Imperial College London





Higgs-to-Invisible Searches with the CMS experiment at the LHC

RICCARDO DI MARIA

IMPERIAL COLLEGE LONDON RICCARDO.DI.MARIA@CERN.CH

Joint APP and HEPP Annual Conference, 27 March 2018, University of Bristol (UK)

Contents

- Introduction and Motivation
- Physics Background
- VBF Higgs-to-Invisible Search
- Combination
- Dark Matter Interpretation
- Conclusions



Motivation

- Strong astrophysical evidence indicates that dark matter (DM) exists.
- There is no evidence yet for non-gravitational interactions between DM and standard model (SM) particles.



3



 The LHC provides an opportunity to probe these interactions by directly producing DM particles.

Why Higgs to Invisible?

- Higgs boson decays to invisible final states predicted by many beyond the SM (BSM) theories, where final state particles can be DM candidates.
- The Higgs boson (125 GeV) measurements are compatible with the SM expectation.
- However, present uncertainties can accommodate BSM properties.
- BSM Higgs decays affect the total Higgs boson width.
- The SM branching ratio H(inv.) is ≈0.12% for H(ZZ(4v)).
- Invisibly decaying Higgs boson is a hint of new physics.



Direct Searches

• Higgs boson has to recoil against a visible system.

vector boson fusion (qqH)



• Missing transverse energy (MET) has to be present in the final state.





VBF H(inv.)

- The final state is characterised by:
 2 jets with large Δη_{jj}; large m_{jj}; large MET well-separated from any jets.
- Expected backgrounds: Z(vv)+jets; W(&)+jets, where l is missed; Top quark, diboson, and QCD multijet.



- Two different approaches used:
 - cut-and-count, results directly translated into a limit on the visible cross-section in a model independent way;
 - *shape*, improves the sensitivity for a SM-like H(inv.).



h

Control Regions



Muon CRs

- Events selected using the same SR p_T^{miss}trig.
 - 2 oppositely charged μ with $p_T > 10$ GeV:
 - at least one with p_T > 20 GeV that passes tighter ID;
 - 60 < m_{uu} < 120 GeV.

- 1 μ with p_T > 20 GeV, passing both tight ID and ISO requirements.
- $m_T < 160$ GeV for the muon-MET system.



Electron CRs

- Events selected using $p_T^{single-electron}_{trig}$ with threshold of 27 GeV and 105 GeV, and imposing ISO requirements due to trigger inefficiency for Z- p_T > 600 GeV.
 - 2 oppositely charged e with $p_T > 10$ GeV:
 - at least one with p_T > 40 GeV that passes tighter ID;
 - 60 < m_{ee} < 120 GeV.

- 1 e with p_T > 40 GeV, passing both tight ID and ISO requirements.
- m_T < 160 GeV for the electron-MET system, and p_T^{miss} > 60 GeV to further reduce QCD multijet contamination.



V+jets Background Estimation

- Z(vv) and W+jets backgrounds in the SR are measured primarily via leptonic CRs.
- Connection between SR and CRs performed via transfer factors (TFs) from MC.
- Background estimates in SR derived via V+jets yields in CRs for each m_{ii} bin.
- TFs account for differences in BR and acceptance (i.e. DY->ℓℓ vs. Z(vv)).
- TFs corrected for experimental effects via efficiencies/scale-factors measured in data.



Cut-and-Count Signal Region

Process	Signal Region	Dimuon CR	Dielectron CR	Single-Muon CR	Single-Electron CR
$Z(\nu\nu)$ (QCD)	799 ± 72	-	-	- /	-
$Z(\nu\nu)$ (EW)	275 ± 34	-	-	- / /	-
$Z(\ell\ell)$ (QCD)	-	90.1 ± 7.9	64.7 ± 5.8	26.8 ± 1.2	4.9 ± 0.2
$Z(\ell\ell)$ (EW)	-	32.7 ± 4.3	25.0 ± 3.4	5.9 ± 0.3	2.4 ± 0.2
$W(\ell\nu)$ (QCD)	497 ± 33	0.2 ± 0.2	0.8 ± 0.6	891 ± 31	533 ± 21
$W(\ell\nu)$ (EW)	145 ± 11	0.1 ± 0.1	- /	416 ± 16	260 ± 11
Top-quark	43.7 ± 9.8	5.3 ± 1.6	3.7 ± 1.1	126 ± 22	83.1 ± 15.4
Dibosons	19.9 ± 6.1	2.6 ± 1.3	0.9 ± 0.5	23.5 ± 4.9	16.1 ± 4.1
Others	3.3 ± 2.6	-	- \ `	25.6 ± 20.7	2.9 ± 2.9
Total Bkg.	1784 ± 97	131 ± 8	95.2 ± 5.9	1515 ± 34	902 ± 24
Data	2053	114	104	1512	914
Signal $m_{\rm H} = 125 {\rm GeV}$	851 ± 148	-	\langle / \rangle	- / /	-

35.9 fb⁻¹ (13 TeV)

11



35.9 fb⁻¹ (13 TeV)



Upper Limits on $\mathcal{B}(H(inv.))$

• The observed and expected 95% confidence level upper limits on $\mathcal{B}(H(inv.))$ assuming SM production rate are:

Analysis	Observed limit	Expected limit	± 1 s.d.	± 2 s.d.	Signal composition
Shape	0.28	0.21	[0.15–0.29]	[0.11–0.39]	52% qqH, 48% ggH
Cut-and-count	0.53	0.27	[0.20–0.38]	[0.15–0.51]	81% qqH, 19% ggH



Combination of H(inv.) Searches

Analysis	Final state	Signal composition	Observed limit	Expected limit
qqH-tagged	VBF-jets + $p_{\rm T}^{\rm miss}$	52% qqH, 48% ggH	0.28	0.21
VH taggod	$Z(\ell\ell) + p_{T}^{miss}$ [11]	79% qqZH, 21% ggZH	0.40	0.42
vii-taggeu	$V(qq') + p_{\mathrm{T}}^{\mathrm{miss}}$ [12]	40% ggH, 3% qqH, 35% WH, 22% ZH	0.50	0.48
ggH-tagged	jets + $p_{\rm T}^{\rm miss}$ [12]	80% ggH, 9% qqH, 6% WH, 5% ZH	0.64	0.58

- [11] <u>CMS EXO-16-052</u>
- [12] <u>CMS EXO-16-048</u>
- The overlap between the various searches has been removed.



Combination of H(inv.) Searches

• The observed (expected) 95% confidence level upper limits on $\mathcal{B}(H(inv.))$ assuming SM production rate is: 0.24 (0.18).



DM Interpretation

- $\mathcal{B}(H(inv.))$ translated into DM-nucleon spin-independent cross-section limits as a function of DM mass (90% CL to compare to direct detection experiments).
- Use Higgs-Portal models [9] assuming scalar/fermion DM candidate.
- LHC limits complementary to direct detection experiments.



Conclusions

• Direct search for Higgs boson decays to invisible final states has been carried out in the VBF production channel.

HIG-17-023	Observed (Expected) Upper Limit @ 95% CL on ${\mathcal B}$ (H(inv.))
Cut-and-count	0.53 (0.27)
Shape	0.28 (0.21)
Combination	0.24 (0.18)

Reference	Observed (Expected) Upper Limit @ 95% CL on ${\mathcal B}({\sf H}({\sf inv.}))$
HIG-16-016 VBF-only (C&C Run1+Run2)	0.44 (0.31)
CMS JHEP 02 (2017) 135 arXiv:1610.09218	0.24 (0.23)
ATLAS JHEP 11 (2015) 206 <u>arXiv:1509.00672</u>	0.25 (0.27)

• A DM interpretation has been provided, translating $\mathcal{B}(H(inv.))$ into DM-nucleon spin-independent cross-section limits as a function of DM mass.

Backup Slides



Dark Matter

- The dark matter is supposed to be a thermal relic of the early Universe.
- The comparison between direct and indirect detection is model dependent.
- A theoretical guidance is needed (LHC DM forum).





arXiv:1603.04156

The CMS Experiment

All the CMS sub-detectors are vital for MET-searches.



Signal Kinematics



Simulation and Object Corrections

 qqH and ggH signals: Powheg2.0 at NLO in QCD, normalised to the σ_H^{inclusive} from YR4 [<u>arXiv:1610.07922</u>].



 Following POG recommendations, e.g. lepton ID and reco efficiencies, hadronic-tau ID, b-tagging efficiencies, jet energy corrections...

NLO Corrections

- (LO QCD, EWK)-Z+jets and (QCD, EWK)-W+jets are corrected with NLO-QCD kfactors as a function of boson p_T and m_{ii}.
- QCD k-factors derived in VBF phase space.
- Large NLO-QCD corrections for QCD-V+jets as shown in the plot.
- Important impact on the analysis:
 - e.g. change the Z/W ratio.
- Smaller NLO-QCD corrections for EWK-V+jets (as expected), ranging between 3-10%



22

The QCD-Z+jets and QCD-W+jets are also corrected with p_T-dependent NLO EWK corrections (from theoretical calculation).

