η' gluonic content from $V \to P\gamma$ and $J/\psi \to VP$ decays

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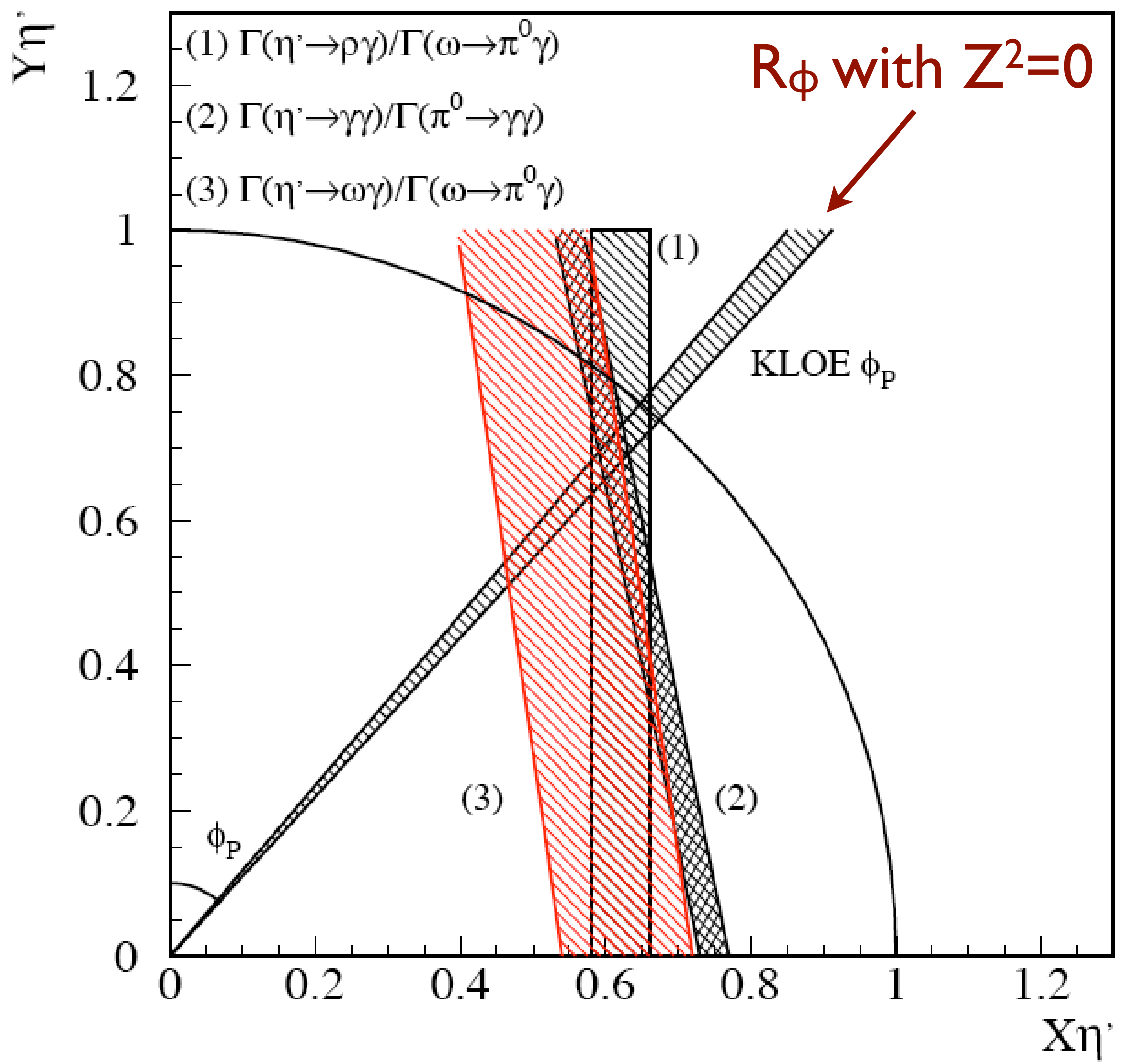
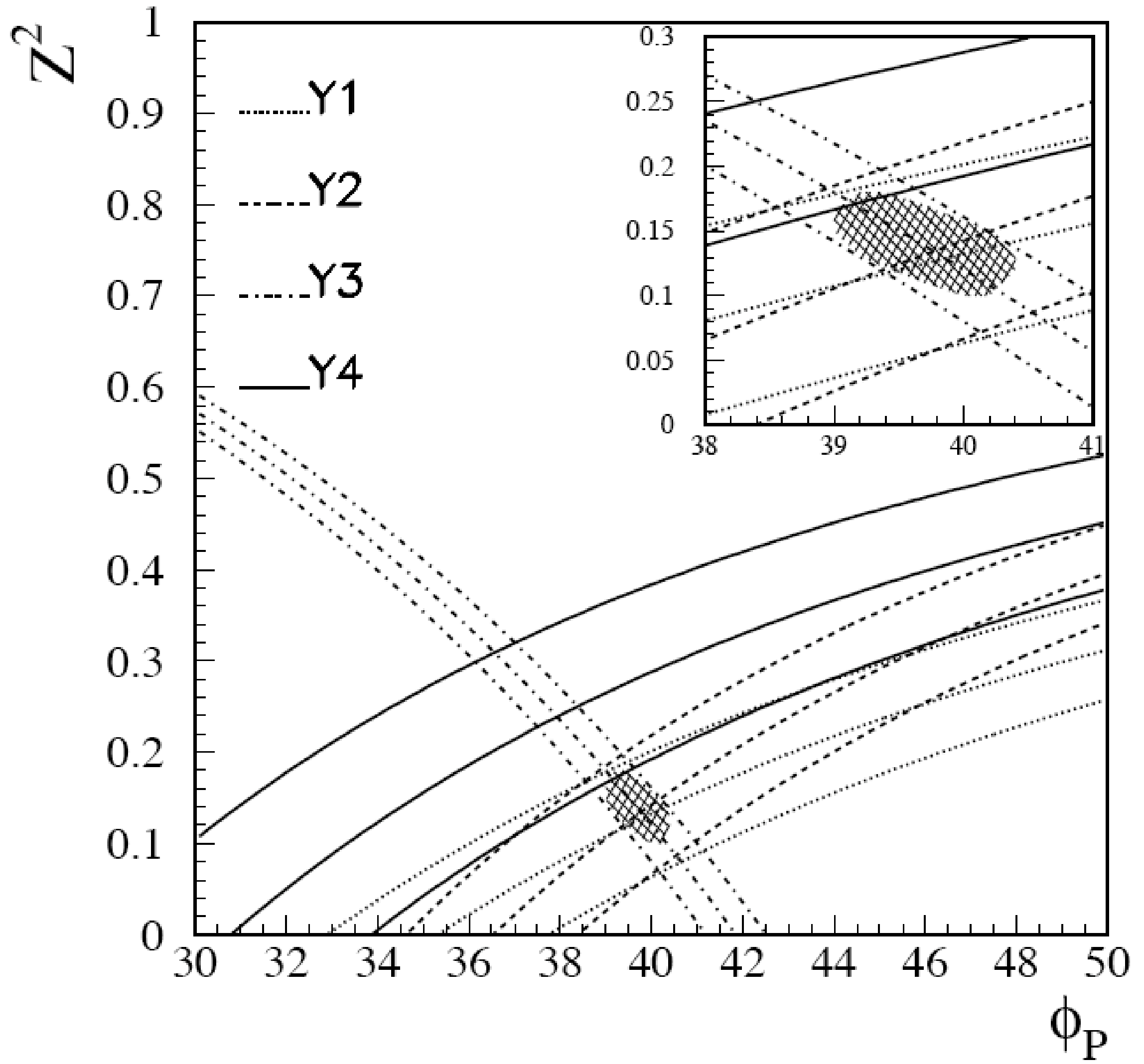
- *Motivation*

