Validation of the MadAnalysis 5 implementation of the ATLAS monojet analysis at 13 TeV LHC with 3.2 fb^{-1} luminosity, arXiv : 1604.07773

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Abstract

In this note we summarise the validation of our implementation of the ATLAS search documented in [1] targeting dark matter and compressed supersymmetric scenarios . This search was performed by ATLAS in the monojet + missing energy final state. The details of this analysis is documented in `https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2015-03/`.

1 Description of the implementation of the analysis

The analysis was implemented using the `MadAnalysis5 v1.4` [2–4] framework with the detector simulator `DELPHES3` [5] . The link to the code can be found in [6]. To validate our analysis we compared the recast against the official ATLAS cutflows (taken from [7]) for the three different benchmark points which we present below along with the masses of the SUSY particles:

- $\tilde{q} \to q\chi_1^0$: $\mathrm{M}_{\tilde{\mathrm{q}},\chi_1^0} = 650, 645$ GeV.
- $\tilde{b} \to b\chi_1^0$: $\mathrm{M}_{\tilde{\mathrm{b}},\chi_1^0} = 350, 345$ GeV.
- $\tilde{t} \to c\chi_1^0$: $\mathrm{M}_{\tilde{\mathrm{t}},\chi_1^0} = 350, 345$ GeV.

The above benchmark points were chosen in a simplified model scenario with light squarks and stops decaying exclusively to the lightest neutralino. The rest of the SUSY particle spectrum was decoupled from this set. Note that the analysis provides cutlfows for the category denoted as EM (exlcusive), and not IM(inclusive). Hence the analysis was validated on the EM category. However we also provide the implementation for the IM category, with the caveat that the cutflow could not be verified.

This analysis targeted compressed SUSY spectrum in addition to WIMP and ADD models. As mentioned we validate our analysis on the cutflows documented for the compressed SUSY

scenario. To increase the sensitivity to small mass splittings between the stop and the neutralino the monojet event selection relies on a hard initial-state-radiation (ISR) jet to identify signal events. The analsyis is then divided in seven signal regions (SR) $M_{1,\dots,7}$ defined according to increasing missing transverse energy $\not{E}_{\mathrm{T}}$.
We used SUSYHIT [8] to generate the spectrum. To validate the analysis we generated 10^5 events for each of the above benchmark points using `MadGraph5_v2.2.3` [9] and passed to `Pythia8` [10] (with the PDF set `NNPDF23LO` [11]) for showering and hadronisation using the `A14` tune to treat the underlying event [12]. We generated up to two additional partons at the matrix element level. We use the CKKW-L [13] matching scheme, as implemented in the code main85.cc of the examples in the PYTHIA8 repository.

The merging parameter needed for the merging was defined as a quarter of the mass of the produced particle. The generated files in the `HEPMC` format were then passed through detector simulation using `DELPHES3` [5] inside `MadAnalysis5`. Jets were reconstructed with an anti-kt [14] algorithm with a jet radius $R = 0.4$ with $p_T > 20$ GeV and $|\eta| < 2.8$ with the FASTJET package inside DELPHES. Electrons were selected with $p_T > 20$ GeV and $|\eta| < 2.47$ and muons with $p_T > 10$ and $|\eta| < 2.4$. The number of events was rescaled to a luminosity of 3.2 fb^{-1} using the tabulated 13 TeV production cross sections for each of the process in question [15].

2 Results and plots

We first discuss the cutflows, and the exclusion curve of the 95% CL limit setting plot in the $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0})$ plane (To be done).

2.1 Cutflows

The ATLAS collaboration provided three cutflow tables for the three above mentionned benchmark points documented in [7] . The comparison between our reimplementation and the official ATLAS results are presented in Tables 1,2,3.
Before applying the cuts and after rescaling the number of events given by `MadGraph-Pythia` to $\sigma \times \mathcal{L}$ (which corresponds to the line "Initial number of events"), we applied a MET filter $E_T^{\text{miss}} > 100$ GeV at the MC level. The number of events after this filter corresponds to the "Total Evts" number in Table 14 of [7]. This number then corresponds to the line "$E_T^{\text{miss}} > 100$ GeV Filter" in Tables 1,2,3. We notice from the cutflow tables that there is a discrepancy between the official numbers and the recasted result after the Monte-Carlo 100 GeV cut. While the source of this discrepancy is not entirely clear, it could be because of a difference in the production cross section values between as used by the collaboration compared to the ones we use in our recast. The second source could be a discrepancy in the PYTHIA tunes. However we note that the relative changes in the cutflow following this discrepancy agrees pretty well for all the benchmark points. As we move to the signal regions, the agreement of the recasted analysis with the official one are within 1-5 %. Hence we can conclude that the validation is pretty good.

