Search for pair production of resonances decaying to top quark + jet in the dilepton final state with the CMS detector

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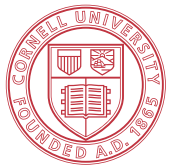

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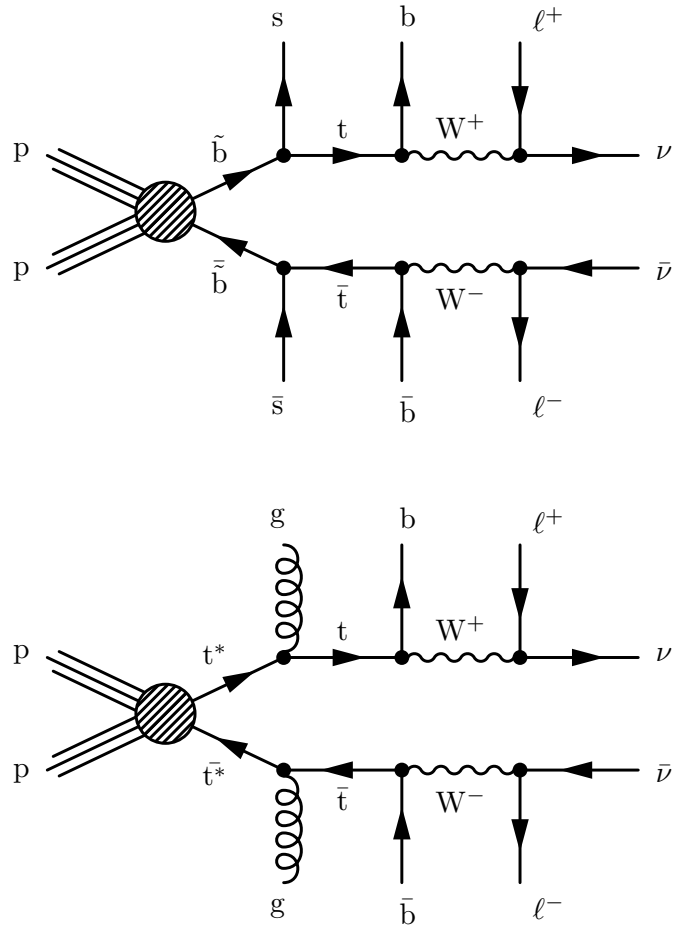
Introduction

- Top quark has large coupling to new particles in certain BSM scenarios
- Search for pair-produced resonances decaying to a top quark and light parton
  - R-parity violating $\tilde{\mathrm{b}} \to \mathrm{t} + \bar{\mathrm{s}}$

    (SUSY with MFV: Csaki, Grossman, and Heidenreich, arXiv:1111.1239)
  - Spin-3/2 top excitation $\mathrm{t}^* \to \mathrm{t} + \mathrm{gluon}$

    (Dicus et al., arXiv:1208.5811)
- Signature in dilepton channel
  - two light flavor jets
  - two b-jets
  - two leptons
  - missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$)



Event selection and backgrounds

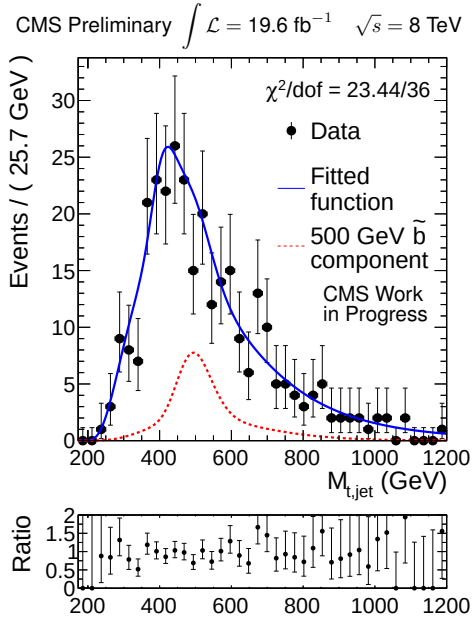
- Analysis based on 19.6 $\text{fb}^{-1}$of data at 8 TeV recorded by CMS detector in 2012

