PHOTOPRODUCTION OF J/ψ AT GLUEX

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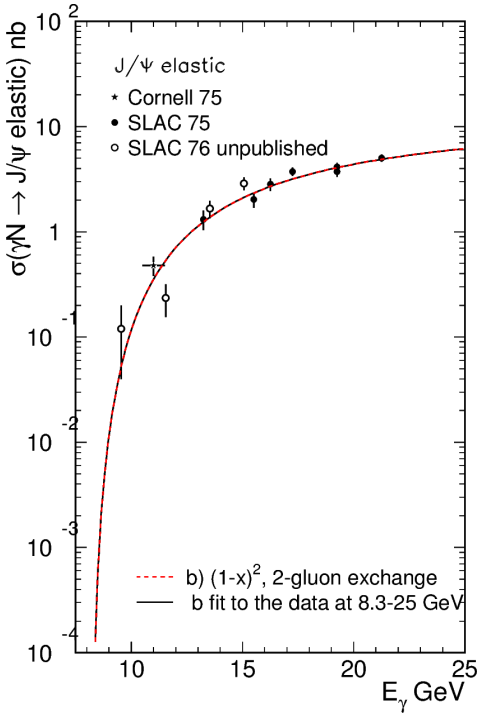
A number of you know me personally, but a number of you pehaps do not. So let me first introduce myself.

- I am Kam Seth, from Northwestern University in Evanston, IL. My small research group, funded by the DOE, consists of two postdoctoral researchers, Associate Professor Amiran Tomaradze, and Research Associate Sean Dobbs, whom you have met during this meeting, and usually two graduate students.
- With that done, let me describe how our long standing interest in hadron physics has led us to propose to join the GlueX Collaboration and participate in its research program.
- We have been engaged in the past in the hunt of QCD exotics (glueballs, hybrids, and exotics of the charmonium region), and in spectroscopy, mainly of charmonium.

It is a surprising fact that although modern hadron spectroscopy began with the 1974 discovery of J/ψ in low energy experiments, $p(80\text{ GeV}) + \text{Be} \to e^+e^-$ at BNL and $e^+ + e^-(\sqrt{s} = 3.1\text{ GeV}) \to e^+e^-, \mu^+\mu^-$, the mechanism of the production of J/ψ is not understood in any but the two obvious annihilation processes, $e^+e^- \to \gamma^* \to J/\psi$, and $p\bar{p} \to 3g^* \to J/\psi$. Many theoretical models, which go by the names of "color singlet model", "color evaporation model", gluon fusion, "NRQCD model", ... exist, but none have universal applicability or success. Among these is the problem of our present interest: low energy photoproduction and electroproduction of charmonium states, in particular the ${}^3S_1$ state J/ψ.

Being experimentalists we certainly believe that the true answer to the production question can only be based on experimental measurements. Unfortuantely, low energy measurements of photo– and electro–production of J/ψ are few, and they become fewer and fewer, and become non-existent as we approach the threshold energy of ~ 8.2 GeV for the real or virtual photon.



With the 6 GeV CEBAF the study of charmonium production was impossible, but the 12 GeV upgrade has made it possible to to study photo– and electro–production of J/ψ, and this is the possibility that has catalyzed our interest in joining the GlueX Collaboration.

We are aware of the fact that there are two pre-existing proposals for studying threshold production of J/ψ:

E12–12005 — Near Threshold Electroproduction of J/ψ at 11 GeV (Hall A)
A$^-$, 60 days, one of 17 Hall A proposals for 1280 days

