Search for New Physics Involving Top Quarks at ATLAS

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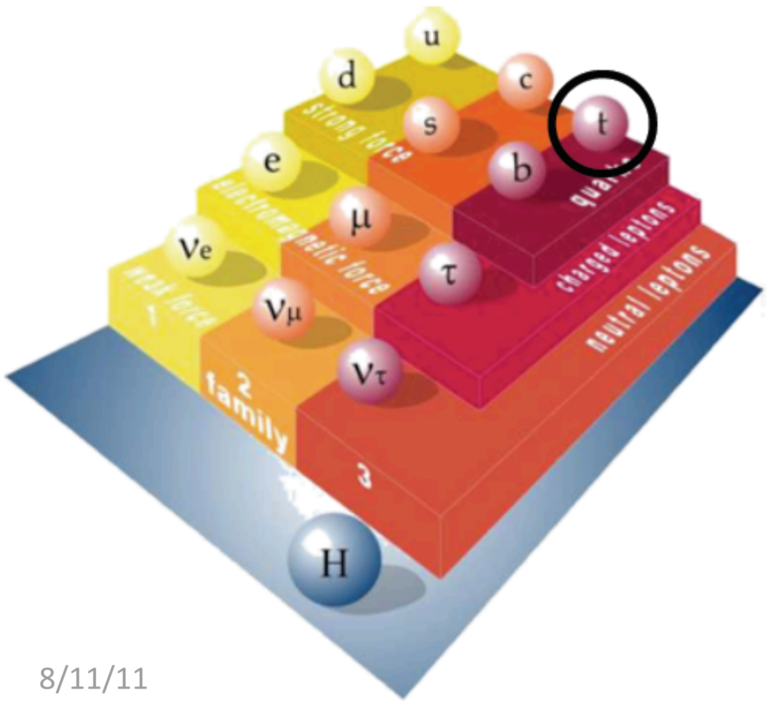
on behalf of the ATLAS Collaboration

DPF
Brown University, August 2011

The Top Quark

- Completes the quark sector (?)

- Properties well defined by SM



- The heaviest fundamental particle with unique properties
  - Large coupling to Higgs boson (~1)
  - Important role in electroweak symmetry breaking?
  - Short lifetime: decays before fragmenting $\tau \approx 5 \cdot 10^{-25}$ s << Λ^{-1}_{QCD}

The most probable place for new physics to show up?

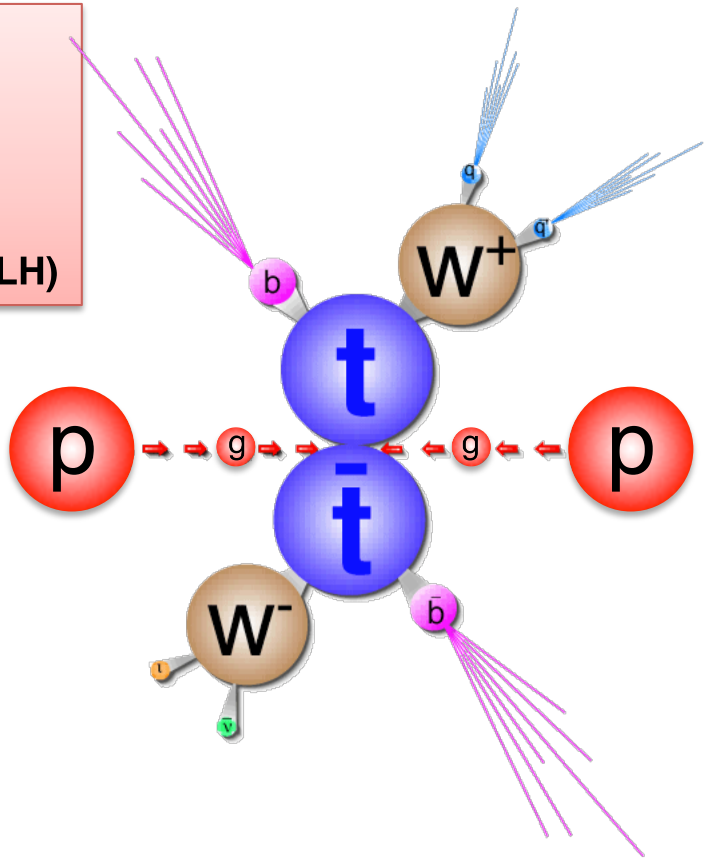
Top Physics at ATLAS

Production
- cross section
- kinematics
- resonant production
- production mechanism (gg, qq)
- **new particles (Z', W', t', stop, LH)**

Boosted top quarks

ttbar system
- spin correlation
- "modified" charge asymmetry
- CPT

Detector calibration
- jet energy scale
- b- and c-tagging efficiency



Top quark decay
- anomalous couplings
- rare decays, FCNC
- branching ratios
- CKM matrix element $|V_{tb}|$
- new particles (e.g. H^+)

