Target Analysis

Water NMR Analysis

Matthew Posik

[1] Temple University
Philadelphia, PA 19122

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Outline

Update From Last Week

- I discovered that when converting the water NMR signal from mV to μV I was applying an extra power of 10
- I also found that if I first use Minuit to find initial parameters
- Then fit the NMR data using ROOT (which uses MIGARD algorithm) gives better fit results
- In addition to fit residuals, X lock in channel was also checked

NMR Water X-Y Signals

6,189 sweeps

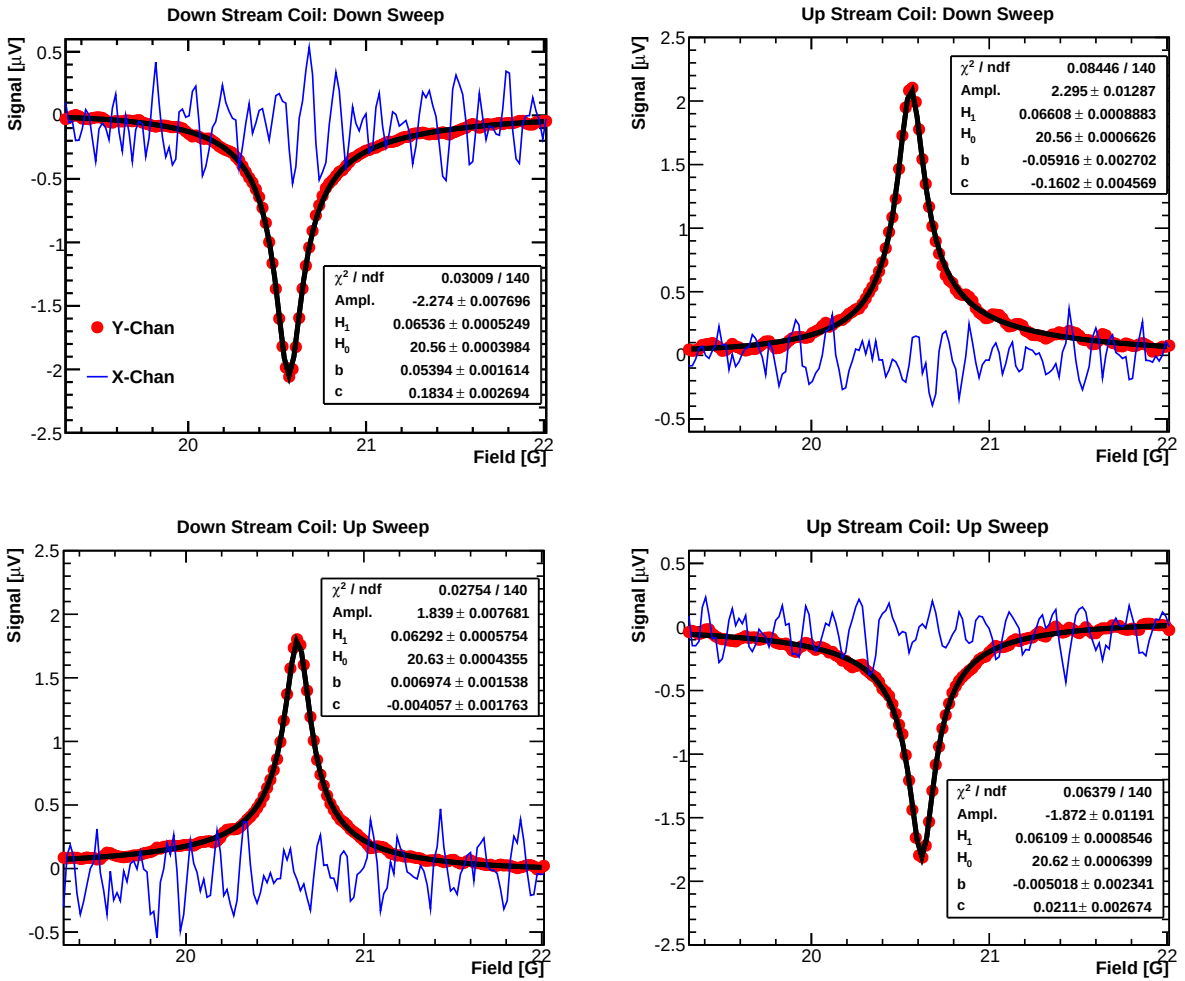

Figure: Presented are the sweep up and sweep down signals for the downstream and upstream coils. The Y lock in channel is

