Sub-Threshold J/ψ Photoproduction

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Jefferson Lab Experiment E03-008

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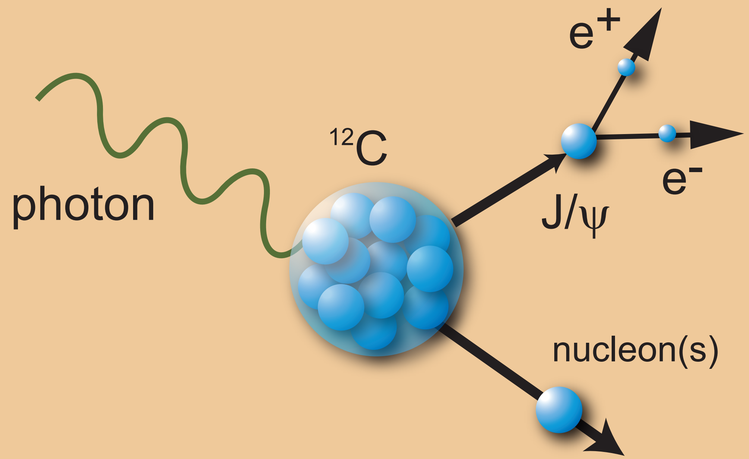
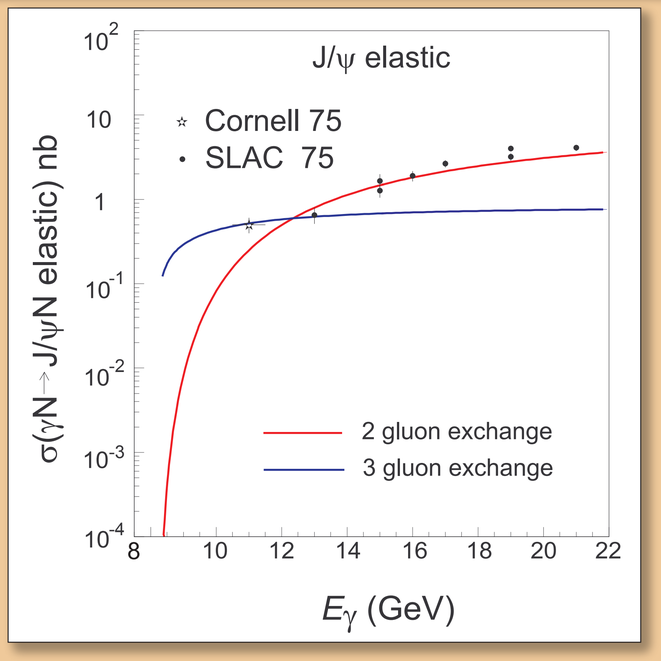
Abstract

We plan to measure the cross section for J/ψ photoproduction from carbon using the SOS and HMS spectrometers in Hall C to detect lepton pairs from charmonium decay. We use an untagged bremsstrahlung beam by passing a high current (60 μA) 6 GeV electron beam through the thick carbon target. We have been approved to run seven days for this exploratory measurement, with the running time divided among two spectrometer settings to scan the *t*-dependence of the cross section. We expect to observe somewhere between 1 and 1000 events at each kinematic setting, with backgrounds at or below the level of 1 count. The kinematics are sub-threshold to production from a free proton, so the experiment will probe rare short distance configurations in the nucleus, and will be sensitive to higher twist effects (such as three-gluon exchange), intrinsic charm contributions, and possible multi-quark resonances involving charmed quarks.



The figure above is a schematic of J/ψ photoproduction. High energy photons are produced in the carbon target and interact with carbon nuclei downstream. If the center of mass energy between the photon and nucleon (or cluster of nucleons) is high enough, a J/ψ meson can be produced. The J/ψ decays about 12% of the time to a pair of electrons or a pair of muons. These leptons will be detected in coincidence in the HMS and SOS spectrometers.



The Cornell data indicate that the cross section flattens out near threshold. Possible explanations are a threshold ehancement of the 3-gluon exchange process as predicted by a model of Laget (blue curve in figure), or a dipole-like form factor model of Strikman.

E03-008 Summary

One of the main goals of nuclear physics is to understand to what extent a nucleus differs from a loosely bound system of quasi-independent nucleons. When nucleons are very close spatially, corresponding to rare high momentum components of the single particle wave function, many interesting and potentially exotic configurations can arise. One way to look for such configurations is with reactions that are significantly sub-threshold to production from a free nucleon. Of all such reactions, photoproduction of charmonium is one of the cleanest because the charm quark content of a nucleon is very small compared to the light quarks. In light meson photoproduction, the quark content of the mesons can originate in the nuclear target, while in the case of charmonium photoproduction, the quark-interchange mechanism is essentially absent, and the reaction must proceed via gluon exchange in order for color to be conserved. In addition, the heavy mass of the charm quark (about 1.5 GeV) ensures a hard scale to the problem, making it more tractable in QCD.

There is currently very little known about sub-threshold J/ψ photoproduction, either theoretically or experimentally. Theoretical estimates that have been made to date show several order-of-magnitude variations. The estimates of the rates expected both with "ordinary" Fermi-smearing assumptions, as well as with more interesting effects, will certainly be refined in the next years, particularly in anticipation of the results of this experiment. Improved data in the above-threshold region from the Stanford Linear Accelerator Center (SLAC) and eventually Jefferson Lab at 12 GeV will help reduce the uncertainties in the free-nucleon cross sections. On the experimental front, very preliminary analysis of lepton-pair photoproduction data from Jefferson Lab's Hall B (CLAS) shows one possible event candidate in the J/ψ mass region, which gives a hint as to the order-of-magnitude of the sub-threshold cross section.

We will increase the sensitivity of the CLAS data by more than two orders of magnitude in an exploratory investigation of sub-threshold J/ψ photoproduction using the two spectrometers in Hall C. We can roughly map out the magnitude and *t*-dependence of the cross section, and perhaps set the stage for more detailed investigations. By using a pair of high-resolution spectrometers to detect lepton pairs from J/ψ decays, we are confident that a significant J/ψ signal will be seen above backgrounds.

Additionally, a measurement of sub-threshold J/ψ production will benefit experiments trying to produce a quark-gluon plasma (QGP). J/ψ suppression in heavy ion collisions has been regarded as one of the more interpretable of the many signals that might indicate the onset of a QGP. Unfortunately, there is presently sufficient uncertainty in the production and propagation mechanisms that the J/ψ suppression data from CERN SPS can potentially be explained by conventional nuclear physics models. Better understanding of how charmonium is produced, and how it interacts with nucleons is needed to understand if the heavy ion data from CERN and the Relativistic Heavy Ion Collider (RHIC) indicate the onset of a new state of matter or not. Experiment E03-008 is designed to address the question of how charmonium is produced in kinematics where the probability that two or more nucleons are in close proximity is enhanced, as may be relevant to heavy ion collisions.