Search for $t\bar{t}$ resonances with ATLAS Detector

Venkat Kaushik
on behalf of ATLAS Collaboration
University of Arizona

Division of Particles and Fields of APS

Aug 10 2011

ATLAS-CONF-2011-087
http://cdsweb.cern.ch/record/1351495?

Outline

- Physics Motivation
- Logistics
- Data/MC Samples, Selection Criteria
- Mass Reconstruction Methods
- QCD Background Estimate
- Data / MC Comparison
- Systematic Uncertainties
- Limits

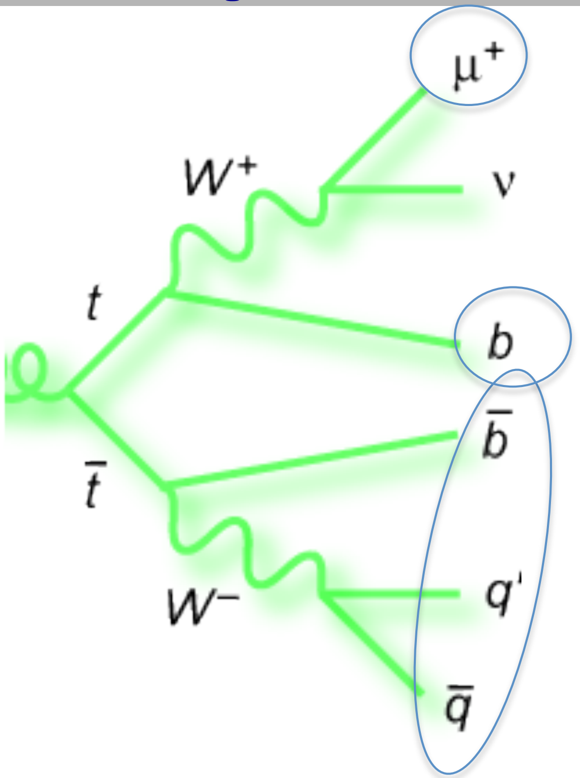
Physics Motivation

- Top is the heaviest of known elementary particles
- Top resonances are predicted by several models
  - Sequential heavy Z' [narrow, Γ=0.03M]
    - SM Z boson-like [except mass which is a free parameter]
  - Topcolor Z'_t [narrow, Γ=1.2%M but large σ × BR]
    - Z' couples strongly to 3rd generation quarks, with no coupling to leptons [leptophobic scenario]
  - Randall-Sundrum (RS) graviton G* [narrow, Γ <0.01M]
    - Only G* is allowed to propagate in extra-dimensions
    - resonance mass and coupling strength are free parameters
  - Kaluza-Klein gluon g_{kk} in RS models [wide]

Benchmark Scenarios

- Topcolor Z' (narrow)
  - Chosen based on current experimental sensitivity
  - Leptophobic Model **IV** (f1 = 1, f2 = 0), $\Gamma = 1.2\% \ M_{Z'}$
- Kaluza-Klein gluon (wide) from RS Models
  - Strong coupling to top quark ($g_L = 1.0$, $g_R = 4.0$)
  - KK gluon primarily decays into top pairs
  - Signal can be interpreted as evidence of extra dimensions
- Previous Searches
  - CDF and DØ exclude masses below m = 900, 820 GeV
  - CMS (recent result in Moriond 2011)

