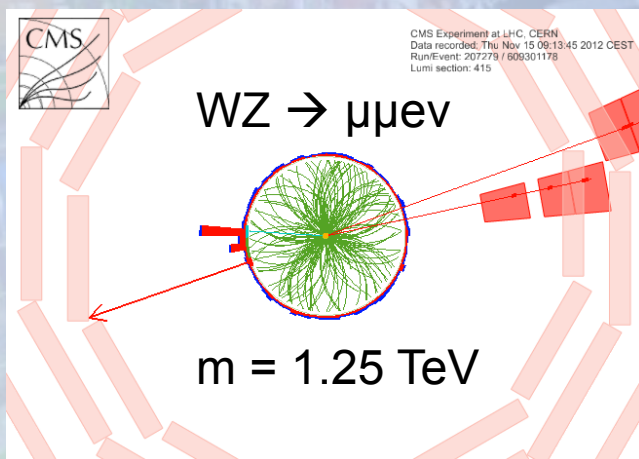


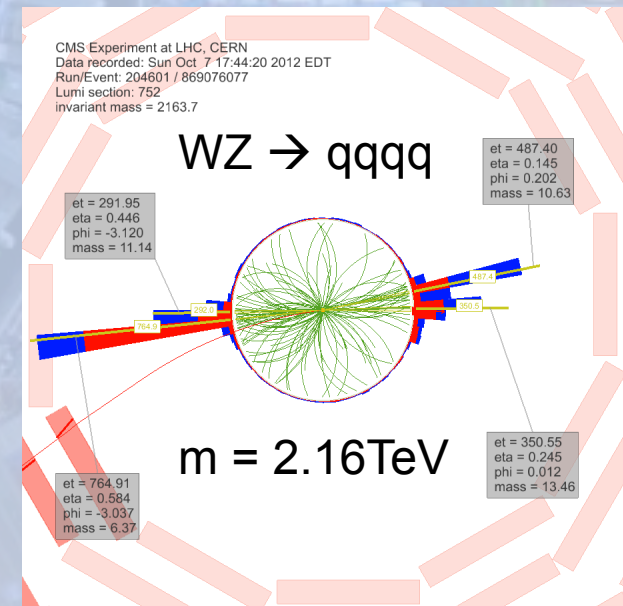


Searches for heavy resonances decaying to pairs of massive vector bosons in CMS



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Theory models

- Many extensions of the Standard Model predict resonances decaying to pairs of vector bosons
- Reference models considered in CMS searches
 - Randall-Sundrum gravitons $G_{RS} \rightarrow WW/ZZ$
 - Original RS1 model
 - Bulk-graviton model with enhanced couplings to WW and ZZ
 - Heavy partners of the SM W boson $W' \rightarrow WZ$
 - With W' couplings from the extended gauge model
 - Low-scale technicolor (LSTC) models $\rho_{TC} \rightarrow WZ$
 - SM Higgs $H \rightarrow WW/ZZ$
 - SM Higgs-like boson in addition to the SM Higgs boson at 125 GeV used as reference model for high mass resonances

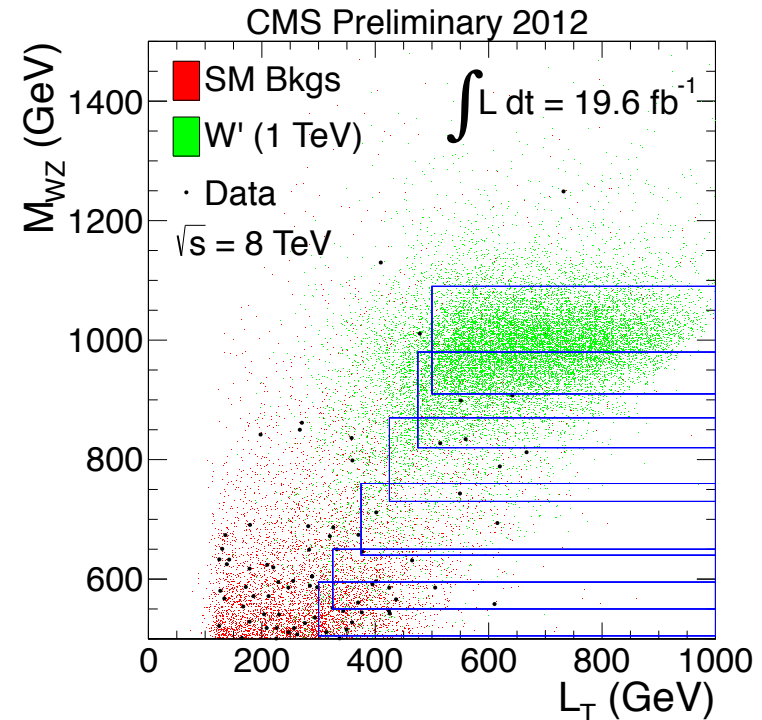
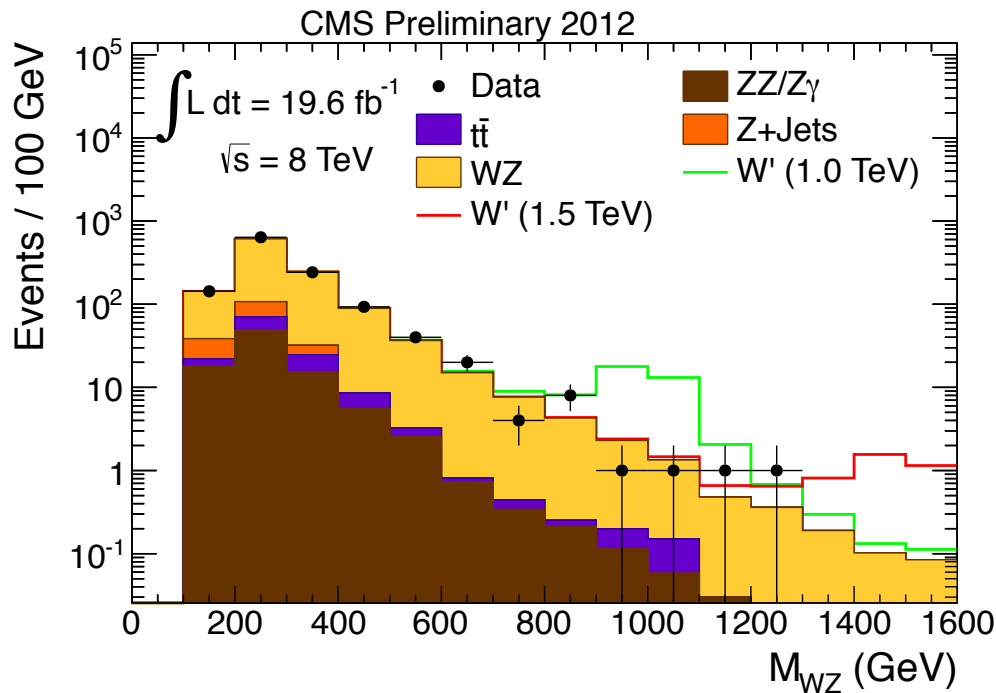
Final states

