Search for a high mass scalar decaying to WW in the di-leptonic channel on 2016 CMS data ($X \rightarrow WW \rightarrow 2\ell 2\nu$)

Alessandro Da Rold, Negin Shafiei, Thomas Kello, Giulio Mandorli
Dimitrios Sidiropoulos Kontos, Gourab Saha, Davide Valsecchi, Suvankar Roy Chowdhury

Facilitators: Piergiulio Lenzi, Lorenzo Viliani, Vitaliano Ciulli

Although we are named SMP group, we searched for BSM physics!!

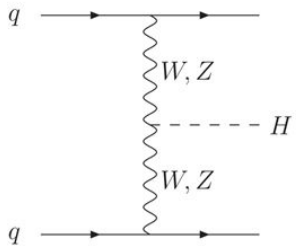
Motivation

- SM provides only one Higgs at 125 GeV

- 125 GeV Higgs might be a part of a larger scalar sector and partially responsible for EW symmetry breaking

- High mass scalar particles can prove vacuum stability up to high energy scale which is also incorporated in 2HDM, Type II SeeSaw Model etc.

Signal & Backgrounds



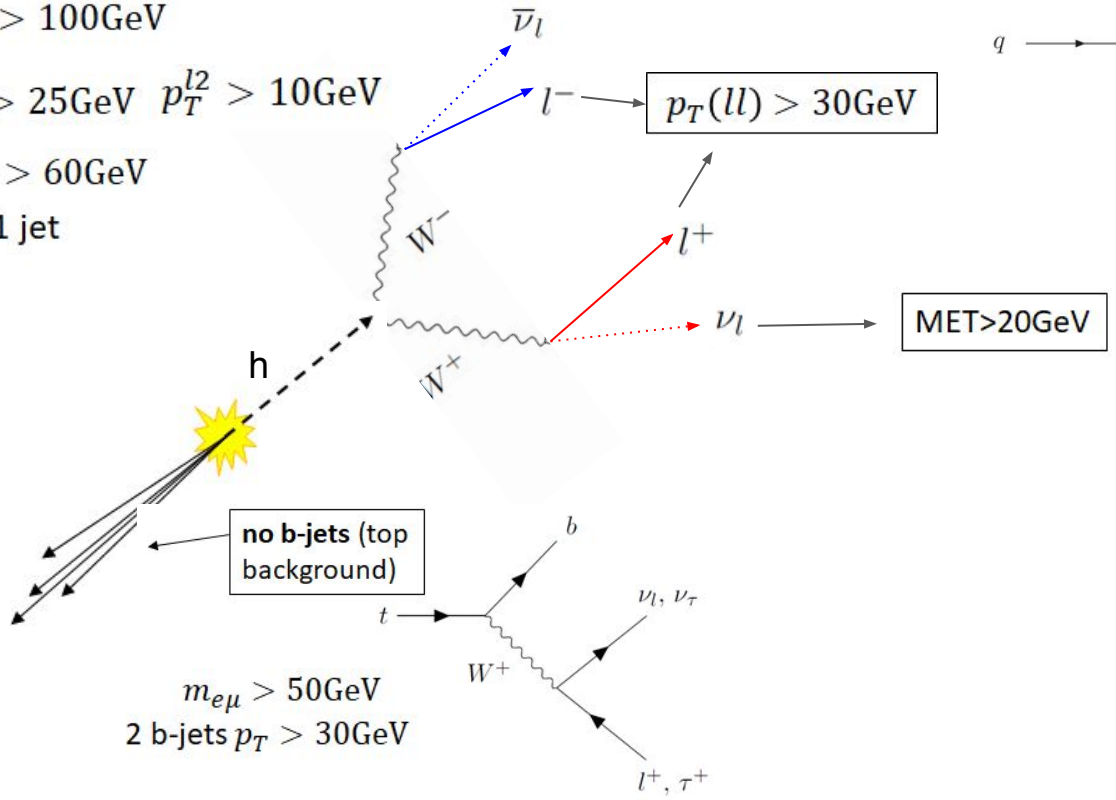
njet>=2 , detajj>3.5
In three categories
mjj>300, mjj>500, mjj>700

