# Prospects for $H \to b\bar{b}$ measurement with LHeC

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on behalf of
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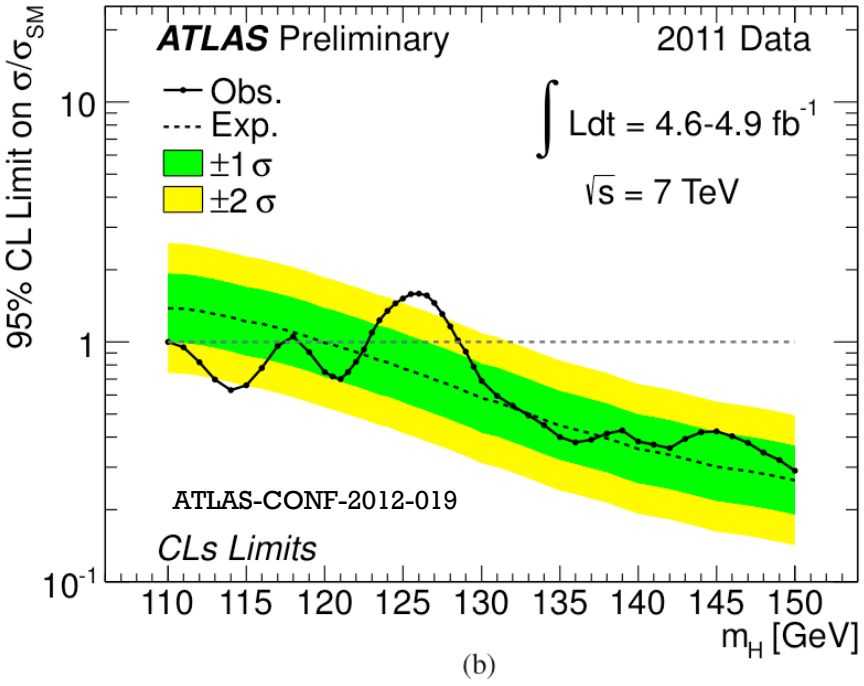
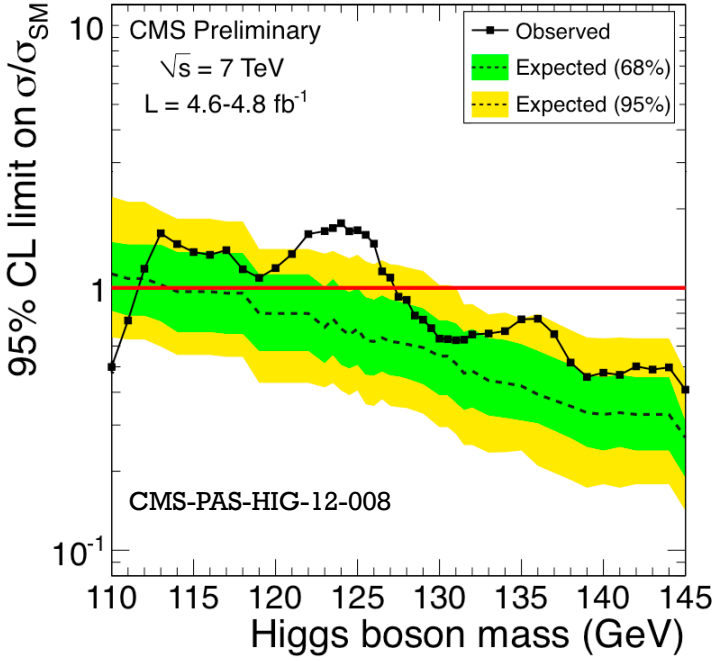
# Higgs at LHC

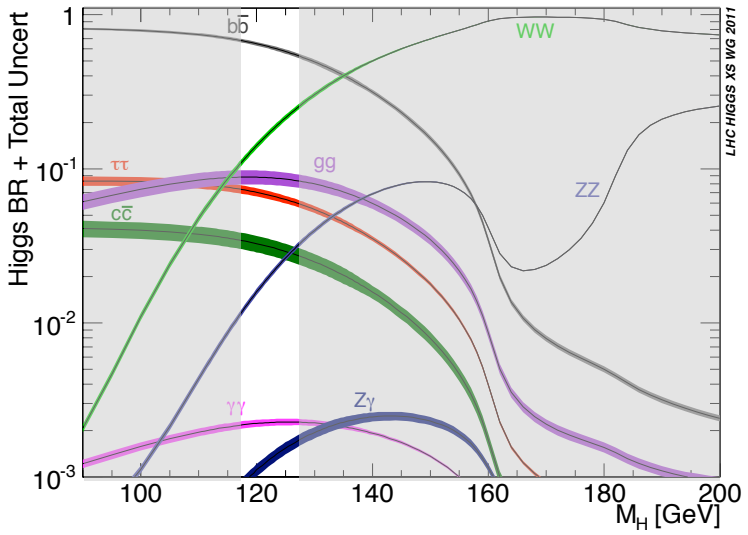
- Constraint to SM Higgs within 117.5 – 127.5 GeV
  - ATLAS and CMS with ~5 $fb^{-1}$ data at $\sqrt{s}$ = 7TeV
- LHC has discovery potential to the mass range with 2012 data



