Search for Anomalous Electroweak Production of WW/WZ/ZZ Boson Pairs in Association with two Jets in p-p Collision at 13 TeV

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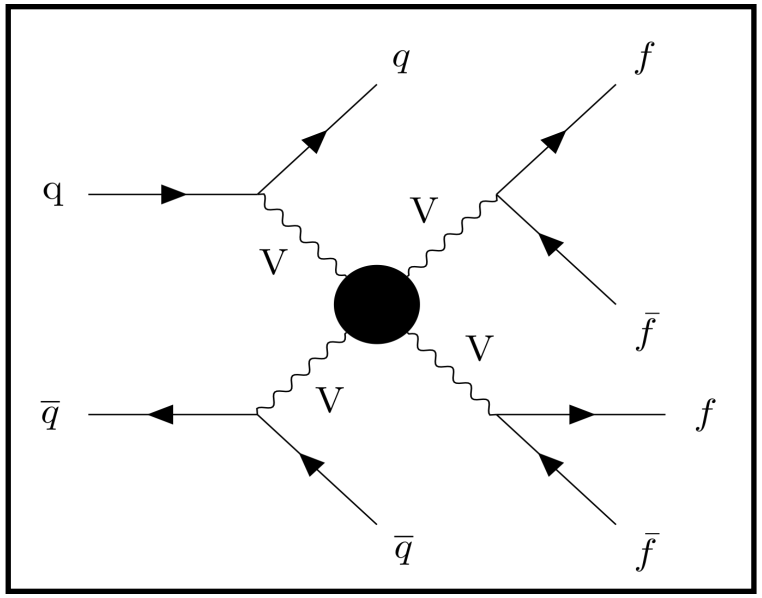
Vector Boson Scattering

- Without Higgs, vector boson scattering cross section would violate unitarity at the TeV scale.

- Vector boson scattering at the LHC probes triple and quartic gauge couplings

- Anomalous triple and quartic gauge couplings (aTGC, aQGC) would indicate the presence of new physics
    - Increases the cross-section at large di-boson mass and transverse momentum.
    - sensitive to new physics contributions in the kinematic tail.

- Anomalous couplings can be introduced as a model independent way using Effective Field Theory (EFT).



aQGC in the EFT Framework

- BSM search using model independent way:
  - Modify triple and quartic gauge couplings by redefining SM Lagrangian.

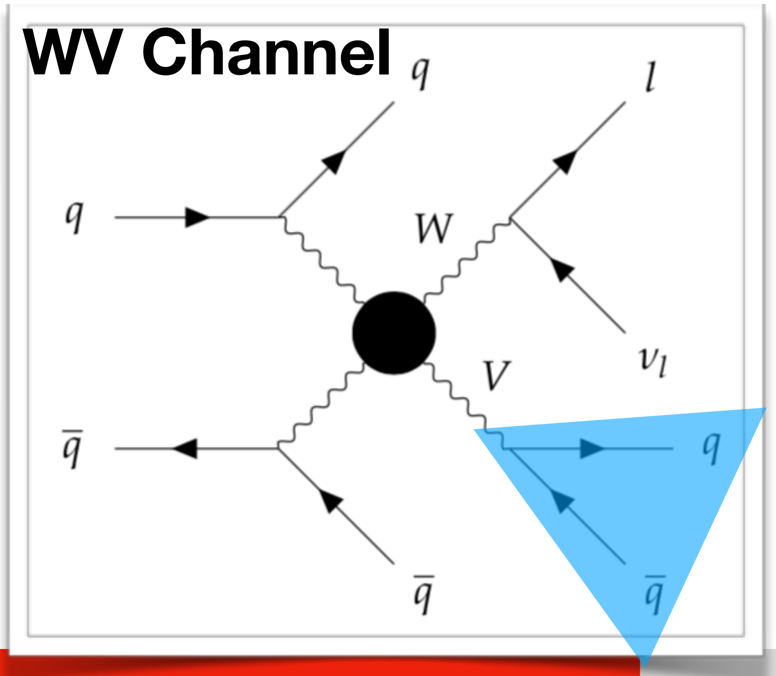
$$L_{SM} \longrightarrow L_{eff} = L_{SM} + \sum_{n=1}^{\infty}\sum_{i}\frac{c_i^{(n)}}{\Lambda^n}\mathcal{O}_I^{(n+4)}$$

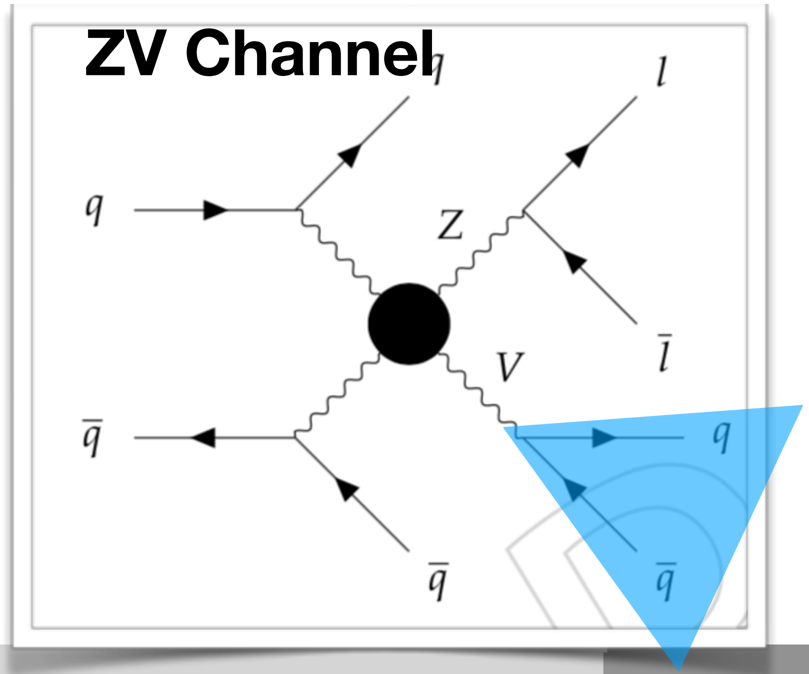
  - $\Lambda >> m$ & $L_{eff} \rightarrow L_{sm}$ as $\Lambda \rightarrow \infty$
  - An effective field theory is the low energy approximation to the new physics, where “low” means < Λ

	$WWWW$	$WWZZ$	$WW\gamma Z$	$WW\gamma\gamma$	$ZZZZ$	$ZZZ\gamma$	$ZZ\gamma\gamma$	$Z\gamma\gamma\gamma$	$\gamma\gamma\gamma\gamma$
$\mathcal{O}_{S,0}, \mathcal{O}_{S,1}$	✓	✓			✓				
$\mathcal{O}_{M,0}, \mathcal{O}_{M,1}, \mathcal{O}_{M,6}, \mathcal{O}_{M,7}$	✓	✓	✓	✓	✓	✓	✓		
$\mathcal{O}_{M,2}, \mathcal{O}_{M,3}, \mathcal{O}_{M,4}, \mathcal{O}_{M,5}$		✓	✓	✓	✓	✓	✓		
$\mathcal{O}_{T,0}, \mathcal{O}_{T,1}, \mathcal{O}_{T,2}$	✓	✓	✓	✓	✓	✓	✓	✓	✓
$\mathcal{O}_{T,5}, \mathcal{O}_{T,6}, \mathcal{O}_{T,7}$		✓	✓	✓	✓	✓	✓	✓	✓
$\mathcal{O}_{T,8}, \mathcal{O}_{T,9}$					✓	✓	✓	✓	✓

Introduction & Motivation-II

- WV/ZV production in association with two jets
    - Semi-leptonic final state with a boosted hadronic W/Z
- **Benefits**:
    - larger branching ratio than same sign analysis.
    - Full WW invariant mass reconstruction (neutrino p_z calculation by constraining W-boson mass)
    - aQGC contribution from all possible vertex (for WVjj process):
        - WWWW, ZZWW, γγWW, γZWW, ZZZZ
    - **It should significantly improve the current limits.**

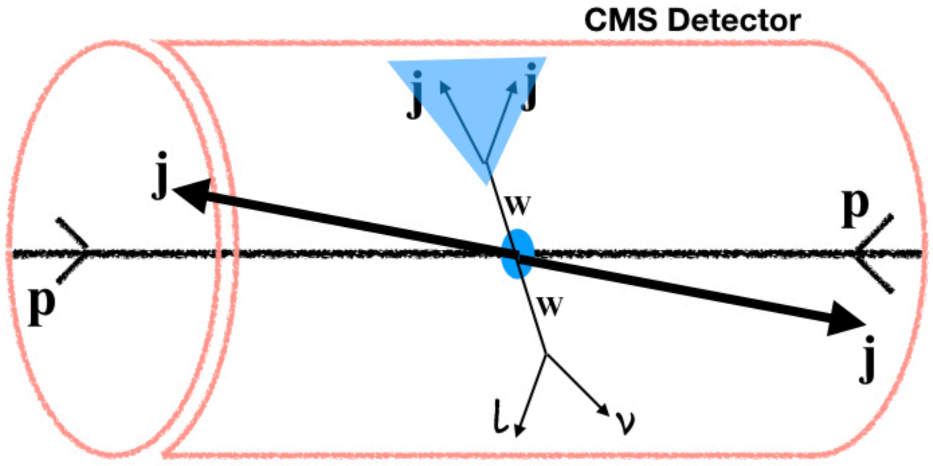

WV Channel


ZV Channel

Reconstructed as a merged jet

Signal Selection

- Optimised for aQGC sensitivity.