$m_{ll} > 100\text{GeV}$

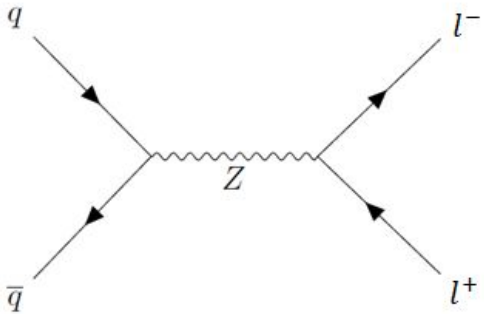
$p_T^{l1} > 25\text{GeV}$ $p_T^{l2} > 10\text{GeV}$

$m_{th} > 60\text{GeV}$

0 & 1 jet



$m_{e\mu} > 50\text{GeV}$
2 b-jets $p_T > 30\text{GeV}$



$Z \to ll$ background (DY)

$e\mu$ requested
no jets
$40\text{GeV} < m_{e\mu} < 80\text{GeV}$
$m_{th} < 60\text{GeV}$

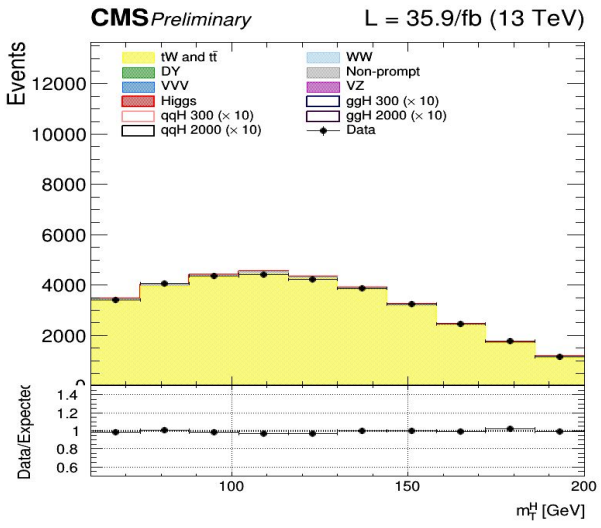
Objects and Triggers (2016 CMS data)

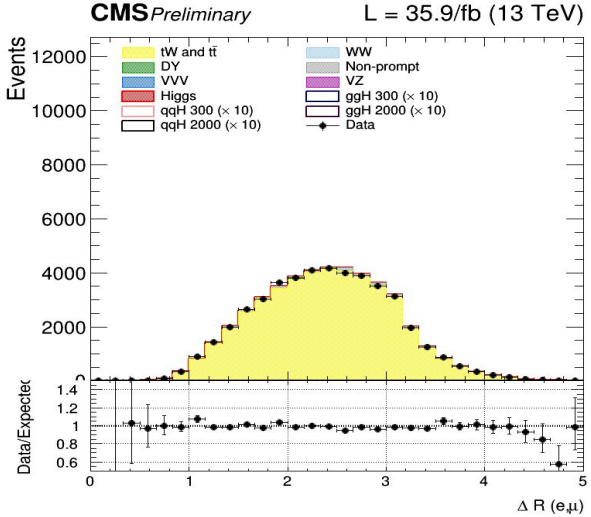
- Trigger
  - **Single Lepton**: HLT_IsoMu24, HLT_IsoTkMu24, HLT_Ele27_WPTight_Gsf, HLT_Ele25_eta2p1_WPTight Gsf
  - **MuonEG**: HLT_Mu8_TrkIsoVVL_Ele23_CaloIdL_TrackIdL_IsoVL, HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL,HLT_Mu12_TrkIsoVVL_Ele23_CaloIdL_TrackIdL_IsoVL_DZ, HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL_DZ
- Muons & Electron
  - Identification and Isolation as used in HIG-16-042 (HWW analysis with 2016 dataset)
- Preselection
  - Presence of an electron-muon pair
  - Leading lepton pt > 25 GeV sub-leading lepton > 10 GeV
  - PFMET > 20 GeV
  - m_{ll} > 12 GeV
  - pT_{ll} > 30 GeV

