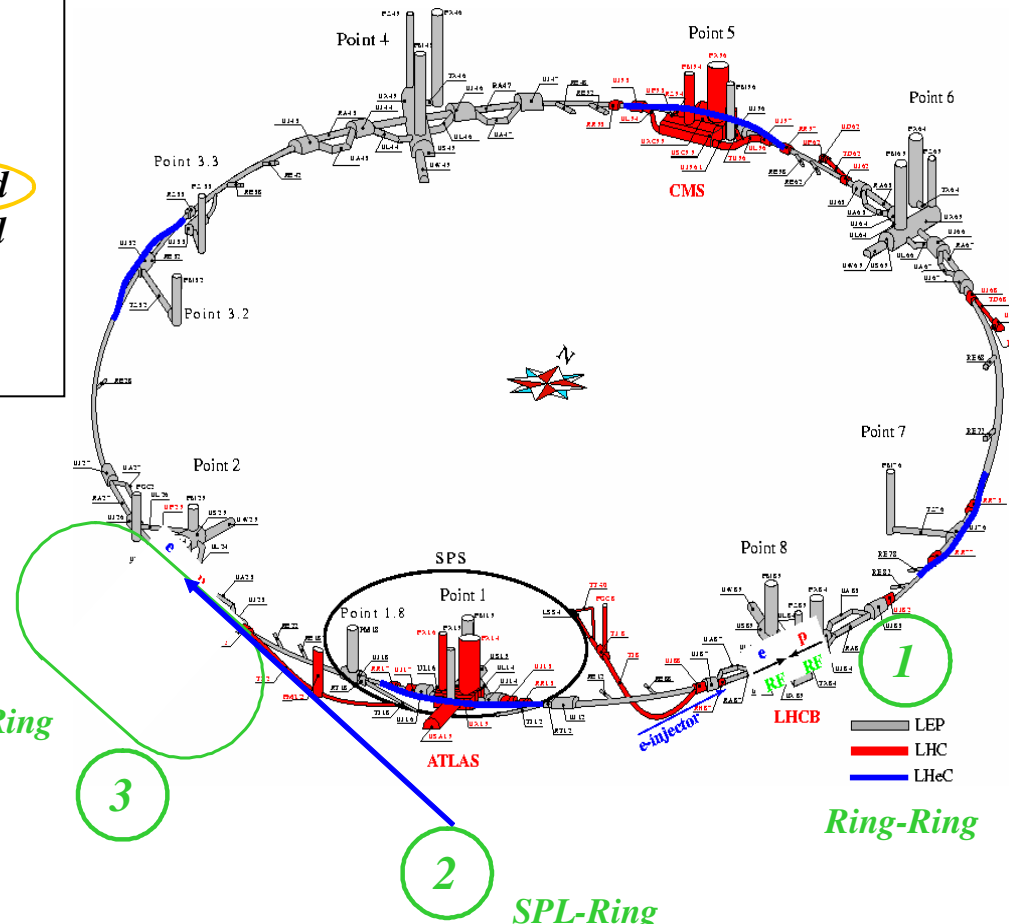


# Status of the LHeC Parameters

## 1.) Base line:

Standard Parameters	Protons	Electrons
	$N_p = 1.15 \cdot 10^{11}$	$N_e = 1.4 \cdot 10^{10}$
	$E_p = 7 \text{ TeV}$	$E_e = 70 \text{ GeV}$
	$nb = 2808$	$nb = 2808$
	$I_p = 582 \text{ mA}$	$I_e = 71 \text{ mA}$
Optics	$\beta_{xp} = 180 \text{ cm}$	$\beta_{xe} = 12.7 \text{ cm}$
	$\beta_{yp} = 50 \text{ cm}$	$\beta_{ye} = 7.1 \text{ cm}$
	$\epsilon_{xp} = 0.5 \text{ nm rad}$	$\epsilon_{xe} = 7.6 \text{ nm rad}$
	$\epsilon_{yp} = 0.5 \text{ nm rad}$	$\epsilon_{ye} = 3.8 \text{ nm rad}$
Beam size	$\sigma_{xp} = 30 \mu\text{m}$	$\sigma_{xe} = 30 \mu\text{m}$
	$\sigma_{yp} = 15.8 \mu\text{m}$	$\sigma_{ye} = 15.8 \mu\text{m}$
Luminosity	$8.2 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$	



