Remarks on FCC-he

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U Liverpool and CERN
For the FCC-he Study Group

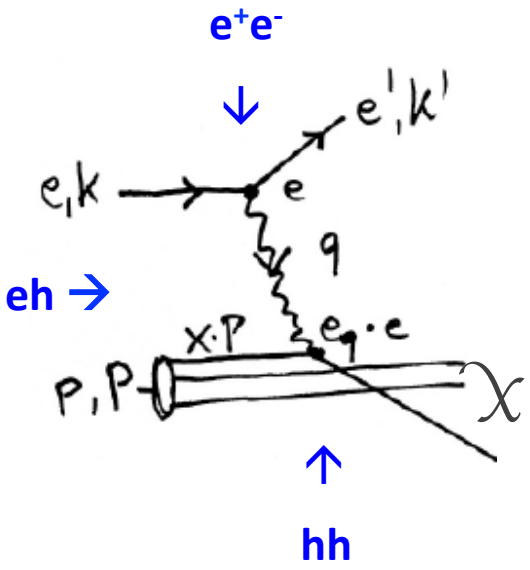
Introduction
Physics
IR and Parameters
Outlook

ICHEP, Valencia, 4th of July, 2014

http://lhec.web.cern.ch

he = ep and eA: part of the FCC study as an configuration designed to be available when pp runs.

Deep Inelastic Scattering [eh → e'X]



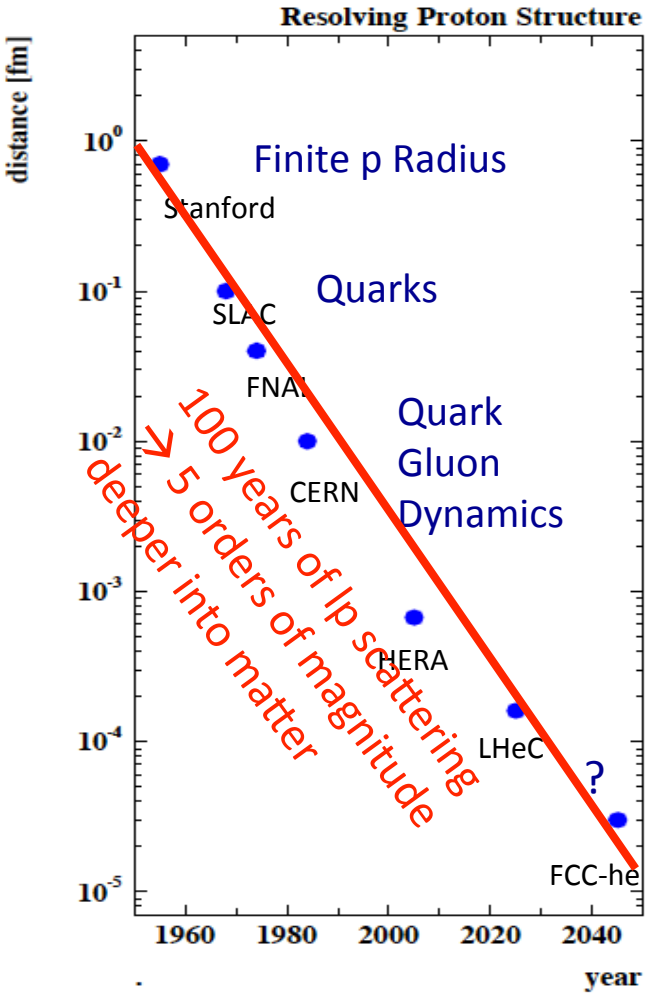
$$x = \frac{Q^2}{sy}$$

$$Q^2 = -(k - k')^2$$

$$y_{lab} = 1 - \frac{E_e'}{E_e}$$

$$s = 4E_eE_p$$

HERA-LHeC-FCC-eh: finest microscopes with resolution varying like $1/\sqrt{Q^2}$



Parton momentum fixed by electron kinematics

Incl. NC (γ,Z) and CC ($W^{\pm}$) independent of hadronisation

Rigorous theory: Operator expansion (lightcone)

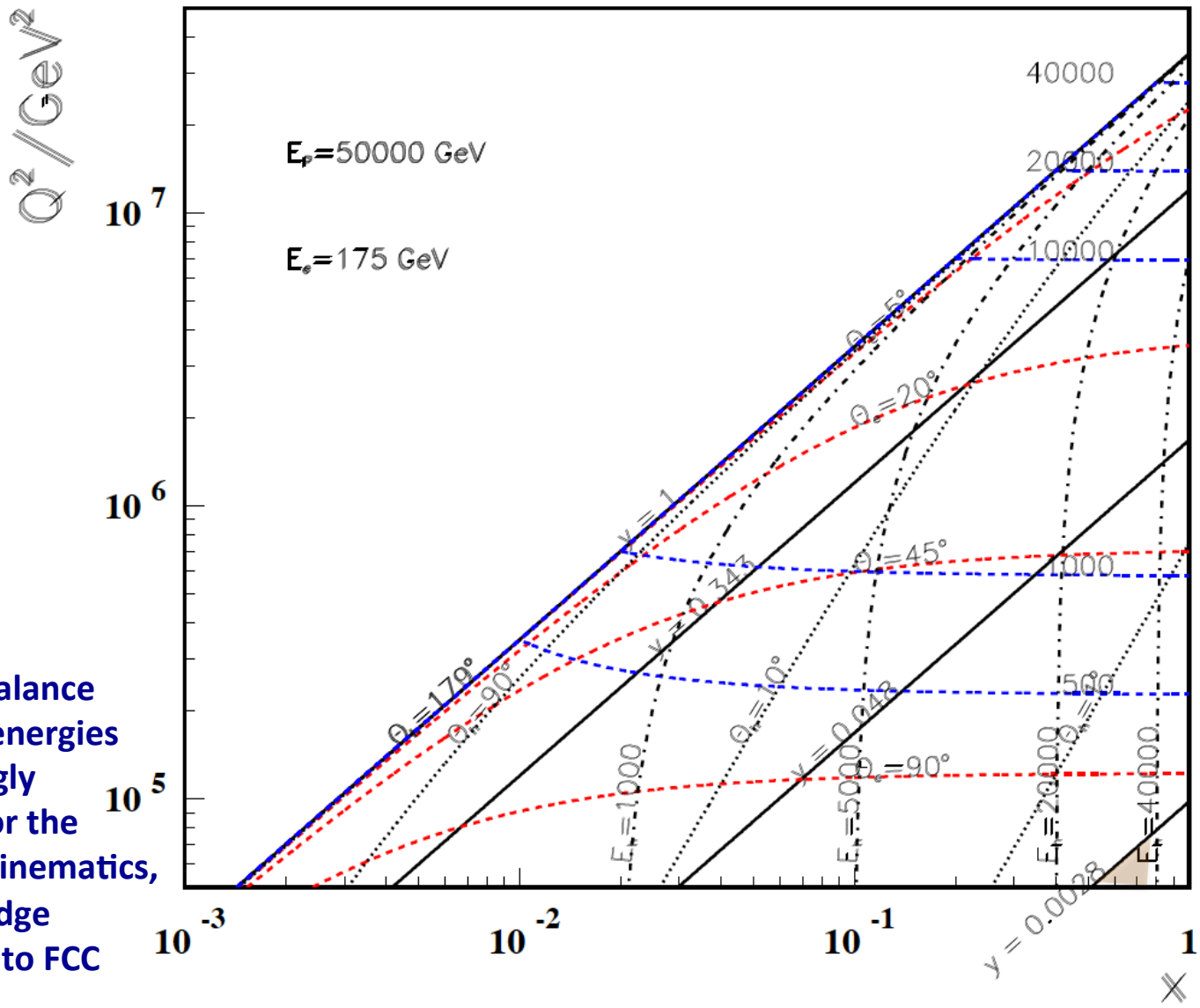
Parton momentum distributions to be measured in DIS

