Sensitivity to new high-mass particles decaying to $t\bar{t}$ in fully boosted regime at a 100 TeV collider

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August 2014

100 TeV collider & BSM models with top decays

- 100 TeV collider can study physics beyond 10 TeV
- Many BSM models predict decays of heavy particles to $t\bar{t}$
  - top is heaviest known particle!
  - decays to “golden" channels (leptons, photons) can be suppressed
- Heavy means ~10 TeV mass range
- Such masses lead to highly boosted top decays pT(t) > 2-3 TeV

Questions:

- How to measure $t\bar{t}$ resonances at the 10 TeV mass scale?:
  - separate decay particles cannot be “resolved”
  - “traditional” calorimetry
- What are sensitivity limits for a “generic” $t\bar{t}$ resonance using boosted techniques?

Current landscape of experimental searches

- **8 TeV: ATLAS & CMS** (CERN-PH-EP-2013-032, Phys.Rev.Lett. 111 (2013) 211804)
  - ATLAS:
    - A narrow leptophobic (narrow) Z' is excluded for M<1.7 TeV
    - KK excitation is excluded up to M=2.1 TeV
    - Upper limits: 0.03 pb up to 3 TeV
  - CMS:
    - Z' is excluded up to 2 TeV
    - KK excitation up to 2.5 TeV
  - → Methods: lepton+jets channel:
    - resolved+ some boosted technique (HepTopTagger)

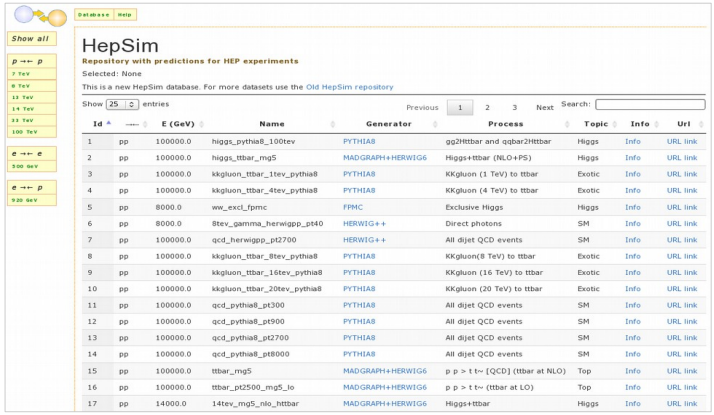
- **14 TeV** for pp with 3000 fb^{-1} (Snowmass13, K.Agashe et al, arXiv:1309.7847)
  - Masses < 4-5 TeV could be excluded (depends on reconstruction scenario)

- Region with M>5 TeV is completely new territory for such searches
- Lepton+jets reconstruction will be very difficult due to large overlap of decay products (especially for e+/e-)

