Interaction Region Design

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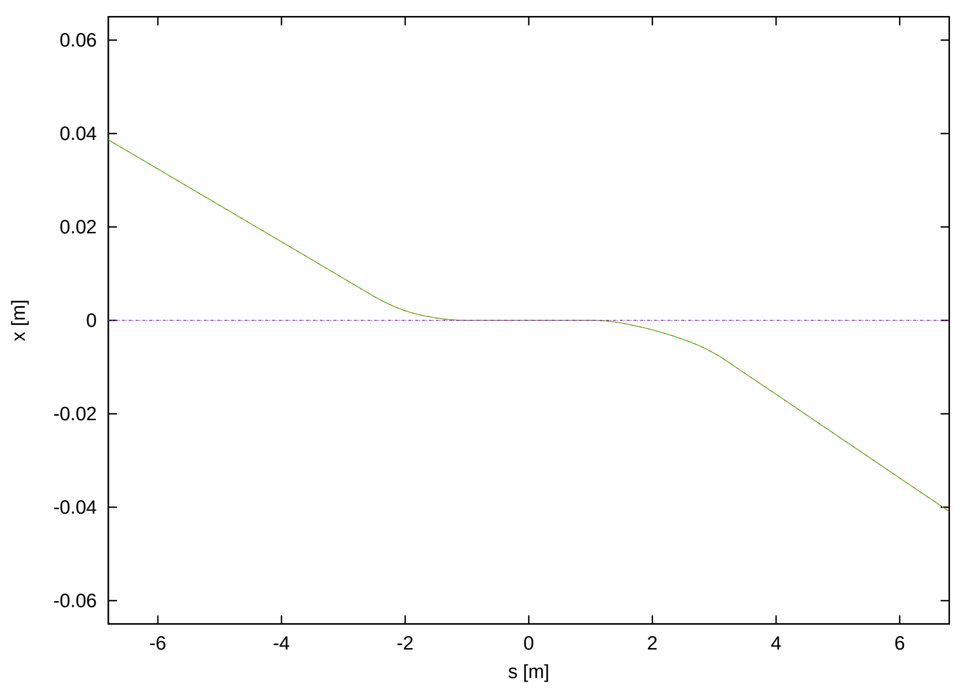
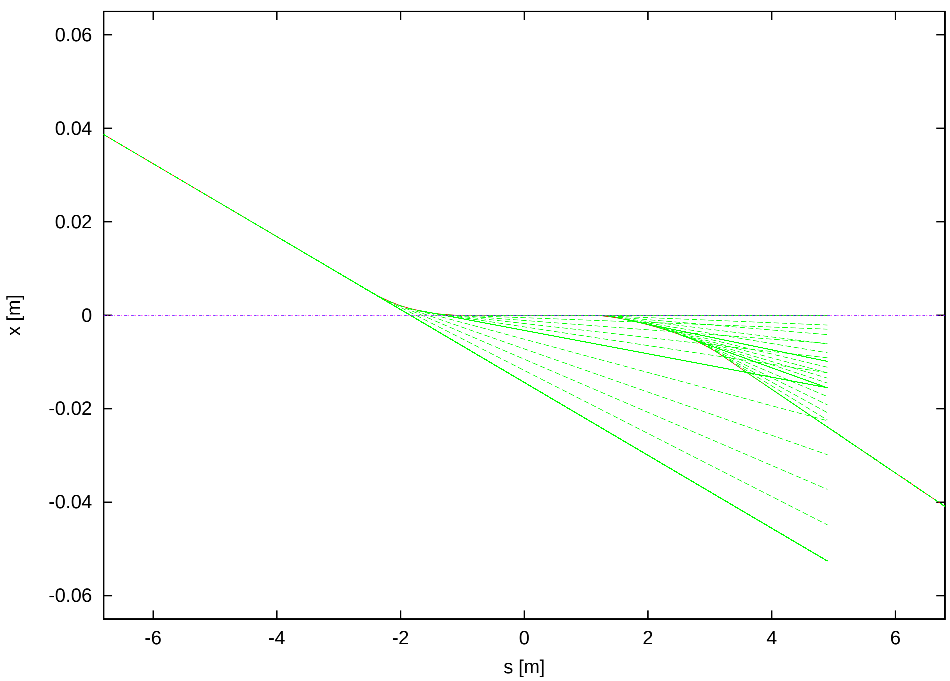
Design goals