KLOE Collaboration, Phys. Lett. B648 (2007) 267





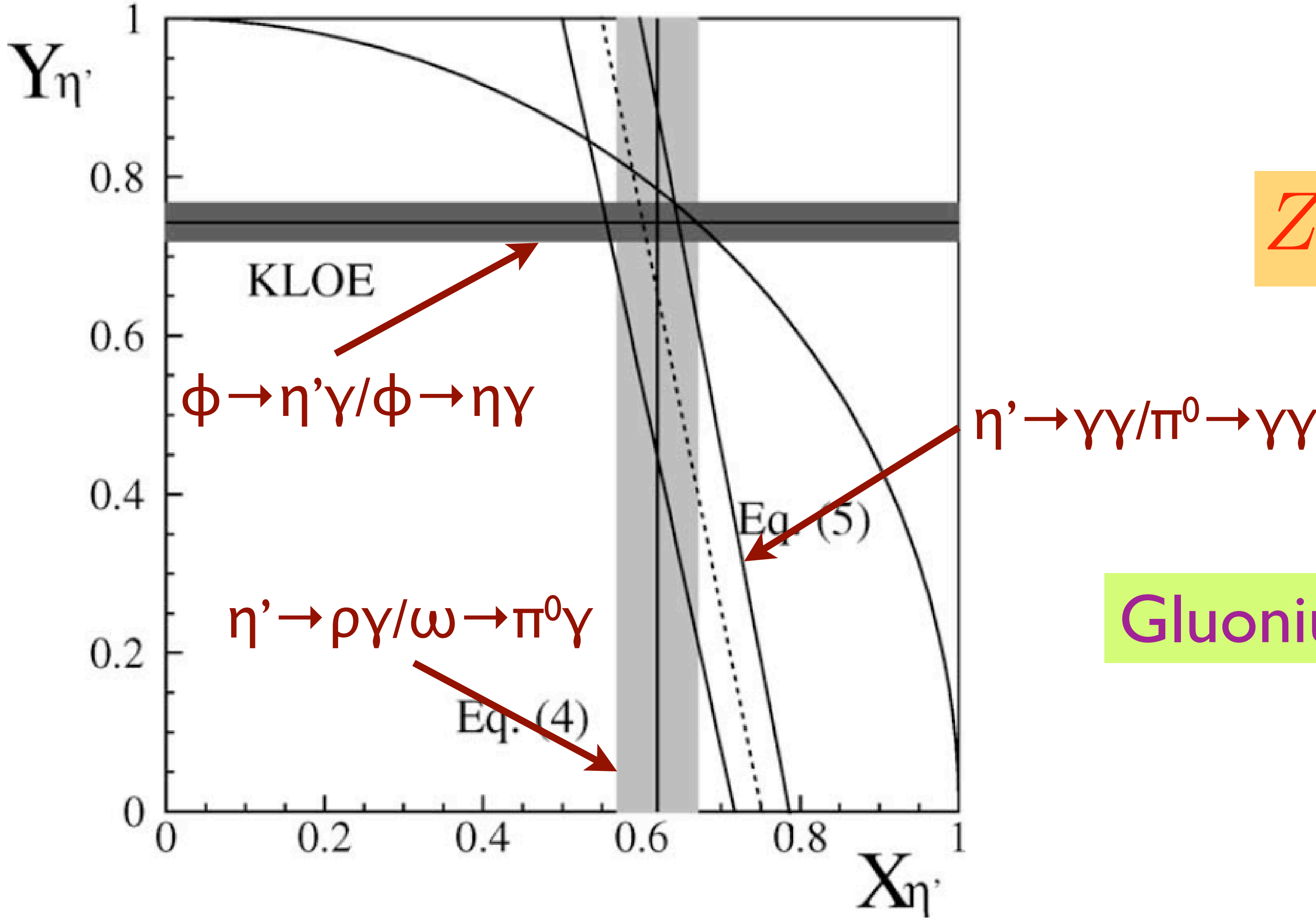
$$\phi_P = (39.7 \pm 0.7)^\circ$$

$$Z^2_{\eta'} = 0.14 \pm 0.04$$

Y1=η'→γγ/π^0→γγ
Y2=η'→ργ/ω→π^0γ
Y3=ϕ→η'γ/ϕ→ηγ
Y4=η'→ωγ/ω→π^0γ

• *Motivation*

KLOE Collaboration, PLB 541 (2002) 45



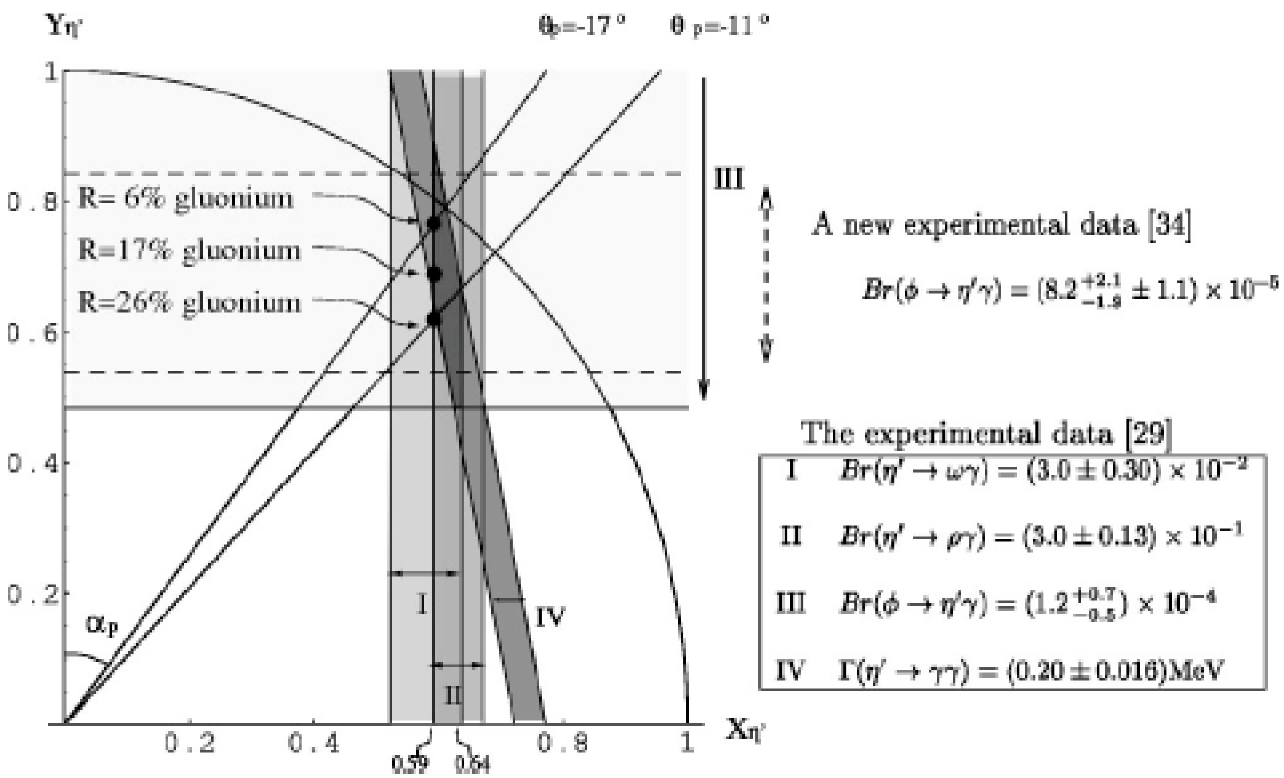
$$Z^2_{\eta'} = 0.06^{+0.09}_{-0.06}$$

Gluonium fraction below 15%

What are the differences between the two analyses?

- improvement in the precision of the new measurements
- the use of the overlapping parameters relating the pseudoscalar and vector wave functions