MC simulation

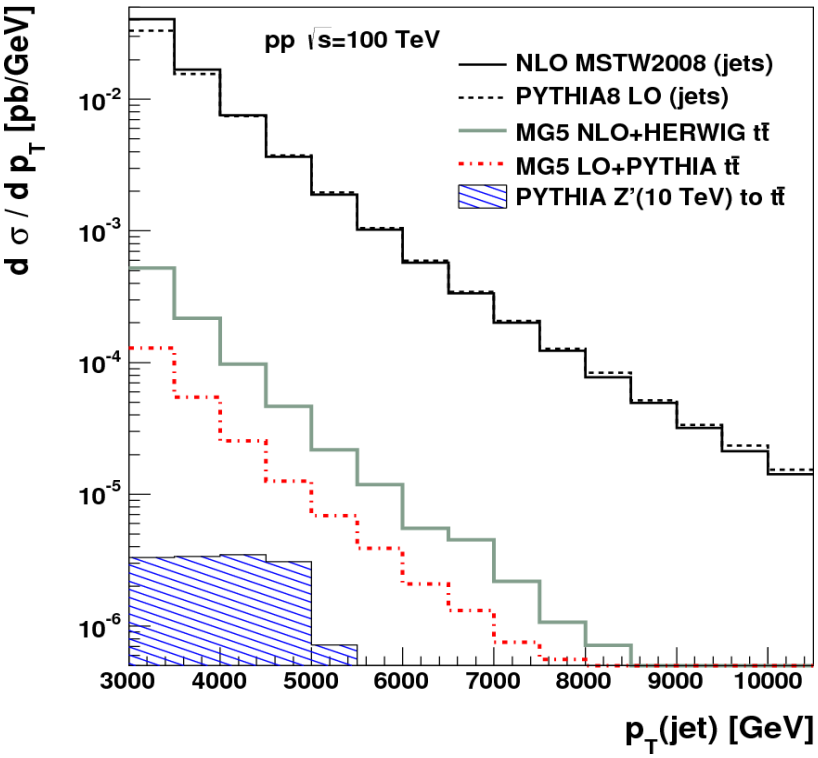
- **Signal (LO QCD). PYTHIA8 for**
  - $f\bar{f} \rightarrow Z0'$ with M=8,10,12,14,16,18,20 TeV. Code 3001. Pure Z' contribution. Γ/M=3%
  - $q\bar{q} \rightarrow g_{KK}$ with M=8,10,12,14,16,18,20 TeV. Code 5006. Pure g_{KK} contribution. Γ/M=16%
- **Background processes:**
  - PYTHIA8 and HERWIG++ for QCD backgrounds
    - NLOjet++ (NLO) to extract the k-factor (MSTW2008nlo68cl for PDF)
  - SM $t\bar{t}$ process was generated with Madgraph (NLO+Herwig)
  - PYTHIA8 for all SM boson processes (like Z/W+jets)
    - Not too realistic, but the usage of "realistic" ALPGEN should not change conclusions
- **All Monte Carlo samples are taken from the HepSim Monte Carlo repository:**
  - https://atlaswww.hep.anl.gov/hepsim/

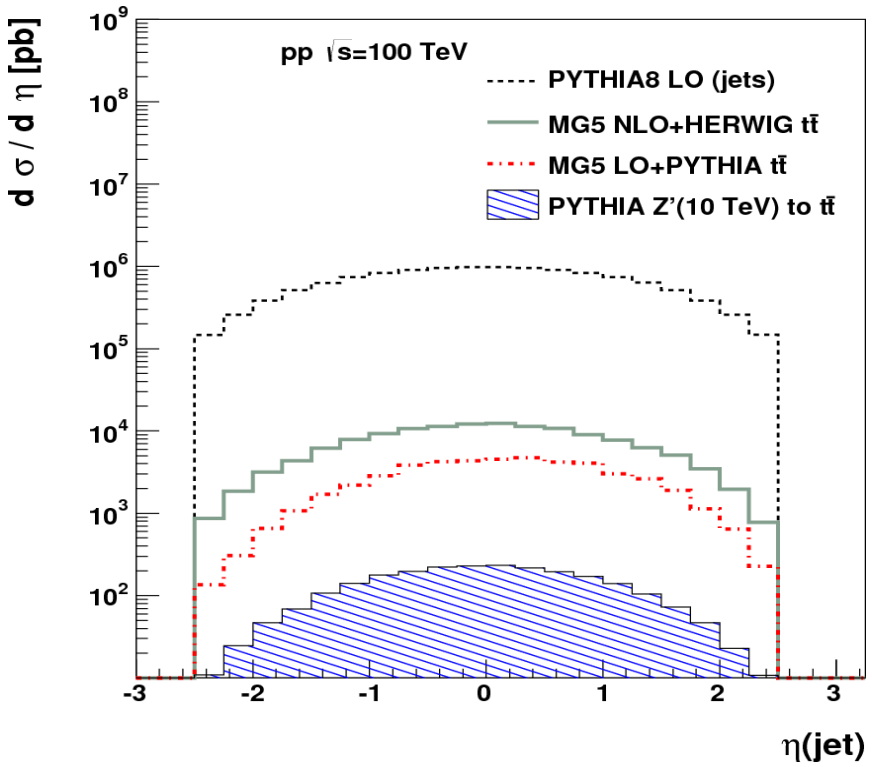
MC samples (100 TeV): qcd_herwigpp_pt2700, qcd_pythia8_pt2700, ttbar_pythia8_pt2700, pythia10tev_wjet2700, ttbar_pt2500_mg5, ttbar_pt2500_mg5_lo, zprime*_pythia8, kkgluon_ttbar_m*_pythia8