final state	SM Higgs searches	non-boosted topologies	boosted topologies (jets or isolation cones overlap)
$ZZ \rightarrow \text{llll}$	H \rightarrow WW/ZZ talk by Cristina Botta this morning	10.1140/epjc/s10052-013-2469-8 (7+8 TeV) H \rightarrow ZZ in 4l	
$WZ \rightarrow \text{lllv}$			CMS-PAS-EXO-12-025 (8 TeV) W'/$\rho_{TC}$$\rightarrow$WZ in 3l+E_T^{miss}
$WW/ZZ \rightarrow \text{llvv}$		CMS-PAS-HIG-13-014 (8 TeV) H \rightarrow ZZ in 2l+E _T ^{miss} 10.1140/epjc/s10052-013-2469-8 (7+8 TeV) H \rightarrow WW in 2l+E _T ^{miss}	
$ZZ/WZ \rightarrow \text{qqll}$		10.1016/j.physletb.2012.11.063 (7 TeV) G_{RS}\rightarrowZZ in 2l+2jets 10.1140/epjc/s10052-013-2469-8 (7+8 TeV) H \rightarrow ZZ in 2l+2jets	10.1007/JHEP02(2013)036 (7 TeV) G_{RS}\rightarrowZZ, W'\rightarrowWZ in 2l+1jet
$WW \rightarrow \text{qqlv}$		10.1140/epjc/s10052-013-2469-8 (7+8 TeV) H \rightarrow WW in 1l+2jet+E _T ^{miss}	CMS-PAS-HIG-13-008 (8 TeV) H\rightarrowWW in 1l+1jet+E_T^{miss}
$ZZ \rightarrow \text{qqvv}$			10.1007/JHEP02(2013)036 (7 TeV) G_{RS}\rightarrowZZ in 1jet+E_T^{miss}
$WW/ZZ/WZ \rightarrow \text{qqqq}$			CMS-PAS-EXO-12-024 (8 TeV) G_{RS}\rightarrowWW/ZZ, W'\rightarrowWZ in 2jets

Focus on latest results – One slide on 7 TeV results with outlook for 8 TeV

$W'/\rho_{TC} \rightarrow WZ 3l + E_T^{\text{miss}}$

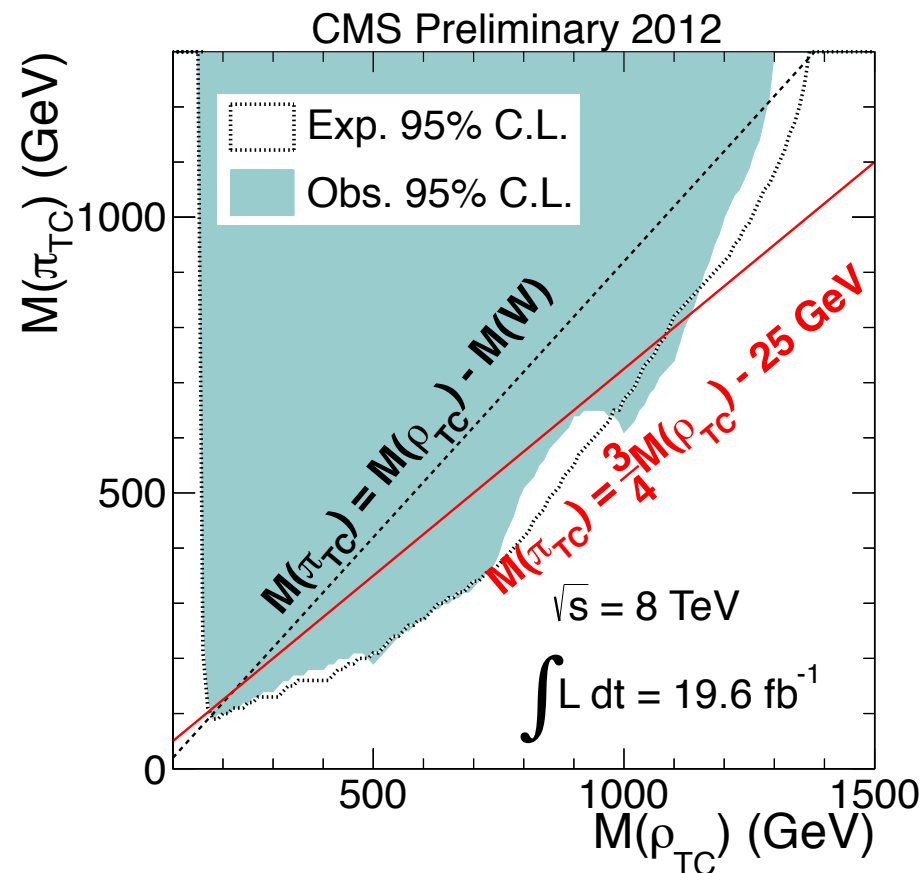
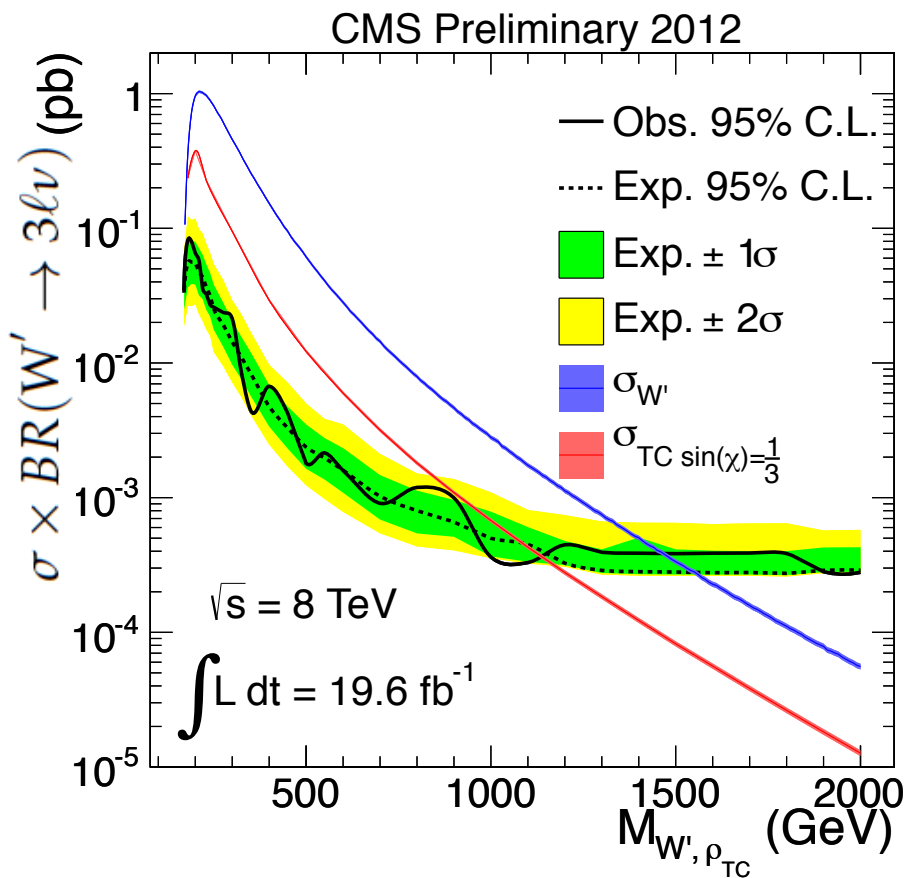
- 2 opposite-sign same-flavor leptons from Z falling in Z mass window
- 1 lepton and E_T^{miss} from W
- Special identification+isolation for leptons from (boosted) Z boson
 - one muon with relaxed muon system requirements (tracker muons)
 - other lepton excluded from particle based lepton isolation
- M_{WZ} and $L_T \equiv \sum p_T^{\text{Lep}}$ cuts optimized for each signal mass



