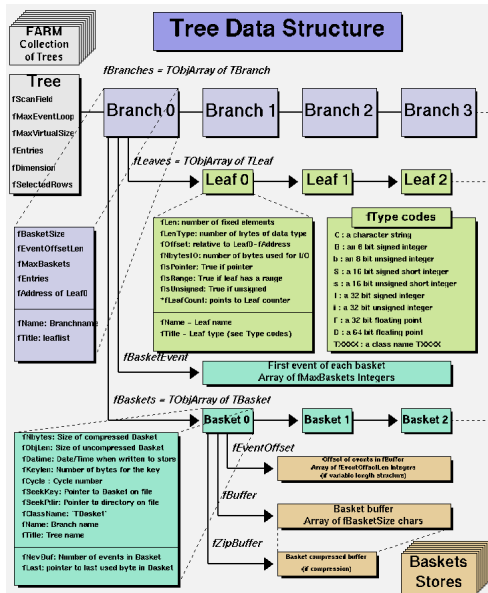
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ROOT File

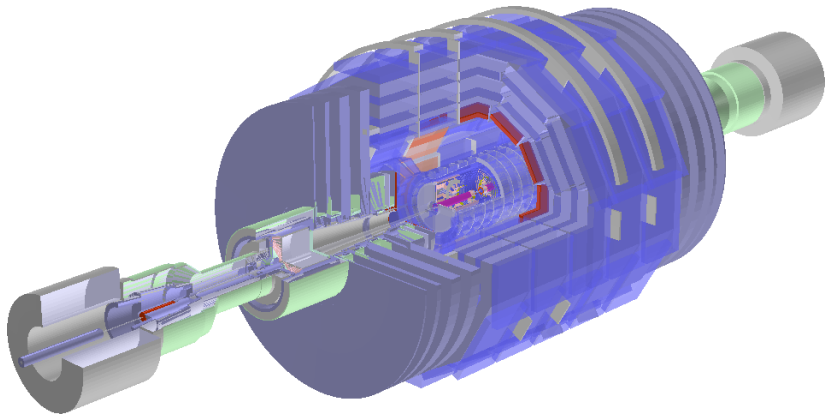


Tree structure

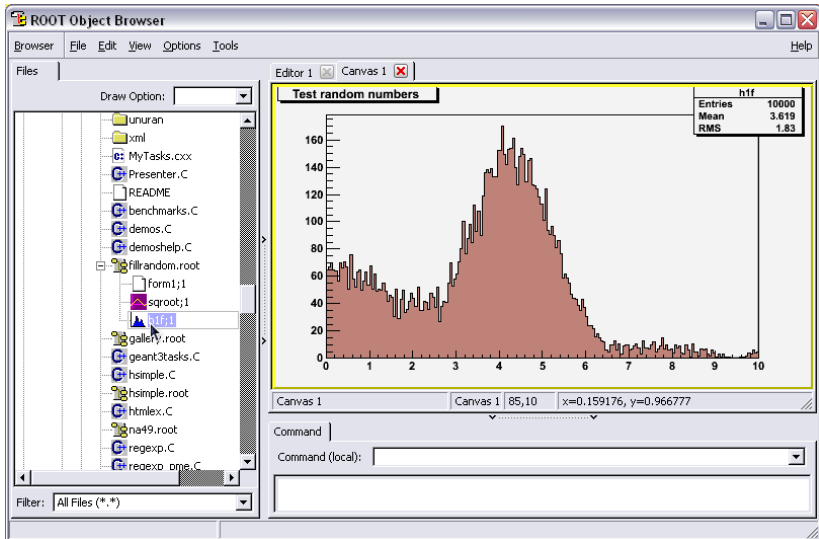


- 3-Vectors and transform
- 4-Vectors and Lorentz Transformations
- Matrix computations
- Numerical algos: derivation, integration, etc
- Minimization functions
- PDF-based analysis
- All standard C, C++ functions: GSL, STL, Boost, etc

