# Requirements for the Injector complex for RR

**From accelerator workpackages for the LHeC CDR plan O.B., M.K. of 11/02/2010 :**

**1.4.) Injector complex design:** CERN contact: Helmut Burkhardt

i. **Electron and positron source design**
ii. **Injector ring design**

Conclusion from previous discussions, as presented and documented at DIS 2008 proc. and EPAC 2008 wepp052 and my talk at Divonne 2008 :

- LEP injectors gone
- SPS should not be used as lepton injector, (impedance)

$\Rightarrow$

LHeC RR needs a new injector - but the requirements are rather modest, and existing designs (example ELFE) can be (down)-scaled to meet these

Request for input and help :
principle ok from Louis Rinolfi
further help and RR, LR collaboration on injectors would be very useful !

# Which particles and intensity ?

**baseline : unpolarized electrons**

**possible upgrade or stage 2 : unpolarized positrons**

**very modest bunch intensity (see interactive parameter list here )**

**LEP2 $4.2\times10^{11}$**

**LHeC RR $1.4\times10^{10}$ 30 times less than in LEP,** 2.24 nC

**to have some margin, aim for $2\times10^{10}$ = 3.2 nC from the injectors**

**allow to fill the 2808 bunches in the ring,** 70 mA circulating in LHeC ring

**filling < 10 min ( 5 bunches / sec,** 16 nA )

**LHeC RR :**

**polarization would not come from injectors, but from natural transverse polarization of the particles stored in the ring**

# 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 $Q_s = 0.12$

$I_{th} = 850$ μA predicted limit at **$N_e = 4.7 \times 10^{11}$**

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 $N_e = 2 \times 10^{10}$**

**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 a first round of estimates : let us assume an injection energy of $E_{inj} = 10$ GeV**

