What Do We Get With 10^7 Tagged Photons per Second?

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Abstract

This paper is suppsed to be a *bottom up* analysis on the number of events we can expect in one year of HALL D running using 10^7 tagged photons per seconds. Based on several more–or–less reasonable assumptions, we find a significant amount of data in the 1.0 to 2.3 GeV/c^2 mass range using an $8GeV$ primary beam electron.

1 The Photon Beam

Based on the rate discussions that took place at the F.S.U. Eight+ workshop, I have decided to compile this document to examine the physics we can potentially reach with $R = 10^7$ tagged photons per second. I have assumed that we have an $8GeV$ electron beam being used to generate tagged photons from a normal bremsstrahlung source. The tagger is able to tag a $3.0GeV$ energy bite topping out at 95% of the beam energy — $4.6GeV$ up to $7.6GeV$. The Bremsstrahlung spectrum is given as: $N(E) = N_0/E$, where $N_0 = R \cdot [\ln(E_{\text{high}}) - \ln(E_{\text{low}})]$. This spectrum is shown in figure 1. For 10^7 tagged photons, there are 3×10^7 untagged photons in the range from $E_\gamma = 1GeV$ up to $E_\gamma = 4.6GeV$. Extending this down to the single–pion threshold at $E_\gamma = 0.3$ GeV/c yields a total 5.4×10^7 untagged photons. Finally to be complete the number of photons between energies E_1 and E_2 is given as:

$$N(E) = N_0 \ln\left(\frac{E_2}{E_1}\right).$$

In addition to the beam rate, we have assumed a $30cm$ long liquid hydrogen target. We use the standard values for the density of hydrogen of $\rho_{LH2} = 0.070gm/cm^3$, or 4.2×10^{22}protons$/cm^3$. This leads to

$$N_{\text{target}} = 1.2 \times 10^{24}\text{protons}/cm^2.$$

With this, we can now compute various production rates:

$$N_{\text{Events}} = N_\gamma \cdot N_{\text{target}} \cdot \sigma.$$

2 Known Photoproduction Cross Sections

Table 1 summarizes some of the known cross sections from photoproduction experiments. This is in no way meant to be complete, but rather indicate that many of the more common cross sections are on the order of $0.5\mu b$, and that typical numbers of events are only a few thousand.

3 Rate Estimates

In table 2 is shown a *spread sheet* calculation for the number of events expected for a uniform cross section of $\sigma = 1.00\mu b$. We assume a tagged rate of 10^7 photons per second distributed

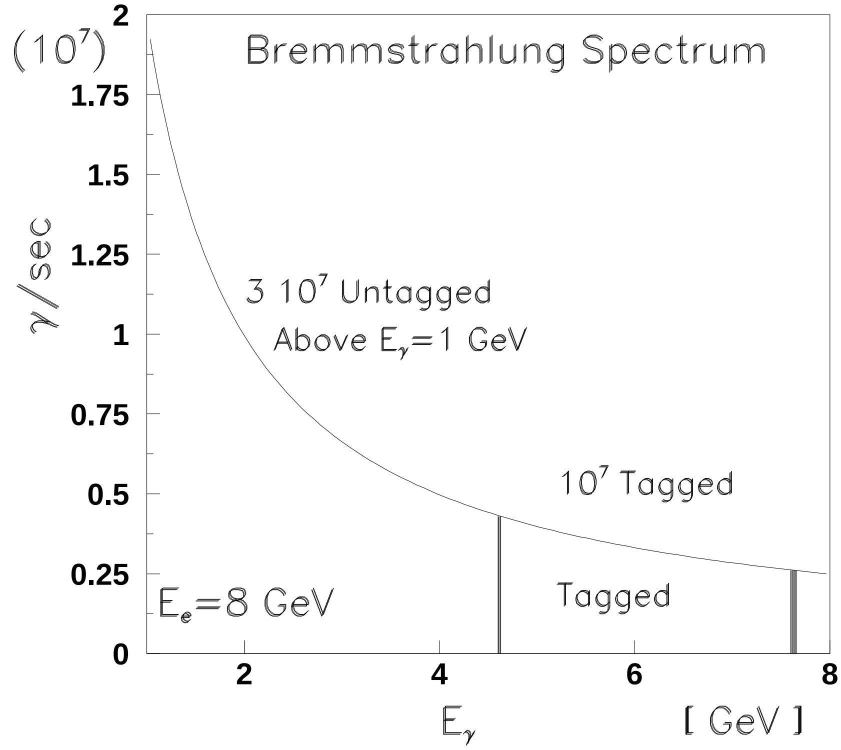

Figure 1: The Photon Energy Spectrum from an $8GeV$ electron beam.

according to the bremsstrahlung spectrum as shown in figure 1. We have cut the spectrum into approximately 0.250 GeV/c wide bins in E_γ. The dependence of the cross sections on t will be discussed in section 4. In computing the number of events per year, we have assumed that there are 100 days of running per year, and that the reconstruction efficiency is 10%.

