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Searches beyond the Standard Model at ATLAS

SUSY search

- Inclusive SUSY search
- Right squark search

MSSM H/A search

- $H/A \to \mu\mu$ decay

SUSY search

SUSY requires the existence of sparticles which are superpartners of ordinary SM particles differing in spin by 1/2.

Particle R = +1	spin	SParticle R = -1	spin
l	1/2	$\tilde{l}_{L/R}$	0
ν	1/2	$\tilde{\nu}_L$	0
q	1/2	$\tilde{q}_{L/R}$	0
g	1	$\tilde{g}$	1/2
γ	1	$\tilde{\gamma}$	1/2
Z^0	1	$\tilde{Z}$	1/2
h^0, H^0, A^0	0	$\tilde{H}^0_{1,2}$	1/2
$W^\pm$	1	$\tilde{W}^\pm$	1/2
$H^\pm$	0	$\tilde{H}^\pm$	1/2
$\tilde{W}^\pm$ and $\tilde{H}^\pm$ mix and form $\tilde{\chi}^\pm_1$, $\tilde{\chi}^\pm_2$			
$\tilde{\gamma}$, $\tilde{Z}$, $\tilde{H}^0_{1,2}$ mix and form $\tilde{\chi}^0_1$, $\tilde{\chi}^0_2$, $\tilde{\chi}^0_3$, $\tilde{\chi}^0_4$			
$\tilde{t}_L$ and $\tilde{t}_R$ mix and form $\tilde{t}_1$, $\tilde{t}_2$			
similar for $\tilde{b}$ and $\tilde{\tau}$			

If SUSY exists at the week scale ($\sim$ 1 TeV), it should be discovered straightforward at LHC energies.

As sparticle masses and decays are strongly related to the origin of SUSY breaking in nature, sparticle detection could provide a tool to discriminate different SUSY breaking mechanisms. The most promising extension of the SM, the MSSM, does not assume any particular SUSY breaking mechanism and has more than one hundred parameters in addition to the SM parameters. The number of MSSM parameters can be drastically reduced if a particular SUSY breaking mechanism is assumed.

- mSUGRA (minimal SUperGRAvity),
- GMSB (Gauge Mediated Symmetry Breaking),
- AMSB (Anomaly Mediated Symmetry Breaking).

Currently most popular mSUGRA Supersymmetry breaking paradigm predicts that SUSY breaking happens in a hidden sector and is mediated to the visible sector (described by MSSM) via gravitational interactions which are universal. In the mSUGRA framework all masses, mixings, and decays of all SUSY and Higgs particles are determined in terms of five parameters:

- the common scalar mass m_0,
- the common fermion mass $m_{1/2}$,
- the common trilinear coupling A_0 at the grand unification energy scale,
- the ratio $\tan\beta$ between the vacuum expectation values of the two Higgs doublets,
- the sign of the Higgsino mass parameter μ.

For a difference from SM which conserves lepton number and baryon number, SUSY can violate both. Minimal mSUGRA model assumes the existence and conservation of R parity which is connected to lepton number, baryon number and spin.

SM: R= +1 ; SUSY: R= -1 ; R parity conservation $\Rightarrow$

- SUSY particles are produced in pairs and
- decay by cascading down to the LSP.

The lightest supersymmetry particle LSP is absolutely stable, massive and undetectable. In mSUGRA model LSP is $\tilde{\chi}_1^0$.
$\Rightarrow$ All SUSY events have $\tilde{\chi}_1^0$ in the final state and the eventual signal is characterized by a high missing energy.

Different regions of mSUGRA five dimensional parameter space have been proposed as SUSY benchmarks and studied at ATLAS in order to optimise search sensitivity and measurement precision.