## 2.) Synchrotron Radiation

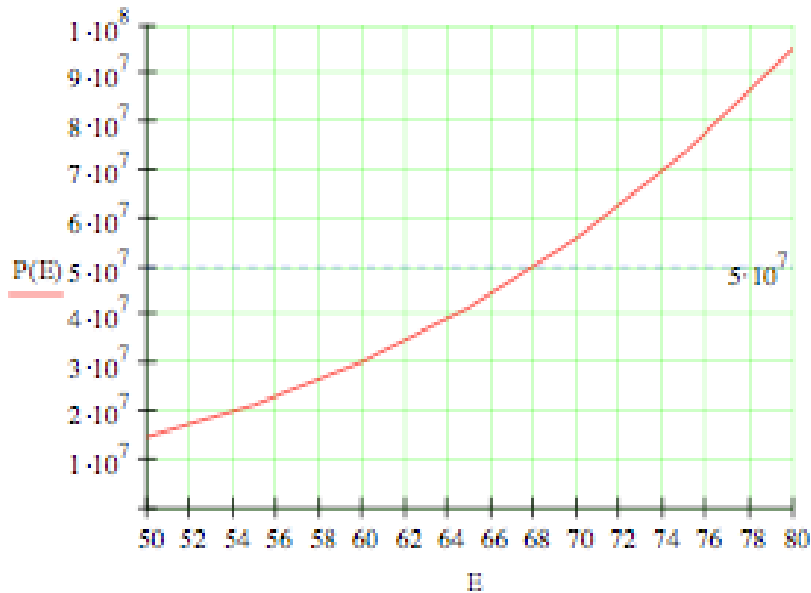
**Energy loss per turn:**

$$E_{turn} = \frac{e^2}{3 \epsilon_0} * \frac{\gamma^4}{\rho}$$

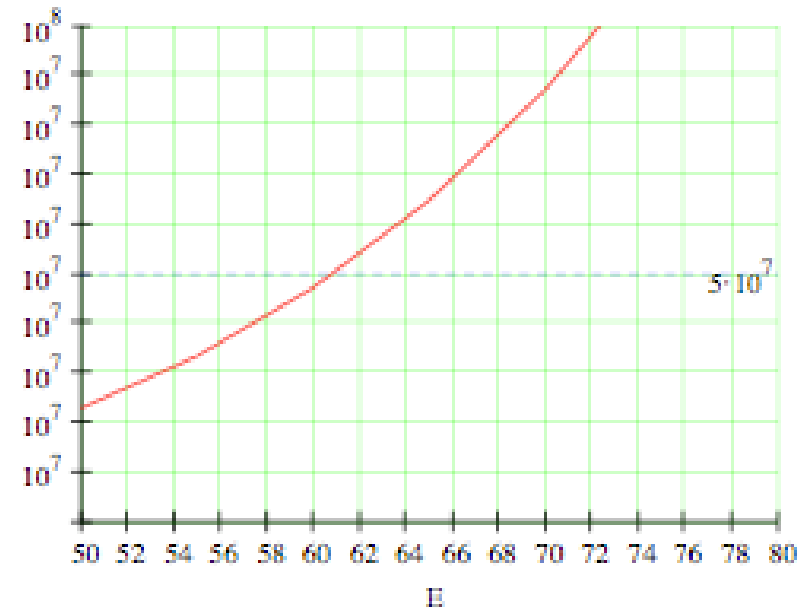
**Synchrotron Radiation Power:**

$$P_\gamma = \frac{e^2 c}{6 \pi \epsilon_0} * \frac{\gamma^4}{\rho^2} * N_e$$

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



$\rho=2700m$

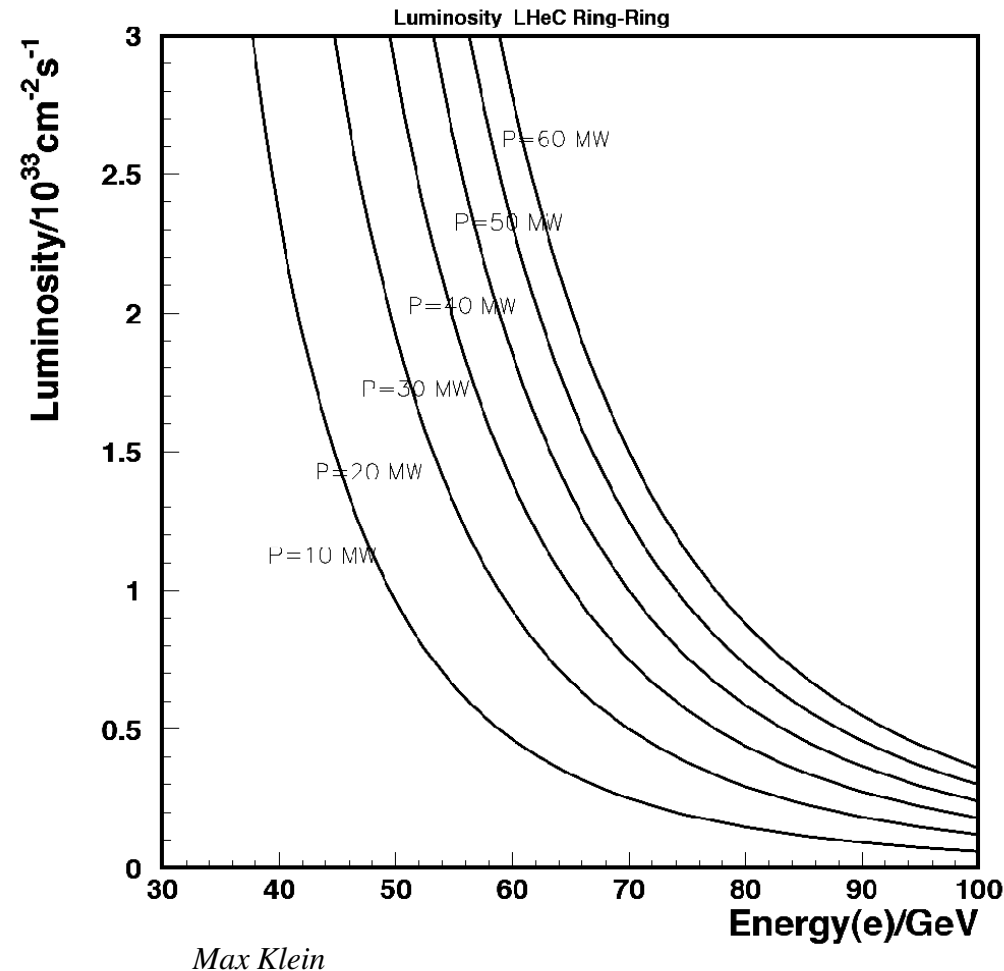


$\rho=1730m$

# Luminosity Ring Ring & Performance Limit

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

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



**Luminosity Performance Limit:**  
 $E_e, I_e$  due to Synchrotron Radiation

$$P_\gamma = \frac{e^2 c}{6\pi \epsilon_0} * \gamma^4 * r^{-2} * N_e$$

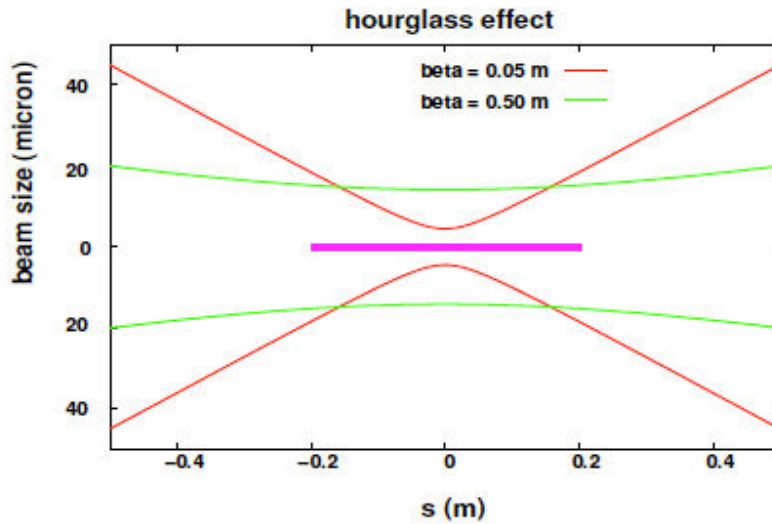
$10^{33}$  can be reached in RR

$E_e = 60$  GeV  $\leftrightarrow$   $P_{syn} = 30$  MW  
 $E_e = 70$  GeV  $\leftrightarrow$   $P_{syn} = 56$  MW \* 2

klystron efficiency: 50%

Overall power consumption:  
 limited to 100 MW

### 3.) Hour glass effect - long bunches



*Reduction of lumi due to changing betas at the IR*

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

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

