Status Report

Interaction Region Design of the LHeC
Ring / Ring Version

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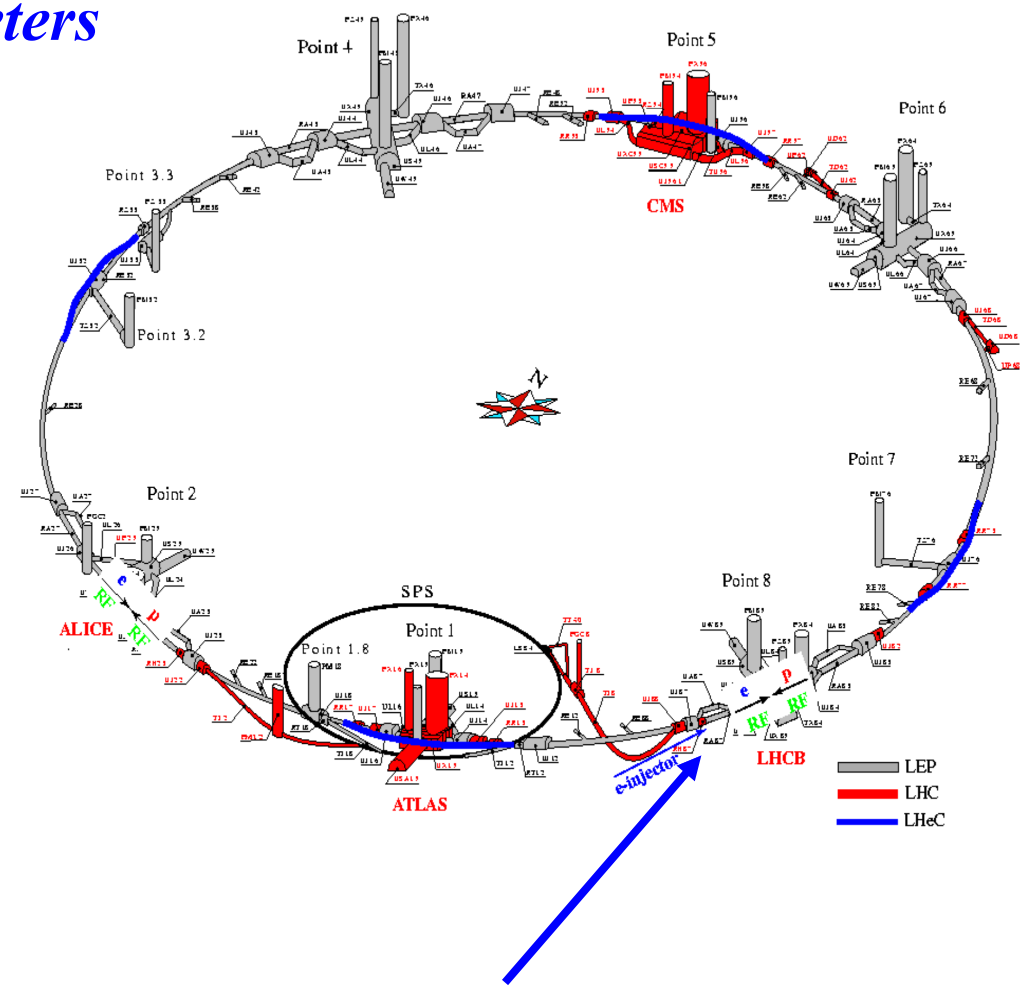
Status: .... ≈ Divonne Workshop + 2 * ε

LHeC Ring-Ring: basic parameters

	Electrons	*Protons*
Beam Energy	*50 GeV*	*7 TeV*
total current	*74 mA*	*544 mA*
part. / bunch	1.4×10^{10}	1.7×10^{11}
hor. emittance	*7.6 nm*	*0.5 nm*
vert. emittance	*3.8 nm*	*0.5 nm*
β hor*	*12.7 cm*	*180 cm*
β vert*	*7.1 cm*	*50 cm*

