Final Higgs --> WW* Results

Lina Galtieri with the low P_T group

and the rest of the H-> WW group (~80 people)

Tatsuya Masubuci, Corrinne Mills, and Christian Schmitt conveners

June 13: approved for unblinding by the Higgs Group

June 27: approval of unblinded analysis by the Higgs Group

Aug 5 : closure talk of unblinded analysis at the Higgs group meeting

Aug 8: Almost final paper draft to the ED Board, updated Aug 20

Expect circulation to ATLAS by end August (I think it will be early September)

Nikhef Workshop (May 13-16/13)

Higgs Workshop: Rome April 14-18/2014

Outline

- Introduction
- HSG3 Group Activities
- Higgs->WW*-> lvlv -> 2 leptons + Etmiss

  emphasis on DF (Nj=0,1) eμ as illustration of methods used

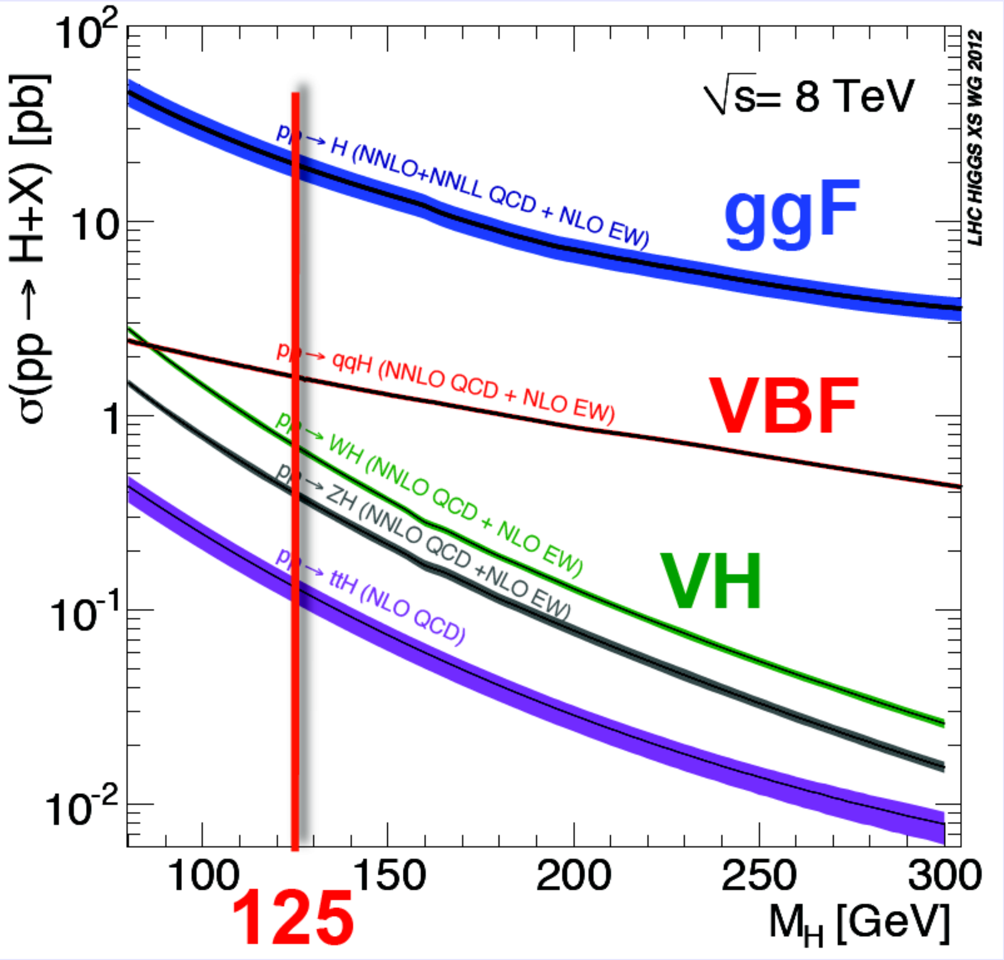
  ggF with Nj ≥ 2 and VBF not fully described

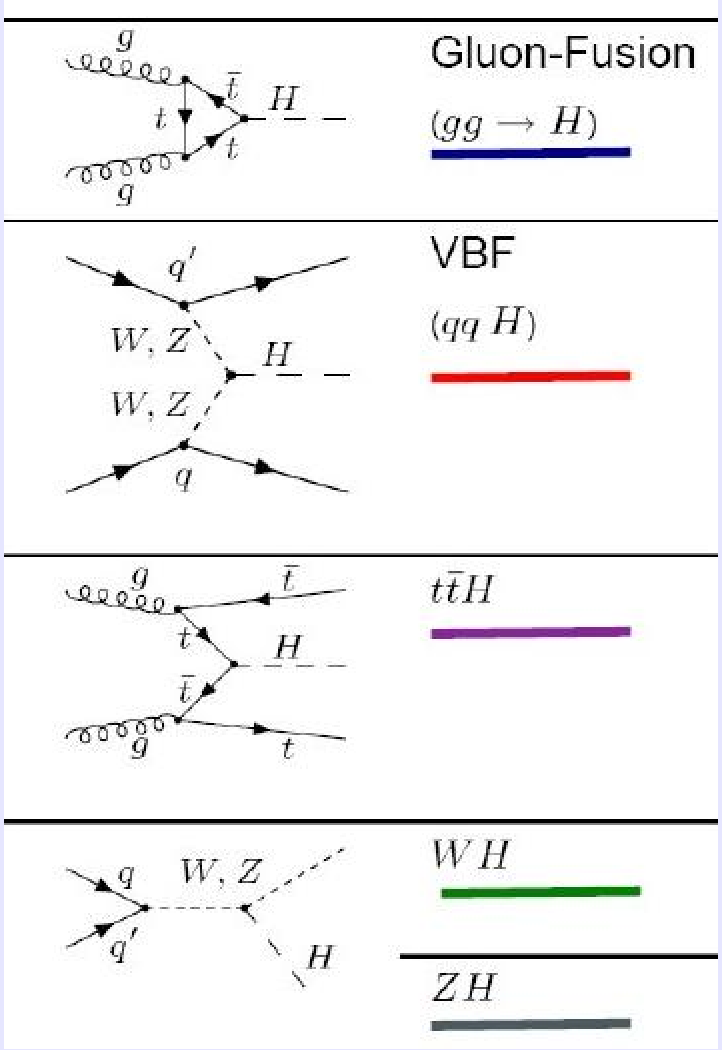
  use of 7 TeV data is also not described

  - Event Selection
  - Backgrounds
  - Modelling checks
  - Results
  - Overall Fit
- Summary

Higgs Production

H->WW group is working on ggf, VBF, VH and ttH recently





~87%

~7%

~0.5%

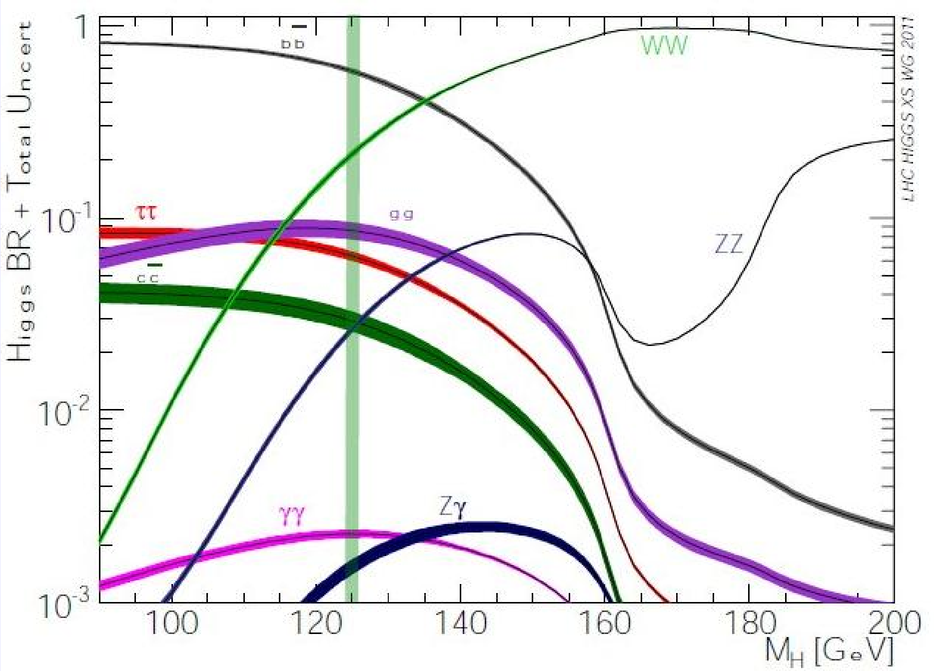
~5%

H->WW* Analyses

1. ggf: H->lvlv (0, 1 jet)
   - eμ, μe DF
   - ee, μμ SF
   - H->lvlv (≥ 2jets) NEW
   - Spin studies (H->eμ,0 j)
2. VBF: H->lvlv (2 jet)
   - eμ,μe DF,SF
   - H->invisible
3. VH: H->lvlv
   - WH and ZH
4. H->WW High Mass Higgs
   - lv lv High Mass
   - lv qq High Mass

Present paper includes: 1. and 2. above (no spin studies, no H->invisible)

BR(H->WW*) ~ 22% for MH=125



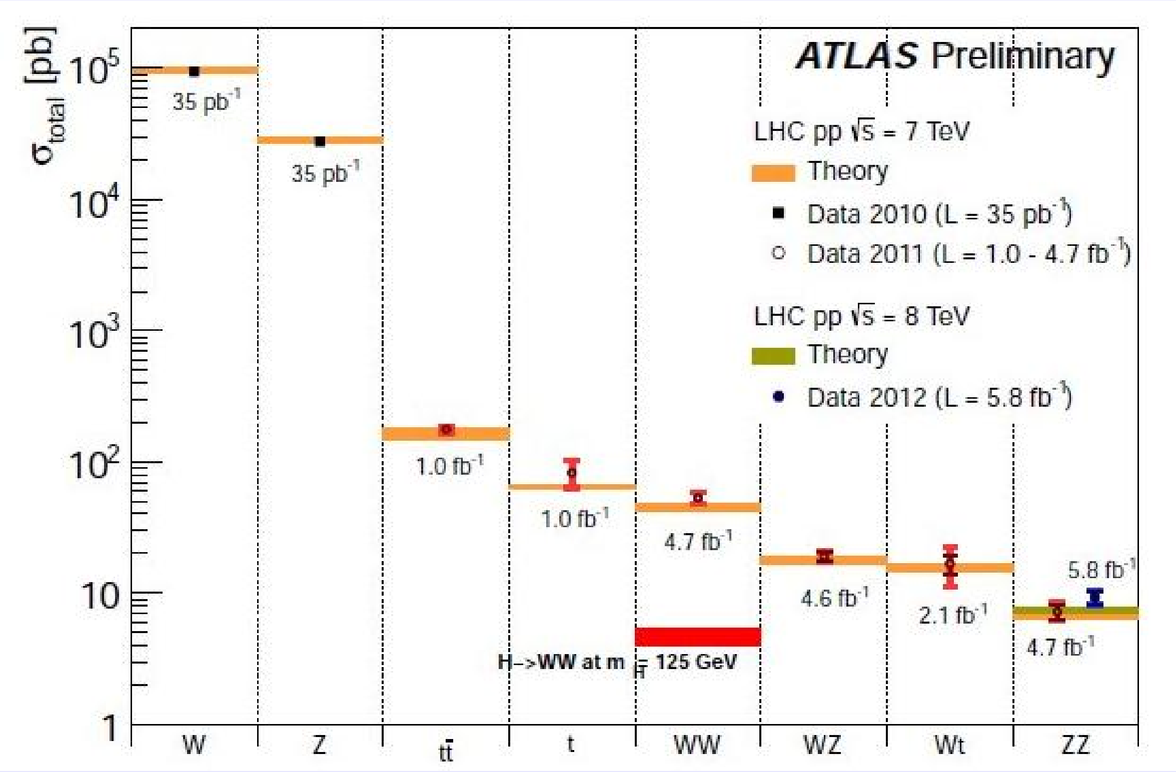
Public Results with 2012 data
Shown at Moriond QCD 2013
Included in Combination paper (May 2013)

H->lνlν: BACKGROUNDS

Background Rejection:

1. W+jets (data driven)
   Misidentified leptons:
   Lepton ID and Iso
2. Wγ and Wγ*
   Conversion veto
   Veto 3rd lepton
3. DY, Z+jets
   E_{Tmiss} > 20 GeV
4. Z-> τ τ -> eν μν
   $P_{T,ll}$ > 30 GeV
5. Top: tt and single top
   0 jet: estimated from MC+correction from data
   1 jet: b-jet veto
6. WW: (irreducible), kinematics (H is spin 0): M_{ll} < 55 GeV, $\Delta\Phi_{ll}$ < 1.8

Boson and Di-boson production at LHC



A Brief History of H->WW Analysis

Analysis started with

ggf: H->lvlv (0, 1 jet) with PT SubLead lepton > 15 GeV
PT Lead lepton > 25 GeV

2010 Simone and Lauren Tompkins from our group suggested addition of the 10-15 Gev low PT bin. They were joined by Chicago, PENN

2011 data: the low PT bin showed an excess of events over background, not seen in the rest of the data

2012 Moriond: preliminary 2012 results, low PT not included

2012 July 4: discovery paper, H--> WW included, no low PT.

2013 Moriond: again no low PT, no time for review.

2013 AMS HSG3 workshop: decided on major improvement in the analysis and on the addition of the low PT bin

2014: low PT is now an important part of the analysis

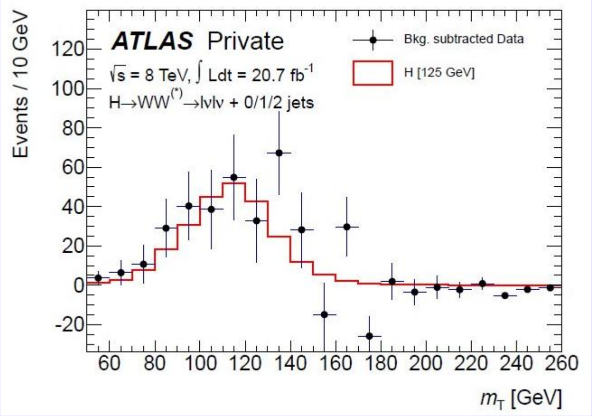
MORIOND 2013 RESULTS: H->WW*->lvlv included in the combination paper

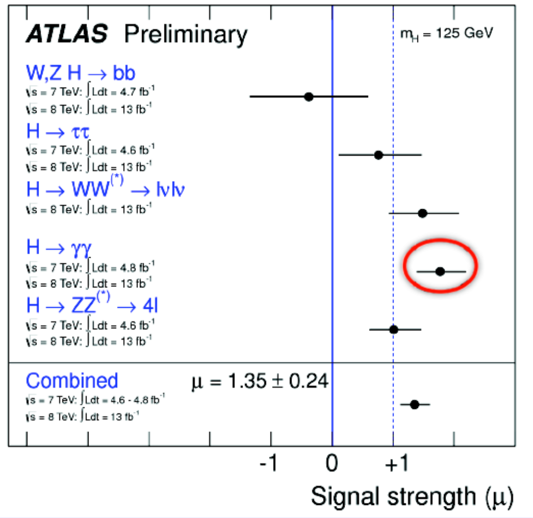
- Largest significance= 4.1 σ at M_H=140 GeV. The signal significance at 125 GeV was 3.8 standard deviation.
- Main sys contribution comes from W+jets, non-WW, $Z\tau\tau$.