Data samples & analysis program are public

Kinematic distributions

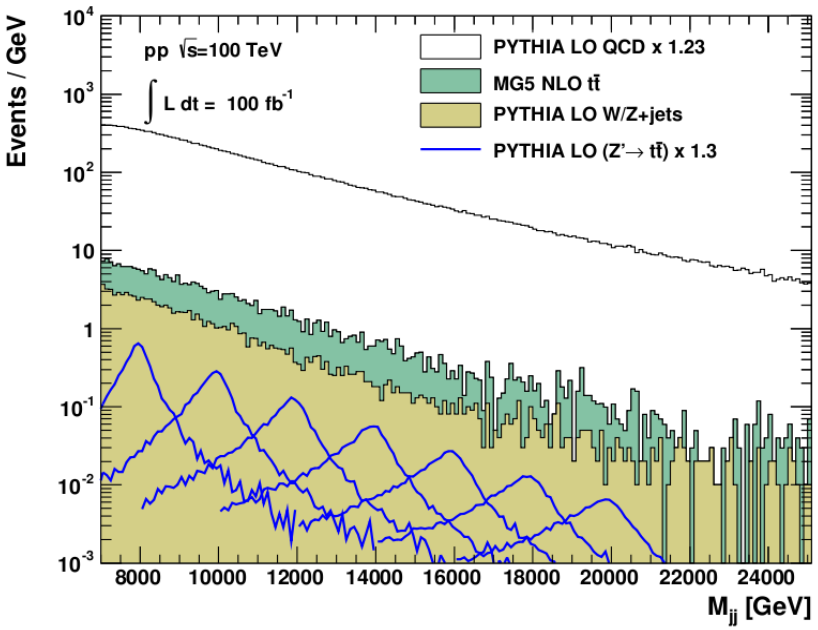




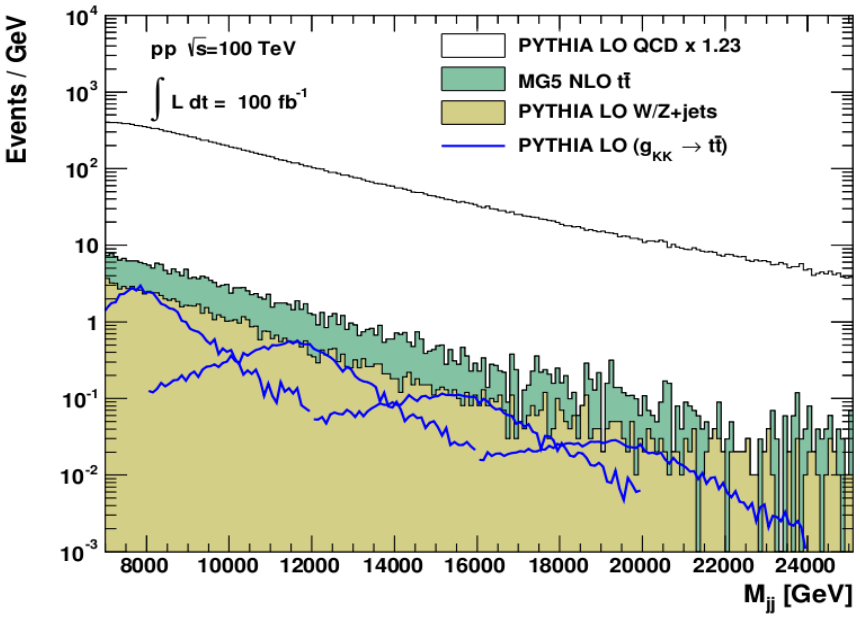
- Jets reconstructed using antiKT5 (R=0.5) from FastJet
- pT(jet)>2.7 TeV and |eta|<2.5
- The k-factor for dijets is ~10%, but larger for $t\bar{t}$
- The distributions look as expected, with a harder pT spectrum for Z'(10 TeV)

Dijet invariant mass for 100 fb^{-1}

$Z' \rightarrow t\bar{t}$



$g_{KK} \rightarrow t\bar{t}$

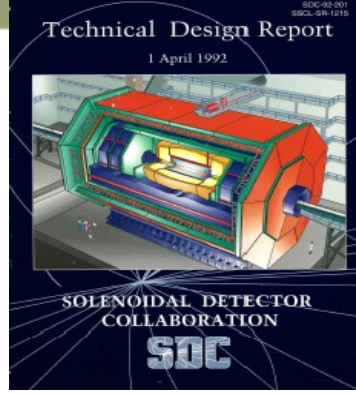


- Look at 2 leading jets above pT>2.7 TeV.
  - all decay channels. Semileptonic decays are included
- Z' model leads to narrow signal (Γ/M ~ 3%)
- g_{KK} is wider (Γ/M ~ 16%) and has larger cross section

Signal(Z')/Bkg ~ 0.001

Not That Obvious:
How to reduce QCD (reducible) and $t\bar{t}$ (irreducible) background for back-to-back jet events?

