

FCC-he – brief overview

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CERN and U Liverpool

Physics
Accelerator and IR
Detector
Organisation

See also talks here on FCC-he (Daniel Schulte), IRs (Rogelio Tomas, Brett Parker) BSM (Monica D'Onofrio), Higgs (Bruce Mellado), Detector (Andrea Gaddi) and others.

LHeC Workshop Chavannes-de-Bogis, June 26th, 2015

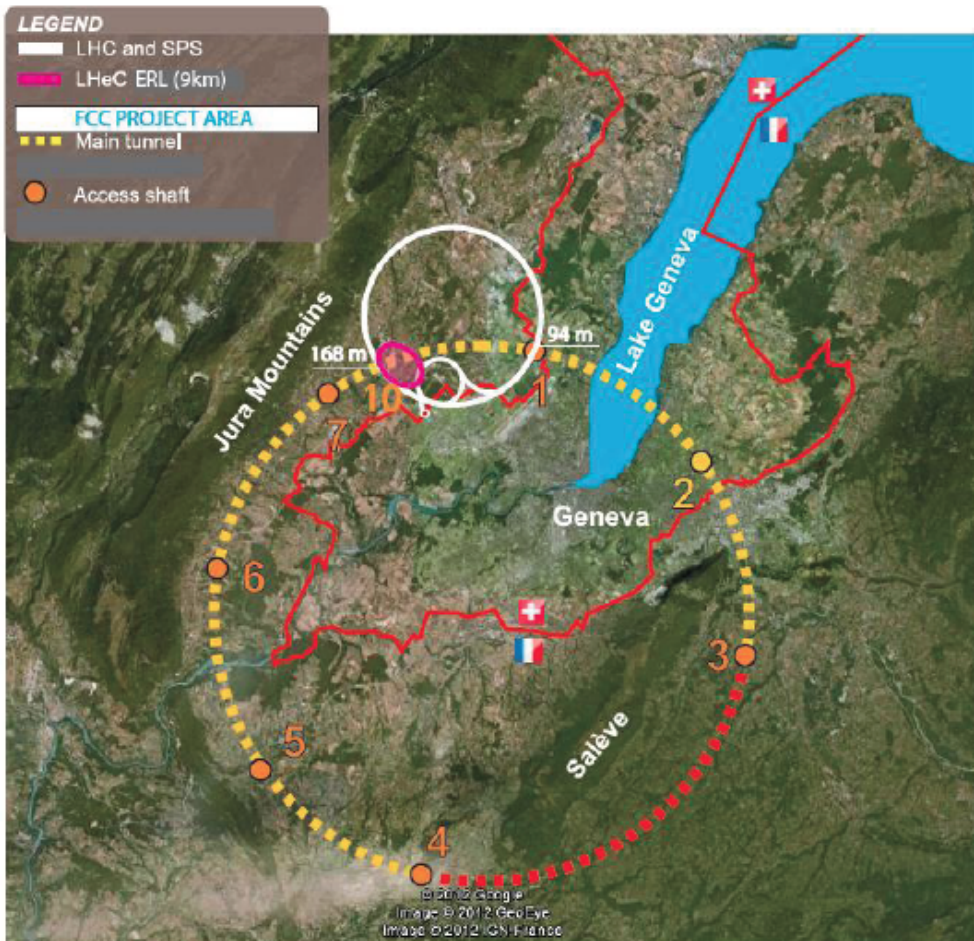


LHeC and the Future Circular Collider (FCC)

