SUSY Parameters Determination with ATLAS

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On behalf of the ATLAS collaboration

Outline

- Introduction
- ATLAS Detector
- mSUGRA Framework
- Mass Measurement Techniques
  - Dilepton endpoint
  - Lepton+jet endpoint
  - Ditau endpoint
  - Right handed squark mass
  - Other mass measurements
- mSUGRA Parameters Determination
- Spin Measurements
  - Neutralino spin measurements
  - Slepton spin measurements
- Conclusions

Introduction

- Discovering Supersymmetry (SUSY) is one of the goals for building the Large Hadron Collider (LHC).
- ATLAS is one of the two general purpose experiments at LHC.
- Current SUSY search activities in ATLAS focus on preparing for data in 2008:
  - Computing System Commissioning (CSC) exercise (results to be published this fall)
    - Study SUSY breaking models: mSUGRA, GMSB, AMSB
    - Choose benchmark points for full detector simulation to understand detector performance, systematics, trigger
    - Focus on data-driven background estimation and early discovery
- In this talk I'll concentrate on SUSY mass and spin measurements within mSUGRA framework.

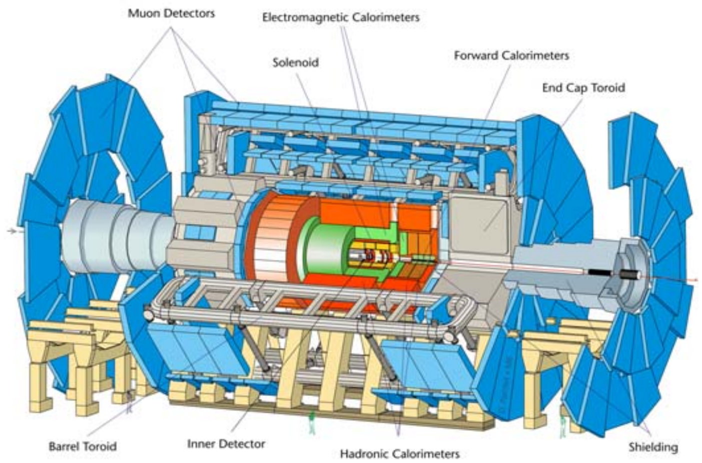
ATLAS - A Toroidal LHC ApparatuS

- LHC's schedule:
  - All technical systems commissioned to 7 TeV operation, and machine closed April 2008
  - Beam commissioning starts May 2008
  - First collisions at 14 TeV - July 2008
  - Pilot run pushed to 156 bunches for reaching 10^{32} $cm^{-2}s^{-1}$ by end 2008
- Luminosity goals:
  - 100 pb^{-1}: a few days of running
  - 1 fb-1: first run ~1-2 months
  - 10 fb^{-1}: first year at initial luminosity

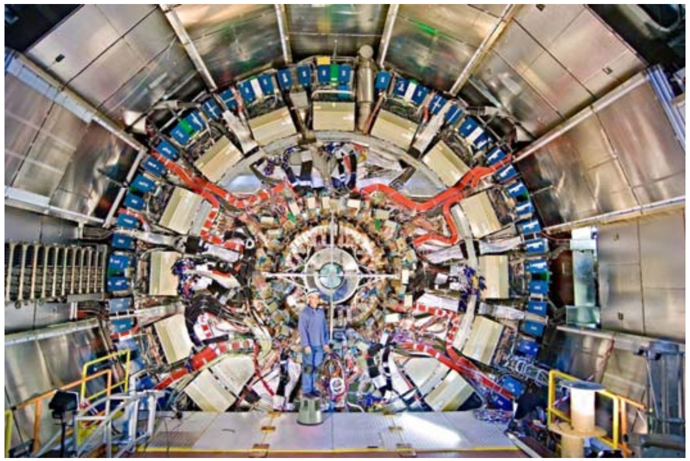
  Initial luminosity: 10^{33} $cm^{-2}s^{-1}$, 10 fb^{-1}/year

  Design luminosity: 10^{34} $cm^{-2}s^{-1}$, 100 fb^{-1}/year
- Early discovery with 1 fb^{-1} at $10^{31\text{-}32}$ $cm^{-2}s^{-1}$:
  - QCD jets and dijets at high E_T
  - high mass lepton pairs
  - Higgs → WW → $ll\nu\nu$
  - Low mass SUSY

  (not a complete list)



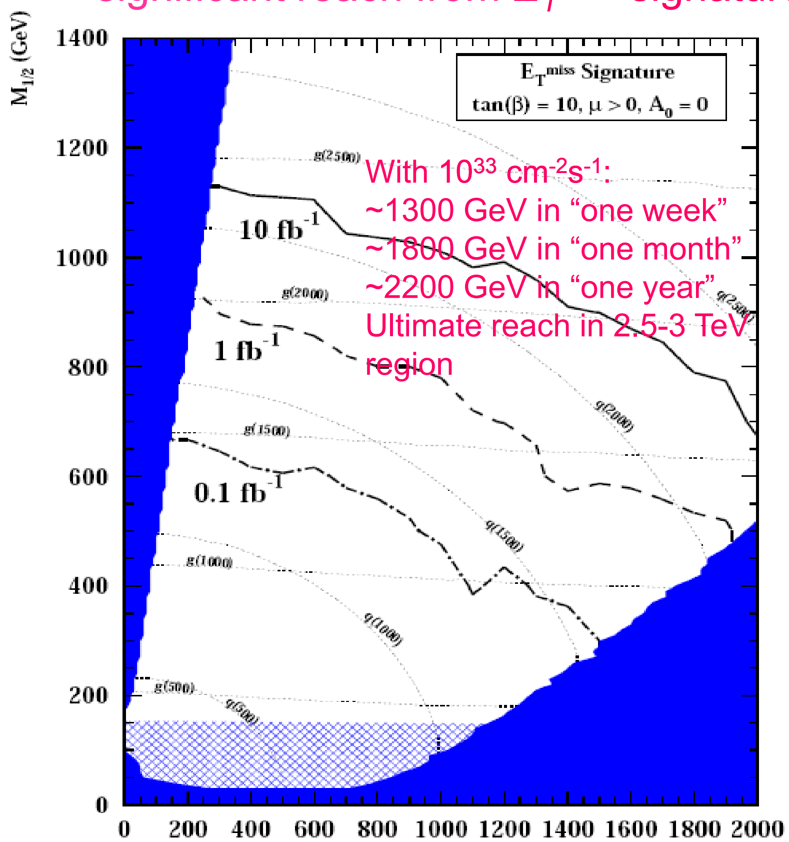
Diameter	**25 m**
Barrel toroid length	**26 m**
End-cap end-wall chamber span	**46 m**
Overall weight	**7000 Tons**



