Updates on H->bb studies at LHeC

Masahiro Tanaka, Masahiro Kuze, Masaki Ishitsuka
~Tokyo Institute of Technology~
Uta Klein
~Liverpool University~

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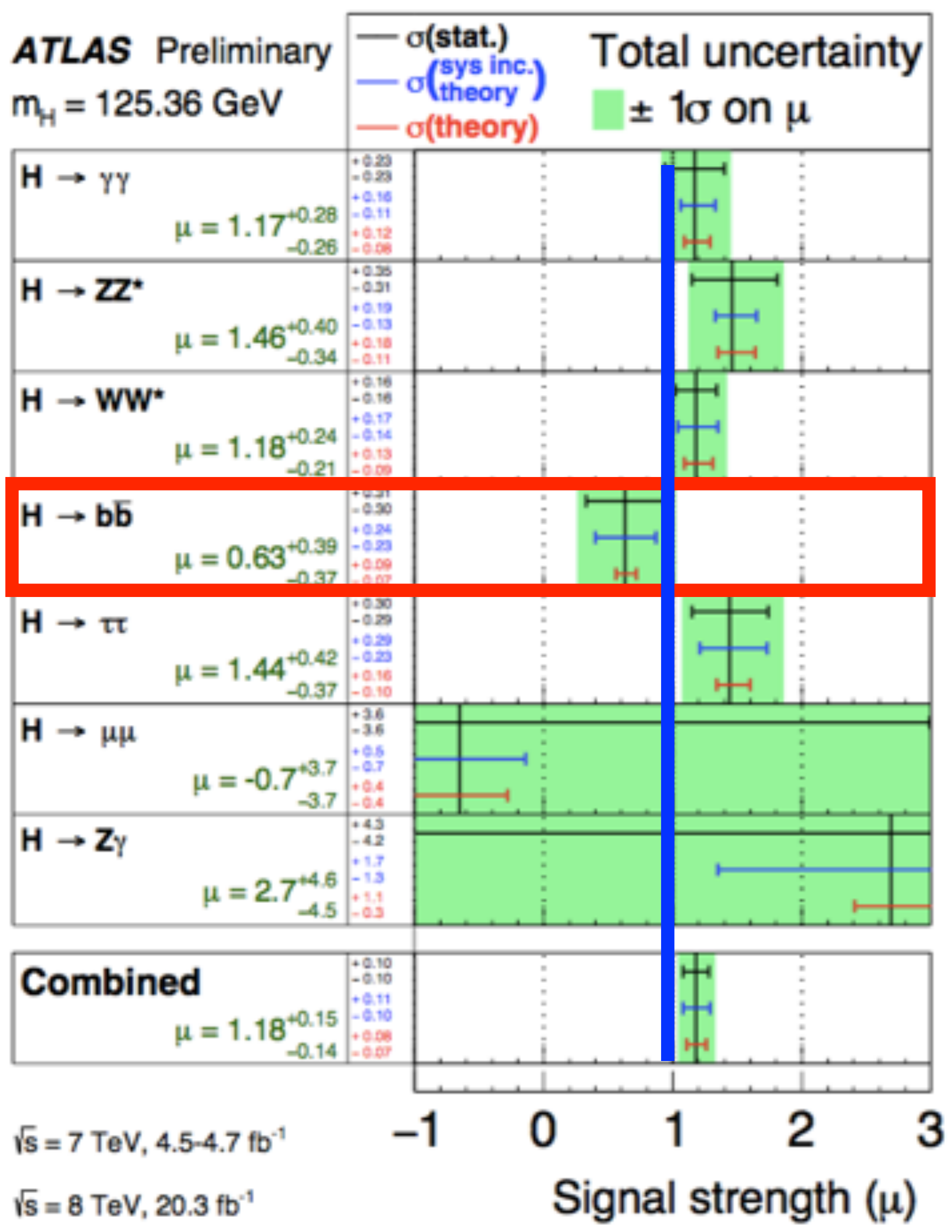
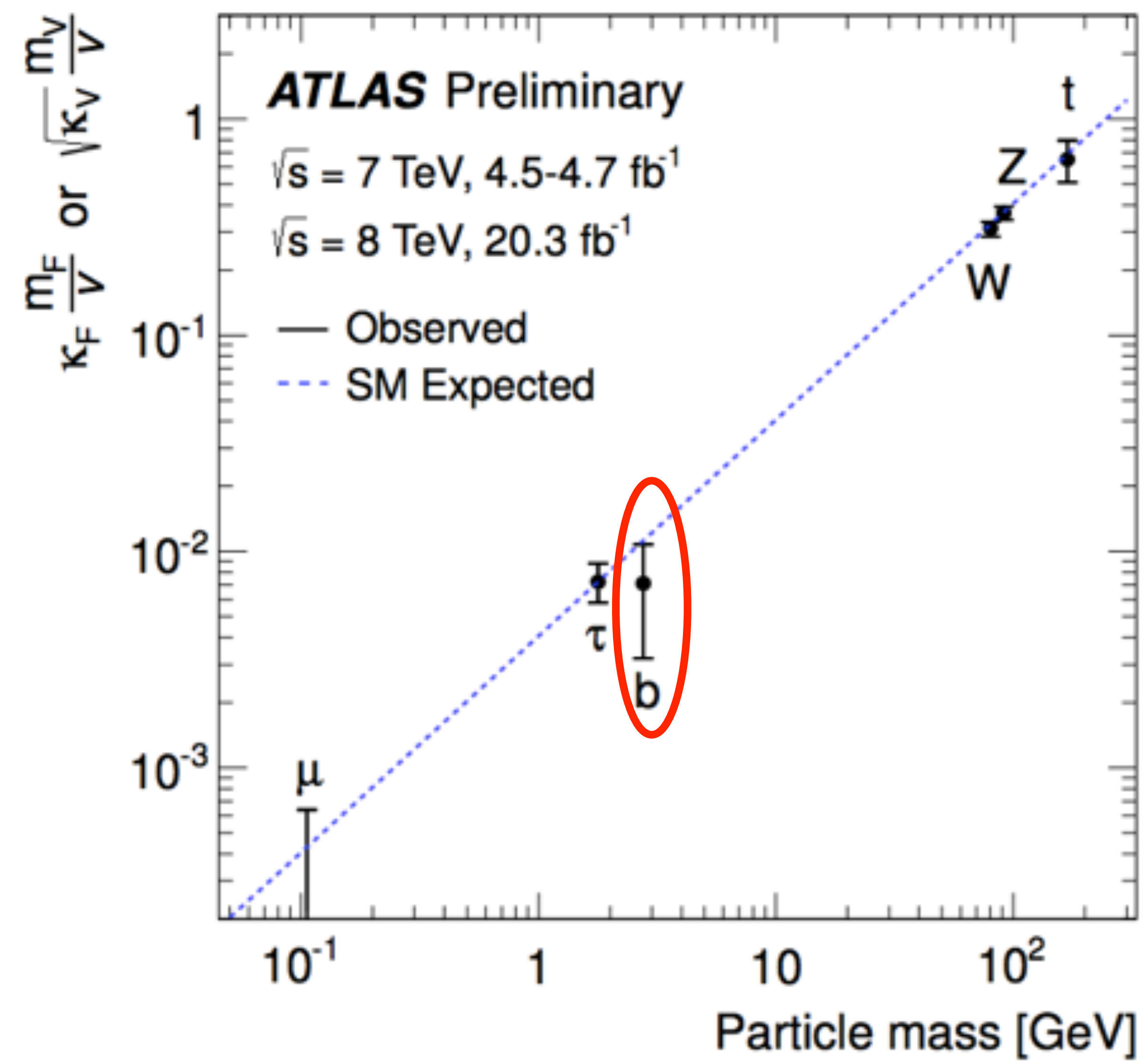
Higgs studies at LHC

- Higgs boson was discovered by ATLAS and CMS in 2012.

➡Next step is measuring each decay channel more precisely to prove linearity between coupling constant and the mass of each particle.



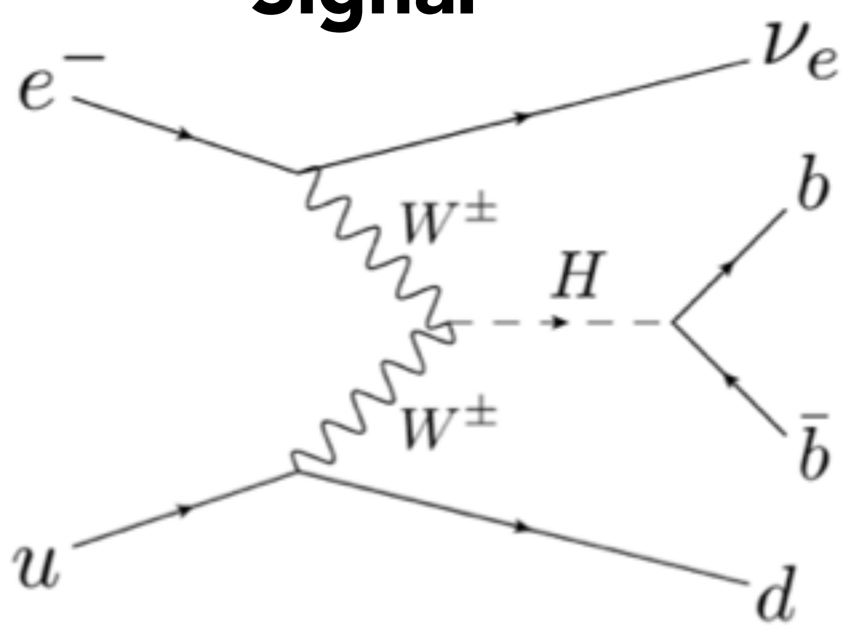


ATLAS-CONF-2015-007

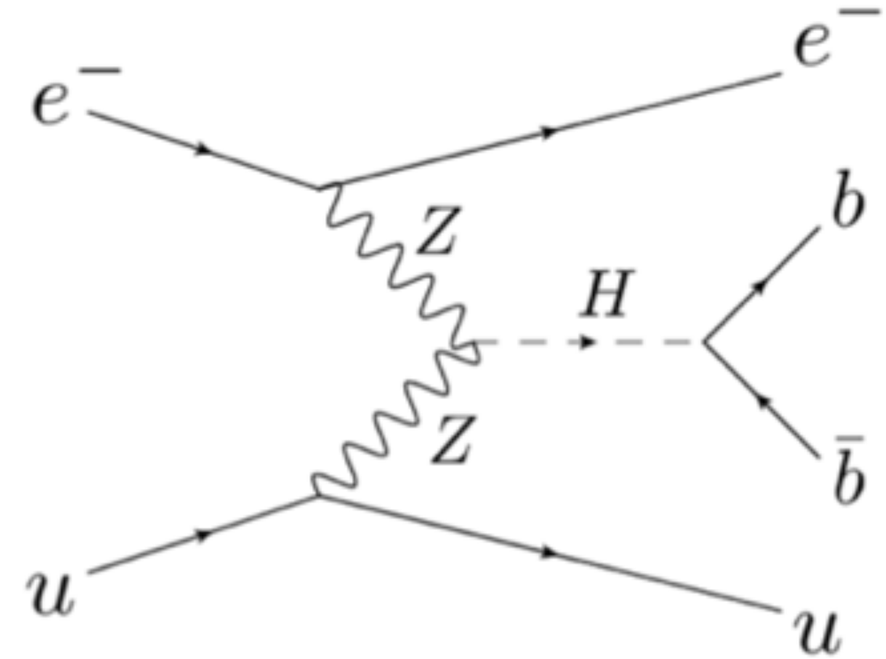
- H->bb channel is challenging due to large number of QCD bkg.
- How about at electron proton collider LHeC ?