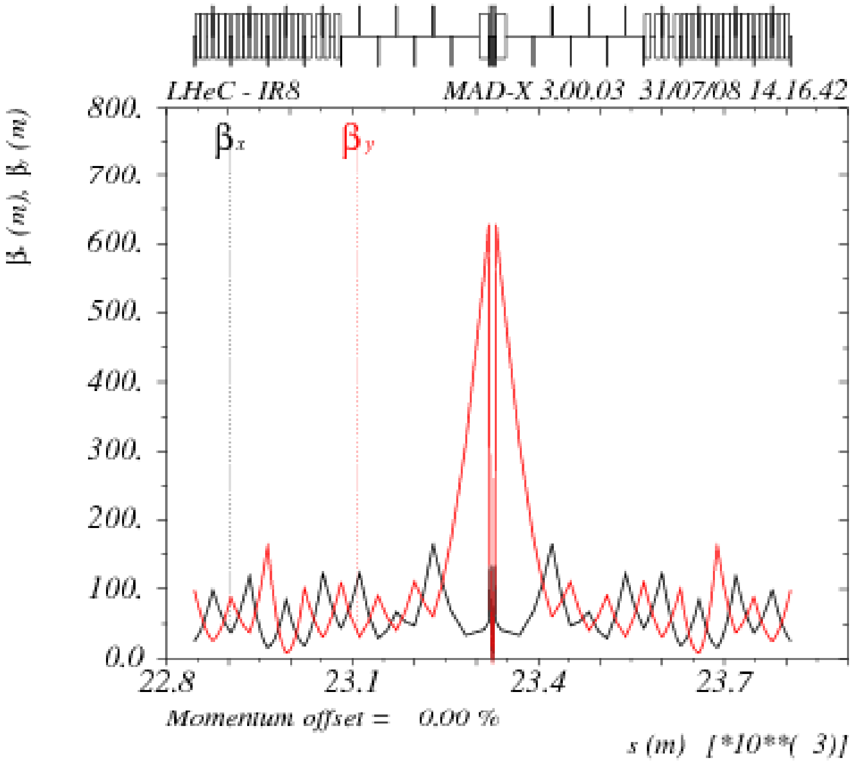
bunch spacing *25 ns*

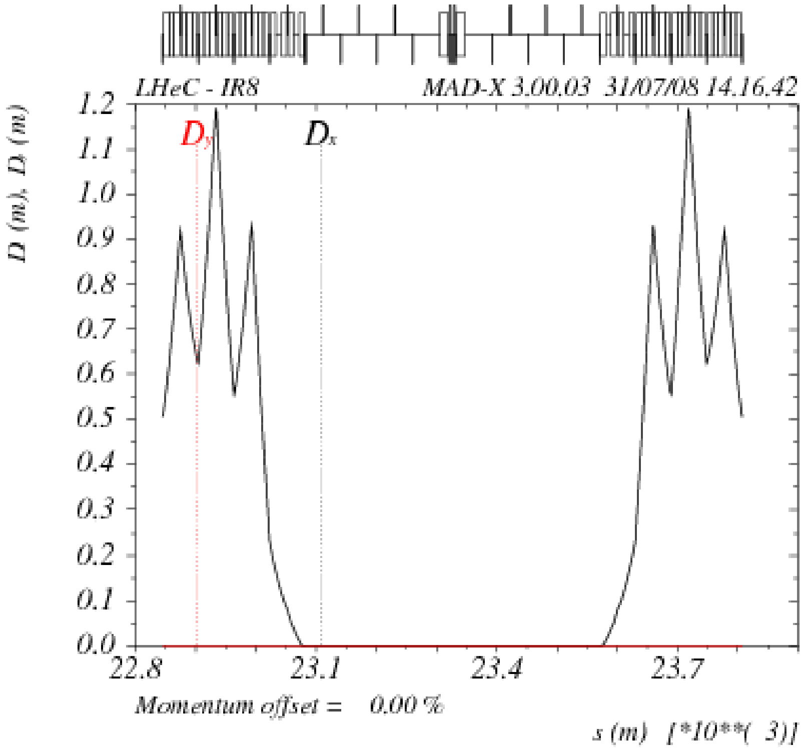
Luminosity $10^{33}\ cm^{-2}\ s^{-1}$



IR Design in Point 8

Status: Beam Optics e-Ring in IR 8





