N_2 Dilution Analysis for saGDH

Xiaohui Zhan(zhanxh@jlab.org)
MIT,Cambridge,MA 02139

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1 Introduction

Experiment E97-110 measured asymmetries for polarized electron scattering off polarized ^{3}He at very low Q^2 range. A small amount of N_2 is added to the target cell to quench unwanted photon emissions which could cause depolarization[1]. To estimate the dilution effect due to ~1% unpolarized N_2 in the target cell, data were taken at almost every kinematics with the N_2 reference cell. In the following, a detailed study of the dilution factor analysis is presented for both cells "Penelope" and "Priapus".

2 N_2 Dilution for Elastic Data

The N_2 dilution factor is defined by:

$$f_{\mathrm{N}_2} = 1 - \frac{N_{\mathrm{N}_2}}{N_{^3\mathrm{He}}} = 1 - \frac{\sigma_{\mathrm{N}_2}}{\sigma_{^3\mathrm{He}}} \cdot \frac{n_{\mathrm{N}_2}}{n_{^3\mathrm{He}}} \tag{1}$$

where $N_{\mathrm{N}_2}(N_{^3\mathrm{He}})$ is the N_2(^{3}He) yield, $\sigma_{^3\mathrm{He}}$ is the ^{3}He cross section from the polarized ^{3}He cell data, σ_{N_2} is the N_2 cross section from the N_2 reference cell. $n_{\mathrm{N}_2}(n_{^3\mathrm{He}})$ is the N_2(^{3}He) density inside the polarized ^{3}He cell under running conditions.The densities can be obtained by two ways. First, one can use the filling density measured when the cell was made (at room temperature) for both N_2 and ^{3}He. Since the temperature is higher in the pumping chamber than the target chamber under running condition, the densities are larger in the target cell than the filling density, and this can be corrected by comparing the ^{3}He filling density with the measured one during the experiment. Another way is by pressure curves, i.e.,a curve of yield vs. pressure, and this can be a check of the filling densities. For Elastic Data, the ratio of the cross sections can be obtained from the slopes of the ^{3}He and N_2 elastic pressure curves[2].

2.1 N_2 and ^{3}He Pressure Curves

The elastic data were taken by using refernece cell with different pressures. The cuts which were applied are:

dpcut	± 2σ deviating from the elastic peak in CorS.dp
gcut	lose graphic cut in R.tr.r_x:R.tr.r_y plane(see Figure 1)
n1	"R.tr.n==1", one track only event
t1	T1 trigger
zcut	"abs(rpr.z)<0.2" cut on target length
thph	"(abs(CorS.th)<0.07)&&(abs(CorS.ph)<0.04)" acceptance cut
PID	PID cut, but little effect for elastic runs

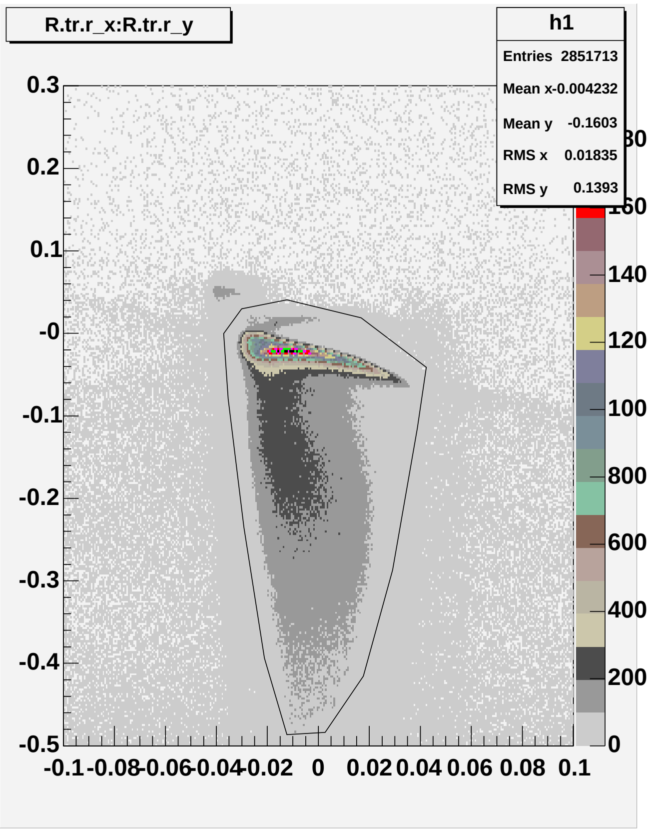

Figure 1: A typical gcut in focal plane.

In target θ-ϕ plane, there is an enhanced region at negative θ, and it is probably caused by rescattering off the collimator. This contamination can be partly reduced through a graphic cut(gcut) in focal plane, and after background(reference cell empty run) substraction, it only has a small effect.

