ROOT

Pocket reference for 1st and 2nd year courses - BSc Physics, Unibo

2023-2024

Contents

A general note: strings between `<` ... `>` are meant to be replaced by suitable ones (without the two kets)

1 General structure

ROOT contains **interpreter** : *Just-In-Time* compilation → prompt : special commands (not standard C++ syntax) with `.`.

Base class `TObject` → `TNamed` → `TH1` (histograms) → `TH1F, TH1D, THIC, TH1S` according to **type representing entries** (not the type of data!!)

2 Basic shell & prompt commands

! Possible to use $\boxed{Tab}$

- `root` launch ROOT
- `.q` quit
- `.L <file.C>` load file (symbols defined in a macro)
- `.help` `.?` full help list
- `.! <cmd>` call any shell command <cmd> without leaving ROOT
- `.files` shows loaded libraries / sources
- `.x <macro>` loads & runs a macro
- `.U <file.C>` unload
- `.! wslview <image-file>` (for WSL users) open image with default photo viewer from inside ROOT

Run a macro:

```
$ [0] .L <name>.C
$ [1] <name>()
```

Load a library (class def) - only with **implementation file**:

```
$ [0] gROOT->LoadMacro(\MyClass.cxx+")
```

or

```
$ [0] .L MyClass.cxx+
```

Produces a **dynamic library** file (`.so`).
To automatically reload when running main macro put at beginning of latter: `R__LOAD_LIBRARY( MyClass.so )`

Possible to type C++ commands directly in shell: **';' are unnecessary, object type can be omitted in declarations, possible to access members with obj name instead than pointer**:

```
$ [0] TH1F *histo=new TH1F(\histname"," Titolo", 100, 0, 10)
$ [1] histname->Draw() // identical to histo->Draw()
```

Note: `#include <iostream>` and `namespace std;` are implicit!

Use prompt as calculator Ordinary operations + embedded library `TMath` :
`TMath::Abs(...), TMath::Exp(...), TMath::Gaus(...), TMath::Pi(), ...`

2.1 Recover session history

Saved in `$/home/.root_hist`

2.2 Check versions

`gcc -v` gcc version

`lsb_release -a` linux OS

2.3 LaTeX

Can be used for labels etc. Same syntax as normal LaTeX

- `x_{1}` $= x_1$
- `x^{1}` $= x^1$

but commands are called with '`#`' instead of '`\`'

3 Macros

Two types of script

Unnamed script all code between $\{\}$ + no declaration of classes, functions + no parameters (ok loops)

Named script like any C++ function + possible to define other functions, classes, use parameters
The executed function has the same name of the file (see Basics)

4 GUI

`TBrowser b` opens root files browser.
Double click on an object (e.g. histo) → opens new **TCanvas** and draws it

Handling TCanvas

if some of the followings not visible, click **View** and check out

Editor single left click on an object in graph → edit display parameters (color etc.)

Toolbar tools to insert text, symbols, etc.

Status bar shows object pointed by mouse & mouse position

Right click on object → contextual menu

Contextual menu

Rebin redefine binning

Fit (of FitPanel) fit a function on data (gaussian, exponential, polynomial etc.) → button `Set Parameters` for chosen distribution

To visualize fit on graph: right click on graph → open `TPaveStats::stats` → `SetOptFit` → se to `111` `SetOptStat` allows do define other options

Canvas options Right click on canvas → `SetLogx`, `SetLogy` for logarithmic scale; `SetGridx`, `SetGridy` for grid

Saving file `File` ▶ `Save` (`Save As`)
Saving as `.C` file (containing the graph as C++ commands) enables to reproduce graph executing macro
Saving as `.root` file → saves canvas and all objects, double click on canvas inside .root (opened through TBrowser) to open and manipulate graph

5 Global variables

List of useful global pointers.

`gROOT` global info on current session: access to **every object created during session**

`gFile` current root file

`gStyle` access functionalities to manage graphic style

`gRandom` access random number generator (see PRNG)

`gPad` current pad (see Canvas)

Suggestion at the beginning of a macro, to eliminate copy created by multiple executions of code in a session:
`delete gROOT->FindObject("<name>");`
`gROOT->FindObject("<name>")` used to retrieve every object from gROOT

General styling

`gROOT->SetStyle("<style>");` set window style. Can be custom one or chosen between default ones:
`Classic, Plain, Modern, Bold, Video, Pub`

6 Managing .root files

`TFile *file = new TFile("<name>.root", "RECREATE");` open file. Options:

- `RECREATE` creates new file if name not found, otherwise overwrites existing one
- `NEW` or `CREATE` (error if already existing, returns empty ptr!)
- `UPDATE`
- `READ` (default)

