Incoherent φ-meson photoproduction from deuterium

A strong attenuation was observed in the φ-meson photoproduction from the Li, C, Al and Cu nuclei, compared to its production from hydrogen, the free proton case. It has been interpreted as the nuclear density effect due to a large φ-N cross section in nuclear matter. To clarify the underlying physics, it is essential to construct a baseline in a low density region, using the simplest nucleus –the deuteron– made of one proton and one neutron.

We measured the differential cross sections and decay asymmetries of incoherent φ-meson photoproduction from a liquid deuterium target near threshold in the very forward direction with linearly polarized photons using the LEPS spectrometer at beamline **BL33LEP**. Highly polarized photons were produced by backward Compton scattering with an ultra-violet Ar laser from 8 GeV electrons in the storage ring of SPring-8. The photon energy was event-by-event determined by measuring the scattering angle of recoil electrons. A liquid deuterium target with an effective length of 16 cm was employed. Charged particles produced at the target were detected at forward angles with the LEPS spectrometer, which consisted of a dipole magnet, a silicon-strip vertex detector, three multi-wire drift chambers, a plastic scintillator behind the target, and a time-of-flight hodoscope placed downstream of the tracking detectors.

The production of φ mesons was identified via the charged kaon decay mode with detection of K^+ and K^- in the final state. A clear signal of φ mesons could be identified in the invariant mass of K^+K^- pairs. The separation of coherent ($\gamma d \rightarrow \phi d$) and incoherent ($\gamma d \rightarrow \phi pn$) interactions were done by fitting the missing mass spectrum, where the reaction of coherent production from deuterons, $\gamma d \rightarrow \phi d$, is peaking at the mass of deuterons 1.875 GeV/c^2. Figure 1 shows the disentanglement done in the missing mass spectra for 8 bins of photon energy in the range of 1.57-2.57 GeV. The overall shapes were nicely reproduced by the sum of individual ones generated by Monte Carlo simulations.

The zero-degree cross sections of incoherent production from deuterium as a function of the photon energy are shown in Fig. 2(a), together with data from hydrogen. The nuclear transparency ratios for deuterium, $Td=\sigma d/(2*\sigma p)$, is evaluated by the ratio of cross sections at zero degrees and are shown in

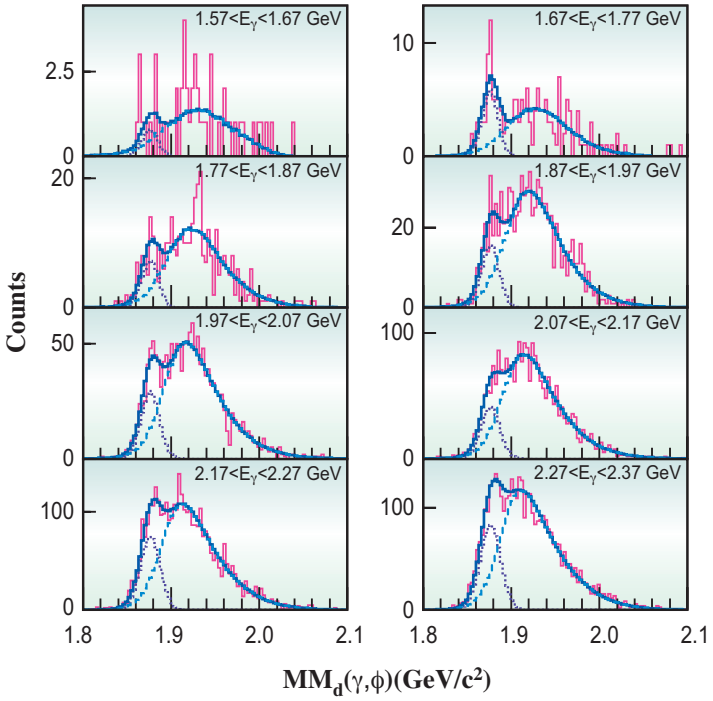

Fig.1. Missing mass spectra assuming the whole deuteron as target, at 1.57<Eγ<2.37 GeV. Each spectrum is fitted with the sum (solid line) of MC-simulated components of coherent (dotted line) and incoherent (dashed line) events.

