Universität Hamburg
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Search for resonances decaying to top quarks

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on behalf of the CMS Collaboration

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PHYSICS AT THE TERA SCALE
Helmholtz Alliance

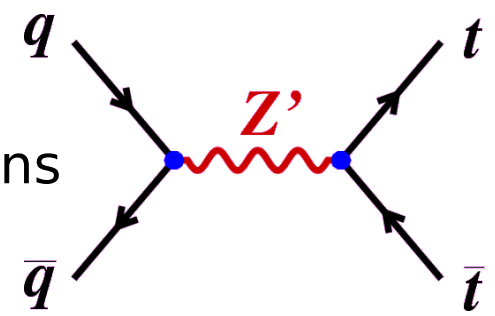
CMS
Compact Muon Solenoid

Introduction

Search program for top quark resonances at CMS:

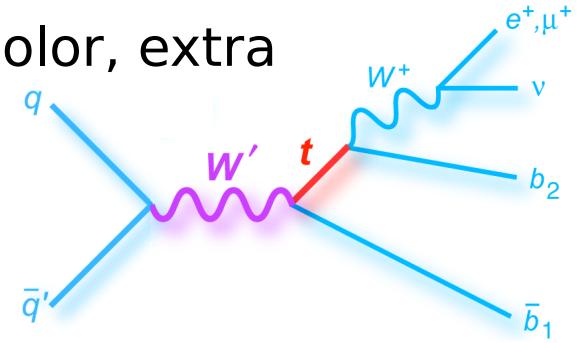
- **$t\bar{t}$**

  Different models predict such resonances:
  topcolor Z', Kaluza Klein excitations, heavy Higgs bosons



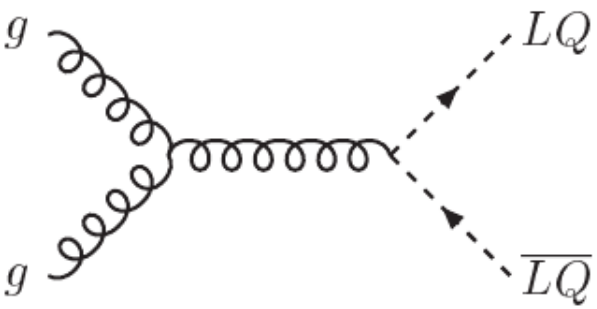
- **t+b**

  W' bosons predicted in Little Higgs models, technicolor, extra dimensions (not covered here)



- **Leptoquarks decaying to t+τ**

  Predicted in Grand Unified Theories (GUT)



Searches based on full 8 TeV dataset

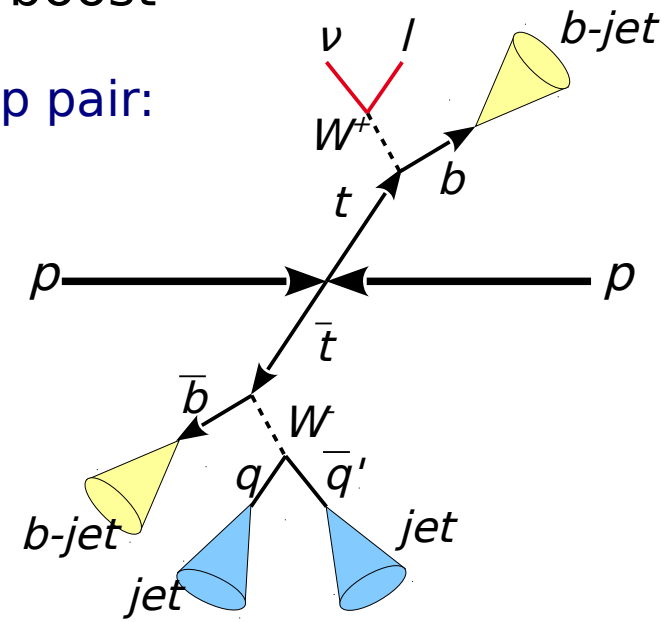
Search for $t\bar{t}$ resonances

CMS PAS B2G-13-008 (accepted by PRD)

$t\bar{t}$ resonances

Top quarks originating from a heavy resonance decay are produced with large boost

SM top pair:



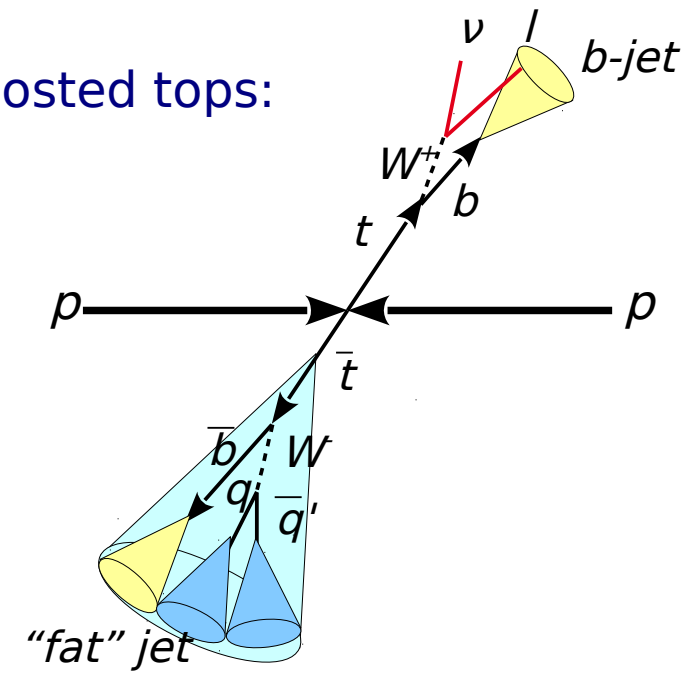
Hadronically decaying top:

- 3 well separated jets (one b jet)

Leptonically decaying top:

- One b jet, isolated lepton, missing transverse energy from neutrino

Boosted tops:



Hadronically decaying top:

- One merged jet → **top tagging**

Leptonically decaying top:

- One b jet, missing E_T, non-isolated lepton

Analysis overview

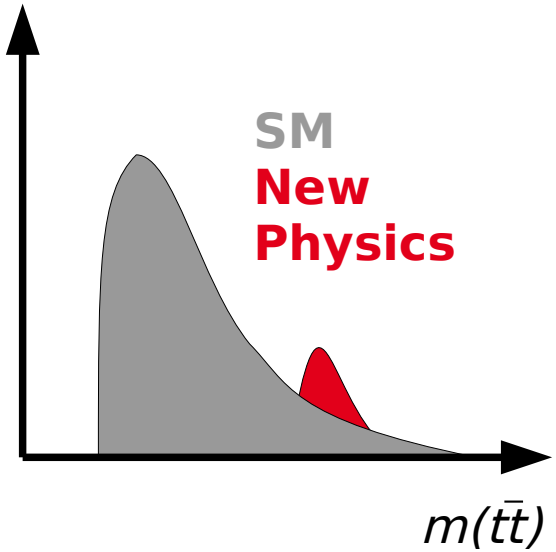
3 analysis channels:

- **Di-lepton:** both top quarks decay to b, l, ν
- **Lepton+jets:** one top quark to b, l, ν, other top quark to hadrons
- **Hadronic:** both top quarks decay to hadrons

→ split into high- and low-mass regions

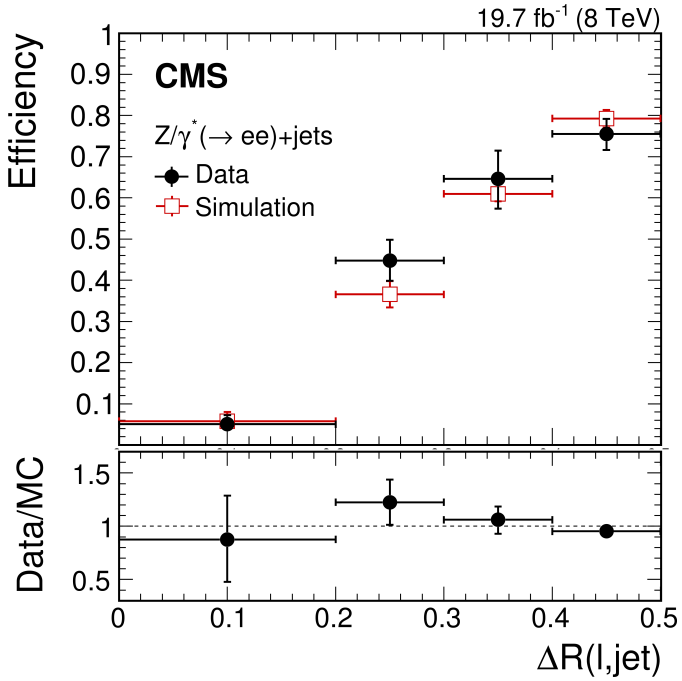
General search strategy:

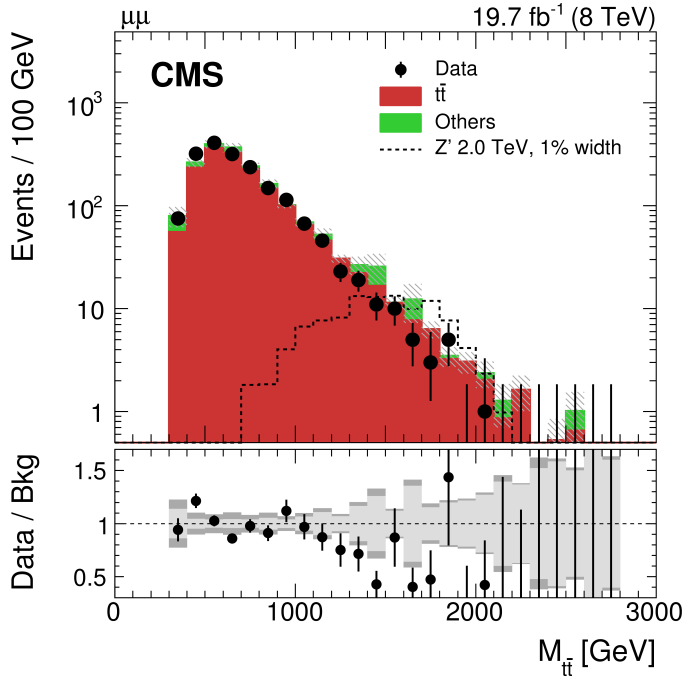
- Select events with the specific signature
- Reconstruct invariant mass of $t\bar{t}$ system
- Search for resonances in $m(t\bar{t})$ distribution

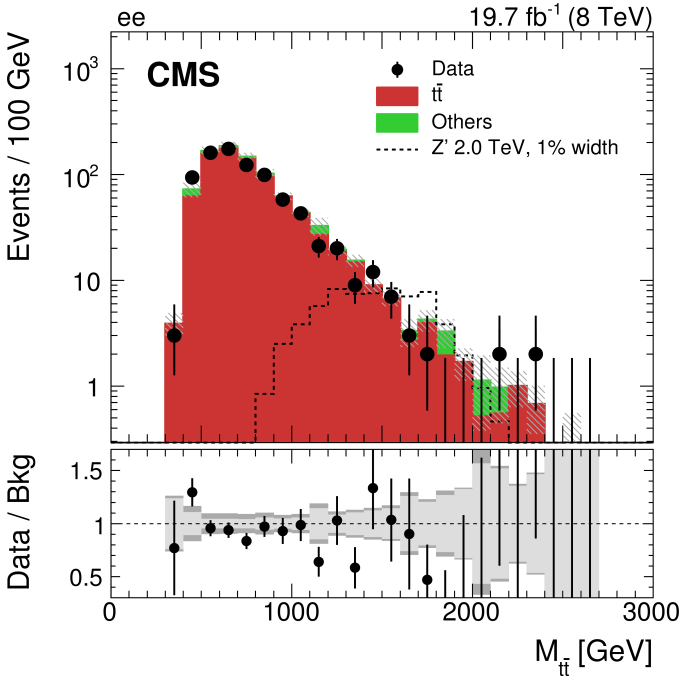


Di-lepton

- Select event with two jets and two electrons or muons
- Leptons required to be close to the jets, cuts on ΔR(l,j) and $p_{T,rel}$(l,j), efficiency probed in Z→ll events
- Three categories: ee, eμ, μμ
- Reconstruct m($t\bar{t}$) from jet+l pairs with neutrinos estimated from missing E_T

