Jets in Higgs searches at ATLAS

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On behalf of the ATLAS Higgs WG

Jet sub-group meeting, 18/05/12

Outline

- H→WW
  - Exclusive binning + VBF/cjv
- H→ττ
  - Inclusive binning + (VBF) (cjv)
- H→γγ
  - The use of PTt
- H→bb
  - Bins in V PT + full jet veto
- Charged Higgs
  - Future directions
- Impact of soft physics

$$H \rightarrow WW \rightarrow \ell\nu\ell\nu, \ell\nu, qq$$

Both final states use exclusive H+0j/1j binning + the VBF bin with the c.j.v.
Jets use anti-kt algorithm with distance parameter R=0.4.
For binning jets are required to have P_T>25 GeV and |η|<4.5
Use S.T. procedure (method B) for theory error propagation

H + 0-jet	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
Jet Veto	54.5 ± 0.2	1285 ± 79	106 ± 6	175 ± 12	95 ± 7	1038 ± 28	217 ± 4	2916 ± 115	2851
$m_{\ell\ell} < 50$ GeV	43.8 ± 0.2	316 ± 20	48 ± 5	30 ± 2	19 ± 2	157 ± 13	69 ± 2	640 ± 34	644
$p_T^{\ell\ell}$ cut	38.8 ± 0.2	285 ± 18	41 ± 4	28 ± 2	18 ± 2	24 ± 7	49 ± 2	444 ± 27	441
$\Delta\phi_{\ell\ell} < 1.8$	37.7 ± 0.2	279 ± 17	39 ± 4	27 ± 2	18 ± 2	23 ± 7	44 ± 1	429 ± 27	427
H + 1-jet	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
1 jet	21.1 ± 0.1	390 ± 55	59 ± 4	1433 ± 80	430 ± 25	357 ± 17	82 ± 3	2752 ± 170	2707
b-jet veto	19.5 ± 0.1	360 ± 51	55 ± 4	401 ± 23	134 ± 8	333 ± 16	73 ± 3	1356 ± 92	1371
$\lvert\mathbf{p}_T^{\mathrm{tot}}\rvert < 30$ GeV	13.0 ± 0.1	252 ± 35	33 ± 3	171 ± 10	78 ± 5	105 ± 8	35 ± 2	674 ± 55	685
$Z \rightarrow \tau\tau$ veto	13.0 ± 0.1	246 ± 34	32 ± 3	165 ± 10	75 ± 5	85 ± 7	35 ± 2	638 ± 53	645
$m_{\ell\ell} < 50$ GeV	10.2 ± 0.1	54 ± 7	14 ± 2	32 ± 2	18 ± 2	26 ± 4	12 ± 1	156 ± 14	171
$\Delta\phi_{\ell\ell} < 1.8$	9.4 ± 0.1	49 ± 7	14 ± 2	30 ± 2	17 ± 2	13 ± 3	10 ± 1	134 ± 13	145
H + 2-jet	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
opp. hemispheres	3.8 ± 0.1	46 ± 1	6 ± 1	138 ± 3	21 ± 1	34 ± 4	8 ± 1	253 ± 5	269
$\lvert\Delta\eta_{jj}\rvert > 3.8$	1.8 ± 0.1	8.3 ± 0.4	0.9 ± 0.2	19.2 ± 0.9	2.2 ± 0.4	8.0 ± 2.0	1.5 ± 0.4	40.2 ± 2.3	40
$m_{jj} > 500$ GeV	1.3 ± 0.1	3.9 ± 0.3	0.4 ± 0.1	6.9 ± 0.4	0.7 ± 0.2	0.9 ± 0.4	0.7 ± 0.3	13.6 ± 0.8	13
$m_{\ell\ell} < 80$ GeV	0.9 ± 0.1	1.1 ± 0.2	0.1 ± 0.1	1.1 ± 0.2	0.2 ± 0.1	0.3 ± 0.3	0.2 ± 0.2	2.9 ± 0.5	2
$\Delta\phi_{\ell\ell} < 1.8$	0.8 ± 0.1	0.7 ± 0.1	0.1 ± 0.1	0.7 ± 0.2	negl.	0.3 ± 0.3	negl.	1.8 ± 0.4	1
Control Regions	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
WW 0-jet	0.1 ± 0.1	465 ± 3	25 ± 2	85 ± 2	41 ± 2	9 ± 2	48 ± 2	673 ± 5	698
WW 1-jet	0.1 ± 0.1	126 ± 2	10 ± 1	83 ± 2	33 ± 2	9 ± 2	11 ± 1	272 ± 4	269
Top 1-jet	1.1 ± 0.1	21 ± 1	1.5 ± 0.2	422 ± 4	165 ± 3	6 ± 2	negl.	615 ± 6	675

Lepton Channels	0-jet ee	0-jet $\mu\mu$	0-jet $e\mu$	1-jet ee	1-jet $\mu\mu$	1-jet $e\mu$
Total bkg.	58 ± 5	114 ± 10	257 ± 13	21 ± 3	37 ± 5	76 ± 6
Signal	3.8 ± 0.1	9.0 ± 0.1	25 ± 0.2	1.1 ± 0.1	2.3 ± 0.1	6.0 ± 0.1
Observed	52	138	237	19	36	90

$H \to WW$

Total inclusive cross sections evaluated at NNLO + NNLL (LHC xsec group) as a function of the Higgs mass. Computation available at NNLO+NNLL for gluon fusion.

