SM Higgs measurements at FCC-ep

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On behalf of the LHeC/FCC ep group

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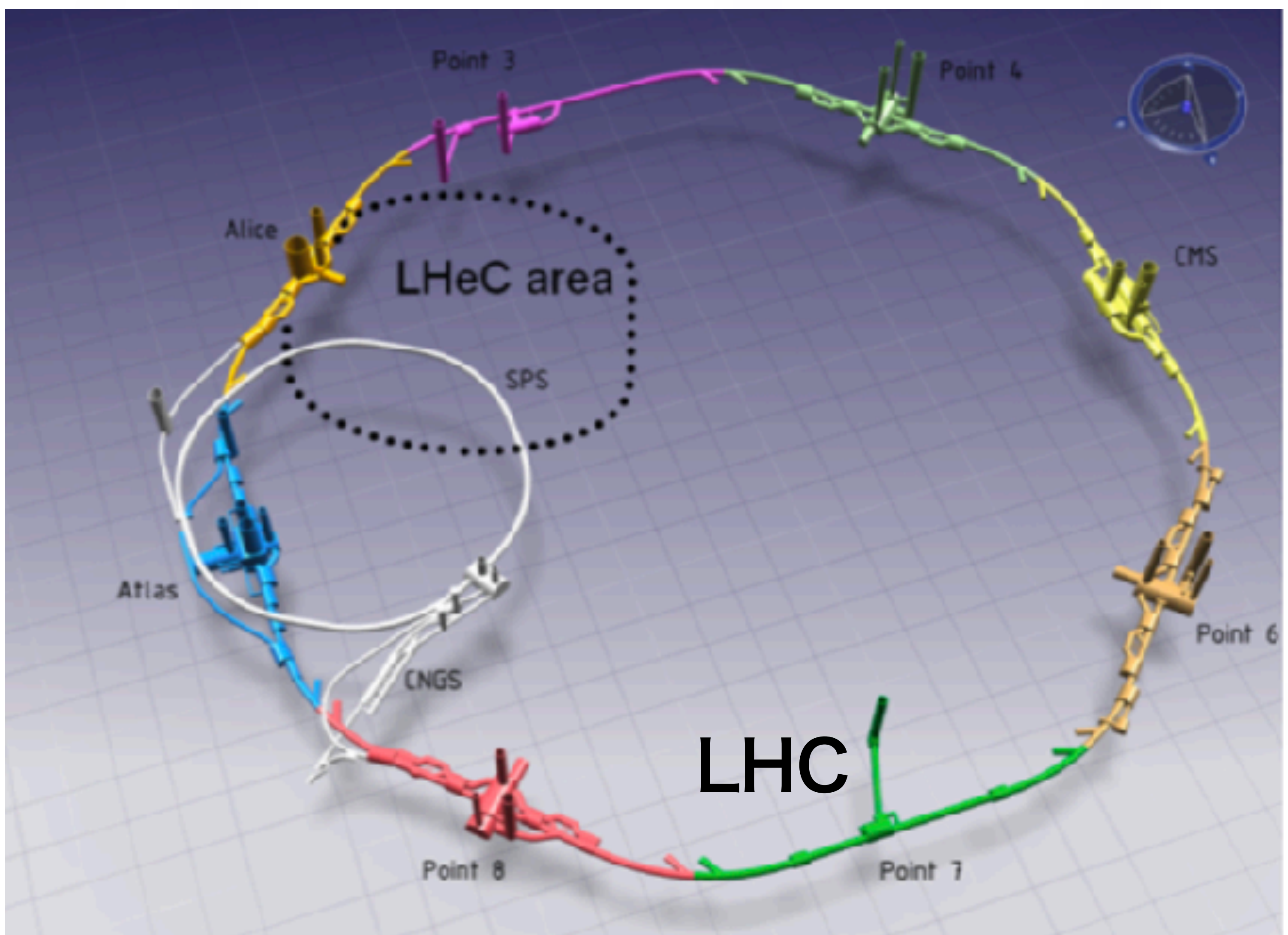
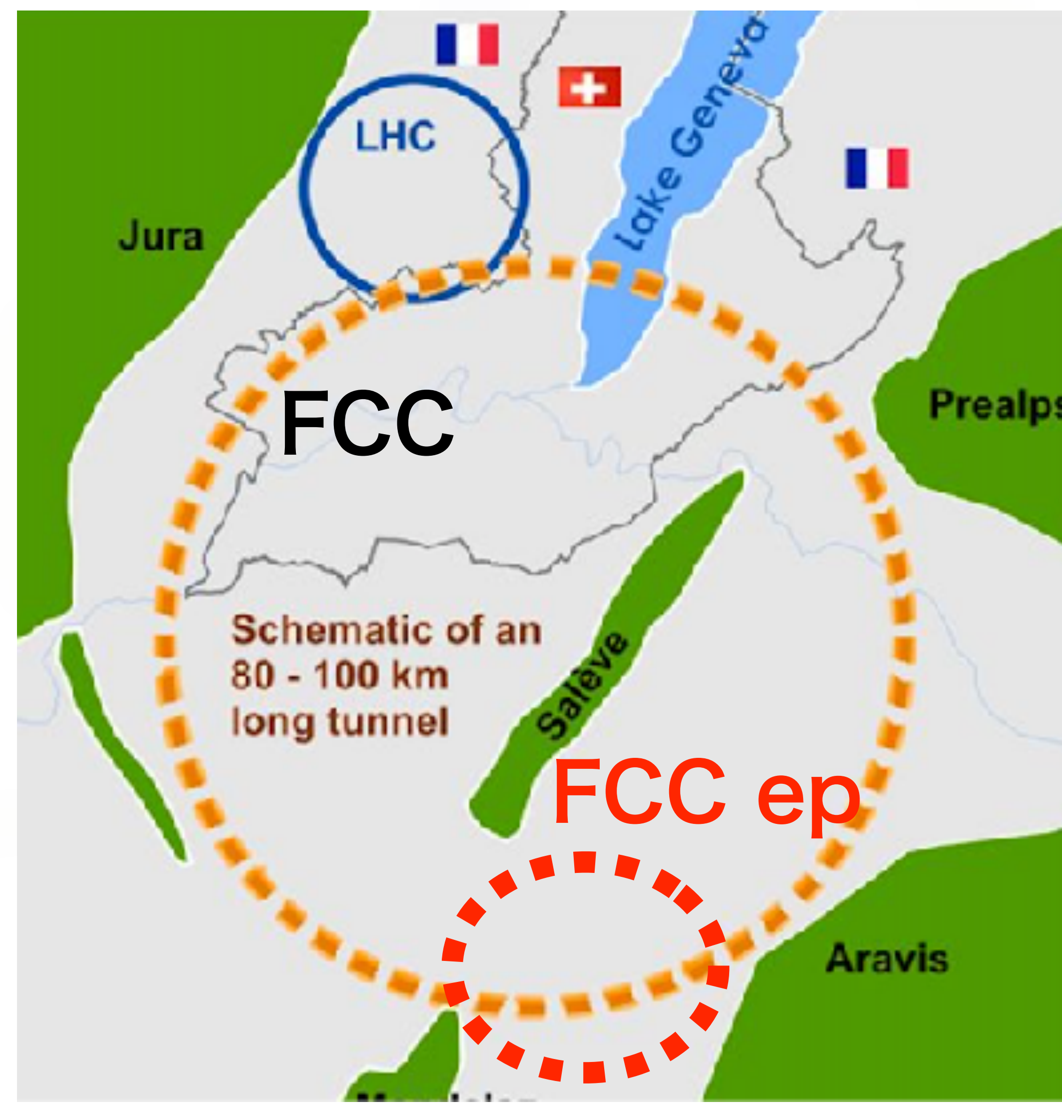
Future ep collider

- LHeC
  - 7 TeV proton of LHC and 60 GeV electron. ($\sqrt{s}$ ~ 1.3 TeV)
- FCC ep
  - 50 TeV proton of FCC and 60 GeV electron. ($\sqrt{s}$ ~ 3.5 TeV)
- Both plan to create new electron facility.

LHeC/HE-LHC layout



FCC ep layout



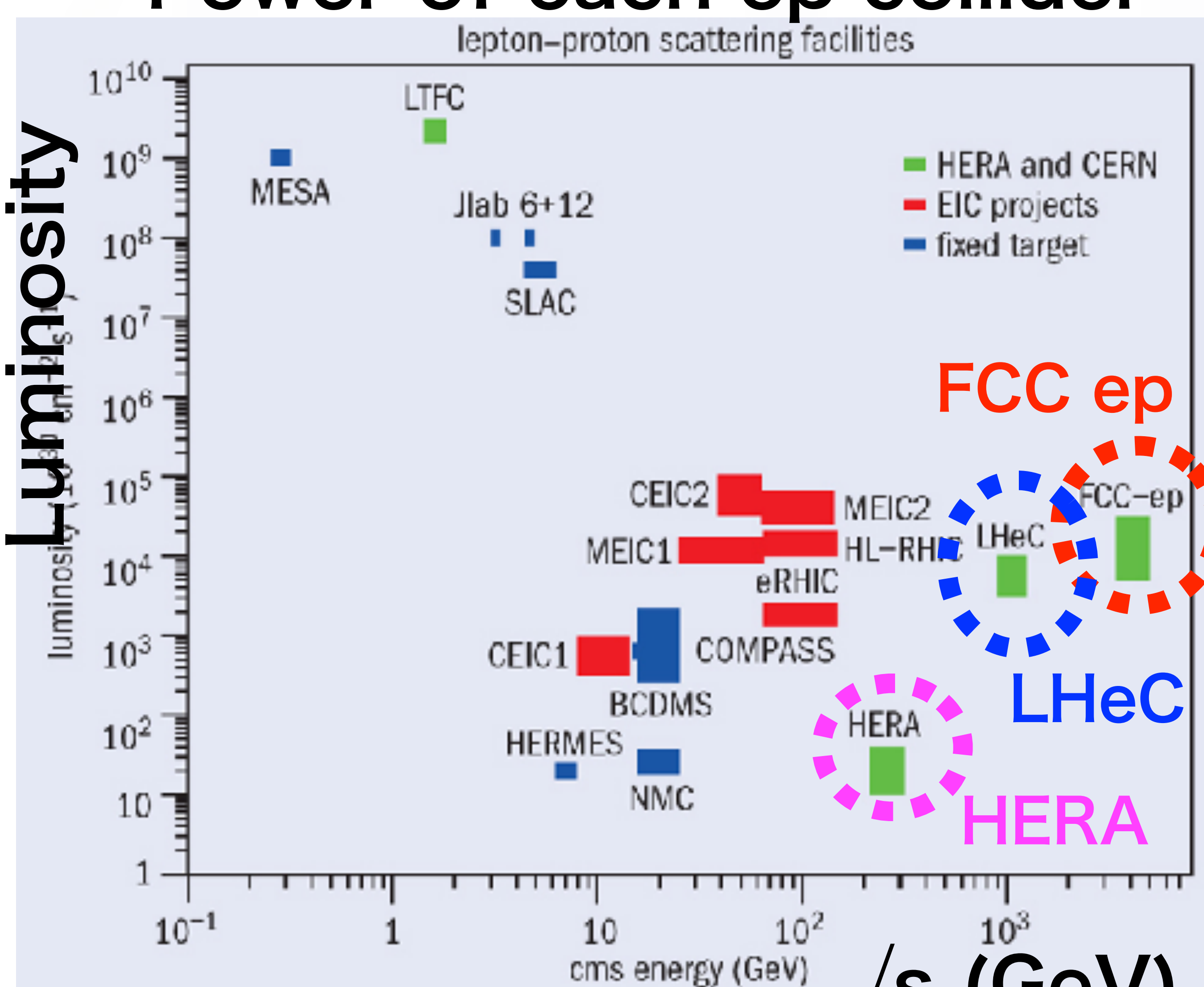
Future ep collider

- Higher energy and luminosity than HERA.

