

Search for resonances in four top quark events in the 2 lepton final state



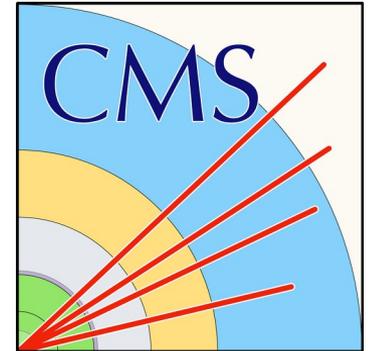
Dominic Stafford

on behalf of the CMS collaboration

18.03.2026

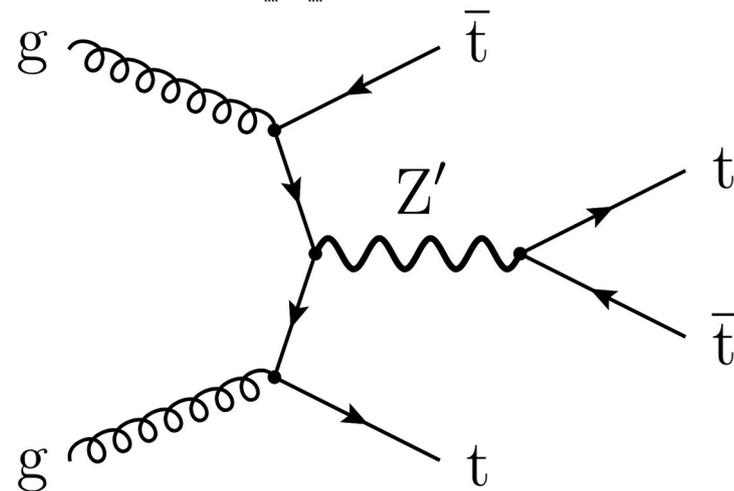
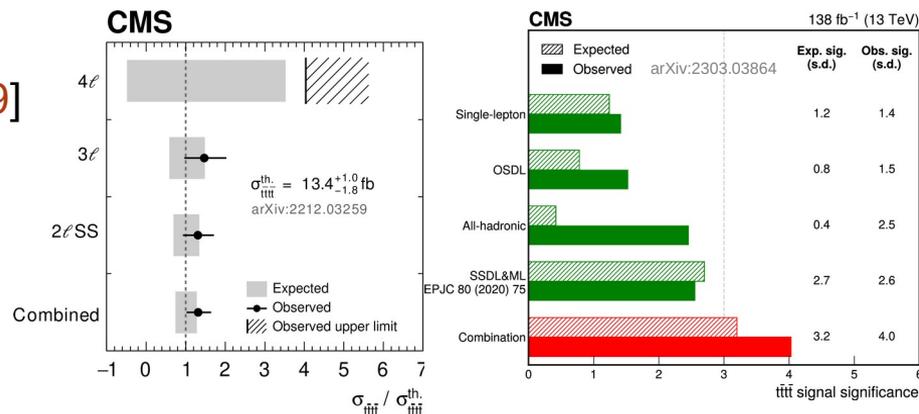
Rencontres de Moriond 2026