[CMS-PAS-EXO-12-025](#)

$W'/\rho_{TC} \rightarrow WZ 3l+E_T^{\text{miss}}$

- No significant excess observed
 - Cut-and-count method for limit setting
 - $W' \rightarrow WZ$ excluded in mass range 0.17 to 1.45 TeV
 - Most stringent limits on ρ_{TC} to date
- $\rho_{TC} \rightarrow WZ$
 $\rho_{TC} \rightarrow W\pi_{TC}$

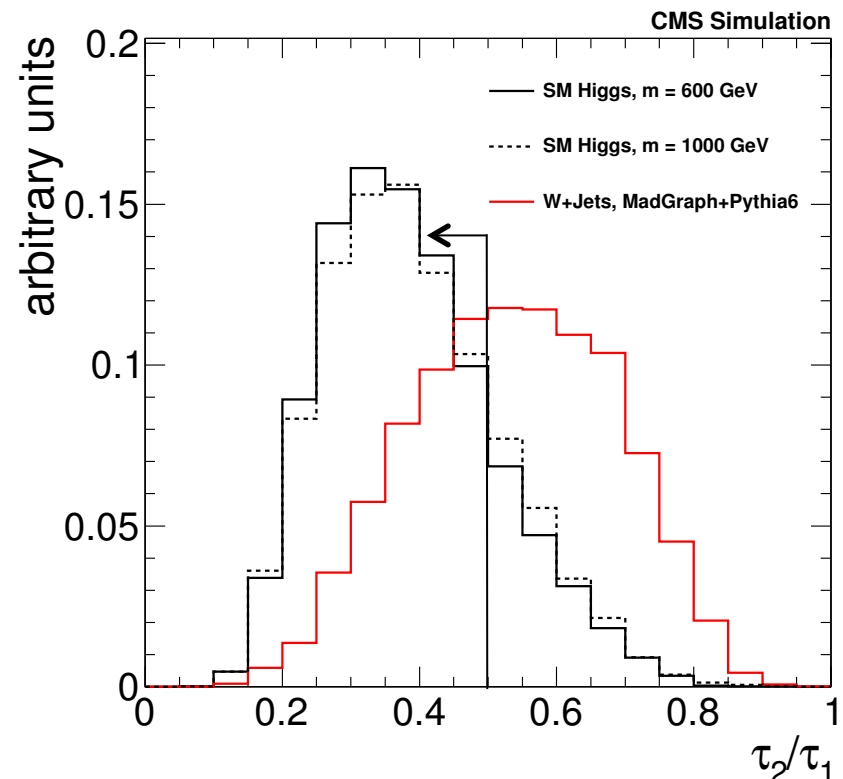
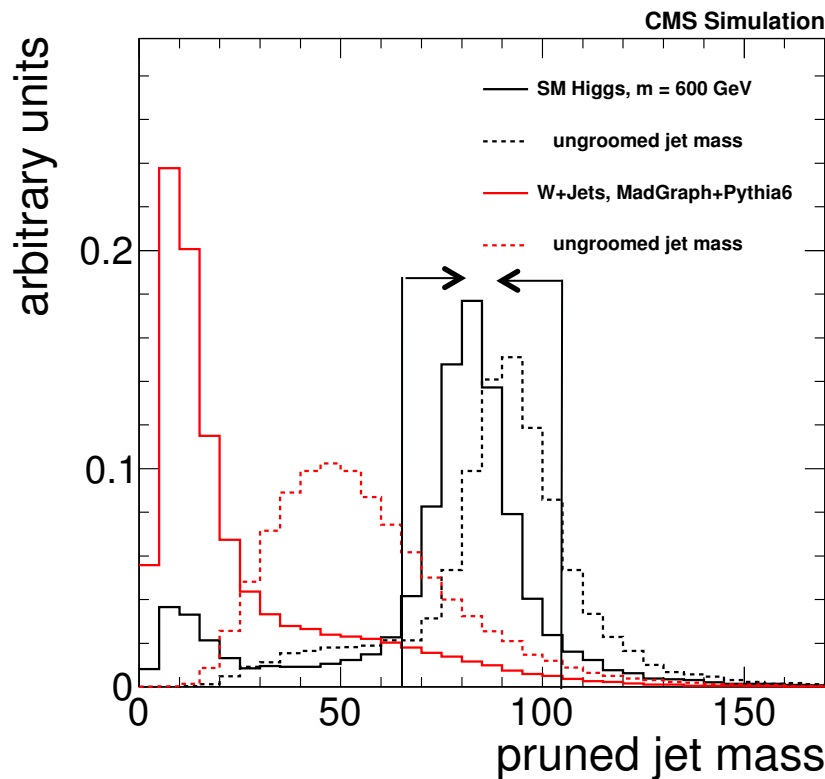


