Validation note for the ATLAS monophoton analysis: ATLAS_EXOT_2014_06

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This note contains details on the implementation and validation of the ATLAS *Search for new phenomena in events with a photon and a missing transverse momentum in pp collision at* $\sqrt{s}$= *8 TeV* [1] within the MadAnalysis5 [2–4] framework. This search looks for a signal with one isolated hard photon with $p_T > 125$ GeV, $E_T^{\rm miss} > 150$ GeV, no leptons and no more than one jet.

I. SIMULATION DETAILS

The ATLAS collaboration provides, in the additional material available at [5], a cut flow for one benchmark point for the MSSM scenario with a compressed $\tilde{q}$–χ_1^0 spectrum, where $\tilde{q}$ refers to any of the first and second generation left- and right-handed squarks and χ_1^0 is the lightest neutralino, the lightest SUSY particle, which is assumed to be detector stable. Moreover acceptance and efficiencies, together with production cross sections, are provided for more benchmark points,[1] see Figs. 24–26 in [5].

The signal process consists in the production of a $\tilde{q}\bar{\tilde{q}}$ pair, with the addition of a hard extra photon, with the subsequent decay of the squarks into a Standard Model (SM) quark and χ_1^0. This process has been generated with MadGraph 5 v1.5.11 [6] using the following syntax:

```
p p > ul ul~ a $ go          (1)
p p > ul ul~ a j $ go
```

and analogously for `ur,cl,cr,dl,dr,sl,sr`.

The squark decays, parton showering and hadronization have been performed with PYTHIA v6.4 [7] implemented in MadGraph 5 through the pythia-pgs package. The MLM matching scheme [8, 9] was used to merge the 0 and 1 jet samples. Finally the samples have then been passed through the tuned version [4] of Delphes 3 [10], available within the MadAnalysis5 package, in which we have implemented the selection cuts.

The simulation parameters have been fixed to the same values used by the ATLAS collaboration, which has provided us with the MadGraph `run_card.dat` and `pythia_card.dat`. In the `run_card.dat` the following cuts, which differ from the MadGraph default `run_card.dat`, have been imposed

```
0 = ptj    1d5 = ptjmax   1d5 = ejmax
80 = pta   1d5 = ptamax   1d5 = eamax
1d2 = drajmax                         ,
```

while the value of `xqcut` has been fixed at $m_{\tilde{q}}/4$.

In the `pythia_card.dat` the following flags have been applied

```
IEXCFILE=0  showerkt=T  imss(21)=24  imss(22)=24,
```

while the value of `qcut` has been fixed equal to `xqcut`.

Finally, the MSSM model parameters have also been fixed at the same values used by ATLAS, by using the SLHA file available on [11]. In this file we have only changed the $\tilde{q}$ and χ_1^0 masses while all the other sparticles masses have been left at the value of 4.5 TeV and the extra Higgs states masses at the value of ~ 750 GeV.

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[1] In particular they are given for the values $(m_{\tilde{q}}, m_{\chi_1^0})$=(100,95), (150,145), (200,195), (250,245), (300,295), (100,90), (150,140), (200,190), (250,240), (300,290), (87,62), (162,137), (237,212), (100,50), (175,125), (250,200) [GeV].

II. VALIDATION

We first compare in Table I the cutflow for $m_{\tilde{q}} = 200$ GeV and $m_{\chi_1^0} = 195$ GeV with the one provided in the additional material on the online documentation [5]. For simplicity, we compare the ATLAS cutflow (calculated combining all the $\tilde{q}\bar{\tilde{q}}$ processes) just with the `ul ul~` process, therefore without combining the various selection efficiencies and cross sections, which has however been done when comparing the acceptance (A) and efficiencies (ϵ) for all the benchmark points and when producing the exclusion curve. We have scaled our initial number of events to the initial value of the ATLAS cutflow. Moreover, we have included in the implementation of the analysis the following details:

- The crack in the detector which makes the photons with $1.37 < |\eta| < 1.52$ undetectable. This has been included in the analysis after a direct discussion with ATLAS.
- The requirement of good vertex and cleaning cuts, not reproducible within a fast detector simulation, has been imposed by rejecting the same fraction of event as they find in ATLAS, passing from cut a) to cut c) of Tab. I, where there is a reduction from 8582 to 8213 events. This scaling has been applied at the level of the first selection cut, $E_T^{\rm miss} > 150$ GeV, where the $E_T^{\rm miss}$ trigger is 100% efficient. In applying this criteria we are however insensitive to any dependence of this cut on a particular model or on different parameter choices of a given model.
- When asking for a tight leading photon, we have further applied a scaling factor of 0.9, to naively take into account the efficiency reconstruction for a tight photon with $p_T > 125$ GeV, see [12].