Trigger Selection

- At L1, p_T^{miss}-based triggers ([60,90] GeV) are used to select signal region (SR) events
- At HLT, triggers with thresholds of 110 or 120 GeV are used, applied to p_T^{miss}_{trig} and H_T^{miss}_{trig} without including muons (same triggers for muon control regions (CR)).
- Since the L1 decision is blind to hadronic activity in HF, leading OR trailing jet with $|\eta|<3.$
- Trigger efficiency parametrised vs offline H_T^{miss}, stable as a function of jets kinematics (B = jet |η| < 3, F = jet |η| > 3 i.e. HF).



V+jets Background Estimation

- Z/W constraint used to improve the precision on Z(vv) estimate, exploiting the larger statistical power of the single-lepton CRs.
- Z/W ratio between CRs: important to cross-check the effect of higher order corrections and if data-to-MC differences are covered by the uncertainties.
- Z/W ratio affected mainly by theoretical systematics.



• Gray bands include both the pre-fit systematic uncertainties and the statistical uncertainty in the simulation.

QCD Estimation

- A QCD multijet enriched CR with inverted $\Delta \phi$ and p_T^{miss} SR selections is used to estimate this background from data.
- The contamination from V+jets backgrounds in the low-Δφ region is estimated from simulation and subtracted (20% unc.) from the event yield measured.
- The QCD multijet MC statistical uncertainty varies between 40-100% as a function of m_{jj}.
 35.9 fb⁻¹ (13 TeV)



Systematic Uncertainties

- Systematic uncertainties are modelled as constrained nuisance parameters.
- Z(vv)+jets and W(lv)+jets backgrounds uncertainties enter in the likelihood as variations of the TFs.

Source of uncertainty	Ratios	Uncertainty vs <i>m</i> _{jj}	Impact on $\sigma \mathcal{B}(H \rightarrow inv) / \sigma_{SM}$			
Theoretical uncertainties						
Renorm. scale V+jets (EW)	$Z(\nu\nu)/W(\ell\nu)$ (EW)	9–12%	48%			
Renorm. scale V+jets (QCD)	$Z(\nu\nu)/W(\ell\nu)$ (QCD)	9–12%	23%			
Fact. scale V+jets (EW)	$Z(\nu\nu)/W(\ell\nu)$ (EW)	2–7%	4%			
Fact. scale V+jets (QCD)	$Z(\nu\nu)/W(\ell\nu)$ (QCD)	2–7%	2%			
NLO EW corr.	$Z(\nu\nu)/W(\ell\nu)$ (QCD)	1–2%	< 1%			
PDF V+jets (QCD)	$Z(\nu\nu)/W(\ell\nu)$ (QCD)	0.5–1%	< 1%			
PDF V+jets (EW)	$Z(\nu\nu)/W(\ell\nu)$ (EW)	0.5–1%	< 1%			
	Experimental uncertainties					
$p_{\rm T}^{\rm miss}$ trigger	All ratios	pprox 2%	18%			
Muon id. eff.	$W(\mu\nu)/W(\ell\nu), Z(\mu\mu)/Z(\nu\nu)$	pprox 1% (per leg)	8%			
Muon reco. eff.	$W(\mu\nu)/W(\ell\nu), Z(\mu\mu)/Z(\nu\nu)$	pprox 1% (per leg)	8%			
Ele. id. eff.	$W(ev)/W(\ell v), Z(ee)/Z(vv)$	pprox 1.5% (per leg)	4%			
Ele. reco. eff.	$W(ev)/W(\ell v), Z(ee)/Z(vv)$	pprox 1% (per leg)	3%			
au veto	$W(CRs)/W(\ell\nu), Z(\nu\nu)/W(\ell\nu)$	\approx 3.5 (3)% for EW (QCD)	13%			
Muon veto	$W(CRs)/W(\ell\nu), Z(\nu\nu)/W(\ell\nu)$	pprox 2.5 (2)% for EW (QCD)	7%			
Ele. veto	$W(CRs)/W(\ell\nu), Z(\nu\nu)/W(\ell\nu)$	≈ 1.5 (1)% for EW (QCD)	5%			
Jet energy scale	$Z(CRs)/Z(\nu\nu), W(CRs)/W(\ell\nu)$	\approx 1 (2)% for Z/Z (W/W)	2%			
Ele. trigger	$W(ev)/W(\ell v), Z(ee)/Z(vv)$	pprox 1%	< 1%			

- Systematic uncertainties on minor backgrounds detailed in backup.
- Before the fit, the total uncertainty in the background estimation in SR is [4.5,6]% as a function of m_{ij}.

Additional Uncertainties

Source	Uncertainty
QCD multijet	30% + conservative 50% from $\Delta \phi$ method validation
Diboson normalisation	15%
Top quark normalisation	10%
Modelling of the Top quark \mathbf{p}_{T} distribution in simulation	10%
b-jet veto for Top quark	3%
b-jet veto for other simulated processes	≈1%
JES	8-15%
Integrated luminosity	2.5%

Event Selection

- Both for *cut-and-count* and *shape*, selection and binning optimised wrt best exclusion limit on $\mathcal{B}(H(inv.))$.
- Optimisation studies performed on $\Delta \eta_{ii}$, $\Delta \phi_{ii}$, and m_{ii}.
- Among the various variables, m_{ii} most sensitive.



Observable	Shape analysis Cut-and-count analysis		Target background
Leading (trailing) jet	$p_{\rm T} > 80$	(40) GeV, $ \eta < 4.7$	All
p_{T}^{miss}		> 250 GeV	QCD multijet, $tar{t}$, W $+$ jets
$\Delta \phi(\pmb{p}_{T}^{miss}, \pmb{p}_{T}^{jet})$		> 0.5	QCD multijet
$ \Delta \phi_{ m jj} $	< 1.5 radians		${\sf Z}(u\overline{ u})+{\sf jets},\;{\sf W}(l u)+{\sf jets}$
$\eta_{\mathrm{j}1}\cdot\eta_{\mathrm{j}2}$	< 0		${\sf Z}(u\overline{ u})+{\sf jets},\;{\sf W}(l u)+{\sf jets}$
$ \Delta\eta_{ m jj} $	> 1	> 4	${\sf Z}(u\overline{ u})+{\sf jets}, {\sf W}(l u)+{\sf jets}$
$ m_{ m jj} $	> 200 GeV	> 1300 GeV	${\sf Z}(u\overline{ u})+{\sf jets},\;{\sf W}(l u)+{\sf jets}$
Muons and electrons	$N_{\mu,e}=0$ with $p_T>$ 10 GeV, $ \eta <$ 2.4 (2.5)		W+jets, Z(ll)+jets
au leptons	${\sf N}_{ au_h}=0$ with $p_{\sf T}>$ 18 GeV, $ \eta <2.3$		W+jets, Z(ll)+jets
Photons	$N_{\gamma} = 0$ with	$p_{T} >$ 15 GeV, $ \eta < 2.5$	$\gamma+jets,V\gamma$
B-jets	$N_{jet} = 0$ with p_{T}	> 20 GeV, CSVv2 > 0.8484	$t\bar{t}$, single top

Control Regions

- The V+jets represent the largest backgrounds in this search (≈95%).
- The V+jets backgrounds are determined through a simultaneous maximumlikelihood fit across 4 CRs and SR.
- p_T^{miss} calculated excluding the p_T of the identified leptons (proxy for SR).
- Specific lepton(s) selections used to construct the CR.
- SR selection applied.
- Hadronic- τ , γ , and additional muon or electron rejected.

Muon CRs

- Events selected using the same SR p_T^{miss}trig.
 - 2 oppositely charged μ with $p_T > 10$ GeV:
 - at least one with p_T > 20 GeV that passes tighter ID;
 - 60 < m_{uu} < 120 GeV.

- 1 μ with p_T > 20 GeV, passing both tight ID and ISO requirements.
- $m_T < 160$ GeV for the muon-MET system.



Electron CRs

• Events selected using $p_T^{single-electron}_{trig}$ with threshold of 27 GeV and 105 GeV, and imposing ISO requirements due to trigger inefficiency for Z-p_T > 600 GeV.



- at least one with p_T > 40 GeV that passes tighter ID;
- 60 < m_{ee} < 120 GeV.

- 1 e with $p_T > 40$ GeV, passing both tight ID and ISO requirements.
- m_T < 160 GeV for the electron-MET system, and p_T^{miss} > 60 GeV to further reduce QCD multijet contamination.



Shape Signal Region



• Data in SR are excluded (left) and included (right) in the fit assuming the absence of any signal.

