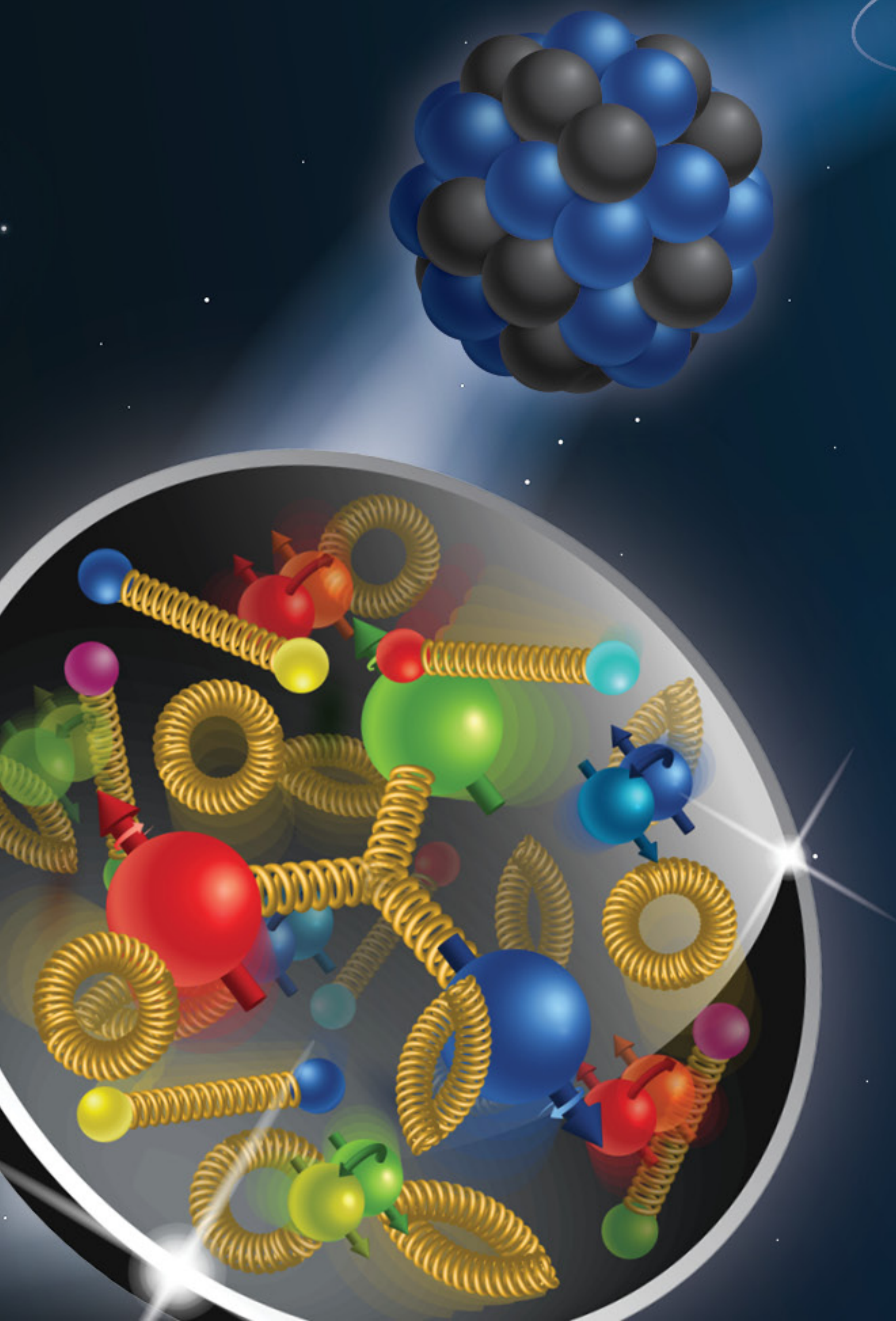

Design and optics of IR8

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on behalf of 2nd IR Design Team

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Electron-Ion Collider

BROOKHAVEN NATIONAL LABORATORY · Jefferson Lab · U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

- Requirements/Constraints
- Analytical guidelines
- IP8 layout
- Hadron optics
- Acceptance optimization
- Forward IR with different magnet configurations
- Electron optics
- Pros and Cons

Requirements/Constraints

- Fit into the existing RHIC IP8 experimental hall.
- Match in to the ARCs 7&9.
- Space for Crab cavities.
- Space for two spin rotators and a snake (~13m each).
- Reuse as many RHIC magnets as possible.
- Meet acceptance requirements.
- High luminosity over a wide energy range and meet engineering requirements

Background information

- Protons go from rear to forward —> second focus is in the forward side.
- IP is shifted by 85cm relative to the center of the hall.
- Crossing angle is 35 mrad with hadron line at 24 mrad and electron line at 11 mrad.
- All work presented is for 275GeV protons with $\beta^*_{x/y} = 80/7.2 \text{ cm}$
- Forward side final focusing quads and two dipole are being considered for Nb_3Sn.
- Max field at the aperture is 9.216T. (12T at the coil -4% for the aperture - 20% operational margin)
- Nb_3Sn work is only focused on the forward side. Rear side magnets are relatively low field and similar to IP6.

