SM Higgs at the LHeC

Masahiro Tanaka
Tokyo Institute of Technology
On behalf of the LHeC/FCC he group

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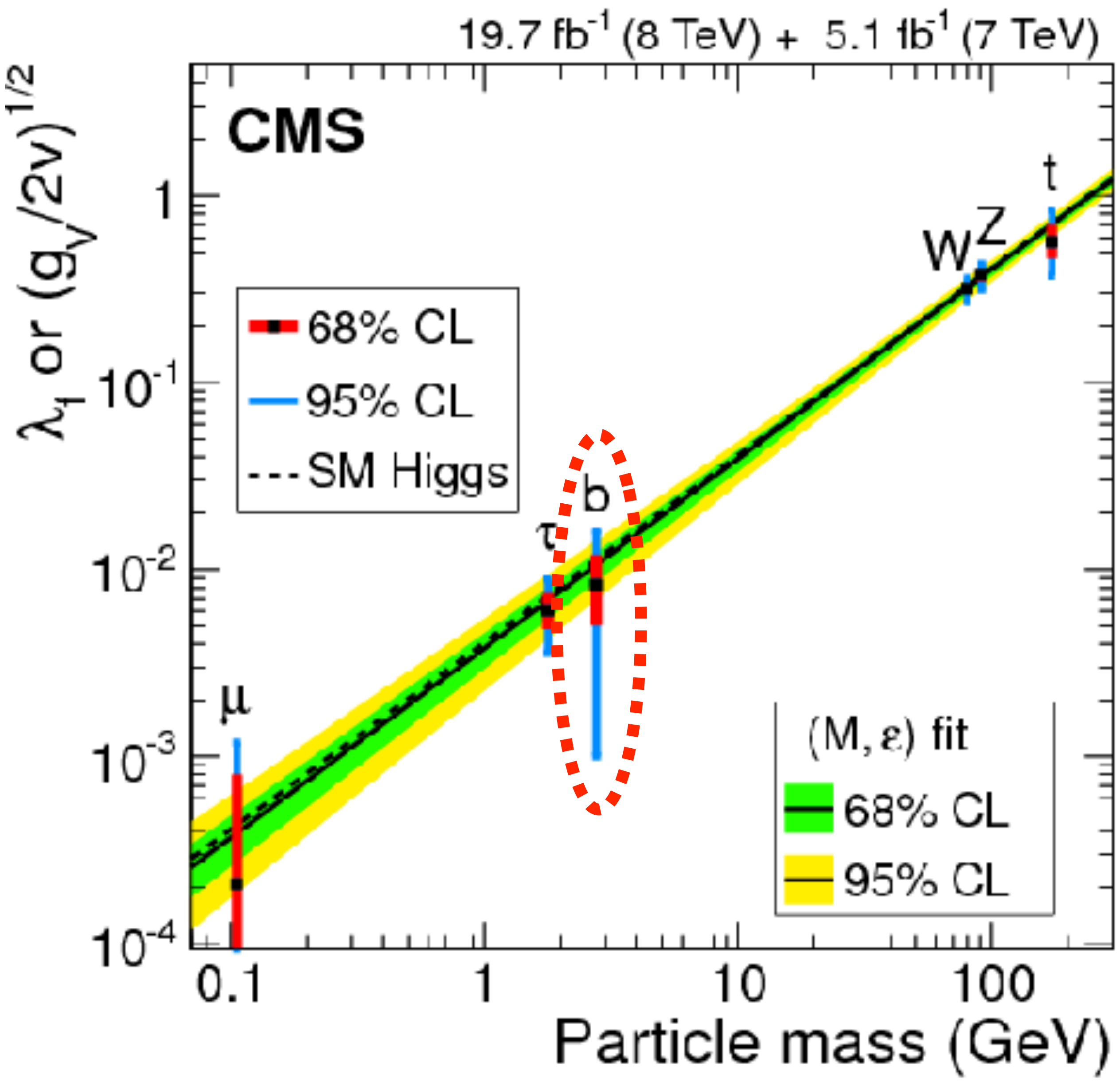
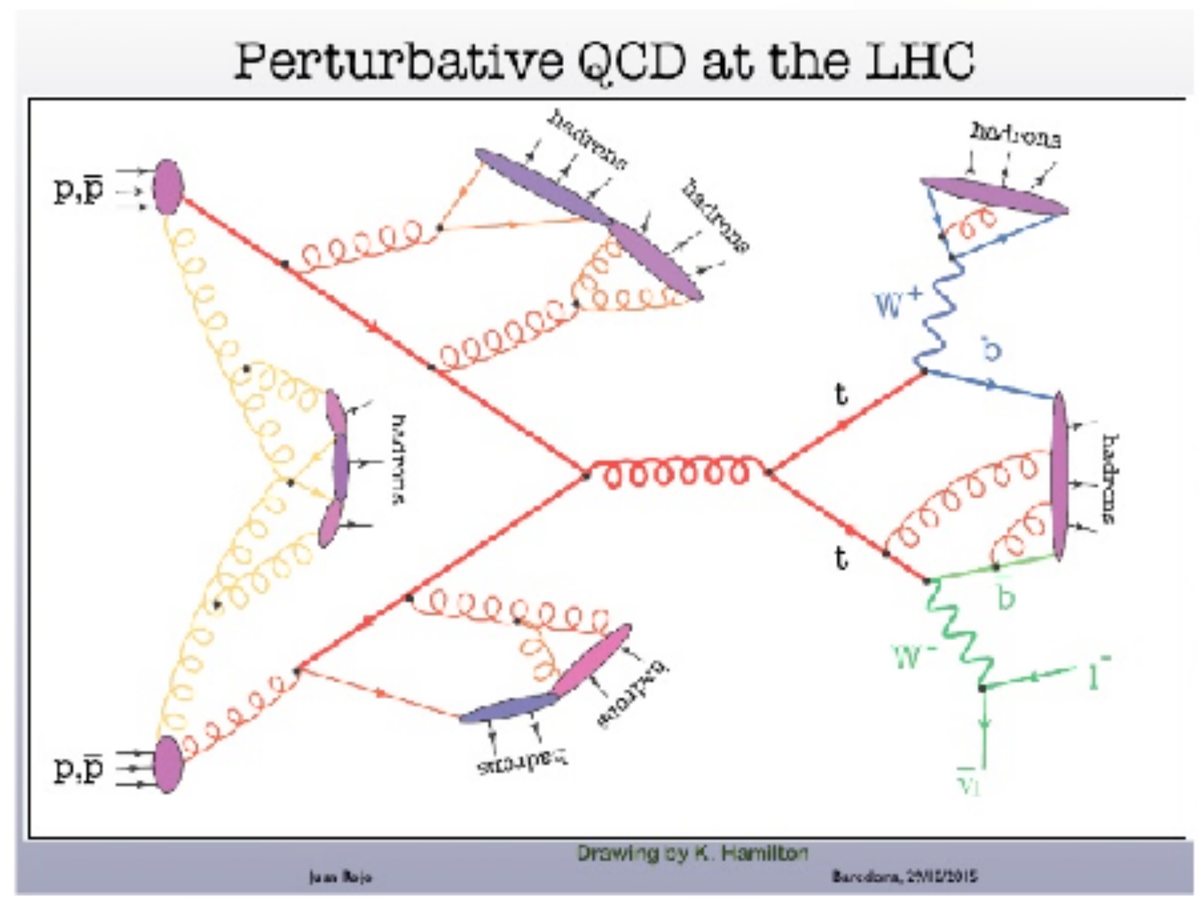
Higgs studies at LHC

- 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.

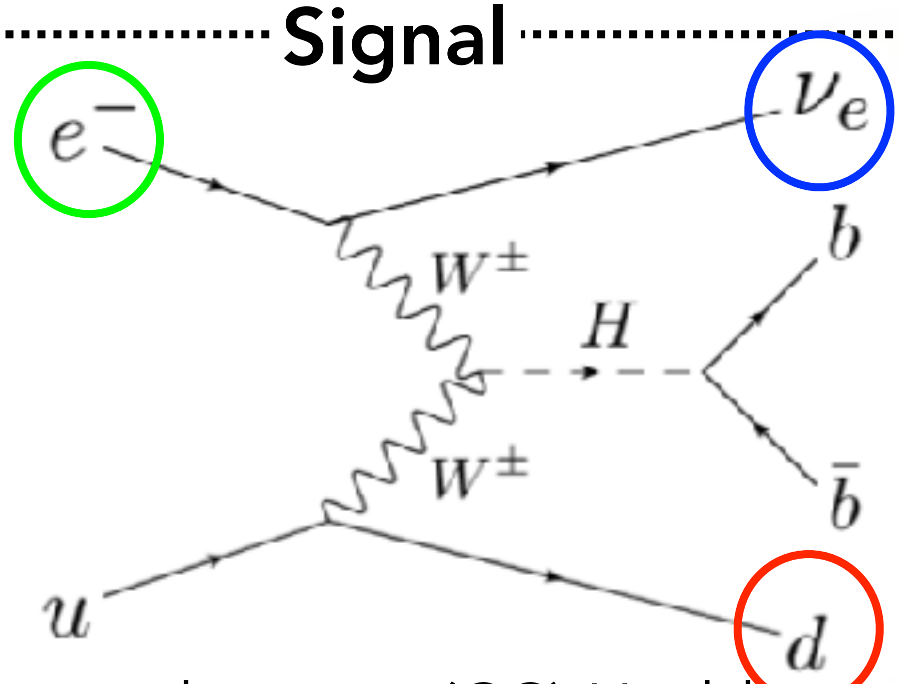




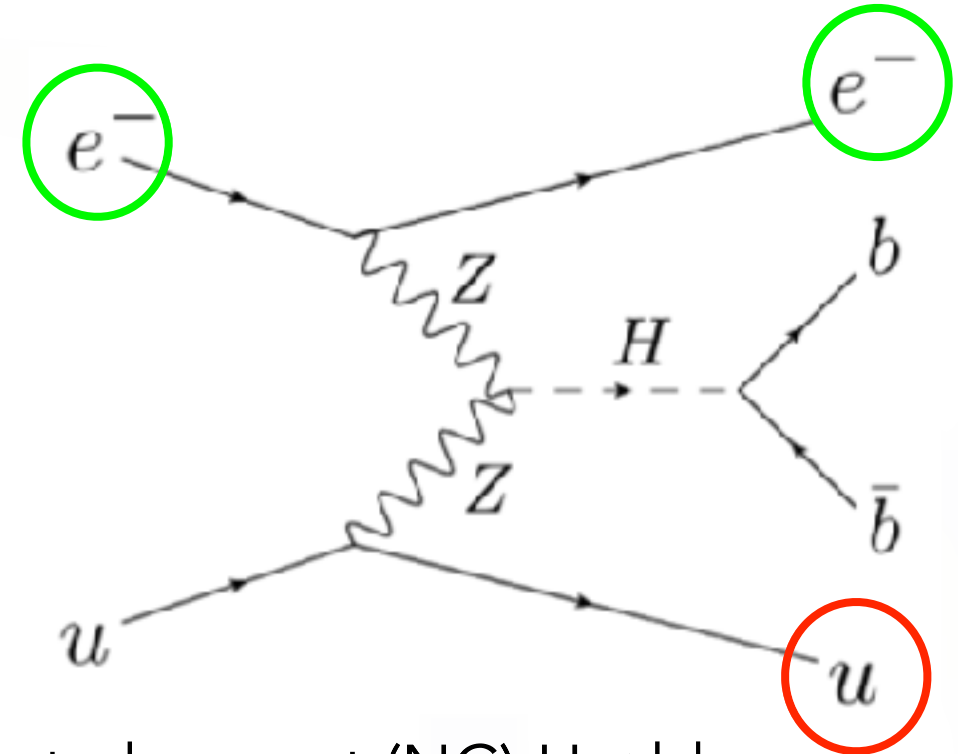
- H→bb channel is challenging due to large number of QCD bkg.
- Electron-proton collider could be an alternative approach.

