E93-018 Λ Cross Sections

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The purpose of this document is to provide some details on the various checks that were carried out in support of the E93-018 $p(e, e', K)\Lambda$ cross sections extracted by Rick Mohring. The details of Rick's method are outlined in his thesis. However, a short summary of the method is presented here for completeness.

The basic principle behind Rick's method, the same as that used for many of the Hall C coincidence experiments, is to perform a direct comparison of experimental yields to those simulated using SIMC. Rick used a modified version of SIMC, in that he generated events in the center-of-mass frame rather than in the lab frame (the event generation is described in section 4.2 of his thesis). Each event was additionally weighted by three scaling factors, one in W, one in Q^2 and one in t (or equivalently θ_{CM}) in order to build in some dependence of the cross section on these variables. The scaling factors used were from parameterizations from earlier data, with the exception of the W scaling function: Rick adopted the method of Doug Koltenuk who attempted to account for the effect of resonances. See section 4.6 for more detail. It should be noted that because the cross sections do not vary much across the spectrometer acceptances, the effect of these weighting factors on the extracted cross section is only a few percent.

A comparison of cross sections extracted by Rick and those of Gabriel is shown in Table . I believe these can be directly compared with each other with three caveats:

1. The W scaling was slightly different. At kinematics 3, the difference is 2.5%.
2. Rick's cross sections are quoted at t_{min} and I believe that Gabriel's cross sections are quoted at the central value of t for each kinematic setting. This is a $< 1\%$ effect.
3. Rick uses a cut in θ^*_K in order to ensure full acceptance in ϕ. I believe that Gabriel's analysis does not use such a cut, because if I remove this cut from Rick's analysis, his number of accepted kaons is consistent with the statistical uncertainties in Gabriel's thesis. This cut, which was about 8° for kin 1-5 and about 12° for kin 6-12, reduces the number of accepted kaons by up to a factor of two. In Rick's analysis, removing this cut changes the extracted cross sections by a few percent.

Rather than focussing on the differences in the two results, I want to first focus on the various studies that have been carried out to check the validity of Rick's method. Note again the difference in the statistical errors: Rick's statistical error is larger because of the θ^*_K cut, applied in order to require the ϕ acceptance to be complete at each kinematic setting. If I remove this cut from Rick's analysis, I recover the same statistical error quoted by Gabriel.

Rick carried out two comparisons with the analysis of Doug Koltenuk, which are both documented in his thesis in section 5.6. The first was to take one of Doug's results at comparable kinematics, and scale it to E93-018 kinematics 3. He used the results of settings "0" and "0L" (see Doug's thesis, p 120). He scaled each result individually to W=1.78 GeV, Q^2=0.51 (GeV/c)^2 (averaging the kinematics of the two) and then to t_{min} (*i.e.*, θ_{CM}=0), and then took the average of the two in order to remove any potential ϕ-dependence. The resulting cross section is 420.4 nb/sr. Scaling this average value to W=1.84 GeV and Q^2=0.52 (GeV/c)^2 results in a cross section of 387.4 nb/sr. This can now be directly compared to Rick's value of 395.3±12.5 nb/sr, agreeing to 2%.

kin	$\langle Q^2 \rangle$ (GeV/c)^2	$\langle W \rangle$ GeV	$-t_{min}$ GeV^2	ϵ	σ_R nb/sr	$(\Delta\sigma/\sigma)$ (STAT/SYS)	σ_G nb/sr	$(\Delta\sigma/\sigma)$ (STAT/SYS)
1	0.52	1.84	0.22	0.552	369.2	2.1/2.5	452.2	1.3/2.1
2				0.771	380.2	2.0/2.5	497.2	1.1/2.3
3				0.865	395.3	1.8/2.6	536.8	0.9/2.2
4	0.75	1.84	0.30	0.462	346.3	2.3/2.5	287.7	1.4/2.2
5				0.724	362.8	1.5/2.6	340.5	0.9/2.2
6				0.834	379.2	1.3/2.6	358.2	0.8/2.3
7	1.00	1.81	0.41	0.380	320.0	2.2/2.5	249.7	1.6/7.0[1]
8				0.678	343.3	1.4/2.8	272.0	1.4 / 2.8
9				0.810	344.8	1.0/3.2	299.3	0.8 / 2.7
10	2.00	1.84	0.74	0.363	221.8	3.1/2.6	90.8	2.0/2.8
11				0.476	233.4	2.9/2.5	98.3	1.9 / 2.9
12				0.613	237.7	2.2/2.5	101.6	1.5 / 3.0