Visualisation



GUI



Root Shower Event Display

File Event Tools View Help

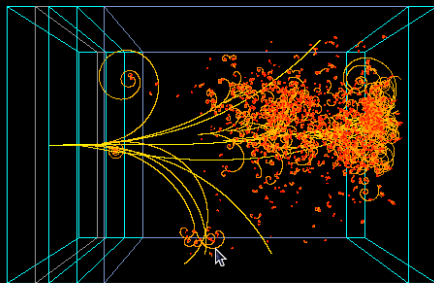
ROOT Shower Monte Carlo
Event Display

Start New Event
Interrupt Simulation
Show Selection

Main Event (Shower) | Selected Track | Statistics | PDG Table

Event

- B0
 - D*(2010)-
 - Unknown
 - e-
 - nu(e) bar
 - pi+
 - pi-
 - mu-
 - nu(mu) bar
 - D(s)*+
 - D(s)+
 - eta0
 - rho(770)+
 - gamma
 - e+
 - e-



Zoom Forward

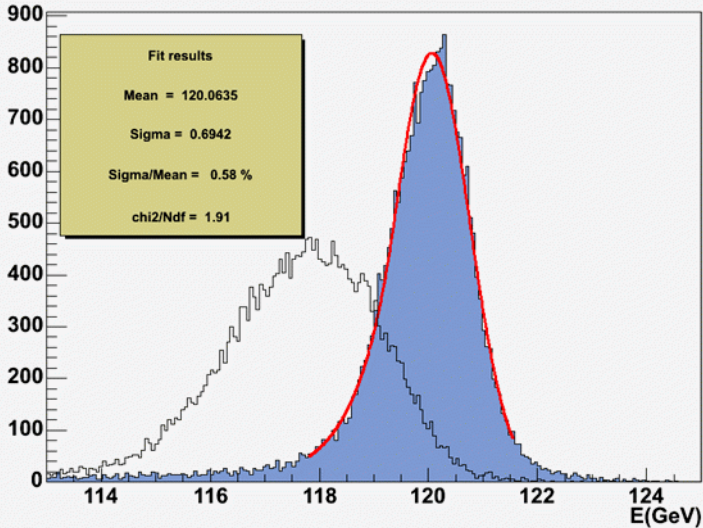
Zoom Backward

Done - Total particles : 5612 - Waiting for next simulation

