T. Lari (INFN Milano)

Supersymmetry searches with the first ATLAS data

Outline

- ATLAS and LHC our nice toys….
- Supersymmetry events at LHC
  - Signatures and corresponding search strategies
- Detector commissioning
  - What we need to understand **before** we start to look for SUSY
- Measurement of Standard Model backgrounds
- Searches, anticipated discovery potential
- Measurements possible with low luminosity

Following the order in which things will happen…

All plots are PRELIMINARY and will be documented shortly
Recent work focuses on early data. Unless otherwise noted, results I will present are for ECM = 14 TeV and $\int L\,dt = 1\ \mathrm{fb}^{-1}$

LHC

27 km ring (in LEP tunnel)

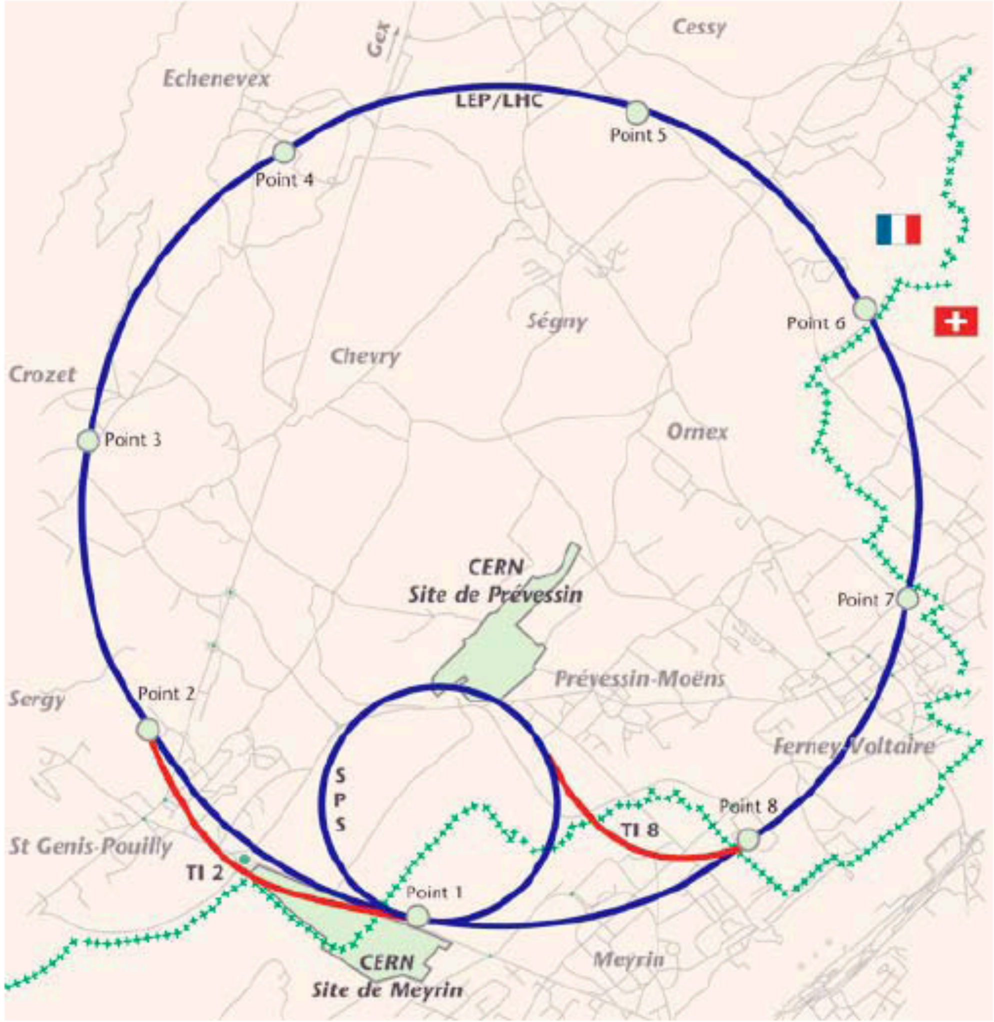
Design performances:

√s = 14 TeV

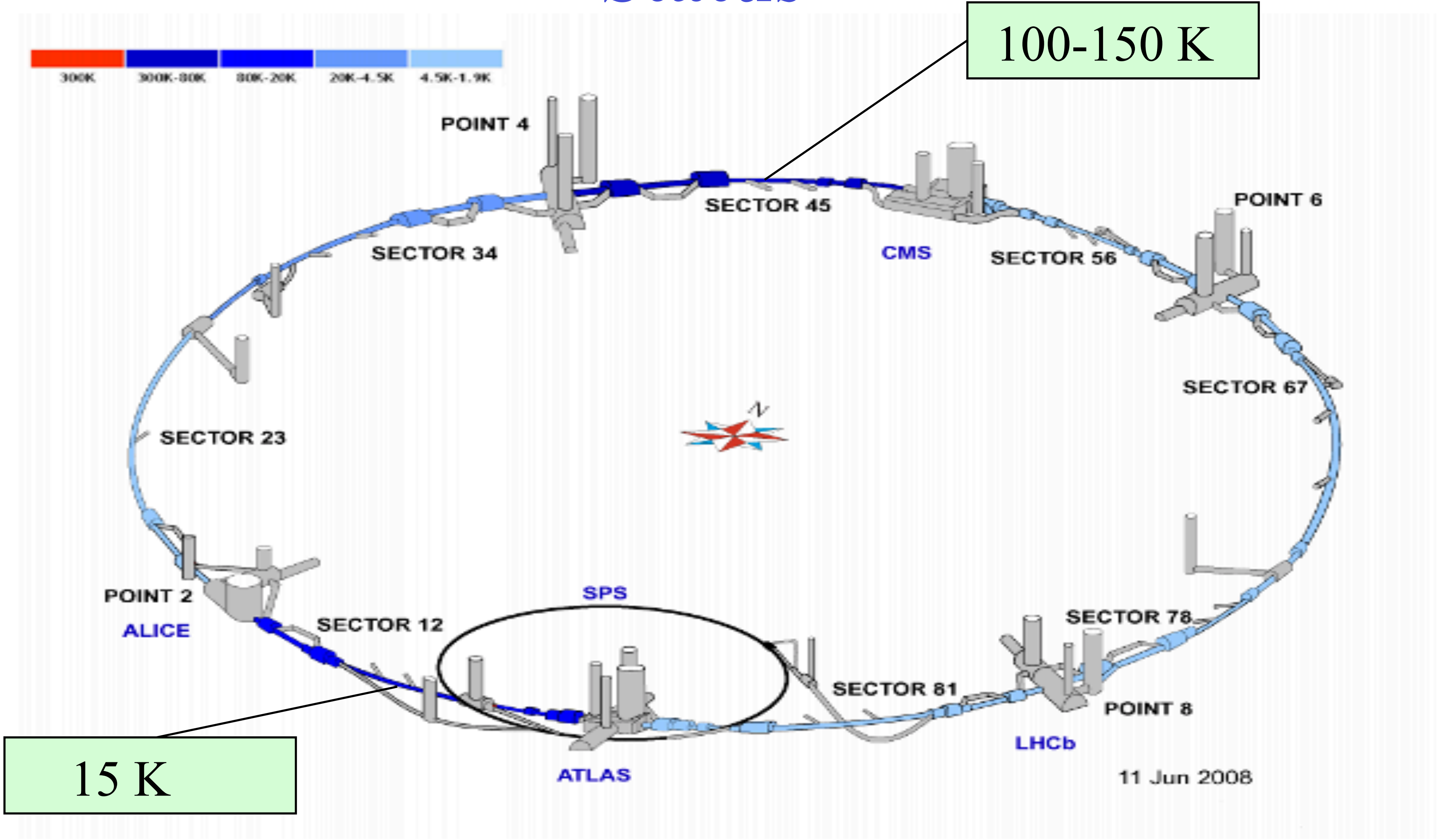
L = 10^{34} cm^2 s^{-1}

Currently in the final stages of cooldown. First collisions later this year.

But it will take a few years to reach design specifications



Status



11 Jun 2008

100-150 K

15 K

When, how much data ?

- First beam injection expected in one month
- Two months to estabilish collisions at 10 TeV

Training the magnets to full current would take too much time, incompatible with data in 2008

- Few weeks of physics run, with gradually increasing luminosity up to O(10^{32} cm^{-2} s^{-1})

→ If everything goes well, we may get 10 pb^{-1} -100 pb^{-1} of data

- Finish magnet commissioning for 14 TeV operation during winter shutdown

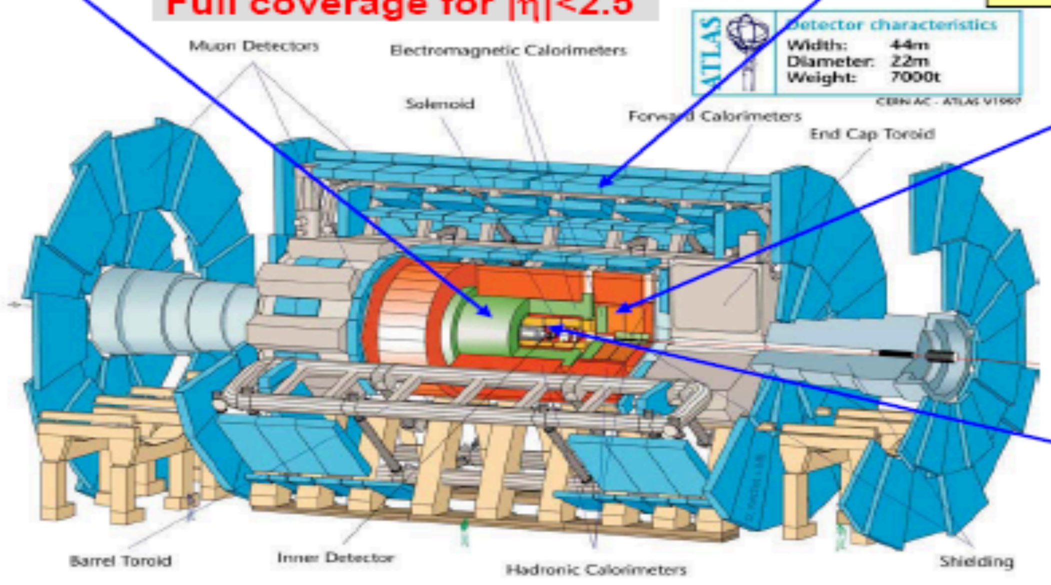
→We can hope a few fb^{-1} of data at full energy next year.

A ToroidaL ApparatuS

EM Calorimeters, $\sigma/E \approx 10\%/\sqrt{E(\mathrm{GeV})} \oplus 0.7\%$
excellent electron/photon identification
Good *E* resolution (e.g., $H \to \gamma\gamma$)

Precision Muon Spectrometer,
$\sigma/p_T \approx 10\%$ at 1 TeV/c
Fast response for trigger
Good *p* resolution
(e.g., $A/Z' \to \mu\mu$, $H \to 4\mu$)

Full coverage for $|\eta|<2.5$



Hadron Calorimeters,
$\sigma/E \approx 50\% / \sqrt{E(\mathrm{GeV})} \oplus 3\%$
Good jet and E_T miss performance
(e.g., $H \to \tau\tau$)

Inner Detector:
Si Pixel and strips (SCT) &
Transition radiation tracker (TRT)
$\sigma/p_T \approx 5 \times 10^{-4}\, p_T \oplus 0.001$
Good impact parameter res.
$\sigma(d_0)=15\mu m@20GeV$ (e.g. $H \to bb$)

Magnets: solenoid (Inner Detector) 2T, air-core toroids (Muon Spectrometer) ~0.5T

Currently in the final stages of installation and commissioning. Struggling to have everything ready by end-July (beam pipe closing, end of access to cavern)

Some comments on first data

- The potential for discoveries will be there pretty soon.
  - If coloured particles with mass < 1 TeV, huge cross sections at LHC. Statistical significance may be very good already with << 1 fb^{-1}
- But we need to understand detector and Standard Model first
  - Simulations unvalidated, MC for SM physics at 10 TeV have large uncertainties
  - We need to check all system work as they are supposed to do!
- This will require both integrated luminosity AND time
  - Fix instrumental problems
  - Re-discover SM (W, Z, top as calibration samples), tune MC and simulation
  - Only once SM understood, we can go for discoveries
- Exspecially important for SUSY!
  - Signature is "excess of events in tail of EtMiss" not a nice peak in invariant mass

Supersimmetry

Things you probably know better than me….

R=+1 *Standard particles*	R=-1 *Superpartners*
Quarks, leptons, neutrinos (spin 1/2)	Squarks, sleptons, sneutrinos (spin-0)
W, Z, gluino (spin-1)	Wino, zino, gluino (spin 1/2)
Higgs (spin-0)	Higgsino (spin ½)

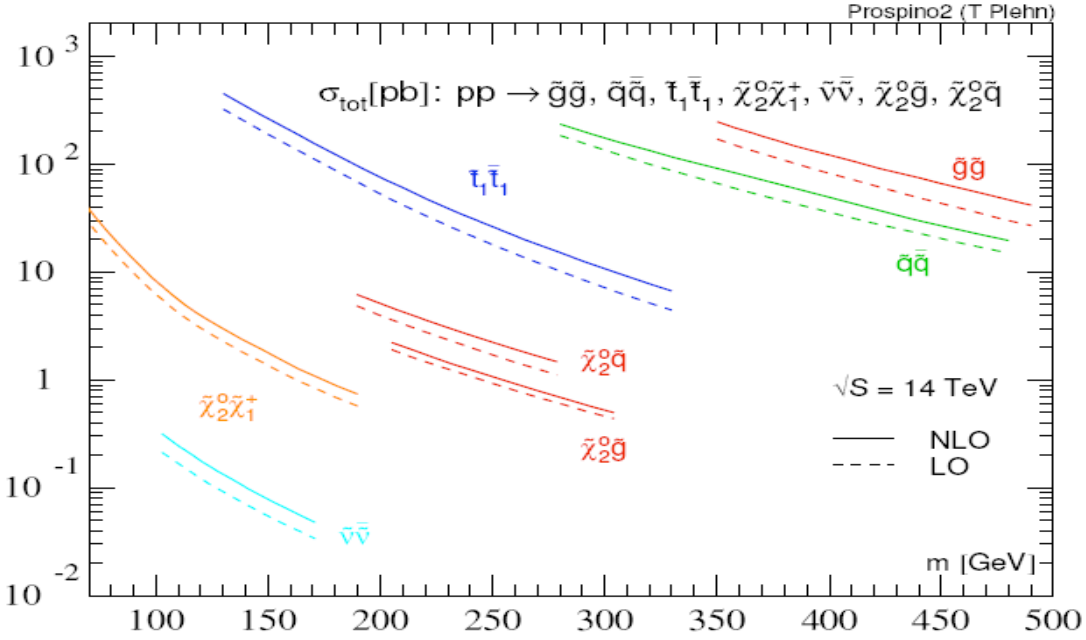
At least two Higgs doublets are needed → **five Higgs bosons**
Wino, Zino, Higgsino mix → 4 charged (chargino) and 4 neutral (neutralino) states

SUSY particles not observed yet → must be heavy → **simmetry is broken**

It is possible to put directly SUSY mass terms in the lagrangian. This gives about **100 free parameters** with the minimal field content above (MSSM model)

Constrained models (with assumptions on the structure of SUSY breaking) have only a few parameters – but assumptions may be wrong.

Signatures at LHC ?



If R-parity conserved, SUSY particles are pair-produced and the lightest (LSP) is stable.

