

NMR in the Production Dewar without Exchange Gas

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1 General conditions

In this document, we report whether the polarimetry signal depends on the presence of exchange gas in the PD. CH₂ runs were done on May 27. A first study with the HD was done during various stages of a target transfer test using the TC (August 7th 2011). These runs can be compared to a previous run done with the same RF power. Although the run conditions were different, we call it “benchmark run”, since it was done with exchange gas. The parameters T_{down} and B span for the other runs are chosen so that there is a minimum time of RF on the target, in order to reduce possible heating. The HD runs are done in the PD2 with Insert 1, the white RF cable and a RF power of -15dbm. The T_{down} was 16s, except for the baseline run (31s). B span was 100G except for the baseline run (300G) which also includes the Fluorine NMR signal. The HD T_1 was not measured but is assumed to be negligible (HD gas with high impurities and no pre-aging). For all the runs, $B_0 = 2850$ Gauss (2948 Gauss for the benchmark run), the RF frequency was 12308 kHz and the phase 137° .

Another set of HD runs with higher statistical precision was done one August 17th – 19th 2011. The conditions were the same as for August 7th except for the RF frequency (12356 kHz), central field (2860 Gauss) and the phase (129°).

2 CH₂ runs

Run 182796235 was taken with exchange gas. The PD temperature was 4.3K and the RF $\lambda/2$ resonance amplitude was 8.938×10^{-4} V. The signal height was $\sim 2 \times 10^{-6}$.

Run 182879284 was taken without exchange gas. The PD temperature was 4.7K and the RF $\lambda/2$ resonance amplitude was 7.773×10^{-4} V. The signal height was $\sim 0.5 \times 10^{-6}$. From run 182796235 and correcting for the difference in temperature and $\lambda/2$ resonance amplitude, we expected a signal height of $\sim 1.6 \times 10^{-6}$.

There is a strong signal change between run without and with exchange gas.

3 First HD study (August 7th 2011)

The runs of interest are:

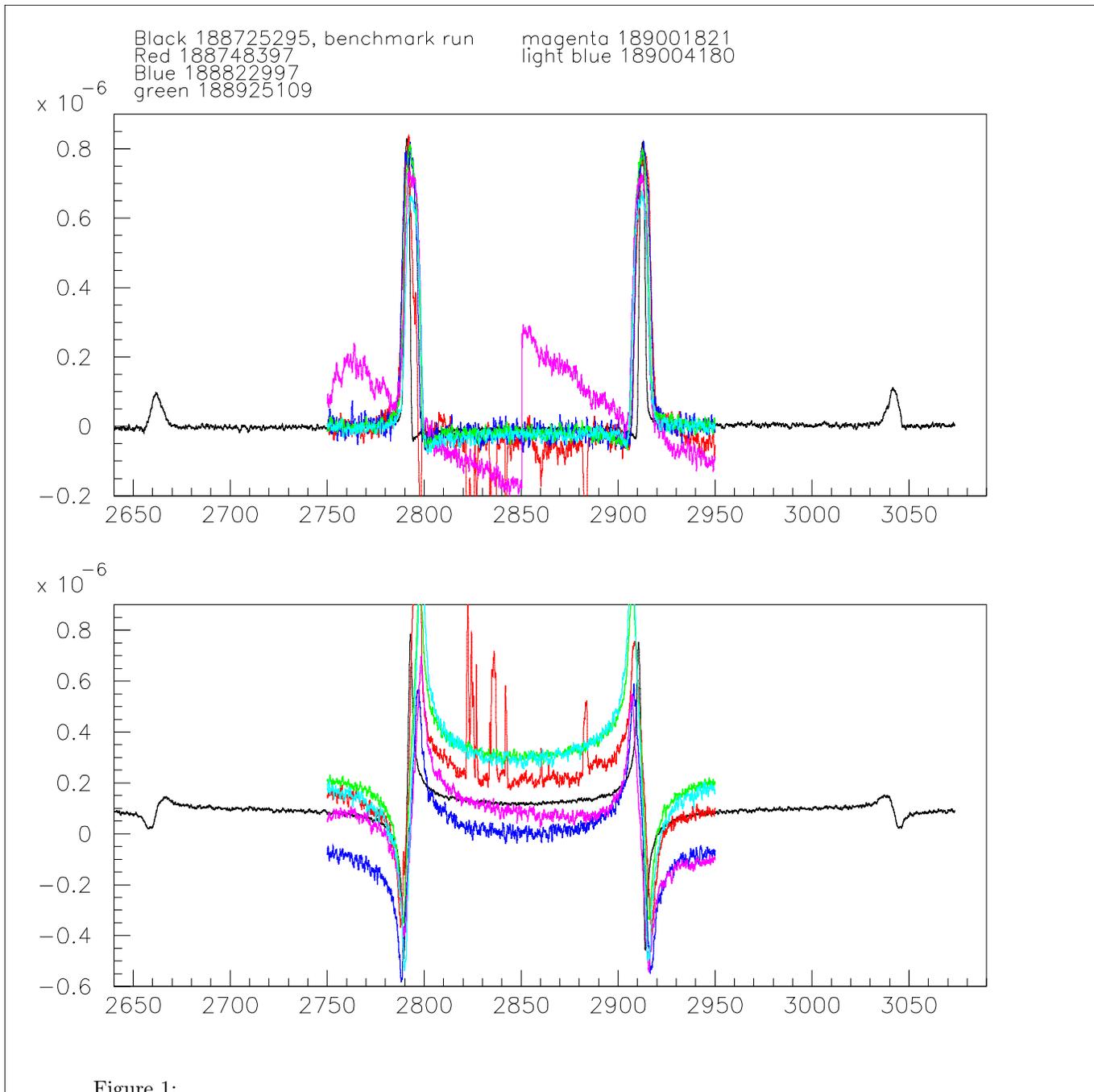
Run #	$\langle T^\circ \rangle$ in K	target	cycles	RF $\lambda/2$ res. freq. (kHz) & phase	RF $\lambda/2$ res. amp	Raw signal strength (Down) Corrected strength	raw signal strength (Up) Corrected strength	Condition	comments
189937628	4.268	HD	83	12305 133°	$2.593 \times 10^{-4} \text{V}$	3.65×10^{-6} 7.07×10^{-6}	3.61×10^{-6} 6.99×10^{-6}	With exchange gas	Benchmark run
188748397	4.855	HD	11	same as above	same as above	*** ***	*** ***	After a few hours pumping on ex. gas	large noise but signal similar as baseline run.
188822997	4.883	HD	7	12304 133°	$2.618 \times 10^{-4} \text{V}$	5.70×10^{-6} 6.46×10^{-6}	5.73×10^{-6} 6.49×10^{-6}	2 hours more of pumping	
188925109	4.878	HD	11	12292 134°	$3.11 \times 10^{-4} \text{V}$	6.76×10^{-6} 6.44×10^{-6}	6.70×10^{-6} 6.39×10^{-6}	48 hours of pumping ex. gas	
189001821	4.794	HD	9	12307 133°	$2.695 \times 10^{-4} \text{V}$	5.39×10^{-6} 5.83×10^{-6}	5.31×10^{-6} 5.74×10^{-6}	TC not attached	strong non flat-baseline.
189004180	3.342	HD	9	12295 134°	$2.916 \times 10^{-4} \text{V}$	8.36×10^{-6} 5.82×10^{-6}	8.27×10^{-6} 5.76×10^{-6}	After pumping varytemp	
189009238	3.329	HD	9	12288 136°	$3.105 \times 10^{-4} \text{V}$	9.33×10^{-6} 6.08×10^{-6}	8.82×10^{-6} 5.75×10^{-6}	TC attached. All the way retracted	
189012112	3.538	HD	9	12291 135°	$3.118 \times 10^{-4} \text{V}$	9.35×10^{-6} 6.07×10^{-6}	9.17×10^{-6} 5.95×10^{-6}	Left Hand threads screwed fully into target but LH join not yet released.	
189013269	3.234	HD	9	assume same as above	assume same as above	10.28×10^{-6} 6.48×10^{-6}	10.48×10^{-6} 6.61×10^{-6}	Broke RH threads. Released and screwed back to touch bottom.	assume RF $\lambda/2$ res. amp of previous run
189021637	3.356	HD	5	12291 135°	$3.116 \times 10^{-4} \text{V}$	9.79×10^{-6} 6.41×10^{-6}	9.27×10^{-6} 6.07×10^{-6}	run after the target was lifted with TC, kept 1h in the TC and put back in PD	
189023009	3.365	HD	9	12292 135°	$3.113 \times 10^{-4} \text{V}$	9.23×10^{-6} 6.06×10^{-6}	9.31×10^{-6} 6.12×10^{-6}	Same as above	
189025953	4.838	HD	9	12291 135°	$3.118 \times 10^{-4} \text{V}$	6.64×10^{-6} 6.26×10^{-6}	6.59×10^{-6} 6.21×10^{-6}	Same as above but higher temperature.	

