$4\ell + \text{MET}$: Status Report

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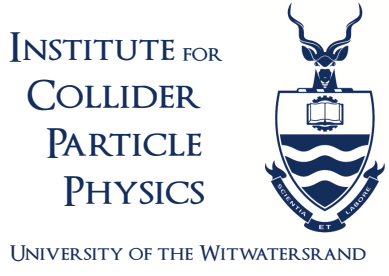


Background model
Template fit

- The *qqZZ* and *ggZZ* backgrounds were modeled using three functions, see slides 16 and 17 here.
- Now we combined background processes into different templates, depending on their shapes.
- Then use the functions below to fit the templates:

$$f^{qqZZ,ggZZ,qqZZEW,VVV,WZ,t\bar{t}}(m_{4\ell}) = C_0 H(m_0 - m_{4\ell})(f_2(m_{4\ell})) + H(m_{4\ell} - m_0) f_3(m_{4\ell}),$$

where:

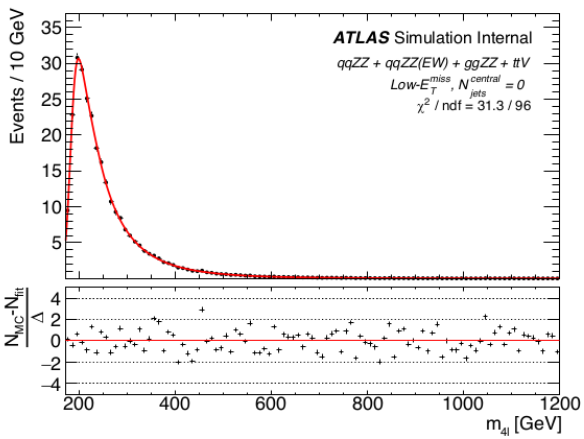
$$f_2(m_{4\ell}) = \left\{\frac{1}{2} + \frac{1}{2} erf\left(\frac{m_{4\ell} - b_1}{b_2}\right)\right\} \frac{1}{1 + \exp\left(\frac{m_{4\ell} - b_1}{b_3}\right)} \left\{\frac{1}{2} + \frac{1}{2} erf\left(\frac{m_0 - b_1}{b_2}\right)\right\} \frac{1}{1 + \exp\left(\frac{m_0 - b_1}{b_3}\right)},$$

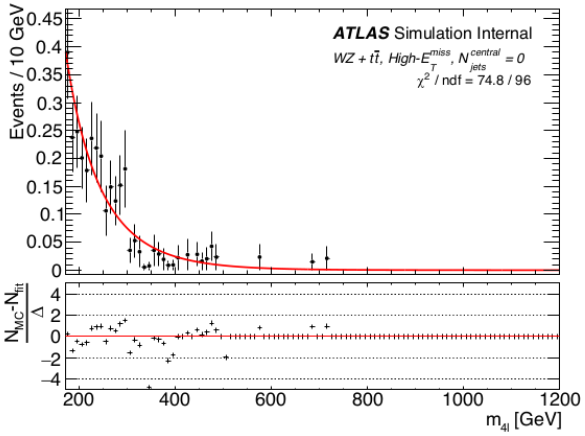
$$f_3(m_{4\ell}) = \left(1 - \frac{m_{4\ell}}{13000}\right)^{c_1} \left\{\left(\frac{m_{4\ell}}{13000}\right)^{c_2} + c_3 log\left(\frac{m_{4\ell}}{13000}\right)\right\} \frac{1}{1 - \frac{1 - m_0}{13000})^{c_1}} \left\{\left(\frac{m_0}{13000}\right)^{c_2} + c_3 log\left(\frac{m_0}{13000}\right)\right\},$$