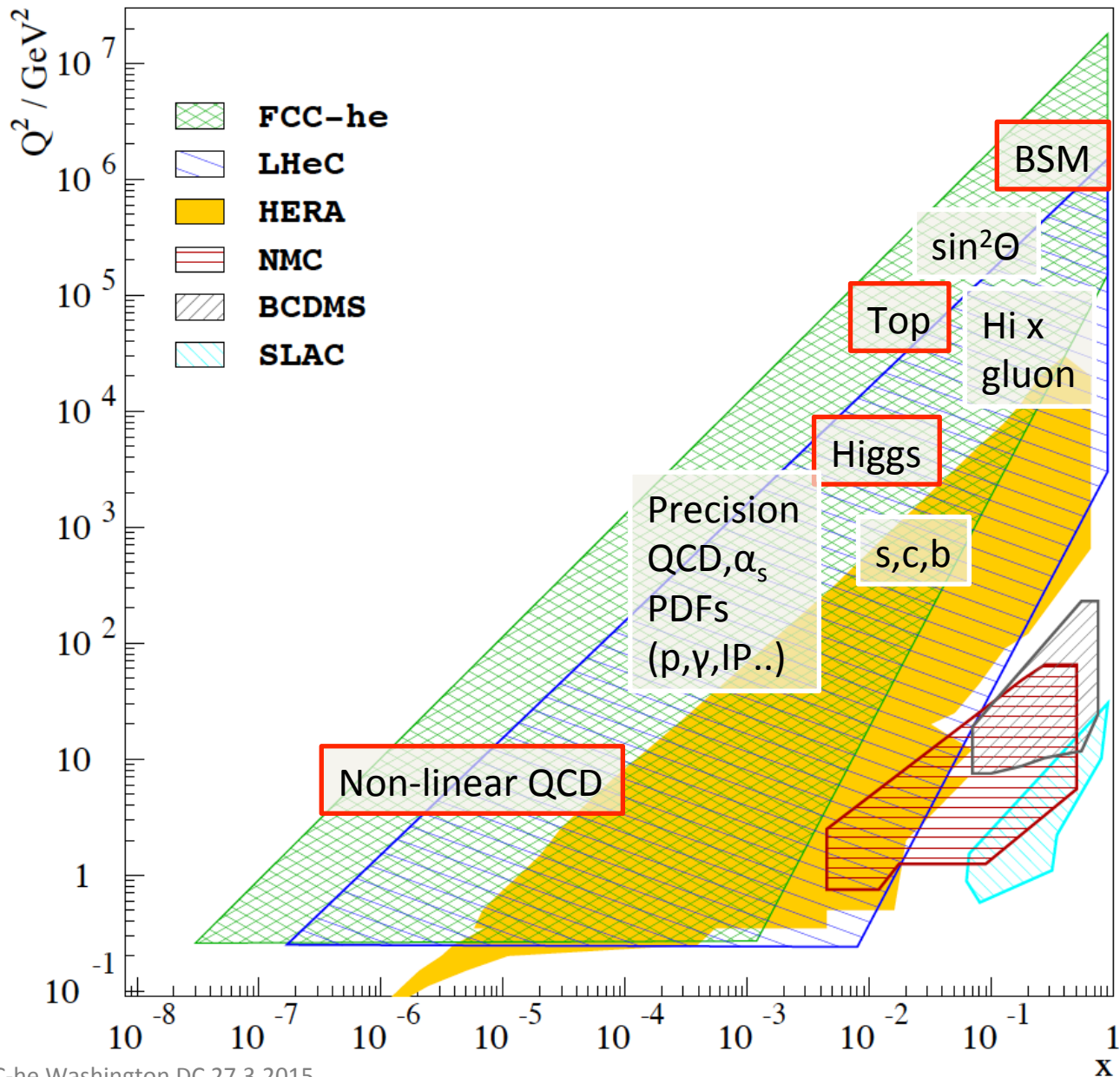
Version 230 mASL

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

- **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



Q^2 -x Range in Deep Inelastic Scattering



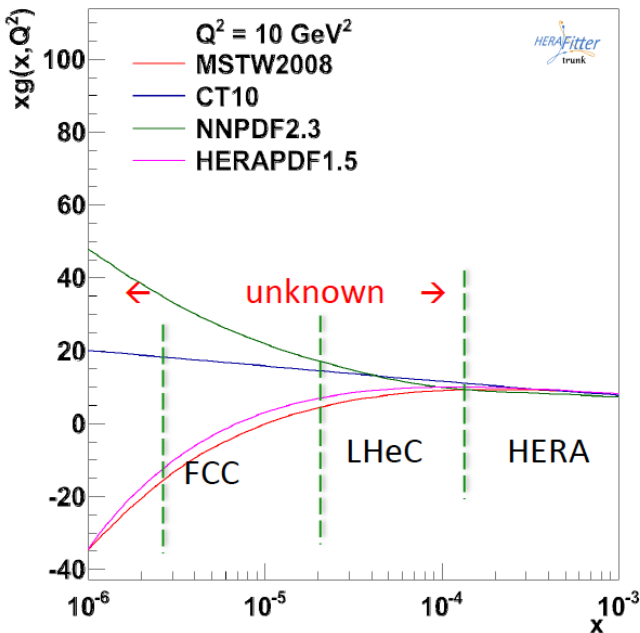
Luminosity:
10 years of
HERA
in one day..

Energy frontier eh Physics

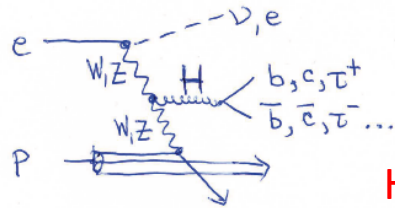
All work in progress

Rise or fall of xg
 Non-linear QCD
 Nuclear structure
 UHEv physics..

Low $x \sim 1/s$

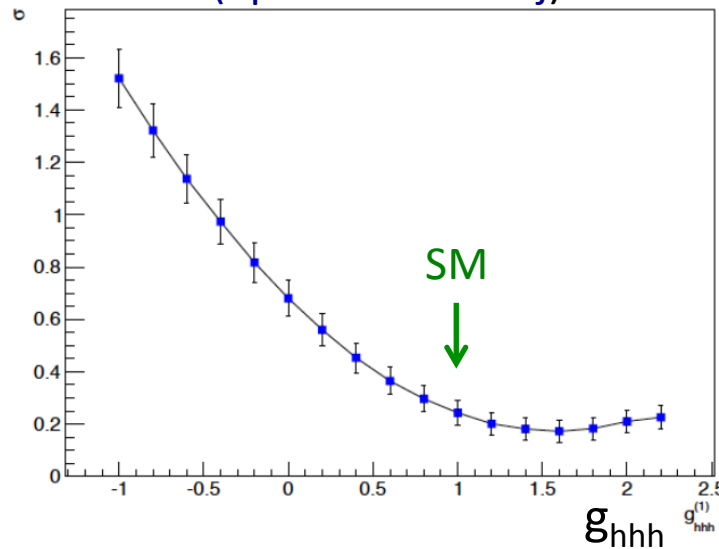


DC: F.Olness, V.Radescu, M.Ploskon



Higgs

$$\sigma(ep \rightarrow vhhX \rightarrow v4bj)$$

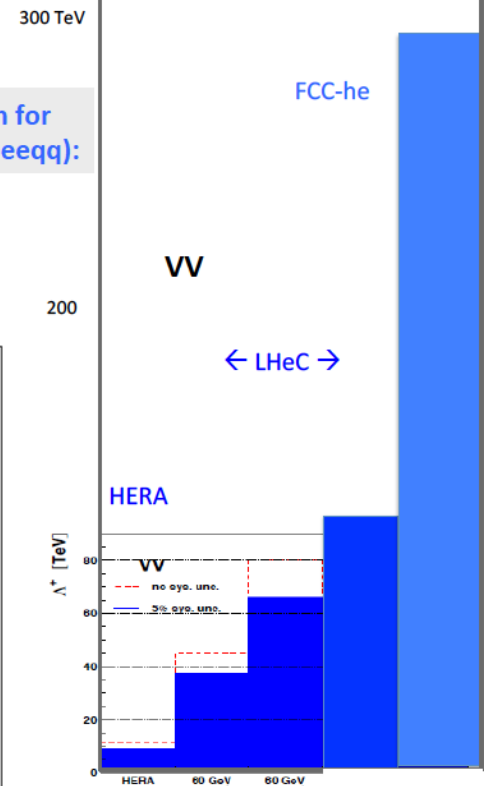


Higgs couplings bb to 1%
 $h-hh$ in $4b$, cut based: $5-8\sigma$
 charm under study..

ep - cost effective Higgs facility

DC: M.K.

