POLARIZED TARGET for E159 and E161

System for E161

- Dilution Refrigerator
- 7T Solenoid
  - Microwaves
  - NMR
  - $^6$LiD
Inverse Spin Temperatures of the World Pol. Data

\[ P = \frac{4 \tanh \left( \frac{g_d\mu_B B}{2kT} \right)}{3 + \tanh^2 \left( \frac{g_d\mu_B B}{2kT} \right)} \]

\[ T^{-1} = 760 \text{ K}^{-1} \]

\[ T^{-1} = 580 \text{ K}^{-1} \]

\[ T^{-1} = 350 \text{ K}^{-1} \]

\[ T^{-1} = 208 \text{ K}^{-1} \]

Saclay '80-'94
Bonn '94
Bochum '00 extrapolated
Virginia '00
Bonn '93-'94

Magnetic Field

Max. Polarization [%]
Fig. 5  Assembly drawing of the frozen spin target dilution refrigerator: A - separator, B - tubular counter-current heat exchanger, C - radiation shield I, D - radiation shield II, E - Evaporator needle valve, F - evaporator, G - condensing capillary, H - needle valve for precooling, I - still, J - heat exchanger between dilute and concentrated streams, K - mixing chamber, L - vacuum jacket, M - 2 silicon surface barrier diodes in evacuate/; box, N - 3 thermometers, O - end cap of mixing chamber, P - indium joint, Q - indium joint; R - boiling heater in still, S - still heat exchanger, T - target, Y - spring for thermal contact and centring, X - waveguide holder and thermal link.
Requires Sealed Roots Pumping System
7 TESLA HORIZONTAL BORE CRYOMAGNETIC SYSTEM
Professor Don Crabb  
University of Virginia  
Charlottesville  
VA 22901  

Our Ref.: GF / DC  
Quotation number : 00- 6073  

June 2, 2000

**QUOTATION**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>PRICE</th>
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<tbody>
<tr>
<td>1</td>
<td>7 Tesla 200mm RT Bore Superconducting Magnet System</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>7 Tesla horizontal cryomagnetic system</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Magnet</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Central Field</td>
<td>7.0 tesla at 4.2 K</td>
</tr>
<tr>
<td></td>
<td>Field homogeneity</td>
<td>$10^{-4}$ over a diameter of 10 mm x 50 mm long (see field map)</td>
</tr>
<tr>
<td></td>
<td>Cold bore</td>
<td>236 mm</td>
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<tr>
<td></td>
<td>Operating current</td>
<td>94 amp</td>
</tr>
<tr>
<td></td>
<td>Field stability in persistent mode $&lt; 10^4$ relative hr$^{-1}$</td>
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</tr>
<tr>
<td></td>
<td><strong>Cryostat</strong></td>
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</tr>
<tr>
<td></td>
<td>Type</td>
<td>Horizontal bore low loss</td>
</tr>
<tr>
<td></td>
<td>Ambient temperature bore</td>
<td>200 mm</td>
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<tr>
<td></td>
<td>Overall length</td>
<td>630 mm</td>
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<tr>
<td></td>
<td>Bore access solid angle</td>
<td>$40^\circ$ at one end, $34^\circ$ at the other</td>
</tr>
<tr>
<td></td>
<td>Overall diameter</td>
<td>785 mm</td>
</tr>
<tr>
<td></td>
<td>Total height</td>
<td>1520 mm</td>
</tr>
<tr>
<td></td>
<td>Bore height</td>
<td>365 mm</td>
</tr>
<tr>
<td></td>
<td>Helium capacity</td>
<td>15 L nominal</td>
</tr>
<tr>
<td></td>
<td>Helium hold time (current lead removed)$&gt; 180$ hrs</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>IPS120-10</strong> Superconducting magnet power supply:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 120 A output current</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ± 10 V output voltage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Current setting to 1 mA from the front panel, 0.1 mA through the supplied software</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Bipolar operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Current stability of $± 3$ mA/°C</td>
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</table>
MICROWAVES

Operate Magnet 6 - 6.5 T

EIO

μWave Frequency 170 - 180 GHz

No Mechanical Tuner

\[ \therefore \] Electrical Tuning Range \sim 200 \text{ MHz}

OK for 6LiD

Power \sim 3W  ok for 6LiD

Tubes(s) need to be acquired
Polarization in $^6$LiD

![](image)

- $^2$H Small
- $^2$H Large
- $^6$Li Small
- $^6$Li Large

Dose / $10^{17}$ e$^-$/cm$^2$
Deuteron Polarization in $^6$LiD

![Graph showing deuteron polarization over time with annotations](image)

- **5T/1K**
- Time / min
- Deuterium Polarization in $^6$LiD graph
- Points indicate polarization changes over time
- Annotations: "fm on" and "μ wave problem"
Cluster models of the ground state wave function:

- $^6\text{Li} = \alpha + d$ Many references, e.g. J.V. Noble, Phys Rev. C9, 1209 (1974) Nucl. Phys. A251, 105 (1975)

- Polarized $^6\text{Li}$ incident on $^{58}\text{Ni}$ and $^{40}\text{Ca}$ targets, no D-state between $\alpha$ and $d$ clusters, E.E. Bertosz et al., TUNL Report XXXVI, 51 (1997)