Acceptance as a function of x_L and p_T

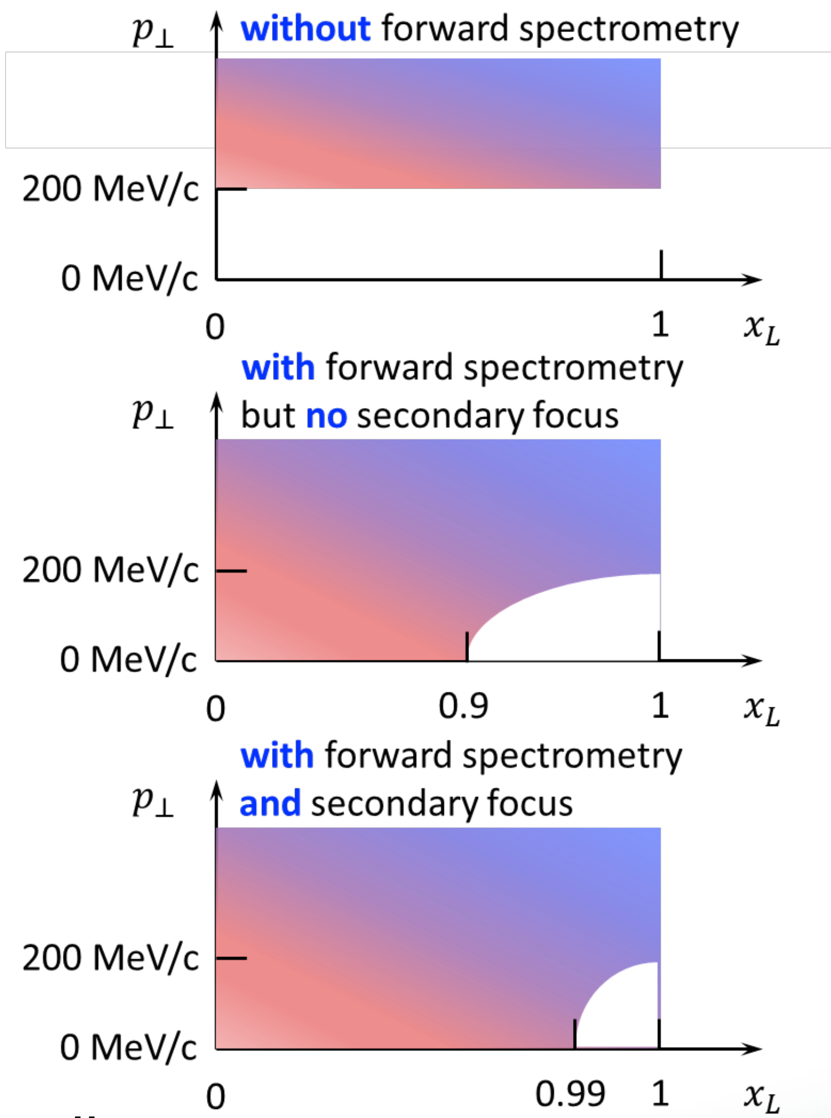
- x_L - fraction of the longitudinal momentum relative to hadron beam
- p_T - fraction of the transverse momentum relative to hadron beam (θ)
- p_T acceptance at $x_L = 1$

$$p_T^{min} > 10\ p_0 \theta_{IP} = 10\ p_0 \sqrt{\frac{\epsilon}{\beta^*}}$$

- x_L acceptance at $p_T = 0$

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

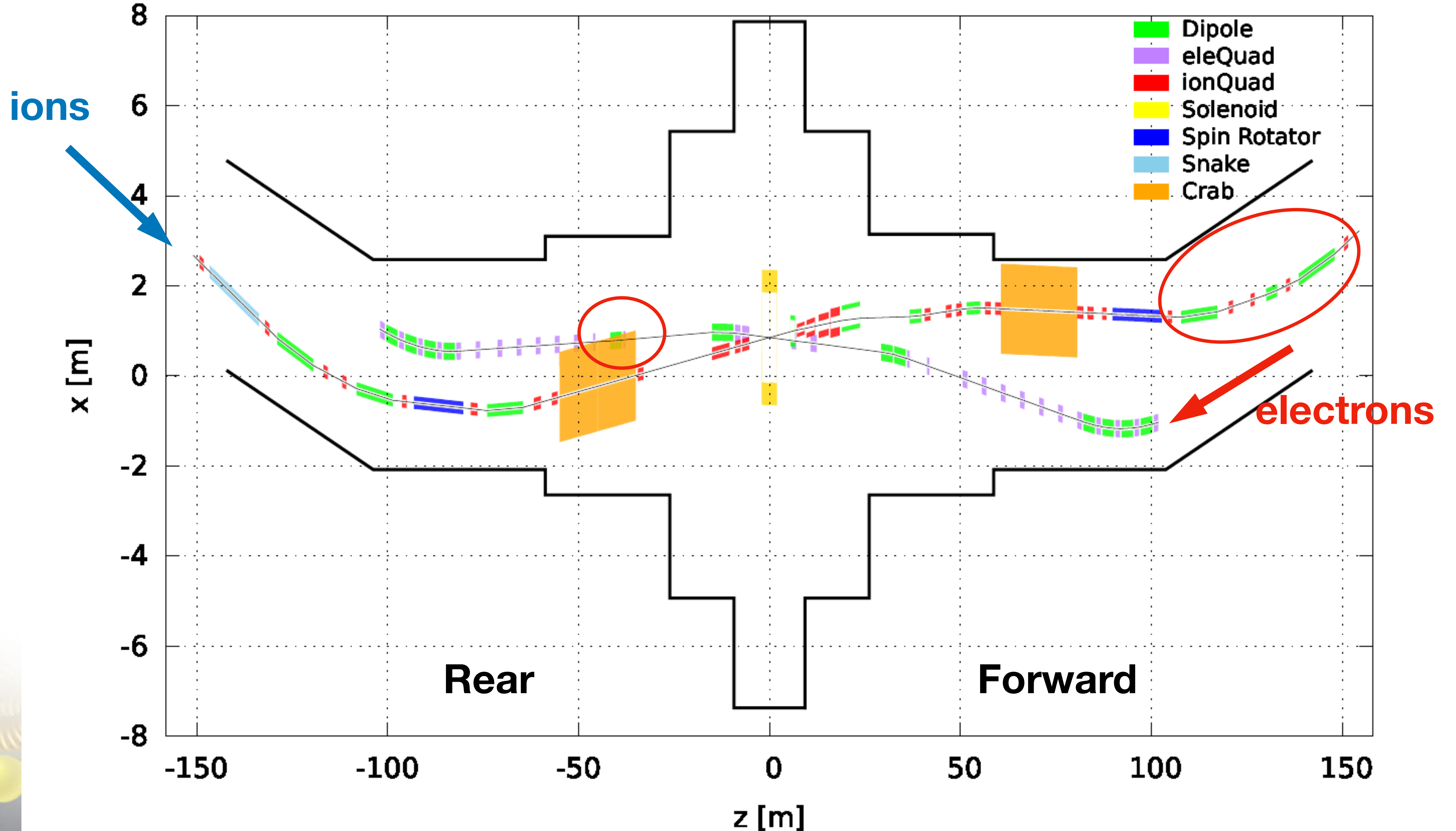
- Secondary focus allow for $|D\sigma_\delta| >> \sqrt{\beta\epsilon}$
- Can reach the fundamental limit $x_L < 1 - 10\sigma_\delta$