Fig. 2(b). Compared with the φ production from a free proton, a significant 25-30% reduction of the φ yield per nucleon is observed for the incoherent production from deuterium.

Because the nuclear transparency ratio is associated with the production from the protons, the most naïve speculation of the observed suppression of nuclear transparency ratio for deuterium is because of a smaller cross section for φ-mesons produced from neutrons. We examined this scenario by studying the exclusive φ events whose final state of a K^+K^- pair and a proton is fully detected in the spectrometer; the kinematics of these events is dominated by interactions with the proton inside deuterium. Though limited by statistics, Fig. 3 clearly shows a similar degree of reduction for quasi-free events from the proton as compared with inclusive reactions. Therefore, the reduction in φ yield occurs on a similar scale for the incoherent production either from the proton or the neutron inside deuterium. Further supporting evidence was obtained in the measurement of decay asymmetry.

In summary, the differential cross sections and decay asymmetries of incoherent φ-meson photoproduction from deuterons were measured at forward scattering angles near threshold. In comparison with those from proton, the production cross section per nucleon shows a significant reduction. The reduction is found to be common for the production from both the proton and the neutron inside deuterium. The present work suggests that the nuclear transparency ratio of φ-meson photoproduction is sensitive to the details of the nuclear structure. It should work as an important baseline used for differentiating the nuclear density effects.

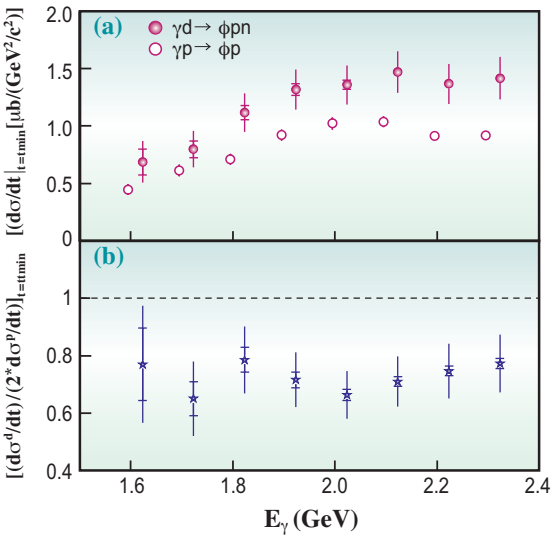

Fig. 2. **(a)** Differential cross section at zero degree as a function of photon energy for incoherent production from deuterium and that from hydrogen. The horizontal bars represent the range of statistical errors. The γp→φp data are shifted by –50 MeV for clarity of display. **(b)** Nuclear transparency ratios of φ-meson photoproduction from deuterium (A=2) are shown as a function of the photon energy.

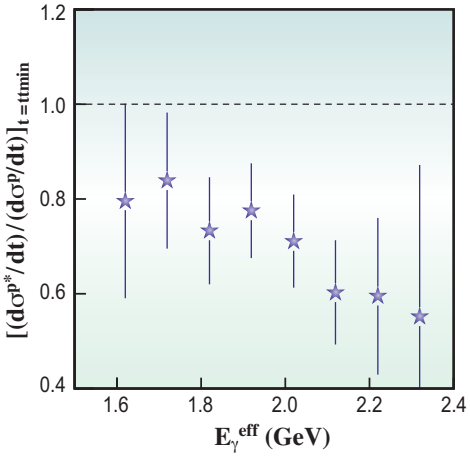

Fig. 3. Ratio of φ-meson photoproduction from the proton inside deuterium and hydrogen as a function of photon energy. The error bars are statistical only.

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