Searches for Supersymmetry in ATLAS

Implications of First ATLAS Data

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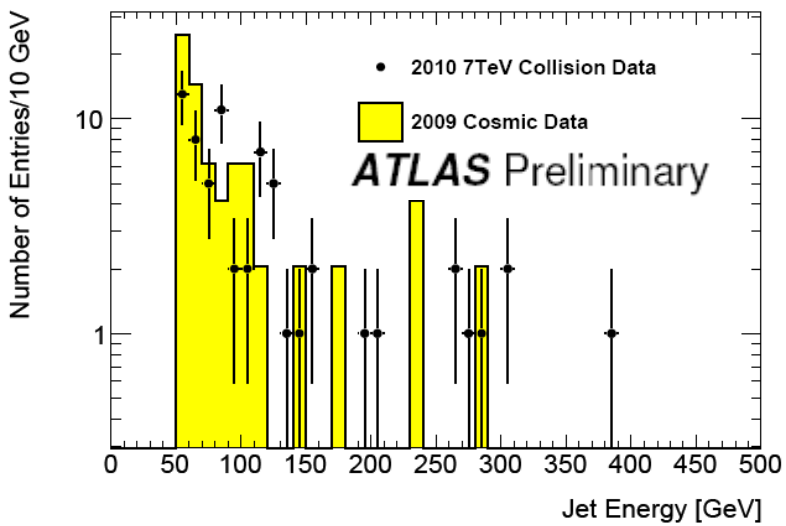
Introduction

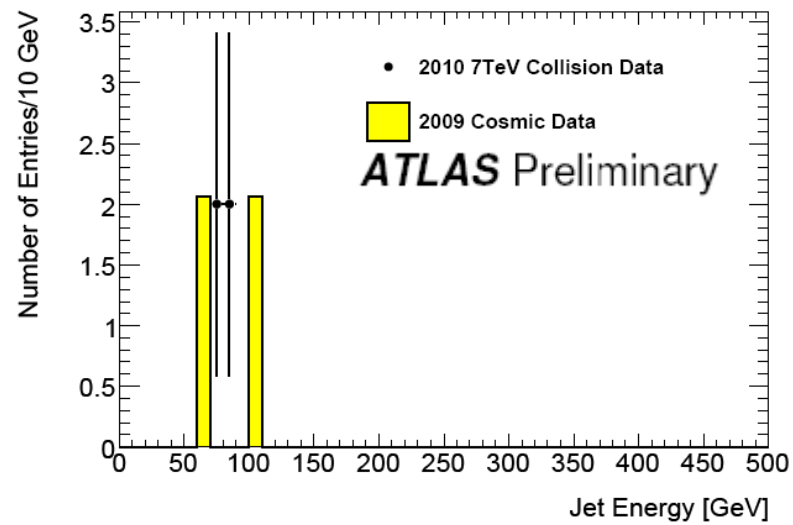
- Supersymmetry is theoretically well motivated
- Sensitivity should quickly exceed Tevatron Limits
  - Sensitivity strongly depends on background understanding
- There are many different models with differing phenomenology
  - It is impossible to study all models
    - A signature based approach is chosen
- Customary choice is mSUGRA (Minimal Supergravity Grand Unification)
  - Representative of a wide range of MSSM scenarios
  - Assume R-parity conservation
    - Implies cascade decays to lightest supersymmetric particle (LSP)
      - Implies large $\not{E}_T$
    - R-Parity violating SUSY scenarios are a topic for future studies
- Supplemented by GMSB (Gauge Mediated SUSY Breaking)
  - Phenomenologically different from mSUGRA by abundance of τ and γ
    - Results for such studies not yet public

Long-lived Stopped Particles

- Several BSM theories predict long-lived massive particles
  - Possible in GMSB and Split-SUSY
  - These massive particles can stop in the ATLAS detector
    - eg R-hadrons
      - Long-lived particles containing a coloured particle
    - Decay time is dependant on particular model
      - Range from nanoseconds to hours
- ATLAS studies focus on gluino R-hadrons within split-SUSY
  - Since they are stopped it is best to look in empty bunch crossings
    - Dominant background is cosmic muon showers in the calorimeter
      - Any significant shower in the calorimeter will be reconstructed as a jet
      - Expect TeV cosmic events at a rate of 6×10^{-4} (~2 per hour)
        - Does not scale with luminosity
      - Assume beam halo and beam gas events to be negligible
  - Signature is a hard jet with a particular shape
    - Cut on several jet shape variables