Shape Signal Region

				<i>m</i> _{jj} range i	n TeV				
Process	0.2-0.4	0.4–0.6	0.6–0.9	0.9–1.2	1.2–1.5	1.5–2.0	2.0-2.75	2.75–3.5	> 3.5
$Z(\nu\nu)$ (QCD)	9367 ± 394	5716 ± 256	3925 ± 184	1665 ± 84	675 ± 43	406 ± 26	151 ± 14	22.6 ± 3.6	7.5 ± 2.1
$Z(\nu\nu)$ (EW)	202 ± 8	230 ± 10	278 ± 13	203 ± 10	131 ± 8	115 ± 8	71.3 ± 6.6	20.9 ± 3.4	11.6 ± 3.1
$W(\ell\nu)$ (QCD)	4786 ± 252	3046 ± 165	2122 ± 125	936 ± 58	361 ± 29	232 ± 19	79.3 ± 8.9	13.4 ± 2.8	4.3 ± 1.5
$W(\ell\nu)$ (EW)	101 ± 15	118 ± 16	135 ± 18	102 ± 13	61.4 ± 7.9	62.2 ± 7.9	39.9 ± 4.8	13.3 ± 1.8	5.6 ± 1.4
Top-quark	206 ± 32	161 ± 25	124 ± 19	60.7 ± 9.3	31.6 ± 6.1	18.3 ± 2.9	11.1 ± 1.8	2.8 ± 0.5	0.9 ± 0.2
Dibosons	219 ± 39	158 ± 28	119 ± 21	50.9 ± 9.1	19.5 ± 3.5	10.4 ± 1.8	2.8 ± 0.5	1.4 ± 0.3	0.4 ± 0.1
Others	77.5 ± 19.5	51.5 ± 11.5	43.8 ± 10.7	14.3 ± 2.9	6.9 ± 1.5	3.7 ± 0.8	2.5 ± 0.6	0.7 ± 0.3	0.3 ± 0.4
Total Bkg.	14960 ± 563	9482 ± 378	6738 ± 281	3032 ± 135	1286 ± 73	849 ± 48	358 ± 28	75.3 ± 9.8	29.9 ± 7.2
Data	16181	10035	7312	3154	1453	919	411	88	29
Signal	591 ± 285	571 ± 232	566 ± 172	472 ± 131	307 ± 64	344 ± 83	228 ± 40	90.3 ± 18.8	37.4 ± 9.1



- Data in SR are excluded in the fit assuming the absence of any signal.
- Both can be used in the <u>simplified likelihood</u> approach to reinterpret the analysis results in different models.

Upper Limits on $\mathcal{B}(H(inv.))$

• The observed and expected 95% confidence level upper limits on $\mathcal{B}(H(inv.))$ assuming SM production rate are:

Analysis	Observed limit	Expected limit	± 1 s.d.	± 2 s.d.	Signal composition
Shape	0.28	0.21	[0.15–0.29]	[0.11–0.39]	52% qqH, 48% ggH
Cut-and-count	0.53	0.27	[0.20–0.38]	[0.15–0.51]	81% qqH, 19% ggH



Combination of H(inv.) Searches

• The observed (expected) 95% confidence level upper limits on $\mathcal{B}(H(inv.))$ assuming SM production rate is: 0.24 (0.18).



Combination of H(inv.) Searches

- The 95% confidence level upper limit on $\mathcal{B}(H(inv.))$ is expressed as for different assumptions on production (non-SM).
- It shows the result parametrising production cross-sections in terms of coupling strength modifiers, *k_F* and *k_V*, which scale the coupling of the Higgs boson to SM fermions and vector bosons.
 35.9 fb⁻¹ (13 TeV)
- The 95% confidence level upper limit on B(H(inv.)) varies between 17-29% within LHC couplings constraints.



Correlation Scheme

Source of uncertainty	Correlation				
Experimental uncertainties					
Luminosity	Correlated across searches				
Muon id. eff.	Correlated across searches				
Muon reco. eff.	Correlated across searches				
Electron id. eff.	Correlated across searches				
Electron reco. eff.	Correlated across searches				
Muon veto eff.	Correlated across searches				
Electron veto eff.	Correlated across searches				
B-jet veto eff.	Correlated across searches				
Hadronic τ veto eff.	Correlated across searches				
Muon energy scale	Correlated across searches				
Electron energy scale	Correlated across searches				
Jet energy scale	Correlated across ggH, $V(qq')$ H and $Z(\ell\ell)$ H searches				
$p_{\rm T}^{\rm miss}$ energy scale	Correlated across ggH, $V(qq')$ H and $Z(\ell\ell)$ H searches				
Muon mis-tag rate	Correlated across single-lepton CR of ggH, $V(qq')$ H and qqH searches				
Electron mis-tag rate	Correlated across single-lepton CR of ggH, $V(qq')$ H and qqH searches				
$p_{\rm T}^{\rm miss}$ trigger eff.	Correlated across ggH, $V(qq')$ H and qqH searches				
Electron trigger eff.	Correlated across ggH, $V(qq')$ H and qqH searches				
Theoretical une	certainties on SM backgrounds				
VV inclusive cross sec.	Correlated across ggH, $V(qq')$ H and qqH searches				
Top-quark inclusive cross sec.	Correlated across ggH, $V(qq')$ H and qqH searches				
VV acceptance	Correlated across ggH, $V(qq')$ H and qqH searches				
Top-quark acceptance	Correlated across ggH, $V(qq')$ H and qqH searches				
$Z + jets/W + jets ratio vs p_T^{miss}$	Correlated between ggH and $V(qq')$ H searches				
$Z + jets / \gamma + jets ratio vs p_T^{miss}$	Correlated between ggH and $V(qq')$ H searches				
Theoretical unc	rertainties on Higgs production				
ggH, qqH and VH inclusive cross sec. from QCD-scale	Correlated across searches				
ggH, qqH and VH inclusive cross sec. from PDF	Correlated across searches				
ggH, qqH and VH acceptance from QCD-scale	Correlated across searches				
ggH, qqH and VH acceptance from PDF	Correlated across searches				
ggH Higgs $p_{\rm T}$ -dependent unc.	Correlated between ggH and $V(qq')$ H searches				
VH EWK corrections	Correlated between $V(qq')$ H and $Z(\ell\ell)$ H searches				



Post-Fit Shape CRs





Pre-Fit Shape CRs







400 500



Events/40 GeV

Data/Pred.







Pre-Fit Shape CRs













36 fb⁻¹ (13 TeV)





Pre-Fit C&C CRs







p_T^{j2} [GeV]

Pre-Fit C&C CRs

Ω











CMS

160

 η^{j1}

 $\boldsymbol{\eta}^{j2}$

35.9 fb⁻¹ (13 TeV)

Data QCD













η^{j2}

Z tag-n-probe

single-muon



 We measure the trigger efficiency in W(μv) MC using no reference trigger (i.e. all events that pass the offline criteria) vs. using single-muon reference trigger.



• No bias due to the choice of the reference trigger observed.

• Simulated efficiencies not used as the emulation of L1 ETM trigger is not very accurate.



46

• Good agreement above 250 GeV of threshold.

Trigger Efficiency



- Inefficiency in the FB category at $\Delta \eta_{jj}$ and m_{jj} is the reflection of the inefficiency seen in the low H_T^{miss} turn-on curves.
- H_T^{miss} observable was chosen as reweighing observable since it was proven to be stable against different inefficiencies based on jet kinematics.

• To show the sensitivity of the efficiency on PU conditions, we derive the efficiency in a couple of coarse bins based on the number of reconstructed vertices.





• Small azimuthal separation $|\Delta \varphi_{jj}|$ comes from a combination between the J^P properties of the Higgs boson and the high p_T regime explored by this search.

$\mathcal{B}(H(inv.))$ vs. m_H



Signal Efficiency vs. m_H



Lepton η distribution discrepancies in CRs

- Disagreement coming from the addition of forward jets (large uncertainties).
- Cross-check: relaxing selection to a mono-jet phase space (single jet in central region), the disagreement is recovered in single-lepton CRs.

Data-MC Disagreement in Trailing Jet p_T

 Comparing shapes between LO V+jets, V+jets + weights (used in the analysis), and NLO V+jets for both Z+jets and W+jets productions, a discrepancy compared to NLO MC is expected, even though we correct the boson p_T and M_{jj} to match higher order predictions.

53

• The trend is very similar to the one observed in data.

C&C and PU Jet ID

see page 16 at this link

$\Delta \phi_{ii} \approx 3$ Region in SR

Shapes of the most relevant kinematic observables compared dividing SR data in 3 exclusive samples: Δφ_{ii} [0,0.2], Δφ_{ii} [0.2,0.5], and Δφ_{ii} [0.5,0.8].

> No spikes has been observed in the $\Delta \phi_{ii}$ [0.2,0.5].

- Jet kinematics becomes softer while lowering $\Delta \phi_{ii}$ requirement.
 - Cross-check: single-muon data events as well as Z(vv) MC confirmed that jets and H_T get softer for events with a small $\Delta \phi_{ii}$.
- Results summarised in the following set of slides [<u>VBF_data_to_data</u>].

Pre-Fit vs. Post-Fit TFs Comparison

- Pre-fit TFs compared with post-fit TFs, coming from either the CR-only fit or the CRs+SR b-only fit.
 - All the observed trends can be explained in terms of the shift observed in the nuisance parameters (details in ANs).
- Studies summarised in the following set of slides [transfer_factor_comparison].

V+jets Background Estimation

 The fractions of events for W+jets events with one lepton below the p_T threshold are found to be flat across m_{jj}, therefore normalization accounting would be applicable.

