Search for exotic resonances with top quarks

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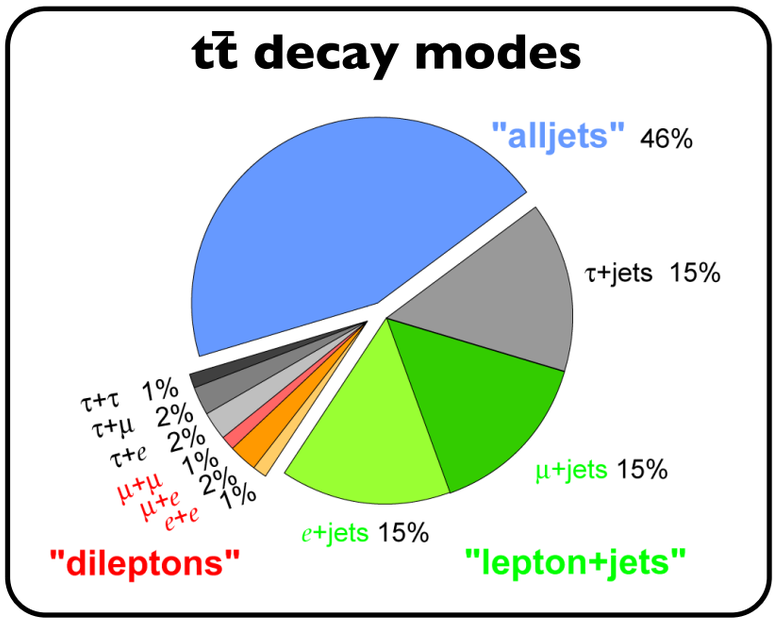
Introduction

- Top quark is a window for new physics because of its unique properties
  - mass of the order of the electroweak breaking scale, decay before hadronization, ...
  - it plays a special role in several scenarios beyond the Standard Model (SM)

- New neutral heavy resonances (Z′) decaying to $t\bar{t}$ pairs predicted in many extensions of the SM:
  - sequential Z′, little Higgs, axigluons, extra dimensions, ...
  - CMS searches for Z′→tt presented here can be interpreted in any of these models



- Charged massive gauge bosons (W′) also predicted in many BSM models
  - the decay to third generation quarks (W′→tb) is one of the most promising channel

- It has also been proposed top quark may be a composite particle *Phys.Rev.D51:3888-3894*
  - a direct test would be to show the existence of an excited top quark (t*)

Analyses presented

- B2G-12-014: search for excited top quarks decaying to a top and a gluon
  - *19.6 fb^{-1} at $\sqrt{s}$ = 8 TeV*
  - *Physics Analysis Summary (PAS)*
- B2G-12-010: search for narrow t+b resonances
  - *19.6 fb^{-1} at $\sqrt{s}$ = 8 TeV*
  - *Physics Analysis Summary (PAS)*
- B2G-12-005: search for BSM $t\bar{t}$ production in all-hadronic final state
  - *19.6 fb^{-1} at $\sqrt{s}$ = 8 TeV*
  - *Physics Analysis Summary (PAS)*
- TOP-11-010: search for $Z' \rightarrow t\bar{t}$ in the dileptonic final state
  - *5.0 fb^{-1} at $\sqrt{s}$ = 7 TeV*
  - *Phys. Rev. D 87, 072002 (2013) - arXiv: 1211.3338*
- B2G-12-006: search for $Z' \rightarrow t\bar{t}$ in the lepton+jets final state
  - *19.6 fb^{-1} at $\sqrt{s}$ = 8 TeV*
  - *Physics Analysis Summary (PAS)*

Search for excited top (t*)

19.6 fb^{-1} @ $\sqrt{s}$ = 8 TeV

- search for excited top quarks decaying to *tg*

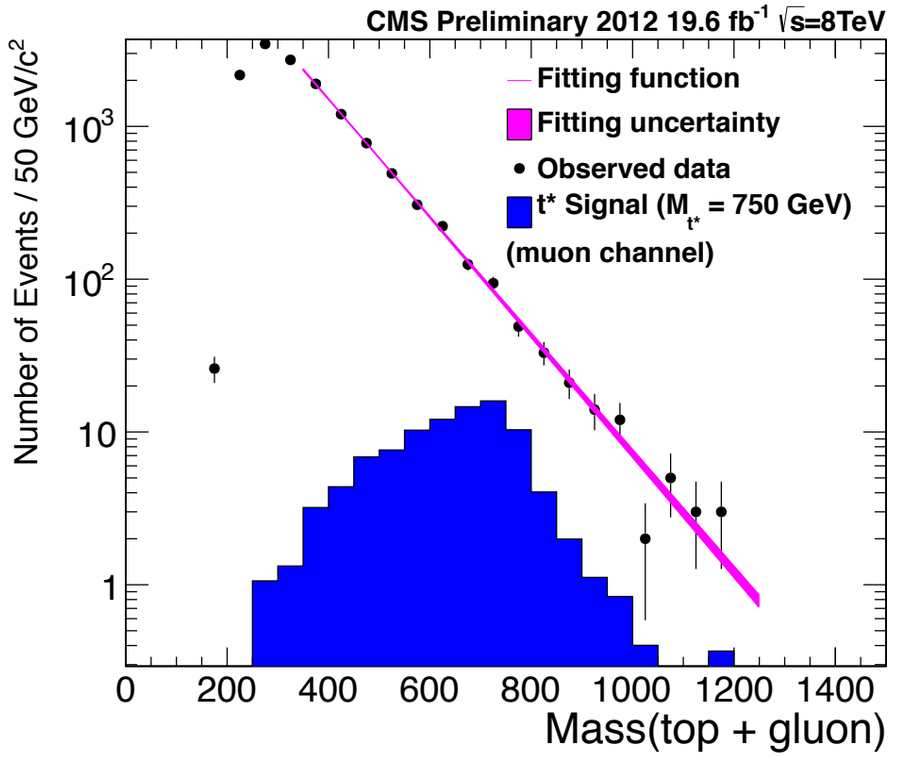
$$t^*t^* \rightarrow tgtg \rightarrow bWgbWg \rightarrow l\nu bbjjjj$$