➡ Extension of Q^2 and Bjorken x ranges.

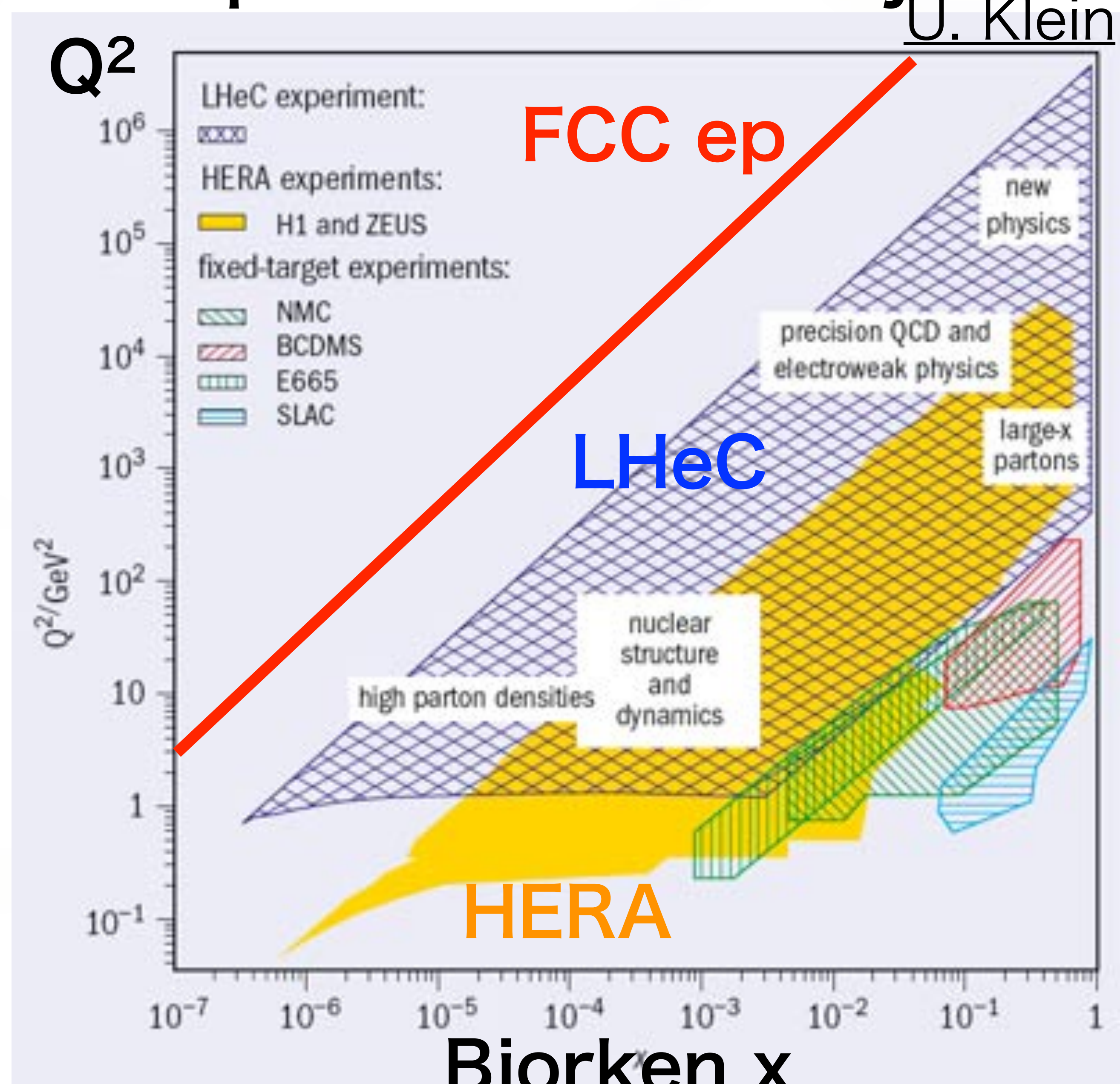
Important for new experiment and development of the theory.

