Search for heavy neutral Higgs in di-boson final state

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on behalf of the CMS collaboration

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Outline

- This talk will cover the results of searching for heavy neutral resonances using CMS 2015/2016 data including
  - **Higgs to WW full leptonic final state HIG-16-023**
  - **Higgs to ZZ to four leptons (lepton = e, μ) HIG-16-033**

Higgs to WW

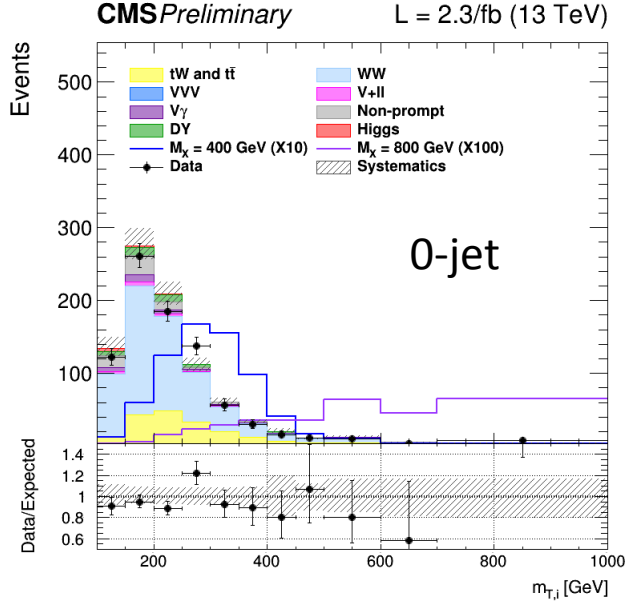
Analysis strategy :
event selection and categorization

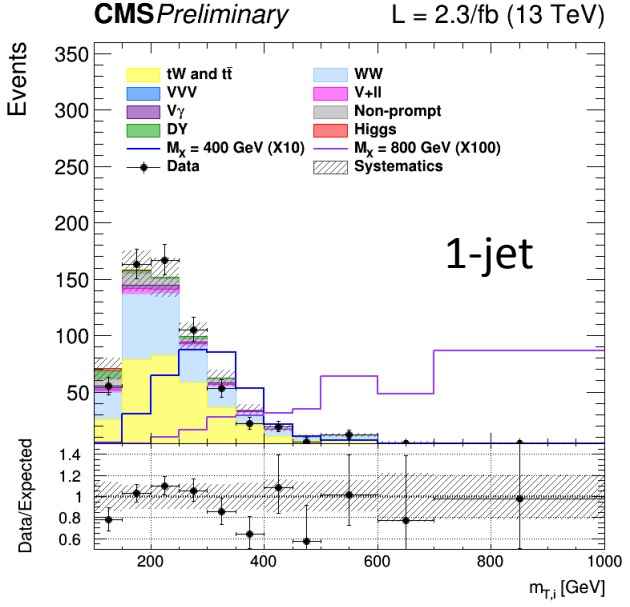
- The analysis uses 2.3fb^{-1} collected in 2015 with 13TeV c.o.m. energy
- Events are required to have one electron and one muon with opposite charge satisfy
  - p_T of the leading and trailing lepton > 20GeV
  - Third lepton veto :
    no additional (loose) leptons with p_T higher than 10 GeV should be present
  - E^{miss}_T > 20GeV (suppress DY->ττ)
  - p^{ll}_T > 30GeV
  - B tagging veto : no additional b-tagged jets with p_T > 20 GeV should be present in the event
  - Transverse mass $m_T = \sqrt{2p_T^{\ell\ell}E_T^{miss}(1-\cos\Delta\phi(\ell\ell,\vec{p}_T^{miss}))}$ > 60GeV

