Solid Target Considerations

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• An order of magnitude estimate of particle absorption and energy loss from:
  – The downstream part of a target
  – The downstream continuation of an undisturbed jet
  – The "spray" induced in the jet by previous bunches
  – The "rain" of liquid metal droplets from the spray attaching to the pipe

• A possible scheme using a "jet" of multiple solid targets

The "spray" and "rain" represent two components of the "storm" discussed by P. Thieberger (MUC-Note #0212)
Simple (2D) calculation of pion absorption

- Gaussian p and pt initial distribution
  \[ \sigma_p = 200 \text{ MeV/c} \quad \sigma_{pt} = 100 \text{ MeV/c} \]
- Track in Larmor Planes
- Assume cylindrical isotropy of tracks (ignoring effect of skew target)
- In material:
  - \( \frac{dE}{dx} \), including E dependence, weighted by azimuthal probability
  - Reducing track weights by \( \frac{dz}{X_L} \) for interactions
- Correct effective \( X_L \) in "spray" or "rain" by average density
- Off center jet approximated by
  \[
  \Delta \phi = \pm \frac{2 \, r_{jet}}{R} \\
  \Delta R = \pm 2 \, r_{jet}
  \]
## Current approximate constants

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Interaction length $(X_L)$</td>
<td>m</td>
<td>0.1</td>
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<tr>
<td>Minimum $dp/dx$</td>
<td>GeV/m</td>
<td>2</td>
</tr>
<tr>
<td>Target velocity</td>
<td>m/s</td>
<td>20</td>
</tr>
<tr>
<td>Time between pulses</td>
<td>ms</td>
<td>20</td>
</tr>
<tr>
<td>Target length</td>
<td>m</td>
<td>$2 \times X_L$</td>
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<tr>
<td>Target radius</td>
<td>cm</td>
<td>0.5</td>
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<tr>
<td>Proton beam angle</td>
<td>mrad</td>
<td>100</td>
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<tr>
<td>Liquid jet spray angle</td>
<td>mrad</td>
<td>133</td>
</tr>
<tr>
<td>Solid target angle</td>
<td>mrad</td>
<td>150</td>
</tr>
<tr>
<td>Initial pipe radius</td>
<td>cm</td>
<td>8</td>
</tr>
<tr>
<td>Initial field</td>
<td>T</td>
<td>20</td>
</tr>
<tr>
<td>Distance to window</td>
<td>m</td>
<td>5</td>
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</table>
Ideal Geometry  Solid target suspended in space

ideal solid

Radius (m)

z (m)

0  2  4
Effects of exiting target

- Source at center of target
- Apply dEdx in half target
- Lower weights by $dl/X_L$ ($X_L$ = inelastic cross section)
- These effects included in all cases
• Note that high pt tracks get out of sides of target
• Lower pt, forward, tracks get absorbed more
Other Situations

1. "ideal Jet"
   - jet remains undisturbed to the dump
   - include dEdx and interactions

2. "Splash"
   - Liquid target is fully dispersed
   - pt ununiform to 20 m/sec
   - droplets ”bounce/splash” off walls maintaining $v_z$

3. "rain" (P. Thieberger)
   - Liquid target is fully dispersed
   - pt ununiform to 20 m/sec
   - Droplets ”stick” to walls, then fall under gravity

4. "Multi-Target"
   - Targets fired from ”blow pipe”
   - Gas jet adds ”crab”
   - Targets stopped in liquid dump
Lower initial momenta have higher dE/dx and stop in materials
Initial pt (GeV/c)

- ideal solid: 1
- ideal jet: 0.99
- splash: 0.88
- rain: 0.78
- multi solid: 1.00
Transmission compared to ”Ideal solid” target

<table>
<thead>
<tr>
<th>Transmission</th>
<th>loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>ideal jet</td>
<td>0.99</td>
</tr>
<tr>
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<td>0.88</td>
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<tr>
<td>rain</td>
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<tr>
<td>multi solid</td>
<td>1.00</td>
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- Splash effect worse if ”splash angle less than 45 deg. assumed
- Rain effect worse if droplets become small and fall slowly in gas (”Fog”)

If such problems are serious, the ”Multi-Solid” target concept could be considered
Conclusion

• “Splash” or Rain” could lose 10-20 % of beam
• Solid targets fired from ”Blow Pipe” avoid this loss
• little gain from ”crab” of solid target

Assuming 50 Hz 4 MW

• Solid targets fired from blow pipe:
  – should survive single shock
  – Can be used for whatever time radiation or shock damage demands
  – Cooling is automatic
Bunch merging

Full: Preliminary simulated design
Dashed: Not yet designed

Long Emittance (mm)

Trans emittance (mm mrad)

Initial

Rebunch → 20 bunches

Combine 1 bunch

New Ring(s) or Helices

Current RFOFO Ring

2 Alternatives for final cooling:

Li Lenses

50 T Solenoids (Muons Inc)

Initial

Final

Initial

Rebunch → 20 bunches

Combine 1 bunch

New Ring(s) or Helices

Current RFOFO Ring

2 Alternatives for final cooling:

Li Lenses

50 T Solenoids (Muons Inc)
mom 200 MeV/c
k -3
circ 45 m
width 95 cm
grad (MeV/m) .25
turns 5
decay loss % 15.8