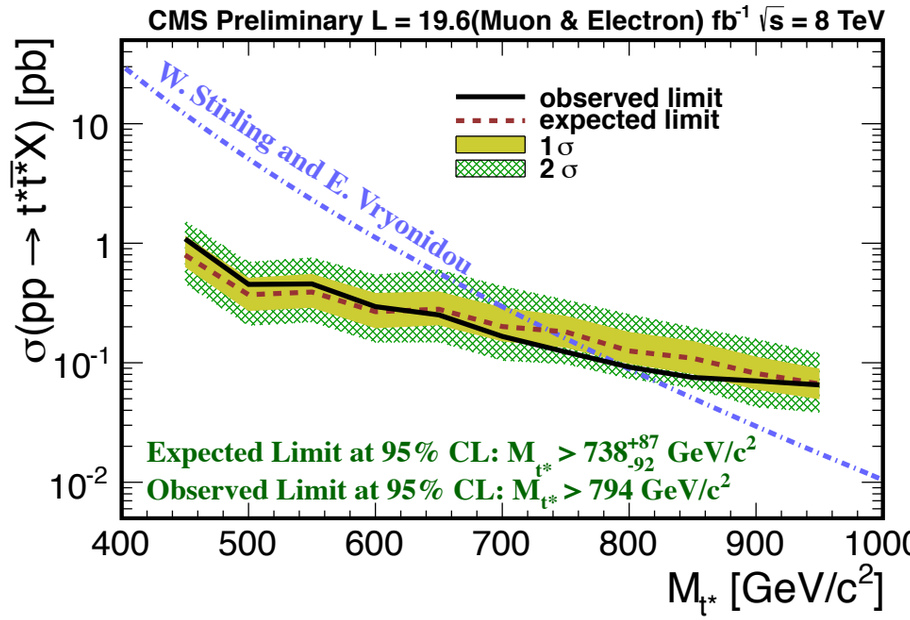
Event selection

- 1 isolated muon (electron) with p_T > 26 (30) GeV
- at least 6 jets with p_T > 30 GeV
  (55, 45, 35 GeV for the first three leading jets)
- at least 1 b-jet
- missing E_T > 20 GeV

- X^2 sorting to choose the best jet combination
- template fit with shapes from MC

Limits: M_{t^*} > **794** GeV (expected 738 GeV)