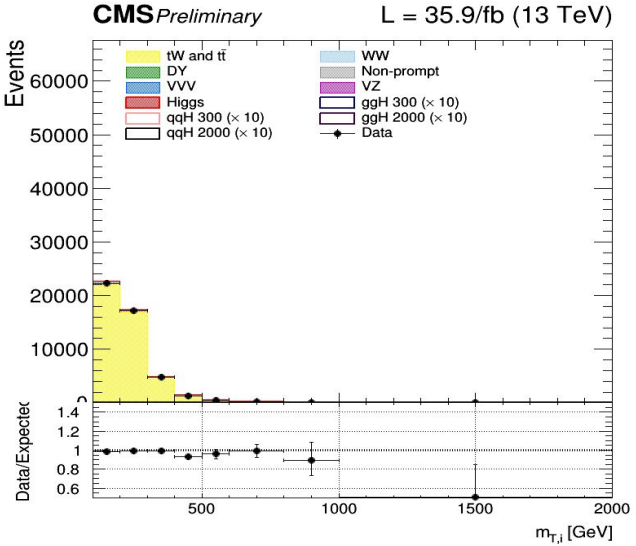
Signal and control region selection

- Normalisation of three main background free in the fit
- DY and t t-bar contribution estimated in control regions
- WW normalization is constrained in signal region
- Control Regions:
  - DY to $\tau\tau$: m_{th} < 60 GeV, 40 < m(eμ) < 80 GeV
  - Top: m(eμ) > 50 GeV, 2-bjets with pT > 30 GeV
- Signal Region:
  - m_{ll}>100 GeV, m_{th} > 60 GeV , bjet veto (Inclusive)
  - 0-jet : pTj < 30 GeV
  - 1-jet
  - VBF: njet>=2 , detajj>3
  - We optimize VBF in three categories of mass :mjj>300 , mjj>500, mjj>700

