

# Beam-Beam effects for the LHeC Ring-Ring option

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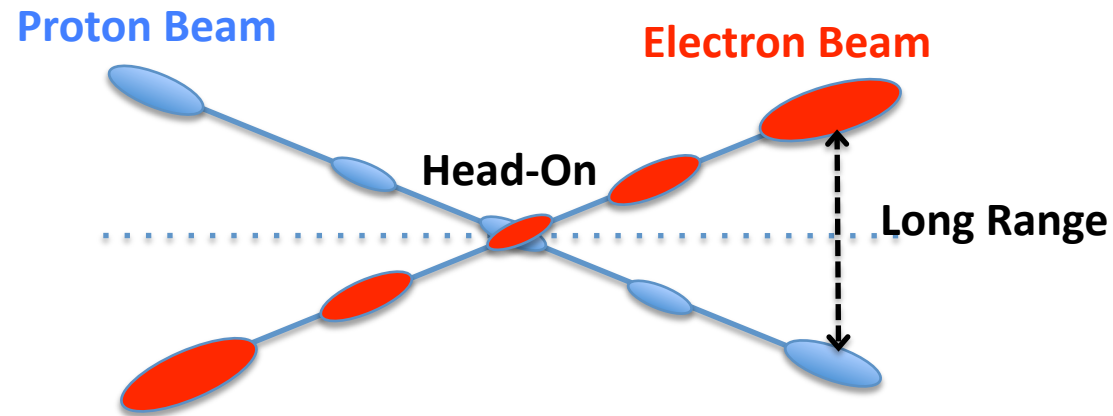


# LHeC Parameters

Parameters	Proton Beam	Electron Beam
Number of bunches	2808	2808
Number of Particles per bunch	$N_p = 1.7 \cdot 10^{11}$	$N_e = 1.96 \cdot 10^{10}$
Energy	$E_p = 7 \text{ TeV}$	$E_e = 60 \text{ GeV}$
Emittance Horizontal	$\epsilon_{x,p} = 0.5 \text{ nm}$	$\epsilon_{x,e} = 5 \text{ nm}$
Emittance Vertical	$\epsilon_{y,p} = 0.5 \text{ nm}$	$\epsilon_{y,e} = 2.5 \text{ nm}$
$\beta_x^*$	180 cm	18 - 40 cm
$\beta_y^*$	50 cm	10 - 20 cm
Bunch Length	7.7 cm	6.6 mm
Crossing angle	+/- 485 mrad	



# Beam-beam Interactions



- Crossing angle needed with 2808 bunches
- One head-on interaction at IP
- long range encounters every 3.75 m in IR
- and...

... all LHC pp collisions effects from IP1 and IP5



# Beam-Beam issues in general:

## Hadron Colliders:

- Beam Losses (dynamic aperture )
- Beam Lifetime
- External noise very important
- ...

## Lepton Colliders:

- Emittance growth (bb limit)
- Background in experiment regions
- ...

**In the LHeC RR option one has to expect all these issues and ...**



# LHeC Beam-beam complications:

- Large **Number of bunches** in both beams (2808)
- Simultaneous collisions of **ep** and **pp** of one proton beam
  - pp collisions in IR1 and IR5
  - ep collisions at another IR } **Different beam-beam properties**
- Stability both proton beams: dominated by **non linear effects**
- Stability of lepton beam: dominated by **damping**



## Known performance issues :

- Optical matching (SPS, Hera and Tevatron experience)
  - ✧  $\sigma_x^e = \sigma_x^p$
  - ✧  $\sigma_y^e = \sigma_y^p$
- Since different emittances for p and e then the beta functions at IP have to be different for the two beams
  - ✧ Restricts choice on  $\beta_e$
- Electron emittance must be controlled (coupling H/V )
- Hadrons beam-beam effects different for two planes



## Beam-beam Tune Shifts:

For the LHeC case beam-beam parameter (approx tune shift):

$$\xi_{x,y}^{e,p} = \frac{r_{e,p}}{2\pi} \frac{N^{p,e} \beta_{x,y}^{*e,p}}{\gamma_{e,p} \sigma_{x,y}^{p,e} (\sigma_x^{p,e} + \sigma_y^{p,e})}$$

LHeC	Proton Beam	Electron Beam (2 IR options)
$\xi_x$	$6.4 \cdot 10^{-4}$	0.065 - 0.144
$\xi_y$	$1.7 \cdot 10^{-4}$	0.036 – 0.072



