Early searches for new physics with τ leptons with the ATLAS detector

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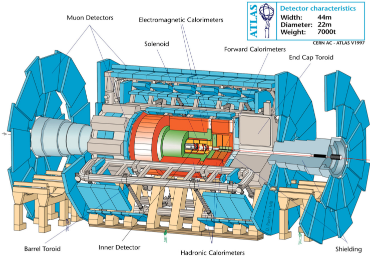
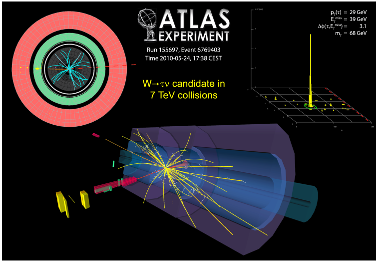
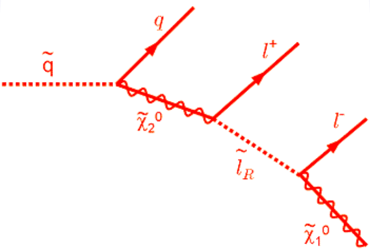
Outline

1. **Reconstruction of**
   - **Jets and E_T^{miss}**
   - **τ Leptons**
2. **Early SUSY searches using data**
   - **Jets + E_T^{miss}**
   - **+ lepton(s)**
3. **Prospects for SUSY discovery**
   - **GMSB with τ at 10 TeV**
   - **MSUGRA with τ at 14 TeV**
4. **Conclusion and Outlook**







1. Reconstruction of Jets, E_T^{miss}, and τ leptons

- topologies of many SUSY scenarios include jets and E_T^{miss}
  - production of heavy squarks $\Rightarrow$ long decay chains with jets
  - if LSP is stable $\Rightarrow$ E_T^{miss}
- often in combination with leptons and/or τ leptons
  - long decay chains often include sleptons $\Rightarrow$ leptons
  - mixing in third family leads in some scenarios to light $\tilde{\tau}_1$ $\Rightarrow$ τ leptons

Jets and Jet Energy Scale

Reconstruction

- anti-k_t algorithm starting from calorimeter topological clusters
- for SUSY searches: $p_T^{jet} > 20$ GeV, $|\eta| < 2.5$
- fakes are expected from calorimeter noise, cosmic rays
- rejection through requirements on energy distribution in calorimeter, energy fraction in electromagnetic calorimeter, timing

Jet Energy Scale (JES)

- reconstructed jets: calibrated to energy scale measured by calorimeters (EM scale)
- EM scale: correct for energy of electron and photons
- goal of JES calibration is to correct energy and p_T of jets measured in calorimeters
- measured p_T^{jet} corrected for non-compensating nature of calorimeter, dead material

Jet energy scale uncertainty

- uncertainty of JES dominant uncertainty for many SUSY studies
- $\approx$10% for 20 GeV$< p_T^{jet} <$50 GeV, $\approx$7% for higher p_T^{jet}

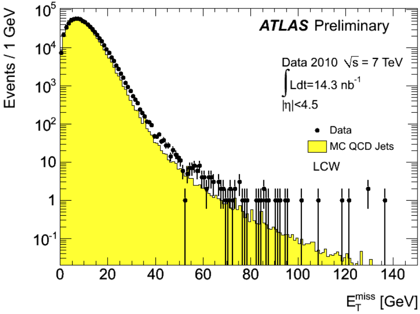
$\Rightarrow$ uncertainty in E_T^{miss} measurement

$\Rightarrow$ results in systematic uncertainty of number of events in searches requiring jets

Performance of E_T^{miss}

ATLAS-CONF-2010-038 and -057

- E_T^{miss} crucial for many SUSY searches
- events recorded with up to 300 GeV of E_T
- E_T^{miss} reconstruction based on calorimeter cells
    - dominant term: contributions from E_T energy deposits in calorimeters
    - corrections: muons, energy loss in cryostat, dead material, non-compensating design
- careful cleaning required:
    - data quality requirements: beam condition, detector status
    - event selections: trigger, primary vertex, timing in calorimeters, jet quality requirements
- data well described by MC for low E_T^{miss}
- small discrepancies for higher E_T^{miss} due to event topology (high p_T jets)