- V boson candidate (reconstructed as merged jet): $p_T > 200$ GeV, $|\eta|<2.4$, $65 < m_V < 105$ GeV
- VBS Topology:
    - High pseudo-rapidity gap between VBF jets: $\Delta\eta_{jj} > 4.0$
    - Larger di-jet invariant mass: $M_{jj} > 800$ GeV
- Additional requirement to enhance aQGC:
    - Zeppenfeld Variable : $Z = \dfrac{\eta - \dfrac{\eta_{j1}+\eta_{j2}}{2}}{|\eta_{j1}-\eta_{j2}|} \quad < \quad 0.3$
    - Centrality:

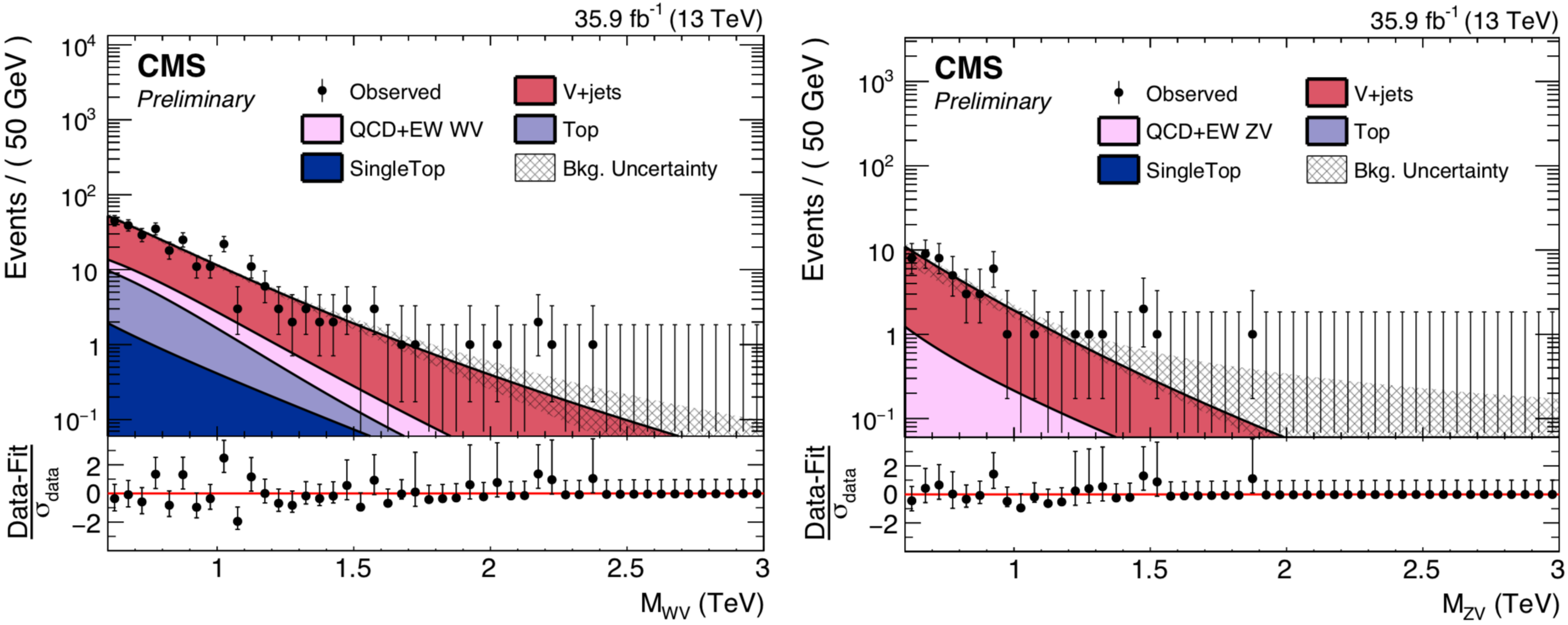
$$\xi_V = min\{\Delta\eta_-, \Delta\eta_+\} > 1.0$$

where,

$$\Delta\eta_- = min\{\eta(V_{had}), \eta(V_{lep})\} - min\{\eta_{j1}, \eta_{j2}\},$$
$$\Delta\eta_+ = max\{\eta_{j1}, \eta_{j2}\} - max\{\eta(V_{had}), \eta(V_{lep})\}$$

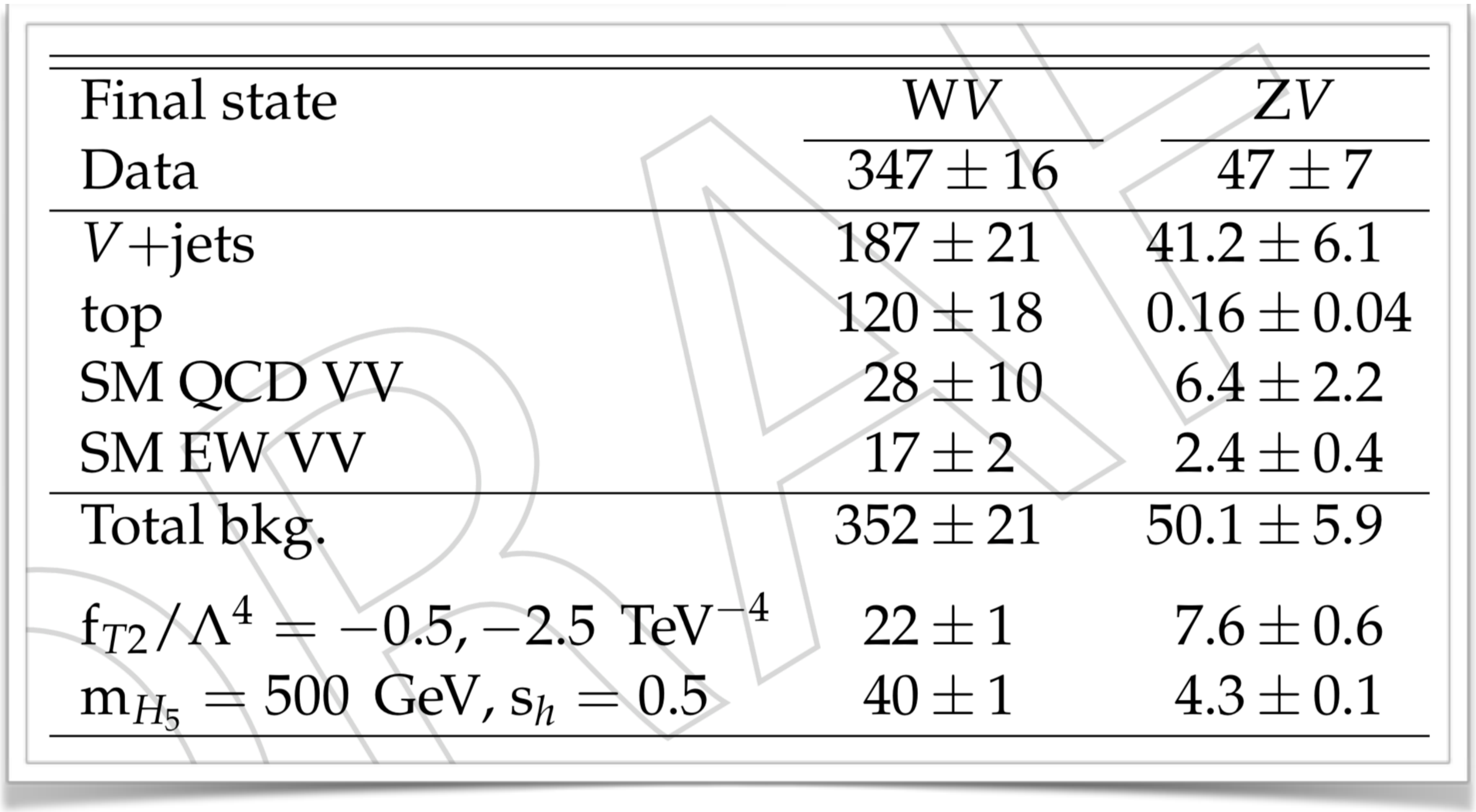
Data driven background estimation for W(Z)+jets