Alexander Kling

principle work is done

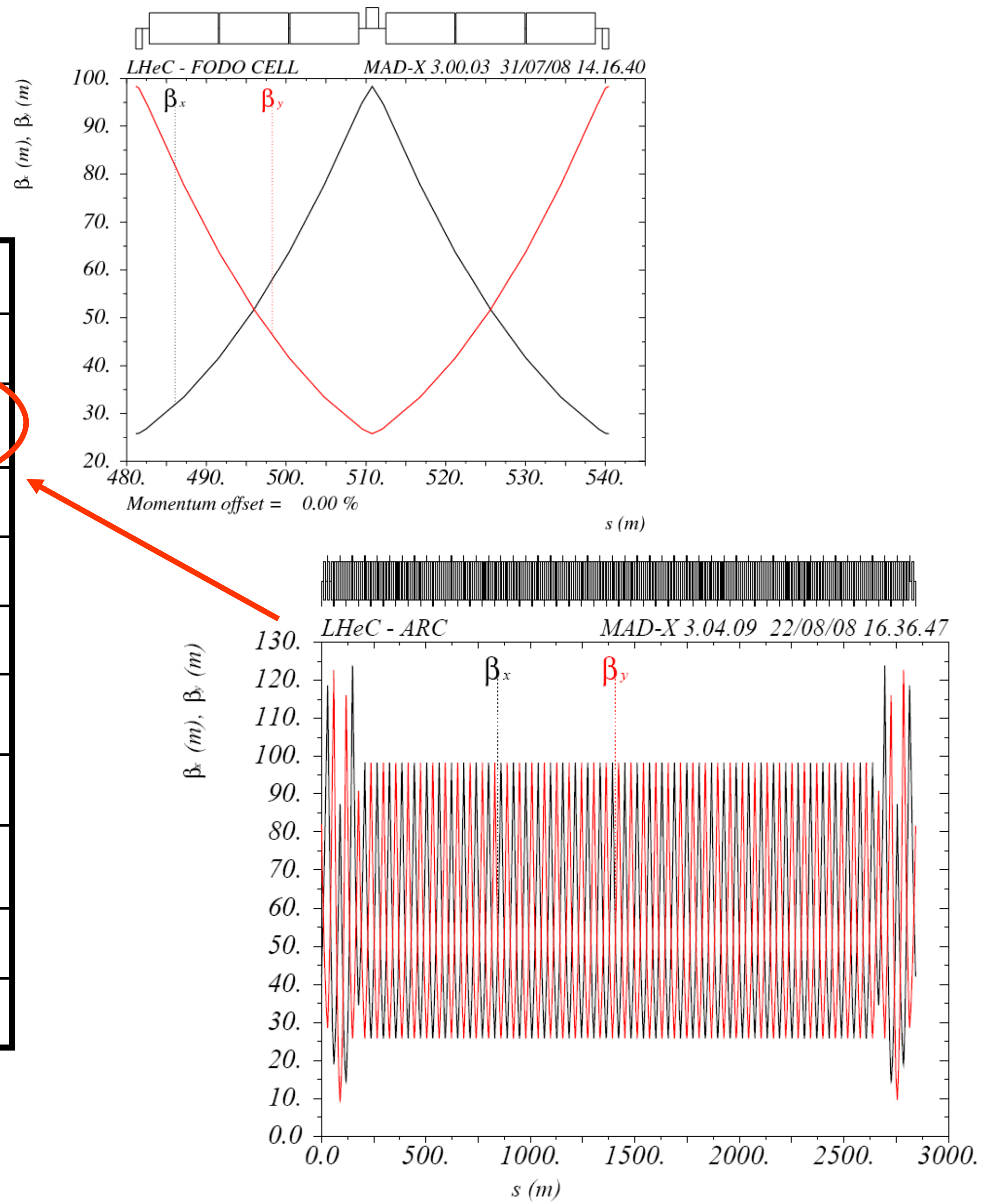
$\beta^*_{hor} = 12.7$ cm
$\beta^*_{vert} = 7.1$ cm

needed: optimisation of cells in the arc to obtain the required ε !!!