LHC xs recommendations

	$K_{NNLO/NLO}$ ($K_{NLO/LO}$)	Scale	PDF+α_s	Scale +PDF
ggF	+25% (+100%)	+12 -7%	±8%	+20 -15%
VBF	<1% (+5-10%)	±1%	±4%	±5%
WH/ZH	+2-6% (+30%)	±1%	±4%	±5%
ttH	- (+5-20%)	+4 -10%	±8%	+12 -18%

The scale uncertainties of the dominant gluon fusion process are treated in special way to properly take into account uncertainties coming from the exclusive jet counting.

They are evaluated on the cross sections:

$\sigma_{\geq 0}$, $\sigma_{\geq 1}$, $\sigma_{\geq 2}$

The exclusive multi-jet cross section can be written as:

$\sigma_0 = f_0\sigma_{\geq 0}$, $\sigma_1 = f_1\sigma_{\geq 0}$, $\sigma_2 = f_2\sigma_{\geq 0}$

$$f_0 = \frac{\sigma_{\geq 0} - \sigma_{\geq 1}}{\sigma_{\geq 0}}$$

$$f_1 = \frac{\sigma_{\geq 1} - \sigma_{\geq 2}}{\sigma_{\geq 0}}$$

$$f_2 = \frac{\sigma_{\geq 2}}{\sigma_{\geq 0}}$$

errors on f_i are computed using selection cuts close to the analysis ones ($E_T^{Miss} > 30$ GeV, $p_T^{Jet} > 30$ GeV, $p_{T\,l1,l2} > 20$ GeV, $|\eta| < 2.5$, $m_{ll} > 12$ GeV) - to be updated

The central values are computed using Powheg.

$\Delta\sigma_{\geq 1}$ (20%), $\Delta\sigma_{\geq 2}$ (70%) are evaluated using HNNLO (NLO $\geq$ 1 jet, LO $\geq$ 2 jet) in ATLAS
$\Delta\sigma_{\geq 2}$ (20%) using MCFM NLO in CMS, agreed to use the LO 70% error in the future.

Proposed strategy for the 2 jet uncertainty in the VBF channel (still on going)

$$H \to WW$$

1) evaluate f_2 using MCFM

2) correct f_2 value using the ratio $f_{2\,\mathrm{POWHEG}} / f_{2\,\mathrm{MCFM}}$

3) check stability of $f_{2\,\mathrm{POWHEG}} / f_{2\,\mathrm{MCFM}}$ respect to analysis cuts (mainly Jet E_T thresholds and $|\eta|$)

Example no VBF cuts

$\sigma_{\geq 2\ \mathrm{jet}}$ $E_T^{Miss} > 25$ GeV, p_T jet > 25 GeV $|\eta| < 4.5$ $p_T l1,l2 > 25,15$ GeV, mH = 150 GeV

MCFM 6.97 ± 0.19 fb Powheg (reweighted) 5.96 ± 0.08 fb (15%)

Example with VBF cuts

Preliminary numbers

cuts used (VBF selection)

variable	details
jet algorithm	kt
jet cone size	0.5
M_{jj}	>350 GeV
$\Delta\eta_{jj}$	> 3.5
$\eta_{j1}\eta_{j2}$	< 0
leptons p_T	> 20, 15 GeV
tag jets p_T	> 30 GeV
E_T^{miss}	> 30 GeV
vetoed jet	> 30 GeV

Table 1: MCFM settings for the Higgs + 2jets calculation.

