Evidence for Higgs using H→WW^*→$l\nu l\nu$ decay mode in the ATLAS detector at LHC

FCPPL team(2012)

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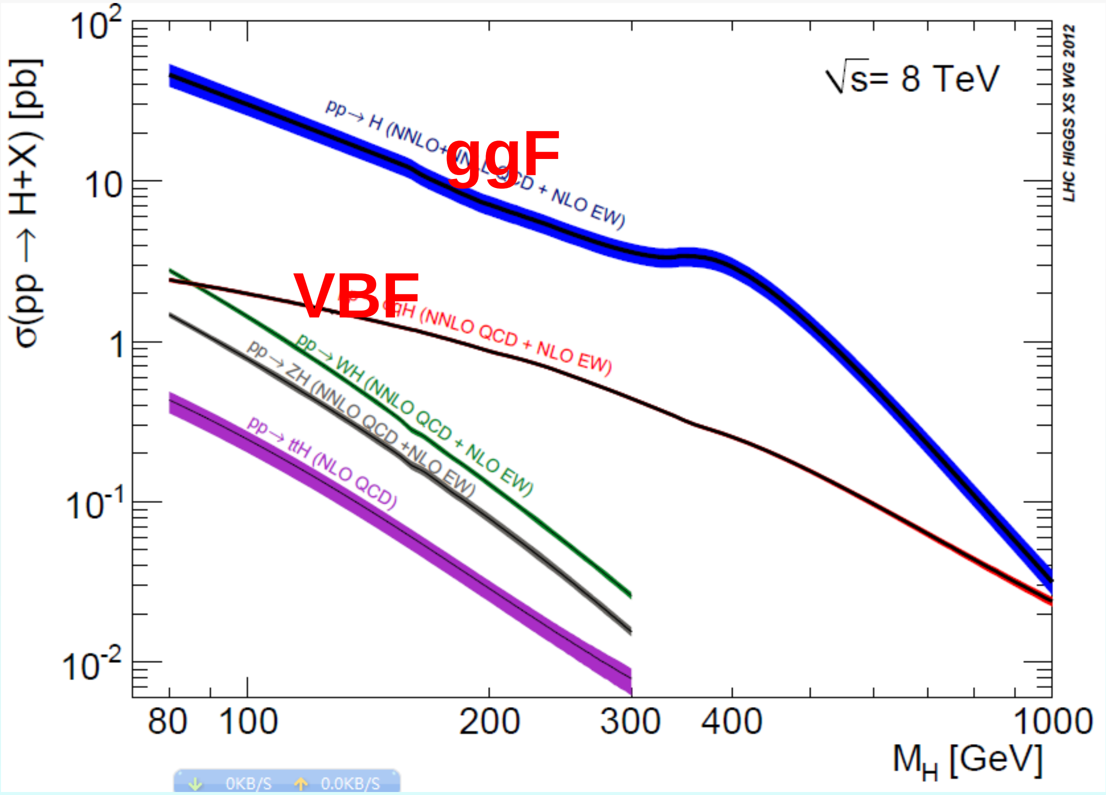
Outline

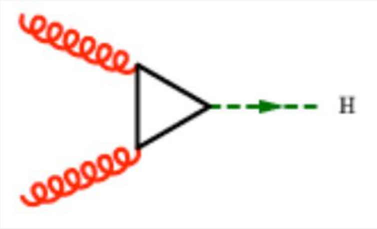
- Introduction
- The evidence
- Our main contribution
- Future plan

Higgs Production

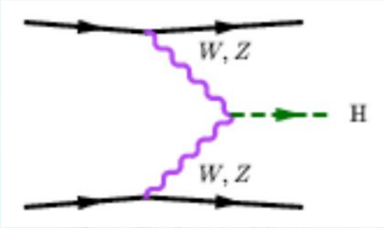
- Higgs is predicted by Standard Model of particle physics, who gives mass to all other massive particles.
- Production mechanisms:



ggF

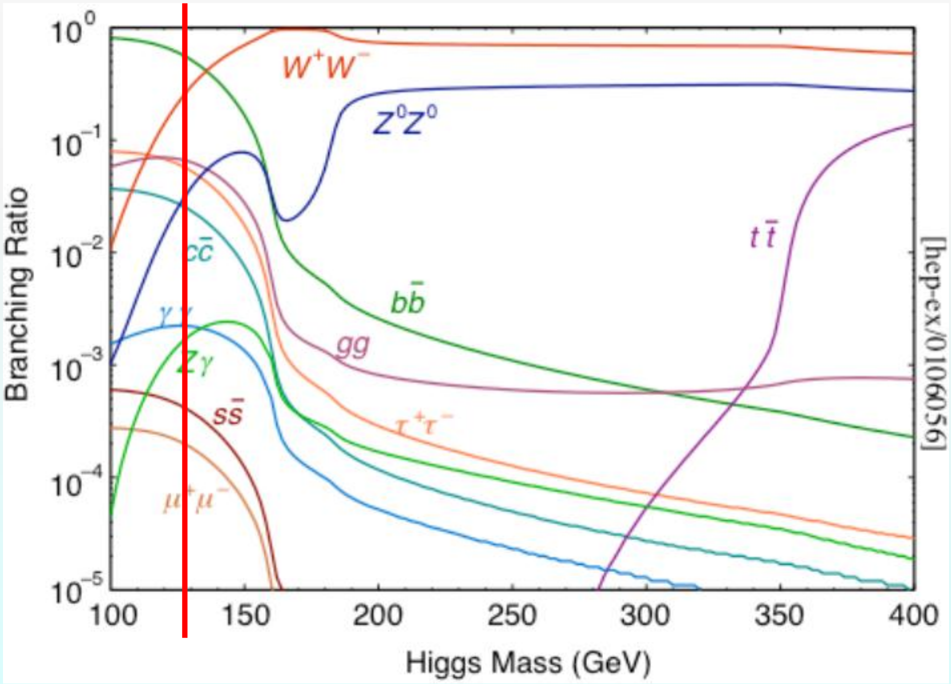


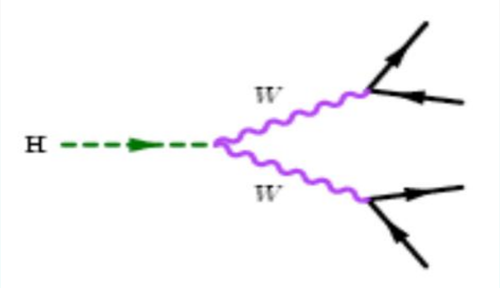
VBF



H→WW decay

- Higgs has several main decay channels:
- H→WW^*→lνlν channel covers a wide m_H range.
- HWW Decay Product:
  - Two high energy leptons
  - Missing energy(denoted as E_T^{miss}) due to invisible nutrinos



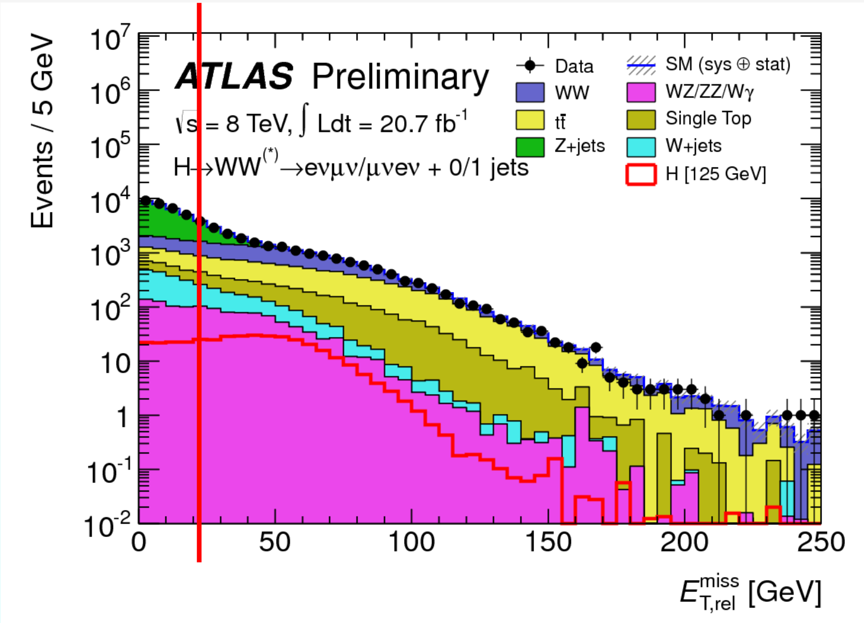


Background Processes

- Potential backgrounds(have similar final state products as H→WW):
- t$\bar{t}$ and Wt: t/ $\bar{t}$→W^+/W^-+b/ $\bar{b}$
- Non resonant WW production
- W+jets: one jet might be recognized as a lepton
- Z/γ^*+jets: Z/γ^*→l^+l^-, fake E_T^{miss} from fail reconstructed jets
- WZ, W γ and Wγ^*: one lepton of three is not well constructed.
- ZZ: Z→l^+l^-

Event Selection I

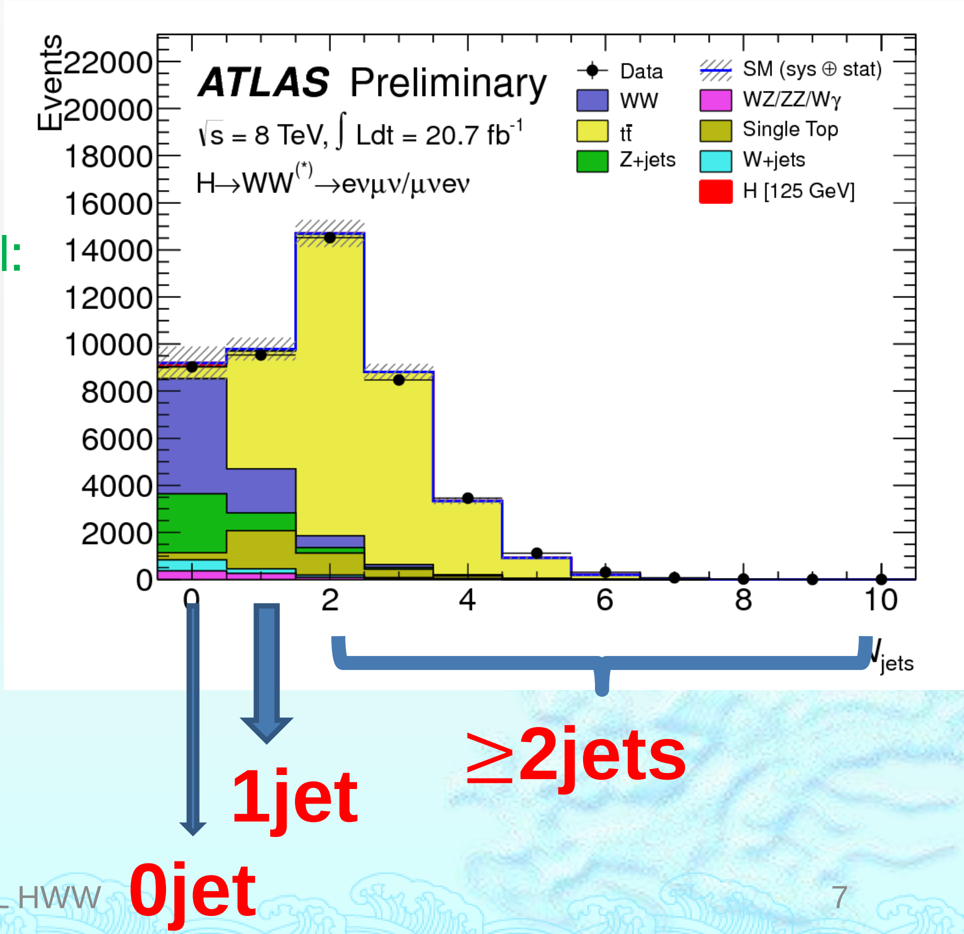
- Cuts are designed to filter those backgrounds, while keeping the signal.
- Two high energy opposite sign leptons. Suppress W+jets.
- Low m_{ll} cut, suppress low mass γ^*+jets
- Z veto: requiring m_{ll} far away from m_Z, suppress Z+jets
- Low $E_{T,rel}^{miss}$ and $P_{T,rel}^{miss}$ cut, suppress Z/γ^*+jets



