Inclusive searches in ATLAS: How can we discover SUSY in 2009

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- background systematics, detector effects (Okawa, Teuscher)
- we discover something real; is it SUSY? (Lari)

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- it will take time to commission the LHC and the detectors and to “re-measure the Std. Model”

“yes, we can”

- the rest of this talk

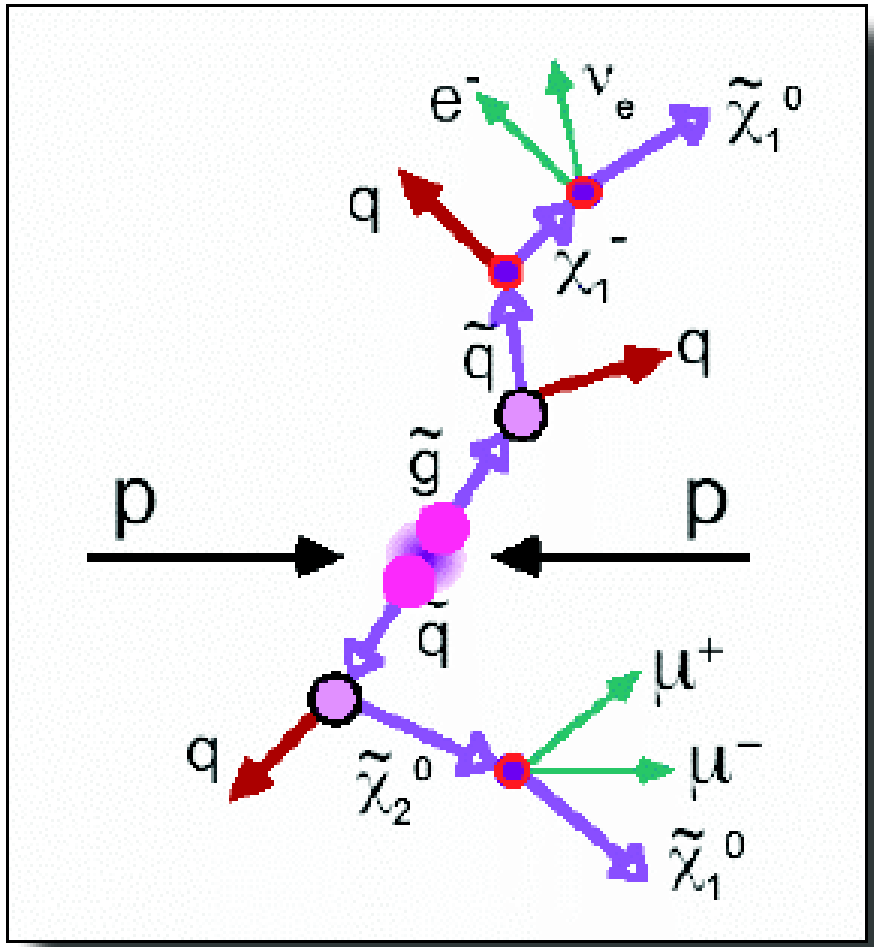
Outline

- General remarks about inclusive SUSY searches
- Strategy in ATLAS for studying inclusive search sensitivity
- Benchmark points
- Parameter scans
- Conclusion

Inclusive searches: general considerations

Inclusive SUSY search strategy relies on fairly general features:

- SUSY production cross section can be calculated in the MSSM (xsec depends only on sparticle mass)
- gluinos/squarks are the heaviest sparticles
- gluino/squark decays give rise to (high pt) jets
- neutralinos/charginos often decay via emission of leptons
- LSP is stable (R-parity conservation) and neutral, escaping detector. Connection to dark matter.



Generic signature is therefore:

- multiple jets, often energetic
- possibly some leptons (lower pt)
- missing Et

Strategy for studying inclusive search sensitivity

Most studies in ATLAS done in the context of Minimal Supersymmetric SM (MSSM) with R-parity conservation

All studies shown here assume $\sqrt{s}$ = 14 TeV

SUSY breaking scenarios considered:

- mSUGRA - minimal SuperGravity (most studied)
- GMSB - Gauge Mediated SUSY Breaking
- AMSB - Anomaly Mediated SUSY Breaking

Can choose to apply constraints from relic dark matter density

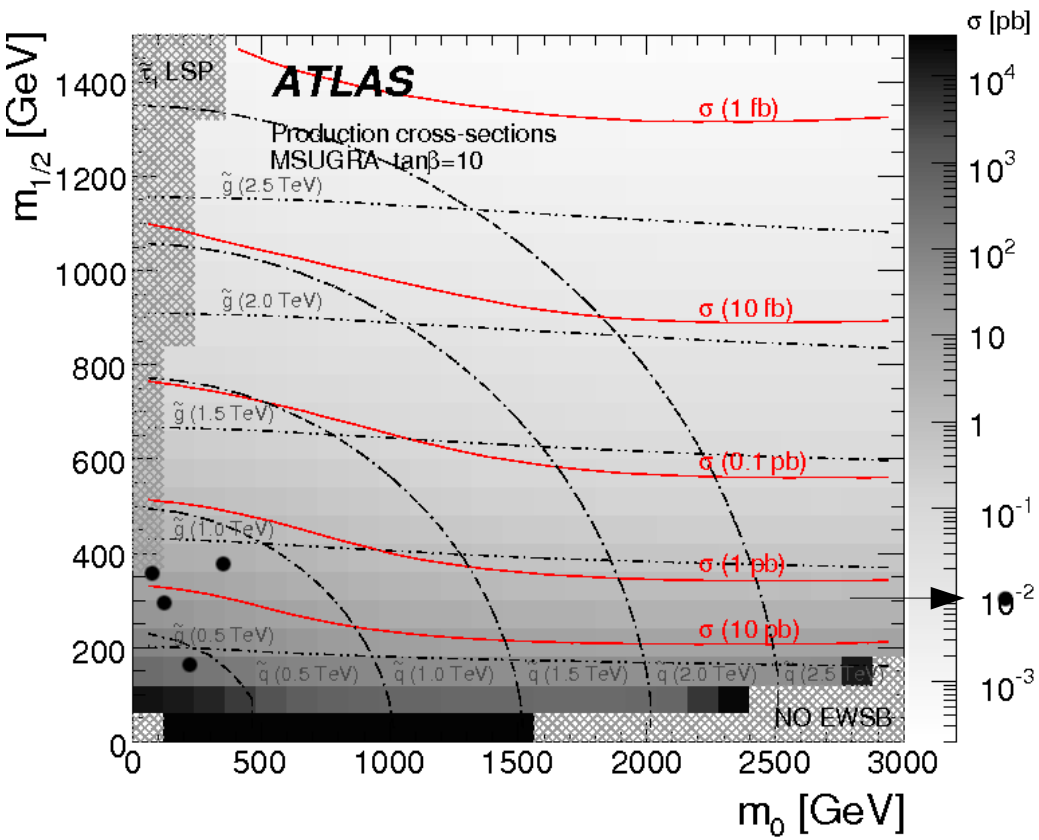
The strategy so far:

- Full detector simulations at selected points consistent with DM constraints and spanning different signatures
- Scans of parameter space with fast detector simulation
- Specialized studies of "exotic" signatures with full simulation:
  - Long-lived states
  - "R-hadron"

Not believing that any of these models is a true description of Nature.
Aim is to cover a broad range of experimental signatures in a self-consistent way

mSugra benchmark points

	m_0 (GeV)	m_1/2 (GeV)	A0 (GeV)	tan(beta)	σ(NLO) (pb)	Comment
SU1	70	350	0	10	10.9	Soft leptons, taus
SU2	3550	300	0	10	7.2	gluino/gaugino production, heavy flavor decays
SU3	100	300	-300	6	27.7	Generic point
SU4	200	160	-400	10	402.2	Low mass point near Tevatron bound
SU6	320	375	0	50	6.1	Tau rich



Common features for all points

- $\mu > 0$
- $m(\tilde{g}) < 1$ TeV
- Comparable $\tilde{g}$ and $\tilde{q}$ masses (except SU2)
- $m(\tilde{g})/m(\tilde{\chi}_1^0) \approx 6\text{-}8$
- NLO xsec used

Std Model background samples:

- ALPGEN for QCD multijet, W/Z+jets (Pythia used for non-4jet analyses). Normalized to NLO xsec.
- MC@NLO for ttbar