BSM

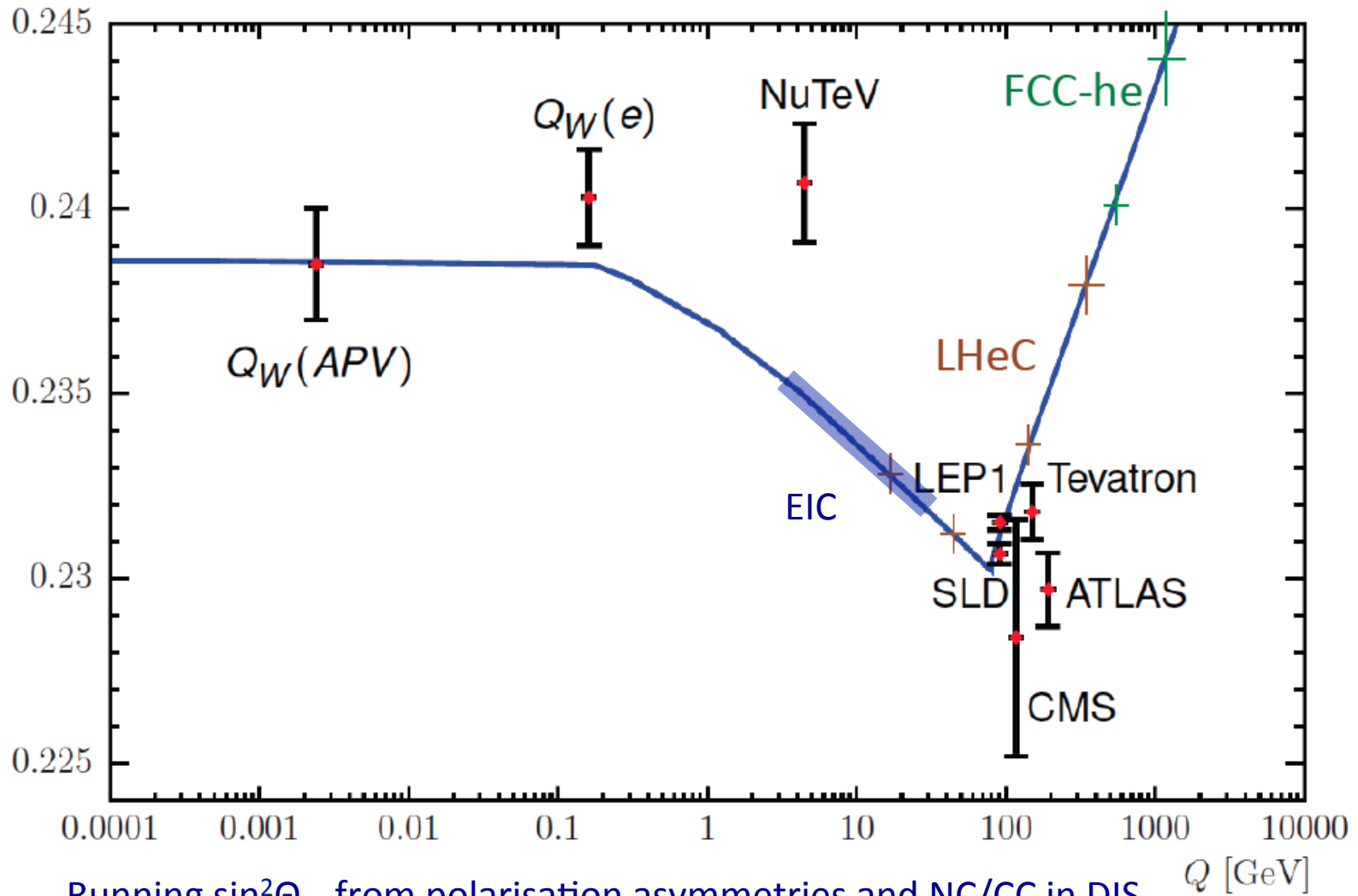


LHeC: see CDR 2012

Cl to 300 TeV
 LQ to 4 TeV
 Compositeness
 ??

