Higgs physics at LHeC and FCC-he

DIS2016, DESY, 12th apr 2016

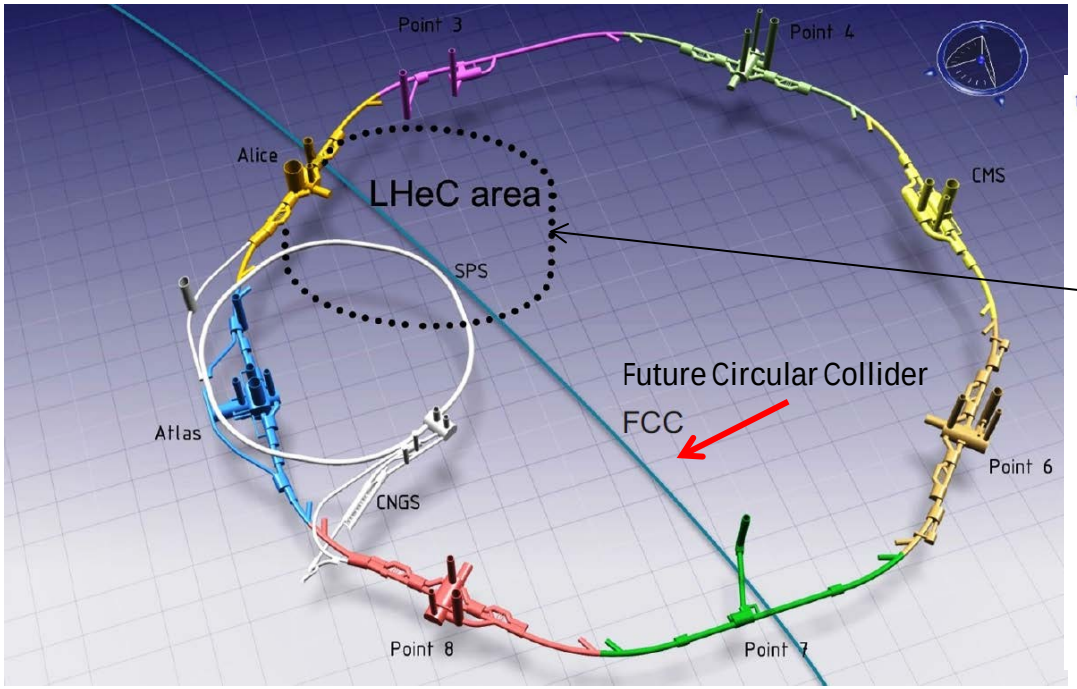
Olaf Behnke (DESY)

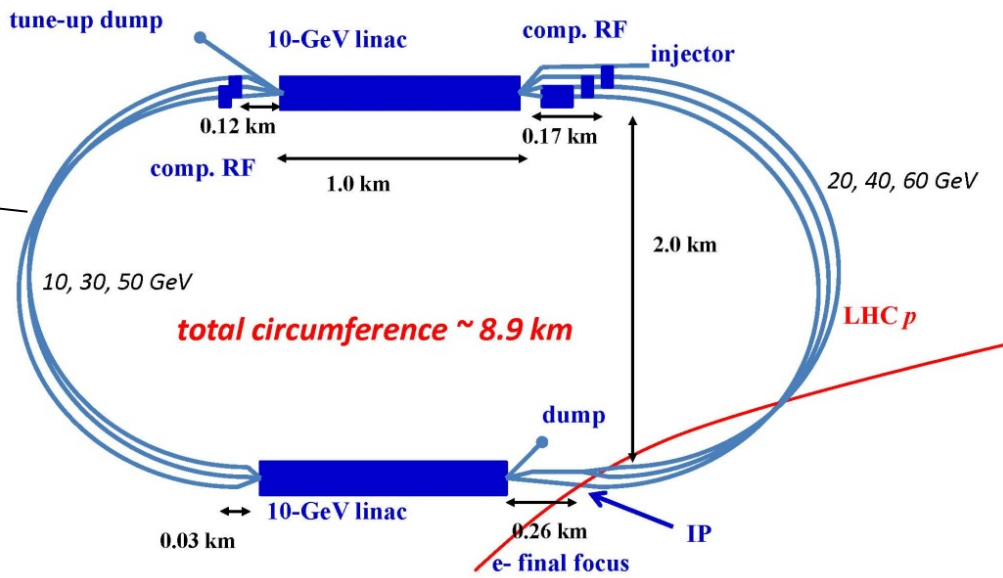
Focusing on new study results since DIS2015

All signal cross sections and signal/background simulations based on specific MadGraph implementations

LHeC and FCC-he

e- accelerator = recirculator with energy recovery

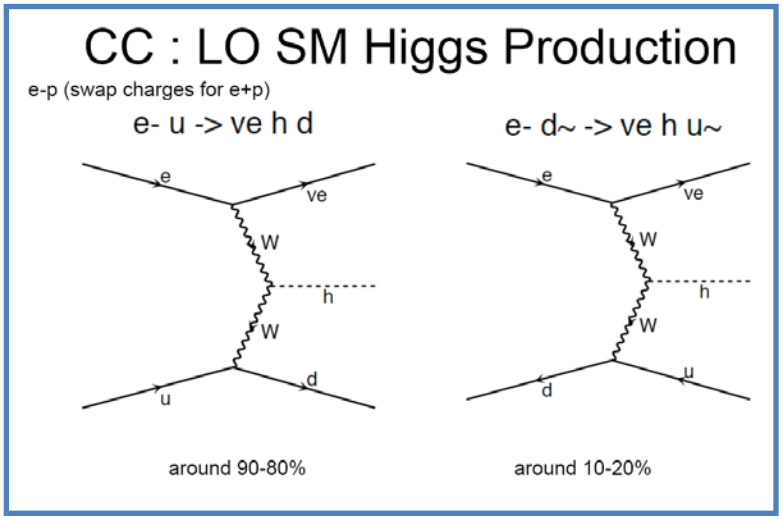


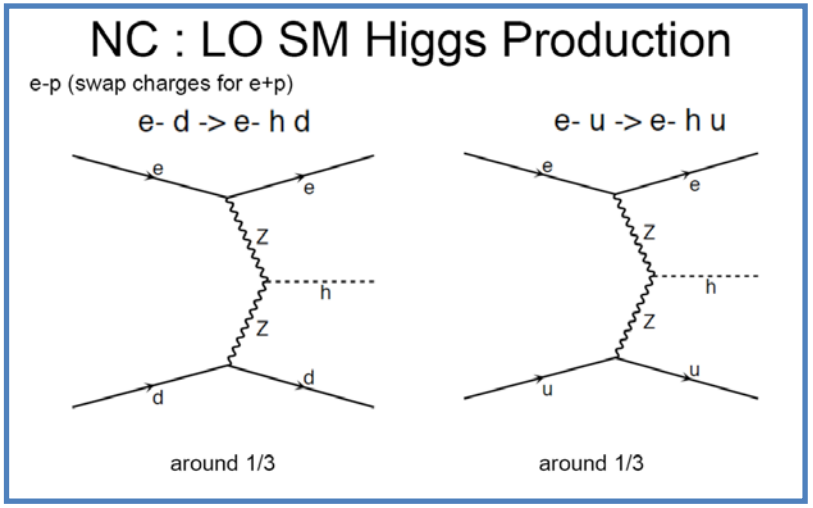


ep Collider	LHeC	FCC-he
Ep	7 TeV	50 TeV
Ee	60 GeV	60 GeV
$L/10^{33}cm^{-2}s^{-1}$	16	10
$\int Ldt$ (10 y)	1000 fb^{-1}	600 fb^{-1}

