Measurement of the pseudoscalar mixing angle and η' gluonium content extraction.

Blessing meeting
23/04/2009

B. Di Micco

I.N.F.N sezione di Roma Tre

Outline

- Model description;
- Refit of all relevant measurements;
- Refit using PDG-2008 and KLOE measurement of $\omega \to \pi^0 \gamma$;
- Refit using lattice evaluation of f_K/f_π
- The paper

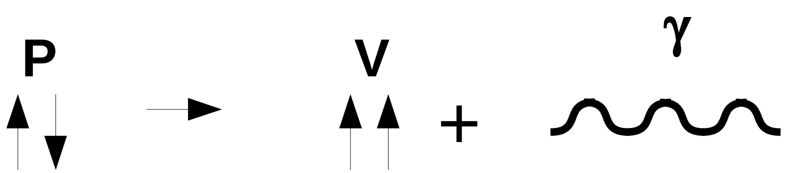
η,η': mixing and gluonium

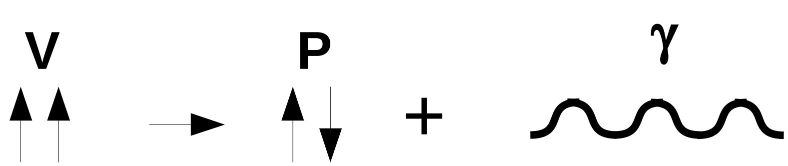
The η,η' mesons wave function can be decomposed in the quark mixing base as in the folowing (J. L. Rosner, Phys. Rev. D 27 (1983) 1101.).

$$|\eta'\rangle = X_{\eta'}|q\bar{q}\rangle + Y_{\eta'}|s\bar{s}\rangle + Z_{\eta'}|G\rangle \qquad |\eta\rangle = \cos\varphi_P|q\bar{q}\rangle - \sin\varphi_P|s\bar{s}\rangle \qquad |q\bar{q}\rangle = \frac{|u\bar{u}\rangle + |d\bar{d}\rangle}{\sqrt{2}}$$

$$X_{\eta'} = \sin\varphi_P \cos\varphi_G$$
$$Y_{\eta'} = \cos\varphi_P \cos\varphi_G$$
$$Z_{\eta'} = \sin\varphi_G$$

The $\phi \rightarrow \eta,\eta'\,\gamma$ transition is modelled according a spin flip transition





$$\Gamma(P \rightarrow V\gamma) = \frac{g^2}{4\pi}|p_\gamma|^3$$

$$\Gamma(V \rightarrow P\gamma) = \frac{1}{3}\frac{g^2}{4\pi}|p_\gamma|^3$$

Only quarks participate to the electromagnetic transition, gluonium is spectator.
It appears in the η' decay amplitudes only through the normalisation to 1 ($Y_{\eta'} \sim \cos\varphi_G$)

Magnetic dipole transition

Decay width:

Quark charge

$$\Gamma(V \to P\gamma) = \frac{2}{3}\alpha\omega^3 \left(\frac{E_P}{m_V}\right) \sum \left|\left\langle V|\frac{\mu_q e_q \sigma_q}{e}|P\right\rangle\right|^2$$

Pauli matrices

example: Matrix element for ρ →ηγ decay

$$|\rho\rangle = \frac{|u\bar{u}> - |d\bar{d}>}{\sqrt{2}}$$

$$\left\langle \rho|\frac{\mu_q e_q \sigma_q}{e}|\eta\right\rangle = \mu cos(\varphi_P)\left(2/3\left\langle u\bar{u}_\rho|u\bar{u}_\eta\right\rangle + 1/3\left\langle d\bar{d}_\rho|d\bar{d}_\eta\right\rangle\right) = \mu cos(\varphi_P)\left\langle q\bar{q}_\rho|q\bar{q}_\eta\right\rangle$$

e/m_q (effective quark mass)

wave function overlapping

$$C_q =< \eta_q|\omega_q >=< \eta_q|\rho > \quad C_s =< \eta_s|\phi_s > \quad C_\pi =< \pi|\omega_q >=< \pi|\rho >$$

In the formulas only the ratios appear: $Z_{NS} = C_q/C_\pi \quad Z_S = C_s/C_\pi$

QCD effects reside in mixing parameters, overlapping parameters and effective quark masses.

V P γ and Pγγ transitions

KLOE [Phys. Lett. B648 (2007) 267] has fitted:

$$\frac{\Gamma(\eta'\to\rho\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{z_q^2}{\cos^2\phi_V}\cdot 3\left(\frac{m_{\eta'}^2-m_\rho^2 m_\omega}{m_\omega^2-m_\pi^2 m_{\eta'}}\right)^3 X_{\eta'}^2$$

$$\frac{\Gamma(\eta'\to\omega\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{1}{3}\left(\frac{m_{\eta'}^2-m_\omega^2 m_\omega}{m_\omega^2-m_\pi^2 m_{\eta'}}\right)^3\left[z_q X_{\eta'}+2\frac{m_s}{\bar{m}}z_s\cdot\tan\phi_V\cdot Y_{\eta'}\right]^2$$

together with the measured branching ratio:

$R_\phi = (4.77 \pm 0.09 \pm 0.19)\times 10^{-3}$

$$R_\phi=\frac{Br(\phi\to\eta'\gamma)}{Br(\phi\to\eta\gamma)}=\cot^2\phi_P\cdot\cos^2\phi_G\left(1-\frac{m_s}{\bar{m}}\frac{z_q}{z_S}\cdot\frac{\tan\phi_V}{\sin 2\phi_P}\right)^2\cdot\left(\frac{p_{\eta'}}{p_\eta}\right)^3$$

and the ratio:

$$\frac{\Gamma(\eta'\to\gamma\gamma)}{\Gamma(\pi^0\to\gamma\gamma)}=\frac{1}{9}\left(\frac{m_{\eta'}}{m_\pi}\right)^3\left(5X_{\eta'}+\sqrt{2}\frac{f_q}{f_s}Y_{\eta'}\right)^2$$

E. Kou, Phys. Rev. D 63 (2001) 54027

V P γ and Pγγ transitions

KLOE [Phys. Lett. B648 (2007) 267] has fitted:

$$\frac{\Gamma(\eta'\to\rho\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{z_q^2}{\cos^2\phi_V}\cdot 3\left(\frac{m_{\eta'}^2-m_\rho^2}{m_\omega^2-m_\pi^2}\frac{m_\omega}{m_{\eta'}}\right)^3 X_{\eta'}^2$$

$$\frac{\Gamma(\eta'\to\omega\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{1}{3}\left(\frac{m_{\eta'}^2-m_\omega^2}{m_\omega^2-m_\pi^2}\frac{m_\omega}{m_{\eta'}}\right)^3\left[z_q X_{\eta'}+2\frac{\bar{m}}{\bar{m}_s}z_s\cdot\tan\phi_V\cdot Y_{\eta'}\right]^2$$

Were taken from a global fit without gluonium:

A. Bramon, R. Escribano, M.D. Scadron
Phys. Lett. B503 (2001) 271

together with the measured branching ratio:

$R_\phi = (4.77 \pm 0.09 \pm 0.19)\times 10^{-3}$

$$R_\phi=\frac{Br(\phi\to\eta'\gamma)}{Br(\phi\to\eta\gamma)}=\cot^2\phi_P\cdot\cos^2\phi_G\left(1-\frac{\bar{m}}{\bar{m}_s}\frac{z_q}{z_S}\cdot\frac{\tan\phi_V}{\sin 2\phi_P}\right)^2\cdot\left(\frac{p_{\eta'}}{p_\eta}\right)^3$$

and the ratio:

$$\frac{\Gamma(\eta'\to\gamma\gamma)}{\Gamma(\pi^0\to\gamma\gamma)}=\frac{1}{9}\left(\frac{m_{\eta'}}{m_\pi}\right)^3\left(5X_{\eta'}+\sqrt{2}\frac{f_q}{f_s}Y_{\eta'}\right)^2$$

E. Kou, Phys. Rev. D 63 (2001) 54027

Escribano couplings

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

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

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

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

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

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

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

All couplings are proportional to g

Fit redone leaving free all parameters

1) Leave the z's parameter free;
2) Add more constraints (needed to perform the fit with larger number of parameters);
3) Check the contribution from $\eta' \to \gamma\gamma \,/\, \pi^0 \to \gamma\gamma$

Deacy width ratio evaluated from Escribano couplings.

