MEIC

Collider Rings and IR Design for MEIC

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for MEIC Collaboration

Center for Advanced Studies of Accelerators

EIC Collaboration Meeting
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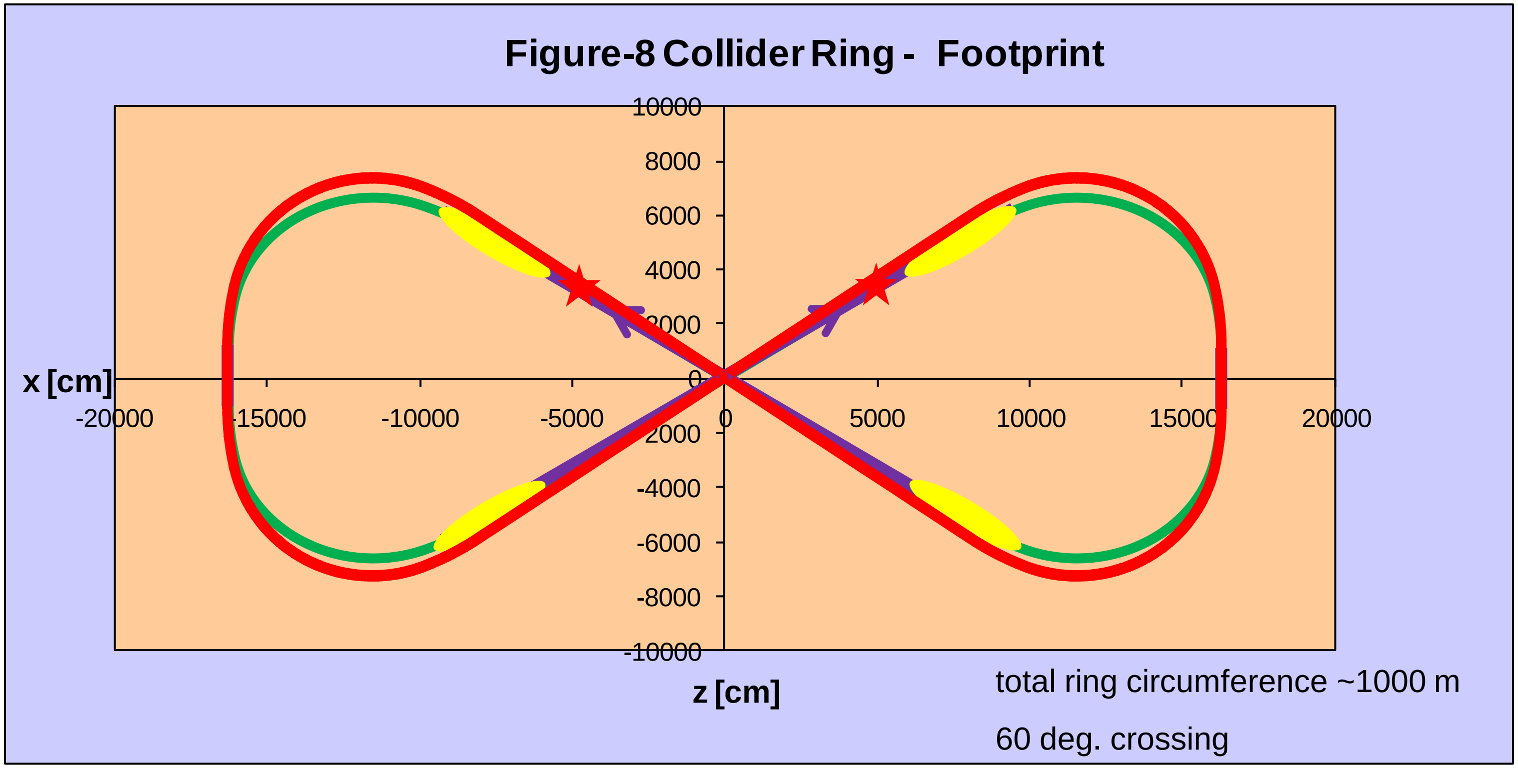
MEIC Figure-8 Collider Rings



- Collider Ring size is a compromise between synchrotron radiation and space charge

3-11 GeV electrons

20-60 GeV ions (with 6 Tesla dipoles)

100 GeV ions (with 8 Tesla dipoles)

MEIC Collider Rings with 'Relaxed' IR Optics

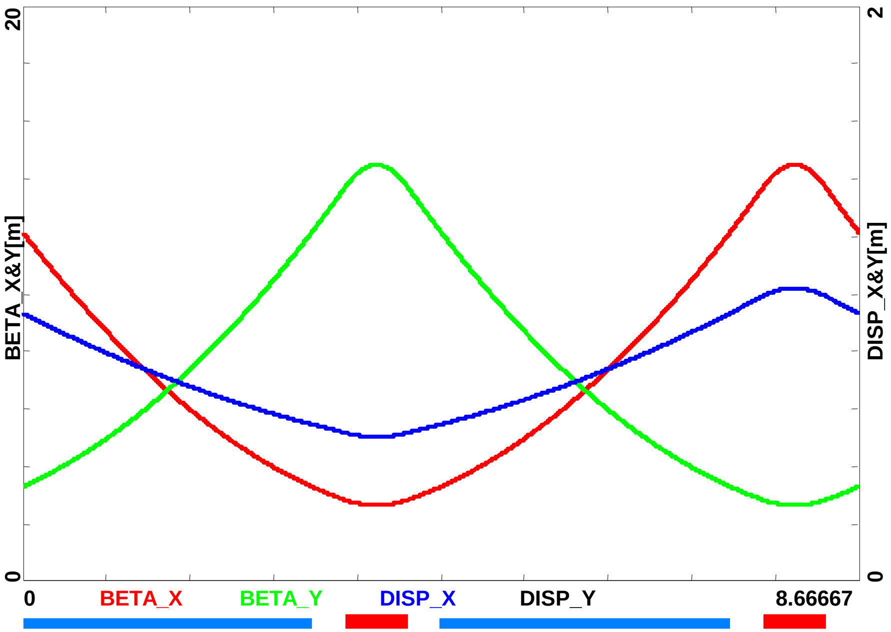
- Larger Figure-8 Rings (~1000 m circumference)
  - 6 Tesla bends for ions at 60 GeV
  - Additional straights to accommodate spin rotators and RF
  - Horizontal IR crossing, dispersion free straights
- 'Relaxed' IR Design: $\beta^{\max} \approx 2.5\times10^{3}\,m$

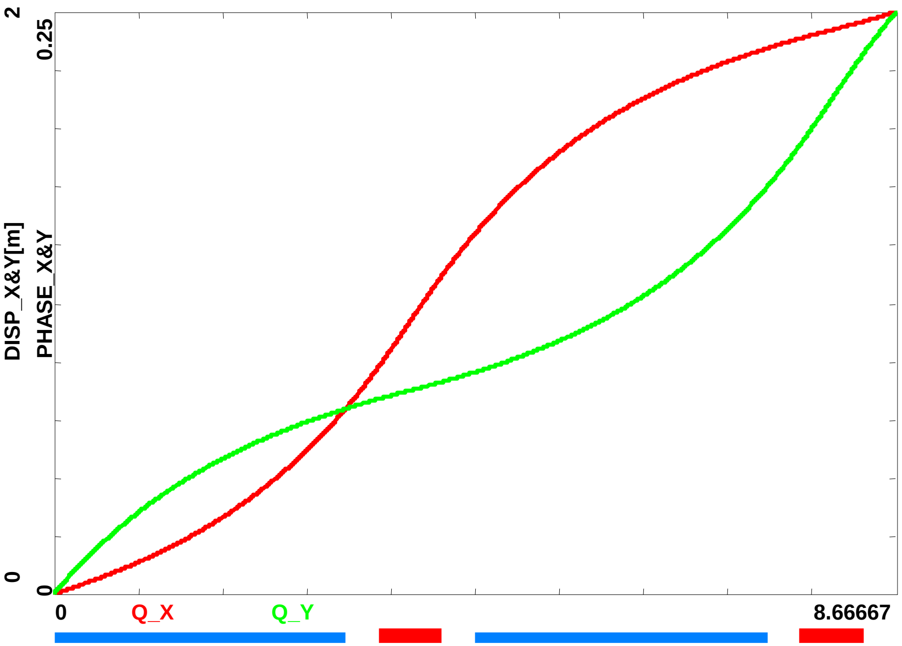
$$\beta_x^* = 10\,cm$$
$$\beta_y^* = 2\,cm$$

- Chromaticity Compensating Optics
  - Uncompensated dispersion in the straights
  - Anti-symmetric dispersion pattern across the IR
  - Dedicated Symmetric Inserts around the IR
- Electron Collider Ring based on emittance preserving Optics