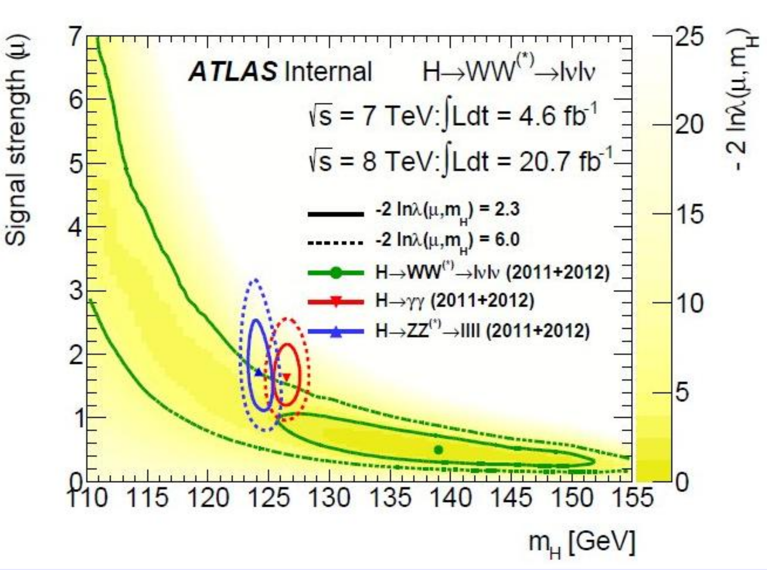
Signal strength from the plot below is μ = 1.01 ± 0.31 (stat+ sys)

combination

H-->WW







- The low P_T bin adds statistics to signal. In addition, extends the banana shaped plot to lower masses.

Moriond 2013 and Present Results

	Signal		Background		S/B	
	eμ	μe	eμ	μe	eμ	μe
Nominal	57	45	353	362	0.16	0.12
Low PT Nj=0,1	12	10	77	127	0.16	0.08
Addition (%)	21%	22%	22%	36%	0.16	0.08

Workshop at Nikhef in May 2013:

Improve the analysis to increase sensitivity.

Add Low PT, optimize object selection, optimize event selection.

Final fit 3 D: M_T (10 bins), M_{ll} (2 bins), PT sublead(3 bins)

Sample Njets=0,1	Signal		Background		S/B	
	eμ	μe	eμ	μe	eμ	μe
All PT bins	176.3	134.8	1910	1661	0.092	0.081
Low PT	34.7	22.7	403	354	0.086	0.064
Low Pt Fractions	20%	17%	21%	21%		

Table made Jan. 2014. Events before the final Higgs window cut, as for the above table

Analysis Strategy

1. Exploit the spin 0 decay properties of the Higgs Boson, to reduce Standard Model WW production
2. Optimize object selection to reduce back., optimize resolutions

3. Optimize event selection to reduce backgrounds, while keeping a reasonable sensitivity to the signal

4. Use Control Regions (CR) to determine Normalization Factors (NF) for each bkg. (details later)
   - Use validation regions (SS) to check validity of model.

5. Check SR with blinded data to verify data/MC agreement

6. Fit final WW* transverse mass (M_T) to evaluate Higgs production
   - 3D fit: MT(10), M_{ll}(2), P_T(3) (sublead lepton) for ggF, Nj=0,1

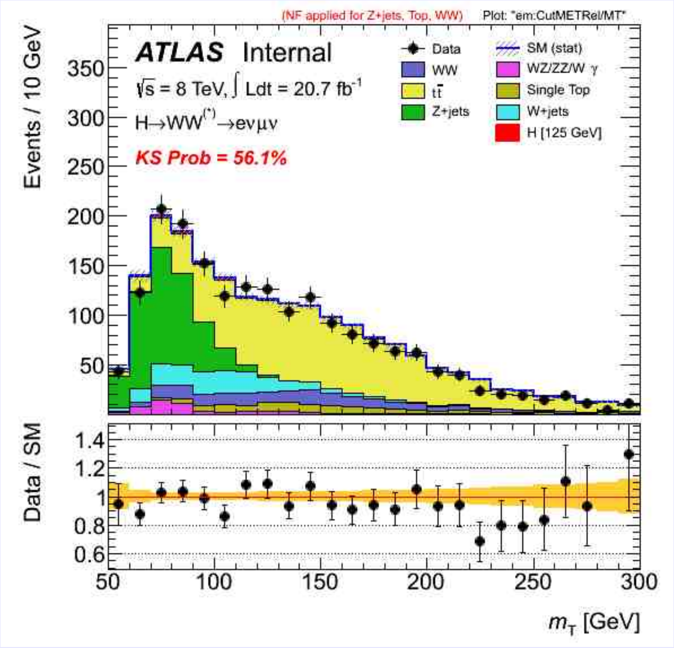
Object selection and Event Preselection

Object selection (see backup for details)

- Leading lepton PT > 22 GeV/c (it was 25 GeV/c)
- Subleading Lepton > 10 GeV/c (Low PT: adds 10-15 GeV)
- Jet P_T > 25 GeV, $|\eta|$ < 2.5, P_T > 30 GeV, $|\eta|$ = 2.5 to 4.5
- b-tagging with MV1 at 85%

Pre-selection

- Exactly two oppositely charged leptons of different flavors
- M_{ll} > 10, 12 GeV (DF, SF: reject Υ)
- E_{Track}^{miss} > 20, 40 GeV (DF, SF: reject QCD multijet,)



M_T after preselection

Event Selection and blinding

The 0 Jet Analysis

- Jet Veto
- $(\Delta\Phi_{ll,}\ E^{miss}) > \pi/2$
- $P_T^{ll} > 30$ GeV
- $M_{ll} < 55$ GeV
- $\Delta\Phi_{ll} < 1.8$

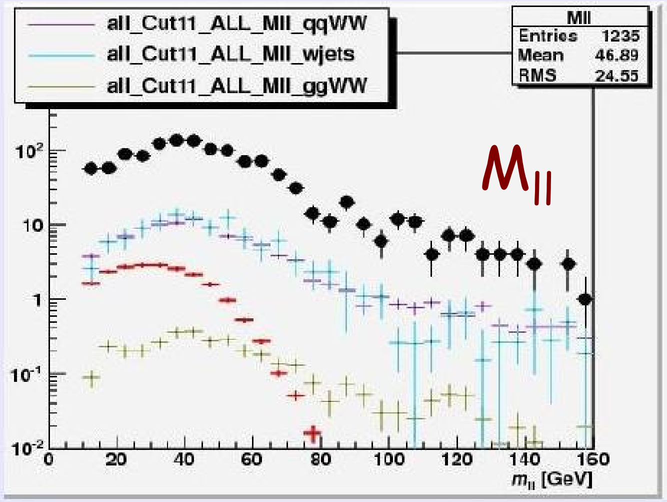
The 1 jet Analysis

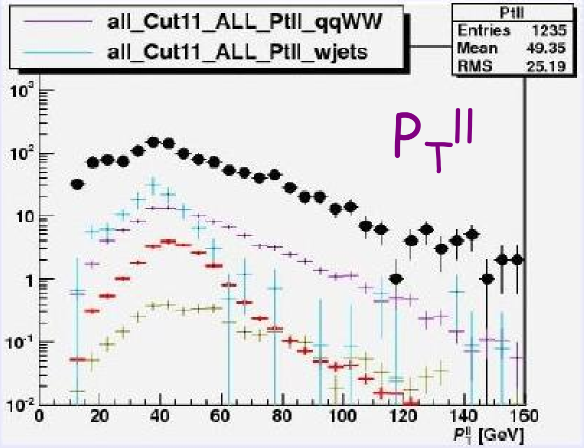
- b-jet veto
- $Z \to \tau\tau$ veto: $|m_{\tau\tau} - m_Z| > 25$ GeV
- $M_{ll} < 55$ GeV
- $\Delta\Phi_{ll} < 1.8$

0,1 Jet blinded if passing all of:

- The pre-selection
- b-jet veto
- $M_{ll} < 55$ GeV
- $\Delta\Phi_{ll} < 1.8$
- $82.5 < M_T < 140$ GeV

$$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{miss})^2 - |\mathbf{p}_T^{\ell\ell} + \mathbf{E}_T^{miss}|^2}$$





LowpT Excess in H->WW Search. 05/07/12, Lina Galtieri

Signal and background Kinematics ?? add comments

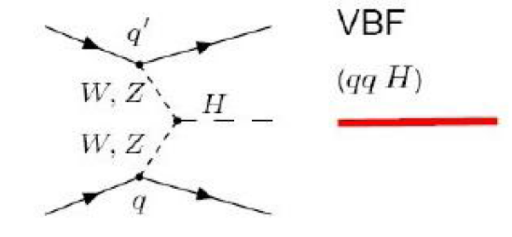
Cuts for ggf ≥ 2jets and VBF

- ggF Nj ≥ 2 event selection

$e\mu$ category
$n_b = 0$
$m_{\tau\tau} < m_Z - 25$
VBF orthogonality
VH orthogonality
$m_{\ell\ell} < 55$
$\Delta\phi_{\ell,\ell} < 1.8\,\mathrm{rad}$
$\frac{3}{4}\, m_H < m_T < m_H$

- VBF orthogonality: reverse a Cl requirement
- VH orthogonality reverse one of the VH requirement

- VBF event selection



$e\mu$ category
$n_b = 0$
$P_T^{\mathrm{sum}} < 15$
$m_{\tau\tau} < m_Z - 25$
$m_{jj} > 600$
$\Delta y_{j,j} > 3.6$
$C_{j3} > 1$
$C_{\ell_1}, C_{\ell_2} < 1$
$m_{\ell\ell}, \Delta\phi_{\ell,\ell}, m_T$
$ee/\mu\mu$ category
$n_b, P_T^{\mathrm{sum}}, m_{\tau\tau}$
$m_{jj}, \Delta y_{j,j}, C_{j3}, C_\ell$
$m_{\ell\ell}, \Delta\phi_{\ell,\ell}, m_T$

- P_t^{sum} is the vector sum of all objects in the event
- C_l stands for centrality of a given lepton with respect to the tag jets (OLV)
- C_{j3}>1 means that a third jet is outside the rapidity gap of the tag jets (CJV)

- The VBF analysis uses a BDT method to optimize signal selection. It uses 8 variable as input.
- Results are compared to cut based analysis

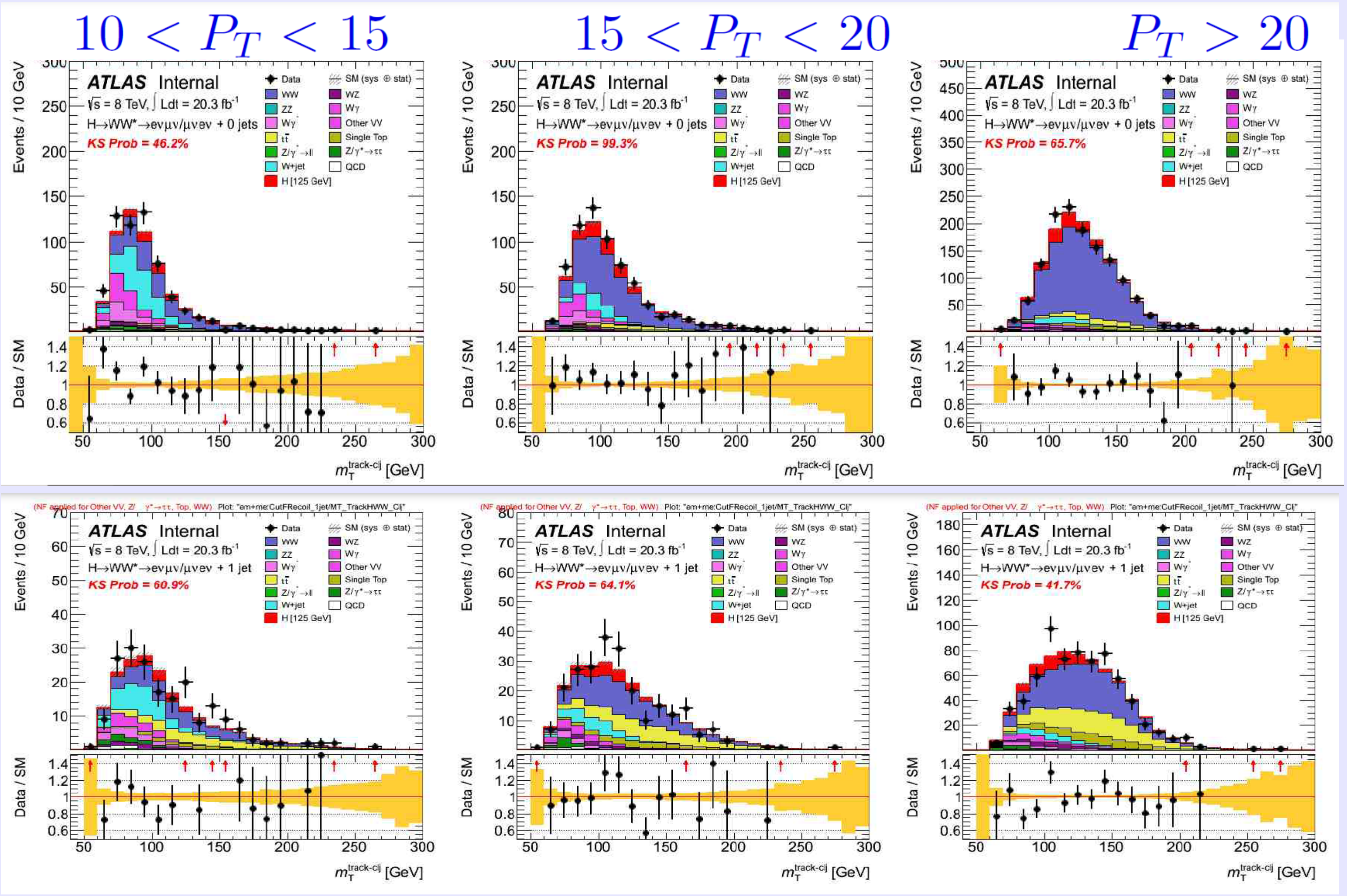
Event yields for the different channels

Table of events after the final selection (m_T Higgs window). The yield and uncertainties (stat+syst) are those obtained after the final fit

