LHeC interaction region

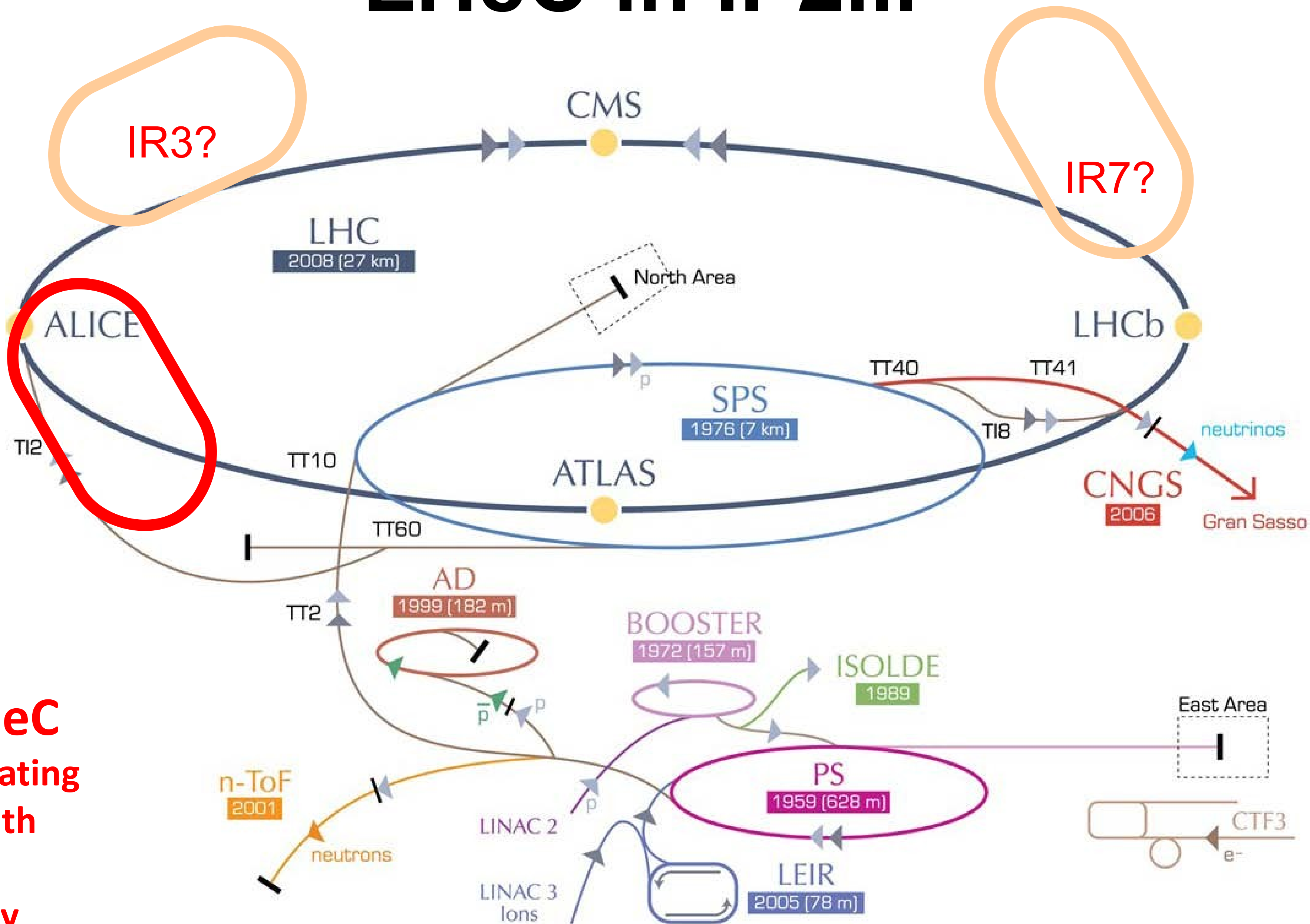
R. Tomas

Many thanks for contributions to J. Abelleira,
N. Bernard, O. Bruning, Y.I. Levinsen, H. Garcia,
M. Klein, P. Kostka, S. Russenschuck, D. Schulte,
L. Thompson and F. Zimmermann

Status and DIS12 feedback

- Concept OK
- IR synchrotron radiation scary
- Detector solenoid to be considered
- B field in e^- Q1 aperture to be considered
- e^-/e^+ compatibility
- Chromaticity correction and FFS synchrotron radiation to be balanced (3 e^- optics designs)

LHeC in IP2...



LR LHeC

recirculating linac with energy recovery

LHeC targets

e- energy ≥60 GeV

luminosity ~10^{33} $cm^{-2}s^{-1}$ or higher !

