

Search for new resonances coupling to third generation quarks at CMS

Alexander Fröhlich
for the CMS collaboration

University of Hamburg

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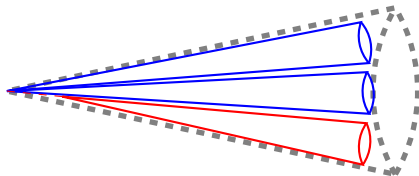
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CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE





- third generation quarks as window to new physics
- interesting decay signatures can be used to distinguish from standard model processes
- heavy vector bosons
 - $Z' \rightarrow t\bar{t}$
- intermediate decays via vector-like partners
 - $Z' \rightarrow Tt, T \rightarrow tH, tZ, bW$
 - $W' \rightarrow tB / Tb, T/B \rightarrow t/b + H$



- searches for decay of very heavy particles
- collimated decay products can be captured in large R jet
- use jet substructure techniques to identify
 - groomed jet mass, e.g. softdrop mass
 - N-subjettiness: measure for a jet to have $\leq N$ subjets
 - subjet b-tagging

Softdrop criterion

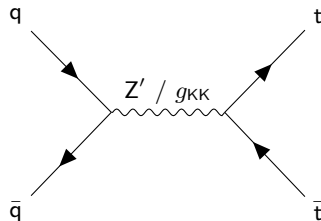
$$\frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}} > z (\Delta R_{1,2}/R_0)^\beta$$

N-subjettiness

$$\tau_N = \frac{1}{d} \sum_i p_{T,i} \min(\Delta R_{1,i}, \Delta R_{2,i}, \dots, \Delta R_{N,i})$$

Search for resonant $t\bar{t}$ production in proton-proton collisions at $\sqrt{s}=13$ TeV

- Combination of searches in multiple channels
 - all hadronic
 - semileptonic
 - dileptonic
- Signal interpreted as heavy Z' or Randall-Sundrum gluon g_{KK}

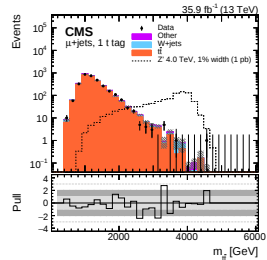
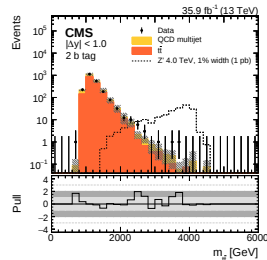


all hadronic channel

- two top tagged jets (softdrop + N-subjettiness)
- categories in $|\Delta y|$ and number of subjet b-tags
- QCD background estimated using anti-tag and probe method

semileptonic channel

- one lepton and two jets
- BDT trained to separate W +jets
- categories based on BDT score and presence of top tagged jet



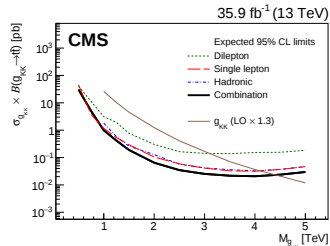
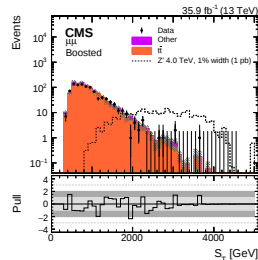
dileptonic channel

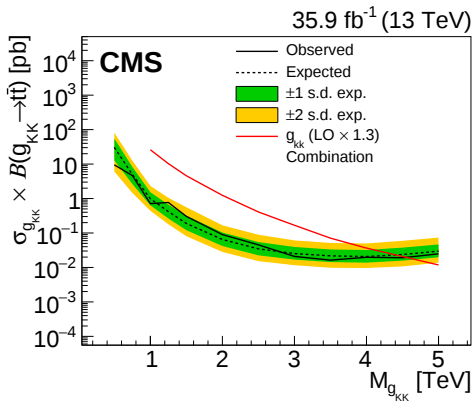
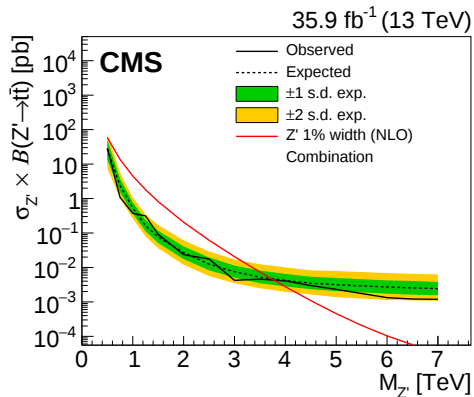
- two opposite charge leptons and two jets
- at least one b tagged jet
- categories in $\Delta R_{\text{sum}} = \Delta R(l_1, j) + \Delta R(l_2, j)$
- S_T used as sensitive variable

$$S_T = \sum_{i=1}^{\text{jets}} p_{T,i} + \sum_{i=1}^{\text{leptons}} p_{T,i} + p_T^{\text{miss}}$$

combination

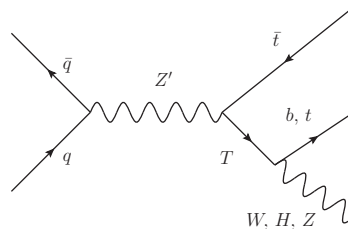
- combination of three statistically independent channels
- enhanced sensitivity compared to individual searches



