Solenoid Compensation Scheme for FCC-ee FF

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Latest parameters of solenoids

- Main solenoid magnetic field: 2 T.
- L* = 2.2 m (from IP to the face of quadrupole).
- Length of main solenoid coil: ±4 m.
- Inner radius of main solenoid coil: 3.76 m.
- Outer radius of main solenoid coil: 3.818 m.
- No iron yoke?.
- From IP to the face of compensating solenoid is 1.25 m.
- Detector’s opening angle is 0.1 rad -> 0.14 rad.
- Full crossing angle is 0.03 rad.

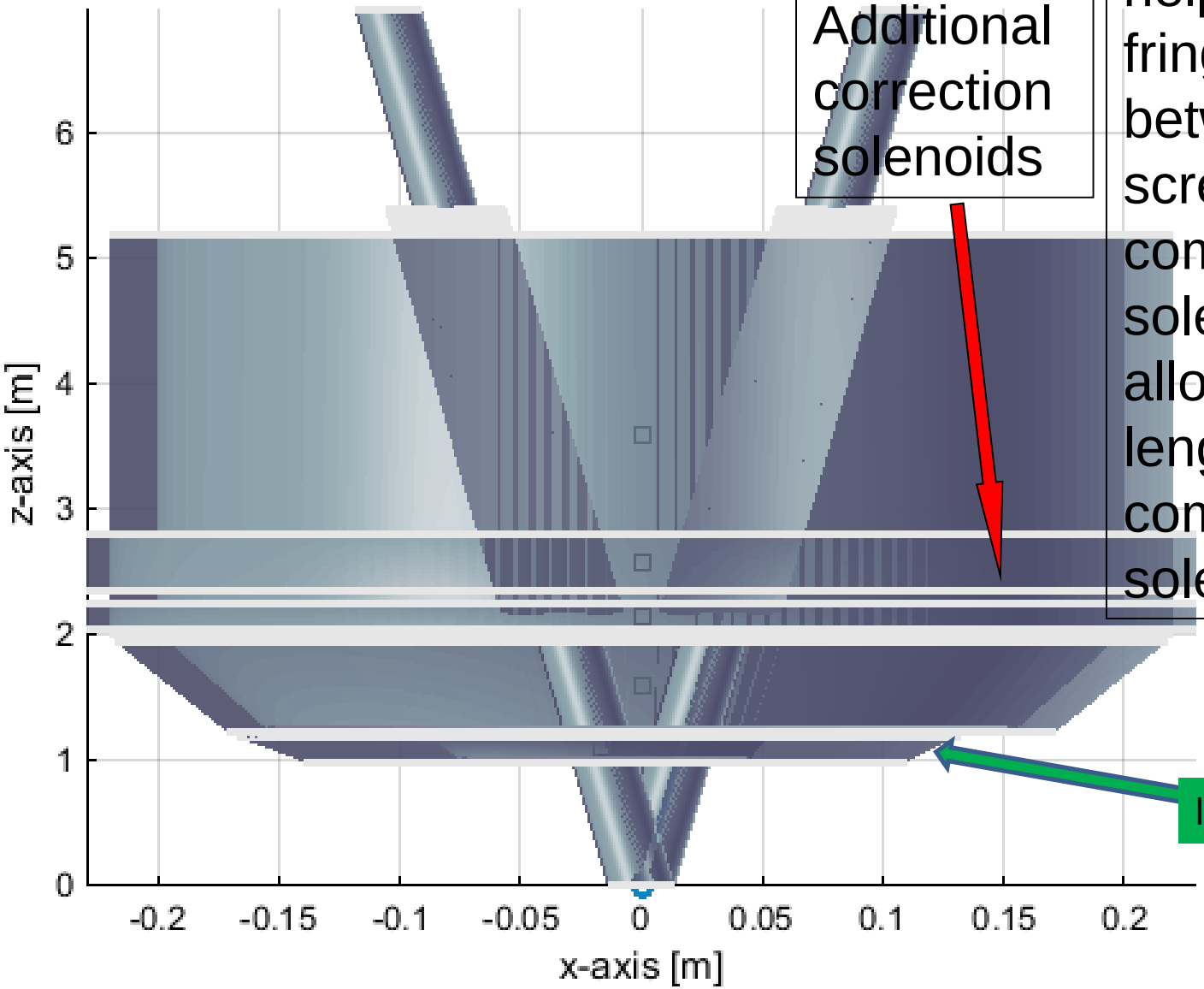
Latest parameters of solenoids

- Vertical emittance:
  - $\varepsilon_y = \kappa \cdot \varepsilon_x + \varepsilon_{y\_solenoid} \leq 1$ pm·rad
  - κ – betatron coupling,
  - ε_x – radial emittance,
  - $\varepsilon_{y\_solenoid}$ – vertical emittance created by solenoids field.
- Conical compensating solenoid
  - $\varepsilon_{y\_cylindrical\_solenoid} / \varepsilon_{y\_conical\_solenoid} \sim 3$