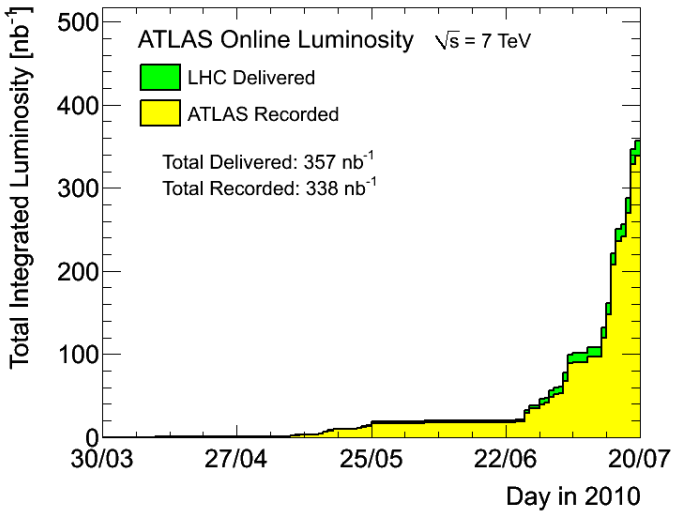
Results from Long-lived

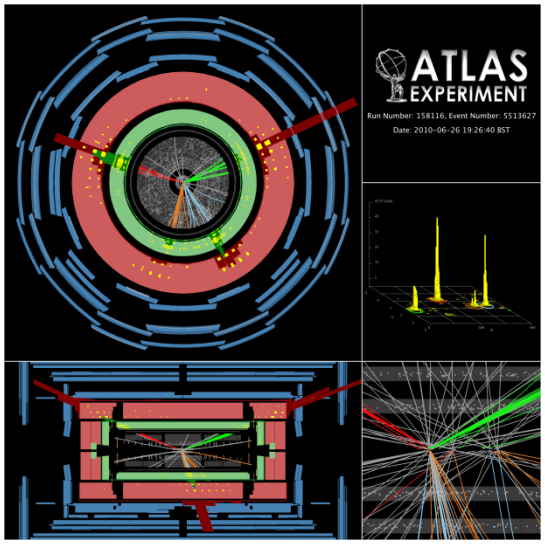




- Looked in empty bunch crossing of this summers data
  - Normalize 2009 cosmic data to 1.29 x 10^6 events found
    - Cosmic data is a very nice control sample for the empty bunch crossings
  - 4 candidates where 4 ± 2.9 were expected from cosmics
  - Left plot shows events without jet shape cuts
- Still early to make any exclusion
  - Collision data is consistent with cosmic data from 2009

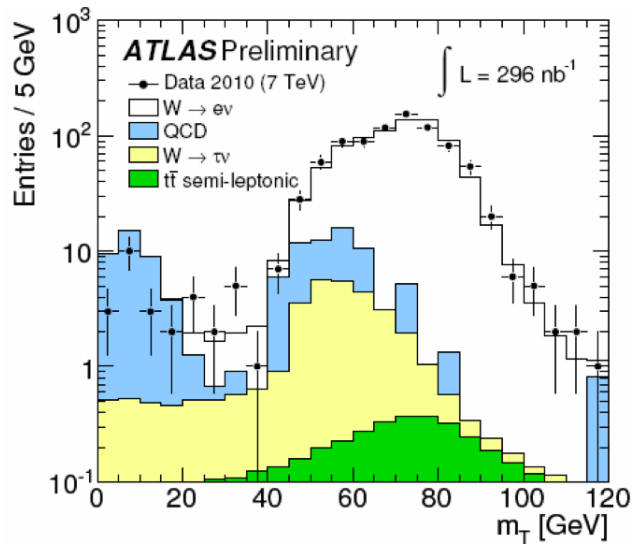
Collision Data

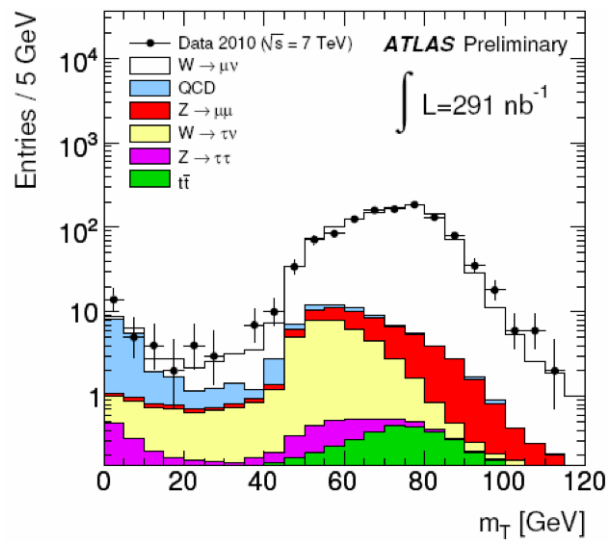




- As of July 20th at noon, ~357 nb^{-1} delivered by LHC
  - 338 nb^{-1} recorded by ATLAS
- Luminosity used is analysis dependant
  - $W \rightarrow \ell\nu$ and $Z \rightarrow \ell\ell$:
    - ~17 nb^{-1} for precision to 300 nb^{-1} for observation
  - SUSY studies: ~70 nb^{-1}
    - Compared to a particular mSUGRA point but do not tune to it
- Event display of event with 4 jets and $\not{E}_T$ ~ 100 GeV

