

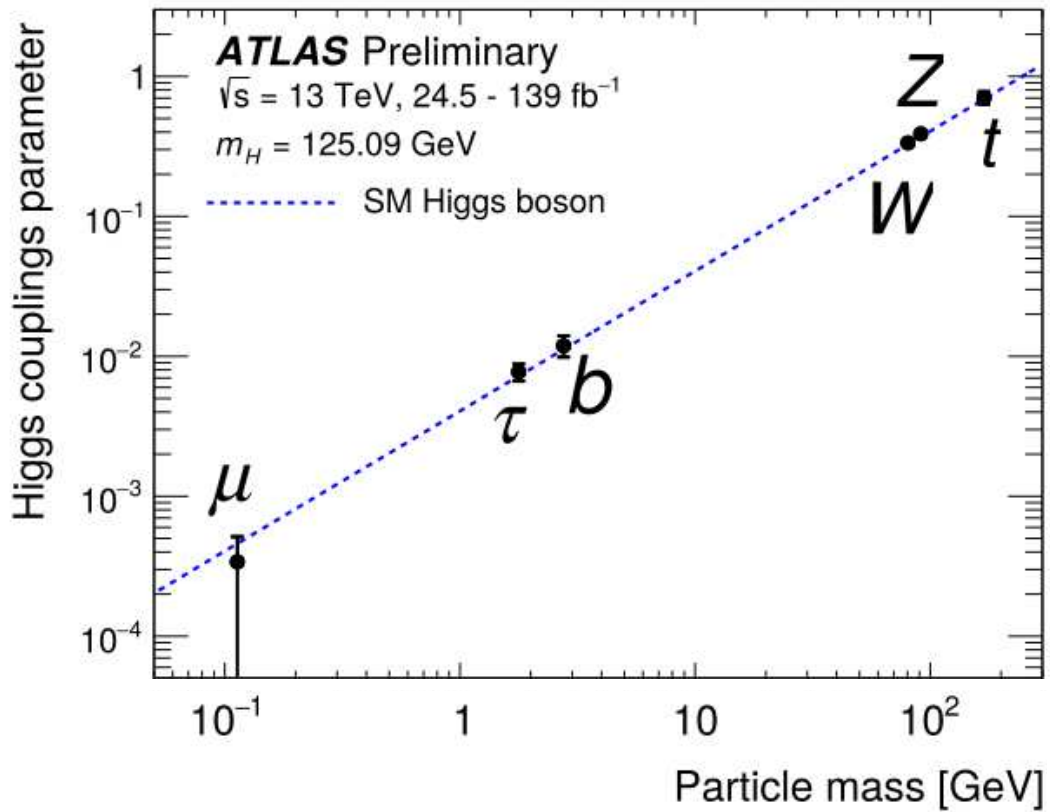
**Fast forward:**

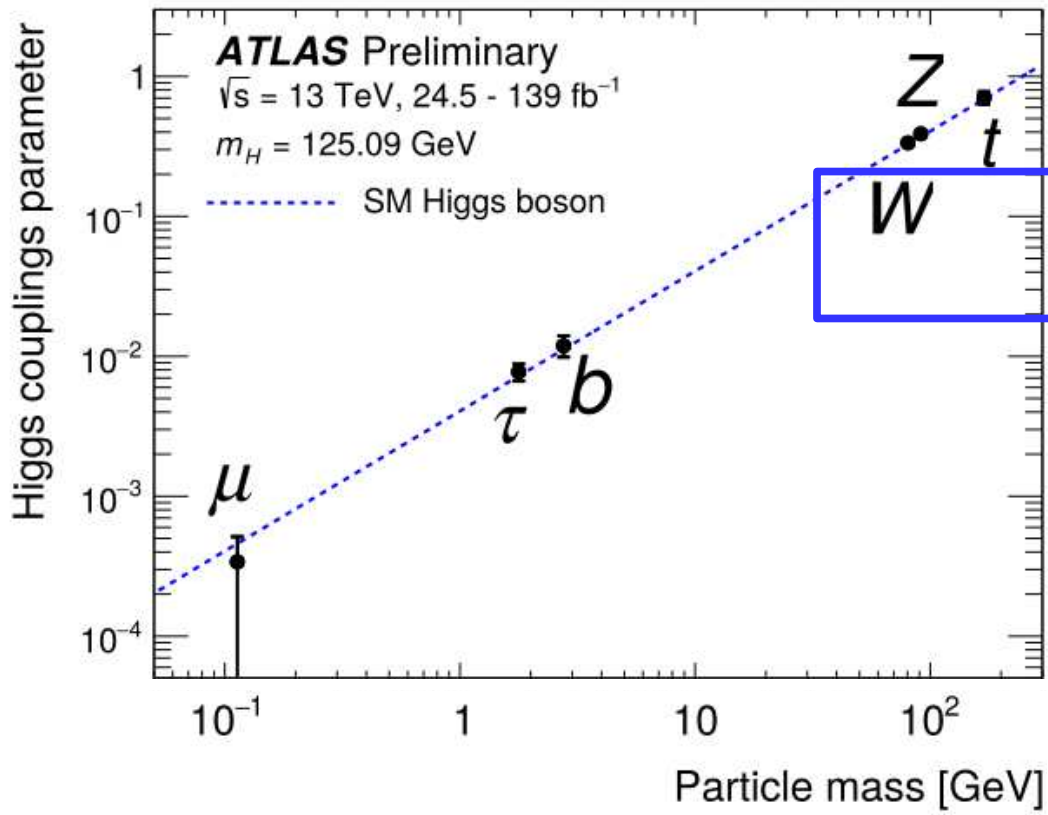
## **Is the Higgs Boson the Higgs Boson?**



Observation of vector-boson-fusion production of Higgs bosons in the  $H \rightarrow WW^* \rightarrow e\nu\mu\nu$  decay channel in  $pp$  collisions at  $\sqrt{s}=13$  TeV with the ATLAS detector  
*ICHEP conference 2020*

Measurements of gluon fusion and vector-boson-fusion production of the Higgs boson in  $H \rightarrow WW^* \rightarrow e\nu\mu\nu$  decays using  $pp$  collisions at  $\sqrt{s}=13$  TeV with the ATLAS detector  
*To be submitted to Physics Review D*