`h->Write();` write object (pointed by `h`) on file

`file->Write();` write all histos in memory in current session

`file-ls();` list content, with indentation for file tree

`TH1F* hs = (TH1F*)file->Get("<name>");` retrieve object from name
Explicit cast suggested

`file->Close();` close

6.1 Decoupling from file

To avoid disappearence of histos from canvas after closing read file(s):
`TH1::AddDirectory(kFALSE);` static! (default value is `kTrue`)
`h->SetDirectory(0);` `h->DrawCopy();` non static

6.2 Make user defined types writeable

In header:

```
#ifndef MYCLASS_H
#define MYCLASS_H
...
class MyClass: public TObject{
  public:
    ...
  private:
```

```
    ...
  ClassDef(MyClass,1)
};
#endif
```

In implementation:

```
#include "MyClass.h"
...
ClassImp(MyClass)
```

7 TList

A container class to store objects of every type inheriting from `TObject`

`TList * list= new TList();`

`list->Add(<ptr>);` with pointer!

`list->At(<idx>)` indexing starts from 0, returns empty pointer if out of range

`list->At(<idx>)->InheritsFrom("TGraph")` check inheritance (boolean)

8 Histograms

1D

`TH1F* <pt-name> = new TH1F( "<name>", "<title>", <NxBins>, <xmin>, <xmax>);`

declare new histogram
range [`xmin` , `xmax`] is equally subdivided in `N` bins

`<pt-name>->Fill(<x>);` fill histo with variable <x> (e.g. from MC generation or read file, data)

`<pt-name>->Fill(<x>, <n>);` fill histo with n identical occurrences of x

`<pt-name>->FillRandom("<funcname>",<Ntimes>,TRandom* rng = nullptr)` fill `N` times generating according to auto normalized function (using `rng`)

`<pt-name>->Draw();` draw histogram

2D

`TH2F* <pt-name> = new TH2F( "<name>","<title>",<NxB>,<xmin>,<xmax>,<NyB>,<ymin>,<ymax>);`

`<pt-name>->Fill(x,y);`

`<pt-name>->Draw();`

`<pt-name>->ProjectionX()` returns `TH1F` of projection w.r.t. x

`<pt-name>->ProjectionY()`

`<pt-name>->GetNbinsX()`

`<pt-name>->GetNbinsY()`

3D

`TH3F* <pt-name> =`
`new TH3F("<name>","<title>",<Nx>,<xmn>,<xmx>,<Ny>,<ymn>,<ymx>,<Nz>,<zmn>,<zmx>);`

ND

`THnSparse* pt = new THSparse( "<name>", "<title>", <Ndims>, <xmin>, <xmax>, <chuncksize>);`

min and max same for all dimensions

8.1 Overlap histos

```
// declare and initialize two histos, with pointers h1, h2
h1->Draw();
h2->Draw("same"); // or h2->Draw("SameHist");
```

8.2 Histo Draw options

`"E"` show error bars

`"hist"` show only histogram

`"lego"` lego plot

`"cont"` contour lines (linee di livello)

`"Surf"` surface

`"P"` draw marker (except empty bins)

`"AXIS"` draw only axis

`"AXIG"` draw only grid (if requested)

`"FUNC"` When histo has fitted function, draw the fit result only.

`"TEXT"` Draw bin contents as text (format set via `gStyle->SetPaintTextFormat`).

`"X+"` The X-axis is drawn on the top side of the plot.

`"Y+"` The Y-axis is drawn on the right side of the plot.

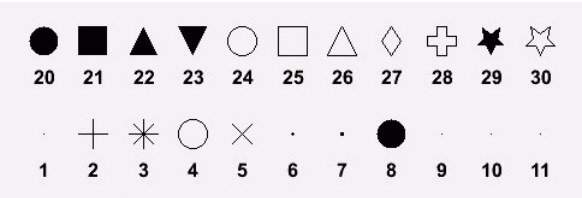
`"MIN0"` Set minimum value for the Y axis to 0, equivalent to `gStyle->SetHistMinimumZero()`.

OPTIONS ARE NOT CASE SENSITIVE

They can also be concatenated without spaces & commas: `"opt1 opt2"`

8.3 Cosmetics for histos

`h1->SetMarkerStyle(<code>);` set style, see ↓ for codes:



`h1->SetMarkerSize(<rel_sz>);`

`h1->GetXaxis()->SetTitle("<title>");` change axis title, same for y with `GetYaxis()`

`h1->GetXaxis()->SetTitleSize(<sz>);` expressed as percent of pad size
unless if precision = 3, when it's in pixels

`h1->GetXaxis()->SetTitleOffset(<ofs>);` 0 is default, 1 is standard offset, 1.x adds 10*x%