CMS-PAS-EXO-12-025

H \rightarrow WW in 1l+1jet+E_T^{miss}

- Search for SM Higgs-like boson in mass range 0.6 to 1.0 TeV
- 1 lepton and E_T^{miss} from W
- Hadronic decay products from W merge into single jet
- Use jet substructure techniques to identify W boson
 - Pruned jet mass and N-subjettiness

$$\tau_N = \frac{1}{d_0} \sum_k p_{T,k} \min((\Delta R_{1,k}), (\Delta R_{2,k}) \dots (\Delta R_{N,k}))$$

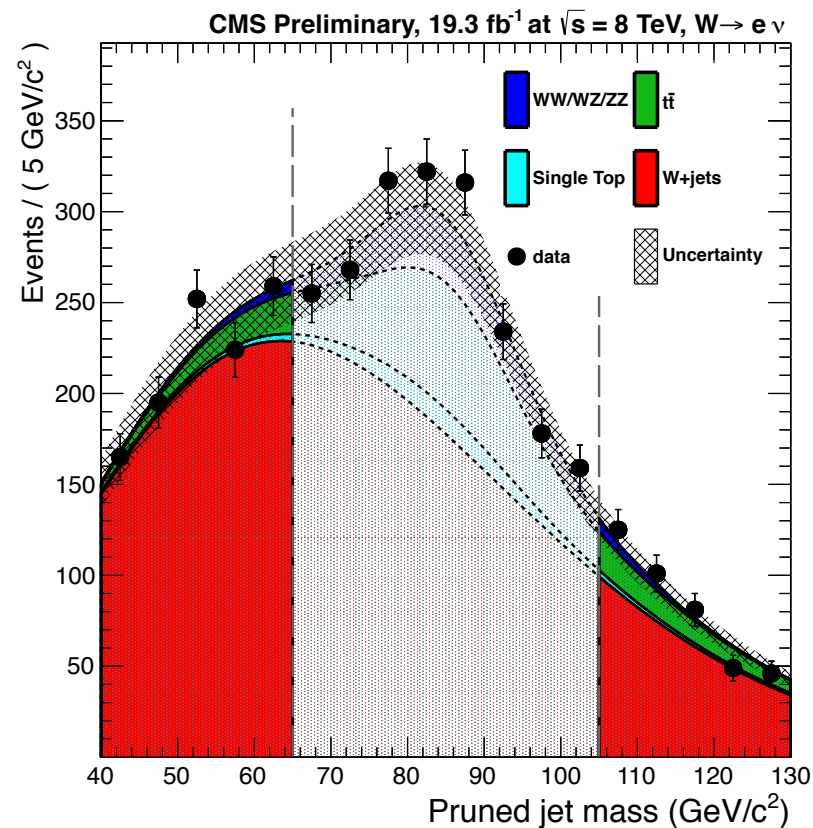
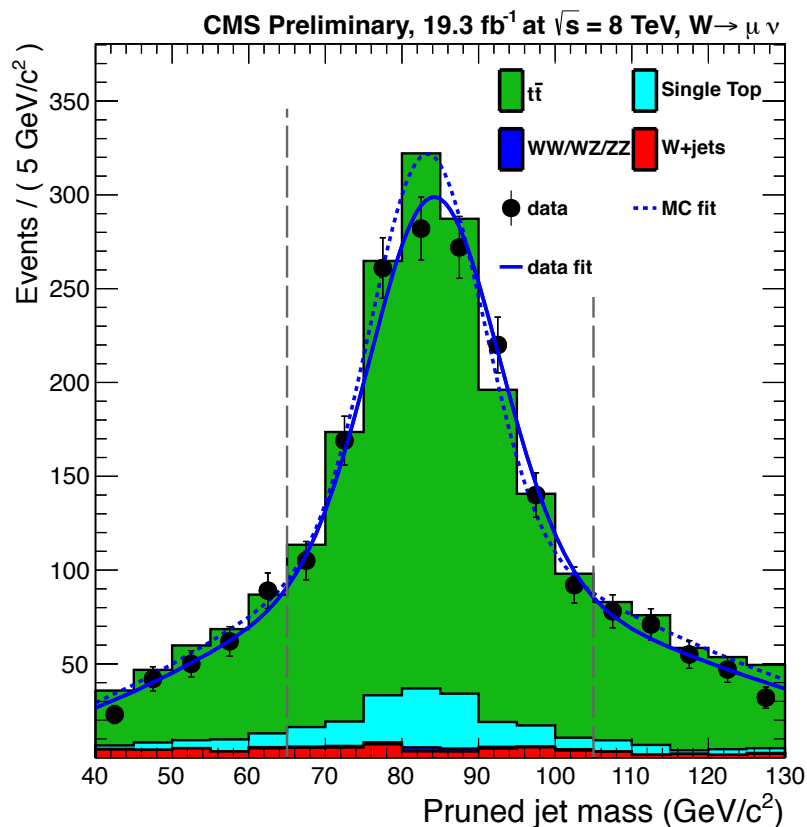


More on jet substructure in talk by Alexander Schmidt this morning

[CMS-PAS-HIG-13-008](#)

