Overview of the latest Hbb physics at LHC

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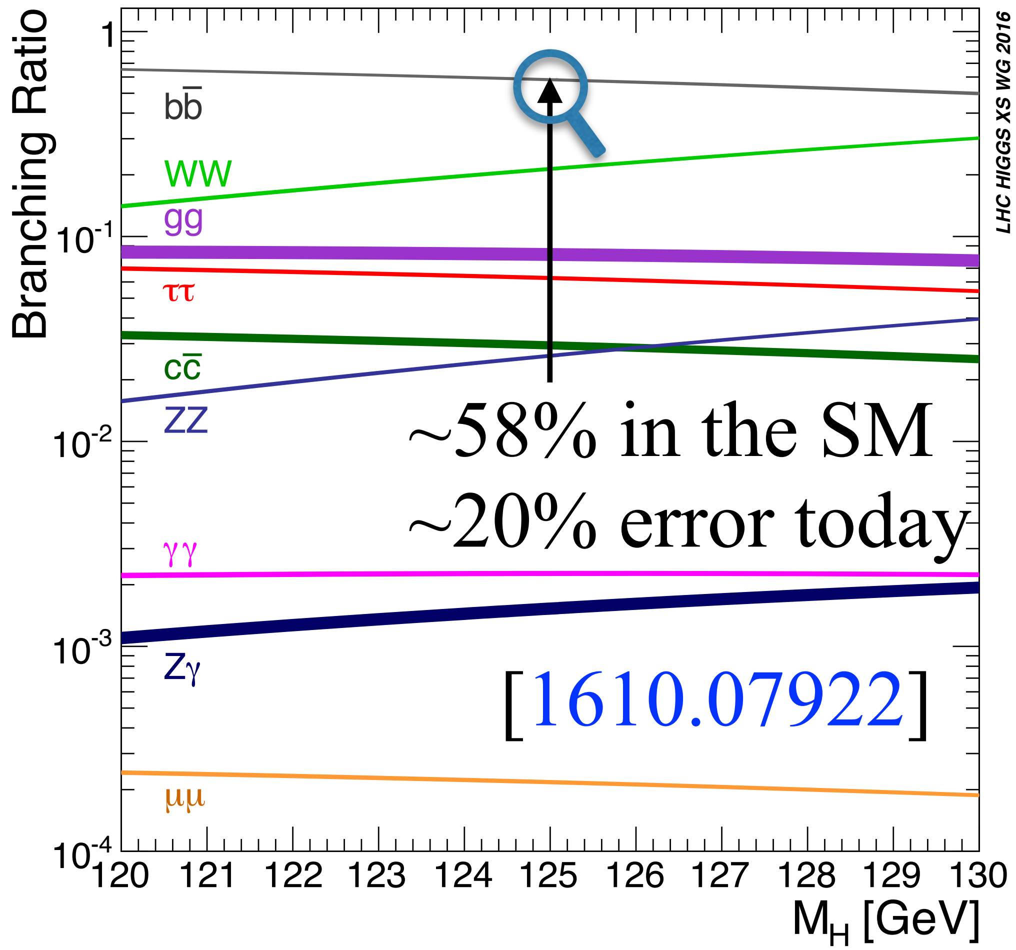
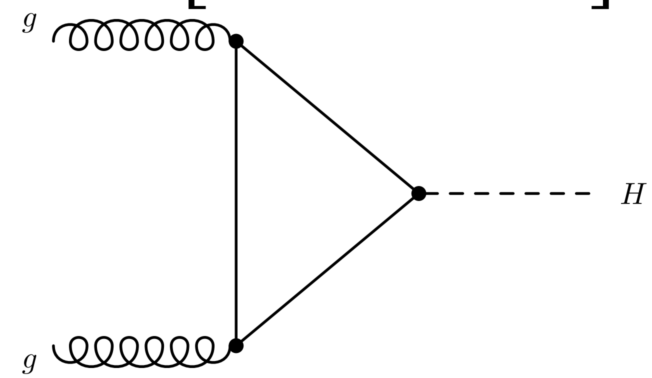
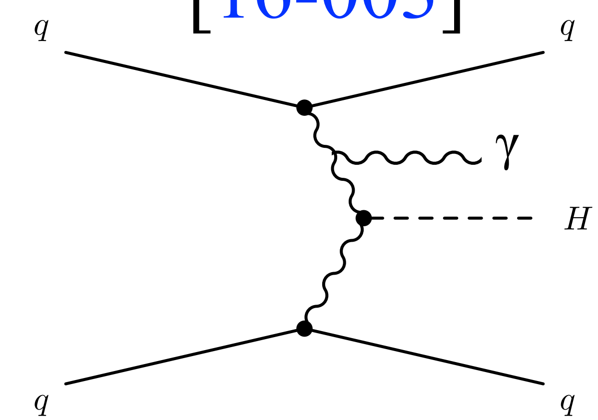
Introduction



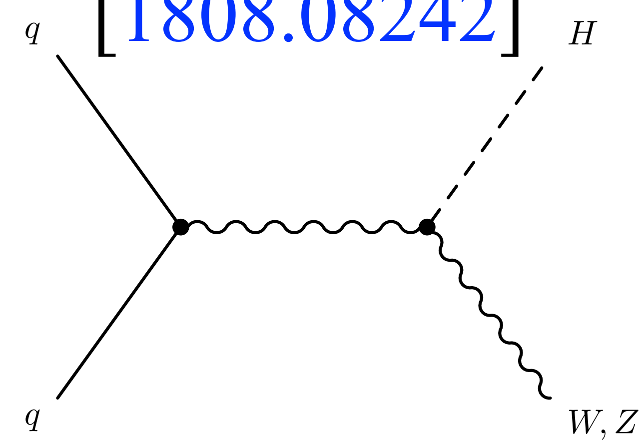
ggF [2018-052] [1709.05543]



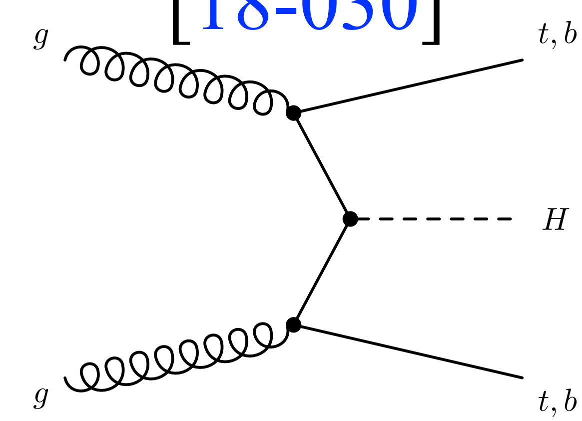
VBF [1807.08639] [16-003]



VH [1808.08238] [1808.08242]

