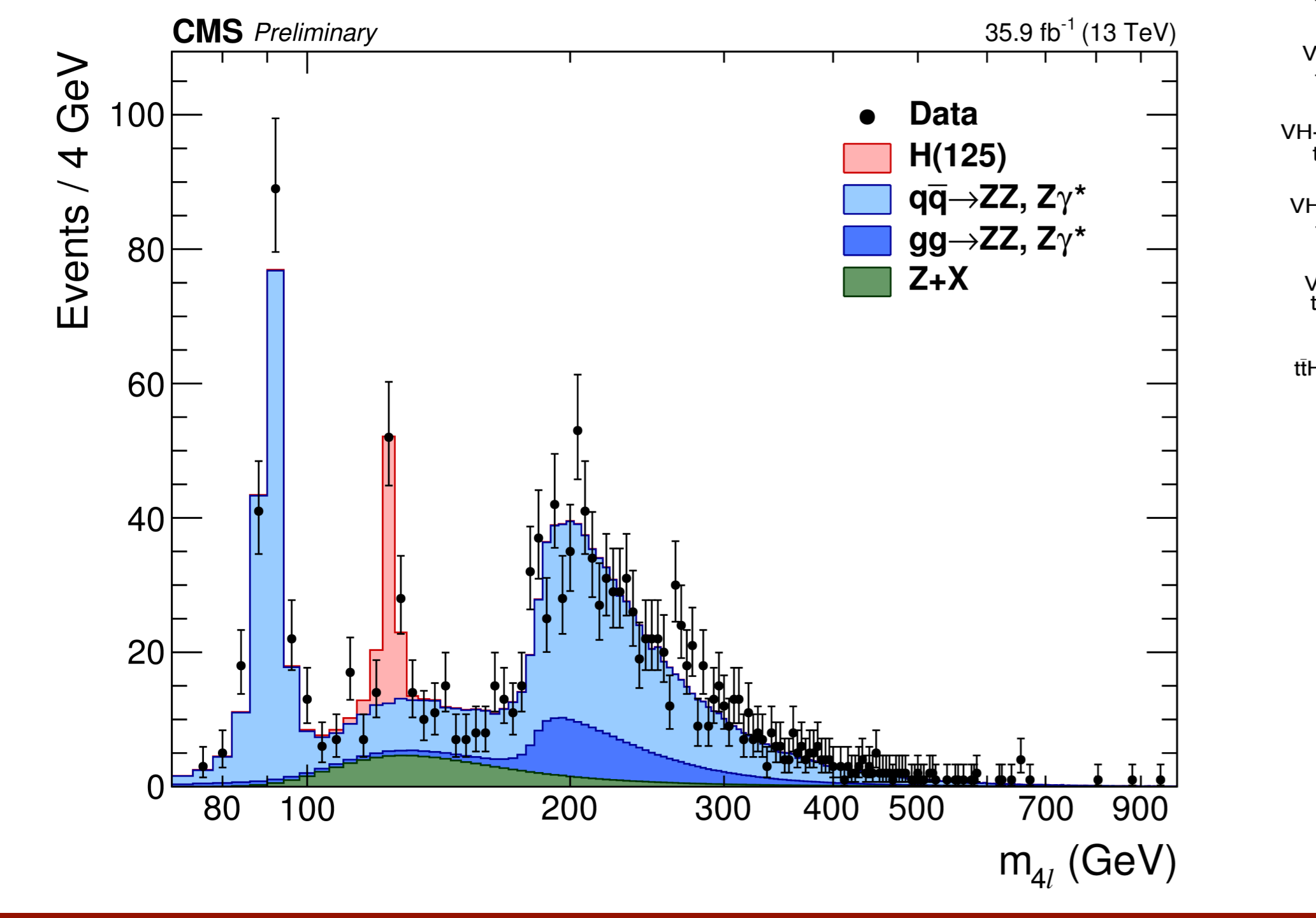# Measurement of properties of the Higgs boson decaying to pair of W and Z boson at 13 TeV with the CMS experiment