4jets + MET channel

Njets + MET = most inclusive signature

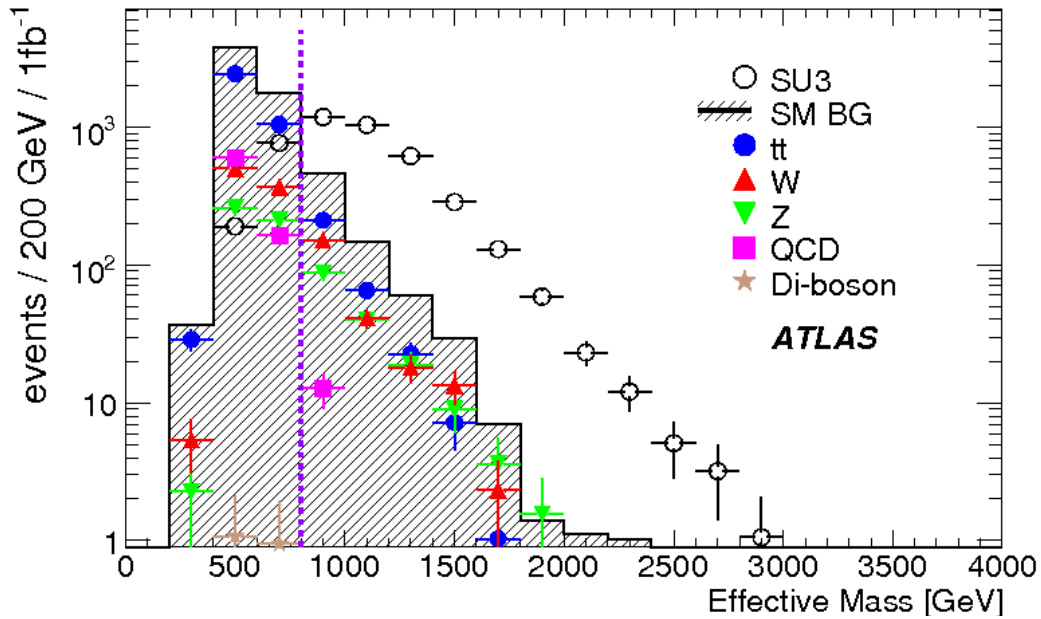
Main backgrounds: ttbar and W/Z+jets contribute roughly equally

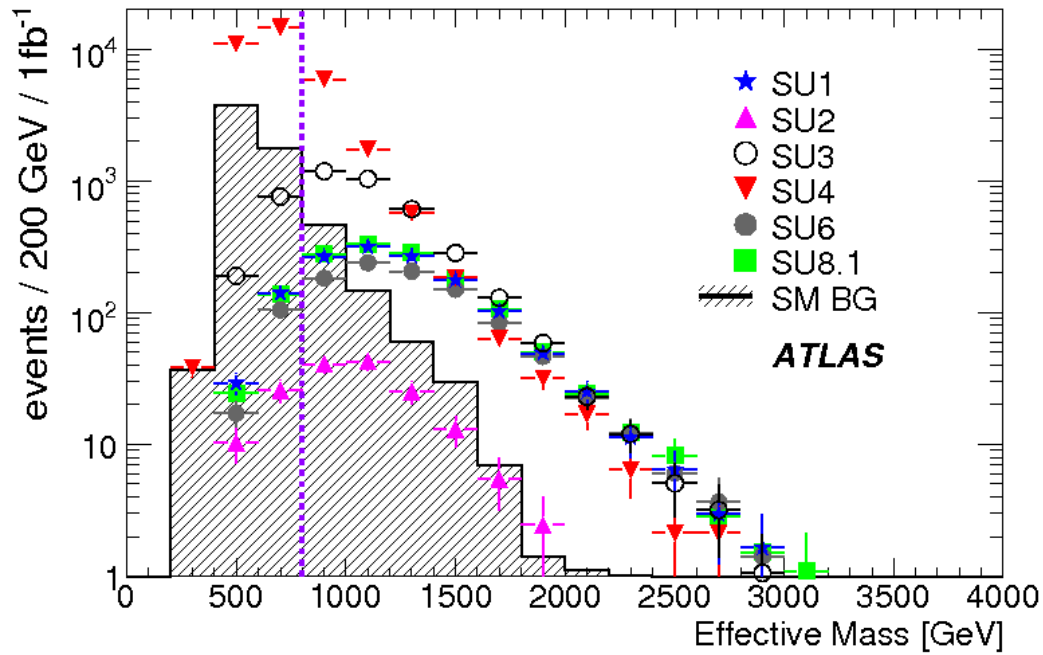
QCD multijet bkg appears to be controllable by cutting on angle between MET and jets (remains to be confirmed with real data)

Simple selection cuts:

- ≥ 4 jets, pt > (100,50,50,50) GeV
- MET > 0.2 Meff
- S_T > 0.2
- Δφ(jet-MET) > 0.2 for 3 leading jets
- Reject events with isolated e or μ
- Meff > 800 GeV

Meff ≡ ∑pt(jets, leptons) + MET

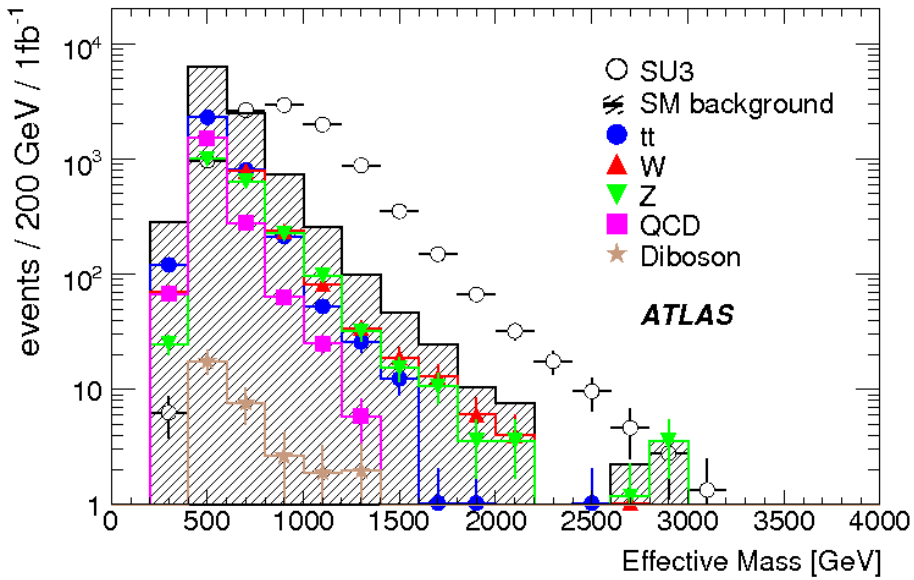




2 (3)jets + MET channel

Similar cuts to 4jets analysis

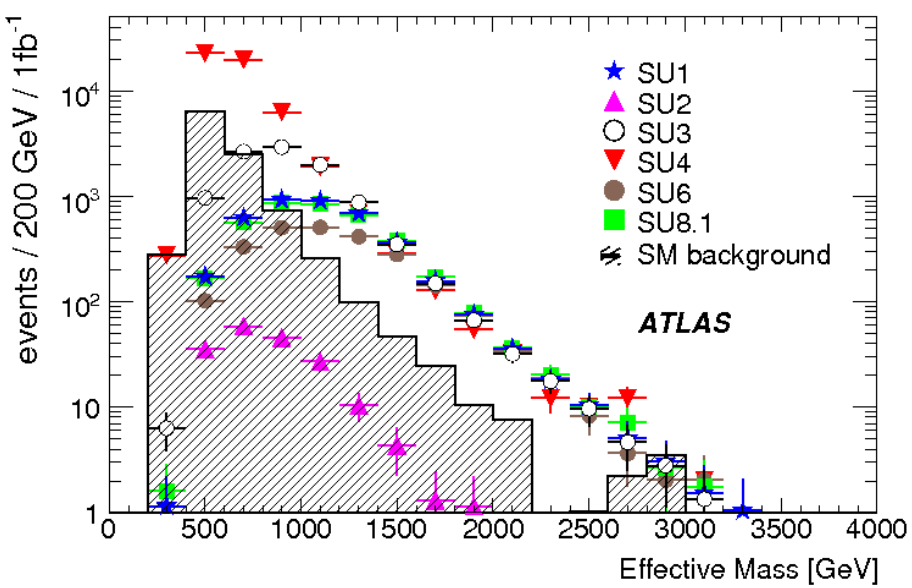
- ≥ 2 (3) jets, pt > 150,100, (100) GeV
- MET > 0.3 (0.25) Meff
- Δφ(jet-MET) > 0.2
- Reject events with isolated e or μ
- Meff > 800 GeV



Analysis based on MT2 has also been studied (using leading 2 jets)

- ≥ 2 (3) jets, pt > 150,100, (100) GeV
- MET > 100 GeV
- Reject events with isolated e or μ
- MT2 > 400 GeV

Slightly better performance to the Meff analysis. Revisit with systematics from real data.



