Cell Wall Thickness from the Elastic Data and Glass Radiation Lengths.

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Abstract

We have used the E94-010 elastic data to determine the wall thickness of the following ^{3}He cells: Be Happy, Armageddon and Jin. The data from Armageddon pointed out that the GE180 radiation length of 11.61 cm previously used was wrong. It was calculated to be 7.04 cm.

1 Introduction.

The wall thickness of the cells is a critical input for both the radiative corrections to our data and the polarimetry:

- The photon radiation is a function of the wall thickness divided by the glass radiation length. Experimental data have to be corrected from these radiations in order to extract to the ideal Born cross section.
- In the NMR polarimetry, the flux calculation depends on the inner volume of the scattering chamber [1]. Wall thickness is necessary to deduce the inner volume from the outer measurement.

The wall thickness can be estimated from the size of the glass tube used to build the cell. A correction has to be applied because of the resizing of the tube. The estimates are given in reference [2]. We refer to these estimates as the "resizing estimates".

After the experiment, measurements using a thin film interferometry method were carried out on the surviving cells (Don't Worry, Sysiphos, Jin, Cuervo, the E94-010 and E95-001 ref. cells and the water cell) [1]. These measurements differ by up to 20% from the resizing estimates. It is worth to note that in the case of Corning 1720 glass, the estimate is systematically lower than the interferometry measurement while in the one case of GE180 target (Cuervo), the estimate is higher.

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Elastic data can be used as a measurement of the wall thickness because of the effect of the photon radiations on the elastic peak. Three cells (Be Happy, Armageddon and Jin) were used for elastic data taking. Among them, two have exploded (Be Happy and Armageddon). The elastic data are the only reliable measurement of the wall thickness available for these targets.

2 Methods.

Three methods can be used to deduce the wall thickness from the elastic data. All of them use a simulation of the spectrometer and the ^{3}He elastic scattering [3], [4]. The methods rely on the facts that the other material thicknesses are measured, that the elastic form factors are well known and that the Monte Carlo properly treats the photon radiations and the Landau straggling.

2.1 Peak Width.

We can match the simulated radiated elastic peak with the experimental data. This method assumes that the spectrometer resolution and beam energy dispersion are known since both of them, in addition to the photon radiations and the Landau straggling, contribute to the width of the elastic peak. Since we have here four parameters, it may seem hopeless to try to disentangle their contributions. However the problem is simplified by the facts that:

- The Landau straggling and beam energy dispersion (a few 10^{-5}) have a negligible contribution to the peak width.
- The effect spectrometer resolution is to enlarge the Gaussian shape that the elastic peak would have in the absence of photon radiations. The effect of the photon radiations is to mishap the Gaussian peak by convoluting it with a radiative elastic tail. Hence the two processes have very different effects and there is only one set of wall thickness and spectrometer resolution that will restore the shape of the experimental peak.

2.2 Ionization Shift.

The Landau straggling shifts the elastic peak by a few MeV. This sizeable effect can be use to determine the wall thickness. However, at the time of E94-010, the beam energy and spectrometer central momentum were not known with sufficient accuracy to make this method reliable. This should be a more robust method than the first one: It is not using any information on the spectrometer resolution, beam energy dispersion or glass radiation length. It uses the density of the crossed matter, the beam energy and spectrometer central momentum value. These quantities will be well under control for the upcoming experiments.

2.3 Elastic Yield.

Since the elastic form factors are well known, we can simulate the elastic yield and compare it to the experimental data. This methods is more delicate than the previous ones since it asks for the following corrections or normalizations:

- Target density
- Beam current
- Computer deadtime

This method incorporates the first one (and the second one if the bean energy and spectrometer central momentum are sufficiently well known) since any satisfactory simulation has to reproduce the shape of the peak in addition to the yield.

3 Analysis of the Wall Thickness of Be Happy and Jin.

We deduced the wall thickness of Be Happy and Jin during the analysis of the elastic cross section [4]. The purpose was actually not to measure the wall thickness but to reproduce the elastic peak. In order to get a good match, we were compelled to set the spectrometer resolution to $2.\times10^{-4}$ and to increase the wall thickness resizing estimate of Jin and Be Happy by 10%. These 10% were confirmed[1] later on by the independent interferometry measurements [1].

The following table displays the results for the C1720 cells.