Higgs in LHeC

Signal



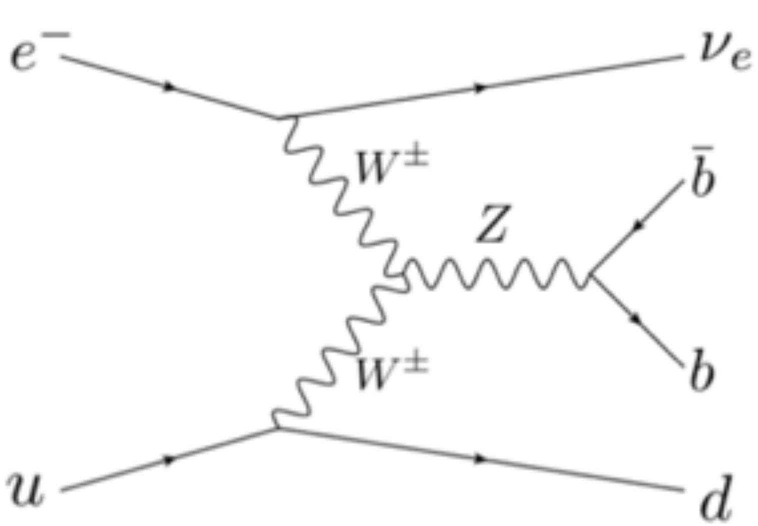
Charged current (CC) H->bb (0.063 pb)



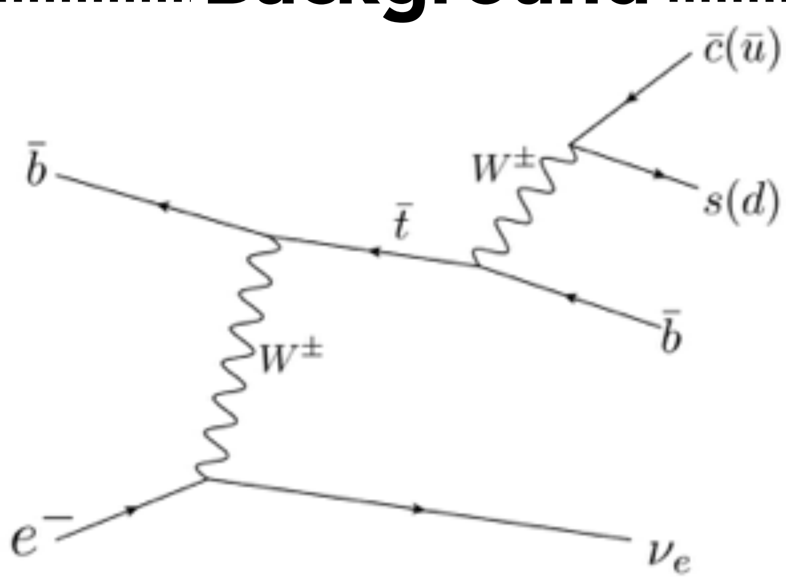
Neutral current (NC) H->bb (0.012 pb)

- CC: H->bb process is chosen as the signal because the cross section is larger than NC: H->bb process and NC rejection cut decreases large number of NC BG.

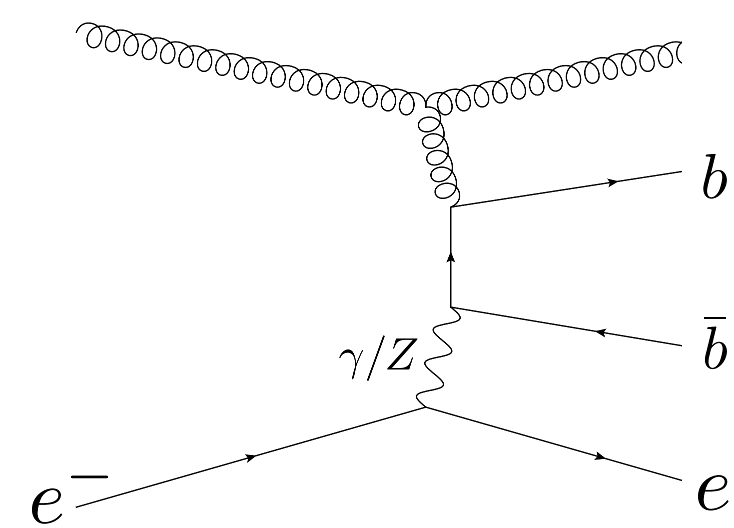
Background



CC Z production (0.29 pb)



Single top production (0.43 pb)

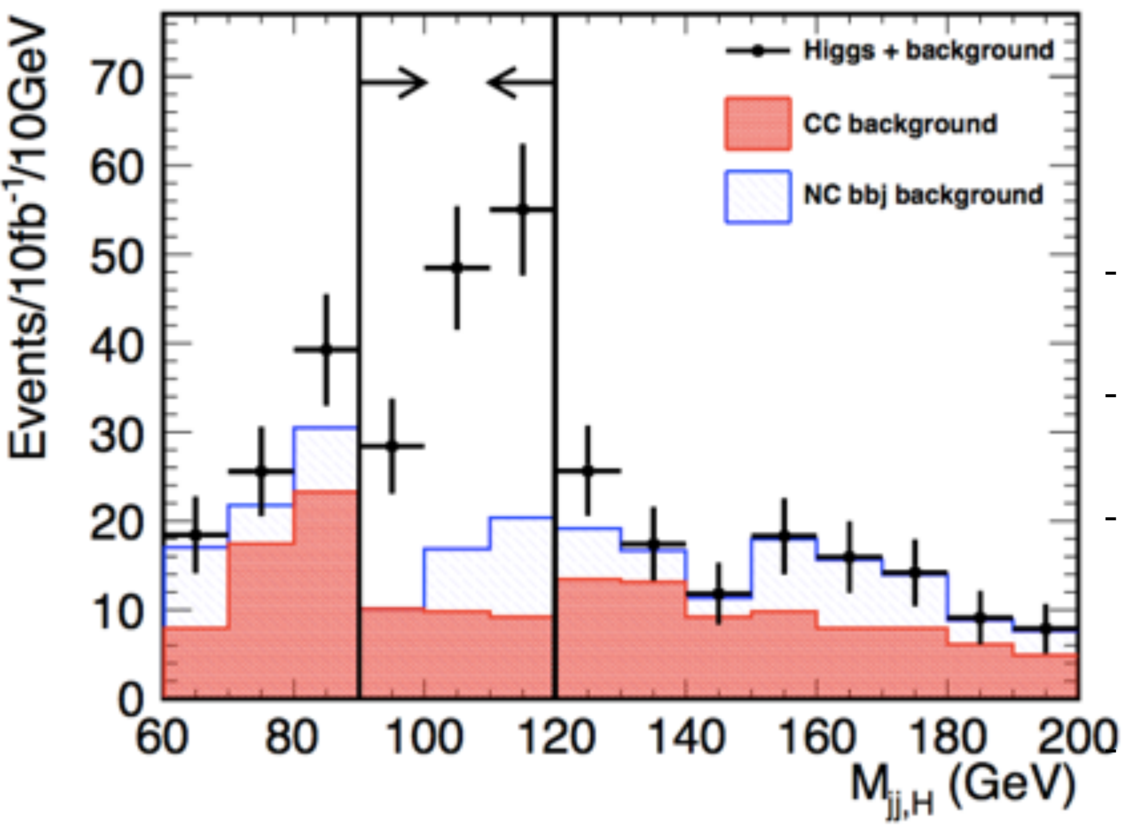


NC multi jets

CDR results and updates

CDR results (before Higgs discovery)

- Previous analysis was performed by K.Kimura (Tokyo Tech) and the result is on LHeC CDR.



	Higgs production	CC DIS	NC bbj	S/N	$S/\sqrt{N}$
cut (1)	816	123000	4630	6.38×10^{-3}	2.28
cut (1) to (3)	178	1620	179	9.92×10^{-2}	4.21
All cuts	84.6	29.1	18.3	1.79	12.3

- 120 GeV Higgs was assumed.
- E_e=150 GeV and luminosity of 10 fb^{-1}.
- CC (inclusive) and NC (with 2 or more b jets) backgrounds were considered.
- PGS was used for detector simulation.

Update of CDR analysis

- Higgs mass was determined to be 125 GeV by ATLAS and CMS.
- E_e=60 GeV and luminosity of 100 fb^{-1}.
- New categorization of background MC (details later.)
- Delphes is used for detector simulation.
- Revised selection cuts.

LHeC in simulation

MadGraph/MadEvent

- Parton level event generation
- Calculation of cross section

▼

Pythia

- Fragmentation
- Hadronization

▼

Delphes

- Detector simulation

▼

H->bb event selection

Generator setup

- Beam of proton: 7 TeV, electron: 60 GeV.
- 125 GeV Higgs.

Detector setup

- Coverage:
  - Calorimeter: $|\eta|<5$ Tracking: $|\eta|<4.7$
- Jet reconstruction:
  - anti k_T algorithm with $\Delta R=0.9$
- HCal resolution

$$\frac{\sigma}{E} = \frac{30\%}{\sqrt{E}} + 3\% \; (|\eta| < 3) \qquad \frac{\sigma}{E} = \frac{60\%}{\sqrt{E}} + 5\% \; (3 < |\eta| < 5)$$

- ECal resolution

$$\frac{\sigma}{E} = \frac{35\%}{E} + \frac{7\%}{\sqrt{E}} + 0.7\% \; (|\eta| < 3)$$

$$\frac{\sigma}{E} = \frac{20\%}{\sqrt{E}} + 2\% \; (3 < |\eta| < 4) \qquad \frac{\sigma}{E} = \frac{40\%}{\sqrt{E}} + 10\% \; (4 < |\eta| < 5)$$

Simulation sample

- Signal sample is charged current H->bb events.
- Background is categorized in detail (by Uta Klein et al. in Liverpool.)
  - Charged current background is separated to 3 types, including single top, including Z and excluding both top and Z.
  - Neutral current background is separated to two types, including Z or photo production event which γ/Z interact with proton.
- 100 fb^{-1} is assumed.

	σ (pb)	Nsample	N/σ (fb^{-1})
Signal H->bb	0.063	200K	3170
CCjjj no top	2.5	300K	120
CC single top	0.43	150K	350
CC Z	0.29	100K	345
NC Z	0.13	100K	770
PAjjj	38	955K	25

- PAjjj
  - Photo production events.
  - Required 3 jets (PT>10 GeV) in final state.
  - All 6 flavor is contained

