

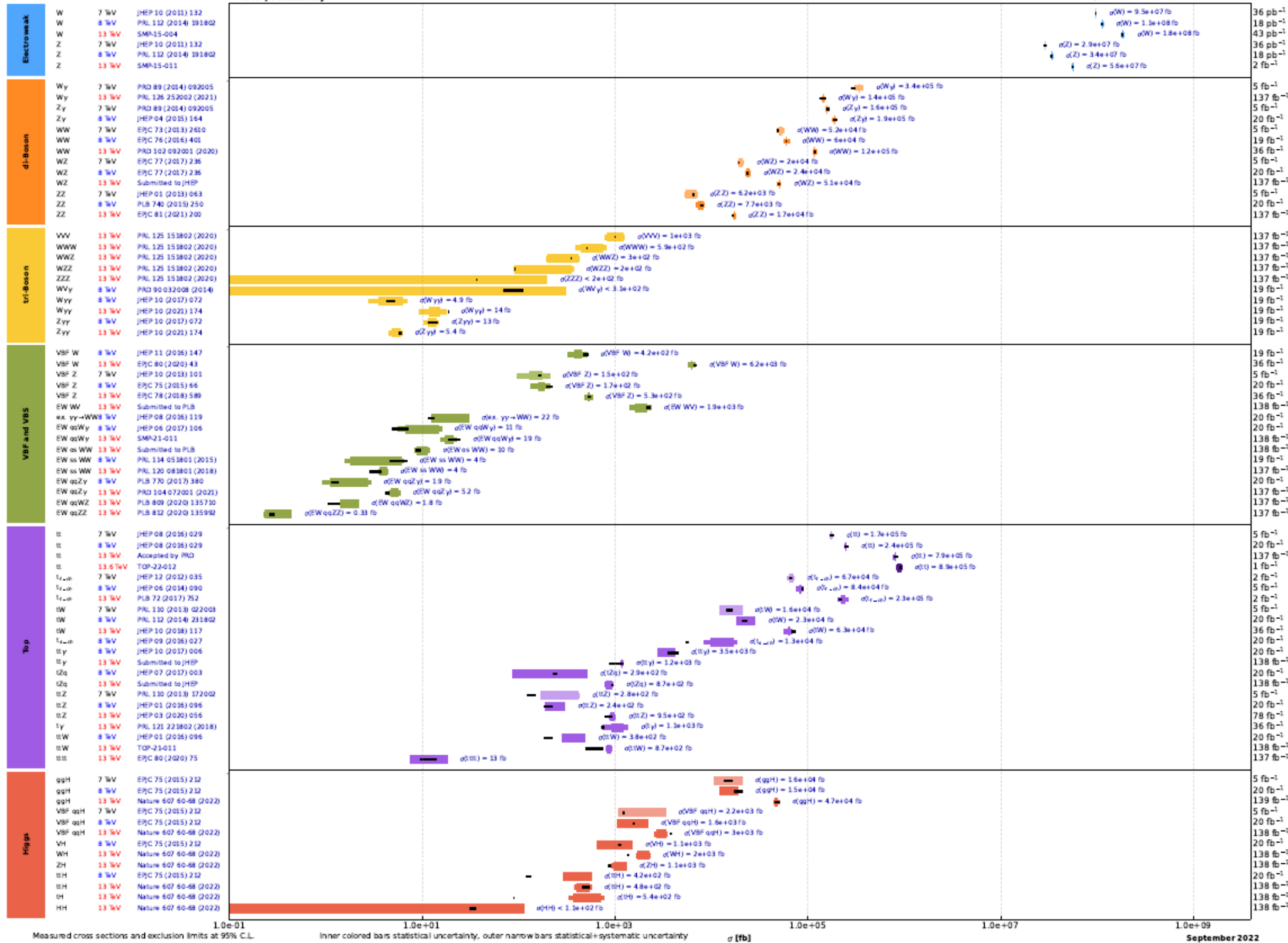
CMS results on Standard Model and Higgs boson

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Overview of CMS cross section results

CMS preliminary

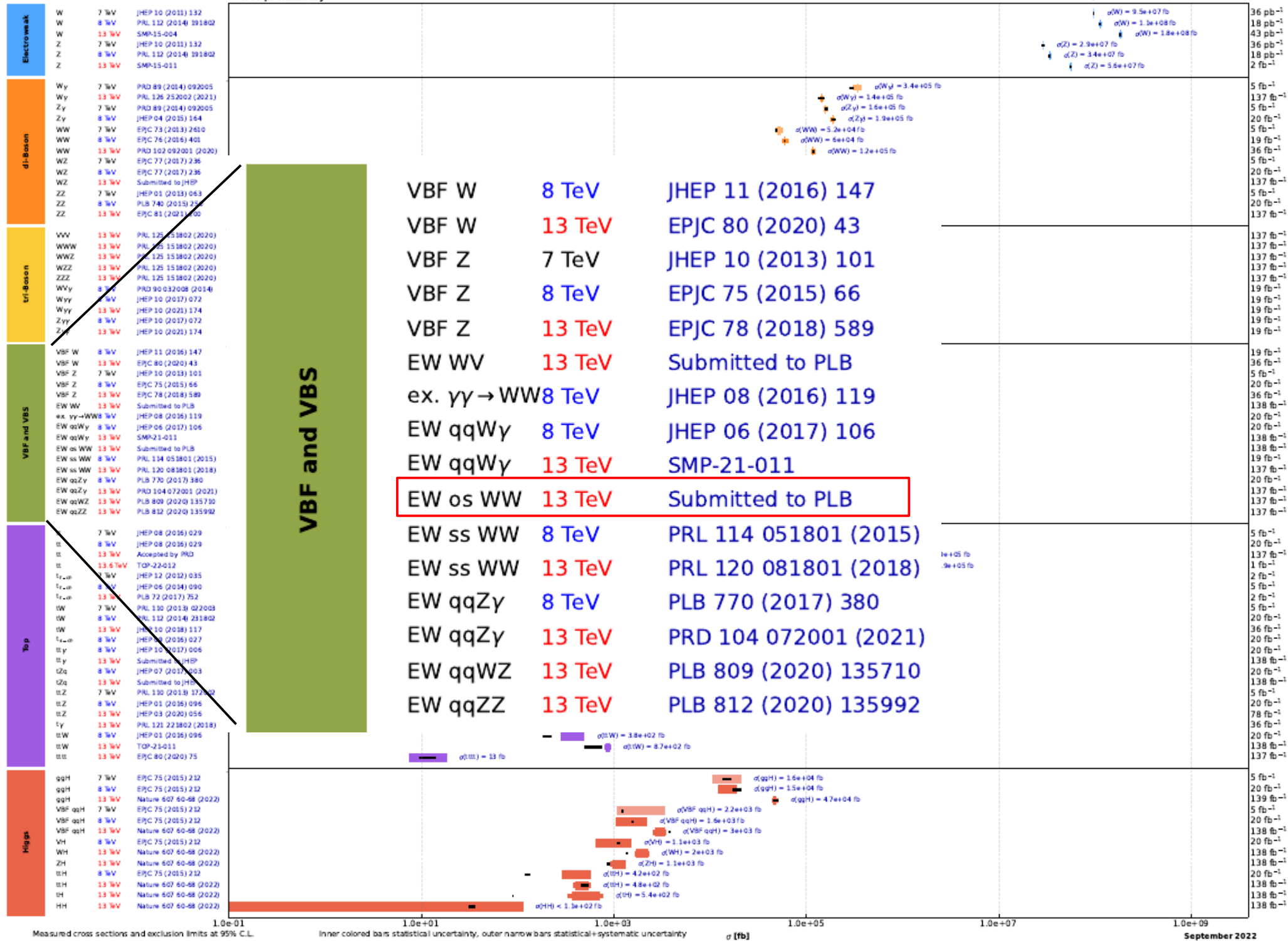
18 pb⁻¹ - 138 fb⁻¹ (7,8,13,13.6 TeV)