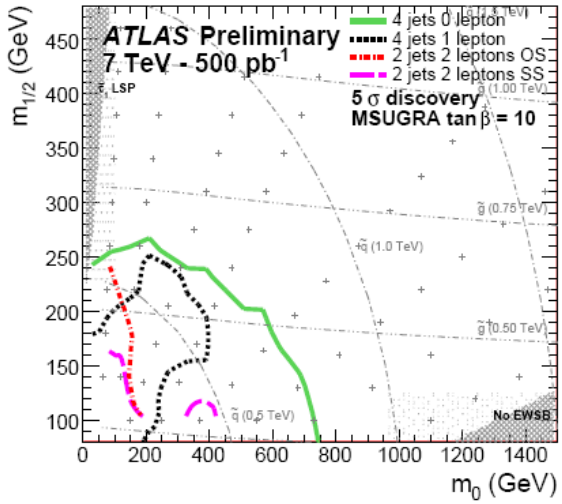
SM W and Z Observations

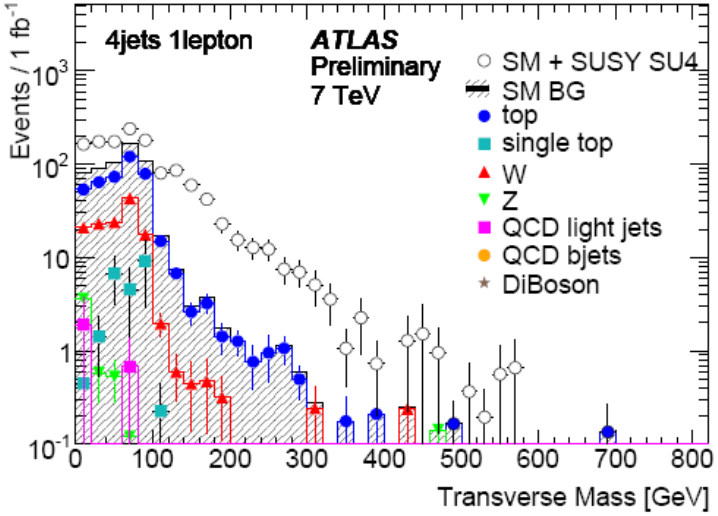




- Understanding SM background is the first step in searches
  - Events with a Lepton and $\not{E}_T$ are important backgrounds
- Observation of 815 W → *eν* and 1111 W → μ*ν* candidates
  - Isolated lepton with p_T > 20 GeV and $\not{E}_T$ > 25 GeV
- Observation of 56 Z → ee and 106 Z → μμ
  - In agreement with NNLO expected x-section
- Overall good agreement with MC prediction

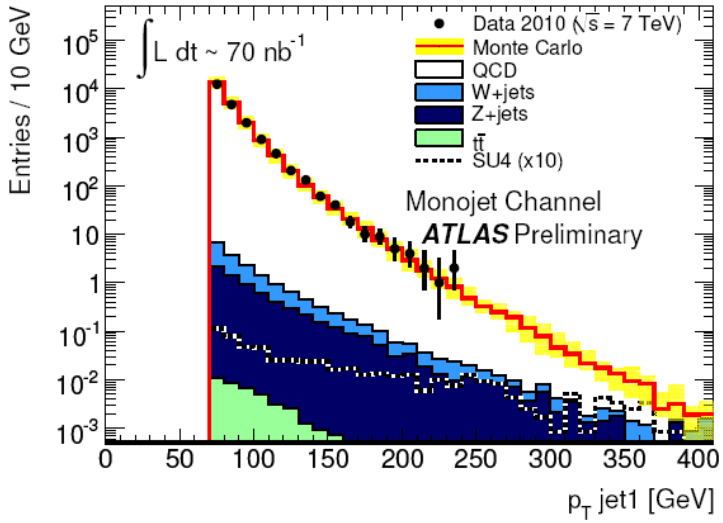
Signature Based MC Studies

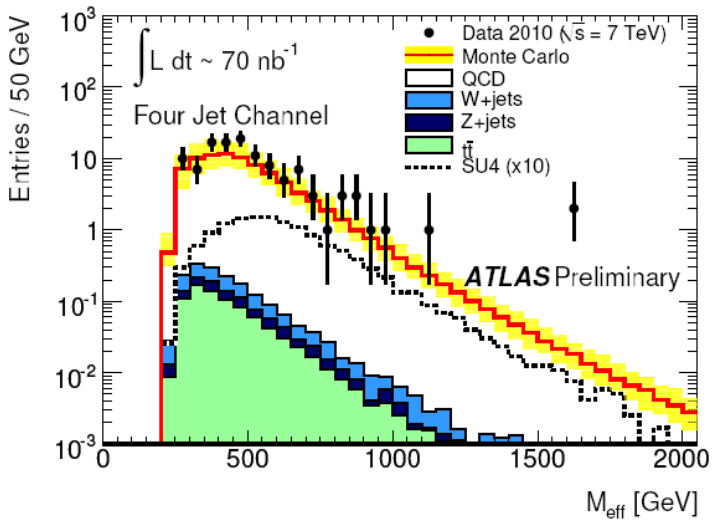




- Many SUSY models predict similar final states
  - Large $\not{E}_T$ because of the escaping LSP
  - Hard jets coming from cascade decay
  - Decays also produce leptons, ℓ
    - ℓ taken as only electron, *e*, and muon, μ, in ATLAS
  - mSUGRA point above Tevatron limit is chosen for comparison
- Divide studies into a grid in (#Jets, #ℓ) plane for final states
  - Different channels have different advantages and disadvantages