4jets + 1 lepton + MET
(e,μ)

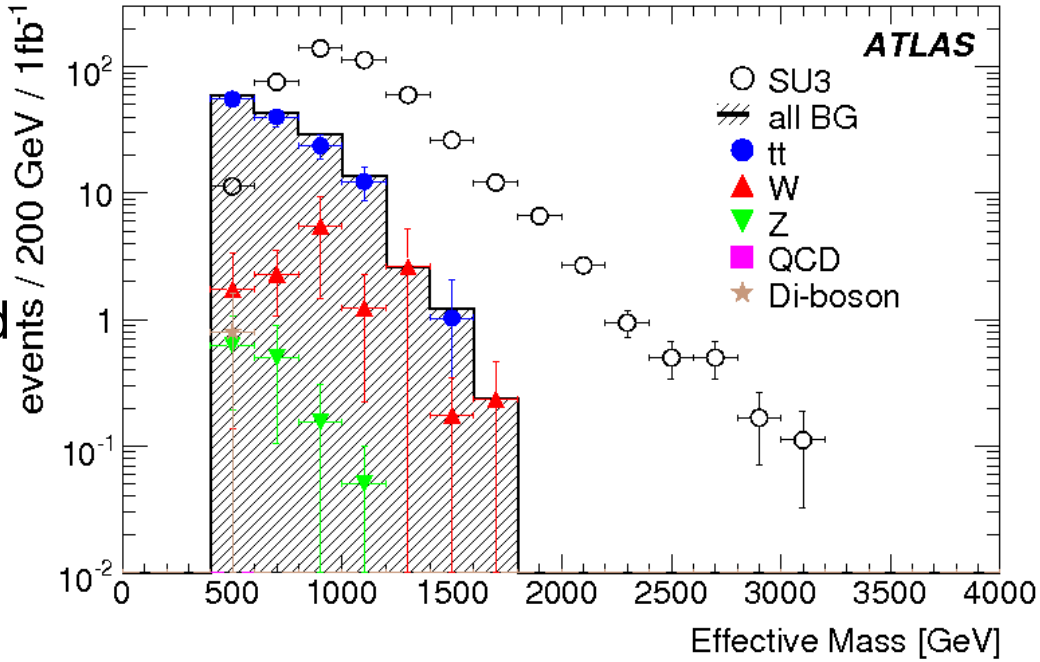
Better control of QCD multijet bkg. Main bkg is dileptonic top with one lepton missed

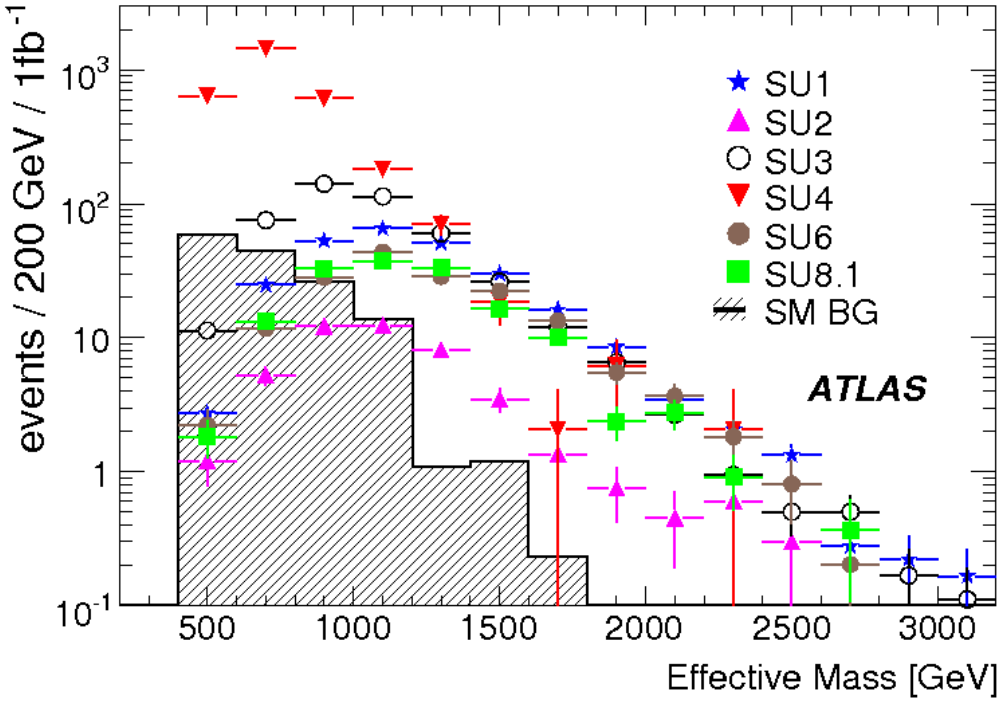
Retain sensitivity to taus through decays to e/μ

Selection cuts:

- ≥ 4 jets, pt > (100,50,50,50) GeV
- MET > 0.2 Meff
- S_T > 0.2
- Exactly 1 isolated e or μ, pt > 20 GeV
- No other isolated leptons with pt > 10
- Transverse mass > 100 GeV
- Meff > 800 GeV

Significance > 5 for all benchmark points (except SU2) even with 100 pb^{-1} assuming we can maintain 20% sys uncertainty on ttbar and W+jets bkg

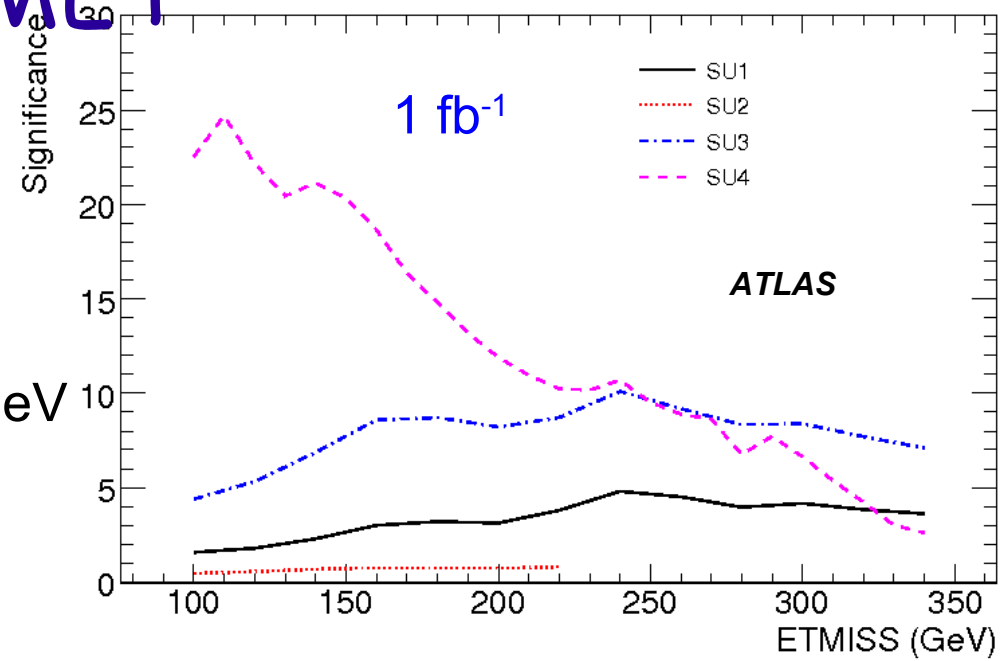




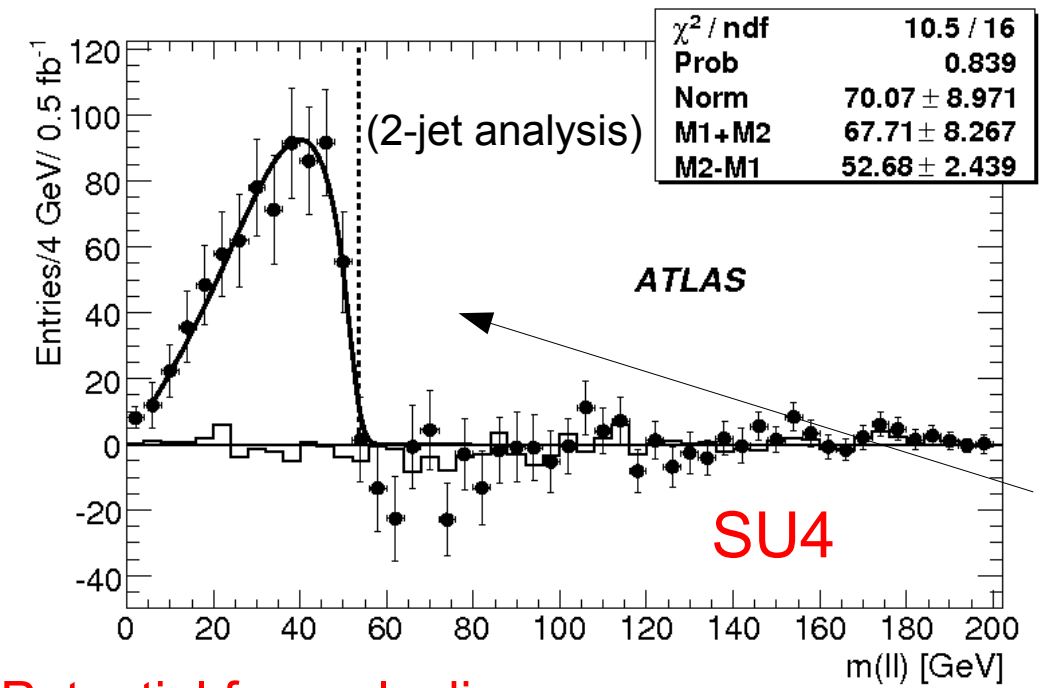
OS dilepton + 4jets + MET

Selection cuts:

- ≥ 4 jets, pt > (100,50,50,50) GeV
- MET > 100 GeV & MET > 0.2 Meff
- S_T > 0.2
- Exactly 2 OS isolated e or μ, pt > 10 GeV
- No other isolated leptons with pt > 10



Main bkg is dileptonic ttbar



OS dileptons from SUSY decay chains (e.g. $\tilde{\chi}_2^0 \rightarrow \ell^+\ell^-\tilde{X}_1^0$) must be same flavor to avoid μ → e γ constraints.

SM backgrounds (e.g. ttbar) populate e and μ equally (OSSF and OSOF)

Search for excess in OSSF-OSOF

Mainly requires understanding relative acceptance of e versus μ.

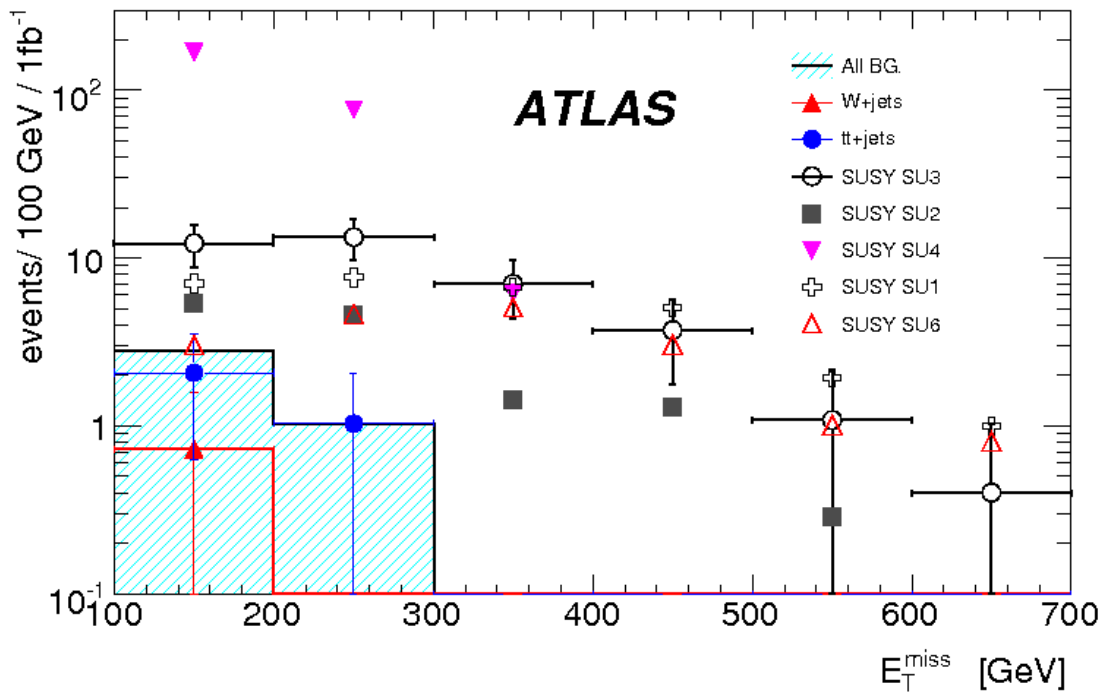
Potential for early discovery

SS dilepton + 4jets + MET

Almost background free

Main bkg is semileptonic ttbar with semileptonic b decay on the other side

Could be a relatively clean early discovery channel



Selection cuts:

- ≥ 4 jets, pt > (100,50,50,50) GeV
- MET > 100 GeV
- Exactly 2 SS isolated e or μ, pt > 20 GeV
- No other isolated leptons with pt > 10

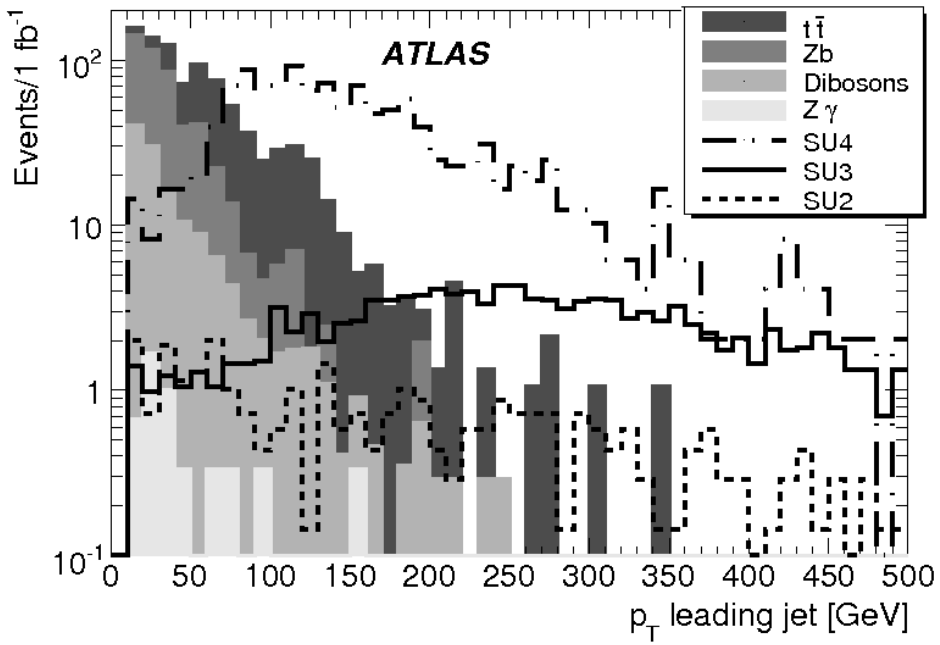
3 lepton channel

3 lepton + jet analysis
- ≥ 3 isolated leptons with pt > 10 GeV
- ≥ 1 jet with pt > 200 GeV

No reliance on MET

Jet cut effective against WZ and Wγ*

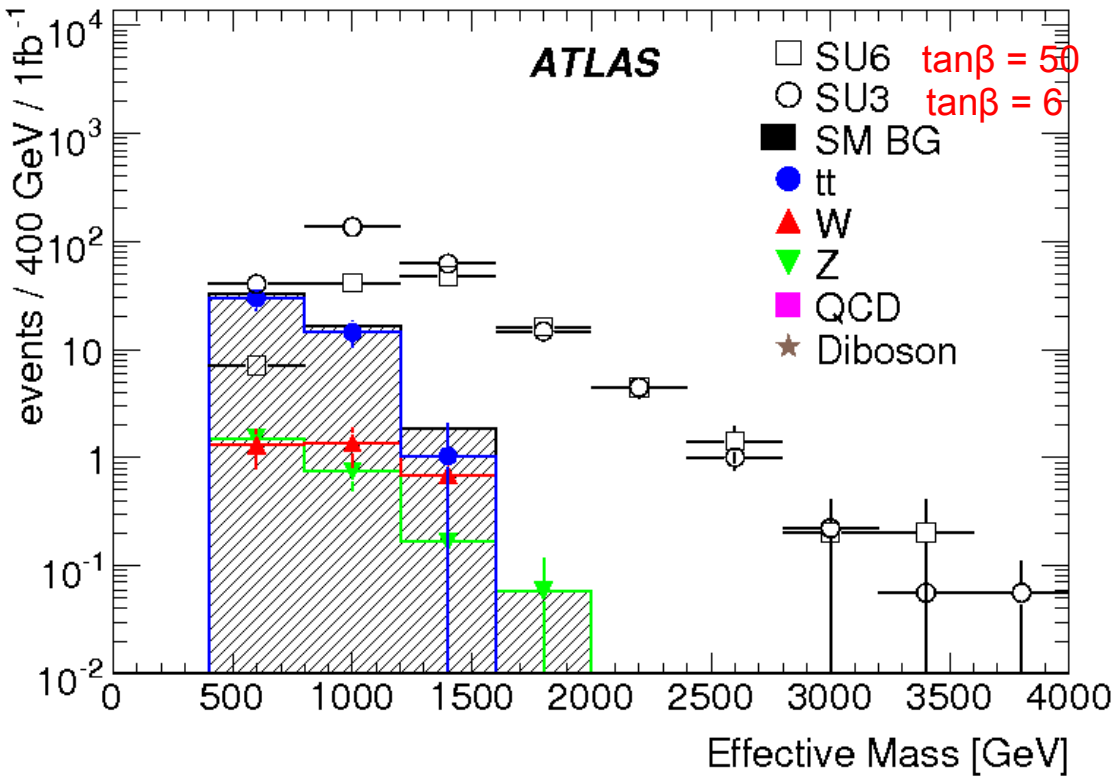
Dominant background is dileptonic ttbar with semileptonic b decay



