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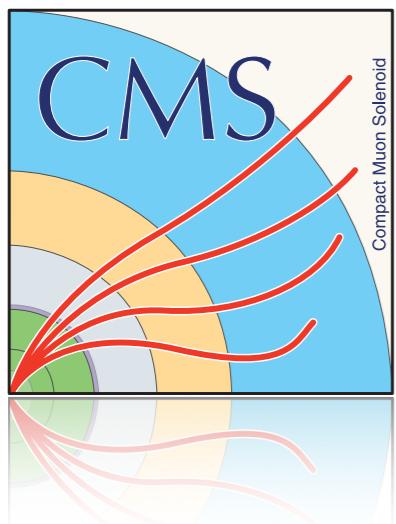
# Measurement of VH production with $H \rightarrow \gamma\gamma$ in CMS experiment

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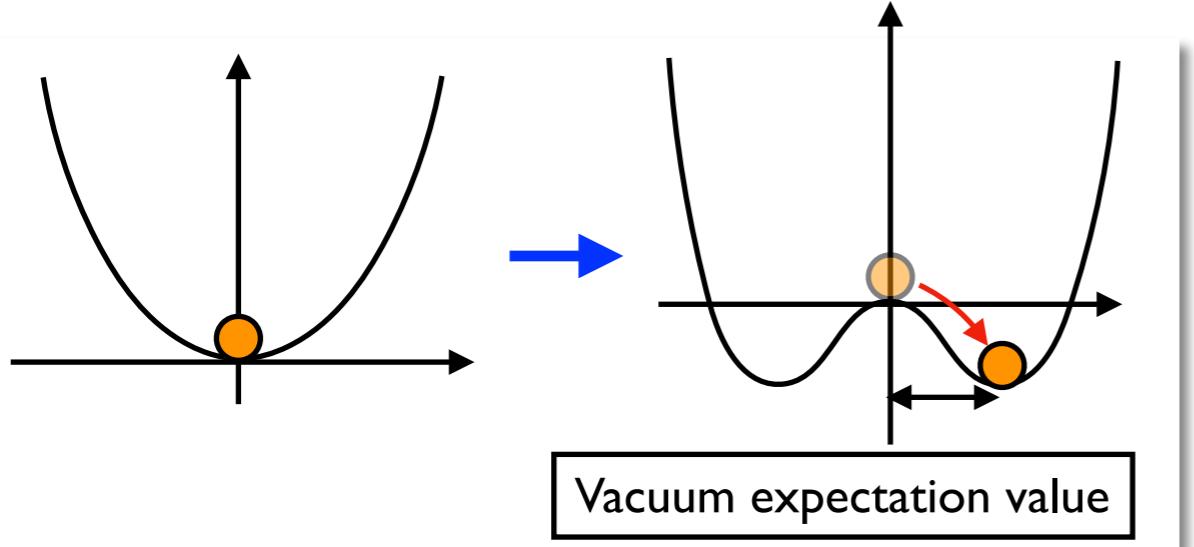
**TW HEP meeting – 22 Jan. 2021**



# Higgs mechanism



## Spontaneous symmetry breaking



Predict



Higgs boson (Spin = 0)

## Origin of mass

three generations of matter (fermions)				
mass charge spin	I u down	II c strange	III t b	top
$\approx 2.2 \text{ MeV}/c^2$ $\frac{2}{3}$ $\frac{1}{2}$	$\approx 1.28 \text{ GeV}/c^2$ $\frac{2}{3}$ $\frac{1}{2}$	$\approx 173.1 \text{ GeV}/c^2$ $\frac{2}{3}$ $\frac{1}{2}$		
$\approx 4.7 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$	$\approx 96 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$	$\approx 4.18 \text{ GeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$		
$\approx 0.511 \text{ MeV}/c^2$ $-1$ $\frac{1}{2}$	$\approx 105.66 \text{ MeV}/c^2$ $-1$ $\frac{1}{2}$	$\approx 1.7768 \text{ GeV}/c^2$ $-1$ $\frac{1}{2}$		
$<1.0 \text{ eV}/c^2$ $0$ $\frac{1}{2}$	$<0.17 \text{ MeV}/c^2$ $0$ $\frac{1}{2}$	$<18.2 \text{ MeV}/c^2$ $0$ $\frac{1}{2}$		
leptons	electron neutrino	$\nu_e$	$\nu_\mu$	$\nu_\tau$