Electroweak Interactions & Unified Theories



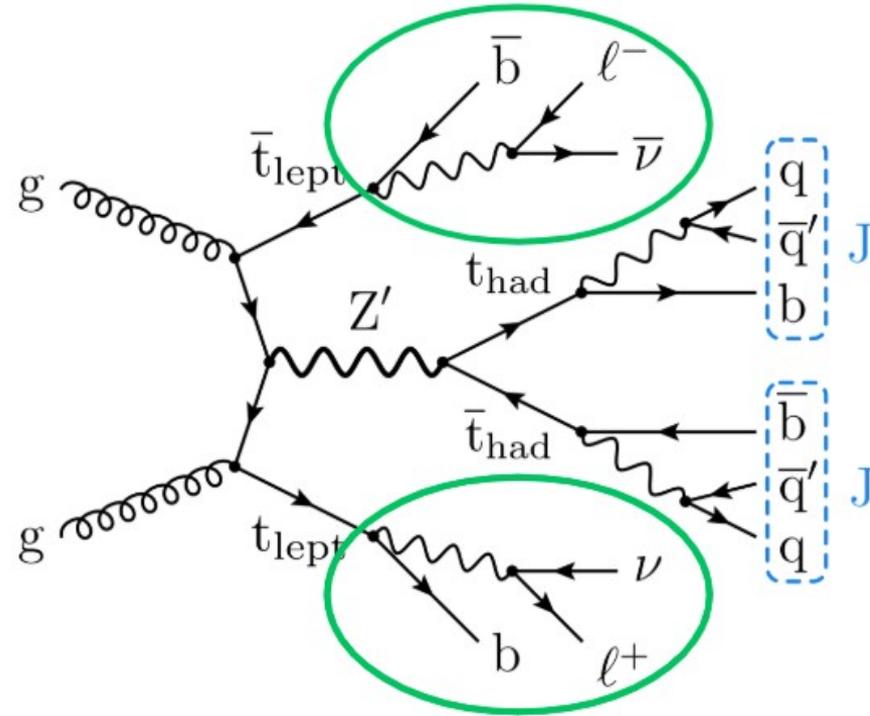
Motivation

- SM 4 top production has been recently observed in Run 2 data [2303.15061,2305.13439]
 - Measured cross section slightly higher than SM theory in all channels [2303.03864,2106.11683]
- Many BSM theories predict new resonances coupling to tops:
 - Top-philic Z' (can be DM mediator)
 - Two Higgs Doublet Models
 - Axion-like particles (ALPs)
- Previous searches for BSM resonances in 4 top final states in 1 lepton channel [2304.01678,B2G-24-009]



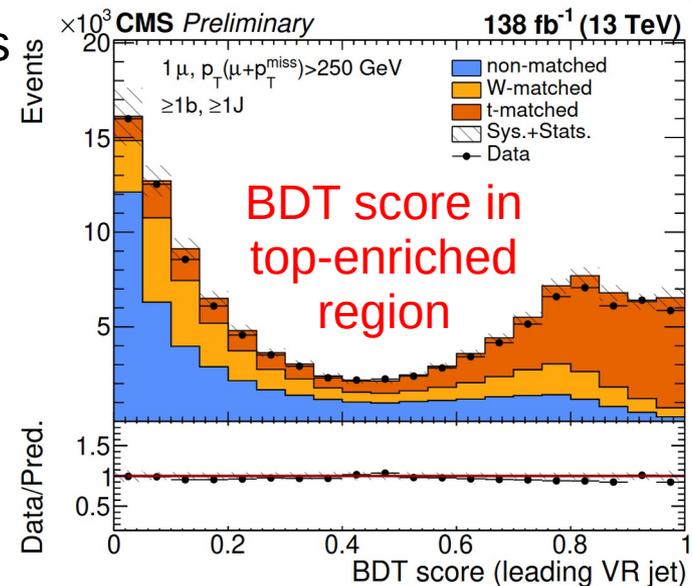
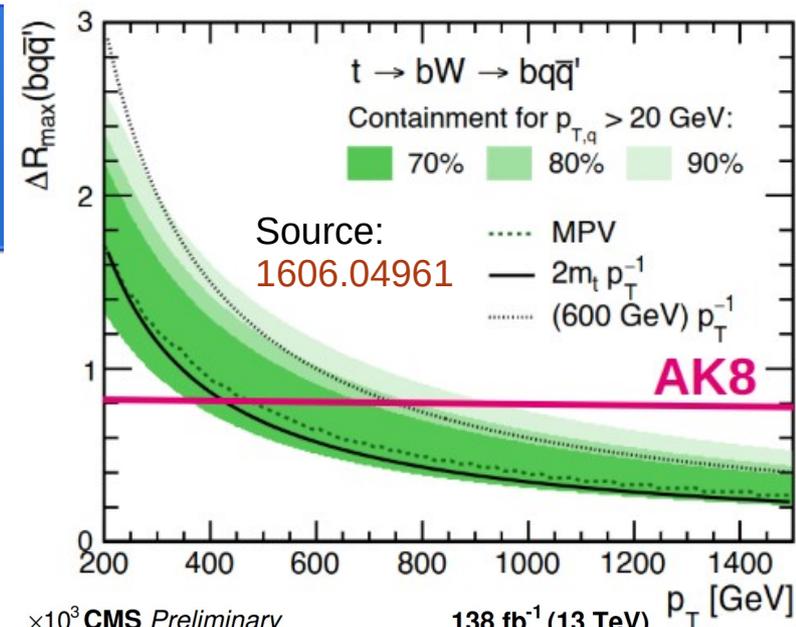
Analysis strategy

- Using 2016-2018 (13 TeV) and 2022 (13.6 TeV) datasets
 - Signal cross sections up to 30% higher for 13.6 TeV compared to 13 TeV
- Select leptonic decays of spectator tops
 - 2 leptons, opposite charge
 - Split into signal categories with 1 and ≥ 2 b-tagged jets (anti- k_T $R=0.4$)
- Reconstruct resonance from two boosted large radius jets



