Summary of Interaction Region and Forward/Backward Det. WG

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DESY

LHeC Workshop
Divonne
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Outline

Joint sessions with Accelerator (and Detector) WG
Will summaries IR and forward/backward detector issues

- IR constraints from detector side

- Status ring-ring IR design
- Status linac-ring IR design

- To-do list

IR Constraints from Detector Side

Two IR designs:

- High luminosity/large Q^2 physics
  - Limited detector acceptance $10^o - 170^o$
- Lower luminosity/low Q^2, low x physics
  - Good forward/backward detector acceptance $1^o - 179^o$ and no magnets in front of calorimeter, i.e. 2 to 3m from IP

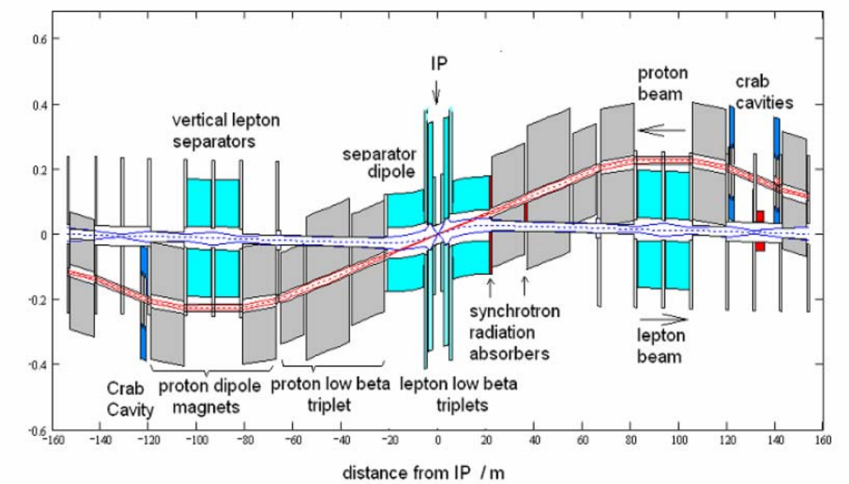
For both IR designs need:

- Good acceptance for luminosity measurement and electron tagging (rear direction w.r.t. proton beam)
- Good acceptance for forward proton and zero degree/forward neutron calorimeter (forward direction)

Somewhat less acceptance acceptable for high luminosity/large Q^2 physics setup

Status Ring-ring IR Design

B.Holzer



spectrometer effect: use dipole fields to separate the beams according to their momentum.

... don't loose too much space:

→ quadrupole triplett of centre

LHC bunch distance: 25 ns

1st parasitic crossing: 3.75m

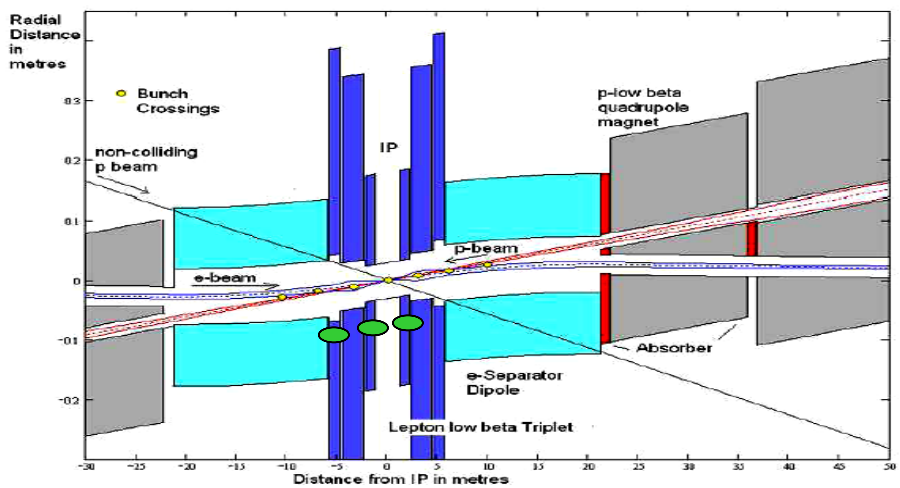
first e-quad positioned at 1.2m

... too far for sufficient beam separation

separation has "to start at the IP"

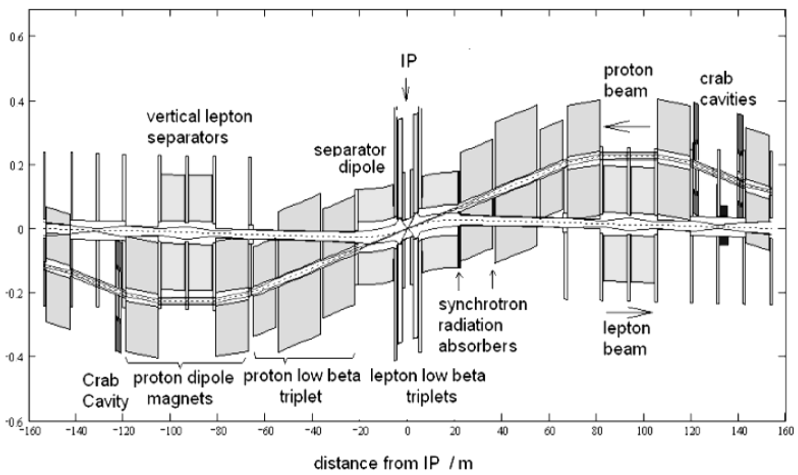
--> support the off-centre-quadrupole separation scheme by crossing angle (≈1.5 mrad) at the IP.