Event selection

Primary cut

$$N_{Jet}\ (p_T > 20\ \mathrm{GeV}) \geq 3$$

$$N_{Bjet}\ (p_T > 20\ \mathrm{GeV}) \geq 2$$

$$Q_h^2 > 400\ \mathrm{GeV}^2,\ y_h < 0.9$$

$$Q_h^2 = \frac{(\sum_{hadron} p_x)^2 + (\sum_{hadron} p_y)^2}{1 - y_h}$$

$$y_h = \frac{\sum_{hadron}(E - p_z)}{E_e}$$

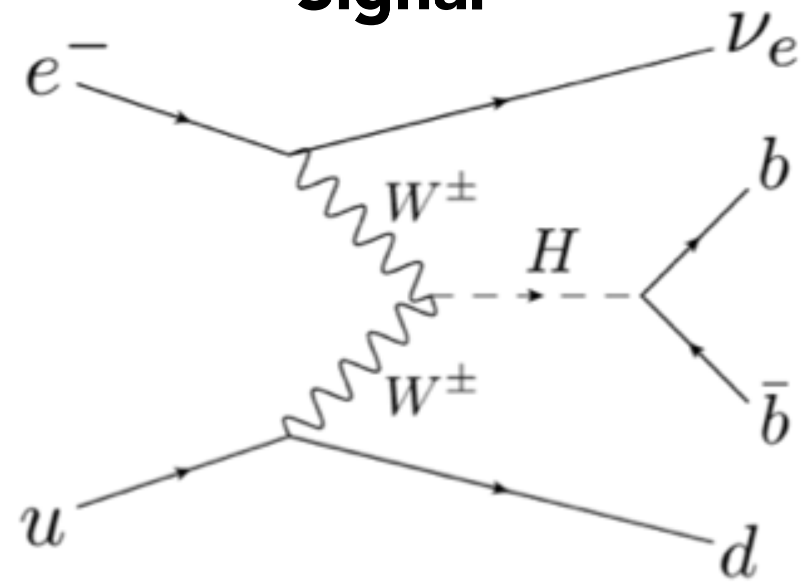
NC rejection

$$E_{miss}^T > 20\ \mathrm{GeV}$$

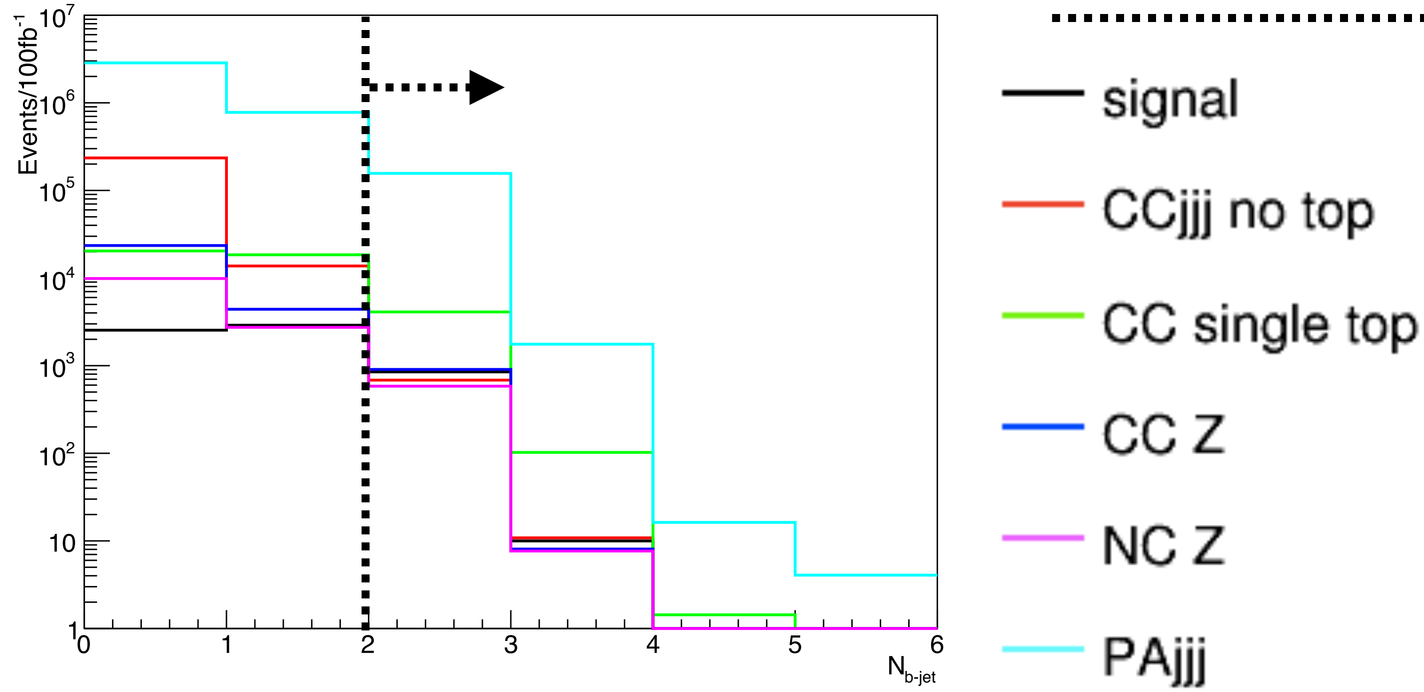
$$N_{electron} = 0$$

$$\Delta\phi_{b,MET} > 0.3$$

Signal



Number of b-tagged jets

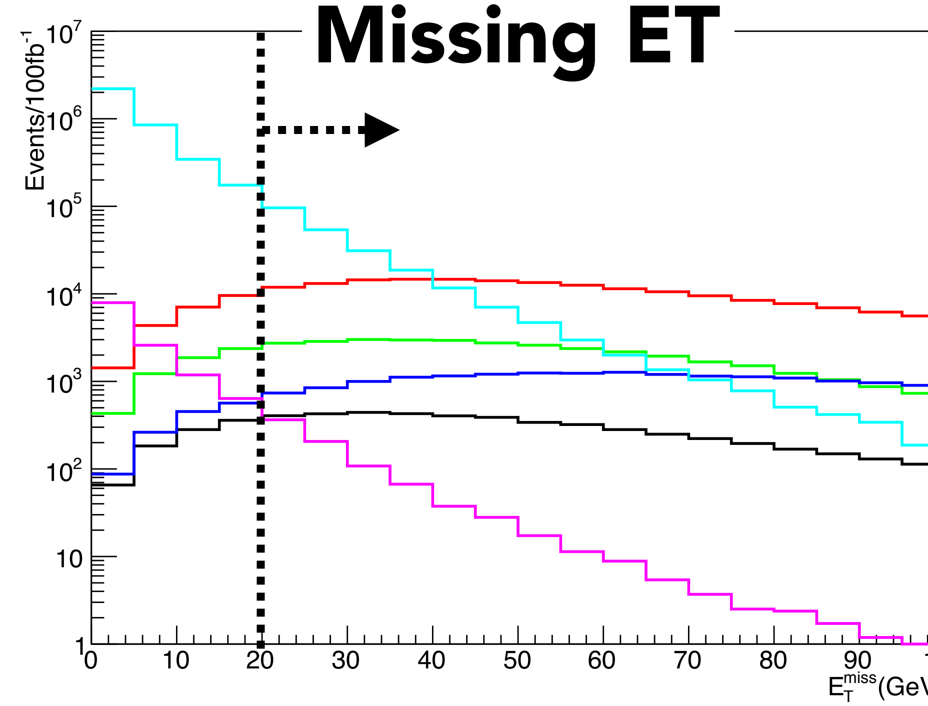


B-tag efficiency model

For |η| < 4.7

- b-jet identification: 60%
- c-jet mis-ID: 10%
- Other jet mis-ID: 1%

Missing ET

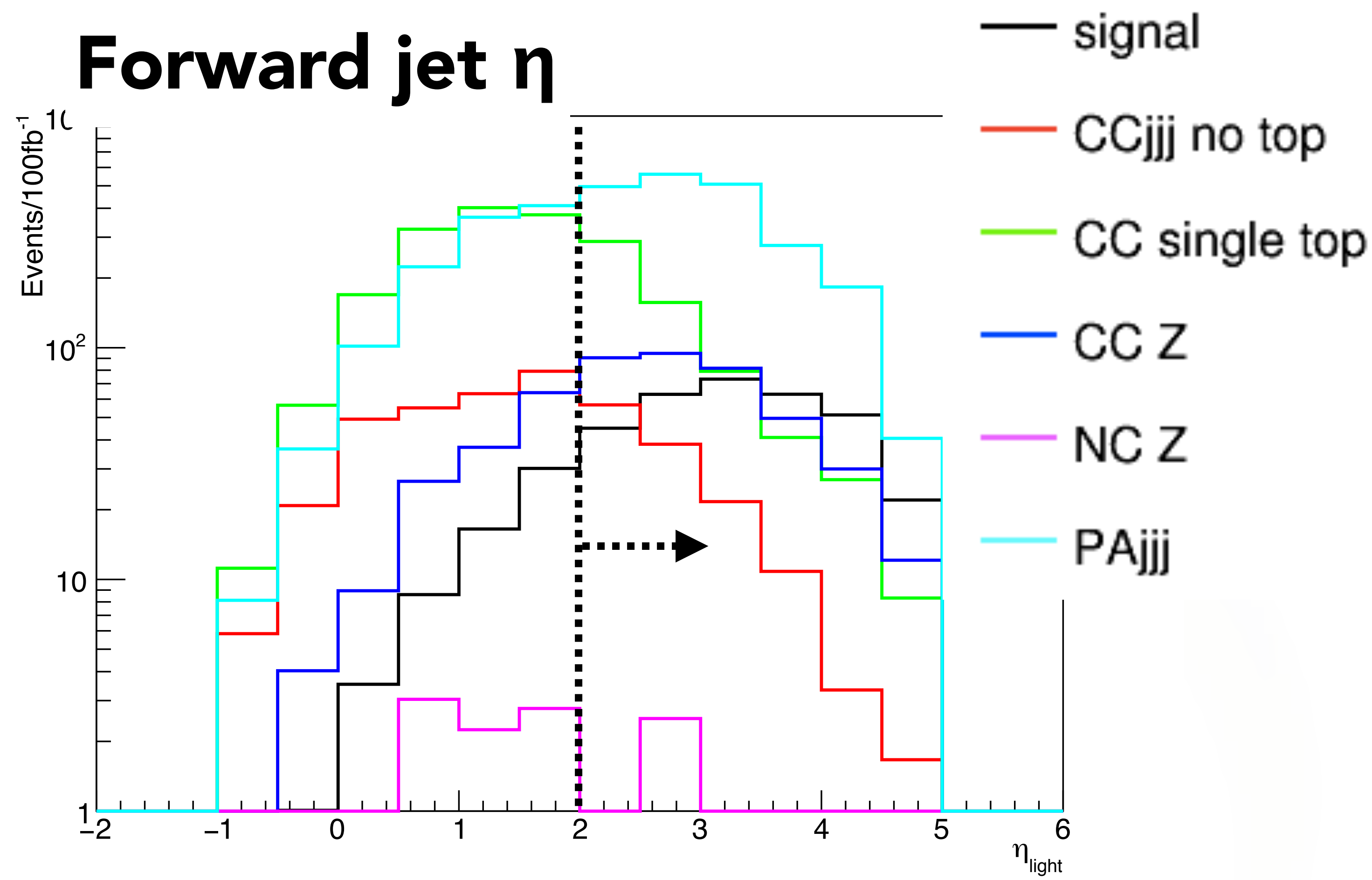


Event selection

Forward jet tagging

- Minimum η jet excluding two b-tagged jets with 1st and 2nd minimum eta
- Regardless of b-tagged or not