$$\frac{\Gamma(\omega\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{1}{9}\left[Z_q\cos(\phi_p)-2\frac{\bar{m}}{m_s}Z_s\tan(\phi_V)\sin(\phi_p)\right]^2\left(\frac{m_\omega^2-m_\eta^2}{m_\omega^2-m_{\pi^0}^2}\right)^3$$

$$\frac{\Gamma(\rho\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=Z_q^2\frac{\cos^2(\phi_p)}{\cos^2(\phi_V)}\left(\frac{m_\rho^2-m_\eta^2}{m_\omega^2-m_\pi^2}\frac{m_\omega}{m_\rho}\right)^3$$

$$\frac{\Gamma(\phi\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{1}{9}\left[Z_q\tan(\phi_v)\cos(\phi_p)+2\frac{\bar{m}}{m_s}Z_s\sin(\phi_p)\right]^2\left(\frac{m_\phi^2-m_\eta^2}{m_\omega^2-m_\pi^2}\frac{m_\omega}{m_\phi}\right)^3$$

$$\frac{\Gamma(\phi\to\pi^0\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\tan^2\phi_V\cdot\left(\frac{m_\phi^2-m_{\pi^0}^2}{m_\omega^2-m_{\pi^0}^2}\cdot\frac{m_\omega}{m_\phi}\right)^3,\quad \frac{\Gamma(K^{+*}\to K^+\gamma)}{\Gamma(K^{*0}\to K^0\gamma)}=\left(\frac{2\frac{m_s}{\bar{m}}-1}{1+\frac{m_s}{\bar{m}}}\right)^2\cdot\left(\frac{m_{K^{*+}}^2-m_{K^{+0}}^2}{m_{K^{*0}}^2-m_{K^0}^2}\cdot\frac{m_{K^{*0}}}{m_{K^{*+}}}\right)^3$$

Fit procedure.

C. Di Donato,
Kloe memo n. 327

The χ^2 is defined as follows:

$$\chi^2 = \Sigma_{i,j=1,3} \left(y_i - y_i^{th}\right) \times V_{ij}^{-1} \left(y_j - y_j^{th}\right)$$

V_{ij} is the error matrix which is a function of theoretical uncertainties, as well as the experim

$$V_{ij} = [B_{ij} + (A_{ik} \times C_{kl} \times A_{lj}^T)]$$

Experimental covariance matrix

Theoretical parameters covariance matrix

B_{ij} **Full covariance matrix (correlation comes from the constrained fit to η' Br)**

$$; A_{ik} = \begin{pmatrix} \frac{\partial y_1^{th}}{\partial f_s} & \frac{\partial y_1^{th}}{\partial f_q} & \frac{\partial y_1^{th}}{\partial C_{NS}} & \frac{\partial y_1^{th}}{\partial C_S} & \frac{\partial y_1^{th}}{\partial \frac{m_s}{m}} \\ \frac{\partial y_2^{th}}{\partial f_s} & \frac{\partial y_2^{th}}{\partial f_q} & \frac{\partial y_2^{th}}{\partial C_{NS}} & \frac{\partial y_2^{th}}{\partial C_S} & \frac{\partial y_2^{th}}{\partial \frac{m_s}{m}} \\ \frac{\partial y_3^{th}}{\partial f_s} & \frac{\partial y_3^{th}}{\partial f_q} & \frac{\partial y_3^{th}}{\partial C_{NS}} & \frac{\partial y_3^{th}}{\partial C_S} & \frac{\partial y_3^{th}}{\partial \frac{m_s}{m}} \end{pmatrix}$$

$$C_{kl} = \begin{pmatrix} \sigma_{f_q}^2 & 0 \\ 0 & \sigma_{f_s}^2 \end{pmatrix}$$

Re-evaluated at each minimization step

The experimental covariance matrix B contains correlation among common used quantities in the fitted relations:

$$\frac{\Gamma(\omega\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)},\frac{\Gamma(\rho\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)},\frac{\Gamma(\phi\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)}$$

→ **Introduces a correlation in the fitted quantities**

$$\frac{\Gamma(\eta'\to\gamma\gamma)}{\Gamma(\pi^0\to\gamma\gamma)}=\frac{Br(\eta'\to\gamma\gamma)\Gamma_{\eta'}}{\Gamma(\pi^0\to\gamma\gamma)}$$

$$\frac{\Gamma(\eta'\to\rho\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{Br(\eta'\to\rho\gamma)\Gamma_{\eta'}}{\Gamma(\omega\to\pi^0\gamma)}$$

	x_1	x_2	x_3	x_4	x_5	x_6
x_2	−34					
x_3	−78	−29				
x_4	−35	−24	32			
x_5	−26	−12	26	8		
x_6	−28	−11	35	11	9	
Γ	32	−2	−24	−5	−88	−8

	Mode	Rate (MeV)		Scale factor
Γ_1	$\pi^+\pi^-\eta$	0.090	±0.008	1.2
Γ_2	$\rho^0\gamma$ (including non-resonant $\pi^+\pi^-\gamma$)	0.060	±0.005	1.2
Γ_3	$\pi^0\pi^0\eta$	0.042	±0.004	1.6
Γ_4	$\omega\gamma$	0.0062	±0.0008	1.2
Γ_5	$\gamma\gamma$	0.00430	±0.00015	1.1
Γ_6	$3\pi^0$	(3.2	±0.6) $\times 10^{-4}$	1.1

Br and Γ strongly correlated (above all $\Gamma(\eta'\to\gamma\gamma)$)

the Γ is measured using:

$$e^+e^-\to\eta' e^+e^-$$

An independent measurement of the η' total width is welcome.

Fit results without $\eta' \to \gamma\gamma$ / $\pi^0 \to \gamma\gamma$

$$\Gamma(P \to V\gamma) = \frac{g^2}{4\pi}|p_\gamma|^3$$

Fit redone a la Escribano

(using couplings and not taking into account correlations)

very similar results

	Fit with width ratios	Escribano *et al.*, JHEP 0705:006 (2007)	Fit with couplings
$\chi^2/n.d.f(Prob)$	1.8/2 (41 %)	4.2/4 (38 %)	4.7/4 (32 %)
Z_G^2	0.03 ± 0.06	0.04 ± 0.09	0.04 ± 0.07
φ_G	$(10 \pm 10)^\circ$	$(12 \pm 13)^\circ$	$(11 \pm 11)^\circ$
φ_P	$(41.6 \pm 0.8)^\circ$	$(41.4 \pm 1.3)^\circ$	$(41.5 \pm 1.1)^\circ$
Z_{NS}	0.85 ± 0.03	0.86 ± 0.03	0.86 ± 0.03
Z_S	0.78 ± 0.05	0.79 ± 0.05	0.78 ± 0.05
φ_V	$(3.16 \pm 0.10)^\circ$	$(3.2 \pm 0.1)^\circ$	$(3.18 \pm 0.10)^\circ$
$m_s/\bar{m}$	1.24 ± 0.07	1.24 ± 0.07	1.24 ± 0.07
Z_K		0.89 ± 0.03	0.89 ± 0.03
g		0.72 ± 0.01	0.72 ± 0.01

disappear in the ratio (Z_K, g)

Table 3: Comparison among the fit results without the $\eta' \to \gamma\gamma/\pi^0 \to \gamma\gamma$ measurement and the Escribano *et al.* results.

Adding the $\eta' \to \gamma\gamma$ / $\pi^0 \to \gamma\gamma$ constraint

	Gluonium allowed	Gluonium at zero
$\chi^2/n.d.f(Prob)$	5/3 (17.5 %)	13/4 (1.1 %)
Z_G^2	0.105 ± 0.037	0 fixed
φ_P	$(40.7 \pm 0.7)^\circ$	$(41.6 \pm 0.5)^\circ$
Z_{NS}	0.866 ± 0.025	0.863 ± 0.024
Z_S	0.79 ± 0.05	0.78 ± 0.05
φ_V	$(3.15 \pm 0.10)^\circ$	$(3.17 \pm 0.10)^\circ$
$m_s/\bar{m}$	1.24 ± 0.07	1.24 ± 0.07