Top Pair: Semi-leptonic Final State



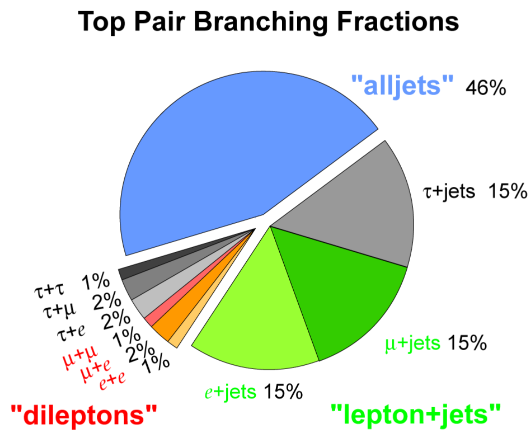
1 lepton [electron or muon] no tau

missing transverse energy

1 jet from leptonic top

3 jets from hadronic top, at least one b-tagged jet

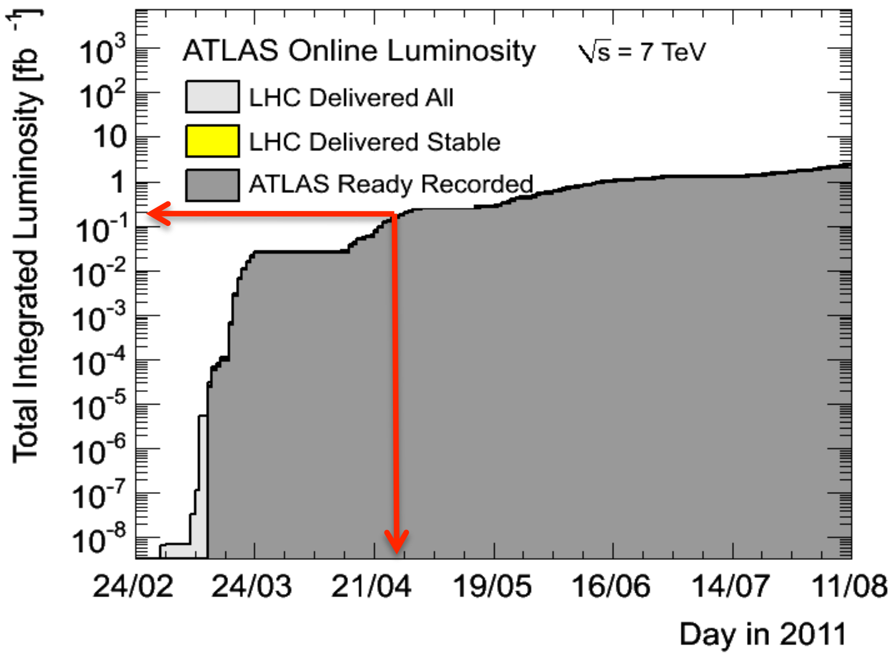
+ additional jets from ISR/FSR



- Select good high pT lepton
- Large missing transverse energy
- Four (or more) good jets
- At least one of the jets identified as a b-jet
- Reconstruct ttbar invariant mass [Mass reconstruction methods]

Dataset / Triggers

- Using 200 pb^{-1} of collider data in 2011 by LHC
  - Corresponds to data collected with all ATLAS subsystems operational and stable beam conditions
  - Uncertainty on luminosity (2010 estimate of 4.5%)
- Single lepton triggers used
  - Electron (threshold of 20 GeV) plateau at 25 GeV
  - Muon (threshold of 18 GeV) plateau at 20 GeV



Simulation - Signal

- Resonance Signal [Z' → ttbar]
  - TopColor [Pythia]

Mass [GeV]	400	500	600	700	800	900	1000
σ×BR (pb)	37.8	20.5	10.0	5.0	2.8	1.6	1.0

  - RS G* [Pythia] k/M_{Pl} = 0.1

Mass [GeV]	500	600	700	800	900	1000	1300
σ×BR (pb)	6.32	3.14	1.53	0.77	0.39	0.21	0.004

  - KK gluons from RS models [MADGRAPH + Pythia]

Mass [GeV]	500	700	1000	1500
σ×BR (pb)	56	17	3.4	0.4

  - QBH (t, anti-t) [BLACKMAX]
    - N = 6 extra dimensions, simplest 2 body final state
    - $M_{threshold}$ = 0.75 (24% tt), 2.5 (38% tt) TeV