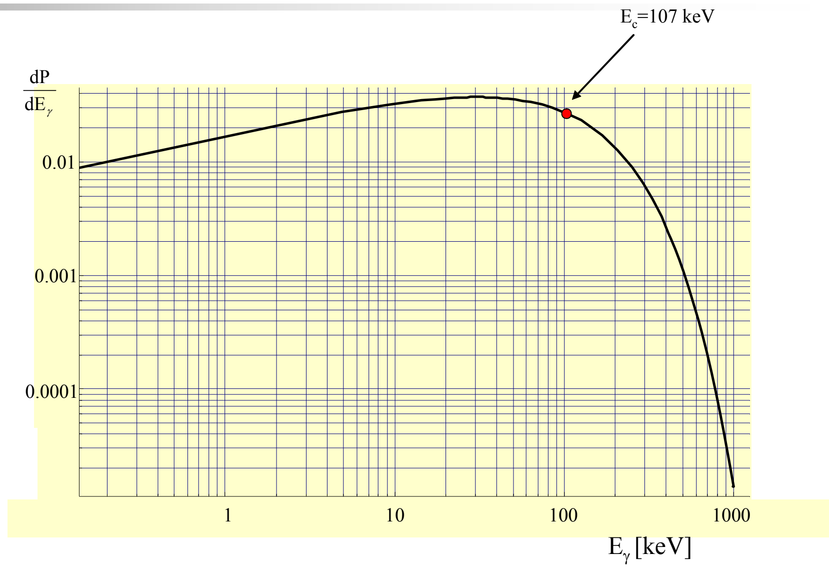
--> ... and the Luminosity Calorimeter ??



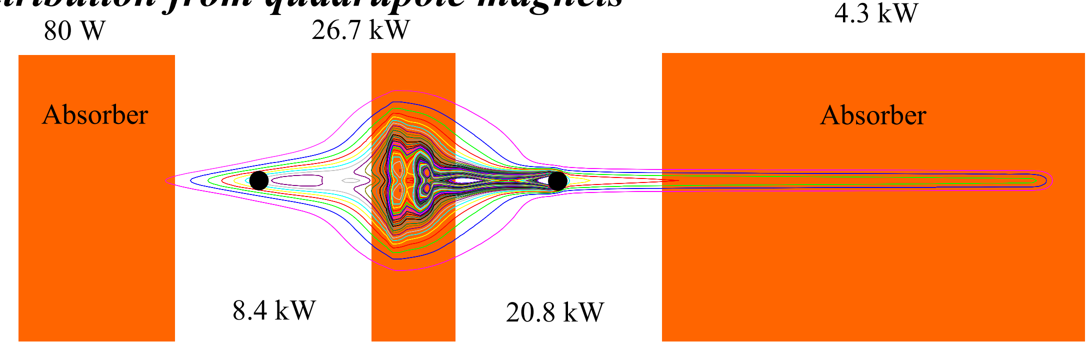
F. Willeke

Synchrotron Radiatoin RR IR





large contribution from quadrupole magnets



Boris Nagorny

overall radiation power in IR: 60 kW (HERA II: 30 kW)

geometry of detector beam pipe and synchrotron radiation masks ?

Ring/Ring

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

LHC upgrade: N_p increased.
Need to keep e tune shift low:
by optimising β & ε (but keep e and p matched).

LHeC profits from LHC upgrade
but not proportional to N_p

Tuneshift Limit:

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

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=0.0484	
	Δνy=0.00029	Δνy=0.0510	
Luminosity	$L=8.5*10^{32}$		
Ultimate Parameter	Protons	Electrons	
	$Np=1.7*10^{11}$	$Ne=1.4*10^{10}$	nb=2808
	Ip=860mA	Ie=71mA	
Optics	βxp=230 cm	βxe=12.7 cm	
	βyp= 60 cm	βye= 7.1 cm	
	εxp=0.5 nm rad	εxe=9 nm rad	
	εyp=0.5 nm rad	εye=4 nm rad	
Beamsize	σx=34 μm		
	σy=17 μm		
Tuneshift	Δνx=0.00061	Δνx=0.056	
	Δνy=0.00032	Δνy=0.062	
Luminosity	$L=1.03*10^{33}$		
Upgrade Parameter	Protons	Electrons	
	$Np=5*10^{11}$	$Ne=1.4*10^{10}$	nb=1404
	Ip=1265mA	Ie=71mA	
Optik	βxp=400 cm	βxe= 8 cm	
	βyp=150 cm	βye= 5 cm	
	εxp=0.5 nm rad	εxe=25 nm rad	
	εyp=0.5 nm rad	εye=15 nm rad	
Beamsize	σx=44 μm		
	σy=27 μm		
Tuneshift	Δνx=0.0011	Δνx=0.057	
	Δνy=0.00069	Δνy=0.058	
Luminosity	$L=1.5*10^{33}$		