- Large background from W (Z) + jets
    - Extrapolate data from side-band to signal region using transfer function (from simulation)
    - Accounts for data-MC differences in shape and normalisation.
- QCD initiated VV contribution taken from simulation (LO Madgraph)
- ttbar and single top background checked in top enriched control region



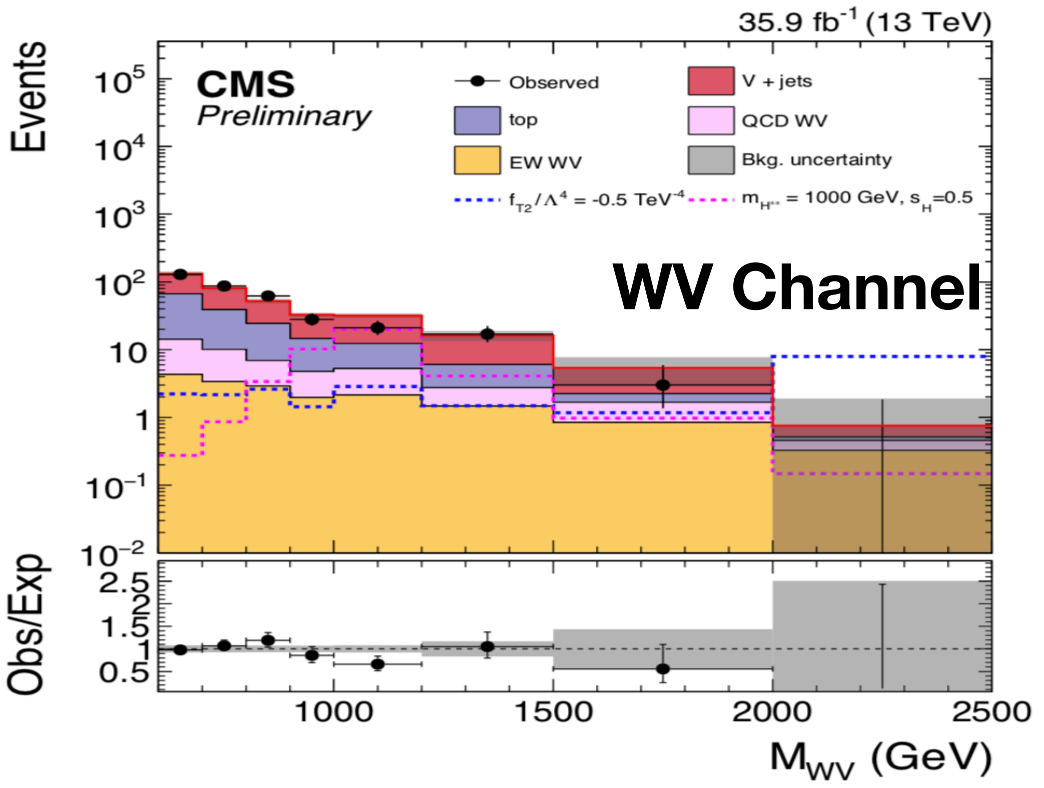
WV/ZV Signal Extraction

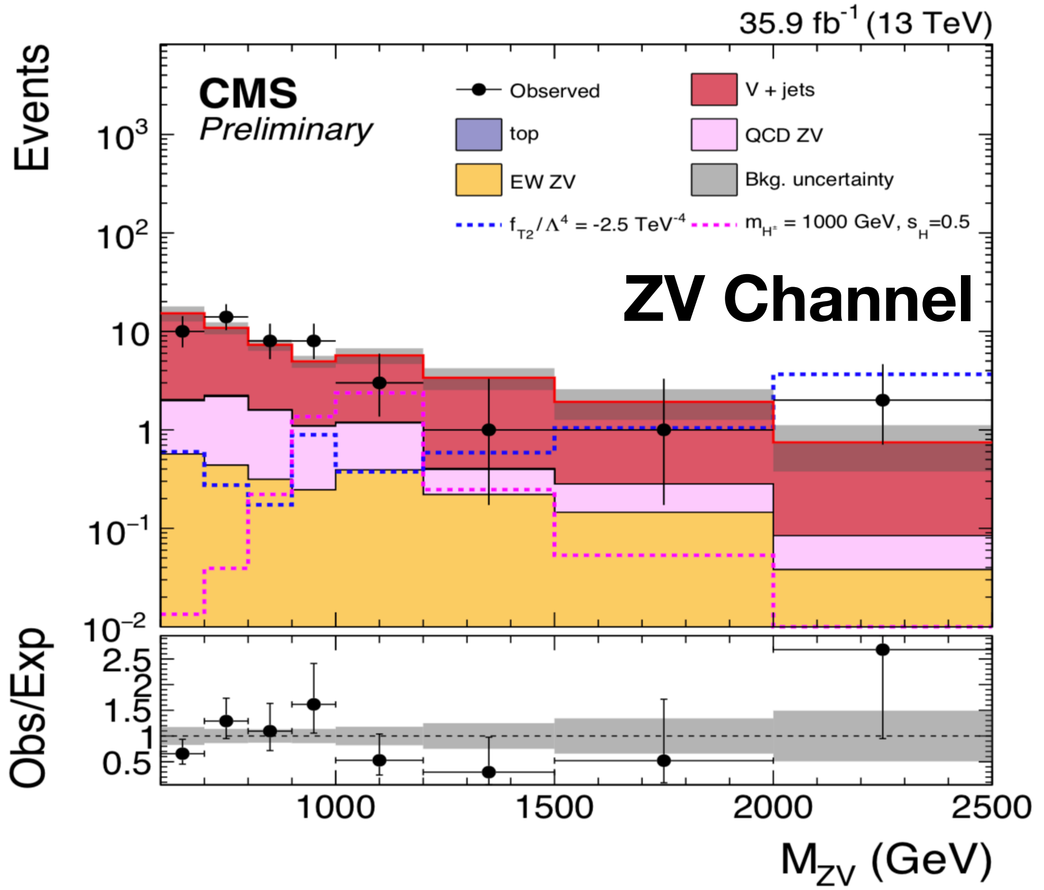
- We used M_{VV} distribution to get the limits for both WV and ZV channel.
    - SM EWK production is treated as background.



Final state	WV	ZV
Data	347 ± 16	47 ± 7
V+jets	187 ± 21	41.2 ± 6.1
top	120 ± 18	0.16 ± 0.04
SM QCD VV	28 ± 10	6.4 ± 2.2
SM EW VV	17 ± 2	2.4 ± 0.4
Total bkg.	352 ± 21	50.1 ± 5.9
$f_{T2}/\Lambda^4 = -0.5, -2.5$ TeV^{-4}	22 ± 1	7.6 ± 0.6
$m_{H_5} = 500$ GeV, $s_h = 0.5$	40 ± 1	4.3 ± 0.1