Higgs at ep collider

Signal



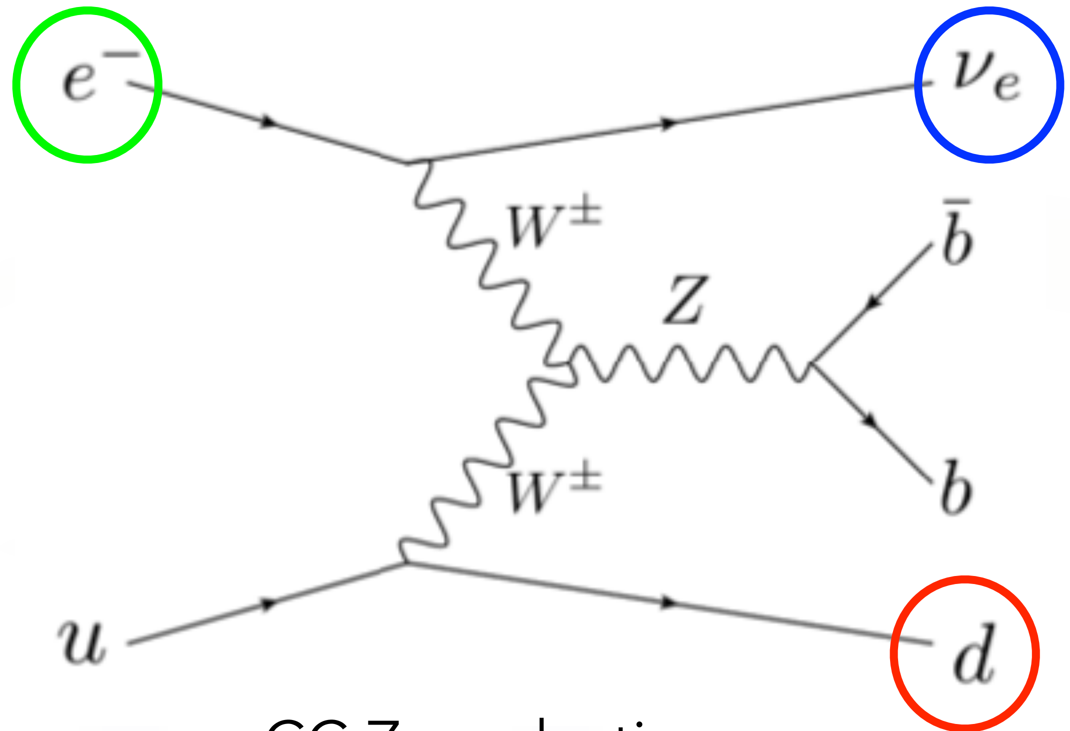
Charged current (CC) H→bb



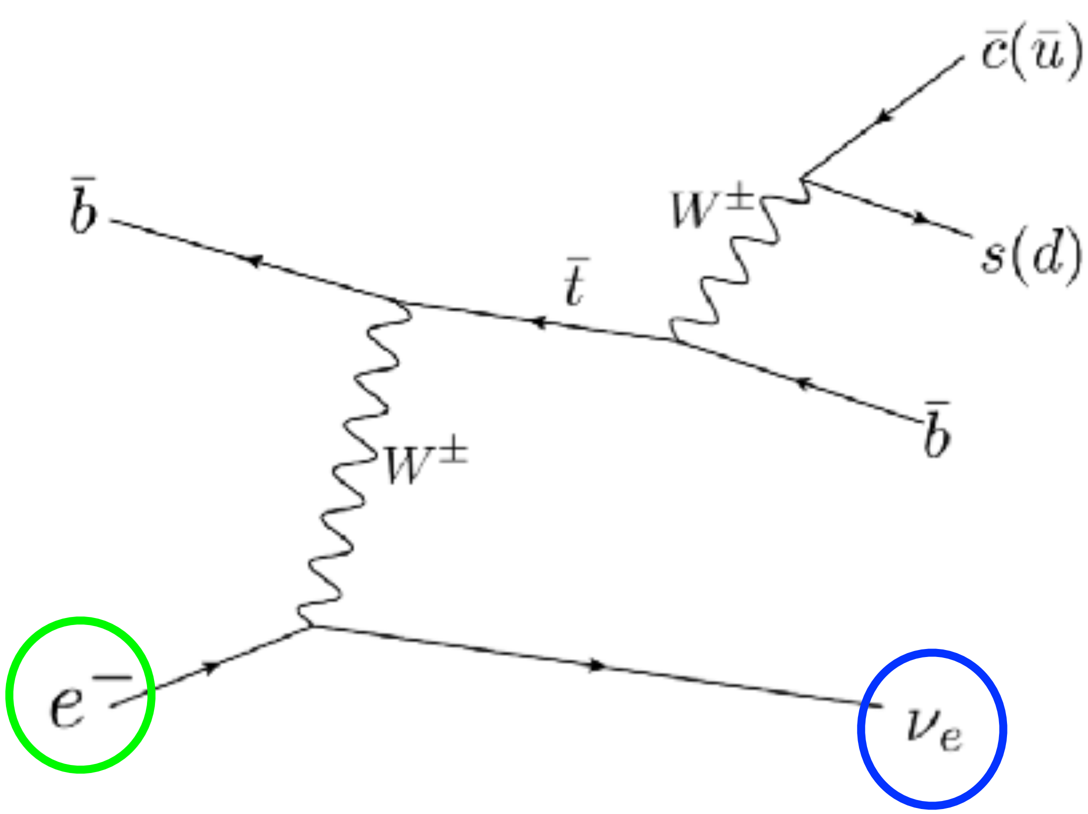
Neutral current (NC) H→bb

- Cross section of CC: H→bb is 4 - 5 times larger than NC: H→bb.
- SM DIS background is lower in CC than NC.
- ‘Clean’ events with fewer hadron background than pp collider.
- No pileup. (One collision per one crossing.)
- Advantage for H→bb (cc) study using Deep Inelastic Scattering events.

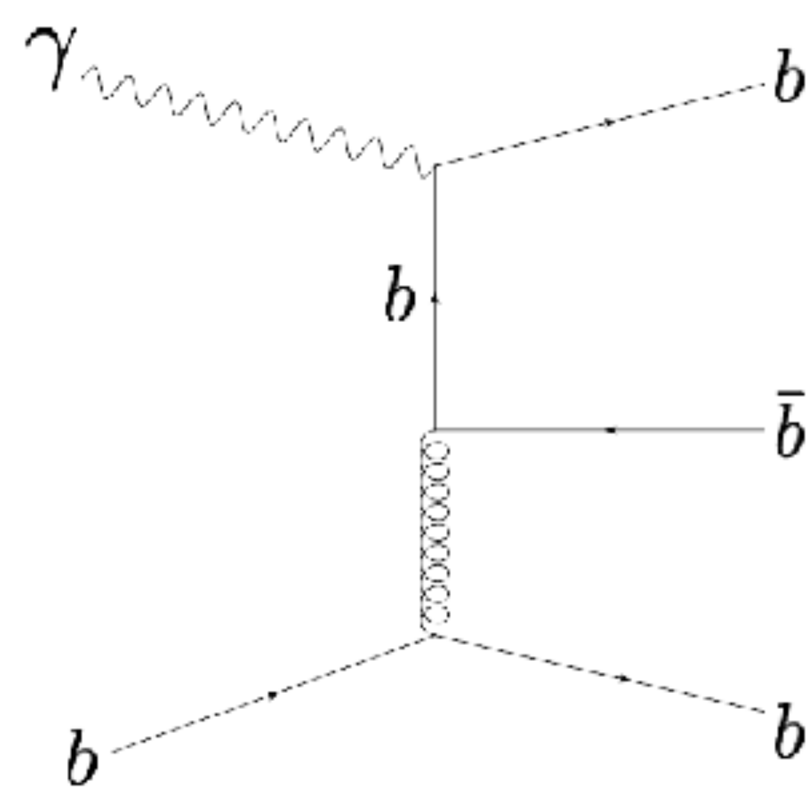
Typical background processes



CC Z production



Single top production



Multi jets

Ep Higgs in simulation

MadGraph/MadEvent
Parton level event generation
Calculation of cross section

▼

Pythia (modified for ep)
Fragmentation
Hadronization

▼

Delphes
Detector simulation

▼

H→bb and H→cc event selection
Both cut based and BDT based analyses are pursued using LHeC analysis strategies so far.

Generator setup

- For LHeC 7 TeV proton & 60 GeV electron.
- Electron polarisation is -80%.

Detector setup

- Reasonable setups for our own LHeC considering current on-going experiment like ATLAS or CMS.

b-tag performance (cut based)

- b-jet: 75%
- c-jet mis-tagging rate: 5%
- Light-jet mis-tagging rate: 1%

LHeC cut based study: Event selection for H→bb (1)

Primary cut

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

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

$Q_h^2 > 500\,\mathrm{GeV}^2,\ y_h < 0.9$

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

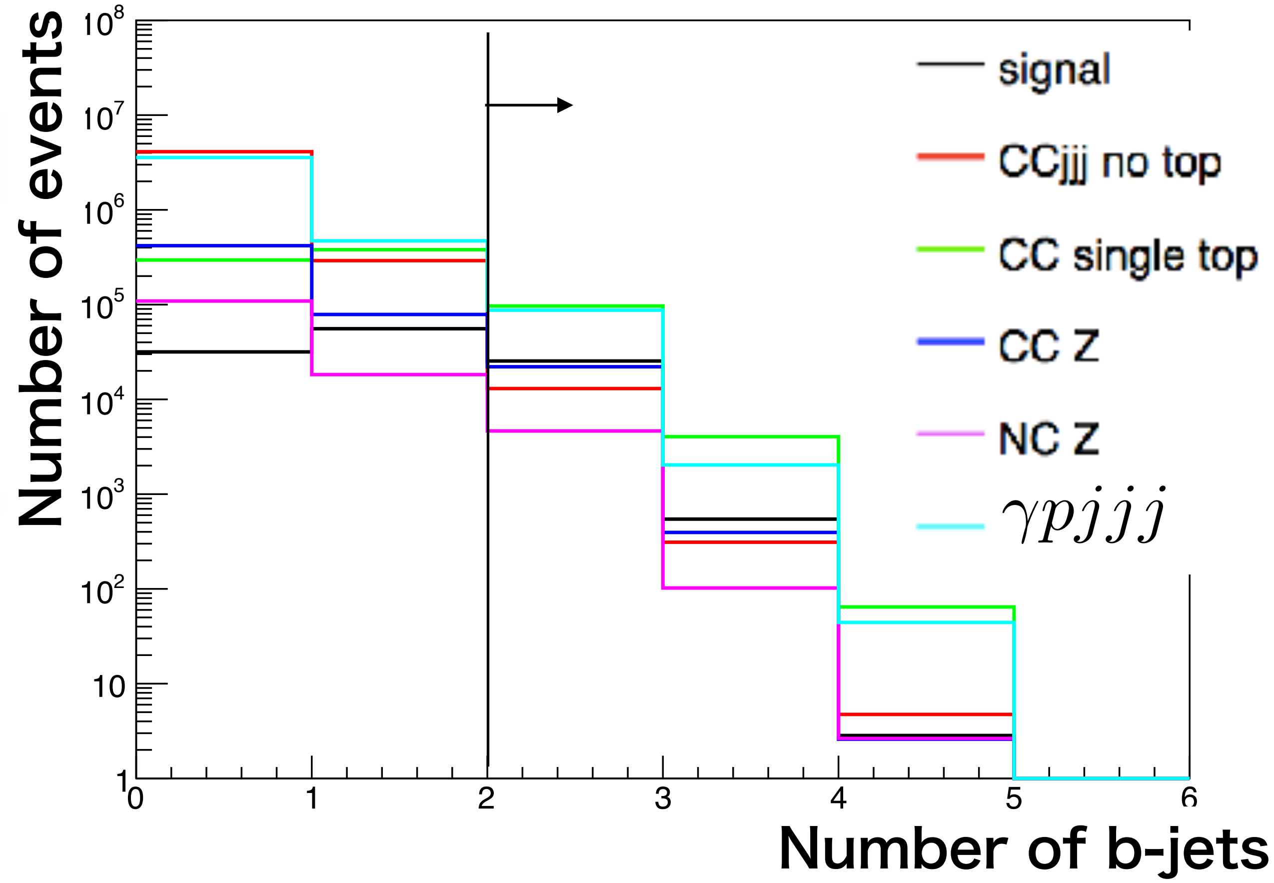
$$y_h = \frac{\sum_{hadron}(E - p_z)}{E_e}$$

