



9th International Workshop on
Top Quark Physics

TOP 2016



Searches for $t\bar{t}$ resonances at $\sqrt{s} = 13$ TeV with the CMS detector

Marino Missiroli

Universidad Autónoma de Madrid

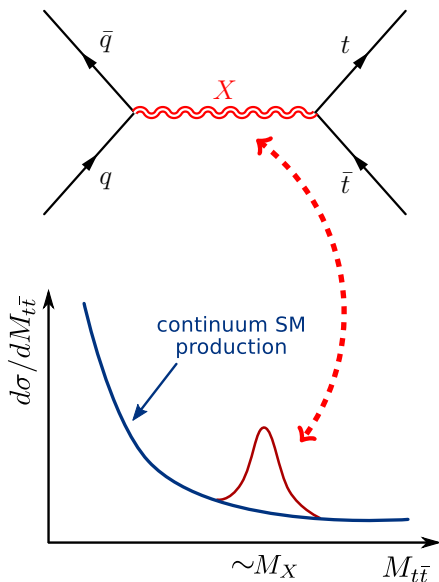
on behalf of the CMS Collaboration

September 20, 2016

introduction

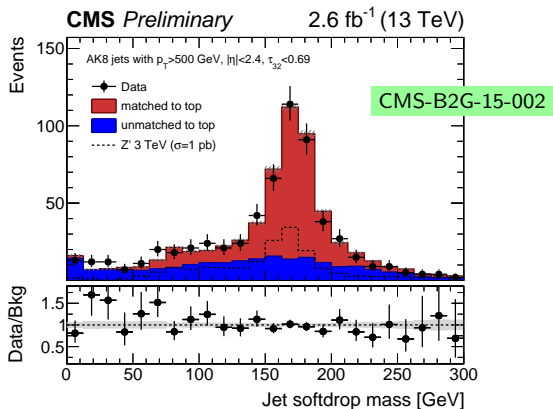
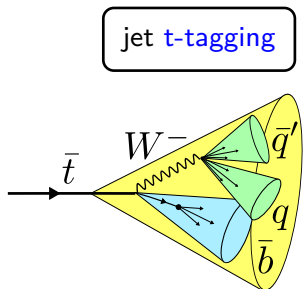
- several models of BSM physics predict new elementary particles which preferentially decay to a $t\bar{t}$ pair
 - heavy Z' bosons in models with extended gauge sectors
 - Kaluza-Klein resonances in models with extra-dimensions

model-independent search
for a high-mass resonance
in the $M_{t\bar{t}}$ spectrum



searches for $t\bar{t}$ resonances

- searches for $X \rightarrow t\bar{t}$ resonances in the $\ell + \text{jets}$ and **all-hadronic** final states with the CMS detector at $\sqrt{s} = 13 \text{ TeV}$ with 2.6 fb^{-1} (2015 dataset)
- two analyses optimized for **high-mass** resonances (M_X up to 4 TeV)
 \Rightarrow dedicated techniques for boosted top quark decays

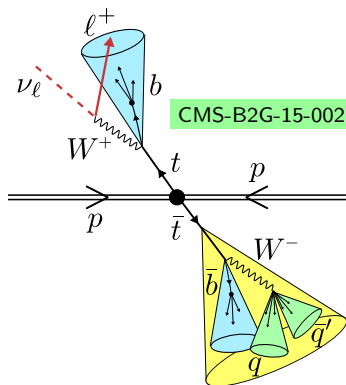


searches for $t\bar{t}$ resonances

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$\ell (= e, \mu) + \text{jets}$ analysis

- final state:
 - exactly 1 high- p_T lepton
 - at least 2 high- p_T jets
 - missing transverse energy (MET)
- no isolation requirement on the lepton
- use of jet b-tagging and t-tagging for final event categorization

