# Tutorial on
# ROOT and Data Analysis

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# Objective

- This tutorial is about doing data analysis using ROOT Tree
- We discuss writing and reading events to/from tree, where trees are defined in various formats
- We start from simpler examples and slowly add more features that makes data storage and analysis easier.
- The programs for the examples discussed here are available in the tutorial directory. You need to look at those programs, when we discuss them, try to understand and use them for practice.
- Please don't hesitate to ask any questions or report your problems and difficulties
- Once we go through the examples, there are some exercises for you to work on.
- Reference: https://root.cern.ch/root/htmldoc/guides/users-guide/ROOTUsersGuide.html

# Tree

ROOT Tree (TTree class) is designed to store large quantities of same-class objects, and is optimized to reduce disk space and enhance access speed.
It can hold all kind of data, such as objects or arrays, in addition to simple types.

<u>An example for creating a simple Tree</u>

```
void tree_example1() {

  TFile *f = new TFile("myfile.root", "RECREATE");
  TTree *T = new TTree("T","simple tree");
  TRandom r;
  Float_t px,py,pt;
  Double_t random;
  UShort_t i;
  T->Branch("px",&px,"px/F");
  T->Branch("py",&py,"py/F");
  T->Branch("pt",&pt,"pt/F");
  T->Branch("random",&random,"random/D");

  for (i = 0; i < 10000; i++) {
    r.Rannor(px,py);
    pt = std::sqrt(px*px + py*py);
    random = r.Rndm();
    T->Fill();
  }

  f->Write();
  f->Close();
}
```

Run the macro:

root -l tree_example1.C

# More on TBranch

- The class for a branch is called TBranch
- A variable in a TBranch is called a leaf (TLeaf)
- If two variables are independent they should be placed on separate branches. However, if they are related it is efficient to put them on same branch
- TTree::Branch() method is used to add a TBranch to TTree
- The branch type is decided by the object stored in it
- A branch can hold an entire object, a list of simple variables, contents of a folder, contents of a TList, or an array of objects.

For example:

```
tree->Branch("Ev_Branch",&event,  "temp/F:ntrack/I:nseg:nvtex:flag/i");
```

Where “event” is structure with one float, three integers, and one unsigned integer.

# Accessing TTree

## Show an entry:

```
root [ ] TFile f("myfile.root")
root [ ] T->Show(10)
======> EVENT:10
 px          = 0.680243
 py          = 0.198578
 pt          = 0.708635
 random      = 0.586894
```

## Scan a few variables:

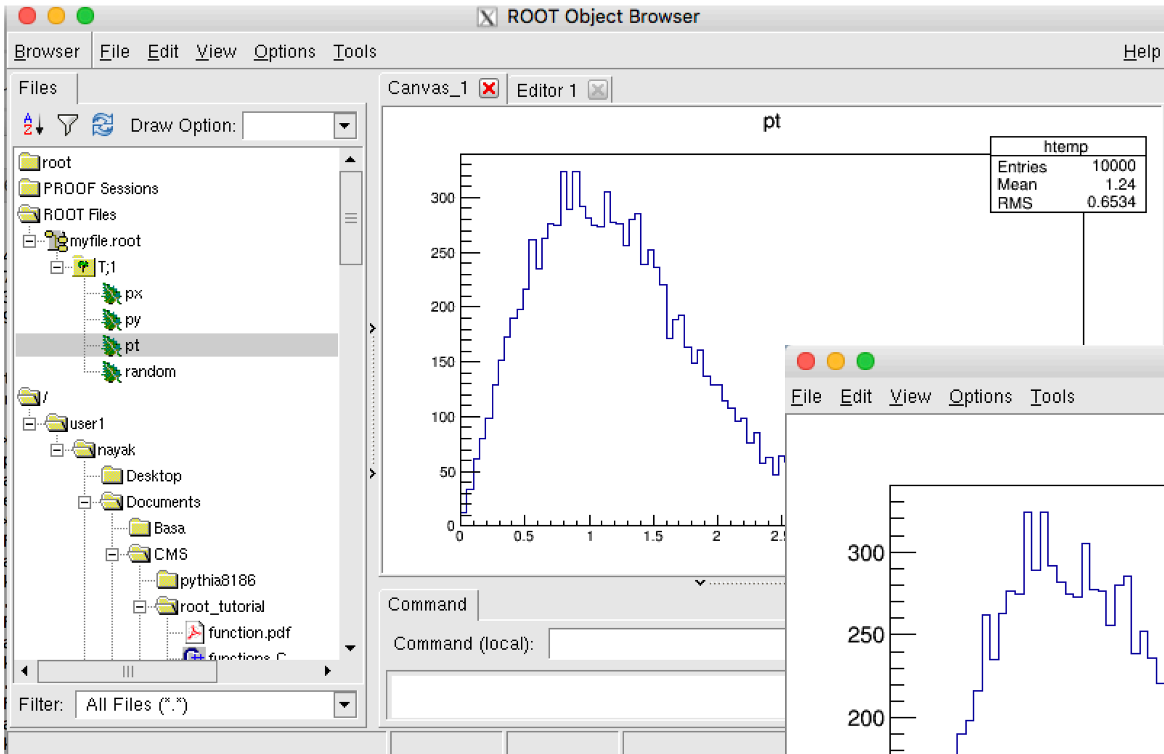
```
root [ ] T->Scan("px:py:pt")
************************************
*    Row   *       px *       py *       pt *
************************************
*        0 * 0.8966467 * -1.712815 * 1.9333161 *
*        1 * 1.5702210 * 0.5797516 * 1.6738297 *
*        2 * 0.6975117 * 0.1442547 * 0.7122724 *
*        3 * 0.0616207 * -1.009907 * 1.0117853 *
*        4 * -0.054552 * 1.3832200 * 1.3842953 *
*        5 * -2.017178 * 1.4682819 * 2.4949667 *
*        6 * 0.8903368 * 2.5101616 * 2.6633834 *
*        7 * -1.098390 * -0.318103 * 1.1435256 *
*        8 * 0.3865155 * 0.0235152 * 0.3872301 *
*        9 * 1.8970719 * 1.9546536 * 2.7238855 *
*       10 * 0.6802427 * 0.1985776 * 0.7086347
```