Muhammad Bilal Kiani (University e INFN Torino) on behalf of
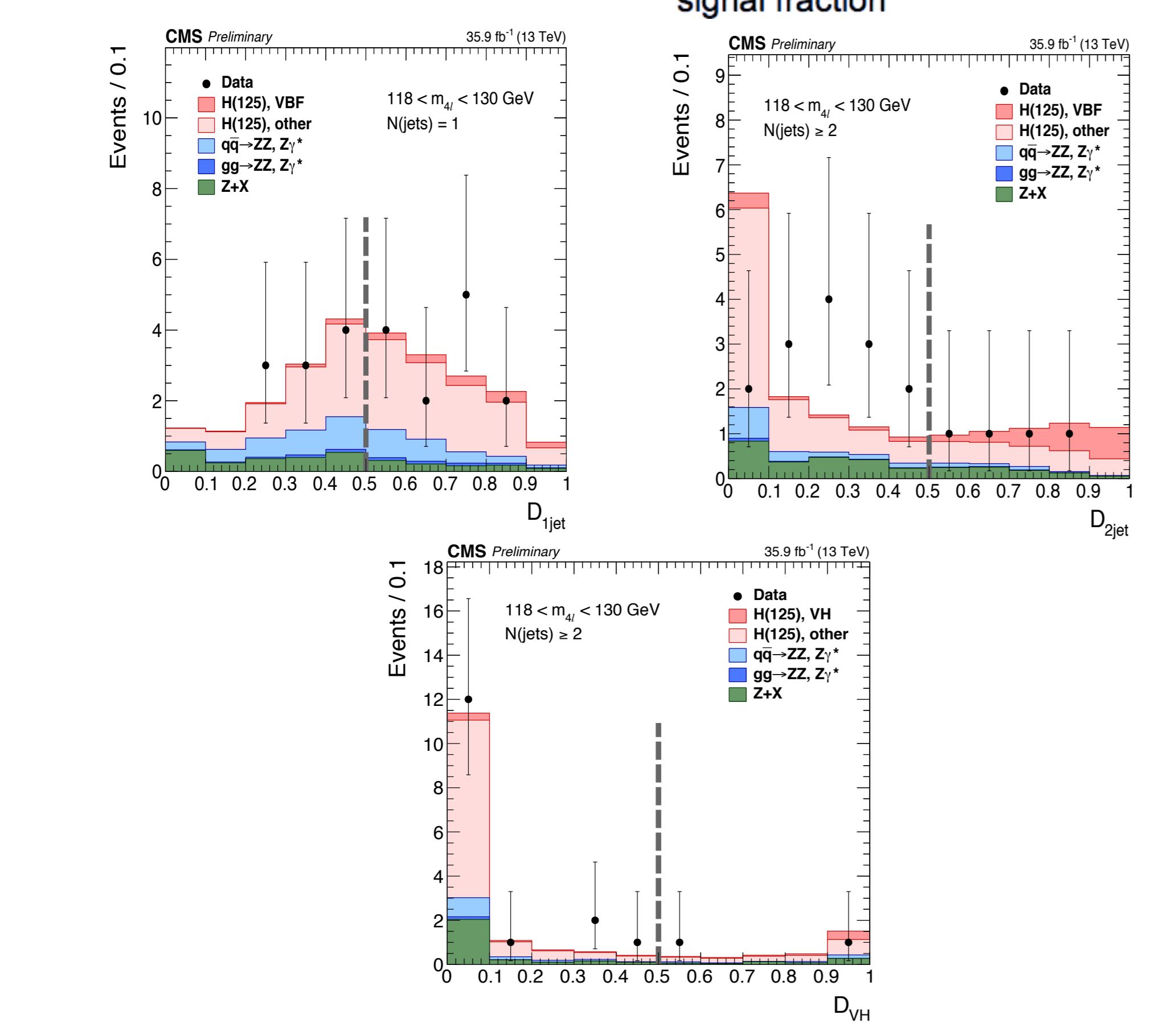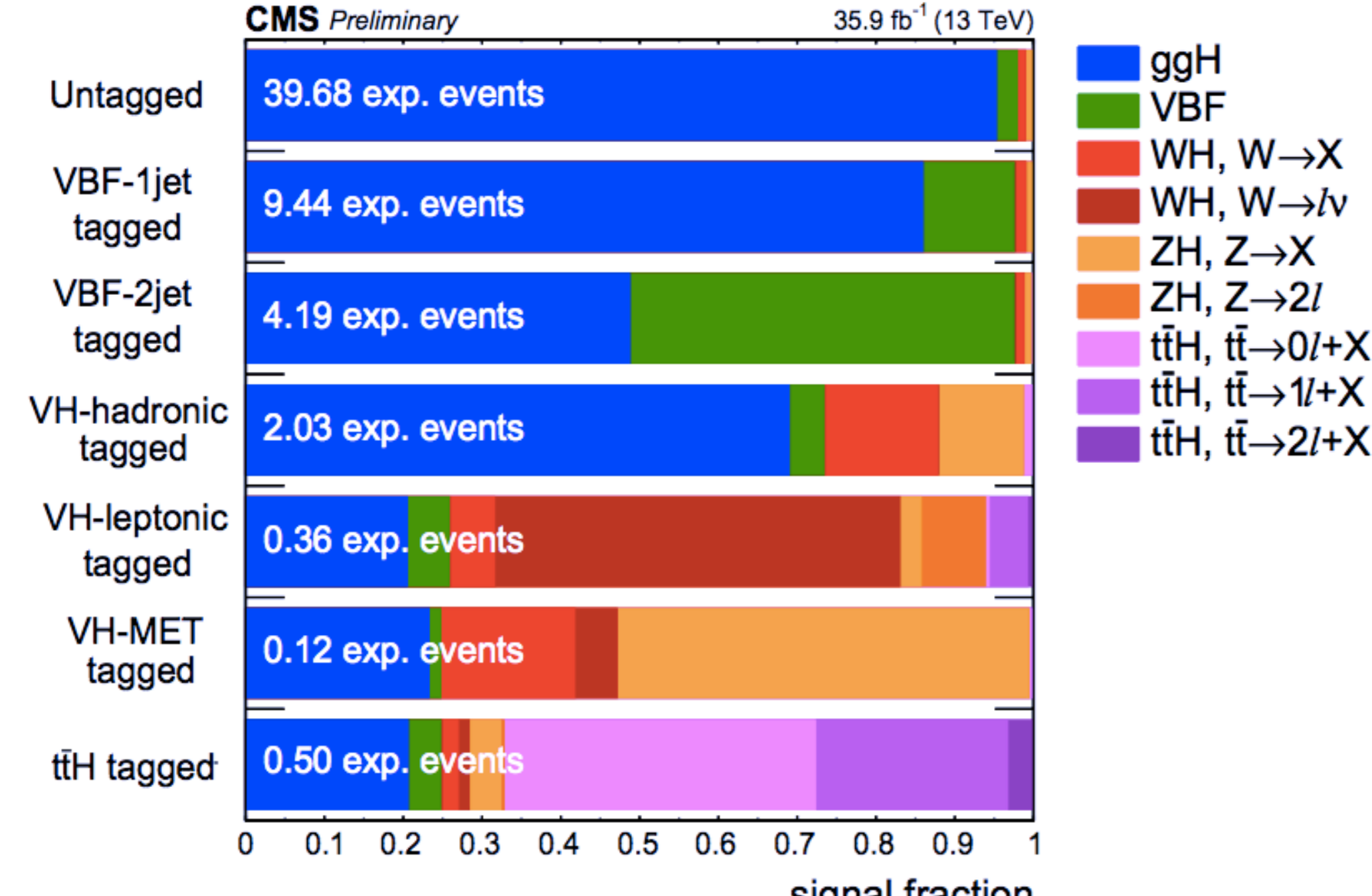The CMS Collaboration

1.1: H→ZZ→4l

➢ The H → ZZ →4ℓ decay channel (ℓ = e, μ) is one of the most important channel for Higgs boson properties

➢Large signal-to-background ratio and precise reconstruction of final state.