Event Selection II

- The analysis is further divided into 3 sub-channels according to the jet multiplicity. (since the backgrounds composition are different in each jet channel)
- Cuts special to each sub-channel:
  - Bjet veto in 1jet and ≥2jets
  - Z→$\tau\tau$ veto in 1jet and ≥2jets
- Cuts common to each sub-channel:
  - Upper cut for m_{ll}
  - Small $\Delta\varphi_{ll}$(spin correlation)

Signal	ggF 125 GeV	VBF 125 GeV
0 jet	60.8%	8.5%
1 jet	26.8%	37.7%
2 jets	13.1%	54.4%

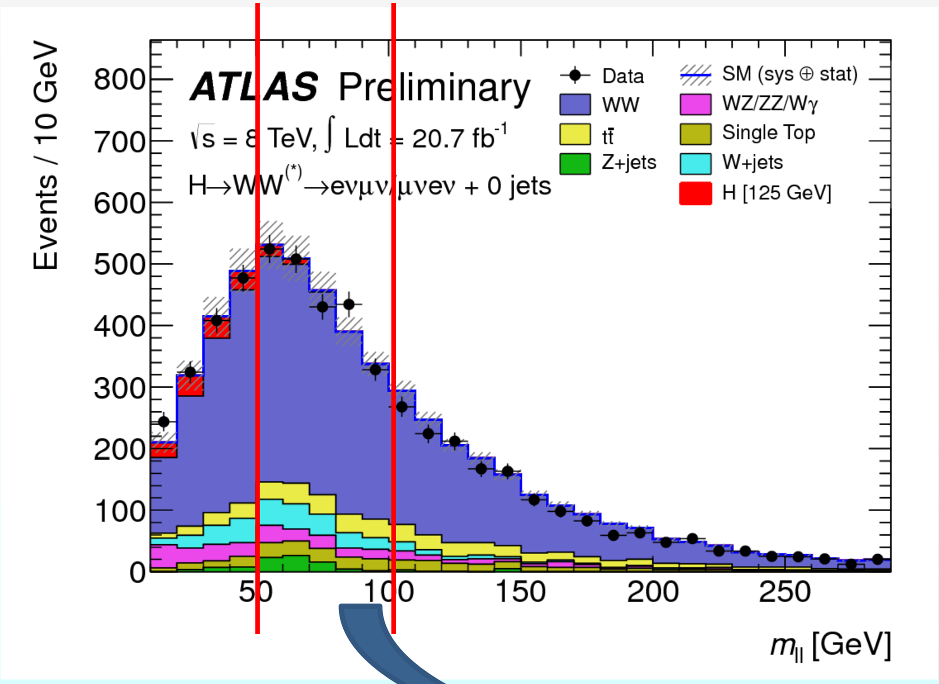


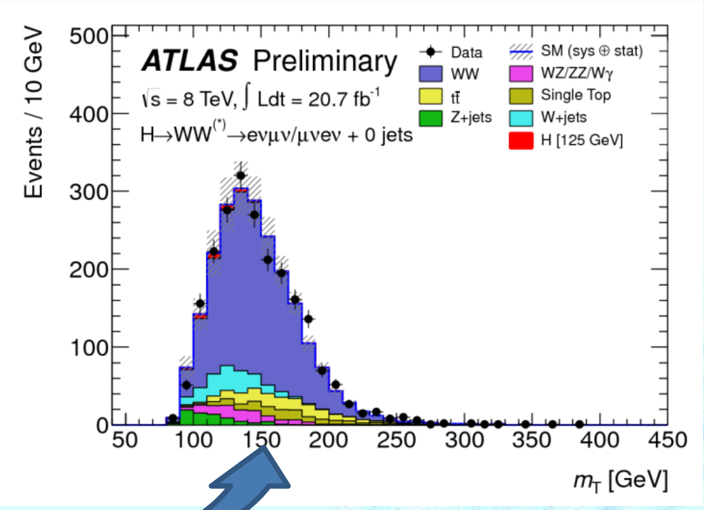
Background determination

- General idea: use data whenever possible
- W+jets: fully data-driven
- WW, top, Z+jets use Control regions to fix the MC with the NF
- WZ/ZZ/Wγ^*, small contribution, MC based

$$m_T = \sqrt{(E_T^{ll} + E_T^{vv})^2 - (\vec{p}_T^{\,ll} + \vec{p}_T^{\,miss})^2}$$

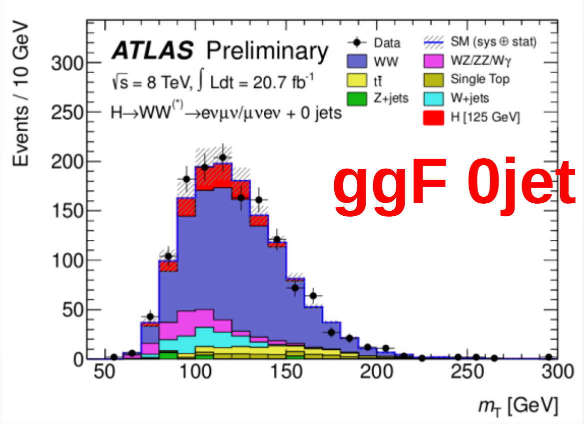
$$E_T^{ll} = \sqrt{\vec{p}_T^{\,ll\,2} + m_{ll}^{\,2}} \text{ and } E_T^{ll} = |p_T^{miss}|$$