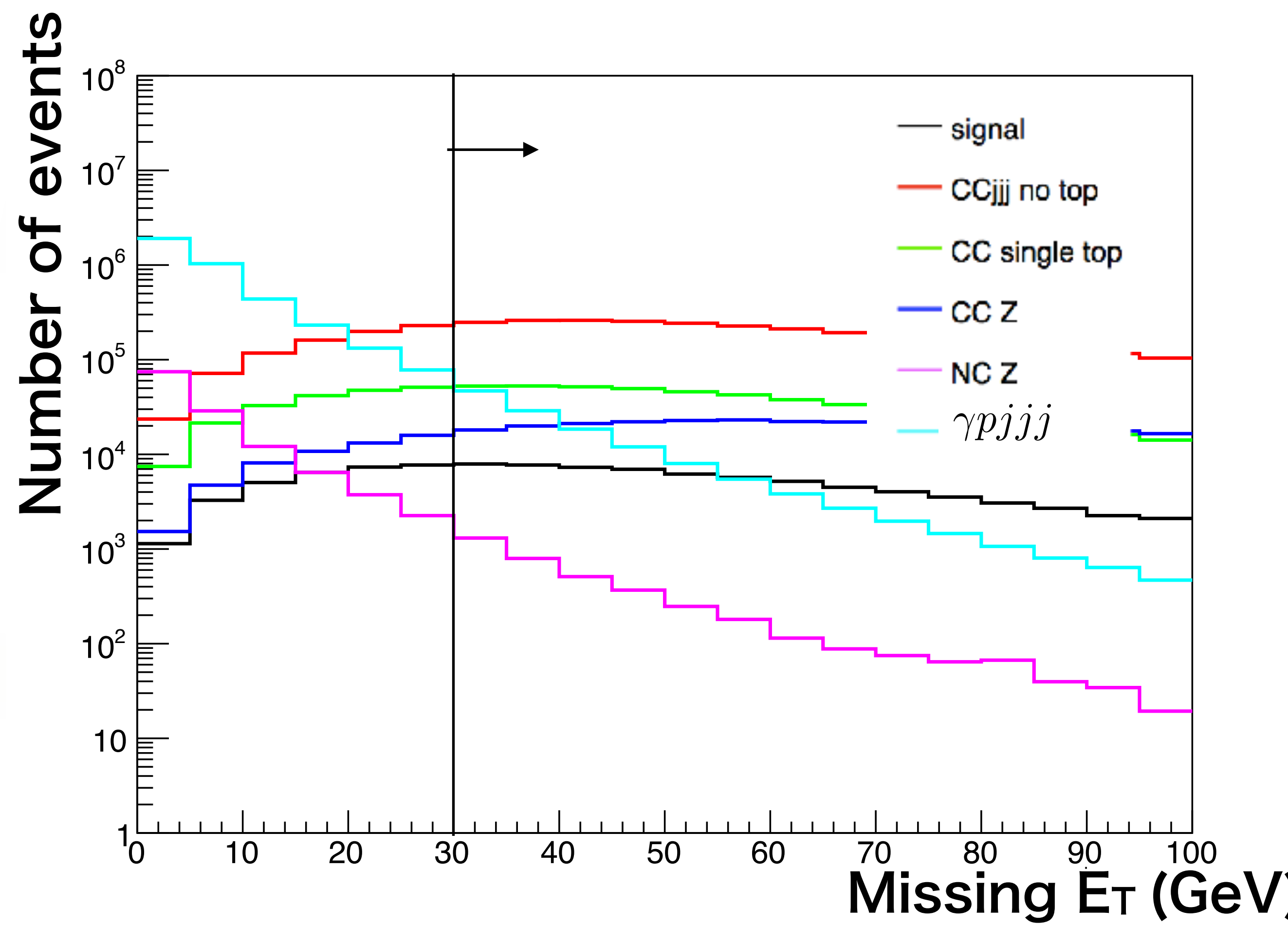
NC DIS event rejection

$E_{miss}^T > 30\,\mathrm{GeV}$

$N_{electron} = 0$

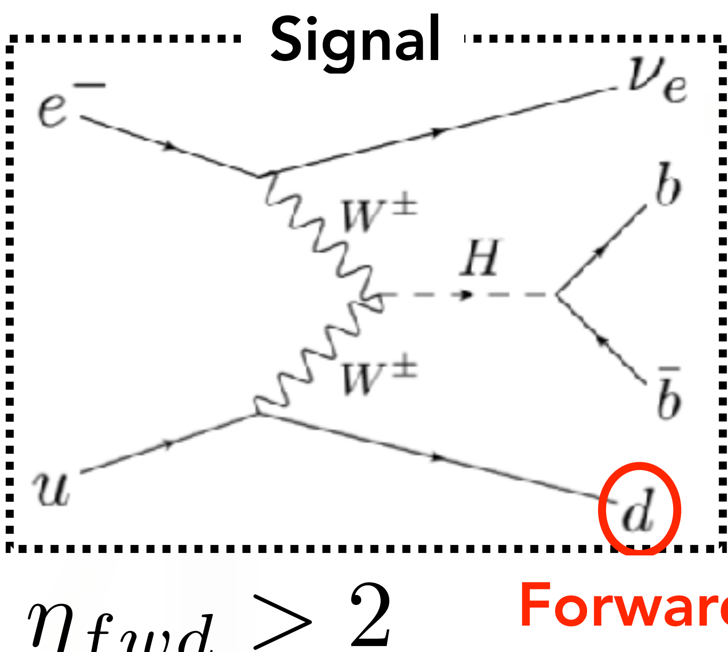
$\Delta\phi_{b,MET} > 0.2$



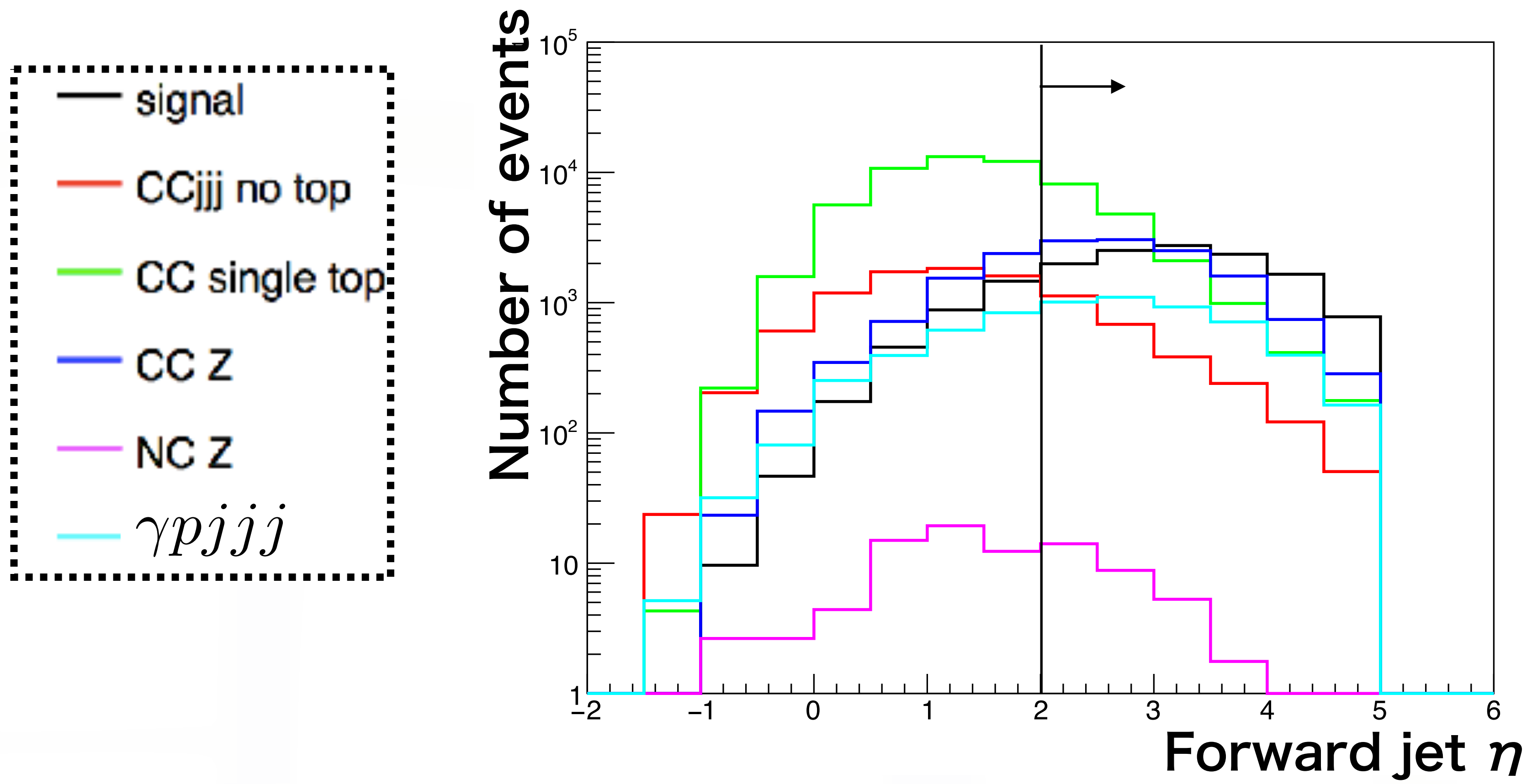


LHeC cut based study: Event selection for H→bb (2)

