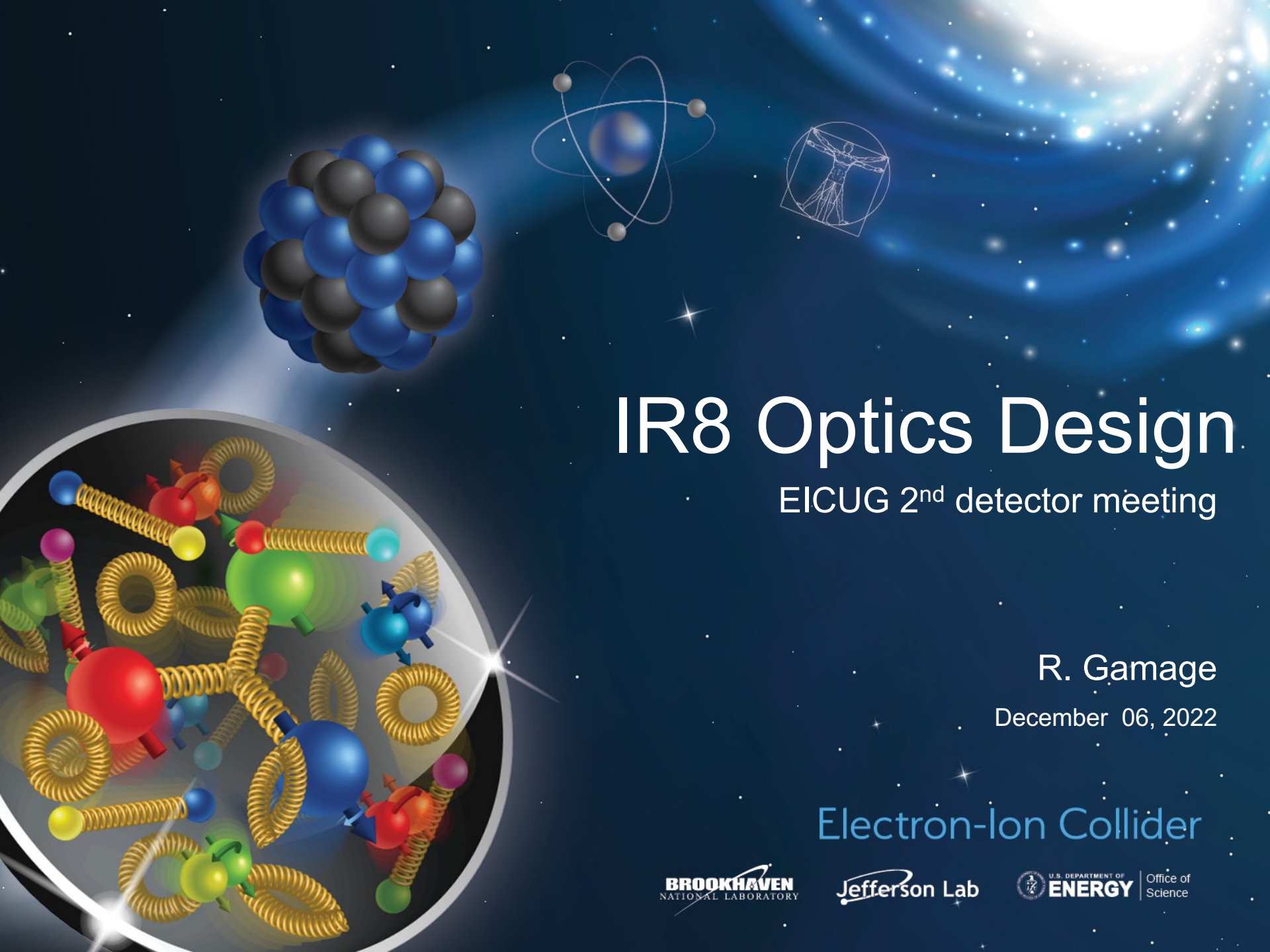


IR8 Optics Design

EICUG 2nd detector meeting

R. Gamage

December 06, 2022

Electron-Ion Collider

BROOKHAVEN NATIONAL LABORATORY

Jefferson Lab

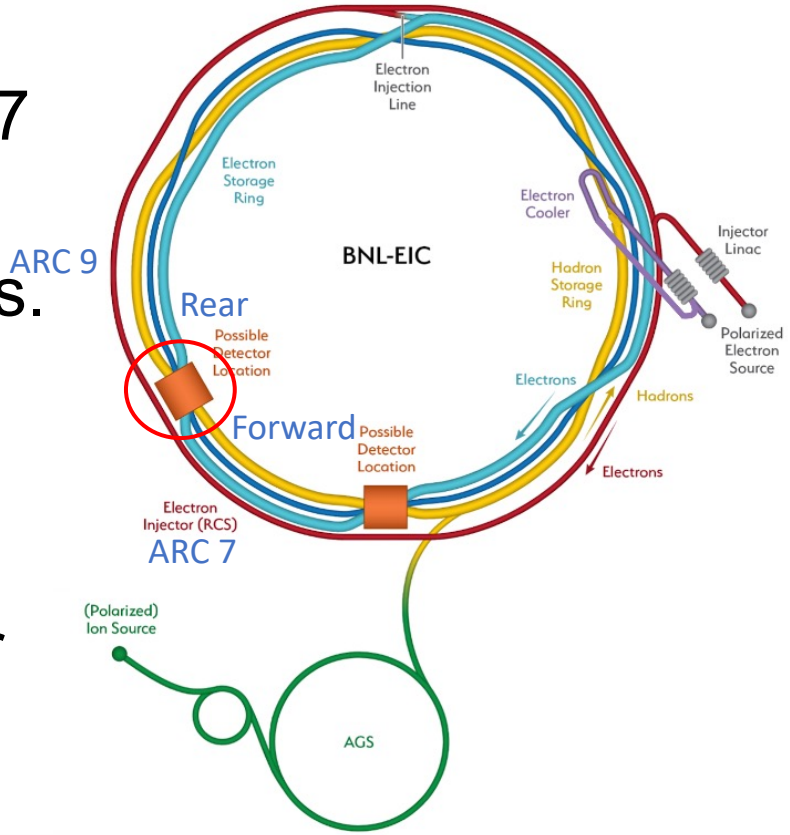
U.S. DEPARTMENT OF ENERGY | Office of Science