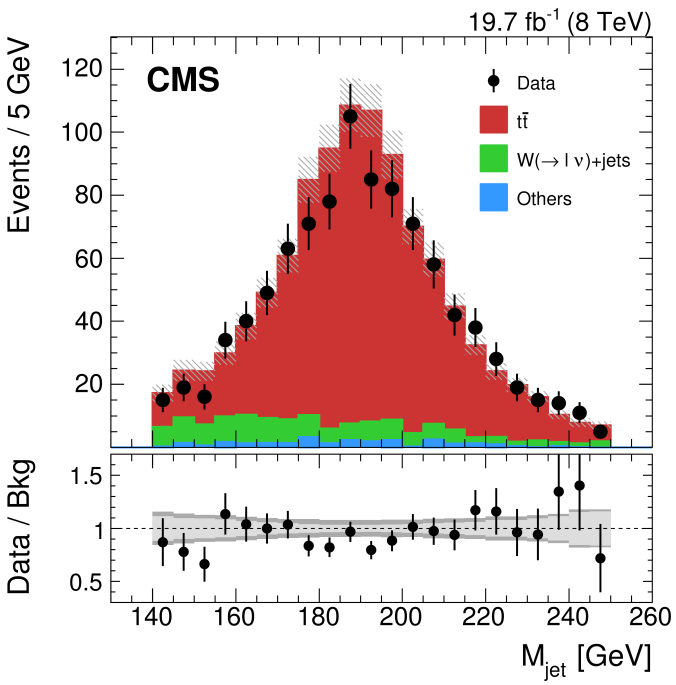


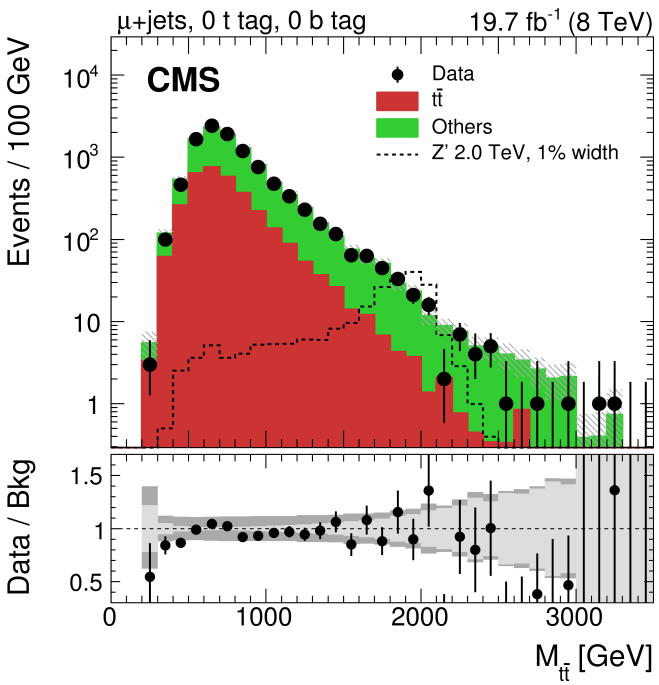


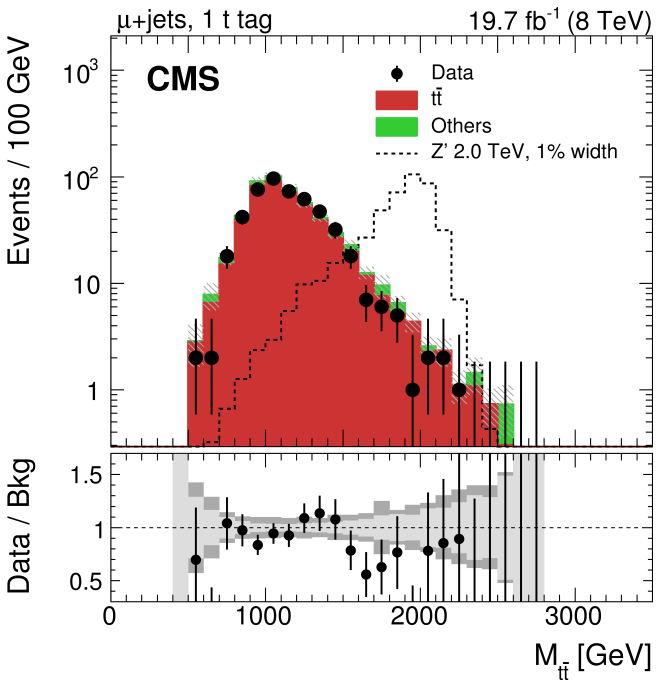


Lepton+jets

- One e or μ, at least 2 jets
- Cuts on $\Delta R(l,j)$ and $p_{T,rel}(l,j)$, cuts on $E_{T,miss}$ and $E_{T,miss}+p_T(l)$
- 6 categories according to number of b and t tags and lepton type
- Use CMS Top Tagger (Cambridge-Aachen jets, R=0.8, with cuts on jet and subjet masses)
- Reconstruct $m(t\bar{t})$ with χ^2 method for best object assignment