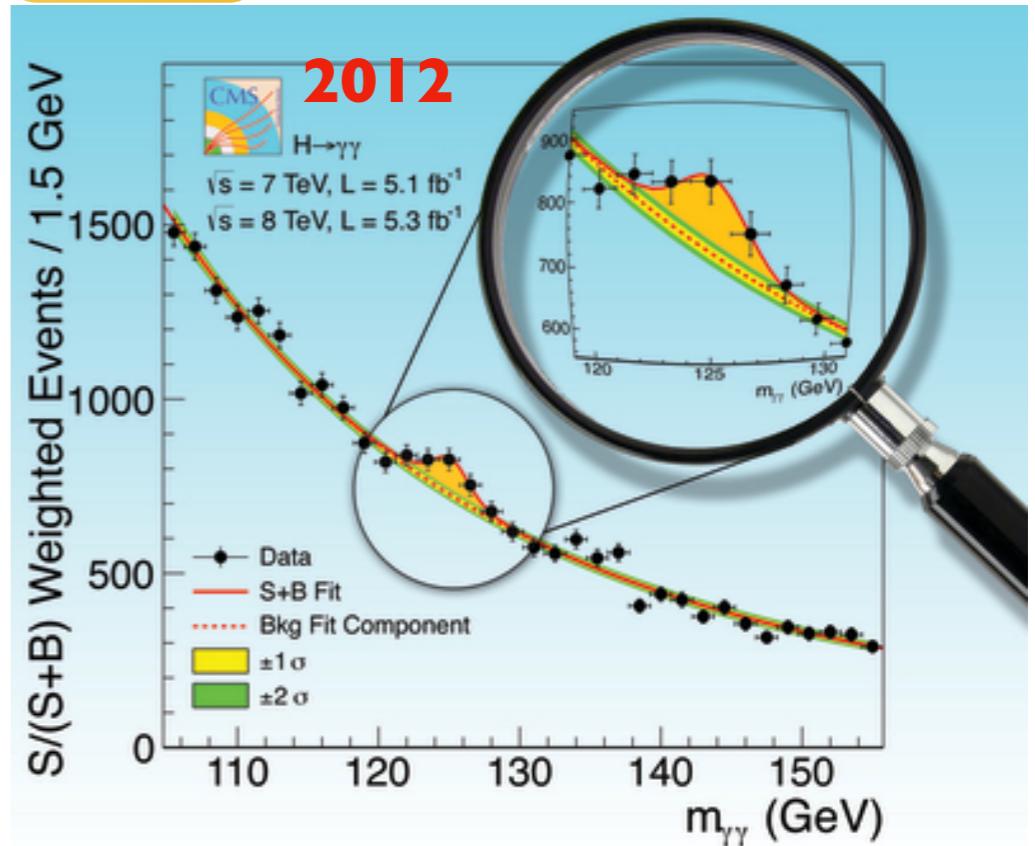
## Obtain mass



$$M_W \neq 0$$

$$M_Z \neq 0$$

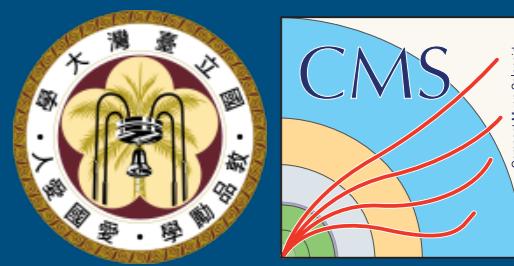
**GAUGE BOSONS**  
VECTOR BOSONS



2013



# Motivation



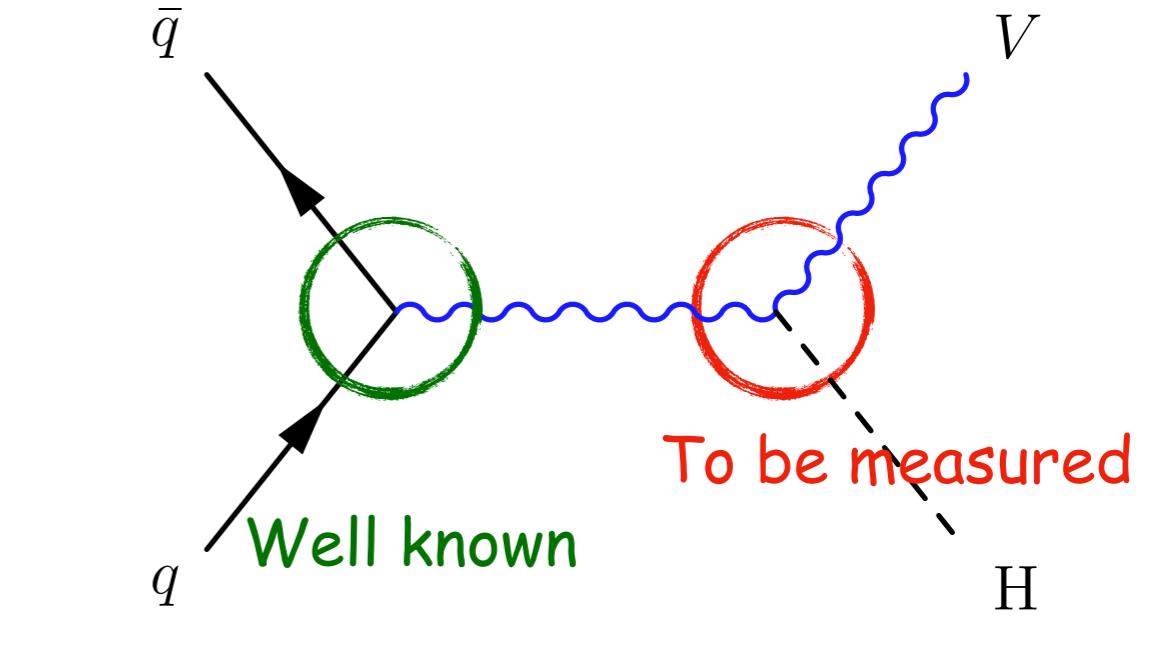
## The Standard Model Lagrangian

$$\mathcal{L}_{\text{SM}} = \dots + g' m_W W_\mu^+ W_\mu^- H + \frac{g' m_W}{2 \cos^2 \theta_W} Z^\mu Z_\mu H + \dots$$

Diagram illustrating the coupling terms in the Standard Model Lagrangian:

