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Signaling the Arrival of the LHC Era

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Beyond the Standard Model at the LHC - I

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SUSY searches at the LHC

I - Inclusive searches

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Introduction:LHC and new physics

New physics expected at the TeV scale made accessible by LHC.

Large effort to develop strategies to ensure sensitivity to a very broad range of signatures for new physics. Main realisation is that:

Potential and speed of new physics discovery determined by our ability to:

- Master and model the performance of very complex detectors
- Understand and Control rare configurations ('tails') of Standard Model

These issues are at the heart of all the most recent experimental studies. I will illustrate them as applied to SUSY, leading new physics candidate.

We take here SUSY as a template theory with:

- Rich spectrum of new particles
- High production cross-section
- Complex decay chains with invisible particles in final state

We focus in particular on the Minimal Supersymmetric Standard Model (MSSM)

Minimal Supersymmetric Standard Model (MSSM)

Minimal particle content:

- A spin $\Delta J = \pm 1/2$ superpartner for each Standard Model particle
- Two higgs doublets with v.e.v's v_1 and v_2 and superpartners. After EW symmetry breaking: 5 Higgs bosons: $h, \; H, \; A, \; H^{\pm}$

If SUSY is unbroken, same mass for ordinary particles and superpartners

No superpartner observed to date

SUSY explicitly broken by inserting in the lagrangian all "soft" breaking terms

The model has 105 free parameters (!)

Additional ingredient: R-parity conservation: $R = (-1)^{3(B-L)+2S}$:

- Sparticles are produced in pairs
- The Lightest SUSY Particle (LSP) is stable

Impose phenomenological constraints (e.g FCNC suppression) to reduce SUSY breaking parameters. End up with 15-20 parameters

Soft parameters are three gaugino masses (M_1, M_2, M_3), higgsino mass (μ), $\tan\beta \equiv v_1/v_2$, sfermion masses, tri-linear couplings A.

Resulting physical spectrum:

quarks	$\longrightarrow$	squarks	$\tilde{q}_L$, $\tilde{q}_R$
leptons	$\longrightarrow$	sleptons	$\tilde{\ell}_L$ $\tilde{\ell}_R$
$W^\pm$,$H^\pm$	$\longrightarrow$	charginos	$\tilde{\chi}^\pm_{1,2}$
γ, Z, H^0_1, H^0_2	$\longrightarrow$	neutralinos	$\tilde{\chi}^0_{1,2,3,4}$
g	$\longrightarrow$	gluino	$\tilde{g}$

For each fermion f two partners $\tilde{f}_L$ and $\tilde{f}_R$ for the two helicity states

Charginos and neutralinos from the mixing of gauginos and higgsinos

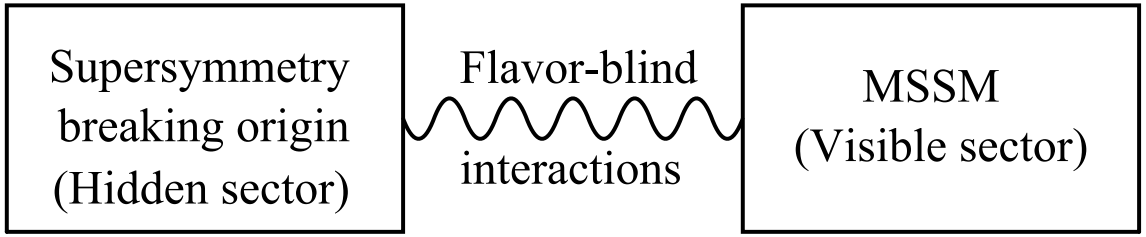
Gaugino soft breaking parameters from measurement of neutralinos/chargino masses

Model still with too many parameters for detailed study of the full parameter space

$\Rightarrow$ seek guidance from SUSY breaking models

Models of SUSY breaking

Spontaneous breaking not possible in MSSM, need to postulate hidden sector



Phenomenological predictions determined by messenger field:

Three examples, sparticle masses and couplings function of few parameters:

- Gravity: mSUGRA. Parameters: $m_0, \ m_{1/2}, \ A_0, \ \tan\beta,$ sgn μ

  Variations:

  – Decouple Higgs bosons from sfermions (NUHM). Add 2 parameters: $m(A), \mu$

  – Give up gaugino mass unification. $m_{1/2} \Rightarrow m_1, m_2, m_3$

- Gauge interactions: GMSB. Parameters: $\Lambda = F_m/M_m, \ M_m, \ N_5$ (number of messenger fields) $\tan\beta, \ sgn(\mu), \ C_{grav}$

- Anomalies: AMSB. Parameters: $m_0, \ m_{3/2}, \ \tan\beta, \ sign(\mu)$

SUSY breaking structure

SUSY breaking communicated to visible sector at some high scale

$m_0, \; m_{1/2}, \; A_0, \; \tan\beta, \; \mathrm{sgn}\,\mu$ (mSUGRA)

Evolve down to EW scale through Renormalization Group Equations (RGE)

$M_1, \; M_2, \; M_3, \; m(\tilde{f}_R), \; m(\tilde{f}_L), \; A_t, \; A_b, \; A_\tau, \; m(A), \; \tan\beta, \mu$

From 'soft' terms derive mass eigenstates and sparticle couplings.

$m(\tilde{\chi}^0_j), \; m(\tilde{\chi}^\pm_j), \; m(\tilde{q}_R), \; m(\tilde{q}_L), \; m(\tilde{b}_1), \; m(\tilde{b}_2), \; m(\tilde{t}_1), \; m(\tilde{t}_2)......$

Structure enshrined in Monte Carlo generators (e.g ISAJET)

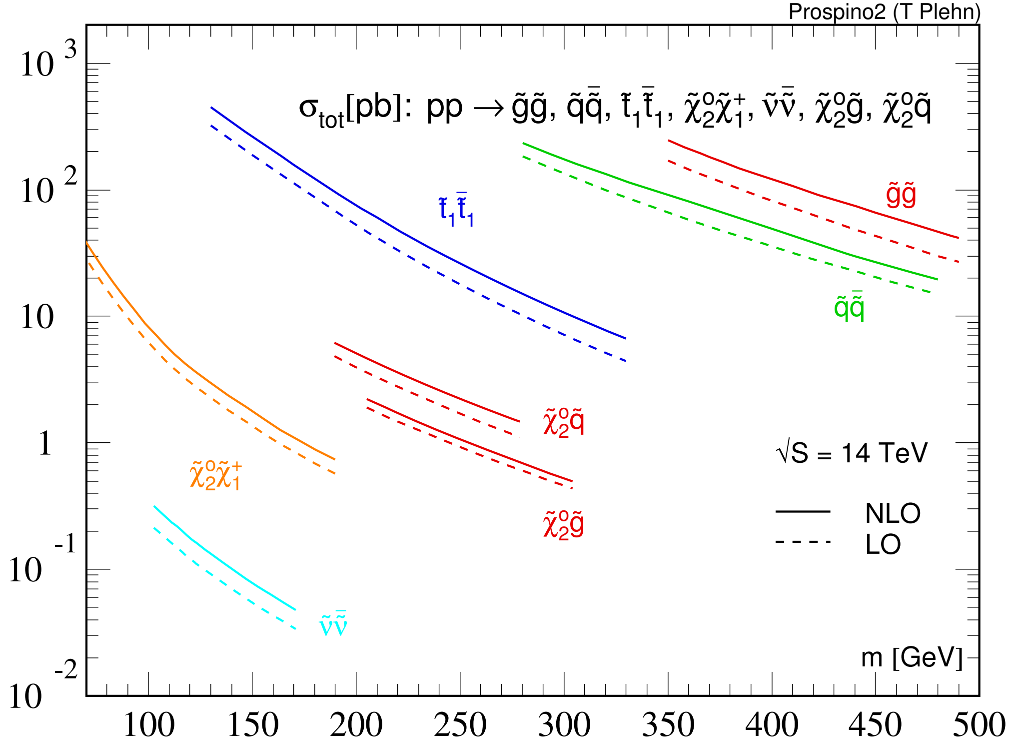
Task of experimental SUSY searches is to go up the chain, i.e. to measure enough sparticles and branching ratios to infer information on the SUSY breaking mechanism

SUSY at the LHC: general features

Production dominated by strongly interacting sparticles: $\tilde{q}$, $\tilde{g}$

$\tilde{q}$ and $\tilde{g}$ production cross-section ∼only function of their masses, ∼independent of details of SUSY model

- $\sigma_{SUSY} \sim 50$ pb for $m_{\tilde{q},\tilde{g}} \sim 500$ GeV
- $\sigma_{SUSY} \sim 1$ pb for $m_{\tilde{q},\tilde{g}} \sim 1000$ GeV

