H→WW→lνlν

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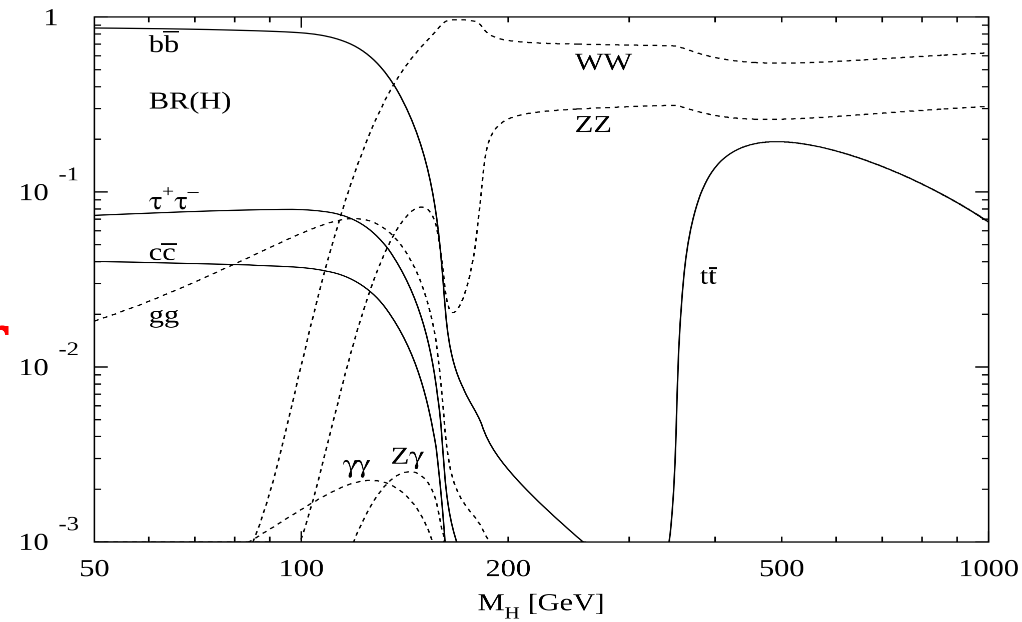
Introduction

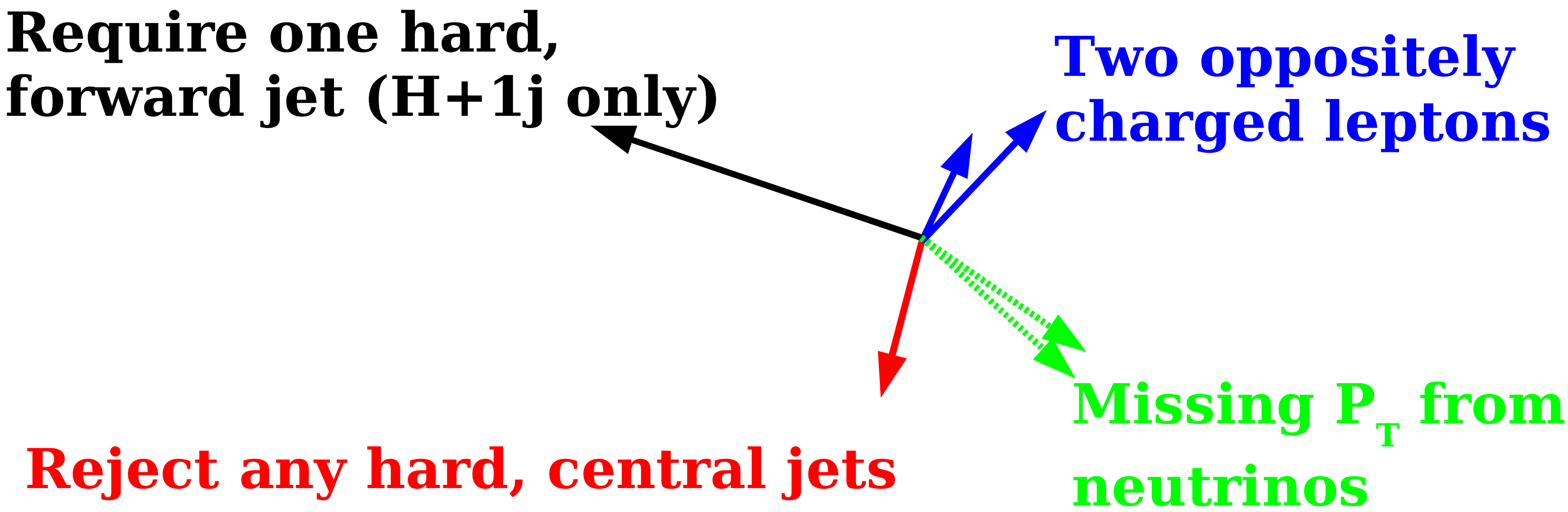
- H→WW is the dominant decay mode of the Standard Model Higgs for a broad range of M_H
  - H→WW→lνlν+0j studied by (e.g.) Dittmar et al.
  - H→WW→lνlν+2j studied by (e.g.) Zeppenfeld et al.

