MIT-Bates Laser Driven Target

- Introduction
- Achieved and expected results
- Installation plan and timeline

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1) A circularly polarized laser is absorbed by potassium vapor, which polarizes the potassium (optical pumping)

2) The vapor is mixed with hydrogen (H) and spin is transferred to the H electrons through spin-exchange collisions $H + \tilde{K} \rightarrow \tilde{H} + K$

3) The H nuclei are polarized through the hyperfine interaction during frequent H-H collisions
Comparison of ABS and LDS

Advantages of the LDS for BLAST

- **Higher FOM** for hydrogen
- **Compact design**, can be installed in the low BLAST field region
- Pumping is not as critical as for the ABS
- Thicker target will reduce scattering events from the cell wall relative to the target gas

Disadvantages

- Thicker target and potassium vapor will reduce the beam lifetime, $\tau_{\text{gas}} = 4-12\text{min}$
- No significant deuterium tensor polarization
- Deuterium vector polarization has not yet been optimized
- Wire chambers may trip more often
This target was intended to be used in the “Precise Determination of the Proton Charge Radius” experiment (RpEX) MIT-Bates Proposal 00-02

Polarized hydrogen is the first priority (vector polarized deuterium can be produced)

We are currently optimizing our results for hydrogen

The current apparatus includes a transport tube and storage cell (or target cell) which increase the number of wall collisions
**LDT target cell**

The LDT target cell has a **small diameter**, \(D=1.25\text{cm}\) (thickness \(\propto D^{-3}\)).

Atoms enter the polarimeter at 90° to the LDS guaranteeing target cell wall collisions.

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**Monte-Carlo simulation results for the average number of wall collisions**

<table>
<thead>
<tr>
<th></th>
<th>Spin-exchange Cell</th>
<th>Transport Tube</th>
<th>Target Cell</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>1180</td>
<td>200</td>
<td>135</td>
<td>1515</td>
</tr>
<tr>
<td>(2)</td>
<td>1145</td>
<td>195</td>
<td>155</td>
<td>1495</td>
</tr>
<tr>
<td>(3)</td>
<td>1140</td>
<td>195</td>
<td>295</td>
<td>1630</td>
</tr>
</tbody>
</table>

(1) Atoms that leave the center sampling hole
(2) Atoms that leave the off-center hole
(3) Atoms that leave the ends of the target cell
Achieved and expected result

\( f_\alpha \) = degree of dissociation

\( P_e \) = H electron polariz.

\( \approx \) H nuclear polariz. \( (p_z) \)

FOM = Figure Of Merit

= flow \( \times \langle p_z \rangle^2 \), or, thickness \( \times \langle p_z \rangle^2 \)

Measurements were made at the center sampling hole of the target cell and without an Electro-Optic Modulator (EOM)

An EOM increases the laser linewidth to better match the doppler absorption profile of potassium

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**Preliminary results**

![Graph showing preliminary results with H\(_2\) flow rate and FOM (10\(^{17}\) atoms/s) on the x-axis and FOM (10\(^{13}\) atoms/cm\(^2\)) on the y-axis]

\( f_\alpha \)

\( P_e \)
### Summary of results

<table>
<thead>
<tr>
<th></th>
<th>Hermes (ABS) ‘96 - ‘01</th>
<th>BLAST (ABS)</th>
<th>(units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>H</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Flow (F)</td>
<td>6.5</td>
<td>4.6</td>
<td>2.5</td>
</tr>
<tr>
<td>thickness (t)</td>
<td>7.5</td>
<td>14</td>
<td>3.0</td>
</tr>
<tr>
<td>(\langle p_z \rangle)</td>
<td>0.88</td>
<td>0.85</td>
<td>0.45</td>
</tr>
<tr>
<td>(F \times \langle p_z \rangle^2)</td>
<td>0.50</td>
<td>0.33</td>
<td>0.051</td>
</tr>
<tr>
<td>(t \times \langle p_z \rangle^2)</td>
<td>5.8</td>
<td>10.1</td>
<td>0.61</td>
</tr>
</tbody>
</table>

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*E.C. Aschenauer*, International Workshop on QCD: Theory and Experiment, Martina Franca, Italy, Jun 16 - 20, 2001

HERMES target cell has elliptical cross section 29 x 9.8 mm

<table>
<thead>
<tr>
<th></th>
<th>IUCF (LDT) 1998</th>
<th>MIT (LDT) Prelim.</th>
<th>(units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>H</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Flow (F)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>thickness (t)</td>
<td>0.3</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td>(f_\alpha)</td>
<td>0.48</td>
<td>0.48</td>
<td>0.56</td>
</tr>
<tr>
<td>(P_{e,\text{atomic}})</td>
<td>0.145</td>
<td>0.102</td>
<td>0.37</td>
</tr>
<tr>
<td>(\langle p_z \rangle)</td>
<td>0.21</td>
<td>0.10</td>
<td>0.34</td>
</tr>
<tr>
<td>(F \times \langle p_z \rangle^2)</td>
<td>0.63</td>
<td>0.42</td>
<td>4.7</td>
</tr>
<tr>
<td>(t \times \langle p_z \rangle^2)</td>
<td>0.63</td>
<td>0.42</td>
<td>4.7</td>
</tr>
</tbody>
</table>

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IUCF target cell had a rectangular cross section 32 x 13 mm
# Installation plan and timeline

<table>
<thead>
<tr>
<th>Target chamber</th>
<th><em>Four months</em> for engineering and drafting, uses ABS polarimeter and turbo pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding field coils</td>
<td>Similar to ABS coils, final design and fabrication <em>4 months</em>, two new power supplies are needed</td>
</tr>
<tr>
<td>Laser system</td>
<td>Uses existing lasers, <em>1 month</em> for installation and transporting the beam into the hall</td>
</tr>
<tr>
<td>Miscellaneous preparation</td>
<td>Gas panel, constructing and testing glassware, control software, interlocks, operating procedure</td>
</tr>
<tr>
<td>Installation and commissioning</td>
<td><em>One extra month</em> is required for installation and commissioning</td>
</tr>
</tbody>
</table>

*Total time required 5-6 months*

More info at http://ldt.mit.edu/proton/ldt_07_31_03.pdf (a report by W. Xu)
**Target chamber**

- Thin aluminum windows for BLAST acceptance
- Target cell is heated (~220 °C)
- ABS turbo pumps will be used and positioned either inside or outside the BLAST toroid

**Holding field coils**

- Two identical coil layers
- 700G at the spin-exchange cell
- 580G at the target cell
- Top coil will be removed during target maintenance
- Hole in center of coils allows the QMA to be positioned below the target chamber
Laser System

- Two Ti:Sapph lasers will need to be positioned on a laser table outside the hall
- One Ti:Sapph and Ar+ laser are expected to be supplied by Bates (already exists)
- The laser beams will be transported to the target by a single fiber
- Fast spin-flipping can be achieved by using stepper motors connected to the lasers