

# Summary of $t\bar{t}$ Resonance Searches

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# $t\bar{t}$ Resonances Overview

- Benchmarks
  - Wide resonance: Randall-Sundrum Kaluza-Klein Gluon
  - Narrow resonance: Topcolor  $Z'$
  - Possible additional benchmark: KK gravitons
- Final states to be analyzed:
  - Boosted lepton+jets
  - Boosted all hadronic
- Results for 14 TeV 300/fb vs 3000/fb and 33 TeV 3000/fb planned for Minnesota

# L+jets Channel

- European Strategy study, see ATL-PHYS-PUB-2013-003
  - Limits at 95% CL for KK gluons: masses below 4.3 TeV (6.7 TeV) are excluded for 300/fb (3000/fb)

model	300 fb <sup>-1</sup>	1000 fb <sup>-1</sup>	3000 fb <sup>-1</sup>	
$g_{KK}$	4.3 (4.0)	5.6 (4.9)	6.7 (5.6)	
$Z'_{\text{topcolor}}$	3.3 (1.8)	4.5 (2.6)	5.5 (3.2)	(limits in brackets for dilepton channel)

- New for Snowmass: boosted/substructure techniques
- Backgrounds: SM  $t\bar{t}$ , W+jets
- Multijet background highly suppressed by lepton requirement
- Full mass reconstruction w/ neutrino pz solution
- Limit setting procedure implemented using Bayesian Analysis Tools (BAT)

