IR8 – layout

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on behalf of 2nd IR Design Team

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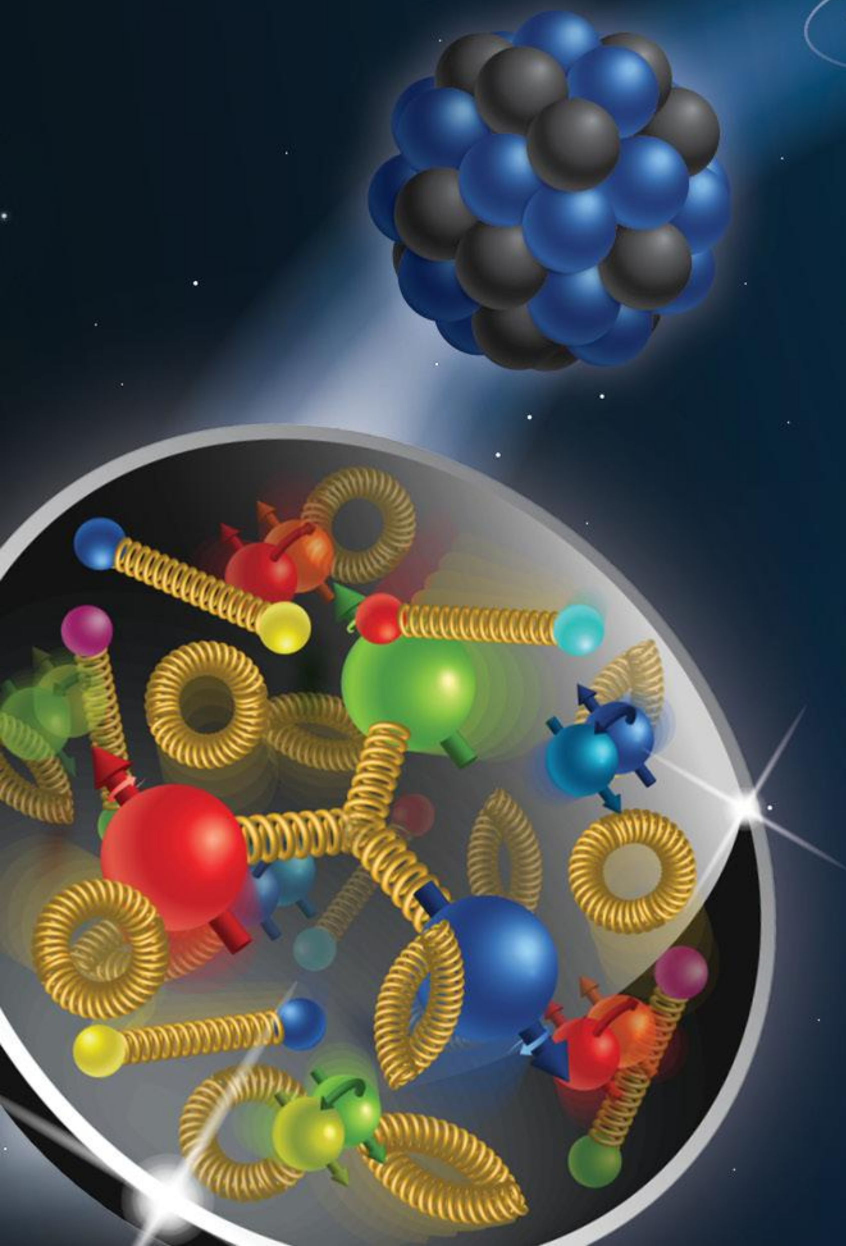


Electron-Ion Collider

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

Beam and Optics Parameters

- Geometric emittance ε is the area occupied by bunch in (x, x') phase space
- ε is a constant typically made as small as possible
- Optics and ε determine the beam parameters at the IP
  - rms beam size $\sigma^* = \sqrt{\varepsilon\beta^*}$
  - rms angular beam divergence $\sigma'^* = \sqrt{\frac{\varepsilon}{\beta^*}}$
  - Transverse momentum spread $\sigma_{pT} = p_{beam}\sigma'^*$
  - Note $\varepsilon = \sigma^*\sigma'^*$
  - Maximum beam size $\sigma^{max} \approx L\sigma'^*$
- Have control over β^* through optics design
- Luminosity

$$L \propto \frac{1}{\sigma_x^*\sigma_y^*} \propto \sigma_x'^*\sigma_y'^* \propto \sigma_{pTx}\sigma_{pTy} \propto \sigma_x^{max}\sigma_y^{max}$$

