There is only one set of the correct values of f^F, f^D and f^S coupling constants in SU(3) invariant Lagrangian of the vector-meson-baryon interactions

C. Adamuščín, **E. Bartoš**, S. Dubnička, A.-Z. Dubničková

Institute of Physics SAS, Bratislava, Slovakia
Dept. of Theoretical Physiscs, Comenius University, Bratislava, Slovakia

June 8th, 2018

MESON 2018
15th International Workshop on Meson Physics

Krakow, Poland

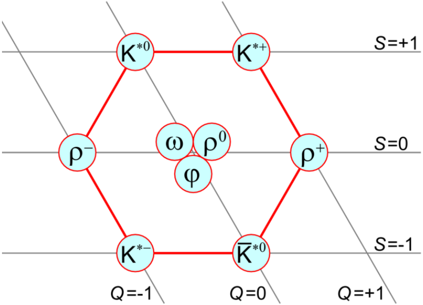
Outlook

1. Introduction
2. Notes on $\omega - \phi$ mixing
3. Derivation of meson-baryon-antibaryon coupling constants
4. Signs of the universal vector meson coupling constants
5. Results and conclusions

Motivation

- prediction of hyperon form factors Λ, Σ^+, Σ^0, Σ^-, Ξ, Ξ^-
- full omega – phi mixing
- correct sign in the ratios of vector meson coupling currents
- is there only one set of coupling constants for baryons?

Vector mesons – spin 1



$J^P = 1^-$

particle	quarks
K^{*0}	$s\bar{d}$
K^{*+}	$u\bar{s}$
ρ^-	$d\bar{u}$
ρ^+	$u\bar{d}$
➤ ω	$\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})$
ρ^0	$\frac{1}{\sqrt{2}}(u\bar{u} - d\bar{d})$
➤ ϕ	$s\bar{s}$
K^{*-}	$s\bar{u}$
$\bar{K}^{*0}$	$d\bar{s}$

ω_8, ω_0 states

$$\omega_8 = \frac{1}{\sqrt{6}}(u\bar{u} + d\bar{d} - 2s\bar{s}), \quad \omega_0 = \frac{1}{\sqrt{3}}(u\bar{u} + d\bar{d} + s\bar{s})$$ — **singlet**

octet: $$V = \begin{pmatrix} \frac{1}{\sqrt{6}}\omega_8 + \frac{1}{\sqrt{2}}\rho^0 & \rho^+ & K^{*+} \\ \rho^- & \frac{1}{\sqrt{6}}\omega_8 - \frac{1}{\sqrt{2}}\rho^0 & \overline{K}^{*0} \\ K^{*-} & K^{*0} & -\frac{2}{\sqrt{6}}\omega_8 \end{pmatrix} \equiv \bar{q}^b q_a - \frac{1}{3}\delta_a^b \bar{q}^c q_c$$

Gell-Mann-Okubo: $m^2 = a_0 + a_1 S + a_2\left(I(I+1) - \frac{1}{4}S^2\right)$

$$m^2_{\omega_8} = \frac{1}{3}\left(4\frac{m^2_{K^{*0}} + m^2_{\overline{K}^{*0}}}{2} - m^2_\rho\right) \cong (933\,\mathrm{MeV})^2$$

$\Rightarrow$ ω_8, ω_0 do not correspond to known physical states $\rho(770)$, $\phi(1020)$

ω_8, ω_0 states

$$\omega_8 = \frac{1}{\sqrt{6}}(u\bar{u} + d\bar{d} - 2s\bar{s}), \quad \omega_0 = \frac{1}{\sqrt{3}}(u\bar{u} + d\bar{d} + s\bar{s})$$ — **singlet**

octet: $$V = \begin{pmatrix} \frac{1}{\sqrt{6}}\omega_8 + \frac{1}{\sqrt{2}}\rho^0 & \rho^+ & K^{*+} \\ \rho^- & \frac{1}{\sqrt{6}}\omega_8 - \frac{1}{\sqrt{2}}\rho^0 & \overline{K}^{*0} \\ K^{*-} & K^{*0} & -\frac{2}{\sqrt{6}}\omega_8 \end{pmatrix} \equiv \bar{q}^b q_a - \frac{1}{3}\delta_a^b \bar{q}^c q_c$$