Simulation – EW Background

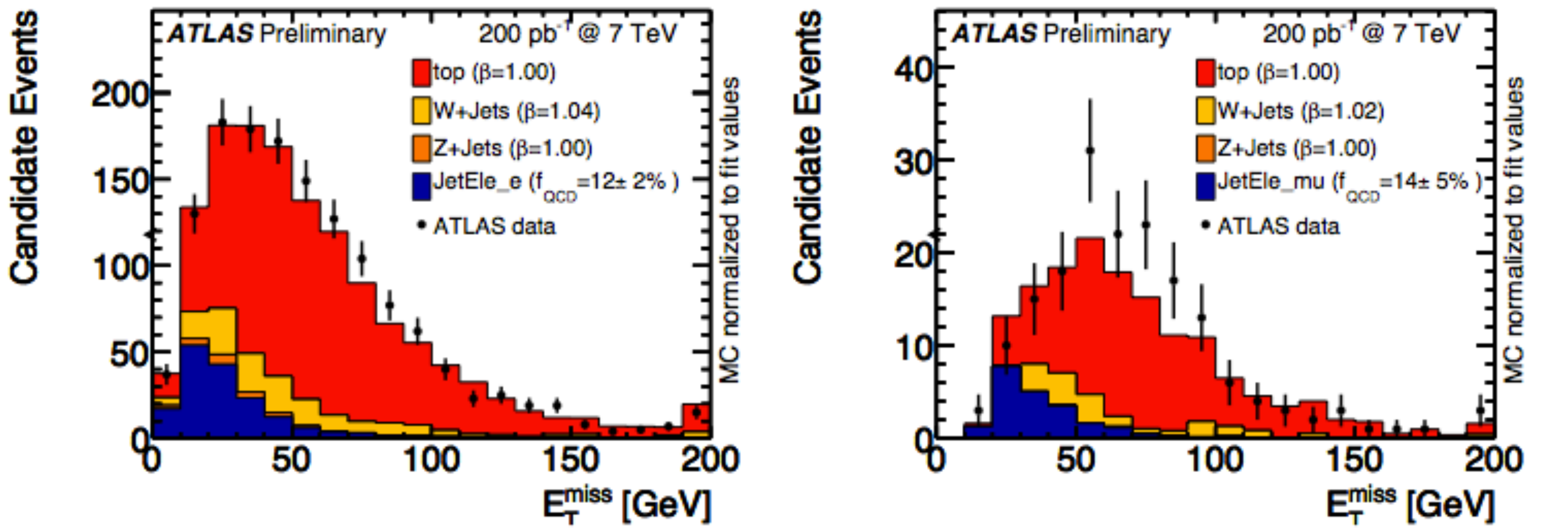
- ttbar [MC@NLO + Herwig/Jimmy]
  - 80.2 pb @ 7 TeV, KF=1.11
- EW single-top
  - s- (1.4 pb) and t- (21.5 pb) channels, Wt (14.6 pb)
- W+jets, Z+jets [Alpgen + Herwig/Jimmy]
  - 0-4Np exclusive, >=5Np inclusive KF=1.22 for all
- Diboson (Herwig + Jimmy)
  - WW (11.75 x 1.52), WZ (3.43 x 1.58), ZZ (0.98 x 1.2) [pb]

Event/Object Selection Criteria

- Isolated lepton with high transverse momentum
  - Electron [p_T > 25 GeV] , Muon [p_T > 20 GeV]
- Missing Transverse Energy (MET)
  - Lepton+MET transverse mass > 25 GeV
  - MET > 35 GeV
- Jets [pT > 25 GeV]
  - Four (or more) calibrated jets, Anti-Kt (0.4 radius)
- B-tag – used identify b quark from top decay
  - Secondary vertex tagger with 50% b-jet identification efficiency and good rejection rate for light jets

QCD Background

- Data-driven estimate for QCD background estimate
  - Jet Electron / Anti-electron methods
    - Jet triggered sample, require highly EM jet with associated tracks – to model the fake electron
    - Electron triggered sample, electron fails quality requirement
- Templates are fitted to selected data in to obtain the QCD fractions.