Overview of CMS cross section results

CMS preliminary

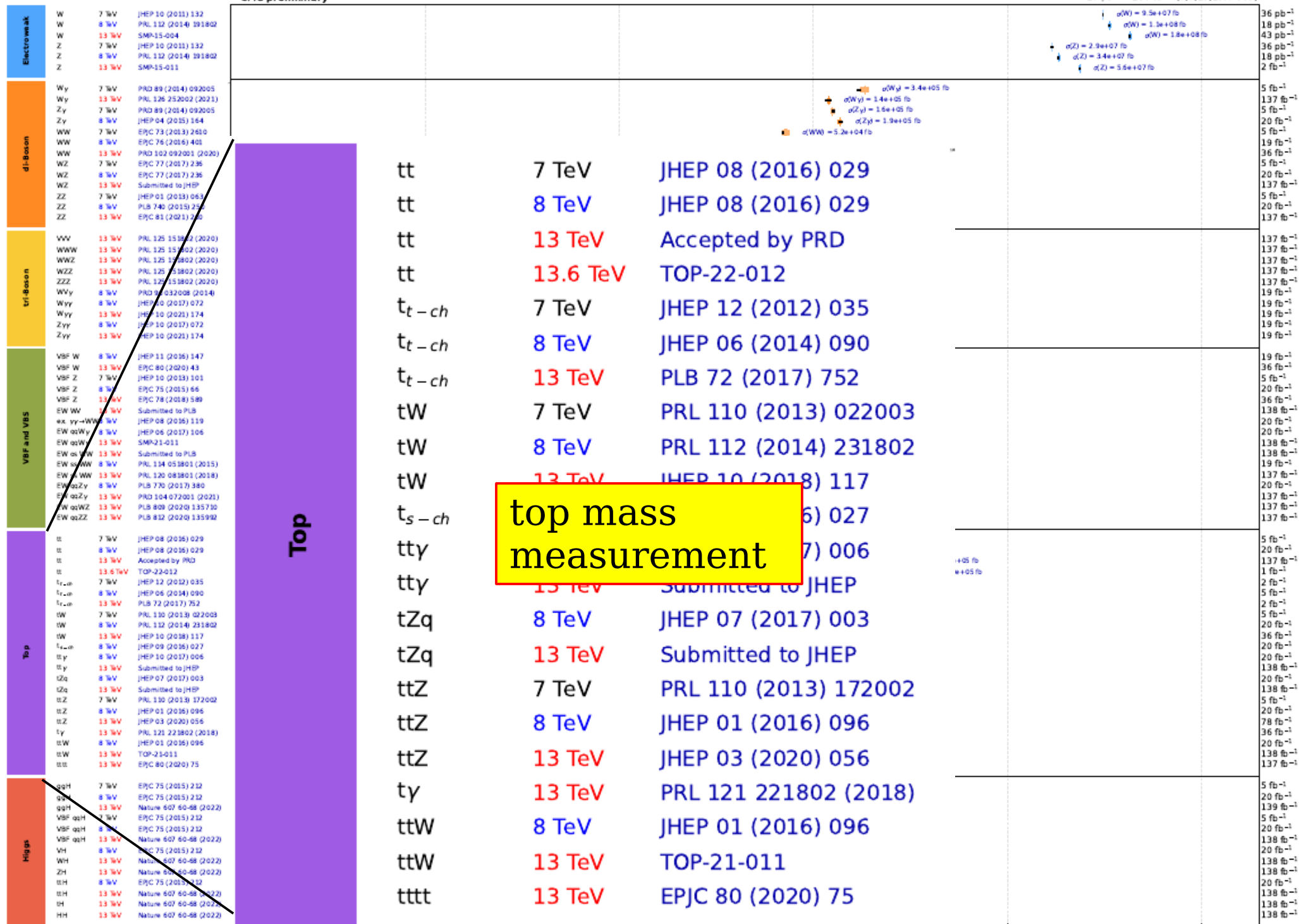
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Overview of CMS cross section results

CMS preliminary

18 pb⁻¹ - 138 fb⁻¹ (7,8,13,13.6 TeV)



top mass measurement

Top

Measured cross sections and exclusion limits at 95% C.L.

See here for all cross section summary plots

Inner colored bars statistical uncertainty, outer narrow bars statistical+systematic uncertainty

Light colored bars: 7 TeV, Medium: 8 TeV, Dark: 13 TeV, Darkest: 13.6 TeV, Black bars: theory prediction

σ [fb]

1.0e+07

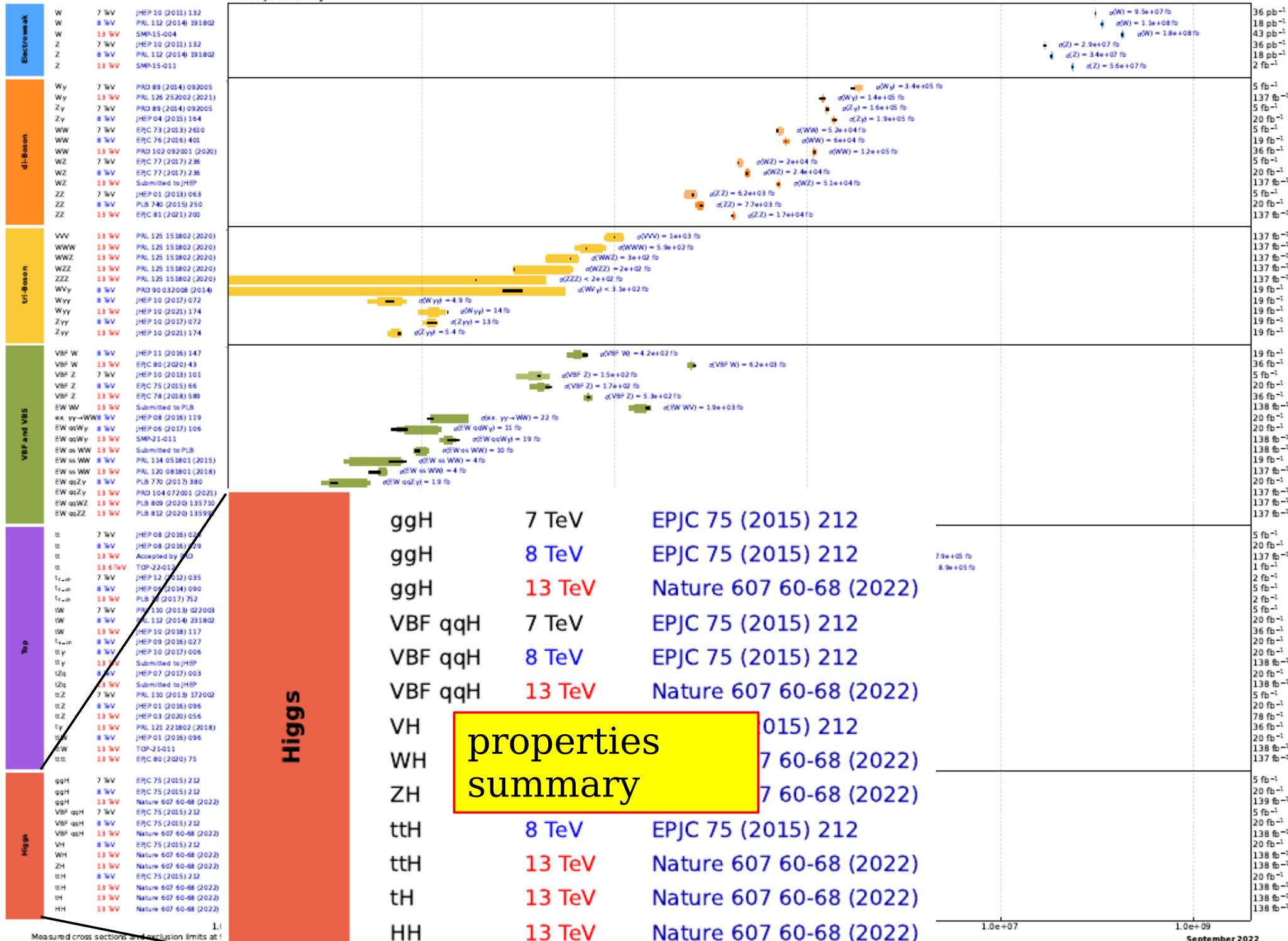
1.0e+09

September 2022

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CMS preliminary

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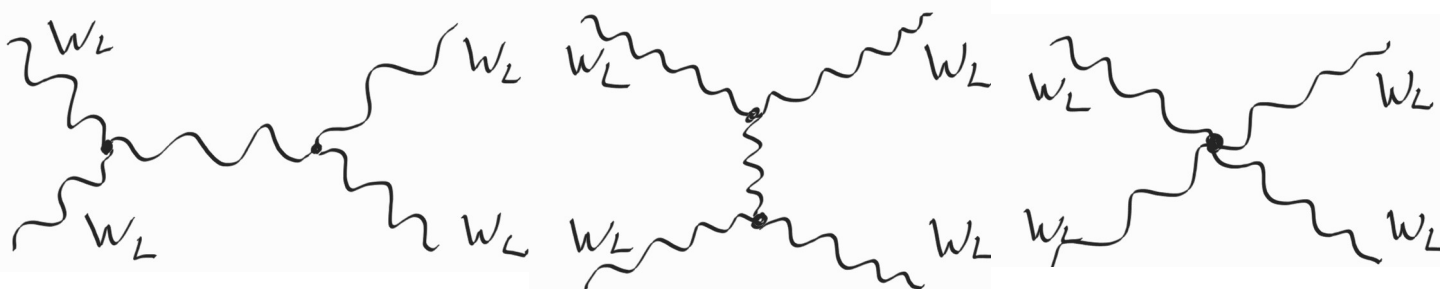