$$t_y^2 \approx 1.7$$

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

## 4.) Crossing angle:

*Ideal luminosity:*

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

*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:*

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

$$E_e = 70 \text{ GeV}$$

*Experience:*

*LEP*      $\Delta \nu_e = 0.048$

*LHC-B*    $\Delta \nu_p = 0.0037$

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

<i>Standard Parameter</i>	<i>Protons</i>	<i>Electrons</i>	
	$N_p = 1.15 * 10^{11}$	$N_e = 1.4 * 10^{10}$	$nb = 2808$
	$I_p = 582 \text{ mA}$	$I_e = 71 \text{ mA}$	
<i>Optics</i>	$\beta_{xp} = 180 \text{ cm}$	$\beta_{xe} = 12.7 \text{ cm}$	
	$\beta_{yp} = 50 \text{ cm}$	$\beta_{ye} = 7.1 \text{ cm}$	
	$\epsilon_{xp} = 0.5 \text{ nm rad}$	$\epsilon_{xe} = 7.6 \text{ nm rad}$	
	$\epsilon_{yp} = 0.5 \text{ nm rad}$	$\epsilon_{ye} = 3.8 \text{ nm rad}$	
<i>Beamsize</i>	$\sigma_x = 30 \mu\text{m}$	$\sigma_x = 30 \mu\text{m}$	
	$\sigma_y = 15.8 \mu\text{m}$	$\sigma_y = 15.8 \mu\text{m}$	
<i>Tuneshift</i>	$\Delta \nu_x = 0.00055$	$\Delta \nu_x = 0.033$	
	$\Delta \nu_y = 0.00029$	$\Delta \nu_y = 0.036$	
<i>Luminosity</i>	$L = 8.5 * 10^{32}$		