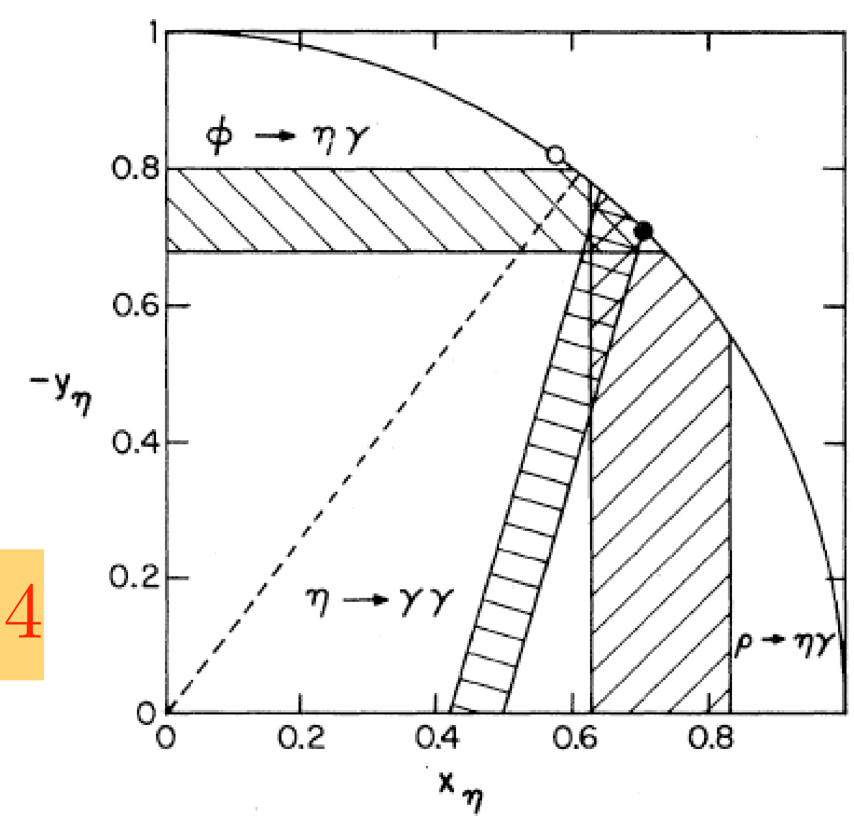
- *Motivation*

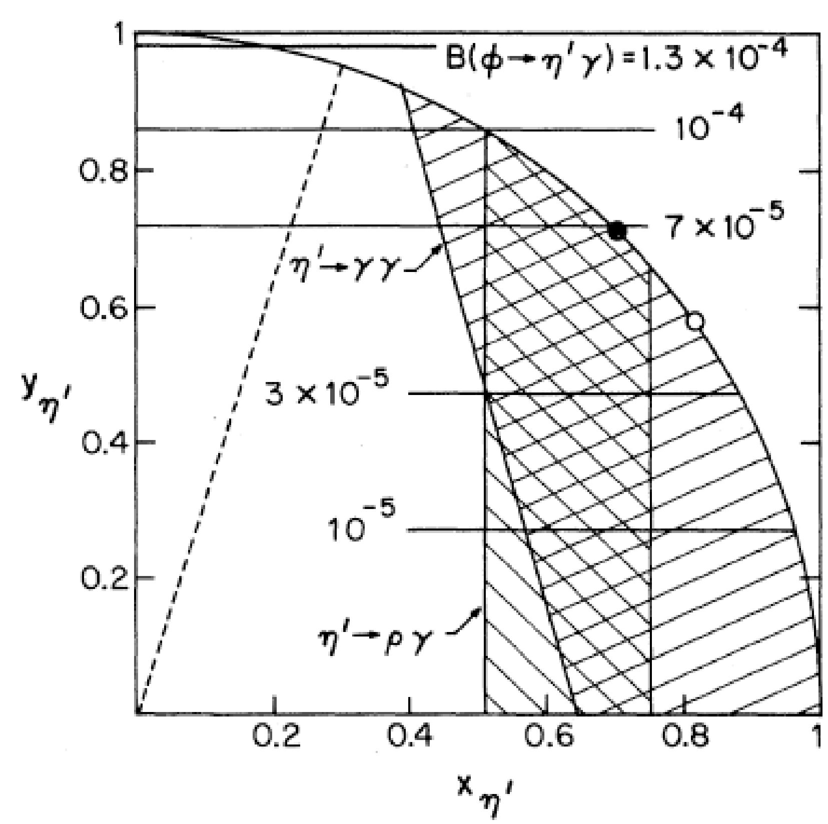


E. Kou, Phys. Rev. D63 (2001) 054027

$$R = \frac{Z_{\eta'}}{X_{\eta'} + Y_{\eta'} + Z_{\eta'}} = (13 \pm 13)\%$$

J. L. Rosner, Phys. Rev. D27 (1983) 1101





$$|Z_\eta| < 0.4$$

Purpose: to perform a phenomenological analysis of $V \to P\gamma$ and $J/\psi \to VP$ decays, with $V=\rho, K^*, \omega, \phi$ and $P=\pi, K, \eta, \eta'$, aimed at determining the gluonic content of the η and η' wave functions

Why? to confirm or not the gluonic content of the η' wave function

Feasible? yes, because we have at our disposal all the needed experimental information

Outline:

- *Notation*
- *$V \to P\gamma$ analysis*
- *$J/\psi \to VP$ analysis*
- *Results*
- *Conclusions*

• *Notation*

We work in a basis consisting of the states

$$|\eta_q\rangle \equiv \frac{1}{\sqrt{2}}|u\bar{u} + d\bar{d}\rangle \qquad |\eta_s\rangle = |s\bar{s}\rangle \qquad |G\rangle \equiv |\mathrm{gluonium}\rangle$$

The physical states η and η' are assumed to be the linear combinations

$$\begin{aligned} |\eta\rangle &= X_\eta|\eta_q\rangle + Y_\eta|\eta_s\rangle + Z_\eta|G\rangle \ , \\ |\eta'\rangle &= X_{\eta'}|\eta_q\rangle + Y_{\eta'}|\eta_s\rangle + Z_{\eta'}|G\rangle \ , \end{aligned}$$

with $X^2_{\eta(\eta')} + Y^2_{\eta(\eta')} + Z^2_{\eta(\eta')} = 1$ and thus $X^2_{\eta(\eta')} + Y^2_{\eta(\eta')} \leq 1$

A significant gluonic admixture in a state is possible only if

$$Z^2_{\eta(\eta')} = 1 - X^2_{\eta(\eta')} - Y^2_{\eta(\eta')} > 0$$

Assumptions:

- no mixing with π^0 (isospin symmetry)
- no mixing with η_c states
- no mixing with radial excitations

- *Notation*

In absence of gluonium (standard picture)

$$Z_{\eta(\eta')} \equiv 0 \quad \Rightarrow \quad \begin{aligned} |\eta\rangle &= \cos\phi_P|\eta_q\rangle - \sin\phi_P|\eta_s\rangle \\ |\eta'\rangle &= \sin\phi_P|\eta_q\rangle + \cos\phi_P|\eta_s\rangle \end{aligned}$$

with $X_\eta = Y_{\eta'} \equiv \cos\phi_P$ and $X^2_{\eta(\eta')} + Y^2_{\eta(\eta')} = 1$

$$X_{\eta'} = -Y_\eta \equiv \sin\phi_P$$

where ϕ_P is the η-η' mixing angle in the quark-flavour basis related to its octet-singlet analog through

$$\theta_P = \phi_P - \arctan\sqrt{2} \simeq \phi_P - 54.7^\circ$$

Similarly, for the vector states ω and ϕ the mixing is given by

$$\begin{aligned} |\omega\rangle &= \cos\phi_V|\omega_q\rangle - \sin\phi_V|\phi_s\rangle \\ |\phi\rangle &= \sin\phi_V|\omega_q\rangle + \cos\phi_V|\phi_s\rangle \end{aligned}$$

where ω_q and ϕ_s are the analog non-strange and strange states of η_q and η_s, respectively.

• *Euler angles*

In presence of gluonium,

$$|\eta\rangle = X_\eta|\eta_q\rangle + Y_\eta|\eta_s\rangle + Z_\eta|G\rangle$$
$$|\eta'\rangle = X_{\eta'}|\eta_q\rangle + Y_{\eta'}|\eta_s\rangle + Z_{\eta'}|G\rangle$$
$$|\iota\rangle = X_\iota|\eta_q\rangle + Y_\iota|\eta_s\rangle + Z_\iota|G\rangle$$

glueball-like state η(1440)? → $|\iota\rangle$

Normalization:

$$X_\eta^2 + Y_\eta^2 + Z_\eta^2 = 1$$
$$X_{\eta'}^2 + Y_{\eta'}^2 + Z_{\eta'}^2 = 1$$
$$X_\iota^2 + Y_\iota^2 + Z_\iota^2 = 1$$

Orthogonality:

$$X_\eta X_{\eta'} + Y_\eta Y_{\eta'} + Z_\eta Z_{\eta'} = 0$$
$$X_\eta X_\iota + Y_\eta Y_\iota + Z_\eta Z_\iota = 0$$
$$X_{\eta'} X_\iota + Y_{\eta'} Y_\iota + Z_{\eta'} Z_\iota = 0$$

→ 3 independent parameters: ϕ_P, $\phi_{\eta G}$ and $\phi_{\eta' G}$

$$\begin{pmatrix} \eta \\ \eta' \\ \iota \end{pmatrix} = \begin{pmatrix} c\phi_{\eta\eta'}c\phi_{\eta G} & -s\phi_{\eta\eta'}c\phi_{\eta G} & -s\phi_{\eta G} \\ s\phi_{\eta\eta'}c\phi_{\eta' G} - c\phi_{\eta\eta'}s\phi_{\eta' G}s\phi_{\eta G} & c\phi_{\eta\eta'}c\phi_{\eta' G} + s\phi_{\eta\eta'}s\phi_{\eta' G}s\phi_{\eta G} & -s\phi_{\eta' G}c\phi_{\eta G} \\ s\phi_{\eta\eta'}s\phi_{\eta' G} + c\phi_{\eta\eta'}c\phi_{\eta' G}s\phi_{\eta G} & c\phi_{\eta\eta'}s\phi_{\eta' G} - s\phi_{\eta\eta'}c\phi_{\eta' G}s\phi_{\eta G} & c\phi_{\eta' G}c\phi_{\eta G} \end{pmatrix} \begin{pmatrix} \eta_q \\ \eta_s \\ G \end{pmatrix}$$

