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Radiation Lengths used in E94010 Analysis v. 3.0

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The radiative corrections depend upon the thickness of material before and after scattering. This short note is intended to estimate the uncertainty associated with the radiation lengths used [1] in the E94010 analysis.

Contents

Pre-Target Material					
Material		thickness (cm.)	error (%)	Rad. Length	% of Tot. thickness
Be	15±1.5mil	0.0381	10	10.80×10^{-4}	19.3
Air	1±0.5in	2.54	50	8.349×10^{-5}	1.5
Al	15.4±1mil	0.0391	6.5	4.397×10^{-3}	78.4
^{4}He		25.7	10	4.534×10^{-5}	0.8
Total			5.5	5.606×10^{-3}	100
Post-Target Material					
Material		thickness (cm.)	error (%)	Rad. Length	% of Tot. thickness
^{4}He		42	6.0	7.410×10^{-5}	0.7
Al	16±1mil	0.0406	6.3	4.566×10^{-3}	44.8
Air		62.6	8.8	2.058×10^{-3}	20.2
Kapton	7.2±0.2mil	0.0183	2.7	6.407×10^{-4}	6.3
Total			4.6	7.338×10^{-3}	100

Table 1: Note *"% of Tot. thickness"* refers to percentage of total post-target thickness

1 Non-Target Material

The thickness of the beryllium window comes from Ed Folts[2]. The aluminum entrance window has been measured with a micrometer. One mil uncertainty is used to accommodate the noticeable distortion of the window. The length of ^{4}He before and after scattering depends on the radius of the scattering chamber which is actually ellipsoidal. The uncertainty corresponds to 1/2 the chamber wall thickness.

The aluminum exit windows used for E94010 have been discarded. Ed recalls using 15 mil aluminum exit windows. Caliper/micrometer measurement of the stock aluminum provided by Ed indicate that it is actually 16mils. The thickness of air after scattering is determined from the survey results, the radius of the target can, and the location of the sieve slit within the collimator box. The latter two each contribute to the uncertainty of 5.5cm. A caliper was used to measure a sample kapton window. The error represents the s.d. There is a titanium window located after the magnetic (momentum analyzing) section of the spectrometer. As such, it should not be included in the radiative corrections[11].

Entrance Window				
Target	Material	In(μm)	error	R.L.
Don't Worry	C1720	135.9$\pm$ 0.6	0.4%	1.282×10^{-3}
Be Happy	C1720	131.8$\pm$ 8.7	6.6%	1.226×10^{-3}
Armegeddon	GE180	130.5$\pm$ 8.7	6.6%	1.854×10^{-3}
Nepheli	C1720	133.2$\pm$13.2	10.0%	1.256×10^{-3}
Sysiphos	C1720	127.6$\pm$ 7.6	7.6%	1.203×10^{-3}
Jin	C1720	135.5$\pm$ 1.6	1.2%	1.278×10^{-3}

Table 2:

2 Target Entrance Window

These values are from Jensen's [6] interferometric measurement. Only *Don't Worry* has records describing which window is upstream and which is downstream. For the other cells, I have averaged the two windows together and the difference between average and measured value is taken as the error.

For *Nepheli*, the windows were not measured at all. An average over the other 10 measured windows is used and twice the standard deviation is used conservatively as the error.

Electron Arm Exit Window				
Target	Material	Out(mm)	error	R.L.
Don't Worry	C1720	0.977 ± 0.038	3.9%	9.213×10^{-3}
Be Happy	C1720	0.960 ± 0.1	10.4%	9.053×10^{-3}
Armegeddon	GE180	1.270 ± 0.1	7.8%	18.040×10^{-3}
Nepheli	C1720	0.956 ± 0.1	10.0%	9.015×10^{-3}
Sysiphos	C1720	0.971 ± 0.020	2.1%	9.156×10^{-3}
Jin	C1720	0.850 ± 0.021	2.4%	8.015×10^{-3}

Table 3: The values here assume 90° scattering.

3 Target Exit Window

3.1 Electron Arm

Don't Worry, *Sysiphos* and *Jin* were measured using optical interferometry [7]. Each cell was measured at four points along the length of the glass. The above value represents the average and standard deviation of the measurements.

Deur [8] provided estimates for the cells *Be Happy* and *Armegeddon* from the elastic cross section with an error estimate of ±0.1mm. He also estimates a wall thickness of 0.92mm for *Jin* which is in reasonable agreement with the interferometry analysis.