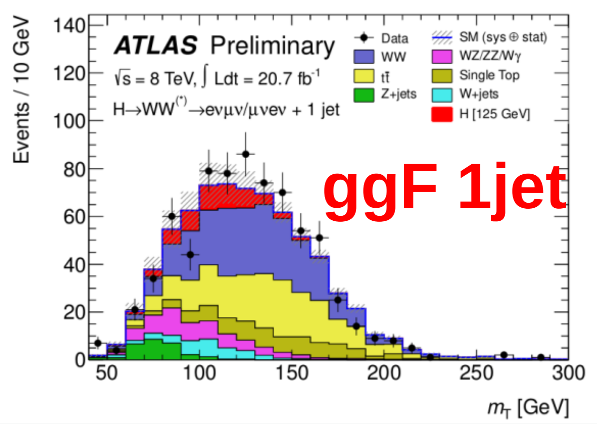


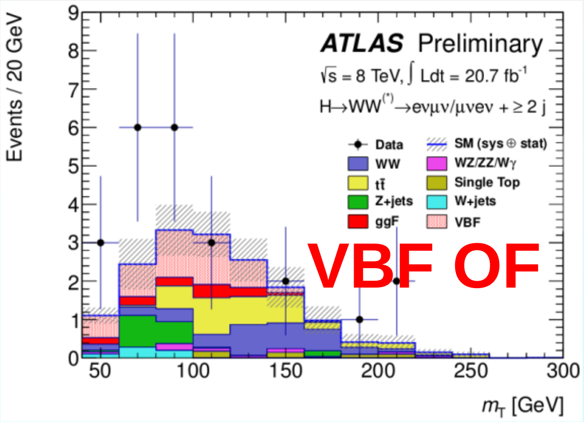


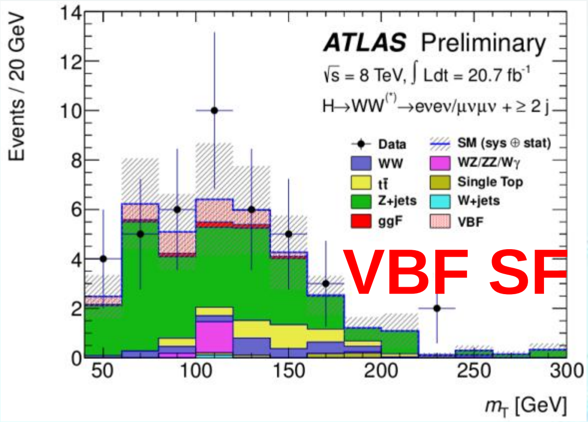
The Evidence: m_T distribution

- m_T distribution of the final selected sample of all jet multiplicity channels.(input for the fit)



