COMPUTING EXERCISE
Study of the production of a pair of gauge bosons (W and Z) at the LHC

The DATA to analyse are organised into a **'Root n-tuple'** which we will provide to you. The Root n-tuple is a file containaining information about the kinematics of "events", each resulting from a **proton-proton interaction**.
These events have three leptons (electrons or muons) and are of two kinds:

1) SIGNAL EVENTS: corresponding to $pp \to W\ Z\ X$ with both bosons disintegrating leptonically (X stands for non identified generic particles),
2) BACKGROUND EVENTS: top-antitop events $pp \to t\bar{t}X$.

We remind that the leptonic decays of the W and Z are:
$W \to \ell\nu$ and $Z \to \ell^+\ell^-$ with ℓ = e or μ.

Since this ntuple is built from a MC file, the two kind of events appear in two separated 'trees" called here "WZSignal" and "$t\bar{t}$". For real data these events appear in the same tree and it is important to devise variables to distinguish between them.
The aim of the exercise is :
1) to look at some important variables,
2) to build the Z invariant mass from the decay leptons,
3) to learn how one can discriminate between the 'signal' and the 'background'
(we will provide an example of an analysis to guide you)

Exercise:
- Open the Root file (the name of the file is *Selected_All_EEM.root*)
- Access the 'branch' WZSignal and $t\bar{t}$ (follow, as guide the macro *Macro.C*) The list of variables describing the event are given in the next page of this document.

- Plot the **transverse momentum** of the most energetic lepton (**pt1**) 'from the Z', for signal (→ Get"WZSignal") and from the background (→Get("ttbar")). (Note the average value and the shape of each distribution. Has this variable a good discriminating power?)

- Compute and plot the **invariant mass** of the Z for ALL events (using the two most energetic leptons). **Suggestion**: look at the slides: how to compute the invariant mass ? how to compute px, py and and p from the variables of the ntuple: E, pt, η

and ϕ ? how to compute the angle between two 'spatial' vectors (px, py and pz) ?

- Plot the isolation variable called **TrackIsoWmu** separately for signal and bkg. Is there a difference? How can one discriminate between signal and background?

- Plot the impact parameter variable called **Trackd0cutWMu** for signal and bkg. Is there a difference? How can one discriminate between signal and background?

- Plot the Z invariant mass for ALL events requesting that the lepton from W has a small impact parameter and is isolated.

- Compare the Z invariant mass with the one in the signal tree (MZ).

- OPTIONAL: Fit the MZ distributions with a Breit-Wigner and extract the fraction of signal events in the total sample.

List of Variables in the ntuple (Br 0,1.. means "Branch 0, 1, ...")

== IMPACT PARAMETER and ISOLATION of the lepton from W
Br 0 :Trackd0cutWMu : Trackd0cutWMu
Br 1 :TrackIsoWmu : TrackIsoWmu

== MISSING TRANSVERSE ENERGY
Br 2 :MET : MET

=== MASS of Z
Br 3 :MZ : MZ

=== MOST ENERGETIC LEPTON FROM THE Z
Br 4 :pt1 : pt1
Br 5 :eta1 : eta1
Br 6 :phi1 : phi1
Br 7 :E1 : E1

=== SECOND ENERGETIC LEPTON FROM THE Z
Br 8 :pt2 : pt2
Br 9 :eta2 : eta2
Br 10 :phi2 : phi2
Br 11 :E2 : E2

===== LEPTON FROM W
Br 12 :pt3 : pt3
Br 13 :eta3 : eta3
Br 14 :phi3 : phi3
Br 15 :E3 : E3

Br 16 :Weight : Event Weight you may neglect this variable