Latest layout

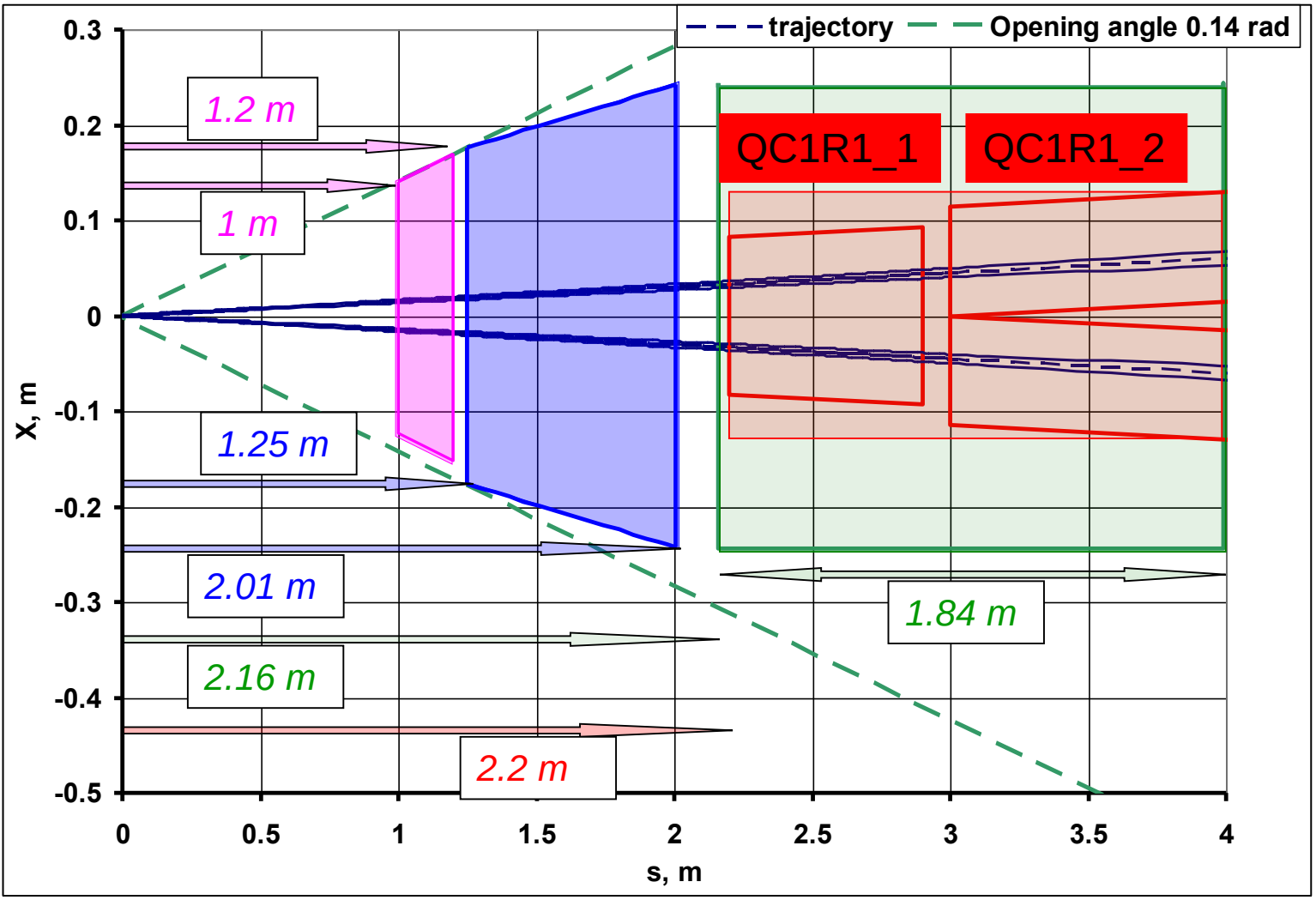
Additional correction solenoids

Additional coils help to optimize fringe fields between screening and compensating solenoids. This allows to increase length of compensating solenoid.