Ion Ring – 90^0 FODO Cell

E = 60 GeV

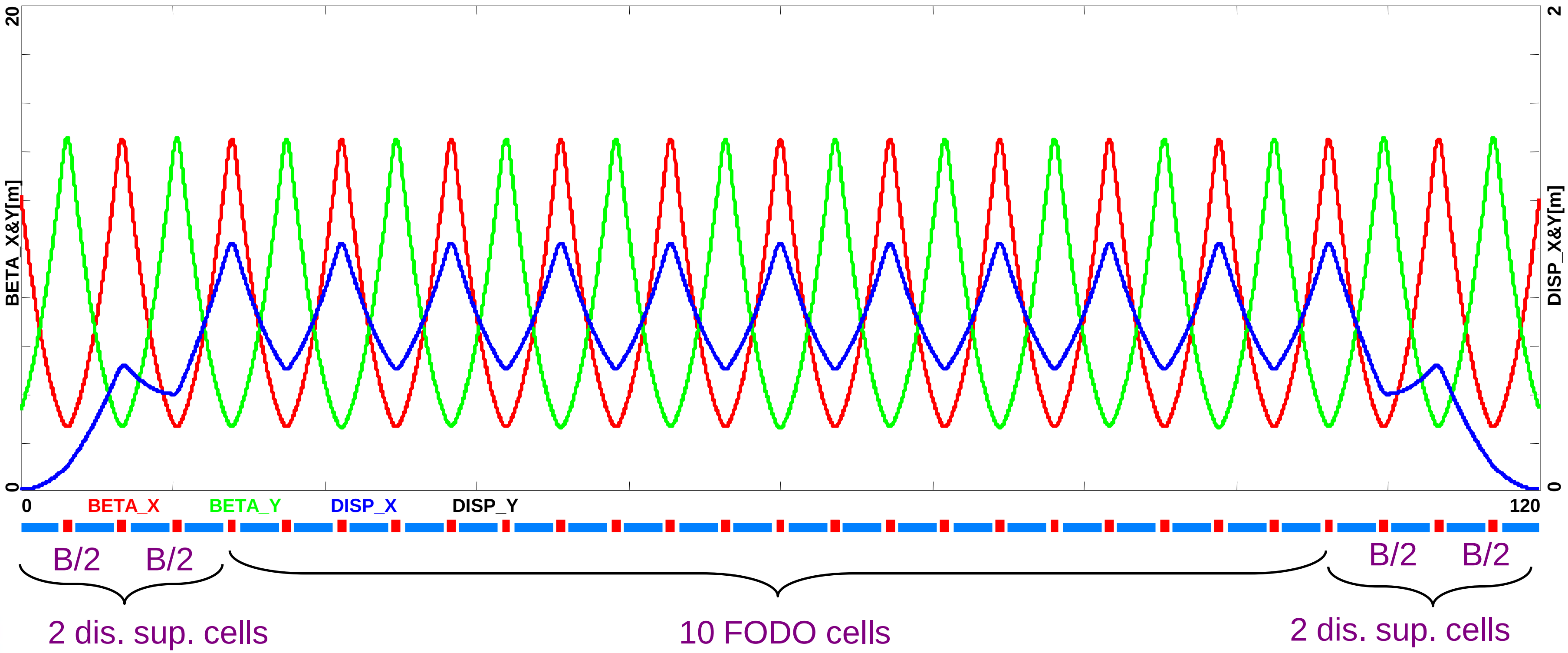




Arc dipoles:	**Arc quadrupoles**
$Lb=300 cm	$Lq=65 cm
$B=58.2 kGauss	$G= 10.5 kG/cm
$ang=5 deg.	
$rho = 34.4 meter	

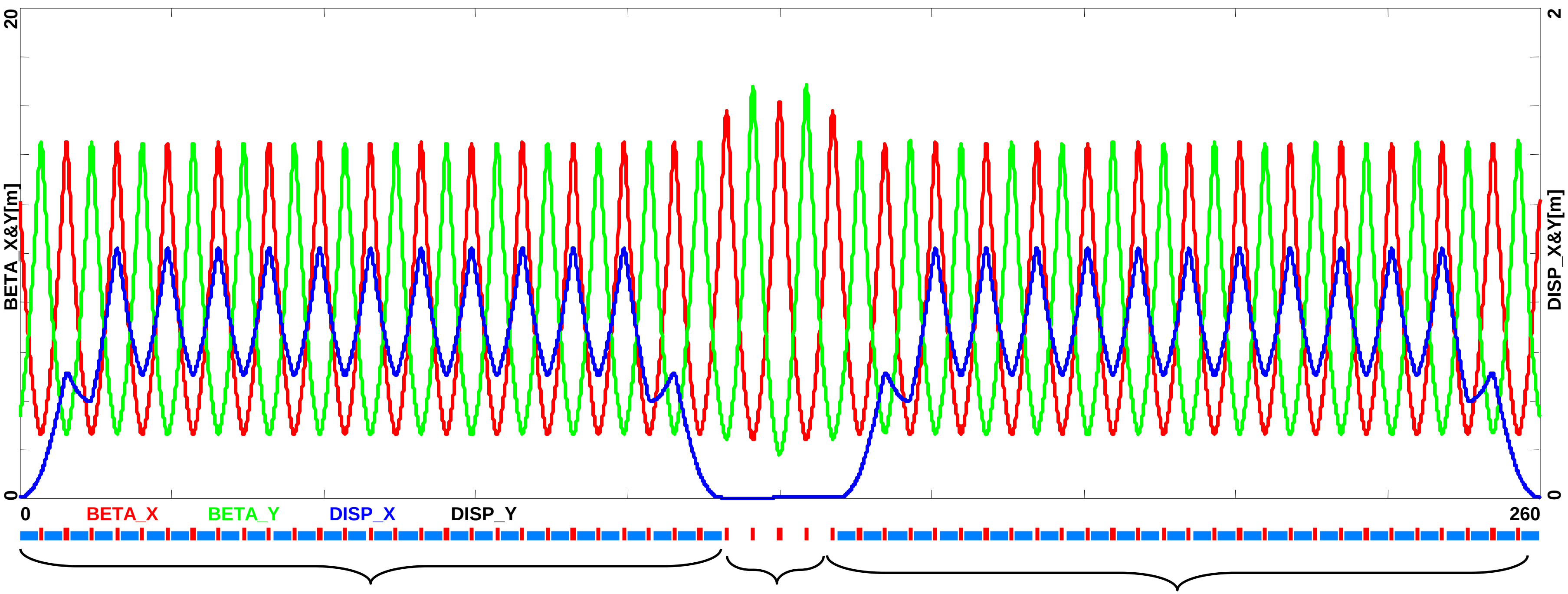
90^0 offers intrinsic cell-to-cell cancellation of beta chromaticity – off momentum beta wave propagates with twice the betatron frequency (180^0 after two cells - cancellation)