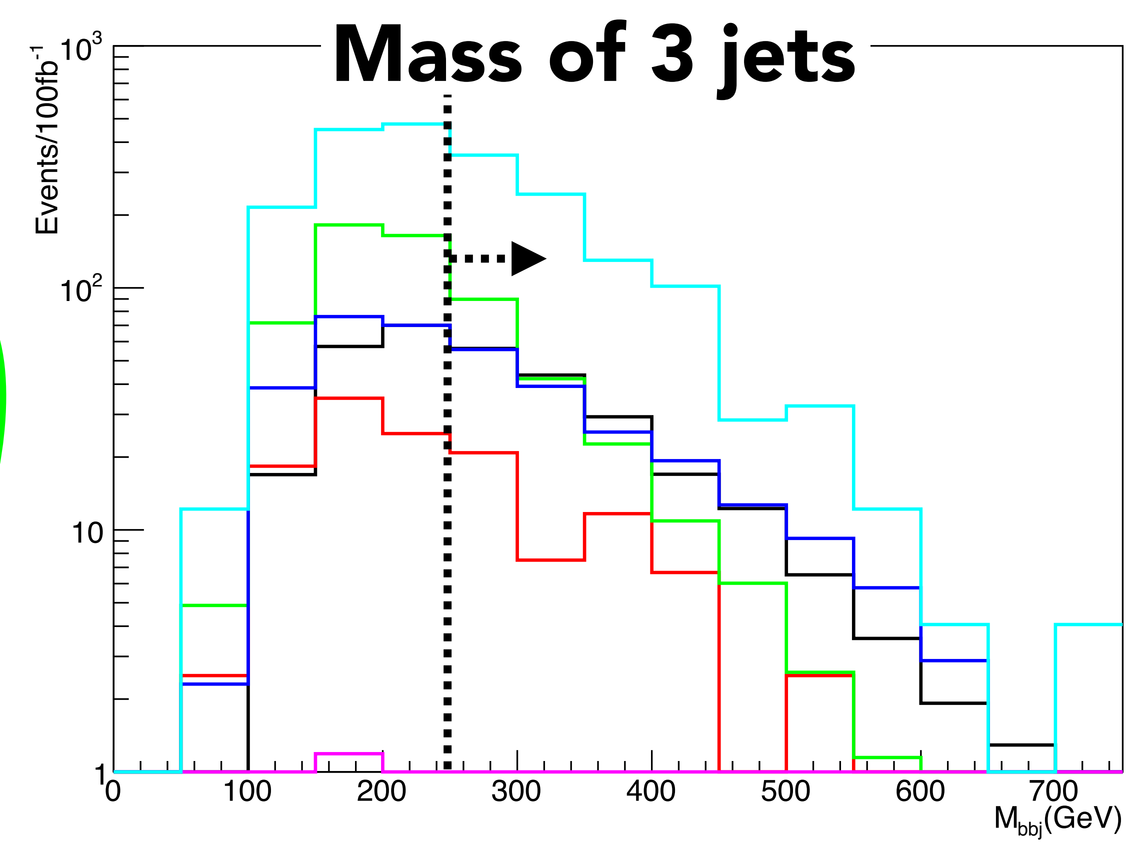
$$\eta_{fwd} > 2$$

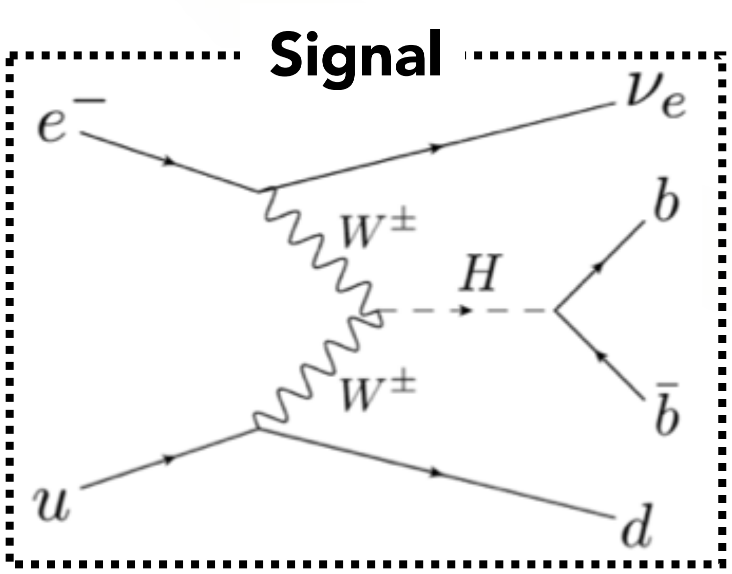


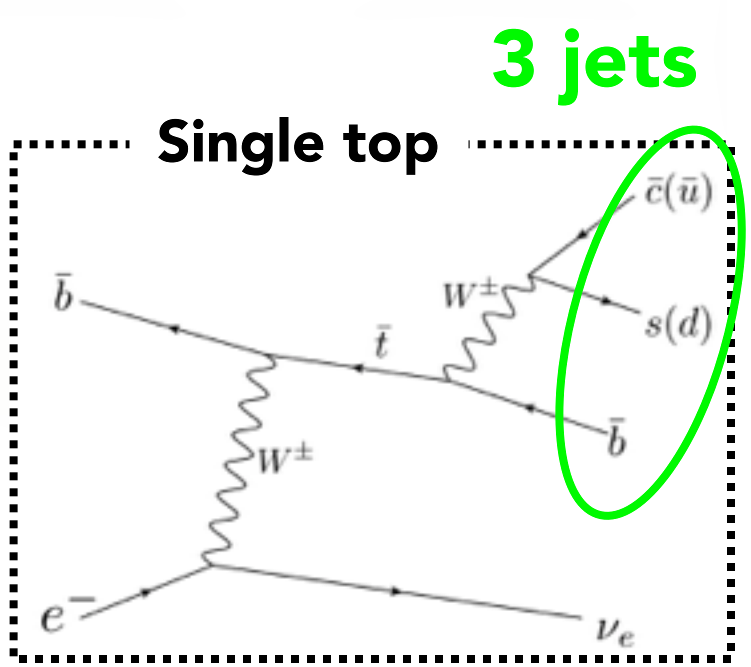
Single top rejection

$$M_{jjj,top} > 250\ \mathrm{GeV}$$

$$M_{jj,W} > 130\ \mathrm{GeV}$$

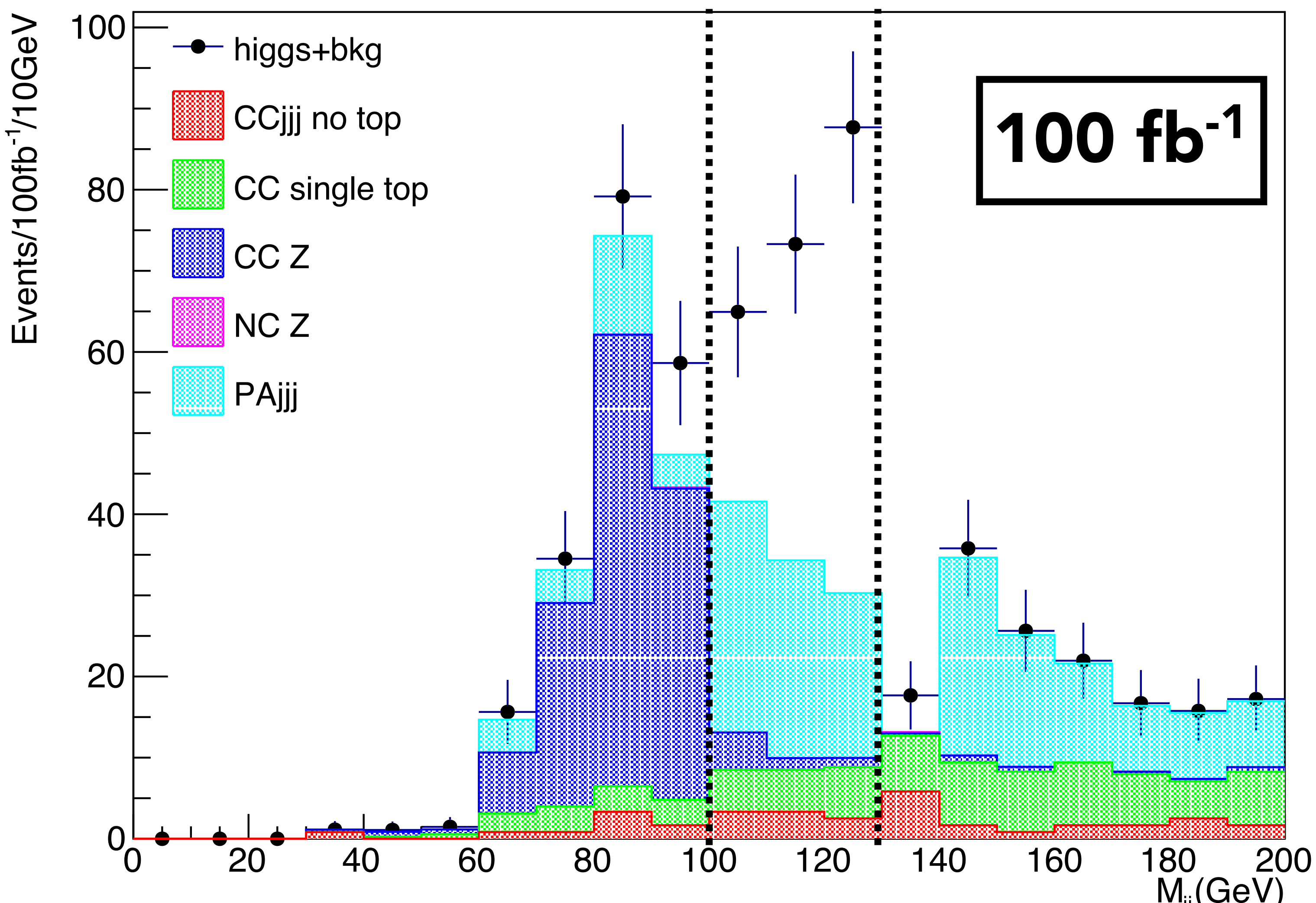






Result

- Mass reconstructed with 1st and 2nd minimum η b-jets.
- Signal region is defined as [100,130] GeV.



Events in signal region

Signal H->bb	119±2
CCjjj no top	9±3
CC single top	17±2
CC Z	7±1
NC Z	0
PAjjj	73±17
CCbkg total	33±4
NCbkg total	73±17

- Errors are weighted

$S/\sqrt{B} = 11.5$

- We can detect H->bb signal in good efficiency.
- Peak around 80 GeV is Z boson from CC background.
- PAjjj background has large statistical error due to small statistics.
- Electron tagging of Photo-production events could further suppress BG under peak.

Dependency on B-tagging coverage

- Coverage of B-tagging is changed and result is compared

B-tag efficiency model

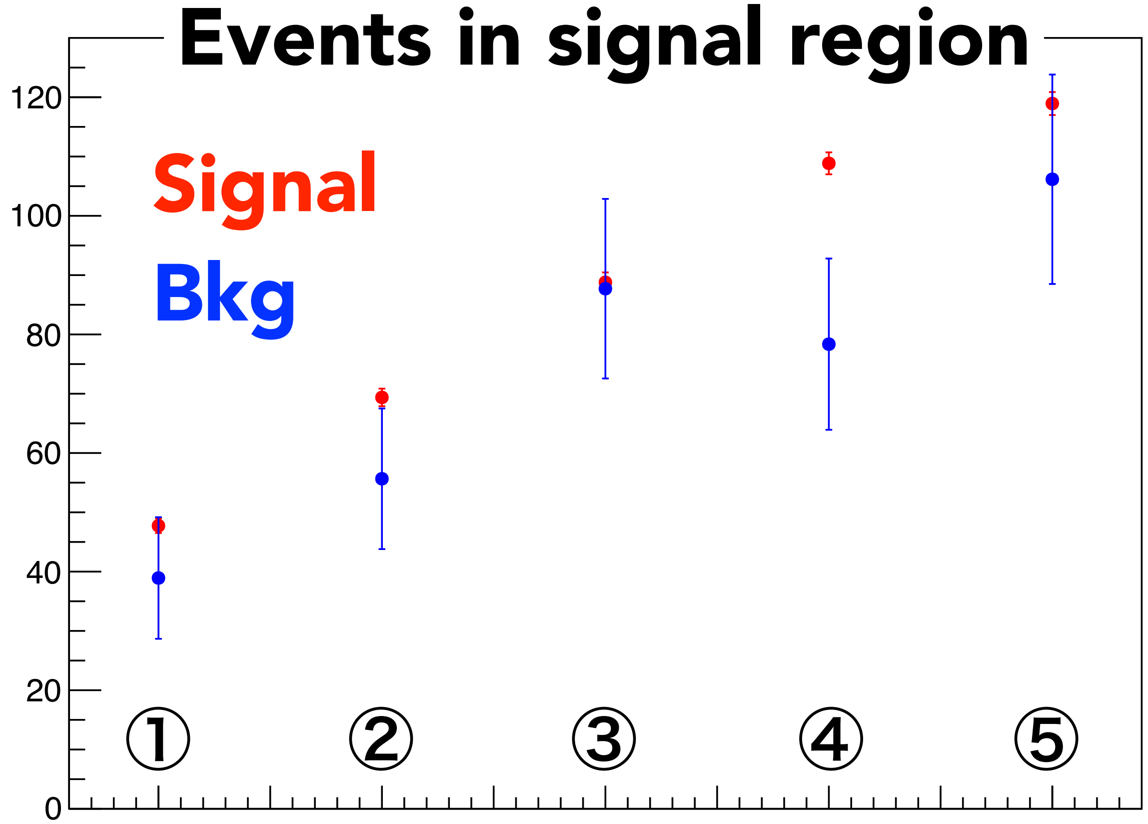
For each η region

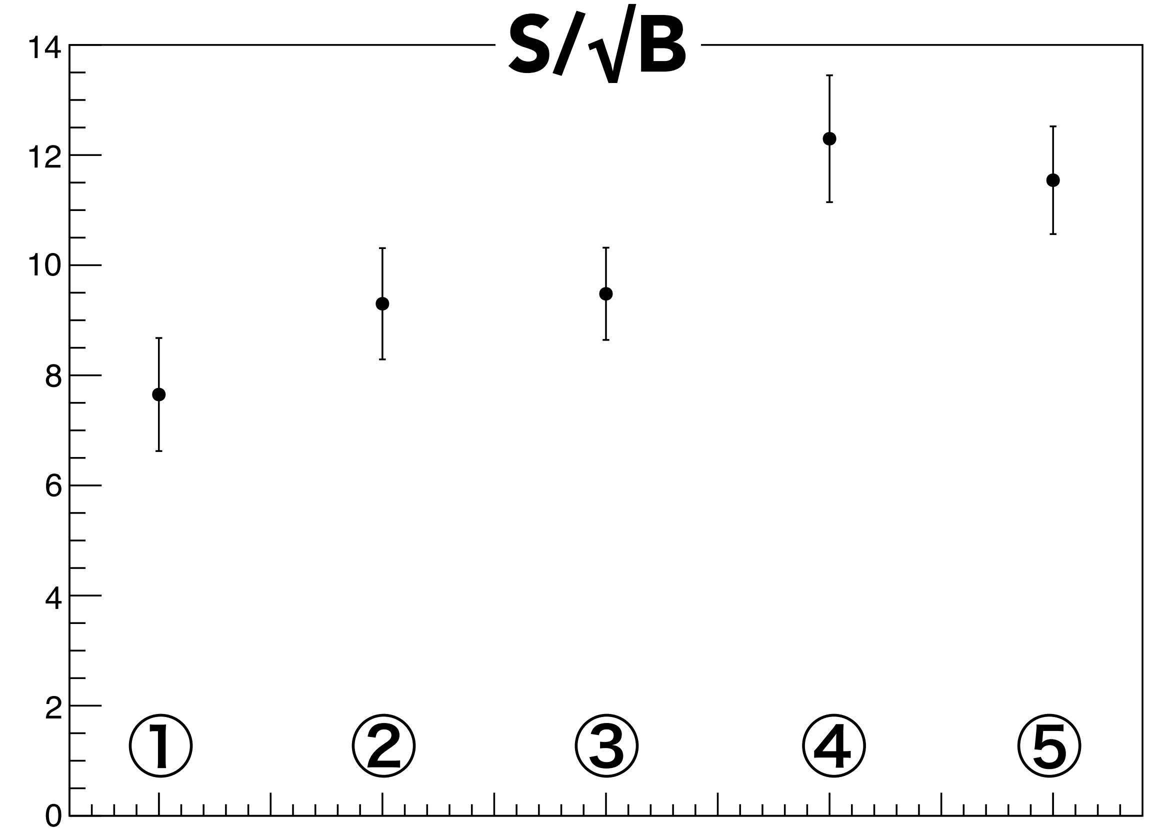
b-jet identification: 60%

c-jet mis-ID: 10%

Other jet mis-ID: 1%

	B-tag coverage
①	$\|\eta\|<2.7$
②	$\|\eta\|<3.2$
③	$\|\eta\|<3.7$
④	$\|\eta\|<4.2$
⑤	$\|\eta\|<4.7$





- Both signal and background increase as coverage of b-tagging is expanded, so S/B is similar but S/√B increase.