	Summary			Composition of $N_{\rm bkg}$						
Channel	$N_{\rm obs}$	$N_{\rm bkg}$	$N_{\rm sig}$	N_{WW}	N_{VV}	N_t	$N_{t\bar{t}}$	$N_{\rm DY}$	N_{Wj}	N_{jj}
$n_j = 0$										
$e\mu$	2642	2390 ± 90	231 ± 35	1510 ± 80	350 ± 60	75 ± 0	130 ± 10	28 ± 4	280 ± 50	16.4 ± 2.8
$ee/\mu\mu$	1108	1040 ± 40	79 ± 15	730 ± 40	68 ± 6	39 ± 1	65 ± 5	50 ± 25	81 ± 15	6.3 ± 2.3
$n_j = 1$										
$e\mu$	1129	1040 ± 40	94 ± 21	440 ± 70	110 ± 40	102 ± 14	270 ± 40	23 ± 6	88 ± 17	8.8 ± 2.1
$ee/\mu\mu$	467	427 ± 18	25 ± 6	183 ± 29	31 ± 4	46 ± 8	119 ± 23	28 ± 15	19 ± 4	0.4 ± 0.1
$n_j \geq 2$, ggF										
$e\mu$	1017	960 ± 70	50 ± 11	138 ± 28	56 ± 18	56 ± 9	480 ± 70	117 ± 21	54 ± 24	63 ± 20
$n_j \geq 2$, VBF										
$e\mu$ bin 1	37	36 ± 4	8.1 ± 1.3	5.0 ± 1.5	2.3 ± 0.7	3.0 ± 0.7	15.6 ± 2.9	3.6 ± 1.5	3.2 ± 1.0	2.3 ± 0.7
" bin 2	14	6.6 ± 1.4	6.2 ± 0.8	1.7 ± 0.7	0.7 ± 0.2	0.3 ± 0.4	2.0 ± 1.0	0.6 ± 0.2	0.4 ± 0.1	0.3 ± 0.1
" bin 3	6	1.2 ± 0.3	4.1 ± 0.8	0.3 ± 0.1	0.1 ± 0.0	0.1 ± 0.0	0.3 ± 0.2	0.2 ± 0.1	0.0 ± 0.0	0 ± 0
$ee/\mu\mu$ bin 1	53	46 ± 5	4.2 ± 0.7	3.1 ± 1.0	1.0 ± 0.3	1.7 ± 0.3	10.1 ± 1.8	28 ± 5	0.9 ± 0.2	0.2 ± 0.1
" bin 2	14	8.4 ± 1.8	3.6 ± 0.5	0.9 ± 0.3	0.3 ± 0.1	0.3 ± 0.2	1.2 ± 0.6	5.2 ± 1.7	0.2 ± 0.1	0 ± 0
" bin 3	6	1.1 ± 0.4	2.3 ± 0.4	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.0	0.2 ± 0.1	0.5 ± 0.3	0 ± 0	0 ± 0

Data-MC distributions from initial analysis

M_T for the 3 P_T bins: DF, Njet=0,1 (before final fit)



Nj=0

Nj=1

Background Strategy

Estimate most background using data and MC:

Channel	WW	Top	$Z/\gamma^* \to \tau\tau$	$Z/\gamma^* \to \ell\ell$	W+jets/QCD	VV
$N_{\rm jet} = 0$						
$e\mu+\mu e$	CR	CR	CR	MC	Data	CR
$ee+\mu\mu$	CR ($e\mu+\mu e$)	CR ($e\mu+\mu e$)	CR ($e\mu+\mu e$)	Data	Data	MC + VR
$N_{\rm jet} = 1$						
$e\mu+\mu e$	CR	CR	CR	MC	Data	CR
$ee+\mu\mu$	CR ($e\mu+\mu e$)	CR ($e\mu+\mu e$)	CR ($e\mu+\mu e$)	Data	Data	MC + VR
$N_{\rm jet} \geq 2$, ggF						
$e\mu+\mu e$	MC	CR	CR	MC	Data	MC + VR
$N_{\rm jet} \geq 2$, VBF						
$e\mu+\mu e$	MC	CR	CR	MC	Data	MC + VR
$ee+\mu\mu$	MC	CR	CR	Data	Data	MC + VR

CR: define a Control Region away from the signal region.

Subtract from data all known backg. from other sources

Normalization Factor= NF= [Data -Sum(back)]/MC(CR) +- stat unc.

Extrapolate to the SR by assigning to NF the systematic uncertaintes on $\alpha = N(SR)^{MC}/N(CR)^{MC}$

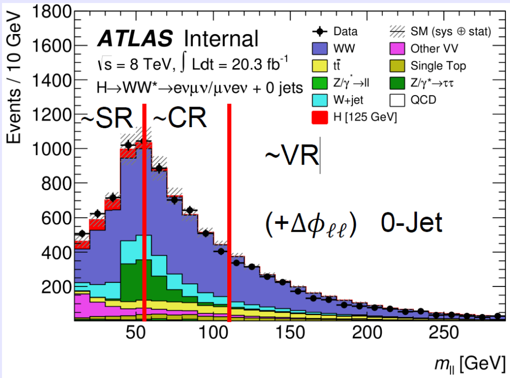
Data: see details below for Z/γ^*-->ll and W+jets/QCD

MC: uncertainties on X-sections and luminosity

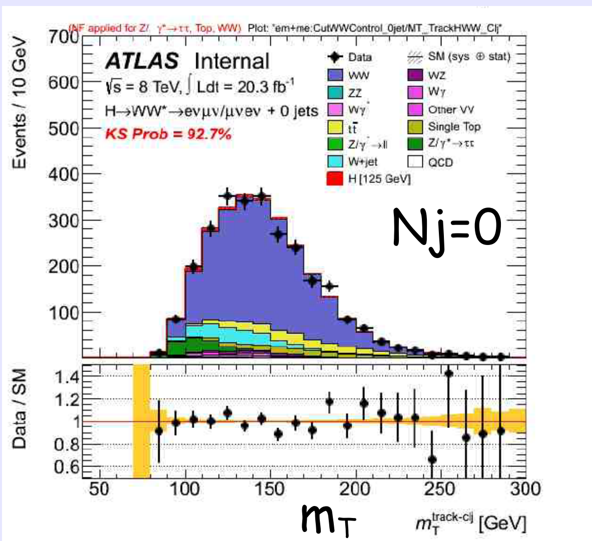
VR: Validation Region

WW Background (CR)

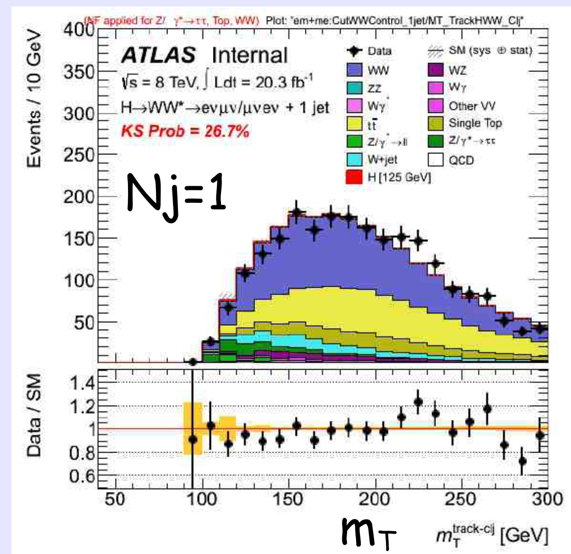
Control Region away from signal region. M_{ll}=55-110 GeV, $\Delta\Phi_{ll}$ < 2.6



Cat.	Summary		Breakdown of N_{exp}					
	N_{obs}	N_{exp}	N_{WW}	N_{top}	N_{Wj}	$N_{Z\tau\tau}$	N_{sig}	N_{rest}
$n_j = 0$	2711	2314	1597	320	182	106	28	108
$n_j = 1$	2646	2576	1095	1095	152	80	4	150



WWCR



NF (Nj=0) = 1.22 + 0.03(stat)+ 0.10 (syst) purity ~70%

NF (Nj=1) = 1.05 + 0.05(stat)+ 0.24 (syst) purity ~45%

Systematics include X-sec, acceptance and luminosity uncertainties

Top Background (CR)

For Njet=0 we use a technique called JVSP (Jet Veto Survival Probability)

First use the MC to evaluate the fraction of top events in the Nj=0 sample. Then use a data sample with at least one b-tag to estimate the probability that no additional jets are reconstructed. Use this to correct the number obtained from MC. Obtain:

NF = 1.12 ± 0.03(stat) ± 0.09(syst)

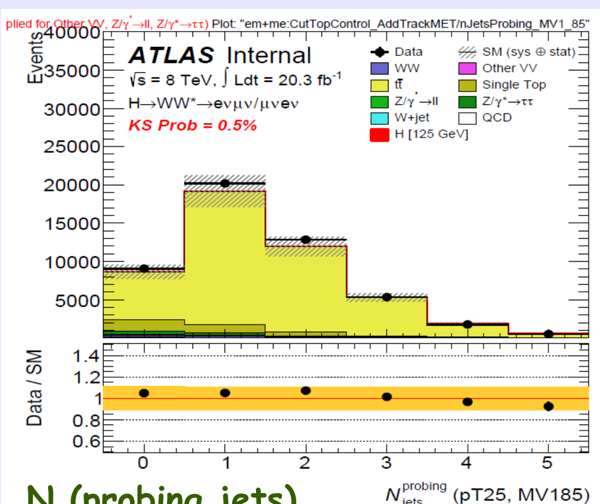
For Njet=1 a JBEE (Jet b-tagging Efficiency Extrapolation is used).

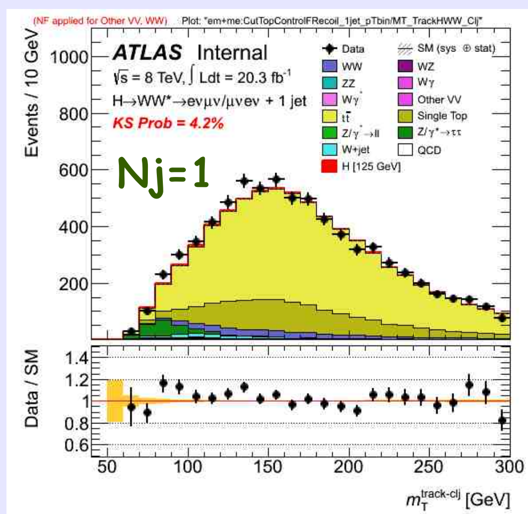
Use data to evaluate the b-tagging efficiency in a 2 jet sample and use it for the NJ=1

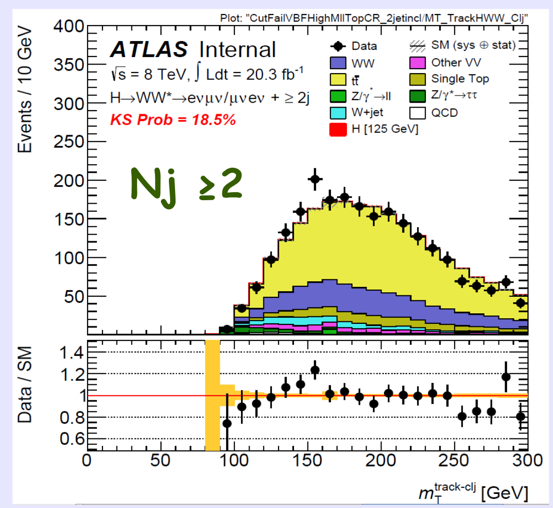
NF = 1.06 ± 0.03 ± 0.04

For 2-jet a CR with M_{ll} > 80 GeV is used

NF = 1.01 ± 0.03(stat) ± 0.04



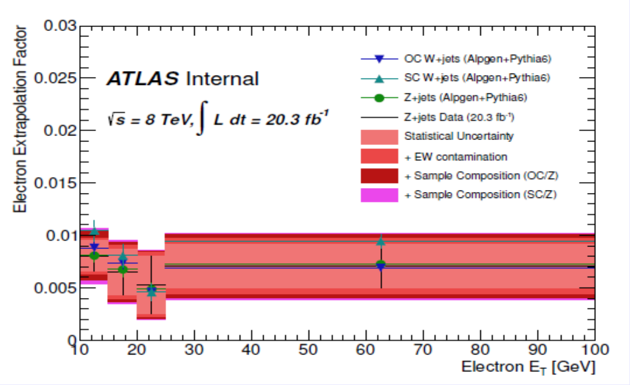




W+jets and QCD (1)

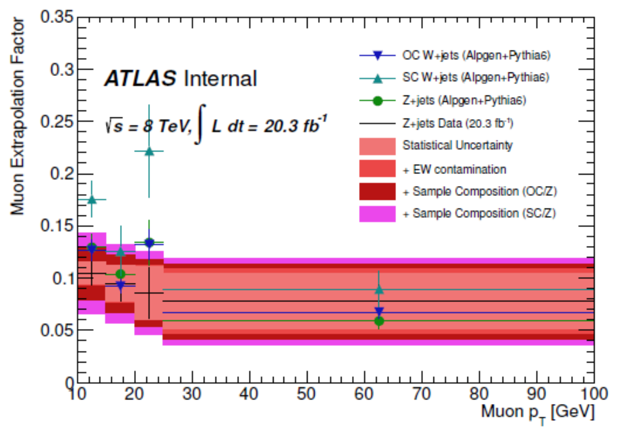
- W+jets: one lepton from W, the other is a misidentified jet or a lepton from hadrons decaying into a heavy quark. It passes lepton ID (see backup)
- QCD: two misindentified leptons from multijet production

