First ATLAS searches for supersymmetry with b-tagged jets and missing transverse energy.

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On behalf of the ATLAS Collaboration

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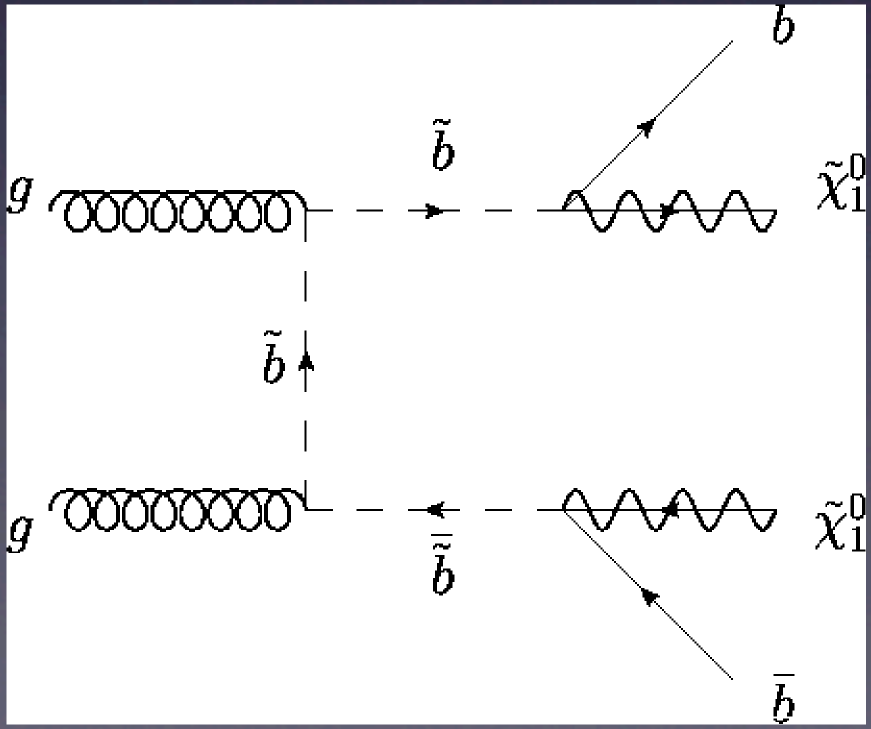
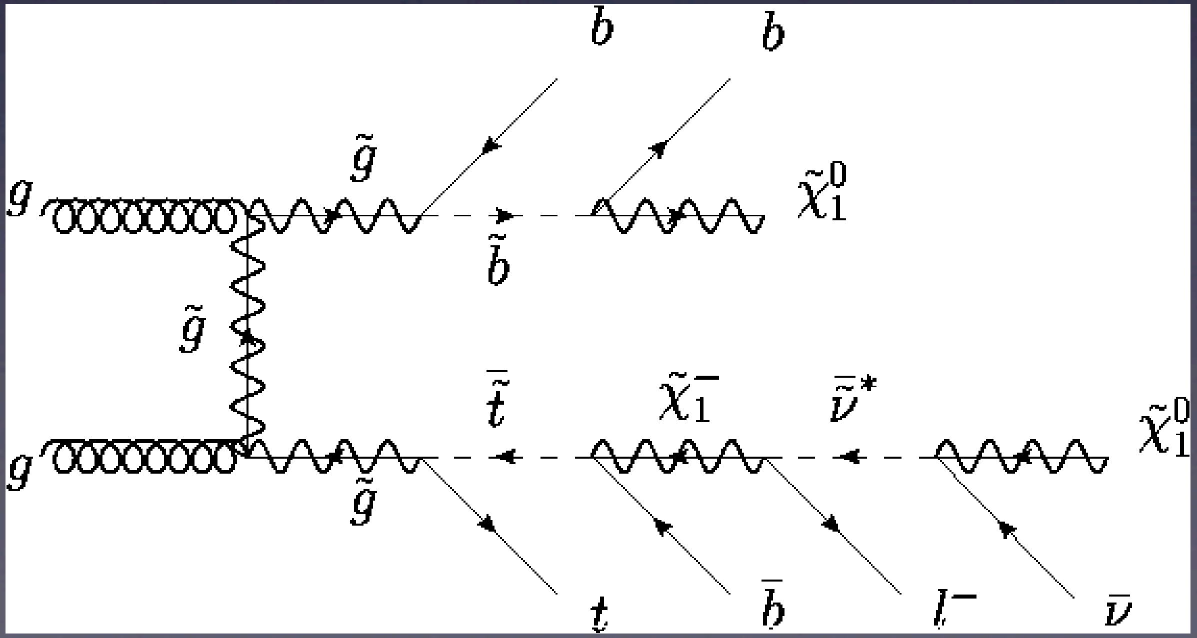
Motivation

- In many SUSY models third generation squarks are light
- Therefore it is worthwhile for ATLAS to conduct searches for R-parity conserving SUSY signatures including decays to b-quarks
- For illustration purposes, although the analysis is in general sensitive to any signature with b-jets in the final state, we consider the SU4 point :

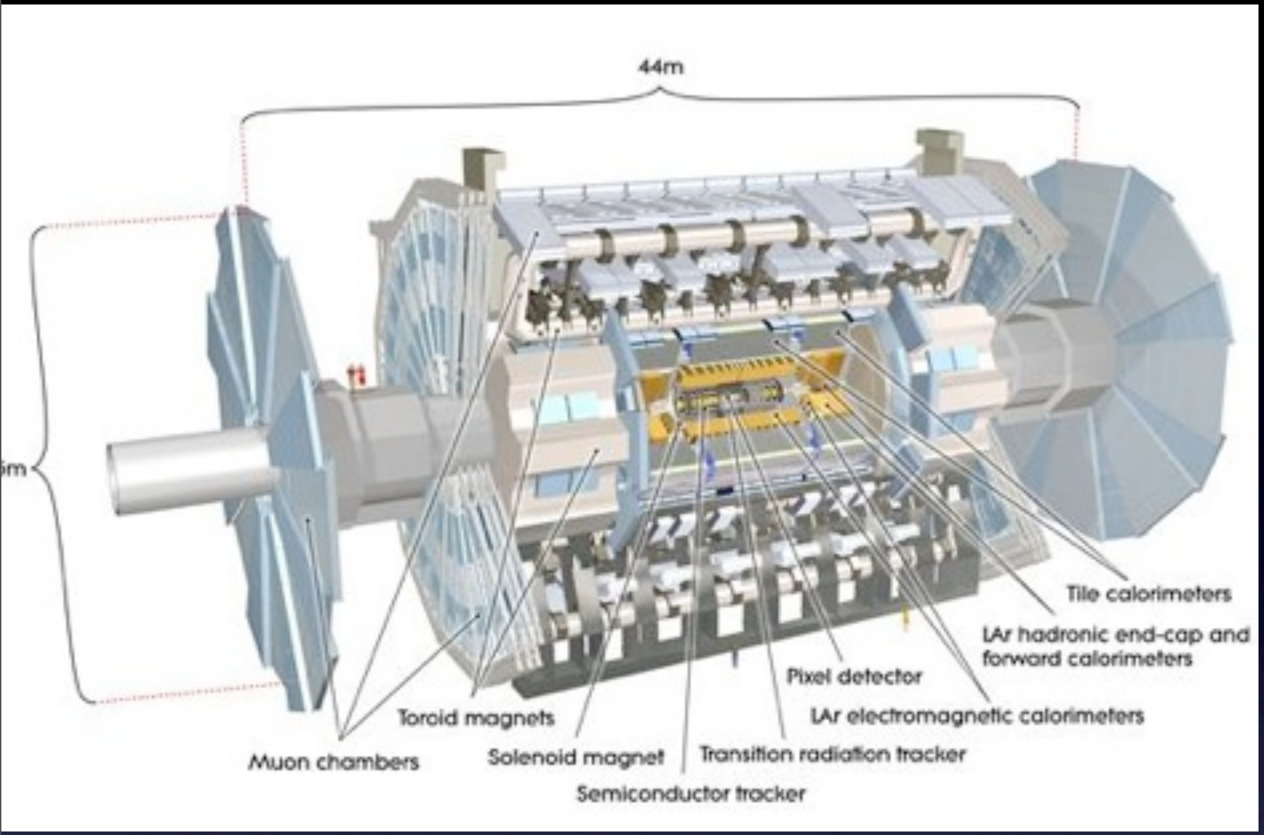
$$m_0 = 200GeV, m_{1/2} = 160GeV, A_0 = -400GeV, tan\beta = 10, \mu > 0$$

- SU4 close to Tevatron bounds





Detectors for Analyses



- Topological clusters formed from energy deposits in calorimeters
- AntiKt jet algorithm, size = 0.4, runs on topological clusters

Hermetic calorimeter coverage important for reconstructing Missing ET :

- Coverage out to $|\eta| < 4.9$

- Calorimeters and Inner Detector systems used for electron reconstruction
- Muon systems and Inner Detector systems used for muon reconstruction

Electron Reconstruction

- Selected based on shower shape variables and track information.
- Reject events with electron candidate $1.37 < |\eta| < 1.52$.
- Less than 10 GeV transverse energy in cone ($\Delta R = 0.2$) around electron candidate in calorimeter
- Require $P_T > 10$ GeV and $|\eta| < 2.47$.

Muon Reconstruction

- Search for matched track in muon and inner detectors.
- Less than 10 GeV transverse energy in cone ($\Delta R = 0.2$) around muon candidate in calorimeter.
- Require $P_T > 10$ GeV and $|\eta| < 2.4$.

Jet Reconstruction

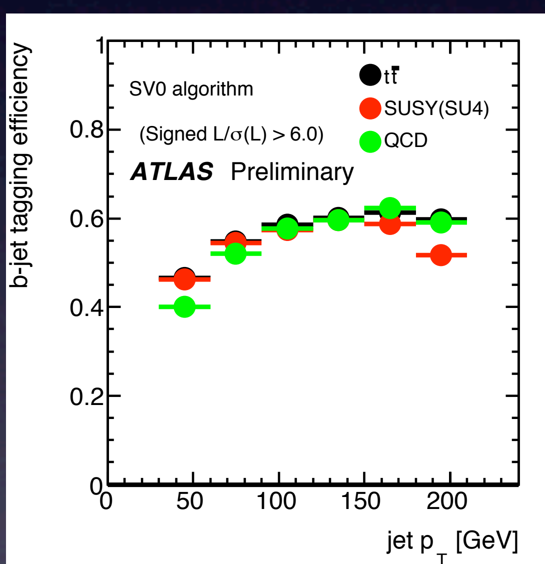
- Jet reconstruction uses topological clusters at electromagnetic (EM) scale.
- Correction is derived from Monte Carlo to take jet energy from electromagnetic scale to jet energy scale.
- Additional jet cleaning cuts are applied to remove jets due to bursts of coherent noise in the calorimeter and cosmic rays.

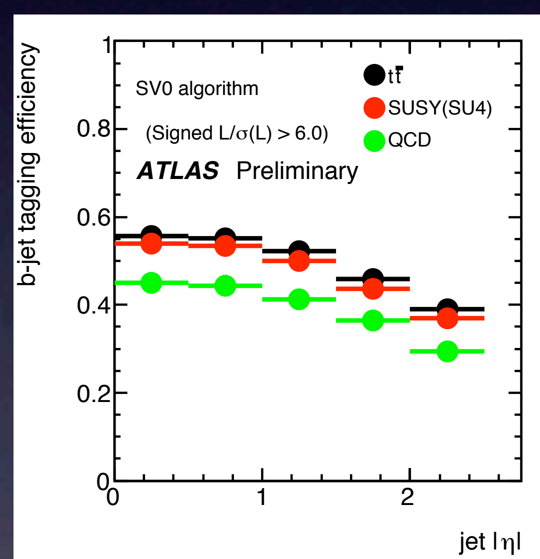
Missing ET (ETMiss) Reconstruction

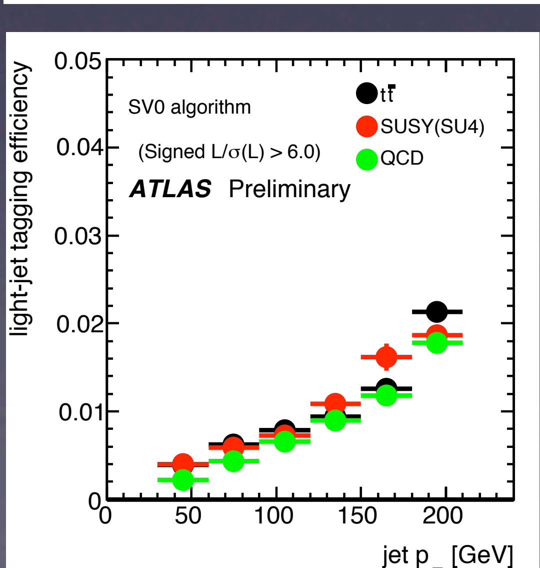
- Calculated from all calorimeter cells, at electromagnetic scale, with $|\eta| < 4.5$.