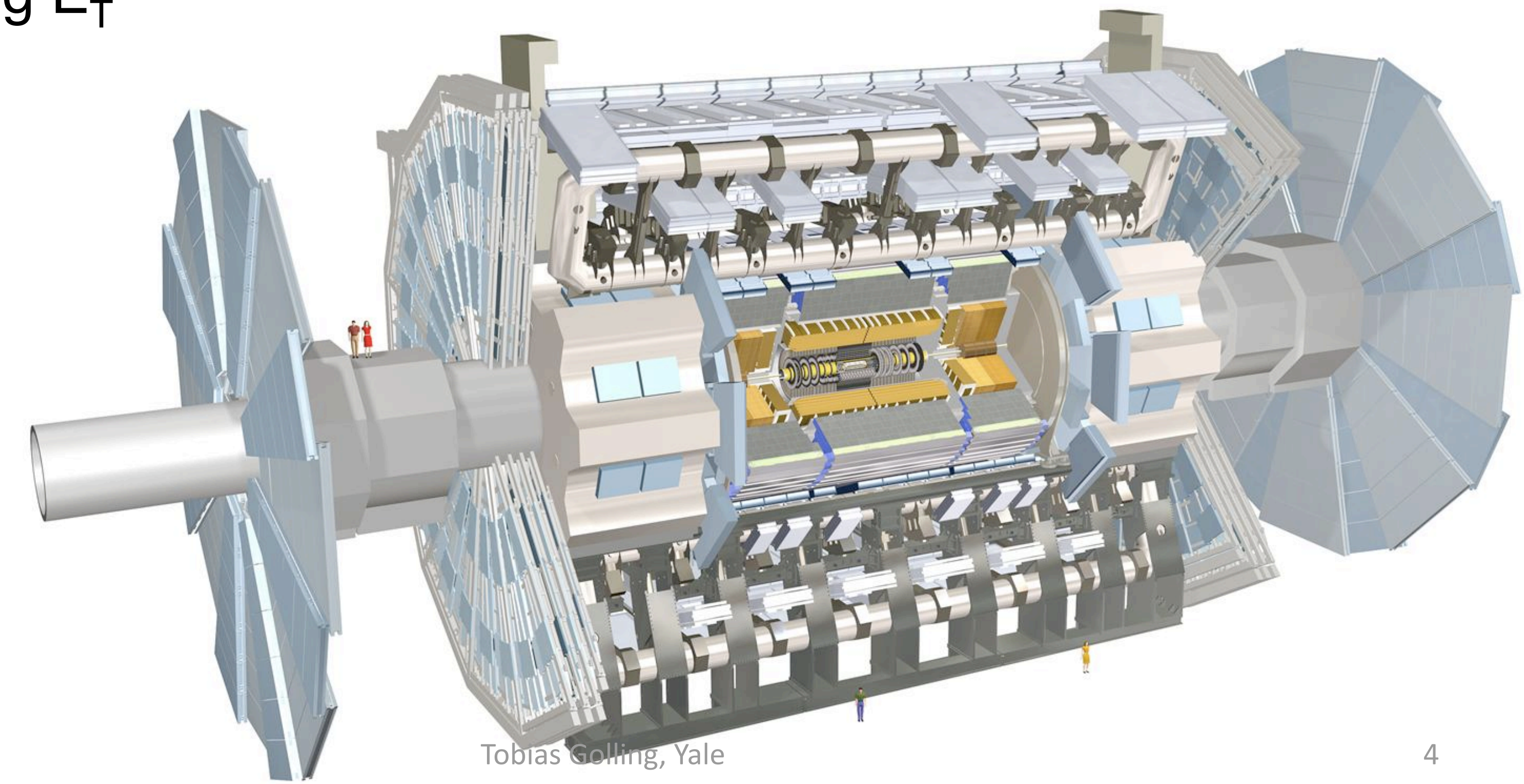
Top mass, charge (ttbar+γ), width, lifetime

W helicity

EW single top quark production

Need the Whole ATLAS Detector for these Measurements

- Jets ($p_T > 20$ GeV, $|\eta| < 2.5$)
- B-tagging
- Electrons ($p_T > 20$ GeV, $|\eta| < 2.5$, isolated)
- Muons ($p_T > 20$ GeV, $|\eta| < 2.5$, isolated)
- Missing E_T