Dependency on HCal resolution

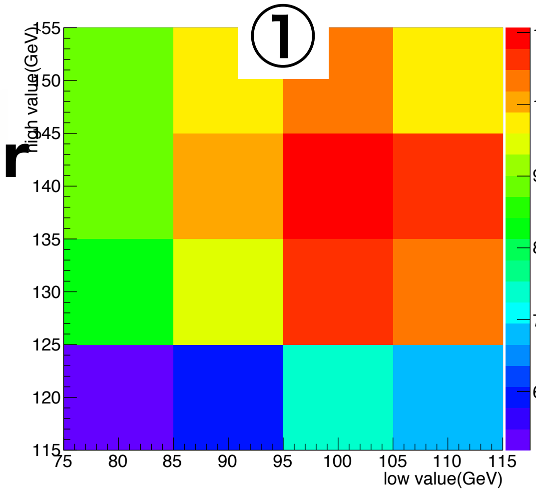
HCal resolution setup

$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} + b \ (|\eta| < 3)$$

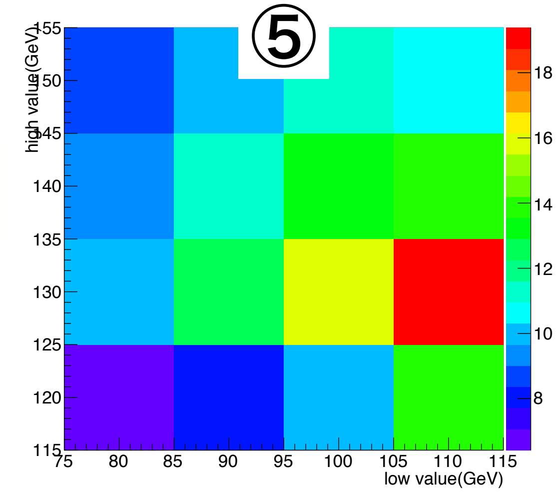
$$\frac{\sigma}{E} = \frac{c}{\sqrt{E}} + d \ (3 < |\eta| < 5)$$

	a(%)	b(%)	c(%)	d(%)
①	60	6	120	10
②	45	4.5	90	7.5
③	30	3	60	5
④	22.5	2.25	45	3.75
⑤	15	1.5	30	2.5

- Signal region is optimized w.r.t each setup

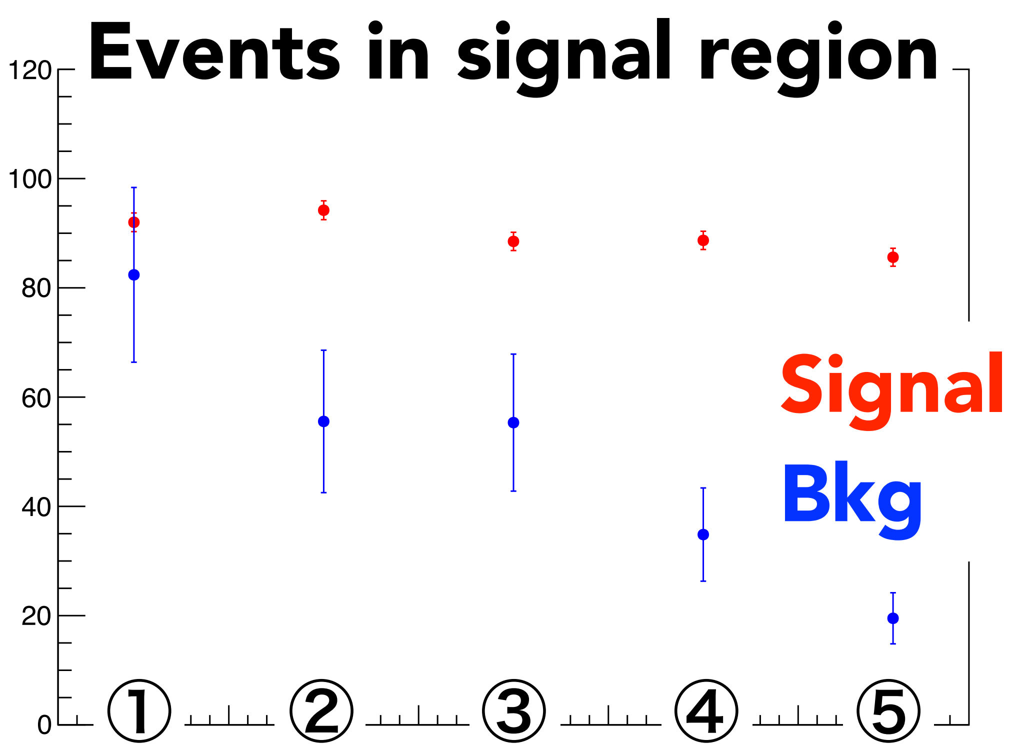


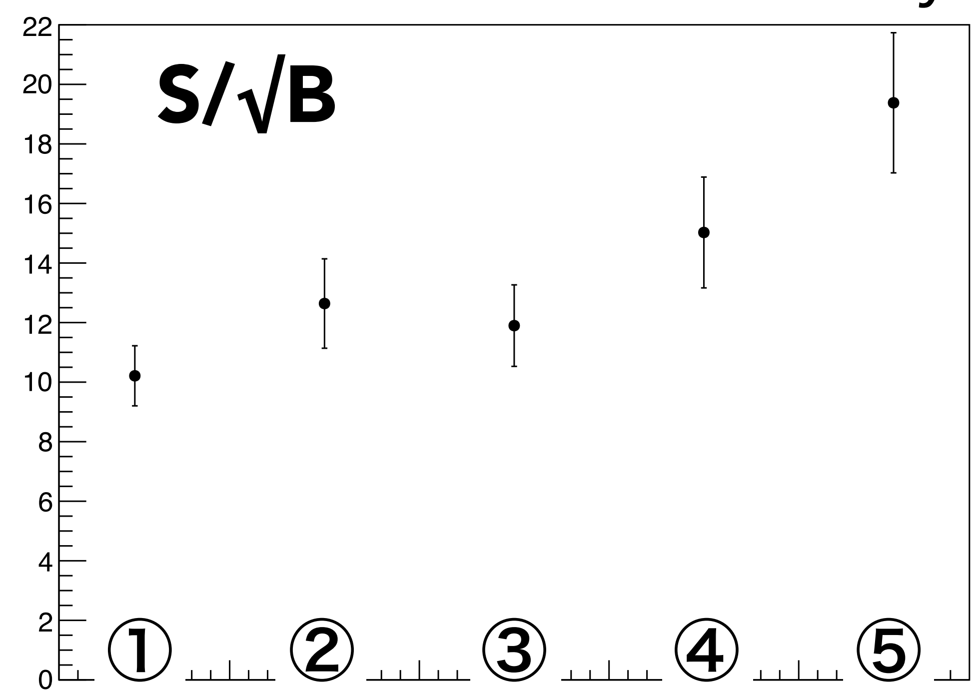
S/√B



$100 < M_{jj} < 140$ GeV　　$110 < M_{jj} < 130$ GeV

- Number of background decrease and S/√B increase as the resolution become better.
- Improvement of hadron calorimeter leads to better result on H->bb analysis in LHeC.





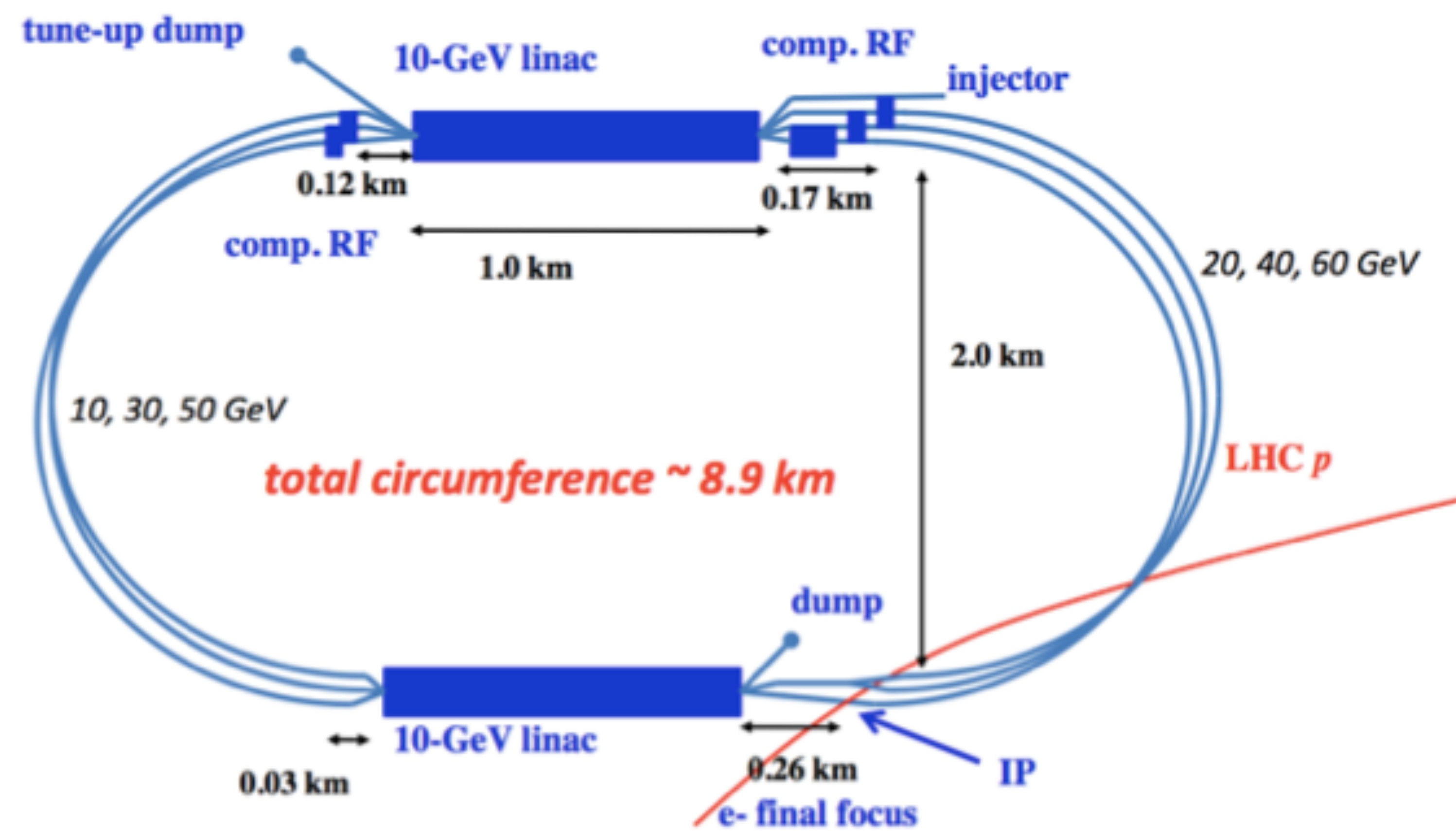
Summary

- LHeC is a future project of electron proton collider.
- LHeC could have advantage on H->bb analysis because QCD background is much less than LHC.
- H->bb studies at LHeC by MC simulation was updated from CDR.
  - 125GeV Higgs, E_e=60 GeV, luminosity of 100 fb^{-1}.
  - New categorization of background MC.
  - Dependency on B-tag coverage and HCal resolution.
- As the result $S/\sqrt{B}=11.5$
- Expanding of B-tag coverage increases the number of both signal and background.
- Improvement of HCal resolution leads to better result of H->bb studies at LHeC.