$H \rightarrow WW$ in $1l+1jet+E_T^{\text{miss}}$

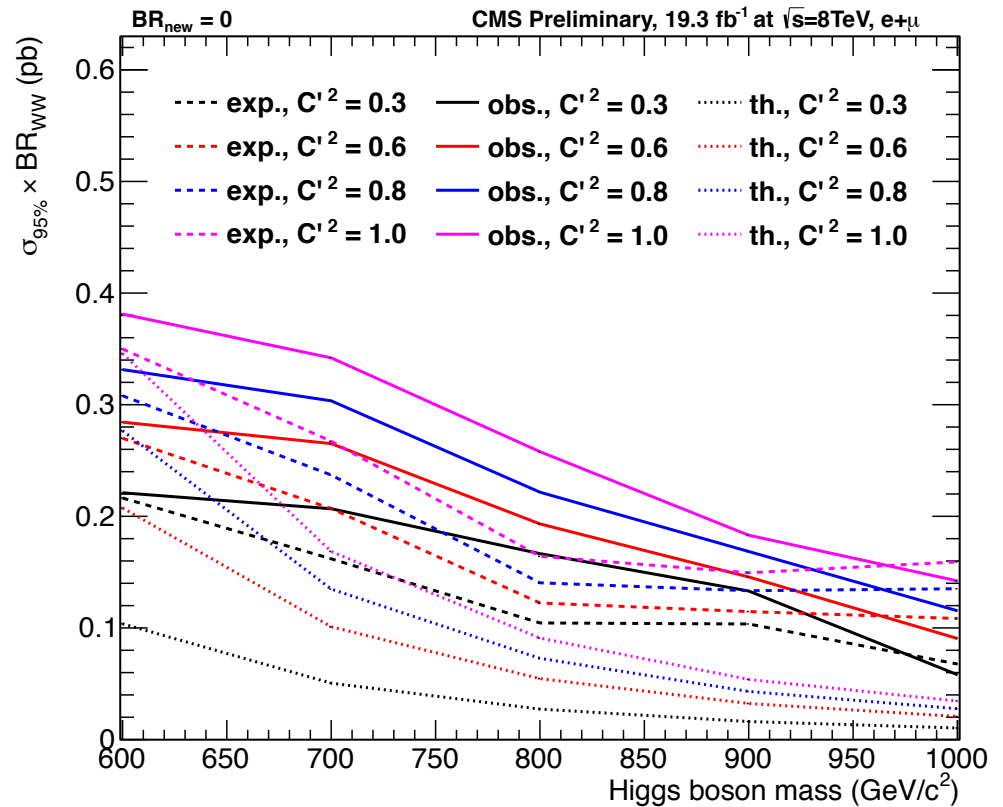
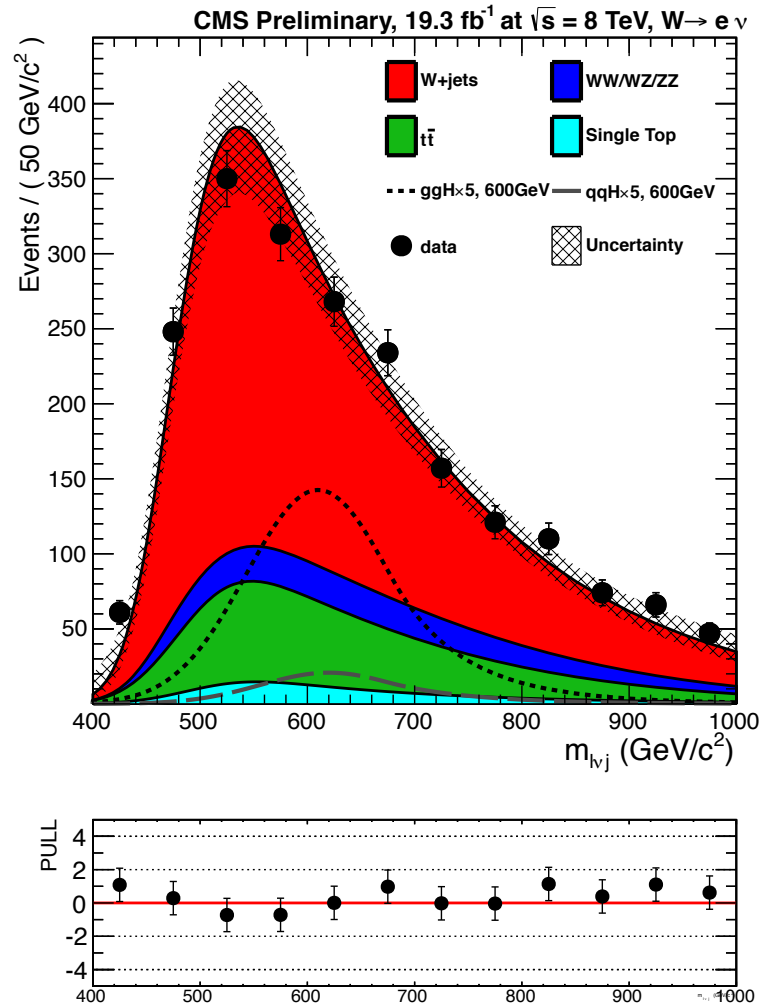
- W-tagging validated in semileptonic $t\bar{t}$ sample
- W+jets background estimated from jet mass side-band
- This channel sees the SM VV background