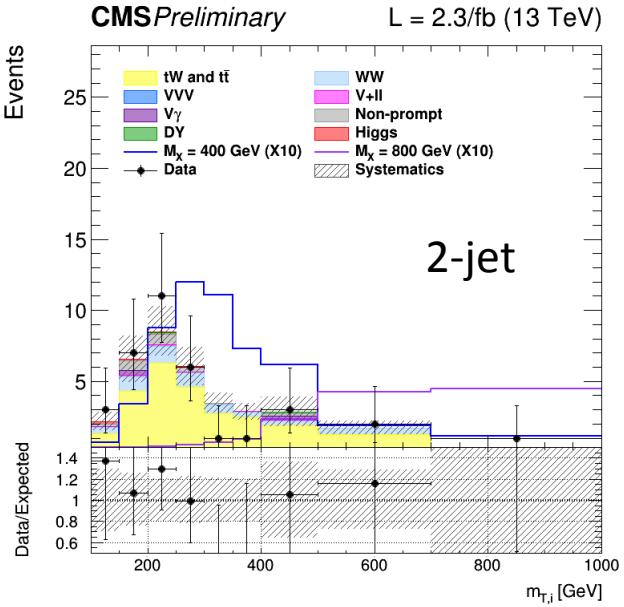
- Event are categorized into
  - The zero-jet and one-jet favored by gluon fusion production
  - The two-jet favored by VBF production
    - m_{jj}>500GeV and $|\Delta\eta_{jj}|$>3.5

Analysis strategy :
signal extraction

- 1D template fit using shape of "improved" transverse mass $m_{T,i}$ including sig/bkg interference (see backup)
- $m_{T,i}$ is defined as $m_{T,i} = \sqrt{(p_{ll} + E_T^{miss})^2 - (\vec{p}_{ll} + \vec{p}_T^{miss})^2}$.
  - uses lepton longitudinal information
  - better distinction among different signal mass hypothesis