Parameters chosen here define the SU4 low mass SUSY model, close to the limit of the Tevatron Run II reach.

$$m_0 = 200 \text{ GeV}, m_{1/2} = 160 \text{ GeV}, A_0 = -400 \text{ GeV}, \tan\beta = 10, \mu > 0.$$

With a production cross section of 260 pb and masses in the range 60 - 450 GeV, $m(\tilde{q}) \sim m(\tilde{g}) \sim$ 410 GeV, SU4 seems to be a promising target for SUSY searches with early ATLAS data. Full detector simulation from 2005 ("Rome data"), based on Geant4 package, is used in the analysis presented here.

Inclusive SUSY search

Supersymmetric events are dominated by the production of gluinos and sqarks. Inclusive SUSY searches regard gluino and sqark events which are characterised by multiple jets, leptons and missing transverse energy and can provide the first evidence of the deviation from the Standard Model by measuring the effective mass of the event which is a global event variable. The effective mass is defined as $M_{EFF} = E_t^{miss} + \Sigma p_t(j)$ where all reconstructed hadronic jets were used.

In the case of SU4 events inclusive searches are sensitive to $\tilde{g}$ decays to 3rd generation squarks. The hardest jet is either a light q jet outgoing from $\tilde{q}_L$ or $\tilde{q}_R$ decay or a b jet originating from $\tilde{b}_1$ produced in the $\tilde{g}$ decay. In order to separate SU4 gluino events from the SM background processes, selection cuts were applied on multijet events with missing transverse energy and jets tagged as b jets.

Event selection

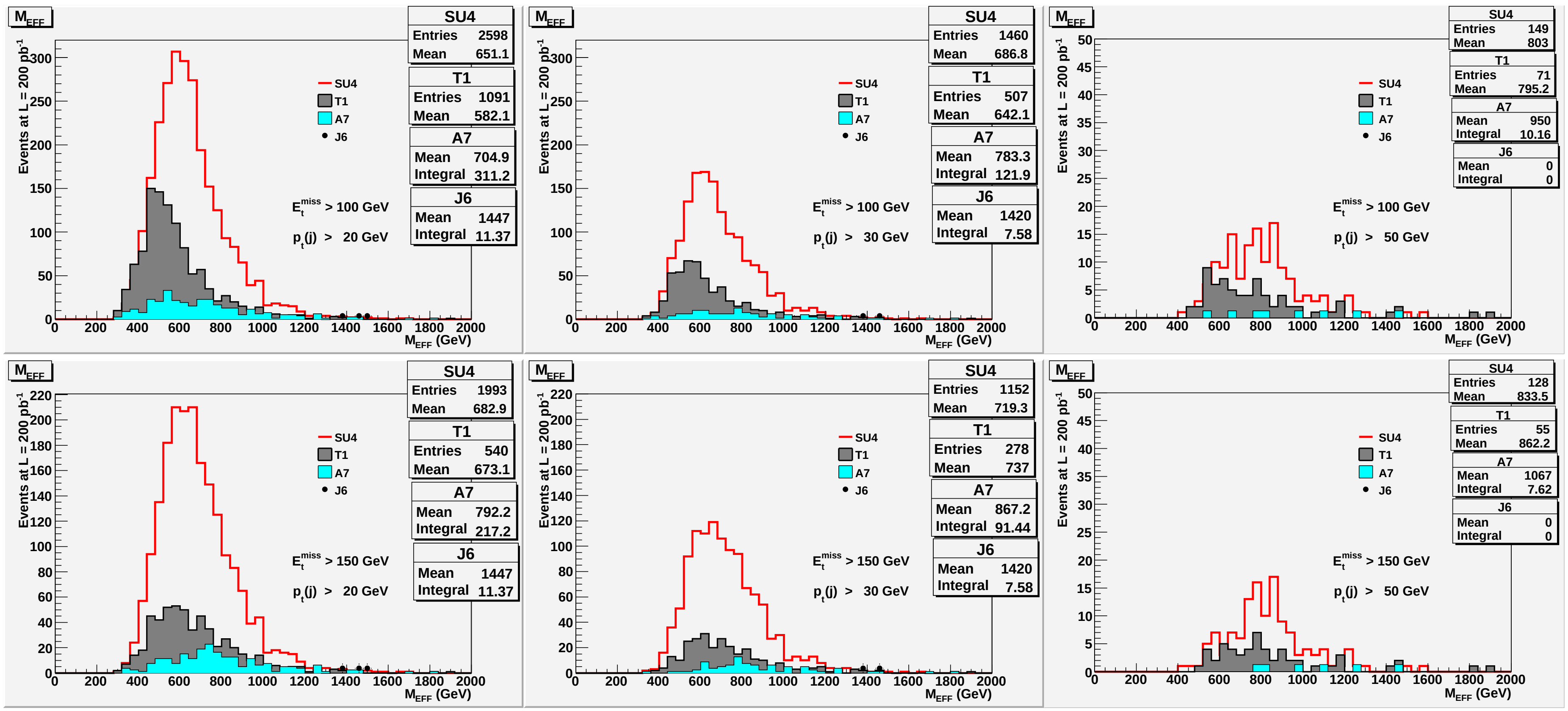
- At least 5 jets in the event where
- at least 2 jets are tagged as b jets;
- the hardest jet has $p_t(j1) > 100$ GeV;
- the other jets have $p_t(j) > p_t^{cut}$, p_t^{cut} = 20, 30, 50 GeV;
- $E_t^{miss} > E_t^{cut}$, E_t^{cut} = 100, 150 GeV;
- $E_t^{miss}/M_{EFF} > 0.2$.