1.0e+07

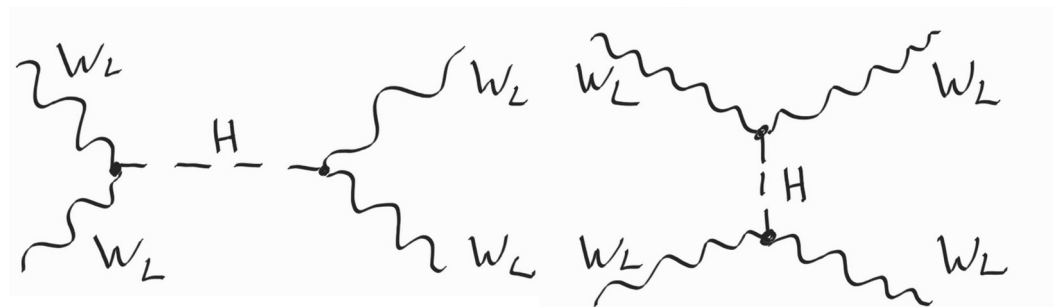
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September 2022

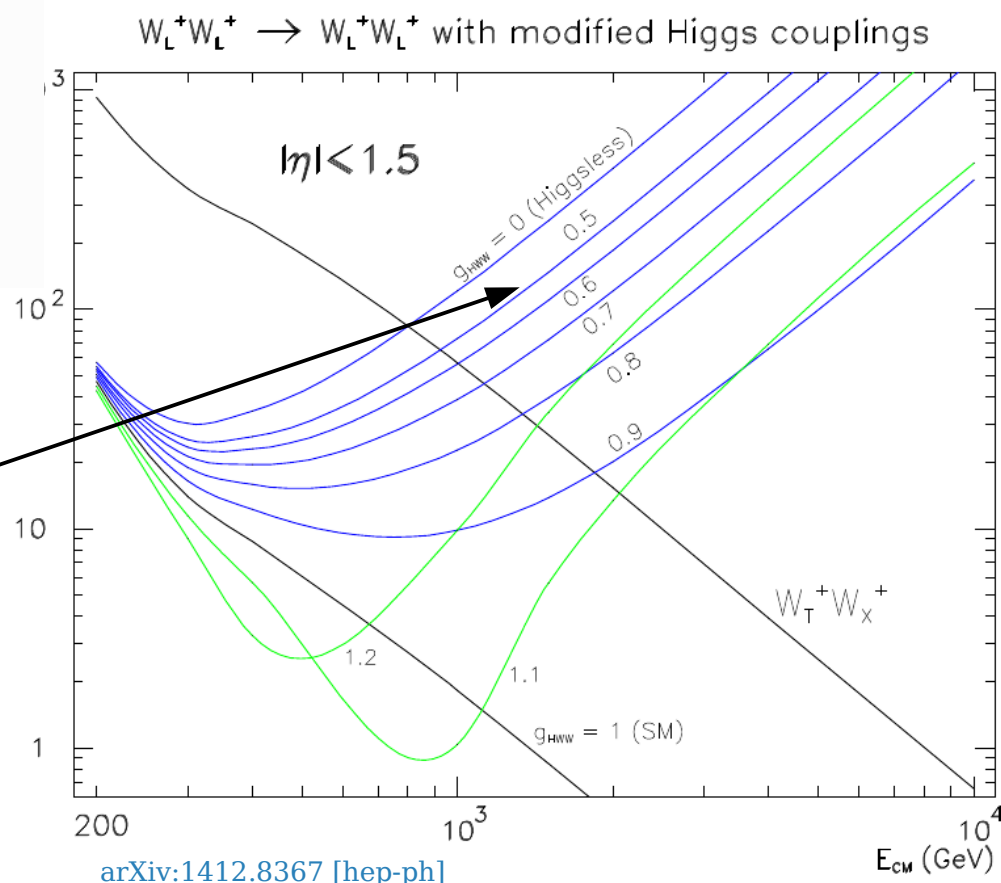
$W_L W_L$ scattering



Higgs diagrams the cancel $E^2 W_L W_L$ scattering cross section dependence



deviations from nominal SM HWW coupling leads to significant cross section increase

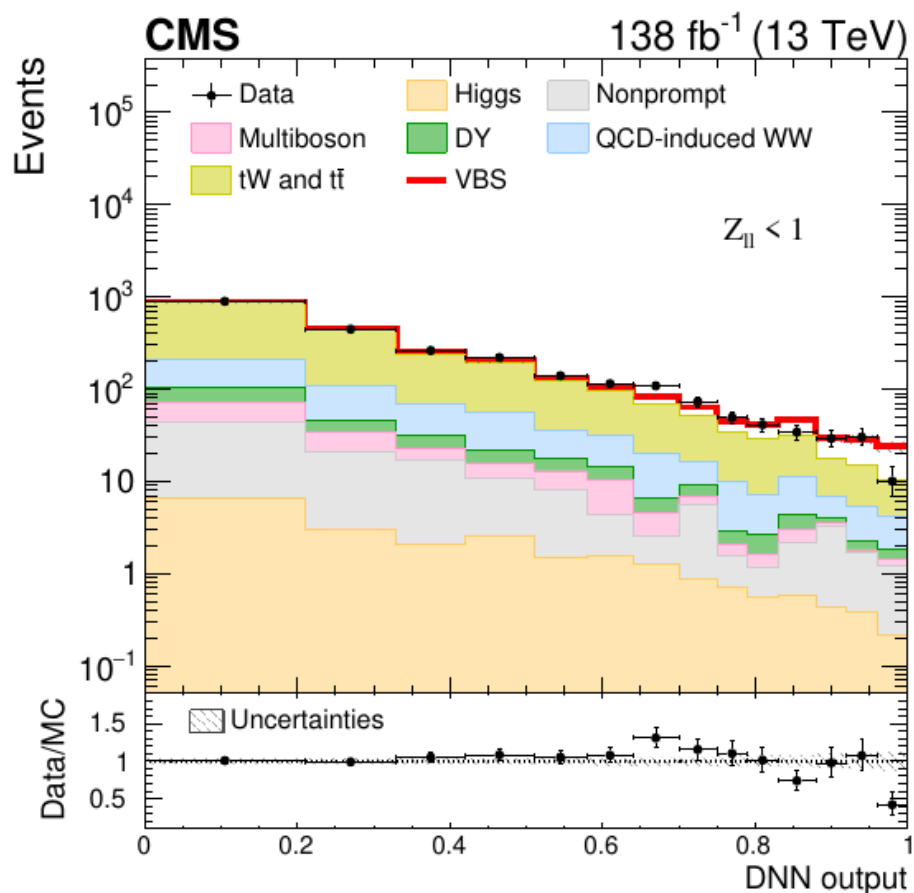
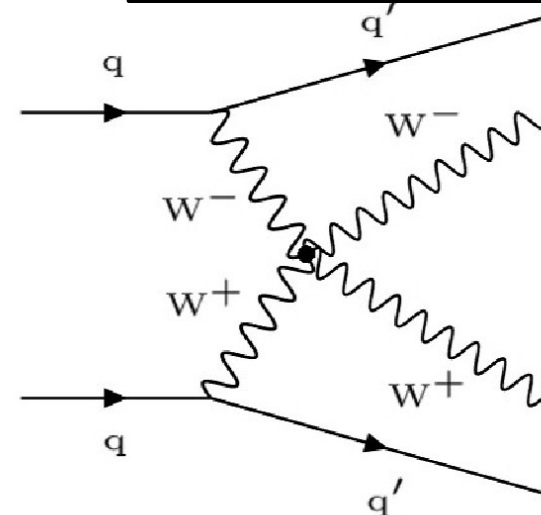


• **signature:**

- two highly η separated jets from scattered quarks
- any $e \mu$ opposite sign pair combination from WW decay
- large missing E_T due to neutrinos

• **background:**

- $t\bar{t}$ (reducible), WW with QCD diagrams, $DY + \text{jets}$



• **signal selection:**

- Deep Neural Network with input from 8 variables describing the leptons and jets kinematics

• **signal measurement:**

- maximum likelihood fit of template shapes in signal- and background-like regions

