Overview of 13 TeV H->WW*->lvlv analysis strategy in ATLAS

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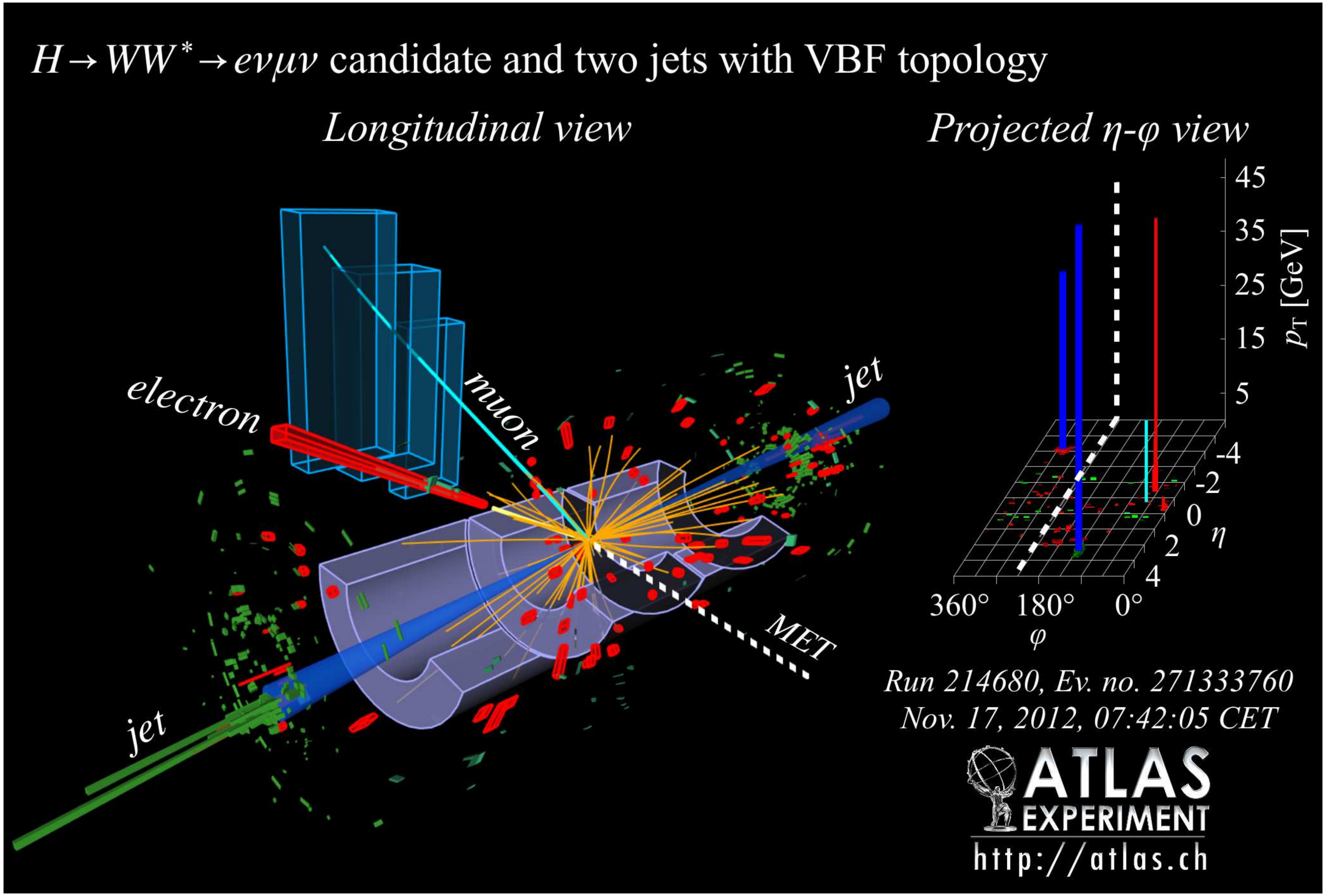

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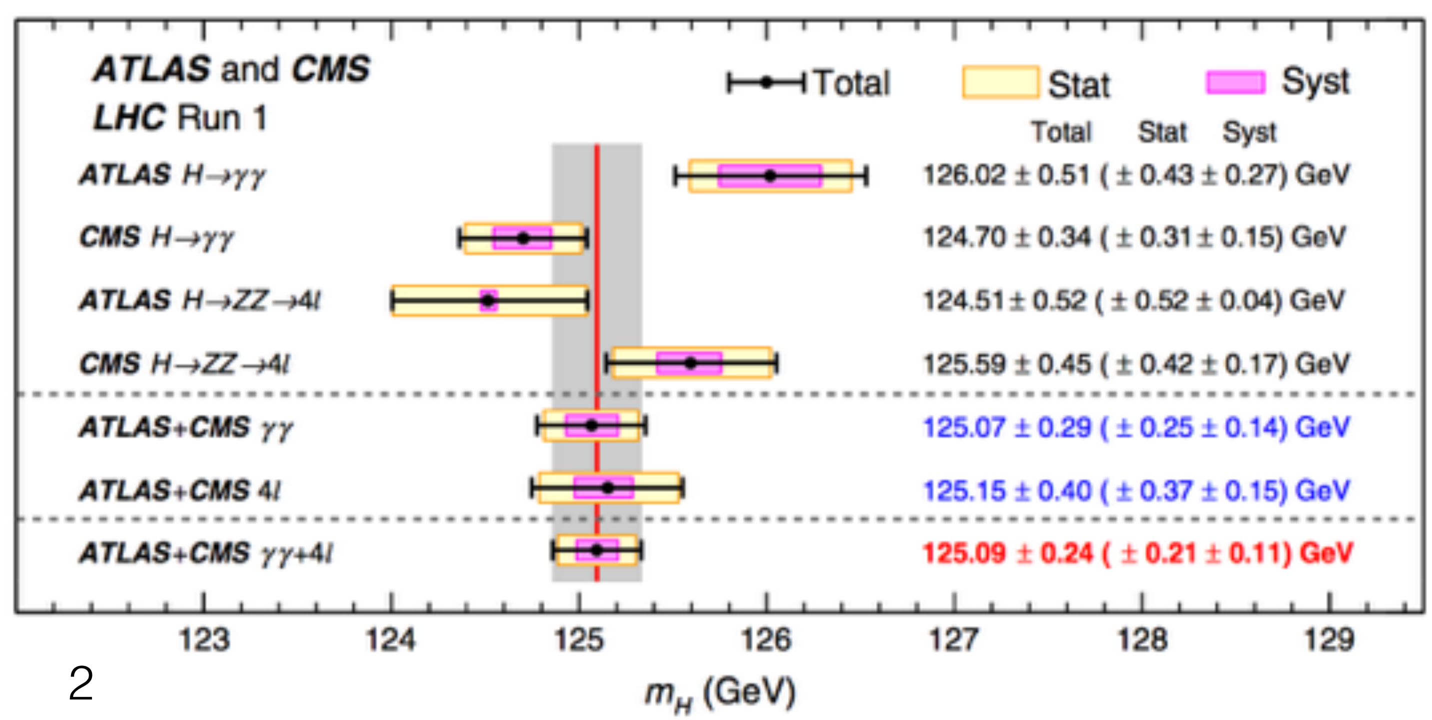
Introduction

- The Brout-Englert-Higgs mechanism provides mass to Standard Model particles
  - Mass the only free parameter. Discovered at ~125 GeV during LHC run 1 by ATLAS and CMS
- **We have entered the precision measurement phase**
  - What are the particles' properties? CP, couplings…
- I'm working on the $H \to WW \to \ell\nu\ell\nu$ ATLAS analysis which will soon be published