What can change in this table? Clearly there are detector advantages to running with a shorter target. Trigger hardware around the target needs fewer channels, so shortening the target by a factor of 2 is not unreasonable. The beam rate could also be raised. CLAS is currently running at about $5 \cdot 10^7$ tagged photons per second over the energy range of $0.8GeV$ up to $3.8GeV$. Doubling the current rate would lead to a total situation not too far off from the current situation in Hall B. Taken together, these of course cancel each other.

Reaction	E_γ [*GeV*]	σ [μb]	*Events*	*Reference*
$\gamma p \to \Delta^{++}\pi^-$	2.8	3.7 ± 0.4		[1]
	4.7	1.0 ± 0.1		[1]
$\gamma p \to \pi^+\pi^-\pi^+\pi^- p$	4-6	4.0 ± 0.5		[2]
	6-8	4.8 ± 0.5		[2]
	8-12	4.5 ± 0.6		[2]
$\gamma p \to \pi^+\pi^-\pi^-\Delta^{++}$	4-6	1.65 ± 0.2		[2]
	6-8	1.8 ± 0.2		[2]
	8-12	1.1 ± 0.2		[2]
$\gamma p \to n\pi^+\pi^+\pi^-$	16.5-21.0		3781	[4],[5]
$\gamma p \to p\pi^+\pi^+\pi^-\pi^-\pi^\circ$	16.5-21.0		2553	[6]
$\gamma p \to \Delta^{++}\pi^+\pi^-\pi^-\pi^\circ$	16.5-21.0	0.6 ± 0.1	2553	[6]
$\gamma p \to \Delta^{++}b_1(1235)$	16.5-21.0	0.6 ± 0.1	2553	[6]
$\gamma p \to a_2^-\Delta^{++}$	19	0.45 ± 0.05	200	[3]

Table 1: A summary of cross sections from some known cross sections.

4 Rate Estimates as a Funtion of t

We now want to flip the rates given in table 2 into corresponding bins of *mass* and t. We consider the idealized reaction in 1 where the mass of X, m_x can vary, but the nucleon N is restricted to either a proton or a neutron, both of which we shall assume have the same mass.

$$\gamma p \to XN \tag{1}$$

We are now interested in the minimum value of t which can be reached for a particular photon energy, E_γ and m_x. We can obtain the smallest and largest values from the center–of–mass quantities as in equation 2 with $s = 2E_\gamma m_N + m_N^2$.

$$t_0(t_1) = \left[\frac{m_\gamma^2 - m_x^2 - m_N^2 + m_N^2}{2\sqrt{s}}\right]^2 - \underbrace{(p_\gamma \pm p_x)^2}_{\text{com}} \tag{2}$$

In the center of mass, we find that the p_γ is given in equation 3.

$$p_\gamma = \frac{m_N E_\gamma}{\sqrt{m_N^2 + 2E_\gamma m_N}} \tag{3}$$

$$p_x = \left[\frac{(s - m_x^2 + m_N^2)^2}{4s} - m_N^2\right]^{\frac{1}{2}} \tag{4}$$

E_γ	γ Rate	Event Rates		*Reconstructed*
4.60 to 4.75	$0.640 \times 10^6/s$	$0.77/s$	66 350/day	660 000/year
4.75 to 5.00	$1.000 \times 10^6/s$	$1.20/s$	103 700/day	1 040 000/year
5.00 to 5.25	$0.970 \times 10^6/s$	$1.16/s$	100 500/day	1 010 000/year
5.25 to 5.50	$0.930 \times 10^6/s$	$1.12/s$	96 400/day	960 000/year
5.50 to 5.75	$0.880 \times 10^6/s$	$1.06/s$	91 200/day	910 000/year
5.75 to 6.00	$0.850 \times 10^6/s$	$1.02/s$	88 100/day	880 000/year
6.00 to 6.25	$0.810 \times 10^6/s$	$0.97/s$	84 000/day	840 000/year
6.25 to 6.50	$0.780 \times 10^6/s$	$0.94/s$	80 900/day	810 000/year
6.50 to 6.75	$0.750 \times 10^6/s$	$0.90/s$	77 800/day	780 000/year
6.75 to 7.00	$0.720 \times 10^6/s$	$0.86/s$	74 600/day	750 000/year
7.00 to 7.25	$0.700 \times 10^6/s$	$0.84/s$	72 600/day	730 000/year
7.25 to 7.50	$0.670 \times 10^6/s$	$0.80/s$	69 500/day	700 000/year
7.50 to 7.60	$0.260 \times 10^6/s$	$0.31/s$	27 000/day	270 000/year
4.60 to 7.60	$10.0 \times 10^6/s$	$12.0/s$	1 037 000/day	10 400 000/year