Higgs physics potential at ep colliders

Direct





Lhec with Ee=60 GeV	CC e^-p	NC e^-p
Polarised σ[fb] P= -80 %	**196**	25

- CC σ comparable to Z^*H at ILC
- Clean environment (s/b~1 and low pile up) compared to pp
- Needs excellent forward detector

Indirect

- Inclusive DIS and jet measurements at LHeC constrain PDFs and α_s → help precision Higgs measurements at LHC
  - not covered in this talk – see Uta Klein, DIS2015, Dallas

ep Higgs "Facility" @ 1ab^{-1}

Total event rates for 1ab^{-1}.

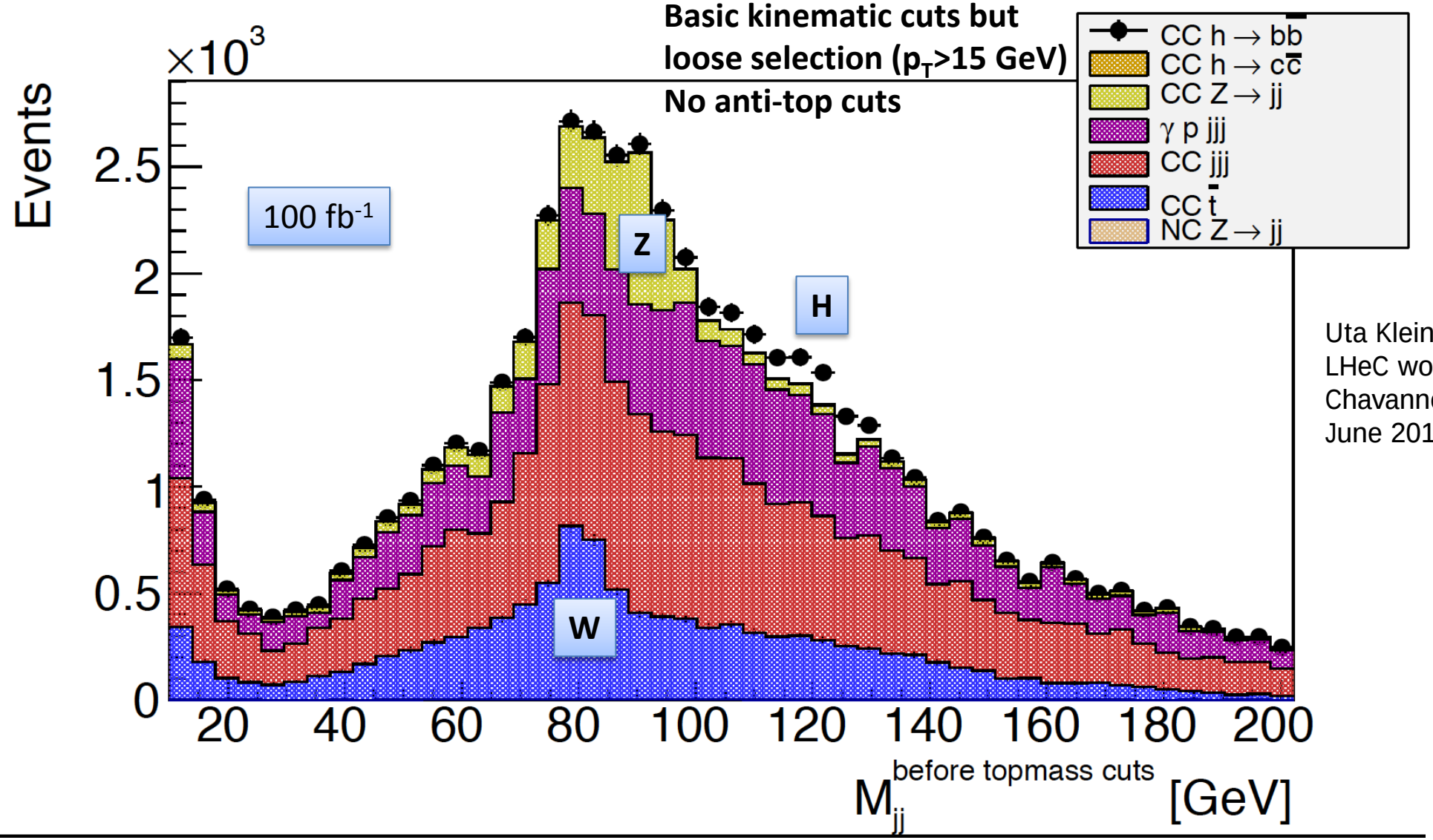
Higgs in e^-p		CC - LHeC	NC - LHeC	CC - FHeC
		$\sqrt{s}$= 1.3 TeV		$\sqrt{s}$= 3.5 TeV
Polarisation		-0.8	-0.8	-0.8
Luminosity [ab^{-1}]		1	1	5
Cross Section [fb]		196	25	850
Decay	BrFraction	N^H_{CC}	N^H_{NC}	N^H_{CC}
$H \to b\bar{b}$	0.577	113 100	13 900	2 450 000
$H \to c\bar{c}$	0.029	5 700	700	123 000
$H \to \tau^+\tau^-$	0.063	12 350	1 600	270 000
$H \to \mu\mu$	0.00022	50	5	1 000
$H \to 4l$	0.00013	30	3	550
$H \to 2l2\nu$	0.0106	2 080	250	45 000
$H \to gg$	0.086	16 850	2 050	365 000
$H \to WW$	0.215	42 100	5 150	915 000
$H \to ZZ$	0.0264	5 200	600	110 000
$H \to \gamma\gamma$	0.00228	450	60	10 000
$H \to Z\gamma$	0.00154	300	40	6 500

Uta Klein, DIS2015, Dallas

New: Delphes detector simulation → track impact parameters, etc.