➢Complete determination of the Higgs kinematics

➢ Measurement of the properties using H → ZZ →4ℓ decay channel has been presented using 2016 dataset corresponds to the integrated luminosity of 35.9 fb⁻¹[1]
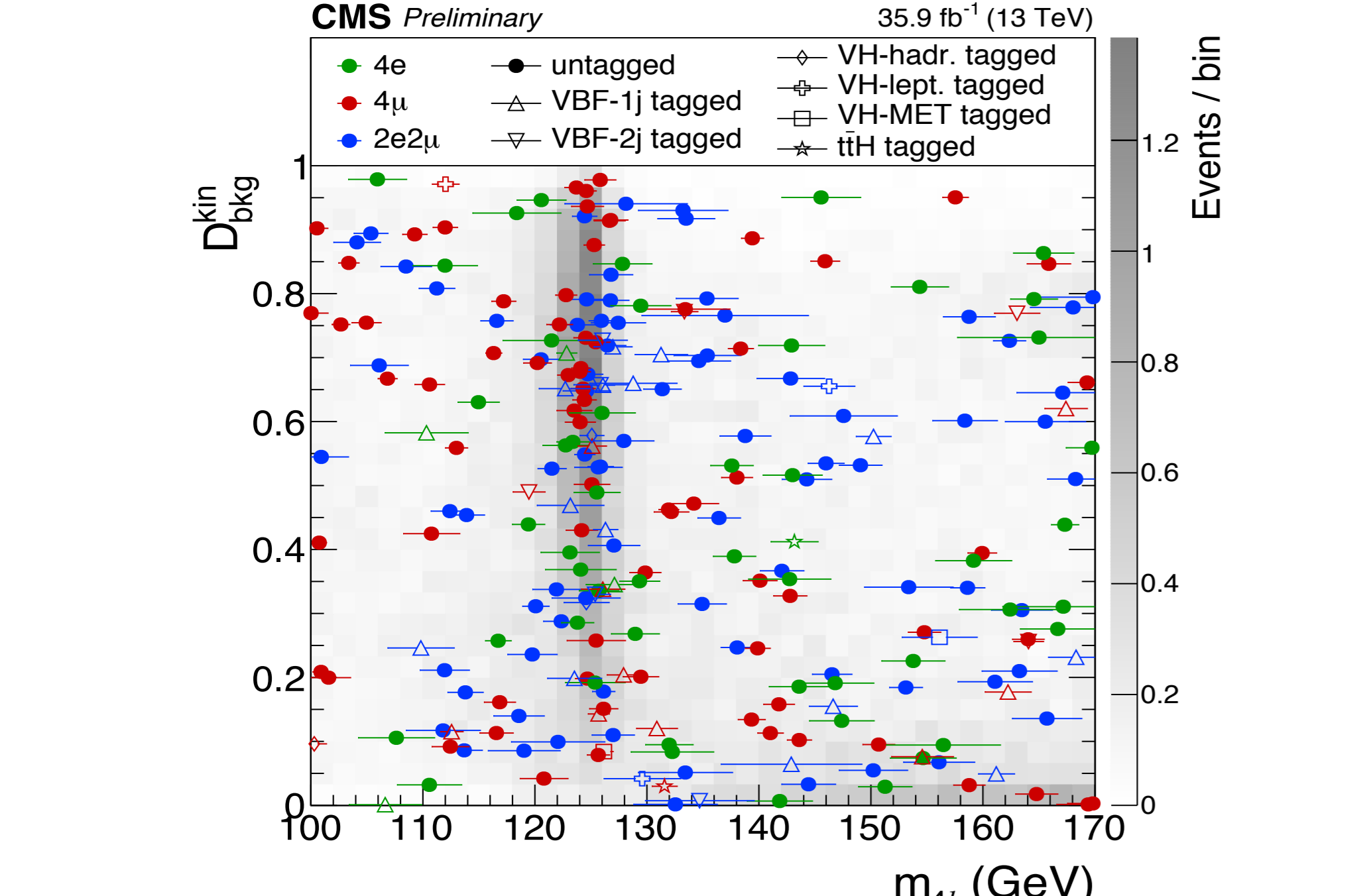

1.2: Event Categorization

➢Events are classified into seven categories by exploiting:

➢ The multiplicity of jets, b tagged jets and additional leptons

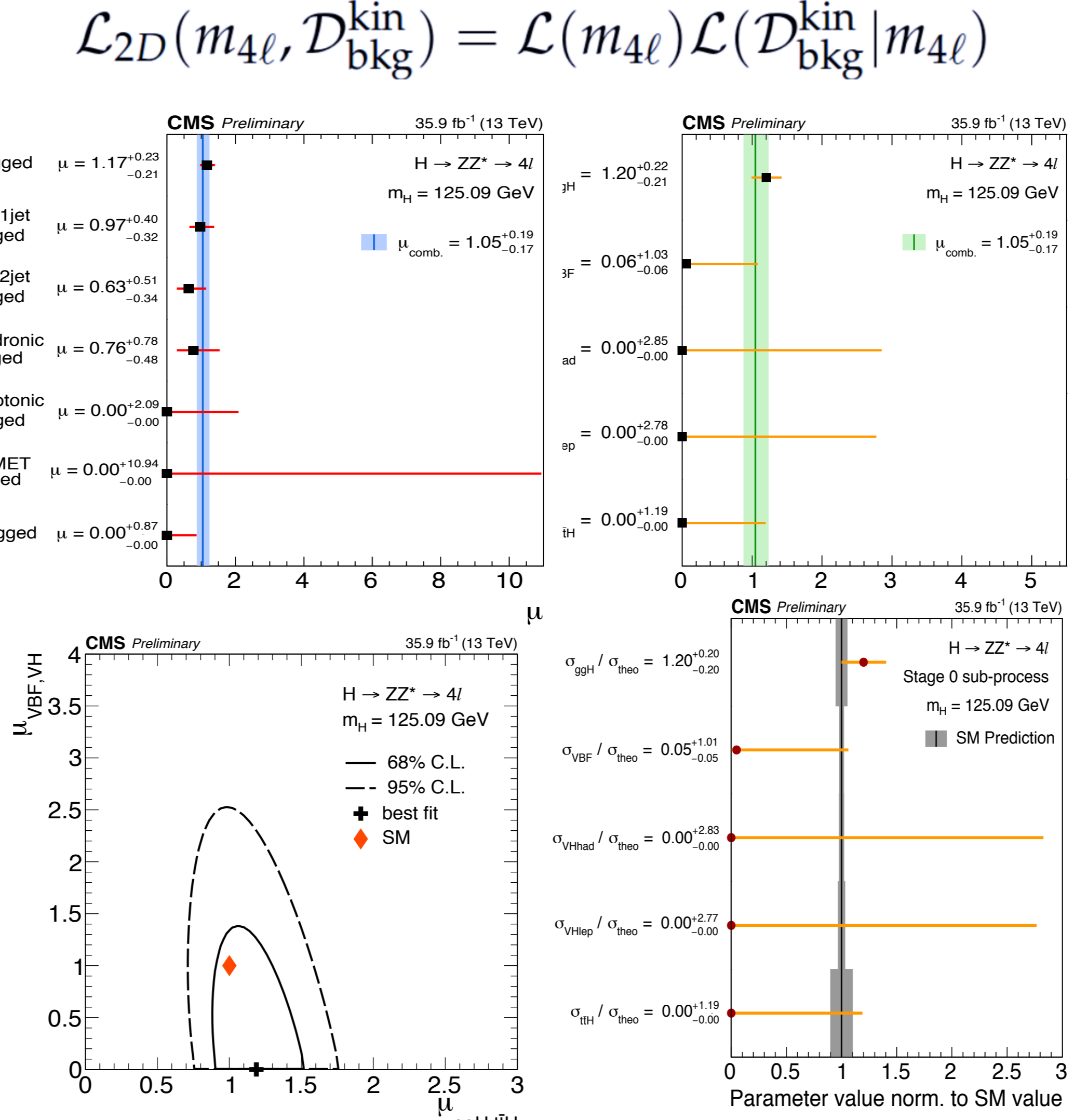➢Production Discriminant to separate ggH+jj and VBF/VH events.(Computed using MELA)

1.3: Kinematic Discriment

➢Decay discriminant computed using MELA package.

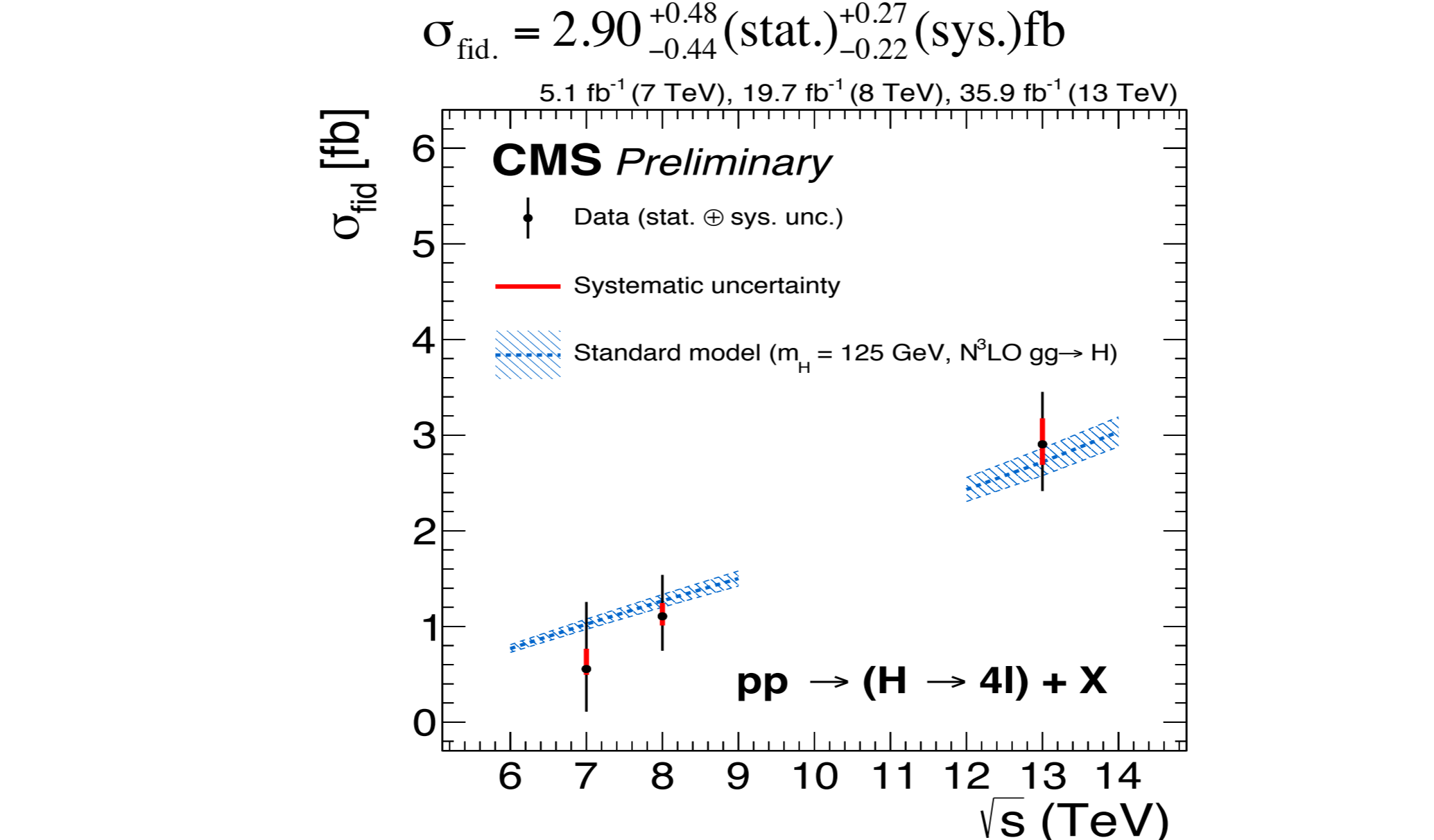➢ Separates Signal and background.