M. Koratzinos

Layout



Luminometer

Compensating Solenoid

Screening Solenoid

Defocusing Quads

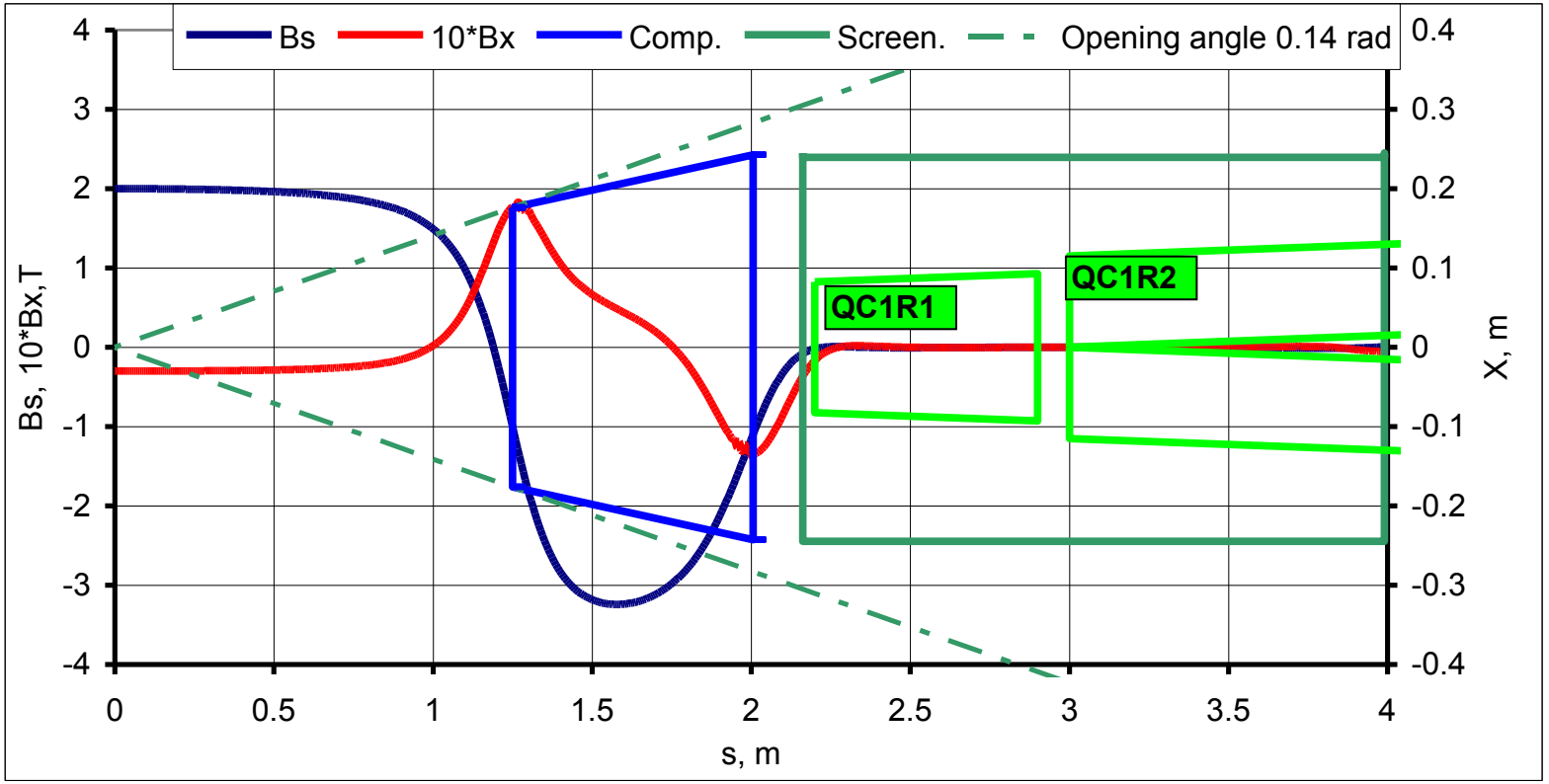
QC1R1_1: L= 0.7 m, K1=-75 / -75 T/m, R = 0.015 m

• QC1R1_2: L= 1.4 m, K1=-173 / -166 T/m, R = 0.0175 m

Layout

Name	Initial azimuth	Initial radius	Final azimuth	Final radius	Length	Coil thickness
	m	m	m	m	m	m
IP	0		0		0	
Luminometer	1	?	1.2	?	0.2	
Main Solenoid	0	3.818	4	3.818	8	0.058
Compensating Solenoid	1.25	0.176	2.006	0.243	0.756	0.02
Screening Solenoid	2.162	0.245	4	0.245	1.838	0.03
QC1R1_1	2.2	0.083	2.9	0.093	0.7	
QC1R1_2	3	0.058	4.4	0.058	1.4	
QC2R1_1	5.7	0.058	6.95	0.058	1.25	
QC2R1_2	7.05	0.058	8.3	0.058	1.25	

