Target & Capture for PRISM

Koji Yoshimura
On behalf of PRISM Target Group

Institute of Particle and Nuclear Science
High Energy Accelerator Research Organization
(KEK)
Contents

- Targetry for PRISM
- Solenoid capture
- Conducting Target
- Summary
What’s PRISM

- PRISM (Phase Rotation Intense Slow Muon source)
- A dedicated secondary muon beam channel with high intensity ($10^{11}$–$10^{12}$ µ/s) and narrow energy spread (a few%) for stopped muon experiments

Sensitivity ~100 x MECO
Requirements of Targetry for PRISM

- **Pion Momentum**
  - ~100 MeV/c
  - backwards capture scheme available!

- **Emittance**
  - As low as FFAG acceptance
    - horizontal 10000\(\pi\), vertical 3000\(\pi\)

- **Method**
  - Solenoid Capture
  - Conducting Target
Simulation Study of Solenoid Capture

- Simulation code
  - MARS, GEANT3
- 12 T field -> 3T
  - 47MeV/c ~ 85 MeV/c
  - Backward
  - 2000 \(\pi\) ~ 3000 \(\pi\) vertical acceptance
Simulation Results

- Target material
  - W is better than C

- B field
  - Determined by Capture field
  - Yield $\propto$ Bfield

- Target radius
  - Thin target is better
SC Solenoid in High Rad. Env

- Thick radiation shield is necessary
  - ~500 W
  - Radiation shield of 25 cm in thickness is needed
- Large bore for absorber
  - High stored energy
  - Expensive magnet
- To optimize design
  - We totally rely on simulation.
  - Simulation code should be experimentally evaluated!

Absorber

- SC Coil

25 cm, 500W

Thickness of Absorber
Direct Measurement of Radiation heat by Beam

- Prototype magnet of 10.9 Tesla
  - Hybrid coil (NbTi, Nb$_3$Sn, HiTc)
  - Indirect cooling with GM cryocooler
  - 10.9 T in 6 cm warm bore
- Beam test with Coil-Mockup
  - Direct measurement of heat load by radiation
  - Study behavior of magnet under heating condition
  - KEK 12 GeV proton
    - $10^{11}$ protons/s
  - Cryo-calorimeter

Ohnishi's Talk

Temperature rise by radiation heat
## Comparison

<table>
<thead>
<tr>
<th></th>
<th>12 T</th>
<th>6 T</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B</strong></td>
<td>12 T</td>
<td>6 T</td>
</tr>
<tr>
<td>Useful aperture R</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Cryost. IR</td>
<td>0.55</td>
<td>0.4</td>
</tr>
<tr>
<td>Coil IR</td>
<td>0.65</td>
<td>0.45</td>
</tr>
<tr>
<td>Coil OR</td>
<td>1.1</td>
<td>0.55</td>
</tr>
<tr>
<td>Coil length</td>
<td>~1.6</td>
<td>~1.6</td>
</tr>
<tr>
<td>S/C</td>
<td>Nb3Sn/NbTi</td>
<td>NbTi</td>
</tr>
<tr>
<td>Stored energy</td>
<td>~190 MJ</td>
<td>~16 MJ</td>
</tr>
<tr>
<td>Coil mass</td>
<td>~20 Ton</td>
<td>2 Ton</td>
</tr>
<tr>
<td>Cost (Estimate)*</td>
<td>~17 M$</td>
<td>~3 M$</td>
</tr>
</tbody>
</table>

*PDG: COST(in M$)=0.523[E/1 MJ])^{0.662}
REALISM

- Baseline option
  - $B=6T$
  - $IR=450$ cm, $L=160$ cm
  - Graphite Target $L=2\lambda=80$ cm
  - Shield thickness 25cm
- Still Necessary for R&D
  - Cooling $\sim 500$ W
  - Quench protection
  - Radiation safety
  - Thin Graphite target
Further R&D Plan of PRISM Solenoid option

- R&D Coil will be constructed this year
  - Half or Quarter size
  - Heating using AC LOSS
  - Or Special heater
  - Cooling Method ~500W
    - Pool boiling
    - Thermo siphon (Using convection)
- Proto-type of graphite target
  - JHF neutrino group (Hayato, Oyabu et.al)
  - Water cooled graphite (40 kW heat)
  - Thinner Target?
- Engineering Design -> Future Upgrade
Conducting Target

- Confine pions inside the target with toroidal field
  - B. Autin, @Nufact01
- Advantage over Solenoid
  - Low emittance beam
  - Linear transport element
    - No SC solenoid channel
    - Cheaper!
  - Cooling condition better?
Comparison of target material

- Mercury is good candidate
  - Minimum Power
  - Easy to cooling
  - Higher pion yield

- Technical Issues
  - How to cut off electrical circuit?
  - Stress due to pinch effect
  - Container
    - Shockwave
    - Cavitation
    - Thicker wall can be used!
      - No reabsorption
  - Window

<table>
<thead>
<tr>
<th></th>
<th>Mercury</th>
<th>Beryllium</th>
<th>Lithium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power [MW]</td>
<td>3.18</td>
<td>9.95</td>
<td>33.6</td>
</tr>
<tr>
<td>Temperature rise per pulse[K]</td>
<td>160</td>
<td>83</td>
<td>142</td>
</tr>
<tr>
<td>Field [T]</td>
<td>22.04</td>
<td>21.12</td>
<td>20.84</td>
</tr>
<tr>
<td>Intensity [MA]</td>
<td>2.49</td>
<td>2.49</td>
<td>2.49</td>
</tr>
<tr>
<td>Frequency [Hz]</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Phase [π]</td>
<td>1.</td>
<td>3.</td>
<td>10.</td>
</tr>
<tr>
<td>Pulse length [ms]</td>
<td>0.264</td>
<td>4.68</td>
<td>3.3</td>
</tr>
<tr>
<td>Target length [m]</td>
<td>0.13</td>
<td>0.407</td>
<td>1.37</td>
</tr>
<tr>
<td>Target radius [m]</td>
<td>0.0226</td>
<td>0.0236</td>
<td>0.024</td>
</tr>
</tbody>
</table>
Setup for current test

- **1st phase**
  - 1000 A DC
  - 100 J

- **2nd phase**
  - 250 KA 2.5ms Pulse (K2K horn PS)
  - 15 KW

- **3rd phase**
  - 1 MW?
  - Beam test?
Mercury Test Loop

- Mercury 18 litter ~ 250 kg
- Study mercury flow
Summary

- Solenoidal Capture
  - Standard scheme
  - Beam test was successfully performed using the mockup
  - Design parameters will be considered.
  - Realistic R&D Model coil

- Conducting Target
  - merits
  - R&D Work has just started!
    - Proof of principle
    - Feasibility test of High current liquid target
Basic Principle

\[ B \propto r \]

(Inside the target)