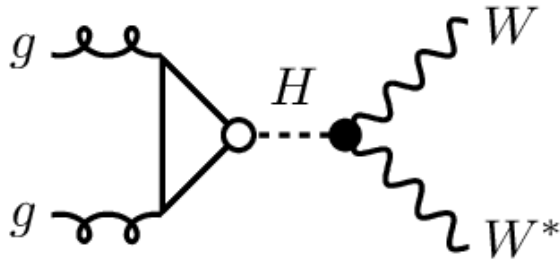


Decays into W bosons picking a special production mode

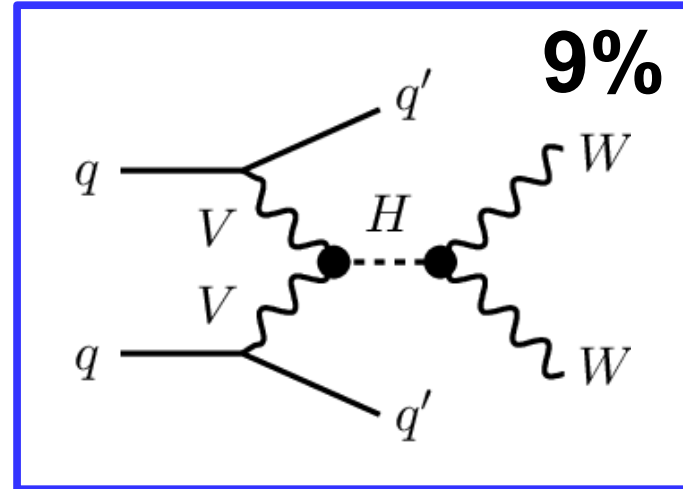


# Vector boson production

87%

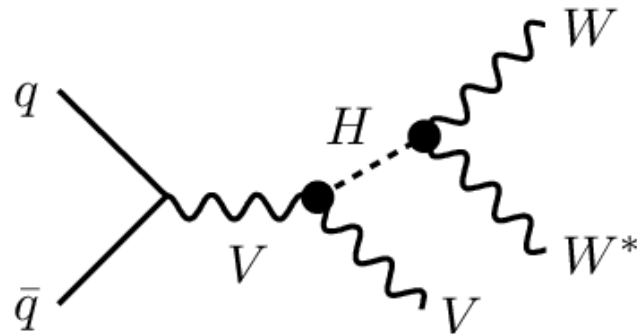


9%