total electrical power for e^-: ≤100 MW

e^+p collisions with similar luminosity

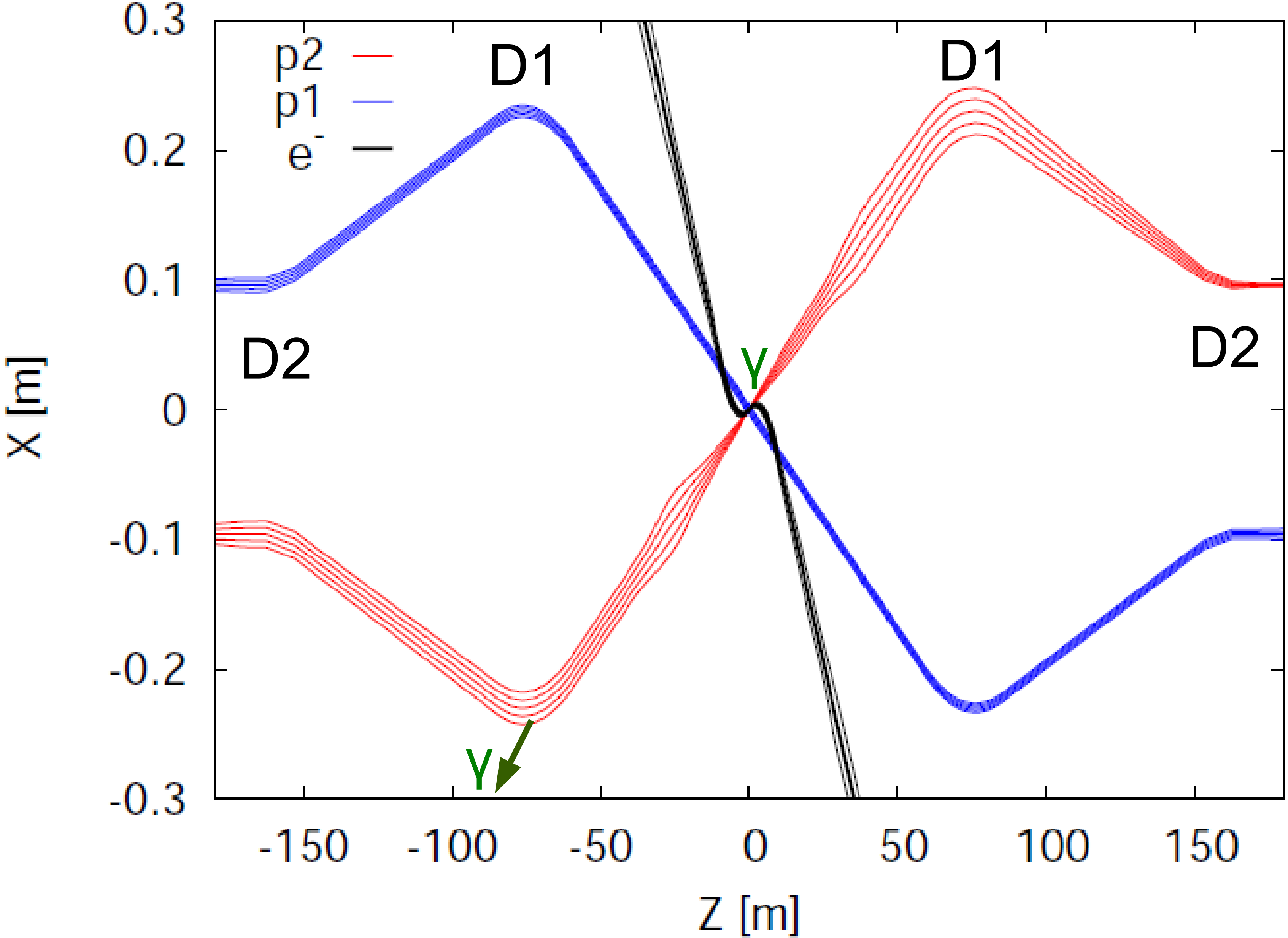
simultaneous with LHC *pp* physics

e^-/e^+ polarization

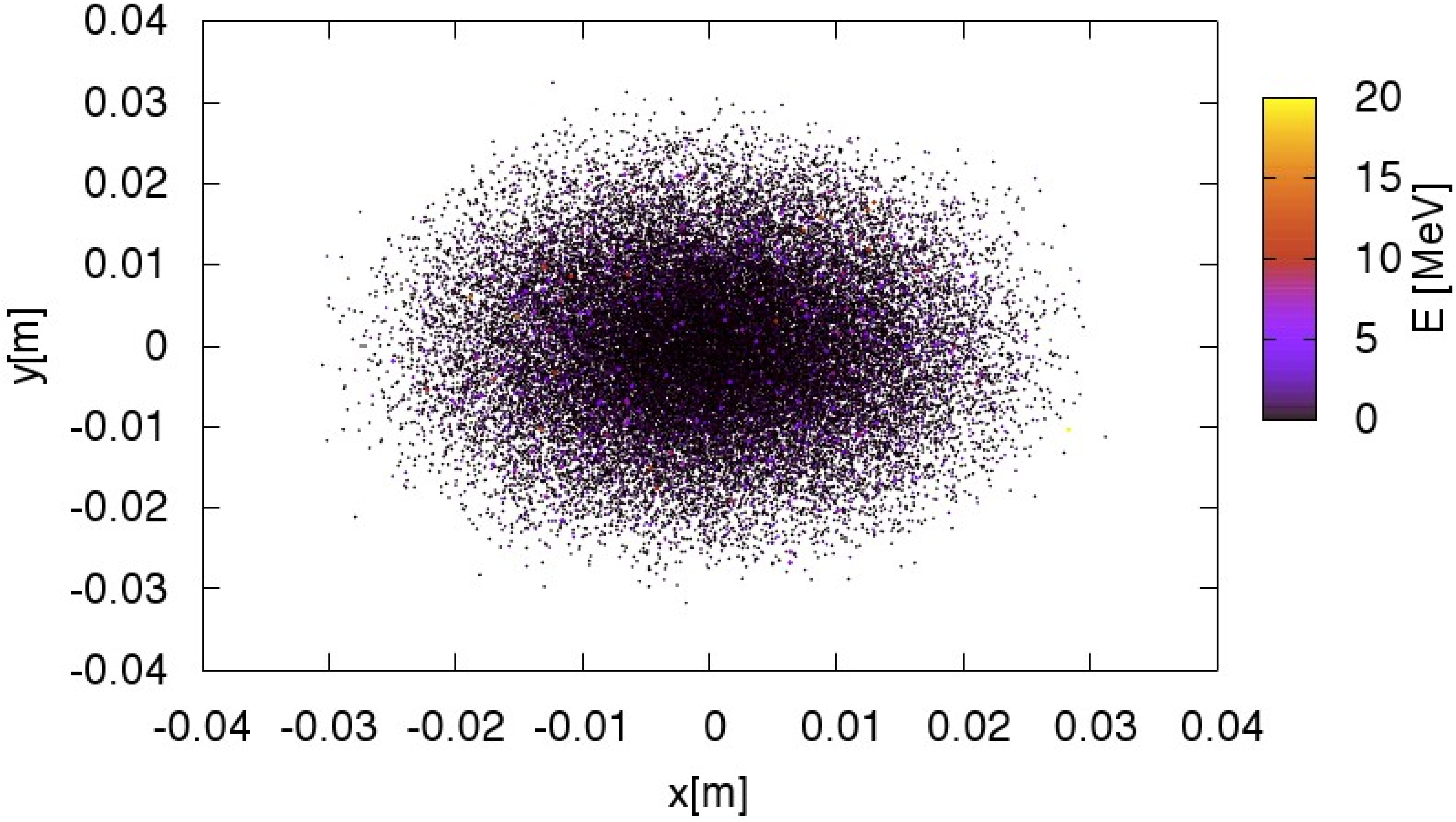
detector acceptance down to 1 deg

	RR HL/HA	LR
Luminosity [$10^{33}cm^{-2}s^{-1}$]	1.3/0.7	0.4
Detector acceptance [deg]	10/1	1
Polarization [%]	40	90
IP beam sizes [μm]	30, 16	7
Crossing angle [mrad]	1	0
e- L* [m]	1.2/6.2	30
Proton L* [m]	23	10
e- $beta^*_{x,y}$ [m]	0.2,0.1/0.4,0.2	0.12
Proton $beta^*_{x,y}$ [m]	1.8, 0.5	0.1
Synchrotron power [kW]	33/51	50