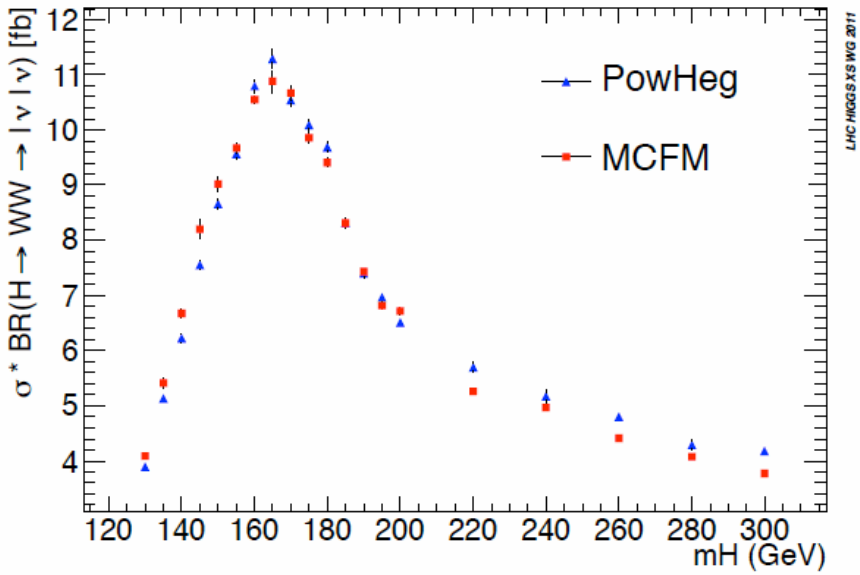
cjv central jet veto

m_H	cjv	σ (MCFM)	σ (POWHEG)
120	n	0.219 ± 0.03	0.202
120	y	0.24 ± 0.04	0.164
160	n	0.97 ± 0.2	1.53
160	y	0.742 ± 0.2	1.26
250	n	0.451 ± 0.08	0.233
250	y	0.29 ± 0.1	0.167

large correction at high mass, a scaling factor has to be applied

Use NLO error here because $\sigma_{\geq 2} A_{2\text{-VBF}} << \sigma_{\geq 1}$

MCFM-Powheg+Pythia comparison.



M_H [GeV]	MCFM [fb]	POWHEG [fb]	Ratio: POWHEG/MCFM
130	4.09 ± 0.05	3.89 ± 0.05	0.95 ± 0.02
135	5.41 ± 0.09	5.13 ± 0.06	0.95 ± 0.02
140	6.67 ± 0.07	6.22 ± 0.08	0.93 ± 0.01
145	8.20 ± 0.18	7.55 ± 0.09	0.92 ± 0.02
150	9.02 ± 0.14	8.66 ± 0.10	0.96 ± 0.02
155	9.67 ± 0.09	9.57 ± 0.11	0.99 ± 0.01
160	10.55 ± 0.07	10.80 ± 0.12	1.02 ± 0.01
165	10.88 ± 0.20	11.29 ± 0.16	1.04 ± 0.02
170	10.67 ± 0.13	10.54 ± 0.11	0.99 ± 0.02
175	9.86 ± 0.10	10.09 ± 0.11	1.02 ± 0.01
180	9.41 ± 0.08	9.69 ± 0.10	1.03 ± 0.01
185	8.31 ± 0.09	8.32 ± 0.09	1.00 ± 0.01
190	7.43 ± 0.05	7.40 ± 0.08	1.00 ± 0.01
195	6.82 ± 0.06	6.97 ± 0.07	1.02 ± 0.01
200	6.72 ± 0.07	6.51 ± 0.07	0.97 ± 0.01
220	5.26 ± 0.05	5.70 ± 0.09	1.08 ± 0.02
240	4.97 ± 0.04	5.17 ± 0.12	1.04 ± 0.02
260	4.41 ± 0.02	4.80 ± 0.07	1.09 ± 0.01
280	4.07 ± 0.04	4.29 ± 0.10	1.05 ± 0.02
300	3.77 ± 0.02	4.18 ± 0.06	1.11 ± 0.02

Scale uncertainty obtained by varying μ_R, μ_F by a factor 2 around m_H.

M_H [GeV]	scale uncertainties
130	23%
160	24%
220	20%

2 jet bin scale uncertainties below 25%

The difference with the Powheg prediction, even if compared after UE, hadronisation and parton shower, is smaller that the scale uncertainy itself.

Taking CMS numbers:
2.1 events from VBF have a theoretical error of about 0.1 events, while the 0.76 events from ggF have an error of 0.2 still dominating the signal uncertainty.

CMS quotes a much larger error 70% from UE in ggF.
It is not clear (to me) why it shoud affect only ggF.
Several tuning have been compared(dt6 , p0, propt0 and proq20 , z2 (reference) tune), see: Physics Letters B 710 (2012) 403–425 for definition.

$H \rightarrow \tau\tau \rightarrow \ell h$

Jet definition: $P_T > 25$ GeV, $|\eta| < 4.5$

Analysis Categories:

VBF:
$N_{jets} \geq 2$
$|\eta_{j1}| * |\eta_{j2}| < 0$
$\min[|\eta_{j1}|, |\eta_{j2}|] < |\eta_{lep}|, |\eta_{\tau}| < \max[|\eta_{j1}|, |\eta_{j2}|]$
$\Delta\eta_{jj} > 3.0$
$M_{jj} > 300$ GeV

