Cross-section measurement for the ggF, H→WW* at ATLAS

Dongshuo Du

Shandong University

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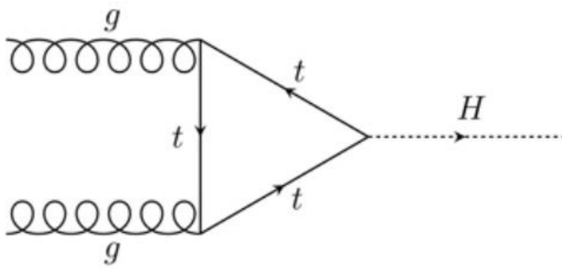
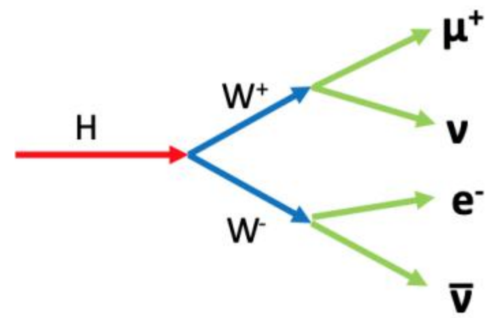
Outline

- Analysis overview
- Definition of signal regions and control regions
- Fake background estimation
- Statistical fit results
- Summary

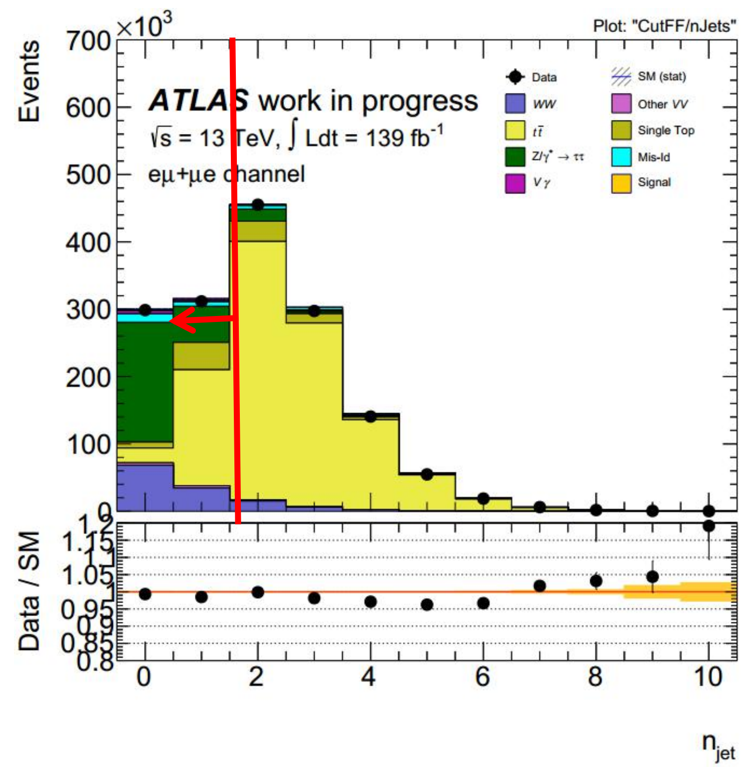
Analysis overview



ggF production

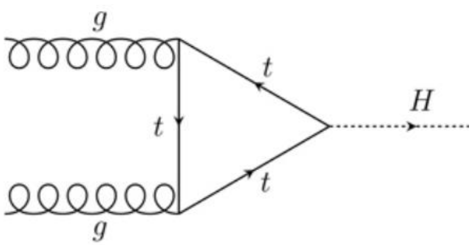


- Only select different flavour (eμ+μe) opposite charge leptons in the final states.
- Classified by the number of jets(0/1).
- Main backgrounds:
  - WW
  - NonWW diboson
  - top
  - Ztautau
  - Wjets

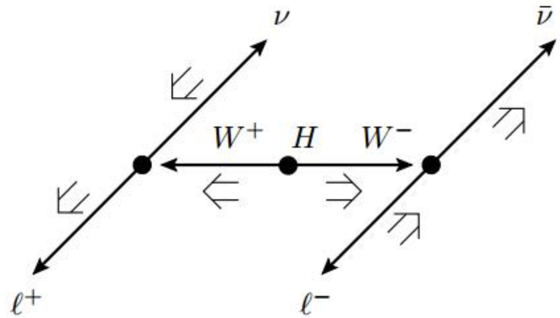


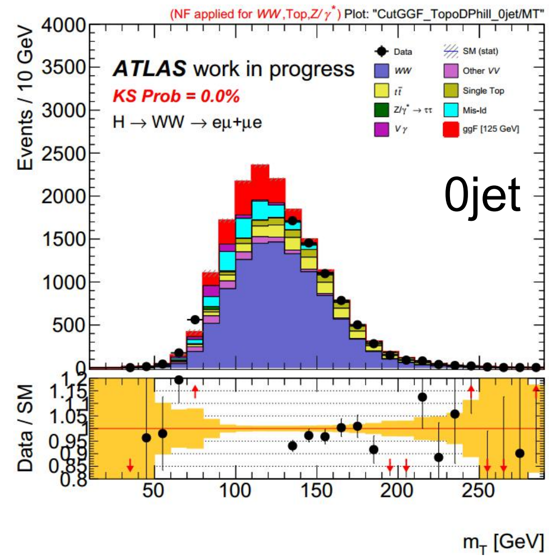
Channel	$qqWW$	Top	Z/γ^*	VV other than $qqWW$	W + jets
$N_{\text{jet}} = 0$	CR	CR	CR	MC+VR	Data
$N_{\text{jet}} = 1$	CR	CR	CR	MC+VR	Data

Signal region definition



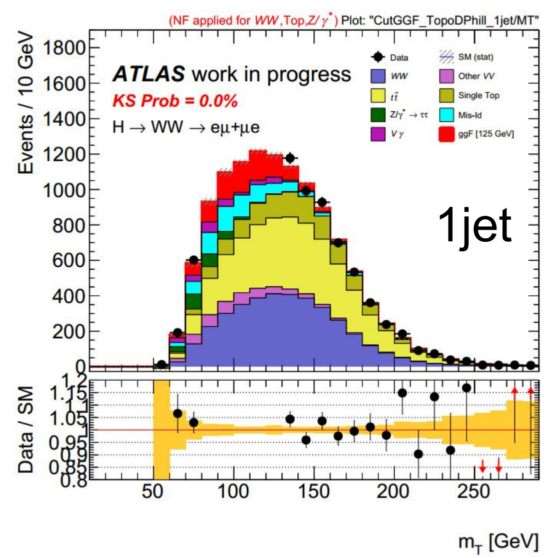
ggF production





Category	$N_{\text{jet}} = 0$	$N_{\text{jet}} = 1$
Preselection	Two isolated leptons ($\ell = e, \mu$) with opposite charge $p_T^{\text{lead}} > 22\text{GeV}$, $p_T^{\text{sublead}} > 15\text{GeV}$ $m_{\ell\ell} > 10\text{GeV}$ $E_T^{\text{miss, track}} > 20\text{GeV}$	
Background rejection	$N_{b\text{-jet}} = 0$	
	$\Delta\phi(\ell\ell, E_T^{\text{miss}}) > \pi/2$ $p_T^{\ell\ell} > 30\text{GeV}$	$\max(m_T^{\ell}) > 50\text{GeV}$ $m_{\tau\tau} < m_Z - 25\text{GeV}$
$H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$ topology	$m_{\ell\ell} < 55\text{GeV}$ $\Delta\phi_{\ell\ell} < 1.8$	

The definition of signal regions and control regions are based on the preselection

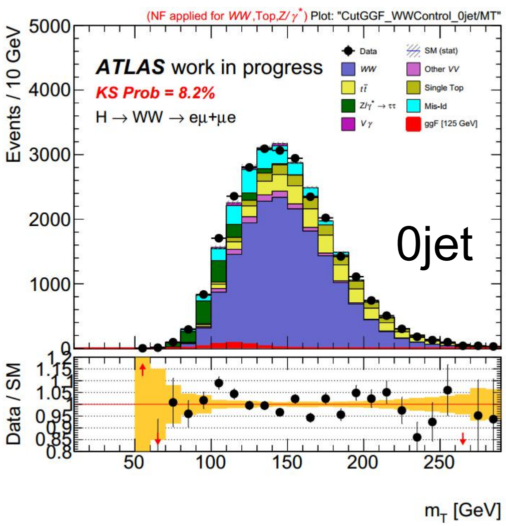


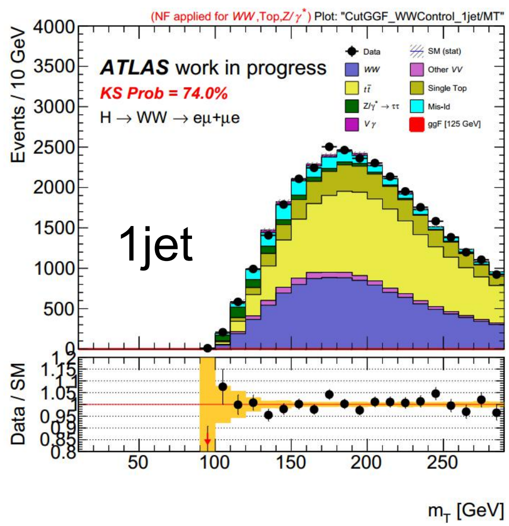
WW control region

CR	$N_{jet} = 0$	$N_{jet} = 1$
WW	$55 < m_{\ell\ell} < 110$GeV	$m_{\ell\ell} > 80$GeV
	$\Delta\phi_{\ell\ell} < 2.6$	$\lvert m_{\tau\tau} - m_Z \rvert > 25$GeV
	b-jet veto	b-jet veto
		$\max(m_T^{\ell}) > 50$GeV
top quark	$N_{b\text{-jet},(20\text{GeV}<p_T<30\text{GeV})} > 0$	$N_{b\text{-jet},(p_T>30\text{GeV})} = 1$
		$N_{b\text{-jet},(20\text{GeV}<p_T<30\text{GeV})} = 0$
	$\Delta\phi(\ell\ell, E_T^{miss}) > \pi/2$	$\max(m_T^{\ell}) > 50$GeV
	$p_T^{\ell\ell} > 30$GeV	$m_{\tau\tau} < m_Z - 25$GeV
	$\Delta\phi_{\ell\ell} < 2.8$	
$Z \to \tau\tau$	no $E_T^{miss, track}$ requirement	no $E_T^{miss, track}$ requirement
	$m_{\ell\ell} < 80$GeV	$m_{\ell\ell} < 80$GeV
	$\Delta\phi_{\ell\ell} > 2.8$	$m_{\tau\tau} > m_Z - 25$GeV
	b-jet veto	b-jet veto