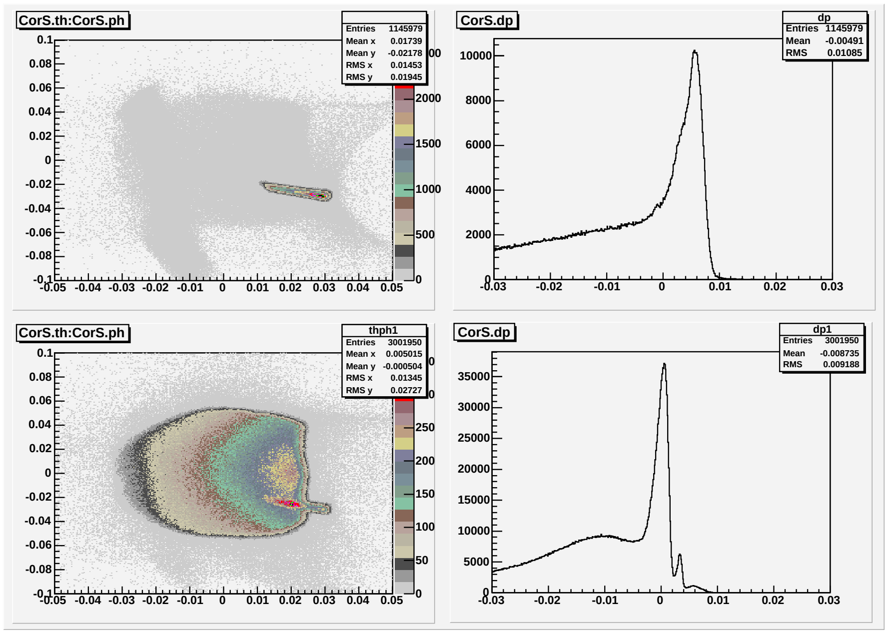

Figure 2: Target θ-ϕ plane plots together with dp plots for an reference cell empty run(up) and a polarized ^{3}He run(down).

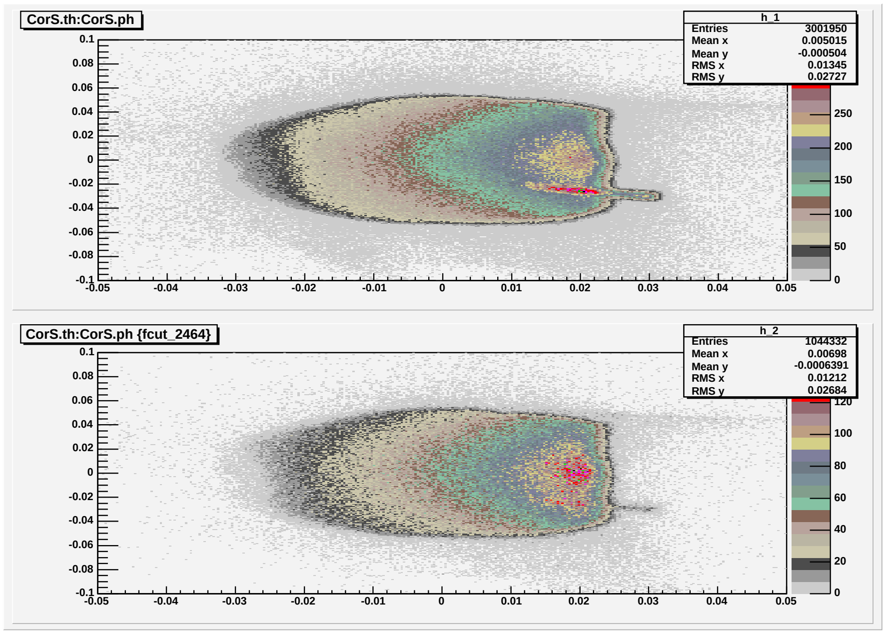

Figure 3: Target θ-ϕ plane plots before and after gcut. We can see an obvious improvement after gcut.

In elastic analysis, we want a very good resolution of the elastic peak position, so a small correction(dpkin) based on CorS.dp[1] was introduced to narrow down the peak width which was smeared due to the acceptance(Figure 4).