# Linear Tune Shifts:

Head-on Linear Tune Shifts achieved so far:

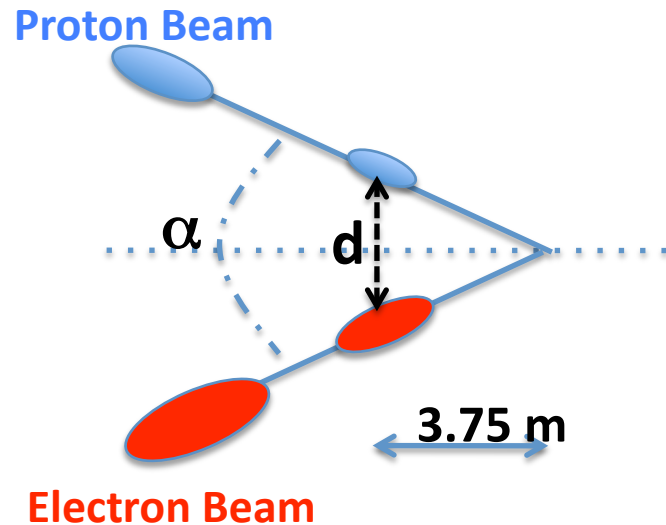
From Experience	LHC pp collisions	LEP (50 GeV) electron
$\Delta Q_{x,y}$	$6 \cdot 10^{-3} / \text{IP}$	0.03 – 0.04 /IP

- **Protons** ep collisions tune shift **small** compared to pp collisions
- For **electrons** tune shift similar to what achieved in **LEP** but for option 2 tune shift very big





# Parasitic Encounters Separation



Long range encounters:

- Every 3.5m in IR
- How many? Depends on the IR layout
- At which distance? Depends on  $\alpha$  and ...

$$d(s) = \alpha \frac{s}{\sqrt{\epsilon\beta(s)}}$$

$$\alpha = 930 \mu rad$$

LHeC	Proton Beam (normalized to $\sigma_e$ )	Electron Beam (normalized to $\sigma_p$ )
$d_x$	5.58 - 8.3	55.8
$d_y$	5.8 - 8.32	29,4



# Beam-beam issues to be addressed

**For any reliable study we need:**

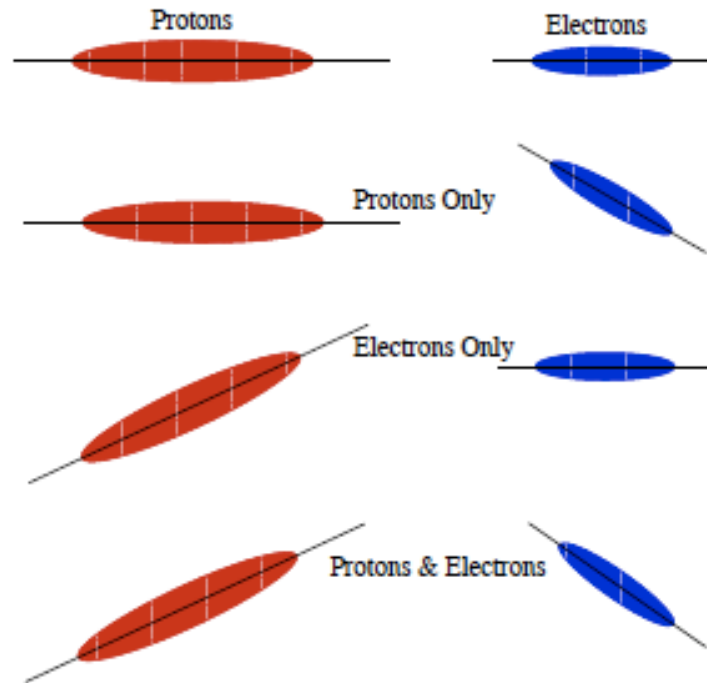
**Interaction region layout with crossing schemes matched in thin lens version.**

**Need to know the collision schemes**

- Long Range Tune shifts
- pp and ep collisions to be studied self consistently
- Dynamic aperture tracking studies
- Multiple bunch effects (colliding with same bunches?)



# Increase d or crab cavities?



## Crab Crossing for the LHeC

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Scenario	$\Delta L/L_0$ [%]	
	400 MHz	800 MHz
Head-On (with CCs)	88	48
Uncross only $e^-$	0.7	
Uncross only $p^+$	88	48
X-Angle (1 mrad)	1.0	

- Increase further the crossing angle and crab cross
- Crab cavities an option study effects on p beams

