LHeC Ring Ring **Injector**

As previously presented and discussed
16/11/2007, DIS 08/04/2008, Divonne 2008, Divonne 2009,
LHeC design meetings on 02/03/2010 and 31/08/2010

The LHeC e-ring requires a new 10 GeV injector, 2.e10 particles / bunch

much less demanding than for LEP : 1/2 energy, 1/20 bunch intensity

5 bunches / sec enough to fill the e-ring with 2808 bunches in < 10 min

the 0.6 GeV pre-injector could be a direct copy of LIL + EPA

Acknowledgement : input and advice from Louis Rinolfi

LHeC RR injector choice

- Basic need : e+,e- injection energy 10 GeV, with rather modest intensity requirements

- LHeC ring uses SC cavities; a lot of cryogenics infrastructure exists for the LHC
  Rather natural to also consider SC technology for the injectors
  Low power needs for the injector --- can use TESLA/XFEL/ILC technology (20MV/m)
  which allows a very compact injector

- LHeC ring, 60 -70 GeV requires ~ 1 GV RF to compensate for the 0.7 GeV energy loss in Syn.Rad.

- Injector could in principal use a straight 10 GeV linac as injector
  at 20MV / m gradient this would be 500 m long

- Reduce cost by recirculation - at few GeV these can be rather compact

for the CDR, consider a SC-RF injector with recirculation

10 GeV injector inspired by ELFE@CERN

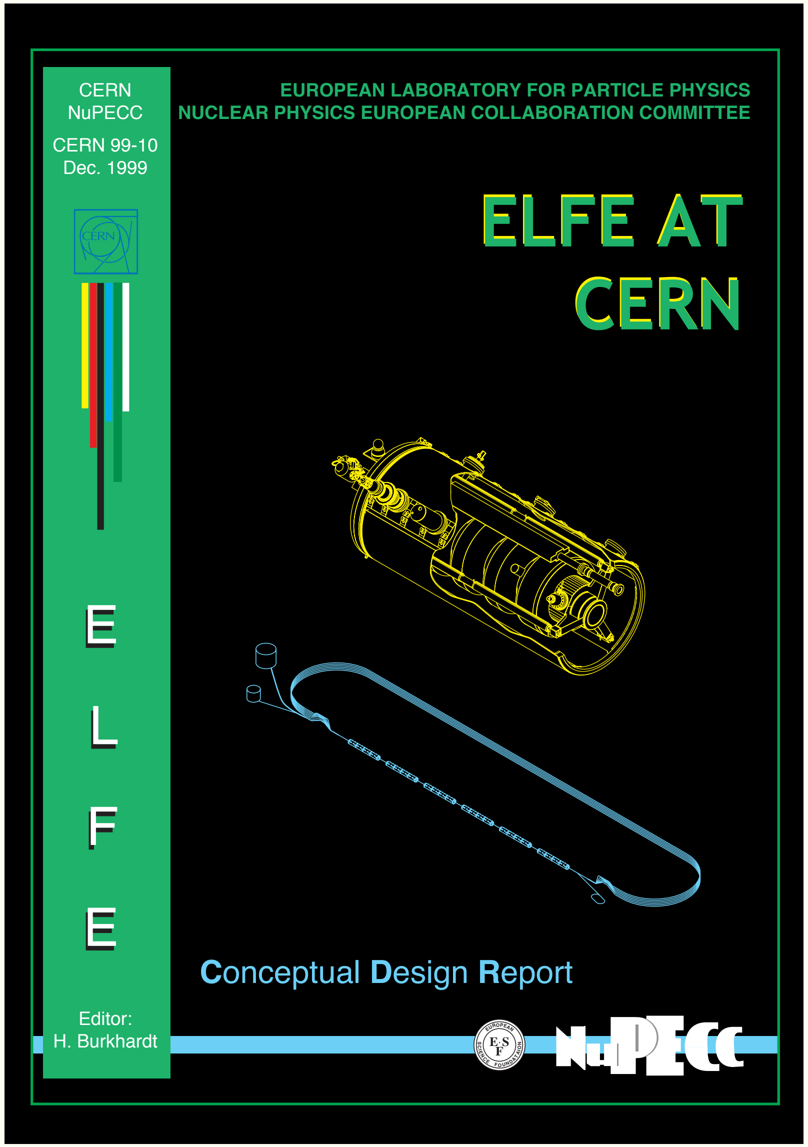


Table 1: ELFE performance parameters.

Top energy	25 GeV
Beam current on target	100 μA
Beam power on target	2.5 MW
Injection energy	0.8 GeV
Number of passes	7
Energy gain per pass	3.5 GeV
Relative r.m.s. momentum spread at top energy	$\leq 10^{-3}$
Emittance at top energy	$\leq$ 30 nm
Bunch repetition time on target	2.8 ns

Table 2: Estimated capital expenditure for the construction of ELFE at CERN.