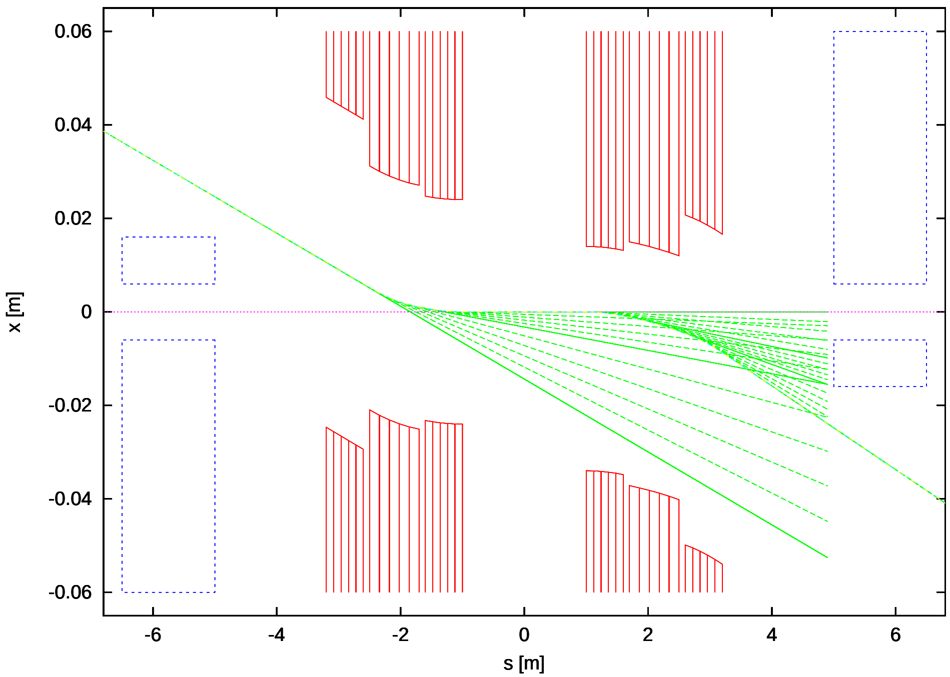
- Beam separation



• Accomodation of synchrotron radiation generated by beam separation



- Beam focusing to small spot sizes to maximize luminosity



Beam separation by a crossing angle

First hadron quadrupole (septum quad) starts 5m from the IP

Required beam separation at septum:
$12\sigma_p + 20\sigma_e + d_{\text{septum}} \approx 25\,\text{mm}$

$\Rightarrow$ Required crossing angle to provide separation without additional dipoles:

$$\Theta \approx 5\,\text{mrad}$$

Large crossing angle reduces luminosity by factor ≈ 5 due to long hadron bunches

Crab Crossing

Required transverse deflecting voltage (according to KEKB design report):

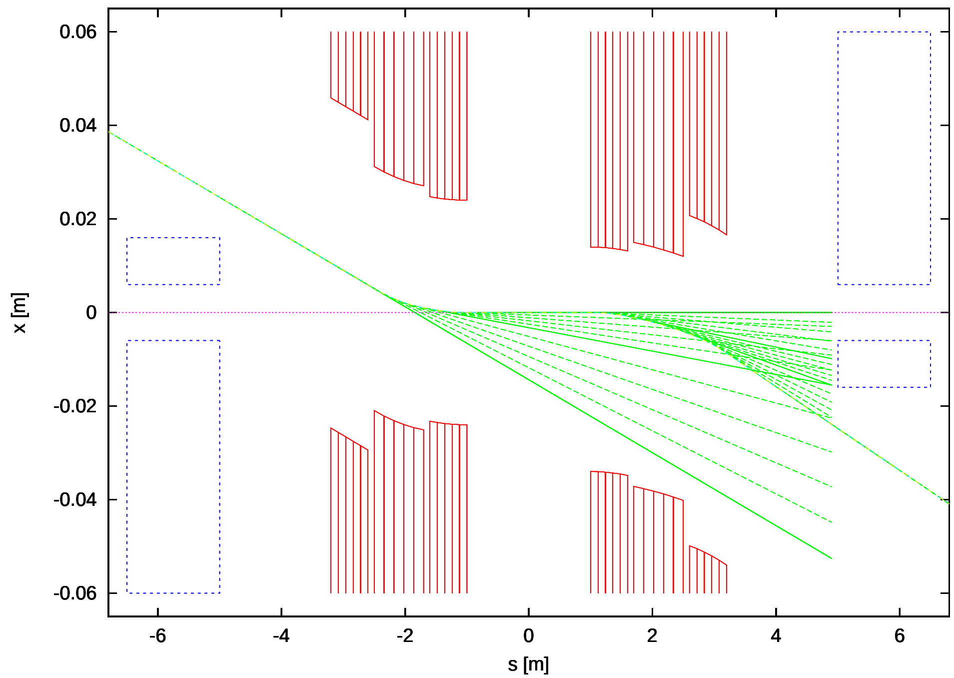
$$V_\perp = \frac{cE \tan \Theta}{e\omega_{\mathrm{RF}}\sqrt{\beta^* \beta_{\mathrm{crab}}}}$$

