BigBite Analysis

Live Time Corrected N2 Dilution, Corrected A2 and Water Cell Calibration Update

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Outline

5.89 A_2 Correction

- Found a mistype in my code:
- For the 5.89 GeV A_2 asymmetry I was actually returning the A_1 asymmetry value
- All other quantities are correct
- Updated the plots in

Corrected A_2

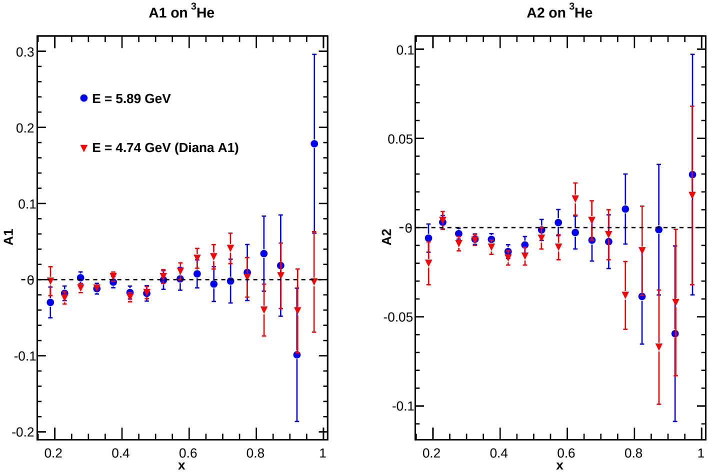

Figure: Comparison of the 4.74 GeV A_2 asymmetries from Diana's thesis (shown in red) and the 5.89 GeV A_2 asymmetries (shown in blue).

N_2 Dilution Factor

- To compute the dilution factor counts from the N_2 reference cell and ^{3}He production cell need to be corrected for:
  - Charge (Q)
  - T2 trigger pre-scale factor (ps)
  - T2 trigger live time (t_{LT})
  - Density of N_2 in the (reference,production) target cells ($\rho_{N_2}^{ref}$,$\rho_{N_2}^{prod}$)
  - $Y = \frac{Nps}{t_{LT}Q\rho}$
  - $D_{N_2} = 1 - \frac{Y_{ref}}{Y_{prod}}$

5.89 GeV Live Times

- There were a lot of runs that did not agree with the HALOG (red markers)
- Only black marker runs were used in N_2 dilution calculation

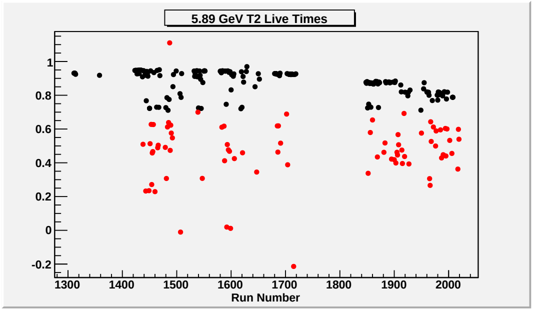

Figure: 5.89 GeV T2 trigger live time calculation. The red markers show runs where the live times were low and did not agree with the HALOG. The black markers show runs with live times that did agree. The runs marked in black were used in the nitrogen dilution factor analysis.

5.89 GeV N_2 Dilution: Dependent Quantities Per Run

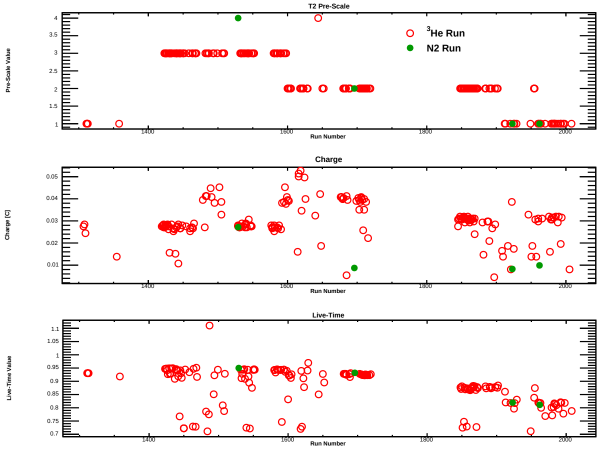

Figure: T2 trigger Pre-scale factor (top), charge (middle) and live time (bottom) as a function of run number.

5.89 GeV Densities

Run	Cell Type	Temp (°C)	Pressure (psig)	Pressure (amg)
1529	N_2 Ref.	41.7	22	2.17
1696	N_2 Ref.	42.0	100	6.77
1923	N_2 Ref.	41.6	113	7.54
1962	N_2 Ref.	41.9	120	7.95
-	Production	-	-	0.113

Table: Nitrogen reference cell densities for some 5.89 GeV runs.