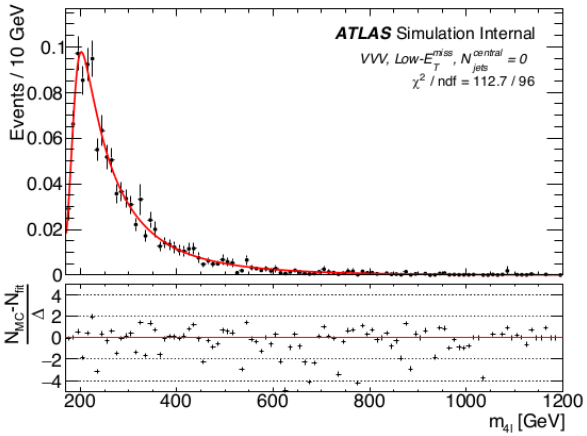
$$C_0 = \frac{f_3(m_0)}{f_2(m_0)}.$$

- Notice that, we removed the exponential function that describes the lower mass region.
- Because we rise the lower range to be $>$ 170 GeV for the new model.

Background model
Template fit



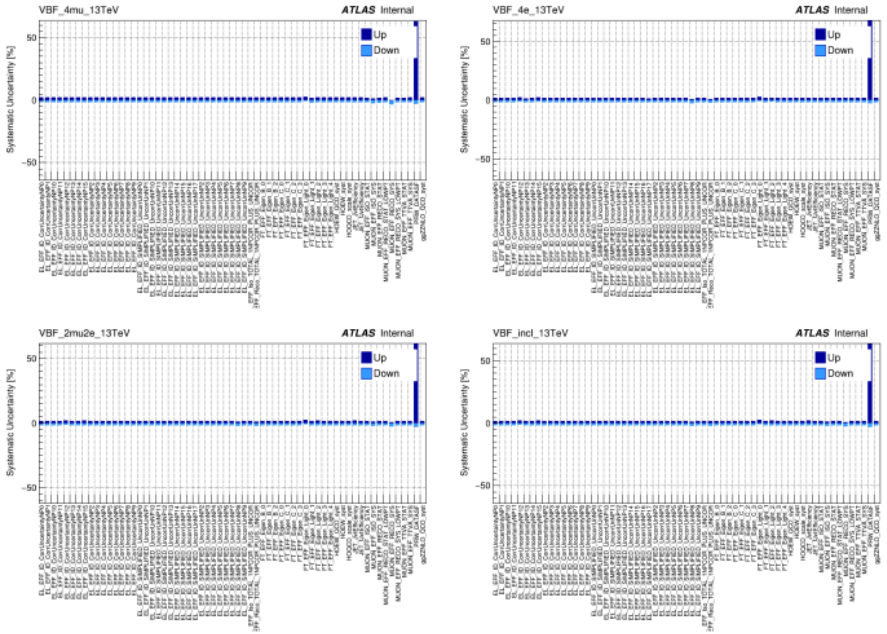




- In total, we have three templates:
  - $qqZZ$, $qqZZ(EW)$, $ggZZ$, and $t\bar{t}V$
  - WZ and $t\bar{t}$
  - VVV
- The plots are shown for LowE_{T}^{miss} and $N_{\mathrm{jets}}^{central}$ category only.
- We decided to remove the $Z + jets$ background from the fit.
- Because it has only about one event for all the categories together, see the cutflow table on the backup slides.

Summary

- We studied a new background model by merging backgrounds together.
- The model fit using analytical function seems to describe background templates.
- AZH samples are ready JIRA. , and DAOD request is almost done
- I started looking at the optimization procedures.
- The bug on the systematic code is fixed, but now there's a problem with PRW.



Thank you!

