HDeque
frozen-spin targets for γ and e experiments with CLAS
A.M. Sandorfi – HDeque Lab design mtg, Aug5’08

• “freezing” spins in a solid HD quantum crystal
• the polarization cycle – gymnastics with solid hydrogen
• HDeque crew
• time table – impacts of HDeque Lab occupancy date
HDice

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External Magnetic field rapidly aligns **Ortho-H$_2$** and **Para-D$_2$**
then spin-exchanges with $H$ and $D$ in HD

HD field/low-temp Polarization

- align spins with high B (15 Tesla) and low T (~12 mK)
- polarize small concentrations of J=1 H₂ and D₂
- o-H₂ and p-D₂ spin-exchanges and polarizes HD
- wait for J=1 H₂ and D₂ to decay

![Graph](HD field-temp pol(J))
Ortho ↔ para decays generate heat, which must be removed to polarize

• HD condensed into target cell with ~ 2000 50 μm Al cooling wires soldered into 60 holes in copper cooling ring

• Composition of a standard target cell with 4 cm of HD (0.9 moles):

<table>
<thead>
<tr>
<th>Material</th>
<th>gm/cm²</th>
<th>mass fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD</td>
<td>0.735</td>
<td>77%</td>
</tr>
<tr>
<td>Al</td>
<td>0.155</td>
<td>16%</td>
</tr>
<tr>
<td>CTFE (C₂ClF₃)</td>
<td>0.065</td>
<td>7%</td>
</tr>
</tbody>
</table>
**HD polarize/run sequence:**

- condense HD gas → liquid → solid in 2-4 °K dewar; *calibrate NMR*
- transfer to dilution refrigerator
  - *polarize at 15 tesla and 12-16 mK*
  - *hold for 2-6 months, waiting for ortho-H₂ and para-D₂ to decay away*
- transfer to 2-4 K dewar for polarization measurement
- transfer to In-Beam-Cryostat
  - *hold target for experiment at 0.2 – 0.7 °K and ~0.1 to 0.9 tesla*
  ⇒ *Spin-relaxation (T₁) decay times ~ a year*
RF flip of H spin

\[ T_1(H) = 260 \text{ d} \]
\[ T_1(D) = 340 \text{ d} \]
\[ T_1(H) = 360 \text{ d} \]
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Steps in making a frozen-spin HD target

- purify HD gas to reduce $H_2$ and $D_2$ levels:
  - distillation at JMU in a “Steadman column”

  - $H_2$-rich
  - HD
  - $D_2$-rich

  measure gas quality:
  - $T_1$ with small samples (time consuming)
  - gas chromatography (at JMU), 0.05 % $H_2$ or $D_2$ accuracy
  - Raman scattering ~0.001% accuracy (future – at Rome and/or UVa)
• inject HD gas through capillary tool and condense in Production Dewar (PD);

pass through triple-point (~127 mbar at 4K) to form a quasi-crystal;
release from injection tool;
cool to 2K
• **Polarization monitoring**  
  - in a 2K/4K  
  *Production Dewar (PD)*

• **thermal equilibrium NMR calibration**

\[ P(H,D) \sim 0.01\% \]
BNL-Jülich Transfer-Cryostat - moves solid HD between dewars

- 11 ft
- Halbach dipole
- 77 K rad shutter
TC 77 K Radiation shutter
• extract from PD with 2K transfer
  Cryostat (TC), containing 0.12 T
  Halbach rare-earth dipole

- transfers are most problematic steps, requiring lots of prep
- alignment: TC turns a 1” thread on the end of an 11 ft screw-driver
- 77 K radiation shutter leaves are few inches from 2K HD and are crucial

- failure rate ~ 1/12 transfers
• transfer to dilution refrigerator (DF);
  polarize at high field (15 T)
  and low temp (~12 mK);
  hold there for >2 months

- DF and PD suspended in pits
  so that top flanges are at same height

• transfer from DF back to PD to
  measure frozen-spin polarization
• **Transfer back to Production Dewar (PD)**

• **NMR**
  - measure frozen-spin polarization

\[ P(H,D) \sim 10^4 \times \text{thermal} \]
• transfer frozen-spin HD to Storage Dewar (SD)
  - automated stabilized OPS
  - 1.6 K and up to 8 Tesla
  - transport at 2-3 tesla
    ⇒ Hall B
• transfer to In-Beam Cryostat (IBC);
  - IBC tipped > 25 °
  - measure NMR in IBC;
  - transfer to PD, measure transfer loss;
  - transfer back to IBC for experiment;

• initial thermal calibration in CLAS IBC would eliminate need for multiple transfer-loss measurements
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• “freezing” spins in a solid HD quantum crystal

• the polarization cycle – gymnastics with solid hydrogen

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Time Line:

- CLAS IBC design in progress
- HDice Lab – North Annex to Test Lab
  GOAL for occupancy ~ mid-May/09
- polarize 1st set of targets Feb-June/2010; 2nd set Aug-Dec/2010
- CLAS IBC installation at end of July, 2010
- e+HD test: Apr/2011
- E08-021(015) run: Nov/2011
HDice Lab

• High-Bay in Test-Lab N-Annex - site fixed, July 25’08
• shortest paved path to Hall-B
• existing power/water utilities
• unaffected by Test-Lab Rehab in 2013
• purchase LHe; cost partly offset by recovery of gas for CHL
• Oct 15’08 - bldg design done
• Jan 5’09 - award contracts
• June-Aug’09 - bldg occupancy ⇒ HDice equipment install