Searches for new heavy resonances in final states with leptons, photons, and jets in CMS

Jan-Frederik Schulte
on behalf on the CMS Collaboration

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Introduction

Searching for new heavy resonances

- Observation of new heavy resonances would be indisputable sign for new physics
- Searching in high mass tails $\rightarrow$ Distinct signature with low SM backgrounds
- Simple signatures allow for largely model-independent searches

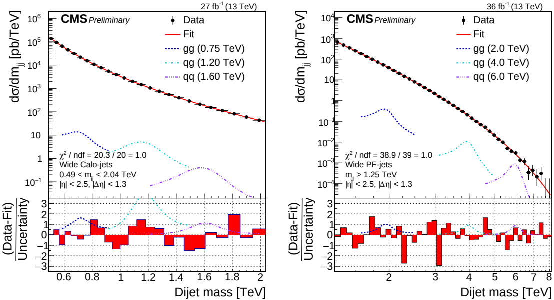
- Covered here are analyses searching for direct two-body decays of resonances into leptons, photons or jets
- Results available on a variety of datasets, ranging from 2 to $36\,\mathrm{fb}^{-1}$ of data at $\sqrt{s} = 13\,\mathrm{TeV}$

Search for dijet resonances

- New particles coupling to quarks and gluons could be observed as resonances in the dijet mass spectrum
- Search motivated by a wide range of hypothetical new particles from W'/Z' bosons to Dark Matter

- Two analysis approaches
  - High mass: Use full event content to reconstruct particle-flow jets
  - Low mass: Saving only limited event information allows for lower trigger threshold $\rightarrow$ Use jets built with calorimeter information only
- Analysis starts from anti-k_t jets with R=0.4, but collects jets with in R=1.1 around the leading jets into wide jets to collect gluon radiation

- Mass spectrum fitted by different parametrizations in low and high mass analysis
- No significant deviations from background fits observed



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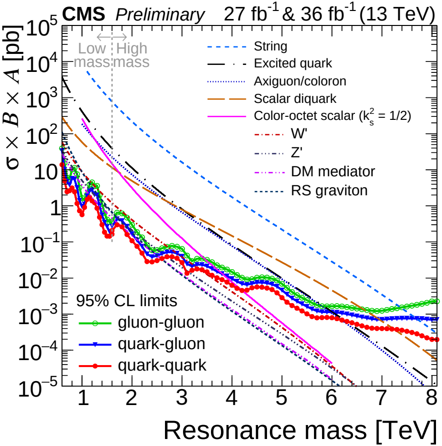
Search for dijet resonances

- Limits set for a multitude of signal models
- Finals states with gluons have more FSR and wider resonances → Limit depends on final state (qq, qg, gg)

Model	Final State	Observed (expected) mass limit [TeV] 36 fb^{-1} 13 TeV
String	qg	7.7 (7.7)
Scalar diquark	qq	7.2 (7.4)
Axigluon/coloron	$q\bar{q}$	6.1 (6.0)
Excited quark	qg	6.0 (5.8)
Color-octet scalar ($k_s^2 = 1/2$)	gg	3.4 (3.6)
W′	$q\bar{q}$	3.3 (3.6)
Z′	$q\bar{q}$	2.7 (2.9)
RS Graviton ($k/M_{PL} = 0.1$)	$q\bar{q}$, gg	1.7 (2.1)
DM Mediator ($m_{DM} = 1$ GeV)	$q\bar{q}$	2.6 (2.5)



- Mass limits reach from 7.7 TeV for string theory inspired resonances to 2-4 TeV on signals like Z'/W' or RS gravitons

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Search for dijet resonances

- To produce Dark Matter at the LHC, mediator particle is needed
- Direct observation of the mediator as a dijet resonance possible, depending on couplings
- Studied are models with Vector or Axialvector mediators
- Quark-couplings are assumed to be 25% of DM couplings
- Limits depend on DM and mediator mass
- 0.6-2.6 TeV for $m_{\mathrm{DM}} = 1\,\mathrm{GeV}$

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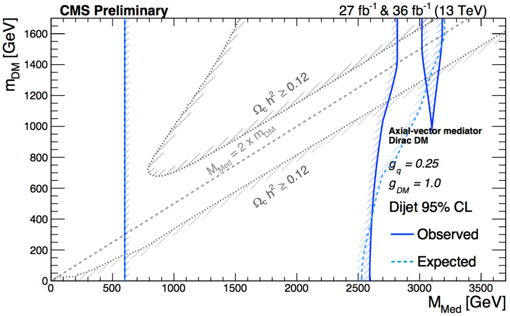
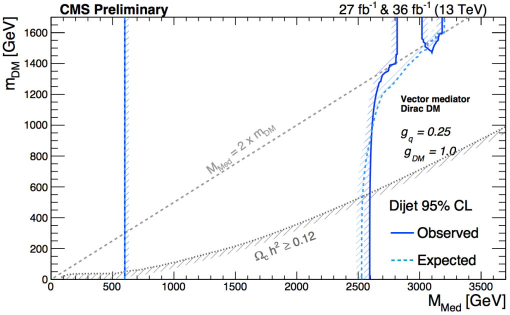
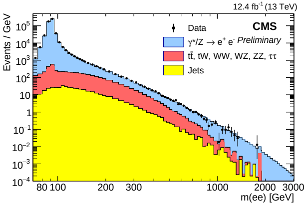
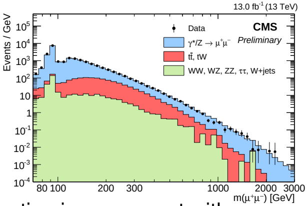