IR requirements & parameters

	1st IR		2nd IR	
	proton	electron	proton	electron
Detector occupied region	-4.5 m +5.0 m Beam elements < 1.5° in main detector		-4.5 m +5.0 m Beam elements < 1.5° in main detector	
Polarimetry	Yes (IR4)	local	Yes (IR4)	local
2nd focus	No		yes	
β^* @ 275 GeV (h), 10 GeV (e)	β^*_x = 80 cm β^*_y = 7.2 cm	β^*_x = 45 cm β^*_y = 5.6 cm	β^*_x = 80 cm β^*_y = 7.2 cm	β^*_x = 45 cm β^*_y = 5.6 cm
ZDC	0.6m x 0.6m x 2m @ s≅30m n: ± 4 mrad		0.6m x 0.6m x 2m @ s≅ 40m n: ± 4 mrad	
Roman Pots	1-5 mrad, @s≅30m		0-5 mrad, @s≅30-45m	
Scattered particle acceptance	p: 0.18 GeV/c < p_T < 1.3 GeV/c		p: 0 GeV/c < p_T < 1.3 GeV/c	
Q^2 tagger		Q^2< 0.1 GeV		
Crossing angle	25 mrad		35 mrad	

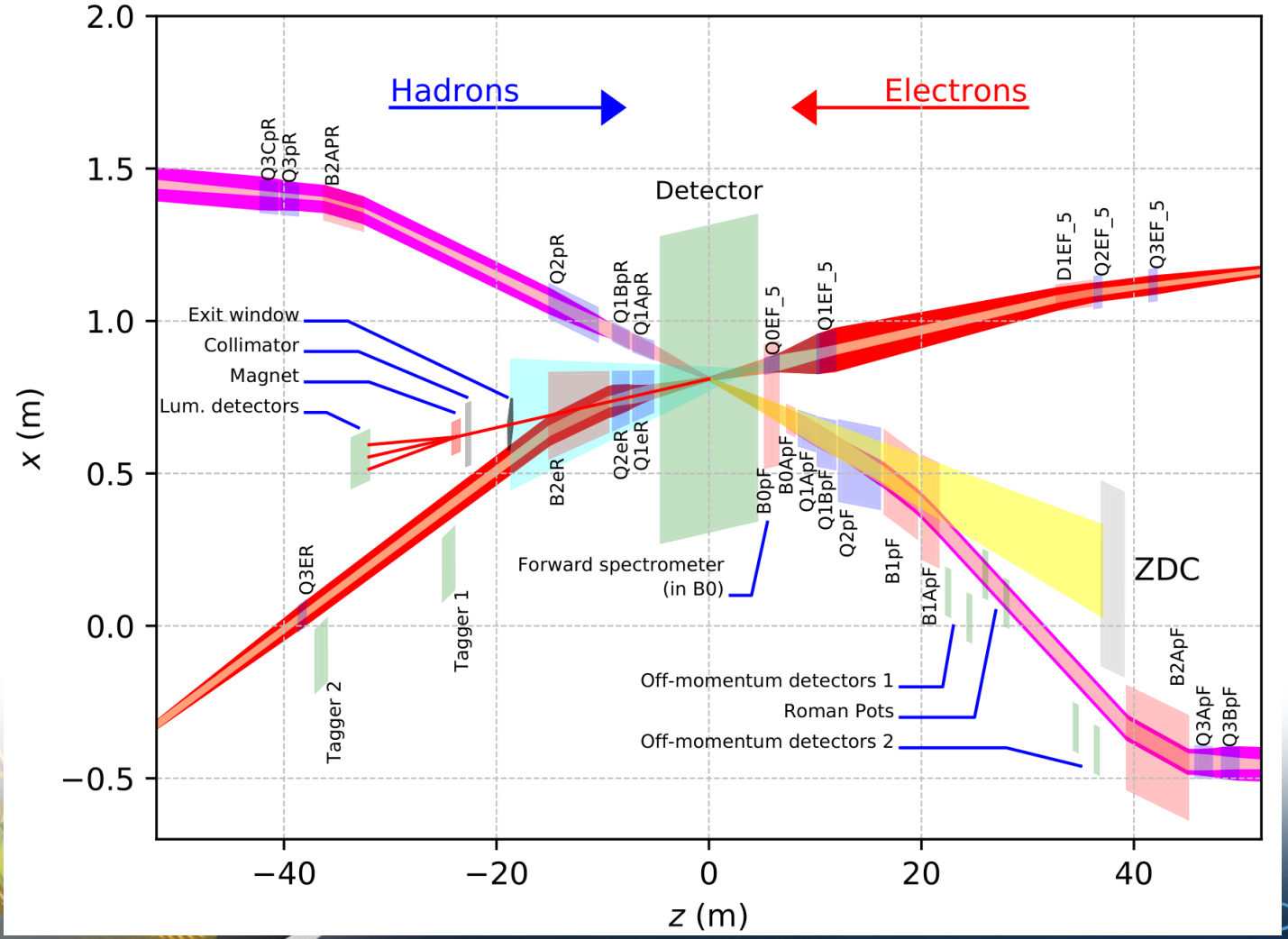
Requirements/Constraints

- Fit into the existing RHIC IR8 experimental hall between ARC 7 and 9.
- Preference for a secondary focus.
- Same accelerator equipment as in IR6 (spin rotators, snake and crab cavities).
- Second colliding IR and detector not in project, but the ability to have one is in the project scope.



