A summary of expected event rates in GlueX

GlueX-doc-xxx

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February 2005

Abstract

This note estimates the number of events that will be present in various experimental final states in GlueX. We find that while there is a very interesting program when running at $10^7\gamma/s$ for 1-2 years, many of the rarer channels that may be crucial for exotic hybrids and strangonia are going to require rates of at least $5\times10^7\gamma/s$.

1 Introduction

This document tries to summarize what is known about photo-production cross sections for a photon energy of about $9\,GeV$. The data come from a series of publications by Ballam *et al.*. Based on these initial numbers, I then try to estimate what the cross sections to specific final states will be. Then using these numbers, I attempt to estimate how many events we will see in a typical GlueX partial wave analysis.

2 Known Cross Sections

The total hadronic cross-section, σ_t, for the reaction:

$$\gamma p \rightarrow \text{Anything}$$

is known to be about $120\mu b$ at $9\,GeV$. This number is used to set the rates at which GlueX takes data. To examine this more closely, we take the $30\,cm$ long liquid hydrogen target in GlueX. This has a number of target centers, N_t given as:

$$N_t = 12.6\times 10^{23} cm^{-2} = 1.26 b^{-1}.$$

Using, σ_t, N_t, and a tagged photon rate, N_γ of:

$$N_{gamma} = 1\times 10^8 \gamma/s$$

we find that the event rate can be written as:

$$\begin{aligned}\mathcal{R} &= \sigma_t \times N_t \times N_{gamma}\\ &= (120\mu b)\times(1.26b^{-1})\times(10^8 s^{-1})\\ &= 15\,kHz\end{aligned}$$

In agreement with the rates in the GlueX design report.

We now look at more specific cross sections as part of the $\sigma_t = 120\,\mu b$, In particular, Table 1 shows measured cross sections for various final states. We now want to guess what the decomposition of some of more specific final states. In Table 2 we make some of these estimates to various final states are. The accuracy of this latter table gets worse as we go to smaller cross sections. As a note, some of these are estimates based on CLAS numbers from 2 to $3\,GeV$ photon energies. The $\eta\pi^+\pi^-$ is between 5 and $10\,\%$ of the $\pi^+\pi^-\pi^\circ$ channel.

Reaction	σ
$\gamma p \to p\pi^+\pi^- X^{neut}$	$20\mu b$
$\gamma p \to p\pi^+\pi^-\pi^\circ$	$10\mu b$
$\gamma p \to n\pi^+\pi^+\pi^- X^{neut}$	$20\mu b$
$\gamma p \to pK^+K^- X^{neut}$	$1\mu b$
$\gamma p \to f_2(1270)p$	$1\mu b$
$\gamma p \to a_2^+(1320)n$	$1\mu b$
$\gamma p \to b_1^\circ(1235)p$	$1\mu b$
$\gamma p \to \rho'(1465)p$	$1\mu b$
$\gamma p \to \rho(770)p$	$20\mu b$
$\gamma p \to \omega p$	$2\mu b$
$\gamma p \to \phi p$	$0.4\mu b$

Table 1: A compilation of known cross sections for photo production at about $9\,GeV$ photon energy.

3 Data Rates

Using typical cross sections from the previous section, we can now estimate how many events will be collected in GlueX in one year of running. There are various assumptions that play into this. First, we assume that 1 year of running corresponds to 10^7 seconds. We also assume that the reconstruction efficiency is only 10%. Lastly, we consider photon beam rates of both $10^7\,\gamma/s$ and $10^8\,\gamma/s$. These numbers bound what GlueX expects to be able to do. In Table 3 are given the number of events per year for various production cross sections. Nominally, for final states with cross sections on the order of $1\,mub$, one to two years of running at 10^7 is likely to give us a good handle on things. For the smaller cross sections, we will require the higher rates. Probably on the order of two to three years at 10^8. This is especially going to be true with strangeness final states, where from Table 1, we see that $K^+K^-X_{neut}$ is about $1\,\mu b$.