Table 1: $p(e,e'K)\Lambda$ unseparated cross sections from the two E93-018 theses.

The second comparison was to directly analyze one set of data from E91-016. He analyzed setting "0" and got a cross section of 426±21 nb/sr, to be compared to Doug's quoted value of 416±20 nb/sr. Jinsoek's result for the same kinematics is 428±22 nb/sr.

The primary difference in method between Doug and Rick was in the event generation: both students used the data/MC method to extract the cross section. Doug generated MC events in the lab frame, whereas Rick generated events in the CM frame. So the good agreement between the two verifies that any required Jacobians to convert from CM/Lab were carried out correctly, and that no trivial errors were introduced by one student and not the other in the analysis procedure. Any issues associated with the details of SIMC are obviously not tested in this procedure.

More recently, the cross sections were calculated "by hand" using acceptance values generated by SIMC. For the hand calculation, the CM virtual photon cross section is:

$$\left(\frac{d\sigma}{d\Omega_K^*}\right) = \left(\frac{1}{\Gamma_0}\right) \times \frac{d\sigma}{d\Omega_E d\Omega_K dE_e} \tag{1}$$

$$= \left(\frac{1}{\Gamma_0}\right) \times \left(\frac{R_c Y_K}{\varepsilon_{TOF} L}\right) \times \left(\frac{1}{\Delta^5}\right) \times \left(\frac{d\Omega_K}{d\Omega_K^*}\right). \tag{2}$$

The factor

$$\Gamma_0 = \frac{\alpha}{2\pi^2} \frac{(W^2 - m_p^2)}{2m_p} \frac{E'}{E} \frac{1}{Q^2} \frac{1}{1-\epsilon} \tag{3}$$

is the usual virtual photon flux. The luminosity factor L is calculated from the beam charge, and also contains all detection efficiencies except that due to the decay of the kaons, which is factored in through ε_{TOF}. For the hand calculation, the radiative correction factor, about 1.2, was estimated by running SIMC with and without radiation turned on. The 5-fold acceptance values (generated by J. Arrington's version of SIMC), had radiation turned off. An additional upward correction of about 10% has to be made to the hand calculation, accounting for the missing mass cut in Rick's analysis that was not applied in the SIMC acceptance extraction. This additional 10% was folded into the radiative correction factor so that a constant value of $R_c = 1.32$ was used at every kinematic point.

In order to make the comparison with the hand calculation, the θ_K^* cut was removed to determine the number of accepted kaons, since it was not present in SIMC. Table contains

kin	Γ_0 ($\times 10^{-4}$ GeV^{-1})	$\frac{d\Omega_K}{d\Omega_K^*}$	L ($\times 10^8$ nb^{-1})	ε_{TOF}	N_K	$\Delta^5 V_{SIMC}$ ($\times 10^{-6}$ GeV-sr^2)	σ_H (nb/sr)	$\frac{\sigma_R}{\sigma_H}$
1	7.218	0.117	1.184	0.328	4098	6.380	354.03	1.04
2	20.84	0.115	3.903	0.320	7017	10.75	378.99	1.00
3	42.29	0.114	2.924	0.316	11622	12.68	352.96	1.12
4	3.586	0.103	1.891	0.341	3143	5.550	333.05	1.04
5	11.09	0.101	9.833	0.335	10017	10.07	363.19	1.00
6	22.54	0.101	7.426	0.330	18545	12.29	362.80	1.05
7	1.980	0.086	2.603	0.347	2381	4.800	314.89	1.02
8	6.482	0.084	8.057	0.340	5160	9.150	352.12	0.97
9	13.73	0.083	9.375	0.340	14672	11.21	327.66	1.05
10	1.008	0.056	1.664	0.400	1218	6.370	210.67	1.05
11	1.519	0.054	1.476	0.400	2335	8.270	224.48	1.04
12	2.589	0.053	1.222	0.400	4125	10.44	218.45	1.09

