Effect of the HD cell Aluminum coating on the polarimetry

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1 Introduction

Some HD cells (14a, 19, 21a) had their downstream Kel-F cap coated with a thin Al. layer to shield against light. Since Al. is a conductor, this coating can affect the NMR polarimetry. We summarize here these effects. The definite test for these effects comes from a CH$_2$ cell for which TE hydrogen and fluorine signals were measured with and without Al. coating. The CH$_2$ cell was the JLab type cell #1 and has no Al. cooling wires.

2 Coating

The coating for cells 14a and 19 followed the same procedure and was done by A. Sandorfi, and T. O’Connell. The resulting Al. layer is about 1.5 micron thick. The face is scratched in a $10 \times 10$ grid. For cell 21a, the thickness is only about 1 micron and the grid is $7 \times 7$. Finally, the Al. purity is different for target 21a: (99.9998% Al purity rather than 99.999998% for the 19, 14a and CH$_2$ cells). The HD cell has a layer of about 1.5 micron coating and its grid is $7 \times 7$ but without coating at the location of the cooling holes. Consequently, its grid pattern differs from the HD cells.

3 Data

The coating main affects the background gain $\lambda/2$ amplitude and its phase. We remark that the Al. cooling wires, which are grounded, do not produce any phase shifts or any strong effect on the amplitude.

The data is analyzed and discussed in detailed in [1], except for the the CH$_2$ coated run (run 176837233, see Fig. 1). The run on an uncoated cell was also taken using CH$_2$ #1 (run 1729323). The characteristics of the two CH$_2$ runs are:
Note: no correction for magnetic field is necessary. The value read for runs with $T_{up} \neq 31s$ are incorrect. Here for ex., since both run used the same RF frequency, which implies the same resonance field.

We compare the coated HD cells with the only measurement done on an uncoated HD cell (target 12) which has unfortunately very low statistics (about 35 times less). We could also compare to the expected signal strength from the CH$_2$ cell without coating but as far as central values are concerned, this is equivalent to comparing the cell 12 since its central value agrees with the CH$_2$ results within a few percents. All signals were corrected for PD temperature difference, some of the RF loss and the fact that TE was not reached at the beginning of some of the data taking [1]. The reference temperature was taken to be 4.27K. The results on cell #12 were scaled by 1.4 to account for the fact that they were taken using the yellow RF cables. The table below summarizes the effects.

<table>
<thead>
<tr>
<th>cell</th>
<th>H signal area (down/up) int over 25 Gauss</th>
<th>$T_1$</th>
<th>D signal area (down/up) int over 25 Gauss</th>
<th>phase offset</th>
<th>$G_0 \lambda/2$ RF amplitude with cell</th>
<th>$G_0 \lambda/2$ RF amplitude without cell</th>
<th>H reduction (d/u)</th>
<th>D reduction (d/u)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#12</td>
<td>$1.431 \times 10^{-3}/1.478 \times 10^{-5}$</td>
<td>$&lt;\text{min}$</td>
<td>$5.362 \times 10^{-6}/4.971 \times 10^{-6}$</td>
<td>0</td>
<td>$326.7$ (yellow cable)</td>
<td>$261.2$ (yellow cable)</td>
<td>-/-</td>
<td>-/-</td>
</tr>
<tr>
<td>#21a</td>
<td>$1.471 \times 10^{-3}/1.492 \times 10^{-5}$</td>
<td>$&lt;\text{min}$</td>
<td>$4.941 \times 10^{-3}/4.879 \times 10^{-5}$</td>
<td>$+174^\circ$</td>
<td>$470$ (white cable)</td>
<td>$655$ (white cable)</td>
<td>$1.028/1.001$</td>
<td>0.92/0.98</td>
</tr>
<tr>
<td>#14a</td>
<td>$0.792 \times 10^{-3}/0.893 \times 10^{-5}$</td>
<td>$38\text{min}$</td>
<td>not analyzed</td>
<td>$-6^\circ$</td>
<td>$358$ (white cable)</td>
<td>$655$ (white cable)</td>
<td>$0.553/0.604$</td>
<td>-/-</td>
</tr>
<tr>
<td>19</td>
<td>$0.789 \times 10^{-3}/0.770 \times 10^{-5}$</td>
<td>$47\text{min}$</td>
<td>not analyzed</td>
<td>$-6^\circ$</td>
<td>$358$ (white cable)</td>
<td>$655$ (white cable)</td>
<td>$0.551/0.521$</td>
<td>-/-</td>
</tr>
<tr>
<td>CH$_2$ w/o Al cap</td>
<td>$5.641\times10^{-5}/5.522\times10^{-5}$</td>
<td>not meas.</td>
<td>-</td>
<td>0</td>
<td>$648$ (white cable)</td>
<td>$648$ (white cable)</td>
<td>-/-</td>
<td>-/-</td>
</tr>
<tr>
<td>CH$_2$ #1 w/ Al cap</td>
<td>$6.070\times10^{-5}/5.807\times10^{-5}$</td>
<td>not meas.</td>
<td>-</td>
<td>$-4^\circ$</td>
<td>NA</td>
<td>NA</td>
<td>$1.076/1.052$</td>
<td>-/-</td>
</tr>
</tbody>
</table>

