An Ultra-Cold Neutron Facility for TRIUMF

TRIUMF special 5-year plan EEC
26 March 2008

Des Ramsay

Schematic of Superfluid He UCN Source

Yasuhiro Masuda
How much room does it need?

12 m

Concrete

Steel

Remote Handling
Target Services

UCN out

Where would it fit?
UCN Facility in Meson Hall

Proposed Proton Beamline to UCN Source

- Beamline 1A optics is untouched
- Red magnets are new
- Green quads from M20
Beam Envelopes for the Proposed Proton Beam
[Jaap Doornbos Design Note – 25 Jan 2008]

final (full size) beam spot:
10 cm hor.
3 cm vert.

Jaap Doornbos
Example of Proton Beam Sharing

- 120 μA
- 80 μA
- 40 μA
- 0 μA

meson hall

UCN source

1 min. 4 min.
Constraints on beam sharing schemes

- The cyclotron beam can’t be interrupted for more than ~1ms (ISAC target)
- The instantaneous meson hall beam should be stable.
Proposed time division of beam

Features of the Proposed Beam Sharing Scheme

- The beam tune of beamline 1A is untouched.
- The instantaneous beam current does not change.
- A gate could be delivered to experimenters during beam-blanking.
- Downstream users only lose ~7% of their averaged beam.
Requirements for the Kicker Magnets

- Two magnets, each 24 mT x 0.75 m, 5 mr deflection.
- Would need about 1000 A, at least 1 ms flat-top
- Current rise and fall times (~5 μs).
- Low inductance (~2 μH; power cables would have to be short)
- Mike Barnes suggests a power supply with several high power semiconductors (IGBTs), capacitor charging power supplies and capacitor banks.
- Power supply is biggest task. Must deliver the fast rise and fall times as well as at flat-top with low (<5%, 1% preferred) ripple and rapid cycle time.
- We definitely need some serious engineering on the kickers. Eventually we would need to test a prototype.

How much will all this cost?
Magnet Requirements

<table>
<thead>
<tr>
<th>Magnet</th>
<th>Bend</th>
<th>Source</th>
<th>Power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1 †</td>
<td>5 mr</td>
<td>new</td>
<td>new</td>
</tr>
<tr>
<td>K2 †</td>
<td>5 mr</td>
<td>new</td>
<td>new</td>
</tr>
<tr>
<td>1U septum</td>
<td>115 mr</td>
<td>new</td>
<td>new</td>
</tr>
<tr>
<td>1UB1</td>
<td>15 deg</td>
<td>new</td>
<td>M11</td>
</tr>
<tr>
<td>1UQ1</td>
<td>focus</td>
<td>M20</td>
<td>M11</td>
</tr>
<tr>
<td>1UQ2</td>
<td>focus</td>
<td>M20</td>
<td>M11</td>
</tr>
<tr>
<td>1UB2</td>
<td>45 deg</td>
<td>new</td>
<td>1B</td>
</tr>
</tbody>
</table>

- Need 5 new magnets and 3 new power supplies.
- † The kickers, K1 and K2 will require engineering and prototyping.

Estimating Magnet Costs

Some examples of magnets:
- S-bend dipole at ISAC – 5 cm gap, 1.35 Tesla x 0.91 m = 1.23 T.m $48 k
- 2AB1/2 Dipole, 1997 – 10 cm gap, 1.43 Tesla x 1.23 m = 1.77 T.m $119 k

We want:
- BN1 – 10 cm gap, 0.973 T x 1.0 m = 0.973 T.m
- BN2 – 10 cm gap, 1.785 T x 1.6 m = 2.86 T.m

should allow ~$100 k each.

The septum could be expensive. The one downstream of T1 was almost $700k because it is very rad-hard.

The kickers are only 0.024 T x 0.75 m, but are fast and have fast power supplies of special design.

Ewart suggests that, including the power supplies we have to buy, that we allow an average of $250k for each of the 5 magnets.
Shielding Requirements

- calculations by Anne Trudel, assuming 40 μA, 500 MeV protons stopping in tungsten target
- assumes 0.5 m empty space around target (no moderator)
- figure shows shielding needed to reduce dose to 3 μSv/hr outside shielding
- integrating shielding gives 125 m³ steel and 375 m³ concrete not allowing for practicalities of stacking the blocks.

Estimating Shielding Costs

TRIUMF Shielding Cost Experience, TRI-DN-89-K26:
- removable concrete: $800/m³
- steel plate block (M20): $11,900/m³
- off-grade steel ingots (M20): $8000/m³

In 2008 dollars, let’s allow $1200/m³ for concrete and $12000/m³ for steel

In 1997, TRIUMF got 125 m³ of re-cycled slightly radioactive steel for $10k ($80/m³). Dominated by shipping costs. Say $300/ m³ in 2008.