Most likely if SUSY exist, production cross section at LHC will dominated by gluino or squark pairs (unless very heavy, not favoured by naturalness)

Assuming stable, weakly interacting LSP (for Dark Matter) the decay of squark and gluinos into LSP produces **energetic jets** (unless degenerate spectrum) , **missing energy**, possibly other stuff from decay chains (tau, photons, electrons, muons, …)

Supersimmetry: experimental point of view

- For discovery, the important thing is to have searches which are sensible to all the signatures (do not miss it!)
- Inclusive, topology-dependent search channels
- Jets + missing energy + N leptons covers all mSUGRA, but also any model with stable LSP, gluinos and squark not degenerate in mass with LSP and not beyond LHC reach
  - mSUGRA is used as template for this kind of searches
- Other possibilities actually easier
  - Metastable charged particles (examples: LSP with small RPV, NLSP decaying to gravitino)
  - Photons from neutralino to gravitino photon prompt decay
- And some harder
  - Degenerate mass spectrum
  - Colored states heavy, only neutralino and chargino production

Search channels

The search channels are defined according to the topology of final sate.
Inclusive signatures, sensitive to a wide range of models

EtMiss +(2-4)jets + no lepton
EtMiss +(2-4)jets + 1 lepton
EtMiss +(2-4)jets + 2 leptons
EtMiss +(2-4)jets + 3 leptons
} For gluino and squark decay to stable LSP

EtMiss +(2-4)(b-)jets
EtMiss +(2-4) jets + τ
} For regions of parameter space with lots of *b* and τ in SUSY decays

EtMiss +(2-4) jets + 2γ — For models with $\chi^0{}_1 \rightarrow G\,\gamma$

Metastable charged particles
Metastable coloured particles
} For models (SUSY and non-SUSY) with such things

3-leptons — Chargino and neutralino direct production

I will speak of the first four channels, as I know them better

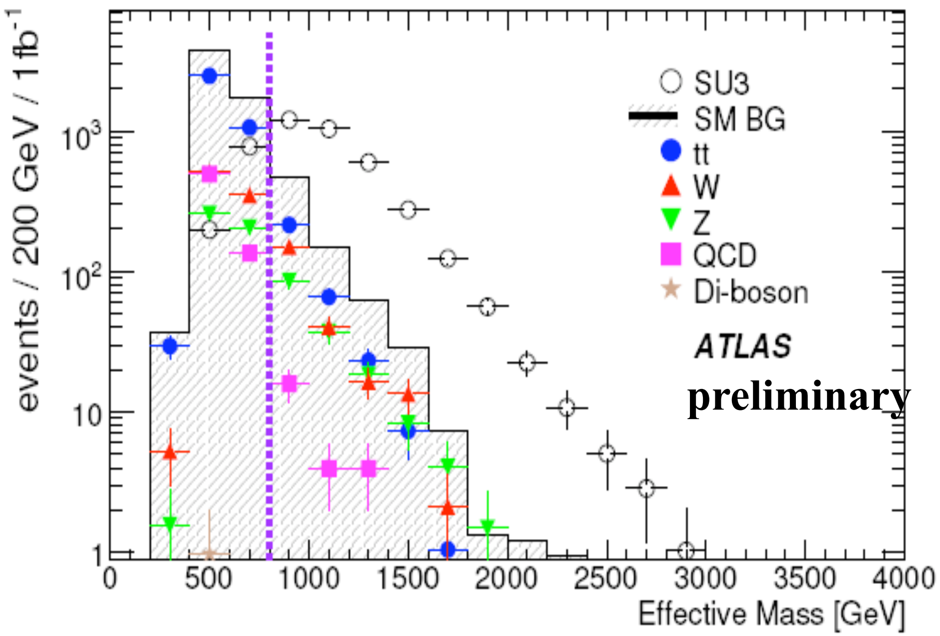
Discovery plot

Typical discovery plot of

jet+E_T^{Miss}+X searches

SM backgrounds are events with energetic neutrinos (tt, W+jets, Z+jets, bb, cc) or fake E_T^{Miss} from detector

If the data were the points and the dashed histogram the MC prediction, would you believe in discovery?



$$M_{eff} = \sum_{i=1}^{N} p_T^{jet,i} + \sum_{i=1}^{N} p_T^{lep,i} + + \not{E}_T$$

<u>Need to understand the detector and Standard Model backgrounds first</u>

Detector commissioning

- This talk is not about the commissioning of the detector (but peraphs it should have been)
- But let me give you an taste of it, for E_T^{miss} measurement
- Of course not the only thing that need to be understood for SUSY
  - Jets, leptons, … : will use Standard Model benchmark process to check them with data
  - Also tune MC on data, measure PDFs, …

Measuring E_T^{MISS}

Missing Transverse Energy = $\sqrt{(-\Sigma Ex)^2 + (-\Sigma Ey)^2}$

ΣEx and ΣEy are computing summing

- Transverse energy of calorimetric cells
  - filtered with a noise-supressing algorithm, and calibrated according to the object they belong to (electrons, photons, tau, jets, isolated clusters)
- An estimate of the energy deposited in the non-sensitive cryostat between EM and hadronic calorimeters
- p_T of reconstructed muons

E_T^{MISS} is due to

Weakly interacting particles (neutrinos, LSP) → **True E_T^{MISS}**

Out-of acceptance particles (calorimeter coverage: $|\eta|<5$)
Non-collision particles (cosmics, beam halo)
Energy lost in non-sensitive material (cables, criostats, …)
Detector problems (dead or noisy cells)
Electronic noise, collision pileup
e/h Calorimeter non-compensation

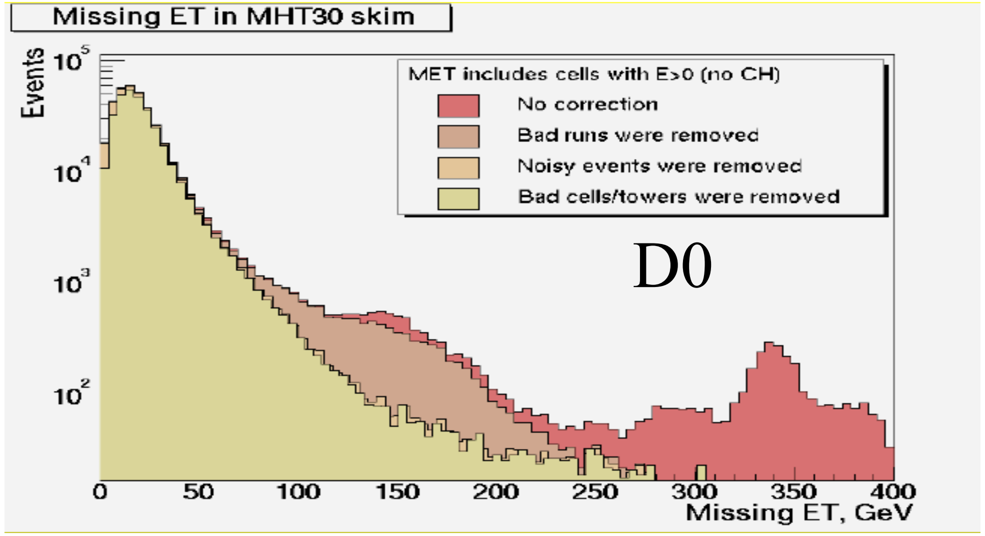
→ **Fake E_T^{MISS}**

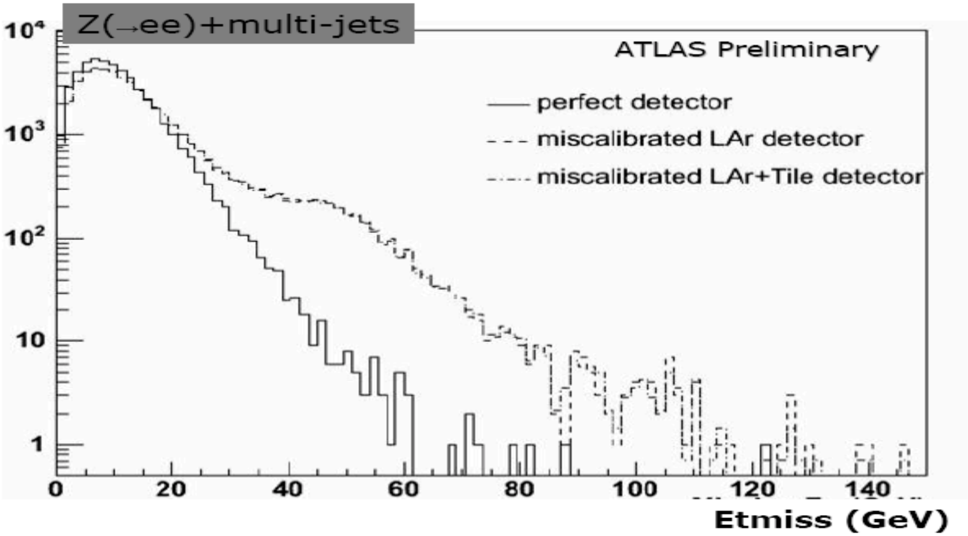
Cleaning of E_T^{MISS} sample

Need to remove all garbage first

- Bad runs and events (malfunctioning detector)
- Events with noisy calorimetry cells
- Events from beam halo, beam gas interactions, cosmics

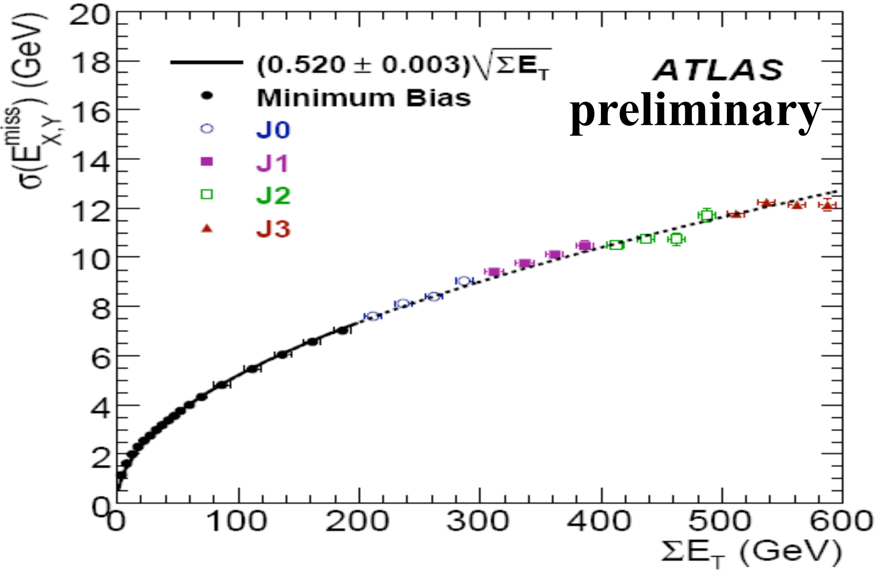
Tools being prepared to monitor and correct event-by-event



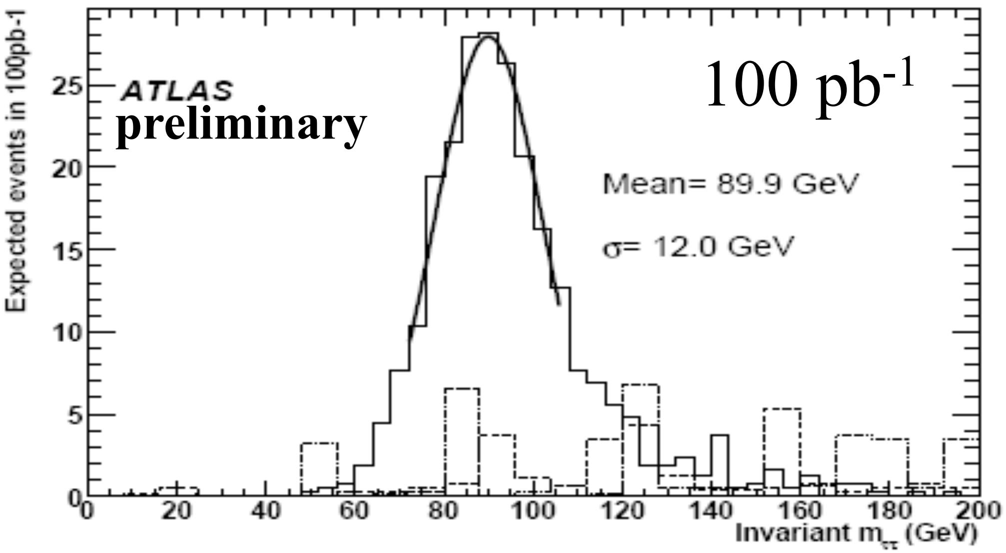


Measuring E_T^{MISS} scale and resolution

Data with zero or known missing energy can be used to check the expected EtMiss performance: generic (prescaled trigger) minimum bias and jet events, Z(ll)+jets, W(l ν)+jets, Z(ττ)+jets, tt



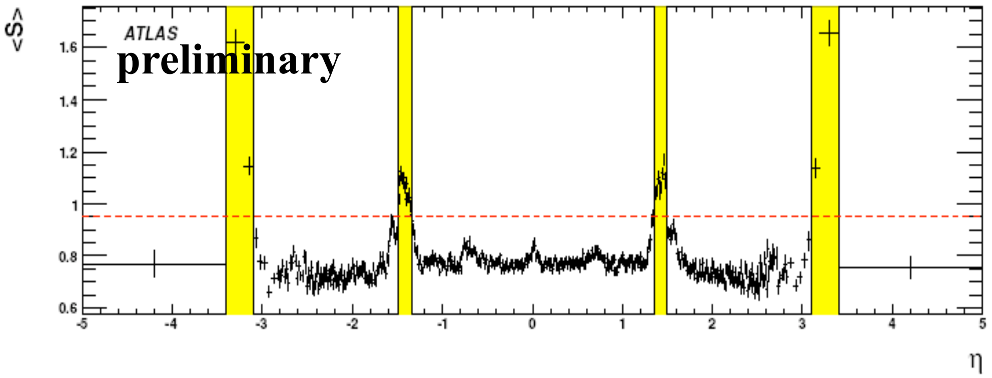
E_T^{MISS} resolution in minimum bias and jet events

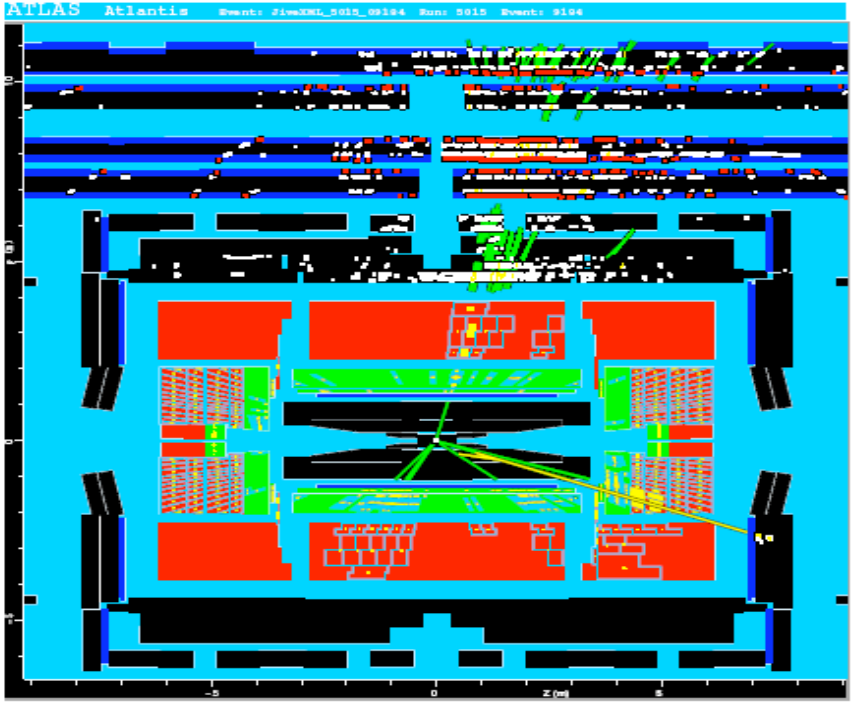


Z invariant mass in Z(ττ).
Reconstructed with collinear approximation
(ν collinear with visible decay of boosted τ)
Calibration of E_T^{miss} scale

Fiducial cuts for E_T^{MISS} based analysis

- Remove events with E_T^{MISS} vector pointing along a jet or muon
- Remove events with jet pointing to regions with poor calorimeter performance
- Detect (rare) leakeage of hadronic showers in muon system





Standard Model backgrounds

Assume commissioning of detector and data reconstruction software done, systematics from detector effect under control.