- In this study:
  - Improve analysis of H→WW→lνlν+0j
  - Explore prospects for H→WW→lνlν+1j
  - Control Samples to estimate background



M. Spira, Fortsch. Phys 46(1998)

Basic Signature



- Dominant background in both H+0j and H+1j channels is QCD WW production

- ttbar background plays an important role in control samples

Monte Carlo

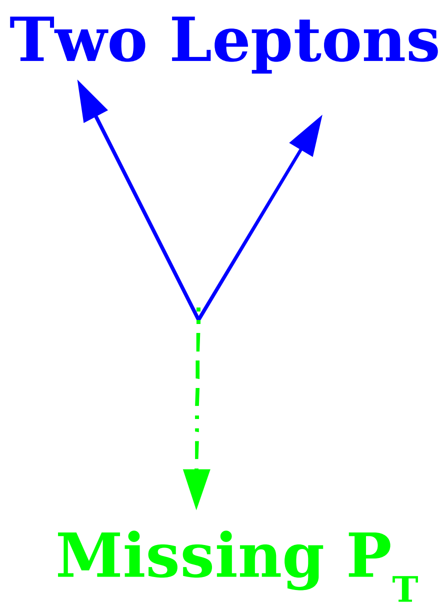
- Signal
  - gg→H→WW→lνlν: MC@NLO/ATLFAST
  - VBF H→WW→lνlν: Pythia/ATLFAST

- Background:
  - QCD WW: Sherpa WW+0/1j
  - ttbar: MC@NLO/ATLFAST
  - EW WW: Matrix Element/Pythia/ATLFAST
  - Z/γ^*+X: MC@NLO/ATLFAST

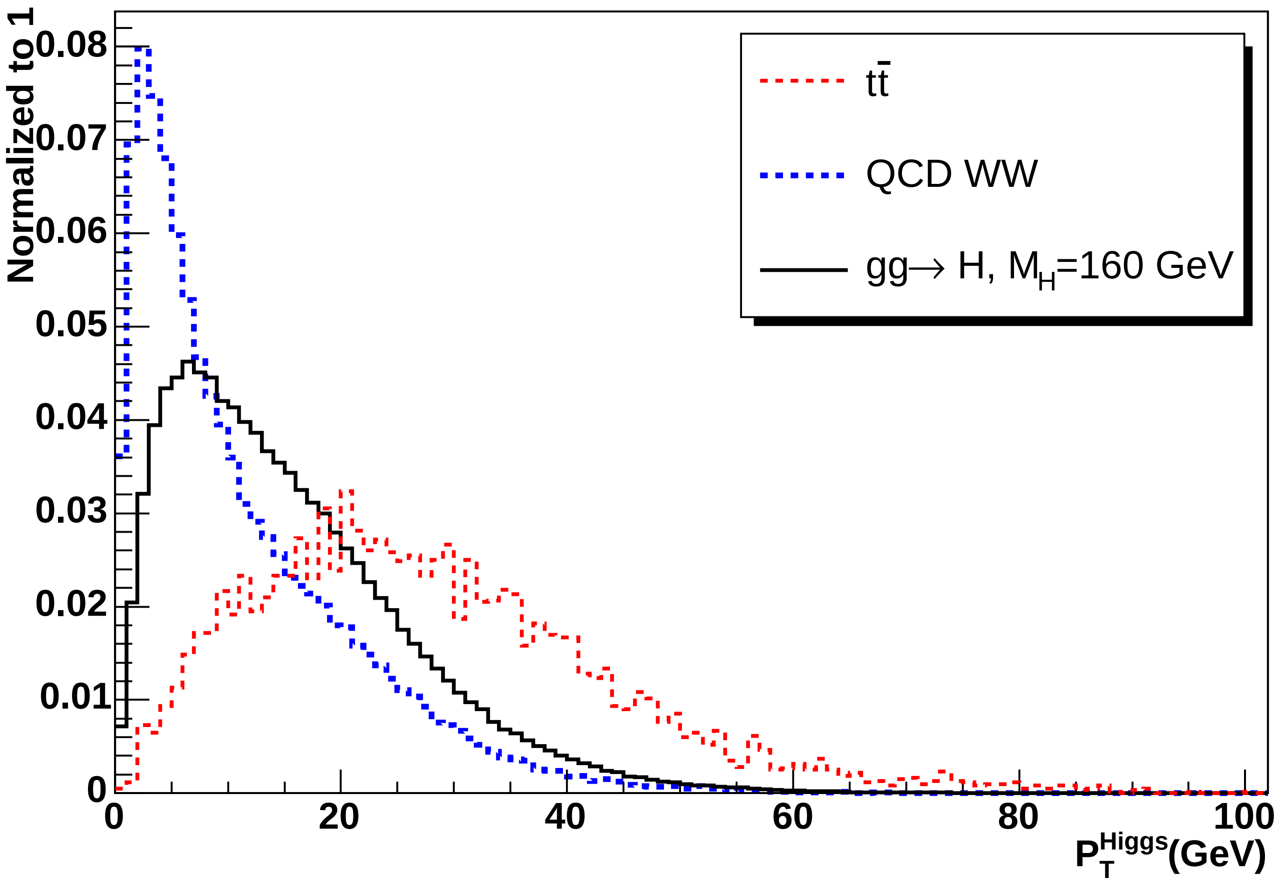
- Cross-sections for all processes (except VBF and EW WW) are taken from MC@NLO