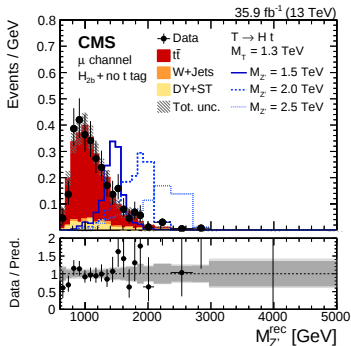


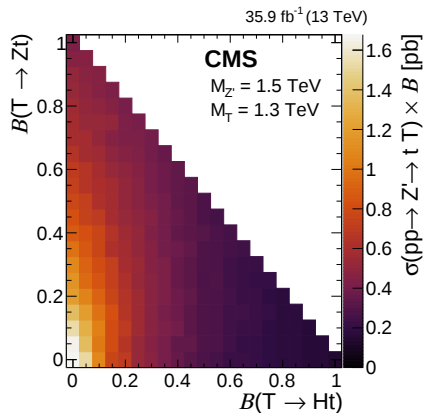
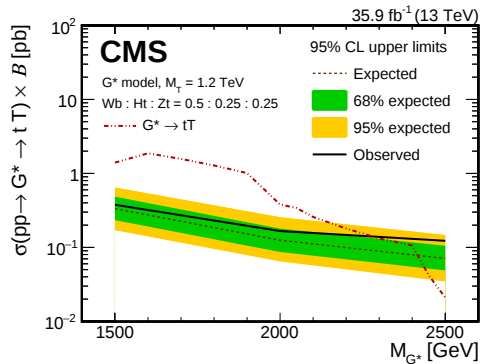
Search for a heavy resonance decaying to a top quark and a vector-like top quark in the lepton+jets final state in pp collisions at $\sqrt{s} = 13$ TeV

- multiple categories covering different possible decay modes ($T \rightarrow bW, tZ, tH$)
 - optimized for $T \rightarrow tZ, tH$
- jet tagging of boosted $W/Z/H$
- signal interpreted in extra dimensional and composite benchmark models



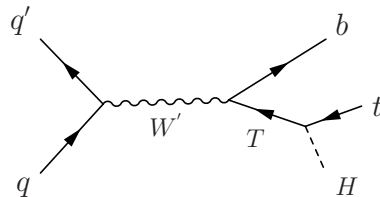
- categories based on softdrop mass, N-subjettiness ratios and subjet b-tags
 - Higgs tag with 2 subjet btags H_{2b}
 - Higgs tag with 1 subjet btag H_{1b}
 - Z/W tag
- sub categories based on presence of top tagged jet
- use reconstructed Z' mass M_Z' as sensitive variable
- $t\bar{t}$ and W+jets backgrounds constrained using dedicated control regions
 - invert softdrop mass criteria of Higgs and Z/W tag
 - 0 or 2 b-tags



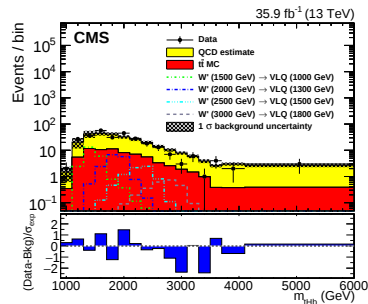


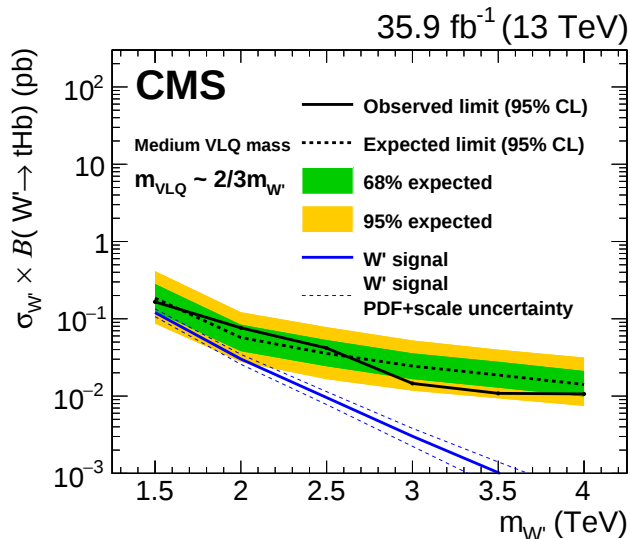
Search for a W boson decaying to a vector-like quark and a top or bottom quark in the all-jets final state

- target $T/B \rightarrow t/b + H$ decay mode
- jet tagging of boosted t and H



- require top, Higgs and b tagged jets
 - top tagging: softdrop, N-subjettiness and subjet b-tag
 - Higgs taggign: softdrop and double b-tag
- use reconstructed W' mass $M'_{W'}$ as sensitive variable
- control regions defined using anti-tags
- QCD background estimated from data in control regions





Summary

- combination of $Z' \rightarrow t\bar{t}$ searches
- exploring intermediate decays via vector-like quarks
 - search for $Z' \rightarrow Tt$
 - search for $W' \rightarrow tB/Tb$

Outlook

- Looking forward to new results exploring the combined datasets of 2016, 2017 and 2018
- Exploring new tagging algorithms and jet substructure techniques