ε ≈ 22 nm for a 72 cell phase advance and E = 70 GeV

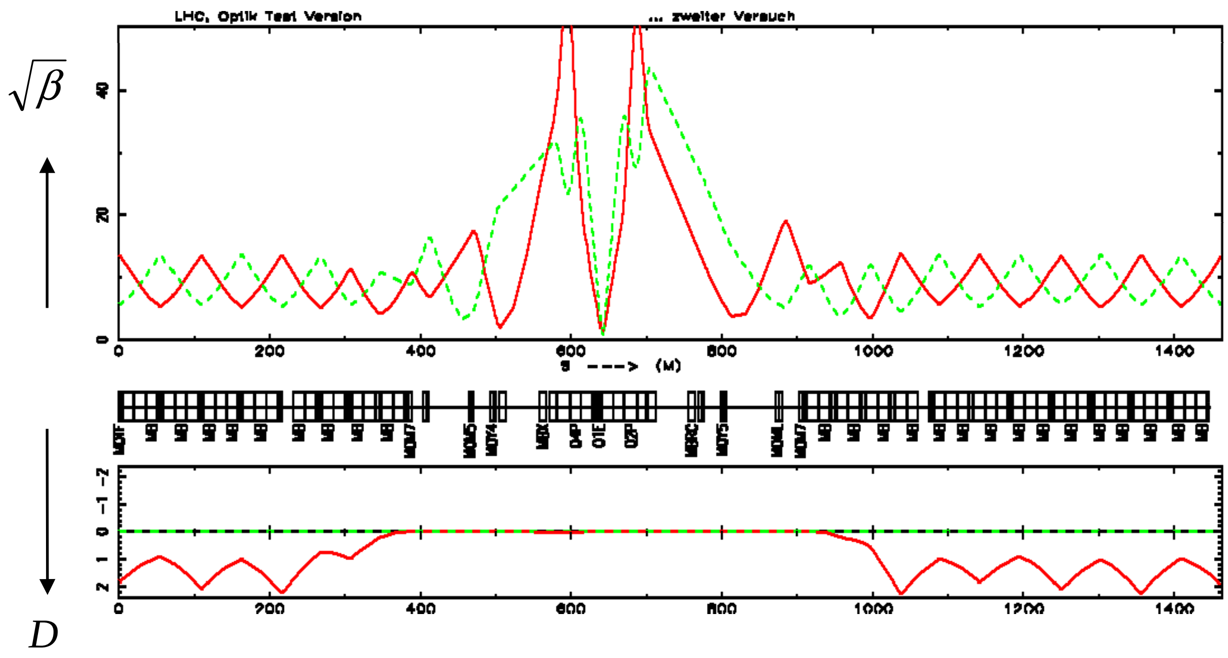
2.) ARC LATTICE

Parameter	Unit	Value
Cell length	m	59.25
Phase Advance hor./ver.	deg	72/72
Bending Radius	m	3060.2
Length of Dipoles	m	8.65
Number of Dipoles/Cell		6
Length of Quadrupoles	m	1.6
Maximum Beta Function	m	98.4
Minimum Beta Function	m	25.9
Maximum Dispersion	m	0.94
Minimum Dispersion	m	0.52



Status: Beam Optics p-Ring in IR 8

... an asymmetric one



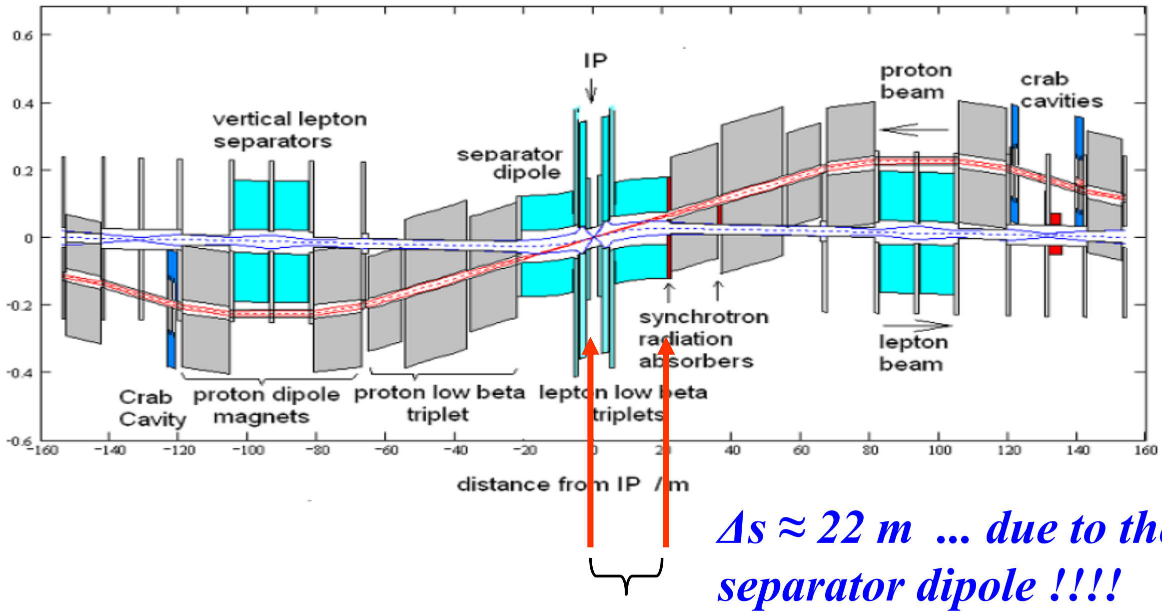
principle work is done

β^*_{hor} = 180 cm
β^*_{vert} = 50 cm

needed: optimisation of magnet strengths in the triplett and IR
symmetrisation of magnet strengths
optimisation of luminosity (i.e. β^* as $\beta_{max} \leq 2500$ m)

Status: Beam Separation Scheme

→ *any IR layout is dominated by the separation scheme*



Δs ≈ 22 m ... due to the separator dipole !!!!

Optimisation needed:

*1/ρ ↔ Δ*k where is the optimum*

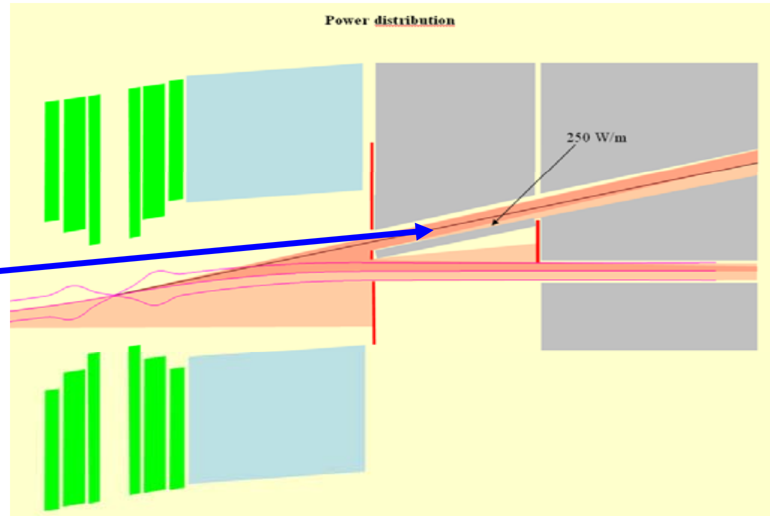
Lessons from Divonne:

synchrotron radiation does not depend too much on dipole effect
(quadrupole focusing fields are dominant contribution)

geometry of synchrotron radiation power ... inside sc magnets !!!