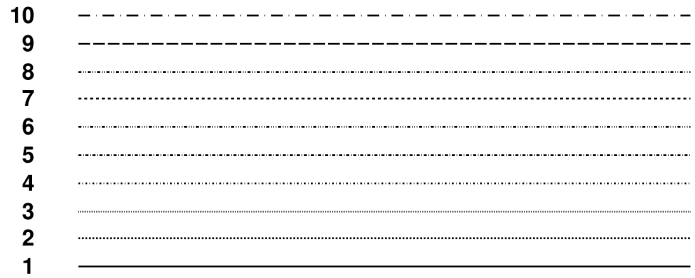
`SetFillColor(<color>);` see after for codes

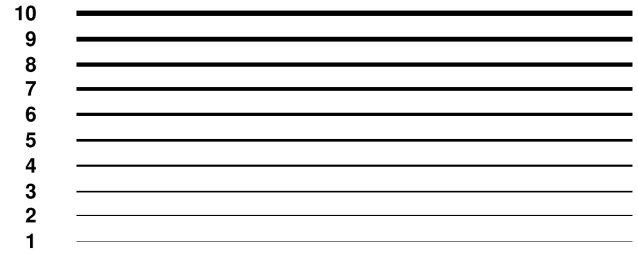
`SetFillColorAlpha(<color>, <transparency ratio>);` allows to manipulate opacity,
e.g. `(kBlue, 0.35)`

`SetLineColor(<color>);` **or** `SetLineColorAlpha(<color>, <transp>);`

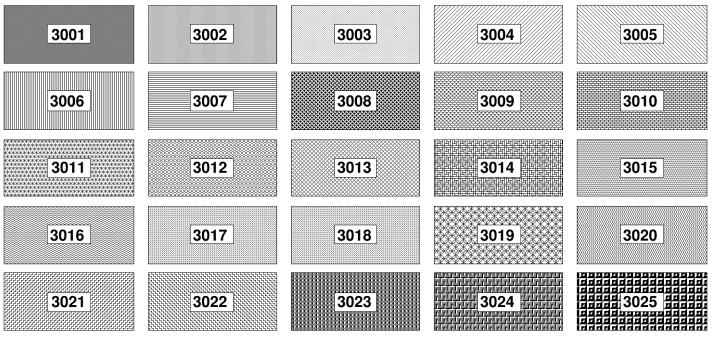
`SetLineStyle(<code>);` see below

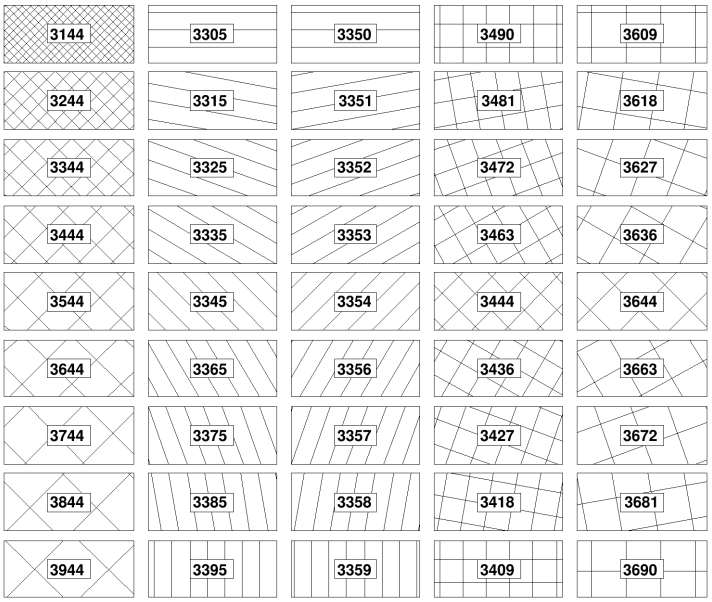
`SetLineWidth(<width>);` see below





`SetFillStyle(<code>);` **0** for hollow, **1001** for solid, **3000 + pattern number** see below





8.4 Other member functions for histos

`GetMean()` mean

`GerRMS()` `GetStdDev()` root of variance / SD

`GetMaximum()` maximum bin content

`GetMaximumBin()` location of maximum ($\neq$ former)

`GetBinCenter( <bin_number> )` center of bin

`GetBinContent( <bin_number> )` content of bin

`GetBinError( <bin_number> )`

`SetBinContent( <bin_number>, <value> )`

`SetBinError( <bin_number>, <value> )`

`GetNbinsX()` number of bins

Note: for out-of-range entries:
`h->GetBinContent(0)` returns number of **underflow**
`h->GetBinContent(h->GetNbinsX()+ 1)` return number of **overflow**

`GetEntries()` total entries (includes under/overflows)

`Integral( <bin_index1>, <bin_index2> )` integral on specified range

`Integral()` total integral

`GetIntegral()` array of cumulative entries

`GetMeanError()` error on mean estimate

`GetRMSError()` `GetStdDevError()` error on RMS estimate

`Sumw2()` create structure to store sum of square of weights. **Strongly suggested** before performing operations on histos