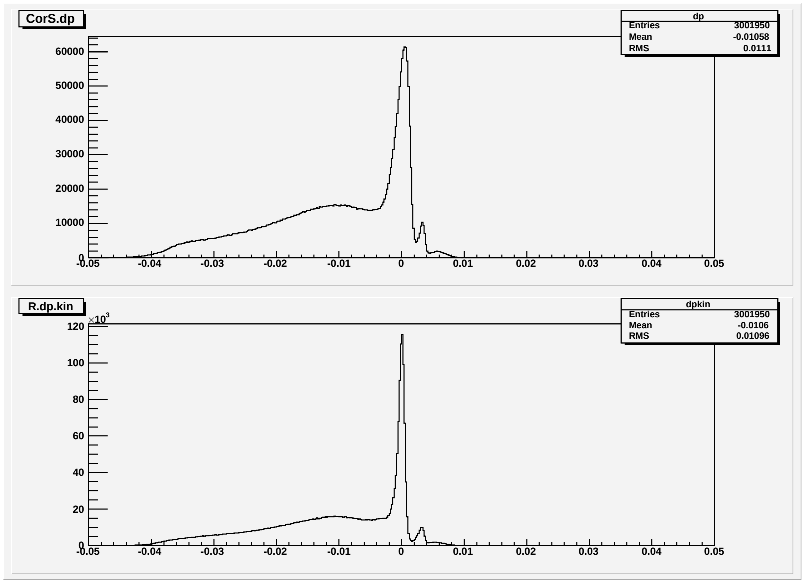

Figure 4: dp plots for Pol. ^{3}He run. The elastic peaks of N_2 and ^{3}He are well separated after dpkin.

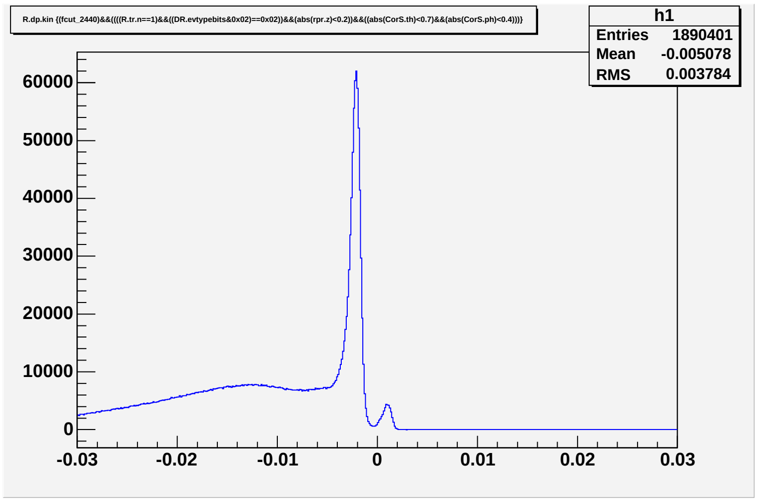

Figure 5: Pol. ^{3}He dpkin plot after background substraction.

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[1] Target relative momentum(delta) after septum shift correction[3].

2.1.1 ^{3}He Pressure Curve

The elasitc ^{3}He reference cell data were taken at 4 different pressures to check the ^{3}He density of the polarized cell under operating conditions. The vertical axis is counts defined by:

$$counts = \frac{Y_{raw} \cdot ps1}{Q \cdot L_{t1} \cdot k} \propto n \cdot \sigma \tag{2}$$

where Y_{raw} is the counts of raw data through all cuts, $ps1$ is the T1 prescale factor, Q is the charge, L_{t1} is the T1 trigger livetime, and k is the one-track-only correction factor defined by $k = \frac{yield_{n1\&\&t1}}{yield_{t1}}$. It is proportional to the product of density n and cross section σ(Figure 6).

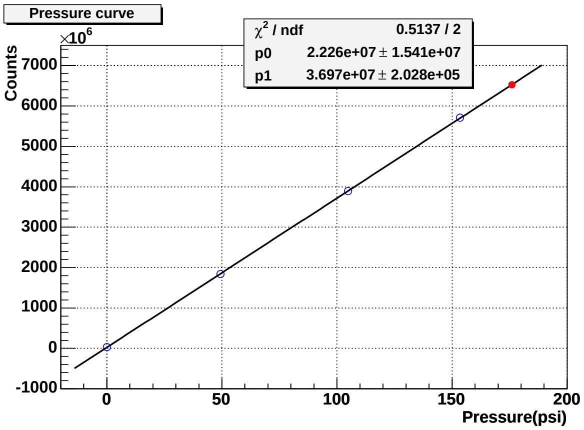

Figure 6: ^{3}He pressure curve. Reference data fit linearly(blue) and extrapolate to the target cell data point(red) to get the target cell pressure P_{target}(in psi).

The density can be extracted by:

$$n = 0.901 \cdot \frac{P_{target}}{14.7} \text{amg} \tag{3}$$

Finally, the ^{3}He density of polarized target cell "Penelope" is $n_{^3\mathrm{He}} = 10.78 \pm 0.03 \pm 0.18$amg ($\pm statistical$ $\pm systematic$)from pressure curve.

