Search for standard model Higgs in $H \rightarrow WW \rightarrow llvv$ channel in ATLAS at $\sqrt{s} = 7\text{TeV}$

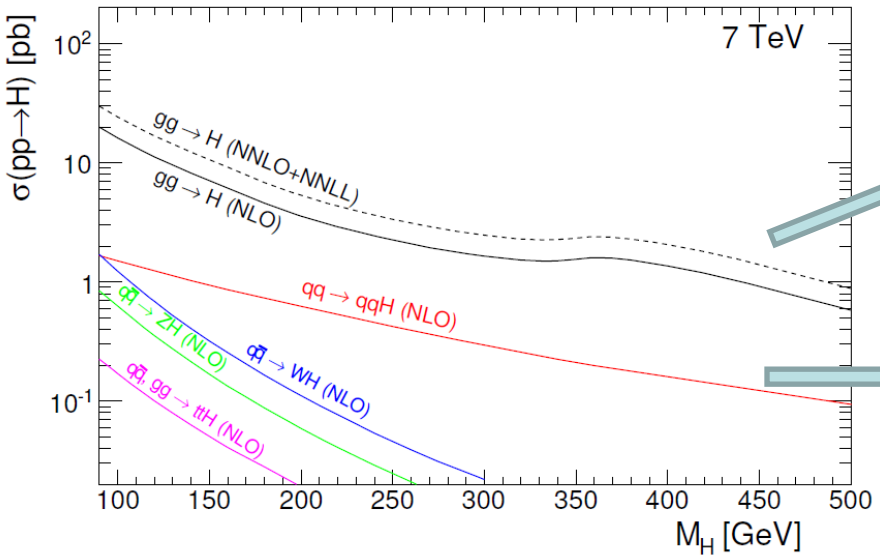
By Hao Liu

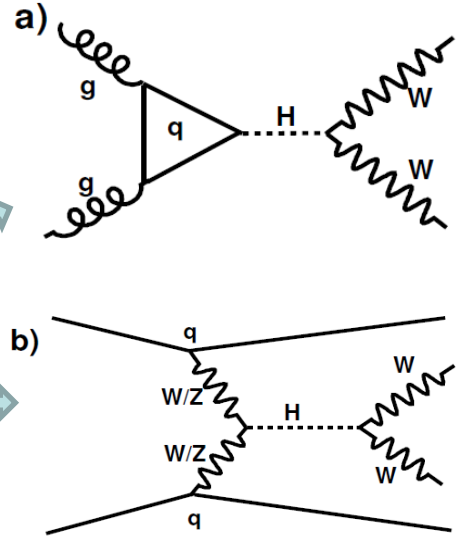
University of Michigan

On the behalf of the ATLAS Collaboration

Higgs Hunting
July 29-31. 2010, Orsay-France

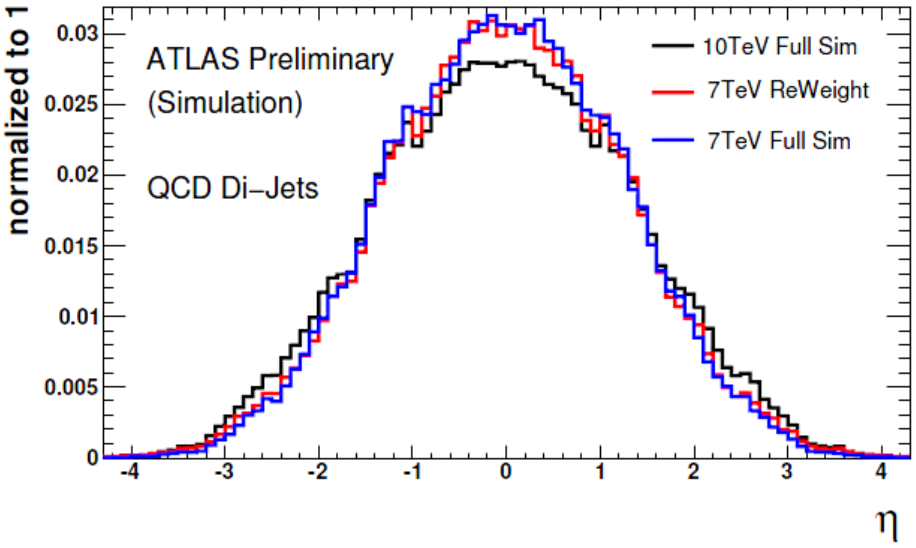
$H \rightarrow WW \rightarrow llvv$ at $\sqrt{s} = 7\text{TeV}$