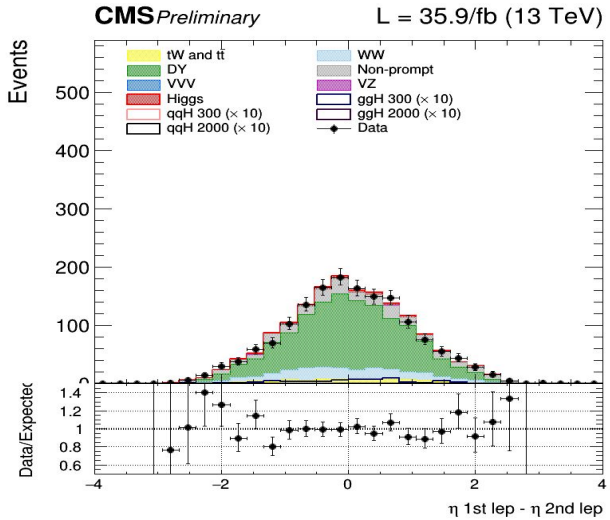
Top control region

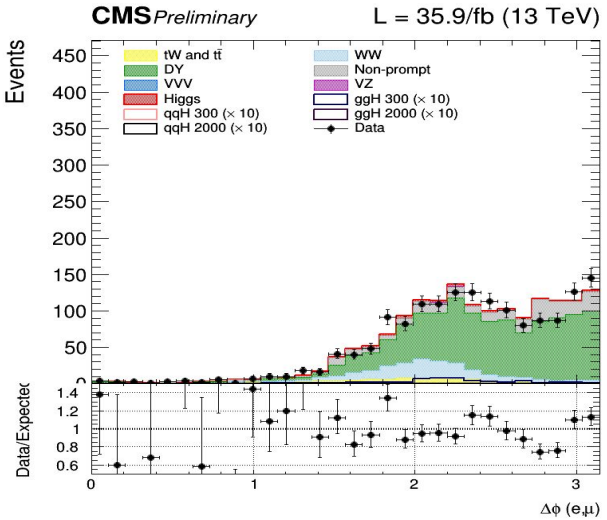


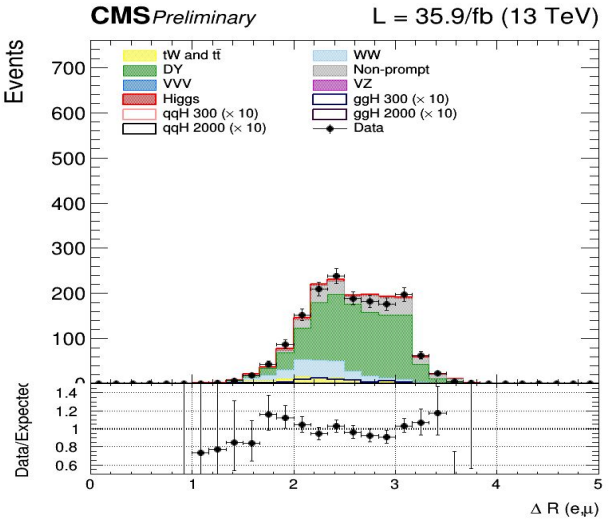




DY control region





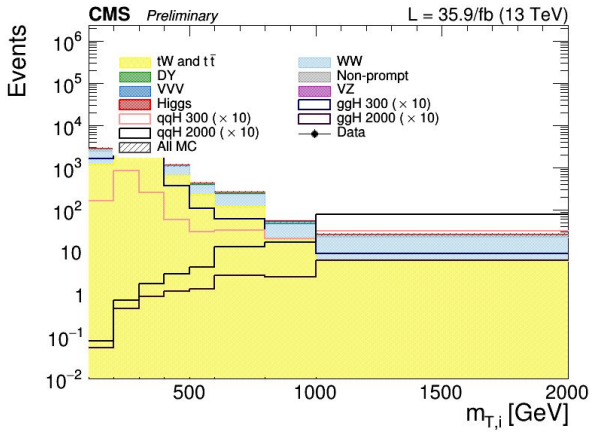


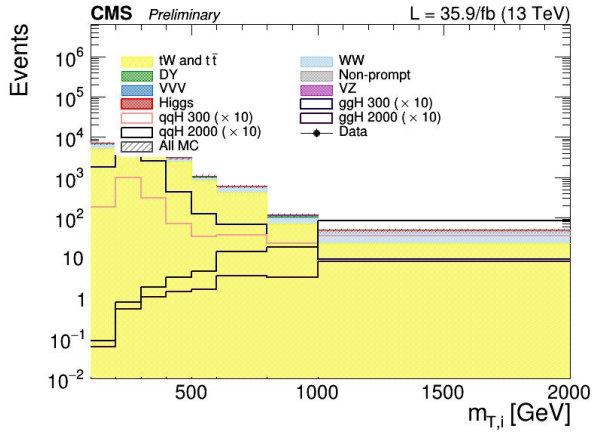
Systematics

- **QCD scale: theoretical uncertainty**
- **Luminosity:** 2.5% uncertainty, does not affect fitted backgrounds (TTJets, DY, WW)
- **B-tagging** (both for heavy and light flavour quarks), **trigger efficiency, electron and muon energy scale:** uncertainty on scale factors with a weight
- **Jet energy scale:** varied trees must be computed, affects also **MET** distribution
- **Monte Carlo statistics:** fitting procedure in control regions affected by limited statistics of simulation

Inclusive analysis: optimisation of the b-veto WPs

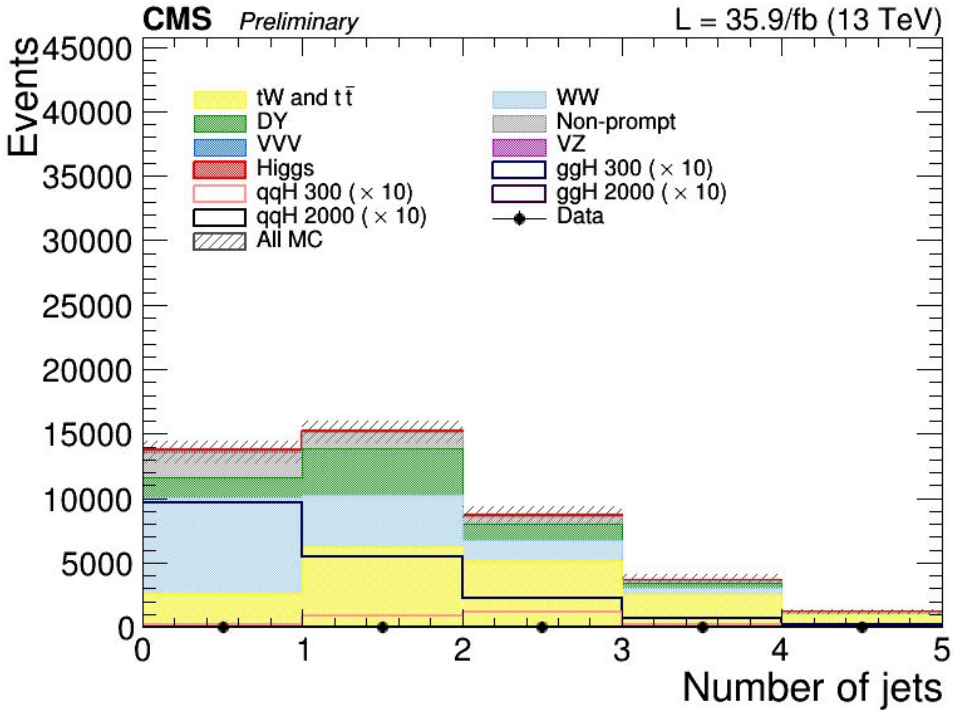
	Loose WP		Medium WP		Tight WP	
Mass	**300GeV**	**2Tev**	**300GeV**	**2TeV**	**300GeV**	**2TeV**
Significance	*2.72*	*1.35*	*2.268*	*1.20*	*1.86*	*1.05*
Limit	*0.6895*	*1.5*	*0,839*	*1.68*	*1.027*	*1.92*