Event Selection for WW+0j

- Two leptons, pass single/double lepton trigger
- b-jet veto, ϵ_b=60%
- Reject if same flavor leptons and 82GeV<M_{ll}<98GeV
- Reject if any jet has P_T>30GeV
- Reject if $|M_Z - M_{\tau\tau}|$<25GeV
- P_T^{miss}>30GeV (Will probably raise this to 40 GeV in ee and $\mu\mu$ channels)
- $\Delta\phi_{ll}$<1.5
- Mass-dependent cuts on M_{ll}, P_T^{Higgs}

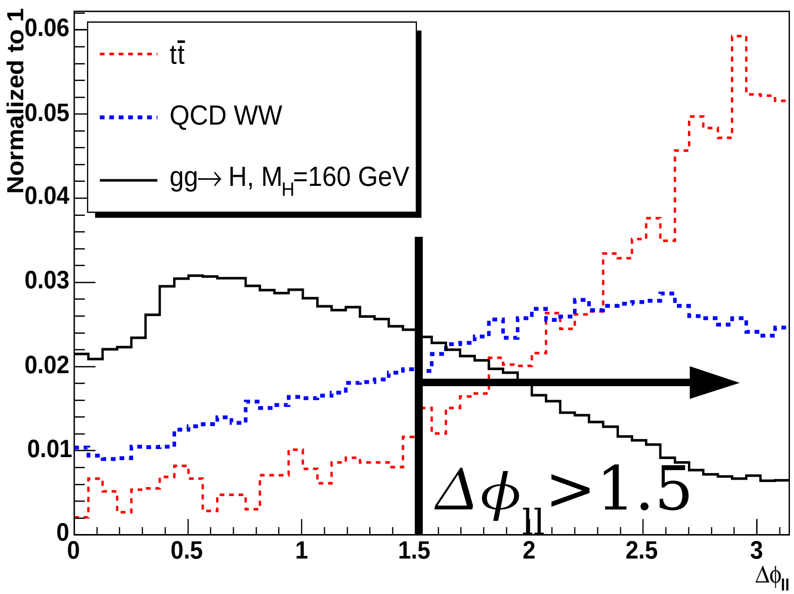


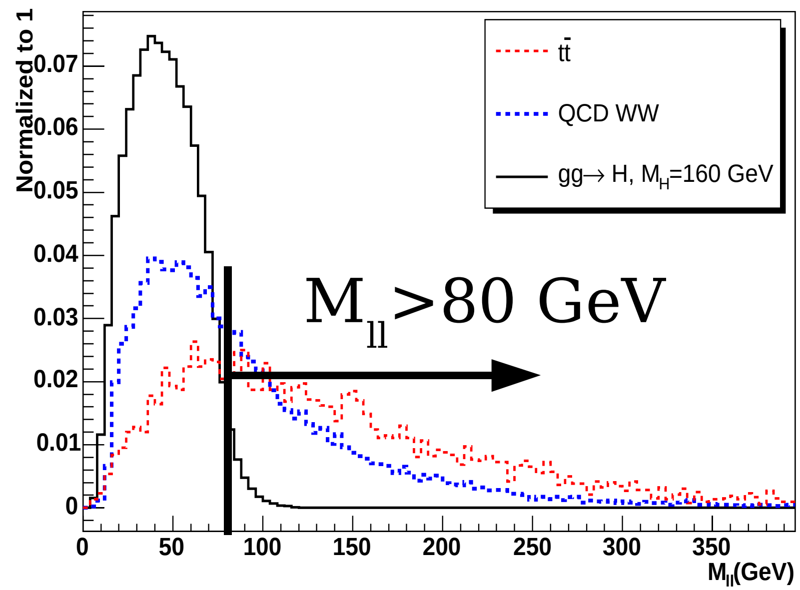
Higgs P_T



