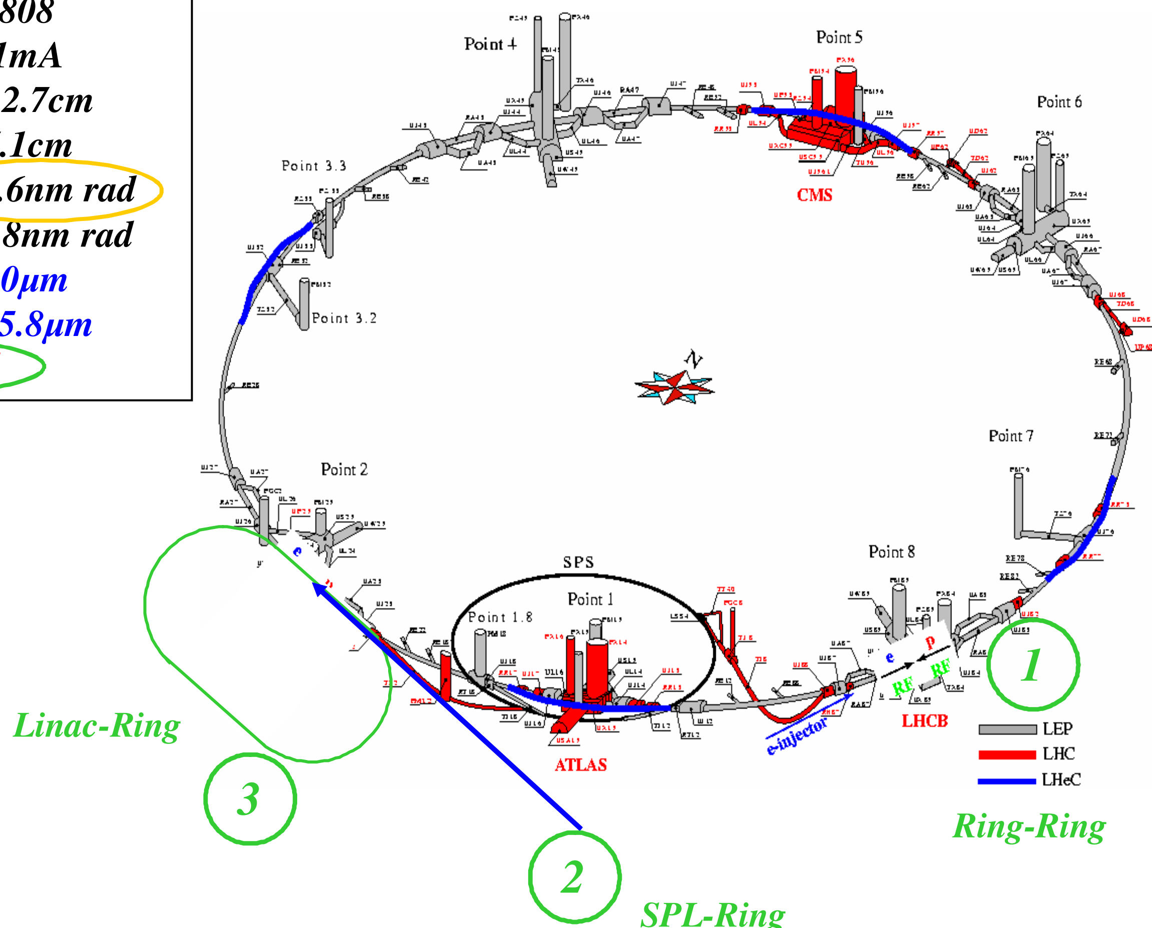
Status of the LHeC Parameters

1.) Base line:

Standard	Protons	Electrons
Parameters	$Np=1.15*10^{11}$	$Ne=1.4*10^{10}$
	$Ep=7$ TeV	$Ee=70$ GeV
	$nb=2808$	$nb=2808$
	$Ip=582mA$	$Ie=71mA$
Optics	$\beta_{xp}=180cm$	$\beta_{xe}=12.7cm$
	$\beta_{yp}=50cm$	$\beta_{ye}=7.1cm$
	$\varepsilon_{xp}=0.5nm$ rad	$\varepsilon_{xe}=7.6nm$ rad
	$\varepsilon_{yp}=0.5nm$ rad	$\varepsilon_{ye}=3.8nm$ rad
Beam size	$\sigma_{xp}=30\ \mu m$	$\sigma_{xe}=30\mu m$
	$\sigma_{yp}=15.8\ \mu m$	$\sigma_{ye}=15.8\mu m$
Luminosity	$8.2*10^{32}\ cm^{-2}\ s^{-1}$	