- all events containing large E_T^{miss} contain high p_T jets (anti-)aligned with E_T^{miss}
- source of fake E_T^{miss} seems to be jet energy mis-measurement
- events can be rejected by cutting on $\Delta\phi(jet, E_T^{miss})$

Performance of τ Reconstruction/Identification

see also talk from Anna Kaczmarska on 'Tau reconstruction with 7 TeV collisions in ATLAS'

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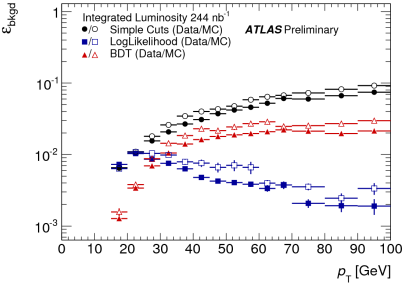

- expected number of real τ in dataset (244nb^{-1}) is small
- study jets from QCD background reconstructed as τ
- additional identification step provides main rejection against QCD
  - Simple cuts on id-sensitive variables
  - Boosted Decision Tree (BDT)
  - LogLikelihood (LLH)

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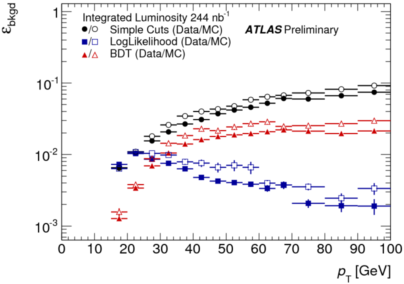

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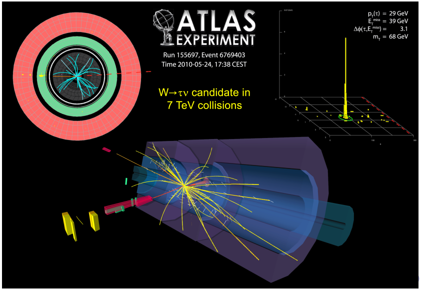
τ in Data - Candidate $W \to \tau\ \nu$

- hadronically decaying τ
- no additional object (electron, muon or jet) was found in the event



2. Early Searches using data

- first comparison of important kinematic variables for SUSY searches
- study using jets and E_T^{miss}
- study using jets and E_T^{miss} and leptons
- integrated luminosity used: $70 \pm 8 nb^{-1}$

Early SUSY searches using data with jets and E_T^{miss}

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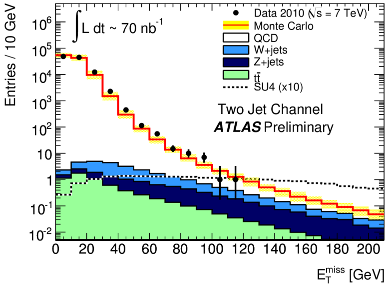

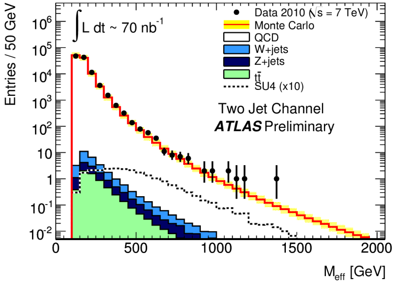

- analysed channels: one to four jets
- preselection:
  - calorimeter jet trigger
  - primary vertex $N_{tracks} > 4$
  - no lepton with $p_T > 10$ GeV
- example: two jet channel $p_T^{jet1} > 70$ GeV, $p_T^{jet2} > 30$ GeV
- $M_{eff} = \sum_{i=1}^{N_{jets}} p_T^{jet,i} + E_T^{miss}$
- number of MC QCD events normalized to number of data events
- uncertainties: energy scale, integrated luminosity, statistical
- overwhelming dominance from QCD