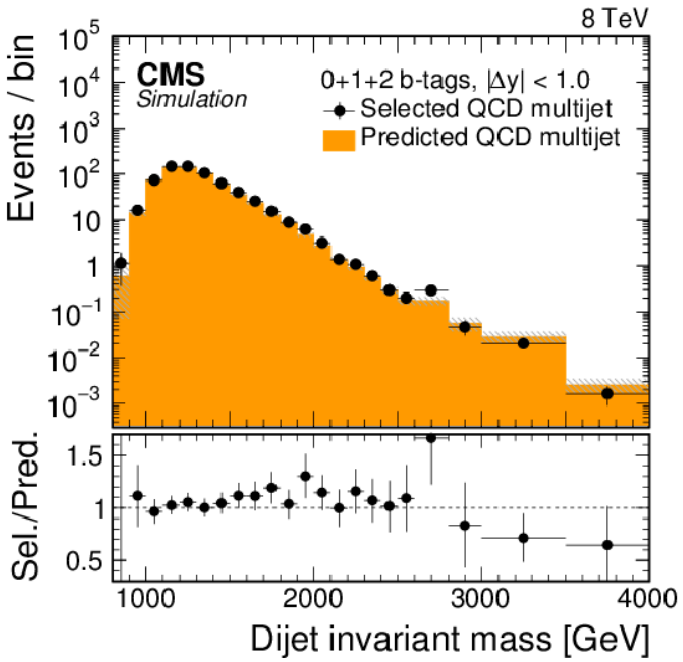


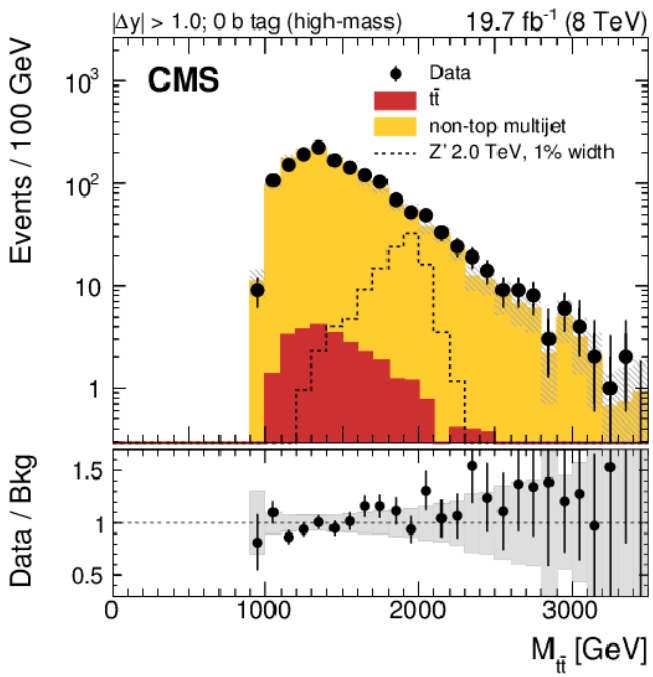


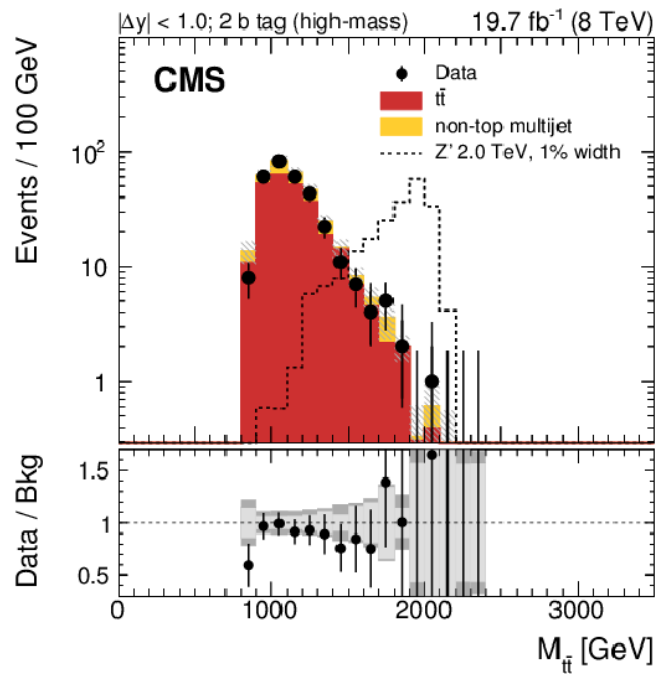


Hadronic high mass

- Dijet events with two high-p_T Cambridge-Aachen jets (R=0.8)
- CMS Top Tagger applied to both jets
- Categories according to number of subjet b-tags and |Δy(j,j)|
- Control regions to estimate top-mistag rate for QCD background model

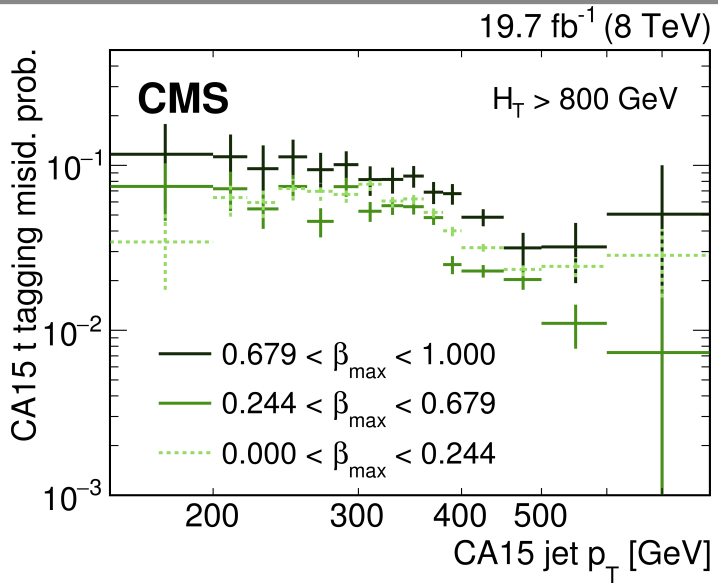


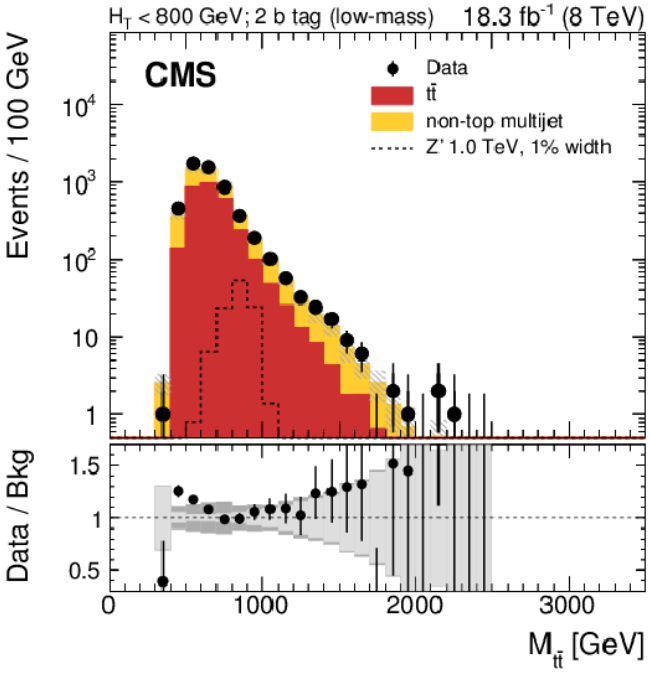


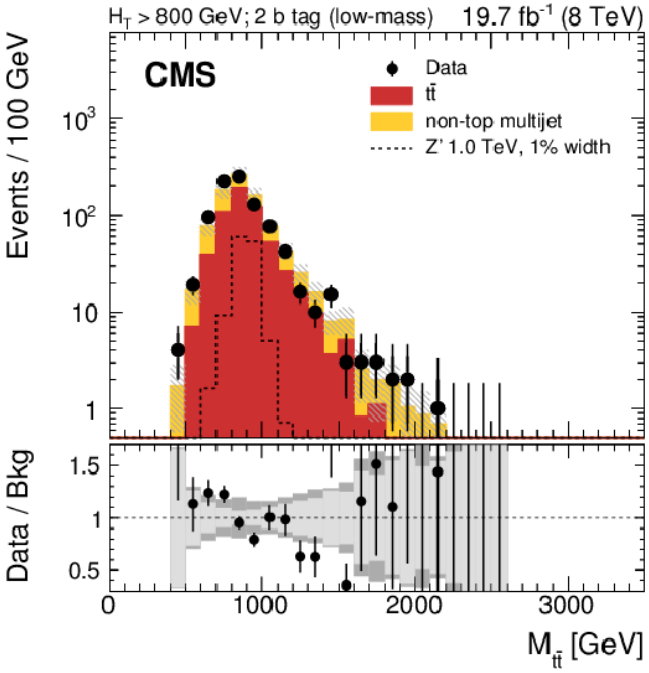


Hadronic low mass

- Dijet events with larger cone (CA jets with R=1.5)
- HEP Top Tagger applied to both jets (Plehn et al., JHEP 1010 (2010) 078)
- Top tagging/mis-tagging rates determined in sidebands for different b tagging points
- Two categories with H_T<800 GeV and H_T>800 GeV