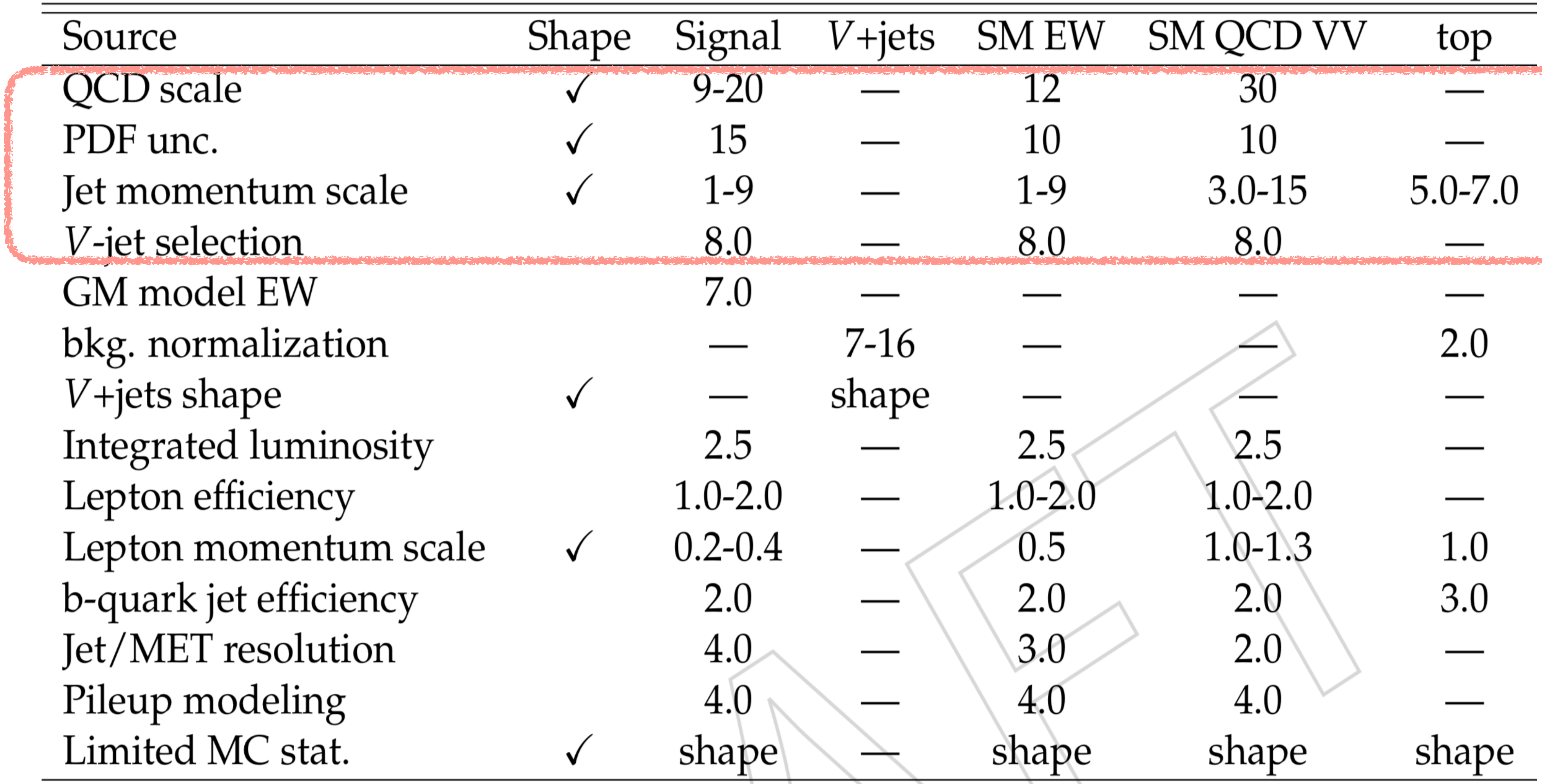
- Before doing this we estimated W+jets (for WV channel) and Z+jets (for ZV channel) in data driven way.





Systematic Uncertainty

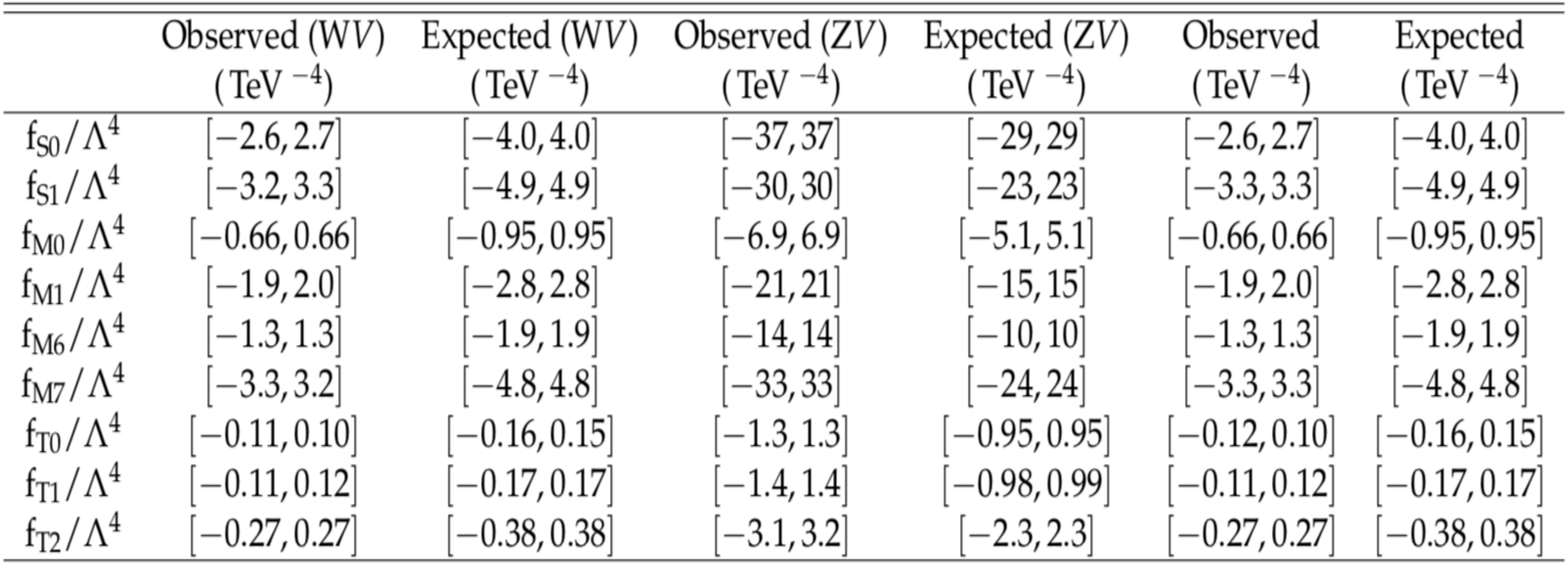
- Systematic uncertainty can affect the shape and normalisation of the M_W distribution.
  - Largest impact is from signal theory uncertainty.
  - Experimental uncertainty is mainly dominated by jet energy scale/resolution and V+jet background estimation.



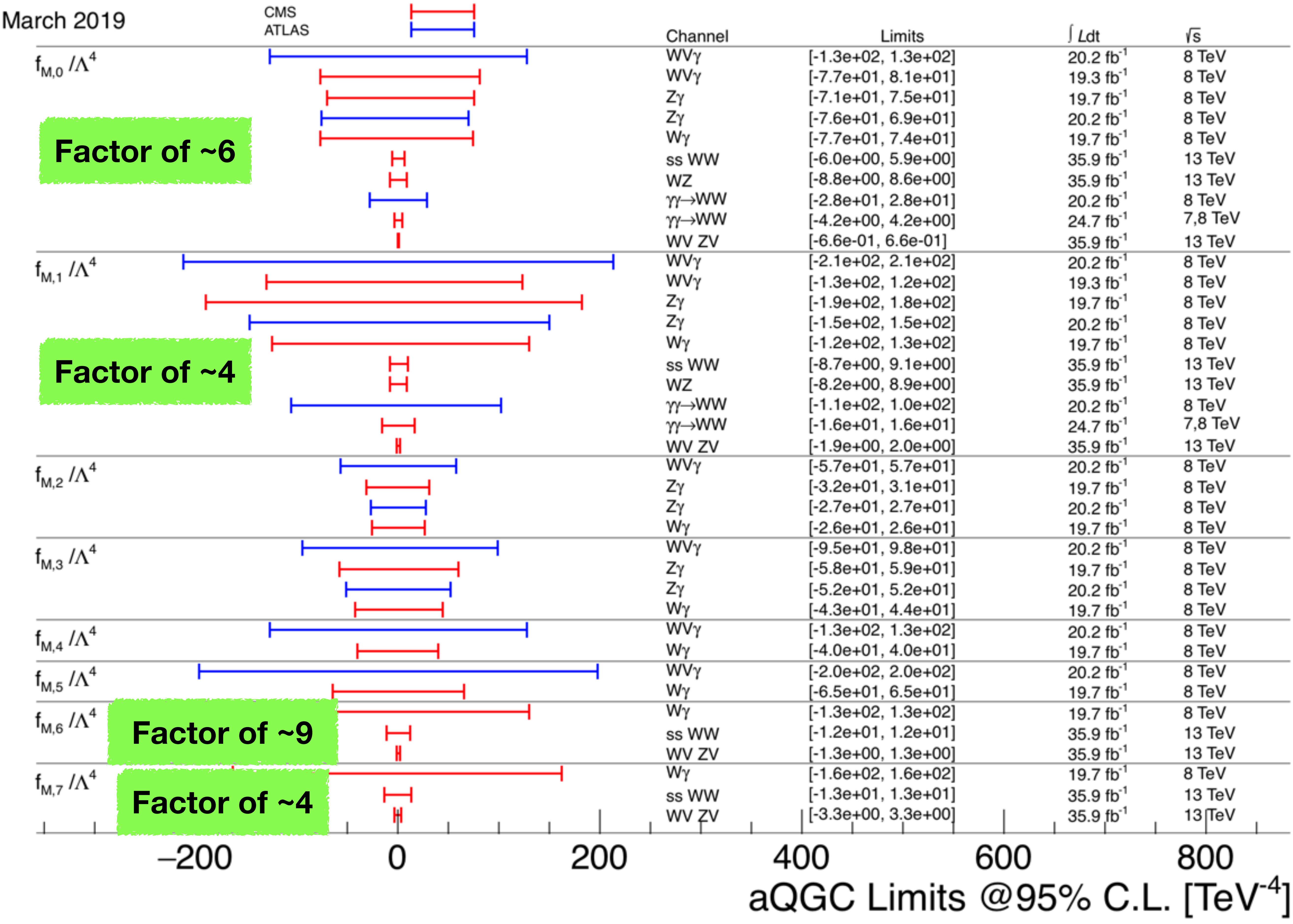
Source	Shape	Signal	*V*+jets	SM EW	SM QCD VV	top
QCD scale	✓	9-20	—	12	30	—
PDF unc.	✓	15	—	10	10	—
Jet momentum scale	✓	1-9	—	1-9	3.0-15	5.0-7.0
V-jet selection		8.0	—	8.0	8.0	—
GM model EW		7.0	—	—	—	—
bkg. normalization		—	7-16	—	—	2.0
V+jets shape	✓	—	shape	—	—	—
Integrated luminosity		2.5	—	2.5	2.5	—
Lepton efficiency		1.0-2.0	—	1.0-2.0	1.0-2.0	—
Lepton momentum scale	✓	0.2-0.4	—	0.5	1.0-1.3	1.0
b-quark jet efficiency		2.0	—	2.0	2.0	3.0
Jet/MET resolution		4.0	—	3.0	2.0	—
Pileup modeling		4.0	—	4.0	4.0	—
Limited MC stat.	✓	shape	—	shape	shape	shape