250 GeV protons (or 100 GeV gold ions)
$\Theta = 5\,\mathrm{mrad}$
$\beta_{\mathrm{crab}} = 400\,\mathrm{m}$
$\omega_{\mathrm{RF}} = 2\pi \cdot 200\,\mathrm{MHz}$

$$V_\perp = 30\,\mathrm{MV}$$

For comparison: RHIC RF voltage is 2 MV, KEKB crab cavity voltage is 1.44 MV

Beam separation with zero crossing angle



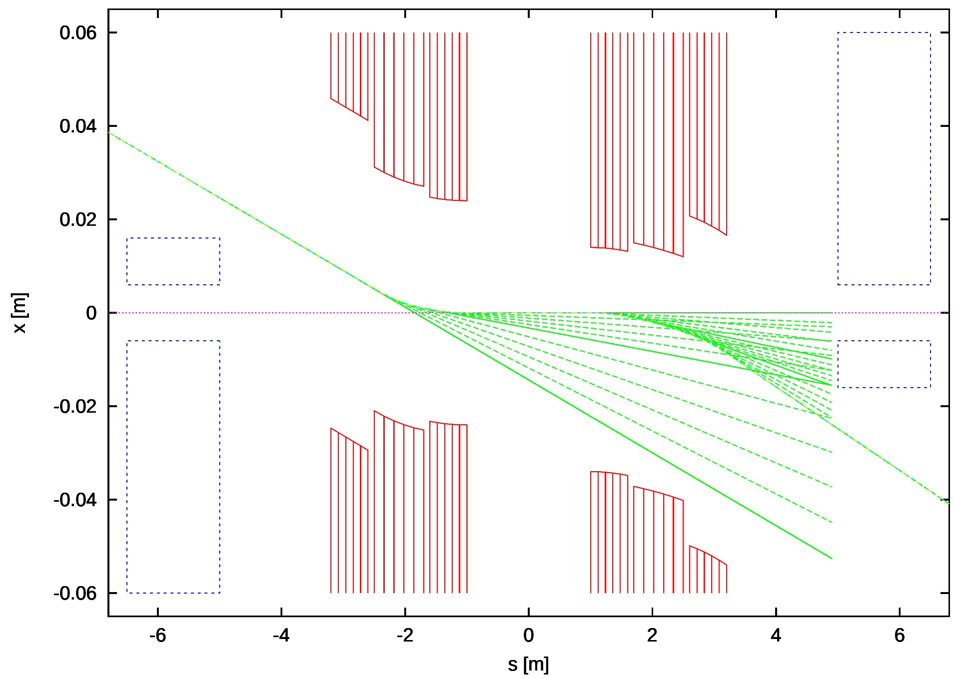
first proton septum quadrupole at 5 m

$\Rightarrow$ keep horizontal beam sizes at 5 m small to minimize required beam separation

- hadrons:
  $\sigma_{x,h} \propto 1/\sqrt{\beta^*_{x,h}}$
  $\longrightarrow$ lower limit on $\beta^*_{x,h}$
  $\longrightarrow$ upper limit on luminosity

- electrons:
  $\sigma_{x,e} \propto \sqrt{\epsilon_{x,e}}$,
  but smaller $\epsilon_{x,e}$ requires larger $\beta^*_{x,e}$ to match beam sizes
  $\longrightarrow$ larger beam-beam parameter
  $\longrightarrow$ luminosity limitation for ring-ring design

Synchrotron radiation issues



Beam separation close to the IP to bring proton low-β quads as close as possible to the IP (5m)

Generation of synchrotron radiation close to the IP

$\longrightarrow$ this synchrotron radiation is generated inside the detector volume

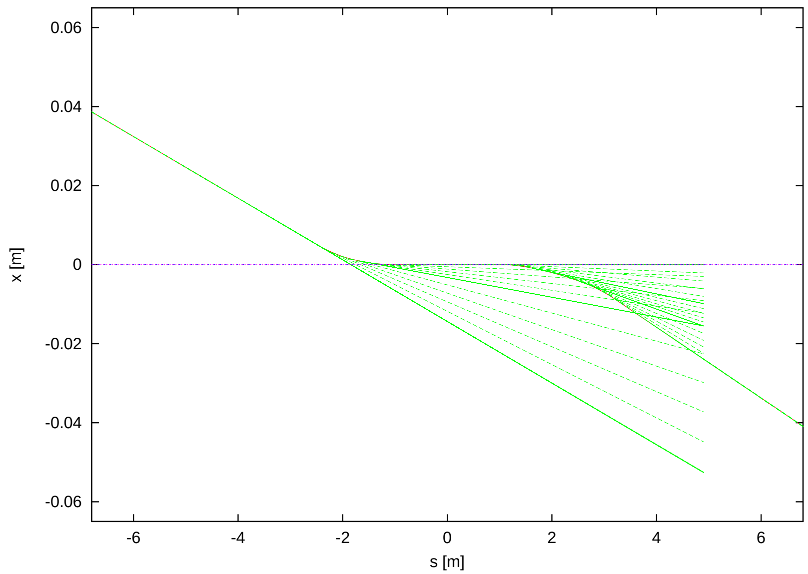
$\longrightarrow$ cannot be collimated, must be passed safely through the IP and the low-β electron quads