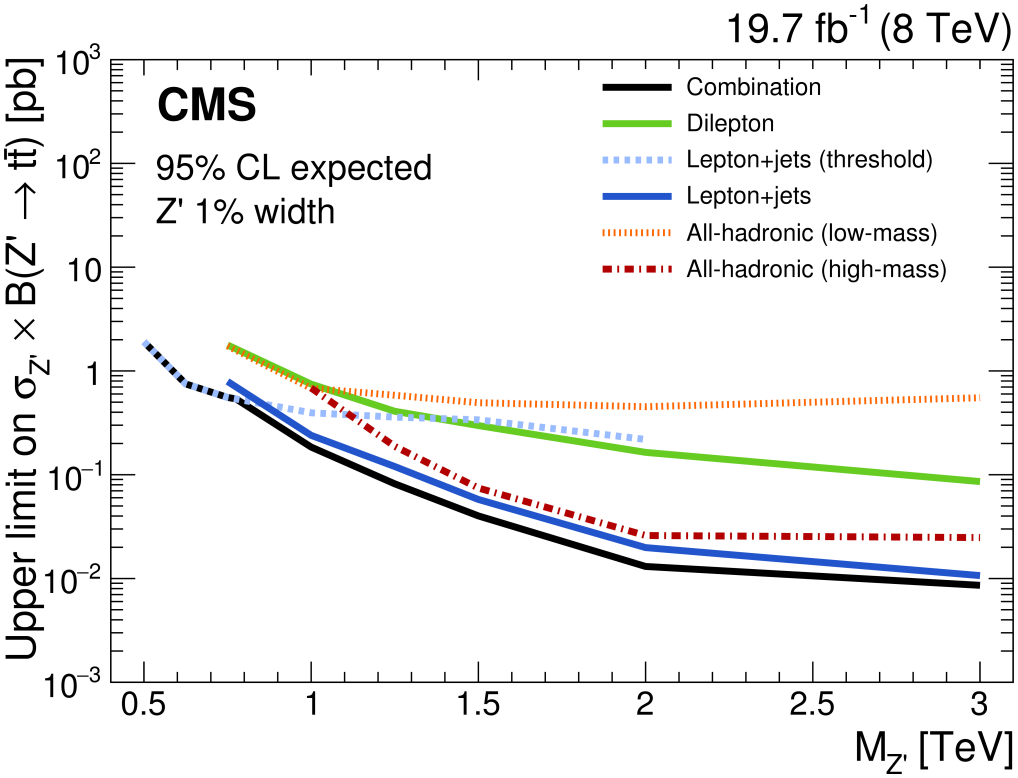


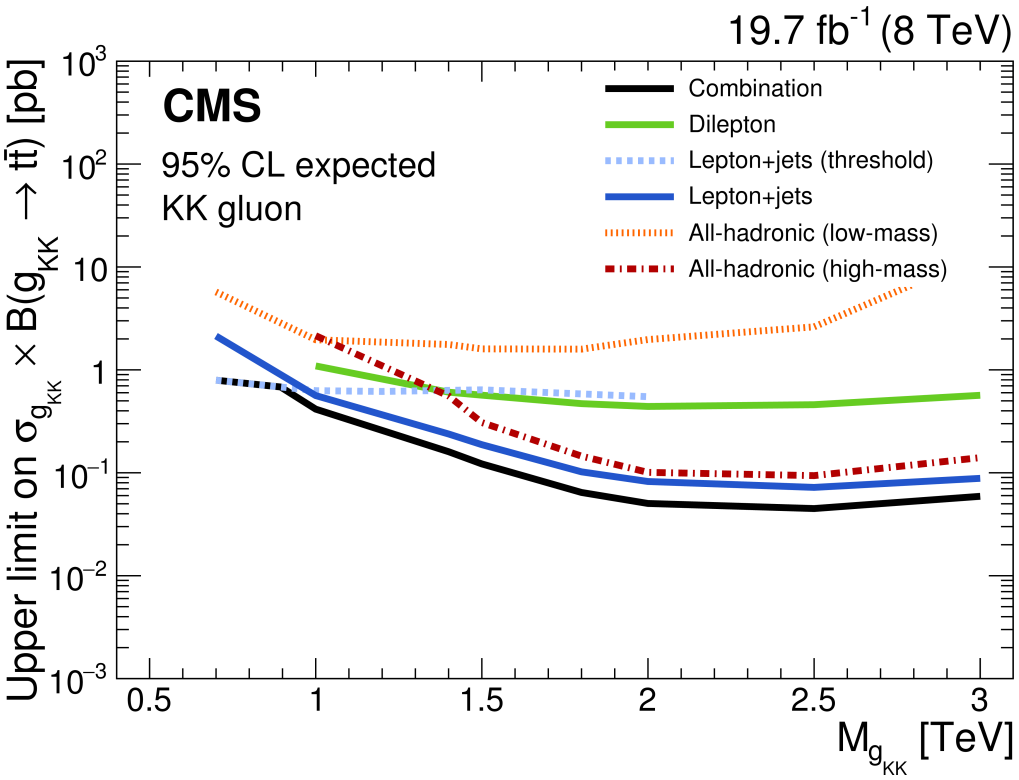




Combination

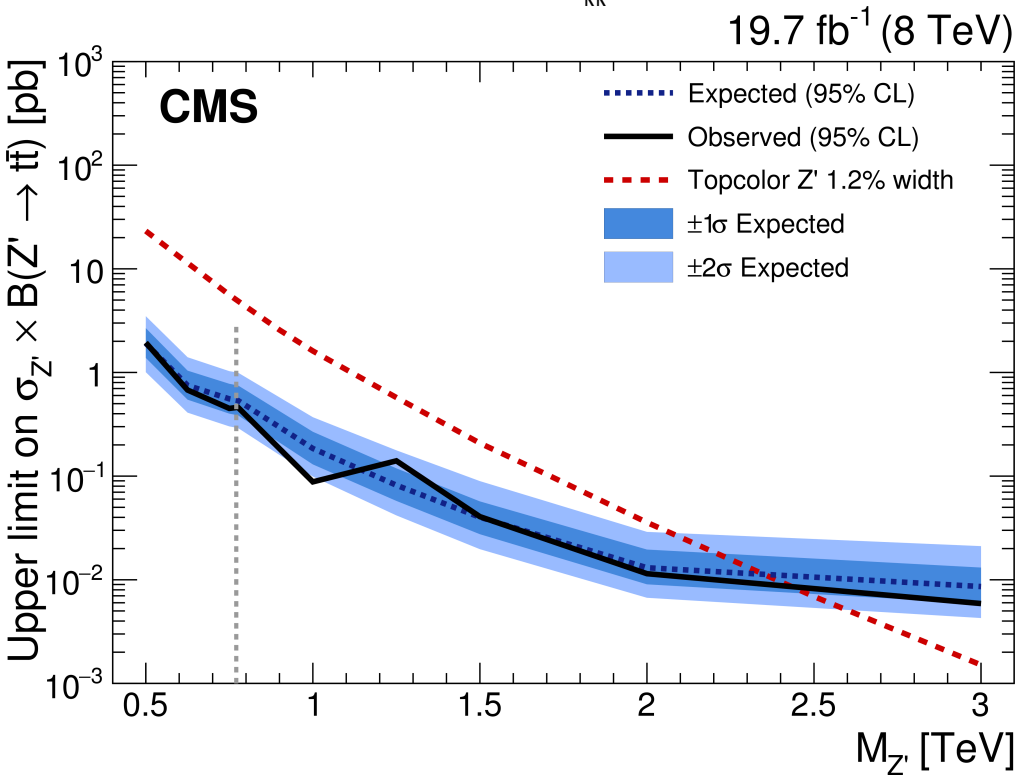
- Combined likelihood fit in all channels
- Perform hypothesis test for topcolor Z' with 1% and 10% width and Kaluza Klein gluons
- Systematic uncertainties included in the fit