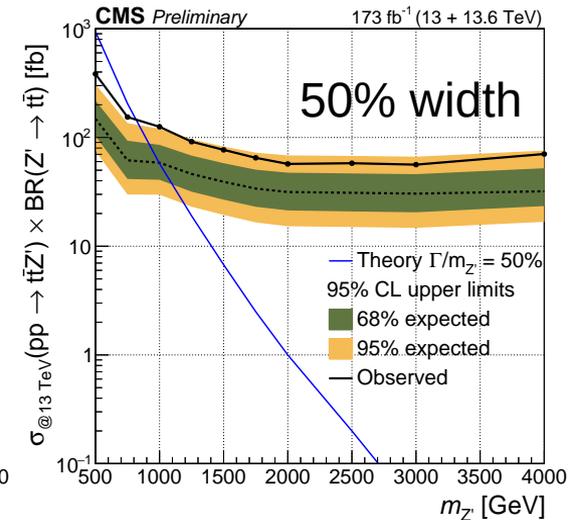
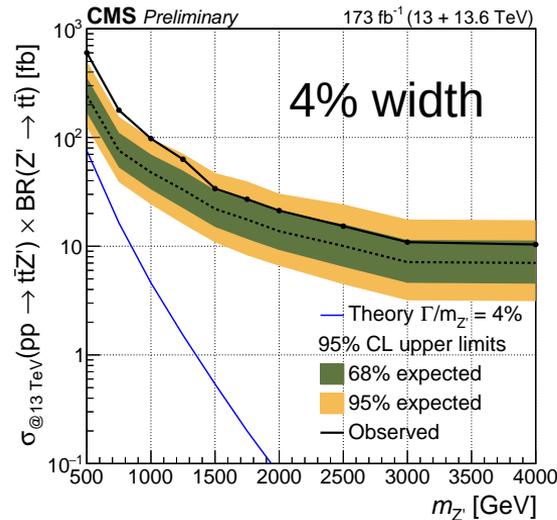
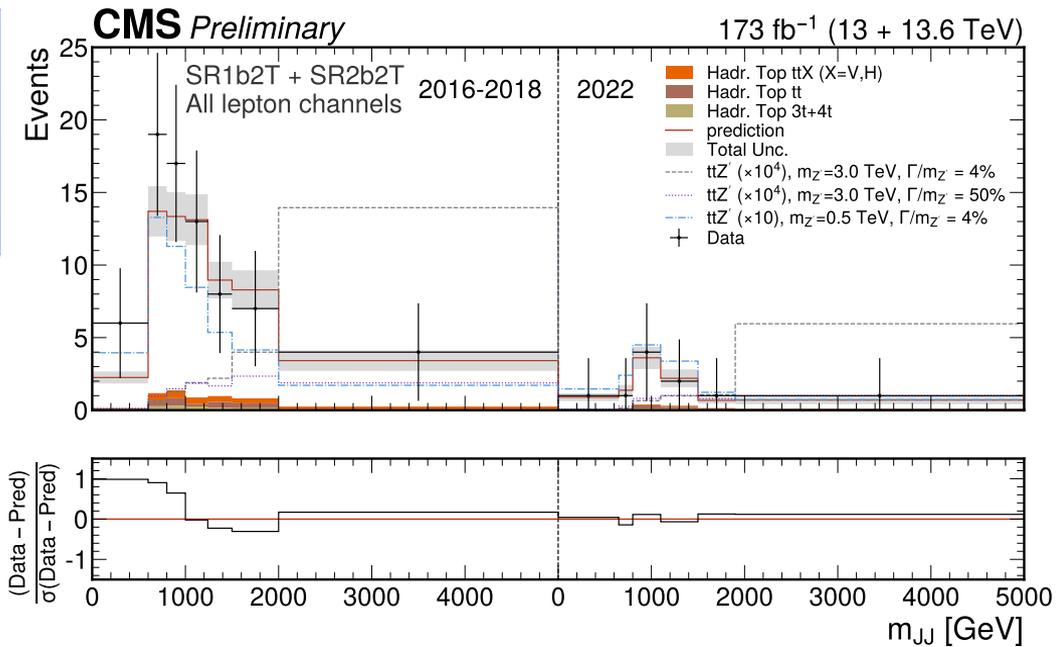
HOTVR Jets

- Standard $R=0.8$ anti- k_T jets only capture very high p_T top quarks
 - 80% efficiency only from 800 GeV p_T
- Solution: variable radius (HOTVR) jets [1606.04961]
 - radius $\propto 1/p_T$
- Developed a new BDT top tagger for HOTVR jets [CMS-DP-2024-038]
 - Signal efficiency of 32% v.s. 20% for previous cut-based tagger for low- p_T jet working point
- Require two HOTVR jets, both tagged with very loose BDT working point
 - 84% signal efficiency, 22% mistagging rate