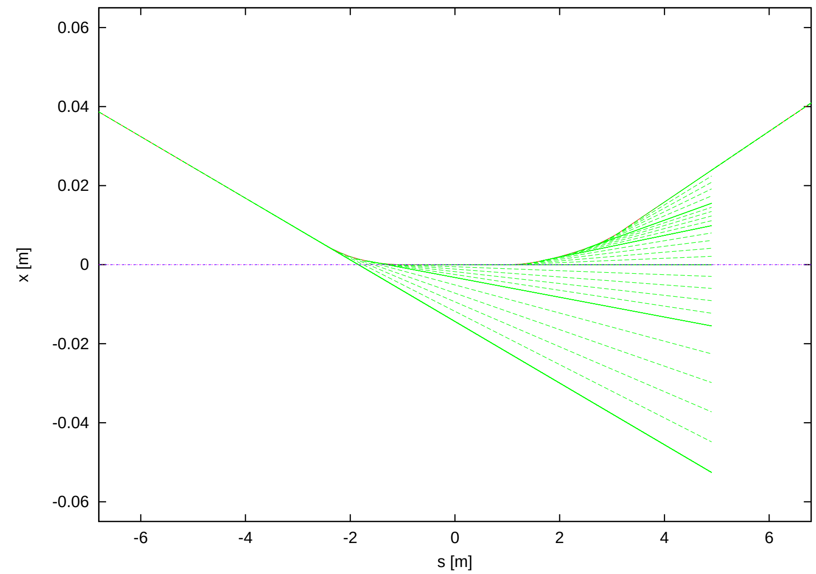
$\longrightarrow$ radiation fan width must be kept small to limit required quad aperture

$\longrightarrow$ separation as close as possible to the IP

$\longrightarrow$ S-shape IR preferred over C-shape

S-shape IR preferred over C-shape:





Low-β focusing

Low-β focusing is limited by hourglass effect:

$$\beta > \sigma_{p,s}$$

Hadron bunchlength $\sigma_{p,s}$ is limited by cryo load and IBS:

$$\sigma_{p,s} \approx 20\,\text{cm}$$

Hadron transverse emittance is given by present RHIC plus electron cooling

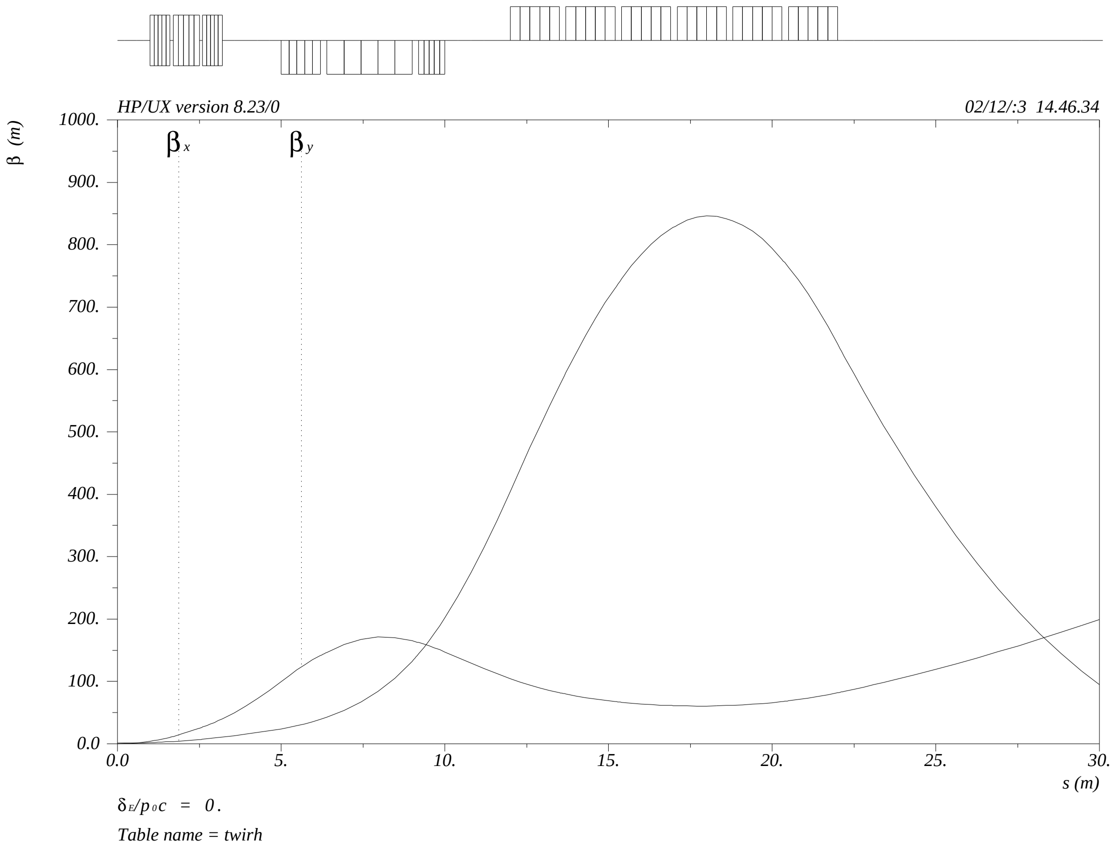
Keep beams at IP as round as possible to maximize luminosity and minimize beam-beam, but be aware of horizontal beam size at the septum