Acceptance as Function of x_L and p_T

- p_T acceptance at $x_L = 1$

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

- x_L acceptance at $p_T = 0$
  - Requires dispersion D

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

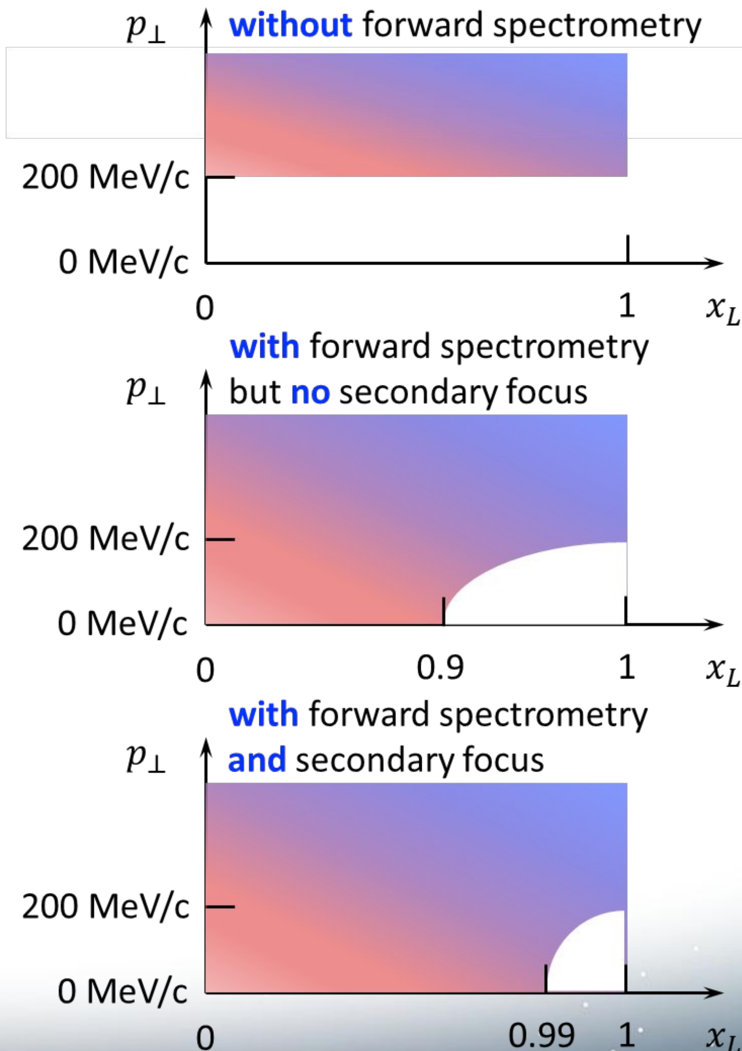
  - $\beta_x^{2nd} \propto \beta_x^*$
  - Secondary focus allows for