8.5 Operations on histos

Form homologue histograms (**same range and number of bins**): overloads for **istances**, **NOT POINTERS**:

```
TH1F h1;
TH1F h2 = 3*h1;
TH1F h3 = h1+h2;
```

Otherwise through methods:

`h->Add(<pt1>, <pt2>, <n1>, <n2>);` sum stored in *h, *h = n1*h1+n2*h2

`h->Multiply(<int>);`

`h->Divide(<pt1>, <pt2>, <n1>, <n2>);` analogous to sum
`h->Divide(<pt1>, <pt2>, <n1>, <n2>, "B");` binomial errors computed (`n1`, `n2` ignored)
`Sumw2()` automatically called on `h` if already done on *one* of summands

8.6 Filling a histo from ascii file

```
TH1F *h1 = new TH1F("h1","Tempi di Caduta",8,-0.5,15.5);

ifstream in;
in.open("maxwell.dat");
Float_t x,y;
while (1) { // always true condition: iterates until break called
   in >> x >> y;
   if(!in.good()) break;
   h1->Fill(y);
}
in.close();
```

9 Graphs

Two classes: `TGraph` (series of N X-Y couples), `TGraphErrors` (derived from former, includes also errors on both X and Y)

TGraph Constructors Derived class!

`TGraph (<int_N>, <db*_x>, <db*_y>)` `N` couples, `x` and `y` are **arrays** of size `N`

`TGraph (const char *filename, const char *format="%lg %lg", Option_t *option="")` input file **must contain 2 separate columns of values** (divided by blank delimiter)
Default format: `"%lg %lg"` (2 double)
To skip columns: `%lg %*lg %lg"`
Additional options to interpret different delimiters: explicitly specified in option argument (`option = "<symbol>"`)

TGraphErrors Constructors

`TGraphErrors (<int_N>,<db*_x>,<db*_y>,<db*_ex> =0, <db*_ey> =0)` analogous to TGraph
`ex`, `ey` = arrays of errors (for negligible/null uncertainty: substitute with `0`)

`TGraphErrors (const char *filename, const char *format="%lg %lg %lg %lg", Option_t *option="")`
input file **must contain at least 3 columns**. If there are 4 (or more, only first 4 read): X, Y, EX, EY. If only 3: X,Y,EY.

COMMA FOR DECIMALS MUST BE REPLACED WITH DOT

9.1 Graph member functions

(`graph` here is the pointer) — inherited by `TGraphErrors` !
Cosmetics:

`graph->SetTitle("<title>");`

`graph->SetMarkerStyle(kOpenCircle);` (here `kOpenCircle` is default code)

`graph->SetMarkerColor(kBlue);` (`kBlue` also default)

`graph->SetLineColor(kBlue);` ...

Statistical properties:

`graph->GetCorrelationFactor();`

`graph->GetCovariance();`

`graph->GetPoint(<i>,<x>,<y>);` returns `i` -th point

`graph->GetX();` `graph->GetY();` returns pointer to array of x / y values

`graph->GetN();`

`graph->Integral();`

Other:

`graph->AddPoint(<x>,<y>);`

`graph->SetPoint(<i>, <x>, <y>);`

`graph->GetXaxis();` pointer to X axis ▶ `graph->GetXaxis()->SetTitle("title")`

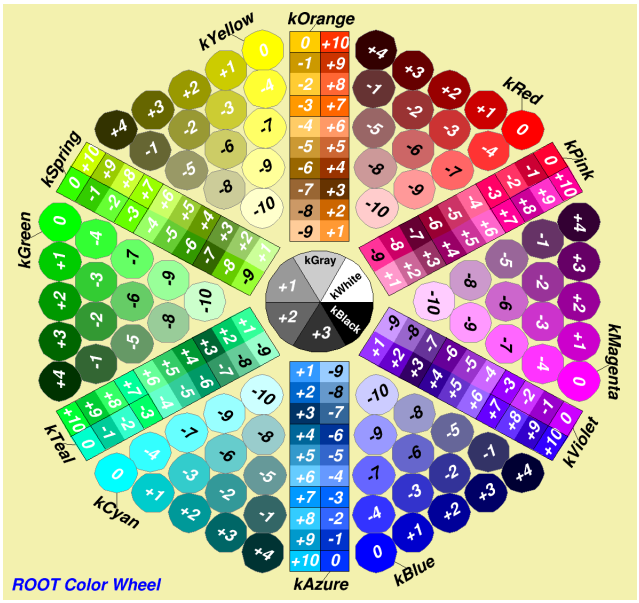
`graph->GetYaxis();` pointer to Y axis ▶ `graph->GetYaxis()->SetTitle("title");`