IR parameters for 10 GeV e on 250 GeV p

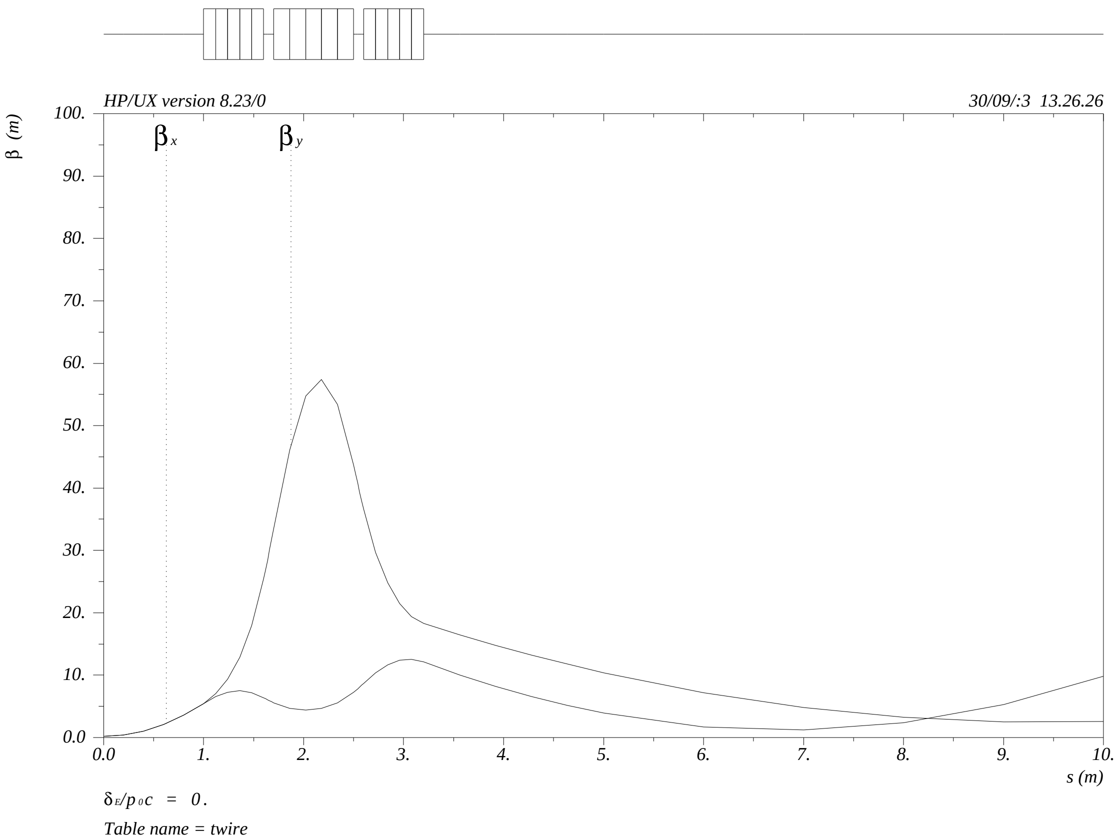
	ring-ring	linac-ring	luminosity ratio $\mathcal{L}_{l-r}/\mathcal{L}_{r-r}$
ϵ_h [nm]	9.5	9.5	
ϵ_e (x/y) [nm]	53/9.5	2.5/2.5	
β_h (x/y) [m]	1.08/0.27	0.27/0.27	
β_e (x/y) [m]	0.19/0.27	0.99/0.99	
σ^* (x/y) [μm]	100/50	50/50	2
N_e/bunch [10^{11}]	1.0	1.4	1.4
N_p/bunch [10^{11}]	1.0	1.0...2.0	1...2
ξ_h (x/y)	0.007/0.0035	0.007/0.007	
ξ_e (x/y)	0.022/0.08		
$\mathcal{L}$ [10^{33} cm^{-2}sec^{-1}]	0.44	1.25...2.5	2.8...5.6