Cut	ATLAS	Rel. decr.	MA5 (`ul ul~`)	Rel. decr.
Nominal	9989		9989	
a. Trigger	8582			
b. Good Vertex	8574			
c. Cleaning cuts	8213			
0. $E_T^{\rm miss} > 150$ GeV	4131		4384	
1. 1 loose γ, $p_T > 125$ GeV, $\|\eta\| < 2.37$	2645	−36.0	2637	−39.8
2. Tight leading γ with $\|\eta\| < 1.37$	2068	−21.8	2052	−22.2
3. Isolated leading γ	1898	−8.2	1856	−9.6
4. $\Delta\phi(\gamma^{\rm leading}, E_T^{\rm miss}) > 0.4$	1887	−0.6	1840	−0.8
5. $N_{\rm jet} \leq 1$ and $\Delta\phi(jet, E_T^{\rm miss}) > 0.4$	1219	−35.4	1234	−33.0
6. Lepton veto	1188	−2.5	1233	−0.1

TABLE I: Cut flow for the nominal point with $m_{\tilde{q}} = 200$ GeV and $m_{\chi_1^0} = 195$ GeV, comparing our simulation to the official ATLAS results [5] for the case of pair production of first and second generation squarks. Reported are the absolute event numbers after each cut as well as the relative decreases in %.

We have then generated signal processes for all the benchmark points for which A and ϵ are provided. In particular we have generated independently the 8 processes of eq.(2) for all the squark of the first and second generation. In Fig. 1 we show the values of $A \times \epsilon$ from the official ATLAS results (upper left panel), our implementation (upper right panel) and the ratio between the two (lower panel). We observe a quite good agreement, within the 10% level, for most of the benchmark points considered.

III. EXCLUSION LIMIT

We now use the results obtained to set limits in the parameter space for the compressed squark scenario and to achieve this we will proceed in two steps:

- We first try to reproduce the exclusion limits in the $m_{\tilde{q}}$-$m_{\chi_1^0}$ plane with the results provided by ATLAS. This will take into account any differences in the calculation of the confidence level (CL).
- We then apply the same prescription to our simulated sample to obtain the final result.

In the unique signal region, 521 events are observed with a SM prediction of $557 \pm 36 \pm 27$. Therefore in order to be excluded at 95% CL, a signal should give 110.63 events. This result has been cross checked with the `exclusion_CLs.py` calculation provided with MA5.