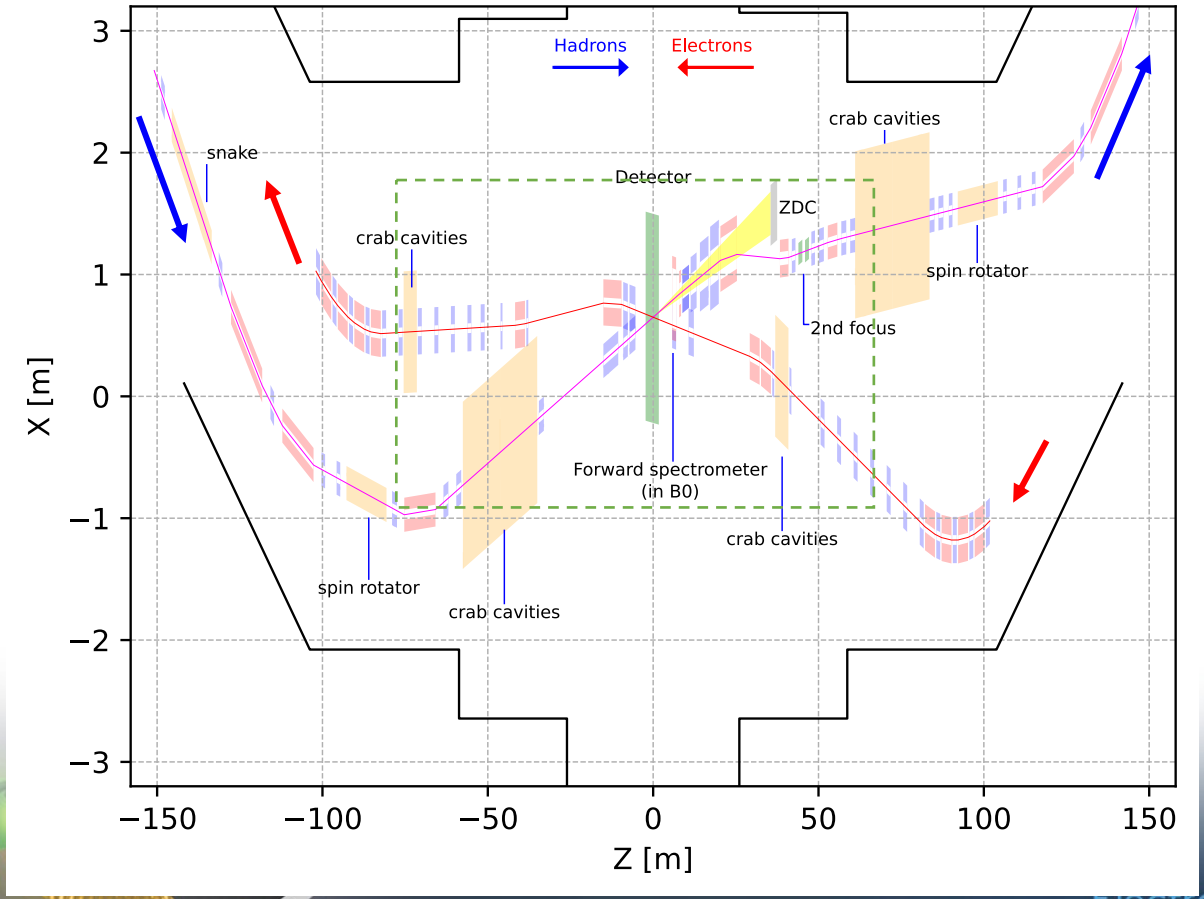
IR6 layout

- 25 mrad crossing angle



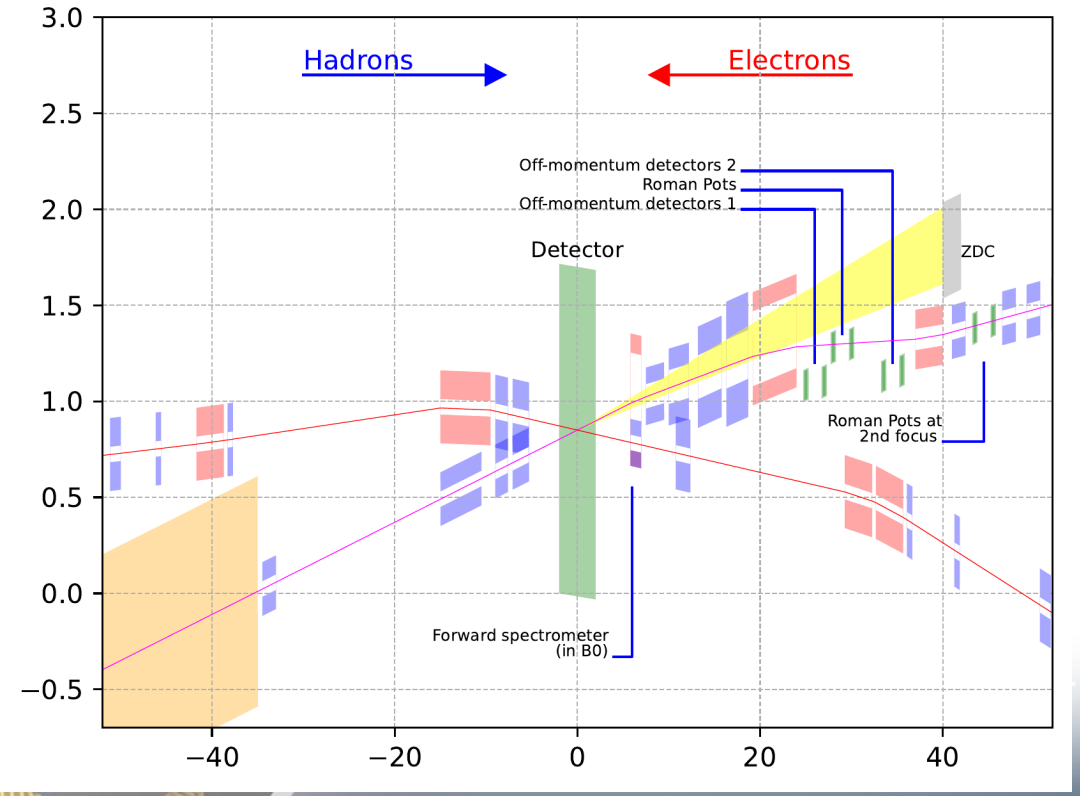
IR8 full layout (colliding)

- 35 mrad crossing angle (driven by accelerator geometry).
- Second focus point at ~47m.
- Space for similar accelerator equipment as IR6.