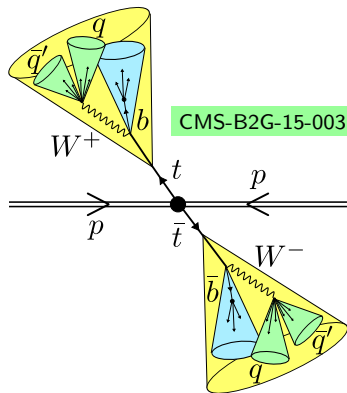


searches for $t\bar{t}$ resonances

- searches for $X \rightarrow t\bar{t}$ resonances in the $\ell + \text{jets}$ and **all-hadronic** final states with the CMS detector at $\sqrt{s} = 13 \text{ TeV}$ with 2.6 fb^{-1} (2015 dataset)
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boosted **all-hadronic** analysis

- final state:
 - dijet topology
 - 2 high- p_T large-radius jets passing t-tagging selection
- use of subjet b-tagging for final event categorization



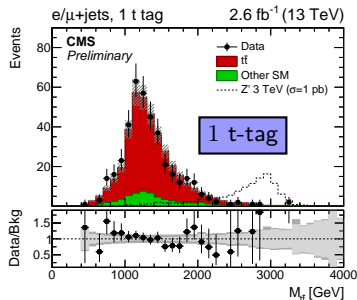
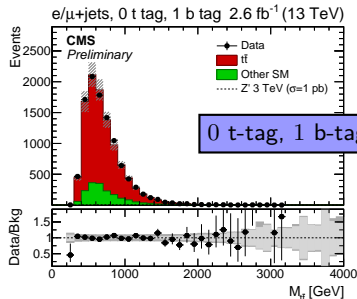
- **lepton selection**: isolation cut replaced by dedicated method based on $p_{T, \text{rel}}^\ell$ (BACK-UP)
- full **kinematic reconstruction** of the $t\bar{t}$ system
- $t\bar{t}$ hypothesis selected with χ^2 discriminator
- main backgrounds: $t\bar{t}$ and $W + \text{jets}$
 - ▶ shapes from MC simulation, normalization from ML-fit using CRs
- $M_{t\bar{t}}$ measured in 6 exclusive categories:

1 t-tag

e/μ channel \otimes 0 t-tag + 1 b-tag

0 t-tag + 0 b-tag

no significant excess in $M_{t\bar{t}}$ in data compared to background model



- 2 t-tagged AK8 jets ($p_T^j > 400$ GeV, $|\eta^j| < 2.4$):
 - ▶ $|\Delta\phi_{jj}| > 2.1$ and $H_T^{\text{jets}} > 1$ TeV
 - ▶ t-tagging selection based on **softdrop mass** and **N-subjettiness ratio** τ_{32} (3% t-mistag rate)

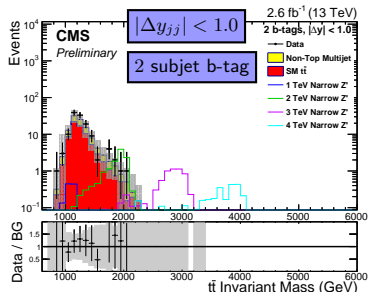
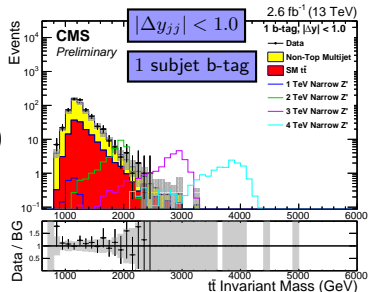
- background model:

- ▶ $t\bar{t}$ from MC simulation
- ▶ data-driven multijet QCD bkg (t-mistag rate measured in data CR)

- $M_{t\bar{t}}$ measured in 6 exclusive categories:

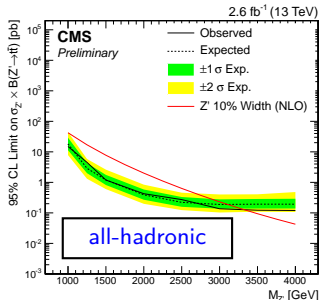
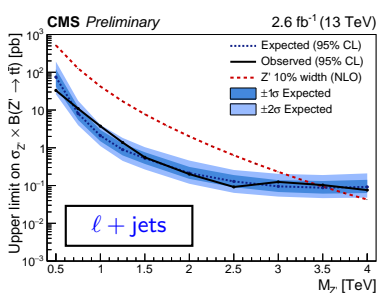
- 2 subjet-b-tag
- $|\Delta y_{jj}| \gtrsim 1.0$ ⊗ 1 subjet-b-tag
- 0 subjet-b-tag

no significant excess in $M_{t\bar{t}}$ in data compared to background model



95% CL upper limits on $\sigma(pp \rightarrow X) \cdot \text{BR}(X \rightarrow t\bar{t})$

- 4 BSM models: Z' boson with 1%-, 10%- and 30%-width, and KK gluon (RS model)



- lower mass limits on M_X already improved wrt Run-1 for large-width signals

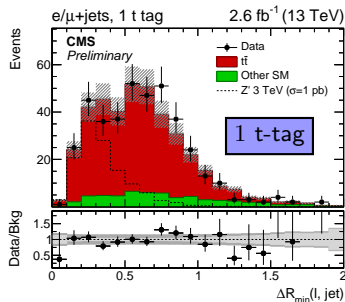
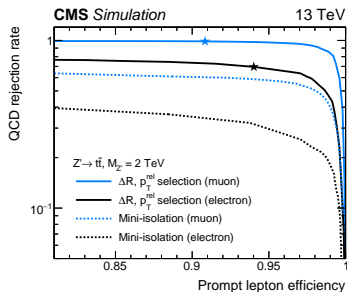
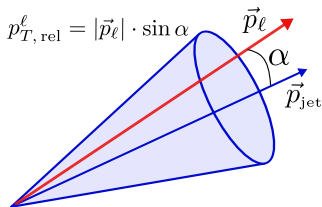
observed mass exclusion region [TeV]

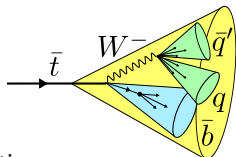
analysis	Z' (1% width)	Z' (10% width)	Z' (30% width)	KK gluon
$\ell + \text{jets}$ (13 TeV)	0.6 – 2.3	0.5 – 3.4	1.0 – 4.0	0.5 – 2.9
all-hadronic (13 TeV)	1.4 – 1.6	1.0 – 3.3	1.0 – 3.8	1.0 – 2.4
combination (8 TeV)	0.5 – 2.4	0.5 – 2.9	not tested	0.5 – 2.8

- first results on $X \rightarrow t\bar{t}$ searches in the $\ell + \text{jets}$ and **all-hadronic** final states with the CMS detector at $\sqrt{s} = 13 \text{ TeV}$
- dedicated methods for boosted $t \rightarrow b\ell\nu$ and $t \rightarrow bjj$ decays retooled for Run-2
- no significant excess observed in data with respect to SM background
- exclusion limits on M_X already competitive with results with full Run-1 dataset
 \implies mass limits already improved for large-width signals
- **combination of 2015 searches** and **update with 2016 data** underway

BACK-UP

- lepton selection optimized for boosted $t \rightarrow b \ell \nu$ decays:
 - ▶ lepton 2D-cut (instead of isolation cut): based on $p_{T, \text{rel}}$ between ℓ and closest jet
$$\Delta R_{\text{min}}(\ell, j) > 0.4 \quad || \quad p_{T, \text{rel}}(\ell, j) > 20 \text{ GeV}$$
- ▶ more effective than mini-isolation and fixed-cone isolation in reducing QCD multijet background



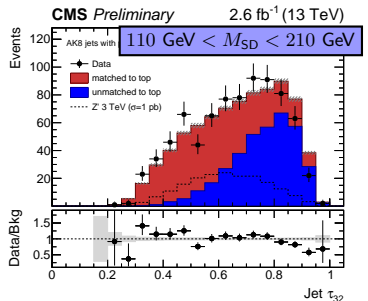
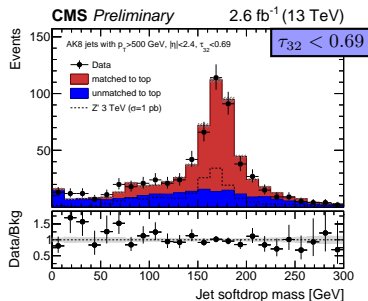