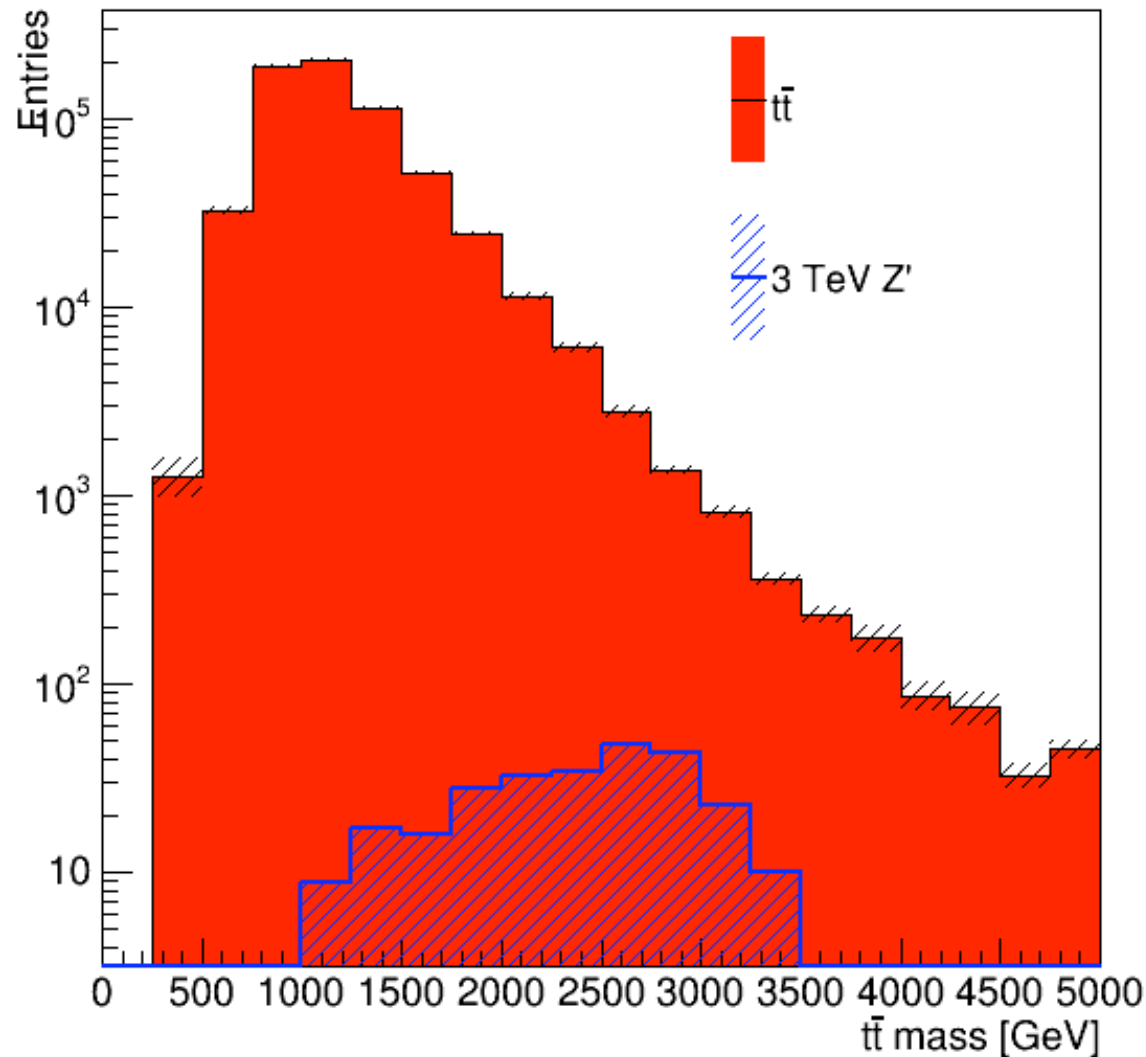
# Boosted l+jets Selection

- Event selection  
(unimplemented in red)
- 1 **miniisolated** lepton with  $p_T > 25$  GeV
- 50 GeV of MET
- 1 b-tagged Akt 0.5 jet
- 1 C/A 0.8 jet (hadronic top)
  - $p_T > 300$  GeV
  - $mass > 120$  GeV
  - $Q_W > 75$  GeV
  - $dR(\text{lep}, \text{topjet}) > 1.0$
- 1 Akt 0.5 jet (leptonic top bjet)
  - $p_T > 50$  GeV
  - $dR(\text{lep}, \text{bjet}) < 1.0$
  - $dR(\text{topjet}, \text{bjet}) > 1.0$