- Increase of β_x^* which in turn increase the β_x^{2nd} may result in a smaller x_L acceptance

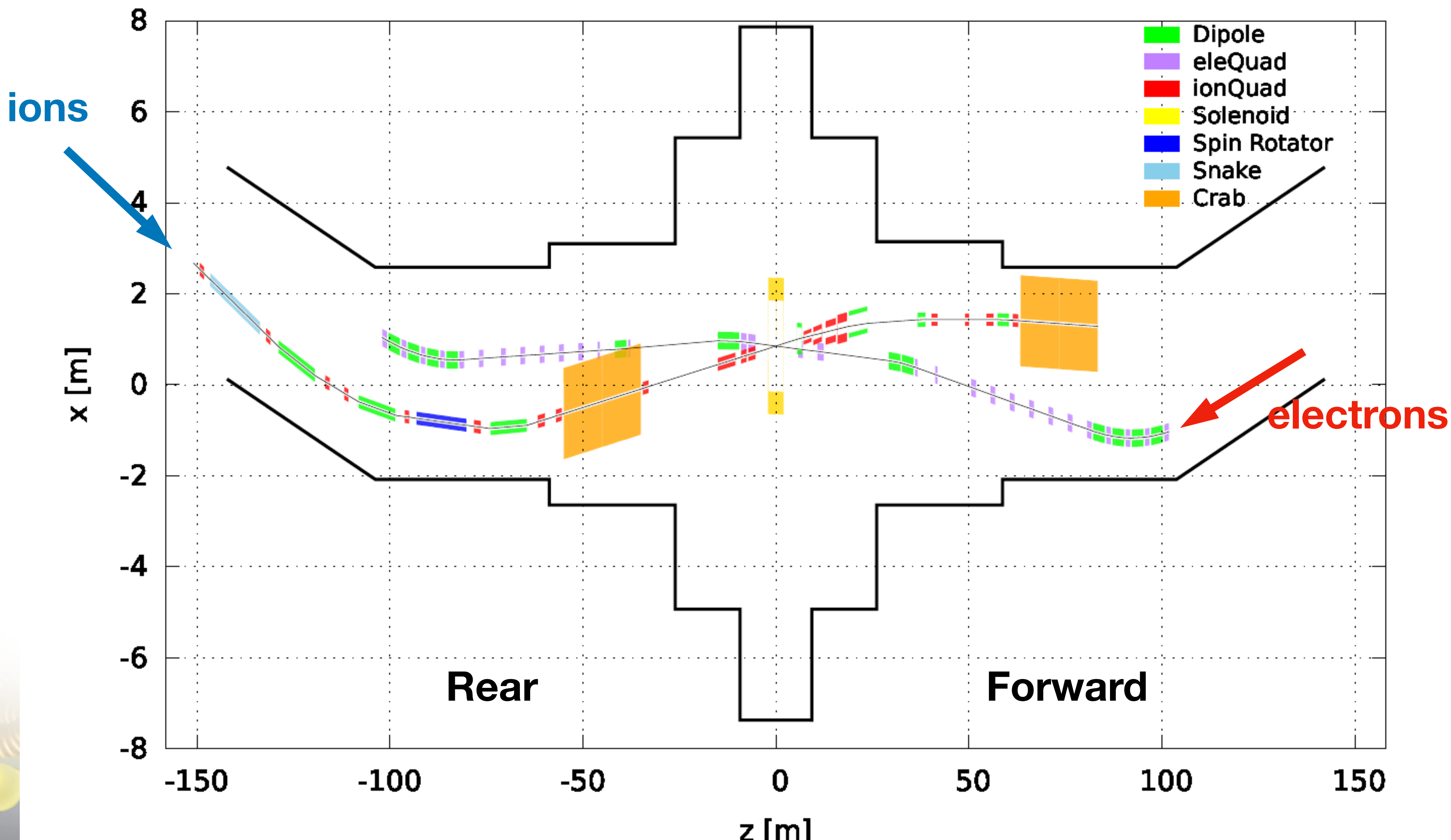
IP8 full layout

- Reserved space for crab cavities and spin rotators on both sides and a snake on rear side.
- Hadron beam line matched to the ARCs on each side.
- Electron beam line matched up-to the spin rotators.