➢**Next-leading-order (NLO) cross-sections are used for both signal and backgrounds**

PDF re-weighting and cross-section scaling



➢**Two methods are used to convert 10 TeV Monte Carlo (MC) for 7TeV analysis**

➢**They give consistent results with 7 TeV full simulated MC**

Signal and Backgrounds

Signal processes

- The signal events are required to have two opposite charged leptons with p_T > 15 GeV, |η| < 2.5 , E_T^{miss} > 30 ($e\mu$) or 40 (ee, $\mu\mu$) GeV and 0, 1 or 2 jets with p_T > 20 GeV, |η| < 3 (*H+1j*) or 4.8 (*H+2j*)
- The vector boson fusion signal has two widely separated jets

Background processes

- Standard model *WW* production is the domiant background for *H+0j*
- Top background ($t\bar{t}$ and single top) is a background for *H+1j* and *H+2j*
- *W+jets* with one mis-identified lepon is the major instrumental background
- Other backgrounds : *Z/γ*+jets, WZ/ZZ,* QCD, *γ+jets*

Trigger

- Single lepton trigger with threshold p_T > 10 GeV

Pile-up

- The pile-up effect is about 3% at instantaneous luminosity $10^{32}cm^{-2}s^{-1}$
- For the first 1 fb^{-1}, the expected LHC luminosity is less than $10^{32}cm^{-2}s^{-1}$

WW Background

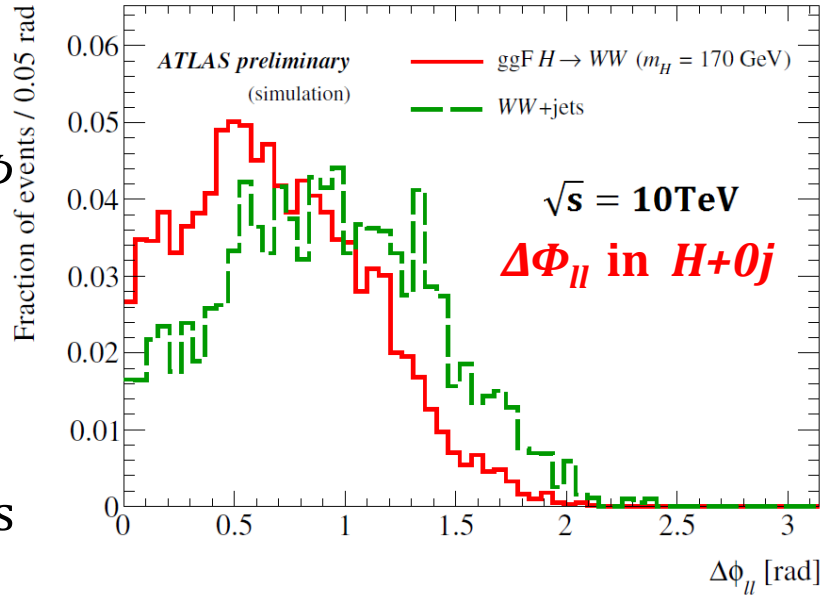
Signal region

- Small opening angle of two leptons in Φ ($\Delta\Phi_{ll}$)

