

# Near-threshold Photoproduction of $\phi$ Mesons from Deuterium

In study the medium modification effects, the  $\phi$  meson, a light vector mesons, is considered as an excellent candidate due to its narrow vacuum width. Pioneering studies have been performed by the KEK-PS E325 Collaboration which gives the first evidence of in-medium modification of  $\phi$  meson at normal nuclear density. Recently, additional studies from JLab ( $\phi$ -N re-scattering,  $\phi$ -N final state interaction, nuclear transparency), LEPS and COSY (nuclear transparency) suggest a larger  $\phi$ -N in-medium total cross section or a larger in-medium  $\phi$  width than those in vacuum. In order to firmly establish the medium modification of  $\phi$  unambiguously, it is crucial to understand reaction mechanisms of  $\phi$  meson production. Deuteron, a loosely bound and the simplest nuclear system thus provides an excellent testing ground. Recently, the LEPS collaboration reports on a nuclear transparency measurement of the incoherent  $\gamma d \rightarrow \phi pn$  photoproduction near threshold at forward angles. However, their experimental observation of a large suppression of the nuclear transparency can not be explained by a recent theoretical study.

In this work, we report the first, kinematically complete measurement of the differential cross section on  $\phi$  meson photoproduction from deuteron, near the production threshold on a free proton, but below the CLAS detector threshold for a triple coincident measurement of proton,  $K^+$  and  $K^-$ . Results from this work have been published as X. Qian *et al.* PLB, 686, 338, (2011) recently. The extracted differential cross section  $\frac{d\sigma}{dt}$  for the initial photon energy from 1.65-1.75 GeV, and above are consistent with predictions based on a quasi-free mechanism (right panel). Our finding is different from the LEPS results on  $\phi$ -meson photoproduction from deuteron in a similar incident photon energy range, but a different momentum transfer region. Furthermore, our results also firmly establish the excess of  $\phi$ -meson production on deuteron (left panel) close to threshold in comparison with the production on proton (middle panel). The extracted cross sections will help provide reliable information on the expected production rate of the  $\phi$ -N bound state, whose existence has been predicted by the QCD van der Waals interaction (multi-gluon exchange), and sub/near threshold production kinematics is preferred.

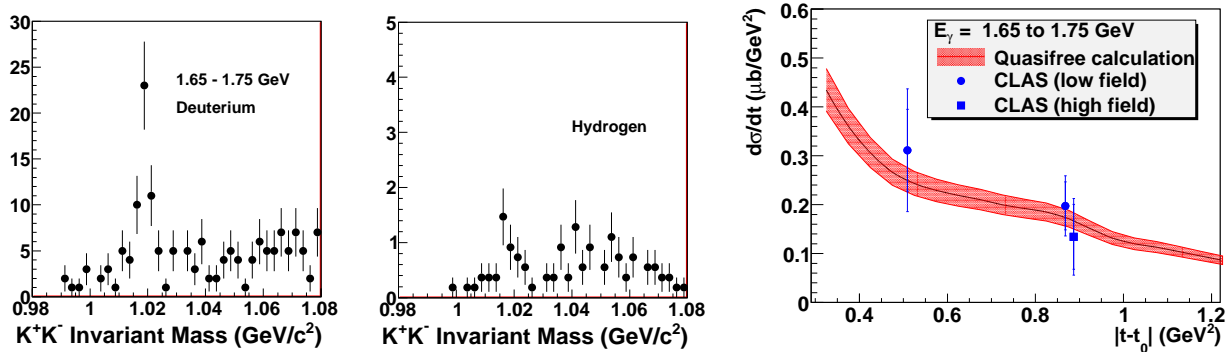


Figure 1: The  $K^+K^-$  invariant mass distribution from deuteron in this work. The  $x$ -bin size is 2.5 MeV. The corresponding distribution from the CLAS hydrogen data in the same photon energy range is shown in the middle panel. More  $\phi$  mesons are produced from deuteron than proton in the near threshold kinematics.  $\phi$  photoproduction differential cross sections from deuteron are plotted as a function of  $|t - t_0|$  together with a quasi-free calculation in the right panel.