Search for t + b resonances

19.6 fb^{-1} @ $\sqrt{s}$ = 8 TeV

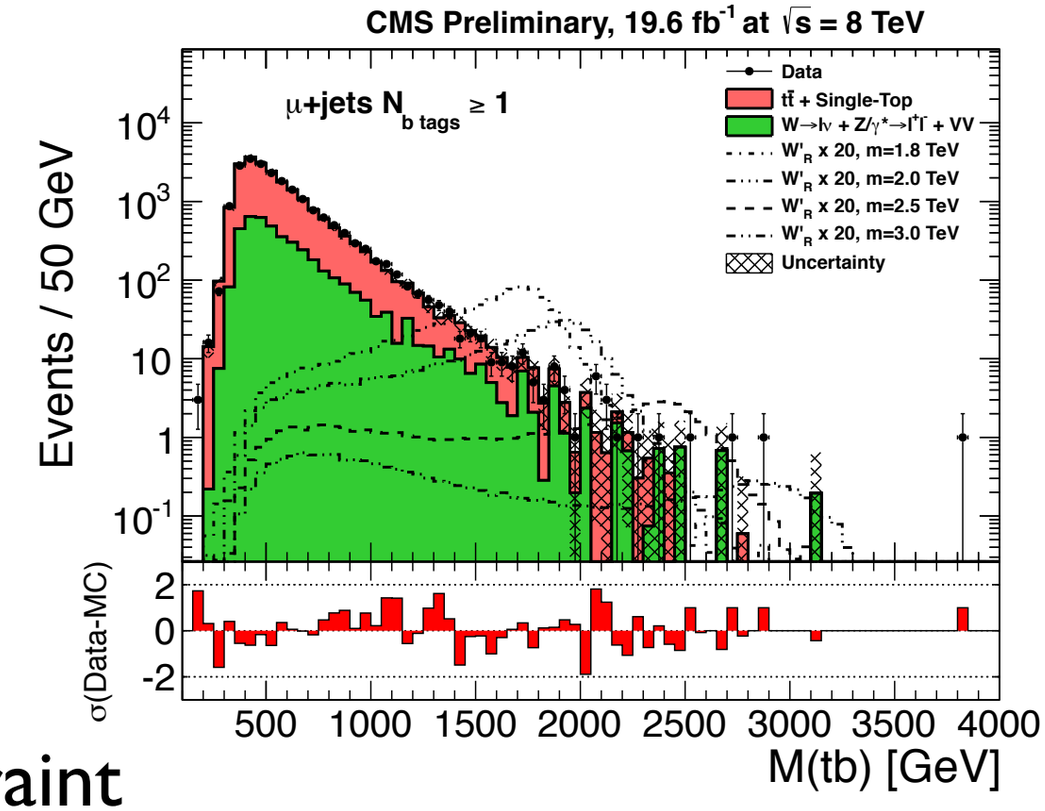
- search for W′ bosons decaying to *tb*

$$W' \to tb \to bWb \to l\nu bb$$

- arbitrary combinations of left- and right-handed couplings allowed

Event selection

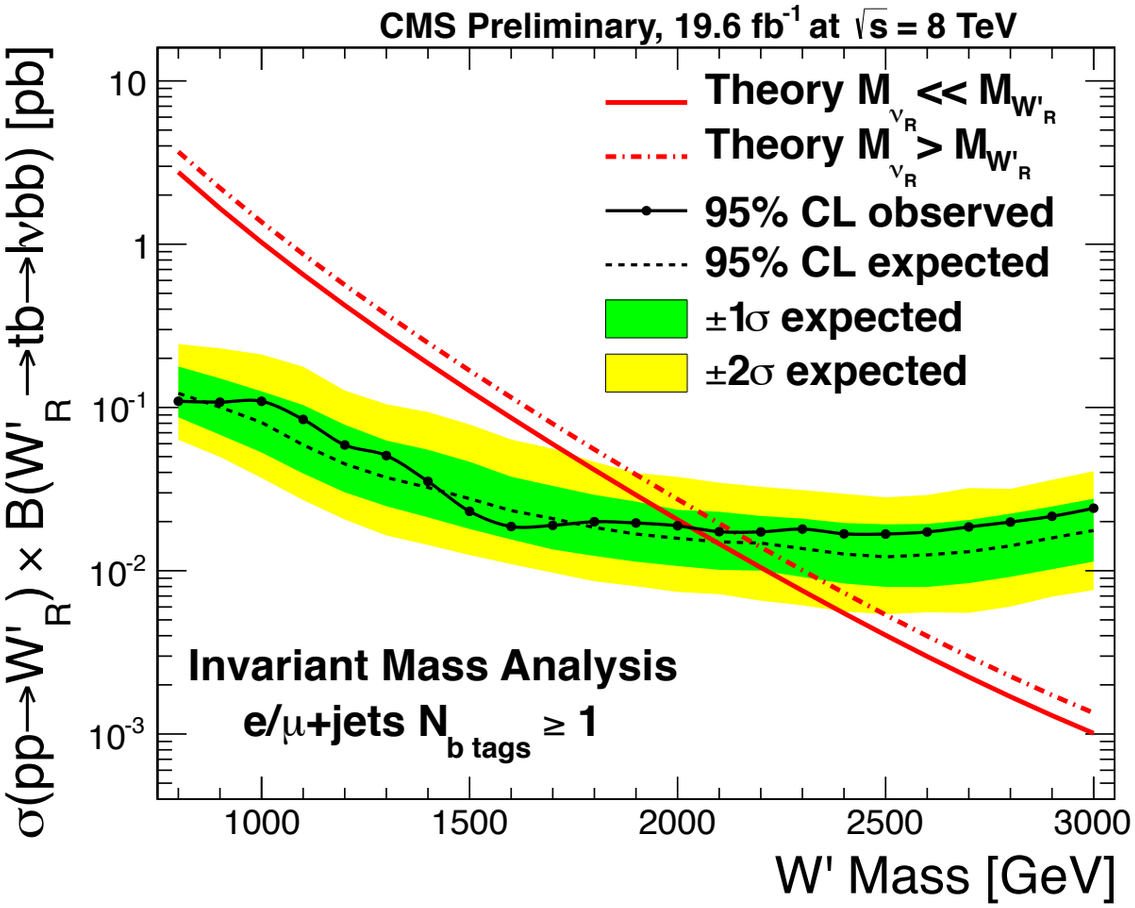
- exactly 1 isolated lepton with $p_T > 50$ GeV
- at least 2 jets with $p_T > 120, 40$ GeV
- at least 1 b-jet
- missing $E_T > 20$ GeV

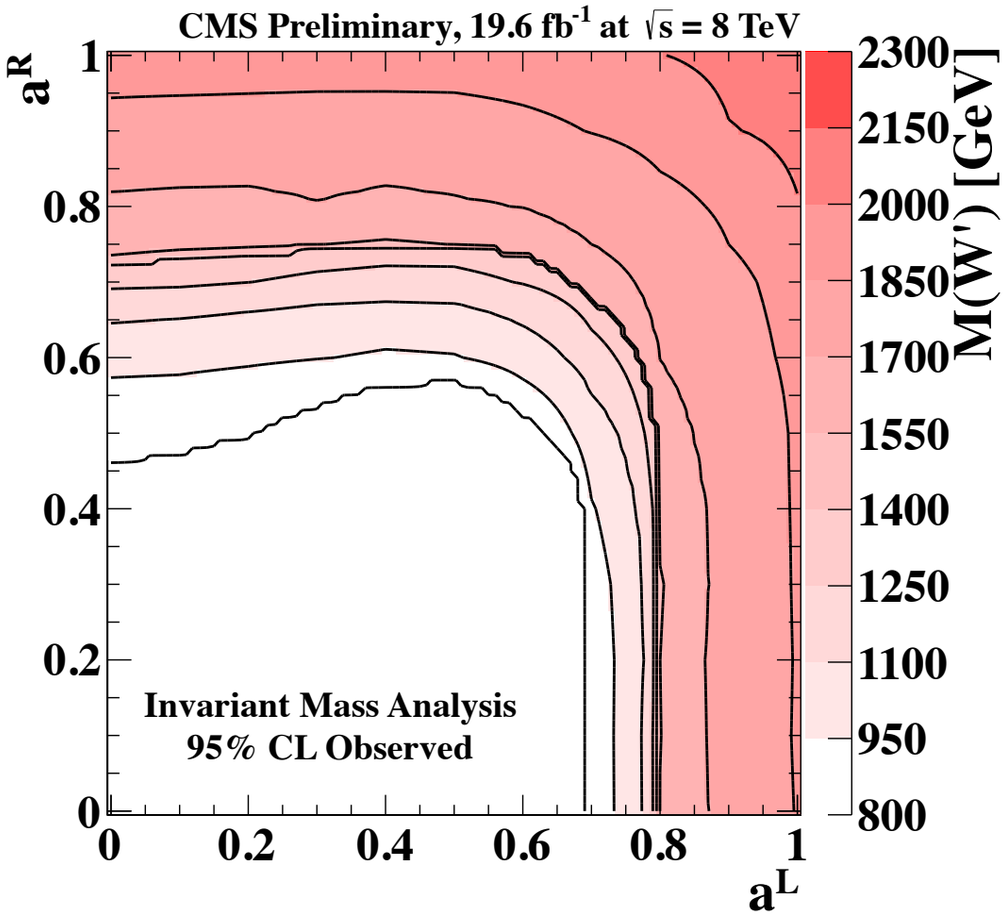


- neutrino z momentum from W mass constraint
- constraint on reconstructed top mass to solve ambiguity on jet assignment
- likelihood fit to a background model taken from MC

Search for t + b resonances (II)

- Set limits for a given combination of left- and right-handed couplings
- Also set limits on the cross section for W'_R