2.1.2 N_2 Pressure Curves

Since there is only ~1% N_2 in the target cell, it is difficult to extract a precise value by fitting the pressure curve. And due to the much higher rate in N_2 elastic run, the inefficiency of VDC must be considered. As a result, the linear fit of Counts vs. Pressures is not good enough to determine the N_2 density in the target cell(Figure 7).

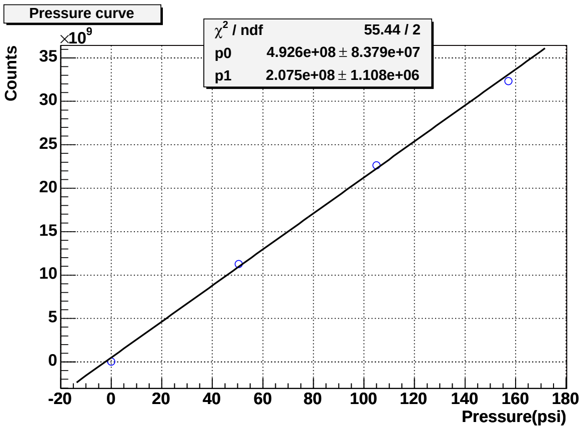

Figure 7: N_2 pressure curve fit linearly.

Although right now we don't know the exact behavior of VDC in such high rate and how it affects the one-track-only factor k, we can try to include this correction in a second order term in the yield and fit the data quadratically(Figure 8).

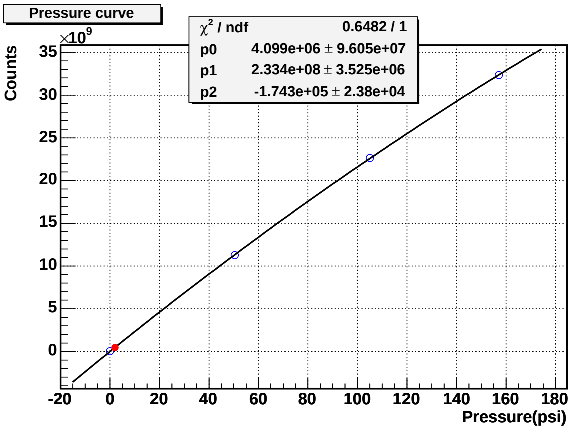

Figure 8: N_2 pressure curve fit quadratically.

The N_2 density is: $n_{\mathrm{N}_2} = 0.1189 \pm 0.0257 \pm 0.0020$amg from the pressure curve above.

2.1.3 N_2 Dilution Factor

Since the yield(counts) is proportional to the product of density and cross section, the ratio of the N_2 cross section to ^{3}He is the ratio of the slopes of their pressure curves. In order to get the slope of N_2 pressure curve, it is resonable to fit the first two points which have lower rate to reduce the impact of VDC ineffeciency(Figure 9).

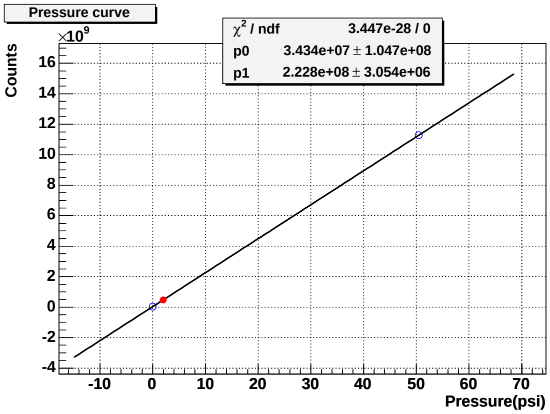

Figure 9: N_2 pressure curve fit with the first two points to get the slope.

The N_2 data were taken in a reference cell with physical properties very similar to the polarized ^{3}He target(see table 1)[4]. Therefore, radiative corrections are not necessary for this N_2 dilution analysis.

Table 1: Cell wall thickness information.

Cell	beam left wall(mm)	beam right wall(mm)
Penelope	0.694	0.622
refcell	0.693	0.638
Priapus	0.760	0.600
refcell	0.711	0.610

Under running conditions, the temperature of the pumping chamber was higher than the target chamber, so the density in the target chamber was larger than the filling densities when the temperatures were the same in both chambers. From the ^{3}He density measurement performed during the experiment, the N_2 dentisy can also be obtained(see table 2).

Table 2: N_2 and ^{3}He densities(amg) of polarized ^{3}He target cell, $\rho_{^3\mathrm{He}}$ and $\rho_{\mathrm{N}_2}$are the filling densities at room temperature[5], $d_{^3\mathrm{He}}$ and d_{N_2} are the densities from the temperature test during the experiment.