Mini-isolation:  $p_T$  cone considered for isolation shrinks with  $p_T$  of lepton

$Q_W$ : invariant mass of the sub-jet pair with the lowest mass, see e.g. ATL-PHYS-PUB-2010-008

# Boosted l+jets Mass Spectrum



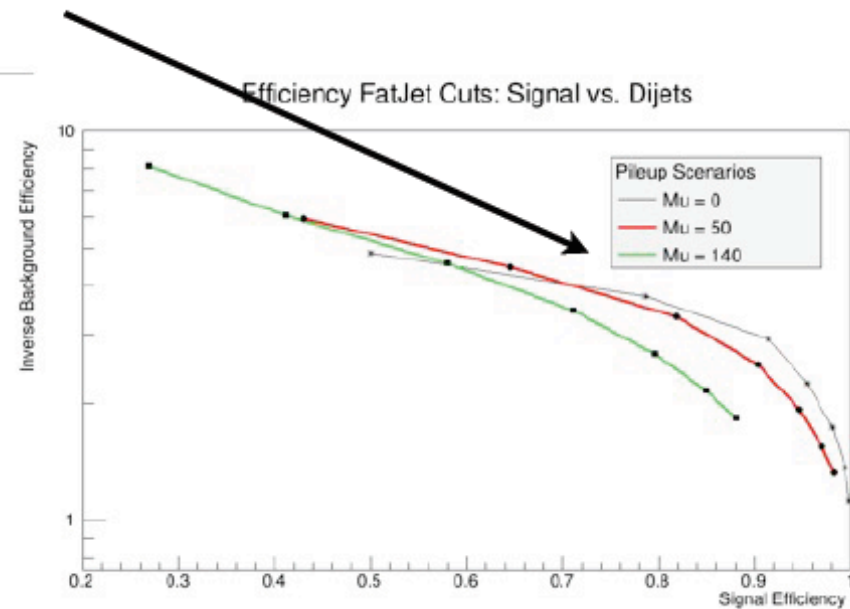
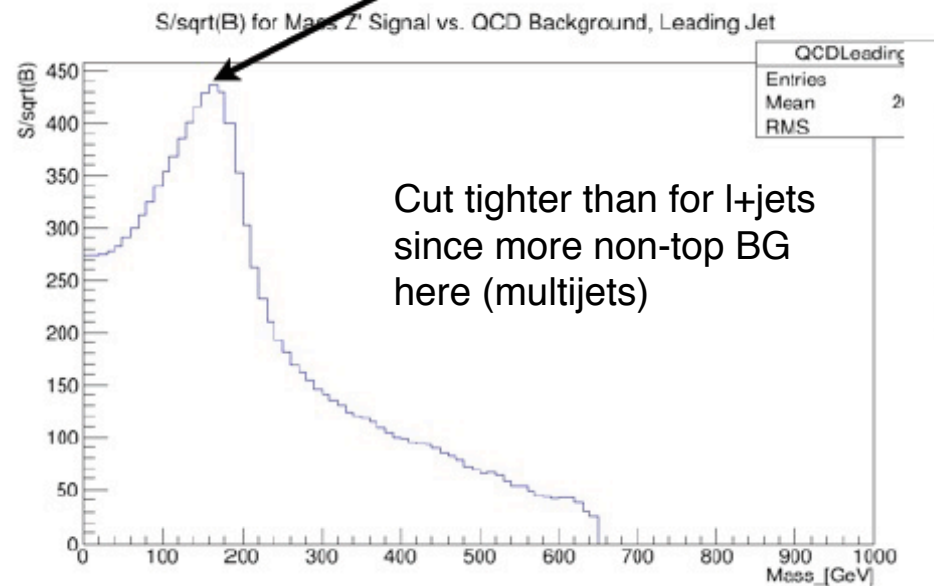
- 14 TeV, 300/fb,  $\langle\mu\rangle=0$
- To do:
  - Look at other signal points/benchmarks
  - Add W+jets BG
  - Calculate limits and discovery reach for all  $\sqrt{s}$ , L and  $\langle\mu\rangle$  scenarios

