

Semi-visible jets images

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Abstract

This is a report about a project, that was done during the CERN Summer Student Programme under supervision of Deepak Kar, Sukanya Sinha and Tasnuva Chowdhury. The aim was to learn about semi-visible jets, generating their images and pre-processing them for training with Machine Learning algorithms.

1 Introduction

A jet is a collimated cone of particles, that are produced by high energy quarks and gluons. However sometimes jets, called semi-visible, are formed from Dark Matter particles.

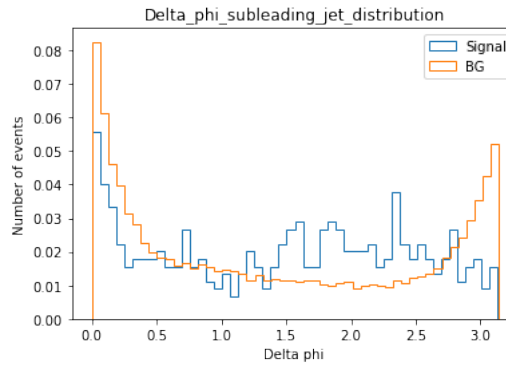
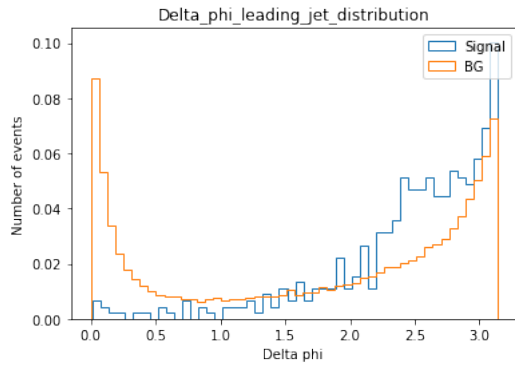
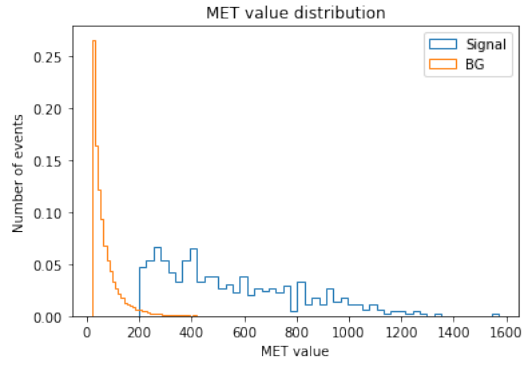
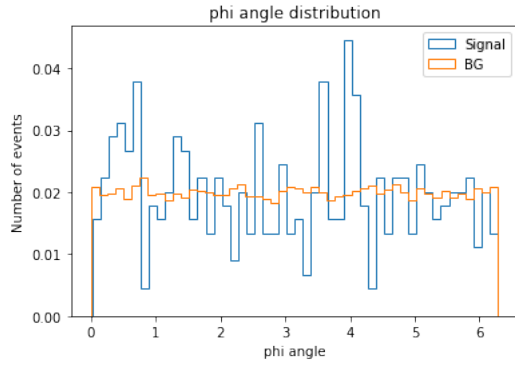
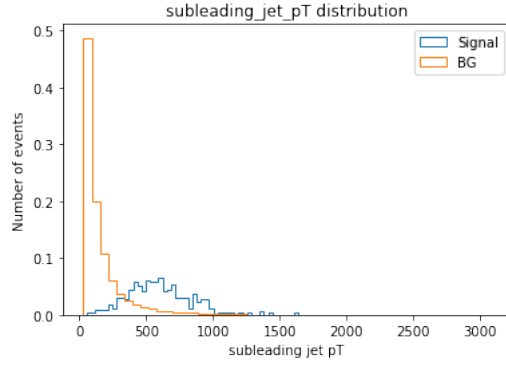
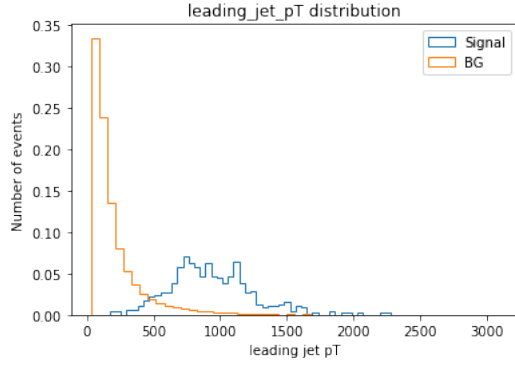
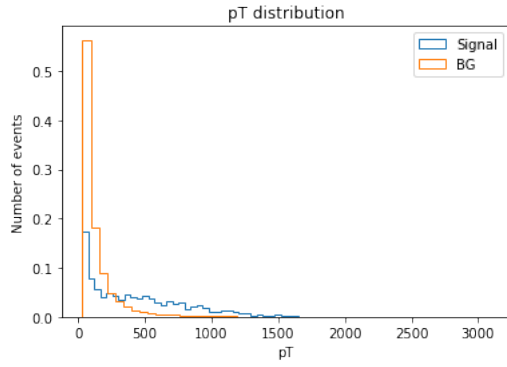
It is assumed that there is a dark sector, consisting of new particles, forces and interactions, which has a communication with Standard Model. In this hidden Dark Matter sector there are dark quarks, binded into dark hadrons. Dark quarks with big transverse momentum shower and produce collimated sprays of dark hadrons. Some of this dark hadrons can decay to visible particles, the ones from Standard Model. These particles are collimated and form a jet, which looks very similar to an ordinary QCD jet, but it's a semi-visible jet, because dark hadrons took part in the formation of this jet.