- $W^-$  boson couples to the Higgs boson ( $H$ ) with strength  $g' m_W$ .
- $Z$  boson couples to the Higgs boson ( $H$ ) with strength  $\frac{g' m_W}{2 \cos^2 \theta_W}$ .

## VH associated production



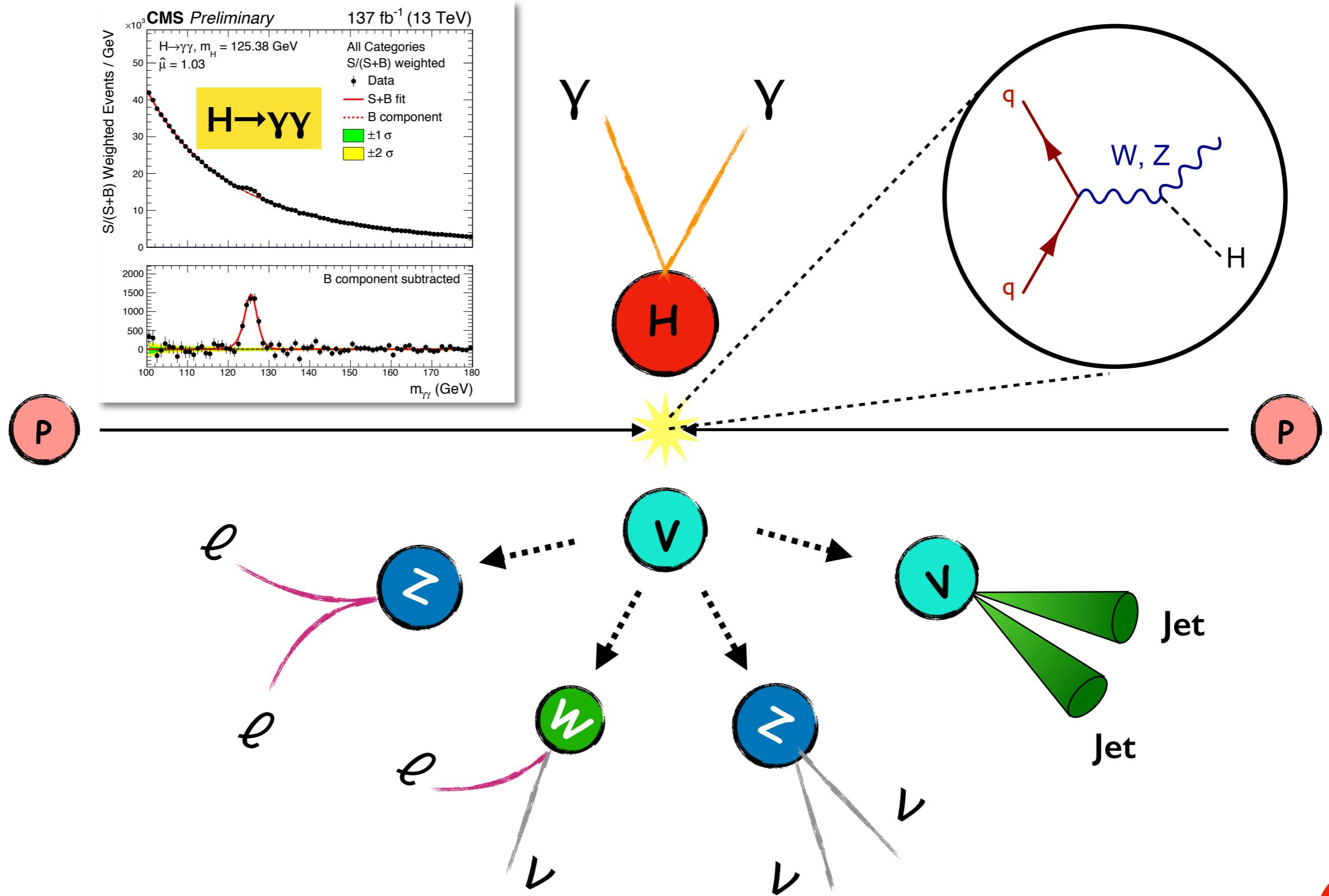
- Coupling strength measurement of **Higgs boson couplings to W and Z boson (HVV)** provides how Higgs boson interacts with W/Z and the understanding of electroweak symmetry breaking.