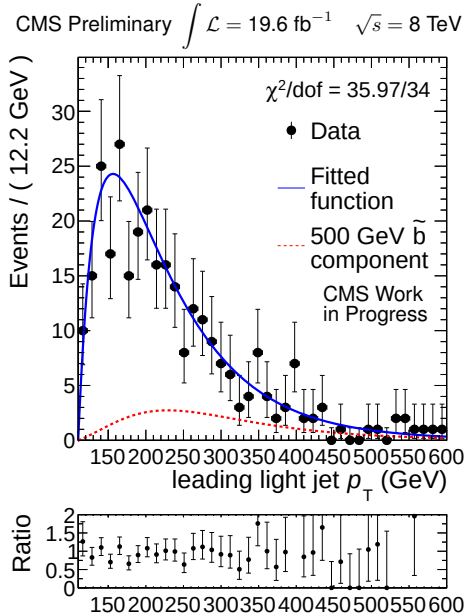
- Event selection
  - Dilepton triggers
  - Two isolated leptons (e or μ) with $p_{\text{T}} > 20$ GeV
  - Two b-tagged jets (CSV tagger) with $p_{\text{T}} > 30$ GeV
  - Two light flavor jets (CSV anti-b-tagged) with $p_{\text{T}} > 30$ GeV
  - Low dilepton mass resonance veto $\text{m}_{\ell^+\ell^-} > 15$ GeV
  - Z veto in ee, $\mu\mu$ channels

- Backgrounds
  - $\text{t}\bar{\text{t}}$ + ISR/FSR (95%)
  - Drell–Yan (2%)
  - Single top (2%)
  - Diboson, $\text{t}\bar{\text{t}} + \text{V}$

Signal and background discrimination

- Need to tell signal apart from large $t\bar{t}$ background
- Signal isolated using three characteristics
  - Signal events contain mass resonances decaying to top quarks and light jets
  - Two light jets from signal have relatively high p_T