Electron Fake Factors



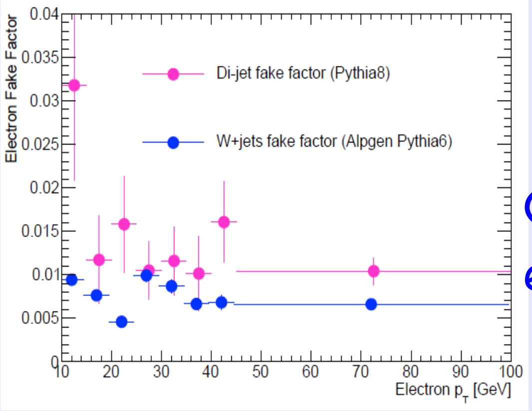
- W+jets: Data-driven background. Estimation based on:
  - W+jets Control Sample passes all SR requirements, except that one of the leptons fails some criteria.
    - Subtract contributions of EWK processes that give prompt or non-prompt leptons not coming from jets (e.g. Wγ, Z->$\tau\tau$).
    - Extrapolation to signal region based on the Fake Factor obtained with a Z+jets sample FF = passing leptons/anti-id leptons.
  - Use a Z+jet sample obtained with the same trigger
    - Remove contamination of all known processes prompt (e.g. WZ) or non-prompt (Zγ, Zγ*) leptons
    - Apply a correction for the remaing (20%) contamination

Muon Fake Factors



W+jets and QCD (2)

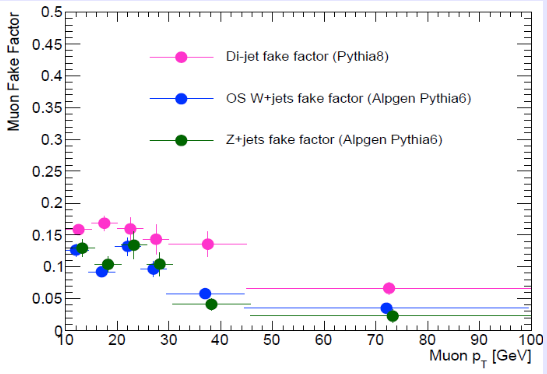
- Sample composition uncertainties (W+jets -vs- Z+jets) are evaluated my MC
- Different flavor composition in OS and SS W+jets leads to differences in the FF for OS and SS events
- Systematic uncertainties on the electron FF vary between 19% and 61%
- For the muons they vary between 25% and 46%



QCD FF electrons

QCD : both leptons are misidentified

- Use Multijet sample, same procedure as for W+jets
- The QCD background is about 10% of the W+jets one.
- The systematic uncertainties are about 50%.
- Contribution to sensitivity to the Higgs is very low

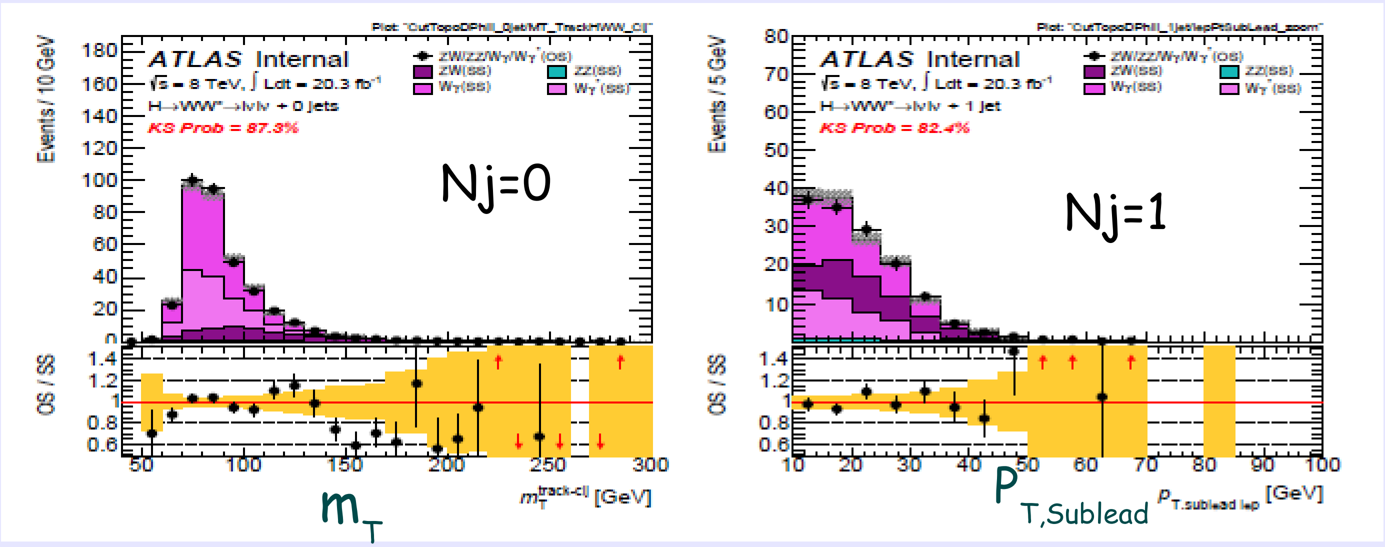


QCD FF muons

Non-WW Background (SSCR)

It includes Wγ, Wγ*, WZ and ZZ. The γ, γ* and Z are equally likely to produce a lepton of either charge relative to the lepton from the W.

- Assume OS=SS for di-boson background (see also backup)



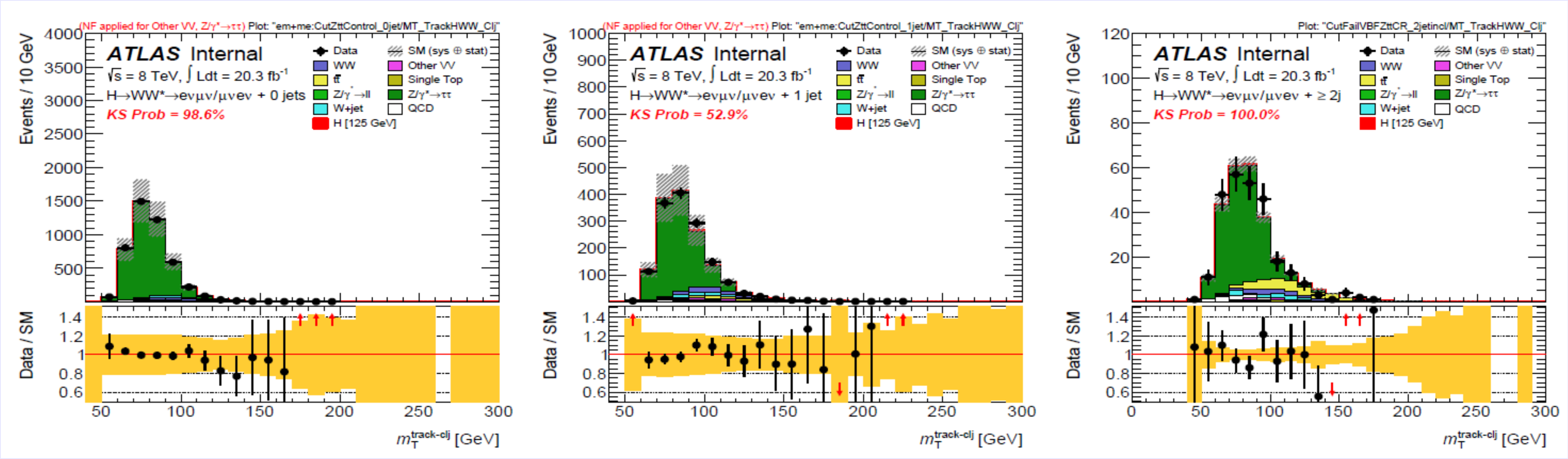
These plots show the comparison of OS and SS plots for the non-WW processes MC

- We use SS data in the SR, after subtracting the W+jets background, compare it to the MC for non-WW and get a Normalization Factor. This avoids theory uncertainties on extrapolation from CR to SR.

NF(0j) = 0.91 ± 0.07(stat) ± 0.17(syst) , NF(1j) = 0.95 ± 0.12(stat) ± 0.21(syst)

Z/γ^*--> tau-tau (CR)

- Define CR that contain little background from other processes
  - Nj=0: M_{ll} < 80 GeV, $\Delta\Phi_{ll}$ > 2.8 rad., Purity= 90%
  - Nj=1: M_{ll} < 80 GeV, $m_{\tau\tau}$ > (M_Z -25 GeV), Purity= 75%
  - Nj≥2: M_{ll} < 70 GeV, $m_{\tau\tau}$ > (M_Z -25 GeV), Purity= 70%



- Good modelling in all the bins!

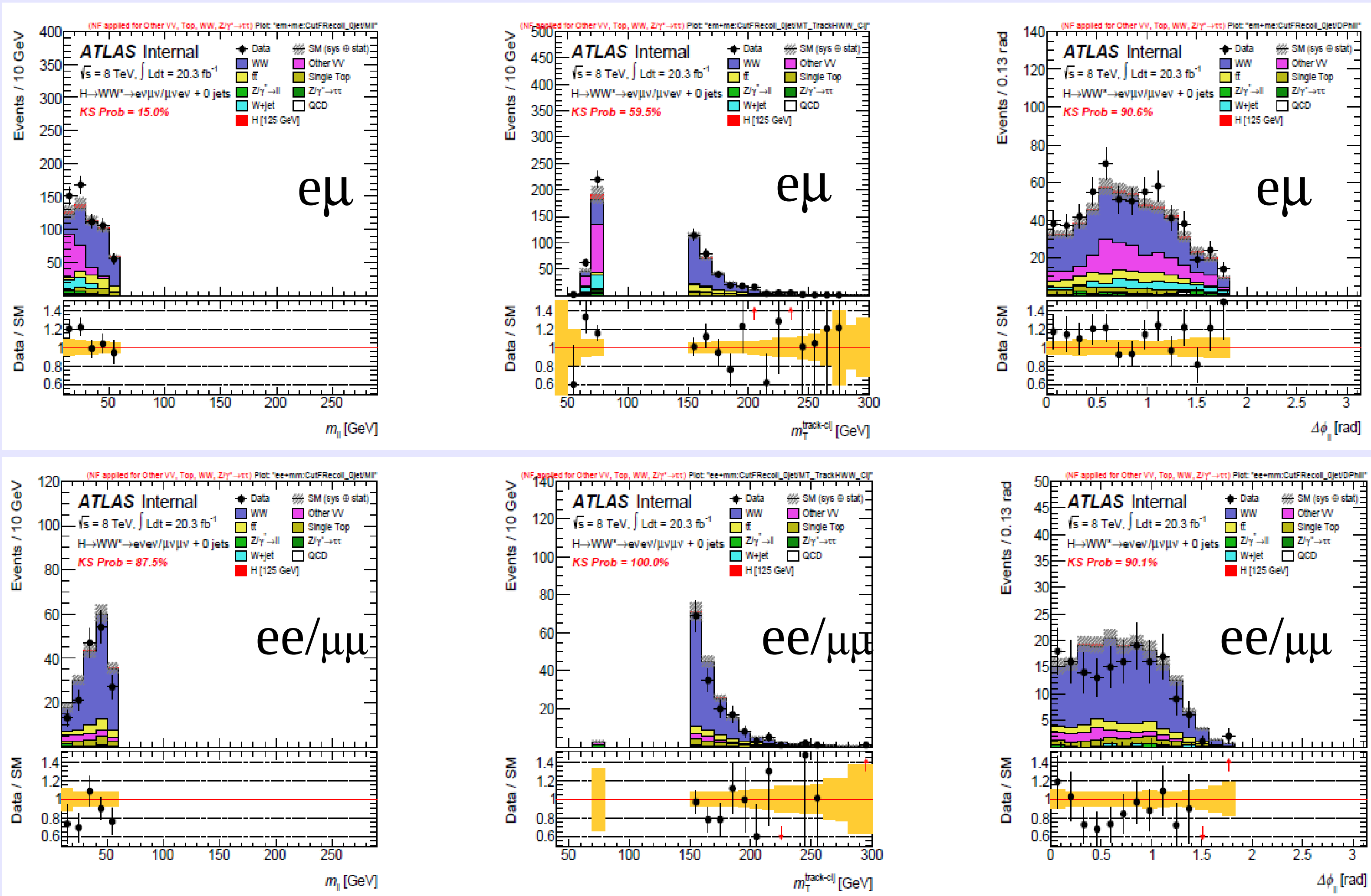
NF(0j) = 1.00 ± 0.02(stat) ± 0.02(syst) NF(≥2j) = 0.97 ± 0.09(stat)

NF(1j) = 1.06 ± 0.04(stat) ± 0.02(syst)

Systematics from QCD scale, PDFs, modeling etc.