4 Data Distributions

We also want to estimate how the data will be distributed as a function of the meson mass. Let us assume that we have a base production cross section, σ for the channel of interest and that the production follows an $e^{-5|t|}$

$\gamma p \to p\pi^+\pi^-\pi^\circ$	5–10μb
$\gamma p \to n\pi^+\pi^+\pi^-$	5–10μb
$\gamma p \to p\pi^+\pi^\circ\pi^\circ$	5–10μb
$\gamma p \to p\pi^+\pi^-\pi^+\pi^-$	$1-3\mu b$
$\gamma p \to p\pi^+\pi^-\pi^\circ\pi^\circ$	$1-3\mu b$
$\gamma p \to p\pi^\circ\pi^\circ\pi^\circ\pi^\circ$	$1-3\mu b$
$\gamma p \to n\pi^+\pi^-\pi^+\pi^\circ$	$1-3\mu b$
$\gamma p \to n\pi^+\pi^\circ\pi^\circ\pi^\circ$	$1-3\mu b$
$\gamma p \to p\pi^+\pi^-\pi^+\pi^-\pi^\circ$	$1-3\mu b$
$\gamma p \to p\pi^+\pi^-\pi^\circ\pi^\circ\pi^\circ$	$1-3\mu b$
$\gamma p \to p\pi^\circ\pi^\circ\pi^\circ\pi^\circ\pi^\circ$	$1-3\mu b$
$\gamma p \to n\pi^+\pi^-\pi^+\pi^-\pi^+$	$1-3\mu b$
$\gamma p \to n\pi^+\pi^-\pi^+\pi^\circ\pi^\circ$	$1-3\mu b$
$\gamma p \to n\pi^+\pi^\circ\pi^\circ\pi^\circ\pi^\circ$	$1-3\mu b$
$\gamma p \to p\pi^\circ\omega$	$1\,\mu b$
$\gamma p \to n\pi^+\omega$	$1\,\mu b$
$\gamma p \to p\pi^+\pi^-\omega$	0.1–0.5 μb
$\gamma p \to p\pi^\circ\pi^\circ\omega$	0.1–0.5 μb
$\gamma p \to n\pi^+\pi^\circ\omega$	0.1–0.5 μb
$\gamma p \to p\pi^+\pi^-\eta$	0.2–1.0 μb
$\gamma p \to p\pi^\circ\pi^\circ\eta$	0.2–1.0 μb
$\gamma p \to p\eta\eta$	0.05–0.2 μb
$\gamma p \to p\omega\eta$	0.05–0.2 μb
$\gamma p \to p\omega\omega$	0.05–0.2 μb
$\gamma p \to p\eta\eta\prime$	0.05–0.2 μb

Table 2: Estimated cross sections for various reactions of interest in searching for hybrid mesons.

$\sigma\ \mu b$	$10^7\gamma/s$		
$1\ \mu b$	$12.6\ Hz$	$1.26\times10^8\ yr^{-1}$	1.26×10^7
$1\ nb$	$0.0126\ Hz$	$1.26\times10^5\ yr^{-1}$	1.26×10^4
$0.1\ nb$	$0.00126\ Hz$	$1.26\times10^4\ yr^{-1}$	1.26×10^3
	$10^8\gamma/s$		
$1\ \mu b$	$126.\ Hz$	$1.26\times10^9\ yr^{-1}$	1.26×10^8
$1\ nb$	$0.126\ Hz$	$1.26\times10^6\ yr^{-1}$	1.26×10^5
$0.1\ nb$	$0.0126\ Hz$	$1.26\times10^5\ yr^{-1}$	1.26×10^4

Table 3: Expected event rates for various production cross sections in photoproduction. The σ column is the cross section. There are then two blocks of three columns, the first for $10^7\gamma/$ and the second for $10^8\gamma/s$. Within these blocks of columns, are the rate of events in Hz, also the expected number of events in one year assuming 10^7 seconds per year. Finally, the third column is the expected number of reconstructed events assuming 10% reconstruction efficiency.

distribution. Looking at Figure 1 which is a plot of $\mid t \mid$ versus meson mass, we can extract the value of $\mid t \mid_{min}$ and $\mid t \mid_{max}$. For a given mass, we can integrate $e^{-5|t|}$ from $\mid t \mid_{min}$ to $\mid t \mid_{max}$. This integral is proportional to the number of events produced in a given mass bin. Carrying out such a procedure, for a distribution with 180 $10\,MeV$ wide mass bins from 1.0 to 2.8, we find that about 21% of the data is in the lowest bin and about 0.3% of the data is in the highest bin.

Let us now let $\sigma = 1\,\mu b$ and take a photon beam rate of $10^7\,\gamma/s$. Assuming 10 % reconstruction efficiency, we estimate that such a spectrum will have about 10^7 events in it after 1 year of running. This data will be distributed roughly as shown in Figure 2. For the highest mass bins, the data has fallen to about 2500 events. GlueX also makes the statement that one year of running with 10^7 will exceed current (E852) pion production data into 3π. For the 3π final state, the cross section is about $10\mu b$, which increases the counts by a factor of 10 in each bin to produce a total of about 10^8 events. For comparison, the high statistics E852 3π analysis being carried out at IU has about 3×10^7 events.