Collider- HERA: $y_h = y_e$: Redundant kinematics

electromagnetic radius

High Q^2

Rutherford backscattering
of dozens of TeV e- energy



FCC-he
175 GeV
60 GeV

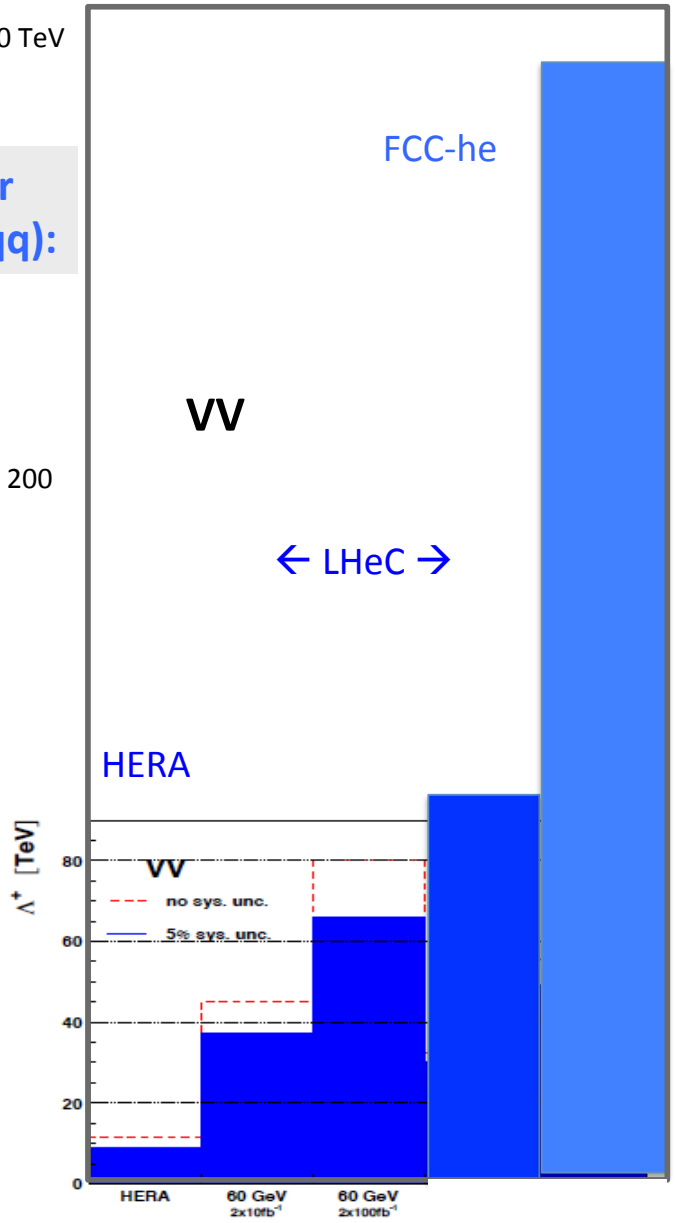
LHeC

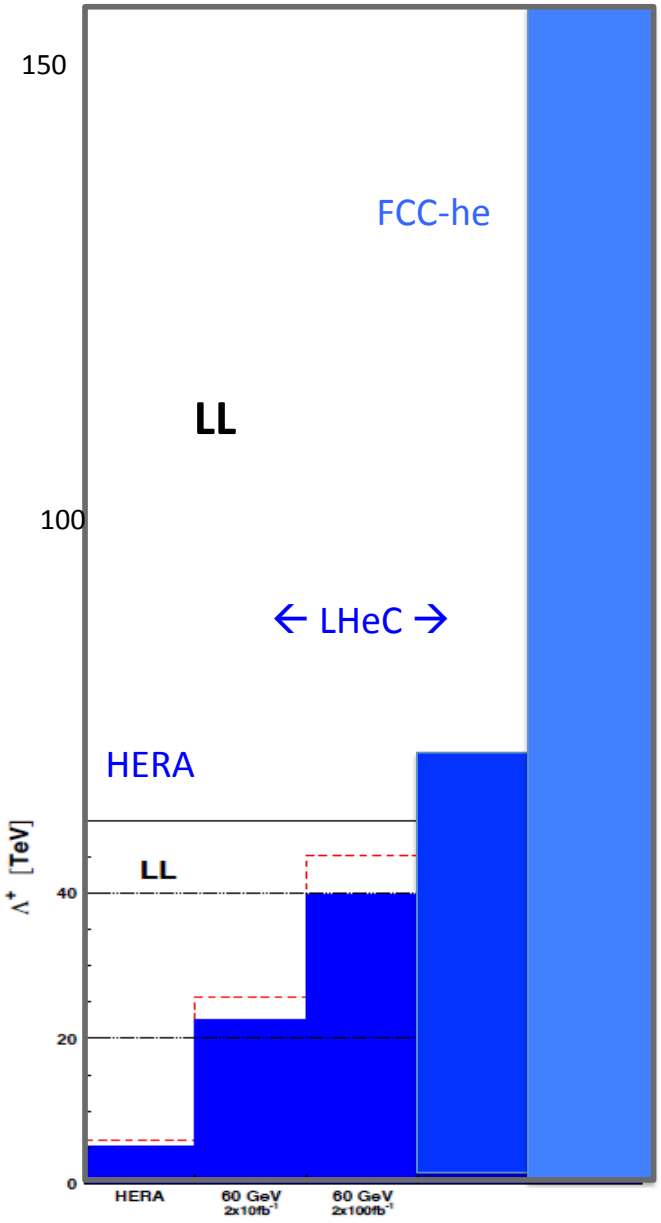
← ϑ_h=1°

← HERA

Large imabalance of e and p energies is surprisingly tolerable for the high Q^2, x kinematics, LHeC to bridge from HERA to FCC