Blinded Signal Region, Njet=0

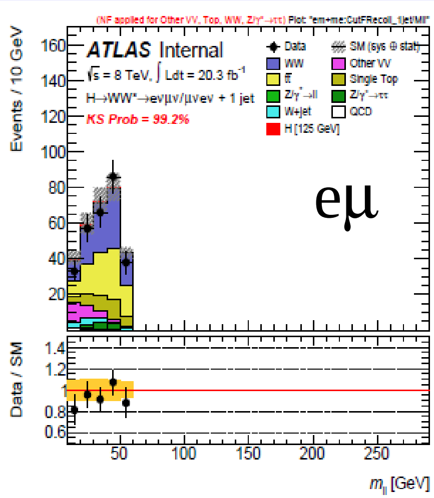
M_{ll}, M_T, $\Delta\Phi_{ll}$ in NJ=0 Signal Region: DF (top), SF (bottom)

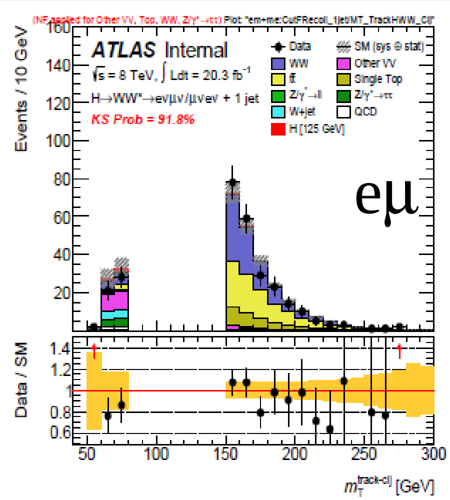


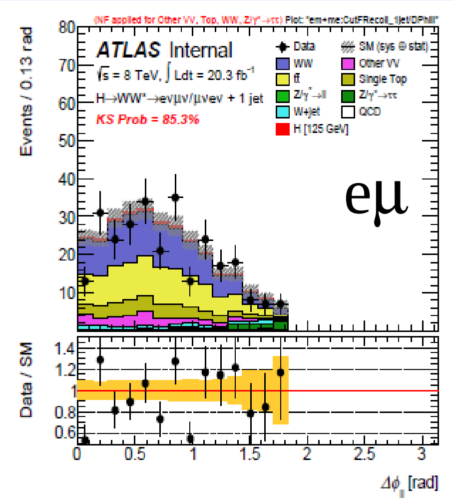
All variables are well modelled

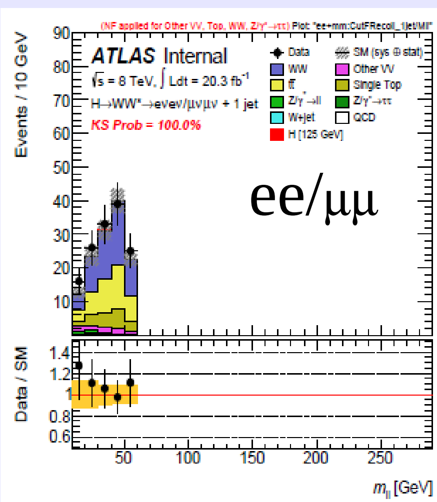
Blinded Signal Region Njet=1

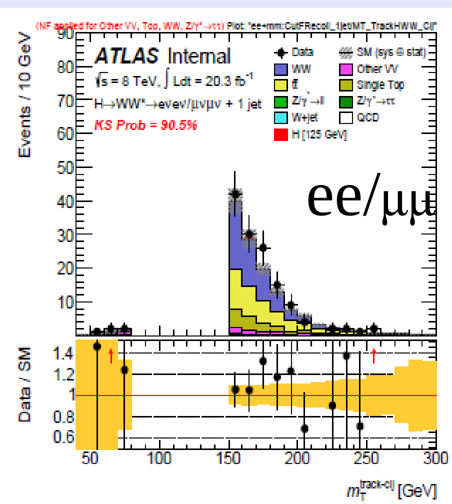
M_{ll}, M_T, $\Delta\Phi_{ll}$ in Nj=1 Signal Region: DF (top), SF (bottom)

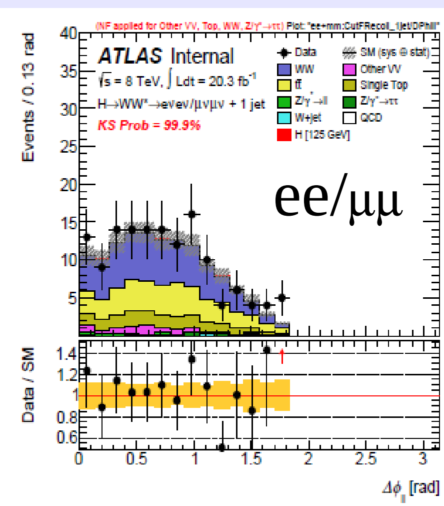








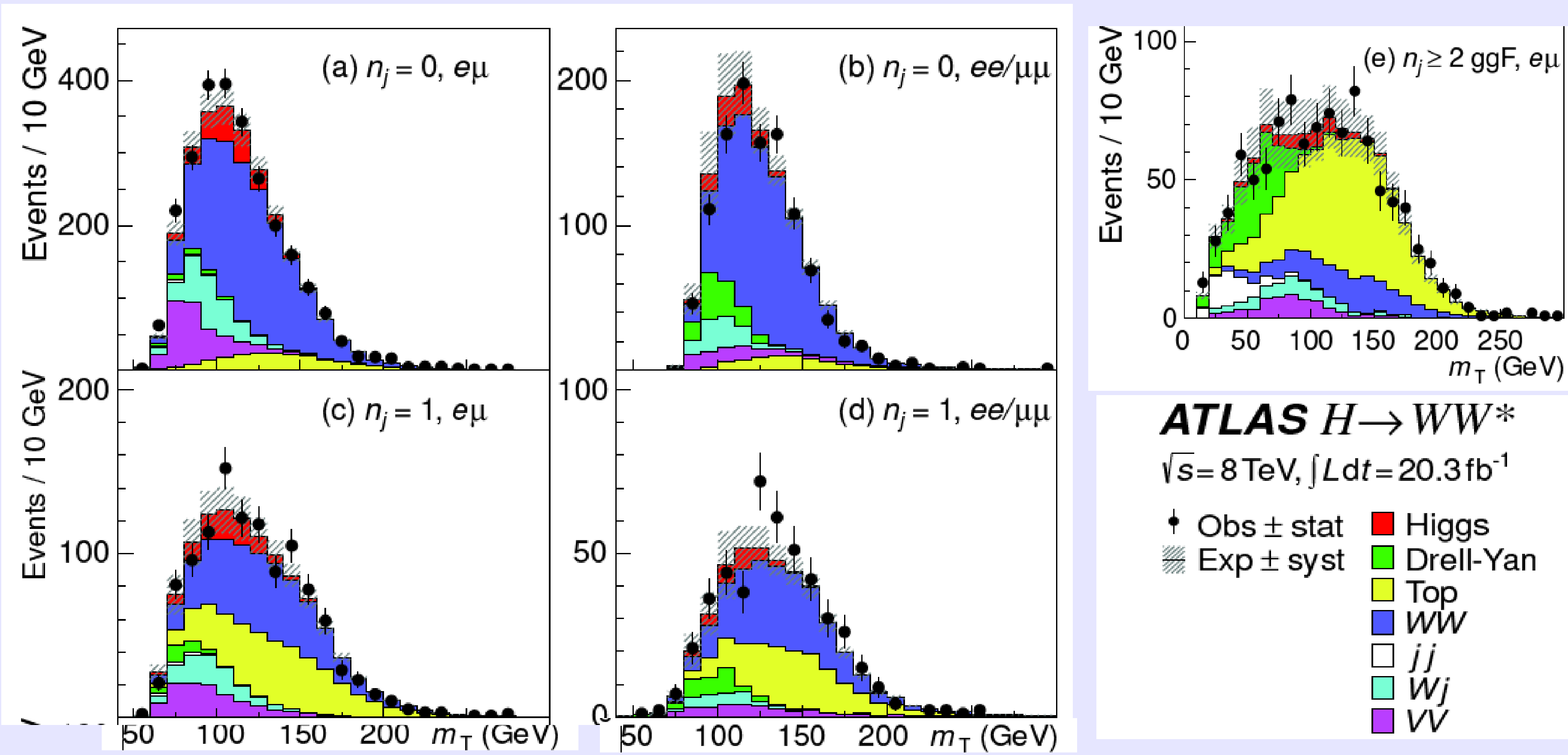




All variables are well modelled. Went ahead and unblinded

Result: M_T distributions for ggF samples

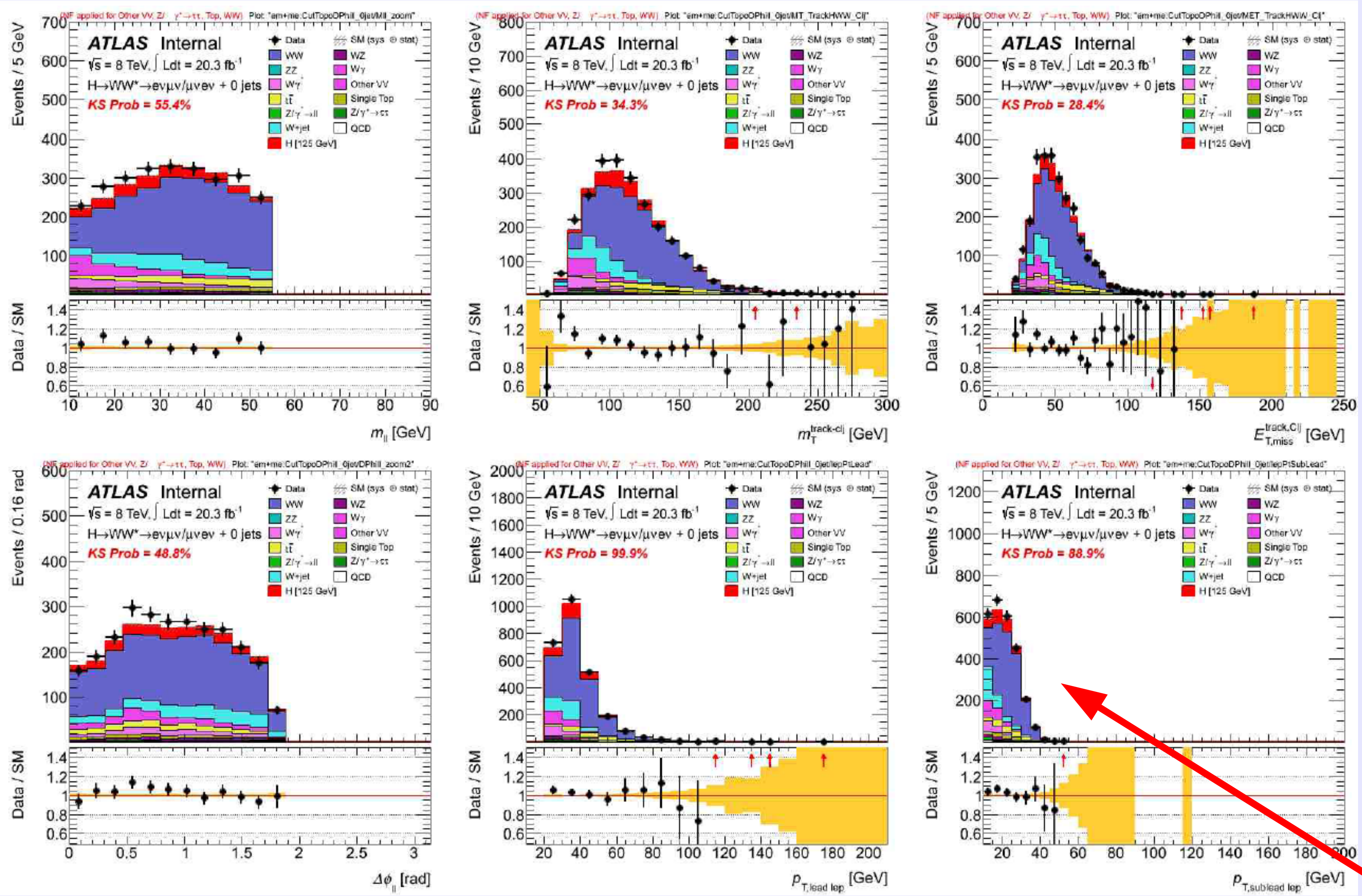
ggF samples Nj=0,1, ≥ 2 from the paper draft (before final fit)



Nj=0 (top 2 left plots) are for DF and SF, NJ ≥ 2, top right
Nj=1 (bottom 2 plots) are for DF and SF
The color chart nomenclature: jj (QCD), Wj (W+jets), VV (non-WW)

Other distributions with DATA/SM

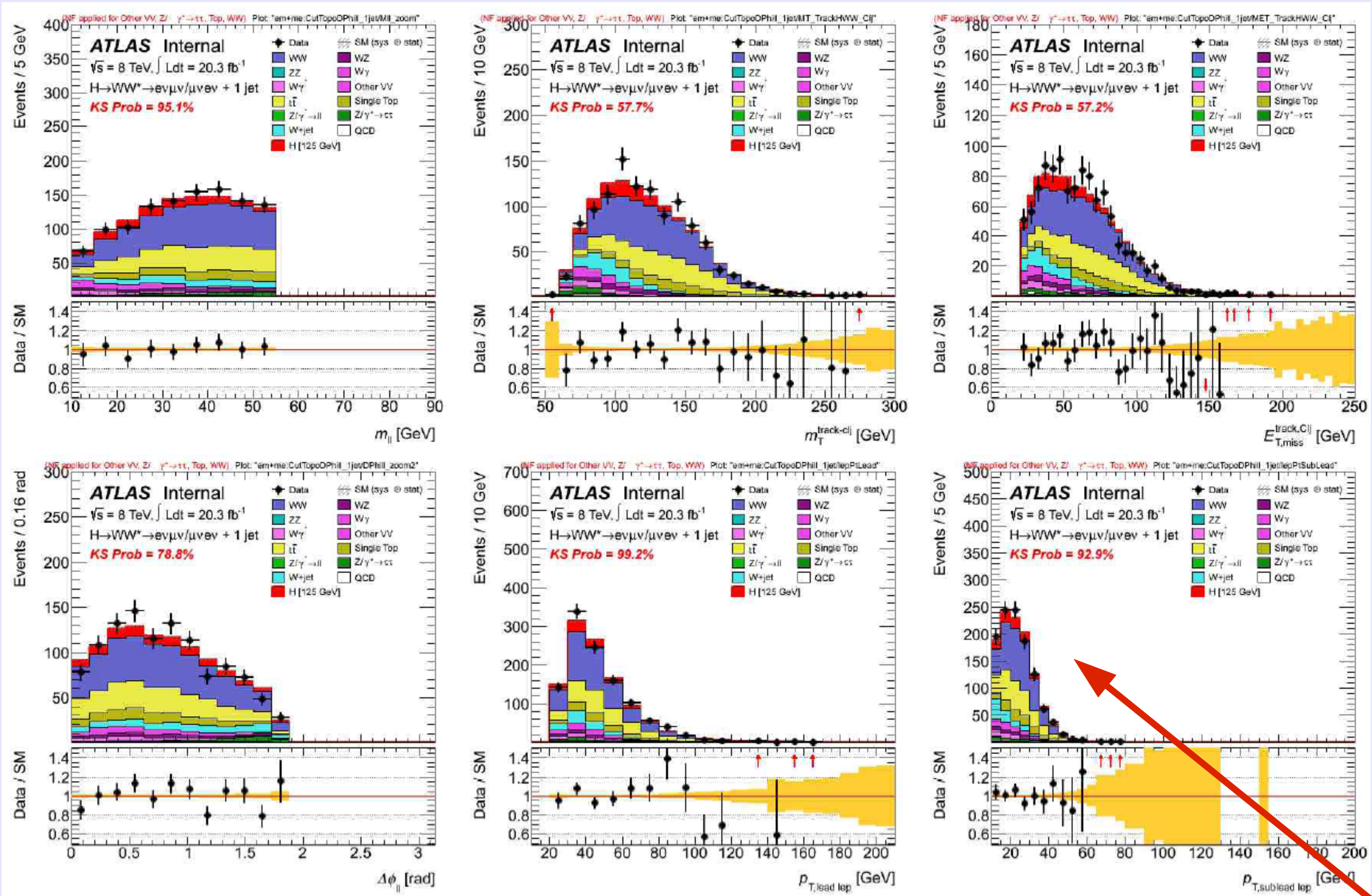
Nj=0: M_{ll}, M_T, E_{Tmiss}, $\Delta\Phi_{ll}$, P_T leptons (Lead and SubLead)



