Search for high mass particles in $WW \rightarrow l\nu\ l\nu$ and $ZZ \rightarrow ll\ \nu\nu$ final states at ATLAS

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Overview

- We human beings are not satisfied with the current framework of physics: dark matter, mass hierarchy, asymmetry between matter and anti-matter, quantum gravity, naturalness......are still not understood
- We are looking for something new by different methods according to tastes: precision measurement of the parameters of the SM, putting a detector on the space station or underground, searching new particles on colliders......
- Di-boson final state is sensitive to the structure of SM, and is a good choice for searching new physics on colliders: the 2 TeV hint in WW/WZ, the 750 GeV dis-appearance in $\gamma\gamma$......
- On LHC, the leptonic signature is more clean than the hadronic one

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This talk is about searching for new particles in di-boson final states by leptonic decays:
$WW \to l\nu\ l\nu$ and $ZZ \to ll\ \nu\nu$

Search for a high-mass Higgs boson decaying into $WW \to l\nu\ l\nu$

ATLAS-CONF-2016-074

Introduction to the analysis

- The information of the two leptons (different flavor) and E_T^{miss} is used to identify the signal by defining a transverse mass: m_T
- The single lepton triggers are used for both electron and muon
- Main backgrounds are WW, top, W+Jet, Drell-Yan, non-WW diboson, h(125)
- Signal interpretation: narrow width approximation and large width approximation higgs-like particles produced by ggF (VBF) in the mass range between 300 (400) GeV and 3000 GeV

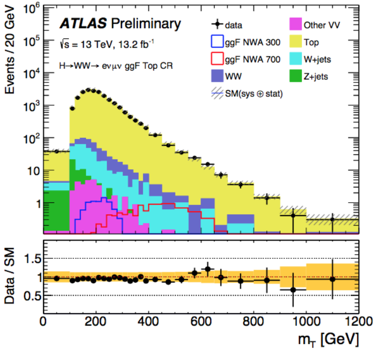
Signal region and control region definition

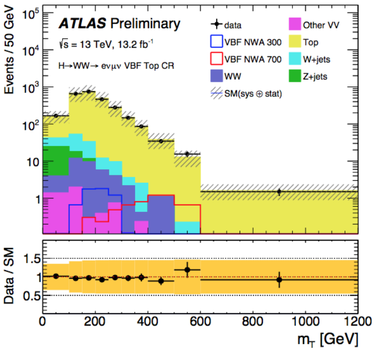
$\mathrm{SR}_{\mathrm{ggF}}$	$\mathrm{SR}_{\mathrm{VBF1J}}$	$\mathrm{SR}_{\mathrm{VBF2J}}$
Preselection cuts: $p_{\mathrm{T}}^{\mathrm{lead}} > 25\,\mathrm{GeV}$, $p_{\mathrm{T}}^{\mathrm{sublead}} > 15\,\mathrm{GeV}$, 3rd lepton veto, $m_{\ell\ell} > 10\,\mathrm{GeV}$		
$N_{b\text{-jet}} = 0$ $\lvert\Delta\eta_{\ell\ell}\rvert < 1.8$ $m_{\ell\ell} > 55\,\mathrm{GeV}$ $p_{\mathrm{T}}^{\mathrm{lead}} > 45\,\mathrm{GeV}$ $p_{\mathrm{T}}^{\mathrm{sublead}} > 30\,\mathrm{GeV}$ $\max(m_{\mathrm{T}}^{W}) > 50\,\mathrm{GeV}$		
Inclusive in N_{jet} but excluding VBF1J and VBF2J phase space	$N_{\mathrm{jet}} = 1$ $\lvert\eta_j\rvert > 2.4$ $\min(\lvert\Delta\eta_{j\ell}\rvert) > 1.75$	$N_{\mathrm{jet}} \geq 2$ $m_{jj} > 500\,\mathrm{GeV}$ $\lvert\Delta y_{jj}\rvert > 4$