Run1 overview

- Higgs-vector boson couplings well established (goes as m_V^2)
- Higgs-fermion couplings also observed (goes as m_f)
- Production modes and decay modes measured to agree with SM within ~30%
- Available run 2 results also agree with SM (see e.g. LianTao Wang@LeptonPhoton2017)

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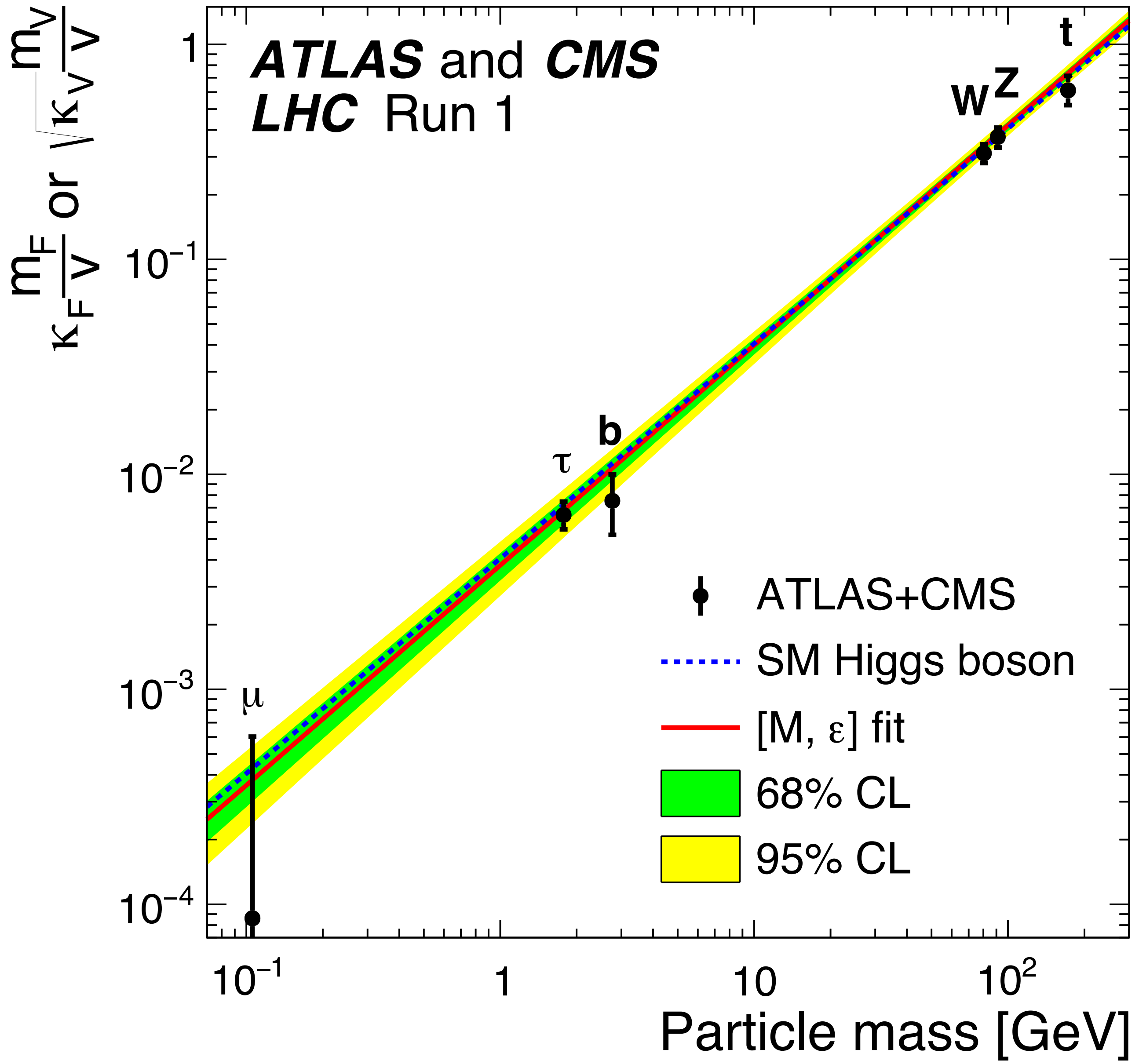
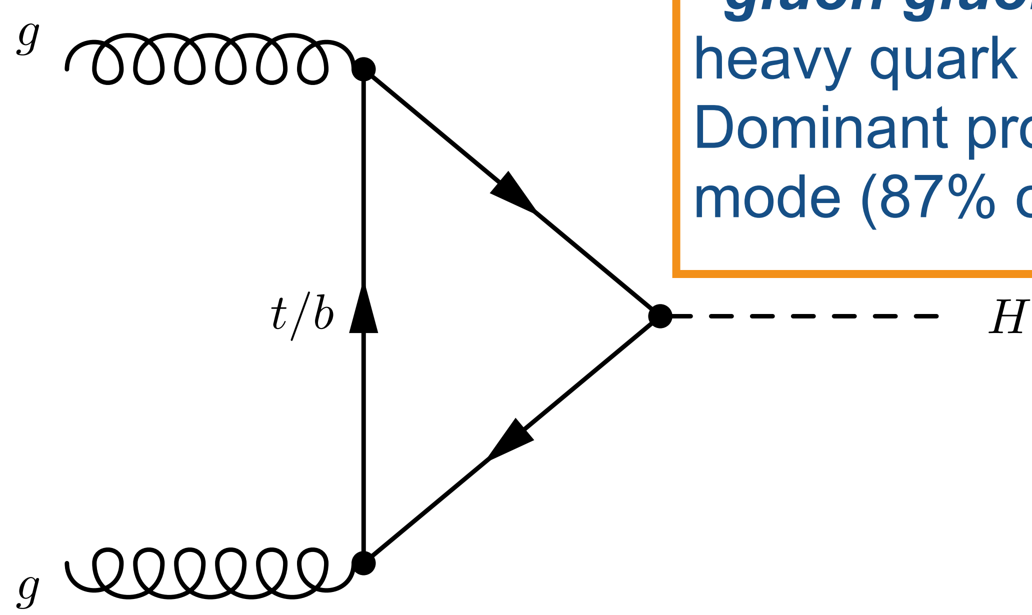
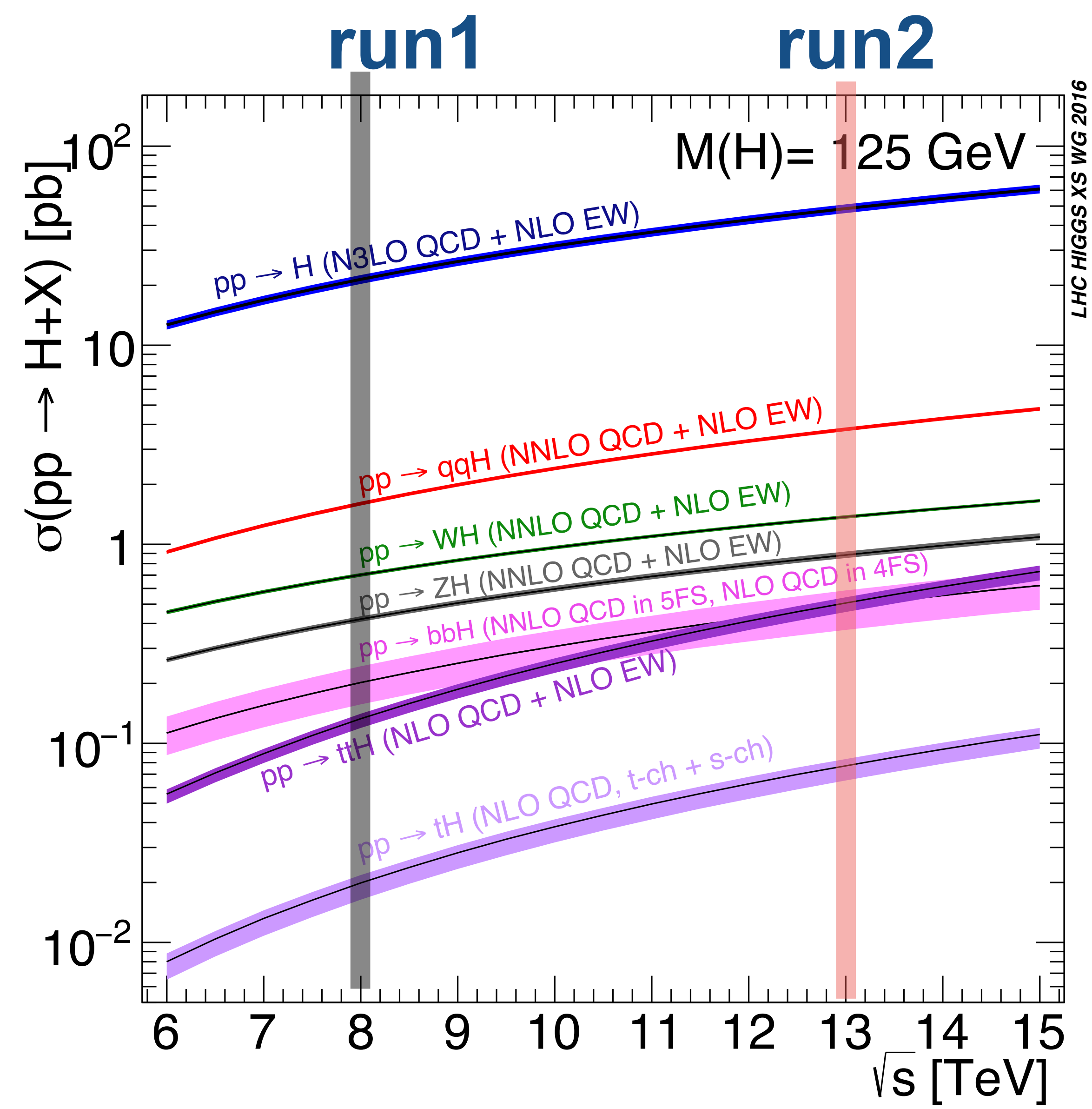