## Print the Tree structure:

```
root [ ] T->Print()

******************************************************************
*Tree    :T        : simple tree                                 *
*Entries :    10000 : Total =        202834 bytes  File  Size =     169658        *
*        :         : Tree compression factor =   1.19            *
******************************************************************
*Br    0 :px       : px/F                                        *
*Entries :    10000 : Total  Size=     40594 bytes  File Size  =     37262        *
*Baskets :        2 : Basket Size=     32000 bytes  Compression=   1.08        *
*................................................................*
*Br    1 :py       : py/F                                        *
*Entries :    10000 : Total  Size=     40594 bytes  File Size  =     37265        *
*Baskets :        2 : Basket Size=     32000 bytes  Compression=   1.08        *
*................................................................*
*Br    2 :pt       : pt/F                                        *
*Entries :    10000 : Total  Size=     40594 bytes  File Size  =     35874        *
*Baskets :        2 : Basket Size=     32000 bytes  Compression=   1.12        *
*................................................................*
*Br    3 :random    : random/D                                   *
*Entries :    10000 : Total  Size=     80696 bytes  File Size  =     58600        *
*Baskets :        3 : Basket Size=     32000 bytes  Compression=   1.37        *
*................................................................*
```

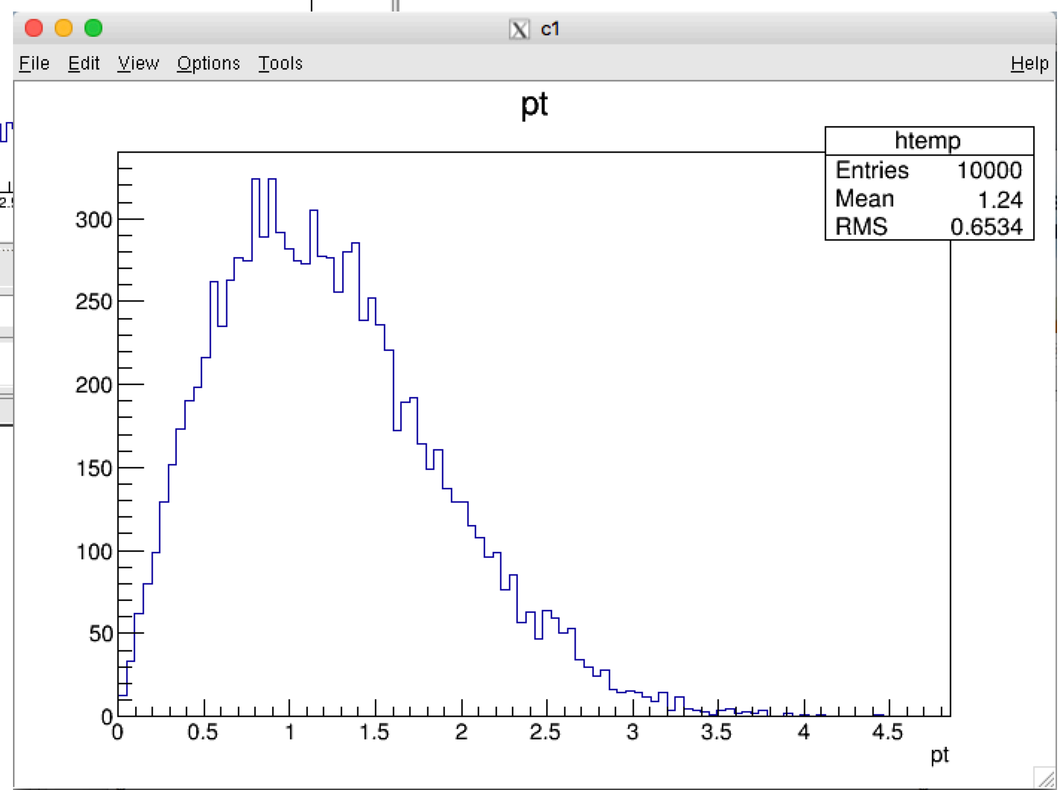
# Accessing TTree

Open and Draw branches using TBrowser:




Using TTree::Draw()

T->Draw("pt")




2D plot:

T->Draw("py:px")

# Simple Analysis using TTree::Draw()

Applying cuts:
T->Draw(“pt”, “px>0&&py>0”)

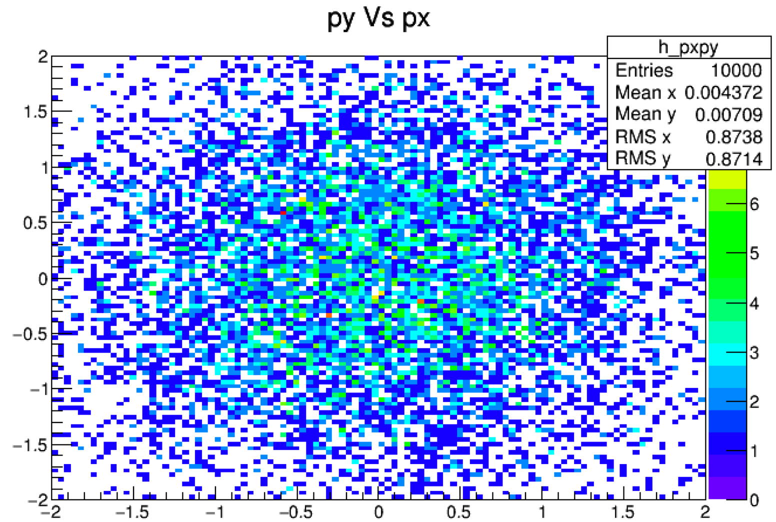
For applying “weights” to the distribution:
Selection = “weight * (boolean expression)”
Where “weight” is a event-by-event weight stored as a branch in the ntuple (e.g. cross section * luminosity for the normalization)

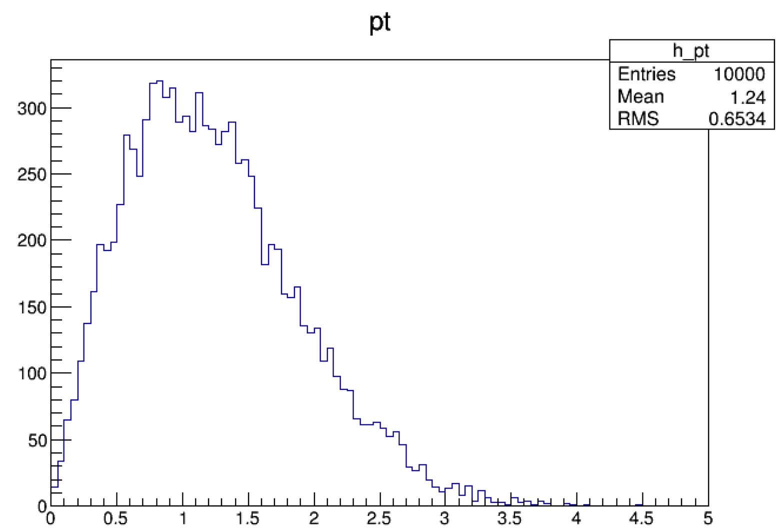
Using TCuts:
TCut c1 = “px > 0”
TCut c2 = “py < 0”
TCut c3 = c1 && c2
T->Draw(“pt”, c3)
T->Draw(“pt”, c1 && c2)
T->Draw(“pt”, c1 && “py > 0”)
TCut c4 = c1 || c2
T->Draw(“pt”, c4)
T->Draw(“pt”, c1 || c2)

Filling Histograms:
TH1F *hist = new TH1F("hist", "", 100, 0., 2.);
T->Draw("pt>>hist");
hist->SetLineColor(2);
hist->Draw("same")