# All-hadronic Channel

- Not yet studied in context of European Strategy
  - Higher branching fraction than  $l+jets$
  - No issue with lepton isolation at high  $p_T$
  - Larger multijet background
- Backgrounds: SM  $t\bar{t}$ , multijets
- Multijet background highly suppressed by
  - Top-tagging (jet substructure)
  - B-tagging
- Full mass reconstruction
- Limit setting procedure implemented using Bayesian Analysis Tools (BAT)

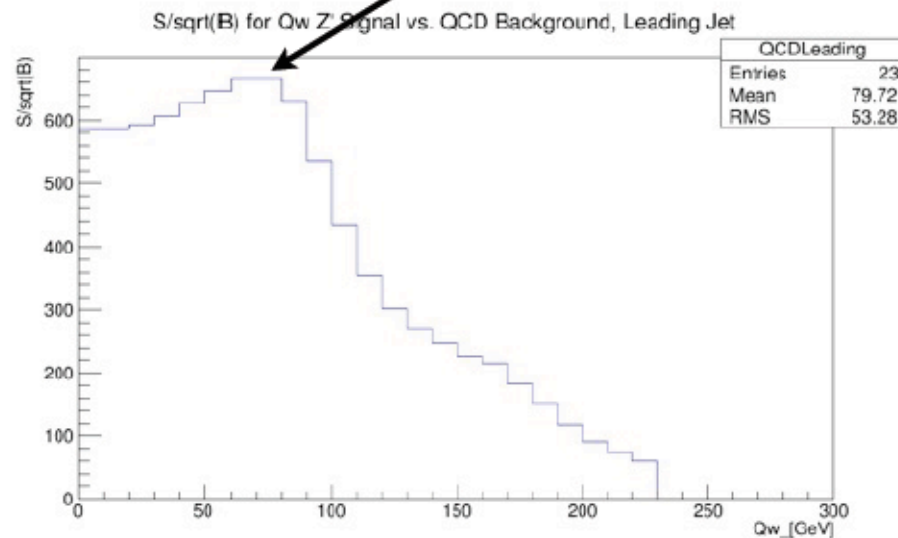
# Boosted all-hadronic Selection

- Preselection : 2 C/A 0.8 jets
  - $p_T > 750$  GeV
  - $|\eta| < 2.0$
- Choose top-tagging by cutting on substructure
- Optimize using  $S / \sqrt{B}$  [plot shows y-axis in a.u.]: *invariant mass*  
→ cut at  $m > 160$  GeV
- Degradation of performance with increasing PU