Ring-ring IR lattice

Hadrons:



Electrons:



HP/UX version 8.23/0
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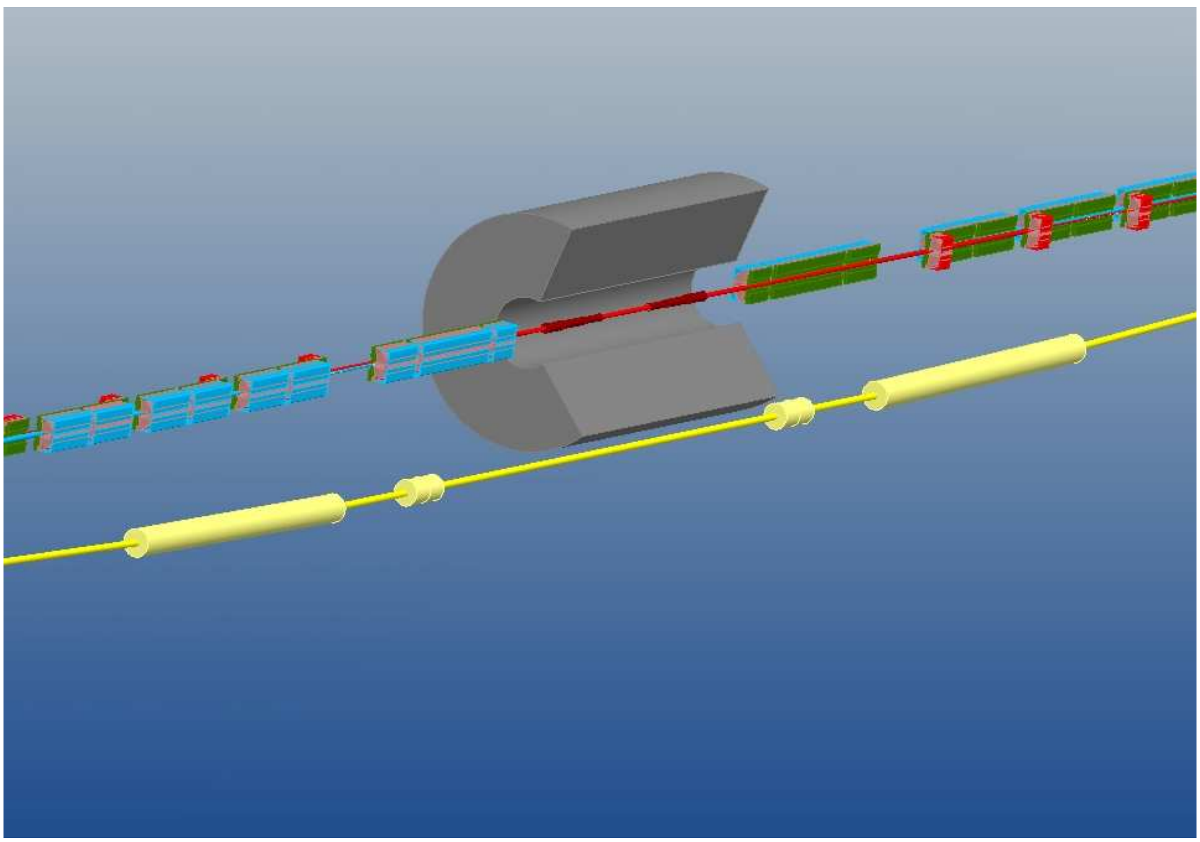
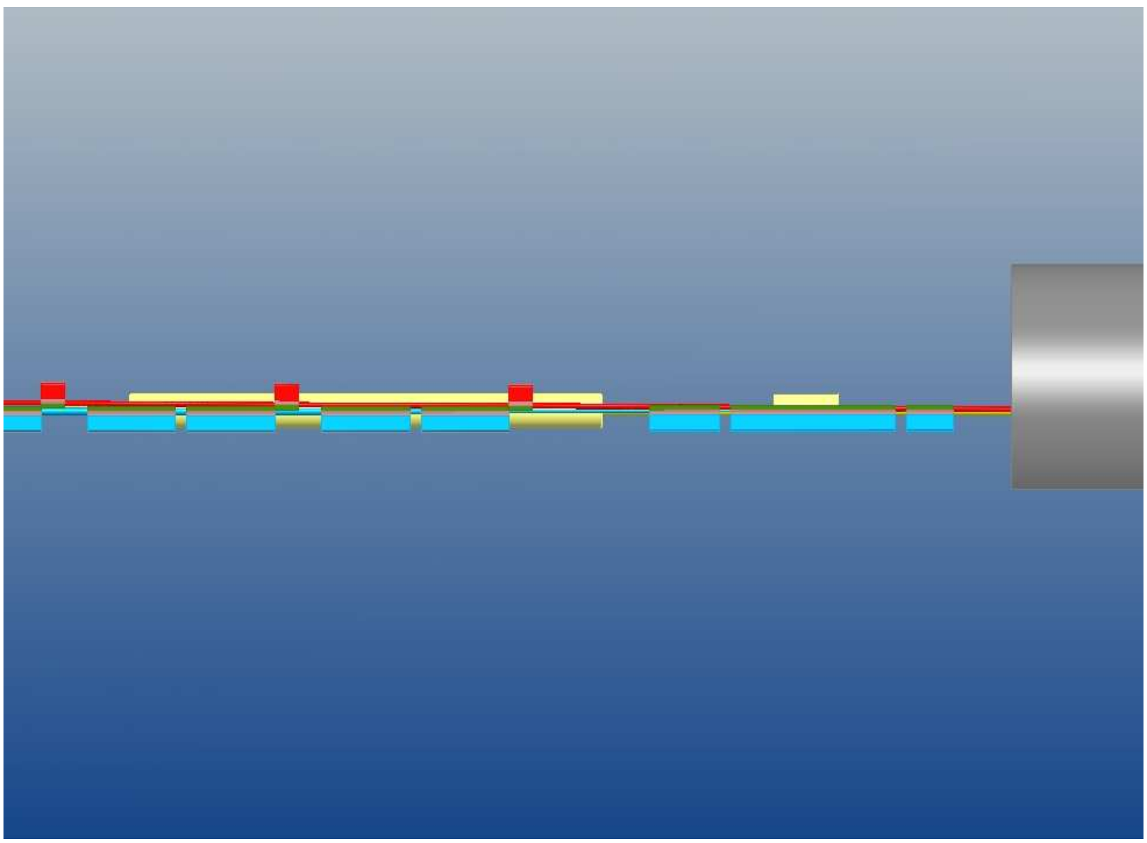