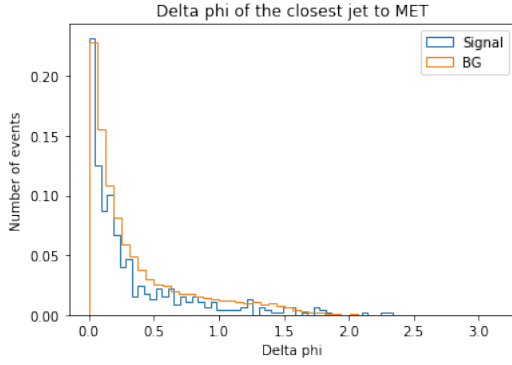
The jets have following characteristics: transverse momentum (p_T), pseudorapidity (η), azimuthal angle (ϕ) and missing transverse energy (MET).

The main goal is to learn how to differentiate background jets from the semi-visible jets. In this project we try to generate an image for each jet and classify the images via Machine Learning techniques.

2 Images pre-processing

At first, we started with plotting some simple distributions of angles and p_T of the jets in signal and background events.





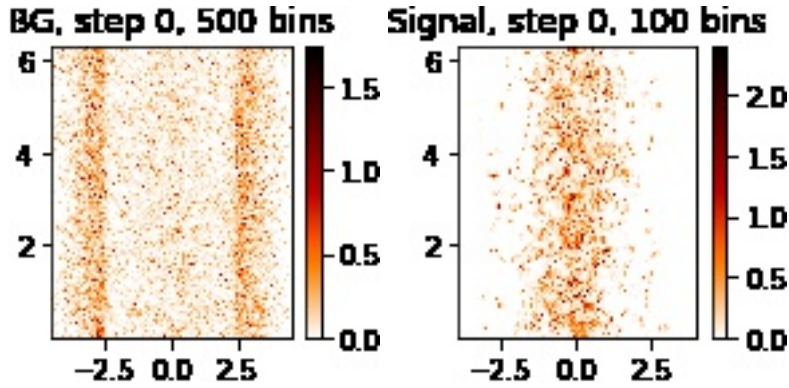
For the Machine Learning algorithms to work more effectively we need to pre-process our images to make it easier for the computer to understand the difference between signal and background events without paying attention on other differences between the images. In this project pre-processing procedure happens in three steps: centering axes, rotating constituents and translating constituents. To begin, each jet is moved so that the center of the jet is at $(\eta, \phi) = (0, 0)$. To make it we get the distance η and ϕ of the constituents from the jet axis.

The second step of pre-processing is to rotate the images around the center of the jet. We rotate the jet so that the first and second highest pT particle constituents are parallel to the phi axis with the second highest particle on the negative side of the highest particle.

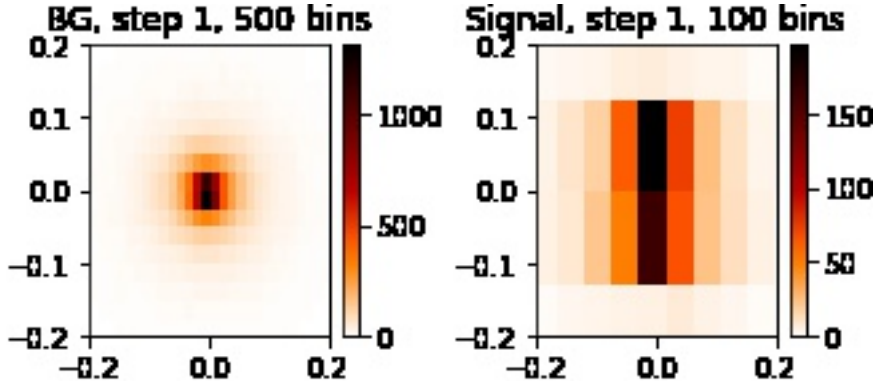
At the last step of pre-processing the highest pT particles are brought at $(\eta, \phi) = (0, 0)$.

Here are the average images after different steps.