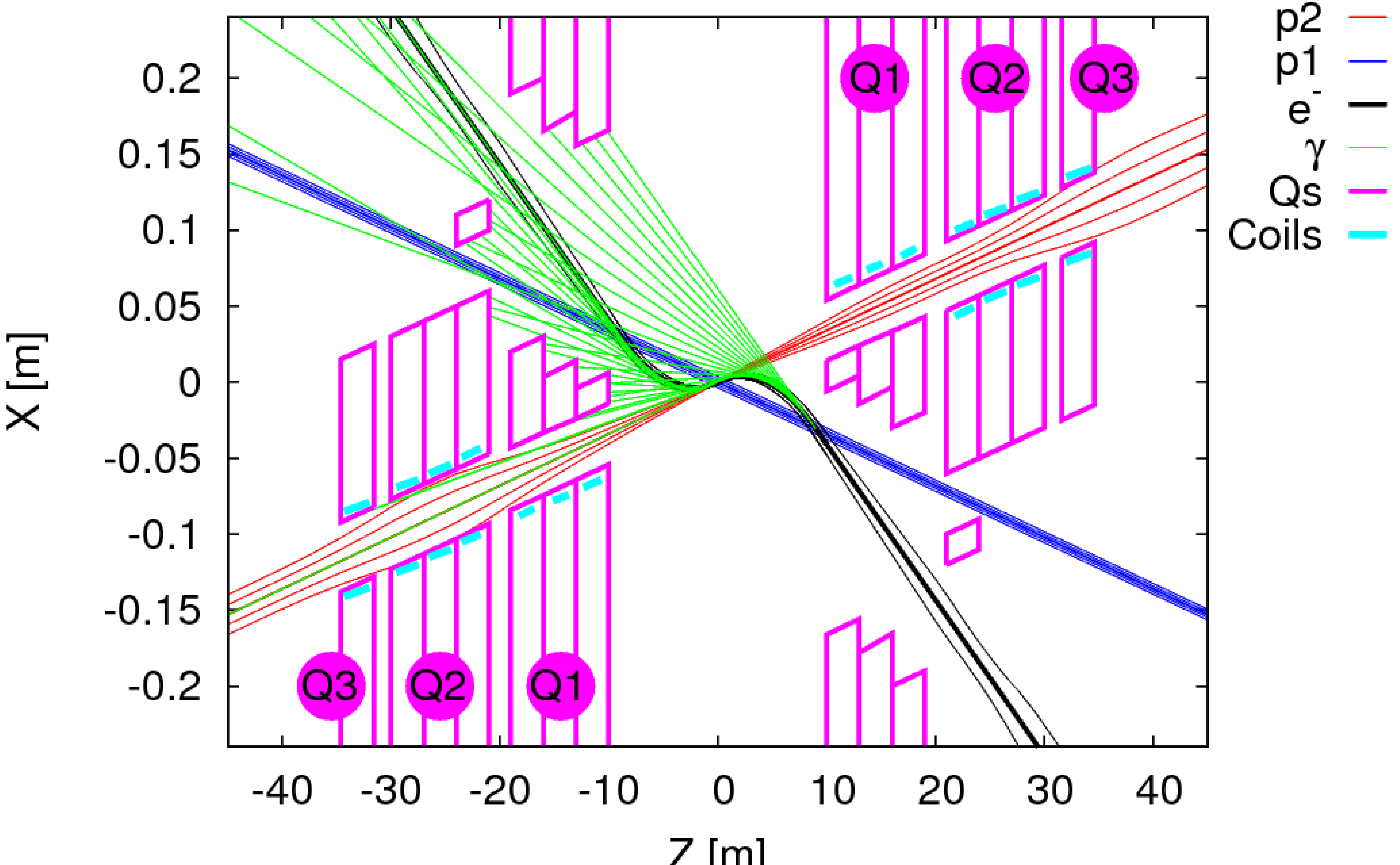
LHeC Linac-Ring IR layout



Beamstrahlung photons at the entrance of D1

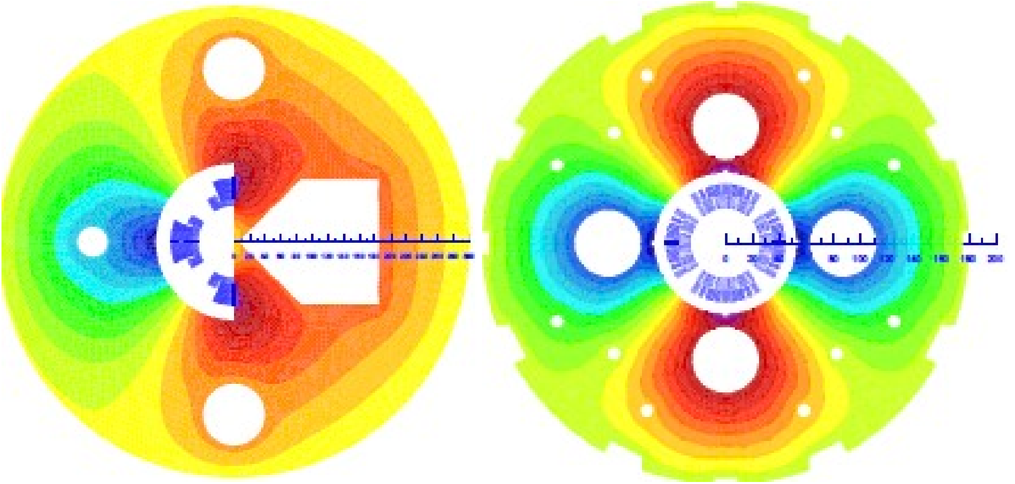


Zooming around the IP



Linac-Ring IR magnets

-High-gradient SC IR quadrupoles based on Nb3Sn for colliding proton beam with common low-field **exit hole for electron beam and non-colliding proton beam**

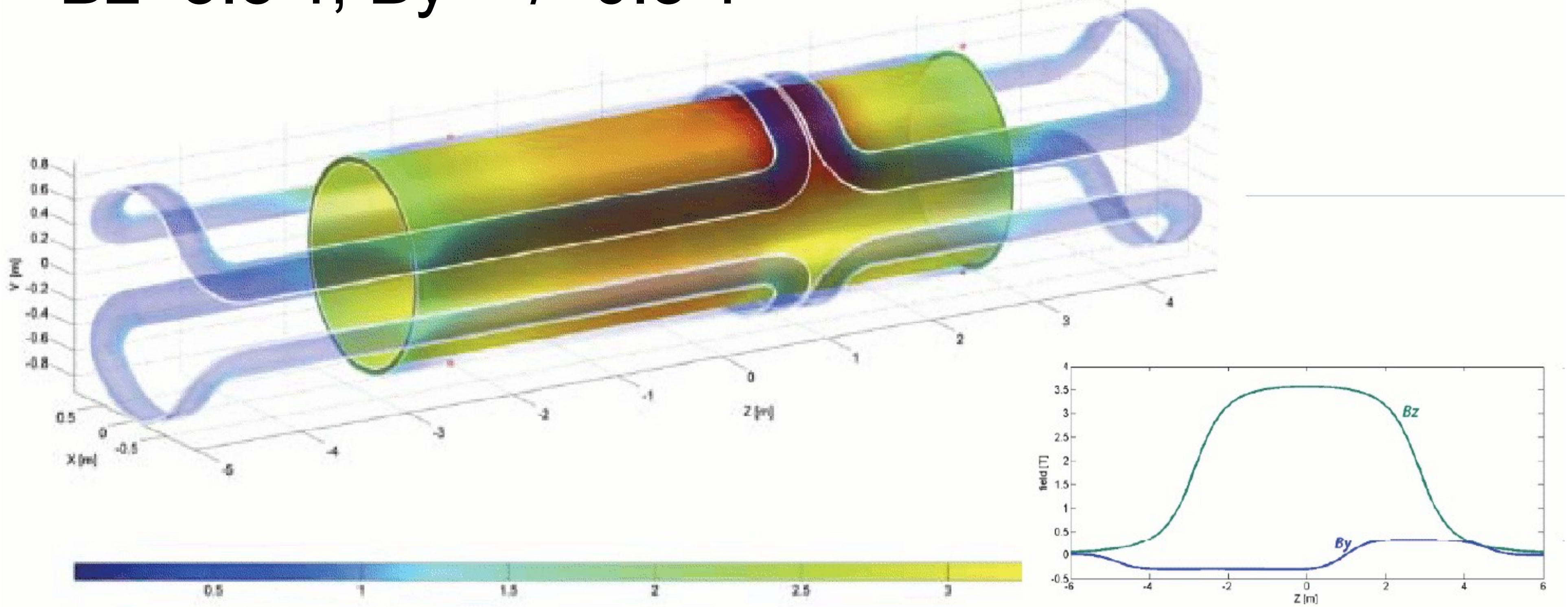


Nb3Sn (HFM46): 5700 A, 175 T/m, 4.7 T at 82% on LL (4 layers), 4.2 K	Nb3Sn (HFM46): 8600 A, 311 T/m, at 83% LL, 4.2 K
46 mm (half) ap., 63 mm beam sep.	23 mm ap.. 87 mm beam sep.
0.5 T, 25 T/m	0.09 T, 9 T/m

