1 A search for highly ionizing, short tracks at the CMS detector

1.1 Characterisation and estimation of the Standard Model backgrounds

After the application of the candidate track selection explained in the previous section the background arising from Standard Model processes is dramatically reduced. However, it still happens sometimes that an electron, muon or tau fails reconstruction. The underlying mechanism and the methods to estimate the leptonic backgound will be in detail explained in Section **??**. Furthermore, there is the possibility that a track is reconstructed out of a set of hits which do not origin from only one single particle. Such tracks are called "fake tracks". Background tracks arising from the wrong combination of hits will be explained in the following Section 1.1.1

The composition of the background after the candidate track selection is shown in Fig. 1.1. This composition can change significantly when imposing further selection cuts on p_T and I_as. This, however, will be addressed during the optimisation procedure. To get a feeling how the composition of the background is affected by further cuts on one of the main variables, the background composition is also shown with the candidate track selection plus an additional I_as cut of 0.05. It can be seen that the fake background is less

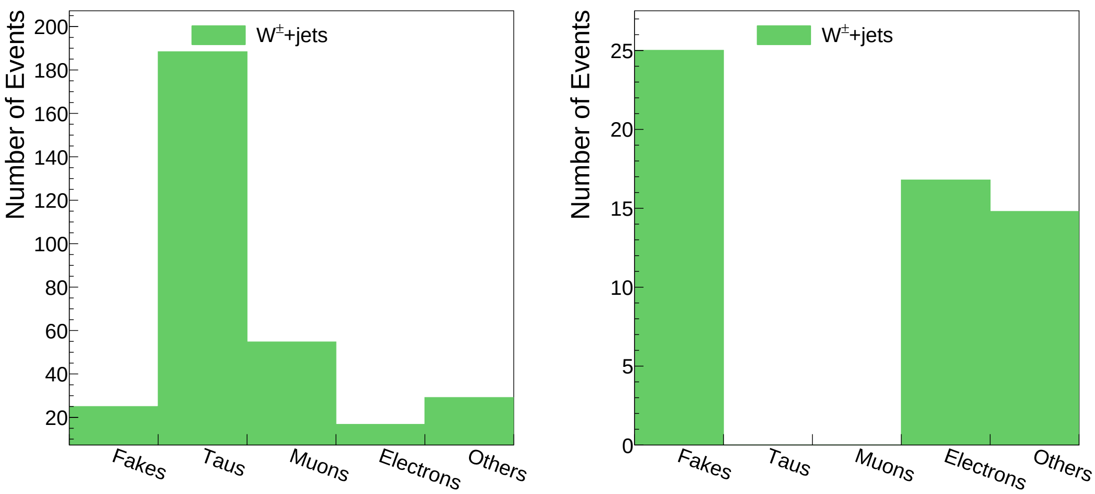

Figure 1.1: Background composition after the full candidate track selection (left) and after the full candidate track selection plus an additional selection cut of $I_\mathrm{as} > 0.05$ (right). Given the limited size of the simulated $W+\mathrm{jets}$ dataset, the uncertainty of the composition is accordingly large.

reduced by an additional selection cut on I_{as}. This gains even more in importance when considering all sources of fake tracks. The fake background is not only present in $W+\text{jets}$ events but essentially in all Standard Model processes.

Still, also the leptonic background can be important. Unfortunately, because of the limited size of the simulated $W+\text{jets}$ dataset, it is not possible to study the leptonic contribution to the background with simulated events. Furthermore, when the simulation of the operativeness of every single detector module is not fully correct, the simulation could highly underestimate the leptonic background.

Therfore, a data-based approach is needed for either of the two background sources: the fake and the leptonic background.

1.1.1 Fake background

Fake tracks are tracks which are not reconstructed out of the track of one single particle. This can happen due to pile up and maybe there are other reasons.