The cuts are used to orthogonal to the SRs

- Purity in control region
  - 67% for 0jet
  - 34% for 1jet
- Normalization factors (*)
  - 1.10 +/- 0.01 (stat.) 0jet
  - 0.89 +/- 0.02 (stat.) 1 jet





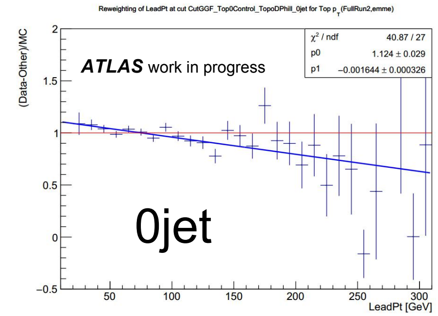
(*) NFs are calculated by using simple 3x3 matrix inversion method

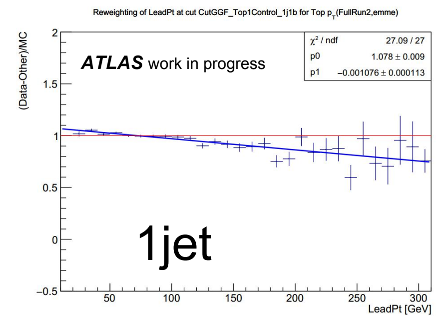
Top pt reweighting

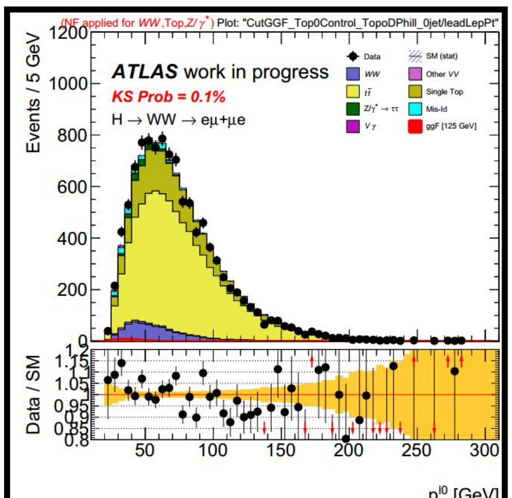
- Lepton pT mismodelling observed in top backgrounds

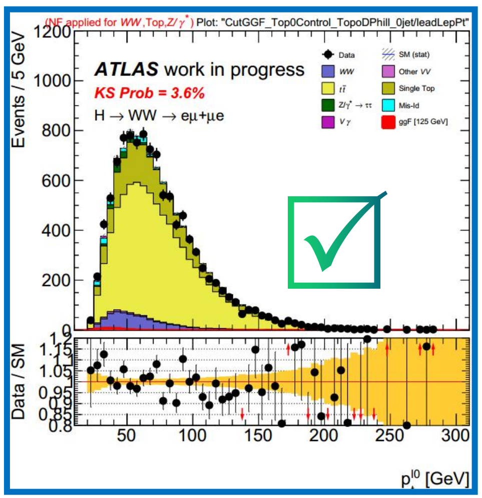
- Reweighting method:
  - Ttbar NNLO reweighting: correction from NLO QCD to NNLO
    - ✓ Used as baseline in this analysis.
  - Lepton pt reweighting: in-situ correction of leading lepton pt
    - Reweighting function:

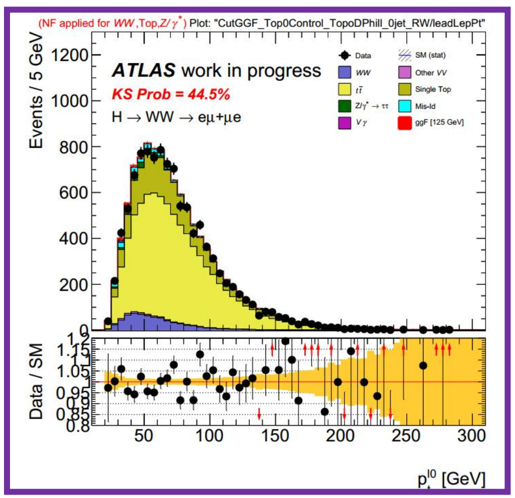
(Data - otherBkg -sig)/top





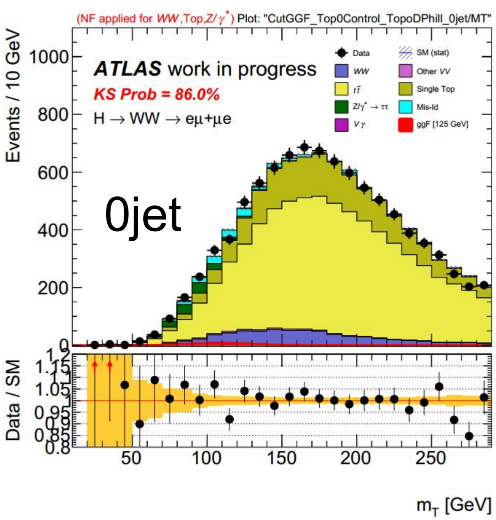


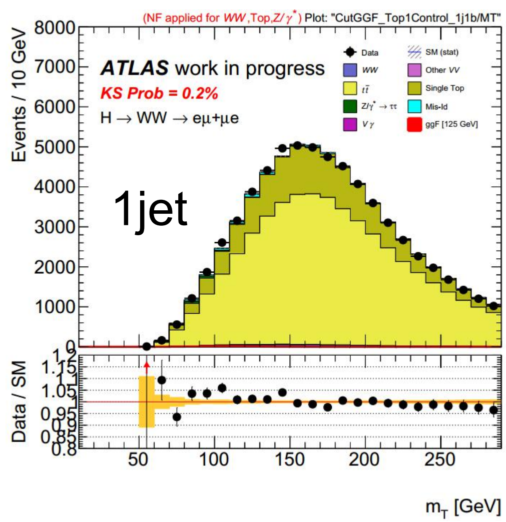




Top control region

CR	$N_{jet} = 0$	$N_{jet} = 1$
WW	$55 < m_{\ell\ell} < 110\text{GeV}$	$m_{\ell\ell} > 80\text{GeV}$
	$\Delta\phi_{\ell\ell} < 2.6$	$\lvert m_{\tau\tau} - m_Z \rvert > 25\text{GeV}$
	b-jet veto	b-jet veto
		$\max(m_T^{\ell}) > 50\text{GeV}$
top quark	$N_{b\text{-jet},(20\text{GeV}<p_T<30\text{GeV})} > 0$	$N_{b\text{-jet},(p_T>30\text{GeV})} = 1$
		$N_{b\text{-jet},(20\text{GeV}<p_T<30\text{GeV})} = 0$
	$\Delta\phi(\ell\ell, E_T^{miss}) > \pi/2$	$\max(m_T^{\ell}) > 50\text{GeV}$
	$p_T^{\ell\ell} > 30\text{GeV}$	$m_{\tau\tau} < m_Z - 25\text{GeV}$
	$\Delta\phi_{\ell\ell} < 2.8$	
$Z \to \tau\tau$	no $E_T^{miss,\,track}$ requirement	no $E_T^{miss,\,track}$ requirement
	$m_{\ell\ell} < 80\text{GeV}$	$m_{\ell\ell} < 80\text{GeV}$
	$\Delta\phi_{\ell\ell} > 2.8$	$m_{\tau\tau} > m_Z - 25\text{GeV}$
	b-jet veto	b-jet veto





□ The cuts are used to orthogonal to the SRs

➢ Purity in control region

- 89% for 0jet
- 98% for 1jet

➢ Normalization factors (*)