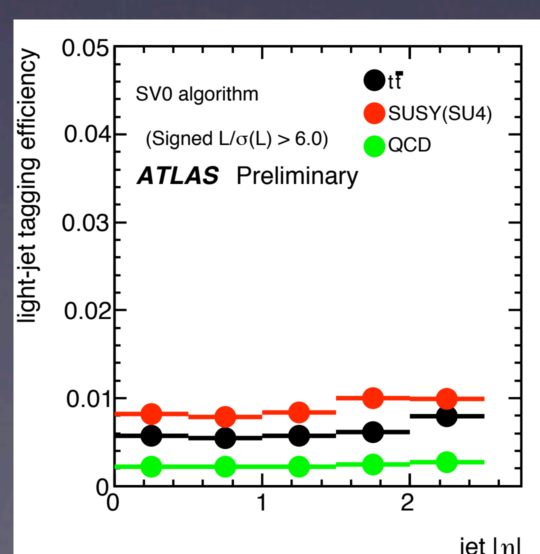
B-Tagging

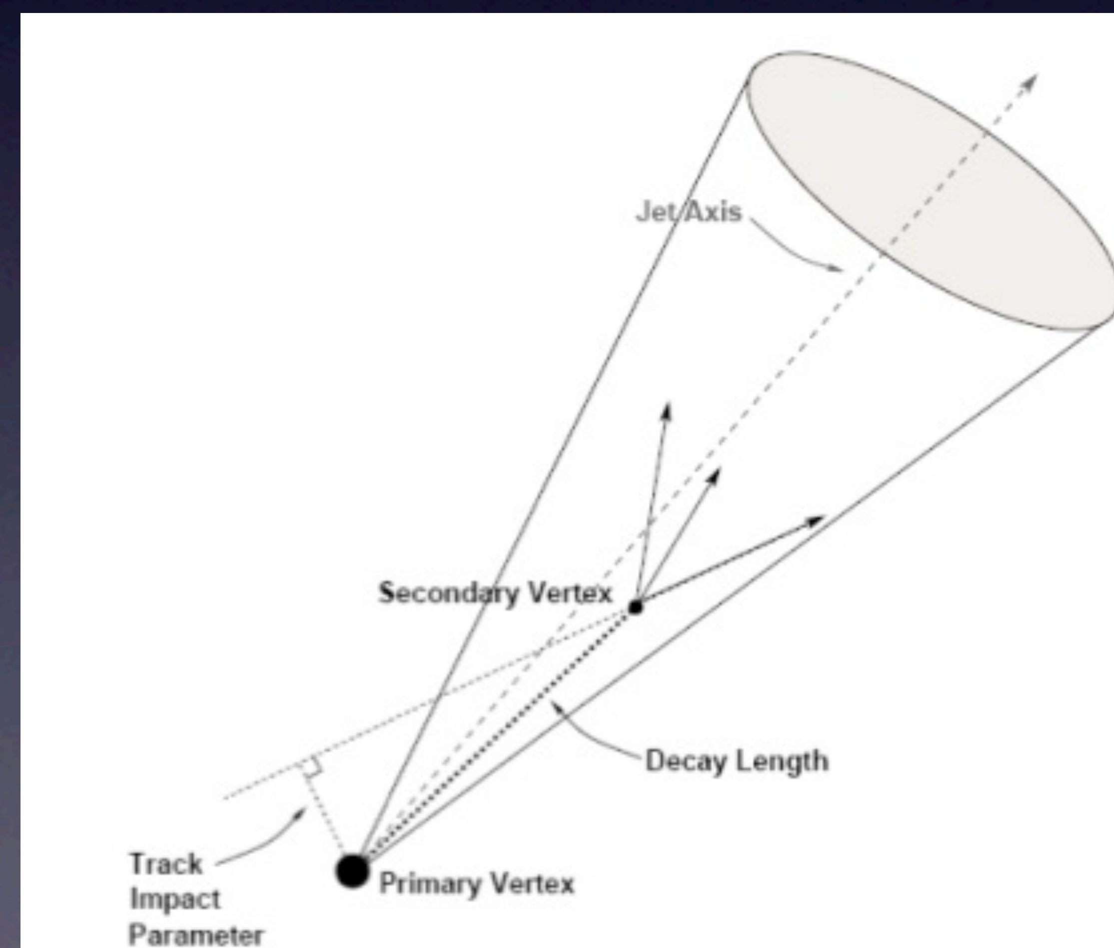
- Algorithm reconstructs secondary vertex using tracks associated with jet.
- A cut is placed on L/σ, where L is the 3D decay length and σ is the vertex resolution.
- Efficiency varies from 40%, at low P_T, to 65%.
- Rejection of light quark jets is at level of 1-2%, and charm jets at 10-20%.
- Require candidate jets to have $P_T > 30$ GeV and also require $|\eta| < 2.5$.







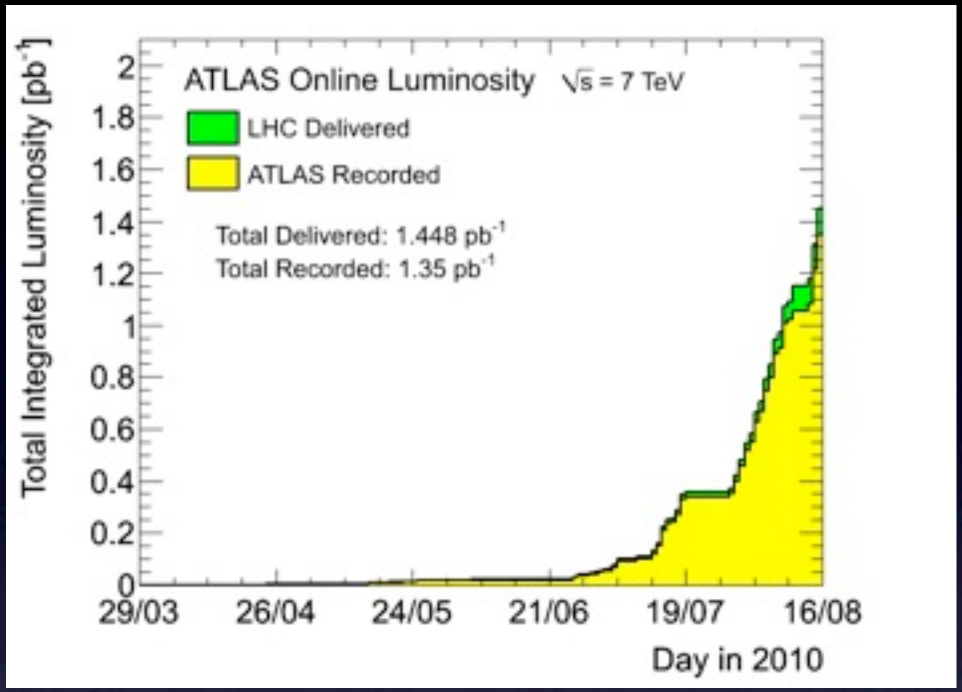




Monte Carlo Datasets

- PYTHIA used for QCD multijet processes.
- ALPGEN used for W + Jets and Z + jets. Samples are normalised using NNLO cross-sections.
- MC@NLO used for top quark samples, which are normalised to NLO+NLL cross-sections.

Datasets Used and Preselection



- 305 nb^{-1} of data used for analyses.
- Searches with zero leptons and 1 b-jet.
- Searches with one lepton (electron or muon, not tau) and 1 b-jet.

- Use lowest unprescaled jet trigger in zero lepton mode - 15 GeV level-1 EM threshold.
- Use 5 GeV level-1 EM trigger and 10 GeV level-2 EM trigger for electron mode.
- Use 6 GeV level-1 Muon trigger for muon mode.

- Require one primary vertex with at least 5 tracks.

Zero-Lepton Mode

Event Selection

- No lepton with $P_T > 10$ GeV.
- Leading jet $P_T > 70$ GeV, second jet $P_T > 30$ GeV (third jet $P_T > 30$ GeV).
- METSignificance > 2 $GeV^{0.5}$.
- At least one b-jet ($L/\sigma > 6$ and $P_T > 30$ GeV).

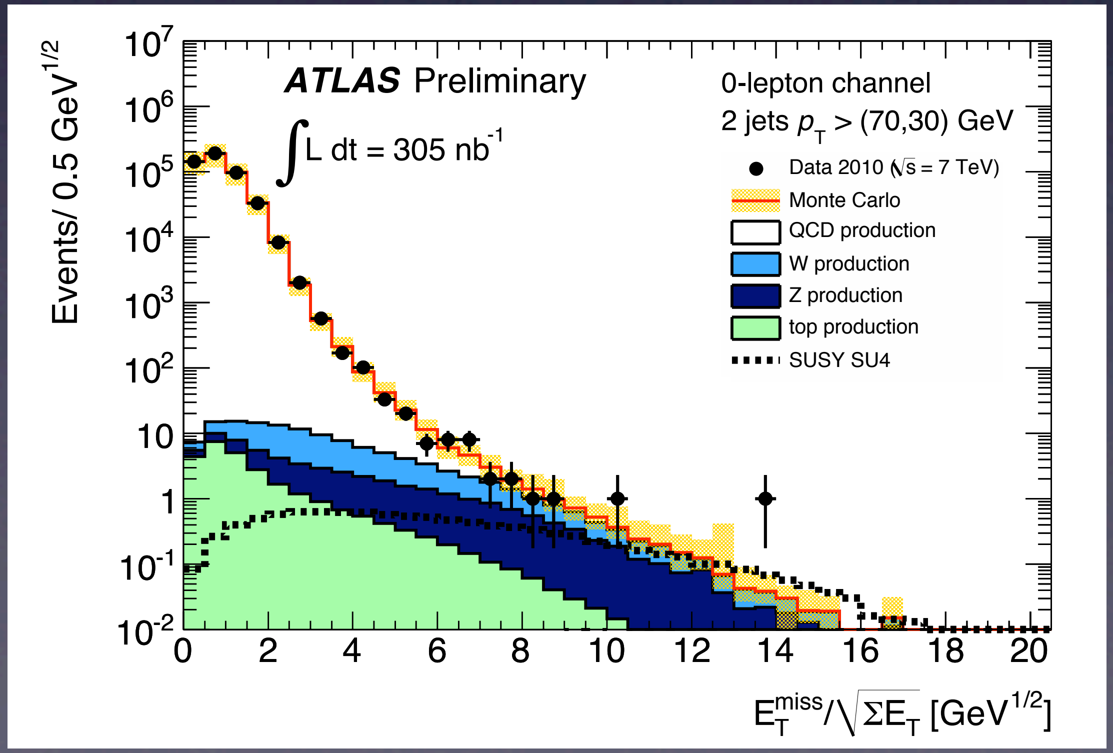
$$METSig = \frac{E_T^{miss}}{\sqrt{\sum E_T}} \qquad E_x^{miss} \equiv -\sum_{i=1}^{N_{cell}} E_i sin\theta_i cos\phi_i \qquad E_y^{miss} \equiv -\sum_{i=1}^{N_{cell}} E_i sin\theta_i sin\phi_i$$

• Reduces impact on using two quantities, ETMiss and Jets, at different energy scales.
• Using METSignificance cuts out events with large sumET and moderate ETMiss - improves data and Monte Carlo agreement due to not perfectly simulating pile-up events at this time.
• METSig approximately corresponds to cutting on ETMiss > 30 GeV.

Backgrounds

	QCD	W+Jets	Z+Jets	Top
Di-Jet, 0 Lepton	1181 ± 36	2.18 ± 0.04	0.74 ± 0.03	4.51 ± 0.02

- Uncertainty quoted is statistical only.
- QCD - estimated using Monte Carlo, but normalise the rate to data control region because Pythia process is leading order.
- Normalize zero-lepton mode in region with METSig < 2 GeV$^{0.5}$.



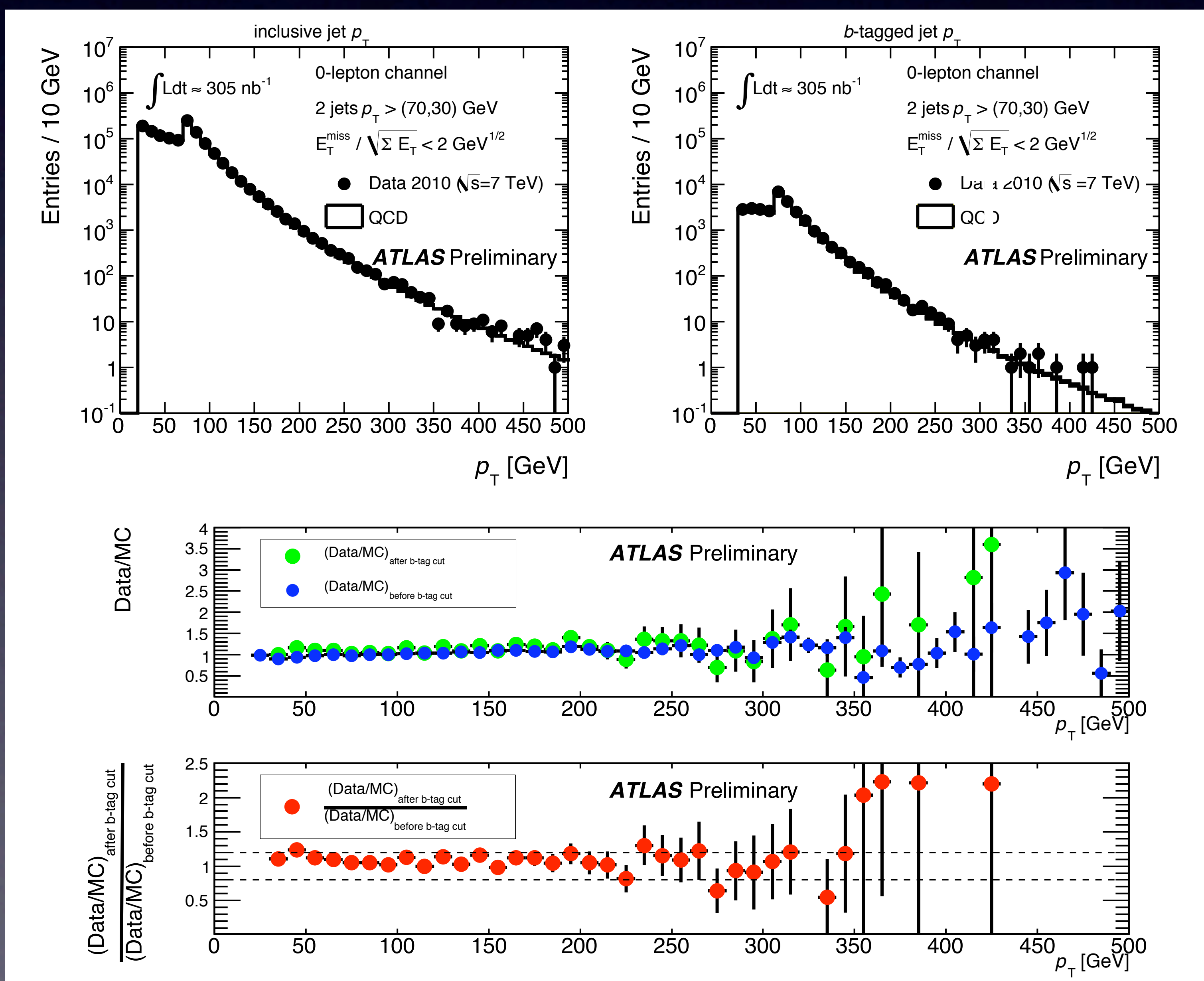
- Zero lepton mode, no METSig cut or b-tag requirement, after QCD normalisation.
- Yellow band includes systematic uncertainties on Monte Carlo.