Early SUSY searches using data with jets and E_T^{miss}

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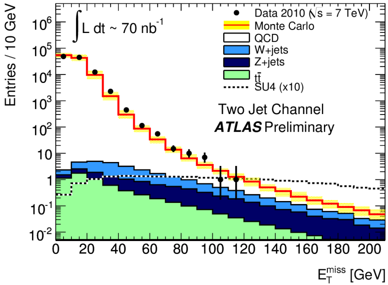

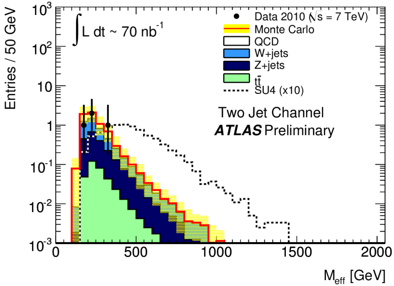

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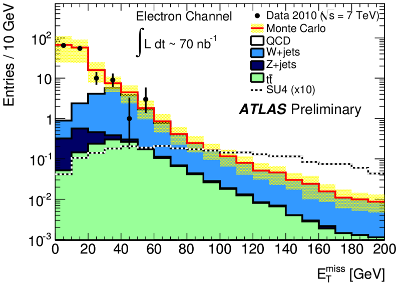
after cuts on E_T^{miss}, M_{eff}, $\Delta\phi(jet, E_T^{miss})$

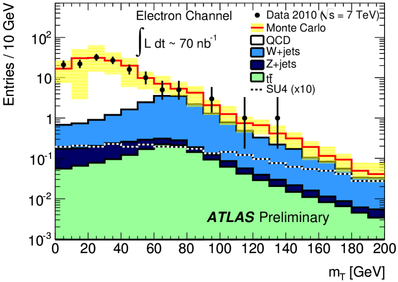
- data: 4 events
- MC: 6.6±3 events

Early SUSY searches with jets + E_T^{miss} + lepton(s)

ATLAS-CONF-2010-066

- search for events containing jets, E_T^{miss}, one (two) additional leptons
- same preselection
- 2 jets with $p_T^{jet} > 30$ GeV
- 1 lepton with $p_T > 20$ GeV, (2^{nd} lepton with $p_T > 10$ GeV)
- additional uncertainty: lepton fake rate
- $m_T^2 \equiv 2|\mathbf{p}_T^\ell||E_T^{miss}| - 2\mathbf{p}_T^\ell \cdot \vec{E}_T^{miss}$
- low $E_T^{miss}(m_T)$: QCD
  high $E_T^{miss}(m_T)$: W+jets, (SUSY)
- reduction by cutting on $m_T(E_T^{miss})$





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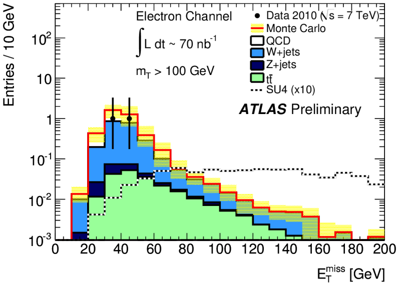
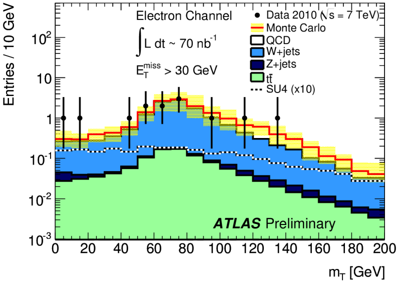
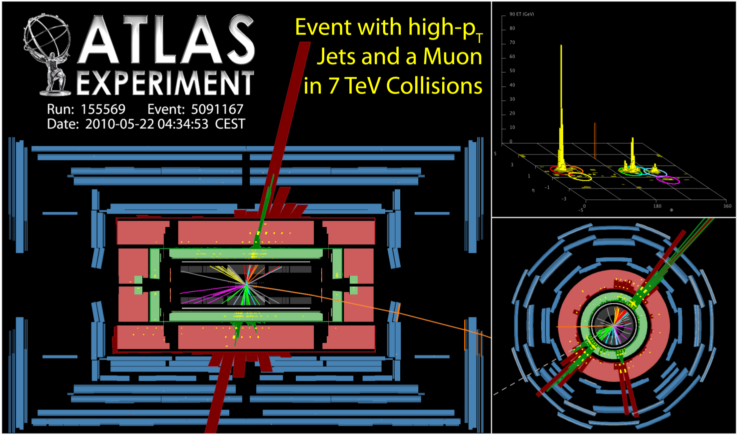
Electron channel: after cuts on E_T^{miss}, m_T