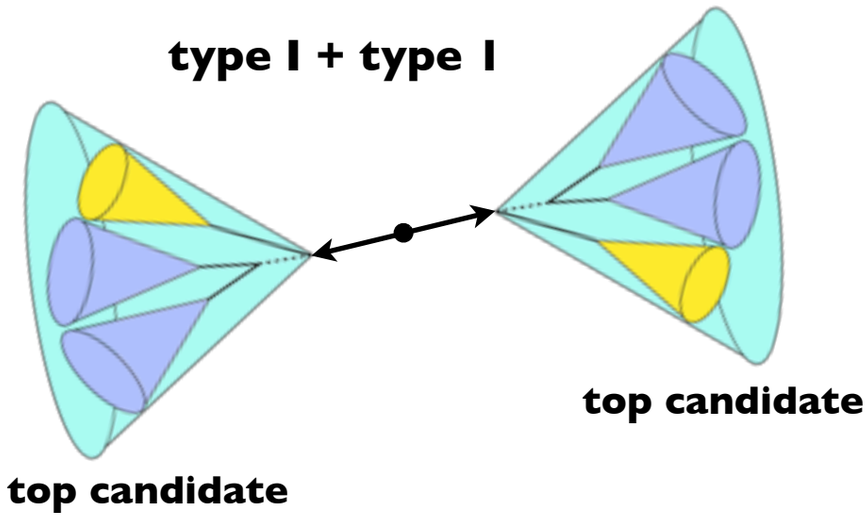
Limits:

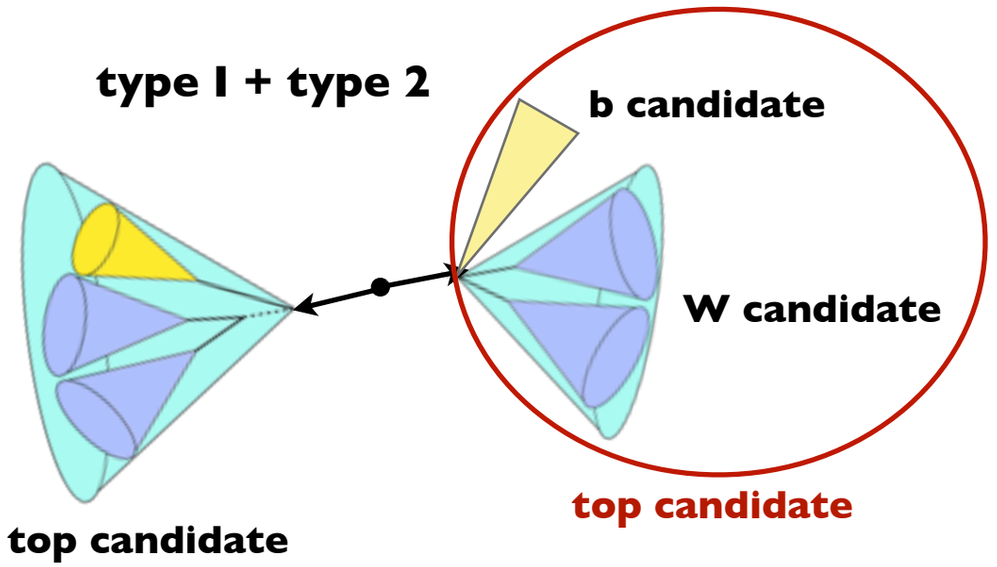
- W'_R > **2.03** TeV (expected 2.09 TeV)

$t\bar{t}$ resonances: **fully hadronic channel**

19.6 fb^{-1} @ $\sqrt{s}$ = 8 TeV

- analysis designed for highly boosted $t\bar{t}$ pair:
  - top decay products can be partially (type 2) or fully merged (type 1)
  - Cambridge-Aachen (CA) jets used