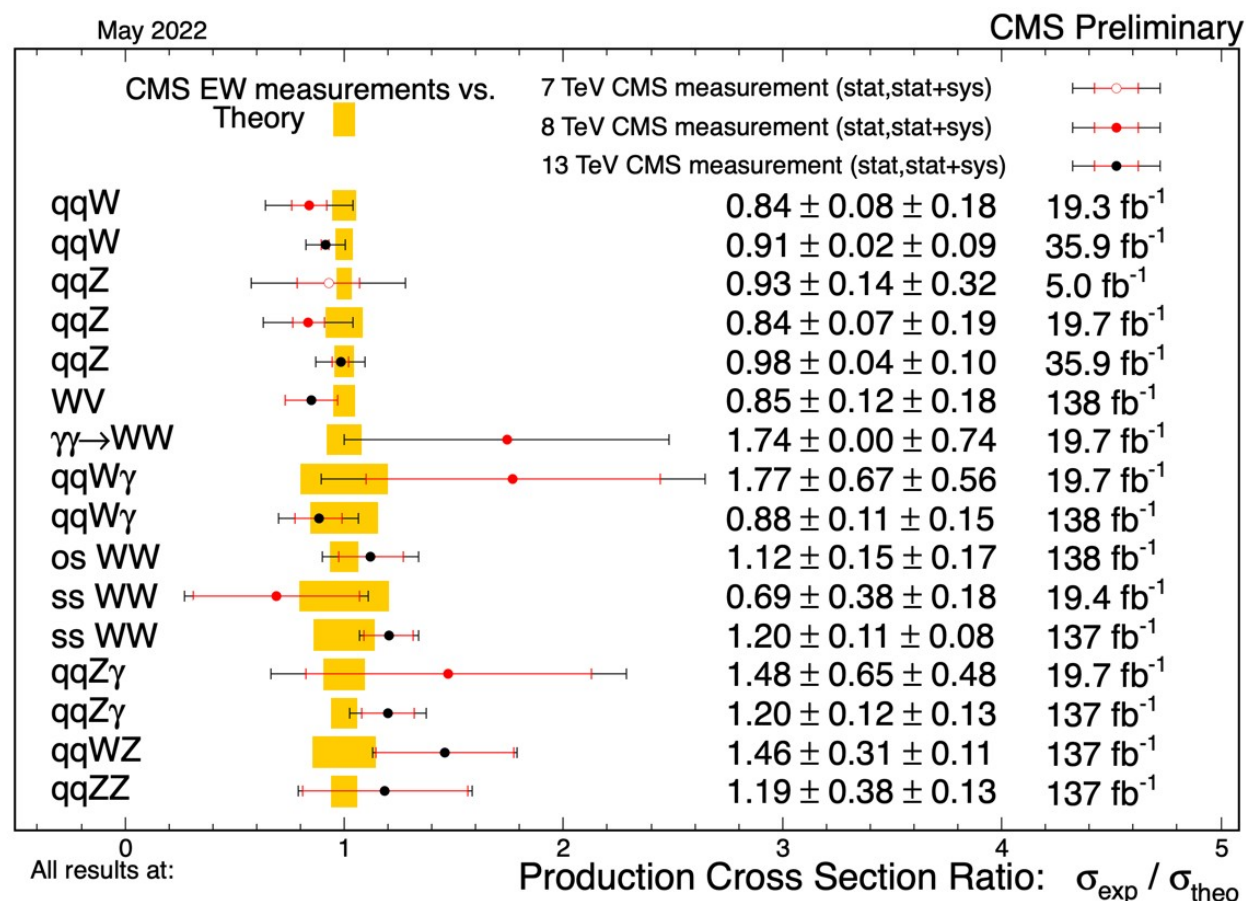
- opposite sign EWK WW scattering:

$$\sigma_{fid}^{obs} = 10.2 \pm 2.0 \text{ fb}$$

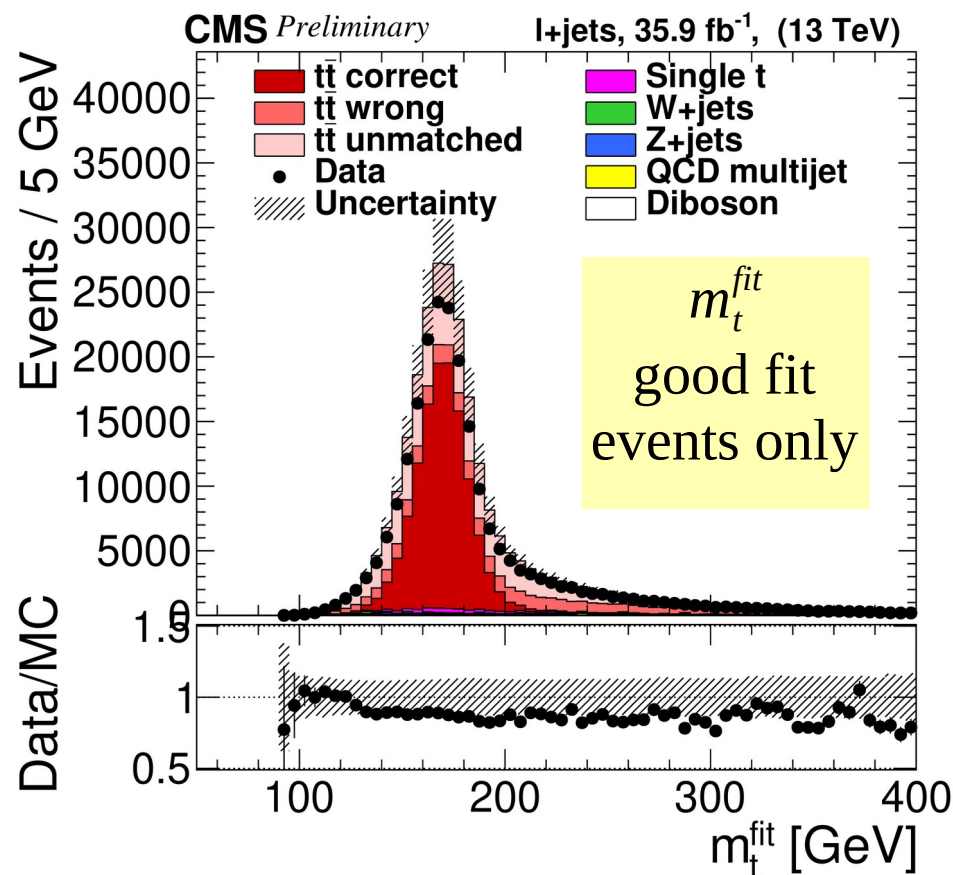
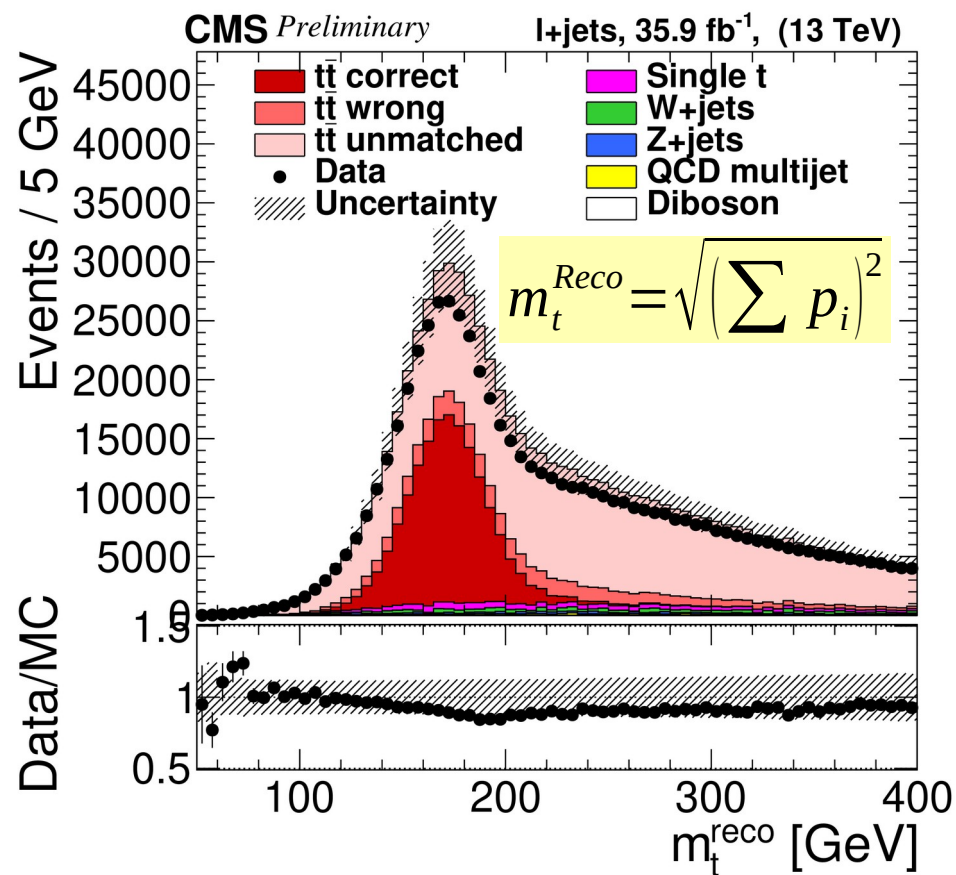
$$\sigma_{fid}^{th} = 9.1 \pm 0.6 \text{ fb}$$