mSUGRA Framework

- The minimal SUSY extension of the SM (MSSM) brings 105 additional free parameters → preventing a systematic study of the full parameter space.
- Assume a specific well-motivated model framework in which generic signatures can be studied.
- mSUGRA framework: Assume SUSY is broken by gravitational interactions → unified masses and couplings at GUT scale → gives five free parameters: m_0, $m_{1/2}$, A_0, $\tan(\beta)$, $\mathrm{sgn}(\mu)$
- Reach sensitivity only weakly dependent on A_0, $\tan(\beta)$, $\mathrm{sgn}(\mu)$.
- R-parity assumed to be conserved: $R=(-1)^{3B+L+2S}$.
  - SUSY particles are produced in pairs
  - LSP (Lightest SUSY Particle) stable, escapes the detector → missing transverse energy.
- Multiple signatures on most of parameter space: E_T^{miss} (dominant signature), E_T^{miss} with lepton veto, one lepton, two leptons same sign (SS), two leptons opposite sign (OS)

significant reach from E_T^{miss} signature



5σ exclusion contours

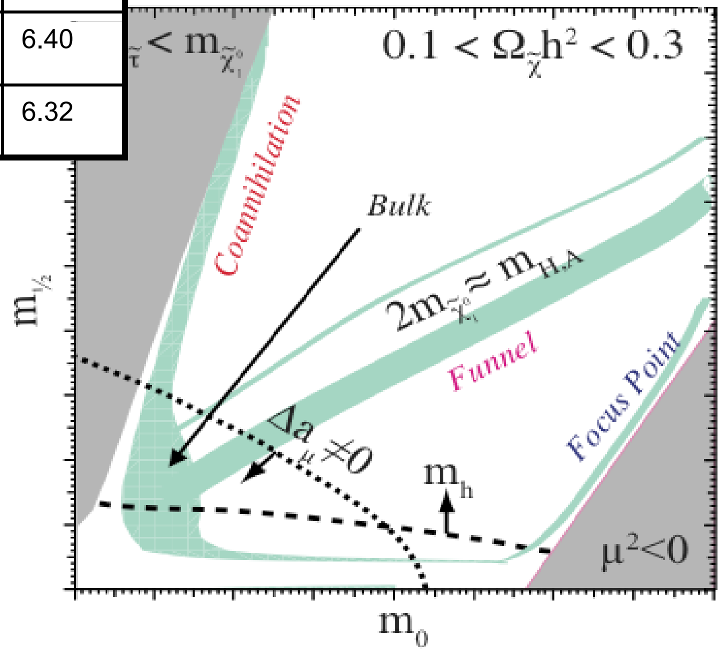
mSUGRA Points in CSC Production

Point	m_0 (GeV)	$m_{1/2}$ (GeV)	A_0 (GeV)	tan(β)	sign(μ)	σ (pb)
Coannihilation - SU1	70	350	0	10	+	7.43
Focus Point - SU2	3550	300	0	10	+	4.86
Bulk - SU3	100	300	-300	6	+	18.59
Low Mass - SU4	200	160	-400	10	+	262
Funnel - SU6	320	375	0	50	+	4.48
Coannihilation - SU8.1	210	360	0	40	+	6.44
Coannihilation - SU8.2	215	360	0	40	+	6.40
Coannihilation - SU8.3	225	360	0	40	+	6.32

ISAJET 7.71, m(top) = 175 GeV
http://www.usatlas.bnl.gov/twiki/bin/view/Projects/AtlasSusyPoints

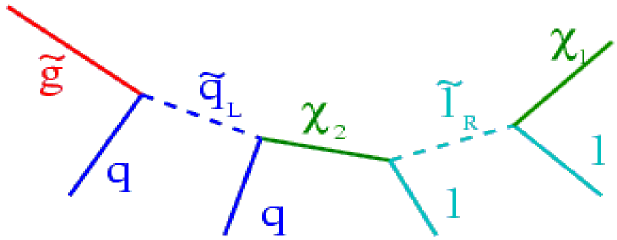
Choose benchmark points in mSUGRA plane to study SUSY exclusively

qualitative picture – no mass scale



- Post WMAP value of $\Omega_M h^2 = 0.14 \pm 0.01$ constrains mSUGRA parameter space.
- Four different annihilation mechanisms can yield correct relic abundance: coannihilation, bulk, funnel, focus point

Mass Measurement Techniques



First decay chain to be reconstructed:

$$\tilde{q}_L \rightarrow q\,\tilde{\chi}_2^0 \rightarrow q\,\tilde{l}_R\,l^{\pm} \rightarrow q l^{\pm} l^{\mp} \tilde{\chi}_1^0$$

- R-parity conservation: SUSY events containing two LSP's which escape the detector. Since LSP's are not detected, we measure kinematic endpoints in invariant mass distributions rather than mass peaks.
- Mass measurement strategy → exploit kinematics of long decay chains.
- $\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{l}_R, \tilde{q}_L, \tilde{q}_R$ masses: kinematic endpoints and stransverse mass
- $\tilde{g}, \tilde{b}_1, \tilde{b}_2$ masses near dilepton endpoint and the mass relation method
- From measurements to model parameters
- Examples of mass measurements in the next slides

Related edge	Kinematic endpoint
l^+l^- edge	$(m_{ll}^{\max})^2 = (\tilde{\xi}-\tilde{l})(\tilde{l}-\tilde{\chi})/\tilde{l}$
l^+l^-q edge	$(m_{llq}^{\max})^2 = \begin{cases} \max\left[\frac{(\tilde{q}-\tilde{\xi})(\tilde{\xi}-\tilde{\chi})}{\tilde{\xi}}, \frac{(\tilde{q}-\tilde{l})(\tilde{l}-\tilde{\chi})}{\tilde{l}}, \frac{(\tilde{q}\tilde{l}-\tilde{\xi}\tilde{\chi})(\tilde{\xi}-\tilde{l})}{\tilde{\xi}\tilde{l}}\right] \\ \text{except for the special case in which } \tilde{l}^2 < \tilde{q}\tilde{\chi} < \tilde{\xi}^2 \text{ and} \\ \tilde{\xi}^2\tilde{\chi} < \tilde{q}\tilde{l}^2 \text{ where one must use } (m_{\tilde{q}} - m_{\tilde{\chi}_1^0})^2. \end{cases}$
Xq edge	$(m_{Xq}^{\max})^2 = X + (\tilde{q}-\tilde{\xi})\left[\tilde{\xi}+X-\tilde{\chi}+\sqrt{(\tilde{\xi}-X-\tilde{\chi})^2-4X\tilde{\chi}}\right]/(2\tilde{\xi})$
l^+l^-q threshold	$(m_{llq}^{\min})^2 = \begin{cases} [\ 2\tilde{l}(\tilde{q}-\tilde{\xi})(\tilde{\xi}-\tilde{\chi})+(\tilde{q}+\tilde{\xi})(\tilde{\xi}-\tilde{l})(\tilde{l}-\tilde{\chi}) \\ -(\tilde{q}-\tilde{\xi})\sqrt{(\tilde{\xi}+\tilde{l})^2(\tilde{l}+\tilde{\chi})^2-16\tilde{\xi}\tilde{l}^2\tilde{\chi}}\ ]/(4\tilde{l}\tilde{\xi}) \end{cases}$
$l^{\pm}_{\text{near}}q$ edge	$(m_{l_{\text{near}}q}^{\max})^2 = (\tilde{q}-\tilde{\xi})(\tilde{\xi}-\tilde{l})/\tilde{\xi}$
$l^{\pm}_{\text{far}}q$ edge	$(m_{l_{\text{far}}q}^{\max})^2 = (\tilde{q}-\tilde{\xi})(\tilde{l}-\tilde{\chi})/\tilde{l}$
$l^{\pm}q$ high-edge	$(m_{lq(\text{high})}^{\max})^2 = \max\left[(m_{l_{\text{near}}q}^{\max})^2, (m_{l_{\text{far}}q}^{\max})^2\right]$
$l^{\pm}q$ low-edge	$(m_{lq(\text{low})}^{\max})^2 = \min\left[(m_{l_{\text{near}}q}^{\max})^2, (\tilde{q}-\tilde{\xi})(\tilde{l}-\tilde{\chi})/(2\tilde{l}-\tilde{\chi})\right]$
M_{T2} edge	$\Delta M = m_{\tilde{l}} - m_{\tilde{\chi}_1^0}$