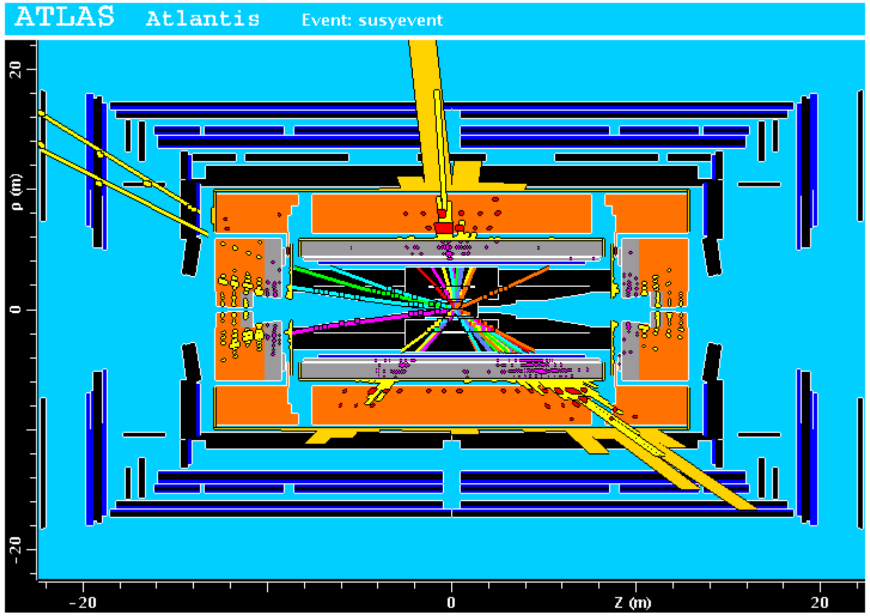


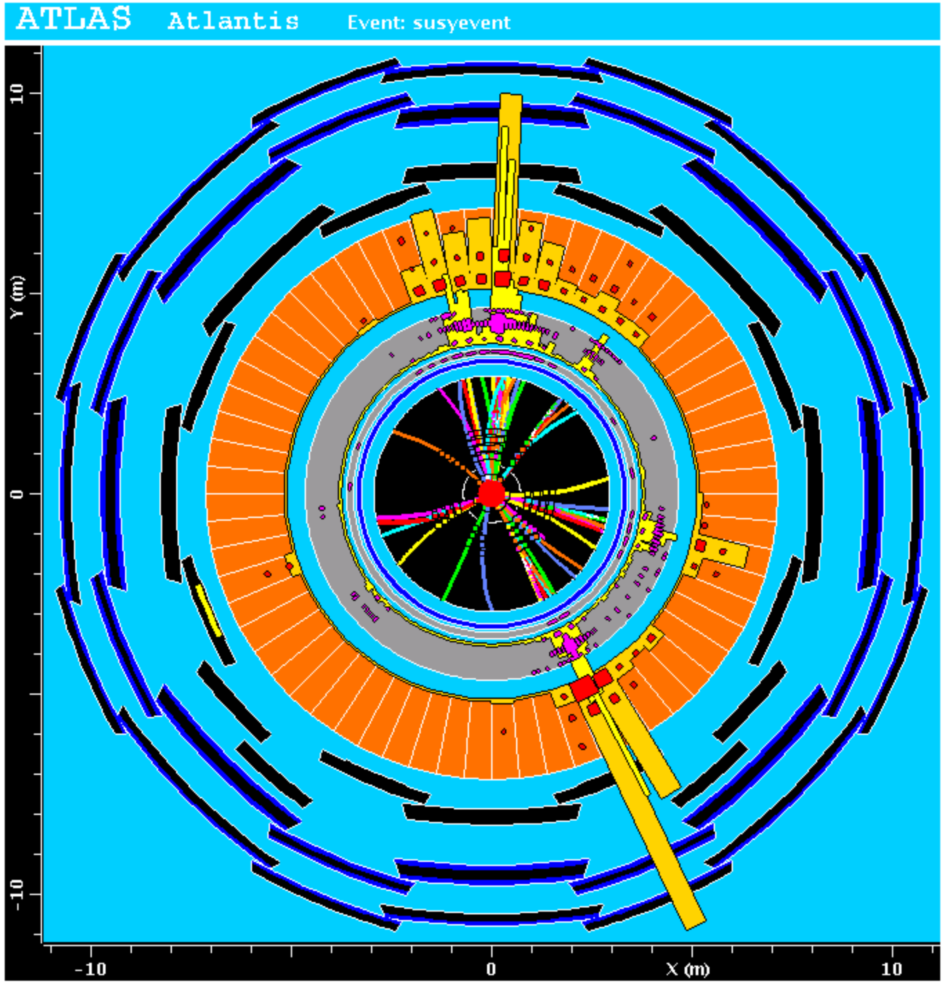
Squarks and gluinos are typically the heaviest sparticles

⇒ If R_p conserved, complex cascades to undetected LSP, with large multiplicities of jets and leptons produced in the decay.

Rich phenomenology, but difficult to disentangle different decay chains

A SUSY event in ATLAS





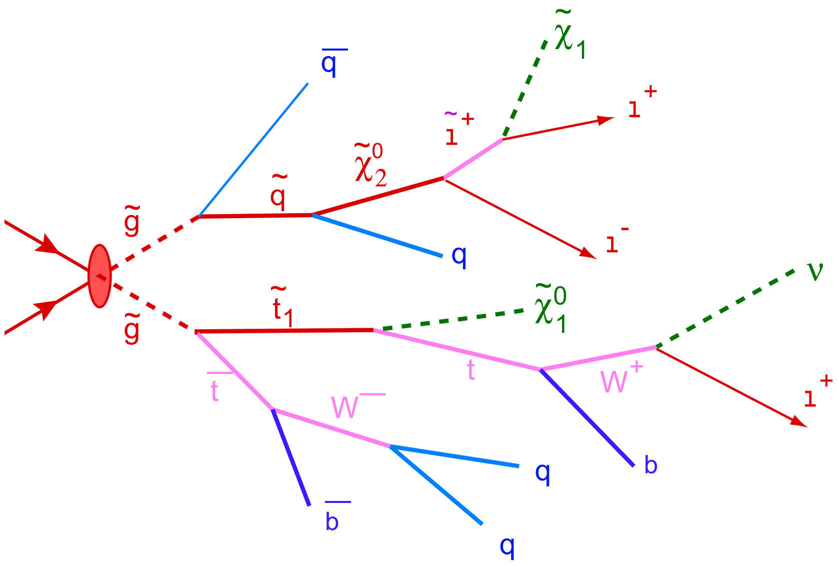
Multi-jet event in Bulk Region

- 6 jets
- 2 high-pt muons
- Large missing E_T

SUSY discovery: basic strategy

Basic assumption: discovery from squark/gluinos cascading to undetectable LSP

Details of cascade decays are a function of model parameters. Focus on robust signatures covering large classes of models and large rejection of SM backgrounds



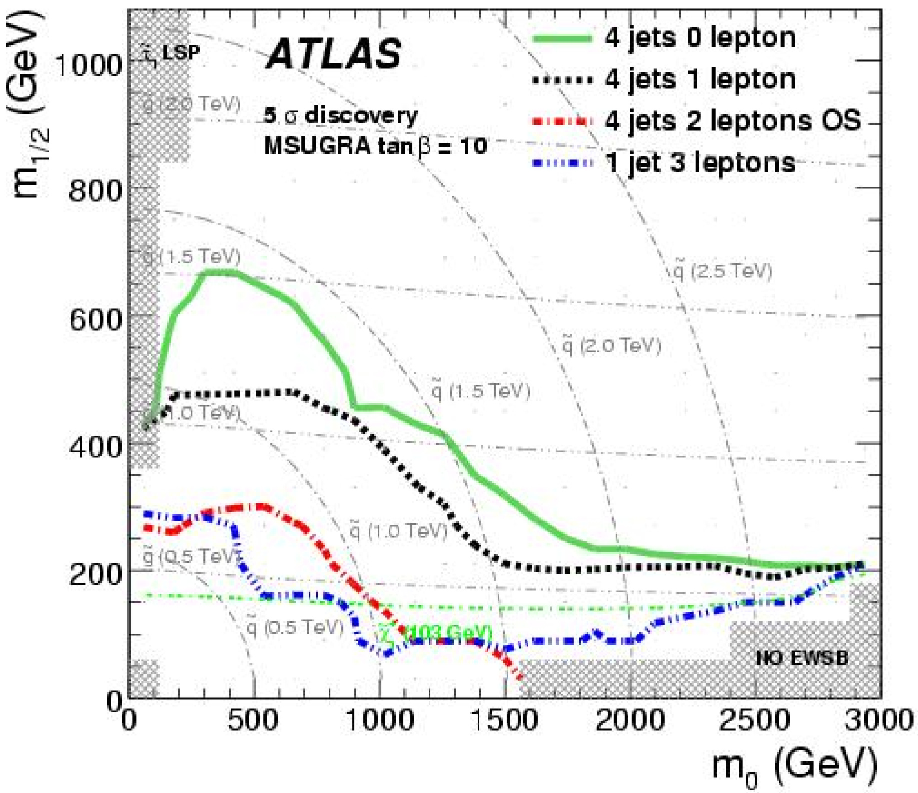
- $\not{E}_T$: from LSP escaping detection
- High E_T jets: guaranteed if squarks/gluinos if unification of gaugino masses assumed.
- Multiple leptons (Z): from decays of Charginos/neutralinos in cascade
- Multiple τ-jets or b-jets (h): Often abundant production of third generation sparticles

Define basic selection criteria on these variables for RPC SUSY with $\tilde{\chi}_1^0$ LSP

Optimisation of criteria on parameter space ongoing, will define set of topologies, and for each define sets of cuts aimed respectively at high and low SUSY masses

Alternative LSP options with different signatures also under study

Inclusive reach in mSUGRA parameter space



ATLAS Reach for 1 fb^{-1}

Includes expected uncertainties on SM backgrounds after 1 fb^{-1} of data:

- 50% on QCD backgrounds
- 20% on $\bar{t}t$, W, Z+jets

Multiple signatures over most of space

Dominated by $\not{E}_T$+jets

Robust if signal observed in a channel, look for confirmation in other channels

ATLAS also scanned model with non universal higgs masses, with in principle different decay patterns, and result are very similar

Most of what I show in the following is new work from ATLAS, to appear in:

The ATLAS Collaboration "Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics", CERN-OPEN-2008-02.