No observed deviations from the SM

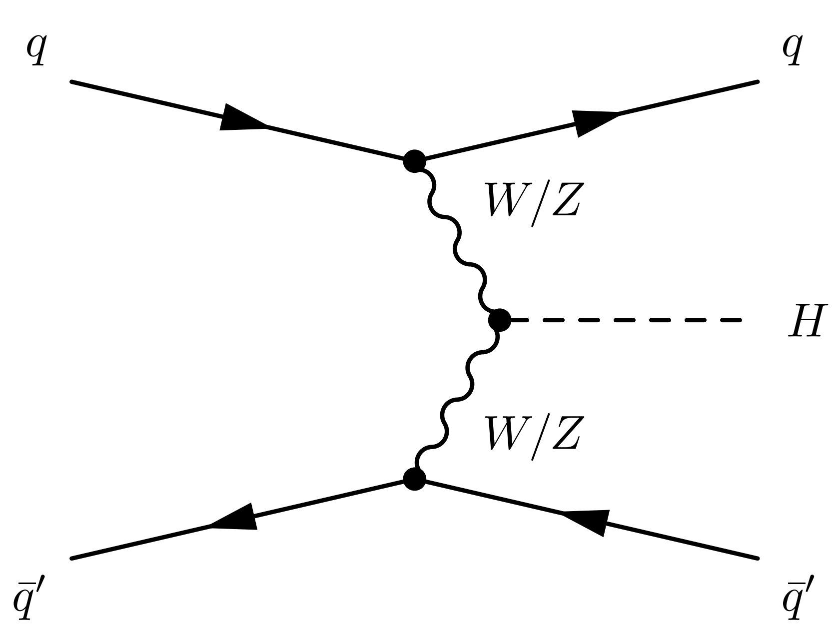
Higgs production

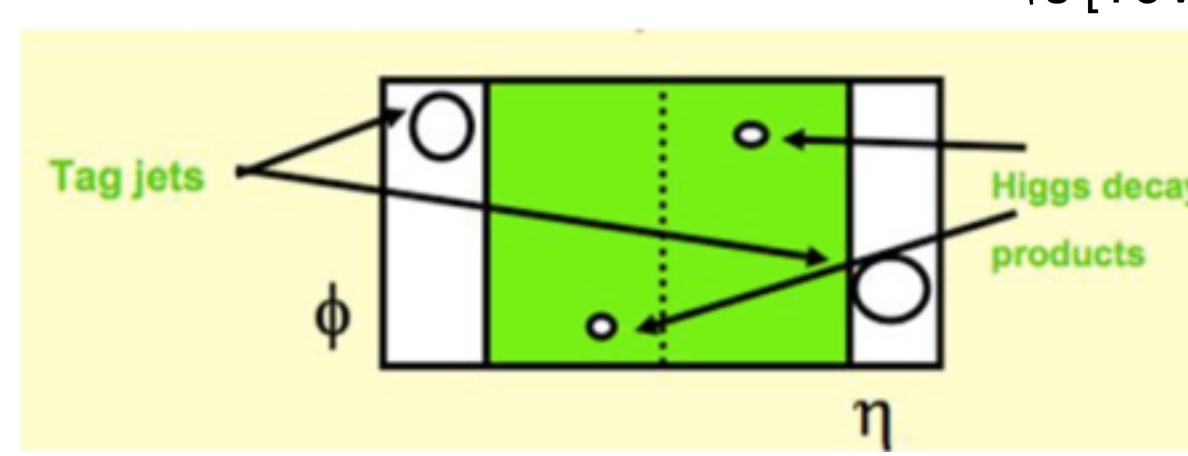


"gluon gluon fusion": heavy quark in loop. Dominant production mode (87% of total)