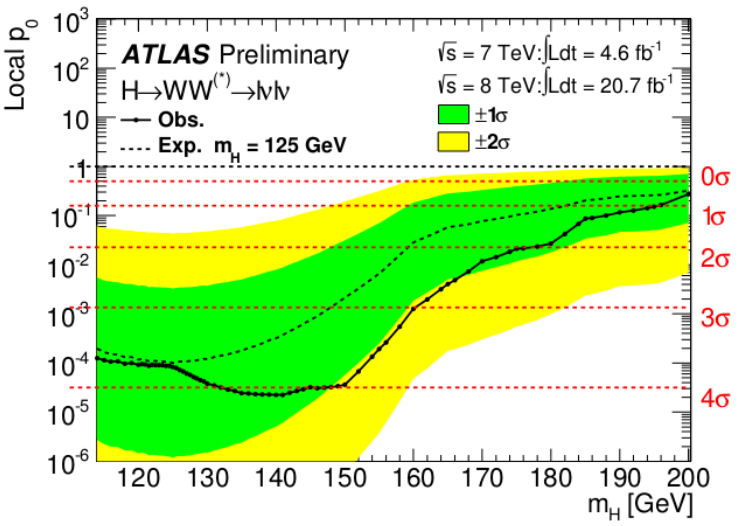


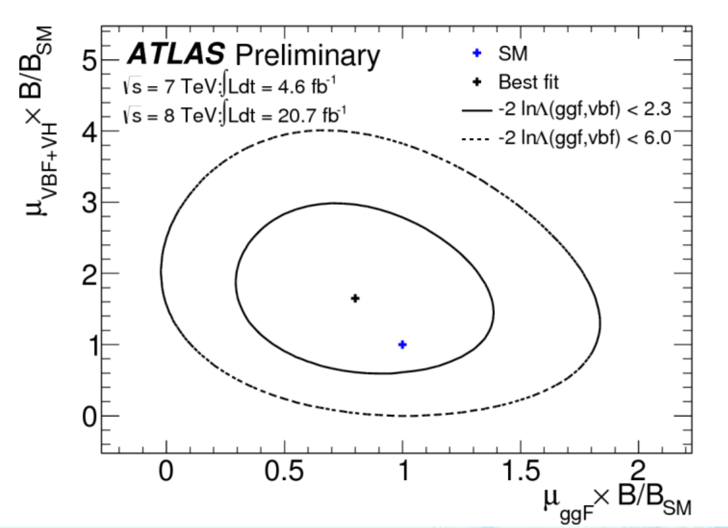




The Evidence: Statistical Conclusion I ——Production Rate

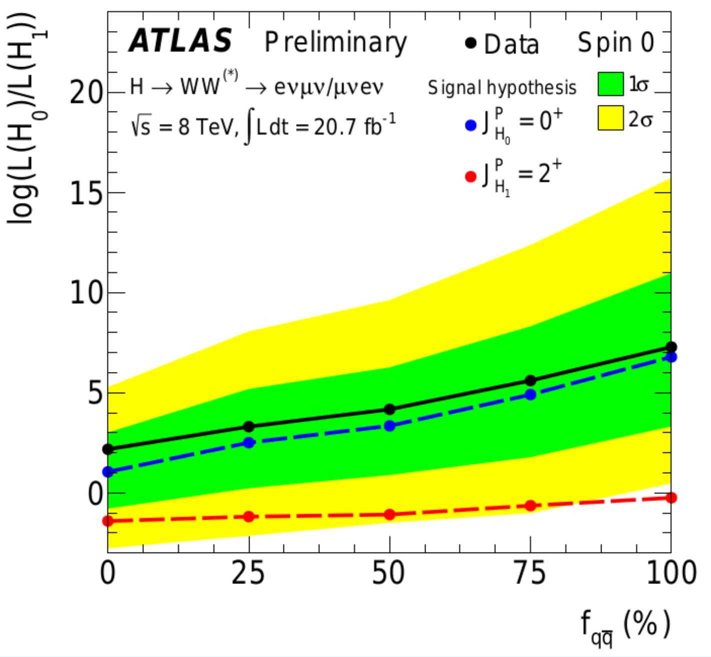
- After combining 2011 and 2012 data, an excess of events over the expected background is observed for m_H ≤150 GeV with the largest significance of 4.1 standard deviations(p_0 = 2 × 10^{-5}) at m_H = 140 GeV. The signal significance at m_H = 125 GeV is 3.8 standard deviations(p_0 = 8 × 10^{-5}).
- the best fit signal strength at m_H = 125 GeV is μ= 1.01 ± 0.31.





The Evidence: Statistical Conclusion II ——Spin Properties

- Two hypothesis have been compared, using only 2012 data: the standard model Higgs with J^P=0^+, and graviton like tensor with minimal couplings with J^P=2^+
- The tested 2^+ hypothesis is excluded in favour of a 0^+ hypothesis at a confidence level which varies between 99% for f_{qq} = 100% and 95% for f_{qq} = 0%.

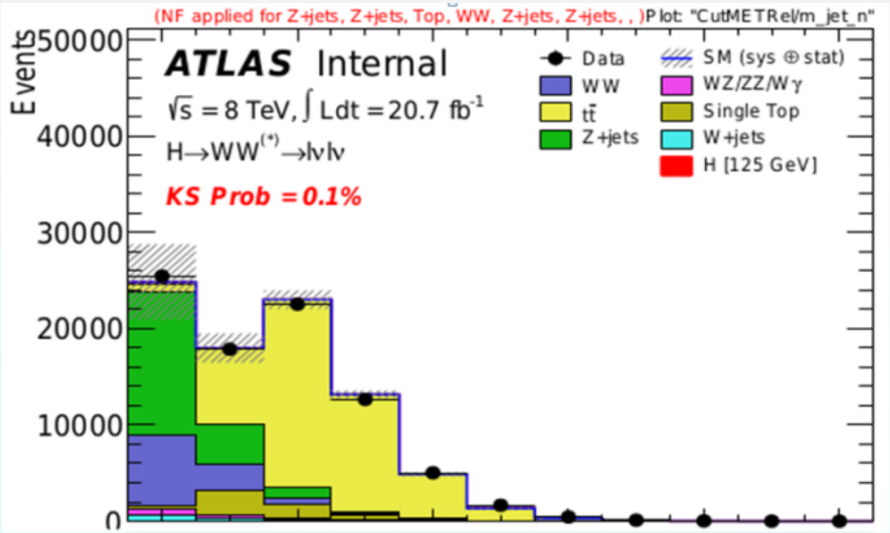


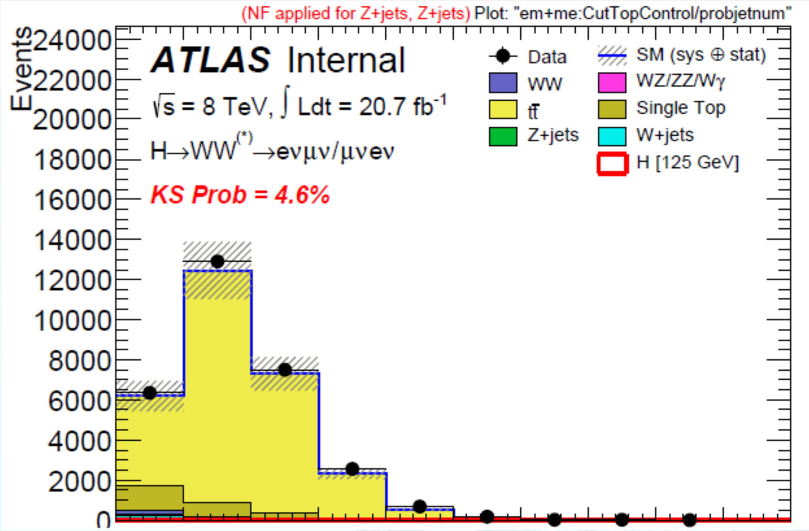
Main contribution: top 0jet estimation

- In the top background estimation in 0jet channel, the so-called JVSP method is used.

$$N^{estimated}_{Top\_0jet} = N^{Data}_{top\_all} \times f^{MC}_{0j} \times \left(\frac{f^{Btag,Data}_{0\,prob.\,jet}}{f^{Btag,MC}_{0\,prob.\,jet}}\right)^2$$

  - $N^{estimated}_{Top\_0jet}$ is the top event with 0 jet and $N^{Data}_{top\_all}$ is the top events with all jets
  - f^{MC}_{0j} is the JVSP---Jet Veto Survival Probabililty, calculated in simulation.(figure 10 left)
  - $\left(\frac{f^{Btag,Data}_{0\,prob.\,jet}}{f^{Btag,MC}_{0\,prob.\,jet}}\right)^2$ is a correction applied to f^{MC}_{0j}, derived from a b-tagged top control region.
  - $f^{Btag,Data}_{0\,prob.\,jet}$ or $f^{Btag,MC}_{0\,prob.\,jet}$ is the fraction of event with no probing jet in data/MC(figure 10 right)
  - Probing jet is defined as jets in event with a distance from the b-jet $\Delta R > 1$.