How fast can the discovery be?

Recent ATLAS analyses consistently carried out assuming 1 fb^{-1} both for background determination and for signal search

Reach in 0-lep channel for 1 fb^{-1}, assuming $m(\tilde{q}) = m(\tilde{g})$ is ~ 1300 GeV

Assuming the same level of background control, reach for ∼100 pb^{-1} is ~ 800 GeV

Probably not realistic, worse control of backgrounds at 100 pb^{-1} than at 1 fb^{-1}

Ingredients of background estimate:

- Understanding of early detector performance: $\not{E}_T$ tails, lepton id, jet scale
- Understanding SM at 14 TeV: : Set X-section scales, MC Tuning,..
- Collecting sufficient statistics of SM control samples:

  QCD jets in appropriate configurations (trigger!), W, Z+jets, $\bar{t}t$

Going through some of the main exclusive analyses, look at techniques for:

- Preliminary cleaning of $\not{E}_T$ sample
- Controlling Instrumental $\not{E}_T$ in QCD events
- Controlling real $\not{E}_T$ from SM processes with neutrinos

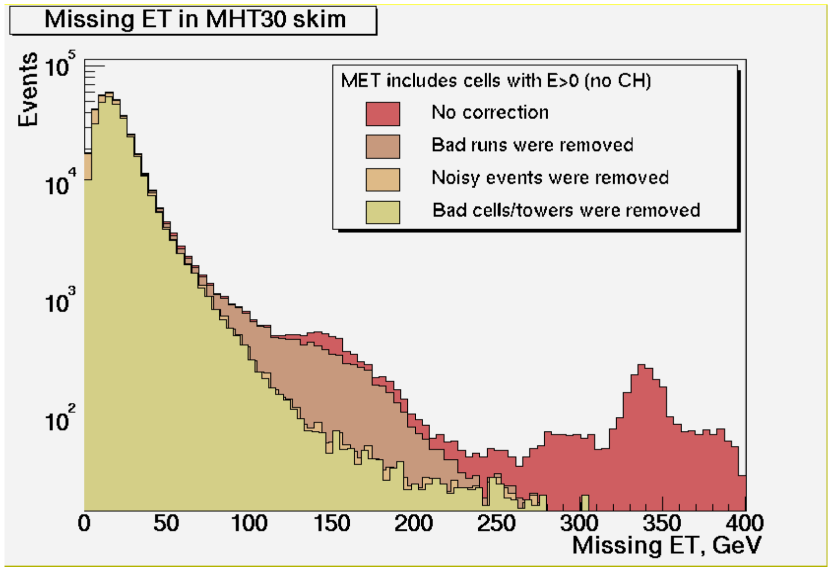
Cleaning of $\not{E}_T$ sample

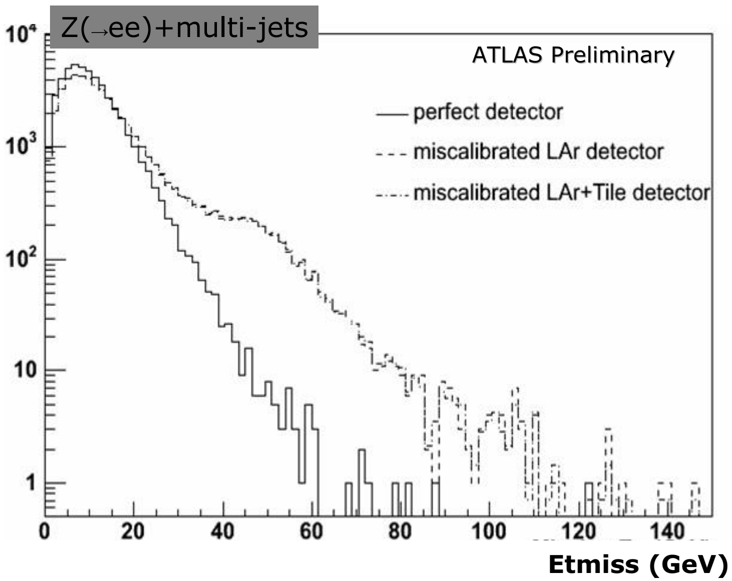
$\not{E}_T$ from mismeasured multi-jet events:

Populated by detector and machine problems

Example of $\not{E}_T$ cleaning in D0

- Reject runs with detector malfunctioning
- Reject events with noise in the detector
- Remove bad cells





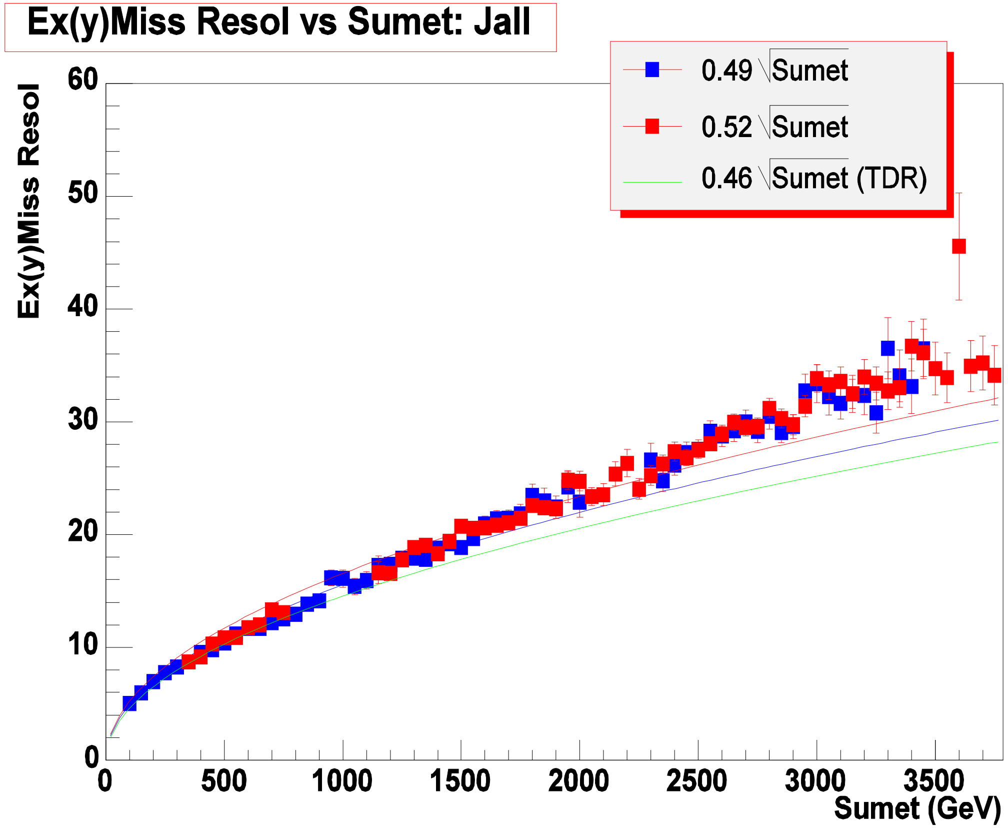
ATLAS example: assume a few HV channels dead in calorimeters

Tools being prepared to monitor and correct event-by-event

$\not{E}_T$ significance

Once detector malfunctioning and external source ubderstotd, $\not{E}_T$ comes from fluctuations in calorimeter response

MonteCarlo study: take events with no real $\not{E}_T$, build distribution of $x(y)$ component of $\not{E}_T$, and take σ



Preliminary ATLAS plot

$\not{E}_T$ resolution can be parametrised as a function of the sum of the E_T deposition in the calorimeter

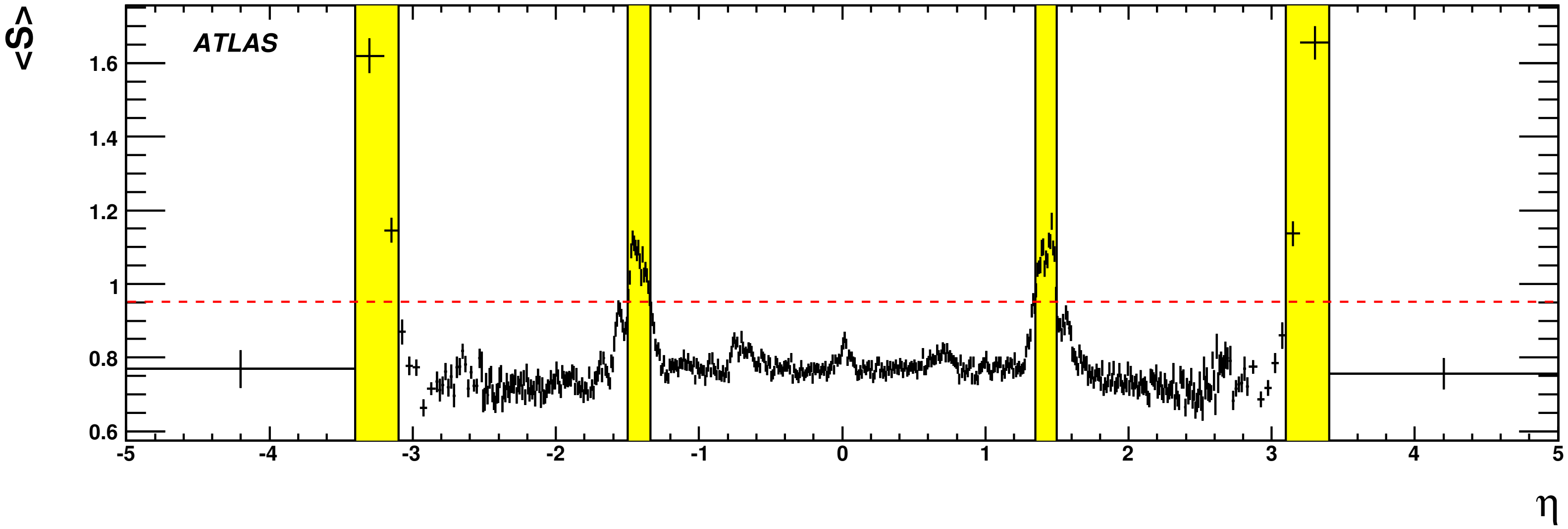
For each event can evaluate significance of measured $\not{E}_T$