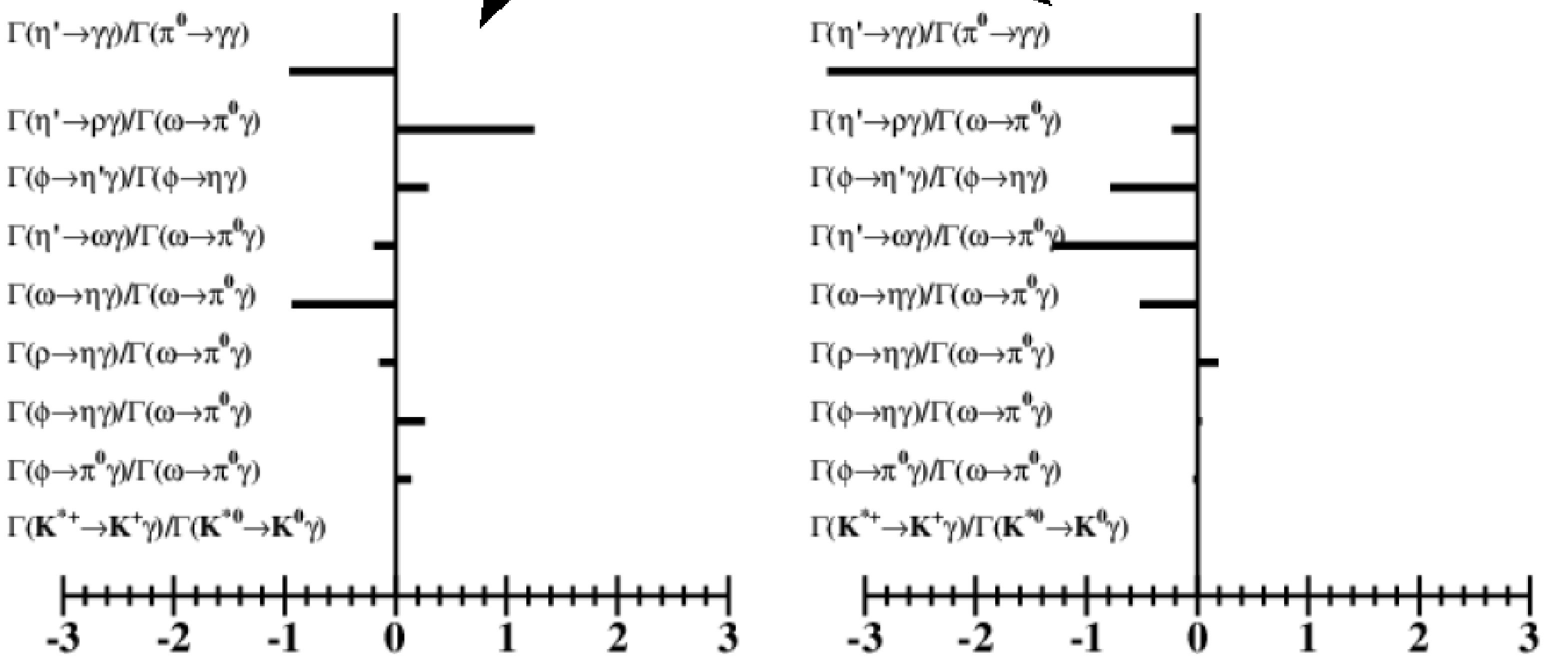
KLOE
(Phys. Lett. B648 (2007) 267

$\phi_P = (39.7 \pm 0.7_{tot})^\circ$

$|\phi_G| = (22 \pm 3)^\circ$

$\sin^2\phi_G = Z^2 = 0.14 \pm 0.04$

Fit pulls



Fit to the couplings with $\eta'\to\gamma\gamma/\pi^0\to\gamma\gamma$

$P\to\gamma\gamma$ measurement included as:

$$\frac{\Gamma(\eta'\to\gamma\gamma)}{\Gamma(\pi^0\to\gamma\gamma)}=\frac{1}{9}\left(\frac{m_{\eta'}}{m_\pi}\right)^3\left(5\sin(\phi_P)\cos(\phi_G)+\sqrt{2}\frac{f_q}{f_s}\cos(\phi_P)\cos(\phi_G)\right)^2$$

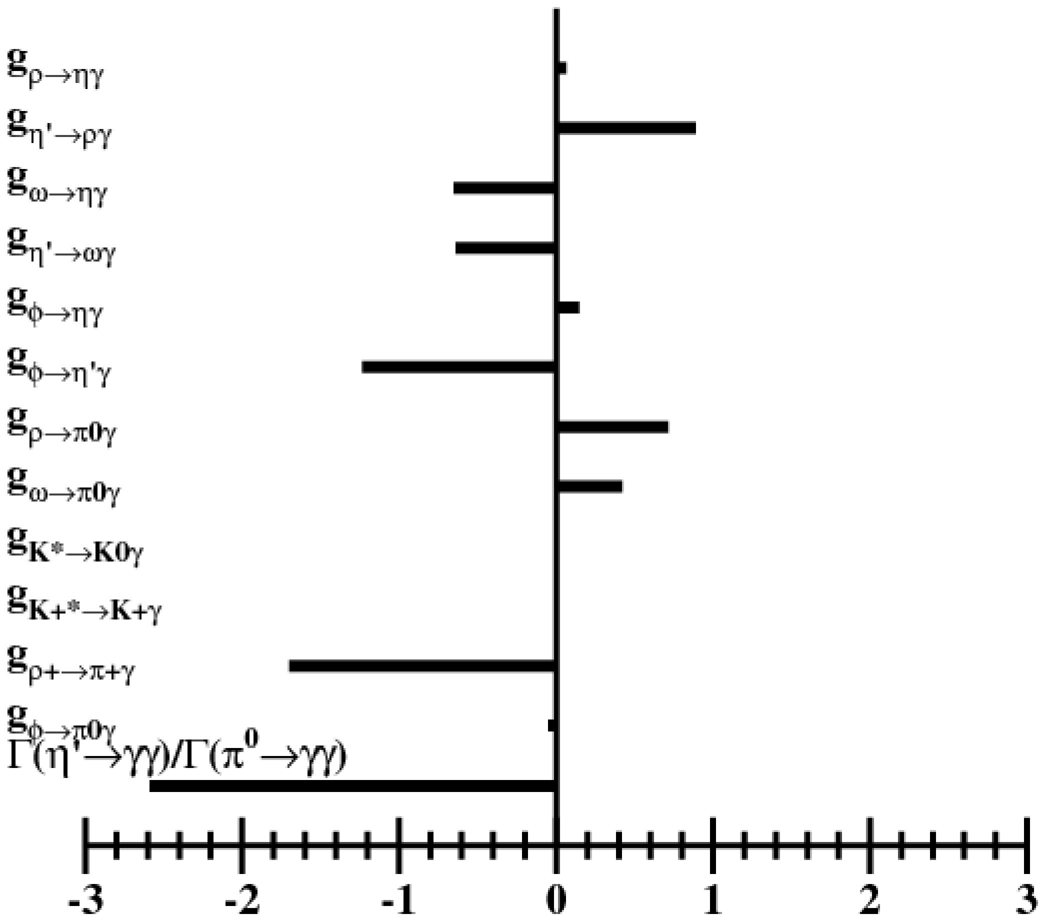
	without glue	**with glue**
	χ^2/ndf = 13/5 (2.3%)	χ^2/ndf = 7.2/4
ϕ_G	fixed at 0	$(20\pm4)^\circ$
ϕ_P	$(40.1 \pm 0.9)^\circ$	$(41.2 \pm 1.1)^\circ$
Z_q	0.85 ± 0.024	0.88 ± 0.03
Z_S	0.80 ± 0.05	0.79 ± 0.05
ϕ_V	$(3.2\pm 0.1)^\circ$	$(3.18 \pm 0.10)^\circ$
$\frac{m_s}{\bar{m}}$	1.24 ± 0.07	1.24 ± 0.07
Z_K	0.89 ± 0.03	0.89 ± 0.03
g	0.72 ± 0.01	0.719 ± 0.010

The gluonium appears also in the fit with couplings.