-Detector integrated dipole: 0.3 T over +/- 9 m

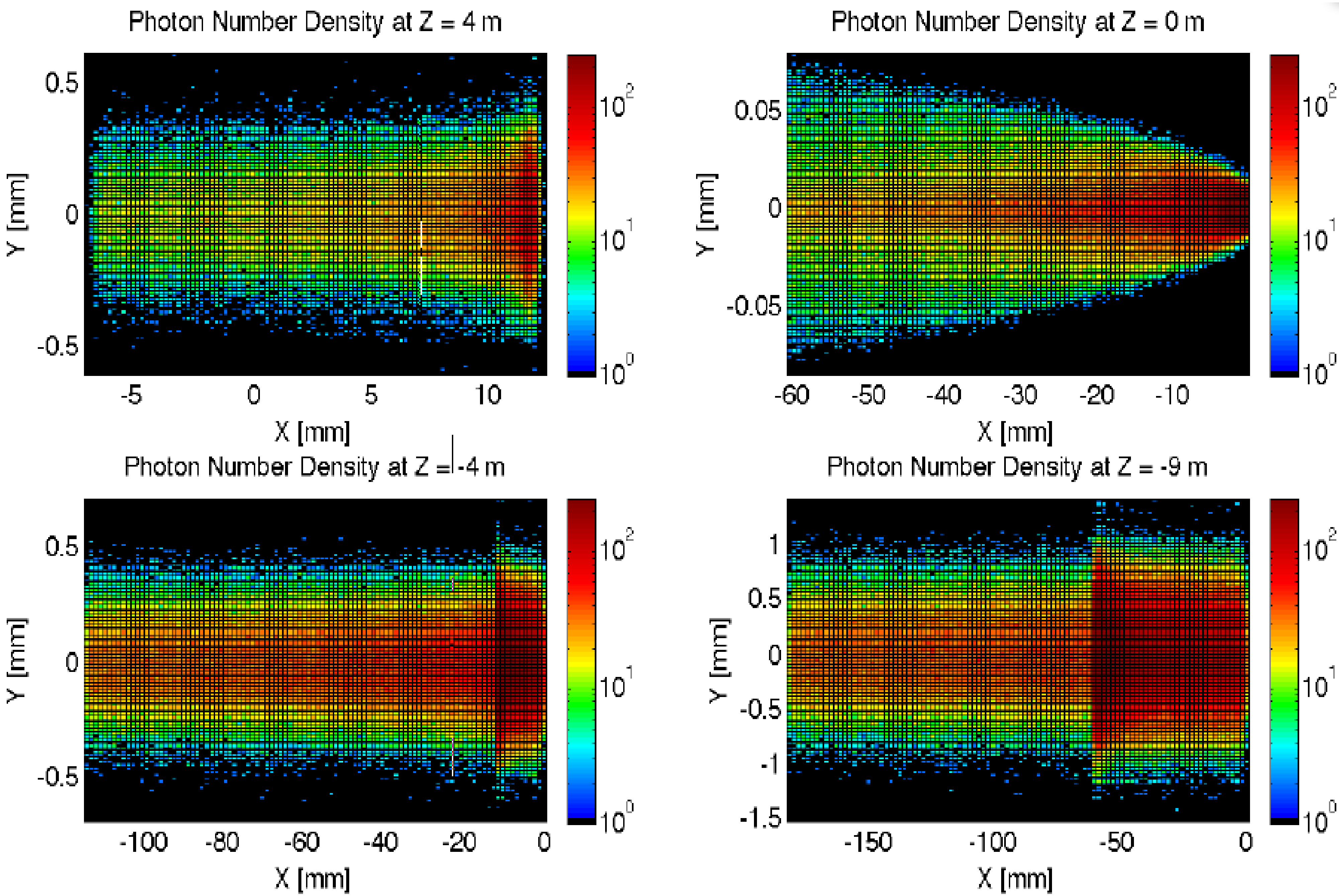
IR magnets

Bz=3.5 T, By=+/- 0.3 T



Stolen from A. Polini, DIS12

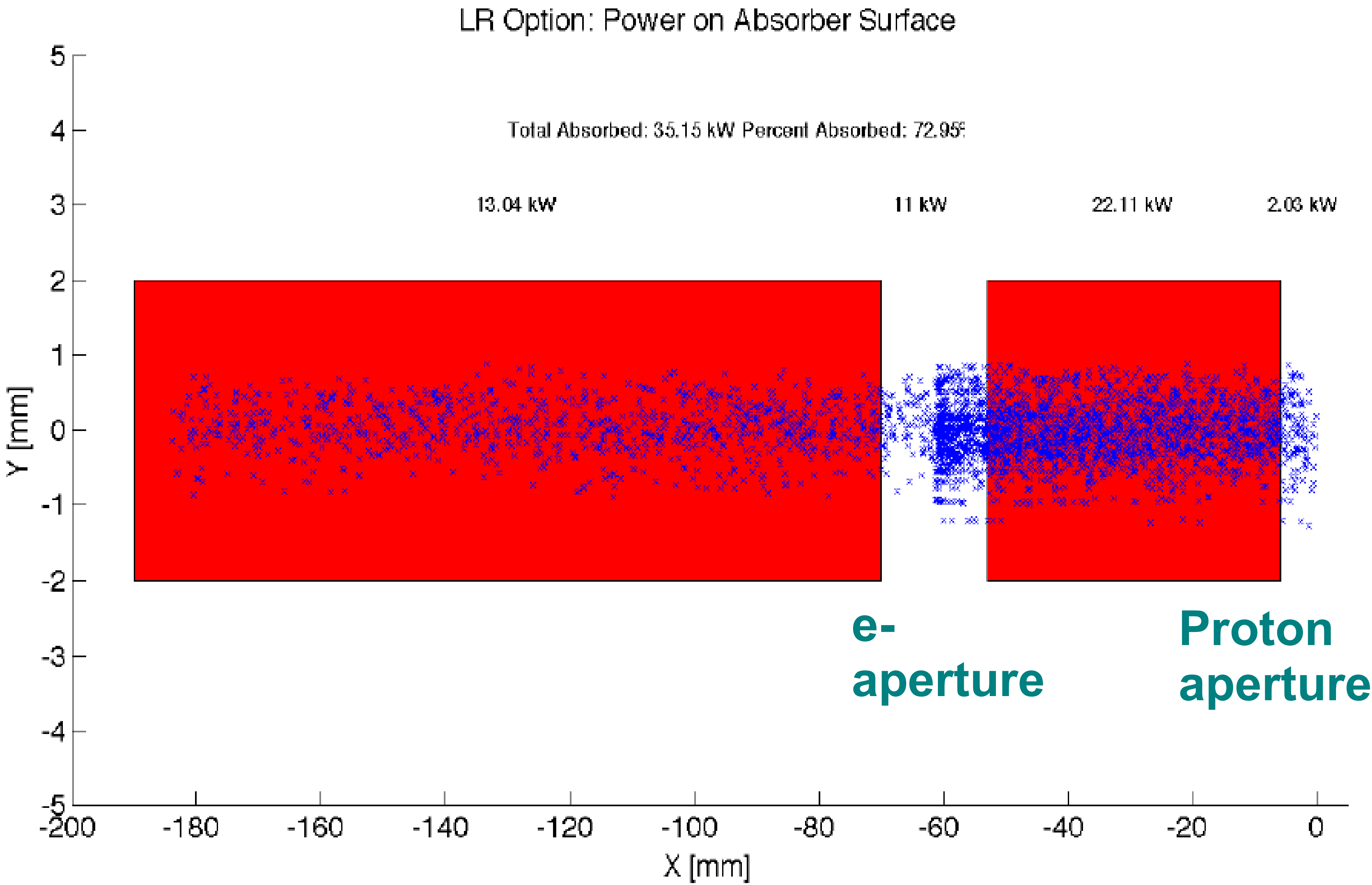
SR photon density at different locations