Assume basic SM distributions understood

Next step is evaluation of the SM background for SUSY searches

For each channel, choose control region C, signal region S, and a mehod to predict background rates in S from measured rate in C

Systematics associated to these methods have been studied with MC data, mostly for 1 fb^{-1} of 14 TeV data.

For many channels two or more independent techniques to predict background rates exist – comparing the results will give confidence in the solidity of the estimate

ATLAS benchmark points: mSUGRA

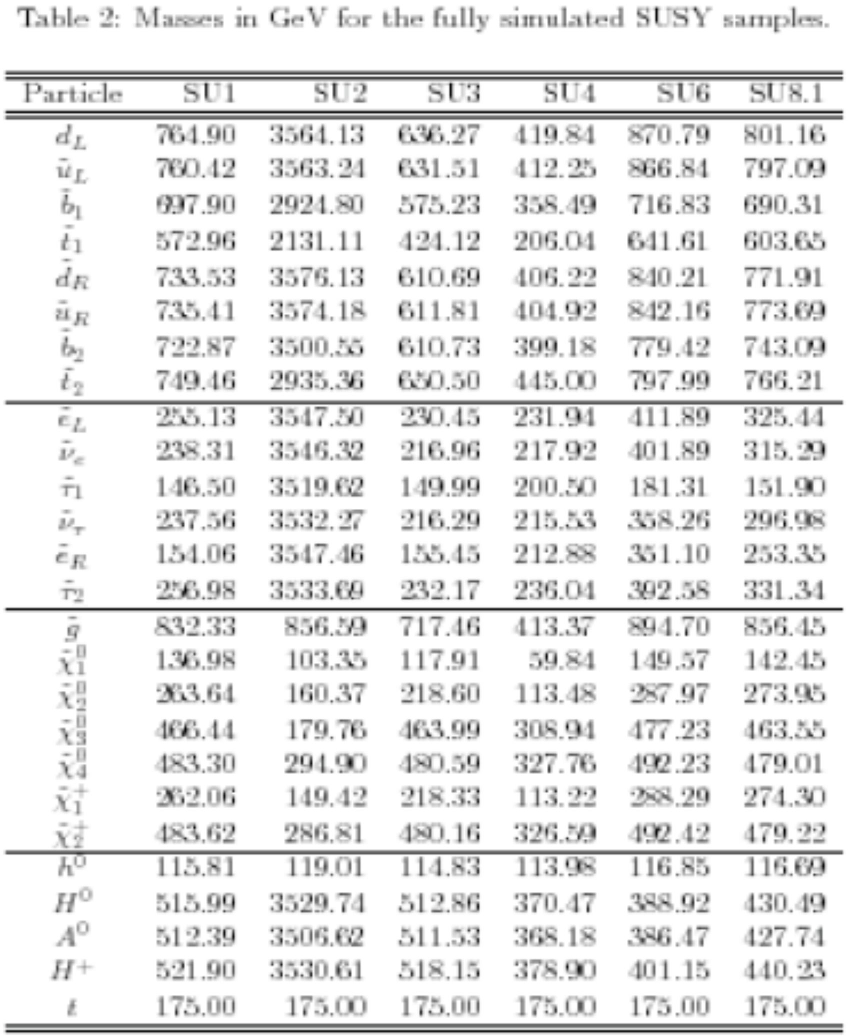


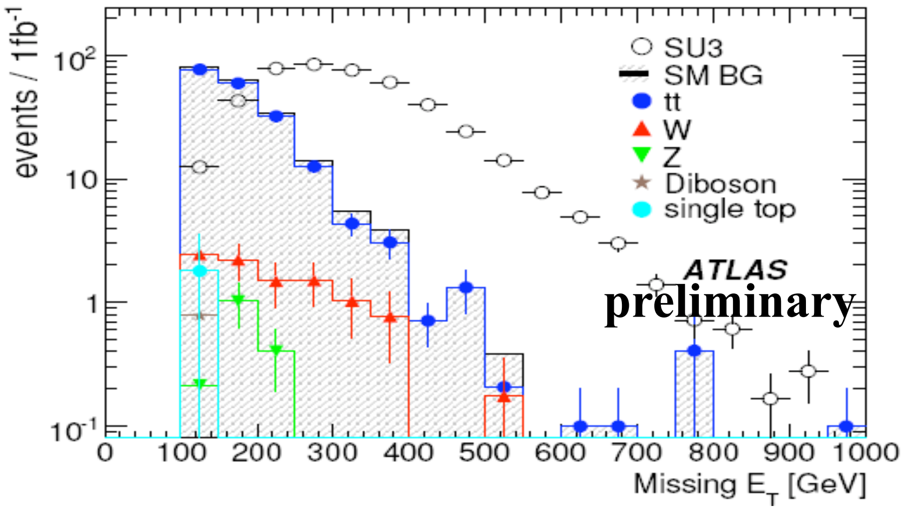
Table 2: Masses in GeV for the fully simulated SUSY samples.

Particle	SU1	SU2	SU3	SU4	SU6	SU8.1
$\tilde{d}_L$	764.90	3564.13	636.27	419.84	870.79	801.16
$\tilde{u}_L$	760.42	3563.24	631.51	412.25	866.84	797.09
$\tilde{b}_1$	697.90	2924.80	575.23	358.49	716.83	690.31
$\tilde{t}_1$	572.96	2131.11	424.12	206.04	641.61	603.65
$\tilde{d}_R$	733.53	3576.13	610.69	406.22	840.21	771.91
$\tilde{u}_R$	735.41	3574.18	611.81	404.92	842.16	773.69
$\tilde{b}_2$	722.87	3500.55	610.73	399.18	779.42	743.09
$\tilde{t}_2$	749.46	2935.36	650.50	445.00	797.99	766.21
$\tilde{e}_L$	255.13	3547.50	230.45	231.94	411.89	325.44
$\tilde{\nu}_e$	238.31	3546.32	216.96	217.92	401.89	315.29
$\tilde{\tau}_1$	146.50	3519.62	149.99	200.50	181.31	151.90
$\tilde{\nu}_\tau$	237.56	3532.27	216.29	215.53	358.26	296.98
$\tilde{e}_R$	154.06	3547.46	155.45	212.88	351.10	253.35
$\tilde{\tau}_2$	256.98	3533.69	232.17	236.04	392.58	331.34
$\tilde{g}$	832.33	856.59	717.46	413.37	894.70	856.45
$\tilde{\chi}_1^0$	136.98	103.35	117.91	59.84	149.57	142.45
$\tilde{\chi}_2^0$	263.64	160.37	218.60	113.48	287.97	273.95
$\tilde{\chi}_3^0$	466.44	179.76	463.99	308.94	477.23	463.55
$\tilde{\chi}_4^0$	483.30	294.90	480.59	327.76	492.23	479.01
$\tilde{\chi}_1^+$	262.06	149.42	218.33	113.22	288.29	274.30
$\tilde{\chi}_2^+$	483.62	286.81	480.16	326.59	492.42	479.22
h^0	115.81	119.01	114.83	113.98	116.85	116.69
H^0	515.99	3529.74	512.86	370.47	388.92	430.49
A^0	512.39	3506.62	511.53	368.18	386.47	427.74
H^+	521.90	3530.61	518.15	378.90	401.15	440.23
t	175.00	175.00	175.00	175.00	175.00	175.00

mSUGRA benchmarks used in the presentation:

- “SU1” (mass scale M ~ 750 GeV)
- “SU3” (mass scale M ~ 620 GeV)
- “SU4” (mass scale M ~400 GeV)

Example: 1-lepton mode



Signal region:

1 isolated elettron or muon with p_T>20GeV

E_T^{Miss} > max(100 GeV, 0.2M_{eff})

1 jet with p_T > 100 GeV

4 jets with p_T > 50 GeV

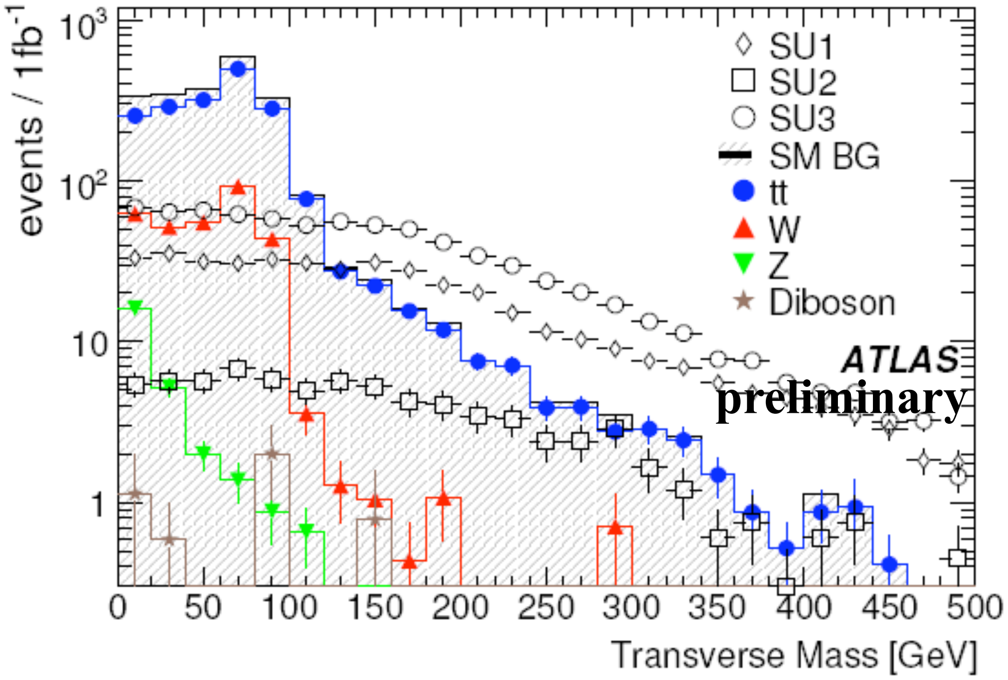
$M_T(l,E_T^{miss})$ > 100 GeV

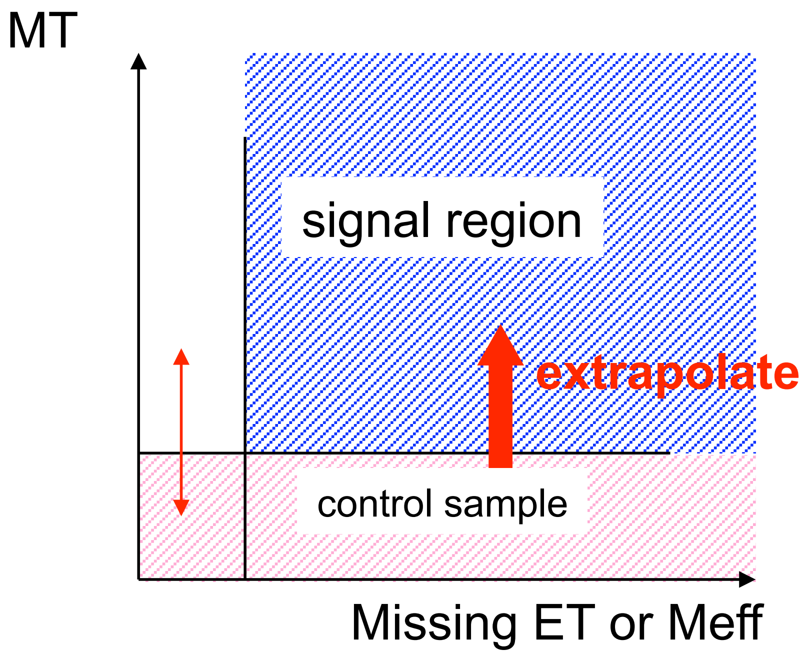
Main background tt. W+jets also important

Techniques studied for the background estimation in 1 lepton mode:

- **Estimate W,tt reversing the cut on M_T** **I will describe this one**
- Estimate tt semileptonic trough top mass reconstruction
- Estimate tt dileptonic (with one missing lepton) using a 2-lepton sample
- Estimate tt dileptonic using HT2 = $p_T^{2nd\ jet} + p_T^{3rd\ jet} + p_T^{4th\ jet} + p_T^{lepton}$
- Estimate tt replacing a sample of reconstructed top with MC decays.
- Estimate W and tt with a combined fit of control samples

Signal and control region

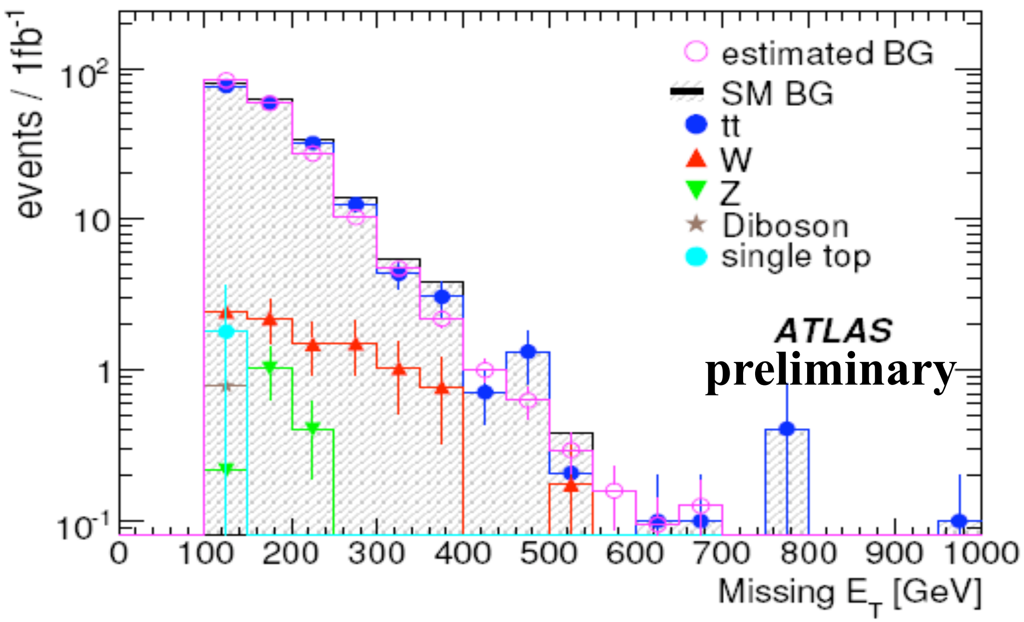


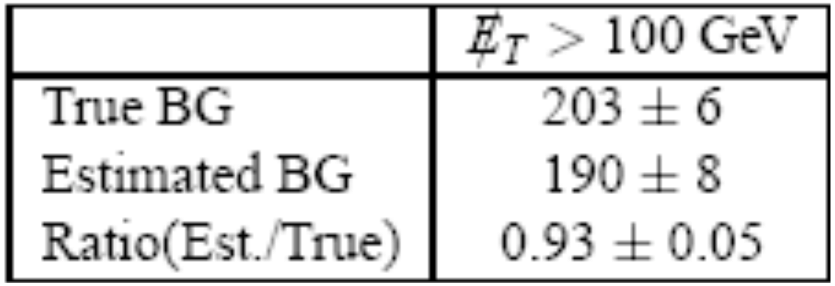


The shape of E_T^{Miss} distribution is the same (for backgr.) in control region (M_T<100 GeV) and signal region (M_T > 100 GeV)

