Phase rotation for the muon collider

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BNL

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Phase rotation

• Many possible scenarios
• Look at single bunch approach
• Compare phase rotation designs
  – Same initial beam distribution (MARS 24 GeV on Hg)
  – Same simulation code (ICOOL)
  – Same assumptions about radii, windows, etc
  – Do survey with simplified simulation model
• Single bunch designs for $p \sim 200$ MeV/c
  – (1) Snowmass 1996
  – (2) Status report 1999
  – (3) Start of PJK NF
  – (4) Start of CERN NF
  – (5) V. Balbekov (MC-273)
## Gradients used in simulations

<table>
<thead>
<tr>
<th>f [MHz]</th>
<th>G [MV/m]</th>
<th>ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.2</td>
<td>PRISM</td>
</tr>
<tr>
<td>30</td>
<td>2.1</td>
<td>Snow</td>
</tr>
<tr>
<td>4</td>
<td></td>
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<tr>
<td>5</td>
<td></td>
<td>PJK</td>
</tr>
<tr>
<td>36.37</td>
<td>6.37</td>
<td>VB</td>
</tr>
<tr>
<td>37</td>
<td>4</td>
<td>SR</td>
</tr>
<tr>
<td>44</td>
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</tr>
<tr>
<td>45</td>
<td>7</td>
<td>PJK</td>
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<td>50</td>
<td>3.3</td>
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<td>SR</td>
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<tr>
<td>8</td>
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<td>PJK</td>
</tr>
<tr>
<td>88</td>
<td>4</td>
<td>CERN</td>
</tr>
<tr>
<td>90</td>
<td>4.2</td>
<td>Snow</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>SR</td>
</tr>
<tr>
<td>100</td>
<td>4.5</td>
<td>Snow</td>
</tr>
</tbody>
</table>
Status report

\[ z = 46 \text{ m} \]

\[ B = 20 \text{ T} \]

\[ d_{rf} = 60 \text{ m} \]

\[ d_{ct} = 5 \text{ m} \]

\[ p_z \text{ [GeV/c]} \]

\[ x_{ct} \text{ [m]} \]
PJK NF

PJK longitudinal phase space
$z = 47 \text{ m}$
CERN NF

\[ z = 61 \text{ m} \]

\[ B = 20 \text{ T} \]

\[ \delta \text{ct} \text{ [m]} \]

\[ p_z \text{ [GeV/c]} \]
Balbekov MC-272 target

<table>
<thead>
<tr>
<th>drift</th>
<th>RF 36</th>
<th>RF 36</th>
<th>drift</th>
</tr>
</thead>
<tbody>
<tr>
<td>z =</td>
<td>0</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

B = 20 3.5 .175 .175 T

- Most recent
- Simplest – 1 frequency
- Shortest – 34 m
- Low solenoid field

VB MC272 profile

Balbekov f = 36.37 MHz
z = 34 m
Parameter variation (1)

1. Transmission vs. \( p_{\text{REF}} \) for different phase shifts.
   - 100 < \( p < 300 \) MeV/c
   - 200 < \( p < 400 \) MeV/c
   - \( \Delta \phi = 0 \)
   - \( G=6, L_{\text{ROT}}=25 \)

2. Transmission vs. phase shift for different reference momenta.
   - \( f=36.37 \) MHz, \( G=6 \) MV/m
   - \( L_{\text{ROT}}=25 \) m, \( B_1=1.75 \) T

3. Transmission vs. taper length for different momentum ranges.
   - \( 100 < p < 300 \) MeV/c
   - \( 200 < p < 400 \) MeV/c

4. Transmission vs. magnetic field for different momentum ranges.
   - \( f=36.37 \) MHz, \( G=6 \) MV/m
   - \( L_{\text{ROT}}=25 \) m, \( L_{\text{TAPER}}=9 \) m
Parameter variation (2)
Modified Balbekov