Fraction of W events

C&C Uncertainty Impact – S+B Fit

C&C Likelihood Scan

C&C Nuisance Pulls

including SR θ

Nuisance Parameters

ć	
CMS_SR_eff_e	
CMS_SR_eff_id_m	
CMS SR eff iso m	
CMS_SR_eff_tk_m	
CMS_VBFHinv_SR_qcd_norm	
CMS_VBFHinv_SR_top_norm	
CMS_VBFHinv_SR_wel_ewk_norm	
CMS_VBFHinv_SR_wel_qcd_norm	
CMS_VBFHINV_SR_WMU_eWK_norm	
CMS VBFHinv SR wtau ewk norm	
CMS_VBFHinv_SR_wtau_qcd_norm	
CMS_VBFHINV_WECR_qcd_norm	
CMS VBFHinv WECR vv norm	
CMS_VBFHinv_WECR_wel_ewk_norm	
CMS_VBFHinv_WECR_wel_qcd_norm	
CMS_VBFHINV_WECR_wtau_ewk_norm	
CMS_VBFHinv_WMCR_qcd_norm	
CMS_VBFHinv_WMCR_top_norm	
CMS_VBFHinv_WMCR_vv_norm	
CMS_VBFHinv_WMCR_wmu_acd_norm	
CMS_VBFHinv_ZEECR_top_norm	
CMS_VBFHinv_ZEECR_vv_norm	
CMS_VBFHINV_ZEECR_wei_qcd_norm	
CMS VBFHiny ZMMCR vv norm	
CMS_VBFHinv_ZMMCR_wmu_ewk_norm	
CMS_VBFHINV_ZMMCR_wmu_qcd_norm	
CMS VBFHinv gaH norm	
CMS_VBFHinv_puweight	
CMS_VBFHinv_qcd_extrap	
CMS_VBFHinv_qqH_norm	
CMS_VBFHinv_top_xsunc	
CMS_VBFHinv_trigweight	
CMS_VBFHINV_VV_XSUNC	
CMS_VBFHinv_zee_qcd_norm	
CMS_VBFHinv_zmumu_ewk_norm	
CMS_VBFHinv_zmumu_qcd_norm	
CMS_VBFHinv_2VV_ewk_norm	
CMS_WZEWK_ratio_from_theory	
CMS_WZQCD_ratio_trom_theory	
CMS_blag_j CMS_eff_e	
CMS_eff_gsf	
CMS_eff_id_m	
CMS_eff_iso_m CMS_eff_tk_m	
CMS_scale_j	
CMS_tauveto_unc	σ τα ου
QCDscale_YH4_ggH	
QCDscale gqH2in	································
QCDscale_qqH	
UEPS	
Lumi 13TeV	
pdf_accept_qqbar	
pdf_gg	
pat_qqbar	