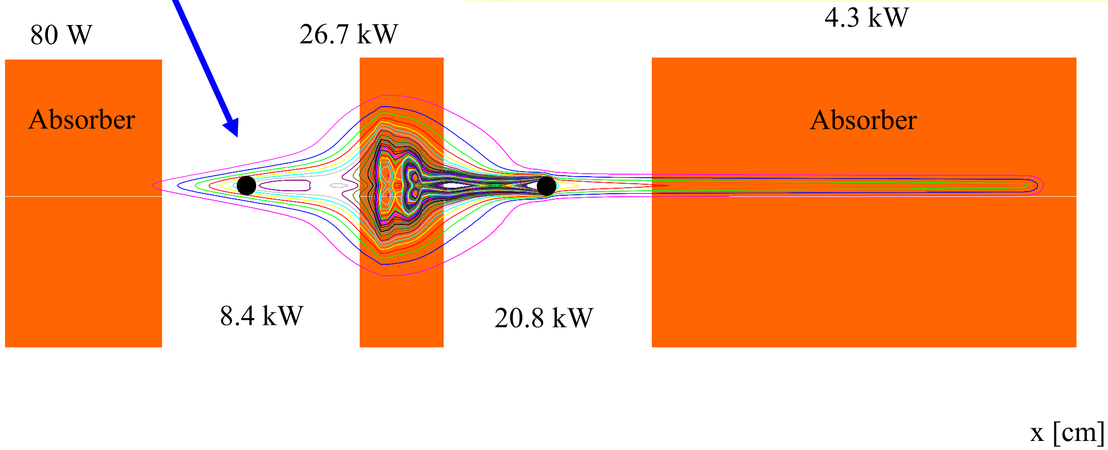
x-angle ... how many σ are needed ?

Status: Separation Scheme ...
Synchrotron Radiation



Needed:

Optimisation of geometry for the
synchrotron light fan ...
... 1/ρ of separation dipole / quadrupoles

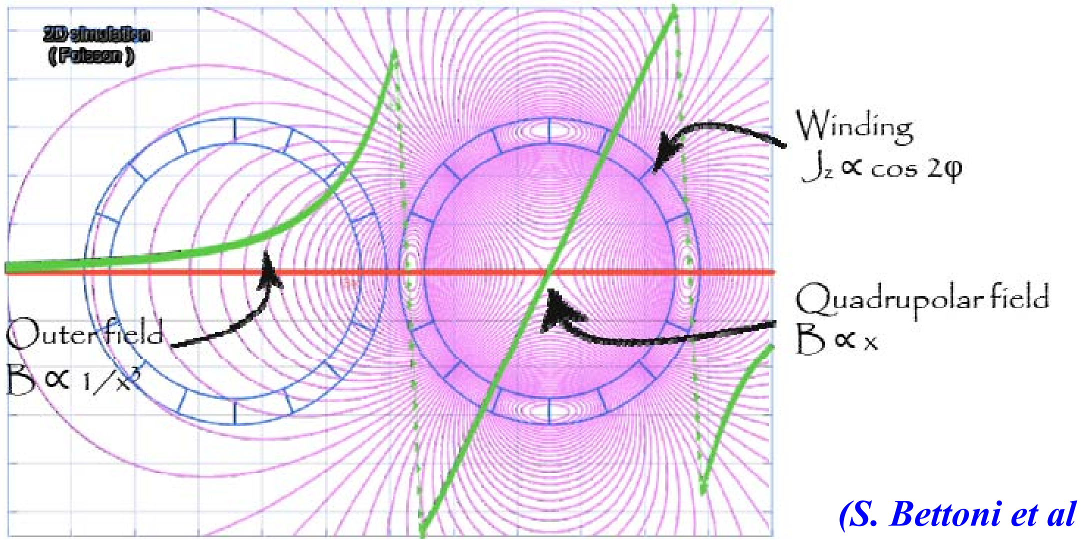


Design of sc Magnets (aperture for beam & light !!!)

Absorber Layout to protect sc. magnets
to shield the experiment
to calculate backscattering to the detector

Status: Separation Scheme ...
Exotic Magnets

A cos (2 φ) magnet producing a quadrupolar field produces also a $1/x^3$ field outside...