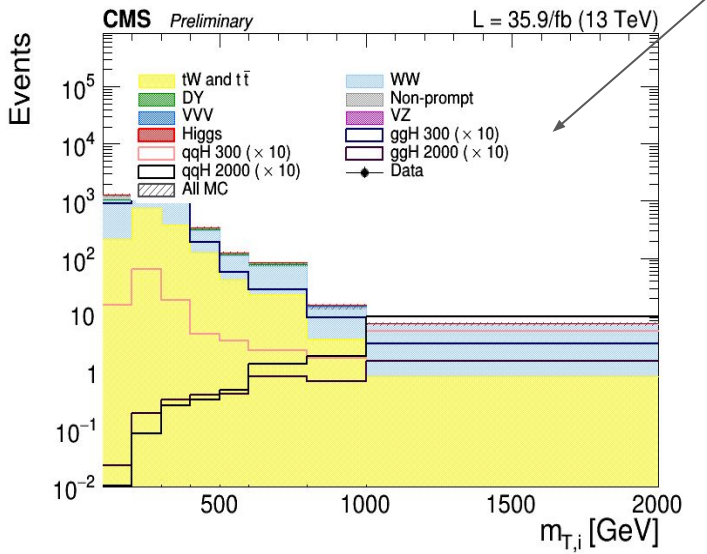
Shape analysis with jet categories

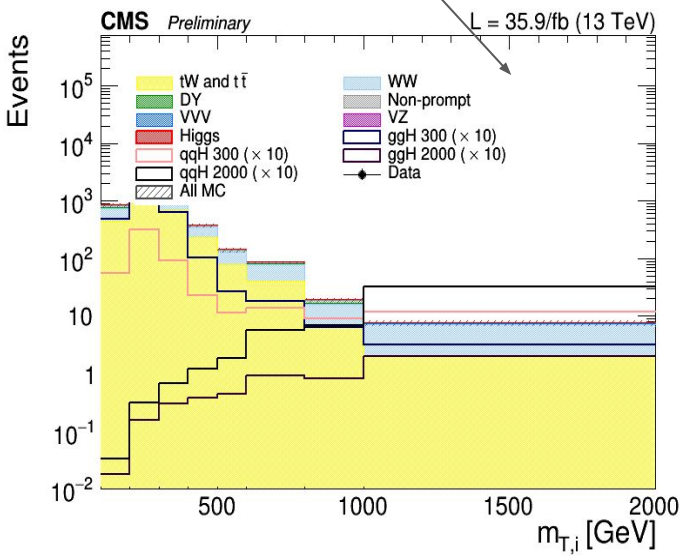
- Distinguish different backgrounds with number of jets categories
- Better significance and limits combining all the exclusive measurements
- **2-jet:** main signal contribution VBF: two separated jets and high invariant mass to enhance the significance (next slide)