$$|D\sigma_\delta| \gg \sqrt{\beta\varepsilon}$$

  - Therefore, one can approach the fundamental limit

$$x_L < 1 - 10\sigma_\delta$$

  - Increase of β_x^* and therefore β_x^{2nd} may result in smaller x_L acceptance

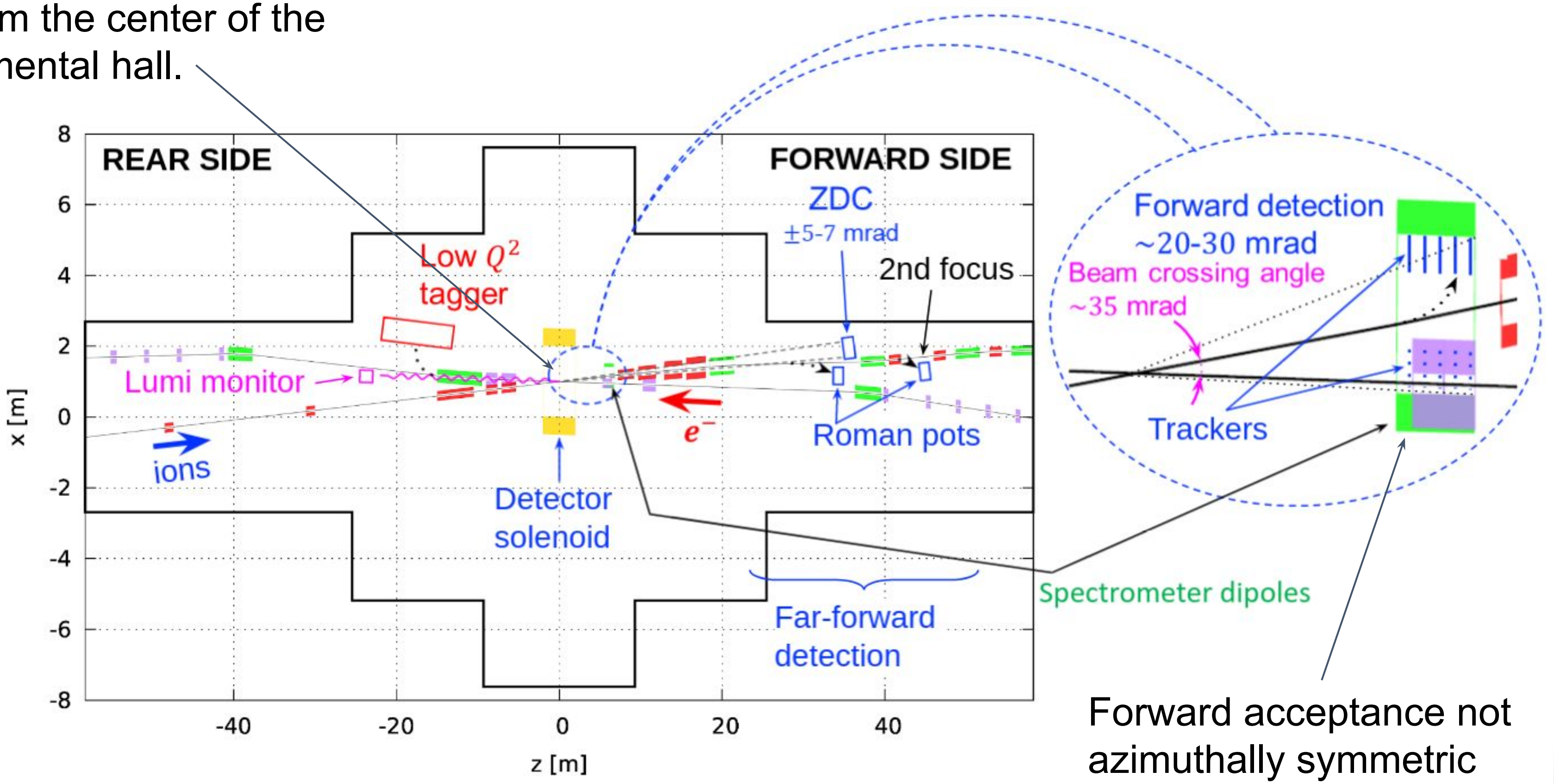


Crossing Angle Choice

- Cannot be too large, ~50 mrad
  - Experimental hall geometry does not allow that.
  - IP must be shifted towards the center to allow for RCS bypass the detector.
  - Requires additional crabbing cavities, not only space limitation (specially in the downstream/ forward side) and cost but additional impedance and other dynamical issues.
  - Crab cavities requires ~1.5m clearance from the wall and the electron beamline.
  - Does not allow to move the final focusing quads closer because of detector space requirements.
  - Unnecessarily large given that Roman pot acceptance of ±5~7 mrad is sufficient; moreover, large roman pot acceptance requires large-aperture magnet posing engineering challenge.
- Cannot be too small, ~25 mrad
  - Hall geometry requires spectrometer dipoles to bend towards the electron beam, bending away as in IR6 is not possible because of the tunnel wall. Smalle crossing angle would cause interference with electron beamline.
  - Relaxes engineering requirements
- Everything seems to point to an optimal crossing angle of 35 mrad