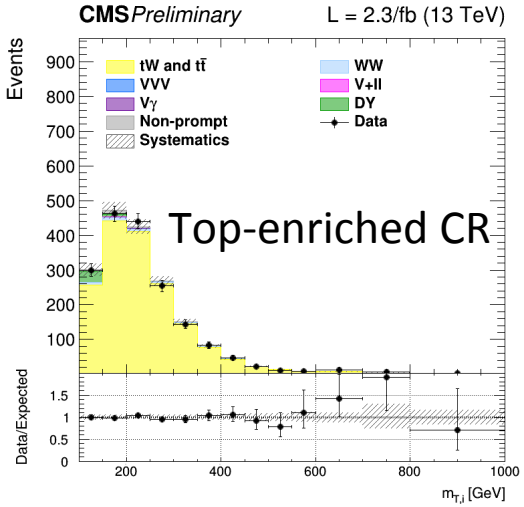


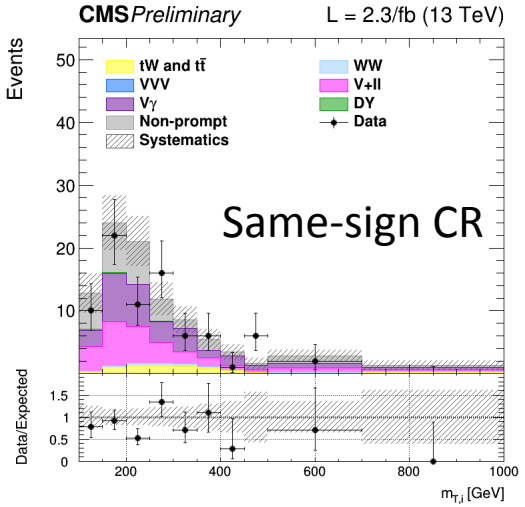




Analysis strategy : background estimation

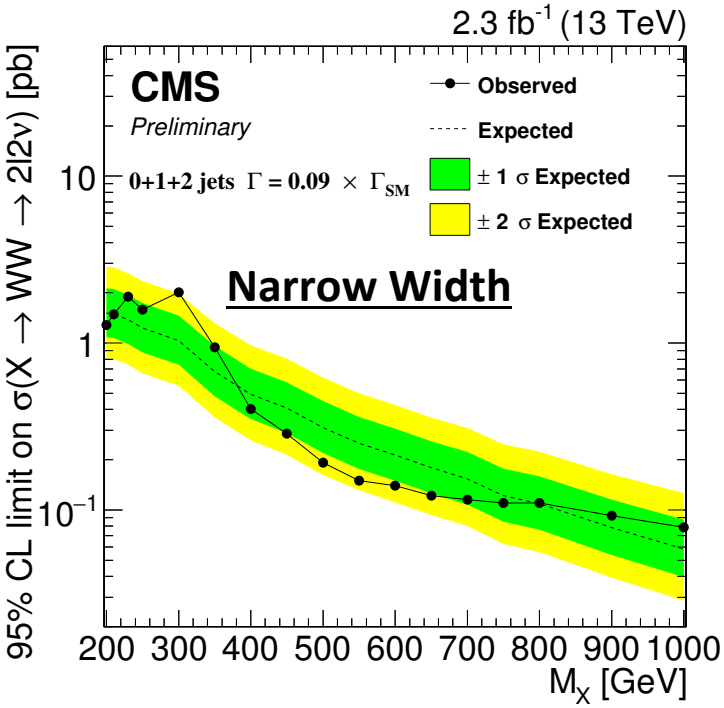
- Top : tW, ttbar
  - Data driven top enriched control region by requiring btagging of jets
- Jet induced background : jet fake identified as lepton
  - Fake rate method : the efficiency that a jet that satisfies loose lepton requirements to also satisfy the standard selection
  - Same sign cross check : eμ pair with same charge
- DY->ττ : $m_T < 60$ GeV and 50 GeV < $m_{ll} < 80$ GeV
- WZ/γ* : normalization controlled by "tri-lepton" control region
- Tri-boson : normalization taken from MC simulation

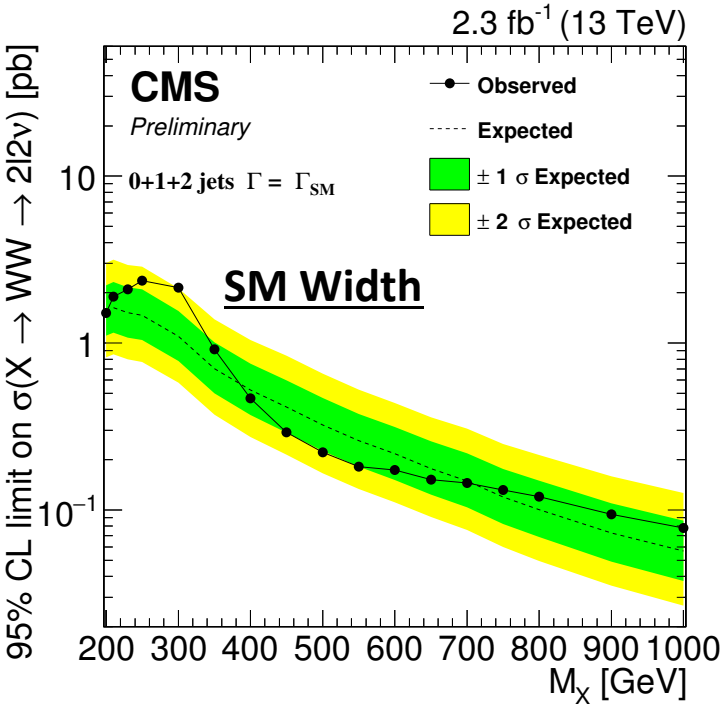




Results:
p-value and limit scan

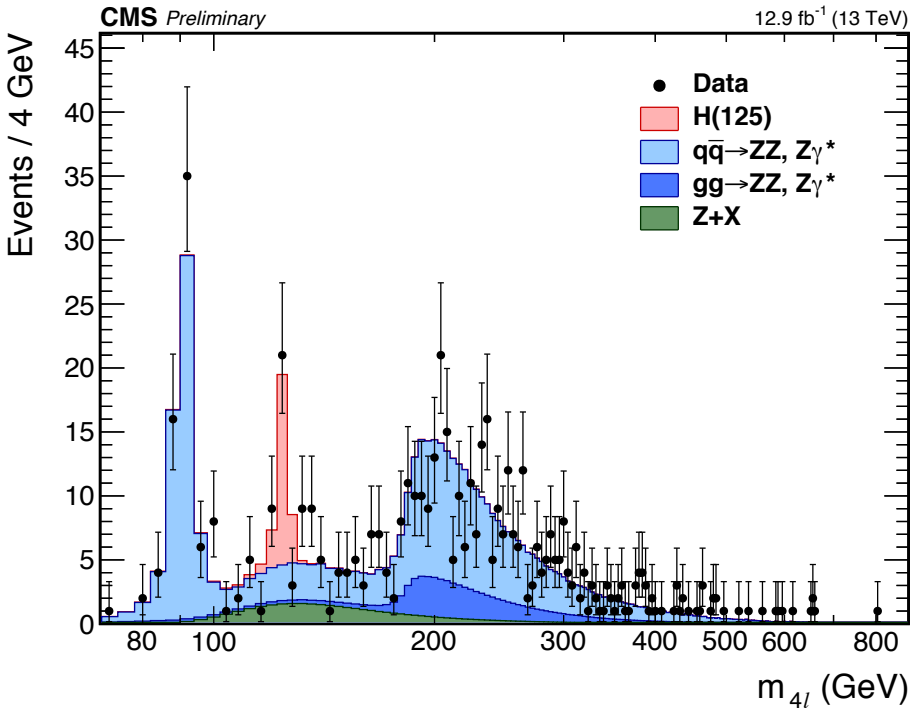
- Local p-value scan doesn't show significant excess from 200GeV to 1TeV
- The expected and observed exclusion limits on the sum of gluon fusion and VBF cross sections times branching ratio are set for difference widths