Quarter Arc Achromat



28 3 meter dipoles

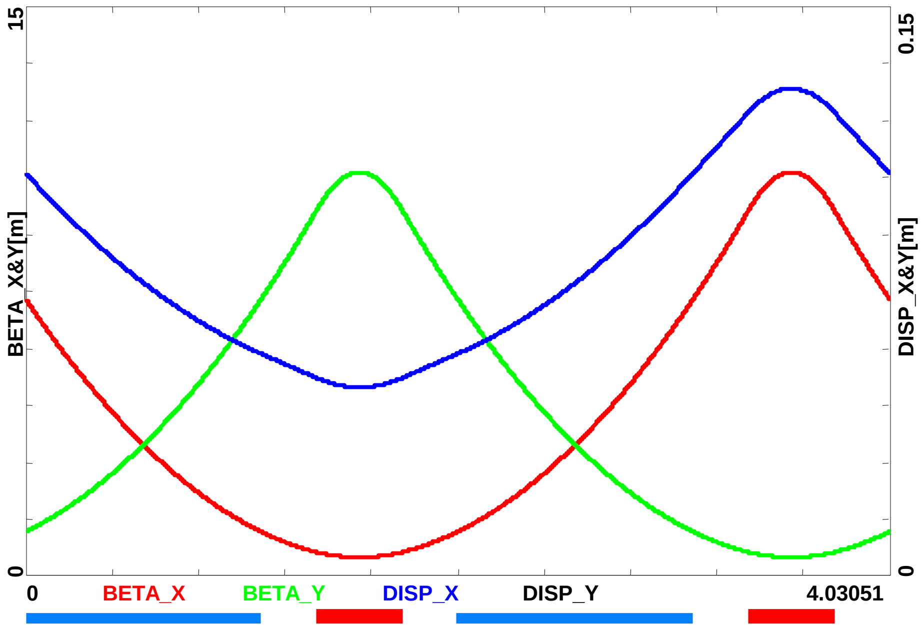
Ion Ring – Arc Optics

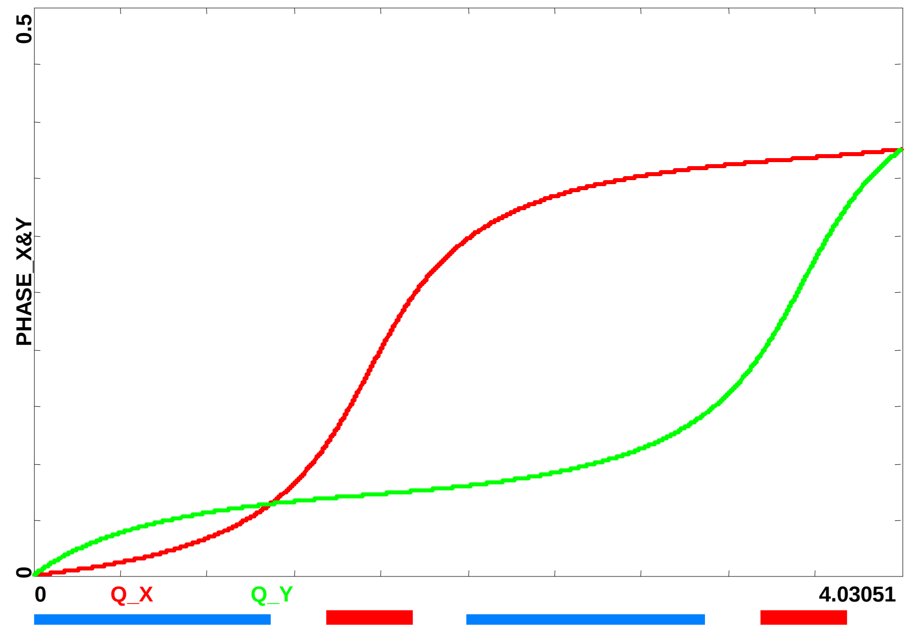


quarter Arc – 120 meter Straight – 20 meter quarter Arc – 120 meter

MEIC Electron Ring – 135^0 FODO Cell

E = 11 GeV





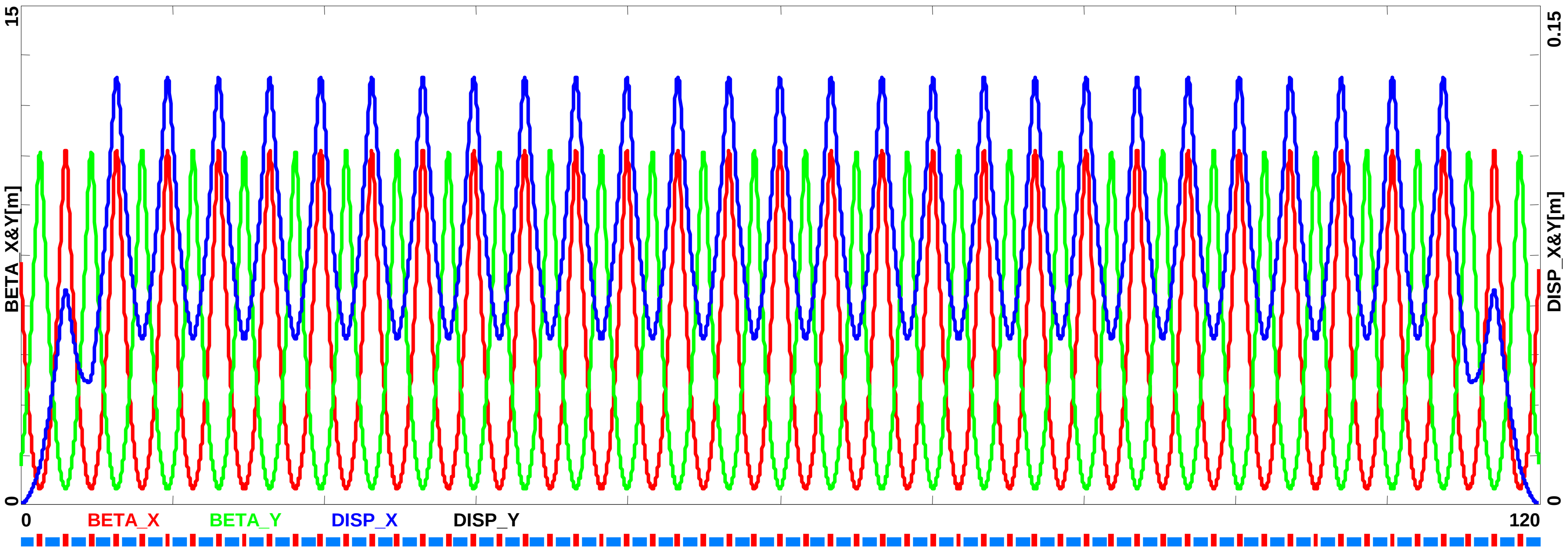
Arc dipoles:	Arc quadrupoles
$Lb=110 cm	$Lq=40 cm
$B=12.5 kGauss	$G= 9 kG/cm
$ang=2.14 deg.	
$rho = 29.4 meter	