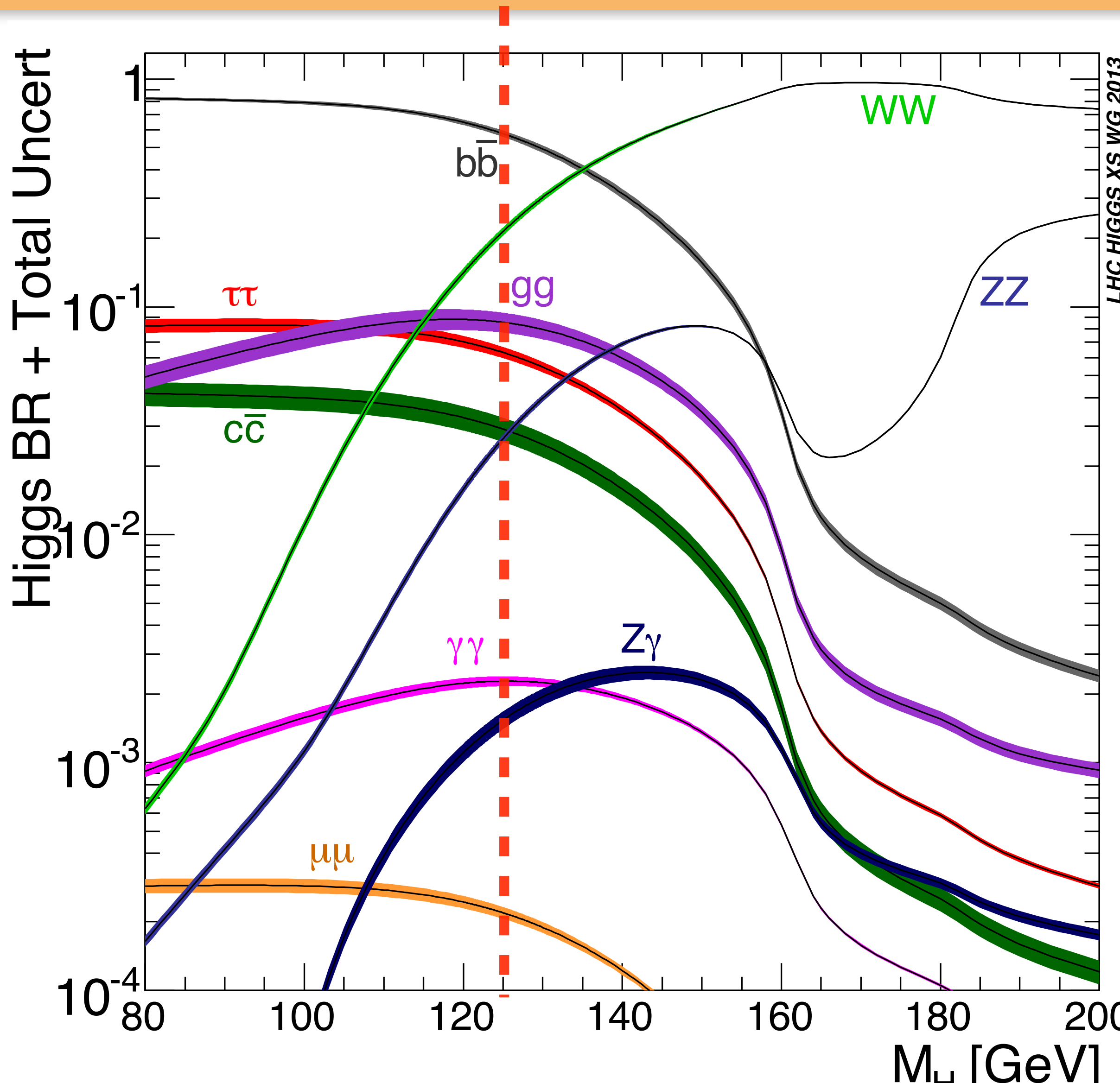
"vector boson fusion": rarer (7% of total), but clean final state topology (more later)





Higgs decay

- "Lucky" that mass value maximises all available production modes
- In ZZ and γγ we can reconstruct final state fully, and compute mass with full resolution
- WW second to most probable
  - We consider only leptonically decaying W: **H → WW → ℓνℓν.** Neutrinos prohibit accurate mass measurement.
  - However directly sensitive to Higgs-W coupling



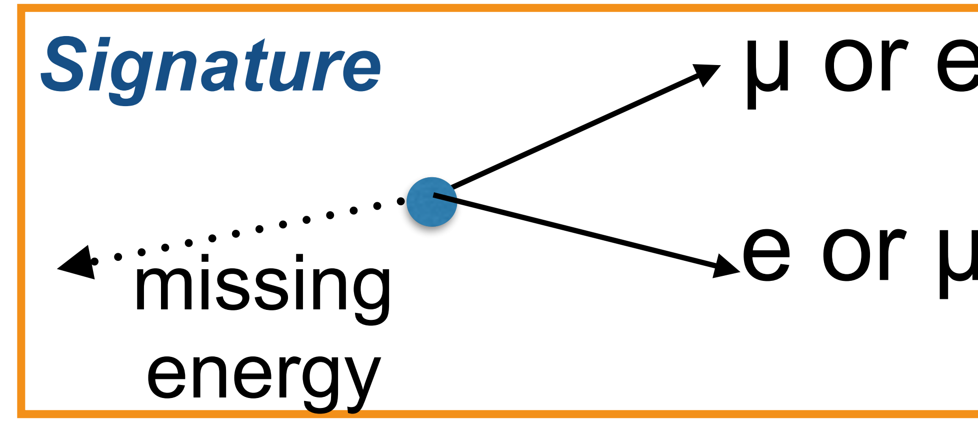
What we measure is the product, normalised to SM prediction.

$$\mu = (\sigma \times BR) / (\sigma \times BR)_{SM},$$

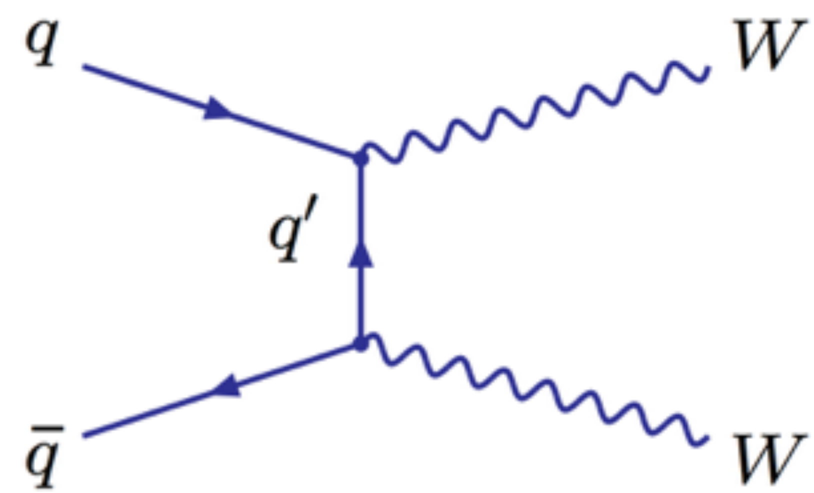
called "signal strength"

H → WW → $\ell\nu\ell\nu$ analysis

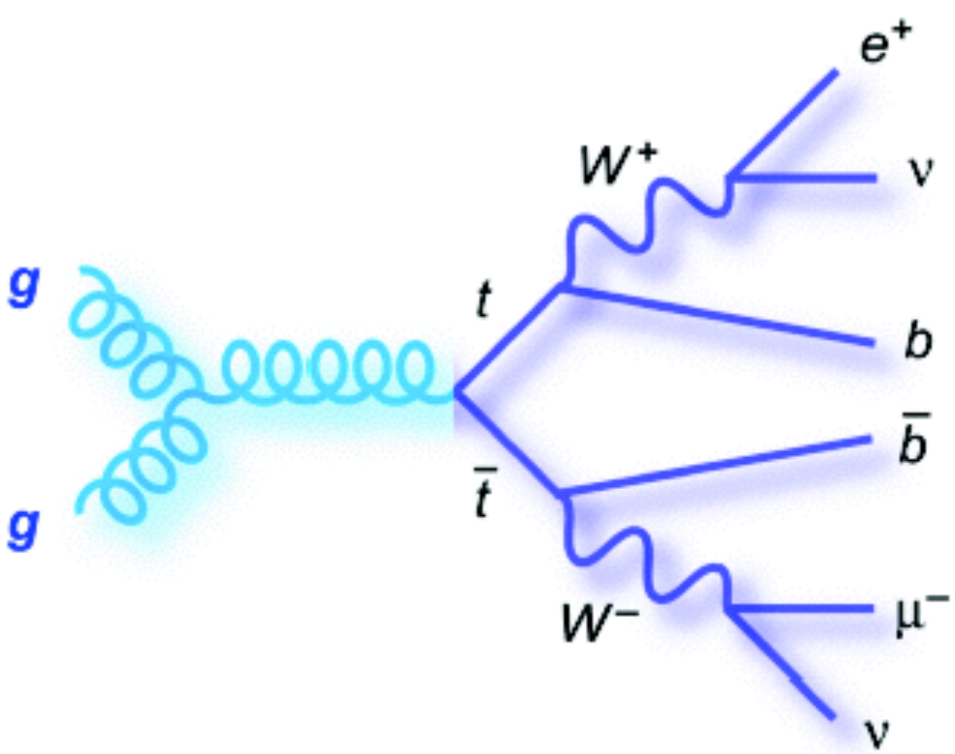
- **How to tag two Ws?** Consider only final states with different flavour, opposite sign leptons (not counting τ which decays hadronically)