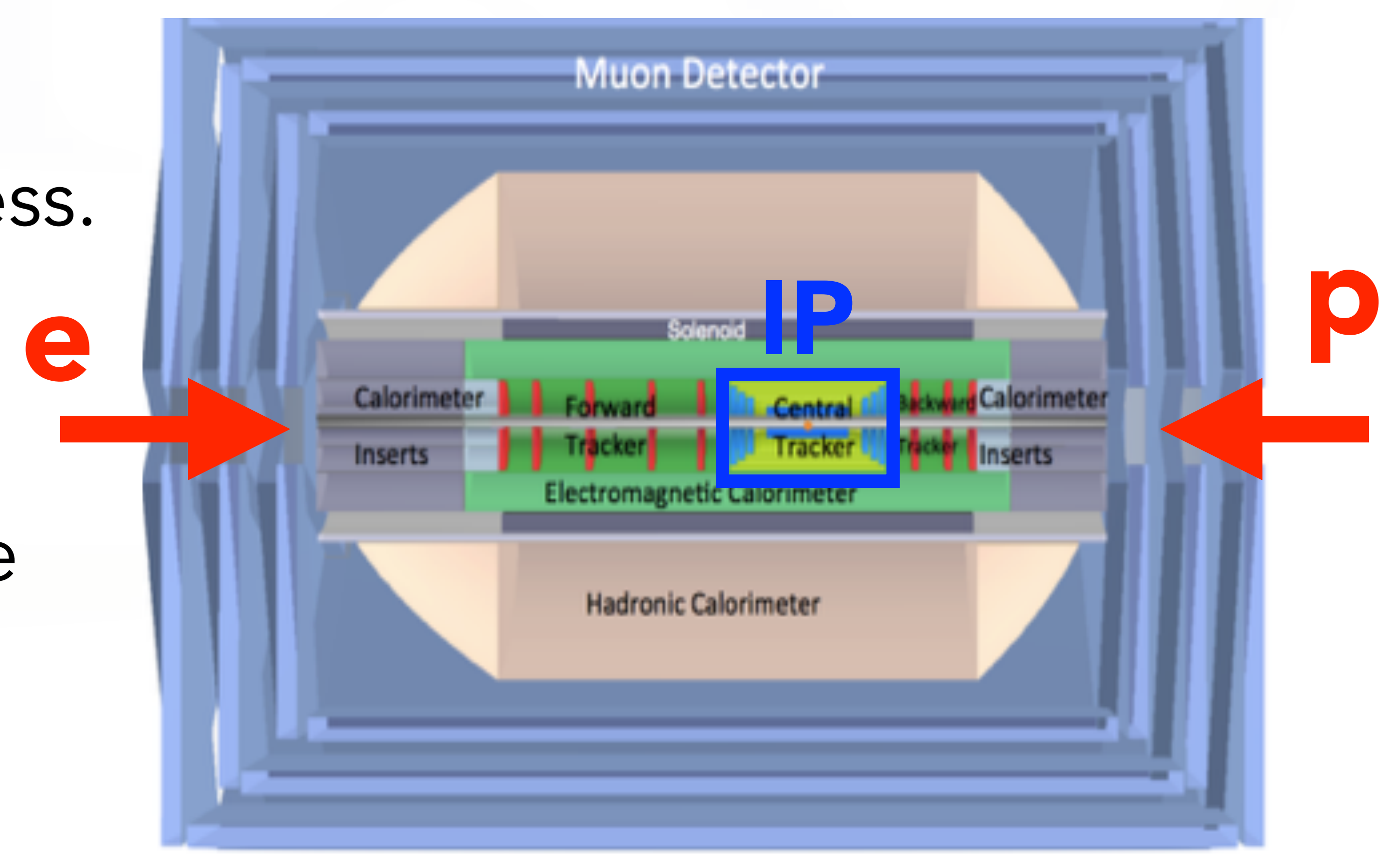
Backup

The LHeC project

- Electron-proton collider
  - Proton beam of LHC is used.
  - **E**nergy **R**ecovery **L**inac for electron facility.
  - Energy of electron: 60 GeV
    proton : 7 TeV
  - 100 fb^{-1}/yr can be collected with LHeC high-lumi option.

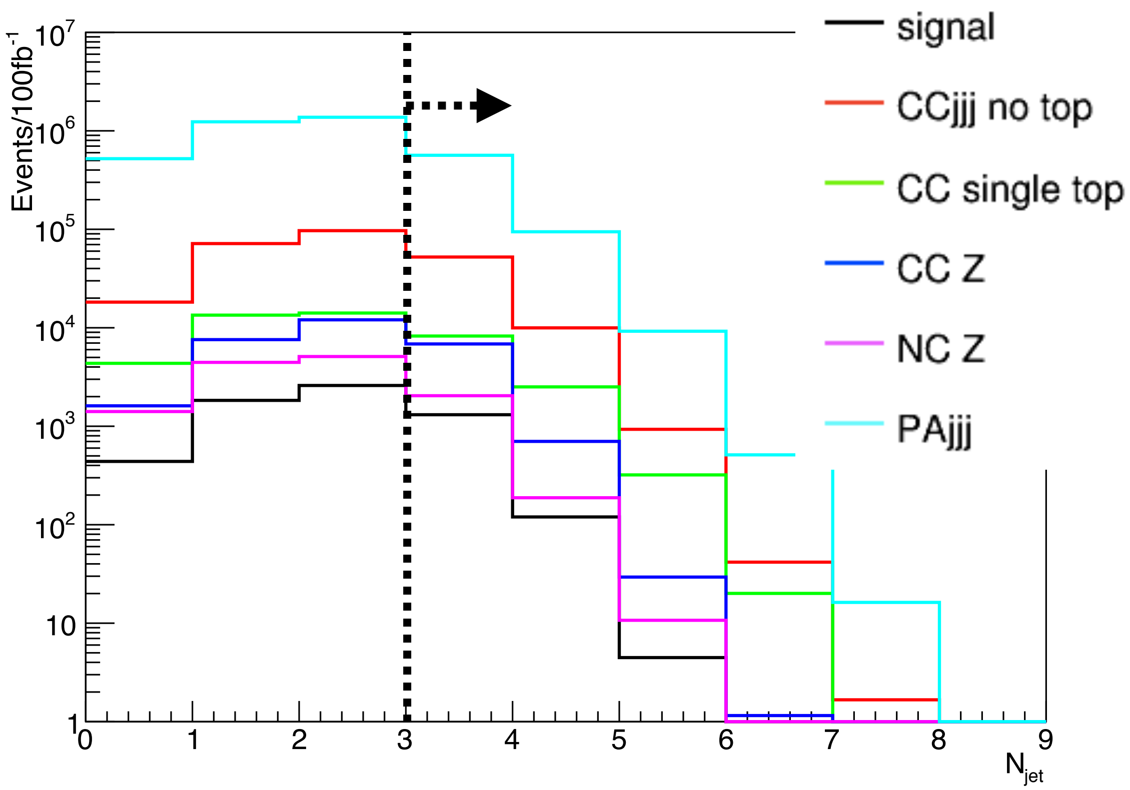


- Detector
  - Detector design study is in progress.
  - Asymmetric structure w.r.t interaction point.
  - Angler coverage to very low angle (large rapidity) is planned.

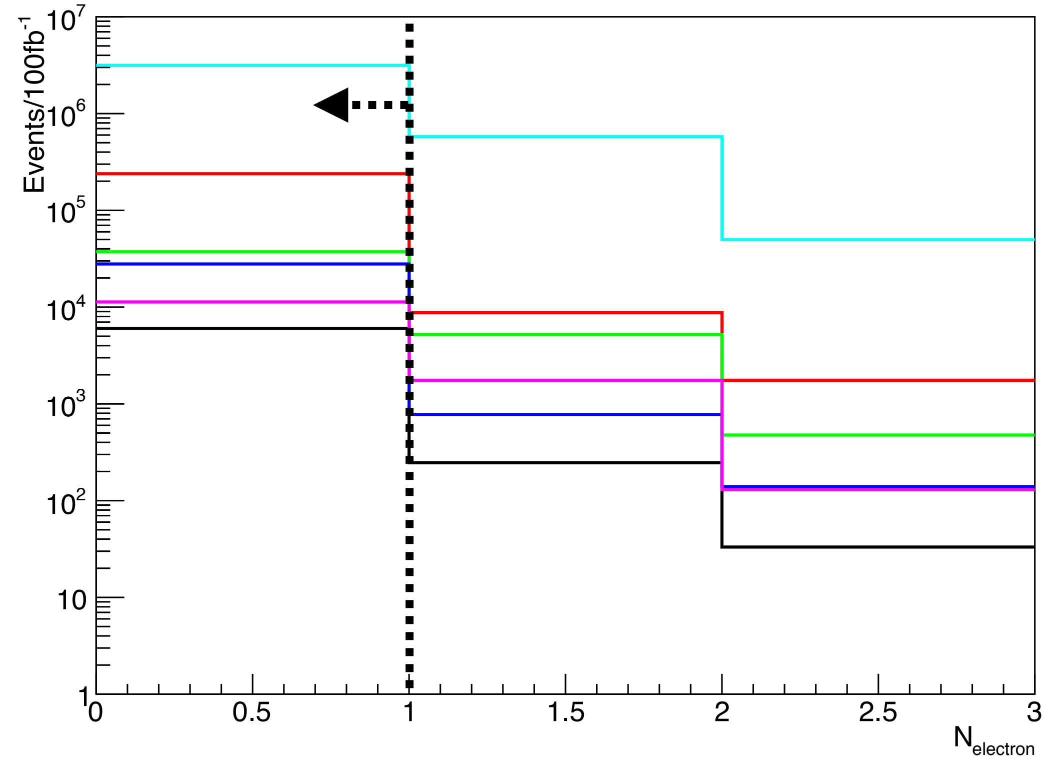


Cut parameters

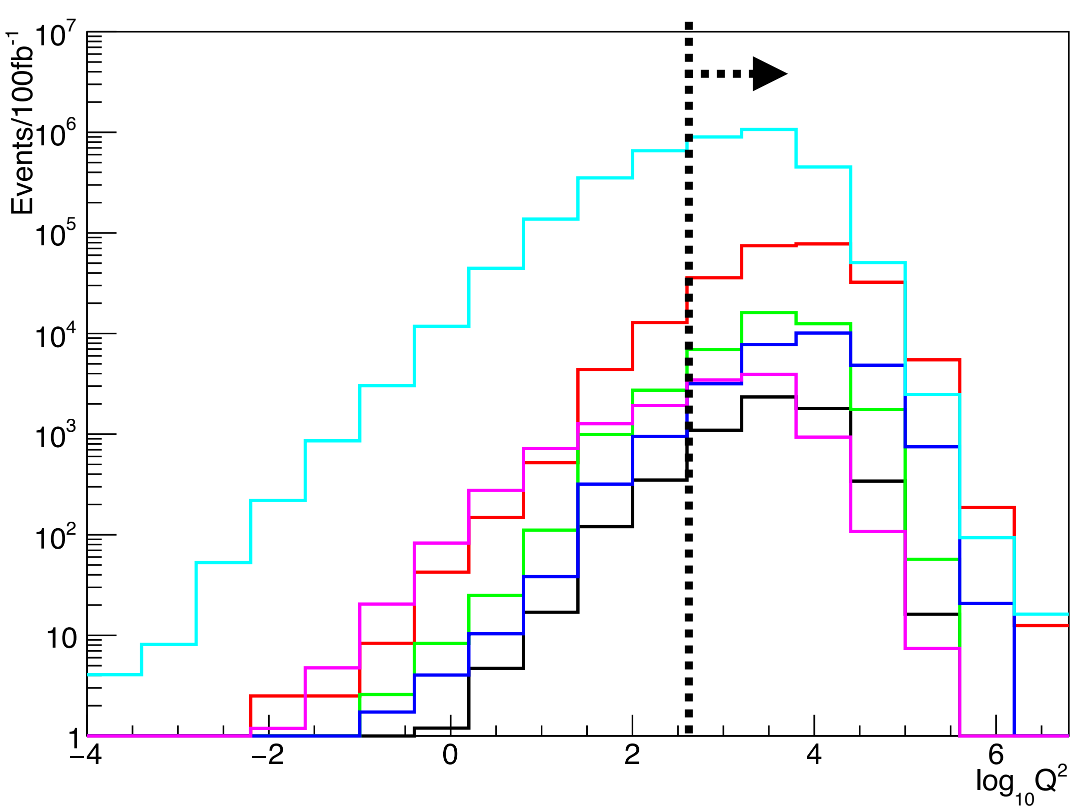
Number of jet (pt>20GeV)