IR8 near IR layout

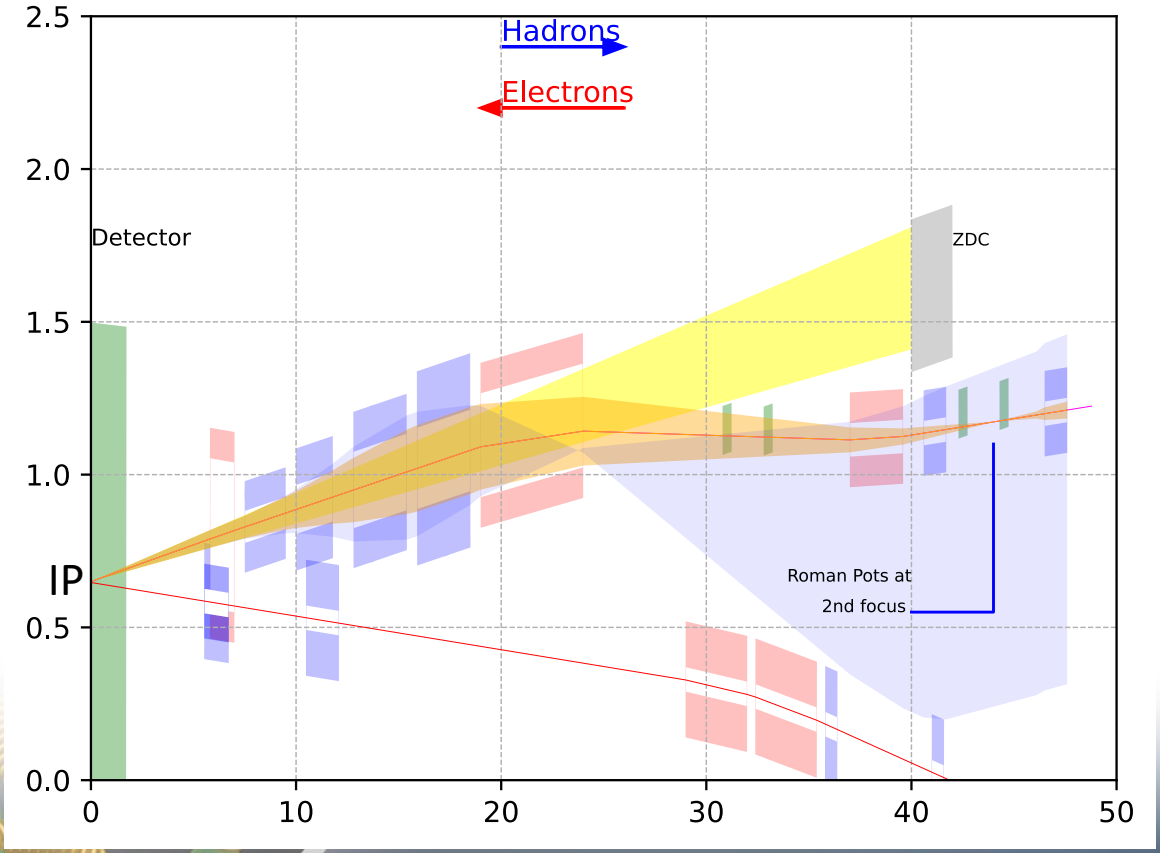
- Space available for luminosity monitor, low Q2 tagger etc..
- All ancillary detectors in outgoing hadron beam side (Forward) integrated



IR8 forward acceptance

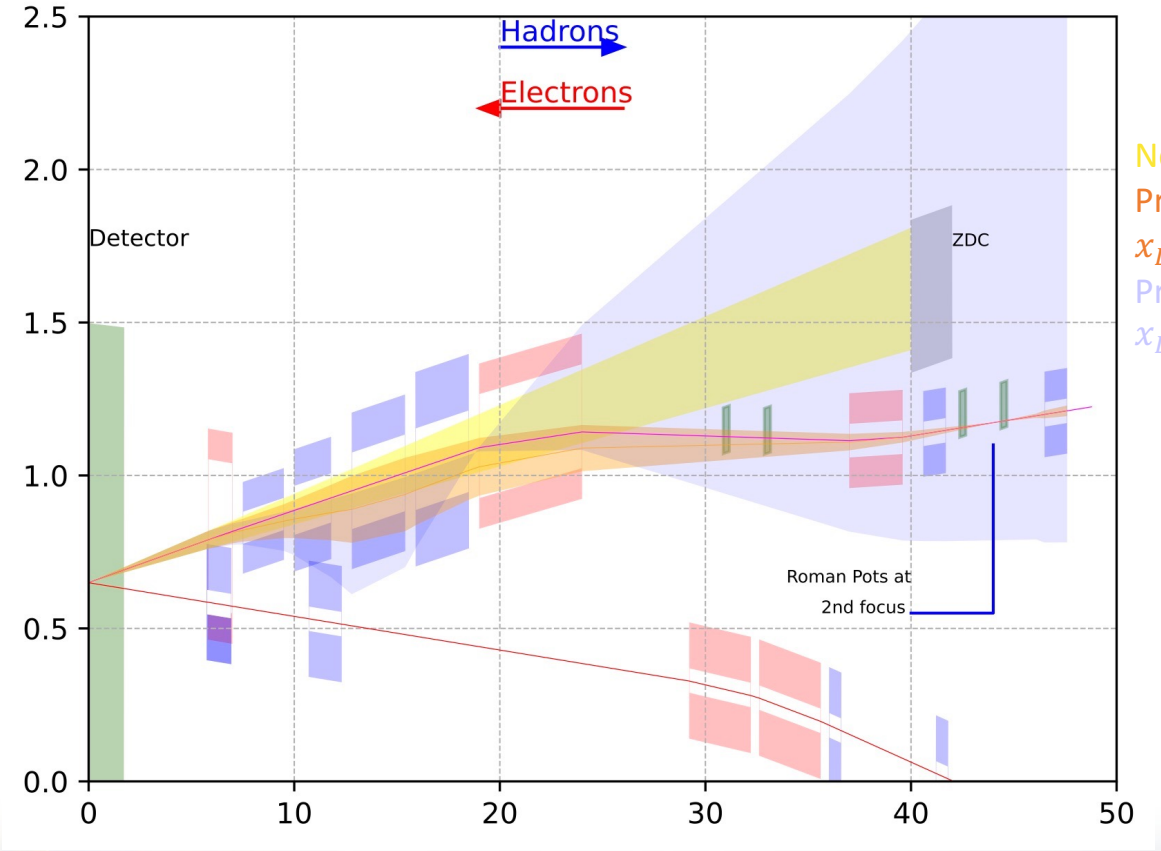
- This is the previous design of the forward region with NbTi magnets
- Final focusing quads and the dipole placements was optimized for forward scattering neutron and proton acceptance.

