Thickness and Density Measurements for the Graphite Target Used in PRIMEX II

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Abstract

Measurements were made for the thickness and density of the graphite target used in the PRIMEX II experiment. This information will be used for obtaining the differential cross sections.

Introduction

In the PRIMEX II experiment the differential cross section for π^0 photo-production is proportional to the π^0 decay width. Therefore, in the PRIMEX experiment it is important to measure the absolute differential cross sections with high accuracy. Absolute cross sections are obtained by dividing the yield of photo-produced π^0s by the number of target atoms/cm^2 in the target. This paper will discuss the thickness (T) and density (ρ) measurements for the graphite target. From these measurements it is possible to calculate the number of atoms/cm^2.

Figure 1 shows a cross section view of the target. Block #1 is *"normal" graphite. The origin and properties of this block are completely unknown.* Block #1 was taped to block #2 with mylar tape.

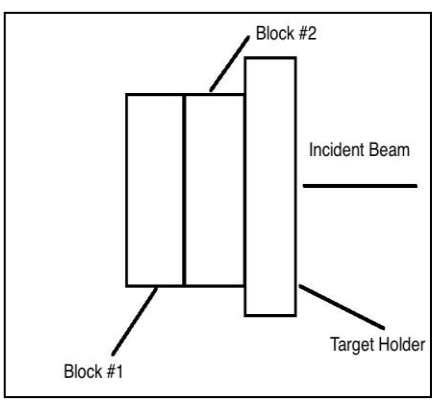

Fig. 1

Block #2 in the diagram is *Highly Ordered Pyrolitic Graphite (HOPG).* This block was epoxyed to the Primex aluminum target holder, and served as the backup target for the carbon target used in the PRIMEX I experiment. The HOPG targets were produced using high temperature (3273 K) Chemical Vapor Deposition (CVD) furnace technology. This process creates atomic layers of carbon oriented to each other in a crystalline form. A nice result of this process is the very low porosity of the material.

The properties of block #2 are detailed in references 1 and 2. In this report we present our results for the density and thickness of block #1. Due to the graphite block's porosity we conducted two different methods for determining the density of the target: Archimedes principle and by performing a direct measurement of the mass and the volume of the target.

Thickness Measurements

The dimensions of the graphite block are a height of roughly 22.867mm and width 22.859mm. Using a digital micrometer (Mitutoyo Micrometer Model NO. 293-721-30) that has an accuracy of 0.001mm we measured the thickness of 5 sections, somewhat similar to a quadrant system set on one surface the graphite block. (Refer to Figure 2) After two separate measurements, we determined the overall central thickness (T) to be 0.9417 ± 0.0001cm.

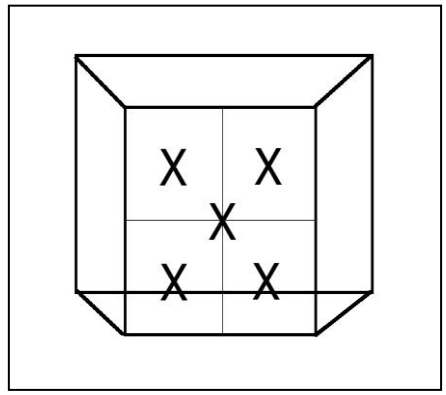

Fig. 2

Density Measurements

In order to obtain a highly accurate density measurement we employed the method of the Archimedes principle by performing buoyancy tests on the graphite block. The apparatus used to weigh the graphite block consisted of a very thin aluminum rod with a spoon that was suspended from a plastic circular base. (Refer to Figure 3) This apparatus and a beaker holder were placed on a scale (0.0001g error) where we measured the weight of the graphite block in air, and again in roughly 100mL of water (High Performance Liquid Chromatography grade, HPLC). A standard thermometer with an accuracy of 1° was used to measure the water temperature, determined to be 22 °C. We then referred to the density of water as a function of temperature in the CRC Handbook of Chemistry and Physics (91st Edition) that was 0.9977 g/cm^3 and then determined a total error of 0.0002 g/cm^3. Measuring the mass of the block in water (W_F) and in air (W_A) along with the book value of the density of water as a function of the temperature $\rho_F(T)$ we would then calculate the density of the graphite block using the water immersion equation:

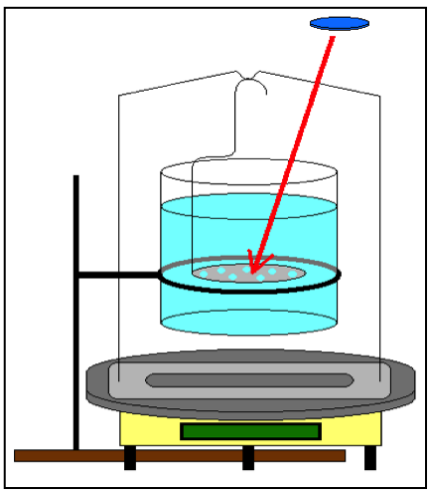

Fig. 3

$$\rho_s = \rho_F(T)\left(\frac{1}{1 - W_F / W_A}\right)$$

Eq. 1

In our preliminary measurements we noticed that the mass of the graphite block increased a substantial amount after being dried then reweighed in the air a second time. We believe this was due to the porosity of the graphite. To account for this systematic error, we measured the mass of the graphite block in water as a function of time. Immersing the graphite block in water we then recorded its weight in 5 sec. intervals (see Fig. 4) After extrapolating the masses at t=0 sec., we determined the weight of the graphite block in water to be 2.423 ± 0.001 g. Substituting this new value into Eq. 1 the density of the graphite block is 1.4939 ± 0.0006 g/cm^3.