CMS-PAS-HIG-13-008

$H \rightarrow WW$ in $1l+1jet+E_T^{\text{miss}}$

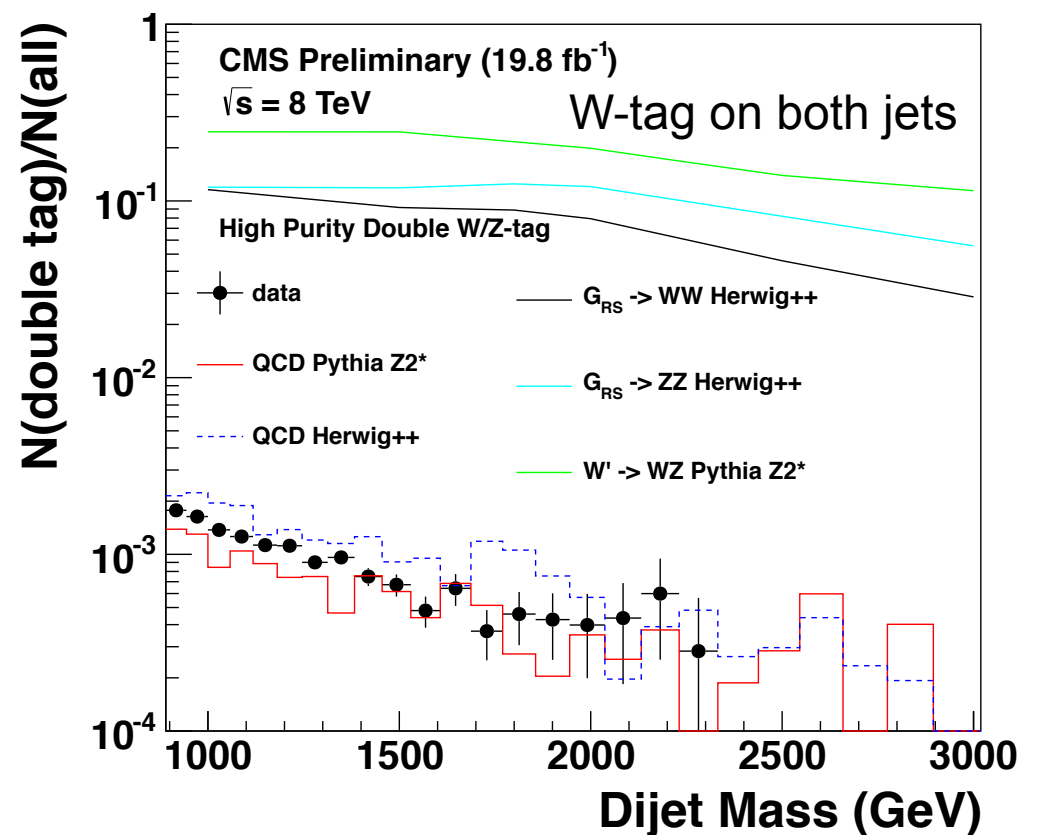
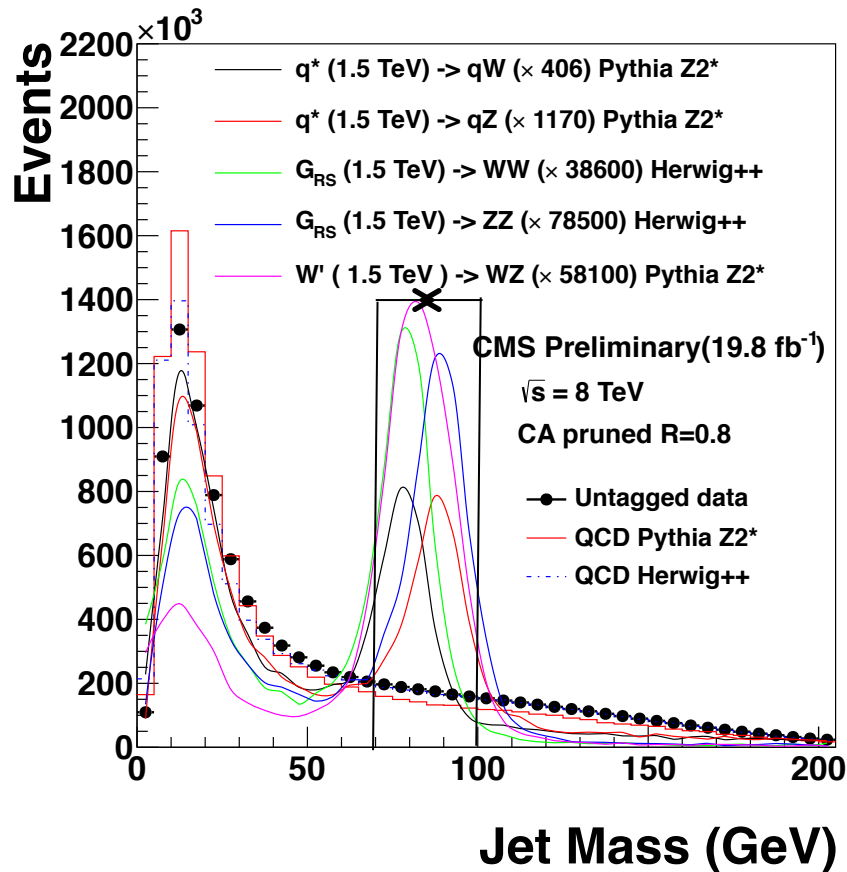
- No significant excess observed
- Set limits in context of BSM heavy singlet scalar additional to the Higgs boson at 125 GeV where C' is the scale factor for its coupling



CMS-PAS-HIG-13-008

$G_{RS} \rightarrow WW/ZZ, W' \rightarrow, WZ$ in 2jets

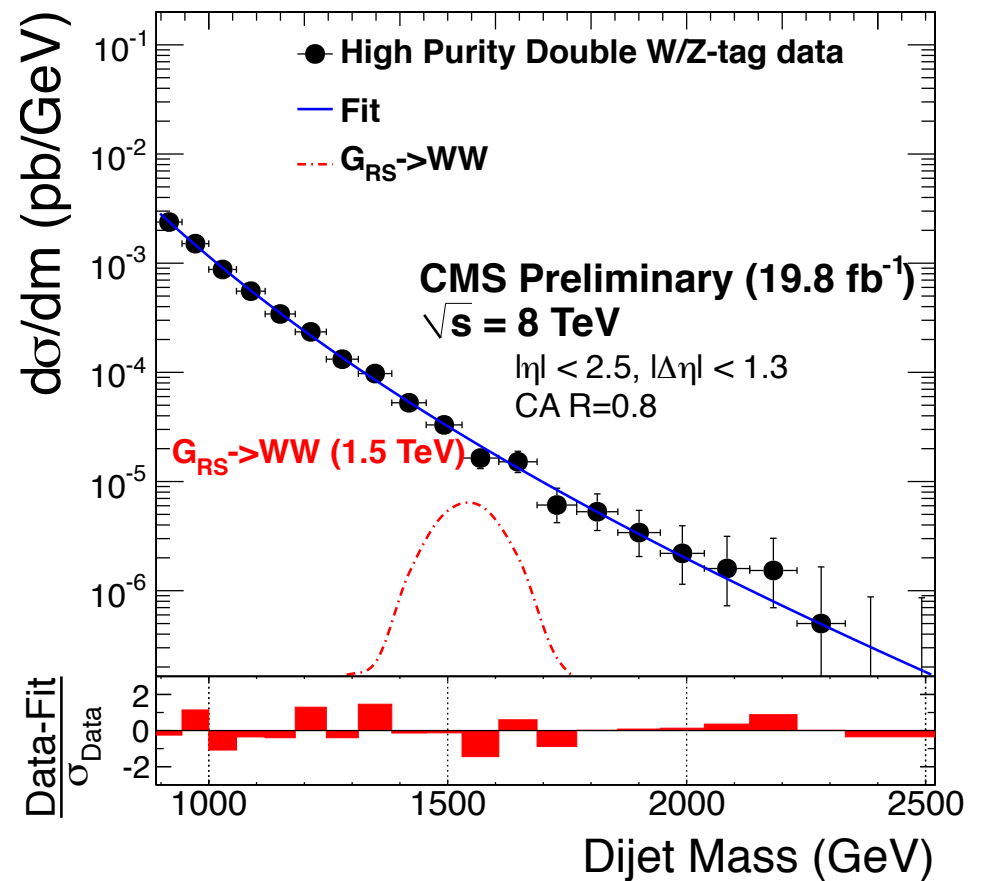
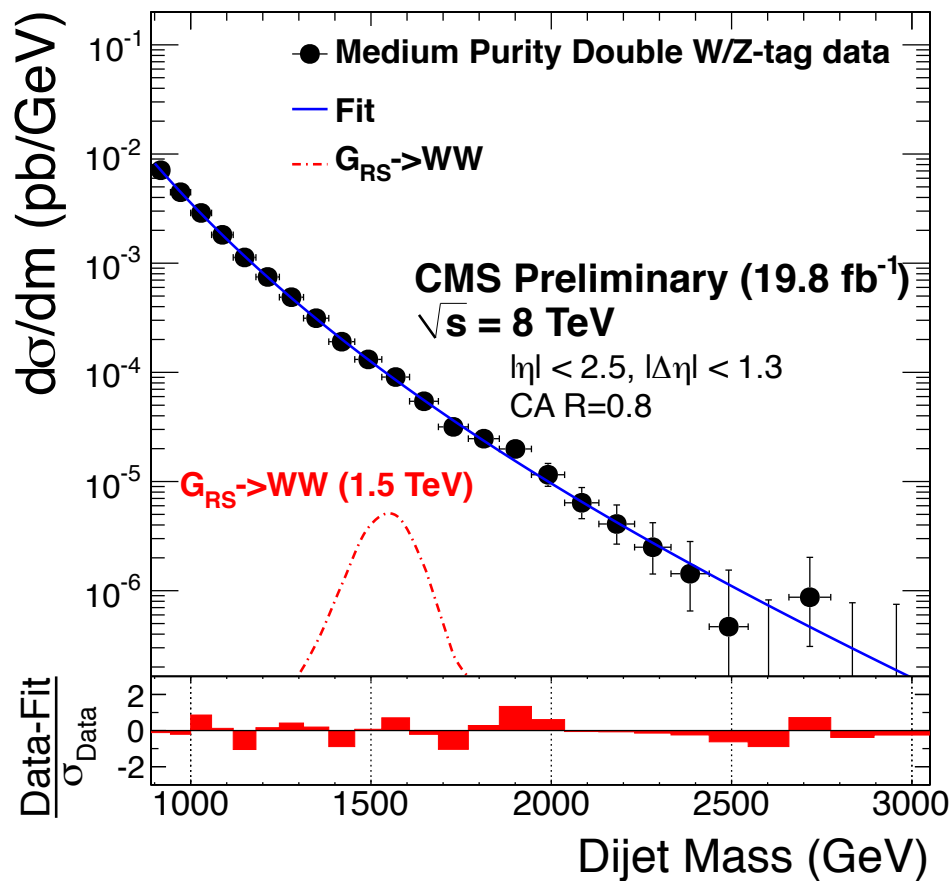
- Search in dijet topology for resonance masses ≥ 1 TeV
- Large QCD background rejected with
 - Angular distribution of dijets: restrict $|\eta_1 - \eta_2| < 1.3$
 - Jet W-tagging based on pruned jet mass and N-subjettiness τ_2/τ_1