Search for New Physics in ttbar Events With Large Missing Transverse Momentum

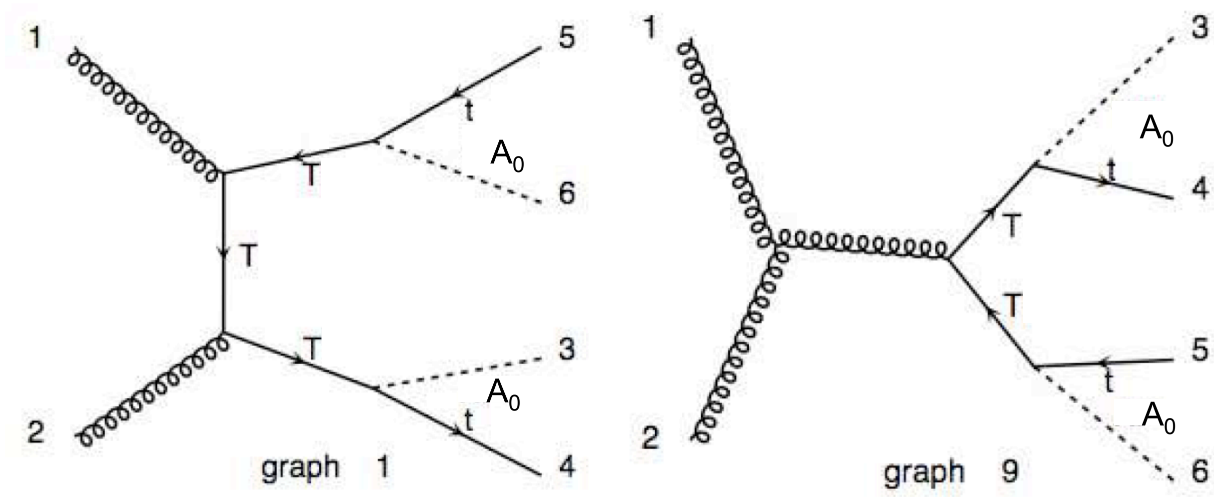
ATLAS-CONF-2011-036

ttbar+E_T^{miss} – Generic Signature

- Stop quark pair production in supersymmetry (assuming the stop squark decays to a top quark and a neutralino: $\tilde{t} \rightarrow t\tilde{\chi}_1^0$)
- Little Higgs models with T-parity conservation
- Models with third generation scalar leptoquarks
- Models with universal extra dimensions with Kaluza-Klein-parity
- Models in which baryon and lepton number conservation arises from gauge symmetries

Benchmark

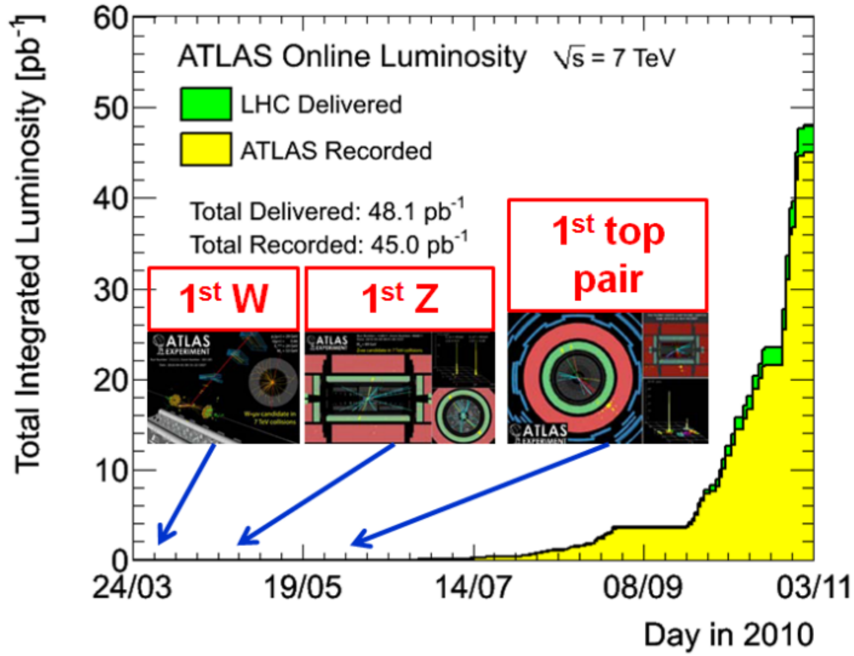
- Pair-produced vector 'quark' T decaying to a top and a scalar neutral A_0
  - A_0 is a dark matter candidate
  - Cross section higher than stop due to spin states



- First limits from CDF this past winter:
  - Excluded: m(T) = 360 GeV for m(A_0) < 100 GeV (using ~5/fb)

Analysis Strategy

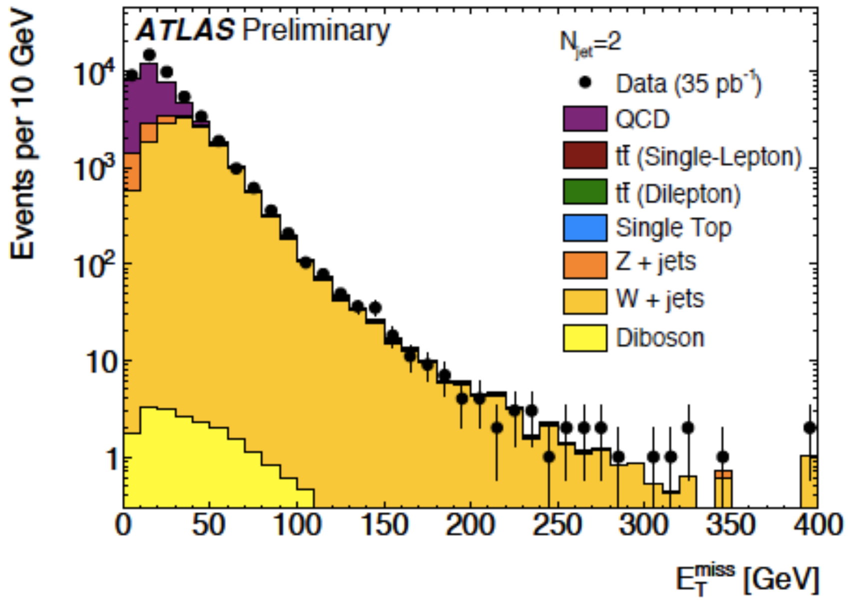
- Event selection to extract signal while minimizing backgrounds
  - Using lepton+jets channel
- Strategy
  - Evidence for signal based on excess of events w.r.t. known backgrounds
  - Understanding of backgrounds is key
  - Use data driven approach wherever possible