DC: G.Azuelos

Scale dependence of $\sin^2\theta_W$

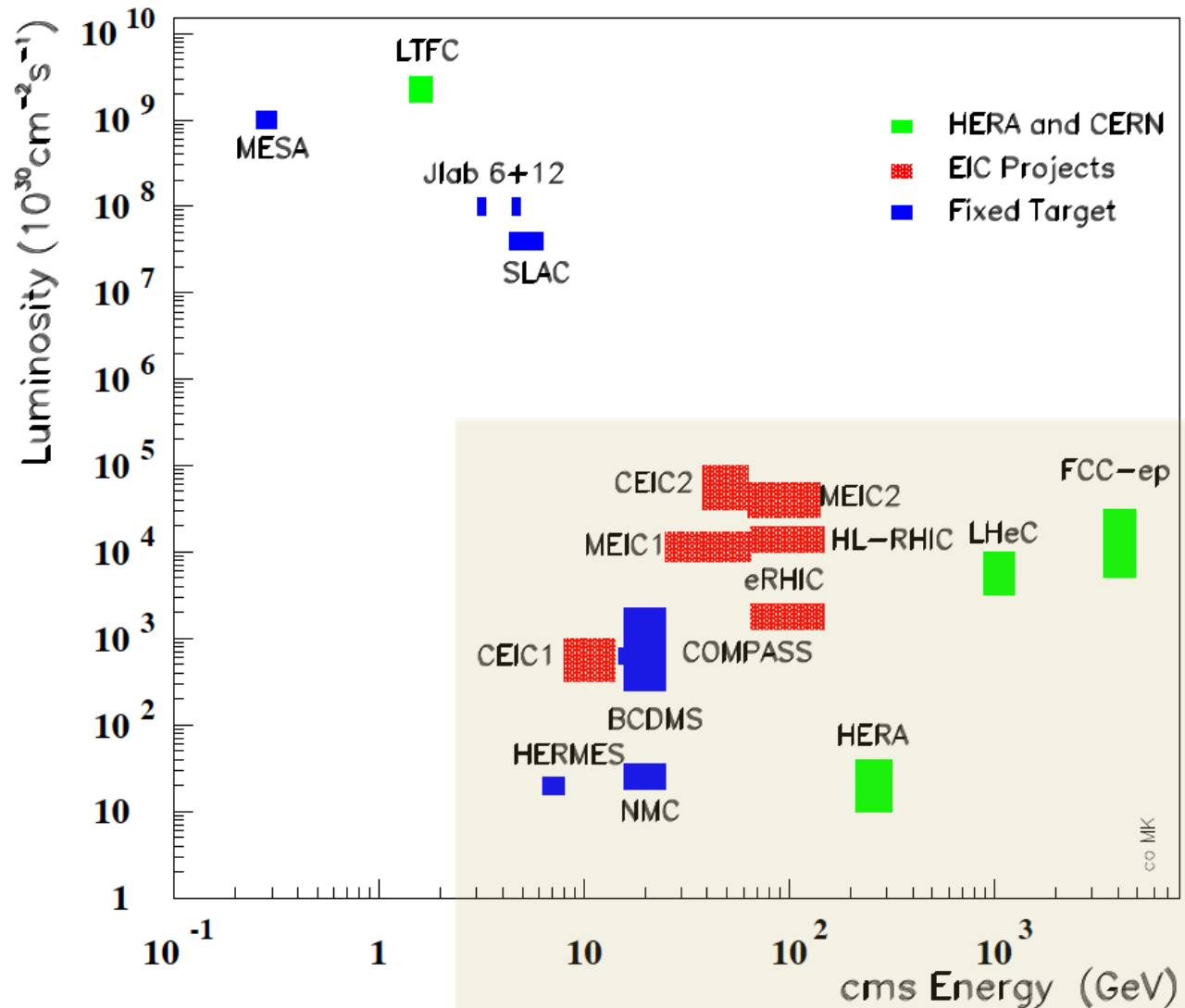


Running $\sin^2\theta_W$ from polarisation asymmetries and NC/CC in DIS

Low scales from MAMI, Jlab and possibly the CERN Testfacility

New ep and eA Colliders are being developed

Lepton-Proton Scattering Facilities



From CERN Courier
MK, H.Schopper
June 2014

With input from
A.Hutton, R.Ent,
F.Maas, T.Rosner

ep colliders 11.2014 Max Klein	CEPC	MEIC	eRHIC	HERA 92-07	CepC	LHeC	SepC	FCC-he
\sqrt{s}/GeV	13	35	122	319	1000	1300	3375	3464
$L/10^{33}$ $\text{cm}^{-2}\text{s}^{-1}$	0.4	5.6	1.5	0.04	4.8	16	8.9	10
E_e/GeV	3	5	15.9	27.6	120	60	80	60
E_p/GeV	15	60	250	920	2100	7000	35600	50000
f/MHz	500	750	9.4	10.4	20	40	40	40
$N_{e/p}10^{10}$	3.7/0.54	2.5/0.42	3.3/3	3/7	1.3/16.7	0.4/22	3.3/5	0.5/10
$\epsilon_{e/p}/\mu\text{m}$.03/.15	54/.35	32/.27	4.6/.09y	250/1	20/2.5	7.4/2.4	10/2
$\beta^*_{e/p}/\text{cm}$	10/2	10/2	5/5	28/18 y	4.2/10	10/5	9.3/75	9/40
comment	Lanzhou	full acc.	“Day1”	HERA II	Booster	ERL (H)	$E_e = M_W$	ERL (HH)
source	X.Chen July 14	McKoewn POETIC14	Litvinenko S.Brook 14	B.Holzer at CERN 2008	Y.Peng Oct. 2014	Frank Z. LHeC 2014	Y.Peng Oct. 2014	Frank Z. IPAC 2014



LHeC HF \rightarrow FCC-he (phase 1)



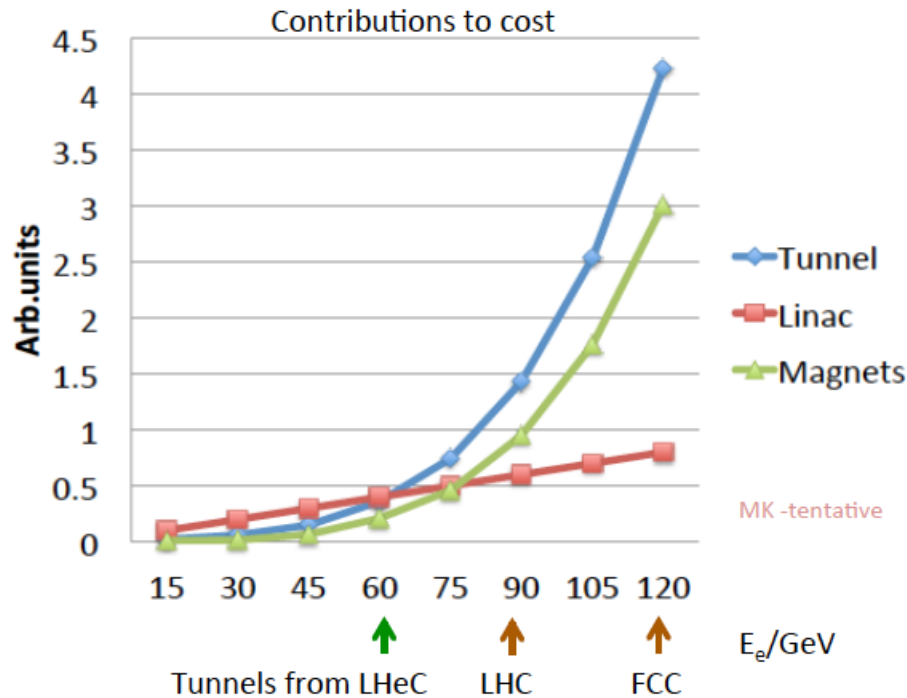
parameter [unit]		FCC-hh
species	e-	p
beam energy (/nucleon) [GeV]	60	7000 \rightarrow 50000
bunch spacing [ns]	25	25
bunch intensity (nucl.) [10¹⁰]	0.4	22 \rightarrow 10
beam current [mA]	25.6	1110 \rightarrow 500
normalized rms emittance [μm]	20	2.5 \rightarrow 2.2
geometric rms emittance [nm]	0.17	0.34 \rightarrow 0.04
IP beta function $\beta_{x,y}^*$ [m]	0.10 \rightarrow 0.07	0.05 \rightarrow 0.3
IP rms spot size [μm]	4.1 \rightarrow 3.5	4.1 \rightarrow 3.5
lepton D & hadron ξ	23 \rightarrow 16	0.0002 \rightarrow 0.0002
hourglass reduction factor H_{hg}		0.80 \rightarrow 0.88
pinch enhancement factor H_D		~ 1.35
luminosity/nucl. [10³³cm⁻¹s⁻¹]		14.4 \rightarrow 9.9

	protons	electrons
beam energy [GeV]	50000	60
Luminosity [$10^{33}\text{cm}^{-2}\text{s}^{-1}$]		13.8-> 13.4
normalized emittance $\gamma\epsilon_{x,y}$ [μm]	2.2 -> 0.15	10
IP beta function $\beta^*_{x,y}$ [mm]	300	45 -> 45
rms IP beam size $\sigma^*_{x,y}$ [μm]	3.5 -> 0.9	1.9 -> 1.9
beam current [mA]	500 -> 150	21-26
bunch spacing [ns]	25	25
bunch population [10^{10}]	10 -> 2	0.4
Effective crossing angle		0.0

$$\mathcal{L} \propto \frac{N_p}{\epsilon_p} \frac{1}{\beta_p} I_e H_{geom} H_{b-b} H_{coll}$$

$O(350\text{fb}^{-1})$ per 5-year period
Assuming no lon gaps

More than 60 GeV E_e ?