The signal strength is the integral done on the lock-in x-channel NMR signal, integrated over 15 Gauss. The bottom numbers given in the same table box (in red) are corrected for the average PD temperature, T_{down} , and the change in the RF $\lambda/2$ resonance amplitude value (no correction was done for change in RF frequency and phase since these changes, if any, are small). So the red numbers can be compared directly. The signals are given in Figs. 1 and 2.

We have not done the error analysis for now.

4 Second HD study (August 17th-19th- 2011)

The runs of interest are:



Mean NMR signals. The top signals (lock-in x-channel) are corrected for temperatures and $\lambda/2$ amplitudes. The bottom plot (lock-in y-channel) are uncorrected.

The benchmark run peaks are (artificially) thinner because of the different T_{down} values used for this run. The peaks from magenta signal that possessed a strong non-flat baseline have been shifted to ease the comparison.

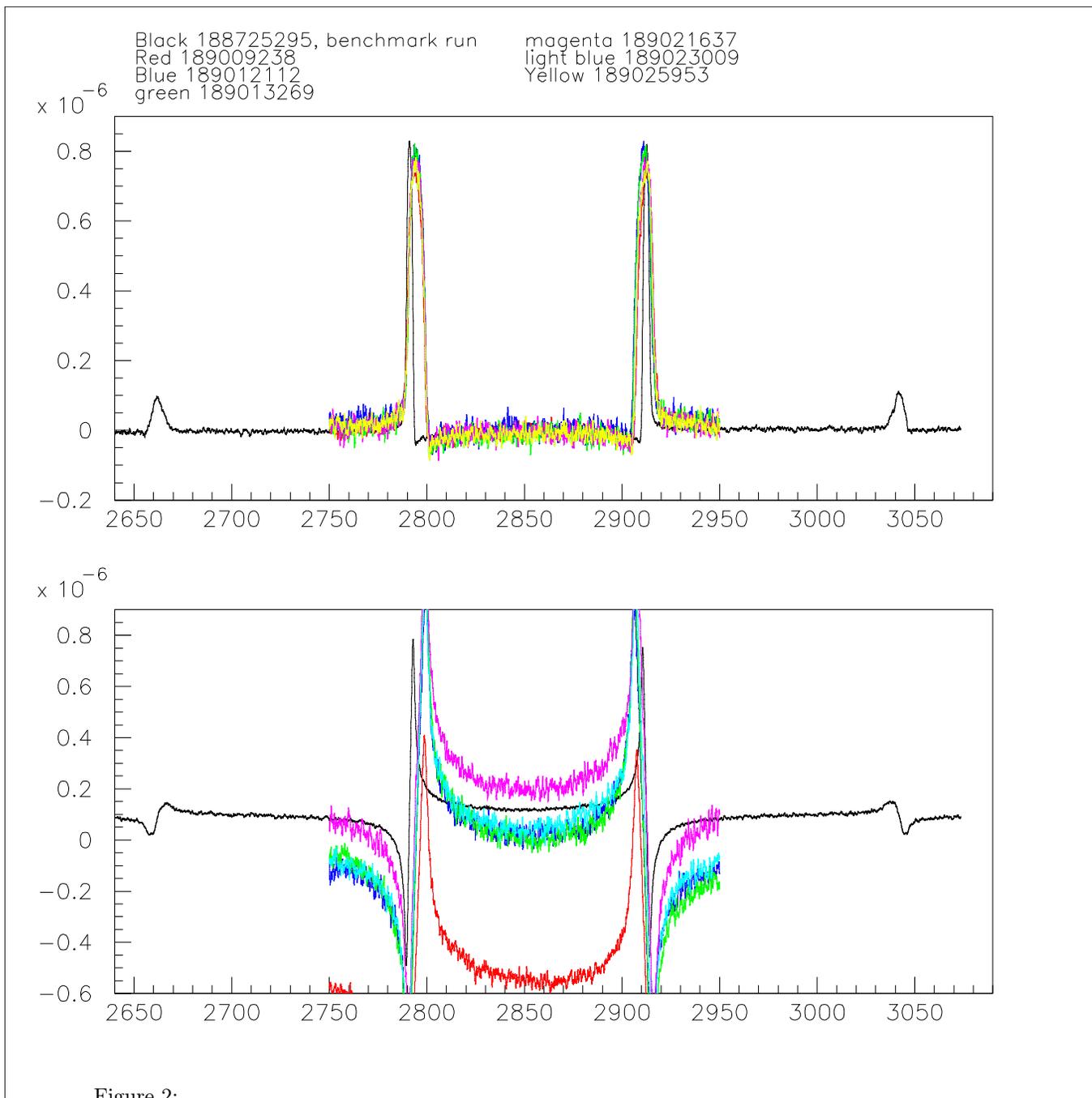


Figure 2:

Mean NMR signals. The top signals (lock-in x-channel) are corrected for temperatures, $\lambda/2$ amplitudes and different baselines. The bottom plot (lock-in y-channel) are uncorrected.

The benchmark run peaks are (artificially) thinner because of the different T_{down} values used for this run. The peaks from magenta signal that possessed a strong non-flat baseline have been shifted to ease the comparison.

Run #	< T° > in K	target	cycles	RF $\lambda/2$ res. freq. (kHz) & phase	RF $\lambda/2$ res. amp	Raw signal strength (Down) Corrected strength	raw signal strength (Up) Corrected strength	Condition	comments
189937628	4.281	HD	83	12356.3 123.5°	$1.75 \times 10^{-4} \text{V}$	4.53×10^{-6} 4.53×10^{-6}	4.59×10^{-6} 4.59×10^{-6}	With exchange gas	Benchmark run at 4.3K
189949228	1.896	HD	30	12356.3 123.6°	$1.748 \times 10^{-4} \text{V}$	10.04×10^{-6} 4.45×10^{-6}	9.91×10^{-6} 4.39×10^{-6}	With exchange gas	Benchmark run at 1.9K
189971774	4.871	HD	109	Same as above	Same as above	4.01×10^{-6} 4.57×10^{-6}	4.04×10^{-6} 4.60×10^{-6}	No exchange gas. 5 hours of pumping	Initial RF resonance peak cd (before pumping) given by previous run. Changed for RF scan taken just after this run. <i>Assumed</i> the ones of this row for correction.
189983543	4.825 (from end of run record)	HD	331	12339.6 125.7°	$1.929 \times 10^{-4} \text{V}$	4.31×10^{-6} 4.42×10^{-6}	4.31×10^{-6} 4.41×10^{-6}	No exchange gas	freq scan done a few hours after run's end gives similar results: f=12336.6, Amp= $1.959 \times 10^{-4} \text{V}$ and phase=125.7°
190025675	3.37	HD	17	12336.4 126.27°	$1.956 \times 10^{-4} \text{V}$	5.89×10^{-6} 4.15×10^{-6}	5.98×10^{-6} 4.21×10^{-6}	No exchange gas	Stopped run early because temperature went to 3.9K.
190029664	3.42	HD	47	12336.4 126.3°	$1.959 \times 10^{-4} \text{V}$	5.82×10^{-6} 4.15×10^{-6}	5.80×10^{-6} 4.14×10^{-6}	No exchange gas	freq scan done a few hours after run's end gives similar results: f=12336.1, Amp= $1.959 \times 10^{-4} \text{V}$ and phase=126.35°
190037814	4.831	HD	101	12331.8 127.0°	$2.018 \times 10^{-4} \text{V}$	4.34×10^{-6} 4.25×10^{-6}	4.30×10^{-6} 4.21×10^{-6}	No exchange gas	
190052243	3.394	HD	100	12327.4 127.7°	$2.080 \times 10^{-4} \text{V}$	6.24×10^{-6} 4.16×10^{-6}	6.18×10^{-6} 4.12×10^{-6}	No exchange gas	phase adjusted by +2°
190063945	4.810	HD	169	12326.7 127.7°	$2.087 \times 10^{-4} \text{V}$	4.58×10^{-6} 4.32×10^{-6}	4.54×10^{-6} 4.27×10^{-6}	No exchange gas	

5 Conclusions

There is large variation of the signal in the case of the CH₂ target, which has no wire to cool itself and thus relies on the exchange gas.

There is no significant variation for the HD runs. For the first set of run, the $\pm 10\%$ fluctuation seen seems to be within the expected uncertainty for the given statistics (compare the three last runs done in similar conditions, apart for the PD temperature). The benchmark run is off by more than 10% but this may be due to the use of different parameters.