Neutrons ± 5 mrad
Protons ± 5 mrad
$x_L = 1$
Protons ± 5 mrad
$x_L = 0.5$



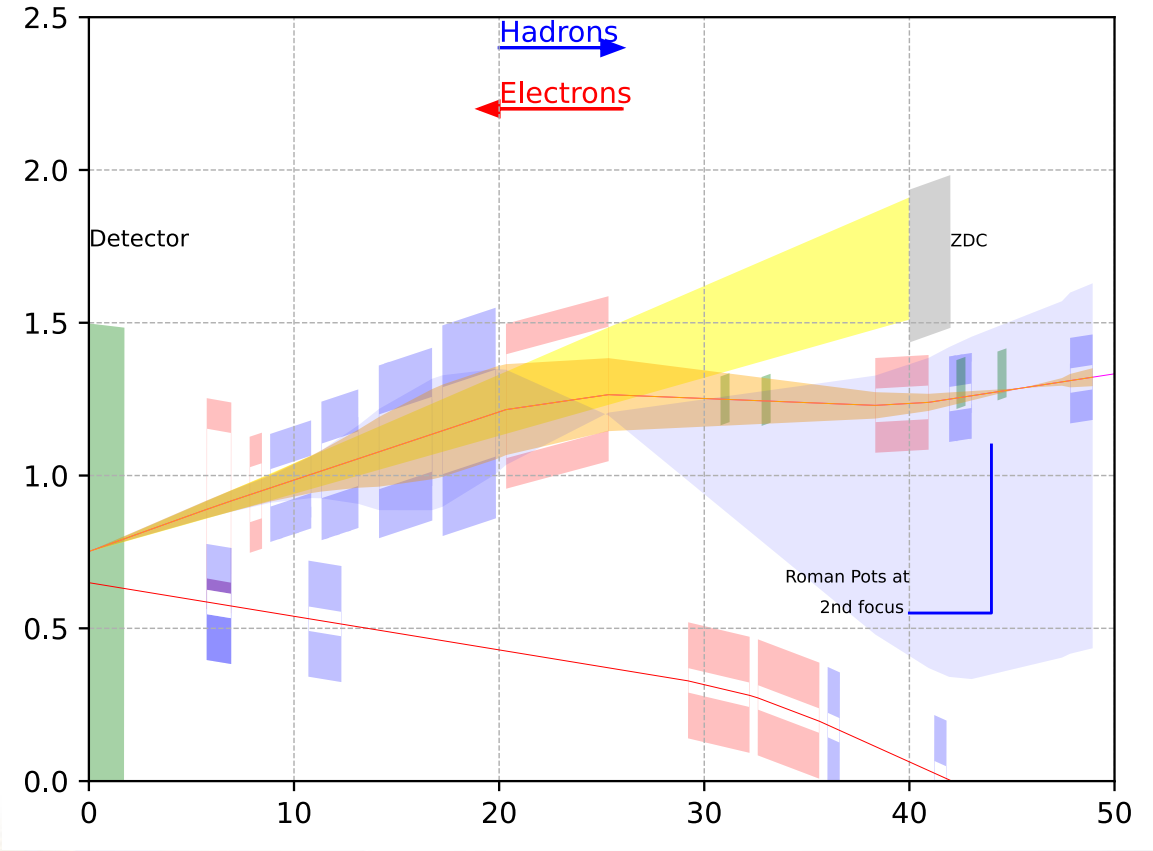
Forward acceptance at 41GeV

- Loss in acceptance without a corrector after B0



275GeV with corrector

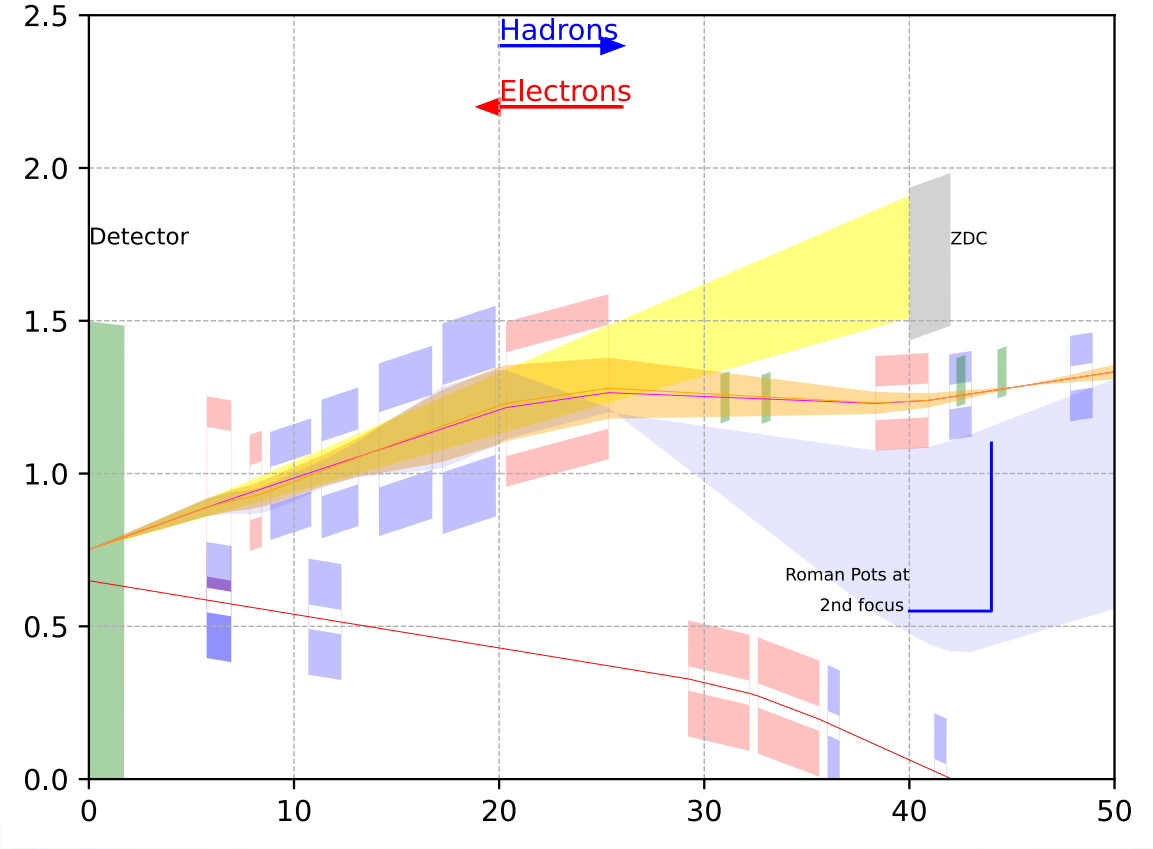
- A corrector was added between B0 and the first FFQ