Main contribution: top 0jet estimation

- Main experimental systematics(only those varied large than 1%):

Experiamental Systematic s	Variation(%)
BJetWeight	-3.1/+4.4
BJetEnergyScale	-2.0/+2.4
FlavRespJetEnergyScale	+1.0/-1.1

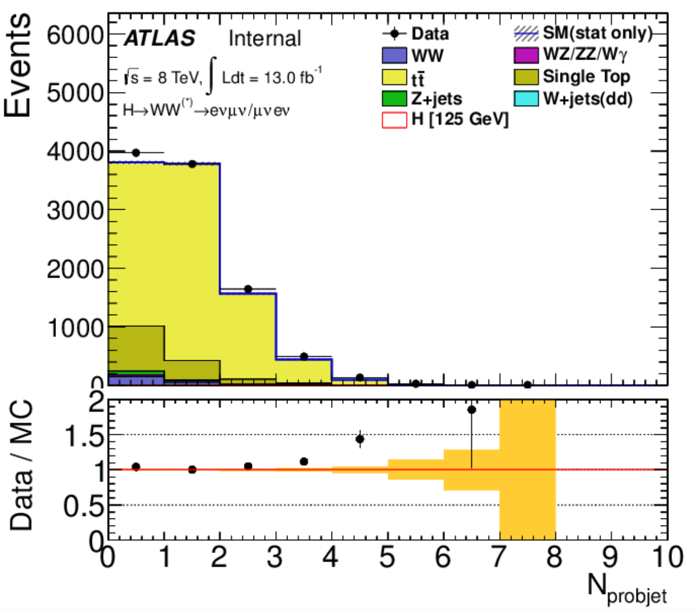
- Theoretical systermatics(this is the main systematics in top 0j estimate)

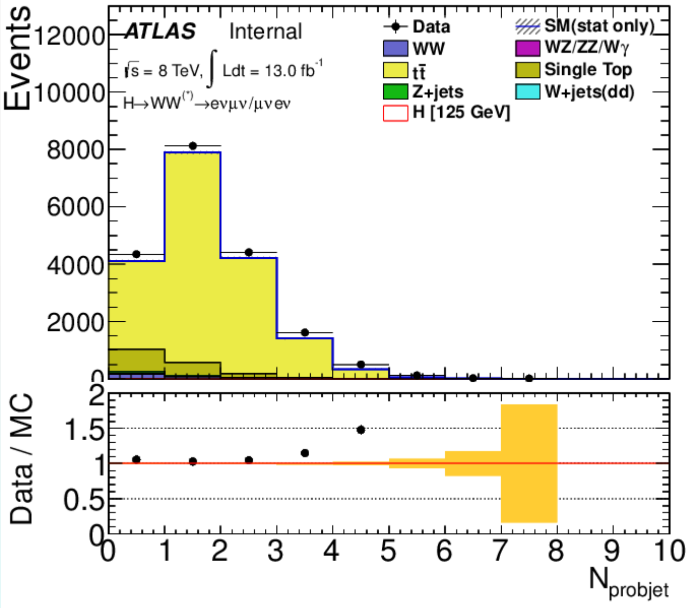
Theoretical Systematics	Variation(%)
Renormalization and Factorization scale(LO, old)	7.5
Sintle top-t$\bar{t}$ interference(LO,old)	4.5
Initial/final state radiation	4.0
MC generator/parton shower+hadronization	< 2.2

- Total systematics: 11.4%

Main contribution: b-tagged sample dependency of top 0jet estimation

- To check the influence of b tagging on the top 0jet estimation, results are compared by using two top control samples: one sample requiring at least one b-jet, the other sample requiring exactly one b-jet.