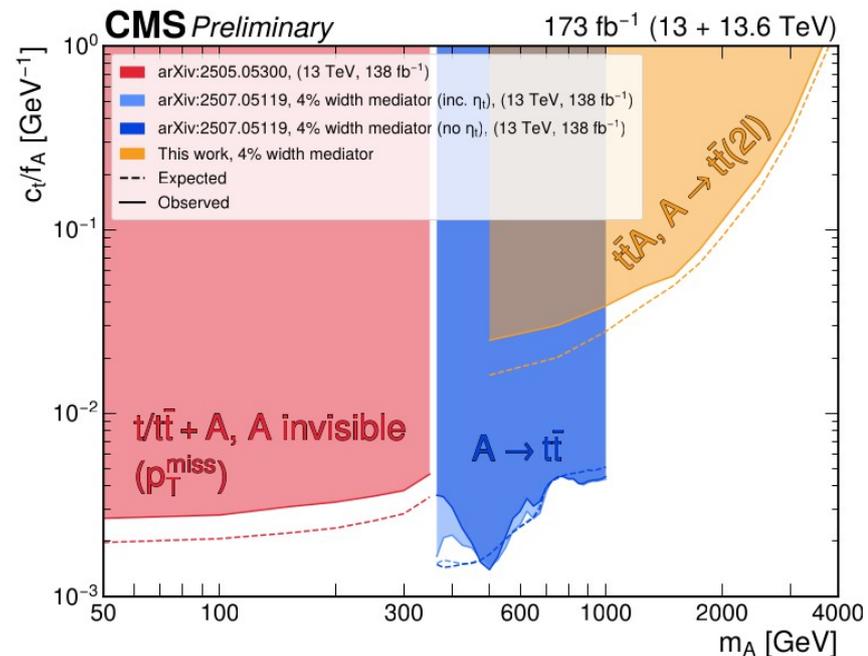
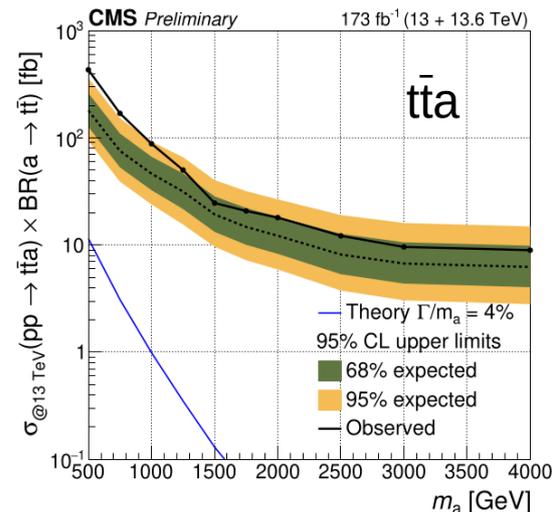
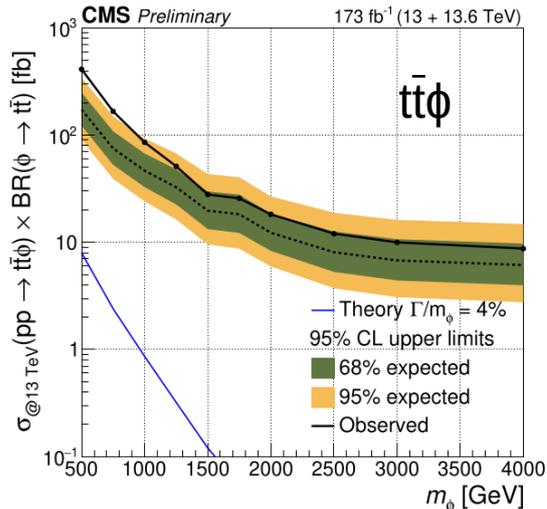
Results ($t\bar{t}Z'$)

- Main background: $t\bar{t}$ (dileptonic) + mistagged HOTVR top jets
 - Estimate mistagged background via transfer factor from 0 top tagged HOTVR region
 - Genuine top jets estimated from simulation
- Fit on invariant mass of HOTVR jets
- Set limits on 4%, 10%, 20% and 50% Z' widths
- For 50% width exclude Z' masses up to 850 GeV (1000 GeV expected)



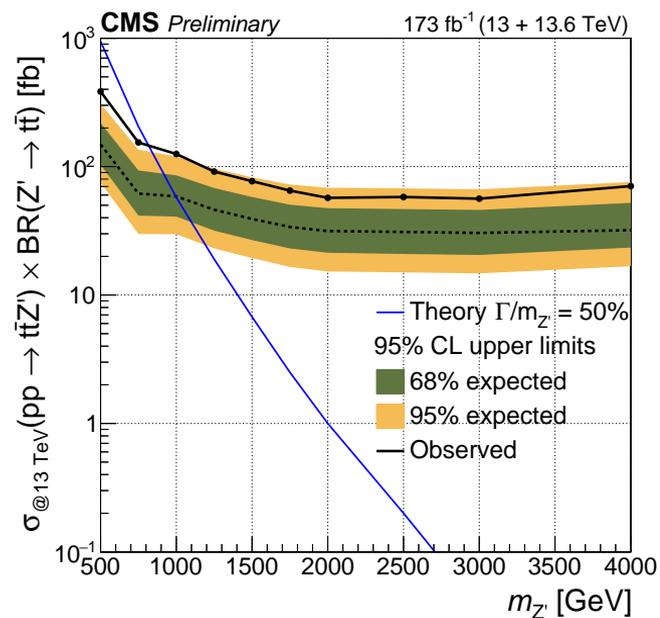
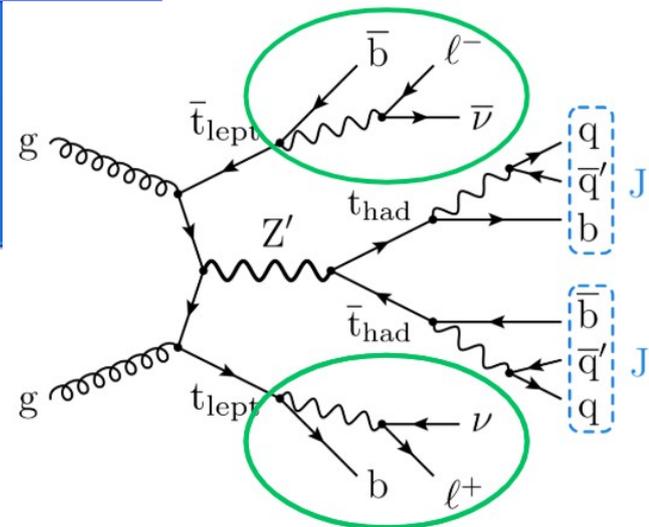
Further Interpretations