Uta Klein, LHeC workshop 24-26 June 2015, Chavannes

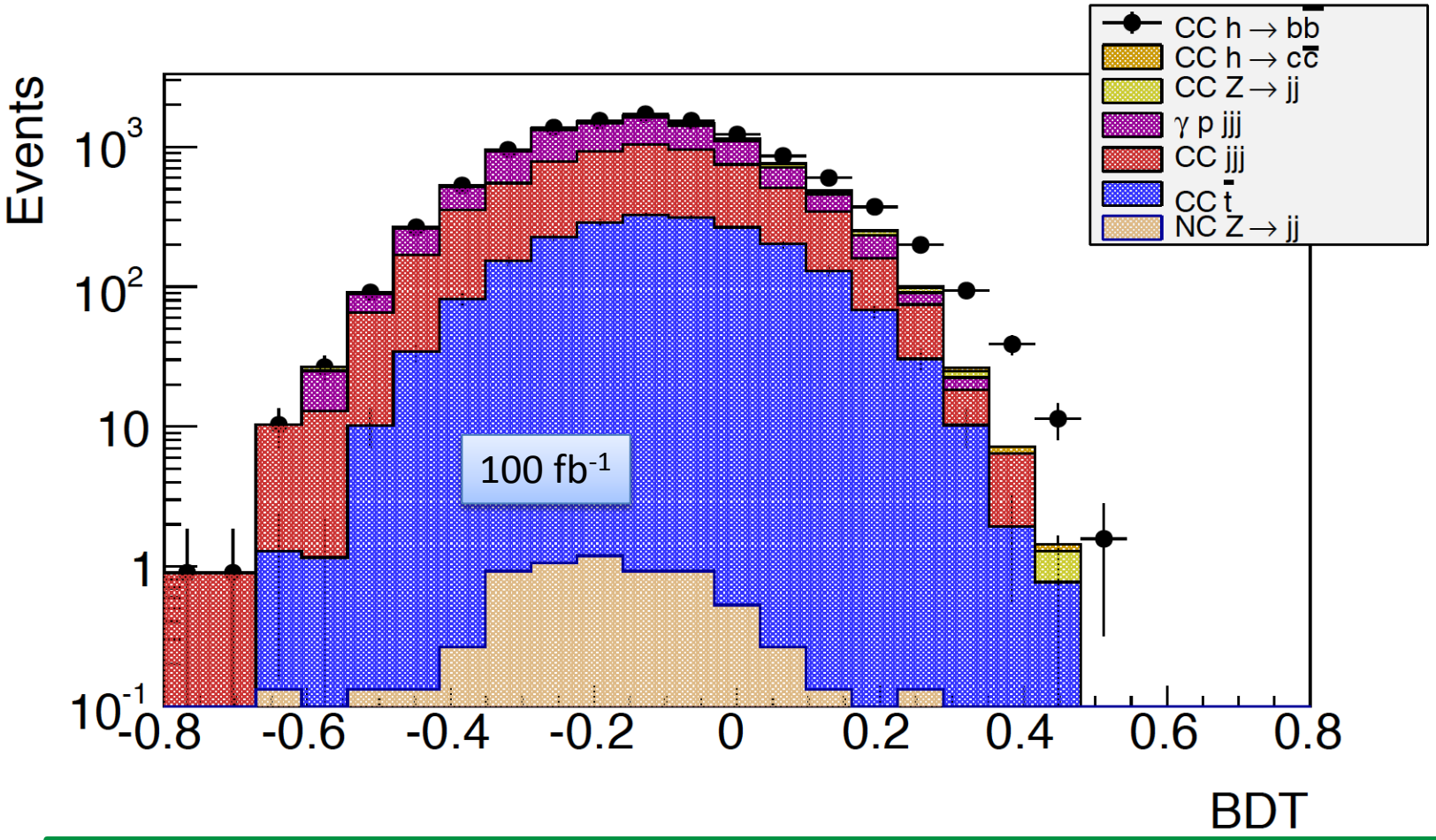
H → bb, simulated Dijet Mass: two jets with lowest η



Uta Klein,
LHeC workshop
Chavannes,
June 2015

→ Train BDT on many kinematic + lifetime tag variables

Update of H→ bb results



Uta Klein,
LHeC workshop
Chavannes,
June 2015

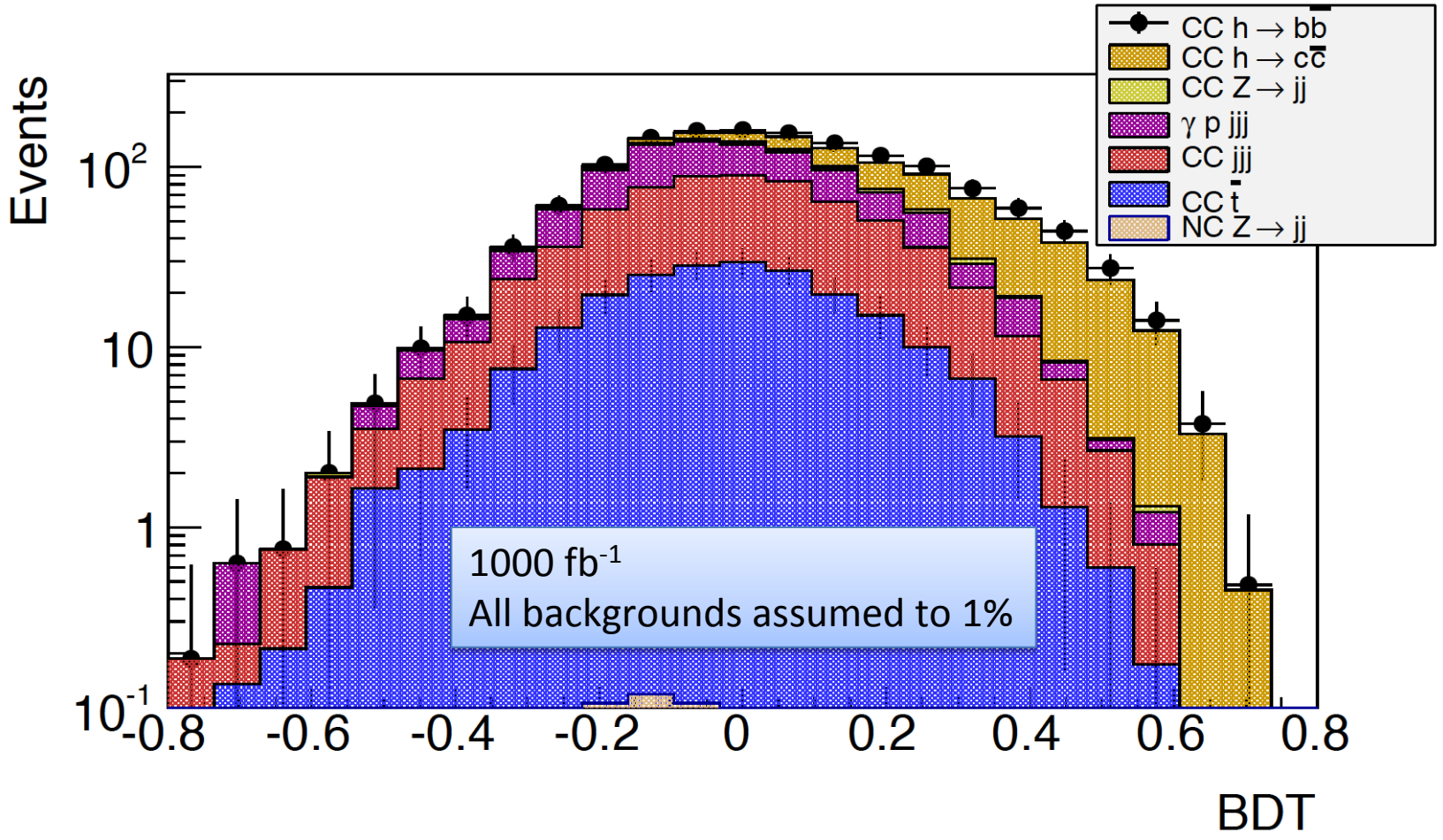
BDT cut >0.2 : H→bb signal events : ~266