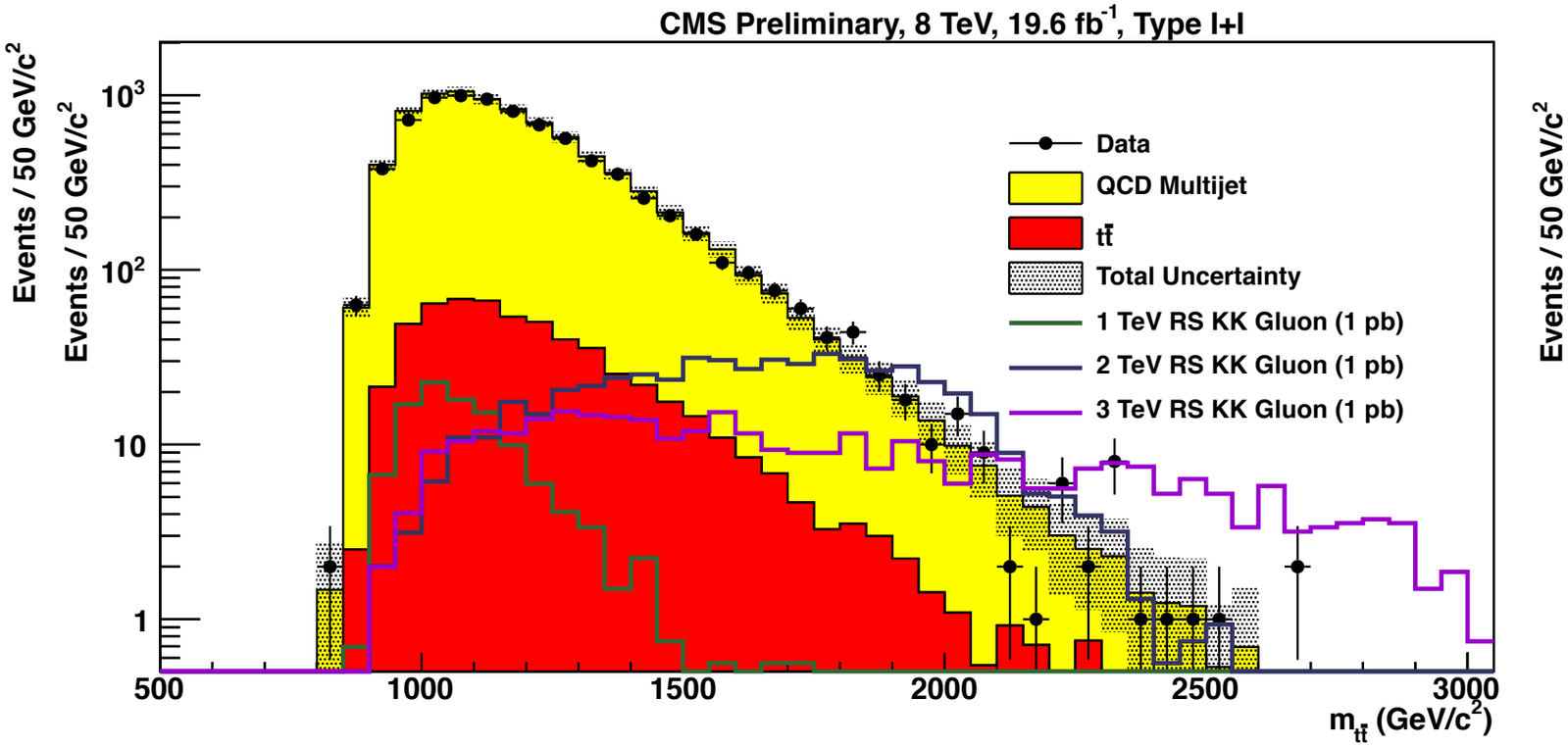




Event selection:

- Type 1+1: at least 2 type 1 top quark candidates with p_T > 400 GeV
- Type 1+2: one type 1 top quark with p_T > 400 GeV and at least 2 jets, one identified as a W candidate (p_T > 200 GeV) and one as b-jet

$t\bar{t}$ resonances: **fully hadronic channel (II)**

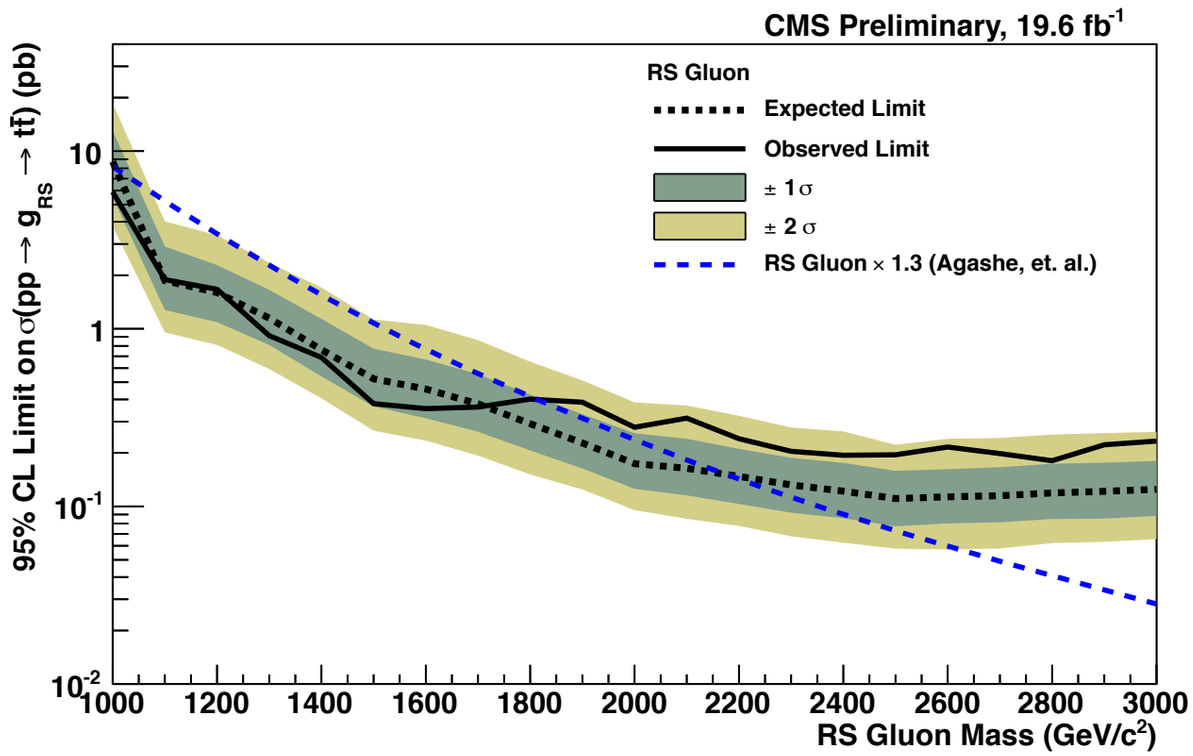


Events / 50 GeV/c2

← **type I + type I**

Limits:

- RS KK gluon: M > **1.8** TeV
- Narrow (1%) Z′: $M_{Z'}$ > **1.6** TeV
- Wide (10%) Z′: $M_{Z'}$ > **2.3** TeV