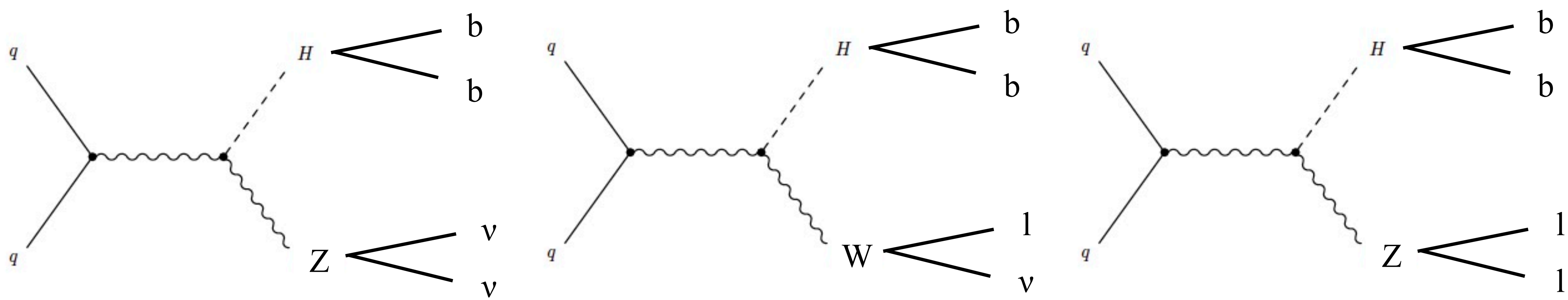


ttH [1712.08895] [18-030]



- Hbb is the most dominant decay of the Higgs boson
- Observation of Hbb was reported by ATLAS and CMS in 2018 at 80 fb^{-1}, and now we are preparing full Run 2 measurement at 140 fb^{-1}