Results – Anomalous Coupling Limits

- Limits for the WV and ZV final states and combination
  - As expected WV significantly more sensitive compared to ZV



	Observed (WV) (TeV $^{-4}$)	Expected (WV) (TeV $^{-4}$)	Observed (ZV) (TeV $^{-4}$)	Expected (ZV) (TeV $^{-4}$)	Observed (TeV $^{-4}$)	Expected (TeV $^{-4}$)
f_{S0}/Λ^4	$[-2.6, 2.7]$	$[-4.0, 4.0]$	$[-37, 37]$	$[-29, 29]$	$[-2.6, 2.7]$	$[-4.0, 4.0]$
f_{S1}/Λ^4	$[-3.2, 3.3]$	$[-4.9, 4.9]$	$[-30, 30]$	$[-23, 23]$	$[-3.3, 3.3]$	$[-4.9, 4.9]$
f_{M0}/Λ^4	$[-0.66, 0.66]$	$[-0.95, 0.95]$	$[-6.9, 6.9]$	$[-5.1, 5.1]$	$[-0.66, 0.66]$	$[-0.95, 0.95]$
f_{M1}/Λ^4	$[-1.9, 2.0]$	$[-2.8, 2.8]$	$[-21, 21]$	$[-15, 15]$	$[-1.9, 2.0]$	$[-2.8, 2.8]$
f_{M6}/Λ^4	$[-1.3, 1.3]$	$[-1.9, 1.9]$	$[-14, 14]$	$[-10, 10]$	$[-1.3, 1.3]$	$[-1.9, 1.9]$
f_{M7}/Λ^4	$[-3.3, 3.2]$	$[-4.8, 4.8]$	$[-33, 33]$	$[-24, 24]$	$[-3.3, 3.3]$	$[-4.8, 4.8]$
f_{T0}/Λ^4	$[-0.11, 0.10]$	$[-0.16, 0.15]$	$[-1.3, 1.3]$	$[-0.95, 0.95]$	$[-0.12, 0.10]$	$[-0.16, 0.15]$
f_{T1}/Λ^4	$[-0.11, 0.12]$	$[-0.17, 0.17]$	$[-1.4, 1.4]$	$[-0.98, 0.99]$	$[-0.11, 0.12]$	$[-0.17, 0.17]$
f_{T2}/Λ^4	$[-0.27, 0.27]$	$[-0.38, 0.38]$	$[-3.1, 3.2]$	$[-2.3, 2.3]$	$[-0.27, 0.27]$	$[-0.38, 0.38]$



	Channel	Limits	$\int Ldt$	$\sqrt{s}$
$f_{M,0}/\Lambda^4$	WVγ	[-1.3e+02, 1.3e+02]	20.2 fb^{-1}	8 TeV
	WVγ	[-7.7e+01, 8.1e+01]	19.3 fb^{-1}	8 TeV
	Zγ	[-7.1e+01, 7.5e+01]	19.7 fb^{-1}	8 TeV
	Zγ	[-7.6e+01, 6.9e+01]	20.2 fb^{-1}	8 TeV
	Wγ	[-7.7e+01, 7.4e+01]	19.7 fb^{-1}	8 TeV
	ss WW	[-6.0e+00, 5.9e+00]	35.9 fb^{-1}	13 TeV
	WZ	[-8.8e+00, 8.6e+00]	35.9 fb^{-1}	13 TeV
	γγ→WW	[-2.8e+01, 2.8e+01]	20.2 fb^{-1}	8 TeV
	γγ→WW	[-4.2e+00, 4.2e+00]	24.7 fb^{-1}	7,8 TeV
	WV ZV	[-6.6e-01, 6.6e-01]	35.9 fb^{-1}	13 TeV
$f_{M,1}/\Lambda^4$	WVγ	[-2.1e+02, 2.1e+02]	20.2 fb^{-1}	8 TeV
	WVγ	[-1.3e+02, 1.2e+02]	19.3 fb^{-1}	8 TeV
	Zγ	[-1.9e+02, 1.8e+02]	19.7 fb^{-1}	8 TeV
	Zγ	[-1.5e+02, 1.5e+02]	20.2 fb^{-1}	8 TeV
	Wγ	[-1.2e+02, 1.3e+02]	19.7 fb^{-1}	8 TeV
	ss WW	[-8.7e+00, 9.1e+00]	35.9 fb^{-1}	13 TeV
	WZ	[-8.2e+00, 8.9e+00]	35.9 fb^{-1}	13 TeV
	γγ→WW	[-1.1e+02, 1.0e+02]	20.2 fb^{-1}	8 TeV
	γγ→WW	[-1.6e+01, 1.6e+01]	24.7 fb^{-1}	7,8 TeV
	WV ZV	[-1.9e+00, 2.0e+00]	35.9 fb^{-1}	13 TeV
$f_{M,2}/\Lambda^4$	WVγ	[-5.7e+01, 5.7e+01]	20.2 fb^{-1}	8 TeV
	Zγ	[-3.2e+01, 3.1e+01]	19.7 fb^{-1}	8 TeV
	Zγ	[-2.7e+01, 2.7e+01]	20.2 fb^{-1}	8 TeV
	Wγ	[-2.6e+01, 2.6e+01]	19.7 fb^{-1}	8 TeV
$f_{M,3}/\Lambda^4$	WVγ	[-9.5e+01, 9.8e+01]	20.2 fb^{-1}	8 TeV
	Zγ	[-5.8e+01, 5.9e+01]	19.7 fb^{-1}	8 TeV
	Zγ	[-5.2e+01, 5.2e+01]	20.2 fb^{-1}	8 TeV
	Wγ	[-4.3e+01, 4.4e+01]	19.7 fb^{-1}	8 TeV
$f_{M,4}/\Lambda^4$	WVγ	[-1.3e+02, 1.3e+02]	20.2 fb^{-1}	8 TeV
	Wγ	[-4.0e+01, 4.0e+01]	19.7 fb^{-1}	8 TeV
$f_{M,5}/\Lambda^4$	WVγ	[-2.0e+02, 2.0e+02]	20.2 fb^{-1}	8 TeV
	Wγ	[-6.5e+01, 6.5e+01]	19.7 fb^{-1}	8 TeV
$f_{M,6}/\Lambda^4$	Wγ	[-1.3e+02, 1.3e+02]	19.7 fb^{-1}	8 TeV
	ss WW	[-1.2e+01, 1.2e+01]	35.9 fb^{-1}	13 TeV
	WV ZV	[-1.3e+00, 1.3e+00]	35.9 fb^{-1}	13 TeV
$f_{M,7}/\Lambda^4$	Wγ	[-1.6e+02, 1.6e+02]	19.7 fb^{-1}	8 TeV
	ss WW	[-1.3e+01, 1.3e+01]	35.9 fb^{-1}	13 TeV
	WV ZV	[-3.3e+00, 3.3e+00]	35.9 fb^{-1}	13 TeV