- data: 2 events
- MC: 3.6±1.6 events





Early SUSY searches with jets + E_T^{miss} + lepton(s)



5 jets with $p_T > 30$ GeV, $M_{eff} = \sum_{i=1}^{N_{jets}} p_T^{jet,i} + \sum_{j=1}^{N_{lep}} p_T^{lep,i} + E_T^{miss} = 900\ GeV$

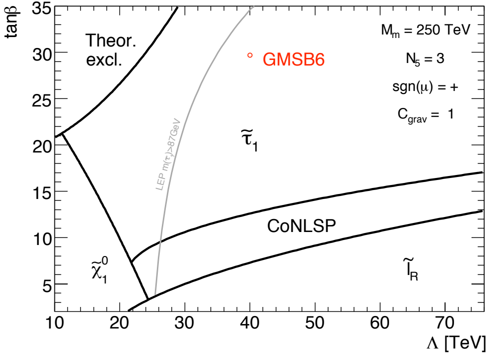
event contains E_T^{miss} aligned to a jet $\Rightarrow$ not passing final selection

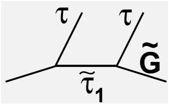
3. Prospects for SUSY searches with τ leptons using Monte Carlo

- estimation of discovery reach with certain integrated luminosity
- possible measurements of SUSY properties
- GMSB scenario
- MSUGRA scenario

Prospects for SUSY discovery - GMSB scenarios

- Gauge mediated supersymmetry breaking:
  - breaking: coupling of messenger particles
  - messenger give mass to the super partners of SM particles through gauge interaction
- LSP (Lightest Supersymmetric Particle)
  - nearly massless, neutral Gravitino $m(\tilde{G}) = \mathcal{O}(\mathrm{eV})$
- NLSP (Next-to-Lightest Supersymmetric Particle)
  - determines phenomenology





Λ: SUSY breaking scale
M_m: messenger mass
N_5: no of messenger fields
$\tan\beta$: ratio Higgs vev
C_{grav}: determines $\tilde{G}$ lifetime

Preselection

- Trigger: $p_T^{jet} > 70$ GeV, $E_T^{miss} > 30$ GeV
- jets: $N_{jets} \geq 2$
  $p_T^{jet1(2)} > 100(50)$ GeV
- τ: $N_\tau \geq 1$, $p_T^\tau > 20$ GeV
  hadronically decaying τ only, LLH
- $E_T^{miss} > 60$ GeV
- $|\Delta\phi(E_T^{miss}, p_T^{jet1})| > 0.2$
- dominant residual BG: $t\bar{t}$, $W \to \tau\nu$, assumed uncertainty of 50%
- $\mathcal{L} = 200\,\mathrm{pb}^{-1}$, $\sqrt{s} = 10$ TeV

