7. Results

In Table 7.1 the final fit parameters to the angular distributions presented in Figures 7.1 and 7.2 are shown. For the process $J/\Psi \rightarrow e^+e^-$ in Figure 7.1, the bin size is 0.025 and the range $-.45 < \cos(\theta^*) < .45$ is fitted. For the process $\Psi' \rightarrow e^+e^-$ displayed in Figure 7.2, the bin size of the abscissa is 0.050 and the range $-.5 < \cos(\theta^*) < .5$ is fitted. The final fit parameters are presented in Table 7.1.

	A	δA	B	δB	# of Events	χ^2/ n.d.f	α	δα
J/Ψ	272.49	4.1634	145.45	47.011	5110.4	1.563	0.53	0.18
Ψ'	159.36	3.9117	177.03	36.336	1744.4	.7526	1.11	0.25

Table 7.1: Final Fit Parameters.

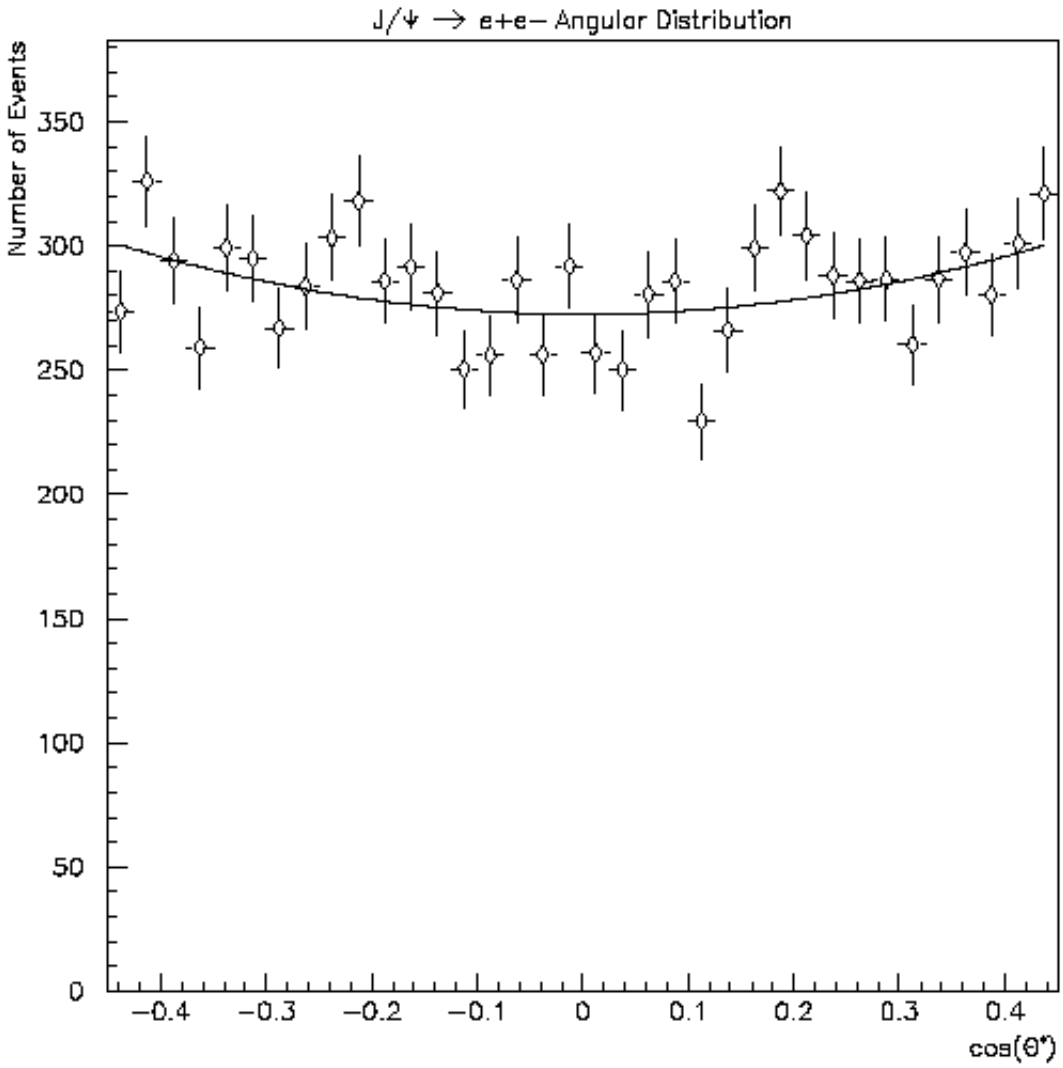

Figure 7.1 : J/Ψ --> e^+e^- Angular Distribution

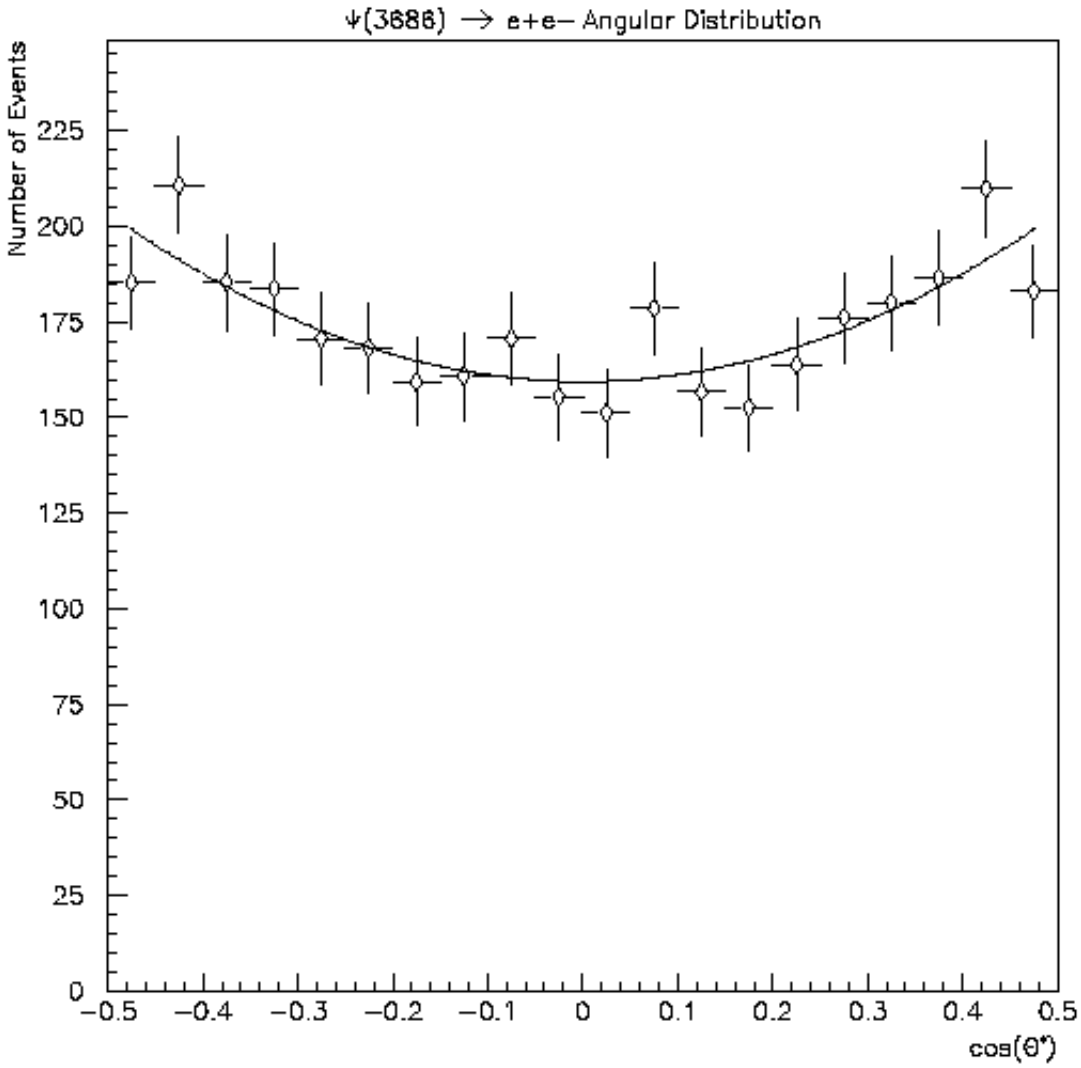

Figure 7.2 : Ψ' --> e^+e^- Angular Distribution

Using these results for the angular distribution parameter, the value for the ratio of the Sachs form factors G_E and G_M dictated by Lorentz invariance at both resonances can be deduced from equation (5.20):

(7.2) $$\left|\frac{G_E}{G_M}\right|^2 = \left(\frac{E_{CM}^{\ 2}}{4m_p^{\ 2}}\right)\left(\frac{1-\alpha}{1+\alpha}\right).$$

The ratio of these strong form factors is zero when α_p is 1. Setting this ratio to one yields α_p derived by Claudson, Glashow, and Wise, where the spin-flip amplitude was set to zero.

Furthermore, from equation (5.16), one can determine the probability that the charmonium atom is produced in a helicity one or helicity zero configuration in the helicity formalism:

(7.3) $$\frac{2\,C_0^{\ 2}}{C_1^{\ 2}} = \frac{1-\alpha}{1+\alpha}.$$

