# Introducing new thesis students to ROOT

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ROOT Train The Trainers

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# Introduction and presentation

- About me: a PostDoc from Naples, graduated in 2021
- Main research background: neutrino detection within the ShiP and SND@LHC Collaboration
- Vital contribution provided by Bachelor and Master students: new thesis, original perspectives on the research, more young life to the group
- Here, talking about their ROOT training and research introduction
- My experience: trained 5 Bachelor and 4 Master students

Hello, my name is

Antonio

# Target of the training

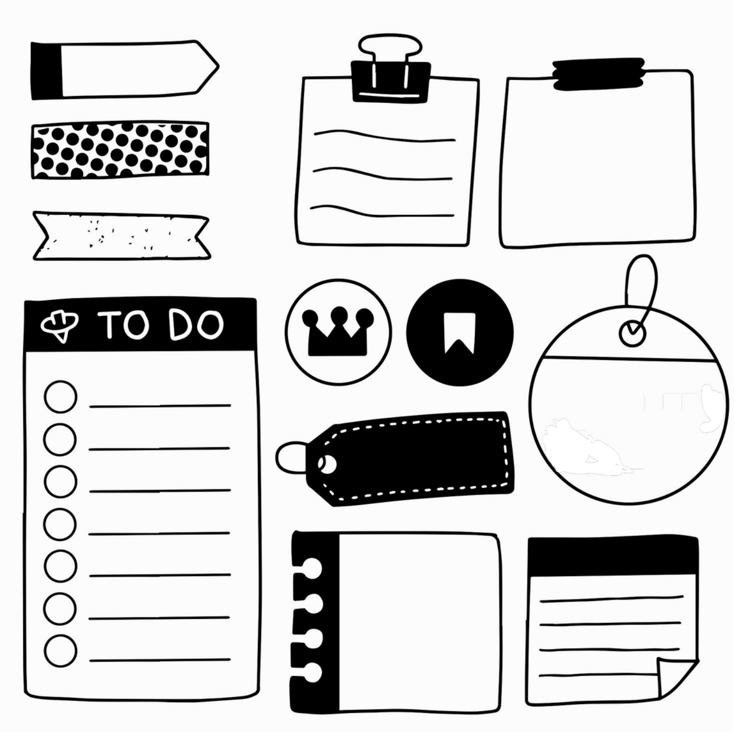
- Two main topologies of students (times here referring to Italian universities)
- Bachelor students (3 years degree):
  - Thesis duration not more than in 3 months, of which 2 in the lab
  - Almost always first time with ROOT
  - Need to focus in a few topics
  - Usually more guided into known coding structures and techniques
- Master students (2 years degree, after Bachelor):
  - Thesis duration about 8 months, of which 7 in the lab
  - May or not may already know ROOT from the Bachelor thesis
  - More freedom in code development and data analysis

# Common goals of the training

- Introduction to the software, focusing on the topics more needed for their analysis of laboratory data
- Starting with general ROOT training: what, why and how to use it
- Then, more focused sessions on data structure and libraries from our libraries
- Duration of the training itself:
  - 1 week for Bachelor students
  - 1-2 weeks for Master students
- After the training, the guidance is generally driven on question/answer basis.

  Learn what you need, when you need it

  (trying not to forget it the day after).



# Used resources

- General resources:
  - ROOT official basic course: https://github.com/root-project/training/tree/master/BasicCourse
  - Tutorial Jupyter/ROOT Notebooks, written as inspiration from the tutorials, but taking samples of our data to show the data format
- Both ROOT C++ and PyROOT are mentioned, then the training is focused towards one language or another, according to student preferences
- Last year students more driven to Python

  (due to a Python course in their courses)