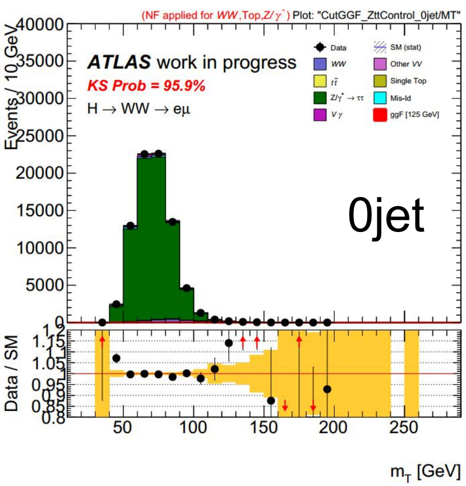
➢ 1.03 +/- 0.01 (stat.) 0jet

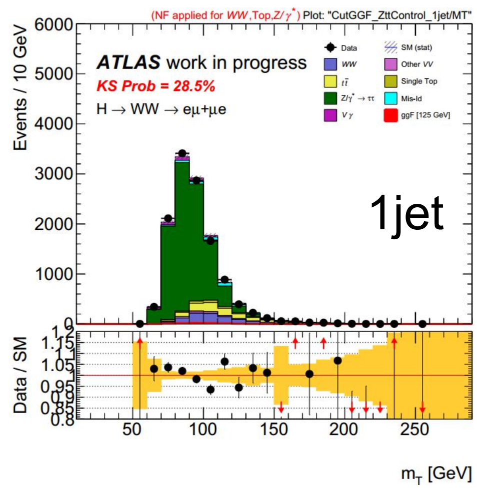
➢ 1.02 +/- 0.01 (stat.) 1 jet

(*) NFs are calculated by using simple 3x3 matrix inversion method

Z→ττ control region

CR	$N_{\text{jet}} = 0$	$N_{\text{jet}} = 1$
WW	$55 < m_{\ell\ell} < 110\text{GeV}$	$m_{\ell\ell} > 80\text{GeV}$
	$\Delta\phi_{\ell\ell} < 2.6$	$\lvert m_{\tau\tau} - m_Z \rvert > 25\text{GeV}$
	b-jet veto	b-jet veto
		$\max(m_T^{\ell}) > 50\text{GeV}$
top quark	$N_{b\text{-jet},(20\text{GeV}<p_T<30\text{GeV})} > 0$	$N_{b\text{-jet},(p_T>30\text{GeV})} = 1$
		$N_{b\text{-jet},(20\text{GeV}<p_T<30\text{GeV})} = 0$
	$\Delta\phi(\ell\ell, E_T^{\text{miss}}) > \pi/2$	$\max(m_T^{\ell}) > 50\text{GeV}$
	$p_T^{\ell\ell} > 30\text{GeV}$	$m_{\tau\tau} < m_Z - 25\text{GeV}$
	$\Delta\phi_{\ell\ell} < 2.8$	
$Z \to \tau\tau$	no $E_T^{\text{miss, track}}$ requirement	no $E_T^{\text{miss, track}}$ requirement
	$m_{\ell\ell} < 80\text{GeV}$	$m_{\ell\ell} < 80\text{GeV}$
	$\Delta\phi_{\ell\ell} > 2.8$	$m_{\tau\tau} > m_Z - 25\text{GeV}$
	b-jet veto	b-jet veto





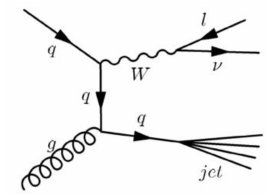
- Purity in control region
  - 94% for 0jet
  - 76% for 1jet
- Normalization factors (*)
  - 0.95 +/- 0.01 (stat.) 0jet
  - 0.90 +/- 0.01 (stat.) 1 jet

□ The cuts are used to orthogonal to the SRs

(*) NFs are calculated by using simple 3x3 matrix inversion method

W+jets: Fake factor method

- Due to poor MC modeling, W+jets background estimated in a data driven way using fake factor method.
- Three ingredients: W+jets control sample, fake factor and flavour correction.



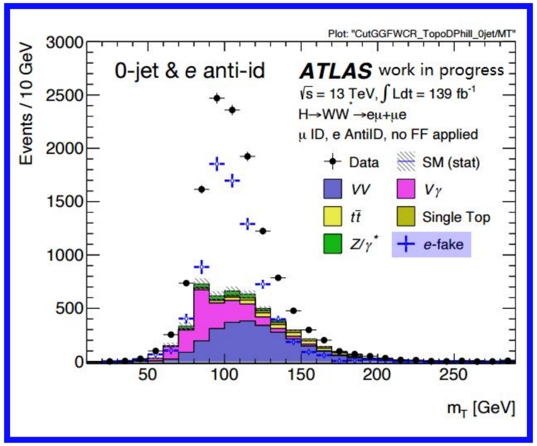
$$N^{W+\text{jets}}_{\text{id+id}} = N^{W+\text{jets}}_{\text{id+anti-id}} \times FF \times CF = (N_{\text{id+anti-id}} - N^{EW}_{\text{id+anti-id}}) \times FF \times CF$$

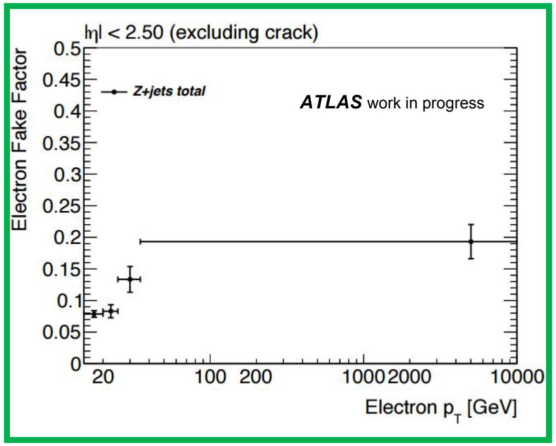
where the fake factor and the flavour correction factors defined as

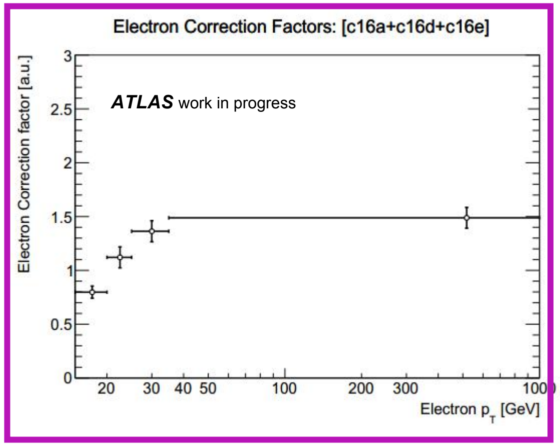
$$FF(p_T,\eta) = \frac{N_{\text{id}}(p_T,\eta)}{N_{\text{anti-id}}(p_T,\eta)}; CF = [\frac{FF(W+jets)}{FF(Z+jets)}]_{MC}$$

Electron identified	Electron anti-identified	Muon identified	Muon anti-identified
$p_T > 15$ GeV		$p_T > 15$ GeV	
$\lvert\eta\rvert < 2.47$,excluding $1.37 < \lvert\eta\rvert < 1.52$		$\lvert\eta\rvert < 2.5$	
$\lvert z_0 \sin\theta\rvert < 0.5$ mm		$\lvert z_0 \sin\theta\rvert < 0.5$ mm	
$\lvert d_0\rvert/\sigma(d_0) < 5$		$\lvert d_0\rvert/\sigma(d_0) < 3$	$\lvert d_0\rvert/\sigma(d_0) < 15$
Pass LHTight if $p_T < 25$ GeV Pass LHMedium if $p_T > 25$ GeV Pass FCTight isolation	Pass LHLoose	Pass Quality Tight Pass FCTight isolation	Pass Quality Medium
AUTHOR = 1			
	Veto against identified electron		Veto against identified muon

- ➢ Fake factor derived in Z+jets control sample with dedicated “3-lepton” selection in which 2 leptons are ”Z-tagged” and an additional “fake candidate” lepton.
- ➢ CF corrects for the different flavour compositions in W+jet(CR) and Z+jets(FF).



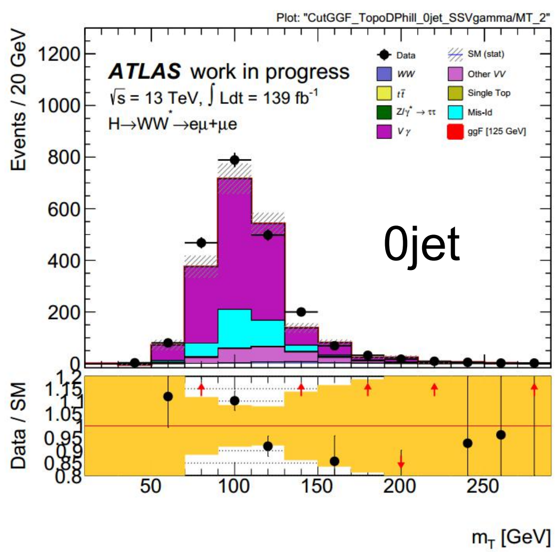


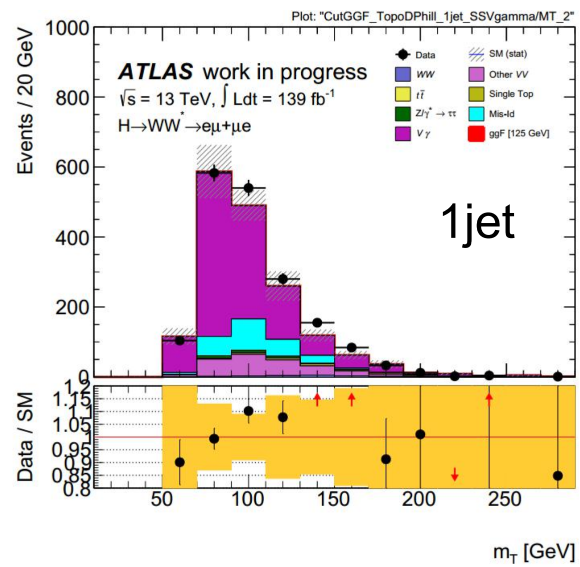


Vgamma validation region

- The definition:
  - Same definition as SR except for lepton charge(Same Sign).
  - Only single-muon trigger.
  - Release author and BLayerRequirement for electron id requirement to enrich the fakes from photons.

