Coupled channel model of the scalar isovector meson photoproduction

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Motivation

- Identification of dominant mechanisms of pseudoscalar pair photoproduction in the $S-$ wave in the isovector channel
- Test of the coupled channel $\pi\eta$, $K\overline{K}$, $\pi\eta'$ scalar isovector amplitudes, used to describe the final state interactions [1]
- Estimation of the $a_0(980)$ photoproduction cross section at photon energies available in new/upgraded JLab experiments GlueX and CLAS12.

Amplitude structure

- For photon energies ∼10 GeV the resonant pseudoscalar pair photoproduction can be treated as a two- stage process. First, a pair of pseudoscalar mesons is produced which can be described in terms of $t-$ channel exchange Born amplitudes. Then, the photoproduced pair is subject to final state rescattering described in terms of the coupled channel unitary amplitudes. The structure of the amplitude is schematically shown in Fig.1

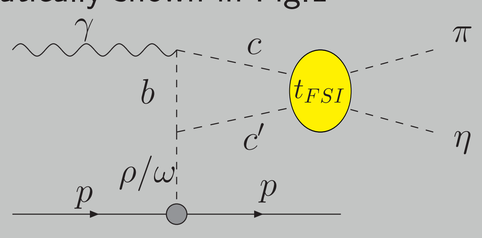

Fig. 1: Diagrammatic representation of the full amplitude

- Here, we extend the model of the resonant $S-$ wave isovector photoproduction described in [2] by including the $\pi\eta'$ channel, so cc' in Fig.1 corresponds to $\pi\eta$, K^+K^-, $K^0\overline{K^0}$ or $\pi\eta'$
- This extends the model's applicability up to the masses corresponding to the $a_0(980)\pi\pi$ threshold (∼1.26 GeV)
- The general form of the amplitude (for the $\pi\eta$ final state) reads

$$A_{\pi\eta} = [1 + ir_{\pi\eta}t_{\pi\eta;\pi\eta}]\, V_{\pi\eta} + ir_{K\overline{K}}t_{\pi\eta;K\overline{K}}\frac{1}{\sqrt{2}}\left(V_{K^+K^-} + V_{K^0\overline{K^0}}\right) + ir_{\pi\eta'}t_{\pi\eta;\pi\eta'}V_{\pi\eta'}$$

where $V_{cc'}$ are respective Born amplitudes, $t_{\pi\eta;cc'}$ - scattering/transition amplitudes and $r_{cc'}$ - kinemetical factors.

Born amplitudes

- Diagrams representing Born amplitudes for intermediate states $\pi\eta$, K^+K^-, $K^0\overline{K^0}$ and $\pi\eta'$ are shown in Fig.2.