WW $\mathrm{CR}_{\mathrm{ggF}}$	Top $\mathrm{CR}_{\mathrm{ggF}}$	WW $\mathrm{CR}_{\mathrm{VBF1J}}$	Top $\mathrm{CR}_{\mathrm{VBF}}$
Preselection cuts: $p_{\mathrm{T}}^{\mathrm{lead}} > 25\,\mathrm{GeV}$, $p_{\mathrm{T}}^{\mathrm{sublead}} > 15\,\mathrm{GeV}$, 3rd lepton veto, $m_{\ell\ell} > 10\,\mathrm{GeV}$			
$N_{b\text{-jet}} = 0$ $\lvert\Delta\eta_{\ell\ell}\rvert > 1.8$	$N_{b\text{-jet}} = 1$ $\lvert\Delta\eta_{\ell\ell}\rvert < 1.8$	$N_{b\text{-jet}} = 0$ $(\lvert\Delta\eta_{\ell\ell}\rvert > 1.8$ or $m_{\ell\ell} < 55\,\mathrm{GeV})$ $p_{\mathrm{T}}^{\mathrm{lead}} > 25\,\mathrm{GeV}$ $p_{\mathrm{T}}^{\mathrm{sublead}} > 25\,\mathrm{GeV}$ –	$N_{b\text{-jet}} \geq 1$ – – $p_{\mathrm{T}}^{\mathrm{lead}} > 25\,\mathrm{GeV}$ $p_{\mathrm{T}}^{\mathrm{sublead}} > 15\,\mathrm{GeV}$ –
$m_{\ell\ell} > 55\,\mathrm{GeV}$ $p_{\mathrm{T}}^{\mathrm{lead}} > 45\,\mathrm{GeV}$ $p_{\mathrm{T}}^{\mathrm{sublead}} > 30\,\mathrm{GeV}$ $\max(m_{\mathrm{T}}^{W}) > 50\,\mathrm{GeV}$			
Excluding VBF VBF1J and VBF2J		VBF1J phase space	VBF1J or VBF2J phase space

Data/MC comparison in top control region

The post-fit normalisation factors (NF) from a simultaneous fit to all signal and control regions are $0.95^{+0.09}_{-0.08}$ and $0.96^{+0.13}_{-0.14}$ in the ggF (left) and the VBF (right) CRs.

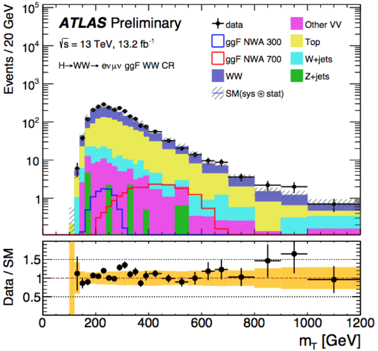


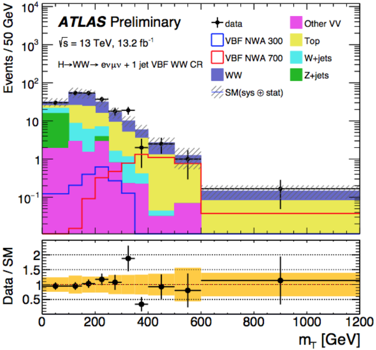


The post-fit purity is 87% in the ggF and 81% in the VBF category.

Data/MC comparison in WW control region

The NF is $1.3^{+0.2}_{-0.1}$ for quasi-inclusive ggF (left) control region, and $1.2^{+0.5}_{-0.3}$ for VBF 1 Jet (right) control region.





The purity is 52% for quasi-inclusive ggF CR and 45% for VBF 1 Jet CR.

Data driven $W + Jets$ background estimation

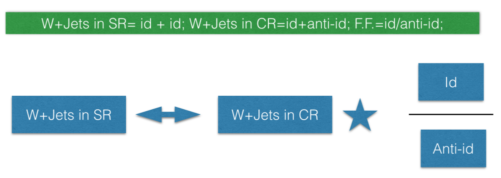
Why the $W + Jets$ could be the background?