Table 4: The absolute kinematic endpoints of invariant mass quantities formed from decay chains of the types mentioned in the text for known particle masses. The following shorthand notation has been used: $\tilde{\chi} = m^2_{\tilde{\chi}_1^0}, \tilde{l} = m^2_{\tilde{l}_R}, \tilde{\xi} = m^2_{\tilde{\chi}_2^0}, \tilde{q} = m^2_{\tilde{q}}$ and X is m^2_h or m^2_Z depending on which particle participates in the "branched" decay.

Allanach *et al*., JHEP 09 (2000) 004

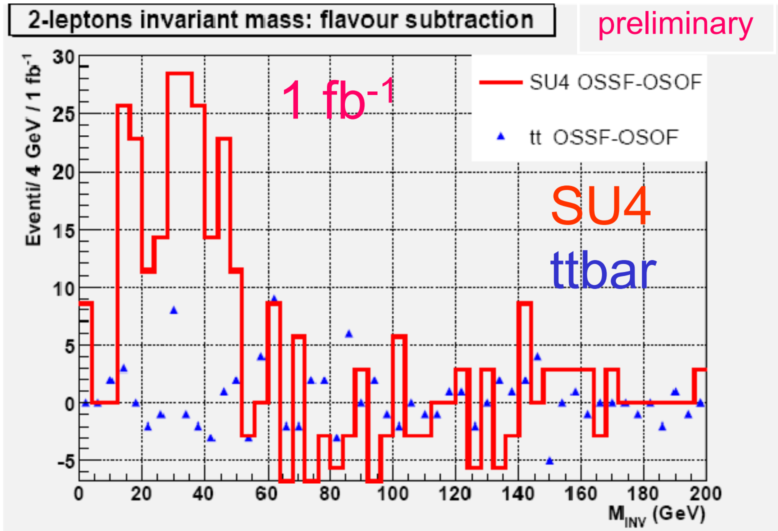
Dilepton Endpoint

$$\tilde{\chi}_2^0 \to \tilde{l}^{\pm} l^{\mp} \to \tilde{\chi}_1^0 l^{\pm} l^{\mp}$$

$$M_{ll}^{\max} = \sqrt{\frac{(M_{\tilde{\chi}_2^0}^2 - M_{\tilde{l}}^2)(M_{\tilde{l}}^2 - M_{\tilde{\chi}_1^0}^2)}{M_{\tilde{l}}^2}}$$

Point SU4 and ttbar

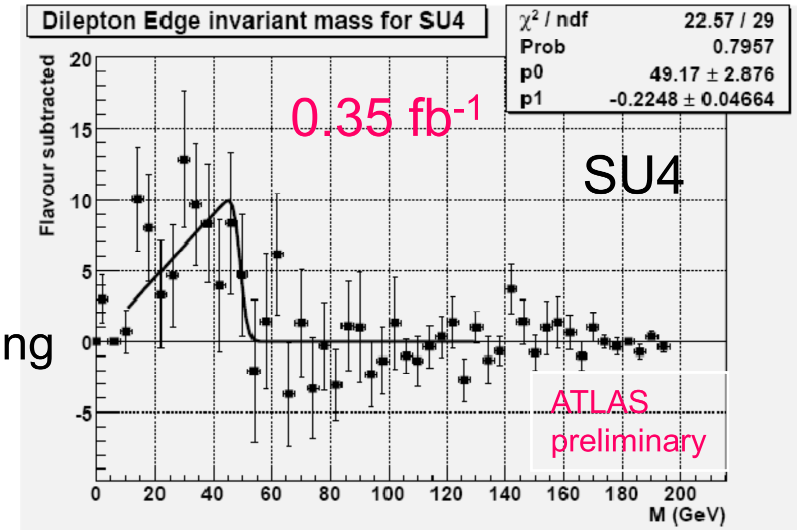
$$M(e^{\pm}e^{\mp}) + M(\mu^{\pm}\mu^{\mp}) - M(e^{\pm}\mu^{\mp})$$



- Event selection:
  - at least 4 jets (Cone4) in event
  - p_T(jet1) > 100 GeV, p_T(jet4) > 50 GeV
  - E_T^{miss} > 120 GeV
  - M^{eff} > 550 GeV $\quad M^{eff} = E_T^{miss} + \sum_{jet} E_{T,jet}$
  - 2 leptons with:
    - p_T > 10 GeV, $|\eta|$ < 2.5
    - isolation cut E_T < 5GeV in 0.3 cone
- Signal significance is 16.5 for 100 pb^{-1}

$$Significance = \sqrt{2((S+B)\cdot \ln(1+\frac{S}{B})-S)}$$

- Flavor subtraction is applied (OSSF-OSOF) to remove SUSY/SM background
- Fit: triangular distribution with a Gaussian smearing
- Expected endpoint: 53.7 GeV
- Fitted endpoint: 49.2 ± 2.9 GeV (1.6σ within expected value)



Full simulation

Lepton+Jet Endpoint

$$\tilde{q}_L \rightarrow q\tilde{\chi}_1^{\pm} \rightarrow q l^{\pm}\tilde{\nu}_l \rightarrow q l^{\pm}\nu_l\tilde{\chi}_1^0$$