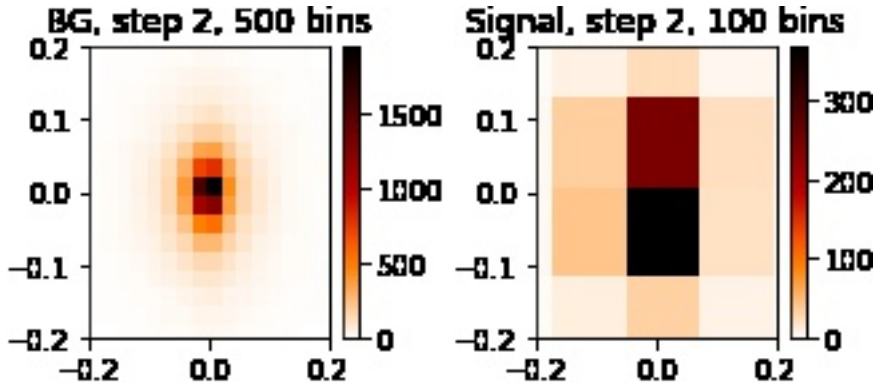
Step 0. The original images for background and signal events.



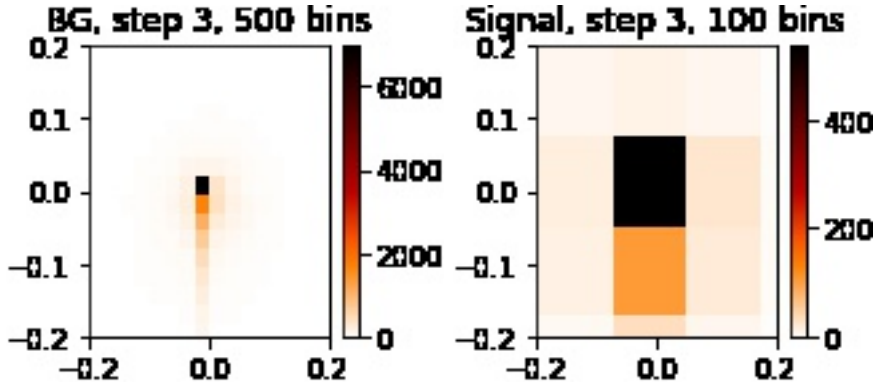
Step 1. The images for background and signal events after centering axes.



Step 2. The images for background and signal events after rotating.

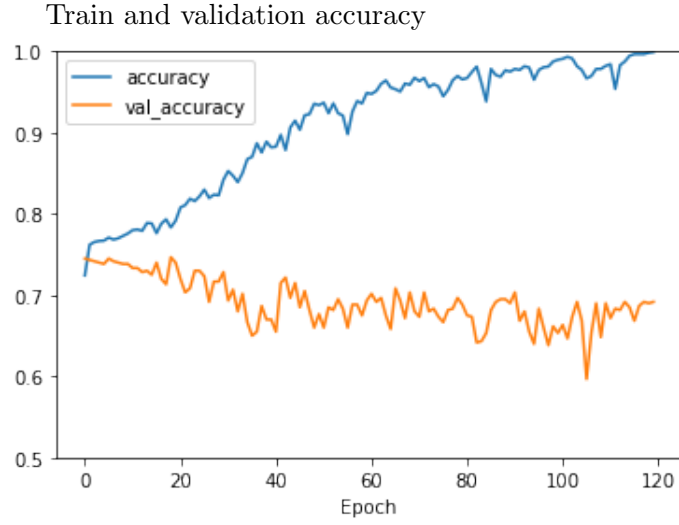


Step 3. The images for background and signal events after translation.

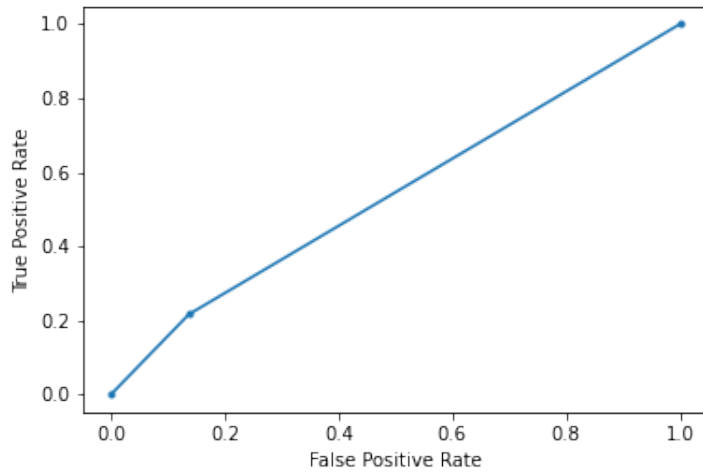


3 Machine learning for image classification

After pre-processing the dataset is divided into two parts for training and for validation. Convolutional Neural Network is used to classify the jet images into background and signal. After trying different layers and other parameters the best result, I've managed to get, is almost 70 % accuracy.



ROC curve in this case



References

Luke de Oliveira, Michael Kagan, Lester Mackey, Benjamin Nachman and Ariel Schwartzman, "Jet-Images – Deep Learning Edition" arXiv:1511.05190v3 [hep-ph] 22 Jan 2017

Timothy Cohen, Mariangela Lisanti, Hou Keong Lou and Siddharth Mishra-Sharma "LHC Searches for Dark Sector Showers" arXiv:1707.05326v2 [hep-ph] 25 Nov 2017