Power of each ep collider



Prospect for PDF study

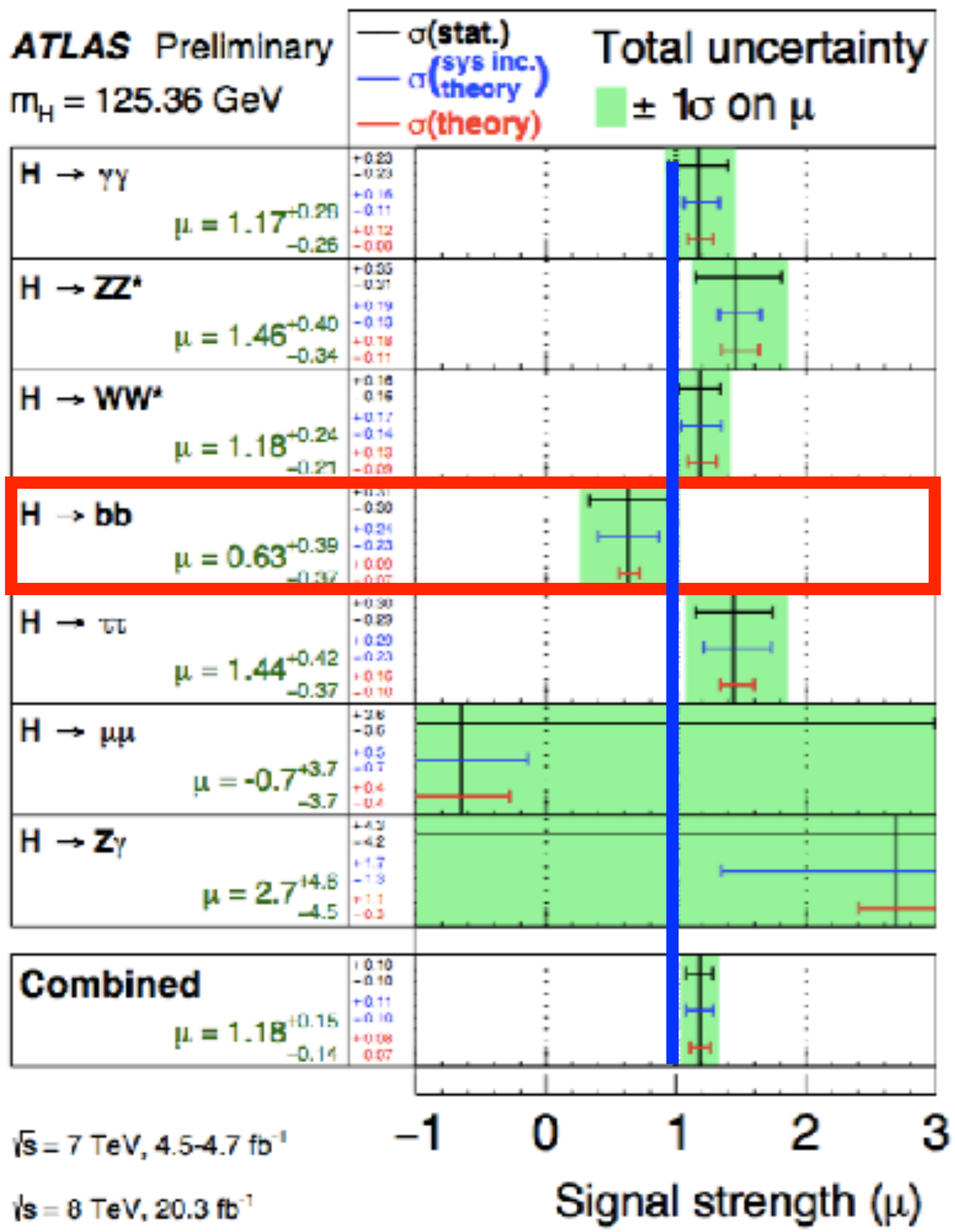
U. Klein

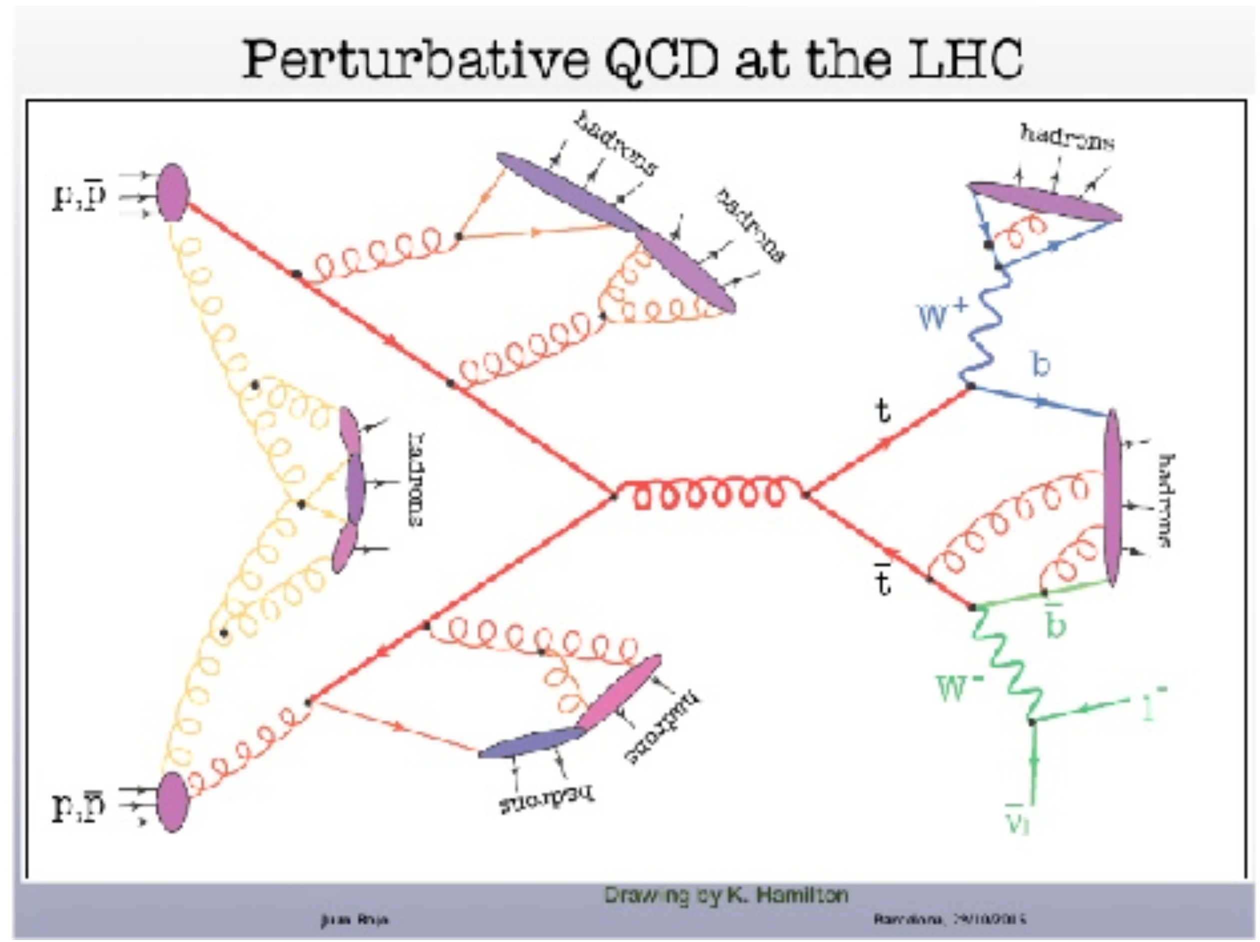


Higgs studies at LHC

- 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.

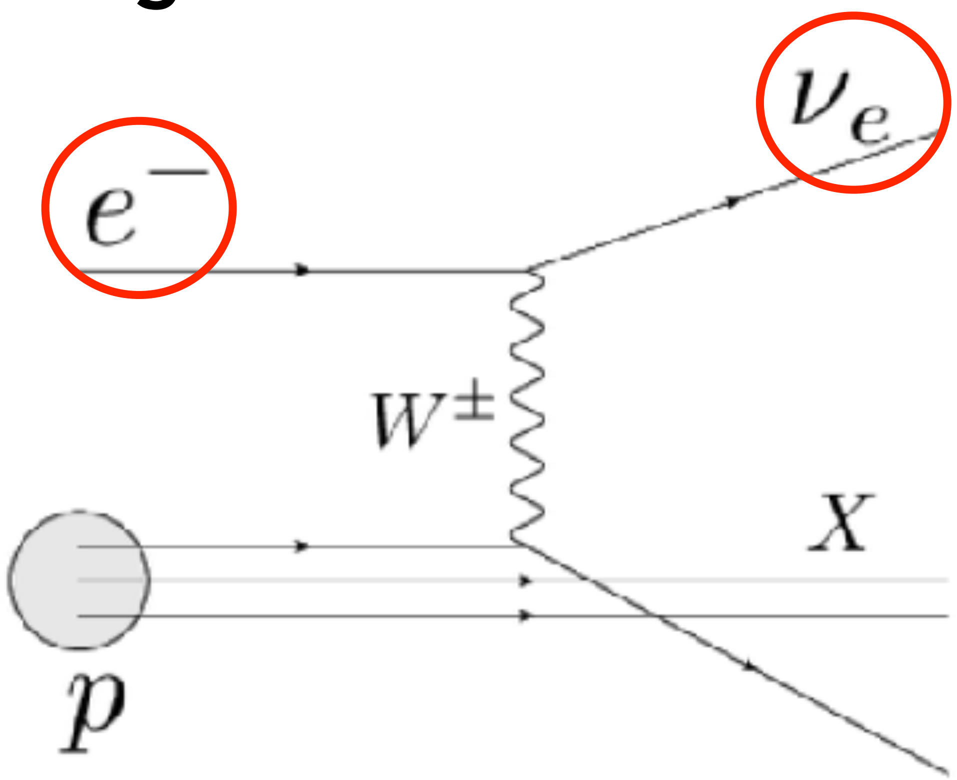




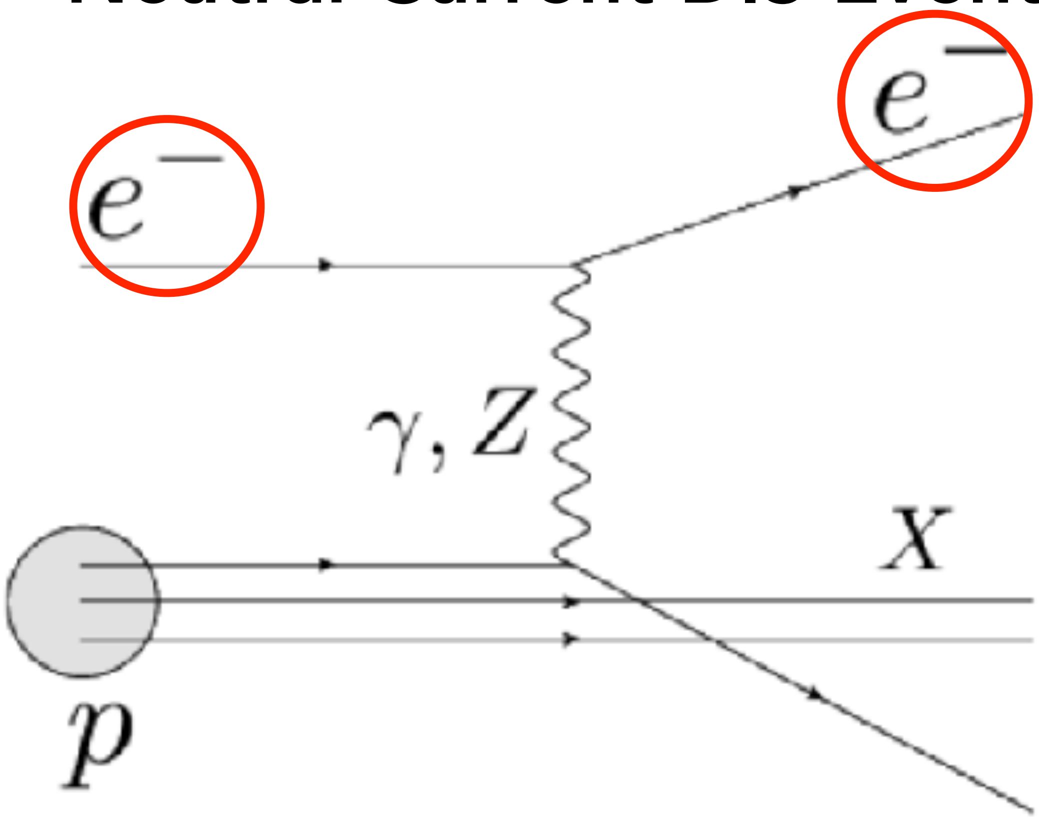
- H->bb channel is challenging due to large number of QCD bkg.
- How about at electron proton collider ?

Deep Inelastic ep Scattering

Charged Current DIS Events



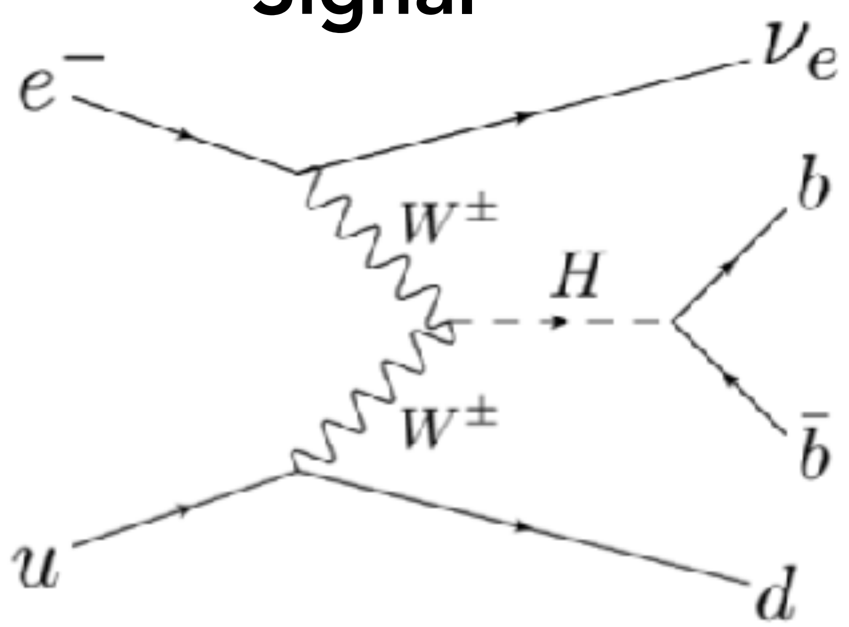
Neutral Current DIS Events



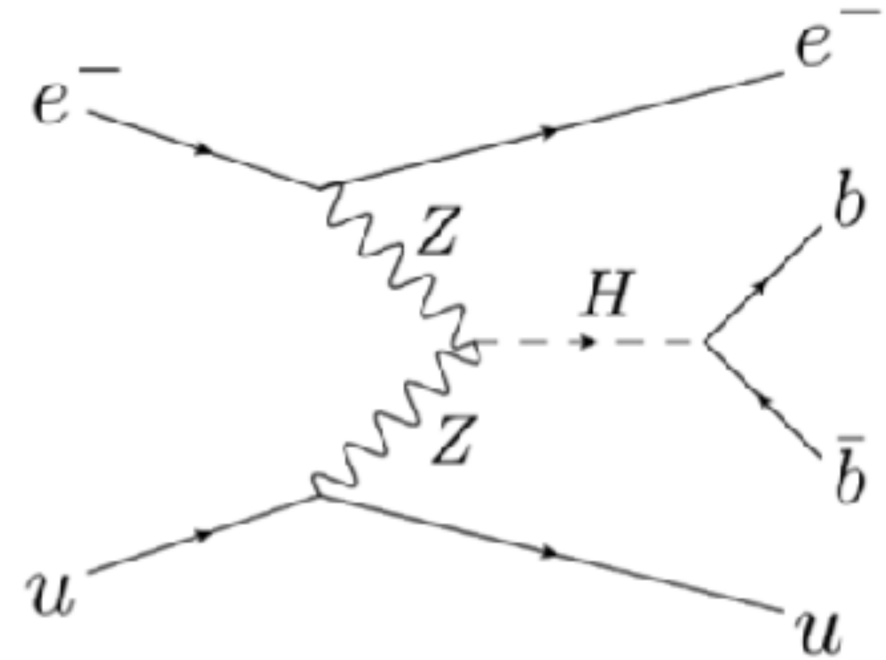
- ‘Clean’ events with fewer hadron background than pp collider.
- No pileup. (about 1 event at FCC ep.)
- Advantage for H→bb (cc) study using Deep Inelastic Scattering events.