IR Design – Detector Acceptance

Luminosity vs. Acceptance

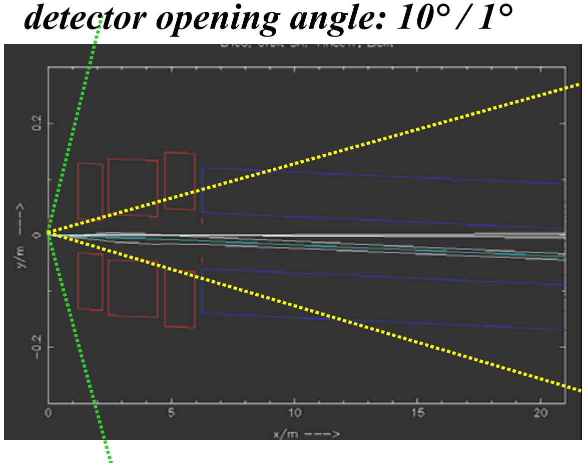
Luminosity and acceptance very much depend on physics program (to be defined during this workshop)

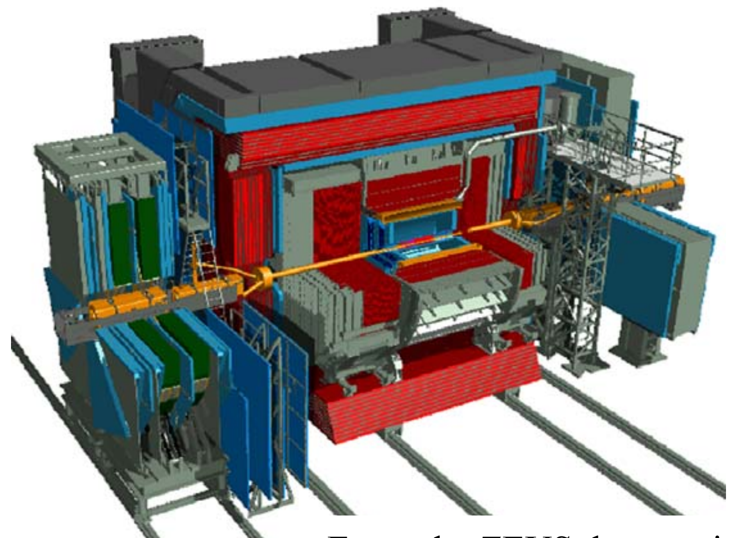
=> Possible scenario two different interaction region setups

$L = 10^{33}\ cm^{-2}\ s^{-1}$, $10° < \theta < 170°$ (prefer magnets not in front of calorimeter)

$L = 10^{31}\ cm^{-2}\ s^{-1}$, $1° < \theta < 179°$

detector opening angle: 10° / 1°





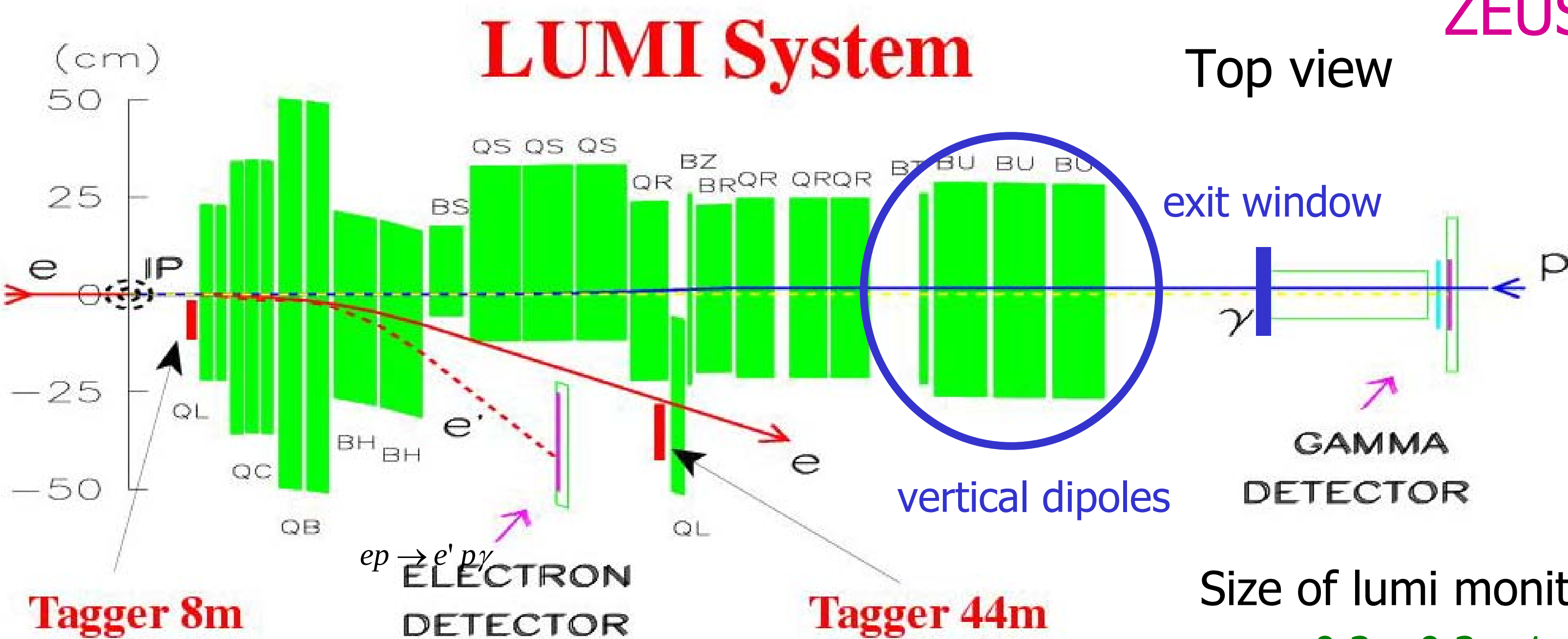
Example: ZEUS detector in HERA II with integrated mini beta quads