There is no direct measurement of *Nepheli*. Steffen [7] makes an estimate for the thickness by comparing the resizing prediction to the interferometry results quoting an error of 9%. To be cautious, we increase the error to ±0.1mm since it is probably not more accurate than the elastic analysis estimate.

Hadron Arm Exit Window				
Target	Material	Out(mm)	error	R.L.
Don't Worry	C1720	1.019±0.010	1.0%	9.609×10^{-3}
Be Happy	C1720	0.960±0.100	10.4%	9.053×10^{-3}
Armegeddon	GE180	1.460±0.240	16.4%	20.746×10^{-3}
Nepheli	C1720	0.956±0.100	10.4%	9.015×10^{-3}
Sysiphos	C1720	1.001±0.015	1.5%	9.440×10^{-3}
Jin	C1720	0.896±0.021	2.4%	8.449×10^{-3}

Table 4: The values here assume 90° scattering.

3.2 Hadron Arm

The value for hadron arm exit thickness of *Armegeddon* is estimated by Deur[9] to be 15% thicker than the electron arm. This is a fairly crude estimate with unknown error. The physical limit for the window thickness is 1.7mm[8] so we use this upper limit to establish an error of ±0.24mm.

For all other cells see the discussion in section 3.1

4 ^{3}He Contribution

^{3}He Before Scattering			
Target	cm	error	R.L.
Don't Worry	19.3	5.0%	4.501×10^{-4}
Be Happy	20.0	5.0%	4.390×10^{-4}
Armegeddon	19.7	5.0%	4.621×10^{-4}
Nepheli	18.4	5.0%	5.190×10^{-4}
Sysiphos	19.8	5.0%	3.746×10^{-4}
Jin	19.75	5.0%	3.846×10^{-4}

Table 5: These values come from the cell diagrams in the GDH logbook [10]. A conservative 1 cm. uncertainty leads to the 5% error.

Table 5: ^{3}He After Scattering			
Target	cm	error	R.L.
Don't Worry	0.84	12%	1.960×10^{-5}
Be Happy	0.83	12%	1.820×10^{-5}
Armegeddon	0.94	11%	1.979×10^{-5}
Nepheli	0.85	12%	2.228×10^{-5}
Sysiphos	0.89	11%	1.684×10^{-5}
Jin	0.85	12%	1.655×10^{-5}

Table 6: These values also come from the GDH logbook [10]. The values shown in the above table are determined by averaging the 4-5 outer diameter measurements to determine a radius and subtracting the glass thickness. The values determined in this way have a standard deviation corresponding to 11-12% uncertainty.

5 Summary

Thickness before scattering								
	Pre Target	err (%)	Glass before	err (%)	^{3}He before	err %	Total Rad. L.	err %
D.W.	.	.	1.282×10^{-3}	0.4	4.501×10^{-4}	5	7.338×10^{-3}	4.2
B.H.	.	.	1.226×10^{-3}	6.6	4.390×10^{-4}	5	7.271×10^{-3}	4.4
Arm.	5.606×10^{-3}	5.5	1.854×10^{-3}	6.6	4.621×10^{-4}	5	7.922×10^{-3}	4.2
Nep.	.	.	1.256×10^{-3}	10.0	5.190×10^{-4}	5	7.381×10^{-3}	4.5
Sys.	.	.	1.203×10^{-3}	7.6	3.746×10^{-4}	5	7.184×10^{-3}	4.5
Jin	.	.	1.278×10^{-3}	1.2	3.846×10^{-4}	5	7.269×10^{-3}	4.3

Table 7:

Thickness after scattering (E-arm)								
	^{3}He After	err (%)	Glass after	err (%)	Post Target	err (%)	Total Rad. L.	err (%)
D.W.	1.960×10^{-5}	12	9.213×10^{-3}	3.9	.	.	4.189×10^{-2}	3.3
B.H.	1.822×10^{-5}	12	9.053×10^{-3}	10.4	.	.	4.128×10^{-2}	8.6
Arm.	2.205×10^{-5}	11	18.04×10^{-3}	7.8	7.338×10^{-3}	4.6	7.492×10^{-2}	7.0
Nep.	2.228×10^{-5}	12	9.015×10^{-3}	9.0	.	.	4.116×10^{-2}	7.4
Sys.	1.684×10^{-5}	11	9.156×10^{-3}	2.1	.	.	4.166×10^{-2}	1.9
Jin	1.655×10^{-5}	12	8.015×10^{-3}	2.4	.	.	3.739×10^{-2}	2.1

Table 8: ^{3}He and glass thicknesses assume 90° scattering. Total assumes 15.5° scattering.