Higgs to ZZ to four leptons

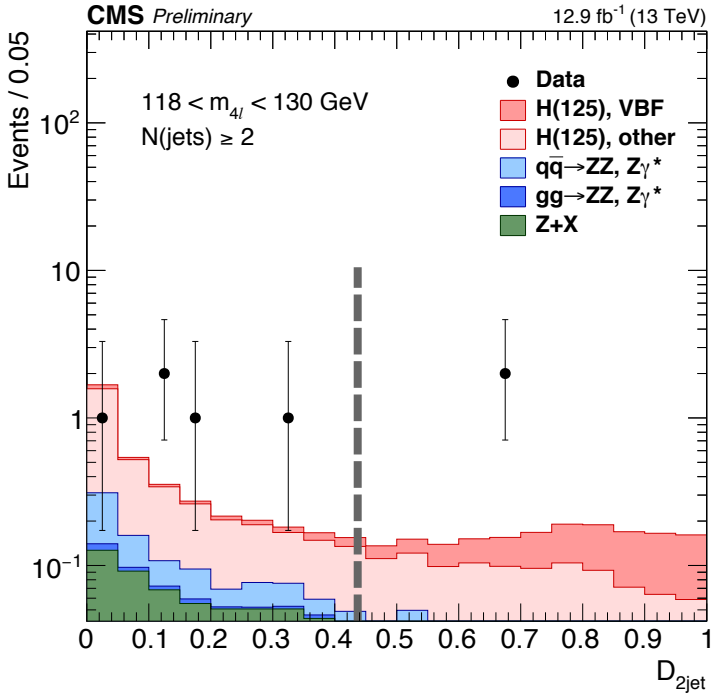
Analysis strategy: event selection



- Analysis uses 12.9 fb^{-1} data collected in 2016 with c.o.m. energy at 13TeV
- Four isolated leptons grouped into 2e2μ, 4e and 4μ final states
  - Electron uses MVA-based ID to gain signal efficiency
  - Muon ID is optimized to avoid loosing efficiency in boost regime (muon p_T >200GeV)
- Include an extra category with relaxed selected electron to gain signal efficiency
- No events are observed with $mass_{4l}$ > 850GeV

Analysis strategy: event categorization

- To separate gluon fusion and VBF production, a matrix-element based discriminant is used.
- The discriminant is used for both measurements for ~125GeV Higgs and high mass resonance search.
- VBF category is defined by events satisfy cut on D_{2jet}
  - $mass_{4l}$ – dependent cut is used for high mass search