0 ℓ SUSY Selections



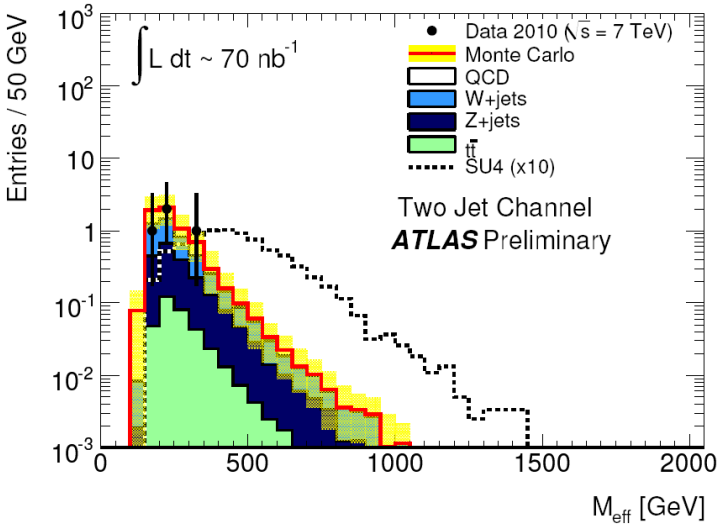


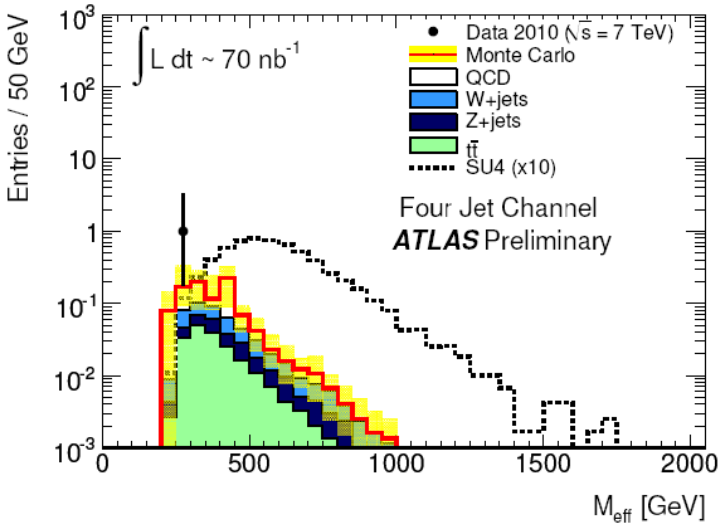
- p_T of leading jet in mono-jet channel
  - Require p_T^{Jet1} > 70 GeV and no additional jets with p_T > 30 GeV
- M_{eff} for 4 jet channel
  - p_T^{Jet1} > 70 GeV , p_T^{Other} > 30 GeV and $\not{E}_T$ > 40 GeV

$$M_{eff} = E_T^{miss} + \sum_{Jet}^{4} p_T$$

- Agreement between the ATLAS measurements and SM MC
  - Shows that the jets are well understood
  - QCD normalized in p_T^{Jet1}>70 GeV , p_T^{Jet2}>30 GeV control region