[arXiv:2205.05711 \[hep-ex\]](https://arxiv.org/abs/2205.05711)

- many more VV scattering measurements made in recent years
- no sign if significant large measured cross section excess over SM expectation



- **decay mode:** leptons + jets
- **top mas observable:** kinematic fit
 - improves signal purity
 - improves mass resolution over plain invariant mass from constituents



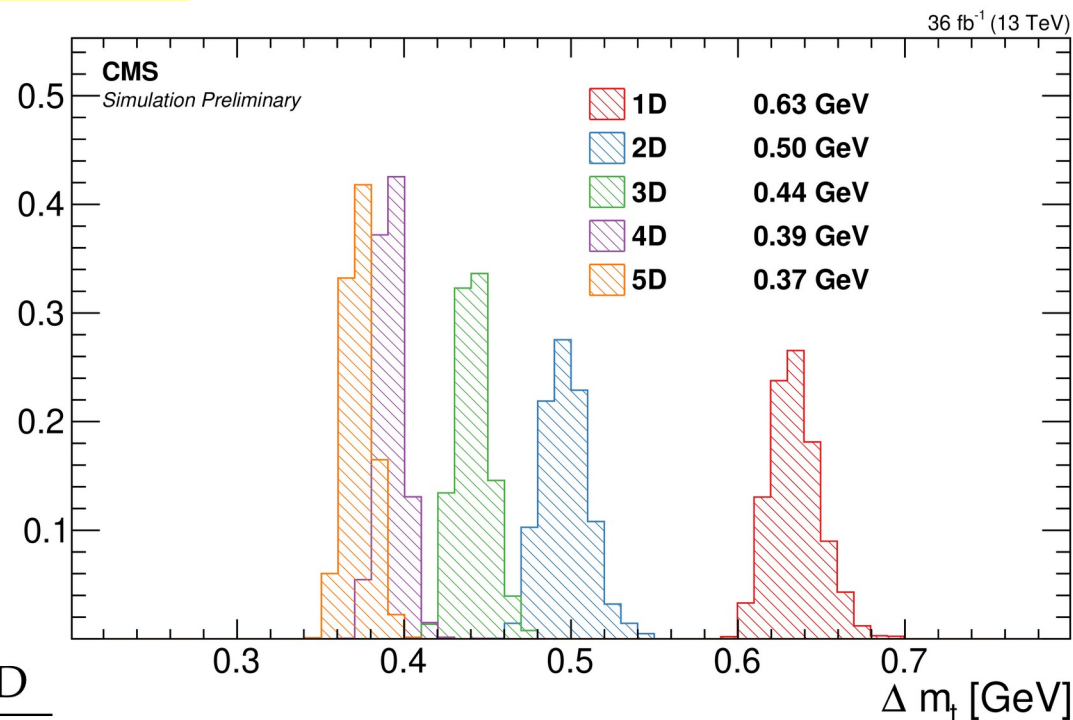
- **top mas estimate:** maximum likelihood fit

$$\lambda(m_t, \vec{\theta} | data) = P(data | m_t) P(\vec{\theta})$$

- **data:** five observables:

- $m_t^{\text{fit}}, m_W^{\text{Reco}},$
- $m_{\text{lb}}^{\text{Reco}}, m_{\text{lb}}^{\text{Reco}}/m_t^{\text{fit}},$
- $R_{\text{bq}}^{\text{Reco}}$

histogram		set label				
observable	category	1D	2D	3D	4D	5D
m_t^{fit}	$P_{\text{gof}} \geq 0.2$	x	x	x	x	x
m_W^{reco}	$P_{\text{gof}} \geq 0.2$		x	x	x	x
$m_{\ell b}^{\text{reco}}$	$P_{\text{gof}} < 0.2$			x	x	x
$m_{\ell b}^{\text{reco}}/m_t^{\text{fit}}$	$P_{\text{gof}} \geq 0.2$				x	x
$R_{\text{bq}}^{\text{reco}}$	$P_{\text{gof}} \geq 0.2$					x



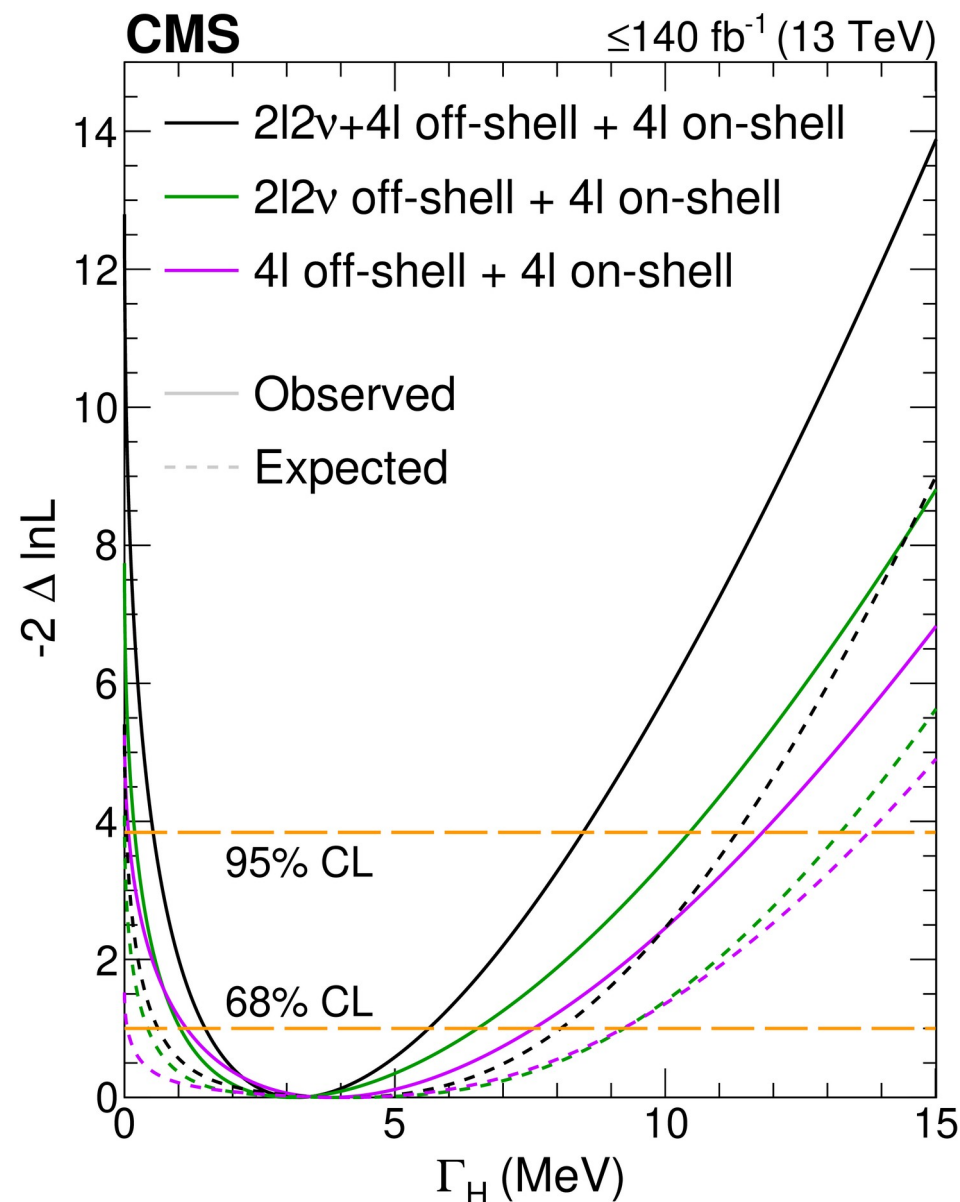
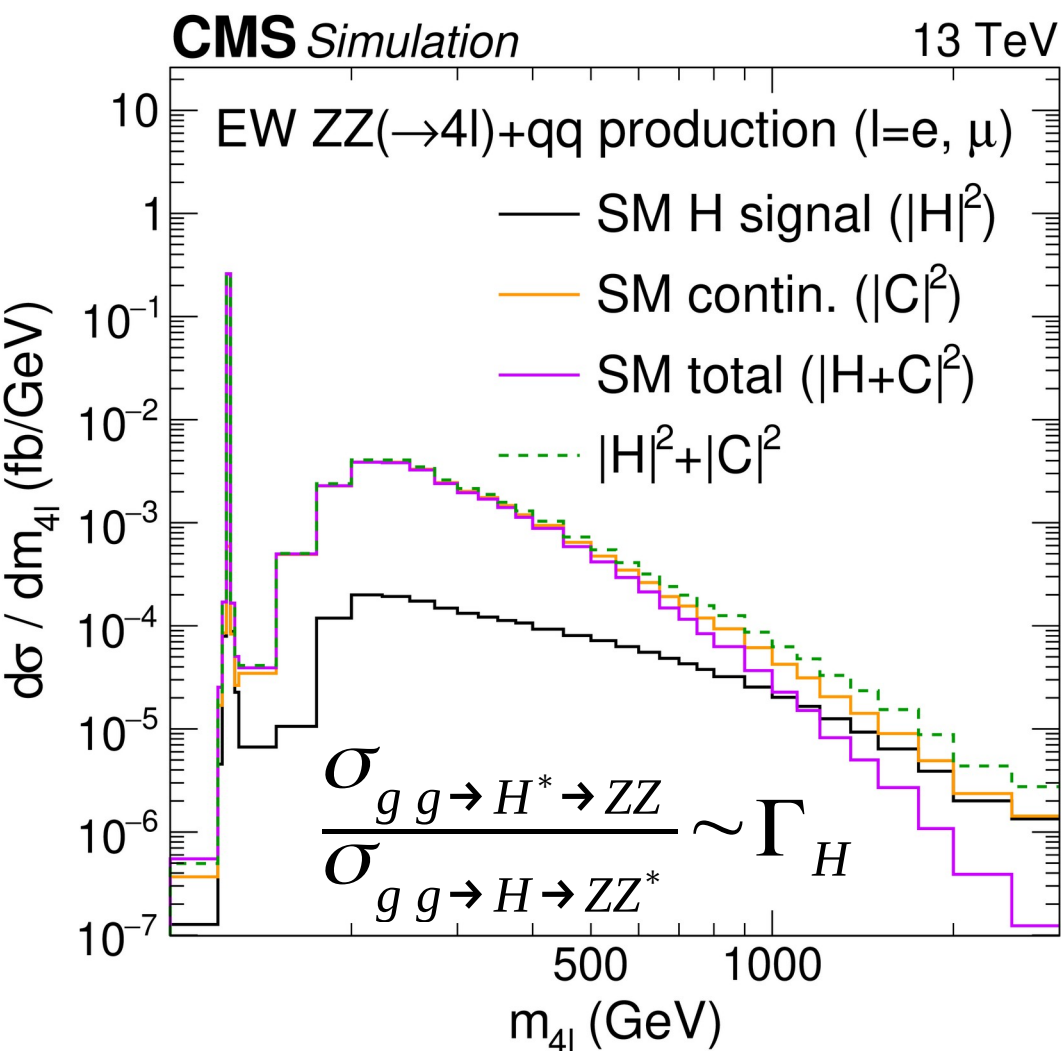
$$m_t = 171.77 \pm 0.38 \text{ GeV}/c^2$$