# A Simple Analyzer

```
void tree_example2() {

  TH2F *h_pxpy = new TH2F("h_pxpy", "py Vs px", 100, -2.0, 2.0, 100, -2.0, 2.0);
  TH1F *h_pt = new TH1F("h_pt", "pt", 100, 0., 5.0);

  TFile *f = new TFile("myfile.root");
  TTree *t1 = (TTree*)f->Get("T");

  Float_t px,py,pt;
  Double_t random;

  t1->SetBranchAddress("px",&px);
  t1->SetBranchAddress("py",&py);
  t1->SetBranchAddress("pt",&pt);
  t1->SetBranchAddress("random",&random);

  Int_t nentries = (Int_t)t1->GetEntries();

  for (Int_t i = 0; i<nentries; i++) {
    t1->GetEntry(i);

    h_pxpy->Fill(px, py);
    h_pt->Fill(pt);

  }

  TCanvas *c1 = new TCanvas();
  h_pxpy->Draw("colz");
  c1->SaveAs("tree_example2_pxpy.png");

  c1->Update();
  h_pt->Draw();
  c1->SaveAs("tree_example2_pt.png");

  f->Close();
}
```




Run the macro:
root -l tree_example2.C

Task: Add histogram attributes (axis title, line color etc..)

# Adding Branch with Arrays

```
//Tree with fixed size arrays
void tree_example3() {

  TFile *f = new TFile("myfile.root", "RECREATE");
  TTree *T = new TTree("T","tree with fixed array");
  TRandom r;
  Float_t px[5],py[5],pt[5];

  T->Branch("px",px,"px[5]/F");
  T->Branch("py",py,"py[5]/F");
  T->Branch("pt",pt,"pt[5]/F");


  for (Int_t i = 0; i < 10000; i++) {
    Float_t x, y;
    for(Int_t j = 0; j < 5; j++){
      r.Rannor(x, y);
      px[j] = x;
      py[j] = y;
      pt[j] = std::sqrt(x*x + y*y);
    }
    T->Fill();
  }

  f->Write();
  f->Close();
}
```

Run Macro:

root -l tree_example3.C

See the contents:

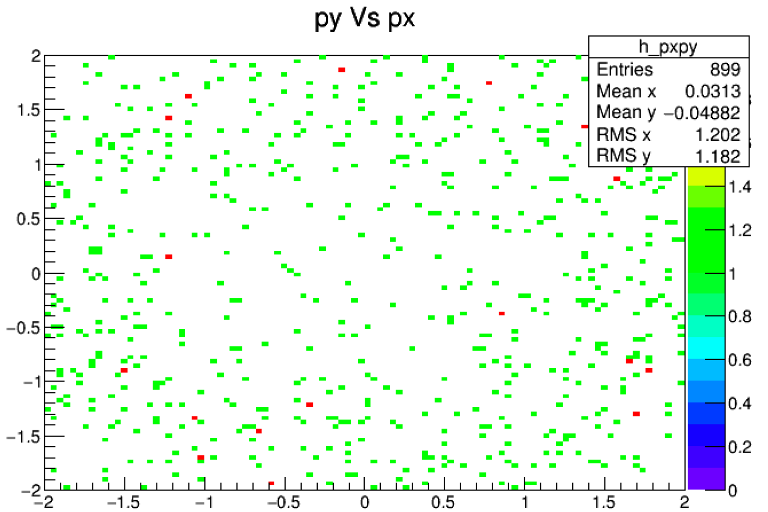
```
root [0] TFile f("myfile.root")
root [1] T->Show(0)
======> EVENT:0
 px                = 0.896647,
                    0.685336, 1.58414, 0.697512, -0.318623
 py                = -1.71282,
                    0.0155619, 0.879379, 0.144255, -0.442143
 pt                = 1.93332,
                    0.685512, 1.81185, 0.712272, 0.544988
```