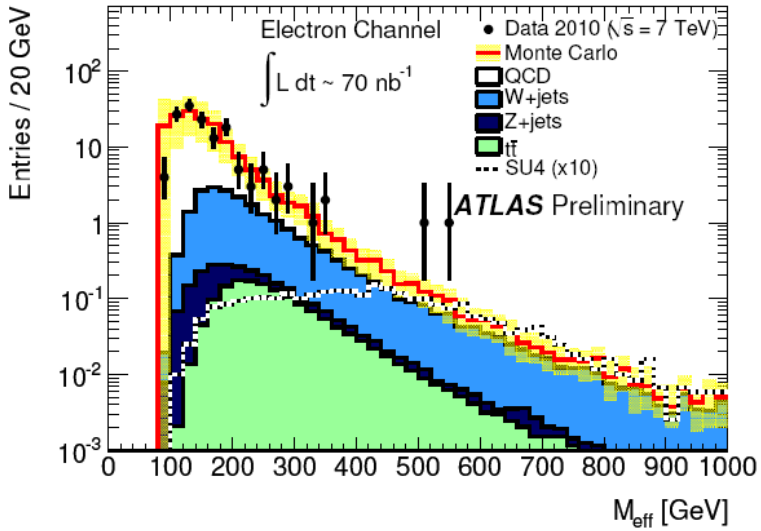
Tighter 0 ℓ SUSY Selections

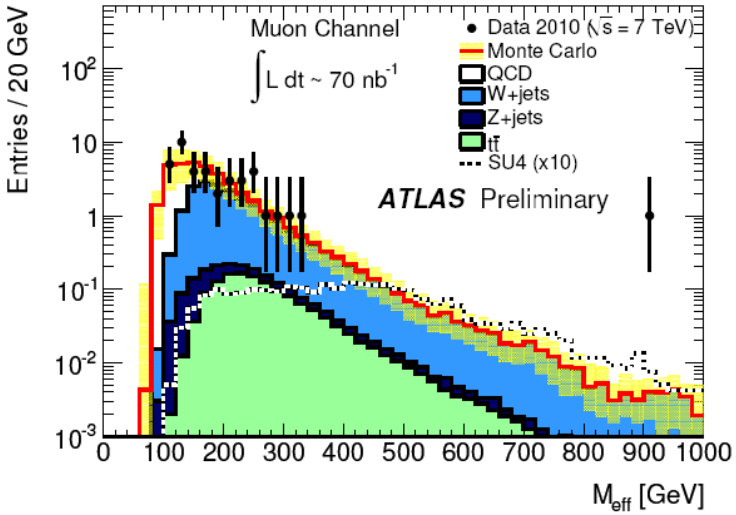




- 2 jet channel: $\not{E}_T > 40$ GeV, $\not{E}_T > 0.3\ M_{eff}$, $\Delta\phi(Jet_i, \not{E}_T) < 0.2$
  - 4 events found where 6.6 ± 3 are expected from MC
- Require a 3rd jet of 30 GeV and loosen to $\not{E}_T > 0.25\ M_{eff}$
  - No data events where 1.9 ± 0.9 are expected from MC
- Require a 4th jet of 30 GeV and loosen to $\not{E}_T > 0.2\ M_{eff}$
  - 1 event is found where 1.0 ± 0.6 are expected from MC
- All data distributions are consistent with normalized MC

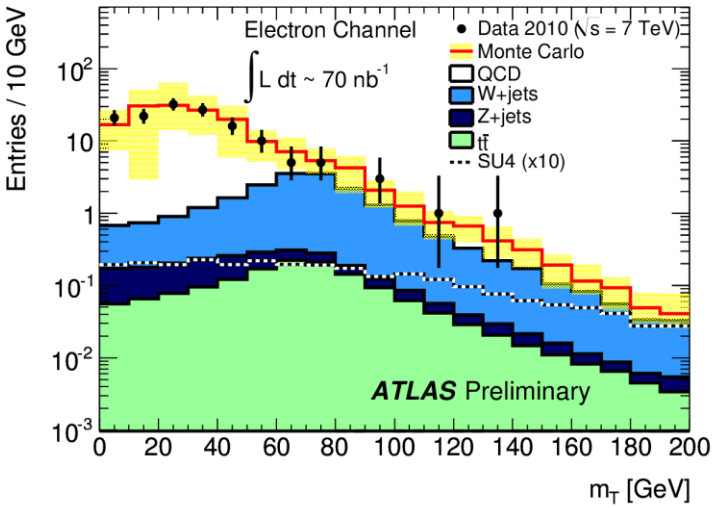
1 ℓ Selections: M_{eff}

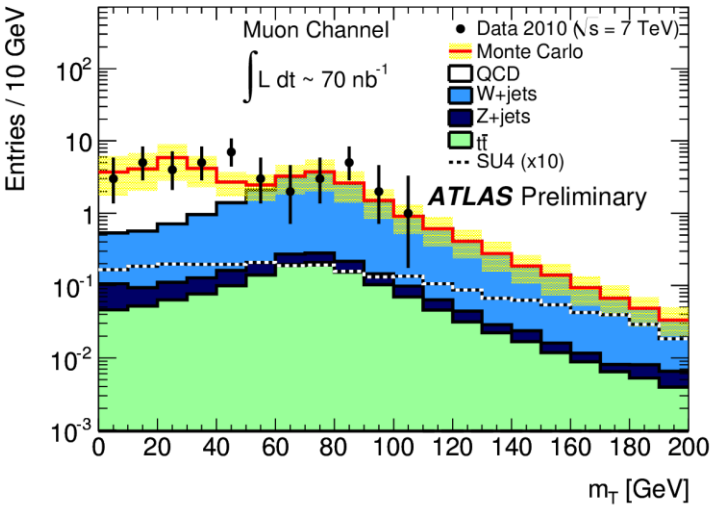




- Split into e and μ channels
- Event selection in addition to standard cleaning cuts
  - 1 ℓ with p_T > 20 GeV and no additional ℓ with p_T > 10 GeV
  - 2 jets with p_T > 30 GeV
- MC normalization done in control regions
  - Pythia QCD: $\not{E}_T$ < 40 GeV; m_T < 40 GeV
  - Alpgen W + jets: 30 GeV < $\not{E}_T$ <50 GeV; 40 GeV < m_T < 80 GeV