`graph->SetMinimum(<double>);` set minimum on Y

`graph->SetMaximum(<double>);` set maximum on Y

9.2 Color reference

See figure



9.3 Drawing TGraph

`graph->Draw(<options>)`

`"A"` draws axis

`"P"` draws points markers (the current one set)

`"E"` draws error bars

`"AI"` draws invisible axis (no labels)

`*` draws star at each point (alternative to P)

`C` draws a smooth curve connecting points

`X+` X axis drawn on the top side

`Y+` Y axis drawn on the right side

`RX` reverse the X axis

`RY` reverse the Y axis

9.4 Drawing TGraphErrors

Along with previous options, some specific ones:

`Z` do **not** draw horizontal and vertical lines at the end of error bars

`>` draw arrow at the end

`|>` filled arrow

`X` do **not** draw error bars

`||` draw only lines at the end of bars, **not** bars themselves

`0` force error bars drawing also for points outside visible range along Y (by default they're not drawn)

`2` draw error rectangles

`3` filled area through the end points

`4` smoothed filled area

`5` like `2`, but countour lines are drawn.

9.5 Additional styling

`gStyle->SetErrorX(<dx>)` if set to 0 removes error along x

`gStyle->SetEndErrorSize(<n_px>)` size of line at the end of error bars. Default $= 1$.

10 Fit

The following syntax is valid both for histos and graphs.

`<pt>->Fit( "<name>", "<option>", "<graphic_opt>", <xmin>, <xmax>);`
where `name` is one of the defaults:

`gaus` `gausn` (normalized)

`landau` `landaun` `expo` `pol1` `pol2` ... `pol9` (polynomial of degree n)

`chebyshev1` `chebyshev2` ... `chebyshev9`

To print list of avaiable functions:

```
TF1::InitStandardFunctions(); // not needed if ‘gROOT->GetFunction()‘ is called before
gROOT->GetListOfFunctions()->ls();
```

`name` can also be a formula accepted by the linear fitter with the operator `++`
(e.g. `x++sin(x)`, for fitting `[0]*x+[1]*sin(x)`)

`<pt>->Fit( TF1* f1,"<option>","<graphi_opt>",<xmin>,<xmax>)` with previously defined function (see after)

`graphic_opt` is analogous to the one for `Draw`, whereas `option` can contain one (or more) of the following:

FOR HISTOS ONLY

`L` use logarithmic likehood method (instead of default Chi square)

`WIDTH` scales histogram bin content by bin width (useful for variable bins)

`MULTITHREAD` forces employment of multithreading whenever possible

FOR GRAPHS ONLY

`W` ignore point errors when fitting TGraphErrors

FOR BOTH HISTOS AND GRAPHS

`R` use fitting range specified in the function range (default is histo's)

`C` in case of linear fit, disables calculation of Chi square (saves CPU time)

`Q` quiet mode: print minimum data

`V` verbose mode: print everything

`S` stores full fit result and returns a `TFitResultPtr` for access

`TF1* fitFunc = <pt>->GetFunction("f1")` recover fit function from histo (analogous for graph)

`fitFunc->GetChisquare()`

`fitFunc->GetNDF();` degrees of freedom

`fitFunc->GetProb();` fit probability

`fitFunc->GetParameter(<i>);` `i`-th parameter value

`fitFunc->GetParError(<i>);` error on `i`-th parameter

ONLY IF "S" OPTION USED:

```
TFitResultPtr r = h->Fit(\fitFunc", \S");
TMatrixD cor = r->GetCorrelationMatrix();
TMatrixD cov = r->GetCovarianceMatrix();
cor.Print();
cov.Print();
```

10.1 Statistics & fit parameters

`gStyle->SetOptStat(<ksiourmen>)` choose statistics parameters to be displayed
(each mode with a value - default **0** if omitted):

- `k` **1** = print kurtosis, **2** = print kurtosis + k. error
- `s` **1** = print skewness, **2** = print skewness + s. error
- `i` **1** =print integral of bins, **2** = print integral of bins with option
- `o` **1** = print number of overflows
- `u` **1** = print number of underflows
- `r` **1** = print SD **2** = print SD + SD error [1]
- `m` **1** = print mean **2** = print mean + mean error
- `e` **1** = print number of entries
- `n` **1** = print histogram name

STARTS FROM THE END:

```
gStyle->SetOptStat(11); // only name + entries
gStyle->SetOptStat(1101); // name, mean, RMS
```

`gStyle->SetOptFit(<pcev>)` analogous for fit parameters:

[1] Actually `r` stands for Root Mean Square, defined according to

$$x_{RMS} = \sqrt{\frac{1}{n}\sum x_i^2}$$

`p` **1** = print Probability

`c` **1** = print Chisquare / Number of d.o.f.