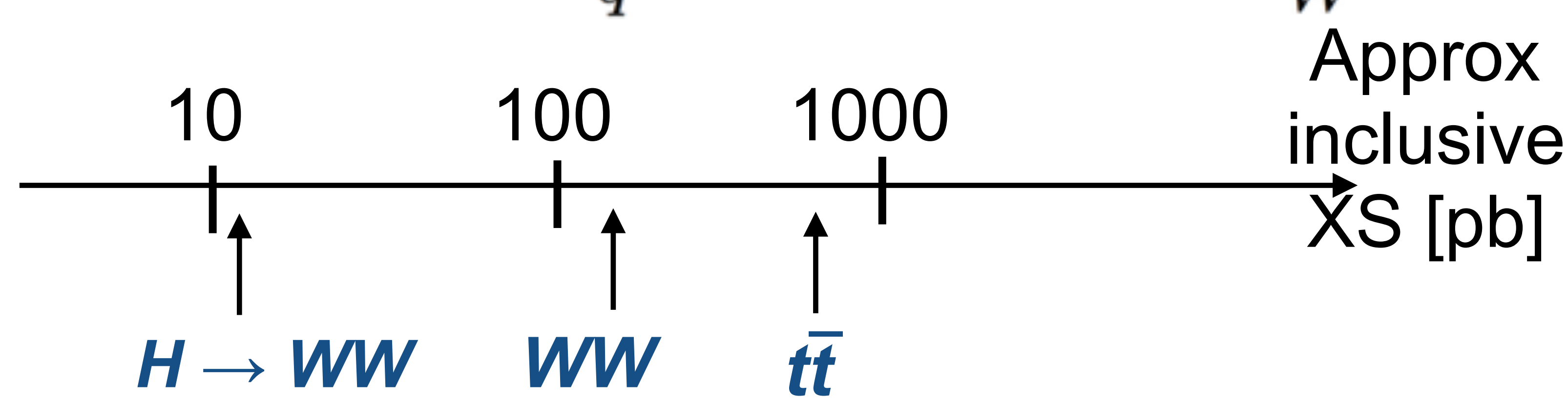


  - Require leptons with high enough energy and "missing transverse energy" from neutrinos



- What backgrounds have the same signature?



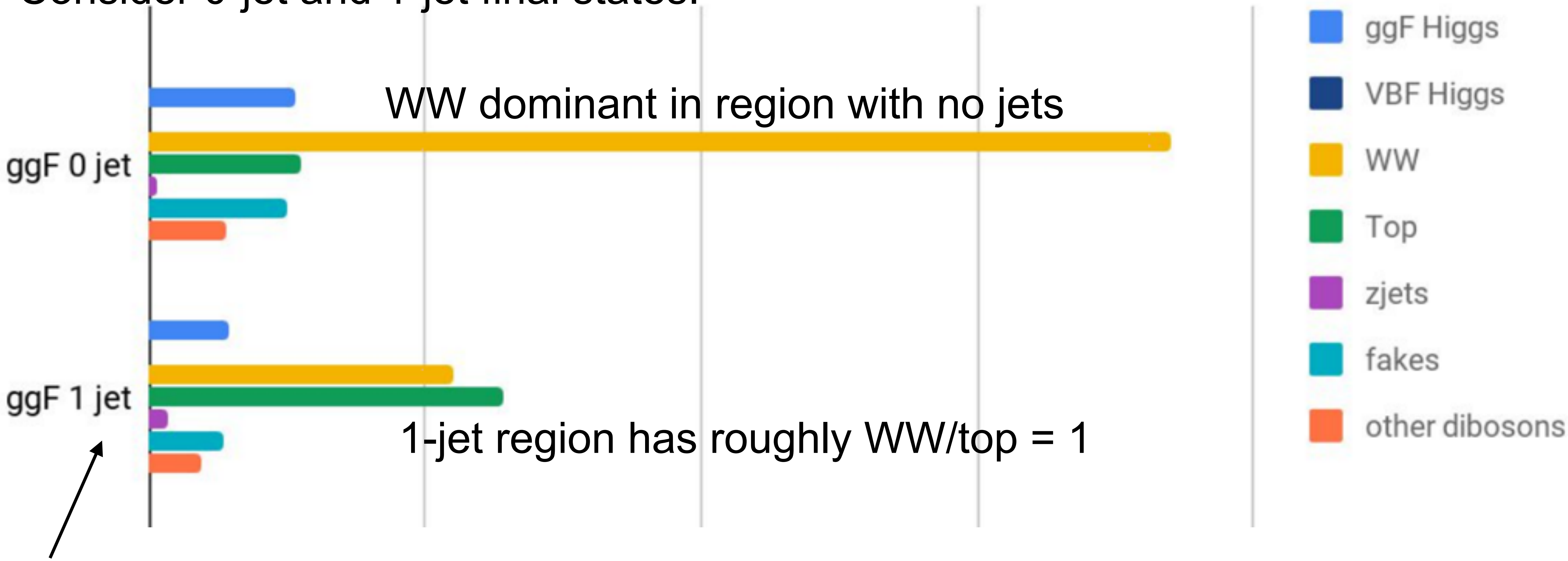


- These two backgrounds largely determine analysis strategy

- Top quarks accompanied by (b-)jets — **divide in bins of number of jets**

gluon-gluon fusion analysis

Consider 0-jet and 1-jet final states:



Require "b-veto" on jet to suppress top quark background

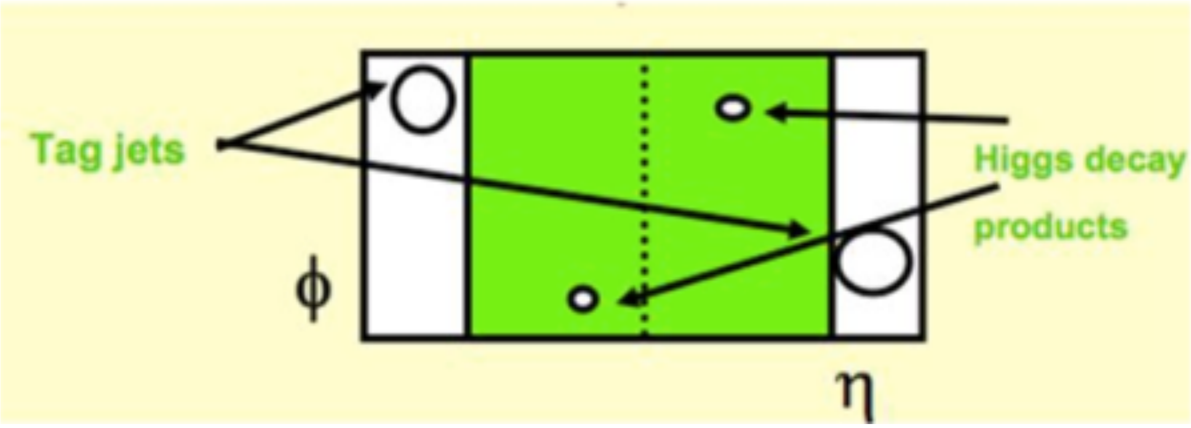
In $H \rightarrow WW \rightarrow \ell\nu\ell\nu\ldots$

angular momentum conservation
+ chirality of weak interaction
$\rightarrow$ **leptons tend to be collimated**

Require small opening angle between electron and muon

Vector boson fusion analysis

- Naturally produces two high-energy jets in forward regions
  - without colour flow between them (no hadronic activity)
- **Clean final state** which is sensitive to Higgs-W/Z coupling