Selection efficiency can be estimated from the numbers of selected and generated events corresponding to the same luminosity. Event selection efficiency for the SU4 gluino events is about 10% and for the remaining SM backgrounds $<$ 1%. At low luminosity jet tagging efficiency is higher than 90% for $p_t(j) >$ 20 GeV and a typical b tagging efficiency is 60% with the mistag probability 2 - 3% .

Regarding datasets used for the SM backgrounds, T1 ($t\bar{t}$), A7 ($W + jets$) and J6 ($multijet$) events remain after applying selection cuts. Dominant SM background process is $t\bar{t}$. The strongest cut against the $t\bar{t}$ events is a cut on a missing transverse energy.

M_{EFF} distribution

M_{EFF} of the SU4 signal and SM backgrounds satisfying selection criteria with $E_t^{miss} > 100$ GeV (above) and $E_t^{miss} > 150$ GeV (below) and $p_t(j) > 20$ GeV (left), $p_t(j) > 30$ GeV (middle), $p_t(j) > 50$ GeV (right). The number of events is normalised to integrated luminosity L = 200 pb^{-1}.



Results

The number of SU4 signal and SM background events satisfying selection criteria
and the S/B ratio obtained for $M_{EFF} > 400$ GeV
together with the SU4 signal statistical significance SU4/$\sqrt{B_{SM}}$
and the statistical error on the SM background rate $\sqrt{B_{SM}}/B_{SM}$;
all at L = 200 pb^{-1}.

E_t^{miss} cut (GeV)	100	100	100	150	150	150
$p_t(j)$ cut (GeV)	20	30	50	20	30	50
SU4	2598	1460	149	1993	1152	128
B_{SM}	1414	635	81	769	376	62
SU4/B_{SM}	1.84	2.30	1.84	2.59	3.06	2.06
SU4/$\sqrt{B_{SM}}$	69.09	57.94	16.56	71.87	59.41	16.26
$\sqrt{B_{SM}}/B_{SM}$	0.03	0.04	0.11	0.04	0.05	0.13

For the effective mass above 400 GeV, a 150 GeV cut on E_t^{miss} suppresses the Standard Model backgrounds to the S/B level of 2.59 for $p_t(j) > 20$ GeV and 3.06 for $p_t(j) > 30$ GeV.

Including only the statistical errors on the SM background rates, with only 200 pb^{-1} of data the SU4 signal statistical significance is far above 5 standard deviations requested for discovery.

An excess of the events above the SM due to the presence of the supersymmetric processes in the low mass SUSY model can be observed in the multijet events with the missing transverse energy.