Control region

- All the selections are same as signal region except $\Delta\Phi_{ll}$ cut is reversed
- Subtract top and *W+jets* contaminations using top and *W+jets* control samples
- Scale factor α is used to extrapolate the background in the signal region :

$$N_{S.R.}^{bkg} = N_{C.R.}^{bkg} \times \alpha$$



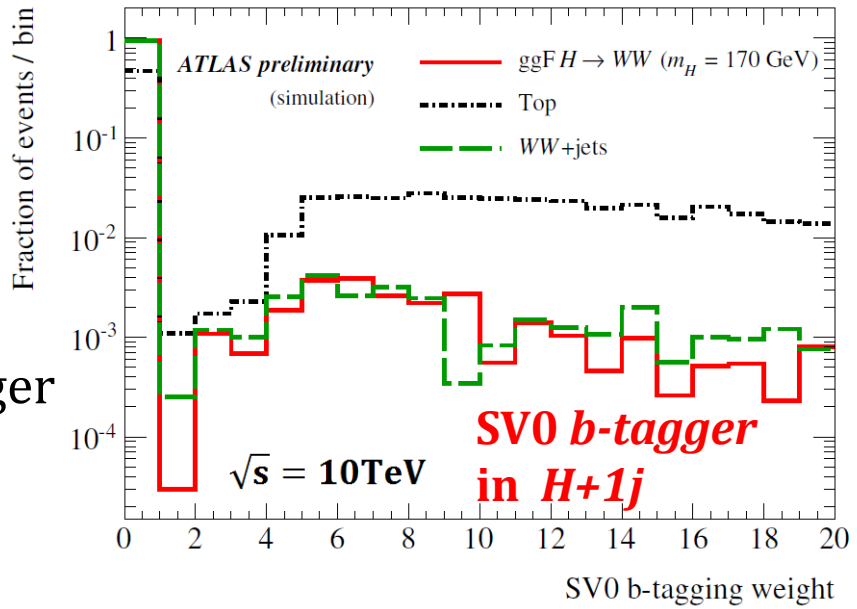
Top Background

Signal region

- b-jet veto using secondary vertex tagger

Control region

- One lepton + four jets for H+0j
- Reverse b-jet veto for H+1j
- Reverse b-jet veto and jets separation for H+2j



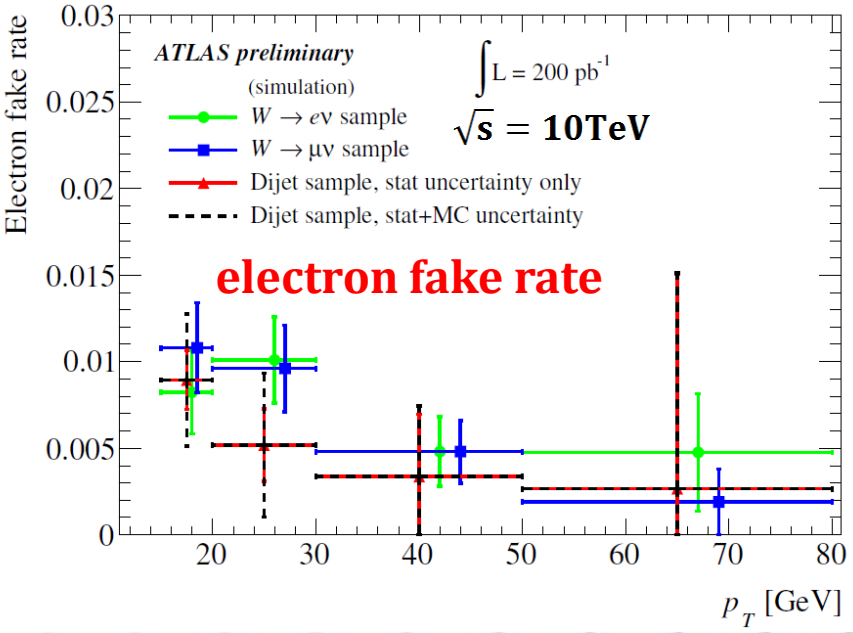
W+jets Background

Signal region

- Apply lepton quality cut on both leptons to suppress the lepton mis-identification rate (fake rate)