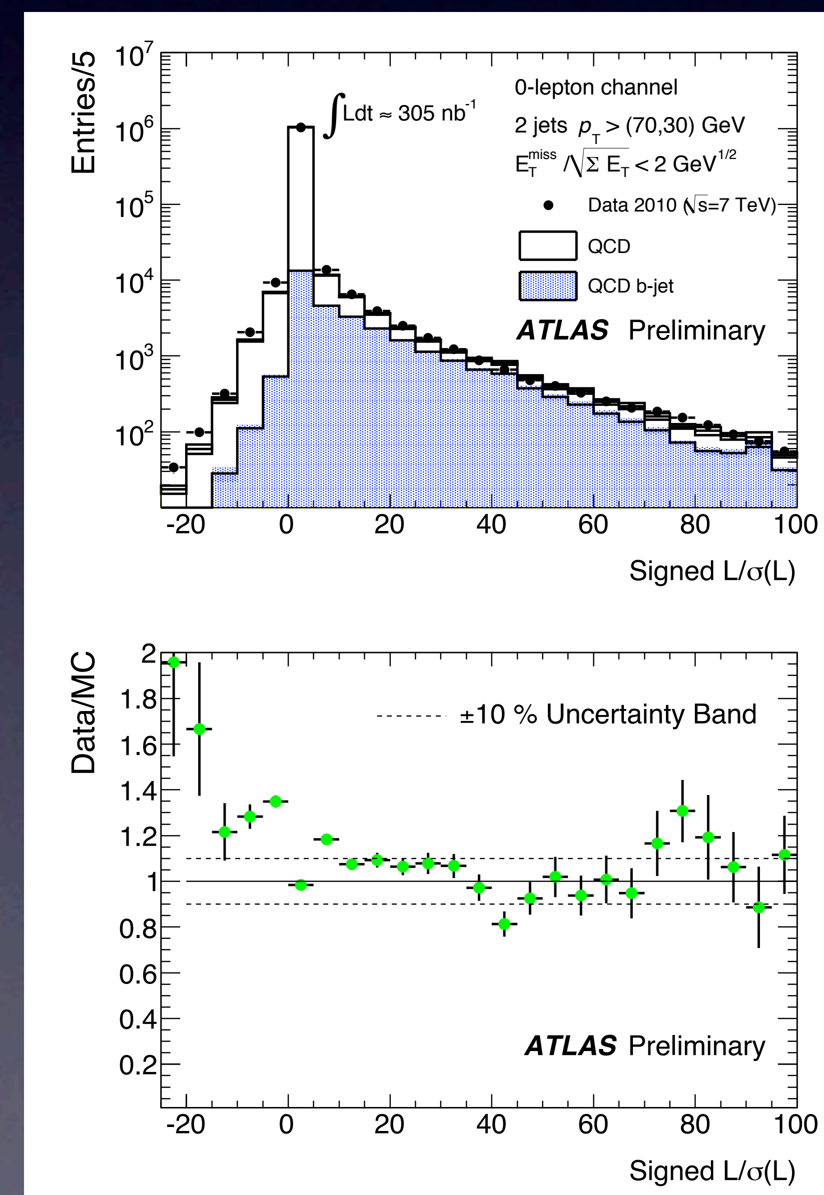
Systematic Uncertainties

- Vary Jet Energy Scale by 7 - 10%, depending on jet P_T and $|\eta|$, for jets and ETMiss. Then recalculate METSig and find affect on event yield - 40%.
- 60% uncertainty on W/Z + Jets yield due to uncertainty on PDF, ISR/FSR and normalization.
- 20% uncertainty on tagging performance (see next page).
- 20% uncertainty due to METSig sensitivity to underlying event and energy of calorimeter cells not in jets.
- 11% uncertainty on luminosity on all backgrounds, except QCD.
- 1% uncertainty applied to account for in-time pile-up.

Tagging Performance Uncertainty

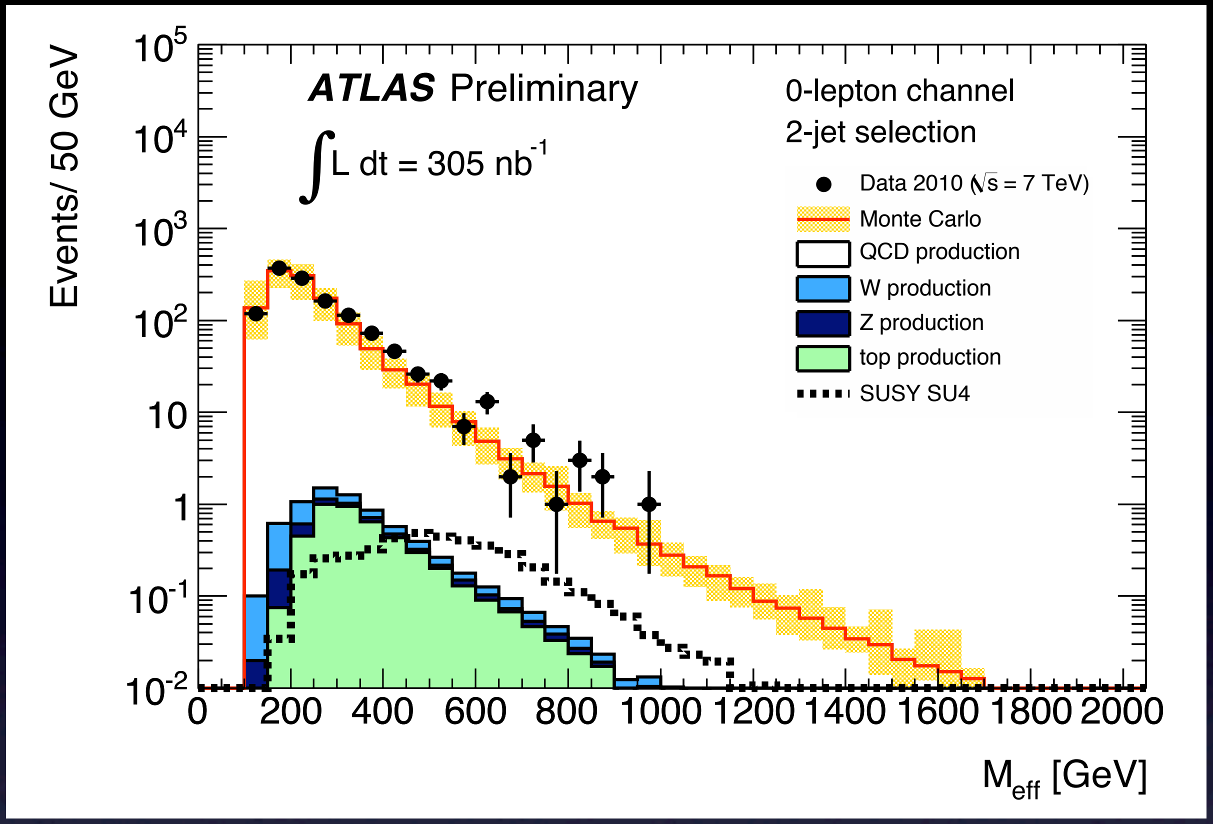
- Di-jet selection + METSig < 2 GeV$^{0.5}$.
- 10% deviation seen between data and monte carlo for $L/\sigma > 6$.
- B-jet content doubled in signal region, compared to control region.
- Assign systematic uncertainty of 20% on tagging efficiency.





Results

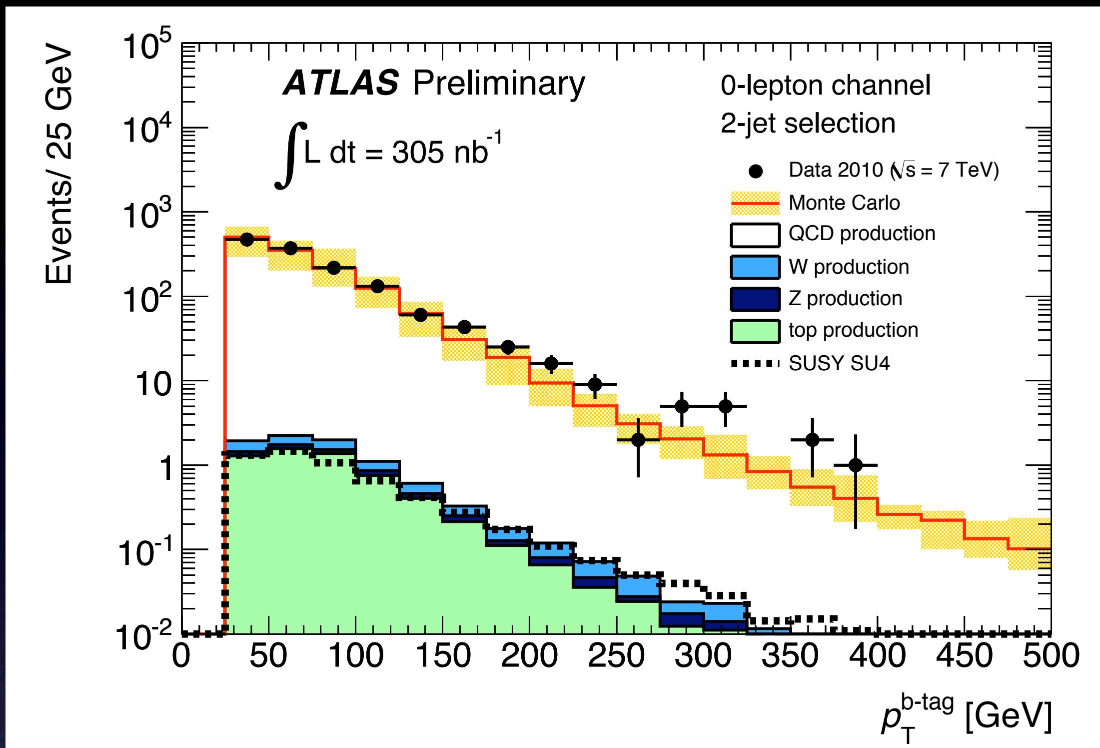
- Good agreement between data and Monte Carlo after all cuts, for di-jet channel.
- Yellow band includes systematic uncertainties on Monte Carlo.