Table 2: Rate Estimates based on $\sigma = 1.00\mu b$ and a tagged rate of 10^7 photons/second incident on a $30.0cm$ long liquid hydrogen target. The number of events per year is assumed to include 100 days of running per year with a 10% reconstruction efficiency.

We can now simplify equation 2 to equation 5.

$$t_0(t_1) = \frac{m_x^4}{4s} - \underbrace{(p_\gamma \pm p_x)^2}_{\text{com}} \tag{5}$$

In figure 2 we now plot the limits on $\mid t \mid$ as a function of m_x for photon energies within the tagging range. Figure 3 shows the same plot, but restricted to values of t smaller than $1GeV/c^2$.

We will now make an assumption that we have a total cross section of $1\mu b$, which is constant as a function of E_γ over our range of photon energies. Additionally, we will assume that the cross section has a t dependence given as $e^{-\alpha|t|}$. The only dependence on m_x will come in via the $t_{\rm min}$ of the given reaction. We next will bin the t versus m_x plane into $10MeV/c^2$ wide bins in m_x, (starting at $1GeV/c^2$), and in five $0.2(GeV/c^2)^2$ wide bins in t, (starting at 0).

For each average photon energy as given in table 2, we examine each bin in the t–m plane. If the value of $\mid t_{min} \mid$ is less than or equal to the average t of the bin, we will assume 100% acceptance. Otherwise, the acceptance is taken as 0%. The number of events in this

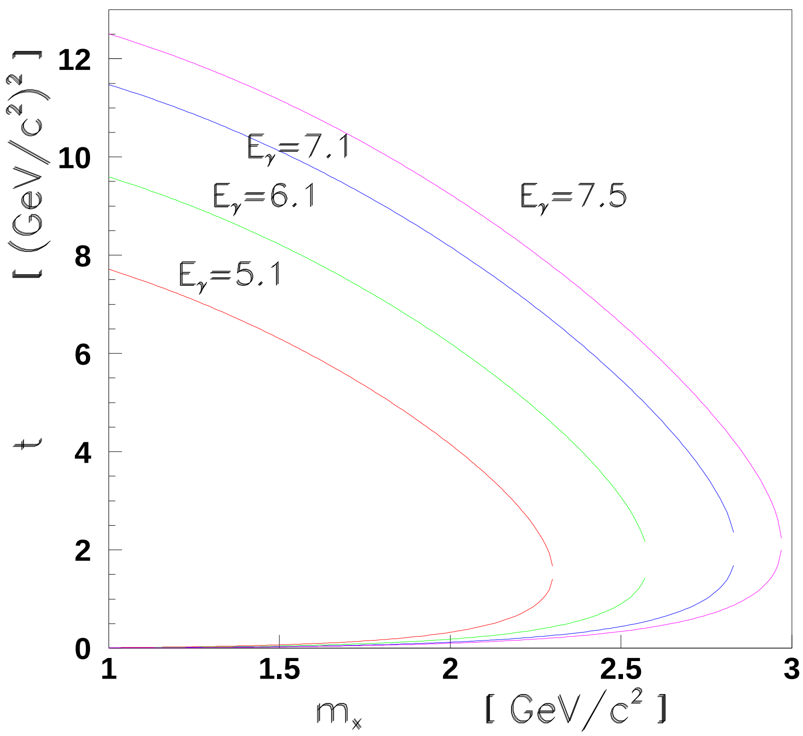

Figure 2: The allowed values of t as a function of m_x for several photon energies. The minimum and maximum photon energies correspond to the ends of the tagging range for an 8GeV electron beam.

bin is then proportional to $e^{-\alpha|t|}$ multiplied by the acceptance. For each individual energy, this is normalized so that the total number of events from *one year of running* are correctly distributed over the plane, (numbers taken from table 2).

