ROOT – A brief introduction

Survival with ROOT != Survival at ROOT != Survival despite ROOT

*

- Introduction to ROOT
  - What is it ?
  - Why is it good ?
- Using ROOT
  - Command line, batch-mode, root console or terminal
  - Scripting/Interpretation
    - Example script comparing two current-mode D/A converter architectures designed for COMPASS
  - Compilation
    - Compiling a script as a " *.so " shared object library
    - Compiling standalone
    - Application development
    - Example standalone application
- GUI of ROOT
  - Human interaction
  - Creating a GUI
- Survival [with/at/despite] ROOT
  - User's guide (refer once)
  - Referring to:
    - $ROOTSYS/tutorials (refer once per problem)
    - $ROOTSYS/test (refer once per problem)
  - HTML source code documentation (refer continuously)
- External library usage from within ROOT
  - DQM of ALICE experiment @ CERN
    - Simplified DAQ operation
  - Understanding the detector data
    - Accessing and decoding data

What is it ?

Well, it is:

- **A library:** *ROOT is a very **large class library** consisting of specialized smaller libraries.* ROOT libraries can be included in ***user programs*** and be used as external libraries:
  - ***GUI** development library*
  - *Library providing **signal-slot** mechanism*
  - *Libraries encapsulating functions for **data analysis**, etc.*

- **A C/C++ interpreter:** ROOT has CINT -an embedded C ***interpreter***- which allows easy algorithm development. You can execute C/C++ statements just like executing commands on a Linux shell or like writing shell scripts.
  - This way of working generates applications running slower, however:
  - Development is ***faster*** and in case of necessity the scripts can easily be compiled into *.so objects/libraries which allows faster execution

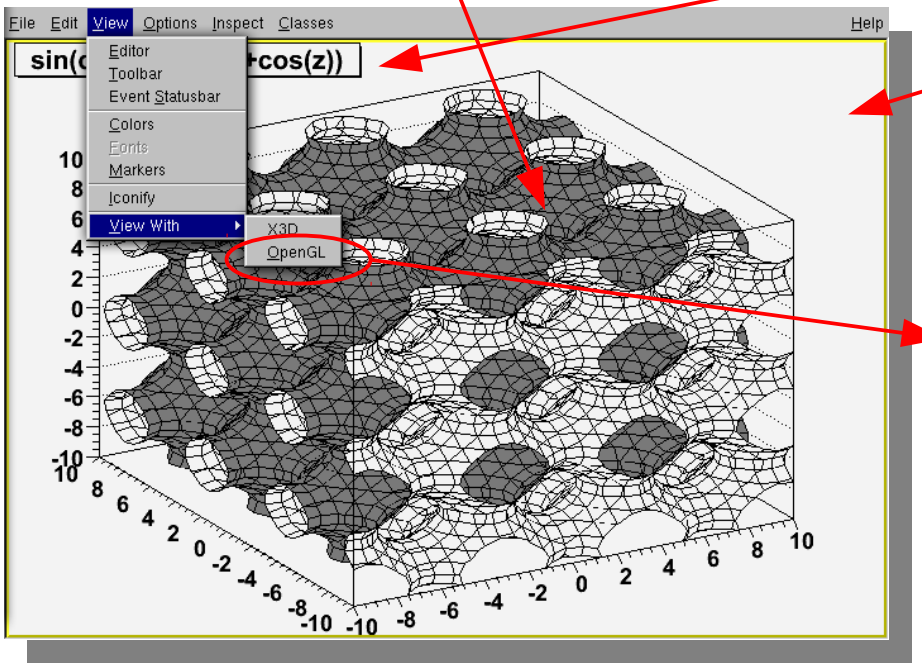
- **A framework:** ROOT provides the ***infrastructure*** needed by the physicists to work
  - Interpreter, histograming and analysis functions, GUI development capability, I/O functions, class libraries, parallel processing and threads, functions specific to sockets and network communication, etc. These are all ***ready to use***, minimizing the effort of development.

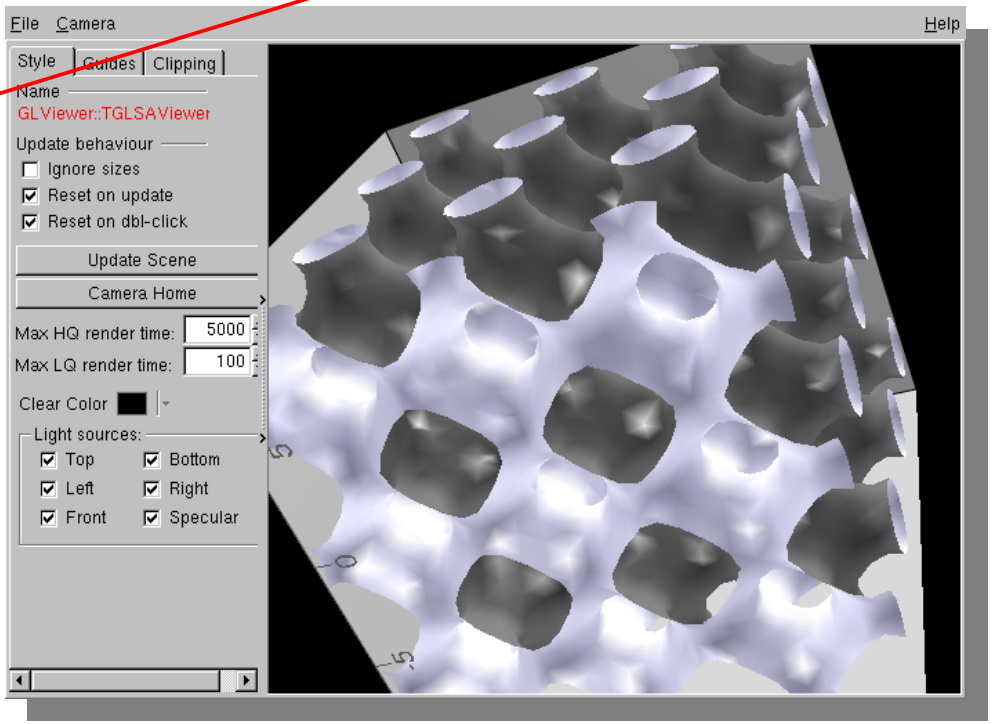
Why is it good ?

Because of the supposed fact that:

- There are advantages of working within a ***framework***, such as the following:
  - No need to write ***many commands*** to achieve a ***specific functionality***
  - High ***reliability*** of developed code due to extensive library usage
  - ***Consistent*** class hierarchy of the developed code
  - ***Flexibility*** of a modular architecture, thus “develop-and-reuse” is easier
  - Physicist can ***focus*** on his/her subject more

```
root [0] TF3 f1("HelloWorld","sin(cos(x)+sin(y)+cos(z))",-10,10,-10,10,-10,10)
root [1] f1->Draw()
<TCanvas::MakeDefCanvas>: created default TCanvas with name c1
root [2] HelloWorld->SetTitle("Something else !..")
```

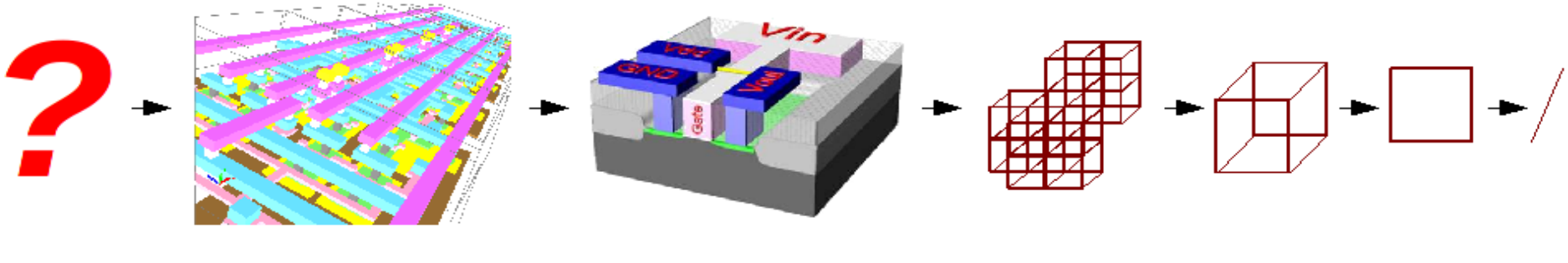




Why is it good ?

Because of the supposed fact that:

- There are advantages of working within an ***object-oriented*** framework:
  - Specific to object-oriented languages, the data are embedded within the class instances, allowing easier ***abstraction***, and leading to more develop-and-***reuse*** of library components
  - Generation of classes out of other classes allows ***further*** development and/or modification of already existing classes
  - ***Hierarchy of classes*** resembles conceptual hierarchy of real-world objects allowing easy abstraction/development



  - Developed code is far from being ***complex***, the data are localized within class instances and are not distributed over many global variables as it is the case for procedural approach (e.g. C or FORTRAN)
  - Removing and/or adding new classes into the developed code does not change the ***architecture*** therefore an architecture can be maintained during development

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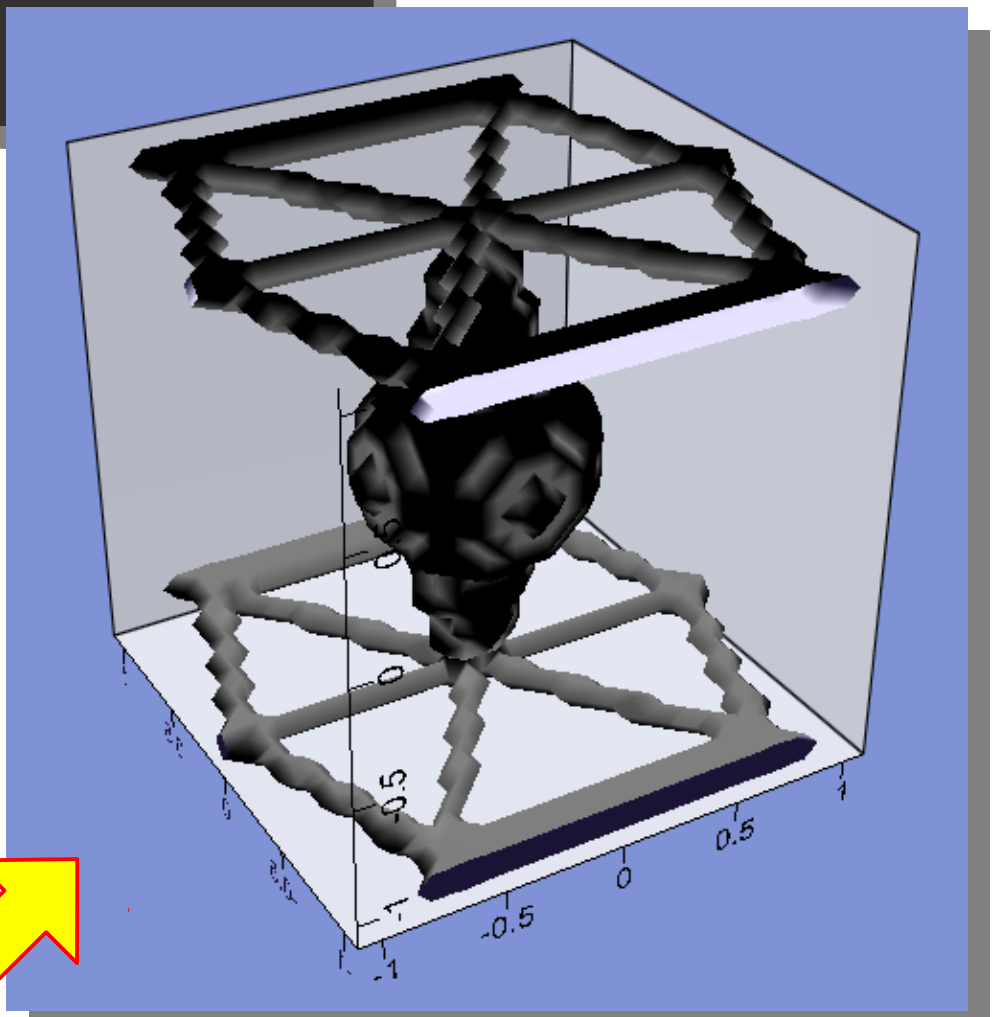
Installation & tie fighter math

Intended usage ?

```
> tar xvfz root_v5.22.00.source.tar.gz
> export ROOTSYS=$HOME/root
> export PATH=$PATH:$ROOTSYS/bin
> export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$ROOTSYS/lib
> cd root
> ./configure
> make
> sudo make install
> _
```

- Set environment, configure, compile and ROOT is ready to be used.

```
# root -l
> TF3 *tieFighter = new
  TF3("tieFighter","(x^2+y^2+z^2<0.2)+
  ((y^2+z^2<0.08)*(x<0.4)*(x>0))+
  (x^2+4*y^2<(1-TMath::Abs(z))*0.12)+
  ((TMath::Abs(z)<0.95)*(TMath::Abs(z)
  >0.9)*(TMath::Abs(x)
  +TMath::Abs(y)*0.3<1))+
  ((TMath::Abs(z)<1)*(TMath::Abs(z)>0.
  89))*((TMath::Abs(x)<0.7)*(TMath::Ab
  s(y)>0.9)+(TMath::Abs(y)<0.035)+
  (x>y*0.7-0.05)*(x<y*0.7+0.05)+(-
  x>y*0.7-0.05)*(-x<y*0.7+0.05)+
  ((TMath::Abs(x)
  +TMath::Abs(y)*0.3<1.05)*(TMath::Abs
  (x)+TMath::Abs(y)*0.3>0.95)))",-
  1.1,1.1,-1.1,1.1,-1.1,1.1);
> tieFighter->Draw()
```

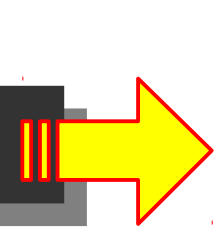


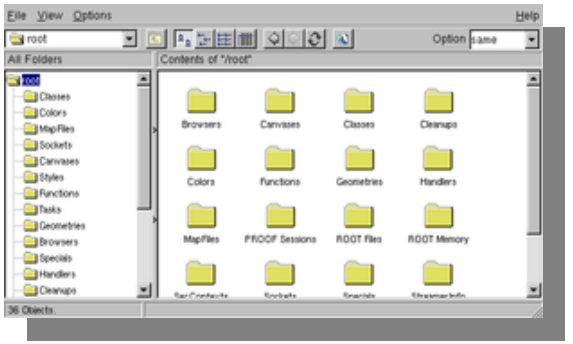
Usage – ROOT Command Line

Invoking commands

- *Invoking C/C++ statements just like invoking shell commands*
  - Almost all C/C++ phrases and all classes of ROOT can be used without the need for inclusion such as "**#include<stdio.h>**". You even do not have to start a function properly like: "**int main()**". Example: we create an instance of the ROOT class named TBrowser and call its instance as "myBelovedBrowser" below:

```
root [0] TBrowser myBelovedBrowser
root [1] _
```