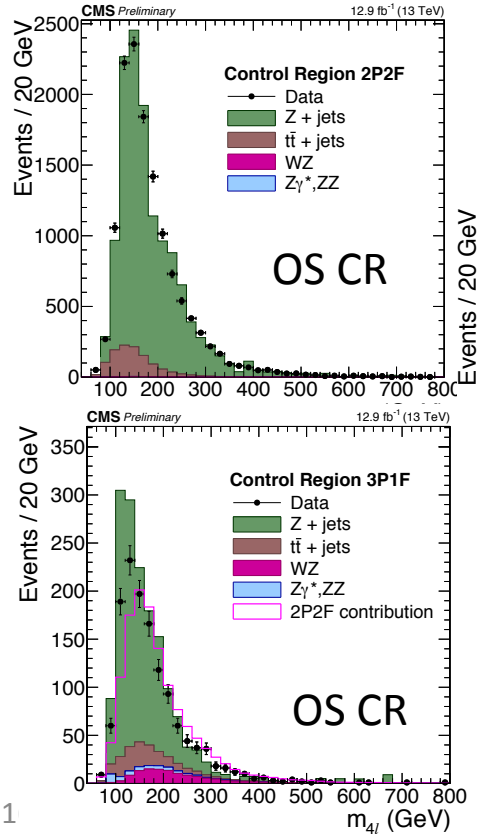


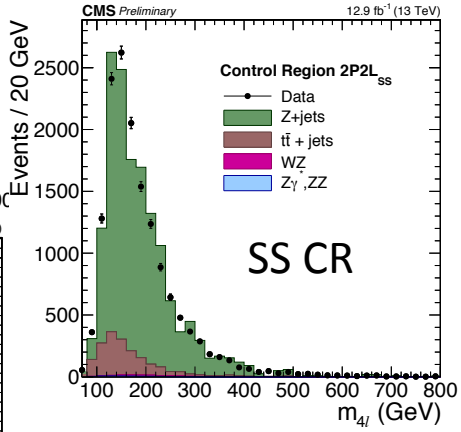
Analysis strategy: background estimation

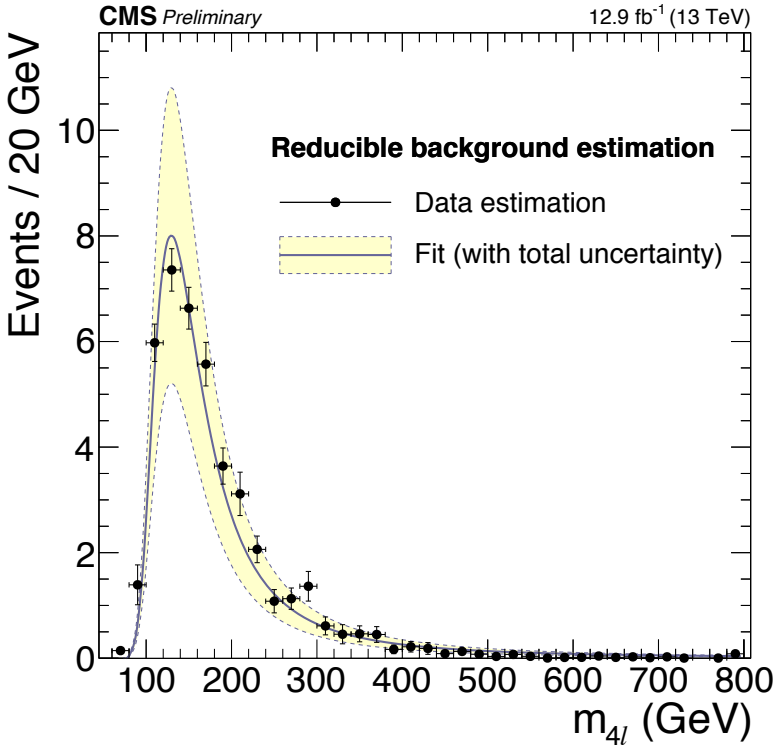
- qqZZ + ggZZ : estimate from MC
  - Mass dependent K factor (NNLO/NLO for qqZZ, NNLO/NLO for ggZZ) are applied
  - NLO electroweak corrections are applied on qqZZ
- Z+X : fake ratio method using data control region
  - Control region defined as
    two leptons which satisfy the final HZZ4L selection,
    plus two additional opposite-sign(OS) or same-sign (SS) leptons satisfy relaxed requirements
  - fake ratio defined in the same way as WW analysis
    (efficiency of "loose" lepton passing the final selection criteria) is used to extrapolate from control region to signal region

Analysis strategy: background estimation

- Z+X : fake ratio method from data control region
  - Estimations from opposite-sign(OS) or same-sign (SS) are combined to give the final Z+X background estimation