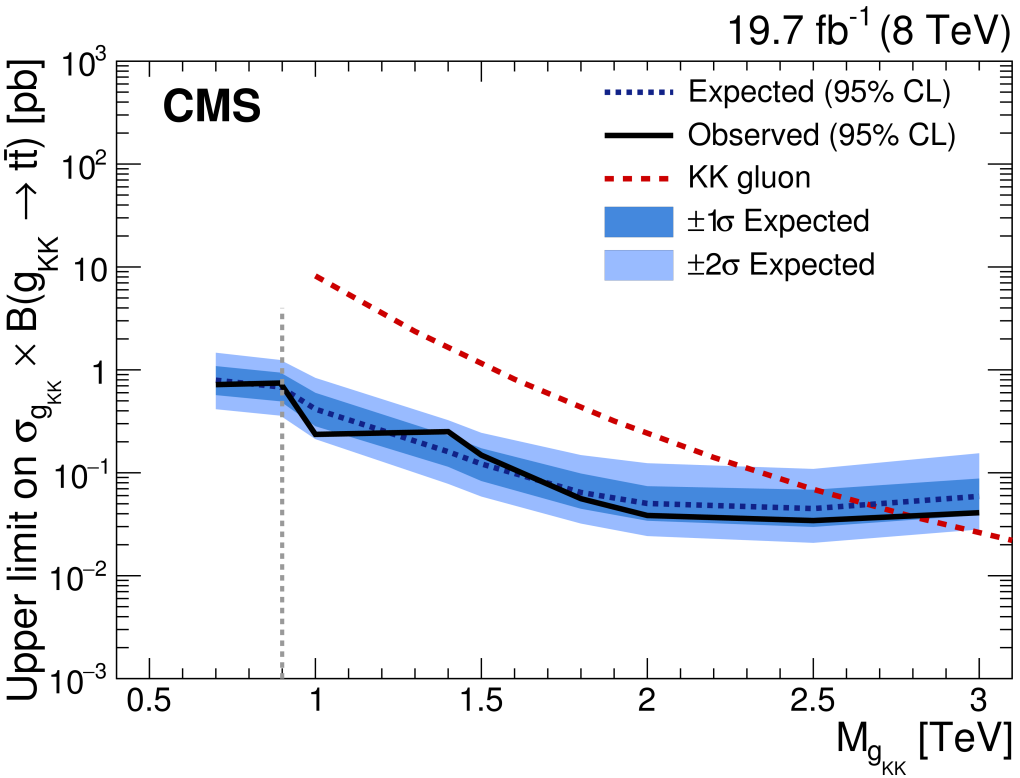




Results

- No hint for new physics in all channels
- Limits on benchmark models:
  - Topcolor Z' (narrow width): m(Z')>2.4 TeV
  - Topcolor Z' (10% width): m(Z')>2.9 TeV
  - KK gluon: $m(g_{KK})>2.8$ TeV



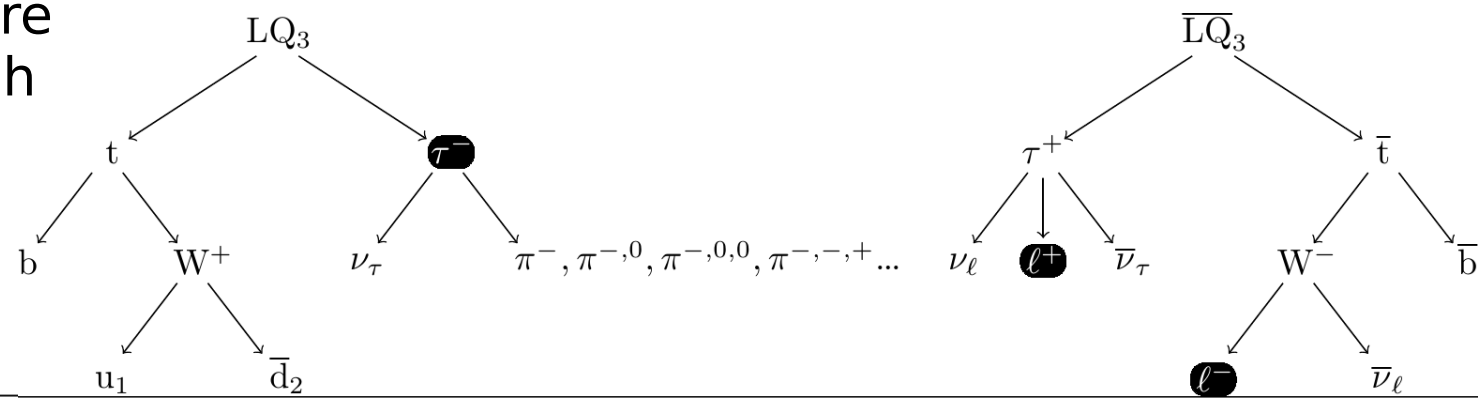


Search for LQ→t+τ

JHEP 07 (2015) 042

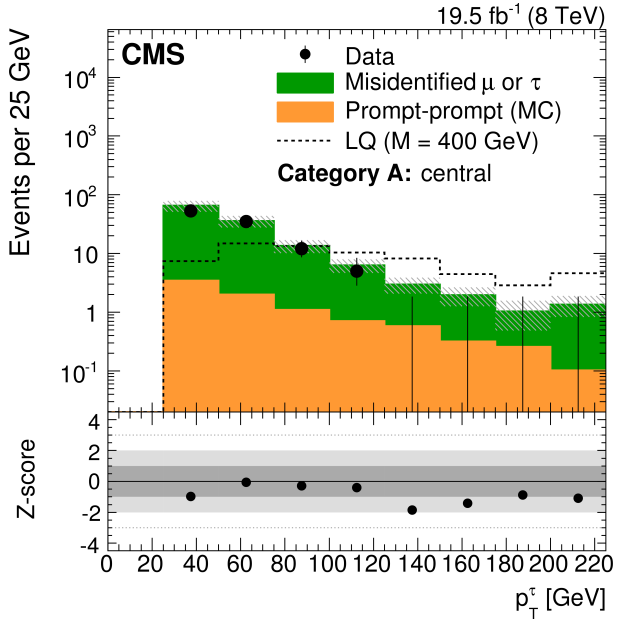
LQ→t+τ overview

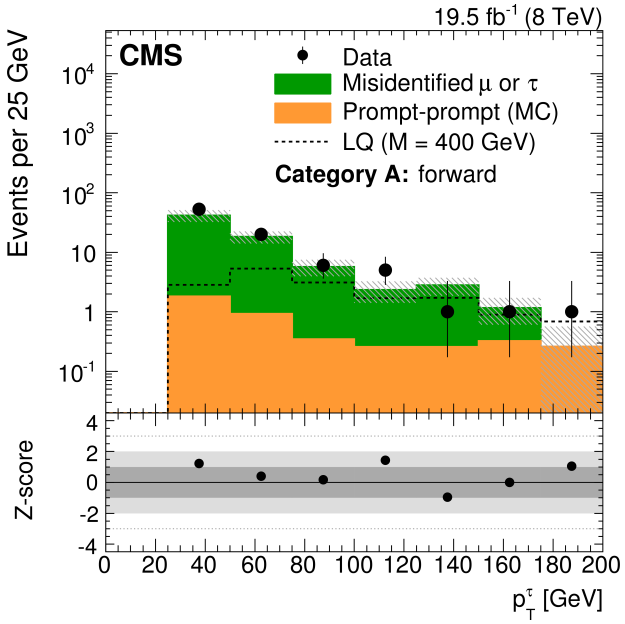
Two event categories are combined for the search