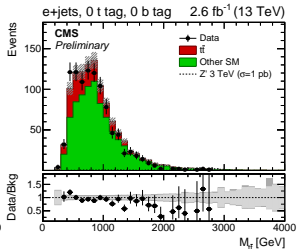
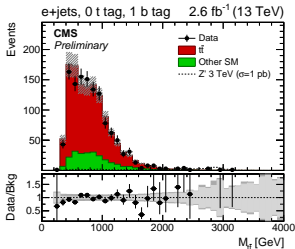
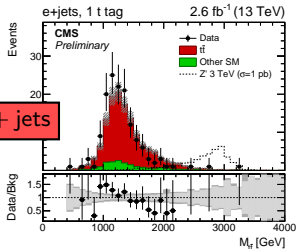
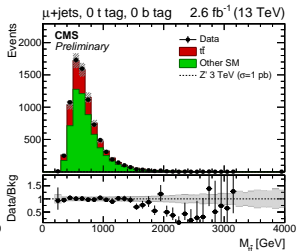
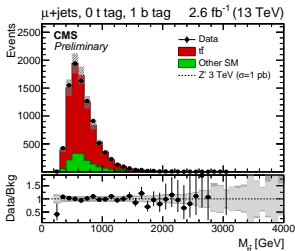
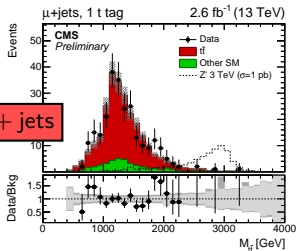
■ **jet t-tagging** selection:

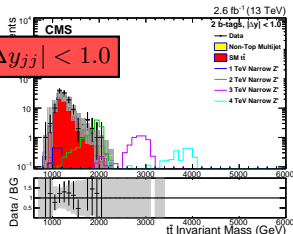
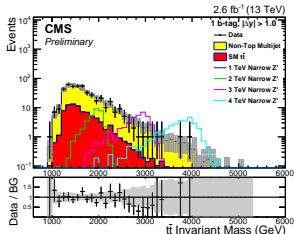
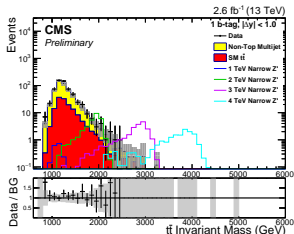
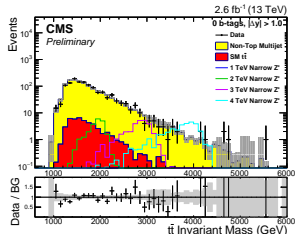
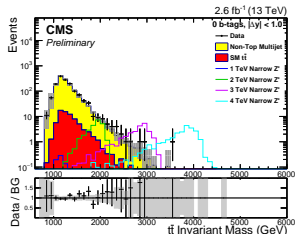
- ▶ AK8 jets with $p_T^{\text{jet}} > 500$ GeV, $|\eta^{\text{jet}}| < 2.4$
- ▶ **softdrop mass**: $110 \text{ GeV} < M_{\text{SD}} < 210$ GeV
- ▶ **N-subjettiness ratio**: $\tau_{32} \equiv \tau_3/\tau_2 < 0.69$

■ t-mistag rate for light-flavor jets around 3%

■ t-tagging efficiency for true top-jets
between 40% and 50% up to $p_T^{\text{jet}} \simeq 1$ TeV



1 t -tag0 t -tag + 1 b -tag0 t -tag + 0 b -tag[background uncertainty band: MC-stats \oplus post-fit sys uncertainties]

2 subjet b -tag1 subjet b -tag0 subjet b -tag[background uncertainty band: MC-stats \oplus pre-fit sys uncertainties]