masking SR θ

Nuisance Parameters

CMS SR eff gst CMS SR eff jsd CMS VBFHinv SR vd norm CMS VBFHinv VECR vd norm CMS VBFHinv WECR vn norm CMS VBFHinv VMCR qd norm CMS VBFHinv VMCR vn norm CMS VBFHinv VMCR vn norm CMS VBFHinv VMCR vn norm CMS VBFHinv ZMCR vn norm CMS VBFHIN vn norm vn norm CMS VBFHIN vm norm vn norm CMS VBFHIN VN NOR vn norm CMS VBFHIN vm norm vn	d	ົ້	Ň	7	c	<u> </u>		N	ω
CMS_SR_eff_dm CMS_SR_eff_km CMS_SR_eff_km CMS_VBFHinv_SR_ev_ev_norm CMS_VBFHinv_SR_wel_evk_norm CMS_VBFHinv_SR_wel_evk_norm CMS_VBFHinv_SR_wel_evk_norm CMS_VBFHinv_SR_wel_evk_norm CMS_VBFHinv_SR_wel_evk_norm CMS_VBFHinv_WECR_vel_evk_norm CMS_VBFHinv_WECR_vel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WECR_wel_evk_norm CMS_VBFHinv_WCR_wel_evk_norm CMS_VBFHinv_WCR_wel_evk_norm CMS_VBFHinv_WCR_wel_evk_norm CMS_VBFHinv_WCR_wel_evk_norm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_evn_orm CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHinv_ZECR_N_N_F CMS_VBFHINV_ZECR_N_N_F CMS_VBFH	CMS_SR_eff_e						111		
CMS_SR eff iso_m CMS_SR eff iso_m CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_SR vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WECR_vcf.norm CMS_VBFHinv_WMCR_nv.norm CMS_VBFHinv_WMCR_nv.norm CMS_VBFHinv_WMCR_nv.norm CMS_VBFHinv_WMCR_nv.norm CMS_VBFHinv_WMCR_nv.norm CMS_VBFHinv_WMCR_nv.norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_no_norm CMS_VBFHinv_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM CMS_VBFHINV_ZECR_NORM	CMS_SR_eff_gsf								
CMS SH.eff.ik.m CMS VBFHinv.SR qod_norm CMS VBFHinv.SR vo_norm CMS VBFHinv.SR vo_norm CMS VBFHinv.SR wellewk.norm CMS VBFHinv.SR wellewk.norm CMS VBFHinv.SR wellewk.norm CMS VBFHinv.VR volter	CMS_SR_eff_id_m								
CMS_VBFHinv_SR qdd_norm CMS_VBFHinv_SR vonorm CMS_VBFHinv_SR vonorm CMS_VBFHinv_SR well_qdd_norm CMS_VBFHinv_SR well_qdd_norm CMS_VBFHinv_SR well_qdd_norm CMS_VBFHinv_SR well_qdd_norm CMS_VBFHinv_WECR qdd_norm CMS_VBFHinv_WECR qdd_norm CMS_VBFHinv_WECR qdd_norm CMS_VBFHinv_WECR vonorm CMS_VBFHinv_WECR well_qdd_norm CMS_VBFHinv_WECR well_qdd_norm CMS_VBFHinv_WECR well_qdd_norm CMS_VBFHinv_WECR qdd_norm CMS_VBFHinv_WECR qdd_norm CMS_VBFHinv_WCR qd_norm CMS_VBFHinv_WCR qd_norm CMS_VBFHinv_WCR qd_norm CMS_VBFHinv_WCR qd_norm CMS_VBFHinv_WCR qd_norm CMS_VBFHinv_WCR qd_norm CMS_VBFHinv_ZECCR vv. norm CMS_VBFHinv_ZECR	CMS_SR_eff_iso_m								
CMS VBFHinv_SR top.norm CMS_VBFHinv_SR_wel_ewk.norm CMS_VBFHinv_SR_wel_ewk.norm CMS_VBFHinv_SR_wel_ewk.norm CMS_VBFHinv_SR_wel_ewk.norm CMS_VBFHinv_WECR_ucl_env.norm CMS_VBFHinv_WECR_ucl_env.norm CMS_VBFHinv_WECR_ucl_env.norm CMS_VBFHinv_WECR_wel_ewk.norm CMS_VBFHinv_WECR_wel_evk.norm CMS_VBFHinv_WECR_wel_evk.norm CMS_VBFHinv_WECR_wel_env.norm CMS_VBFHinv_WECR_wel_evk.norm CMS_VBFHinv_WECR_wel_evel_norm CMS_VBFHinv_WECR_wel_evel_norm CMS_VBFHinv_WECR_wel_evel_norm CMS_VBFHinv_WECR_wel_evel_norm CMS_VBFHinv_WECR_wel_evel_norm CMS_VBFHinv_WECR_wel_evel_norm CMS_VBFHinv_WECR_wel_evel_norm CMS_VBFHinv_WECR_wel_evel_norm CMS_VBFHinv_WMCR_top.norm CMS_VBFHinv_WMCR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS_VBFHINV_ZMMCR_top.norm CMS	CMS_SH_EII_IK_III								
CMS VBFHinv_SR_vv.norm CMS_VBFHinv_SR_wel_qd_norm CMS_VBFHinv_SR_wel_qd_norm CMS_VBFHinv_SR_wel_qd_norm CMS_VBFHinv_SR_wel_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_wel_qd_norm CMS_VBFHinv_WECR_wel_qd_norm CMS_VBFHinv_WECR_wel_qd_norm CMS_VBFHinv_WECR_wel_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WECR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_QHCR_qb_norm CMS_VBFHinv_QHCR_qb_norm CMS_VBFHinv_QHCR_vn_norm CMS_VBFHinv_QHCR_vn_norm CMS_VBFHinv_QHCR_vn_norm CMS_VBFHinv_QHCR_vn_norm CMS_VBFHinv_QHCR_vn_norm CMS_VBFHinv_QHCR_vn_norm CMS_VBFHinv_QHCR_vn_norm CMS_VBFHinv_QHCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMMCR_vn_norm CMS_VBFHinv_ZMVcR_vn_norm CMS_VBFHinv_ZMVcR_vn_norm CMS_VBFHinv_ZMVcR_vn_norm CMS_VBFHinv_ZMVcR_vn_norm CMS_VBFHinv_ZMVcR_vn_norm CMS_VBFHinv_ZMVcR_vn_norm CMS_VBFHinv_ZMVcR_vn_norm CMS_VBFHinv_ZMVcR_vn_norm CMS_VBFHinv_ZMVcR_Vn_norm CMS_VBFHinv_ZMVcR_Vn_norm CMS_VBFHinv_ZMVcR_VN_NOR CMS_VBFHinv_ZMVcR_VN_NOR CMS_VBFHINV_ZMVcR_VN_NOR CMS_VBFHINV_ZMVcR_VN_NOR CMS_VBFHINV_ZMVcR_VN_NOR CMS_VBFHINV_ZMVcR_VNR_NOR CMS_VBFHINV_ZMVcR_VNR_NOR CMS_VBFHINV_ZMVcR_VNR_NOR CMS_VBFHINV_ZMVcR_VNR_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_ZWV_QCN_NOR CMS_VBFHINV_Z	CMS_VBFHinv_SR_dcd_10111								
CMS_VBFHinv_SR_weil_ded_norm CMS_VBFHinv_SR_weil_ded_norm CMS_VBFHinv_SR_wmu_dewk_norm CMS_VBFHinv_SR_wmu_ded_norm CMS_VBFHinv_SR_wtau_ded_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_well_ded_norm CMS_VBFHinv_WECR_well_ded_norm CMS_VBFHinv_WECR_well_ded_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZMMCR_v_norm CMS_VBFHinv_ZM_dCn_norm CMS_VBFHinv_ZM_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHinv_ZW_dCn_norm CMS_VBFHINV_ZW_dCn_norm CMS_SW_ZEUCD_ratio_fon_theory CMS_VBFHINV_ZW_dCn_norm CMS_VBFHINV_ZW_dCn_norm CMS_VBFHINV_ZW_dCn_norm CMS_VBFHINV_ZW_dCn_norm CMS_VBFHINV_ZW_dCn_norm CMS_VBFHINV_ZW_dCn_n	CMS VBEHiny SB w norm		• • • • • • • •	•••••		• • • • • • • • •			
CMS_VBFHinv_SR_wml_evk_norm CMS_VBFHinv_SR_wml_evk_norm CMS_VBFHinv_SR_wtal_evk_norm CMS_VBFHinv_WECR_dd_norm CMS_VBFHinv_WECR_dd_norm CMS_VBFHinv_WECR_vel_evk_norm CMS_VBFHinv_WECR_vel_evk_norm CMS_VBFHinv_WECR_vel_evk_norm CMS_VBFHinv_WECR_dd_norm CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WMCR_vr_norm CMS_VBFHinv_WMCR_vr_norm CMS_VBFHinv_WMCR_vr_norm CMS_VBFHinv_WMCR_vr_norm CMS_VBFHinv_ZECR_vr_norm CMS_VBFHinv_ZECR_vr_norm CMS_VBFHinv_ZECR_vr_norm CMS_VBFHinv_ZECR_vr_norm CMS_VBFHinv_ZECR_vr_norm CMS_VBFHinv_ZECR_vr_norm CMS_VBFHinv_ZECR_vr_norm CMS_VBFHinv_ZECR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMMCR_vr_norm CMS_VBFHinv_ZMWCR_vr_norm CMS_VBFHinv_ZMWCR_vr_norm CMS_VBFHinv_ZMWCR_vr_norm CMS_VBFHinv_ZMWCR_vr_norm CMS_VBFHinv_ZMWCR_vr_norm CMS_VBFHinv_ZMWCR_vr_norm CMS_VBFHinv_ZMWCR_vr_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHinv_ZW_dR_norm CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV_ZW_dR_NORM CMS_VBFHINV	CMS VBEHinv SB wel ewk norm		• • • • • • • •	•••••	• • • • • • •	• • • • • • • • •			
CMS_VBFHinv_SR_wmu_gdc_norm CMS_VBFHinv_SR_wtau_gdc_norm CMS_VBFHinv_WECR_gdc_norm CMS_VBFHinv_WECR_gdc_norm CMS_VBFHinv_WECR_up_norm CMS_VBFHinv_WECR_wel_gdc_norm CMS_VBFHinv_WECR_wel_gdc_norm CMS_VBFHinv_WECR_wel_gdc_norm CMS_VBFHinv_WECR_wel_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WECR_wal_gdc_norm CMS_VBFHinv_WMCR_qdc_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_ZEECR_top_norm CMS_VBFHINV_TZECR_TOP_NORM CMS_VBFHINV_ZECR_TOP_NOR	CMS VBFHiny SR wel acd norm		• • • • • • • •						
CMS_VBFHinv_SR_wtau_ged_norm CMS_VBFHinv_SR_wtau_ged_norm CMS_VBFHinv_WECR_vel.norm CMS_VBFHinv_WECR_vel.norm CMS_VBFHinv_WECR_vel.ged_norm CMS_VBFHinv_WECR_vel.ged_norm CMS_VBFHinv_WECR_wtau_ged_norm CMS_VBFHinv_WECR_wtau_ged_norm CMS_VBFHinv_WECR_wtau_ged_norm CMS_VBFHinv_WMCR_ded_norm CMS_VBFHinv_WMCR_ded_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_ZECR_vv_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMCR_top_	CMS VBFHinv SR wmu ewk norm		• • • • • • • •						
CMS_VBFHinv_SR_wtau_gd_norm CMS_VBFHinv_WECR_gd_norm CMS_VBFHinv_WECR_top.norm CMS_VBFHinv_WECR_top.norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WMCR_top.norm CMS_VBFHinv_WMCR_top.norm CMS_VBFHinv_WMCR_wnu_ewk_norm CMS_VBFHinv_WMCR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZMMCR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZMMCR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZMMCR_top.norm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_nOrm CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VBFHIN_ZZM_QM_NORM CMS_VB	CMS_VBFHinv_SR_wmu_qcd_norm								1
CMS_VBFHinv_SR_wtau_gcd_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_ucl_norm CMS_VBFHinv_WECR_wtau_gcd_norm CMS_VBFHinv_WECR_wtau_gcd_norm CMS_VBFHinv_WCR_dcd_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_ZECR_top_norm CMS_VBFHinv_ZECR_top_norm CMS_VBFHinv_ZECR_top_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_VBFHINV_ZMMCR_top_norm CMS_V	CMS_VBFHinv_SR_wtau_ewk_norm	_							
CMS_VBFHinv_WECR_top_norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WECR_wel_ewk_norm CMS_VBFHinv_WCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_top_norm CMS_VBFHINT_ZMMCR_TOP_NORM CMS_VBFHINT_ZMMCR_TOP_NORM CMS_VBFHINT_ZMMCR_TOP_NORM CMS_VBFHINT_ZMMCR_TOP_NORM CMS_VBFHINT_ZMMCR_TOP_NORM CMS_VBFHINT_ZMMCR_TOP_NORM CMS_VBFHINT_ZMMCR_TOP_NORM CMS_VBFHINT_ZMMCR_TOP_NORM CMS_VBFHINT_ZMMCR_TOP_NOR	CMS_VBFHinv_SR_wtau_qcd_norm	· · ·		. .					
CMS_VBFHinv_WECR_vv.norm CMS_VBFHinv_WECR_vv.norm CMS_VBFHinv_WECR_wel_qdc_norm CMS_VBFHinv_WECR_wel_qdc_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_WCR_qd_norm CMS_VBFHinv_ZECR_top_norm CMS_VBFHinv_ZECR_top_norm CMS_VBFHinv_ZECR_top_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_vn_norm CMS_VBFHinv_ZMCR_N_Norm CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_N_NORM CMS_VBFHinv_ZMCR_NORM CMS_VBFHinv_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_VBFHINV_ZMCR_NORM CMS_SMS_SCIE_I	CMS_VBFHINV_WECK_dca_norm								
CMS VBFHinv_WECR_wel_ewk_norm CMS VBFHinv_WECR_wel_ewk_norm CMS VBFHinv_WECR_wel_ewk_norm CMS VBFHinv_WECR_wel_ewk_norm CMS VBFHinv_WECR_top_norm CMS VBFHinv_WMCR_up_norm CMS VBFHinv_WMCR_up_norm CMS VBFHinv_WMCR_up_norm CMS VBFHinv_WMCR_up_norm CMS VBFHinv_ZEECR_uv_norm CMS VBFHinv_ZECR_uv_norm CMS VBFHINV_ZECR_UP_NORM CMS VBFHINV_ZECR_UP_NO	CMS_VBFHIIV_WECH_IOP_IOIII						•••••		
CMS VBFHinv_WECR_WeLged_norm CMS_VBFHinv_WECR_well_ged_norm CMS_VBFHinv_WECR_well_ged_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_ZECR_top_norm CMS_VBFHINZ_ZECR_top_norm CMS_VBFH	CMS VBEHiny WECB wel ewk norm		• • • • • • • •	•••••					
CMS_VBFHinv_WECR_vtau_gdc_norm CMS_VBFHinv_WMCR_qdc_norm CMS_VBFHinv_WMCR_qdc_norm CMS_VBFHinv_WMCR_uv_norm CMS_VBFHinv_WMCR_uv_norm CMS_VBFHinv_ZEECR_uv_norm CMS_VBFHinv_ZEECR_uv_norm CMS_VBFHinv_ZEECR_uv_norm CMS_VBFHinv_ZEECR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMMCR_uv_norm CMS_VBFHinv_ZMUCR_uv_norm CMS_VBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZMUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UBFHINV_ZWUCR_UV_NORM CMS_UV_UV_NORM CM	CMS_VBFHinv_WECR_wel_acd_norm		• • • • • • • •	•••••				• • • • • • •	
CMS_VBFHinv_WMCR1 qcd_norm CMS_VBFHinv_WMCR1 qcd_norm CMS_VBFHinv_WMCR1 qcd_norm CMS_VBFHinv_WMCR1 qcd_norm CMS_VBFHinv_ZEECR1 top_norm CMS_VBFHinv_ZEECR1 top_norm CMS_VBFHinv_ZEECR1 qcd_norm CMS_VBFHinv_ZEECR1 qcd_norm CMS_VBFHinv_ZEECR1 qcd_norm CMS_VBFHinv_ZEECR1 qcd_norm CMS_VBFHinv_ZEECR1 qcd_norm CMS_VBFHinv_ZMMCR1 v_norm CMS_VBFHinv_ZMMCR1 qcd_norm CMS_VBFHinv_ZMMCR1 qcd_norm CMS_VBFHinv_ZMMCR1 qcd_norm CMS_VBFHinv_ZMMCR1 qcd_norm CMS_VBFHinv_ZMMCR1 qcd_norm CMS_VBFHinv_ZMMCR1 qcd_norm CMS_VBFHinv_ZMMCR1 qcd_norm CMS_VBFHinv_ZMMCR1 qcd_norm CMS_VBFHinv_ZMQ1 qcd_norm CMS_VBFHinv_ZMQ2 qcd_norm CMS_VBFHinv_top_revelat CMS_VBFHinv_top_revelat CMS_VBFHinv_top_revelat CMS_VBFHinv_top_revelat CMS_VBFHinv_zee_qdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CMS_VBFHINZ_ZEEQdd_norm CM	CMS VBFHinv WECB wtau ewk norm		• • • • • • • •		• • • • • • •				