• *Euler angles*

$$X_\eta = \cos\phi_P \cos\phi_{\eta G} \ , \quad X_{\eta'} = \sin\phi_P \cos\phi_{\eta' G} - \cos\phi_P \sin\phi_{\eta G} \sin\phi_{\eta' G} \ ,$$
$$Y_\eta = -\sin\phi_P \cos\phi_{\eta G} \ , \quad Y_{\eta'} = \cos\phi_P \cos\phi_{\eta' G} + \sin\phi_P \sin\phi_{\eta G} \sin\phi_{\eta' G} \ ,$$
$$Z_\eta = -\sin\phi_{\eta G} \ , \quad Z_{\eta'} = -\sin\phi_{\eta' G} \cos\phi_{\eta G} \ .$$

In the limit $\phi_{\eta G}=0$:

$$X_\eta = \cos\phi_P \ , \quad Y_\eta = -\sin\phi_P \ , \quad Z_\eta = 0 \ ,$$
$$X_{\eta'} = \sin\phi_P \cos\phi_{\eta' G} \ , \quad Y_{\eta'} = \cos\phi_P \cos\phi_{\eta' G} \ , \quad Z_{\eta'} = -\sin\phi_{\eta' G} \ .$$

• *A model for VPγ M1 transitions*

We will work in a conventional quark model context: P and V are simple quark-antiquark S-wave bound states

→ all these hadrons are thus extended objects with characteristics spatial extensions fixed by their respective P and V wave functions

SU(2) limit → identical spatial extension within each isomultiplet

SU(3) broken → constituent quark masses with $m_s > m$ and different spatial extensions for each isomultiplet

Ingredients of the model:

i) a VPγ magnetic dipole transition proceeding via quark or antiquark spin flip amplitude $\propto \mu_q = e_q/2m_q$

ii) spin-flip V→P conversion amplitude corrected by the relative overlap between the P and V wave functions

iii) OZI-rule reduces considerably the possible transitions and overlaps

U(1)$_A$ anomaly →

$$C_\pi \equiv \langle \pi | \omega_q \rangle = \langle \pi | \rho \rangle \qquad C_K \equiv \langle K | K^* \rangle$$

$$C_q \equiv \langle \eta_q | \omega_q \rangle = \langle \eta_q | \rho \rangle \qquad C_s \equiv \langle \eta_s | \phi_s \rangle$$

• A model for VPγ M1 transitions

Amplitudes:

$$g_{\rho^0\pi^0\gamma} = g_{\rho^+\pi^+\gamma} = \tfrac{1}{3} g \ , \quad g_{\omega\pi\gamma} = g\cos\phi_V \ , \quad g_{\phi\pi\gamma} = g\sin\phi_V \ ,$$

$$g_{K^{*0}K^0\gamma} = -\tfrac{1}{3} g\, z_K \left(1 + \frac{\bar{m}}{m_s}\right) \ , \quad g_{K^{*+}K^+\gamma} = \tfrac{1}{3} g\, z_K \left(2 - \frac{\bar{m}}{m_s}\right) \ ,$$

$$g_{\rho\eta\gamma} = g\, z_q X_\eta \ , \quad g_{\rho\eta'\gamma} = g\, z_q X_{\eta'} \ ,$$

$$g_{\omega\eta\gamma} = \tfrac{1}{3} g \left(z_q X_\eta \cos\phi_V + 2\frac{\bar{m}}{m_s} z_s Y_\eta \sin\phi_V \right) \ ,$$

$$g_{\omega\eta'\gamma} = \tfrac{1}{3} g \left(z_q X_{\eta'} \cos\phi_V + 2\frac{\bar{m}}{m_s} z_s Y_{\eta'} \sin\phi_V \right) \ ,$$

$$g_{\phi\eta\gamma} = \tfrac{1}{3} g \left(z_q X_\eta \sin\phi_V - 2\frac{\bar{m}}{m_s} z_s Y_\eta \cos\phi_V \right) \ ,$$

$$g_{\phi\eta'\gamma} = \tfrac{1}{3} g \left(z_q X_{\eta'} \sin\phi_V - 2\frac{\bar{m}}{m_s} z_s Y_{\eta'} \cos\phi_V \right) \ ,$$

with $g_{\omega\pi\gamma} = g\ \cos\phi_V = e\, C_\pi \cos\phi_V / \bar{m}$

and $z_q \equiv C_q / C_\pi$, $z_s \equiv C_s / C_\pi$, $z_K \equiv C_K / C_\pi$

$$\Gamma(V \to P\gamma) = \frac{1}{3} \frac{g^2_{VP\gamma}}{4\pi} |\mathbf{p}_\gamma|^3 = \frac{1}{3} \Gamma(P \to V\gamma)$$

• *Data fitting*

R. E. and J. Nadal, JHEP 05 (2007) 6

The overlapping parameters $z_{q,s}$ and the mixing parameters $X_{\eta(\eta')}$ and $Y_{\eta(\eta')}$ cannot be determined independently

Thus we start assuming $C_q = C_s = C_K = C_\pi = 1$ → $z_q = z_s = z_K = 1$

→ χ^2/d.o.f.=31.2/6 gluonium allowed for η and η'

or χ^2/d.o.f.=45.9/8 gluonium not allowed with $\phi_P=(41.1\pm1.1)^\circ$

Then we leave the overlapping parameters free

Three possibilities:

i) $Z_\eta=Z_{\eta'}=0$ → gluonium not allowed for η or η'

ii) $Z_\eta=0$ → gluonium allowed only for η'

iii) $Z_{\eta'}=0$ → gluonium allowed only for η

i) assuming $Z_\eta=Z_{\eta'}=0$ from the beginning, we get from χ^2/d.o.f.=14.0/7 to

$$g = 0.72 \pm 0.01\ \text{GeV}^{-1}\ , \quad \phi_P = (41.5 \pm 1.2)^\circ, \quad \phi_V = (3.2 \pm 0.1)^\circ\ ,$$

$$\frac{m_s}{\bar{m}} = 1.24 \pm 0.07\ , \quad z_K = 0.89 \pm 0.03\ , \quad z_q = 0.86 \pm 0.03\ , \quad z_s = 0.78 \pm 0.05\ .$$

χ^2/d.o.f.=4.4/5

- *Data fitting*

ii) assuming $Z_\eta=0$ from the beginning, we get

$$g = 0.72 \pm 0.01\ \text{GeV}^{-1}\ , \quad \frac{m_s}{\bar{m}} = 1.24 \pm 0.07\ , \quad \phi_V = (3.2 \pm 0.1)^\circ\ ,$$

$$\phi_P = (41.4 \pm 1.3)^\circ,\ |\phi_{\eta' G}| = (12 \pm 13)^\circ,$$

χ^2/d.o.f.=4.2/4

$$z_K = 0.89 \pm 0.03\ , \quad z_q = 0.86 \pm 0.03\ , \quad z_s = 0.79 \pm 0.05\ ,$$

Accepting the absence of gluonium for the η meson, the gluonic content of the η' wave function amounts to $|\phi_{\eta' G}|=(12\pm13)^\circ$ or $(Z_{\eta'})^2=0.04\pm0.09$ and the η-η' mixing angle is found to be $\phi_P=(41.4\pm1.3)^\circ$

Transition	$g^{exp}_{VP\gamma}$(PDG)	$g^{th}_{VP\gamma}$(Fit 1)	$g^{th}_{VP\gamma}$(Fit 2)
$\rho^0 \to \eta\gamma$	0.475 ± 0.024	0.461 ± 0.019	0.464 ± 0.030
$\eta' \to \rho^0\gamma$	0.41 ± 0.03	0.41 ± 0.02	0.40 ± 0.04
$\omega \to \eta\gamma$	0.140 ± 0.007	0.142 ± 0.007	0.143 ± 0.010
$\eta' \to \omega\gamma$	0.139 ± 0.015	0.149 ± 0.006	0.146 ± 0.014
$\phi \to \eta\gamma$	0.209 ± 0.002	0.209 ± 0.018	0.209 ± 0.013
$\phi \to \eta'\gamma$	0.22 ± 0.01	0.22 ± 0.02	0.22 ± 0.02

no gluonium

gluonium

- ## *Data fitting*

iii) assuming $Z_{\eta'}=0$ from the beginning, we get

$$g = 0.72 \pm 0.01\ \text{GeV}^{-1}\,, \quad \frac{m_s}{\bar{m}} = 1.24 \pm 0.07\,, \quad \phi_V = (3.2 \pm 0.1)^\circ\,,$$
$$\phi_P = (41.5 \pm 1.3)^\circ\,, \quad |\phi_{\eta G}| \simeq 0^\circ\,,$$
$$z_q = 0.86 \pm 0.04\,, \quad z_s = 0.78 \pm 0.06\,, \quad z_K = 0.89 \pm 0.03\,,$$