3 lepton + MET analysis also studied
- ≥ 3 isolated leptons with pt > 10 GeV
- ≥ 1 OSSF pair with M > 20 GeV
- Track-based isolation (cone 0.2) < 1 (2) GeV for e (μ)
- MET > 30 GeV
- M(OSSF) < M_Z - 10 GeV

Generally inferior to 3ℓ+jet analysis for all benchmark pts, but would cover scenarios without hard jets

Tau channel



Same cuts as the 4jets+MET analysis, plus

- ≥ 1 tau, pt > 40 GeV, |η| < 2.5
- MT > 100 GeV (using visible momentumof hardest tau and MET)

Complete overlap with 4jets+MET channel

Nevertheless, interesting to consider tau channel to obtain complementary info on the nature of the BSM physics (stau LSP, e/μ/τ universality, ...)

Bjet channel

B-tagging via a combination of 3D impact parameter and sec. vtx identification

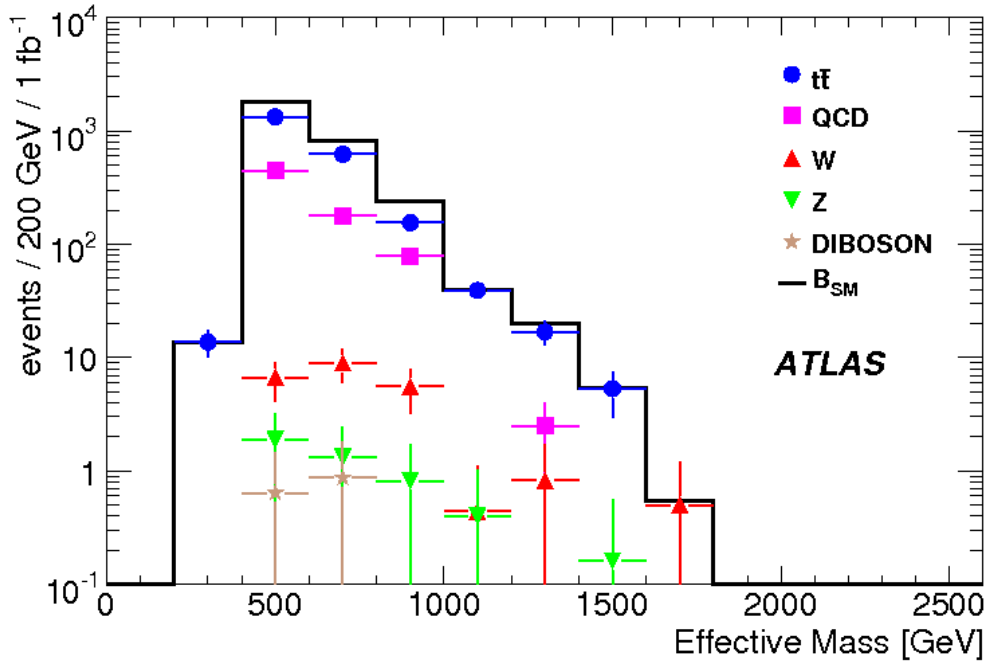
Light-jet rejection by a factor of roughly 100 (for 300 GeV jets), with an efficiency of around 60%

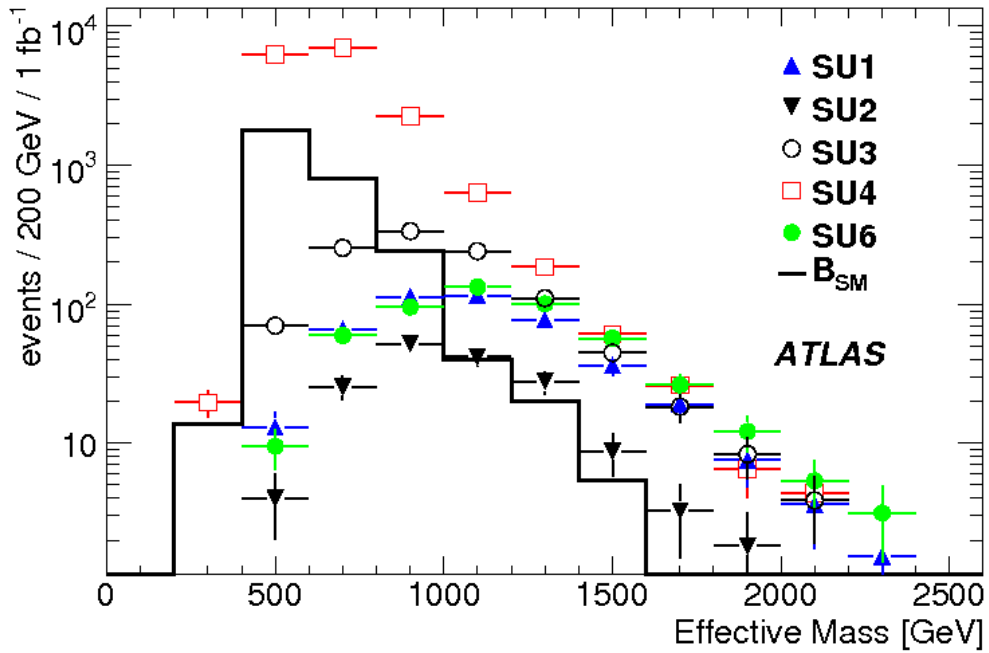
Selection cuts:

- ≥ 4 jets, pt > (100,50,50,50) GeV
- MET > 0.2 Meff
- S_T > 0.2
- ≥ 2 btagged jets
- Meff > 600, 800, 1000 GeV

Bjet requirement helps to control QCD multijet background (similar in philosophy to 1-lepton channel)