Good news:
Cockcroft will contribute to that workpackage
(Rob Appleby et al) ***talk cancelled***

Luminosity Measurement at HERA

ZEUS

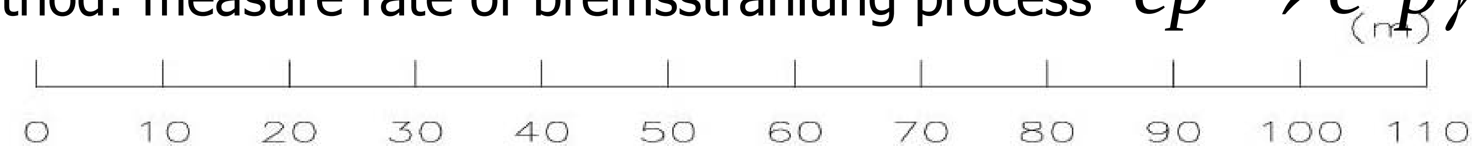
Top view



Size of lumi monitor

- ~ 0.3 x 0.3 x 1 m (without filter)
- ~ 3m long with filters

Method: measure rate of bremsstrahlung process $ep \rightarrow e' p\gamma$

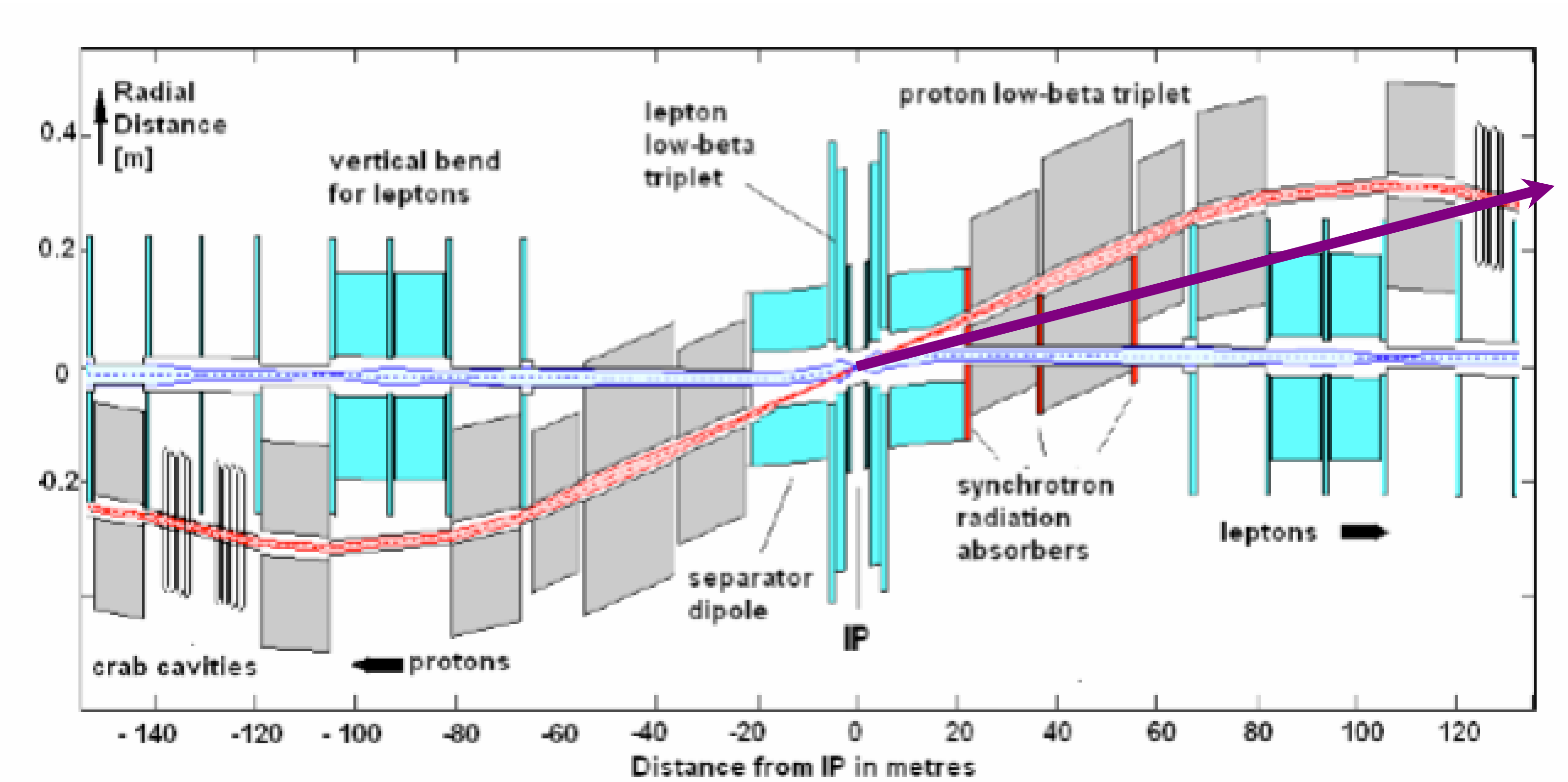


Lumi Monitor Acceptance

- Width of Bethe Heitler photons similar to electron beam divergence
- Acceptance at HERA II ±3σ.
  - At bit too tight. Should be larger.