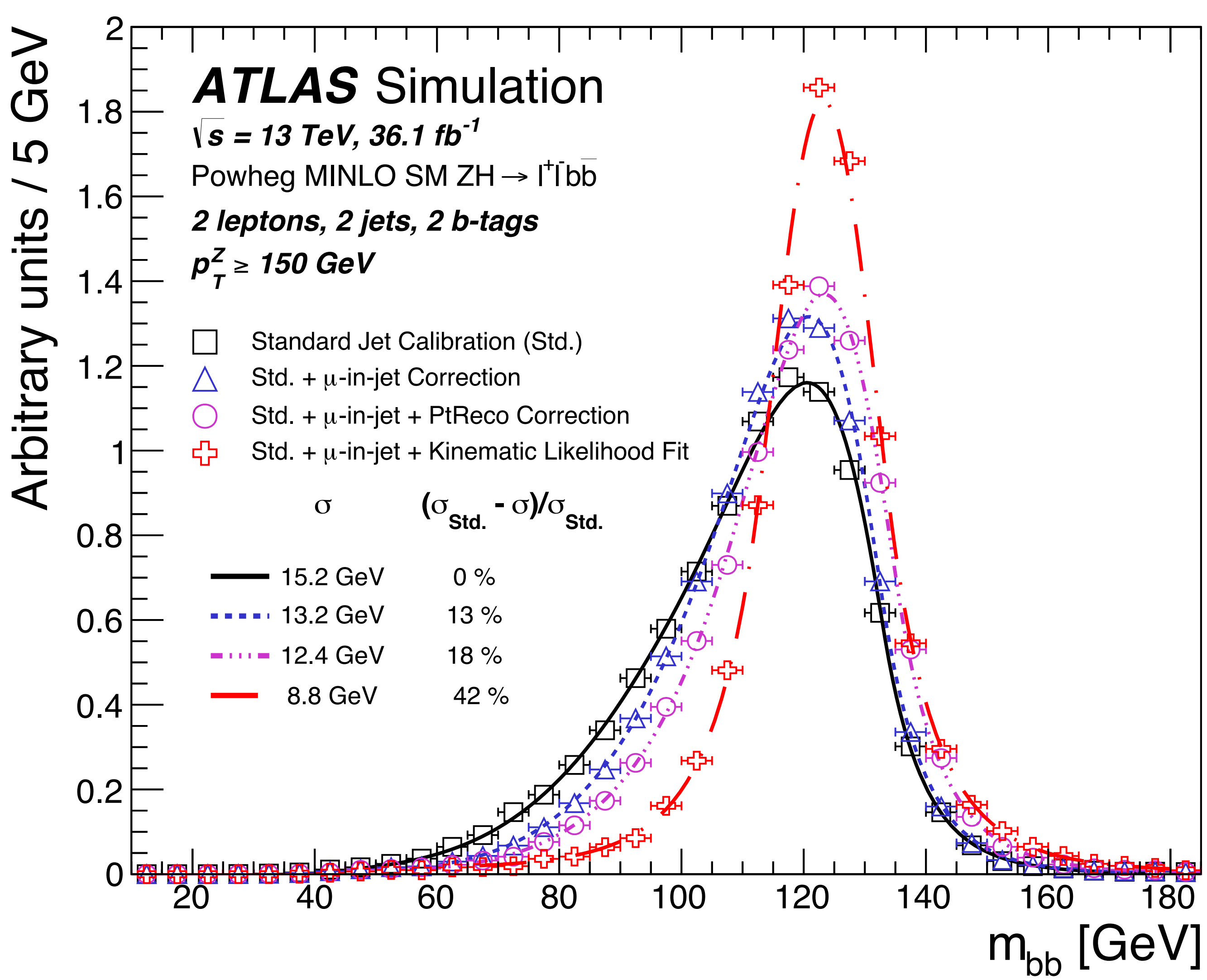
VHbb analysis

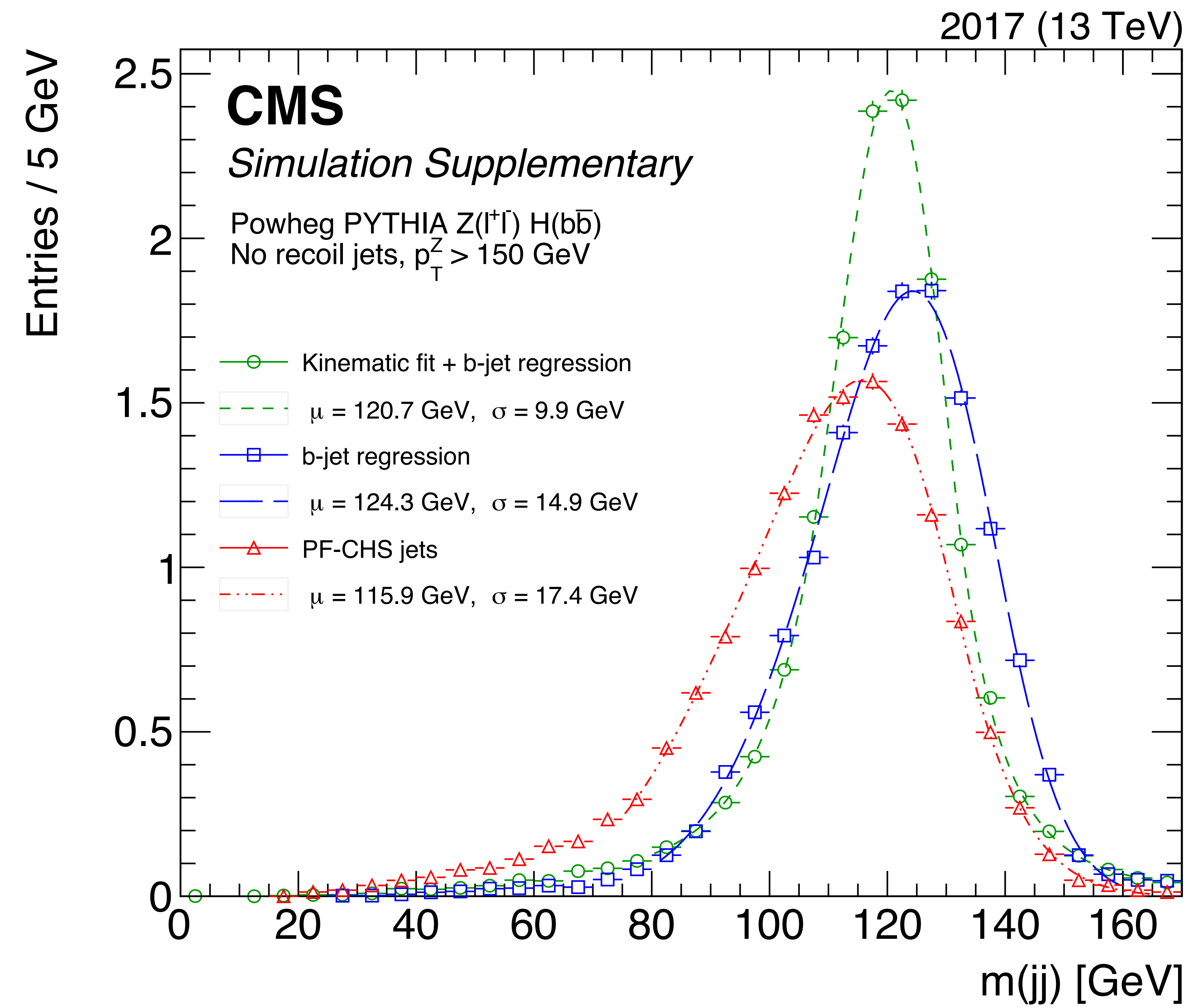


- Channels: 0-lepton, 1-lepton, 2-lepton
- Main background: V+jets, ttbar, single top, diboson, multi-jet
- Event categorisation: (2jet, 3jet) × (pT(V) bins)
- Dedicated b-jet energy correction
- Multivariate analysis (MVA)

b-jet energy corrections

[1808.08238]
[1808.08242]