SubLead lepton distribution divided in 3 bins for final fit

Nj=1 Variables

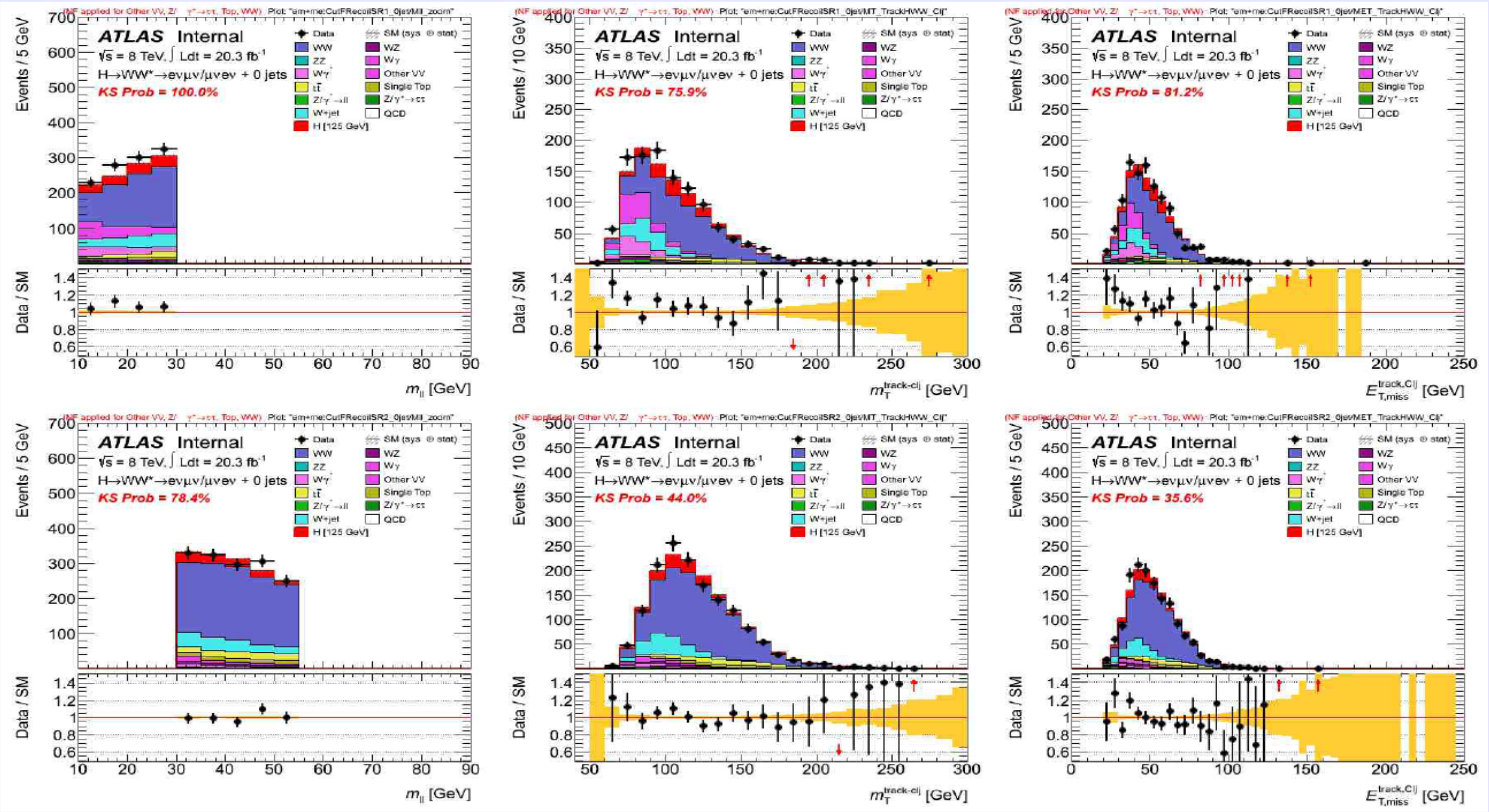
M_{ll}, M_T, E_{Tmiss}, $\Delta\Phi_{ll}$, P_T leptons (Lead and SubLead)



SubLead lepton distribution divided in 3 bins for final fit

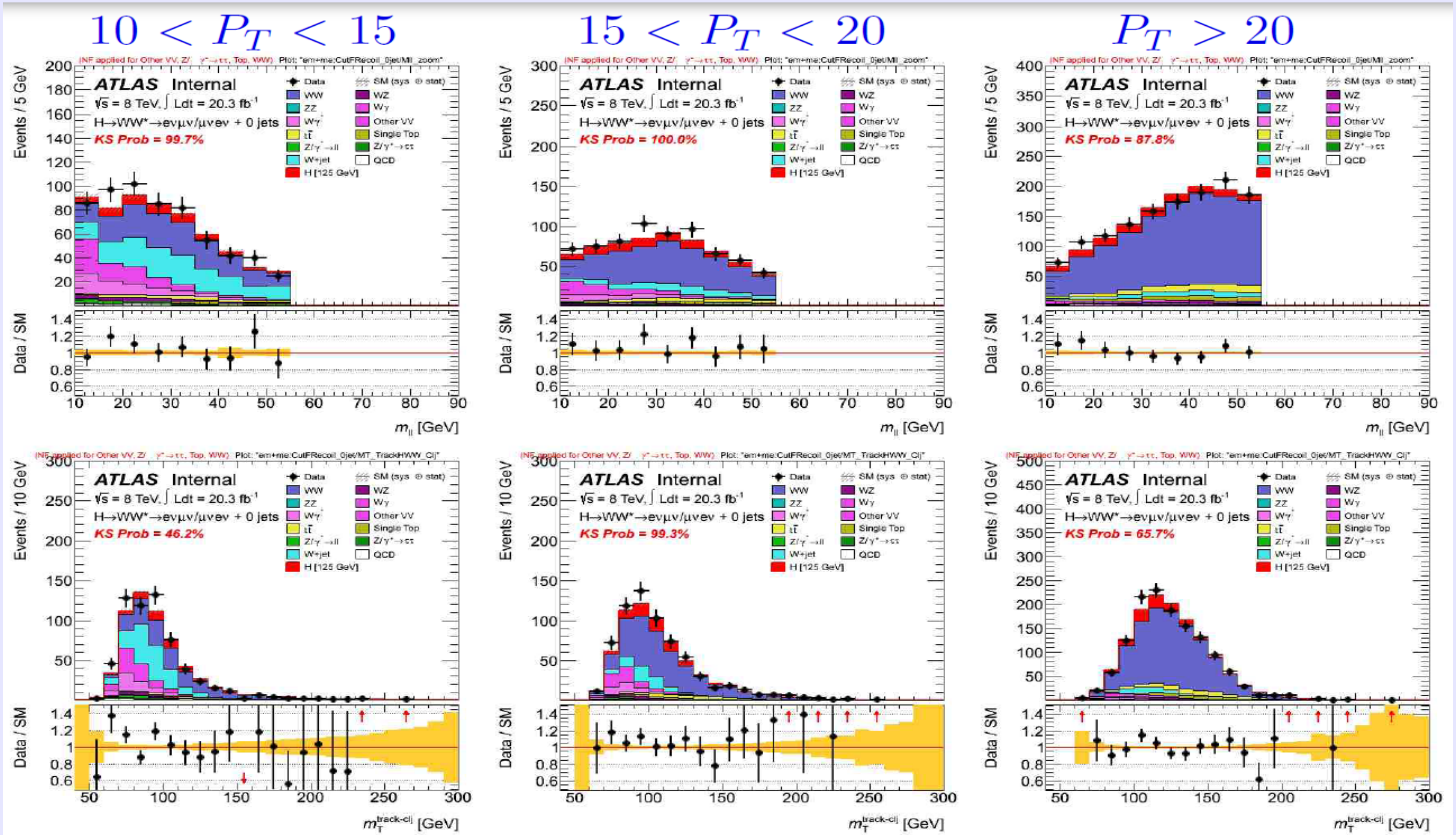
SR1 and SR2 M_{ll}, M_T, E_{Tmiss}: Nj=0

The final fit divides the SR into two M_{ll} bins (10-30 and 30-55)



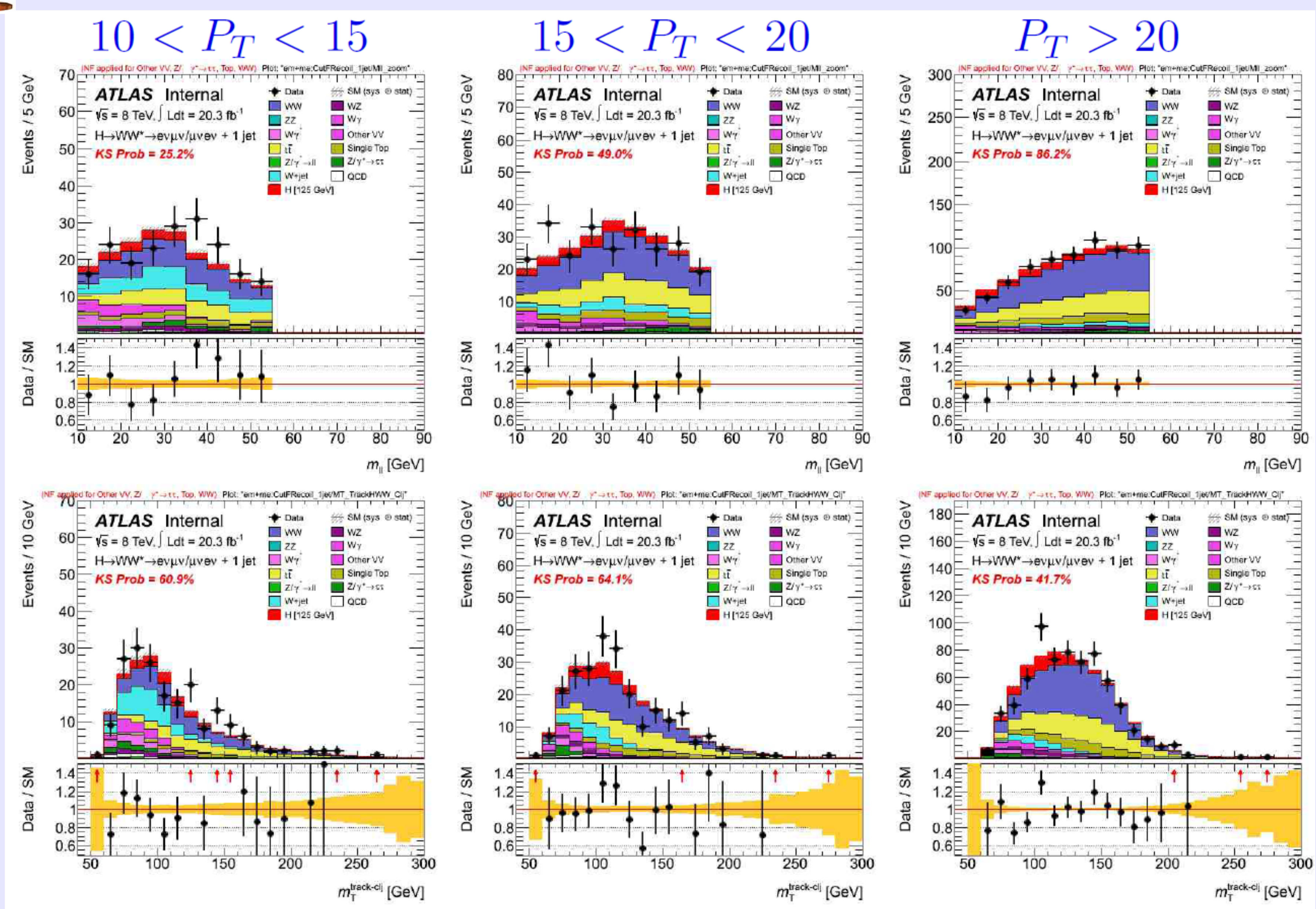
Nj=0, 3 P_T bins: M_{ll} (top), M_T (bottom)

The final fit divides the data into 3 bins in SubLead lepton PT



All distribution have a reasonable Data/MC ratio

Nj=1 3 PT bins: M_{ll}, M_T



Fit Model (very simplified!)

Likelihood includes many terms:

- Poisson for a given signal region i in bin b of the m_T distrib: (N_{ib})
- Poisson for a CR for background k: N_k
- Gaussian constraints for the systematic uncertainties affecting the signal and background yields
- Poison term for each sample, for the observed result to take the value from the fit.