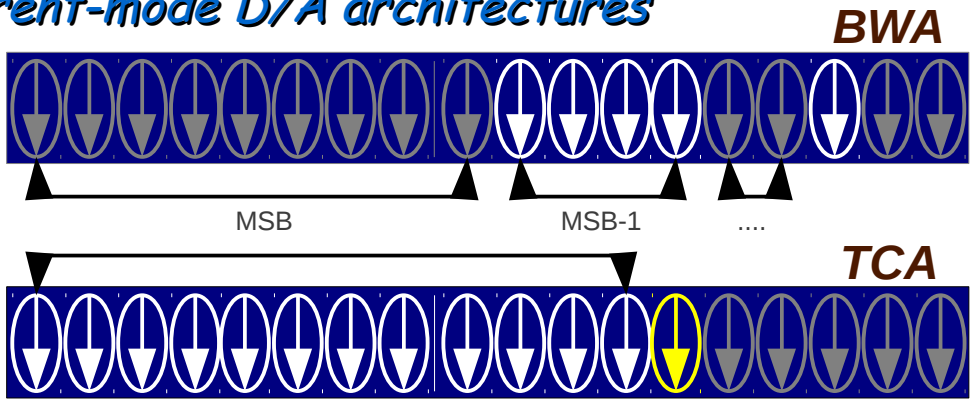
  - Or we write a loop on the fly:

```
root [0] for (int i=0 ; i<10 ; i++) {
end with '}', '@':abort > printf("Square root of %d is %d \n", i*i, i);
end with '}', '@':abort > }
Square root of 0 is 0
Square root of 1 is 1
Square root of 4 is 2
Square root of 9 is 3
Square root of 16 is 4
Square root of 25 is 5
Square root of 36 is 6
Square root of 49 is 7
Square root of 64 is 8
Square root of 81 is 9
root [1] _
```

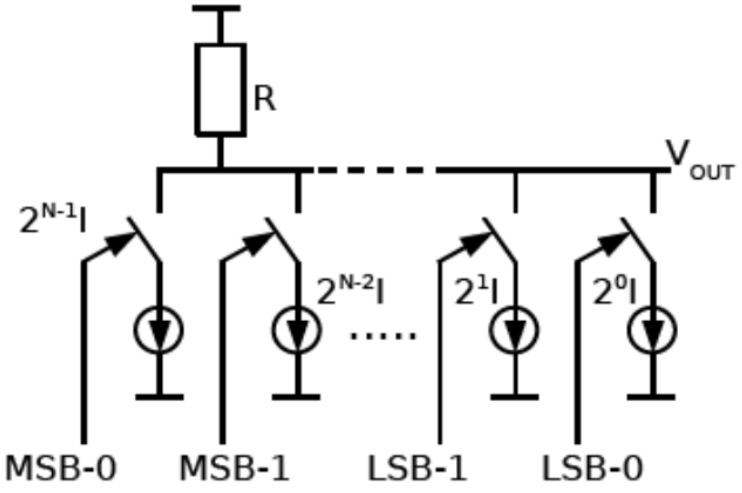
Usage - Scripting

An example script to compare two current-mode D/A architectures

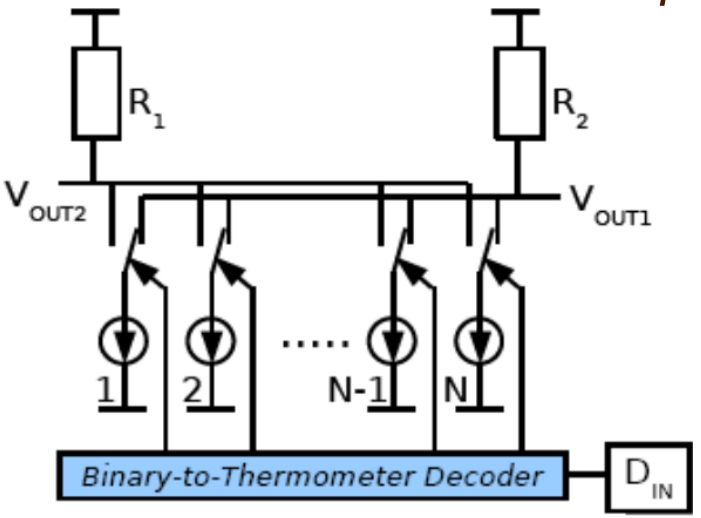
- A **10-Bit** current-mode D/A converter
- Two possible **architectures**
- Have to **choose one**
- Need for **qualitative comparison**
- Monte Carlo (MC) is a **must**



- Generate random numbers out of a Gaussian with a x_c **of 1** and a σ **of 0.02**
- Let these numbers to be the unit current sources forming the two D/As
  - ***TCA Case***: *each step is represented by an addition of a single current source defining the output voltage*
  - ***BWA Case***: *let the sum of the first* $2^{(N-1)}$ *sources form MSB, sum of the next* $2^{(N-2)}$ *sources to form the next bit after MSB, and so on.*
- Calculate INL and DNL for both of the architectures in RMS and compare.



Binary weighted (BWA)



Thermometer coded (TCA)

Usage - Scripting

An example script to compare two current-mode D/A architectures

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mimariKarsilastirici.C | mimariKarsilastirici2.C

```
27 {
28    gROOT->Reset();
29
30    // edit these parameters for other simulations ----------
31    int noofbits=10;
32    int noofiteration4rms=100, nob=100; // nob : no of bins in distro
33    double sigma=0.02, centroid=1.0;
34    const Int_t kUPDATE = 50;
35    bool update=kTRUE;
36    //-------------------------------------------------------
37
38    int nop=pow(2.0, noofbits);
39    int boyut = pow(2, 1*noofbits);
40    double Iu[boyut]; // 2^noofbits current source
41    int lastIncremented=0;
42    TCanvas *c1 = new TCanvas("c1", "Binary vs Thermometer",1200,850);
43    TPad *pad1 = new TPad("pad1","Unit Current Source",0.0,0.0,1.0,1.0);
44    pad1->Draw();
45    pad1->Divide(5, 4, 0.001, 0.001);
46    pad1->cd(5)->SetFillColor(47); pad1->cd(5)->SetGrid() ;
47    pad1->cd(6)->SetFillColor(47); pad1->cd(6)->SetGrid() ;
48    pad1->cd(7)->SetFillColor(47); pad1->cd(7)->SetGrid() ;
49    pad1->cd(8)->SetFillColor(47); pad1->cd(8)->SetGrid() ;
50    pad1->cd(9)->SetFillColor(47); pad1->cd(9)->SetGrid() ;
51    pad1->cd(10)->SetFillColor(47); pad1->cd(10)->SetGrid();
52    pad1->cd(11)->SetFillColor(21); pad1->cd(11)->SetGrid();
53    pad1->cd(12)->SetFillColor(21); pad1->cd(12)->SetGrid();
54    pad1->cd(13)->SetFillColor(21); pad1->cd(13)->SetGrid();
55    pad1->cd(14)->SetFillColor(21); pad1->cd(14)->SetGrid();
56    pad1->cd(15)->SetFillColor(21); pad1->cd(15)->SetGrid();
57    pad1->cd(16)->SetFillColor(21); pad1->cd(16)->SetGrid();
58
59    pad1->cd(1);
60    TH1F *h1f = new TH1F("h1f", "Test random numbers",nob,0.9,1.1);
61    TH1F *h1f_ins = new TH1F("h1f_ins", "Current Iu[i] Set", nob, 0.9, 1.1);
62    TH1F *h1f2= new TH1F("h1f2","Test random numbers COPY",nob,0.9,1.1);
63    TGraph *graph = new TGraph(nop);
64    graph->SetMarkerSize(0);
65    TF1 *gaus = new TF1("gaus","gaus(0)",0.9,1.1);
66    gaus->SetParameters(1, centroid, sigma);
67    gaus->Draw();
68    if (update) c1->Update();
69
70    TH1F *rms_dnl = new TH1F("rms_dnl", "DNL in RMS [LSB unit]",nop-2, 0, nop-2);
71    TH1F *rms_inl = new TH1F("rms_inl", "INL in RMS [LSB unit]",nop, 0, nop);
72    TH1F *rms_dac = new TH1F("rms_dac", "D/A Output in RMS [LSB unit]",nop, 0, nop);
73    TH1F *b_rms_dnl = new TH1F("b_rms_dnl", "b_DNL in RMS [LSB unit]",nop-2, 0, nop-2);
```

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mimariKarsilastirici.C | mimariKarsilastirici2.C

```
182          b_inl[i]=(i+1.0-b_dac[i]);
183          b_rms_inl->SetBinContent(i, b_rms_inl->GetBinContent(i)+b_inl[i]*b_inl[i]);
184          if (i>0 && i<nop) {
185              b_dnl[i-1]=Iu[0]-b_dac[i]+b_dac[i-1];
186              b_rms_dnl->SetBinContent(i-1, b_rms_dnl->GetBinContent(i-1)+(b_dnl[i-1]-Iu[0
187          }
188          b_dac_inl->SetBinContent(i, b_inl[i]-Iu[0]);
189          if (i>0) b_dac_dnl->SetBinContent(i-1, b_dnl[i-1]);
190      }
191      pad1->cd(12);
192      b_dac_inl->Draw();
193      pad1->cd(13);
194      b_dac_dnl->Draw();
195      if (update) c1->Update();
196      pad1->cd(17);
197      delta_dac->Draw();
198      pad1->cd(18);
199      b_cumulatif->Draw();
200      pad1->cd(11);
201      b_dac_ter->Draw();
202
203    } // end loop
204
205     for (int i=0 ; i<nop ; i++) { // calculate RMS
206          rms_dac->SetBinContent(i, sqrt(rms_dac->GetBinContent(i)/noofiteration4rms));
207          if (i<nop-1) rms_dnl->SetBinContent(i, sqrt(rms_dnl->GetBinContent(i)/noofiterat
208          rms_inl->SetBinContent(i, sqrt(rms_inl->GetBinContent(i)/noofiteration4rms));
209          b_rms_dac->SetBinContent(i, sqrt(b_rms_dac->GetBinContent(i)/noofiteration4rms))
210          if (i<nop-1) b_rms_dnl->SetBinContent(i, 1.55-3*(-Iu[0]/2+sqrt(b_rms_dnl->GetBin
211          b_rms_inl->SetBinContent(i, sqrt(b_rms_inl->GetBinContent(i)/noofiteration4rms))
212      }
213      pad1->cd(8);
214      rms_dac->Draw();
215      pad1->cd(9);
216      rms_inl->Draw();
217      pad1->cd(10);
218      rms_dnl->Draw();
219      pad1->cd(14);
220      b_rms_dac->Draw();
221      pad1->cd(15);
222      b_rms_inl->Draw();
223      pad1->cd(16);
224      b_rms_dnl->Draw();
225      if (update) c1->Update();
226
227    gBenchmark->Stop("binary_vs_thermometer");
228 }
```

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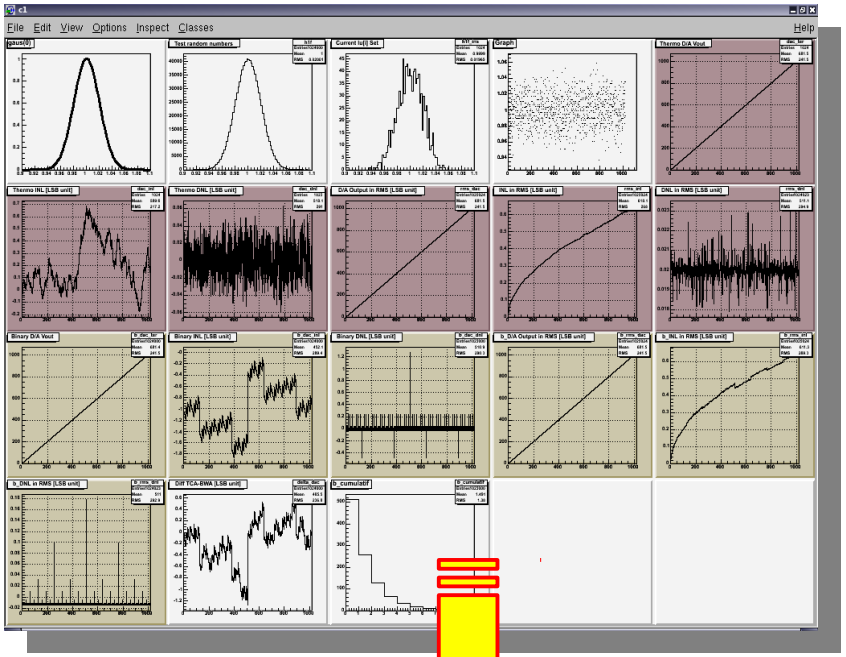
ArchitectureComparer.C

- *Beware that the script does **not** have a **name***
- *Note how the unnamed script starts (**no** header inclusion) and ends (**no** return value).*

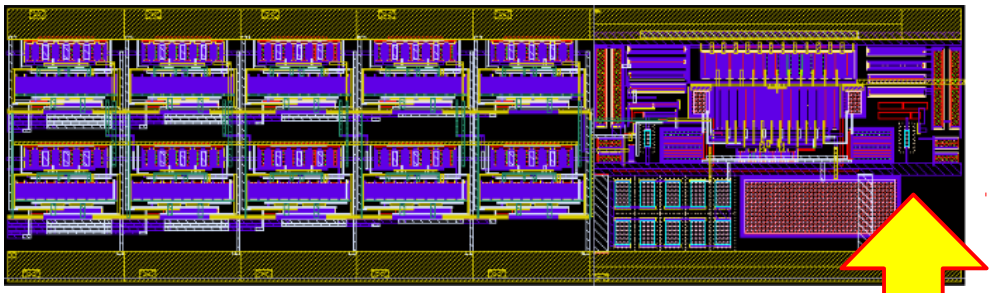
Usage - Scripting

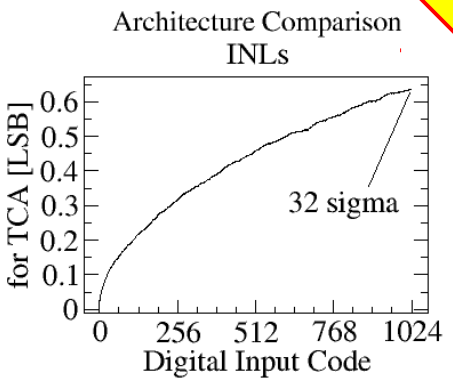
An example script to compare two current-mode D/A architectures

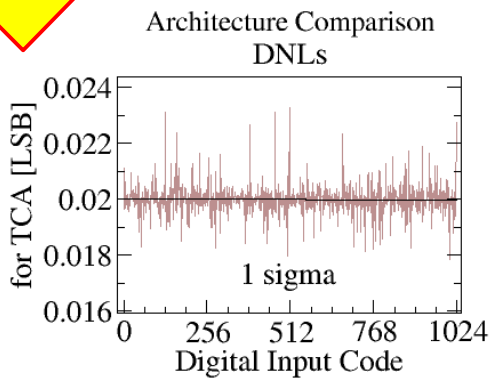


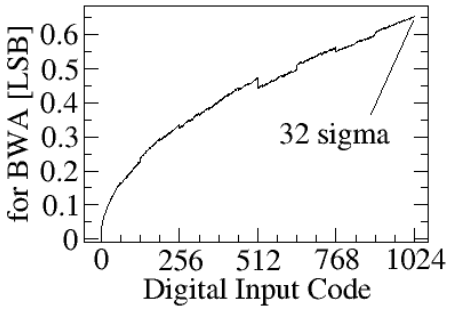
- *INLs are almost identical.*
- *DNLs are quite different, TCA behaves much better, however it will occupy a huge space on the chip layout*
- *Decided, designed the D/A accordingly, delivered it to the experiment people and published the paper*
- *Mission complete !!*