*... no problems expected*

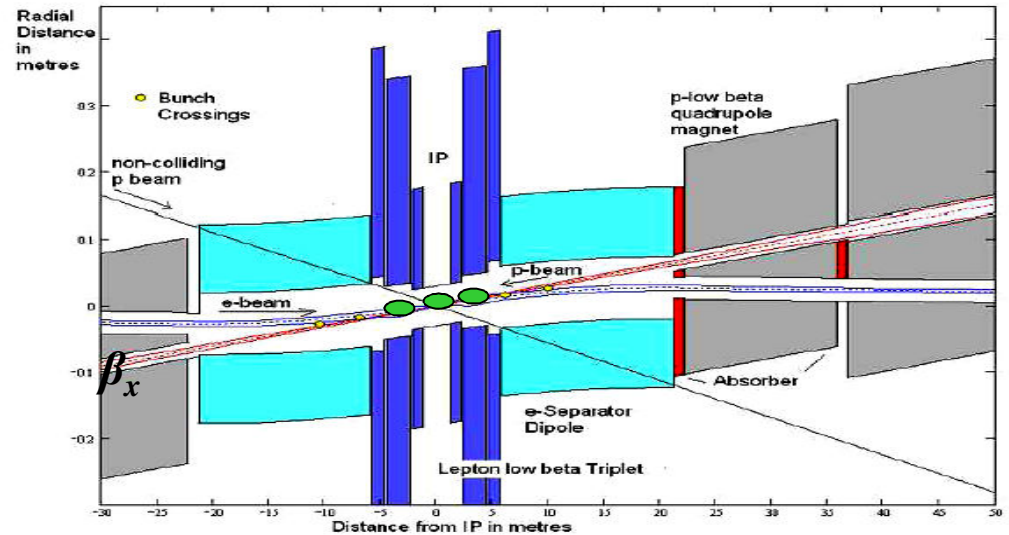
*except long range interactions ... to be studied*

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

First parasitic crossing:  $s=3.75m$

$$\varepsilon_{ex} = 7.6 \text{ nm}$$

$$\varepsilon_{px} = 0.5 \text{ nm}$$



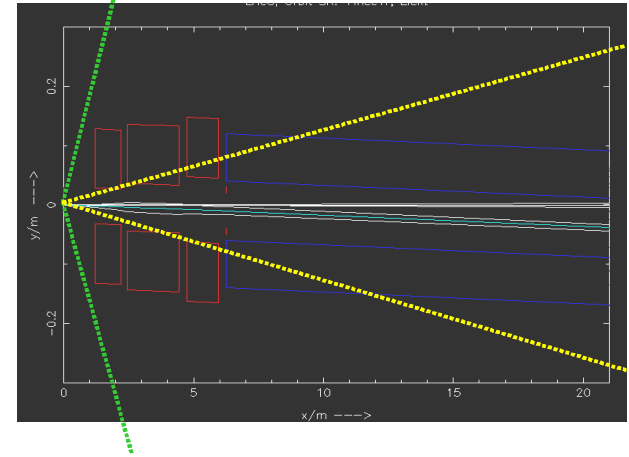
F. Willeke

	$\beta_x$	$\beta_y$	$\sigma_x$	$\sigma_y$	
$S=3.75m$	10m	24m	0.07mm	0.11mm	p
	135m	98m	1.01mm	0.61mm	e

$$\text{Separation: } 5\sigma_p + 5\sigma_e = 0.35\text{mm} + 5\text{mm} \approx 5.5 \text{ mm}$$

$$\rightarrow X\text{-angle} \approx 1.4 \text{ mrad}$$

## 7.) finally the 1° option



	E [eV]	$\epsilon_x$	$\epsilon_y$	$n_b$	$L_b$ [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)	$\theta$ [radians]	L( $\theta$ )	$\beta_x^*$ [m]	$\beta_y^*$ [m]	$\sigma_x$ [m]	$\sigma_y$ [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)	<u>1.60241E+31</u>	1.44E-003	8.65303E+30	0.6286496380	0.348263254	6.91E-05	3.64E-05	6.2