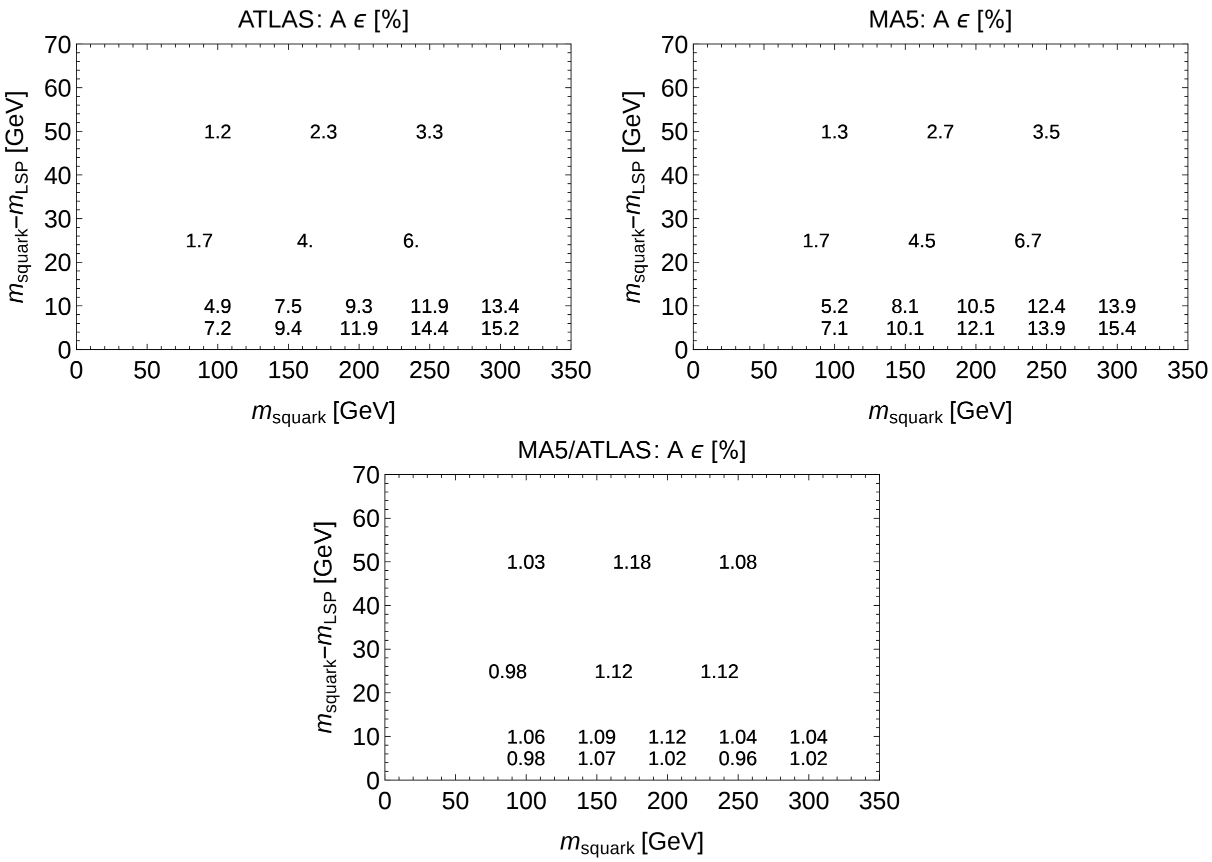

FIG. 1: Values of $A \times \epsilon$ for the official ATLAS result (upper left panel), our implementation (upper right panel) and the ratio between the two (lower panel).

From the table of cross sections, acceptance and efficiencies we have evaluated the 95% CL exclusion contour for our results and for the ATLAS values. As we can see in Fig. 2 the recomputation of the official limit (solid red line) differs from the official curve quoted in [5] (dashed red line, with the 1σ theory error bars) being in particular more conservative. This could be explained by the fact that ATLAS makes also use of data in the control regions, as well as the data in the signal region, to compute the exclusion limits.

Comparing then these results with those obtained through MA5 (solid blue line) we observe that, as expected from the $A \times \epsilon$ comparison of Fig. 1, our results have a good agreement in all the considered regions of $\tilde{q}$ mass and mass splitting with χ_1^0.

IV. ACKNOWLEDGMENT

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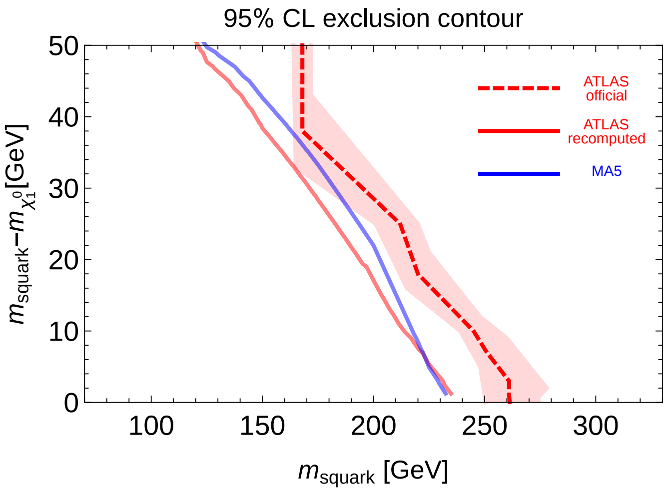

FIG. 2: Comparison between the official 95% CL observed exclusion limit from ATLAS (dashed red line, with the 1σ theory error bars), the recomputation of the ATLAS limit (solid red line) and the MA5 results (solid blue line).

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