Signature: **two forward jets with Higgs decay products in between**

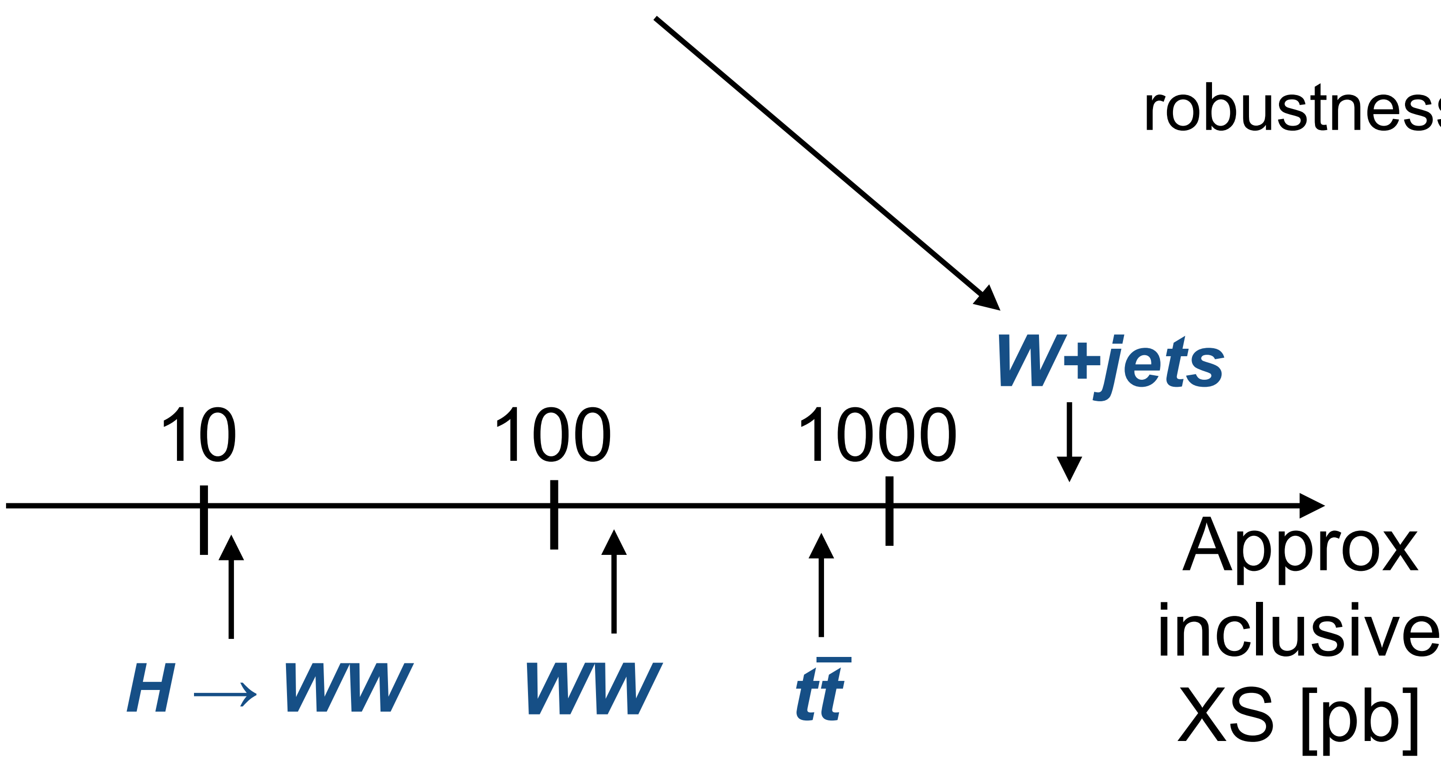
- Event selection:
  - Require two high-energy jets with large rapidity gap
  - Suppress central jet activity
  - Require leptons to be between the tagged jets in rapidity

Dominant background:
top quark events.
Require b-veto on additional jets

Event and object selections

- Select events with single- and di-lepton triggers
- We require leptons to be of high quality. Why?
- W+jets give rise to "fake" lepton background when a jet is mis-identified as a lepton

electrons and muon quality requirement	explanation
impact parameter	track should point to primary vertex
isolation	suppress other activity in vicinity of lepton
robustness	shower shape, matching between subsystem signals…



Lepton quality cuts suppress misidentification rate

Important to have W+jets fake background under control

Background estimation

Measure normalisation α = data/MC in Control Regions. Shape taken from MC.

requirements to enhance purity

Control Region	Requirements to enhance purity
WW Control Region	b-veto, high di-lepton invariant mass
Top Control Region	b-tag
$Z \to \tau\tau$ Control Region	No missing energy cut, large di-lepton opening angle

Signal Region

Extrapolate with α

Taken from MC, validate yield and shape in validation region — Non-WW Diboson (Vγ, ZZ, WZ)

