LHeC Linac Configurations

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3 post-Divonne options

defined in a **"5 experts" discussion on 16 October 2009**:
Max Klein, Chris Adolphsen, Oliver Brüning, John Osborne, Frank Zimmermann

"least expensive"

60 GeV pulsed, 1.5 km long linac, arc radius 100-160 m with dogbone (3%-5% energy loss at 30 GeV), 31.5 MV/m, 4 access shafts;

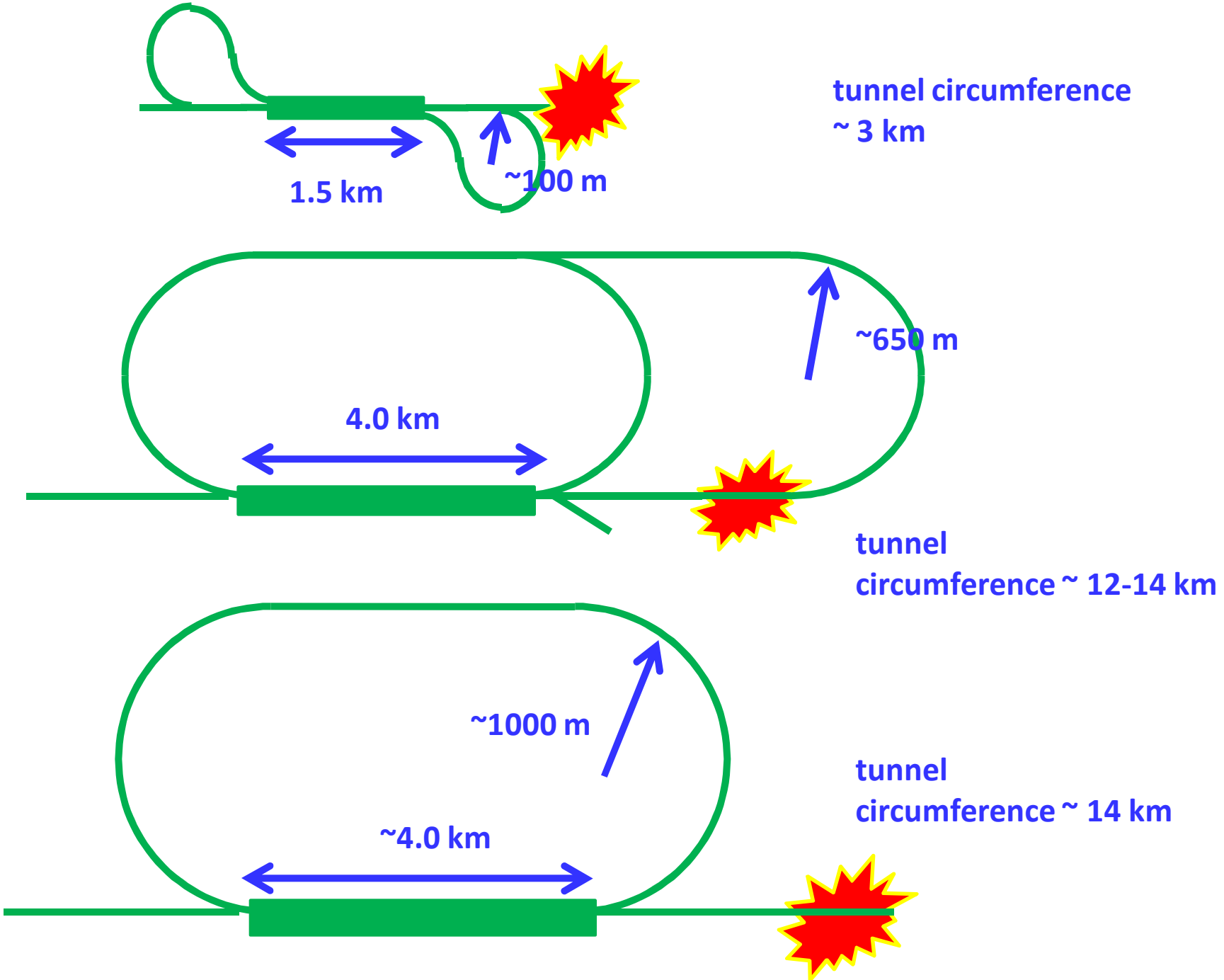
note that dogbone doubles the radius for the same energy loss!