	Category A	Category B
Lepton selection	Same-sign $\mu\tau_h$ pair	$\mu\tau_h$ or $e\tau_h$ pair (category A events are removed)
Jet selection	At least two jets	At least three jets
E_T^{miss} requirement	No E_T^{miss} requirement	$E_T^{miss} > 50\,GeV$
S_T and τ lepton p_T requirements	Optimized for each LQ mass hypothesis	$S_T > 1000\,GeV$, $p_T^\tau > 20\,GeV$
Background estimation	Main component containing misidentified muons & τ leptons estimated using data events	Estimated via simulation, corrections applied for τ lepton misidentification rate and top quark and W p_T distributions
Search regions	2 search regions binned in $\widetilde{\lvert\eta\rvert}$	8 search regions in 4 τ lepton p_T regions for $\mu\tau_h$ and $e\tau_h$ channels

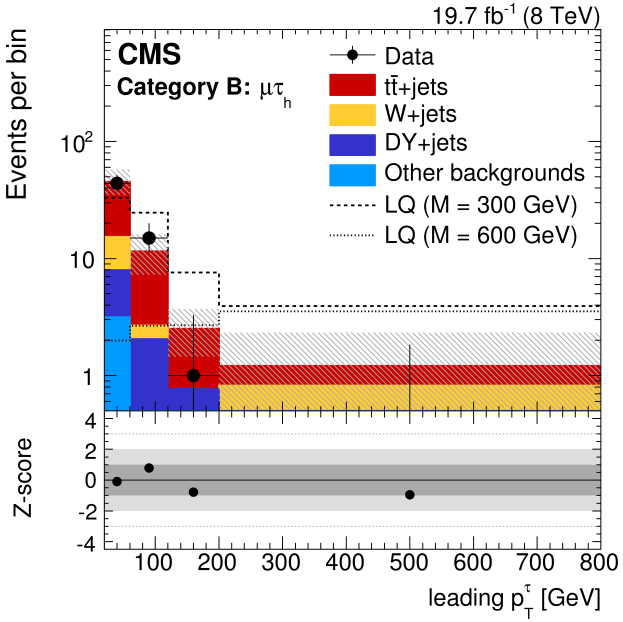