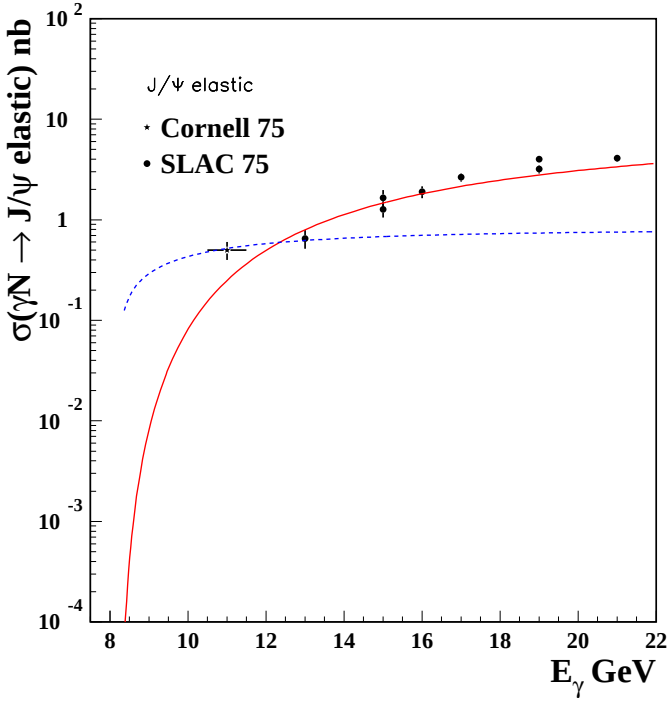
E12–12001 — Timelike Compton Scattering and J/ψ photoproduction on the proton in e^+e^- pair production with CLAS12 at 11 GeV (Hall B)
A$^-$, 120 days, one of 20 Hall B proposals for 1491 days

It is not my purpose to be critical of these proposals, but to present to you our proposal to measure J/ψ photoproduction with the GlueX detector as part of its general program of measuring meson production. We believe that we can make excellent measurements with good precision in the range $E_\gamma \approx 8.7 - 11.5$ GeV. We believe that these measurements can be the first made at JLab. We are enthusiastic and optimistic because of the preliminary studies we have made using the available GlueX software and event generator. The results are, of course, preliminary, but very encouraging.

- We simulate $\gamma + p \to J/\psi + p$, $J/\psi \to e^+e^-$ using the event generator provided by E. Chudakov. Events with $E_\gamma = 8.4 - 11.7$ GeV are accepted, assuming coherent and incoherent photon production. The 2–gluon J/ψ production model of Brodsky et al. is used.

- We simulate the detector response using the `sim-recon-2012-11-16` code version and reconstruct the events with the Mattione analysis libraries.

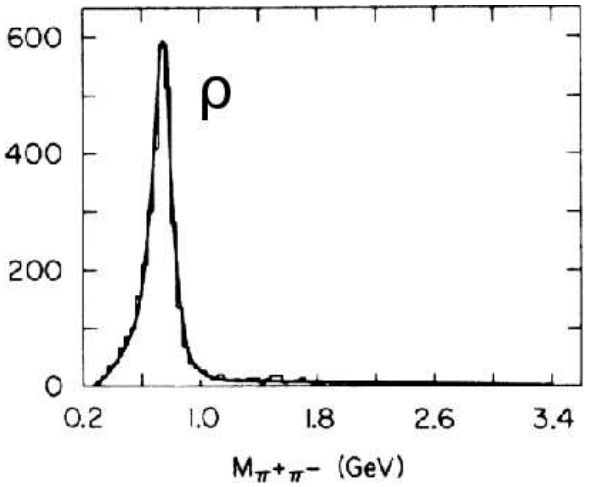
- The major challenge for this analysis is separating the J/ψ signal from its backgrounds, of which there are two primary ones:
  - High mass $\pi^+\pi^-$ pairs from $\gamma p \to p\pi^+\pi^-$
  - Non-resonant (Bethe–Heitler) $\gamma p \to pe^+e^-$ production

