30 T ON TARGET NEUTRINO FACTORY/MUON COLLIDER
FRONT-END

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The main objective of the study is to investigate the effects of a higher magnetic field on the target. The Neuffer front end consists of

- Target and capture section
- Bunching and rf phase rotation sections
- Cooling lattice

![Diagram of the Front-End](image)

Figure 1: Layout of the Front-End.

**Different Components of the Front-End**

- **Capture Section**: Hg jet target; 2-3 ns 8 GeV proton (24 GeV). Solenoidal channel: Length ≈ 12 m, 30 (20) ≥ B_z ≥ 2.6 (1.75) T
- **Decay Drift**: Length ≈ 100 m, B_z ≈ 2.6 (1.75) T
- **Adiabatic Bunching**: 27 cavities with 13 different ↓ frequencies and changing ↑ gradients. Length ≈ 50 m, B_z = 1.75 T
  - 333 ≤ f ≤ 234 MHz
  - 10 MV/m

- **Phase Rotator**: 72 cavities with 15 different ↓ frequencies; constant gradient. Length ≈ 50 m, B_z = 1.75 T
  - 232 ≤ f ≤ 201 MHz
  - Grad = 12.5 MV/m

- **Cooling**: Solenoidal FOFO lattice; Length ≈ 50 m, B_z = ±2.8 T; Grad. = 15.25 MV/m, f = 201.25 MHz

**Cooling Section**

A novel aspect of this design comes from using the windows on the rf cavity as the cooling absorbers. This is possible because the near constant β function does not significantly increase the emittance heating at the window location. The window consists of a 1 cm thickness of LiH with a 75 µm layer of Be on the rf cavity field side and, 25 µm layer of Be on the opposite side. (The Be will, in turn, have a thin coating of TiN to prevent multipactoring). The alternating 2.8 T solenoid field is produced with one solenoid per half cell, located between the rf cavities.

**Bunching and Phase Rotation Region**

In the scheme the correlated beam is first adiabatically bunched using a series of rf cavities with decreasing frequencies and increasing gradients. The beam is then phase rotated with a second string of rf cavities with decreasing frequencies and constant gradient. The final rms energy spread in the new design is 10.5%.

![Diagram of the Cooling Section](image)

Figure 2: Schematic of 2 cells of the buncher or rotator section.

![Diagram of the Cooling Lattice](image)

Figure 3: Schematic of one cell of the cooling section. Beta function is constant ≈ 80 cm. Windows are absorbers.
Simulation Performance: 20 T Solenoid on Target

Figure 4: Longitudinal phase space at the end of the channel.

Figure 5: Normalized transverse emittance (left) and longitudinal emittance (right) along the front-end for a momentum cut $0.1 \leq p \leq 0.3$ GeV/c.

Number of $\mu/p$ in $A_\perp$ and $A_L$: Final values are 0.176 with 24 GeV and 0.08 with 8 GeV protons on target.

<table>
<thead>
<tr>
<th>Table 1: Table of Results</th>
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<tr>
<td>$&lt;p_z&gt;$ Mean Momentum (MeV/c)</td>
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<tr>
<td>rms Energy Spread (MeV)</td>
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<tr>
<td>$\epsilon_N^\perp$ (mm-rad)</td>
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<td>$\epsilon_N^{\text{equal.}}$ (mm-rad)</td>
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<td>$\epsilon_L$ (mm)</td>
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<td>$A_\perp$ (mm-rad)</td>
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<td>$A_L$ (mm)</td>
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<td>No. $\mu/p$ in $A_\perp$ and $A_L$</td>
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Simulation Performance: 30 T Solenoid on Target

We use a MARS generated $\pi$s file for an optimized target system with 8 GeV proton on Hg. The magnetic field on Target, Capture, Drift is naively scaled by a factor of $\frac{3}{2}$ and the radius of the pipeline is decrease to 25 cm same size as the Be windows in Buncher and Rotator sections.

Figure 6: Comparison between 20 and 30 T examples: (left) transverse emittance vs $z$; (right) number of muons per incident proton on target vs $z$. Final values: for 20 T is 0.08; for 30 T is 0.11.

Figure 7: (Left) Magnetic field (T) on the total length of the front end; (Right) magnetic field (T) on the capture region.

In this examples the constant magnetic field on both bunching and rotator sections was $2.6 T (1.75 \times \frac{3}{2})$. If we reduce the field to the standard $1.75 T$ and disregard the lack of matching at the different magnetic field inter-phases, then

Figure 8: Comparison between 20 and 30 T examples: number of $\mu$s per incident proton on target vs $z$. Final values: for 20 T 0.08; for 30 T 0.10.
Suggested Conclusions

- New 8 GeV MARS 15 increases the efficiency of the front-end by $\approx 30\%$
- For a larger magnetic field on target ($20 \, T \implies 30 \, T$), the efficiency increases by $\approx 30\%$. 