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

1.1 Simulated samples

For the investigation of the various backgrounds to this search, the analysis relies also on simulated sample. An extensive introduction to the techniques and tools required for the simulation of SM and beyond SM processes can be found in Section **??**.

In the following two sections an overview about the used SM (Section 1.1.1) and SUSY samples (Section 1.1.2) is given. All samples are reweighted to match the measured distribution of primary vertices in data.

1.1.1 SM Background samples

To investigate the sources of background, various simulated SM samples were used. In order to have the possibility to make use of the dE/dx variables, a special data format of the simulated samples is required (called RECO format). Unfortunately, not all SM processes were available in this format in which also the information about the energy release in the tracking system is included. However, as this analysis needs to rely anyways on a data-based background estimation method, because of the limited quality of the dE/dx simulation. this does not constitute a serious problem, but only limit the possibility of an extensive comparison between data and simulation going beyond shape comparisons.

In Table 1.1 all SM samples are listed which were available in the RECO format and are used in the analysis. Due to the immense size of the samples (between 5 and 70 TB) and in order to match a reasonable storage space a reduction was done by selecting only events which contain at least one leading jet with a minimum transverse momentum of $p_{\mathrm{T}} > 60\,\mathrm{GeV}$.

Table 1.1: Available and used Standard Model background samples containing $\Delta E/\Delta x$ information.

Process	Cross section [pb]	$\mathcal{O}_{\mathrm{calculation}}$
W + jets	36703.2	NNLO [1]
$t\bar{t}$ + jets	245.8	NNLO [2]
Z$\rightarrow \ell\ell$ ($\ell = e, \mu, \tau$)	3531.9	NNLO [1]
QCD ($50\,\mathrm{GeV} < \hat{p}_{\mathrm{T}} < 1400\,\mathrm{GeV}$)	9374794.2	LO

Table 1.2: Used Standard Model background samples without $\Delta E/\Delta x$ information.

Process	Cross section [pb]	$\mathcal{O}_{\text{calculation}}$
W + jets	36703.2	NNLO [1]
Z$\rightarrow \ell\ell$ ($\ell = e, \mu, \tau$) + 1,2,3,4 jets	3531.9	NNLO [1]

In addition, further simulated samples not containing the energy information are used. These are needed to study the backgound inclusively in the variable I_{as}. They are listed in Table 1.2.

1.1.2 Signal samples

For the investigation of a possible signal, events containing either chargino pair production $q\bar{q} \rightarrow \tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ or chargino neutralino production $q\bar{q} \rightarrow \tilde{\chi}_1^{\pm}\tilde{\chi}_1^{0}$ are simulated. The simulation is done with the matrix-element event generator MADGRAPH [3] The parton showering and hadronization processes are then simulated with Pythia 6 [4]. A last step is needed to simulate the interations of the generated particles with the detector material, which is done with GEANT4 [5, 6].

Furthermore, a speacial treatment for long-lived particles is required. In order to get the right detector simulation of the energy loss of the long-lived particles which decay after the beam pipe, the lifetime of the chargino cannot be set in the matrix-element generator but needs to be specified within GEANT4. This also means, that the decay products are only existing in the detector simulation, but are not accessible as particles in the event generators.

To narrow down the required computing sources, the simulation was only done for a few lifetimes (1 cm, 5 cm, 10 cm, 50 cm, 100 cm, 1 000 cm and 10 000 cm). To get still a tight scan over the lifetime space, other lifetimes were generated using lifetime reweighting. This can be done by determining for every event a weight which is depending on the individual proper lifetime of the chargino (in case of chargino pair production it depends on the individual lifetime of the two charginos). The event weight is given by

$$w = \prod_{i=1}^{n} \frac{\tau^{\text{gen}}}{\tau^{\text{target}}} \cdot \exp\left[t_i \cdot \left(\frac{1}{\tau^{\text{target}}} - \frac{1}{\tau^{\text{gen}}}\right)\right],$$

where n is the number of charginos in the event, τ^{gen} is the generated mean lifetime in the particle's rest frame and t_i is the individual proper lifetime of the chargino. The resulting mean lifetime is then given by τ^{target}. A derivation of this formula can be found in Appendix **??**. With the reweighting procedure a tight covering of the lifetime space could be achieved with lifetimes of c$\tau = a \cdot 10^n$ for n=0,1,2,3,4 and a=$[1, 9]$. Figure **??** shows the exponential distribution of the individual proper lifetime of the charginos after reweighting a simulated sample with $c\tau^{\text{gen}} = 50$ cm to a lifetime of $c\tau^{\text{target}} = 10$ cm. Fitting the exponential spectrum should result in the correct mean proper lifetime as parameter of the fit. It can be seen, that the reweighting procedure can reproduce the targeted lifetime