Signal Composition(*):
70% VBF/ 28% ggH/2% VH

≥1 Jet:
$N_{jets} \geq 1$
Fail VBF selection

Signal Composition(*)
76% ggH/15%VBF/9%VH

0 Jet:
$N_{jets} \geq 0$

low MET channel:
MET < 20 GeV

high MET channel:
MET ≥ 20 GeV

Signal Composition(*)
98% ggH/< 2% VBF + VH

Signal Modelling:

ggH production:
POWHEG+PYTHIA. Higgs pt spectrum reweighted to agree with HqT.
NNLO + NNLL cross section (from YR1)

VBF production:
POWHEG + PYTHIA
NNLO QCD + NLO EWK cross section (YR1)

VH:
PYTHIA, NNLO QCD + NLO EWK cross section (YR1)

(*): *after full event selection, electron and muon channels combined, low and high MET channels combined*

$H \to \tau\tau \to \ell\ell$

Jet definition: $P_T > 20$ GeV, $|\eta| < 4.5$

Analysis Categories:

VBF:

$N_{jets} \geq 2$ ($P_T > 40$ GeV, $P_T > 25$ GeV)

$\Delta\eta_{jj} > 3.0$

$M_{jj} > 350$ GeV

Jet Veto

Signal Composition(*):

80% VBF/19% ggH/1% VH

VH:

$N_{jets} \geq 2$ ($P_T > 40$ GeV, $P_T > 25$ GeV)

$\Delta\eta_{jj} < 2.0$

$50 < M_{jj} < 120$ GeV

Signal Composition(*):

56% ggH/37% VBF/7% VH

≥1 Jet:

$N_{jets} \geq 1$ ($P_T > 40$ GeV)

$M_{\tau\tau j} > 225$ GeV

Fail VBF and VH channels

•

Signal Composition(*)

72% ggH/21%VBF/7%VH

0 Jet:

$N_{jets} = 0$ ($P_T > 40$ GeV)

Signal Composition(*)

95% ggH/3%VBF/2%VH

Jet Veto: no third jet ($P_T > 20$ GeV), $\min(|\eta_{j1}|,(|\eta_{j2}|) < |\eta_{j3}| < \max[|\eta_{j1}|,|\eta_{j2}|$

(*): after full event selection, electron and muon channels combined, low and high MET channels combined

$$H \to \tau\tau \to hh$$

≥ 1 Jet:

$N_{jets} \geq 1$ ($P_T > 40$ GeV, $|\eta| < 4.5$)

$M_{\tau\tau j} > 225$ GeV

Signal Composition$^{(*)}$

57% ggH/32%VBF/11%VH

Method B implementation for ggH

Inclusive uncertainties, $\Delta_{\mathrm{Total}}, \Delta_{\geq 1}, \Delta_{\geq 2}$: assumed un-correlated
estimated via scale variations using HNNLO

Exclusive cross section

$$\sigma_0 = \sigma_{\mathrm{total}} - \sigma_{\geq 1}\,, \qquad f_0 = \frac{\sigma_0}{\sigma_{\mathrm{total}}}$$

$$\sigma_1 = \sigma_{\geq 1} - \sigma_{\geq 2}\,, \qquad f_1 = \frac{\sigma_1}{\sigma_{\mathrm{total}}}$$

Correlation matrix $\{\sigma_{\mathrm{TOT}}, \sigma_0, \sigma_1, \sigma_{\geq 2}\}$

$$C = \begin{pmatrix} \Delta^2_{\mathrm{total}} & \Delta^2_{\mathrm{total}} & 0 & 0 \\ \Delta^2_{\mathrm{total}} & \Delta^2_{\mathrm{total}} + \Delta^2_{\geq 1} & -\Delta^2_{\geq 1} & 0 \\ 0 & -\Delta^2_{\geq 1} & \Delta^2_{\geq 1} + \Delta^2_{\geq 2} & -\Delta^2_{\geq 2} \\ 0 & 0 & -\Delta^2_{\geq 2} & \Delta^2_{\geq 2} \end{pmatrix}.$$

Example: Lep-Had channel

$\Delta_{\mathrm{Total}}, \Delta_{\geq 1}, \Delta_{\mathrm{VBF}}$: calculated with HNNLO

Δ_{VBF} ~ 90% [LO with HNNLO] → one of the major systematic uncertainty in VBF channel
use Δ (LO) to preserve coherence of the perturbation series

For as long as $\sigma_{\mathrm{VBF}}^{\mathrm{ggF}} / \sigma_{\geq 1Jet}$ small (~ few percent)
→ determine Δ_{VBF} with MCFM (H+2 jets at NLO), ~ 25 %
→ use Δ_{VBF} with MCFM also in determining Δ_1

Do the same thing for ggF in the VH bin. No especial treatment for VBF signal

Studies on Jet Veto: ggF

Central jet-veto reduces ggH contribution to VBF sample
but H+3 jets production is know at LO only → large uncertainty

Some internal studies from Mellado et al:
→ evaluate scale variation for ggH with jet veto [MCFM]

M_H =165 GeV, jets $P_T > 25$ GeV, $\eta_{jj} > 3$.