Finally, the summed distribution from all photon energies is formed. This leads to an expected number of events in each bin from one year of running. Figure 4 shows this distribution for slope parameters of $\alpha = 5$, (upper left), and $\alpha = 9$ (lower left). For the lowest t–bin, (0.0 to 0.2), the data extend up to nearly $2GeV/c^2$ in mass. Nearly all of these bins have over $50,000$ events per bin — this is a very large number for Partial Wave Analysis!. Examination of the next two bins, (0.2 to 0.4 and 0.4 to 0.6), we extend our mass reach up to about $2.3GeV/c^2$. Here the statistics have dropped a bit, but we still have over $10,000$ events per bin in most bins — again a large number.

In order to try and put these numbers in perspective, we have rebinned the data in a

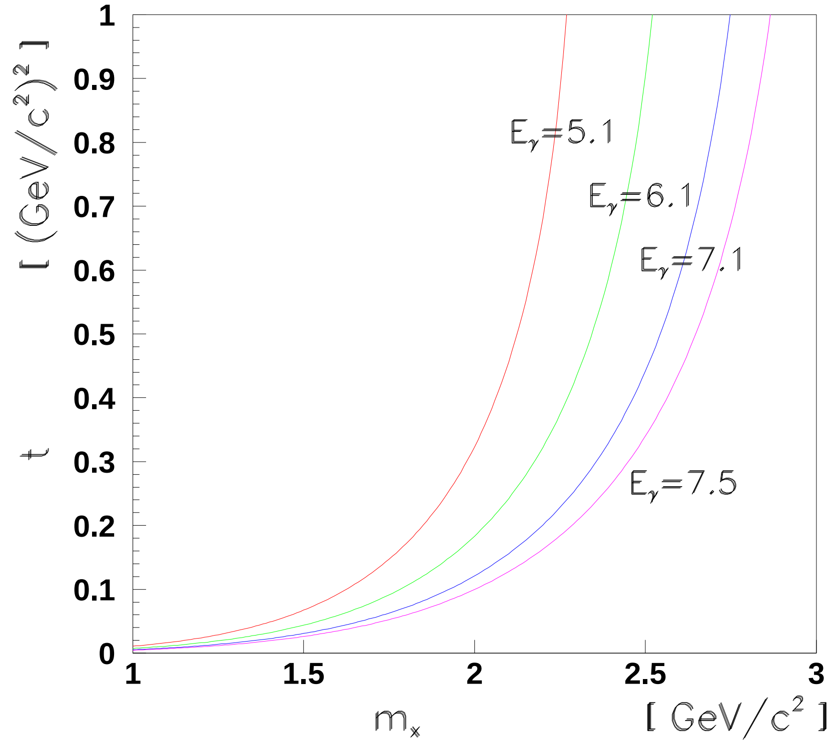

Figure 3: The minimum values of t as a function of m_x for several photon energies. The minimum and maximum photon energies correspond to the ends of the tagging range for an 8GeV electron beam.

fashion similar to that used by E852. In their 3π analysis, the bin width is $5MeV/c^2$ rather than our $10MeV/c^2$, and all data have been put into a single bin in t. At the peak of the $\pi_2(1670)$ they have about 4000 events per bin. Our data are shown in the upper right–hand plot of figure 4 in the same form, and the $\pi_2(1670)$ has been marked on our figure. We have about $100,000$ events per bin at the same place.