Higgs at ep collider

Signal



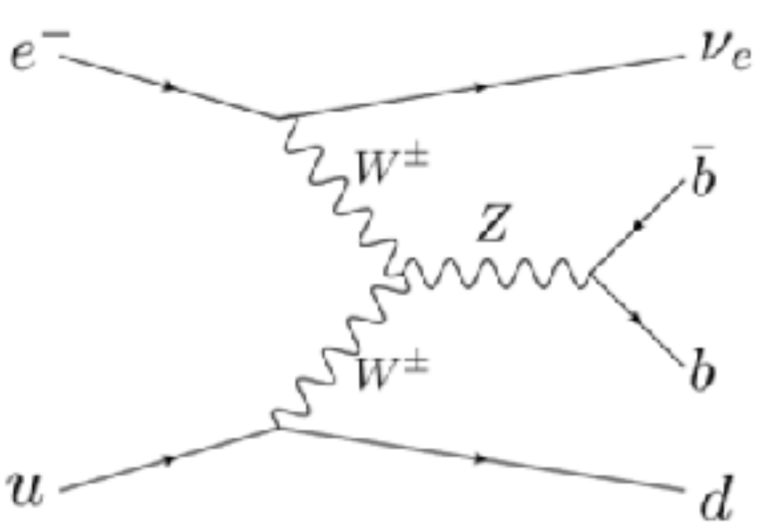
Charged current (CC) H→bb



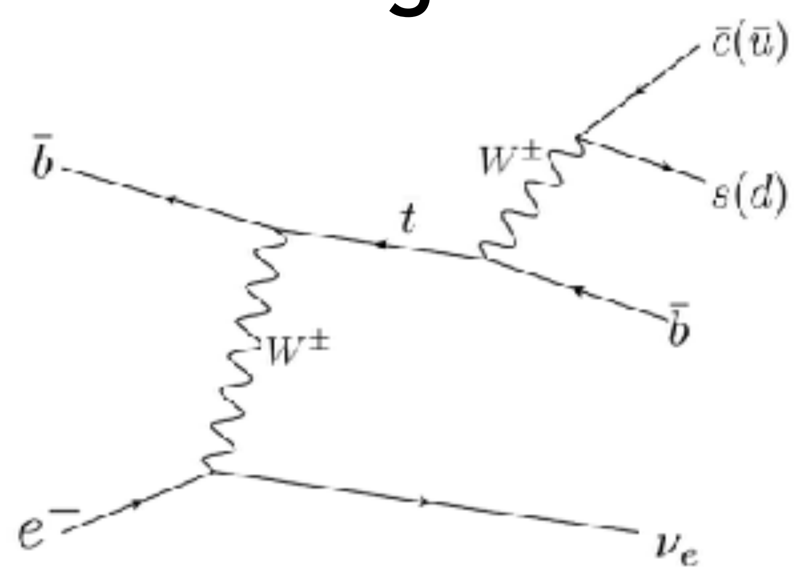
Neutral current (NC) H→bb

- We focus currently on CC: H→bb because the cross section is 4 - 5 times larger than NC: H→bb.

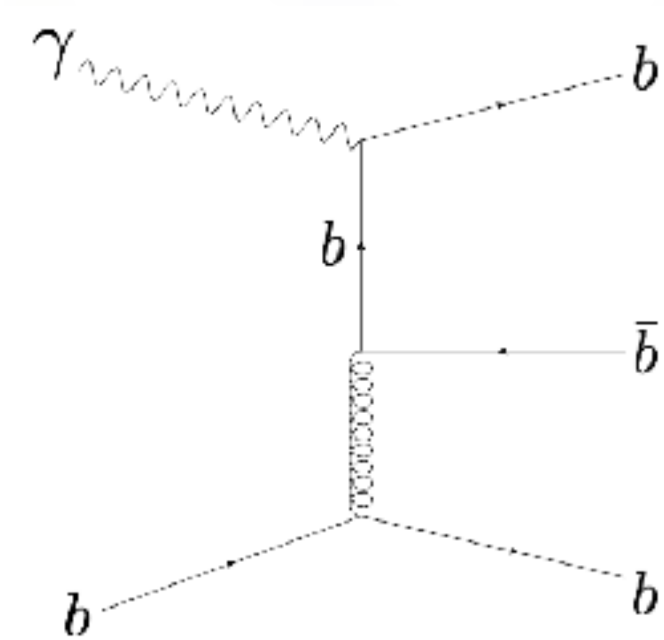
Background



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 analysis are pursued using LHeC analysis strategies so far.

Generator setup
- LHeC: 7 TeV proton & 60 GeV electron.
- FCC ep: 50 TeV proton & 60 GeV electron.

Detector setup
- Reasonable setups for our own FCC ep considering current on-going experiment like ATLAS or CMS.

- B-tag performance
  - B-jet: 60%
  - C-jet: 10%
  - Light-jet: 1%

Event selection for H→bb

Primary cut

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

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

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

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

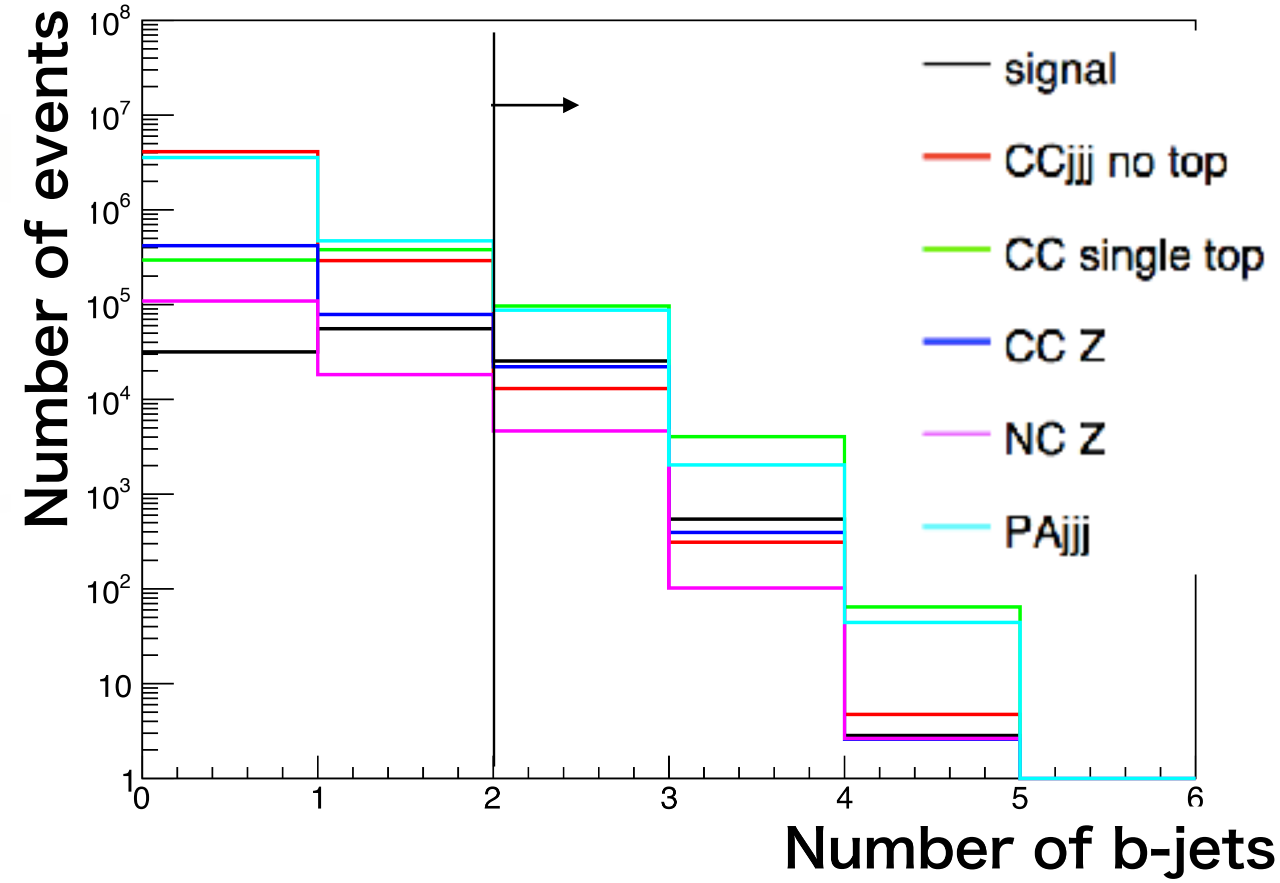
$$y_h = \frac{\sum_{hadron}(E - p_z)}{E_e}$$

