

LOI12-19-003: *Measuring the Neutral Pion Polarizability*

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This Letter of Intent is for an experiment to measure neutral pion electric and magnetic polarizabilities in di-pion photo production on lead target via the Primakoff effect. Coherent scattering on a large-Z nuclei enhances the (instantaneous) interaction with the Coulomb field and the reaction is proportional to the $\gamma + \gamma^* \rightarrow \pi^0\pi^0$ amplitude. Pion polarizabilities can be extracted by performing amplitude analysis and matching with chiral perturbation theory, to isolate contribution from the t-channel one-pion exchange.

The experiment aims to improve the uncertainties in determination of the di-pion spectrum by approximately an order of magnitude (see Fig. 16) as compared to the existing data (from Crystal Ball experiment in the 1990s) and add data points in the low mass range $W < 400$ MeV. Since polarizabilities are defined via a low energy expansion filling in the low mass region, as proposed by this experiment is very important. The claim is that such reduction in data uncertainties will enable to extract polarizabilities within 1%. It should be remarked, however, that cutting out the invariant mass distribution to eliminate contribution from iso-scalar resonances (see Sec 4.4.1) is inappropriate. Even though the quantities of interest appear to dominate the spectrum near threshold, iso-scalar resonance production is part of the same amplitude and should be used together with threshold parametrization to constrain the fits. In fact, Dai and Pennington [1] argue that in the mass region $350 < W < 600$ MeV that should be studied, (due to much weaker correlation between the measured uncertainties in the Compton cross-section and polarizabilities at these invariant masses). It would be useful to make a quantitative estimate of the sensitivity to the polarizabilities using the models discussed in [1]. Having this work done ahead of time would be helpful since one could use the same techniques to analyze the data when available.

Another issue that should be addressed relates to the connection between the Primakoff (virtual) photon exchange in real photon scattering. At scattering angle $\theta \sim 0.25^\circ$ the invariant momentum transfer is comparable to the pion mass squared, $\sqrt{-t}/m_\pi \sim 30\%$. Since extraction of polarizabilities assumes on-shell photons corrections to amplitude due to photon virtuality should be accessed.

The experimental conditions require no changes to the Hall D/GlueX set up as the experiment is proposed to run concurrently with the approved

experiment to measure charge pion polarizabilities. The neutral pion measurements will take further advantage of the high resolution FCAL. Given that that both measurements are equally important we find the propose effort well justified.

[1] Ling-Yun Dai and Michael R. Pennington. *Phys. Rev.*, D94, 116021, 2016.