S/B = 1.16 and S/√S+B=12 → κ(Hbb) = 5% for 100 fb^{-1}

→κ(Hbb) = 1.5% for 1000 fb^{-1}

→ confirmation of CDR findings arxiv:1206.2913

Update of H→ cc results



Uta Klein,
LHeC workshop
Chavannes,
June 2015

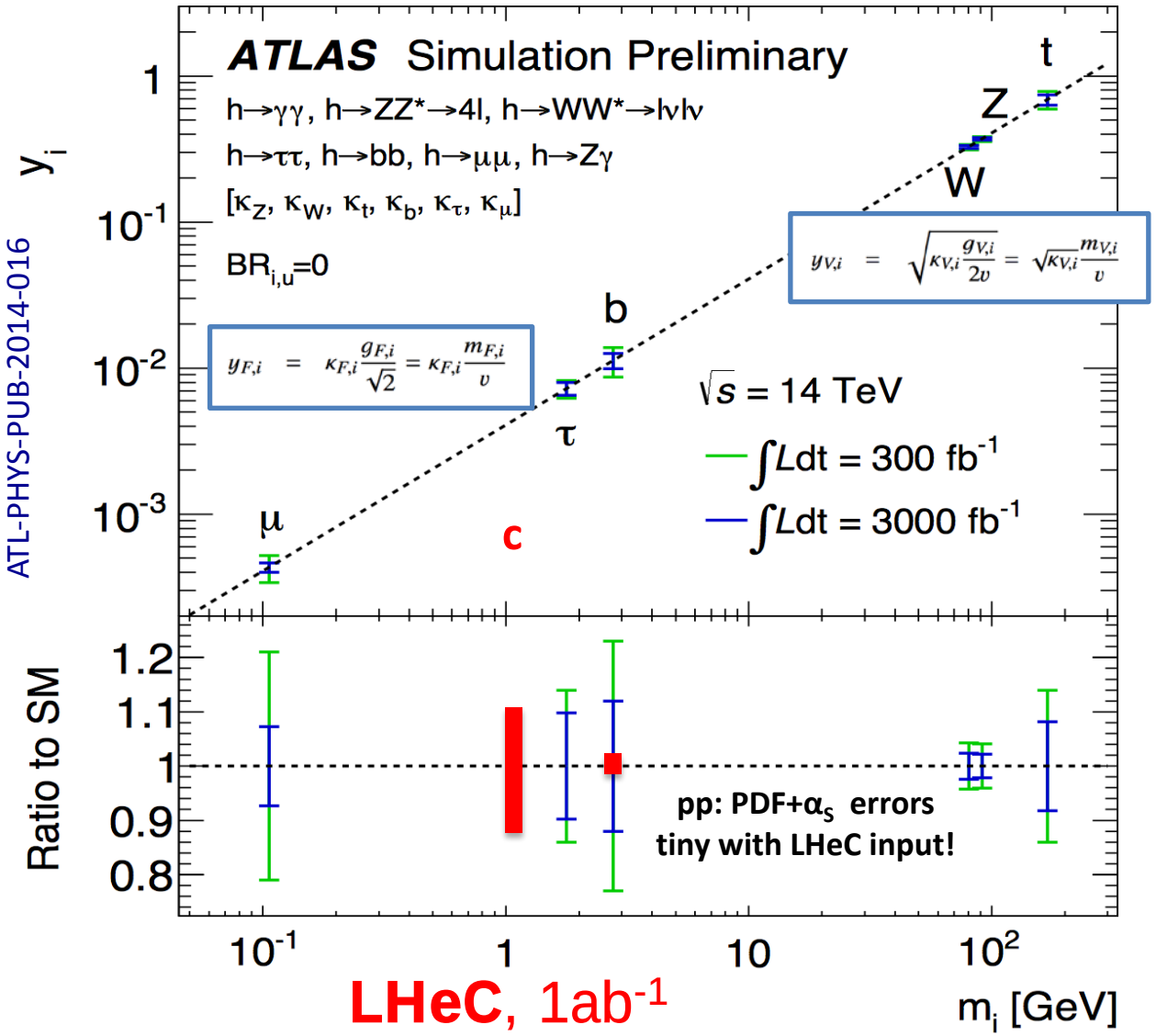
BDT cut >0.3: H→cc signal events : ~133 S/√S+B=1.5

➔ k(Hcc) = 7% for 1000 fb^{-1}

➔ Clear potential to measure Hcc at LHeC

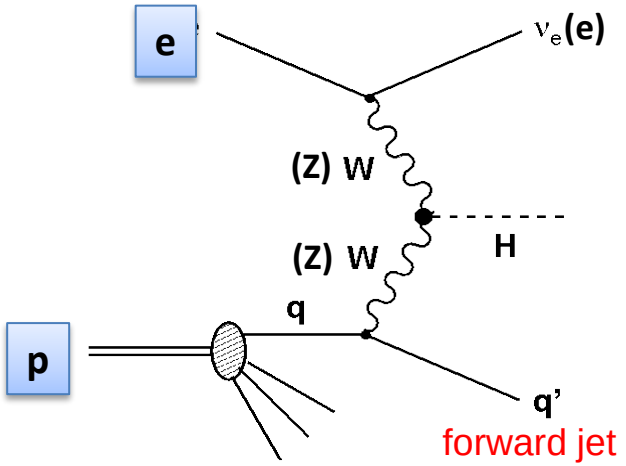
→ Ongoing optimisation, e.g. using R=0.7 jets to increase statistics

Higgs Couplings at HL-LHC + LHeC *running simultaneously*



LHeC, 1ab^{-1}

"Work in progress" (Uta Klein)