Gell-Mann-Okubo: $m^2 = a_0 + a_1 S + a_2\left(I(I+1) - \frac{1}{4}S^2\right)$

$$m^2_{\omega_8} = \frac{1}{3}\left(4\frac{m^2_{K^{*0}} + m^2_{\overline{K}^{*0}}}{2} - m^2_\rho\right) \cong (933\,\mathrm{MeV})^2$$

$\Rightarrow$ ω_8, ω_0 do not correspond to known physical states $\rho(770)$, $\phi(1020)$

Sakurai's $\omega - \phi$ mixing

(ϕ, ω) express with (ω_8, ω_0) states: $M = \begin{pmatrix} m^2_{\omega_8} & m^2_{08}/2 \\ m^2_{08}/2 & m^2_{\omega_0} \end{pmatrix}$

orthogonal matrices (preserving distance):

$$R_1 = \begin{pmatrix} -p & q \\ q & p \end{pmatrix} \quad R_2 = \begin{pmatrix} p & q \\ -q & p \end{pmatrix} \quad \boxed{p^2 + q^2 = 1}$$

diagonal matrix: $\begin{pmatrix} m^2_\phi & 0 \\ 0 & m^2_\omega \end{pmatrix} = R^T M R, \quad \begin{pmatrix} \phi \\ \omega \end{pmatrix} = R^T \begin{pmatrix} \omega_8 \\ \omega_0 \end{pmatrix}$

inverse relation for M $\Rightarrow$ $\boxed{p^2 m^2_\phi + q^2 m^2_\omega = m^2_{\omega_8}}$

$p = \pm 0.6290,\ q = \pm 0.7775 \quad \leftrightarrow \quad \theta \sim 39^\circ \rightarrow$ **eight** mixing versions

Sakurai's $\omega - \phi$ mixing

(ϕ, ω) express with (ω_8, ω_0) states: $M = \begin{pmatrix} m^2_{\omega_8} & m^2_{08}/2 \\ m^2_{08}/2 & m^2_{\omega_0} \end{pmatrix}$

orthogonal matrices (preserving distance):

$$R_1 = \begin{pmatrix} -p & q \\ q & p \end{pmatrix} \quad R_2 = \begin{pmatrix} p & q \\ -q & p \end{pmatrix} \quad \boxed{p^2 + q^2 = 1}$$

diagonal matrix: $\begin{pmatrix} m^2_\phi & 0 \\ 0 & m^2_\omega \end{pmatrix} = R^T M R, \quad \begin{pmatrix} \phi \\ \omega \end{pmatrix} = R^T \begin{pmatrix} \omega_8 \\ \omega_0 \end{pmatrix}$

inverse relation for M $\Rightarrow$ $\boxed{p^2 m^2_\phi + q^2 m^2_\omega = m^2_{\omega_8}}$

$p = \pm 0.6290,\ q = \pm 0.7775 \quad \leftrightarrow \quad \theta \sim 39^\circ \rightarrow$ **eight** mixing versions

$\omega - \phi$ mixing versions

1. $$\omega = 0.629\,\omega_8 + 0.778\,\omega_0 \qquad \omega = \sin\theta\,\omega_8 + \cos\theta\,\omega_0$$
$$\phi = -0.778\,\omega_8 + 0.629\,\omega_0 \qquad \phi = -\cos\theta\,\omega_8 + \sin\theta\,\omega_0$$
2. $$\omega = -0.629\,\omega_8 + 0.778\,\omega_0 \qquad \omega = -\sin\theta\,\omega_8 + \cos\theta\,\omega_0$$
$$\phi = -0.778\,\omega_8 - 0.629\,\omega_0 \qquad \phi = -\cos\theta\,\omega_8 - \sin\theta\,\omega_0$$
3. $$\omega = 0.629\,\omega_8 - 0.778\,\omega_0 \qquad \omega = \sin\theta\,\omega_8 - \cos\theta\,\omega_0$$
$$\phi = 0.778\,\omega_8 + 0.629\,\omega_0 \qquad \phi = \cos\theta\,\omega_8 + \sin\theta\,\omega_0$$
4. $$\omega = -0.629\,\omega_8 - 0.778\,\omega_0 \qquad \omega = -\sin\theta\,\omega_8 - \cos\theta\,\omega_0$$
$$\phi = 0.778\,\omega_8 - 0.629\,\omega_0 \qquad \phi = \cos\theta\,\omega_8 - \sin\theta\,\omega_0$$
5. $$\omega = 0.629\,\omega_8 + 0.778\,\omega_0 \qquad \omega = \sin\theta\,\omega_8 + \cos\theta\,\omega_0$$
$$\phi = 0.778\,\omega_8 - 0.629\,\omega_0 \qquad \phi = \cos\theta\,\omega_8 - \sin\theta\,\omega_0$$
6. $$\omega = -0.629\,\omega_8 + 0.778\,\omega_0 \qquad \omega = -\sin\theta\,\omega_8 + \cos\theta\,\omega_0$$
$$\phi = 0.778\,\omega_8 + 0.629\,\omega_0 \qquad \phi = \cos\theta\,\omega_8 + \sin\theta\,\omega_0$$
7. $$\omega = 0.629\,\omega_8 - 0.778\,\omega_0 \qquad \omega = \sin\theta\,\omega_8 - \cos\theta\,\omega_0$$
$$\phi = -0.778\,\omega_8 - 0.629\,\omega_0 \qquad \phi = -\cos\theta\,\omega_8 - \sin\theta\,\omega_0$$
8. $$\omega = -0.629\,\omega_8 - 0.778\,\omega_0 \qquad \omega = -\sin\theta\,\omega_8 - \cos\theta\,\omega_0$$
$$\phi = -0.778\,\omega_8 + 0.629\,\omega_0 \qquad \phi = -\cos\theta\,\omega_8 + \sin\theta\,\omega_0$$