Factor of ~6

Factor of ~4

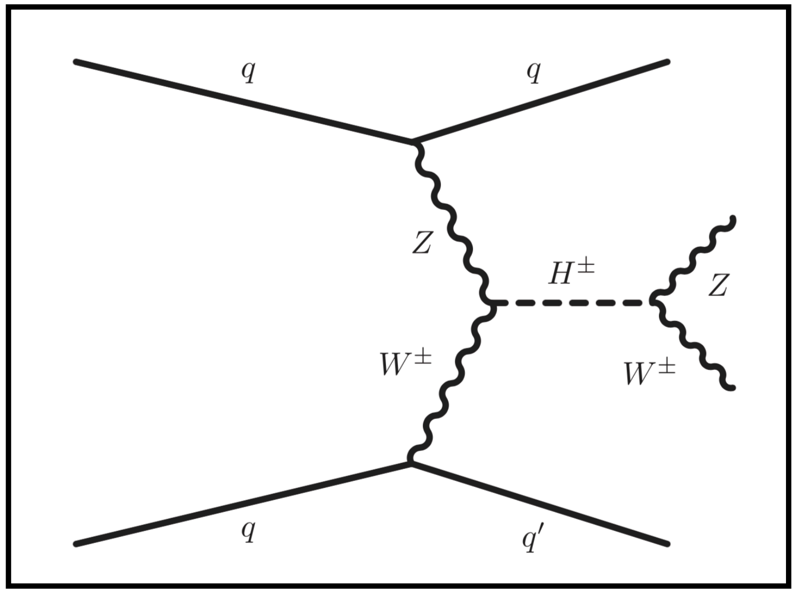
Factor of ~9

Factor of ~4

Introduction & Motivation-III

(Result interpretation using charged Higgs model)

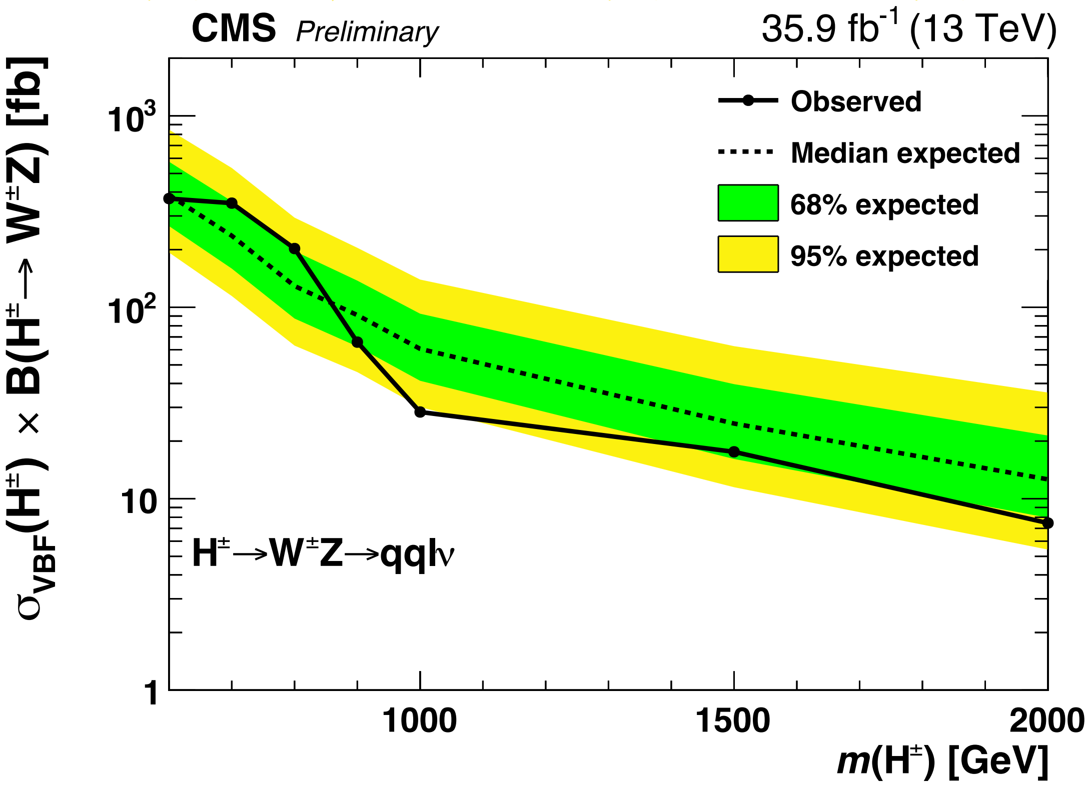
- Considering extended Higgs sector model: **Georgi, Machacek (GM) model**.
  - Extension of scalar sector using triplet Higgs field.
- Main feature:
  - Maintains custodial symmetry at tree level.
  - provides majorana mass to neutrino via Type-II Seesaw mechanism.