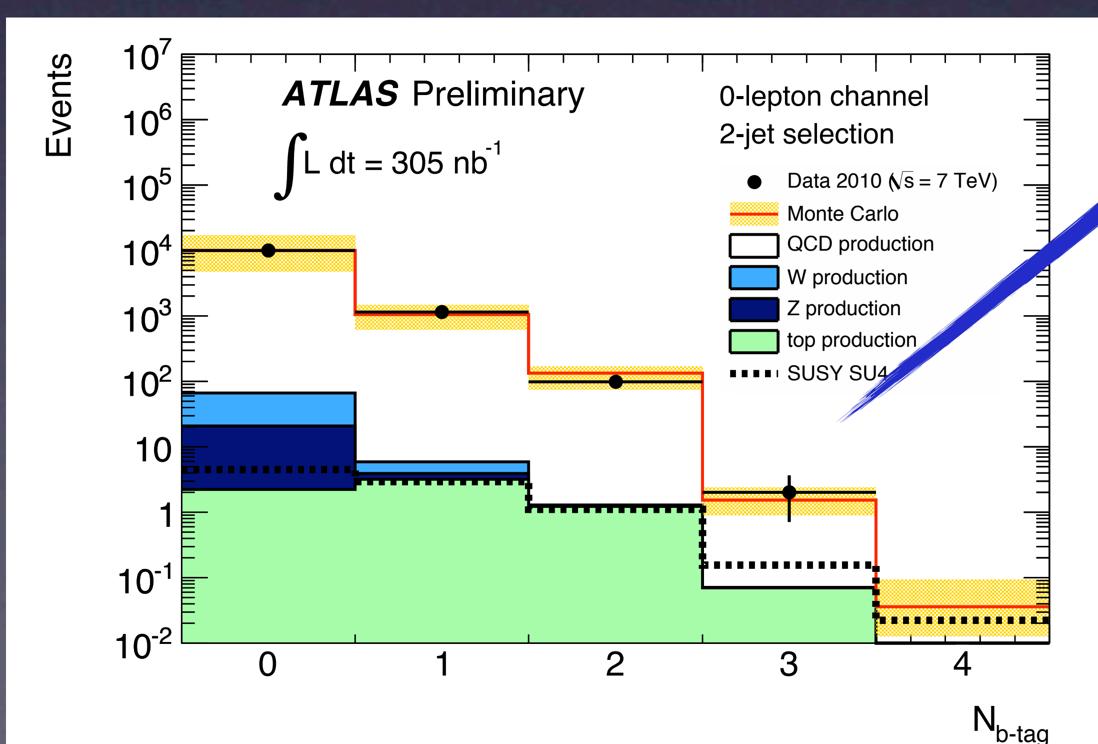


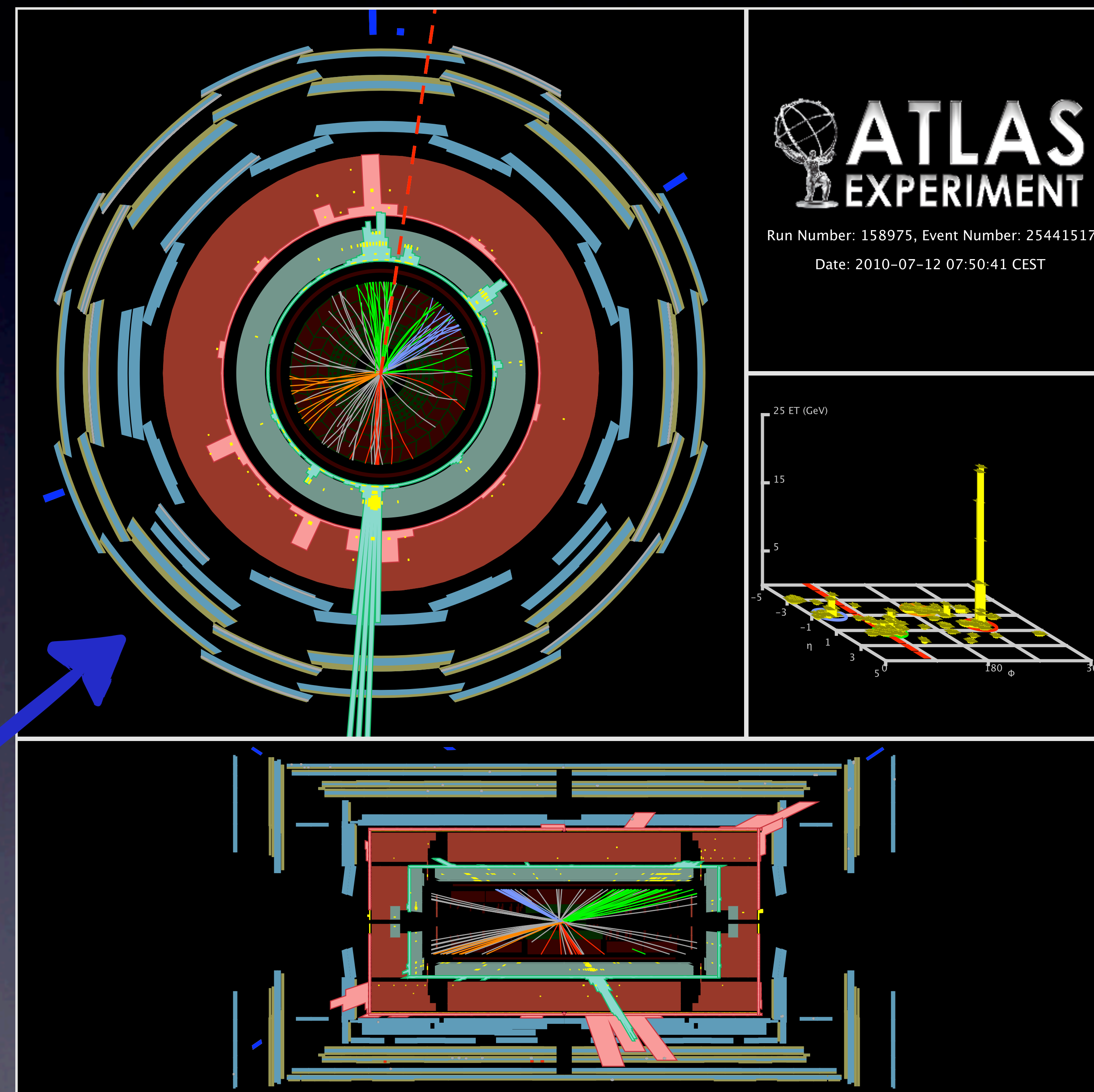
$$M_{Eff} \equiv E_T^{miss} + \sum_{i=1}^{njet} |p_T^{(i)}| + \sum_{j=1}^{nlep} |q_T^{(j)}|$$

	Data	SM Expectation	SU4
Jet P_T > (70,30) GeV	474243	$(4.7^{+2.1}_{-1.9}) \times 10^5$	9.95 ± 0.06
METSig > 2 GeV$^{0.5}$	11190	$(1.1^{+0.5}_{-0.6}) \times 10^4$	8.71 ± 0.06
At least1 b-tagged jet	1253	1190 ± 430	4.23 ± 0.04

Additional Zero-Lepton Di-Jet Results

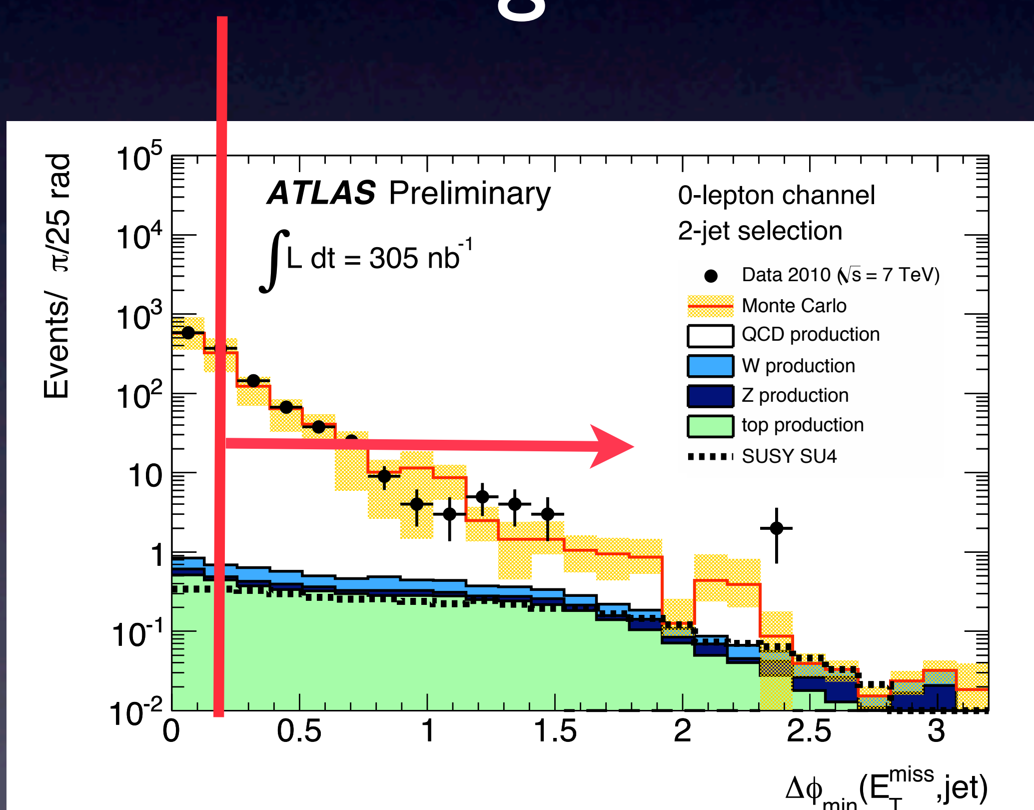


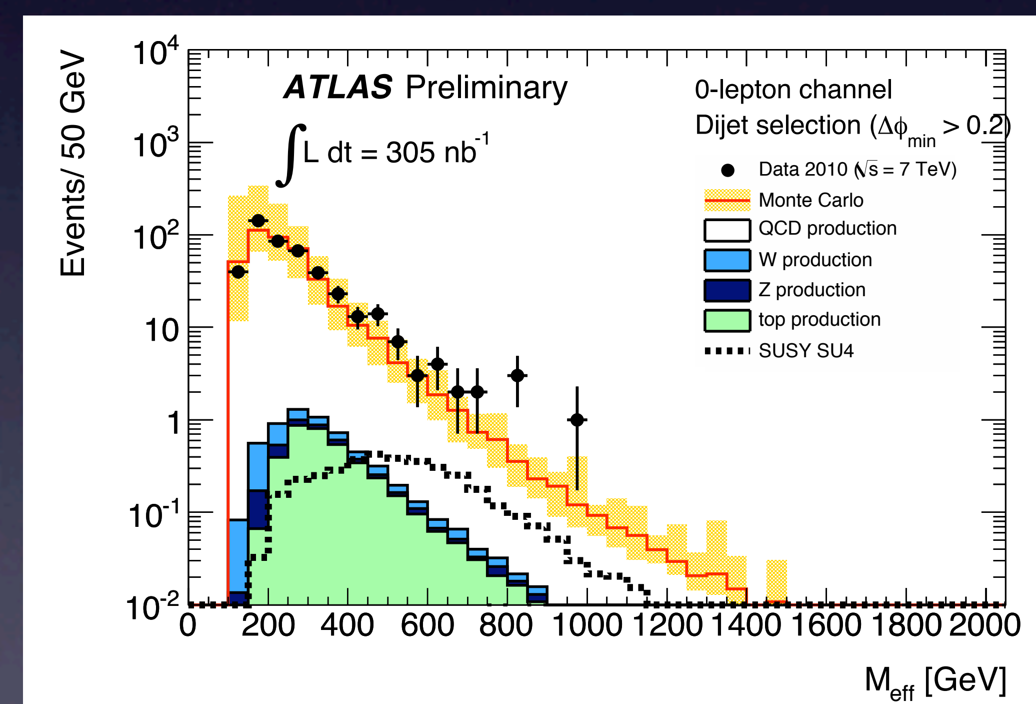




Additional QCD Suppression

- Cutting on the azimuthal distance between the leading jets and the ETMiss vector is known to further suppress QCD backgrounds.





- Find 446 events in data compared with 410 (+150,-180) expected from the Standard Model.

One-Lepton Mode

Event Selection

- At least one lepton (electron OR muon) with $P_T > 20$ GeV.
- Leading and second jet $P_T > 30$ GeV.
- METSignificance > 2 $GeV^{0.5}$.
- At least one b-jet ($L/\sigma > 6$ and $P_T > 30$ GeV).

Backgrounds

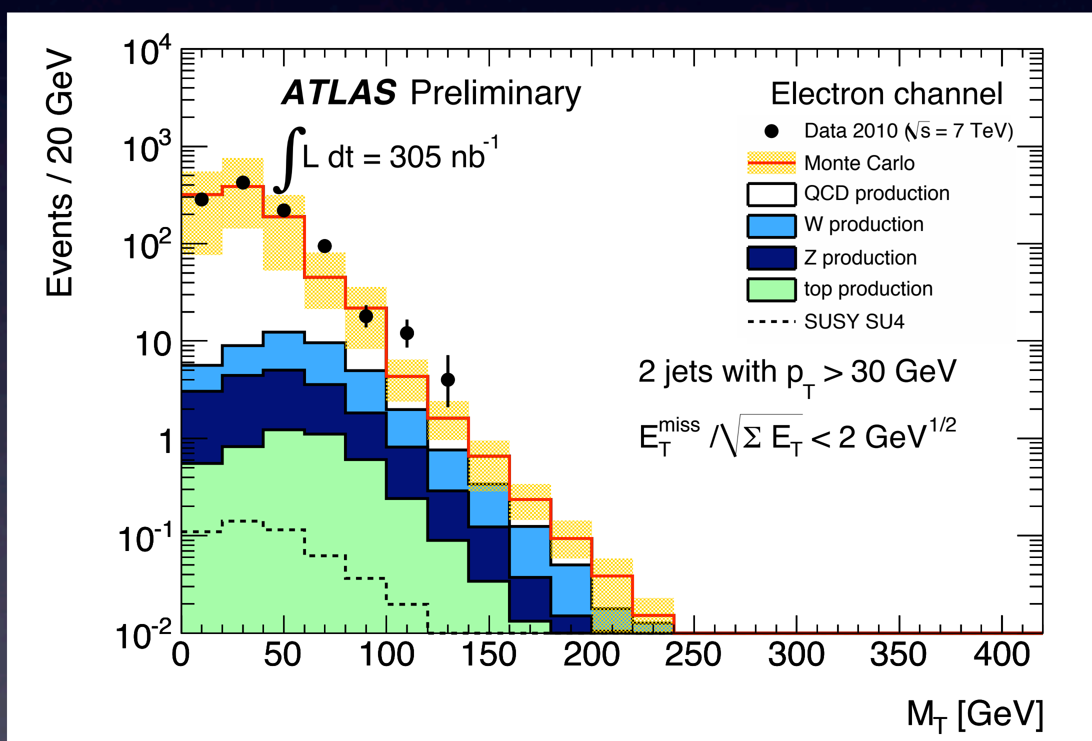
	QCD	W+Jets	Z+Jets	Top
Di-Jet, 1 Electron	0.78 ± 0.31	1.00 ± 0.03	0.10 ± 0.01	2.95 ± 0.01
Di-Jet, 1 Muon	0.49 ± 0.14	1.09 ± 0.03	0.20 ± 0.01	2.93 ± 0.01

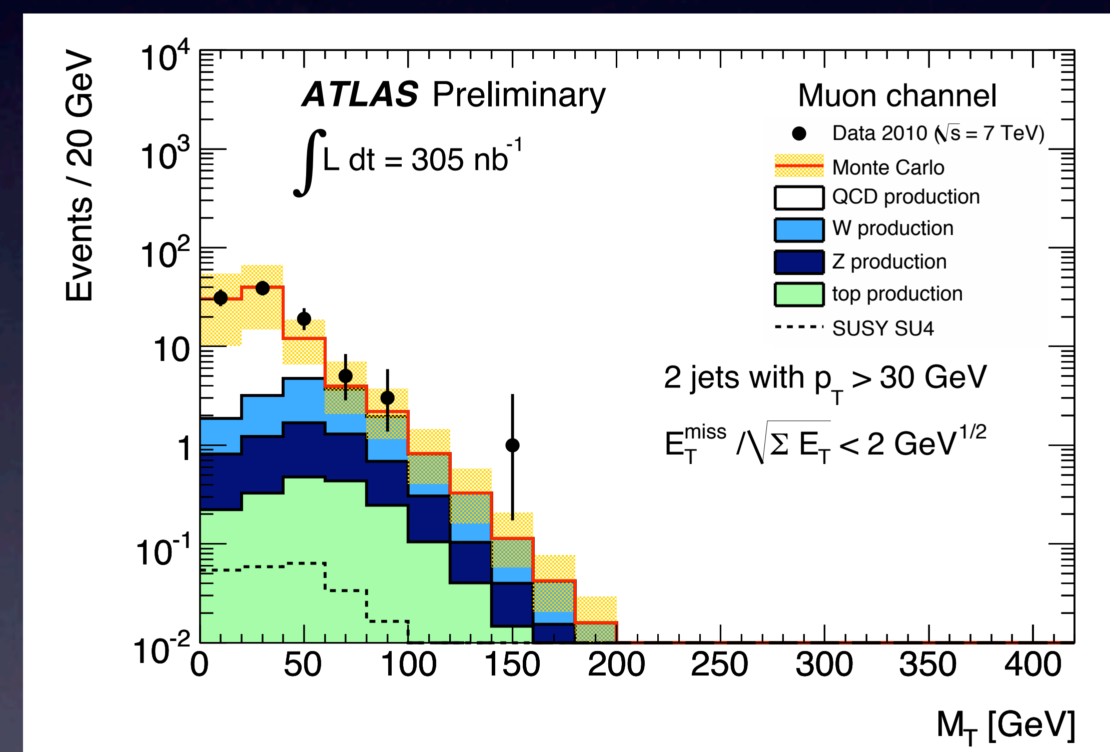
- Uncertainty quoted is statistical only.
- Main background is top quark pair production.
- W+Jet, Z+Jet and top quark Monte Carlo normalised to data using theoretical cross-sections.
- QCD rate again normalised to data in control region (see next slide).