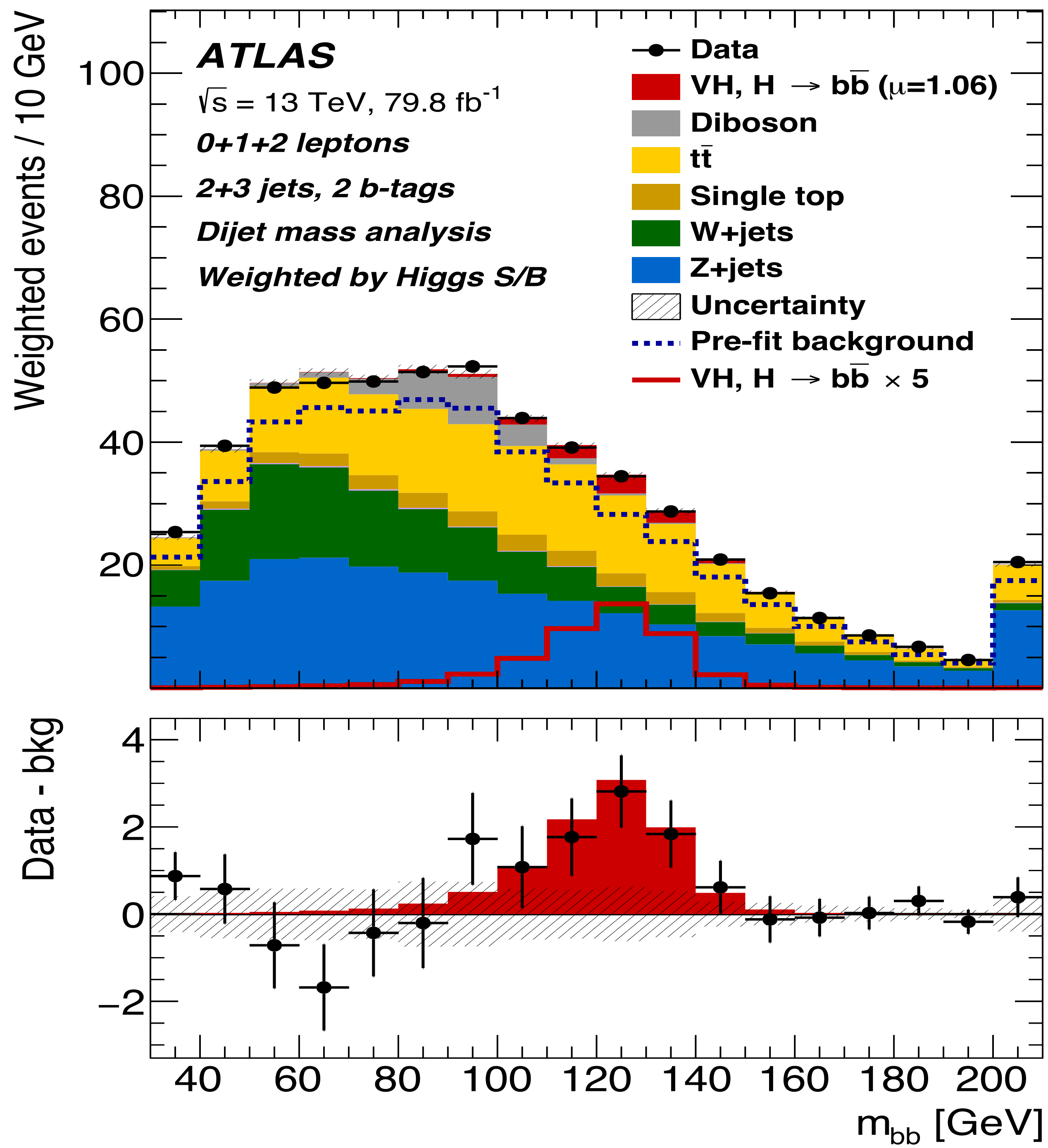


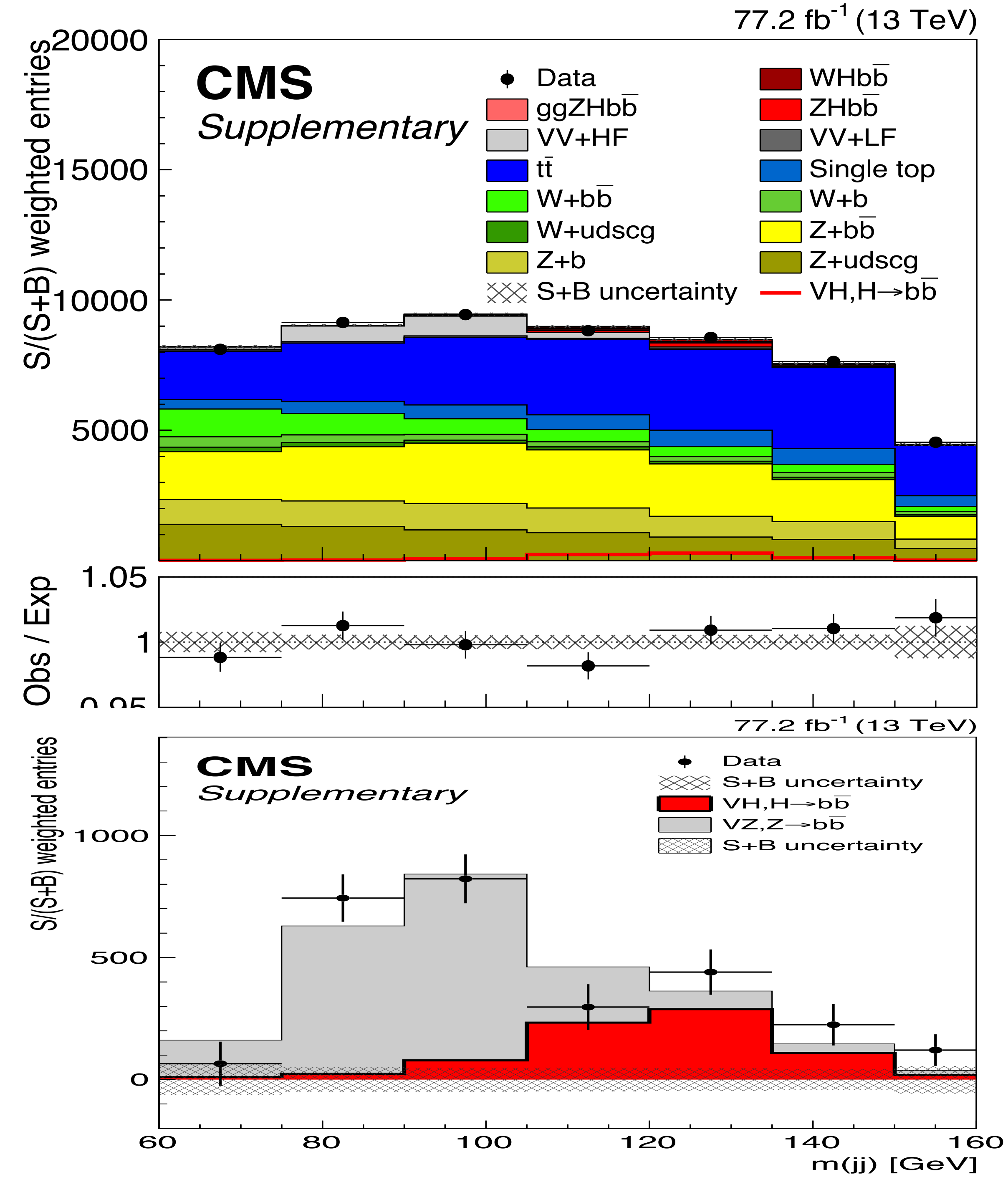


- ATLAS (left): Muon-in-jet, PtReco, Kinematic Fit
- CMS (right): Regression, FSR, Kinematic Fit

m(bb) distributions

[1808.08238]
[1808.08242]