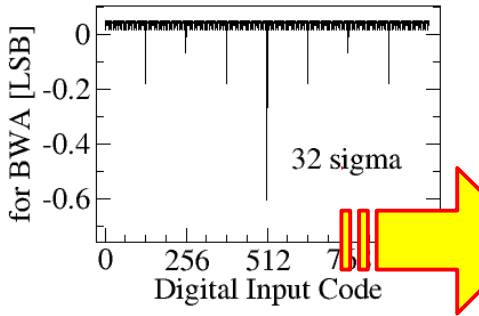
Used within the CMAD front-end ASIC designed for RICH-I detector of the COMPASS experiment at CERN

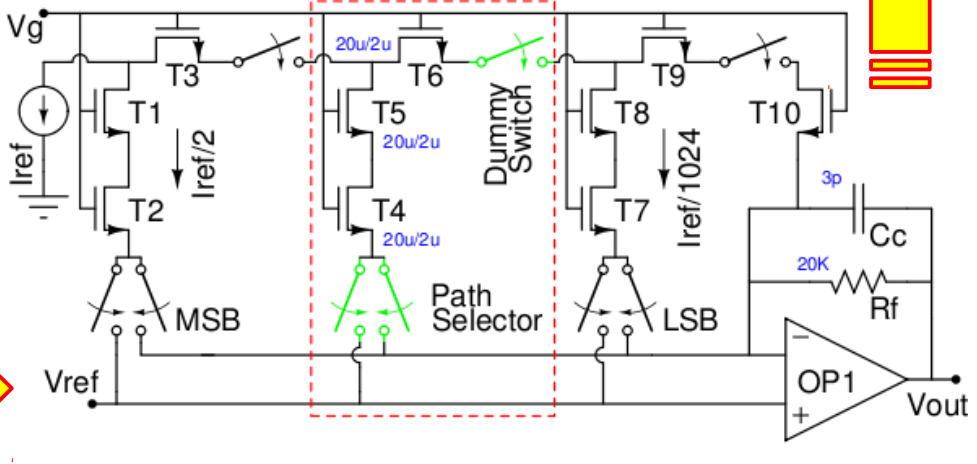












Usage - Compilation

Compiling a script into a "*.so" library

- ArchitectureComparer.C is ***interpreted*** by CINT "***slowly***"
- When ***compiled***, the script will be ***executed***, instead of being interpreted, this is "***fast***"
- With ***almost*** no modification, one can compile the script into a "*.so" library
- "..almost no modification.." actually means:
  - Header files of the classes used must be included (e.g. if *TCanvas* is used then I need the following statement to be inside my code: "`#include<TCanvas.h>`")
  - The function must be given a name, preferably same as the file name. (e.g. for "name.*C*" as the file name, I would write "`int name() {}`")

- Now the script is ready for being compiled into an "***.so***" lirary:

```
> root ArchitectureComparer.C++
root [0] Processing ArchitectureComparer.C++...
Info in <TUnixSystem::ACLiC>: creating shared library
  /home/oc/Documents/HEP_Okulu/workDir/root/./ArchitectureComparer_C.so
```

- I can use my library later at any time I wish so:

```
oc@olmak2:~/Documents/HEP_Okulu/workDir/root$ root -l
root [0] .L ArchitectureComparer_C.so
root [1] ArchitectureComparer()
```

Usage - Compilation

Compiling a script into a "*.so" library

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mimariKarsilastirici.C | mimariKarsilastirici2.C

```
#include <TFile.h>
#include <TNtuple.h>
#include <TH2.h>
#include <TProfile.h>
#include <TCanvas.h>
#include <TFrame.h>
#include <TROOT.h>
#include <TSystem.h>
#include <TRandom.h>
#include <TBenchmark.h>
#include <TCint.h>
#include <TGraph.h>
#include <TF1.h>

int mimariKarsilastirici2() {
   gROOT->Reset();

   // edit these parameters for other simulations ----------
   int noofbits=10;
   int noofiterationforms=100, nob=100; // nob : no of bins in distro
   double sigma=0.02, centroid=1.0;
   const Int_t kUPDATE = 50;
   bool update=kTRUE;
   //-------------------------------------------------------

   int nop=pow(2.0, noofbits);
   int boyut = pow(2, 1*noofbits);
   double Iu[boyut]; // 2^noofbits current source
   int lastincremented=0;
   TCanvas *c1 = new TCanvas("c1","Binary vs Thermometer",1200,850);
   TPad *pad1 = new TPad("pad1","Unit Current Source",0.0,0.0,1.0,1.0);
   pad1->Draw();
   pad1->Divide(5, 4, 0.001, 0.001);
   pad1->cd(5)->SetFillColor(47);  pad1->cd(5)->SetGrid() ;
   pad1->cd(6)->SetFillColor(47);  pad1->cd(6)->SetGrid() ;
   pad1->cd(7)->SetFillColor(47);  pad1->cd(7)->SetGrid() ;
   pad1->cd(8)->SetFillColor(47);  pad1->cd(8)->SetGrid() ;
   pad1->cd(9)->SetFillColor(47);  pad1->cd(9)->SetGrid() ;
   pad1->cd(10)->SetFillColor(47); pad1->cd(10)->SetGrid();
   pad1->cd(11)->SetFillColor(21); pad1->cd(11)->SetGrid();
   pad1->cd(12)->SetFillColor(21); pad1->cd(12)->SetGrid();
   pad1->cd(13)->SetFillColor(21); pad1->cd(13)->SetGrid();
   pad1->cd(14)->SetFillColor(21); pad1->cd(14)->SetGrid();
   pad1->cd(15)->SetFillColor(21); pad1->cd(15)->SetGrid();
   pad1->cd(16)->SetFillColor(21); pad1->cd(16)->SetGrid();

   pad1->cd(1);
```

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mimariKarsilastirici.C | mimariKarsilastirici2.C

```
        if (i>0 && i<nop) {
            b_dnl[i-1]=Iu[0]-b_dac[i]+b_dac[i-1];
            b_rms_dnl->SetBinContent(i-1, b_rms_dnl->GetBinContent(i-1)+(b_dnl[i-1]-Iu[0
        }
        b_dac_inl->SetBinContent(i, b_inl[i]-Iu[0]);
        if (i>0) b_dac_dnl->SetBinContent(i-1, b_dnl[i-1]);
    }
    pad1->cd(12);
    b_dac_inl->Draw();
    pad1->cd(13);
    b_dac_dnl->Draw();
    if (update) c1->Update();
    pad1->cd(17);
    delta_dac->Draw();
    pad1->cd(18);
    b_cumulatif->Draw();
    pad1->cd(11);
    b_dac_ter->Draw();

   } // end loop

    for (int i=0 ; i<nop ; i++) { // calculate RMS
        rms_dac->SetBinContent(i, sqrt(rms_dac->GetBinContent(i)/noofiteration4rms));
        if (i<nop-1) rms_dnl->SetBinContent(i, sqrt(rms_dnl->GetBinContent(i)/noofiterat
        rms_inl->SetBinContent(i, sqrt(rms_inl->GetBinContent(i)/noofiteration4rms));
        b_rms_dac->SetBinContent(i, sqrt(b_rms_dac->GetBinContent(i)/noofiteration4rms))
        if (i<nop-1) b_rms_dnl->SetBinContent(i, 1.55-3*(-Iu[0]/2+sqrt(b_rms_dnl->GetBin
        b_rms_inl->SetBinContent(i, sqrt(b_rms_inl->GetBinContent(i)/noofiteration4rms))
    }
    pad1->cd(8);
    rms_dac->Draw();
    pad1->cd(9);
    rms_inl->Draw();
    pad1->cd(10);
    rms_dnl->Draw();
    pad1->cd(14);
    b_rms_dac->Draw();
    pad1->cd(15);
    b_rms_inl->Draw();
    pad1->cd(16);
    b_rms_dnl->Draw();
    if (update) c1->Update();

   gBenchmark->Stop("binary_vs_thermometer");
   return 0;
}

```

Ln 1, Col 1 INS

ArchitectureComparer2.C

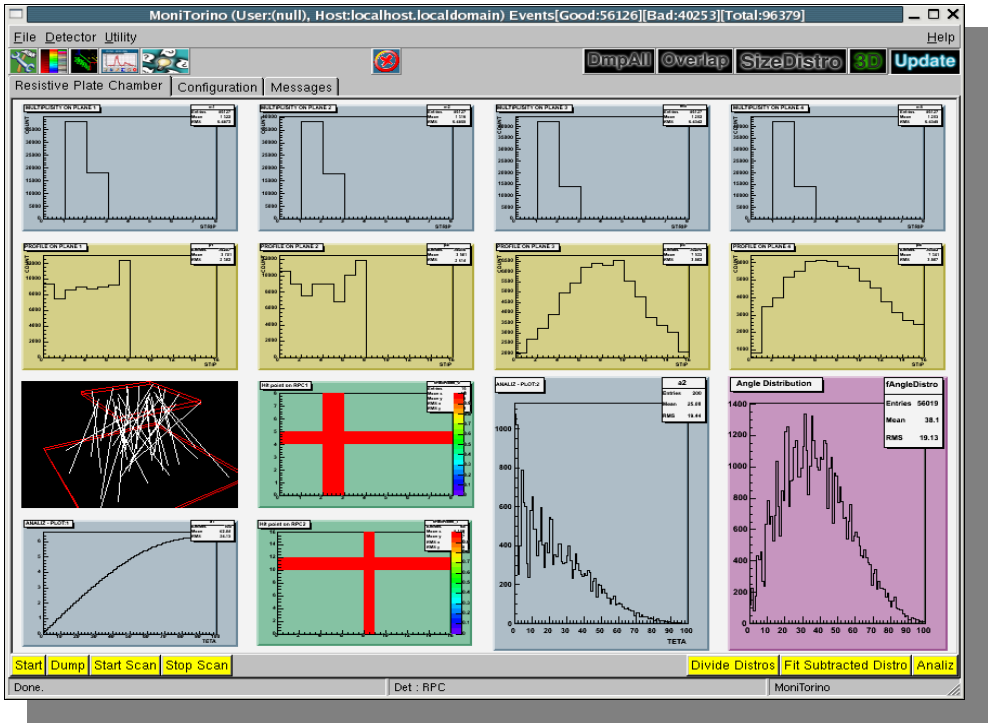
- *Beware that the script **does** have a name*
- *Note how the **named** script starts (**header inclusion**) and ends (**with** a return value).*

Usage – Compiling Standalone

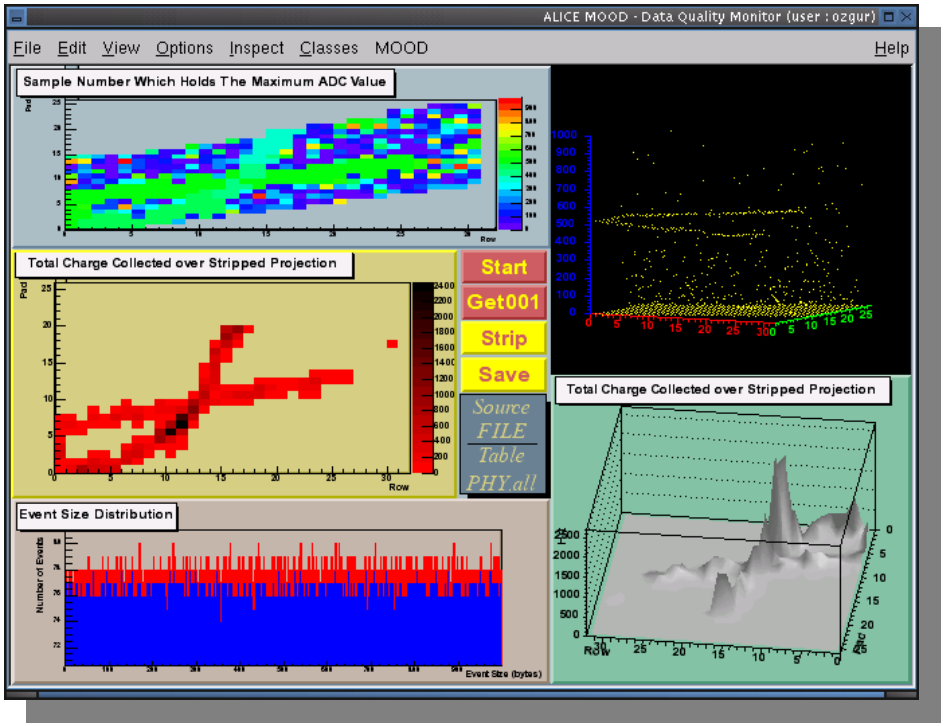
Application development

- ArchitectureComparer() can be loaded into ROOT environment by "***.L***" and can be invoked as if it was a *native ROOT command*
- It will be executed *much faster*
- It will need ROOT to have already been installed
- ***However***, it is also possible to have a standalone application which uses ROOT classes ***as external libraries*** without the need for ROOT environment for execution.

On-line monitoring and off-line analysis tool (MoniTorino) developed for an educational double RPC experiment measuring angle distributions of cosmic particles at the university and INFN of Turin/Italy



Very first version of the data quality monitoring tool, namely MOOD (Monitor Of On-line Data), developed for the ALICE experiment at CERN.



