The 325 MHz Solution

David Neuffer
Fermilab

January 15, 2013
Outline

- Front End for the IDS Neutrino Factory
  - Basis for engineering/costs
    - Rf, requirements
    - Engineering required
  - Redesign for 325 MHz
    - ??

- rf gradient/ B concerns
  - Transit Time Factor
  - Pill-box radius
Front End rf

- **μCol-vFact Front End** was matched to 201.25 MHz
  - matched to Fermilab Linac
  - Cooling at 200, 400, 600, 800 …MHz

- **Project X** is matched to 1300 MHz (**ILC**)
  - match to 650 /325/ 162.5…
    - 433, 216.67, …
  - match to 162.5 or 216.7 is similar to 201.25

- **Match to 325 MHz is not as straightforward**
  - requires ~500 → 325 MHz rf in Buncher /Rotator
  - apertures are more restricted
IDS Baseline Buncher and φ-E Rotator

- Drift (π→μ)
- “Adiabatically” bunch beam first (weak 320 to 232 MHz rf)
- Φ-E rotate bunches – align bunches to ~equal energies
  - 232 to 202 MHz, 12MV/m
- Cool beam 201.25MHz
Rf Buncher/Rotator/Cooler requirements

- **Buncher**
  - 37 cavities (13 frequencies)
  - 13 power supplies (~1—3MW)

- **RF Rotator**
  - 56 cavities (15 frequencies)
  - 12 MV/m, 0.5m
  - ~2.5MW (peak power) per cavity

- **Cooling System – 201.25 MHz**
  - 100 0.5m cavities (75m cooler), 15MV/m
  - ~4MW /cavity – most expensive item

---

<table>
<thead>
<tr>
<th>Front End section</th>
<th>Length</th>
<th>#rf cavities</th>
<th>frequencies</th>
<th># of freq.</th>
<th>rf gradient</th>
<th>rf peak power requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buncher</td>
<td>33m</td>
<td>37</td>
<td>319.6 to 233.6</td>
<td>13</td>
<td>4 to 8</td>
<td>~1 to 3.5 MW/freq.</td>
</tr>
<tr>
<td>Rotator</td>
<td>42m</td>
<td>56</td>
<td>230.2 to 202.3</td>
<td>15</td>
<td>12.5</td>
<td>~2.5MW/cavity</td>
</tr>
<tr>
<td>Cooler</td>
<td>75m</td>
<td>100</td>
<td>201.25MHz</td>
<td>1</td>
<td>16 MV/m</td>
<td>~4MW/cavity</td>
</tr>
<tr>
<td>Total</td>
<td>~240m</td>
<td>193</td>
<td></td>
<td>29</td>
<td>~1000MV</td>
<td>~550MW from cooling</td>
</tr>
</tbody>
</table>
**rf constraints**

- **Transit time factor**
  
  \[ T = \sin \left( \frac{\pi g}{\beta \lambda} \right) \]

  - \( T = 0.8 \) (200MHz,0.5m)
  - \( \rightarrow 0.52 \) (325MHz,0.5m)
  - \( \rightarrow 0.21 \) (450 MHz,0.5m)
  - \( \rightarrow 0.75 \) (450 MHz,0.25m)

  \( \rightarrow \) must use shorter rf cavities

- **Pillbox radius:**
  
  \[ E = E_o J_0 \left( 2.405 \frac{r}{r_0} \right) \]

  \[ r_0 = \frac{2.405}{2\pi} \lambda_{RF} \]

  - \( r_0 = 0.38 \) m at 300 MHz
  - \( r_0 = 0.255 \) m at 450 MHz
Components of 325MHz System

Drift
- 20T → 2T

Buncher
- $P_o = 250\text{MeV/c}$
- $P_N = 154\text{ MeV/c}; N=12$
- $V_{rf} : 0 \rightarrow 15\text{ MV/m}$
  - (2/3 occupied)
- $f_{RF} : 550 \rightarrow 371\text{MHz}$

Rotator
- $V_{rf} : 20\text{MV/m}$
  - (2/3 occupied)
- $f_{RF} : 370 \rightarrow 326\text{MHz}$
- $N=12.05$
- $P_0, P_N \rightarrow 245\text{ MeV/c}$

Cooler
- 325 MHz
- 25 MV/m
- 2 1.5 cm LiH absorbers /0.75m
Propagation through the transport

\[ Z = 1 \text{m} \]

\[ Z = 58 \text{m} \]

\[ Z = 78 \text{m} \]

\[ Z = 104 \text{m} \]

\[ Z = 151 \text{m} \]

-20m

-40m

0.8 GeV/c

0.0 GeV/c
Variant 325MHz System

- Drift
  - 20T → 2T

- Buncher
  - \( P_0 = 250 \text{MeV/c} \)
  - \( P_N = 154 \text{ MeV/c}; \ N = 12 \)
  - \( V_{rf} : 0 \rightarrow 15 \text{ MV/m} \)
    - (2/3 occupied)
  - \( f_{RF} : 490 \rightarrow 365 \text{MHz} \)

- Rotator
  - \( V_{rf} : 20 \text{MV/m} \)
    - (2/3 occupied)
  - \( f_{RF} : 364 \rightarrow 326 \text{MHz} \)
  - \( N = 12.045 \)
  - \( P_0, P_N \rightarrow 245 \text{ MeV/c} \)

- Cooler
  - 325 MHz
  - 25 MV/m
  - 2 1.5 cm LiH absorbers /0.75m
Simulation Results

- Simulation obtains
  - ~0.125 μ/p within acceptances
  - with ~60m Cooler
  - shorter than baseline

- But
  - uses higher gradient
  - 325 MHz – less power
Variations

➢ Gradient is a bit higher than IDS baseline or initial Muon Collider version
  ▪ 15/20/25 MV/m $\rightarrow$ 0.125 $\mu$/p
  ▪ 12.5/18/22.5 $\rightarrow$ 0.115
  ▪ 12/16/20 MV/m $\rightarrow$ 0.102
  ▪ 12/15/18 MV/m $\rightarrow$ 0.095

➢ Apertures are smaller
  ▪ Use higher field transport to make beam smaller?
  ▪ 2T $\rightarrow$ 3T? (with stronger focusing making the beam smaller
    • first try had similar to baseline (not much better…)}
Summary

- 325 Mhz Front End Possible
  - similar capture to baseline
  - shorter system

- Needs higher gradient rf and a bit stronger transverse focusing
I need you to help prepare me for my meeting tomorrow.

Write up some answers to the questions we could never anticipate.

I wouldn’t expect much out of my first draft.