Results

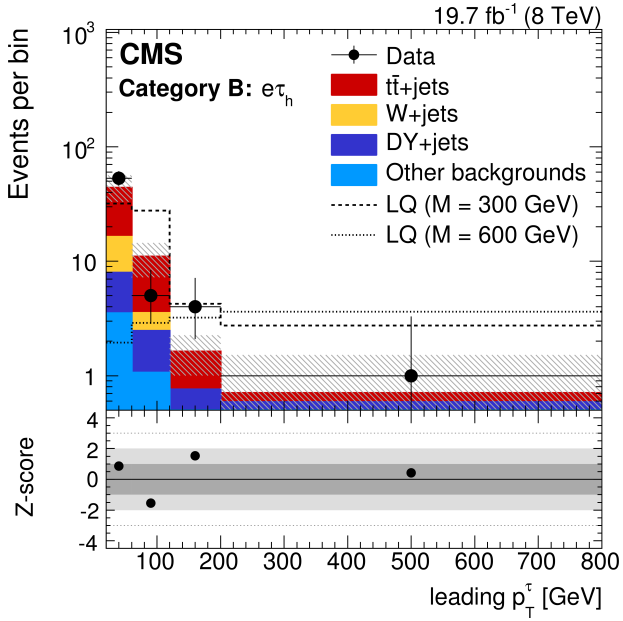




No significant excess observed in data

Perform combined binned likelihood fit to extract limits on LQ production

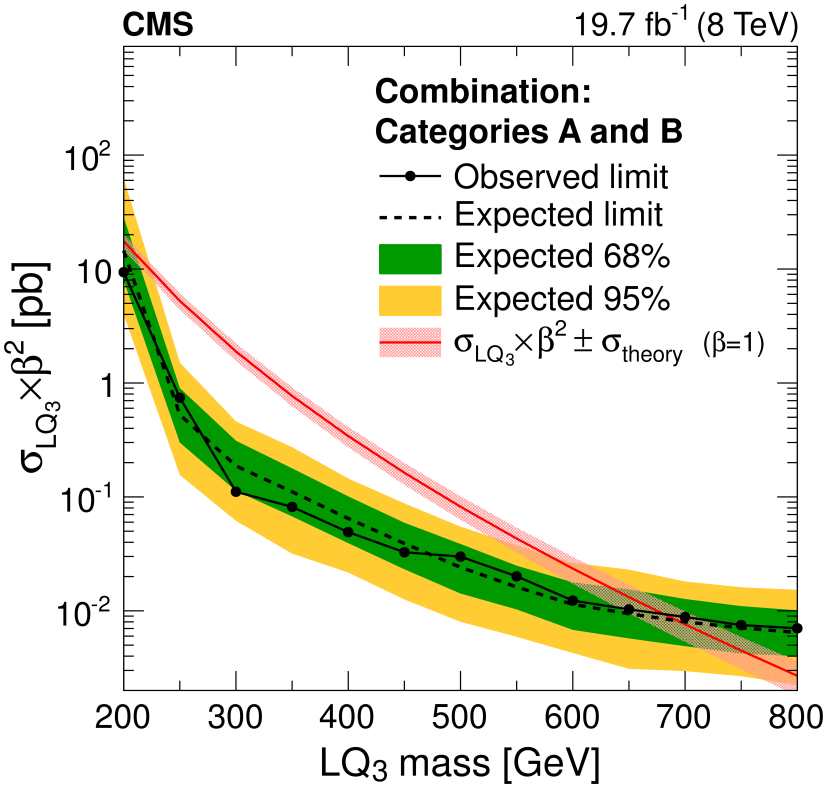


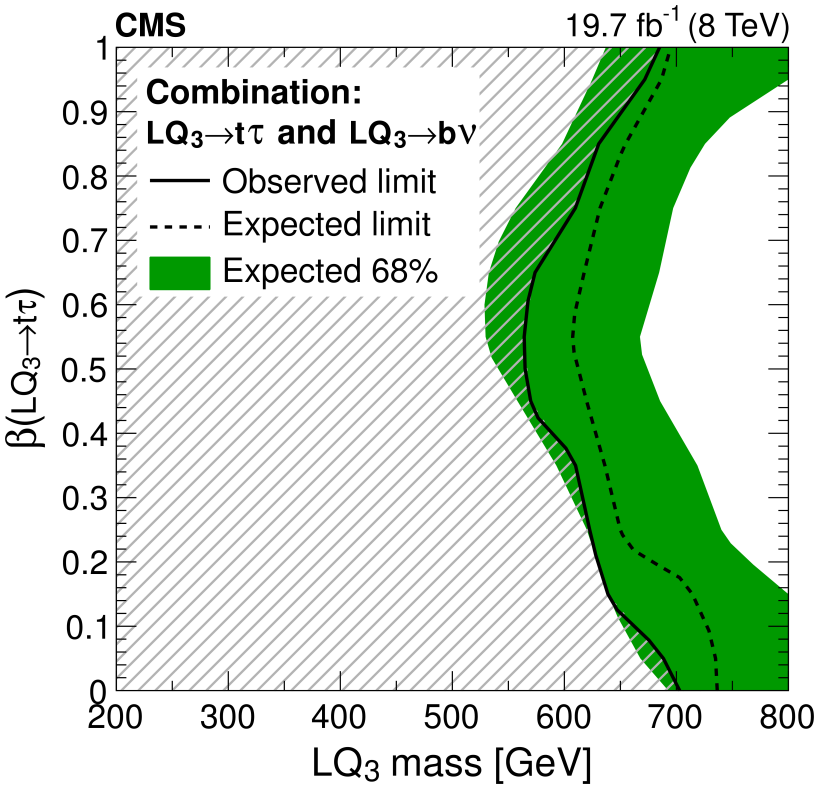


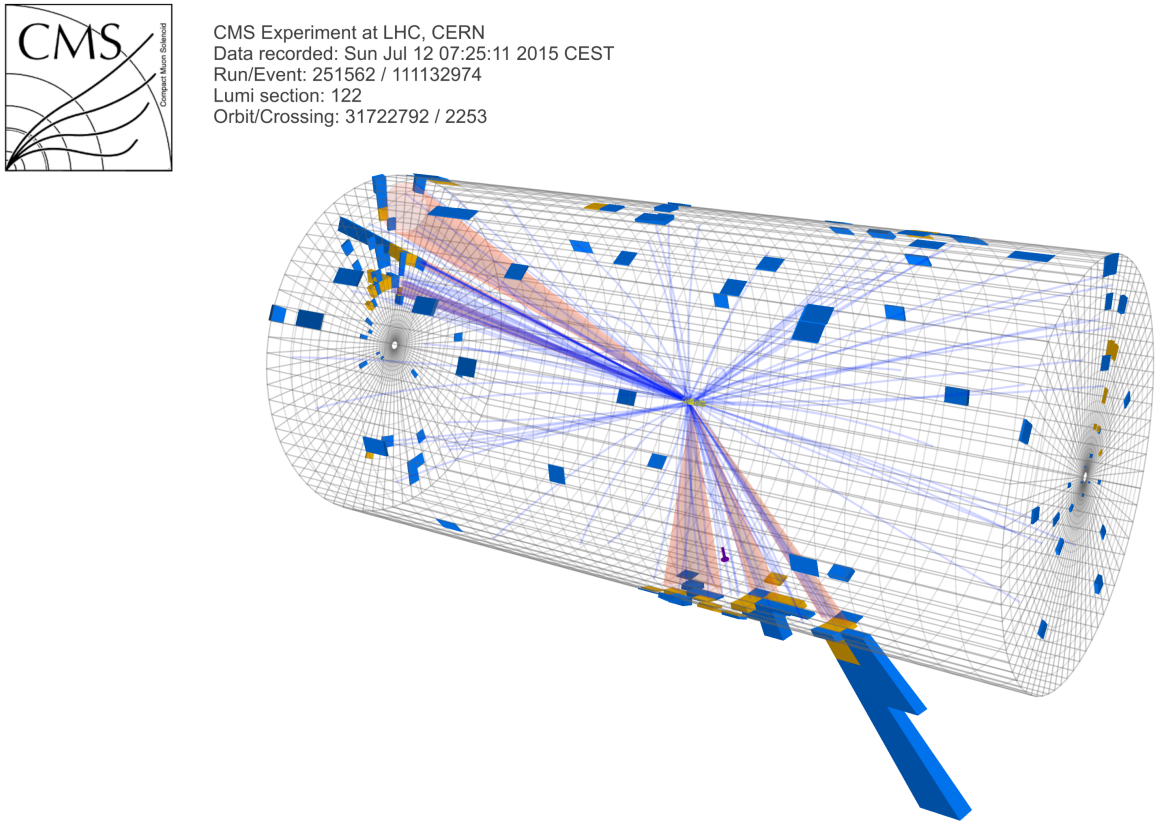
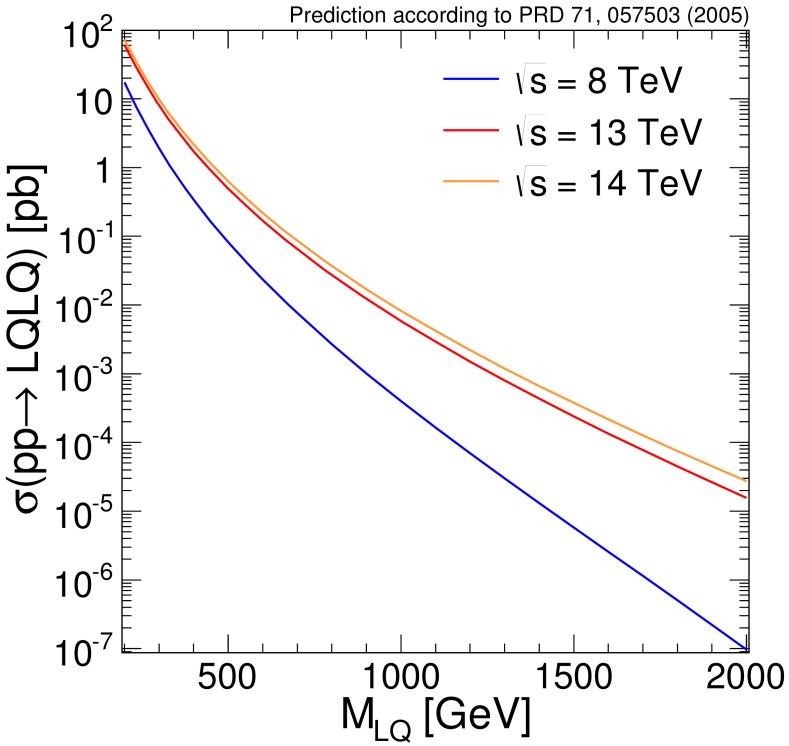
Limits

- Leptoquarks can be excluded up to m=685 GeV (696 GeV expected) for BR(LQ→t+τ)=100%
- Search is combined with LQ→b+ν (re-interpretation of sbottom→b+LSP search for m(LSP)=0):

  m(LQ)>703 GeV for LQ→b+ν





Outlook

- Searches for top resonances have not revealed any hint for new physics
- At 13 TeV run: Multi-TeV signals will be enhanced significantly
- Developed analysis techniques for high-p_T top quarks will be important