135^0 FODO offers emittance preserving optics – 〈H〉 minimum

Synchrotron radiation power per meter less than 20 kW/m

MEIC

Quarter Arc Achromat



2 dis. sup. cells

2B/3 B/3

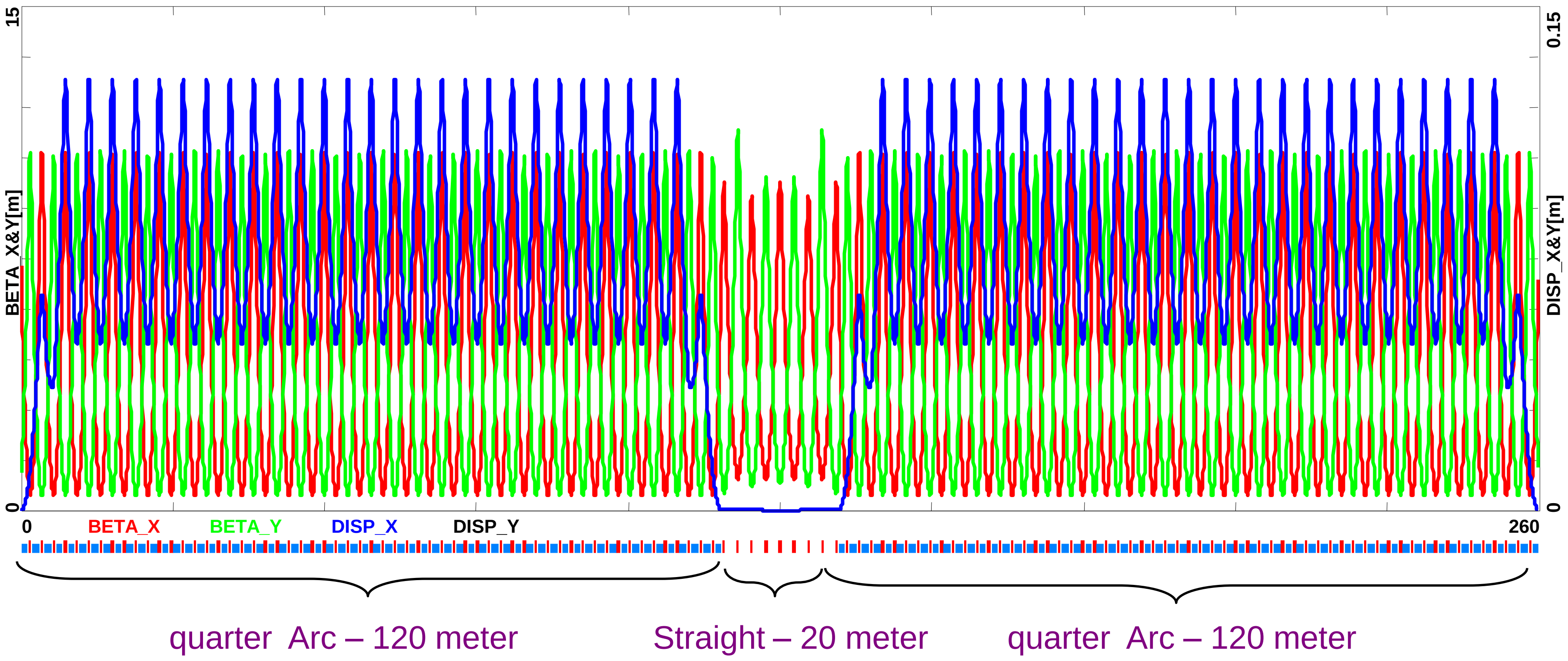
26 FODO cells

2 dis. sup. cells

2B/3 B/3

60 1.1 meter dipoles

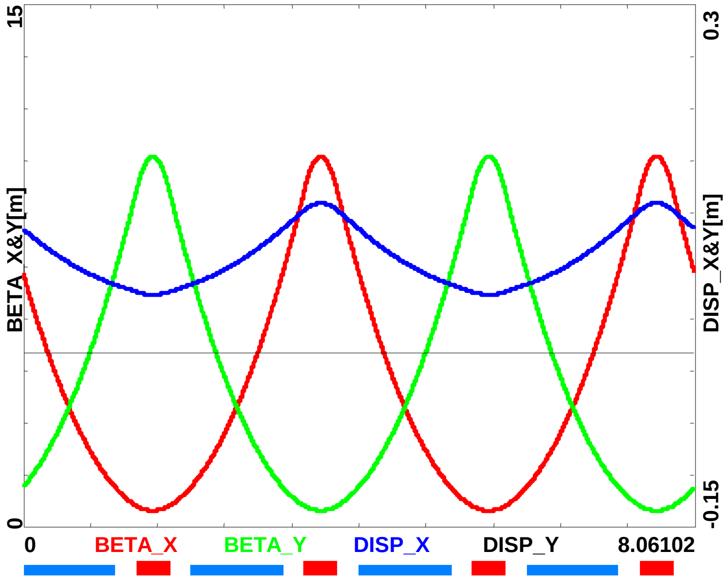
MEIC Electron Ring – Arc Optics



Flexible Momentum Compaction Cell

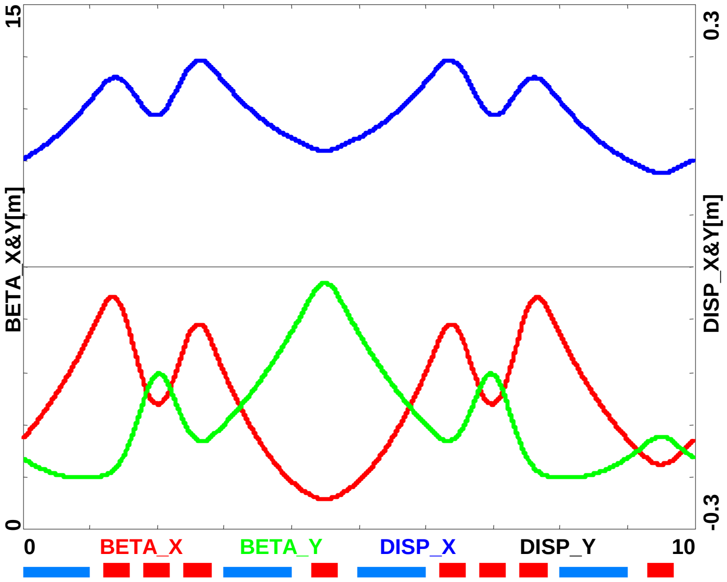
E = 11 GeV

135^0 FODO



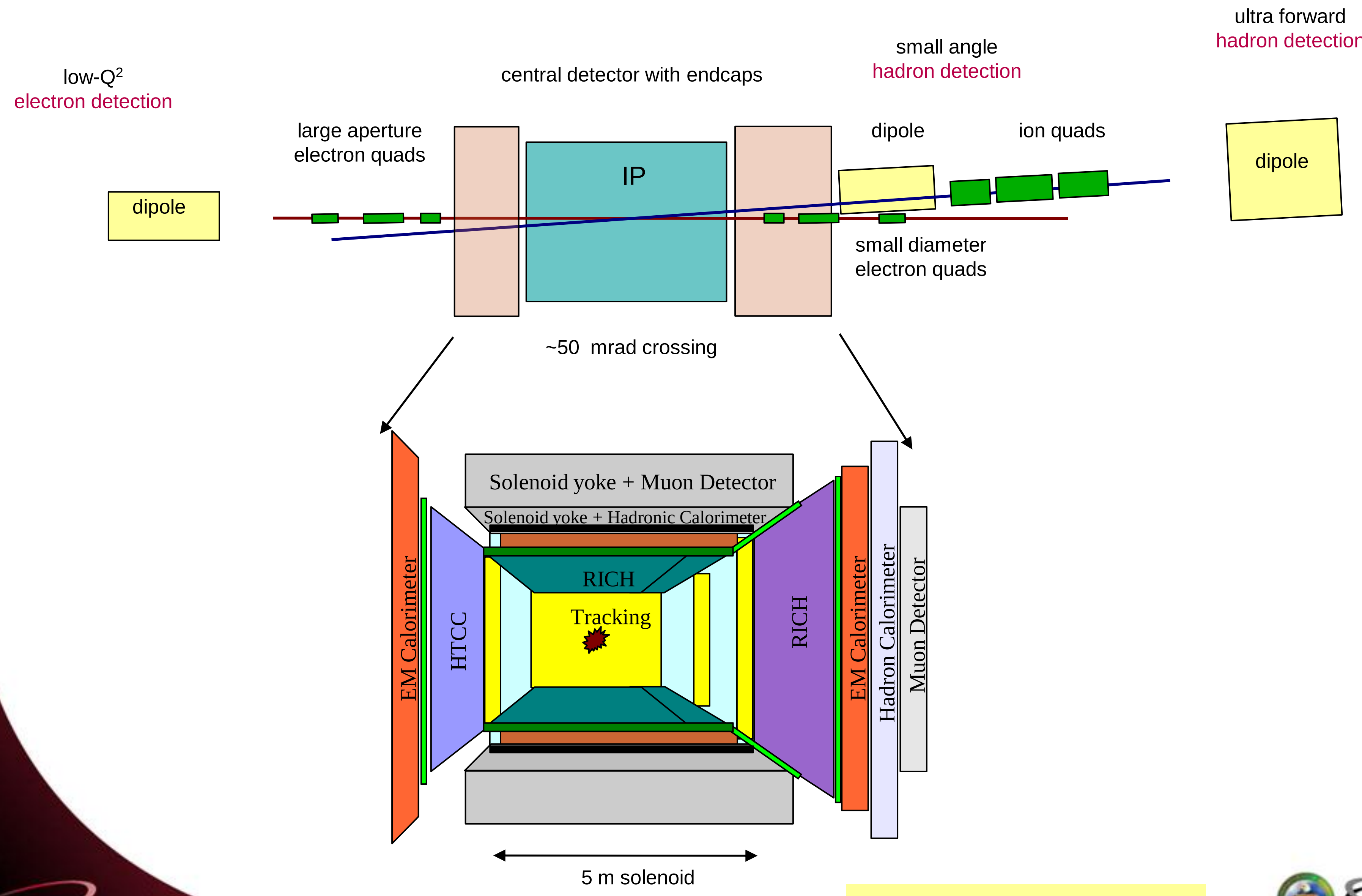
ε_x

Theoretical Emittance Minimum FMC Cell



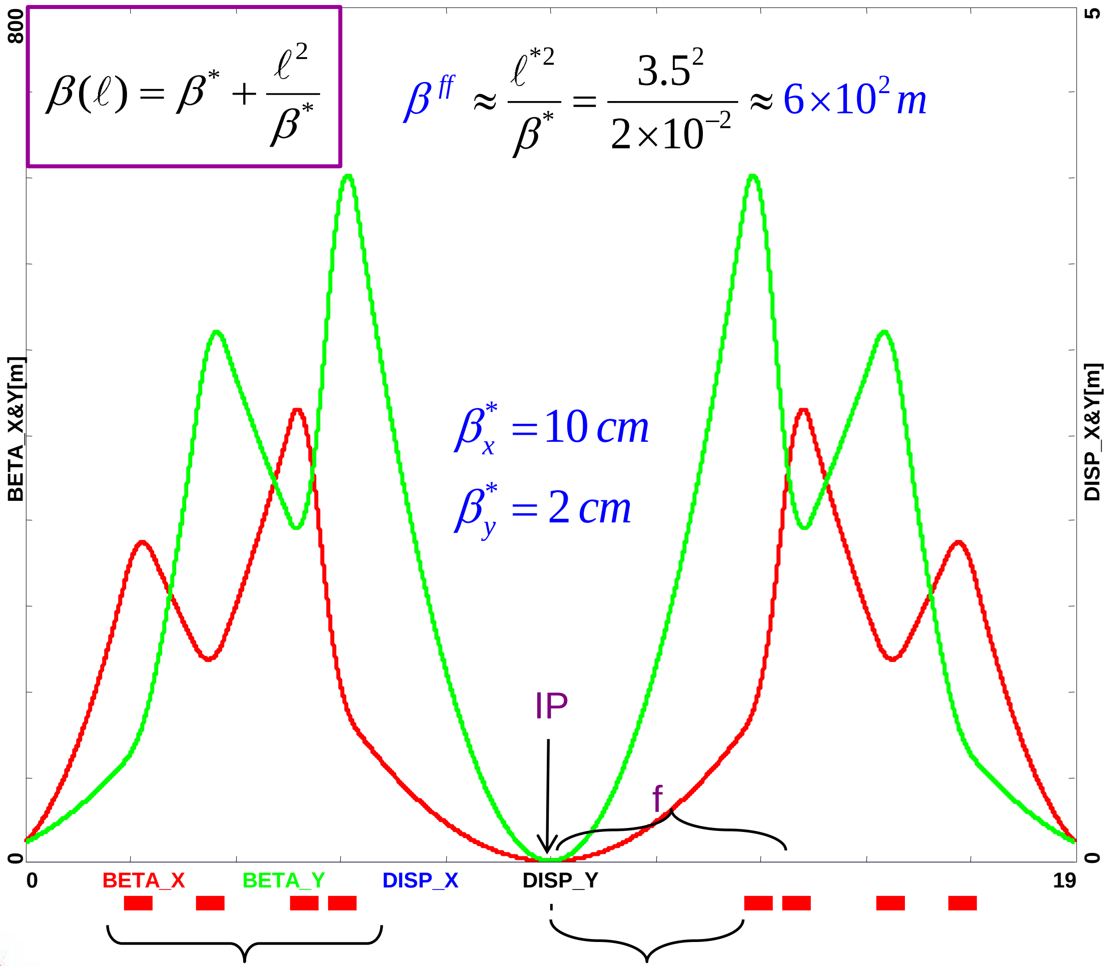
$$\varepsilon_x / 2$$

Detector and IR layout



Pawel Nadel-Turonski

MEIC IR Optics (electrons)



$$\beta(\ell) = \beta^* + \frac{\ell^2}{\beta^*}$$

$$\beta^{ff} \approx \frac{\ell^{*2}}{\beta^*} = \frac{3.5^2}{2\times10^{-2}} \approx 6\times10^2\, m$$

$$\beta_x^* = 10\, cm$$

$$\beta_y^* = 2\, cm$$

FF doublets

$\ell^* = 3.5\mathrm{m}$

$$\zeta_{IR} \propto \frac{f^2}{\beta^*}\frac{1}{f} = \frac{f}{\beta^*}$$

$$\zeta_1 := \frac{1}{4\pi}\int_0^l \beta_x \underbrace{(-g_0 + \eta_0 g_1)}_{\beta^{\max} g_0^{FF}} ds;$$

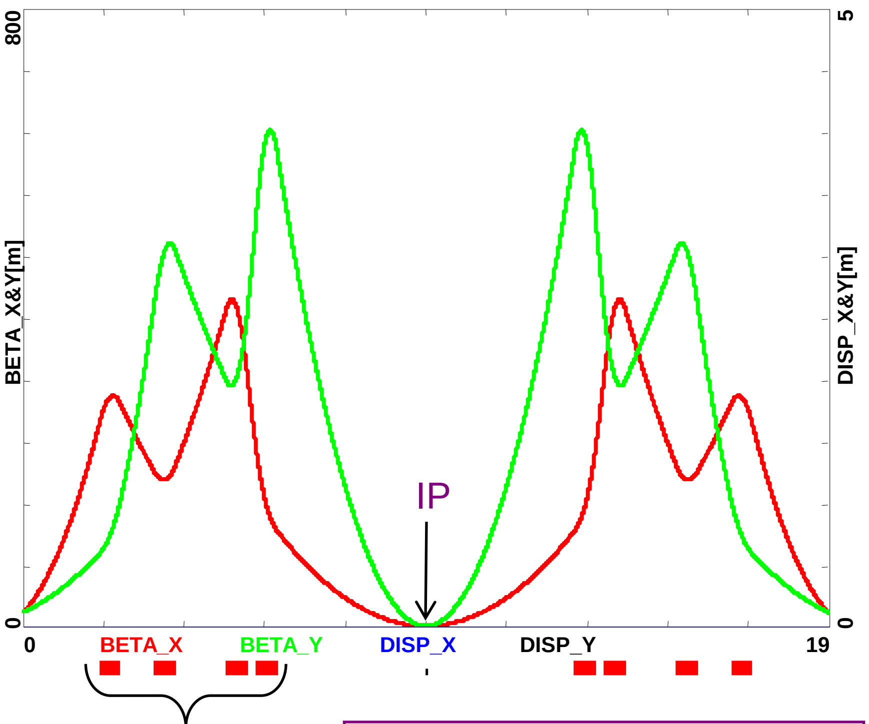
Natural Chromaticity:

$\zeta_x = -47$ $\zeta_y = -66$

MEIC IR Optics (electrons at 5 GeV)