$t\bar{t}$ resonances: **dileptonic channel**

Event selection

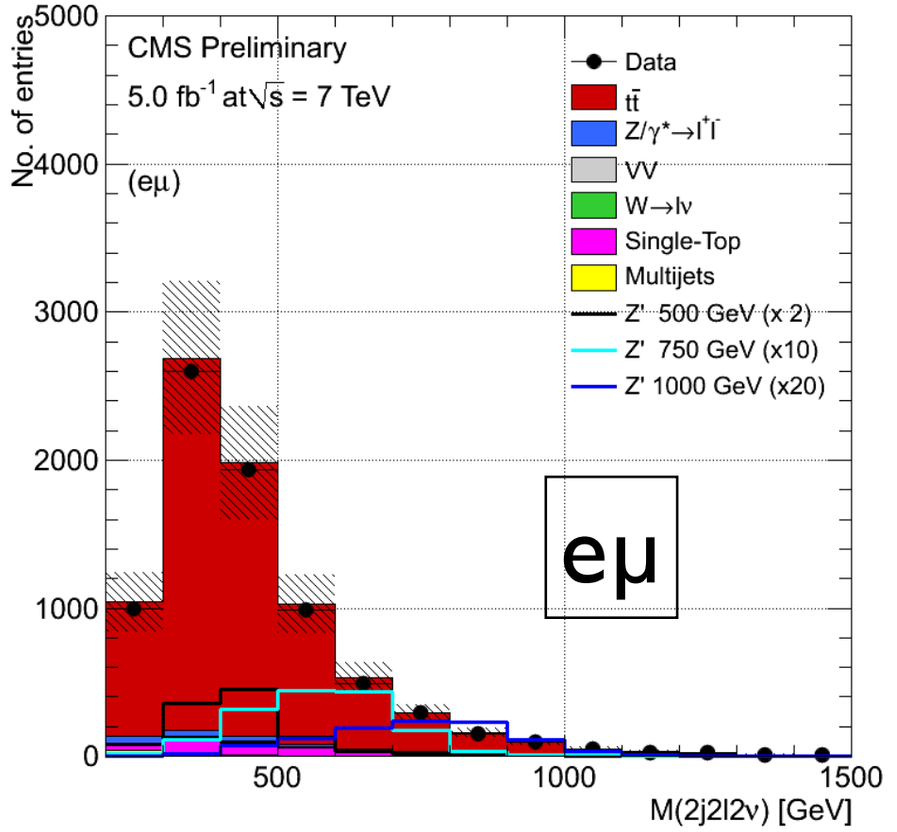
5.0 fb^{-1} @ $\sqrt{s}$ = 7 TeV

- 2 isolated leptons (electron or muon) with p_T > 20 GeV
- quarkonia and Z boson vetoes
- at least 2 jets with p_T > 30 GeV with at least 1 b-tagged jet
- missing E_T > 30 GeV in ee and μμ channels

- three channels (ee, eμ, μμ)
- a multivariate approach used to increase the analysis sensitivity
- it is based on a Bayesian neural network (BNN)

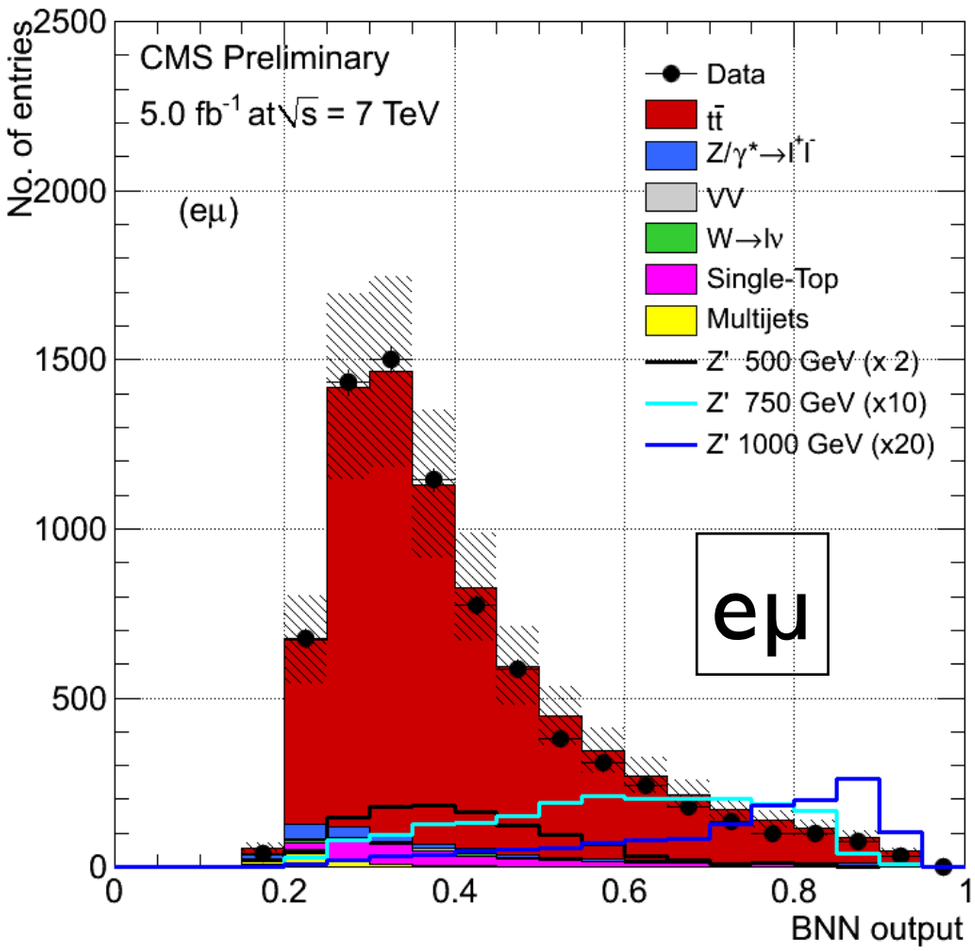
$$\mathcal{D}(\mathbf{x}) = \frac{p(\mathbf{x}|\mathcal{S})}{p(\mathbf{x}|\mathcal{S}) + p(\mathbf{x}|\mathcal{B})}$$

