Radphi Normalization

Richard Jones, University of Connecticut
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Definitions

The Radphi experiment is able to measure absolute photoproduction cross sections, with the following restrictions.

1. only differential cross sections are measured directly; total cross sections are inferred by extrapolating the shape of the angular distributions in kinematical regions where the detector acceptance is small or zero.
2. only *nuclear* differential cross sections are measured directly; these can be compared with $\gamma\, p$ cross sections under the assumption that nuclear medium effects are small and final-state nuclear rescattering can be neglected.
3. beam loss between the tagger and the Radphi target is negligible.

The last restriction is really an assumption because we did not do any tagging efficiency measurements at the position of the Radphi target during the data-taking period. The following arguments are offered to justify this assumption.

1. The Hall B collimator used during Radphi running was a factor more than two larger than the Radphi target (see Ref. 1).
2. There was vacuum in the photon beam line up to the CLAS target.
3. The CLAS target was empty during Radphi running
4. The windows on the CLAS target amount to less than 100μm of Al, which amounts to roughly 0.001 radiation lengths.
5. Between the CLAS target and the Radphi target was a helium tube of length 17.6m, which amounts to 0.004 radiation lengths (including the windows).

This factor of 0.5% is absorbed into the systematic error on the cross section normalization.

Methods

The total number of beam photons that passed through the target during the live time of the experiment is the sum of the scalers on the tagging counters multiplied by two efficiency factors, whose product is traditionally called the *tagging efficiency*. The first is a geometrical factor that arises because only a portion of the full bremsstrahlung beam actually strikes the target. This factor is somewhat energy-dependent and has been computed by Dan Sober [1]. The second is what may be called an electronic factor because it corrects the raw scalers for over-counting effects such as double-pulsing and noise. It also corrects for electrons that produce hits in more than one tagging counter, either due to scattering or overlaps in the tagging focal plane.

The geometric efficiency factors for each tagging channel listed in Ref. 1 were computed assuming that the photon beam was centered on the Radphi target. M. Kornicer has studied the azimuthal dependence of the trigger rates for the recoil proton. By comparing real data with Monte Carlo distributions for a variety of beam-target offsets, he has determined that the beam was centered at a distance of 5±1mm from the geometric center of the target. Dan Sober repeated his beam-target overlap calculations for a variety of misalignment conditions Ref. 2. Using row 6 from his tables gives the best estimate for the actual geometric tagging efficiency during the Radphi experiment.

The electronic factor is measured using the Radphi event data in the following way. In a region far from the tagging coincidence peak, the the tagger TDC spectrum for each counter is flat, reflecting the ungated singles rate in that channel. Dividing the count rate in these spectra by the number of triggers measures the instantaneous singles rate in each tagging counter during the live time of the experiment. The fraction of these tagger randoms in a given channel that survive the tagger left-right coincidence and multi-channel cluster reduction is the electronic tagging efficiency factor. Note that any inefficiencies in the tagging counters themselves do not affect the normalization because their effect is to reduce both the tagged yield and the tagged luminosity measurement by the same amount, thus leaving the extracted cross section unaffected. The only issue relevant to the tagging efficiency is that there are *bona fide* hits in the focal plane which are *not* associated with a beam photon that is incident on the Radphi target.

The following tables contain a summary of the results for the beam-target normalization of the Radphi run, summer 2000.

Table 1. Sums of tagger scalers for all Radphi runs from summer 2000 with efficiency corrections. Comparison of independent results for left and right phototubes on the same tagging counter give an indication of the systematic errors in the electronic efficiency correction.

tagging	**mean**	**scaler sums (millions)**		**electronic efficiency**		**geometric efficiency**	**corrected sums (millions)**	
channel	**energy**	**left**	**right**	**left**	**right**		**left**	**right**
0	5.36	3699458	3775168	0.991	0.960	0.863	3160994	3126362
1	5.31	4300158	4055751	0.856	0.900	0.860	3165873	3141589
2	5.25	5210688	5075301	0.886	0.920	0.858	3960917	4006374
3	5.19	3816867	3768385	0.825	0.822	0.856	2694933	2650968
4	5.14	3870819	3821344	0.915	0.916	0.853	3022860	2987743
5	5.09	3925902	4032448	0.838	0.787	0.851	2801211	2701041
6	5.04	3495443	3690538	0.906	0.856	0.850	2691385	2683365
7	4.99	3871306	3850625	0.844	0.851	0.848	2770753	2779848
8	4.94	4050589	4058072	0.936	0.944	0.847	3211426	3243613
9	4.89	4371042	4278568	0.828	0.853	0.846	3059832	3086227
10	4.83	4308394	4451110	0.934	0.916	0.845	3398850	3443714
11	4.77	4761774	4791641	0.835	0.843	0.843	3354479	3406415
12	4.71	4922668	4790014	0.935	0.959	0.842	3875987	3866952
13	4.64	4616306	4623731	0.867	0.873	0.841	3365875	3392299
14	4.59	3690572	3762464	0.770	0.745	0.839	2385684	2351882
15	4.55	3476928	3788175	0.844	0.776	0.838	2459036	2463344
16	4.51	3872493	3849338	0.983	0.987	0.837	3185603	3181172
17	4.46	3945529	4030928	0.893	0.860	0.836	2945425	2897379
18	4.41	4063000	4071731	0.923	0.917	0.835	3131564	3119378
							58642687	**58529666**

Table 2. Integrated live luminosity for all Radphi runs from summer 2000 after tagging efficiency corrections.

tagging channel	**mean energy**	**integrated luminosity (pb^{-1}) left**	**right**
0	5.36	1.022	1.011
1	5.31	1.024	1.016
2	5.25	1.281	1.296
3	5.19	0.872	0.857
4	5.14	0.978	0.966
5	5.09	0.906	0.874
6	5.04	0.870	0.868
7	4.99	0.896	0.899
8	4.94	1.039	1.049
9	4.89	0.990	0.998
10	4.83	1.099	1.114
11	4.77	1.085	1.102
12	4.71	1.254	1.251
13	4.64	1.089	1.097
14	4.59	0.772	0.761
15	4.55	0.795	0.797
16	4.51	1.030	1.029
17	4.46	0.953	0.937
18	4.41	1.013	1.009
sum		**18.966**	**18.929**

Systematic Errors

The differences between quantities derived from left and right phototubes come out as low as 0.2% in the averaged quantities. That agreement is really only a check of the consistency between the two methods used to measure tagger rate: the scalers and the height of the TDC randoms continuum in the data. The beam-target misalignment correction amounts to roughly 4% in the tagging efficiency. This the largest uncertainty in the normalization. A conservative estimate for the systematic error is this 2% coming from beam-target misalignment. Statistical errors on the normalization are negligible.

References

1. D. Sober (May 17, 2005) private communication.
2. D. Sober (June 7, 2005) private communication.
3. D. Sober (August 26, 2002) Hall B tagged photon beam information.

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