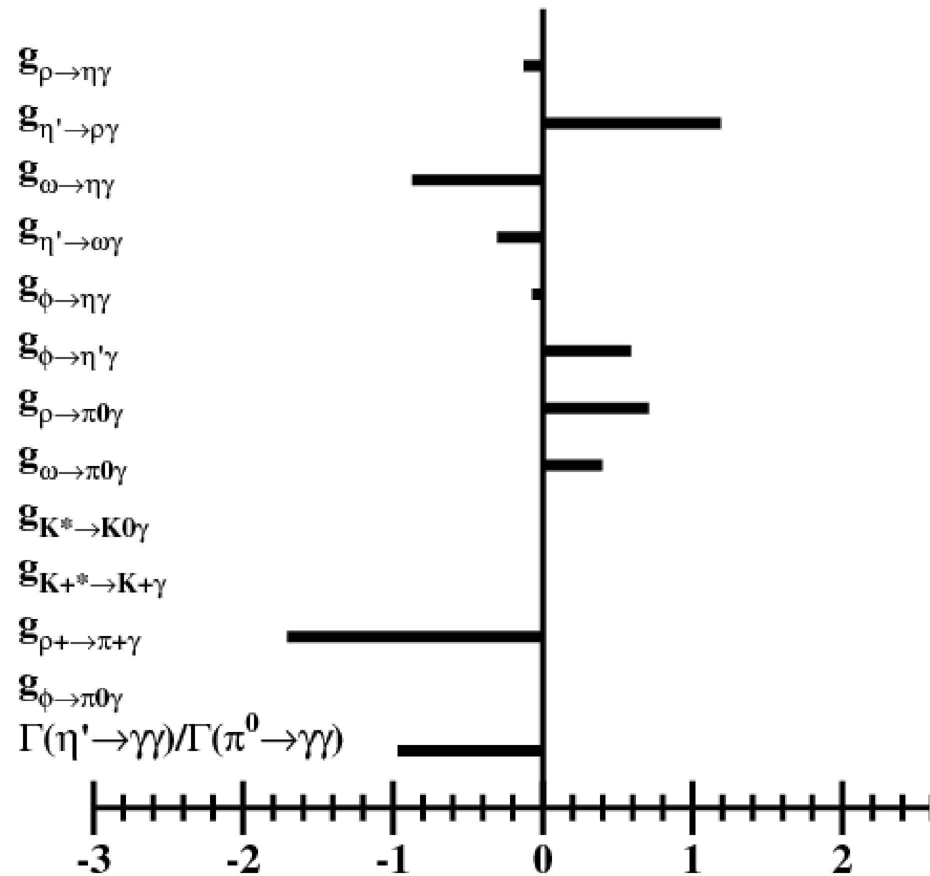
$Z_{\eta'}^2 = 0.11\pm 0.05$

Pulls comparison

without glue



with glue



Update using PDG2008 results

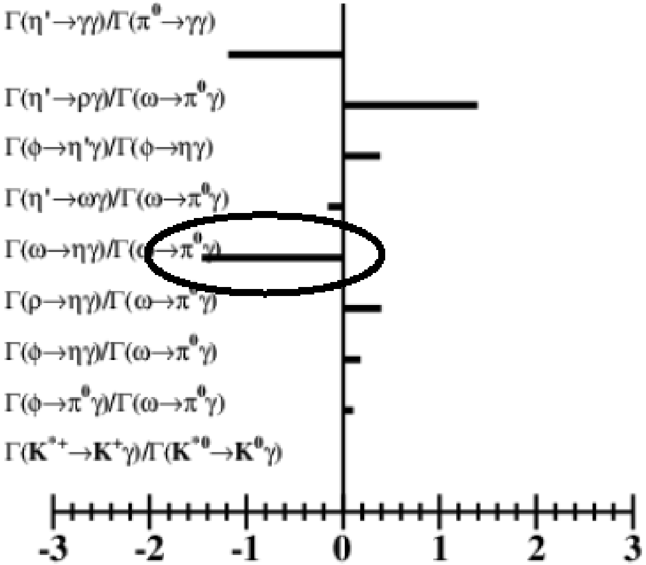
	Gluonium allowed	Gluonium at zero
$\chi^2/n.d.f(Prob)$	$7.9/3$ (5 %)	$15/4$ (5×10^{-3}))
Z_G^2	0.097 ± 0.037	0 fixed
φ_P	$(41.0 \pm 0.7)^\circ$	$(41.7 \pm 0.5)^\circ$
Z_{NS}	0.86 ± 0.02	0.858 ± 0.021
Z_S	0.79 ± 0.05	0.78 ± 0.05
φ_V	$(3.17 \pm 0.09)^\circ$	$(3.19 \pm 0.09)^\circ$
$m_s/\bar{m}$	1.24 ± 0.07	1.24 ± 0.07

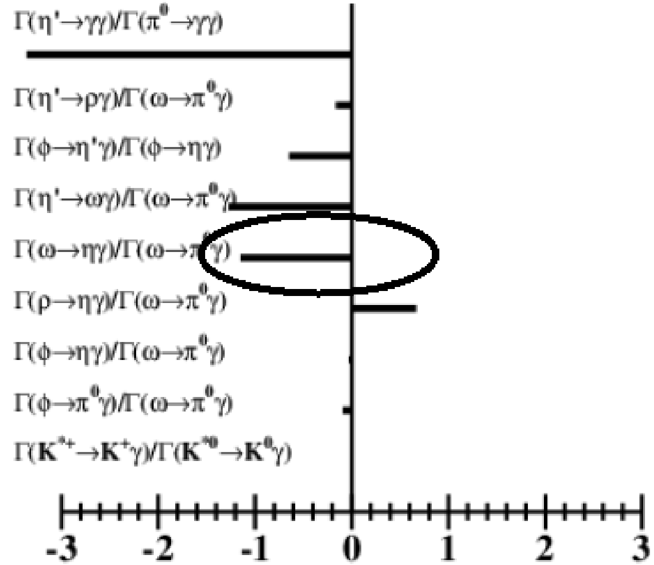
PDG08

The same gluonium content but unsatisfying fit quality.

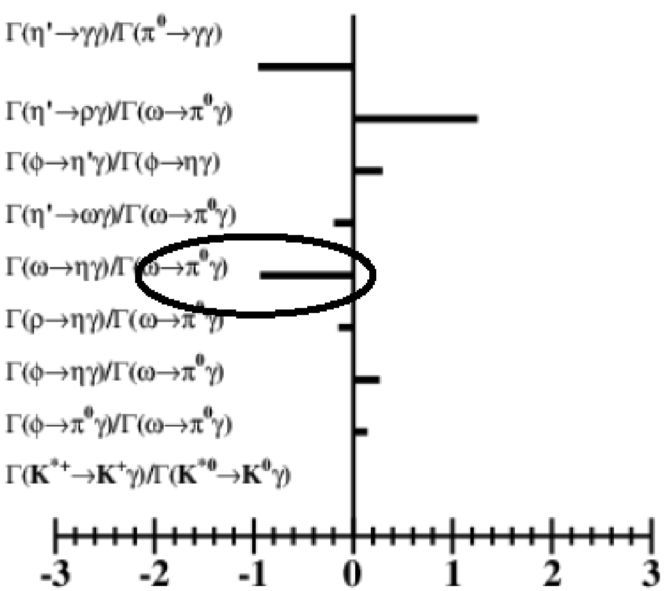
	Gluonium allowed	Gluonium at zero
$\chi^2/n.d.f(Prob)$	$5/3$ (17.5 %)	$13/4$ (1.1 %)
Z_G^2	0.105 ± 0.037	0 fixed
φ_P	$(40.7 \pm 0.7)^\circ$	$(41.6 \pm 0.5)^\circ$
Z_{NS}	0.866 ± 0.025	0.863 ± 0.024
Z_S	0.79 ± 0.05	0.78 ± 0.05
φ_V	$(3.15 \pm 0.10)^\circ$	$(3.17 \pm 0.10)^\circ$
$m_s/\bar{m}$	1.24 ± 0.07	1.24 ± 0.07