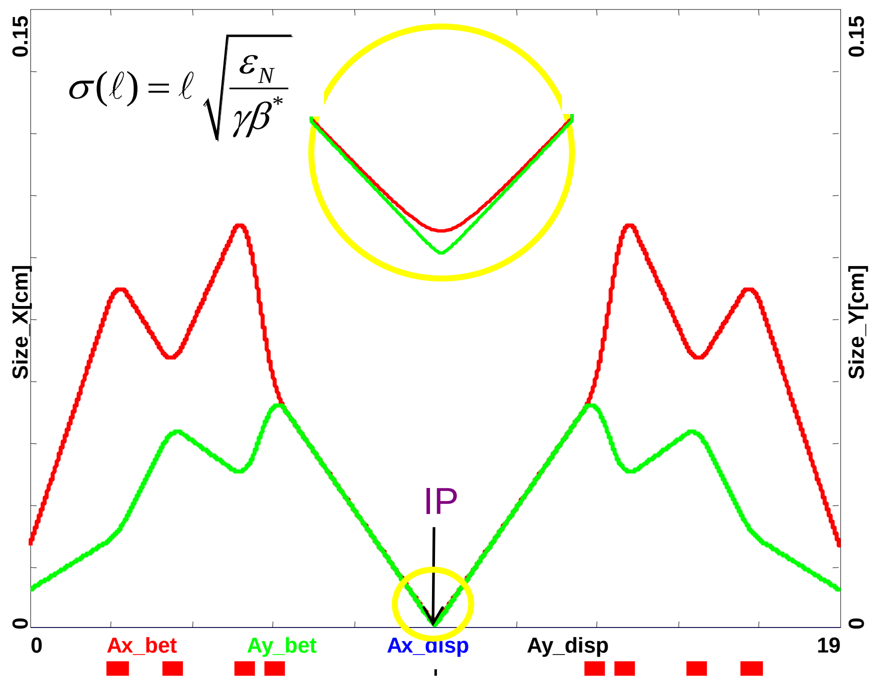
$$\varepsilon_N^x = 22\times10^{-6} m \qquad \beta_x^* = 10\, cm$$

$$\varepsilon_N^y = 4.4\times10^{-6} m \qquad \beta_y^* = 2\, cm$$



Q4 Q3 Q2 Q1

Q1	G[kG/cm] =	-2.8
Q2	G[kG/cm] =	3.1
Q3	G[kG/cm] =	-2.0
Q4	G[kG/cm] =	2.0

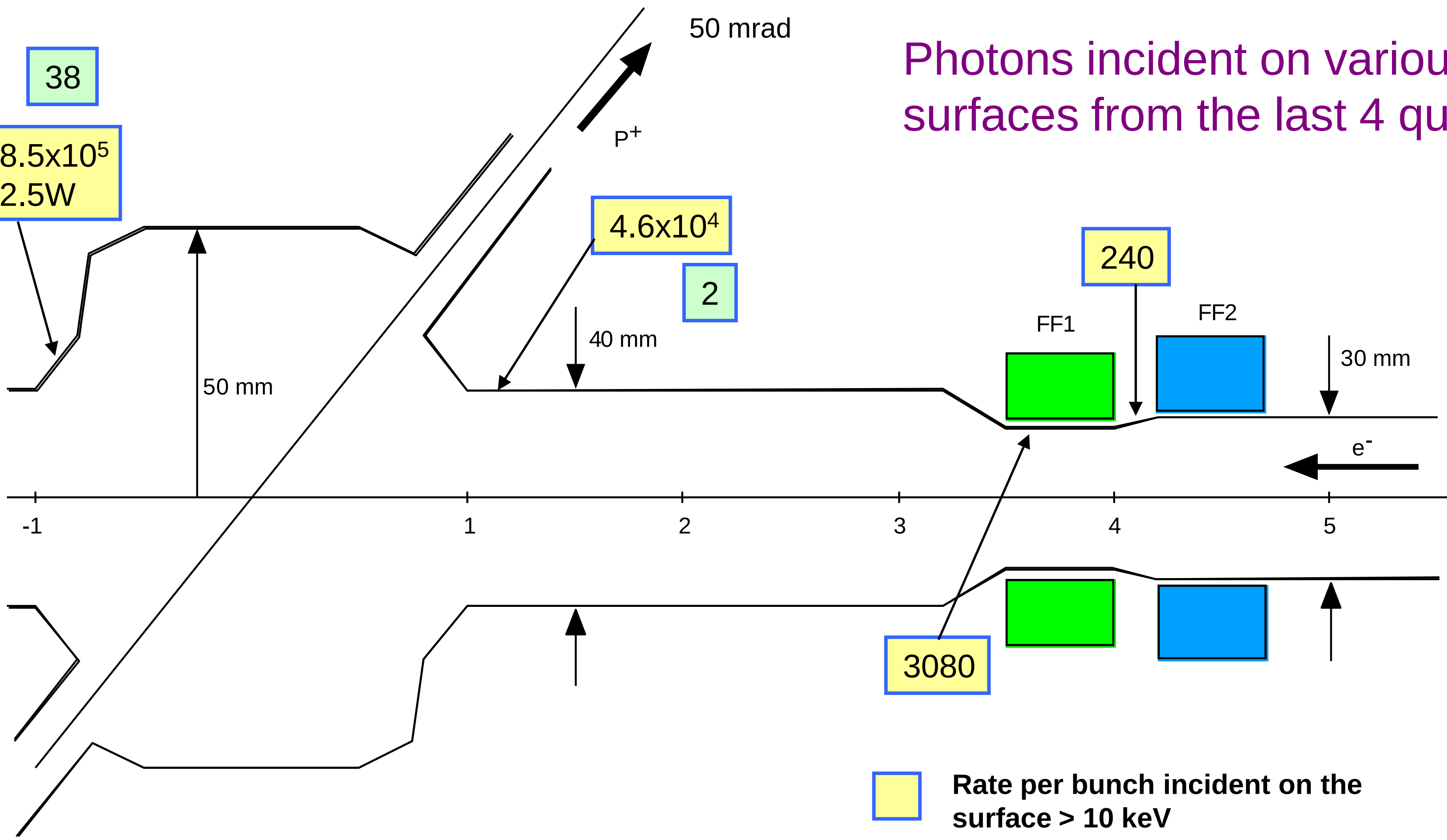


$$\sigma_x^* = 15\times10^{-6} m$$

$$\sigma_y^* = 3\times10^{-6} m$$

Jefferson Lab

MEIC Synchrotron Radiation Background



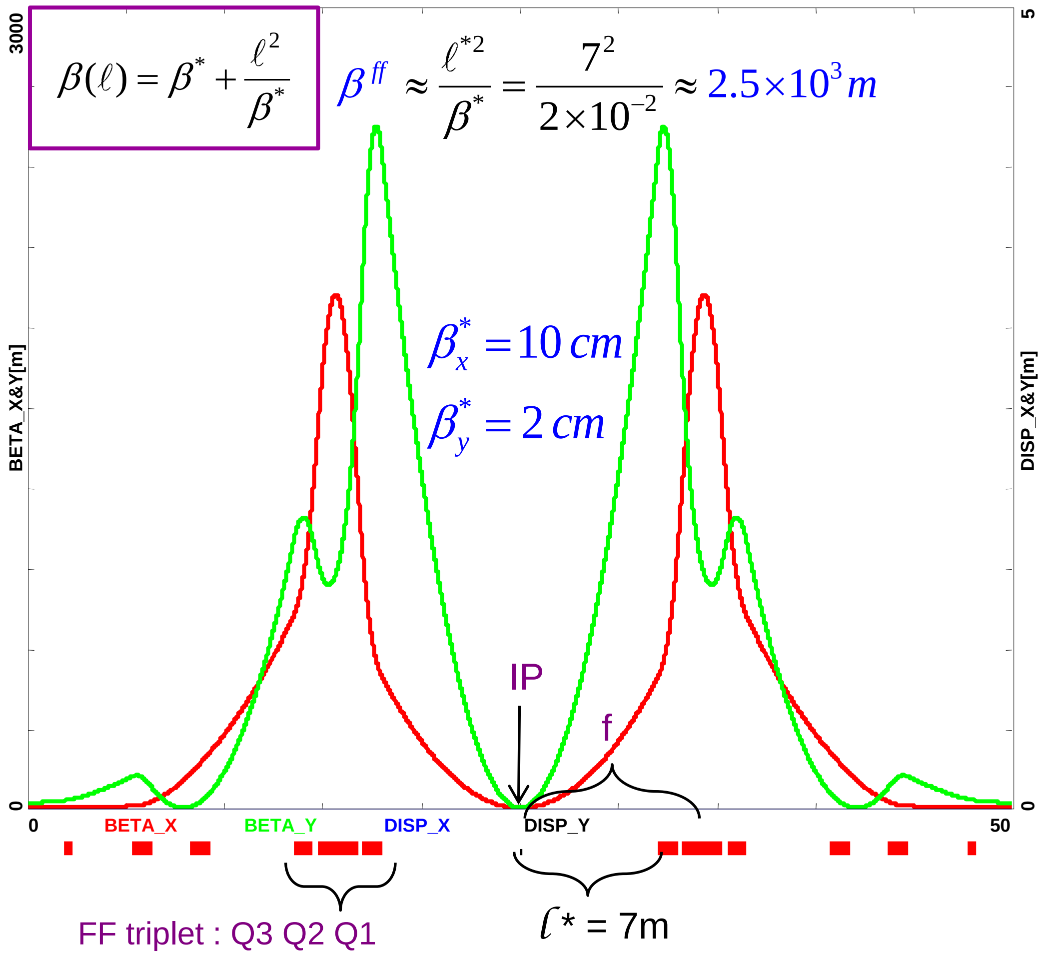
Photons incident on various surfaces from the last 4 quads

Beam current = 2.32 A
2.9×10^{10} particles/bunch

Rate per bunch incident on the surface > 10 keV (yellow)

Rate per bunch incident on the detector beam pipe assuming 1% reflection coefficient and solid angle acceptance of 4.4 % (green)

IR Optics (ions)