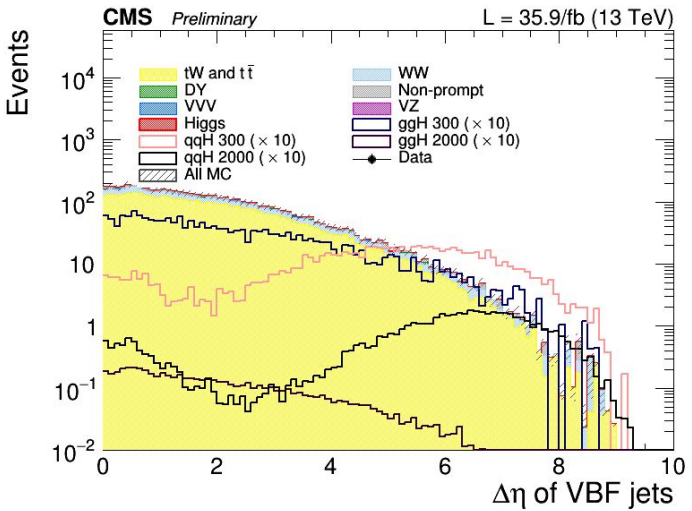
Combined final results (0-jet & 1-jet)

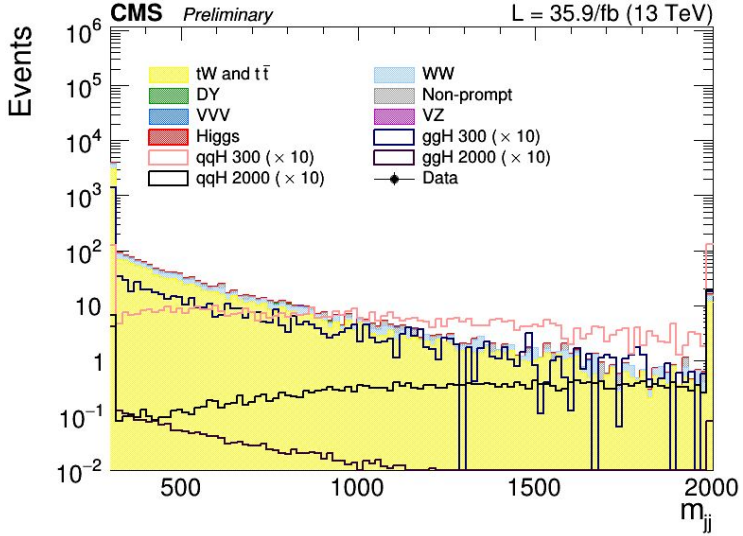
	0-jet		1-jet	
Mass	**300 GeV**	**2 TeV**	**300 GeV**	**2 TeV**
Significance	*2.27*	*0.37*	*1.538*	*1.00*
Limit	*0.8*	*6.28*	*1.195*	*2.13*