Normalisation of QCD Background

- Normalize QCD in region with METSig < 2 and require transverse mass (M_T) < 40 GeV.
- W+Jets, Z+Jets and top quark pair backgrounds estimated from Monte Carlo and subtracted from data before QCD normalization is calculated.

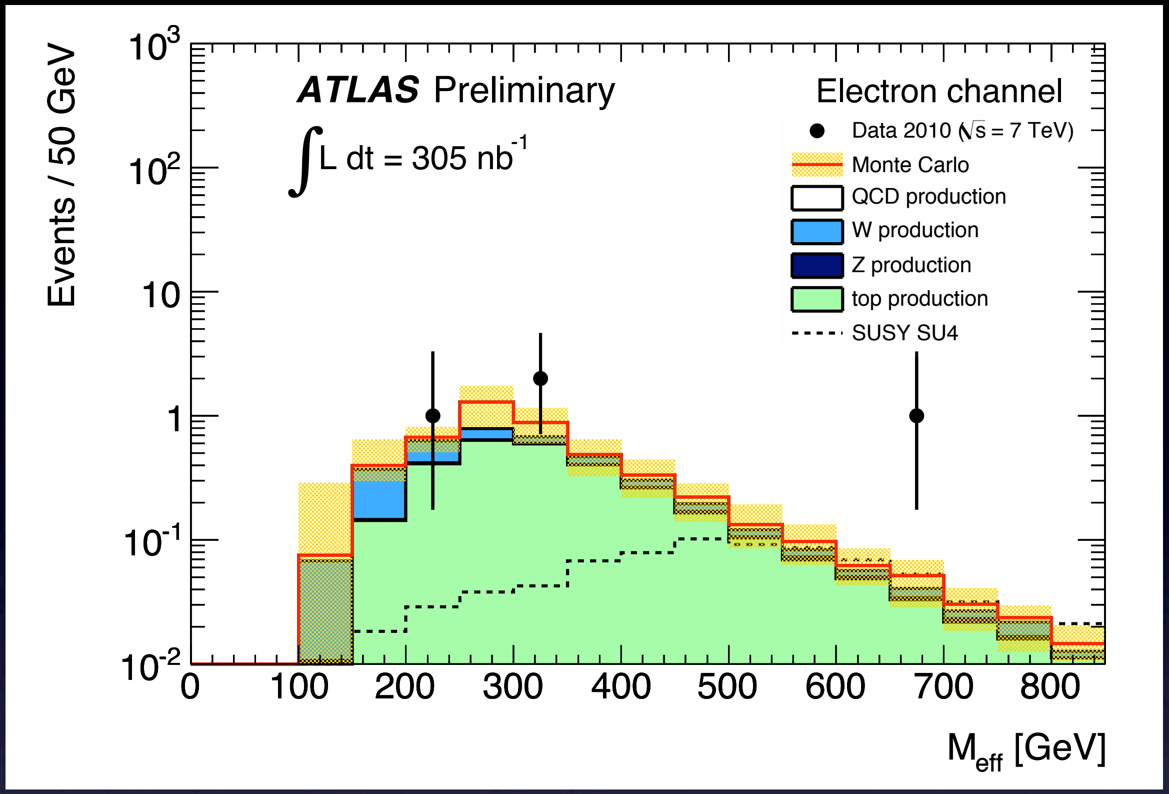
$$M_T^2 \equiv 2|p_T^l||E_T^{miss}| - 2p_T^l \cdot \vec{E_T^{miss}}$$

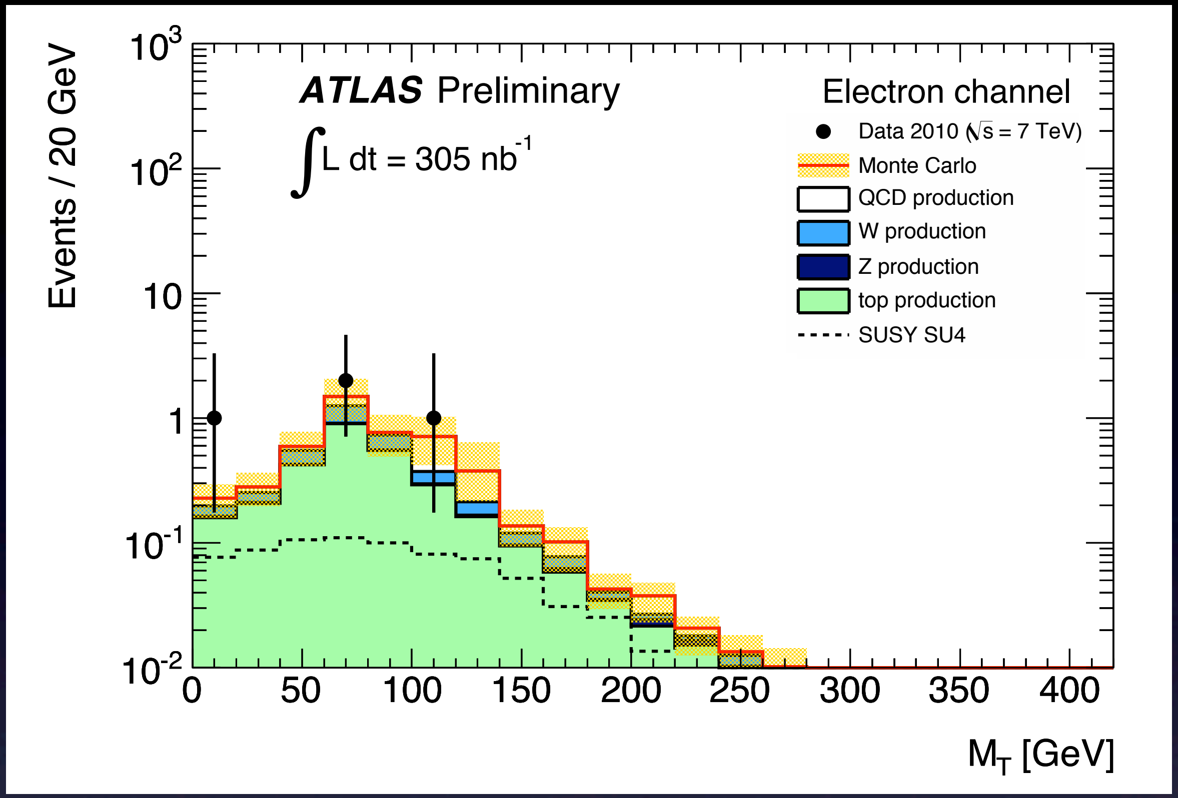




- M_T distributions for electron (left) and muon (right) channels after QCD normalisation. No b-tag requirement is applied.
- Total uncertainty on QCD normalization is increased from 20% to 50%.

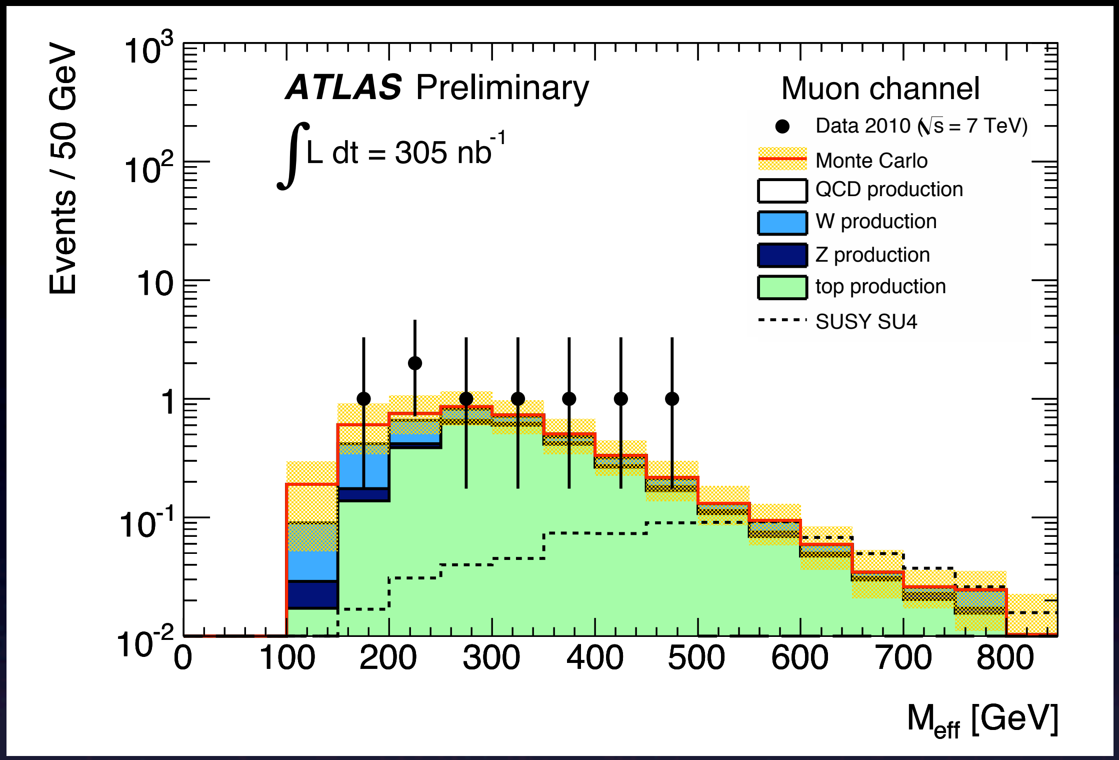
Di-Jet Electron Channel

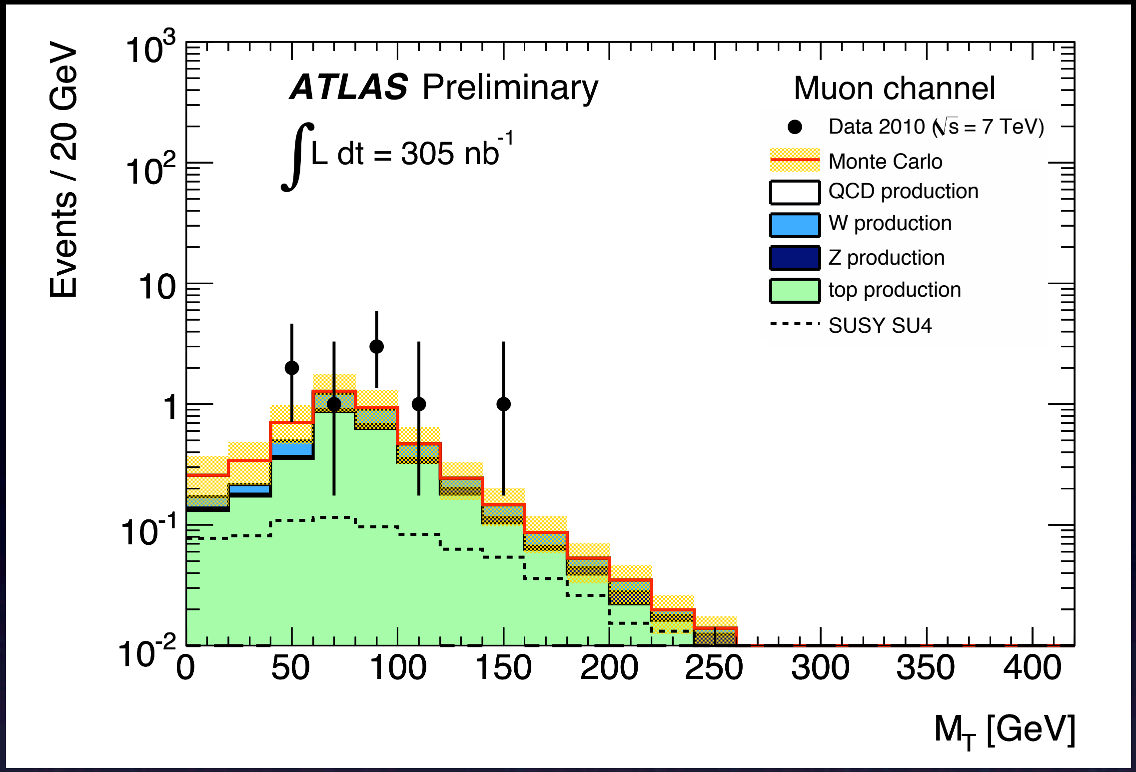




	Data	SM Expectation	SU4
Jet P_T > (30,30) GeV	557	520^{+360}_{-330}	1.65 ± 0.02
METSig > 2 $GeV^{0.5}$	31	39^{+28}_{-20}	1.40 ± 0.02
At least one b-tagged jet	4	$4.8^{+1.7}_{-1.5}$	0.81 ± 0.02

Di-Jet Muon Channel





	Data	SM Expectation	SU4
Jet P_T > (30,30) GeV	138	130^{+70}_{-60}	1.58 ± 0.02
METSig > 2 $GeV^{0.5}$	40	37^{+28}_{-19}	1.34 ± 0.02
At least one b-tagged jet	8	$4.7^{+1.7}_{-1.5}$	0.80 ± 0.02