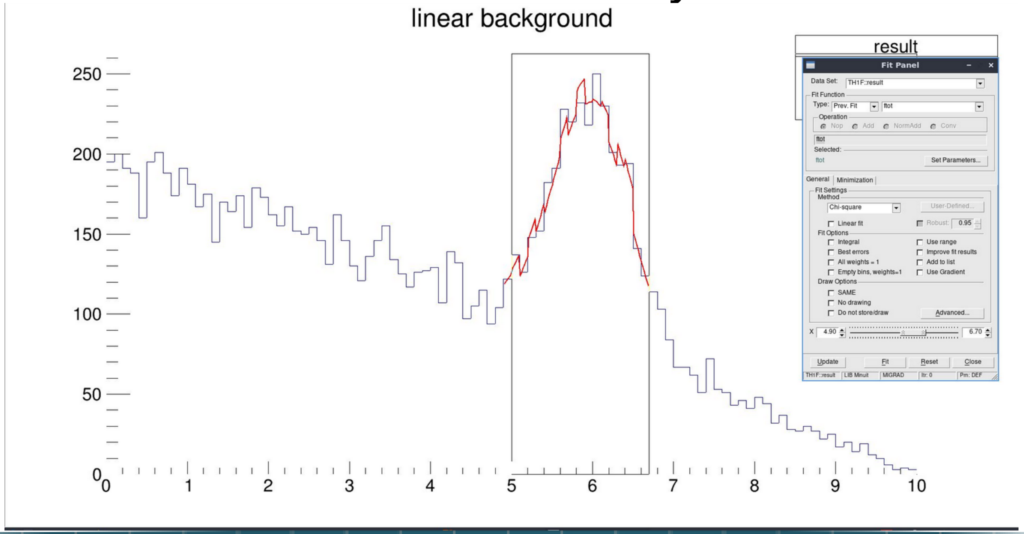
# Bachelor training topics

- Presenting here the topics and feedback received
- The workflow is usually:
  - Introduction to the C++/Python language (usually not required);
  - **Running ROOT with terminal, executing and compiling macros.**
- All bachelor thesis work done in execution mode (root -l mymacro.C). ACLiC compilation mentioned, but rarely used

**HELLO WORLD**

# Bachelor training topics

- The workflow is usually:
  - Introduction to the C++/Python language (usually not required);
  - Running ROOT with terminal, executing and compiling macros;
  - **Presenting data with graphs and histograms, simple fits**
- First showing how to edit histogram and perform fit with the ROOT GUI, then how to replicate the commands in the macro.
- Most of the students prefer to find the “most suitable” fit range and initial parameters with the Fit Panel GUI, then they use them in the macro.



Data Set: TH1F::result

Type: Prev. Fit | ftot

ftot

Selected: ftot

Method: Chi-square

□ Linear fit ☑ Robust: 0.95

□ Integral □ Use range

□ Best errors □ Improve fit results

□ All weights = 1 □ Add to list

□ Empty bins, weights=1 □ Use Gradient

□ SAME

□ No drawing

□ Do not store/draw

X 4.90 6.70

TH1F::result | LIB Minuit | MIGRAD | Itr: 0 | Pm: DEF

# Bachelor training topics

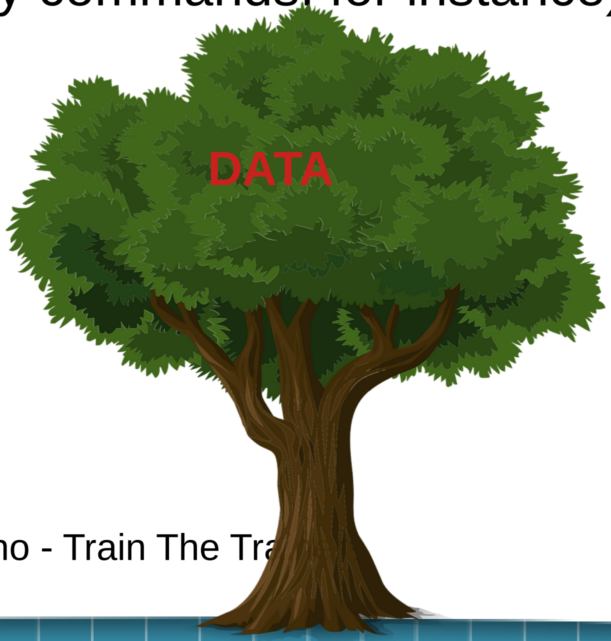
- The workflow is usually:
  - Introduction to the C++/Python language (usually not required)
  - Running ROOT with terminal, executing and compiling macros
  - Presenting data with graphs and histograms, simple fits
  - **TFile and TTree I/O**
- Great appreciation for TBrowser and TTreeViewer

# Bachelor training topics

- The workflow is usually:
  - Introduction to the C++/Python language (usually not required)
  - Running ROOT with terminal, executing and compiling macros
  - Presenting data with graphs and histograms, simple fits
  - **TFile and TTree I/O**
- Great appreciation for TBrowser and TTreeViewer
- Initially, TTree readout is shown in the “old way”, with SetBranchAddress (this applies to C++, for PyROOT is automatic). Main reasons for this approach:
  - More control in the flow: you “see” the variable storing the value;
  - Can be explained along the TTree creation and writiing, with Branch();
  - Easier to generalize to any convoluted data structure with MakeClass (RDataFrames and TClonesArrays do not usually get along well, at least to my experience)