Control region

- Select a *W+jets* dominated region with one lepton passing the full identification and isolation requirements and one lepton passing a similar but loosened selection
- Multiply by the fake rate to estimate *W+jets* contribution in the signal region



Other Backgrounds

- *Z/γ**+jets background : invariant mass cut : m_{ll} > 50 GeV and not in [80, 100] GeV
- *WZ/ZZ* background : third lepton veto
- QCD background : lepton isolation to reduce the misidentification rate

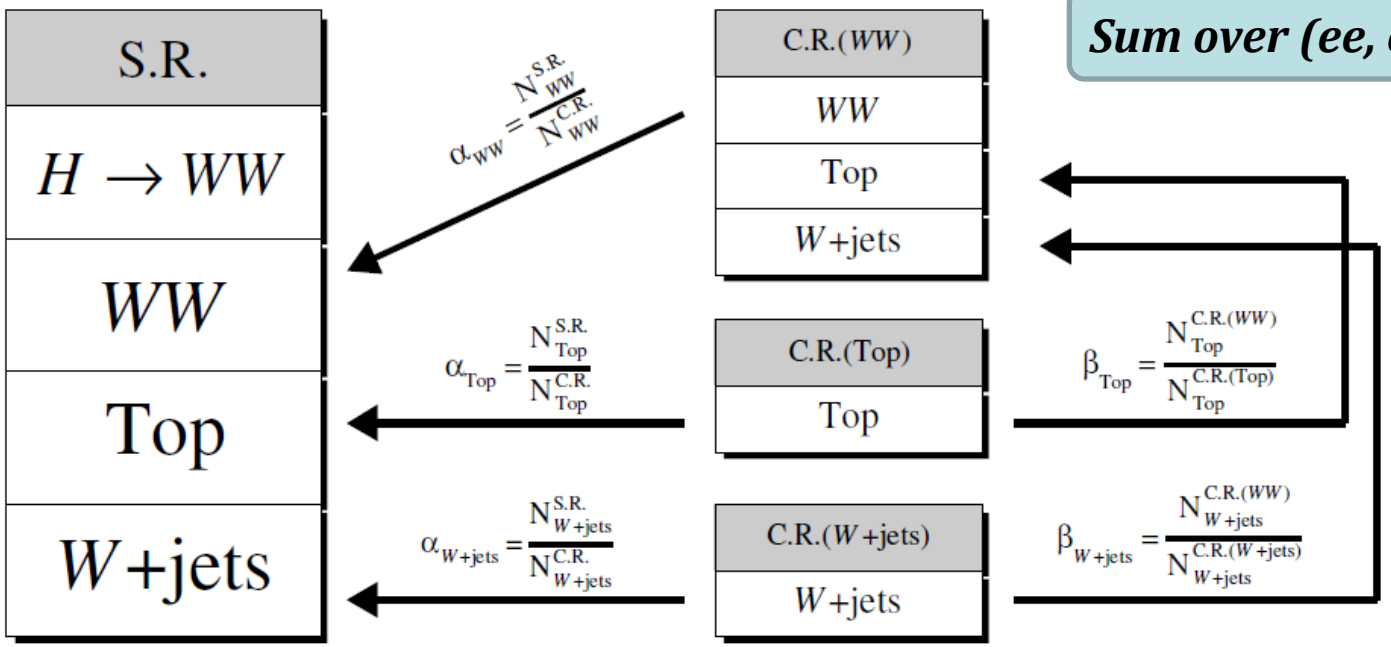
Small contribution in the signal region , estimated by MC

Summary for Signal and Backgrounds

Signal and main backgrounds event number at 1 fb^{-1} in the signal region

M_H (GeV)	120	130	140	150	160	170	180	190	200
SM WW	26.3	35.4	43.8	50.1	55.2	58.5	60.6	61.7	62.4
top	4.9	6.7	9.1	11.6	14.0	16.3	17.2	17.9	18.2
W+jets	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Total background	36.8	47.7	58.5	67.3	74.8	80.4	83.4	85.2	86.2
Signal	4.1	10.4	18.5	26.3	39.5	35.4	26.2	16.8	11.0