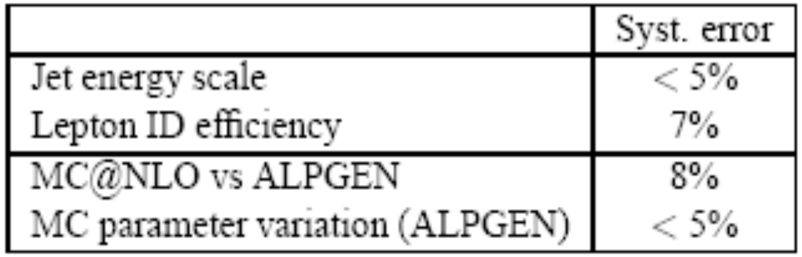
- The shape of background E_T^{Miss} distribution can be measured control sample
- Normalized to signal sample selection in the interval 100 GeV < E_T^{Miss} < 200 GeV

Background estimate





	$\not{E}_T > 100$ GeV
True BG	203 ± 6
Estimated BG	190 ± 8
Ratio(Est./True)	0.93 ± 0.05

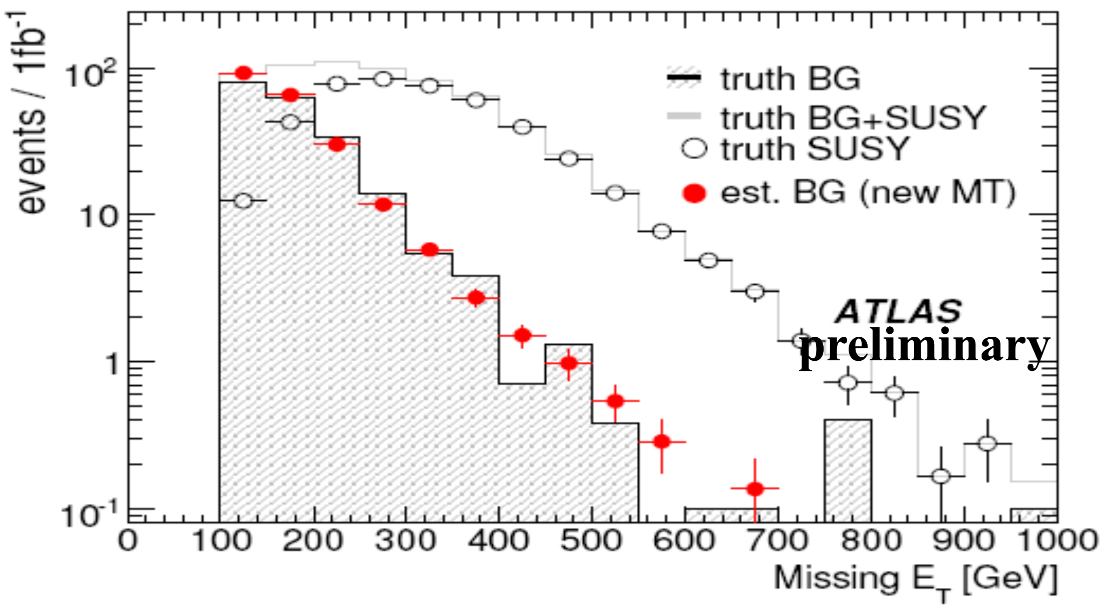


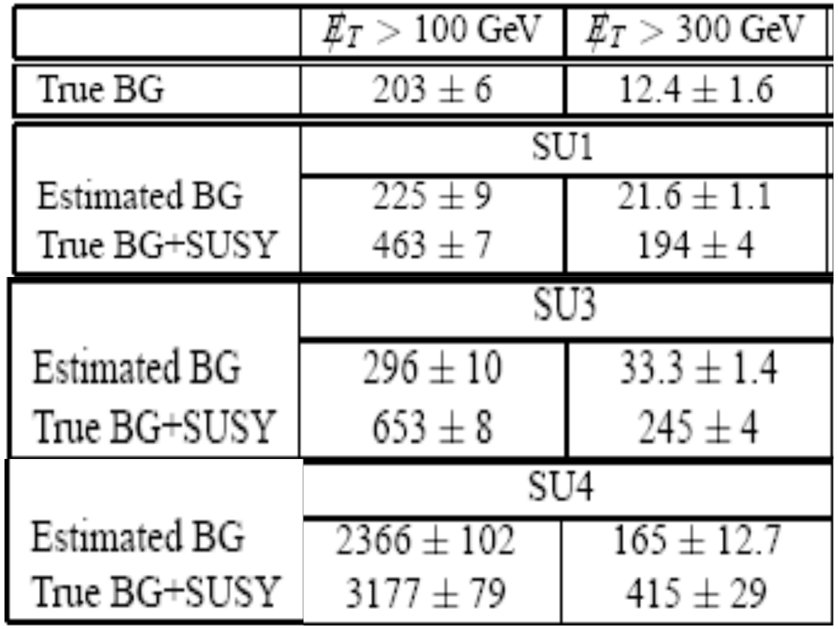
	Syst. error
Jet energy scale	$< 5\%$
Lepton ID efficiency	7%
MC@NLO vs ALPGEN	8%
MC parameter variation (ALPGEN)	$< 5\%$

The background is estimated to better than 20% precision, including the expected systematics on detector response and on W,Z, top production.

The other techniques to estimate backgrounds provide a similar precision

If signal is there…





	$\not{E}_T > 100$ GeV	$\not{E}_T > 300$ GeV
True BG	203 ± 6	12.4 ± 1.6
	SU1	
Estimated BG	225 ± 9	21.6 ± 1.1
True BG+SUSY	463 ± 7	194 ± 4
	SU3	
Estimated BG	296 ± 10	33.3 ± 1.4
True BG+SUSY	653 ± 8	245 ± 4
	SU4	
Estimated BG	2366 ± 102	165 ± 12.7
True BG+SUSY	3177 ± 79	415 ± 29

In presence of signal there is a contamination of control samples and an overestimate of background. The signal is still visible.

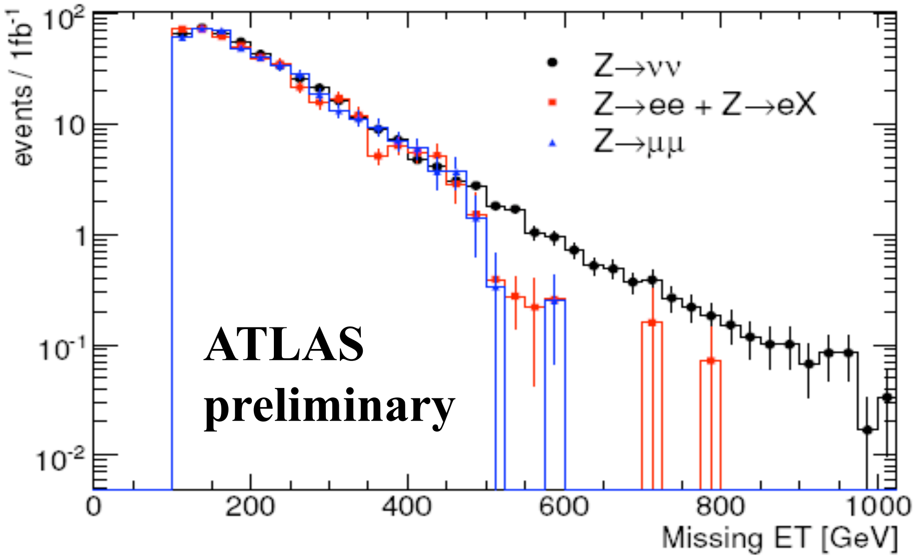
Once discovery is estabilished, it is possible to correct for this effect (to measure cross section) assuming a flat distribution for signal M_T (good aproximation)

Estimate of Z(νν)+jets

Important for the 0 lepton channel.

Two methods:

- Replace the leptons of Z(ll)+jets with EtMiss to predict Z(νν)+jets, with corrections for acceptance, BR, and trigger/selection efficiencies of the two leptons. Main uncertainty is statistics.
- Use MC, but fixing the parameters of MC to reproduce the observed rate of Z(ll)+jets

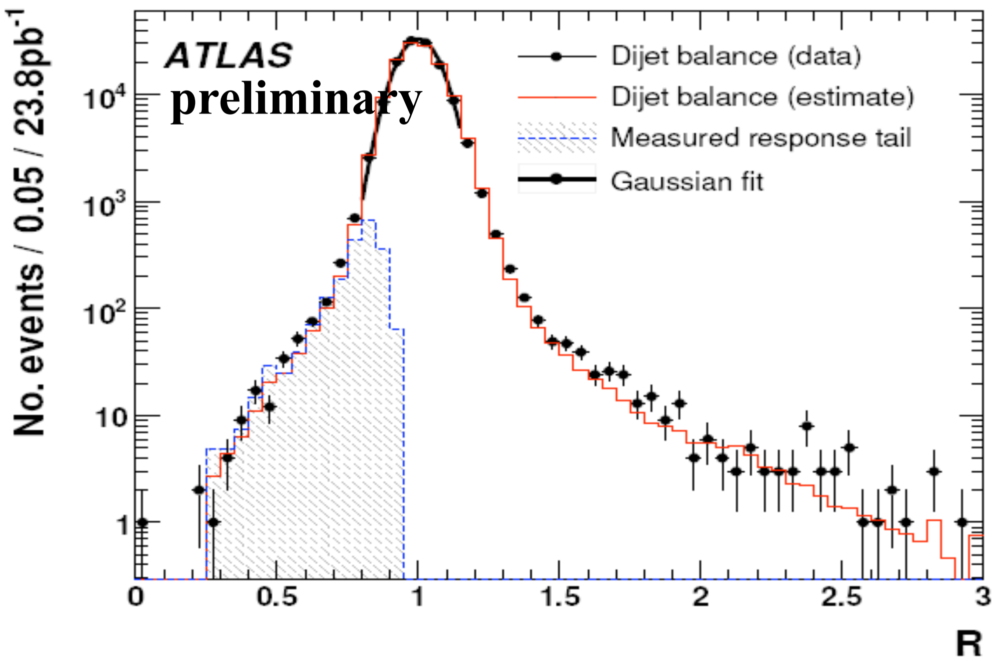


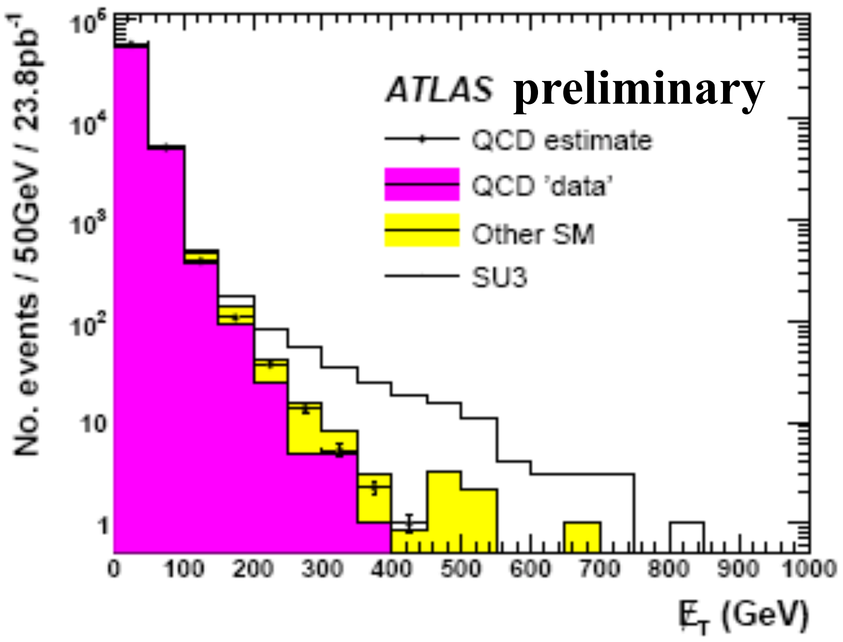
Description	Relative uncertainty $\Delta N/N$ (%)
MC generator systematics	
ALPGEN parameter variation	6.3
Detector systematics	
Electron energy scale	0.05
Electron energy resolution	0.03
Electron id efficiency	0.50
Muon energy scale	0.30
Muon energy resolution	0.39
Muon id efficiency	1.00
$\not{E}_T$ scale (soft part)	4.5
Total systematics (quadratic sum)	~ 8
Total statistics	~ 13
Total uncertainties	~ 15

	$\not{E}_T > 300$ GeV	$M_{\rm eff} > 800$ GeV
jet energy scale	6%	6%
jet energy resolution	1%	1%
$\not{E}_T$ soft component scale	1%	$< 1\%$
lepton energy scale	$< 1\%$	$< 1\%$
lepton id efficiency	2%	2%

QCD background

- The gaussian part of jet resolution measured with γ+jets or Z+jets
- Tail measured asking EtMiss aligned with a jet
- This is sensitive both to mismeasured jets and to neutrinos from B, D decays
- The background is then estimated from a jet sample (w/o E_T^{Miss}) *smeared* according to the measured jet response function



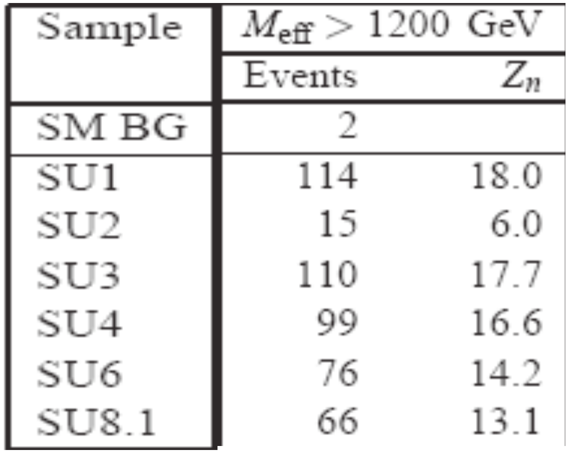


Summary on background estimates

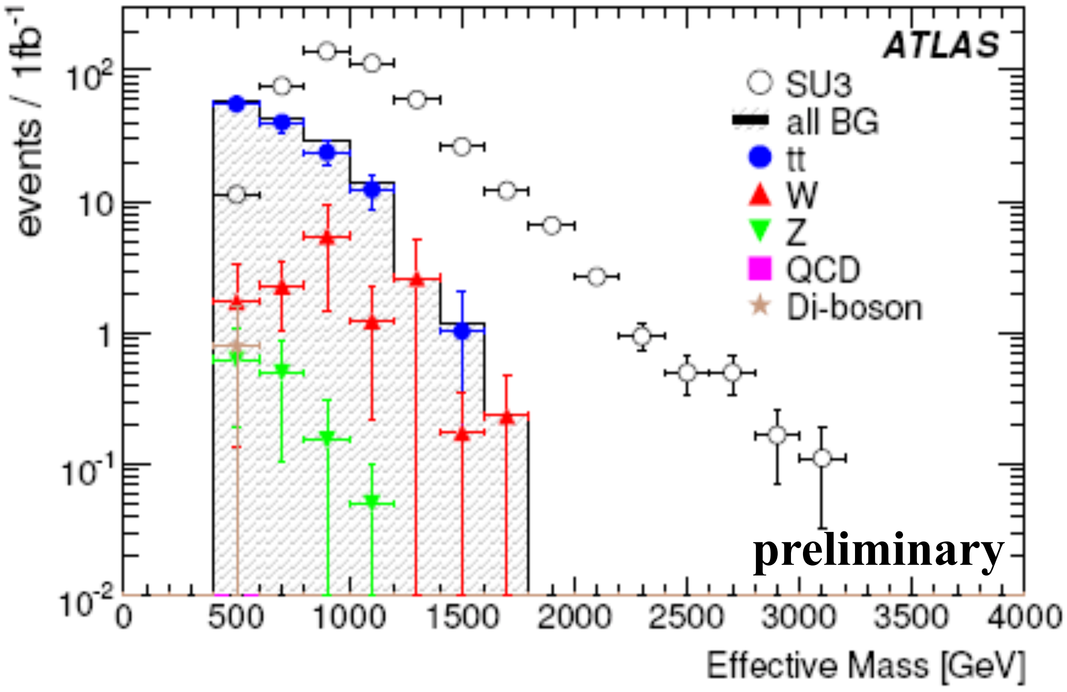
- A big effort has been made in last two years to develop techniques to estimate from data backgrounds to SUSY
- These studies show it should be possible to know the top, W and Z beckgrounds to 20% precision and the QCD background to 50% precision, with 1 fb^{-1} of data.
- These numbers have been used in the optimization of search cuts and in the evaluation of discovery potential (see next slides)

Searches: 1 lepton channel

1. *Lepton Cuts:* One and only one isolated lepton with $p_T > 20$ GeV satisfying the selection criteria described earlier.
2. *Lepton Cuts:* No additional leptons with $p_T > 10$ GeV/c. This ensures no overlap with the 0-lepton, 2-lepton, and 3-lepton analyses.
3. *Jet Cuts*: Four Jets, the hardest with $p_T > 100$ GeV and the fourth with $p_T > 50$ GeV.
4. $\not{E}_T$ *Cuts*: $\not{E}_T > 100$ GeV and $\not{E}_T > 0.2 M_{\mathrm{eff}}$.
5. *TS Cut*: Transverse sphericity $S_T > 0.2$.
6. *MT Cut*: Transverse mass $M_T > 100$ GeV.
7. M_{eff} *cut*: $M_{\mathrm{eff}} > 800$ GeV.