- Start with the charecterization of the fake background
- How are fakes defined
- reference to the chapter where the track reconstruction is explained
- Show plot with fake rate in different samples
- Show dependency of fakes for the numbr of hits
- Show ias plot for fakes
- Explain background estimation method

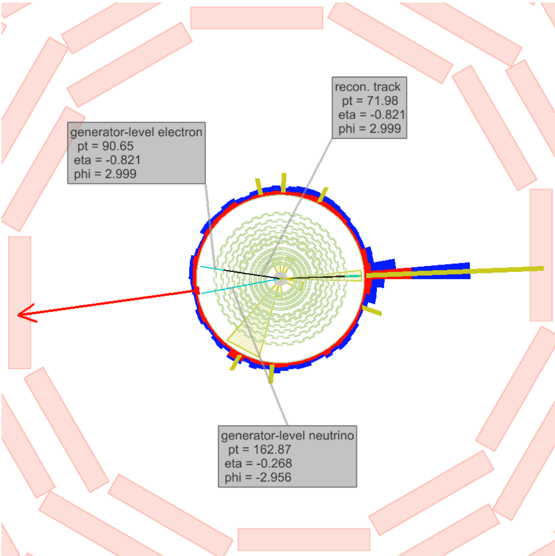

Figure 1.2: Visualization of an $W \to e\nu_e$ event contributing to the SM background. In light blue the generator-level particles e and ν_e of the W decay are shown. The ν_e, only weakly interacting does not show any signature in the detector, whereas the electron ($p_\mathrm{T} \simeq 90\,\mathrm{GeV}$) leaves a track (black line) with $p_\mathrm{T} \simeq 70\,\mathrm{GeV}$ in the tracker. No ECAL energy deposits in the direction of the electron are visible. This is caused by the fact that the corresponding ECAL energy deposits were not read out in this event. An ISR jet ($p_\mathrm{T} \simeq 230\,\mathrm{GeV}$) causes the $\not{E}_\mathrm{T}$ (read arrow) in the event.

1.1.2 Leptonic background

The leptonic background of the presented search is caused by non-reconstructed leptons which undergo hence the lepton veto selection. However, at least non-reconstructed electrons or taus should in principle deposit enough energy in the calorimeters such that they can still be vetoed by the calorimeter isolation requirement. As muons don't deposit much energy in the calorimeters, this reason does not hold for them. In the following, the sources of the three different leptonic backgrounds shall be charectized.

Electrons

To avoid the background source from unreconstructed electrons, all tracks pointing to a dead or noisy ecal cells are vetoed, as described in the previous section. By this selection, almost all electrons are efficiently rejected. In the simulated W + jets sample only one simulated event remains which pass all candidate track selection criteria and where the candidate track can be matched to a generator-level electron. This event is visualised in Fig 1.2. In this event no energy deposits in the ECAL are read out, which suggests, that this ECAL tower was neither working properly in 2012. Additionally, electrons can do bremstrahlung which can change the direction of the electron significantly. Thus, the energy deposits in the ECAL can possibly not be matched to the original electron.

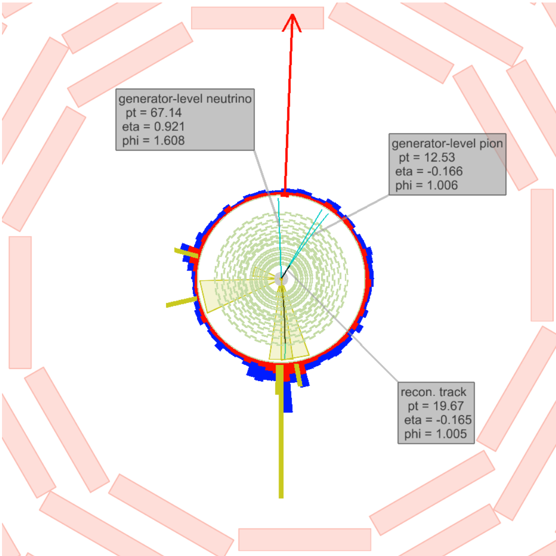

Figure 1.3: Visualization of a $W^+ \to \tau^+\nu_\tau \to \pi^+\nu_\tau$ event contributing to the SM background. In light blue the generator-level particles π^+ and ν_τ are shown. The reconstructed track (black line) is very short because the pion interacts with the tracker material via the strong force.

Taus

The tau background is contributing through the hadronic decay of a tau lepton to one charged pion $\tau \to \pi^\pm\nu$. Unreconstructed taus are typcically low energetic and can therfore bypass the calorimeter isolation criterium. Because of nuclear interactions in the tracker, they can result in short reconstructed tracks which can easily be highly mismeasured in p_T. Thus, pions can also contribute even when imposing a tighter selection in the transverse momentum. Such an event is shown in Fig. 1.3.

