Determination of the charge flip rate through the decay of Z bosons in electron pairs at the ATLAS experiment

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1. Introduction

Supersimmetry is a promising candidate to describe the physics beyond the Standard Model, and one of the possible search channel which are exploited at the ATLAS experiment [2] at the LHC include the presence of high momentum same sign leptons [3,4] with equal or different flavour (at this stage we consider only electrons and muons). In fact this kind of topology characterize only the new physics while requiring also large lepton momentum and large missing transverse energy.

The main background to this SUSY search channel is the production of jets (QCD) which have a huge cross-section: the presence of one or two fake leptons coming from jet misidentification (QCD) can give rise to same sign dileptons events.

Another important background, from the point of view of the cross-section, is represented from $t\bar{t}$ quark production, but this process gives mainly opposite sign leptons because both the selected high momentum leptons are the decay products of the W boson and cannot come from the b mesons which produces lower momenta particles.

The second most important background to this SUSY search results then to be the case of semileptonic $t\bar{t}$ production and decay with an additional process which "flip" the charge of one of the produced leptons. In this case both W bosons produced from the $t\bar{t}$ decay semileptonically, and one of the two leptons can undergo a hard bremsstrahlung process, with the most energetic lepton having a charge different from the original one. The hard bremsstrahlung is a process where an electron emits a photon in external (and internal, since the two are not distinguishable) bremsstrahlung traversing the material in the tracking volume and the photon later converts into an e^+e^- pair: at the end one detects three tracks coming from the electron, forming a "trident" pattern. Since the charge flip rate for muons is negligible the dilepton $t\bar{t}$ background is significant only for the $e^{\pm}e^{\pm}$ and $e^{\pm}\mu^{\pm}$ channels.

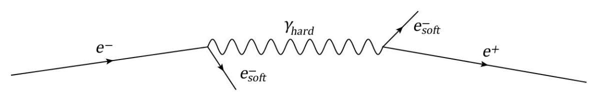

Figure 1. An electron hard bremsstrahlung: the two soft electrons are lost in the detector and the resulting process is an apparent charge flipping.

In the hard bremsstrahlung case, for instance,

$$e^-_{hard} \rightarrow e^-_{soft} + \gamma_{hard} \rightarrow e^-_{soft} + e^-_{soft} + e^+_{hard}$$

the reconstructed positron contains most of the energy of the original electron but with opposite charge, therefore it produces an apparent charge flipping. In Fig. 1 this charge flipping process is depicted. These kind of events are also called "trident" because in the final state one would observe three electrons all or them are detectable.

2. Analysis

Studying the probability of this process is then important to estimate $t\bar{t}$ background. Unfortunately the final amount of this kind of events is quite sparse (of the order of unity) and then a detailed study, even on Montecarlo would require a huge statistics. A better way to obtain a consistent statistics and a clear sample is to use the decay of Z bosons in pair of opposite sign electrons. The charge flipping phenomenon is evident while plotting the invariant mass of same sign dielectrons where one observe a peak in the Z mass region (Fig. 2) which can be justified only with this kind of process.

From the amount of same sign dielectrons falling in the Z mass region one can have a first estimate of the flip charge rate probability α, which is measured to be about 1%. This is an averaged value of the probability of this process which, being dependent on the amount of traversed material could be different for the Z boson decay in electrons and the $t\bar{t}$ decay because of the possible different kinematical distribution of these processes. So it is important to measure this quantity in a differential way to observe if these differences

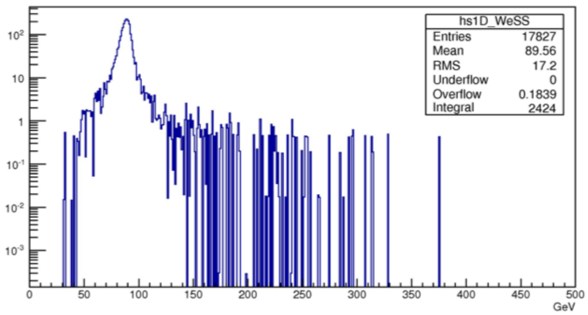

Figure 2. same sign dielectron invariant mass in the ATLAS data

are relevant or not.

This work can be easily done with Montecarlo samples and the result is that already studying the dependence vs the pseudo rapidity variable $|\eta|$ there is difference between this two processes. It then became important to extend the study also in another kinematical variable like the transverse momentum P_T.

To this purpose the study was extended to the measurement (using the MC) of α in two dimensions using both η and P_T variables. The resulting probability is shown in Fig. 3, and a consistency check is done with $t\bar{t}$ sample, justifying the use of the rate measured with the Z boson decays.

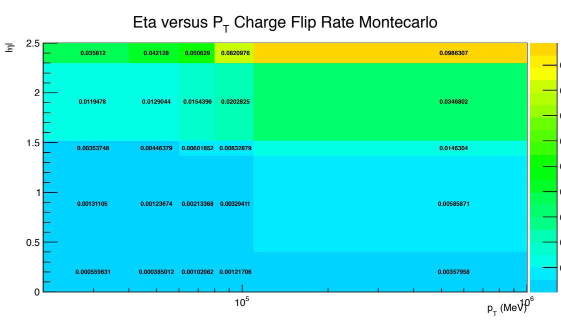

Figure 3. Differential charge flip probability extracted from Z to dielectrons Montecarlo

3. Results

A closure test was done on the Montecarlo itself starting from the differential probability and counting the expected same sign events. Taking into account all effects the number where almost equal giving support to the method. This probability was then applied to the $t\bar{t}$ sample to estimate the number of same sign dielectron an electron-muon events due to this background in the SUSY search signal sample.

In a previous analysis done with small statistics (35 pb^{-1}) everything was consistent but when turning to a larger statistic (order of pb^{-1}) a difference of about 20% was noticed between the expected same sign dielectric events collected in the data and the predicted ones in MC. So in this case a weighting of the event has been applied for the estimation of this background. This discrepancy is due a slightly different cross section used in the simulation and to bad simulation of the materials encountered by the electrons on their path.

To solve this problem we started to develop a "data driven" method which should permit to extract the charge flip rate directly from the data, without any use of the Montecarlo. The first step has been to apply this method to the Montecarlo itself to cross-check if we were able to derive this quantity without biases. The methods consists to extract the charge flip rate with the subtraction of the same-sign distribution from the weighted opposite sign one. To first approximation this methods give reasonable values but still need to be refined because of substantial differences in some of the bins. Correction to the method are under study.

REFERENCES

1. ATLAS Collaboration is made of about 2500 Physicists coming from 167 Institutions of the following countries: Argentina, Armenia, Australia, Austria, Azerbaijan, Belarus, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, France, Georgia, Germany, Greece, Israel, Italy, Japan, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Taiwan, Turkey, UK, USA, CERN, JINR.
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