- Interpreted in terms of scalar (ϕ) and pseudoscalar (a) mediators
 - Same mass and width ranges as for $t\bar{t}Z'$
- Also interpreted pseudoscalar mediator as an ALP coupling only to top quarks
 - Compared with other CMS limits, inspired by [2303.17634]
 - $t\bar{t}$ resonance search [2507.05119]
 - Limits below $t\bar{t}$ threshold from t/\bar{t} +invisible search [2505.05300] (assuming ALP is LLP since decays via top loop)



Conclusions

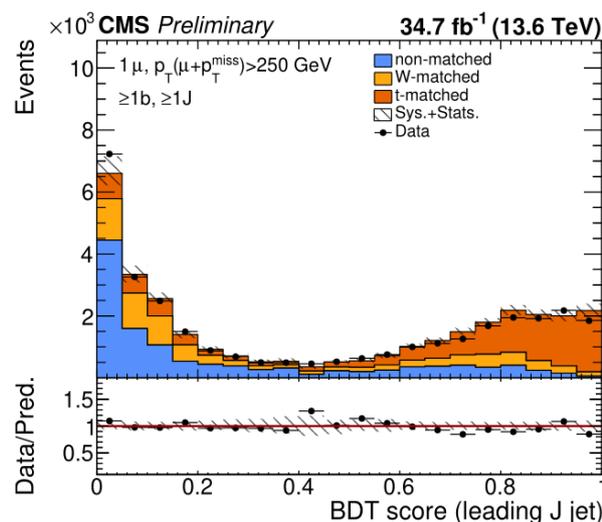
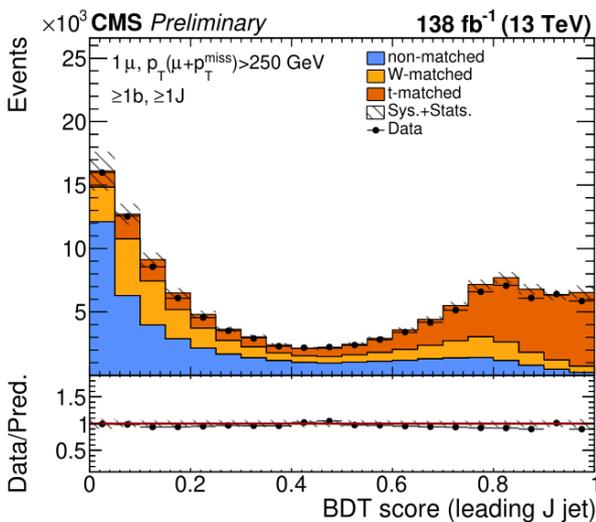
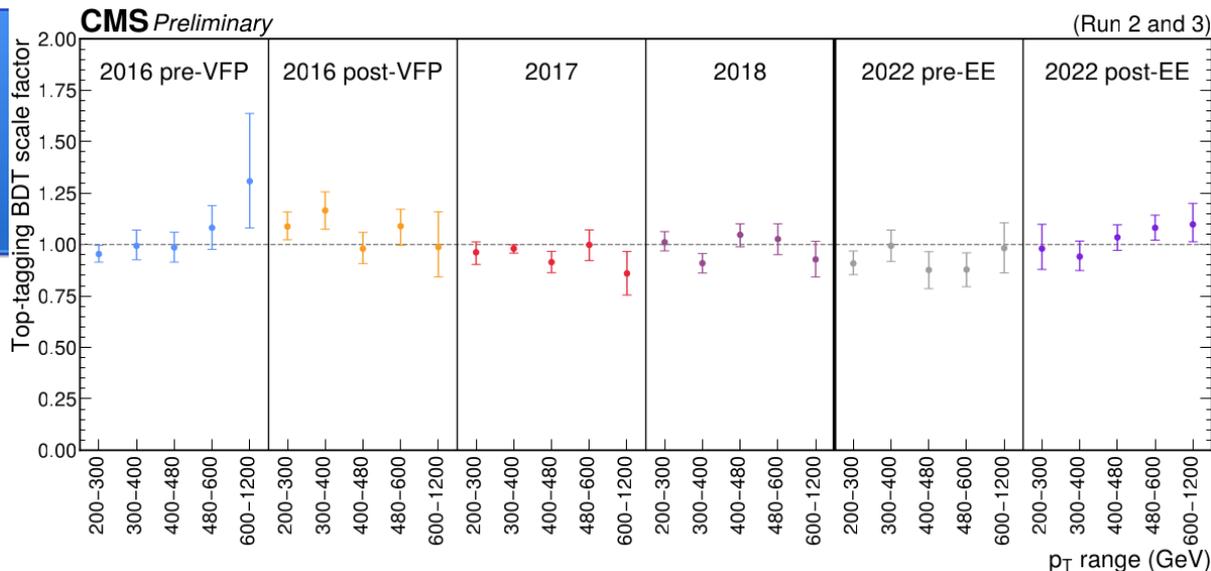
- Four top final states offer new search channel for BSM resonances
- First search in 2 lepton channel
 - Combining 13 TeV and 13.6 TeV data
- Developed new BDT top tagger for variable radius jets
- Exclude Z' mediators up to 850 GeV (1000 GeV expected) for 50% width
- Also provide scalar, pseudoscalar and ALP exclusions
- Statistically limited analysis: still a lot of phase space to explore!