$\tilde{q} \to q\tilde{\chi}_1^0$ (650/645) cutflow				
cut	# events (Official)	relative change	# events MA5	relative change
Initial number of events	4544	-	4544	-
$E_T^{\rm miss} > 100$ GeV	1917	58 %	2031	55 %
Trigger	1604	16 %	-	-
Event cleaning	1592	1 %	-	-
Lepton veto	1591	0.01 %	2022	0.4 %
$N_{\rm jets} \leq 4$	1492	6 %	1883	7 %
$\Delta\phi(E_T^{\rm miss}, {\rm jets}) > 0.4$	1409	5 %	1798	5 %
Jet Quality	1343	4 %	-	-
$p_T^{\rm j1} > 250$ GeV	435	67 %	426	76 %
$E_T^{\rm miss} > 250$ GeV	404	7 %	402	6 %
M1 : $\rm E_T^{miss} = [250 - 300]$ GeV	58	86 %	57	86 %
M2 : $\rm E_T^{miss} = [300 - 350]$ GeV	65	84 %	69	83 %
M3 : $\rm E_T^{miss} = [350 - 400]$ GeV	59	86 %	57	86 %
M4 : $\rm E_T^{miss} = [400 - 500]$ GeV	85	79 %	81	80 %
M5 : $\rm E_T^{miss} = [500 - 600]$ GeV	53	87 %	57	86 %
M6 : $\rm E_T^{miss} = [600 - 700]$ GeV	34	91 %	36	91 %
M7 : $\rm E_T^{miss} > 700$ GeV	49	89 %	46	90 %

2.2 Exclusion plot

$\tilde{b} \to b\tilde{\chi}_1^0$ (350/345) cutflow				
cut	# events (Official)	relative change	# events MA5	relative change
Initial number of events	12096	-	12096	-
$E_T^{\text{miss}} > 100$ GeV	4250	65 %	4305	64 %
Trigger	3450	19 %	-	-
Event Cleaning	3421	0.1 %	-	-
Lepton veto	3418	0.030 %	4297	0.2 %
$N_{\text{jets}} \leq 3$	3180	7 %	3782	%
$\Delta\phi(E_T^{\text{miss}}, \text{jets}) > 0.4$	3015	5 %	3614	7%
Jet Quality	2842	5 %	-	-
$p_T^{\text{j1}} > 250$ GeV	761	72 %	769	79 %
$E_T^{\text{miss}} > 250$ GeV	693	9 %	715	7 %
M1 : $\mathrm{E_T^{miss}} = [250 - 300]$ GeV	134	81 %	131	82 %
M2 : $\mathrm{E_T^{miss}} = [300 - 350]$ GeV	139	82 %	129	82 %
M3 : $\mathrm{E_T^{miss}} = [350 - 400]$ GeV	111	85 %	115	84%
M4 : $\mathrm{E_T^{miss}} = [400 - 500]$ GeV	145	80 %	138	81 %
M5 : $\mathrm{E_T^{miss}} = [500 - 600]$ GeV	78	89 %	81	89 %
M6 : $\mathrm{E_T^{miss}} = [600 - 700]$ GeV	41	94 %	38	95 %
M7 : $\mathrm{E_T^{miss}} > 700$ GeV	46	94 %	42	95 %

$\tilde{t} \to c\tilde{\chi}_1^0$ (350/345) cutflow				
cut	# events (scaled to σ and $\mathcal{L}$)	relative change	# events (Official)	relative change
Initial number of events	12096	-	12096	-
$E_T^{\text{miss}} > 100$ GeV	3930	67 %	4127	66 %
Trigger	3162	20%	-	-
Event cleaning	3140	0.7 %	-	-
Lepton veto	3138	0.06 %	4122	0.1 %
$N_{\text{jets}} \leq 3$	2926	3 %	3864	7 %
$\Delta\phi(E_T^{\text{miss}}, \text{jets}) > 0.4$	2776	5 %	3638	6 %
Jet Quality	2618	3%	-	-
$p_T^{\text{j1}} > 250$ GeV	698	72 %	682	81 %
$E_T^{\text{miss}} > 250$ GeV	636	9 %	603	11 %
$\mathrm{M1} : \mathrm{E_T^{miss}} = [250 - 300]$ GeV	124	79%	114	81 %
$\mathrm{M2} : \mathrm{E_T^{miss}} = [300 - 350]$ GeV	130	80 %	122	79 %
$\mathrm{M3} : \mathrm{E_T^{miss}} = [350 - 400]$ GeV	104	84 %	109	82 %
$\mathrm{M4} : \mathrm{E_T^{miss}} = [400 - 500]$ GeV	129	80 %	123	79 %
$\mathrm{M5} : \mathrm{E_T^{miss}} = [500 - 600]$ GeV	74	89 %	67	89 %
$\mathrm{M6} : \mathrm{E_T^{miss}} = [600 - 700]$ GeV	35	95 %	39	94 %
$\mathrm{M7} : \mathrm{E_T^{miss}} > 700$ GeV	40	94 %	37	94 %

Table 1: Cutflow for the benchmark point $\tilde{t} \to c\tilde{\chi}_1^0$ (350/345) in the three Signal Regions.

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