Target	Resizing estimate [2]	Elastic	Interferometry [1]
Don't Worry	0.86 mm	/	1.02(e-arm) / 0.98 (h-arm)
Be Happy	0.87 mm	0.96 mm	/
Sysiphos	0.84 mm	/	1.00(e-arm) / 0.98 (h-arm)
Jin	0.84 mm	0.92 mm	0.85(e-arm) / 0.90 (h-arm)

4 Analysis of Armageddon's Wall Thickness.

4.1 First Analysis.

The width of the elastic peak for the data taken with Armageddon suggested that the wall thickness was much larger than the corrected value of 1.2 mm [1]. The width of the experimental elastic peak can be matched by the simulation if we increase the size of the wall by 75%, see figure 1.

[1] Only Jin wall thickness, for the electron arm side, is close to the resizing estimate. In the case of the other C1720 cells, the results are about 10 to 20 % higher.

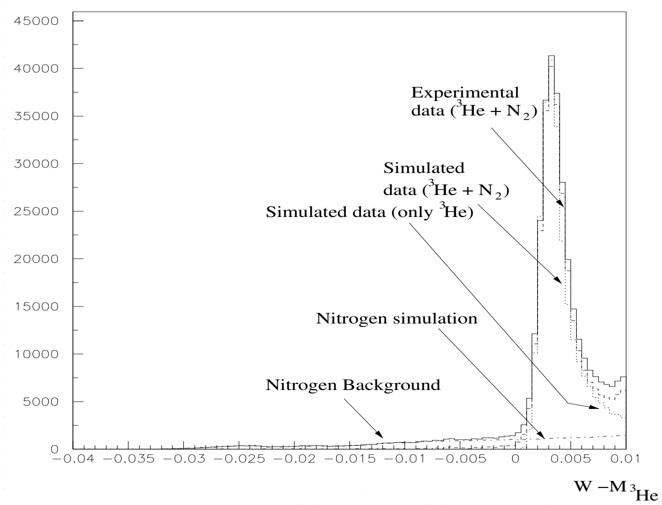

Figure 1. Experimental and simulated elastic data for Armageddon. The wall thickness of Armageddon was taken as 1.91 mm. The nitrogen background was simulated although it does not affect the width of the elastic peak.

4.2 Second Analysis.

An hypothesis which could have partly explained the large wall thickness for Armageddon was that the beginning of the quasi-elastic peak may have contaminated and enlarged the elastic peak (the two-body break-up threshold is at 5.5 MeV from the elastic peak center), see figure 1. However we did not find a satisfactory way of simulating the quasi-elastic near the threshold. Hence we did not include it in the simulation and we tried to carry out an analysis as insensitive as possible of this contamination.

By computing the absolute yield for Armageddon and Be Happy (both sets of data were taken at the same kinematic, so only the photon radiations are responsible for any difference of shape and yield) and subtracting the two yields, we obtain a spectrum that should minimize the quasi-elastic (and Nitrogen) contamination.

The figure 2 gives the experimental yield for both electron and "hadron" arms. The figures 3 and 4 are the simulations for wall thicknesses of respectively 1.23 mm and 1.87 mm. 1.87 mm provides the best match to the data. Values of 1.60 mm, 1.97 mm and 2.09 mm were also tried. The radiation length of c1720 (for Be Happy) was taken as 10.61 cm and the radiation length of GE180 as 11.42 cm.

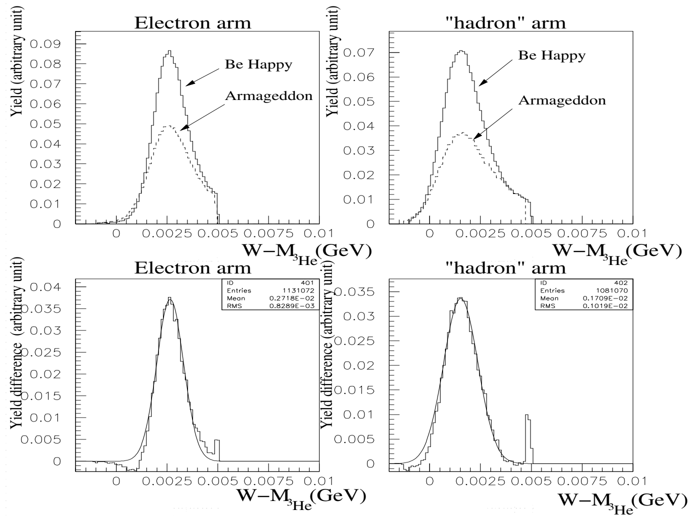

Figure 2. Experimental yield of Be Happy and Armageddon for the electron arm (top left plot) and "hadron" arm (top right plot). The bottom plots are the yield difference for each arms. The data were taken at the same elastic kinematic (E=1.718 GeV, E_p=1.721 GeV, θ=15.5^o). The difference between Be Happy and Armageddon comes only from the radiation in the cell wall. The elastic peak for Armageddon was shifted to the left in order to compensate for the larger energy loss by Ionization.