# Higgs at LHeC

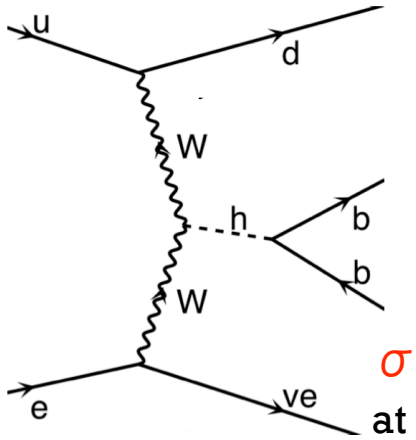
- Constraint to SM Higgs within 117.5 – 127.5 GeV
  - ATLAS and CMS with ~5 $fb^{-1}$ data at $\sqrt{s}$ = 7TeV
- LHC has discovery potential to the mass range with 2012 data
- Following discovery, LHeC aims to measure $Hb\bar{b}$ coupling
  - Branching ratio to $b\bar{b}$ pair: 52 – 67% at 117.5 – 127.5 GeV
  - $H \rightarrow b\bar{b}$ is still challenging channel with large QCD background
  - Measurement of Higgs to fermion coupling is essential to confirm Higgs field is accounting for fermion mass via Yukawa couplings
  - It is important to show that it is a SM Higgs (see CP study talk)
  - $H \rightarrow b\bar{b}$ may be observed in exclusive production mode in clean environment



# Higgs at LHeC

## Signal

CC: $H \rightarrow b\bar{b}$ (BR ~ 0.7 at $M_H$=120GeV)

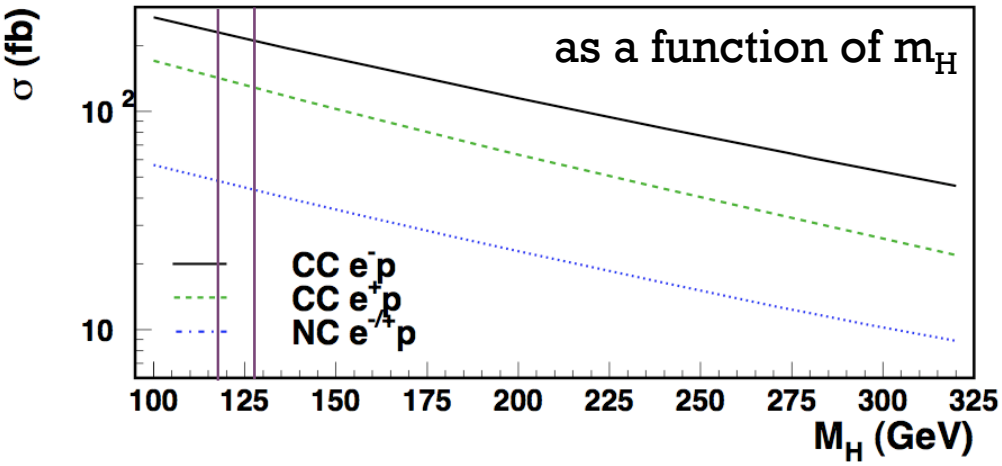


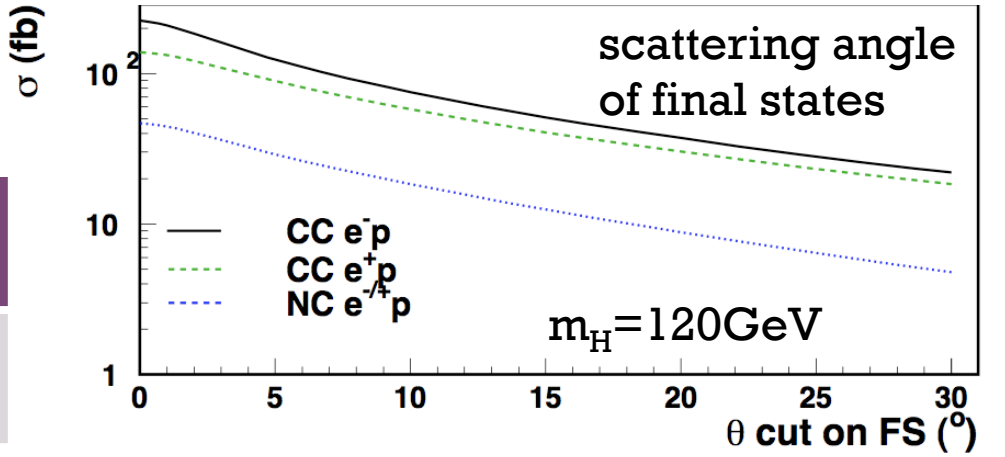

$\sigma \sim 0.16$ pb
at $\sqrt{s}$=2.05TeV

CC Higgs production cross-section ($M_H$ = 120 GeV)

| Electron beam energy | 50 GeV | 100 GeV | 150 GeV |
|---|---|---|---|
| cross-section (fb) | 81 | 165 | 239 |