The higher statistics data are in good agreement with the benchmark run, within typically 5% and with a maximum deviation of 11%. The signals without exchange gas are however systematically lower than the benchmark run with exchange gas. We also notice that, after all corrections are applied, runs done at higher temperature tend to have a higher signal than those done at lower temperature, for both cases with and without exchange gas. We do not know if this is

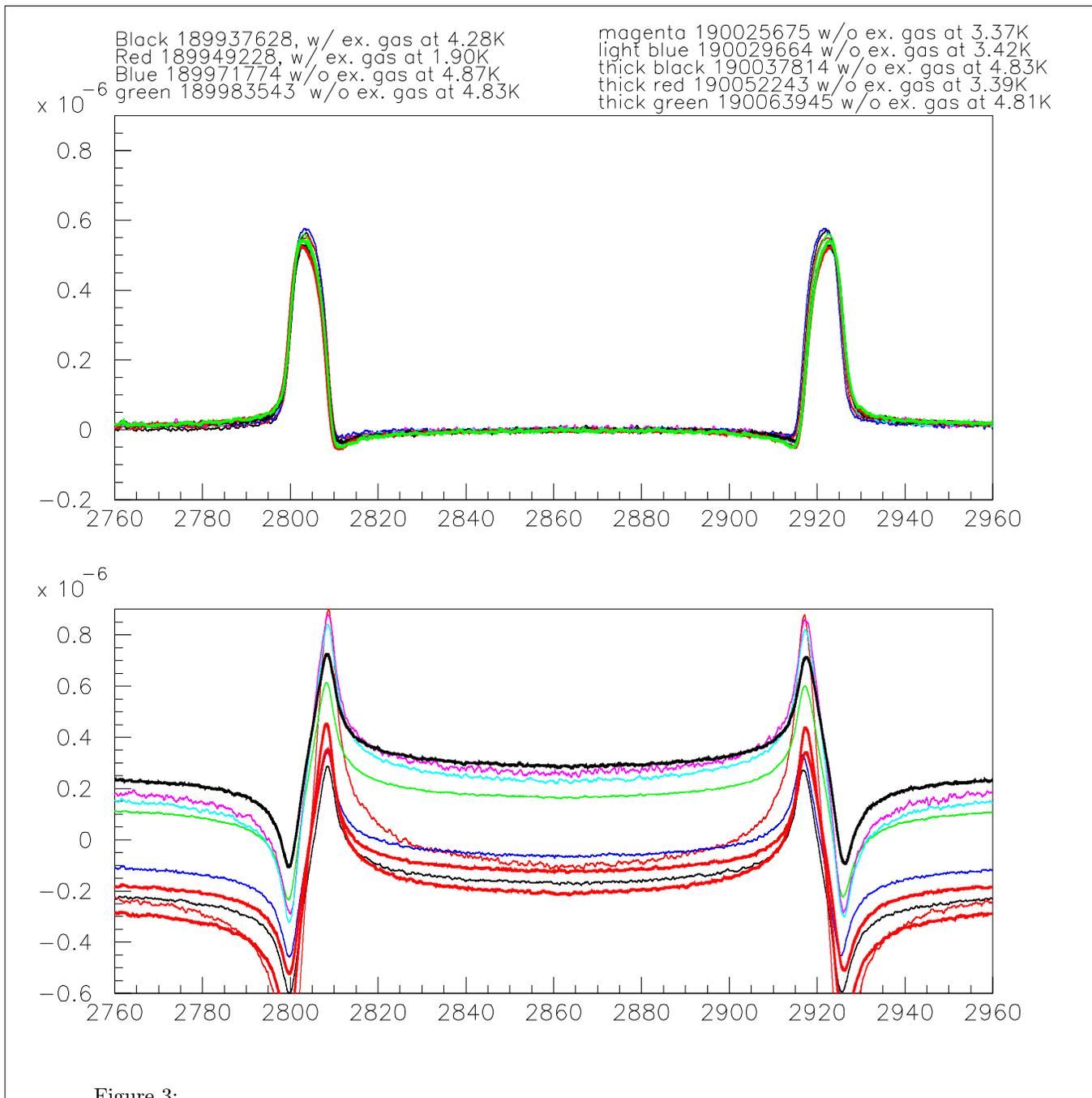


Figure 3:

Mean NMR signals from higher statistical precision runs. The top signals (lock-in x-channel) are corrected for temperatures and $\lambda/2$ amplitudes. The bottom plot (lock-in y-channel) are uncorrected.

significant.

It may be important to recall that these runs were done with a lower RF power than usual and we minimized the time during the RF was turned on. Hence, the RF heating of the target was minimized.