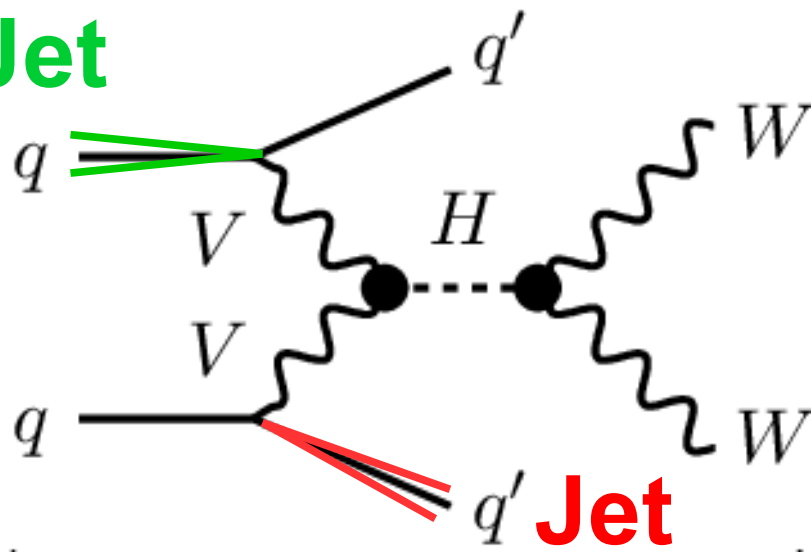


\* With V being W most of the times

4%



**Jet**

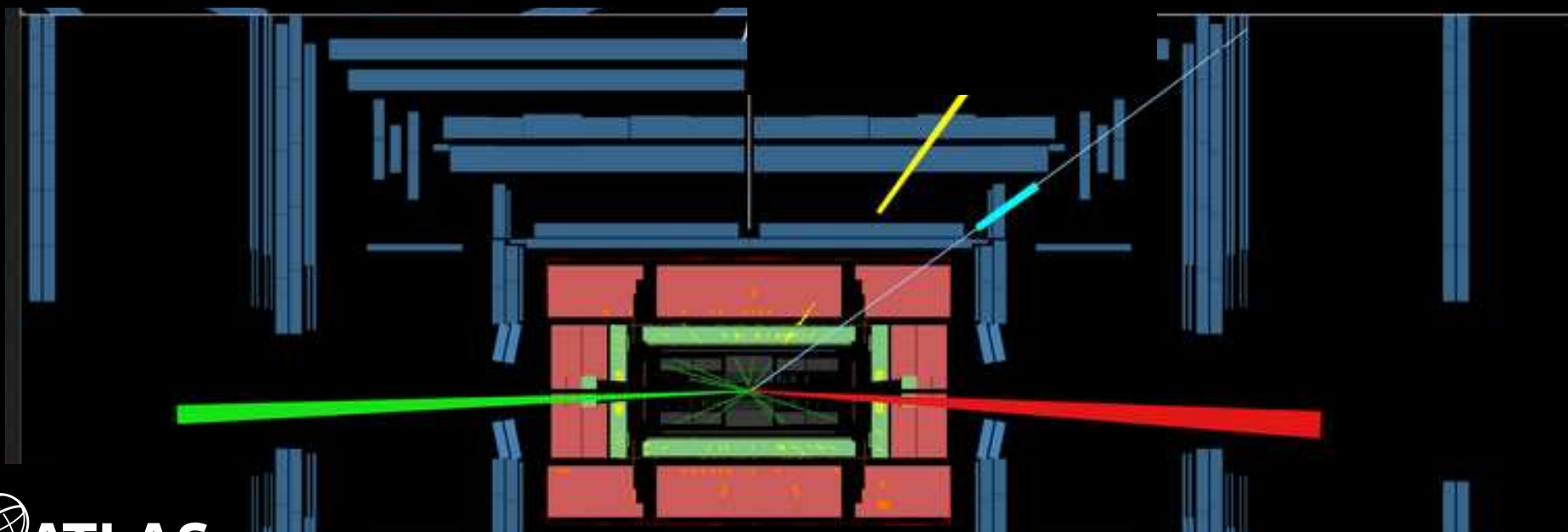


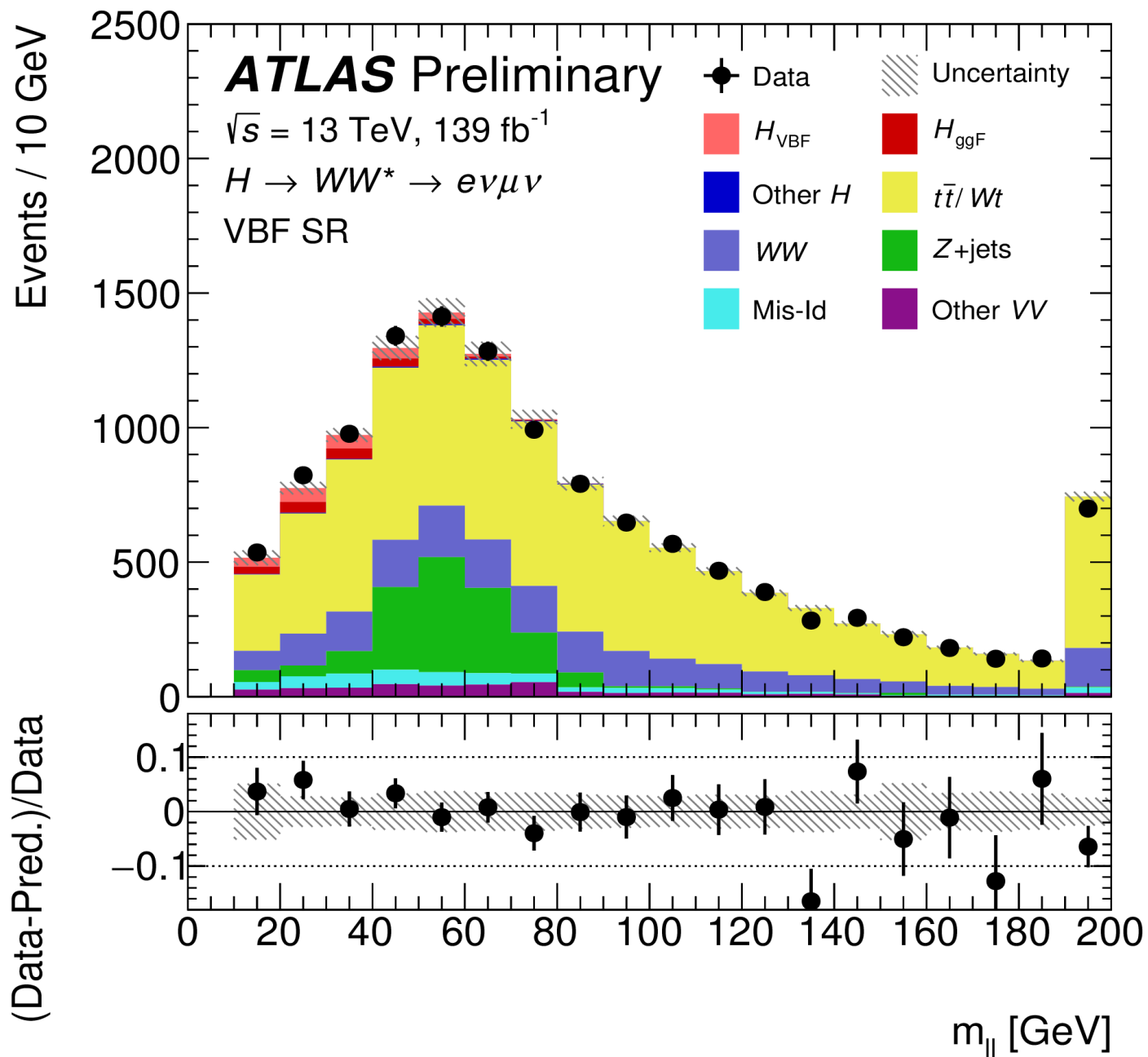
**Electron**

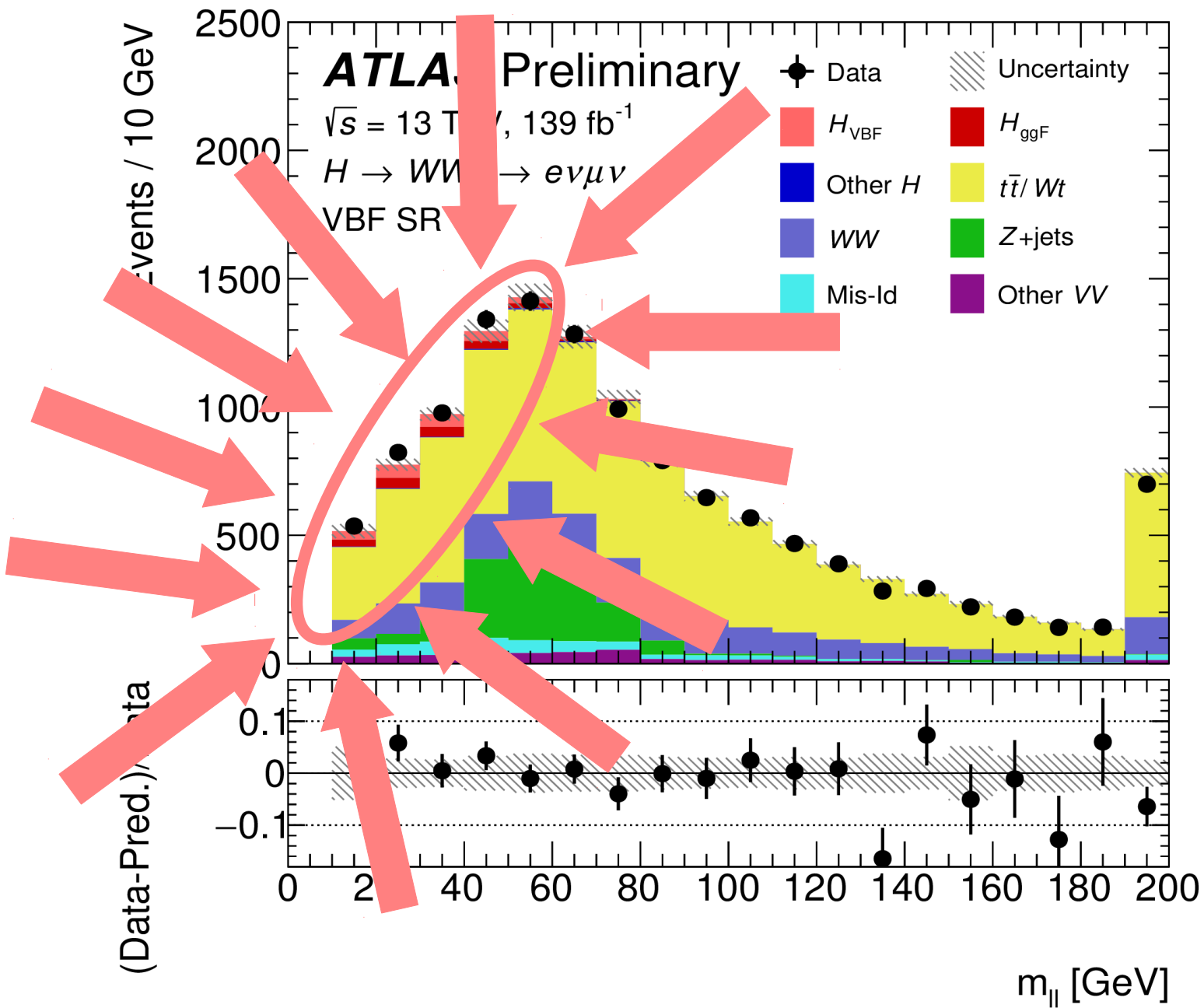
(+neutrino)