Conclusions

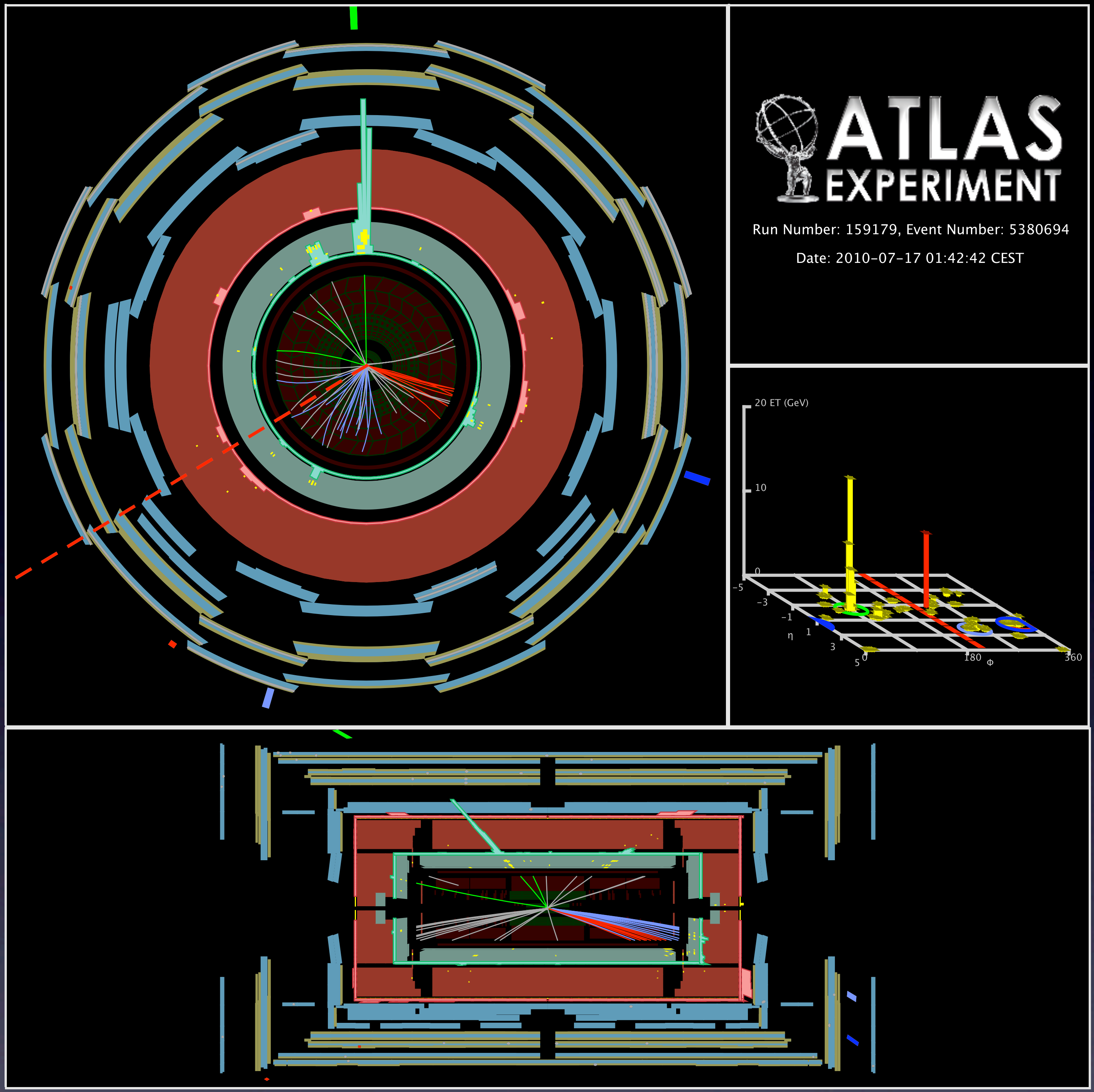
- Comparisons of a data sample of 305 nb^{-1} with Monte Carlo samples have been presented.
- Good agreement has been seen in zero-lepton, electron and muon channels between data and Standard Model expectations.
- Using larger datasets we plan to use more refined techniques to estimate the Standard Model expectation.

BACKUP

Details of 3 b-jet Event

Run	158975
Event	25441517
MEff (GeV)	432
ETMiss (GeV,Φ)	(46.1, 1.40)
METSig ($GeV^{0.5}$)	2.0

Jet	P_T (GeV), η (rad.), Φ (rad.), L/σ
Leading Jet	182, 0.30, -1.63, 0
Second Leading Jet	108, 1.15, 1.59, 8.3
Third Leading Jet	54.5, -1.08, 0.58, 19.5
Fourth Leading Jet	42.2, -1.70, -2.8, 12.9
Fifth Leading Jet	21.9, -1.48, -2.34, 0



- Event with one b-tagged candidate and isolated electron candidate.

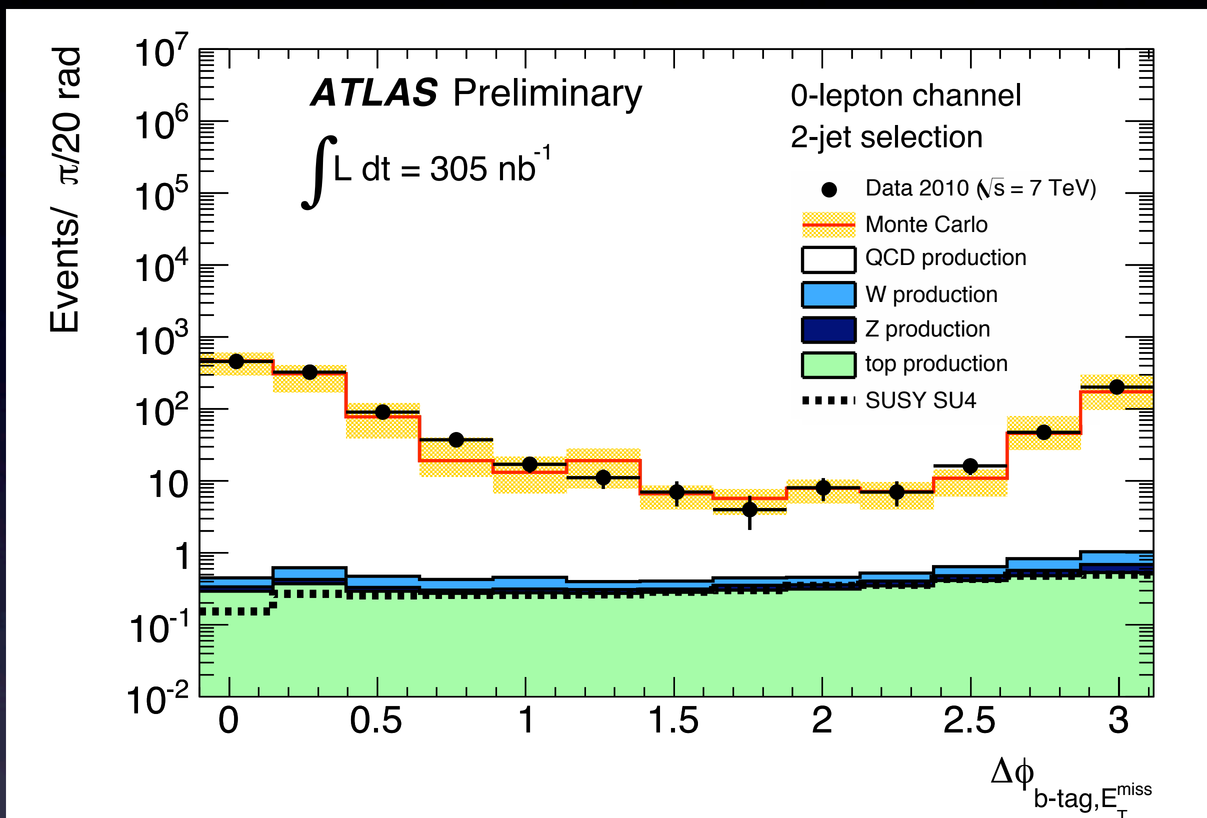
Details of One-Electron Event

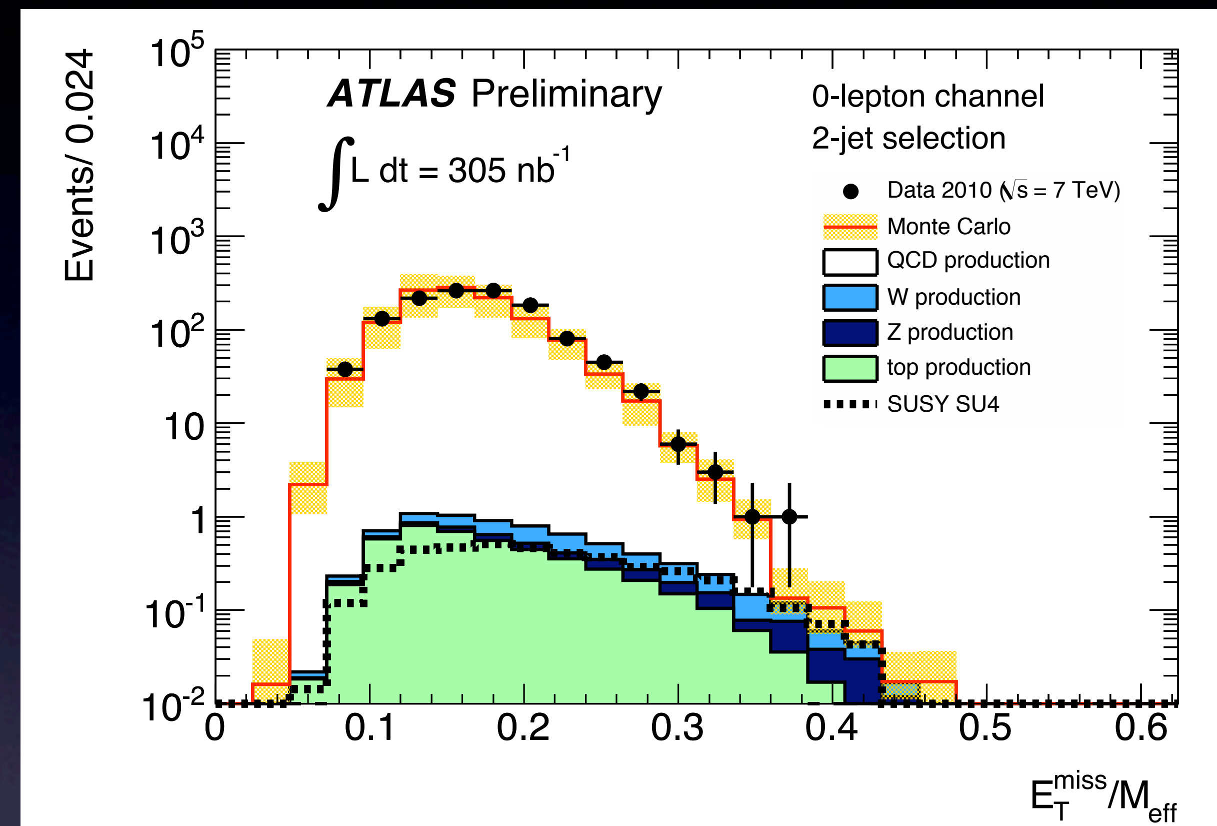
Run	159179
Event	5380694
MEff (GeV)	202.3
ETMiss (GeV,Φ)	(31.3, -2.78)
METSig ($GeV^{0.5}$)	2.1
Electron (P_T (GeV), η (rad.), Φ (rad.), E_T in isolation cone ΔR=0.2 (GeV))	(42.3, -0.47, 1.58, 1.9)
M_T (GeV)	60.4

Details of One-Electron Event

Jet	P_T (GeV), η (rad.), Φ (rad.), L/σ
Leading Jet	56.3, 1.57, -0.33, 15.4
Second Leading Jet	39.5. 2.19, -1.86, 0
Third Leading Jet	32.0, 0.72, 2.02, 0