Table 2: Comparison between cross sections calculated by hand and Rick's values. A constant radiative correction/missing mass acceptance correction factor of 1.32 was applied to the hand calculation.

the values used to calculate the hand cross section, and figure 2 shows the ratio of Rick's cross sections to the hand calculation. The Q^2 dependence of the hand calculation is very consistent with Rick's extracted cross sections. The remaining differences can be accounted for by Rick's more careful treatment of the kaon detection efficiency, kinematic variations in the radiative corrections, and use of the scaling functions to quote point cross sections at fixed values of Q^2, W and θ_K^*. This confirms that Rick's method of extracting the cross section is self-consistent. It does not test the reliability of SIMC to determine the detection acceptance. However, SIMC has be thoroughly tested in several experiments with varying conditions, against hydrogen elastic cross sections, so it is reasonable to assume that SIMC can reliably reproduce the experimental acceptance of the SOS/HMS pair.

The luminosity, detection efficiencies, and kaon yields used by Gabriel and Rick were very similar. This analysis therefore demonstrates that any differences in the two analyses must come from the treatment of the acceptance.

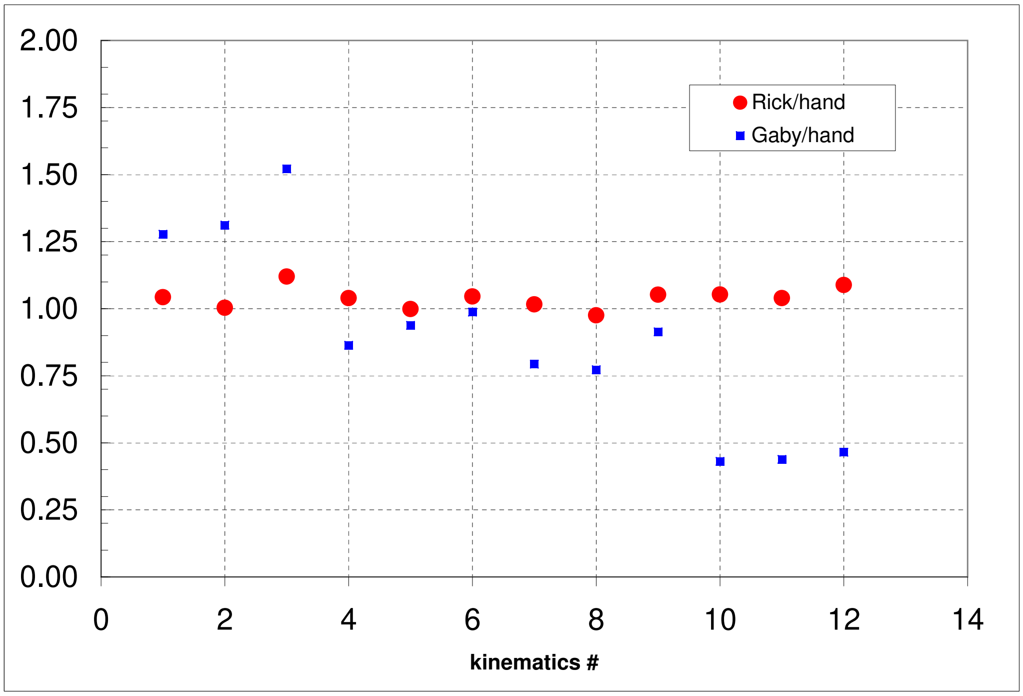

Figure 1: Ratio of cross sections determined by Gabriel and Rick to the hand calculation, using a 5-fold acceptance generated by SIMC.