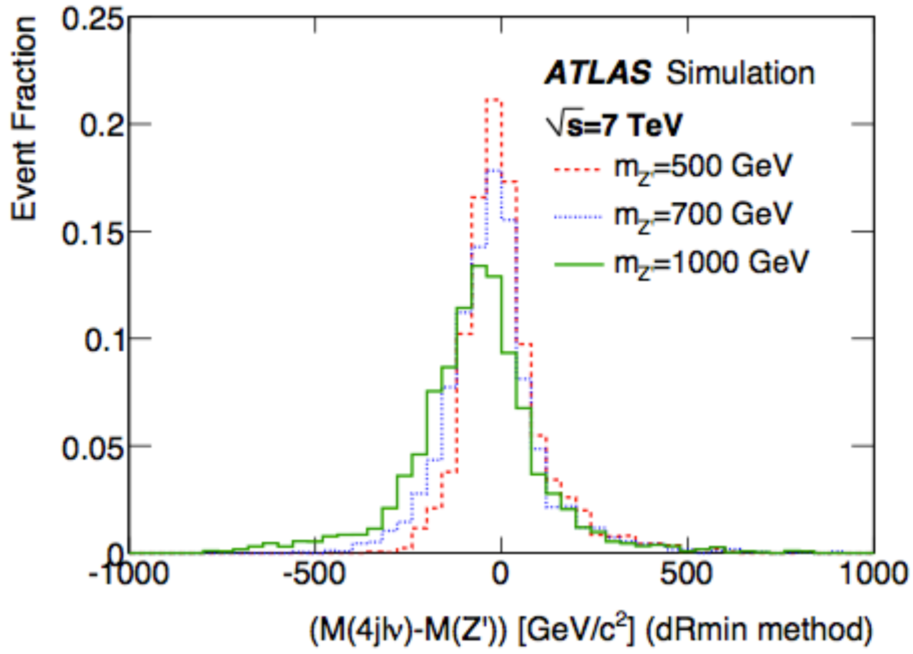


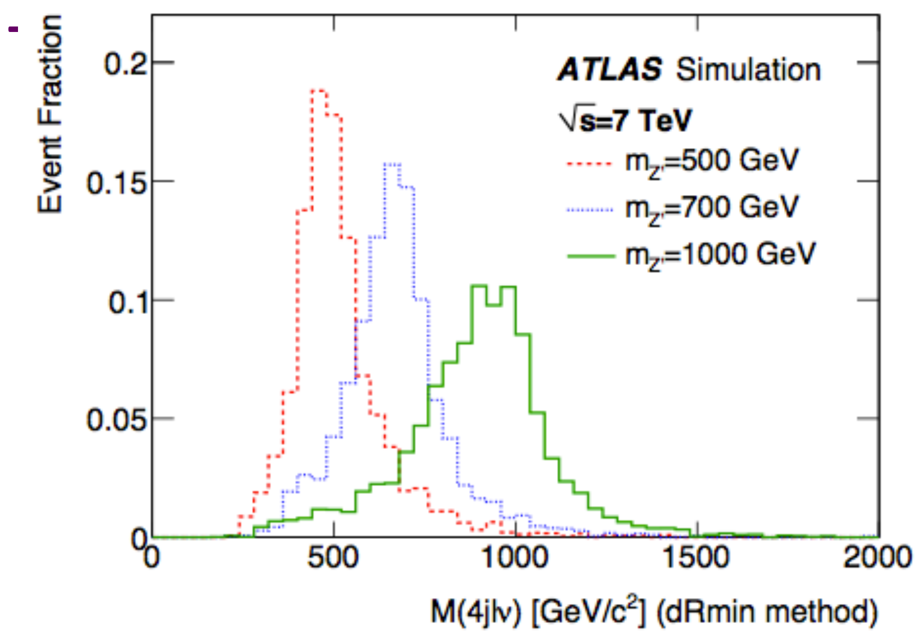
Mass Reconstruction Methods - I

- Four hardest Jets [Simple method]
  - 4 highest pT jets assumed to come from ttbar decay
  - Solve for neutrino longitudinal momentum
  - Choose smaller of the two solutions
    - Impose W-boson mass constraint
    - Ensure discriminant of quadratic equation is null