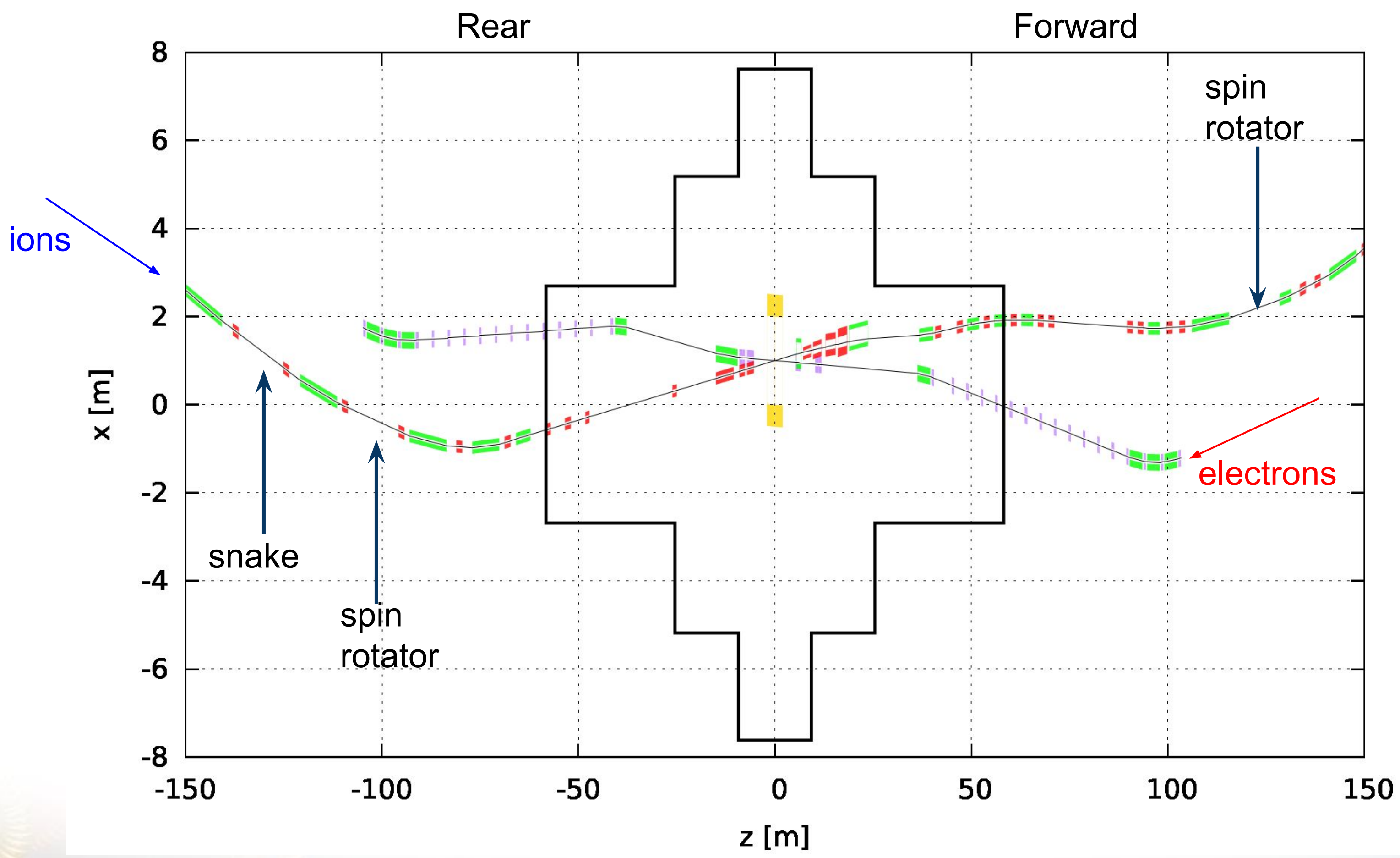
IR8 magnet layout

IP is 1m towards the center of the ring from the center of the experimental hall.



Forward acceptance not azimuthally symmetric because of electron dipole

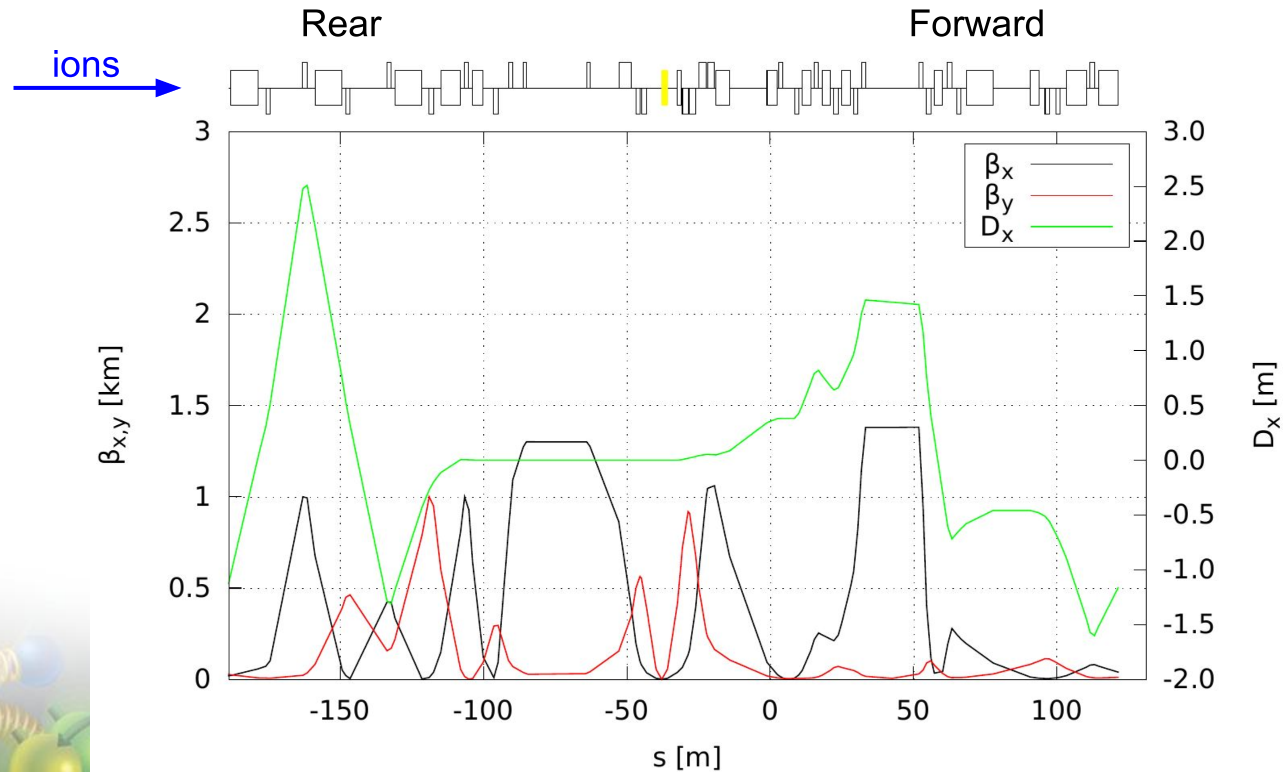
IR8 layout



Rear
Forward
ions
electrons
snake
spin rotator
spin rotator
x [m]
z [m]
8
6
4
2
0
-2
-4
-6
-8
-150
-100
-50
0
50
100
150