CMS_VBFHinv_WMCR_qcd_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_WMCR_top_norm CMS_VBFHinv_EECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZMMCR_wm_dod_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHinv_top_top_top_top_top_top_top_top_top_top	CMS_VBFHinv_WECR_wtau_qcd_norm						•		
CMS_VBFHinv_WMCR_vv.norm CMS_VBFHinv_WMCR_vv.norm CMS_VBFHinv_ZECR_vv.norm CMS_VBFHinv_ZECR_vv.norm CMS_VBFHinv_ZECR_vv.norm CMS_VBFHinv_ZECR_vv.norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHinv_ZMMCR_wn_orm CMS_VBFHinv_ZMMCR_mvl_qd_norm CMS_VBFHinv_ZMMCR_mvl_qd_norm CMS_VBFHinv_ZMMCR_nvn_qdq_norm CMS_VBFHinv_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_VBFHINT_top_reveight CMS_TBFHINT_top_reveight CMS_TBFHINT_top_reveight CMS_TBFHINT_top_reveight CMS_TBFHINT_top_reveight CMS_TBFHINT_top_reveight CMS_TBFHINT_top_reveight CMS_TBFHINT_top_reveight CMS_TBFHINT_top_reveight	CMS_VBFHinv_WMCR_qcd_norm			_					
CMS_VBFHinv_WMCR_wm_ewk_norm CMS_VBFHinv_WMCR_wm_ewk_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEECR_top_norm CMS_VBFHinv_ZEMCR_wel_qdc_norm CMS_VBFHinv_ZMMCR_top_norm CMS_VBFHinv_ZMMCR_wmu_ewk_norm CMS_VBFHinv_ZMMCR_wmu_ewk_norm CMS_VBFHinv_ZMMCR_wmu_ewk_norm CMS_VBFHinv_ZMMCR_wmu_ewk_norm CMS_VBFHinv_2MMCR_wmu_ewk_norm CMS_VBFHinv_2MMCR_wmu_ewk_norm CMS_VBFHinv_100 = prove CMS_VBFHinv_100 = prove CMS_VBFHinv_200 = prove	CMS_VBFHinv_WMCR_top_norm								
CMS VBHinv UMCH wmL qed. norm CMS VBHinv ZBECR top.norm CMS VBHinv ZBECR v. norm CMS VBHinv ZBECR v. norm CMS VBHinv ZMMCR top.norm CMS VBHinv ZMMCR wn. qed. norm CMS VBHinv ZMMCR norm CMS VBHinv Zee qed. norm CMS ZEWK ratio from theory CMS sett get CMS get get C	CMS_VBFHinv_WMCR_vv_norm								
CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZEECR_top.norm CMS_VBFHinv_ZMMCR_top.norm CMS_VBFHinv_ZMMCR_top.norm CMS_VBFHinv_ZMMCR_top.norm CMS_VBFHinv_Und_top.norm CMS_VBFHinv_Und_top.norm CMS_VBFHinv_Und_top.norm CMS_VBFHinv_top.reveight CMS_VBFHIN_top.reveight CMS_VBFHIN_TV CMS_VBFHINT_TV_top.reveight CMS_VBFHINT_TV	CMS_VBFHinv_WMCR_wmu_ewk_norm								
CMS VBFHinv ZEECR w/ norm CMS VBFHinv ZEECR w/ norm CMS VBFHinv ZEECR w/ norm CMS VBFHinv ZMMCR top norm CMS VBFHinv ZMMCR top norm CMS VBFHinv ZMMCR wnu ewk norm CMS VBFHinv ZMMCR wnu ewk norm CMS VBFHinv 2000 cms cms cms cms cms cms cms cms cms vbFHinv qdf norm CMS VBFHinv qdf norm CMS VBFHinv top reweight CMS VBFHinv top reweight CMS VBFHinv zee qcd norm CMS vBFHinv zee qcd norm QCDscale gqHz norm QCDscale qqHz norm QCDscale q	CMS_VBFHIIV_WMCR_WIIU_QCU_I0III								
CMS VBFHinv ZMC 4 wei qd norm CMS VBFHinv ZMC 4 up norm CMS VBFHinv ZMMCR uv norm CMS VBFHinv ZMMCR uv norm CMS VBFHinv ZMMCR norm CMS VBFHinv ZMMCR norm CMS VBFHinv ZMMCR norm CMS VBFHinv ZMMCR norm CMS VBFHinv 2000 CMS VBFHinv top reveight CMS VBFHinv top reveight CMS VBFHinv top reveight CMS VBFHinv top reveight CMS VBFHinv zee ewk norm CMS VBFHIN zee ewk norm CMS EBFHIN zee ewk norm CMS	CMS_VBFHIIV_ZEECR_Up_I0III			•••••	• • • • • • •	• • • • • • • • •	•••••		
CMS VBFHinv_ZMMCR top_norm CMS VBFHinv_ZMMCR wmu_ewk_norm CMS VBFHinv_ZMMCR wmu_ewk_norm CMS VBFHinv_ZMMCR wmu_edg1orm CMS VBFHinv_Qd2_norm CMS VBFHinv_Qd2_norm CMS VBFHinv_qd2_norm CMS VBFHinv_qd2_extrap CMS VBFHinv_top_reweight CMS VBFHinv_trgweight CMS VBFHinv_trgweight CMS VBFHinv_trgweight CMS VBFHinv_zee_qd2_norm CMS VBFHinv_zee_ewk_norm CMS VBFHinv_zee_ewk_norm CMS VBFHinv_zee_qd2_norm CMS VBFHinv_zee_qd2_norm CMS VBFHinv_zee_dd_norm CMS vBFHinv_zw_dd_norm CMS vBFHINV_zw_dd_norm	CMS_VBFHinv_ZEECR_VV_norm		• • • • • • • •	•••••	• • • • • • •		•••••		
CMS_VBFHinv_ZMMCR, wni_ewk_norm CMS_VBFHinv_ZMMCR, wmi_ewk_norm CMS_VBFHinv_ZMMCR, wmi_ewk_norm CMS_VBFHinv_gelatingweight CMS_VBFHinv_gelatingweight CMS_VBFHinv_top reweight CMS_VBFHinv_top_reweight CMS_VBFHinv_top_suinc CMS_VBFHinv_top_suinc CMS_VBFHinv_top_weight CMS_VBFHinv_top_weight CMS_VBFHinv_top_suinc CMS_VBFHINV_top_suinc CMS_VBFHINV_top_sui	CMS VBFHinv ZMMCR top norm		•••••						
CMS_VBFHinv_ZMMCR, wmu_gdx_norm CMS_VBFHinv_ZMMCR4, wmu_gdx_norm CMS_VBFHinv_ZMMCR4, wmu_gdx_norm CMS_VBFHinv_Duweight CMS_VBFHinv_top reveight CMS_VBFHinv_top reveight CMS_VBFHinv_top reveight CMS_VBFHinv_top reveight CMS_VBFHinv_top reveight CMS_VBFHinv_top reveight CMS_VBFHinv_top reveight CMS_VBFHinv_trate_gdx_norm CMS_VBFHinv_zee_gdx_norm CMS_Secie_j CMS_eff_e CMS_eff_e CMS_eff_e CMS_eff_e CMS_eff_e CMS_eff_e CMS_eff_gdx CMS_eff_g	CMS VBFHiny ZMMCR vv norm		•••••						
CMS_VBFHinv_ZMMCR_wmu_qcd_norm CMS_VBFHinv_eletrigweight CMS_VBFHinv_eletrigweight CMS_VBFHinv_qd_extrap CMS_VBFHinv_top reweight CMS_VBFHinv_top reweight CMS_VBFHinv_trigweight CMS_VBFHinv_trigweight CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qcd_norm CMS_VBFHinv_zee_qd_norm CMS_VBFHinv_zee_qd_norm CMS_VBFHinv_zee_qd_norm CMS_dff_df_gf CMS_dff	CMS_VBFHinv_ZMMCR_wmu_ewk_norm								
CMS VBFHinv_glerityweight CMS VBFHinv_glweight CMS VBFHinv_glweight CMS VBFHinv_top reveight CMS VBFHinv_trate ewk norm CMS VBFHinv_zee ewk norm CMS VBFHinv_zee ewk norm CMS VBFHinv_top reveight CMS eff e CMS eff e	CMS_VBFHinv_ZMMCR_wmu_qcd_norm								
CMS_VBFHinv_ggH_norm CMS_VBFHinv_qgH_norm CMS_VBFHinv_top_reweight CMS_VBFHinv_top_reweight CMS_VBFHinv_top_reweight CMS_VBFHinv_trigweight CMS_VBFHinv_trigweight CMS_VBFHinv_zee_qcd_norm CMS_VBFHINV_zee_qcd_norm CMS_	CMS_VBFHinv_eletrigweight					· • · · · · · · · ·	.		
CMS_VBFHinv_gduegin CMS_VBFHinv_gduegin CMS_VBFHinv_top_reweight CMS_VBFHinv_top_sunc CMS_VBFHinv_top_weight CMS_VBFHinv_top_weight CMS_VBFHinv_top_weight CMS_VBFHinv_top_exercise CMS_VBFHINV_top_exercise CMS_VBFHINV_	CMS_VBFHINV_ggH_norm								
CMS VBFHinv_oqH_norm CMS VBFHinv_topreveight CMS_VBFHinv_trigweight CMS_VBFHinv_trigweight CMS_VBFHinv_zee_extraction CMS_VBFHINV_Zee_extraction CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_VBFHINV_ZEE CMS_	CMS VBFHinv and extran				· · · · · ·	• • • • • • • • •			
CMS VBFHinv_top_reweight CMS VBFHinv_top_xsunc CMS VBFHinv_trigweight CMS VBFHinv_trigweight CMS VBFHinv_trigweight CMS VBFHinv_zee_ewk_norm CMS VBFHinv_zee_ewk_norm CMS VBFHinv_zee_ewk_norm CMS VBFHinv_zw_ewk_norm CMS VBFHinv_zw_edd_norm CMS VBFHinv_zw_edd_norm VBFHINZ ZJets_SR_norm Iumi_13TeV pdf_accept_qdpar	CMS_VBEHinv_gdL_norm		• • • • • • • •	•••••	• • • • • • •	• • • • • • • • •			
CMS_VBFHinv_tige_vsinc CMS_VBFHinv_tige_vsinc CMS_VBFHinv_trapedevk_norm CMS_VBFHinv_zee_evk_norm CMS_VBFHinv_zee_od_norm CMS_VBFHinv_zee_od_norm CMS_VBFHinv_zee_od_norm CMS_VBFHinv_zev_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_VBFHinv_zvv_od_norm CMS_Beff_e CMS_eff_gst CMS_eff_gst CMS_eff_gst CMS_eff_e CMS_eff_gdt CMS_eff_e CMS_eff_gdt CMS_	CMS VBFHinv top reweight		• • • • • • • •	•••••					
CMS VBFHinv, trigweight CMS VBFHinv, zwaunc CMS VBFHinv, zee, ewk, norm CMS VBFHinv, zee, edc, norm CMS VBFHinv, zwe, edc, norm CMS VBFHinv, zwe, ewk, norm CMS VBFHINV, zwk, ewk, norm	CMS_VBFHinv_top_xsunc						•		
CMS VBFHinv, vv xsunc CMS VBFHinv, zee, ewk, norm CMS VBFHinv, zee, ewk, norm CMS VBFHinv, zmumu, ewk, norm CMS VBFHinv, zw, edk, norm CMS VBFHINV, edk, statustor, well, statusto	CMS_VBFHinv_trigweight								
CMS_VBFHinv_zee_ewk_norm CMS_VBFHinv_zee_edc_norm CMS_VBFHinv_zee_edc_norm CMS_VBFHinv_zev_ewk_norm CMS_VBFHinv_zvv_edc_norm CMS_VBFHinv_zvv_edc_norm CMS_VBFHinv_zvv_edc_norm CMS_VBFHinv_zvv_edc_norm CMS_VBFHinv_zvv_edc_norm CMS_Beff_e CMS_eff_gsf CMS_eff_gsf CMS_eff_gsf CMS_eff_gsf CMS_eff_gsf CMS_scale_i CMS_scale_i CCMS_staugeto unc CDScale_gdf4II QCDscale_accept_gdf4II Umi_STeV pdf_accept_gdpar	CMS_VBFHinv_vv_xsunc								
CMS_VBFHINV_Zee_doc_norm CMS_VBFHinv_zmumu_ewk_norm CMS_VBFHinv_zw_ewk_norm CMS_VBFHinv_zw_ewk_norm CMS_VBFHinv_zw_ewk_norm CMS_VBFHinv_zw_ewk_norm CMS_VBFHinv_zw_ed_norm CMS_VEWK_ratio_from_theory CMS_VEWK_ratio_from_theory CMS_eff id_m CMS_eff id_m CMS_MS_MS_MS_MS_MS_	CMS_VBFHinv_zee_ewk_norm	· · ·				•	.		
CMS_VBFHinv_zmumu_qcd_norm CMS_VBFHinv_zwv_qcd_norm CMS_VBFHinv_zwv_qcd_norm CMS_VBFHinv_zwv_qcd_norm CMS_VBFHinv_zwv_qcd_norm CMS_VBFHinv_zwv_qcd_norm CMS_VBFHinv_zwv_qcd_norm CMS_tauveto CMS_eff gst CMS_eff gst CMS_eff gst CMS_eff gst CMS_eff i d CMS_eff i d CMS_eff i d CMS_eff i d CMS_scale_j CMS_stauveto unc QCDscale_gqHZin QCDscale_gqHZi	CMS_VBFHINV_zee_qcd_norm								
CMS_VBFHinz_zvv_qed_norm CMS_VBFHinz_zvv_qed_norm CMS_VBFHinz_zvv_qed_norm CMS_VZEWK_ratio_from_theory CMS_WZQCD_ratio_from_theory CMS_eff iso_m CMS_eff iso_m CMS_	CMS_VBFHINV_ZMUMU_ewk_norm								
CMS VBFHinv_zvv god_norm CMS VZEWK_ratio_from_theory CMS_WZQCD_ratio_from_theory CMS_btag_l CMS_eff_gat CMS_eff_gat CMS_eff_igat CMS_e	CMS_VBFHinv_zvv_ewk_norm		• • • • • • • •			· · · · · · · · · · · · · · · ·			
CMS_WZEWK_ratio_from_theory CMS_wZQCD_ratio_from_theory CMS_stag CMS_stag CMS_stag CMS_stag CMS_stag CMS_stag CMS_stag CMS_stag CMS_stag CMS_staggt CMS_staggt CDScale_g74_ggt QCDscale_g74	CMS_VBFHinv_zvv_acd_norm		•••••	•••••	• • • • • • •				
CMS_WZQCD_ratio_from_theory CMS targ_ CMS eff e CMS eff id_m CMS edf id_m QCDscale copt QCDscale except QCDscale except QCDscale except QCMS eff id_m QCDscale except QCDscale except QCMS eff id_m QCDscale except QCDscale except QCMS eff id_m QCDscale except QCMS eff id_m QCMS eff id_m (MIN if id_m) (MIN if id_m (MIN if id_m) (MIN if id_m) (MIN if id_m (MIN if id_m) (MIN if id	CMS WZEWK ratio from theory		•••••						
CMS_btag_j CMS_eff get CMS_eff i get CMS_eff i get CMS_eff i get CMS_eff iso_m CMS_eff is	CMS_WZQCD_ratio_from_theory			_					
CMS_eff ig CMS_eff igf CMS_eff igf CMS_eff iso m CMS eff iso m CMS eff iso m CMS eff ik m CMS tauveto unc QCDscale gqH2in QCDscale g	CMS_btag_j								
CMS_eff_gst CMS_eff_ia_m CMS_eff_is_m CMS_eff_is_m CMS_scale_j CMS eff_is_m CMS_scale_i CMS_eff_is_m CMS_scale_i CMS_stauveto unc QCDscale_vCP4_ggH QCDscale_ggHzin	_CMS_eff_e					•			
CMS eff iso_m CMS eff iso_m CMS eff iso_m CMS set iso	CMS_ett_gst								
CMS eff 10 m CMS eff 10 m CMS scale_j CMS tauveto unc CCDscale_VR4_ggH QCDscale_gqH2in QCDscale_gqH2i	CMS_eff_Id_ff	· · ·				· · · · · · · · · · · · · · · · · · ·		r	
CMS_scale_ CMS_stauveto_unc CDScale_YR4_ggq CCDscale_grH4_ggq CCDscale_gqH2in	CMS_eff_tk_m	····	• • • • • • • •						
CMS tauveto unc OCDscale Y14 ggH OCDscale accept gqH OCDscale ggH2in OCDscale ggH2in OCDscale gqH2in OCDscale gqH OCDscale gqH OCDsc	CMS scale i		• • • • • • • •					T T	
OCDscale_YIA4_ggH # 0 OCDscale_accept_qdH # 0 OCDscale_ggHzin # 0 OCDscale_ggHzin # 2 OCDscale_ggHzin # 2 OCDscale_ggHzin # 2 OCDscale_ggHzin # 2 UEPS Zlets_SR_norm Iumi_13TeV pdf_accept_qdpar	CMS tauveto unc		•••••						
QCDscale_accept_gqH 00 9 with the second	QCDscale_YR4_ggH							l tr i	<u> </u>
QCDscale_ggH2in QCDscale_ggH UEPS ZJets_SR_norm lumi_13TeV pdf_accept_gdpar pdf_gg	QCDscale_accept_qqH] 🕁 🚊	감독
UCUScale_qqH UEPS ZJets_SR_norm lumi_13TeV pdf_accepi_qqbar pdf_gg	QCDscale_ggH2in	L						1.11	₹ 74
UEPS ZJets SR nom lumi 13TeV pdf_accept_qdbar dg	QCDscale_qqH	L						E	₽
2Jets_5n_10011 lumi13FeV pdf_accept_qdbar pdf_gg	UEPS							1 -	
pdf_accept_gdpar	ZJets_SR_norm								
pdf_gg	ndf accent orbar	⊢ …		•••••				1	
	pdi_decepi_qqbdi pdf aa		•••••	•••••				1	
par_qqpar	pdf_qqbar			•••••					