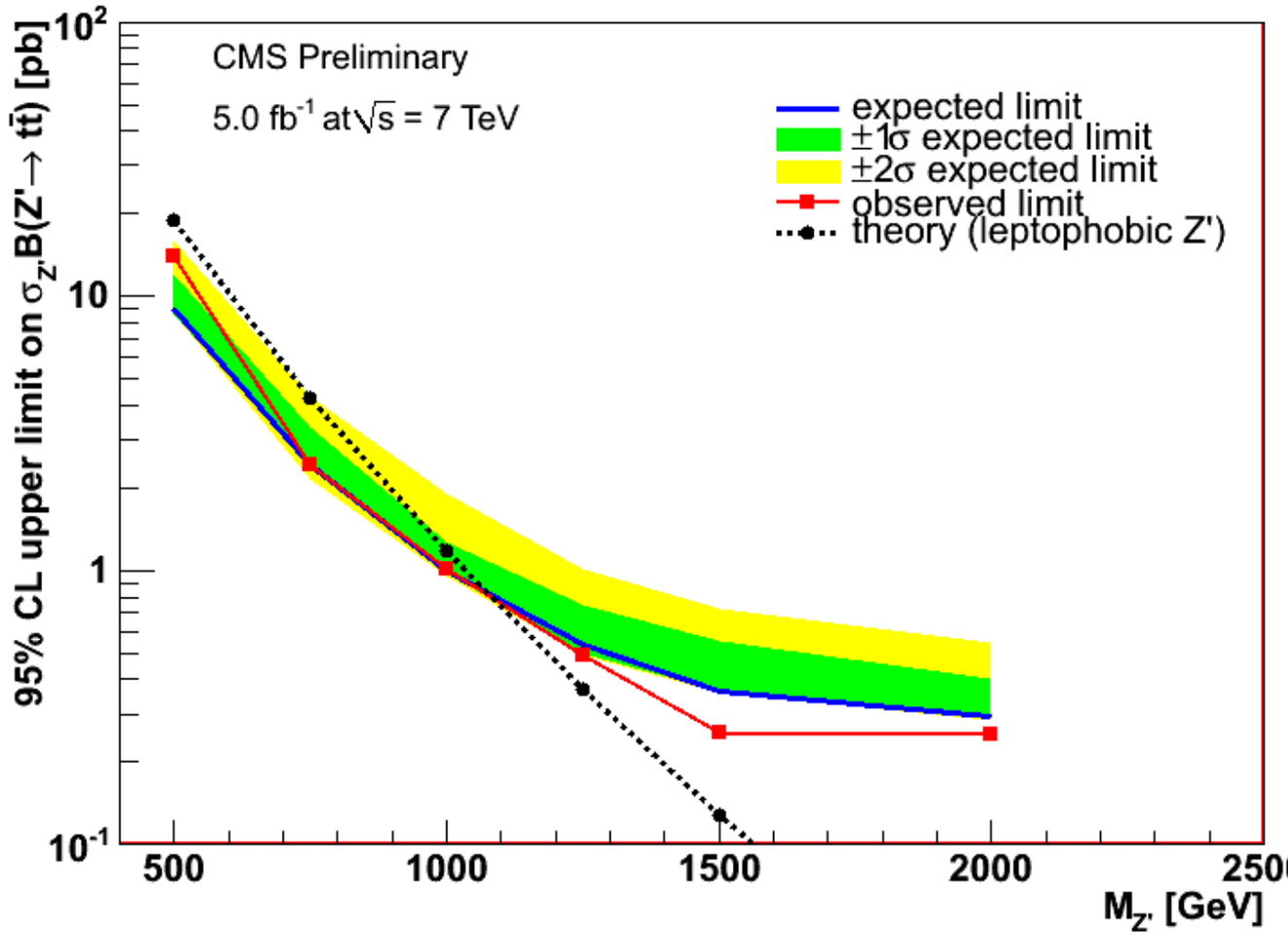
17 variables used as input to train the BNN



$t\bar{t}$ resonances: **dileptonic channel (II)**

- network trained for Z′ with mass 750 GeV
- good agreement between data and expectations





- $M_{Z'}$ < **1.1 TeV** excluded at 95% CL

$t\bar{t}$ resonances: lepton+jets channel

- two complementary strategies used:

19.6 fb^{-1} @ $\sqrt{s}$ = 8 TeV

  - **threshold search**: optimized to identify top with small boost
  - **boosted search**: for top decay products partially or fully merged ($M_{Z'}$ > 1 TeV)

Event selection (threshold search)

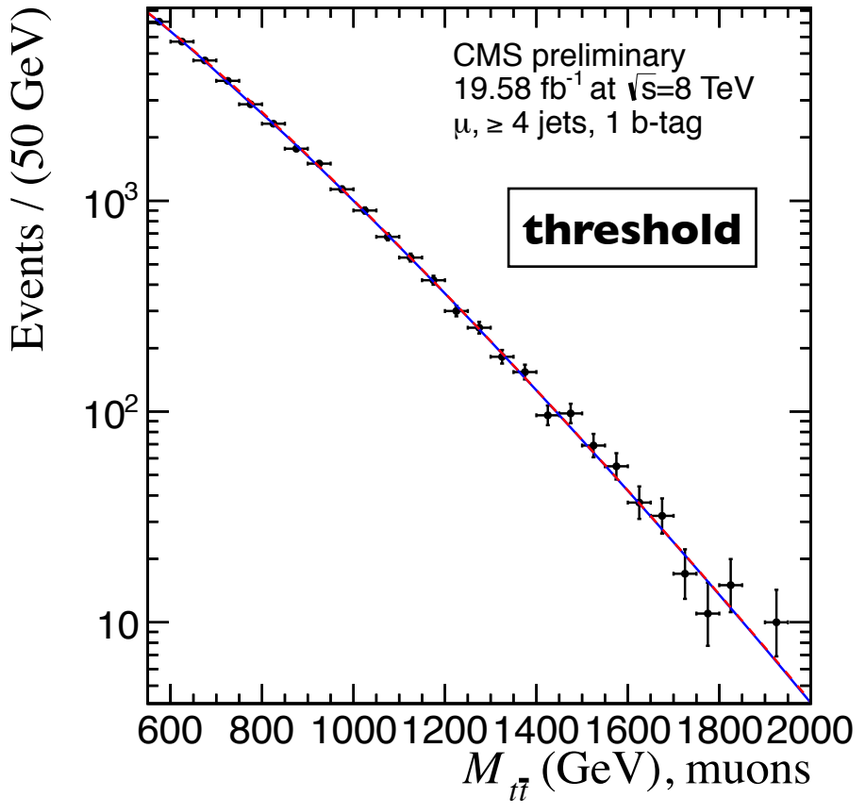
- one isolated electron (muon) with p_T > 30 (26) GeV
- at least 4 jets with p_T > 70, 50, 30, 30 GeV
- missing E_T > 20 GeV
- events split into 4 categories according to the lepton flavor and # of b-jets (1 or ≥2)