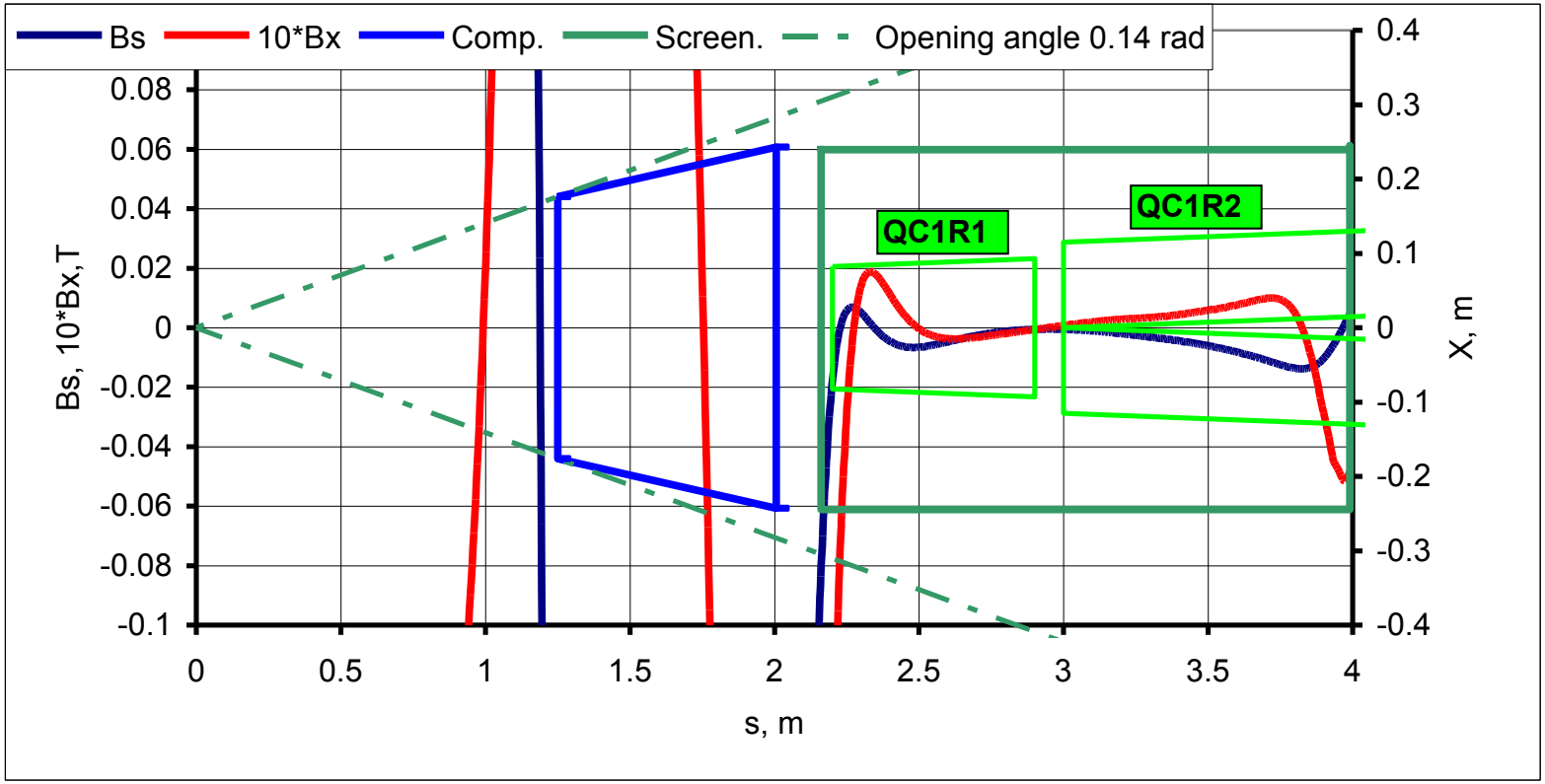
Field distribution



Transverse half size:

- main solenoid field - L_{geom} = 1.25 m, B_s = 2 T
- compensating solenoid - R = 0.176 / 0.243 m, L_{geom}= 0.756 m, B_s ~ 3.3 T
- screening solenoid - R = 0.245 m , L_{geom} = 1.838 m