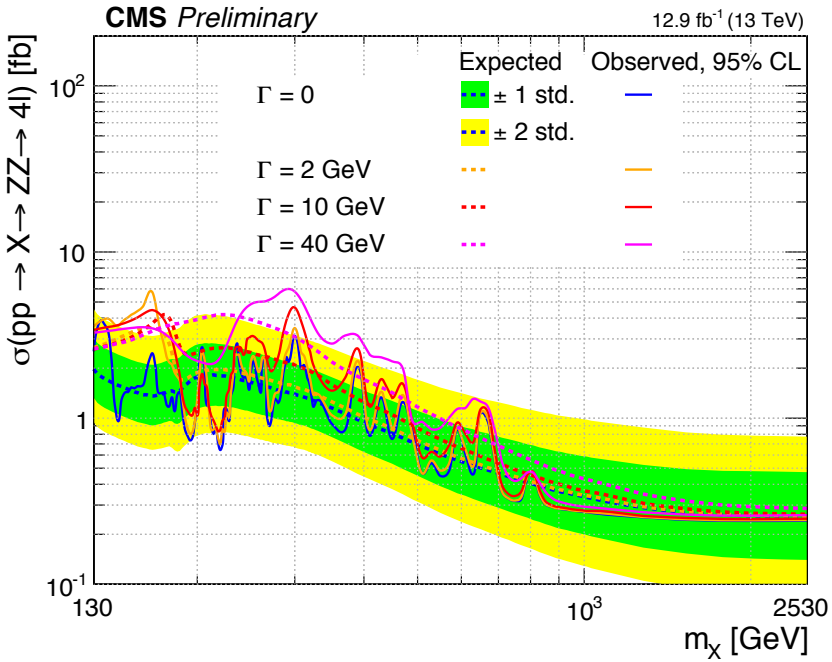






Results:
cross section upper limit

- An unbinned maximum likelihood fit of the m_{4l} distribution is performed over the full range between 100 and 3000GeV.
- The fraction of VBF and VH production f_{VBF} can be either fixed to a certain value or left unconstrained in the fit when scan over of m_{4l} spectrum.
- Limits on the pp->X->ZZ->4l cross section are set as a function of m_X and Γ_X with f_{VBF} unconstrained are scanned from 130GeV to 2.5TeV.