Thickness after scattering (H-arm)								
	^{3}He After	err (%)	Glass after	err (%)	Post Target	err (%)	Total Rad. L.	err (%)
D.W.	1.960×10^{-5}	12	9.609×10^{-3}	0.9	.	.	4.337×10^{-2}	1.1
B.H.	1.822×10^{-5}	12	9.053×10^{-3}	10.4	.	.	4.128×10^{-2}	8.6
Arm.	2.205×10^{-5}	11	20.75×10^{-3}	10.0	7.338×10^{-3}	4.6	8.505×10^{-2}	9.1
Nep.	2.228×10^{-5}	12	9.015×10^{-3}	9.0	.	.	4.116×10^{-2}	7.4
Sys.	1.684×10^{-5}	11	9.440×10^{-3}	1.5	.	.	4.273×10^{-2}	1.5
Jin	1.655×10^{-5}	12	8.449×10^{-3}	2.4	.	.	3.902×10^{-2}	2.1

Table 9: ^{3}He and glass thicknesses assume 90° scattering. Total assumes 15.5° scattering.

6 Conclusion

The thicknesses before scattering are known to about 5%. The thicknesses after are known to better than 10%.

We have found significant differences from the radiation lengths used in the previous analysis [1]. In particular, we were using incorrect thicknesses for beamline beryllium and aluminum windows, and the target exit aluminum windows. Also, we were incorrectly including the spectrometer titanium window, which in fact does not affect the momentum determination. The following tables quantify the change.

Thickness before scattering			
	Old	New	Diff(%)
BH	5.370×10^{-3}	7.271×10^{-3}	+35.4
AR	6.021×10^{-3}	7.922×10^{-3}	+31.6
NE	5.455×10^{-3}	7.381×10^{-3}	+35.3
SY	5.309×10^{-3}	7.184×10^{-3}	+35.3
JN	5.415×10^{-3}	7.269×10^{-3}	+34.2

Thickness after scattering. e-arm			
	Old	New	Diff(%)
BH	4.389×10^{-2}	4.128×10^{-2}	-5.9
AR	7.611×10^{-2}	7.492×10^{-2}	-1.6
NE	4.390×10^{-2}	4.116×10^{-2}	-6.3
SY	4.389×10^{-2}	4.166×10^{-2}	-5.1
JN	3.965×10^{-2}	3.739×10^{-2}	-5.7

Thickness after scattering. h-arm			
	Old	New	Diff(%)
BH	4.389×10^{-2}	4.128×10^{-2}	-5.9
AR	7.611×10^{-2}	8.505×10^{-2}	-11.7
NE	4.390×10^{-2}	4.116×10^{-2}	-6.3
SY	4.389×10^{-2}	4.273×10^{-2}	-2.7
JN	3.965×10^{-2}	3.902×10^{-2}	-1.6

Initial analysis of the inelastic cross sections seems to indicate that the new Armegeddon values are not quite right.

1. Feng Xiong. M.I.T. Thesis (2002), http://hallaweb.jlab.org/publications/Talks/Thesisfiles/xiong-thesis.pdf See diagram on p.107 for location of various materials wrt. target.
2. Ed Folts, JLAB HALLA staff. Private communication. Prior to the 2003 set of polarized ^{3}He experiments the beryllium window was always 15 mils due to safety requirements.
3. Duality and small angle GDH will run with a 5 mil beryllium window. There will be no aluminum entrance window. The exit aluminum windows may be reduced to 10 mil.
4. Seonho Choi "Target Parameters of E94010". July 8, 2001.
5. Al Gavalya, JLAB Hall A staff. Private communication. gavalya@jlab.org
6. J. Steffen Jensen. Caltech Thesis (2000).
7. J. Steffen Jensen, "Cell Wall Thickness Measurements for E94-010 and E95-001", March 6, 2000.
8. A. Deur. "Cell Wall Thickness from the Elastic Data and Glass Radiation Lengths.", January 19, 2002.
9. A. Deur. Private communication. deurpam@jlab.org
10. http://www.jlab.org/e94010/cells.html
11. Thanks to Todd Averett for pointing this out.