Usage - Compiling Standalone

Standalone application version of the example

File Edit View Search Tools Documents Help

New Open Save Print... Undo Redo Cut Copy Paste Find Replace

firstApp.cxx

```
#include "TApplication.h"
#include "TCanvas.h"
#include "TLine.h"
#include "TF3.h"

int main(int argc, char **argv)
{
    // ROOT application object is created
   TApplication myBelovedApplication("App", &argc, argv);

    // Create a canvas and start signal-slot communication between
    // myBelovedApplication and the window manager of the operating system
   TCanvas *canvas = new TCanvas("canvas", "My Beloved Canvas", 500, 400);
   canvas->Connect("Closed()", "TApplication", &myBelovedApplication, "Terminate()");

    // Write your application (same command as in the example)
   TF3 *func = new TF3("func","sin(cos(x)+sin(y)+cos(z))",-10,10,-10,10,-10,10);

    // Make the object visible
   func->Draw();

    // Update the objects on the canvas
   canvas->Update();

    // Leave the application on its own (event loop)
   myBelovedApplication.Run();

   // Once finished, it will return a zero to the operating system
   return 0;
}
```

Class headers are included

Usual C/C++ start

C++ Tab Width: 8 Ln 6, Col 32 INS

Usage – Compiling Standalone

Standalone application version of the example

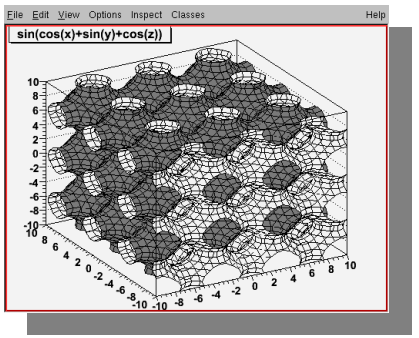
- *An elegant method to write applications is via **Makefile**, but we will not do it here*

- To compile the code in the previous page:
  - **g++ -L/usr/lib/root -lCore -lCint -lRIO -lNet -lHist -lGraf -lGraf3d -lGpad -lTree -lRint -lPostscript -lMatrix -lPhysics -lz -pthread -lm -ldl -rdynamic -pthread -m64 -I/usr/include/root -L/usr/lib/root -lCore -lCint -lRIO -lNet -lHist -lGraf -lGraf3d -lGpad -lTree -lRint -lPostscript -lMatrix -lPhysics -lz -lGui -pthread -lm -ldl -rdynamic firstApp.cxx -o firstApp**

- *Remembering all the above things is hard, therefore we will use:*
  - ***root-config**: a command-line tool to make lives of ROOT users easy (libraries usually have tools like this one)*
  - *It returns appropriate lines needed for compilation*
  - *Usually used in-between " ` ", aka escape symbol*

  - **g++ `root-config --glibs --cflags` firstApp.cxx -o firstApp**

```
oc@olmak2:~/ISOTDAQ/root$ ./firstApp &
[1] 16811
oc@olmak2:~/ISOTDAQ/root$ _
```



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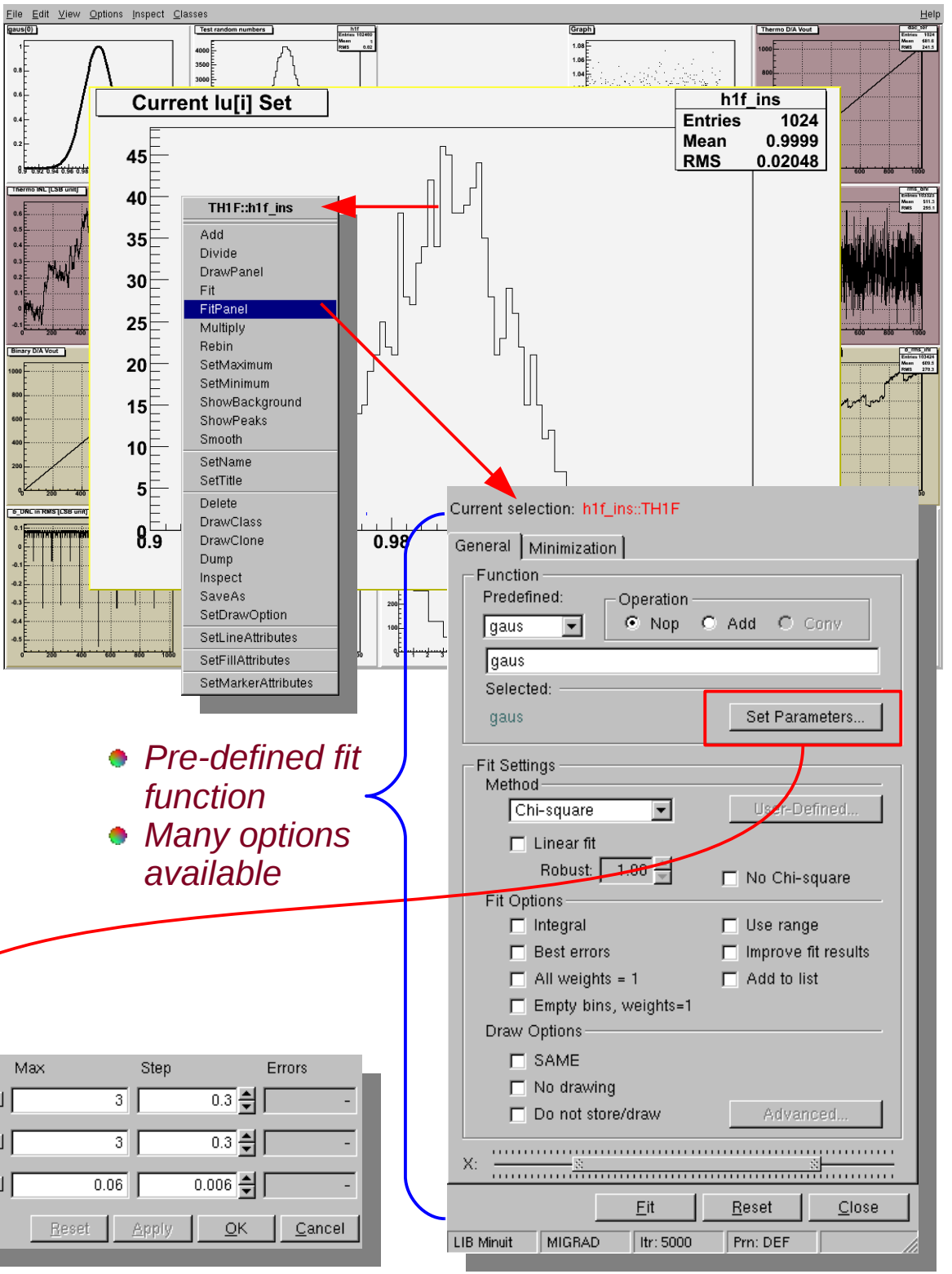
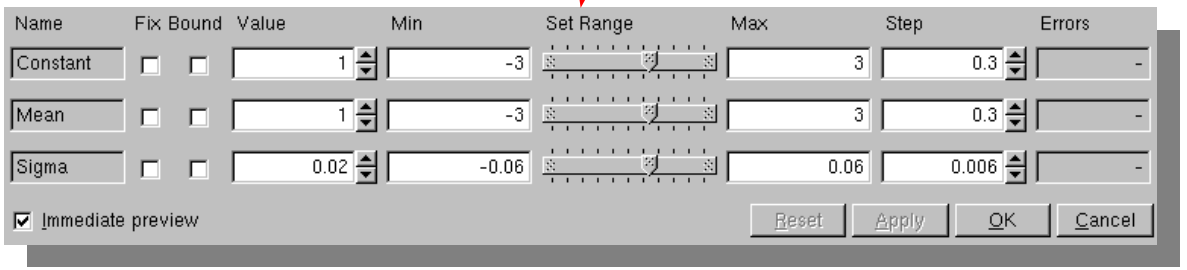
Usage

GUI – Human interaction

- All created windows and everything but everything on these windows (canvases, pads, histograms, titles, pave texts, sub-windows, axises, etc.) are either ROOT class instances or are instances of derived classes.
- Right click would bring a menu of some of the member functions of the instances created on the heap

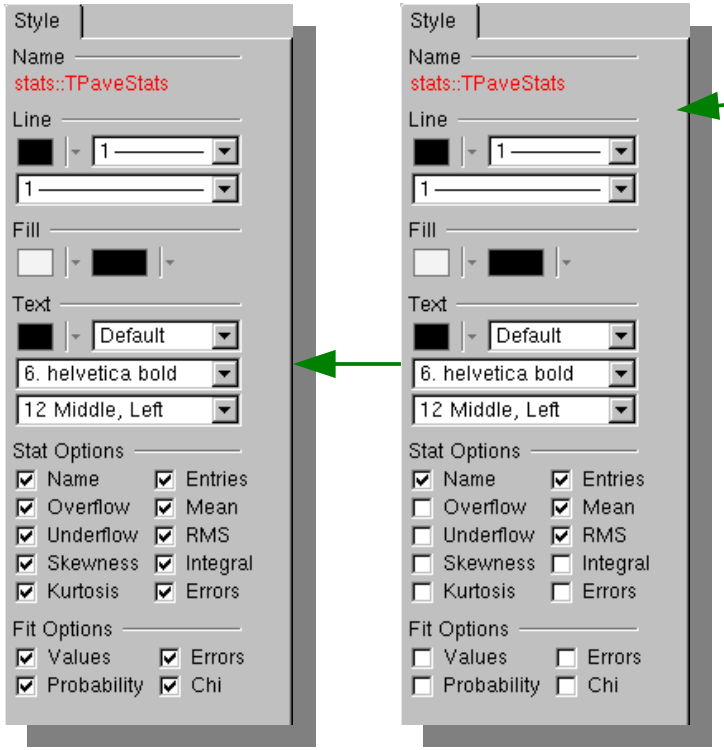


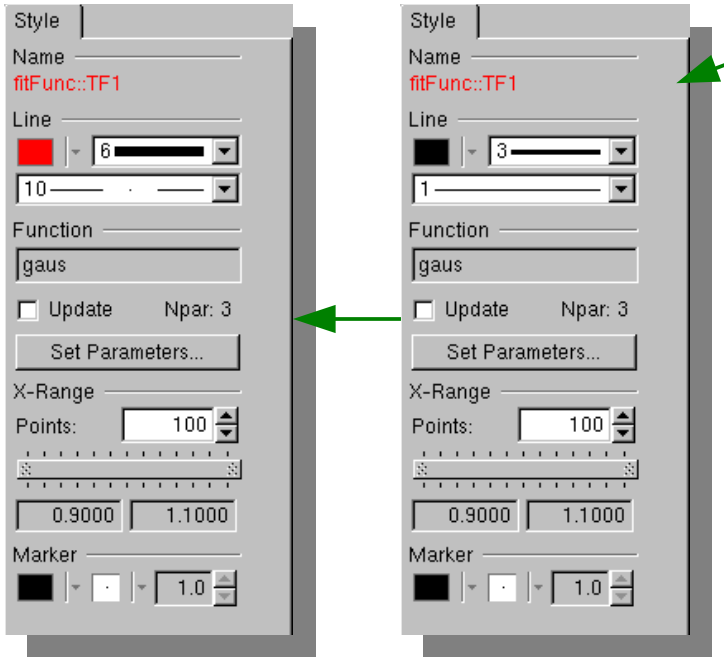
- *Pre-defined fit function*
- *Many options available*

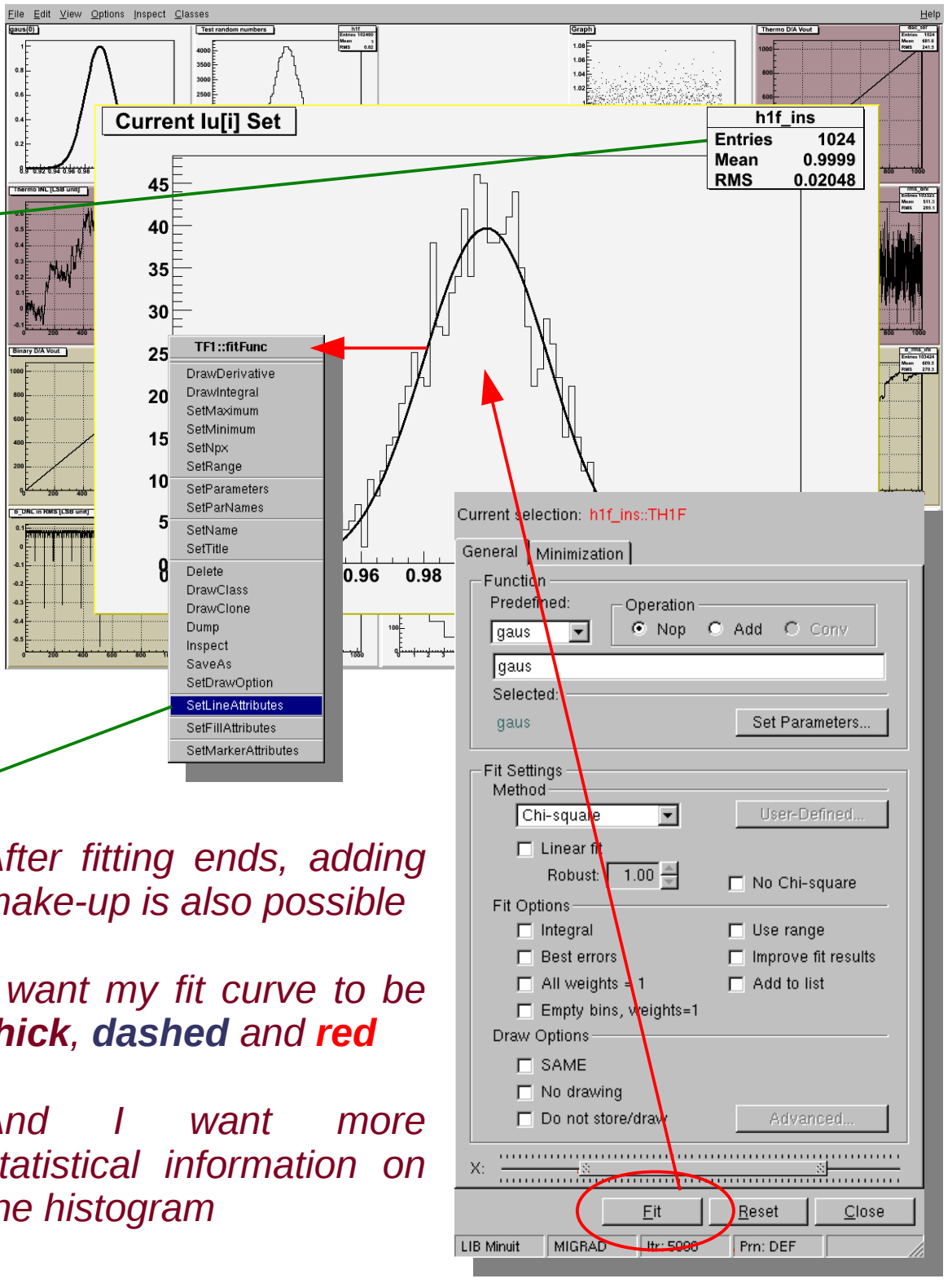


Usage

GUI - Human interaction





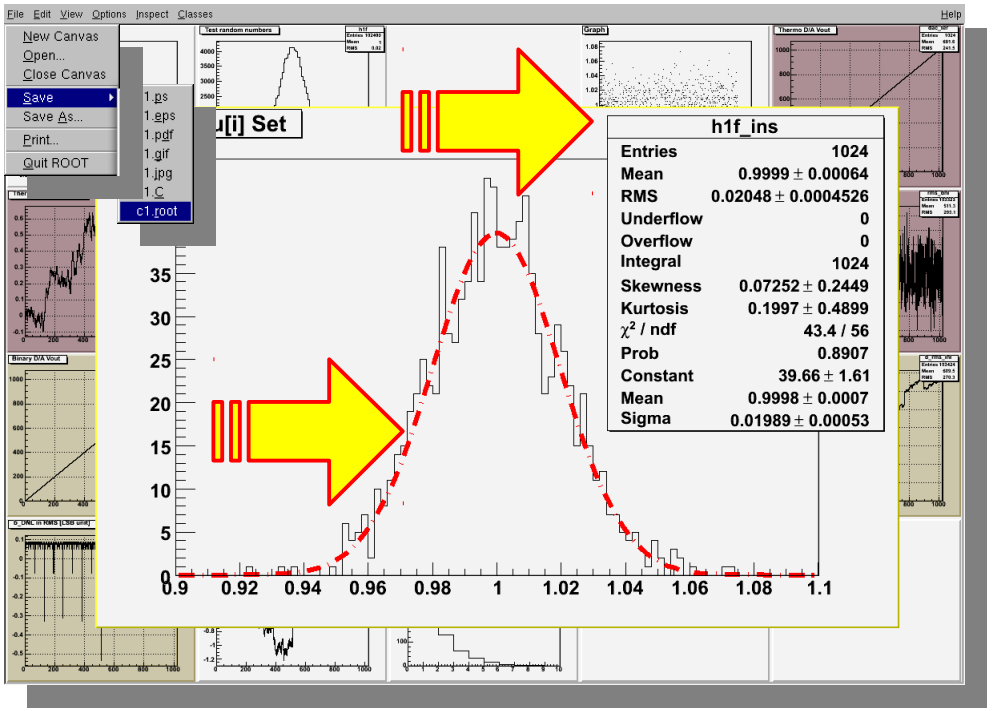


- *After fitting ends, adding make-up is also possible*
- *I want my fit curve to be **thick**, **dashed** and **red***
- *And I want more statistical information on the histogram*

Usage

GUI – Human interaction

- We have developed the code needed, performed the analysis, made the results more visible by adding make-up, ***BUT*** the mission is not yet complete !
- The ***work*** should be ***saved*** !
- There are many available methods:
  - It can be saved as a *.C source code
    - To get the results again it must be reinterpreted by ROOT (e.g. "**`root -l code.C`**")
  - It can be saved as a *.root file
    - Content can be directly browsed by a TBrowser object (e.g. "**`TBrowser a`**")
  - It can be saved as a picture:
    - ps, eps, gif v.b.