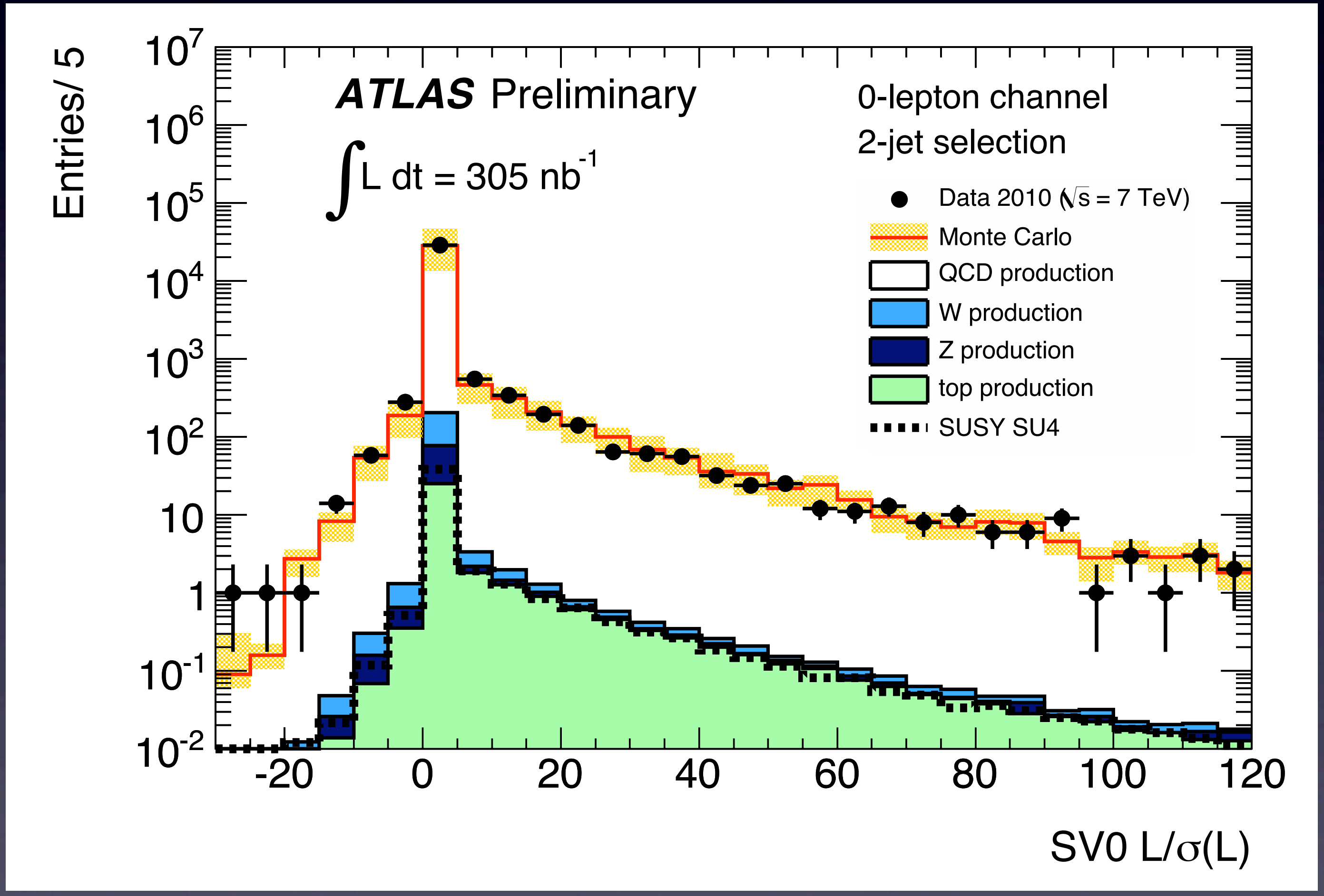
Additional Zero-Lepton Di-Jet Results





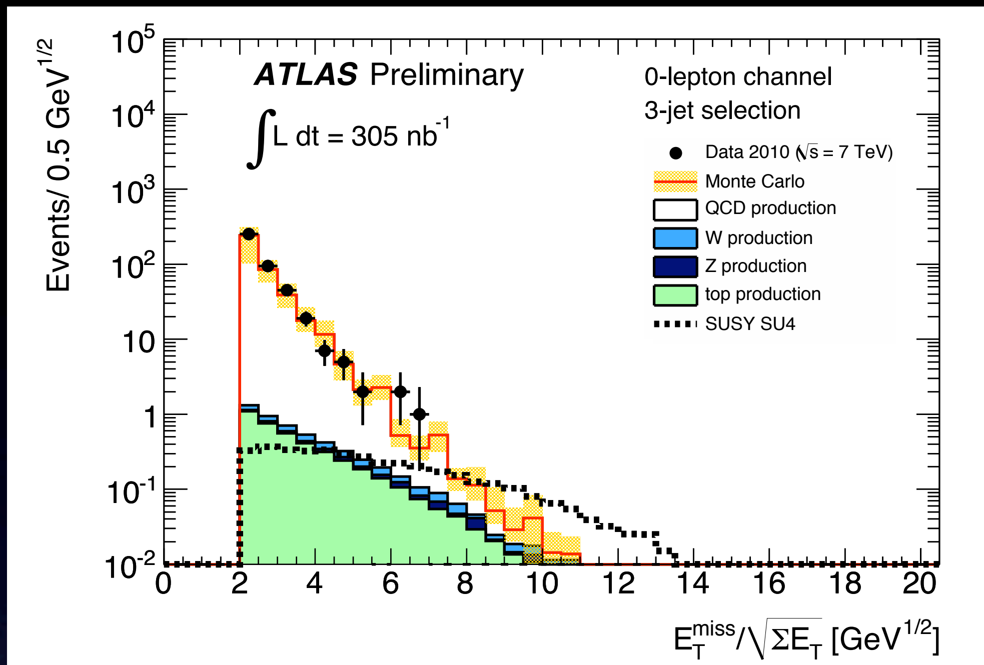
- Azimuthal angle between b-tagged jet and ETMiss vector
- Ratio of ETMiss and Effective Mass
- Both show good agreement between data and Monte Carlo

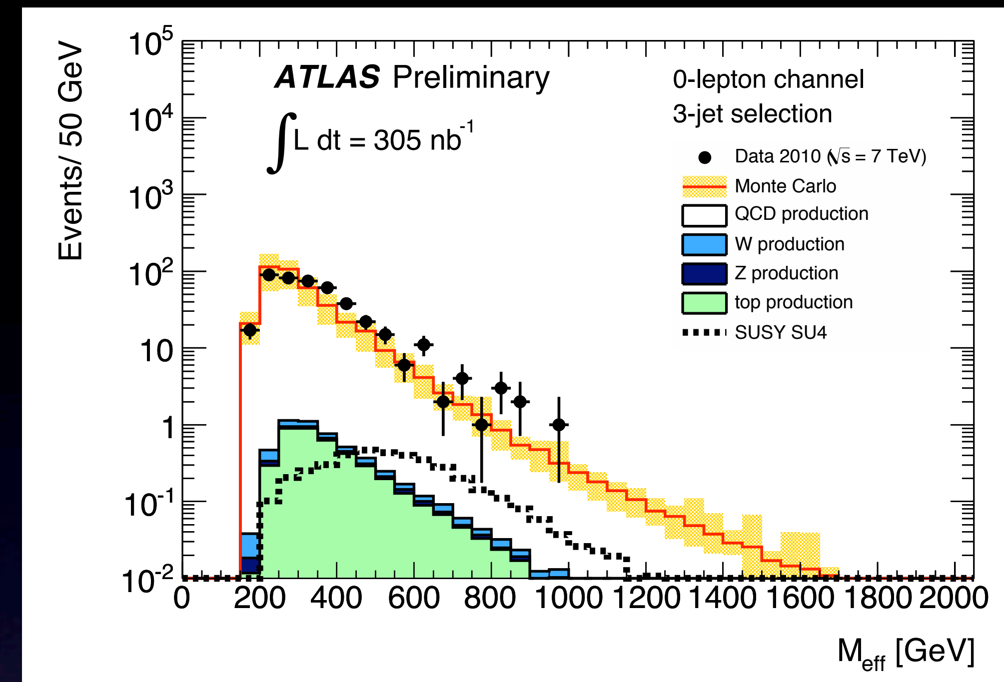
Additional Zero-Lepton Di-Jet Results



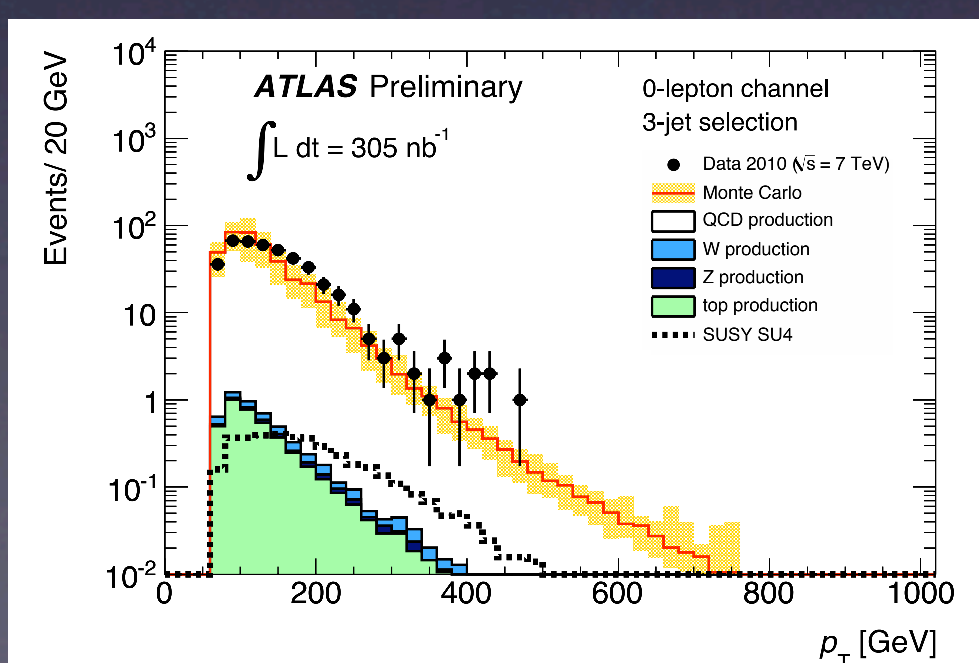
- All cuts, except b-tag requirement

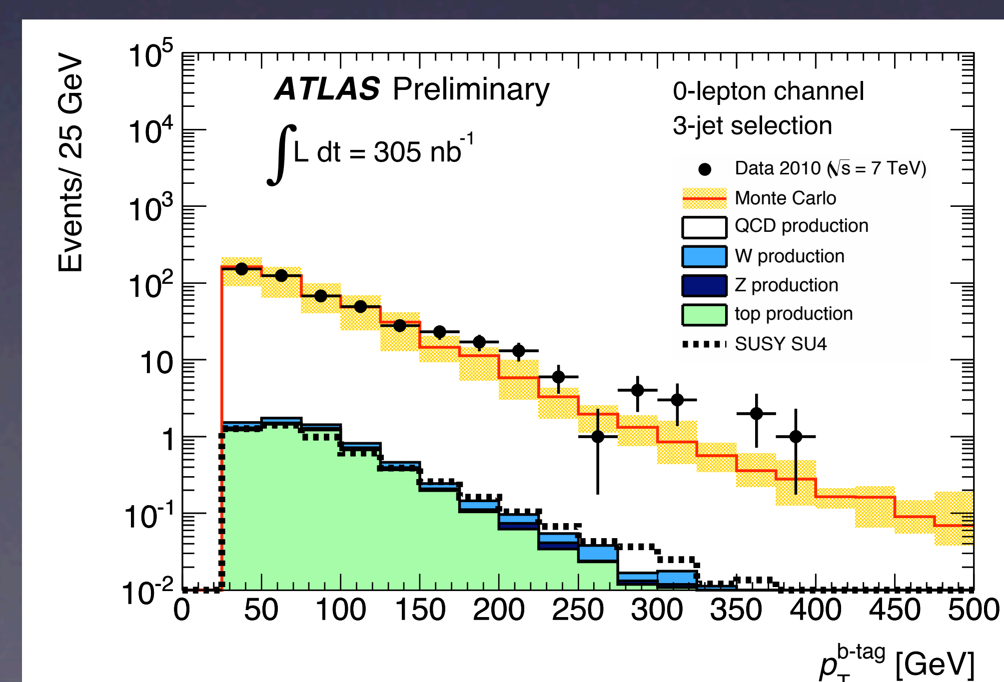
Zero-Lepton Tri-Jet Results



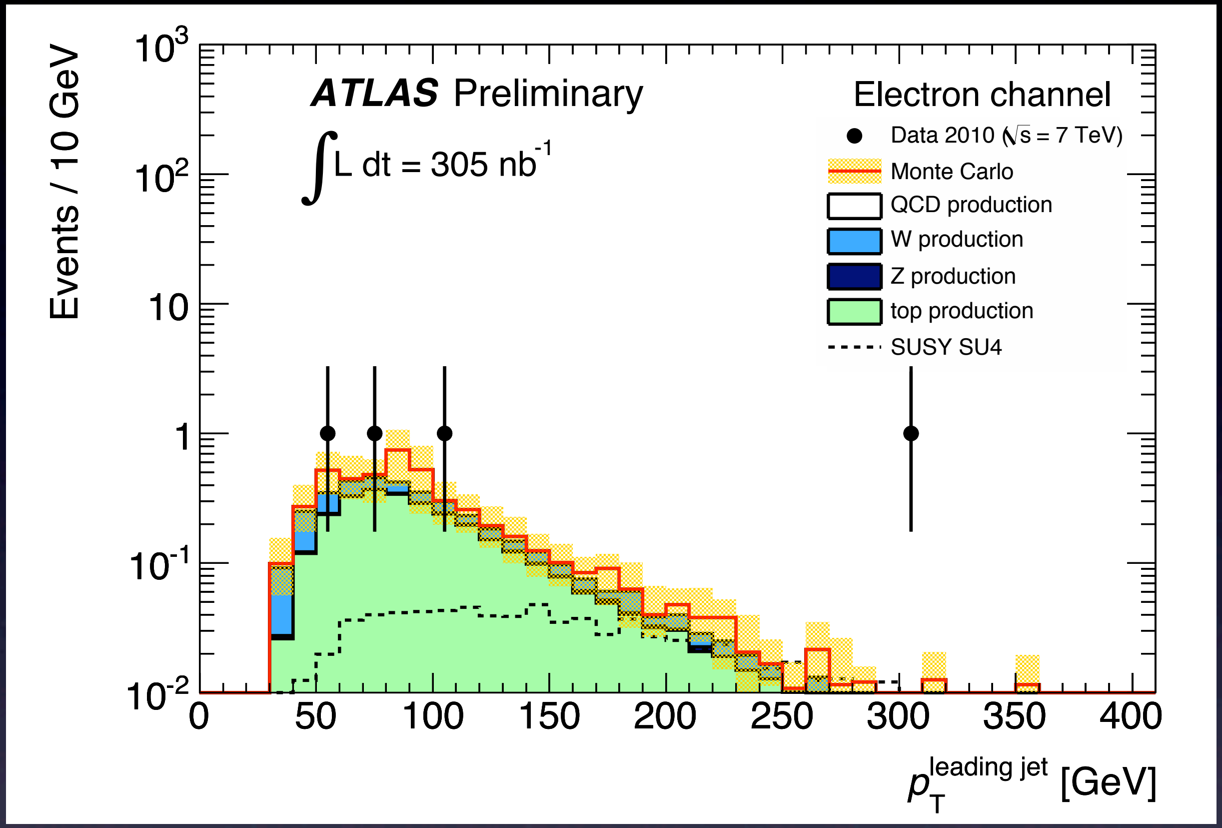


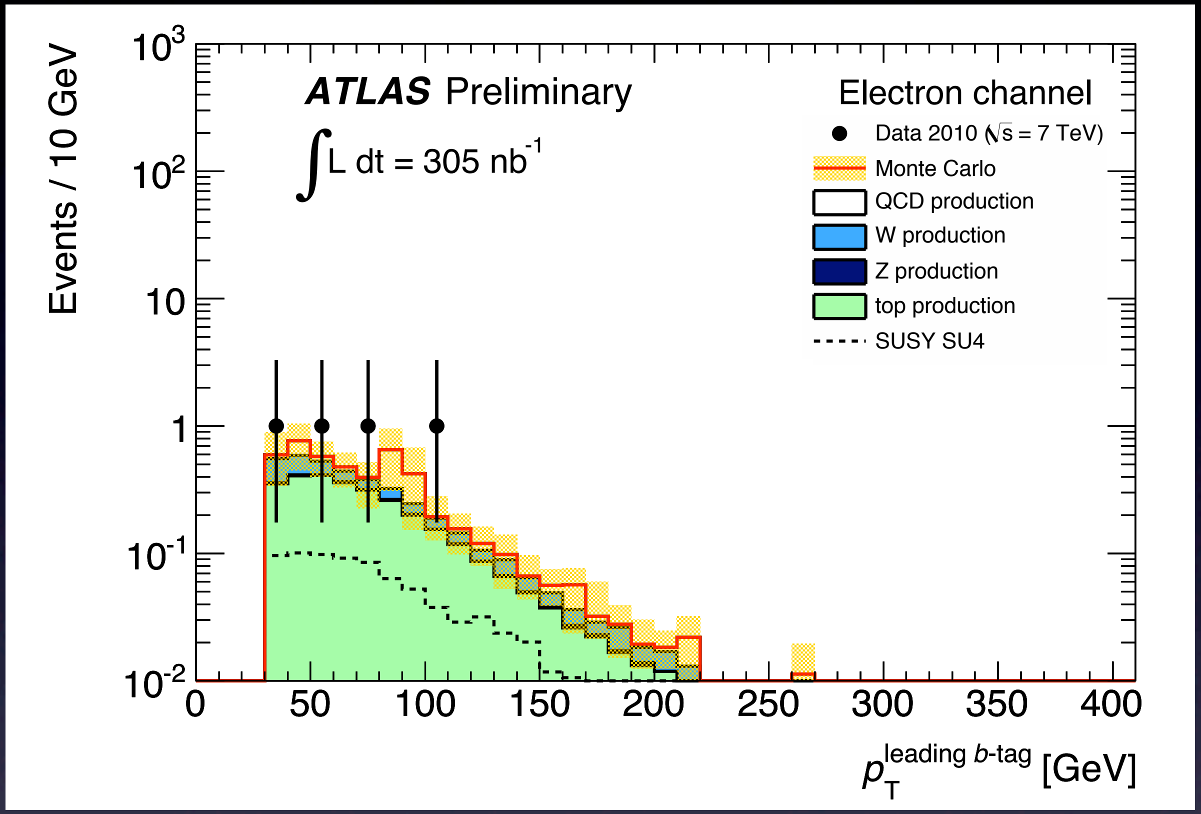
- Require third jet P_T > 30 GeV in addition to di-jet cuts
- 429 data events compared to 400 ± 160 expected standard model events