▸ Higgs P_T cut is an important difference w.r.t. previous analyses

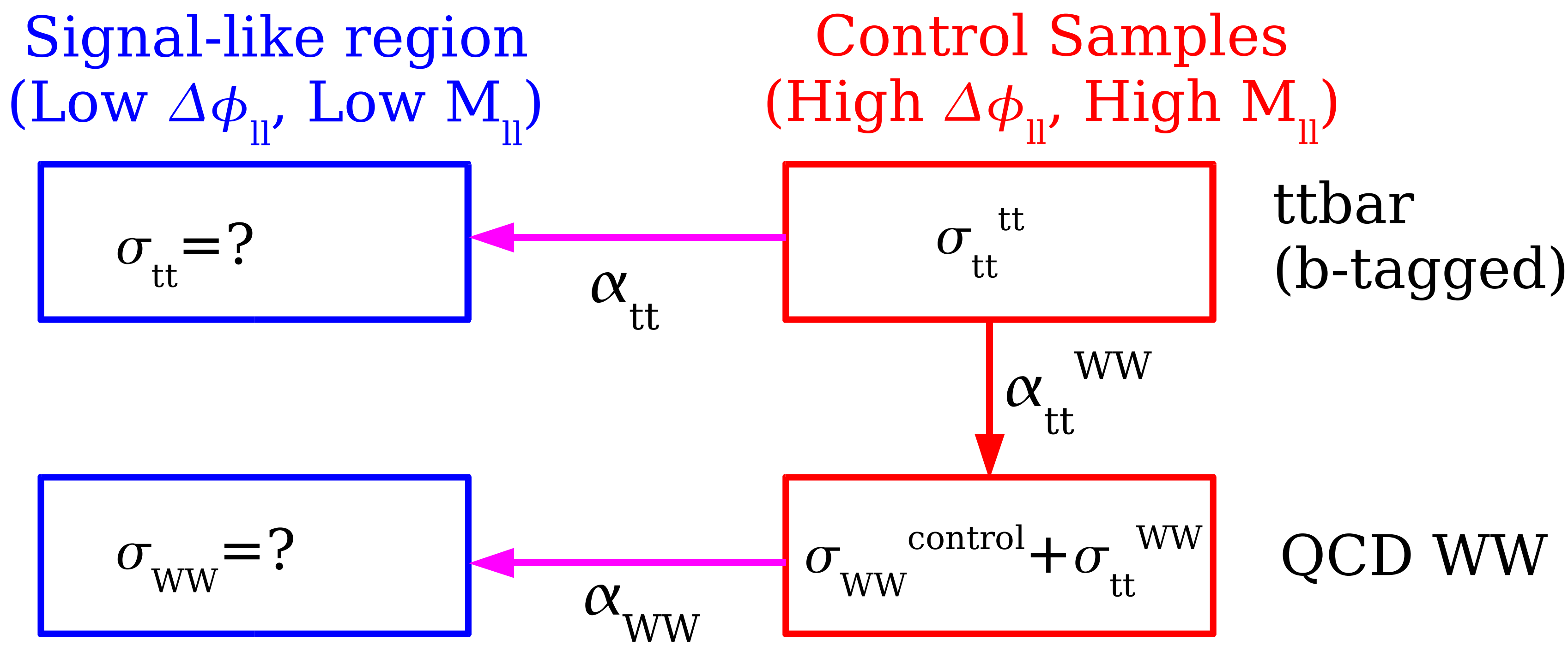
Control Samples(1)





- Require $\Delta\phi_{ll}>1.5$
  - $M_{ll}>80$GeV to remove signal contamination
- Construct b-tagged control sample to measure ttbar background
  - $\Delta\phi_{ll}$ cut stays the same, but M_{ll} cut is removed

Control Samples(2)



- Define:
  - α_{WW}=(QCD WW bg)/(QCD WW in control samp.)
  - α_{tt}=(tt bg)/(ttbar in tt control sample)
  - α_{tt}^{WW}=(tt in WW sample)/(tt in tt sample)