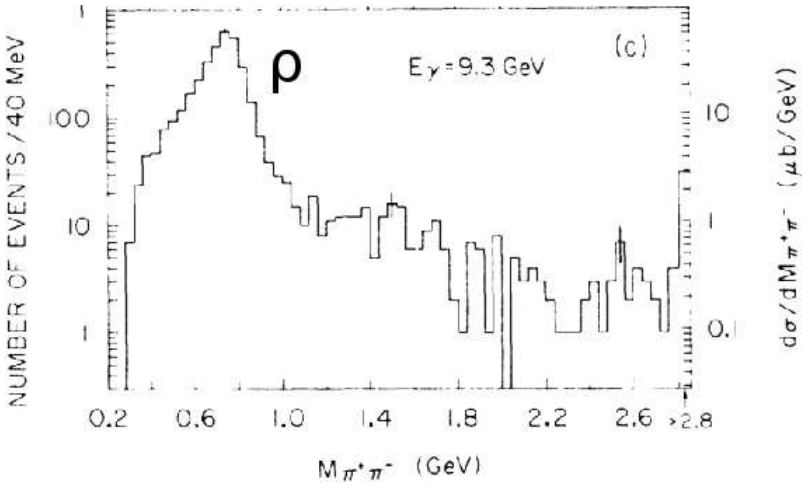


The main background to the $\gamma p \to p e^+ e^-$ final state is the reaction $\gamma p \to p\pi^+\pi^-$. We can estimate the size of this background using existing SLAC measurements.

- The total cross section has been measured to be $\sigma(\gamma p \to p\pi^+\pi^-) = 14.7 \pm 0.6$ μb (PRD 8, 1277 (1973)).
- A more detailed analysis of $\gamma p \to p\pi^+\pi^-$ found 12 events with $M(\pi^+\pi^-) > 2.8$ GeV out of a total of 3480 measured events (PRD 7, 3150 (1973)).
- Therefore, $\sigma(\gamma p \to p + (\pi^+\pi^-)_{>2.8\ \mathrm{GeV}}) = 14.7\ \mu\mathrm{b} \times (12/3480) = 51$ nb.
- We hope to measure J/ψ production cross sections near threshold in the range of 1 pb – 500 pb, so we need e/π discrimination on the level of