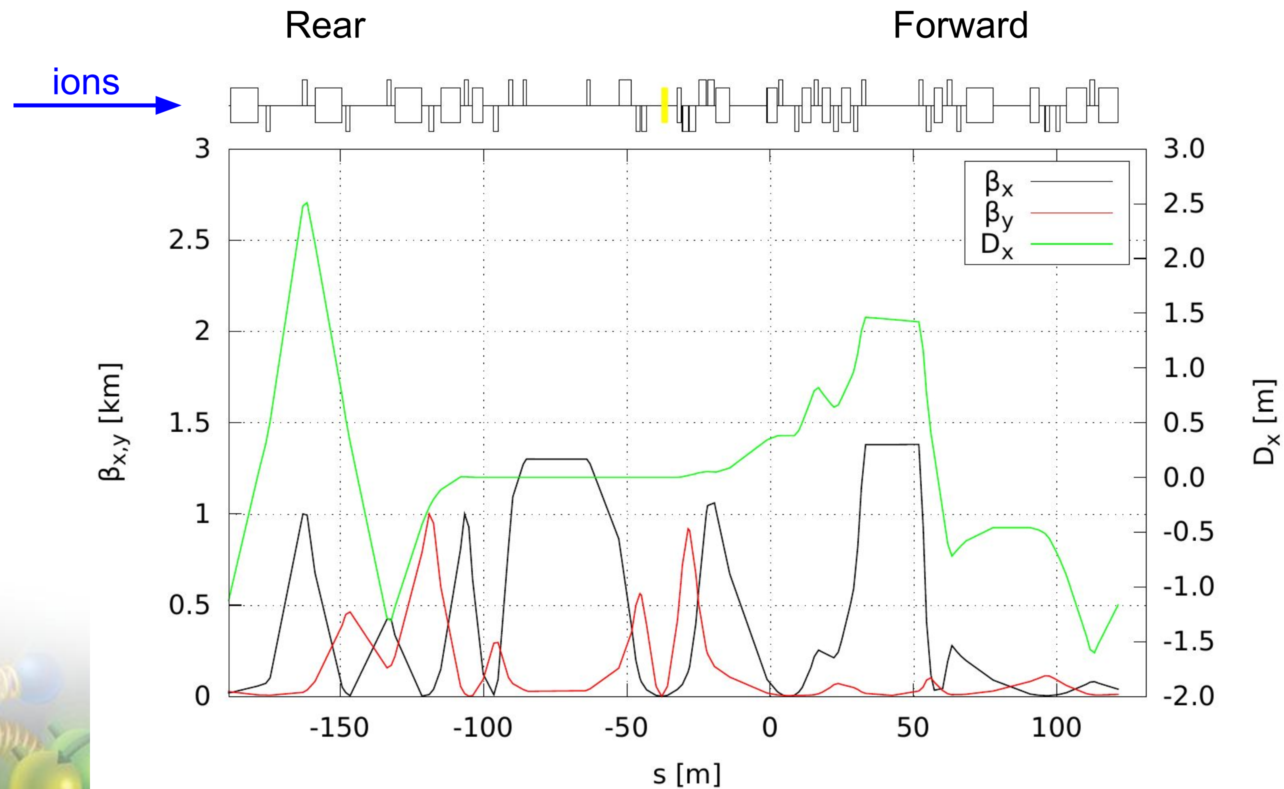
IR8 Ion optics from 135 to 275 GeV

- Removed the unintentional second focus in the rear IR
- Doublet optics with reversible polarity of the second quad depending on the energy.
  - $\beta^*_{x/y}$ = 80/7.2 cm (>135GeV)
  - $\beta^*_{x/y}$ = 37/2.5 cm (<135GeV)
- Match into ARCs need further improvement.