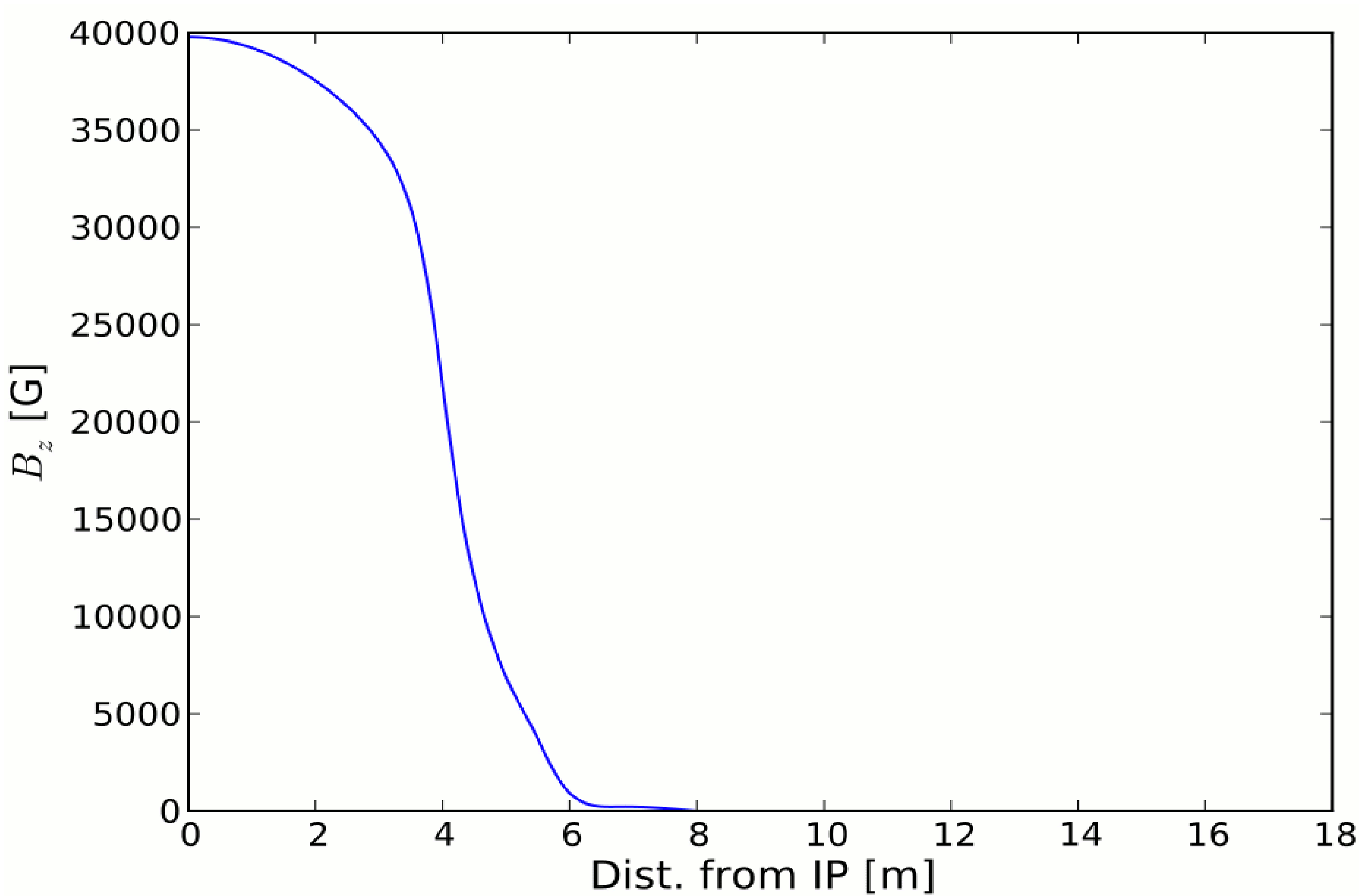
Linac-Ring IP Beam pipe

Inner Dimensions:
Circular(x)=2.2cm;   Elliptical(-x)=-10., y=2.2cm

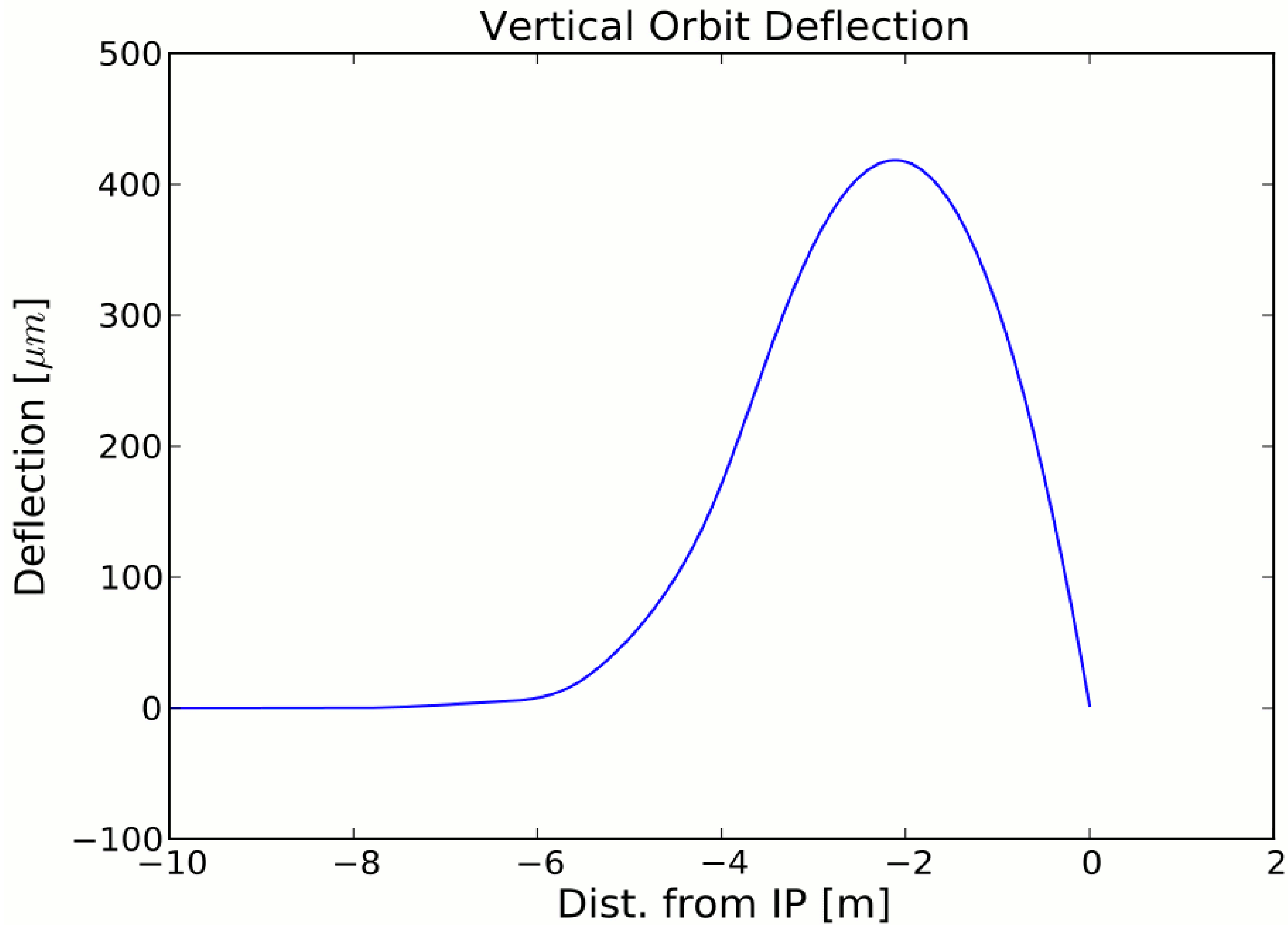
LR: Power on absorber surface



Approximation of solenoid field to the ILD case



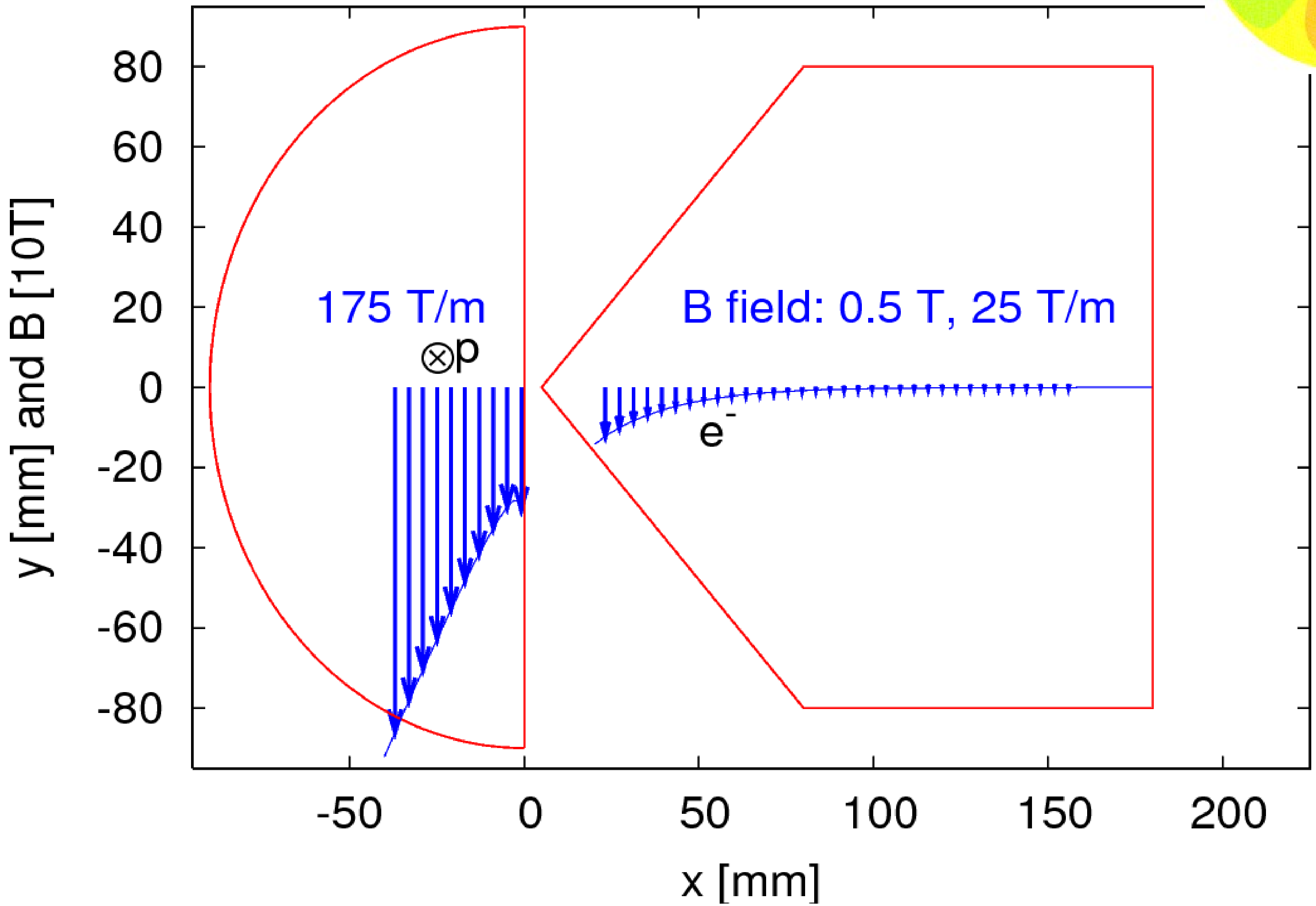
Effect of ILD solenoid in the e⁻ vertical orbit

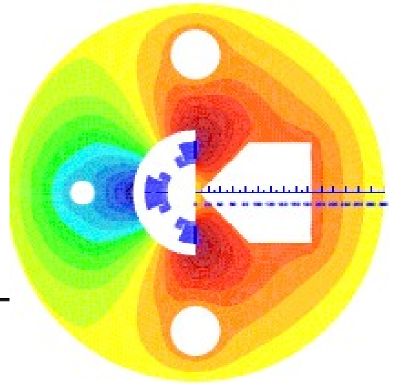


0.5mm max excursion, 50μrad at the IP
(few % lumi loss, correctable)