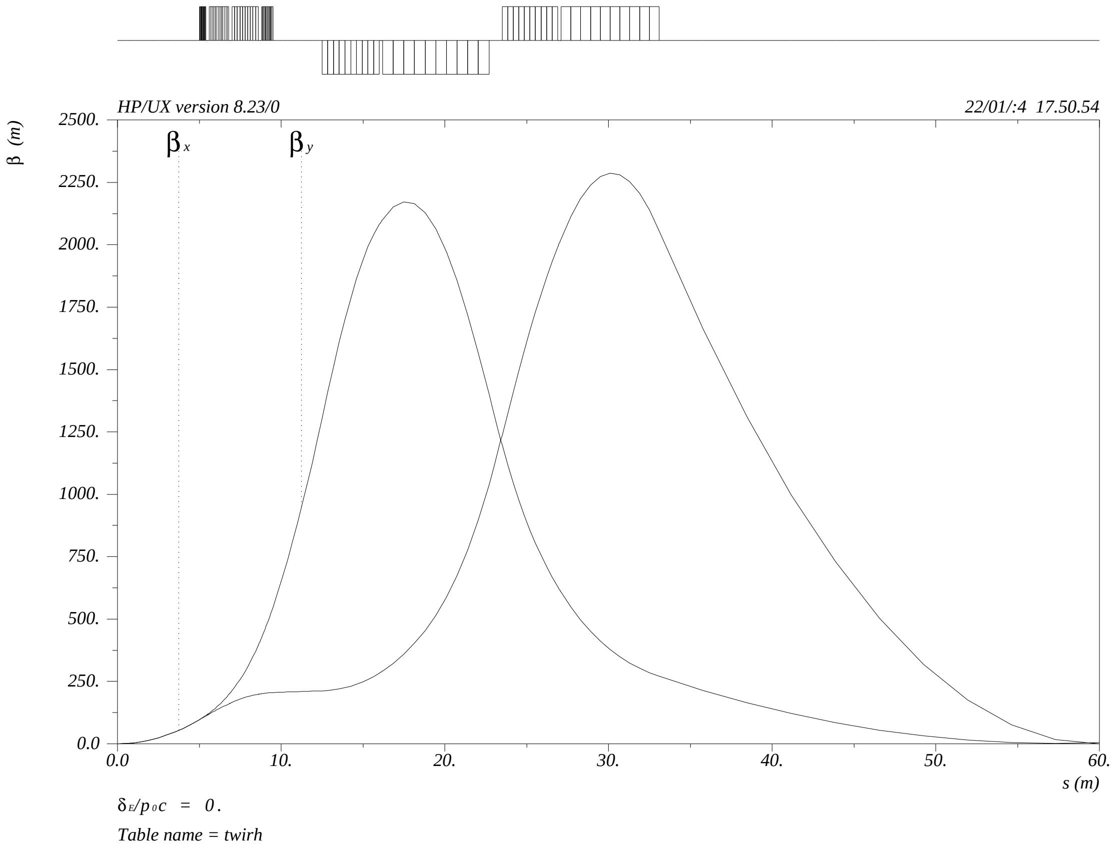
β (m)
β_x
β_y
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.0
0.0
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
s (m)
δ_E/p_0c = 0.
Table name = twire