$\sigma_{H+\geq 2}$ = 233 fb with MCFM [NLO] , $\Delta_{H+\geq 2} \sim 25$ %
$\sigma_{H+\geq 3}$ = 32.3 fb [third jet with $P_T > 25$ GeV, $|\eta| < 2.5$], $\Delta_{H+\geq 2} \sim 50$ %

$\sigma_{H+\geq 2,\,CJV} = \sigma_{H+\geq 2} - \sigma_{H+\geq 3}$
→ $\Delta_{H+\geq 2,\,CJV} \sim 30$ %

Small increase in ggF uncertainty in the VBF bin
25% → 26%

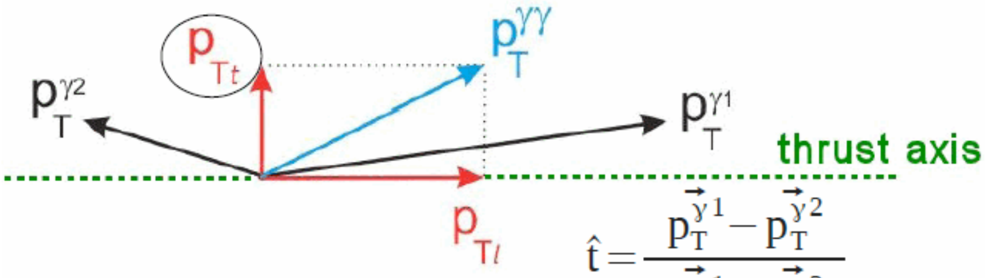
NB: F. Tackmann suggested not to go below $P_T > 20$ GeV
→ method B will break down

$H \to \gamma\gamma$

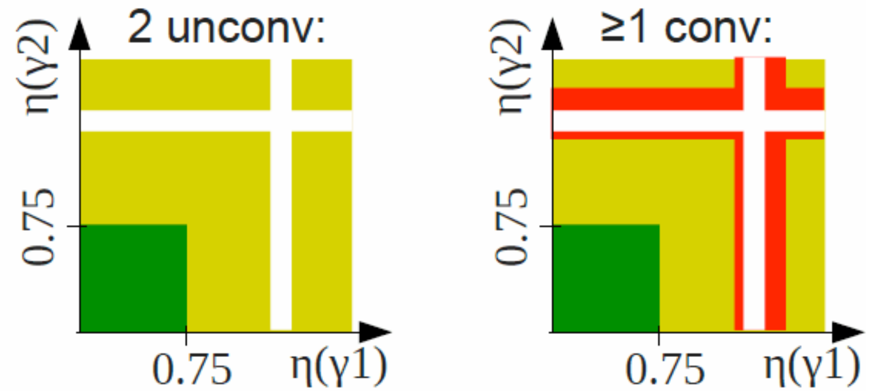
- Link to paper: Phys. Rev. Lett. 108, 111803 (2012)
- Diphoton trigger (E_T > 20 GeV)
- Photon selection:
  - Fiducial cuts: $|\eta| < 2.37$, excluding crack $1.37 < |\eta| < 1.52$
  - Isolation: E_T,corrected < 5 GeV (cone size ΔR=0.4)
  - Tight identification
  - p_T cuts: 40 GeV (leading photon), 25 GeV (subleading photon)
- Pointing algorithm to deduce the directions of the two photons
- Invariant diphoton mass must be in the range 100-160 GeV
- 22 489 events found in 4.9 fb^{-1}

$H \to \gamma\gamma$

- 9 categories based on:
  - converted/unconverted photons
  - 3 eta regions
  - $p_{Tthrust}$



$$\hat{t} = \frac{\vec{p}_T^{\gamma 1} - \vec{p}_T^{\gamma 2}}{\|\vec{p}_T^{\gamma 1} - \vec{p}_T^{\gamma 2}\|}$$



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Category	conversion	eta	pTt
1	both unconverted	both |η| <0.75	< 40 GeV
2			> 40 GeV
3		one |η| >0.75	< 40 GeV
4			> 40 GeV
5	at least one converted	both |η| <0.75	< 40 GeV
6			> 40 GeV
7		one |η| >0.75	< 40 GeV
8			> 40 GeV
9		one 1.3 <|η| < 1.75	

Hoping to add the VBF category

$VH(\rightarrow bb)$

- The exclusive 2-jet, 2-btag bin is used for the VH→bb analyses (with asymmetric p_T cuts of 25, 45 GeV)

- Analysis performed in the following p_T^V bins: <50, 50-100, 100-150, 150-200, >200, except for in Z→vv channel (bins of E_T^{miss} 120-160, 160-200, >200)

- Baseline signal MC is LO scaled to NNLO QCD+NLO EW inclusive cross section (additional scaling vs p_T^V for NLO EW corrections)