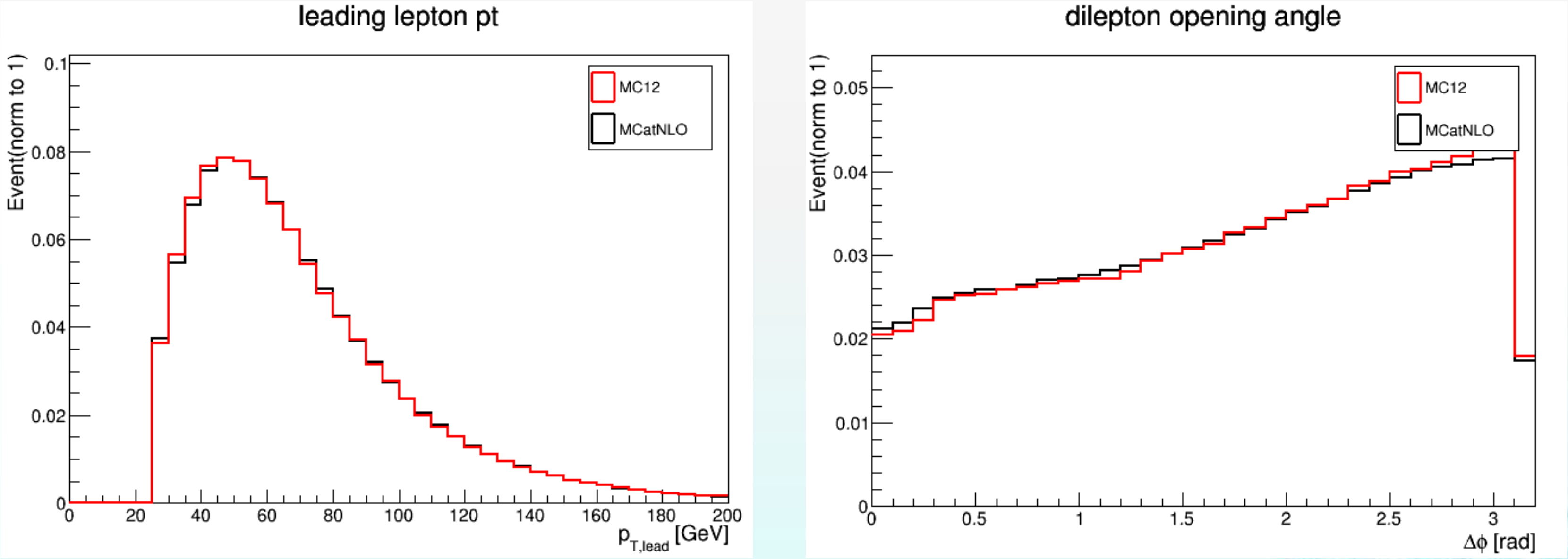




- Results data/MC: 1.064 $\pm$ 0.052(=1b-jet) 1.035 $\pm$ 0.046($\geq$1b-jet)
- Conclusion: the data/MC ratio is stable wrt. the b-jet control sample.

Main contribution: on-going improved theoretical uncertainty reevaluation

- Renormalization and Factorization scale uncertainties and single top-ttbar interference uncertainty are being reevaluated using MCatNLO.
- Here are some performance plots of the reevaluation.



Main contribution: on-going improved theoretical uncertainty reevaluation

- Systematic Table of the value of $f_{0j}^{MC} / (f_{0\,prob\,jet}^{MC})^2$ for different choice of the Renormalization(RF) and Factorization(FF) factors.

	FF=0.5	*FF=1*	*FF=2*
RF=0.5	0.5040±0.0021 (-0.8±0.4)%	0.5132±0.0022 (+1.0±0.4)%	0.5172±0.0023 (+1.8±0.4)%
RF=1	0.5050±0.0020 (-0.6±0.4)%	0.5080±0.0020	0.5101±0.002 (+0.4±0.4)%
RF=2	0.5027±0.0019 (-1.1±0.4)%	0.5080±0.0019 (<0.1±0.4)%	0.5048±0.0019 (-0.6±0.4)%

- The maximum variation is chosen to be the systematic err: 1.8%
- Single top-t$\bar{t}$ interference uncertainty(Diagram Subtraction(DS) vs. Removal(DR))

	DS	DR
$f_{0j}^{MC} / (f_{0\,prob\,jet}^{MC})^2$	0.5080±0.0020	0.5098±0.0019 (+0.4±0.4)%

Main contribution: Low pt Analysis

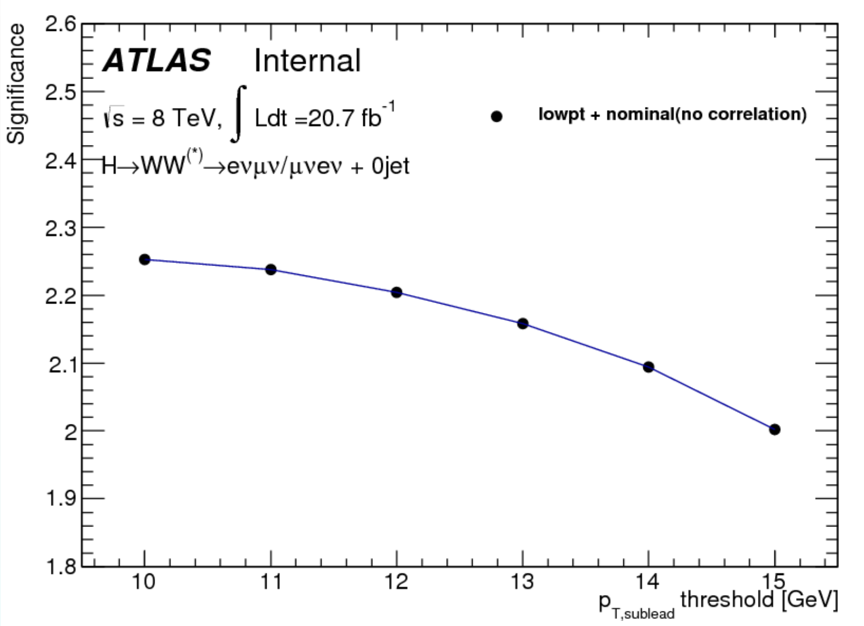
- An estimation of the significance gain is done using the same sets of cuts as nominal analysis for the OF 0/1 jet channel.
- The formula of the significance calculation.
  - lowpt+nominal significance(no correlation):

