Study of N* resonances in eta photoproduction

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Outline

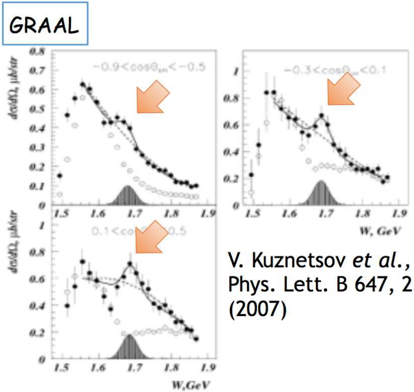
- Motivation
- Effective Lagrangian approach
- Analysis
- Results

Motivation

An interesting experimental result- neutron anomaly

A narrow resonance-like structure at Elab=1680(MeV) in $\gamma n \to \eta n$

No such structure in $\gamma p \to \eta p$

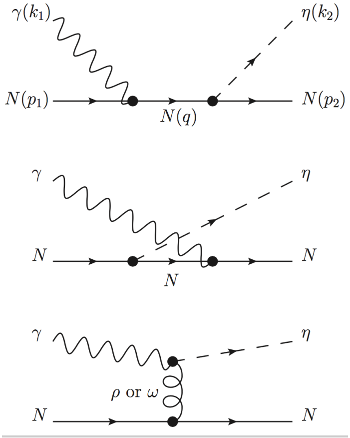


V. Kuznetsov *et al.*, Phys. Lett. B 647, 23 (2007)

Effective Lagrangian approach

- We can write the effective Lagrangians for the Yukawa vertices by satisfying the symmetry such as gauge invariance, Lorentz invariance, angular momentum conservation and parity. We can get the invariant amplitudes straightforward from the effective Lagrangians and get the result of physical observables, especially total crosssection, and differential crosssection.

Feynman diagrams



Lagrangian

$$\mathcal{L}_{\gamma NN} = -e\bar{N}\not{A}N - i\frac{e\kappa_N}{2M_N}\bar{N}\sigma_{\mu\nu}q^{\nu}A^{\mu}N + h.c.$$

$$\mathcal{L}_{\eta NN} = -ig_{\eta NN}\bar{N}\gamma_5\eta N + h.c.$$

$$\mathcal{L}_{VNN} = -g^{v}_{VNN}\bar{N}\not{V}N - i\frac{g^{t}_{vNN}}{2M_N}\bar{N}\sigma_{\mu\nu}q^{\nu}V^{\mu}N + h.c.$$

$$\mathcal{L}_{\gamma\eta V} = \frac{eg^{\gamma\eta V}}{4M_{\eta}}\epsilon_{\mu\nu\sigma\rho}F^{\mu\nu}V^{\sigma\rho}\eta + h.c.$$

$$\mathcal{L}^{1/2}_{\gamma NN*} = \frac{e\mu_{\gamma NN*}}{2(M_N + M_{N*})}\bar{N}\Gamma^{a}_{5}\sigma_{\mu\nu}F^{\mu\nu}N + h.c.$$

$$\mathcal{L}^{1/2}_{\eta NN*} = -ig_{\eta NN*}\bar{N}\Gamma\gamma_5\eta N * +h.c.$$

Numerical calculation

Determination of strong couplings for the resonance of spin 1/2

$$g^{1/2}_{\eta NN*} = (\frac{4\pi M_{N*}}{p_f(\sqrt{M_N^2 + p_{\eta N}^2} - M_N)}\Gamma_{N*\to\eta N})^{1/2}$$

Determination of photon coupling from the helicity amplitudes

$$e\mu^{1/2}_{\gamma NN*} = \pm[\frac{M_{N*}M_N}{p_{\gamma N}}]^{1/2}|A^{N*}_{1/2}|$$

Numerical calculation

We introduce the form factor satisfying the gauge invariance(current conservation). Here, the cut-off masses are determined such that the data are well reproduced.

$$F_x^M = \frac{\Lambda^4}{\Lambda^4 + (x - M^2)^2} \qquad x = s, t, u$$

Invariant amplitudes

$$i\mathcal{M}_t^V = \frac{-ieg_{\gamma\eta V}F_t^V}{M_\eta\{(k1-k2)^2 - M_V^2\}}\epsilon_{\mu\nu\sigma\rho}k1^\mu\epsilon^\nu(k1-k2)^\sigma$$

$$\times\, \bar{u}(p2)[g_{VNN}^v\gamma^\rho - \frac{g_{VNN}^t}{4M_N}\{(\not{k}1-\not{k}2)\gamma^\rho - \gamma^\rho(\not{k}1-\not{k}2)\}]u(p1)$$

$$i\mathcal{M}_s^N = \frac{eg_{\eta NN}}{(k1+p1)^2 - M_N^2}\bar{u}(p2)[\gamma_5 F_s^N \not{k}1 + F_c(\not{p}1 + M_N)\not{\epsilon}$$

$$-\, \frac{\kappa_N F_s^N}{2M_N}\gamma_5(\not{k}1 + \not{p}1 + M_N)]u(p1)$$

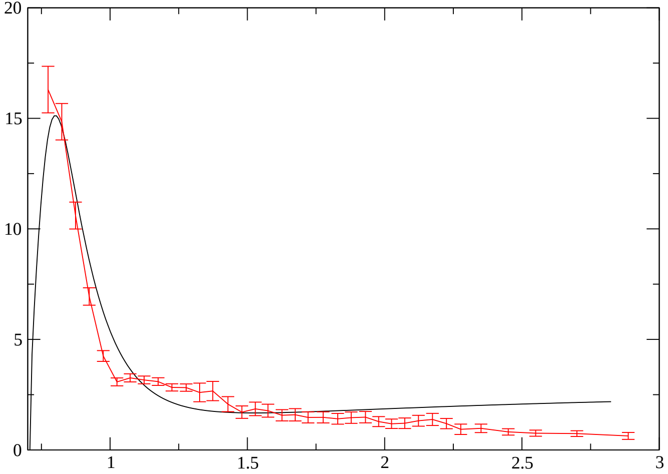
$$i\mathcal{M}_u^N = \frac{eg_{\eta NN}}{\{(k2-p1)^2 - M_N^2\}}\bar{u}(p2)[\not{\epsilon}\{F_c(\not{p}2 + M_N) - F_s\not{k}1\}\gamma_5]$$