- Fake factors and correction factors are re-derived specific for Vgamma VR, use the same method as previous slides.





Fit setup

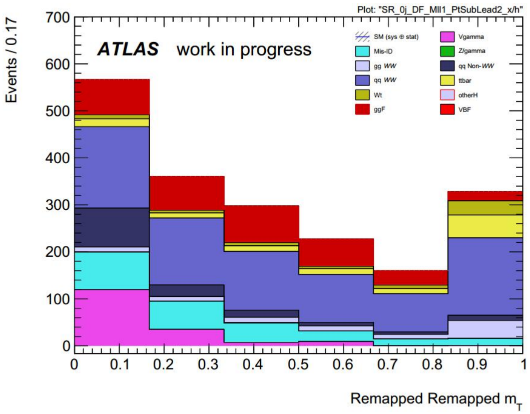
- Perform binned profile likelihood fit to extract signal strength μ_{ggF} :

$$\mathcal{L}(\mu,\boldsymbol{\theta}) = \underbrace{\prod_{i\in\text{bins}} \text{Pois}(N|\mu s_i(\boldsymbol{\theta}) + \gamma_i b_i(\boldsymbol{\theta}))}_{\text{SR bins + CRs likelihood}} \underbrace{\prod_{i\in\text{bins}} \text{Pois}(m_i|\gamma_i\tau_i)}_{\text{Constraint on MC stat. unc.}} \underbrace{\prod_{\theta\in\boldsymbol{\theta}} \text{Gaus}\left(\tilde{\theta}\middle|\theta\right)}_{\text{Constraint on syst. unc.}}$$

- mT used as discriminant variable in the final fit.
  - [80-130] GeV considered, outside as over/under-flow.

- 8 signal regions:

N_j	$m_{\ell\ell}$	p_T^{sublead}
$N_{\text{jet}} = 0$	[10-30, 30-55]	[15-20, 20-∞]
$N_{\text{jet}} = 1$	[10-30, 30-55]	[15-20, 20-∞]



- Optimize the sensitivity by re-mapping the MT distribution
  - [<90, 90–100, 100–110, 110–120, 120–130, >130] GeV for both 0 and 1jet

Systematics uncertainties

- Theory uncertainties:
  - ggF signal: ggF jet bin migration, α_s, shower
  - VBF: scale, shower, pdf, matching
  - WW: α_s, pdf, scale, QSF,CSSKIN , ckkw (truth level),ggWW scale
  - Top: Interference (Wt only), matching, shower, scale, ISR, FSR, pdf
  - Z$\tau\tau$: generator, pdf, scale, α_s

- Experimental uncertainties follow the ATLAS recommendation:
  - Trigger
  - Pileup reweighting
  - MET
  - Electron and muon related
  - Jet
  - Flavour tagging
  - Luminosity

Expected fit results

- Sensitivity：

$$\mu_{ggF} = 1.000^{+0.158}_{-0.144}$$

$$= 1.000^{+0.051}_{-0.050}(\text{Data } Stat)^{+0.047}_{-0.044}(MC\ Stat)^{+0.100}_{-0.089}(Exp)^{+0.109}_{-0.094}(Theo)$$

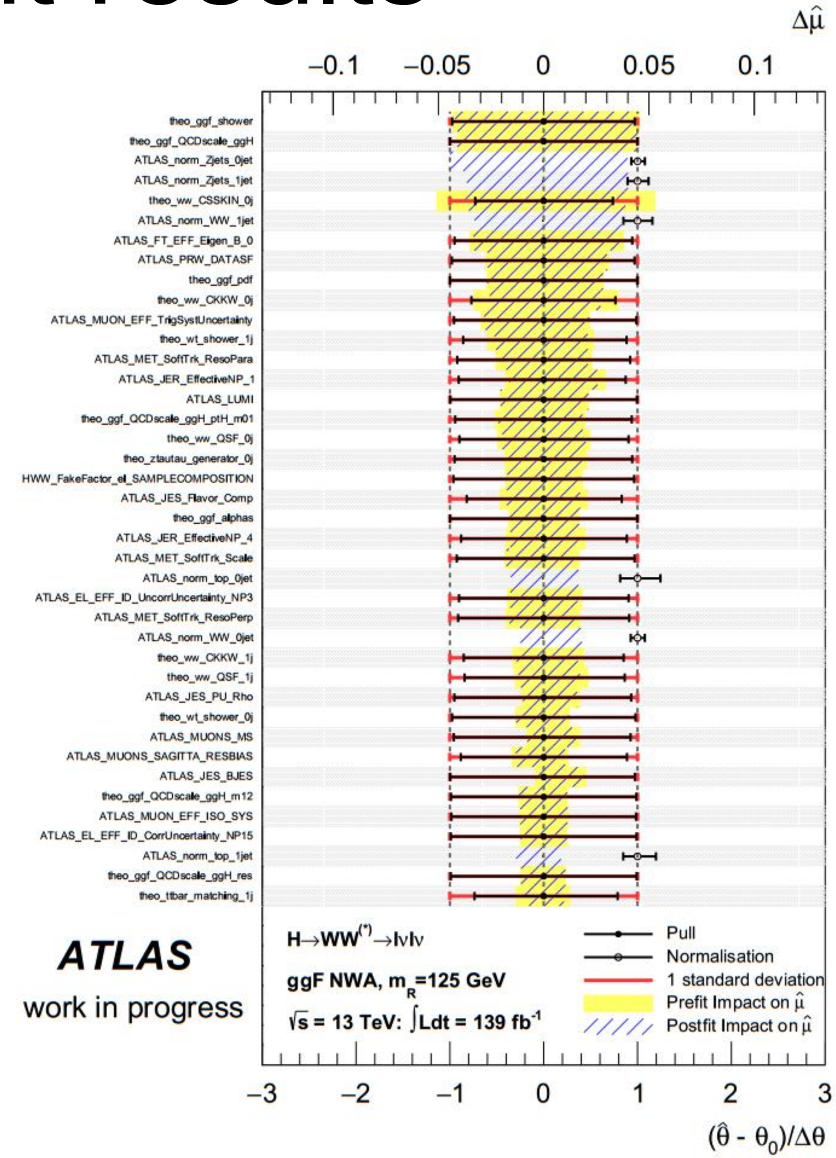
- Significance:

  8.3

- Only top 40 are shown

- No large constraints

- Use independent framework to reprodcue and validated the fit results



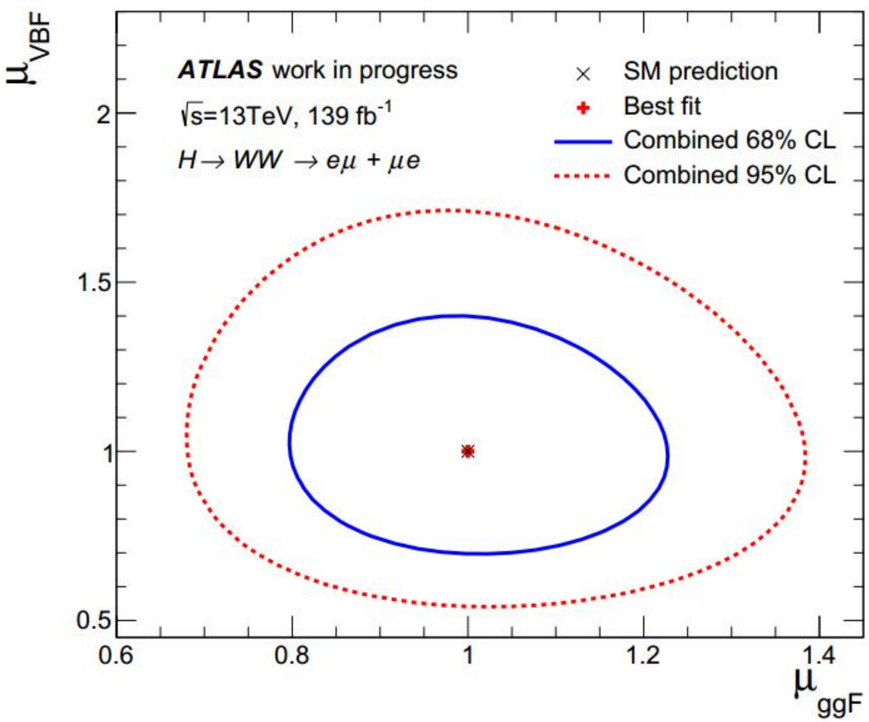
Combined fit results(ggF+VBF)

- Perform ggF + VBF combined fit.

- Expected sensitivity:

$$\mu_{ggF} = 1.000^{+0.147}_{-0.137}$$

$$\mu_{VBF} = 1.000^{+0.252}_{-0.209}$$



Summary

- Presented the full Run 2 $H \rightarrow WW^*$ analysis.
  - ggF 0/1 jet fit result:

$$\mu_{ggF} = 1.000^{+0.158}_{-0.144}$$

- ggF+VBF combined fit results:

$$\mu_{ggF} = 1.000^{+0.147}_{-0.137}$$

$$\mu_{VBF} = 1.000^{+0.252}_{-0.209}$$

- Aiming to publish before Moriond 2021.