Most (to date) precise single
top mas measurement

$$R_{\text{bq}}^{\text{reco}} = (p_T^{b1} + p_T^{b2}) / (p_T^{q1} + p_T^{q2})$$

Run-1,2: $\Gamma_H^{\text{obs}} = 3.2_{-1.7}^{+2.4} \text{ MeV}$
 $\Gamma_H^{\text{SM}} = 4.1 \text{ MeV}$

arXiv:2202.06923 [hep-ex]



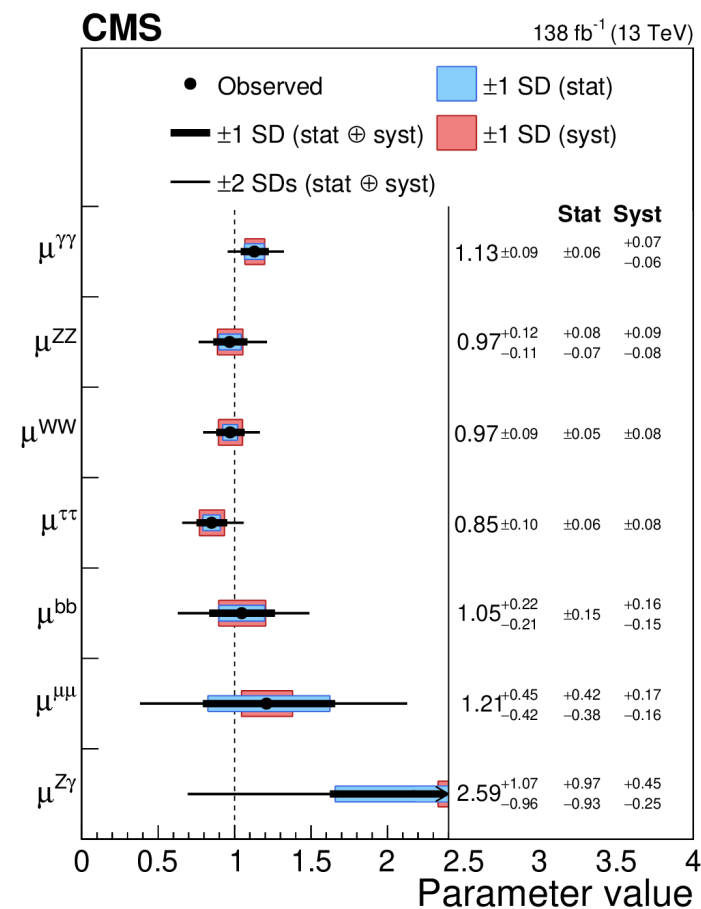
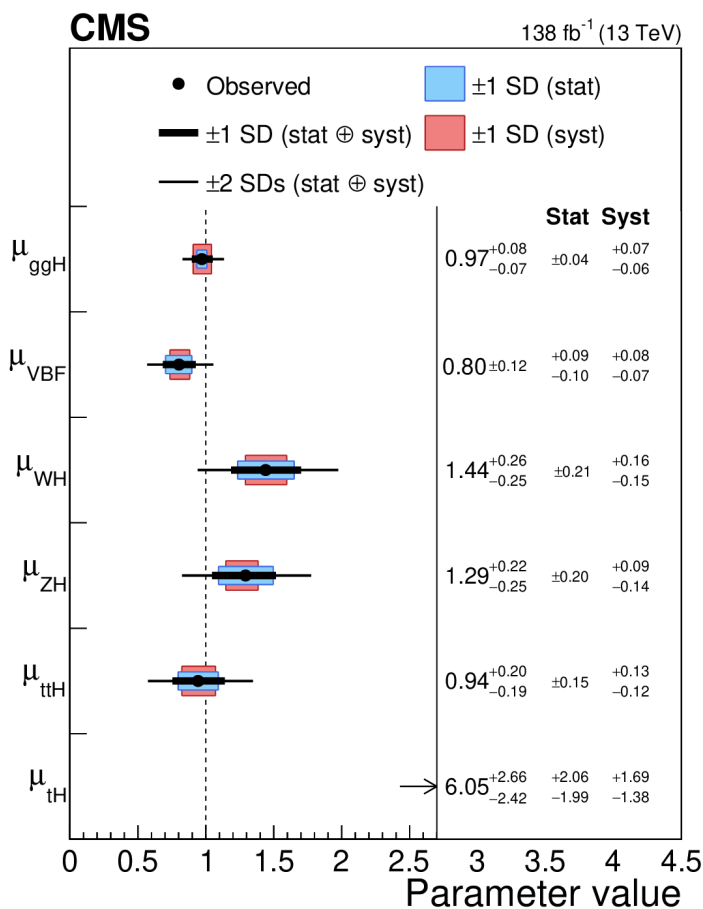
Production modes