Sum over (ee, eμ, μμ) × (0j, 1j, 2j)



α :scale factor from control region to signal region

β :scale factor from control region to control region

Systemtics and 95% C.L. Exclusion Limit

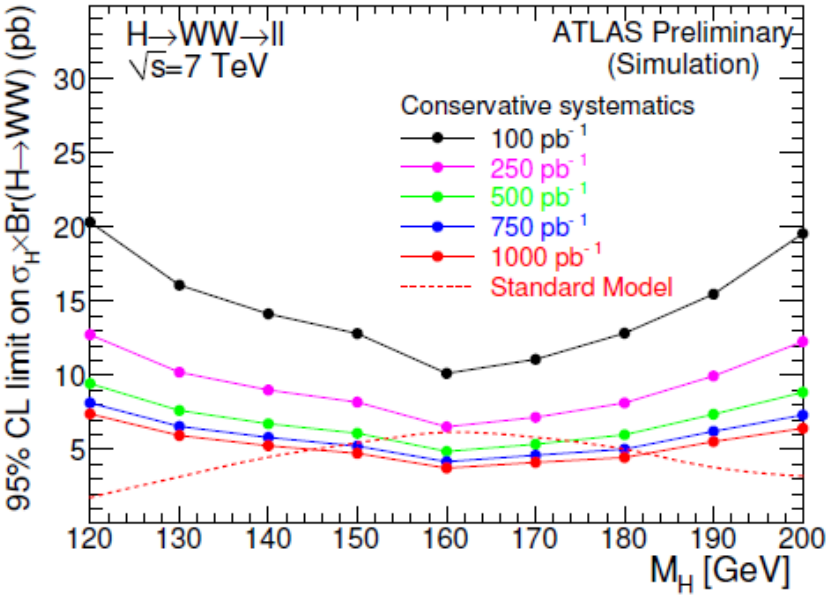
Conservative systematics: **systematics from 10 TeV analysis**

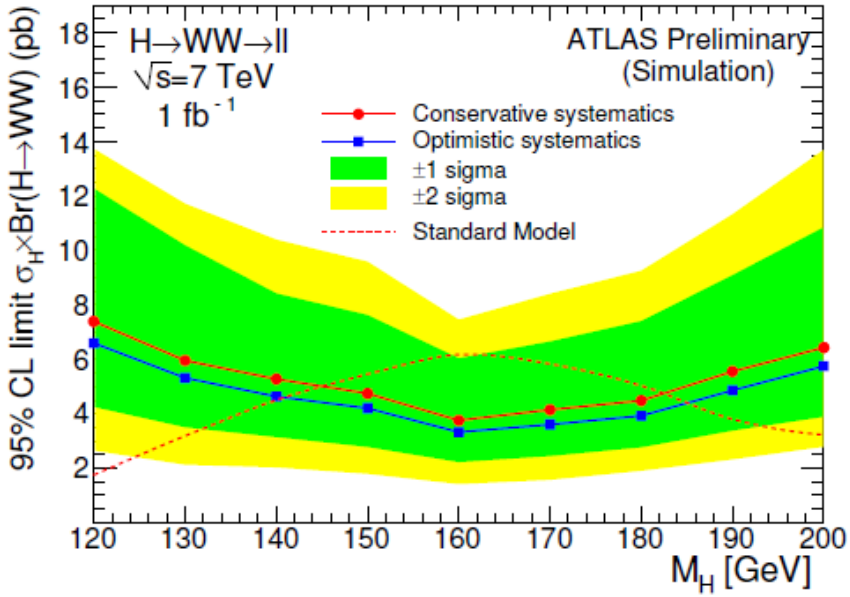
Analysis channel	$\sigma_{\alpha_{WW}}$	$\sigma_{\alpha_{top}}$	$\sigma_{\alpha_{W+\text{jets}}}$	$\sigma_{\beta_{top}}$	$\sigma_{\beta_{W+\text{jets}}}$
$H+0j$	7.3%	108%	100%	74%	100%
$H+1j$	17%	52%	91%	20%	78%
$H+2j$	54%	43%	–	18%	–

Dominated by limited MC statistics

Optimistic systematics : **capping the top and *W+jets* backgrounds systematics at 10%**

Combined exclusion limit at 95% C.L.