Interaction of baryons and mesons

SU(3) lagrangian for vertex meson–baryon–antibaryon:

$$\mathcal{L}_{VB\bar{B}} = \frac{\mathrm{i}}{\sqrt{2}} f^F \left[\bar{B}^\alpha_\beta \gamma_\mu B^\beta_\gamma - \bar{B}^\beta_\gamma \gamma_\mu B^\alpha_\beta\right] (V_\mu)^\gamma_\alpha + \\ + \frac{\mathrm{i}}{\sqrt{2}} f^D \left[\bar{B}^\beta_\gamma \gamma_\mu B^\alpha_\beta + \bar{B}^\alpha_\beta \gamma_\mu B^\beta_\gamma\right] (V_\mu)^\gamma_\alpha + \\ + \frac{\mathrm{i}}{\sqrt{2}} f^S \bar{B}^\alpha_\beta \gamma_\mu B^\beta_\alpha \omega_{0\mu} \,,$$

baryon, antibaryon, vector meson matrices

$$B = \begin{pmatrix} \frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & \Sigma^+ & p \\ \Sigma^- & -\frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & n \\ \Xi^- & \Xi^0 & -\frac{2}{\sqrt{6}}\Lambda \end{pmatrix}, \quad \bar{B}, \quad V$$

Nucleon and hyperon coupling constants

calculating and inserting ω–ϕ mixing leads to

$$\begin{aligned}\omega:\quad &+\Big[(3f^F - f^D)\,\overline{\mathrm{p}}\mathrm{p} + (3f^F - f^D)\,\overline{\mathrm{n}}\mathrm{n} -\\ &- 3(\overline{\Xi}^0\Xi^0 + \overline{\Xi}^-\Xi^-)\,f^F + (2\overline{\Sigma}^0\Sigma^0 - \cdots - \overline{\Xi}^-\Xi^-)\,f^D\Big]\sin\theta +\\ &+ \sqrt{6}\Big[\overline{\mathrm{p}}\mathrm{p} + \overline{\mathrm{n}}\mathrm{n} + \overline{\Sigma}^0\Sigma^0 + \overline{\Sigma}^+\Sigma^+ + \cdots + \overline{\Xi}^-\Xi^-\Big]\,f^S\cos\theta\end{aligned}$$

$$\downarrow$$

$$\begin{aligned} f_{\rho\mathrm{NN}} &= \tfrac{1}{2}\big[f^D + f^F\big]\\ f_{\omega\mathrm{NN}} &= \tfrac{1}{\sqrt{2}} f^S\cos\theta + \tfrac{1}{2\sqrt{3}}(3f^F - f^D)\sin\theta\\ f_{\phi\mathrm{NN}} &= -\tfrac{1}{\sqrt{2}} f^S\sin\theta + \tfrac{1}{2\sqrt{3}}(3f^F - f^D)\cos\theta\end{aligned}$$

Relations of nucleon and hyperon coupling constants

$$f_{\rho NN}, f_{\omega NN}, f_{\phi NN} \quad \Rightarrow \quad f^F, f^D, f^S \quad \Rightarrow \quad f_{\rho HH}, f_{\omega HH}, f_{\phi HH}$$

1.
$$f^F = \frac{1}{2}\left[f_{\rho NN} + \sqrt{3}(-f_{\phi NN}\cos\theta + f_{\omega NN}\sin\theta)\right]$$
$$f^D = \frac{1}{2}\left[3f_{\rho NN} - \sqrt{3}(-f_{\phi NN}\cos\theta + f_{\omega NN}\sin\theta)\right]$$
$$f^S = \sqrt{2}(f_{\omega NN}\cos\theta + f_{\phi NN}\sin\theta)$$

... ...