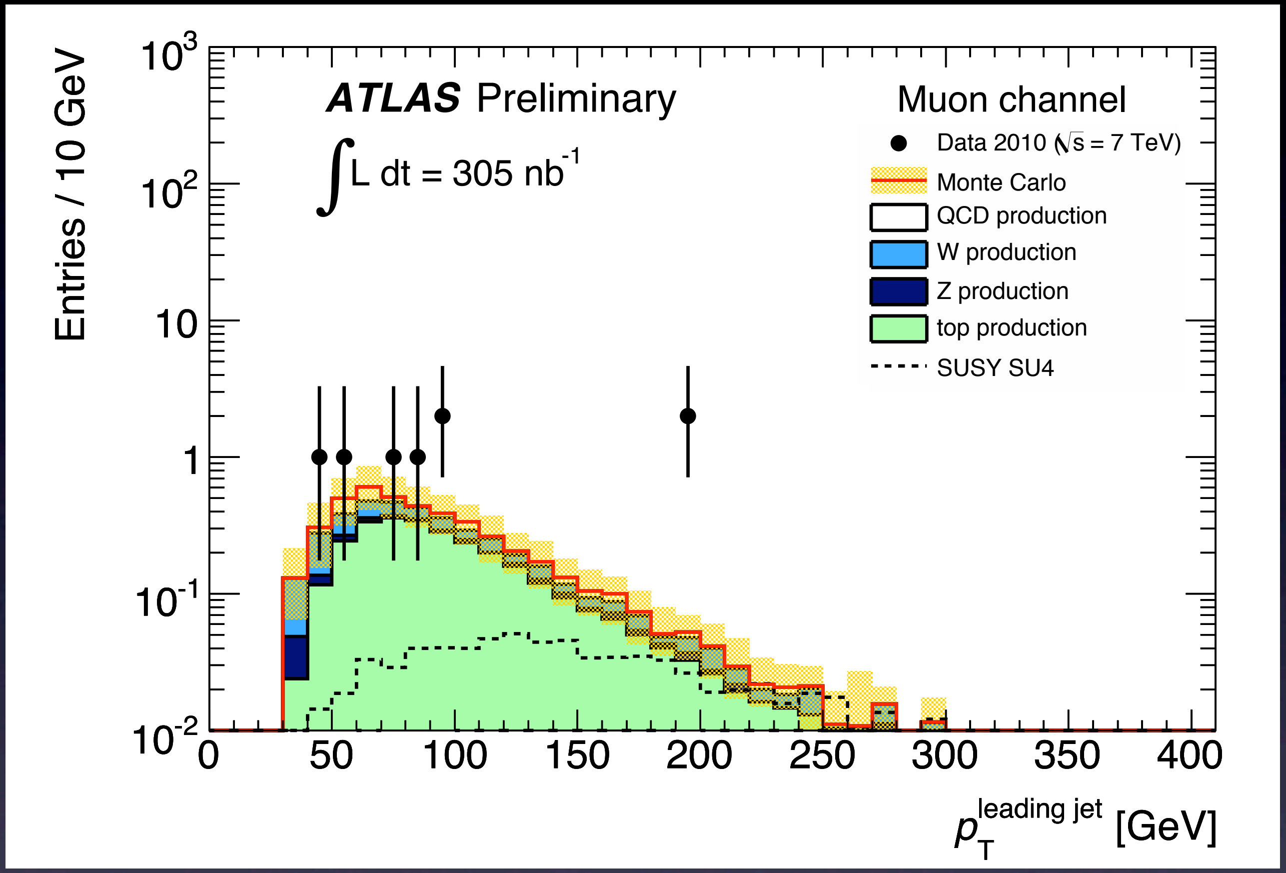
Additional Results in Di-Jet Electron Channel

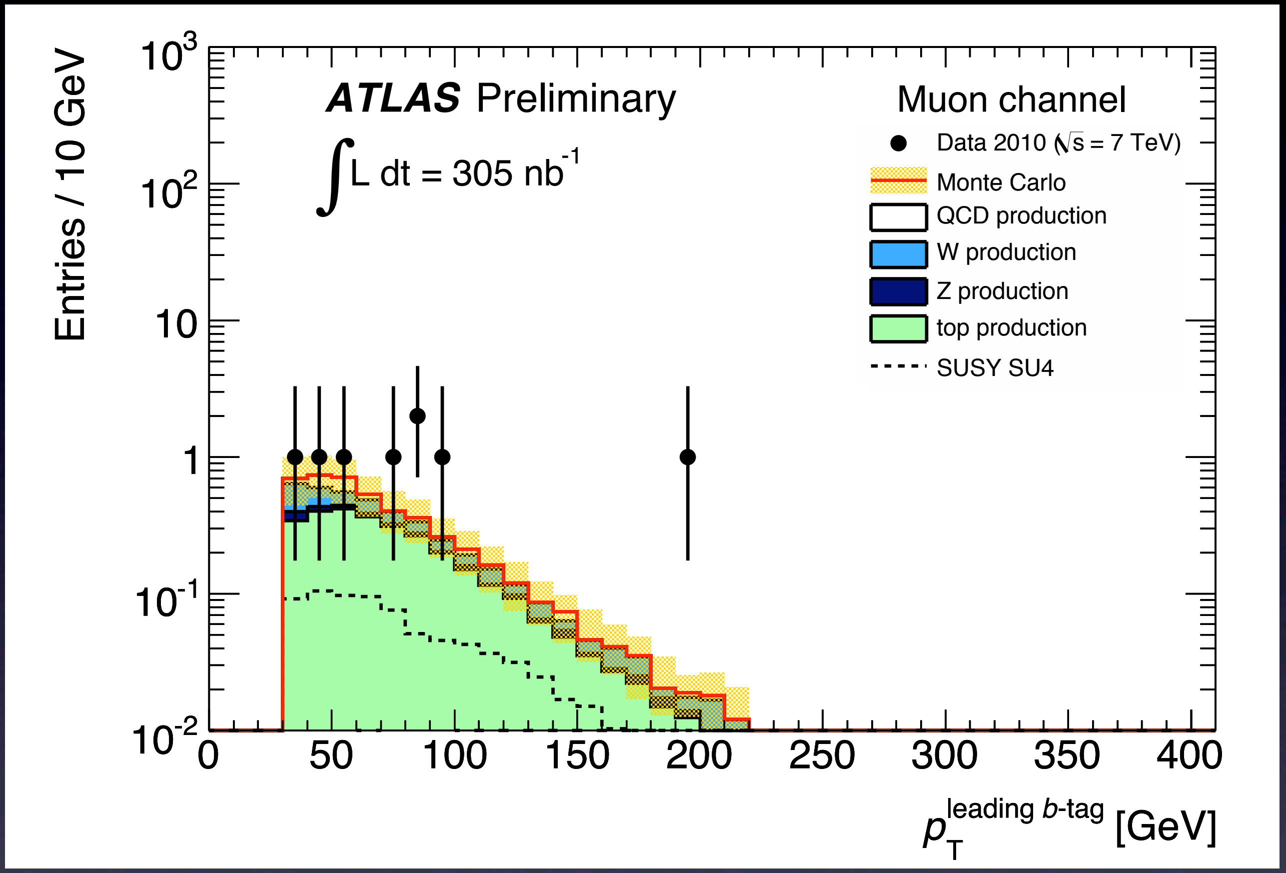




Good agreement seen for leading jet candidate and leading b-tagged jet candidate.

Additional Results in Di-Jet Muon Channel





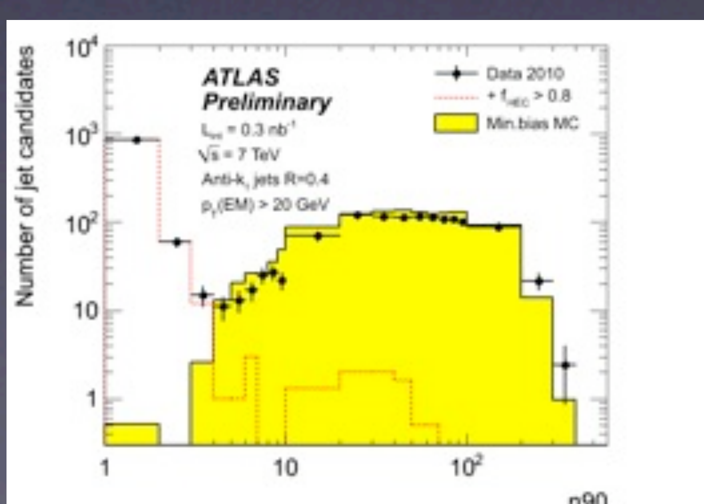
Good agreement seen for leading jet candidate and leading b-tagged jet candidate.

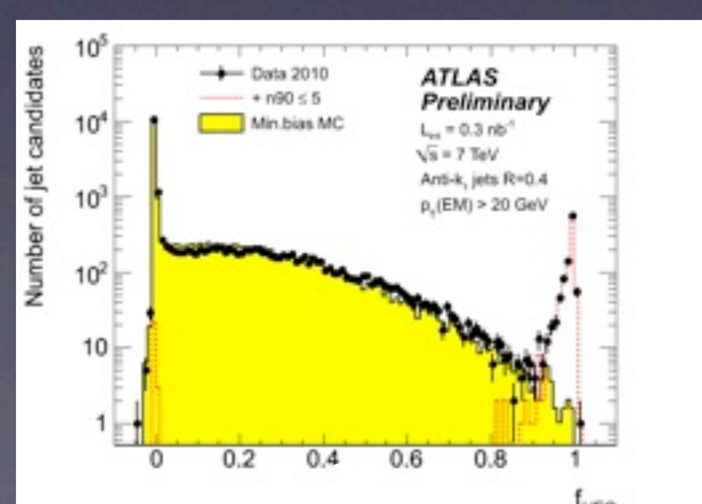
Jet Reconstruction

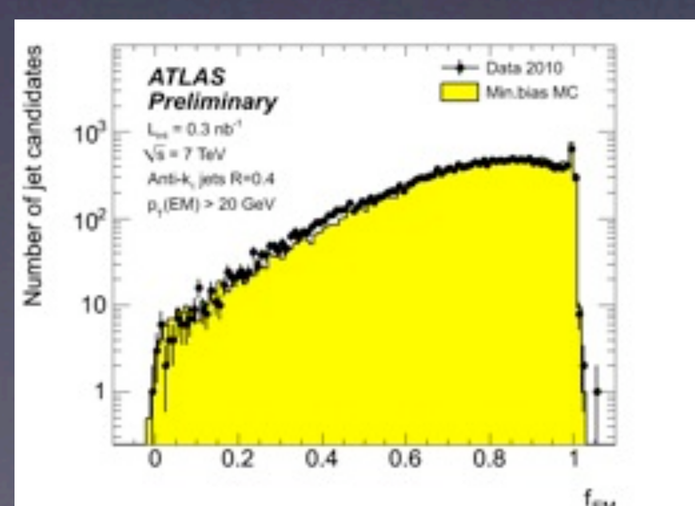
- Jet reconstruction uses topological clusters at electromagnetic (EM) scale
- Correction is derived from Monte Carlo to take jet energy from electromagnetic scale to jet energy scale.

Select Good Quality Jets

- Fraction of energy in HEC (f_{HEC}) > 0.8 AND number of cells containing more than 90% of jet energy, n_{90}, < 6 - vetoes noise bursts in HEC
- Fraction of energy in HEC > 1- Q, where Q is fraction of energy contained in known bad calorimeter cells - vetoes noise bursts in HEC
- Veto jets with more than 95% of energy in electromagnetic calorimeter, f_{EM}, AND quality factor, calculated from cells in EM calorimeter, > 0.8 - vetoes noise bursts in EM calorimeter
- Require jet energy-squared-weighted time to be within 50 ns of collision time - vetoes cosmic rays







Overlap Removal

- If an electron candidate and jet candidate are found within $\Delta R < 0.2$, the object is interpreted as an electron
- If a muon candidate and a jet are found within $\Delta R < 0.4$, the object is interpreted as a jet.
- If an electron candidate and a jet are found within $0.2 < \Delta R < 0.4$, the object is interpreted as a jet

Further Monte Carlo Details

- QCD Multijets - Pythia 6.4.21 with ATLAS MC09 tune.
- W/Z+jets - ALPGEN + CTEQ6L1 PDFs. Cross-section at NNLO taken from FEWZ.
- Top quarks - MC@NLO + use HERWIG and JIMMY for FSR and underlying event. CTEQ6.6 NLO PDFs.
- SU4 - Herwig++ and mass spectrum from ISAJET. Cross-section at NLO from prospino.