Can use this variable to map the response of the detector

Instrumental background: definition of fiducial region for jets

Use a sample of 2-jet events ($p_T > 280$ GeV), apply basic cuts to reject events containing neutrinos

- For each event calculate $S = \not{E}_T / \sqrt{\Sigma E_T}$
- For each jet in the event, take $\eta(jet)$, and fill one entry in the plot
- For each bin in η calculate the average value of S



Observe clear degradation at interface between calorimeters

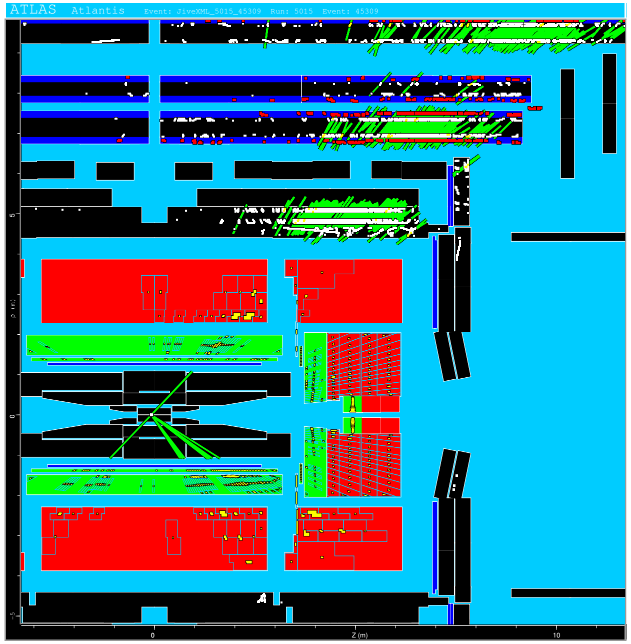
Reject high $\not{E}_T$ events with a jet falling in yellow regions

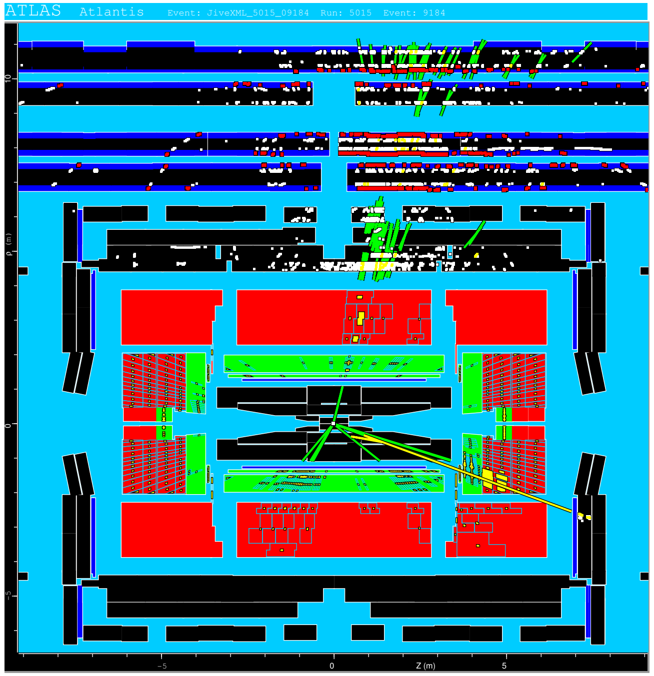
Instrumental background: beyond fiducial cuts

Scan fully simulated jet events in ATLAS ($P_T(jet) \gtrsim 500$ GeV) with

$\Delta \not\!\!E_T > 250$ GeV (F. Paige, S. Willocq)

$\not\!\!E_T$ from: Jet leakage from cracks, Fake muons from cracks, Jet punch-through





Problematic events characterised by large occupancy in muon chambers.

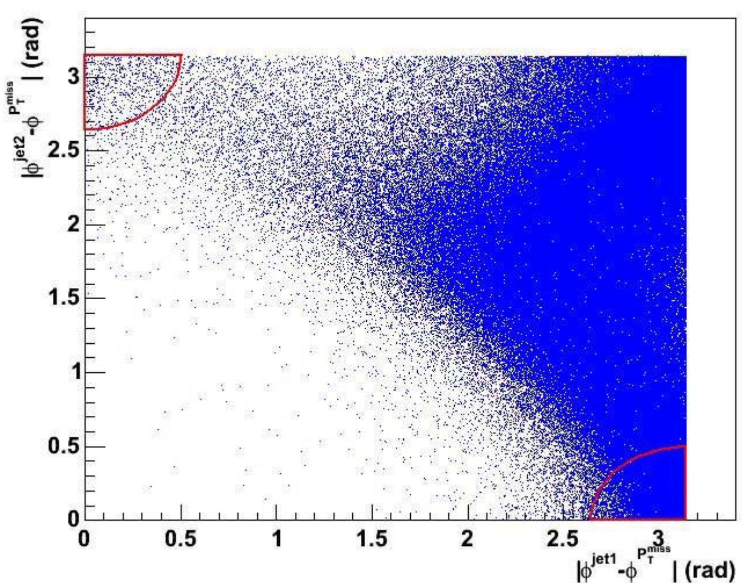
Can develop criteria based on the muon chambers to further reduce tails

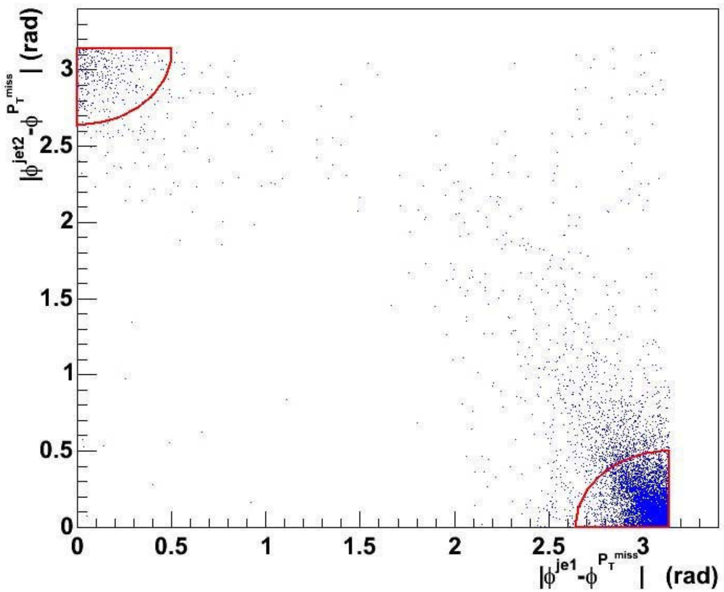
Instrumental background: Rejecting specific topologies

Next step is rejection of topologies which likely to yield instrumental $\not\!\!E_T$

One jet is undermeasured, expect that $\not\!\!E_T$ be aligned with its p_T. If two-jet events, this will be measured as the second jet in the event

If one jet overmeasured jet energy measurement: $\not\!\!E_T$ back to back with respect to it





From CMS TDR: $|\phi^{jet2} - \phi^{\not E_T}|$ vs. $|\phi^{jet1} - \phi^{\not E_T}|$ Left plot: Signal Right plot: QCD

At this point, we are entering the domain of analysis cuts

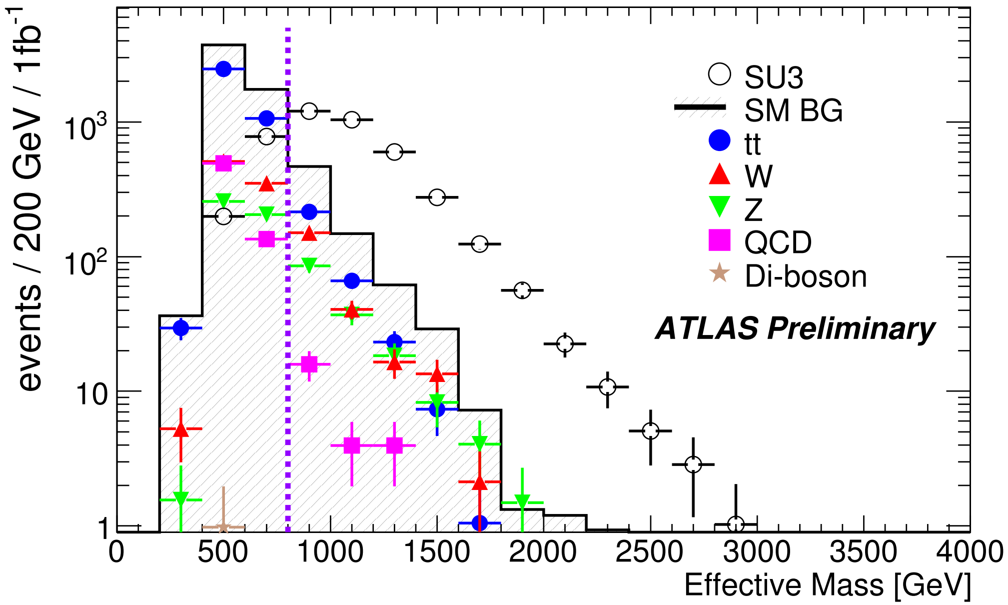
Inclusive signature for zero leptons

SUSY selection:

- 4 jets ($P_T < 100, 50, 50, 50$) GeV)
- $\not{E}_T > 100$ GeV and $\not{E}_T > 0.2 M_{\text{eff}}$
- $\Delta\phi(j, \not{E}_T) > 0.2$
- Transverse sphericity> 0.2

Plot $M_{\text{eff}} = \Sigma_{i=1}^{4} |p_{T(jet_i)}| + E_T^{\text{miss}}$

Typical cut: $M_{\text{eff}} > 800$ GeV



SU3 benchmark Point: $m_0 = 100$ GeV, $m_{1/2} = 300$ GeV, $\tan\beta = 6$, $A = -300$ GeV, $\mu > 0$

QCD background reduced to $\lesssim 5\%$ after all cuts, but with large uncertainites!

Comparable contributions from: • $\bar{t}t$+jets • W+jets • Z+jets

Counting experiment: need precise estimate of background processes in signal region

Complex multi-body final states: can not rely on MonteCarlo alone.

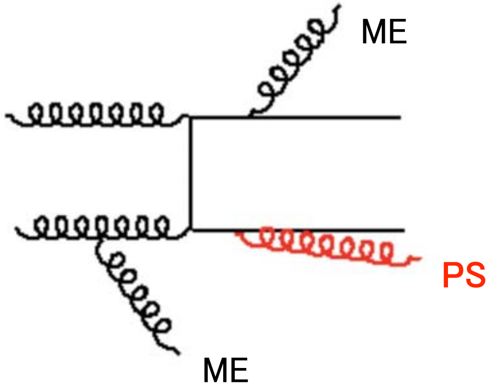
SM backgrounds: Monte Carlo issues

SUSY processes: high multiplicity of final state jets from cascade decays

Require high jet multiplicity to reject backgrounds: ~ 4 jets

Additional jets in $t\bar{t}, W, Z,$ production from QCD radiation

Two possible way of generating additional jets:



- Parton showering (PS): good in collinear region, but underestimates emission of high-p_T jets
- Matrix Element (ME): requires cuts at generation to regularize collinear and infrared divergences

Optimal description of events with both ME and PS switched on

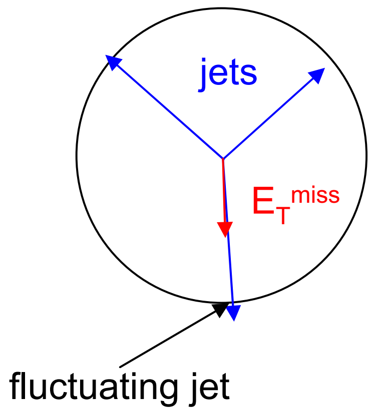
Need prescription to avoid double counting, i.e. kinematic configurations produced by both techniques

Additional issue: normalisation (no NLO calculation possible)

Instrumental backgrounds: data-driven estimate

MonteCarlo estimate of QCD background hard. It requires:

- Good MonteCarlo simulation of QCD multijets
- Excellent understanding of detector incorporated in simulation
- $\not\!\!E_T$ is from tails of response: need to simulate huge number of events



$\Rightarrow$ Develop multi-step data-driven estimate

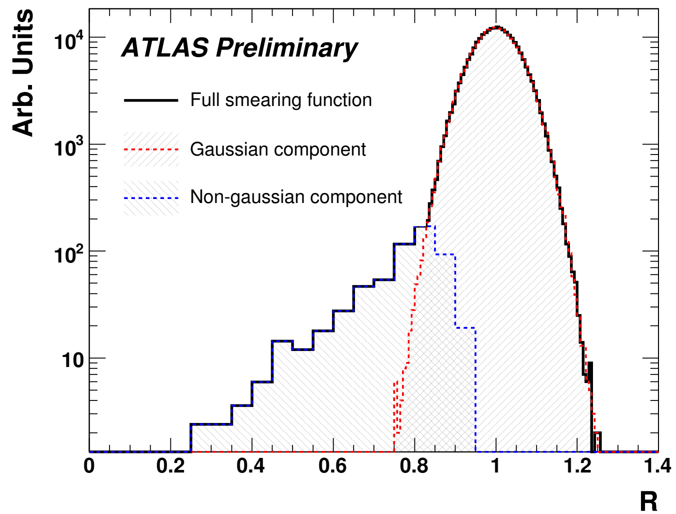
Step 1: Measure the gaussian part of response with balance of γ+jet events

Step 2: Measure the non-gaussian part of response and combine it with the gaussian part

- Require: 3 jets, $p_T(J) > 250, 50, 25$ GeV, $\not\!\!E_T > 60$ GeV
- One and only one jet parallel to the $\not\!\!E_T$ vector
- Define the true $P_T(J)$ as: $\vec{p}_T(J, \text{true}) \simeq \vec{p}_T(J) + \vec{\not\!\!E}_T$

Plot:

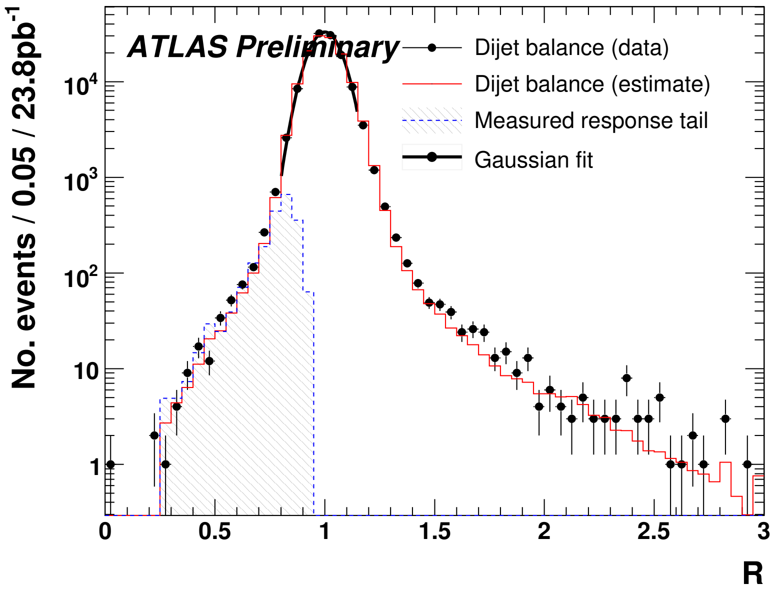
$$R_2 = \frac{\vec{p}_T(J) \cdot \vec{p}_T(J, \text{true})}{|\vec{p}_T(J, \text{true})|^2}$$



Finally normalize the two estimates from the balance of a sample of 2-jet events

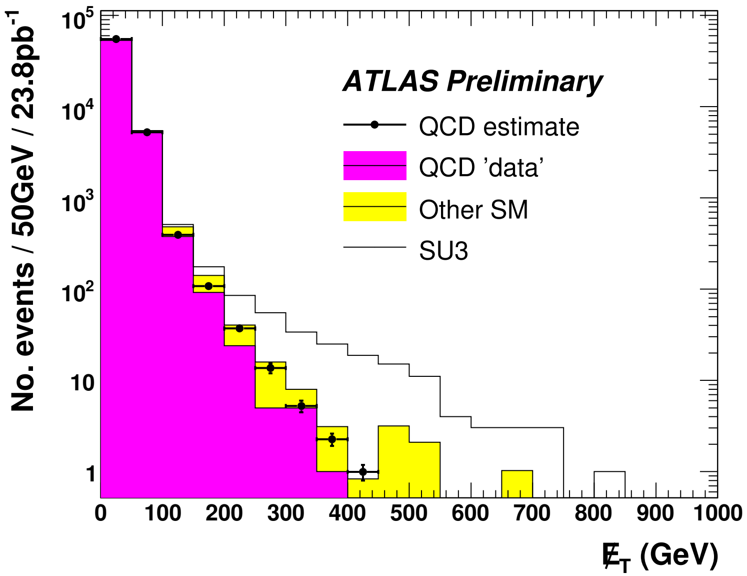
Closure test: compare estimated response curve with 'data' from balance of a sample of two-jet events. Plot for each jet:

$$R_3(j) = 1 + \frac{\vec{\not{E}}_T \cdot \vec{p}_T(j')}{|\vec{p}_T(j')|^2}$$



Step 3: Seed event selection and jet p_T smearing:

Smear according to measured function jet P_T in multi-jet events with low $\not{E}_T$ ('seed events')



Plot the $\not{E}_T$ distribution for the smeared 'seed'events is plotted, normalised to simulated QCD events with $\not{E}_T < 50$ GeV

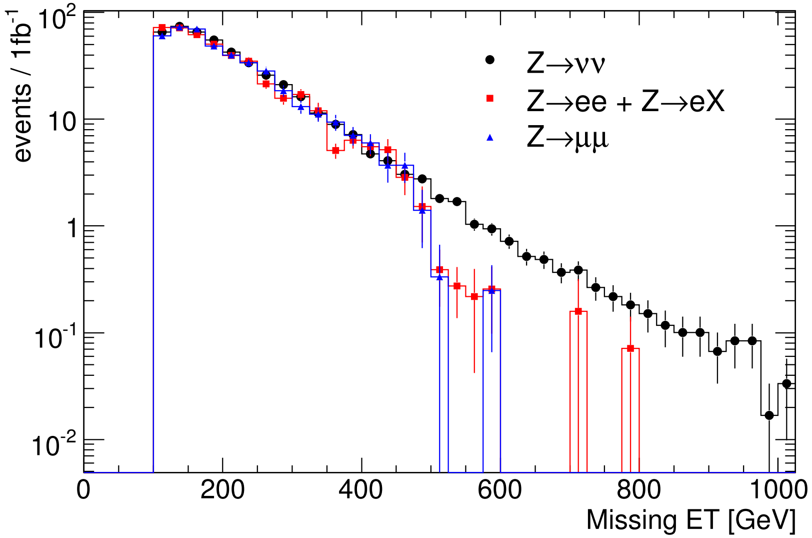
Good agreement between the estimated and 'data' distributions

Dominant systematic errors are the P_T bias in event selection and the statistical error on 'Mercedes' events.