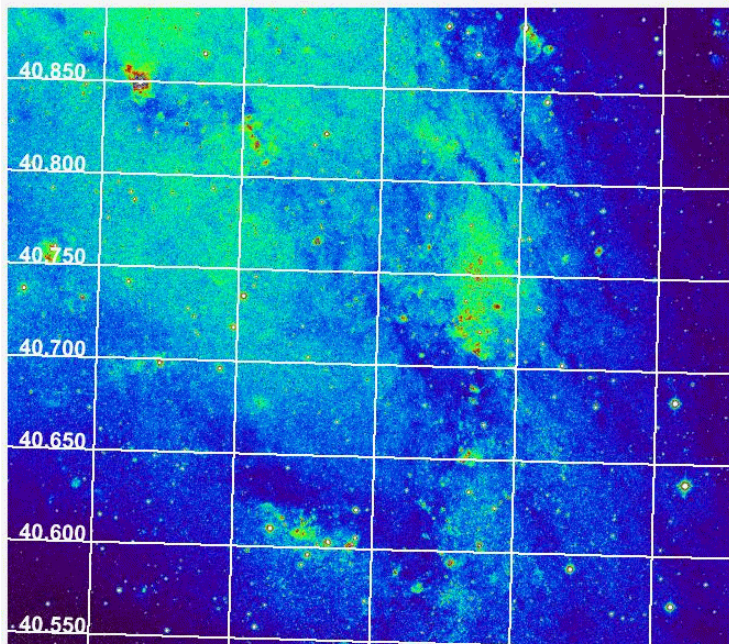
Particle = e+, E = 3.503e-002

Data analysis

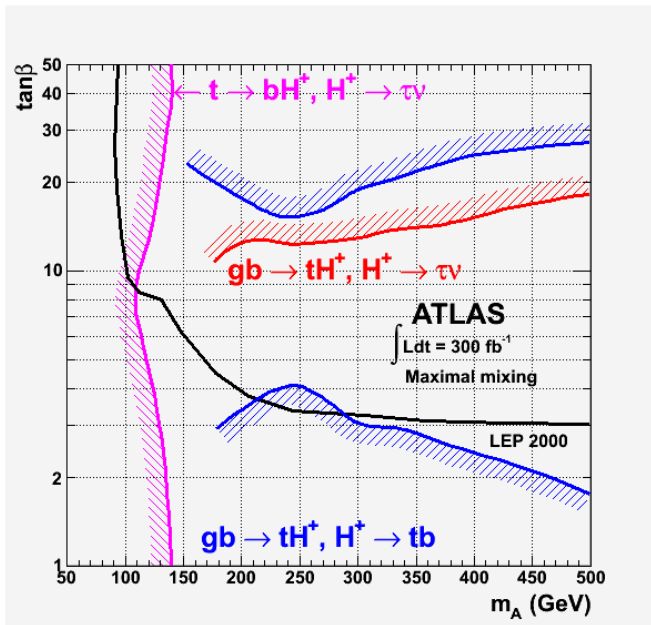
Resolution in S9 at Corner of Xtals 204/224/205/225 @ 120 GeV without compensation



Data analysis



Data analysis



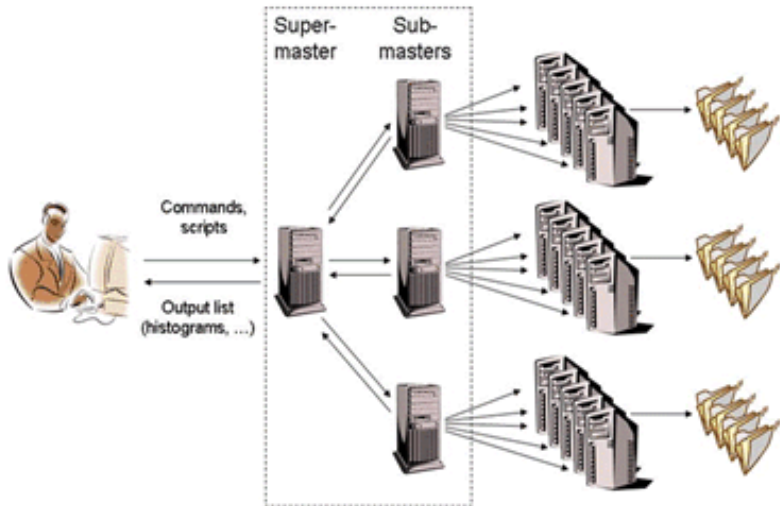
PROOF

Client

Master

Slaves

Files



Integration with other tools

Interpreters:

- C++ (Cling)
- Python
- Ruby (not in ROOT6 yet)

Simulation software:

- Geant-3, Geant-4
- Pythia-6, Pythia-8
- DB: MySQL, Postgres, Oracle, SQLite, ODBC
- CAD: OpenCascade
- OpenFOAM, R
- Grid, AFS, ...