$$+\, \frac{\kappa_N F_u^N}{2M_N}\not{k}1\not{\epsilon}(\not{p}2 - \not{k}1 + M_N)\gamma_5]u(p1)$$

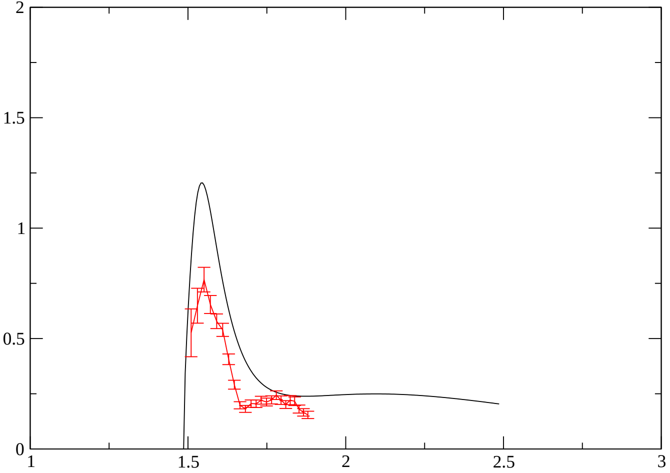
Invariant amplitudes

$$i\mathcal{M}_s^{N*} = \frac{e\kappa_{\gamma NN*} g_{\eta NN*} F_s^{N*}}{(M_N + M_{N*})\{(k1+p1)^2 - M_{N*}^2 - iM_{N*}\Gamma_{\eta NN*}\}}$$
$$\times\ \bar{u}(p2)\gamma_5\Gamma(\not{k}1 + \not{p}1 + M_{N*})\Gamma\not{\epsilon}\not{k}1 u(p1)$$
$$i\mathcal{M}_u^{N*} = \frac{e\kappa_{\gamma NN*} g_{\eta NN*} F_u^{N*}}{(M_N + M_{N*})\{(k2-p1)^2 - M_{N*}^2 - iM_{N*}\Gamma_{\eta NN*}\}}$$
$$\times\ \bar{u}(p2)\gamma_5\Gamma(\not{k}2 - \not{p}1 + M_{N*})\Gamma\not{\epsilon}\not{k}1 u(p1)$$

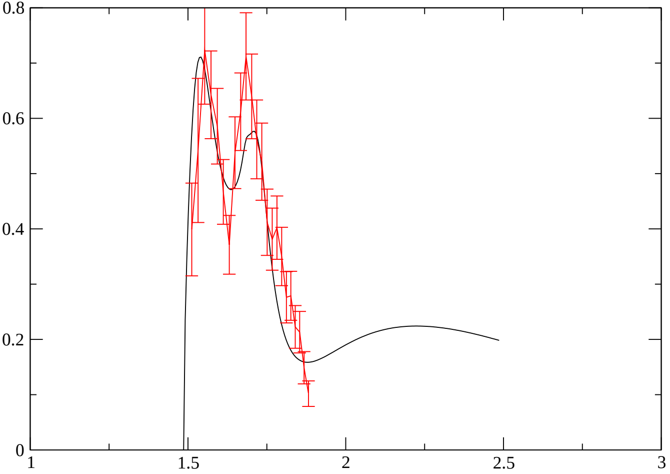
Result-Total Crosssection vs Elab



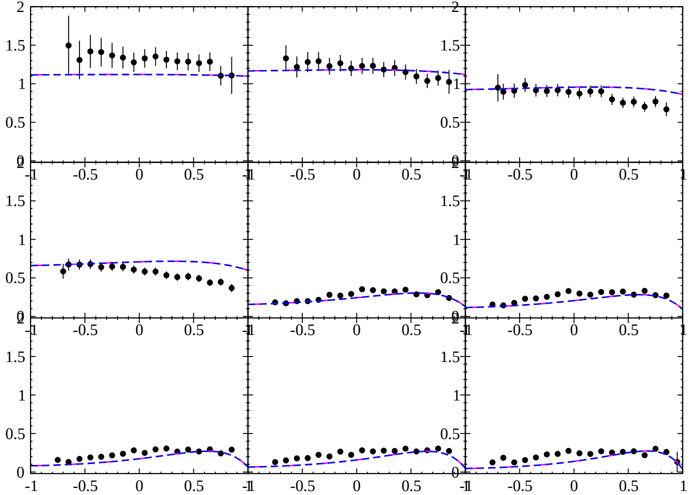
Result-Diffrential Crosssection vs Elab(proton)



Result-Diffrential Crosssection vs Elab(Neutron)



Result-Diffrential Crosssection vs cosx



Summary

- An interesting experimental result- A narrow resonance-like structure at 1680MeV only in $\gamma n \to \eta n$ total cross section
- To interpret this measurement, I considered the effects of N*(1535), N*(1650), N*(1685) using the Effective Lagrangian approach.
- By determining the coupling constants from the width and helicity amplitude of N*, I compared my results(total cross sections, differential cross sections) with the experimental results.

Thank you very much.