Backup

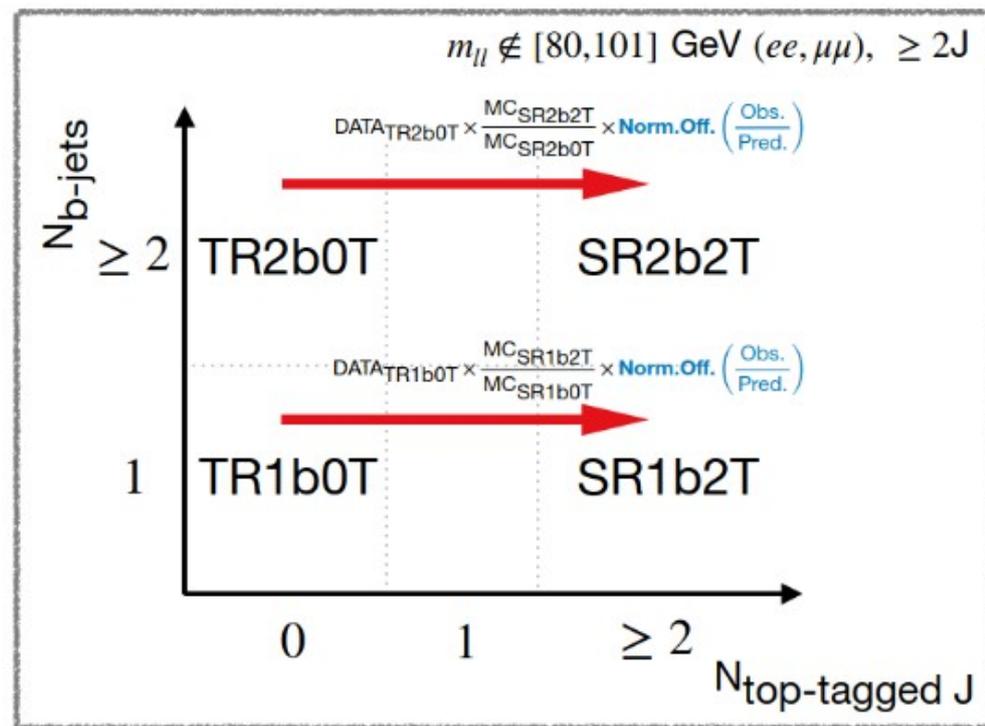
BDT Scale Factors

- Scale factor corrections for b-tagging efficiency derived in top enriched region
- Semileptonic tt:
 - 1 muon
 - ≥ 1 b-tagged $R=0.4$ jet
 - ≥ 1 HOTVR jet in opposite hemisphere
- No mistag SF since mistags estimated by data-driven method