"high luminosity"

60 GeV cw, 4 km long linac, arc radius 640 m (3% energy loss at 60 GeV), 13 MV/m, 6 access shafts

"high energy"

140 GeV pulsed, 4 km long linac, arc radius 1000 m (3% energy loss at 70 GeV), 31.5 MV/m, 6 access shafts


tunnel circumference
~ 3 km
1.5 km
~100 m
~650 m
4.0 km
tunnel
circumference ~ 12-14 km
~1000 m
tunnel
circumference ~ 14 km
~4.0 km

example parameters

	LHeC-RR	LHeC-RL high lumi	LHeC-RL 100 GeV	LHeC-RL high energy	ILC	XFEL
e^- energy at IP [GeV]	60	60	100	140	(2×)250	20
luminosity [10^{32} cm^{-2}s^{-1}]	29	29† (2.9‡)	2.2	1.5	200	N/A
bunch population [10^{10}]	5.6	0.19† (0.02‡)	0.3 (1.5)	0.2 (1.0)	2	0.6
e^- bunch length [μm]	~10,000	300	300	300	300	24
bunch interval [ns]	50	50	50 (250)	50 (250)	369	200
norm. hor.&vert. emittance [μm]	4000, 2500	50	50	50	10, 0.04	1.4
average current [mA]	135	7† (0.7‡)	0.5	0.5	0.04	0.03
rms IP beam size [μm]	44, 27	7	7	7	0.64, 0.006	N/A
repetition rate [Hz]	CW	CW	10 [5% d.f.]	10 [5% d.f.]	5	10
bunches/pulse	N/A	N/A	71430	14286	2625	3250
pulse current [mA]	N/A	N/A	10	10	9	25
beam pulse length [ms]	N/A	N/A	5	5	1	0.65
cryo power [MW]	0.5	20	4	6	34	3.6
total wall plug power [MW]	100	100	100	100	230	19

Example LHeC-RR and RL parameters. Numbers for LHeC-RL high-luminosity option marked by `†' assume energy recovery with $\eta_{ER}$=90%; those with `‡' refer to η_{ER}=0%. ILC and XFEL numbers are included for comparison. Note that optimization of the RR luminosity for different LHC beam assumptions leads to similar luminosity values of about 10^{33}cm^{-2}s^{-1}