Back-up

Event preselection

- Preselection:
  - Exactly two opposite-charge , different-flavour (e,μ) leptons.
  - $p_T^{Lead} > 22GeV, p_T^{Sublead} > 15GeV$
  - $m_{ll} > 10GeV$
  - $p_T^{miss} > 20GeV$
- The defination of Signal regions and control regions are based on the preselection

Triggers used in this analysis:

An OR combination of unprescaled single lepton and dilepton triggers.

Lepton	**Level-1 Trigger**	**High Level Trigger**
2015		
e	L1_EM20VH	HLT_e24_lhmedium_L1EM20VH
	L1_EM22VHI	HLT_e60_lhmedium
	L1_EM22VHI	HLT_e120_lhloose
μ	L1_MU15	HLT_mu20_iloose_L1MU15
	L1_MU20	HLT_mu50
$e\mu$	L1_EM15VH_MU10	HLT_e17_lhloose_mu14
2016–2018		
e	L1_EM22VHI	HLT_e26_lhtight_nod0_ivarloose
	L1_EM22VHI	HLT_e60_lhmedium_nod0
	L1_EM22VHI	HLT_e140_lhloose_nod0
μ	L1_MU20, L1_MU21	HLT_mu26_ivarmedium
	L1_MU20, L1_MU21	HLT_mu50
$e\mu$	L1_EM15VH_MU10	HLT_e17_lhloose_nod0_mu14

MC samples

Process	Generator	σ.Br(pb)	Precision $\sigma_{incl.}$
ggF $H \rightarrow WW$	POWHEG+ Pythia8	10.4	N^3LO+NNLL
VBF $H \rightarrow WW$	POWHEG+ Pythia8	0.808	NNLO
WH $H \rightarrow WW$	POWHEG +PYTHIA 8 (MINLO)	0.293	NNLO
ZH $H \rightarrow WW$	POWHEG +PYTHIA 8 (MINLO)	0.189	NNLO
inclusive $Z/\gamma^\star \rightarrow \ell\ell$ ($40 \geq m_{\ell\ell} \geq 10$GeV)	SHERPA 2.2.1	6.80×10^3	NNLO
inclusive $Z/\gamma^\star \rightarrow \ell\ell$ ($m_{\ell\ell} \geq 40$GeV)	SHERPA 2.2.1	2.107×10^3	NNLO
$(W \rightarrow \ell\nu)\gamma$	SHERPA 2.2.8	453	NLO
$(Z \rightarrow \ell\ell)\gamma$	SHERPA 2.2.8	175	NLO
$t\bar{t}$ di-leptonic(e,μ, τ)	POWHEG+Pythia8	76.96	NNLO+NNLL
Wt leptonic	POWHEG+Pythia8	6.99	NLO
$q\bar{q}/g \rightarrow WW \rightarrow \ell\nu\ell\nu$	SHERPA 2.2.2	12.5	NNLO
$qq \rightarrow WWqq \rightarrow \ell\nu\ell\nu jj$	SHERPA 2.2.2	0.095	NNLO
$Z^{(*)}Z^{(*)} \rightarrow 2\ell 2\nu$	SHERPA 2.1	6.53	NLO
$gg \rightarrow WW \rightarrow 2\ell 2\nu$	SHERPA 2.2.2	0.47	NLO
$q\bar{q}/g \rightarrow \ell\nu\ell\ell$	SHERPA 2.2.2	2.98	NNLO
$q\bar{q}/g, gg \rightarrow \ell\ell\ell\ell$	SHERPA 2.2.2	1.269	NNLO

Back

NFs calculation

(simple 3x3 matrix inversion method)

- Calculate the value of NFs:

Num_WW_ZttCR: the number of WW events in Ztt CR
Num_Top_ZttCR: the number of Top events in Ztt CR
Num_Zjet_ZttCR: the number of Zjets events in Ztt CR

Num_WW_TopCR: the number of WW events in Top CR
Num_Top_TopCR: the number of Top events in Top CR
Num_Zjet_TopCR: the number of Zjets events in Top CR

Num_WW_WWCR: the number of WW events in WW CR
Num_Top_WWCR: the number of Top events in WW CR
Num_Zjet_WWCR: the number of Zjets events in WW CR

$$\begin{pmatrix} \mathrm{Num\_WW\_ZttCR} & \mathrm{Num\_Top\_ZttCR} & \mathrm{Num\_Zjet\_ZttCR} \\ \mathrm{Num\_WW\_TopCR} & \mathrm{Num\_Top\_TopCR} & \mathrm{Num\_Zjet\_TopCR} \\ \mathrm{Num\_WW\_WWCR} & \mathrm{Num\_Top\_WWCR} & \mathrm{Num\_Zjet\_WWCR} \end{pmatrix} \times \begin{pmatrix} NF\_WW \\ NF\_Top \\ NF\_\mathrm{Zjets} \end{pmatrix} = \begin{pmatrix} \mathrm{data}\_ZttCR \\ data\_TopCR \\ data\_WWCR \end{pmatrix}$$

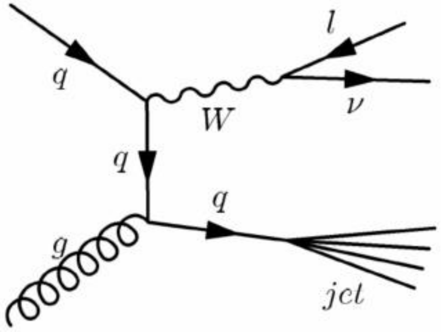
The NF for each sample can be calculated by the 3-dimensional matrix.

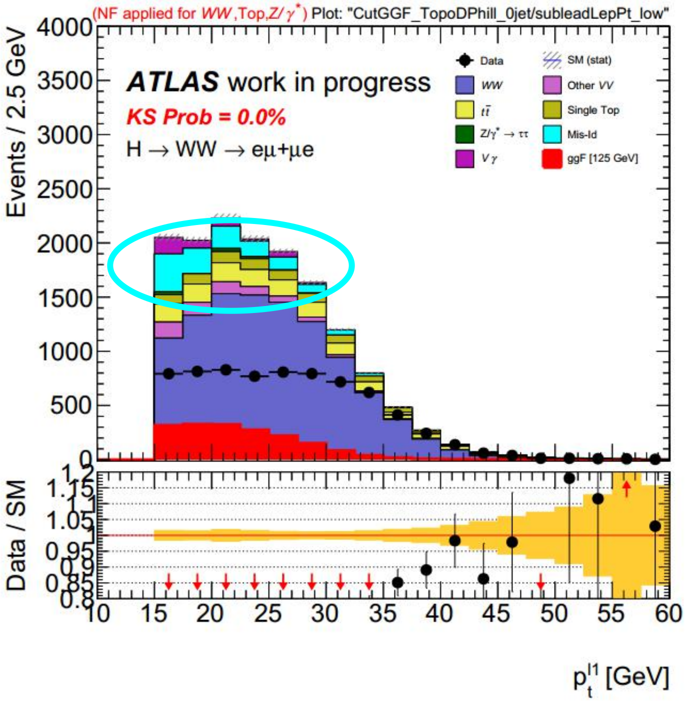
- NF uncertainties and correlations are computed by using toys.

The toy NFs are created by randomly varying input counters (data and MC) according to a gaussian distribution using the uncertainties of the input quantities.

Fake backgrounds

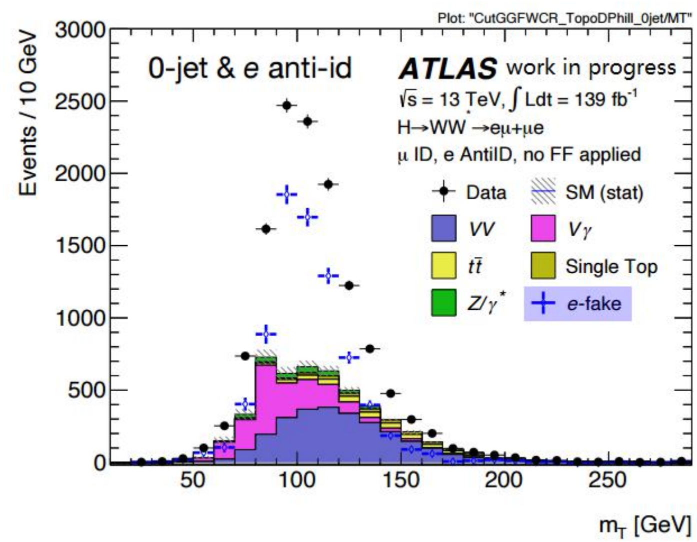
- Jets misidentified as leptons
  - ➢ Mainly come from Wjets
- Non-negligible background in the analysis
  - ➢ Mainly contributed to the low pt region
  - ➢ Hard to reduce by using kinematic selection cut
- Due to poor MC modeling, data driven fake factor method are chosen.
  - ➢ Estimate in W+jets CR where a single lepton is “anti-identified”.
  - ➢ The anti-ID events are extrapolated to the SR by fake factor.





W+jets Control region

- The defination of W+jets CR is the same as SR but with one lepton satisfing ID requirement and another satisfing a looser anti-ID requirement
  - ➢ 4 region in total(0,1×e/μ fake)



- Fake yields are determined by subtracting prompt contribution from data in Wjets CR.

- The contribution of fake in the SRs are determined by the fake yield in Wjets CR and fake factor.