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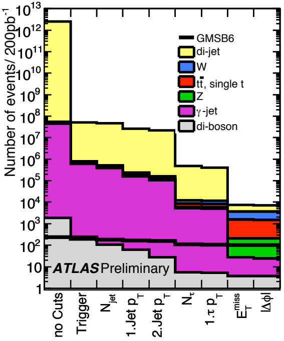
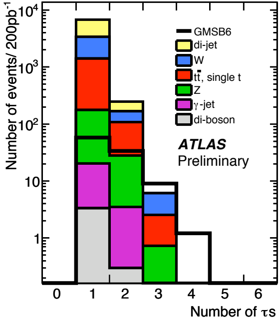
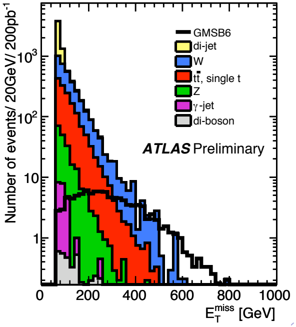
Cutflow



N_τ (after cuts)

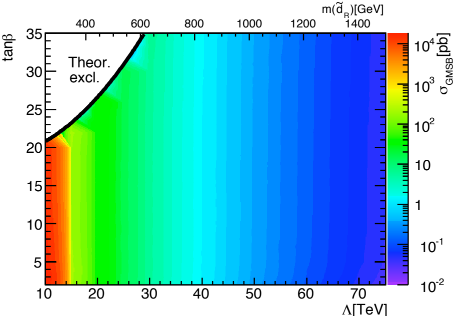


E_T^{miss} (after cuts)

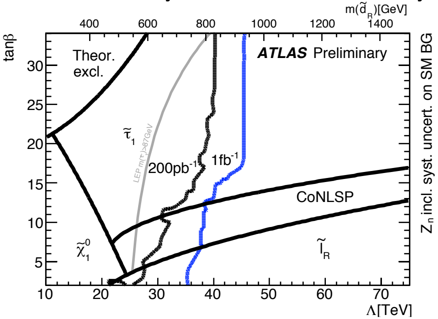


Discovery Potential

Total GMSB cross section (in pb)



Int. luminosity needed for 5σ discovery

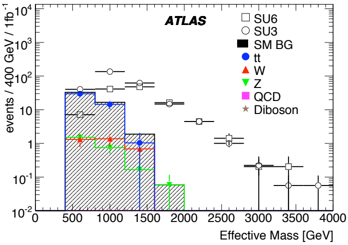


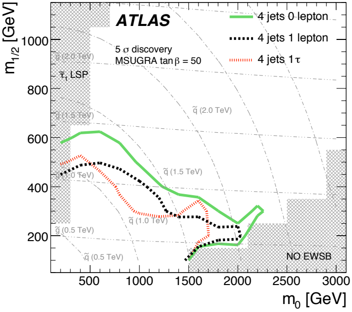
- decreases with Λ due to increasing SUSY masses
- dependence on *tan*β small

- decrease with Λ due to decreasing cross section
- increase with *tan*β depending on NLSP

- 10TeV ⇒ 7TeV: reduction of GMSB6 (BG) cross section by factor of ≈ 3(1.5)
- need approximately four times the amount of data for discovery