NMR Water Fit Residuals

6,189 sweeps

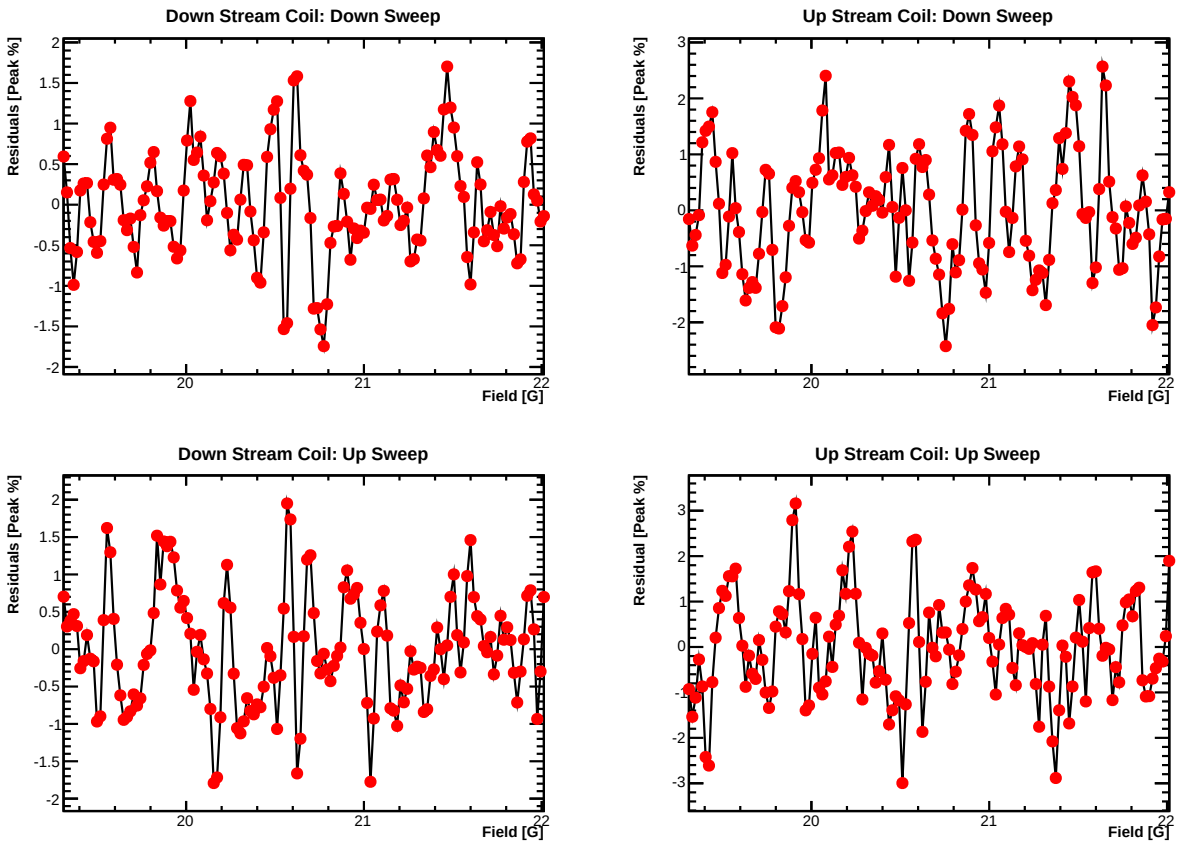

Figure: Presented are the sweep up and sweep down fit residuals for the downstream and upstream coils. The fit residual is defined as 100(data - fit)/peak.