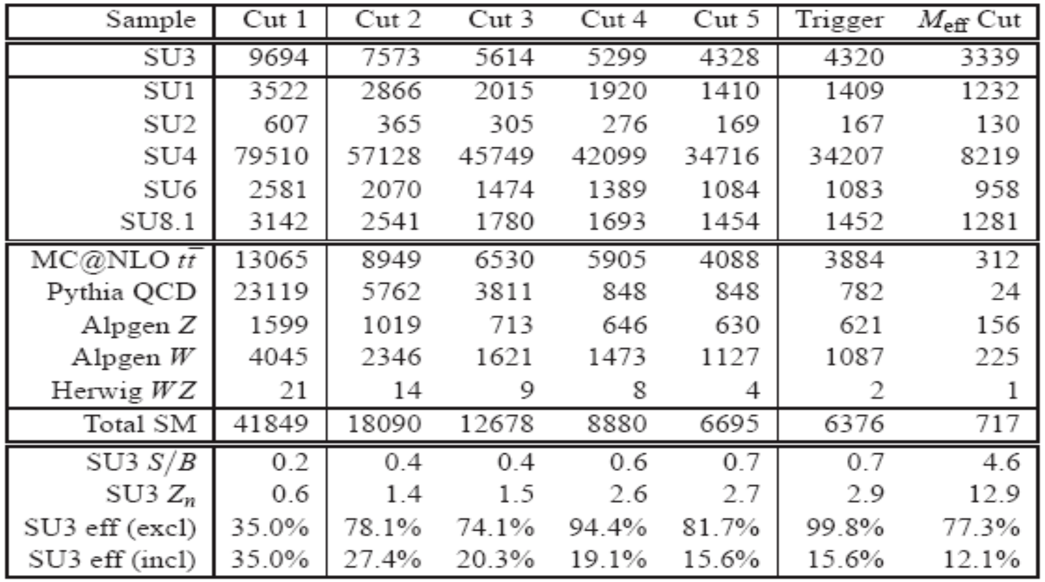


Sample	$M_{\mathrm{eff}} > 1200$ GeV	
	Events	Z_n
SM BG	2	
SU1	114	18.0
SU2	15	6.0
SU3	110	17.7
SU4	99	16.6
SU6	76	14.2
SU8.1	66	13.1

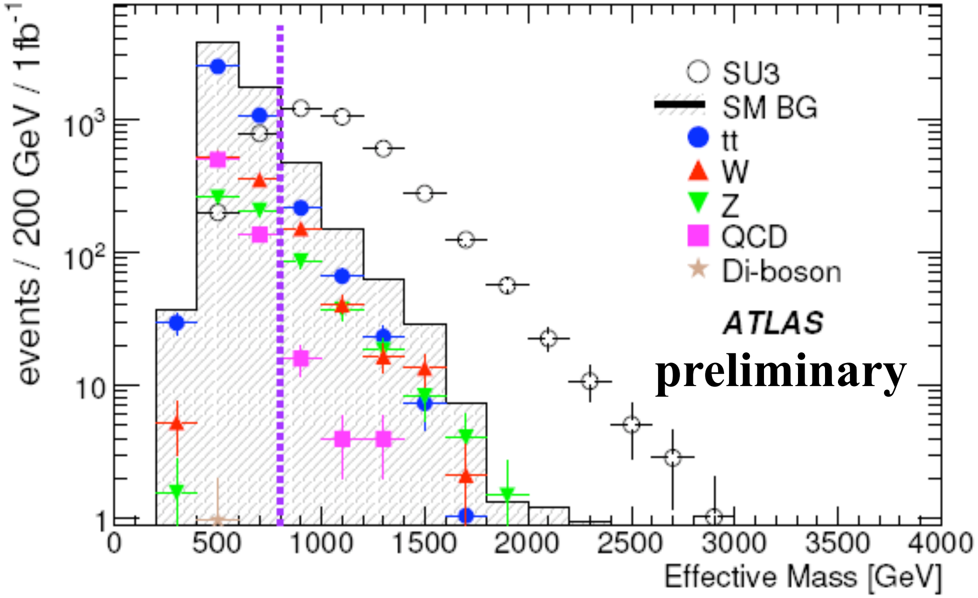


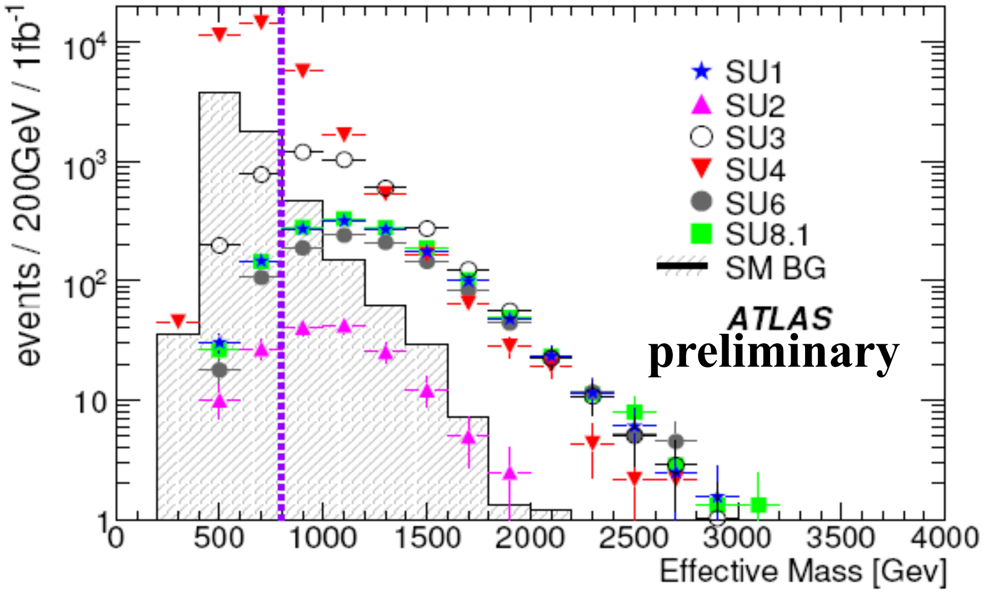
Searches: 0-lepton channel

- At least 1 jet with p_T>100 GeV
- At least 4 jets with p_T>50 GeV
- E_T^{miss} > max(100 GeV,0.2*M_{eff})
- Transverse sphericity > 0.2
- .Δϕ (jet, met) > 0.2 for jets 1,2,3
- Lepton veto (pt>20GeV)



Sample	Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Trigger	M_{eff} Cut
SU3	9694	7573	5614	5299	4328	4320	3339
SU1	3522	2866	2015	1920	1410	1409	1232
SU2	607	365	305	276	169	167	130
SU4	79510	57128	45749	42099	34716	34207	8219
SU6	2581	2070	1474	1389	1084	1083	958
SU8.1	3142	2541	1780	1693	1454	1452	1281
MC@NLO $t\bar{t}$	13065	8949	6530	5905	4088	3884	312
Pythia QCD	23119	5762	3811	848	848	782	24
Alpgen Z	1599	1019	713	646	630	621	156
Alpgen W	4045	2346	1621	1473	1127	1087	225
Herwig WZ	21	14	9	8	4	2	1
Total SM	41849	18090	12678	8880	6695	6376	717
SU3 S/B	0.2	0.4	0.4	0.6	0.7	0.7	4.6
SU3 Z_n	0.6	1.4	1.5	2.6	2.7	2.9	12.9
SU3 eff (excl)	35.0%	78.1%	74.1%	94.4%	81.7%	99.8%	77.3%
SU3 eff (incl)	35.0%	27.4%	20.3%	19.1%	15.6%	15.6%	12.1%



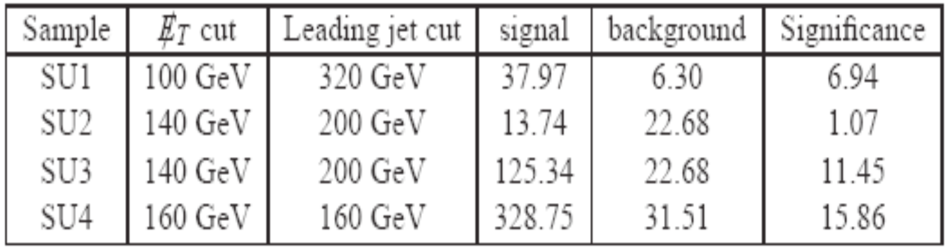


Searches: 2 lepton channels

Opposite sign

Takes advantage of decays like

Two leptons with pT > 10 GeV
1 jet with pT > **x**, 4 jets with pt>50GeV
EtMiss > **x**, EtMiss > 0.2 Meff
Transverse sphericity ST > 0.2

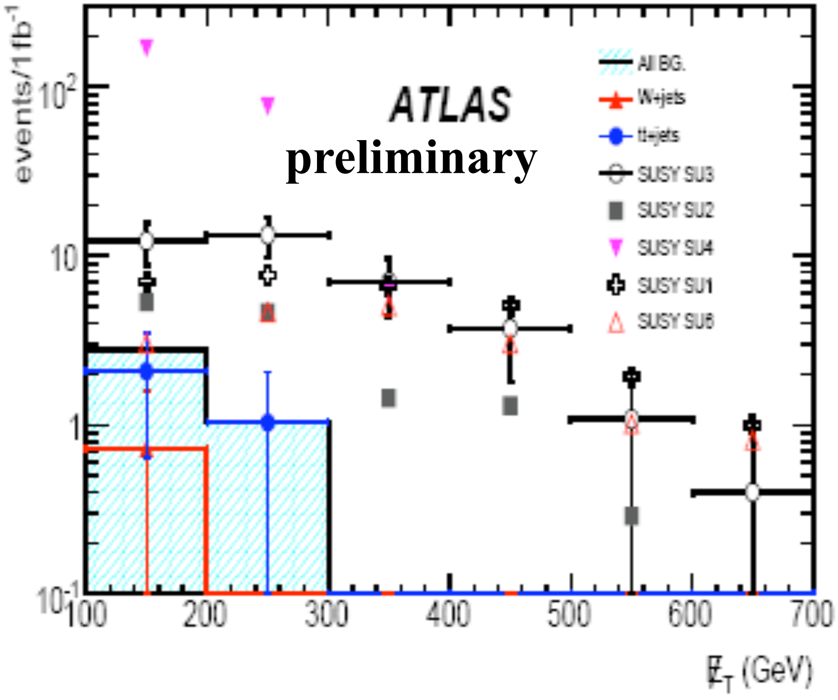


Sample	$\not\!\!E_T$ cut	Leading jet cut	signal	background	Significance
SU1	100 GeV	320 GeV	37.97	6.30	6.94
SU2	140 GeV	200 GeV	13.74	22.68	1.07
SU3	140 GeV	200 GeV	125.34	22.68	11.45
SU4	160 GeV	160 GeV	328.75	31.51	15.86

Main background (> 95 %) is tt

Same sign

Takes advantage of majorana nature
Of gluinos. Very little SM background.



Flavour subtraction

If leptons are from indipendent decay chains

$$N(e^+e^-)+N(\mu^+\mu^-)= N(e+\mu^-)+N(\mu^+e^-)$$

The distributions from $\chi^0 \rightarrow \chi^0$ ll decays can be obtained using

$$\boldsymbol{\beta\, N(e^+e^-) + (1/\beta)\, N(\mu^+\mu^-) - N(e^+\mu^-) - N(e^-\mu^+)}$$

where $\beta = \varepsilon(\mu)/\varepsilon(e)$ [efficiency ratio, can be measured from Z data]

Most of Standard Model background cancels in the subtraction

Except Z(ll)+jets, ZZ, ZW, which contribute far less than tt.

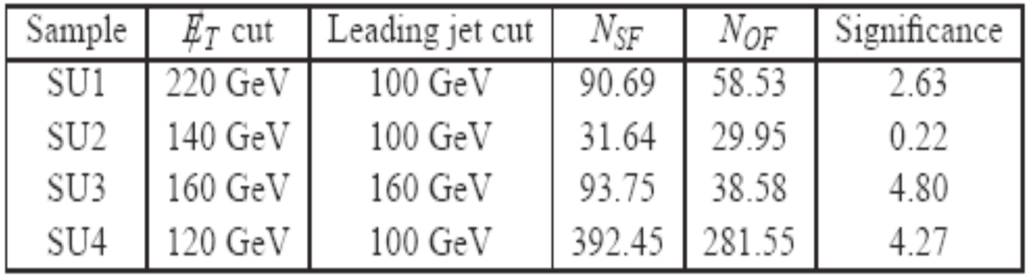
Flavour subtraction can be used in searches.