√s= **1.3 TeV**

→ Many more decay channels still to be explored for LHeC

Invisible Higgs@LHeC Higgs → 'dark' sectors

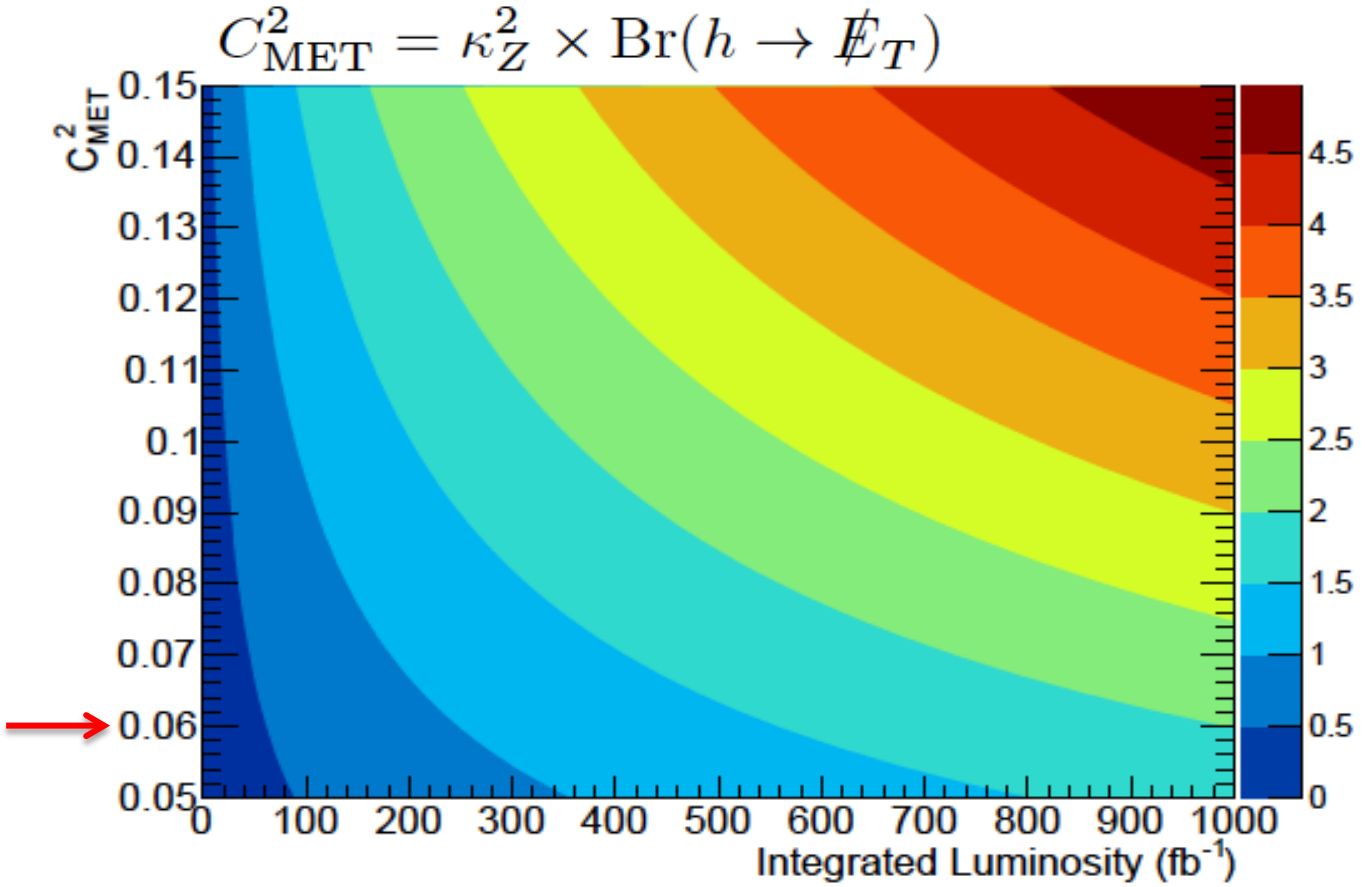
Y.-L. Tang et al., arXiV: 1508.01095

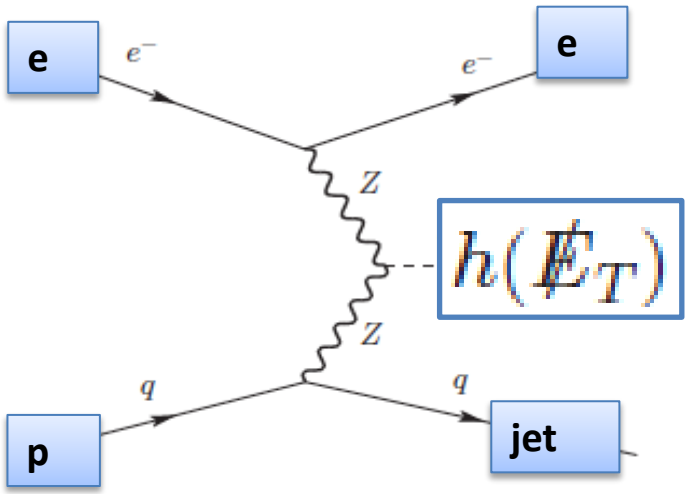
HL-LHC @ 3 ab^{-1} [arXiv:1411. 7699]