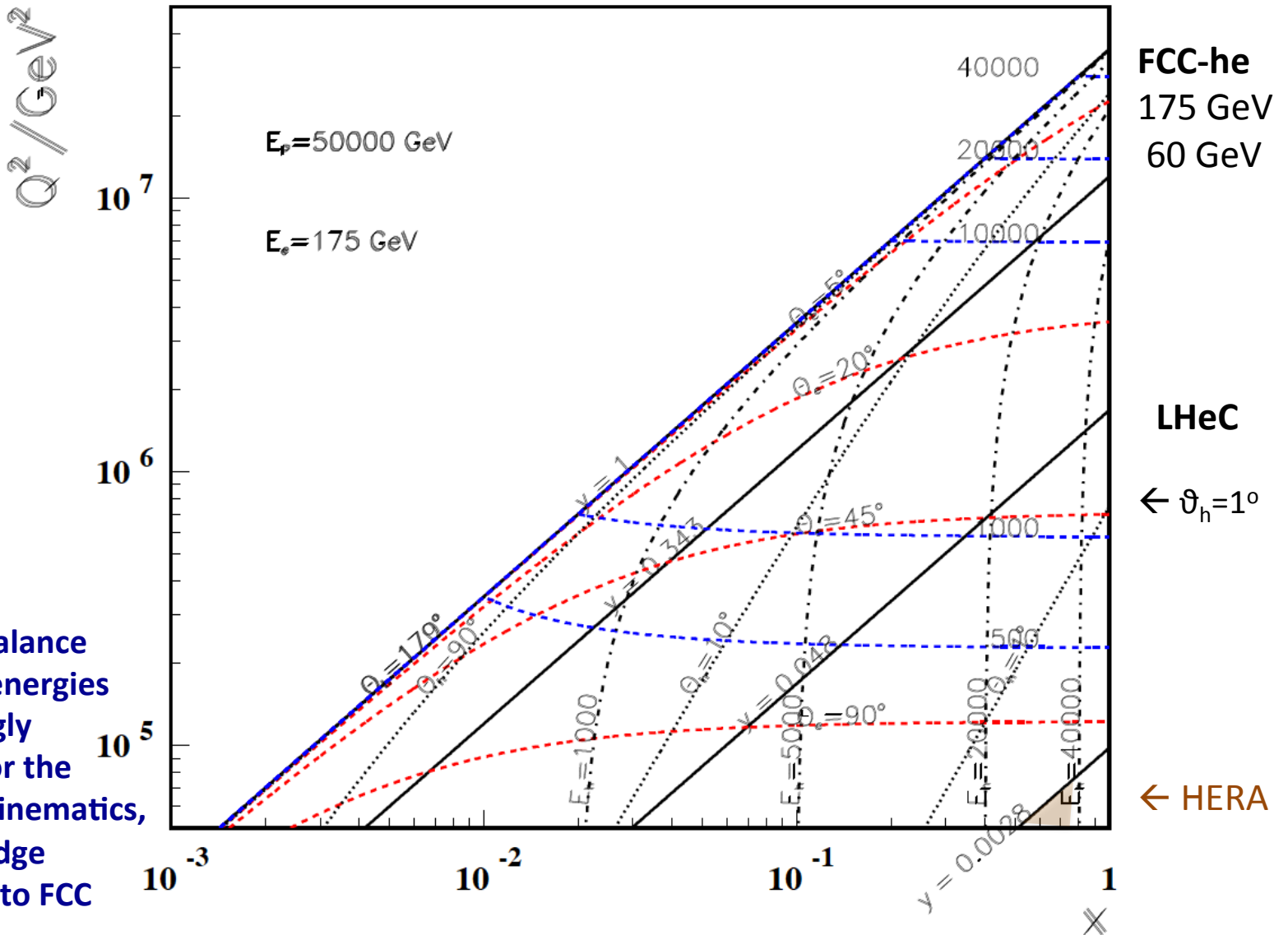


Higher E_e is desirable for BSM, RPV SUSY., hhh, forward angular coverage.
It could be thought of with the LHC or FCC tunnels, or an e-p linac (Litvinenko)

Still: plan for synchronous ep and pp operation and appropriate cost, power, effort..
It thus appears most natural to consider the LHeC ERL as the electron beam for eh