Cell	$\rho_{^3\mathrm{He}}$	ρ_{N_2}	$d_{^3\mathrm{He}}$	d_{N_2}	Date
Penelope	9.28	0.0939	10.81±0.02	0.1094±0.0002	07/06/2003
Priapus	8.96	0.0962	10.76±0.03	0.1155±0.0003	07/24/2003
			10.76±0.01	0.1155±0.0001	07/30/2003
			10.726±0.002	0.1152±0.0000	08/03/2003
			10.718±0.029	0.1151±0.0003	08/12/2003
			10.84±0.03	0.1164±0.0003	08/13/2003

The measured densities were used for the dilution factor extraction, $p1$ is the pressure curve slope.

$$\frac{\sigma_{\mathrm{N}_2}}{\sigma_{^3\mathrm{He}}} = \frac{p1_{\mathrm{N}_2}}{p1_{^3\mathrm{He}}} \tag{4}$$

$$\frac{\sigma_{\mathrm{N}_2}}{\sigma_{^3\mathrm{He}}} = \frac{p1_{\mathrm{N}_2}}{p1_{^3\mathrm{He}}} \tag{5}$$

Finally, the dilution factor for cell “Penelope”(elastic):

$$f = 0.9390 \pm 0.0139$$

3 N_2 Dilution for Inelastic Data

In this experiment, a large amount of data were taken in the inelastic region by cell “Priapus”. Since in the inelastic region, the yield of N_2 cannot be separated from the ^{3}He as in the elastic case, we can only use the yield of N_2 reference run together with an empty run and production run in the same kinematic condition to extract the dilution factor, so a precise density information is needed. Unfortunatly, there was no elastic polarized ^{3}He run taken corresponding to the pressure curve setting, so it is impossible to check the fill densities by pressure curves. However, through the elastic analysis, we can see that the fill densities are reliable.

The cuts which were applied are slightly different from elastic case:

dpcut	[-0.045,0.045] in CorS.dp
gcut	lose graphic cut in R.tr.r_x:R.tr.r_y plane
n1	“R.tr.n==1”, one track only event
t1	T1 trigger
zcut	“abs(rpr.z)<0.3” cut on target length
thph	“(abs(CorS.th)<0.05)&&(abs(CorS.ph)<0.04)” acceptance cut
PID	PID cuts from Cherenkov, preshower, and shower

To extract the dilution factor for each kinematic setting, the N_2 density information is crucial. The density in the target cell is already available(see table 2), and the reference cell density(in amg) is calculated by:

$$\rho = \frac{273.15}{T} \cdot (\frac{P}{14.7} + 1) \tag{6}$$

where T is the reference cell temperature in Kelvin, and P is the pressure in psig[2]. RTDs were not installed on the reference cell during this experiment, therefore we’ll assume a beam ON temperature is about (30± 5) Celsius, and the density can be calculated from the pressure approximatly by:

$$\rho = 0.901 \cdot (\frac{P}{14.7} + 1) \tag{7}$$

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[2] psig: pressure relative to atmospheric pressure (14.7 psi at STP)

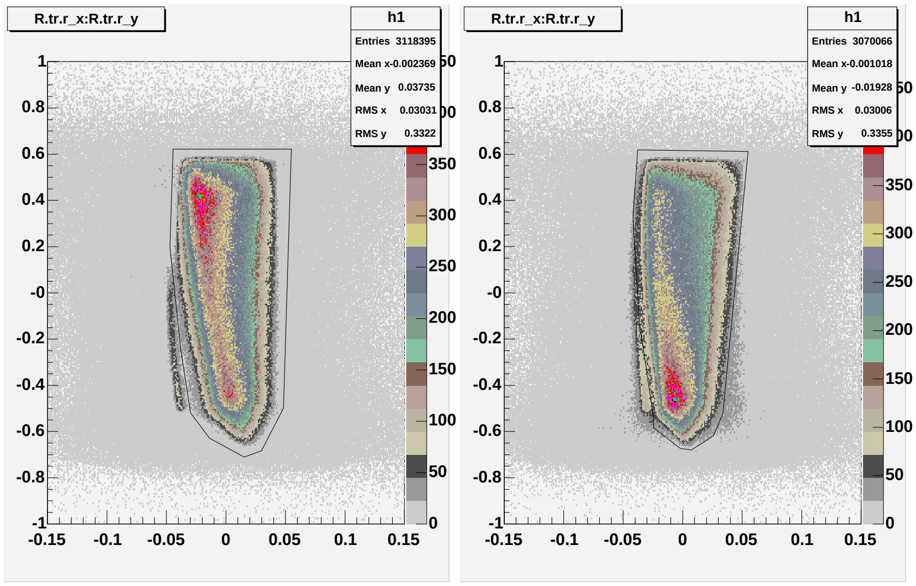

Figure 10: Typical gcuts for inelastic runs, $W = 1067 MeV$(left), $W = 2003 MeV$(right).