Forward jet tagging



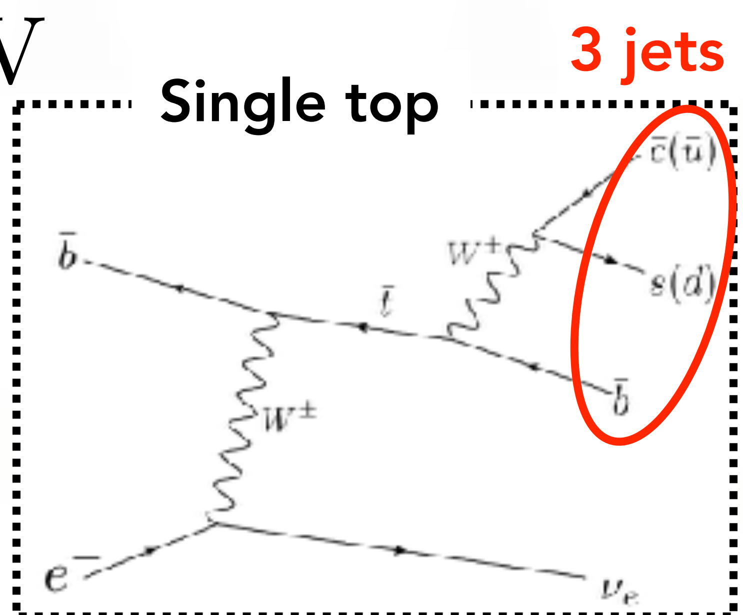
$$\eta_{fwd} > 2$$

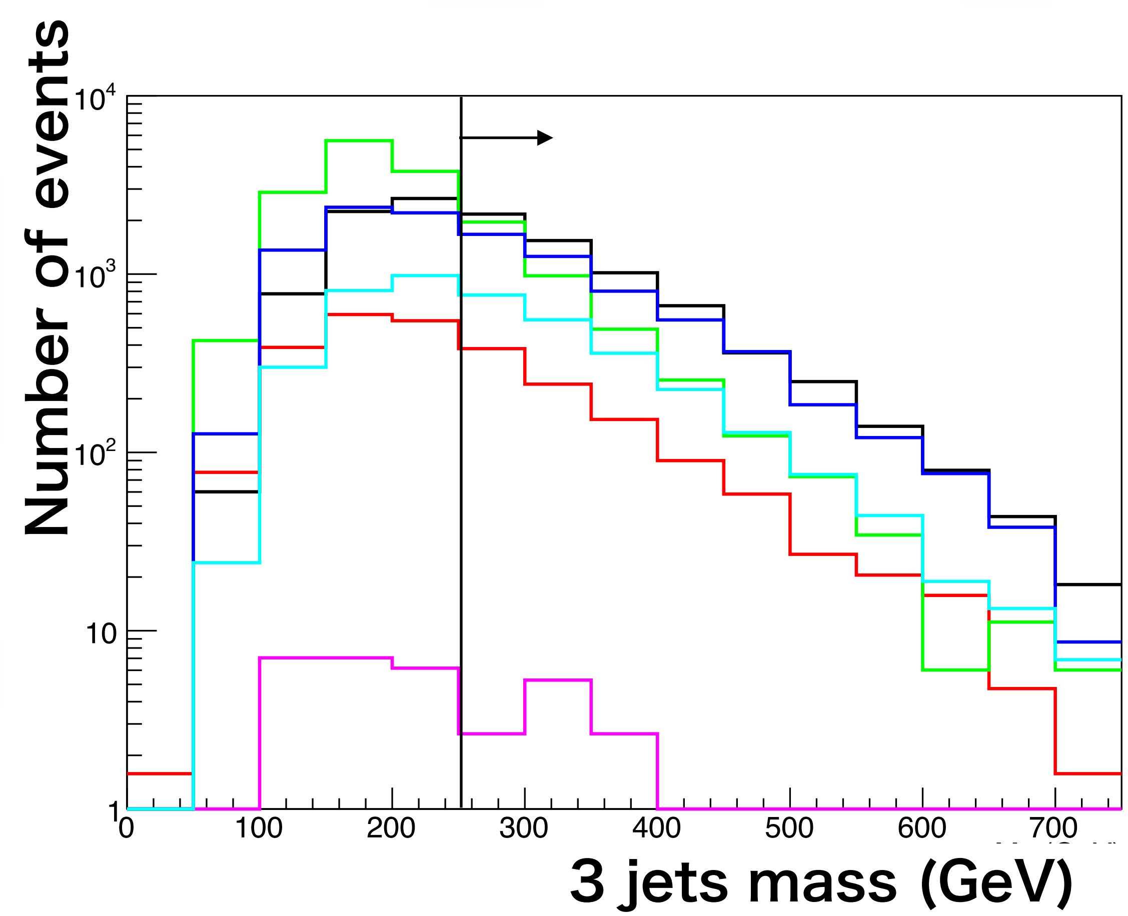


Single top rejection

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

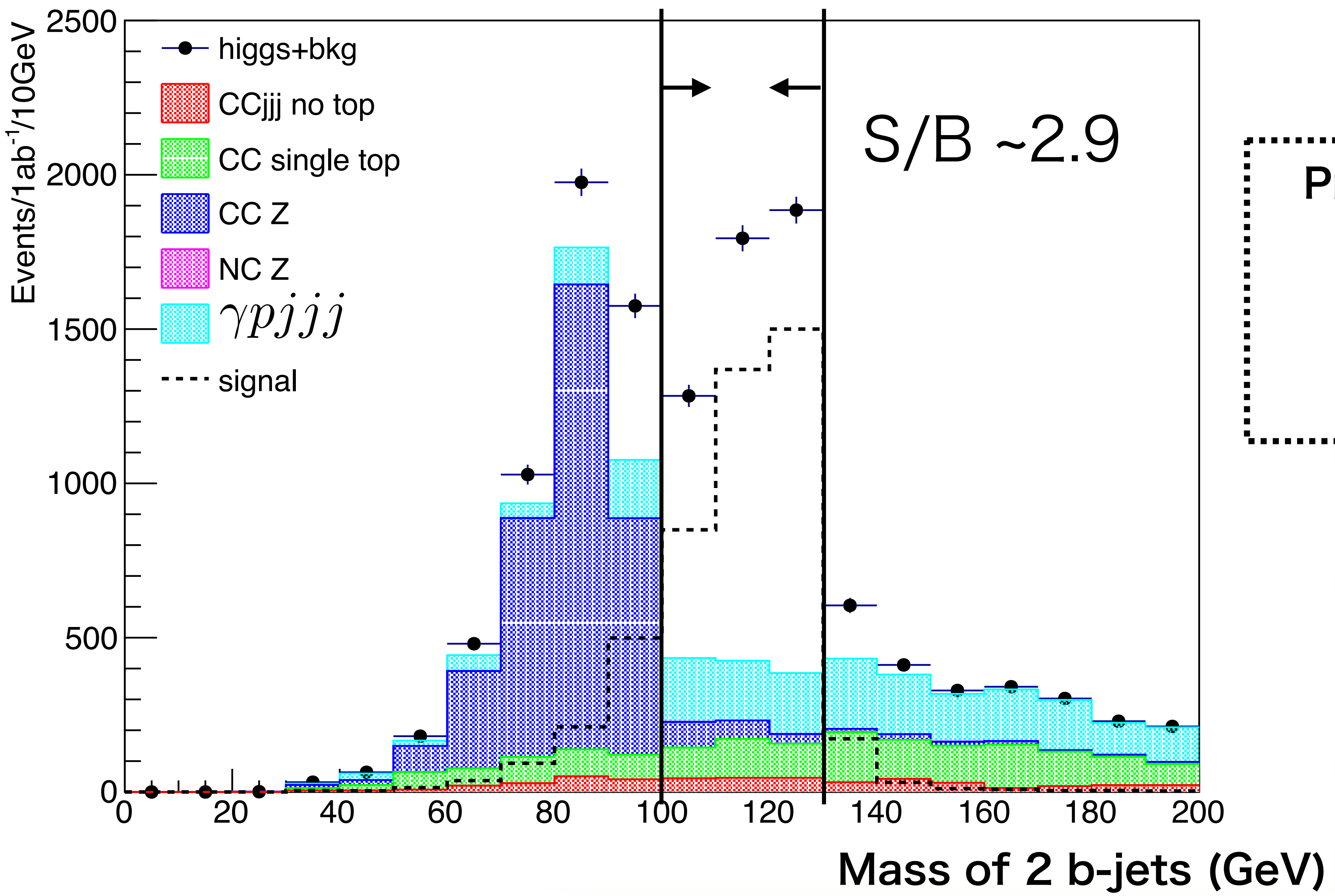
$$M_{jj,W} > 130\ \mathrm{GeV}$$





Cut based results: H→bb at LHeC

- Assumed 1000 fb^{-1} of statistics. (~10 years running for LHeC.)
- Veto efficiency of 90% for photo-production background is assumed, using forward electron tagging.



Precision of coupling constant
(Statistics error only)

$$\kappa = \frac{\sqrt{N_s + N_b}}{2N_s}$$

Signal: 3600

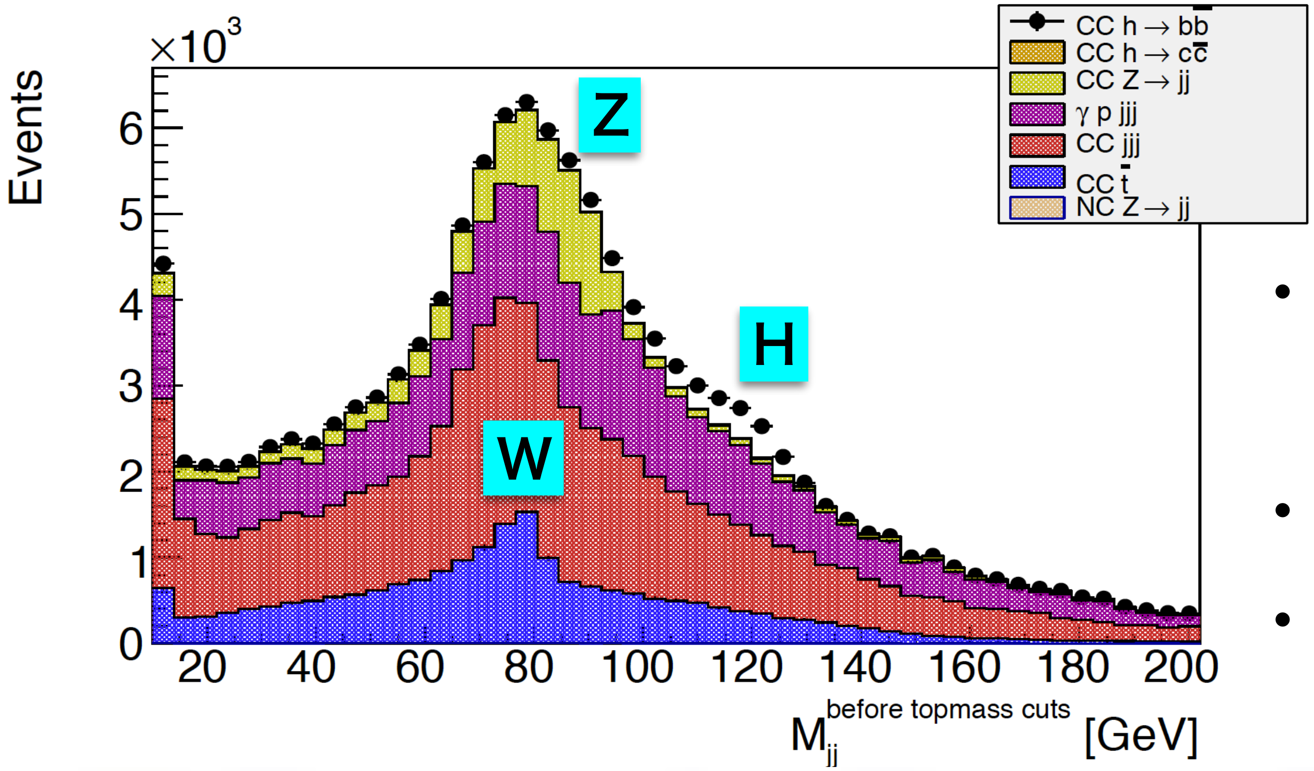
Bkg: 1250

κ (Hbb) ~ 0.97%

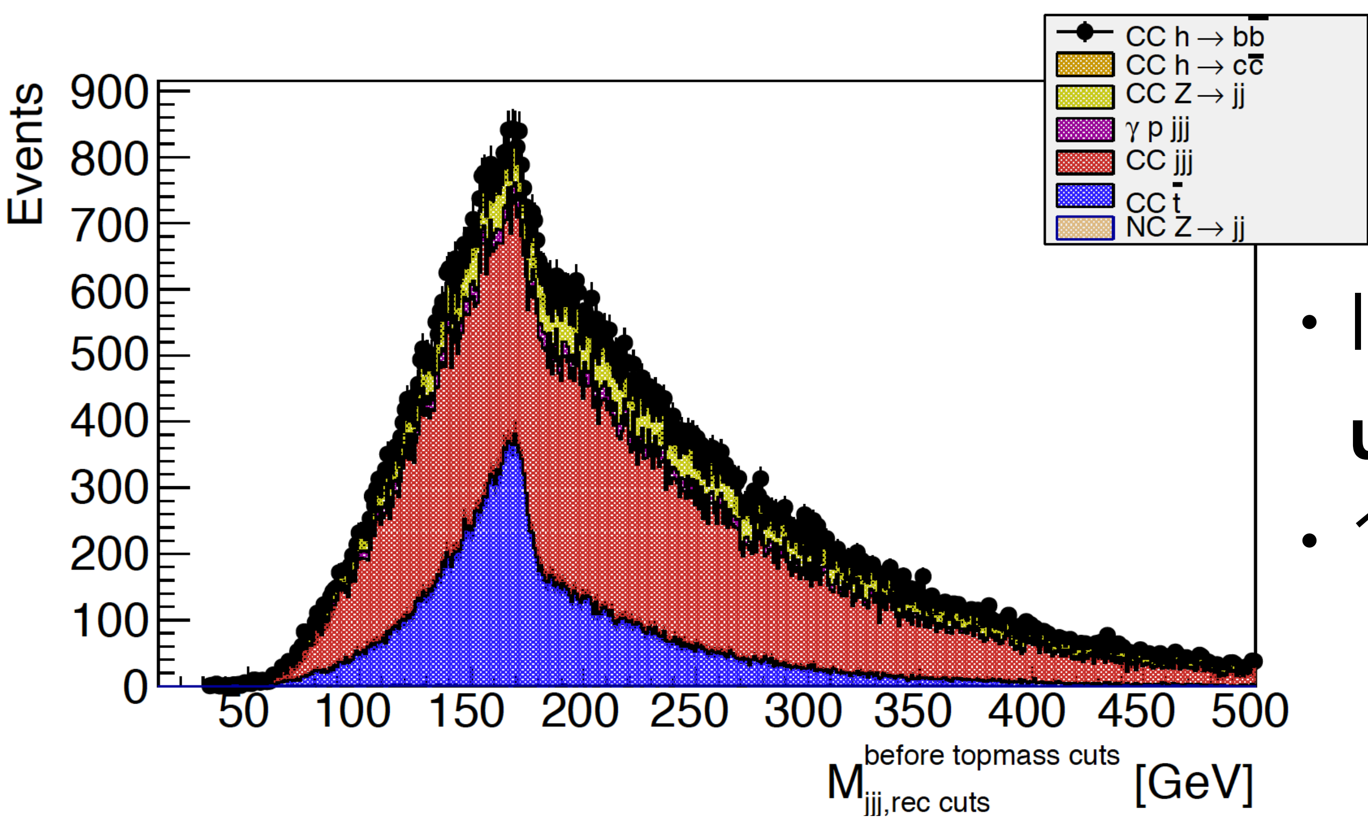
- Note: In previous presentations we considered twice number of background for coupling error over-conservatively.