Reach for Λ (CI eeqq):



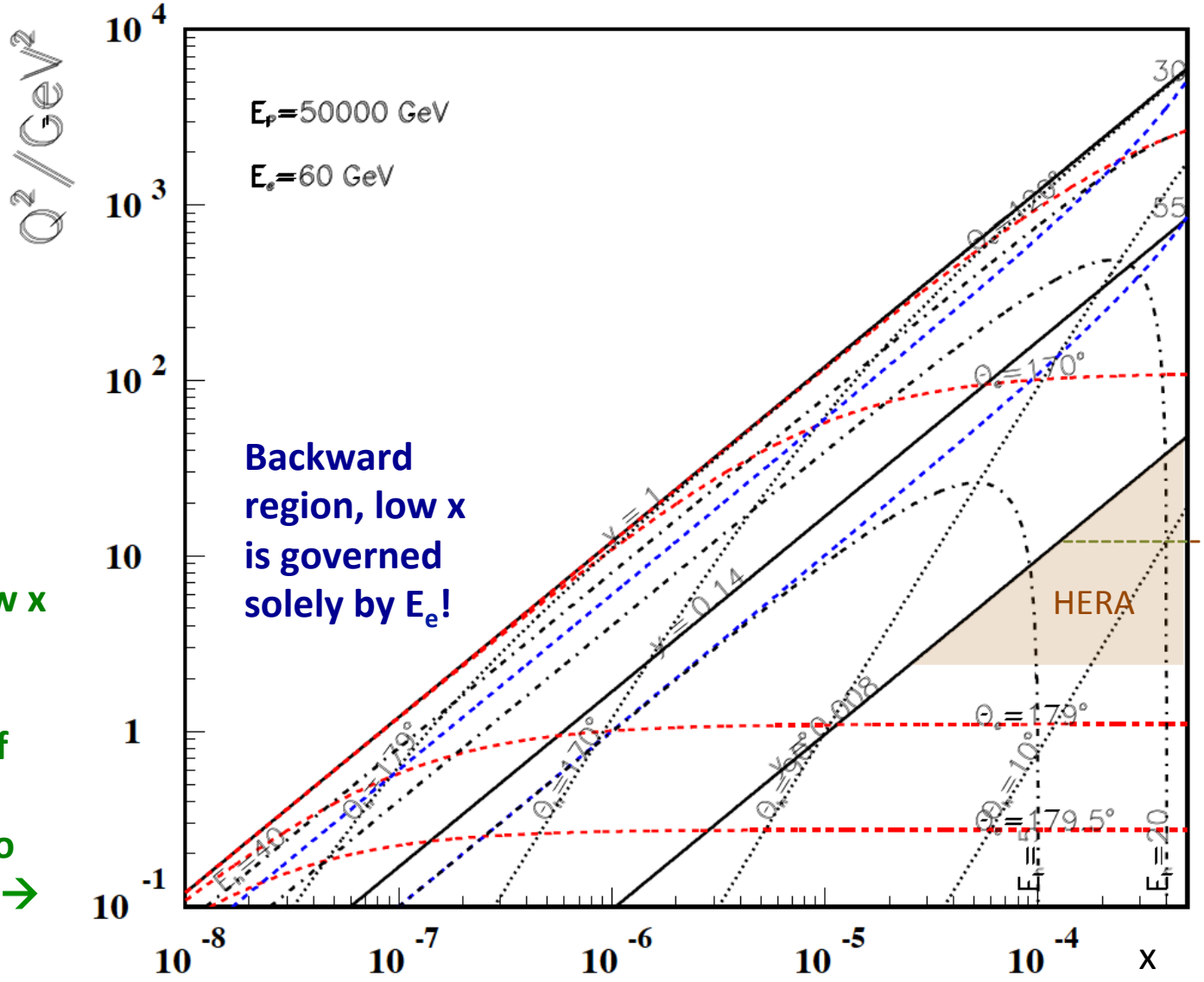


FCC - rough scaling only – very preliminary

LHeC: see CDR 2012

Also see physics talks at kickoff: Cole, D'Onofrio, Klein (2x)

Low x



FCC-he
60 GeV

LHeC

← 179°
@ 180 GeV
.. very low x requires not the maximum of E_e

Very low x reaches direct range of UHE neutrino physics →

For $x < 10^{-3}$ no (average) energy deposition exceeding the electron beam energy