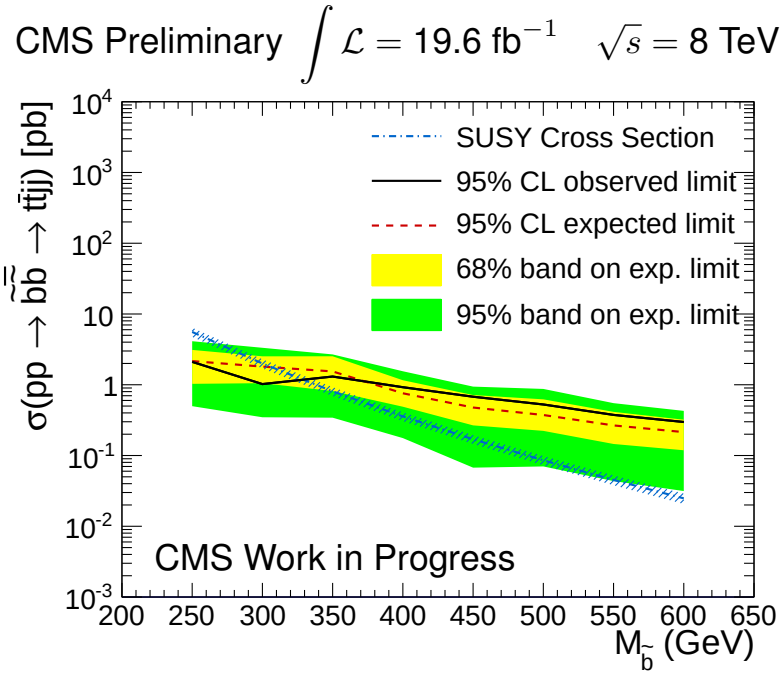


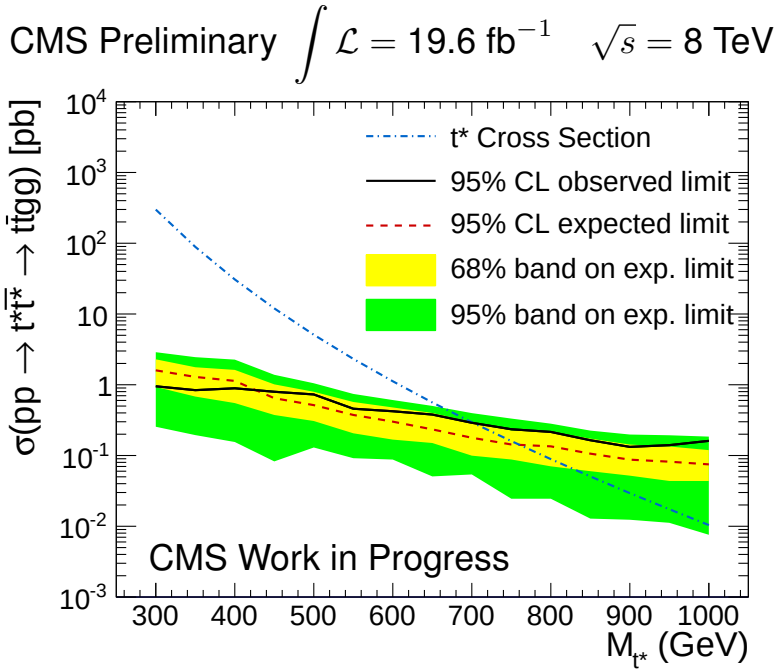
Analysis strategy

- Reconstruct BSM resonance
  - Reconstruct four-momenta of neutrinos from leptonic $W^{\pm}$ decays with kinematic method
    (Sonnenschein, arXiv:hep-ph/0603011 and Cheng et al., arXiv:0707.0030;
    CMS top mass measurement, arXiv:1209.2393)
  - Combine neutrinos with visible decay products of BSM particles – leptons, b-jets and light jets

- Perform shape analysis
  - Parameterize mass and light jet p_{T} spectra in signal and background
  - Construct unbinned extended maximum likelihood from mass and 2D light jet p_{T} shapes
    - Normalization determined from 2D light jet p_{T} fit
  - Calculate confidence intervals on signal cross section

Results





- Upper limits on $\tilde{b}$ and t^* are set
  - R-parity violating $\tilde{b}$ excluded between 250 and 333 GeV
    - First LHC result on this model
  - t^* excluded between 300 and 703 GeV
    - Consistent with previous CMS t^* search in lepton+jets channel (B2G-12-014)

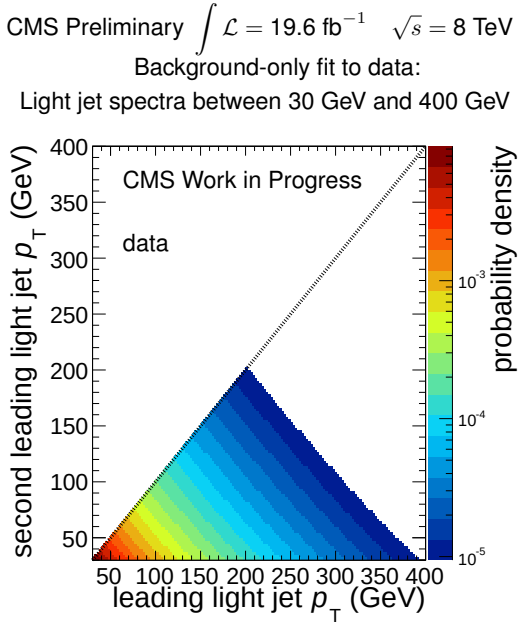
Backup

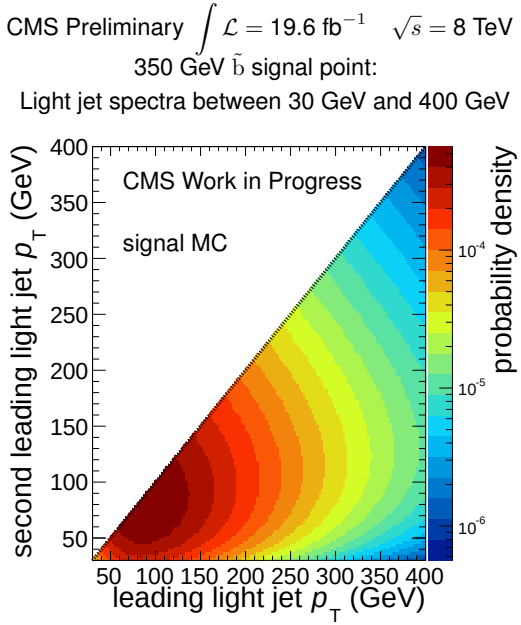
Details of the mass reconstruction procedure

