Lifetime and AFP loss study of ^{3}He target cells

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Abstract

In order to get the true lifetime of cells and to estimate the AFP loss of an NMR measurement, a study was done on a standard cell (Duke) and on two ice-cone cells (Pinocchio and Patton) in comparing several methods.

1 Introduction

During an NMR measurement the spin of the ^{3}He atoms are flipped by the processus of Adiabatic Fast Passage (AFP). But by this mechanism, a certain number of ^{3}He atoms don't follow the AFP and the cell loses polarization. The result is a smaller measured lifetime than the true one.

2 AFP loss test

To estimate this loss of polarization, we have performed AFP loss tests that consists of taking 10 NMR measurements quickly one after the other. Because the lifetime is measured with a "cold" target (oven and lasers are off), the AFP loss test must be performed in the same conditions.

The AFP loss test gave a relative AFP loss of 0.68% per meas. for Duke, 0.52% per meas. for Pinocchio and 0.51% per meas. for Patton.

3 Lifetime

There are three independent methods to estimate the true lifetime: the first two require a spindown and AFP loss tests and the other requires at least three spindowns with NMR measurements taken at different time intervals.

3.1 From the global correction equation

An equation was written by A. Deur to get the true lifetime from spindown and AFP loss test:

$$\Gamma_{true} = \Gamma_{meas.} + \frac{n}{T}\, ln(1-\delta) \tag{1}$$

With $\Gamma = \frac{1}{\tau}$ (τ is the lifetime), n is the number of sweeps, T is the time between the beginning and the end of the spindown and δ is the relative AFP loss (in %).

By applying this equation on the measured lifetime extracted from the spindowns, we get:

Duke	dt (hrs)	τ_{meas} (hrs)	τ_{true} (hrs)
	1.5	42.83	53.11
	3.0	47.79	53.58
	6.0	49.53	54.07
Pinocchio	dt (hrs)	τ_{meas} (hrs)	τ_{true} (hrs)
	1.5	17.24	18.41
	3.0	18.09	18.68
	6.0	18.58	18.94
Patton	dt (hrs)	τ_{meas} (hrs)	τ_{true} (hrs)
	1.5	40.12	55.20
	3.0	43.03	50.42
	6.0	45.65	49.50

where dt is the interval time between NMR measurements.

3.2 Correction point by point from AFP loss

The second method consists of correcting point by point the spindown data with the AFP relative loss as following:

$$NMR_c(i) = NMR(i) + \sum_{n=1}^{i} \delta * NMR(n) \tag{2}$$

Fitting $NMR(i)$ gives the measured lifetime and fitting NMR_c the true lifetime (or corrected lifetime) as fig.1, fig.2 and fig.3 show.

Duke	dt (hrs)	τ_{meas} (hrs)	τ_{corr} (hrs)
	1.5	42.82	52.57
	3.0	47.79	53.88
	6.0	49.53	52.39
Pinocchio	dt (hrs)	τ_{meas} (hrs)	τ_{corr} (hrs)
	1.5	17.24	19.29
	3.0	18.09	19.09
	6.0	18.58	19.31
Patton	dt (hrs)	τ_{meas} (hrs)	τ_{corr} (hrs)
	1.5	40.12	48.51
	3.0	43.03	47.57
	6.0	45.65	48.03