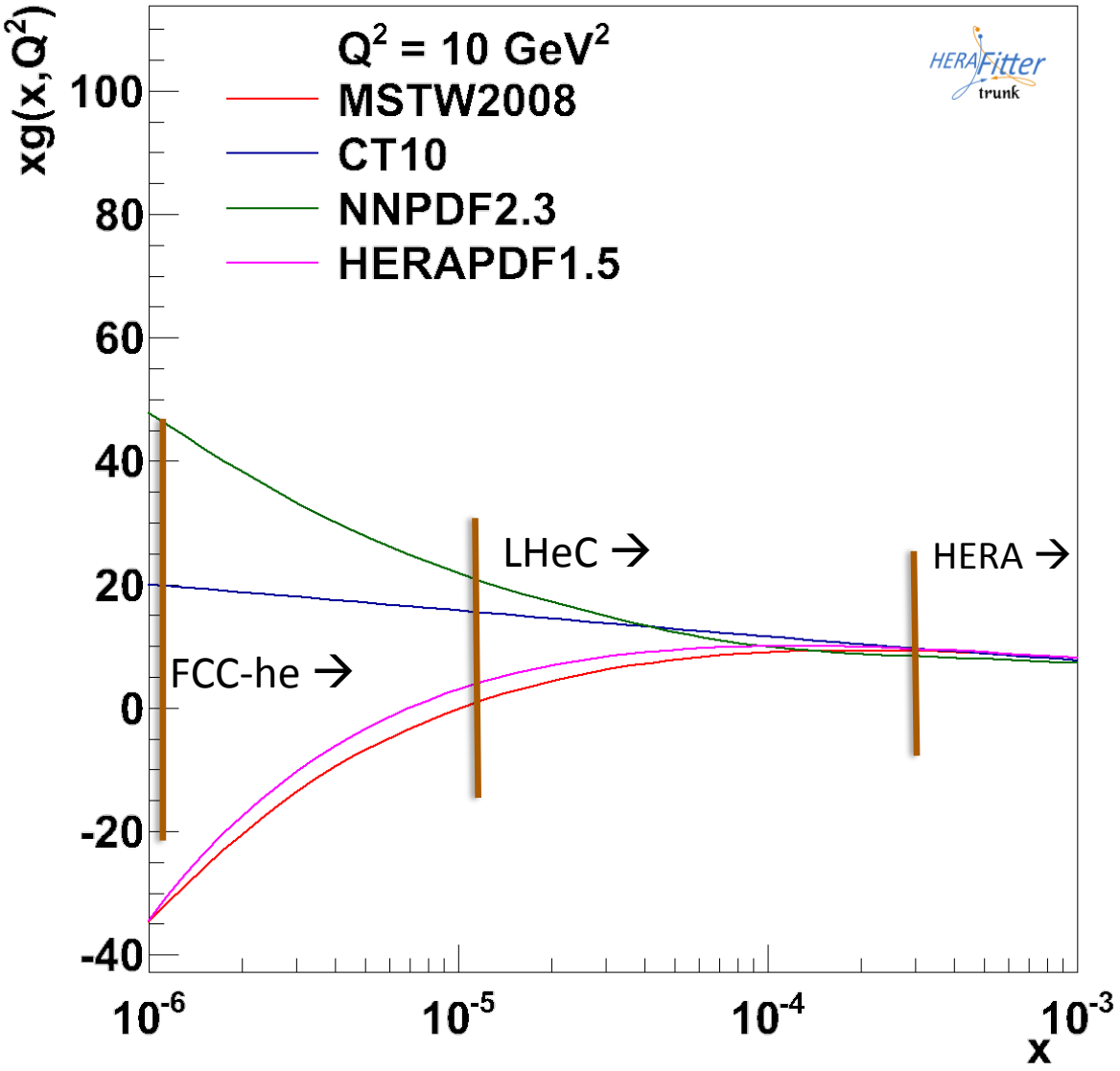
PDFs – example: gluon xg at low x

No clue about xg for $x < 10^{-4}$

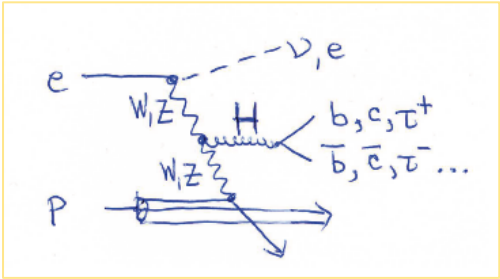
Evolution law unlikely to be linear DGLAP

Precision PDFs for FCC search program test of factorisation, resummation…

Affects FCC-pp rates because $x = M/\sqrt{s}\, \exp(\pm y)$



From Higgs facility (LHeC) to Higgs 'factory' (FCC-he)

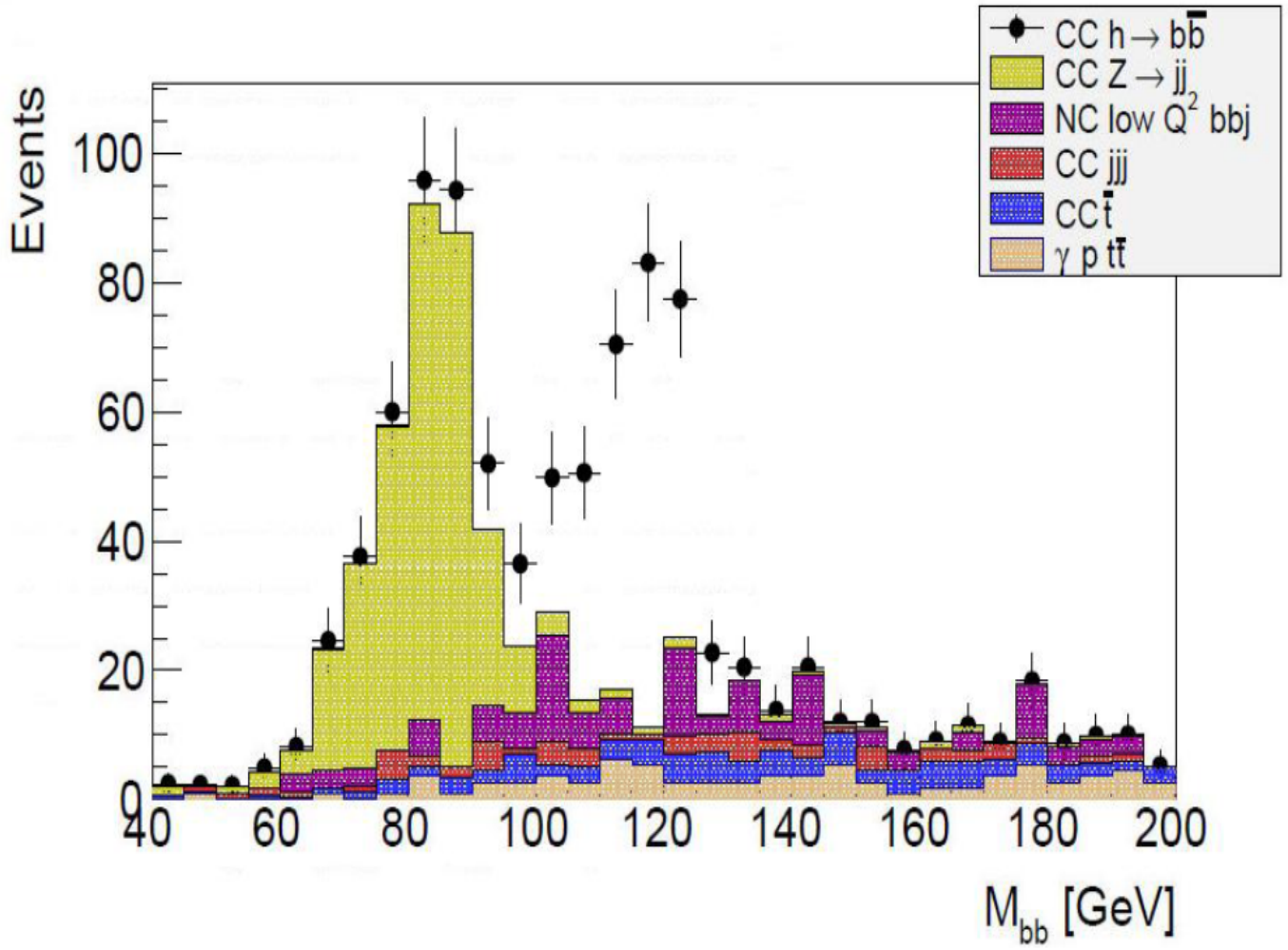


Higgs in e^-p		CC - LHeC	NC - LHeC	CC - FHeC
Polarisation		-0.8	-0.8	-0.8
Luminosity [ab^{-1}]		1	1	5
Cross Section [fb]		196	25	850
Decay	BrFraction	N^H_{CC}	N^H_{NC}	N^H_{CC}
$H \to b\bar{b}$	0.577	113 100	13 900	2 450 000
$H \to c\bar{c}$	0.029	5 700	700	123 000
$H \to \tau^+\tau^-$	0.063	12 350	1 600	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