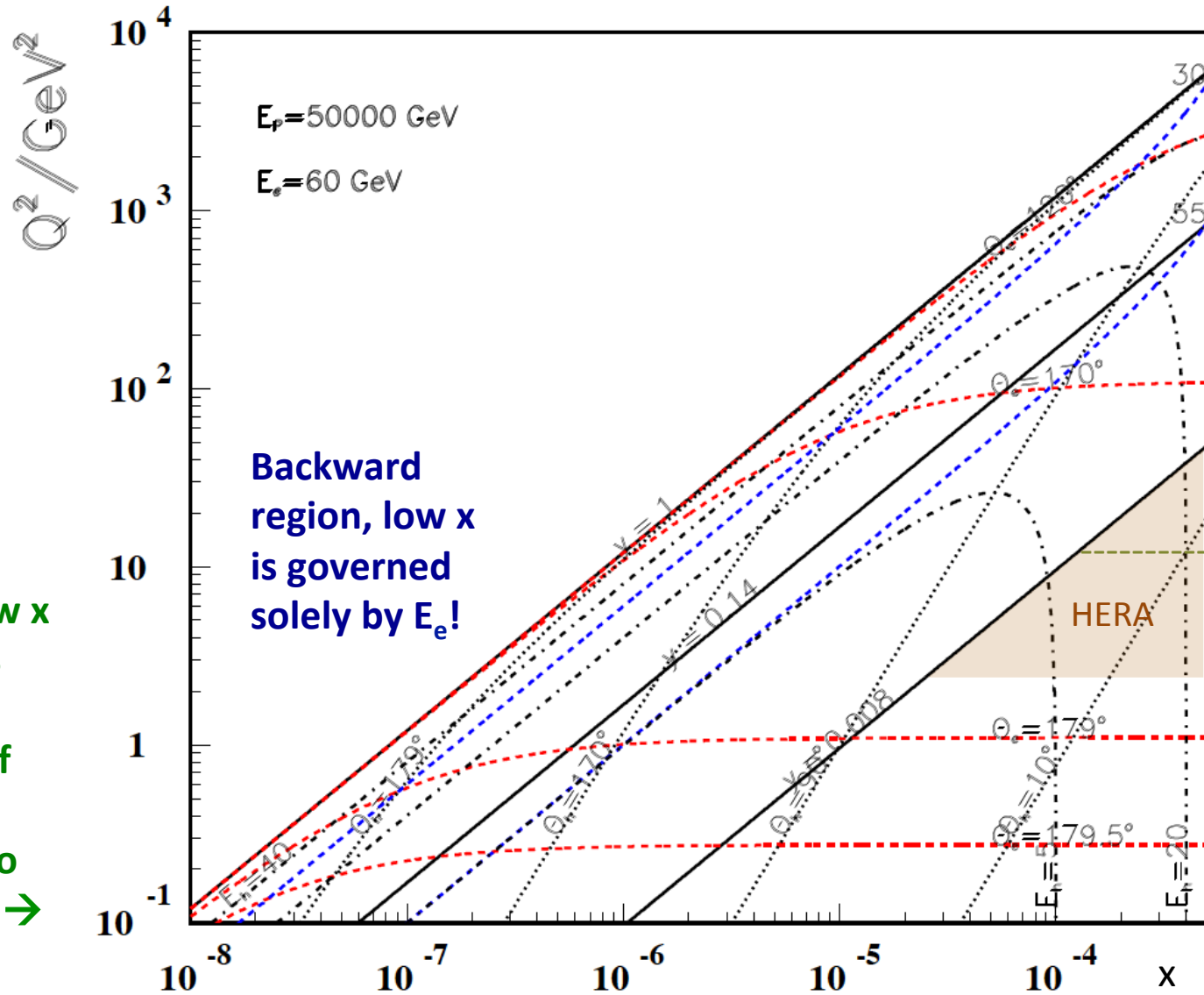
High Q^2

Rutherford backscattering
of dozens of TeV e- energy



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

Low x



FCC-he
60 GeV

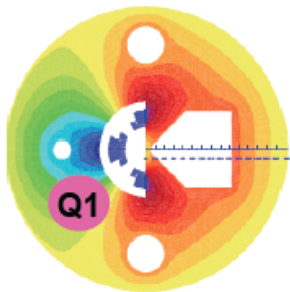
LHeC

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

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

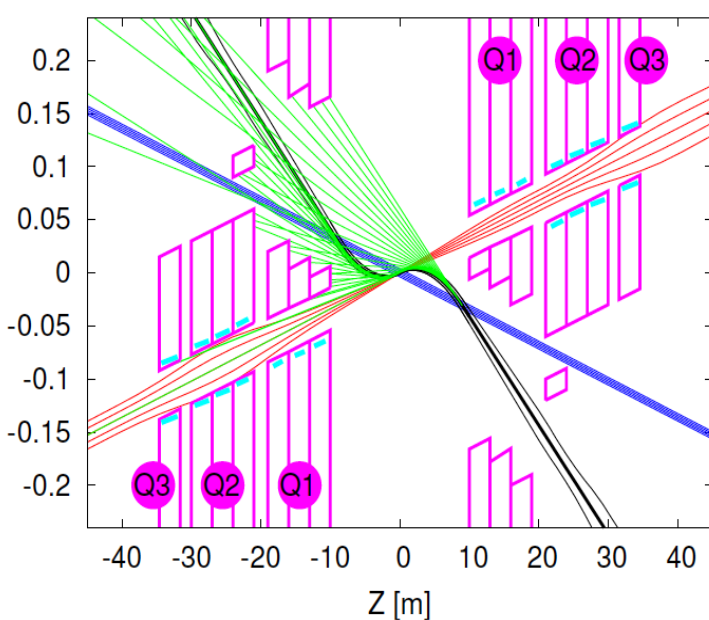
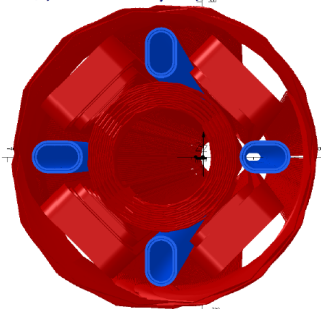
Interaction Regions for ep with Synchronous pp Operation