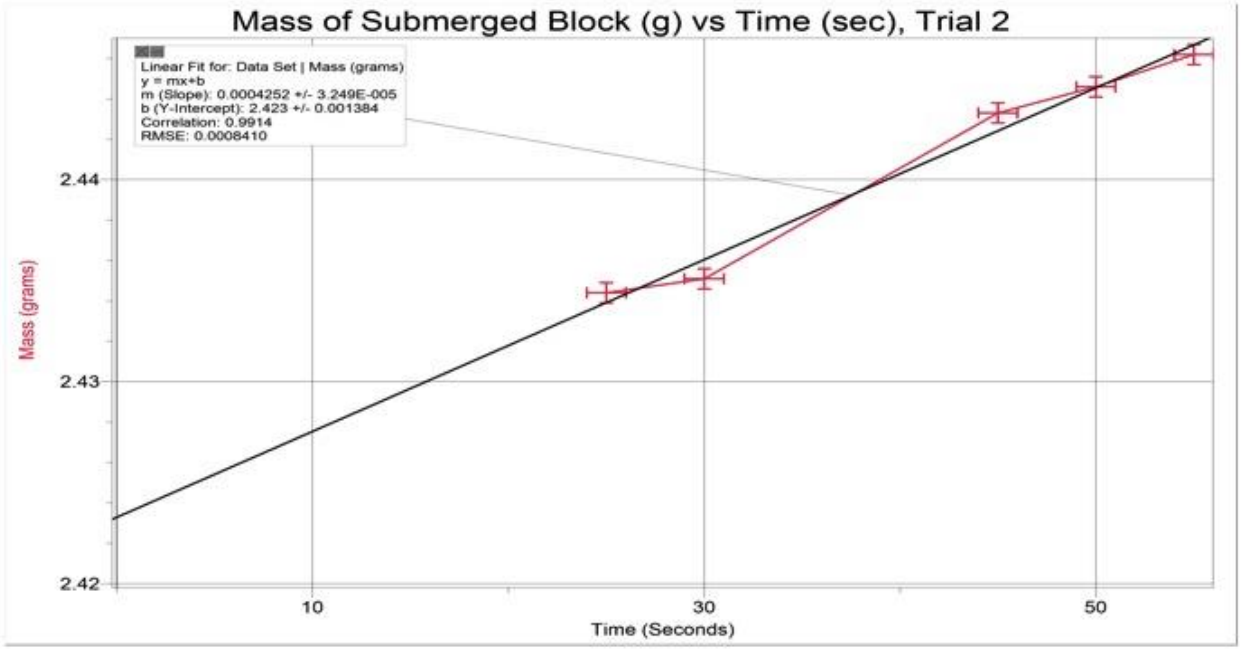

Fig. 4

Another method to determine the density of the graphite target is by making direct measurements on the height, width and thickness to determine the volume of the block. The average mass of the graphite block in air is 7.2972 ± 0.0015 g, and the total volume is estimated as 4.922 ± 0.0042 cm^3 . This gives a density estimate of 1.483 ± 0.001 g/cm^3. This differs by -8% from the density measurements by the Archimedes principle.

Results

Block #	#1 (graphite)	#2 (HOPG)	Combined
Density (g/cm^3)	1.4938 ± 0.0006	2.1979 ± 0.0003	---------
Central thickness (cm)	0.9417 ± 0.0001	0.9662 ± 0.0001	---------
ρT (g/cm^2)	1.4068 ± 0.0006	2.1236 ± 0.0004	3.5304 ± 0.0007
Fraction uncertainty in ρT	0.04%	0.02%	0.02%

References

[1] Philippe Martel and Rory Miskimen, "*Analysis of Primex Targets",* UMass internal report, October 2004.

[2] P. Martel, et. al., "*Nuclear Targets for a Precision Measurement of the Neutral Pion Radiative ±Width*", NIM A 612 (2009), pp. 46-49.

Appendix

A piece of the HOPG block was sent away for an elemental analysis using two methods, Optimum Combustion Methodology (detects C, H, N, and O) and PIXE (Proton Induced X-ray Emission, detects 72 elements). The second column in the table labeled abundance gives the respective mass ratios.

Element	Abundance	Error (PIXE)
Carbon	99.63%	
Hydrogen	< 0.10%	
Nitrogen	< 0.05%	
Oxygen	0.19%	
Aluminum	0.00611%	0.00263%
Silicon	0.00568%	0.00144%
Chlorine	0.00285%	0.00067%
Calcium	0.00302%	0.00054%
Titanium	0.00037%	0.00017%
Vanadium	0.00079%	0.00011%
Chromium	0.00020%	0.00005%
Iron	0.00105%	0.00006%
Copper	0.00025%	0.00004%
Zinc	0.00033%	0.00005%

Table 2