Using 2010 data set: L_{int} = 35 pb^{-1}

Event Selection

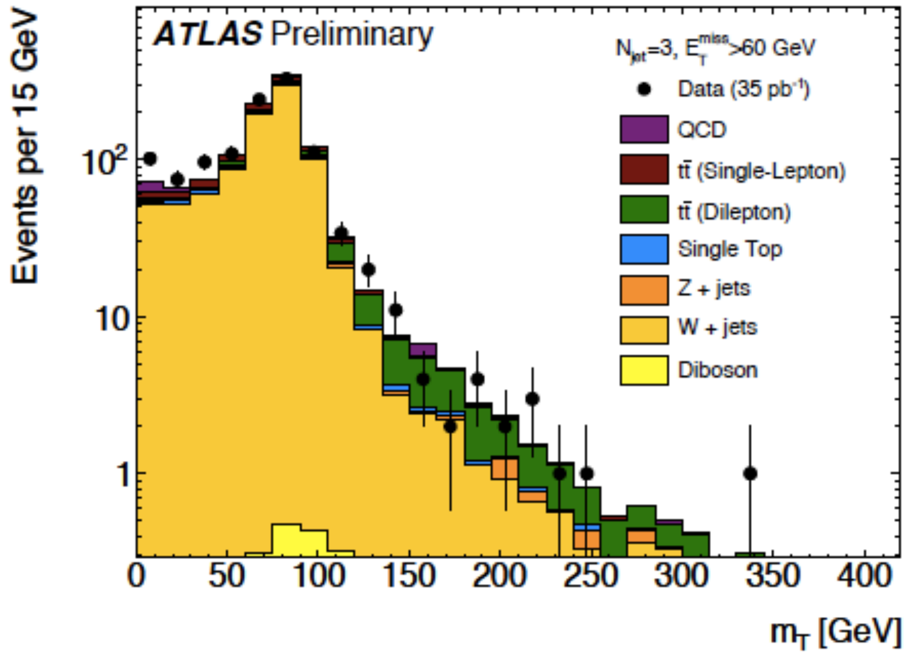
- Two channels: e+jets, μ+jets
- Standard ttbar selection
  - Single lepton triggers
  - ≥4 jets with p_T>20 GeV and |η|<2.5
  - One isolated lepton
    - Electron p_T>20 GeV, |η|<2.5
    - Muon p_T>20 GeV, |η|<2.5
  - Large E_T^{miss}
- Additional selection
  - E_T^{miss}>80 GeV
  - W boson transverse mass m_T>120 GeV
  - Tight second lepton veto



E_T^{miss} well described in 2-jet control region

ttbar Dilepton Background

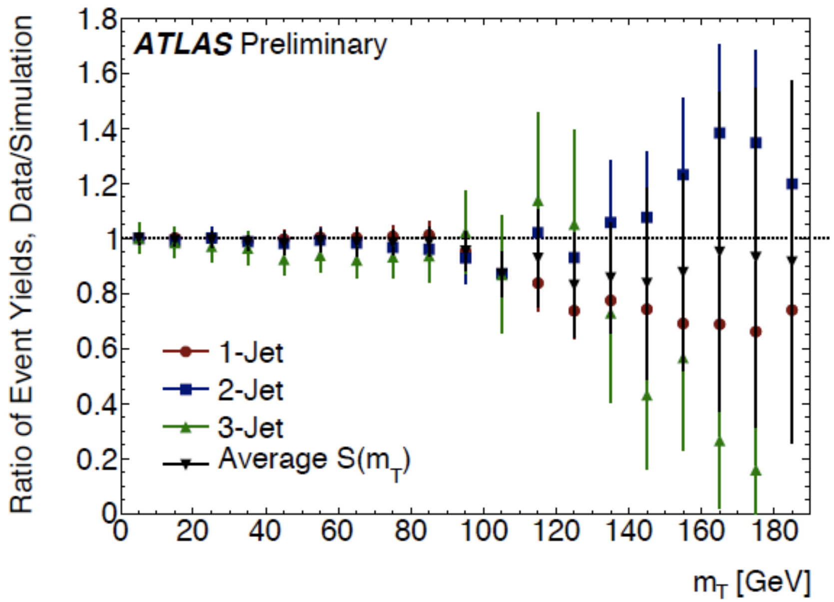
- Dominant background is ttbar dilepton in which one of the leptons is
  - not reconstructed
  - outside the detector acceptance
  - a τ lepton
- ttbar dileptons include two high-p_T neutrinos, resulting in large E_T^{miss} and m_T tails.
- Second lepton veto removes ~50% of this background, rejecting events with
  - second lepton candidate satisfying looser selection criteria or
  - isolated track with $p_T > 12$ GeV
- Second lepton efficiency validated in data in signal-depleted control regions



m_T well described in 3-jet control region

Single Lepton Background

- ttbar l+jets and W+jets
  - Extract this background from data
- Normalize MC prediction in W transverse mass peak (60-90 GeV)
- Extrapolate to signal region m_T>120 GeV
  - Validate m_T shape in data in events with ≤3 jets and reject events with b-tagged jets to reduce the ttbar dilepton background
  - Good agreement between data and MC