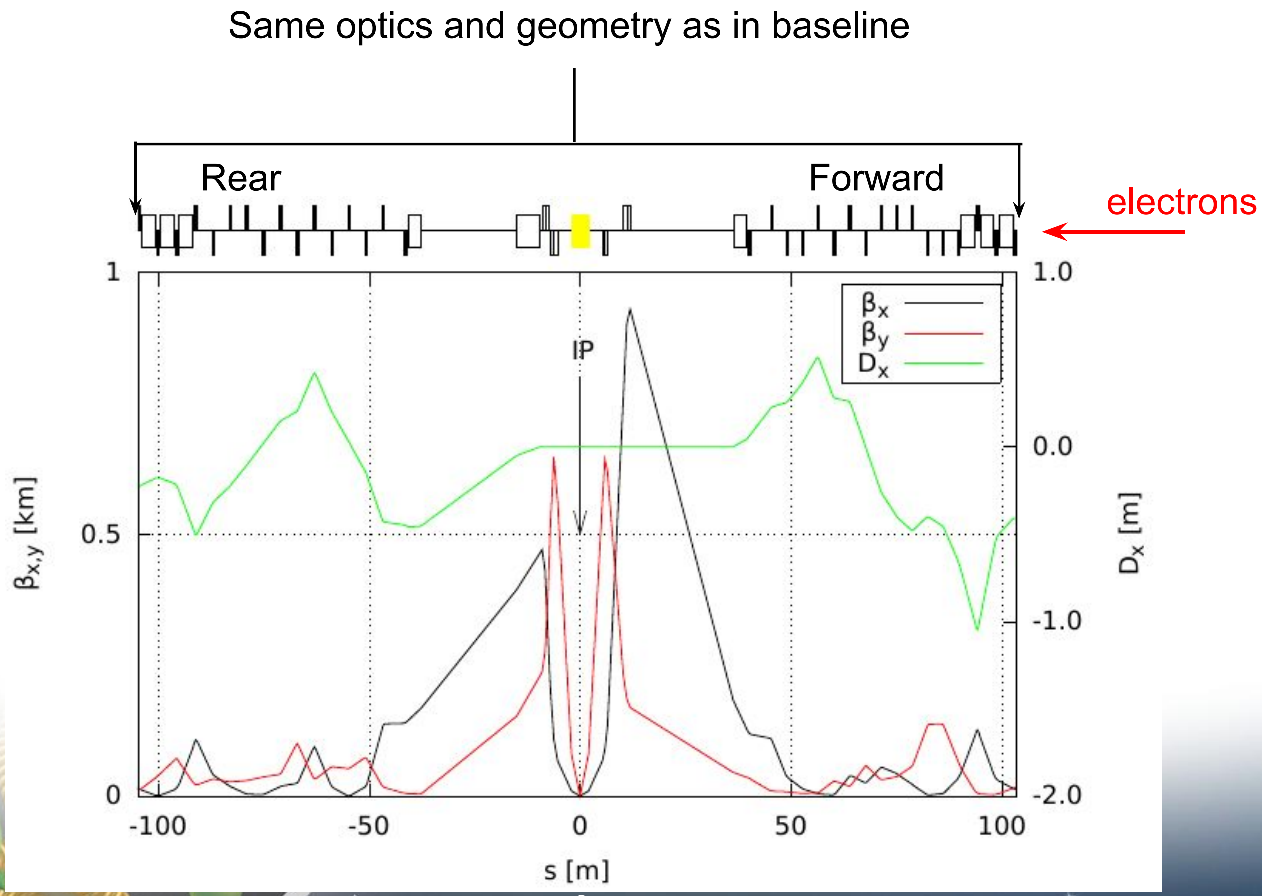
IR8 Ion beamline match into ARCS

- Forward side has few quadrupoles with strengths almost double what the magnet can provide
  - Add supporting magnets to increase the magnetic length
- Rear side optics need further optimization to reduce the high peaks in both horizontal and vertical
  - Work in progress



IR8 Electron optics (18GeV)

- Electron optics and geometry are very similar to the IR6
- Special care was given to keep the relative angle between the IP and spin rotators the same as IR6
- Not yet matched all the way to the ARCs



Acceptance optimization constraints

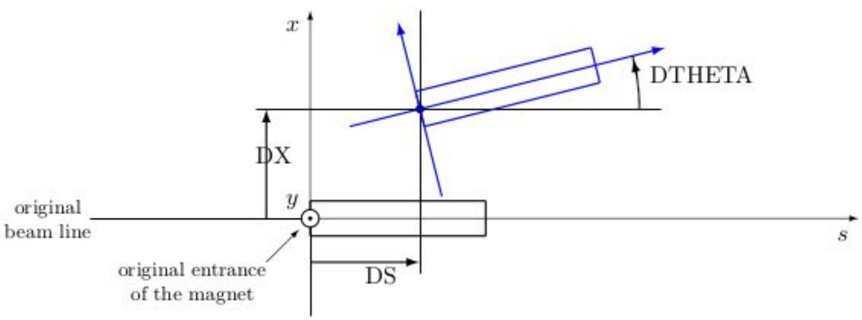
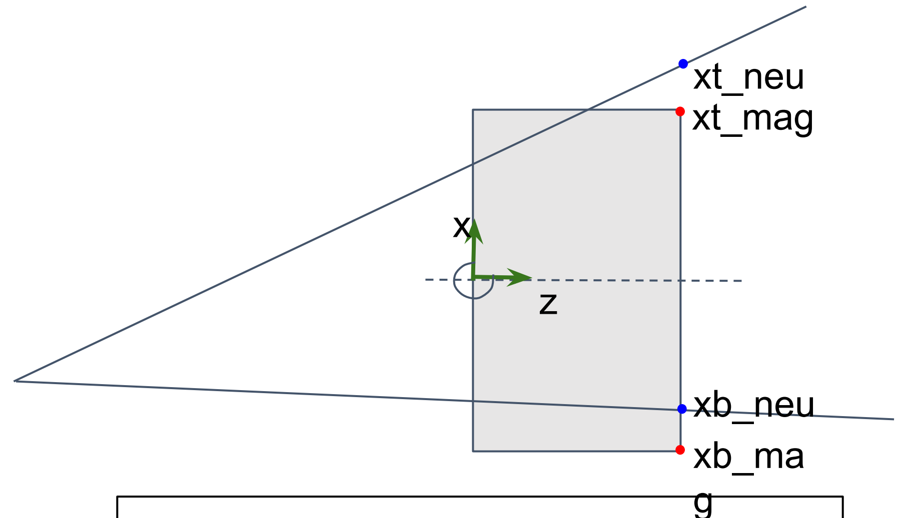