➢Important variable for 2D measurements.

1.4: Signal Strength

➢Defined as the measured cross section relative to the expectation for the SM Higgs boson
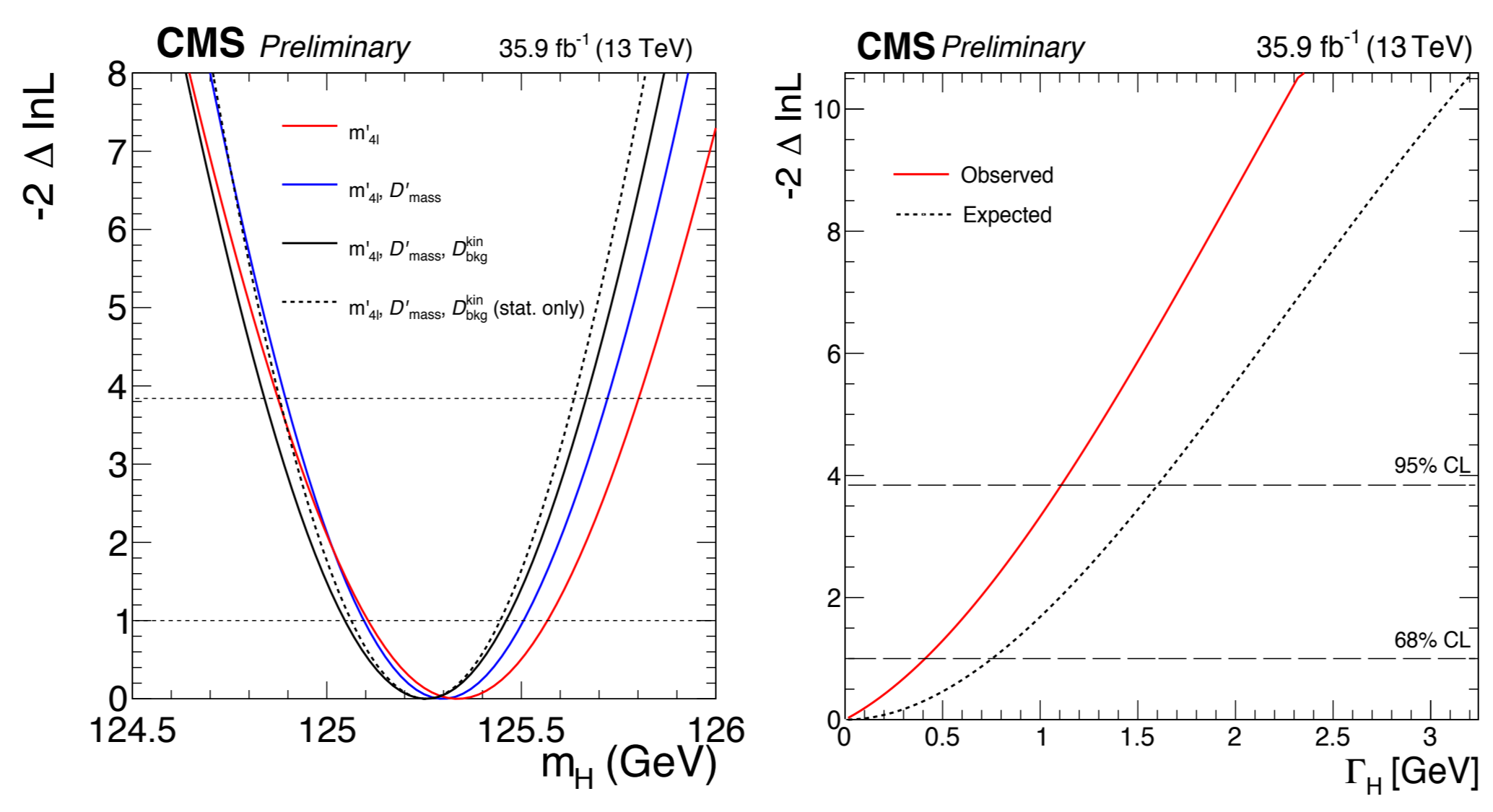
➢A 2D likelihood scan:

$$\mathcal{L}_{2D}(m_{4\ell}, \mathcal{D}_{bkg}^{kin}) = \mathcal{L}(m_{4\ell})\mathcal{L}(\mathcal{D}_{bkg}^{kin}|m_{4\ell})$$