2.) Synchrotron Radiation

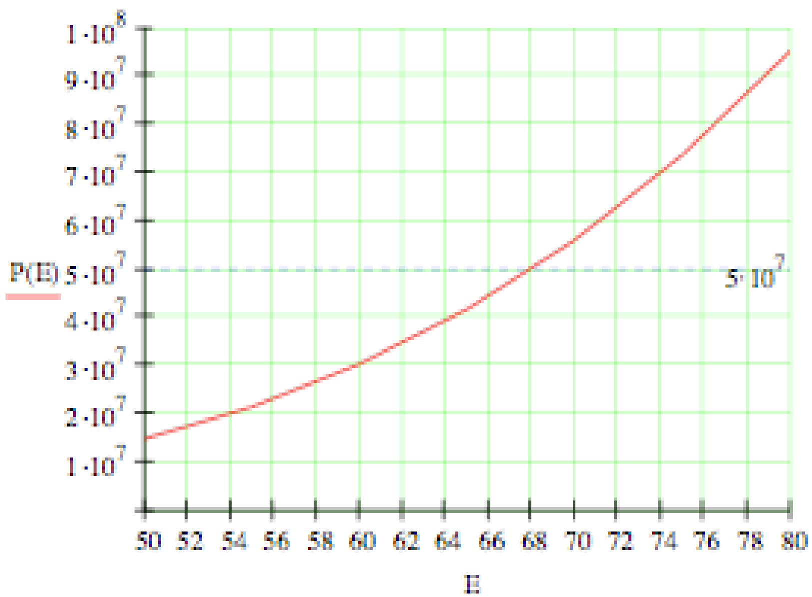
Energy loss per turn:

$$E_{turn} = \frac{e^2}{3\,\varepsilon_0} * \frac{\gamma^4}{\rho}$$

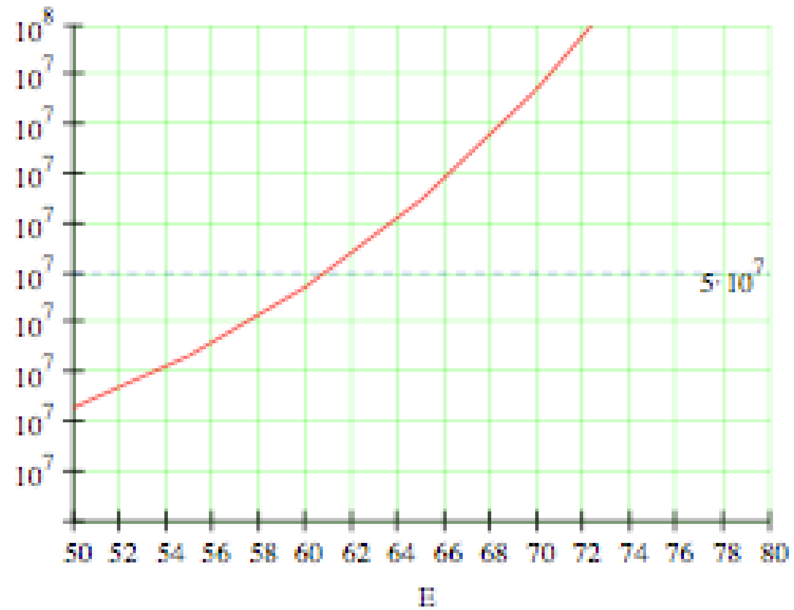
Synchrotron Radiation Power:

$$P_\gamma = \frac{e^2 c}{6\pi\,\varepsilon_0} * \frac{\gamma^4}{\rho^2} * N_e$$

	1.73km	2.7km
75 GeV	120	73
70 GeV	90	56
60 GeV	50	30
50 GeV	23	14



ρ=2700m

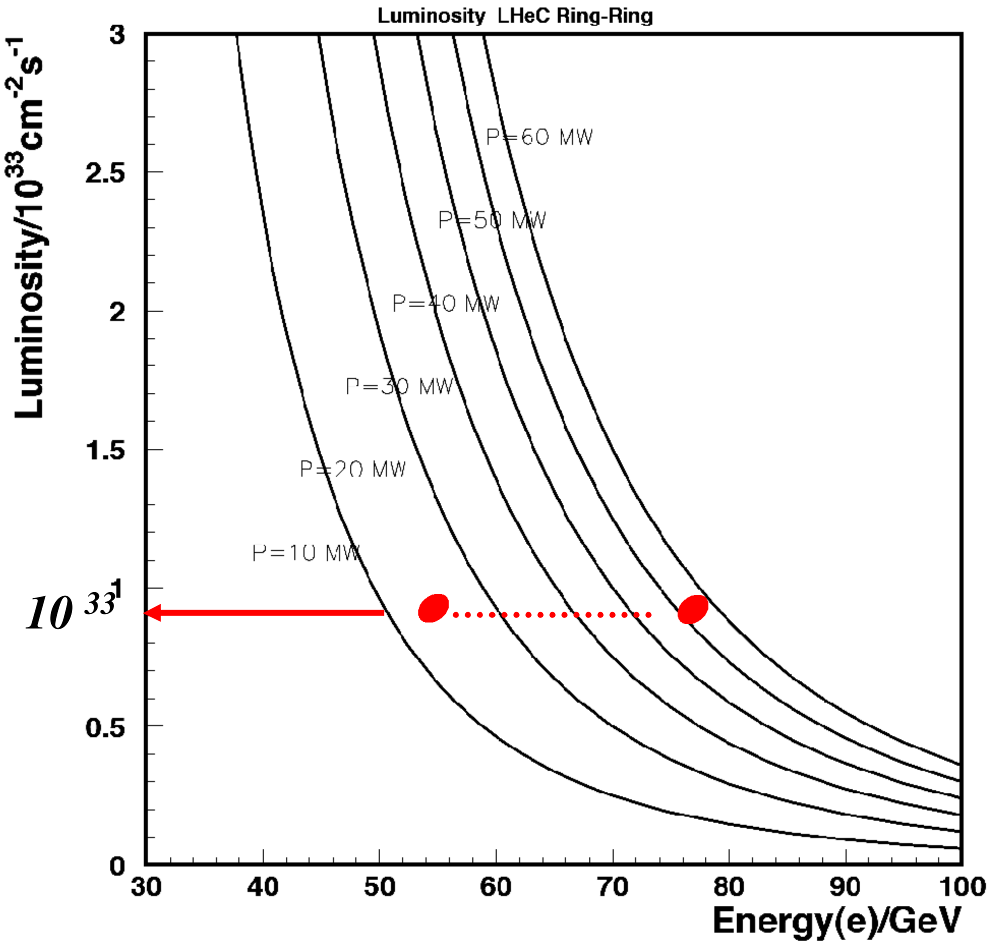


ρ=1730m

Luminosity Ring Ring & Performance Limit

Design values limited by 50 MW available rf power
--> $E_e \approx 70$ GeV.

$$L = \frac{\sum_{i=1}^{n_b} (I_{ei} * I_{pi})}{e^2 f_0 2\pi \sqrt{\sigma_{xp}^2 + \sigma_{xe}^2} * \sqrt{\sigma_{yp}^2 + \sigma_{ye}^2}}$$