Sensitivity depends critically on btag performance for high pt jets



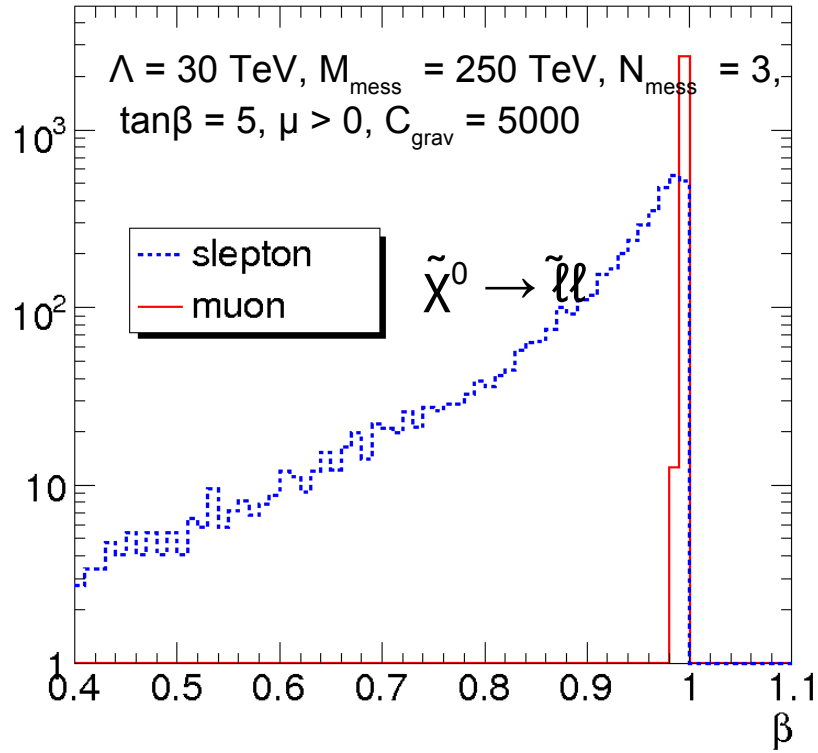


Long-lived heavy particles

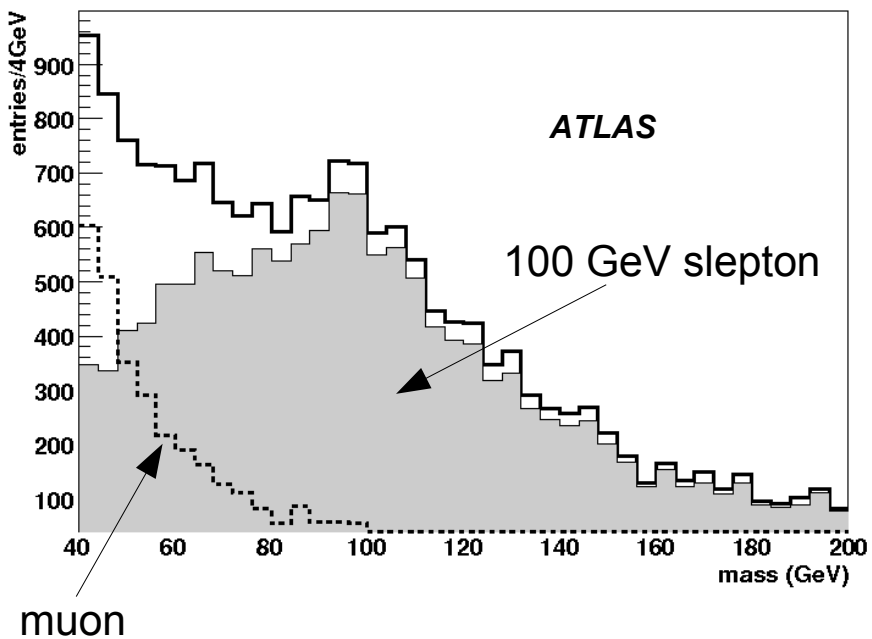
Long-lived heavy particles appear in many SUSY scenarios, e.g.:

- GMSB at high tanβ where NLSP is a slepton which couples weakly to gravitino
- R-hadrons formed from stable $\tilde{g}$ or $\tilde{t}$

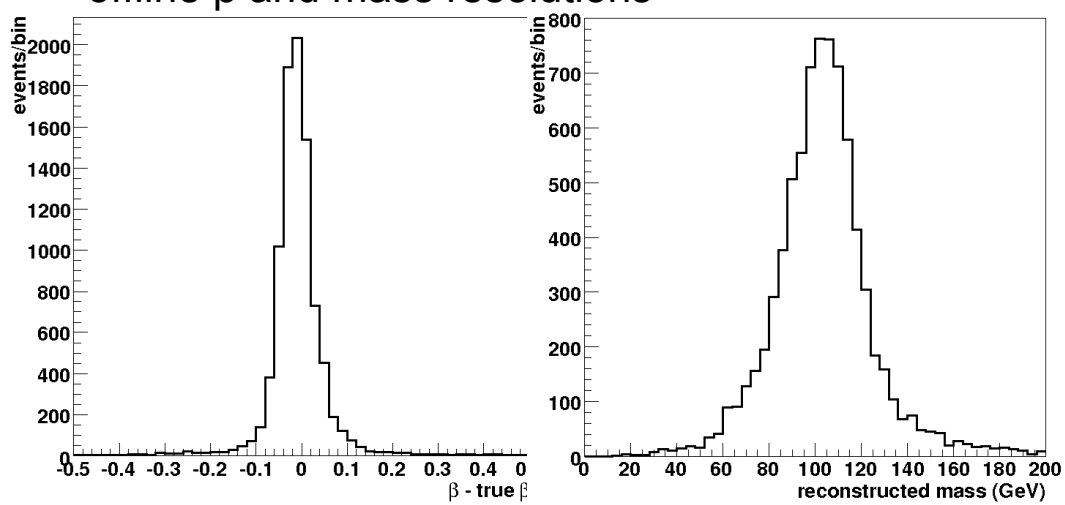
Trigger and DAQ are critical



Mass measurement with L2 trigger based on time-of-flight (~3ns time resolution)



offline β and mass resolutions



Scans of SUSY parameter space

Attempt to look wider in parameter space

- mSUGRA grid, tanβ=10. No constraints applied other than direct searches.
- Same as above with tanβ = 50
- mSUGRA random sampling, compatible with DM and other constraints
- GMSB grid. N_{mess}=5 → slepton NLSP with prompt decay to e,μ,τ
- NUHM grid, subject to DM constraints

Using fast, parametrized simulation of ATLAS detector

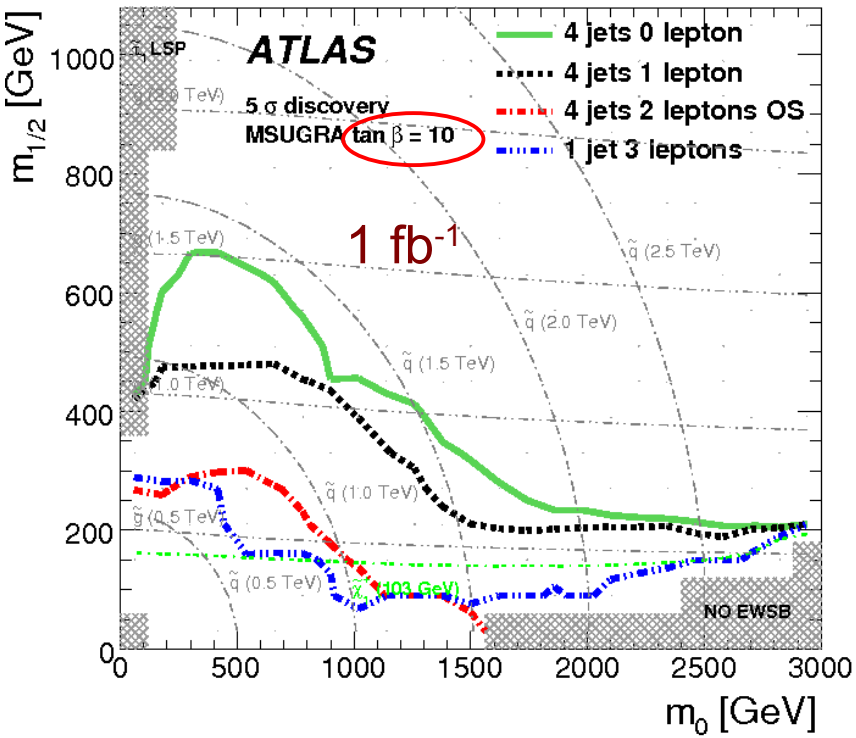
Systematics on background estimation included (based on full sim studies):

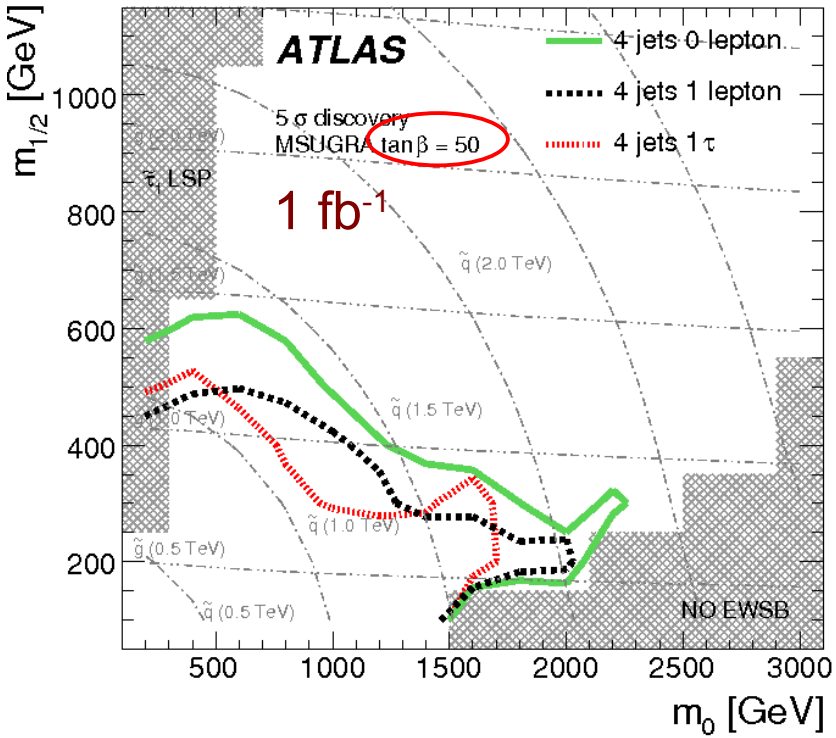
- 50% for QCD multijet
- 20% for W/Z+jets and ttbar

SUSY cross sections from leading order HERWIG. NLO cross sections for backgrounds.