$$\mu = \sigma^{\text{exp}} / \sigma^{\text{SM}}$$

Decay modes

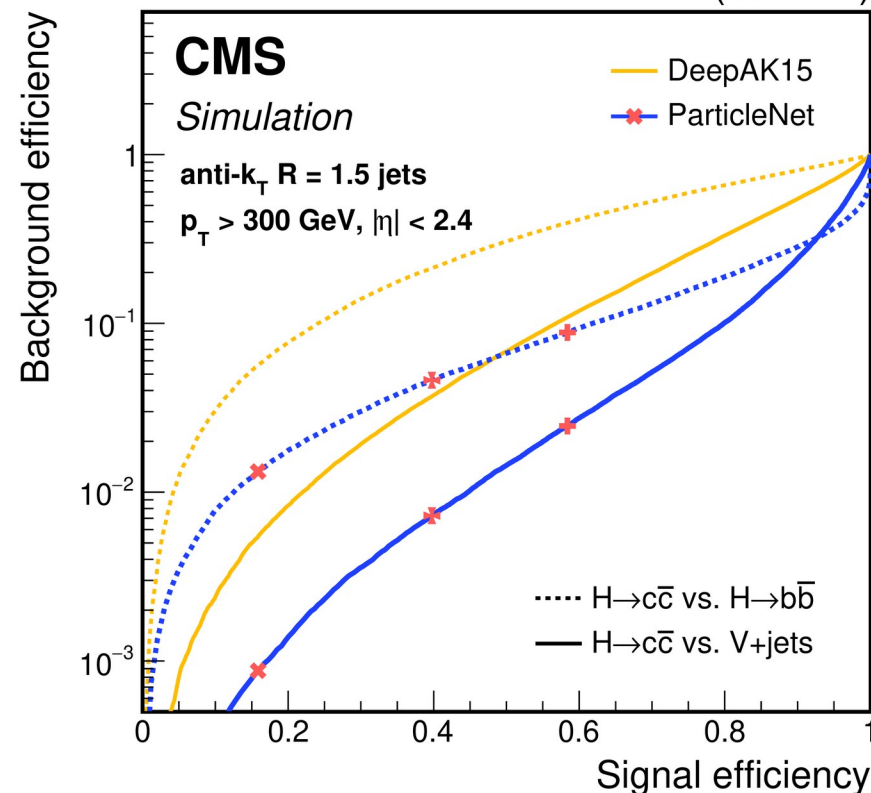
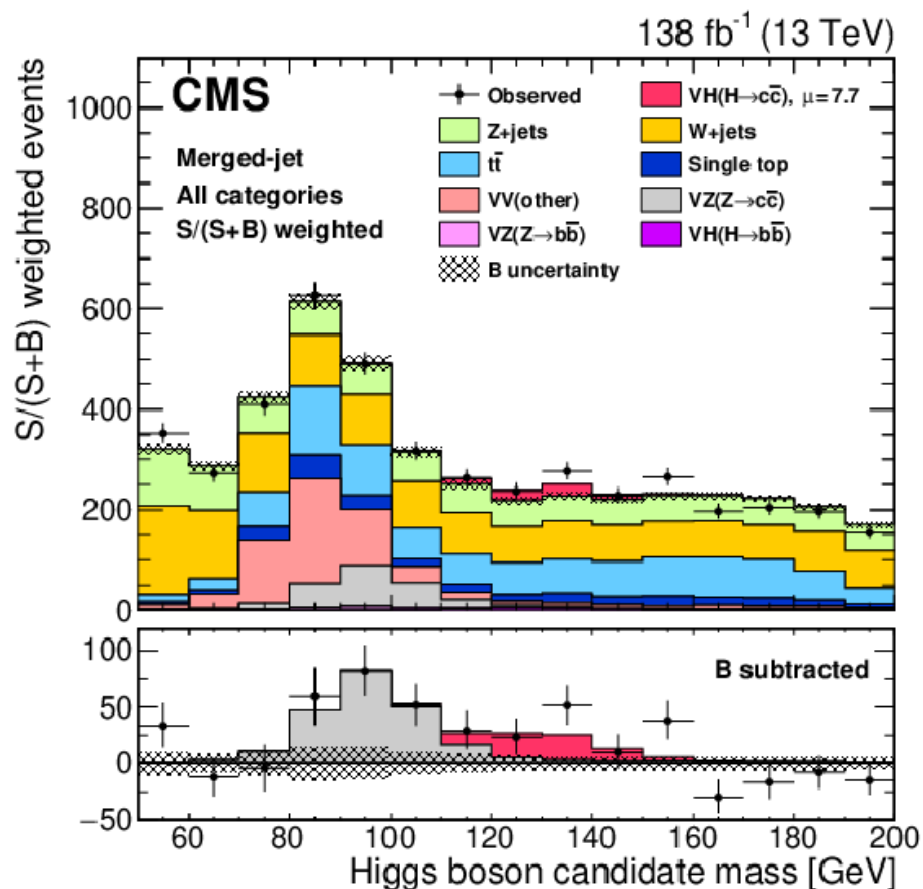
$$\mu = \text{BR}^{\text{exp}} / \text{BR}^{\text{SM}}$$

all strength modifiers
are at 1 within at
most two standard
deviations



(13 TeV)

- $\text{BR}(H \rightarrow c\bar{c}) = 0.029 \gg \text{BR}(H \rightarrow 4l)$
- huge background from QCD $c\bar{c}$ pairs
- use of VH production mode to get additional selection handles
- use of improved c-tagging



$$\sigma_{VZ(Z \rightarrow c\bar{c})} = 1.01^{+0.22}_{-0.21} \sigma_{\text{SM}}$$

$$\sigma_{VH(H \rightarrow c\bar{c})} < 14 \sigma_{\text{SM}} @ 95 \% \text{ CL}$$

Higgs decays to light leptons

• **$H \rightarrow \mu\mu$:**

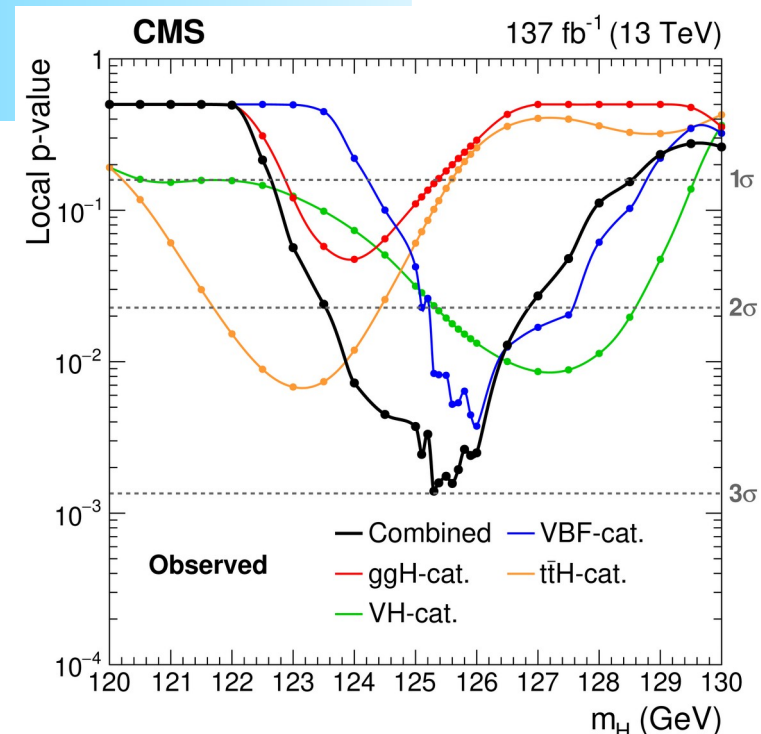
- $BR(H \rightarrow \mu\mu) = 2.2 \cdot 10^{-4} \simeq 2 \cdot BR(H \rightarrow 4l(e,\mu))$

$$\frac{\sigma_{pp \rightarrow H \rightarrow \mu\mu}^{\text{obs}}}{\sigma_{\text{SM}}} = 1.19^{+0.4}_{-0.39} (\text{stat})^{+0.15}_{-0.14} (\text{sys})$$