Cross section
1pb ep→ νHX

Luminosity
> 10^{34} crucial
for H → HH
0.5 fb
and rare decays

H → bbar



ep (new) Simulation 100 fb^{-1}
With DIS and yp (top..) background, cut based!
See Poster U. Klein Higgs in ep – this conference

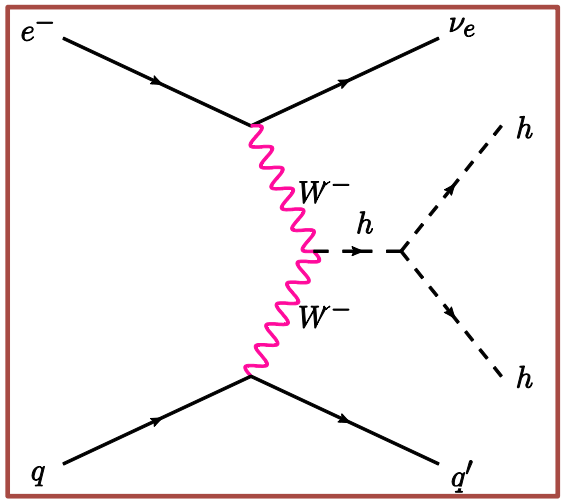
LHeC

Clean Higgs physics in ep LHeC
cut based analysis
S/B ~ 1

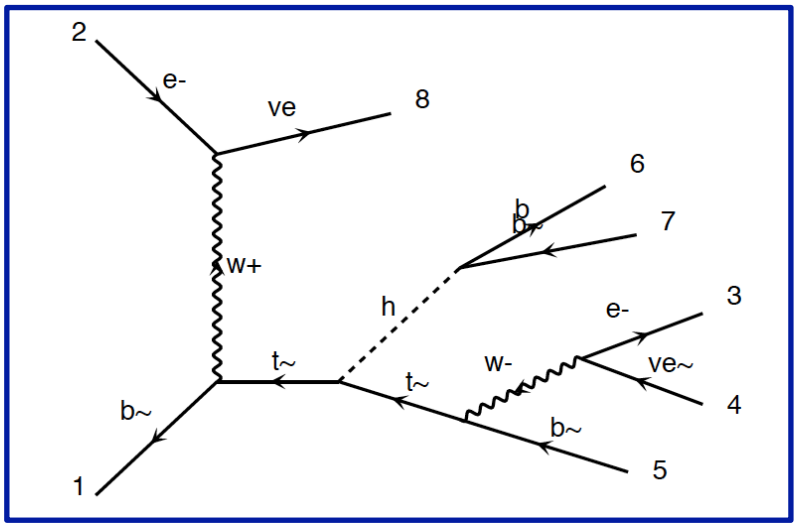
With FCC_he have an order of magnitude more Higgs bosons (higher cross section) than with LHeC and the ILC

100 times this signal!

HH and tHt in ep



New Tentative Studies



FCC-he unpolarised
Cross section at 3.5 TeV:

Processes	E_e (GeV)	σ(fb)	σ_{eff}(fb)
$e^-p \to \nu_e hhj, h \to b\bar{b}$	60	0.04	0.01
	120	0.10	0.024
	150	0.14	0.034

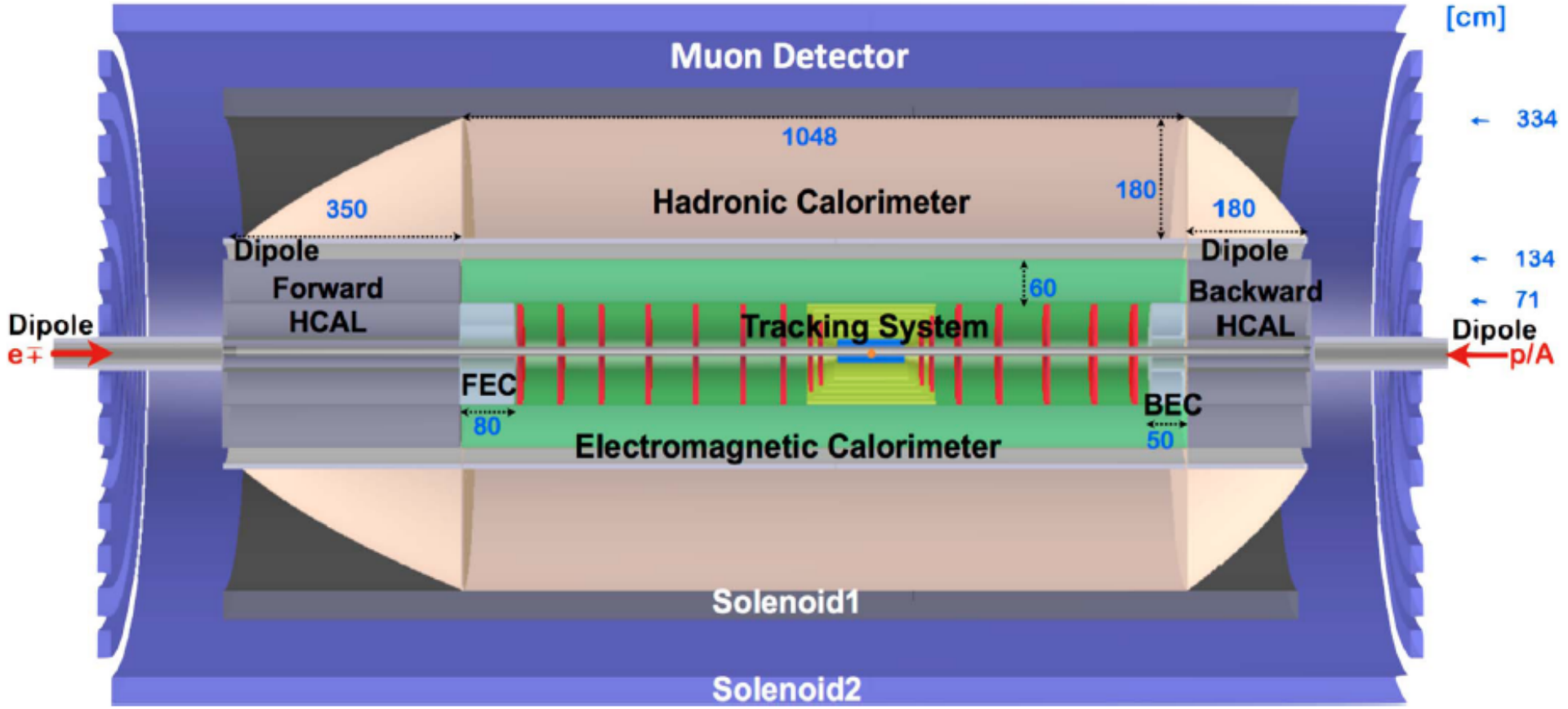
total : 0.7 fb
fiducial : 0.2 fb
using pt(b,j)>20 GeV
ΔR(j.b)>0.4
η(j) <5
η(b) < 3