Systematic Errors(1)

- Jet Energy Scale Calibration
  - Scale jet energies up & down by 5% in the barrel and 10% in the endcaps
- Missing P_T
  - Smear x and y components by 5 GeV each
- PDF uncertainties
  - Consider PDF uncertainty in α_{WW} only
  - Generate QCD WW (MC@NLO) with CTEQ6 central value PDF set and each of the 40 error PDF sets

Systematic Errors(2)

- $\Delta\alpha_{WW}$=1%(Jet E. scale calibration)
  $\oplus$2%(P_T^{miss})
  $\oplus$4.5%(PDF)=5.0%
- $\Delta\alpha_{tt}$=7%(Jet E. scale calibration)
  $\oplus$1%(P_T^{miss})=7.1%
- $\Delta\alpha_{tt}^{WW}$=9%(Jet E. scale calibration)
  $\oplus$1%(P_T^{miss})=9.1%
- More work needs to be done to understand theoretical errors
  - gg→WW (via quark box) contribution needs to be addressed

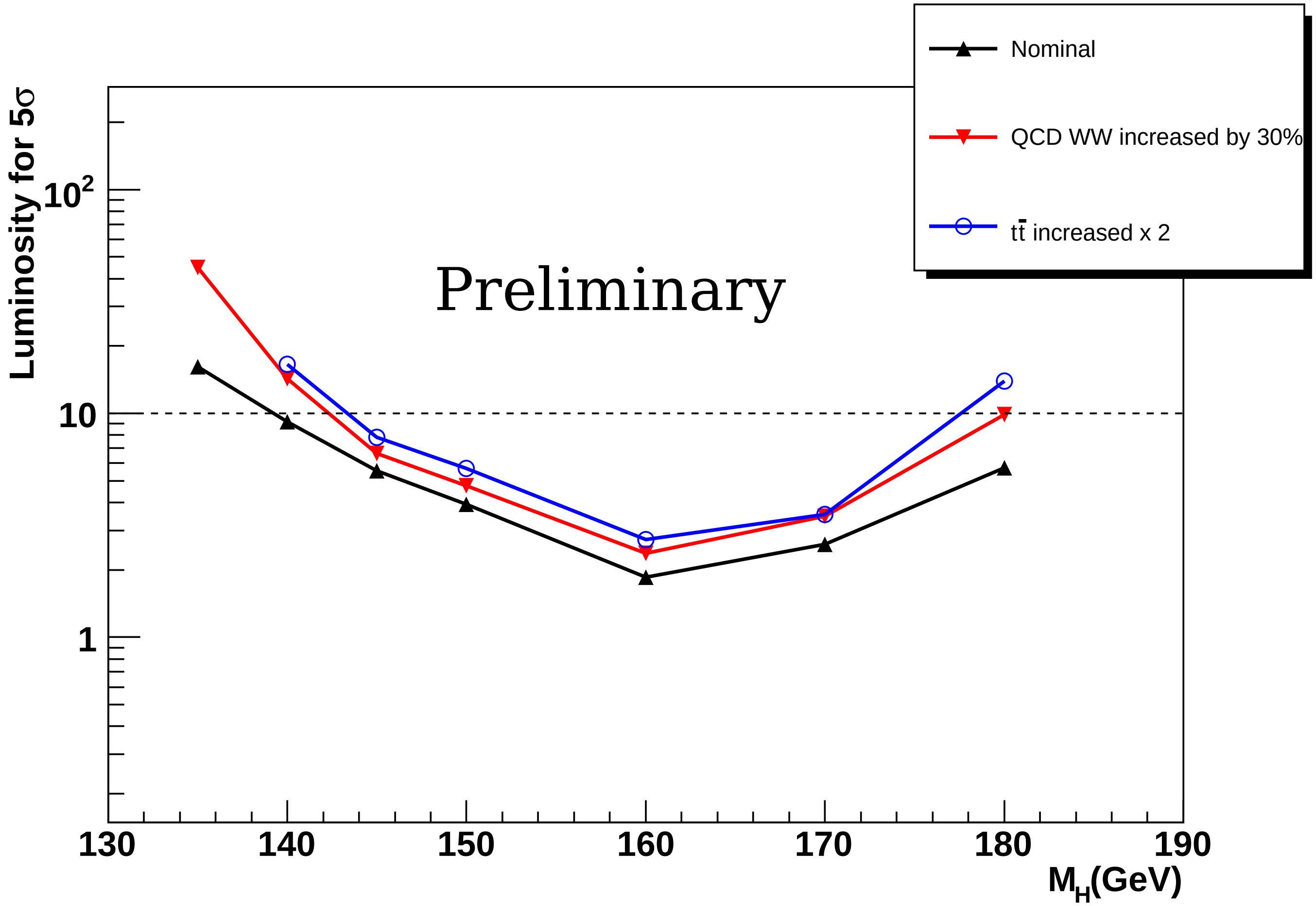
Results for WW+0j

Sample	ggH	VBF	ttbar	EW WW	QCD WW	Z+X
Signal-like	71	2.1	9.73	0.05	105	30.36
WW control	2.2	0.04	54.4	0.13	155	46.5
tt control	0.29	0.01	32.44	0	2.14	7.83