$\mathrm{Br}(h \to \not{E}_T)$ < 3.5% @90% C.L., MVA based

LHeC, @ 1ab^{-1}, P_e=-0.9, <u>cut based</u>

$\mathrm{Br}(h \to \not{E}_T)$ < 6% @ 2σ level



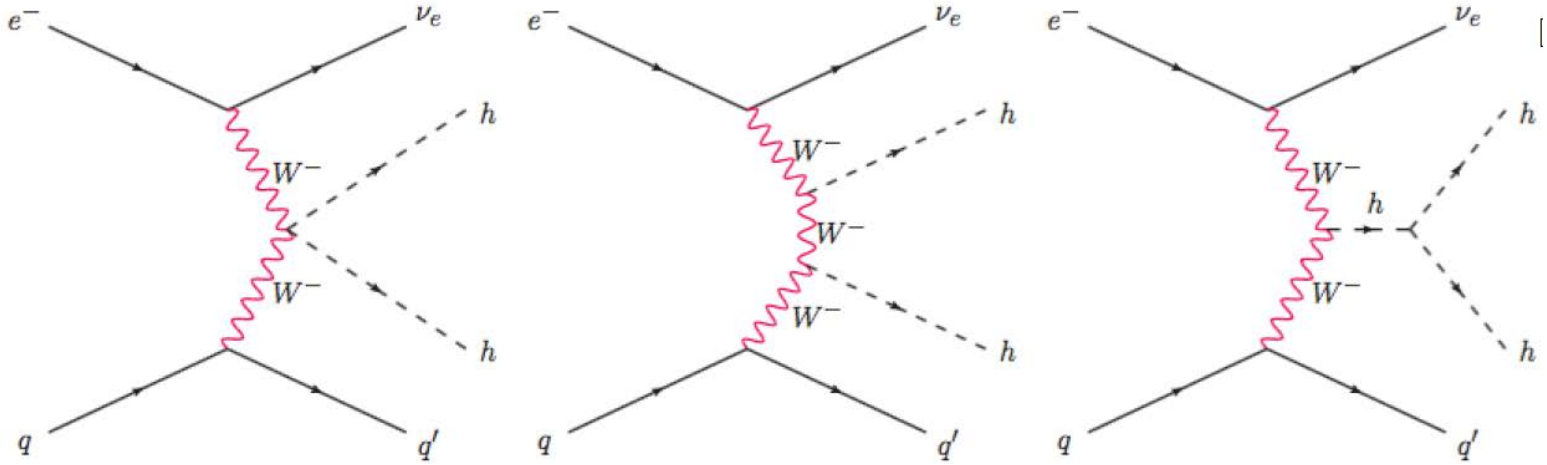


Colours: expected statistical significance

→ Nice sensitivity
→ FCC-he: even much enhanced potential

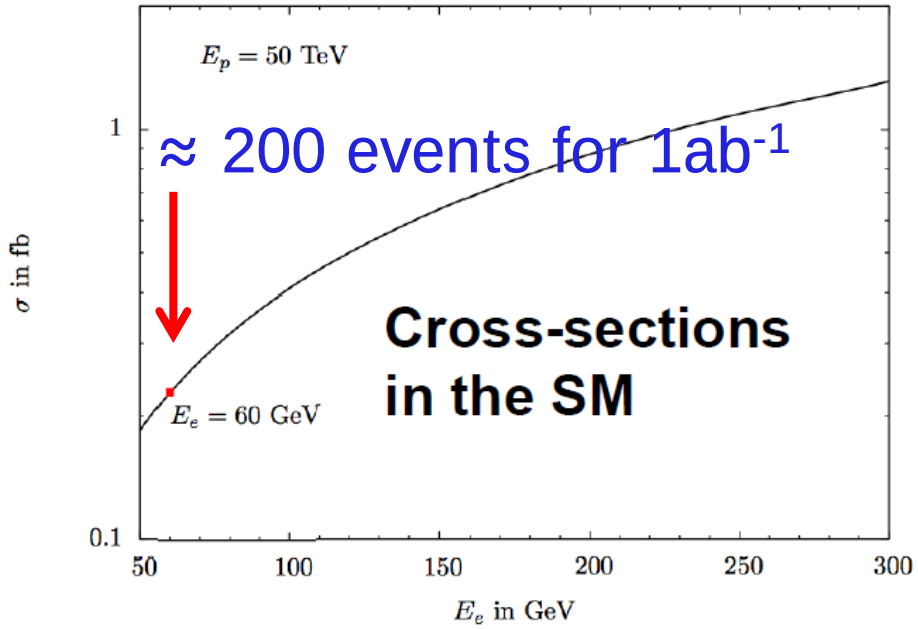
Double Higgs Production at **FCC-he**

M. Kumar et al.,
arXiV: 1509.04016



SM diagrams

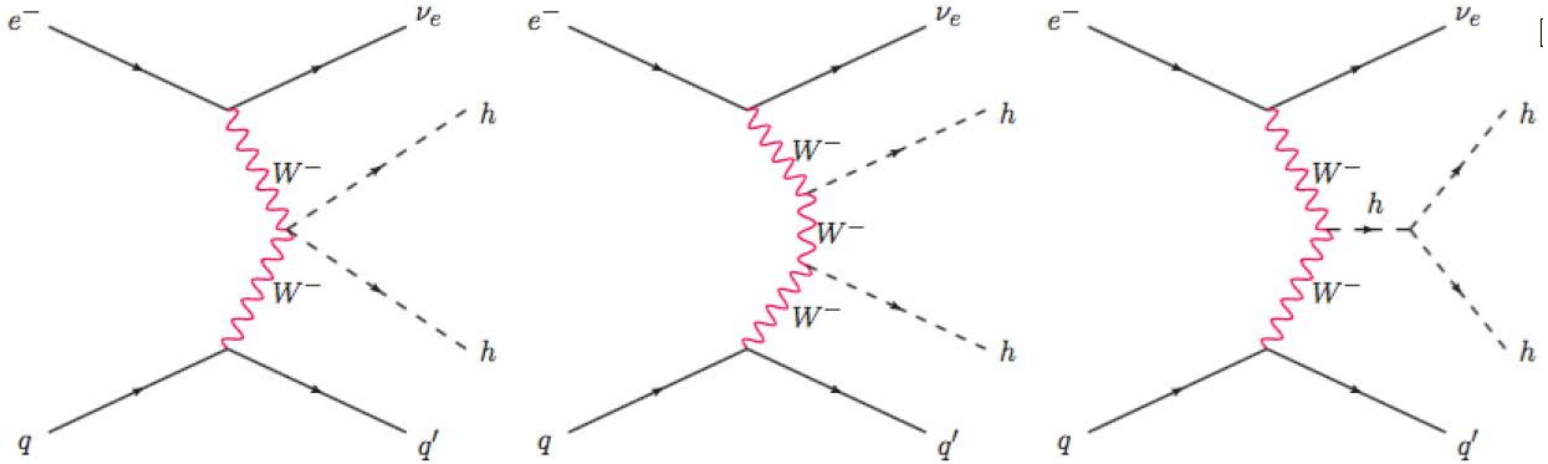
→ Expect high sensitivity to BSM contributions (anomalous couplings)



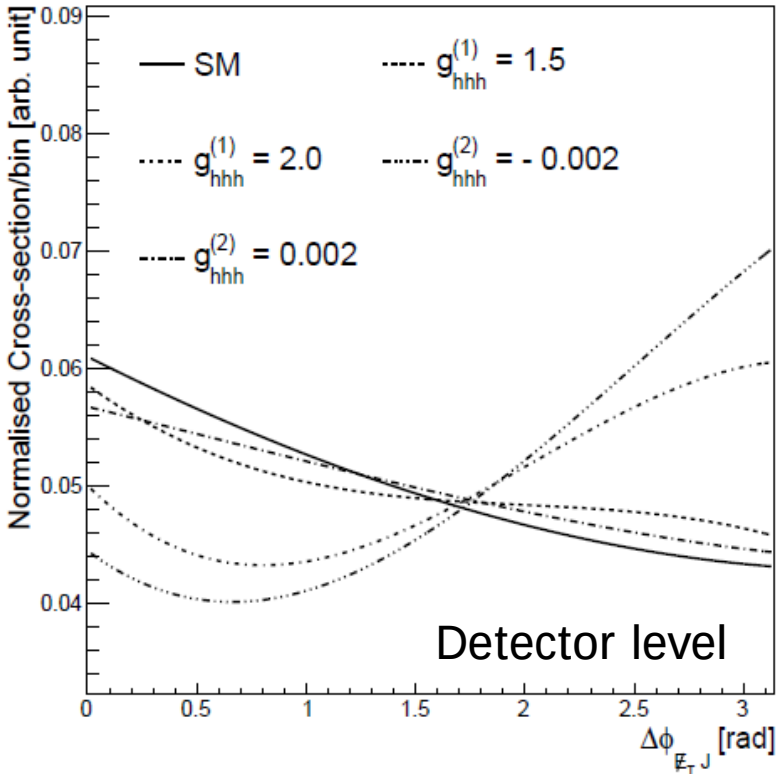
Kumar et al: focus on
HH → bbbb decay channel