# LHeC injector, possible schemes

**Basically : e-, injection energy 10 GeV, with very modest intensity requirements**

**LHeC ring uses SC cavities.**

**Natural choice would be to use the same technology for the injectors.**

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

**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**

# 10 GeV injector inspired by ELFE@CERN

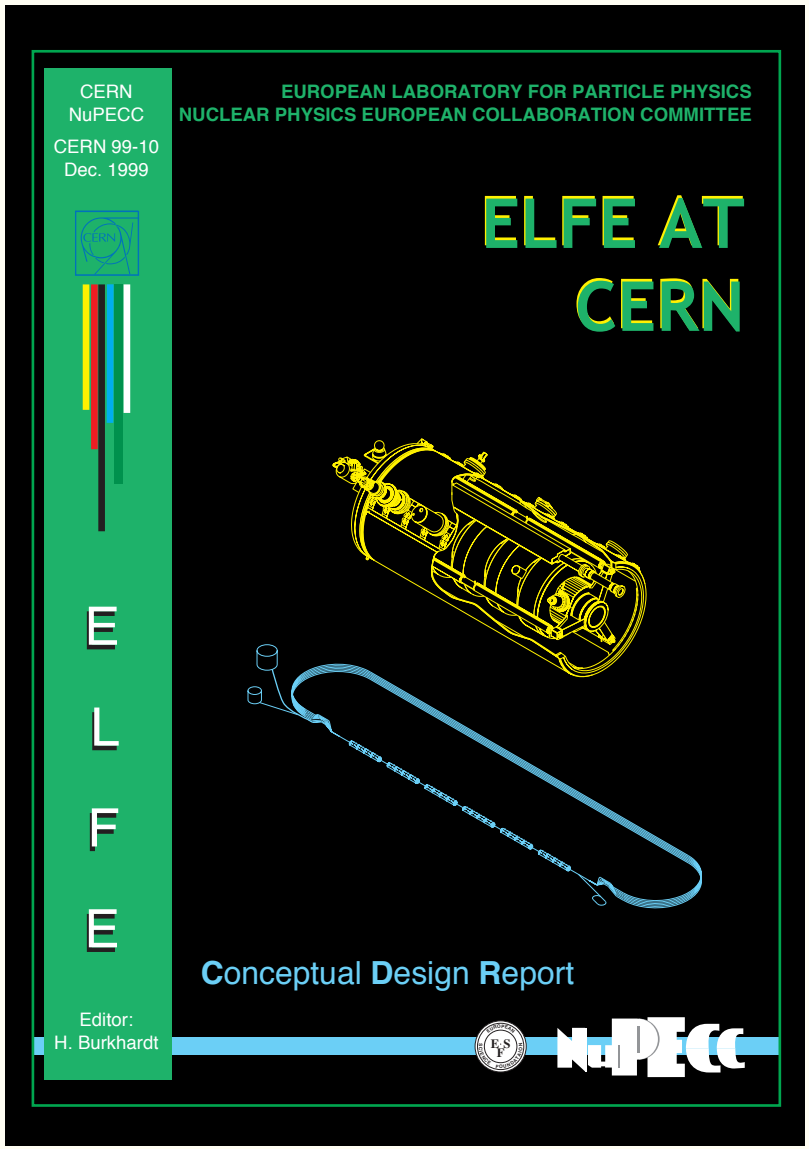



Table 1: ELFE performance parameters.

| | |
|---|---|
| Top energy | 25 GeV |
| Beam current on target | 100 $\mu$A |
| 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

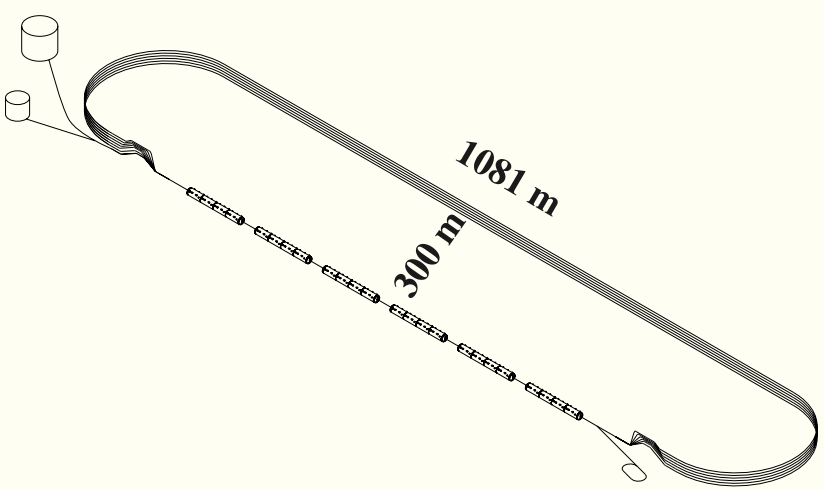
$f_{rf}$ = 352 MHz, gradient 8 MV / m

$V_{rf}$ = 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 GHz, gradient 20 MV/m