Cross-sections (in fb) for M_H=160GeV

- Systematics for this mass after $2fb^{-1}$:
  - ttbar normalization in b-tagged sample: 14.2%
  - ttbar normalization in WW sample: 14.2%(stat.) ⊕9.1%(syst.) = 16.87%
  - WW normalization in WW sample: 7.3%(stat.) ⊕5.9%(tt subtraction) = 9.4%
  - WW normalization in signal-like region: 9.4%(control samp.)⊕5.0%(syst)=10.6%
- Away from the WW threshold, systematic errors become more and more important

Luminosity Plot for WW+0j

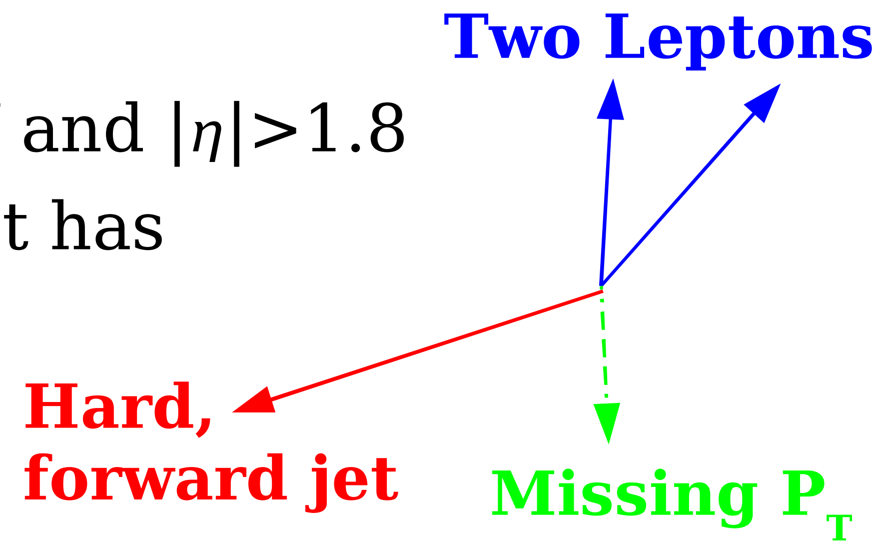


- We calculate error on tt & QCD WW from control samples and assume 10% uncertainty for other backgrounds

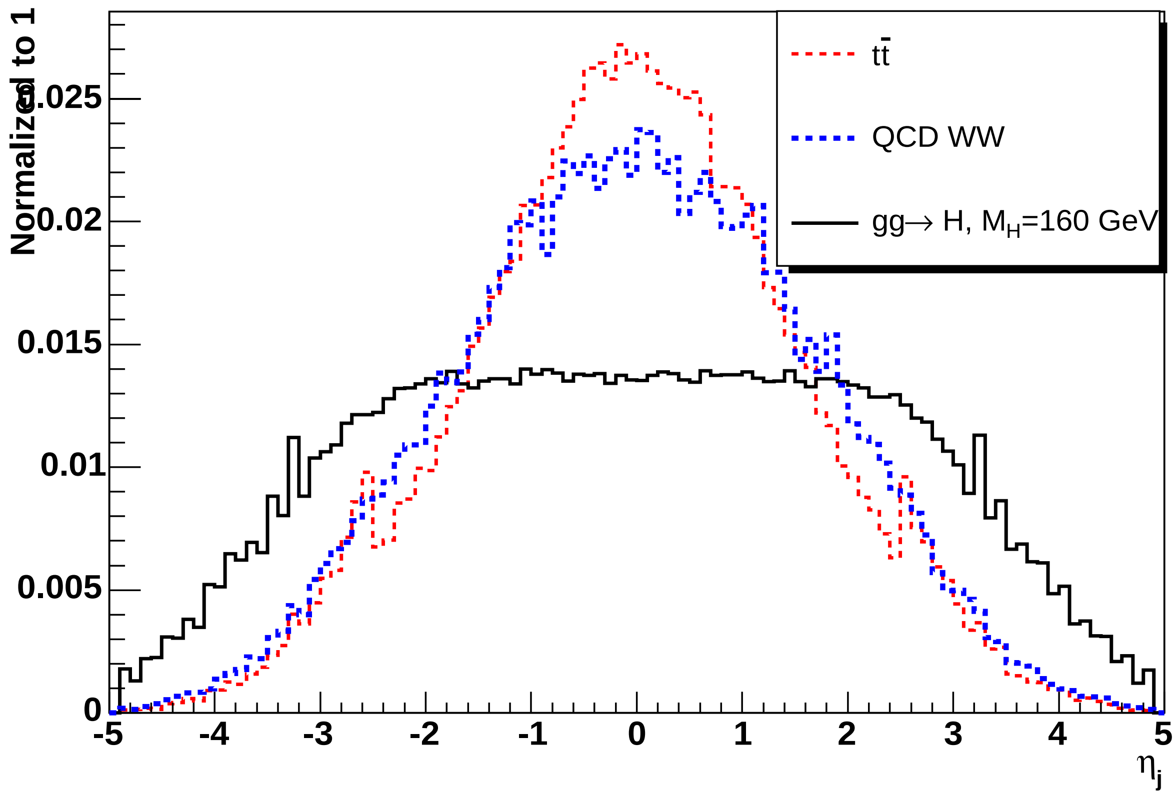
- Controlling and reducing theoretical errors is crucial for this channel