5.89 GeV Yields Per Bin

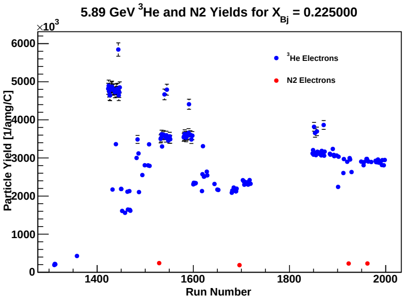

Figure: Yields in bin 5 for electrons scattering off of nitrogen in the reference and production cells.

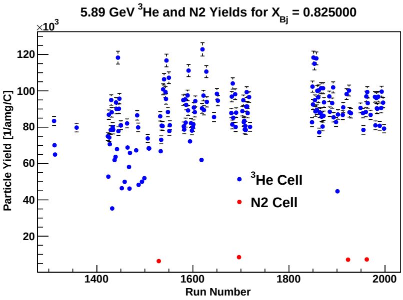

Figure: Yields in bin 17 for electrons scattering off of nitrogen in the reference and production cells.

4.74 and 5.89 GeV N_2 Dilution Factors

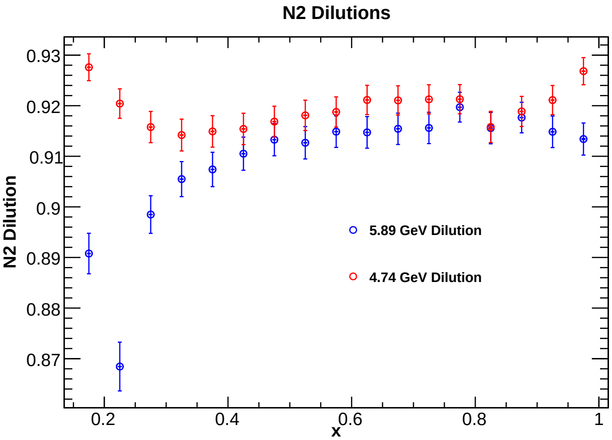

Figure: Comparison of the 4.74 GeV nitrogen dilution factor with live time corrections (red markers), see talk from 03/01/2012 and 5.89 GeV nitrogen dilution factor with live time corrections (blue markers)

Water Calibration

- Last week I numerically solved 3 Bloch equations describing the proton polarization in 3 directions (x,y,z)
- However, we can combine the 3 Bloch equations into 1 effective equation assuming $T1 = T2$
- The effective polarization equation can be solved numerically, however we need an analytic form to fit the NMR data
- The effective polarization equation can be analytically approximated

Bloch Equations Parameters

- T_1: Longitudinal relax time
- T_2: Transverse relax time
- H_0: Resonance field
- H_1: Transverse field component
- $H(t) = H_0 + \alpha t$: field component along z axis (α = 1.2 G/s)
- γ: gyro-magnetic ratio of the proton
- χ: $\frac{\mu_{p,H_2O}}{kT}$
- μ_{p,H_2O}: magnetic moment of proton in water
- k: Boltzmann constant
- T: Temperature of target chamber

Bloch Equations

- Bloch equations describe time evolution of the water polarization

$$\frac{dP_x(t)}{dt} = -\frac{1}{T_2}P_x(t) + \gamma\left(H(t) - H_0\right)P_y(t) + \frac{1}{T_2}\chi H_1 \quad (1)$$

$$\frac{dP_y(t)}{dt} = -\gamma\left(H(t) - H_0\right)P_x(t) - \frac{1}{T_2}P_y(t) + \gamma H_1 P_z(t) \quad (2)$$

$$\frac{dP_z(t)}{dt} = -\gamma H_1 P_y(t) - \frac{1}{T_1}P_z(t) + \frac{1}{T_1}\chi H(t) \quad (3)$$

Effective Polarization

$$P_{eff} = k\sqrt{P_x^2 + P_y^2 + P_z^2} \tag{4}$$

where $k = \pm 1$

$$\frac{dP_{eff}}{dt} = \frac{P_x \dot{P}_x + P_y \dot{P}_y + P_z \dot{P}_z}{P_{eff}} \tag{5}$$

$$\frac{dP_{eff}(t)}{dt} = \frac{1}{T_1}\left(P_{eff}(t) - P_{eq}(t)\right) \tag{6}$$

where $P_{eq}(t) = \chi \frac{H_1^2 + \alpha t(H_0 + \alpha t)}{\sqrt{(H_1^2 + \alpha^2 t^2)}}$

$$\frac{P_x}{P_{eff}} = \frac{H_1}{\sqrt{H_1^2 + \alpha^2 t^2}} \tag{7}$$

$$\frac{P_z}{P_{eff}} = \frac{\alpha t}{\sqrt{H_1^2 + \alpha^2 t^2}} \tag{8}$$

Effective Polarization Solution

$$P_{eff}(t) = e^{-(t-t_i)/T_1}\left(P_{eq}(t_i) + \frac{1}{T_1}\int_{t_i}^{t} e^{(u-t_i)/T_1} P_{eq}(u)du\right) \quad (9)$$