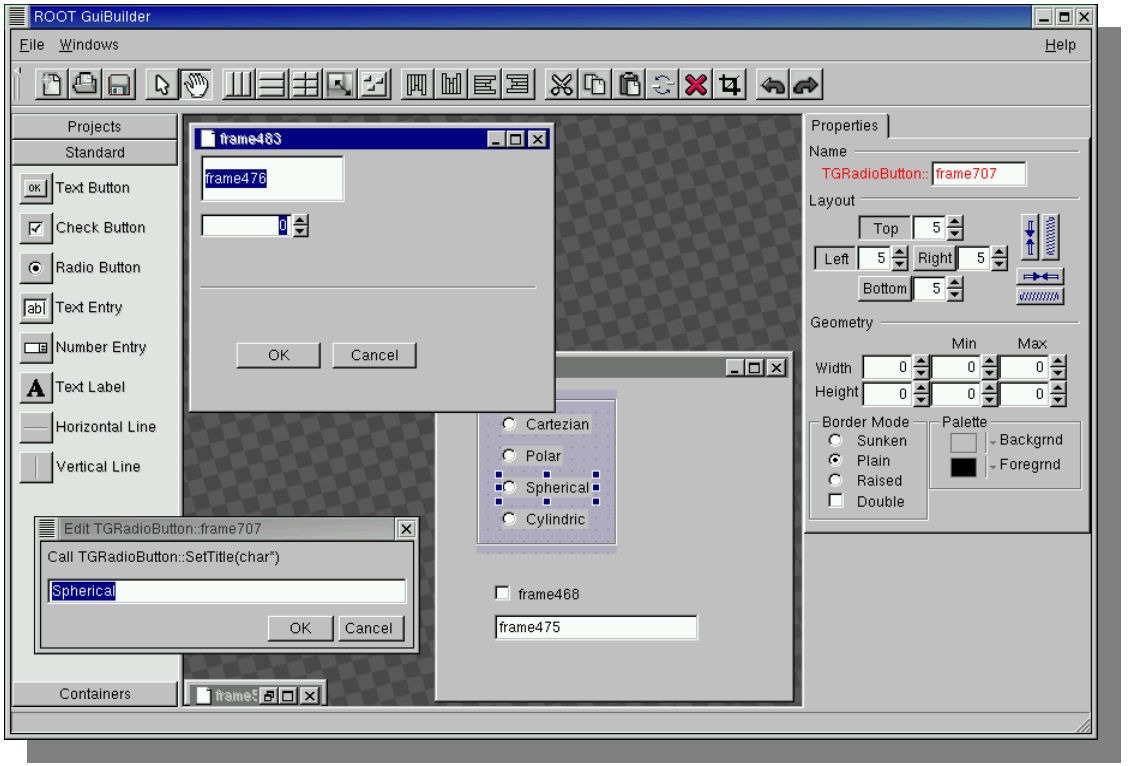
- ***Thicker***, ***dashed*** *and* ***red***
- *More statistical information*

Example

Creating a GUI

- Users can design GUIs for their applications developed with ROOT libraries
- There are two main ways of doing so, usually iteratively used:
  - Writing source code
  - Using an instance of "***TRootGuiBuilder***" class

```
oc@olmak2:~/ISOTDAQ/workDir/root$ root -l
root [0] TRootGuiBuilder a
root [1] _
```



- Graphically prepared application is saved as *.C script and development of actual code is continued over this "template".
- ***Educative:*** ***design*** the GUI, ***save*** it, ***read*** *it !!*
- ***Saves time***: you do not have to memorize ROOT GUI classes
- ***Save frequently against frequent crashes not to lose work !!***

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Survival with/at/despite ROOT

User's Guide

- Meeting with a new library stands upon 4 legs: *(subjective)*
  i. User's manual
  ii. Source code documentation
  iii. Set of examples showing library usage (tutorial, test, example, etc.)
  iv. You, reading these resources and trying them out

- ***We are lucky:*** ***ROOT has all these things !!*** Meeting with ROOT ***is trivial !!***

- ***User's guide***, tells us on which ideals the library has been developed, its architecture and "***hello world***" examples with a lot of relevant explanations.
- It ***does not change*** fast, it is rather ***static***.
- It must be studied/digested ***once*** at the beginning
- For many of us, only having a ***skin-deep look*** renders ***enough*** for every new ***major release*** (i.e. change of major version number)

- ***All*** the things mentioned within this lecture ***and more***, written ***fluently*** with a lot of useful tricks can be found in ROOT User's Guide.

Survival with/at/despite ROOT

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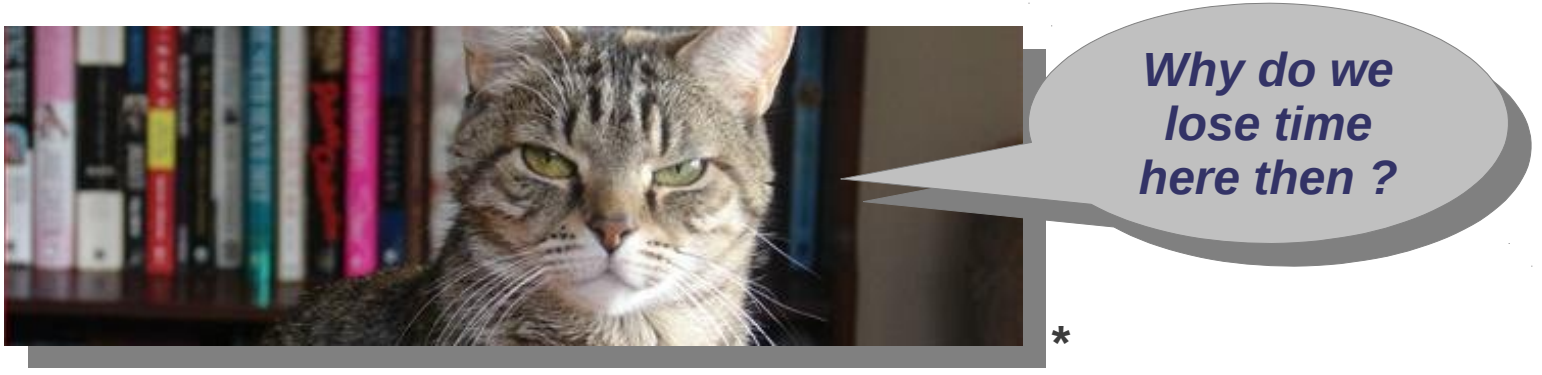

*

Survival with/at/despite ROOT

User's Guide

ROOT User's Guide is more than ~500 pages ! Moreover ...

... it just teaches a language but not what to say in that language !

*

Survival with/at/despite ROOT

Effective function of $ROOTSYS/tutorials directory

- The line separating ***death*** and ***life*** while ***scripting***
- Not to be memorized; to be ***referred continuously*** while ROOTing; the lowest level of scripting examples, a teacher

- Learning to use a new library, especially in languages where almost everything is hard without library support, is ***equivalent*** to learning a new programing language
- A language is best learned by ***practicing***
- This directory is where you practice ROOT ***scripting*** language

- To get acquainted with ROOT, open (with your favorite text editor) ***all but all*** the scripts, have a look at each code, run with ***root -l xxx.C*** and understand what they do; not deeply, just to have an idea

- This is vital because:
  - Understanding ***what percentage*** of the tutorial codes can actually run without problems is important. Is the library you will use ***perfect*** ?
  - The scripts within this directory are the ***starting points*** for your future developments.
  - You do not have to remember which one does what.
  - However, you ***must be able to say*** "***there was something in the tutorials directory that does a similar thing...***" when you need assistance

Survival with/at/despite ROOT

Effective function of $ROOTSYS/test directory

- The line separating ***death*** and ***life*** while ***compiling standalone applications***
- Not to be memorized; to be ***referred continuously*** while ROOTing; the lowest level of application examples, a teacher

- Learning to use a new library, especially in languages where almost everything is hard without library support, is ***equivalent*** to learning a new programing language
- A language is best learned by ***practicing***
- This directory is where you practice ***application development*** with ROOT

- To get acquainted with ROOT, open (with your favorite text editor) ***all but all*** the source codes, have a look at each code, compile with ***make xxx*** and understand what they do; not deeply, just to have an idea

- This is vital because:
  - Understanding ***what percentage*** of the test codes can actually run without problems is important. Is the library you will use ***perfect*** ?
  - The source codes within this directory are the ***starting points*** for your future developments.
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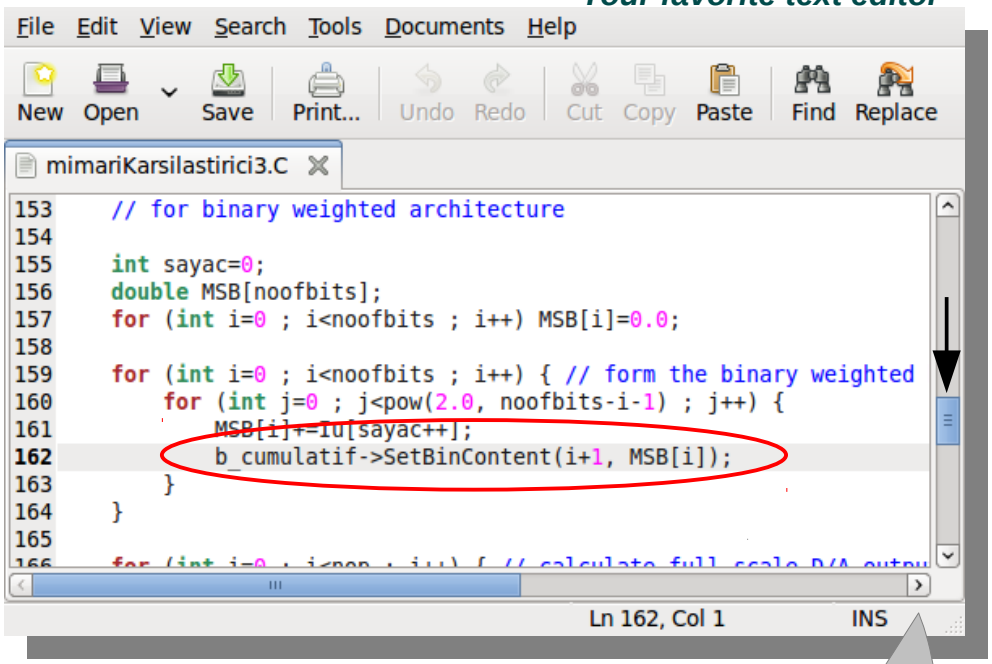
Survival with/at/despite ROOT

Usage of HTML documentation

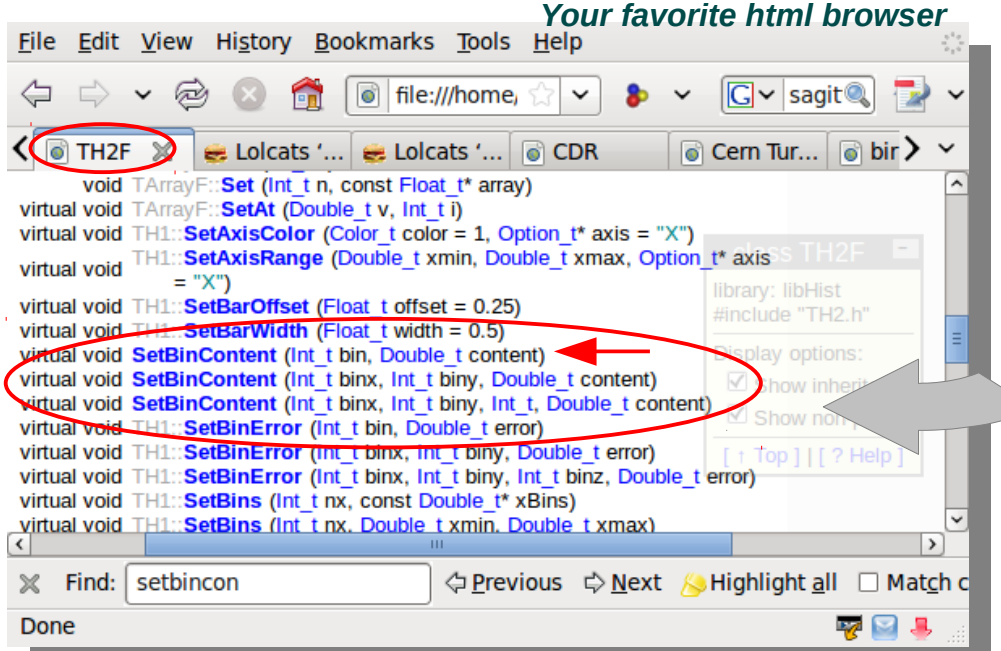
- ***The line*** in-between death and life
- It is not something to learn, it is to refer in a cyclic manner while ROOTing (documentation which is the closest to what you actually use)
- ***On-line/live:*** it is generated out of the version you use at the time, therefore:
  - *Un-like user's guides, it is **not static**; it is not full of "**old**" knowledge; it is **valid** and **up-to-date**, truly useful*
  - Equivalent to reading the source code of the ROOT library, ***least error-prone*** technique to learn what the command you use in your code actually does