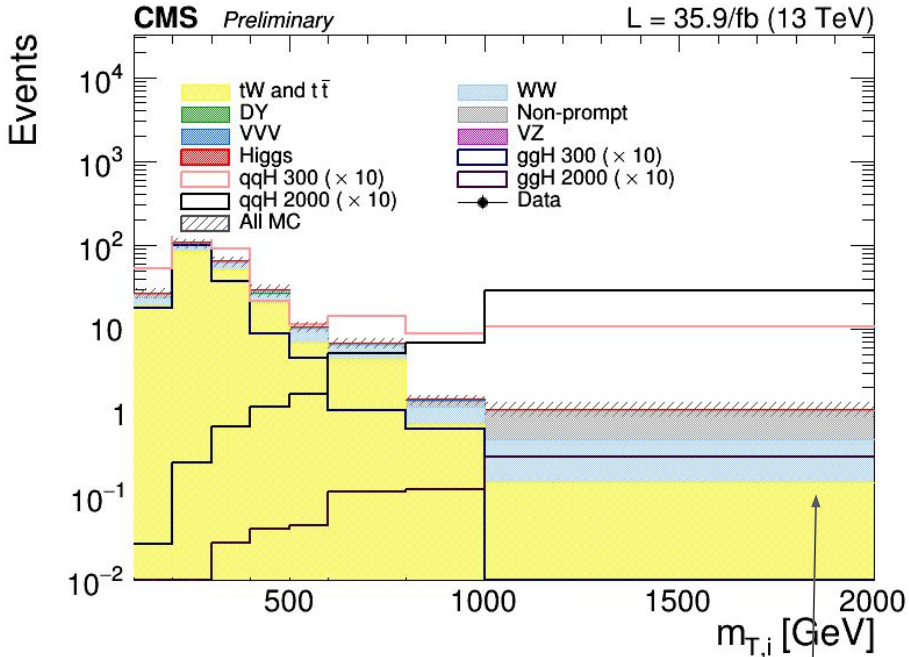


VBF category cut optimization





detajj> 3.5, Mjj > 500 GeV



The gluon fusion contribution decreases at high mass in this category

VBF working point choice

	2j		2j + Δη		2j + Δη + 300		2j + Δη + 500		2j + Δη + 700	
Mass	**300 GeV**	**2 TeV**	**300 GeV**	**2 TeV**	**300 GeV**	**2 TeV**	**300 GeV**	**2 TeV**	**300 GeV**	**2 TeV**
Significance	*0.44*	*0.81*	*0.82*	*1.35*	*0.85*	*1.42*	*1.12*	*1.50*	*1.28*	*1.80*
Limit	*4.4*	*2.55*	*2.26*	*1.51*	*2.11*	*1.46*	*1.55*	*1.37*	*1.33*	*1.19*

Combination of jet analysis

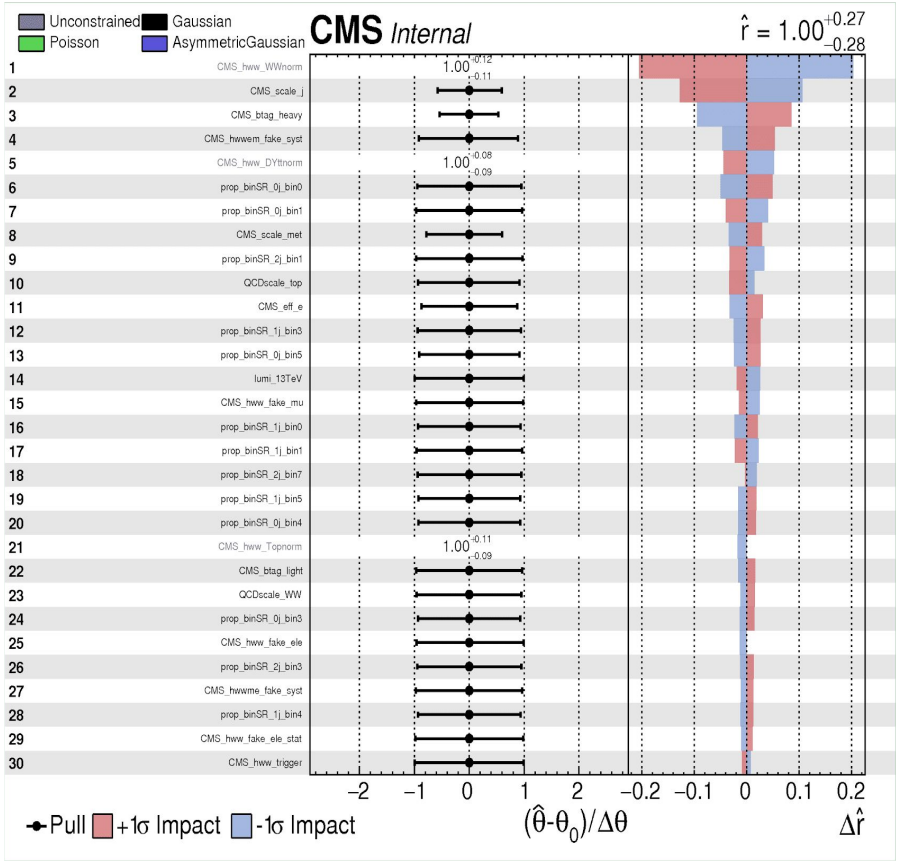
INCLUSIVE

	300 GeV	2 TeV
Expeted Significance	2.72	1.35
Expected Limit	0.69	1.5

JET COMBINATION

	300 GeV	2 TeV
Expected Significance	3.53	2.20
Expected Limit	0.50	0.94

300 GeV



Conclusion

We search for a high mass resonance using the 2016 data

We studied background rejection and signal region categorization

We included experimental and theoretical systematics and produced expected limits and expected significances in SM-like Higgs hypothesis for different masses

We had fun!