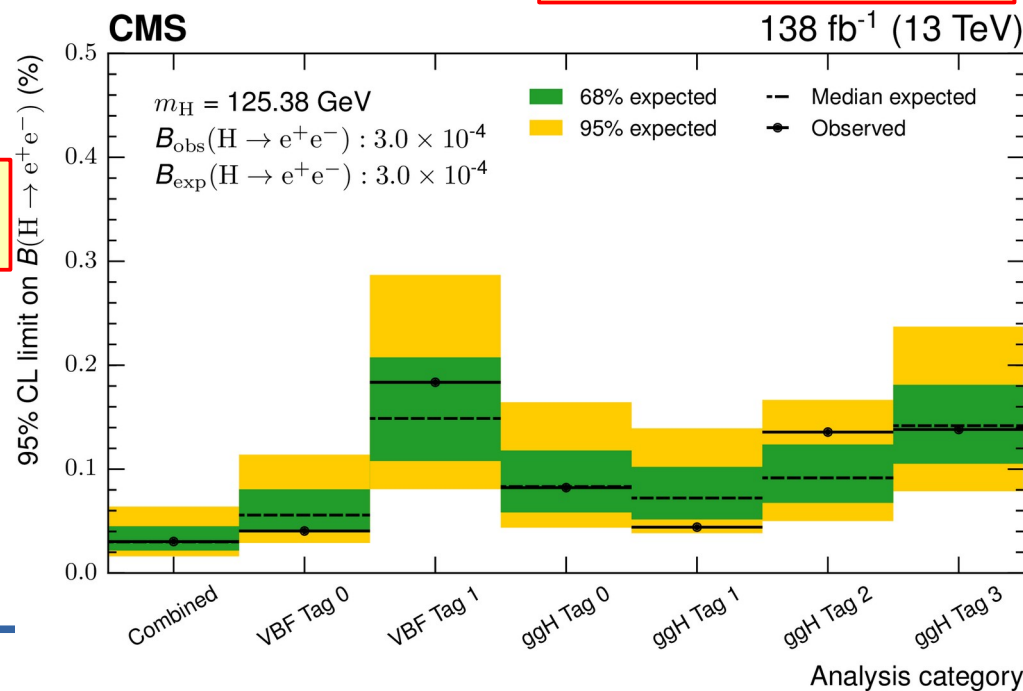
• **$H \rightarrow ee$:**

- $BR(H \rightarrow ee) = 5 \cdot 10^{-9}$

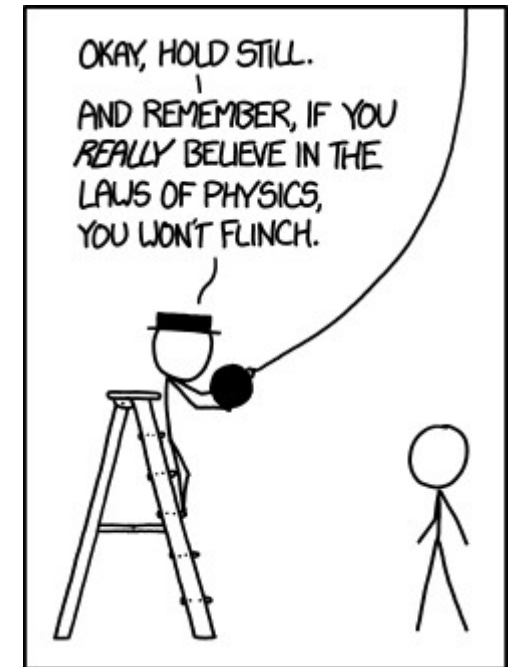
$$BR(H \rightarrow ee) < 3 \cdot 10^{-4} @ 95\% \text{ CL}$$



arXiv:2208.00265 [hep-ex]



- The CMS Collaboration has a plethora results on Standards Model physics
- ever increasing integrated luminosity allows for study of more and more rare processes, like Vector Boson Scattering
- so far all results support our confidence in Standard Model



<https://xkcd.com/1670/>

Backup slides

- opposite sign EWK WW scattering:

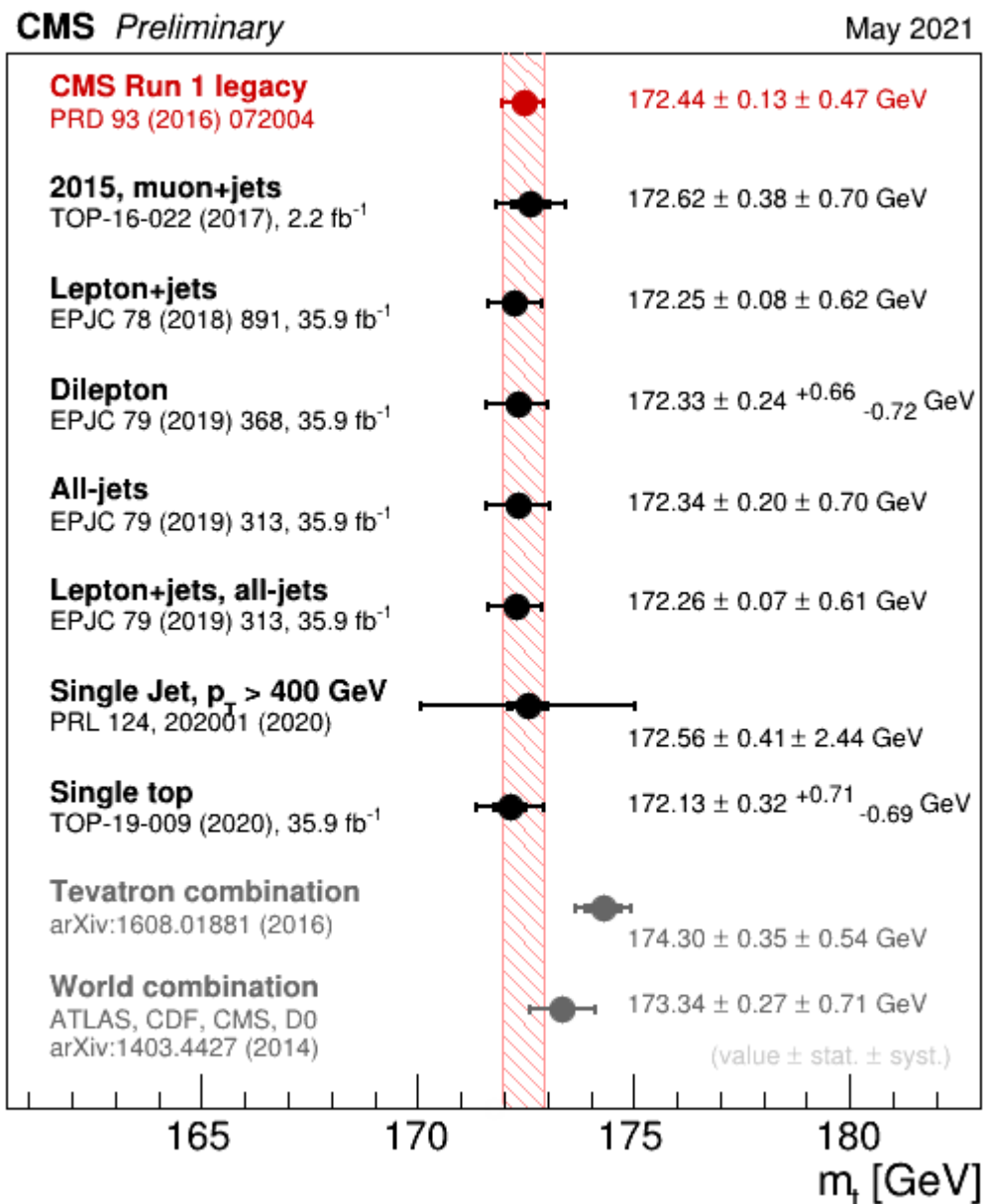
$$\sigma_{fid}^{obs} = 10.2 \pm 2.0 \text{ fb} \quad \sigma_{fid}^{th} = 9.1 \pm 0.6 \text{ fb}$$

[arXiv:2205.05711 \[hep-ex\]](https://arxiv.org/abs/2205.05711)

Table 3: Definition of the fiducial volume similar to the reconstructed SR.

Objects	Requirements
Leptons	$e\mu, ee, \mu\mu$ (not from τ decay), opposite charge
	$p_T^{\text{dressed } \ell} = p_T^\ell + \sum_i p_T^{\gamma_i}$ if $\Delta R(\ell, \gamma_i) < 0.1$
	$p_T^{\ell_1} > 25 \text{ GeV}, p_T^{\ell_2} > 13 \text{ GeV}, p_T^{\ell_3} < 10 \text{ GeV}$
	$ \eta < 2.5$
	$p_T^{\ell\ell} > 30 \text{ GeV}, m_{\ell\ell} > 50 \text{ GeV}$
Jets	$p_T^j > 30 \text{ GeV}$
	$\Delta R(j, \ell) > 0.4$
	At least 2 jets, no b jets
	$ \eta < 4.7$
	$m_{jj} > 300 \text{ GeV}, \Delta\eta_{jj} > 2.5$
p_T^{miss}	$p_T^{\text{miss}} > 20 \text{ GeV}$

top mass results



$H \rightarrow ZZ, \gamma\gamma$, Run-1+2016: $m_H = 125.38 \pm 0.14 \text{ GeV}$

$H \rightarrow ZZ$ only Runs-1,2: $m_H = 125.09 \pm 0.15 \text{ GeV}$