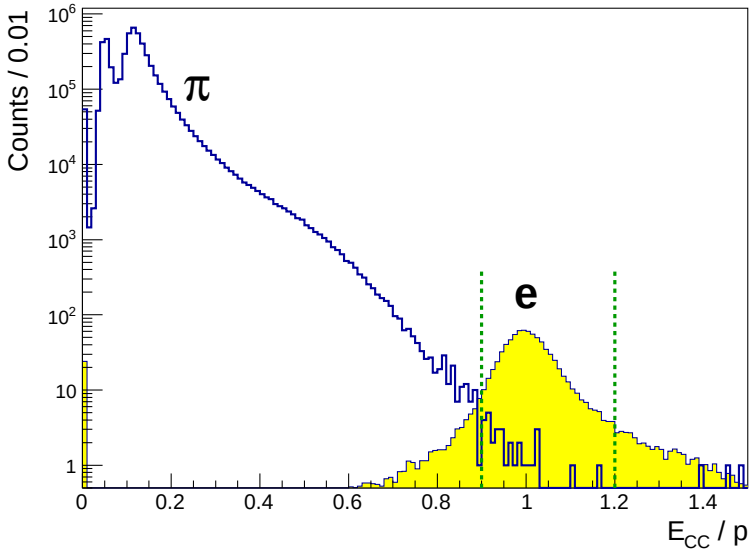
$$\mathbf{(2 - 100) \times 10^{-5}}$$



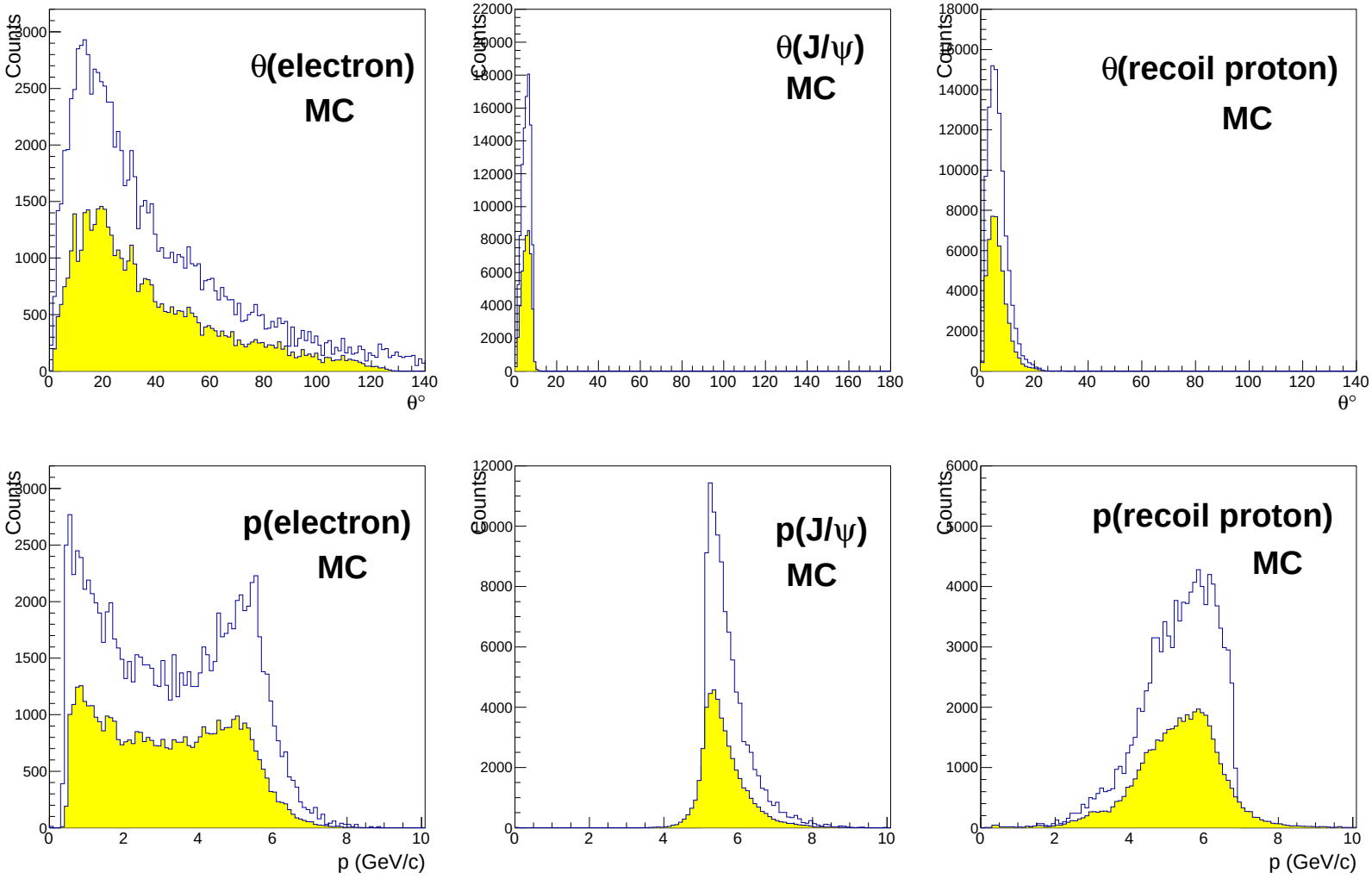


We can distinguish between electrons and pions using the variable E/p, where where p is the reconstructed momentum of the charged particle in the tracking chambers, and E is the energy deposited by the charged particle in the electromagnetic calorimeter.

- Electrons deposit all of their energy into the calorimeter, yielding $E/p \approx 1$.
- Pions leave mainly ionization energy in the calorimeter, with most having $E/p \ll 0.5$.
- Using MC simulated events, we find that if we select events with $E/p = 0.9 - 1.2$, efficiency for electrons of $\epsilon(e^{\pm}) = 85\%$, and efficiency for pions $\epsilon(\pi^{\pm}) = 6 \times 10^{-6}$. In other words, we reject pions at the level of 6×10^{-6}. This is better than needed.