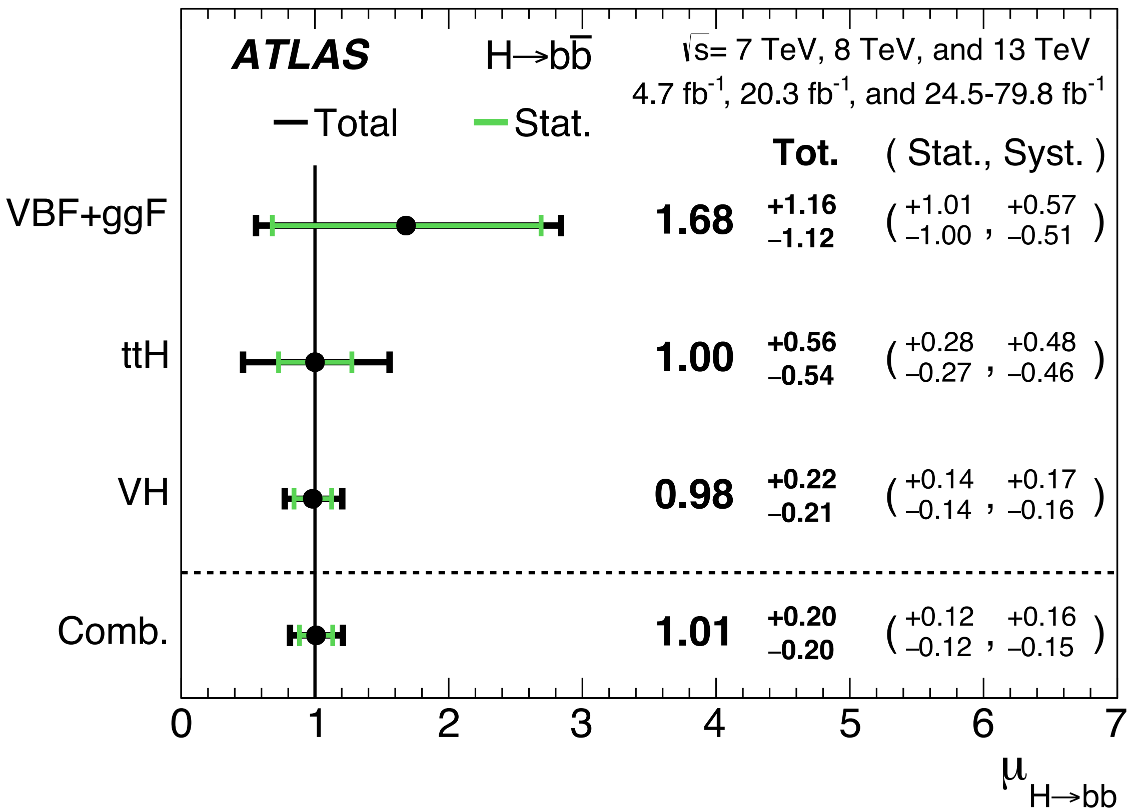


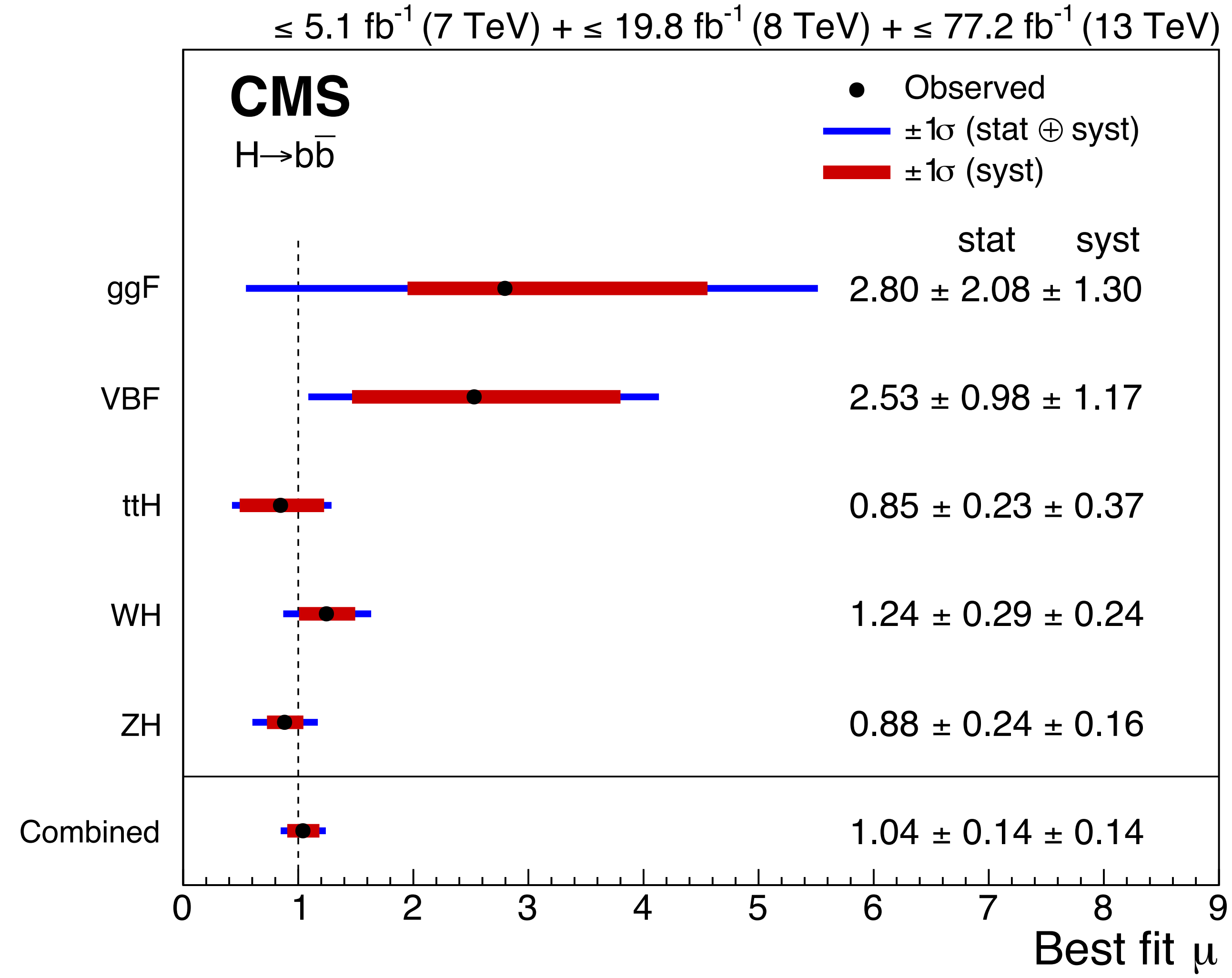


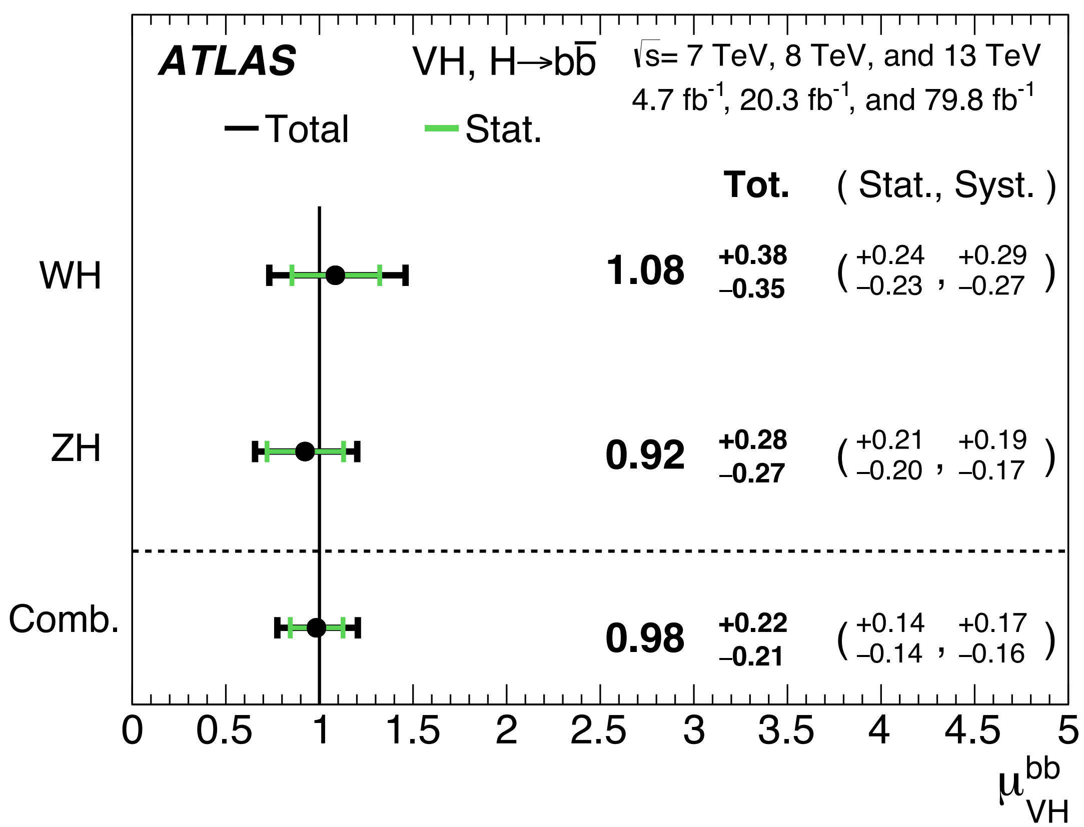
- Excess was found in m(bb) and measured in MVA

Signal strength

[1808.08238]
[1808.08242]