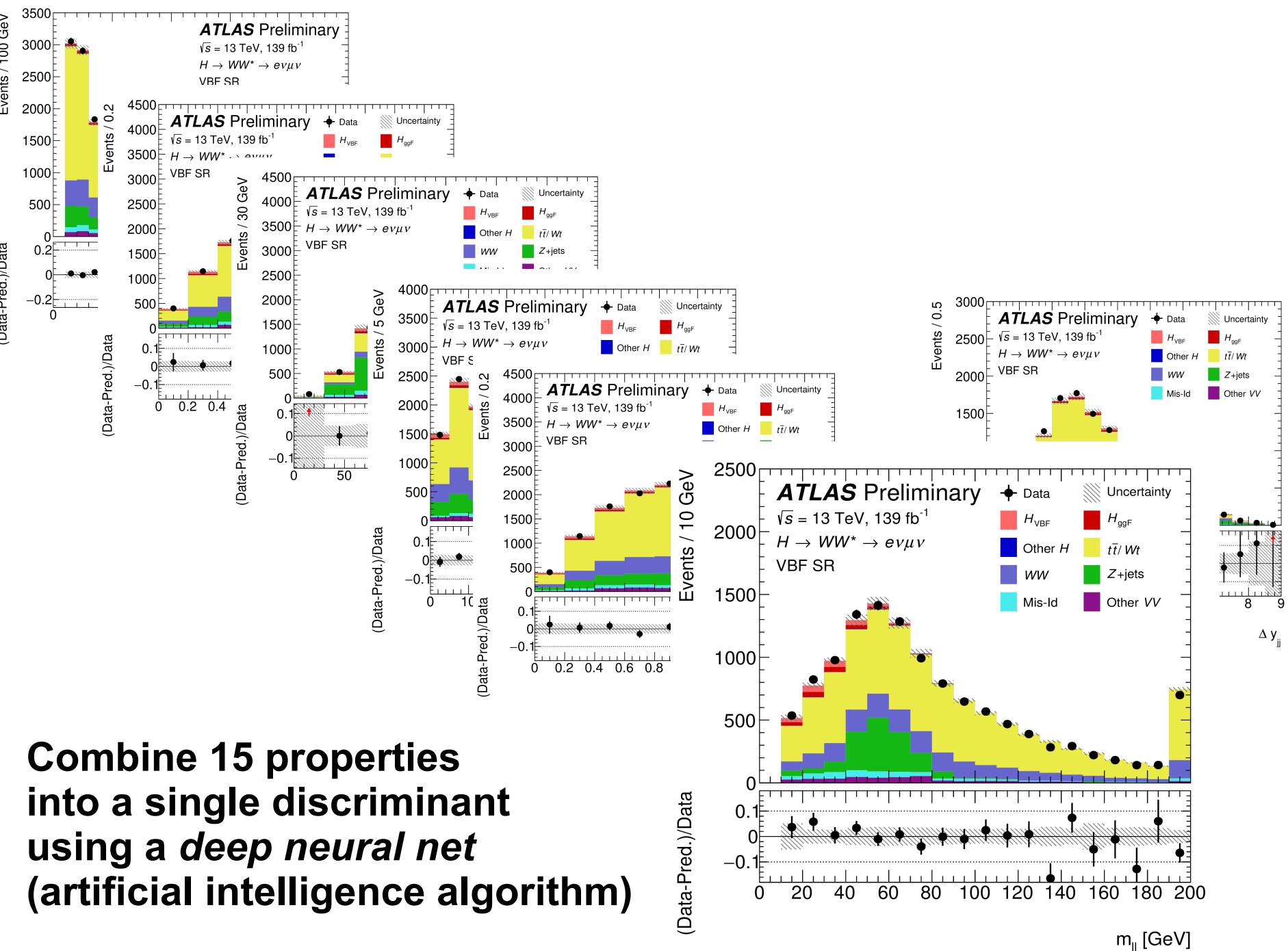
**Muon**

(+neutrino)