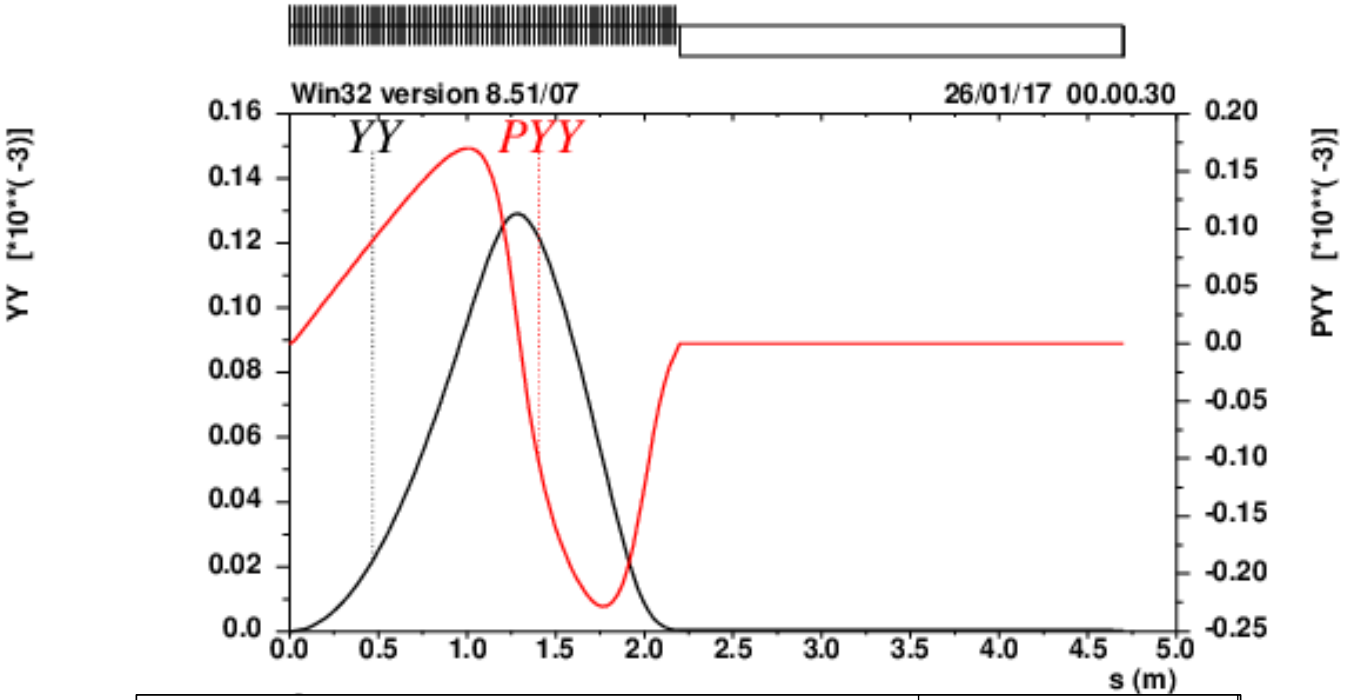
Field distribution

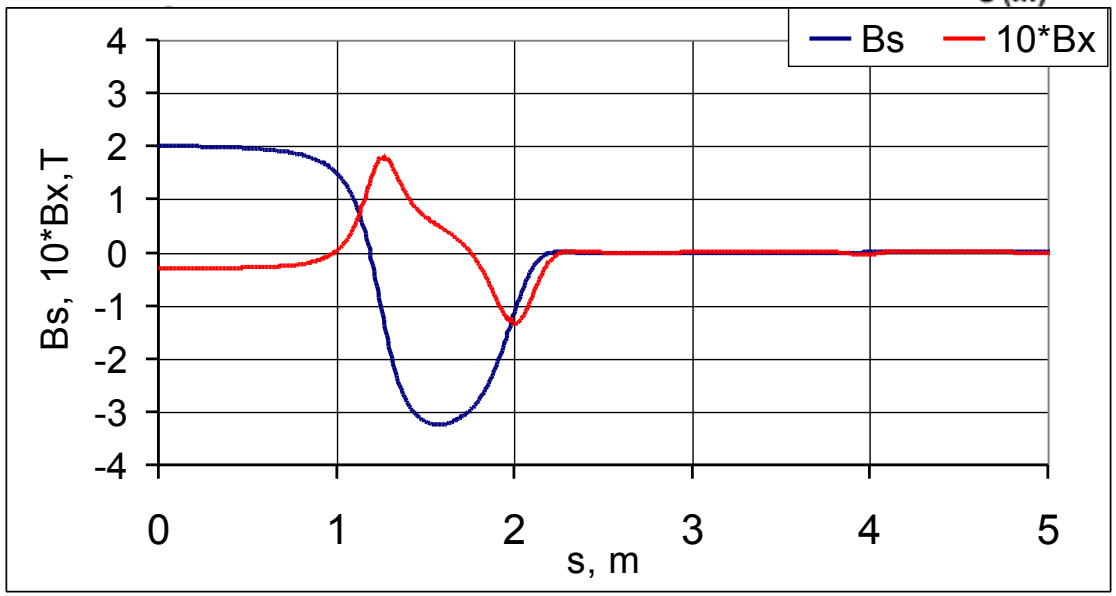


Edge field in quad area: B_s<0.01 T B_x<0.002 T

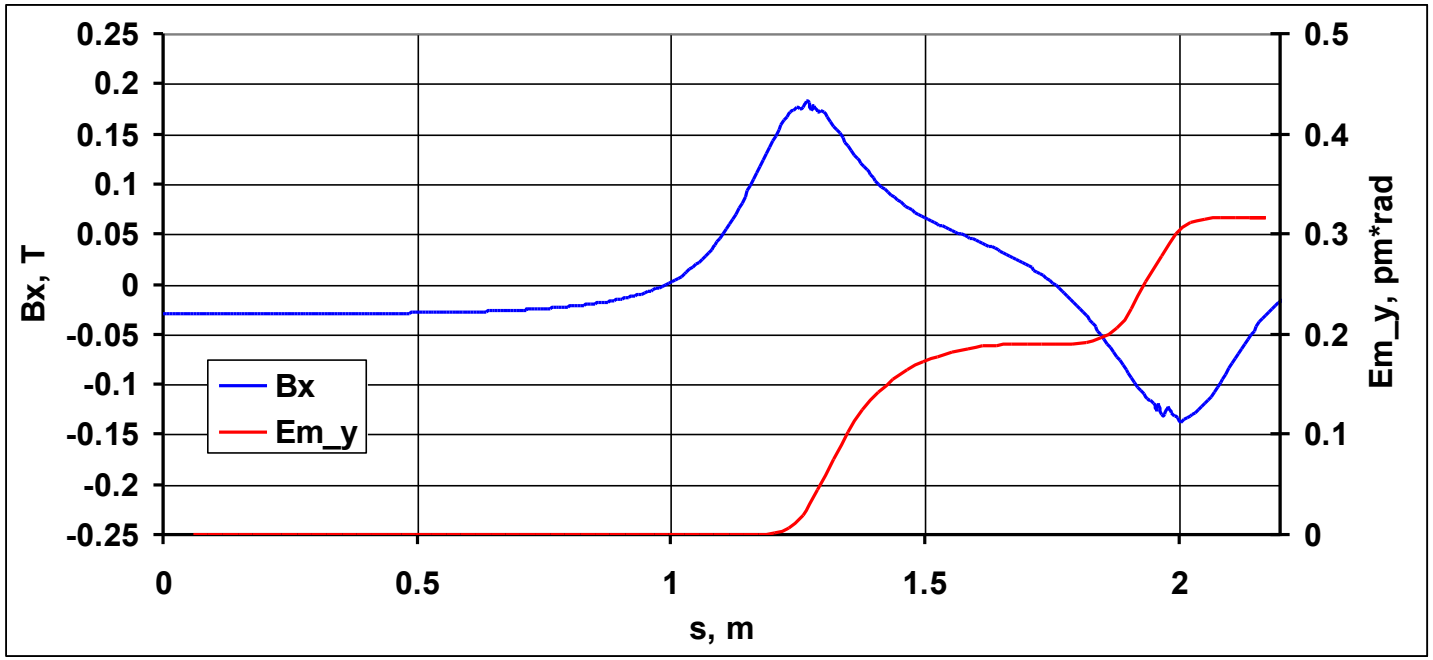
It is necessary additional corrections of screening area and steel yoke area.

Beam Orbit at IR





Emittance calculation



- I_2 = 5.65*10^{-4} m^{-1}
- I_5 = 1.99*10^{-11} m^{-1}

$$I_{5y} = h_y^3 \oint \mathrm{H}_y(s)ds = 6.00 \cdot 10^{-14}\ m^{-1}$$

$$\varepsilon_y = 3.83 \cdot 10^{-13} \cdot \frac{\gamma^2}{J_y} \cdot \frac{I_{5y}}{I_2} = 0.32\ pm*rad$$