CMS-PAS-EXO-12-024

$G_{RS} \rightarrow WW/ZZ, W' \rightarrow, WZ$ in 2jets

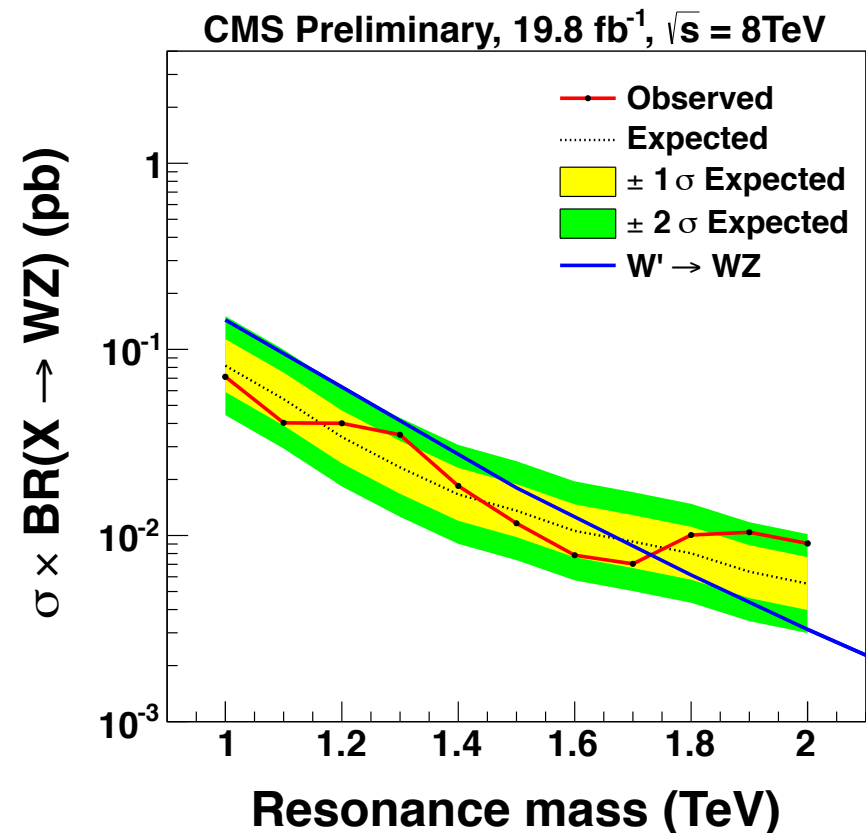
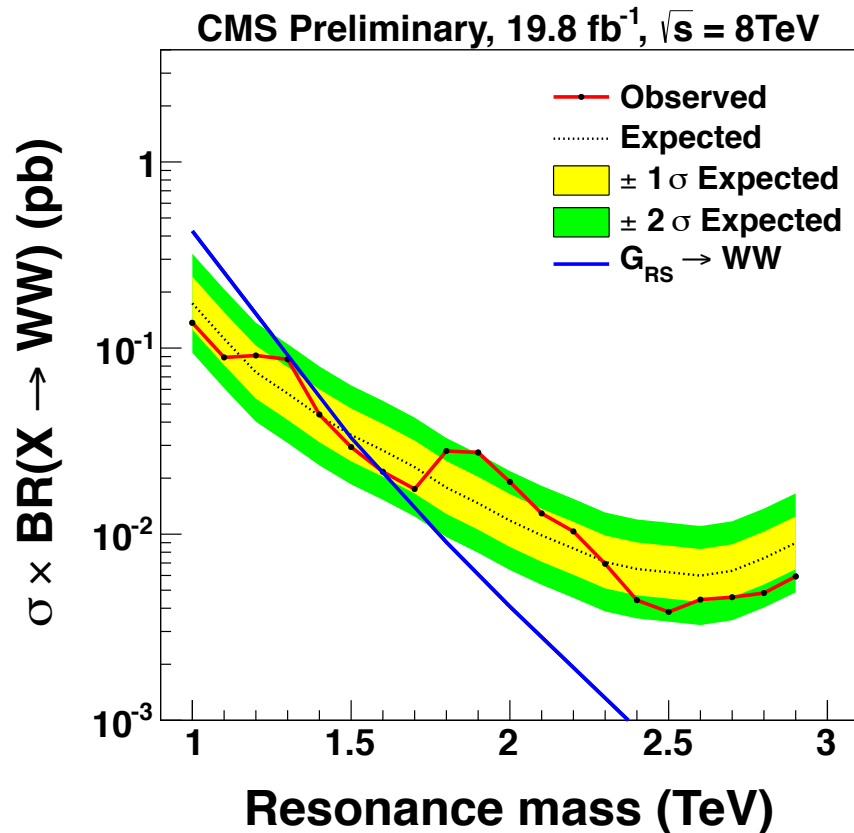
- Background estimated from smooth fit (S+B) to data (no need for BG MC)
- Search in high-purity ($\tau_2/\tau_1 < 0.5$) and medium-purity ($0.5 < \tau_2/\tau_1 < 0.75$) selections simultaneously