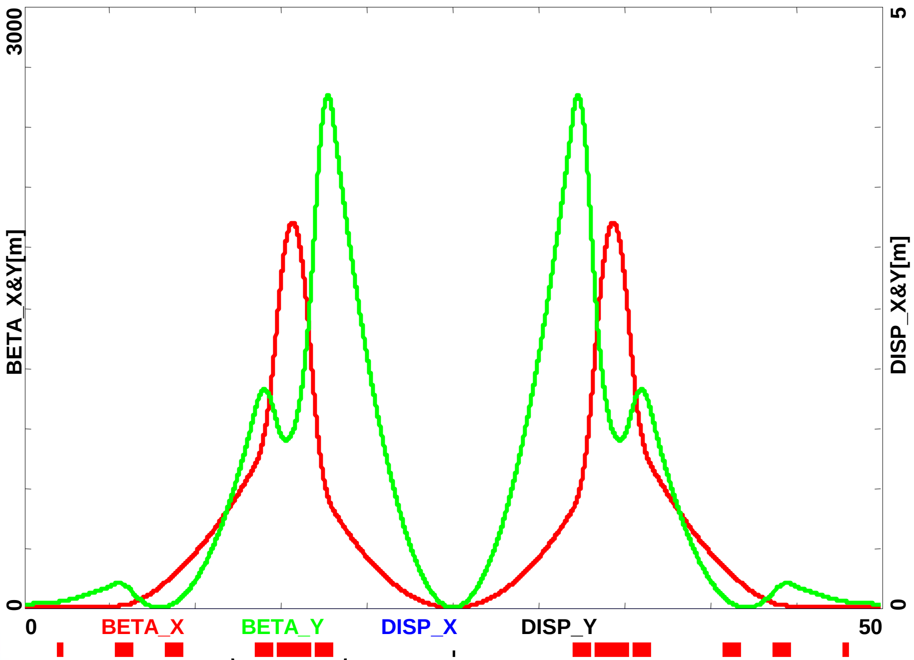
$$\zeta_{IR} \approx \frac{f^2}{\beta^*}\frac{1}{f} = \frac{f}{\beta^*}$$

$$\zeta_1 := \frac{1}{4\pi}\int_0^l \underbrace{\beta_x (-g_0}_{\beta^{max} g_0^{FF}} + \eta_0\, g_1)\, ds;$$

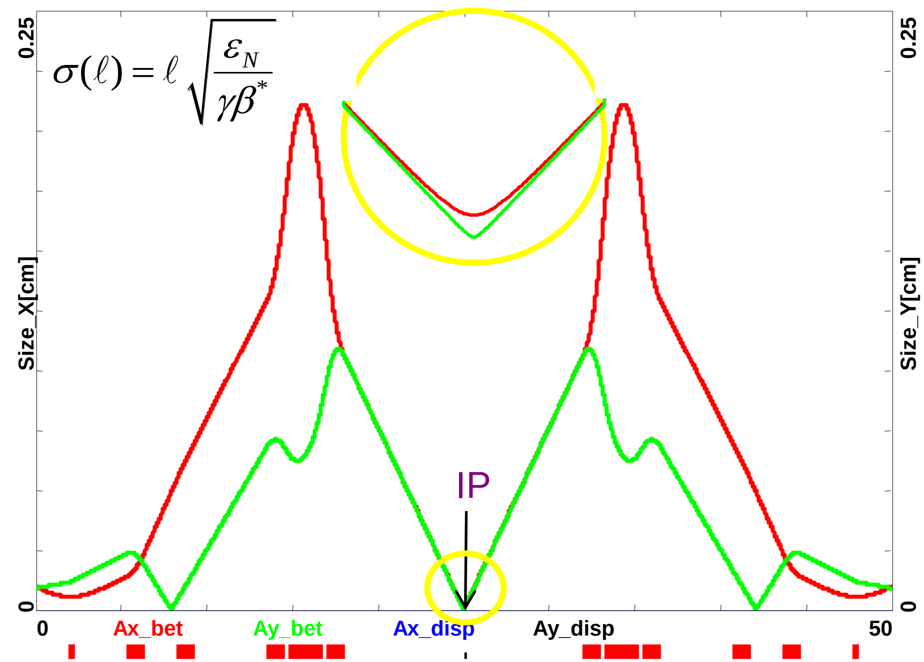
Natural Chromaticity:
ζ_x = -88 ζ_y = -141

MEIC IR Optics (ions) at 60 GeV

$$\varepsilon_N^x = 0.15\times10^{-6}m \qquad \beta_x^* = 10\,cm$$
$$\varepsilon_N^y = 0.03\times10^{-6}m \qquad \beta_y^* = 2\,cm$$



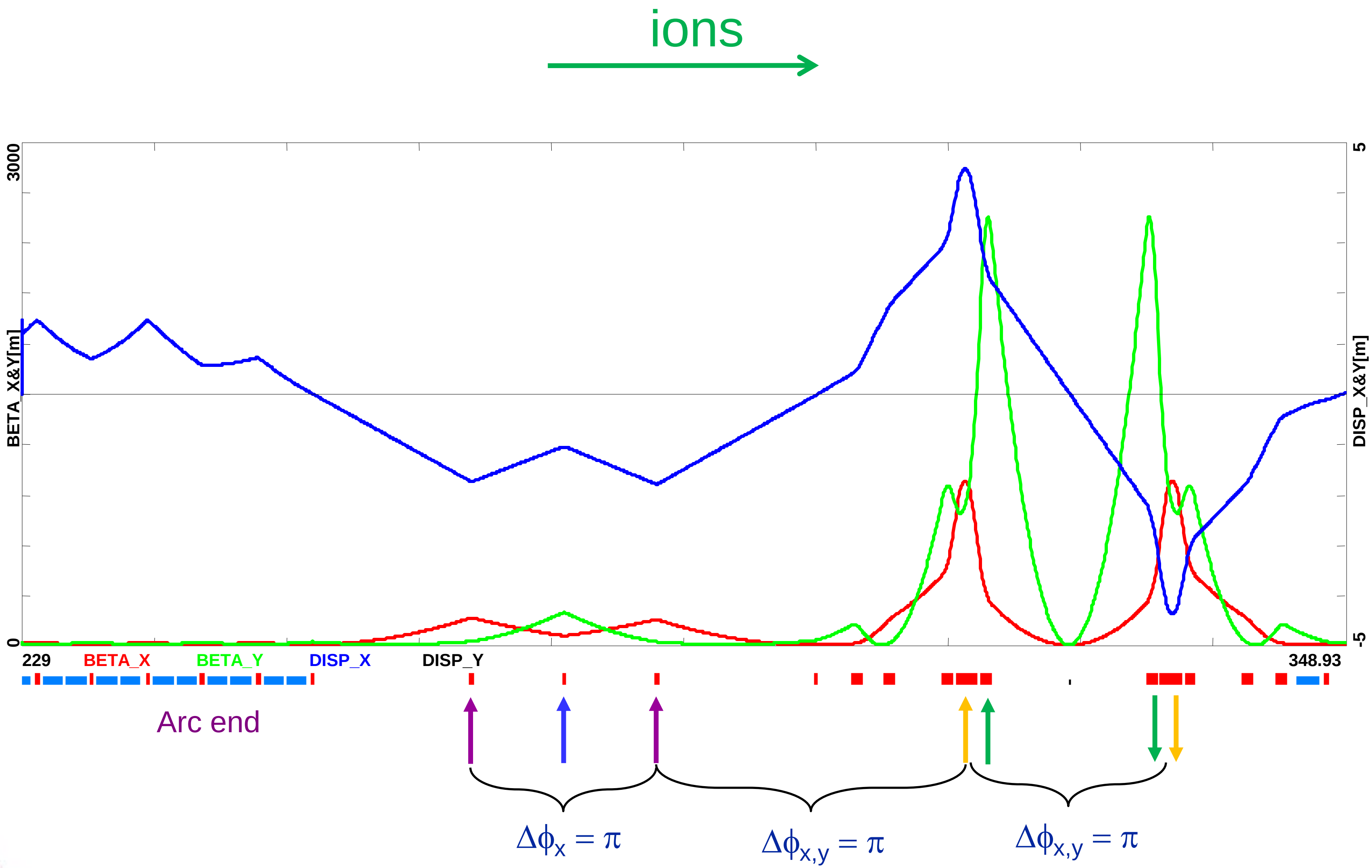
FF triplet : Q3 Q2 Q1



Q1	G[kG/cm] = -9.7
Q2	G[kG/cm] = 6.9
Q3	G[kG/cm] = -6.8

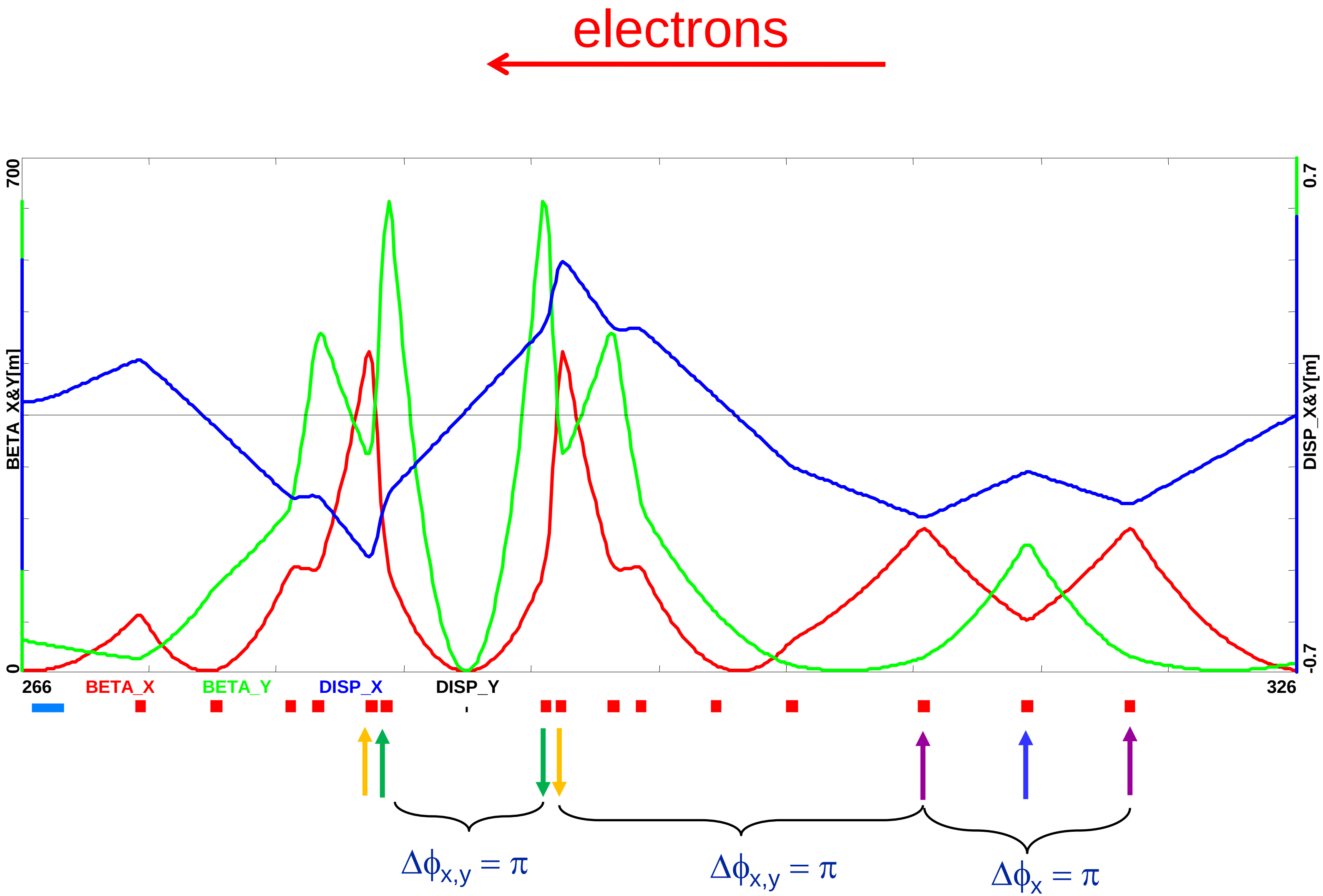
$$\sigma_x^* = 15\times10^{-6}m$$
$$\sigma_y^* = 3\times10^{-6}m$$