Fields in Q1

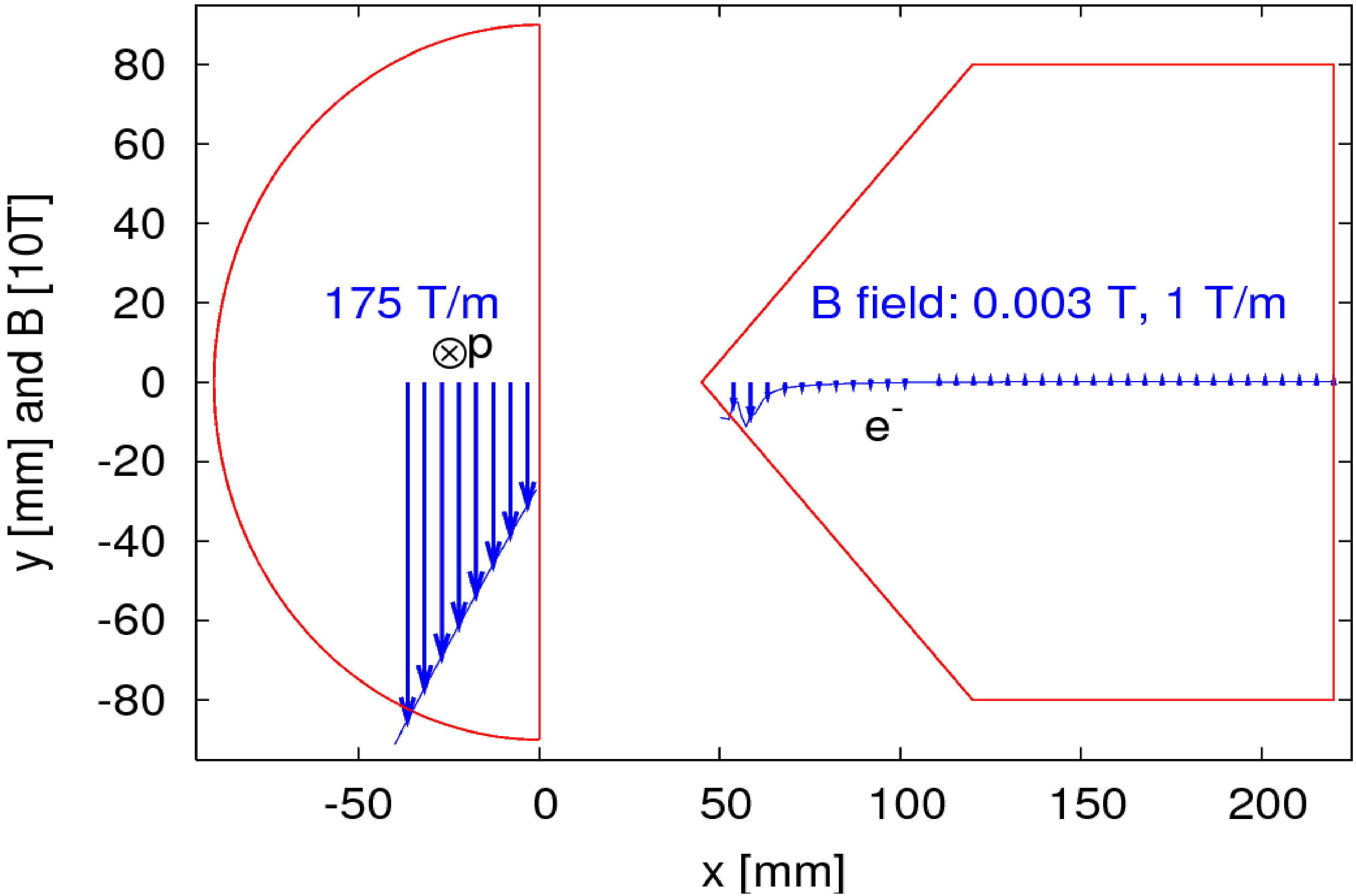
Poor quality in p aperture





strong field and gradient in e^- aperture

Fields in Q1 with larger beam separation



Larger separation helps a lot for field quality

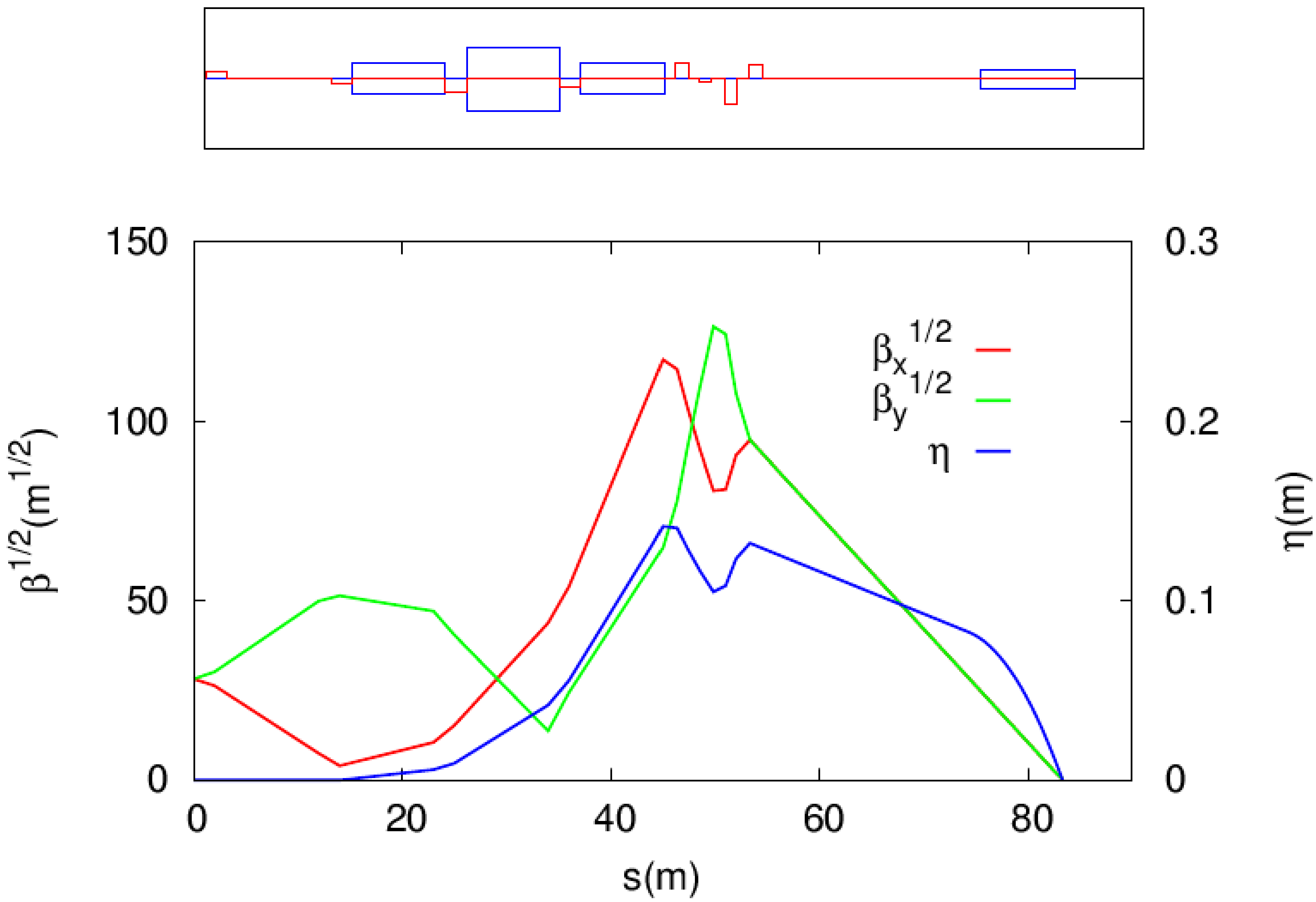
Larger beam separation

- Best way is to increase also L*
- L*=20 m and B=0.15T:
  - Beam separation = 130 mm
  - Photon critical energy = 360 keV
  - IR synchrotron power = 25 kW (factor 2 lower!)
  - Half quadrupole might not be necessary anymore
- This introduces larger chromaticity in LHC → larger beta* → lower luminosity
- Unless the LHeC IP could be IP3 or IP7 to adopt ATS optics-like approach