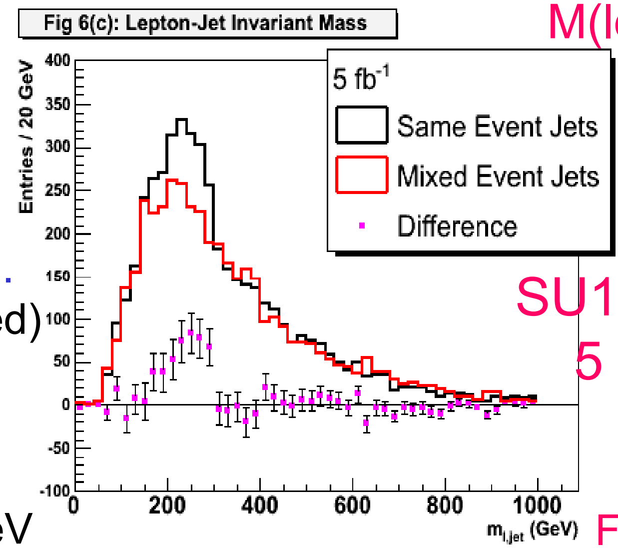
$$M_{lq}^{\max} = \sqrt{\frac{(M_{\tilde{q}_L}^2 - M_{\tilde{\chi}_1^{\pm}}^2)(M_{\tilde{\chi}_1^{\pm}}^2 - M_{\tilde{\nu}_l}^2)}{M_{\tilde{\chi}_1^{\pm}}^2}}$$

Point SU1 and ttbar

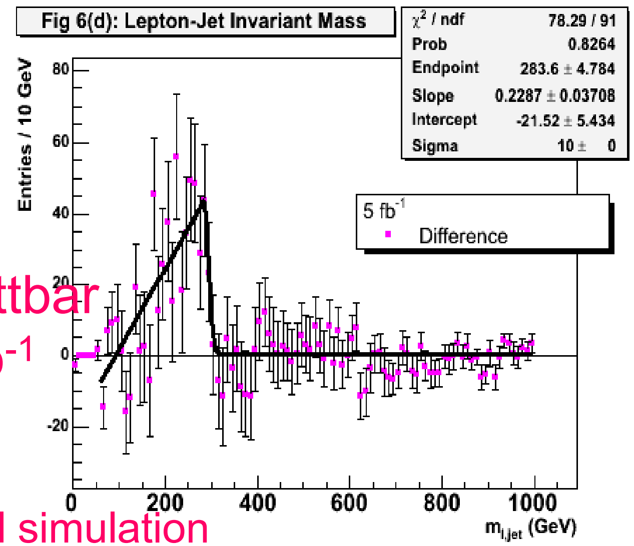
Event selection:

- one lepton (electron, muon) p_T > 20 GeV, |η|<2.5, chi2/dof<10 for muon
- EMlikelihood > 0.95, lepton isolation cut E_T < 10GeV in 0.45 cone
- Cone7 (R=0.7) jets, ΔR(lepton,jet) > 0.7
- to reduce lepton+jets and dilepton ttbar background:
  - leading and second leading jet with E_T > 200 GeV
  - transverse mass M_T < 60 GeV or M_T > 100 GeV
  - E_T^{miss} > 250 GeV

- Use mixed event technique to subtract combinatorial jet background: randomly pair jets from a different event (satisfying same event selection) with the lepton.
- Assumptions of the technique:The jet from signal decay chain and the jet from the decay of the other squark have similar kinematic distributions. And the squarks are produced at rest so the event is roughly spherical. Both are valid for SU1 but not for ttbar.
- Subtract mixed-event-jet distributions from same-event-jets distribution to obtain an inferred "correct jet" distribution. (normalization correction applied)
- Statistical significance of discovery is 5σ with 5 fb^{-1}.
- Expected endpoint: 284 GeV
- Fitted endpoint: 283.6±4.8 GeV



M(lq)



SU1+ttbar
5 fb^{-1}

Full simulation

Atlas note: Cooke *et.al* ATL-COM-PHYS-2007-002

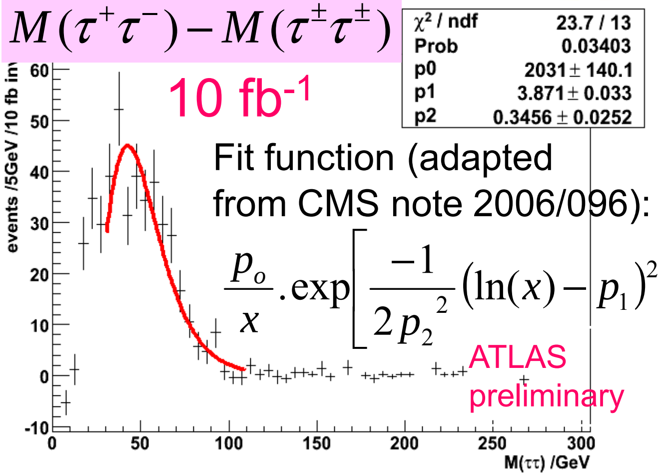
Ditau Endpoint

$$\tilde{\chi}_2^0 \rightarrow \tilde{\tau}_1^{\pm}\tau^{\mp} \rightarrow \tilde{\chi}_1^0 \tau^{\pm}\tau^{\mp}$$

$$M_{\tau\tau}^{\max} = \sqrt{\frac{(M^2_{\tilde{\chi}_2^0} - M^2_{\tilde{\tau}_1})(M^2_{\tilde{\tau}_1} - M^2_{\tilde{\chi}_1^0})}{M^2_{\tilde{\tau}_1}}}$$

Point SU3 and BG: Z+jets,W+jets, ttbar, bb+jets, dijets, multijets

$M(\tau^+\tau^-) - M(\tau^{\pm}\tau^{\pm})$

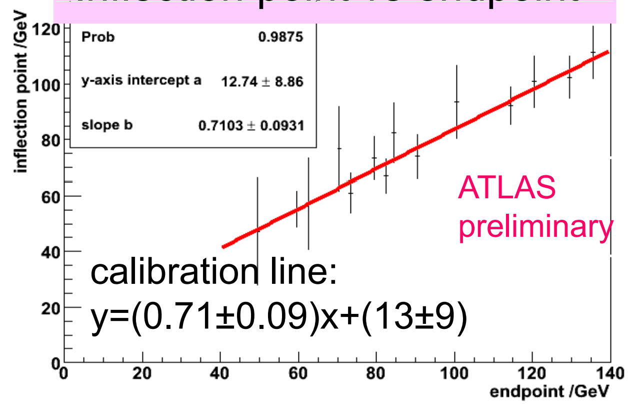


$$\frac{p_o}{x}.\exp\left[\frac{-1}{2p_2^{\,2}}(\ln(x)-p_1)^2\right]$$

$$x_{IP} = \exp\left[\frac{1}{2}p_2^{\,2}\left(3+\sqrt{(1+\frac{4}{p_2^{\,2}})}\right)+p_1\right]$$

- Focus on hadronic decays since LHC vertex detectors cannot cleary identify $\tau \rightarrow l\nu\nu$
- Event selection:
  - E_T^{miss} > 230 GeV
  - at least 4 jets with p_T > 30 GeV, at least 3 jets with p_T > 50 GeV, at least 1 jet with p_T > 220GeV
  - ΔR(tau,tau) < 2
- Linear fit: endpoint susceptible to fit range. And bad approximation of shape at the edge.
- New approach: approximate shape, extract endpoint from other trait. Measure inflection point (x_{IP}):
  - more stable to change of fitting range or binning
  - need calibration for endpoint:
    - change involved masses (see in backup slide)
    - measure inflection point as function of known endpoint