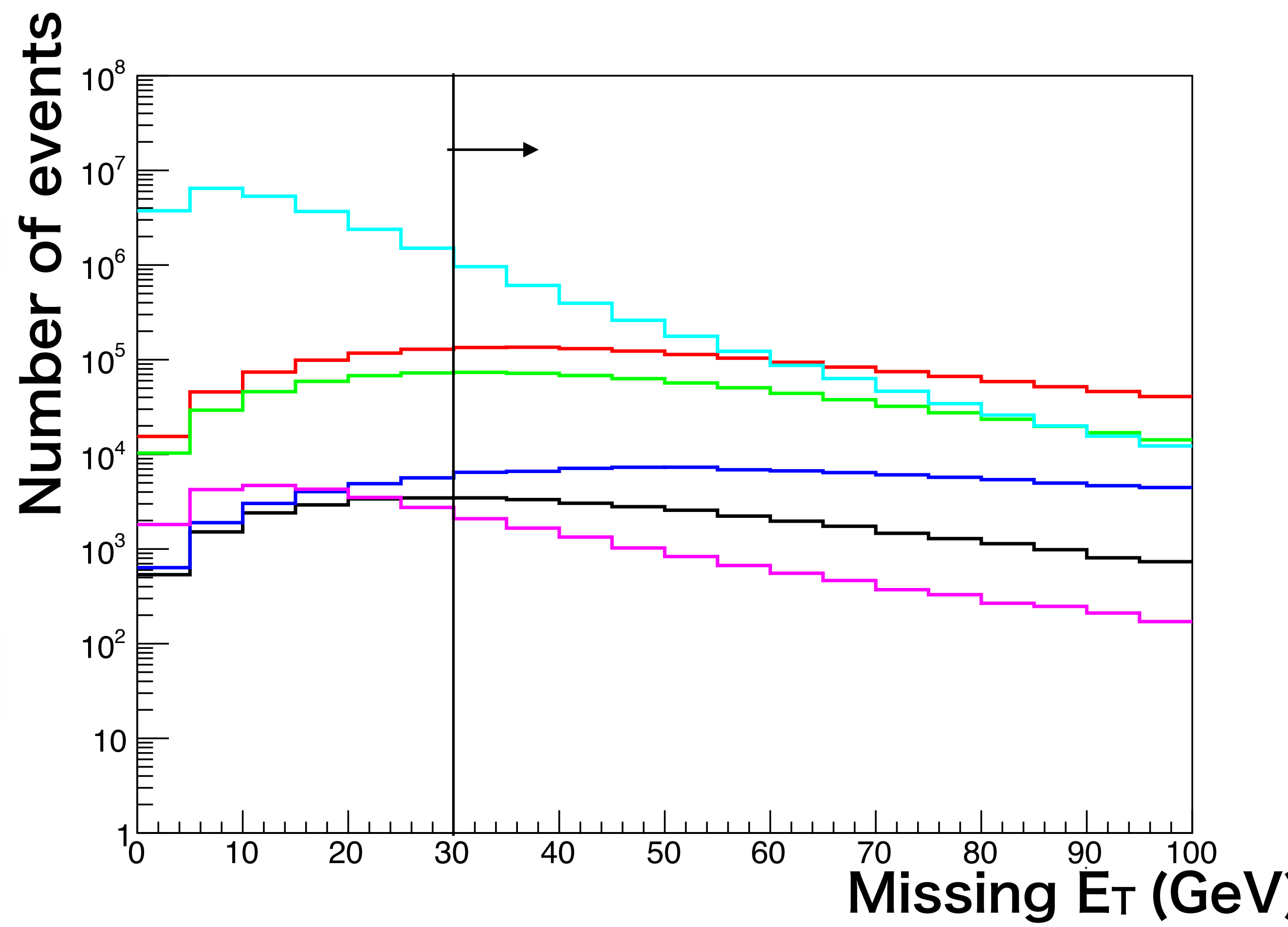
NC DIS event rejection

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

$$N_{electron} = 0$$

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





Event selection for H→bb

Forward jet tagging

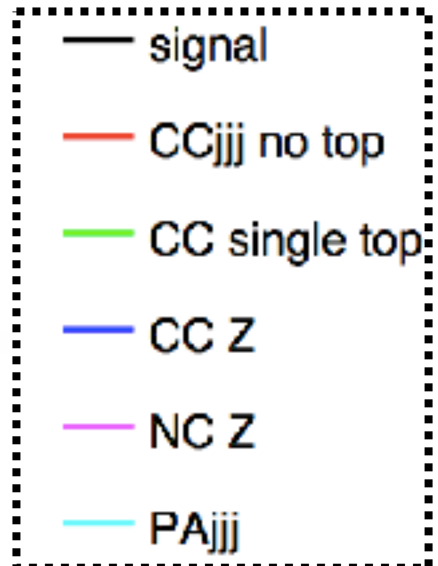
- Minimum η jet excluding two b-tagged jets with 1st and 2nd minimum eta.
- Regardless of b-tagged or not.