- Polarized $^6\text{LiD}$ neutron polarization in $\alpha + d$ model. Neutron is 1.5 times more likely to be in D-state of $d$ cluster in Li than in the free deuteron, L.L. Frankfurt and M.I. Strikman, Nucl. Phys. A405, 557, 1983

\[
\text{Neutron pol. } \lambda_n = \frac{\lambda_0^6 \sigma_0 + \lambda_0^3 \sigma_3}{\sigma_0 + \sigma_3} = \frac{(1 - \frac{3}{2} \rho_0) \sigma_0 + (1 - \frac{3}{2} \rho_0 \delta^6) \sigma_3}{\sigma_0 + \sigma_3}
\]

\[
\text{Using } \sigma_3 = 3 \sigma_0
\]

\[
\lambda_n = 1 - \frac{3}{4} \rho_0 (1 + \delta^6); \quad \delta^6 = 1.5.
\]

\[
\lambda_{^6\text{Li}}^{\text{D}} = 1 - \frac{3}{4} \cdot 0.05(1 + 1.5) = 90.6\%; \quad \lambda_n^6\text{Li} = 88.8\%
\]

No $P$-states, no unpolarized EM correction

- $^6\text{Li} = \alpha + n + p$ neutron polarization in Li in 3-body Fadeev formalism. Incorrect angular momentum decomposition for D and Li overestimates neutron polarization, N.W. Schellingerhout et al., Phys. Rev. C48, 2714 (1993)

Paper: \[ P_n = P_s + \frac{1}{4} P_D \]

True: \[ P_n^+ = P_s - \frac{1}{2} P_D \]
Nitrogen contributes with only one third of the polarizable nucleons in ammonia and it polarizes only up to one sixth of the corresponding hydrogen or deuterium polarization. The net contribution of the polarized nucleons in $^{14}$N to the hydrogen or deuterium spin asymmetries is then $-0.27 - 0.33$. This work Ref. to the hydrogen, and Jean and E. L. Tomusiak. Its magnetic moment is less $-0.24 - 0.33$. Ref. to the hyperfine splitting, and by the Institute of Nuclear and Particle Physics. S. Coon. R. Wirinpa. are even $-0.02$. Ref. to the needed in DIS spin structure experiments [3.1].

$^{15}$N has $I^e = \frac{1}{2}^-$. The shell model gives an even better description of $^{15}$N than of $^{14}$N. Its magnetic moment is less than $7\%$ away from the Schmidt line value $-0.26\mu_N$. Thus we would expect the proton in $^{15}$N to be aligned antiparallel to the nuclear spin $1/2$ of the time. The model-independent estimates for this isotope agree in sign and are of similar magnitude as the shell-model prediction. The correction to the spin asymmetries due to the presence of $^{15}$N are even smaller than those due to $^{14}$N, because in the former the neutron contributions are entirely negligible, and its nuclear polarization can be measured with better precision than that of the latter.

Table III summarizes the results of this and other works. The row for $A = 3$ lists only the proton polarization for $^3$H (neutron polarization for 'He).

I would like to thank Keith Giffioen for calling my attention to Ref. [16], and B. Alex Brown. S. Coon. R. Wirinpa. and D. G. Cnbb for helpful discussions. This work was supported by Department of Energy Contract No. DEFG05-86ER40261 and by the Institute of Nuclear and Particle Physics of the University of Virginia.

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TABLE III. Nucleon polarizations.

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</thead>
<tbody>
<tr>
<td>$^2$H</td>
<td>0.94</td>
<td></td>
<td>0.926</td>
<td></td>
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<tr>
<td>$^3$H</td>
<td>0.93</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>0.86</td>
<td>0.865</td>
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<tr>
<td>$^3$He</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.57</td>
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<tr>
<td>$^6$Li</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.59</td>
</tr>
<tr>
<td>$^{14}$N</td>
<td>-0.26</td>
<td>-0.33</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$^{15}$N</td>
<td>-0.22</td>
<td>-0.24</td>
<td>-0.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\alpha P^2 = 0.933$
Figure 4: Measured polarization of $^6$Li and $^7$Li nuclei as a function of the measured deuteron polarization. The EST predictions for the lithium polarizations basing on the deuteron polarization are shown by the full lines is validated by the data.
32.7 MH2
System for E159

- Same Dilution Refrigerator

- Same magnet (at 5T)

- $^{15}\text{NH}_3$ and $^{15}\text{ND}_3$

- Microwaves

- NMR expected 2-3% (4x as 4-5%)
Proton Polarization Build-up

Polarization (%)

Time (minutes)

\( \frac{\Delta T}{1/K} \)
Deuteron Polarization Buildup

Polarization (%) vs. Time (minutes)

5T/1K

After 'cold' irradiation
Microwaves

Magnet at 5T

μWave frequency ~ 140 GHz

Same conditions as for E143, E155, E155x and Gen(JLAB)

Reproducible & well understood

Have all necessary equipment
d - butanol TE Conventional NMR

Channel Number (Total Range 600 KHz)
d - butanol Raw TE Signal - Baseline

Channel Number Full Scale = 600 KHz