Inflection point vs endpoint



- Expected endpoint: 98.3 GeV. Fitted endpoint: ($97 \pm 9^{stat} \pm 6^{syst}$) GeV

Fast simulation

Right Handed Squark Mass

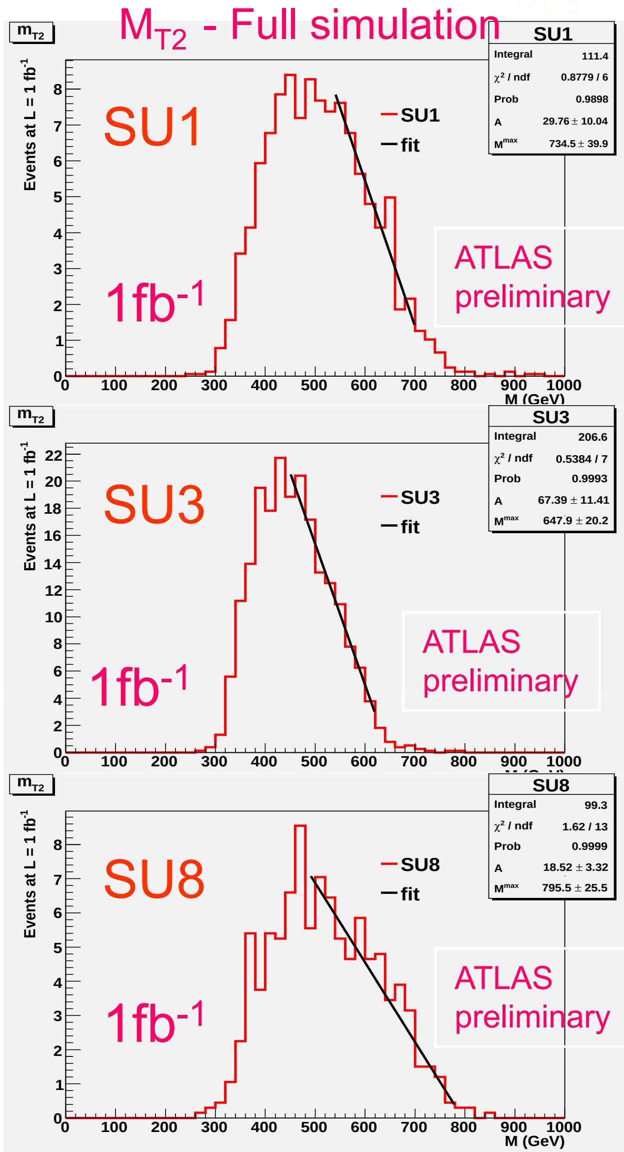
- in mSUGRA large branching ratio for $\tilde{q}_R \to \tilde{\chi}_1^0 q$
- Signal is two hard jets plus large E_T^{miss}
- Event selection:
  - no electron, muon, tau and no b-jets
  - at least 2 jets (light jets)
  - p_T(jet1), p_T(jet2) > max(200GeV, 0.25M^{eff})
  - |η(jet1)|, |η(jet2)| < 2, ΔR(jet1,jet2) > 0.1
  - E_T^{miss} > max(200GeV, 0.25M^{eff}) GeV
  - transverse sphericity S_T > 0.2
- Calculate the stransverse mass of the two hard jets w.r.t E_T^{miss} of the event. The endpoint gives the mass of right-handed squark:

Points SU1, SU3, SU8.1 and BG

$$M_{T2}^2 \equiv \min_{\not{p}_{T,1}+\not{p}_{T,2}=\not{p}_T} \{\max[M_T(p_{T,j1},\not{p}_{T,1}), M(p_{T,j2},\not{p}_{T,2})]\}$$

	$\tilde{q}_R$ mass in GeV		
	SU1	SU3	SU8
Expected mass	735	637	773
Mass from linear fit	735±40	648±20	796±26

S/√B at 100 pb^{-1}	4.36	8.09	3.89



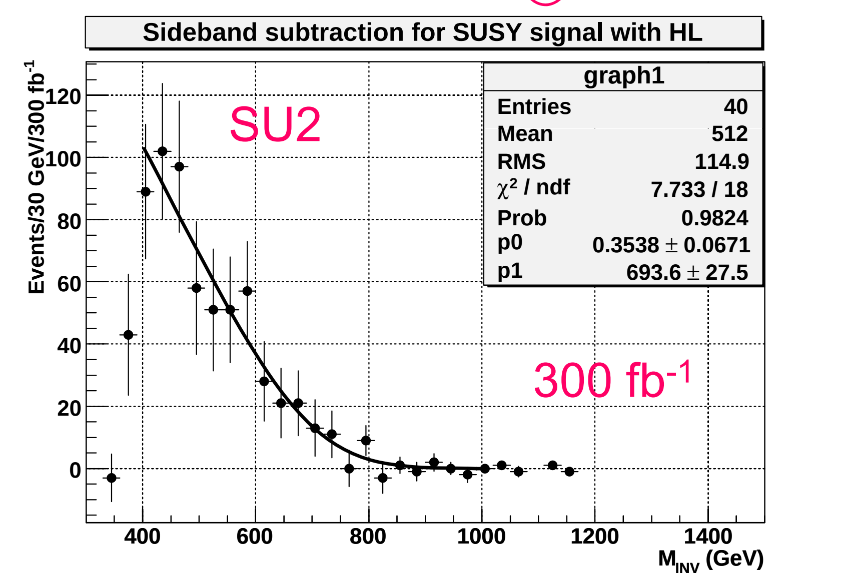
stransverse mass: Lester *et al.*, Phys.Lett. B463 (1999) 99

More Mass Measurements

Two examples from the reconstruction of gluino decays.

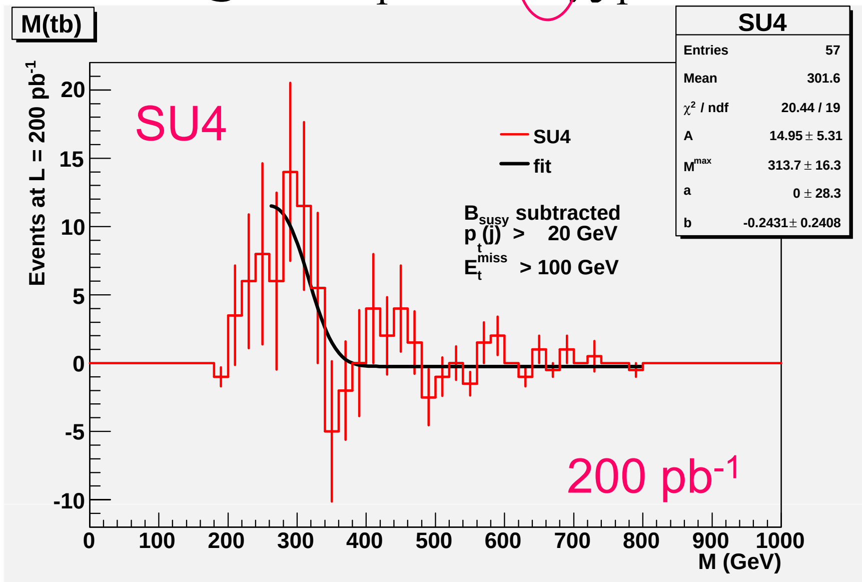
Points SU2, SU4 and BG

$$\tilde{g} \to \tilde{\chi}_2^0 t\bar{t}$$



Fast simulation $M(t\bar{t})$

$$\tilde{g} \to \tilde{t}_1 t \to tb\tilde{\chi}_1^\pm$$



Full simulation $M(tb)$

- Expected endpoint: 696 GeV.
- Fitted endpoint: (694 ± 28) GeV
- Details in:

Atlas Note: De Sanctis *et al.* SN-ATLAS-2007-062

- Expected endpoint: 300 GeV.
- Fitted endpoint: (314 ± 16) GeV
- Details in:

Atlas Note: Krstic *et al.* ATL-PHYS-PUB-2006-028

mSUGRA Parameters Determination – An Example

From a given set of mass measurements one can perform a fit of the mSUGRA parameters.

Variable	Value (GeV)	Errors Stat. (GeV)	Scale (GeV)	Total
$m_{\ell\ell}^{max}$	77.07	0.03	0.08	0.08
$m_{\ell\ell q}^{max}$	428.5	1.4	4.3	4.5
$m_{\ell q}^{low}$	300.3	0.9	3.0	3.1
$m_{\ell q}^{high}$	378.0	1.0	3.8	3.9
$m_{\ell\ell q}^{min}$	201.9	1.6	2.0	2.6
$m_{\ell\ell b}^{min}$	183.1	3.6	1.8	4.1
$m(\ell_L) - m(\tilde{\chi}_1^0)$	106.1	1.6	0.1	1.6
$m_{\ell\ell}^{max}(\tilde{\chi}_4^0)$	280.9	2.3	0.3	2.3
$m_{\tau\tau}^{max}$	80.6	5.0	0.8	5.1
$m(\tilde{g}) - 0.99 \times m(\tilde{\chi}_1^0)$	500.0	2.3	6.0	6.4
$m(\tilde{q}_R) - m(\tilde{\chi}_1^0)$	424.2	10.0	4.2	10.9
$m(\tilde{g}) - m(\tilde{b}_1)$	103.3	1.5	1.0	1.8
$m(\tilde{g}) - m(\tilde{b}_2)$	70.6	2.5	0.7	2.6

SPS1a point, 300 fb^{-1} , Fast simulation

Atlas Note: Gjelsten *et.al.* ATL-PHYS-2004-007

Fit using SFITTER program:
(R. Lafaye, T. Plehn, D. Zerwas, hep-ph/0512028)

	SPS1a	Δmasses	Δedges
m_0	100	3.9	**1.2**
$m_{1/2}$	250	1.7	**1.0**
tanβ	10	1.1	**0.9**
A_0	-100	33	**20**

Sign(μ) fixed

- A first determination of the parameters with a precision at the percent level.
- Note that the precision can be improved significantly by using the measured edges, thresholds and mass differences in the fit instead of the masses.

Neutralino Spin Measurements

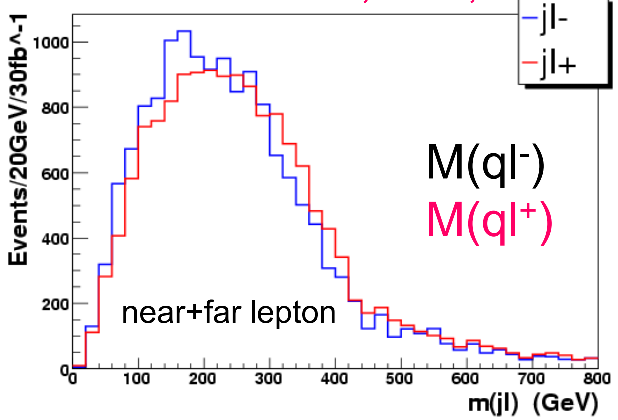
- If SUSY signals are observed at the LHC, it will be vital to measure the spins of the new particles to demonstrate that they are indeed the predicted super-partners.
- In left squark decay chain: due to neutralino spin ½, angular distribution of slepton is not spherically symmetric and invariant mass $M(ql^{\pm}_{near})$ is charge asymmetric:

$$\tilde{q}_L \rightarrow q\,\tilde{\chi}^0_2 \rightarrow q\,\tilde{l}_R\,l^{\pm}_{near} \rightarrow q l^{\pm}_{far} l^{\mp} \tilde{\chi}^0_1$$

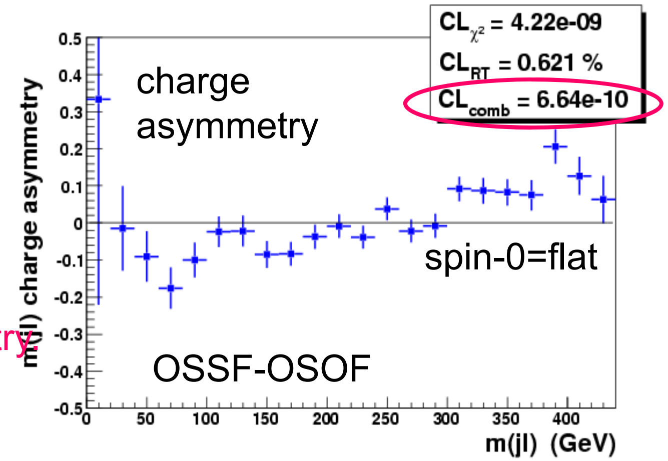
spin-0 spin-1/2 spin-0

Charge asymmetry: $A^{+-} = \dfrac{s^+ - s^-}{s^+ + s^-}$ $\quad s^{\pm} = \dfrac{d\sigma}{d(m_{ql^{\pm}})}$

Fast simulation, SU3, 30 fb^{-1}



- Asymmetry is suppressed by squark/antisquark cancellation, but at LHC much more squark than antisquark will be produced.
- Event selection:
  - E_T^{miss} > 100 GeV
  - at least 4 jets (Cone4) with p_T > 100, 50, 50, 50 GeV
  - Two OS leptons (electron, muon) with p_T > 10 GeV, $|\eta|$ < 2.5
  - isolation cut E_T < 10 GeV in 0.2 cone
- Effect on asymmetry due to SM background is found to be negligible.
- Low confidence level (<10^{-9}) ⇒ good evidence of a non-zero asymmetry.
- 10 fb^{-1} would be sufficient to detect charge asymmetry.