Additional slides

Event Selection	
QUADRUPLET SELECTION	- Require at least one quadruplet of leptons consisting of two pairs of same-flavour opposite-charge leptons fulfilling the following requirements: - p_T thresholds for three leading leptons in the quadruplet: 20, 15 and 10 GeV - At most 1 calo-tagged, stand-alone or silicon-associated muon per quadruplet - Leading di-lepton mass requirement: $50 < m_{12} < 106$ GeV - Sub-leading di-lepton mass requirement: $m_{\text{threshold}} < m_{34} < 115$ GeV - $\Delta R(\ell, \ell') > 0.10$ for all lepton pairs in the quadruplet - Remove quadruplet if alternative same-flavour opposite-charge di-lepton gives $m_{\ell\ell} < 5$ GeV - Keep all quadruplets passing the above selection
ISOLATION NEEDS UPDATING	- Contribution from the other leptons of the quadruplet is subtracted - Muon track isolation ($\Delta R = 0.30$): $\Sigma p_T / p_T < 0.15$ - Muon calorimeter isolation ($\Delta R = 0.20$): $\Sigma E_T / p_T < 0.30$ - Electron track isolation ($\Delta R = 0.20$) : $\Sigma E_T / E_T < 0.15$ - Electron calorimeter isolation ($\Delta R = 0.20$) : $\Sigma E_T / E_T < 0.20$
IMPACT PARAMETER SIGNIFICANCE	- Apply impact parameter significance cut to all leptons of the quadruplet - For electrons: $d_0/\sigma_{d_0} < 5$ - For muons: $d_0/\sigma_{d_0} < 3$
BEST QUADRUPLET	- If more than one quadruplet has been selected, choose the quadruplet with highest Higgs decay ME according to channel: 4μ, $2e2\mu$, $2\mu2e$ and $4e$
VERTEX SELECTION	- Require a common vertex for the leptons: - $\chi^2/\text{ndof} < 5$ for 4μ and < 9 for others decay channels

Additional slides
Cutflow table

	$qqZZ^*$	$ggZZ^*$	$qqZZ^*$ EW	$t\bar{t}V$	VVV	$Z+jets$	WZ	$t\bar{t}$	Expected
4ℓ	2516.52±4.50	348.96±0.71	32.85±0.28	8.60±0.05	19.04±0.11	10.35±8.28	5.12±0.34	2.68±0.20	2944.13±14.48
b-veto	2451.45±4.47	341.64±0.70	30.67±0.27	2.14±0.02	18.48±0.11	10.35±8.28	4.96±0.33	1.77±0.15	2861.46±14.34
$N_{\text{Jets}}^{\text{central}} = 0$	1625.63±3.87	212.93±0.56	3.10±0.11	0.41±0.01	9.40±0.07	9.69±8.27	2.85±0.26	0.78±0.08	1864.79±13.23
$p_{\text{T}}^{4\ell} > 30$ & $\text{metSig} > 2.0$	82.73±0.94	21.12±0.18	0.51±0.03	0.33±0.01	7.22±0.07	0.32±0.32	1.69±0.19	0.53±0.07	114.44±1.80
$p_{\text{T}}^{4\ell} > 15$ & $\text{metSig} > 1.5$	258.04±1.74	58.30±0.29	0.99±0.04	0.37±0.01	8.17±0.07	1.82±1.54	2.13±0.21	0.65±0.07	330.47±3.99
$N_{\text{Jets}}^{\text{central}} \geq 1$	825.82±2.24	128.71±0.43	27.56±0.25	1.73±0.02	9.08±0.08	0.66±0.35	2.11±0.21	0.99±0.12	996.67±3.71
$p_{\text{T}}^{4\ell} > 10$ & $\text{metSig} > 3.5$	10.46±0.23	2.25±0.06	0.30±0.02	0.93±0.02	4.68±0.06	0.01±0.01	0.76±0.13	0.63±0.11	20.02±0.63
$p_{\text{T}}^{4\ell} > 0$ & $\text{metSig} > 2.5$	51.55±0.66	10.66±0.13	1.35±0.05	1.25±0.02	6.19±0.07	0.01±0.01	1.09±0.15	0.75±0.11	72.83±1.19

- The ZZ^* estimated to be 97% of the total background.
- 85% from $qqZZ$, 11% from $ggZZ$, and 1% from $qqZZ(EW)$.
- The rest of backgrounds combined are $\sim$ 3%.