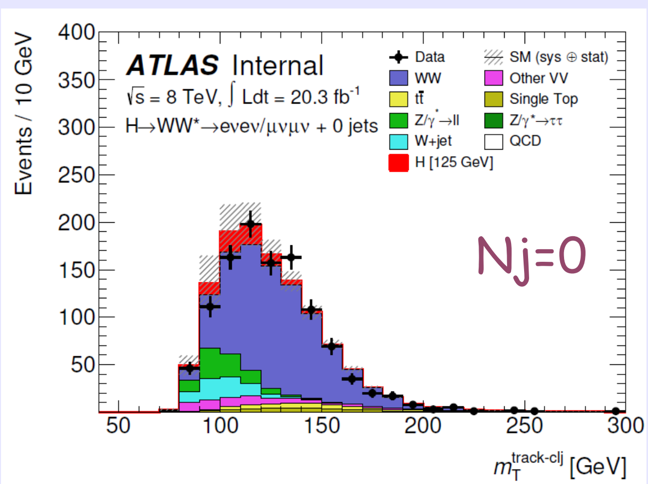
The variable used in the fit is m_T, except for VBF where the BDT score is used. The number of bins chosen depend on the statistics available on each sample

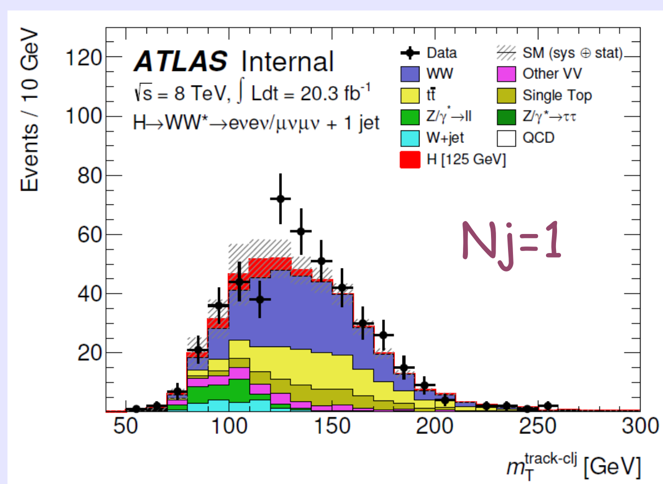
SR in categories i	Data sample in bins b		
		$\otimes\, m_{\ell\ell}$	$\otimes\, P_T^{\ell 2}$
$n_j = 0$, $e\mu$ category	m_T	$\otimes\, [10, 30, 55]$	$\otimes\, [10, 15, 20, \infty]$
$n_j = 0$, $ee/\mu\mu$	m_T	$\otimes\, [12, 55]$	$\otimes\, [10, \infty]$
$n_j = 1$, $e\mu$	m_T	$\otimes\, [10, 30, 55]$	$\otimes\, [10, 15, 20, \infty]$
$n_j = 1$, $ee/\mu\mu$	m_T	$\otimes\, [12, 55]$	$\otimes\, [10, \infty]$
$n_j \geq 2$ ggF, $e\mu$	m_T	$\otimes\, [10, 55]$	$\otimes\, [10, \infty]$
$n_j \geq 2$ VBF, $e\mu$	O_{BDT}	$\otimes\, [10, 50]$	$\otimes\, [10, \infty]$
$n_j \geq 2$ VBF, $ee/\mu\mu$	O_{BDT}	$\otimes\, [12, 50]$	$\otimes\, [10, \infty]$

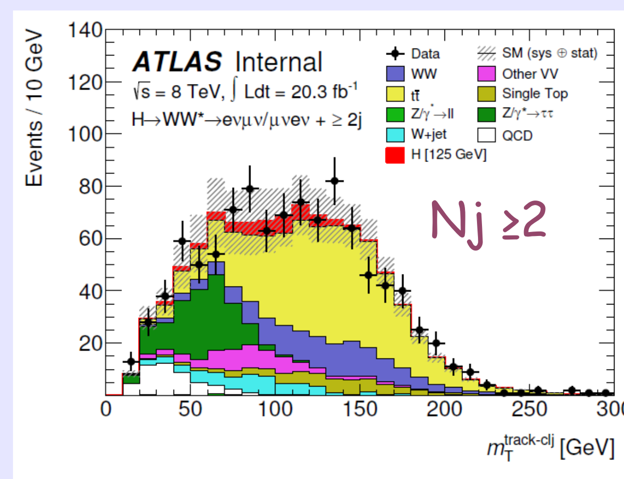
$P_{T,l2}$ is the SubLead lepton P_T

Fit Results

- The aim of the fit is to measure
  - μ: the signal strength
  - Z_0: the significance in unit of Standard Deviations
- The number of signal events and background events, the NF's, the systematic uncertainties etc. are nuisance parameters (~250 of them) to be determined by the fit
- Plots of m_T after the fit are shown below





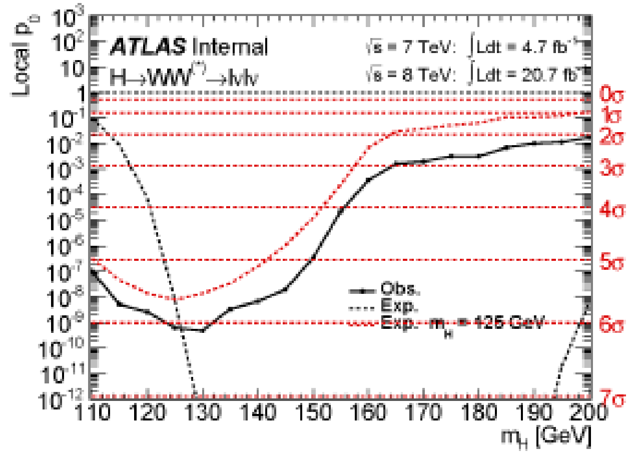


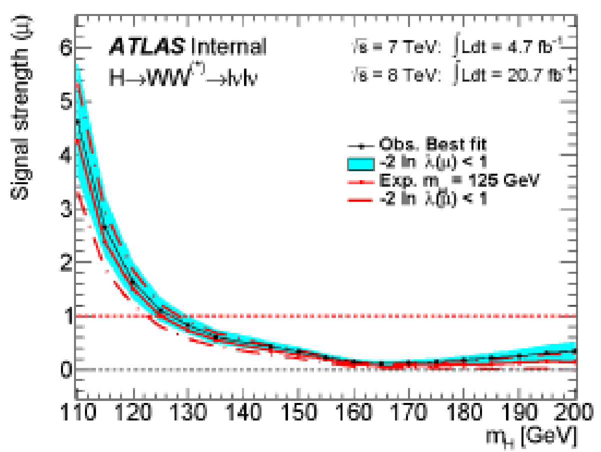
- Plots are not very different from those shown earlier

Results (1)

	version	2012 ggF0/1j	2012 ggF2j	2011 ggF0/1j	2012 VBF BDT VBF+VH/Global	2011 VBF BDT	Combine
Z_{exp}	unblind	4.40	1.17	1.84	2.34/2.93	1.08	5.77
	current	4.33	1.19	1.68	2.38/2.96	1.08	**5.64**
Z_{obs}	unblind	4.88	1.44	1.82	3.63/4.06	-0.93	6.53
	current	4.65	1.49	1.07	3.68/4.12	-0.92	**6.07**
μ_{obs}	unblind	1.18	1.22	0.99	1.58/1.41	-0.65	1.17+0.24/-0.22
	current	1.15	1.25	0.64	1.60/1.41	-0.65	**1.10+0.23/-0.21**

	Obs	Exp
Z0	6.07	5.64
μ	$1.10 + 0.23/-0.21$	$1.00 + 0.22/-0.20$





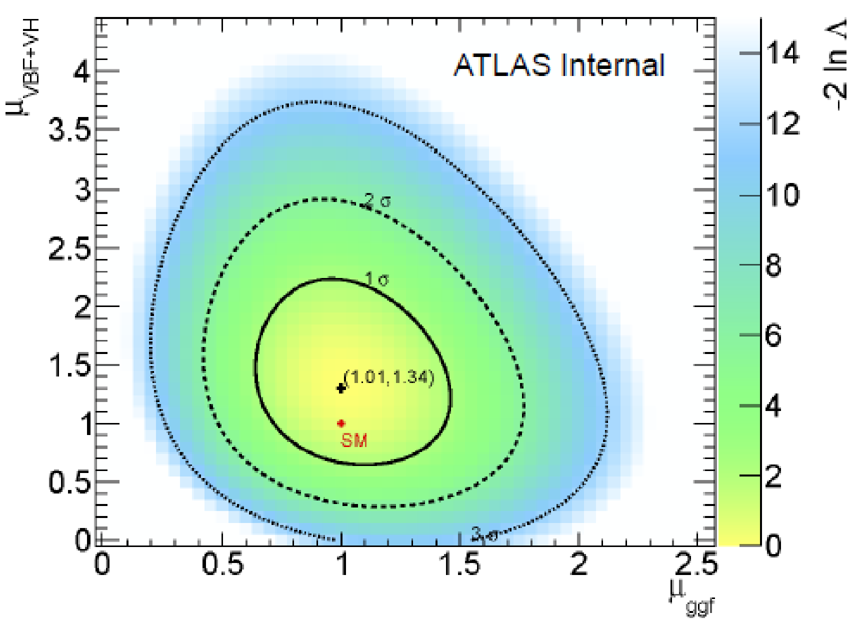
Uncertainties after the fit

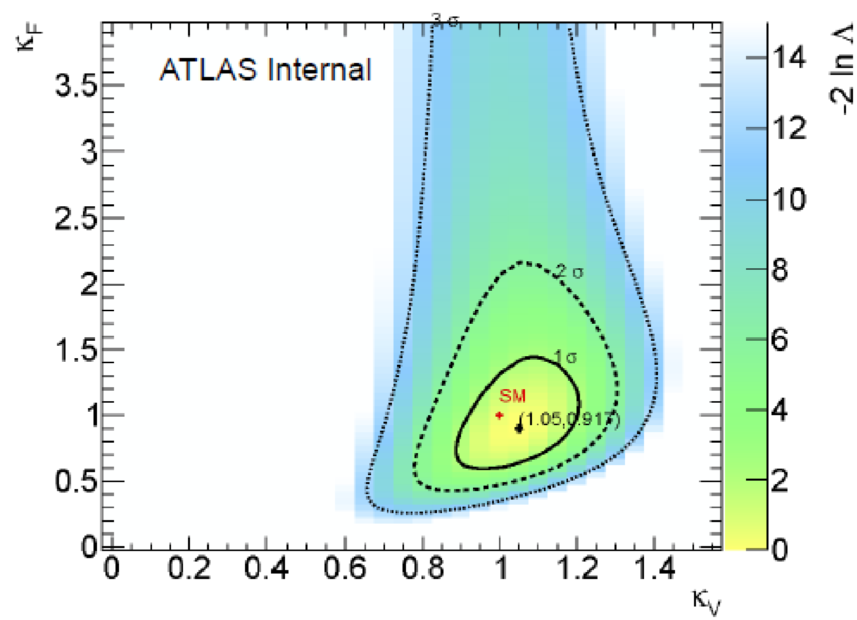
Source	Observed $\mu = 1.11$ Error +	Error −	Plot of error (scaled by 100)	Observed $\mu_{\mathrm{ggF}} = 1.02$ Error +	Error −	Plot of error (scaled by 100)	Observed $\mu_{\mathrm{VBF}} = 1.33$ Error +	Error −	Plot of error (scaled by 100)
Data statistics	0.16	0.16		0.19	0.19		0.47	0.42	
Signal regions	0.13	0.13		0.15	0.14		0.40	0.37	
Profiled control regions	0.10	0.10		0.12	0.12		0.22	0.19	
Profiled signal regions	-	-	-	0.03	0.03		0.10	0.08	
MC statistics	0.04	0.04		0.06	0.06		0.05	0.05	
Theoretical systematics	0.14	0.12		0.18	0.15		0.25	0.17	
Signal $H \to WW^* \mathcal{B}$	0.05	0.04		0.05	0.04		0.07	0.04	
Signal ggF normalization	0.07	0.06		0.10	0.07		0.03	0.03	
Signal ggF acceptancce	0.05	0.04		0.07	0.05		0.08	0.08	
Signal VBF normalization	0.01	0.01		-	-	-	0.07	0.04	
Signal VBF acceptancce	0.02	0.02		-	-	-	0.18	0.10	
Background WW	0.06	0.06		0.08	0.08		0.08	0.07	
Background top quark	0.03	0.03		0.03	0.03		0.06	0.06	
Background misid. factor	0.05	0.05		0.07	0.07		0.02	0.02	
Others	0.02	0.02		0.02	0.02		0.03	0.02	
Experimental systematics	0.07	0.06		0.08	0.08		0.19	0.14	
Background misid. factor	0.03	0.03		0.04	0.04		0.02	0.01	
Bkg. $Z/\gamma^* \to ee, \mu\mu$ in $n_j \leq 1$	0.02	0.02		0.03	0.03		0.01	0.01	
Muons and electrons	0.04	0.04		0.05	0.04		0.03	0.02	
MET quantities	0.02	0.02		0.02	0.02		0.05	0.05	
Jets	0.03	0.02		0.03	0.02		0.16	0.11	
Others	0.03	0.02		0.03	0.03		0.07	0.06	
Integrated luminosity	0.03	0.03		0.03	0.02		0.06	0.03	
Total	0.23	0.21		0.28	0.26		0.56	0.48	
			-30 -15 0 15 30			-30 -15 0 15 30			-60 -30 0 30 60

Results(2)

Combined Results at $m_H = 125$ GeV

ggF	Obs (Exp)	VBF	Obs (Exp)
Z0	4.26 (4.42)	**Z0**	3.26 (2.43)
μ	$1.01 + 0.29/-0.25$	**μ**	$1.34 + 0.57/-0.48$
8 TeV XS	$4.7 \pm 0.8(stat) \pm 0.8(sys)$ pb	**XS**	$0.53 \pm 0.16(stat) \pm 0.10(sys)$ pb





Summary

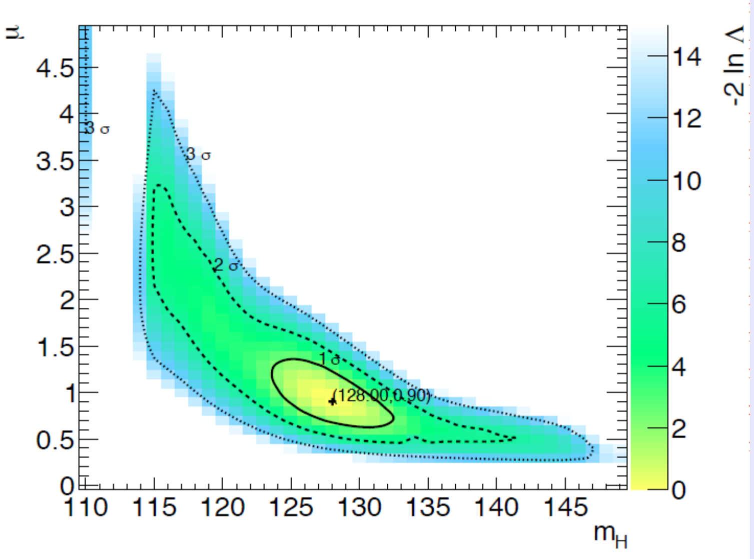
- The H-->WW analysis is close to completion. Paper to go out to the collaboration in a few weeks

- Lots of improvements over the previously published results: significance went from 3.8 to 6.1

- The addition of the lowpT bin in the analysis has improved the plot on the left considerably.