Number of electron



Momentum transfer Q^2



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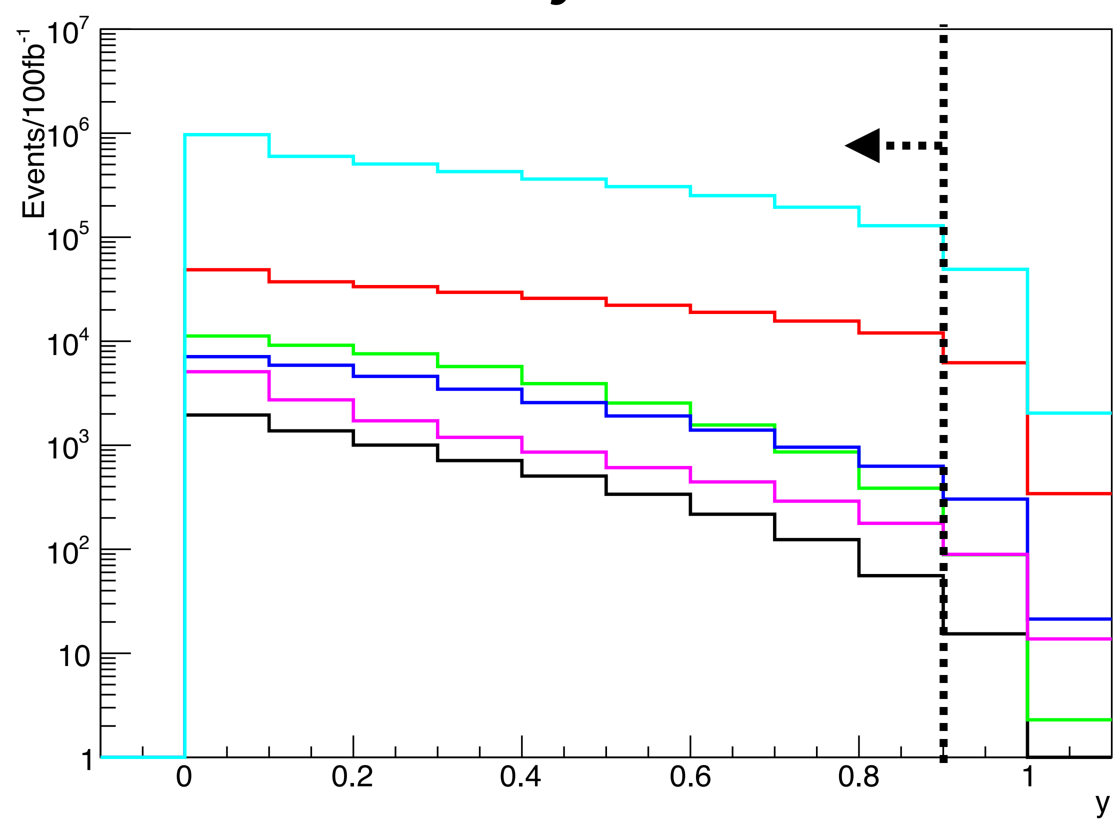
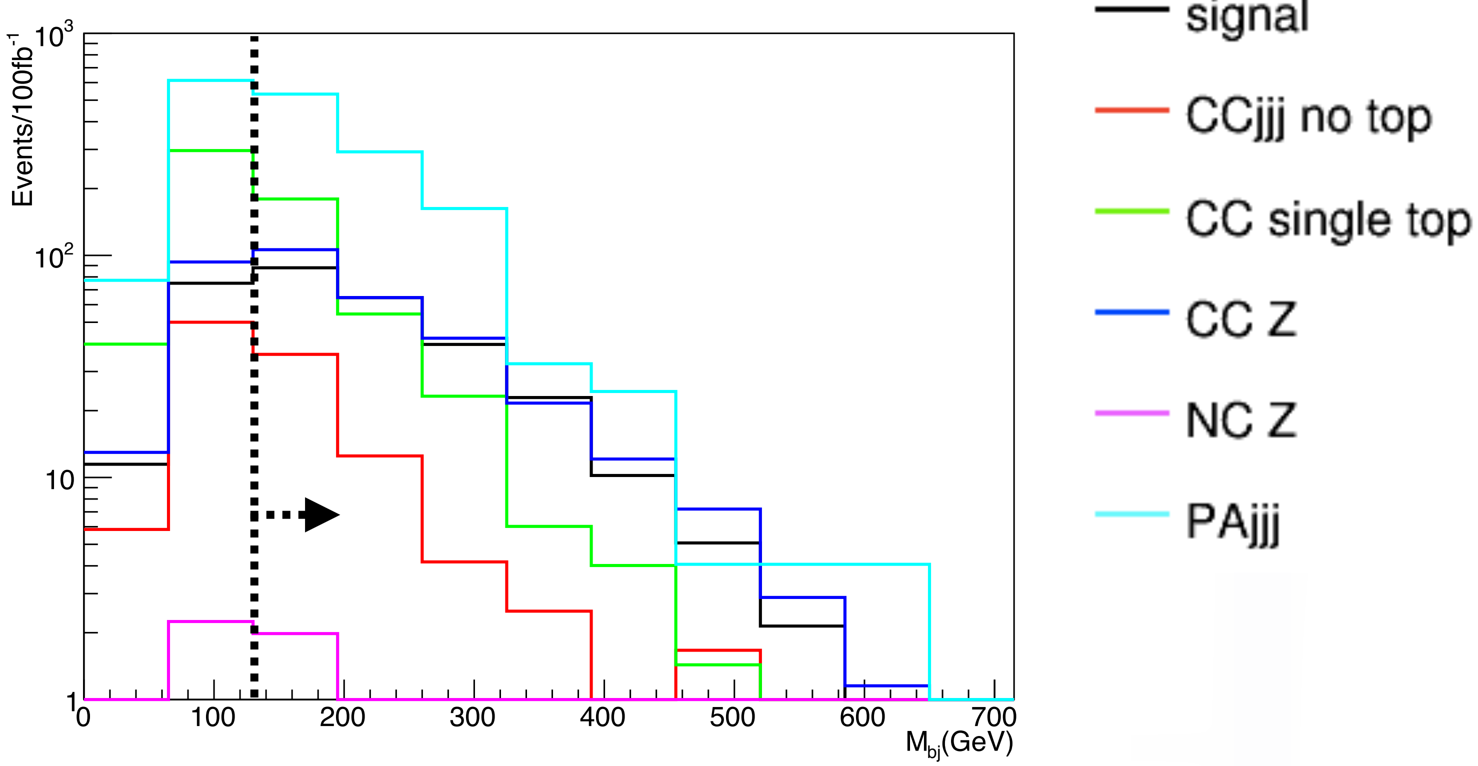