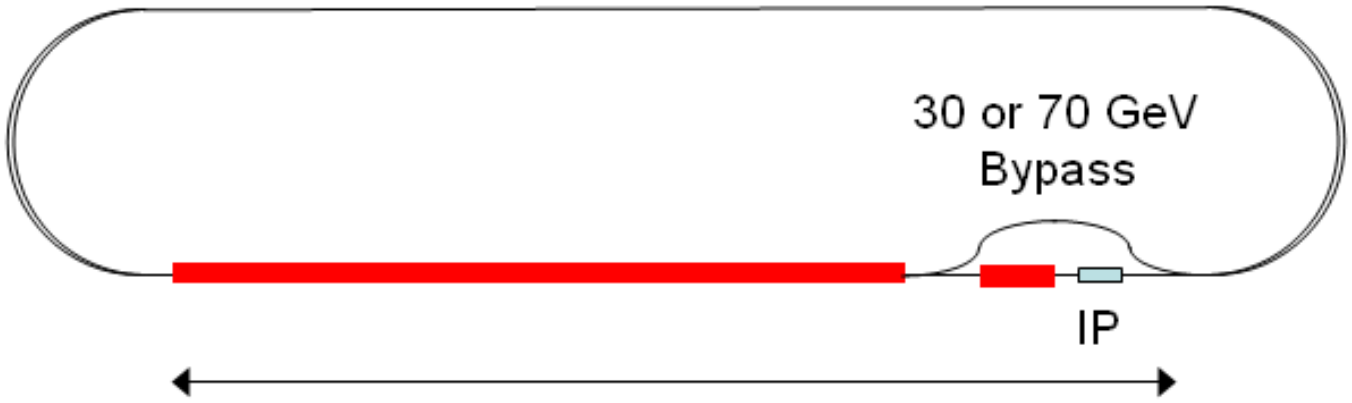
F.Z., PAC2009 & Divonne '09

(alternative) layouts from Chris Adolphsen, October 2009

Arc Radius = 120 m

Length = 1.5 + 4*.12 + 0.3 (IR?) = 2.3 km

Arc Radius = 700 m



Length = 3.9 + 0.3 + 0.3 (IR?) = 4.5 km

	Least Expensive	High Luminosity	High Energy
IP Energy (GeV)	60	60	140
Energy before IP Bypass (GeV)		58.3	138.3
Lum (10^32 cm^-2 sec^-1)	~ 2	~ 30	~ 2
Recover Beam Energy	No	Yes	No
Beam Duty	5% (1 ms, 50 Hz)	CW	5% (1 ms, 50 Hz)
Charge per bunch (10^10 e)	1.5	0.2	1.5
Bunch Spacing (ns)	250	50	250
Beam Current (mA)	9.6	6.4	9.6
Linac Gradient (MV/m)	31.5	13.0	31.5
Inj Energy	0.5	0.5	0.5
Dump Enregy	60	0.4	140
Pre-Bypass Energy Gain (GeV)	30.3	28.9	70.4
Post-Bypass Energy Gain (GeV)		1.7	1.7
Arc Layout	Dogbone	Half Circle	Half Circle
Max Arc Energy (GeV)	30.8	29.4	70.9
Arc Radius (m)	120	700	700
1st Pass Synch Loss (% Max E)	2.0	0.17	2.2
2nd Pass Synch Loss (% Max E)		2.72	
3rd Pass Synch Loss (% Max E)		0.17	
Total Synch Loss (% Max E)	2.0	3.1	2.2
Total Synch Loss (GeV)	0.0	1.8	3.0
Synch Emit Growth (microns)	50.6	0.02	3.5
Number of PreB RF Units (26 Cavities	38	86	86
RF Unit Length with Cold Boxes (m)	40	44	44
Number of ~4 MW Cryoplants	2	7	7
Linac Gap for Cryoplant (m)	12	12	12
Length of Pre-IP Linac (km)	1.5	3.9	3.9
Length of Post-IP Linac (km)		0.30	

from Chris Adolphsen's excel file

detailed parameters list

Some questions or comments (sent to Chris only last Saturday)

(1)The original plan was to keep the wall plug power constant equal to 100 MW. Chris' option #3 cannot have the same wall plug power as option #1. Could he/we easily **update the numbers and derive the luminosity expected, for each of the 3 cases, at 100 MW w-p power?**

(2) Which of the three configurations do the **cost and power estimates** of the file refer to ? Since ERL is mentioned, I assume it is for option #2. Estimated cost and power **for all three scenarios?**

(3) Why do we need to have **six access shafts for options #2 and #3?** Why could we not just have two shafts, one on either side of the linac? For the LHC, the cryoplants are separated by 3-4 km. Which part is the bottleneck?

(4) If the **total fill factor for XFEL and ILC**, computed over the full length of the linac, is much lower than the fill factor per optical cell, this must presumably be due to spare cavities and/or cells which do not accommodate cavities. Is there a recipe or guiding principle for the reason(s) and the magnitude of this reduction of the fill factor?

(5) **Which energy recovery efficiency has been assumed for scenario #2?**

(6) Should there perhaps a **factor of "2 pi" instead of "4"** for some of the length estimates in the excel file?