One jet is mis-identified as a lepton by one of the following ways: heavy flavour hadron decays, punch through, gamma conversion......

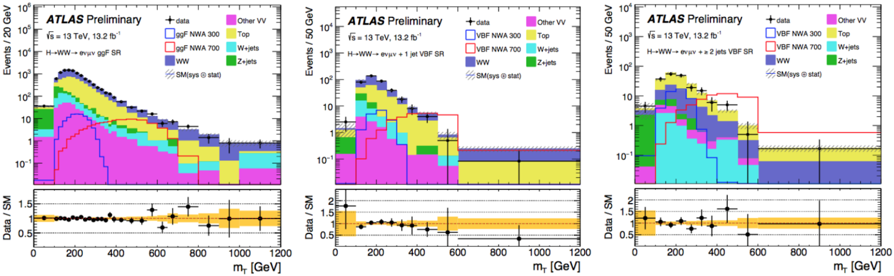
Why data driven?

W+Jet cross section is very large, thus we can not afford a MC simulation with the same luminosity as data; and the fake mechanism is too complicated to be simulated well.

Fake factor method



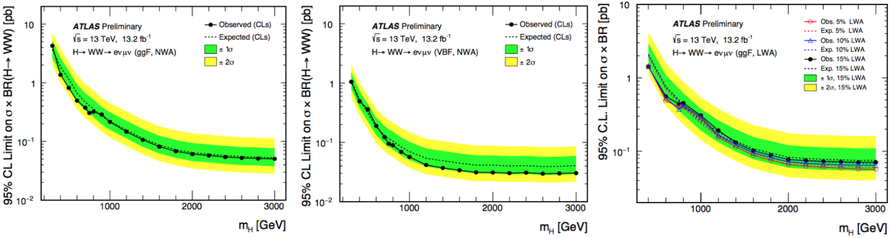
The data is consistent with background



ggF (left), VBF-1Jet (middle), VBF-2Jet (right)

Result and interpretation

Upper limit for high mass higgs-like particles is set



NWA-ggF (left), NWA-VBF (middle), LWA-ggF (right)

Search for a high-mass new particle decaying into $ZZ \to ll\ \nu\nu$

ATLAS-CONF-2016-056

Introduction to the analysis

- The final state signature is same as the analysis before, however the two leptons are from the same Z boson decays, thus the definition of the transverse mass is different

$$(m_{\mathrm{T}}^{ZZ})^2 \equiv \left(\sqrt{m_Z^2 + \left|p_{\mathrm{T}}^{\ell\ell}\right|^2} + \sqrt{m_Z^2 + \left|E_{\mathrm{T}}^{\mathrm{miss}}\right|^2} \right)^2 - \left|\vec{p}_{\mathrm{T}}^{\,\ell\ell} + \vec{E}_{\mathrm{T}}^{\mathrm{miss}}\right|^2$$

~~$$m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - |\mathbf{p}_{\mathrm{T}}^{\ell\ell} + \boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}}|^2}$$~~

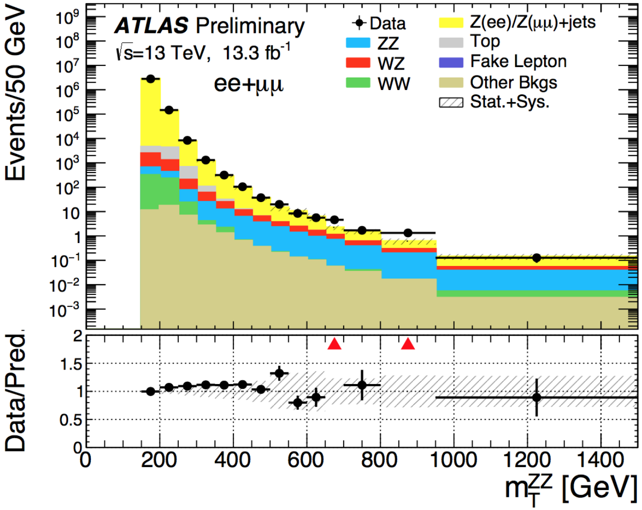
- Main background: ZZ, WZ, Z+Jets, non-resonant-ll
- Signal interpretation: narrow width higgs-like particle, RS graviton