Event Selection for WW+1j

- Select W pairs:
  - Two leptons, pass single/double lepton trigger
  - b-jet veto, ϵ_b=60%
  - Z Rejection cuts and P_T^{miss}>30GeV
- Other cuts:
  - Leading jet has P_T>30GeV and $|\eta|$>1.8
  - Reject if any subleading jet has P_T>30GeV and $|\eta|$<2.5
  - P_T^{tot}(H+j)<25GeV
  - $\Delta\phi_{ll}$<1.2
  - M_H-dependent cuts on M_{ll}, M_T
  - Exclude VBF events with $\Delta\eta_{jj}^{max}$ cut



Leading Jet Pseudorapidity



- We require $|\eta|>1.8$
  - Cut on pseudorapidity of the leading jet is the main difference between this analysis and H+0j

Control Samples, Systematics

- Control samples are similar to H+0j
  - Cuts are the same as the main event selection, with $\Delta\phi_{ll}>1.2$, $M_{ll}>80$GeV
- Systematic errors are evaluated the same way as for WW+0j:
  - $\Delta\alpha_{WW}$=3% (Jet E. Scale calibration)
    $\oplus$2% (Missing P_T)
    $\oplus$7% (PDF uncertainty)=7.9%
  - $\Delta\alpha_{tt}$=9% (Jet E. Scale calibration)
    $\oplus$2% (Missing P_T)=9.2%
  - $\Delta\alpha_{tt}^{WW}$=8% (Jet E. Scale calibration)
    $\oplus$1.5%(Missing P_T)=8.1%