😕 Not a great idea from the point of view of statistical errors (SUSY substantial em rate subtracted)

🙂 Very clean channel, most of statistical uncertainties cancel in subtraction → may be competitive with early data

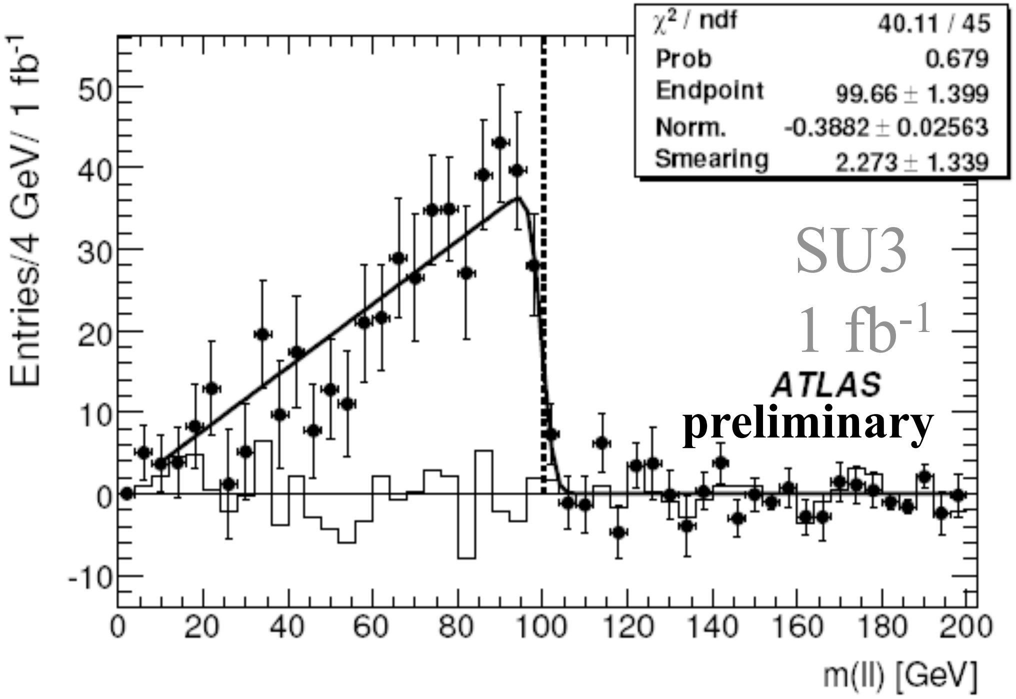
Supersymmetry searches

Inclusive search 4 getti+E_T^{miss}+2l with flavour subtraction



Sample	$\not{E}_T$ cut	Leading jet cut	N_{SF}	N_{OF}	Significance
SU1	220 GeV	100 GeV	90.69	58.53	2.63
SU2	140 GeV	100 GeV	31.64	29.95	0.22
SU3	160 GeV	160 GeV	93.75	38.58	4.80
SU4	120 GeV	100 GeV	392.45	281.55	4.27

After discovery, the maximum of two lepton invariant mass is one of the first measurements we expect to do



Other search channels

- **jets+3leptons**

Does not require EtMiss. Like 2-lepton SS, need to control additional leptons from B decays in tt events.

- **Jets+EtMiss+taus**

Competitive at high tanβ, but requires understanding of taus

- **Jets+EtMiss+b-jets**

Can also be competitive, but requires good understanding of b-tagging

- **Jets+EtMiss+photons**

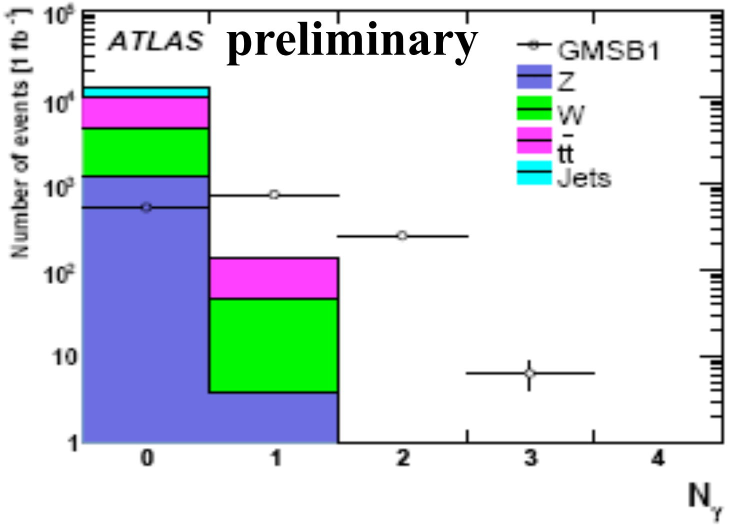
Does very well for GMSB (c Gg)

- **Metastable charged particles**

Requires dedicated trigger and reconstruction for efficient detection. Background surviving all cuts very small, discovery limited by signal rate.

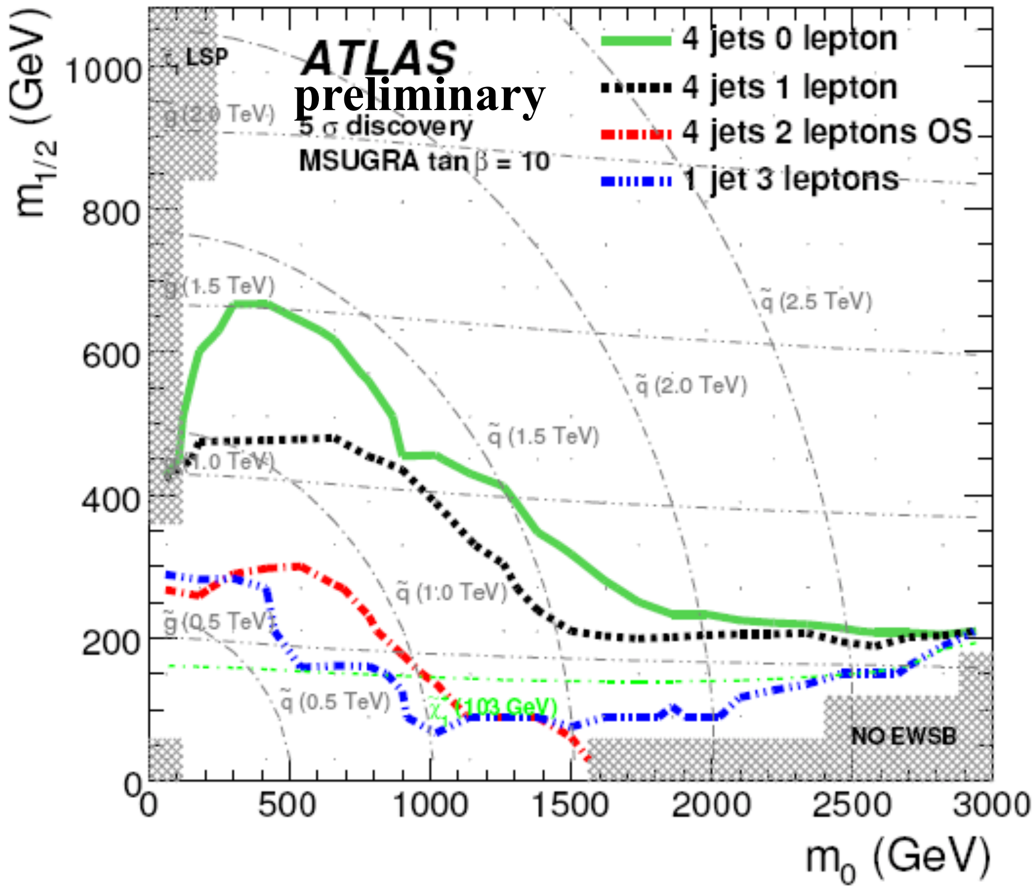
Sample	Cut 1	Cut 2	S/B	$S/\sqrt{B}$	Z_n
SU2	35	13	1.1	3.7	2.7
SU3	139	94	7.8	27.1	11.5
SU4	1284	312	26.0	90.0	24.4

Results from the 3leptons (cut1) and jets (cut2) search



Number of photons (pt>20GeV) after cuts on jets and missing energy

Discovery potential

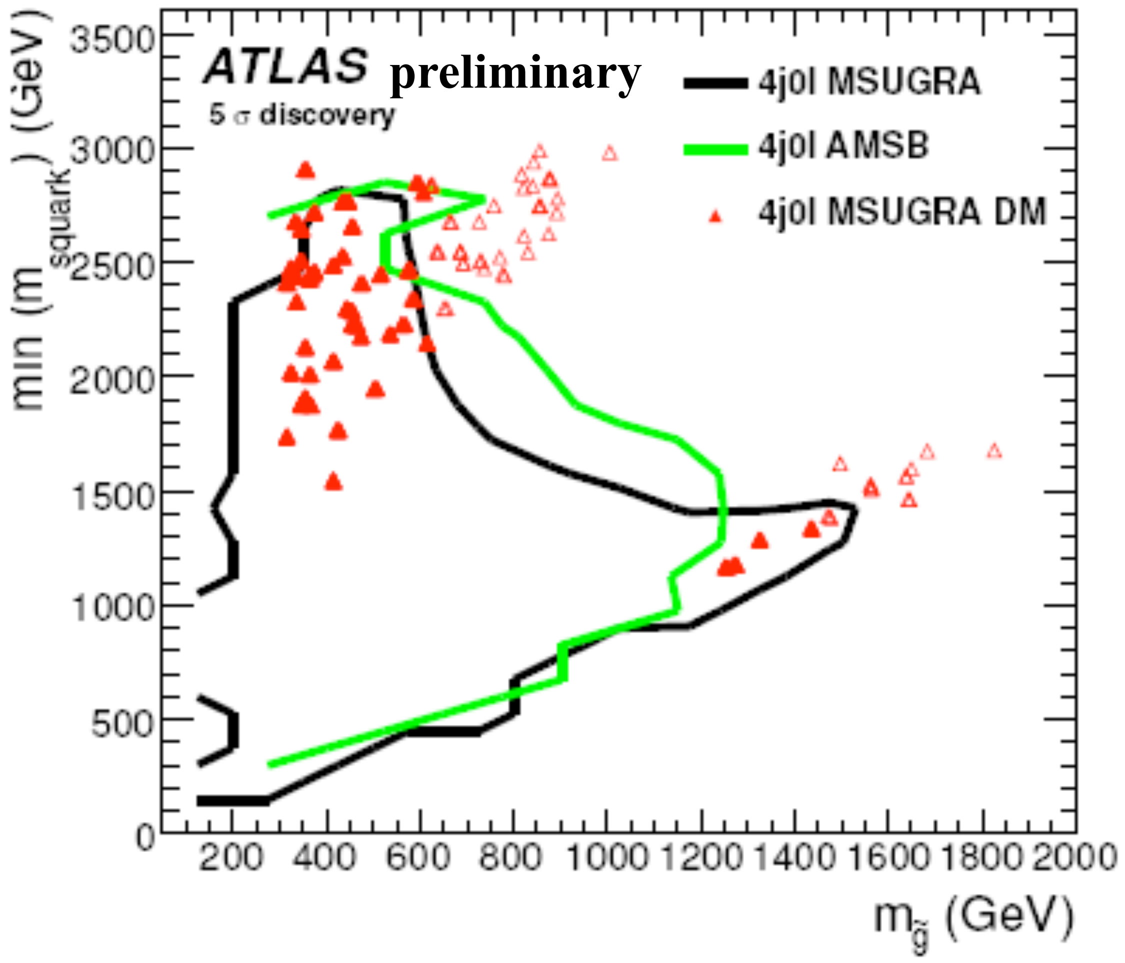


5σ evidence after 1 fb^{-1} (including systematics) expected if squarks lighter than ~1300 GeV

0-lepton and 1-lepton best modes for mSUGRA

No attempt to combine channels yet

Supersymmetry searches



Similar discovery potential for different models, in terms of gluino/squark mass, as long as

$m(\tilde{q}), m(\tilde{g}) >> m(\chi)$

After discovery

The ATLAS collaboration, *Observation of an excess of events with jets and missing energy in pp collisions at* $\sqrt{s} = 14$ *TeV*

This means some colored particle decaying in something invisible.

Next phase is figuring out what it is.

Effective mass peak, cross section should give us an idea of the mass scale.

The relative contribution of various search channels will also be useful

to kill models/regions of parameter space.

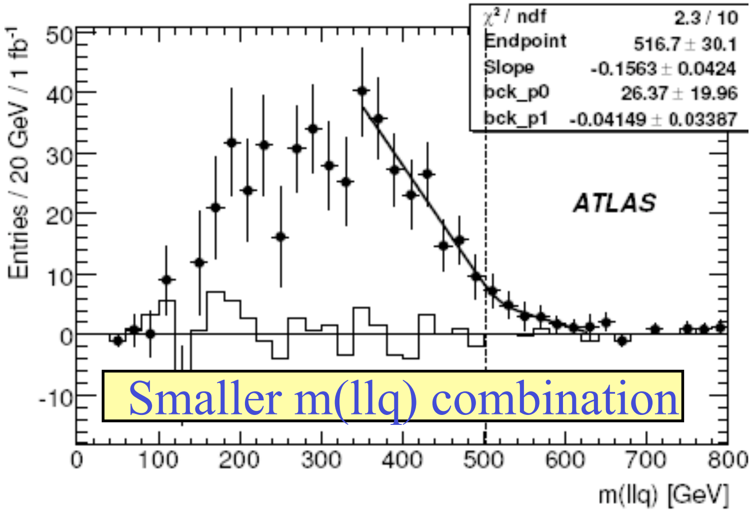
Kinematical endpoints to reconstruct masses

Eventually, much more information is there: shapes of invariant mass distributions, angular distributions (measure spins), event rates…

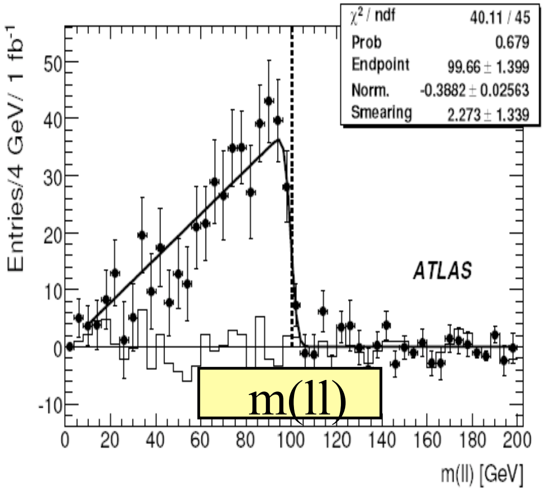
Here, I would like to show what we may be able to do with limited statistics (1 fb^{-1})

for a partcular point in parameter space (mSUGRA SU3)

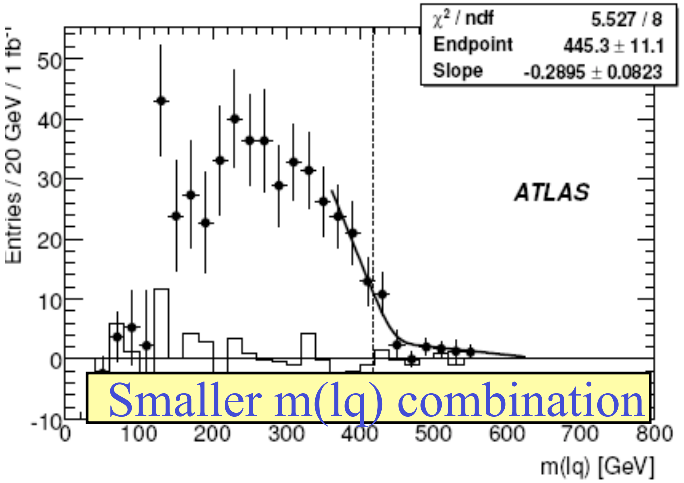
Lepton, lepton+jets endpoints



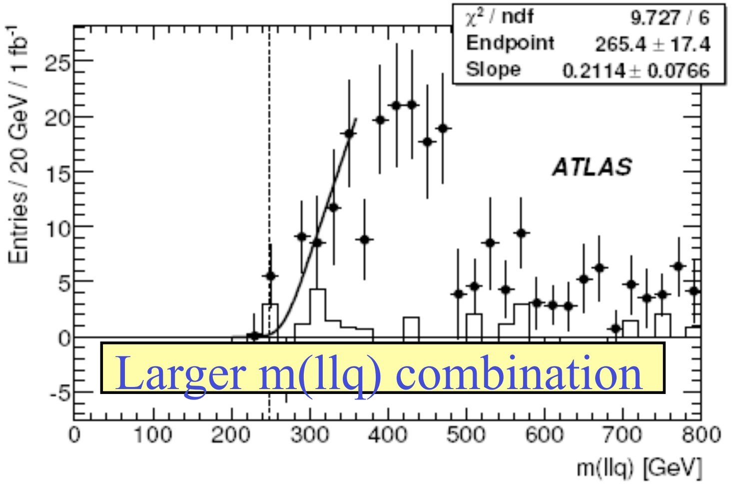
Smaller m(llq) combination



m(ll)