NMR Water Coil Signals

6,189 sweeps

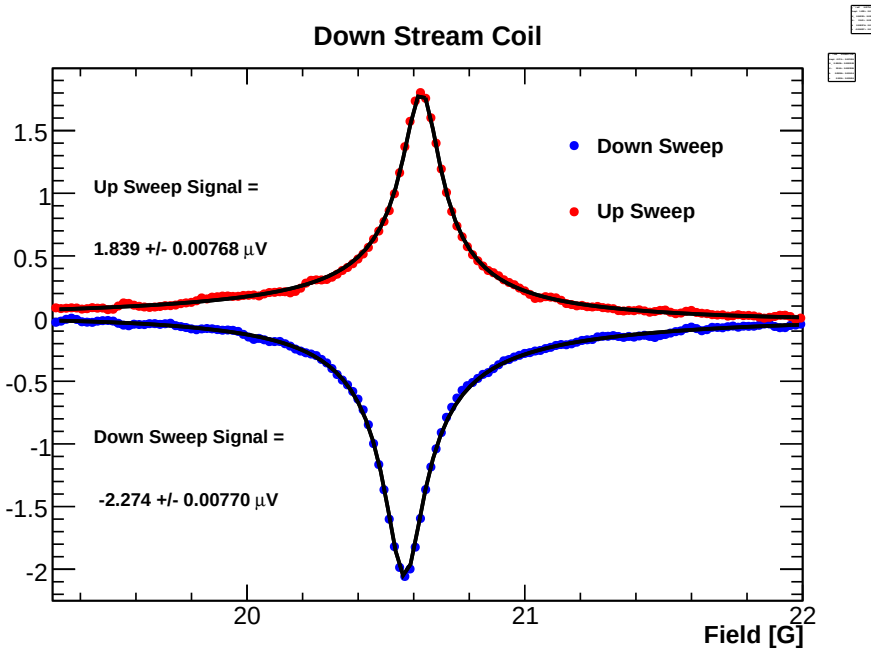

Figure: Presented are the sweep up and sweep down signals for the downstream coil. The error associated with the amplitude is statistical only.

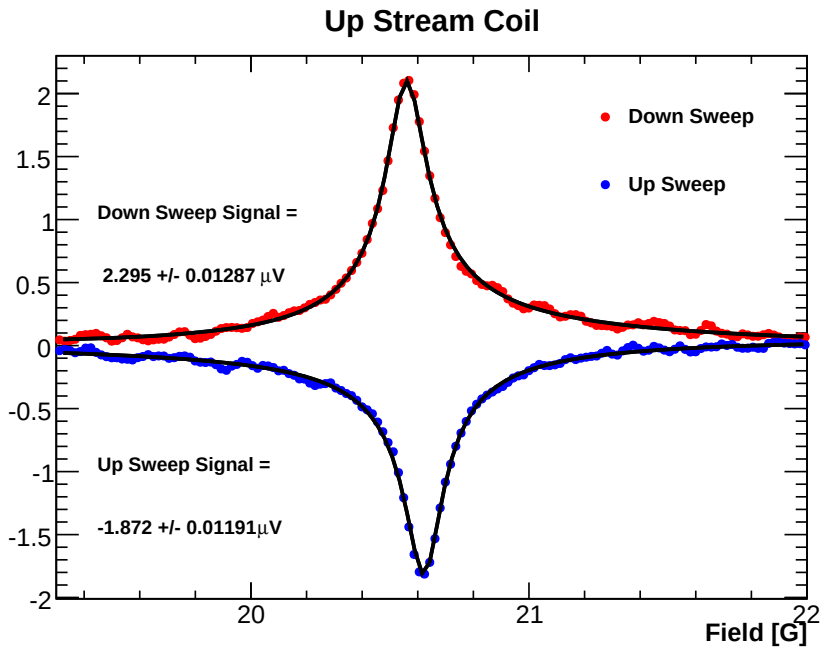

Figure: Presented are the sweep up and sweep down signals for the upstream coil. The error associated with the amplitude is statistical only.

Water NMR Fit: Summary/Comments

- Since the upstream and downstream coil measurements are in agreement we can combine like sweeps via:

$$\overline{S} = \frac{\sum_i w_i |S_i|}{\sum_i w_i}, \quad \sigma_{\overline{S}} = \sqrt{\frac{1}{\sum_i w_i}}, \quad w = \frac{1}{\sigma_S^2}$$

- Where S is the NMR signal and σ_S is the statistical uncertainty on the signal

Table: Up and down sweep signals and stat. errors from up and down stream coils and the combined coil results for 6,189 sweeps.