χ^2/d.o.f.=4.4/4

Accepting the absence of gluonium for the η' meson, the gluonic content of the η wave function amounts to $|\phi_{\eta G}|\simeq 0^\circ$ or $(Z_\eta)^2=0.00\pm0.12$ and the η-η' mixing angle is found to be $\phi_P=(41.5\pm1.3)^\circ$

The current experimental data on VPγ transitions indicate within our model a negligible gluonic content for the η and η' mesons

• *Data fitting*

Using the latest experimental data on $(\rho,\omega,\phi)\to\eta\gamma$ (SND) and $\phi\to\eta'\gamma$ (KLOE), we get

$$\phi_P = (42.7 \pm 0.7)^\circ , \quad z_q = 0.83 \pm 0.03 \; , \quad z_s = 0.79 \pm 0.05 \; , \quad \chi^2/\text{d.o.f.}=4.0/5$$

$$\phi_P = (42.6 \pm 1.1)^\circ , \quad |\phi_{\eta' G}| = (5 \pm 21)^\circ , \quad z_q = 0.83 \pm 0.03 \; , \quad z_s = 0.79 \pm 0.05 \; , \quad \chi^2/\text{d.o.f.}=4.0/4$$

→ confirmation of the null gluonic content of the η and η' wave functions

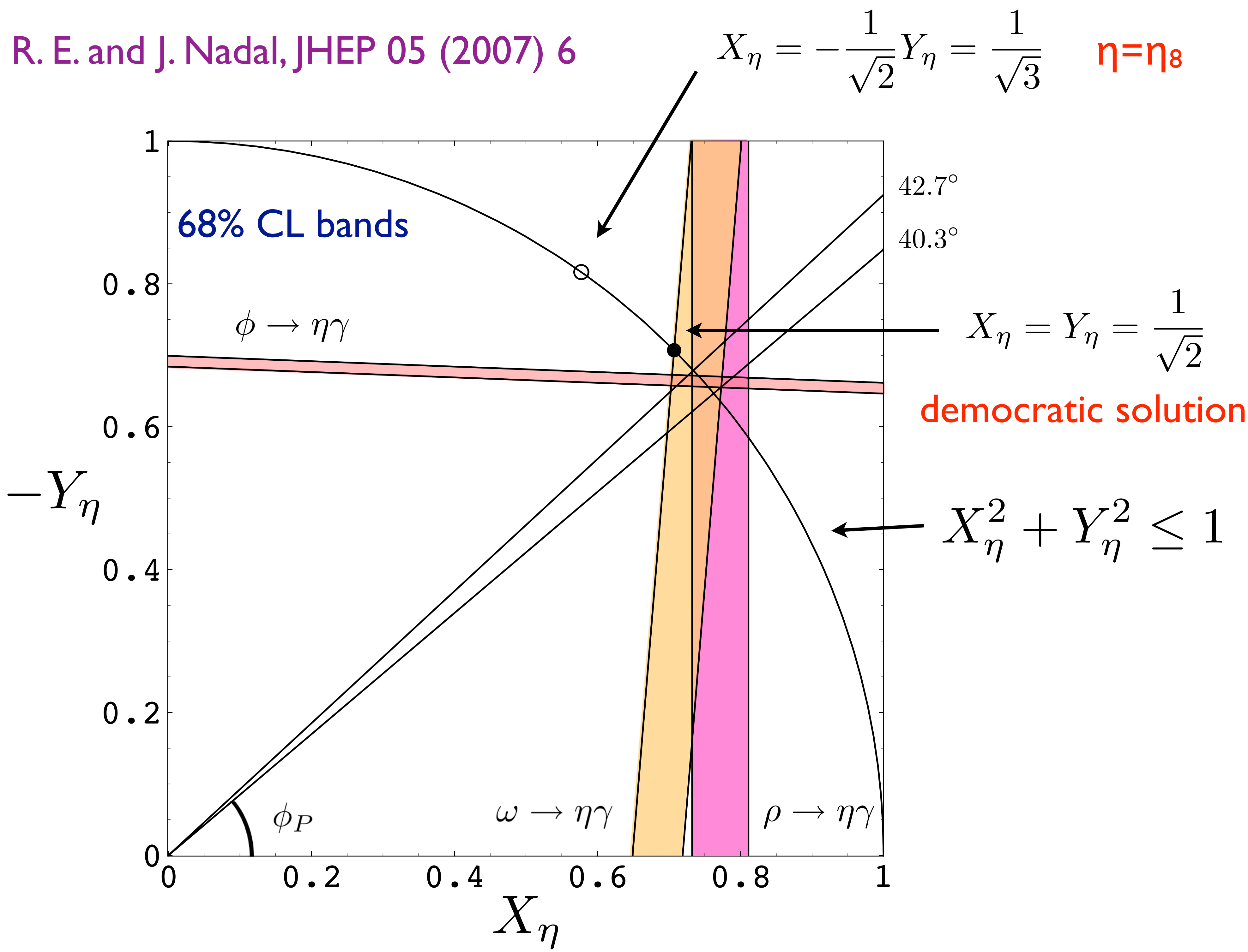
Transition	$g^{\text{exp}}_{VP\gamma}$(latest)	$g^{\text{th}}_{VP\gamma}$(Fit 3)	$g^{\text{th}}_{VP\gamma}$(Fit 4)
$\rho^0 \to \eta\gamma$	0.429 ± 0.023	0.436 ± 0.017	0.437 ± 0.028
$\eta' \to \rho^0\gamma$	0.41 ± 0.03 (PDG)	0.40 ± 0.02	0.40 ± 0.04
$\omega \to \eta\gamma$	0.136 ± 0.007	0.134 ± 0.006	0.134 ± 0.009
$\eta' \to \omega\gamma$	0.139 ± 0.015 (PDG)	0.146 ± 0.006	0.146 ± 0.013
$\phi \to \eta\gamma$	0.214 ± 0.003	0.214 ± 0.017	0.214 ± 0.012
$\phi \to \eta'\gamma$	0.216 ± 0.005	0.216 ± 0.019	0.216 ± 0.018

no gluonium (→ Fit 3)

gluonium (→ Fit 4)