8.
$$f^F = \frac{1}{2}\left[f_{\rho NN} - \sqrt{3}(f_{\phi NN}\cos\theta + f_{\omega NN}\sin\theta)\right]$$
$$f^D = \frac{1}{2}\left[3f_{\rho NN} + \sqrt{3}(f_{\phi NN}\cos\theta + f_{\omega NN}\sin\theta)\right]$$
$$f^S = -\sqrt{2}(f_{\omega NN}\cos\theta - f_{\phi NN}\sin\theta)$$

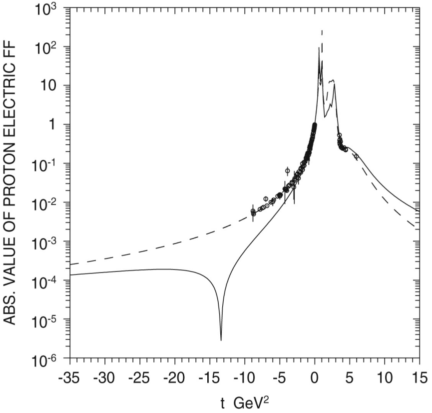
Values of ratios of coupling constants

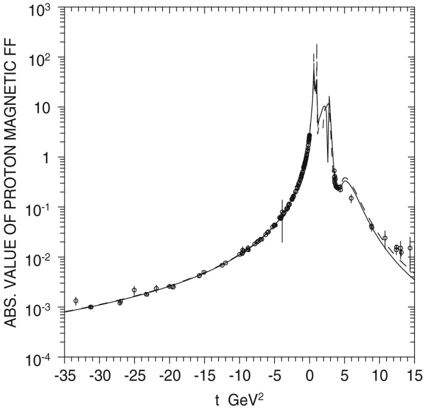
How to get the numerical values of coupling constants?

1. Unitary & Analytic model $\rightarrow$ provides only ratios of coupling constants by fitting procedure of all experimental data

$$\frac{f^{(1)}_{\rho NN}}{f_\rho} = 0.3747, \quad \frac{f^{(1)}_{\omega NN}}{f_\omega} = 1.5717, \quad \frac{f^{(1)}_{\phi NN}}{f_\phi} = -1.1247$$

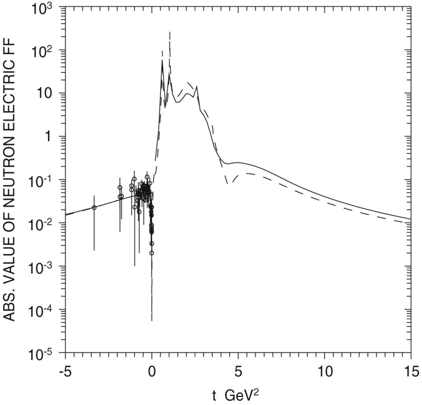
Proton form factors with U&A model

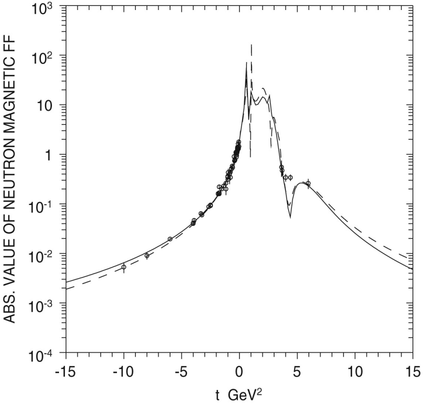




Theoretical behavior of proton electric and magnetic form factors.

Neutron form factors with U&A model





Theoretical behavior of neutron electric and magnetic form factors.

Values of ratios of coupling constants

How to get the numerical values of coupling constants?