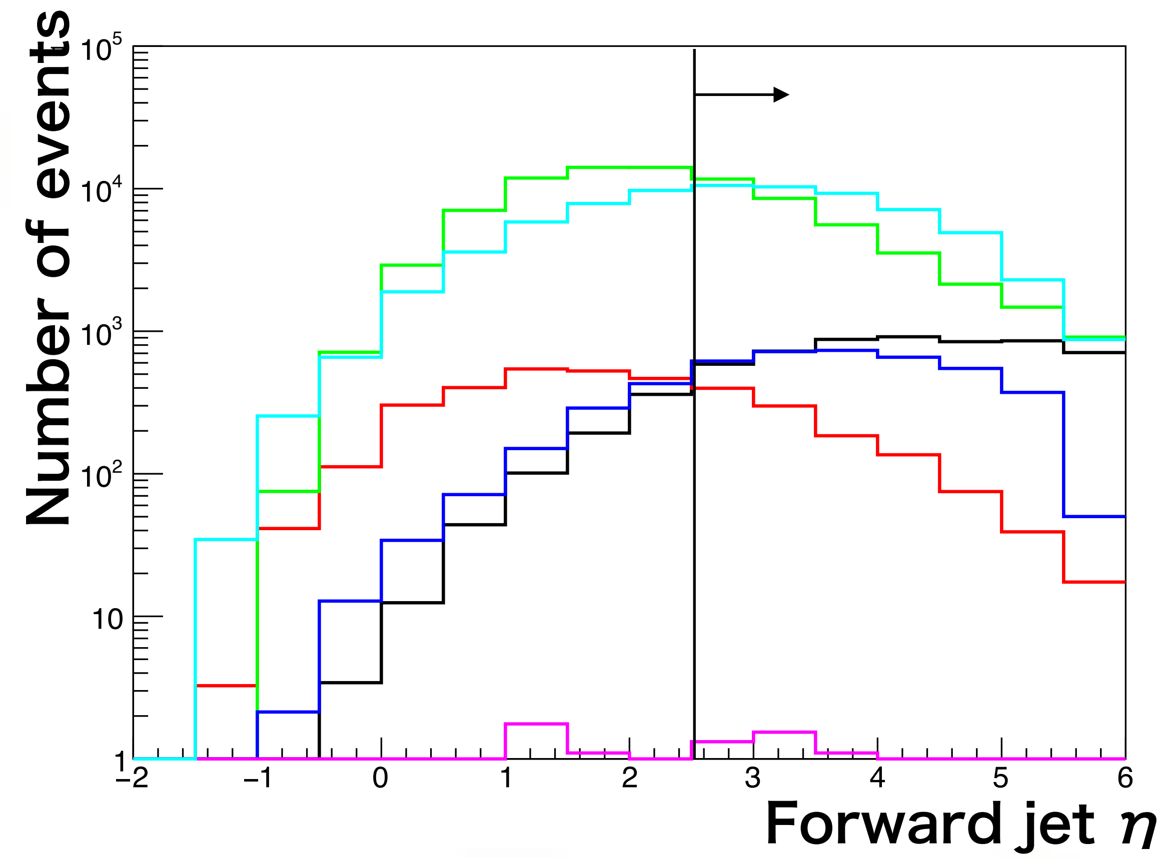
$$\eta_{fwd} > 2$$

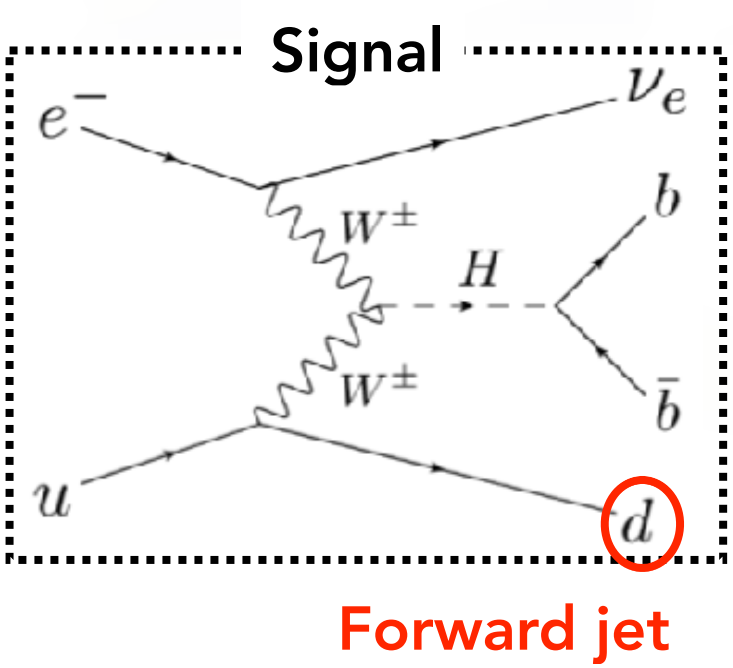
Single top rejection

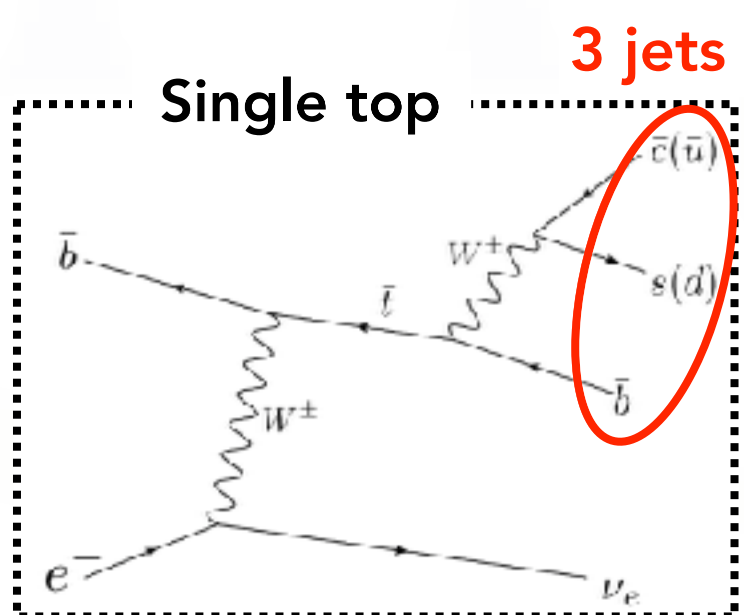
$$M_{jjj,top} > 250\ \text{GeV}$$

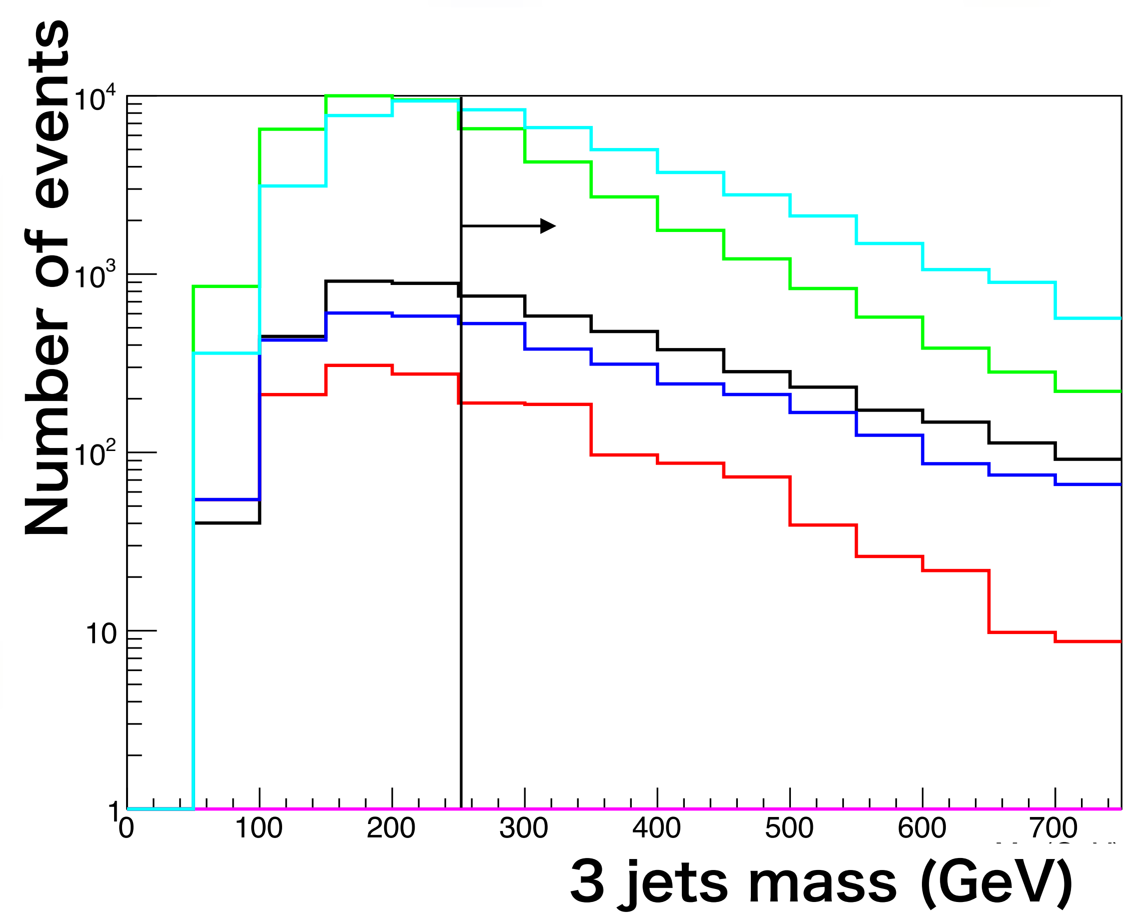
$$M_{jj,W} > 130\ \text{GeV}$$





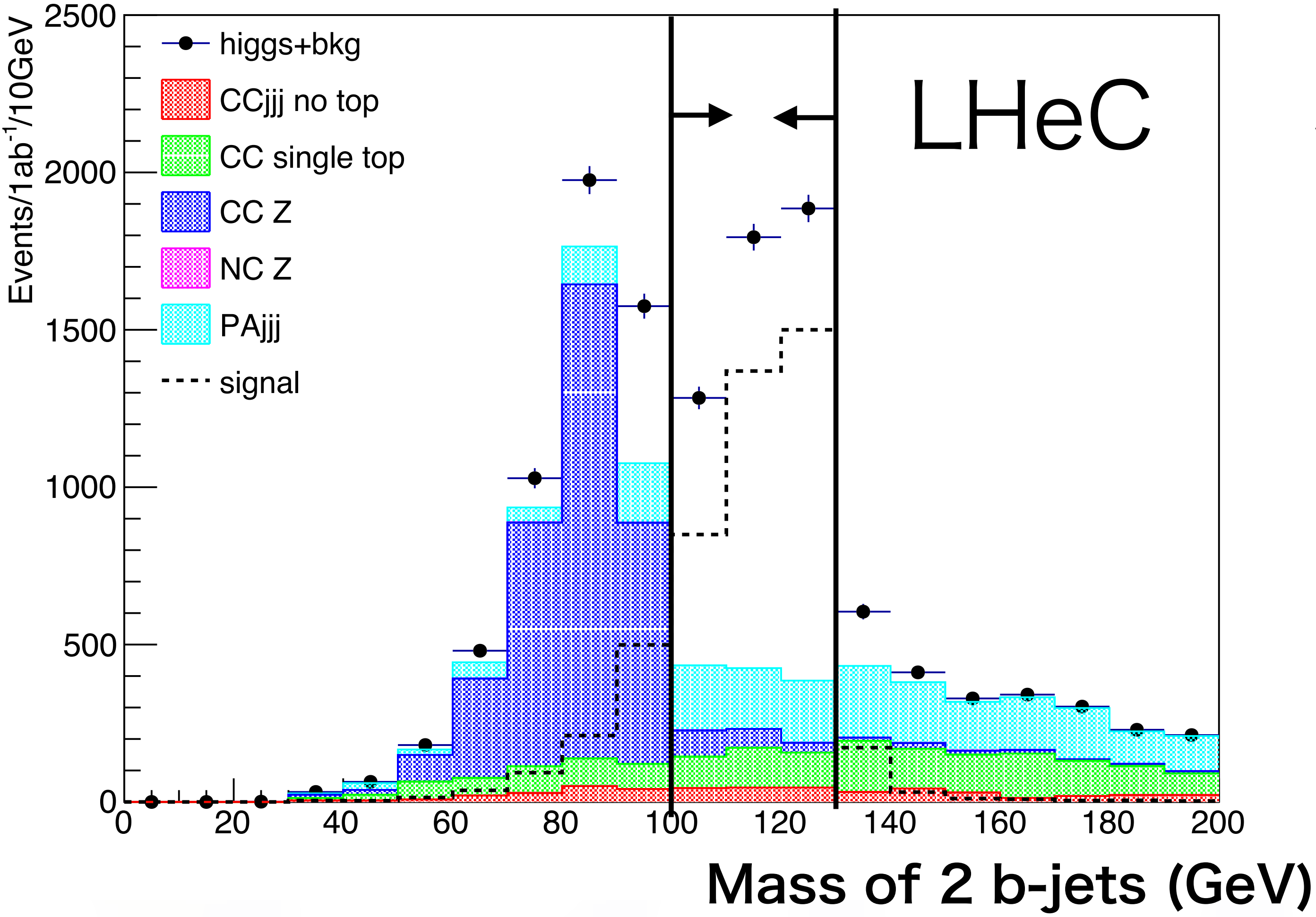


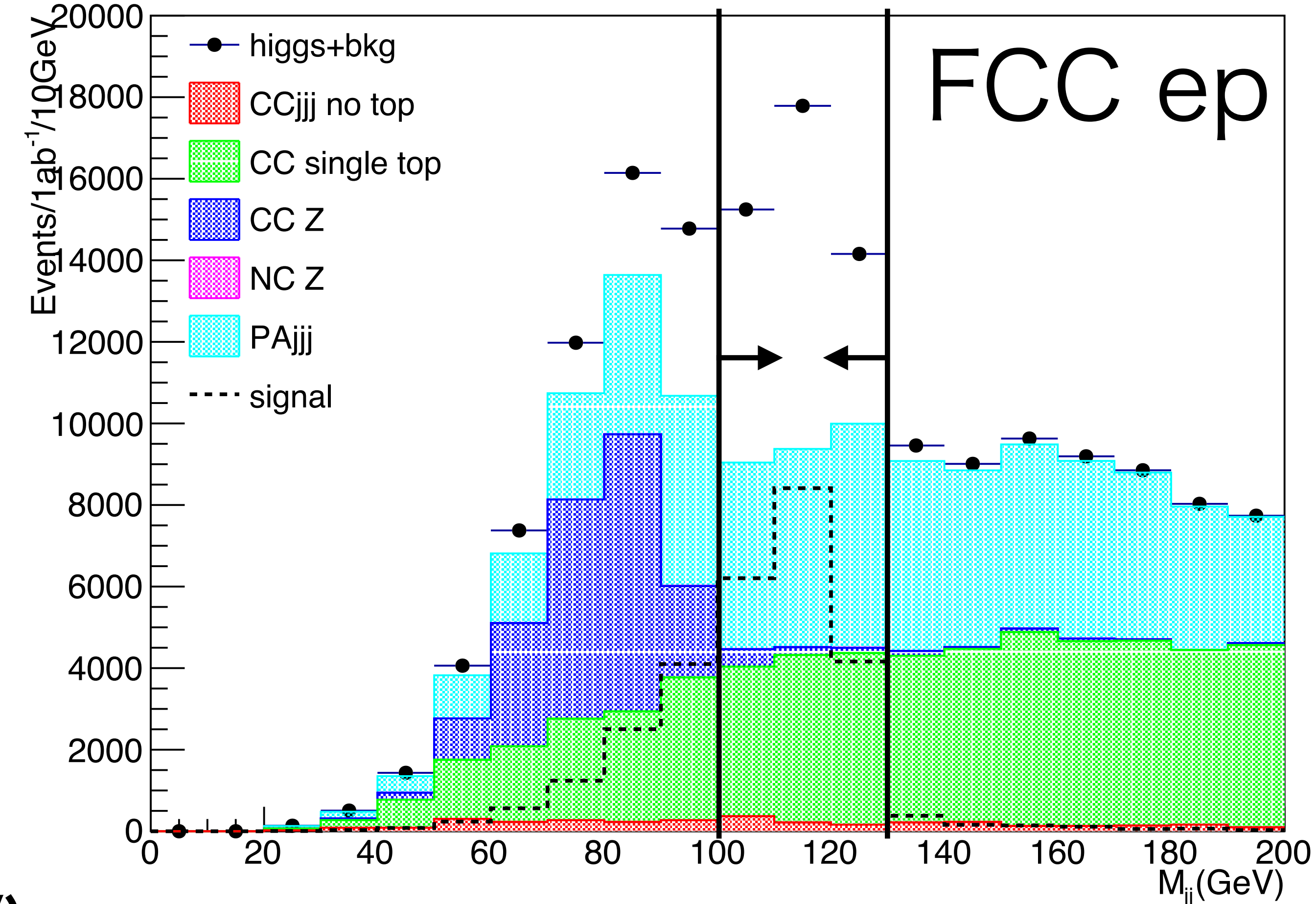




Cut based results H→bb at LHeC and FCC ep

- Assumed 1000 fb^{-1} of statistics. (~10 years running for LHeC.)