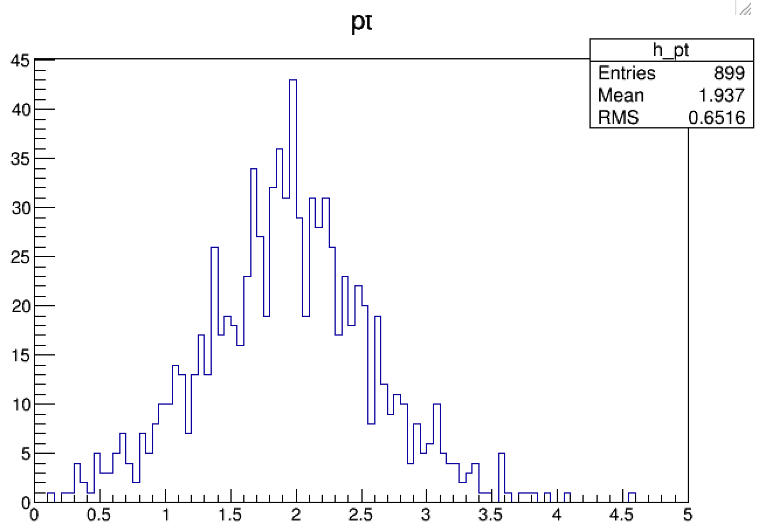
```
//Tree with variable size arrays
void tree_example4() {

  TFile *f = new TFile("myfile.root", "RECREATE");
  TTree *T = new TTree("T","tree with fixed array");
  TRandom r;
  Float_t px[10],py[10],pt[10];
  Int_t np;

  T->Branch("np",&np,"np/I");
  T->Branch("px",px,"px[np]/F");
  T->Branch("py",py,"py[np]/F");
  T->Branch("pt",pt,"pt[np]/F");


  for (Int_t i = 0; i < 1000; i++) {

    Float_t x, y;
    np = (Int_t)(r.Rndm()*10);
    for(Int_t j = 0; j < np; j++){
      r.Rannor(x, y);
      px[j] = x;
      py[j] = y;
      pt[j] = std::sqrt(x*x + y*y);
    }
    T->Fill();
  }

  f->Write();
  f->Close();
}
```

```
root [1] T->Show(4)
======> EVENT:4
 np              = 7
 px              = -0.924715,
                   0.567014, 0.261468, -0.545032, 0.156111, -0.698435,
                   0.297523
 py              = -1.52197,
                   0.0129729, -1.429, -0.23653, 1.7405, -1.03075,
                   0.217231
 pt              = 1.78087,
                   0.567162, 1.45273, 0.594144, 1.74749, 1.2451,
                   0.368388
```

# Reading Branch with Arrays

```
void tree_example5() {

  TH2F *h_pxpy = new TH2F("h_pxpy", "py Vs px", 100, -2.0, 2.0, 100, -2.0, 2.0);
  TH1F *h_pt = new TH1F("h_pt", "pt", 100, 0., 5.0);

  TFile *f = new TFile("myfile.root");
  TTree *t1 = (TTree*)f->Get("T");

  Float_t px[10],py[10],pt[10];
  Int_t np;

  t1->SetBranchAddress("np",&np);
  t1->SetBranchAddress("px",px);
  t1->SetBranchAddress("py",py);
  t1->SetBranchAddress("pt",pt);

  Int_t nentries = (Int_t)t1->GetEntries();

  for (Int_t i = 0; i<nentries; i++) {
    t1->GetEntry(i);

    //Find the object with highest pt and fill its distributions
    Float_t hPt = 0;
    Int_t h_index = -1;
    if(np>0){
      for(Int_t j = 0; j < np; j++){
        if(pt[j] > hPt){
          hPt = pt[j];
          h_index = j;
        }
      }

      h_pxpy->Fill(px[h_index], py[h_index]);
      h_pt->Fill(pt[h_index]);
    }

  }

  TCanvas *c1 = new TCanvas();
  h_pxpy->Draw("colz");
  c1->SaveAs("tree_example5_pxpy.png");

  c1->Update();
  h_pt->Draw();
  c1->SaveAs("tree_example5_pt.png");

  f->Close();
}
```



# Branch with Vectors

Advantage: No need to define arrays with MAX SIZE

```
//Tree with vectors
#include <vector>

void tree_example6() {

  TFile *f = new TFile("myfile.root", "RECREATE");
  TTree *T = new TTree("T","tree with fixed array");
  TRandom r;
  std::vector<Float_t> px, py, pt;
  Int_t np;

  T->Branch("px", "std::vector<Float_t>", &px);
  T->Branch("py", "std::vector<Float_t>", &py);
  T->Branch("pt", "std::vector<Float_t>", &pt);

  for (Int_t i = 0; i < 1000; i++) {

    //clean vectors for each event
    px.clear(); py.clear(); pt.clear();
    //Fill vectors for each event
    Float_t x, y;
    np = (Int_t)(r.Rndm()*10);
    for(Int_t j = 0; j < np; j++){
      r.Rannor(x, y);
      px.push_back(x);
      py.push_back(y);
      pt.push_back(std::sqrt(x*x + y*y));
    }
    T->Fill();
  }

  f->Write();
  f->Close();
}
```