- This equation does not have an exact analytic solution
- Equation does have an approximate analytical solution
- Can expand in three regions

Approximate Solution: Case 1

- if $t_i \leq t < t_a$, $\alpha|t| >> H_1$
- Expand square root

$$\frac{H_1^2 + H_0\alpha u + \alpha^2 u^2}{\alpha u\sqrt{1 + \frac{H_1^2}{\alpha^2 u^2}}} \simeq -\left(H_0 + \alpha u + \frac{H_1^2}{2\alpha u}\right) \tag{10}$$

Solution in this region:

$$P_{eff}(t) \simeq e^{-(t-t_i)/T_1}\left(P_{eq}(t_i) - \frac{\chi}{T_1}\int_{t_i}^{t} e^{(u-t_i)/T_1}\left(H_0 + \alpha u + \frac{H_1^2}{2\alpha u}\right)du\right) \tag{11}$$

Approximate Solution: Case 2

- if $t_a \leq t < t_b$, $|u| << T_1$
- Expand exponential

$$e^{(u-t_i)/T_1} \simeq e^{-t_i/T_1}\left(1+\frac{u}{T_1}+\frac{u^2}{2T_1^2}\right) \tag{12}$$

Solution in this region:

$$P_{eff}(t) \simeq e^{-(t-t_i)/T_1}[P_{eq}(t_i) - \frac{\chi}{T_1}\int_{t_i}^{t_a} e^{(u-t_i)/T_1}\left(H_0+\alpha u\right)du$$

$$+\frac{\chi}{T_1}e^{-t_i/T_1}\int_{t_a}^{t}\left(1+\frac{u}{T_1}+\frac{u^2}{2T_1^2}\right)\frac{H_1^2+H_0\alpha u+\alpha^2u^2}{\sqrt{H_1^2+\alpha^2u^2}}du]$$

Approximate Solution: Case 3

- if $t_b \leq t < t_f$, $\alpha|t| >> H_1$
- Expand square root

$$\frac{H_1^2 + H_0\alpha u + \alpha^2 u^2}{\sqrt{H_1^2 + \alpha^2 u^2}} \simeq \frac{H_0\alpha u + \alpha^2 u^2}{\alpha u} \frac{1}{sqrt 1 + \frac{H_1^2}{\alpha^2 u^2}} \simeq (H_0 + \alpha u) \tag{13}$$

Solution in this region:

$$P_{eff}(t) \simeq e^{-(t-t_i)/T_1} [P_{eq}(t_i) - \frac{\chi}{T_1} \int_{t_i}^{t_a} e^{(u-t_i)/T_1} (H_0 + \alpha u)\, du$$

$$+ \frac{\chi}{T_1} e^{-t_i/T_1} \int_{t_a}^{t_b} \left(1 + \frac{u}{T_1} + \frac{u^2}{2T_1^2}\right) \frac{H_1^2 + H_0\alpha u + \alpha^2 u^2}{\sqrt{H_1^2 + \alpha^2 u^2}} du$$

$$+ \frac{\chi}{T_1} \int_{t_b}^{t} e^{(u-t_i)/T_1} (H_0 + \alpha u)\, du]$$

Approximate Analytical Solution

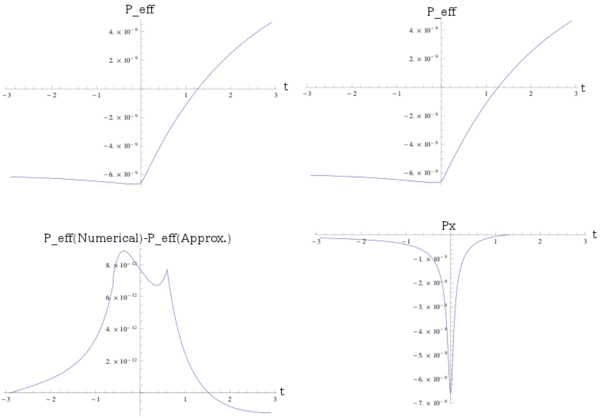

Figure: The top left plot shows the effective polarization solved numerically and the top right plot shows the approximate solution to the effective polarization. The bottom left plot shows the difference between the numerical and approximate effective polarization solutions. The bottom right plot shows the what the NMR signal should look like with no background contribution.

Water Calibration Summary

- Approximate analytical form of effective polarization is in good agreement with numerical effective polarization
- Level of agreement matches what Sbastien Incerti calculated (E94010 Technical Note 10)

What's Next

- Look more into in-plane angle shift
- Look at run by run pion asymmetries
- Fit approximate analytic solution to NMR data
- Compute preliminary 4-pass g_1,g_2 and d_2