`e` **1** = print errors

`v` **1** = print name/values of parameters (only non-fixed) **2** = print name/value of *all* parameters

`gStyle->SetOptFit(1)` is **equivalent** to `gStyle->SetOptFit(111)` (!)

11 Functions

In 1 variable (x): class **TF1**. User-defined function (and function objects, lambda) or built-in function objects → **TFormula**
For more dimensions (variables) **TF2, TF3**.

`TF1 *f1 = new TF1("f1", "sin(x)/x",<xmin>,<xmax>);`

`TF1 *f2 = new TF1("f2", "f1 * 2",0,10);` previously defined functions can be used in definition of new ones

`TF1 *f3 = new TF1("f3","[0]*x*sin([1]*x)",-3,3);` possible to use parameters

`f3->SetParameter(<index>, <value>);` to **initialize** one of them

`f3->SetParameters(<value1>, <value2>, ..., <valuek>);` following order!

See TFormula for more info

For user-defined:

```
Double_t MyFunction(Double_t *x, Double_t *par){
    Float_t xx = x[0];
    Double_t val = TMath::Abs(par[0]*sin(par[1]*xx)/xx);
    return val;
}
```

Note: important to follow this signature!

`TF1 *f4 = new TF1("f4",MyFunction,0,10,2);`
last constructor parameter is **number of parameters in MyFunction**

`TF1 *f5 = new TF1("f5", [](double *x, double *p){ <function body> }, <xmin>, <xmax>, <npar>);`
use of lambdas is also possible

`TF1 *f6 = new TF1("f6", "[](double *x, double *p){ <function body> }", <xmin>, <xmax>, <npar>);`
also as string expression (JIT will do the rest)

Cosmetics

`f1->SetLineColor(kRed);`

`f1->SetLineStyle(2);` 2 = dashed, 3 = dotted, 4 = dasheddotted

Member functions:

`f1->Eval(<x_value>);` evaluate on a point

`f1->Integral(<a>, <b>);` compute $\int_a^b f1$

`f1->SetMaximum(<value>);` set maximum for Y axis

`f1->SetMinimum(<value>);` minimum for Y axis

`f1->SetRange( <x_min> , <x_max> );` set interval for indipendent variable to `[x_min,x_max]`

12 TMath and TFormula

TMath

`TMath::Abs(<x>)`

`TMath::AreEqualAbs(<x>,<y>,<eps>)` returns true if `TMath::Abs(x-y) < eps`

`TMath::ASin(<x>)` ; `TMath::ASinH(<x>); TMath::ATan(<x>); TMath::ACos(<x>); TMath::ACosH(<x>)`

`TMath::Cos(<x>)` ; `TMath::CosH(<x>)`

`TMath::Sin(<x>)` ; `TMath::SinH(<x>)`

`TMath::Tan(<x>)` ; `TMath::TanH(<x>)`

`TMath::Ln10()` returns $\ln 10$

`TMath::LogE()` returns $\log_{10} e$

`TMath::Ldexp(<x>, <exp>)` where `exp` is integer. Returns $x \cdot 2^{exp}$

`TMath::Log(<x>)` natural logarithm

`TMath::Log10(<x>)` returns $\log_{10} x$

`TMath::Log2(<x>)` returns $\log_2 x$

`TMath::Max(<x>,<y>)` returns maximum value between `x` and `y` (for integers, doubles... everything)

`TMath::Min(<x>,<y>)` same but for minimum

`TMath::Nint(<x>)` rounds `x` to mearest integer

`TMath::Power(<x>,<y>)` returns x^y

`TMath::Prob(<chi2>,<ndof>)` returns probability for $\chi^2 =$ `chi2` with `ndof` degrees of freedom

`TMath::Sq(<x>)` returns x^2

`TMath::Sqrt(<x>)` returns $\sqrt{x}$

`TMath::Gaus(<x>,<mean>,<sigma>,<Bool_norm>)` boolean for normalization, default false. If true value divided by $\sqrt{2\pi}\sigma$

`TMath::Factorial(<int>)` returns double

`TMath::Erf(<x>)` error function [2]

`TMath::Erfc(<x>)`

`TMath::ErfInverse(<x>)` x must be in $]-1,1[$ `TMath::ErfcInverse(<x>)` x must be in $]0,2[$

CONSTANTS

`TMath::E()` returns e

`TMath::G()` returns G

`TMath::Gn()` returns g

[2]
$$Erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} \, \mathrm{d}t$$

`TMath::H()` returns h `TMath::Hbar()` returns $\hbar$

`TMath::K()` returns k_B

`TMath::Na()` returns N_A

`TMath::Pi()` returns π

`TMath::R()` returns R

`TMath::Sigma()` returns σ (Stefan-Boltzmann)