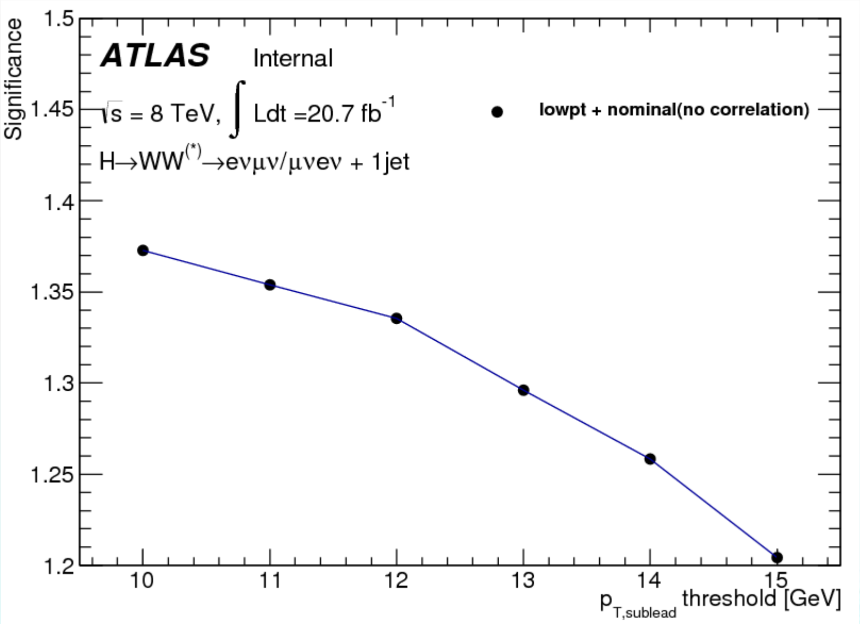
$$\text{sig} = \frac{S_{lowpt} + S_{nominal}}{\sqrt{B_{lowpt} + B_{nominal} + \delta^2_{B_{lowpt}} + \delta^2_{B_{nominal}}}}$$

  - uncertainty of background is assumed to be the same in lowpt and nominal analysis

Main contribution: Low pt Analysis

- Results: Significance gain distributions are show below for OF 0/1 jet channel. Low pt alone significance is also show for comparison





- Significance gain: 12.5%(14.0%) for 0(1) jet

Future plan: New FCPPL and New Program

- We have new team this year:

New FCPPL team(2013)	
LAL	NJU/USTC
Zhiqing Zhang	Shenjian Chen
Sebasien Binet	Yingchun Zhu
Yichen Li(joint PhD)	

- The new program in the future:

New Programs	
1.Low Pt Analysis	Re-optimize selection cuts
	Use multivariate technique
	Improve background rejection
2.Perform Higgs property measurement	
3.Search for heavy neutral Higgs boson in the WW channel	

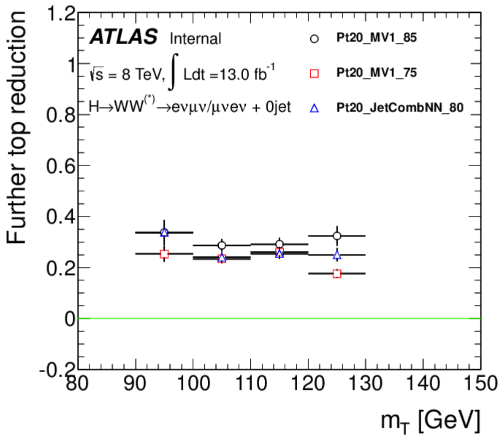
That's all! Thank you!

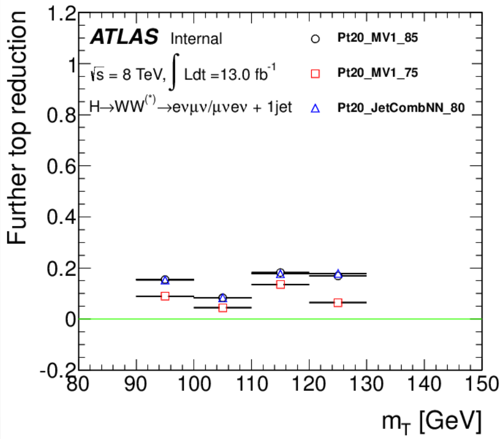
Back up: sub-threshold b-jet veto

- An attempt of applying sub-threshold b-jet veto cut to further suppress top background in the signal region is made.
- Three cases are considered:
  - MV1 algorithm working at 85%
  - MV1 algorithm working at 75%
  - JetCombNN algorithm working at 80%

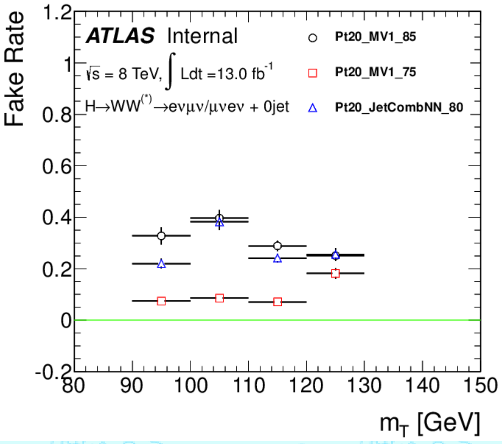
Back up: sub-threshold b-jet veto

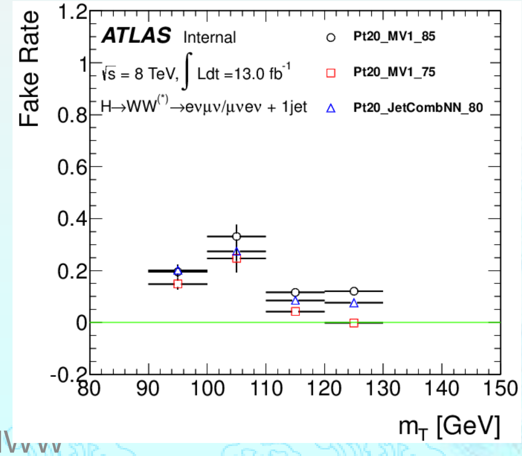
- Top reduction rates: the fraction of top events excluded by sub-threshold b jet veto





- Fake rate: the fraction of non-top events in the events excluded by sub-threshold b veto





Back up: sub-threshold b-jet veto

- Conclusion:
  - Sub-threshold b jet veto is more efficient in 0jet channel than in 1jet channel.
  - All three b veto cases share almost the same ability of top reduction.
  - The MV1_75 has the smallest fake rate.