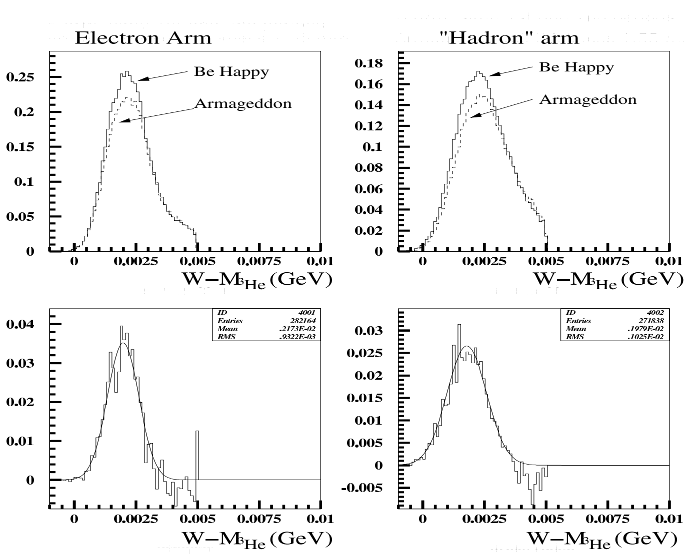

Figure 3. Simulation trying to reproduce the experimental data of figure 2. The wall thickness of Be Happy was taken according to the results of section 3. The wall thickness of Armageddon was taken as 1.23 mm. Note that the units for the yield are different from the figure 2.

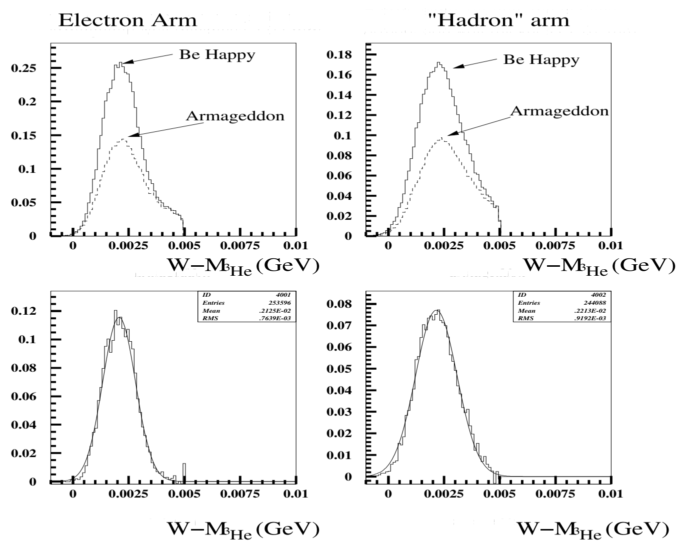

Figure 4. Same as figure 2 but for a Armageddon's wall thickness of 1.87 mm.

The conclusions of the second analysis are:

1. The quasi-elastic contamination does not affect significantly the measurement of the wall thickness.
2. The large wall thickness of Armageddon (with a radiation length of 11.42 cm) is confirmed.

4.3 Third Analysis.

The large thickness found for Armageddon brings two problems:

- The maximum size of the tube used for the building of the target is 1.7 mm. A larger wall thickness would imply an addition of glass during the making of the target which is not part of the procedure.
- The new flux calculated with 1.8 mm wall thickness [5] increases the target polarization by 20%. It makes the elastic asymmetry measured with Armageddon inconsistent with the simulation [6].

As a consequence a third analysis was carried out. We used again the elastic yields of Armageddon and Be Happy. The differences between the second and the third analysis are:

- We divided the yield of Be happy by the one of Armageddon instead of subtracted it (We learned from the second analysis that the quasi-elastic contamination does not affect the wall thickness measurement). This has the advantage to cancel systematic effects factorizing the yield. Hence it should be a more robust comparison.

- As a way of having a sense of the systematic error on the wall thickness, we have varied , in addition of the thickness of Armageddon, the HRS momentum resolution and the thickness of Be Happy.

