

# Injecting from Booster to RR and MI in the NOvA Era

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# Introduction

- Currently we are injecting protons from Booster to MI where they are slipped stacked and accelerated to 120 GeV.
- In the NOvA era the protons will be injected from Booster to Recycler where they will be slipped stacked and then injected to MI for Acceleration.
- The capability to inject protons from Booster directly to MI will be preserved.

# Current Operation

- Protons are injected in MI through the MI-8 line. The transfers are synchronous with  $F_{rf}=52,811,400$  Hz.

<b>Phase Lock Frequency (Hz)</b>	<b>52,811,400</b>
<b>Transfer Momentum (MeV)</b>	<b>8,884</b>
<b>Transfer beta</b>	<b>0.994469</b>
<b>Transfer gamma</b>	<b>9.52386</b>
<b>MI Radius (m)</b>	<b>528.3013</b>
<b>Booster Radius (m)</b>	<b>75.4716</b>

# Injecting from Booster to the Recycler

- We need to change both the RF lock frequency and the beam momentum.
- By changing the RF lock frequency from 52,811,400 to 52,809,000 both the momentum and the Radius coming out of the Booster will change:
  - $Dp=17.79$  MeV
  - $DR=5.07$  mm
- In order to match the Recycler momentum the beam momentum out of the Booster has to change by  $-33.92$  MeV. Since the momentum has already increased by  $17.79$  MeV by changing the lock frequency the total momentum change has to be  $-51.71$  MeV. The Booster bend field or  $I_{max}$  has to change by:

$$\frac{dB}{B} = \frac{dI}{I} = \frac{\gamma^2 - \gamma_t^2}{\gamma^2} \left( \frac{dp}{p} \right) = 0.673 \frac{-51.71}{8,884} = -3.914 \times 10^{-3} \quad \text{or } DI_{max} = -3.8 \text{ A}$$

- The Booster Radius will change by  $DR=-4.83$  mm. The total change in the Booster Radius is  $0.24$  mm
- The Recycler Radius is  $7 \times 0.24 \text{ mm} = 1.68 \text{ mm}$  larger than the MI Radius!

# Injecting from Booster to MI

- In this case we would like to Inject in MI with the Recycler central momentum of 8,850 MeV. The MI bend field is changed to center the RR Momentum in MI. Since we know the MI Radius we can calculate the new RF lock frequency to be 52,809,175.71 Hz.
- By changing the the RF lock frequency from 52,809,00 Hz to 52,809,175.71 Hz both the beam momentum and Radius out of the Booster will change:
  - DP=-1.296 MeV
  - DR=-0.3712 mm
- We want no NET change of Momentum out of Booster so I<sub>max</sub> will have to change

by:

$$\frac{dB}{B} = \frac{dI}{I} = \frac{\gamma^2 - \gamma_i^2}{\gamma^2} \left( \frac{dp}{p} \right) = 0.673 \left( \frac{1.753}{8,850} \right) = 9.855 \times 10^{-5}$$

$$dI_{MAX} = 0.096A$$

- The Booster radius will then change by DR=0.122 mm. Total change in Booster Radius is -0.25 mm.

# Summary

- We will need two RF lock frequencies ( $\Delta f = 176$  Hz) and two  $I_{\max}$  ( $\Delta I_{\max} = 0.1$  A) settings in order to inject from Booster in both RR and MI.
- The default beam momentum for both injections will be the RR central momentum of 8,850 MeV.
- The Bend Field in MI will have to be adjusted in order to center the RR momentum in the MI aperture.
- A frequency jump will be required during the RR to MI transfers.