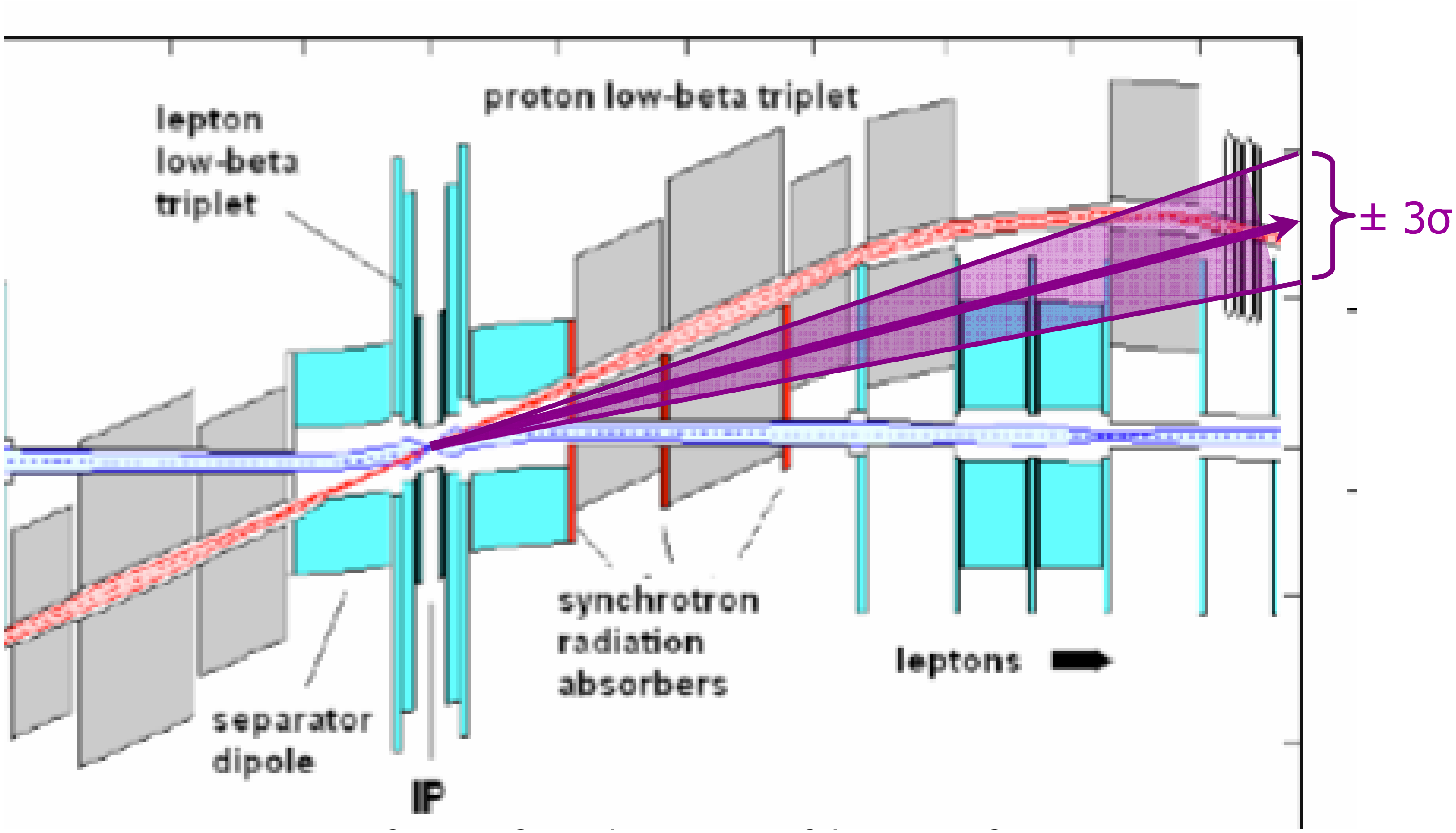
	horizontal		vertical	
	LHeC	HERA II	LHeC	HERA II
beta (m)	0.127	0.63	0.071	0.26
emittance (nm)	7.6	22	3.8	3.96
beam size (mm)	0.031	0.118	0.016	0.032
divergence (mrad)	0.245	0.187	0.231	0.123
photon width (mm) at 92m	22.5	17.2	21.3	11.4
photon width (mm) at 85m	20.8		19.7	
+-3 sigma (mm) at 21.5m	32		30	
+-3 sigma (mm) at 85m	125		118	