Other Backgrounds

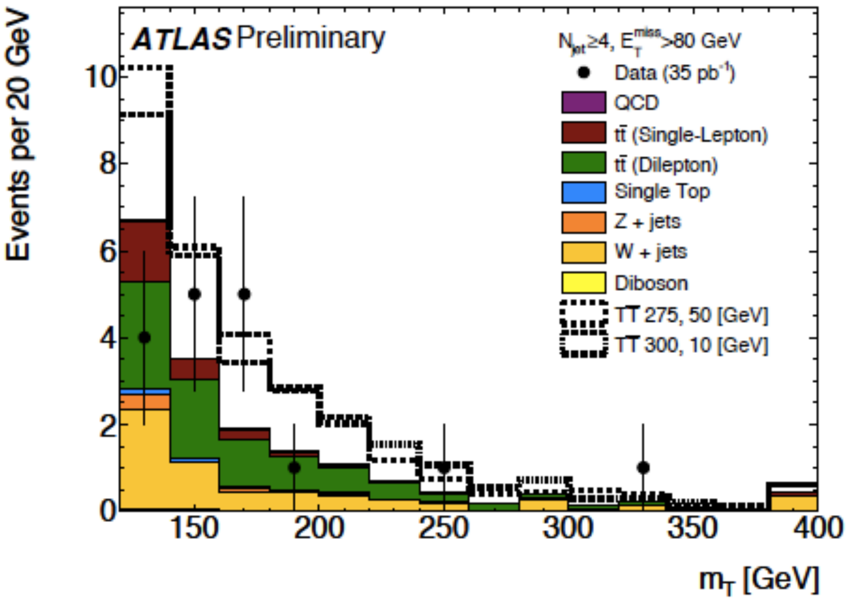
- QCD multi-jet background estimated in data-driven way making use of the fact that lepton isolation efficiency is different in QCD multi-jet events

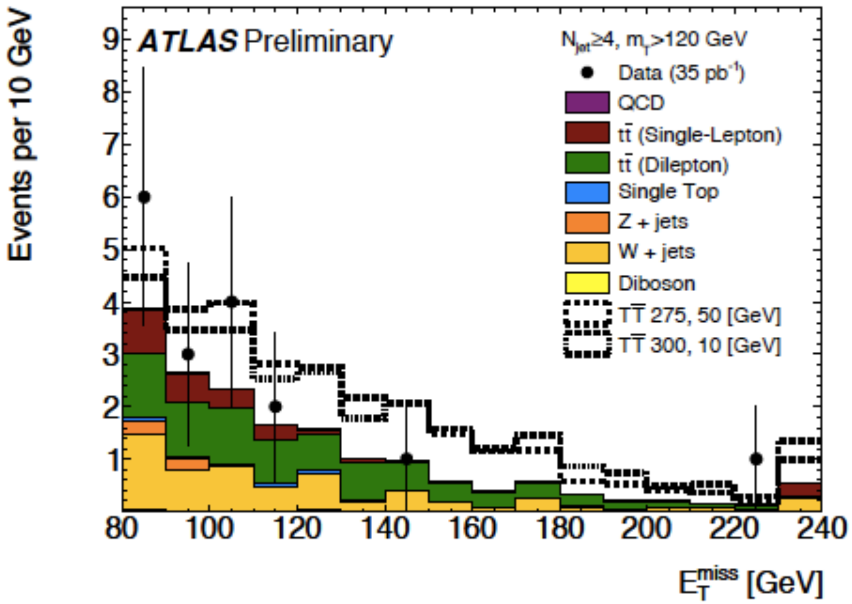
- Single top, diboson, Z+jets backgrounds are tiny and estimated from (N)NLO theory cross section

Summary of Yields

- No evidence of an excess over the SM prediction
- Errors include systematic uncertainties dominated by uncertainties on the data-driven techniques

Source	Yield
Single-Lepton $t\bar{t}/W$	8.4 ± 1.6
Dilepton $t\bar{t}$	7.6 ± 2.0
Z+jets	0.4 ± 0.1
Dibosons	$0.2 \pm <0.1$
Single Top	0.4 ± 0.1
QCD	0.2 ± 0.6
Total Background	17.2 ± 2.6
Data	17





Results

Source	Relative Error
Dilepton $t\bar{t}$, Single Top, Dibosons, Z+jets	
Cross Section	15%
Dilepton Veto	15%
Jet Energy Scale & Resolution	11%
Luminosity	3.4%
Lepton ID	3%
Monte Carlo Statistics	1%
Total	25% (2.1 events)
Single Lepton Backgrounds	
Spread in $S(m_T)$	15%
Normalization	10%
b-Tag Veto	3%
QCD Shape	1%
Total	18% (1.6 events)
QCD	
Normalization in Control Regions	100%
Muon Statistics	0.6 events
Total	0.6 events

ATLAS Preliminary:

- At 95% confidence level:
  - M(T)=300 GeV excluded for $M(A_0)$< 10 GeV

Search for New Physics in ttbar Resonances

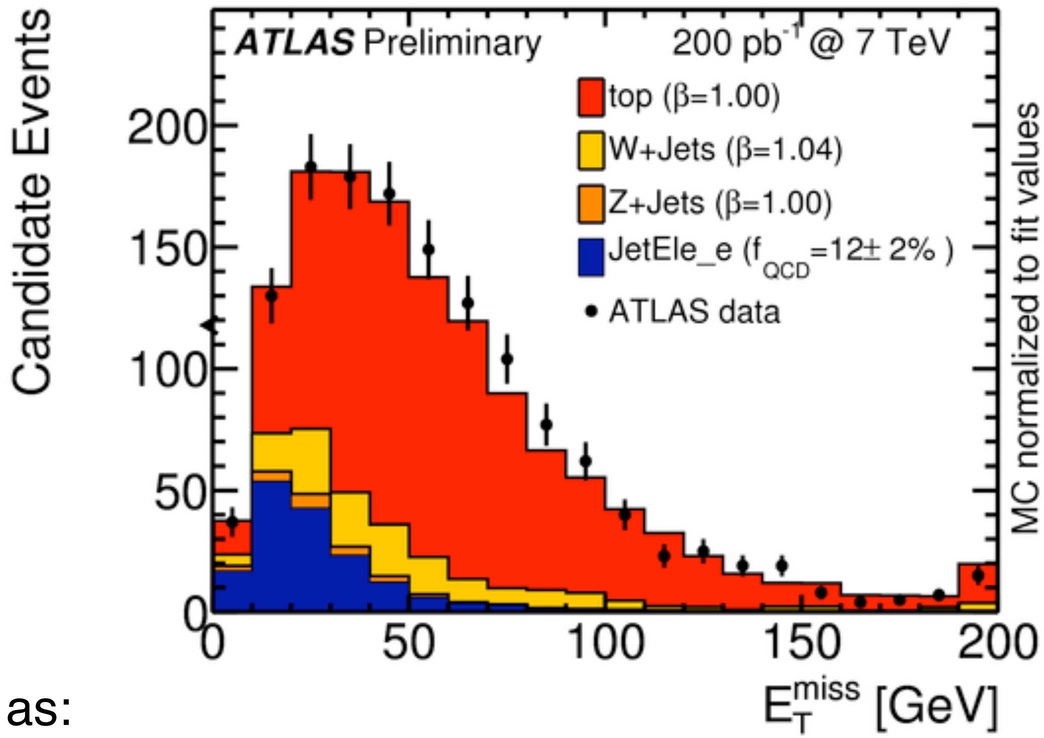
ATLAS-CONF-2011-087

ttbar Resonances

- Search for resonances decaying to ttbar pairs in single lepton channel:
  - Kaluza Klein gluon g_{KK} (coloured) in Randall Sundrum model (arXiv:0910.1350[hep-ph]) predicts wide ttbar resonance
  - leptophobic Z' (colourless) in Topcolor model (arXiv:hep-ph/9411426) predicts narrow ttbar resonance
- L_{int}=200 pb^{-1}
- Single lepton ttbar event selection including b-tagging
- Documented in ATLAS-CONF-2011-087

Data-Driven Background Estimates

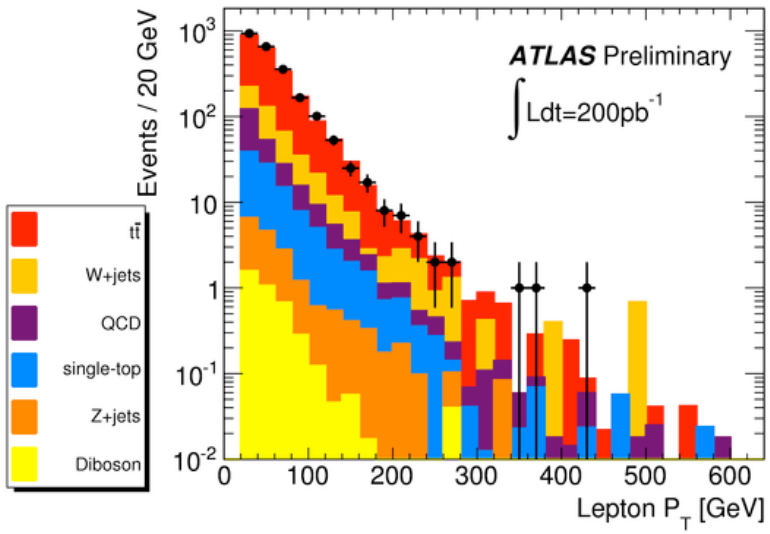
- QCD multi-jets
  - Use fake e/μ in multi-jet data sample to model QCD E_T^{miss} distribution (shape)
  - QCD normalization: Fit E_T^{miss} spectrum



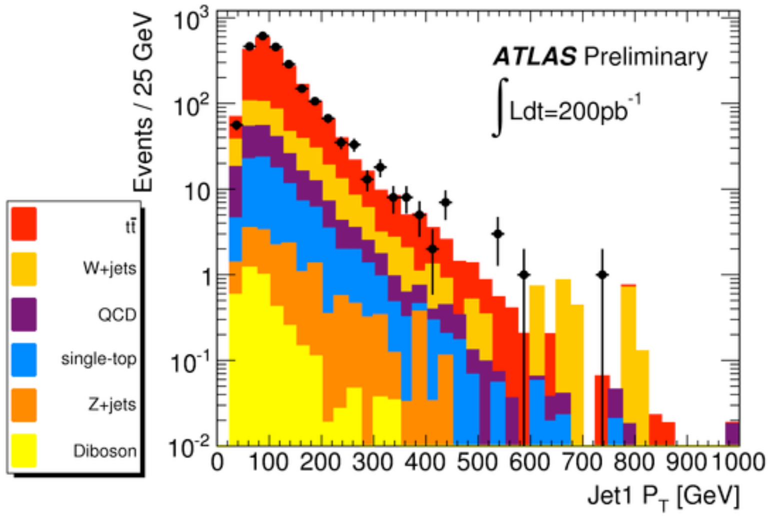
- W+jets enriched data sample selected as:
  - 30 GeV<E_T^{miss}<80 GeV
  - 40 GeV<m_T<80 GeV
  - Veto events with b-jets
- Fit jet multiplicity distribution and extract W+jets scale factors in each jet bin