IR Chromaticity Compensation



Chromaticity Compensation with four families of sextupoles

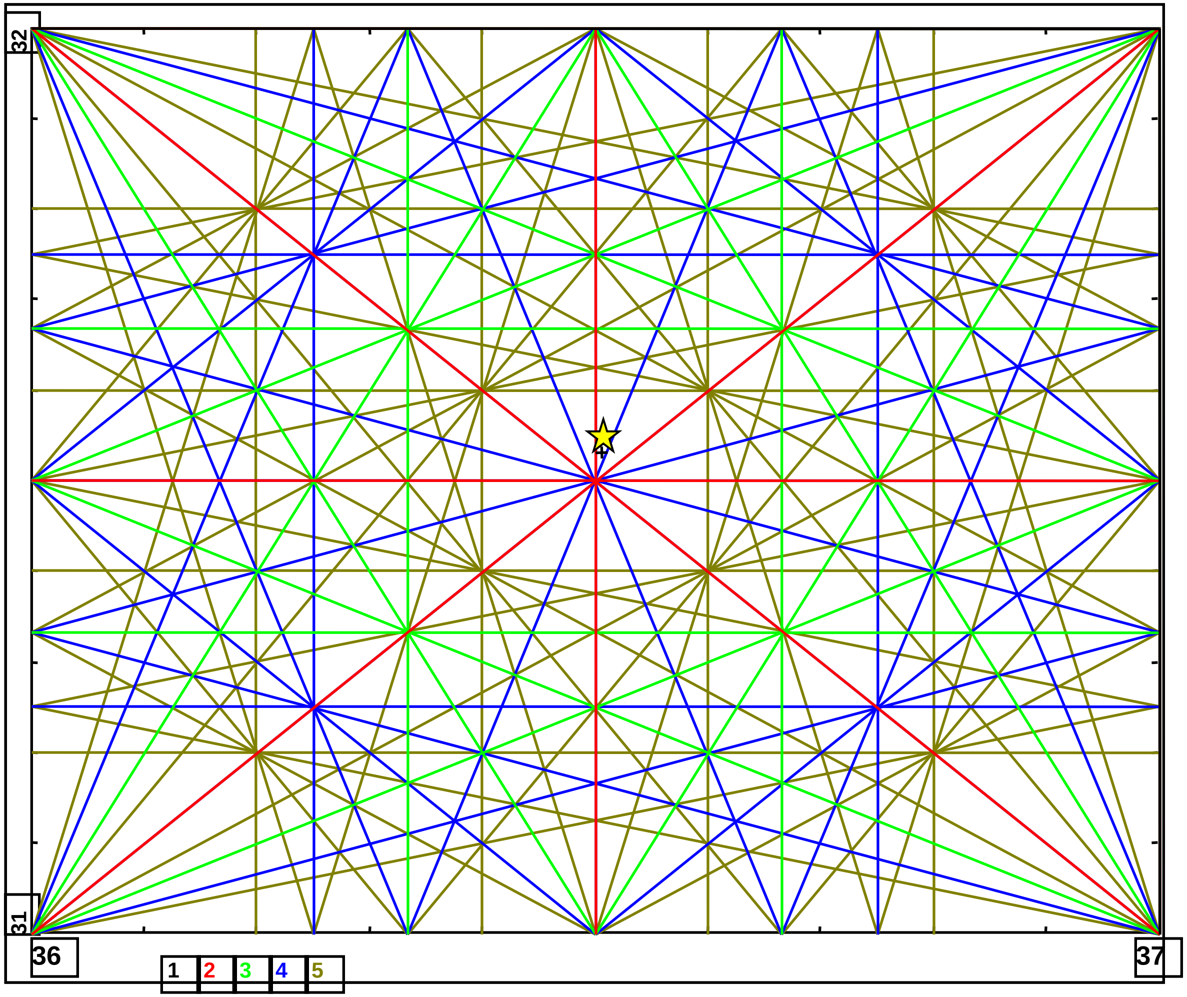
MEIC Chromaticity Compensation



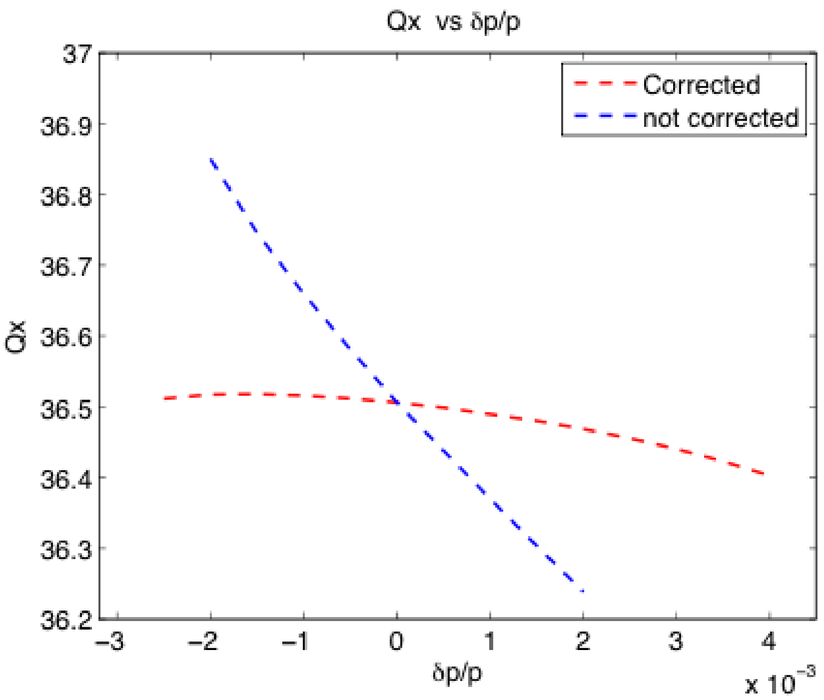
Chromaticity Compensation with four families of sextupoles