- Systematic uncertainties in the theory predictions calculated from:
  - Standard scale/pdf uncertainties in inclusive computation
  - Difference between the inclusive and differential NLO EW corrections (due to an approximation in how the correction is applied)
  - Difference between cut efficiencies vs p_T^V at hadron level between Powheg+Herwig and Pythia (several effects here)

- Systematic uncertainties in the m_{bb} shape (vs p_T^V) for the V+hf backgrounds calculated comparing aMC@NLO, Powheg+Pythia/Herwig and Alpgen

Bin	$ZH \to \ell^+\ell^- b\bar{b}$ p_T^Z[GeV]				$WH \to \ell\nu b\bar{b}$ p_T^W[GeV]				$ZH \to \nu\bar{\nu}b\bar{b}$ E_T^{miss}[GeV]		
	0-50	50-100	100-200	>200	0-50	50-100	100-200	>200	120-160	160-200	>200
Number of events for $80 < m_{b\bar{b}} < 150$ [GeV]											
Data	139	164	62	13	622	597	276	15	103	22	24
Signal	1.4 ± 0.2	2.0 ± 0.3	1.7 ± 0.3	0.4 ± 0.1	4.7 ± 0.9	5.2 ± 1.0	4.1 ± 0.9	1.4 ± 0.3	2.3 ± 0.5	1.3 ± 0.3	1.8 ± 0.5
Top	18	25	7	0	260	383	219	8.6	42	9	4
W+jets	-	-	-	-	285	181	72	12	13	7	4
Z+jets	132	126	58	5.6	0.4	0.3	0.1	0.0	33	12	7
Diboson	8	6	4	1	13	13	8	1	5	5	4
Multijet	-	-	-	-	64	42	4	1	1.2	0.2	0.4
Total Bkg	157 ± 15	157 ± 11	70 ± 7	6 ± 2	625 ± 36	620 ± 24	303 ± 13	23 ± 4	94 ± 10	33 ± 5	20 ± 5
Components of the Background Systematic Uncertainties [%]											
B-tag Eff	3.1	2.8	2.2	7.7	1.4	1.7	2.5	11.3	4.1	9.2	15.6
Bkg Norm	5.2	5.0	5.2	5.6	4.0	2.8	2.7	5.5	3.1	3.9	4.2
Jets/E_T^{miss}	1.0	2.8	3.5	3.1	2.1	1.6	1.6	6.4	8.2	10.7	16.9
Leptons	0.4	0.5	1.1	3.6	1.0	0.4	0.7	6.1	-	-	-
Luminosity	0.2	0.1	0.2	0.4	0.1	0.1	0.1	0.2	0.2	0.5	0.8
Pile Up	0.7	1.8	1.5	6.9	0.6	0.7	1.1	2.5	0.7	2.6	1.9
Theory	7.3	1.7	7.2	23.4	3.1	1.0	1.1	11.9	3.7	6.3	11.1
Total Bkg	9.6	6.9	10.0	26.6	5.8	3.9	4.4	19.6	10.4	16.1	26.0
Components of the Signal Systematic Uncertainties [%]											
B-tag Eff	10	11	13	16	10	11	13	15	13	16	21
JES/MET	6.5	4.6	4.0	3.7	6.7	6.8	7.8	4.7	11.0	5.4	9.9
Leptons	1.1	1.5	1.5	3.6	3.2	4.2	5.0	5.5	-	-	-
Luminosity	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Pile Up	0.7	1.2	2.4	3.4	1.4	3.9	3.2	3.4	0.5	0.8	2.1
Theory	5	5	5	5	13	13	13	13	13	13	13
Total Signal	13.6	13.3	14.9	18.3	18.5	19.4	21.4	21.5	21.8	21.7	26.8

Parton Showering and FSR Questions/Considerations

- How do we establish the impact of the b-jet FSR after the Higgs decay and its uncertainties?

- Is there any interplay to be considered between the b-jet FSR and the NNLO calculations?

- How can we constrain the impact of the parton shower tune on jet substructure observables and/or ΔR distributions between jets?

Background Modeling Questions/Considerations

- How can we estimate uncertainties when only NLO/NNLO predictions (w/o PS) are available (see already previous slide)?

- Do we need to worry about the stability of the calculations after our phase space cuts (which include angular variables)? (for ttjj, or W+jets for instance)

- How can we get a good idea of the importance of interference between processes (single-top and W+bb, for instance) and estimate a correction?

Jets for Charged Higgs

Searches till today didn't use:

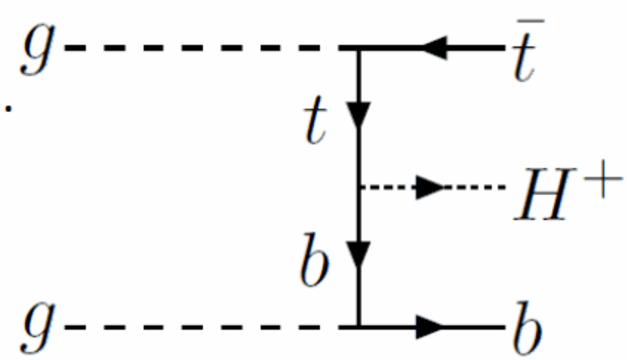
- jet binning.
- central jet veto.
- jet clusterization in the boosted regime.