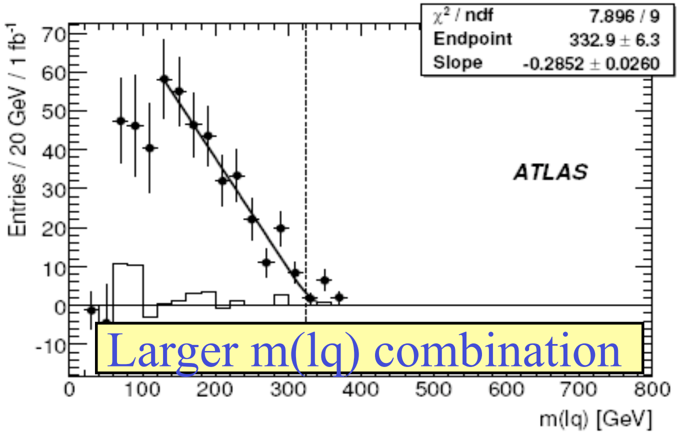


Smaller m(lq) combination



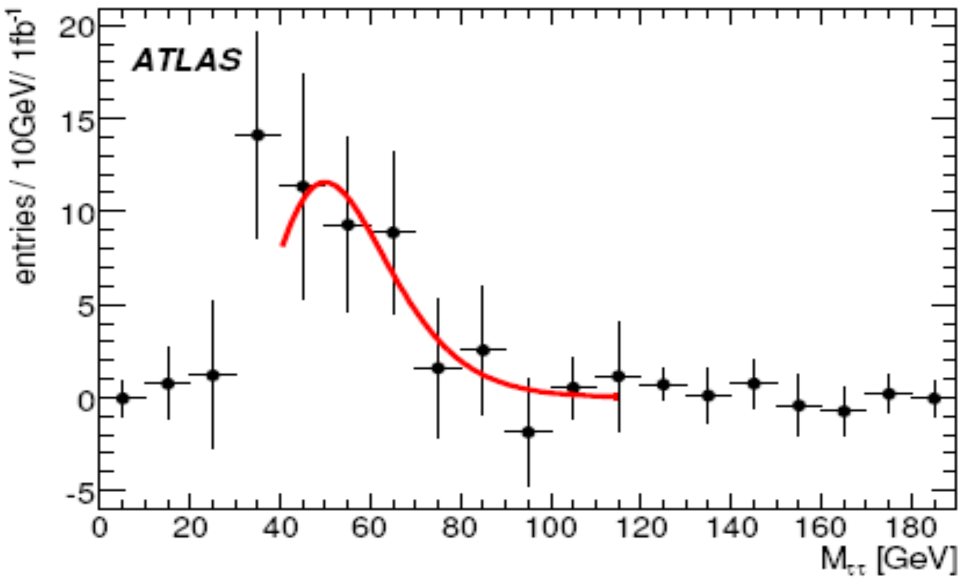
Larger m(llq) combination

SU3, 1 fb^{-1}
Each edge/threshold
Measures a relation
Between the masses
(q,χ^0_2,l,χ^0_1)



Larger m(lq) combination

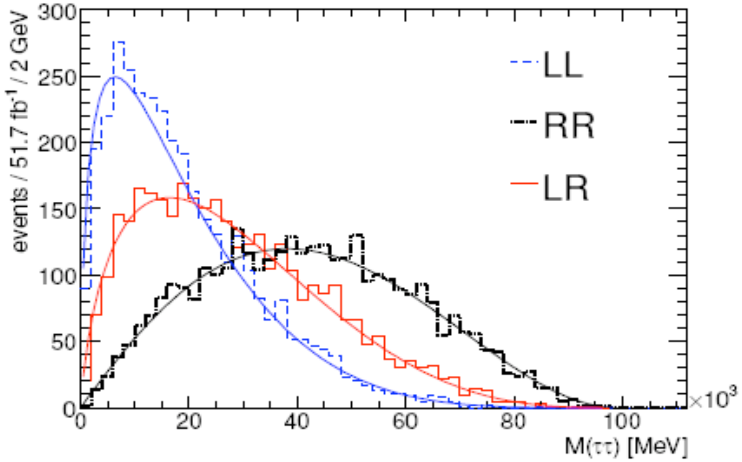
Di-tau endpoints



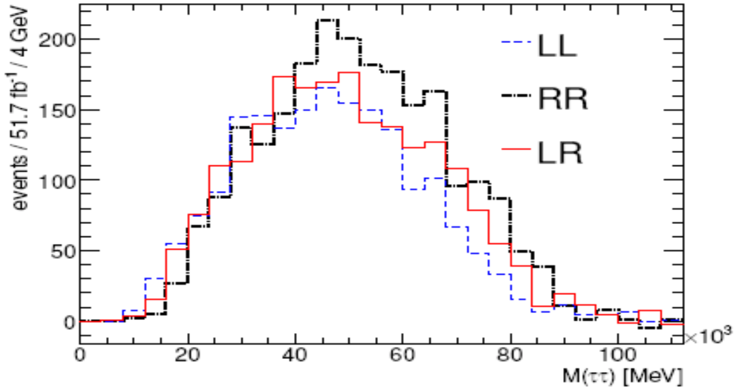
The inflection point in the fit function is proportional to the true endpoint

Allows to get an handle on stau mass

Dominant systematic error (7 GeV) is from polarization effects

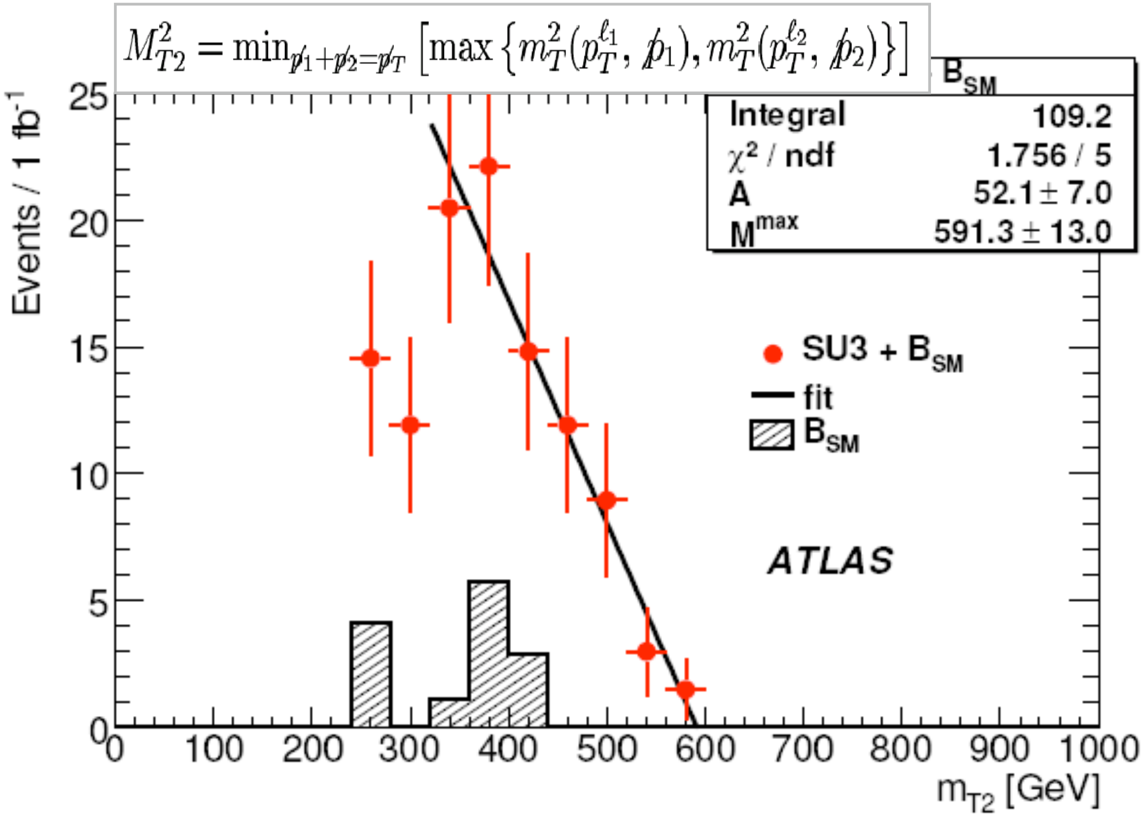


Effect of polarization: MC Truth level, τ → πν only



Effect of polarization: all decays, after detector reconstr.

Stransverse mass endpoint



$$M_{T2}^2 = \min_{\not p_1 + \not p_2 = \not p_T}\left[\max\left\{m_T^2(p_T^{\ell_1}, \not p_1), m_T^2(p_T^{\ell_2}, \not p_2)\right\}\right]$$

In mSUGRA the chi01 is mostly bino, and the qR decays as

$$\tilde{q}_R \rightarrow \tilde{\chi}_1^0 q$$

A 2-jet selection then selects q_R pair production:

- $\not E_T > \max(200\ \text{GeV}, 0.25 M_{\text{eff}})$ and $M_{\text{eff}} > 500$ GeV
- Two jets with $p_T > \max(200\ \text{GeV}, 0.25 M_{\text{eff}})$, $|\eta| < 1$ and $\Delta R > 1$
- No additional jet with $p_T > \min(200\ \text{GeV}, 0.15 M_{\text{eff}})$
- No isolated leptons and no jets tagged as b-jets
- Transverse sphericity $S_T > 0.2$

And the "stransverse mass" can be used to measure a relation between the q_R and χ01 masses

The mT2 kink method may be used to measure the χ01 and q_R mass separately. We have not studied this possibility yet.

Mass fit

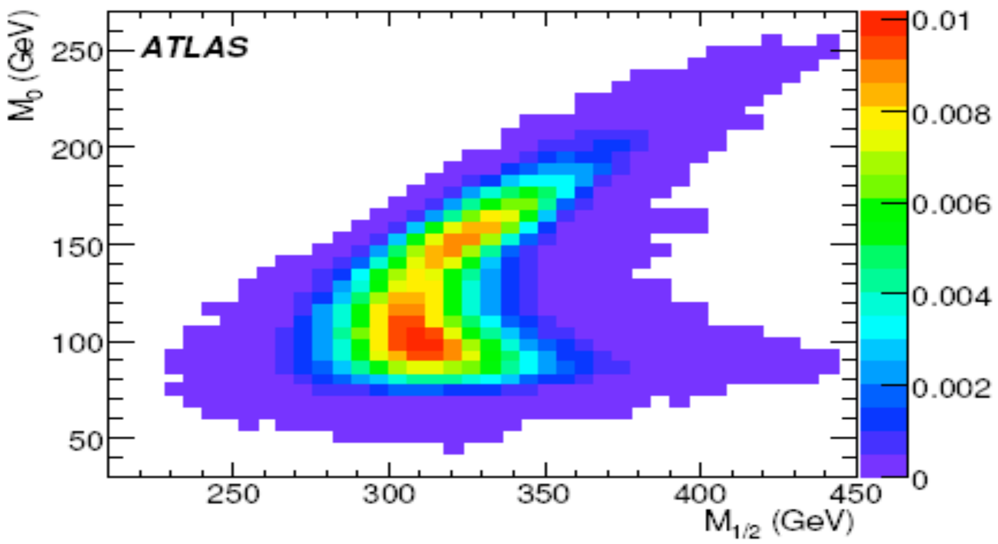
- The relation of the lepton+jets (and dilepton) edges and the masses can be inverted to get the masses

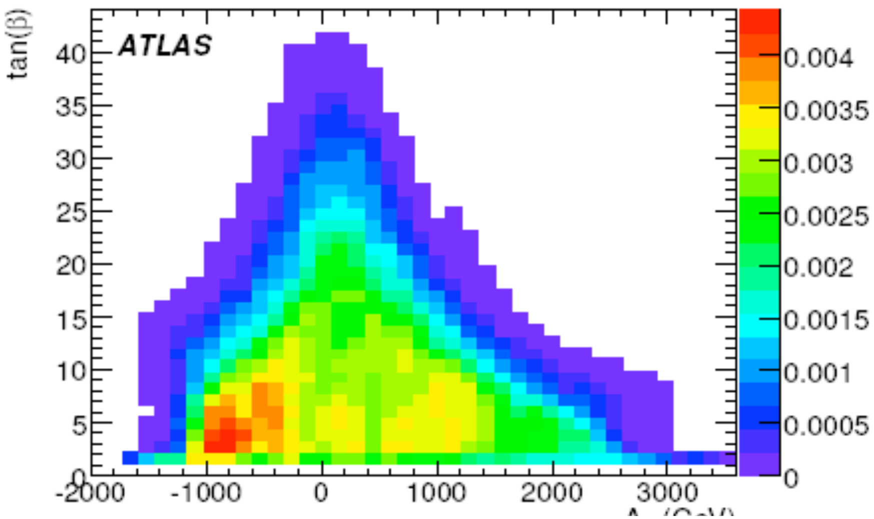
$$\chi^2 = \sum_{k=1}^{n} \frac{(m_k^{\mathrm{max}} - t_k^{max}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L}))^2}{\sigma_k^2}$$

Observable	SU3 m_{meas} [GeV/c^2]	SU3 m_{MC} [GeV/c^2]
$m_{\tilde{\chi}_1^0}$	$88 \pm 60 \mp 2$	118
$m_{\tilde{\chi}_2^0}$	$189 \pm 60 \mp 2$	219
$m_{\tilde{q}}$	$614 \pm 91 \pm 11$	634
$m_{\tilde{\ell}}$	$122 \pm 61 \mp 2$	155
Observable	SU3 Δm_{meas} [GeV/c^2]	SU3 Δm_{MC} [GeV/c^2]
$m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$	$100.6 \pm 1.9 \mp 0.0$	100.7
$m_{\tilde{q}} - m_{\tilde{\chi}_1^0}$	$526 \pm 34 \pm 13$	516.0
$m_{\tilde{\ell}} - m_{\tilde{\chi}_1^0}$	$34.2 \pm 3.8 \mp 0.1$	37.6

- Requires the decay chain to be known, but the system is overconstrained (5 relations, 4 endpoints) so different hypothesis can be tested
- Statistical errors very large for 1 fb^{-1}, but we still get a measurement of the 4 masses

A first go at parameter space





- With 1 fb-1, we can hope to constrain only models with few parameters.
- mSUGRA fits performed with Fittino
- M0, m1/2 determined with good precision (2%-10%)

Parameter	SU3 value	fitted value	exp. unc.	theo. + exp. unc.
		sign(μ) = +1		
$\tan\beta$	6	7.4	4.6	–
M_0	100 GeV	98.5 GeV	±9.3 GeV	±9.5 GeV
$M_{1/2}$	300 GeV	317.7 GeV	±6.9 GeV	±7.8 GeV
A_0	−300 GeV	445 GeV	±408 GeV	–
		sign(μ) = −1		
$\tan\beta$		13.9	±2.8	–
M_0		104 GeV	±18 GeV	–
$M_{1/2}$		309.6 GeV	±5.9 GeV	–
A_0		489 GeV	±189 GeV	–

Conclusioni

- The first fb^{-1} of (reasonably well-understood) data at 14 TeV will allow us to push far beyond the Tevatron in the search for supersymmetry
- The 2008 data will be very useful for detector commissioning and the understanding of Standard Model processes – needed to begin to exploit the LHC potential
- ATLAS has developed search strategies for the different signal topologies which are expected in SUSY models
- For each topology data-driven techniques to estimate the MS backgrounds have been studied. In many channels, different indendent estimates will be available.
- The jets+missingenergy+(0 o 1) leptons are the most promising mSUGRA, reaching up to ~1300 GeV in squark mass for 1 fb^{-1}
- Several interesting measurements may be possible from the very beginning