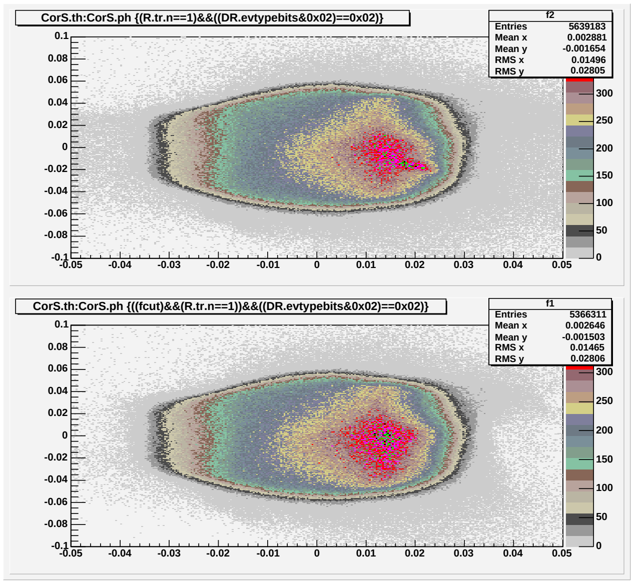

Figure 11: Target θ-ϕ plane plots before and after gcut.

The pressures of reference cell were recorded both by hand and by EPICS, and they were both used[3]. For EPICS reading, the baseline of the pressure gauge would drift by a few psi, one way to correct it is by looking at the pressure recorded of the nearest empty reference

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[3] EPICS reading were used only when the hand recorded value was not available.

cell run. Empty reference cell is assumed to be actually empty, so by comparing it's reading with the vacuum pressure(-14.7psig), the offset can be determined for that short period[6].

The N_2 dilution factor can be calculated by:

$$f_{\mathrm{N}_2} = 1 - \frac{N_{\mathrm{N}_2}}{N_{^3\mathrm{He}}} \tag{8}$$

$$\frac{N_{\mathrm{N}_2}}{N_{^3\mathrm{He}}} \propto \frac{(Y_{\mathrm{N}_2} - Y_{empty}) \cdot x_{\mathrm{N}_2}}{Y_{^3\mathrm{He}} - Y_{empty}} \tag{9}$$

$$x_{\mathrm{N}_2} = \frac{\rho_{target}}{\rho_{ref}} \tag{10}$$

where Y is the yield for each kind of run, x_{N_2} is the ratio of the N_2 densities of the polarized target cell to the reference cell. By a rough estimation, $\frac{N_{\mathrm{N}_2}}{N_{^3\mathrm{He}}}$ has error less than ~3%, and this becomes ~0.3% for f.
From the data, we found that for low central momentum settings, the yield from the cell is large, then we need to define the cell dilution factor by:

$$f_{cell} = 1 - \frac{N_{empty}}{N_{^3\mathrm{He}}} \tag{11}$$

$$\frac{N_{empty}}{N_{^3\mathrm{He}}} \propto \frac{Y_{empty}}{Y_{^3\mathrm{He}} - (Y_{\mathrm{N}_2} - Y_{empty}) \cdot x_{\mathrm{N}_2}} \tag{12}$$

There were 8 different settings(Figure 12).