You get only pointers to vectors in TTree::Show() method

TTree::Draw() works only for basic type vectors

```
root [1] T->Show(4)
======> EVENT:4
 px              = (vector<float>*)0x11a9d10
 py              = (vector<float>*)0x11abcf0
 pt              = (vector<float>*)0x11ace80
root [2] T->Draw("px")
```

```
//Read Tree with vectors as branch
#include <vector>

void tree_example7() {

  TH2F *h_pxpy = new TH2F("h_pxpy", "py Vs px", 100, -2.0, 2.0, 100, -2.0, 2.0);
  TH1F *h_pt = new TH1F("h_pt", "pt", 100, 0., 5.0);

  TFile *f = new TFile("myfile.root");
  TTree *t1 = (TTree*)f->Get("T");

  std::vector<Float_t> *px = new std::vector<Float_t>();
  std::vector<Float_t> *py = new std::vector<Float_t>();
  std::vector<Float_t> *pt = new std::vector<Float_t>();


  t1->SetBranchAddress("px", &px);
  t1->SetBranchAddress("py", &py);
  t1->SetBranchAddress("pt", &pt);

  Int_t nentries = (Int_t)t1->GetEntries();

  for (Int_t i = 0; i<nentries; i++) {
    t1->GetEntry(i);

    //Find the object with highest pt and fill its distributions
    Float_t hPt = 0;
    Int_t h_index = -1;
    if(pt->size() > 0){
      for(Int_t j = 0; j < pt->size(); j++){
        if((*pt)[j] > hPt){
          hPt = (*pt)[j];
          h_index = j;
        }
      }

      h_pxpy->Fill((*px)[h_index], (*py)[h_index]);
      h_pt->Fill((*pt)[h_index]);
    }

  }
```

# Exercises

- There are two root files in your tutorial directory: “ntuple_array.root” and “ntuple_vector.root”
- They contain events simulated with the process pp → Z → $e^+e^-$ or $\mu^+\mu^-$
- The tree contains branches for momentum, particle ID etc.. for generated electron/muon (branch names like genParticlePx etc..), momentum, identification, isolation variables etc.. for reconstructed electrons and muons (branch names like muonPx, electronPx etc..)
- File “ntuple_array.root” contains tree with branches as variable arrays
- File “ntuple_vector.root” contains tree with branches as vectors

- Write your own macro/code (two separate macro for two input files) to read the trees from the files
- Select events where you have two generated muons (or electrons) of opposite charge. Combine the momenta of the generated $\mu^+\mu^-$ ($e^+e^-$) pair to get the momentum of Z boson. Plot the mass of the generated Z boson
- Select events where you have two reconstructed muons (or electrons) of opposite charge. Combine the momenta of the reconstructed $\mu^+\mu^-$ ($e^+e^-$) pair to get the momentum of Z boson. Plot the mass of the reconstructed Z boson

# Branch with Event Class – I

First write your own Event class in a separate header file.
An example “MyEvent.h”:

```
#ifndef __MYEVENT__
#define __MYEVENT__
#include <iostream>
#include "TObject.h"

class MyEvent{
 public:
  MyEvent(){ px = 0; py = 0; pt = 0;};
  virtual ~MyEvent(){};

  void setPx(float x_){ px = x_;};
  void setPy(float y_){ py = y_;};
  void setPt(float t_){ pt = t_;};

  float getPx(){return px;};
  float getPy(){return py;};
  float getPt(){return pt;};

 private:
  float px;
  float py;
  float pt;
  ClassDef(MyEvent,1)
};
#endif
```

```
#include "MyEvent.h"

ClassImp(MyEvent);
```

Create a shared object file, using the command in root prompt:

.L MyEvent.h+

It will create a .so file, like MyEvent_h.so, in the same directory.
Note: It uses ACLiC to generate dictionaries

OR, you can use the rootcint.
For that, use the Makefile given in the tutorial directory.
Just use the command “make”

# Branch with Event Class - II

```
//Example of Tree using MyEvent Class
#include "MyEvent.h"

void tree_example8() {

  TFile *f = new TFile("myfile.root", "RECREATE");
  TTree *T = new TTree("T","tree with class");
  TRandom r;
  Float_t px,py,pt;

  MyEvent *event = new MyEvent();
  T->Branch("Event", "MyEvent", &event);

  for (Int_t i = 0; i < 10000; i++) {
    r.Rannor(px,py);
    pt = std::sqrt(px*px + py*py);

    event->setPx(px);
    event->setPy(py);
    event->setPt(pt);

    T->Fill();
  }

  f->Write();
  f->Close();
}
```

To run this program, you need to first load the library containing the class definition, as follows:

root –l

.L libMyEvent.so

.L tree_example8.C

tree_example8()

See the tree content using TTree::Show() and in TBrowser

```
root [3] T->Show(0)
======> EVENT:0
 Event           = (MyEvent*)0x1c023c0
 px              = 0.896647
 py              = -1.712815
 pt              = 1.933316
```

# Branch with Event Class - III

```
//Example of reading Tree using MyEvent Class
#include "MyEvent.h"

void tree_example9() {

  TH2F *h_pxpy = new TH2F("h_pxpy", "py Vs px", 100, -2.0, 2.0, 100, -2.0, 2.0);
  TH1F *h_pt = new TH1F("h_pt", "pt", 100, 0., 5.0);

  TFile *f = new TFile("myfile.root");
  TTree *t1 = (TTree*)f->Get("T");

  Float_t px,py,pt;
  MyEvent *event = new MyEvent();

  t1->SetBranchAddress("Event", &event);

  Int_t nentries = (Int_t)t1->GetEntries();

  for (Int_t i = 0; i<nentries; i++) {
    t1->GetEntry(i);

    h_pxpy->Fill(event->getPx(), event->getPy());
    h_pt->Fill(event->getPt());

  }

  TCanvas *c1 = new TCanvas();
  h_pxpy->Draw("colz");
  c1->SaveAs("tree_example9_pxpy.png");

  c1->Update();
  h_pt->Draw();
  c1->SaveAs("tree_example9_pt.png");

  f->Close();
}
```

Run this program, as follows:

root –l

.L libMyEvent.so

.L tree_example9.C

tree_example9()

Look at the produced plots.