Present LHeC RR IR Layout



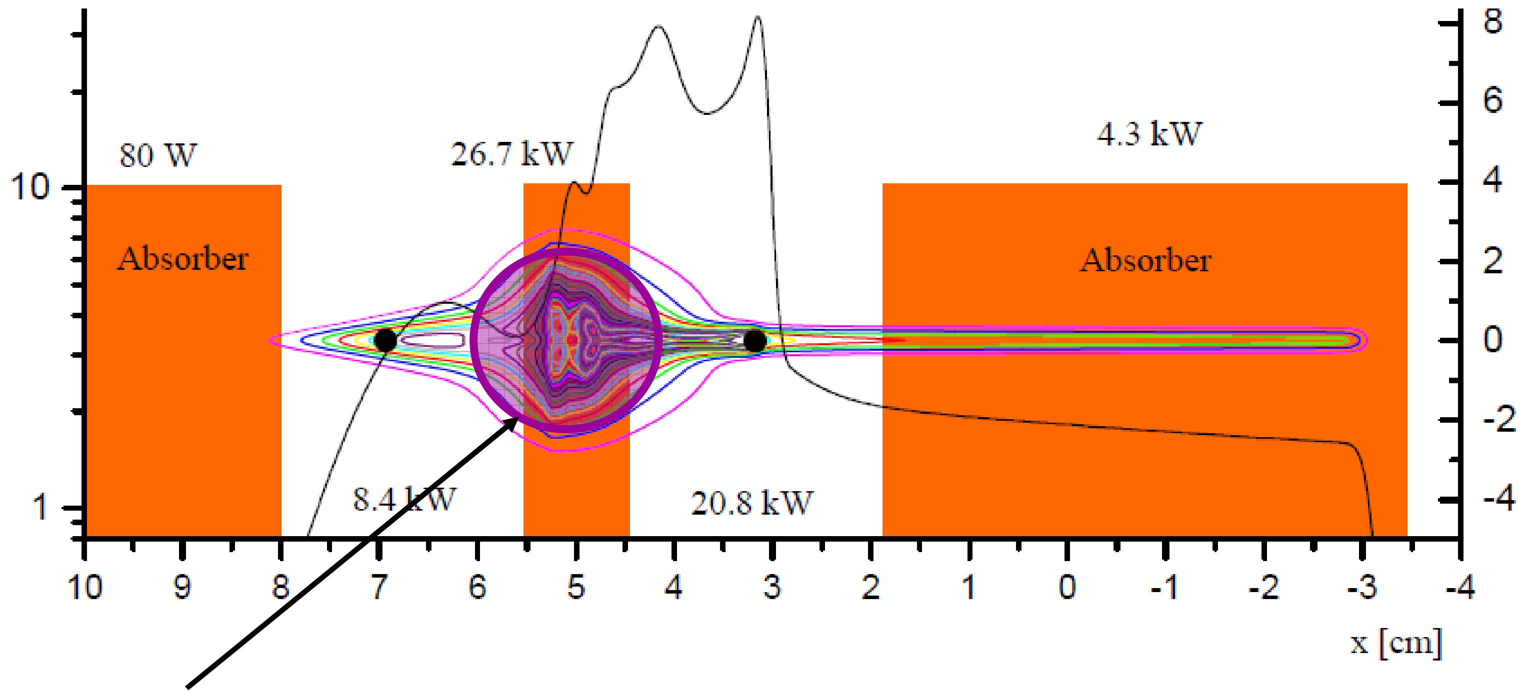
Arrow indicates direction of lumi photons
Photons would "go through" superconducting proton magnet

Present LHeC RR IR Layout



Acceptance – Synchrotron Radiation

2D distribution of synchrotron radiation (B.Nagorny)
power (kW/cm²)



± 3 σ contour of Bethe Heitler photons at absorber 21.2m from IP
Synchrotron radiation power about 30kW

Luminosity Measurement

- Present RR IR design not yet compatible with luminosity monitor
- Crossing design more difficult for integration of lumi monitor
- Large synchrotron radiation power
- Holes in magnets ????

- Luminosity measurement will be difficult due to large rate (pile-up) and potentially large synchrotron radiation power

- Haven't yet looked at Linac/Ring design

Status LINAC/Ring IR Design

R.Tomas

2008

- Wish list for e^- p IR
- Conceptual design for 20 GeV electron beam
- Conceptual design for 50 GeV electron beam
- Proton triplet optics with $l^* = 10$m
- Electron triplet optics with $l^* = 20$m (50GeV)

2009

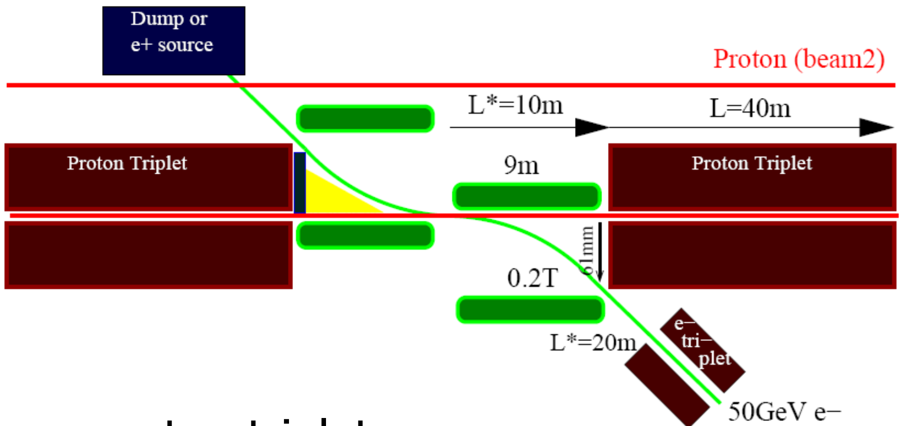
- Conceptual design for 100 GeV electron beam
- Synchrotron radiation and beam pipe
- Detector acceptance

Wish List for IR

- Head-on collisions (with dipoles)
- Low radiation power $\approx$ 10 kW
- Critical photon energy $<$ 500 keV
- βs below 0.25m both for e^- and p
- Same geometric e^- and p emittances $(\epsilon_{e,n}, \epsilon_{p,n}) = (20, 3.75)\ \mu$m

- Head-on collisions very nice from detector point of view
- But: assuming 50ns instead of 25ns bunch separation
- Should use nominal parameters. Is head-on still going to work?