Higgs production cross-section at $\sqrt{s}$ = 1.98TeV ($E_e$=140GeV, $E_p$=7TeV)



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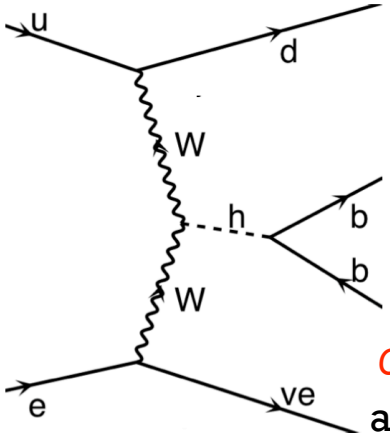


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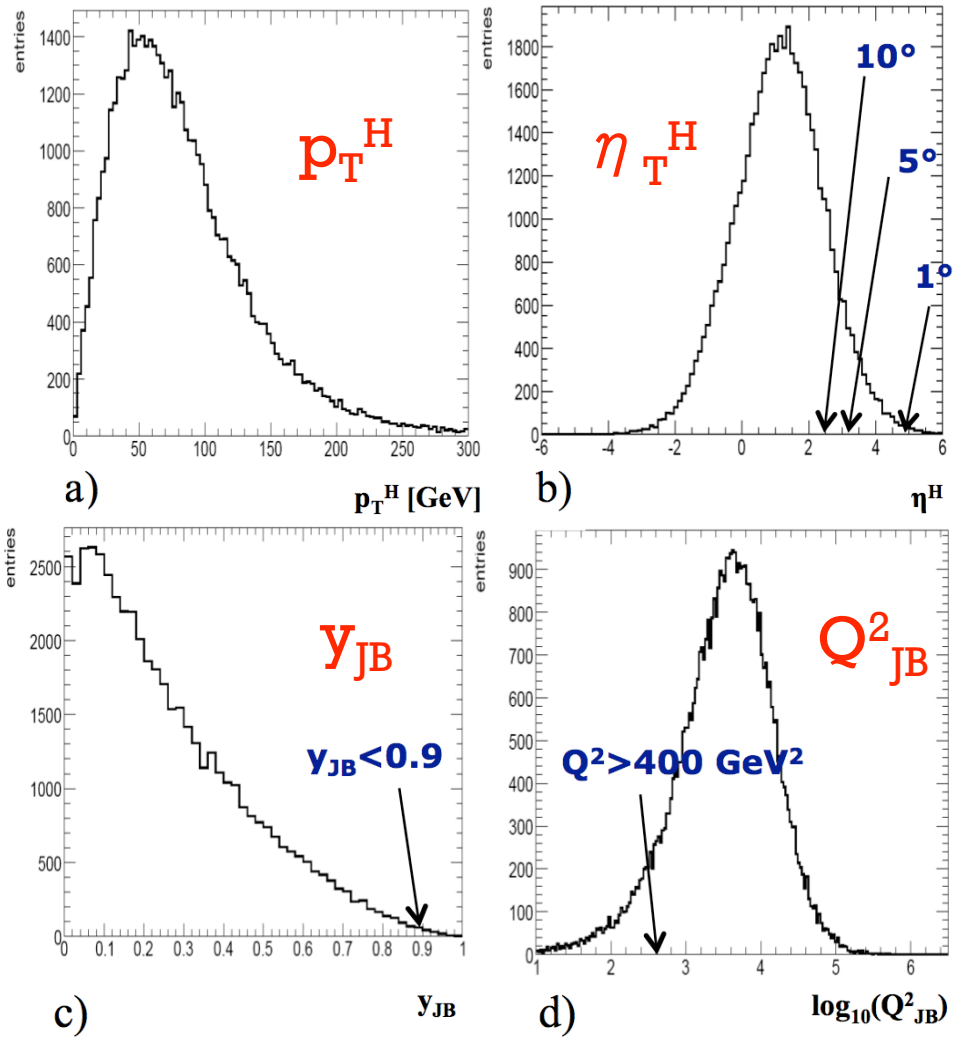
Kinematic distributions of generated Higgs
($m_H$=120GeV, $E_e$=150GeV, $E_p$=7TeV)



# Higgs at LHeC

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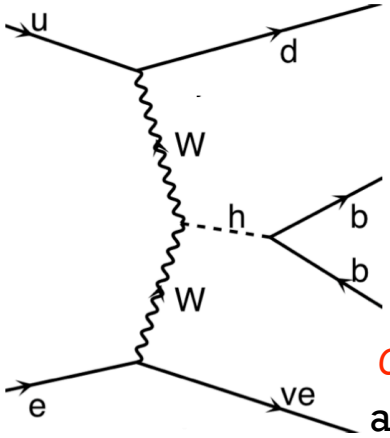
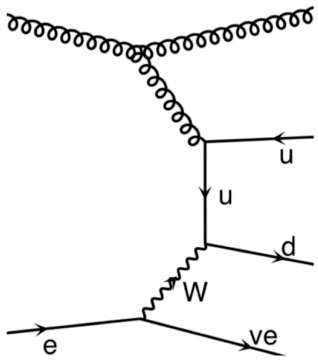