System	MCHF	MCHF	MCHF
Injection	20.400		
RF system	10.868		
Cryogenics	63.000		
Magnets	55.209		
Vacuum	19.410		
Beam diagnostics	9.400		
Power converters	11.165		
Control system	10.000		
Accelerator components		199.452	
Electrical power distribution	29.031		
Civil engineering	109.700		
Experimental hall(s)	31.200		
Cooling, ventilation, etc.	25.773		
Access control, etc.	2.050		
Conventional construction		197.414	
Total			397.206

with LEP RF for free

downscaled ELFE

ELFE@CERN design,

to some extend based on CEBAF

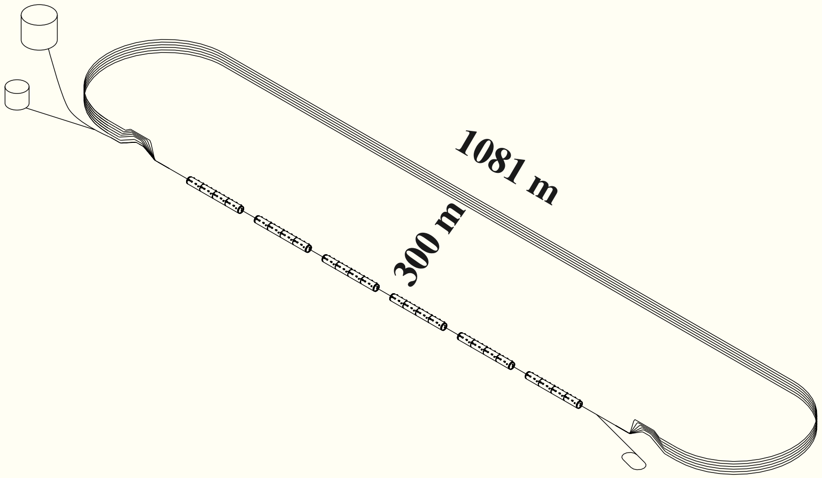
f_{rf} = 352 MHz, gradient 8 MV / m

V_{rf} = 3.5 GV, 72 rf-modules

7 passes (last at 21.5 GeV)

L = 3924 m of which Linac 1081 m

ϱ = 56.9 m



LHeC injector

f_{rf} ~ 1.3 GHz, 20 MV/m all inclusive as ILC

Linac L = 156 m 7× shorter

0.6 GeV e+/e- EPA LEP pre-injector/ accumulator

V_{rf} = 3.13 GV, 3 passes ; last 6.9-10 GeV

energy loss scaling E^4

allows for much shorter bends

6.9 GeV, ϱ = 2 m

gives 1% energy loss

and 10^{-3} energy spread

Pre-injector Accumulator

Accumulator needed for e+

also helps to get 2×10^{10} for e-

the old LEP-EPA would do :

from Vol.I LEP design report:

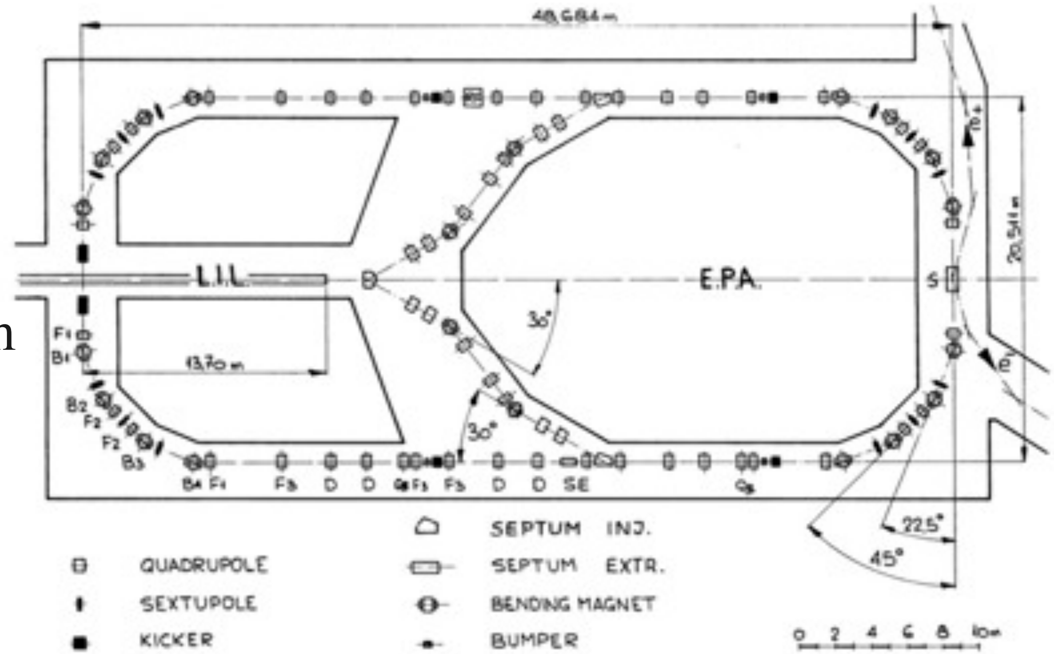
E = 0.6 GeV, Circumference = 125.665 m

8 bunches, total 2.e11

or **2.5e10 / bunch**

1.14s cycle length

would allow to fill the e-ring in **7 minutes**



Magnet specification for injectors :

a little early to fix details -- but the old EPA magnets would do, also for recirculator