Linac/Ring IR Design 50GeV



Assuming 50ns bunch spacing.

Distance of dipole to IP should be increased slightly or large radius (radially outside calorimeter)

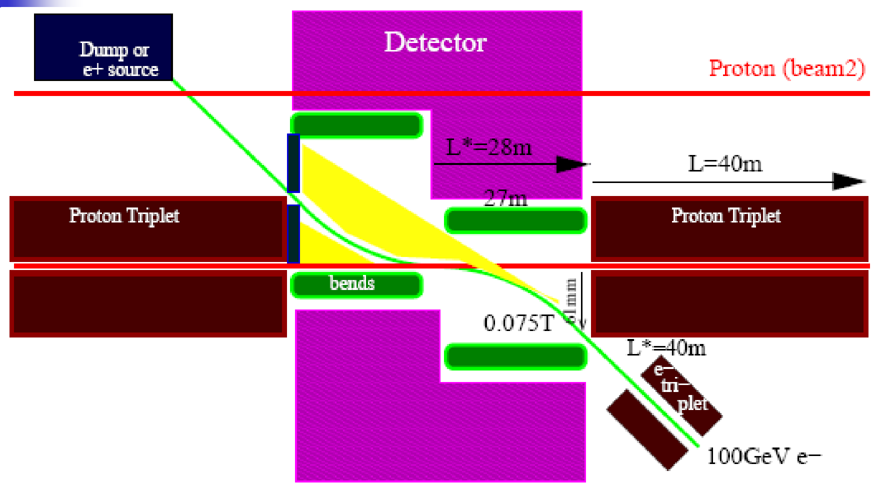
proton triplet

	Q_1			Q_2			
β^* [m]	Aper [mm]	Grad [T/m]	B_p [T]	Aper [mm]	Grad [T/m]	B_p [T]	ξ
0.25	23	176.7	4.0	32	115.0	3.7	635
0.18	23	264.5	6.0	32	180.0	5.7	660
0.10	26	318.6	8.4	36	250.0	9.1	1250

electron triplet

	Q_1			Q_2			
β^* [m]	Aper [mm]	Grad [T/m]	B_p [T]	Aper [mm]	Grad [T/m]	B_p [T]	ξ
0.10	21	13	0.26	23	15	0.3	1100

Linac/Ring IR Design 100GeV



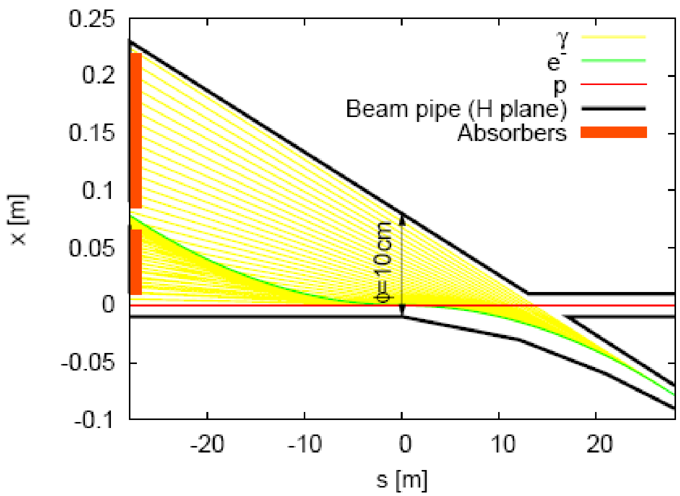
Assuming 50ns bunch spacing.

Distance of dipole to IP should be increased slightly or large radius (radially outside calorimeter)

proton triplet

	Q_1			Q_2			
β^*	Aper	Grad	B_p	Aper	Grad	B_p	ξ
[m]	[mm]	[T/m]	[T]	[mm]	[T/m]	[T]	
0.20	33	131.4	4.4	42	125.0	5.3	990