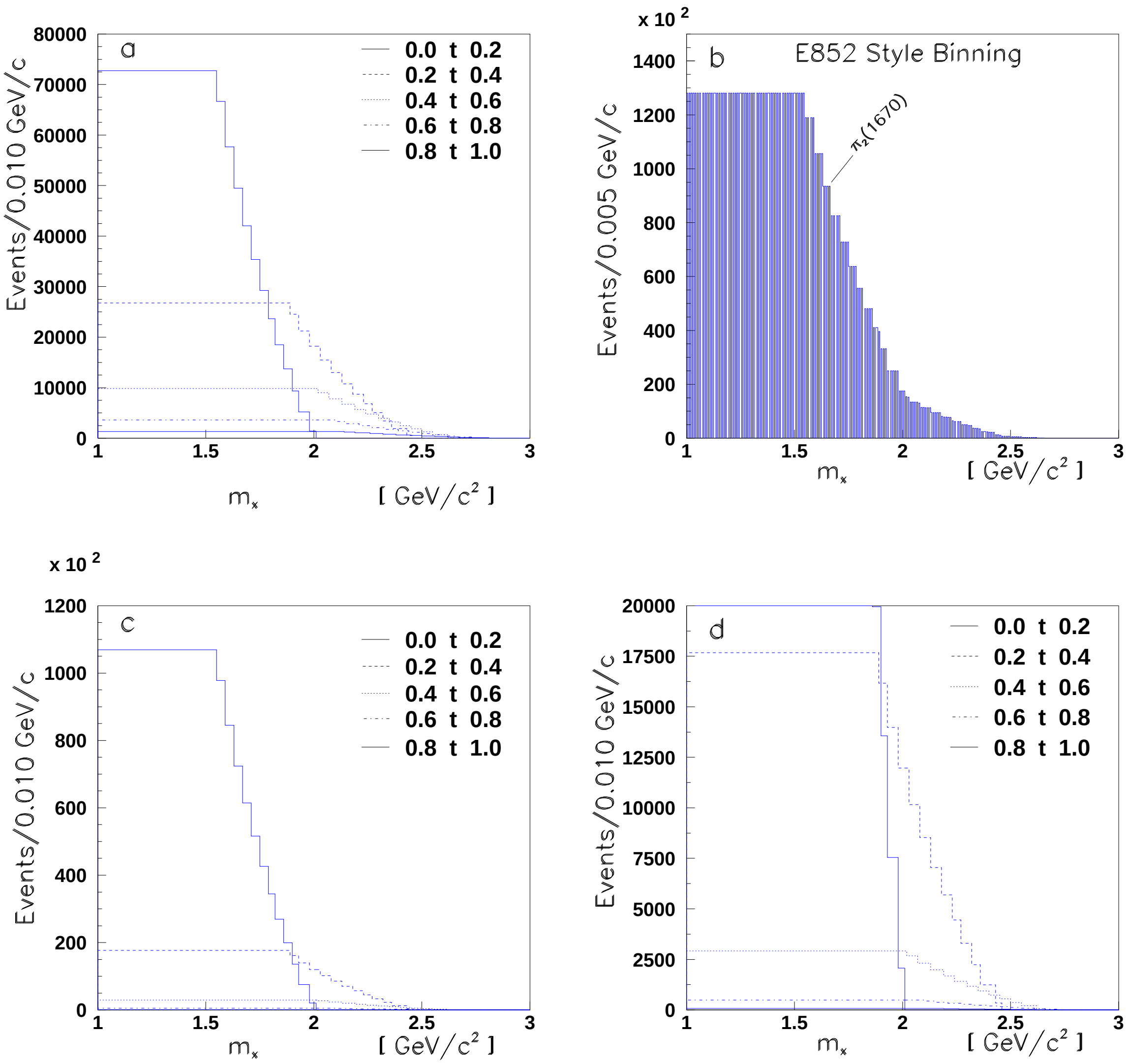

Figure 4: The distribution of events from the full photon beam based on the one year of running data from table 2. The data are assumed to be binned in $10MeV/c^2$ wide bins, and there are five bins in t between 0.0 and 1.0. The upper left–hand figure assumes a slope parameter of $\alpha = 5$, while the lower left–hand figure uses $\alpha = 9$. The lower right–hand figure is an expanded view of the lower left–hand one. Finally, the upper right hand figure shows the data binned in E852 style bins.

5 Conclusions

This report has presented a *bottom up* analysis of the expected event rate in one year of running HALL D with an $8GeV$ electron beam. Most of the results are easily scaled to other assumptions. We reiterate that our assumptions are as follows:

- We have a tagged bremsstrahlung beam produced from an 8 GeV primary electron beam. We are tagging a 3 GeV wide bite from $E_\gamma = 4.6$ GeV up to $E_\gamma = 7.6$ GeV. The total tagged rate is $10^7/s$.
- The photon beam is incident on a 30 cm long liquid hydrogen target.
- The total cross section is independent of E_γ and is set to $1.00\mu b$.
- We have assumed 100 days of running per year with 100% efficiency.
- We have assumed a 10% reconstruction efficiency for good events.
- The cross section is assumed to have a t dependence of $e^{-\alpha|t|}$. We have examined two values of α.

Under these assumptions, we can collect statistics which appear to be about 25 times larger than the current best E852 statistics in one year of running.

References

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