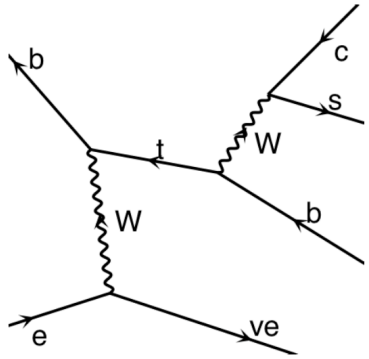

$\sigma \sim 0.16$ pb
at $\sqrt{s}$=2.05TeV

## Background (examples)

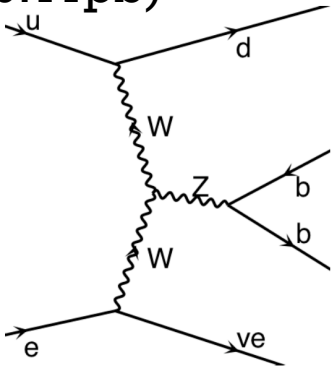
CC: 3 jets (~57pb)



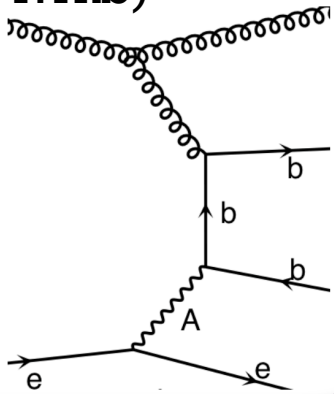

CC: single top production (~4.1pb)




CC: Z production (~0.11pb)




NC: b pair production (~1.1nb)




NOTE: numbers are after pre-selection in generator

# LHeC in simulation

Event generation
- SM Higgs production
- CC & NC background

by MadGraph/MadEvent

↓

- Fragmentation
- Hadronization

by PHYTHIA (+ mod. for ep)

↓

Fast detector simulation

by PGS

↓

$H \rightarrow b\bar{b}$ selection

- Calculate cross-section with tree-level Feynman diagrams
- Generate final state of outgoing particles

Input parameters:
- 150 GeV electron beam
- 7 TeV proton beam
- 120 GeV SM Higgs boson mass

+ 60 GeV configuration as comparison

Generator level cuts
- $p_T > 5$GeV (for parton besides b)
- $|\eta| < 5.0$
- For NC: Number of b quarks $\geqq 2$
  (NOTE: according to simulation study with artificially increased b-tag mis-ID, essentially all NC BG after selection are due to events with two true b quarks)

# LHeC in simulation

Event generation
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Fast detector simulation

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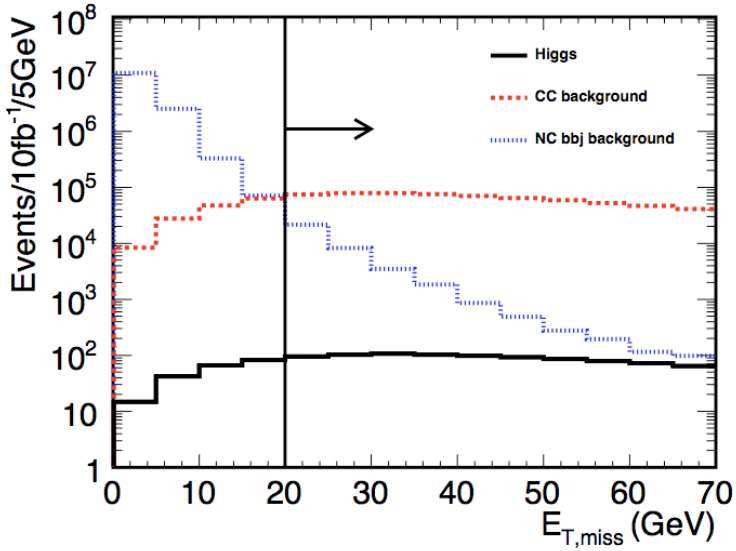
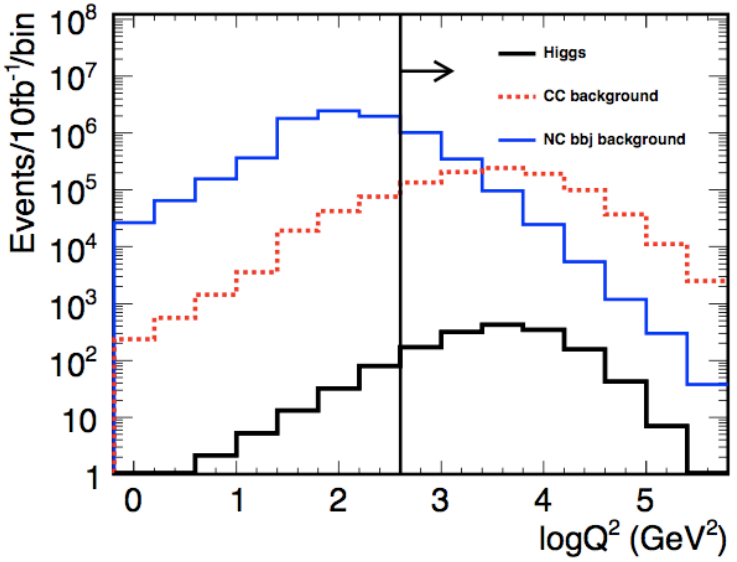
$H \rightarrow b\bar{b}$ selection