Here $C_1^{\ 2}$ is the probability for the charmonium atom to be produced in a helicity one configuration, and $2C_0^{\ 2}$ is the probability for helicity zero production. We can then solve for $C_1^{\ 2}$ from the normalization condition $C_1^{\ 2} + 2\,C_0^{\ 2} = 1$.

Resonance	α_p	$\lvert G_E/G_M \rvert^2$	C_1^2
J/Ψ(3097)	0.53 +/- .18	0.84	.77
Ψ(3686)	1.11 +/- .25	0.	1

Table 7.2 : Sachs form factor ratio and helicity one production probability derived from the angular distribution parameter.

As seen in table 7.2, the charmonium 1^{--} resonances are predominately created via the helicity one channel. As the energy scale increases, or more significantly as the ratio of the proton mass to the charmonium mass decreases, helicity one production increases as well. We note that in e^+e^- annihilation the ratio of the electron mass to the charmonium mass is zero, and the angular distribution parameter for charmonium production by e^+e^- annihilation is 1.

Historically only the J/Ψ angular distribution parameter has been measured by experiments. Attempts to generate the Ψ' angular distribution parameter have been hindered because the exclusive cross section falls off as Q^{-2}. In Table 7.3 a comparison is made with the other experimental values. Within the statistical errors, the thesis value is consistent with the world average.

Experiment	α_p at J/Ψ
Mark I[95]	1.45 +/- 0.56
DASP[96]	1.70 +/- 1.70
Mark II[97]	0.61 +/- 0.23
DM2[98]	0.62 +/- 0.11
Mark III[99]	0.58 +/- 0.14
Fermilab E760[22]	0.69 +/- 0.26
World Average	0.63 +/- .08
Fermilab E835(this thesis)	0.53 +/- 0.18

Table 7.3 : Previous experimental results for the angular distribution parameter α_p.