“fake” lepton background, data driven estimate — W+jets Control Region

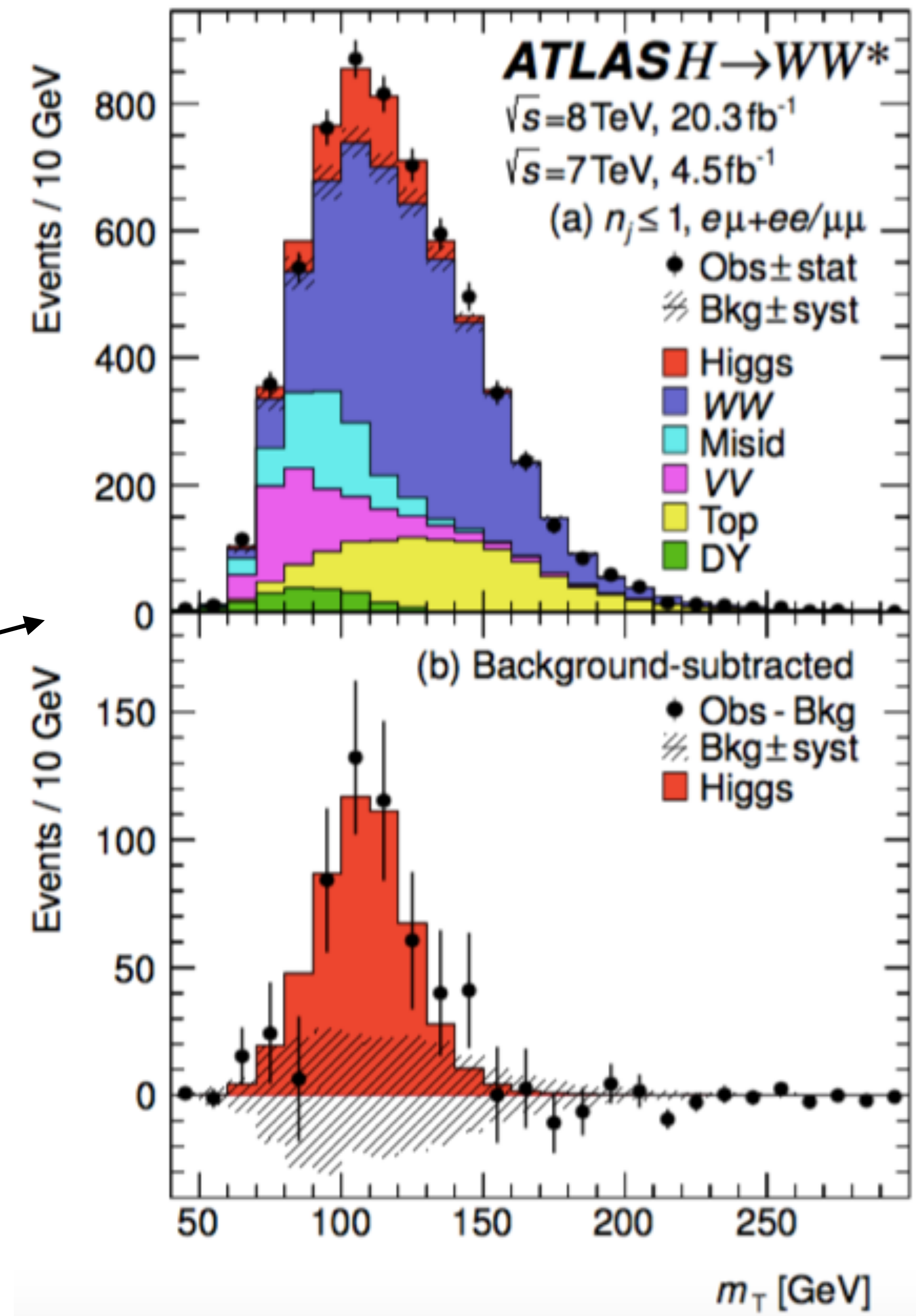
Fit procedure

gluon-gluon fusion analysis

- cut-based
- signal region in previous slide in reality made up of 16 regions (based on number of jets, e-μ invariant mass, …)
- Binned likelihood fit to **transverse mass** distribution, simultaneously using signal and control regions

run 1

10.1103/PhysRevD.92.012006



vector-boson fusion analysis

- Multi-variate treatment: Boosted Decision Tree (BDT) discriminant.
- Fit to the four bins in the BDT output

Systematic uncertainties

- Systematic uncertainties enter the likelihood fit as Gaussian terms with a nuisance parameter. The different sources of uncertainties are
  - Experimental systematics (pile-up reweighting, luminosity, jet energy scale and resolution…)
  - Theoretical uncertainties (matrix element, renormalisation/ factorisation scale, parton shower…)
  - W+jets fake background systematics

Over 100 individual contributions of systematic uncertainties

The dominant ones are WW theory uncertainties and W+jets fake background uncertainties

The vector boson fusion measurement is also limited by data statistics

Summary and outlook

- The 13 TeV ATLAS $H \rightarrow WW \rightarrow \ell\nu\ell\nu$ cross section measurement strategy has been outlined
    - We hope to publish soon with 36/fb (2015+2016) dataset. Currently going through internal review process…
    - Personal focus has been on fake lepton backgrounds.

First gluon-gluon fusion results at 13 TeV.
Stay tuned!

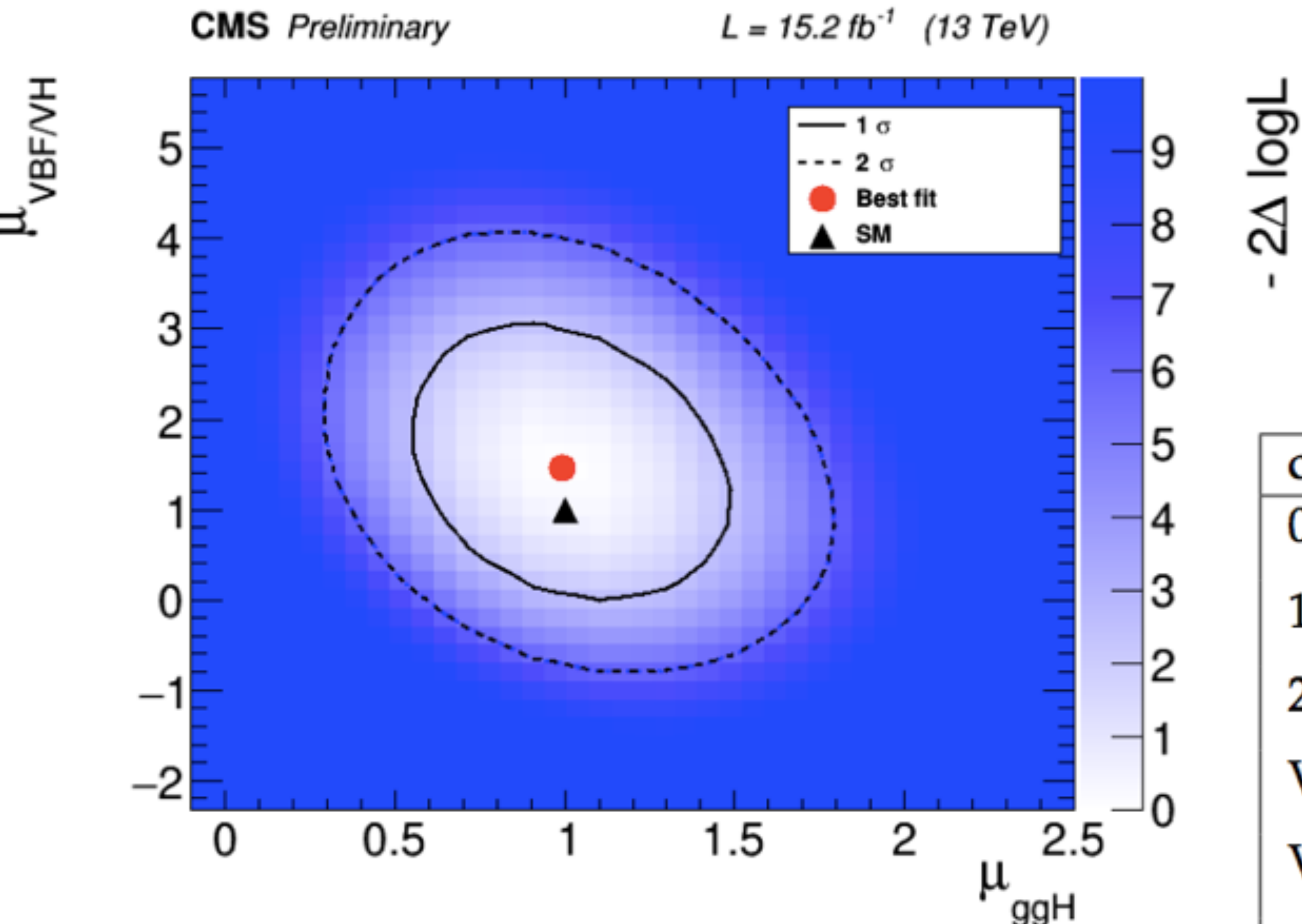
Outlook

- After publication, focus will shift toward run 2 legacy paper
- Will contain ~3.5x the amount of data compared to coming publication