HFL tagged BDT based analysis

- Focus on vertex resolution for experimental Tevatron like HFL tagging and the choice R parameter of anti-kt algorithm



- Invariant Di-jet Mass using 2 lowest eta **un-tagged** jets.
- 100% photo production background.
- No anti top cut.

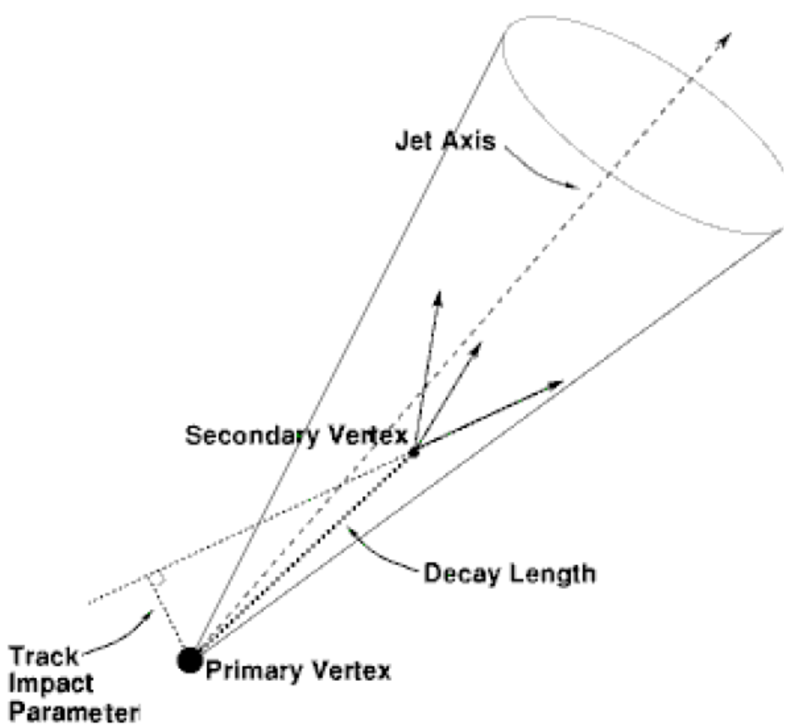


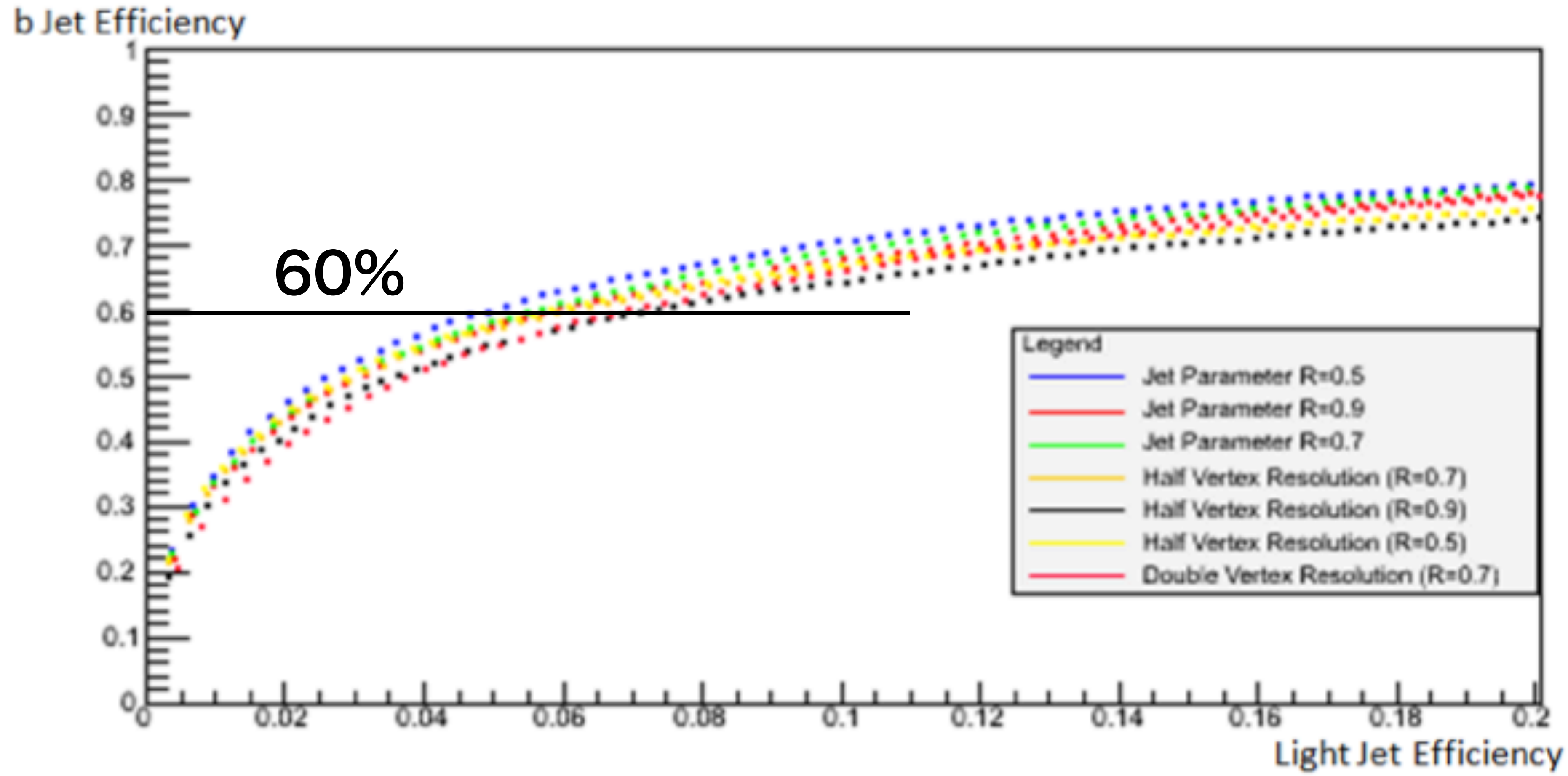
- Invariant Mass of 3 highest p_T **un-tagged** jets.
- 10% photo production background.

B-tagging efficiency

U Klein and D Hampson (Liverpool)

Using Tevatron-like heavy flavor tagging techniques
(No neural network for HFL tagging yet)



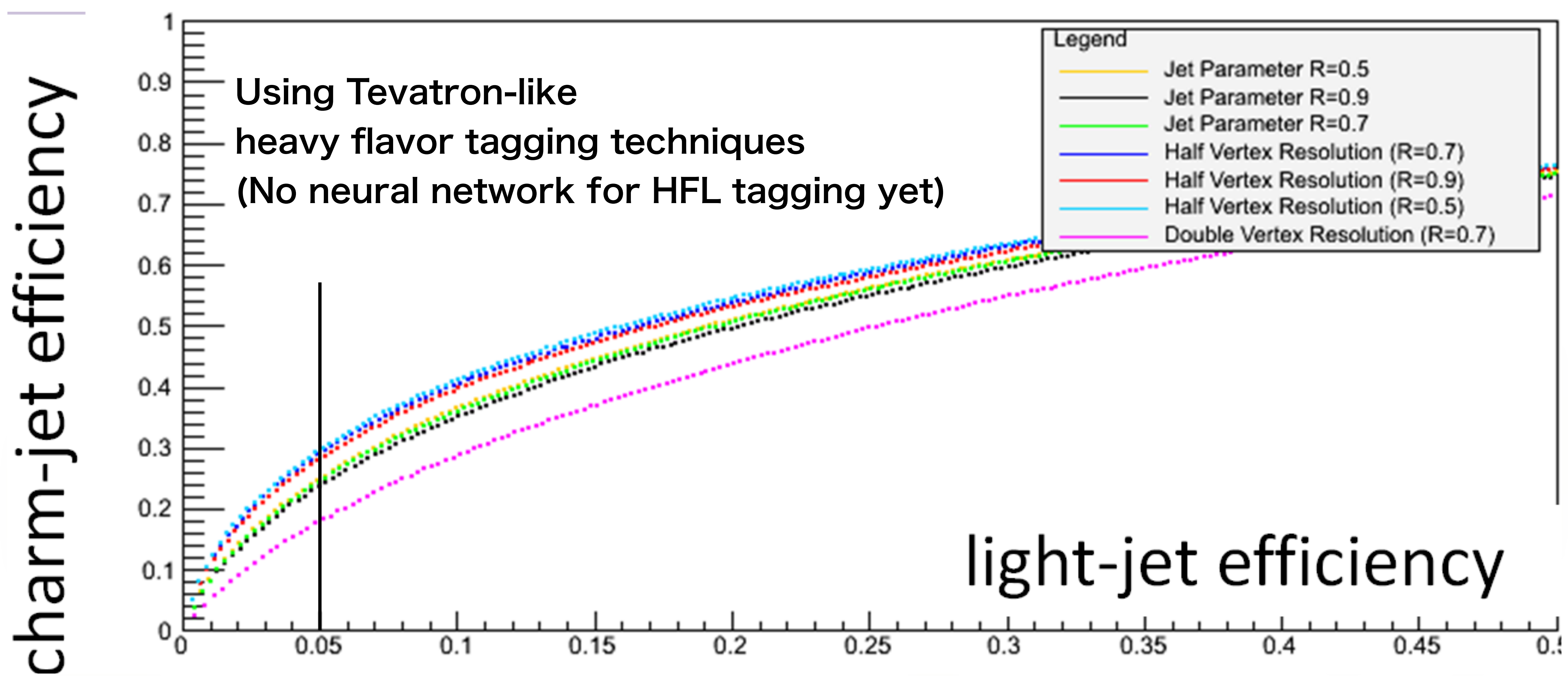


Nominal vertex resolution: 10 um (p_T < 5GeV)

- 60% of b-tag efficiency with higher contamination of light jet (~5%).
- Smaller R parameter or half vertex resolution can reduce light jet contamination.