Electron identified	Electron anti-identified	Muon identified	Muon anti-identified
$p_T > 15$ GeV		$p_T > 15$ GeV	
$\|\eta\| < 2.47$,excluding $1.37 < \|\eta\| < 1.52$		$\|\eta\| < 2.5$	
$\|z_0 \sin\theta\| < 0.5$ mm		$\|z_0 \sin\theta\| < 0.5$ mm	
$\|d_0\|/\sigma(d_0) < 5$		$\|d_0\|/\sigma(d_0) < 3$	$\|d_0\|/\sigma(d_0) < 15$
Pass LHTight if $p_T < 25$ GeV Pass LHMedium if $p_T > 25$ GeV Pass FCTight isolation	Pass LHLoose	Pass Quality Tight Pass FCTight isolation	Pass Quality Medium
AUTHOR = 1			
	Veto against identified electron		Veto against identified muon

$$N^{i,i}_{>0\,\text{fakes}} = F_2(N^{i,a} - N^{i,a}_{2\,\text{prompt}}) + F_1(N^{a,i} - N^{a,i}_{2\,\text{prompt}}) - F_1F_2(N^{a,a} - N^{a,a}_{2\,\text{prompt}}).$$

F_1: FF of 1st lep (e)

F_2: FF of 2nd lep (μ)

i = id, a = anti-id

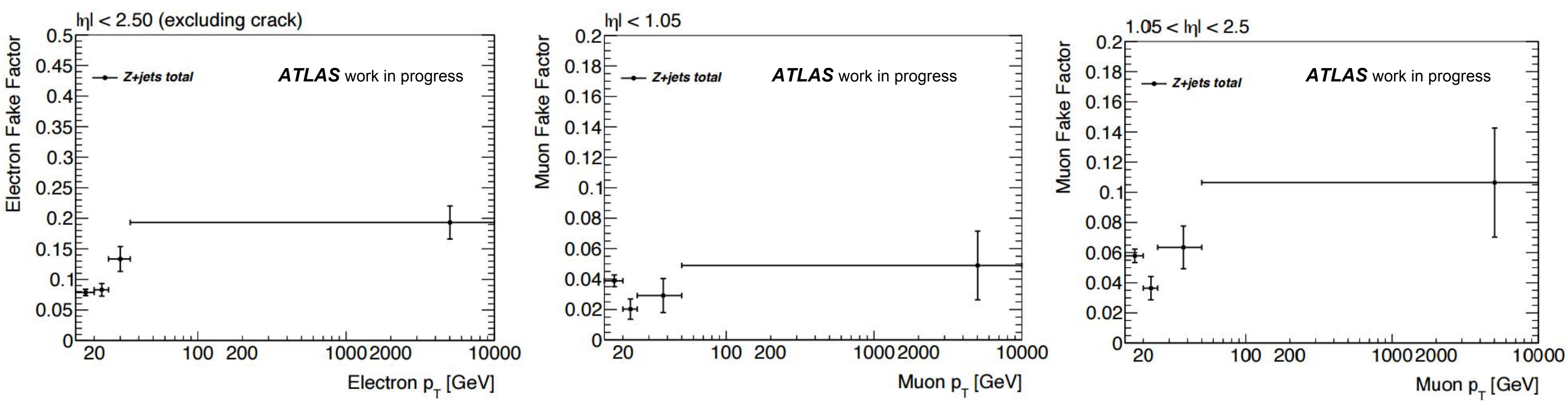
Fake factor extrapolation

- Fake factor derived in Z+jets control sample with dedicated "3-lepton" selection in which 2 leptons are "Z-tagged" and an additional "fake candidate" lepton.

$$F = \frac{N^{\mathrm{i,i,i}}_{data} - N^{\mathrm{i,i,i}}_{non-Z+jets,MC}}{N^{\mathrm{i,i,a}}_{data} - N^{\mathrm{i,i,a}}_{non-Z+jets,MC}}$$

i = ID, a = anti-ID

- Binned in η (only muons) and pT

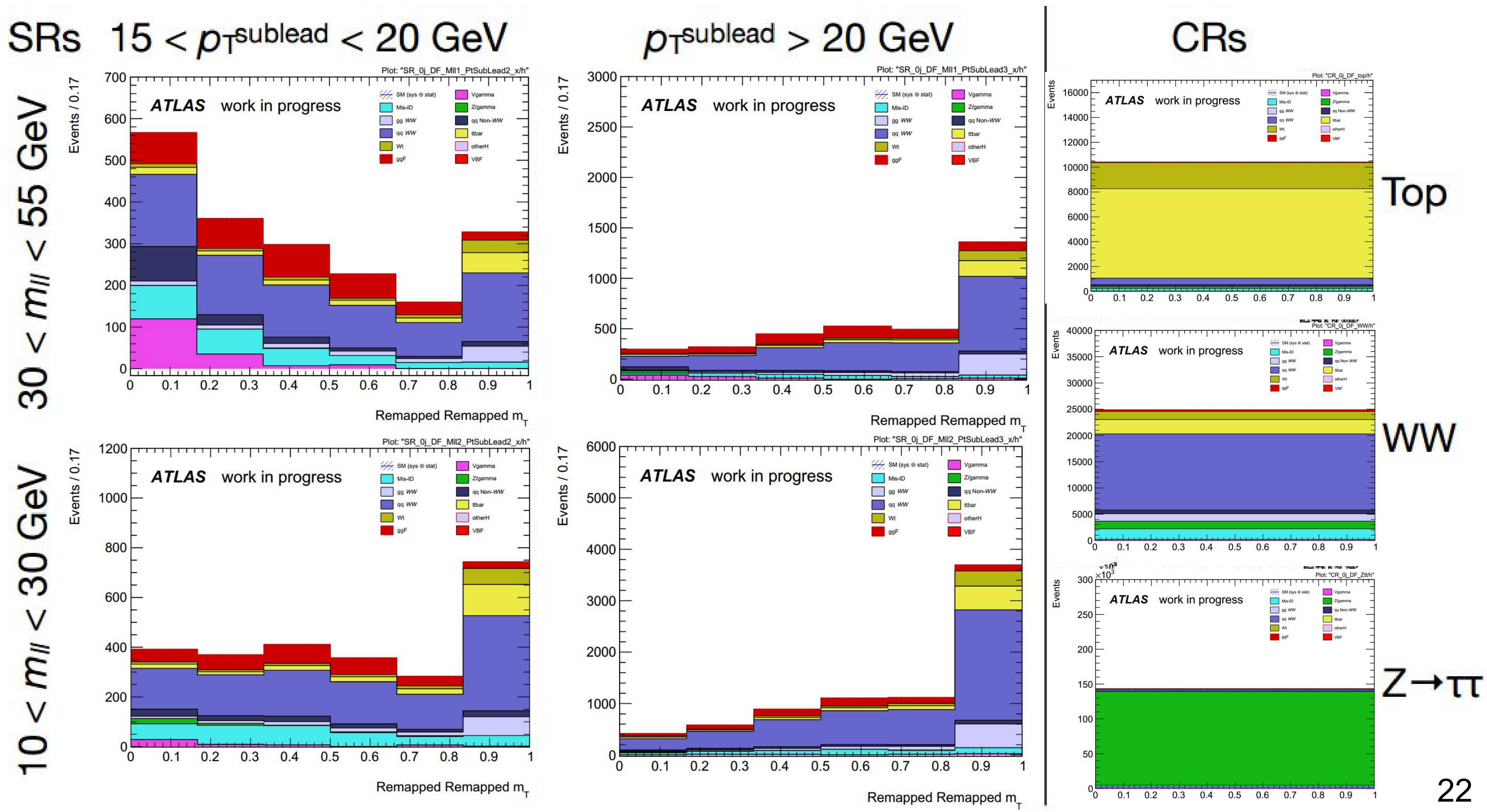


- Correction to FFs due to different flavour compositions in W+jet and Z+jets.

$$f^W = \frac{f^{W,\mathrm{MC}}}{f^{Z,\mathrm{MC}}} \times f^{Z,\mathrm{data}}$$

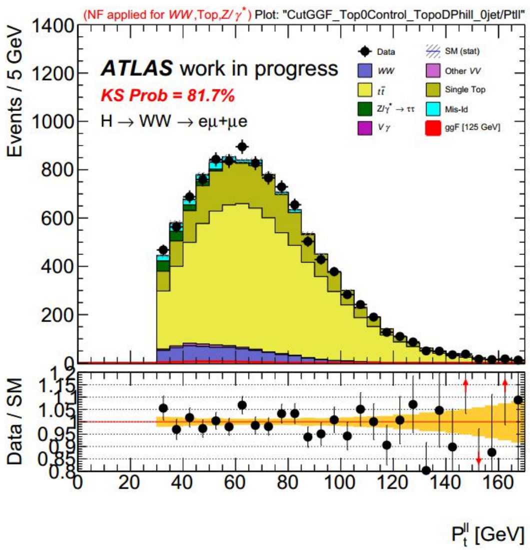
The MT distribution in 0jet SRs after remapping