Neutrons ± 5 mrad
Protons ± 5 mrad
$x_L = 1$
Protons ± 5 mrad
$x_L = 0.5$

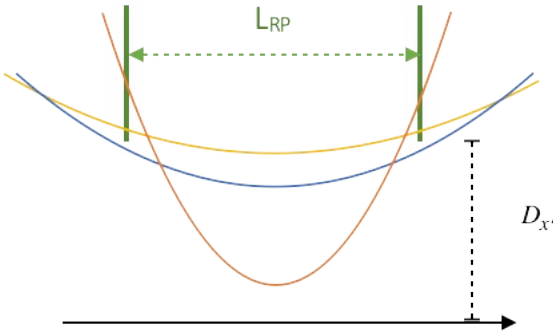
Geant4 simulations by Alex Jentsch :
https://wiki.bnl.gov/eic-detector-2/images/8/86/IP8_HSR_lattice_performance_10_13_22_v3.pdf

41GeV with corrector



Neutrons ± 5 mrad
Protons ± 5 mrad
$x_L = 1$
Protons ± 5 mrad
$x_L = 0.5$

IR8 second focus



$$D_x\Delta > 10\sigma_x = 10\sqrt{\epsilon_x\left(\beta_x + \frac{L_{RP}^2}{4\beta_x}\right) + D_x^2\delta^2}$$

Parameters at the 2nd focus

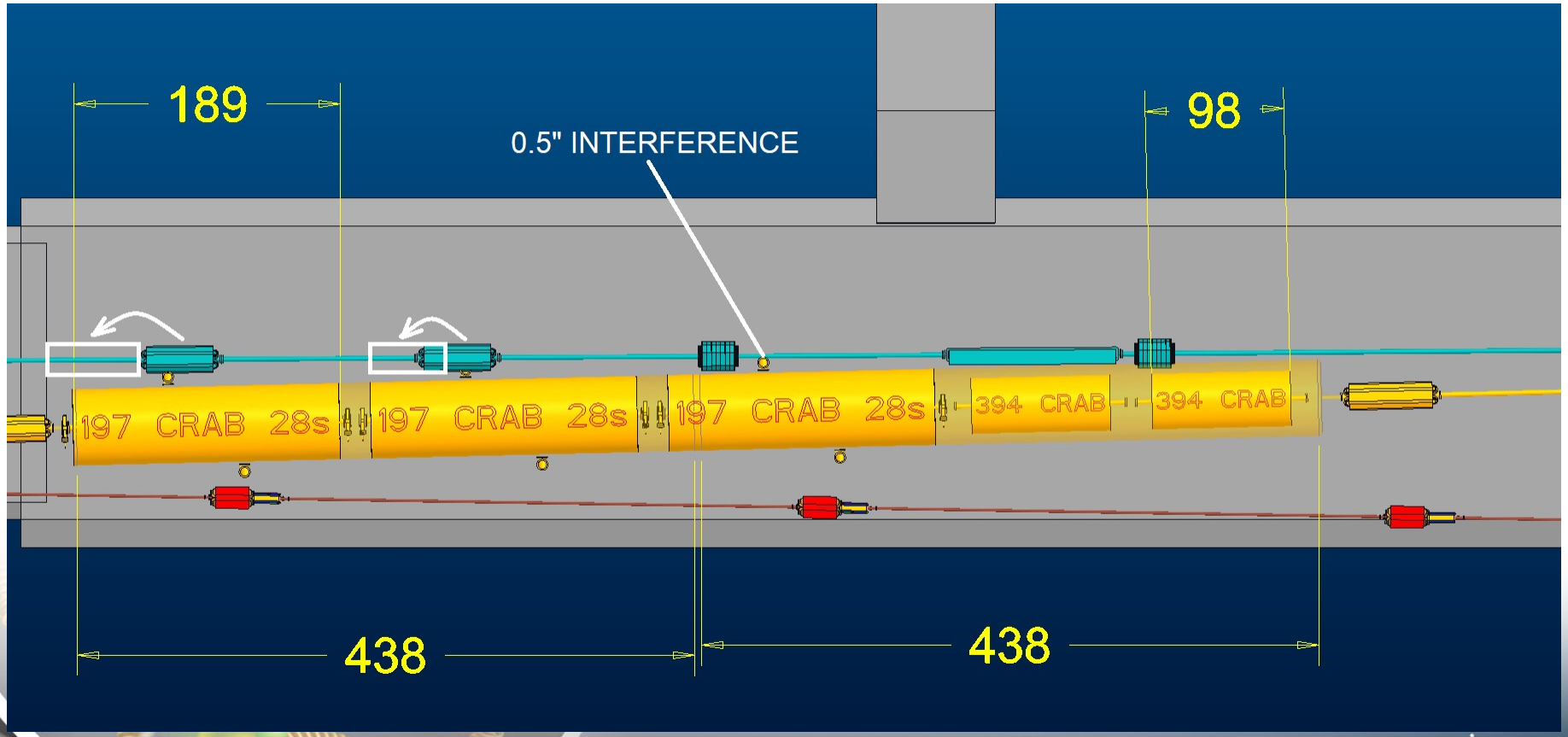
Parameter	Value	Units
β_x	0.498	m
D_x	0.465	m
ϵ_x	11.3	nm
σ_δ	$6.8e^{-4}$	-