Do you get the same distributions as example2?

# Branch with Event Class - IV

```
//Tree with vector<MyEvent> as branch
#include <vector>
#include "MyEvent.h"

void tree_example10() {

  TFile *f = new TFile("myfile.root", "RECREATE");
  TTree *T = new TTree("T","tree with vector");
  TRandom r;
  std::vector<MyEvent> *events = new std::vector<MyEvent>();

  T->Branch("Events", "std::vector<MyEvent>", &events);

  for (Int_t i = 0; i < 1000; i++) {

    //clean vectors for each event
    events->clear();
    //Fill vectors for each event
    Float_t px, py;
    Int_t np = (Int_t)(r.Rndm()*10);
    for(Int_t j = 0; j < np; j++){
      r.Rannor(px, py);
      Float_t pt = std::sqrt(px*px + py*py);
      MyEvent event;
      event.setPx(px);
      event.setPy(py);
      event.setPt(pt);
      events->push_back(event);
    }
    T->Fill();
  }

  f->Write();
  f->Close();

  delete events;
}
```

In the previous example, you have one object (particle) per entry. However, you normally have many particles per event. In this case, you can use vector<MyEvent> as the branch.

Run this program, as follows:

root –l

.L libMyEvent.so

.L tree_example10.C

tree_example10()

# Branch with Event Class - V

```
//Read Tree with vector<MyEvent> as branch
#include <vector>
#include "MyEvent"

void tree_example11() {

  TH2F *h_pxpy = new TH2F("h_pxpy", "py Vs px", 100, -2.0, 2.0, 100, -2.0, 2.0);
  TH1F *h_pt = new TH1F("h_pt", "pt", 100, 0., 5.0);

  TFile *f = new TFile("myfile.root");
  TTree *t1 = (TTree*)f->Get("T");

  std::vector<MyEvent> *events = new std::vector<MyEvent>();

  t1->SetBranchAddress("Events", &events);

  Int_t nentries = (Int_t)t1->GetEntries();

  for (Int_t i = 0; i<nentries; i++) {
    t1->GetEntry(i);

    //Find the object with highest pt and fill its distributions
    Float_t hPt = 0;
    Int_t h_index = -1;
    if(events->size() > 0){
      for(Int_t j = 0; j < events->size(); j++){
        MyEvent event = events->at(j);
        if(event.getPt() > hPt){
          hPt = event.getPt();
          h_index = j;
        }
      }

      MyEvent event =events->at(h_index);
      h_pxpy->Fill(event.getPx(), event.getPy());
      h_pt->Fill(event.getPt());
    }

  }

  TCanvas *c1 = new TCanvas();
  h_pxpy->Draw("colz");
  c1->SaveAs("tree_example11_pxpy.png");

  c1->Update();
  h_pt->Draw();
  c1->SaveAs("tree_example11_pt.png");

  f->Close();

  delete events;
}
```

Run this program, as follows:

root –l

.L libMyEvent.so

.L tree_example11.C

tree_example11()

Look at the produced plots.

Do you get the same distributions as example7?

# Exercises

- Read the Tree from “ntuple_array.root”
- Write your own class for each particle type, like MyGenParticle.h, MyElectron.h, MyMuon.h
- Create a new tree with branches like vector<MyGenParticle>, vector<myMuon>, vector<MyElectron>
- Write the events from “ntuple_array.root” to new tree and write the new tree to a new file.

- Read your new tree from the newly created file and do the following exercises as before.
- Select events where you have two generated muons (or electrons) of opposite charge. Combine the momenta of the generated $\mu^+\mu^-$ ($e^+e^-$) pair to get the momentum of Z boson. Plot the mass of the generated Z boson
- Select events where you have two reconstructed muons (or electrons) of opposite charge. Combine the momenta of the reconstructed $\mu^+\mu^-$ ($e^+e^-$) pair to get the momentum of Z boson. Plot the mass of the reconstructed Z boson

# Analysis using “MakeClass” method

It is a useful method provided by ROOT to do data analysis using Tree.
(You can also look at “MakeSelector” method, which is not discussed here)