- Assumptions
  - All decays occur on-shell
  - Top and W mass are known
  - All missing energy comes from leptonic $W^{\pm}$ decays
- Conservation of four-momentum reduces to quartic equation
  - Two possible pairings of leptons and b-jets $\Rightarrow$ up to 8 solutions
  - Solve for neutrino four-momenta $\Rightarrow$ reconstruct top quarks
- If no real solution exists, use resampling method
  - Vary all jets independently within resolution and re-solve quartic equation
  - Repeat 1000 times and choose sampling with least χ^2 that has neutrino solution
- Combine top quarks and light jets to reconstruct BSM particle candidates
  - Two possible pairings of top quarks and jets $\Rightarrow$ up to 16 solutions
  - Choose solution with smallest mass separation

Light jet p_{T} spectrum

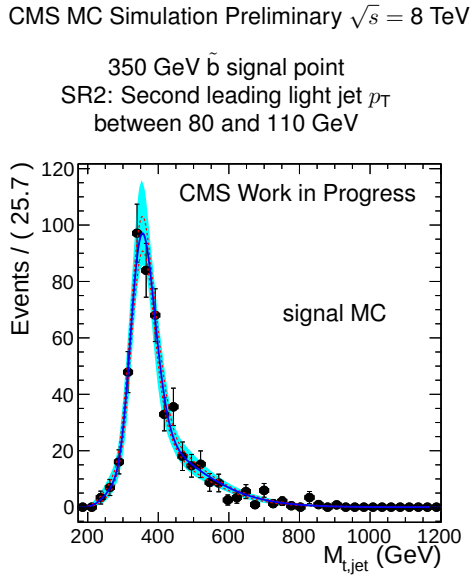
- Background
  - Light jets produced via ISR/FSR
  - Typically one high-p_{T} light jet
  - Assume light jets are sampled from same steeply falling distribution with long tail, and ordered by p_{T}
- Signal
  - Both jets can have high p_{T}
  - Allow for correlations between light jets

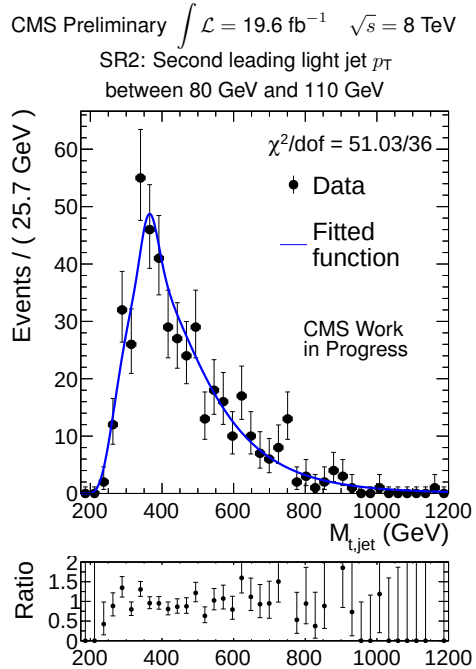




Mass spectrum

- Signal
  - Spectrum peaks at mass of BSM particle
- Background
  - Non-resonant production
  - Event selection sculpts peak
- Mass shape is binned in four regions of 2$^{\text{nd}}$ leading light jet p_{T}
  - Four independent copies of mass shape
  - Normalization in each bin determined from 2D light jet p_{T} fit





Statistical analysis

- Define unbinned extended maximum likelihood using
  - 3D pdf from reconstructed mass and 2D light jet p_{T} distributions
  - Constraint function incorporating systematic effects
- Maximize likelihood for signal+background and background-only hypotheses, scanning over signal cross section
  - Pseudo-experiments generated from best fit values for both hypotheses
  - Test statistic is profile likelihood ratio
  - Construct unified intervals on the cross section
- Observation is consistent with background-only expectation; set limits on both models

Signal + background fit results

Results of likelihood maximization with signal cross section set to observed cross section upper limit