	Vgamma	Mis-ID	Z/gamma	gg WW	qq Non-WW	qq WW	ttbar	Wt	ggF	VBF
CR_0j_DF_WW	226.26 ± 30.76	1983.52 ± 39.84	1444.56 ± 58.84	1417.04 ± 4.02	746.86 ± 7.98	14515.54 ± 43.67	2736.49 ± 10.71	1547.18 ± 14.80	303.14 ± 1.92	3.75 ± 0.06
CR_0j_DF_Ztt	2265.89 ± 95.21	2310.59 ± 85.72	134863.84 ± 253.03	101.39 ± 1.07	358.86 ± 3.55	2670.79 ± 18.24	169.82 ± 2.65	84.54 ± 3.44	144.44 ± 1.32	1.51 ± 0.04
CR_0j_DF_top	22.35 ± 9.81	210.43 ± 18.05	150.07 ± 8.92	73.58 ± 0.93	76.42 ± 2.27	534.48 ± 9.28	7229.43 ± 17.14	2097.28 ± 17.05	45.19 ± 0.73	1.24 ± 0.03
SR_0j_DF_Mll1_PtSubLead2_x	172.72 ± 27.97	230.39 ± 11.08	11.78 ± 8.47	90.29 ± 1.00	147.64 ± 3.18	788.17 ± 9.76	111.80 ± 2.12	64.06 ± 2.96	328.93 ± 1.97	3.39 ± 0.06
SR_0j_DF_Mll1_PtSubLead3_x	99.33 ± 21.43	168.40 ± 13.88	24.65 ± 32.29	312.65 ± 1.89	133.17 ± 3.05	1777.97 ± 15.03	272.58 ± 3.41	158.12 ± 4.70	492.66 ± 2.43	6.55 ± 0.08
SR_0j_DF_Mll2_PtSubLead2_x	53.82 ± 14.23	351.26 ± 10.45	35.26 ± 5.81	142.19 ± 1.25	124.03 ± 2.81	1205.93 ± 12.30	216.98 ± 2.97	111.40 ± 3.89	316.29 ± 1.94	3.25 ± 0.05
SR_0j_DF_Mll2_PtSubLead3_x	73.07 ± 29.87	457.54 ± 19.28	40.11 ± 5.72	663.99 ± 2.75	232.17 ± 3.93	4562.96 ± 24.14	700.98 ± 5.46	437.42 ± 7.87	642.11 ± 2.78	8.21 ± 0.09

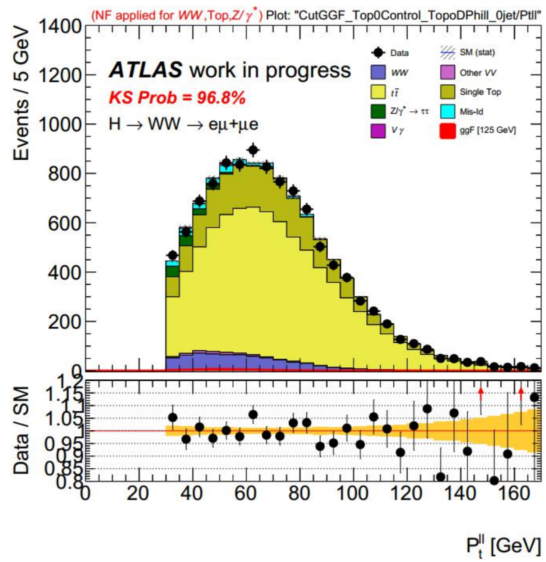


0-jet Top CR

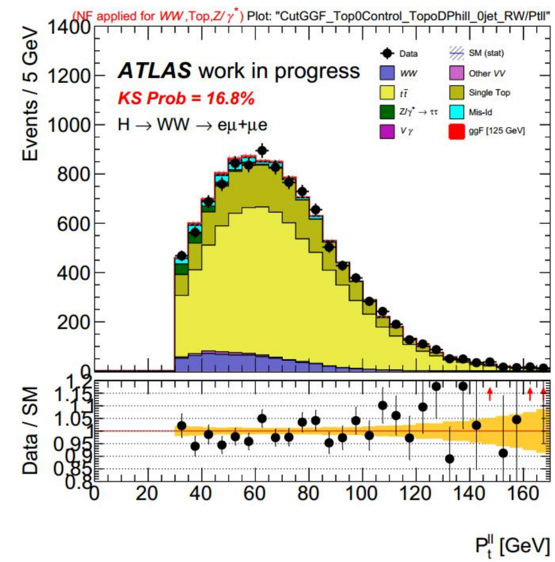
Before RW

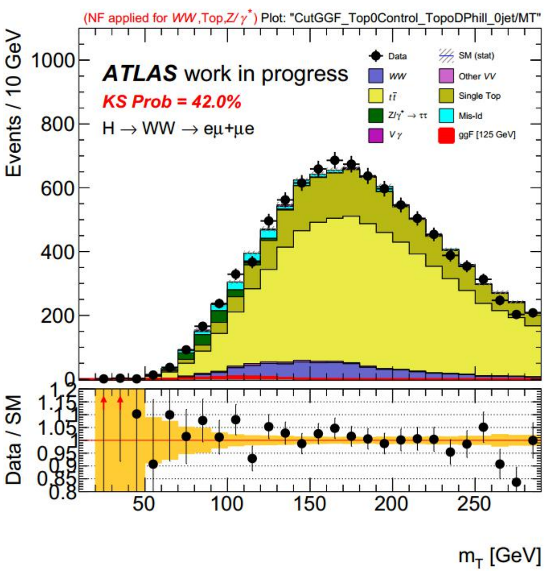


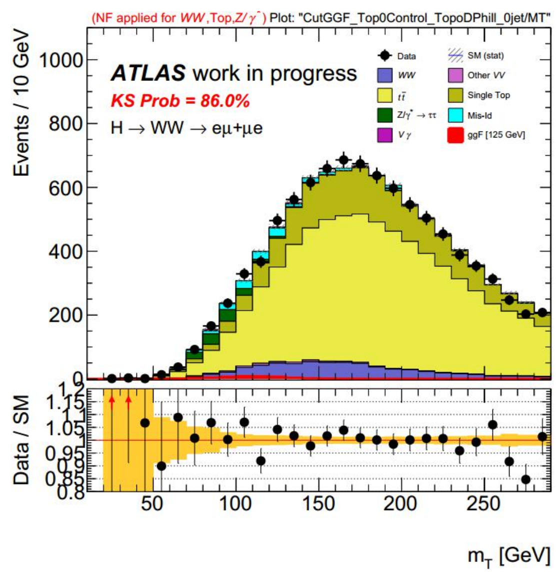
TTbar NNLO RW

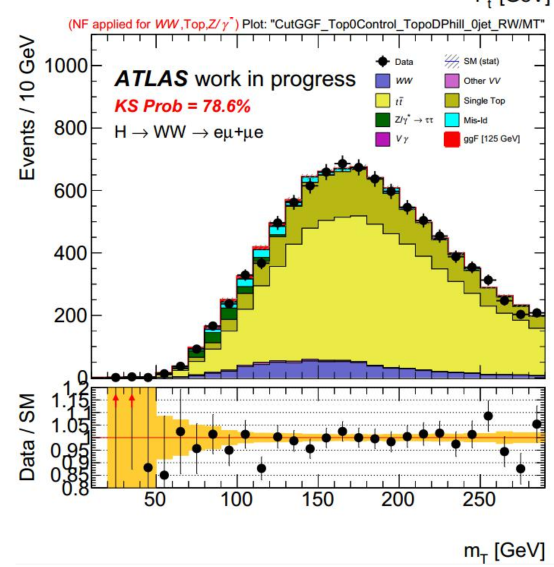


Lead Lep pt RW









Sample composition(OS Wjet vs Zjets)

Samples		Electron Flavour Composition (%)				
		Bottom	Charm	Strange	Light	Other
W + jets	ID	1.501 ± 0.379	17.244 ± 1.442	8.162 ± 0.940	66.176 ± 3.338	6.918 ± 0.870
	Anti-ID	1.501 ± 0.132	26.544 ± 0.622	13.358 ± 0.415	57.403 ± 1.010	1.193 ± 0.115
Z + jets	ID	21.141 ± 0.693	7.912 ± 0.365	7.483 ± 0.345	54.837 ± 1.139	8.627 ± 0.381
	Anti-ID	13.734 ± 0.165	12.222 ± 0.140	16.013 ± 0.159	55.991 ± 0.346	2.040 ± 0.053

