FCC-he machine parameters

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FCC Kick-Off Meeting

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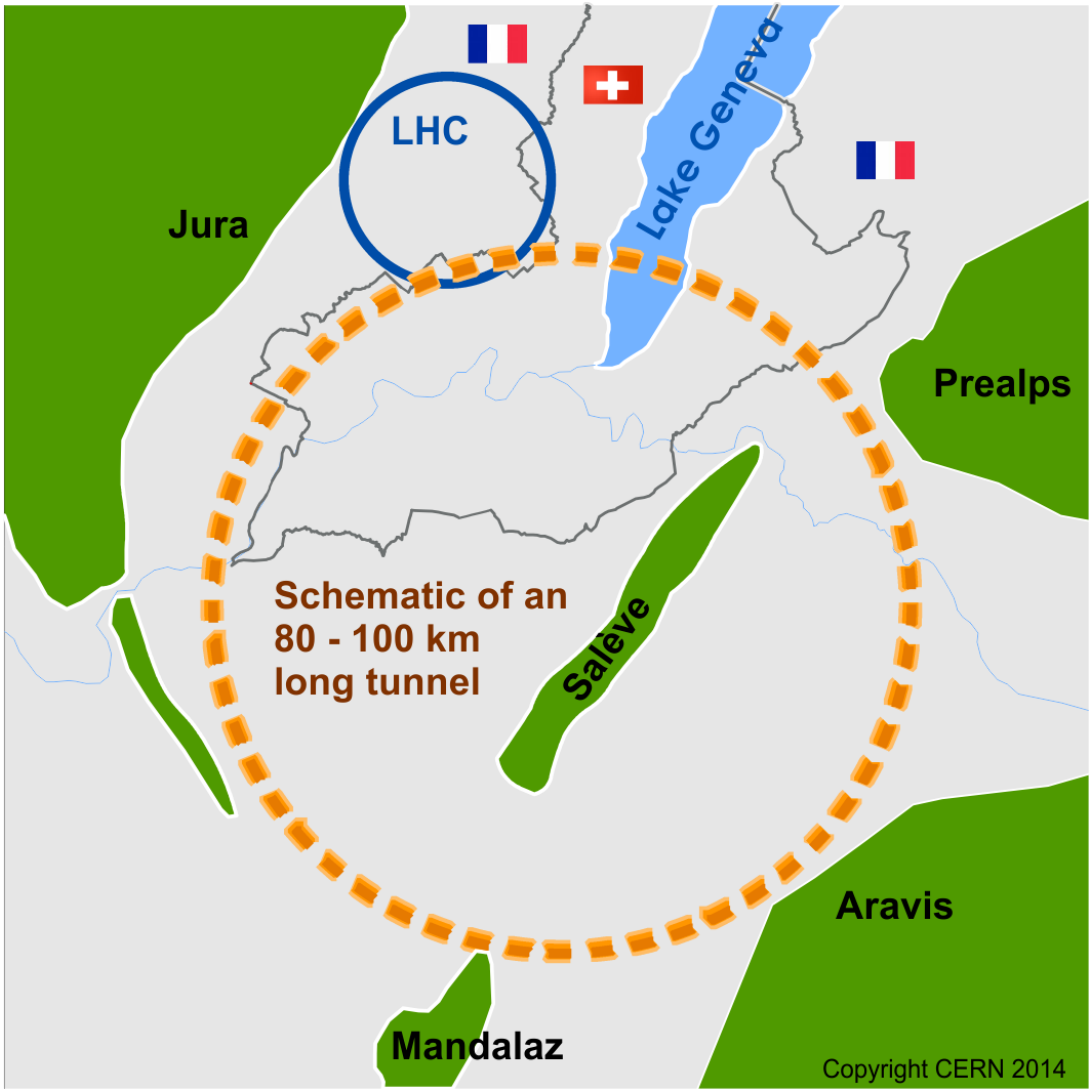
Future Circular Collider Study
CDR and cost review for the next ESU (2018)

- 80-100 km tunnel infrastructure in Geneva area
- *pp*-collider (*FCC-hh*) defining the infrastructure requirements
- e^+e^- collider (*FCC-ee*) as potential intermed. step and ***p-e* (*FCC-he*)** option
- international collaboration hosted by CERN



~16 T ⇒ 100 TeV *pp* in 100 km
~20 T ⇒ 100 TeV *pp* in 80 km

deep inelastic *eh* scattering – glorious history

1911, Ernest Rutherford

Coulomb scattering , model of the atom; first observation of inelastic scattering

1953-57 (Nobel Prize 1961) Robert Hofstadter

electron scattering in atomic nuclei, structure of the nucleons

1968-69 (Nobel Prize 1990) Jerome Friedman, Henry Kendall , and Richard E. Taylor

deep inelastic scattering of electrons on protons and bound neutrons, development of the quark model

key parameters for *FCC-he*

$e^{\pm}$ energy = 80 (*pol.*), 120, 175 GeV

***p* energy = 50 TeV (or equiv. *A* energy)**

#IPs = 1

IP spot size determined by *p*

$e^{\pm}$ current from *FCC-ee* (baseline)