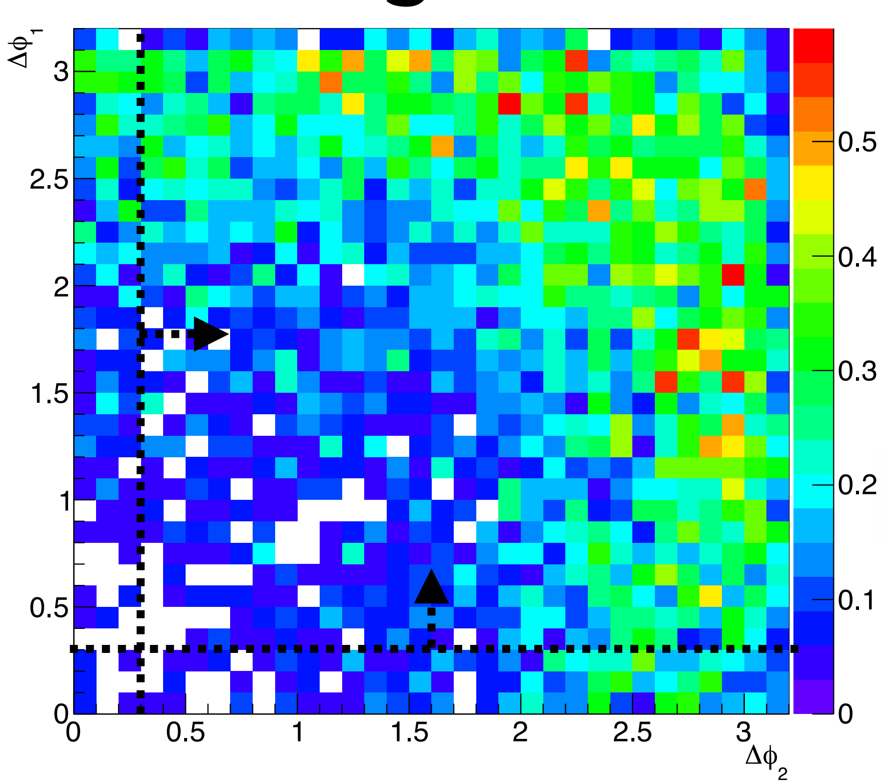
Cut parameters

Mass of 2 jets

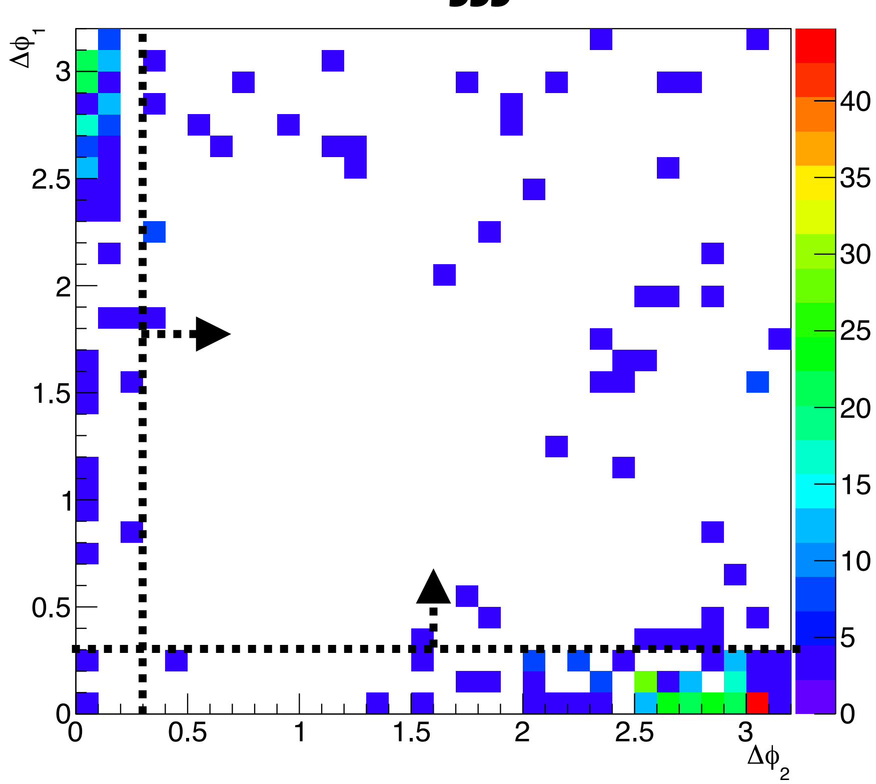


Δφ between MET and 2 b-jets

Signal

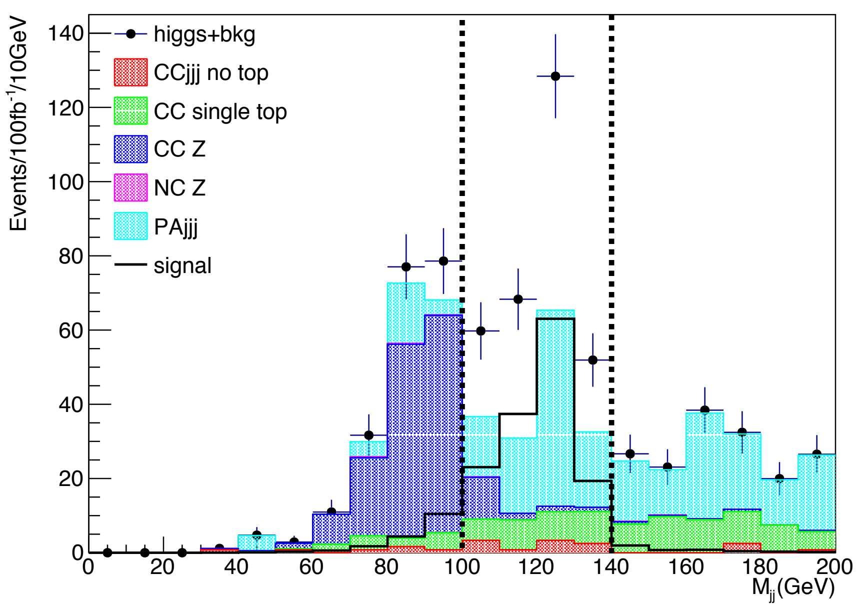


PAjjj

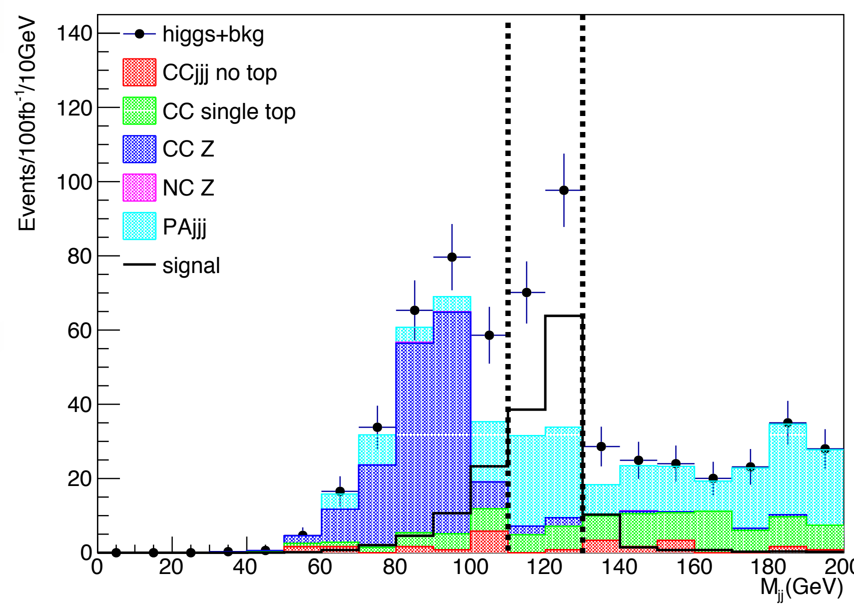


2 b-jets masses in HCal resolution comparison

①



②



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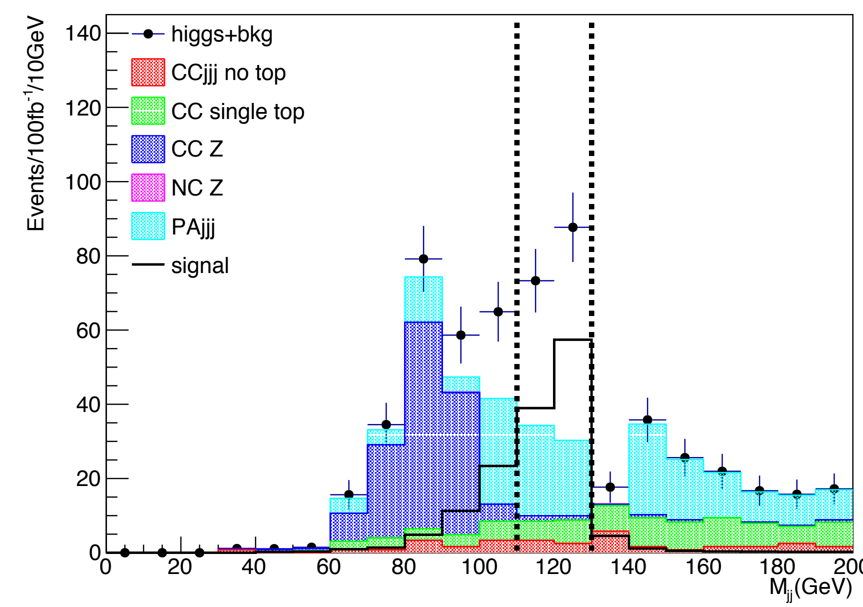

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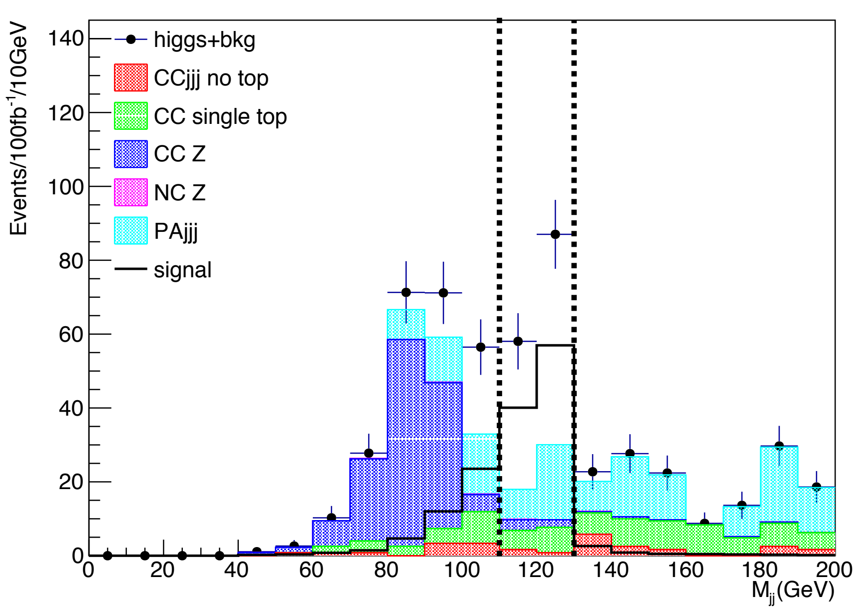

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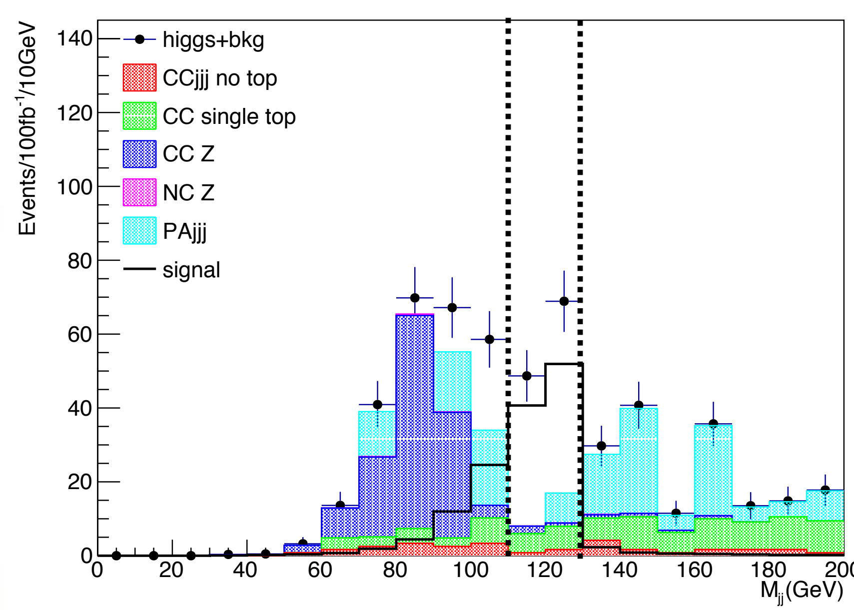

①
②
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④
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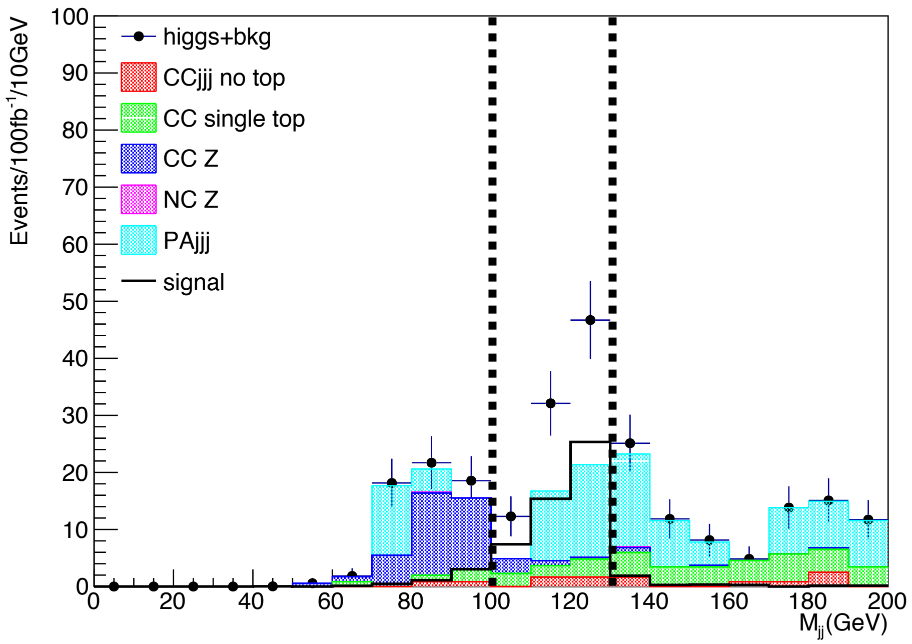
Better ↓

2 b-jets masses in B-tag coverage comparison

①



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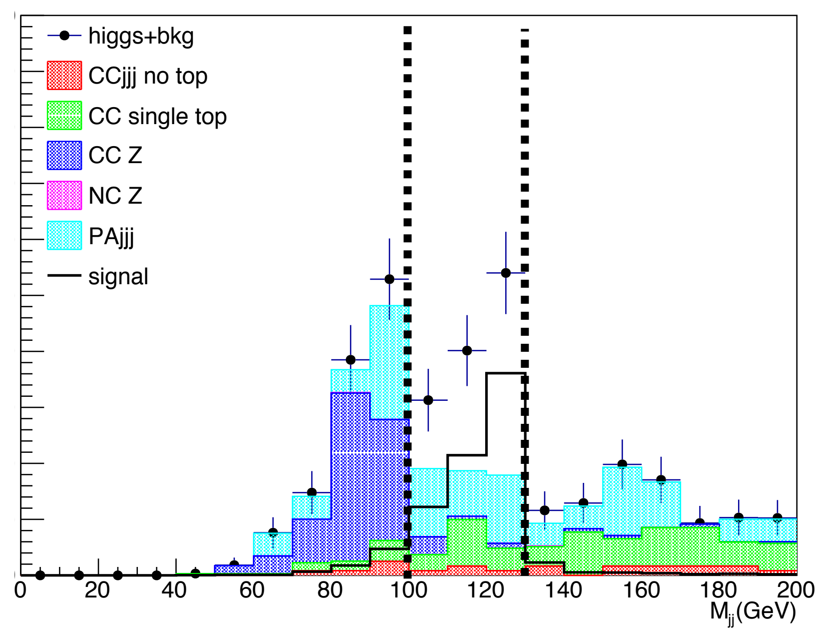

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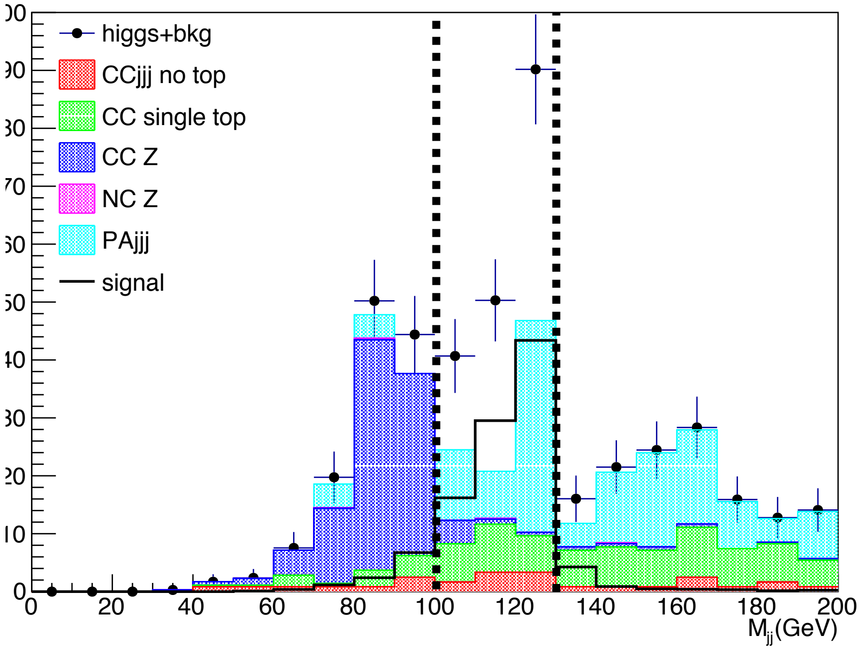

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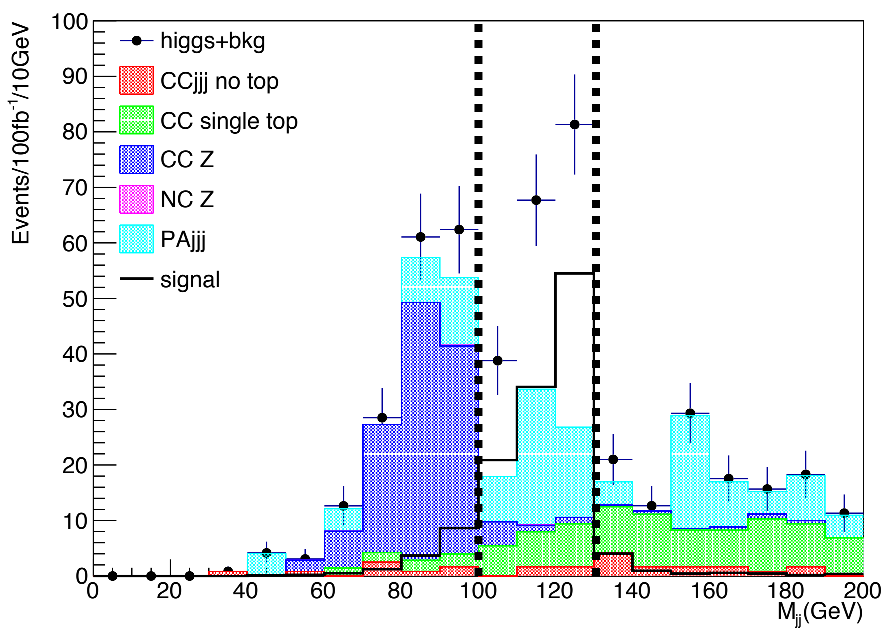

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