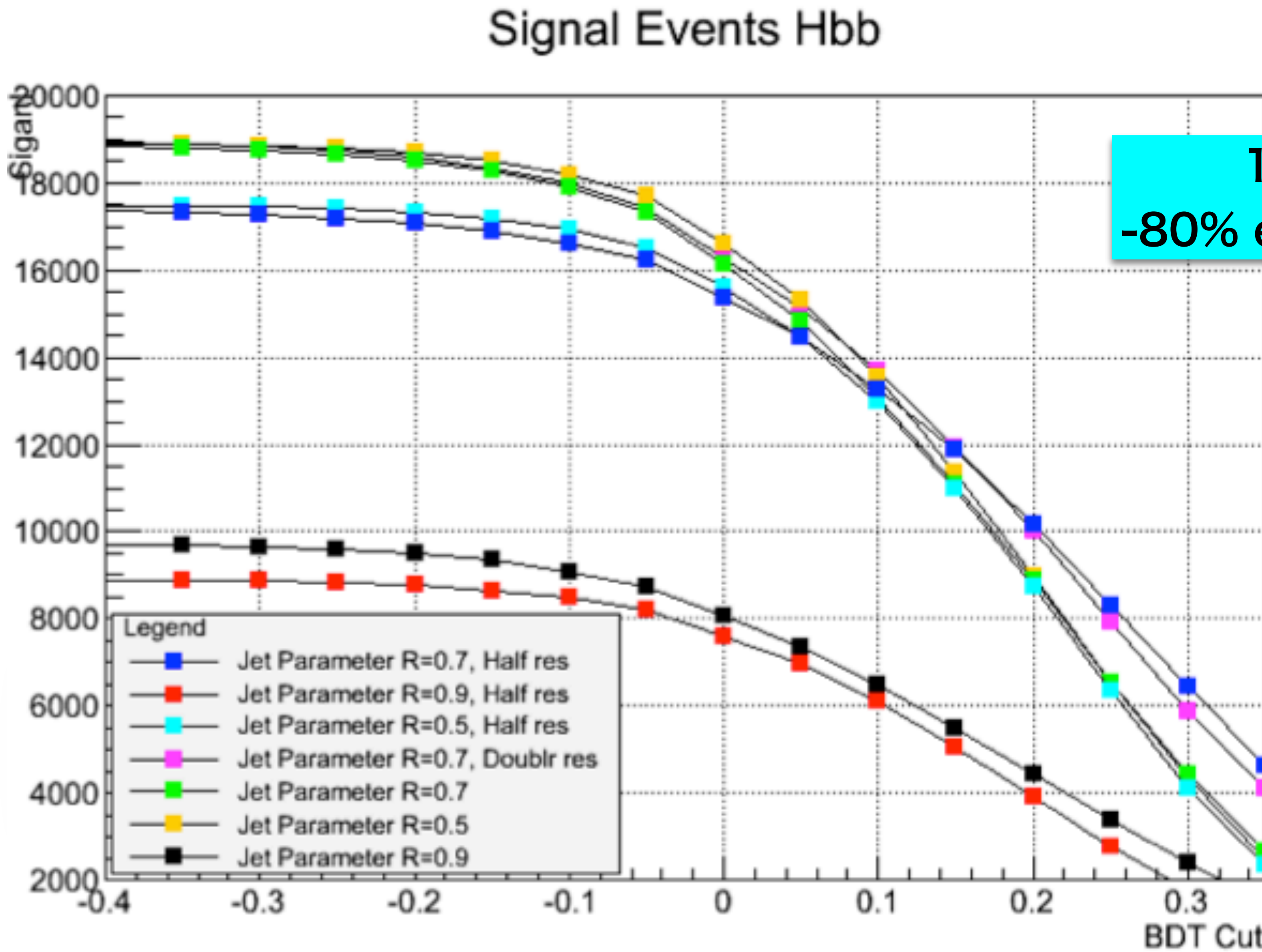
Heavy flavor tagging efficiency

U Klein and D Hampson (Liverpool)



- Significant improvement in charm jet tagging efficiency from 23-24% for a R = 0.9 to 30% using R = 0.5 anti-kt jets and half nominal vertex resolution at light jet tagging efficiency 5%.
- Charm tagging is very sensitive to vertex resolution.
  → double resolution set-up (in pink) clearly disfavoured.

BDT results: H→bb at LHeC



1000 fb^{-1}
-80% e- polarisation

- Using BDT, we can get ~5 times more signal events than cut based analysis.
- All backgrounds assumed to be same as for the cut based analysis for about 15,000 H→bb events

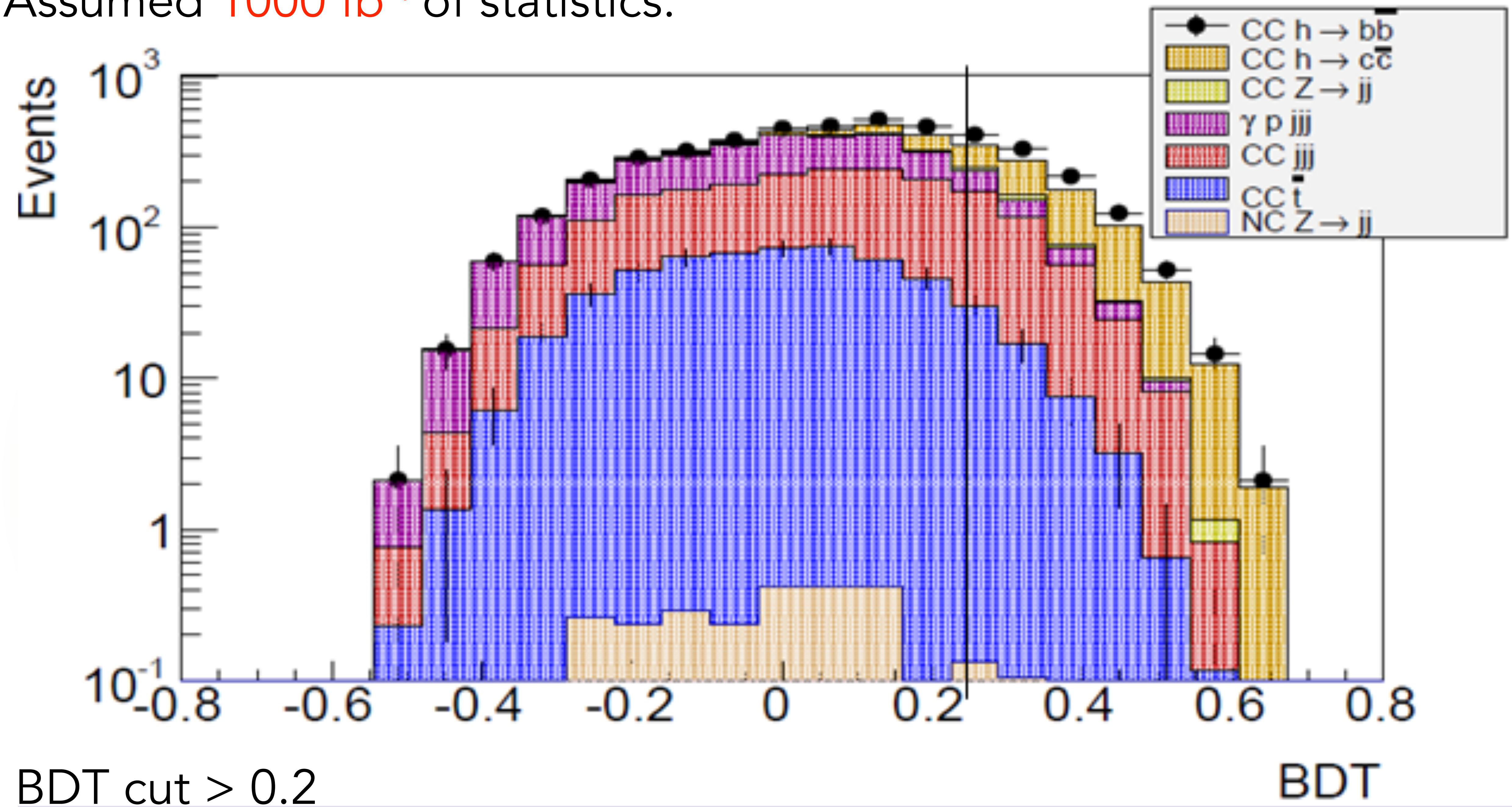
➡ We get κ(Hbb) ~0.6% instead of ~0.97% (cut based), results are consistent.

Conservative result since light jet contamination is factor 10 worse than ATLAS b-tagging performance.

BDT results: H→cc at LHeC

U Klein and D Hampson (Liverpool)

- Assumed 1000 fb^{-1} of statistics.



BDT cut > 0.2

Hcc signal events: 474

$S/\sqrt{S+B} = 12.8$

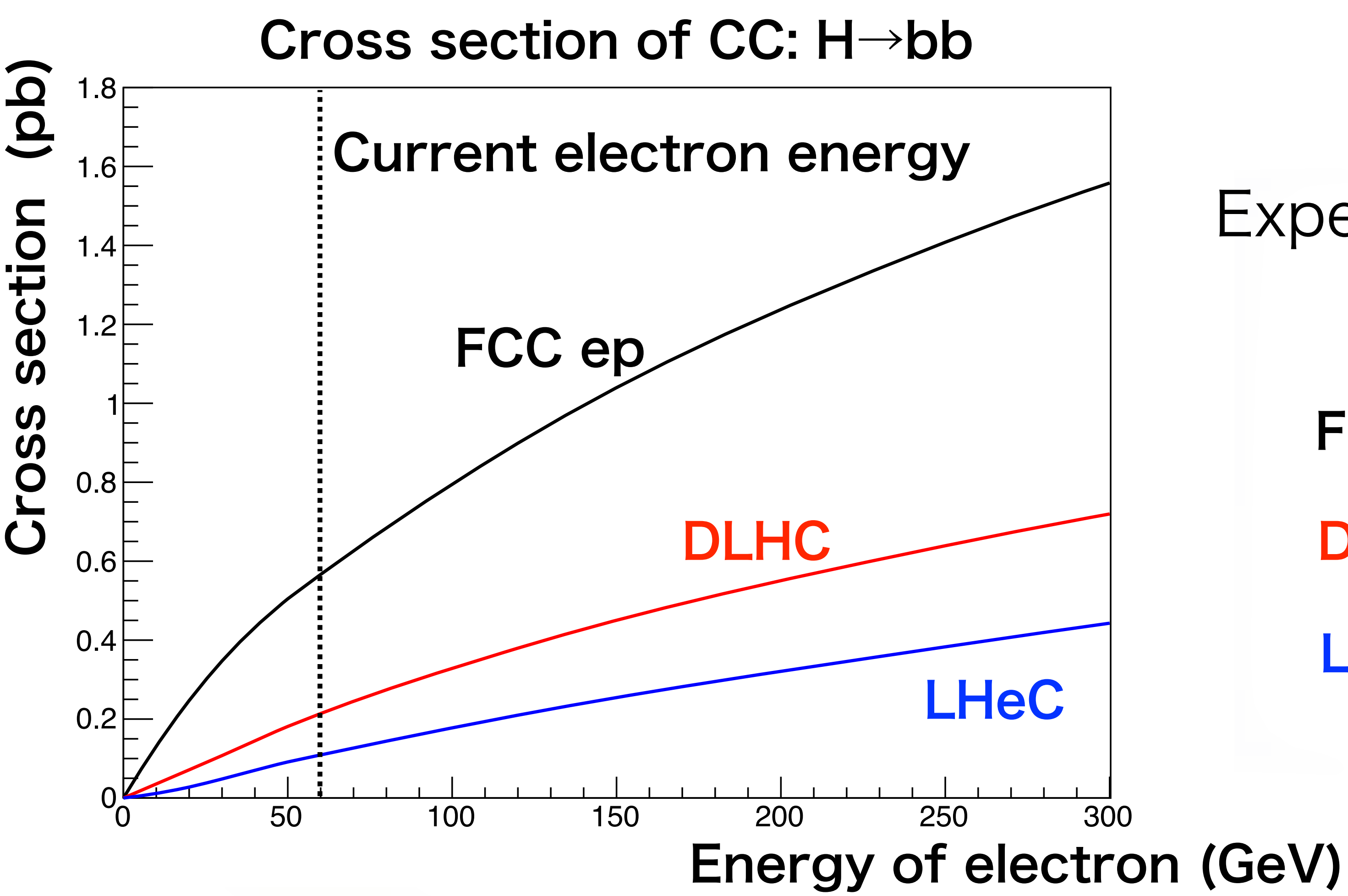
→κ(Hcc) = 4% for 1000 fb^{-1}

Clear potential to access the Higgs to charm decay channel.

Coupling constant measurement at future ep colliders

- Assume a 60 GeV polarized electron beam and 1000 fb^{-1} (~10 years running)
- Expected number of signal events and error of coupling constant from BDT results.
- Background assumed to be known to ~2%

U Klein (Liverpool)



Expected number of signal events
(E_e = 60 GeV)

FCC ep (~85,000 H→bb events)

DLHC (~35,000 H→bb events)

LHeC (~15,000 H→bb events)

	LHeC (E_p = 7 TeV $\sqrt{s}$ ~1.3 TeV)	**DLHC** (E_p = 14 TeV $\sqrt{s}$ ~1.8 TeV)	**FCC ep** (E_p = 50 TeV $\sqrt{s}$ ~ 3.5 TeV)
κ (Hbb)	0.5%	0.3%	0.2%
κ (Hcc)	4%	2.8%	1.8%

Summary

- SM Higgs measurement at future e-p colliders.
- Plan to make ERL. (**E**nergy **R**ecovery **L**inac)
  (Electron energy is 60 GeV at current plan.)
- Precision of coupling constants are estimated to be
  - Hbb: 0.5%
  - Hcc: 4%

  assuming 1 ab^{-1} at LHeC. (Statistics error only.)

  ➡ Big potential for measurements of Higgs coupling.
- Other Higgs coupling ($H\tau\tau$ or HWW) can be measured with high precision.
- Big potential for BSM search. (See next talks.)