IP8 full layout …another option

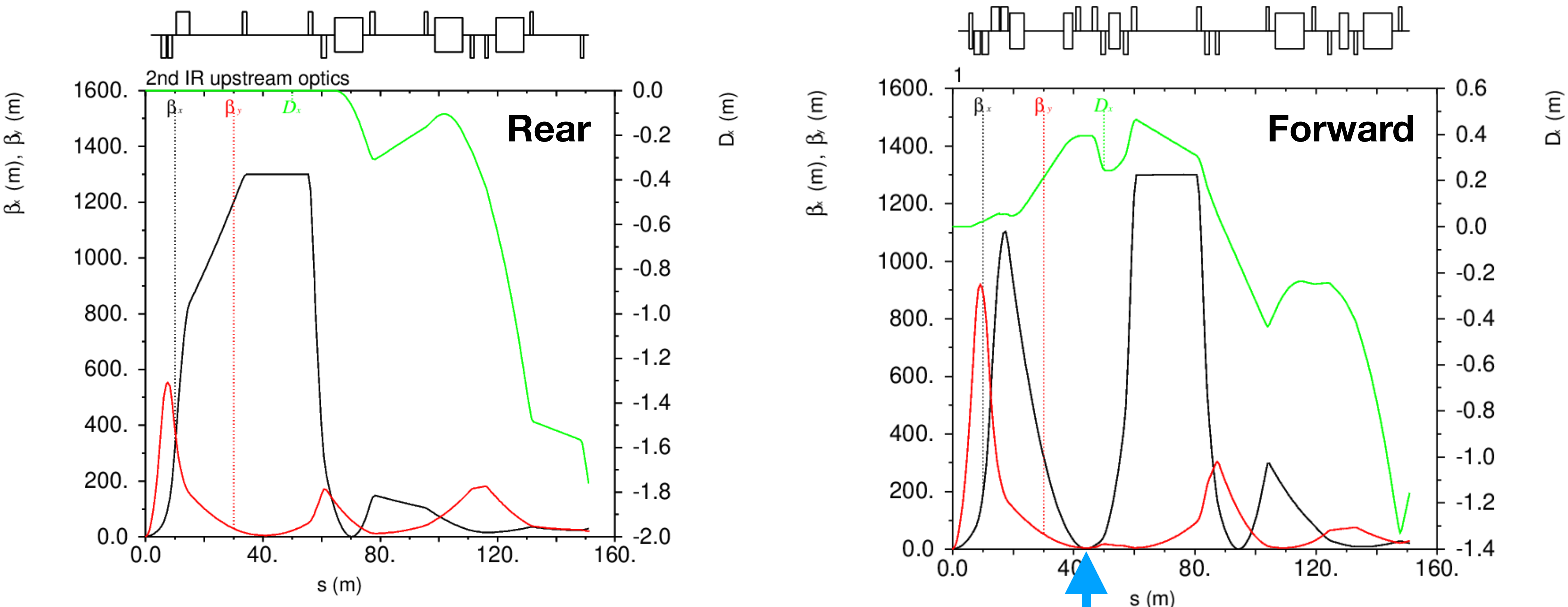
- Hadron beam line at 27 mrad and electrons at 8 mrad.
- Forward side match still in progress.