Double Higgs Production at FCC-he: Observable

M. Kumar et al.,
arXiV: 1509.04016



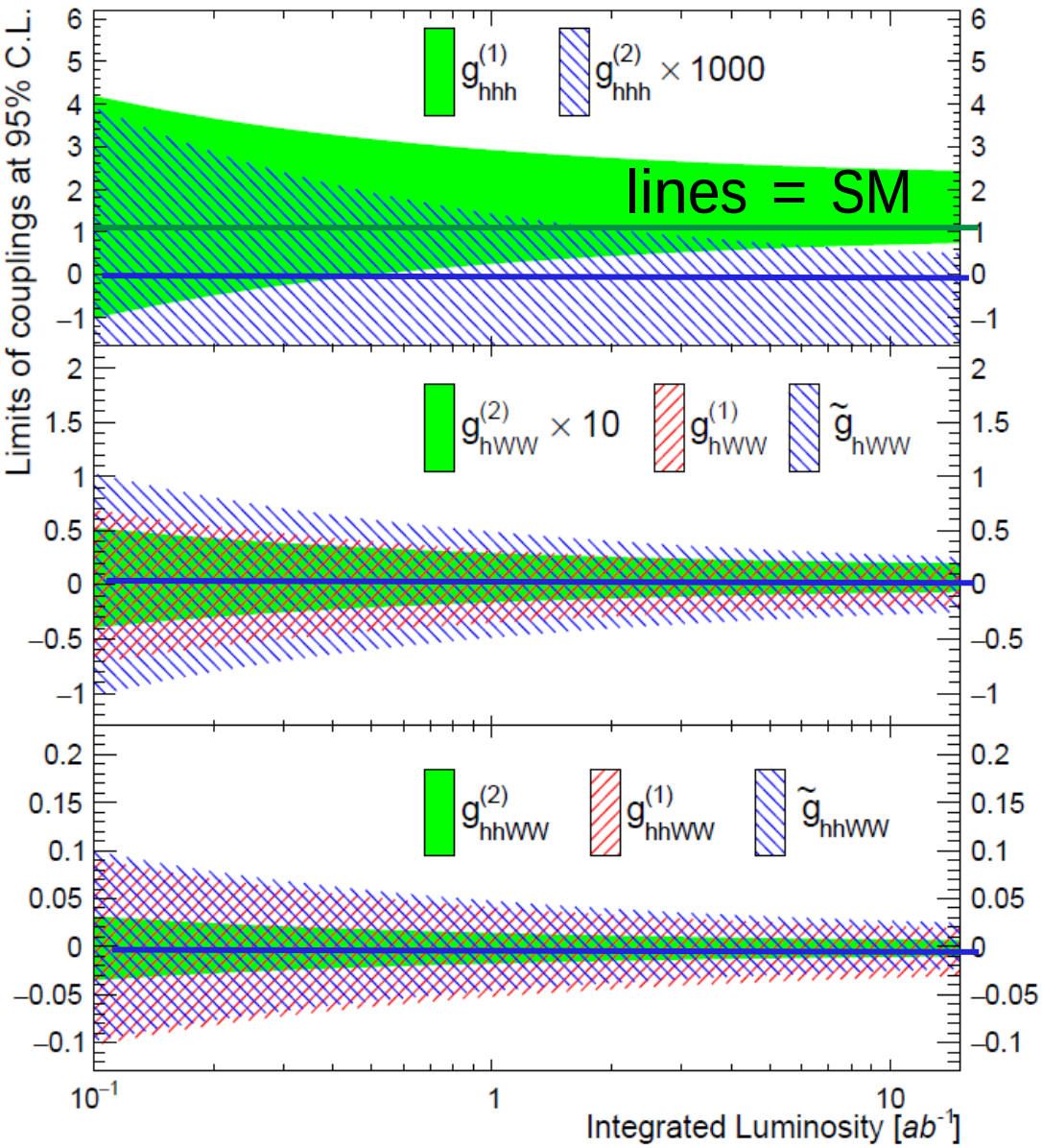
SM diagrams

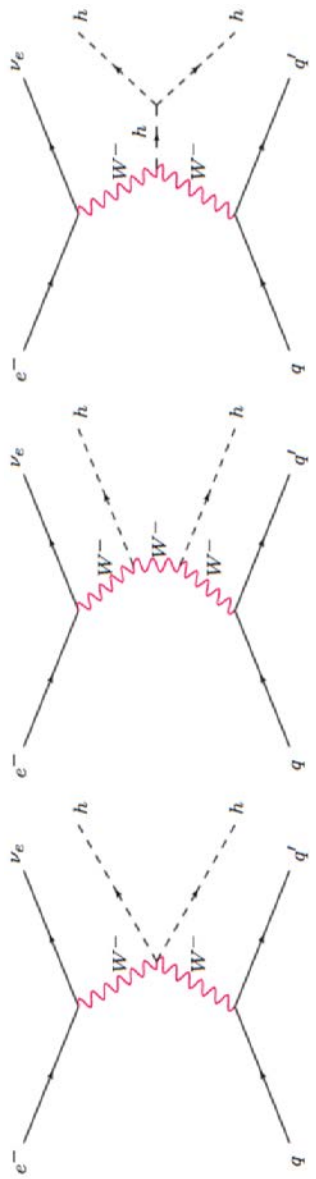


Fit to distribution of
$\Delta\phi$ between q' jet and missing E_T

Double Higgs Production at FCC-he: Limits

M. Kumar et al.,
arXiV: 1509.04016





→ For ~1 ab^{-1} obtain sensitive results

→ For E_e=120 GeV and 10 ab^{-1} expect $0.84 < g_{hhh}^{(1)} < 1.19$

Summary

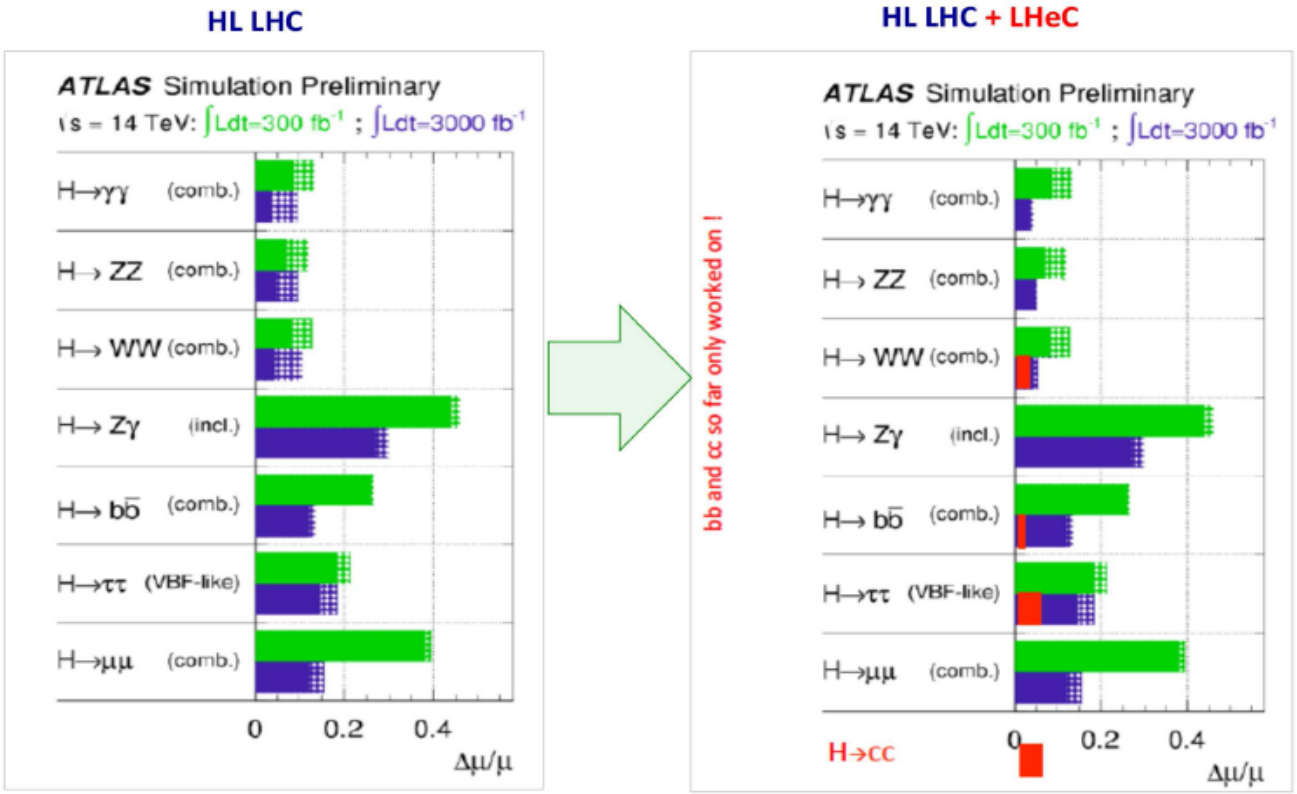
- LHeC and Fcc-he → provide important information on Higgs, complementary to other machines, e.g.
  - H→ bb, H → cc at LHeC
  - HH production at FCC-he → anomalous HHH and HHWW couplings
- We have a fantastic machine at work – the LHC – it would be a pity not to exploit the greatly enhanced physics potential **by adding an electron beam to the HL-LHC complex at CERN**