Moving to heavier Charged Higgs ($M_{H^+} > M_{top}$):

- New production mechanism (more jets in the event).
- New decay possible (can decay to hadronic top +bjet).

$\downarrow$

- Increasing the Higgs width.



Issues to think about:

- Uncertainties from jet/bjet counting (2/3/4 b jets).
- Overlap between ttbar and ttbb/ttcc (only alpgen has a tool for solution).
- NLO (MC and xsec) for a Charged Higgs at 300-600 GeV

Parton shower effect in VBF bin (for ggF and VBF signal)

- Comparison of Powheg+pythia to Powheg+Herwig
- Efficiency of each cut wrt the one before (except inclusive which is wrt to total):

ggF	Powheg +pythia	Powheg +Herwig
inclusive	0,350	0,350
rel. diff (%)		*-0,1*
2 jets:	0,093	0,103
rel. diff (%)		*11,7*
$\|\Delta\eta jj\|$ cut	0,242	0,263
rel. diff (%)		*8,8*
mjj cut	0,386	0,370
rel. diff (%)		*-4,3*
$\|\Delta\varphi(\gamma\gamma\text{-}jj)\|$ cut	0,804	0,809
rel. diff (%)		*0,7*

VBF	Powheg +pythia	Powheg +Herwig
inclusive	0,380	0,378
rel. diff (%)		*-0,7*
2 jets:	0,567	0,567
rel. diff (%)		*0,0*
$\|\Delta\eta jj\|$ cut	0,737	0,725
rel. diff (%)		*-1,6*
mjj cut	0,738	0,733
rel. diff (%)		*-0,8*
$\|\Delta\varphi(\gamma\gamma\text{-}jj)\|$ cut	0,932	0,935
rel. diff (%)		*0,3*

- Number of expected events:

	Powheg + pythia			Powheg + Herwig			rel diff. (%)
	ggF	VBF	tot	ggF	VBF	tot	
0-jet	63.34	3.80	67.69	63.75	3.80	67.55	-0.2
2-jet	0.45	1.53	1.98	0.52	1.49	2.02	1.7

17% diff 0.2% diff

- Additional uncertainty to be added?

Underlying effect in VBF bin (for ggF and VBF signal)

- Comparison of two pythia tunes: AMBT2 and Perugia2011
- Efficiency of each cut wrt the one before (except inclusive which is wrt to total):

ggF	default tune	Perugia tune
inclusive	0,350	0,351
rel. diff (%)		*0,1*
2 jets:	0,093	0,100
rel. diff (%)		*8,1*
|Δηjj| cut	0,242	0,272
rel. diff (%)		*12,3*
mjj cut	0,386	0,405
rel. diff (%)		*4,9*
|Δφ(γγ-jj)| cut	0,804	0,816
rel. diff (%)		*1,6*

VBF	default tune	Perugia tune
inclusive	0,380	0,381
rel. diff (%)		*0,0*
2 jets:	0,567	0,586
rel. diff (%)		*3,3*
|Δηjj| cut	0,737	0,740
rel. diff (%)		*0,4*
mjj cut	0,738	0,753
rel. diff (%)		*2,0*
|Δφ(γγ-jj)| cut	0,932	0,937
rel. diff (%)		*0,5*

- Number of expected events:

	DEFAULT			PERUGIA2011			rel. diff.
	ggF	VBF	ggF+VBF	ggF	VBF	ggF+VBF	(%)
inclusive	64.34	5.33	69.67	64.42	5.34	69.76	0.1
0-jet	63.34	3.80	67.69	63.85	3.70	67.55	-0.2
2-jet	0.45	1.53	1.98	0.58	1.63	2.21	11.6