(7) **Consistency of arc radius definition?** [2.1, 3.0 and 2.2% loss of E_max?]

synergy with Higgs factory?

model:

Higgs physics with a gamma gamma collider based on CLIC-1 -"CLICHÉ"

D. Asner, H. Burkhardt, A. De Roeck, John R. Ellis, J. Gronberg,
S. Heinemeyer, M. Schmitt, D. Schulte, M. Velasco, F. Zimmermann,
Eur.Phys.J.C28:27-44,2003

$\gamma\gamma$ Higgs factory based on two LHeC cw ERLs

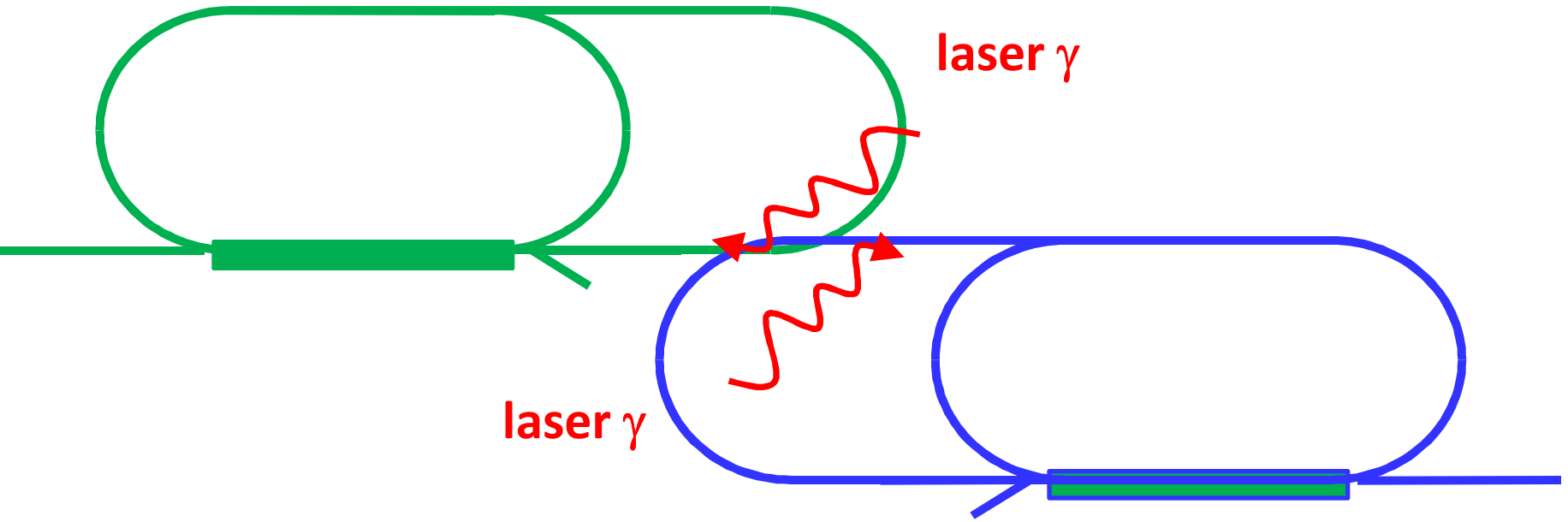


Table 1: *Example parameters for a CLIC 1 collider.*

variable	symbol	value	CLICHE	LHeC CW
total power consumption for RF	P	150 MW		ditto
beam energy	E	75 GeV		ditto
beam polarization	P_e	0.80		ditto
bunch population	N	4×10^9		cw
number of bunches per train	n_b	154		4x10^{16}/s
number of trains per rf pulse	n_t	11	7x10^{14}/s	(η_{ER}~0.9)
repetition rate	$f_{\rm rep}$	100 Hz		[7 mA]
rms bunch length	σ_z	30 μm		~300 μm
crossing angle	θ_c	$\geq$ 20 mrad		
normalised horizontal emittance	ϵ_x	1.4 μm		~5 μm
normalised vertical emittance	ϵ_y	0.05 μm		
nominal horizontal beta function at the IP	β_x^*	2 mm		~0.5 mm
nominal vertical beta function at the IP	β_y^*	20 μm		ditto
e^-e^- geometric luminosity	$\mathcal{L}$	$0.9–4.8 \times 10^{34}$ cm^{-2}s^{-1}		

summary

- work in progress
- parameters of 3 linac configurations
  to be further discussed with Chris
- + input from CERN cryo & RF experts
  for infrastructure requirements(?)
- goal: improved understanding &
  parameter convergence

- Higgs factory with ~10^{34} $cm^{-2}s^{-1}$ luminosity
  based on two LHeC cw ERLs