Backup

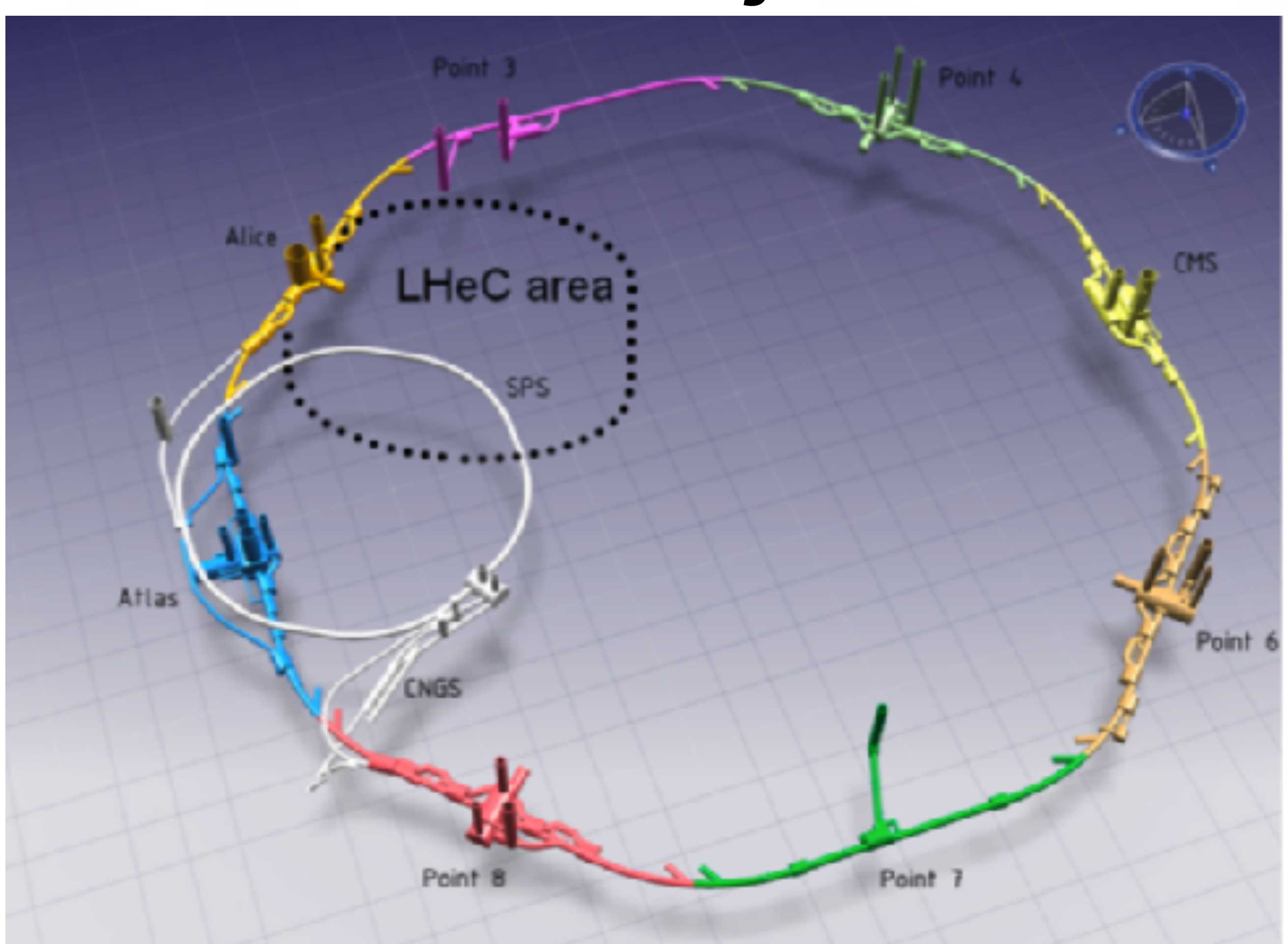
LHeC project

- 7 TeV proton of LHC and 60 GeV electron. ($\sqrt{s}$ ~ 1.3 TeV)
- Plan to create new electron facility ERL (**E**nergy **R**ecovery **L**inac.)
- Higher energy and luminosity than HERA.

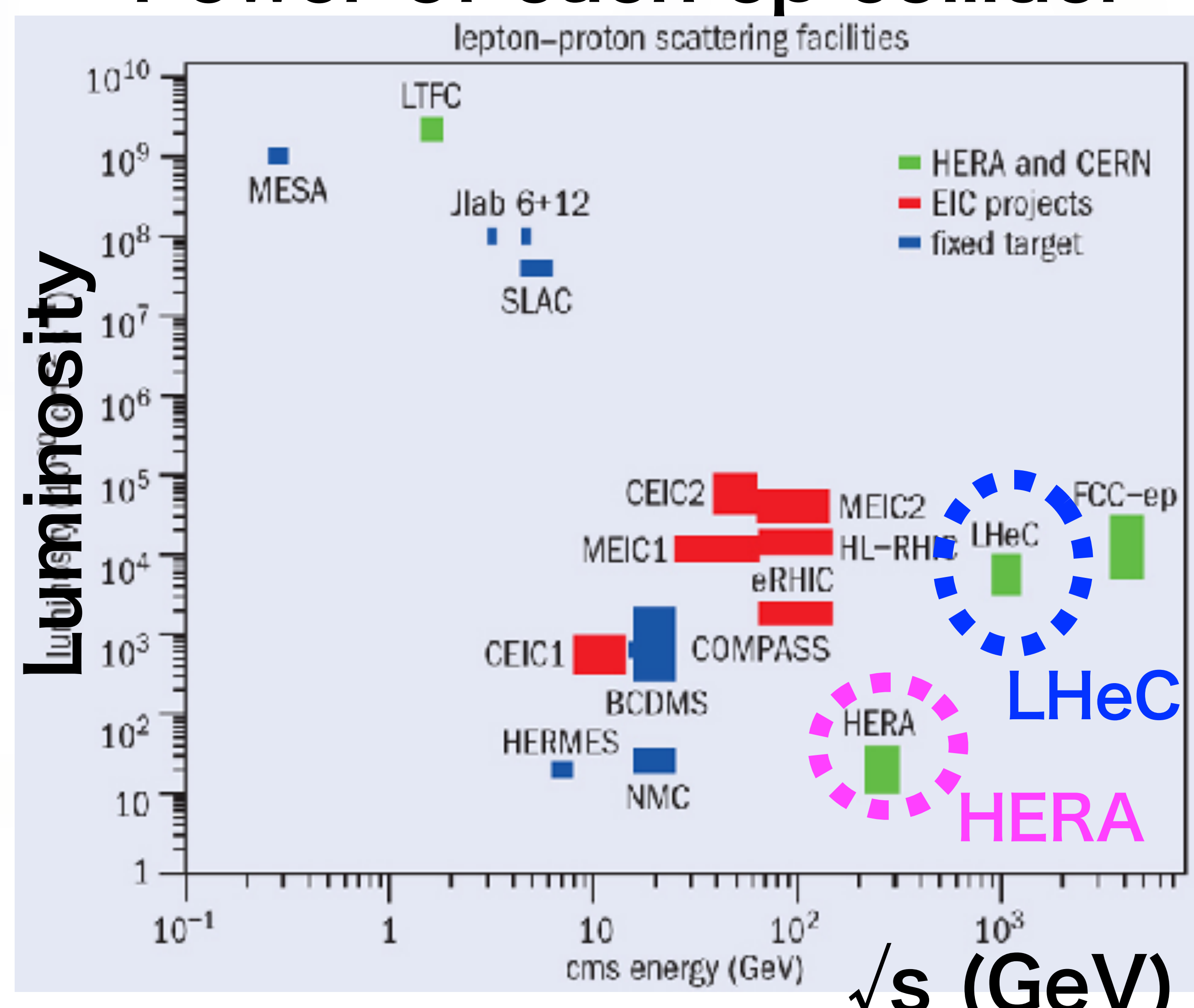
➡Extension of Q^2 and Bjorken x ranges.

Important for new experiment and development of the theory.