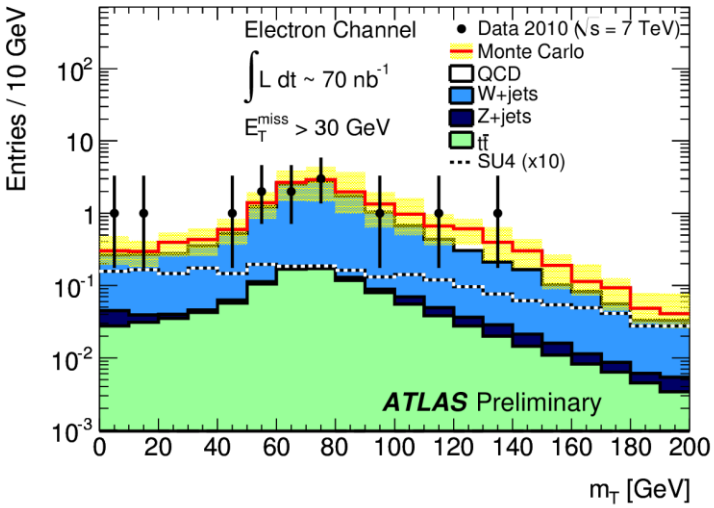
1 ℓ Selections: M_T

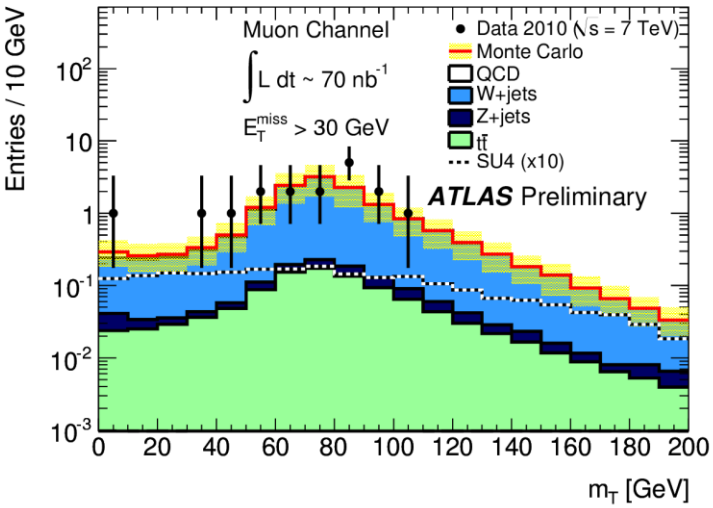




- Transverse mass after selection cuts
- Electron channel
  - 143 events in data compared to 157 ± 85 from MC
- Muon channel
  - 40 events in data compared to 37 ± 14 from MC
- Jet energy scale uncertainly represented by yellow band