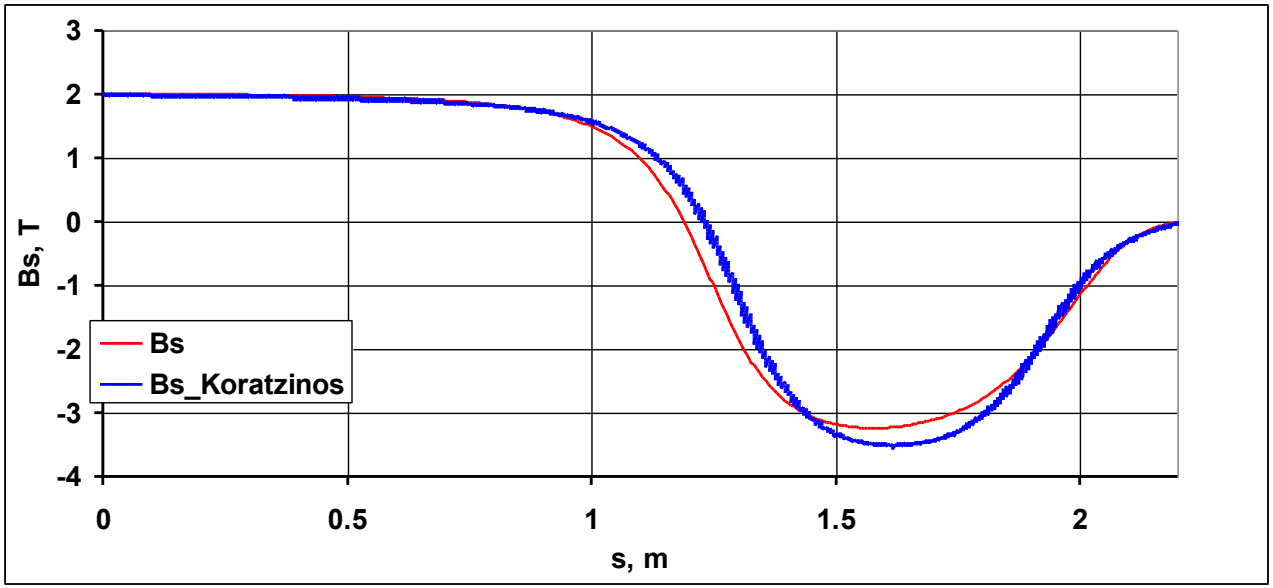
For 2 IP

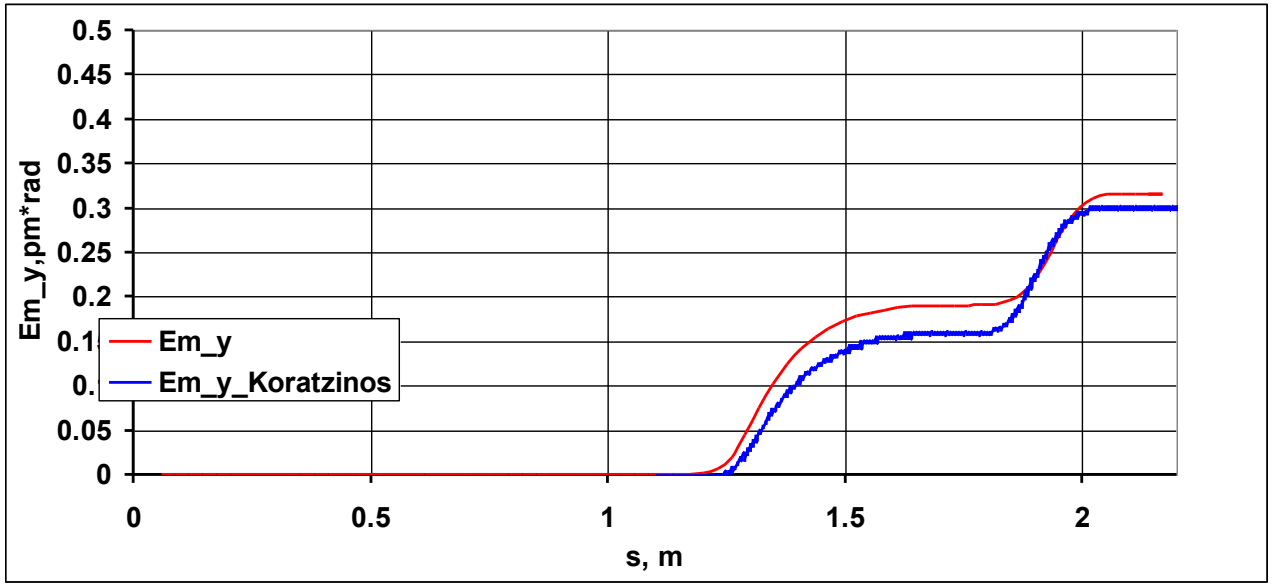
$$I_{5y} \sim B_x^5 \qquad \varepsilon_y \sim B_x^5$$