Muons

Muons can fail reconstruction when they are pointing torwards a bad cathode strip chamber. This is taken into account in the candidate track selection. However, some of the muons still fail reconstruction when they fall within the gap between stations 0 and 1 of the DT system at $\eta = 0.25$. The muon reconstruction efficiency drops from around 99% to a value of around 94% as shown in **??**. This possibility is illustrated in a simulated event shown in Fig 1.4. In **??** events are rejected when the track is pointing in a region of $0.15 < |\eta| < 0.35$. In this search, this cut was omitted to maximise signal acceptance. Due to the additional selection in I_as, muons can easily be efficiently supressed. E.g. in the event example shown in Fig 1.4, the muon has an I_as value of about 0.02.

In general, all leptons are rather minimal ionizing, especially muons and pions. Electrons can more easily interact with the shell electrons of the tracker material, but still the I_as spectrum is quickly decreasing compared to the signal. To have the possibility to make an optimisation in the two main discriminating variables p_T and I_as, the background estimation methods are designed to work for all different p_T and I_as selection cuts. A

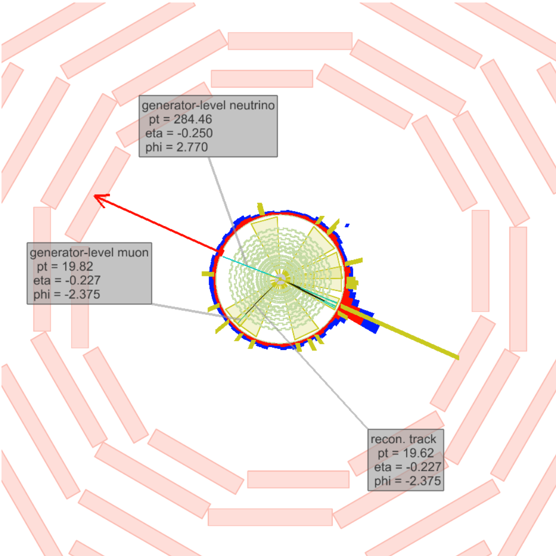

Figure 1.4: Visualization of an $W \to \mu\nu_\mu$ event contributing to the SM background. In light blue the generator-level particles μ and ν_μ of the W decay are shown.

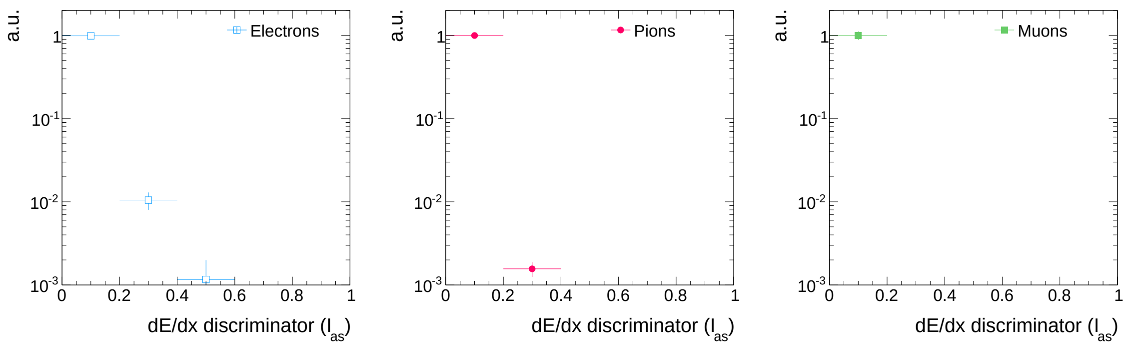

Figure 1.5: Normalised $I_{\rm as}$ distribution for electrons (left), pions (middle) and muons (right). For all leptons the $I_{\rm as}$ distribution is rapidly falling.

comparison of the $I_{\rm as}$ distribution for all four different bkg sources is shown in Fig 1.5.

1.1.3 Systematic uncertainties

- Background consist of particles which make high energy deposits and are high pt
- In general: Low background search

1.2 Optimization of search sensitivity

- Show plots
- show table

- Include NlostOuter here, too

1.3 Statistical Methods/ Limit setting

1.4 Results

- Data cutflowtable
- Tables with results
- One plot (4 bins: Prediction and data)

1.5 Interpretation

1.5.1 Systematic uncertainties of simulated signal samples

1.5.2 Exclusion limits

- 1-d limits
- 2-d limits

Bibliography