# Master training topics

- If the student did not use ROOT before, a first week with the same topics of the Bachelor. Then, more advanced topics:
  - **Different ways of reading TTrees: TTreeReader,RDataFrame**
- Usually, TTreeReader used for loop-based procedural macros. Very useful alternative to SetBranchAddress, requires less knowledge of data types
- RDataFrame (as long as RVec operations) essential for vector-based computations in C++ codes
- However, in Python codes, export to pandas remains preferable as it gives more options (sort and groupby commands, for instance)



# Master training topics

- If the student did not use ROOT before, a first week with the same topics of the Bachelor. Then, more advanced topics:
  - Different ways of reading TTrees: TTreeReader,RDataFrame,
  - **Creating their own ROOT-based classes**
- Here, ACLiC or MakeClass compilation of C++ classes is used.
- Then the classes can be loaded into ROOT C++ and PyROOT scripts

**ClassDef(myclass,5)**

**ClassImp(myclass)**

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  - Different ways of reading TTrees: TTreeReader,RDataFrame,
  - Creating their own ROOT-based classes
  - **Advanced ROOT libraries:** TGeometry, TMVA, RooFit (depending on the thesis topic)
- Each of these libraries comes with a nice manual and tutorials
- Usually, at this point students are independent enough to study the references on their own → just provide them, and answer their questions

# Final remarks

- Today, HEP research is more and more directed towards scipy and sklearn algorithms and libraries
- Easier and wider interface to commercial and advanced classifiers, especially for machine learning applications
- However, ROOT still considered the main toolkit to introduce new researchers with, for the following reasons:
  - A clear and self-contained toolkit for physicists: in the same Canvas, you see the histogram, statistics, fit results, etc.
  - Comfortable data storage and inspection: TTrees in .root files can be inspected on the fly, and can be much more convoluted than .csv files
- Many thanks to all the ROOT developers for their continuous work!

# TTree Readout

- Initially, TTree readout is shown in the “old way”, with SetBranchAddress (of course in C++, for PyROOT is automatic). Main reasons for this approach:
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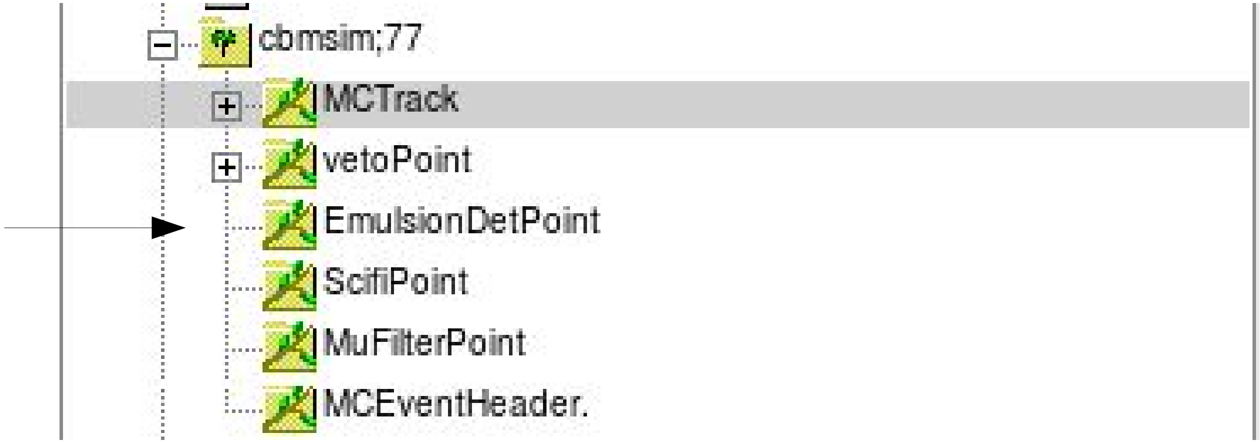
These are all TClonesArrays of ROOT based objects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MCTrack
vetoPoint
EmulsionDetPoint
ScifiPoint
MuFilterPoint
MCEventHeader.