Polarisation, max lumi, tuning cuts, bb and WW decays may provide O(10%) precision - tentative

Require time for reliable result (detector, analysis, backgrounds..)

Uta Klein, Masahiro Khuze, Bruce Mellado et al

FCC-he Detector (B) – 0.1



Crab cavities for p instead of dipole magnet for e bend to ensure head on collisions

1000 H → μμ may call for better muon momentum measurement

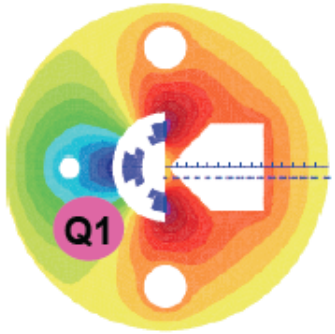
H→ HH → 4b (and large/low x) call for large acceptance and optimum hadr. E resolution

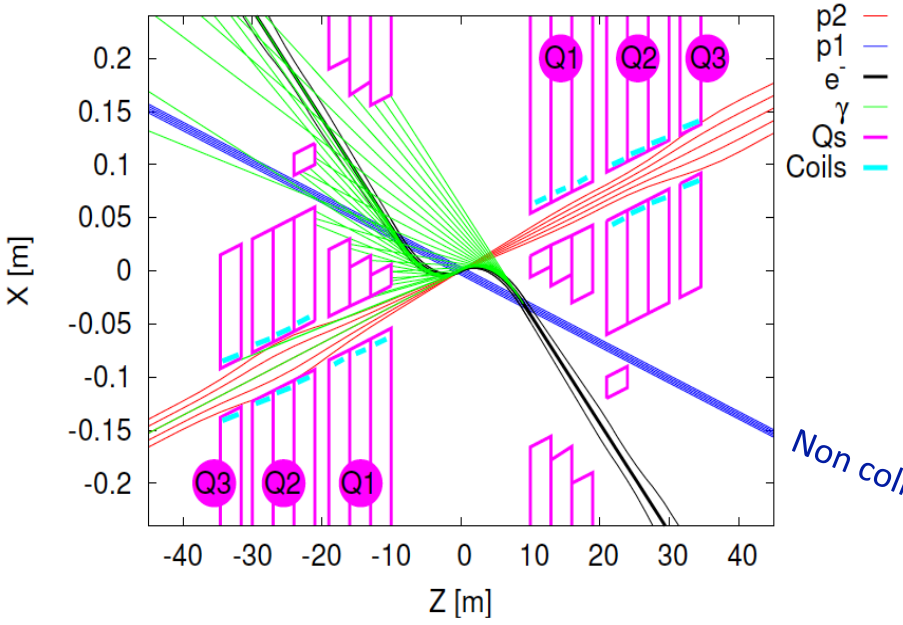
Detector for FCC scales by about ln(50/7) ~2 in fwd, and ~1.3 in bwd direction

Full simulation of LHeC and FCC-he detectors vital for H and H-HH analysis

P.Kostka et al.

Interaction Regions for ep with Synchronous pp Operation

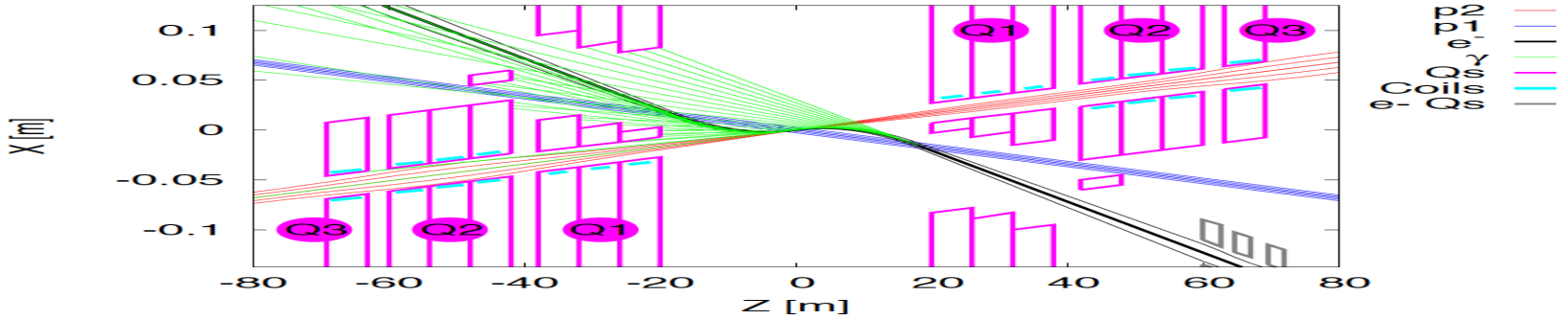




Non colliding p beam

LHeC (CDR)
60 GeV * 7 TeV

Still work in progress:
may not need half
quad if L*(e) < L*(p)



Tentative: ε_p=2μm, β*=20cm → σ_p=3μm ≈σ_e matched! ε_e=5μm ..