Data driven estimates: $Z \to \nu\nu +$ jets

Select samples of $Z \to \mu\mu(ee, eX)$+multijets from data

Apply same cuts as for SUSY analysis (4 jets+Etmiss), remove leptons and calculate $\not{p}_T$ of events from the vector sum of their momenta (normalized to 1 fb^{-1})



Number of $N_{Z\to\nu\nu}$ per $\not{E}_T$ bin calculated from $N_{Z\to\ell\ell}$ applying corrections for:

- Fiducial for leptons (P_T and η cuts)
- Kinematic cuts to select pure Z sample
- Lepton id efficiency
- $BR(Z \to \nu\nu)/BR(Z \to \ell\ell)$

First two from MC, last one from data

Low statistics at high $\not{E}_T$, improve precision through fit of the shape

Main uncertainites from:

• MC used for corrections ($\sim 6\%$) • $\not{E}_T$ scale ($\sim 5\%$) • Statistics of control sample ($\sim 13\%$)

Method under study using shapes from MC and normalisation from data.

Normalisation needs to be multiplied by $BR(Z \to \nu\nu)/BR(Z \to ee) \sim 6$

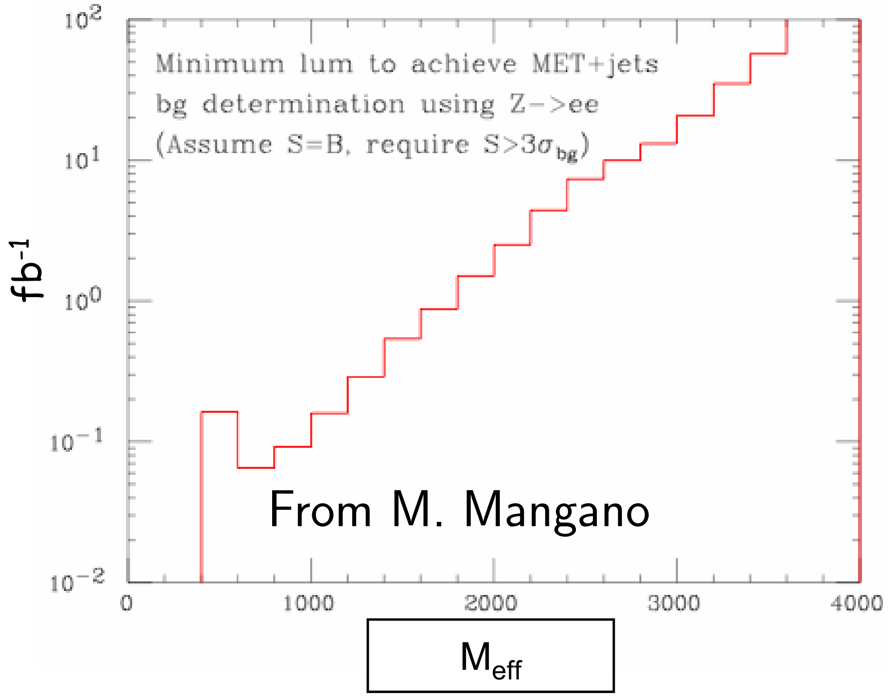
Assuming SUSY signal $\sim Z \to \nu\nu$ bg, evaluate luminosity necessary for having

$N_{SUSY} > 3 \times \sigma_{bg}$

Stat error on background:

$$\sigma_{bg} = \sqrt{N(Z \to ee)} \times \frac{BR(Z \to \nu\nu)}{BR(Z \to ee)}$$

For each bin where normalisation required, need ~ 10 reconstructed $Z \to \ell\ell$ events. Need to consider acceptance/efficiency factors as well



Several hundred pb^{-1} required. Sufficient if we believe in shape, and only need normalisation. Much more needed to perform bin-by-bin normalisation

Inclusive signature with one lepton

$\not\!\!E_T$+jets signature is most powerful and least model-dependent

BUT control of SM and instrumental backgrounds might require long time

The channel single lepton + jets + $\not\!\!E_T$ has somewhat smaller parameter space coverage, but might be easier to control

Same kinematic cuts as for 0 lep+jets

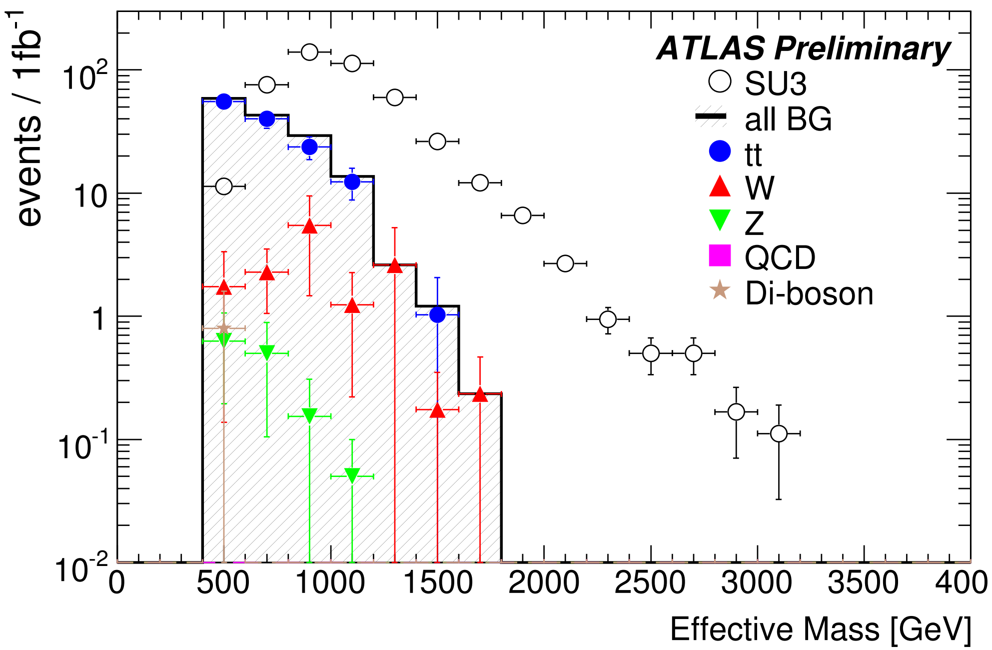
In addition require one lepton

Cut on M_T, transverse mass of the lepton and $\not\!\!E_T$

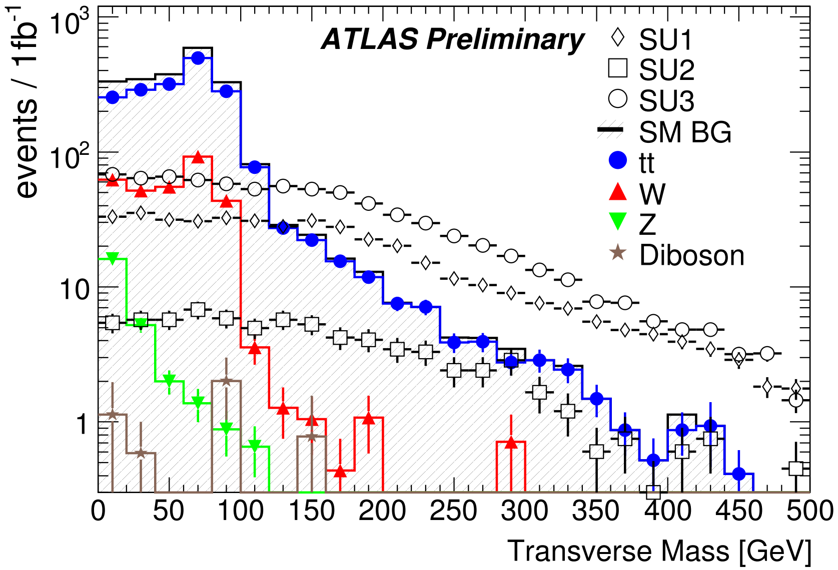
$\bar{t}t$ dominant, $W+$ jets becomes important for higher $\not\!\!E_T$, QCD negligeable

Need data-driven evaluation of single lepton backgrounds from $\bar{t}t$ and W

Use M_T evaluation as illustrative example



One lepton background evaluation with M_T method



M_T variable gives excellent discrimination against $\bar{t}t$, $W+$ jets

Main discriminant value together with $\not{E}_T$

Invert the M_T cut to evaluate background?