For shielding volume add 20% to Anne’s integrated volumes, giving 150 m³ steel, and 450 m³ concrete.
Summary of Major Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCN source apparatus</td>
<td>$250 k</td>
<td>$2.4 M</td>
</tr>
<tr>
<td>5 magnets</td>
<td>$1.25 M</td>
<td></td>
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<tr>
<td>Installation</td>
<td>$250 k per magnet</td>
<td>$1.25 M</td>
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<tr>
<td>Moderator</td>
<td>$1 M - $3 M</td>
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<tr>
<td>150 m$^3$ steel</td>
<td>$300/m$^3$ - $12000/m$^3</td>
<td>$45 k - $1.8 M</td>
</tr>
<tr>
<td>450 m$^3$ removable concrete</td>
<td>$1200/m$^3</td>
<td>$540 k</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$6.5 M - $10.2 M</td>
</tr>
</tbody>
</table>

Other Costs  
(*may be covered by $1.25M “installation”*)

- Stands, vacuum boxes, pipes, bellows, monitors, safety equipment,…
- Spallation target cooling loop
- Room temperature heavy water system.
- Liquid helium supply system (new central helium liquefier separate budget)
- Remote handling equipment

TRIUMF infrastructure support

- engineering and prototyping of fast kicker -- Mike Barnes estimates engineer, designer and technician on 50% for 2 years (3 FTE-year).
- detailed cost estimates for the project – 1 FTE-year
- project engineer and project manager.
- engineering, design, and technical support for actual installation
Recap

- It is feasible to build an Ultra Cold Neutron Source at TRIUMF
- Development of the heart of the source can proceed initially in Japan
- The source would need a 40 $\mu$A proton beam which can be split off from the existing meson hall beam using kickers
- Detailed costing, and engineering of details should begin as soon as possible at TRIUMF

Summary

- This is a good project
- TRIUMF can do it

END
Conceptual to technical design for the UCN source and experiment

Other Issues:
- radiation, remote handling
- cryogenics
- neutronics
- division of labor
  - Masuda, Golub very interested in cryogenics and neutronics
  - Acsion (private company in Pinawa, MB) interested in neutronics (MCNP)
  - need TRIUMF support to bring to fruition

meson hall remote handling

transfer flask
hot cell entrance
hot cell window
Cost and Schedule

UCN-A Construction (Capital Equipment) Costs:

$454K DOE
  - $308K for the source and $146K for the experiment

$640K NSF
  - SCS and AFP/polarizer magnets

$4.1M from collaborating institutions

*We are not requesting any additional construction funds from either the NSF or the DOE for the current UCN-A measurement.*

Rescoping the capabilities of the source and integrating with LANSCE’s resource scheduling produced delays, however, it also produced cost savings of 50,000$/mo in operations

A.R. Young

LANSCE Area B

Experiment commissioning Underway
Initial goal is 0.2% measurement of A-correlation

UCNA

Brad Filipponi
Interior dimensions: 23.8×28.9 m²
7.2 m NS between N wall and dump
RF gallery 8×8 m²
Cryogenic: 4×6 m²
Main linac
injector linac
50 kw dump: 4×3 m²
Equipment racks & PS: 4×2 m²
Total footprint approx ?
This includes shielding of 1.5 m concrete

Details of the Beamline Elements
[Jaap Doornbos Design Note – 25 Jan 2008]

<table>
<thead>
<tr>
<th>Element</th>
<th>Length (m)</th>
<th>Field (kG)</th>
<th>radius (cm)</th>
<th>angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL1A Q6</td>
<td>0.5238</td>
<td>2.50</td>
<td>1.98</td>
<td>5.156</td>
</tr>
<tr>
<td>drift</td>
<td>2.50</td>
<td>0.75</td>
<td>0.24</td>
<td>5 mrad</td>
</tr>
<tr>
<td>kicker K1</td>
<td>2.50</td>
<td>0.75</td>
<td>0.24</td>
<td>5 mrad</td>
</tr>
<tr>
<td>drift</td>
<td>2.75</td>
<td>1.50</td>
<td>2.79</td>
<td>115 mrad</td>
</tr>
<tr>
<td>kicker K2</td>
<td>1.50</td>
<td>1.50</td>
<td>9.73</td>
<td>15.34°</td>
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<tr>
<td>drift</td>
<td>1.00</td>
<td>0.5238</td>
<td>3.00</td>
<td>5.156</td>
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<tr>
<td>septum</td>
<td>1.00</td>
<td>3.00</td>
<td>5.156</td>
<td></td>
</tr>
<tr>
<td>drift</td>
<td>1.60</td>
<td>0.5238</td>
<td>3.00</td>
<td>5.156</td>
</tr>
<tr>
<td>bend BN1</td>
<td>6.00</td>
<td>1.00</td>
<td>17.85</td>
<td>45.0°</td>
</tr>
</tbody>
</table>
Shane Koscielniak tried to fit e-linac and UCN in Proton Hall. Space is tight, probably too tight. Sharing beam with ISAC is difficult technically.
Where would it fit?

Proposed Proton Beamline to UCN Source

• Beamline 1A optics is untouched
• Red magnets are new
• Green quads from M20