- Hbb combination: ATLAS 5.4 (5.5) σ, CMS (5.6) 5.5 σ
- Need to improve systematic uncertainties in VHbb

Systematic uncertainties

[1808.08238]
[1808.08242]

Source of uncertainty		σ_μ
Total		0.259
Statistical		0.161
Systematic		0.203
Experimental uncertainties		
Jets		0.035
$E_{\mathrm{T}}^{\mathrm{miss}}$		0.014
Leptons		0.009
b-tagging	b-jets	0.061
	c-jets	0.042
	light-flavour jets	0.009
	extrapolation	0.008
Pile-up		0.007
Luminosity		0.023
Theoretical and modelling uncertainties		
Signal		0.094
Floating normalisations		0.035
Z + jets		0.055
W + jets		0.060
$t\bar{t}$		0.050
Single top quark		0.028
Diboson		0.054
Multi-jet		0.005
MC statistical		0.070

Uncertainty source	$\Delta\mu$	
Statistical	+0.26	−0.26
Normalization of backgrounds	+0.12	−0.12
Experimental	+0.16	−0.15
b-tagging efficiency and misid	+0.09	−0.08
V+jets modeling	+0.08	−0.07
Jet energy scale and resolution	+0.05	−0.05
Lepton identification	+0.02	−0.01
Luminosity	+0.03	−0.03
Other experimental uncertainties	+0.06	−0.05
MC sample size	+0.12	−0.12
Theory	+0.11	−0.09
Background modeling	+0.08	−0.08
Signal modeling	+0.07	−0.04
Total	+0.35	−0.33

- ATLAS at 80 fb^{-1} (left), CMS at 41 fb^{-1} (right)
- Exp: b-tagging, jet, lumi
- Modeling: Sig, Bkg

Boosted Hbb analysis

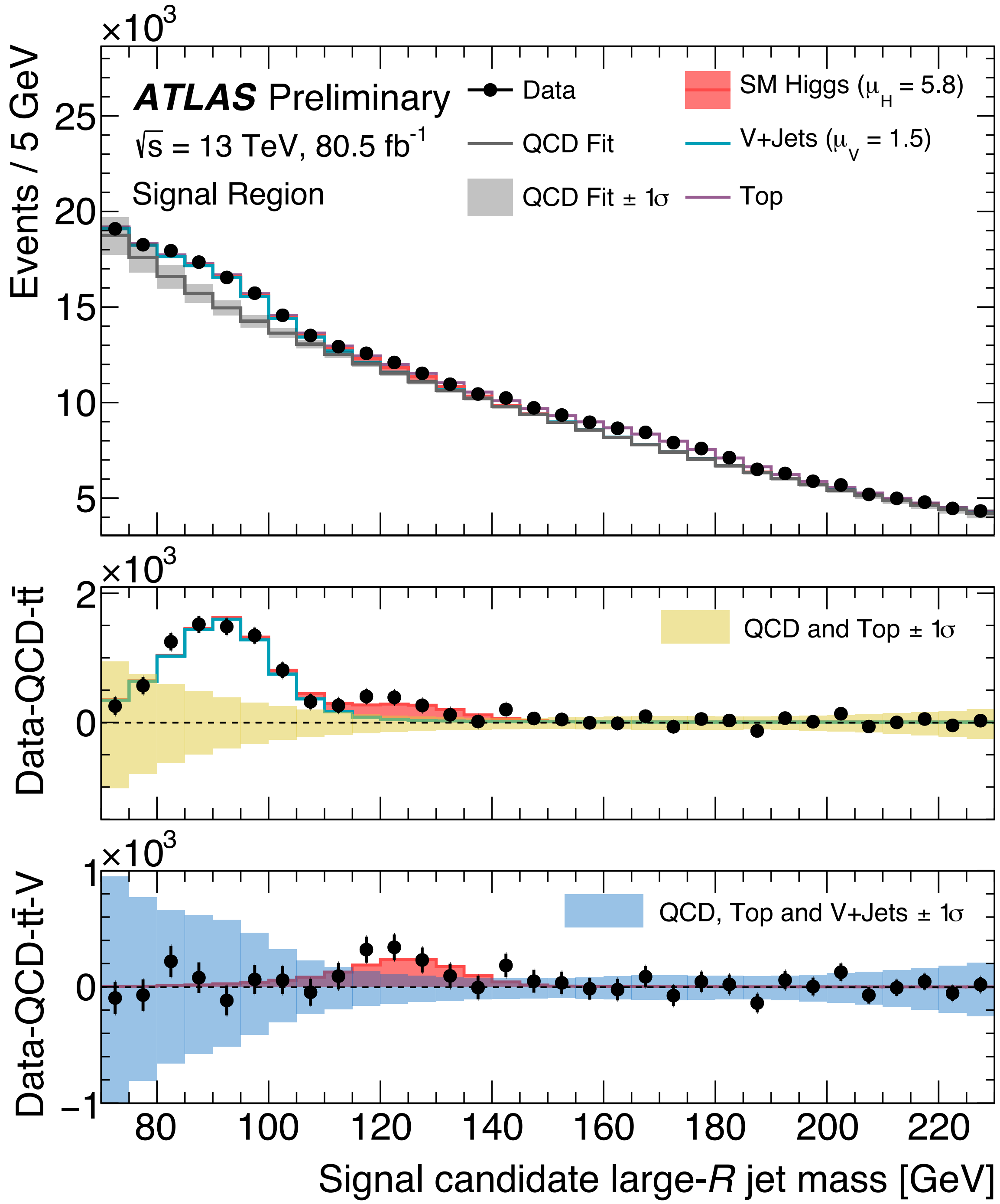
[2018-052]
[1709.05543]