(S. Bettoni et al in Divonne)

Needed: Still needed ... urgently needed ...

a first design of sc half quadrupoles

magnet cryostats with aperture for the second beam

a first statement about the techical feasibility for the exotic magnets

Status: Separation Scheme ...
Crossing Angle

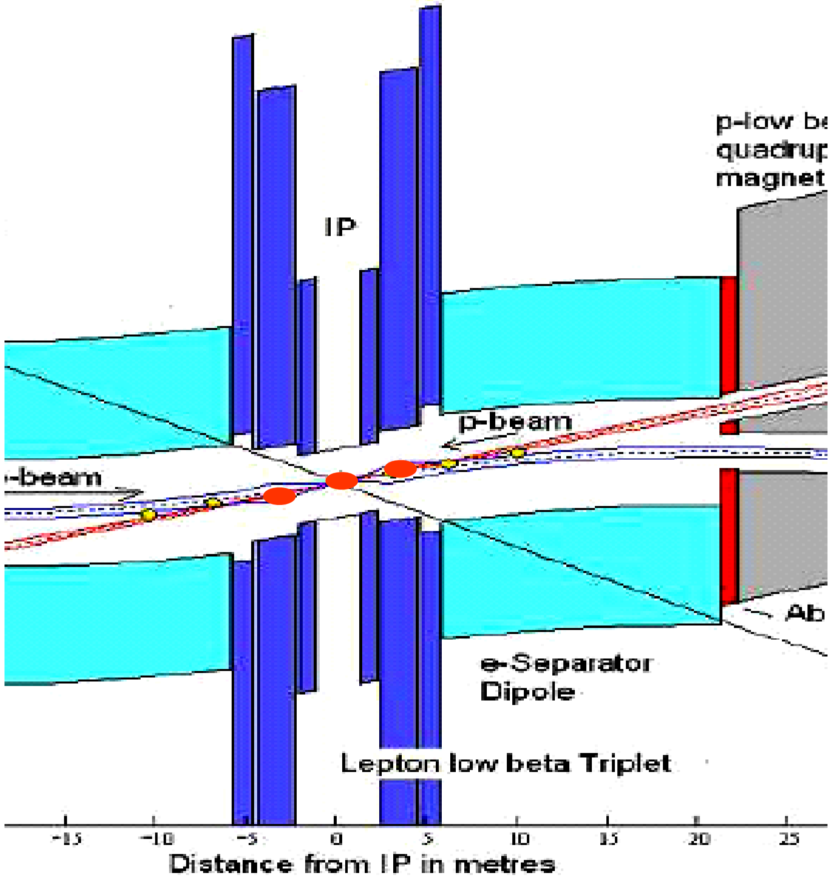
fast beam separation needed
crossing angle to support early separation

LHC bunch distance: 25 ns = 7.5 m
1st parasitic crossing: 3.75m

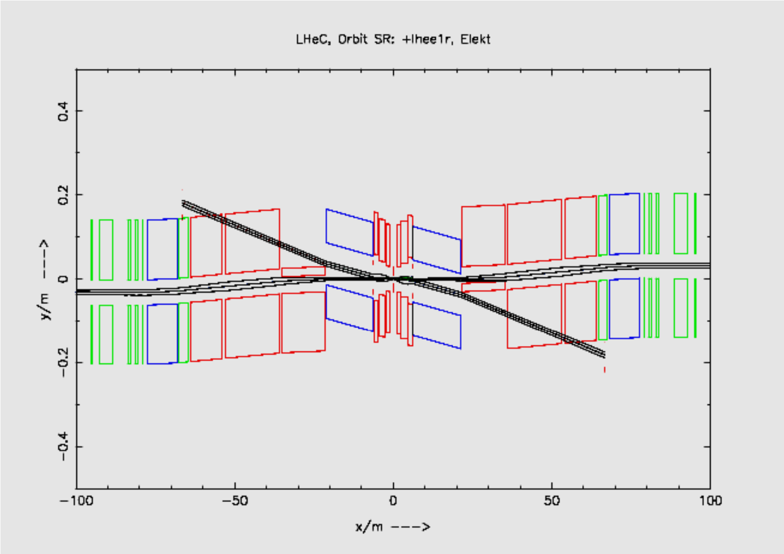
first e-quad: positioned at s = 1.2m
... too late for sufficient beam separation

separation has "to start at the IP"

--> support the off-centre-quadrupole separation scheme
by crossing angle at the IP.



Status: Separation Scheme ...
Crossing Angle



program to calculate the beam optics (10 σ),

calculate the electron orbit, align the e-quads to the e-beam (min. synchrotron rad.)
track the p-beam through the e-quads
optimise the beam separation according to crossing angle and separation fields

s	ε_x / ε_y	β_x	β_y	σ_x	σ_x	
3.75m	$5*10^{-10}$ rad m	10m	24m	0.07mm	0.11mm	p
	7.6 nm / 3.8 nm	135m	98m	1.01mm	0.61mm	e

separation requirement: dominated by e-beam dimensions

$$10\sigma + 10\sigma = 0.7mm + 10.1mm \approx 11mm$$
$$\rightarrow X - angle = 2.9mrad$$