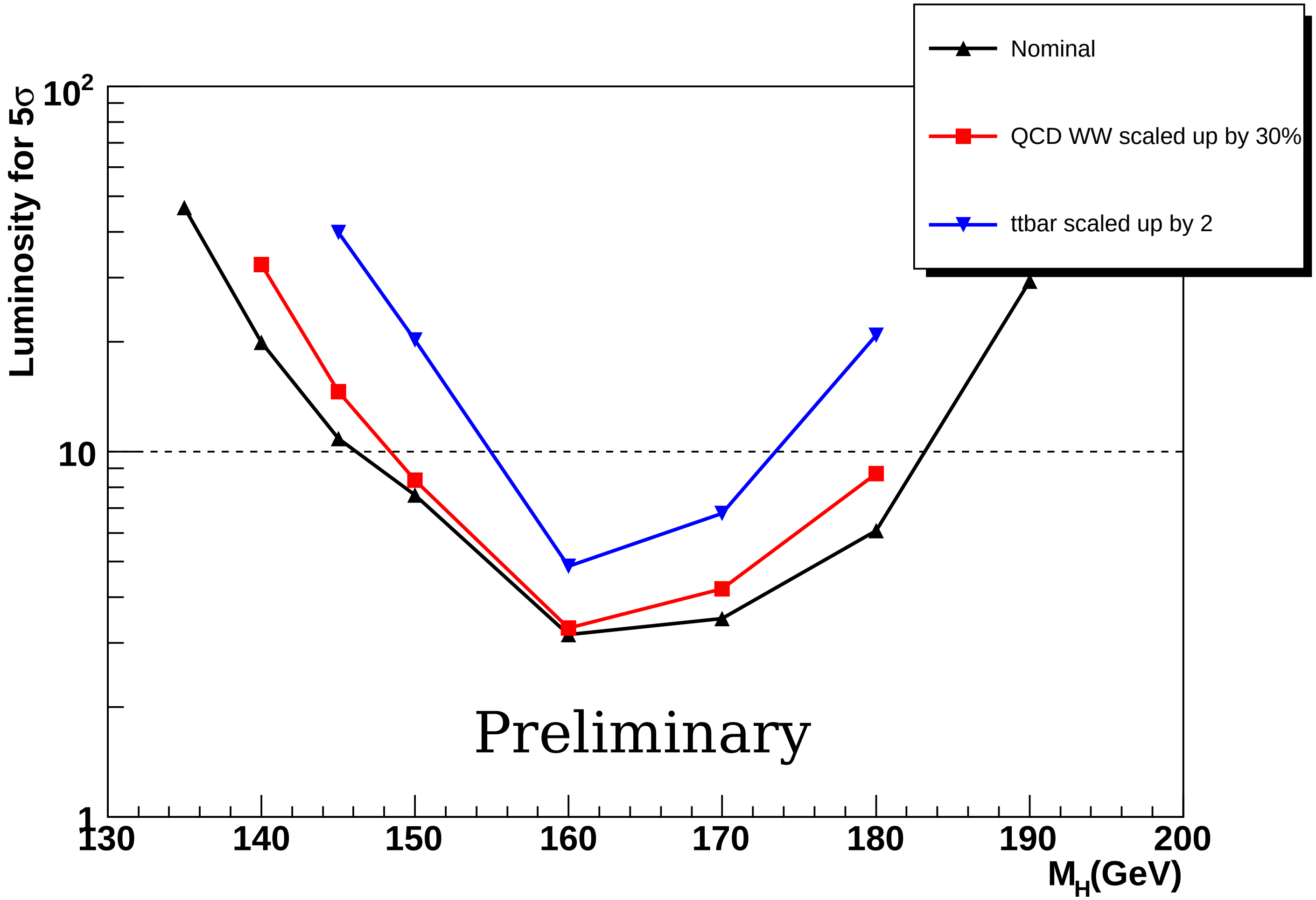
Results for WW+1j

Sample	ggH	VBF	ttbar	EW WW	QCD WW	Z+x
signal-like	26.91	3.82	8.97	0.24	24.57	9.51
WW control	1.52	0.09	51.1	1.49	51.8	17.55
tt control	0.63	0.08	70	0.03	1.91	9.09

Cross-sections (in fb) for M_H=160 GeV

- Systematics for this mass after $3fb^{-1}$:
  - ttbar norm. in b-tagged sample: 7.4%
  - ttbar norm. in WW sample: 7.4%(stat)⊕8.1%(syst)= 11%
  - WW norm. in WW sample: 12.4%(stat) ⊕ 10.85%(tt sub.)=16.4%
  - WW norm. in signal-like region: 16.4%(control samp.) ⊕ 7.9%(syst.)=18.2%
- Analysis is effectively leading order, expect greater sensitivity to higher order corrections

Luminosity Plot for WW+1j



- WW+1j is a discovery channel, but off-shell effects in top backgrounds (which will lead to an increase in this background) may be important

Future Directions

- Try to extract the extrapolation coefficients from data
  - For WW+0j, low Higgs P_T is a relatively pure sample for QCD WW+0j background
  - For WW+1j, events where the leading jet is central should be rich in QCD WW events
  - For the ttbar background in both WW+0j and WW+1j, b-tagging may provide an unbiassed control sample
- More detailed studies of systematic effects: need to understand in more detail:
  - what the jet energy scale uncertainty will be
  - what the missing P_T resolution will be
  - other effects...

Summary

- We have introduced a new discovery channel: H+1j with $H \rightarrow WW \rightarrow l\nu l\nu$
  - s/b is close to 0.7 at M_H=160 GeV; compare to WW+0j (s/b~0.5) and WW+2j (s/b>~2)
- We have defined control samples and demonstrated signal extraction in the H+0j and H+1j with $H \rightarrow WW \rightarrow l\nu l\nu$ channels
- Some important questions remain:
  - Higher order corrections to WW background
  - Off-shell effects in top background
  - Can we construct control samples to validate the extrapolation coefficients we're currently taking from Monte Carlo?
  - Experimental systematics (e.g. b-tagging uncert.)