Signal	Amplitude [μV]	Error [μV]	Error [%]
$S_u^{(1)}$	-1.872	0.0119	0.636
$S_u^{(2)}$	1.839	0.00768	0.418
$S_d^{(1)}$	2.295	0.0129	0.562
$S_d^{(2)}$	-2.274	0.0077	0.337
$\overline{S_u}$	1.8487	0.00645	0.349
$\overline{S_d}$	2.2795	0.00661	0.290

Water NMR Fit: Summary/Comments

- Appears to be little signal if any in X channel (failed to fit NMR X signal)
- Residuals around 1.5% of amplitude value
- Statistical errors on NMR signals $< 1\%$ on all sweeps and coils
- Up and down sweeps in both coils are in agreement, combine to one sweep up and sweep down measurement
- Need to determine a systematic error

Water Calibration Constant (1)

The signal induced in the pick-up coils by the rotating spins at resonance are proportional to the macroscopic magnetization of the sample:

$$S = kM = k\mu nP$$

- S: amplitude of the lock in amplifier signal
- k: proportionality constant, taking into account gains, losses in the cables etc...
- μ: magnetic moment of the sample
- n: density of spins
- P: polarization of the sample

Water Calibration Constant (2)

The ratio of the ^{3}He NMR signal height S_{He} to the water NMR signal height S_w can be written as:

$$\frac{S_{He}}{S_w} = \frac{G_{He}}{G_w}\frac{\mu_{He}}{\mu_p}\frac{n_{He}}{n_p}\frac{\Phi_{He}}{\Phi_w}\frac{P_{He}}{P_w}$$

- S_{He}: amplitude of helium signal
- S_w: amplitude of water signal
- G_{He}: gain of the pick-up coil preamplifier in helium configuration
- G_w: gain of the pick-up coil preamplifier in water configuration
- μ_{He}: magnetic moment of ^{3}He nucleus
- μ_p: magnetic moment of the proton in water
- n_{He}: density of ^{3}He nuclei in the helium target
- n_p: density of protons in the water target
- Φ_{He}: total magnetic flux of helium cell through pick-up coils
- Φ_w: total magnetic flux of water cell through pick-up coils
- P_{He}: polarization of the helium target
- P_w: polarization of the water sample

Water Calibration Constant: P_w

- The water polarization can be computed using Boltzmann statistics

$$P_w = Tanh\left(\frac{\mu_p H_0}{k_B T_w}\right)$$

- with k_B being the Boltzmann constant and T_w begin the temperature of the water cell
- However, we can use the Bloch equations to numerically calculate the water polarization
- There are two sources of error that arise when using the Bloch equations
  - The start and end points of the integration (H-field)
    - Sweep range H = 18 - 24 G
    - Vary start and stop points by 2 G
  - The uncertainty in T_w
    - Still new to analyze

Water Calibration Constant: P_w Uncertainty Results

Table: Results of varying integration limits on water polarization.

H_i [G]	H_f [G]	Up Sweep Value $\times 10^{-9}$	Down Sweep Value $\times 10^{-9}$
18	24	6.59397	7.7827
18	26	6.59397	7.9373
16	24	6.47505	7.7827

Table: Uncertainty results from Bloch equation.

Parameter	Value	Units	Uncertainty Source [%]
Up sweep P_w	6.59397	-	1.8
Down sweep P_w	7.7827	-	2.0

Water Calibration Constant (3)

$$P_{He} = c_w \frac{S_{He}}{n_{He}\Phi_{He}}$$

$$c_w = \frac{1}{S_w}\frac{G_w}{G_{He}}\frac{\mu_p}{\mu_{He}} n_p \Phi_w P_w$$

Table: Parameters used to compute the water constant. Highlighted parameters still need to be calculated.

Parameter	Description	Value	Units	Uncertainty [%]	Source
S_w	Sweep Up Sweep Down	1.849 2.280	μV μV	0.349 0.290	Fit Fit
G_w	Gain of pick-up coil pre-amp. for water cell	20	-	-	-
G_{He}	Gain of pick-up coil pre-amp. for ^{3}He cell	1	-	-	-
μ_p/μ_{He}	-	1.3127	-	neg.	-
n_p	at 22°C	2482	amg	0.1	see M. Romalis thesis
Φ_w	Magnetic flux through pick-up coil	-	cm^2	-	-
P_w	Sweep Up Sweep Down	6.59397 7.7827	- -	1.8 2.0	Model of Bloch Eqs. Model of Bloch Eqs.

Summary and To Do

- Get water cell temperature
- Fit ^{3}He NMR data
- Look at how acceptance holes affect asymmetries
- Begin systematic error on BB cuts (All or subset of runs?)