1. Unitary & Analytic model $\rightarrow$ provides only ratios of coupling constants by fitting procedure of all experimental data

$$\frac{f^{(1)}_{\rho NN}}{f_\rho} = 0.3747, \quad \frac{f^{(1)}_{\omega NN}}{f_\omega} = 1.5717, \quad \frac{f^{(1)}_{\phi NN}}{f_\phi} = -1.1247$$

2. We need also values f_ρ, f_ω, f_ϕ

Universal constants of vector mesons

The lepton width $\Gamma(V \to e^+e^-)$

$$\Gamma_i = \frac{\alpha^2 m_i}{3} \frac{f_i^2}{4\pi}$$

coupling constant	value
$\mid f_\omega \mid$	17.058
$\mid f_\phi \mid$	13.542
$\mid f_\rho \mid$	4.956

- ω, ϕ, ρ masses and widths – PDG [Patrignani et al., 2016]
- ρ', ρ'' widths from e^+ e^- decay widths [Donnachie and Clegg, 1989]

$$\Gamma_{\omega' \to e^+e^-} = \frac{1}{9}\Gamma_{\rho' \to e^+e^-}, \quad \Gamma_{\omega'' \to e^+e^-} = \frac{1}{9}\Gamma_{\rho'' \to e^+e^-}$$

- What we can say about **the signs** of coupling constants?

Universal constants of vector mesons

The lepton width $\Gamma(V \to e^+ e^-)$

$$\Gamma_i = \frac{\alpha^2 m_i}{3} \frac{f_i^2}{4\pi}$$

coupling constant	value
$\mid f_\omega \mid$	17.058
$\mid f_\phi \mid$	13.542
$\mid f_\rho \mid$	4.956

- ω, ϕ, ρ masses and widths – PDG [Patrignani et al., 2016]
- ρ', ρ'' widths from $e^+ e^-$ decay widths [Donnachie and Clegg, 1989]

$$\Gamma_{\omega' \to e^+ e^-} = \frac{1}{9} \Gamma_{\rho' \to e^+ e^-}, \quad \Gamma_{\omega'' \to e^+ e^-} = \frac{1}{9} \Gamma_{\rho'' \to e^+ e^-}$$

- What we can say about **the signs** of coupling constants?

Hadronic electromagnetic current

EM current in the quark form: $J^{\mathrm{h}}_\mu = \frac{2}{3}\bar{u}\gamma_\mu u - \frac{1}{3}\bar{d}\gamma_\mu d - \frac{1}{3}\bar{s}\gamma_\mu s$

$$\mathbf{J}^{\mathbf{h}}_{\boldsymbol{\mu}} = \underbrace{\frac{1}{2}(\bar{u}\gamma_\mu u - \bar{d}\gamma_\mu d)}_{\frac{1}{\sqrt{2}}J^\rho_\mu} + \underbrace{\frac{1}{6}(\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d)}_{\frac{S_\omega}{3\sqrt{2}}J^\omega_\mu} - \underbrace{\frac{1}{3}\bar{s}\gamma_\mu s}_{\frac{S_\phi}{3}J^\phi_\mu}$$

$$J^\phi_\mu = \bar{s}\gamma_\mu s, \quad J^\omega_\mu = \frac{1}{\sqrt{2}}(\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d), \quad J^\rho_\mu = \frac{1}{\sqrt{2}}(\bar{u}\gamma_\mu u - \bar{d}\gamma_\mu d)$$

$$J^{\omega 8}_\mu = (\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d - 2\bar{s}\gamma_\mu s)/\sqrt{6}, \quad J^{\omega 0}_\mu = (\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d + \bar{s}\gamma_\mu s)/\sqrt{3}$$

1.	$S_\omega = +1, S_\phi = +1$	$J^\rho_\mu/\sqrt{2} + J^\omega_\mu/(3\sqrt{2}) - J^\phi_\mu/3$	$= \mathbf{J}^{\mathrm{h}}_\mu$
…	…	…	
8.	$S_\omega = -1, S_\phi = +1$	$J^\rho_\mu/\sqrt{2} - J^\omega_\mu/(3\sqrt{2}) - J^\phi_\mu/3$	