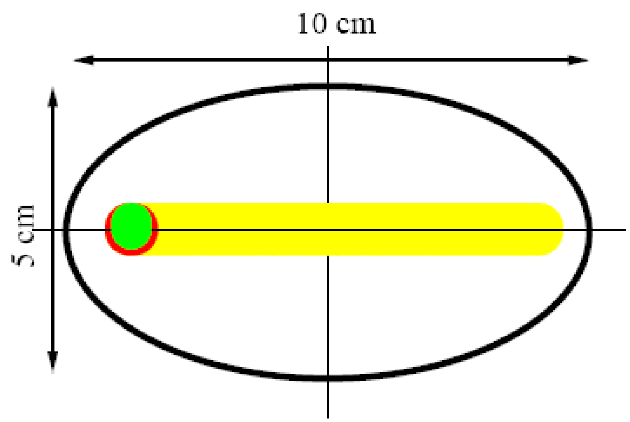
Synchrotron Radiation L/R Design



100 GeV electron beam

Synchrotron radiation

- Power 4.2kW
- Critical energy 0.5MeV

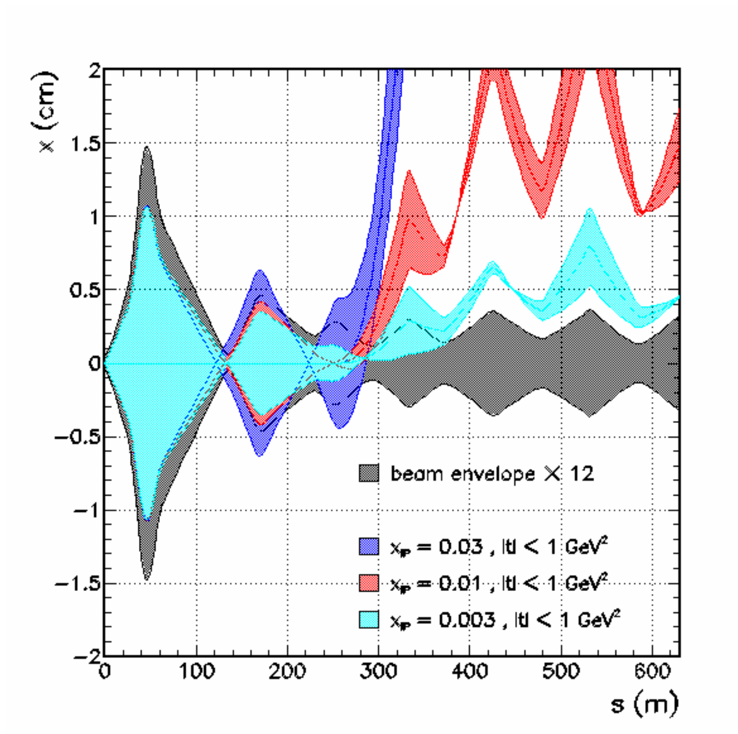


Large horizontal spread at IP

Disadvantage of weak bent

Forward Detectors

Acceptance of forward proton spectrometer P. v.Mechelen



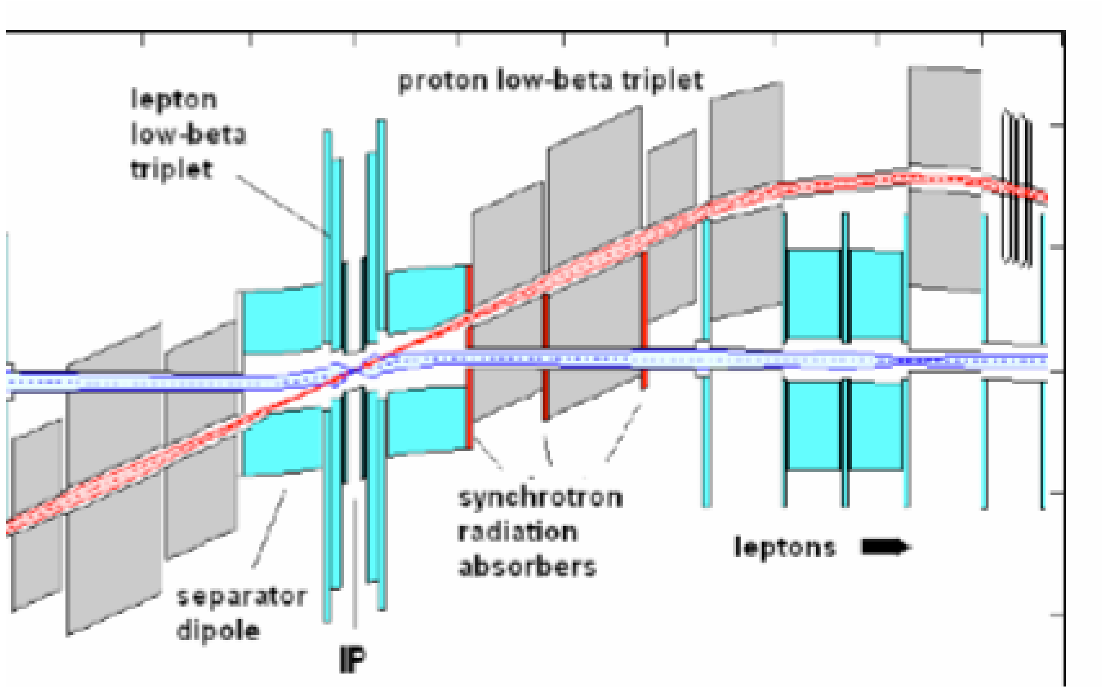
First study looks fine

Have to look at acceptance of zero degree/forward neutron calorimeter

Is aperture of proton quads sufficient?

Rear Detectors

Problem with acceptance of luminosity monitor already mentioned



Space for electron tagger(s) should be sufficient

To be checked

To do List

Ring/Ring Option

- Solve lumi acceptance problem. Holes in magnets???
- Work on lower luminosity/large acceptance IR

LINAC/Ring Option

- Use nominal parameter for bunch spacing (Will head-on collisions still work?)

Both options

- Optimize design (machine parameters?, detector acceptance)
- Study synchrotron radiation: masks, absorbers, detector background
  → will determine size of central beam pipe
  (May need first guess of injection optics as well)
- Look at second (unused) proton beam. Beam separation, parasitic crossings?
- Acceptance of forward/backward detectors
- Study proton background (beam gas due to S.R.) not for CDR
- R&D on technical components
- Keep in mind how to switch from 1° to 10° IR setups. Modular design.