$$x_L < 1 - 10\frac{\sqrt{\beta_x^{2nd}\epsilon_x + D_x^2\sigma_\delta^2}}{D}$$

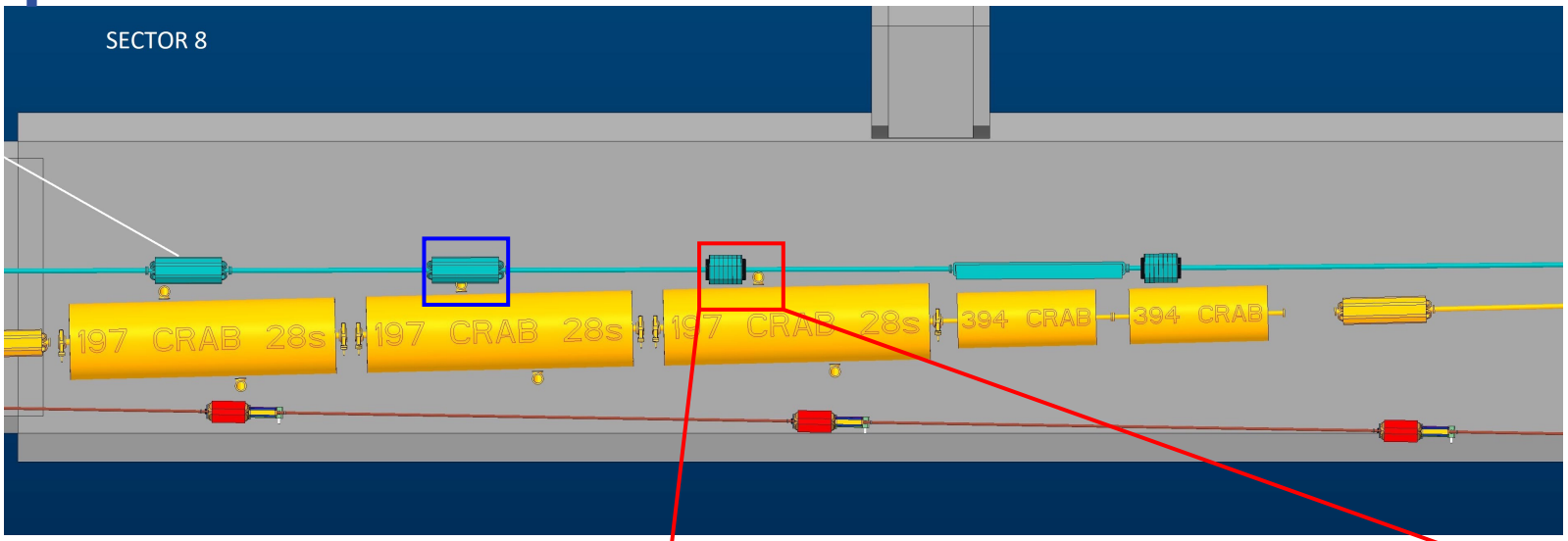
- Optimal $\beta_x^{2nd} = \frac{L_{RP}}{2}$
- For the current design, $x_L < 0.9930$
- Max x_L for the given momentum spread is 0.9932 (using $x_L < 1 - 10\sigma_\delta$)

Space constraints

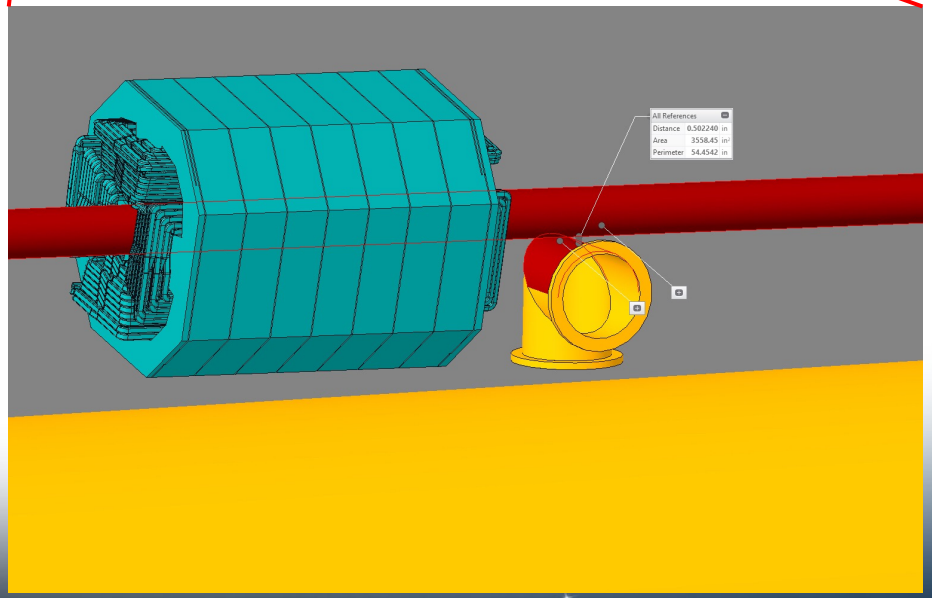
Rear side hadron crab cavity (yellow) interference on the ESR (blue).



Space constraints



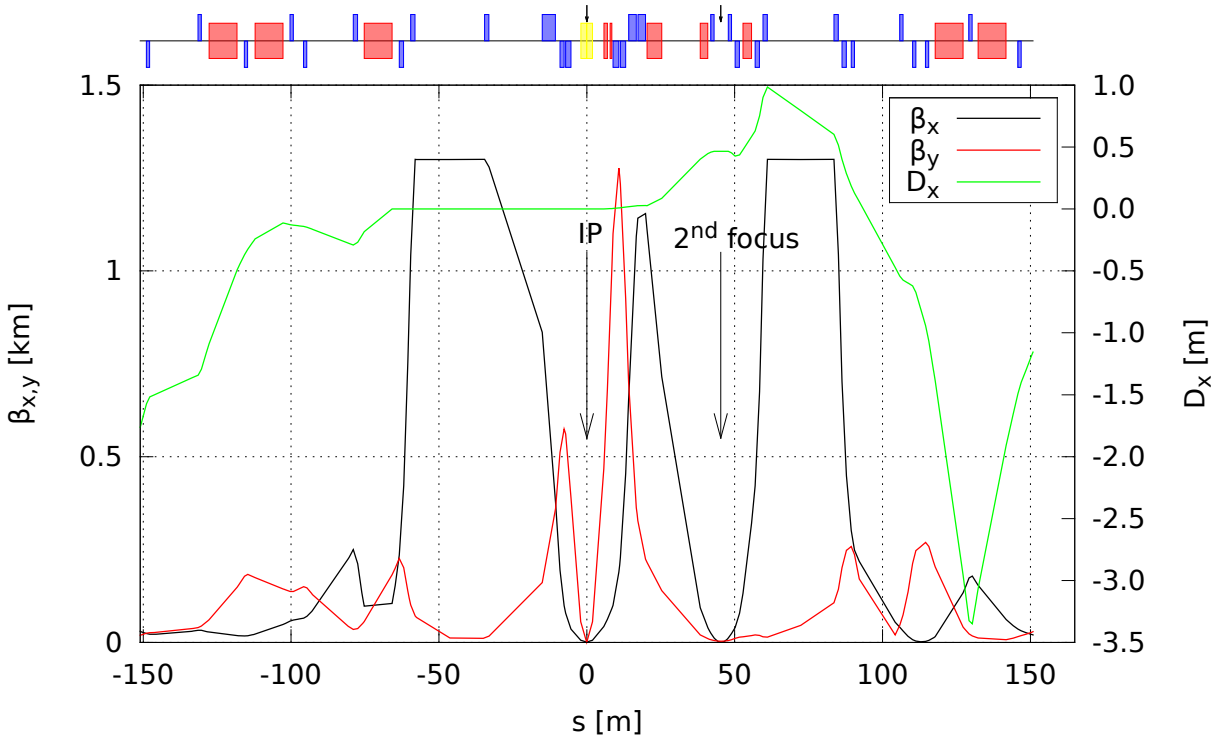
Fixed by moving the IP to x=0.65m from x=0.85 which also helped clearing the forward side hadron crab cavities from the wall.