A. J. Barr, Phys. Lett. B596 (2004) 205

ATLAS note: M. Biglietti *et al*. ATL-PHYS-PUB-2007-004

Slepton Spin Measurements

- A new method for measuring the spin of sleptons using an angular variable which is sensitive to the polar angle in direct slepton pair production:

$q\bar{q} \rightarrow Z^0/\gamma \rightarrow \tilde{l}^+\tilde{l}^- \rightarrow \tilde{\chi}_1^0 l^+ \tilde{\chi}_1^0 l^-$ SUSY

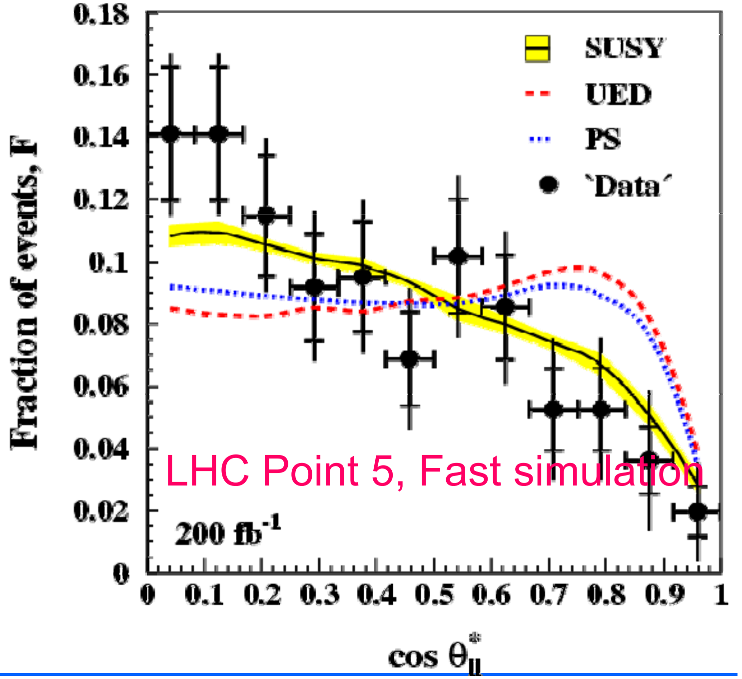
$q\bar{q} \rightarrow Z^0/\gamma \rightarrow l_1^+ l_1^- \rightarrow \gamma_1 l^+ \gamma_1 l^-$ UED

- The angular variable $\cos\theta_{ll}^*$ is interpreted as the cosine of the polar angle between each lepton and the beam axis in the longitudinally boosted frame in which the pseudorapidities of the leptons are equal and opposite: $\cos\theta_{ll}^* = \cos(2\tan^{-1} e^{-\frac{1}{2}\Delta\eta}) = \tanh(\frac{1}{2}\Delta\eta)$

- $\cos\theta_{ll}^*$ is on average smaller for SUSY than for UED (Universial Extra Dimensions) so it can be employed as a spin-discriminant in slepton/KK-lepton pair production in hadron colliders.

- Event selection: Two OSSF electrons or muons, E_T^{miss} > 100 GeV, $p_T(l_1)$ > 40 GeV, $p_T(l_2)$ >30 GeV, M_{ll} <150 GeV, M_{T2}<100GeV, no jet with p_T > 100 GeV, no b-jets, transverse recoil < 100 GeV.

- LHC Point 5, SPS1a, SPS1b, SPS3, SPS5 points allow slepton spin determination with 100-300 fb^{-1}.



A. J. Barr, J. High Energy Phys. 02 (2006) 042

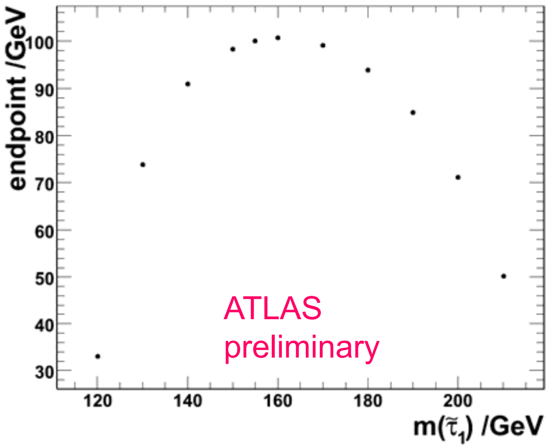
Conclusions

- LHC brings experimental physics into a new territory.
- ATLAS is the place to discover the SUSY particles if they exist.
- Understanding the detector response and the Standard Model (SM) background will be a challenge at the beginning.
- Current CSC activities provide fully simulated data to the performance and physics groups. Excellent opportunity to study SUSY models, SM backgrounds, detector performance, systematics in detail.
- Lots of techniques exist to measure the masses (edges, thresholds, mass differences) and spin of SUSY particles and to determine the underlying model parameters with a few fb^{-1} data, one year of running at low luminosity.
- Waiting for the data at LHC!

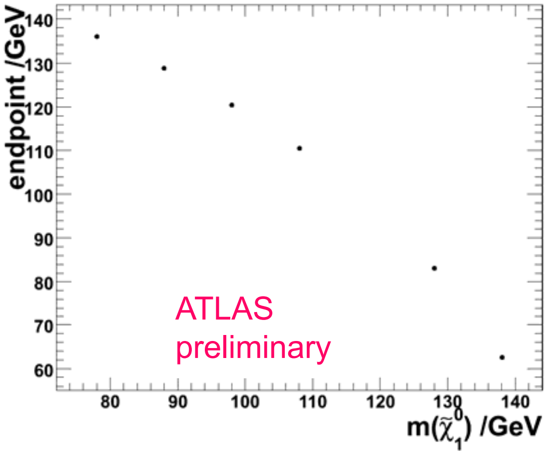
Backup Slides

Ditau endpoint versus masses involved

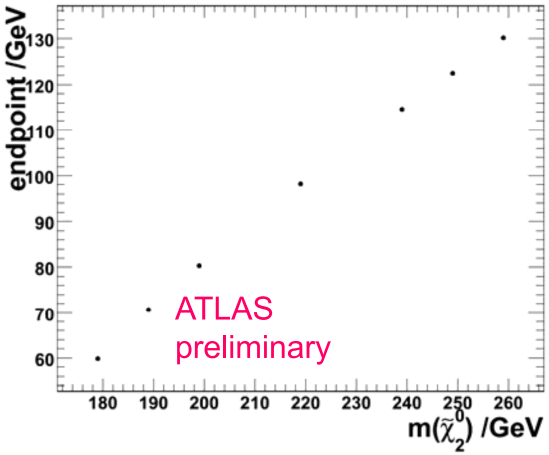
Endpoint vs M(stau1)



Endpoint vs M(Chi10)



Endpoint vs M(Chi20)



Point SU1

$$\sigma(\tilde{q}_R\tilde{g}) = 1.757\ pb\ ,\quad \sigma(\tilde{q}_L\tilde{g}) = 1.620\ pb\ ,$$
$$\sigma(\tilde{q}_L\tilde{q}_R) = 0.885\ pb\ ,\quad \sigma(\tilde{q}_L\tilde{q}_L) = 0.665\ pb\ ,$$
$$\sigma(\tilde{g}\tilde{g}) = 0.554\ pb\ ,\quad \sigma(\tilde{q}_L\tilde{\chi}_2^0) = 0.154\ pb\ .$$