Signal and Background Yields

- good agreement of data with SM expectation

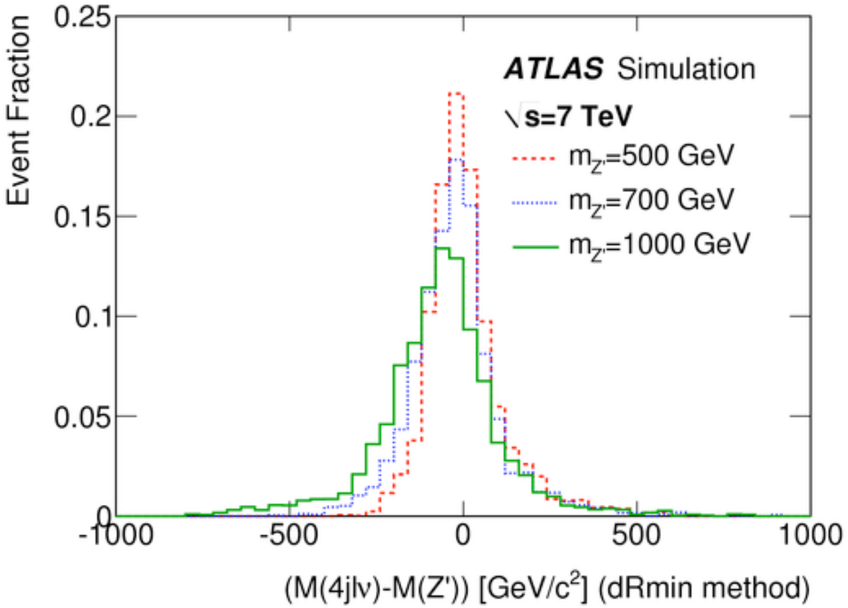


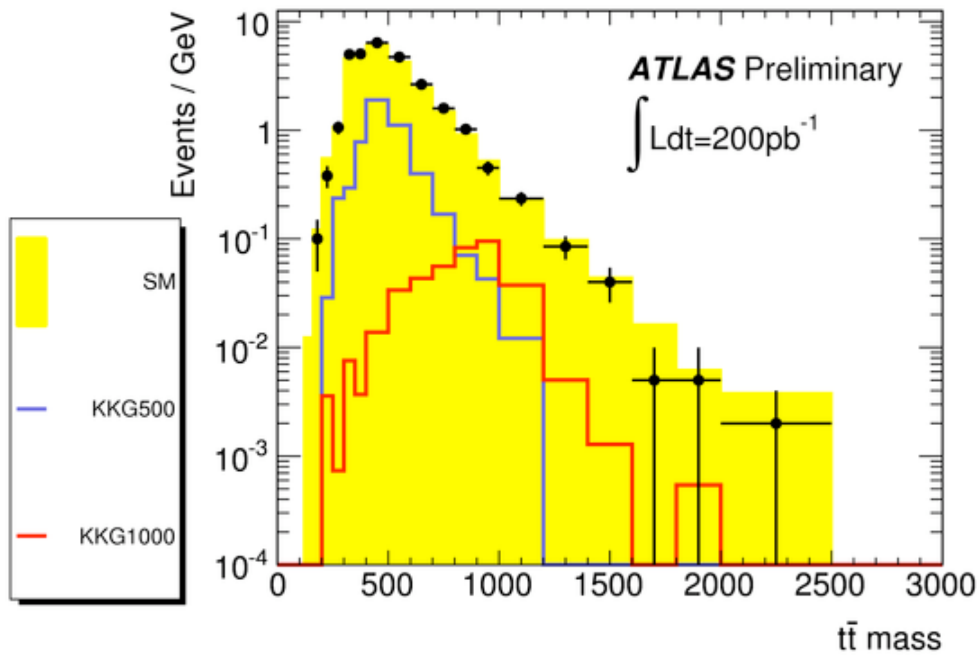
	Electron channel	Muon channel
$t\bar{t}$	724	988
Single top	36	50
W+jets	93	172
Z+jets	6	8
Diboson	2	2
Total MC Background	861	1220
QCD Background	35	105
Total Expected	896	1325
Data observed	935	1396
Z', $m = 500$ GeV	15	21
g_{KK}, $m = 700$ GeV	68	93