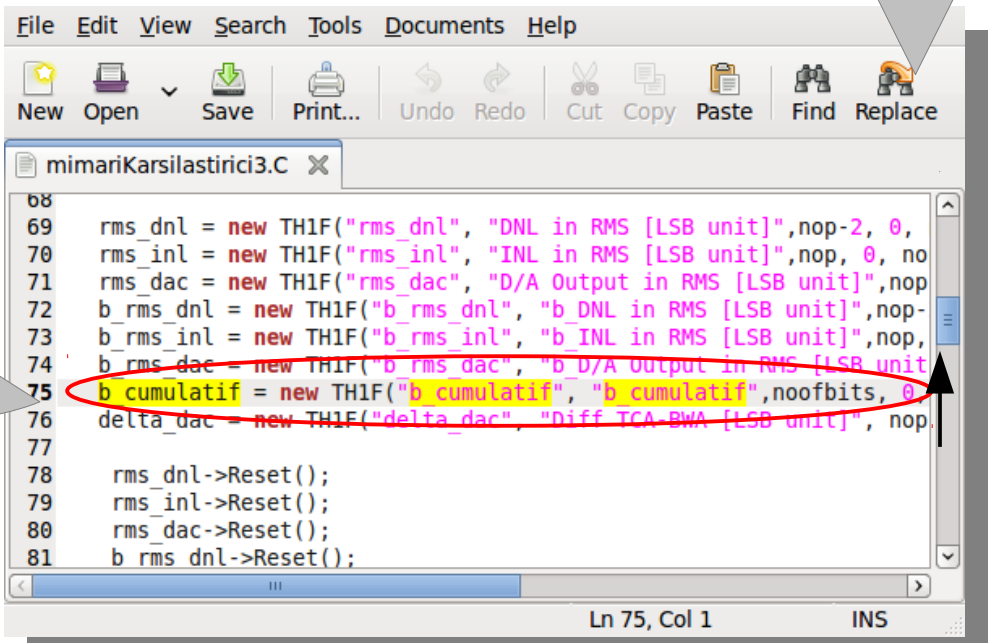
Your favorite text editor



Search for b_cumulatif via Ctrl-F to see what objects instance it is: an instance of TH1F class

Your favorite html browser





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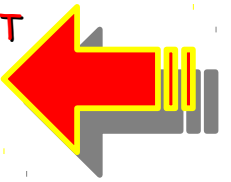
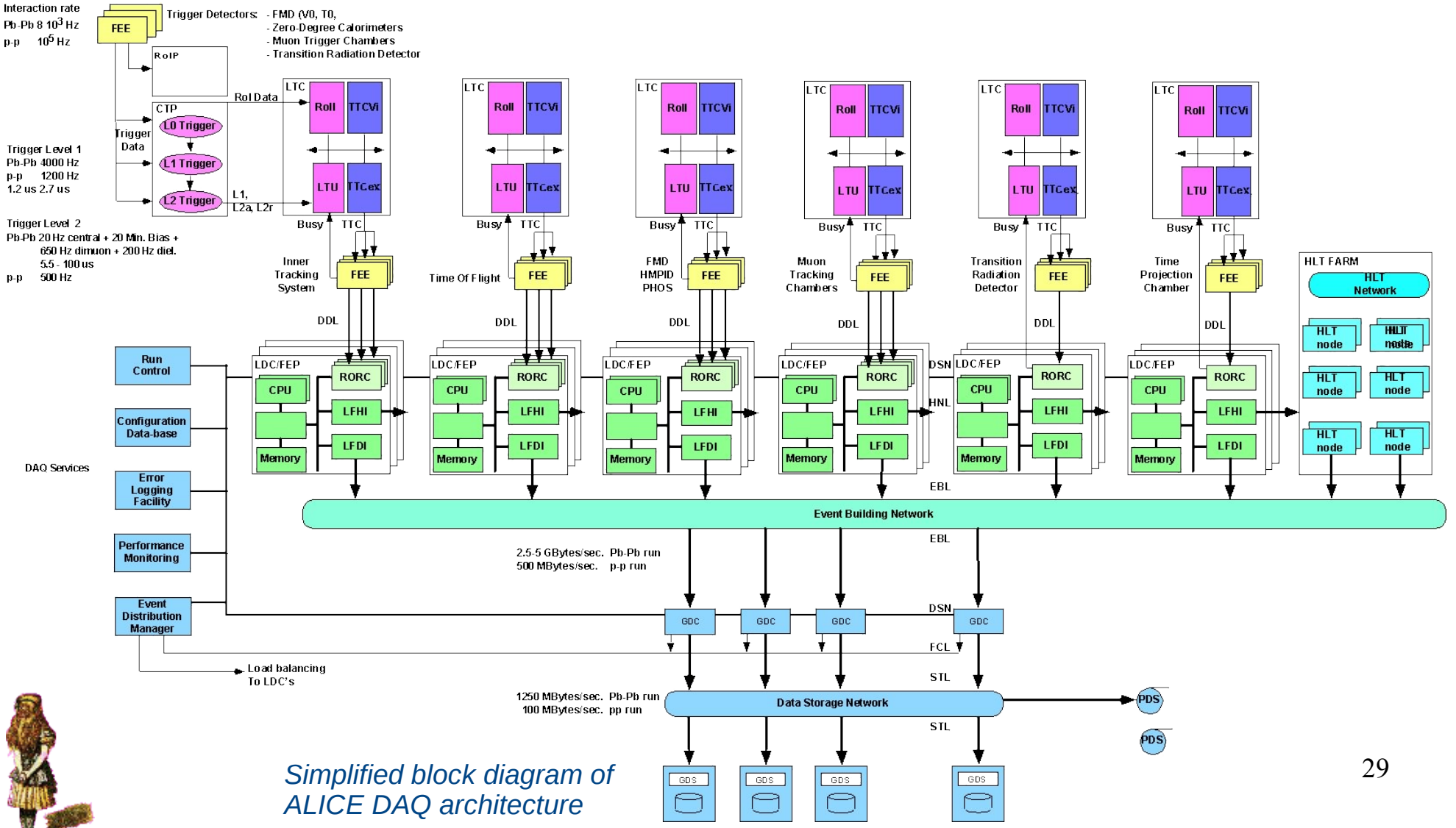


External library usage from within ROOT

Example: Data quality monitoring application for ALICE experiment at CERN

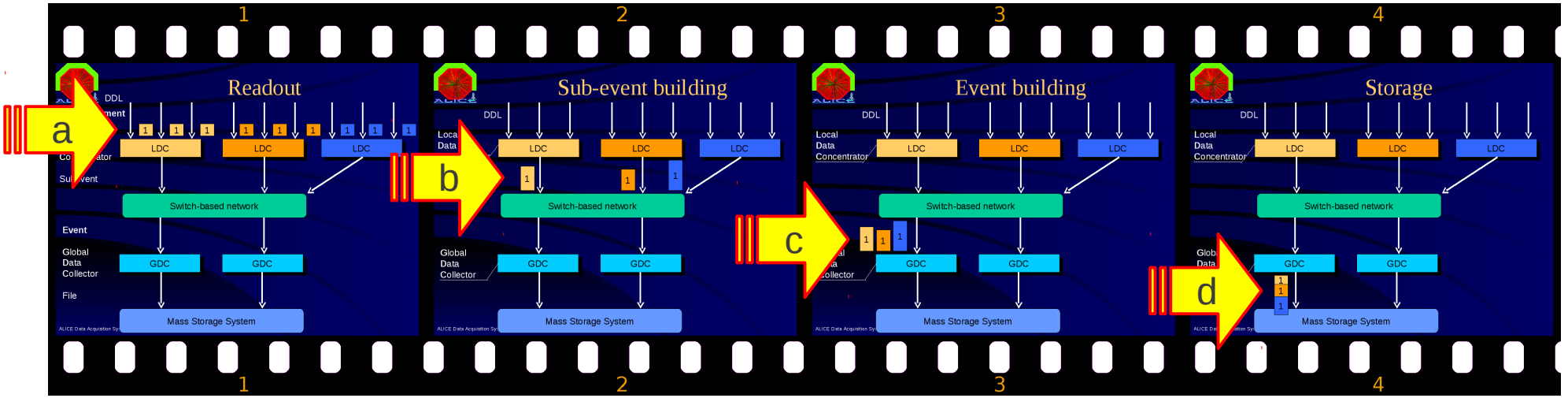
- **Large-scale** experiments having a **deep hierarchy** of sub-systems
- These systems need to be **monitored at different levels** (e.g. LDC, GDC, etc). This is because the quality of the data depends on many parameters (human, accelerator, detector slow control, etc.)
- Access to data is established by a **C/C++ library** provided by the **DAQ team**



Simplified block diagram of ALICE DAQ architecture

External library usage from within ROOT

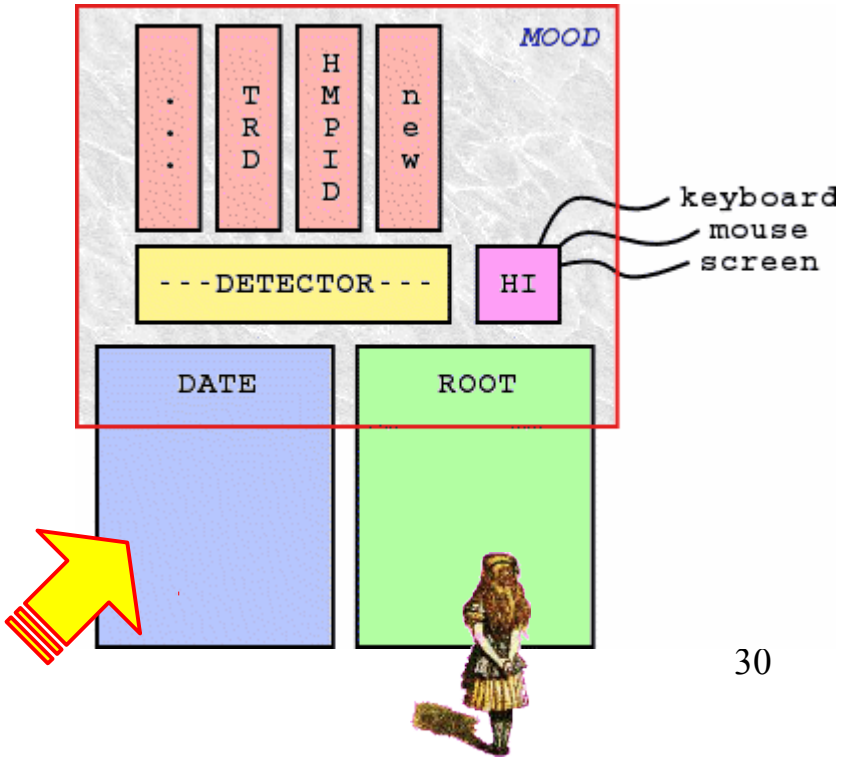
Simplified DAQ operation



* Further simplified architecture (from Pierre Vande Vyvre's presentation)

- FE ASICs reading out the detectors generate ***payloads*** *(a)*
- Payloads travel further down within the DAQ network into LDCs (Local Data Collector) to get together, forming the ***event fragments*** *(b)*
- Event fragments move further down to GDCs (Global Data Concentrator) and are put together, forming ***sub-events*** *(c)*
- Sub-events get together forming the ***super-event*** and are sent to ***permanent data storage*** for *off-line analysis* *(d)*

- ***Our task*** is to develop a ***monitoring application*** using ***DATE*** library for data access and ***ROOT*** class library for GUI, event display, and analysis.



External library usage from within ROOT

Accessing data via monitoring functions provided by an external library

```
oc@olmak-x200:~$ root -l
root [0] gSystem->Load("${DATE_MONITOR_DIR}/{DATE_SYS}/libmonitor.so");
root [1] monitorSetDataSource(":"); /* Enable local on-line monitoring*/
root [2] int *event;
root [3] monitorGetEventDynamic( &event );
root [4] printf( "%08x %08x \n", event[0], event[1] );
0000878c da1e5afe
Root [5] .q
oc@olmak-x200:~$ _
```

DATE Event Format

0 - Total size of the event (0000878c)
1 - Unique DATE event signature (da1e5afe)
2 - Size of the header (base & extension)
3 - Base event header structure version
4 - Type of event
5 - Number of the run associated to the event
6 - Unique event identification
7 - Level 2 trigger associated to the event
8 - Detector pattern associated to the event
9 - Attributes associated to the event
10 - ID of the LDC
11 - ID of the GDC
12 - Time stamp at the creation of the event

Super Event header

<Equipment Header "n">
<Data associated to the equipment "n">

Data generated by a specific part of a detector (payload)

<Equipment Header "n-1">
<Data associated to the equipment "n-1">

Payload

...

Summary

```
Root [0] → Load the monitoring library
Root [1] → Set data source
Root [2] → Variable to cast data onto
Root [3] → Get the data into the variable
Root [4] → Show the first two "words"
Root [4] → End the session
```

This is ~literally more information than your government has about you :)

External library usage from within ROOT

Parsing and/or casting the detector data – Decoding payload

- Beginning of an ALICE ***TPC*** (Time Projection Chamber) event (total size is roughly 60 Mbyte)
- ***Yellow***, ***green*** and ***magenta*** highlighted parts represent data headers generated by different levels of hardware within the DAQ chain (***event*** / ***equipment*** / ***hardware*** headers)
- The rest is ***raw data*** generated by the TPC
- A TPC "***word***" is also analyzed below (a decoding example):
  - A phrase composed of 4 words of ***10 bits***
  - A phrase composed of 5 words of ***8 bits***
  - A single word of ***40 bits***
  - A phrase composed of 5 words of, from left to right ***4, 8, again 4, 10, and 14 bits*** (we are interested in this level)