Linac L = 150 m 7× shorter

$V_{rf}$ = 3 GV, 3 passes ; last 7-10 GeV

energy loss scaling $E^4$

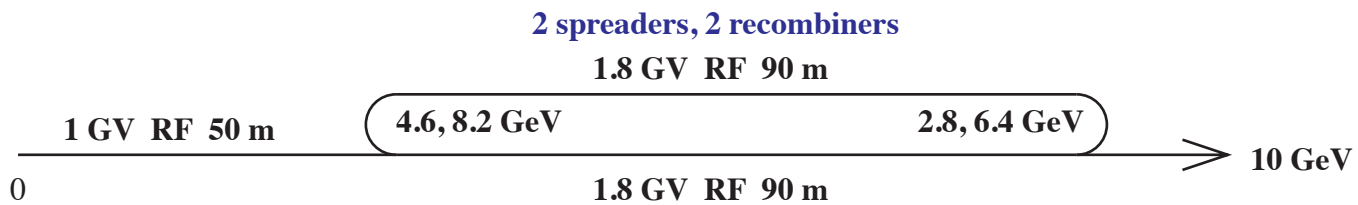
allows for much shorter bends

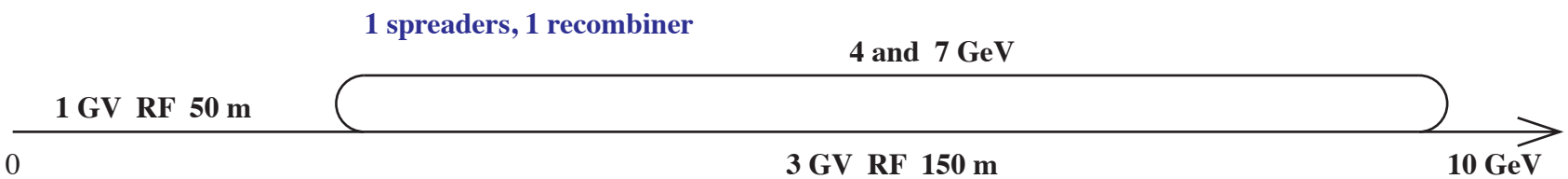
7 GeV, ϱ = 2 m

gives 1% energy loss

and $10^{-3}$ energy spread

# Injector options with recirculation

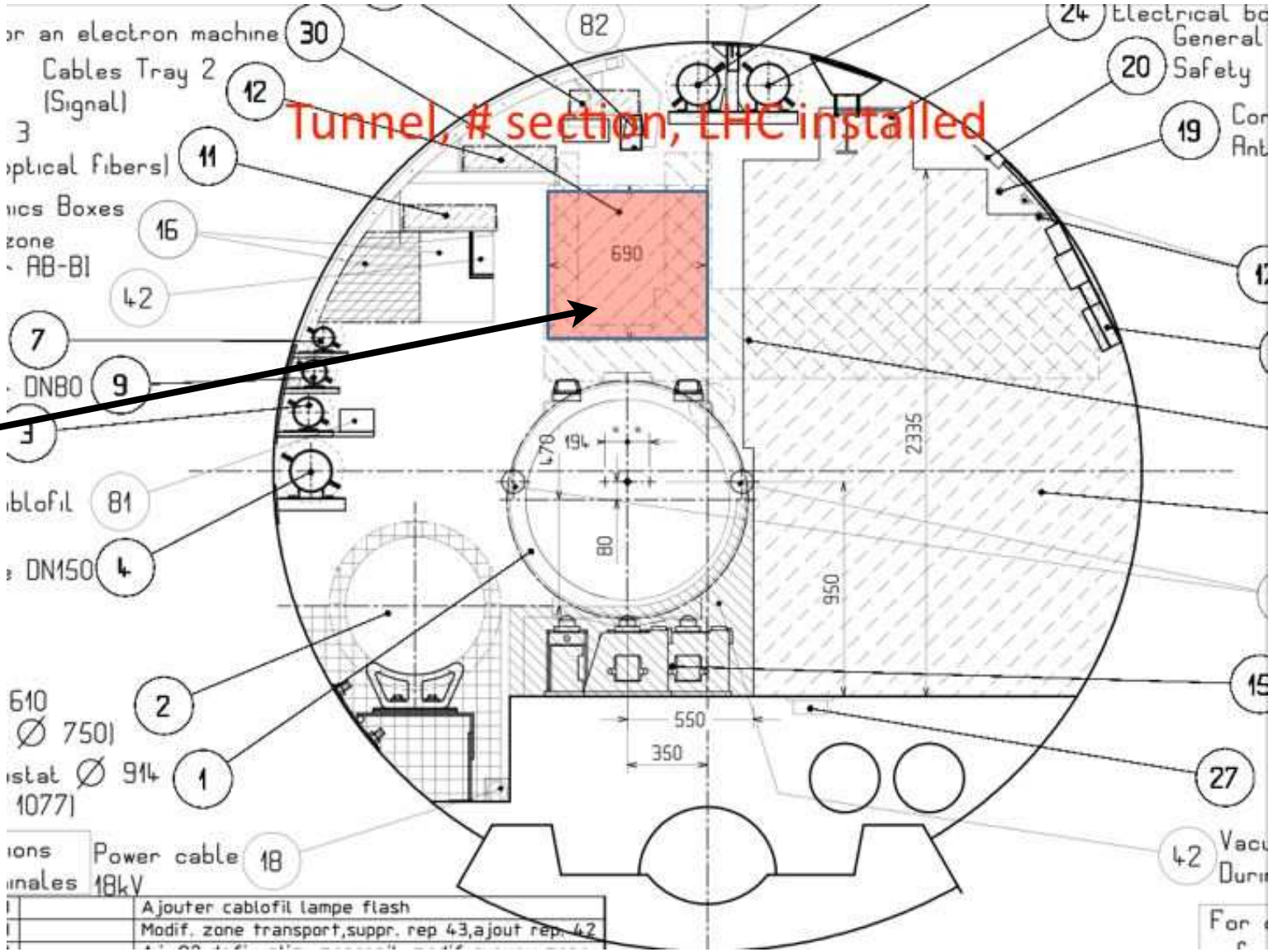



**gaining a lot with just 2 re-circulation, 3 passages through the LINAC**

# Where to inject ?

**inject from outside**



# Injection where ? Several possibilities. Bypass ?