	Process	Pre-fit (MC)	CR-only Fit	CRs+SR b-only Fit	s+b Fit
Double electron	Тор	3.523	3.722 ± 1.111	3.067 ± 0.974	3.714 ± 1.063
	Diboson	0.910	0.944 ± 0.548	0.899 ± 0.514	$0.944~\pm~0.530$
	QCD $W ightarrow e u + jets$	0.790	0.818 ± 0.601	0.827 ± 0.593	0.818 ± 0.435
	$EW \ Z o e e + jets$	25.060	25.004 ± 3.402	26.224 ± 3.485	24.977 \pm 3.232
	$QCD\ Z\ \rightarrow\ ee\!+\!jets$	68.280	64.752 ± 5.816	72.087 ± 5.586	64.762 ± 6.054
	Observed		104	104	104
Single electron	QCD Multijet	2.871	2.915 ± 2.949	2.992 ± 2.993	2.909 ± 3.137
	Тор	80.120	83.029 ± 15.434	71.696 ± 14.021	82.813 ± 15.513
	Diboson	15.570	16.038 ± 4.041	14.666 \pm 3.572	16.014 ± 4.208
	EW $W ightarrow e \nu + { m jets}$	256.900	259.068 ± 10.347	266.159 ± 9.528	259.184 ± 9.710
	$\texttt{QCD} \ W \ \rightarrow \ e \nu \! + \! jets$	525.600	531.129 ± 21.212	545.350 \pm 19.192	531.319 ± 20.023
	QCD $W ightarrow \mu u + ext{jets}$	0.093	0.094 ± 0.003	0.097 ± 0.003	0.094 ± 0.003
	EW $W ightarrow au u + ext{jets}$	0.673	0.676 ± 0.290	0.701 ± 0.298	0.677 ± 0.308
	QCD $W ightarrow au u + ext{jets}$	1.875	1.902 ± 0.804	1.926 ± 0.812	$1.904~\pm~0.795$
	EW $Z ightarrow l l$ +jets	2.408	2.428 ± 0.183	2.492 ± 0.183	2.430 ± 0.172
	$QCD\ Z\ \rightarrow\ ll{+}jets$	4.942	4.964 ± 0.238	5.196 ± 0.229	4.967 ± 0.249
	Observed		914	914	914
Double muon	Тор	5.479	5.307 ± 1.622	4.226 ± 1.438	5.289 ± 1.603
	Diboson	2.756	2.622 ± 1.356	2.513 ± 1.191	2.615 ± 1.321
	EW $W ightarrow \mu u + ext{jets}$	0.151	0.143 ± 0.151	0.157 ± 0.162	0.143 ± 0.150
	<code>QCD</code> $W ightarrow \mu u + ext{jets}$	0.217	0.204 ± 0.222	0.231 ± 0.244	0.203 ± 0.148
	EW $Z ightarrow \mu \mu +$ jets	34.930	32.669 ± 4.344	34.297 ± 4.492	32.630 ± 4.223
	<code>QCD</code> $Z ightarrow \mu \mu +$ jets	101.500	90.031 ± 7.882	100.533 ± 7.185	90.037 \pm 7.823
	Observed		114	114	114
Single muon	QCD Multijet	25.410	25.617 ± 20.071	24.237 ± 15.570	25.513 ± 16.718
	Тор	125.200	126.599 ± 22.478	108.745 \pm 20.585	126.291 \pm 22.410
	Diboson	23.670	23.520 ± 4.897	21.948 ± 4.627	23.496 ± 4.823
	EW $W ightarrow \mu u + ext{jets}$	421.700	415.708 \pm 15.956	427.372 \pm 13.821	415.924 \pm 14.992
	<code>QCD</code> $W ightarrow \mu u + ext{jets}$	904.400	890.997 ± 31.104	915.428 \pm 27.641	891.369 ± 30.394
	EW $Z ightarrow ll+$ jets	6.025	5.938 ± 0.292	6.159 ± 0.272	5.942 ± 0.265
	$QCD\ Z\ \rightarrow\ ll\!+\!jets$	27.250	26.800 ± 1.191	28.003 ± 1.091	26.816 ± 1.136
	Observed		1512	1512	1512