$Z' \to ee/\mu\mu$

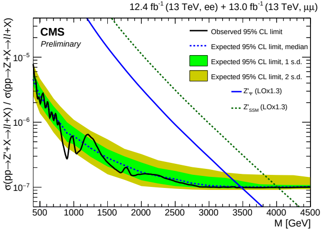




- Select electrons (muons) with $p_T > 35(53)$ GeV
- Use dilepton invariant mass as discriminating variable
- Selection efficiencies of $\approx$70(90)% at 1 TeV

- Mass resolution is 1-1.5 (5.5-8.5)% at 2 TeV for electron (muon) pairs
- Comparable to intrinsic signal widths of 1-3%

- SM backgrounds are estimated mostly from simulation
- Irreducible Drell-Yan background normalized to NNLO(NLO) in QCD(EWK) with mass dependent correction factors



- Observation in agreement with background expectation
- Exclusion limits are set on the ratio $\sigma(Z')/\sigma(Z)$ using an unbinned maximum likelihood fit to the data
- Translates into lower mass limits of 4 TeV in the SSM benchmark model

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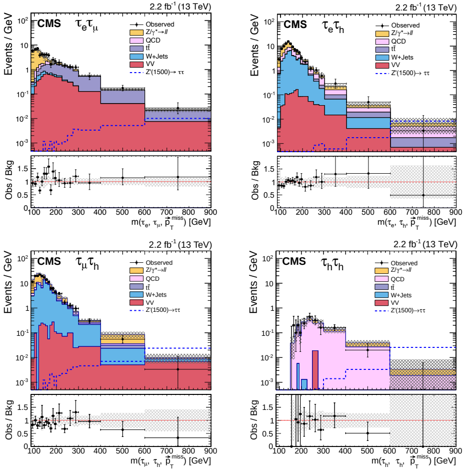
- Search for a Z' also performed in decay to $\tau\tau$
- Especially motivated by models preferring Z' couplings to the third generation

- Consider both hadronic (τ_h) and leptonic $\tau_{e,\mu}$ decays
- 4 combinations: $\tau_h\tau_h$, $\tau_h\tau_e$, $\tau_h\tau_\mu$, $\tau_e\tau_\mu$
- Expect two back-to-back τ
  - $\Delta R(\tau, \tau) > 0.5$, $\Delta\phi(\tau, \tau) < -0.95$
- $E_T^{miss} > 30\,\text{GeV}$
- Selection on compatibility of E_T^{miss} and τ directions
- Combined τ, τ, E_T^{miss} mass as discrimination variable
- SM backgrounds are estimated mostly from data control regions



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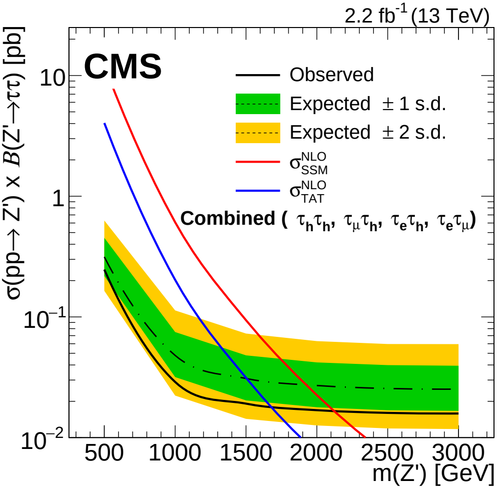
$Z' \to \tau\tau$

- No significant deviations from background estimations
- Exclusion limits are computed combining all four event categories

- Lower mass limit for a SSM Z': 2.1 TeV
- In topcolor-assisted technicolor (TAT), the coupling to the third generation is enhanced
- However, as the Z' production is dominated by light quark annihilation, the overall exclusion limit is weaker: 1.7 TeV