Basic Principle:

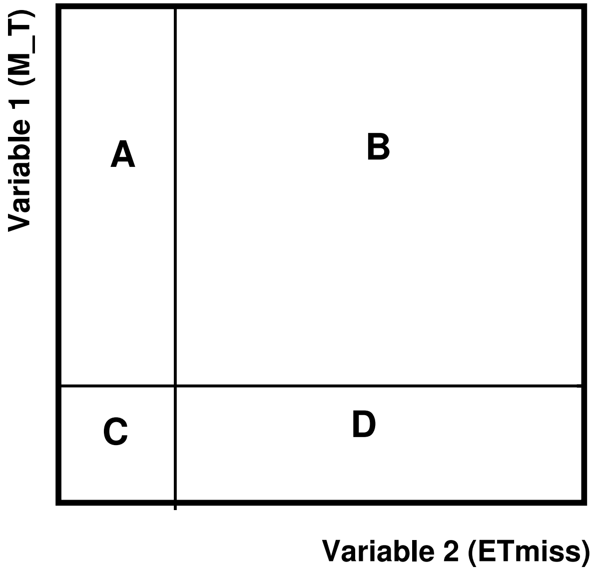
B is *signal region*, $\sim$no signal in A,C,D

D is *control region*

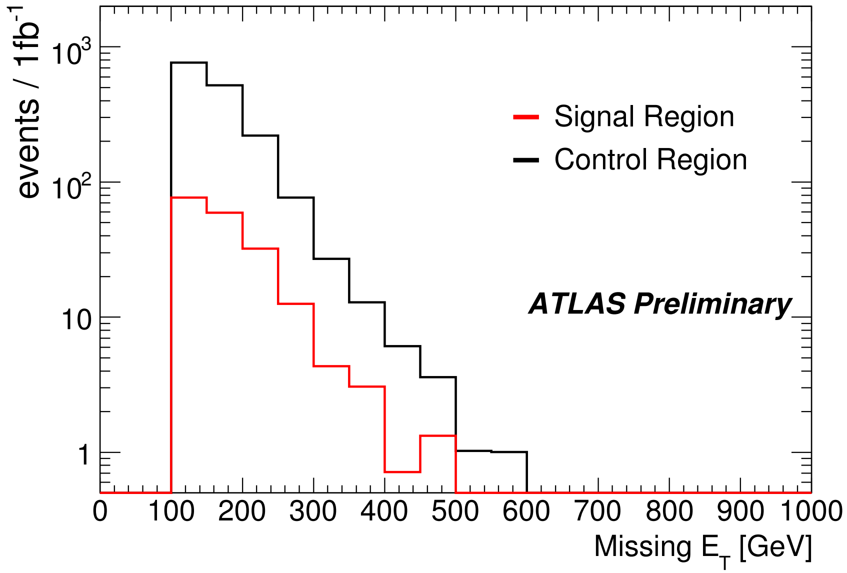
If shape of $\not{E}_T$ the same in (A+B) and (C+D):

$$N(B) = N(D) \times \frac{N(A)}{N(C)}$$

Where $N(X)$ is BG in region X



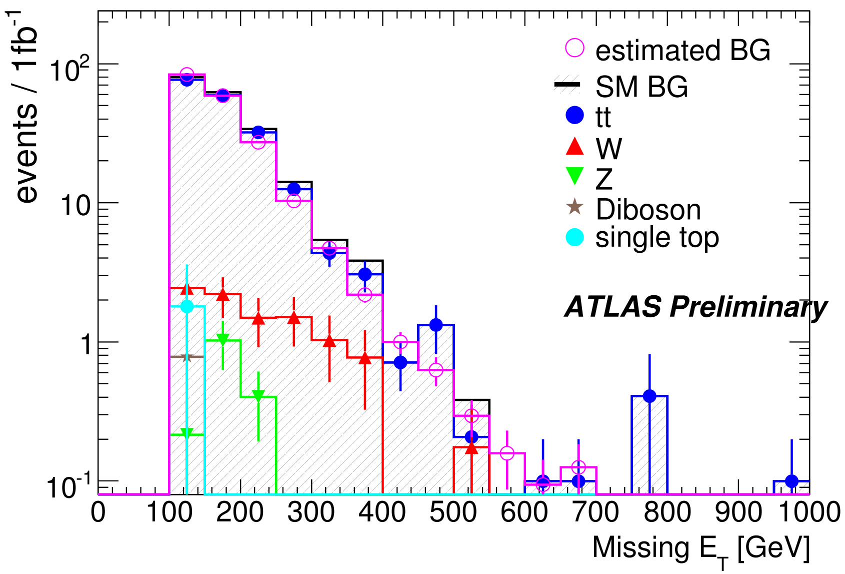
M_T method: results without signal



$\not{E}_T$ distributions in signal and control region approximately consistent

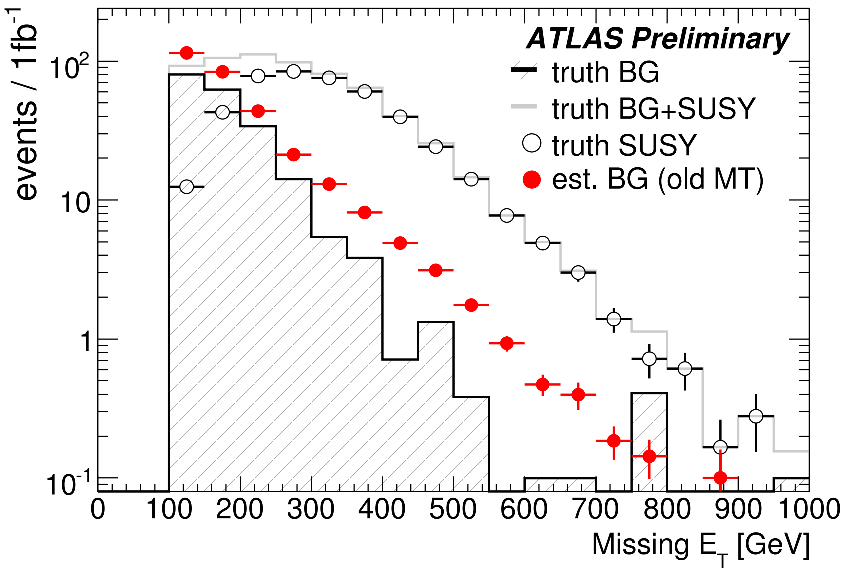
Estimate background in absence of signal:

	$\not{E}_T > 100$ GeV	$\not{E}_T > 300$ GeV
True BG	203 ± 6	12.4 ± 1.6
Estimated BG	190 ± 8	9.4 ± 0.7
Ratio(Est./True)	0.93 ± 0.05	0.76 ± 0.11



Good estimate of background

What if there is signal?



Example: assume SU3 signal.

	$\not{E}_T > 100$ GeV	$\not{E}_T > 300$ GeV
True BG	203 ± 6	12.4 ± 1.6
Estimated BG	296 ± 10	33.3 ± 1.4
True BG+SUSY	653 ± 8	245 ± 4

Clear overestimate of background, dependent on amount of signal

Work in progress to master the issue of signal contamination, two directions of exploration:

- Iteration procedure: if excess observed, use properties of excess to correct for estimate.

  Example in M_T method: assume that all events observed in signal region are from signal, and with some ansatz on signal shape, extrapolate back in control region

- Combined fit determining the composition of control sample allowing for SUSY contribution

Only preliminary work, very active field of investigation

2-leptons + $\not\!\!E_T$ + jets inclusive search

Significantly lower reach than other channels, but also lower backgrounds

Different topologies, corresponding to different SM background sources

- Same-Sign Same-flavour (SSSF)
- Same-sign Opposite-Flavour (SSOF)

Gluino Majorana particle, in gluino decay same probability for positive and negative lepton

Very little SM background, dominated by $\bar{t}t$, very sensitive to lepton isolation

- Opposite-Sign Same-Flavour (OSSF)
- Opposite-Sign Opposite-Flavour (OSOF)

In OS-SF pair two leptons may come from decay of same gaugino $\Rightarrow$

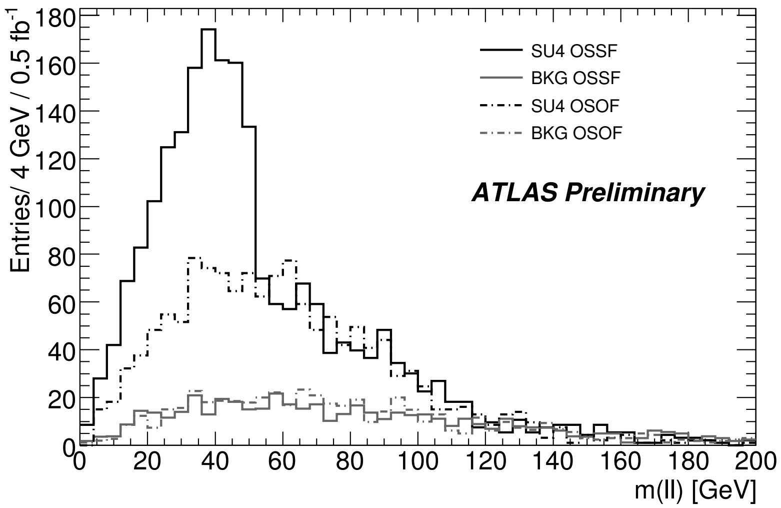
OS-SF invariant mass distribution may exhibit structure, not present in OS-OF pairs