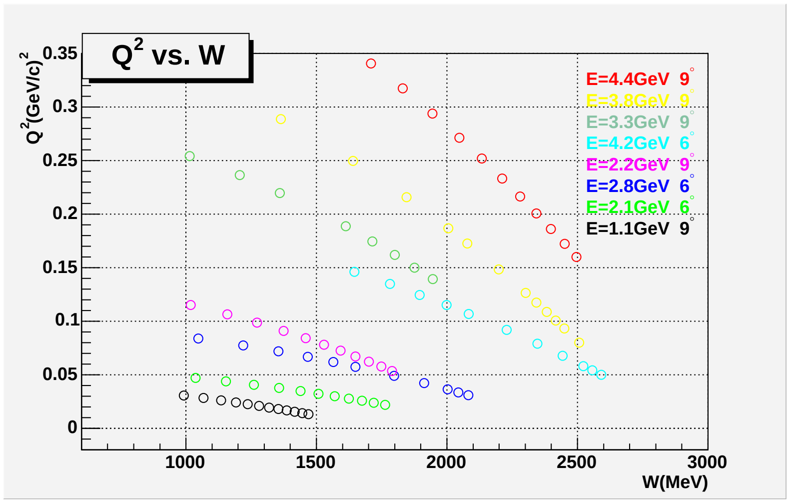

Figure 12: 8 different settings for 6 and 9 degree

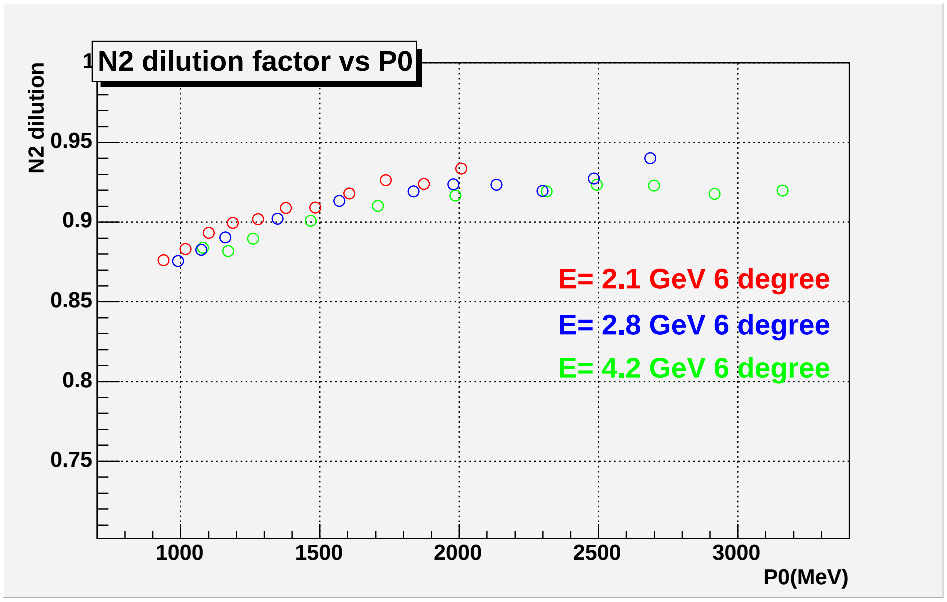

Figure 13: N2 dilution factors vs. $P0$ at 6 dgree.

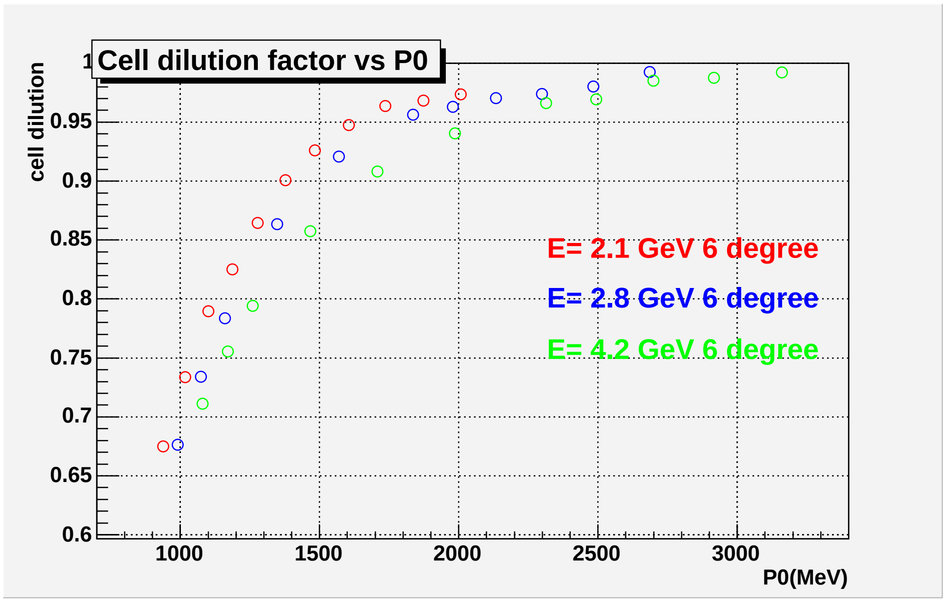

Figure 14: Cell dilution factors vs. $P0$ at 6 dgree.

From these plots, we can see that the N_2 dilution factors have some variation but small, and the cell dilution factors have a significant increase with the central momentum due to the larger background induced by radiation from the cell in lower momen-