(if built; SR power ≤ 50 MW)

or

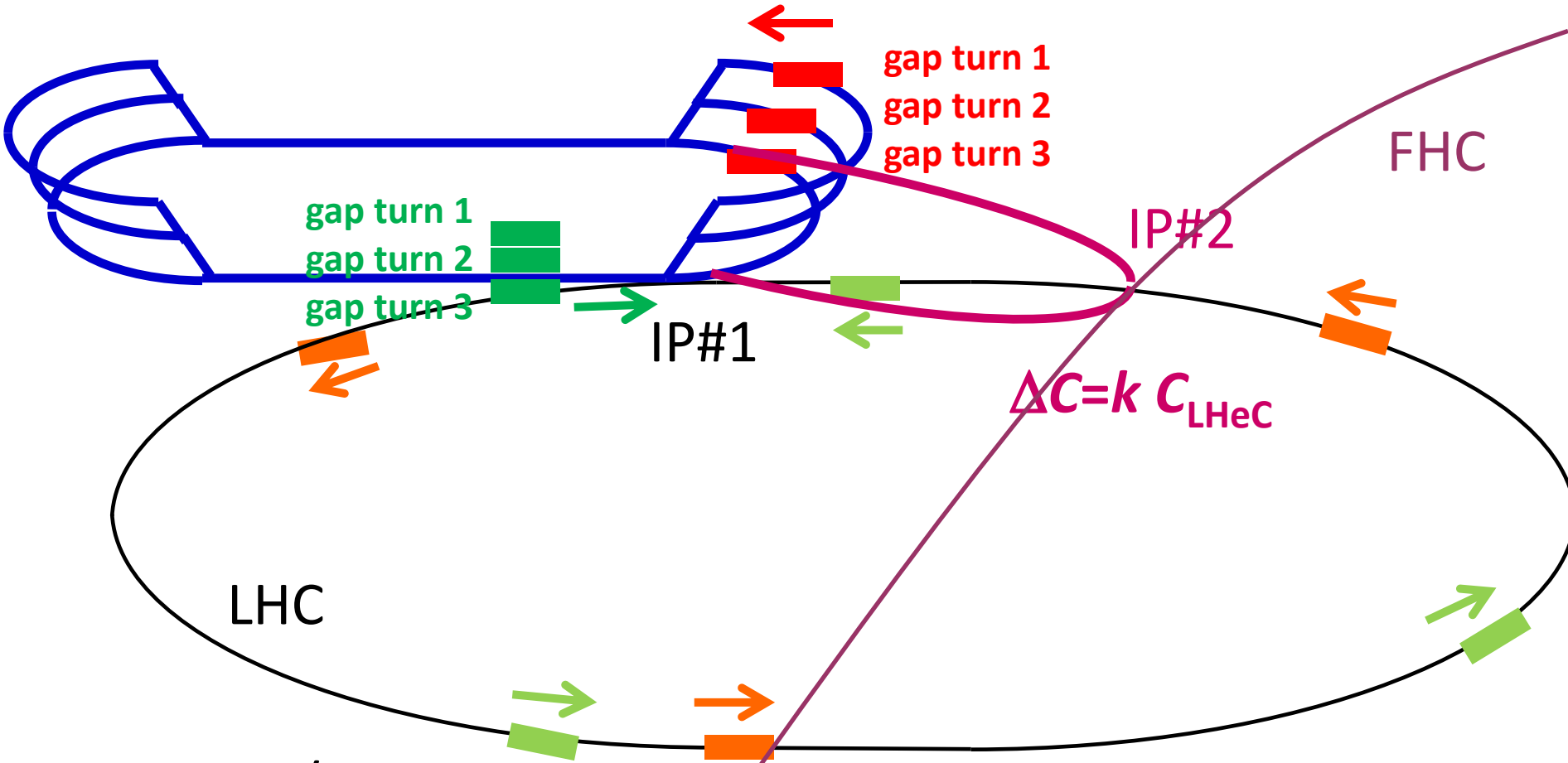
e^{-} current from pushed *LHeC ERL* (backup)

(without FCC-ee)

baseline (!) parameters for *FCC-he with FCC-ee*

collider parameters	$e^{\pm}$ scenarios			protons
species	$e^{\pm}$	$e^{\pm}$	$e^{\pm}$	p
beam energy [GeV]	80	120	175	50000
bunches / beam	4490	1360	98	10600
bunch intensity [10^{11}]	0.7	0.46	1.4	1.0
beam current [mA]	152	30	6.6	500
rms bunch length [cm]	0.15	0.12	0.15	8
rms emittance [nm]	3.3 (x)	0.94 (x)	2 (x)	0.04, 0.02
$\beta_{x,y}$*[mm]	6.0, 3.0	22, 11	10, 5	500, 250
$\sigma_{x,y}$* [μm]	4.5, 2.3			
beam-b. parameter ξ	0.05	**0.13**	0.042	0.017
hourglass reduction	**~0.24**	~0.60	**~0.36**	
CM energy [TeV]	4.0	4.9	5.9	
luminosity[10^{34}cm^{-2}s^{-1}]	**2.3**	**1.2**	**0.15**	