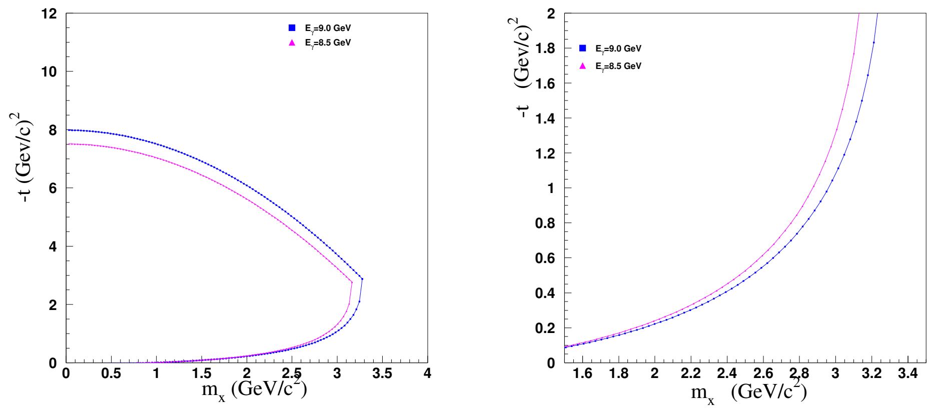

Figure 1: The limits on $\mid t \mid$ for photo-production as a function of the mass of the meson system.

5 Sensitivities to Final States

Estimating the sensitivity to final states requires a number of assumptions. The PWA is carried out in each mass bin of the data. We could increase bib-by-bin statistics by going from 10 to 20 MeV wide bins. However, if we want to know something about the t-distribution of a given bin, we will need to divide things into several t-bins. Probably a safe assumption is that we need about $25,000$ counts in a given mass bin to be able to carry out a solid measurement. For a small signal, we need about 2% of this number per bin over about 10 bins, or on the order of 5000 events. This is roughly a $0.5\,nb$ cross section at 10^7 and a $0.05\,nb$ cross section at 10^8. The left hand plot in Figure 2 shows how long one would need to run at 10^7 photons per second to reach the 25000 number for a $1\,\mu b$ cross section. Essentially, for masses below about $2.4\,GeV/c^c$, this will be met in a year of running.

For final states in which the base cross section is $100\,nb$, five years of running would be required to reach this number for masses below $2\,GeV/c^2$ at $10^7\,\gamma/s$. This cross section is probably an upper limit for final states involving kaons. Pushing the primary beam rate up to $5\times 10^7\gamma/s$ as quickly as possible is going to be crucial for programs involving strange particles in the final states.

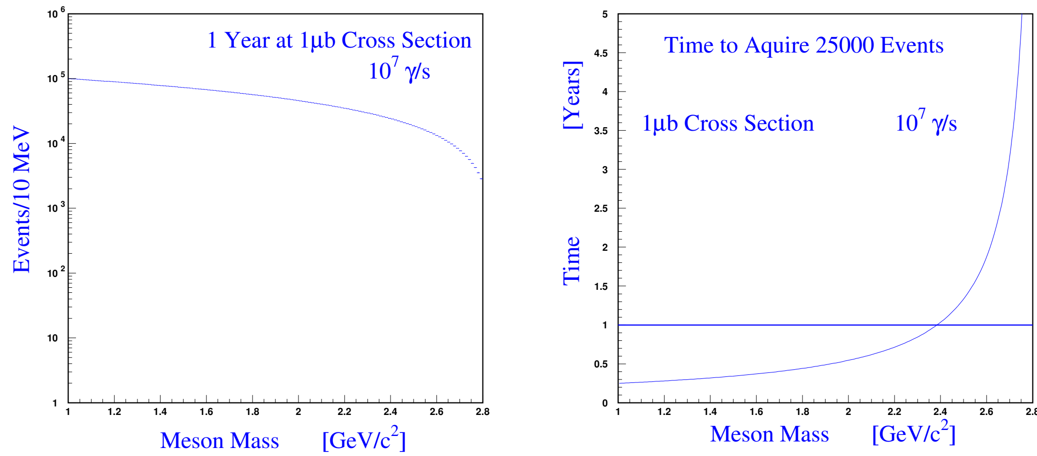

Figure 2:

6 Conclusions

The GlueX experiment can expect a solid physics program from running about two years at a rate of $10^7 \gamma/s$. However, to be fully analyze channels that contain η, K's or possbly even ω's, the rates are likely going to need to increase to at least 5×10^7 to collect sufficient statistics in a two year period. Even rarer channels are going to require running for longer periods of time.