Comparison between CR-only and CRs+SR Backgrounds from B-only Fit and S+B Fit

Comparison between CR-only and CRs+SR Backgrounds from B-only Fit and S+B Fit

	Process	Pre-fit (MC)	CR-only Fit	CRs+SR b-only Fit	s+b Fit
Signal region	QCD Multijet	3.270	3.274 ± 2.658	3.375 ± 2.786	3.274 ± 2.533
	Тор	42.790	43.758 ± 9.778	39.274 ± 9.953	43.650 ± 9.744
	Diboson	19.420	19.863 ± 6.094	17.868 ± 5.633	19.825 ± 7.073
	EW $W ightarrow e u + jets$	46.630	46.315 ± 3.570	49.779 \pm 3.652	46.351 ± 3.550
	QCD $W ightarrow e u + jets$	133.300	132.393 ± 8.818	142.894 \pm 9.020	132.484 ± 9.486
	EW $W ightarrow \mu u + jets$	40.500	40.167 ± 7.922	48.113 ± 8.308	40.204 ± 7.796
	QCD $W ightarrow \mu u + ext{jets}$	215.500	213.933 ± 20.061	241.497 ± 18.540	214.086 ± 22.063
	EW $W ightarrow au u$ +jets	58.830	58.442 ± 3.964	62.748 ± 4.020	58.486 \pm 4.336
	QCD $W ightarrow au u$ +jets	152.300	151.194 ± 9.962	163.312 ± 9.896	151.291 ± 10.667
	EW $Z \rightarrow l l + jets$	0.697	0.695 ± 0.201	0.821 ± 0.217	0.695 ± 0.204
	$QCD\;Z o ll o l$	8.500	8.434 ± 1.760	9.475 ± 1.862	8.441 ± 1.751
	EW $Z ightarrow u u$ +jets	284.300	274.758 ± 33.130	302.989 ± 34.530	274.497 ± 33.215
	QCD $Z ightarrow u u +$ jets	862.500	790.886 ± 66.235	928.114 \pm 51.633	791.084 ± 71.234
	Total Background	1868.5	1784.1	2010,3	1784,4
	Observed	XXX	XXX	2053	2053
	gg Higgs (100% $B(H \rightarrow inv)$)	168.500	XXX	XXX	53.404 ± 40.043
	qq Higgs (100% $B(H \rightarrow inv)$)	682.100	XXX	XXX	214.934 \pm 88.797

Goodness Of Fit

- Running first on data on CRs and SR:
 - Best fit test statistic: 4.86766 (red line).
- Running then on 500 toy MC datasets to determine the distribution of the goodness of fit indicator:
 - mean expected limit: r < 3.37701 +/- 0.113894 @ 95%CL (500 toyMC) median expected limit: r < 2.69243 @ 95%CL (500 toyMC) 68% expected band : 1.12946 < r < 5.87749 95% expected band : 0.367177 < r < 10.4835</p>

CL_S method

- The limit is computed using the modified frequentist approach CL_s (confidence level) [2,3] based on asymptotic formulas [4,5], exploiting a simultaneous maximum likelihood fit to the signal region as well as the control regions, in which the systematic uncertainties are incorporated as nuisance parameters.
- Perform a single bin counting experiment assuming $B(H \rightarrow inv.) = 100\%$.
- CL_s statistic is used, which is the number of times more likely the signal hypothesis is than the background hypothesis.

$$CL_s = rac{P(q_\mu \geqslant q_\mu^{obs} | \mu \cdot s + b)}{P(q_\mu \geqslant q_\mu^{obs} | b)} \qquad \qquad q_\mu = -2 \ln rac{\mathcal{L}(obs | \mu \cdot s + b, \hat{ heta}_\mu)}{\mathcal{L}(obs | \hat{\mu} \cdot s + b, \hat{ heta})}$$

• Excluding signal models which are less than 5% likely to give data means to exclude everything with $CL_{S+B} < 5\%$.

Feynman diagrams for the combination of H(inv.) searches