30% diff 6% diff

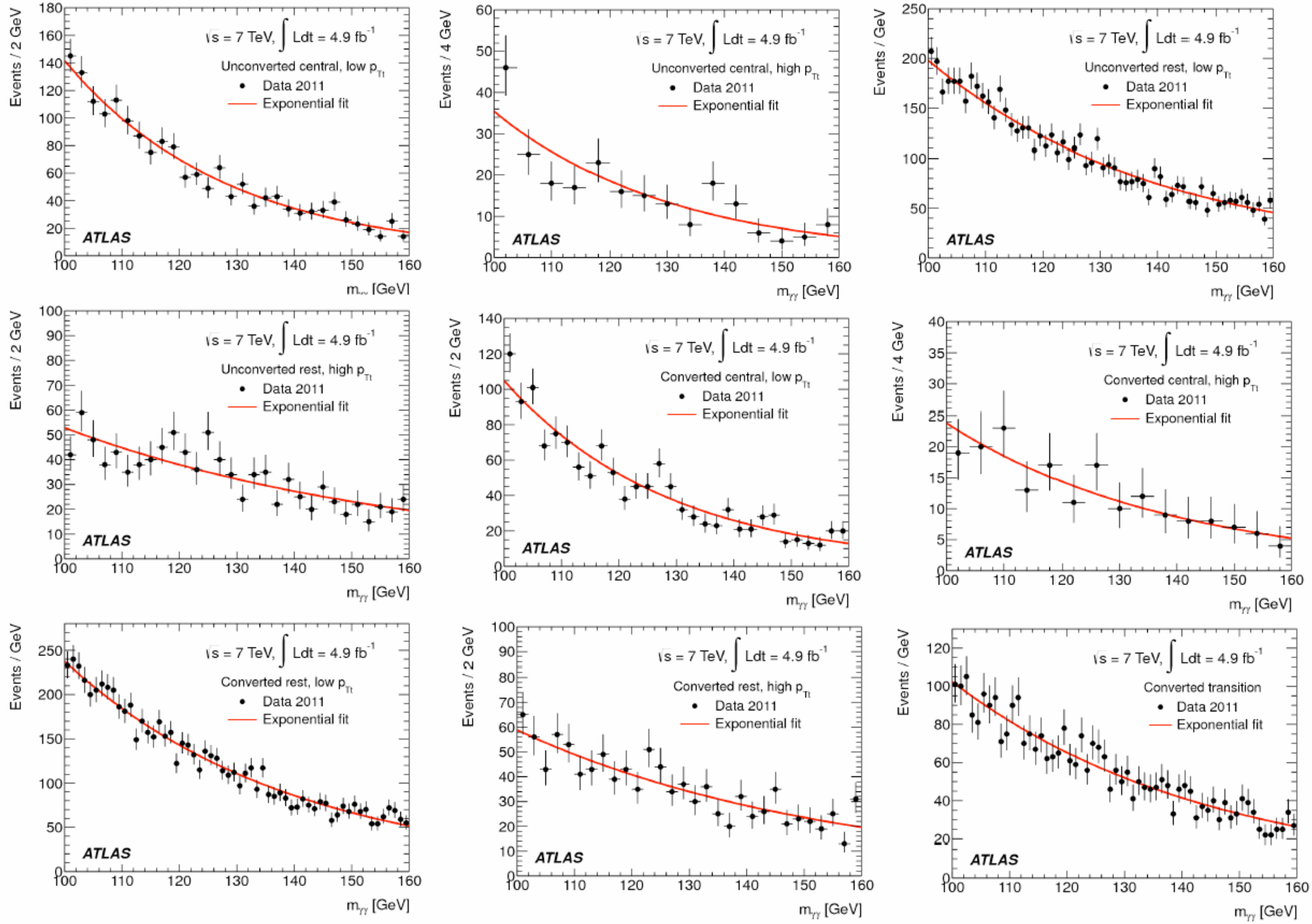
- Additional uncertainty to be added?

Points for Discussion

Jet binning us used widely at ATLAS

- ❑ **Use the S.T. procedure (method B)**
  - ❑ **In the short term we will stick to it, but we are open to other methods, as well**
- ❑ **Need coherent treatment of the uncertainties of VBF and VH (tth too?)**
- ❑ **Need coherent treatment of the jet veto uncertainties in the VBF bin**
- ❑ **Need to agree on the theory errors due to soft physics (important for VBF, also for ggF+2j?)**
- ❑ **Need to address issues raised by the VH(→bb) and heavy charged higgs search**

Additional Slides



√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Unconverted central, low p_Tt
Data 2011
Exponential fit
ATLAS
Events / 2 GeV
m_γγ [GeV]
√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Unconverted central, high p_Tt
Data 2011
Exponential fit
ATLAS
Events / 4 GeV
m_γγ [GeV]
√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Unconverted rest, low p_Tt
Data 2011
Exponential fit
ATLAS
Events / GeV
m_γγ [GeV]
√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Unconverted rest, high p_Tt
Data 2011
Exponential fit
ATLAS
Events / 2 GeV
m_γγ [GeV]
√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Converted central, low p_Tt
Data 2011
Exponential fit
ATLAS
Events / 2 GeV
m_γγ [GeV]
√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Converted central, high p_Tt
Data 2011
Exponential fit
ATLAS
Events / 4 GeV
m_γγ [GeV]
√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Converted rest, low p_Tt
Data 2011
Exponential fit
ATLAS
Events / GeV
m_γγ [GeV]
√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Converted rest, high p_Tt
Data 2011
Exponential fit
ATLAS
Events / 2 GeV
m_γγ [GeV]
√s = 7 TeV, ∫ Ldt = 4.9 fb^-1
Converted transition
Data 2011
Exponential fit
ATLAS
Events / GeV
m_γγ [GeV]