Notes:
1) While we have data on $G_0$, no data are available for the NMR gain $G_1$.
Figure 1:
Time evolution of the raw NMR signal (not phase corrected) for the \( \text{CH}_2 \) run with Al. cap.
\[ \lambda/2 \] RF amplitude for cells 14a and 19. Comparing CH\textsubscript{2} before and after the HD cells were made, we estimated for the \( \lambda/2 \) RF amplitude for cells 14a and 19 to be 689 \( \mu V \). This is 6\% higher than the cell 12 run and the signals from cells 14a and 19 are thus corrected with a 6\% reduction.

2) No RF scan without (coated) cell were done for cells 19 and 14a, because those were done before the Al. cap issues were identified. The results for cells 19 and 14a assume no change in the RF circuitry and hence, no change in the “true” RF \( \lambda/2 \) amplitude.

The signals are shown on the figure 2.

4 RF scans

One effect of the coating is to change the amplitude of the \( \lambda/2 \) RF amplitude. The question arises whether this should be corrected for or not for the NMR amplitude.

In paper [2], the Fig. 2 shows the transducer gain \( G_1 \) (see eq. 4 of [2]) and the background gain \( G_0 \). In practice, \( G_1 \) is proportional to the polarization (obtained for example by measuring a signal from a constant polarization, in function of frequency). \( G_0 \) is proportional the gain of the circuit (obtained by the frequency scan). This Fig. 2 makes it clear that because of the zero suppression given by Eq. 5, \( G_1 \) is unrelated to \( G_1 \) near the \( \lambda/2 \) peak (i.e. near the zero suppression for a tuned circuit). From [2], a 100\% change in the capacitances that model the cross-coils induces a 0.1\% change in \( G_1 \). So large changes in \( G_0 \) (from RF scans \( \lambda/2 \) amplitude) occur when a cell with Al. coated cap is installed, while the NMR signal is almost not affected, since it’s proportional to \( G_1 \) (effect suppressed by a factor 1000). Minor corrections may remain on \( G_1 \) since since the data were not taken exactly on the zero-suppression frequency.

Other changes in the \( \lambda/2 \) amplitude were observed, for which it seems the NMR signal should be corrected for:

1) When the RF circuit was unstable due to broken/flaky connectors;
2) During NMR tests with and without exchange gas.

In case 1) it is obvious that the gain correction should be made. It is not truly a change in gain but rather a change in amount of RF power transmitted.

In case 2, it seems justified too to make the gain correction from experience but it is not clear why. Maybe the temperature affects the filling factor by changing the geometry of the coil? It is also possible that part of the gain change should not be corrected for since it might be due to change in the circuit itself.

To conclude, the rule for gain correction to follow is: “Correct for \( \lambda/2 \) RF amplitude change in all cases except when the changes are due to cells with Al. cap”. This is verified for both the amplitude and the phase.
Figure 2:
Results for the NMR sweeps.
5 Conclusion

The Al. layer is effect very large on both the background gain $G_0$ and apparently the NMR signal for cells 14a and 19. However, the only effects seen for the CH$_2$ and 21a cells are on the phase and gain $G_0$. In another hand, later data showed that NMR done at high Rf power on cells with long $T_1$ should display a significant offset compared to the expected TE value. This is because the target, after flipping some of its spins in the NMR Fast Passage process (the amount of spin flips, i.e. polarization loss, is proportional to the RF power) does not reach back TE in time for the next sweep because of its long $T_1$. Ref. [??] shows that NMR measures a signal about 6% lower than the expected TE for a cell with a 8.1 min $T_1$. Very naively scaling linearly, this means about 30% losses for cells 14a and 19 and small losses for the CH$_2$ and 21a cells. This is in qualitative agreement with what is seen. We conclude from this that the change in signal size seen for cells 14a and 19 is not likely to be due to the Al. cap.

To summarize, the Al. cap modifies significantly the background gain $G_0$ (amplitude and phase) but seems to leave the NMR signal undisturbed. The $G_0$ modifications are still a nuisance for the NMR measurement because we cannot readily quantify any possible change of gain $G_1$ in the circuitry once the target is installed, since the information on $G_0$ become unreliable. This can be fixed by taking no-cell NMR runs before and after the measurement. Also, the signals will be off-phase compared to the expectation from the $G_0$ measurement. In the worst case, since both the x and y channels of the lock-in are a mix of absorption and dispersion signals, the magnetic field sweep-range may be too small on both channels to capture the full signal. This can be fixed by assuming no change in the phase compared to a no-cell run.

References