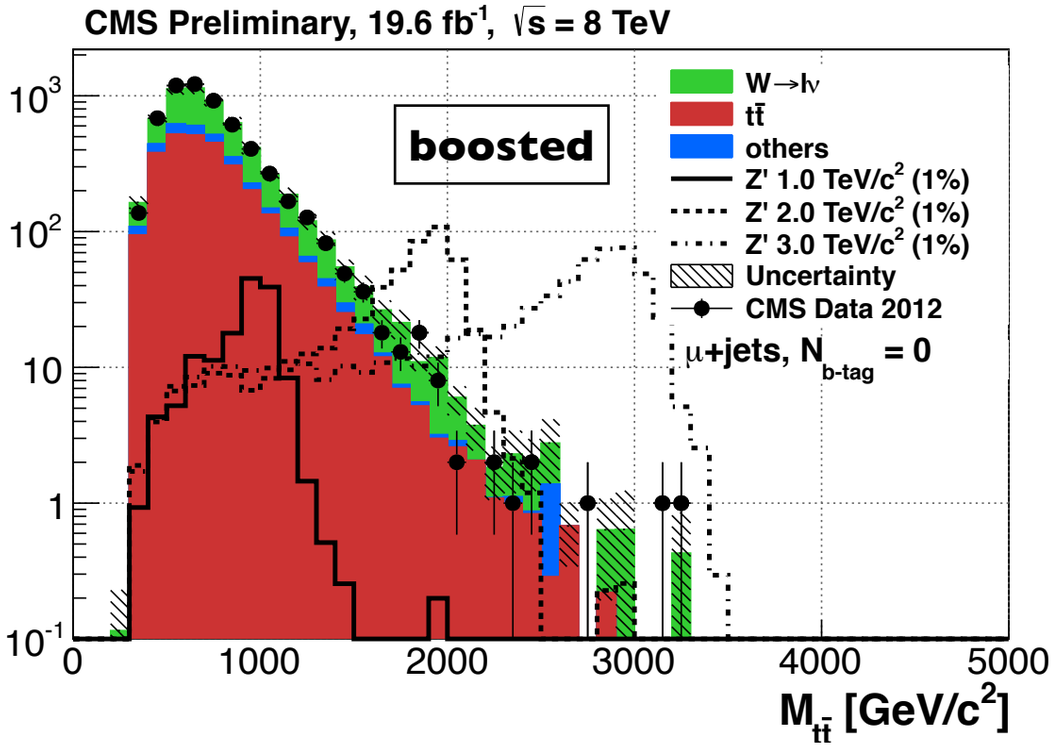
Event selection (boosted search)

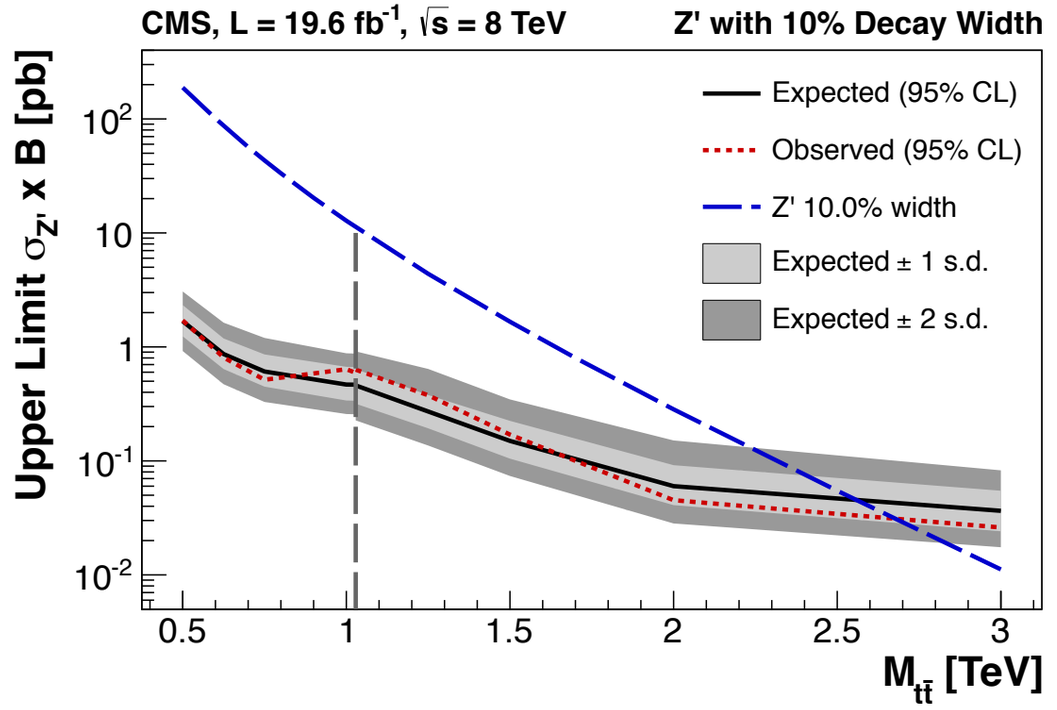
- one electron (muon) with p_T > 35 (45) GeV (no isolation requirement)
- at least 2 jets with p_T > 150, 50 GeV with ΔR(jet, lepton) > 0.5
- H^{lep}_T > 150 GeV (H^{lep}_T = *scalar sum of* E_T^{miss} *and lepton* p_T) and E_T^{mis} > 50 GeV
- events split into 4 categories according to the lepton flavor and # of b-jets (0 or ≥1)

$t\bar{t}$ resonances: lepton+jets channel (II)

- M_{tt} reconstruction: X^2 sorting to choose the best jet combination (both analyses)







Limits:

- Narrow (1.2%) Z′: $M_{Z'}$ > **2.1** TeV
- Wide (10%) Z′: $M_{Z'}$ > **2.7** TeV
- KK gluon: M_{KK} > **2.5** TeV

Summary

- Exotic resonances, decaying to top quarks, predicted in many BSM models
- CMS looked for these new resonances using different final states
  - *no evidence of new physics*
- Five analyses have been presented:
  - B2G-12-014: search for $t^* \rightarrow tg$
    limits: **794** GeV
  - B2G-12-010: search for $W' \rightarrow tb$
    limits: **2.03** TeV for $M_{\nu R} << M_{W'R}$
  - B2G-12-005: search for $Z' \rightarrow tt$ in fully hadronic final state
    limits: **1.6** (**2.3**) TeV for 1% (10%) Z' and **1.8** TeV for RS KK gluon
  - TOP-11-010: search for $Z' \rightarrow tt$ in dileptonic final state
    limits: **1.1** TeV for leptophobic Z'
  - B2G-12-006: search for $Z' \rightarrow tt$ in lepton+jets final state
    limits: **2.1** (**2.7**) TeV for 1.2% (10%) Z' and **2.5** TeV for RS KK gluon

BACKUP

The CMS detector