For example:
produce a tree using the tree_example8.C program, to start from a simpler one
Load the file in root and use following command:

```
root -l
TFile f("myfile.root")
.ls
T->MakeClass("MyClass")
```

It creates two files MyClass.h and MyClass.C

Edit MyClass.C (modifying MyClass::Loop() function) to add histograms, do event selections, save the histograms to file

Then, run the program as following:

```
root –l
.L MyClass.C
MyClass m
m.Loop()
```

# Analysis using “MakeClass” method

```
void MyClass::Loop()
{
//Add/define output file, histograms here, like:
TH2F *h_pxpy = new TH2F("h_pxpy", "py Vs px", 100, -2.0, 2.0, 100, -2.0, 2.0);
TH1F *h_pt = new TH1F("h_pt", "pt", 100, 0., 5.0);

 if (fChain == 0) return;

   Long64_t nentries = fChain->GetEntriesFast();

   Long64_t nbytes = 0, nb = 0;
   for (Long64_t jentry=0; jentry<nentries;jentry++) {
      Long64_t ientry = LoadTree(jentry);
      if (ientry < 0) break;
      nb = fChain->GetEntry(jentry);   nbytes += nb;
      // if (Cut(ientry) < 0) continue;

     //Add event selection and histogram filling here
     Float_t hPt = 0;
    Int_t h_index = -1;
    if(pt->size() > 0){
      for(Int_t j = 0; j < pt->size(); j++){
        if((*pt)[j] > hPt){
          hPt = (*pt)[j];
          h_index = j;
        }
      }
      h_pxpy->Fill((*px)[h_index], (*py)[h_index]);
      h_pt->Fill((*pt)[h_index]);
    }
   }
//Plot the histograms here
h_pxpy->Draw("colz");
}
```

# LorentzVector

ROOT provides general four-vector classes that can be used either for the description of position and time (x, y, z, t) or momentum and energy (px, py, pz, E)

TLorentzVector

- It provides a general four vector class that has various methods to initialize, set and get various quantities of a four vector (e.g., pt, eta, phi, mass etc..)
- Perform arithmetic operations, Lorentz transformations
- Compute angular separation between four vectors
- A small example of using TLorentzVector is given in next slide
- More details: https://root.cern.ch/doc/master/classTLorentzVector.html

More advanced four-vector classes are provided by ROOT MathCore library:
https://root.cern.ch/root/html518/MATHCORE_Index.html
For example:
ROOT::Math::LorentzVector<ROOT::Math::PxPyPzE4D<double> >

# Example for TLorentzVector

```
//Example using TLorentzVector
#include "TLorentzVector.h"
#include <vector>

void tree_example12() {

  TH2F *h_etaVsPhi = new TH2F("h_etaVsPhi", "eta vs phi", 100, -2.5, 2.5, 100, -3.14, 3.14);
  TH1F *h_mass = new TH1F("h_mass", "mass", 100, 40., 140.);

  TFile *f = new TFile("ntuple_array.root");
  TTree *t1 = (TTree*)f->Get("ntupleProducer/tree");

  Float_t muonPx[10], muonPy[10], muonPz[10];
  Int_t nMuon;

  t1->SetBranchAddress("nMuon", &nMuon);
  t1->SetBranchAddress("muonPx", muonPx);
  t1->SetBranchAddress("muonPy", muonPy);
  t1->SetBranchAddress("muonPz", muonPz);

  Int_t nentries = (Int_t)t1->GetEntries();

  for (Int_t i = 0; i<nentries; i++) {
    t1->GetEntry(i);

    std::vector<TLorentzVector> *muons = new std::vector<TLorentzVector>();
    muons->clear();
    //Compute muon eta, phi and fill them.
    if(nMuon>0){
      for(Int_t j = 0; j < nMuon; j++){
        float muonE = sqrt(muonPx[j]*muonPx[j] + muonPy[j]*muonPy[j] + muonPz[j]*muonPz[j]);
        TLorentzVector mu(muonPx[j], muonPy[j], muonPz[j], muonE);
        //apply pT cut
        if(mu.Pt() < 20) continue;

        h_etaVsPhi->Fill(mu.Eta(), mu.Phi());

        muons->push_back(mu);
      }
    }
```

# Example for TLorentzVector

```
      //Fill mass if there are two muons
      if(muons->size() >= 2){
        TLorentzVector dimuon = (*muons)[0]+(*muons)[1];
        h_mass->Fill(dimuon.M());
      }

      delete muons;
    }

    TCanvas *c1 = new TCanvas();
    h_etaVsPhi->Draw("colz");
    c1->SaveAs("tree_example12_etaVsphi.png");

    c1->Update();
    h_mass->Draw();
    c1->SaveAs("tree_example12_dimuonMass.png");

    f->Close();
}
```

Run the macro:

root -l tree_example12.C