Discriminating variables

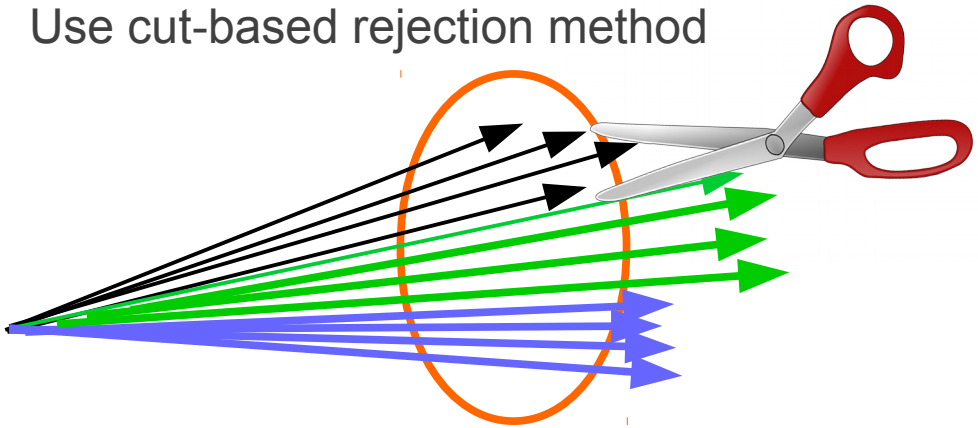


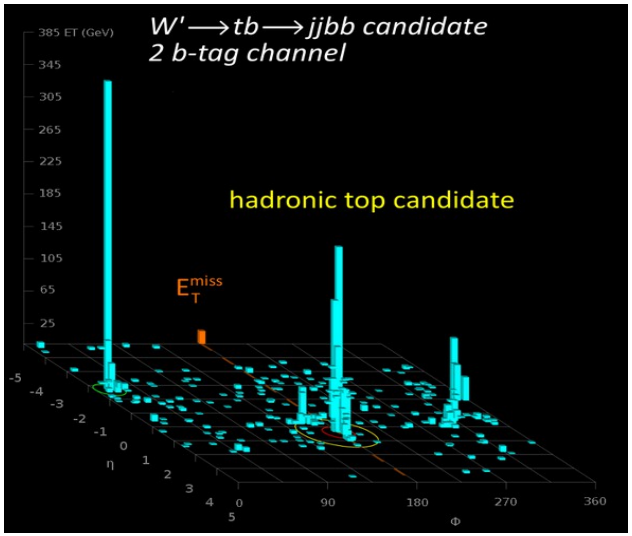
- Use jet substructure signatures (SSC-SR-1217 TDR 1992 p 3-26)
- Tremendous recent progress in advancing such approach
- Most basic variables used in this study:
  - Jet mass
  - τ_{32} and τ_{21} (N-subjettiness jet characteristics)
  - Jet shapes (eccentricity)
  - $\sqrt{d_{12}}$ splitting scale
  - R^{eff} effective jet radius (weighted with energy radial distance to jet center)
  - b-tagging
  - high-pT muons
- Use cut-based rejection method

J.Thaler, K. Van Tilburg, JHEP 1103:015, 2011

S.C., J.Proudfoot, Phys. Rev. D81 (2010) 114038

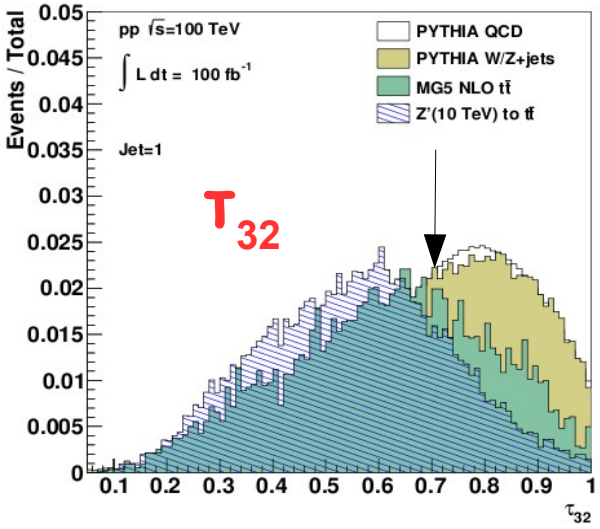
J. M. Butterworth, B. E. Cox, and J. R. Forshaw, Phys. Rev. D65 (2002) 96014