Masses (GeV)

$m_{\tilde{q}_L} = 756$ $\quad m_{\chi_1^\pm} = 262$

$m_{\tilde{\nu}_l} = 240$ $\quad m_{\chi_1^0} = 137$

Branching Ratios

$BR(\tilde{q}_L \to \chi_2^0 q) = 0.32$

$BR(\tilde{q}_L \to \chi_1^\pm q) = 0.65$

$BR(\chi_1^\pm \to \tilde{\nu}_l l^\pm) = 0.20$

$BR(\chi_1^\pm \to \tilde{\nu}_\tau \tau^\pm) = 0.20$

$BR(\chi_1^\pm \to \tilde{\tau}_1^\pm \nu_\tau) = 0.20$

$BR(\chi_1^\pm \to \tilde{l}_L^\pm \nu_l) = 0.04$

$BR(\chi_1^\pm \to W^\pm \chi_1^0) = 0.09$

More Branching Ratios and Masses

$\tilde{\chi}_2^0 \to \tilde{l}_L^{\pm} l^{\mp} \approx 6\%$ $\quad m_{\tilde{\chi}_2^0} - m_{\tilde{l}_L} = 8.5\,GeV$

$\tilde{\chi}_2^0 \to \tilde{l}_R^{\pm} l^{\mp} \approx 3\%$ $\quad m_{\tilde{l}_R} - m_{\tilde{\chi}_1^0} = 17\,GeV$

$\tilde{\chi}_2^0 \to \tilde{\tau}_1^{\pm} \tau^{\mp} \approx 19\%$ $\quad m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} = 9.5\,GeV$

$\tilde{\chi}_2^0 \to \tilde{\tau}_2^{\pm} \tau^{\mp} \approx 2\%$ $\quad m_{\tilde{\chi}_2^0} - m_{\tilde{\tau}_2} = 6.6\,GeV$

small mass splittings, hence soft leptons and taus

Point SU2

$$\sigma(\tilde{\chi}^0\tilde{\chi}^0) = 0.22\ pb$$

$$\sigma(\tilde{\chi}^0\tilde{\chi}^\pm) = 3.06\ pb$$

$$\sigma(\tilde{\chi}^\pm\tilde{\chi}^\pm) = 1.14\ pb$$

$$\tilde{g} \rightarrow \tilde{\chi}^0 t\bar{t} = 27.9\%$$

$$\tilde{g} \rightarrow \tilde{\chi}^+ t\bar{b} = 22\%$$

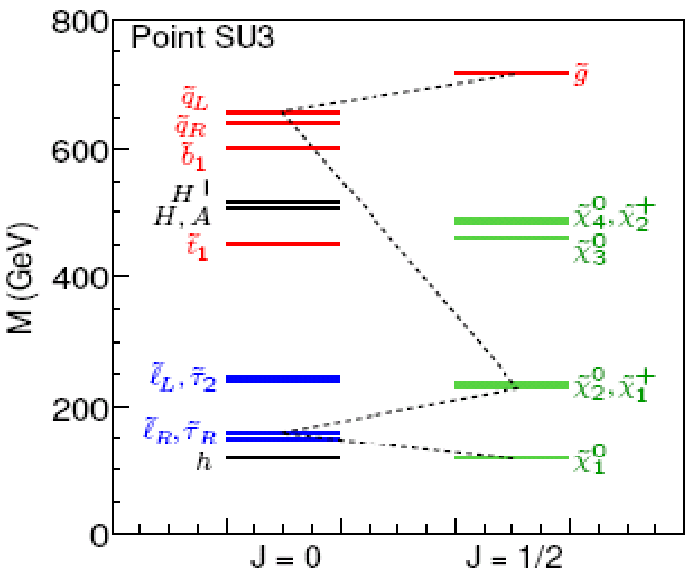
$$\tilde{g} \rightarrow \tilde{\chi}^- \bar{t}b = 22\%$$

$$\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 l^+ l^- = 3.3\%$$

$$\tilde{\chi}_3^0 \rightarrow \tilde{\chi}_1^0 l^+ l^- = 3.8\%$$

Point SU3

$$\sigma(\tilde{q}_R\tilde{g}) = 4.469\ pb\ , \quad \sigma(\tilde{q}_L\tilde{g}) = 4.426\ pb\ ,$$
$$\sigma(\tilde{q}_L\tilde{q}_R) = 2.085\ pb\ , \quad \sigma(\tilde{q}_L\tilde{q}_L) = 1.716\ pb\ ,$$
$$\sigma(\tilde{g}\tilde{g}) = 1.544\ pb\ , \quad \sigma(\tilde{q}_L\tilde{\chi}_2^0) = 0.203\ pb\ .$$



$\tilde{u}_L \to \tilde{\chi}_1^+ d = 65.7\%$ $\quad$ $\tilde{u}_R \to \tilde{\chi}_1^0 u = 99.3\%$

$\tilde{u}_L \to \tilde{\chi}_2^0 u = 32.5\%$ $\quad$ $\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 W^\pm = 28.9\%$

$\tilde{\chi}_2^0 \to \tilde{\tau}_1^\pm \tau^\mp = 75.4\%$ $\quad$ $\tilde{\chi}_2^0 \to \tilde{l}_R^\mp l^\pm = 8.8\%$

$m(\tilde{\chi}_2^0) - m(\tilde{\tau}_1^\pm) = 69\text{GeV}$ $\quad$ $m(\tilde{\chi}_2^0) - m(\tilde{l}_R) = 64\text{GeV}$

$m(\tilde{\tau}_1^\pm) - m(\tilde{\chi}_1^0) = 32\text{GeV}$ $\quad$ $m(\tilde{l}_R) - m(\tilde{\chi}_1^0) = 37\text{GeV}$

Point SU4

$$\sigma(\tilde{g}\tilde{g}) = 56\ pb \quad \sigma(\tilde{q}_L\tilde{q}_L) = 13\ pb$$

$$\sigma(\tilde{g}\tilde{q}_L) = 53\ pb \quad \sigma(\tilde{q}_R\tilde{q}_R) = 11\ pb$$

$$\sigma(\tilde{g}\tilde{q}_R) = 58\ pb \quad \sigma(\bar{t}_1\bar{t}_1) = 30\ pb$$

$$\tilde{g} \to \tilde{b}_1 b = 47\% \quad \tilde{q}_L \to \tilde{\chi}_1^{\pm} q = 65\%$$

$$\tilde{g} \to \tilde{t}_1 t = 42\% \quad \tilde{q}_L \to \tilde{\chi}_2^{0} q = 32\%$$

$$\tilde{q}_R \to \tilde{\chi}_1^{0} q = 98\%$$

$$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 l^+ l^- = 13\%$$

$$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 q\bar{q} = 76\%$$