■ Signal strength measurement of VH production directly reflects the parameters of HVV coupling.

signal strength

$$\mu = \frac{\sigma_{\text{obs}}}{\sigma_{\text{SM}}}$$

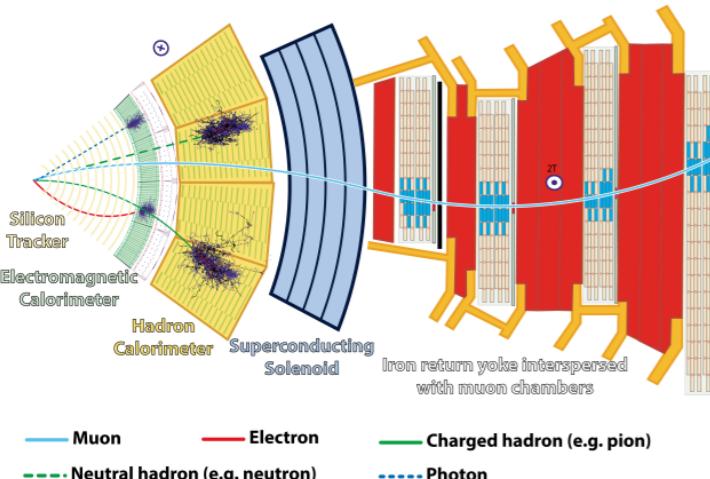
# WH/ZH production with Higgs to $\gamma\gamma$