Mass Reconstruction

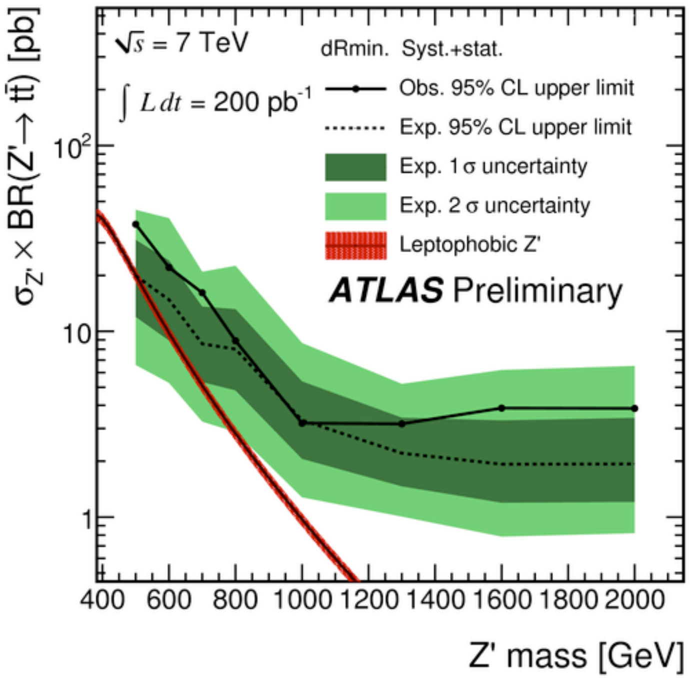
- Mass reconstruction:
  - p_Z of neutrino obtained from W mass constraint
  - Jets far from the rest of the activity of the event are discarded: $\Delta R_{min} > 2.5 - 0.015 \times m_j$ (m_j=jet mass)
  - m_{ttbar} from E_T^{miss}, lepton and 4 leading jets (3 if only 3 remain)

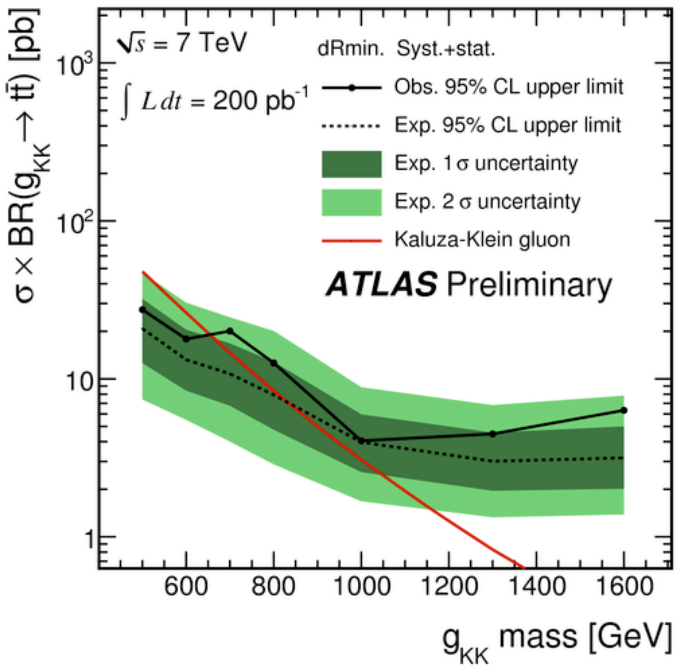




Results

- Z' in top color model narrow resonance:
  - cannot exclude mass range for now
  - probe already x-sections of few pb at $m_{Z'}$~1 TeV





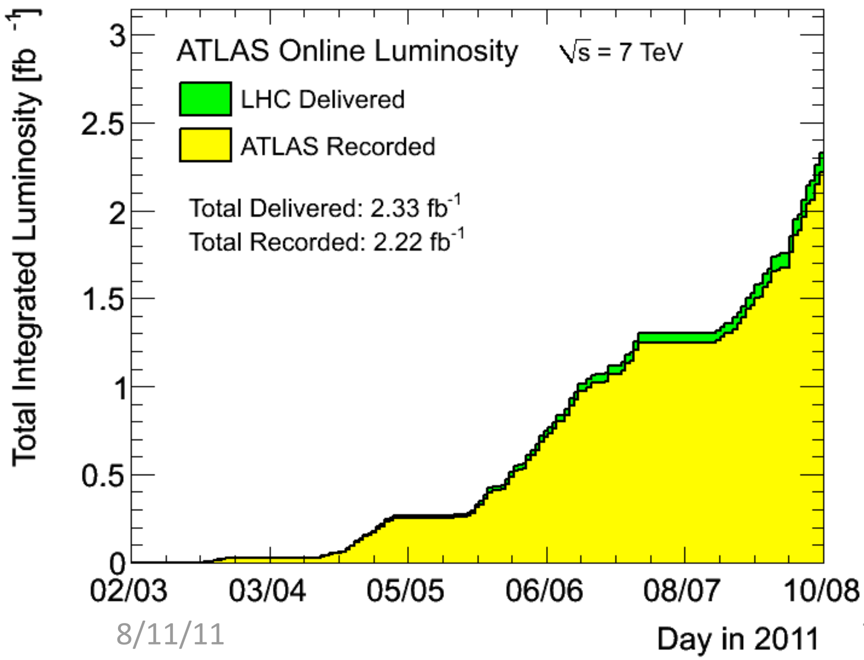
- g_{KK} in Randall Sundrum model (wide resonance):
  - M(g_{KK})>650 GeV @ 95%CL
  - will soon probe up to 1 TeV

Summary and Outlook

- A variety of new physics searches are carried out in top quark final states at ATLAS

- Sensitive to many models beyond the Standard Model

- No significant excess has been observed yet



- The discovery potential will further improve
  - With increasing integrated luminosity
  - By using more sophisticated analysis techniques
  - By further reducing systematics