1.5: Fiducial cross section

➢The integrated fiducial cross section is measured:

$$\sigma_{fid.} = 2.90^{+0.48}_{-0.44}(stat.)^{+0.27}_{-0.22}(sys.)fb$$

1.6: Mass and Width

➢Performed a 3D fit $m_H = 125.26 \pm 0.20(stat.) \pm 0.08(sys.)GeV$

➢Constrain width from on-shell production

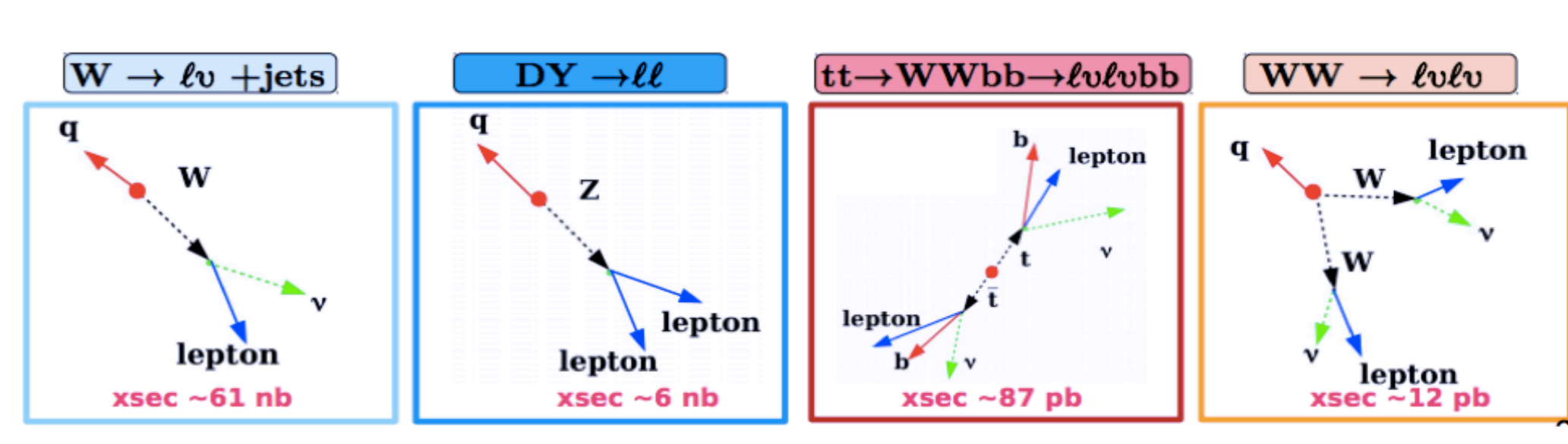## 1.7: Anomalous Coupling

➢Run 1 and Run2 combined results[2]

➢Only three event categories: VBF, VH and untagged

➢ Discriminants to suppress background, to separate BSM and SM, and to isolate interference of BSM and SM

➢Effective cross-section ratios f_{ai} and coupling phases ϕ_{ai} allowed 68% CL (central values with uncertainties) and 95% CL (ranges in square brackets) intervals
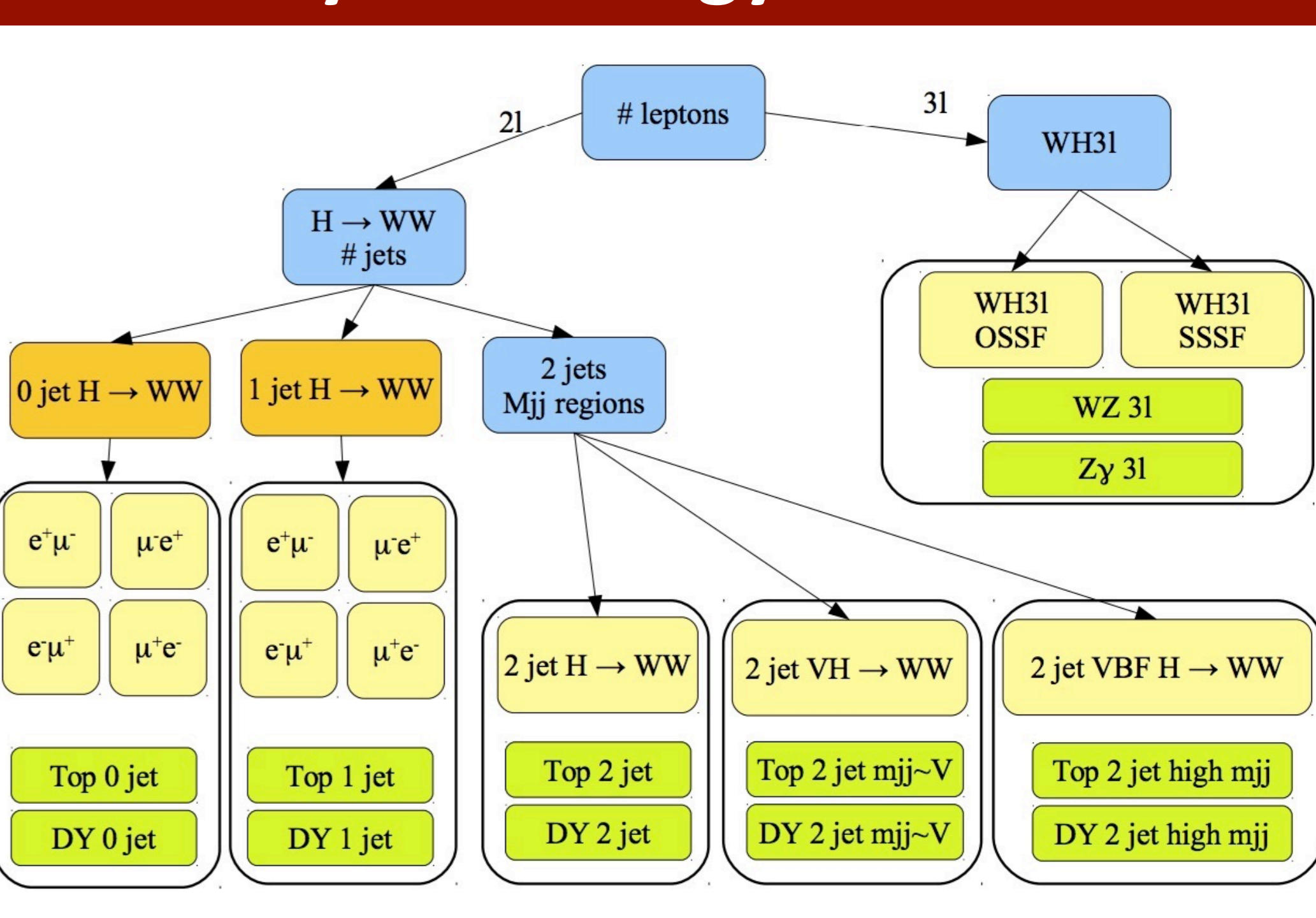
Combined (Run 1 & 2)