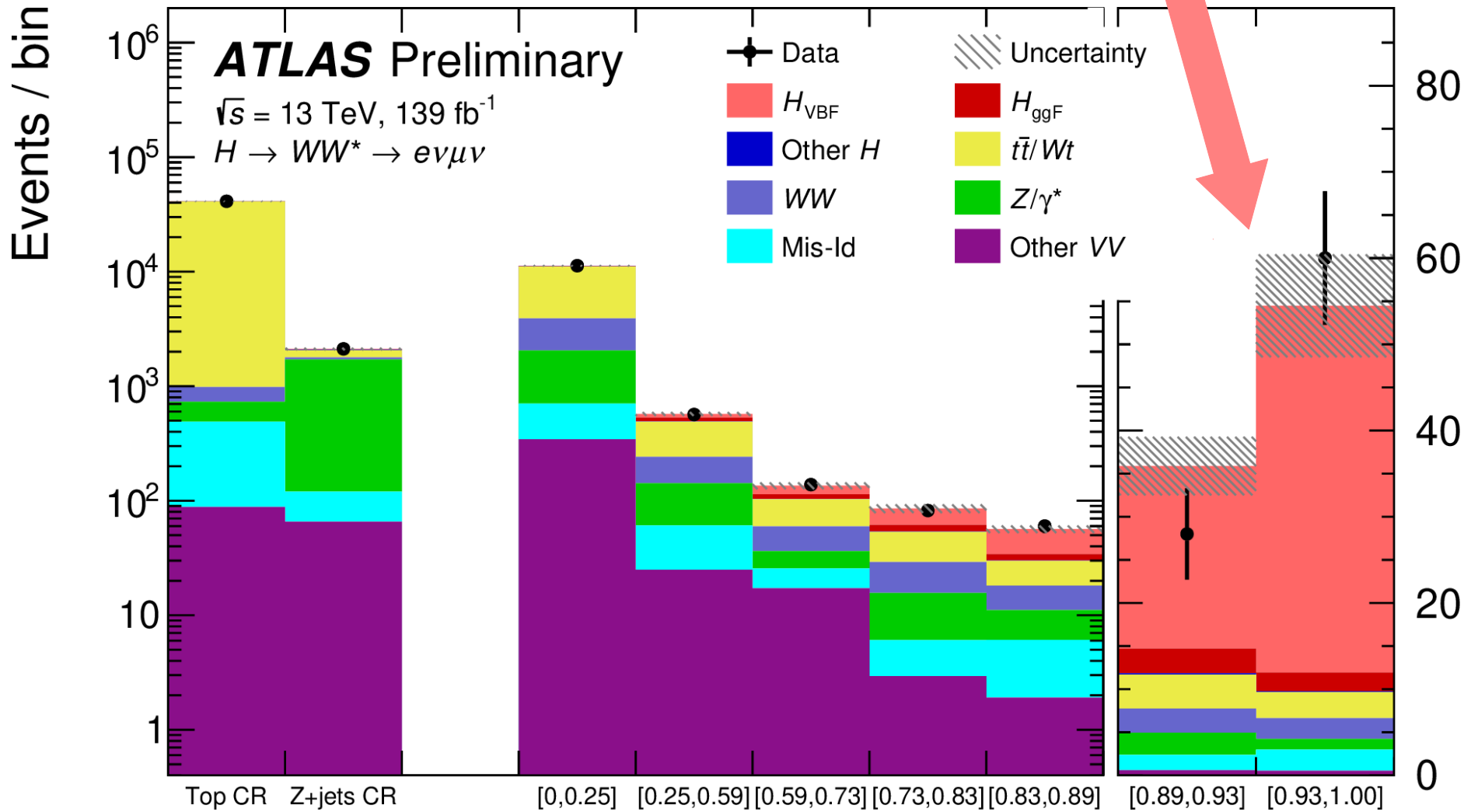






Combine 15 properties into a single discriminant using a *deep neural net* (artificial intelligence algorithm)