A central problem in ep collider



DC: B. Parker: sweet spot quad

Q1, Version 2.5 Optics, Full Model

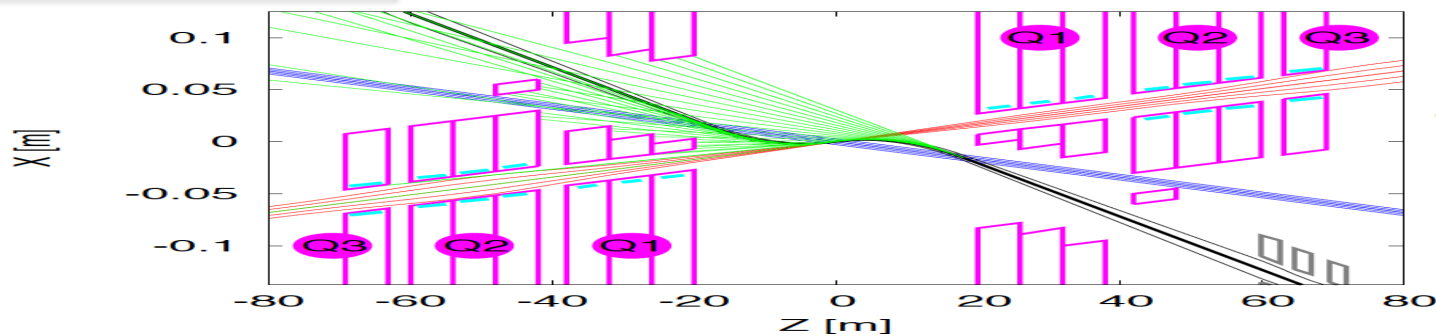


p2
p1
e-
γ
Qs
Coils

Beam-beam
DC: E.Nissen

LHeC (CDR)
60 GeV * 7 TeV

Non colliding p beam

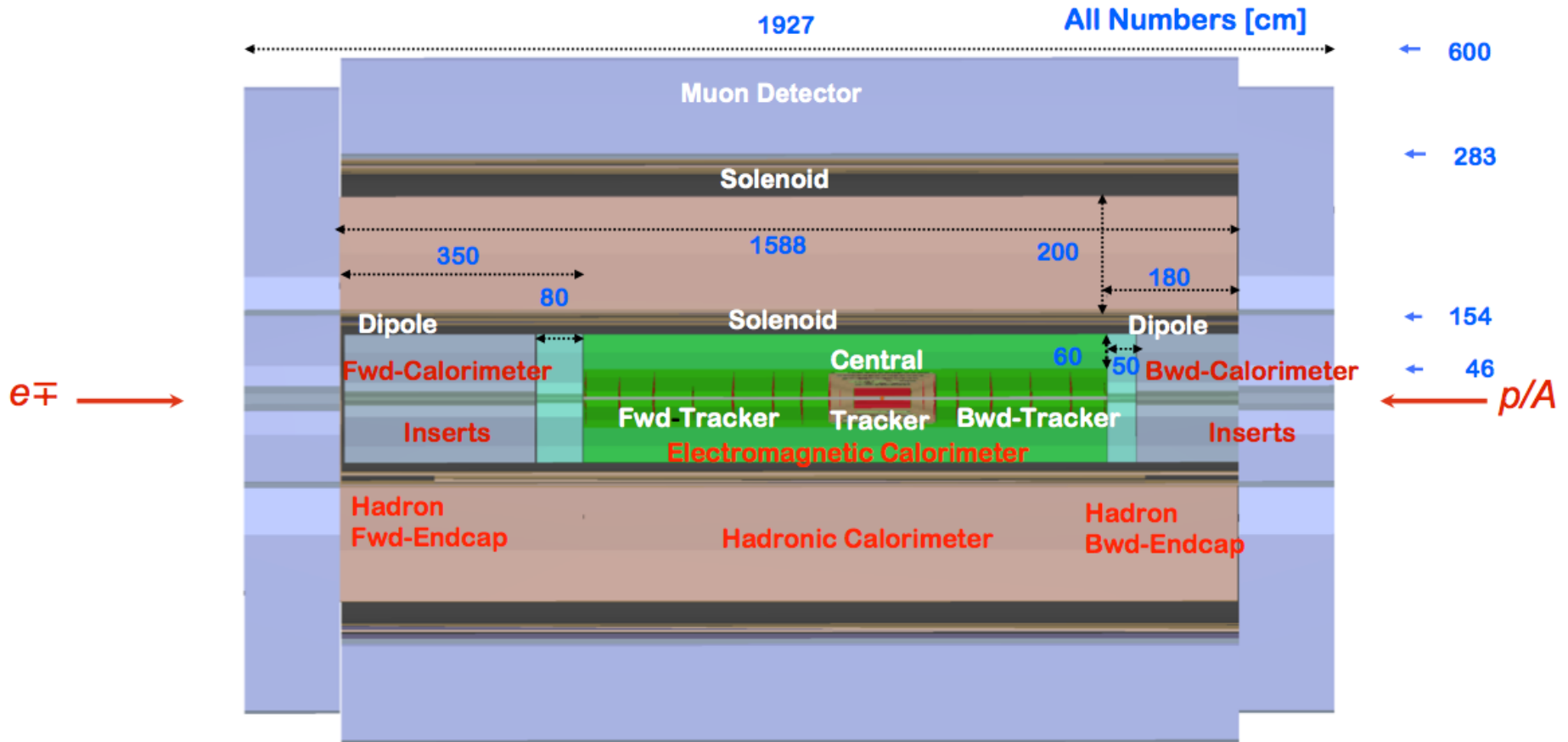


e-
p1
p2
γ
Qs
Coils

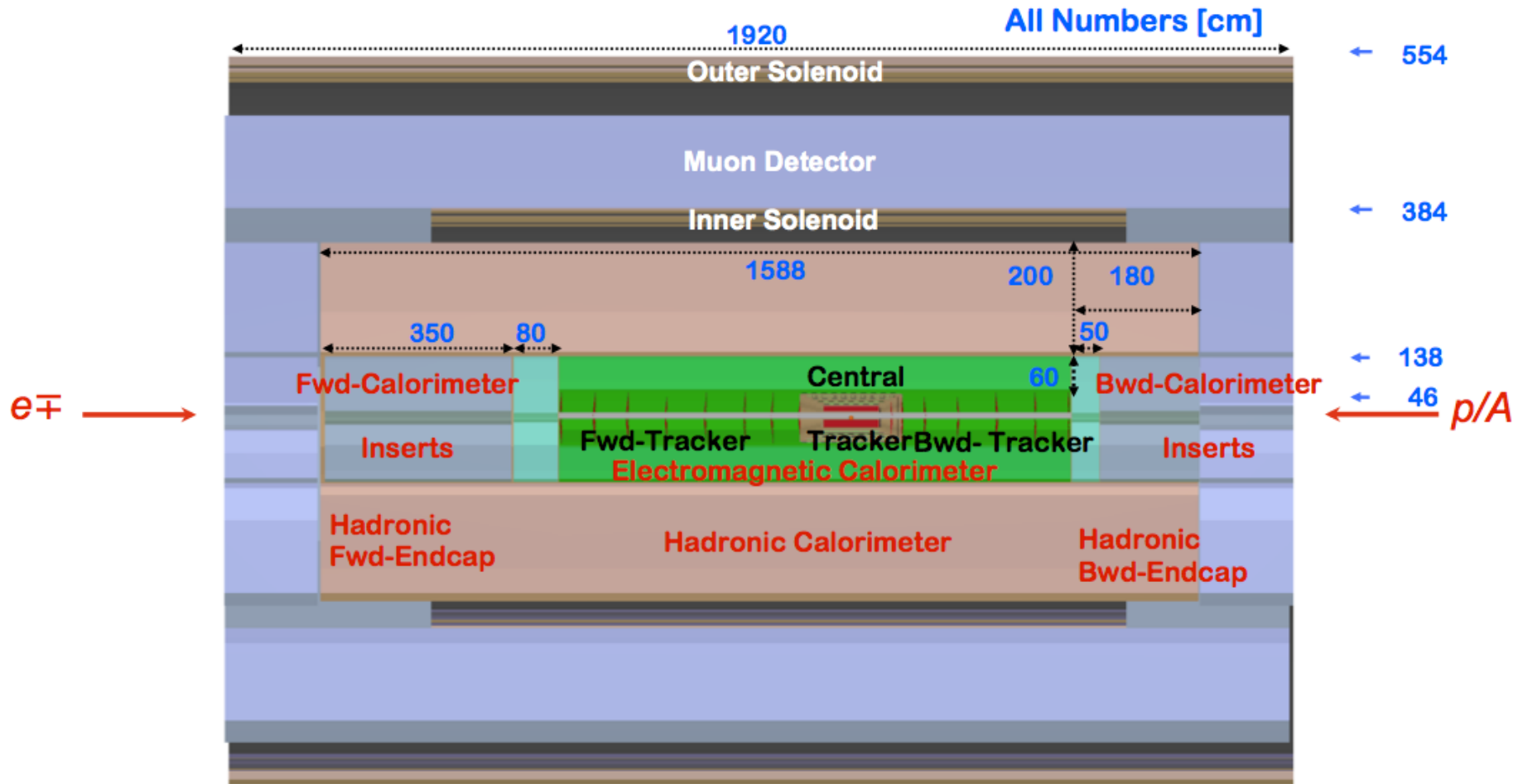
FCC-he (ERL)
60 GeV * 50 TeV

Tentative: $\epsilon_p = 2\mu\text{m}$, $\beta^* = 20\text{cm} \rightarrow \sigma_p = 3\mu\text{m} \approx \sigma_e$ matched! $\epsilon_e = 5\mu\text{m}$..

FCC-he study (version 1).



FCC-he study (version 2).