Signal: 3700

Bkg: 1200

κ (Hbb) ~ 0.9%

Signal: 19000

Bkg: 28000

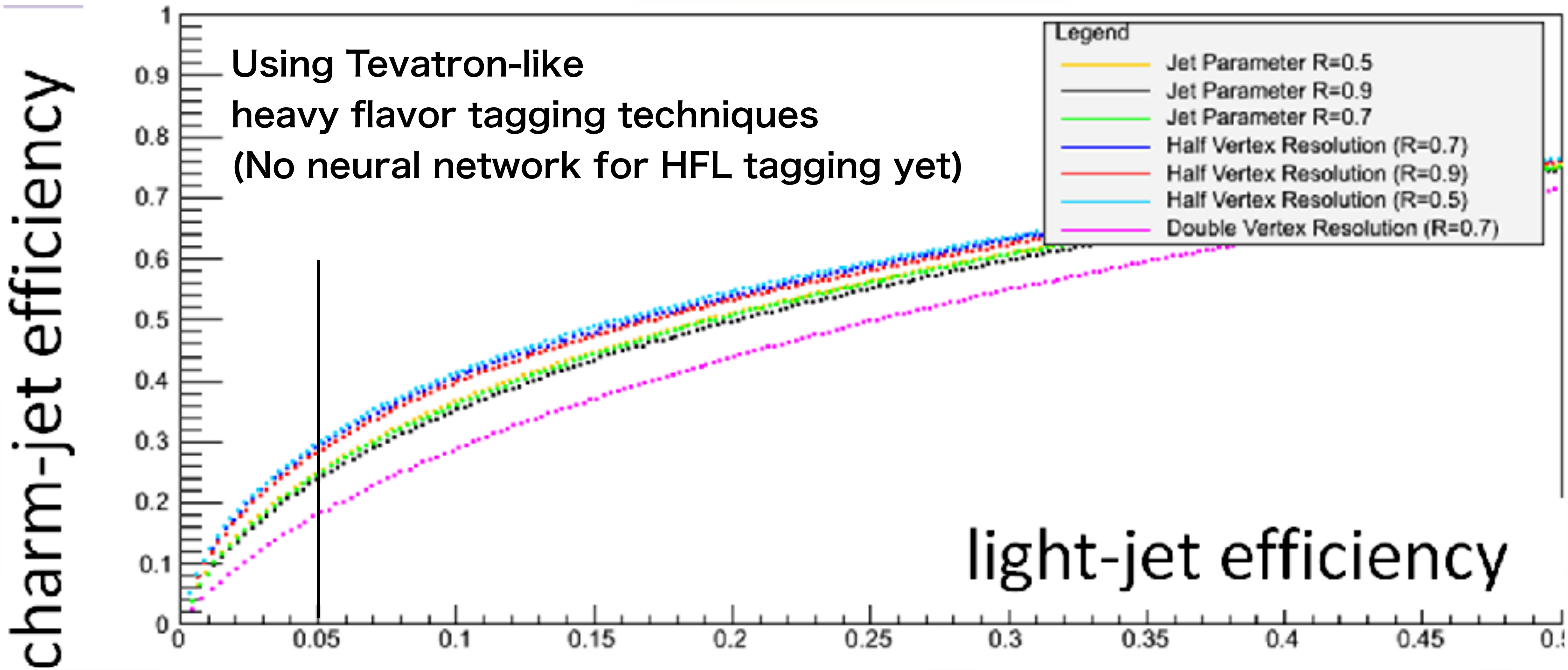
κ (Hbb) ~ 0.6%

Precision of coupling constant
(Statistics error only)

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

Heavy flavor tagging efficiency

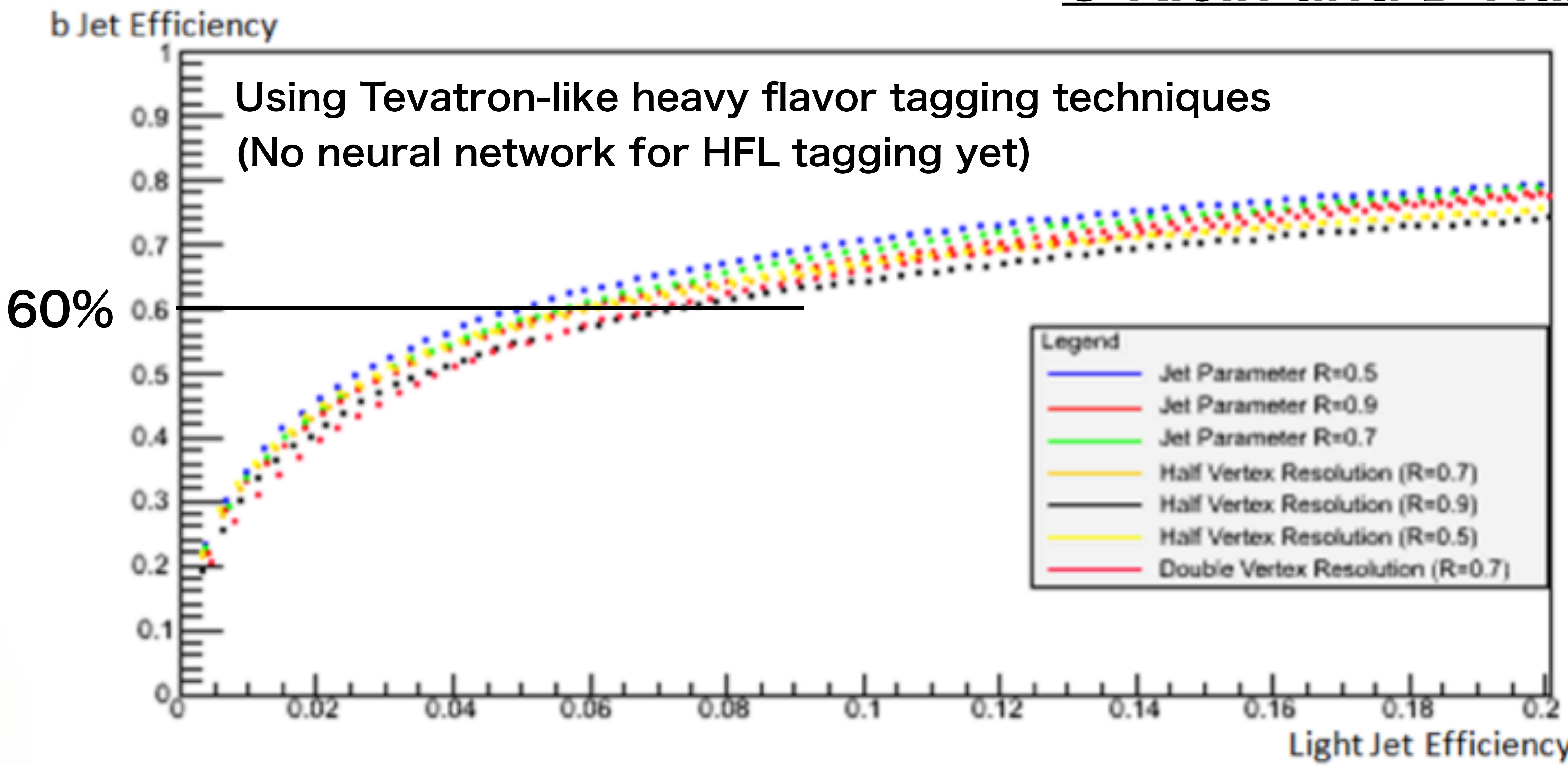
U Klein and D Hampson



- Significant improvement in charm jet tagging efficiency from 23-24% (R = 0.9, nominal) 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.