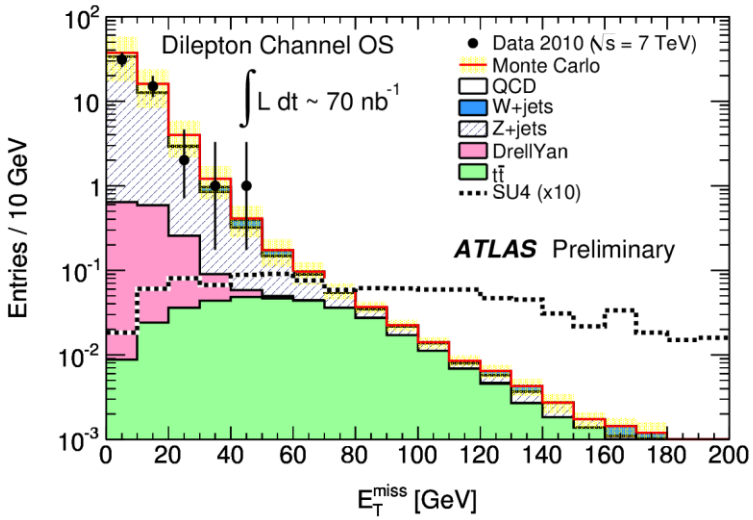
1 ℓ Selections: With $\not{E}_T$ cut

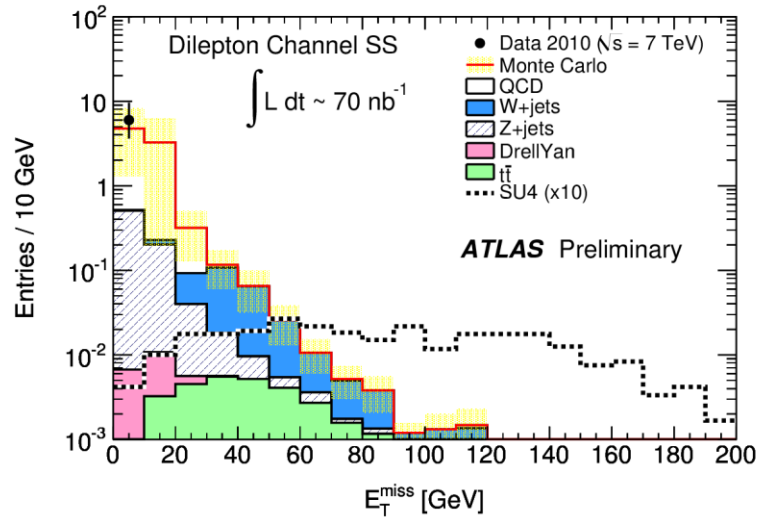




- Additionally require $\not{E}_T$> 30 GeV
- Electron channel
  - 13 events in data compared to 16 ± 7 from MC
    - With m_T > 100 GeV: 2 data events survive compared with 3.6 ± 1.6
- Muon channel
  - 17 events in data compared to 15 ± 7 from MC
    - With m_T > 100 GeV: 1 data event survives compared with 2.8 ± 1.2

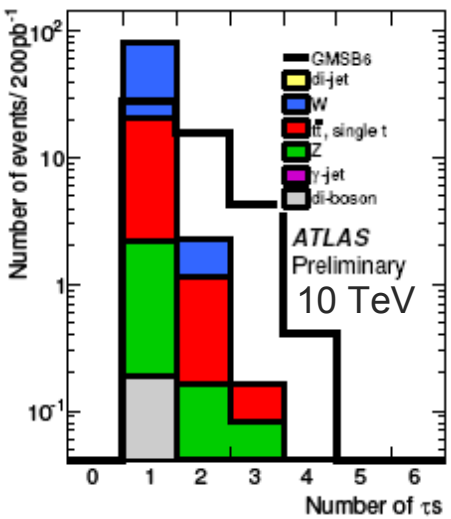
2 ℓ Selections

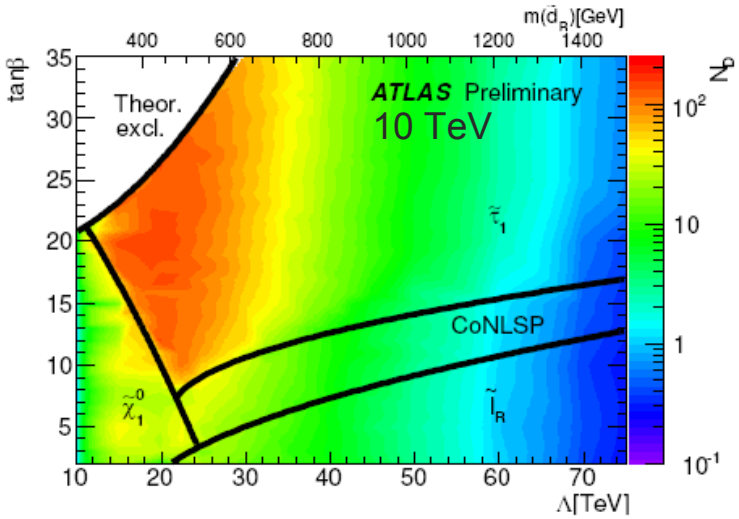


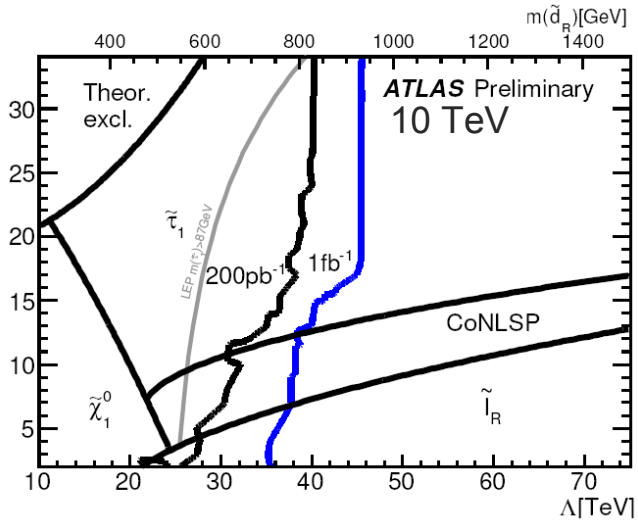


- 2ℓ channel is split into same-sign and opposite sign
- Additionally require a 2nd ℓ with p_T > 10 GeV
  - Two events in data for OS channel compared to 2 ± 0.8 from MC
  - No SS channel events pass selection
- Check rates consistent in QCD dominated control region
  - 5 GeV < $m_{\ell\ell}$ < 15 GeV

Future Plans for GMSB







- Focus on parameter space which differs from mSUGRA
- Expect up to 4 τ in final state for stau NLSP
  - Good exclusion possibilities for ~200 pb^{-1} with 10 TeV
- τ are complicated objects and take more time to understand
  - Studies with data must wait for thorough understanding of τ
- A neutralino NLSP decays to γ and a gravitino
  - Studies with high p_T γ are in progress