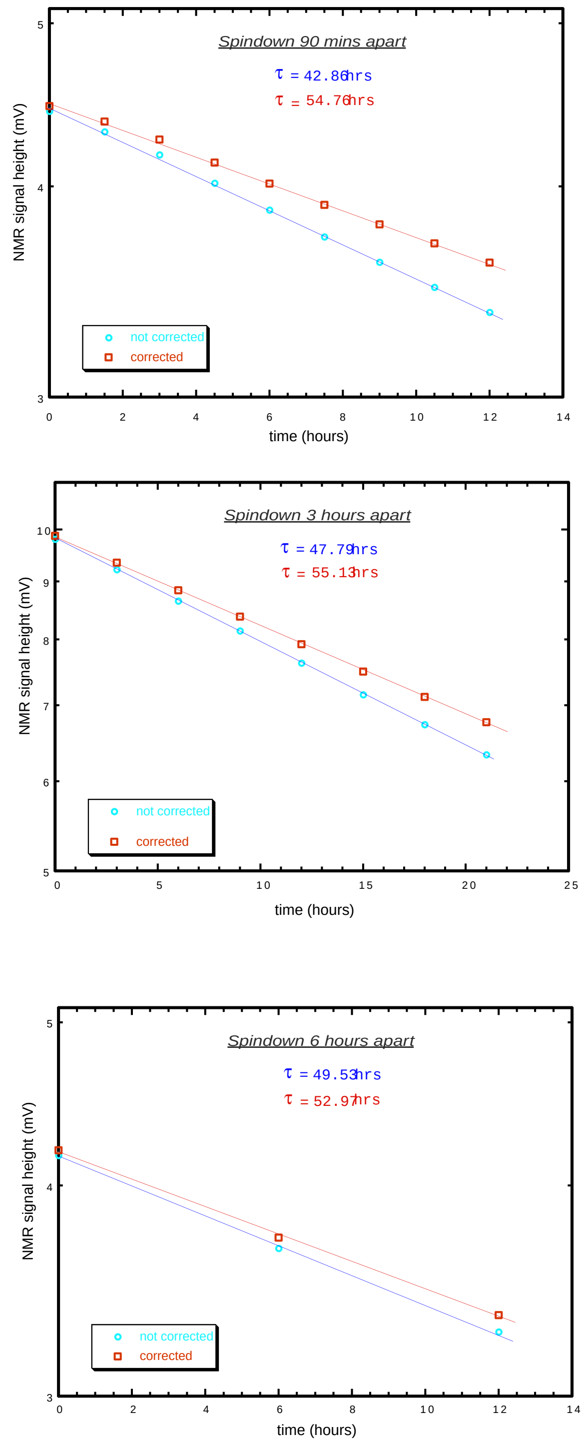

Figure 1: Three spindowns performed on Duke using different time intervals: in blue, the value of the measured lifetime; in red, the lifetime corrected by the "correction point by point" method.