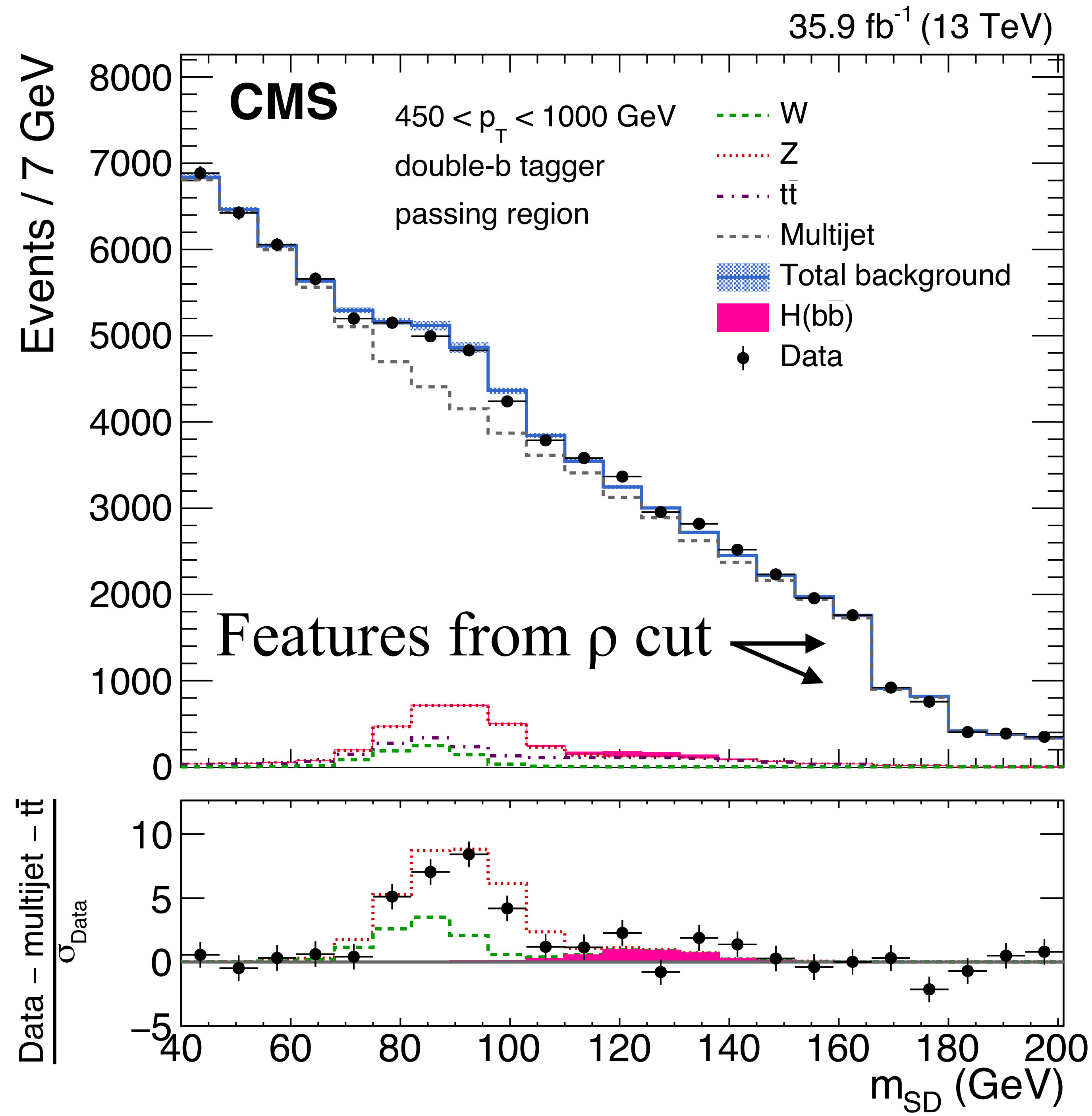
	ATLAS at 80 fb^{-1}	CMS at 36 fb^{-1}
Large-R jet	R=1.0, pT>480 GeV, $\|\eta\|<2$	R=0.8, pT>450 GeV, $\|\eta\|<2.5$
Hbb tagging	at least 2 variable radius track jets, leading 2 b-tags (77%)	$N^{1}_{2}{}^{DDT}{}_{(26\%)}<0$, double-b tagger (33%)
Boosted Cut	2m(J)/pT<1	$-6.0<\rho=\log(m(J)^2/pT^2)<-2.1$
QCD model	0tag CR data and parametric function to fit m(J)	0tag CR data and pass-fail ratio as function of pT and ρ
V+jet model	MC fitted to data	MC fitted to data
ttbar model	MC fitted to data using muon CR	MC fitted to data using muon CR

- Mainly targeting high pT ggF using large-R jets
- Sensitive to new physics, anomalous couplings

m(J) distributions

[2018-052]
[1709.05543]