• *Results*

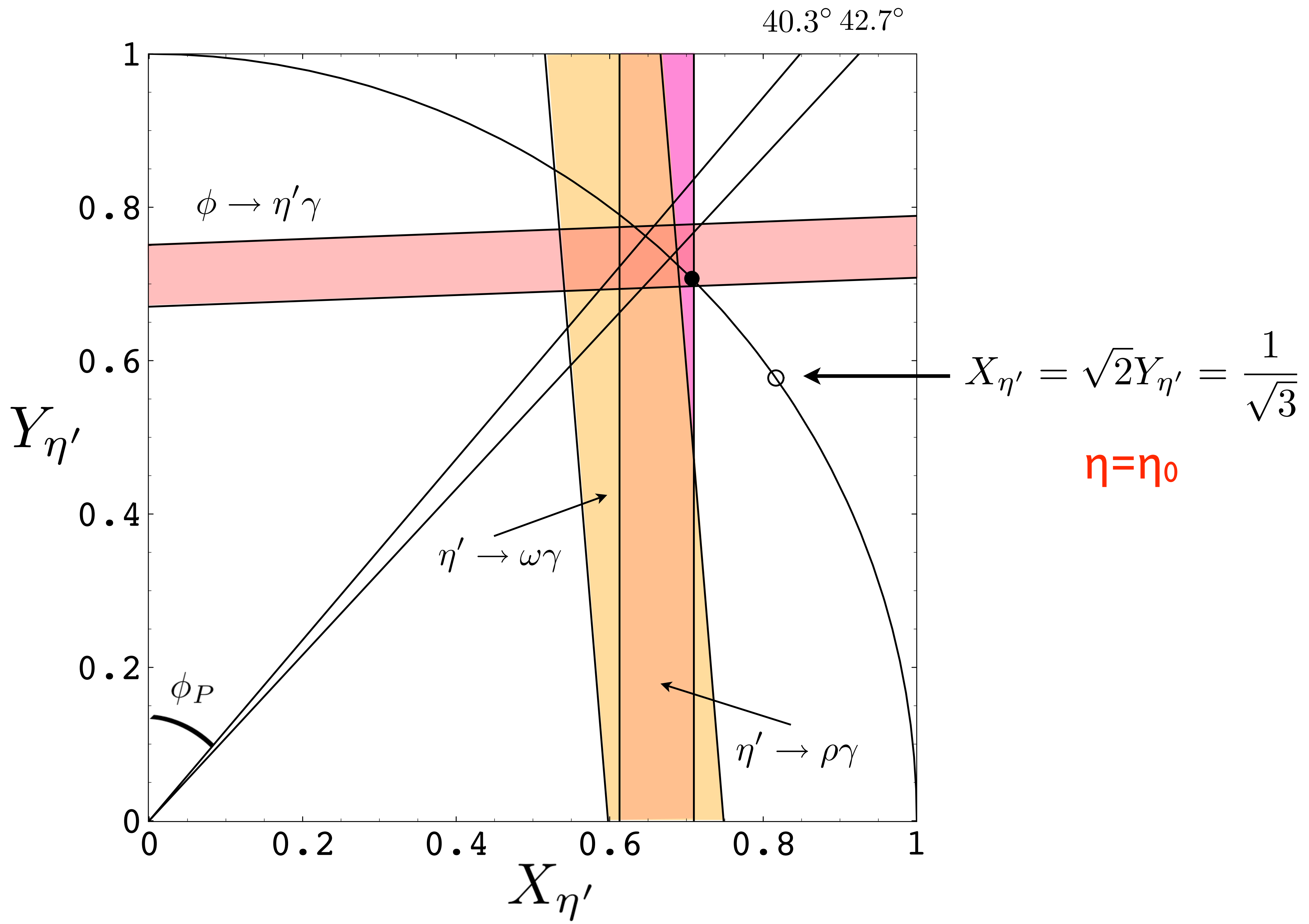
R. E. and J. Nadal, JHEP 05 (2007) 6



✔ importance of $\phi \to \eta\gamma$

✔ importance of the slopes (ϕ_V)

• *Results*

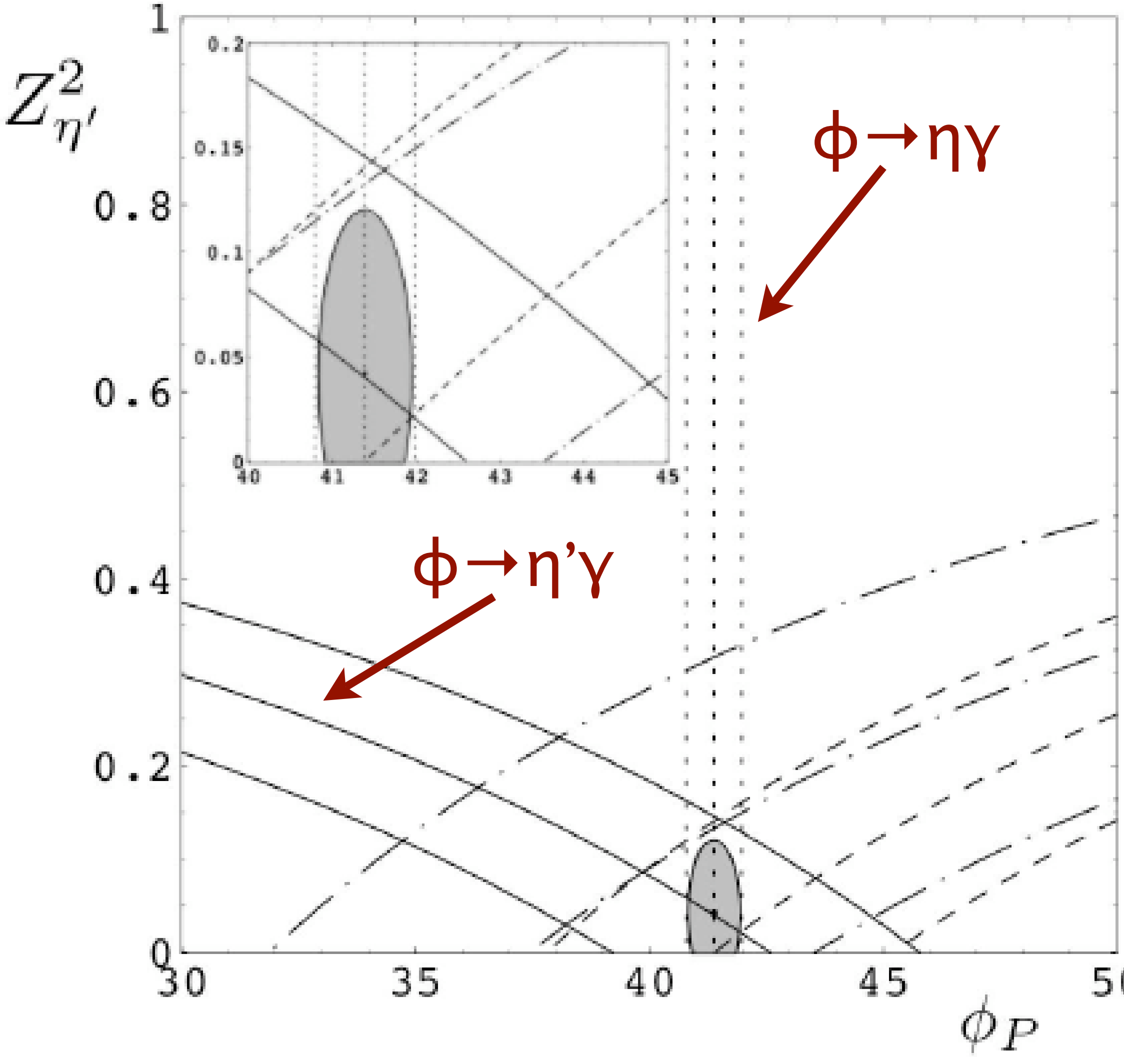


✔ importance of constraining even more $\phi \to \eta'\gamma$

➡ More refined data for this channel will contribute decisively to clarify this issue