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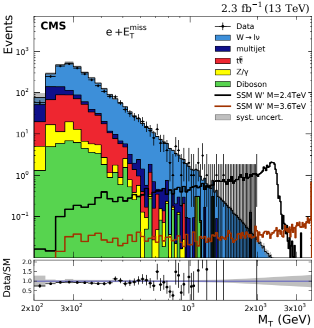
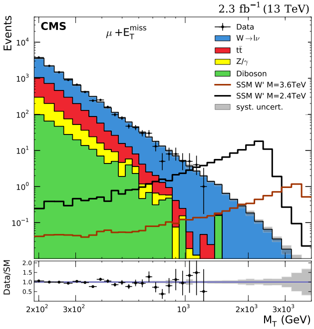
$W' \to e/\mu\nu$

- W' bosons predicted in many models with additional gauge groups
- Clear signature: high p_{T} lepton + $E_{\mathrm{T}}^{\mathrm{miss}}$
- Single lepton trigger result in relatively high p_{T} thresholds: 130 (53) GeV for electrons (muons)
- Two-body decay results in back-to-back topology: Require $|\Delta\Phi\ (\vec{p}_{\mathrm{T}}^{\ell}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})\ | > 2.5$ and $0.4 < p_{\mathrm{T}}^{\ell}/E_{\mathrm{T}}^{\mathrm{miss}} < 1.5$
- Dominant irreducible $W \to \ell\nu$ background estimated from MC, normalized to cross section calculated in NNLO (NLO) in QCD (EWK)

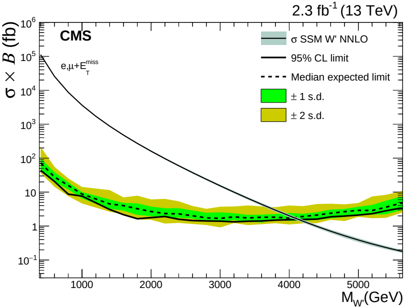


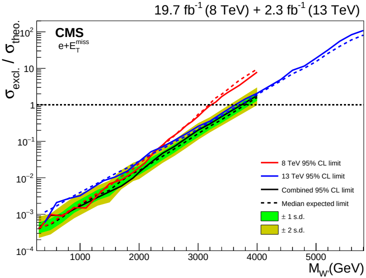


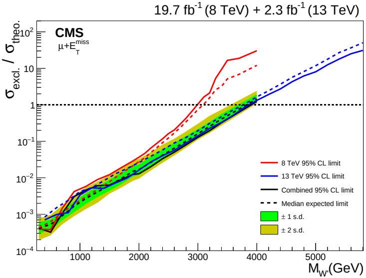
arXiv:1612.09274, accepted by Phys. Lett. B

$W' \to \ell\nu$

- No significant excess → Set exclusion limits
- Limits sets on SSM benchmark model with ≈8% BR into each lepton, no decays into W,H,Z bosons
- Lower mass limit: 3.6 (3.9) TeV in electron (muon) channel
- Combining both channels + 8 TeV data→ limit reaches 4.1 TeV







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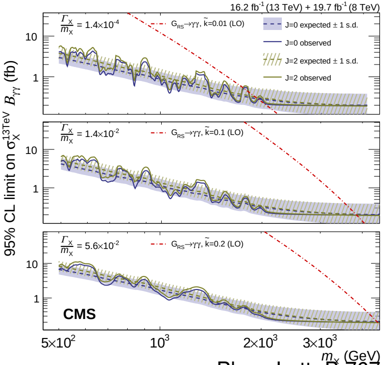
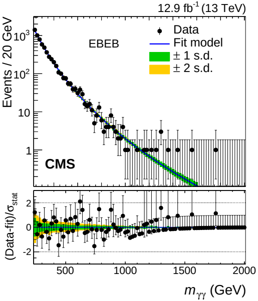
Diphoton resonances

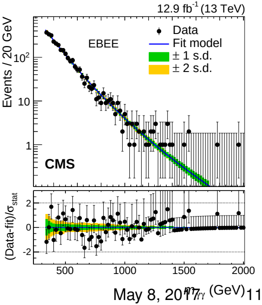
- Resonances decaying to two photons predicted in several BSM models
- Examples: RS gravitons or models with extended Higgs sectors

- Select photons with $p_T > 65$ GeV, photon pair with highest sum p_T chosen

- Background estimated from fit to the data
- Combining 8 and 13 TeV data, limits on $m_{G_{RS}}$ reach from 1.75 to 4.45 TeV, depending on couplings







Phys. Lett. B 767 (2017) 147

Summary

- Extensive search program for heavy resonances decaying to leptons, photons, and jets at CMS
- So far no significant hint for the existence of new physics, despite some excitement last year
- Data at $\sqrt{s} = 13$ TeV offers sensitivity to new resonances in the multi-TeV range, with limits getting close to 8 TeV for specific string resonance models
- Further progress will be slower as more and more data comes in, but the centre-of-mass energy stays the same
- Still a lot of information to be gained from last year's dataset and more results to come in the next weeks and month
- After that, full steam ahead for this years data taking. Let's hope we will get surprised!