The J/ψ Way to Nuclear Structure

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We propose to investigate the properties of nuclear matter by measuring the elastic scattering of J/ψ on nuclei with high precision. The J/ψ mesons are produced from the photons emitted in high energy electron-proton or electron-nucleus scattering in the low-x region. The measurement could be performed at the future ENC, EIC or LHeC facilities.

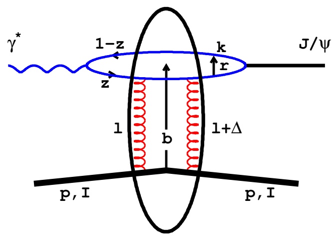

Figure 1: Elastic scattering of a J/ψ meson on a proton or ion.

In recent years HERA has shown that deep inelastic electron-proton reactions at high energy can be described by the scattering of small quark-antiquark dipoles. In this so called low-x region, the incoming target proton frequently remains intact. This happens because, in leading order QCD, the $q\bar{q}$ pair interacts elastically with the nucleon by exchanging *two* gluons with transverse momenta, $\vec{l}$ and $\vec{l}+\vec{\Delta}$. The transverse momenta of the gluons are large, however their difference, $\vec{\Delta}$, can be very small so that the net momentum transfer to the nucleon is small. The reaction can therefore leave a proton or a nuclear target in its ground state or in a slightly excited state.

Of particular interest is the charmed dipole elastic or quasi-elastic scattering on nuclei with a subsequent transformation into the J/ψ vector meson. In this reaction the momentum transfer can be well measured because it is equal to the difference between the transverse momenta of the incoming virtual photon and the final meson. The advantage of J/ψ scattering is its high cross section and smallness of the dipole. In addition, the momenta of the decay products of $J/\psi \rightarrow \mu^+\mu^-$ or e^+e^- can be very precisely measured. The smallness of the dipole in low-x reactions assures that the interaction is mediated by gluon exchange only. Thus, the deflection of the J/ψ measures directly the intensity and the spatial distribution of the nuclear fields.

The measurement of J/ψ scattering on nuclei could become an important source of information on nuclear structure and high density QCD. The interaction of a dipole with a nucleus

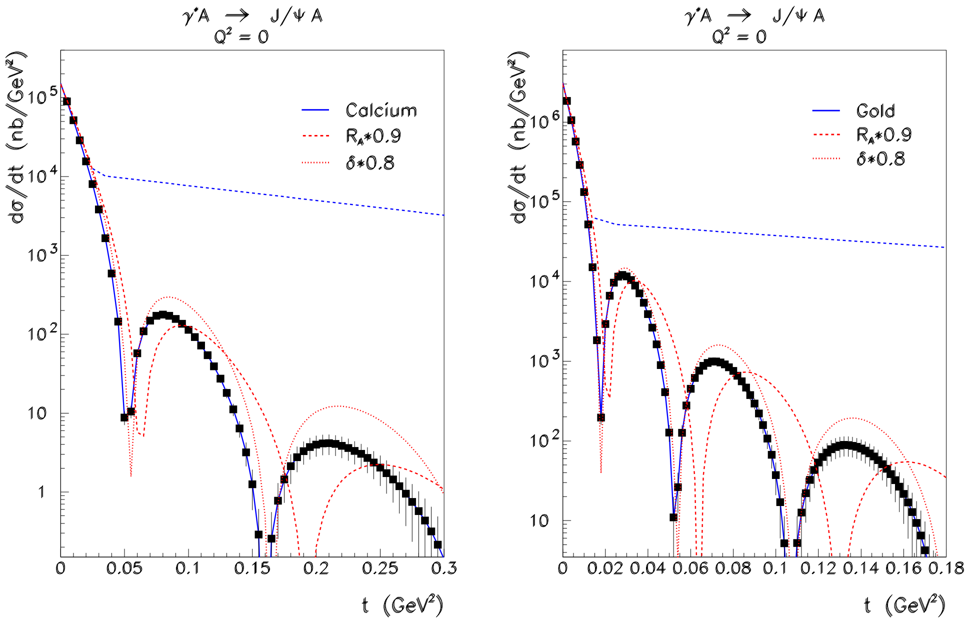

Figure 2: The prediction of the dipole model for the t distribution of coherent J/ψ photoproduction on nuclei assuming that the single nucleon distribution can be identified with the Woods-Saxon distribution. The statistical errors of the simulated measurements are based on the assumed collected sample of 10^6 events. The upper dashed line shows the sum of the coherent and incoherent process in case of no correlations.

can be viewed as a sum of dipole scatterings on the nucleons forming the nucleus. The size of the charmed dipole in elastic J/ψ scattering is around 0.15 fm; i.e., it is much smaller than the nucleon radius. It is therefore possible that dipoles interact with smaller objects than nucleons; e.g., with constituent quarks or hot spots. Taking the conventional point of view and assuming that the nucleus is built out of nucleons and that dipoles scatter on the ensemble of nucleons the dipole model predicts the nuclear cross sections shown in Figure 2.

Figure 2 shows the coherent and incoherent cross sections for scattering on nuclei. In the coherent process the nucleus remains in its ground state. In the incoherent process the nucleus gets excited and frequently breaks into nucleons or nucleonic fragments. Experimentally we expect to be able to distinguish cases where the nucleus remains intact and cases where the nucleus breaks up. In the nuclear breakup process, there are several free neutrons and protons in the final state, as well as other fragments. The number of free nucleons could depend on the value of the momentum transfer. The free nucleons and fragments have high momenta and different charge-to-mass ratios than the nuclear beam, and should therefore be measurable in specialized detectors. However, we do not have a one-to-one correspondence between an intact nucleus and a coherent scattering process since incoherent processes can lead to an intact nucleus in an excited state. The excited states of the nucleus without breakup can be, at least partly, identified and well measured.

The measurement of t-distributions together with the measurement of nuclear debris could become a source of invaluable information about the nuclear equation of state. Thus, the J/ψ is an ideal probe to investigate the inner structure of gluonic fields which keep the nuclei together [1].

References

[1] A. Caldwell and H. Kowalski, arXiv:0909.1254, DESY 09-145, MPP-2009-163