Extra

- CMS run2 15/fb results

HIG-16-021

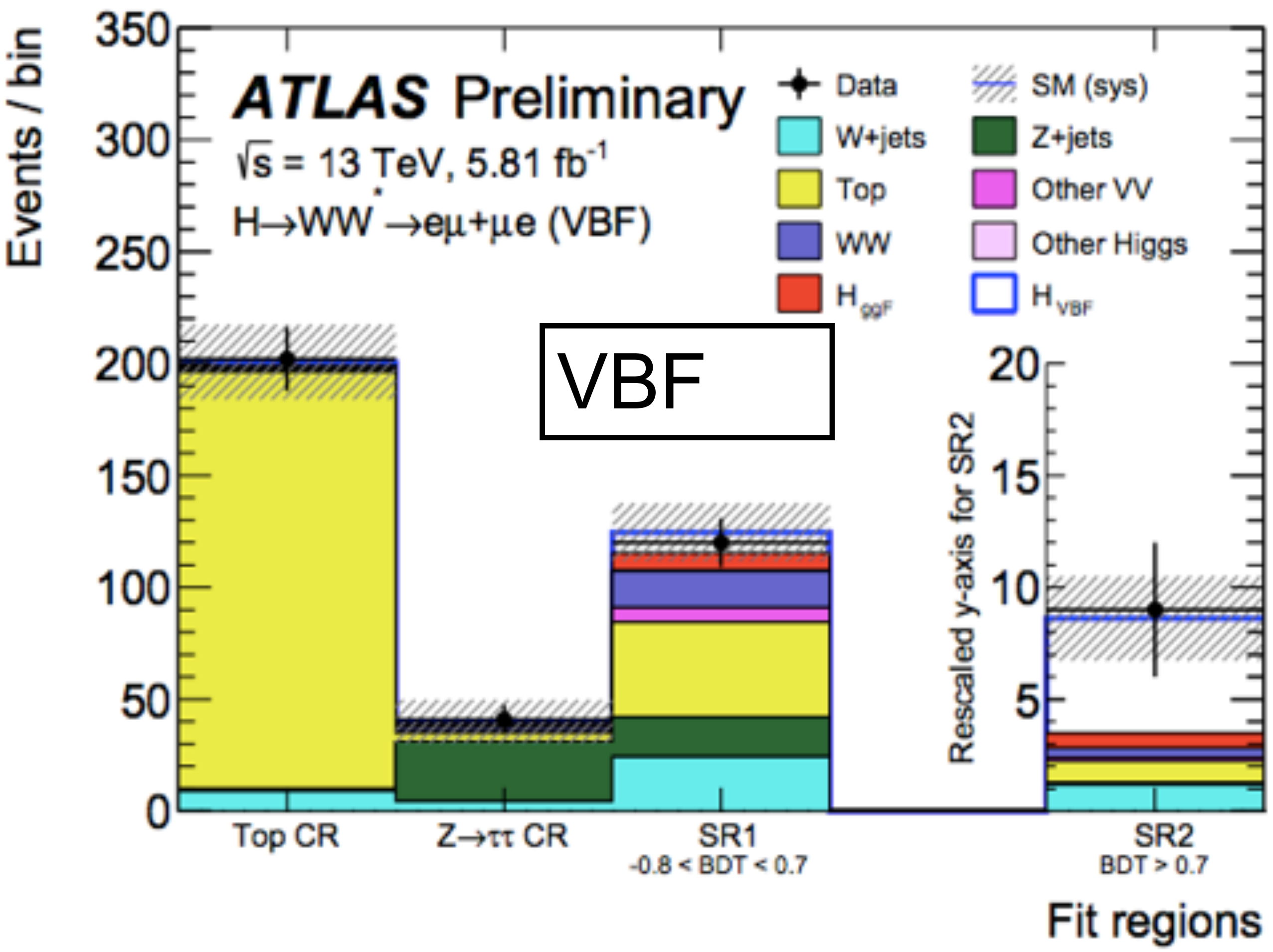


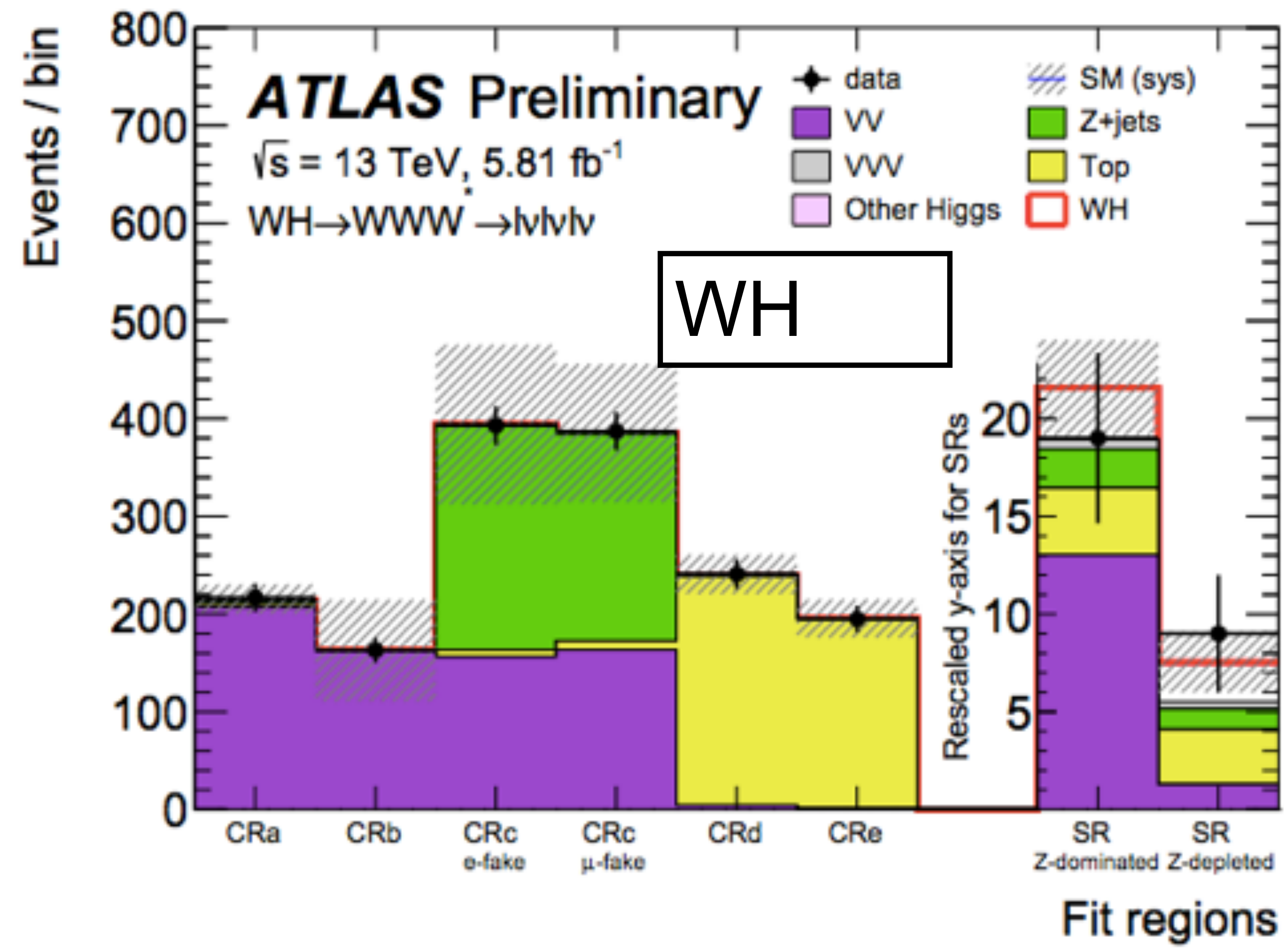
category	significance	σ/σ_{SM}
0-jet	2.7 (2.9)	$0.9^{+0.4}_{-0.3}$
1-jet	2.1 (2.5)	$1.1^{+0.4}_{-0.4}$
2-jet	2.0 (1.0)	$1.3^{+1.0}_{-1.0}$
VBF 2-jet	2.2 (1.5)	$1.4^{+0.8}_{-0.8}$
VH 2-jet	1.0 (0.4)	$2.1^{+2.3}_{-2.2}$
WH 3-lep	0.0 (0.5)	$-1.4^{+1.5}_{-1.5}$
combination	4.3 (4.1)	$1.05^{+0.27}_{-0.25}$

Extra

- ATLAS VBF and VH results 5.8/fb

ATLAS-CONF-2016-112





$$\mu_{\mathrm{VBF}} = 1.7^{+1.0}_{-0.8}(\mathrm{stat})^{+0.6}_{-0.4}(\mathrm{sys})$$

$$\mu_{WH} = 3.2^{+3.7}_{-3.2}(\mathrm{stat})^{+2.3}_{-2.7}(\mathrm{sys})$$