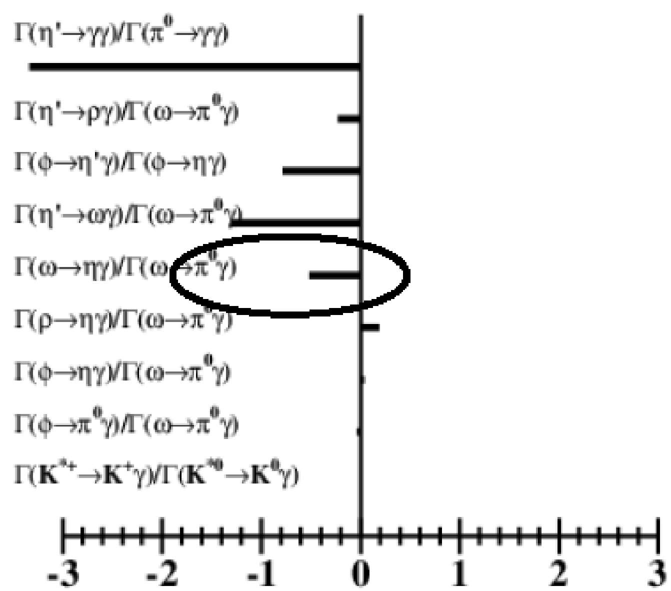
PDG06





PDG08





PDG06

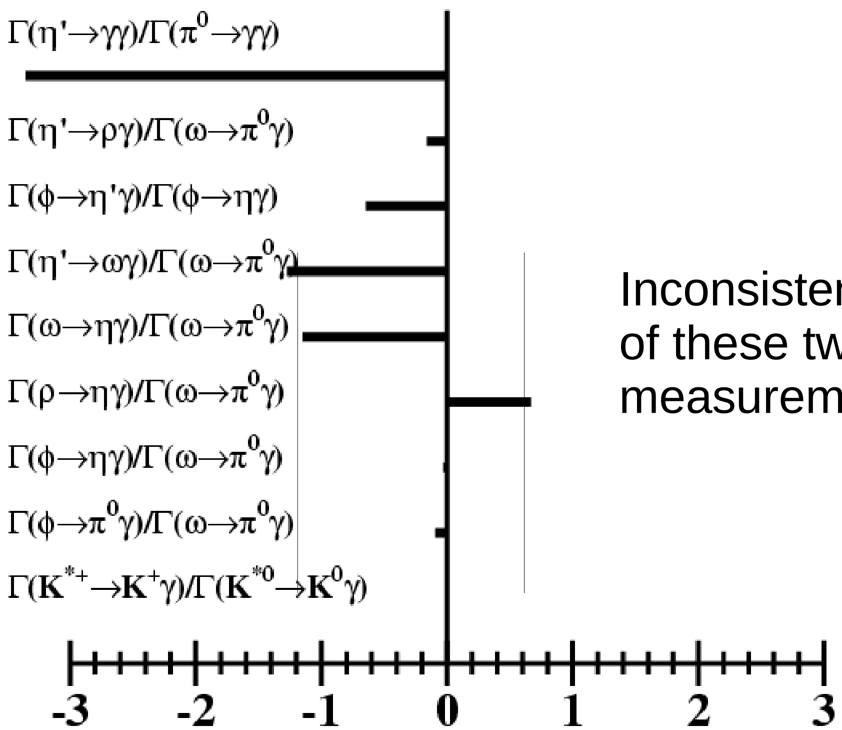
$\omega\to\eta\gamma$ pull has increased in both gluonium hypothesis

Check if the η'→ γγ / π⁰ →γγ introduces any distorstion

$$\frac{\Gamma(\omega\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{1}{9}\left[Z_q\cos(\phi_p)-2\frac{\bar{m}}{m_s}Z_s\tan(\phi_V)\sin(\phi_p)\right]^2\left(\frac{m_\omega^2-m_\eta^2}{m_\omega^2-m_{\pi^0}^2}\right)^3$$

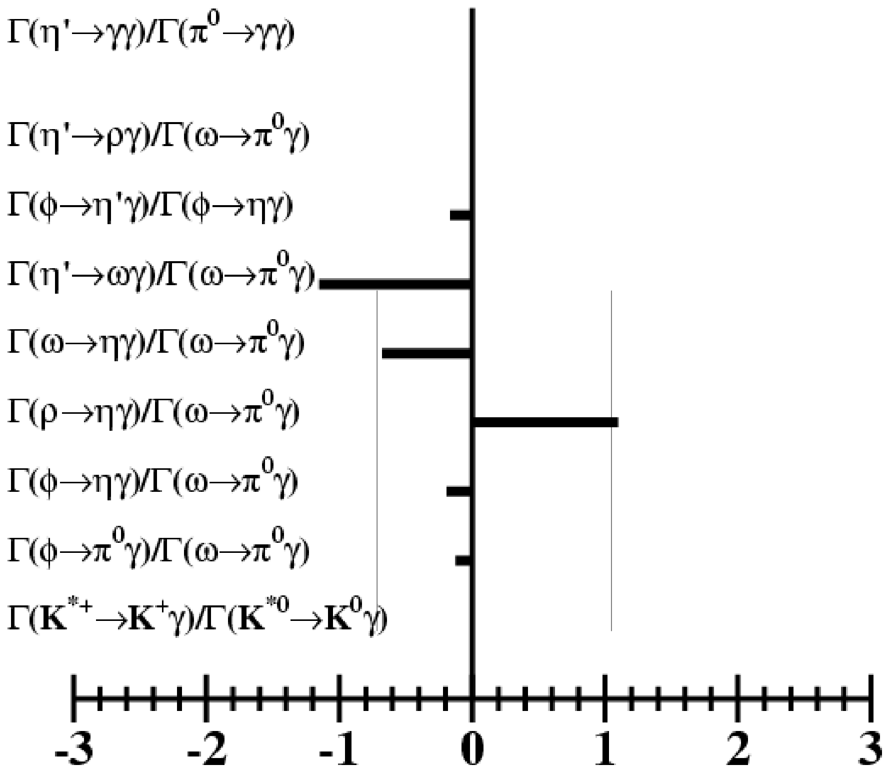
$$\frac{\Gamma(\rho\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=Z_q^2\frac{\cos^2(\phi_p)}{\cos^2(\phi_V)}\left(\frac{m_\rho^2-m_\eta^2}{m_\omega^2-m_\pi^2}\frac{m_\omega}{m_\rho}\right)^3$$

with $\eta'\to\gamma\gamma$ / $\pi^0\to\gamma\gamma$



Inconsistency of these two measurements

without $\eta'\to\gamma\gamma$ / $\pi^0\to\gamma\gamma$



The $\omega \to \eta\gamma$ partial width changed from

$(4.9 \pm 0.5)\times10^{-4}$ to $(4.6 \pm 0.4)\times10^{-4}$

This value is determined by the global PDG fit, and it is mainly determined by:

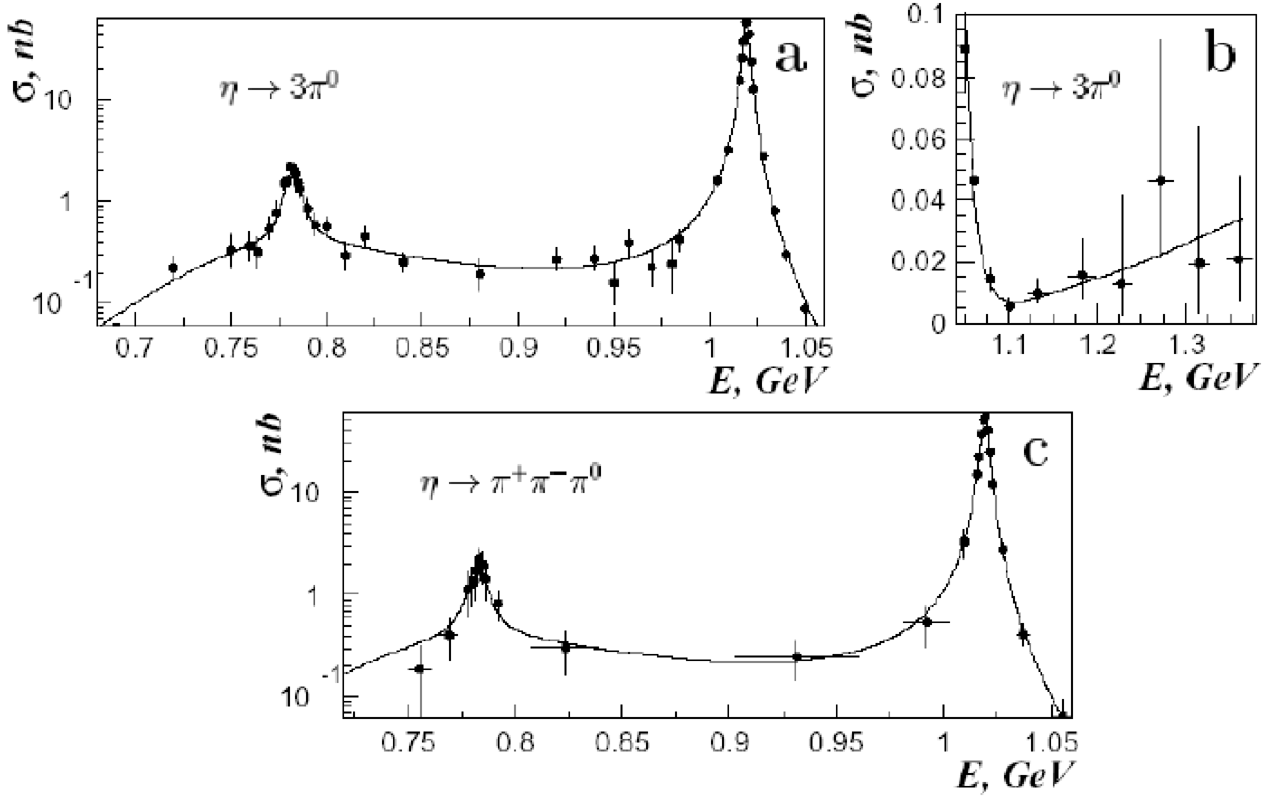
$\Gamma(e^+e^-) \times \Gamma(\eta\gamma)/\Gamma^2_{total}$ $\Gamma_9\Gamma_5/\Gamma^2$