Crude optimization by scanning MET and Meff cuts (significance is corrected for the "trials factor" using a Monte Carlo technique)

mSUGRA discovery reach in 4jets

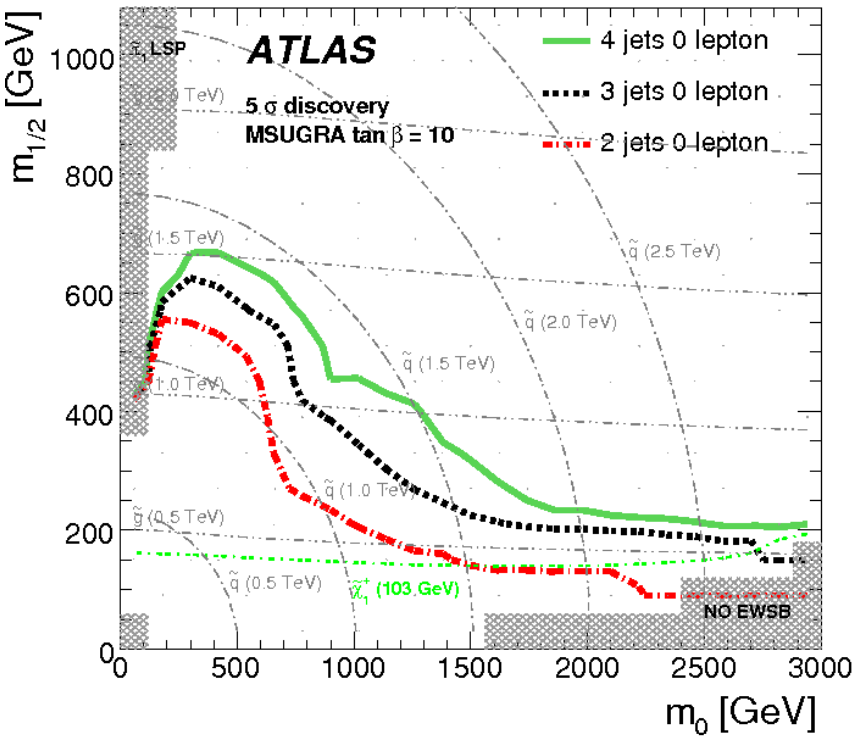


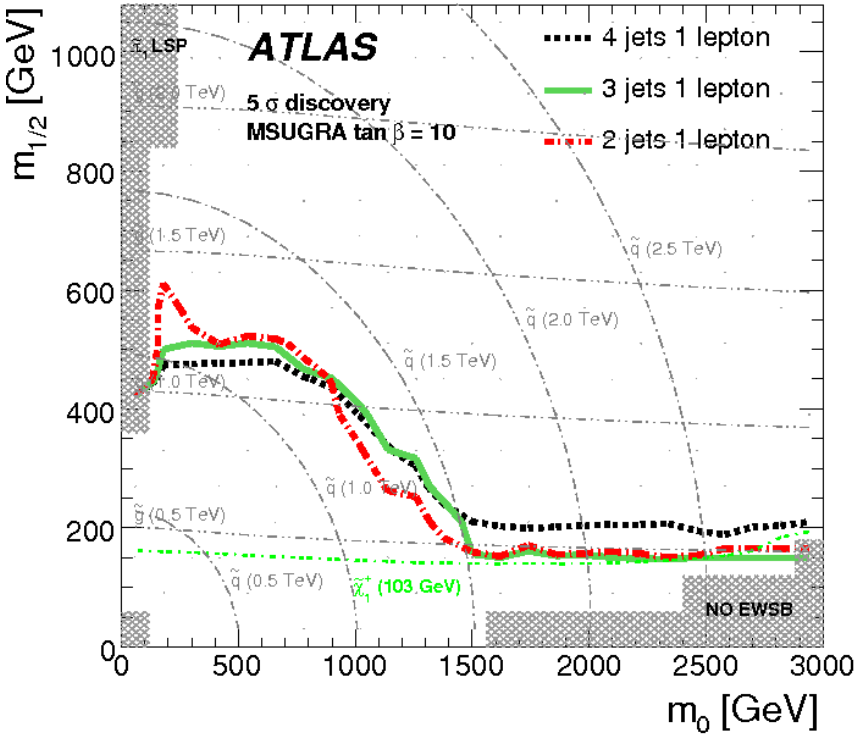


0-lepton mode can probe close to 1.5 TeV in min[m($\tilde{g}$), m($\tilde{q}$)] for 1 fb^{-1}

Reach is roughly independent of tanβ for 0- and 1-lepton modes

mSUGRA discovery reach vs number of jets





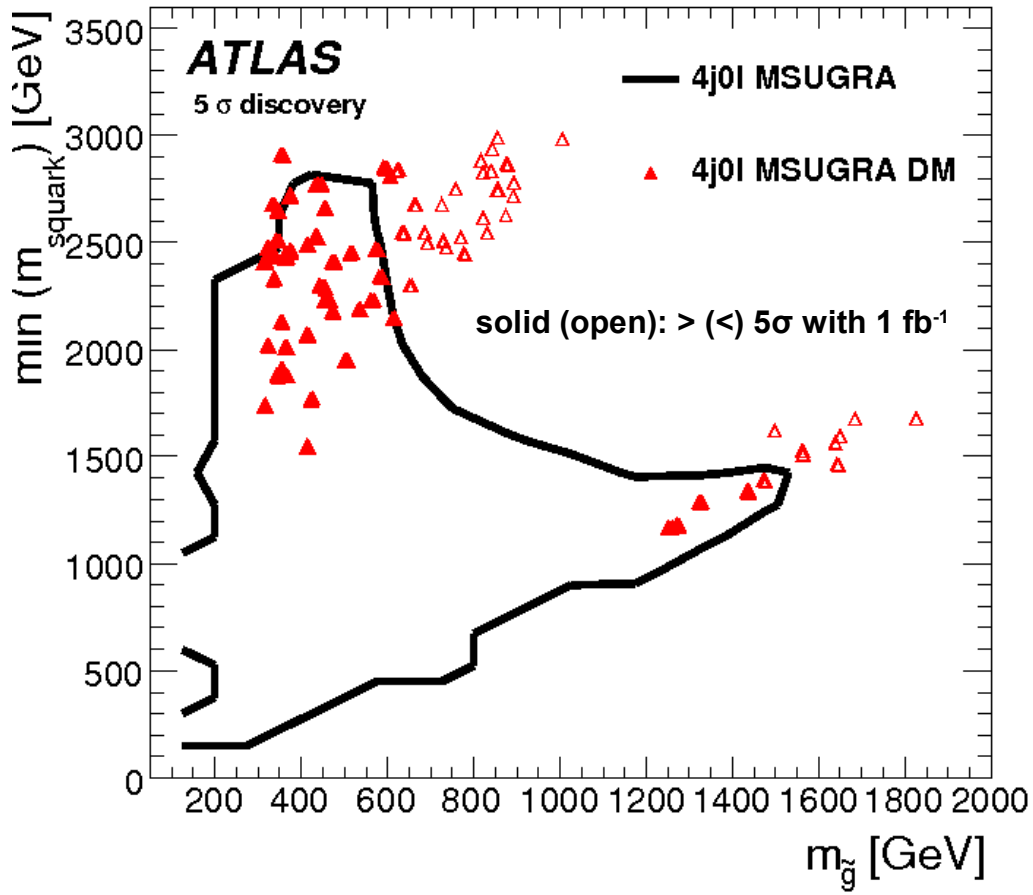
4-jet requirement seems best in 0-lepton mode