For further material see e.g. LHeC workshop, Chavannes, 24-26 june 2015
htpps://indico.cern.ch/event/356714

Backup slides

Max Klein

HIGGS PHYSICS AT THE LHEC
SUMMARY

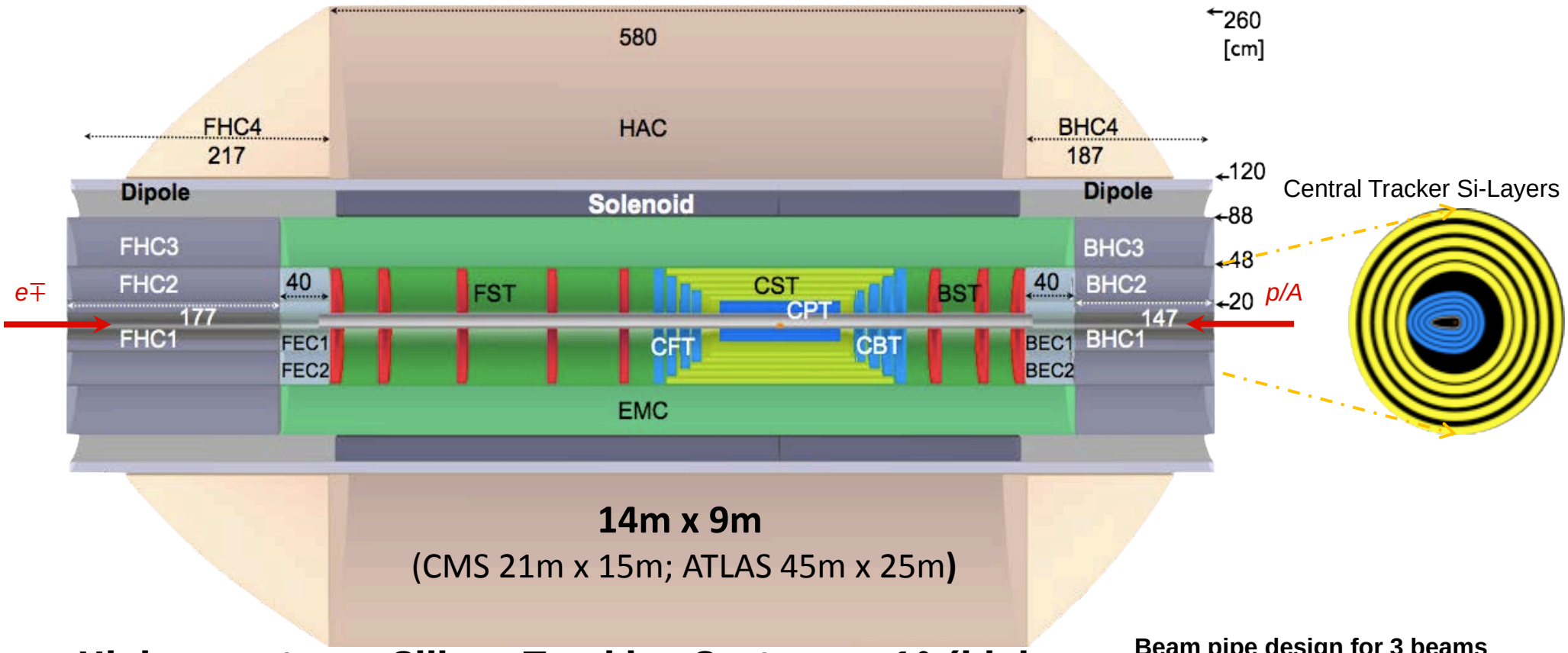


- GLUON FUSION AND W FUSION $\Rightarrow$ PDF+α_s UNCERTAINTY REMOVED (hatched bands)
- $H\bar{b}b$ MEASURED TO PERCENTAGE PRECISION;
- $\tau\tau$ AND $\bar{c}c$ ALSO MEASURABLE

Turn LHC into precision Higgs facility: add PDFs add ep channels (bb,cc.)

S.Forte ECFA 9/15

Baseline Detector Design A. Polini and P. Kostka



- **High acceptance Silicon Tracking System ~1° (high tagging capabilities e.g. for b-jets up to η~3)**
- **Liquid Argon EM Calorimeter**
- **Iron-Scintillator Hadronic Calorimeter**
- **Forward Backward Calorimeters: Si/W Si/Cu**
- **Taggers for e , γ, p and n**

Beam pipe design for 3 beams