Figure 24.1: Alignment errors in the (x, s)-plane



dx1 = xt_neutron - xt_magnet <= 0
dx2 = xb_neutron - xb_magnet >= 0

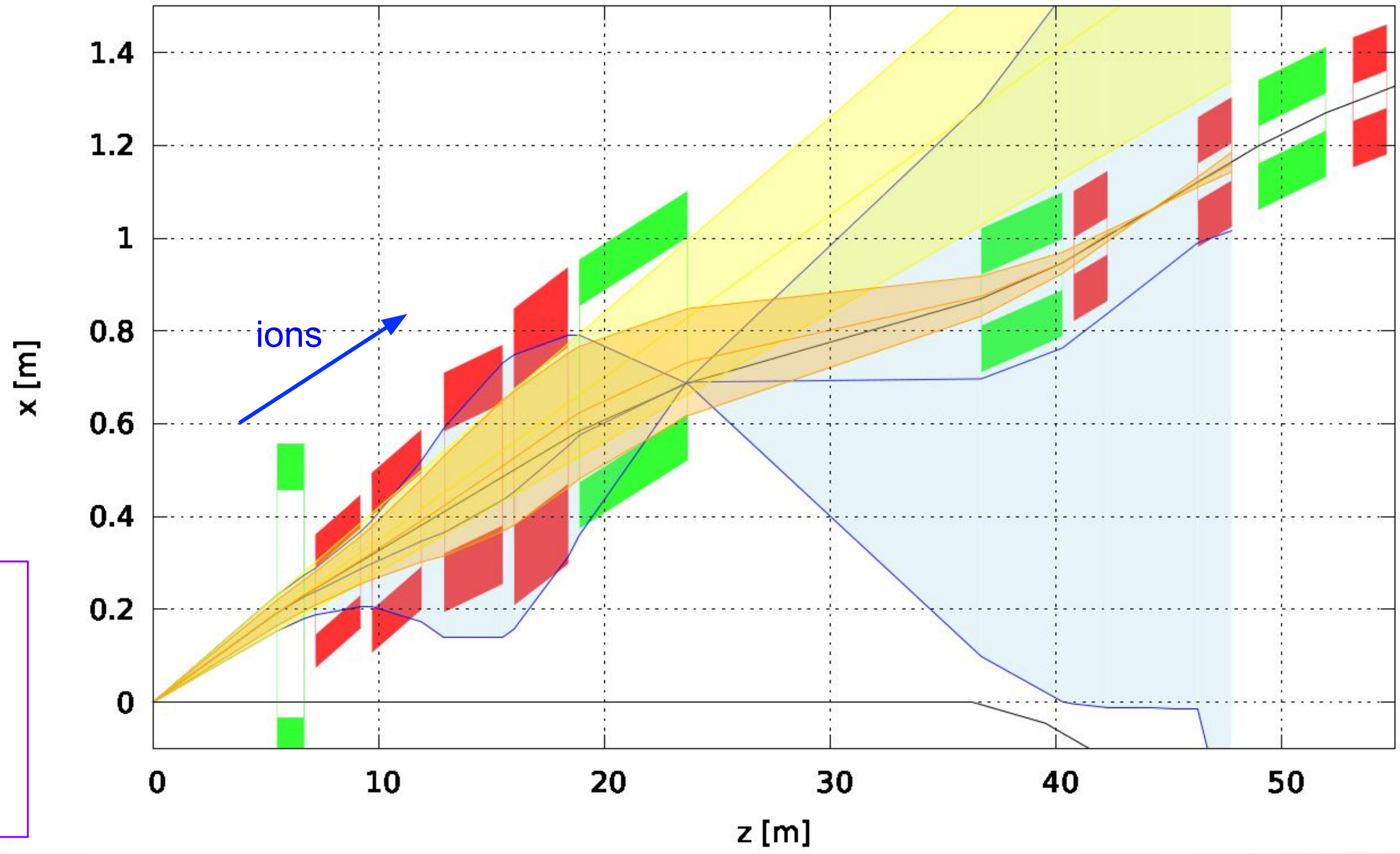
- Similar constraints for the high p_T protons.
- Applied to both entrance and exit of each magnet.
- Totaling 8 constraints per magnet.
- Variables we can use in MADX -> (magnet physical aperture, magnet length), DX and DTHETA