CMS-PAS-EXO-12-024

$G_{RS} \rightarrow WW/ZZ, W' \rightarrow, WZ$ in 2jets

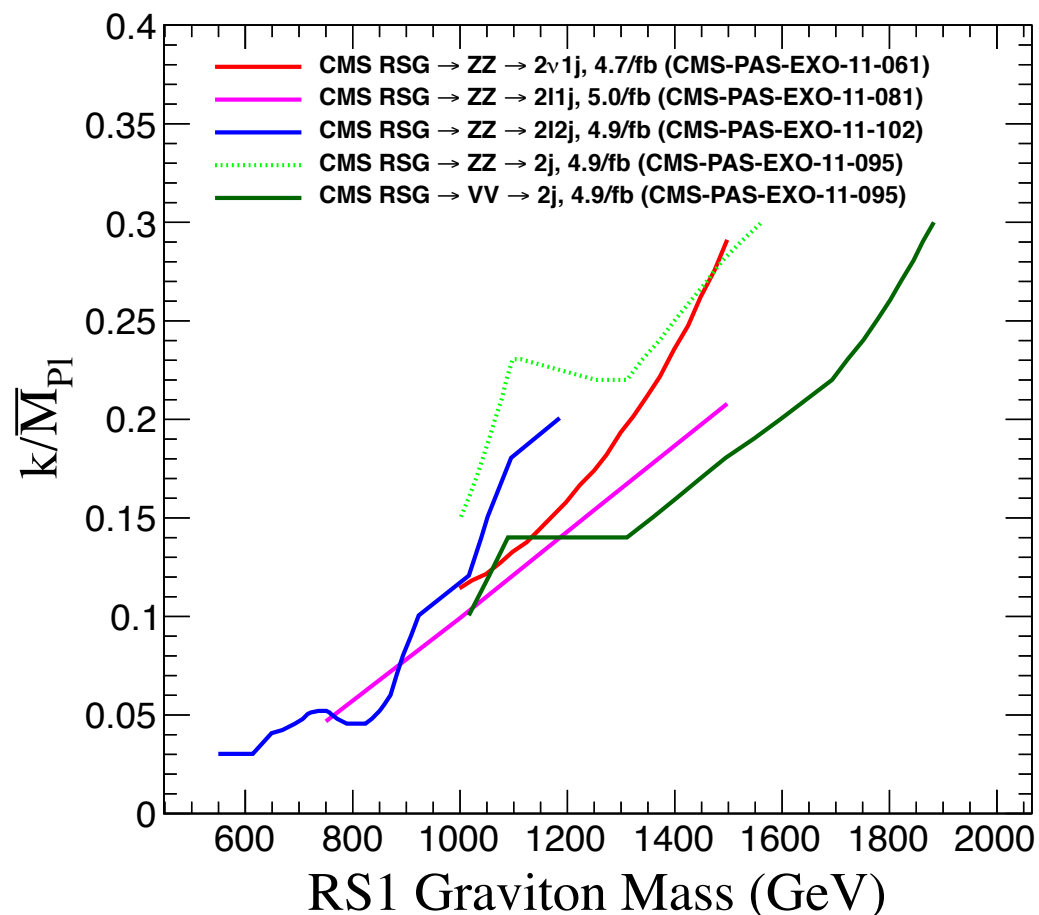
- No significant excess found
- G_{RS1} ($k/\overline{M}_{PL}=0.1$) $\rightarrow WW(ZZ)$ excluded in mass range 1.0 to 1.59(1.17) TeV
- $W' \rightarrow WZ$ excluded in mass range 1.0 to 1.73 TeV
- $q^* \rightarrow qW(qZ)$ excluded in mass range 1.0 to 3.23(3.00) TeV
- Most stringent limits to date in all final states WW, ZZ, WZ, qW, qZ



CMS-PAS-EXO-12-024

$G_{RS} \rightarrow WW/ZZ$ – 7 TeV results

- Compare analyses sensitivity in 2-D plane of coupling k/\overline{M}_{Pl} and G_{RS} mass
- Complementarity between results in different channels
- Full combination foreseen for 8 TeV results



[10.1016/j.physletb.2012.11.063](https://arxiv.org/abs/10.1016/j.physletb.2012.11.063) RSG \rightarrow ZZ in 2l+2jets

[10.1007/JHEP02\(2013\)036](https://arxiv.org/abs/10.1007/JHEP02(2013)036) RSG \rightarrow ZZ, $W' \rightarrow WZ$ in 2l+jet, jet+ E_T^{miss}

[10.1016/j.physletb.2013.05.040](https://arxiv.org/abs/10.1016/j.physletb.2013.05.040) RSG \rightarrow WW/ZZ, $W' \rightarrow WZ$ in 2jets

Conclusions

- Broad program of searches for VV resonances in CMS
 - Aim at covering all possible final states for best sensitivity over the full resonance mass range
 - Plan to update all 7 TeV searches
 - 8 TeV searches will result in a combination
- 3 new 8 TeV results presented today
- Set most stringent limits on G_{RS1} ($k/M_{PL}=0.1$) \rightarrow $WW(ZZ)$, $W' \rightarrow WZ$ and $q^* \rightarrow qW(qZ)$
- No discovery so far, but keeping a close eye on these final states since they occur in several extensions to the SM