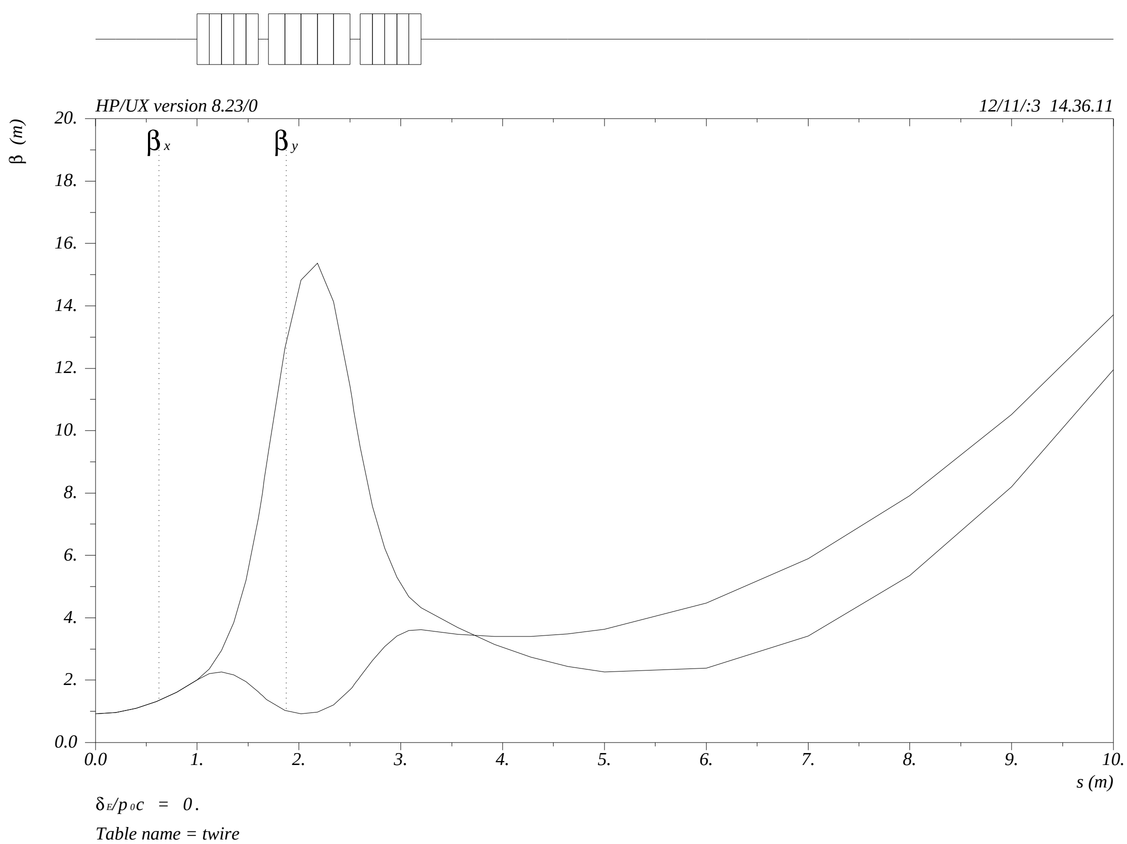


Linac-ring IR lattice

Hadrons:



Electrons:



HP/UX version 8.23/0
12/11/:3 14.36.11
β (m)
βx
βy
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.0
0.0
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
s (m)
δE/p0c = 0.
Table name = twire

Conclusion

- Design considerations and limitations for (eRHIC) electron-ion IR have been presented.

- IR design solutions for both ring-ring and linac-ring option of eRHIC exist.

- Linac-ring option provides at least 2.8 times more luminosity for 10 GeV e on 250 GeV p.

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