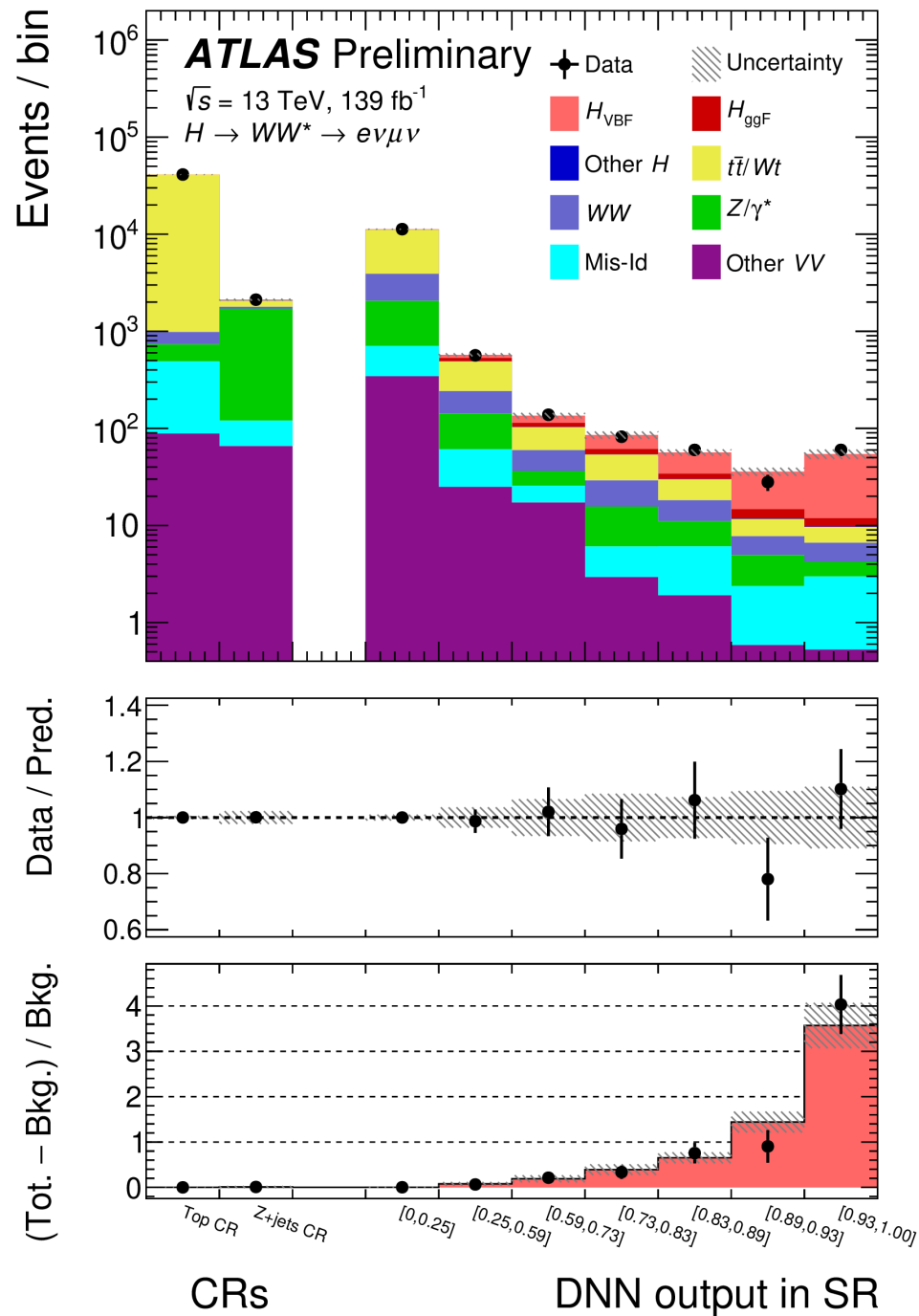


**Control:**  
 Does the AI do  
 its thing?

**Final data sample: Here is the Higgs**

→ **start investigating  
 Vector Boson Fusion mechanism**

# Backup



# Understanding the Higgs boson using its decay to light



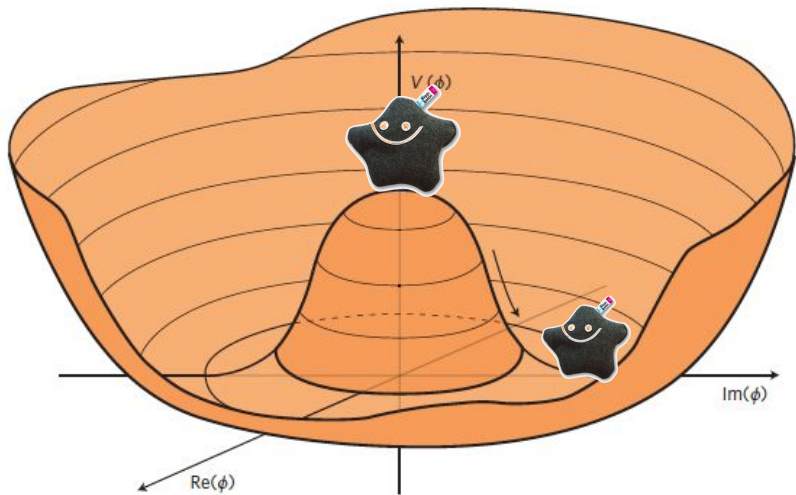
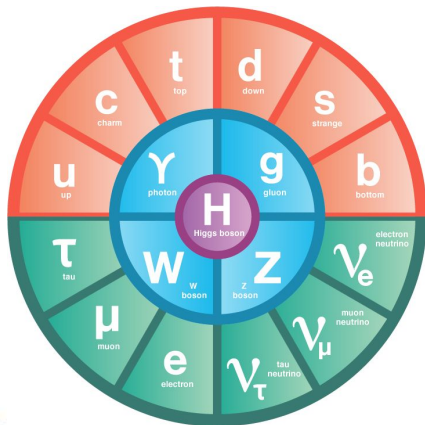
= Higgs boson  
(particle zoo)

Dr. Jonathon Langford

Imperial College  
London



# Why measuring the Higgs boson is important?



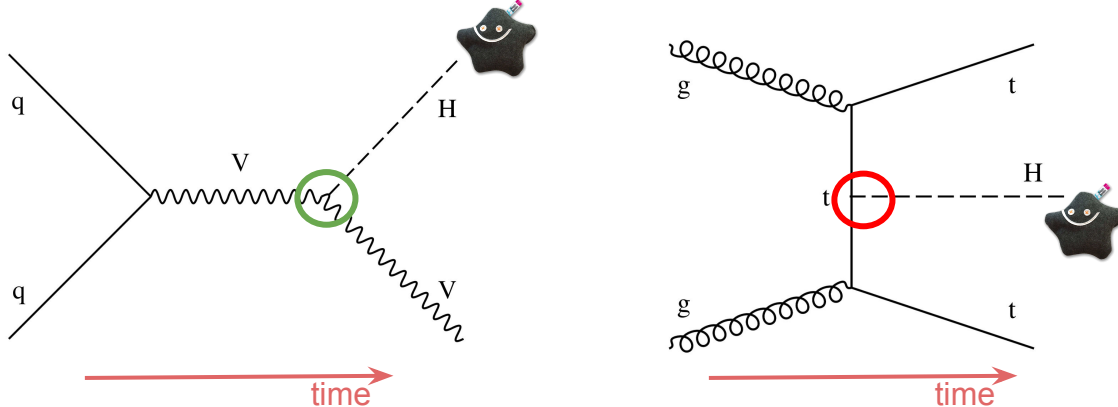
# From discovery to precision

Cross section = measure of probability of interaction

- Since discovery (2012) we have recorded about 14x more data



- Many ways Higgs boson can be produced @ LHC...



- Measure rates precisely -> understand fundamental interactions!

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### Measurements of Higgs boson production cross sections and couplings in the diphoton decay channel at $\sqrt{s} = 13$ TeV

**The CMS collaboration**  
E-mail: [cms-publication-committee-chair@cern.ch](mailto:cms-publication-committee-chair@cern.ch)