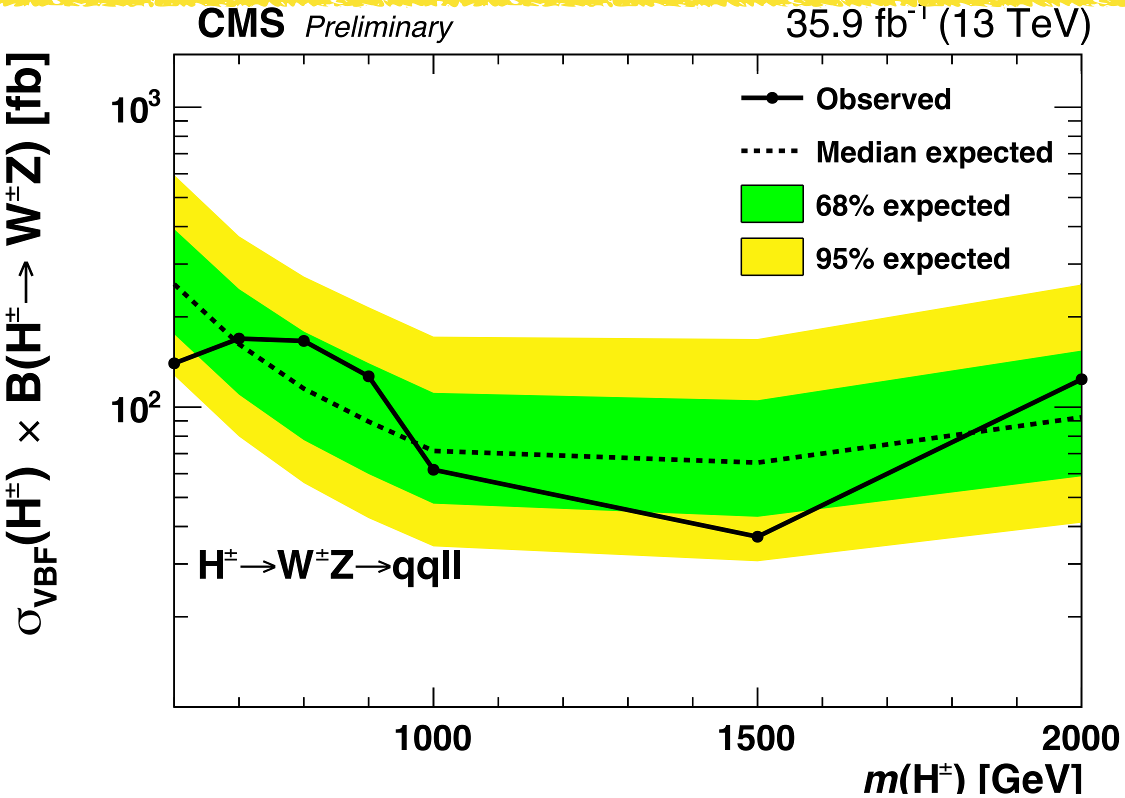


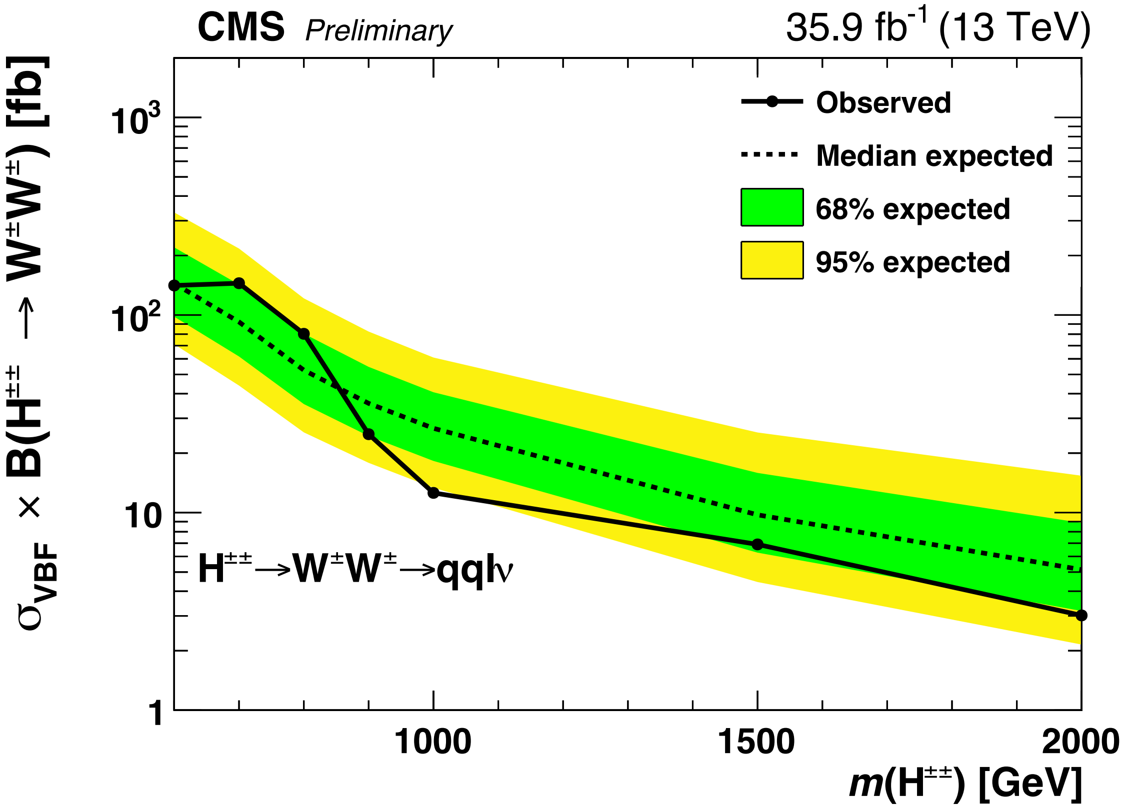
- It has triplet field:
  - Allows fermiophobic $H^{\pm\pm}$ and $H^{\pm}$produced via VBF.
  - Higher cross-section of $H^{\pm\pm} \rightarrow WW$

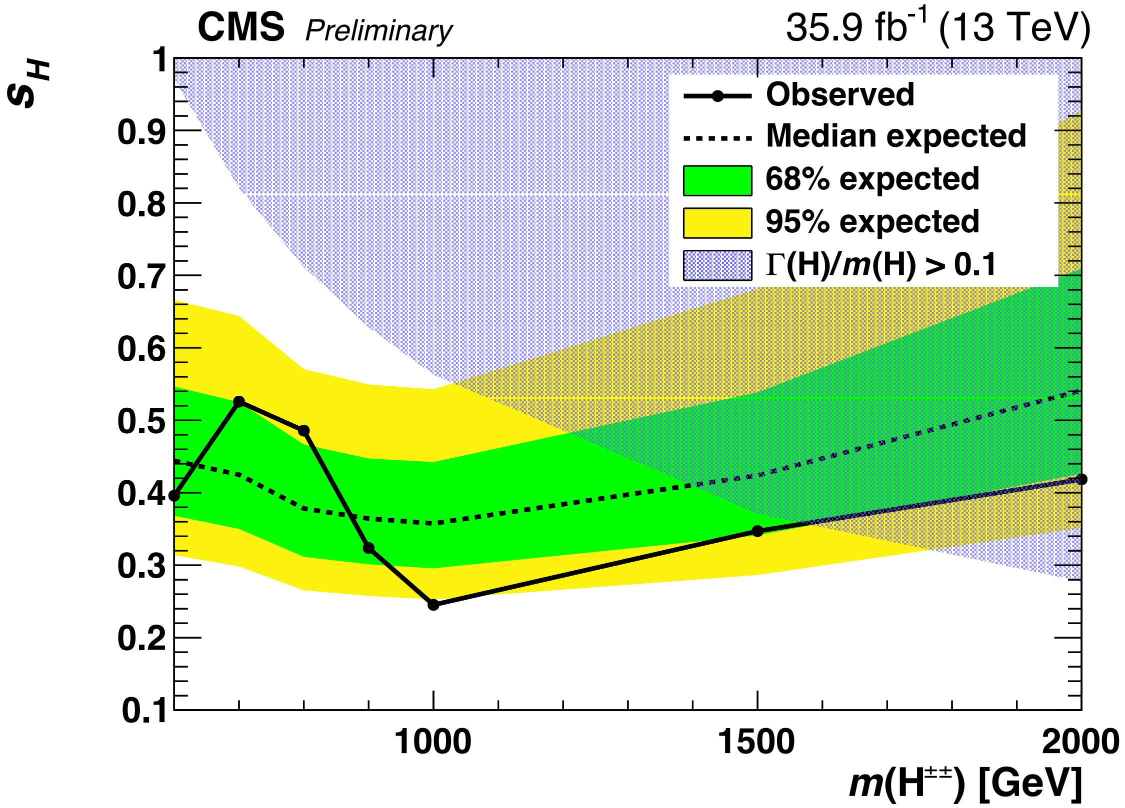
Charged Higgs Limits

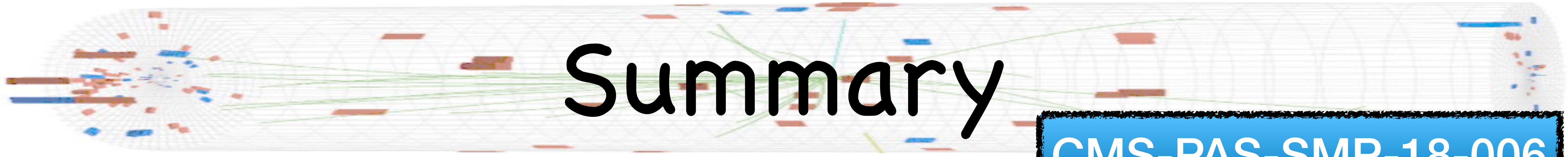
- Model independent limit on singly and doubly charged Higgs production.









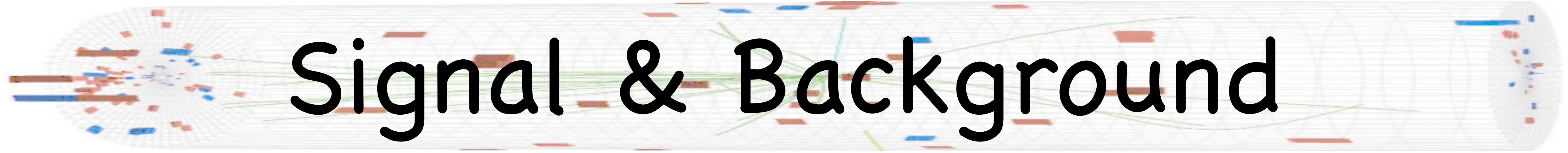


Summary

CMS-PAS-SMP-18-006

- Search for aQGC in WVjj and ZVjj at 13 TeV
    - Data sample of 35.9 fb^{-1} collected with CMS detector in 2016.
- Semi-leptonic final states not sensitive to SM EW production yet with 35.9 fb^{-1} data sample
    - But give stringent limits on AQGC
    - Signal extraction was done using invariant mass of WV/ZV system ($M_{wv/zv}$)
    - **Significant improvement in limits with respect to the fully leptonic searches**
- **Using same final state, set the model independent limit on the resonant charged Higgs production.**

Thank You...



Signal & Background

- **VVJJ (aQGC EWK):** Electroweak production of VVJJ with contributions from aQGC.
- **VVJJ (EWK) :** Electroweak production of WWJJ.
- **VVJJ (QCD initiated)**: Irreducible background for analysis.
- **W+Jets:** Most dominating background.
- tt **Jets**: Top quark always decays to one b-quark and one W boson. So, $t\bar{t} \rightarrow bWbW \rightarrow bl\nu l\nu$, if we mis-measure one lepton and one b quark form jets.
- **Drell-Yan:** Z/Gamma decays to l^+l^- and we mis-measure one l because of acceptance or inefficiency effects, gives missing energy.
- **Single top production**: Here $t \rightarrow bW \rightarrow bl\nu$, and 3 jets is reconstructed.