`TMath::Sqrt2()` returns $\sqrt{2}$

TFormula

`gaus(<const>,<mean>,<sigma>)` not normalized

`landau(<mpv>,<sigma>)`

`expo(<const>,<slope>)` e^{A+Bx}

`pol<N>(<p1>, ... ,<pN>)` polynomial $\sum_{i=1}^{N} pi \cdot x^i$

`sqrt(<x>)`

`sq(<x>)` x^2

`pow(<x>,<y>)` x^y

`<x>*<y>`

`<x>^<n>` or `<x>**<n>`

`<x>/<y>`

`sin(<x>)` `cos(<x>)` `tan(<x>)`

`asin(<x>)` `acos(<x>)` `atan(<x>)`

`sinh(<x>)` `cosh(<x>)` `tanh(<x>)`

`asinh(<x>)` `acosh(<x>)` `atanh(<x>)`

`exp(<x>)`

`log(<x>)`

`log10(<x>)`

`e` | `pi`

`ln10` | `sqrt2`

In function initialization, values can be replaced either with the variable `x` or parameters `[i]`.
Some special ones, where `n` **is the starting index for numbering.**

`gaus(<n>)` not default normalized gaussian with three parameters

`gausn(<n>)` normalized gaussian with three parameters

`expo(<n>)` exponential with two parameters

`pol<N>(<n>)` polynomial with `N` parameters

13 Legend

`TLegend *leg = new TLegend(<x1>,<y1>,<x2>,<y2>,"<title>");`
$(x1, y2)$ = bottom left corner, $(x2, y2)$ = upper right corner **in normalized coordinates**
so 1 = **pad** height / width

$$x = \frac{absolute\ \ horizontal\ \ position}{screen\ \ width} \qquad y = \frac{absolute\ \ vertical\ \ position}{screen\ \ height}$$

x goes from left to right, y from bottom to top
Careful when using more pads (see **Canvas syntax**)

```
leg->AddEntry(graph,"Punti sperimentali");
leg->AddEntry(f,"Fit Lineare");
leg->AddEntry(<object>,"<description>");
leg->AddEntry(<object>,"<description>", "<option>"); // alternative syntax
```

Possible options (even more than one of these):

`l` line

`e` error bar

`p` point

```
leg->Draw("Same");
```

`leg->SetTextAlign(<nm>);` with nn = 11, ..., 13

11	21	31
12	22	32
13	23	33

Cosmetics (`gStyle` member functions)

```
gStyle->SetLegendBorderSize(<n>);
gStyle->SetLegendFillColor(<color>);
gStyle->SetLegendFont(<n>); // see below
gStyle->SetLegendTextSize(<size>); // see below
```

font code (`<n>`) = 10 × font number + precision

Example of fonts with precision = 2:

12 : *ABCDEFGH abcdefgh 0123456789 @#$*

22 : **ABCDEFGH abcdefgh 0123456789 @#$**

32 : ***ABCDEFGH abcdefgh 0123456789 @#$***

42 : ABCDEFGH abcdefgh 0123456789 @#$

52 : *ABCDEFGH abcdefgh 0123456789 @#$*

62 : **ABCDEFGH abcdefgh 0123456789 @#$**

72 : ***ABCDEFGH abcdefgh 0123456789 @#$***

82 : ABCDEFGH abcdefgh 0123456789 @#$

92 : *ABCDEFGH abcdefgh 0123456789 @#$*

102 : **ABCDEFGH abcdefgh 0123456789 @#$**

112 : ***ABCDEFGH abcdefgh 0123456789 @#$***

122 : ΑΒΧΔΕΦΓΗ αβχδεφγη 0123456789 ≅#∃

132 : ABCDEFGH abcdefgh 0123456789 @#$

142 : ♈♉♊♋ ♏♐♑♒ 🗀🗁🗎🗐 ✍✂✍

152 : *ΑΒΧΔΕΦΓΗ αβχδεφγη 0123456789 ≅#∃*

14 Canvas syntax

`TCanvas* myCanvas = new TCanvas();`

`TCanvas* myCanvas = new TCanvas("<name>", "<title>", <x_pxs>, <y_pxs>);`

`TCanvas* myCanvas = new TCanvas("<name>", "<title>", <top_x>, <top_y>, <x_pxs>, <y_pxs>);`

`myCanvas->Print("<file-name>.<extension>", "<option>");` prints canvas to file. Possible formats:

- `.ps` (Postscript, default one) with options `Portrait` or `Landscape`,
- `.eps` (encapsulate Postscript), `.pdf` with option `Title: <title>`,
- `.svg, .tex, .gif, .gif+<N>` (animated gif, where `N` is the delay in units of 10ms)
- `.xpm, .png, .jpg, .tiff, .cxx, .xml, .json, .root`

`myCanvas->SetCanvasSize(<x_px>,<y_px>);`

`myCanvas->SetWindowSize(<x_px>,<y_px>);`
If canvas size exceeds window size, scrollbars are displayed

`myCanvas->GetWh();` get value of window height

`myCanvas->GetWw();` get value of window width

`myCanvas->ToggleToolBar();` hides if shown or vice versa

`myCanvas->SetLogx();` `myCanvas->SetLogy();` `myCanvas->SetLogz();` set logarithmic scale

Pads

`myCanvas->Divide(<nx>, <ny>)` divides equally into nx×ny pads

`myCanvas->Divide(<nx>, <ny>, <x_margin>, <y_margin>, <color>)` Same; margins are given as **percent of canvas**. `color` is the color of new pads;

Pads can be divided in sub-pads.