- Generic detector with
  - Coverage:
    - Tracking: $|\eta| < 3$
    - Calorimeter: $|\eta| < 5$
  - Calorimeter resolution
    - EM: $1\% \oplus 5\%/\sqrt{E}$
    - Hadron: $60\%/\sqrt{E}$
    - Cell size: $(\Delta\eta, \Delta\phi) = (0.03, 0.03)$
  - Jet reconstructed by cone algorithm ($\Delta R=0.7$)
  - b-tag performance
    - Flat efficiency for $|\eta| < 3$
    - Efficiency/mis-ID
      - b-jet: 60%
      - c-jet: 10%
      - Other jets: 1%

# Selection of $H \rightarrow b\bar{b}$

- NC rejection
  - Exclude electron-tagged events
  - $E_{T,miss} > 20GeV$
  - $N_{jet}$ ($p_T > 20GeV$) $\geqq 3$
  - $E_{T,total} > 100GeV$
  - $y_{JB} < 0.9$, $Q^2_{JB} > 400GeV$
- b-tag requirement
  - $N_{b\text{-}jet}$ ($p_T > 20GeV$) $\geqq 2$
- Higgs invariant mass
  - $90 < M_H < 120GeV$
- Single top rejection
  - $M_{jjj,top} > 250GeV$
  - $M_{jj,W} > 130GeV$
- Forward jet tagging
  - $\eta_{jet} > 2$ (lowest $\eta$ excluding b-tagged




$H \rightarrow b\bar{b}$
CC BG
NC BG

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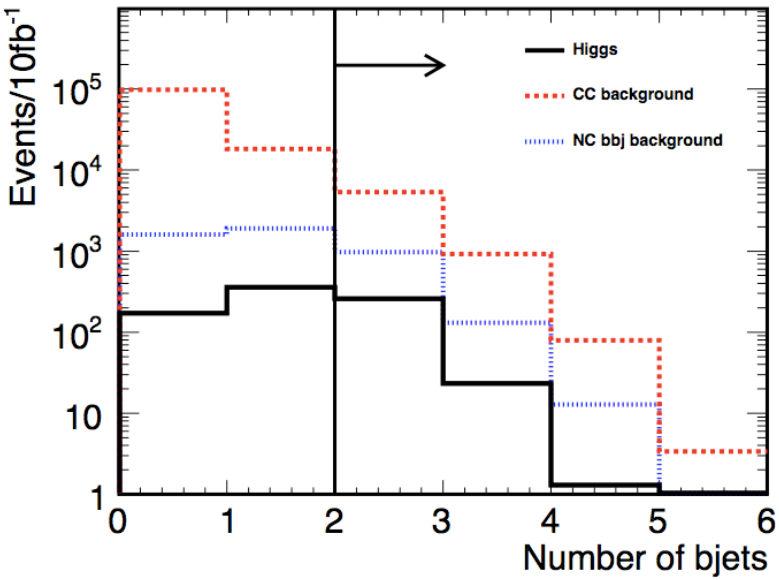


**b-tag efficiency model**

for $|\eta| < 3$

| | |
|---|---|
| b-jet identification: | $\varepsilon = 60\%$ |
| c-jet mis-ID: | $\varepsilon = 10\%$ |
| Other jet mis-ID: | $\varepsilon = 1\%$ |

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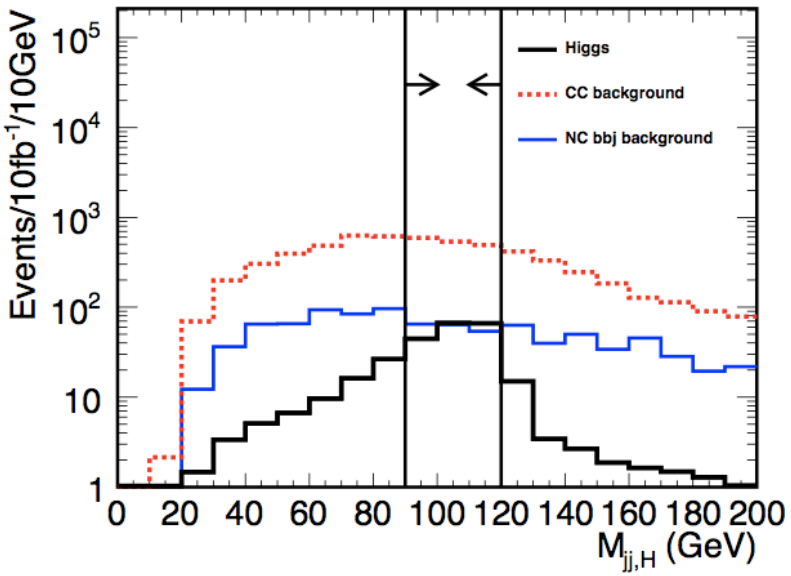
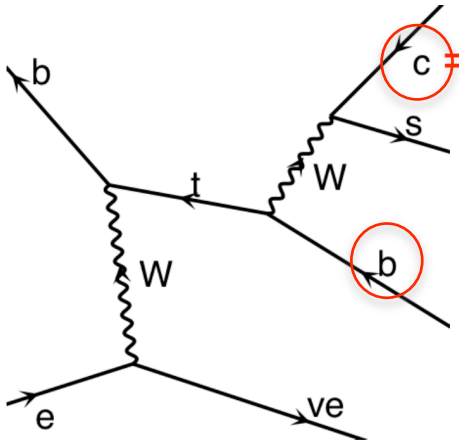