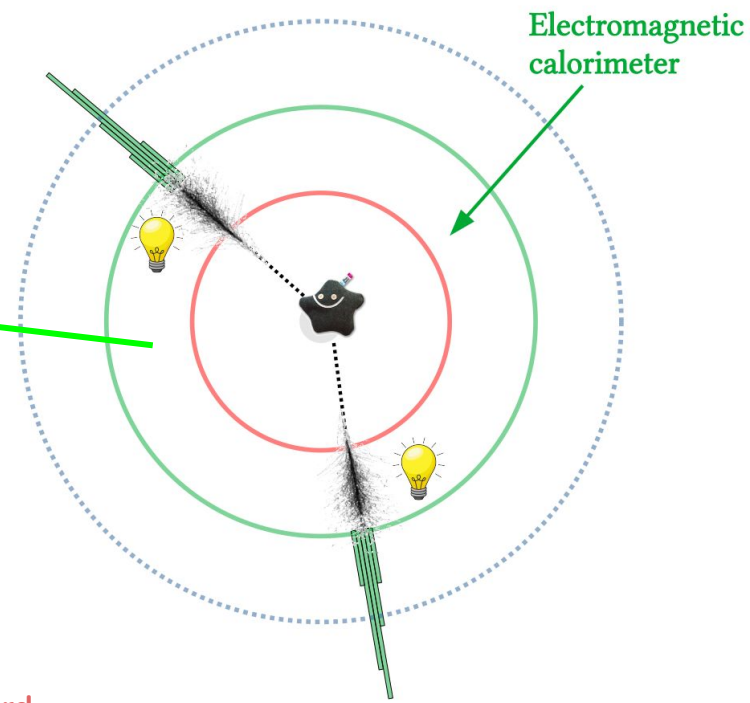
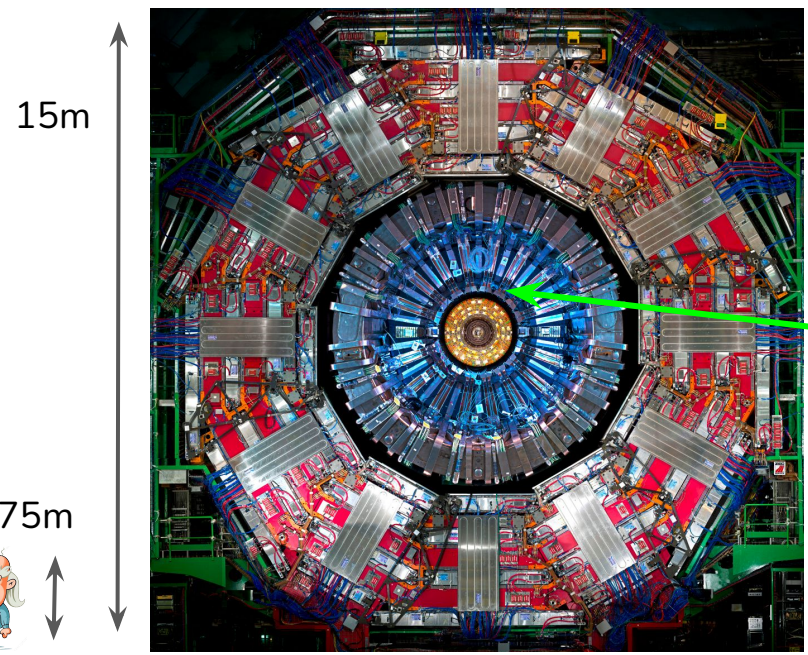
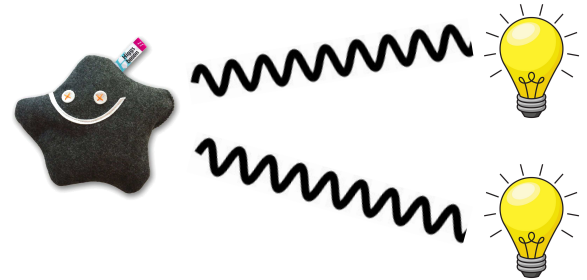
**ABSTRACT:** Measurements of Higgs boson production cross sections and couplings in events where the Higgs boson decays into a pair of photons are reported. Events are selected from a sample of proton-proton collisions at  $\sqrt{s} = 13$  TeV collected by the CMS detector at the LHC from 2016 to 2018, corresponding to an integrated luminosity of  $137 \text{ fb}^{-1}$ . Analysis categories enriched in Higgs boson events produced via gluon fusion, vector boson fusion, vector boson associated production, and production associated with top quarks are constructed. The total Higgs boson signal strength, relative to the standard model (SM) prediction, is measured to be  $1.12 \pm 0.09$ . Other properties of the Higgs boson are measured, including SM signal strength modifiers, production cross sections, and its couplings to other particles. These include the most precise measurements of gluon fusion and vector boson fusion Higgs boson production in several different kinematic regions, the first measurement of Higgs boson production in association with a top quark pair in five regions of the Higgs boson transverse momentum, and an upper limit on the rate of Higgs boson production in association with a single top quark. All results are found to be in agreement with the SM expectations.

**KEYWORDS:** Hadron-Hadron scattering (experiments), Higgs physics

[JHEP 07 \(2021\) 027](#)