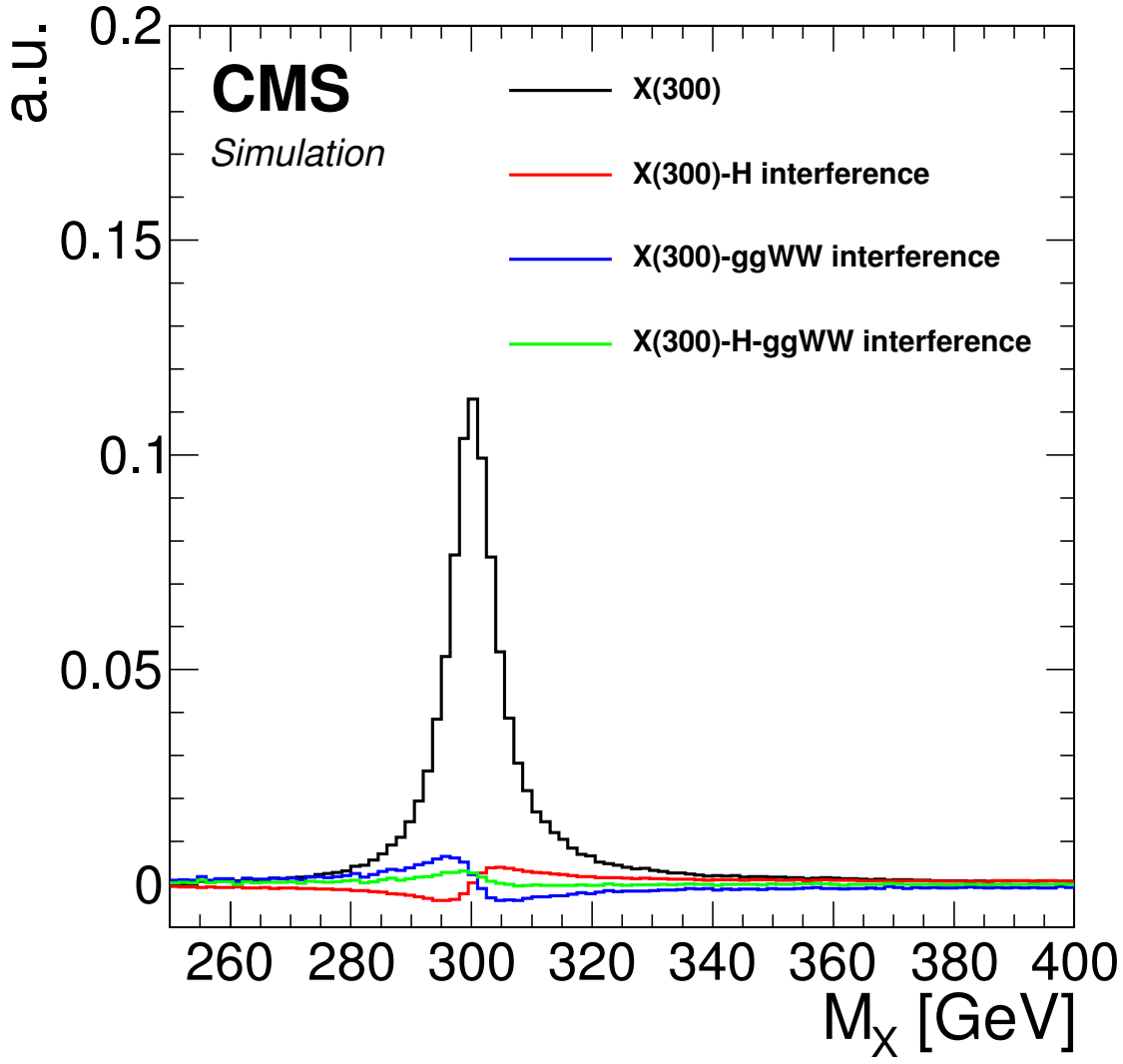


Summary

- Analyses of searching for high mass resonance decay to WW, ZZ-to-four-lepton, are updated with 13TeV data collected by CMS in 2015/2016.
- No significant excess is observed under a few hundred GeV to TeV resonance assumption. Upper limits on the cross section are set as a function of resonance mass and width.
- Data with full 2016 run are expected to be ~30fb^{-1}
  - Stay tune with results with 3 three time statistics in the near future!

Back up

Higgs to WW


CMS
Simulation
X(300)
X(300)-H interference
X(300)-ggWW interference
X(300)-H-ggWW interference
a.u.
0.2
0.15
0.1
0.05
0
260
280
300
320
340
360
380
400
M_X [GeV]

p-value scan

Mass [GeV]	$\Gamma = 0.09 \times \Gamma_{SM}$ p-value (signif.)	$\Gamma = 0.25 \times \Gamma_{SM}$ p-value (signif.)	$\Gamma = 0.49 \times \Gamma_{SM}$ p-value (signif.)	$\Gamma = \Gamma_{SM}$ p-value (signif.)
200	0.50 (0)	0.50 (0)	0.50 (0)	0.56 (0)
210	0.58 (0)	0.45 (0.1)	0.35 (0.4)	0.24 (0.7)
230	0.21 (0.8)	0.22 (0.8)	0.23 (0.7)	0.26 (0.6)
250	0.29 (0.5)	0.20 (0.8)	0.15 (1.0)	0.12 (1.2)
300	0.014 (2.2)	0.015 (2.2)	0.016 (2.1)	0.018 (2.1)
350	0.16 (1.0)	0.17 (1.0)	0.18 (0.9)	0.23 (0.7)
400	0.50 (0)	0.49 (0)	0.49 (0)	0.57 (0)
450	0.51 (0)	0.50 (0)	0.50 (0)	0.52 (0)
500	0.50 (0)	0.51 (0)	0.50 (0)	0.52 (0)
550	0.50 (0)	0.51 (0)	0.51 (0)	0.51 (0)
600	0.50 (0)	0.50 (0)	0.51 (0)	0.51 (0)
650	0.50 (0)	0.50 (0)	0.54 (0)	0.50 (0)
700	0.50 (0)	0.50 (0)	0.50 (0)	0.50 (0)
750	0.50 (0)	0.54 (0)	0.50 (0)	0.40 (0.3)
800	0.50 (0)	0.55 (0)	0.39 (0.3)	0.29 (0.6)
900	0.29 (0.6)	0.27 (0.6)	0.24 (0.7)	0.22 (0.8)
1000	0.18 (0.9)	0.18 (0.9)	0.18 (0.9)	0.18 (0.9)

Higgs to ZZ to four leptons

Limits for pure VBF production