VALUE (units 10^{-8})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.31±0.28 OUR FIT	Error includes scale factor of 1.1.				
3.18±0.28 OUR AVERAGE					
3.10±0.31±0.11	33k	[24] ACHASOV	07B	SND	0.6–1.38 $e^+e^- \to \eta\gamma$
$3.17^{+1.85}_{-1.31}\pm0.21$	17.4k	[25] AKHMETSHIN	05	CMD2	0.60-1.38 $e^+e^- \to \eta\gamma$
3.41±0.52±0.21	23k	[26,27] AKHMETSHIN	01B	CMD2	$e^+e^- \to \eta\gamma$

ACHASOV 07B: Phys. Rev. D76 (2007) 077101

$\omega \to \eta\gamma$ branching ratio measurement from SND

The branching ratio is extracted with a global fit to the $e^+e^- \to \eta\gamma$ with a VMD model with $\rho, \omega, \phi, \rho'$ included (ρ' parameters varied to compute systematics and constrained from $e^+e^- \to \eta\rho$).



ω contribution overwhelmed by the $\rho \to \eta\gamma$ contribution
no correlation matrix is given in the paper

The fit is dominated by the SND measurement

$\Gamma(\eta\gamma)/\Gamma_{total}$

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
4.6 ±0.4	**OUR FIT**	Error includes scale factor of 1.1.			
6.3 ±1.3	**OUR AVERAGE**	Error includes scale factor of 1.2.			
6.6 ±1.7		[53] ABELE	97E	CBAR	0.0 $\overline{p}p \to 5\gamma$
8.3 ±2.1		ALDE	93	GAM2	38 $\pi^- p \to \omega n$
3.0 $^{+2.5}_{-1.8}$		[54] ANDREWS	77	CNTR	6.7–10 γ Cu

1.2 σ

In Crystal Barrel the channel $p\overline{p} \to \eta\,\omega$ is used that is 6 times larger than $p\overline{p} \to \eta\,\rho$, the $\omega \to \eta\gamma$ Br was normalized to the $\omega \to \pi^0\gamma$ Br

Using $\omega \to \eta\gamma$ from PDG average

Giorgio request

	Gluonium allowed	Gluonium at zero	Gluonium allowed (no $P \to \gamma\gamma$ constraint)
$\chi^2/n.d.f(Prob)$	3.9/3 (27.5 %)	13/4 (1.1 %)	2.07 /2 (35 %)
Z_G^2	0.111 ± 0.036	0 fixed	0.06 ± 0.05
φ_P	$(40.6 \pm 0.7)°$	$(41.5 \pm 0.5)°$	$(41.2 \pm 0.8)°$
Z_{NS}	0.890 ± 0.025	0.882 ± 0.023	0.88 ± 0.03
Z_S	0.79 ± 0.05	0.78 ± 0.05	0.78 ± 0.05
φ_V	$(3.15 \pm 0.10)°$	$(3.18 \pm 0.09)°$	$(3.17 \pm 0.09)°$
$m_s/\bar{m}$	1.24 ± 0.07	1.24 ± 0.07	1.24 ± 0.07

Results using KLOE Br($\omega\rightarrow \pi^0 \gamma$)

KLOE Br($\omega\rightarrow \pi^0 \gamma$) = 8.09 ± 0.14 %

PDG08 = 8.92 ± 0.24 %

3σ away

$\omega\rightarrow \eta\gamma$ from PDG average

	Gluonium allowed	Gluonium at zero
$\chi^2/n.d.f(Prob)$	4.16/3 (25 %)	13/4 (1.1 %))
Z_G^2	0.109 ± 0.036	0 fixed
φ_P	$(40.5 \pm 0.7)^\circ$	$(41.4 \pm 0.5)^\circ$
Z_{NS}	0.935 ± 0.025	0.926 ± 0.023
Z_S	0.83 ± 0.05	0.82 ± 0.05
φ_V	$(3.3 \pm 0.09)^\circ$	$(3.3 \pm 0.09)^\circ$
$m_s/\bar{m}$	1.24 ± 0.07	1.24 ± 0.07

No big effect on Z_G but important contribution to $Z_{S,NS}$ and ω–ϕ mixing angle

Referee request: try to find a more robust estimate of f_q and f_s

Estimates used in our previous paper

$$\frac{\Gamma(\eta'\to\gamma\gamma)}{\Gamma(\pi^0\to\gamma\gamma)}=\frac{1}{9}\left(\frac{m_{\eta'}}{m_\pi}\right)^3\left(\frac{f_\pi}{f_q}5\sin(\phi_P)\cos(\phi_G)+\sqrt{2}\frac{f_\pi}{f_s}\cos(\phi_P)\cos(\phi_G)\right)^2$$

T. Feldmann, Int. J. Mod. Phys. A 15 (2000) 159

source	f_q/f_π	f_s/f_π	ϕ_q	ϕ_s
Mass matrix and radiative decays[16,17]	[1.0]	[1.4]	44°	
$U(1)_A$ anomaly & meson masses[18]	1.0	1.4	[42°]	
Phenomenology[2,19,20,21]	[1.1 – 1.2]	[1.1 – 1.3]	[28°-34°]	[35°-41°]
NJL quark model & phenom.[22]	[1.07]	[1.36]	[44.1°]	[40.6°]
Current mixing model & phenom.[43]	[0.98]	[0.66]	[35.9°]	[26.2°]
Phenomenology[23]	[1.00]	[1.45]	39.2°	
GMO mass formula[42]	[1.13]	[1.16]	[31.2°]	[35.4°]
χPT & $1/N_C$ expansion & phenom.[24]	[1.08]	[1.43]	[44.8°]	[40.5°]
FKS scheme & theory[26]	1.00	1.41	42.4°	
FKS scheme & phenom.[26]	1.07	1.34	39.3°	
Vector meson dominance & phenom.[44]	[1.09]	[1.55]	[47.5°]	[42.1°]
Energy dependent scheme & phenom.[45]	[1.10]	[1.46]	[38.9°]	[41.0°]

Better to avoid phenomenological calculations.

Value used up to now, 1% error assumed. Reasonable if compared to $U(1)_A$ anomaly and meson masses.

Alternative approach

E. Kou, Phys. Rev. D 63 (2001) 54027

Isospin conservation implies:

$$if_q p^\mu = \left\langle 0 \left| \bar{\psi} \gamma^\mu \gamma^5 \psi \right| \frac{u\bar{u}+d\bar{d}}{\sqrt{2}} \right\rangle \qquad if_\pi p^\mu = \left\langle 0 \left| \bar{\psi} \gamma^\mu \gamma^5 \psi \right| \frac{u\bar{u}-d\bar{d}}{\sqrt{2}} \right\rangle$$

$$f_q = f_\pi; \qquad f_s = \sqrt{f_K^2 - f_\pi^2}$$

$f_q / f_\pi = 1$ **with no error**

$$\frac{f_s}{f_\pi} = \sqrt{2\frac{f_K^2}{f_\pi^2} - 1}$$

$f_K/f_\pi = 1.189(7)$

Lattice-UKQCD:

Follana et al., Phys. Rev. Lett. 100 (2008) 062002

$$\boxed{\frac{f_s}{f_\pi} = 1.352 \pm 0.007}$$

0.5% error
but 4% difference with our previous value.