Organisation

Coordination Group

Gianluigi Arduini
Nestor Armesto
Oliver Brüning
Stefano Forte
Andrea Gaddi
Erk Jensen
Max Klein
Peter Kostka
Bruce Mellado
Paul Newman
Daniel Schulte
Frank Zimmermann

The FCC-he task is to provide a realistic option (ep/A beams, IR, physics programme) for the FCC study by 2017.

The IAC has a mandate for future ep/A colliders at CERN and it has been most natural to integrate the FCC-he into the LHeC development.

Eols for FCC-he are very welcome

Physics Groups + Convenors

PDFs, QCD	Fred Olness, Voica Radescu
Higgs	Uta Klein, Masahiro Kuze
BSM	Georges Azuelos, Monica D'Onofrio
Top	Olaf Behnke, Christian Schwanenberger
Nuclei	Nestor Armesto
Small x	Paul Newman, Anna Stasto

FCC

Coordination

Michael Benedikt
Frank Zimmermann
+ many
Erk Jensen
Daniel Schulte
ep coordinators:
Oliver Brüning
Max Klein

FCC Physics Coordination

hh Fabiola Gianotti
Michelangelo Mangano
Austin Ball
ee Alain Blondel
John Ellis
Patrick Janot
ep Monica D'Onofrio
Max Klein

FCC-eh at Washington

Parallel Session on Accelerator

Introduction	Max Klein
ep Collider	Frank Zimmermann
Circular ERL	Alessandra Valloni
Beam-Beam	Ed Nissen
Linear ERL	Vladimir Litvinenko

Parallel Session Detector+Physics

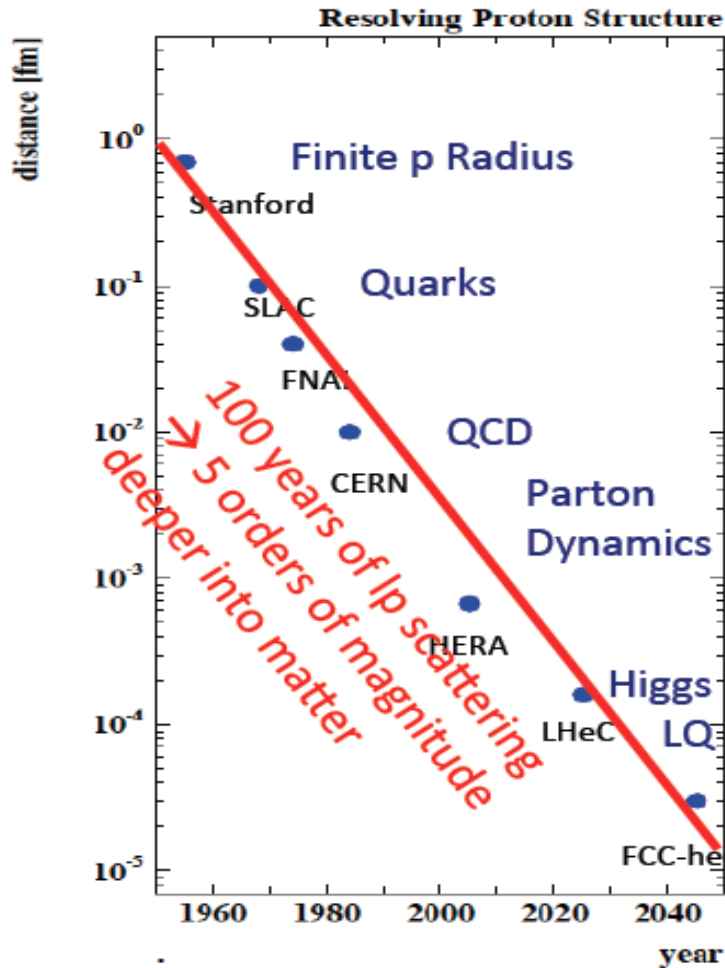
Detector	Peter Kostka
IR	Brett Parker
Higgs in ep	Max Klein
PDFs	Fred Olness
BSM	Georges Azuelos
eA	Mateusz Ploskon

Contribution to joint thy/exp hh-he-ee session: PDFs and α_s Voica Radescu
Also covered in other talks in that session (Markus Kluge, Higgs) → *synergy*

Thanks to all *he* speakers at Washington

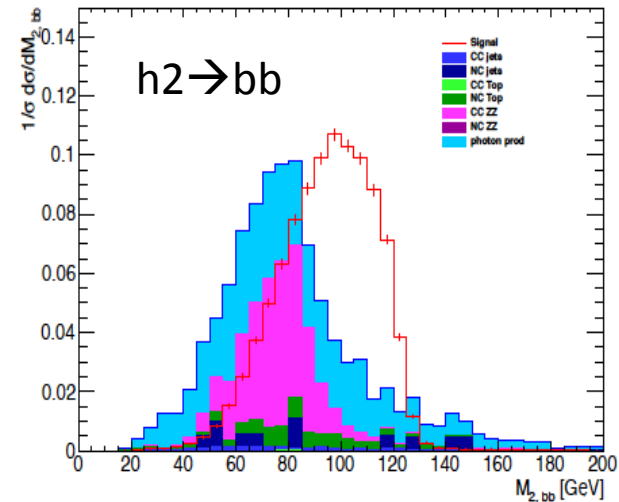
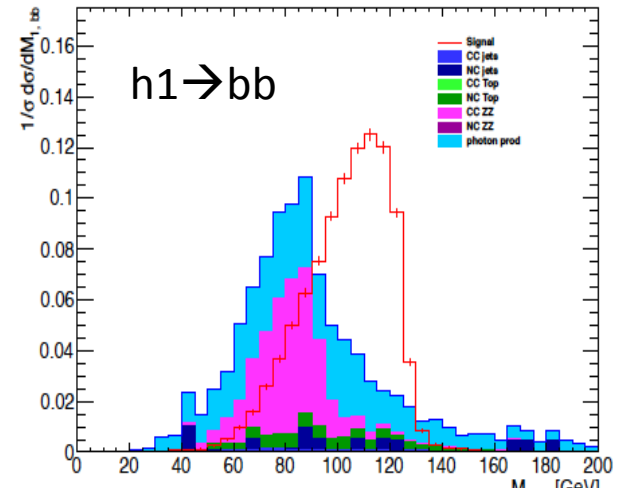
Two Reasons for FCC-he

The world's cleanest microscope



cf F.Olness, V.Radescu, M.Ploskon

New Physics in Higgs, QCD, BSM ($l=q?$)



Two h seen in new DELPHES cut based analysis of h-hh-4b in CC ep at FCC-he

cf G.Azuolos, M.Klein

Remarks on FCC-he