Institut de Physique Nucléaire de Lyon
Internship carried out from 2018/03/12 to 2018/07/13

Master 2 internship report

Signal vs background discrimination in γ+jet events, recorded by the CMS experiment at LHC.

Author :
Maxime Giraud

Supervisor :
Viola Sordini

Version 0.1 du
June 13, 2018

Acknowledgments

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Acronyms and abbreviations

IPNL	Institut de Physique Nucléaire de Lyon
CERN	Centre Européen pour la Recherche Nucléaire
LHC	Large Hadron Collider
CMS	Compact Muon Solenoid
MC	Monte-Carlo
MVA	MultiVariate Analysis
ANN	Artificial Neural Network

Introduction

γ+jet event classification in LHC collisions

1.1 CMS experiment at LHC

The Compact Muon Solenoid (CMS) is a particle physics detector built on the Large Hadron Collider (LHC) at CERN in switzerland and France. The goal of CMS experiment is to investigate the physics beyond the Standard Model. CMS is designed as a general-purpose detector, capable of studying many aspects of proton collisions at 0.9-13 TeV, the center-of-mass energy of the LHC particle accelerator.
It is made of multiple particle detectors designed to measure the energy and momentum of products of the collisions. The first layer called the "Tracker" reconstruct the paths of high-energy muons, electrons and hadrons as well as see tracks coming from the decay of very short-lived particles.
Next the "Electromagnetic Calorimeter" is designed to measure with high accuracy the energies of electrons and photons.
The Hadronic Calorimeter measures the energy of hadrons and provides indirect measurement of the presence of non-interacting, uncharged particles such as neutrinos.
Theses layers all fit inside a large solenoid magnet of 3.8 Tesla, this allows the charge/mass ratio of particles to be determined from the curved track that they follow in the magnetic field. Finally the "Muon detectors and return yoke" are placed outside of the solenoid.

1.2 Hadronic jets in proton-proton collisions

In particle physics, jets are the experimental signatures of quarks and gluons produced in high-energy processes.
These particles having a net colour charge cannot exist freely due to couloour-confinement, thereby they are not directly observed in nature. Instead, they come together to form colour-neutral hadrons by a process called hadronisation that leads to a collimated spray of hadrons called a jet. The detailed understanding of both the jet energy scale and of the transverse momentum resolution is of crucial importance for many physics analyses.

Collision data

Y en a beaucoup...

2.1 Monte-Carlo simulation

Tres jolie ville !

2.2 CMS data

blabla cms !

2.3 MVA variables

CHiso γ: Charged Hadron isolation

NHiso γ: Neutral Hadron isolation

Photoniso γ: Photon isolation

$\sigma_{i\eta i\eta}$: Energy weighted spread within the 5x5 crystal matrix centred on the crystal with the largest energy deposit in the supercluster. Obtained by measuring position by countinig crystals.

$\sigma_{i\eta i\varphi}$: Energy weighted spread within the 5x5 crystal matrix centred on the crystal with the largest energy deposit in the supercluster. Obtained by measuring position by countinig crystals.

η_{width} γ: Shower width in η

φ_{width} γ: Shower width in φ

R_9 γ: Energy sum of the 3x3 crystals centred on the most energetic crystal in the supercluster divided by the supercluster's energy. Lower values of R_9 for converted photons than those of unconverted photons.

Had/Em : Hadronic calorimeter energy deposit over Electromagnetic calorimeter energy deposit

E_{nxm}/E_{5x5} : Energy of most energetic nxm crystal set over energy of 5x5 crystal set

ρ: Pile-up energy, median of the transverse energy density per unit area.

Input variable analysis

A large set of variables is available from CMS data. MVA training can be time consumming and the "dimensionality curse" forces us to select only a few of them based on two main criteria :

Background vs Signal discrimination : Variables with most differences of shape for background and signal will be picked.

Low correlation between variables : Needed in order to reduce redundancy of input data and thus will permit to reduce MVA complexity (for example number of hidden neurons in ANN).

reference [Collaboration 2015].

3.1 Background vs Signal discrimination

It is necessary to pick the smallest set of input variable for the MVA. This selection is done by looking at variable shape for background and signal data from MC simulation.

3.2 Variable correlations

Training data needed-quantity increases with network complexity. So correlation between variables must be avoided in order to get the minimum redundancy.

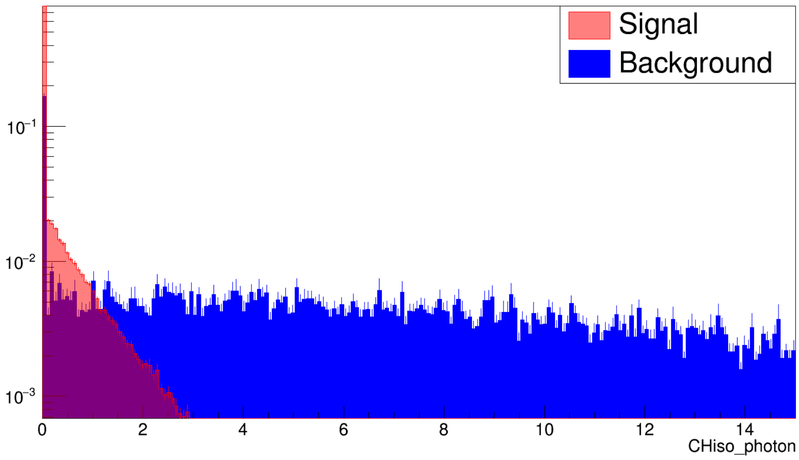

Figure 3.1: Charge hadron isolation for background and signal, here is a good discrimination between them

MultiVariate Analysis

4.1 Boosted Decision Tree

Yep !

4.2 Artificial Neural Network

Le train de tes injures roule sur le rail de mon indiférence....

4.3 Results

Conclusion and future outlook

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