Fit with new values for f_q and f_s

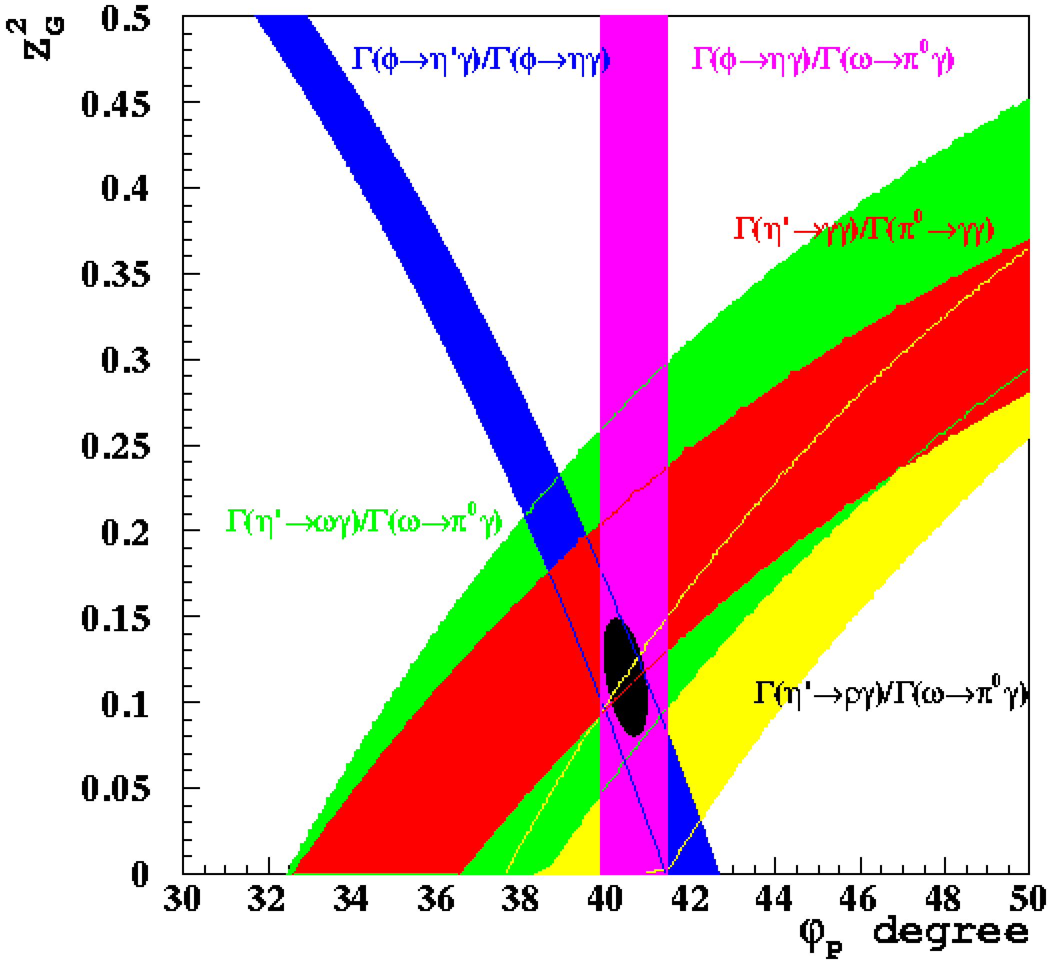
	Gluonium allowed	Gluonium at zero
$\chi^2/n.d.f(Prob)$	4.6/3 (20.5 %)	14.7/4 (.5 %)
Z_G^2	0.115 ± 0.036	0 fixed
φ_P	$(40.4 \pm 0.6)^\circ$	$(41.4 \pm 0.5)^\circ$
Z_{NS}	0.936 ± 0.025	0.927 ± 0.023
Z_S	0.83 ± 0.05	0.82 ± 0.05
φ_V	$(3.32 \pm 0.09)^\circ$	$(3.34 \pm 0.09)^\circ$
$m_s/\bar{m}$	1.24 ± 0.07	1.24 ± 0.07

5% difference in the gluonium content

Fit with old values for f_q and f_s

	Gluonium allowed	Gluonium at zero
$\chi^2/n.d.f(Prob)$	4.16/3 (25 %)	13/4 (1.1 %))
Z_G^2	0.109 ± 0.036	0 fixed
φ_P	$(40.5 \pm 0.7)^\circ$	$(41.4 \pm 0.5)^\circ$
Z_{NS}	0.935 ± 0.025	0.926 ± 0.023
Z_S	0.83 ± 0.05	0.82 ± 0.05
φ_V	$(3.3 \pm 0.09)^\circ$	$(3.3 \pm 0.09)^\circ$
$m_s/\bar{m}$	1.24 ± 0.07	1.24 ± 0.07

Measurements contributions



What to put in the paper?

In order to use the same experimental informations, but using our way we normalise all quantities to $\Gamma(\omega \to \pi^0\gamma)$.

In this way the fit is independent from the coupling **g.**

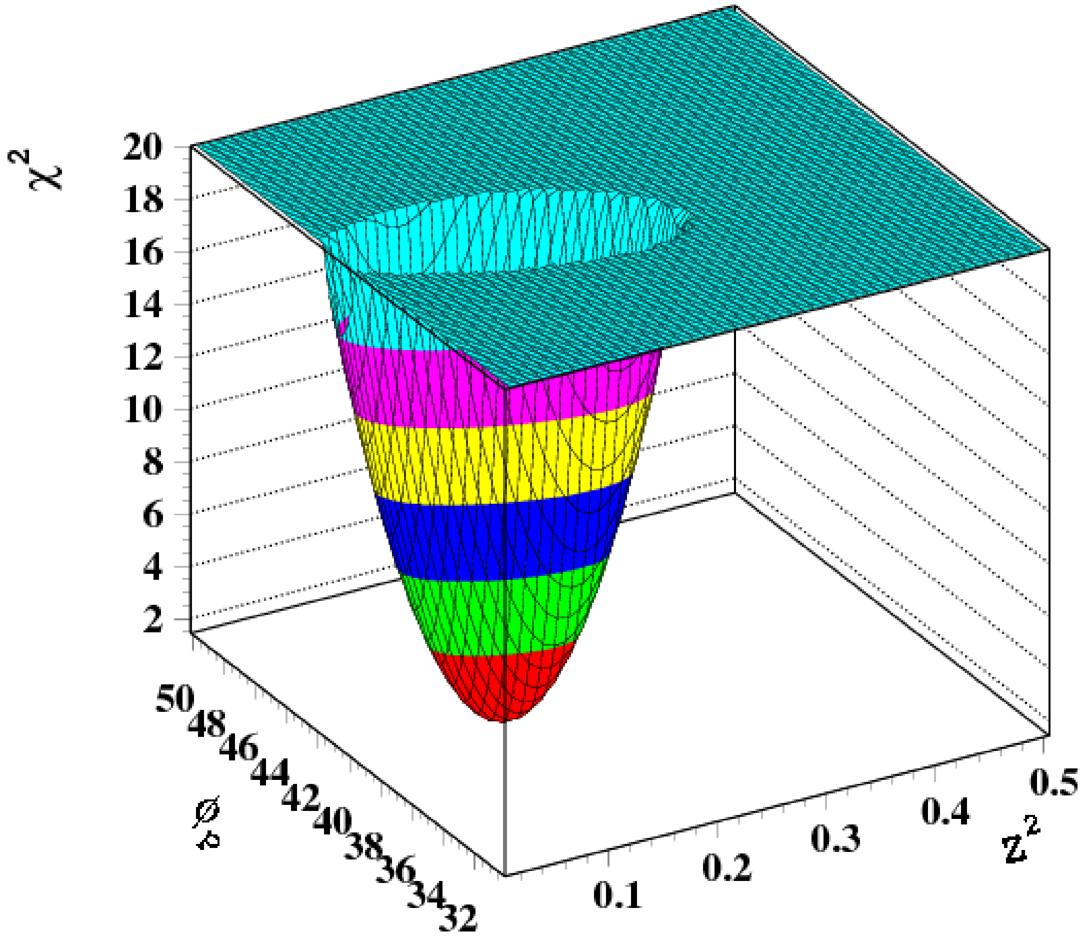
Discrepancy between our definition of $\Gamma(\eta' \to \rho\gamma)/\Gamma(\omega \to \pi^0\gamma)$ and Escribano definition of g's