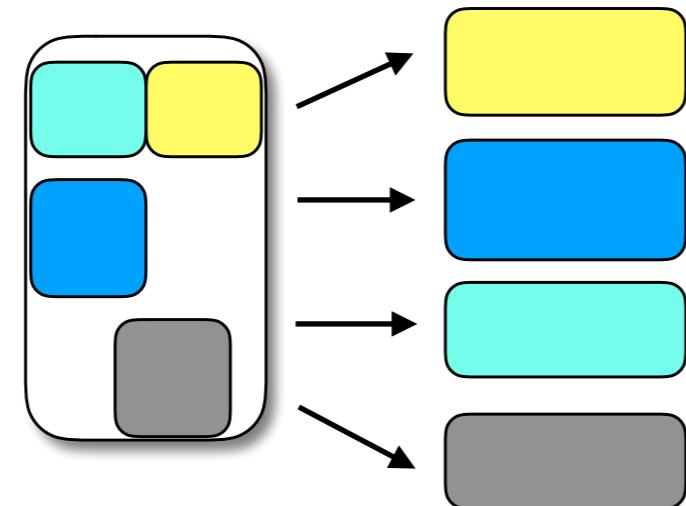
# Analysis flow



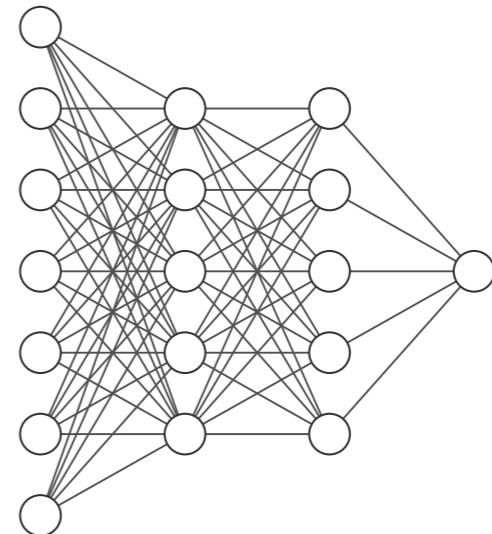
## Event reconstruction



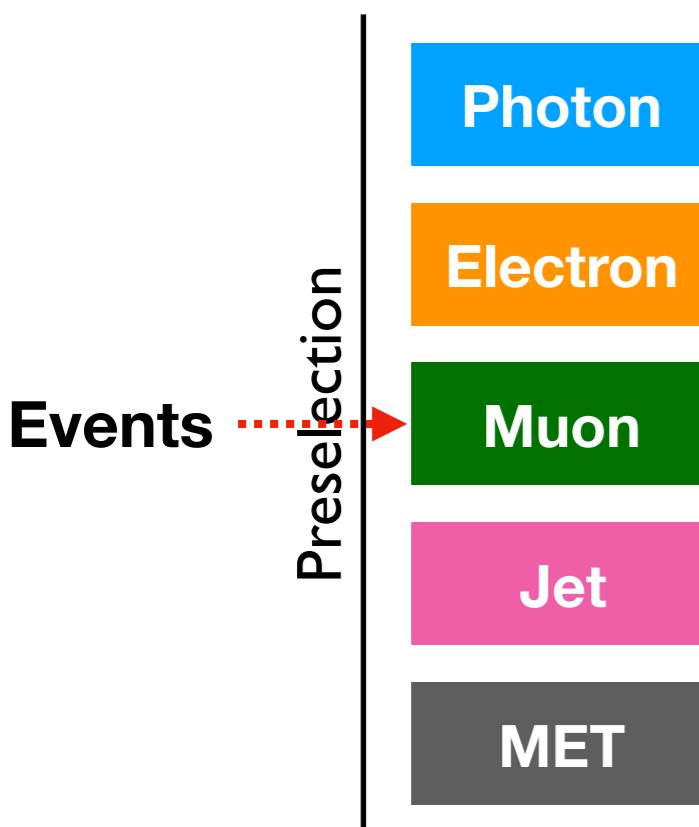
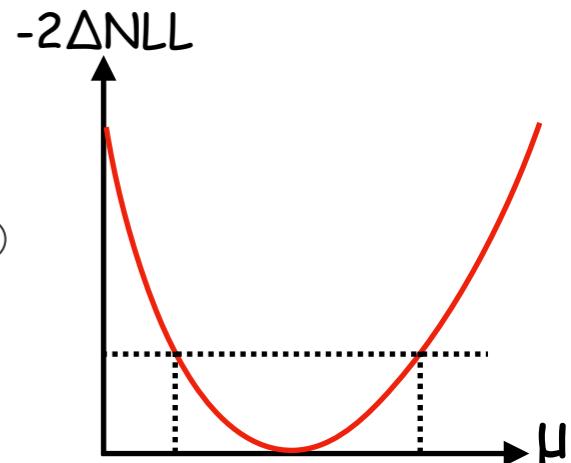
## Event categorization



## Bkg subtraction



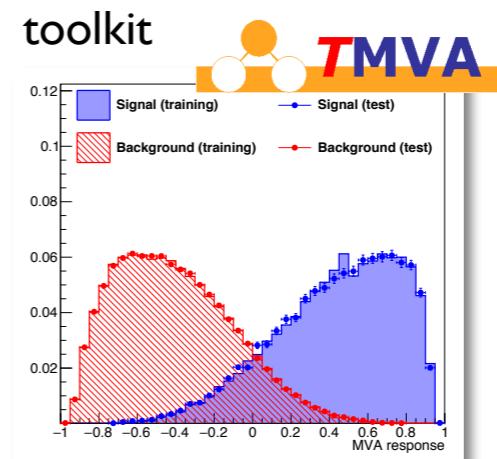
## Results



- Three categories in VH Leptonic decay and one VH Hadronic decay



- Machine learning technique is applied for background subtraction
- Use Adaptive Boost Decision Tree in TMVA toolkit

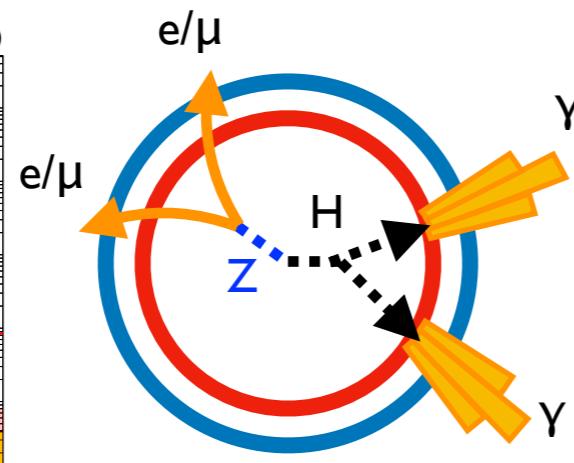
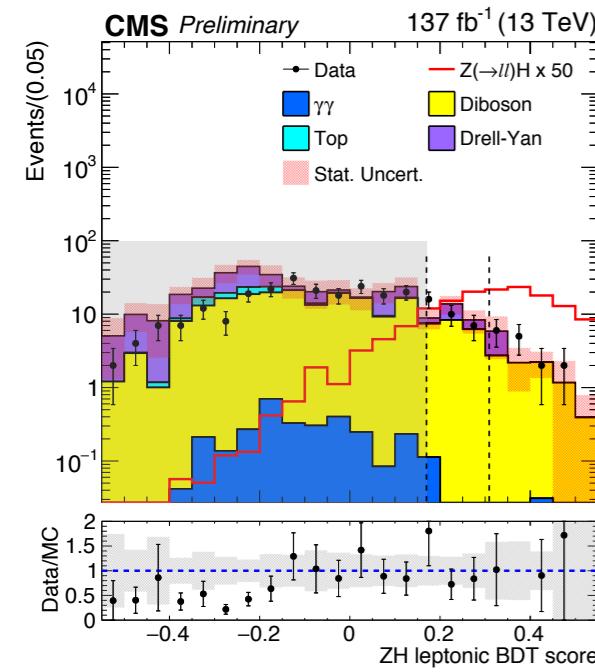