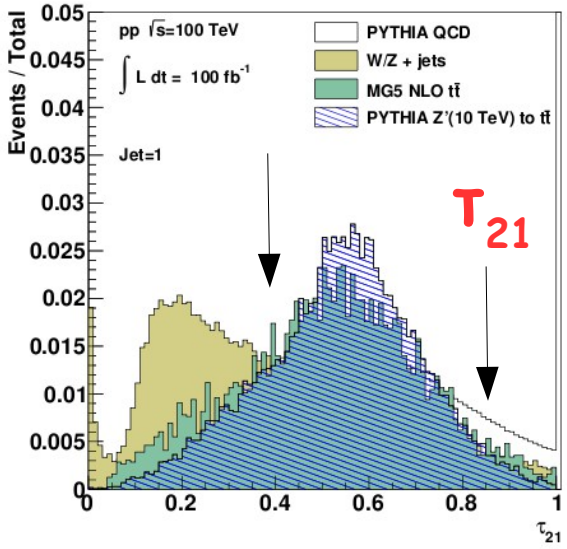


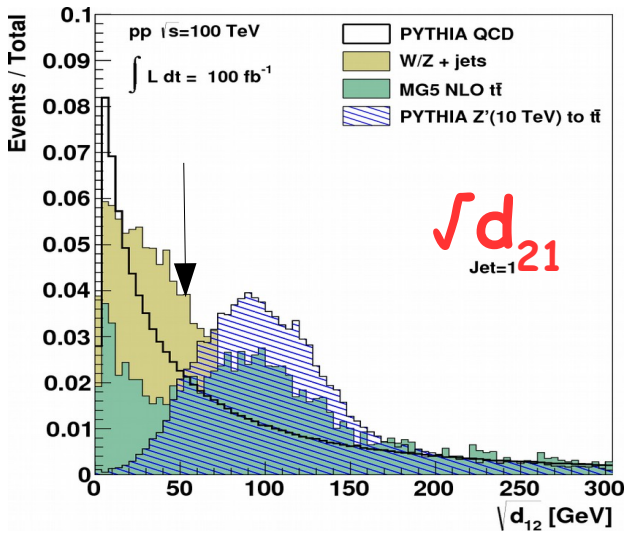


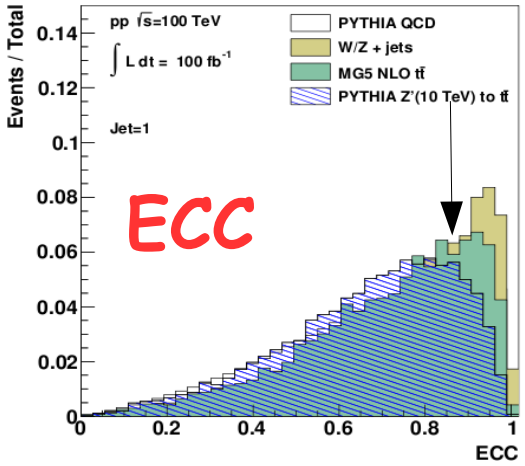
Heavy particles decaying to $t\bar{t}$ at a 100 TeV collider. S.Chekanov et. al (ANL)

Discriminating variables (lead. jet)









- τ_{32} **>0.75** reduces QCD and boosted W/Z
- τ_{21} **<0.3** reduces W/Z
- τ_{21} **>0.8** reduces QCD background
- $\sqrt{d_{12}}$ > 50 GeV reduces QCD,W/Z, some $t\bar{t}$

Correlation between variables:
~10% for τ_{32} , τ_{21} , mass
~30% correlation between d_{12} mass, ECC

Summary

- Limit extraction is still in progress
- We hope to finish this study in 1 week and present it at the “Next step..” meeting at FNAL