`myCanvas->cd(<pad_num>)` sets current pad. Starts from `1`, `0` is parent pad (frame). Current pad can be retrieved through `gPad`. It goes by rows, so the numbering looks like:

$$\begin{bmatrix} 1 & \to & n \\ n+1 & \to & 2n \\ \vdots & \vdots & \vdots \\ (m-1)n+1 & \to & mn \end{bmatrix}$$

styling options for canva with single pad can be applied to single pads through global pointer

```
myCanvas->Divide(2,2);
myCanvas->cd(1);
gPad->SetLogy();
```

15 Pseudo-Random number generation: TRandom

Classes with algorithms employed:

- `TRandom` ..... Linear Congruential Generator

  ↖ *It's a* **very bad** *generator, not to be used!*

- `TRandom1` ..... RANLUX
- `TRandom2` ..... Tausworthe
- `TRandom3` ..... Mersenne Twister

15.1 Methods for generic distributions

Called on global pointer `gRandom` or on `TRandom*` pointer after declaration

`Uniform(<double_1>, <double_2>)` uniform distribution on $]$`double_1, double_2`$]$ based on `Rndm()`

`Rndm()` uniform in $]$`0, 1`$]$

`Uniform(<double>)` uniform distribution on $]$`0, double`$]$

`Integer(<int_max>)` uniform **integer** distribution on $[$`0, int_max - 1`$]$

`Gaus(<mean>, <sigma>)` (careful, just one '`s`')

`Poisson(<mean>)` **integer** poissonian distribution

`PoissonD(<mean>)` **double** poissonian distribution

`Binomial(<n_tot>, <prob_of_succ>)`

`Exp(<tau>)`

`Landau(<mpv>, <sigma>)` Landau distribution: `mpv` is the *most probable value* (moda) and sigma is *not* the SD (which is undefined)

15.2 Random generation from a generic function

```
TF1 *f1 = new TF1("f1", "<expression>", <xmin>, <xmax>);
double rd = f1->GetRandom();
```

`r` is now a random variable distributed according to the PDF defined by `f1`. It is not necessary to manually ensure that `f1` is normalized: **normalization is carried out automatically**, the only requirement on the function is **continuity**.

`histo->FillRandom("<function>", <n>)` fills the histogram with `n` extractions from a random variable distributed according to `function` (name). Same considerations as before apply.

15.3 Filling an histo with randomly generated values

```
for(Int_t j=0;j<ngen;j++){ // generation loop
   Double_t x = gRandom->Uniform(xmin,xmax); // extraction
   h->Fill(x); // filling
}
```

16 Benchmark

`TBenchmark *b = new TBenchmark();` initialize

`b->Start("<name>");` start benchmark with specified name
(more with different names from same b)

`b->Stop("<name>");` stop benchmark with specified name

`b->Print("<name>");` print parameters

`b->Show("<name>");` = stop + print

17 Trees

Data structures for storage of homologous units made of *heterogeneous* objects. Useful for data persistance, optimization of memory usage (thanks to compression) and I/O speed - expecially in WORM - and flexibility in analysis.
Can handle **any** data type. Direct access to any point; only object (even partially) placed on memory.
Organised in TBranches, themselfs structured in TLeafs

17.1 Filling

```
TTree *T = new TTree("T","test"); // create the tree
Float_t x,y,z;
T->Branch("x",&x,"x/F"); // create branches
T->Branch("y",&y,\y/F"); // <name>/<type>
T->Branch("z",&z,\z/F");
for(Int_t i=0;i<100;i++){
  ... // read or generate x y z, very costly operations
  T->Fill(); // fill the tree, for each entry
}
```

17.2 Reading and representing

```
T->Print(); // list of contained variables

T->Draw(\x"); // show variable. Histo layout chosen by ROOT

TH1F *h1=new TH1F("h1","hist from tree",50,-4, 4);
T->Draw("x>>h1"); // to fill user defined histo

T->Draw("x","x>0");        // selection on 1v
T->Draw("x","y>0 && x<10") // selection on 2vv

Tout->Draw(\sqrt(x*x+y*y)"); // operation on variables

T->Draw(\y:x");   // 2d correlation plot
T->Draw(\z:y:x"); // 3d
```