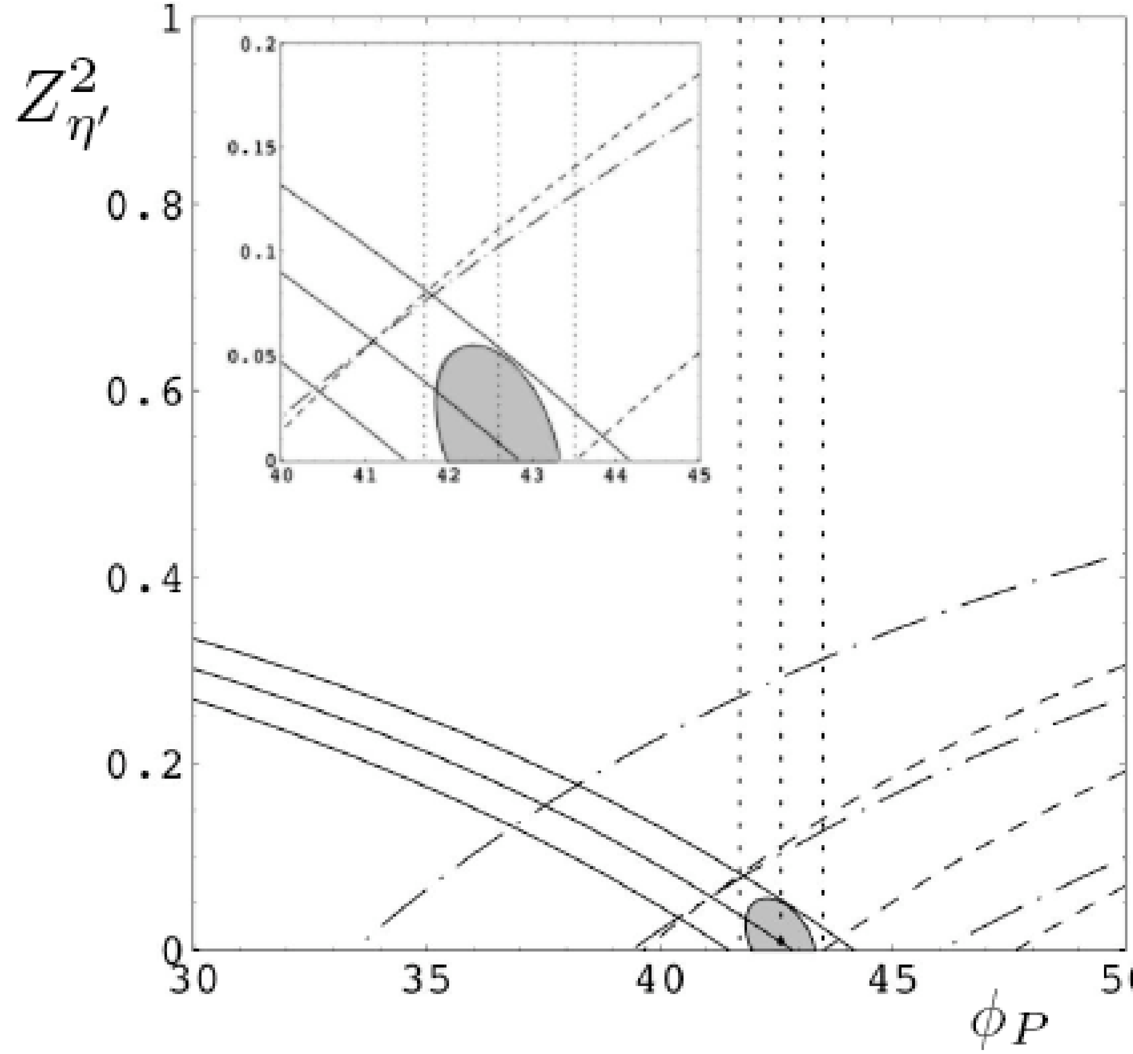
- *Results*

PDG'06 data



$(\phi_P, Z^2_{\eta'}) = (41.4^\circ, 0.04)$

latest data

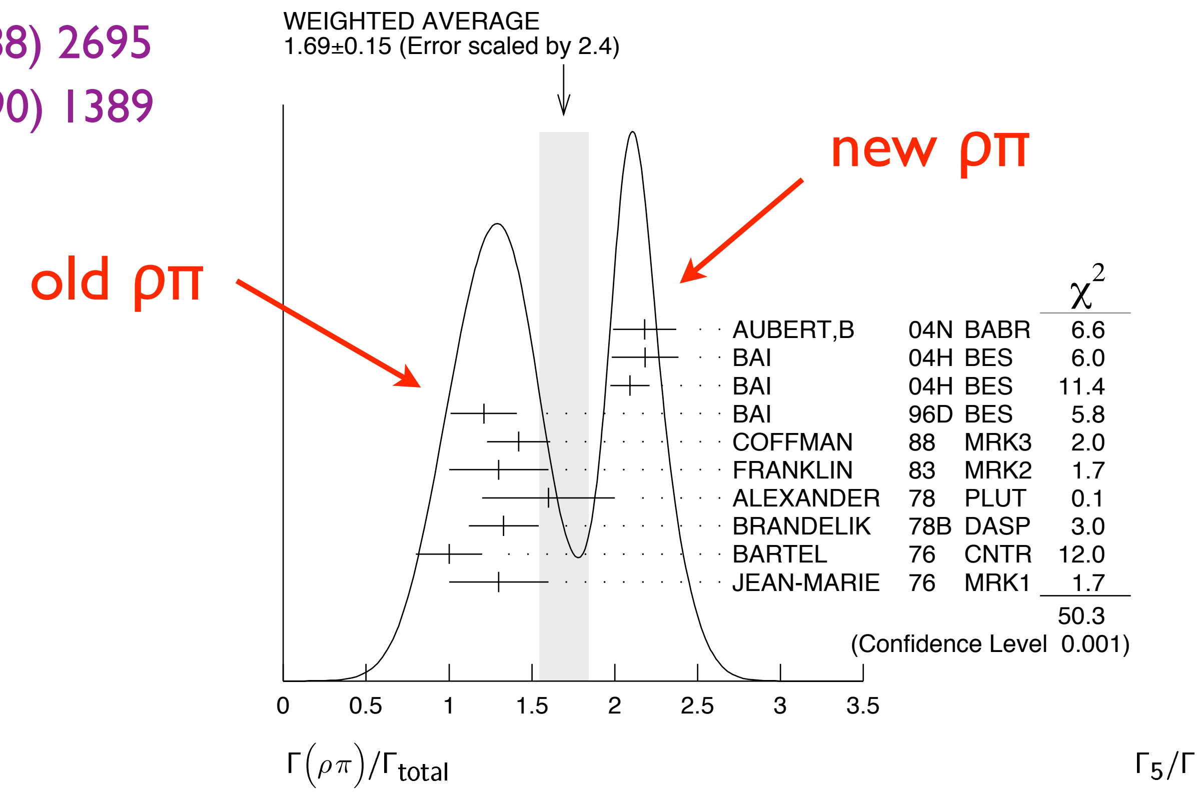


$(\phi_P, Z^2_{\eta'}) = (42.6^\circ, 0.01)$

• $J/\psi \to VP$ analysis

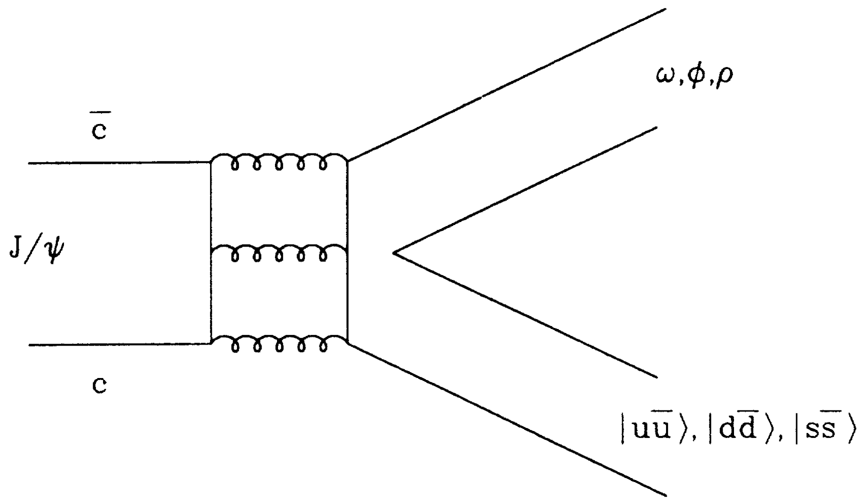
BR×10^{-3}	PDG'97*	PDG'07	
$\rho\pi$	12.8 ± 1.0	16.9±1.5	BABAR Coll., Phys. Rev. D70 (04) 072004 BES Coll., Phys. Rev. D70 (04) 012005
$K^{*+}K^{-}$ + c.c.	5.0 ± 0.4	=	
$K^{*0}\bar{K}^{0}$ + c.c.	4.2 ± 0.4	=	
$\omega\eta$	1.58 ± 0.16	1.74±0.20	BABAR Coll., Phys. Rev. D73 (06) 052003
$\omega\eta'$	0.167 ± 0.025	0.182±0.021	BES Coll., Phys. Rev. D73 (06) 052007
$\phi\eta$	0.65 ± 0.07	0.74±0.08	BES Coll., Phys. Rev. D71 (05) 032003
$\phi\eta'$	0.33 ± 0.04	0.40±0.07	
$\rho\eta$	0.193 ± 0.023	=	
$\rho\eta'$	0.105 ± 0.018	=	
$\omega\pi^0$	0.42 ± 0.06	0.45±0.05	BES Coll., Phys. Rev. D73 (06) 052007
$\phi\pi^0$	< 0.0068	<0.0064 C.L. 90%	BES Coll., Phys. Rev. D71 (05) 032003

*MARK III Coll., Phys. Rev. D38 (88) 2695
DM2 Coll., Phys. Rev. D41 (90) 1389

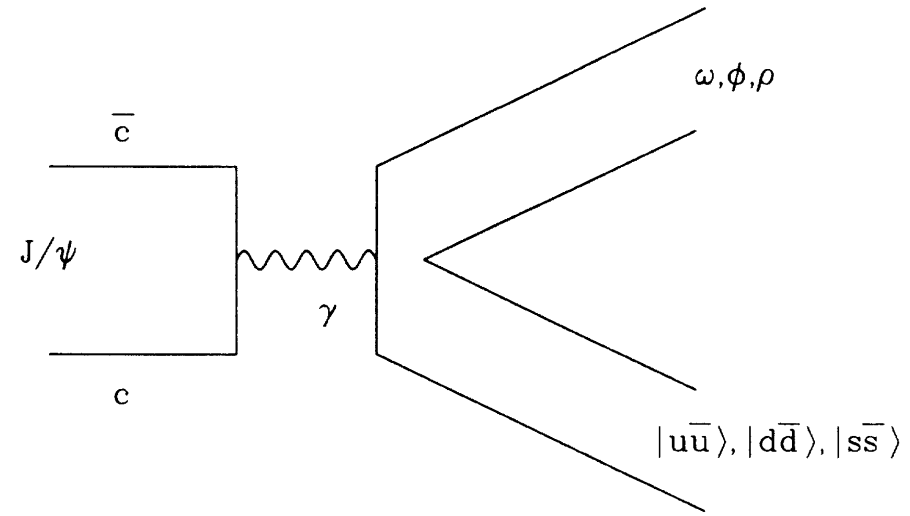


• *A model for J/ψ→VP transitions*

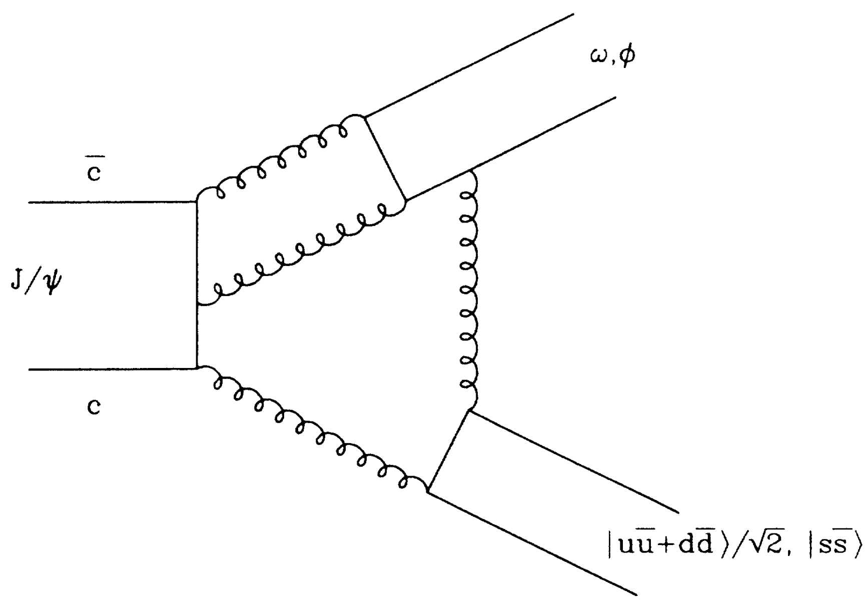
Amplitudes:



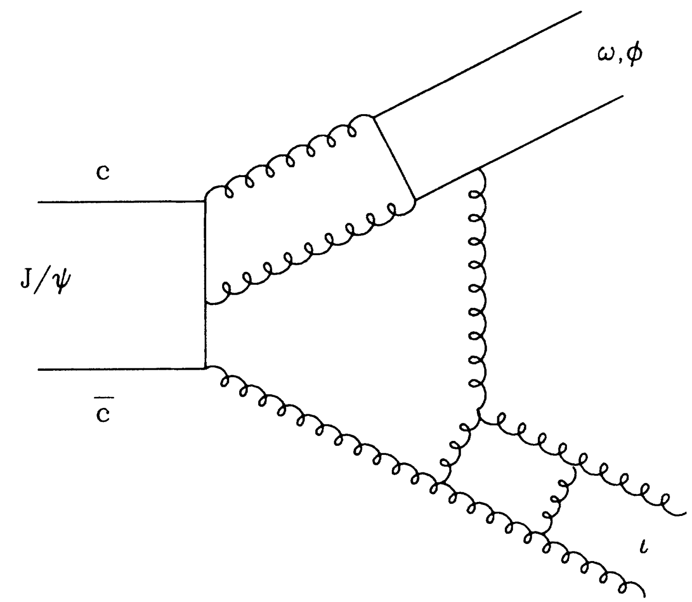
strong singly disconnected (SOZI) ≡ g



electromagnetic singly disconnected (eSOZI) ≡ e



strong doubly disconnected (DOZI) ≡ rg



DOZI for J/ψ→V+Glueball ≡ r'g

• *A model for $J/\psi \to VP$ transitions*

Amplitudes:

TABLE VIII. General parametrization of amplitudes for $J/\psi \to P+V$.

Process	Amplitude
$\rho^+\pi^-, \rho^0\pi^0, \rho^-\pi^+$	$g+e$
$K^{*+}K^-, K^{*-}K^+$	$g(1-s)+e(1+s_e)$
$K^{*0}\bar{K}^0, \bar{K}^{*0}K^0$	$g(1-s)-e(2-s_e)$
$\omega\eta$	$(g+e)X_\eta+\sqrt{2}rg[\sqrt{2}X_\eta+(1-s_p)Y_\eta]+\sqrt{2}r'gZ_\eta$
$\omega\eta'$	$(g+e)X_{\eta'}+\sqrt{2}rg[\sqrt{2}X_{\eta'}+(1-s_p)Y_{\eta'}]+\sqrt{2}r'gZ_{\eta'}$
$\phi\eta$	$[g(1-2s)-2e(1-s_e)]Y_\eta+rg(1-s_v)[\sqrt{2}X_\eta+(1-s_p)Y_\eta]+r'g(1-s_v)Z_\eta$
$\phi\eta'$	$[g(1-2s)-2e(1-s_e)]Y_{\eta'}+rg(1-s_v)[\sqrt{2}X_{\eta'}+(1-s_p)Y_{\eta'}]+r'g(1-s_v)Z_{\eta'}$
$\rho^0\eta$	$3eX_\eta$
$\rho^0\eta'$	$3eX_{\eta'}$
$\omega\pi^0$	$3e$
$\phi\pi^0$	0

A. Seiden *et al.*, Phys. Rev. D38 (1988) 824

s, s_e, s_p and s_v are SU(3)-breaking parameters

Simplifications of our analysis:

i) second order SU(3)-breaking contributions s_p and s_v are neglected

ii) $x \equiv 1-s_e = m/m_s$ with $m_s/m = 1.24 \pm 0.07$ and $\phi_V = (3.2 \pm 0.1)^\circ$

iii) $Z_\eta = 0$ from $V \to P\gamma$ and $P \to V\gamma$ decays
R. E. and J. Nadal, JHEP 05 (2007) 6

• *Results*

R. E., arXiv:0807.4201 [hep-ph]

a) gluonium not allowed for η' → $Z_{\eta'}=0$

i) $x=1$ and $\phi_V=0°$ → $\chi^2/\text{d.o.f.}=3.4/4$ with $\phi_P=(40.2\pm2.4)°$

ii) $x=0.81\pm0.05$ and $\phi_V=(3.2\pm0.1)°$ → $\chi^2/\text{d.o.f.}=4.2/4$ with $\phi_P=(40.5\pm2.4)°$

with $s=(29\pm3)\%$ and $|r|=(37\pm1)\%$ in i)

b) gluonium allowed for η' → $Z_{\eta'}\neq0$

i) $x=1$ and $\phi_V=0°$ → $\chi^2/\text{d.o.f.}=1.9/2$ with $\phi_P=(45.0\pm4.3)°$ and $(Z_{\eta'})^2=0.30+0.15-0.38$

ii) as before → $\chi^2/\text{d.o.f.}=3.0/2$ with $\phi_P=(44.5\pm4.3)°$ and $(Z_{\eta'})^2=0.28+0.16-0.44$

with $s=(27\pm3)\%$, $|r|=(36\pm8)\%$ and $|r'|=(12\pm22)\%$ in i)

Remarks:

- the effect of second order SU(3)-breaking contributions s_P and s_V is negligible
- the same fits with the pion modes removed are slightly better
- the same fits with the old data are worse, $\chi^2/\text{d.o.f.}=7.3/4$ vs. $\chi^2/\text{d.o.f.}=3.4/4$ for instance

• *Summary of the $V \to P\gamma$ analysis and conclusions*

We have performed a phenomenological analysis of radiative $V \to P\gamma$ and $P \to V\gamma$ decays with the purpose of determining the gluon content of the η and η' mesons

1) The current experimental data on $VP\gamma$ transitions indicate within our model a negligible gluonic content for the η and η' mesons,

$$Z_\eta^2 = 0.00 \pm 0.12 \quad \text{and} \quad Z_{\eta'}^2 = 0.04 \pm 0.09$$

2) Accepting the absence of gluonium for the η meson, the gluonic content of the η' wave function amounts to $|\phi_{\eta' G}|=(12\pm13)^\circ$ or $(Z_{\eta'})^2=0.04\pm0.09$ and the η-η' mixing angle is found to be $\phi_P=(41.4\pm1.3)^\circ$

3) The use of these different overlapping parameters (a specific feature of our analysis) is shown to be of primary importance in order to reach a good agreement

4) The latest experimental data on $(\rho,\omega,\phi) \to \eta\gamma$ and $\phi \to \eta'\gamma$ decays confirm the null gluonic content of the η and η' wave functions

5) More refined experimental data, particularly for the $\phi \to \eta'\gamma$ channel, will contribute decisively to clarify this issue

• *Summary of the $J/\psi \to VP$ analysis and conclusions*

We have performed an updated phenomenological analysis of an accurate and exhaustive set of $J/\psi \to VP$ decays with the purpose of determining the quark and gluon content of the η and η' mesons

1) The current experimental data on $J/\psi \to VP$ decays are described in terms of one mixing angle in a consistent way

2) Accepting the absence of gluonium for the η' meson, the η-η' mixing angle is found to be $\phi_P=(40.2\pm2.4)^\circ$ or $\theta_P=(-14.5\pm2.4)^\circ$, in agreement with recent phenomenological estimates

3) The values found for $(Z_{\eta'})^2=0.30+0.15-0.38$ or $\phi_{\eta' G}=(33+10-24)^\circ$ suggest within the model some small gluonic component of the η'

4) The inclusion of the vector mixing angle (not included in previous analyses) is irrelevant

5) The recent values of $BR(J/\psi \to \rho\pi)$ by BABAR and BES Coll. are crucial in order to get a consistent description of data