Mass Reconstruction Methods - II

- dRmin method [Reduce tails in mass spectrum]
  - Attempts to reduce long non-gaussian tails in mass resolution which is dominated by ISR/FSR
  - Among 4 leading good-jets, remove a jet that is close to a lepton or a jet satisfying $\Delta R_{\min} > 2.5 - 0.015 m_j$

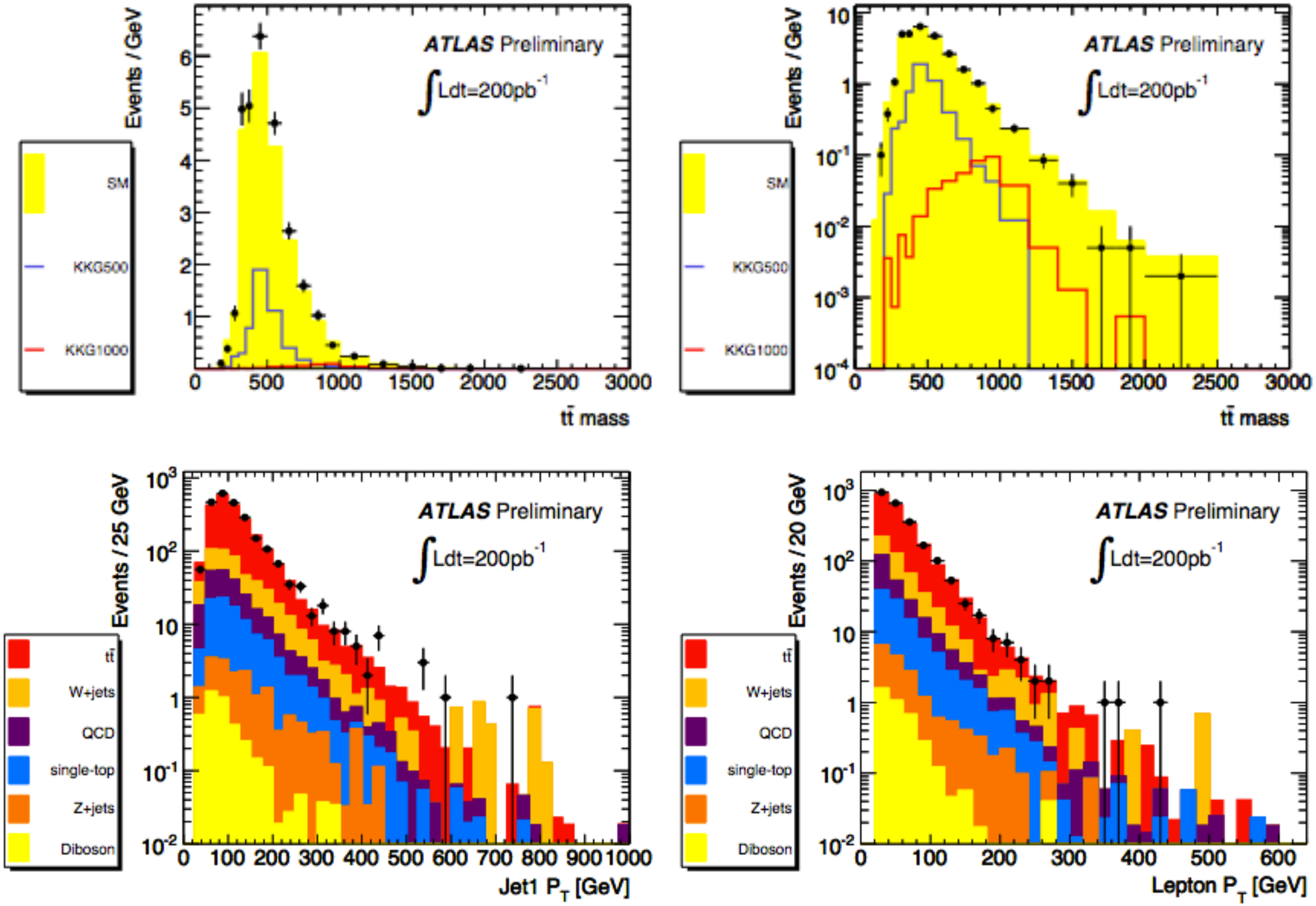




Event Yields – Data/MC

	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

Data / Background Expectation



Systematic Uncertainties

- Systematic uncertainties affecting the shape of ttbar invariant mass
  - b-tagging efficiency (11 %)
  - Jet energy scale and resolution and pileup effects (9 %)
  - Electron energy scale and resolution
  - Muon momentum scale and resolution
  - W+jets, ttbar, singletop, diboson shape and normalization
  - QCD normalization
  - PDF uncertainties, Parton shower and hadronization model
- Systematic uncertainties affecting normalization
  - Luminosity
  - Trigger and object reconstruction efficiencies