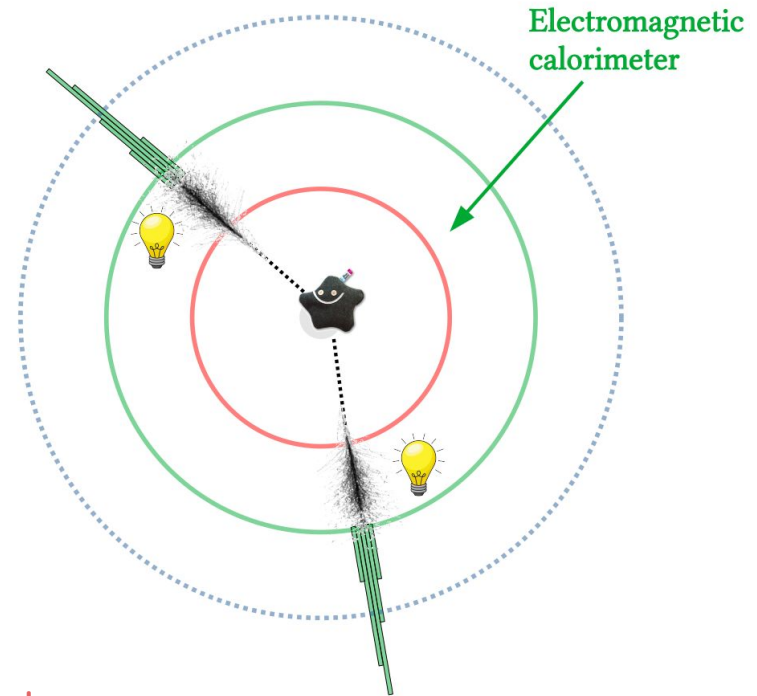
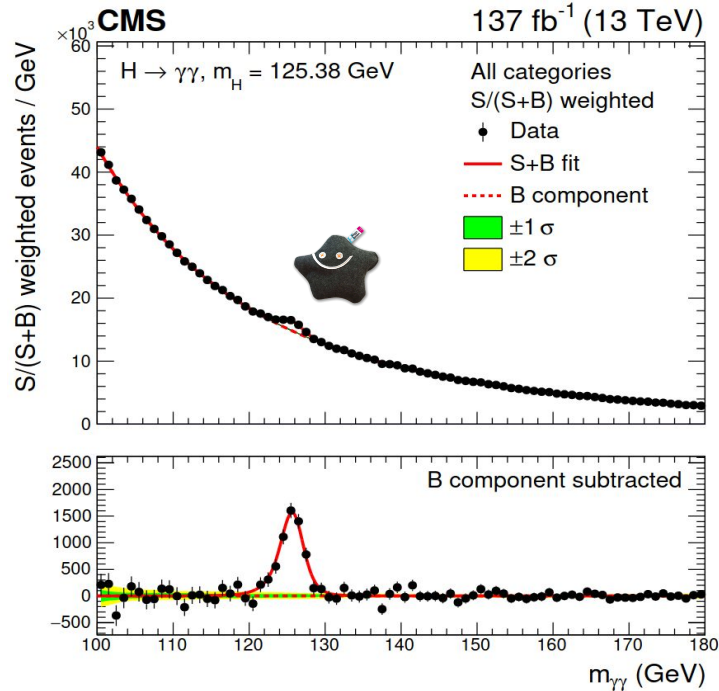
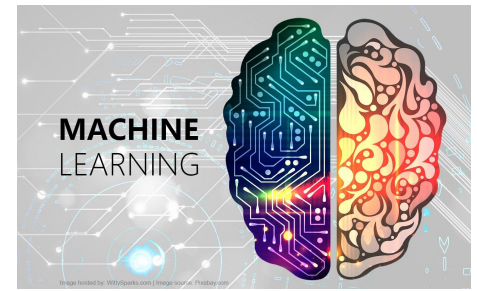
# Finding the needle in the haystack

- About 1 Higgs boson produced in 40 million collisions per second!
- Only 0.2% decay to photons... but it is a clean signature to detect



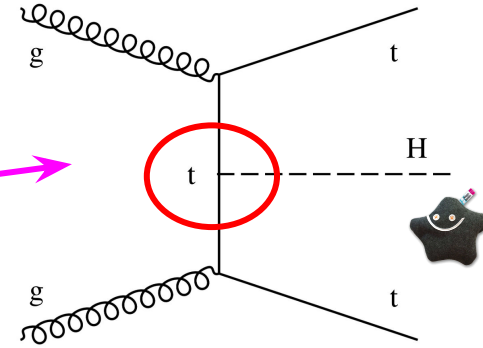
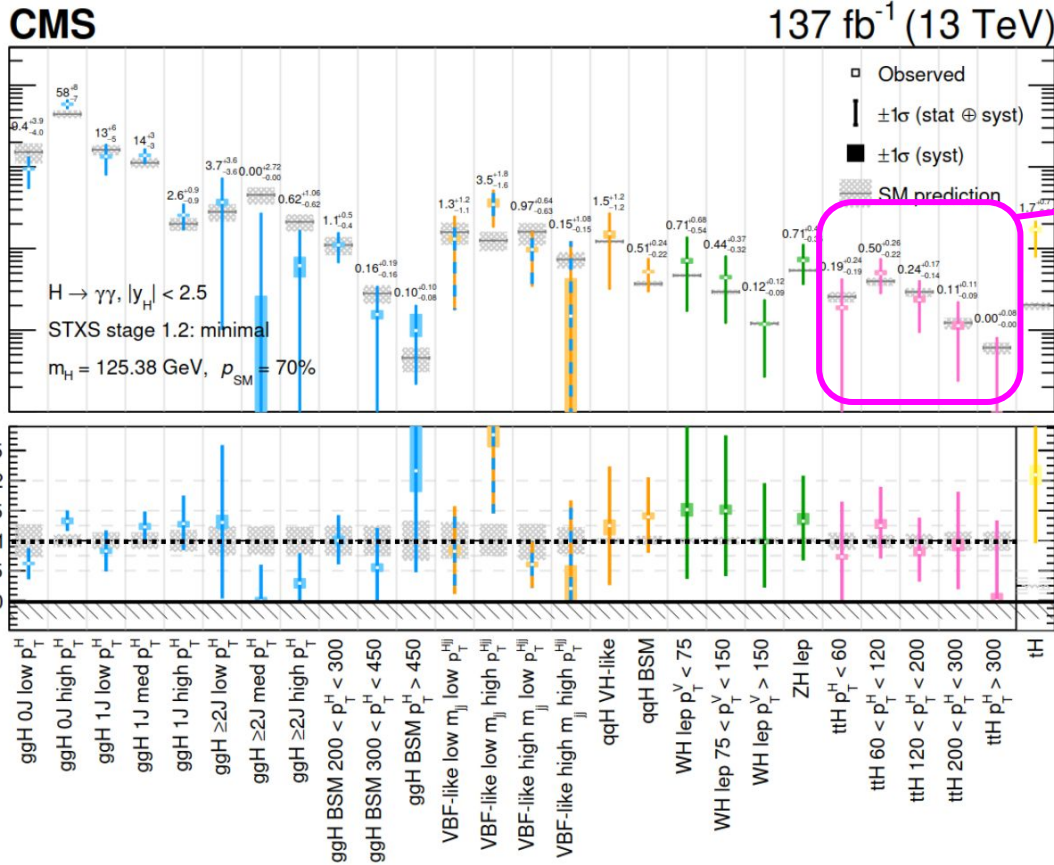
# Finding the needle in the haystack

- Machine learning: reject “backgrounds” faking Higgs boson
- Measure photon energy and direction -> calculate mass!



# What have we learnt?

- Isolate different Higgs boson interactions



- No significant deviations from expectation!



# Impact and looking forward

- Highest number of cross sections (27) measured simultaneously in single decay channel
- Run 3 (2022-2025) + HL-LHC (2029-2038) will accumulate around 30x more data
- Deeper understanding of our universe, may reveal entirely new sector of fundamental physics