Event selection

Pre-selection		
	Exact one pair of ee or $\mu\mu$	
	$p_T > 30$ (20) GeV	
	$\|m_{ll} - m_Z\| < 15$ GeV	
	Topology selection	
Variable	Cut value	Function
E_T^{miss}	>120 GeV	Reduce Z+Jets
ΔR_{ll}	<1.8	Z is boosted
$\|\Delta\phi(\vec{p}_T^{ll}, \vec{E}_T^{miss})\|$	>2.7	Momentum balance
$\|p_T^{missjet} - p_T^{ll}\|/p_T^{ll}$	<0.2	Momentum balance
$\|\Delta\phi(jets, \vec{E}_T^{miss})\|$	>0.4	Reduce jet mis-measurement
p_T^{ll}/m_T	<0.7	Reduce bad E_T^{miss}
Number of b-jets	=0	Reduce top background

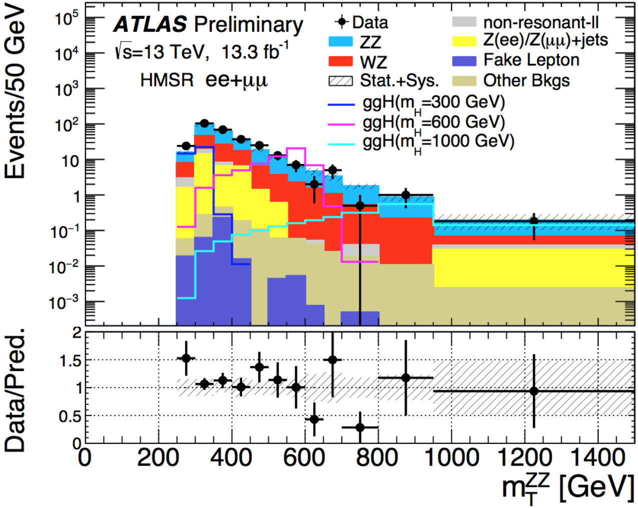
Data and MC comparison after pre-selection

The background modeling is good even at pre-selection level

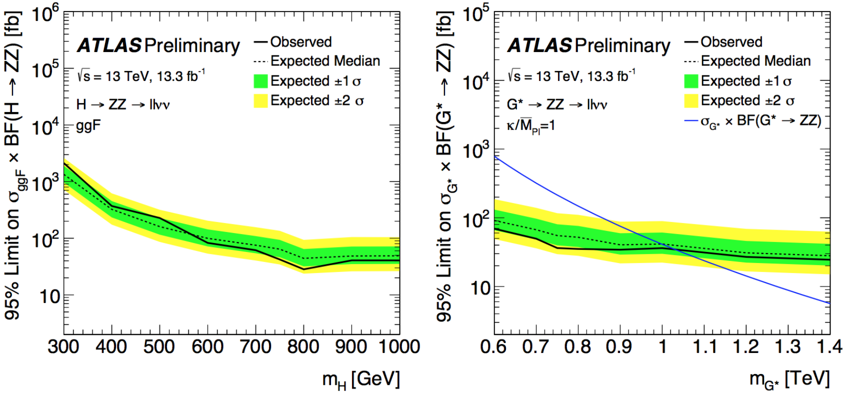


Data and MC comparison in the signal region

The data is consistent with background



Result and interpretation



higgs-like particle (left), graviton (right)

Summary

- New particles are searched in $WW \to l\nu\ l\nu$ and $ZZ \to ll\ \nu\nu$ final states!
- All of them escaped from the excellent ATLAS detector!
- The capture is still ongoing, and we have more data now!

Your questions and Comments are welcome!