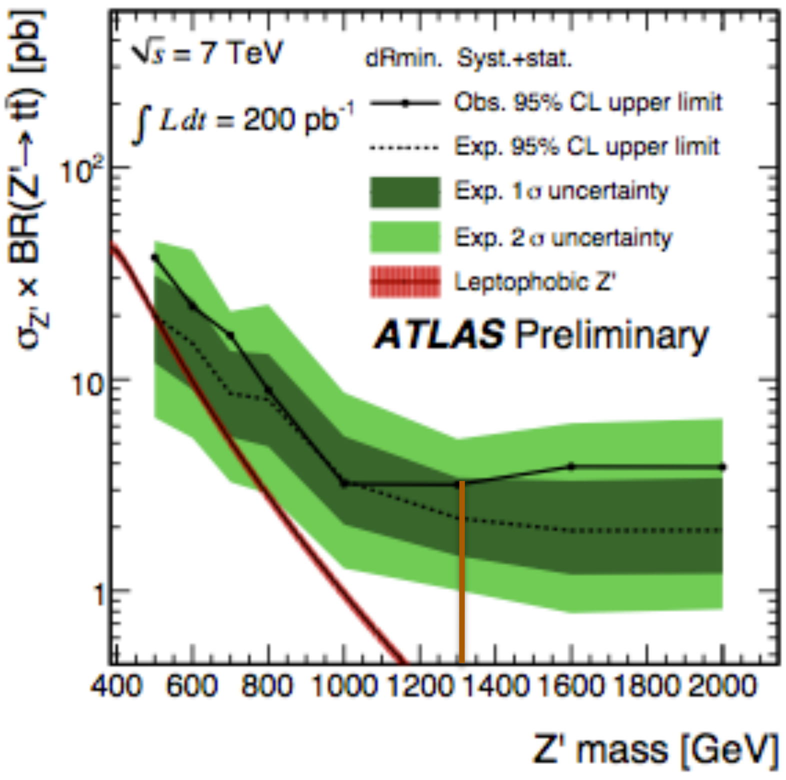
Limits - I

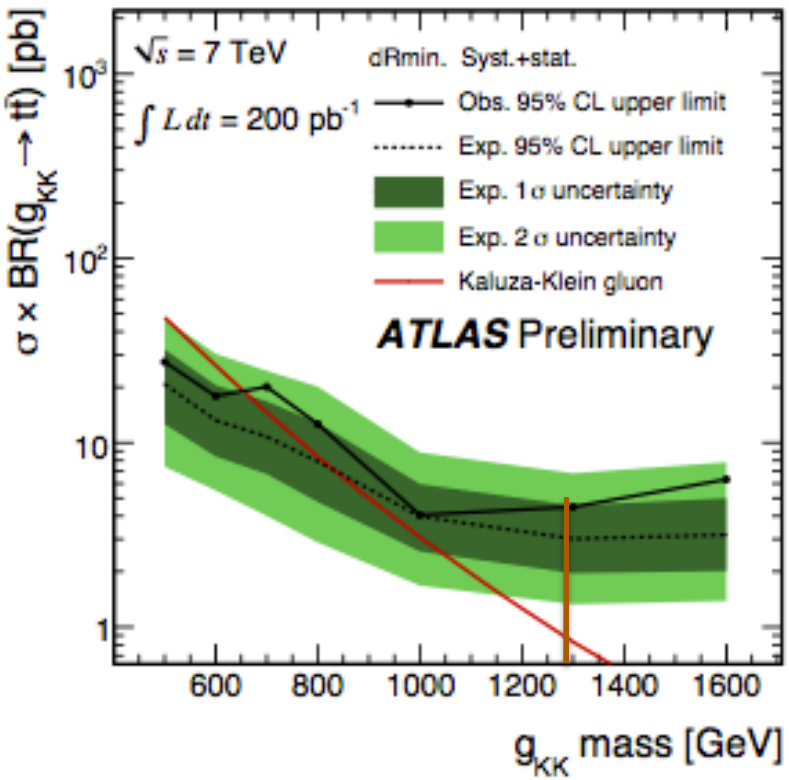
- Use reconstructed m(tt) to search for evidence of new physics
  - Null hypothesis: Data consistent with SM prediction
  - If so, set limits on max allowed cross-section for BSM processes for benchmark scenarios: function of m(tt)
- Statistical Approach: Bayesian
  - Define a likelihood function for each bin of m(tt)
  - Overall likelihood is product of all (including channels)
  - Calculate posterior probability density using Bayes theorem
  - Assume flat (or zero) prior for $\sigma >= 0$ ($\sigma < 0$)

Limits - II

- Step 1: Test Null Hypothesis
  - BumpHunter tool (G. Choudalakis dijet final states)
- Step 2: Set upper limits
  - Upper limit is identified as 95% point of the posterior probability
  - For including systematics – generate pseudo-experiments (5000 expts) and vary the Poisson mean in every bin subject to systematic uncertainties according to a Gaussian.
  - Expected limits (based on MC expectation)
  - Observed limits (based on Data)

Results





- 95% C.L Upper Limits $\sigma \times BR(Z' \to t\bar{t})$
- Observed 38 pb to 3.2 pb
- Expected 20 pb to 2.2 pb

- 95% C.L Upper Limits $\sigma \times BR(g_{KK} \to t\bar{t})$
- Observed 32 pb to 6.6 pb