- Parametric model for Signal and background with data driven
- Profile likelihood ratio for the signal strength measurement

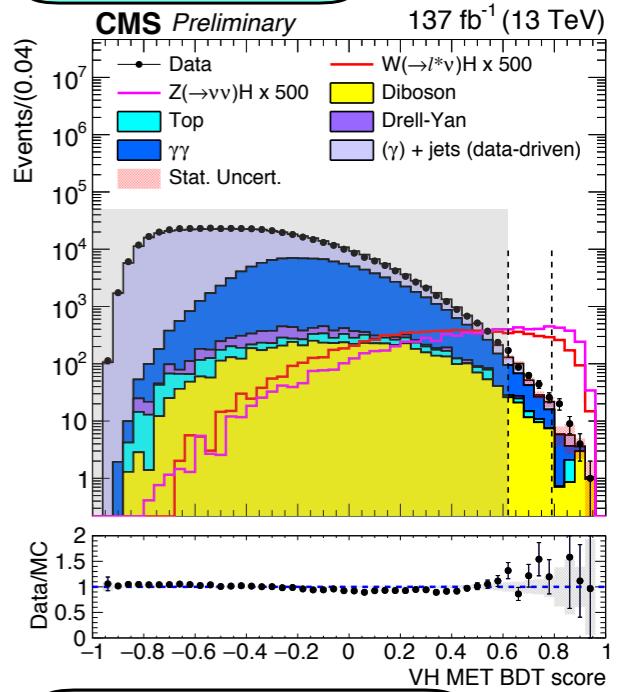
# MVA discriminator



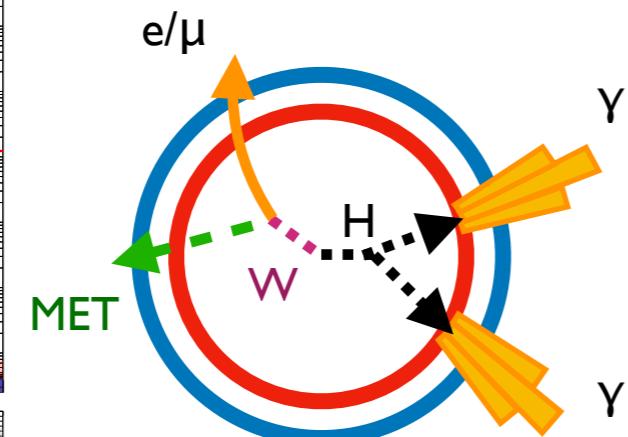
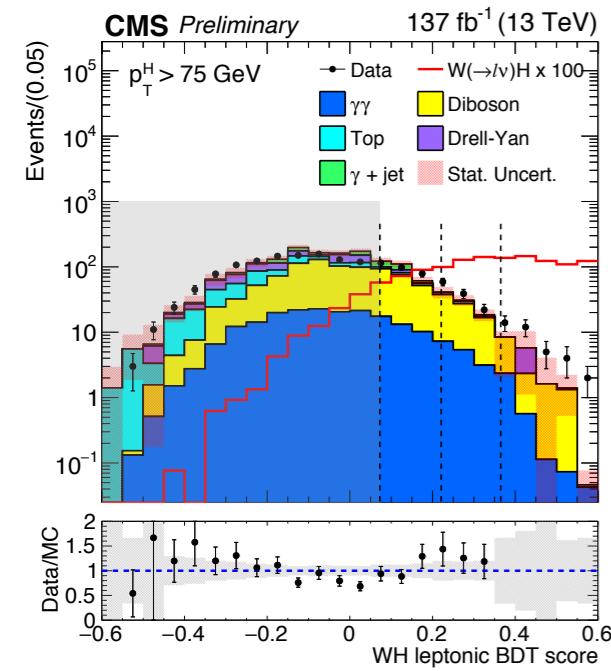
ZHLeptonic Tag