Hadronic electromagnetic current

EM current in the quark form: $J^{\mathrm{h}}_\mu = \frac{2}{3}\bar{u}\gamma_\mu u - \frac{1}{3}\bar{d}\gamma_\mu d - \frac{1}{3}\bar{s}\gamma_\mu s$

$$\mathbf{J}^{\mathbf{h}}_{\boldsymbol{\mu}} = \underbrace{\frac{1}{2}(\bar{u}\gamma_\mu u - \bar{d}\gamma_\mu d)}_{\frac{1}{\sqrt{2}}J^\rho_\mu} + \underbrace{\frac{1}{6}(\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d)}_{\frac{S_\omega}{3\sqrt{2}}J^\omega_\mu} - \underbrace{\frac{1}{3}\bar{s}\gamma_\mu s}_{\frac{S_\phi}{3}J^\phi_\mu}$$

$$J^\phi_\mu = \bar{s}\gamma_\mu s, \quad J^\omega_\mu = \frac{1}{\sqrt{2}}(\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d), \quad J^\rho_\mu = \frac{1}{\sqrt{2}}(\bar{u}\gamma_\mu u - \bar{d}\gamma_\mu d)$$

$$J^{\omega 8}_\mu = (\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d - 2\bar{s}\gamma_\mu s)/\sqrt{6}, \quad J^{\omega 0}_\mu = (\bar{u}\gamma_\mu u + \bar{d}\gamma_\mu d + \bar{s}\gamma_\mu s)/\sqrt{3}$$

$$\left.\begin{array}{lll} 1. & S_\omega = +1, S_\phi = +1 & J^\rho_\mu/\sqrt{2} + J^\omega_\mu/(3\sqrt{2}) - J^\phi_\mu/3 \\ \ldots & \ldots & \ldots \\ 8. & S_\omega = -1, S_\phi = +1 & J^\rho_\mu/\sqrt{2} - J^\omega_\mu/(3\sqrt{2}) - J^\phi_\mu/3 \end{array}\right\} = \mathbf{J}^{\mathbf{h}}_{\boldsymbol{\mu}}$$

Ratings of meson constants

- EM current as meson fields: $J_\mu^{\mathrm{h}} = -\frac{m_\rho^2}{\boldsymbol{f_\rho}}\rho_\mu - -\frac{m_\omega^2}{\boldsymbol{f_\omega}}\omega_\mu - \frac{m_\phi^2}{\boldsymbol{f_\phi}}\phi_\mu$
- comparison of coefficient $\frac{1}{\sqrt{2}}, \frac{1}{3\sqrt{2}}, \frac{1}{3}$ with $\frac{1}{f_\rho}, \frac{1}{f_\omega}, \frac{1}{f_\phi}$ (up to unknown constant) $\Rightarrow$

$$\frac{1}{f_\rho} : \frac{1}{f_\omega} : \frac{1}{f_\phi} = \begin{cases} 1. & \sqrt{3} : +\sqrt{\frac{1}{3}} : -\sqrt{\frac{2}{3}} & \sqrt{3} : +\sin\theta : -\cos\theta \\ \dots & \dots & \dots \\ 4. & \sqrt{3} : -\sqrt{\frac{1}{3}} : +\sqrt{\frac{2}{3}} & \sqrt{3} : -\sin\theta : +\cos\theta \\ 5. & \sqrt{3} : +\sqrt{\frac{1}{3}} : +\sqrt{\frac{2}{3}} & \sqrt{3} : +\sin\theta : +\cos\theta \\ \dots & \dots & \dots \\ 8. & \sqrt{3} : -\sqrt{\frac{1}{3}} : -\sqrt{\frac{2}{3}} & \sqrt{3} : -\sin\theta : -\cos\theta \end{cases}$$

Ratings of meson constants

- EM current as meson fields: $J_\mu^{\rm h} = -\frac{m_\rho^2}{\boldsymbol{f_\rho}}\rho_\mu - -\frac{m_\omega^2}{\boldsymbol{f_\omega}}\omega_\mu - \frac{m_\phi^2}{\boldsymbol{f_\phi}}\phi_\mu$
- comparison of coefficient $\frac{1}{\sqrt{2}}$, $\frac{1}{3\sqrt{2}}$, $\frac{1}{3}$ with $\frac{1}{f_\rho}$, $\frac{1}{f_\omega}$, $\frac{1}{f_\phi}$ (up to unknown constant) $\Rightarrow$

$$\frac{1}{f_\rho} : \frac{1}{f_\omega} : \frac{1}{f_\phi} = \begin{cases} 1. & \sqrt{3} : +\sqrt{\frac{1}{3}} : -\sqrt{\frac{2}{3}} & \sqrt{3} : +\sin\theta : -\cos\theta \\ \dots & \dots & \dots \\ 4. & \sqrt{3} : -\sqrt{\frac{1}{3}} : +\sqrt{\frac{2}{3}} & \sqrt{3} : -\sin\theta : +\cos\theta \\ 5. & \sqrt{3} : +\sqrt{\frac{1}{3}} : +\sqrt{\frac{2}{3}} & \sqrt{3} : +\sin\theta : +\cos\theta \\ \dots & \dots & \dots \\ 8. & \sqrt{3} : -\sqrt{\frac{1}{3}} : -\sqrt{\frac{2}{3}} & \sqrt{3} : -\sin\theta : -\cos\theta \end{cases}$$