- Expected 24 pb to 2.9 pb

Summary

- Many BSM models predict existence of new resonances that decay into top quark pairs
  - TopColor Z' and RS g_{KK} scenarios chosen for study
- 200 pb^{-1} of data is analyzed
  - ttbar invariant mass spectrum is reconstructed
  - different reconstruction schemes compared
    - Linearity and Resolution
  - SM Background estimate using simulation
    - QCD, W+jets estimate using data-driven approach
    - Data and MC agreement consistent with SM prediction
  - Limit set on cross-section x BR as a function of ttbar invariant mass
  - Able to probe a ~ pb range for masses up to 1 TeV

BACKUP SLIDES

Systematic Uncertainties -II

Source	Top	W+jets	Other	Z', $m_{Z'}$ = 500 GeV
Jet energy scale	+13% -7.5%	+26% -18%	+15% -8.7%	+14% -8.1%
Jet energy resolution	+12%	+20%	+36%	+14%
Jet reconstruction efficiency	-3.9%	-6.4%	-9.2%	-3.9%
b-jet energy scale	+5.3% +3.5%	+4.6% +2.6%	+2.2% +6.8%	+5.3% +3.4%
b-tagging efficiency (incl. mistag rate)	+20% -18%	+46% -41%	+34% -34%	+21% -19%
Top quark mass	+3.3% -5.0%	- -	- -	- -
$m_{t\bar{t}}$ Shape	±4.0%	-	-	-
Parton shower & Fragmentation	±5.8%	-	-	-
Final-state radiation (FSR)	+7.2% -7.6%	- -	- -	+6.3% -3.2%
Initial-state radiation (ISR)	+4.3% -8.2%	- -	- -	+3.6% -1.2%
ISR+FSR	- -4.1%	- -	- -	+2.5% -4.2%