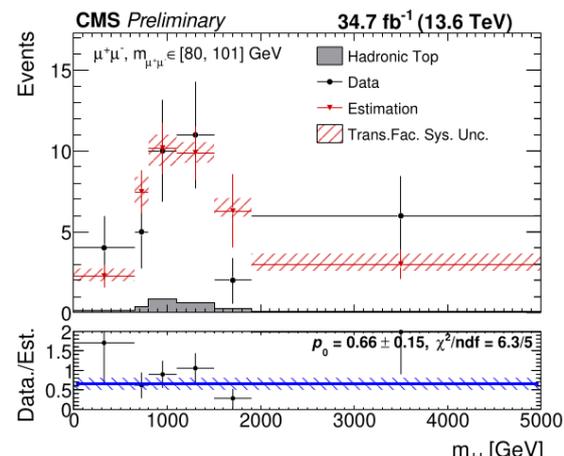
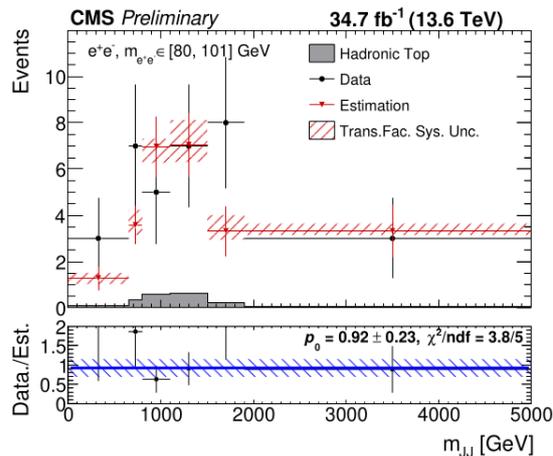
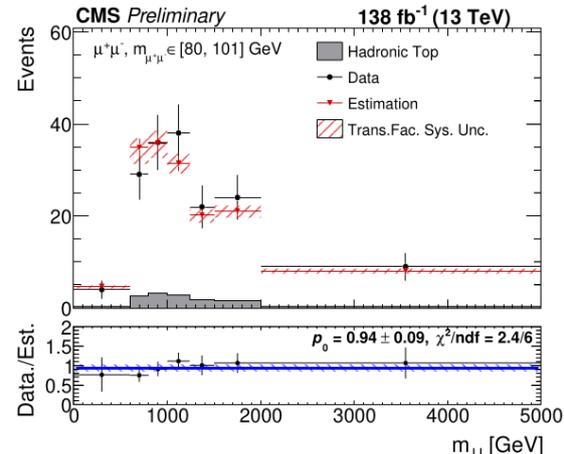
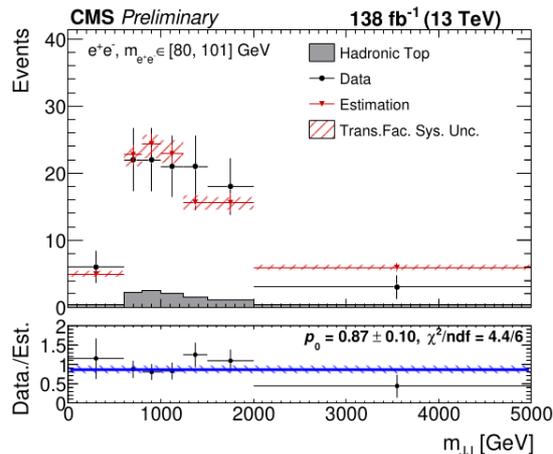
Background estimation

- Propagate data from transfer region with identical selection except 0 top tags to SR using MC ratio
- Separately for each dilepton flavour, n_{btags} and m_{JJ} bin
- Subtract any events with jets matched to top quarks in TR – estimate from MC in SR

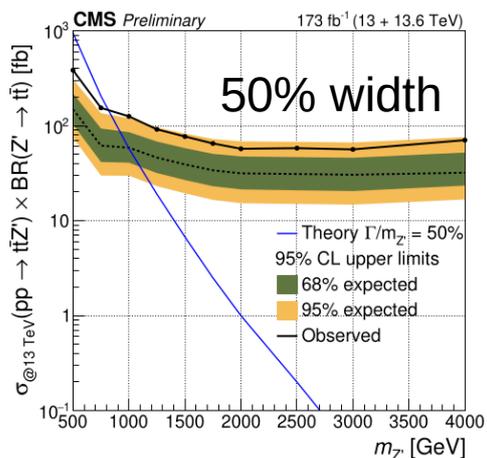
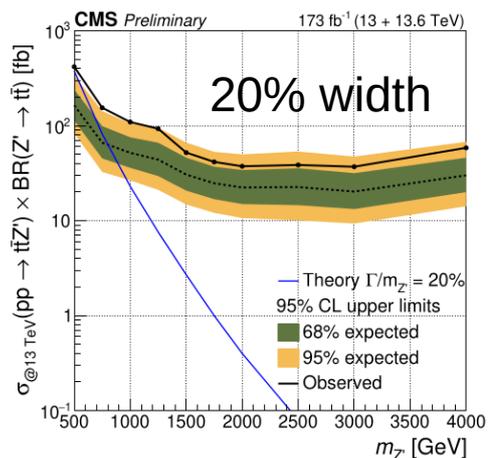
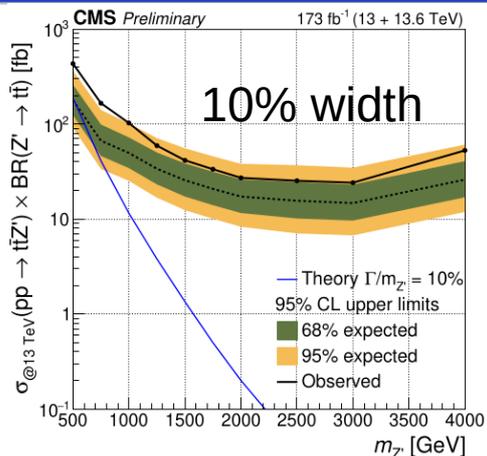
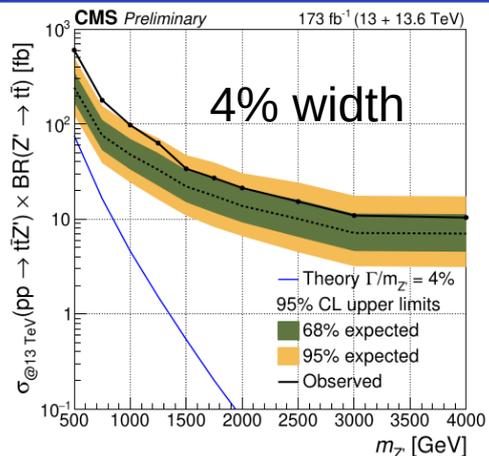