Parameter	Observed	Expected
$f_{a3}\cos(\phi_{a3})$	$0.00^{+0.26}_{-0.09}$ [−0.38, 0.46]	$0.000^{+0.010}_{-0.010}$ [−0.25, 0.25]
$f_{a2}\cos(\phi_{a2})$	$0.01^{+0.12}_{-0.02}$ [−0.04, 0.43]	$0.000^{+0.009}_{-0.008}$ [−0.06, 0.19]
$f_{\Lambda1}\cos(\phi_{\Lambda1})$	$0.02^{+0.08}_{-0.06}$ [−0.49, 0.18]	$0.000^{+0.003}_{-0.002}$ [−0.60, 0.12]
$f_{\Lambda1}^{Z\gamma}\cos(\phi_{\Lambda1}^{Z\gamma})$	$0.26^{+0.30}_{-0.35}$ [−0.40, 0.79]	$0.000^{+0.019}_{-0.022}$ [−0.37, 0.71]

2.1: H→WW→2l2ν

➢H → WW →eνμν decay channel has been presented using 2015(2.3fb⁻¹) and 2016(12.9 fb⁻¹) dataset[3].
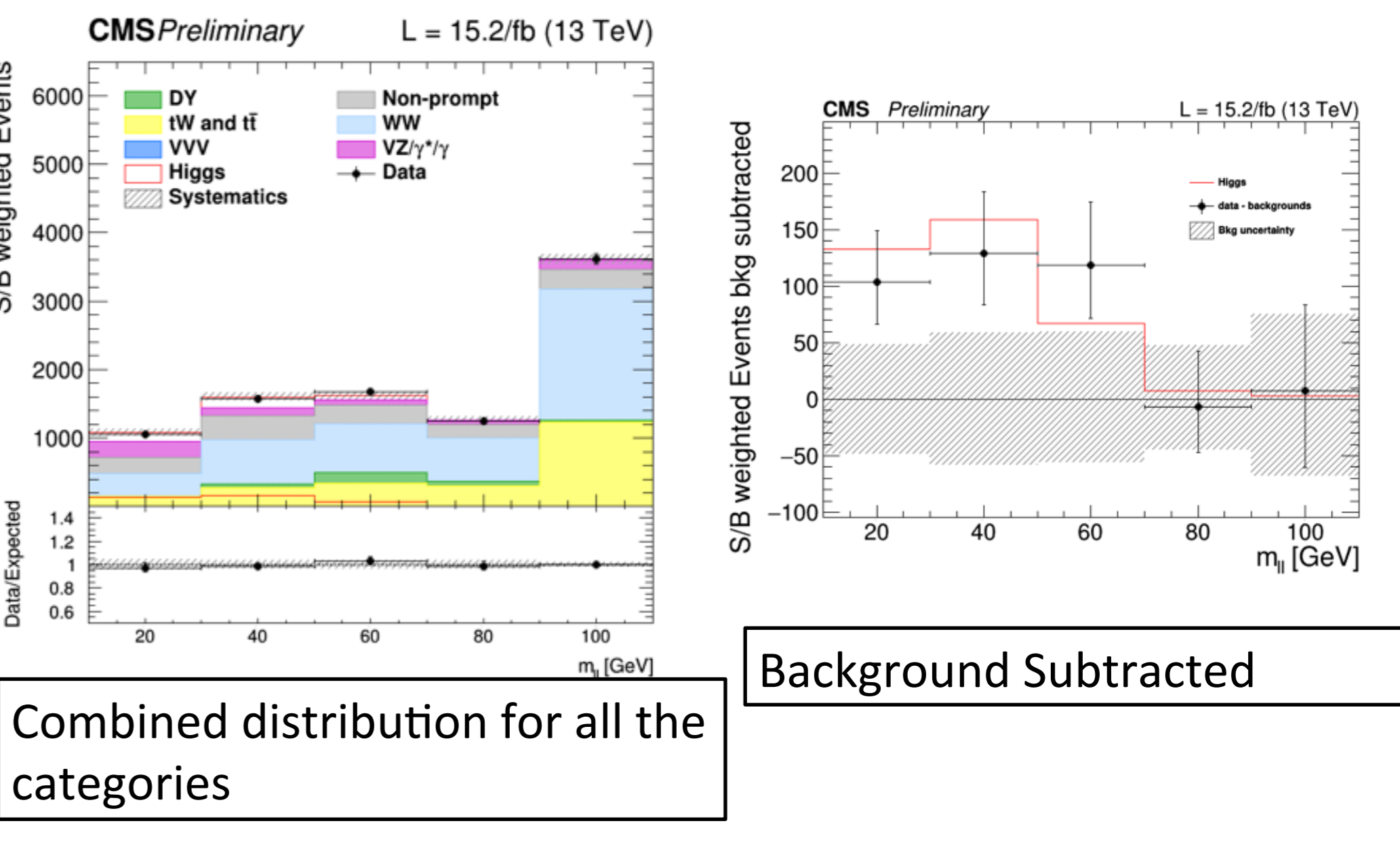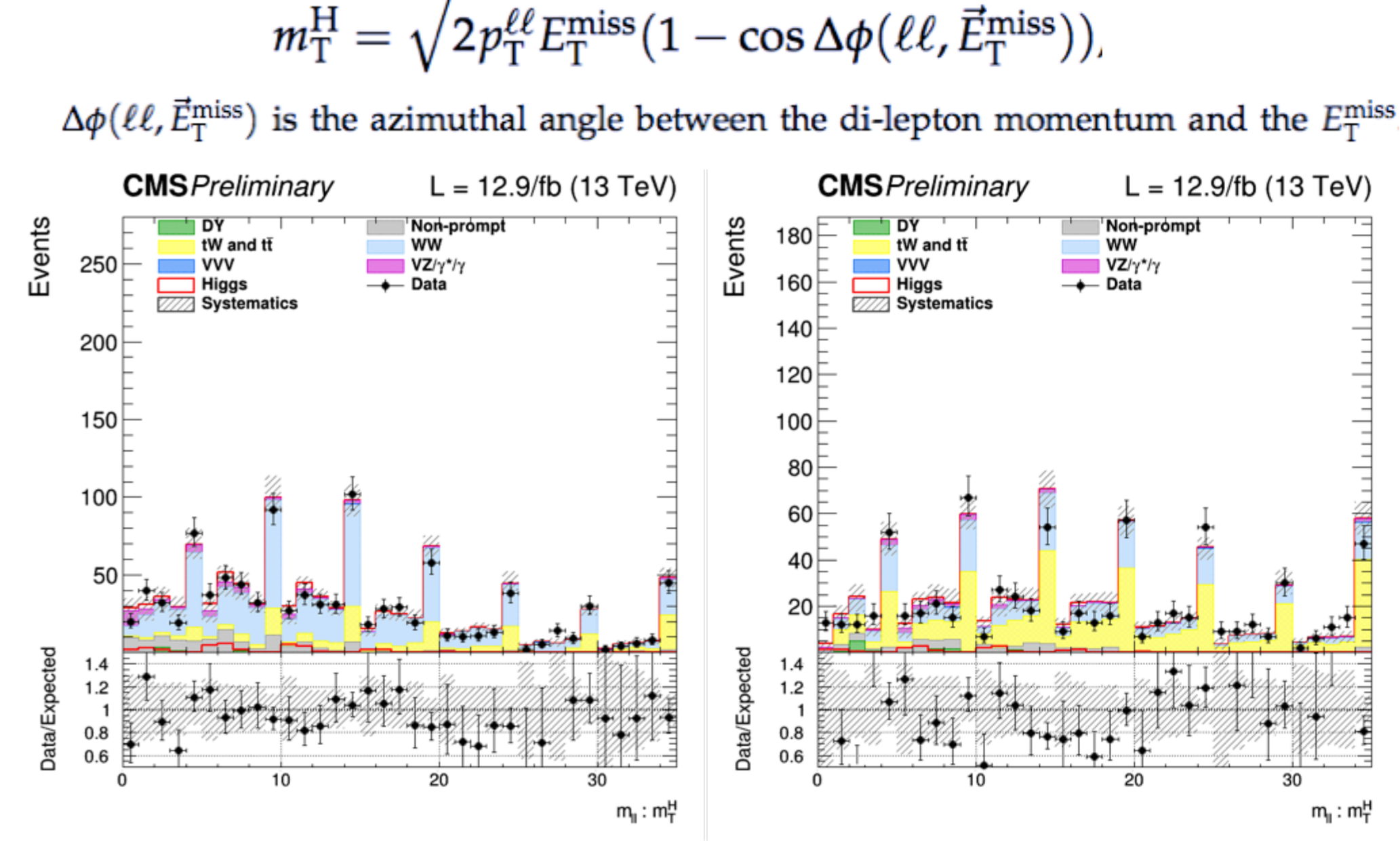
➢Better performance w.r.t same flavor