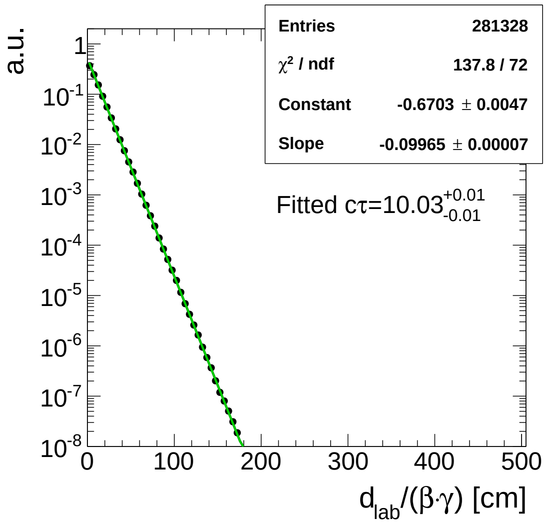

Figure 1.1: Normalized distribution of the proper lifetime $d_{\mathrm{lab}}/\left(\beta\gamma\right)$ of all charginos contained in a signal sample with a generated lifetime of $c\tau^{\mathrm{gen}} = 50\,\mathrm{cm}$ reweighted to a lifetime of $c\tau^{\mathrm{target}} = 10\,\mathrm{cm}$.

of 10 cm.

All samples were generated for different chargino masses always almost mass-degenerate to the lightest neutralino. The mass gap between chargino and neutralino was set to 5 GeV. However, as this analysis does not make use of the other decay products and the lifetime is set in GEANT4, the mass gap does not play any role. Six different masses from 100 GeV to 600 GeV are simulated. This leads then to a total number of 42 signal samples. In Table 1.3 the NLO-NLL cross sections at $\sqrt{s} = 8\,\mathrm{TeV}$ for $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ and $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{0}$ production with wino-like charginos and degeneracy between $m_{\tilde{\chi}_1^{\pm}}$ and $m_{\tilde{\chi}_1^{0}}$ are listed [7,8]. The cross section does not dependent on the lifetime of the chargino.

Table 1.3: Produced signal simulated samples with corresponding cross sections

$m_{\tilde{\chi}_1^{\pm}}$ [GeV]	$\sigma_{\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}}$ [pb]	$\sigma_{\tilde{\chi}_1^{0}\tilde{\chi}_1^{\mp}}$ [pb]
100	5.8234	11.5132
200	0.37924	0.77661
300	0.06751	0.14176
400	0.01751	0.03758
500	0.00553	0.01205
600	0.00196	0.00431

1.2 Event selection

1.2.1 Datasets and triggers

- Datasets and triggers used in the analysis
- signal samples generated with Madgraph and pythia
- They are decayed in Geant to only pions. Around ten different lifetimes were simulated
- For other lifetimes: lifetime reweighting is done PLOT
- For five diffenrent masses (100-500 GeV)

1.2.2 Preselection

- Motivate different selection cuts
- Reference DT search for most of them

1.2.3 Main discriminating variables

- dE/dx
- pt
- Show some MC signal bkg comparioson plots (only Wjets?)

1.3 Sources of backgrounds

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

1.3.1 Fake tracks

- Definition of fake tracks
- How can they fake the signal

1.3.2 Muons

- How can muons fake the signal

1.3.3 Pions

- How can pions fake the signal

1.3.4 Electrons

- How can electrons fake the signal

1.4 Background estimation methods

1.4.1 Fake background

1.4.2 Leptonic background

1.4.3 Systematic uncertainties

1.5 Optimization of search sensitivity

- Show plots
- show table
- Include NlostOuter here, too

1.6 Statistical Methods/ Limit setting

1.7 Results

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

1.8 Interpretation

1.8.1 Systematic uncertainties of simulated signal samples

1.8.2 Exclusion limits

- 1-d limits
- 2-d limits

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