BACKUP

Data and simulations

Signal

- Scalar (300 GeV, 2 TeV) produced in gluon-gluon fusion → 0-jet, 1-jet
- Scalar (300 GeV, 2TeV) produced in vector-boson fusion → 2-jet

Backgrounds

- DY to tau tau
- TTJets
- WW
- GluGluHToWWTo2L2NuPowheg_M125
- VBFHToWWTo2L2NuPowheg_M125
- VVV

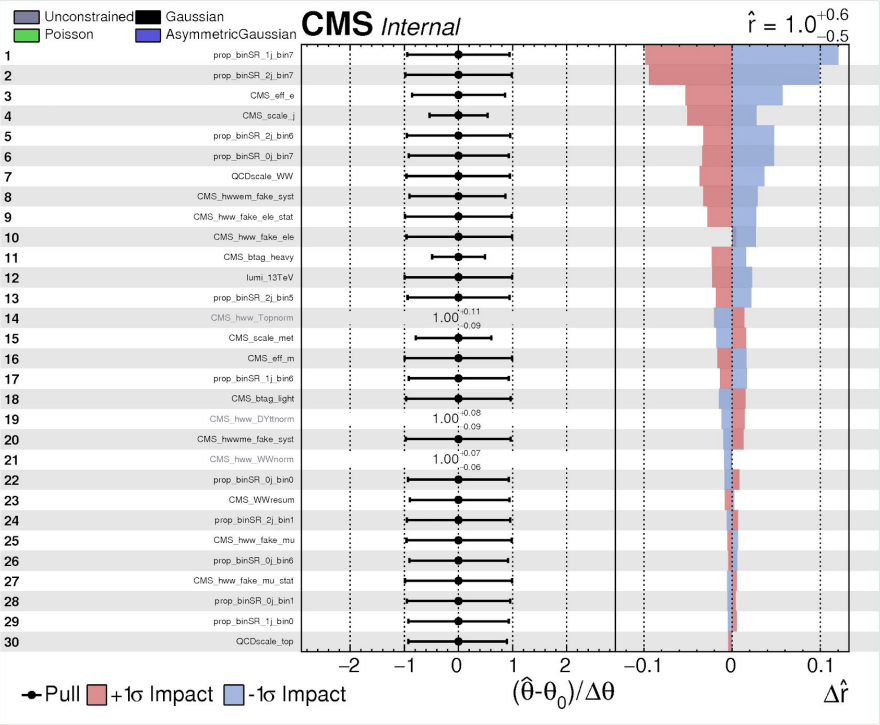
...

Data

Full 2016 dataset, 36 fb-1

- SingleElectron
- SingleMuon
- DoubleMuon
- DoubleEG
- MuonEG

2000 GeV


Unconstrained
Gaussian
Poisson
AsymmetricGaussian
CMS Internal
$\hat{r} = 1.0^{+0.6}_{-0.5}$
1 prop_binSR_1j_bin7
2 prop_binSR_2j_bin7
3 CMS_eff_e
4 CMS_scale_j
5 prop_binSR_2j_bin6
6 prop_binSR_0j_bin7
7 QCDscale_WW
8 CMS_hwwem_fake_syst
9 CMS_hww_fake_ele_stat
10 CMS_hww_fake_ele
11 CMS_btag_heavy
12 lumi_13TeV
13 prop_binSR_2j_bin5
14 CMS_hww_Topnorm
15 CMS_scale_met
16 CMS_eff_m
17 prop_binSR_1j_bin6
18 CMS_btag_light
19 CMS_hww_DYttnorm
20 CMS_hwwme_fake_syst
21 CMS_hww_WWnorm
22 prop_binSR_0j_bin0
23 CMS_WWresum
24 prop_binSR_2j_bin1
25 CMS_hww_fake_mu
26 prop_binSR_0j_bin6
27 CMS_hww_fake_mu_stat
28 prop_binSR_0j_bin1
29 prop_binSR_1j_bin0
30 QCDscale_top
$1.00^{+0.11}_{-0.09}$
$1.00^{+0.08}_{-0.09}$
$1.00^{+0.07}_{-0.06}$
−2 −1 0 1 2
−0.1 0 0.1
Pull
+1σ Impact
-1σ Impact
$(\hat{\theta}-\theta_0)/\Delta\theta$
$\Delta\hat{r}$