B-tagging efficiency

U Klein and D Hampson

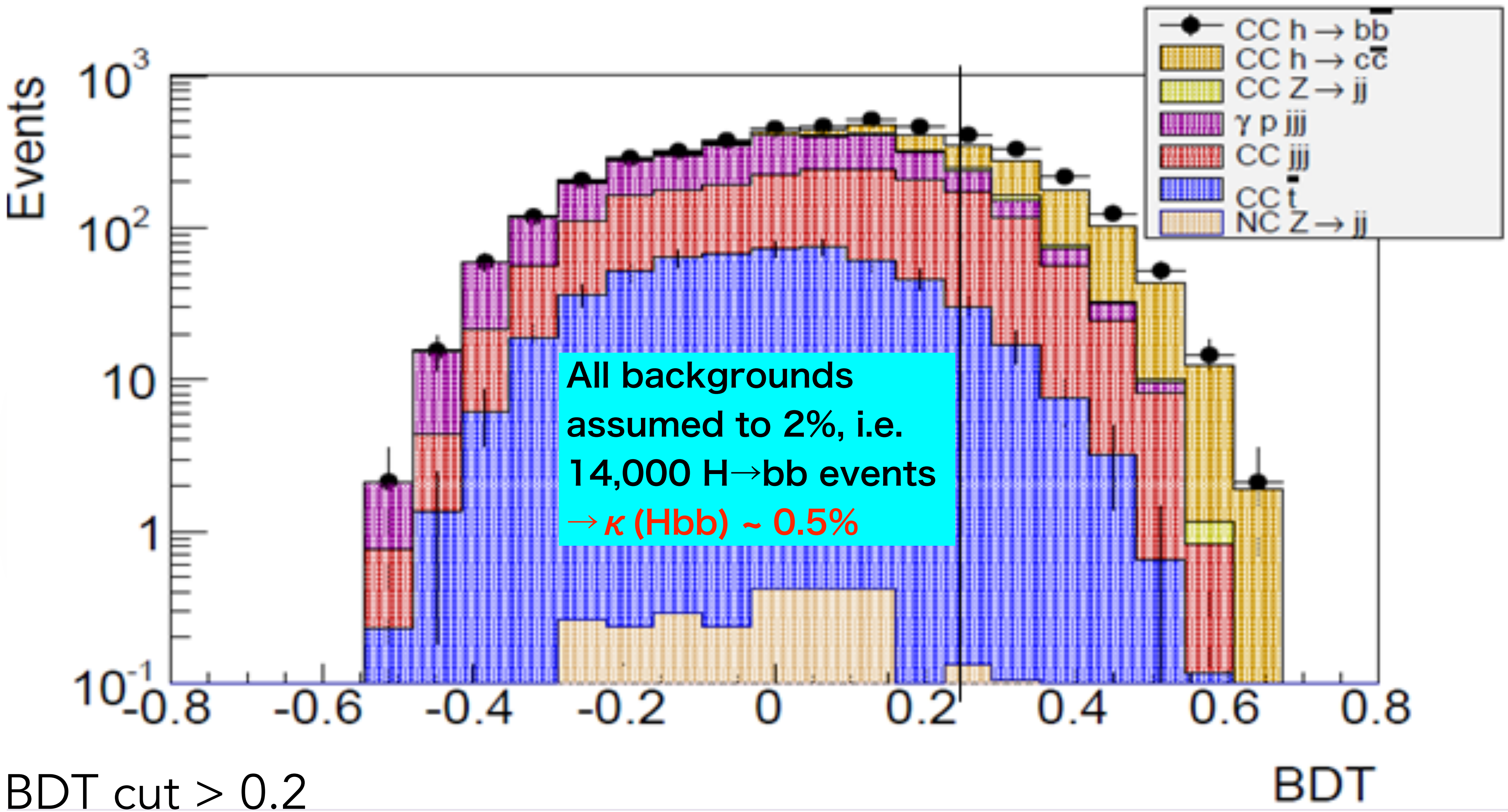


- We can get less light jet contamination at 60% b-tag efficiency using smaller jet radii.

BDT results H→cc at LHeC

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

U Klein and D Hampson



BDT cut > 0.2

Hcc signal events: 474

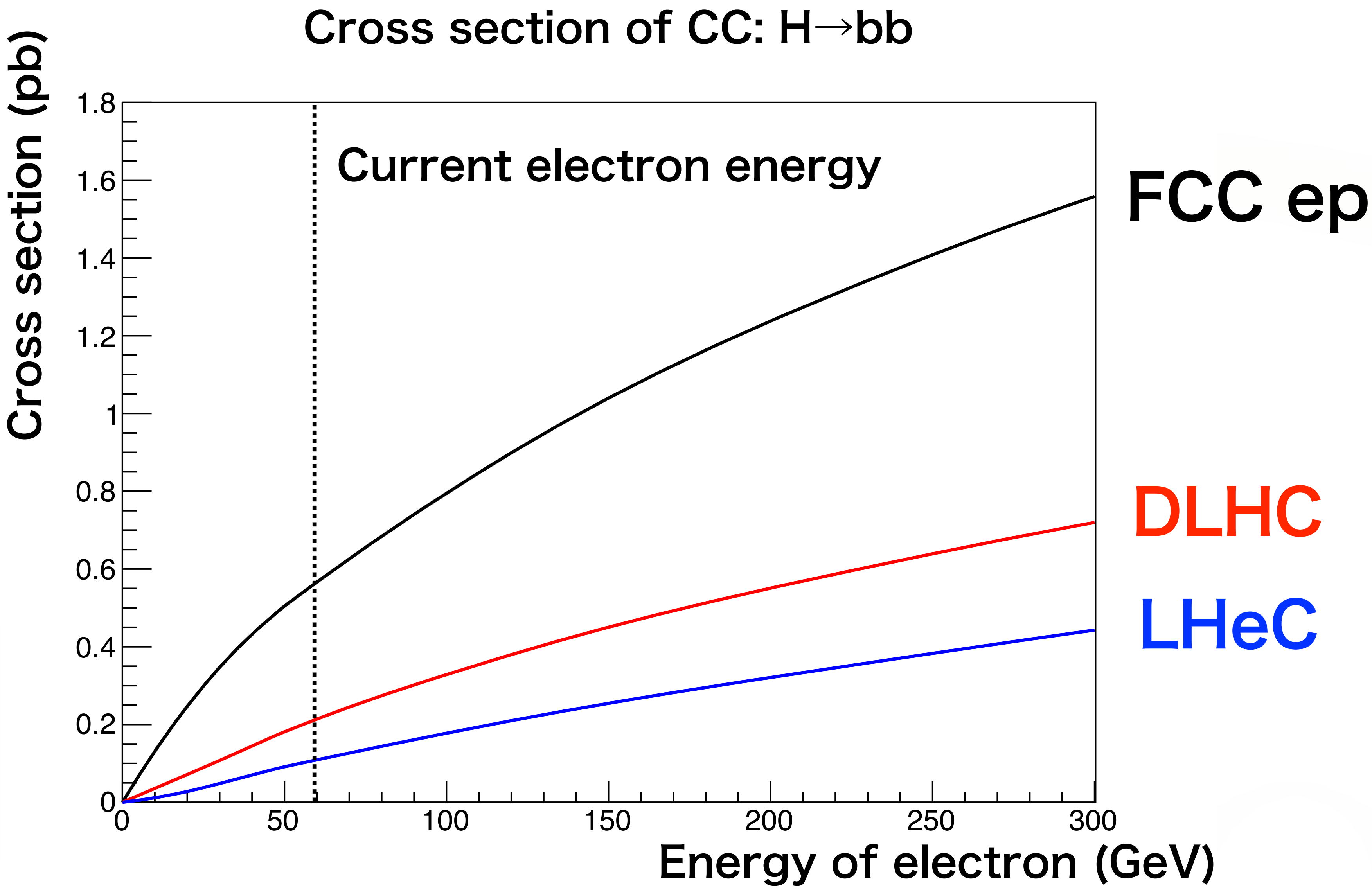
$S/\sqrt{S+B} = 12.8$

→κ(Hcc) = 4% for 1000 fb^{-1}

Clear potential to access the Higgs to charm decay channel.

Coupling constant measurement at future ep collider

U Klein



- Estimate measurement error of coupling constant from BDT result.
- Assume 1 ab^{-1} respectively.

	LHeC (~1.3 TeV)	DLHC (~1.8 TeV)	FCC ep (~3.5 TeV)
Hbb	0.5%	0.3%	0.2%
Hcc	4%	2.8%	1.8%

Summary

- SM Higgs measurement at future ep collider FCC ep.
- Plan to make new electron facility.
  (Electron energy is 60 GeV at current plan.)
- Precision of coupling constants are estimated to be
  - Hbb: 0.2%
  - Hcc: 1.8%

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

  ➡ Big potential for measurements of coupling.

Next step

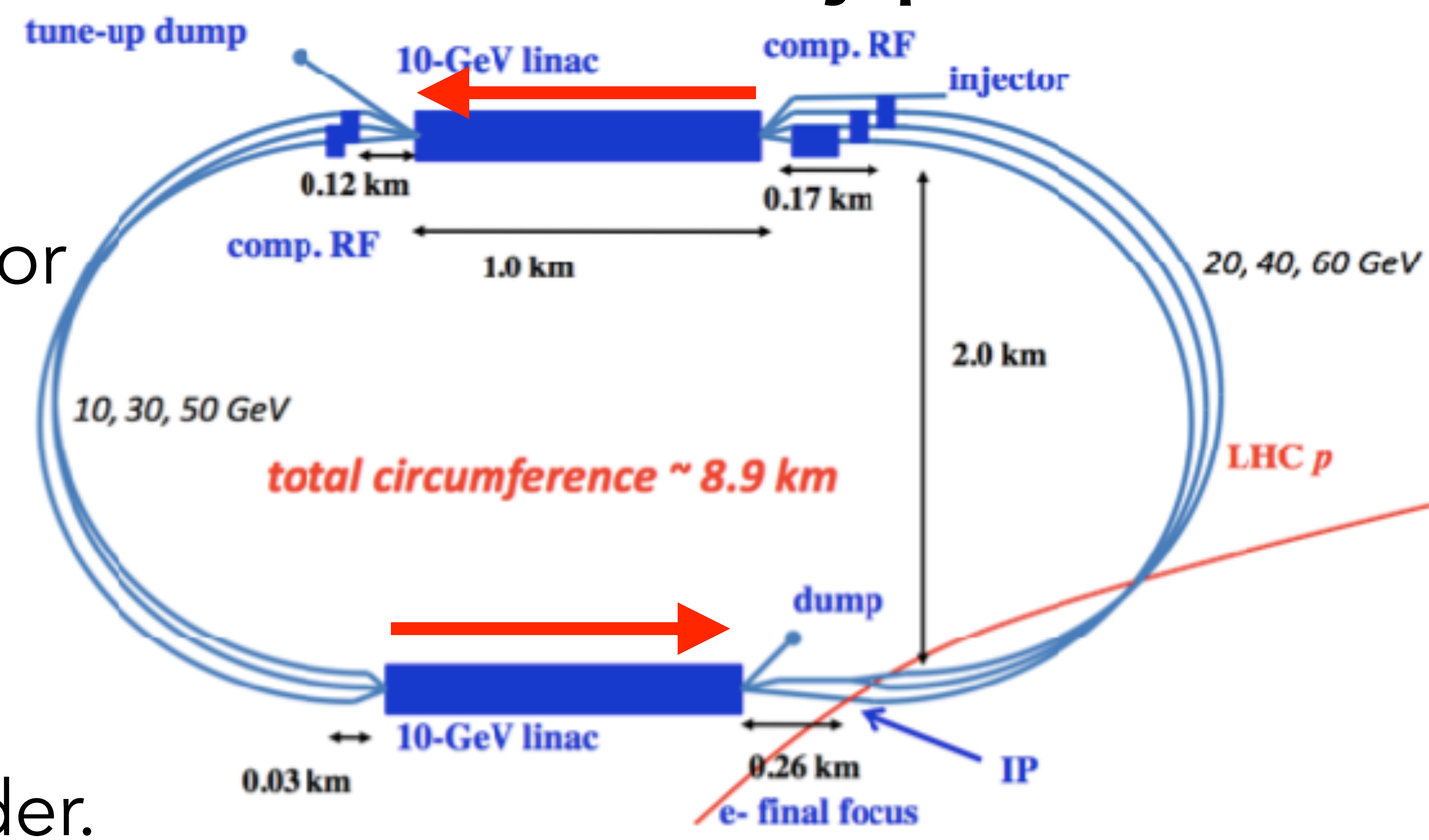
- Other decay channels to enhance complementarity between ep and pp.
- CP properties studying azimuthal difference.
  ($\Delta\varphi$ between forward jet and missing ET.)

Backup

Future ep collider

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

Electron facility plan



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

Detector plan