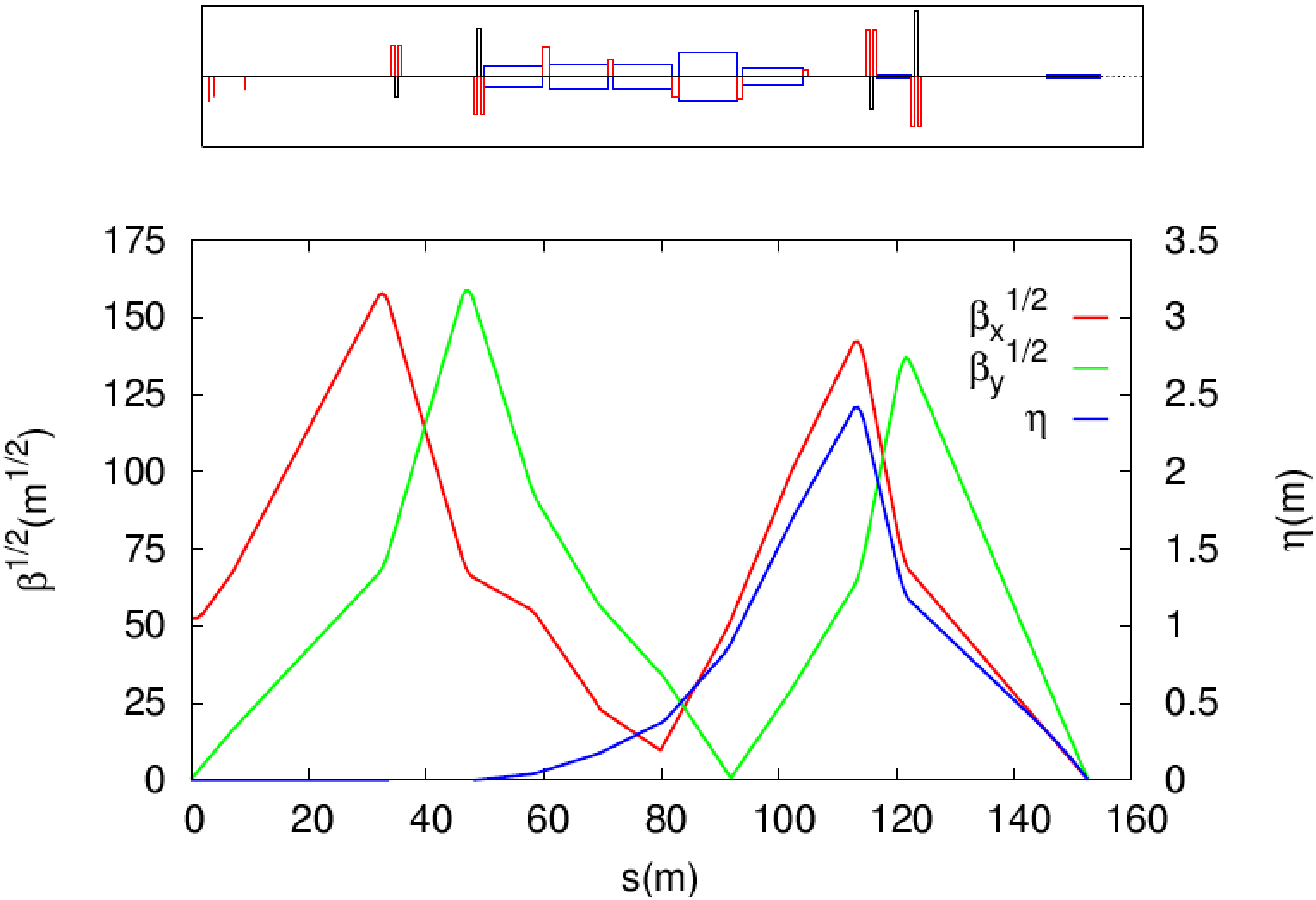
e^-/e^+ compatibility

- All e^- IR and FFS dipoles and quadrupoles should be bipolar
- The solenoid polarity can stay unchanged, the orbit correction system should do
- The field in the Q1 e^- aperture should be negligible → another motivation for larger beam separation

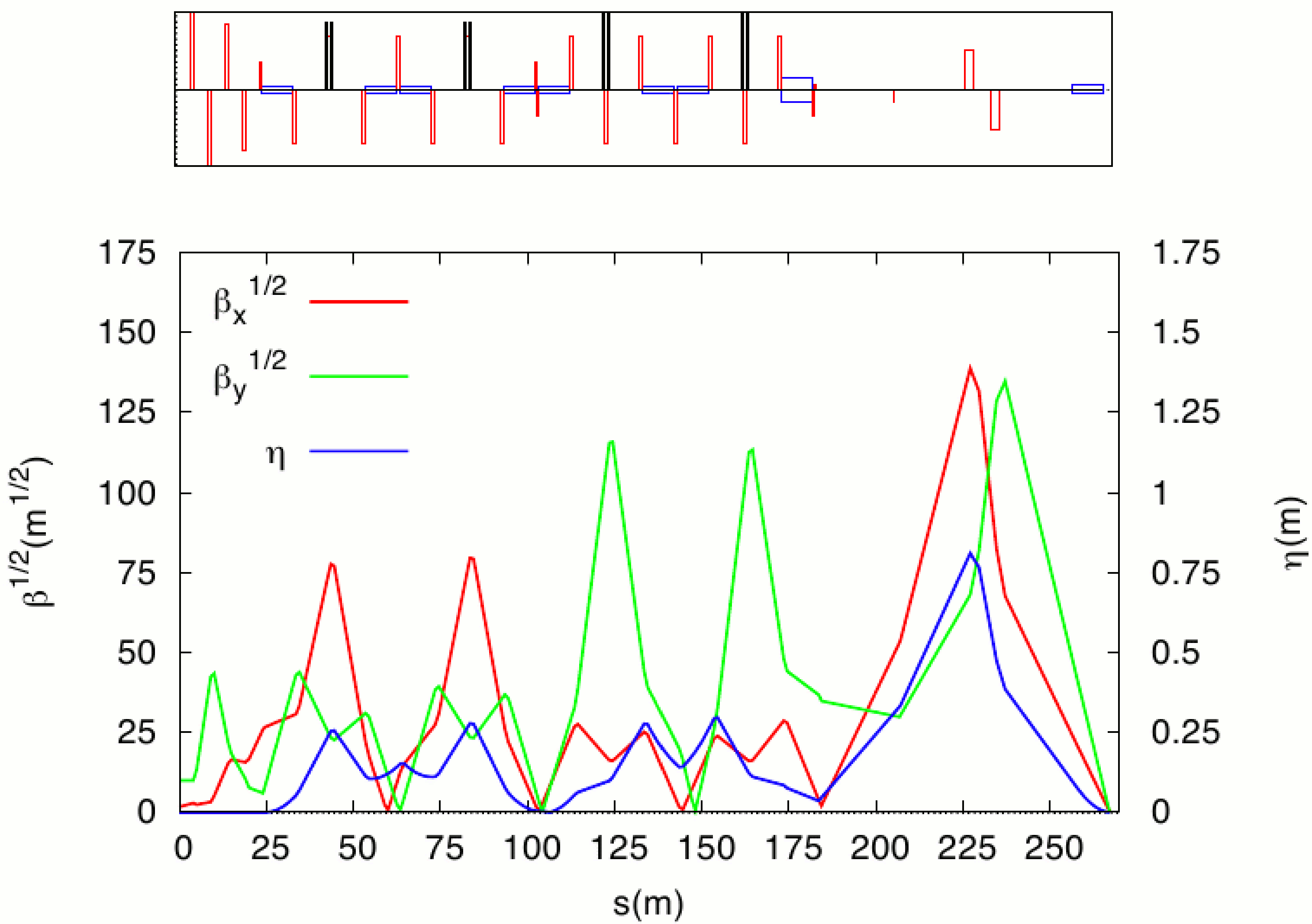
e⁻ FFS optics I: Triplet



e^- FFS optics II: Doublet, local chromaticity correction



e⁻ FFS optics III: Doublet, trad. chromaticity correction



e^- FFS quadrupoles

	triplet			doublet - local			doublet - traditional		
Name	Gradient [T/m]	Length [m]	Radius [mm]	Gradient [T/m]	Length [m]	Radius [mm]	Gradient [T/m]	Length [m]	Radius [mm]
Q1	19.7	1.34	20	−19.1	1.1	36	-20.54	2.5	36
Q2	−38.8	1.18	32	17.7	1.1	37	20.31	2.5	35
Q3	−3.46	1.18	20	−14.7	1.1	41	-6.59	0.3	17
Q4	22.3	1.34	22	11.8	1.1	41	2.85	0.3	13

e^- FFS options: performance comparison

	Triplet	doublet-local	doublet-trad.
Length [m]	90	150	260
Δσx/σx (no SR) [%]	9	1.5	5.7
Δσy/σy (no SR) [%]	21	1.7	14.1
Δσx/σx (with SR)[%]	10	141	39.3
Δσy/σy (with SR)[%]	21	1.9	14.3
ΔL/L with SR [%]	**-14**	**-46**	**-23**