⇒ 44% of remaining BG is single-top…




⇒ 10% mis-ID

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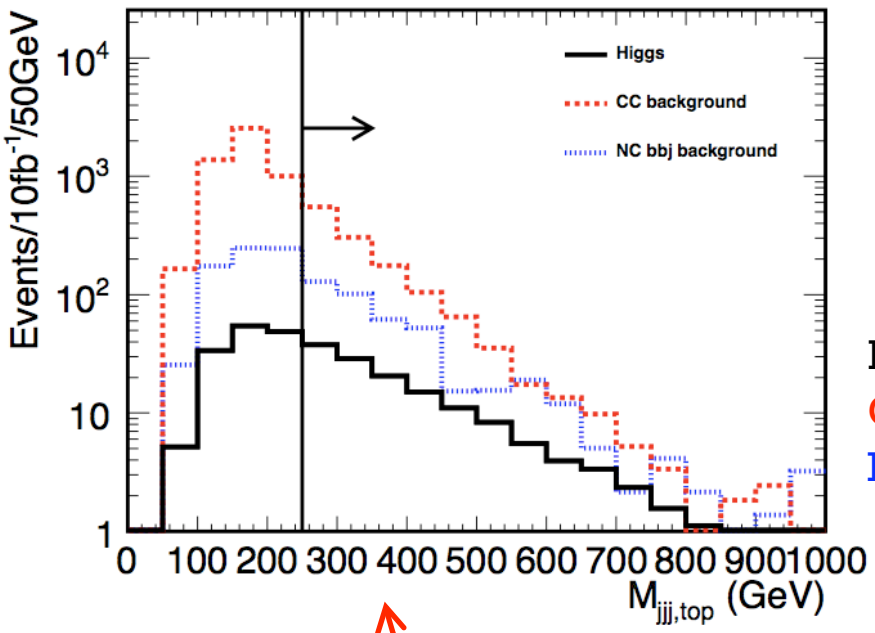