$f = 40.25 \text{ MHz}$
$L_{\text{ROT}} = 25 \text{ m}$
phase = low
$z = 39 \text{ m}$

Modified Balbekov

$f = 40.25 \text{ MHz}$
$L_{\text{ROT}} = 25 \text{ m}$
phase = high
$z = 39 \text{ m}$

$p_z \left[ \text{ GeV/c} \right]$ vs. $\delta(\text{ct}) \left[ \text{ m} \right]$
<table>
<thead>
<tr>
<th></th>
<th>B1</th>
<th>f</th>
<th>G</th>
<th>LROT</th>
<th>Tr</th>
<th>Tr</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>[ T ]</td>
<td>[MHz]</td>
<td>[Mv/m]</td>
<td>[m]</td>
<td>100-300</td>
<td>200-400</td>
</tr>
<tr>
<td>VB</td>
<td>1.75</td>
<td>36.37</td>
<td>6.37</td>
<td>20</td>
<td>0.277</td>
<td>0.334</td>
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<tr>
<td></td>
<td>1.75</td>
<td>36.37</td>
<td>6</td>
<td>25</td>
<td>0.302</td>
<td>0.341</td>
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<tr>
<td></td>
<td>1.75</td>
<td>40.25</td>
<td>6</td>
<td>25</td>
<td>0.303</td>
<td>0.344</td>
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<tr>
<td>PJK</td>
<td>1.25</td>
<td>60-30-45</td>
<td>8-5-7</td>
<td>43</td>
<td>0.257</td>
<td>0.277</td>
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<tr>
<td></td>
<td>1.75</td>
<td>66-30-42</td>
<td>8-5-7</td>
<td>43</td>
<td>0.286</td>
<td>0.324</td>
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<tr>
<td>CERN</td>
<td>1.75</td>
<td>44</td>
<td>2</td>
<td>30</td>
<td>0.179</td>
<td>0.240</td>
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<tr>
<td></td>
<td>1.75</td>
<td>44</td>
<td>4</td>
<td>30</td>
<td>0.180</td>
<td>0.258</td>
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<tr>
<td>SR</td>
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<td>60-30-60-37</td>
<td>5-4-4-4</td>
<td>42</td>
<td>0.268</td>
<td>0.301</td>
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<tr>
<td>Snow</td>
<td>5</td>
<td>90-50-30</td>
<td>4-3-2</td>
<td>42</td>
<td>0.227</td>
<td>0.273</td>
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</tbody>
</table>

Transmissions include 6 m bunchlength cut
Realistic design

\[ L_{\text{TAP}} = 4 \text{ m} \]
\[ B_1 = 1.75 \text{ T} \]
\[ f = 40.25 \text{ MHz} \]
\[ G = 6 \text{ MV/m} \]
\[ L_{\text{ROT}} = 25 \text{ m} \]
\[ L_{\text{DRIFT}} = 10 \text{ m} \]

- Tapered wall
- Be window after target
- Extended rf cavities
- Be windows on rf cavities
- Periodic solenoid channel
Design details
Effect of particle charge

Modified Balbekov
f = 40.25 MHz
L_{ROT} = 25 m
phase = low
z = 39 m
positive particles

Modified Balbekov
f = 40.25 MHz
L_{ROT} = 25 m
phase = low
z = 39 m
negative particles

g32L
positive particles
z = 39 m

g33L
negative particles
z = 39 m
Performance summary

<table>
<thead>
<tr>
<th>case</th>
<th>sign</th>
<th>$\Delta p$ [MeV/c]</th>
<th>$\mu / p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>100-300</td>
<td>0.39</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>100-300</td>
<td>0.12</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>250-450</td>
<td>0.32</td>
</tr>
<tr>
<td>4</td>
<td>+</td>
<td>200-400</td>
<td>0.47</td>
</tr>
<tr>
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<td>-</td>
<td>200-400</td>
<td>0.20</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>300-500</td>
<td>0.23</td>
</tr>
</tbody>
</table>

All cases use 6 m bunch cut