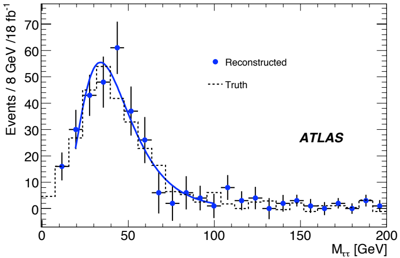
MSUGRA scenarios - Discovery reach

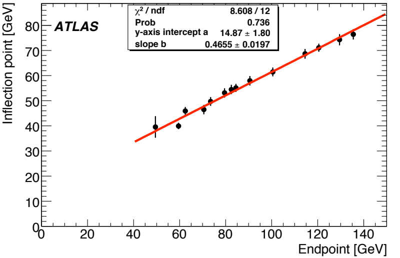




- minimal supergravity model: SUSY breaking is mediated via gravity
- $m_{0(1/2)}$: mass of scalars (fermions) at GUT scale
- $\tilde{\tau}$ also often NLSP leading to τ final states: $\tilde{\chi}_2^0 \rightarrow \tilde{\tau}\tau \rightarrow \tilde{\chi}_1^0 \tau^{\pm}\tau^{\mp}$
- $\mathcal{L} = 1\,\mathrm{fb}^{-1}$, $\sqrt{s}$ =14 TeV
- selection
  - jets: $N_{jets} \geq 4$, $p_T^{jet1(2,3,4)}$ >100(50) GeV
  - E_T^{miss} >100 GeV
  - $|\Delta\phi(E_T^{miss}, p_T^{jet})| > 0.2$
  - no lepton
  - τ: $N_\tau \geq 1$, p_T^τ >40 GeV, LLH>4
  - E_T^{miss} >0.2 M_{eff}
  - M_T >100 GeV
- discovery reach for MSUGRA in 4jets+1τ channel up to $m_{\tilde{q}} \approx$1.1 TeV

Mass edge measurement





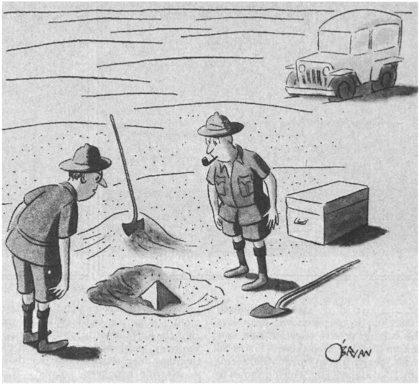
- besides study of discovery reach also study of SUSY properties
- invariant mass of $2\tau \Rightarrow$ mass edge
- due to peculiar τ decay mass edge not sharp
  $\Rightarrow$ invariant mass endpoint cannot be measured directly
- fit invariant mass distribution
- measure inflection point of fit function
- calibration curve of inflection points vs. theoretical kinematic endpoints as been determined with different masses of $\widetilde{\chi}_2^0$, $\widetilde{\tau}$, $\widetilde{\chi}_1^0$
- linear correlation between inflection and endpoint $\Rightarrow$ measuring inflection point $\equiv$ measuring endpoint

Conclusion and Outlook

- performance of Jet, E_T^{miss}, τ reconstruction has been studied with first data
  $\Rightarrow$ working well
- observation of first τ candidates in data
- early searches for SUSY show good agreement between data and BG expectation

- discovery potential using τ leptons has been studied in various scenarios (MSUGRAb, GMSB)
- methods to measure SUSY properties have been developed

- future searches in different channels (1τ, 2τ, 1τ +lepton) with increased luminosity promise to yield interesting results



"This could be the discovery of the century. Depending, of course, on how far down it goes."

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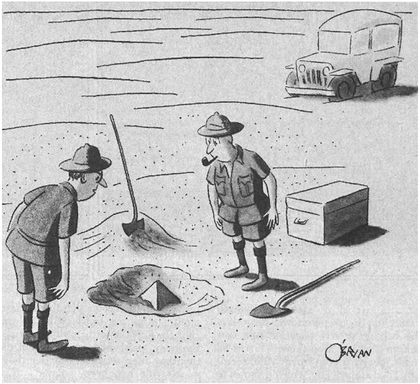

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Thank you for your attention

Backup slides

Performance in $\tau + E_T^{miss}$ events

ATLAS-CONF-2010-059

- require only one τ candidate
- $E_T^{miss} > 15$ GeV
- study $\Delta\phi$ between E_T^{miss} and τ and the transverse mass
- fake E_T^{miss} due to misreconstructed jet energy
- E_T^{miss} often points opposite to the τ candidate direction
- rate of events with E_T^{miss} along τ candidate slightly higher in data
- shape of transverse mass well described by simulation
- used dataset: 15.6nb^{-1}