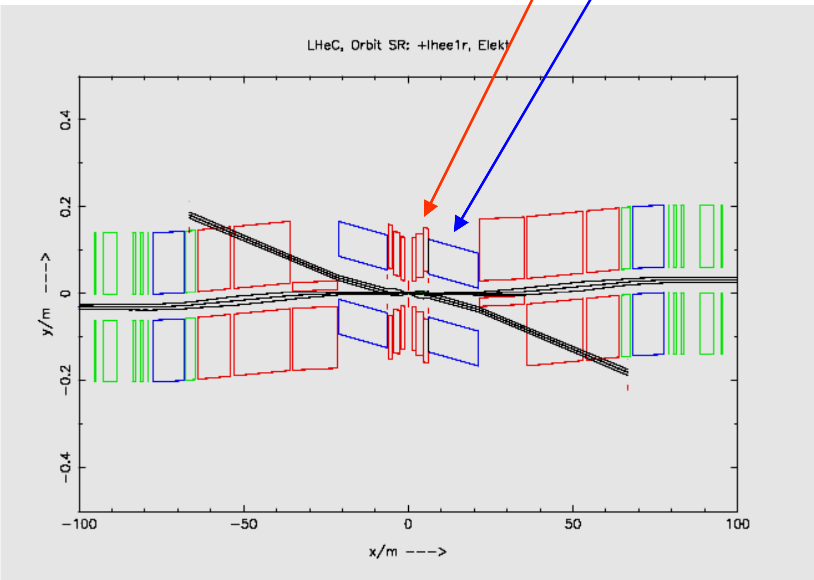
$$5\sigma + 5\sigma = 0.35\ mm + 5\ mm \approx 5.5\ mm$$
$$\rightarrow X - angle = 1.5\ mrad$$

IR Design: Beam Separation Scheme

prefered separation scheme: crossing angle = 1.5 mrad

quadrupole triplett off axis
separation dipole

const. bending radius:
ρ= 26315 m



further optimisation possible: large contribution to synchrotron radiation from focusing fields

... nota bene: ρ (arc dipoles) = 3060 m

* ***separation at first proton magnet (half quadrupole) 37mm***
* ***synchrotron light calculations done for x-angle of 0.5mrad and 1.5 mrad keeping the overall separation constant.***
* ***crab cavities needed***

How many σ do we really need ???

Status: Tune Shift

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

Proton Tuneshift:

	$\Delta\nu_{px}$	$\Delta\nu_{py}$
LHeC	***5.6*10 -4***	***2.9*10 -4***
HERA-UPGRD	***1.1*10 -3***	***3.1*10 -4***
LHC-B	***3.7*10 -3***	***3.7*10 -3***

LHeC Standard Parameter

$N_p = 1.1*10^{11}$ $\quad \varepsilon(p) = 5*10^{-10}$

$N_e = 1.4*10^{10}$ $\quad \varepsilon_{xy}(e) = 7.6nm / 3.8nm$

$\beta_{xp} = 1.8\, m$ $\quad \beta_{xp} = 0.127\, m$

$\beta_{yp} = 0.5\, m$ $\quad \beta_{yp} = 0.071\, m$

Electron Tuneshift:

	$\Delta\nu_{ex}$	$\Delta\nu\, e_y$
LHeC	***0.048***	***0.051***
HERA-UPGRD	***0.024***	***0.037***
LEP	***0.04***	

← *pro IP*

Status: Tune Shift

LHC Ultimate Parameter

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

Electron Tuneshift:

	$\Delta\nu_{px}$	$\Delta\nu_{py}$
LHeC	**0.21**	**0.22**

$n_b = 1404$

LHeC Standard Parameter

$N_p = 5*10^{11}$

$N_e = 1.4*10^{10}$

$\varepsilon(p) = 5*10^{-10}$

$\varepsilon_{xy}(e) = 7.6nm / 3.8nm$

$\beta_{xp} = 1.8\, m$

$\beta_{yp} = 0.5\, m$

$\beta_{xe} = 0.127\, m$

$\beta_{ye} = 0.071\, m$

Solution: increase proton β function to relax

Electron Tuneshift:

	$\Delta\nu_{ex}$	$\Delta\nu\, e_y$
LHeC	**0.06**	**0.07**

$L = 1.44*10^{33}$

LHeC relaxed Parameter

$N_p = 5*10^{11}$

$N_e = 1.4*10^{10}$

$\varepsilon(p) = 5*10^{-10}$

$\varepsilon_{xy}(e) = 22nm / 10nm$

$\beta_{xp} = 3.6\, m$

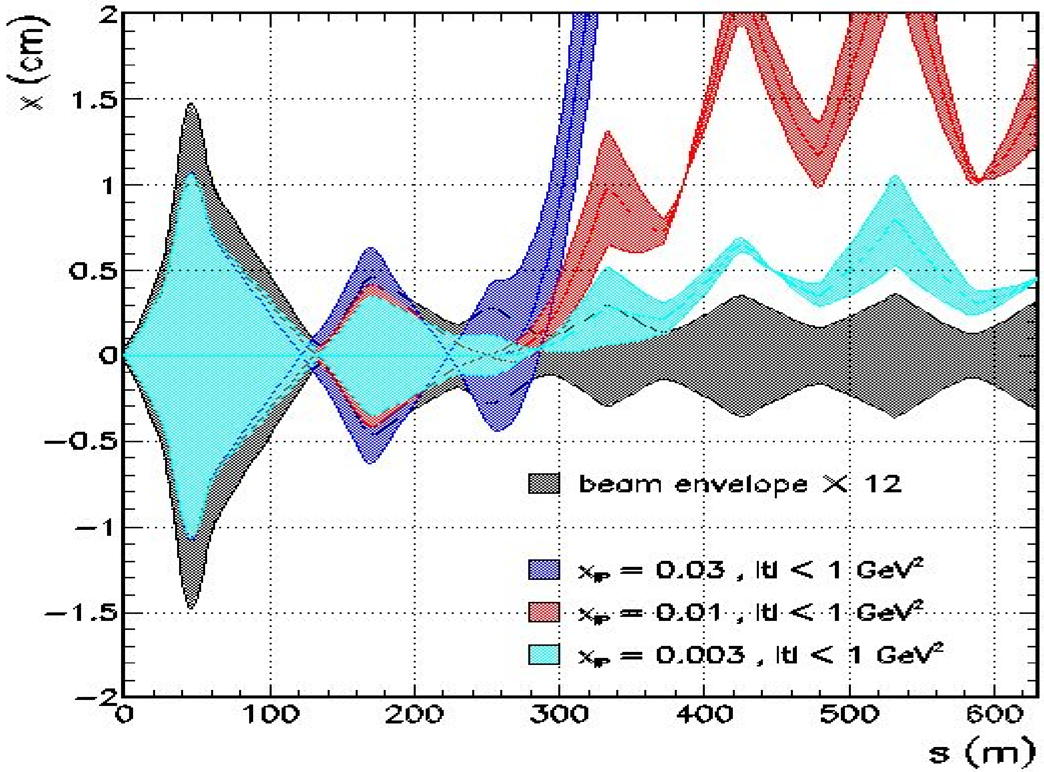
$\beta_{yp} = 1.0\, m$

$\beta_{xe} = 0.08\, m$

$\beta_{ye} = 0.05\, m$

Status: Separation Scheme ...
Detector Contributions

tracking off momentum particles ...
... the forward detector colleagues

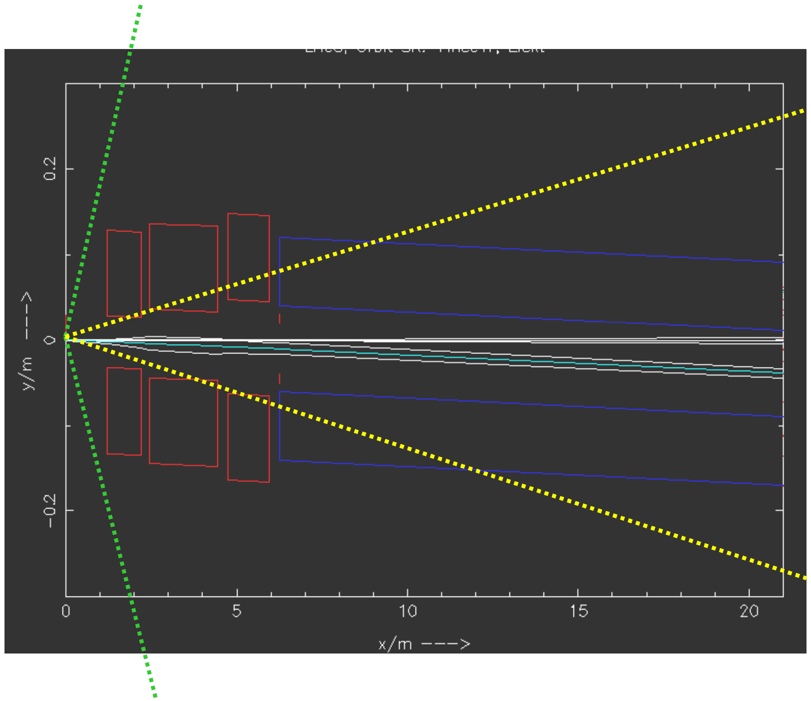


Status: Separation Scheme ...

the 1 ° Option

two options discussed at the moment:

10° / 1°



Status:

SUMMARY: To Do List e & p optics

- ***Design straight sections 1-7 :** replace dummy straight sections by bypass regions (Helmut) needed for emittance budget*
- ***Include Rf sections ... null problemo***
- ***Include sextupoles for correction of chromatic lattice functions.***
- ***Include energy offset - change of damping partition numbers.***
- ***Optimise Phase Advance in the FoDo to reduce electron beam emittance .***
- ***Optimisation of β* (given the aperture constraints of the new hardware)***

- ***hardware for p-Ring Optics ???***
- ***absorber layout ???***
- ***... what about the 1° option ???***
- ***... and what about the convener ???***