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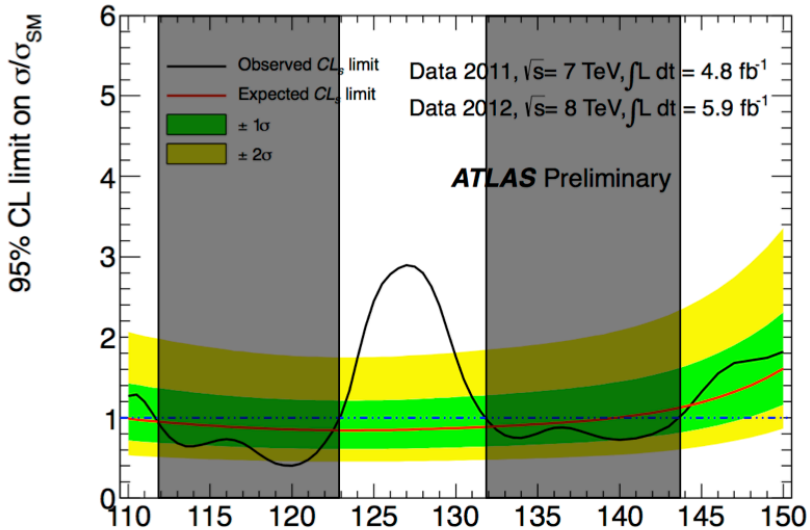
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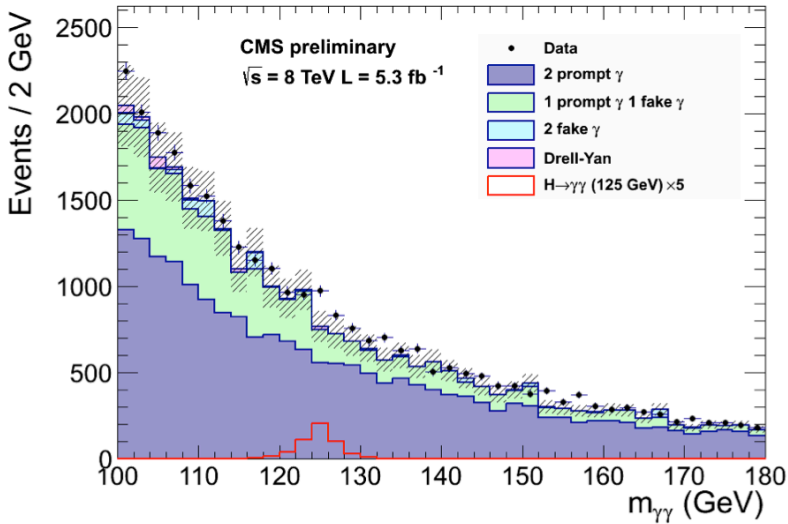
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Higgs discovery

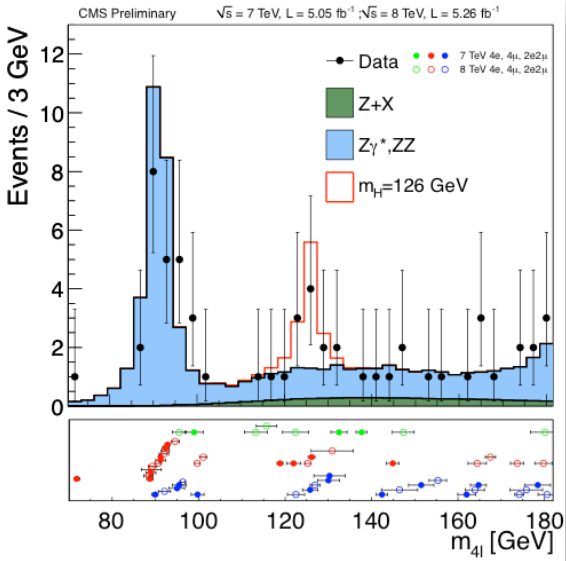


Higgs discovery

2012 8 TeV



Higgs discovery



Scope of applications

Outside of HEP and Nuclear Physics ROOT is used in:

- astronomy
- biology, bioengineering, bioinformatics
- computational neuroscience
- finance
- machine learning
- medicine
- natural language processing

Community

Visit for details and downloads!

Mail list, forums and jira are available for discussion and reports.

Most user issues from novice till expert level are discussed.

Upstream is quite effective in patch review.

Thank you for attention!