Beam parameters

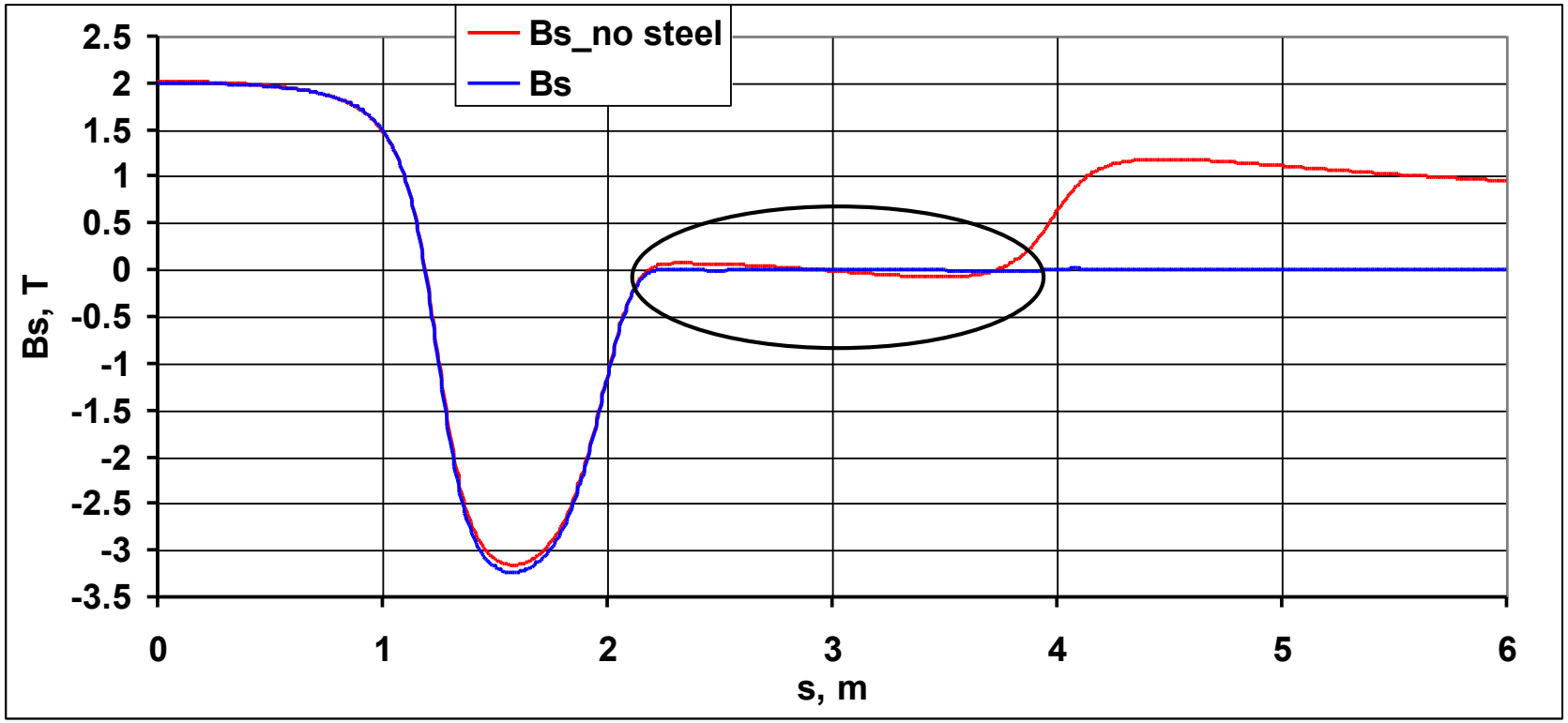
Parameter	Unit
Beam energy, GeV	45
Q_x	0.08
Q_y	0.14
$\beta_{x\ IP}$, m	0.5
$\beta_{y\ IP}$, m	0.001
Emittance, pm*rad	105
Ver. Emittance, pm*rad	0.316
Emittance Ratio (v./h.)	0.003
Energy spread	2.4E-04
Energy loss of particle per turn, MeV	32.64
Energy loss of particle (in solenoids), keV	76.5
I2, m^{-1}	$5.65*10^{-4}$
I5, m^{-1}	$1.99*10^{-11}$
I2_solenoid, m^{-1} (2 IP)	$1.97*10^{-6}$
I5_solenoid, m^{-1} (2 IP)	$6.00*10^{-14}$

Comparison of latest results





Field distribution



Inhomogeneity:

- No iron: Bs ~ 1 kGs
- With iron: Bs ~ 50 Gs

Summary

- Vertical emittance for current geometry is small.
- Residual magnetic field in FF area is less than 50 Gs.
- Absence of detector’s solenoid iron yoke requires distributed solenoid coils.