Max Klein

Luminosity Performance Limit:
E_e, I_e due to Synchrotron Radiation

$$P_\gamma = \frac{e^2 c}{6\pi\, \varepsilon_0} * \gamma^4 * r^{-2} * N_e$$

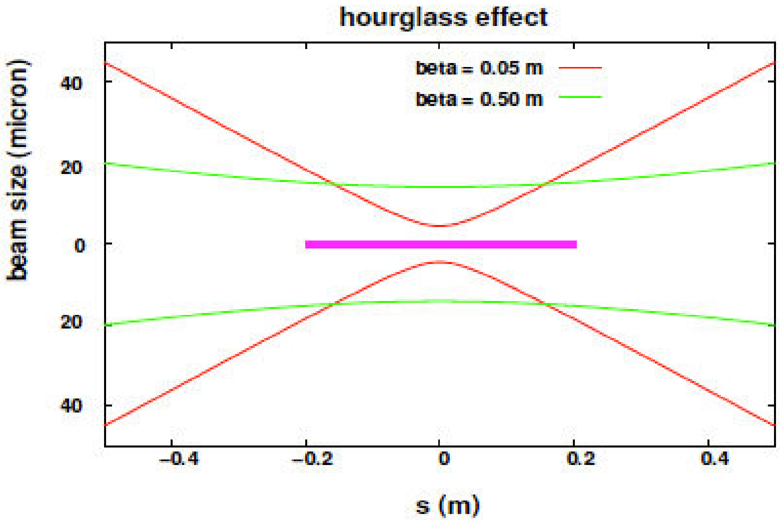
10^{33} can be reached in RR

E_e = 60 GeV ↔ P_{syn} = 30MW
E_e = 70 GeV ↔ P_{syn} = 56MW * 2

klystron efficiency: 50%

Overall power consumption:
limited to 100MW

3.) Hour glass effect - long bunches



Reduction of lumi due to changing betas at the IR

$$R = \frac{L}{L_0} = \int_{-\infty}^{\infty} \frac{e^{-t^2}}{\sqrt{1+\frac{t^2}{t_x^2}} * \sqrt{1+\frac{t^2}{t_y^2}}} \sqrt{\pi} dt$$

$$t_x^2 = \frac{2*\left(\sigma_{xp}^2 + \sigma_{xe}^2\right)}{\left(\sigma_{zp}^2 + \sigma_{ze}^2\right)*\left(\sigma_{xp}^2/\beta_{xp}^2 + \sigma_{xe}^2/\beta_{xe}^2\right)} \approx 10$$

$$t_y^2 \approx 1.7$$

$$\sigma_z \approx 8cm \quad \rightarrow \quad R \leq 15\%$$

4.) Crossing angle:

Ideal luminosity:

$$\boldsymbol{L} = \frac{\sum_{i=1}^{n_b} (\boldsymbol{I}_{ei} * \boldsymbol{I}_{pi})}{e^2 f_0 2\pi \sqrt{\sigma_{xp}^2 + \sigma_{xe}^2} * \sqrt{\sigma_{yp}^2 + \sigma_{ye}^2}}$$

Loss factor due to crossing angle:

$$S = \frac{1}{\sqrt{1 + \left(\frac{\sigma_s}{\sigma_x} \tan\frac{\phi}{2}\right)^2}} \approx \frac{1}{\sqrt{1 + \left(\frac{\sigma_s}{\sigma_x} \frac{\phi}{2}\right)^2}}$$

$$S \approx 50\%$$

For a crossing angle of 1.5 mrad …

crab cavities would be a good idea.

5.) Beam Beam tune shift:

Tuneshift Limit:

$$\Delta \nu_{xe} = \frac{\beta_{xe} r_e}{2\pi \gamma_e} * \frac{N_p}{\sigma_{xp}(\sigma_{xp} + \sigma_{yp})}$$

$$E_e = 70\,GeV$$

Experience:

LEP $\Delta\nu_e = 0.048$

LHC-B $\Delta\nu_p = 0.0037$

HERA $\Delta\nu_e = 0.051$
$\Delta\nu_p = 0.0022$

Standard Parameter	Protons	Electrons	
	$Np=1.15*10^{11}$	$Ne=1.4*10^{10}$	nb=2808
	Ip=582 mA	Ie=71mA	
Optics	βxp=180 cm	βxe=12.7 cm	
	βyp= 50 cm	βye= 7.1 cm	
	εxp=0.5 nm rad	εxe=7.6 nm rad	
	εyp=0.5 nm rad	εye=3.8 nm rad	
Beamsize	σx=30 µm	σx=30 µm	
	σy=15.8 µm	σy=15.8 µm	
Tuneshift	Δνx=0.00055	Δνx=0.033	
	Δνy=0.00029	Δνy=0.036	
Luminosity	$L=8.5*10^{32}$		