# Boosted all-hadronic Selection

- Preselection : 2 C/A 0.8 jets
  - $p_T > 750$  GeV
  - $|\eta| < 2.0$
- Choose top-tagging by cutting on substructure
- Optimize using  $S / \sqrt{B}$  [plot shows y-axis in a.u.]:  $Q_W = \text{minimum di-subjet inv. mass}$   
→ cut at  $Q_W > 70$  GeV

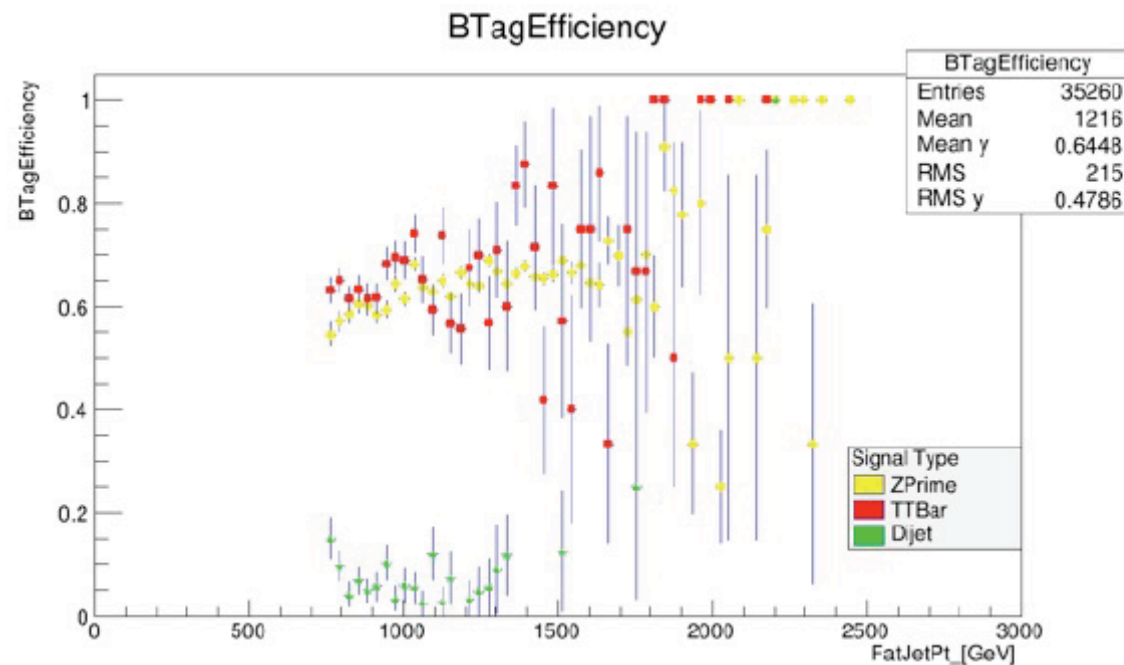


- additional cuts on splitting scales do not help

- plan to use N-subjets and N-subjettiness, but not yet available in our format

# Boosted all-hadronic: b-tagging

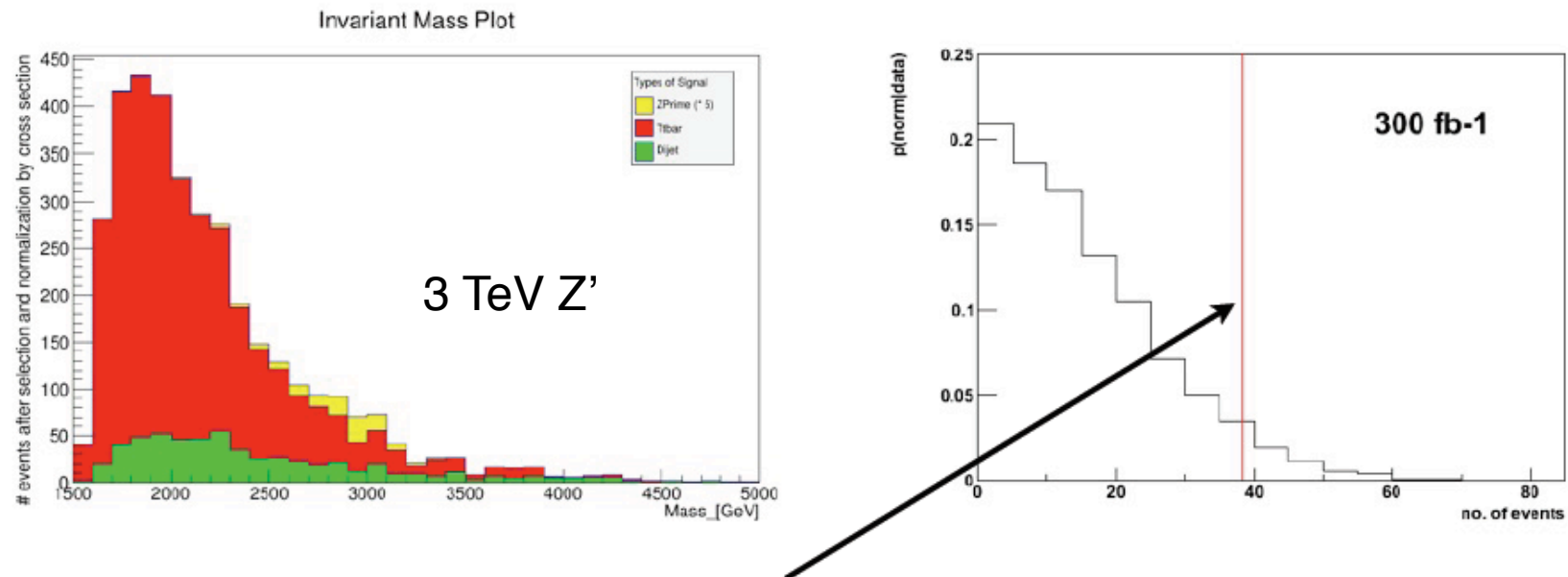
- b-tagging efficiency vs.  $p_T$  (default Delphes working point)
- Does not look realistic ... (does not drop for large  $p_T$ )
- Require 2 b-tags (b-tagged akt5 jet overlapping with C/A 0.8 jet)



- Low MC statistics : take average efficiency for ttbar and QCD samples and weight by efficiency squared
- Will also try more realistic b-tagging efficiency curve

# Boosted all-hadronic: Prelim. Results

- invariant di-fatjet mass for  $300 \text{ fb}^{-1}$  ( $Z'$  scaled up by factor 5)



- define signal mass window as 2500 – 3500 GeV for 3 TeV  $Z'$
- limit setting code using Bayesian Analysis Toolkit
- 95% CL limit for  $300 \text{ fb}^{-1}$  for 3 TeV  $Z'$  :  $1.8 \sigma_{\text{SM}}$
- $3000 \text{ fb}^{-1}$  :  $0.5 \sigma_{\text{SM}}$
- These are preliminary limits ...*
  - stat. uncertainty only!*
  - expected to improve top-tagging and to worse b-tagging at high  $p_T$  (realistic!)*

# Summary & Outlook

- Search for  $t\bar{t}$  resonances in  $l$ +jets and all-hadronic final states in full swing
  - optimized event selection, new: **substructure**
  - exercised the full chain (including limits) for 3 TeV  $Z'$
- Next steps
  - Generate 2, 4, 5 TeV mass points for  $Z'$  :  $\sim 1$  week
  - Run KK graviton samples through Delphes : 1 – 2 weeks
  - Run over (large)  $W$ +jets BG samples: 1 – 2 weeks
  - Calculate more substructure variables (e.g. N-subjettiness) and improve top-tagging
  - Additional top-tagging studies in progress (not shown here): Template Overlap Method for hadronic and semileptonic top decays
  - In addition: choose more realistic b-tagging efficiency curve
  - Include a limited set of dominant systematics (QCD multijet normalization, JES, b-tagging)
  - Expect to have expected cross-section and mass reaches in time for Minnesota!
- **No show-stoppers for Minnesota!**