Validation of background estimation

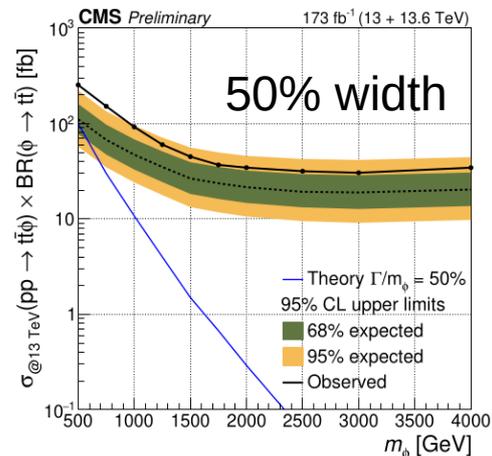
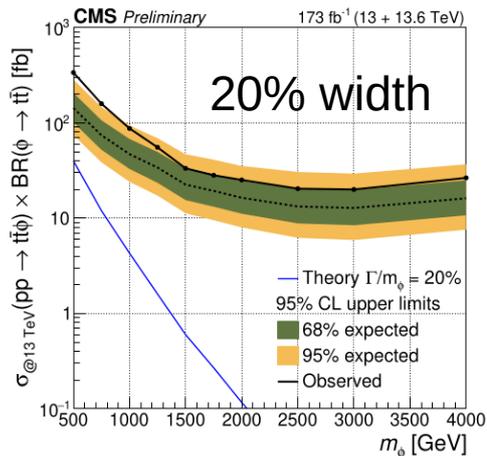
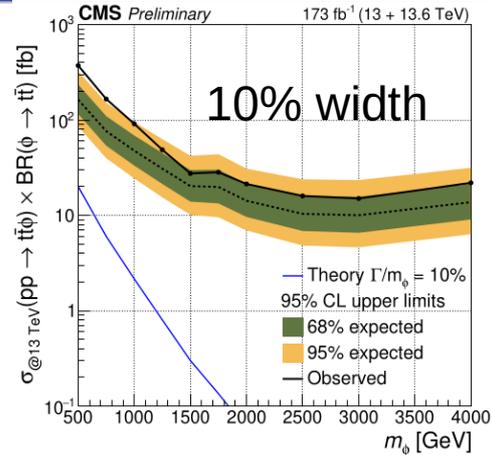
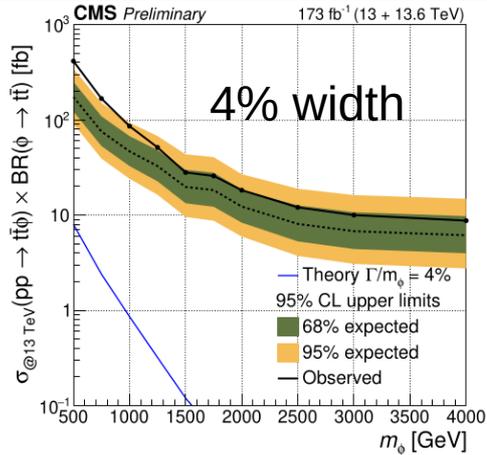
- Validate modeling of tt+jets using Z+jets
 - 2 opposite charge dileptons
 - No R=0.4 jet requirement
 - ≥ 2 HOTVR jets
- Produce data-driven prediction
- Shape well described
- Slight normalisation offset
 - From mismodelling of correlation between tagging 1st and 2nd jet
 - Correction derived and applied in SR



$t\bar{t}Z'$ limits - all widths



$t\bar{t}\phi$ limits - all widths



$t\bar{t}a$ limits - all widths