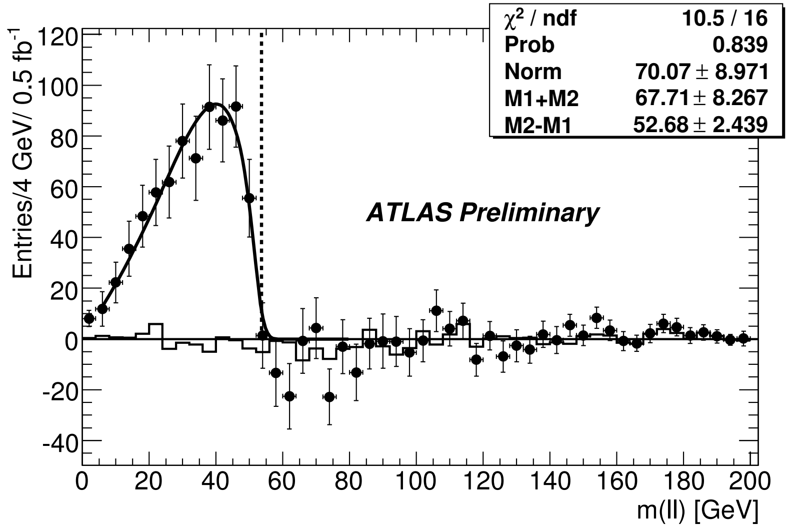
$$\tilde{q}_L \to \tilde{\chi}_2^0 \; q, \quad \tilde{\chi}_2^0 \hookrightarrow \tilde{\ell}^{\pm}_{R(L)} \; \ell^{\mp}, \quad \tilde{\ell}^{\pm}_{R(L)} \hookrightarrow \tilde{\chi}_1^0 \; \ell^{\pm}$$

$$\tilde{q}_L \to \tilde{\chi}_2^0 \; q, \quad \tilde{\chi}_2^0 \hookrightarrow (Z^*) \; \tilde{\chi}_1^0, \quad (Z^*) \hookrightarrow \ell^+ \; \ell^-$$

$$\tilde{q}_L \to \tilde{\chi}_2^+ \; q', \quad \tilde{\chi}_2^+ \hookrightarrow \tilde{\nu}_\ell \; \ell^{\pm}, \quad \tilde{\nu}_\ell \hookrightarrow \tilde{\chi}_1^{\pm} \; \ell^{\mp}$$

Flavour subtraction method





For $\bar{t}t$ and SUSY backgrounds same number of $e^+\mu-$, μ^+e^-, e^+e^-, $\mu^+\mu^-$ pairs

Only $Z/\gamma \to e^+e^-, \mu^+\mu^-$ has same-flavour leptons, strongly reduced by $\not{E}_T$+jets requirement

Fully subtract backgrounds by plotting for each $m(\ell\ell)$ bin: $N(e^+e^-)/\beta + \beta N(\mu^+\mu^-) - N(e^\pm\mu^\mp)$

With $\beta \sim 0.86$ ratio of electron and muon reconstruction efficiencies

Bulk of background uncertainty included in statistical error of subtracted distribution:

$S \equiv (N(OSSF) - N(OSOF))/\sqrt{N(OSSF) - N(OSOF)}$

Main additional systematic comes from uncertainty on β, order 10% with 1 fb^{-1}

For the appropriate parameter values, this might be the fastest discovery channel

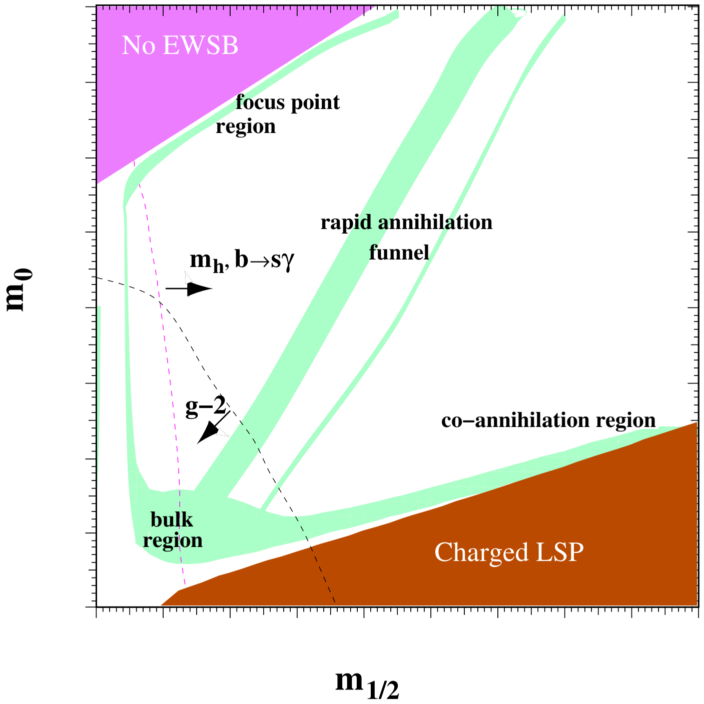
Backup

ATLAS Benchmarks

Large annihilation sross-section required by WMAP data

Boost annihilation via quasi-degeneracy of a sparticle with $\tilde{\chi}_1^0$, or large higgsino content of $\tilde{\chi}_1^0$

Regions in mSUGRA $(m_{1/2}, m_0)$ plane with acceptable $\tilde{\chi}_1^0$ relic density (e.g. Ellis et al.):



- SU3: Bulk region. Annihilation dominated by slepton exchange, easy LHC signatures fom $\tilde{\chi}_2^0 \to \tilde{\ell}\ell$
- SU1: Coannihilation region. Small $m(\tilde{\chi}_1^0) - m(\tilde{\tau})$ (1-10 Gev). Dominant processes $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to \tau\tau$, $\tilde{\chi}_1^0\tilde{\tau} \to \tau\gamma$ Similar to bulk, but softer leptons!
- SU6: Funnel region. $m(\tilde{\chi}_1^0) \simeq m(H/A)/2$ at high $\tan\beta$ Annihilation through resonant heavy Higgs exchange. Heavy higgs at the LHC observable up to ∼800 GeV
- SU2: Focus Point high m_0, large higgsino content, annihilation through coupling to W/Z Sfermions outside LHC reach, study gluino decays.
- SU4: Light point. Not inspired by cosmology. Mass scale ~ 400 GeV, at limit of Tevatron reach

Parameters and cross-sections of benchmark Points

SU1: $m_0 = 70\,\mathrm{GeV}$, $m_{1/2} = 350\,\mathrm{GeV}$, $A_0 = 0$, $\tan\beta = 10$, $\mu > 0$.

SU2: $m_0 = 3550\,\mathrm{GeV}$, $m_{1/2} = 300\,\mathrm{GeV}$, $A_0 = 0$, $\tan\beta = 10$, $\mu > 0$.

SU3: $m_0 = 100\,\mathrm{GeV}$, $m_{1/2} = 300\,\mathrm{GeV}$, $A_0 = -300\,\mathrm{GeV}$, $\tan\beta = 6$, $\mu > 0$.

SU4: $m_0 = 200\,\mathrm{GeV}$, $m_{1/2} = 160\,\mathrm{GeV}$, $A_0 = -400\,\mathrm{GeV}$, $\tan\beta = 10$, $\mu > 0$.

SU6: $m_0 = 320\,\mathrm{GeV}$, $m_{1/2} = 375\,\mathrm{GeV}$, $A_0 = 0$, $\tan\beta = 50$, $\mu > 0$.

Signal	σ^{LO} (pb)	σ^{NLO} (pb)	N
SU1	8.15	10.86	200 K
SU2	5.17	7.18	50 K
SU3	20.85	27.68	500 K
SU4	294.46	402.19	200 K
SU6	4.47	6.07	30 K

Particle	SU1	SU2	SU3	SU4	SU6
$\tilde{u}_L$	760.42	3563.24	631.51	412.25	866.84
$\tilde{b}_1$	697.90	2924.80	575.23	358.49	716.83
$\tilde{t}_1$	572.96	2131.11	424.12	206.04	641.61
$\tilde{u}_R$	735.41	3574.18	611.81	404.92	842.16
$\tilde{b}_2$	722.87	3500.55	610.73	399.18	779.42
$\tilde{t}_2$	749.46	2935.36	650.50	445.00	797.99
$\tilde{e}_L$	255.13	3547.50	230.45	231.94	411.89
$\tilde{\nu}_e$	238.31	3546.32	216.96	217.92	401.89
$\tilde{\tau}_1$	146.50	3519.62	149.99	200.50	181.31
$\tilde{\nu}_\tau$	237.56	3532.27	216.29	215.53	358.26
$\tilde{e}_R$	154.06	3547.46	155.45	212.88	351.10
$\tilde{\tau}_2$	256.98	3533.69	232.17	236.04	392.58
$\tilde{g}$	832.33	856.59	717.46	413.37	894.70
$\tilde{\chi}_1^0$	136.98	103.35	117.91	59.84	149.57
$\tilde{\chi}_2^0$	263.64	160.37	218.60	113.48	287.97
$\tilde{\chi}_3^0$	466.44	179.76	463.99	308.94	477.23
$\tilde{\chi}_4^0$	483.30	294.90	480.59	327.76	492.23
$\tilde{\chi}_1^+$	262.06	149.42	218.33	113.22	288.29
$\tilde{\chi}_2^+$	483.62	286.81	480.16	326.59	492.42