IR8 ion optics

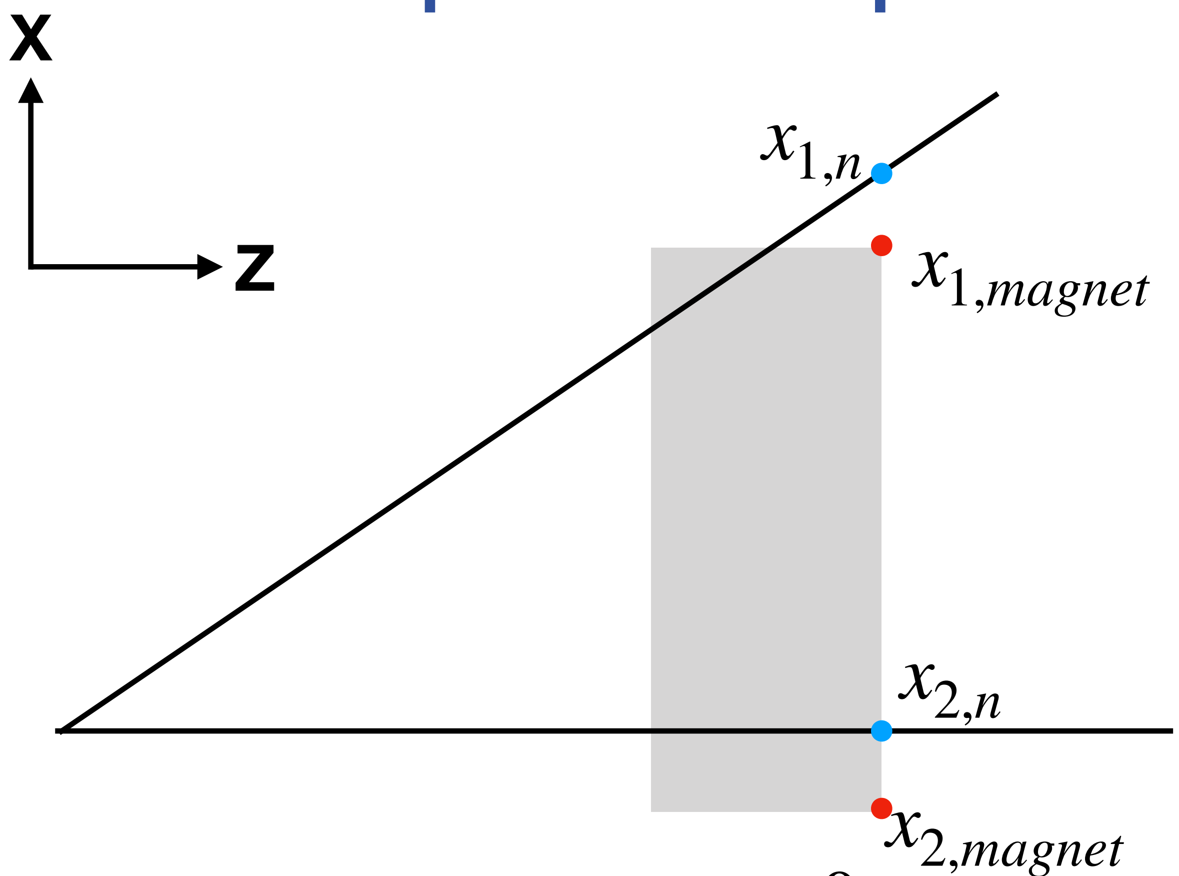
- Baseline NbTi optics
- IP is at S=0

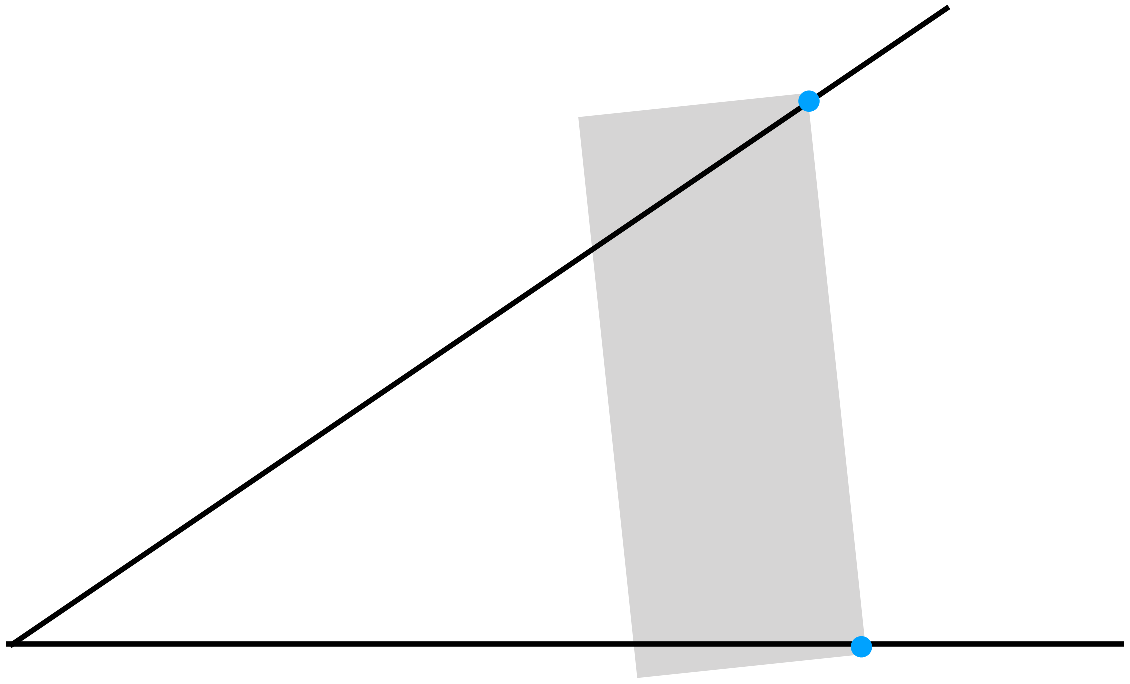
Protons



Second Focus

Acceptance optimization constraints



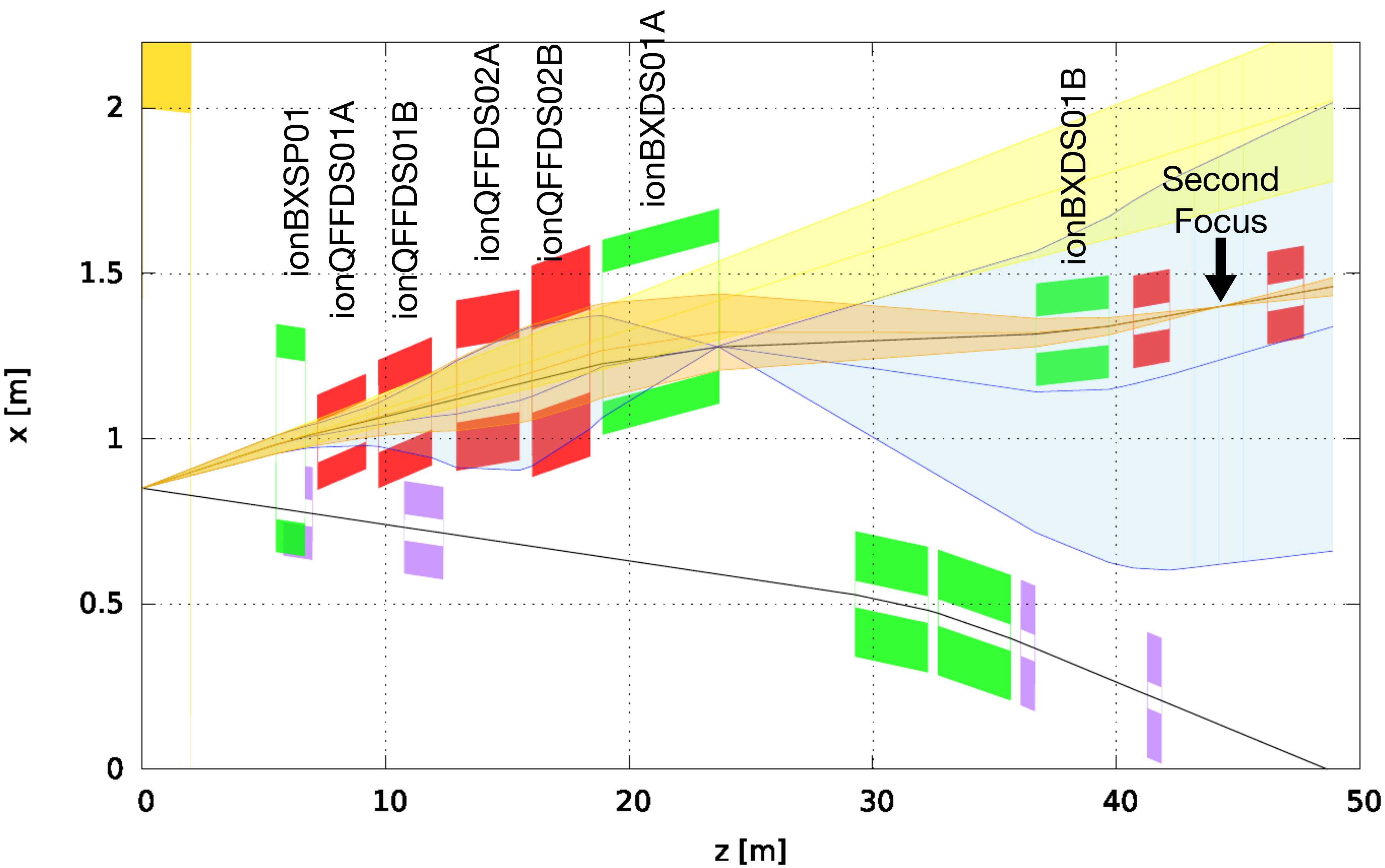


$$x_{1,magnet} - x_{1,n} \geq 0$$
$$x_{2,magnet} - x_{2,n} \leq 0$$

- Similar constraints for high p_T and $x_L = 1$protons
- Applied to both sides of the magnet
- Total of 8 constraints per magnet
- Variables that can be used: magnet shift in x, rotation around y, (magnet aperture, magnet length)

IR8 Forward acceptance with NbTi magnets

- This is the current design with NbTi magnets.