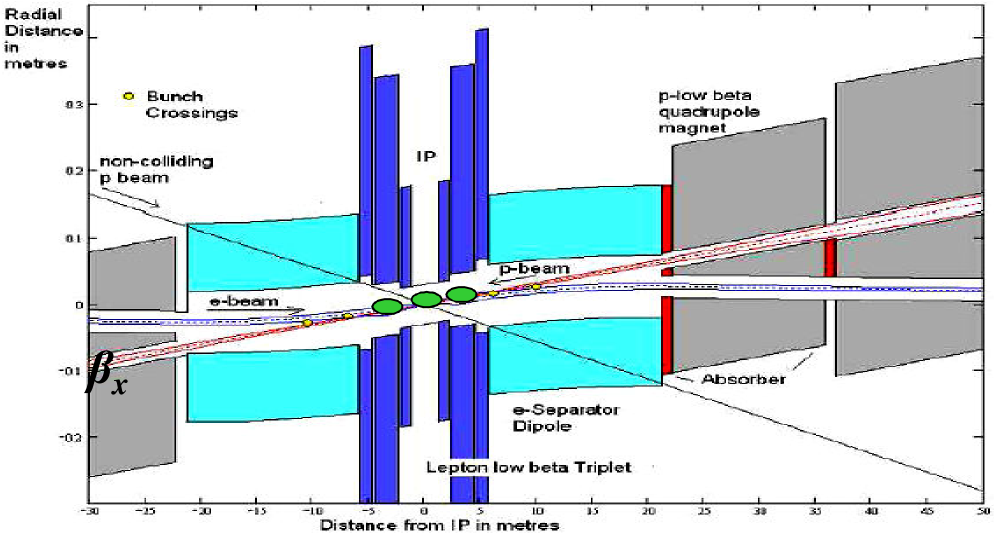
… no problems expected

except long range interactions … to be studied

6.) the crossing angle:
in the end the source of many problems

First parasitic crossing: s=3.75m

$$\varepsilon_{ex} = 7.6\,nm$$
$$\varepsilon_{px} = 0.5\,nm$$



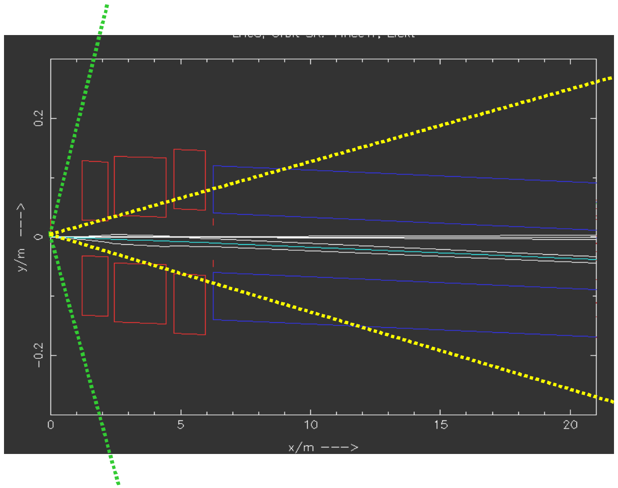
F. Willeke

	β_x	β_y	σ_x	σ_y	
S=3.75m	10m	24m	0.07mm	0.11mm	p
	135m	98m	1.01mm	0.61mm	e

Separation: $5\sigma_p + 5\sigma_e$ ***=0.35mm+ 5mm ≈5.5 mm***

→ ***X-angle ≈ 1.4 mrad***

7.) finally the 1 º option



	E [eV]	ε_x	ε_y	n_b	$L_{b\,[m]}$	f	N
p	7.00E+012	5.00E-010	5.00E-010	2808	7.50E-002	1.12E+004	1.15E+011
e	7.00E+010	7.60E-009	3.80E-009	2808	7.00E-003	1.12E+004	1.40E+010

	L(0)	θ [radians]	L(θ)	β^*_x [m]	β^*_y [m]	σ_x [m]	σ_y [m]	l* [m]
10˚	8.48653E+32	1.50E-003	4.50E+032	0.127	0.071	7.97E-06	5.96E-06	1.2
1˚ (QB)	1.60241E+31	1.44E-003	8.65303E+30	0.628649638	0.348263254	6.91E-05	3.64E-05	6.2

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