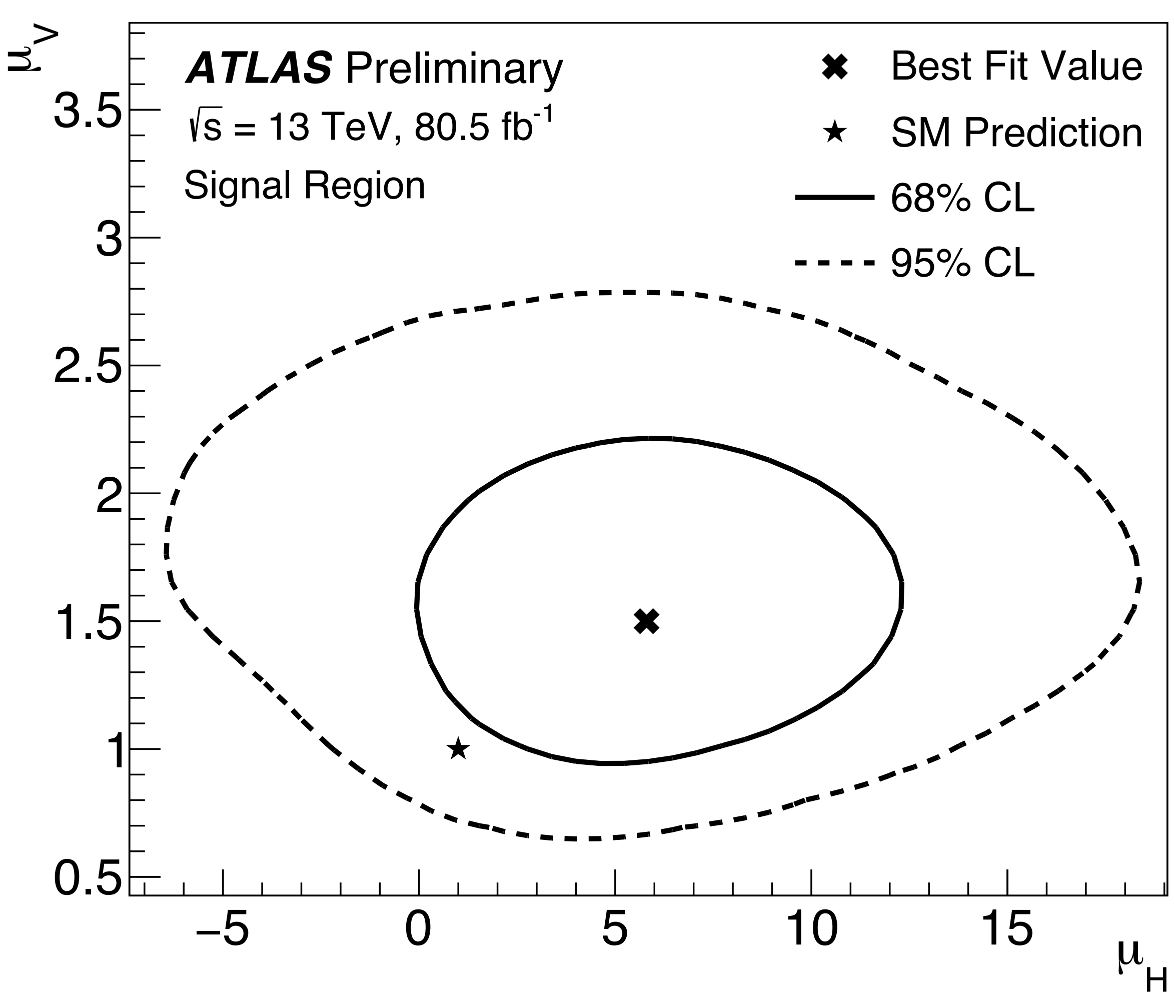


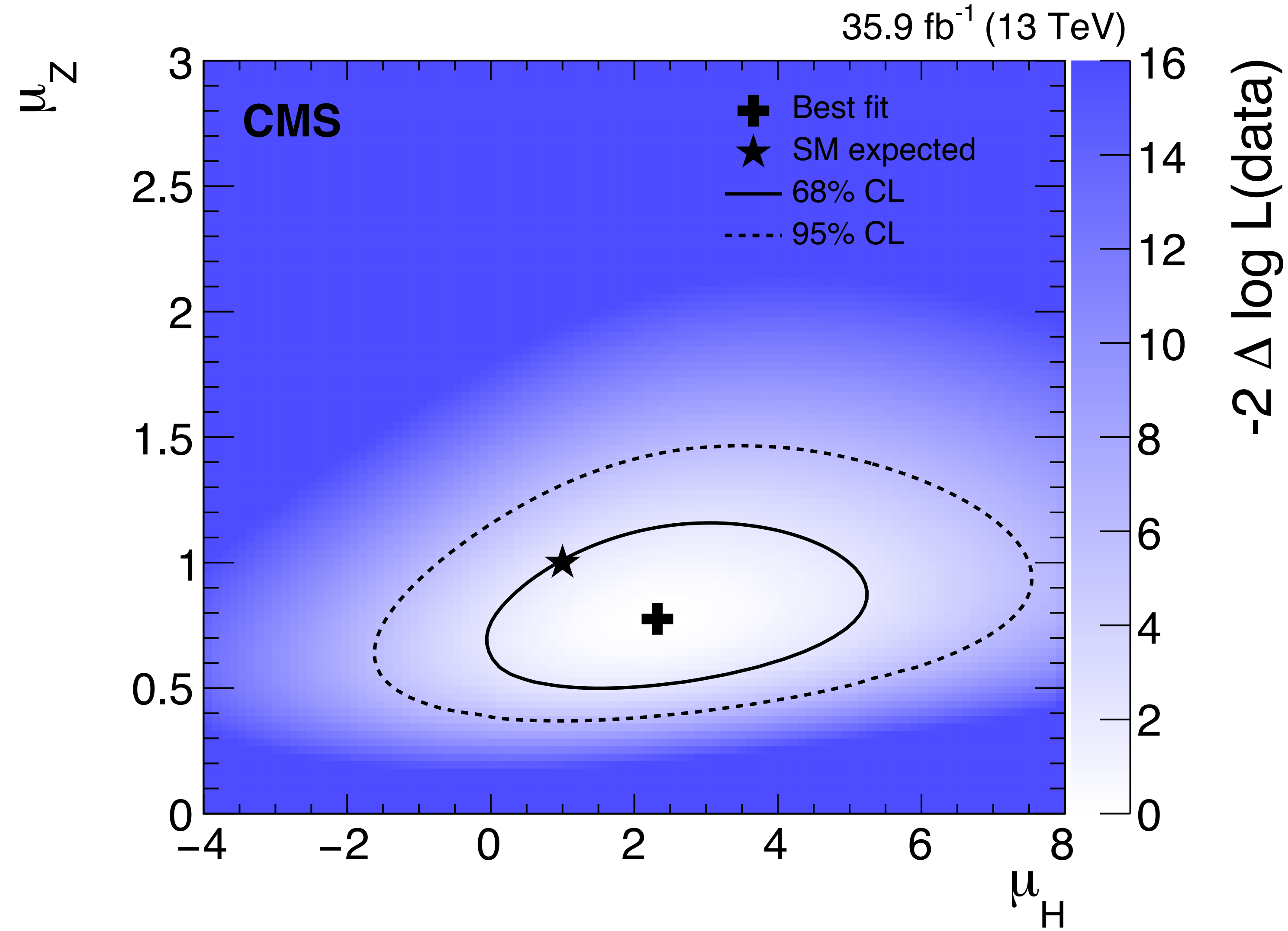


- Signal strength is measured for μ_V and μ_H

Signal strength

[2018-052]
[1709.05543]





- ATLAS at 80 fb-1: $\mu_V = 1.5$, 5σ, $\mu_H = 5.8$, 1.6σ
- CMS at 36 fb-1: $\mu_Z = 0.78$, 5.1 (5.8) σ, $\mu_H = 2.3$, 1.5 (0.7) σ → Observation of Z+jets in single-jet

Systematic uncertainties

[2018-052]
[1709.05543]

Source	Type	V+jets	Higgs
Jet energy and mass scale	Norm. & Shape	15%	14%
Jet mass resolution	Norm. & Shape	20%	17%
V + jets modeling	Shape	9%	4%
$t\bar{t}$ modeling	Shape	$< 1\%$	1%
b-tagging (b)	Normalisation	11%	12%
b-tagging (c)	Normalisation	3%	1%
b-tagging (l)	Normalisation	4%	1%
$t\bar{t}$ scale factor	Normalisation	2%	3%
Luminosity	Normalisation	2%	2%
Alternative QCD function	Norm. & Shape	4%	4%
W/Z and QCD (Theory)	Normalisation	14%	–
Higgs (Theory)	Normalisation	–	30%

Systematic source	W/Z	H
Integrated luminosity	2.5%	2.5%
Trigger efficiency	4%	4%
Pileup	<1%	<1%
$N_2^{1,\mathrm{DDT}}$ selection efficiency	4.3%	4.3%
Double-b tag	4% (Z)	4%
Jet energy scale / resolution	10/15%	10/15%
Jet mass scale (p_T)	0.4%/100 GeV (p_T)	0.4%/100 GeV (p_T)
Simulation sample size	2–25%	4–20% (ggF)
H p_T correction	—	30% (ggF)
NLO QCD corrections	10%	—
NLO EW corrections	15–35%	—
NLO EW W/Z decorrelation	5-15%	—

- ATLAS (top) and CMS (bottom)
- Experimental: Jet energy/mass scale/ resolution (15–20%), Hbb tag (~10%)
- Theory: W/Z (15%) and ggF (30%)
- Uncertainty on pT(H) spectrum is propagated to overall normalisation

Summary

- Overview of the latest Hbb physics at LHC is presented (please also check the other channels)
- Using Run 2 data up to 80 fb^{-1}, the Hbb rate is consistent with SM, with about 20% of total error
- Boosted Hbb providing sensitivity to SM/BSM
- Let's get ready for the full Run 2 measurement with new techniques and improved systematics

- Thank you!