- The paper will include an Higgs cross section measurement, as well as a fiducial cross section measurement

Preliminary



The new banana plot

BACKUP

Changes to leptons, jets and MET

1. Added dilepton trigger + reduced the Leading lepton PT to 22 GeV/c; efficiency went up by a factor 3.4 (em), 3.3 (me)
2. Lepton PT 10-25 GeV: used the Very Tight LH for the electrons
   PT>25: Cut based Medium++ with CBL (conv. bit and B layer)
3. Reoptimized isolation, d0sig and Z0sinθ (more stringent cuts)
   Bottom line after 1,2,3
   Total efficiency up by 1.03, background down by 0.83
4. Reoptimized muons as well: change not significant

5. Changed jets from EM to LC for consistency between the tagging jets and those used for MET calculation. Reoptimized PT and JVF cuts to 25/30/0.5 (central/forward/JVF).
   2% Pileup migration, small wrt theoretical uncertainties

6. MET update : switch to Jet Corrected Track MET due to better M_T resolution and 8% improvement in significance.

Objects

Triggers: single and dilepton (ee,μμ, eμ),

Electron PID: VTLH for pT < 25 GeV, Medium++ with b-layer and conversion bit for pT > 25 GeV,

Muons: staco combined

Jets: LC calibration, pT > 25=30 GeV (central/fwd), |JVF| >0.5 for pT < 50 GeV and |η < 2.4,

b-tagging: MV1 85% OP, pT > 20 GeV.

Most prominent differences since Moriond '13:

Single --> single+dilepton triggers,

cut-based --> likelihood electron identification,

EM jets --> LC calibration,

Calo-$E_T$miss --> trk-$E_T$miss

lepton pT 15/25 GeV --> 10/22 GeV.

3 PT bins: 10-15, 15-20, > 20 GeV/c

M

Lepton Identification

E_T (GeV)	electron ID	calo. isolation topoEtConeCor	track isolation Ptcone	impact parameters
10-15	Very Tight LH	$(iso(0.3))/E_T < 0.20$	$(iso(0.4))/E_T < 0.06$	$d_0/\sigma_{d_0} < 3.0$, $z_0 \sin\theta < 0.4$ mm
15-20		$(iso(0.3))/E_T < 0.24$	$(iso(0.3))/E_T < 0.08$	
20-25		$(iso(0.3))/E_T < 0.28$	$(iso(0.3))/E_T < 0.10$	
> 25	Medium++ with "CBL"			

Table 8: Electron selection as a function of E_T. "CBL" refers to the conversion flag and b-layer hit requirements extended to all η.

Use of the electron likelihood ID, helped a lot!

p_T (GeV)	calo. isolation EtConeCor	track isolation Ptcone	impact parameters
10-15	$(iso(0.3))/p_T < 0.06$	$(iso(0.4))/E_T < 0.06$	$d_0/\sigma_{d_0} < 3.0$, $z_0 \sin\theta < 1.0$ mm
15-20	$(iso(0.3))/p_T < 0.12$	$(iso(0.3))/E_T < 0.08$	
20-25	$(iso(0.3))/p_T < 0.18$	$(iso(0.3))/E_T < 0.12$	
> 25	$(iso(0.3))/p_T < 0.30$		

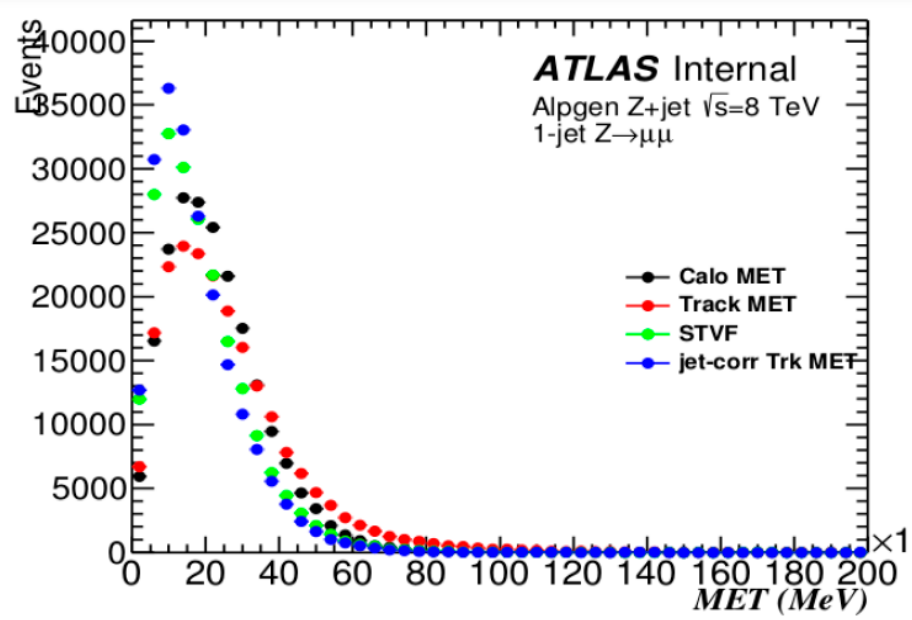
Table 10: Muon selection as a function of p_T.

Changes

METRelFinal to TrackMET

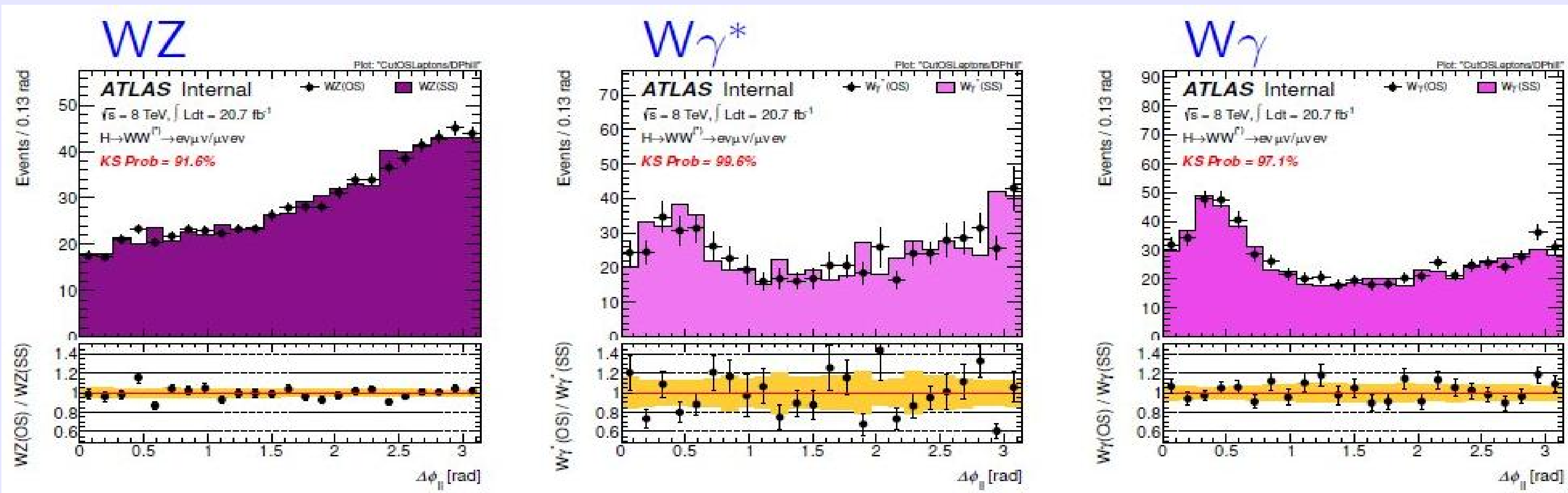
E_T^{miss}	Mean	RMS	Integral of tail
jet-corrected Track E_T^{miss}	0.020	1.37	23.41
Track E_T^{miss}	0.13	1.80	39.86
Calo	0.05	1.50	28.34
STVF	0.021	1.47	27.17

MET - true MET in 1J, x-direction



Non-WWBackground

- Assumes OS=SS for di-boson background. Confirmed below from MC prediction in OS (dots) and SS (colored histograms)



Tomoe

WW Extrapolation Systematics

sub-ℓ p_T	α_i	Scale	Parton-shower	Matching	EWK-Corr	PDFs	Total
[10 – 15] GeV	α_{0j}^{DF} (SR1)	0.73 ± 0.59	2.2 ± 0.29	0.44 ± 0.4	1.2 ± 0.33	0.96	2.8
	α_{0j}^{DF} (SR2)	0.69 ± 0.63	1.5 ± 0.3	0.49 ± 0.41	0.82 ± 0.34	0.79	2.1
[15 – 20] GeV	α_{0j}^{DF} (SR1)	1.2 ± 0.53	1.7 ± 0.26	0.9 ± 0.36	0.69 ± 0.3	0.79	2.6
	α_{0j}^{DF} (SR2)	0.83 ± 0.46	1 ± 0.23	1 ± 0.32	0.47 ± 0.26	0.68	2
[20) GeV	α_{0j}^{DF} (SR1)	0.72 ± 0.41	-1.9 ± 0.2	3.1 ± 0.28	-0.25 ± 0.23	0.61	3.8
	α_{0j}^{DF} (SR2)	0.76 ± 0.29	-2.4 ± 0.14	3.9 ± 0.2	-0.4 ± 0.16	0.67	4.8
[10,) GeV	α_{0j}^{SF} (SR)	0.77 ± 0.23	-1.2 ± 0.12	2.4 ± 0.16	0.14 ± 0.13	1.1	2.9
	α_{0j}^{DF} (VR)	0.59 ± 0.26	4.3 ± 0.13	-5.1 ± 0.17	1.6 ± 0.14	1.6	7
	α_{0j}^{SF} (VR)	0.59 ± 0.26	4.3 ± 0.13	-5.1 ± 0.17	1.6 ± 0.14	2.2	7

1-Jet

sub-ℓ p_T	α_i	Scale	Parton-shower	Matching	EWK-Corr	PDFs	Total
[10 – 15] GeV	α_{1j}^{DF} (SR1)	3.1 ± 1.1	-2.4 ± 0.54	-3.4 ± 0.74	-0.85 ± 0.6	0.55	5.4
	α_{1j}^{DF} (SR2)	3.2 ± 1	-2 ± 0.5	1.9 ± 0.68	-0.9 ± 0.56	0.55	4.5
[15 – 20] GeV	α_{1j}^{DF} (SR1)	1.6 ± 1	-3 ± 0.5	0.7 ± 0.7	-1.5 ± 0.57	0.48	3.9
	α_{1j}^{DF} (SR2)	1.5 ± 0.83	-3 ± 0.41	2.4 ± 0.56	-1.6 ± 0.46	0.45	4.5
[20) GeV	α_{1j}^{DF} (SR1)	1 ± 0.7	-3.6 ± 0.33	5.3 ± 0.46	-2.8 ± 0.38	0.62	7.1
	α_{1j}^{DF} (SR2)	1.3 ± 0.48	-3.1 ± 0.23	5.6 ± 0.32	-2.7 ± 0.26	0.62	7.1
[10,) GeV	α_{1j}^{SF} (SR)	0.81 ± 0.38	-2.3 ± 0.18	3.8 ± 0.25	-2.1 ± 0.21	0.86	5.1

Table 25: Scale, PDF, parton-shower/underlying-event, and matching uncertainties on the WW extrapolation parameters α for the NLO $q\bar{q}, qg \to WW$ processes. The row-to-row correlations in the parton-shower and matching uncertainties are shown explicitly by including the signed difference in the comparison. The statistical uncertainty is folded into the systematic uncertainty when the latter is less than the former.

W+jets Uncertainties

Table 20: Summary of systematic uncertainties (quoted as percentages) on the Z + jets fake factor measurement. Same-sign and opposite-sign uncertainties are quoted separately because the correction factor uncertainties differ. For the correction factor uncertainties, the statistical, correlated systematic, and uncorrelated systematic components quoted in Table 19 are summed in quadrature.

	electrons				muons			
	stat.	EW syst.	corr. factor	**total**	stat.	EW syst.	corr. factor	**total**
$10 < p_T < 15$	18	11	20	**29 (OS)**	10	3	22	**25 (OS)**
			25	32 (SS)			35	37 (SS)
$15 < p_T < 20$	34	19	20	**44 (OS)**	18	5	22	**29 (OS)**
			25	46 (SS)			35	40 (SS)
$20 < p_T < 25$	52	25	20	**61 (OS)**	29	9	22	**37 (OS)**
			25	63 (SS)			35	46 (SS)
$p_T > 25$	30	23	20	**43 (OS)**	34	21	22	**46 (OS)**
			25	45 (SS)			35	53 (SS)

Uncertainties on Signal and Background

TABLE XIX. Leading uncertainties on yields (in %) for the signal and cumulative background processes in the 8 TeV analysis. Entries marked with "-" show that the corresponding uncertainties either do not apply or are lower than 2.5% and 1% for the signal and background processes, respectively.

Systematic source	$n_j = 0$	$n_j = 1$	$n_j \geq 2$ ggF	$n_j \geq 2$ VBF
Uncertainties on N_{sig}				
ggF signal $n_j = 0$ eff. scale	9.6	16.8	14.7	-
ggF signal $n_j = 1$ eff. scale	-	13.0	16.0	-
2-jet incl. ggF signal scale	-	-	-	12.9
3-jet incl. ggF signal scale	-	-	-	3.1
Inclusive ggF signal scale	7.3	6.3	5.5	-
$H \to WW^*$ branch. frac.	4.3	4.3	4.3	4.3
ggF acceptance model	4.1	3.8	4.3	4.1
VBF acceptance model	-	-	0.6	5.5
PDF model	8.4	7.2	1.7	3.6
Luminosity	2.8	2.8	2.8	2.8
Jet energy scale & resol'n	6.1	3.7	7.5	6.1
$P_{\mathrm{T}}^{\mathrm{miss\,(no\,jet)}}$ scale & resol'n	1.3	2.9	-	1.2
Light- and c-jet mistag	-	1.8	3.6	1.5

Systematic source	$n_j = 0$	$n_j = 1$	$n_j \geq 2$ ggF	$n_j \geq 2$ VBF
Uncertainties on N_{bkg}				
WW theoretical model	1.9	1.7	2.7	3.4
VV theoretical model	0.7	1.8	2.5	1.1
PDF model	0.7	-	1.3	0.9
$t\bar{t}/Wt$ theoretical model	0.6	0.7	1.9	3.5
$Z \to \tau\tau$ model	-	-	2.4	2.0
F_{recoil} efficiency	3.4	1.5	-	-
W+jets fake factor	2.2	1.5	2.8	0.9
Jet energy scale & resol'n	2.1	3.2	3.4	20.5
Electron ID, scale, resol'n	1.3	1.3	1.3	1.0
Muon ID, scale, resol'n	0.7	0.9	0.8	1.5
$P_{\mathrm{T}}^{\mathrm{miss\,(no\,jet)}}$ scale & resolution	-	-	-	6.9
$Z \to \ell\ell$ in BDT	-	-	-	5.8
Pile-up model	0.7	0.6	-	3.2
QCD estimate	-	-	2.3	1.1
b-tagging efficiency	-	2.6	6.3	2.4
Light- and c-jet mistag	-	1.3	2.7	1.4