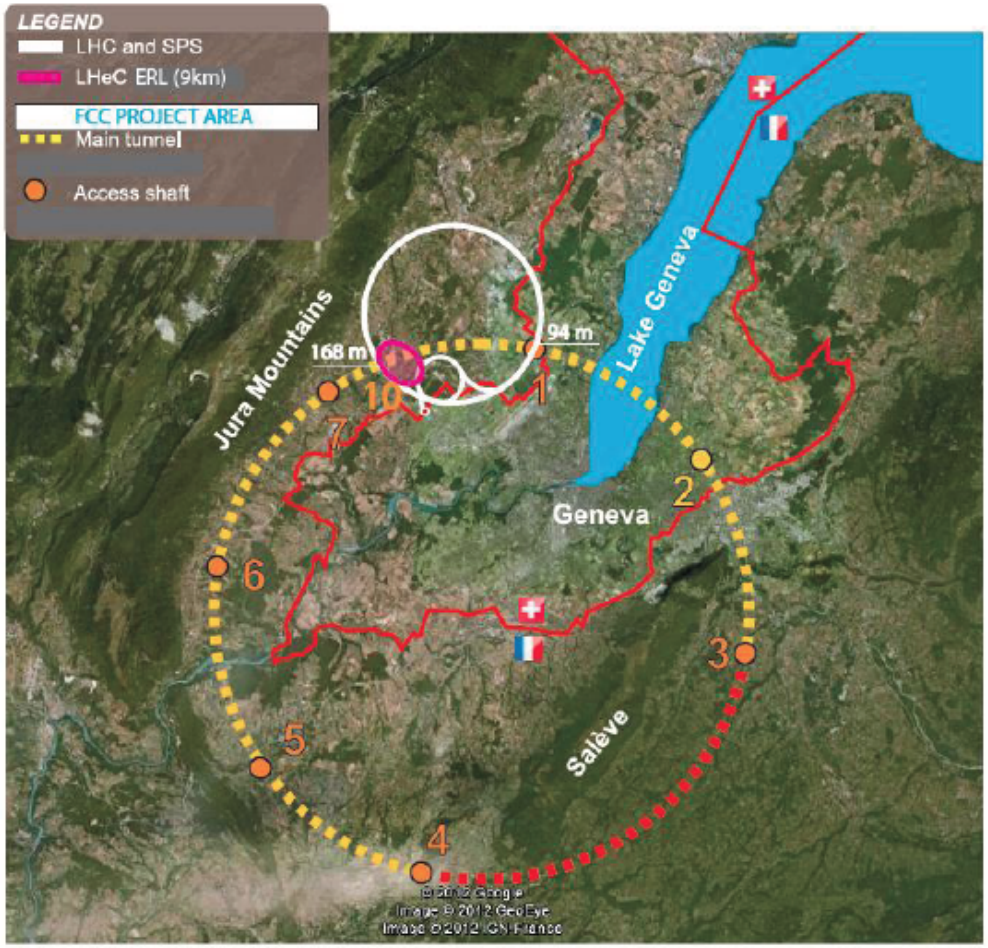
FCC-he (ERL)
60 GeV * 50 TeV

LHeC and the Future Circular Collider (FCC)

Version 230 mASL

- **Phase 1** : ep collisions at LHC P2
- **Phase 2** : ep collisions in FCC near LHC P2
- European Strategy Paper (2012), the 'plan' position for passes under the LHeC ERL
- However, FCC is 150m deeper than ERL
- FCC tunnel location/depth still to be optimised

	SPS	LHC	FCC	Between LHC/FCC
Point 1	40m	96m	190m	94m
Point 10	40m	50m	218m	168m



J Osborne at IAC Meeting 6/14

collider parameters	FCC ERL	FCC-ee ring		protons
species	e^- (e^+?)	$e^\pm$	$e^\pm$	p
beam energy [GeV]	60	60	120	50000
bunches / beam	-	10600	1360	10600
bunch intensity [10^{11}]	0.05	0.94	0.46	1.0
beam current [mA]	25.6	480	30	500
rms bunch length [cm]	0.02	0.15	0.12	8
rms emittance [nm]	0.17	1.9 (x)	0.94 (x)	0.04 [0.02 y]
$\beta_{x,y}$*[mm]	94	8, 4	17, 8.5	400 [200 y]
$\sigma_{x,y}$* [μm]	4.0	4.0, 2.0		equal
beam-b. parameter ξ	(D=2)	**0.13**	**0.13**	0.022 (0.0002)
hourglass reduction	0.92 (H_D=1.35)	**~0.21**	~0.39	
CM energy [TeV]	3.5	3.5	4.9	
luminosity[10^{34}cm^{-2}s^{-1}]	**1.0**	**6.2**	**0.7**	

F.Zimmermann
ICHEP14, June

PRELIMINARY

Possible Developments and Discoveries

AdS/CFT

Instantons

Odderons

Non pQCD

QGP

N^kLO

Resummation

Saturation and BFKL

Non-conventional PDFs …

Take QCD as an important area

Breaking of Factorisation

Free Quarks

Unconfined Color

New kind of coloured matter

Quark substructure

New symmetry embedding QCD

QCD may break .. (Quigg DIS13)

The LHeC and the FCC-he are not more of the same but may change our view on the substructure of matter (why differ leptons from quarks?) and lead beyond the SM!

New LHeC International Advisory Committee

Guido Altarelli (Rome)
Sergio Bertolucci (CERN)
Nichola Bianchi (Frascati)
Frederick Bordry (CERN)
Stan Brodsky (SLAC)
Hesheng Chen (IHEP Beijing)
Andrew Hutton (Jefferson Lab)
Young-Kee Kim (Chicago)
Victor A Matveev (JINR Dubna)
Shin-Ichi Kurokawa (Tsukuba)
Leandro Nisati (Rome)
Leonid Rivkin (Lausanne)
Herwig Schopper (CERN) – **Chair**
Jurgen Schukraft (CERN)
Achille Stocchi (LAL Orsay)
John Womersley (STFC)

*) IAC Composition June 2014, and
Oliver Brüning Max Klein ex officio

The IAC was invited in 12/13 by the DG with the following

Mandate 2014-2017

Advice to the LHeC Coordination Group and the CERN directorate by following the development of options of an ep/eA collider at the LHC and at FCC, especially with:

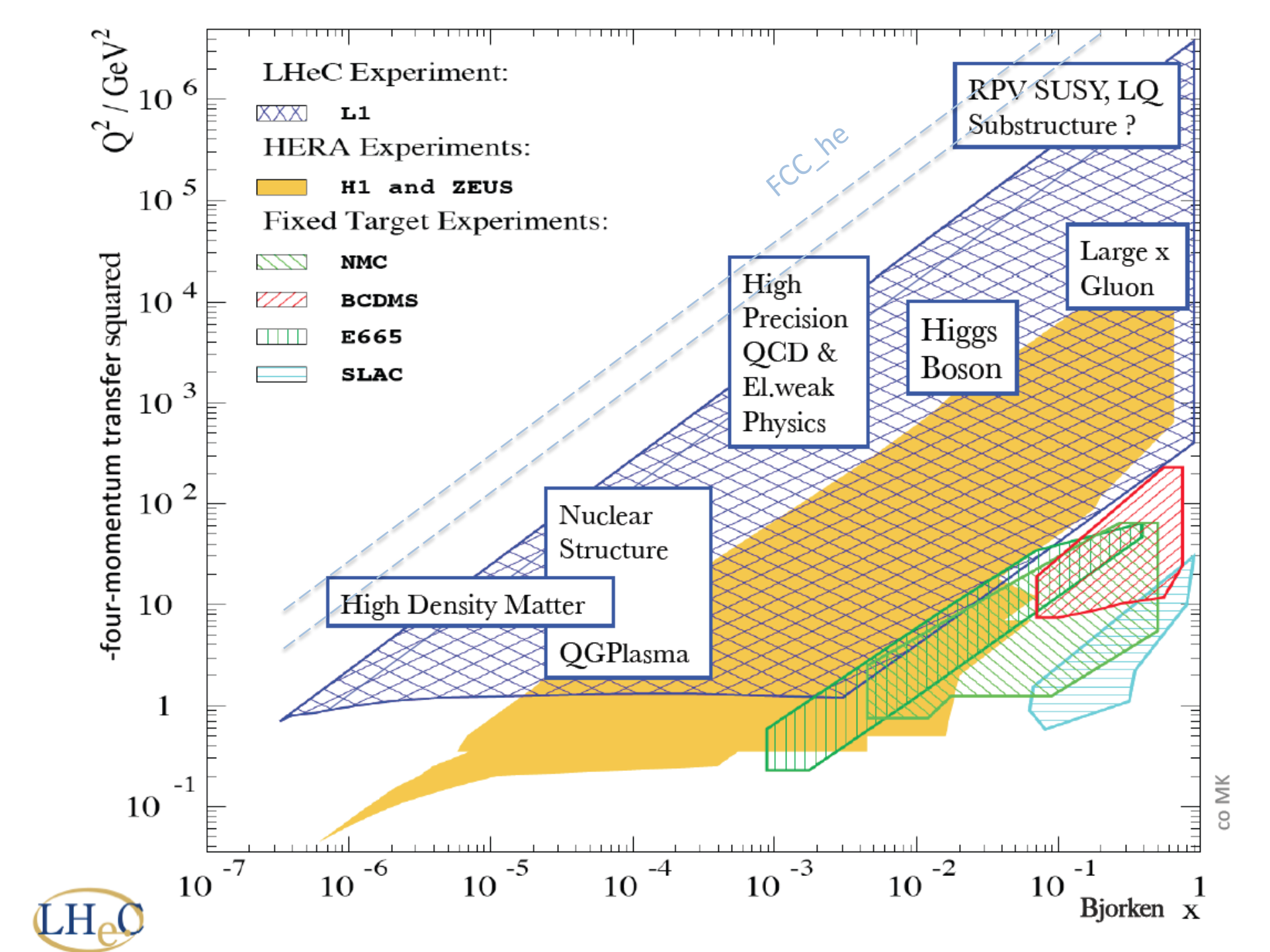
Provision of scientific and technical direction for the physics potential of the ep/eA collider, both at LHC and at FCC, as a function of the machine parameters and of a realistic detector design, as well as for the design and possible approval of an ERL test facility at CERN.

Assistance in building the international case for the accelerator and detector developments as well as guidance to the resource, infrastructure and science policy aspects of the ep/eA collider.

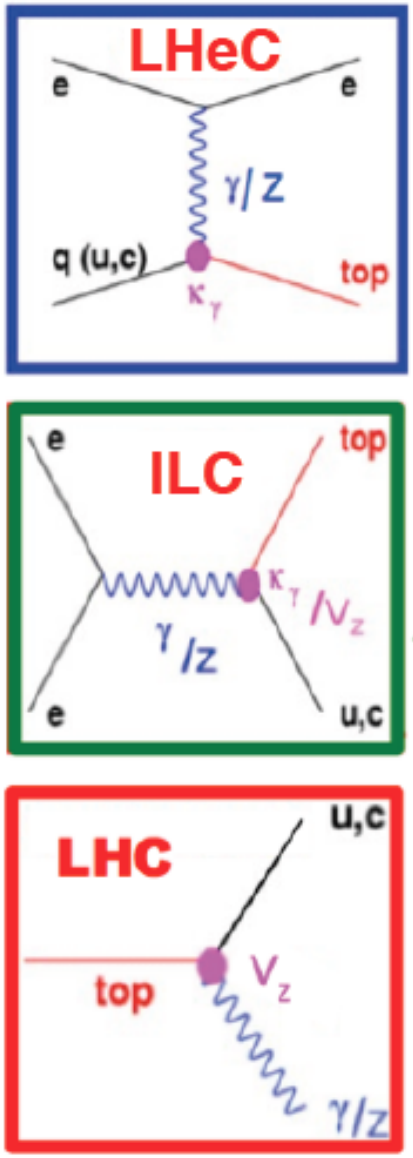
Thank you

Further information: FCC kickoff meeting at Geneva, (2 plenaries, 7 parallel) + FCC-hh workshop, May 14

lhec.web.cern.ch


LHeC Experiment:
L1
HERA Experiments:
H1 and ZEUS
Fixed Target Experiments:
NMC
BCDMS
E665
SLAC
FCC_he
RPV SUSY, LQ
Substructure ?
Large x
Gluon
High
Precision
QCD &
El.weak
Physics
Higgs
Boson
Nuclear
Structure
High Density Matter
QGPlasma
Q^2 / GeV^2
-four-momentum transfer squared
Bjorken x
co MK

FCNC Top Couplings at Colliders



95% C.L.

$|v_{tuZ}|$

ZEUS
L3
CDF
DØ
H1
2.1 fb^{-1}, 7 TeV
5 fb^{-1}, 7 TeV +
20 fb^{-1}, 8 TeV
ATLAS: 300 fb^{-1}
√s= 14 TeV
LHeC
100 fb^{-1}
ILC
500 fb^{-1}
√s= 250 GeV

1, 10^{-1}, 10^{-2}, 10^{-3}

10^{-3}, 10^{-2}, 10^{-1}

→ test SUSY, little Higgs, technicolor... $|\kappa_{tu\gamma}|$