Centrality and Zeppenfeld Definition

Boson Centrality (Phys. Rev. D 95, 032001)

$$\xi_V = min\{\Delta\eta_-, \Delta\eta_+\}$$

where,

$$\Delta\eta_- = min\{\eta(V_{had}), \eta(V_{lep})\} - min\{\eta_{j1}, \eta_{j2}\},$$

$$\Delta\eta_+ = max\{\eta_{j1}, \eta_{j2}\} - max\{\eta(V_{had}), \eta(V_{lep})\}$$

- **ξ > 0 : Both W's should be within VBF jets**
- **ξ < 0 : One or both lepton are at larger |η| than the VBF jets**

Zeppenfeld w.r.t. Leptonic W (Phys. Rev. D 54, 6680)

$$Z_{Whad} = \frac{\eta_{Whad} - \frac{\eta_{j1} + \eta_{j2}}{2}}{|\eta_{j1} - \eta_{j2}|}$$

Zeppenfeld w.r.t. Leptonic W (Phys. Rev. D 54, 6680)

$$Z_{Wlep} = \frac{\eta_{Wlep} - \frac{\eta_{j1} + \eta_{j2}}{2}}{|\eta_{j1} - \eta_{j2}|}$$

Event Selection

WV Channel

- Final Selection Electrons (Muons)
  - Exactly 1 lepton
  - For electrons exclude region $1.4442 < \eta < 1.566$
  - MET > 80 GeV (50 GeV)
  - Fat Jet (having radius parameter 0.8):
    - $65 < m_W < 105$, Tau2/Tau1 < 0.55
  - VBF jets (having radius parameter 0.4):
    - $m_{jj} > 800$ GeV, dEta > 4.0
  - Boson-Centrality > 1.0
  - Leptonic zeppenfeld < 0.3
  - Hadronic zeppenfeld < 0.3
  - $m_{WV} > 600$

ZV Channel

- Final Selection
  - Exactly 2 leptons
  - $76 < m_{LL} < 107$
  - Large radius parameter jet:
    - $65 < m_Z < 105$, Tau2/Tau1 < 0.55
  - VBF jets:
    - $m_{jj} > 800$ GeV, dEta > 4.0
  - $m_{ZV} > 600$
- Fit m_{VV} distribution to get limits

aQGC parameters to probe

$$\mathcal{L}_{S,0} = \left[(D_\mu\Phi)^\dagger D_\nu\Phi\right] \times \left[(D^\mu\Phi)^\dagger D^\nu\Phi\right]$$

$$\mathcal{L}_{S,1} = \left[(D_\mu\Phi)^\dagger D^\mu\Phi\right] \times \left[(D_\nu\Phi)^\dagger D^\nu\Phi\right]$$

$$\mathcal{L}_{M,0} = \mathrm{Tr}\left[\hat{W}_{\mu\nu}\hat{W}^{\mu\nu}\right] \times \left[(D_\beta\Phi)^\dagger D^\beta\Phi\right]$$

$$\mathcal{L}_{M,1} = \mathrm{Tr}\left[\hat{W}_{\mu\nu}\hat{W}^{\nu\beta}\right] \times \left[(D_\beta\Phi)^\dagger D^\mu\Phi\right]$$

$$\mathcal{L}_{M,2} = \left[B_{\mu\nu}B^{\mu\nu}\right] \times \left[(D_\beta\Phi)^\dagger D^\beta\Phi\right]$$

$$\mathcal{L}_{M,3} = \left[B_{\mu\nu}B^{\nu\beta}\right] \times \left[(D_\beta\Phi)^\dagger D^\mu\Phi\right]$$

$$\mathcal{L}_{M,4} = \left[(D_\mu\Phi)^\dagger \hat{W}_{\beta\nu}D^\mu\Phi\right] \times B^{\beta\nu}$$

$$\mathcal{L}_{M,5} = \left[(D_\mu\Phi)^\dagger \hat{W}_{\beta\nu}D^\nu\Phi\right] \times B^{\beta\mu}$$

$$\mathcal{L}_{M,6} = \left[(D_\mu\Phi)^\dagger \hat{W}_{\beta\nu}\hat{W}^{\beta\nu}D^\mu\Phi\right]$$

$$\mathcal{L}_{M,7} = \left[(D_\mu\Phi)^\dagger \hat{W}_{\beta\nu}\hat{W}^{\beta\mu}D^\nu\Phi\right]$$

The operators in the red box are the one which we considered in our analysis.

- **Dimension 8 operators:** Lowest dimension operators that modify the quartic boson interactions.

$$\mathcal{L}_{T,0} = \mathrm{Tr}\left[\hat{W}_{\mu\nu}\hat{W}^{\mu\nu}\right] \times \mathrm{Tr}\left[\hat{W}_{\alpha\beta}\hat{W}^{\alpha\beta}\right]$$

$$\mathcal{L}_{T,1} = \mathrm{Tr}\left[\hat{W}_{\alpha\nu}\hat{W}^{\mu\beta}\right] \times \mathrm{Tr}\left[\hat{W}_{\mu\beta}\hat{W}^{\alpha\nu}\right]$$

$$\mathcal{L}_{T,2} = \mathrm{Tr}\left[\hat{W}_{\alpha\mu}\hat{W}^{\mu\beta}\right] \times \mathrm{Tr}\left[\hat{W}_{\beta\nu}\hat{W}^{\nu\alpha}\right]$$

$$\mathcal{L}_{T,3} = \mathrm{Tr}\left[\hat{W}_{\alpha\mu}\hat{W}^{\mu\beta}\hat{W}^{\nu\alpha}\right] \times B_{\beta\nu}$$

$$\mathcal{L}_{T,4} = \mathrm{Tr}\left[\hat{W}_{\alpha\mu}\hat{W}^{\alpha\mu}\hat{W}^{\beta\nu}\right] \times B_{\beta\nu}$$

$$\mathcal{L}_{T,5} = \mathrm{Tr}\left[\hat{W}_{\mu\nu}\hat{W}^{\mu\nu}\right] \times B_{\alpha\beta}B^{\alpha\beta}$$

$$\mathcal{L}_{T,6} = \mathrm{Tr}\left[\hat{W}_{\alpha\nu}\hat{W}^{\mu\beta}\right] \times B_{\mu\beta}B^{\alpha\nu}$$

$$\mathcal{L}_{T,7} = \mathrm{Tr}\left[\hat{W}_{\alpha\mu}\hat{W}^{\mu\beta}\right] \times B_{\beta\nu}B^{\nu\alpha}$$

$$\mathcal{L}_{T,8} = B_{\mu\nu}B^{\mu\nu}B_{\alpha\beta}B^{\alpha\beta}$$

$$\mathcal{L}_{T,9} = B_{\alpha\mu}B^{\mu\beta}B_{\beta\nu}B^{\nu\alpha}$$

Ref: Phys.Rev. D74 (2006) 073005

Neutrino $p_{\nu z}$ calculation

(To reconstruct leptonic W-boson invariant mass)

$$p_{\nu z} = \frac{1}{2 \times A}[-b \pm \sqrt{b^2 - 4 \times A \times C}]$$

Where,

$$A = 4(E_l^2 - p_{lz}^2)$$

$$b = -4ap_{lz}$$

$$C = 4E_l^2 p_{\nu T}^2 - a^2$$

$$a = M_w^2 - M_l^2 + 2(p_{lx}p_{\nu x} + p_{ly}p_{\nu y})$$

Full calculation: link

- Picked solution which is closest to lepton p_z.
- If roots are complex then take real part.

Data driven background estimation for V+jets (Alpha-Ratio Method)

- **To get V+jet contribution from data in signal region:**

$$N_{signal}^{Data,W+Jets}(M_{WW}) = \alpha(M_{WW}) \times N_{sideband}^{Data}(M_{WW})$$

- **Alpha (taken from MC) is defined as:**

$$\alpha(M_{WW}) = \frac{N_{signal}^{MC,W+Jets}(M_{WW})}{N_{sideband}^{MC,W+Jets}(M_{WW})} = \frac{N_{signal}^{Data}(M_{WW})}{N_{sideband}^{Data}(M_{WW})}$$

Large background from W (Z) + jets

- ☑ Extrapolate data from side-band to signal region using alpha (also known as transfer function)
- ☑ Accounts for data-MC differences in shape and normalisation.

Results - Anomalous Coupling Limits

aQGC Parameters Previous published limits		Our Limits		
		WV Channel	ZV Channel	Combined Limit
FS0	[-7.7,7.7]	[-2.6,2.7]	[-37,37]	[-2.6, 2.7]
FS1	[-22,22]	[-3.2,3.3]	[-30,30]	[-3.3,3.3]
FT0	[-0.46,0.44]	[-0.11,0.10]	[-1.3,1.3]	[-0.12,0.10]
FT1	[-0.28,0.31]	[-0.11,0.12]	[-1.4,1.4]	[-0.11,0.12]
FT2	[-0.89,1.0]	[-0.27,0.27]	[-3.1,3.2]	[-0.27,0.27]
FM0	[-4.2,4.2]	[-0.66,0.66]	[-6.9,6.9]	[-0.66,0.66]
FM1	[-8.7,9.1]	[-1.9,2.0]	[-21,21]	[-1.9,2.0]
FM6	[-12,12]	[-1.3,1.3]	[-14,14]	[-1.3,1.3]
FM7	[-13,13]	[-3.3,3.2]	[-33,33]	[-3.3,3.3]

Reference:

1. https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC#aQGC_Results