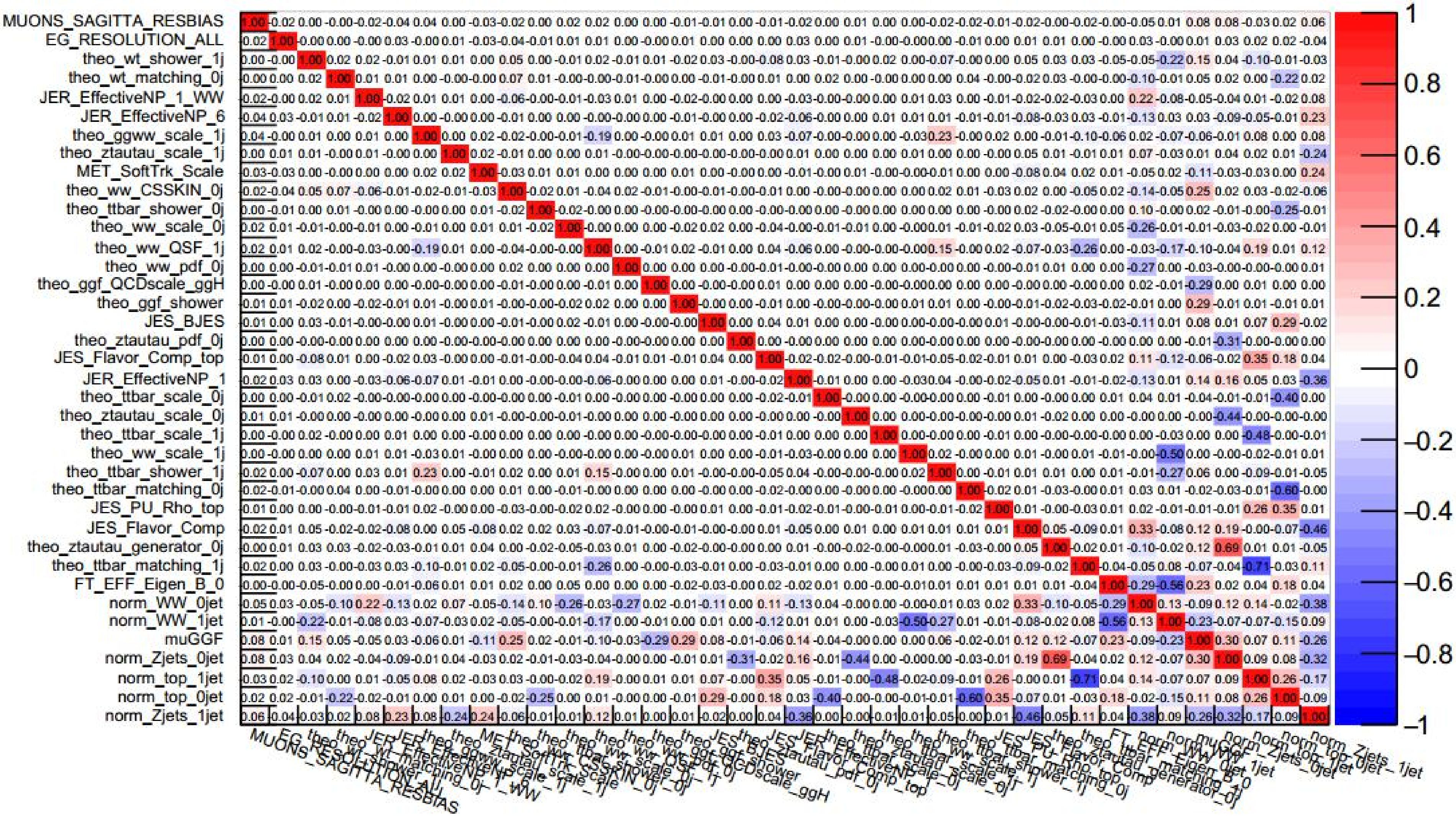
Table 19: Sample composition of fake electrons in POWHEG Z + jets and W + jets V21 samples.

Samples		Muon Flavour Composition (%)				
		Bottom	Charm	Strange	Light	Other
W + jets	ID	7.656 ± 1.243	77.599 ± 5.260	6.400 ± 1.143	5.150 ± 0.966	3.194 ± 0.791
	Anti-ID	4.905 ± 0.212	84.517 ± 1.167	5.066 ± 0.211	4.658 ± 0.207	0.854 ± 0.089
Z + jets	ID	58.686 ± 1.717	26.729 ± 0.963	4.329 ± 0.335	4.313 ± 0.333	5.943 ± 0.401
	Anti-ID	58.951 ± 0.389	31.262 ± 0.238	5.447 ± 0.086	3.586 ± 0.068	0.753 ± 0.031

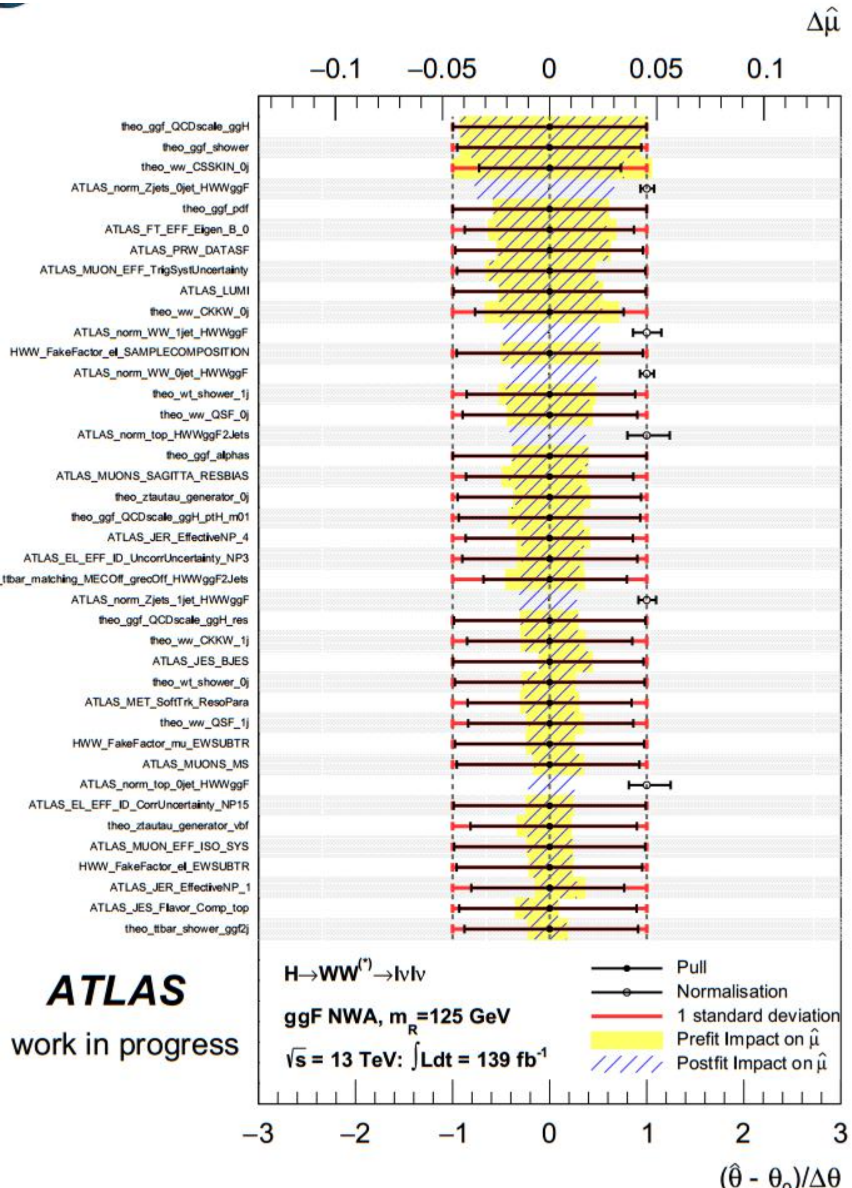
Table 20: Sample composition of fake muons in POWHEG Z + jets and W + jets V21 samples.

Correlation plot(ggF0/1)

ATLAS work in progress



Combined fit(2pois)



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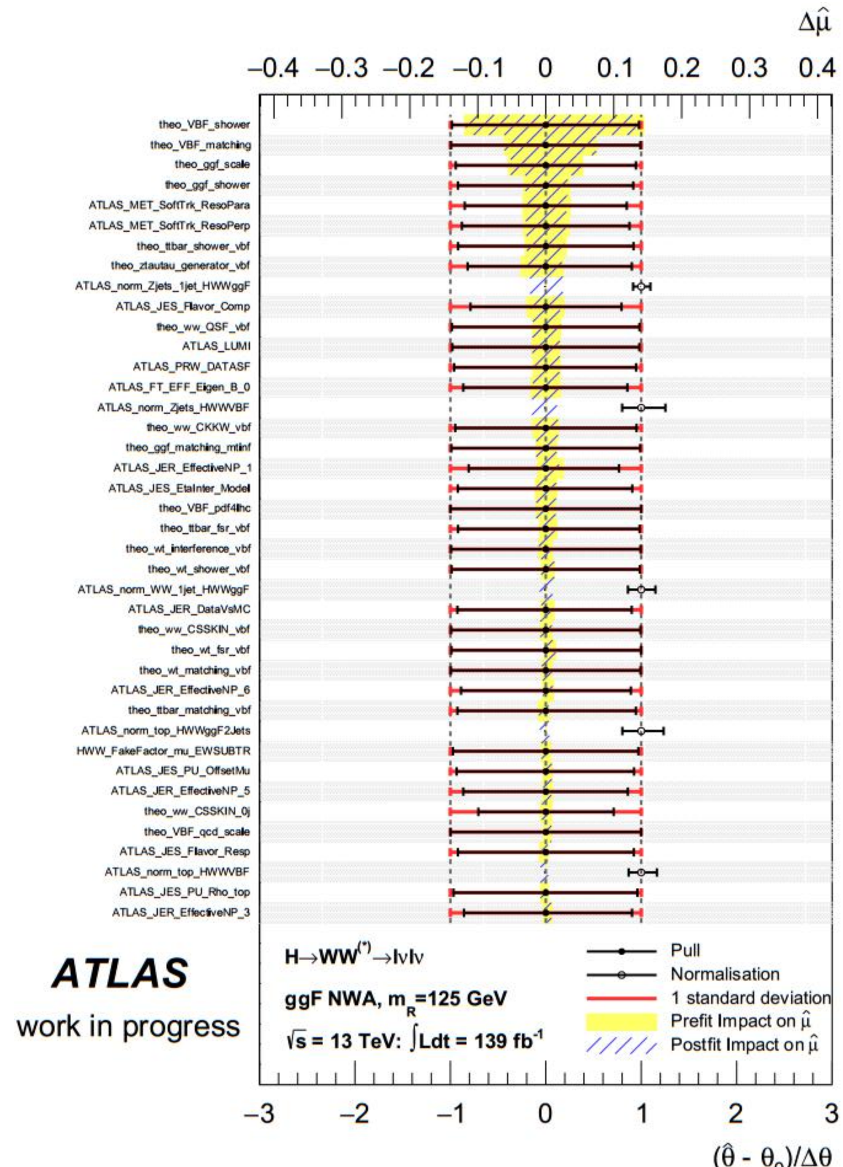

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