We have taken the spectrometer resolution as $1.\times10^{-4}$, $2.\times10^{-4}$ (nominal value) and $3.\times10^{-4}$. We time the wall thickness of Be Happy by the factors 0.9, 1.0 (nominal value) and 1.1. It turns out that the determination of the wall thickness of Armageddon is not significantly sensitive to the spectrometer resolution (at least in the ranges previously mentioned). A 5% shift in the wall thickness of Be Happy (which is a reasonable size of the uncertainty) changes the determination of the wall thickness of Armageddon by about 3%. In addition to that, the sensitivity of the method seems to be accurate only to the 0.1 mm level. This may come from the fact that the shape and height of the elastic peak is less and less sensitive to the target thickness while a sharp "Dirac" peak is very sensitive.

We show here only the best match (with the nominal values of spectrometer resolution and wall thickness of Be Happy). The best fit to the data is given by a thickness of 2.06 mm. See figure 5.

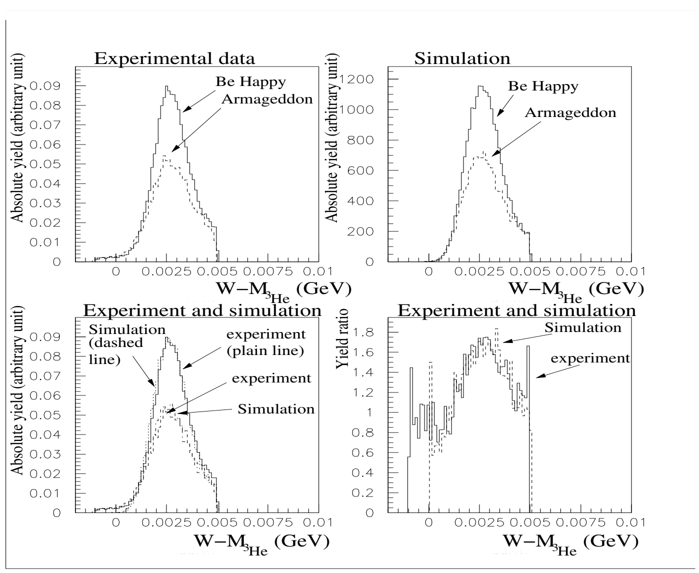

Figure 5. Yield of Be Happy and Armageddon: The top left plot presents the experimental data. The top right one is the simulation with a spectrometer resolution of $2.\times10^{-4}$ a wall thickness of Armageddon of 2.06 mm and a wall thickness of Be Happy of 0.96 mm. On the bottom left plot are the two

previous plots on top of each other. The bottom left plot is the ratio of the yield of Be Happy by the Yield of Armageddon (plain line is the experimental ratio while dashed line is the simulation).

The result of this analysis shows that the large wall thickness could not be due to inaccurate inputs for the spectrometer resolution and the wall thickness of Be Happy. It also confirms the two previous analysis.

4.4 GE180 and Corning 1720 Radiation Lengths.

The photon radiation depends on the radio (thickness)/(radiation length). It is actually this ratio that we determine using the elastic data. Using the composition and density of the Corning 1720 and the GE180, we have checked the radiation length of both glasses. We have found that the Corning 1720 radiation length previously used is correct but not the one of GE180 (we found 7.04 cm instead of 11.42 cm).

Using this new input, the wall thickness of Armageddon decreases to 1.27 mm. The uncertainty decreases from 0.13mm to 0.10 mm. The thickness is satisfactorily below the 1.7 mm limit. With this new result, we are back to a consistency between the measured elastic asymmetry from Armageddon data and the predicted one. In addition, it confirms the prediction of [1] based on the fact that for the other GE180 cell (Cuervo), the interferometry method gave a number 13.3% lower than the resizing estimate.

5 Conclusion

This work has shown that the wall thickness of the Helium cells can be deduced from the elastic data. The suspicious numbers first found for Armageddon are to be accounted for a wrong radiation length for the GE180 glass. This analysis confirms the interferometry analysis [1], that is:

- For C1720, the resizing estimate predicts a wall thickness about 10 to 20% lower.
- For GE180, the resizing estimate predicts a wall thickness about 10% higher.

The following tables give the characteristics of the glasses and summarize the wall thicknesses estimated with the elastic data. We recall that the estimate based on the interferometry method was 1.182±0.106 mm [1].

Glass	Density (g/cm^3)	Rad. length (g/cm^2)	Rad. length (cm)
C1720	2.53	26.83	10.61
GE180	2.76	19.43	7.04

Target (glass)	Wall thickness (mm)
Be Happy (c1720)	0.86
Jin (c1720)	0.92
Armageddon (GE180) (analysis 1)	1.17
Armageddon (analysis 2)	1.15
Armageddon (analysis 3)	1.27±0.10

The third analysis should be more robust than the two previous ones and we should use this result as a wall thickness of Armageddon.

References

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