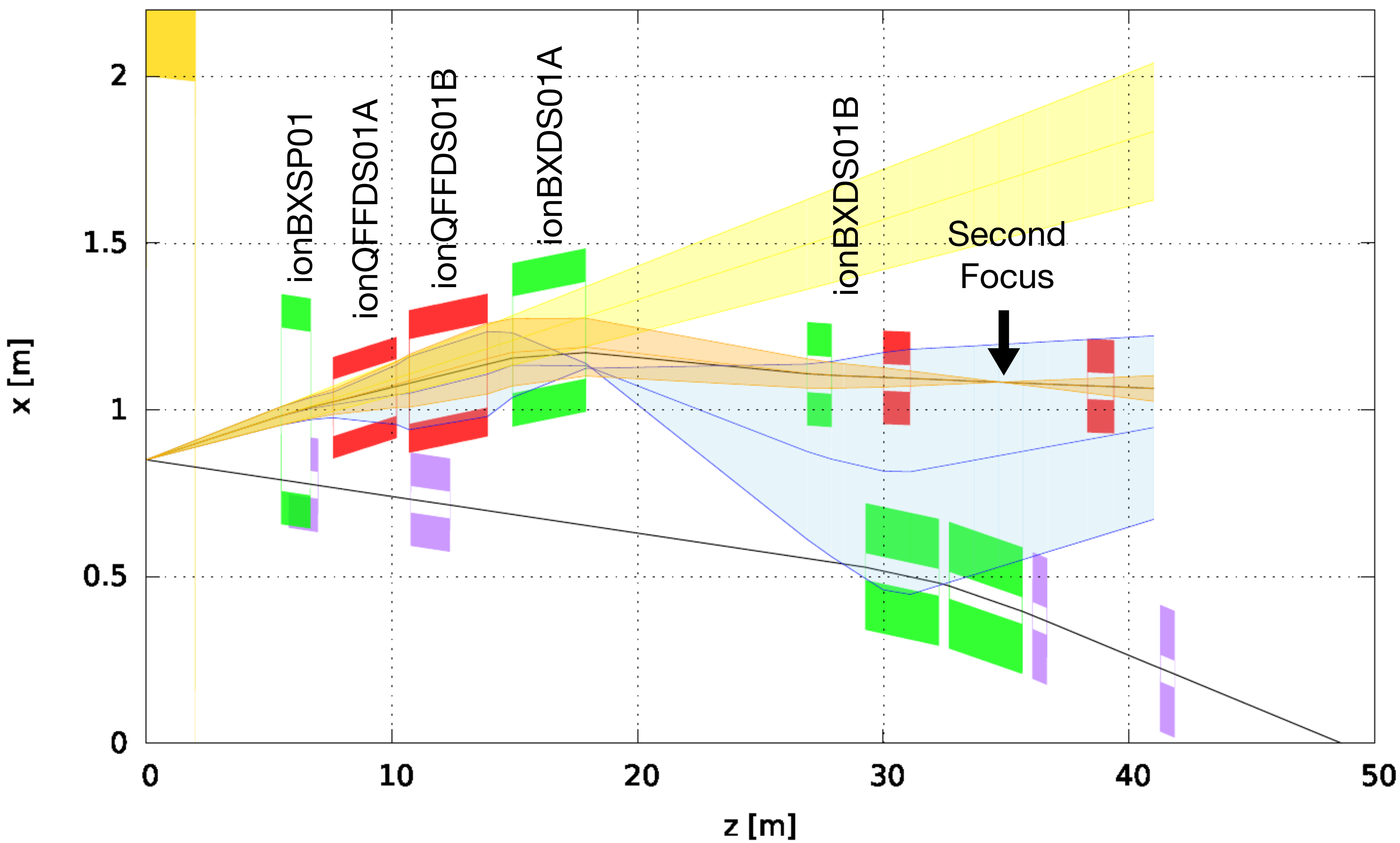
Neutrons $\pm 5\text{mrad}$

Protons $\pm 5\text{mrad}$
$\Delta p/p = 0$
$p_T = 1.37\text{GeV}, x_L = 1$

Protons $\pm 5\text{mrad}$
$\Delta p/p = -0.5$
$p_T = 0.69\text{GeV}, x_L = 0.5$

IR8 Forward with Nb3Sn magnets option 1

- Two Nb_3Sn quads and two dipoles with correctors.



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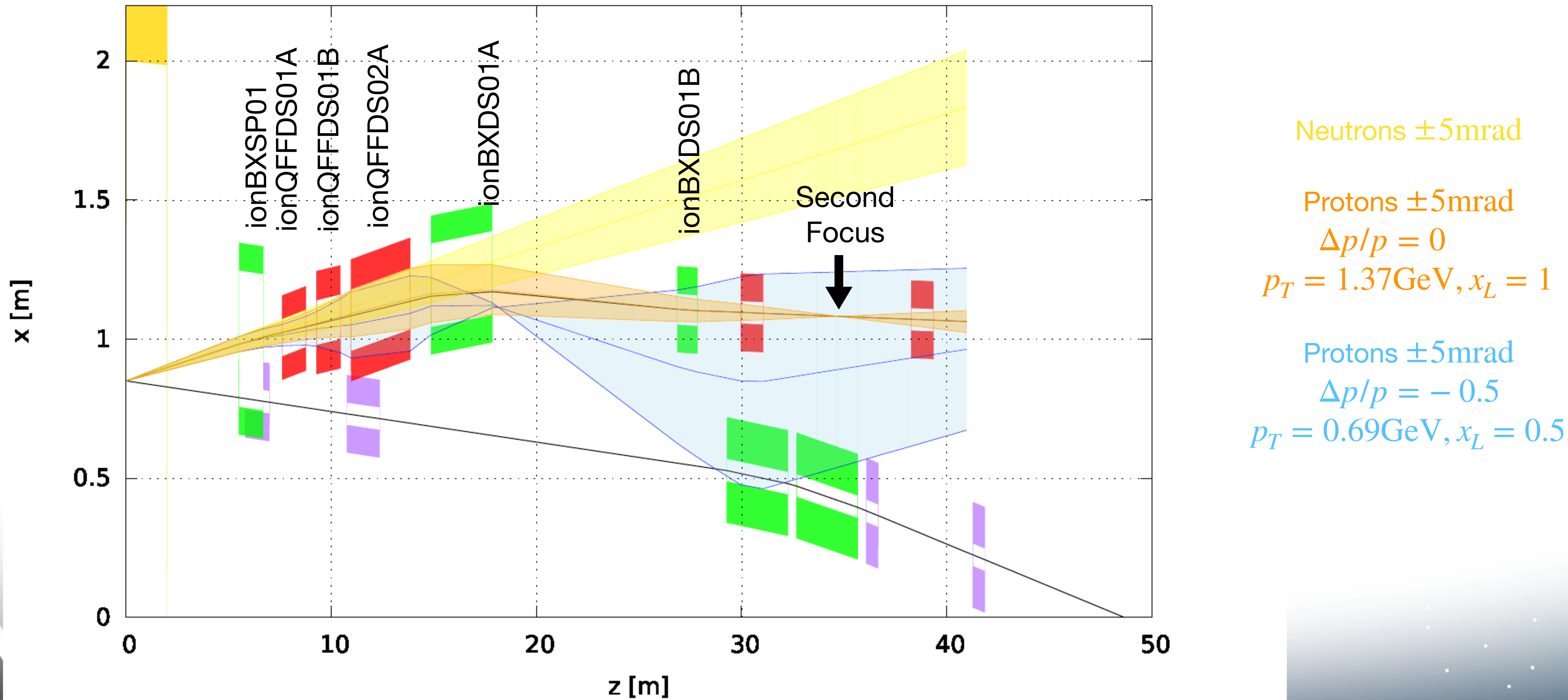
Protons $\pm 5\text{mrad}$
$\Delta p/p = -0.5$
$p_T = 0.69\text{GeV}, x_L = 0.5$

IR8 Forward with Nb3Sn magnets option 2

- Three magnets working as a doublet with the third powered off at low energy operation.
- Can reach smaller β^* with same β_{max} at low energies due to shorter focal length.
- Can tailor the apertures to the acceptance better.