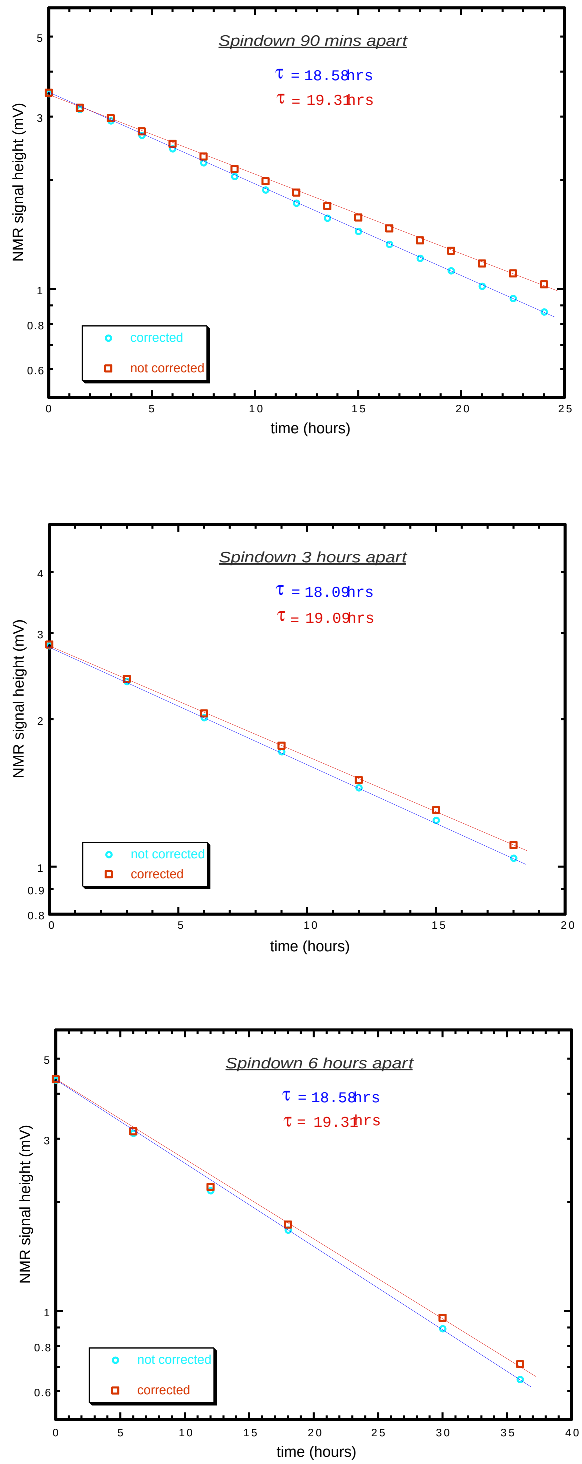

Figure 2: Three spindowns performed on Pinocchio using different time intervals: in blue, the value of the measured lifetime; in red, the lifetime corrected by the "correction point by point" method.

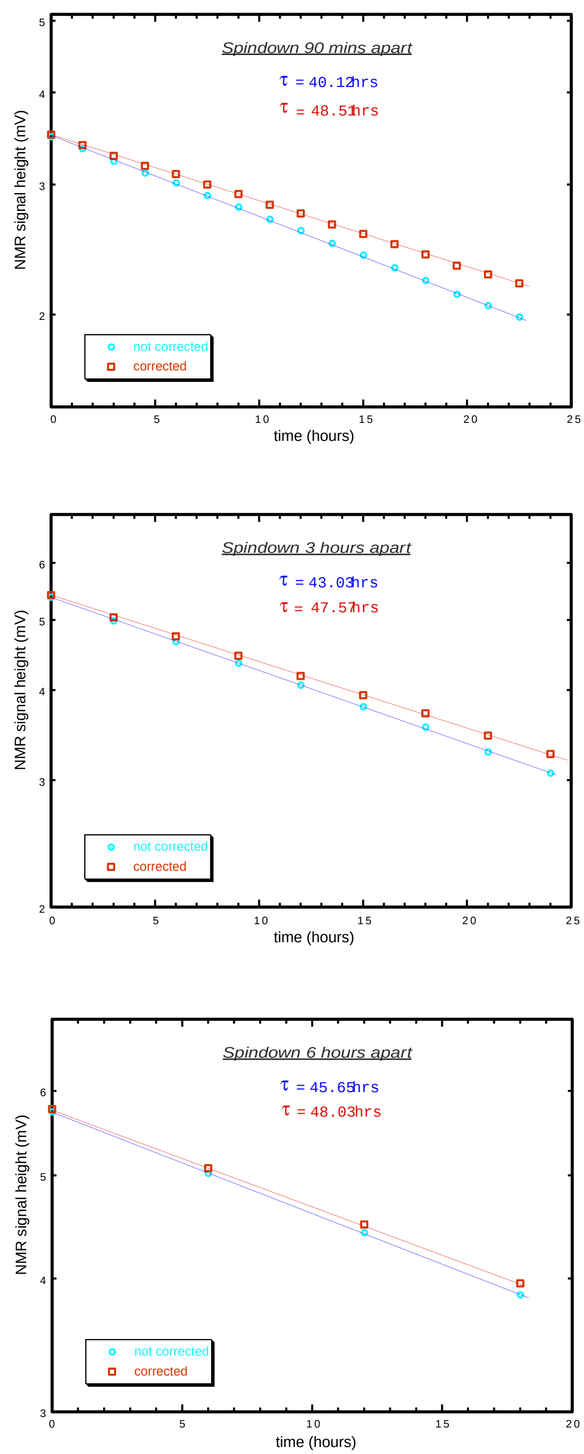

Figure 3: Three spindowns performed on Patton using different time intervals: in blue, the value of the measured lifetime; in red, the lifetime corrected by the "correction point by point" method.

3.3 Multiple-spindown test

Another method to get the true lifetime of a cell is to performed several spindowns with different delays between NMR measurements. The test was done with delays of 90 minutes, 3 hours and 6 hours. The results are in the following table.