LHeC - ion gaps & circumference



$C_{LHeC} = C_{LHC}/n$

future: $C_{LHeC+} = C_{FHC}/m$

m, n (=3), k: integer

LHeC Higgs factory (LHeC-HF) parameters

parameter [unit]		
species	***e-***	***p***
beam energy (/nucleon) [GeV]	60	7000
bunch spacing [ns]	25	25
bunch intensity (nucleon) [10^{10}]	**0.1 → 0.4**	**17 → 22**
beam current [mA]	**6.4 → 25.6**	**860 → 1110**
normalized rms emittance [μm]	50 → **20**	**3.75 → 2.5**
geometric rms emittance [nm]	**0.43 → 0.17**	**0.50 → 0.34**
IP beta function $\beta_{x,y}$* [m]	**0.12 → 0.10**	**0.10 → 0.05**
IP rms spot size [μm]	7.2 → **4.1**	7.2 → **4.1**
lepton *D* & hadron ξ	**6 → 23**	**0.0001 → 0.0004**
hourglass reduction factor H_{hg}	0.91 → **0.70**	
pinch enhancement factor H_D	1.35	
luminosity / nucleon [10^{33} cm^{-1}s^{-1}]	**1.3 → 16**	

preliminary (!) parameters for *FCC-he-ERL w/o FCC-ee*

parameter [unit]		
species	***e-***	***p***
beam energy (/nucleon) [GeV]	**60**	**50000**
bunch spacing [ns]	25	25
bunch intensity (nucleon) [10^{10}]	**0.4**	**10**
beam current [mA]	**25.6**	**500**
normalized rms emittance [μm]	**20**	**2.0**
geometric rms emittance [nm]	**0.17**	**0.04**
IP beta function $\beta_{x,y}$* [m]	**0.10**	**0.4**
IP rms spot size [μm]	**4.0**	**4.0**
lepton *D* & hadron ξ	**32**	**0.0002**
hourglass reduction factor H_{hg}	**0.94**	
pinch enhancement factor H_D	1.35	
luminosity / nucleon [10^{33} cm^{-1}s^{-1}]	**6.4**	

ERL electrical power budget

system	wall plug power	
	baseline	**LHeC-HF**
cryogenics	21 MW (Q_0=2.5x10^{10})	**11 MW (Q_0=5x10^{10})**
RF operation & microphonics control	24 MW (802 MHz)	**12 MW (401 MHz)**
addt'l RF power to compensate SR losses	24 MW (I_e=6.4 mA)	**96 MW (I_e=25.6 mA)**
injector	7 MW	**7 MW**
magnets (arcs + IR)	4 MW	**4 MW**
total	~80 MW	**~130 MW**

summary

colliding beams from *FCC-ee* and *FCC-hh* yields ***FCC-he*** luminosity of about **$2x10^{34}$ $cm^{-2}s^{-1}$ at E_e=80 GeV** and **$2x10^{33}$ $cm^{-2}s^{-1}$ at 175 GeV**; ERL option would deliver ~$6x10^{33}$ $cm^{-2}s^{-1}$ at 60 GeV

total electric power for *e* branch ~100-150 MW for all cases

running scenarios to be defined: *he* collisions concurrent with *ee* and/or *hh*? optimized parameters (i.e. **dedicated *he* operation**) might gain another factor 2-6…

spare slides

ambitious (!) parameters for *FCC-he with FCC-ee*

collider parameters	$e^{\pm}$ scenarios			protons
species	$e^{\pm}$	$e^{\pm}$	$e^{\pm}$	p
beam energy [GeV]	**60**	120	**250**	**50000**
bunch spacing [μs]	0.125	2	33	**0.125 to 33**
bunch intensity [10^{11}]	3.8	3.7	3.5	**3.0**
beam current [mA]	477	39.8	1.6	384 (max)
rms bunch length [cm]	0.25	0.21	0.18	**2**
rms emittance [nm]	6.0, 3.0	7.5, 3.75	4, 2	0.06, 0.03
$\beta_{x,y}$*[mm]	5.0, 2.5	4.0, 2.0	9.3, 4.5	500, 250
$\sigma_{x,y}$*[μm]	5.5, 2.7			
beam-b. parameter ξ	**0.13**	0.050	0.056	0.017
hourglass reduction	**0.42**	**0.36**	0.68	
CM energy [TeV]	3.5	4.9	7.1	
luminosity[10^{34}cm^{-2}s^{-1}]	**21**	**1.2**	**0.07**	

shown in past workshops (e.g. Beijing 2012)