Backup

Stima degli effetti sistematici

Systematic errors for 1 fb^{-1} (current best guess from combined performance studies)

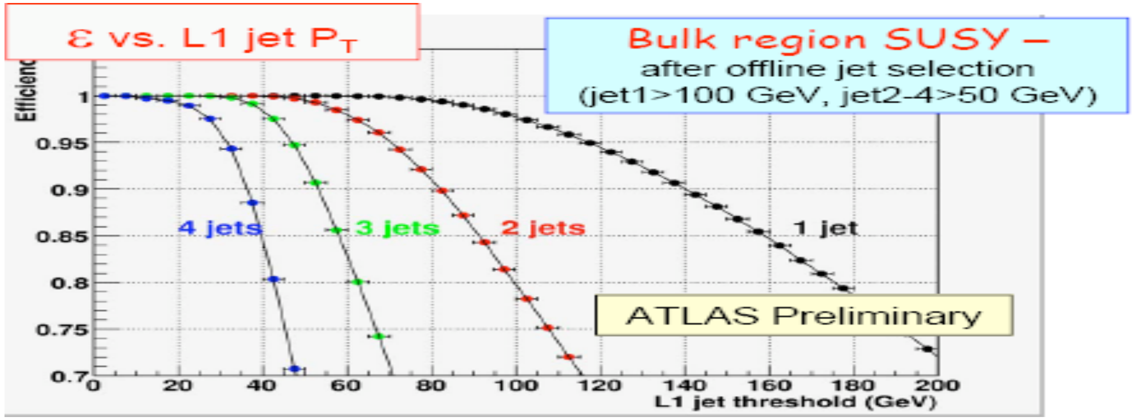
- Jet energy scale and resolution: 10%
- EtMiss: recomputed after scaling or smearing jet energy
- Electron efficiency, resolution, and scale: 0.5%, 0.2%, and 1%
- Muon efficiency, resolution, and scale: 1%, 0.2%, 4% for $p_T <$ 100 GeV
- b-tagging efficiency: 5%

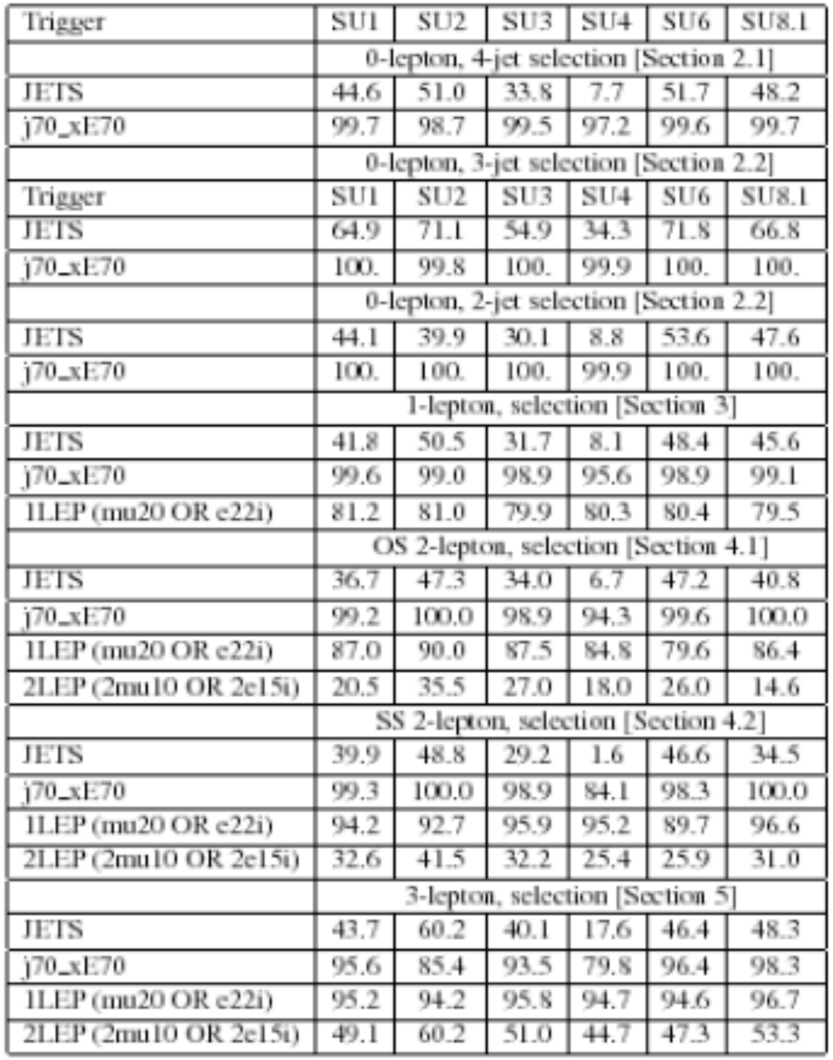
Trigger

- Jet+EtMiss trigger very efficient for SUSY events which pass offline selection
- EtMiss trigger may take some time to be understood: rely on jets trigger in the beginning

At 10^31-10^32 they select SUSY events with high efficiency too

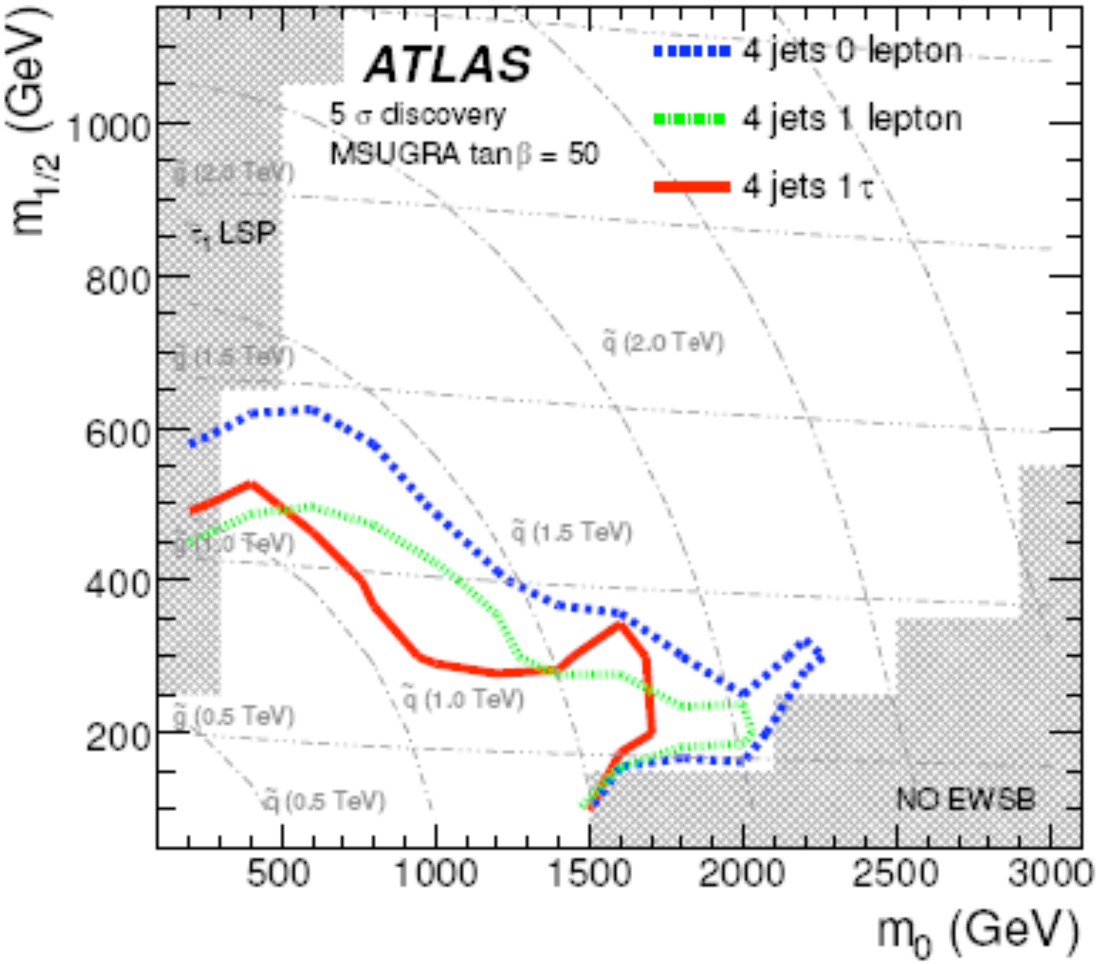
Allow an unbaiased measurement of EtMiss trigger efficiency



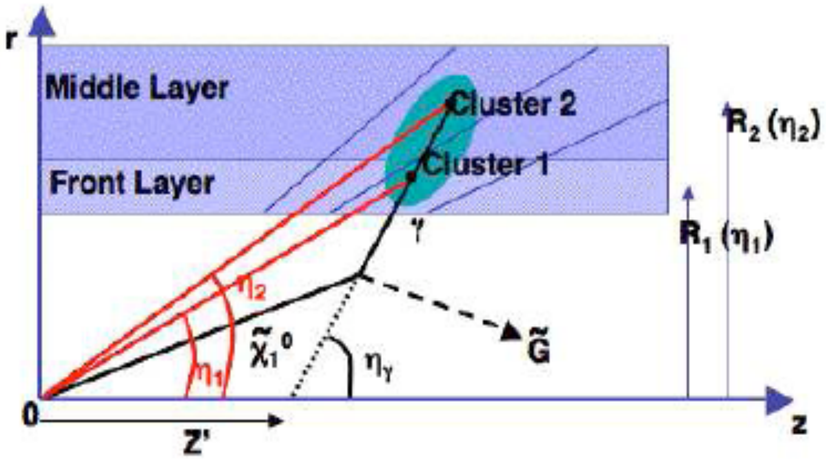


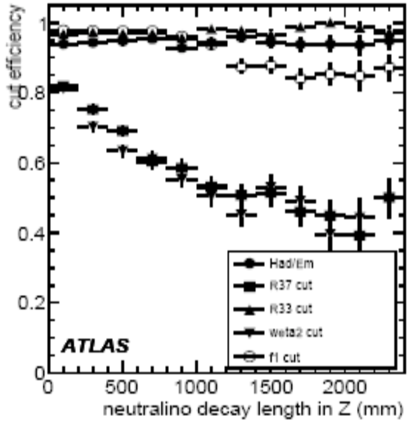
Trigger	SU1	SU2	SU3	SU4	SU6	SU8.1
	0-lepton, 4-jet selection [Section 2.1]					
JETS	44.6	51.0	33.8	7.7	51.7	48.2
j70_xE70	99.7	98.7	99.5	97.2	99.6	99.7
	0-lepton, 3-jet selection [Section 2.2]					
Trigger	SU1	SU2	SU3	SU4	SU6	SU8.1
JETS	64.9	71.1	54.9	34.3	71.8	66.8
j70_xE70	100.	99.8	100.	99.9	100.	100.
	0-lepton, 2-jet selection [Section 2.2]					
JETS	44.1	39.9	30.1	8.8	53.6	47.6
j70_xE70	100.	100.	100.	99.9	100.	100.
	1-lepton, selection [Section 3]					
JETS	41.8	50.5	31.7	8.1	48.4	45.6
j70_xE70	99.6	99.0	98.9	95.6	98.9	99.1
1LEP (mu20 OR e22i)	81.2	81.0	79.9	80.3	80.4	79.5
	OS 2-lepton, selection [Section 4.1]					
JETS	36.7	47.3	34.0	6.7	47.2	40.8
j70_xE70	99.2	100.0	98.9	94.3	99.6	100.0
1LEP (mu20 OR e22i)	87.0	90.0	87.5	84.8	79.6	86.4
2LEP (2mu10 OR 2e15i)	20.5	35.5	27.0	18.0	26.0	14.6
	SS 2-lepton, selection [Section 4.2]					
JETS	39.9	48.8	29.2	1.6	46.6	34.5
j70_xE70	99.3	100.0	98.9	84.1	98.3	100.0
1LEP (mu20 OR e22i)	94.2	92.7	95.9	95.2	89.7	96.6
2LEP (2mu10 OR 2e15i)	32.6	41.5	32.2	25.4	25.9	31.0
	3-lepton, selection [Section 5]					
JETS	43.7	60.2	40.1	17.6	46.4	48.3
j70_xE70	95.6	85.4	93.5	79.8	96.4	98.3
1LEP (mu20 OR e22i)	95.2	94.2	95.8	94.7	94.6	96.7
2LEP (2mu10 OR 2e15i)	49.1	60.2	51.0	44.7	47.3	53.3

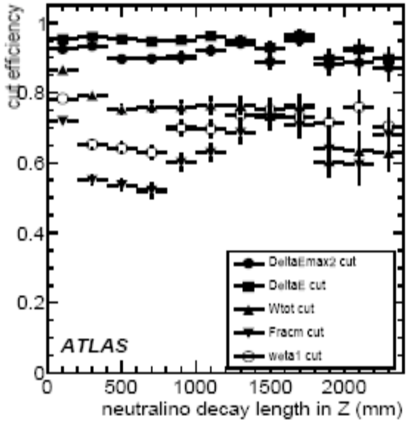
Supersymmetry searches



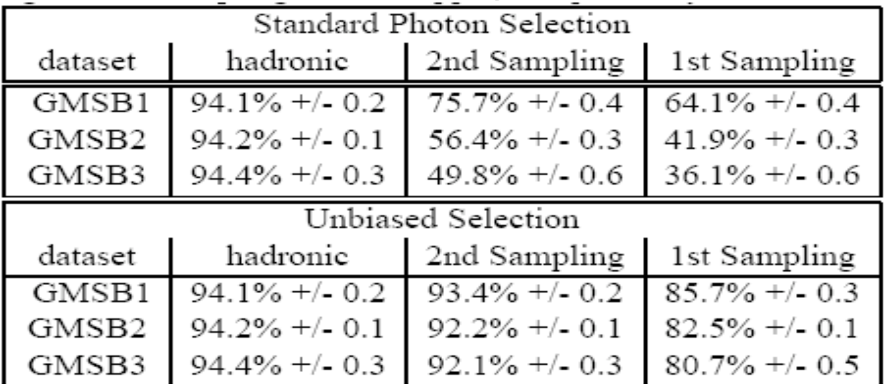
Misura della vita media







- La vita media puo’ essere misurata usando Z’
- I tagli di selezione standard forniscono un efficienza di selezione dei fotoni che diminuisce all’aumentare di Δη
- Questo causa perdita di segnale e complica la misura della vita media (occorre conoscere l’efficienza)
- Tagli ottimizzati forniscono un efficienza migliore e piu’ piatta, con un rate di fakes da getti accet



	Standard Photon Selection		
dataset	hadronic	2nd Sampling	1st Sampling
GMSB1	94.1% +/- 0.2	75.7% +/- 0.4	64.1% +/- 0.4
GMSB2	94.2% +/- 0.1	56.4% +/- 0.3	41.9% +/- 0.3
GMSB3	94.4% +/- 0.3	49.8% +/- 0.6	36.1% +/- 0.6
	Unbiased Selection		
dataset	hadronic	2nd Sampling	1st Sampling
GMSB1	94.1% +/- 0.2	93.4% +/- 0.2	85.7% +/- 0.3
GMSB2	94.2% +/- 0.1	92.2% +/- 0.1	82.5% +/- 0.1
GMSB3	94.4% +/- 0.3	92.1% +/- 0.3	80.7% +/- 0.5

Supersymmetry searches