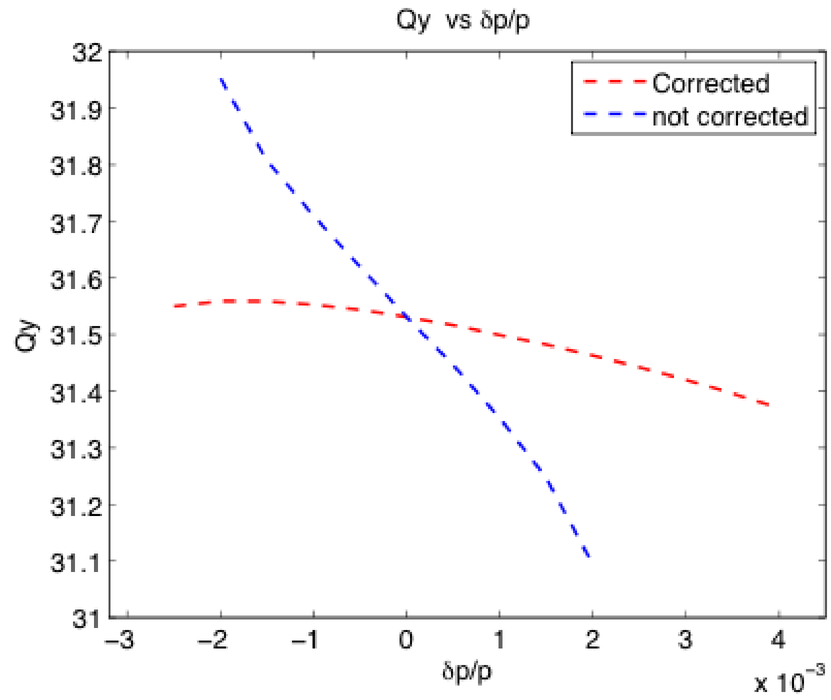
MEIC Collider Ring – Tune Diagram

Working point above half integer a la KEKB: Q_x=36.506 Q_y=31.531



Tune Chromaticity Correction



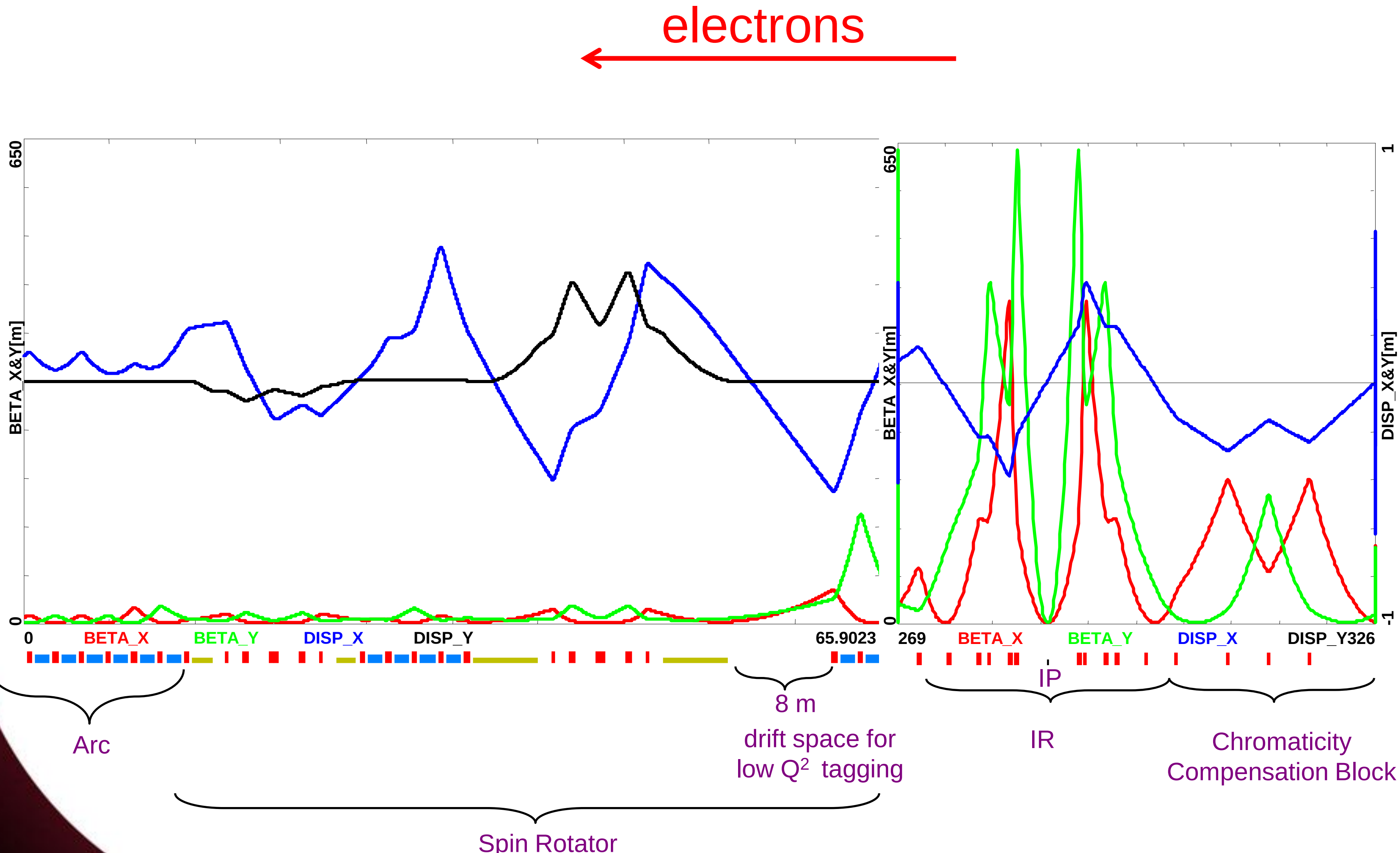


Large momentum acceptance and dynamic aperture

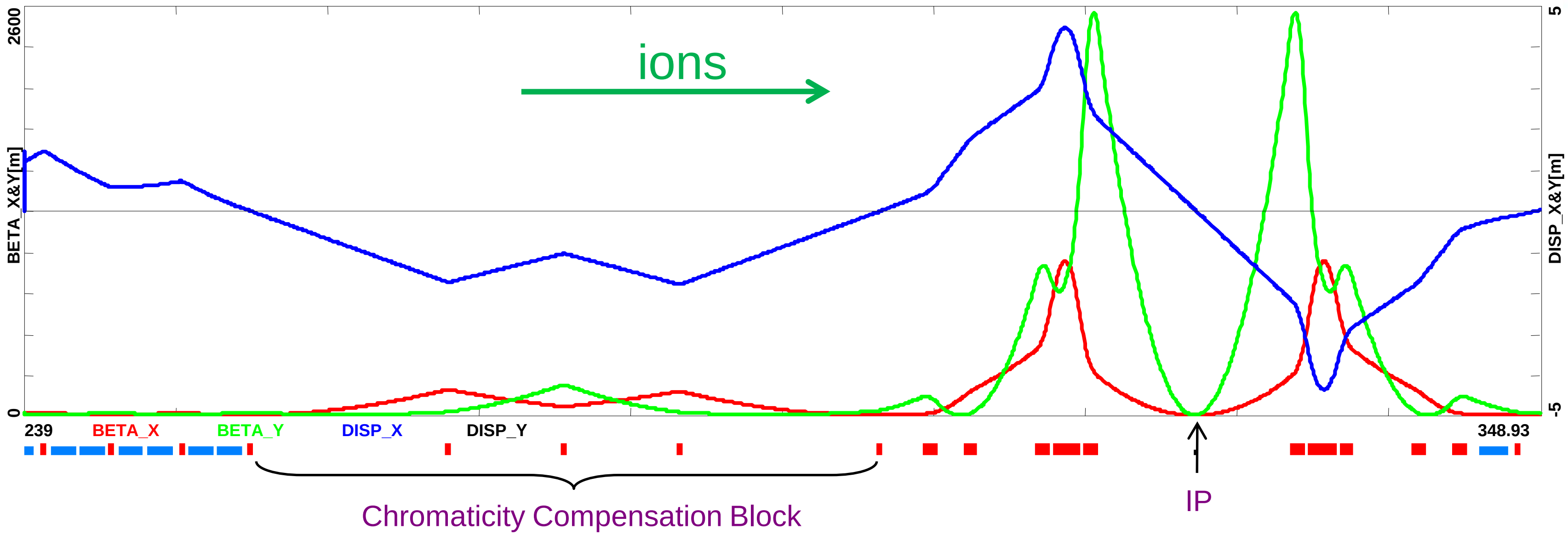
$$\frac{\Delta p}{p} = \pm 1.5 \times 10^{-3}$$

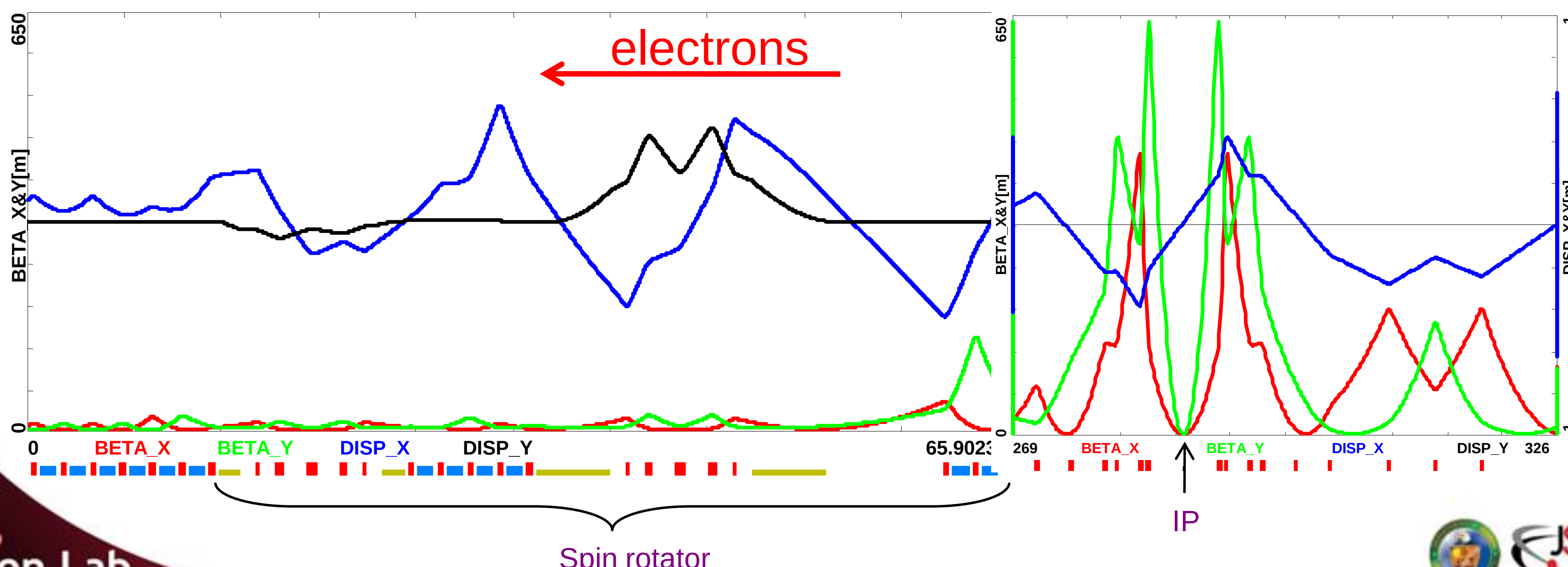
Hisham Sayed, Old Dominion Univ.

Arc – Spin Rotator – IR



MEIC Electron and Ion IRs – Overlay





Summary

- Complete design of Figure-8 Collider Rings (~ 1000 m circumference)
  - Emittance preserving Arcs based on 135^0 FODO lattice (11 GeV electrons)
  - Periodic dispersion Arcs based on 90^0 FODO lattice (60 GeV ions)
- 'Relaxed' IR Design: $\beta^{max} \approx 2.5 \times 10^3 m$ → $\beta^*_{x,y} = 10 / 2\, cm$
- Chromatic compensation with sextupoles – IR chromaticity
  - 'Dispersive' Straights – disp. leakage from the Arcs (by design)
  - Anti-symmetric dispersion pattern across the IR
  - Dedicated Optics Symmetric inserts
  - Beta Chromaticity compensation (immediate vicinity of the IP)
  - Large Momentum Acceptance open, DA tracking… $\frac{\Delta p}{p} = \pm 1.5 \times 10^{-3}$