LHeC layout

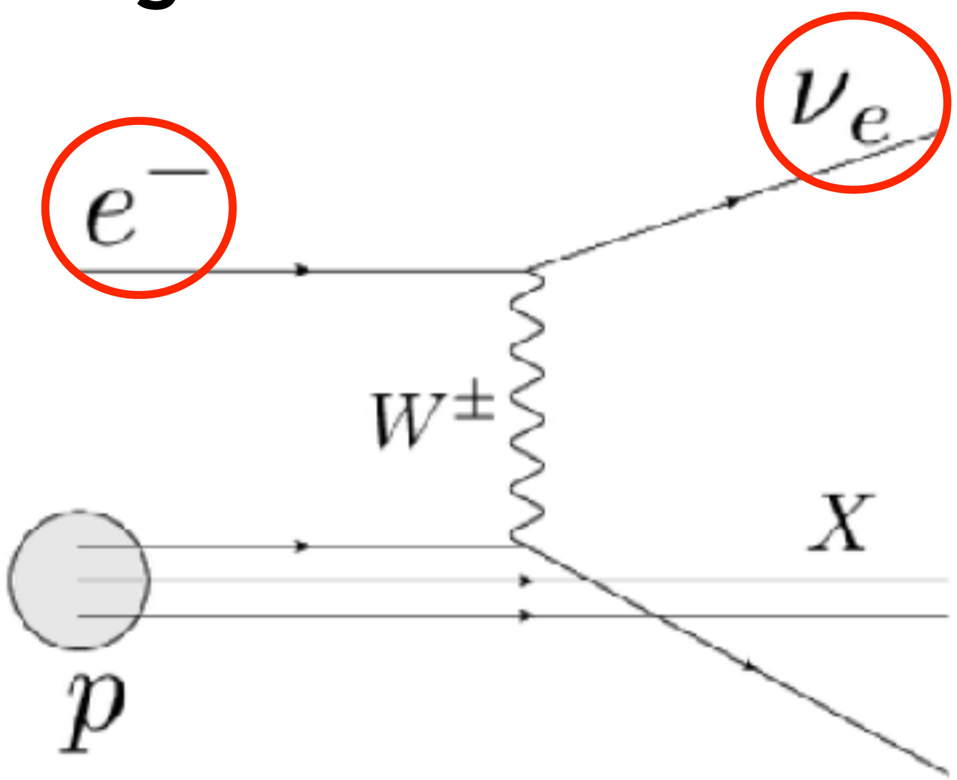


Power of each ep collider

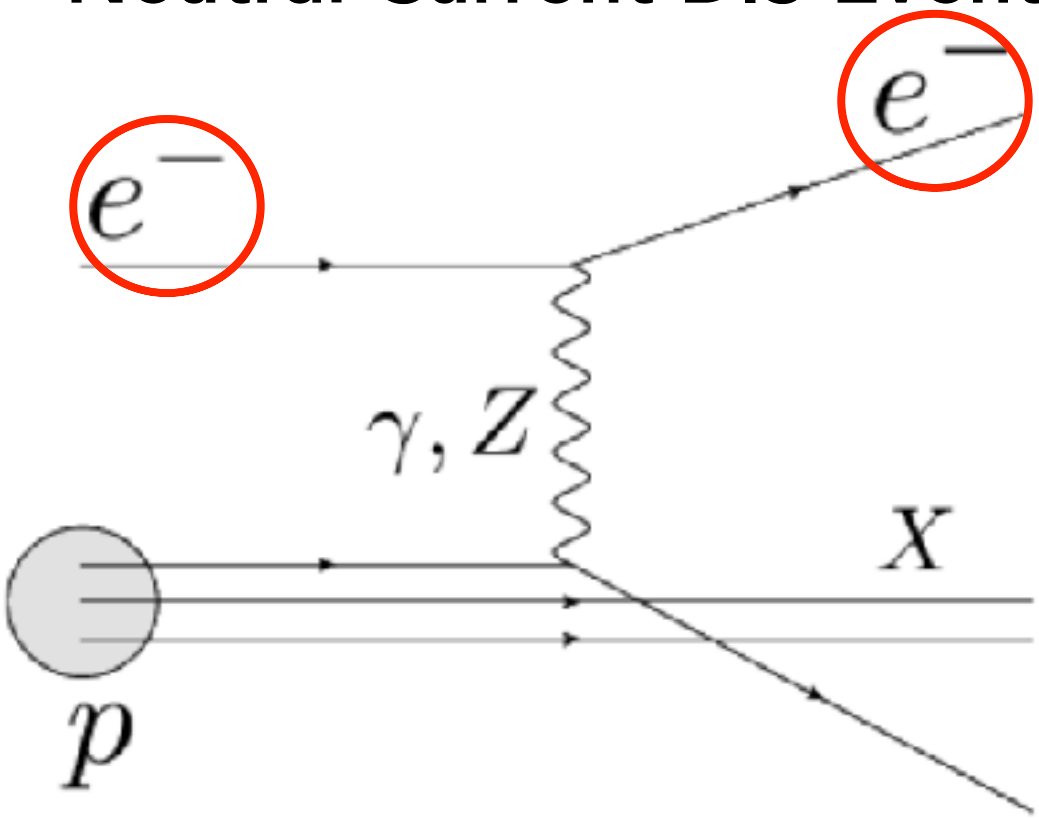


Higgs in Deep Inelastic ep Scattering

Charged Current DIS Events



Neutral Current DIS Events



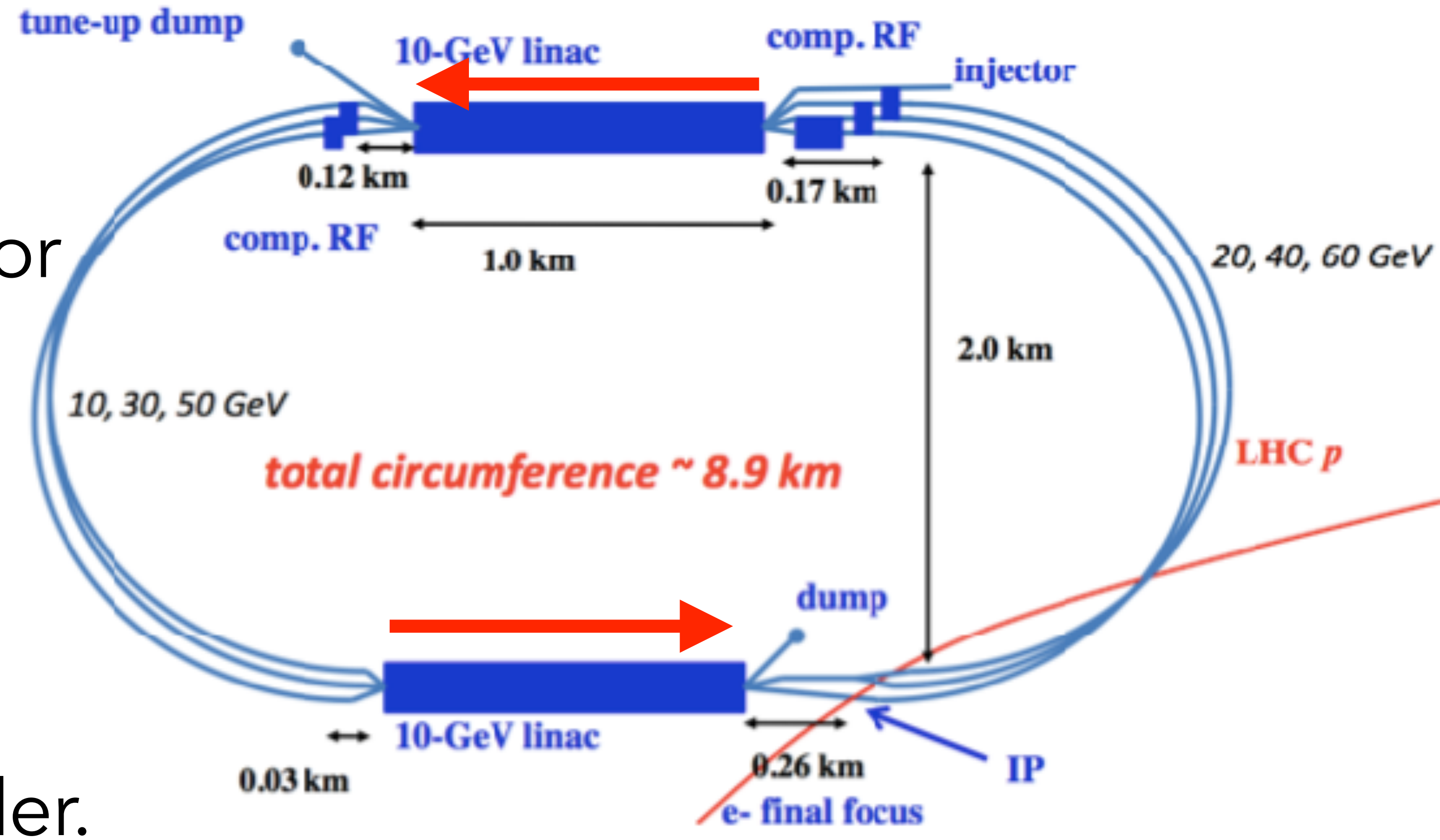
- 'Clean' events with fewer hadron background than pp collider.
- No pileup. (One collision per one crossing.)
- Advantage for H→bb (cc) study using Deep Inelastic Scattering events.

Future ep collider

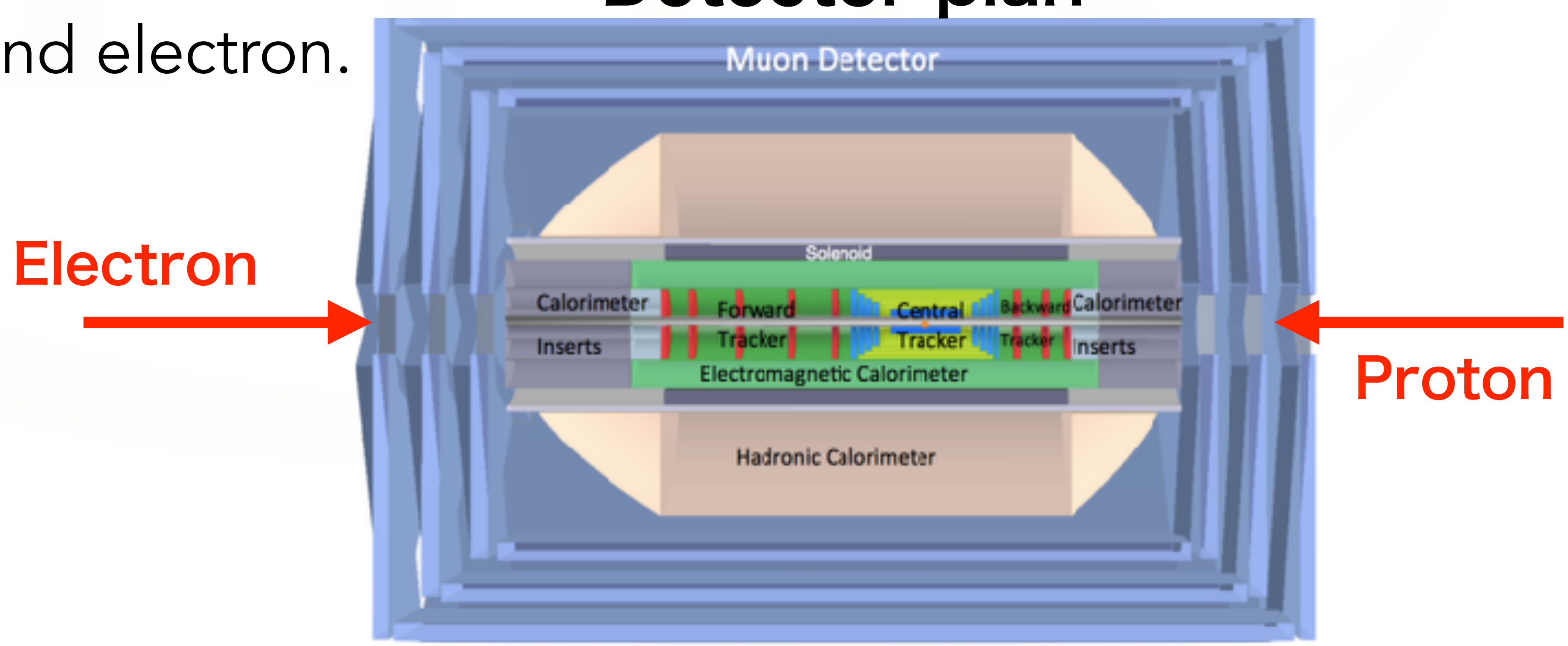
- Electron facility.
  - ERL (**E**nergy **R**ecovery **L**inac).
  - Combination of linear accelerator and rings for turning.
  - Accelerated to 60 GeV.

- Detector plan for future ep collider.
  - Asymmetric layout for unbalanced energy of proton and electron.

Electron facility plan



Detector plan



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- Higher energy and luminosity than HERA.

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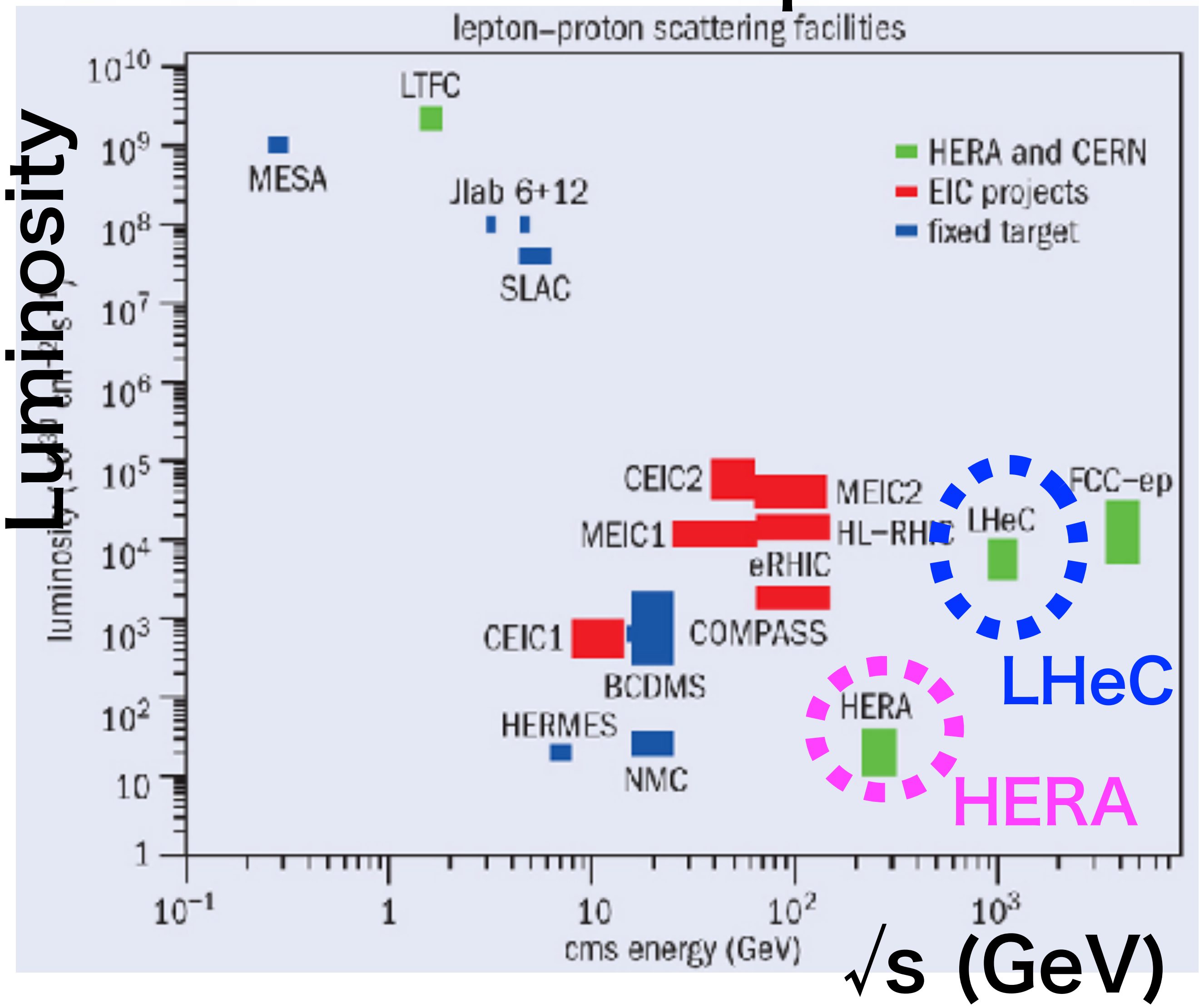

Prospect for PDF study

U. Klein