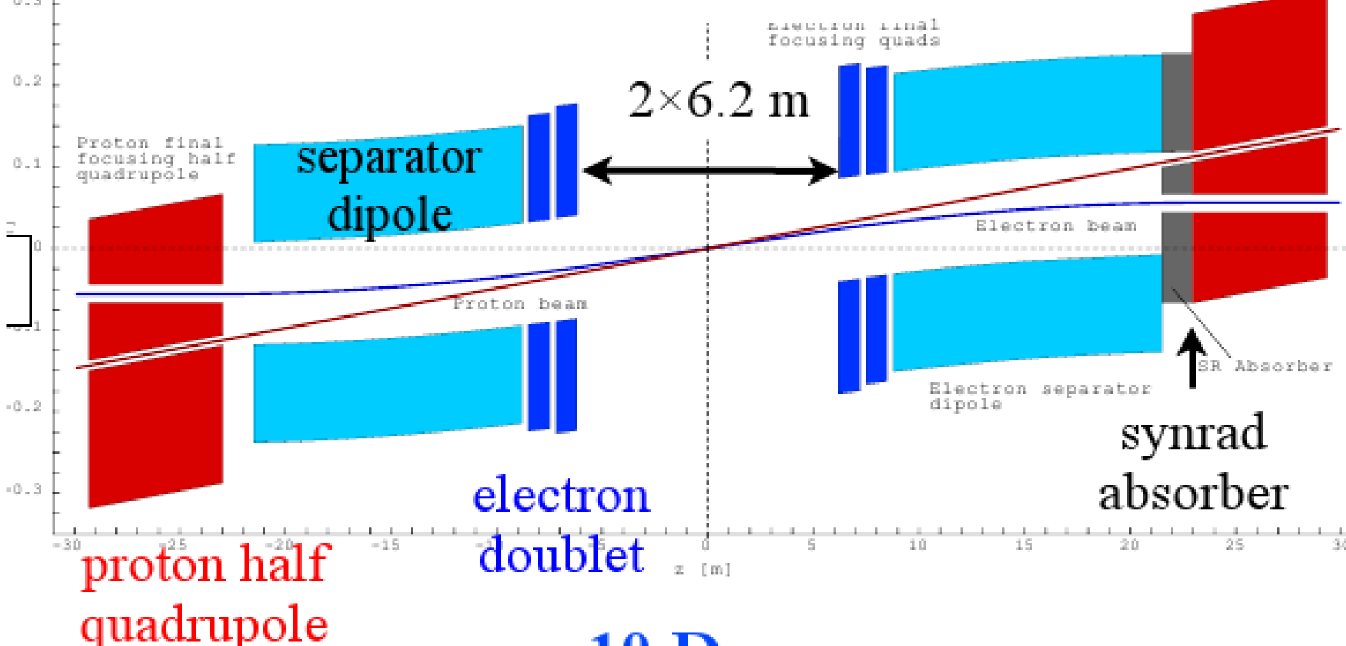
Chromaticity correction requires a long FFS and introduces significant emittance growth due to SR

Conclusions

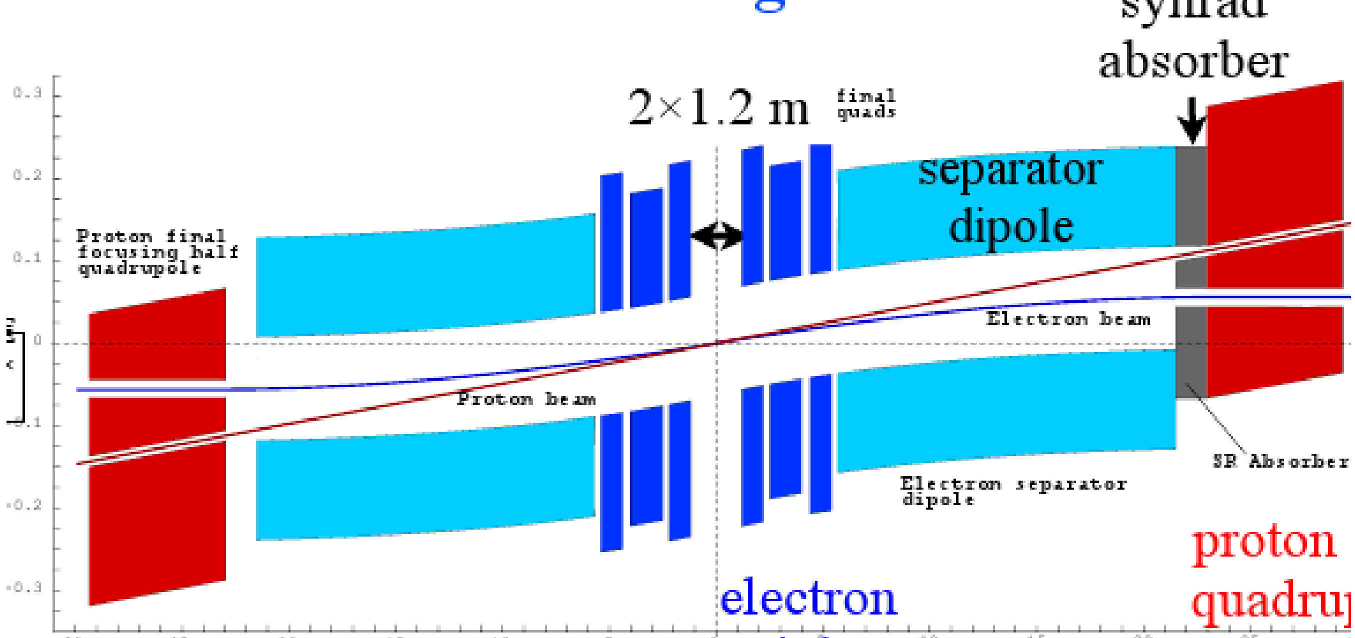
- SR and back shining from absorber is the largest concern (lower bend/SR welcome), followed by SR power in the spin rotator
- Solenoid effects are reasonably small
- Q1 field quality might impose larger beam separation and longer L* (→reduce By/SR)
- Optimization of L* and β* within the LHC
- e^- FFS optics: balance between chromaticity correction, SR and length
- Common effort needed for the global optimization → study group

Ring-Ring HA & HL layouts

1 Degree

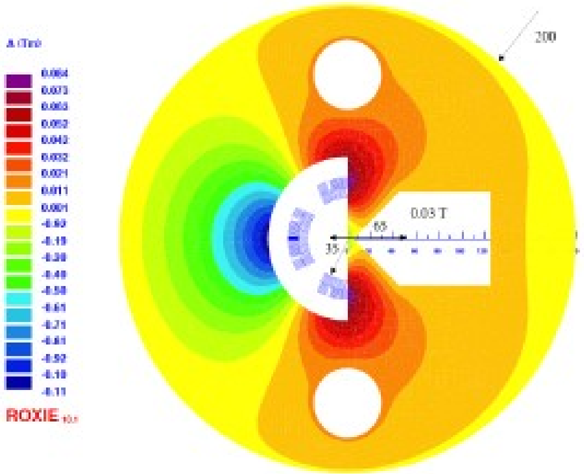


10 Degree

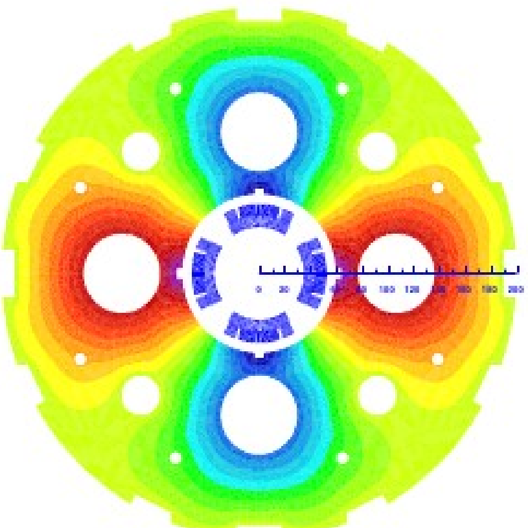


Ring-Ring proton quadrupoles

Q1: Half Quadrupole with field free regions for the e-beam



Q2: Single aperture



Standard tech: NbTi

	Q1	Q2
Radial aperture	35 mm	36 mm
B_0	137 T/m	137 T/m
g_0	2.5 T	-
Beam separation	65 mm	107 mm
operation percentage on the load line of the sc	77%	73%
B_{fringe} e-aperture	0.03 T	0.016 T
g_{fringe} e-aperture	0.8 T/m	0.5 T/m