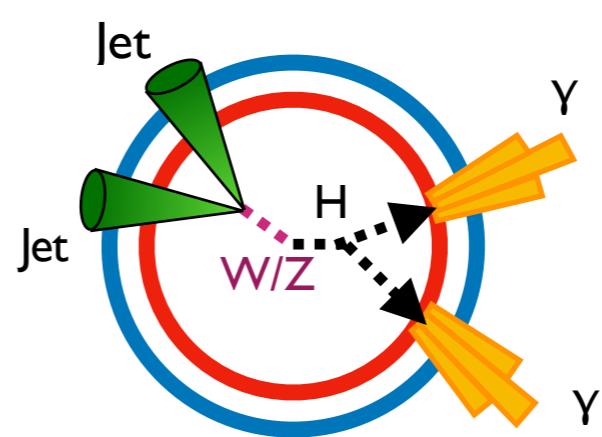
VH MET Tag



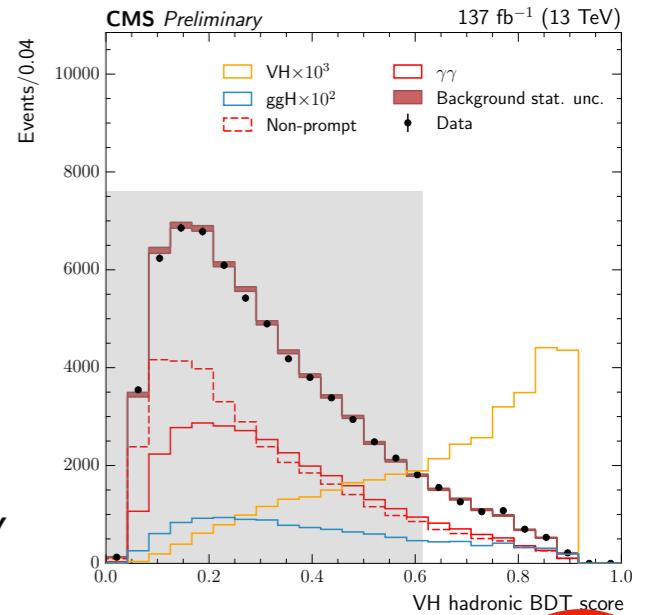
WHLeptonic Tag



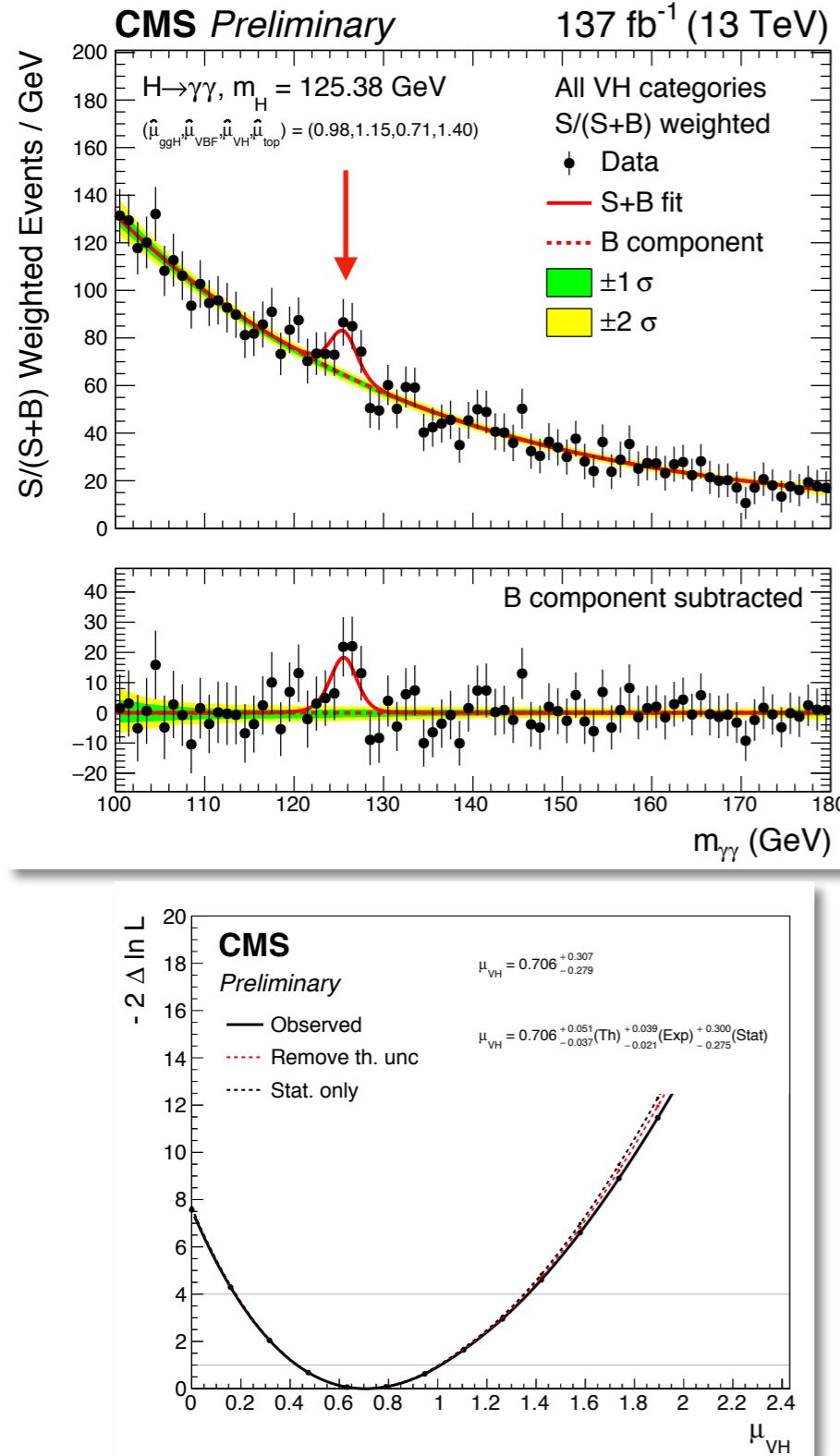
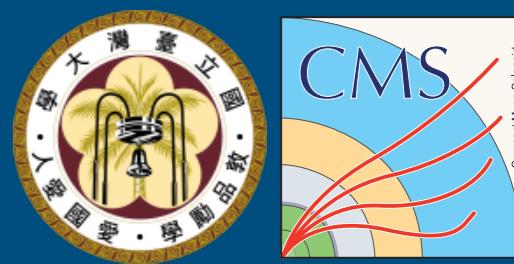
$VH(\rightarrow \gamma\gamma)$