➢Main backgrounds:

2.2: Analysis Strategy

2.3: 2D Unrolled $m_{\ell\ell} : m_T^H$

➢Used 2D Unrolled $m_{\ell\ell} : m_T^H$ distribution 0/1/ 2(H→WW)Jet

$$m_T^H = \sqrt{2p_T^{\ell\ell}E_T^{miss}(1 - \cos\Delta\phi(\ell\ell, \vec{E}_T^{miss}))},$$

$\Delta\phi(\ell\ell, \vec{E}_T^{miss})$ is the azimuthal angle between the di-lepton momentum and the E_T^{miss}

Combined distribution for all the categories

Background Subtracted

2.4: Significance & Signal Strength

category	significance	σ/σ_{SM}
0-jet	2.7 (2.9)	$0.9^{+0.4}_{-0.3}$
1-jet	2.1 (2.5)	$1.1^{+0.4}_{-0.4}$
2-jet	2.0 (1.0)	$1.3^{+1.0}_{-1.0}$
VBF 2-jet	2.2 (1.5)	$1.4^{+0.8}_{-0.8}$
VH 2-jet	1.0 (0.4)	$2.1^{+2.3}_{-2.2}$
WH 3-lep	0.0 (0.5)	$-1.4^{+1.5}_{-1.5}$
combination	4.3 (4.1)	$1.05^{+0.27}_{-0.25}$

2015 data μ = 0.89$^{+0.44}_{-0.31}$

2016 data μ = 1.4$^{+0.3}_{-0.3}$

➢**Signal Strength:** Combined with 2015 results for a Higgs boson mass of 125 GeV

$$1.05 \pm 0.26(0.25 \pm 0.03(theory) \pm 0.07(systematic))$$

References

[1] The CMS Collaboration ,"Measurements of properties of Higgs boson decaying in to four-lepton final state in pp collisions at √s = 13 TeV", **arXiv:1706.09936. CMS-HIG-16-041**

[2] The CMS Collaboration, "Constraints on anomalous Higgs boson couplings using the production and decay information in the four-lepton final state". **arXiv:1707.00541. CMS-HIG-17-011**

[3] The CMS Collaboration, "Higgs to WW measurement at 13 TeV with 2015 and 2016 data". **CMS PAS HIG-16-021**