IR8 hadron optics

- Limited matching space requires some high gradient magnets (quadrupoles) than what is available from existing RHIC magnets.
- All new near IR magnets include 7 FFQs, 2 Dipoles, 1 corrector and B0.
- All magnets are assumed to be NbTi

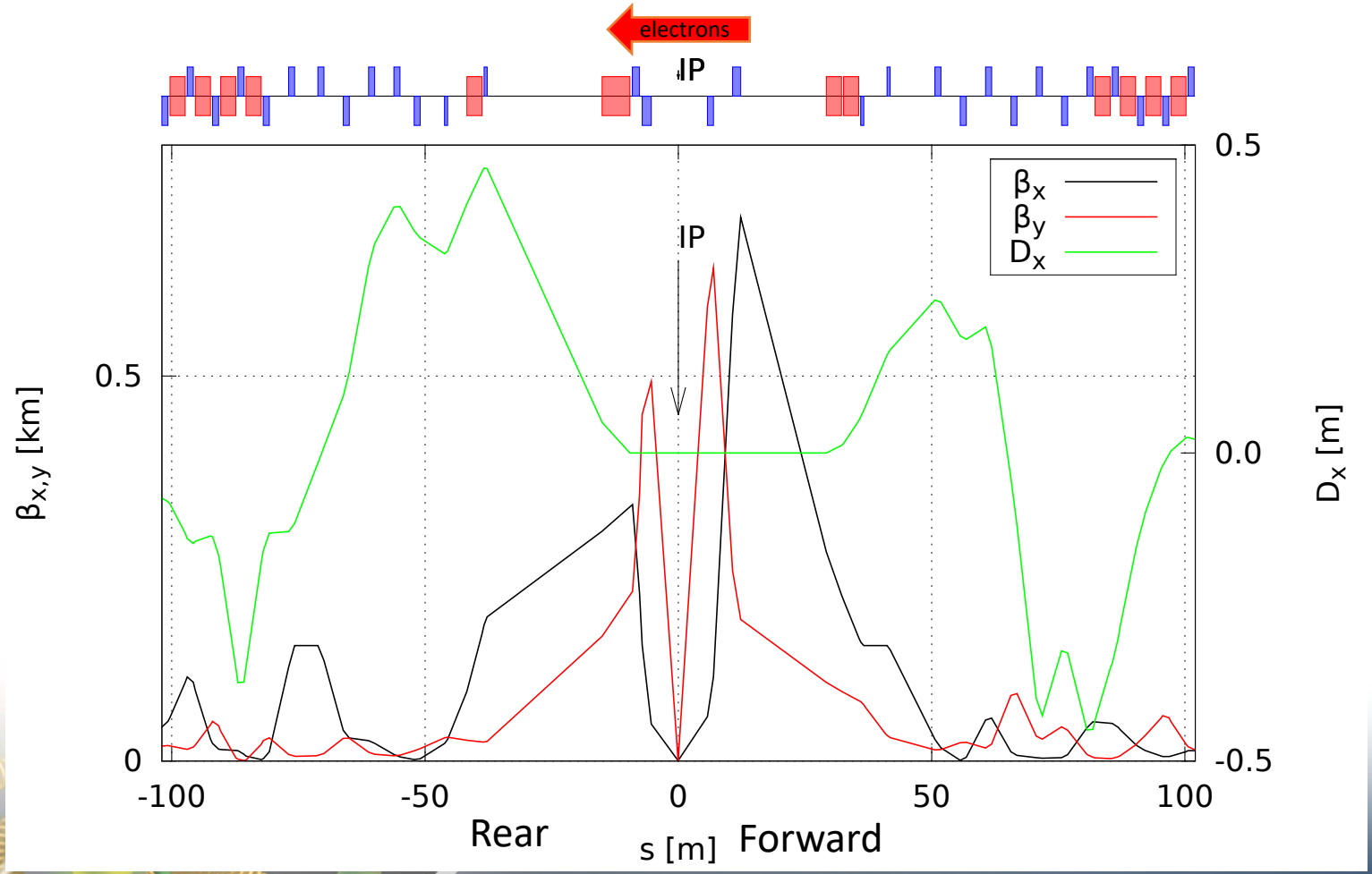
Type	RHIC	NEW	?
Quad	11	3	4
Dipole	5	0	1



Only showing the dipoles and quadrupoles. Other equipment such as crab cavities, spin rotators are not included here.

IR8 electron optics

- Optics and design similar to IR6



Summary 2nd IR (IR8)

- Second colliding IR and detector not in project, but the ability to have one is in the project scope.
- There are many constraints for the IR8 design (particularly equipment, space and arc matching) that the 2nd IR design must satisfy.
- The IR8 with the second focus adds complementarity to IR6.
- Work to be done includes,
  - Crab cavity space requirement for the 35 mrad crossing angle.
  - Clearance check for the RCS (Rapid Cycling Synchrotron) bypass.
  - Account for luminosity sharing by moving the IP by 0.056m away from IR6.
  - Low energy lattices (41,100 for protons and 5,10 for electrons)
  - Further study needed for the feasibility of the IR magnets.
  - Nb3Sn magnets are being evaluated as an option.
  - Chromaticity compensation with two IR's in the HSR.

Thank you!