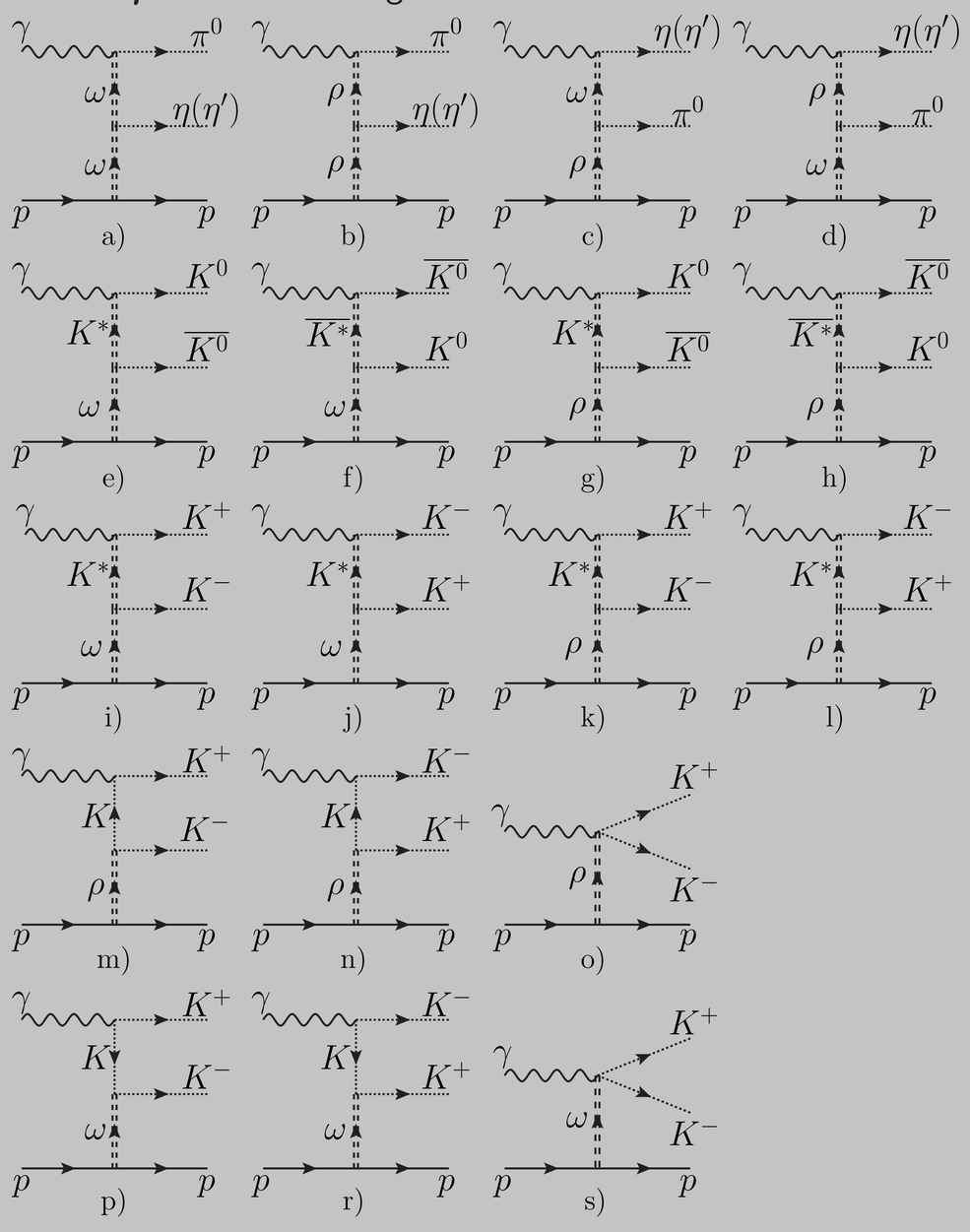

Fig. 2: Diagrammatic representation of Born amplitudes

- Contact diagrams o) and s) are necessary for current conservation in amplitudes where charged pseudoscalar pair is produced due to charged pseudoscalar exchange

Results

Having defined the double differential cross section as

$$\frac{d\sigma}{dtdM_{\pi\eta}} = \frac{1}{4}\frac{1}{(2\pi)^3}\frac{|k|}{32m^2{E_\gamma}^2}\sum_{\lambda_\gamma,\lambda,M,\lambda'}|\langle\lambda' M|A_{\pi\eta}|\lambda_\gamma\lambda\rangle|^2, \quad (1)$$

where λ_γ, λ and λ' are respectively the helicities of the photon, initial i final proton, we calculated for the photon energy $E_\gamma = 9GeV$:

- Mass dependent Born cross sections for three channels, shown in Fig.3:

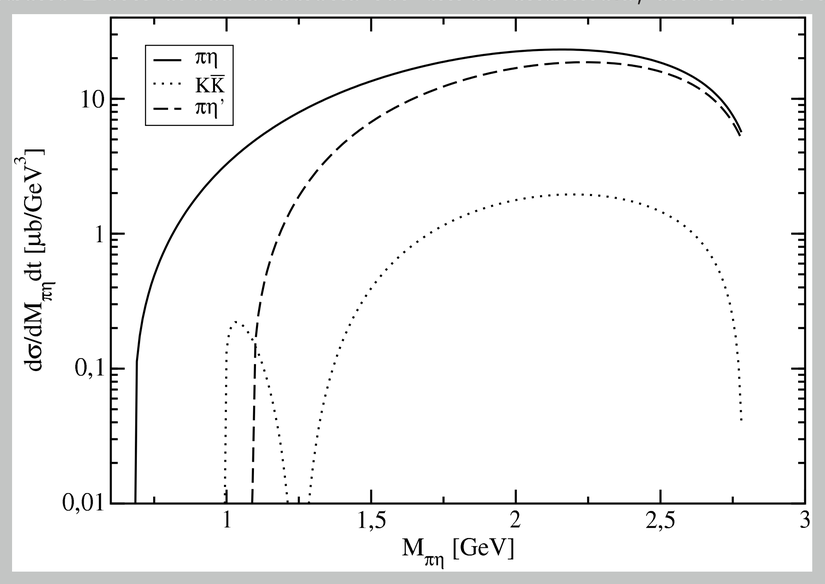

Fig. 3: Effective mass dependence of Born cross sections at t=-0.4 GeV^2

- $t-$ dependent Born cross sections for three channels, shown in Fig.4:

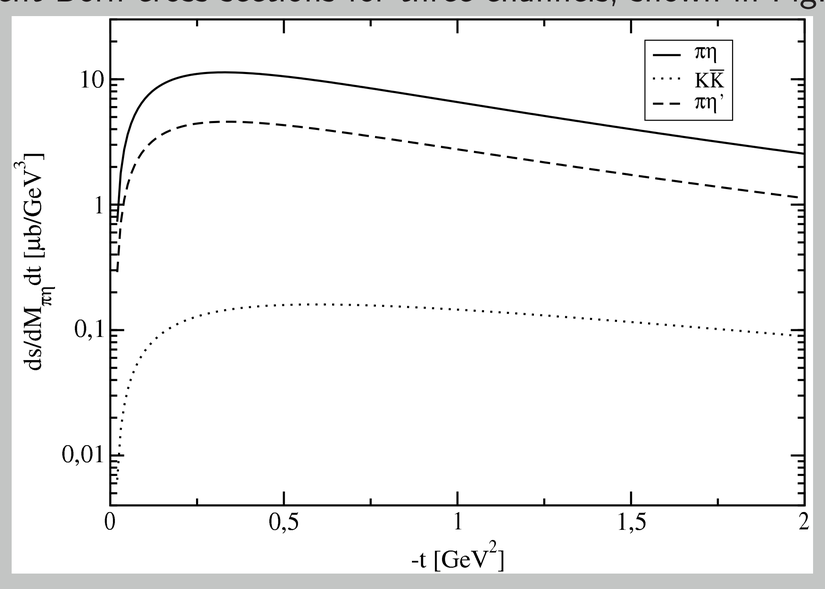

Fig. 4: $t-$ dependence of Born cross sections at $M_{\pi\eta}$=1.4 GeV

- Full (ie. including final state interaction in all three channels) mass distribution compared with the Born mass distribution, both shown in Fig.5:

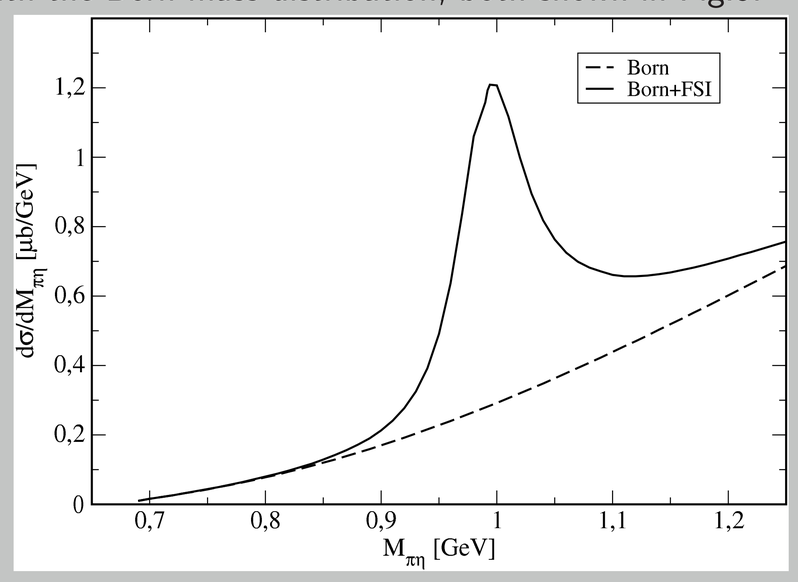

Fig. 5: Mass distribution calculated using Born and full amplitude

Conclusions and outlook

- We constructed the model of coupled channel $\pi\eta$, $K\overline{K}$ and $\pi\eta'$ photoproduction, which for effective masses around 1 GeV exhibits a clear signal of $a_0(980)$
- Inclusion of the $\pi\eta'$ channel in the analysis does not influence the shape of the $a_0(980)$ resonance line as compared to the two channel model [2] but may be crucial for description of $a_0(1450)$ photoproduction
- Some experimental analyses, like [3], suggest that the model of $a_0(1450)$ photoproduction may require the inclusion of $a_0(980)\sigma$ and $\omega\rho$ channels

References

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[2] Ł. Bibrzycki, R. Kamiński, Int. J. of Mod. Phys. A 31, 1650139 (2016)

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