VHHadronic Tag

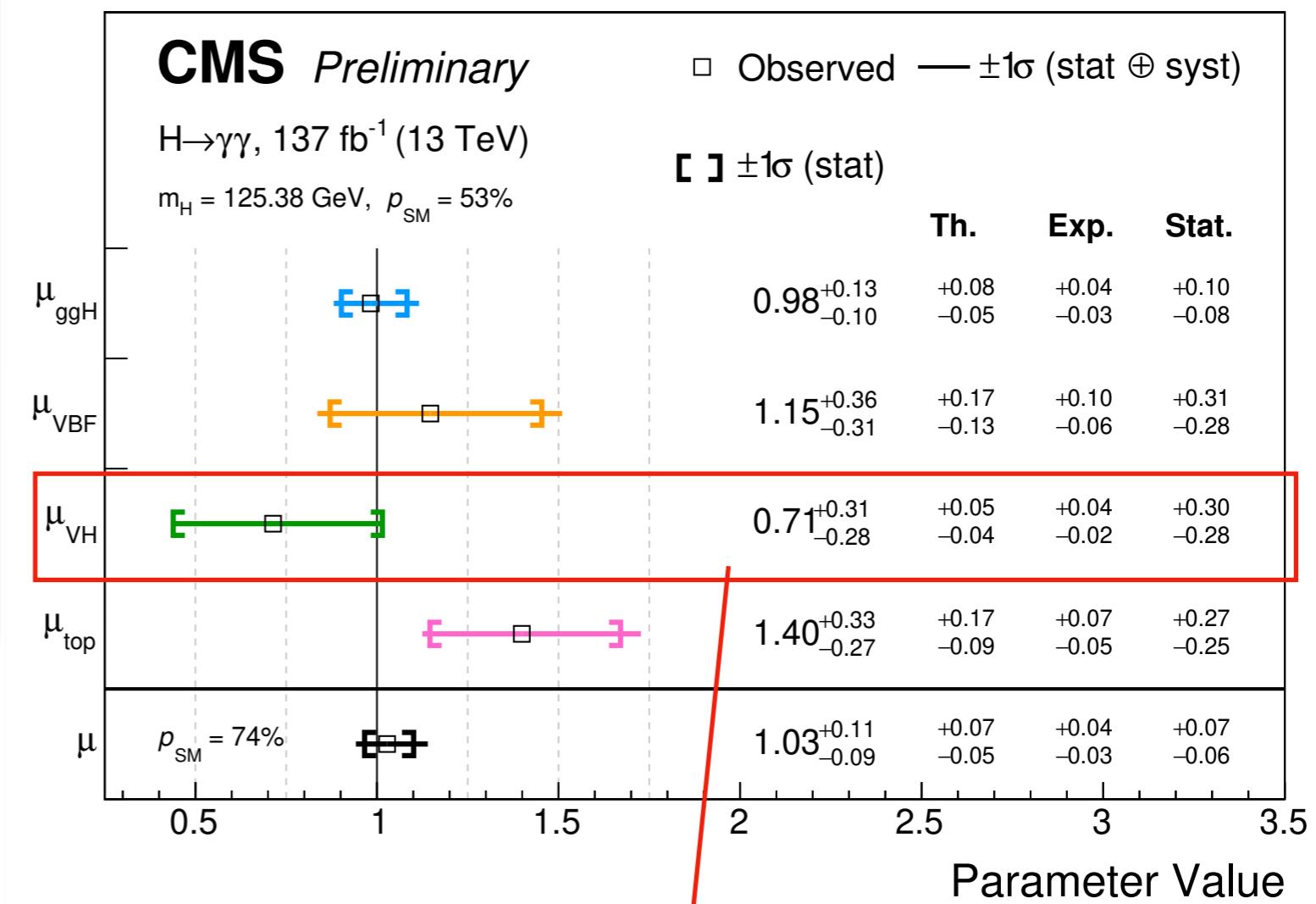


# Preliminary result



**CMS-PAS-HIG-19-015**

**137  $\text{fb}^{-1}$**



Observed (expected) significance =  $2.9\sigma$  ( $3.6\sigma$ )  
 VH inclusive result satisfies the Standard Model Prediction