IR8 second focus parameters

Parameer	NbTi	Nb3Sn #1	Nb3Sn #2	Units
Energy	275	275	275	GeV
$\beta^*_{x/y}$	80/7.2	80/7.2	80/7.2	cm
$\beta_{max\ x/y}$	1050/973	565/801	594/890	m
β_x	58	53	50	cm
D_x	0.39	0.43	0.41	m
x_L	0.992896	0.992965	0.99296	
dQ1	-10.69	-7.09	-7.45	
dQ2	-12.89	-14.25	-13.96	

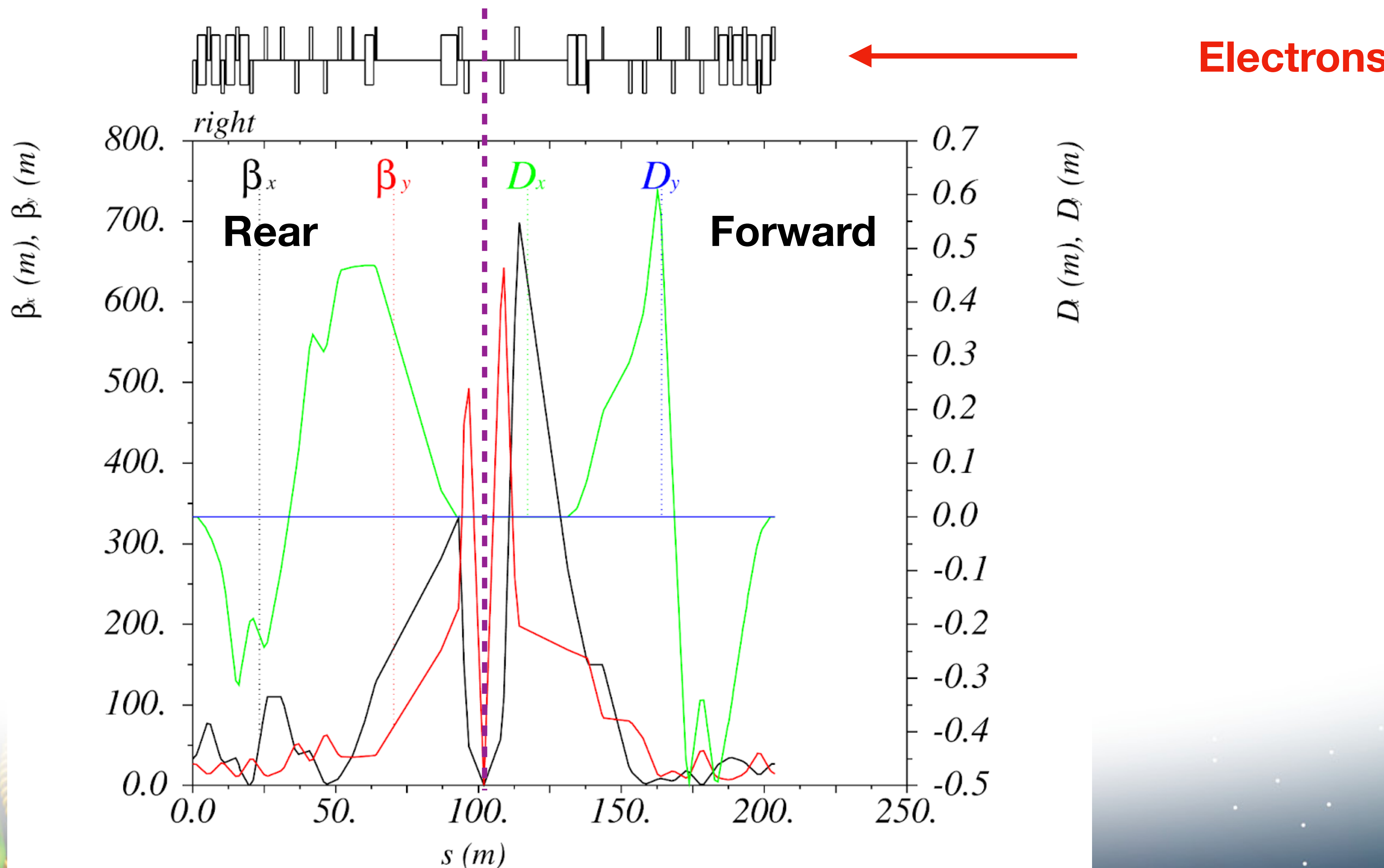
$$x_L \ < \ 1 - 10 \frac{\sqrt{\beta_x^{2nd}\epsilon_x + D_x^2\sigma_\delta^2}}{D}$$

For a momentum spread
$\sigma_\delta = 6.8e^{-4}$,
maximum x_L is given by
$x_L < 1 - 10\sigma_\delta = 0.99320$

*NbTi : current version, Nb3Sn #1 : With two quads, Nb3Sn#2 : First quad split

IR8 electron optics

- Ongoing work to adjust the electron beam line to accommodate hadron crab cavities.



Pros and cons

- Pros
  - Compact IP to second focus section leaves more space for matching in to ARC7.
  - In general similar or potentially slightly better acceptance performance to be quantified.

- Cons
  - Crosstalk: Greater crossing angle but shorter quadrupoles and stronger fields. NbTi version has 4 magnets at nearly full strength.
  - Technologically challenging.

Summary

- Forward side match in to ARC7 needs further improvement.
- Satisfy crab cavity space requirement.
- Nb_3Sn
  - Current work is preliminary and was performed a stepping point for magnet design.
  - Future work will involve exploring increasing the luminosity and/or acceptance.

Thank you!