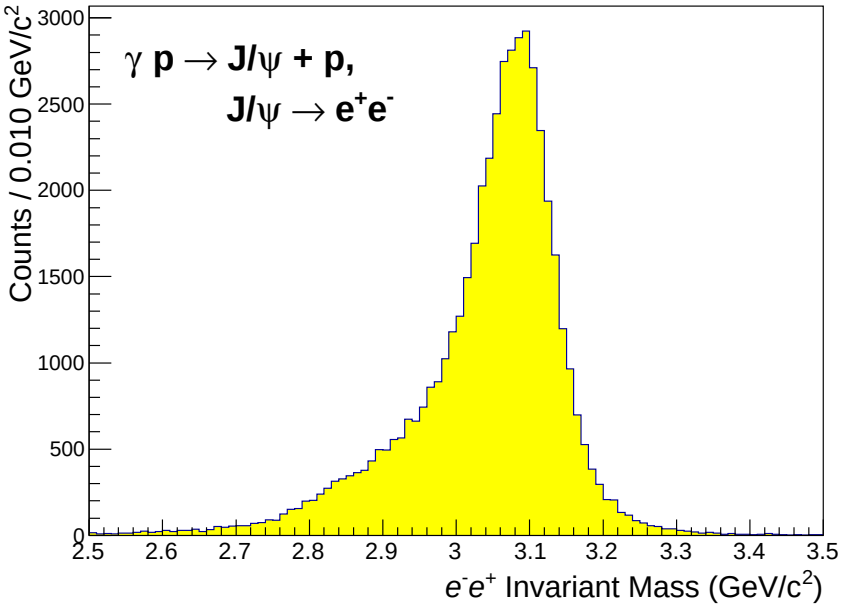
We have been making MC simulations, both at the generator level and the reconstructed level (i.e., though the detector, using the currently available software) for the kinematical characteristics of the proton, the J/ψ, and the electrons. A few of these are illustrated in the following plots.



Open Histograms — Generator Level

Shaded Histrograms — Reconstruction Level

$\gamma p \to J/\psi p$, $J/\psi \to e^+e^-$ signal MC



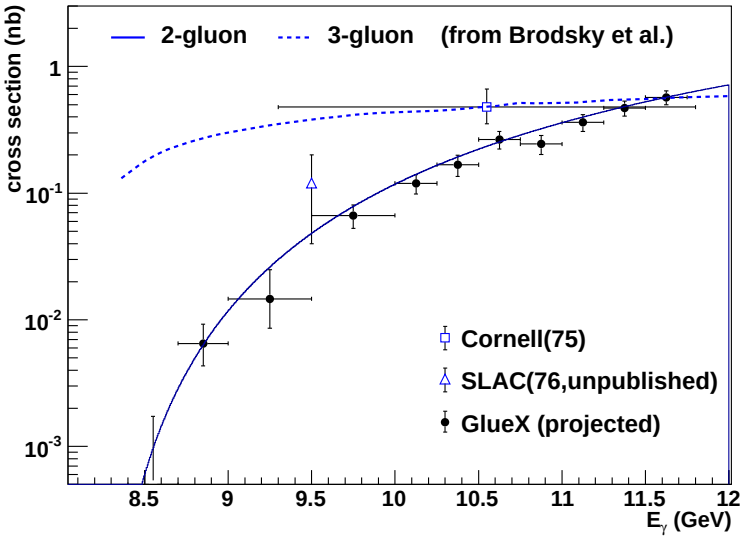
- This plot illustrates the reconstructed $J/\psi \to e^+e^-$ signal. The reconstruction efficiency is $\epsilon \approx 45\%$.
- Obviously, more work needs to be done to improve the J/ψ peak shape, whose long tail is due to radiation by the e^+ and e^-.

Estimated number of $\gamma p \to J/\psi p$, $J/\psi \to e^+e^-$ events

- To estimate the expected yield of J/ψ in a typical GlueX run, we assume an incident photon flux of $N = 2 \times 10^7$ with $E_\gamma = 8 - 11.8$ GeV.
- Assuming the two–gluon exchange model of Brodsky et al., we obtain an expected production rate of 3×10^{-3} $J/\psi/s$.
- For a Monte Carlo efficiency of $\sim 45\%$, with $\mathcal{B}(J/\psi \to e^+e^-) \approx 6\%$, and a total running time of 5×10^6 seconds (~ 2 months), we expect to reconstruct a total of

$$(3 \times 10^{-3}\ J/\psi/s) \times (5 \times 10^6 s) \times 0.45 \times 0.06 \approx 400\ J/\psi$$

in 2 months.



Summary

- We have made MC studies for the proposal to measure $\gamma p \to J/\psi p$, $J/\psi \to e^+e^-$ at GlueX. The results are very promising and we are excited about the prospects.
- This measurement can be made in parallel with other measurements.
- There are several next steps to be taken:
  - Backgrounds will be studied in more detail, including a generic sample of γp decay products.
  - We will look into how to increase the efficiency for electron reconstruction, including bremsstrahlung recovery.