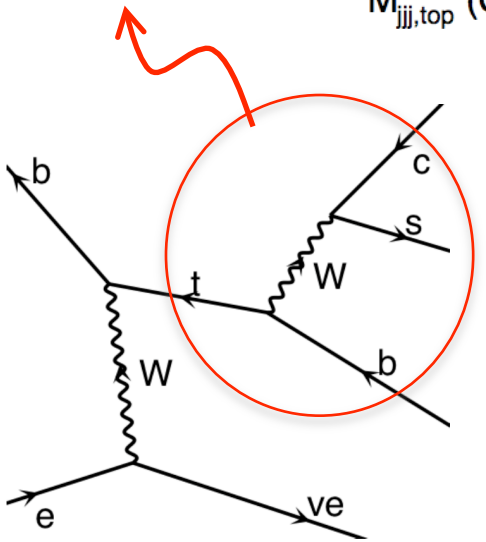

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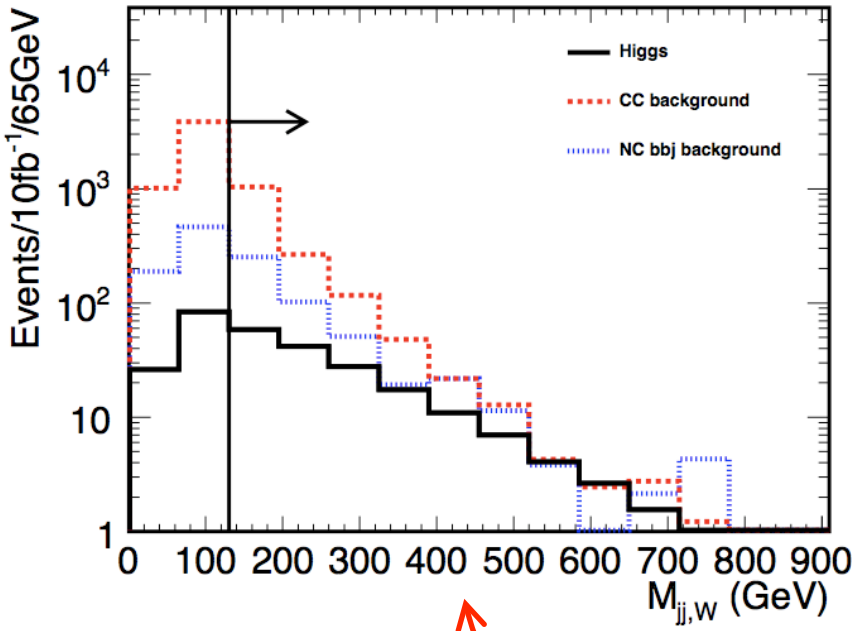
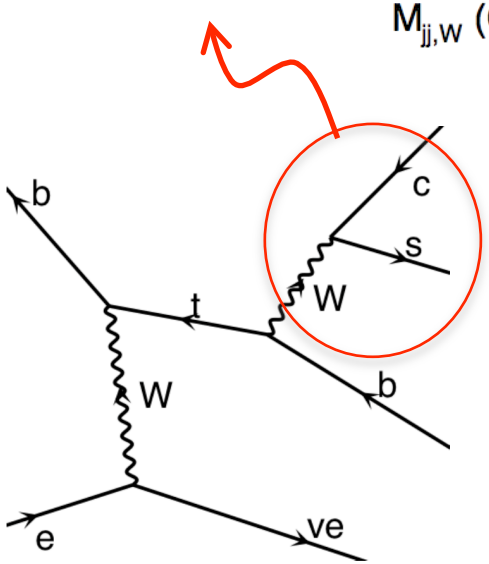



$H \rightarrow b\bar{b}$
CC BG
NC BG



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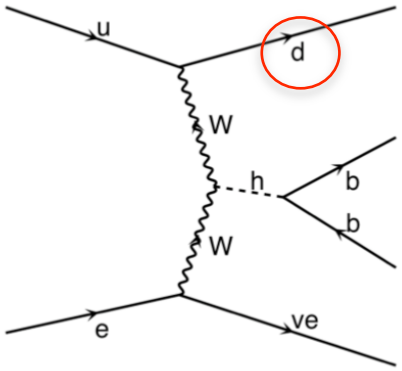
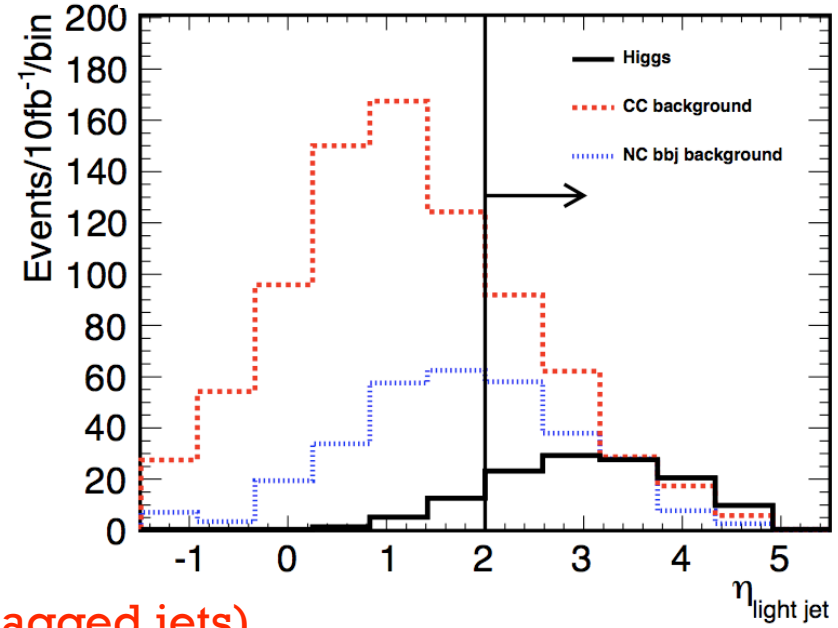
$H \rightarrow b\bar{b}$ signal