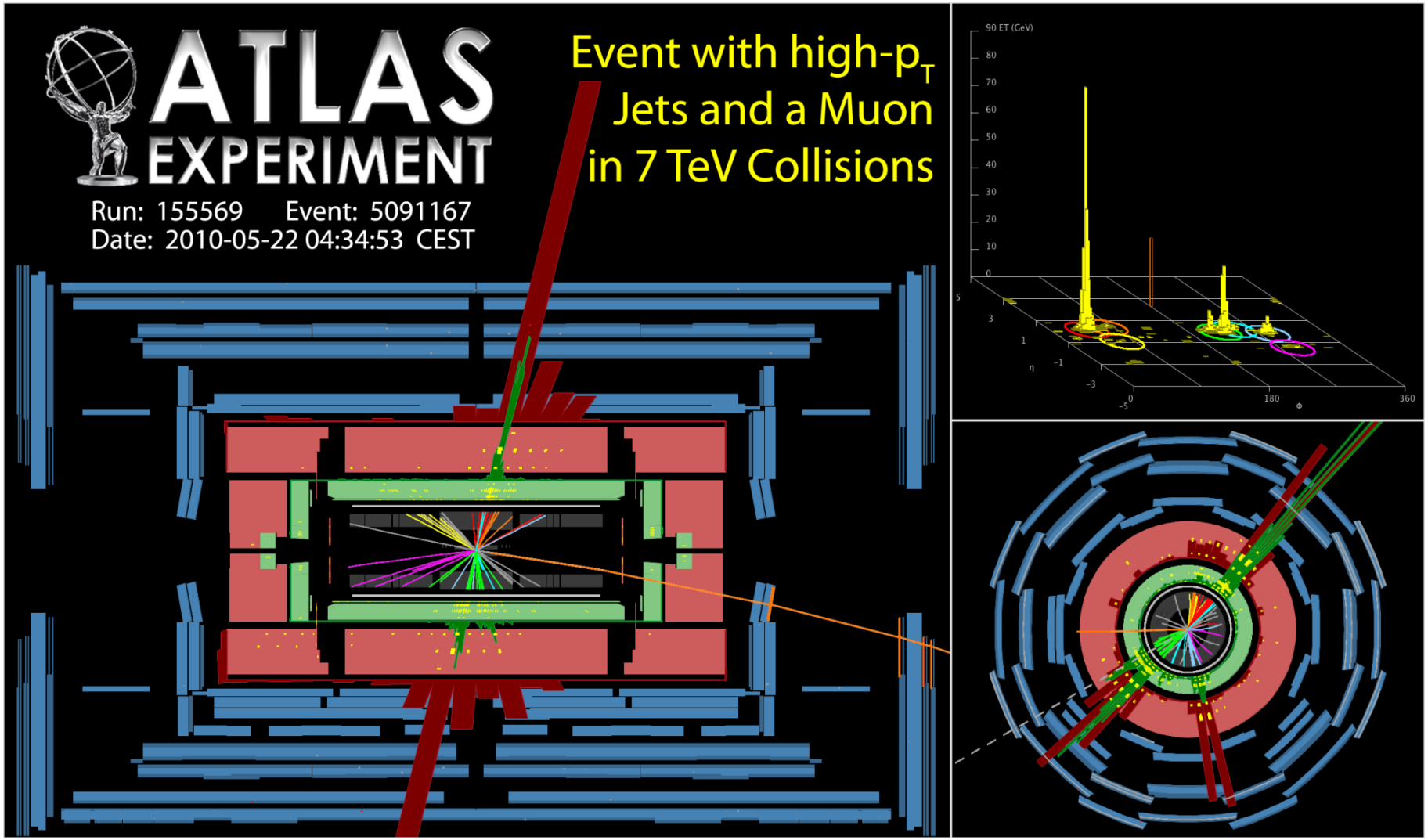
Conclusions

- First results from W/Z observations and SUSY searches
  - Indicate that SM background simulations are well tuned
- More data is needed to achieve nominal performance
  - Better understanding of physics objects
- Reconstruct about 500 $Z \rightarrow \ell\ell$ per pb^{-1}
  - Nominal ℓ performance expected with ~ 100 pb^{-1}
- Several studies being performed
  - All show good agreement with expectations for low statistics
    - Greater statistics will allow for data-driven background estimates
  - Other studies aside from what was shown here
- Using inclusive signature based SUSY searches
  - Probe regions beyond Tevatron limits with a few dozen pb^{-1}
- Sensitive to new physics this year

End

- Questions?
  - Backup slides follow

900 GeV Muon Event



mSUGRA SU4 point

- Low mass point
- Inclusive SUSY events
- near Tevatron bound
  - m0 = 200 GeV
  - m1/2 = 160 GeV
  - A0 = -400 GeV
  - tan β= 10
  - μ > 0
- High σ
  - σ ~ 42 pb at LO
  - σ ~ 60 pb at NLO