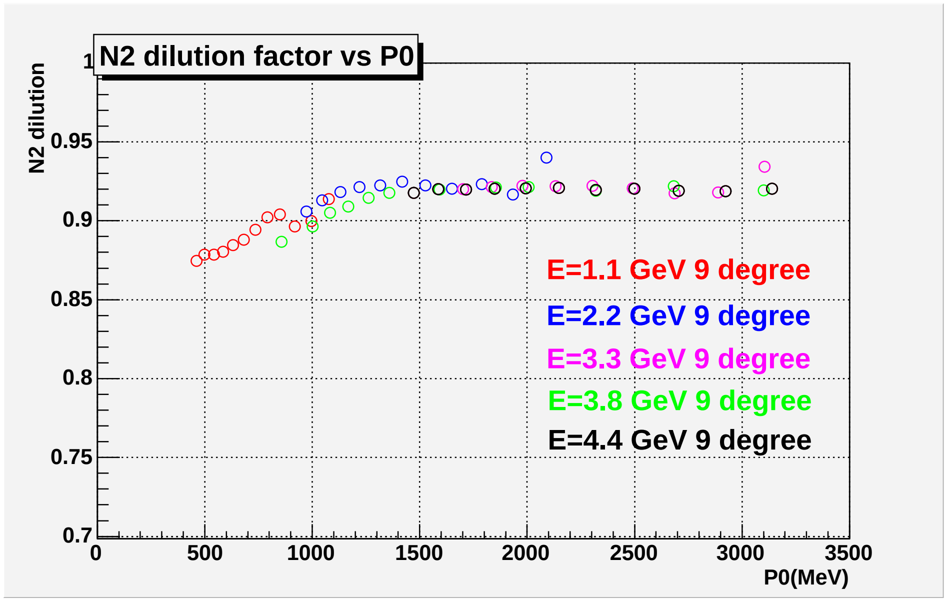

Figure 15: N2 dilution factors vs. $P0$ at 9 dgree.

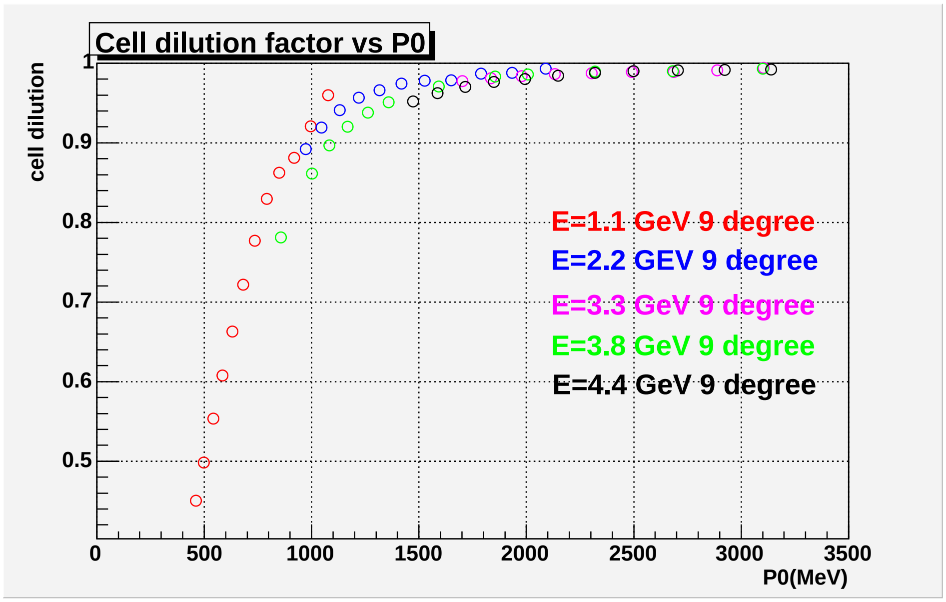

Figure 16: Cell dilution factors vs. $P0$ at 9 dgree.

tum region. For setting at 2.1GeV 6 degree, the last four high momentum setting points are given by using cell “Penelope”. Since another 2 settings(E=2.1GeV, P0=2006.7MeV, P0=1872.7MeV)have data taken with “Priapus” without reference cell runs, the N_2 dilution factors for those runs can only be obtained by correcting the dilution factors of “Penelope”

at the same settings. Due to the small amount N_2, this correction is small($\sim$0.5%). For dilution factors from the glass cell, this difference should also affect the radiative correction. From Table 1, we can see that the difference of the beam right wall thickness between these cells are within 5%, and the glass dilution factors connect well between these two cells, so we can just use the "Penelope" dilution data at least for now. For 9 degree data, there are 3 settings(E=3.8GeV, P0=2884MeV, P0=2495MeV, P0=2158MeV)at which the reference cell runs were missing. At this time, we have to interpolate between settings.
The complete list of dilution factors can be found in Jaideep's database.

References

[1] P. Solvignon,*Nitrogen cross sections and dilution factor for* $1.0<Q^2<4.0(GeV/c)^2$, E01-012 Analysis Report 08, January 2006

[2] X. Zheng, Ph.D. thesis, MIT, 2002

[3] V. Sulkosky, *Manual on Shift Corrections due to the Septum Saturation Effect*, E97-110 Tech-note 09, Septumber 2006

[4] HALOG record, http://hallaweb.jlab.org/adaq/log/html/0307_archive/030719191846.html

[5] J. Singh, *Cell Data Table*, http://galileo.phys.virginia.edu/research/groups/spinphysics/celldata2003.htm

[6] J. Singh, *Run Summary Page*, http://www.jlab.org/%7Esinghj/runsummary/