IR8 forward layout

Neutrons ±7mrad

Protons ±5mrad
$\Delta p/p = 0$
p_T = 1.37 GeV, x_L=1

Protons ±7mrad
$\Delta p/p = -0.5$
p_T = 0.96 GeV, x_L=0.5



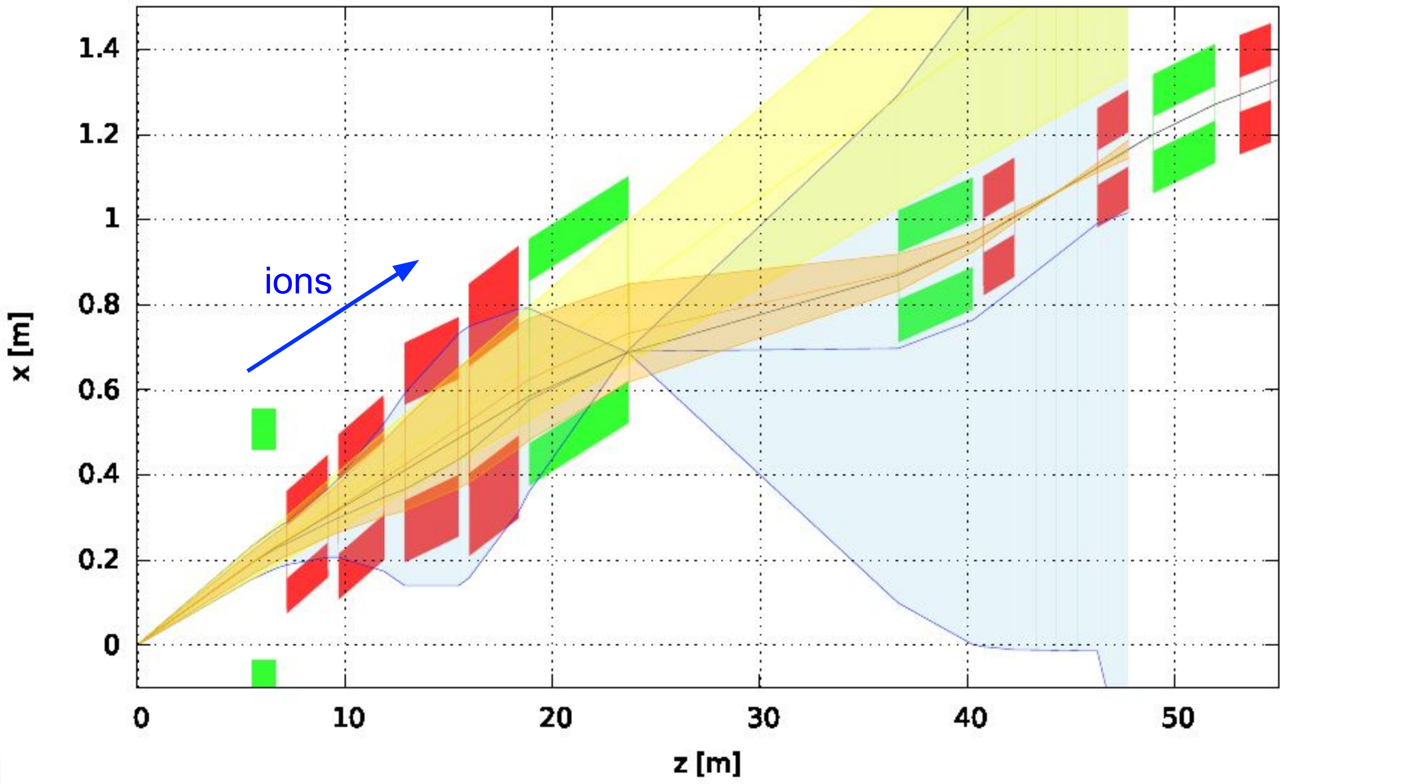
Final focusing quadrupoles strengths are higher than what can be safely reached.

IR8 forward layout after 15% bore reduction

Neutrons ±7mrad

Protons ±5mrad
Δp/p = 0
p_T = 1.37 GeV, x_L=1

Protons ±7mrad
Δp/p = -0.5
p_T = 0.96 GeV, x_L=0.5



Summary

- Hadron beamline
  - Further optimization is needed for a proper match into ARCs in terms of geometry and optics.
  - Increasing the magnet lengths in the forward side FFQ to improve acceptance may be an option.
  - B0 dipole field and aperture needs further study.
- Electron beamline
  - Not yet matched in to ARCs
  - spin rotators angle relative to the IP is the same as IR6

Thank you!