Numerical values

- Unitary & Analytic model $\rightarrow$ provides only ratios of coupling constants by fitting procedure of all experimental data
  - $\frac{f^{(1)}_{\rho NN}}{f_\rho} = 0.3747,$
  - $\frac{f^{(1)}_{\omega NN}}{f_\omega} = 1.5717,$
  - $\frac{f^{(1)}_{\phi NN}}{f_\phi} = -1.1247$
- absolute values $f_\rho, f_\omega, f_\phi \rightarrow$ from lepton widths
- signs and ratios $f_\rho, f_\omega, f_\phi \rightarrow$ from currents

$$\frac{f^{(1)}_{\rho NN}}{f_\rho}, \quad \frac{f^{(1)}_{\omega NN}}{f_\omega}, \quad \frac{f^{(1)}_{\phi NN}}{f_\phi} \quad \Rightarrow \quad f^{(1)}_{\rho NN}, \quad f^{(1)}_{\omega NN}, \quad f^{(1)}_{\phi NN}$$

but they depend on ω–ϕ mixing!

Numerical values

- Unitary & Analytic model $\rightarrow$ provides only ratios of coupling constants by fitting procedure of all experimental data

$$\frac{f^{(1)}_{\rho NN}}{f_\rho} = 0.3747, \quad \frac{f^{(1)}_{\omega NN}}{f_\omega} = 1.5717, \quad \frac{f^{(1)}_{\phi NN}}{f_\phi} = -1.1247$$

- absolute values $f_\rho, f_\omega, f_\phi \rightarrow$ from lepton widths
- signs and ratios $f_\rho, f_\omega, f_\phi \rightarrow$ from currents

$$\frac{f^{(1)}_{\rho NN}}{f_\rho}, \quad \frac{f^{(1)}_{\omega NN}}{f_\omega}, \quad \frac{f^{(1)}_{\phi NN}}{f_\phi} \quad \Rightarrow \quad f^{(1)}_{\rho NN}, \quad f^{(1)}_{\omega NN}, \quad f^{(1)}_{\phi NN}$$

but they depend on ω–ϕ mixing!

Numerical values of f^F, f^D, f^S

1. $f^{(1)}_{\rho NN} = +1.8570$, $f^{(1)}_{\omega NN} = +26.8101$, $f^{(1)}_{\phi NN} = +15.2307$

... ...

8. $f^{(1)}_{\rho NN} = +1.8570$, $f^{(1)}_{\omega NN} = -26.8101$, $f^{(1)}_{\phi NN} = +15.2307$

1. ... 8. $\Big\}$ relations for f^F, f^D, f^S $\sim$ $f(f_{\rho NN}, f_{\phi NN}, f_{\omega NN})$

combine to 1 result: $f_1^F = 5.2774$, $f_1^D = -1.5634$, $f_1^S = 43.0274$

similarly f_2^F, f_2^D, f_2^S and higher $f_1^{F'}$, $f_1^{D'}$, $f_1^{S'}$, $f_2^{F'}$, $f_2^{D'}$, $f_2^{S'}$

Numerical values of f^F, f^D, f^S

1. $f^{(1)}_{\rho NN} = +1.8570$, $f^{(1)}_{\omega NN} = +26.8101$, $f^{(1)}_{\phi NN} = +15.2307$

...