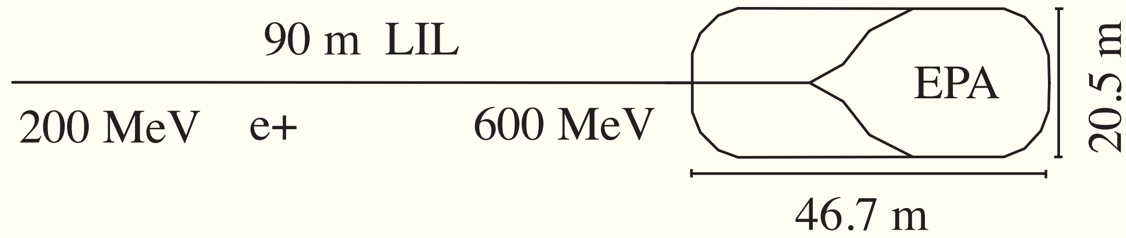
LHeC injector with recirculation

600 MeV complex

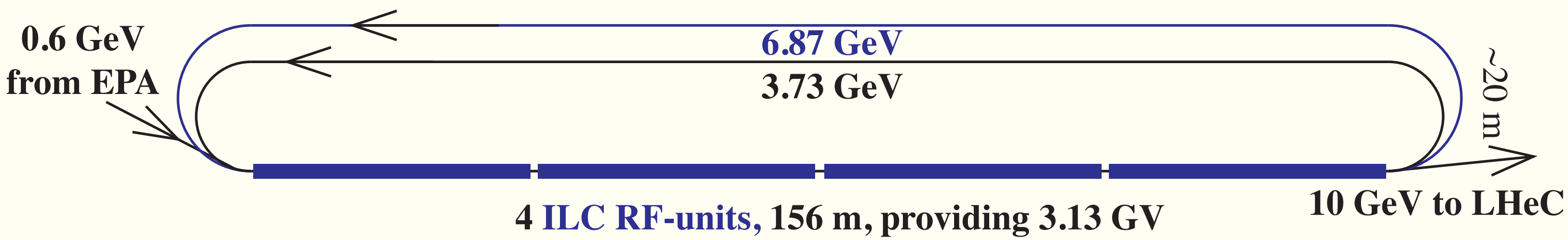
e- source

e+ convertor

accumulator



followed by the acceleration from 0.6 GeV to 10 GeV for injection into the LHeC



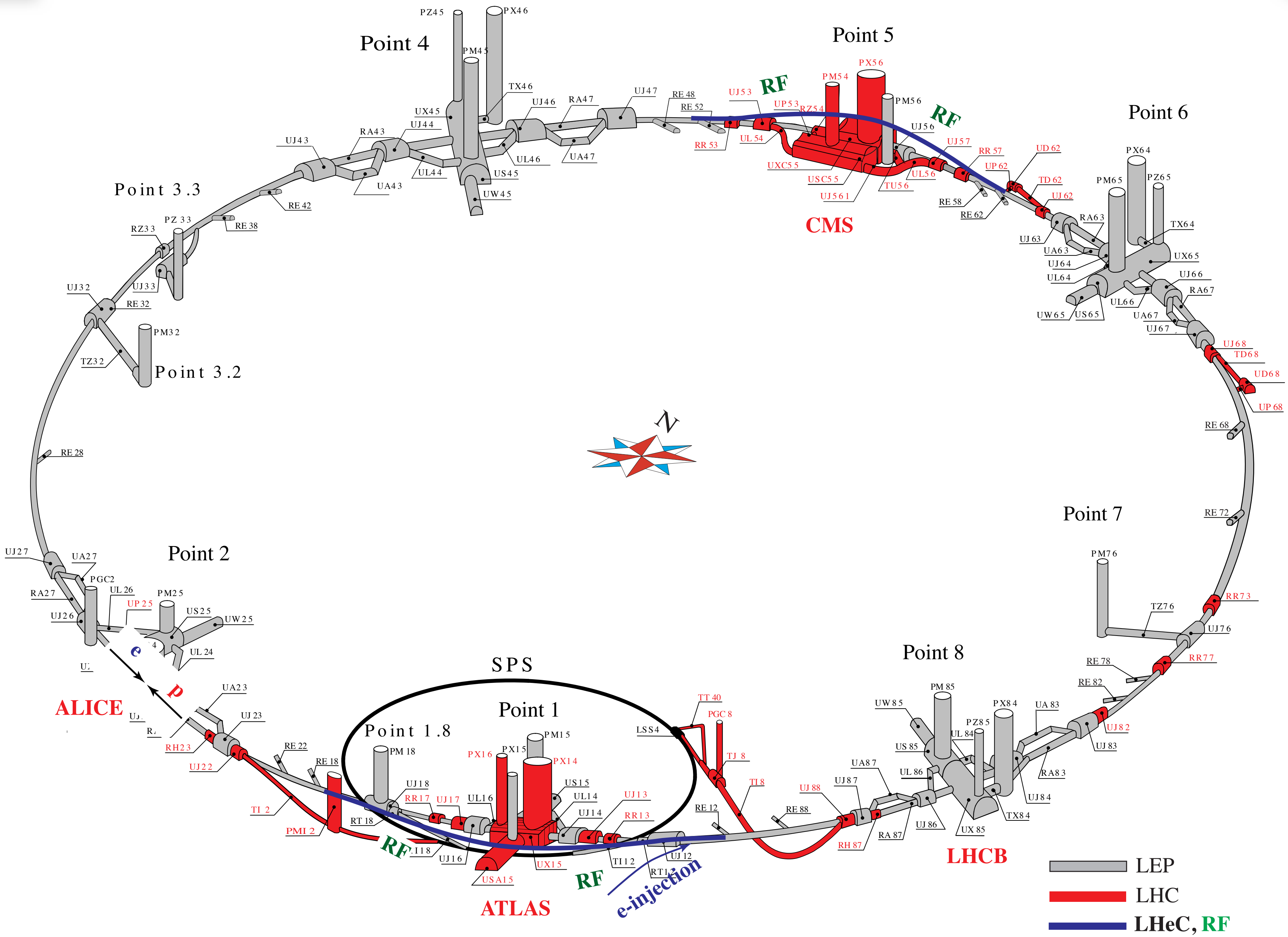
just 2 re-circulations, 3 passages through the LINAC

RF gradient/length from [ILC reference design report]

ILC : 38 m long RF-units which include one quad

ILC needs 560 units, 4 ILC units needed here

LHeC RR layout with bypasses, RF and injection



Conclusion

- the LHeC RR requires a new 10 GeV injector with relatively modest requirements

For the CDR, describe a possible solution, built by a combination of known designs :

- a straight copy of the LIL+EPA e+, e- pre-injector
- a largely downscaled and simplified ELFE accelerator to 10 GeV,
- using only 2 re-circulations
- a compact rf-section using 4 ILC rf-modules

Backup Slides

Injection energy into the LHeC e-ring

LEP had in the beginning 20 GeV and later 22 GeV injection energy

reason : TMCI limit (main large ring limitation - Panofsky-Wenzel)

$$I_{th} = \frac{\omega_s E}{e \sum \beta\, k_\perp(\sigma_s)}$$

with

$\omega_s = 2\pi\, Q_s\, f_{rev}$

$k_\perp = 5.5$ kV / pCm (for $\sigma_z = 1$cm, 20% higher at 5mm)

$\sum \beta_y\, k_\perp = 40$ m 10^{15} V/Asm

E = 22 GeV $Q_s = 0.12$

$I_{th} = 850\ \mu A$ predicted limit at **$N_e = 4.7\times10^{11}$**

Ref.: A. Hofmann, B. Zotter Cham. 94, Cham 97,

LEP impedance, measured with coh. tune shift method, see SL-MD-Note-231, H.Burkhardt et al., 1997

rather broad band 2 GHz, mostly from cavities (+ a bit from bellows), rather x/y symmetric

For LHeC we only require $N_e = 2\times10^{10}$

at similar impedance (less from cavities, more from smaller pipe)

at slightly lower Qs :

Not likely to come close to the TMCI limit.

Could therefore inject at much reduced beam energy compared to LEP

However few GeV probably not practical for magnet stability; would also required strong damping wiggler.

For the CDR : take an injection energy of **$E_{inj} = 10$ GeV**