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 $\beta^{*}_{x/y} = 80/7.2$
- Forward side final focusing quads and two dipole correctors are being considered for Nb$_3$Sn.
- Max field at the aperture is 9.216T. (12T at the coil -4% for the aperture - 20% operational margin)
- Nb$_3$Sn 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 ($\theta$)
- $p_T$ acceptance at $x_L = 1$

\[ p_{T,\text{min}} > 10 p_0 \theta_{IP} = 10 p_0 \sqrt{\epsilon / \beta^*} \]

- $x_L$ 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 $\beta_x^*$ which in turn increase the $\beta_x^{2nd}$ may result in a smaller $x_L$ acceptance

\[ D = 1 - 10 \beta^* \epsilon + D_2^2 \sigma_\delta^2 \]
IP8 full layout

• Reserved space for 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.
IR8 ion optics

Baseline NbTi pics
IP is at S=0

Rear

Forward

2nd IR upstream optics

Second Focus

Protons
Acceptance optimization constraints

- 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)

\[
\begin{align*}
xt_{\text{neutron}} - xt_{\text{magnet}} &\leq 0 \\
xb_{\text{neutron}} - xb_{\text{magnet}} &\geq 0
\end{align*}
\]
IR8 Forward acceptance with NbTi magnets

- This is the current design with NbTi magnets.

Neutrons $\pm 5\text{mrad}$

$\Delta p/p = 0$

$p_T = 1.37\text{GeV}, x_L = 1$

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$_3$Sn quads and two dipoles with correctors.

Neutrons $\pm 5$ mrad
$\Delta p/p = 0$
$p_T = 1.37$ GeV, $x_L = 1$

Protons $\pm 5$ mrad
$\Delta p/p = -0.5$
$p_T = 0.69$ 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 $\beta^*$ with same $\beta_{max}$ at low energies due to shorter focal length.
- Can tailor the apertures to the acceptance better.

Neutrons ±5mrad

Protons ±5mrad
\[ \Delta p/p = 0 \]
\[ p_T = 1.37 \text{GeV}, x_L = 1 \]

Protons ±5mrad
\[ \Delta p/p = -0.5 \]
\[ p_T = 0.69 \text{GeV}, x_L = 0.5 \]
IR8 second focus parameters

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

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<th>Parameter</th>
<th>NbTi</th>
<th>Nb3Sn #1</th>
<th>Nb3Sn #2</th>
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NbTi : current version
Nb3Sn #1 : With two quads
Nb3Sn#2 : First quad split

\[x_L < 1 - 10\sigma_\delta = 0.99320\]
IR8 electron optics
Pros and cons

• Pros
  • Compact IR 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.
  • Technologically challenging.
Thank you!