Summary

- Study $H \rightarrow WW \rightarrow llvv$ from gluon-gluon fusion and vector boson fusion production with different lepton flavors and jet multiplicities in the final state at $\sqrt{s} = 7\text{TeV}$
- Use the data-driven methods to estimate the major background : standard model *WW,* top *and W+jets*
- Use MC to estimate other backgrounds *Z/γ*+jets, WZ/ZZ,* QCD, *γ+jets*

ATLAS will exclude the Higgs mass range from 140 to 180 GeV, if it is not there, at 95% C.L. with 1 fb^{-1} integrated luminosity ($\sqrt{s} = 7\text{TeV}$) in $H \rightarrow WW \rightarrow llvv$ channel using optimistic systematics

Backup: profile likelihood method

Likelihood function $L(\mu, \theta)$

μ: scale factor for signal normalization (μ =1 is Standard Model)

θ: nuisance parameters, e.g. background number in the signal region

Log Likelihood Ratio $\lambda(\mu) = L\left(\mu, \hat{\hat{\theta}}\right) / L\left(\hat{\mu}, \hat{\theta}\right)$

Numerator: likelihood from test or data, i.e. SM without Higgs

Denominator: null hypothesis, i.e. SM with Higgs m_H = 170 GeV, ($\hat{\mu} = 1$)

Likelihood Maximization

Numerator : μ is fixed to the hypothesis, maximized by $\hat{\hat{\theta}}$

Denominator : maximized over $\left(\hat{\mu}, \hat{\theta}\right)$

Ensemble tests to reject the hypothesis 95% C.L

Use $0.5\chi^2$ distribution of $-2log(\lambda(\mu))$ to calculate μ *at which p-value is equal to 0.05*

Likelihood function for multiple channels

The combined likelihood function is a product of multiple Poisson and Gaussian terms. Each Poisson term corresponds the number counting in a signal or control region and each Gaussian term corresponds the systematic error of α or β

Backup: systematics

	α_{WW}	α_{top}	α_{W+jets}	β_{top}	β_{W+jets}
$H+0j$ analysis					
WW MC Q^2 Scale	5.1%	–	–	–	–
Top MC Q^2 Scale	–	27%	–	12%	–
Jet E Scale + Resolution	1.5%	66%	3%	61%	3%
b-tagging eff.	–	4.3%	–	4.3%	–
Wt contribution	–	40%	–	40%	–
MC Statistics	5.3%	71%	100%	8%	100%
Total Uncertainty	7.3%	108%	100%	74%	100%
$H+1j$ analysis					
WW MC Q^2 Scale	11%	–	–	–	–
Top MC Q^2 Scale	–	23%	–	7%	–
Jet E Scale + Resolution	9%	27%	20%	11%	57%
b-tagging eff.	–	34%	–	15%	–
MC Statistics	10.1%	17%	89%	6%	53%
Total Uncertainty	17.2%	52%	91%	20%	78%
$H+2j$ analysis					
WW MC Q^2 Scale	45%	–	–	–	–
Top MC Q^2 Scale	–	38%	–	8%	–
Jet E Scale + Resolution	15%	8%	–	2.5%	–
b-tagging eff.	0.4%	10%	–	16%	–
MC Statistics	27%	17%	–	1.4%	–
Total Uncertainty	54%	43%	–	18%	–

- The dominant systematic error is from limited MC statistics
- Other small systematics, e.g. lepton identification uncertainty, are neglected