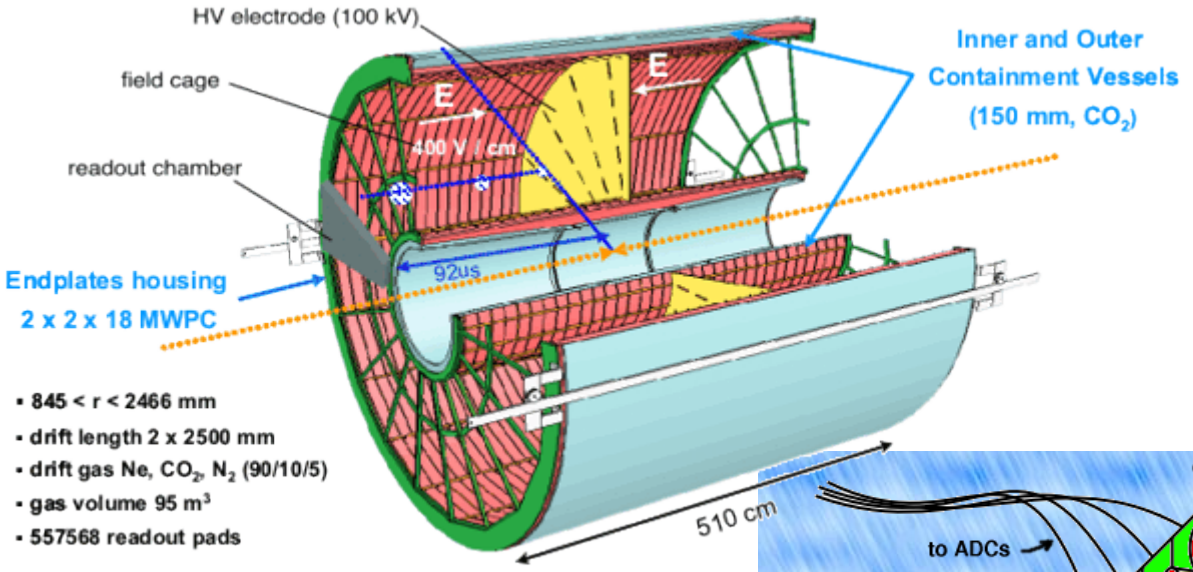
```
0000:0000 8c870000 fe5a1eda 44000000 04000300 07000000 78130000 00000000 f842bf06
0000:0020 01000000 00000000 00000000 f0000000 00000000 20000000 03000000 ffffffff
0000:0040 d30e0b43 48870000 11000000 69000000 00000000 00000000 00000000 04000000
0000:0060 01000000 02000000 03000000 04000000 05000000 06000000 07000000 08000000
0000:0080 3ef4d043 0f3df4e0 430f3df8 d0430f3d f8e0430f 3df4d043 0f3ef4d0 430f3ef4
0000:00a0 d0430f3d f4d0830f 3ef4d043 0f3ef8d0 430f3df4 d0430f3d f8d0830f 3df8e003
0000:00c0 0f3ef8d0 430f3df4 d0430f3d f4e0830f 3ef4d083 0f3df0d0 830f3df4 d0830f3d
0000:00e0 f4e0430f 3ef4d043 0f3ef8d0 430f3df4 e0830f3d f0d0430f 3df4e043 0f7298a1
0000:0100 aaaa00a8 66a8aa3d f8d0830f 3ef4d043 0f3ef4d0 430f3df4 e0830f3e f4d0430f
0000:0120 3df0d043 0f3ef8d0 430f3df8 e0430f3d f4e0430f 3df4e043 0f3df8e0 430f3df4
0000:0140 d0830f3e f4d0830f 3ef4e083 0f3ef8d0 430f3ef4 e0430f3d f4d0430f 3df4d043
0000:0160 0f3df4e0 430f3df4 d0830f3d f4d0430f 3df4e043 0f3ef8c0 430f3df4 e0430f3c
0000:0180 f8e0830f 7298a1aa aa01a866 a8aa2bac b0c20a2a b0c0c20a 2bacb0c2 0a2bb0b0
0000:01a0 c20a2aac b0c20a2b acb0c20a 2ab0b082 0a2aacb0 c20a2bb0 b0820a2b acb0c20a
0000:01c0 2bacb0c2 0a2bb0c0 c20a2bac b0820a2b b0b0c20a 2bb0b0c2 0a2bacc0 020b2bac
0000:01e0 b0c20a2b acb0c20a 2aacb0c2 0a2bacb0 c20a2bac b0020b2b acb0c20a 2bacb0c2
0000:0200 0a2bacc0 c20a2cac b0c20a72 98a1aaaa 02a866a8 aa2bacb0 020b2cac c0c20a2c
0000:0220 b0c0020b 2cb0c0c2 0a2cb0c0 c20a2cb0 c0c20a2b acc0020b 2cb0c002 0b2bb0c0
0000:0240 020b2cac c0c20a2c b0c0020b 2cb0c002 0b2cb0b0 c20a2bb0 c0020b2c acc0c20a
0000:0260 2bacc002 0b2cb0c0 c20a2cb0 c0c20a2c acb0c20a 2bb0c002 0b2bacc0 c20a2cb0
0000:0280 c0020b2c b0c0020b 2bacc0c2 0a2bb0c0 c20a7298 a1aaaa03 a866a8aa 28a070c2
0000:02a0 09279c60 c209279c 80020a27 9c70c209 289c70c2 09279c70 c20928a0 80c20928
0000:02c0 a070c209 27a070c2 0927a080 c209279c 70020a27 9c80c209 279c70c2 09289c70
```

```
          5.      4.      3.      2.      1.    (char, 8 bit)
        .---'--..---'--..---'--..---'--..---'--.
        |       ||      ||      ||      ||      |
a = 0100000101000101010111010100100101101111   (40 Bit Word)
        |       ||      ||      ||      ||      |
        '----v---''----v---''----v---''----v---'
             4.      3.      2.      1.    (10 Bit Word)
```

Seq.	bin	dec	(10 Bit Words, trailer)
Channel.	1111	15	(yellow)
Hardware.	10010110	150	(light blue)
Pattern A	0100	4	(orange)
10BitWord	0101011010	346	(magenta)
2AAA Pat.	0100000101000 1	4177	(green)

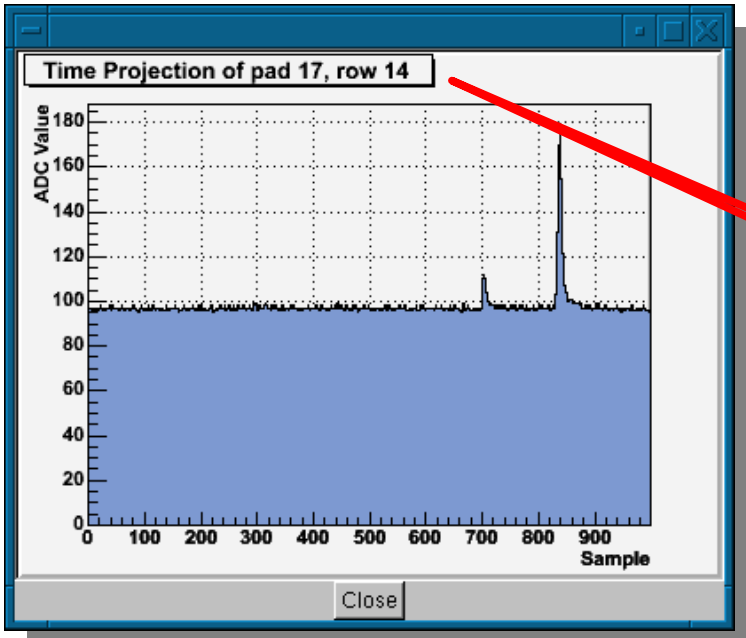
External library usage from within ROOT

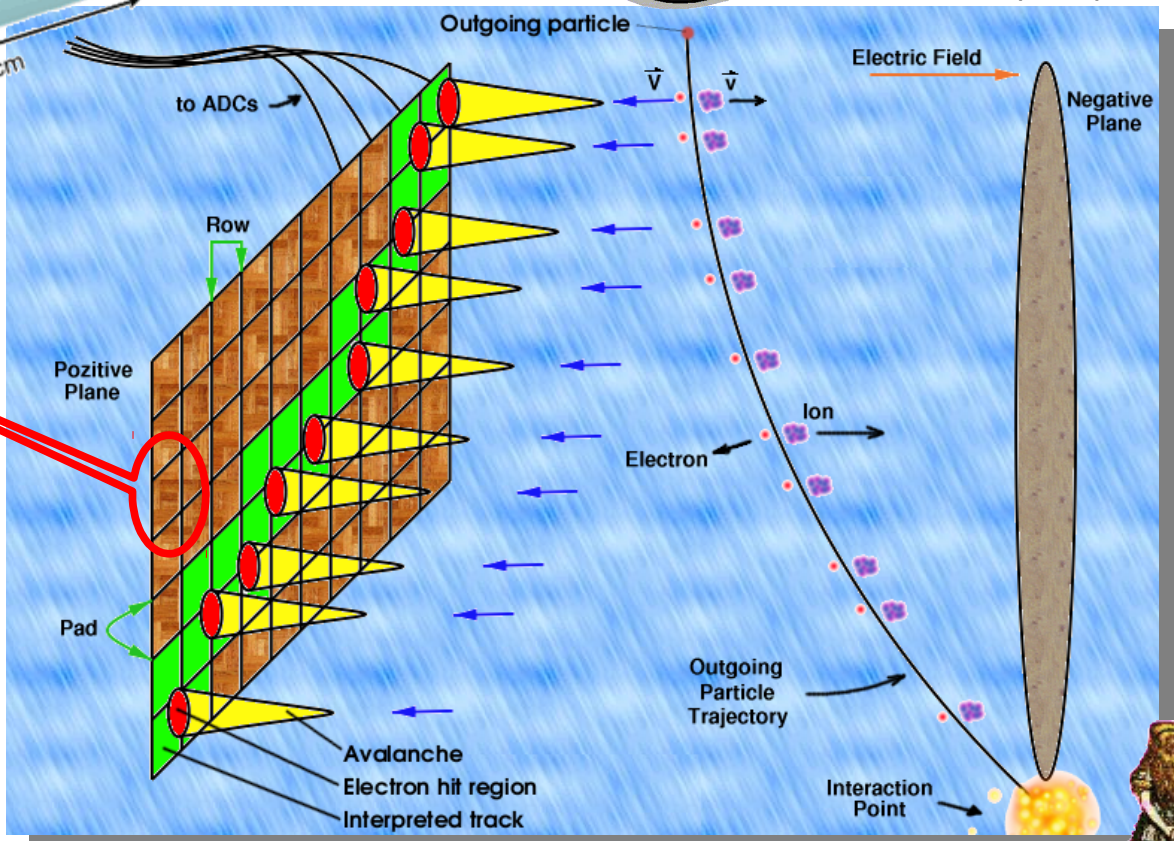
Understanding the detector data



- **For our example, let us choose the *Time Projection Chamber* detector of *ALICE experiment*.**

TPC detection principle

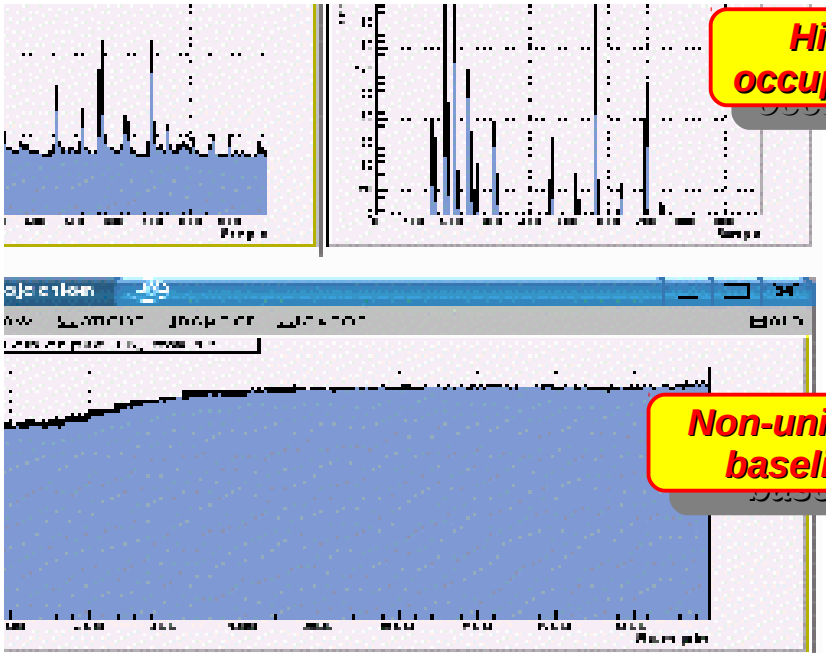




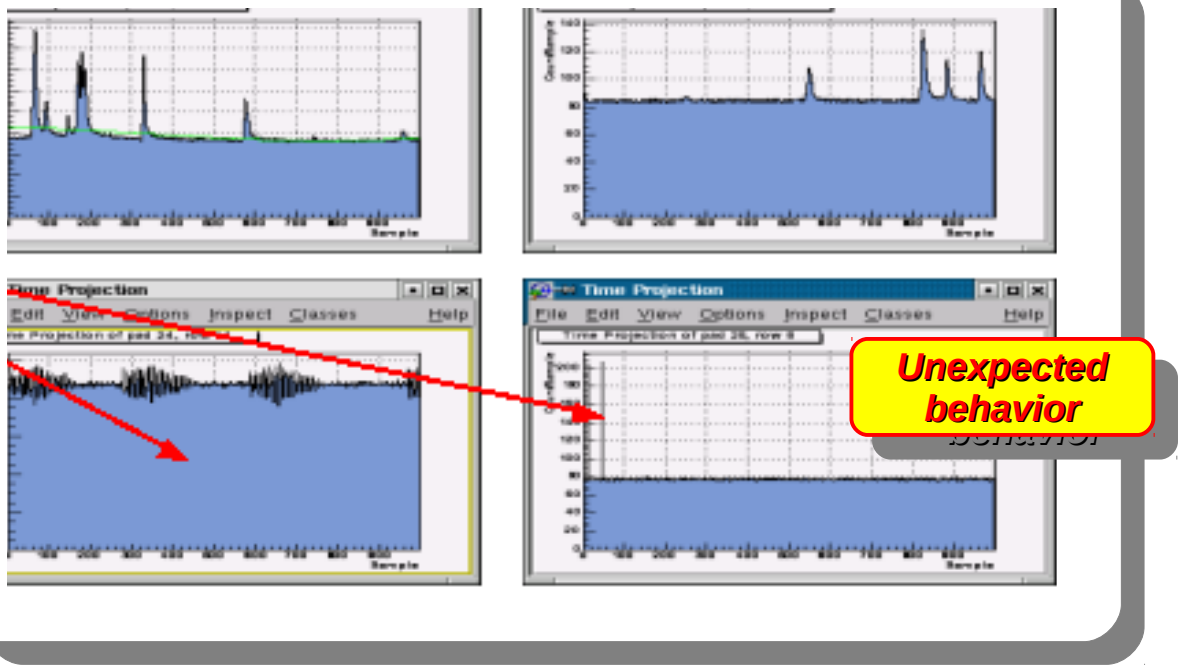
What do we expect to see ?

What errors do we expect to catch via the monitoring tool ?