Coordinate:
z-axis along proton beam




$H \rightarrow b\bar{b}$
CC BG
NC BG

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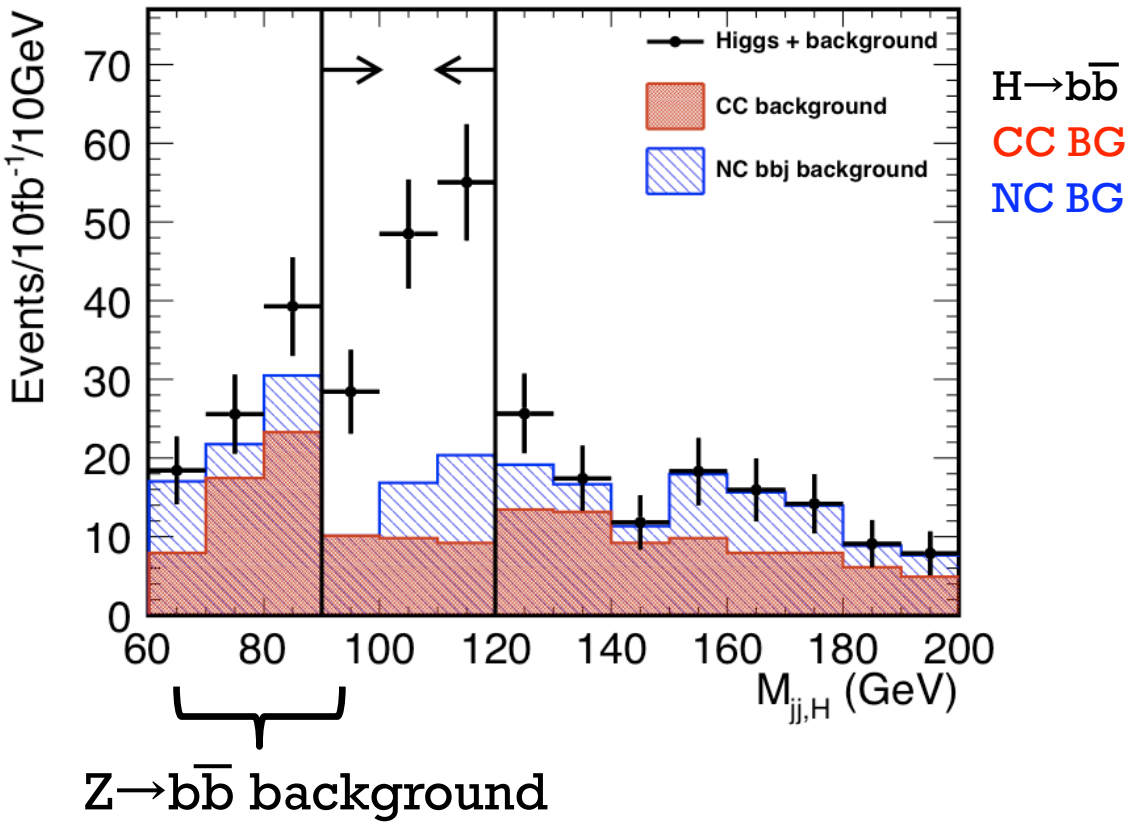
Higgs invariant mass after all selection



# Results

- Beam energy:
  - Electron beam 150 GeV
  - Proton beam 7 TeV
- SM Higgs mass 120 GeV
- Luminosity 10 $fb^{-1}$

Signal and background cut flow

| | H→bb | CC DIS | NC bbj | S/N | S/√N |
|---|---|---|---|---|---|
| **NC rejection** | 816 | 123000 | 4630 | $6.38\times10^{-3}$ | 2.28 |
| **+ b-tag requirement + Higgs invariant mass** | 178 | 1620 | 179 | $9.92\times10^{-2}$ | 4.21 |
| **All cuts** | 84.6 | 29.1 | 18.3 | 1.79 | 12.3 |

# Comparison with 60GeV option

- Beam energy:
  - Electron beam 150 GeV ⇒ 60 GeV
  - Proton beam 7 TeV
- SM Higgs mass 120 GeV
- Luminosity 10 $fb^{-1}$ ⇒ 100 $fb^{-1}$

| | $E_e$ = 150 GeV (10 $fb^{-1}$) | $E_e$ = 60 GeV (100 $fb^{-1}$) |
|---|---|---|
| **H → bb signal** | 84.6 | 248 |
| **S/N** | 1.79 | 1.05 |
| **S/√N** | 12.3 | 16.1 |

# Summary

- Once the discovery of SM Higgs is made by LHC, next goal is to establish Higgs field as origin of fermion mass
  ⇒ Measurement of $Hb\bar{b}$ coupling is essential
- Sensitivity to $H \rightarrow b\bar{b}$ was estimated by simulation study of LHeC
- LHeC has potential to measure $H \rightarrow b\bar{b}$
  - 150 GeV electron beam with 10 $fb^{-1}$
    - 85 signal events expected with $S/N \sim 1.8$, $S/\sqrt{N} \sim 12.3$
  - 60 GeV electron beam with 100 $fb^{-1}$
    - 248 signal events expected with $S/N \sim 1.1$, $S/\sqrt{N} \sim 16.1$
- We can explore other channels
  - NC Higgs production in ZZ fusion
  - Other light Higgs decay channels

# backup

# LHeC in simulation

**Event generation**
- SM Higgs production
- CC & NC background

by MadGraph/MadEvent

**References:**

*J. Alwall et al., MadGraph/MadEvent v4: The New Web Generation , JHEP 09 (2007) 028, arXiv:0706.2334 [hep-ph]12105*

- Fragmentation
- Hadronization

by PHYTHIA (+ mod. for ep)

*T. Sjostrand, S. Mrenna, and P. Z. Skands, PYTHIA 6.4 Physics Manual , JHEP 05 (2006) 026, arXiv:hep-ph/0603175*

**Fast detector simulation**

by PGS

*PGS. http://www.physics.ucdavis.edu/~conway/research/software/pgs/pgs4- general.htm*

$H \rightarrow b\bar{b}$ selection