	Duke	Pinocchio	Patton
dt (hours)	τ (hours)	τ (hours)	τ (hours)
1.5	42.98	17.24	40.12
3.0	47.79	18.09	43.03
6.0	49.54	18.58	45.65

By plotting $1/\tau$ vs. 1/dt (see fig.4), the data are well fit by a straight line. The intersection between the fit and the y-axis gives the true lifetime in the limit of no AFP losses (dt goes to infinity).

The value of the true lifetime found by this method is for Duke 52.59 hours, for Pinocchio 19.07 hours and for Patton 47.47 hours.

4 Estimation of the AFP loss

As we can see, the AFP loss test overestimates the polarization loss of an NMR measurement. As an estimation, we can extract the AFP loss value from (1) as following:

$$\delta = 1 - exp\left[\frac{T}{n}\left(\Gamma_{true} - \Gamma_{meas.}\right)\right] \tag{3}$$

Using (2), the relative AFP loss is in average 0.32% per measurement for Duke, 0.42% for Pinocchio and 0.29% for Patton. Then by correcting point by point and fitting again, the corrected lifetime becomes in average 50.02 hours for Duke, 18.97 hours for Pinocchio and 45.68 hours for Patton.

5 Conclusion

By comparing all the methods, we get good agreement between multiple-spindown and the correction-point-by-point methods at about 1% relative. However from Alexandre's equation and also from the AFP loss estimation, that is a second form of that equation, the difference with the multiple-spindown results can go as high as 9% relative.

Thus, since the multiple-spindown procedure requires 5 or 6 days which is too long during an experiment, we will trust the "correction point by point" method.

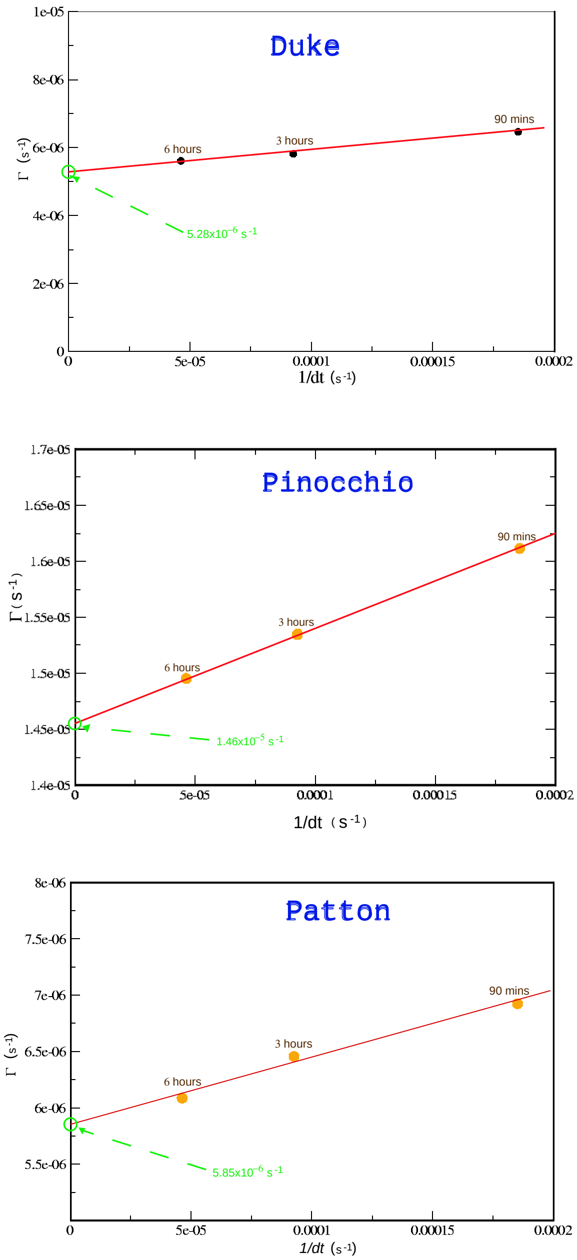

Figure 4: Results of multiple spindowns with NMR measurements taken at 90 minutes apart, 3 hours apart and 6 hours apart.