8. $f^{(1)}_{\rho NN} = +1.8570$, $f^{(1)}_{\omega NN} = -26.8101$, $f^{(1)}_{\phi NN} = +15.2307$

1. ... 8. } relations for f^F, f^D, f^S $\sim$ $f(f_{\rho NN}, f_{\phi NN}, f_{\omega NN})$

combine to 1 result: $f_1^F = 5.2774$, $f_1^D = -1.5634$, $f_1^S = 43.0274$

similarly f_2^F, f_2^D, f_2^S and higher $f_1^{F'}$, $f_1^{D'}$, $f_1^{S'}$, $f_2^{F'}$, $f_2^{D'}$, $f_2^{S'}$

Hyperon EM form factors

$$f_{\rho NN}, f_{\omega NN}, f_{\phi NN} \quad \Rightarrow \quad f^F, f^D, f^S \quad \Rightarrow \quad f_{\rho HH}, f_{\omega HH}, f_{\phi HH}$$

We need them:

- to calculate the unknown vector-meson coupling constants for hyperons
- to construct U&A model of hyperons
- to calculate quantities describing EM structure of hyperons, e. g., charge mean squared radius

Conclusions

- We revisited ω—ϕ mixing configurations satisfying Gell-Mann-Okubo quadratic mass formula and quark representation of ω_8, ω_0 mesons
- We have specified the signs of universal vector meson coupling constants f_ρ, f_ω, f_ϕ
- We have derived and evaluated the f^F, f^D, f^S coupling constants in SU(3) invariant lagrangian
- Their values do not depend on the configuration of ω—ϕ mixing
- Universal vector-meson coupling constants f_V's play an essential role in a prediction of $1/2^+$ octet hyperon electromagnetic form factor behaviors.

References

Donnachie, A. and Clegg, A. B. (1989).
Omega-primes and Glueballs.
Z.Phys., C42:663.

Gell-Mann, M. (1961).
The Eightfold Way: A Theory of strong interaction symmetry.

Patrignani, C. et al. (2016).
Review of Particle Physics.
Chin. Phys., C40(10):100001.

Sakurai, J. and Barry, G. (1969).
Currents and Mesons.
Chicago Lectures in Physics. University of Chicago Press.

ideal mixing angle $\boldsymbol{\theta = 35.3^\circ}$

1. $\omega = \sin\theta\,\omega_8 + \cos\theta\,\omega_0$ $\qquad \omega = +\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})$
   $\phi = -\cos\theta\,\omega_8 + \sin\theta\,\omega_0$ $\qquad \phi = +s\bar{s}$

4. $\omega = -\sin\theta\,\omega_8 - \cos\theta\,\omega_0$ $\qquad \omega = -\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})$
   $\phi = \cos\theta\,\omega_8 - \sin\theta\,\omega_0$ $\qquad \phi = -s\bar{s}$

5. $\omega = \sin\theta\,\omega_8 + \cos\theta\,\omega_0$ $\qquad \omega = +\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})$
   $\phi = \cos\theta\,\omega_8 - \sin\theta\,\omega_0$ $\qquad \phi = -s\bar{s}$

8. $\omega = -\sin\theta\,\omega_8 - \cos\theta\,\omega_0$ $\qquad \omega = -\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})$
   $\phi = -\cos\theta\,\omega_8 + \sin\theta\,\omega_0$ $\qquad \phi = +s\bar{s}$

~~2.~~ $\omega = -\sin\theta\,\omega_8 + \cos\theta\,\omega_0$ $\qquad \omega = +\frac{1}{3\sqrt{2}}(u\bar{u} + d\bar{d}) + \frac{4}{3\sqrt{2}}s\bar{s}$
   $\phi = -\cos\theta\,\omega_8 - \sin\theta\,\omega_0$ $\qquad \phi = -\frac{2}{3}(u\bar{u} + d\bar{d}) + \frac{1}{3}s\bar{s}$

... ...

Decays of ω and ϕ mesons

ω	$\rightarrow$	$\pi^+\pi^-\pi^0$	89.20%
	$\rightarrow$	$\pi^0\gamma$	8.40%
	$\rightarrow$	$\pi^+\pi^-$	1.53%
ϕ	$\rightarrow$	K^+K^-	48.90%
	$\rightarrow$	$K^0_L K^0_S$	34.20%
	$\rightarrow$	$\rho\pi + \pi^+\pi^-\pi^0$	15.32%

π^+	$u\bar{d}$
π^-	$d\bar{u}$
π^0	$\frac{u\bar{u}-d\bar{d}}{\sqrt{2}}$
ρ^0	$\frac{u\bar{u}-d\bar{d}}{\sqrt{2}}$
K^+	$u\bar{s}$
K^-	$s\bar{u}$
K^0_L	$\frac{d\bar{s}-s\bar{d}}{\sqrt{2}}$
K^0_S	$\frac{d\bar{s}+s\bar{d}}{\sqrt{2}}$