- Electronic issues
  - Stack-at errors
  - *Non-configurable FE, etc.*
  - *Unexpected behavior*
- *Detector issues*
  - *Gas mixture and dynamics*
  - *Occupancy, etc.*
  - *Unexpected behavior*
- *General*
  - *Temperature & supply variations*
  - *Peak formation*
  - *Baseline fluctuations, etc.*
  - *Unexpected behavior*



- A channel generating the same value all the time
- Un-familiar condition within the detector



Compiling Standalone

Standalone application

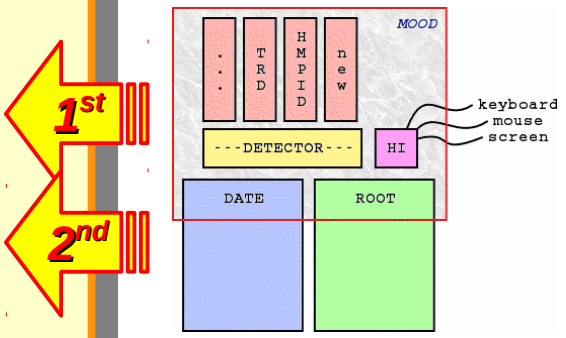
- *An elegant method to write applications is via **Makefile**, but we will not do it here*

- To compile a code similar to the one on the previous page:
  - **g++ -L/date_home -lbase -laz -lgui -thread -lm -lmst -ldynamic -lnonStand -lshift -lcustomDet -lmntrno {...} secondApp.cxx -o secondApp**

- *Remembering all the above things is hard, therefore we will use:*
  - ***date-config**: a command-line tool to make lives of DATE users easy (libraries usually have tools like this one, remember ?)*
  - *It returns appropriate lines needed for compilation*
  - *Usually used in-between " ` ", aka escape symbol*

  - **g++ `date-config --glibs --cflags` secondApp.cxx -o secondApp**

g++
`root-config *--glibs --cflags*`
`date-config *--glibs --cflags*`
thirdApp.cxx -o thirdApp



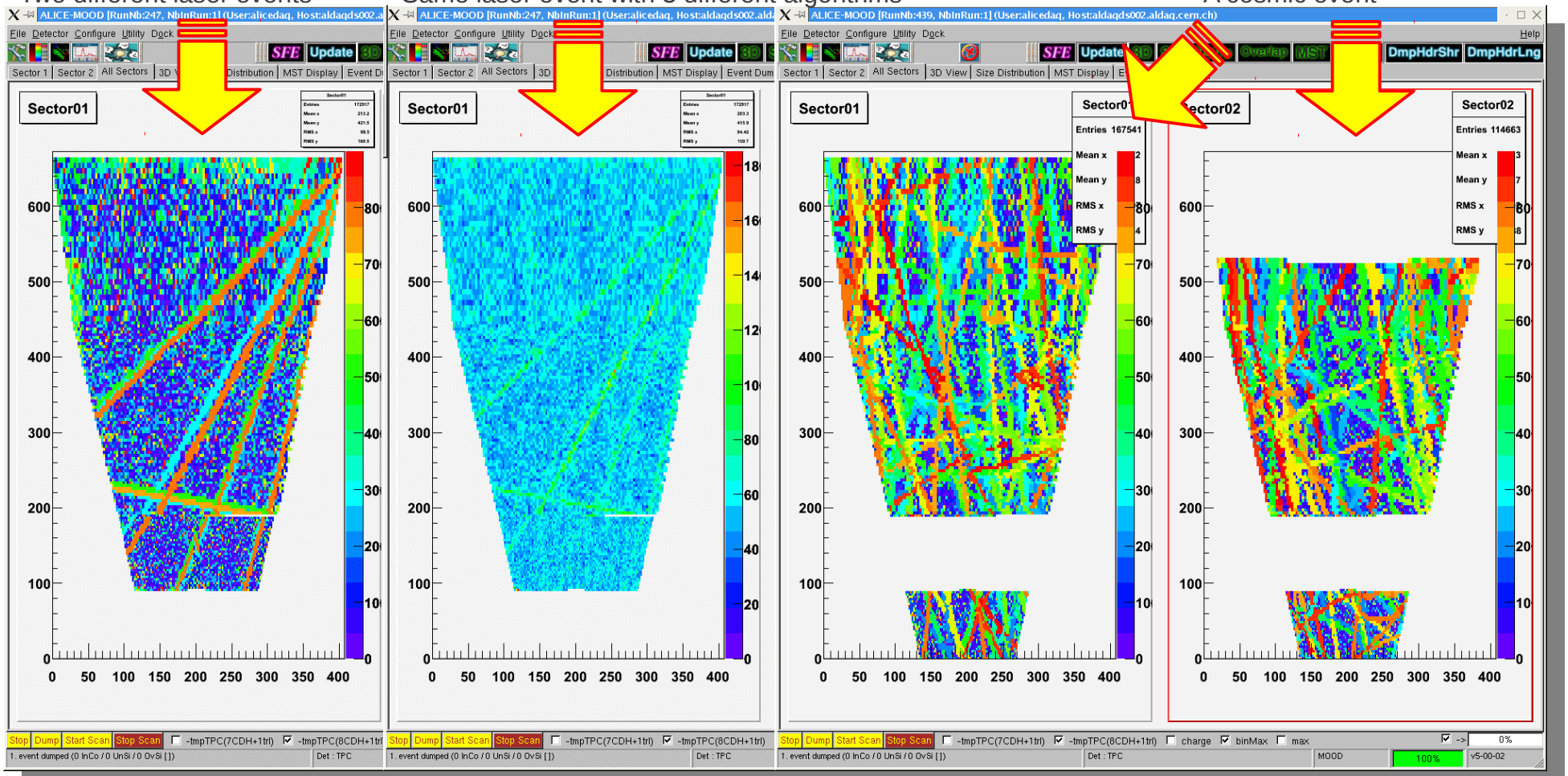
External library usage from within ROOT

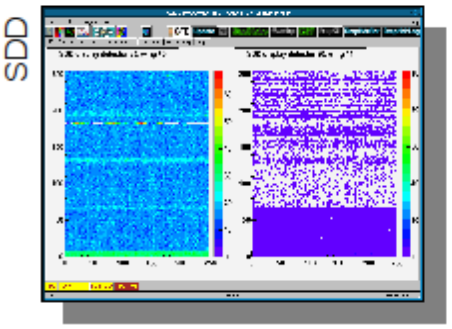
Full featured application being delivered to detector people

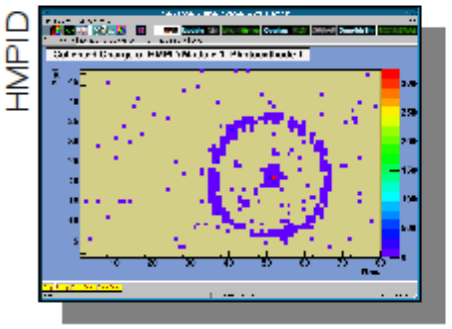
Two different laser events

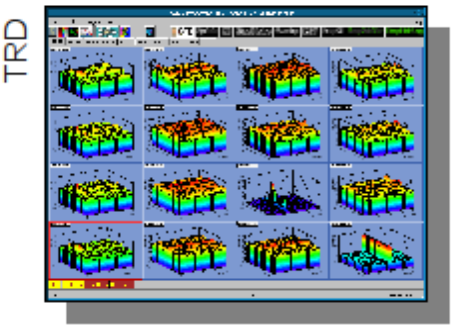
Same laser event with 3 different algorithms

A cosmic event





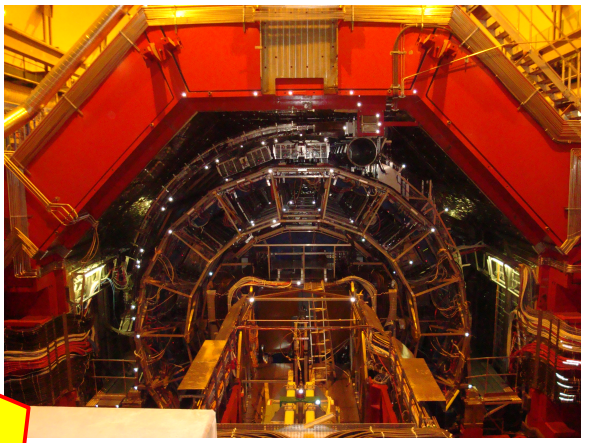


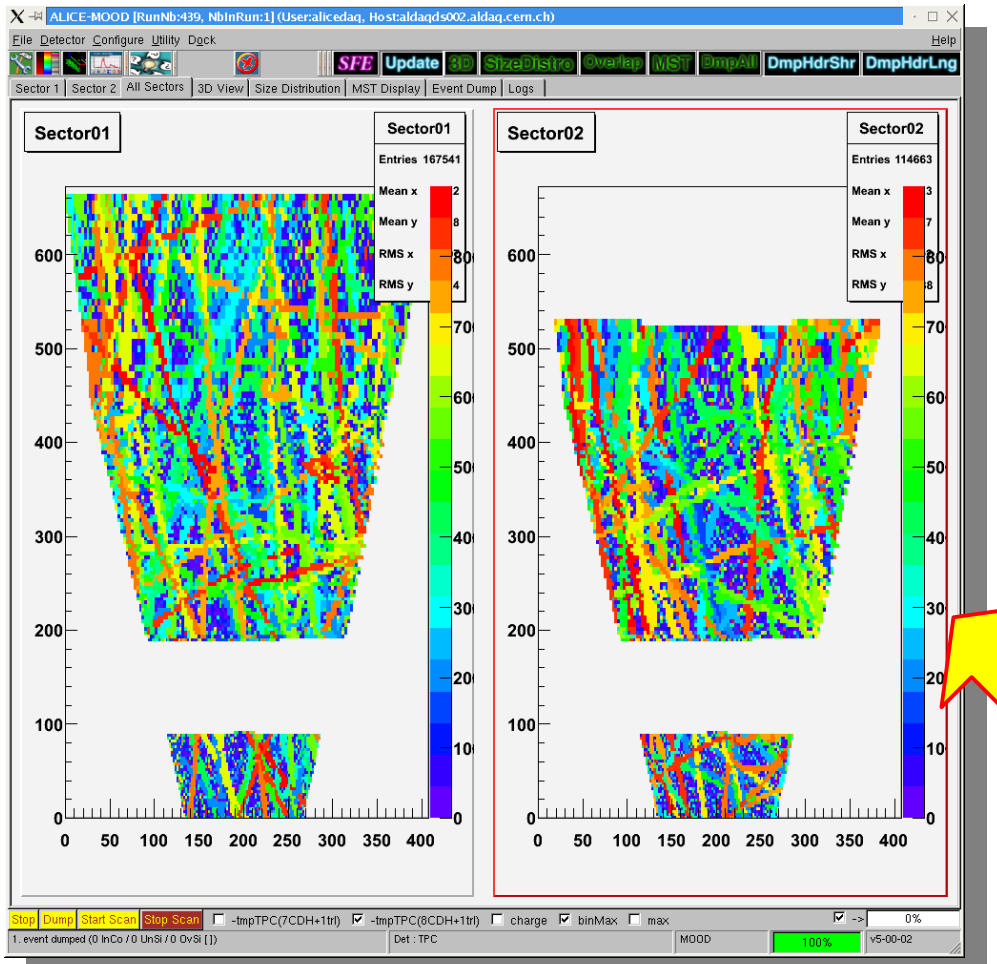


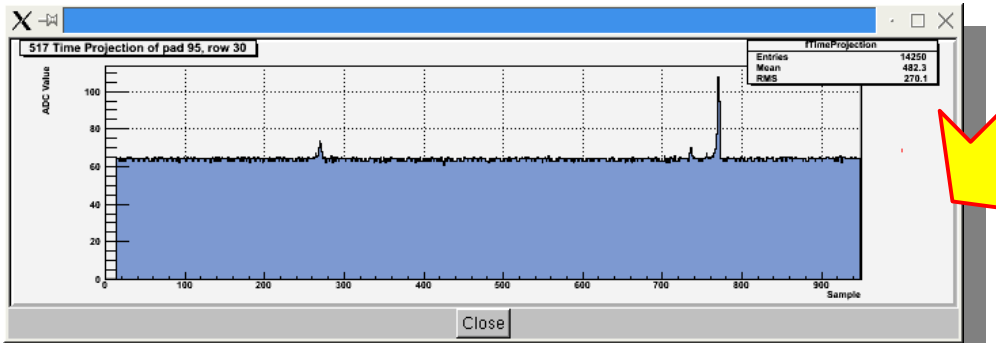
Coding or design ?

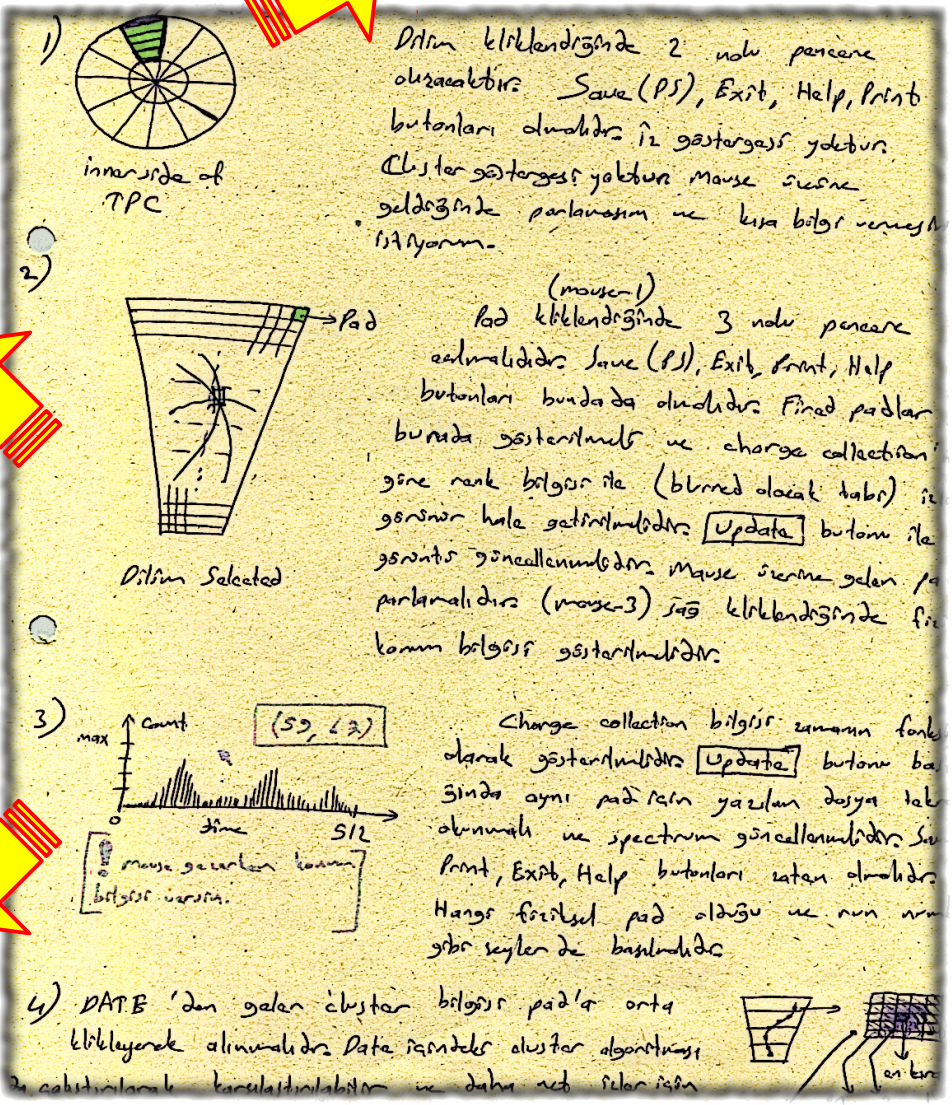
Think, design, write, implement and only then start coding

From 2002 To today









ROOT – A brief introduction

Survival with ROOT != Survival at ROOT != Survival despite ROOT

- Introduction to ROOT
  - What is it ?
  - Why is it good ?
- Using ROOT
  - Command line, batch-mode, root console or terminal
  - Scripting/Interpretation
    - Example script comparing two current-mode D/A converter architectures designed for COMPASS
  - Compilation
    - Compiling a script as a " *.so " shared object library
    - Compiling standalone
    - Application development
    - Example standalone application
- GUI of ROOT
  - Human interaction
  - Creating a GUI
- Survival [with/at/despite] ROOT
  - User's guide (refer once)
  - Referring to:
    - $ROOTSYS/tutorials (refer once per problem)
    - $ROOTSYS/test (refer once per problem)
  - HTML source code documentation (refer continuously)
- External library usage from within ROOT
  - DQM of ALICE experiment @ CERN
    - Simplified DAQ operation
  - Understanding the detector data
    - Accessing and decoding data

*