Comparable reach vs jet multiplicity in 1-lepton channel (also OS dilepton)

mSUGRA random scan

Similar reach compared to results without DM and other constraints

Sensitivity is mainly driven by $\tilde{g}$ and $\tilde{q}$ masses



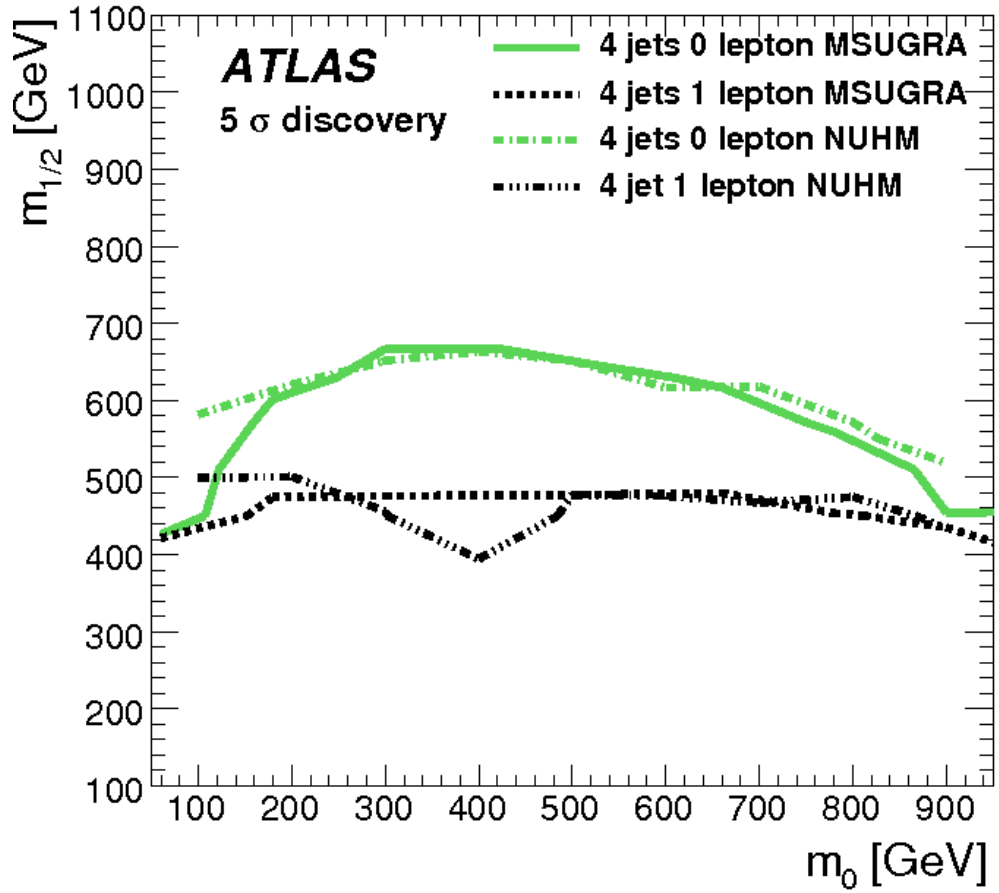
NUHM parameter scan

NUHM model:

similar to mSUGRA but doesn't assume that m(Higgs) ≈ m(squark,slepton) at the GUT scale

Scan $m_{½}$ vs m_0

For each point, adjust μ and M_A to be consistent with DM constraints



Similar sensitivity to mSUGRA

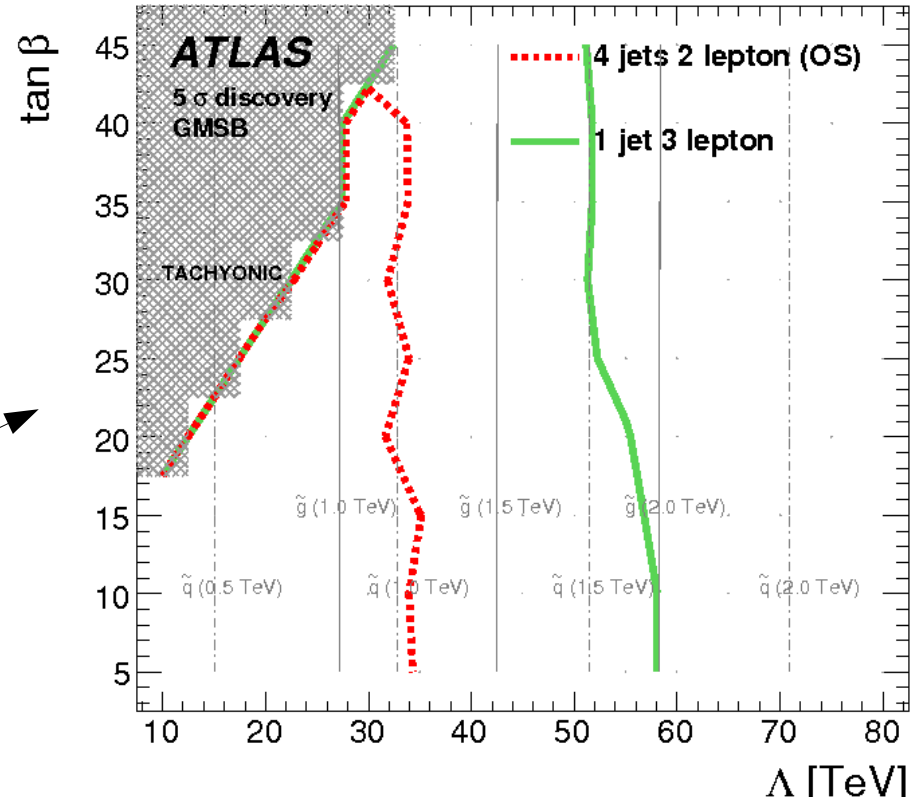
GMSB parameter scans

N_{mess} = 5: all events have ≥ 2 leptons or taus

Scan in tanβ vs Λ plane

C_{grav} = 1, M_{mess} = 500 GeV

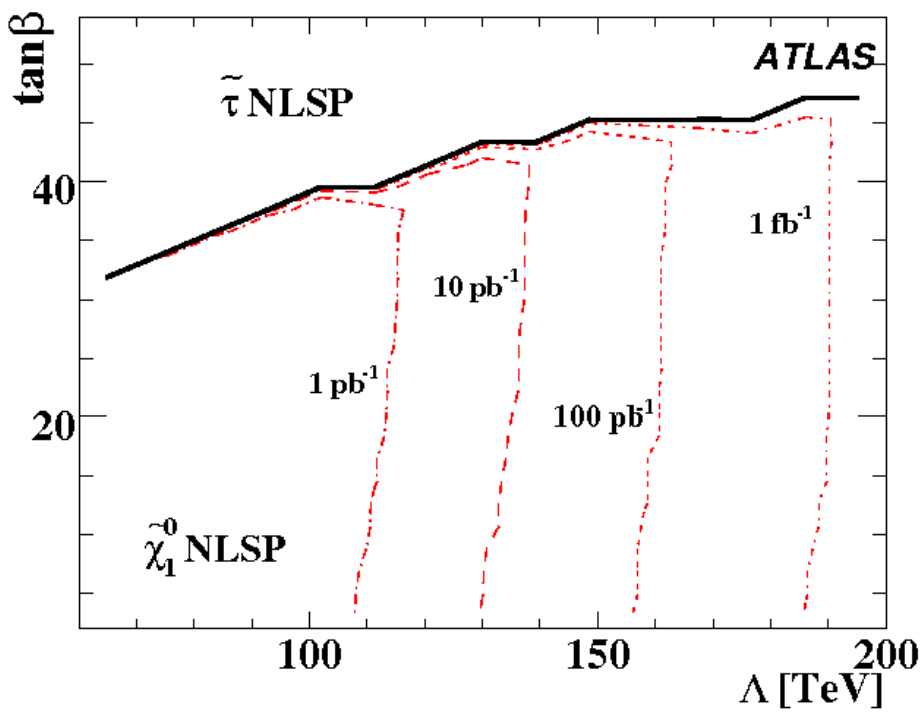
3-lepton reach (for 1 fb^{-1}) is close to 2 TeV for all tanβ



N_{mess} = 1: neutralino NLSP, decaying promptly to $\tilde{G}$ + γ

Scan in tanβ vs Λ plane

C_{grav} = 1, M_{mess} = 500 GeV



How can we discover SUSY in 2009

ATLAS sensitivity to SUSY via inclusive searches has been studied for a wide variety of signatures involving combinations of jets, leptons (e,μ,τ), missing Et, bjets, photons and long-lived particles

Studies were based on full simulation of Standard Model backgrounds and a number of SUSY benchmark points.

Supplemented by parameter scans of mSUGRA, NUHM and minimal GMSB models, using fast (parametrized) simulations

With 1 fb^{-1} of integrated luminosity, and assuming 50% (20%) systematic uncertainty on QCD multijet (W/Z + jet) backgrounds, ATLAS should be able to observe squarks and gluinos with a mass up to 1-1.5 TeV. Observation of an excess in several different inclusive searches is possible in many generic scenarios.

Many of the benchmark points can be discovered with 100 pb^{-1} (assuming the same systematic uncertainty on bkg as 1 fb^{-1})

Whether or not this will happen in 2009 remains to be seen.