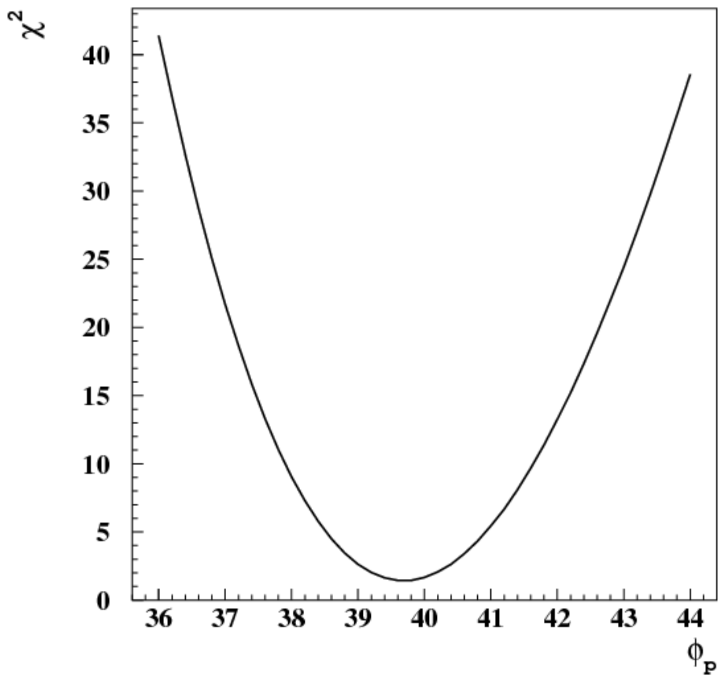
$$\frac{\Gamma(\eta' \to \rho\gamma)}{\Gamma(\omega \to \pi^0\gamma)} = \frac{\frac{g^2_{\eta' \to \rho\gamma}}{4\pi}|p^{\eta'}_{\gamma}|^3}{\frac{g^2_{\omega \to \pi^0\gamma}}{12\pi}|p^{\omega}_{\gamma}|^3} = 3\frac{|p^{\eta'}_{\gamma}|^3}{|p^{\omega}_{\gamma}|^3}\frac{g^2 Z_q^2 X_{\eta'}^2}{g^2 \cos^2\phi_V} = 3\frac{|p^{\eta'}_{\gamma}|^3}{|p^{\omega}_{\gamma}|^3}\frac{Z_q^2}{\cos^2\phi_V}\sin^2\phi_P \cos^2\phi_G$$

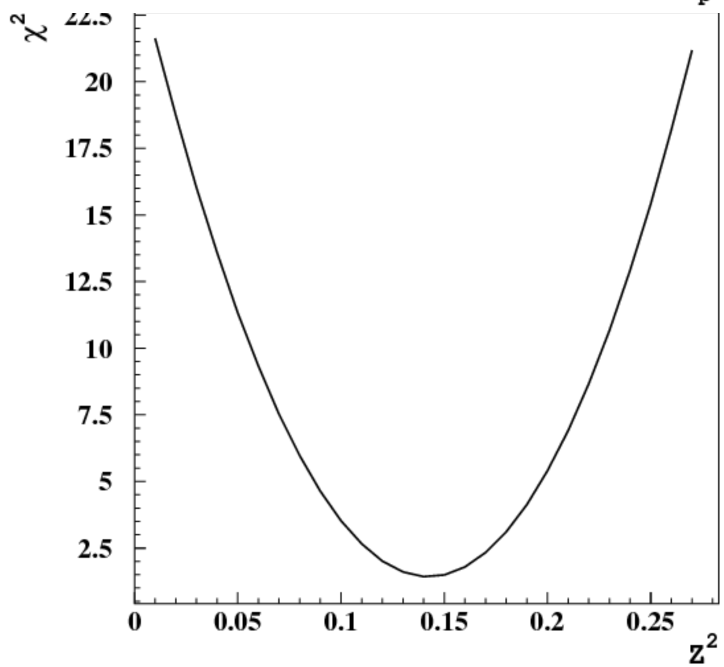
while in our paper:

$$\Gamma(\eta' \to \rho\gamma)/\Gamma\left(\omega \to \pi^0\gamma\right) = \frac{C_{NS}}{\cos\varphi_V} \cdot 3\left(\frac{m^2_{\eta'} - m^2_{\rho}}{m^2_{\omega} - m^2_{\pi}}\frac{m_{\omega}}{m_{\eta'}}\right)^3 \cos^2\phi_G \sin^2\varphi_P$$

Check of the χ^2 behaviour







Only one minimum in the whole parameters' domain.

Check of the Escribano hypothesis

Fit redone using Escribano fit parameters:
$C_{NS} = 0.86 \pm 0.03$ $C_S = 0.78 \pm 0.05$

	Fit	**Paper**
z^2	0.12 ± 0.03	0.14 ± 0.04
ϕ_p	$(40.0 \pm 0.7)^\circ$	$(39.7 \pm 0.7)^\circ$

The fit is very stable respect to the overlapping parameters

Differences between Escribano and our fit

Our fit | **Escribano**

Differences between Escribano and our fit

Our fit

Only ϕ_p and Z^2 are left free

Escribano

All theoretical parameters are left free

Differences between Escribano and our fit

Our fit

Only ϕ_p and Z^2 are left free

The ratios of Γ's are used in the fit.

Escribano

All theoretical parameters are left free

The Γ's are used in the fit.

Differences between Escribano and our fit

Our fit	Escribano
Only ϕ_p and Z^2 are left free	All theoretical parameters are left free
The ratios of Γ's are used in the fit.	The Γ's are used in the fit.
4 measured quantities are used in the fit	11 measured quantities are used in the fit

Differences between Escribano and our fit

Our fit	Escribano
Only ϕ_p and Z^2 are left free	All theoretical parameters are left free
The ratios of Γ's are used in the fit.	The Γ's are used in the fit.
4 measured quantities are used in the fit	11 measured quantities are used in the fit
DATA from PDG '06 + KLOE R_ϕ '07	DATA from PDG '06

Escribano amplitudes

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

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

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

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

$z_q = C_{NS}$

$z_s = C_s$

Constrain

ϕ_p, Z_G

Escribano amplitudes

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

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

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

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

$Z_q = C_{NS}$

$Z_s = C_s$

Constrain ϕ_p, Z_G

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

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

Fix the parameters $m_s/\bar{m}$, ϕ_V, g

Escribano amplitudes

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

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

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

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

$z_q = C_{NS}$

$z_s = C_s$

Constrain ϕ_p, Z_G

tan ϕ_V << 1 (ϕ_V = 3.2°)

$$R_\phi = \frac{Br(\phi\to\eta'\gamma)}{Br(\phi\to\eta\gamma)} = \cot^2\phi_P \cdot \cos^2\phi_G \left(1 - \frac{m_s}{\bar{m}} \frac{C_{NS}}{C_S} \cdot \tan\frac{\phi_V}{\sin 2\phi_P}\right)^2 \cdot \left(\frac{p_{\eta'}}{p_\eta}\right)^3$$

Escribano amplitudes

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

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

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

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

$z_q = C_{NS}$

$z_s = C_s$

Constrain ϕ_p, Z_G

$\tan\phi_V << 1$ ($\phi_V = 3.2°$)

$$R_\phi = \frac{Br(\phi \to \eta'\gamma)}{Br(\phi \to \eta\gamma)} = \cot^2\phi_P \cdot \cos^2\phi_G \left(1 - \frac{m_s}{\bar{m}} \frac{C_{NS}}{C_S} \cdot \tan\frac{\phi_V}{\sin 2\phi_P} \right)^2 \cdot \left(\frac{p_{\eta'}}{p_\eta} \right)^3$$

Contains terms up to $\tan^2\phi_V$, but it is not $o(\tan^2\phi_V)$

Escribano amplitudes

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

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

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

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

$z_q = C_{NS}$
$z_s = C_s$

Constrain ϕ_p, Z_G

$\tan\phi_V \ll 1$ ($\phi_V = 3.2°$)

$$R_\phi = \frac{Br(\phi\to\eta'\gamma)}{Br(\phi\to\eta\gamma)} = \cot^2\phi_P \cdot \cos^2\phi_G \left(1 - \frac{m_s}{\bar{m}}\frac{C_{NS}}{C_S} \cdot \tan\frac{\phi_V}{\sin 2\phi_P}\right)^2 \cdot \left(\frac{p_{\eta'}}{p_\eta}\right)^3$$

$$+\left(\frac{C_{NS}}{C_S}\frac{m_S}{\bar{m}}\tan\phi_V\right)^2 \left(1 + 2\cos^2\phi_P\right)\left(\frac{p_{\eta'}}{p_\eta}\right)^3 + o\left(\tan^2\phi_V\right)$$

KLOE fit with full formula

$$R_\phi = \frac{Br(\phi \to \eta' \gamma)}{Br(\phi \to \eta \gamma)} = \cot^2 \phi_P \cdot \cos^2 \phi_G \left(1 - \frac{m_s}{\overline{m}} \frac{C_{NS}}{C_S} \cdot \tan \frac{\phi_V}{\sin 2\phi_P} \right)^2 \cdot \left(\frac{p_{\eta'}}{p_\eta} \right)^3$$

$$+ \left(\frac{C_{NS}}{C_S} \frac{m_S}{\overline{m}} \tan \phi_V \right)^2 \left(1 + 2\cos^2 \phi_P \right)$$

	Fit	Paper
z^2	0.14 ± 0.03	0.14 ± 0.04
ϕ_p	$(39.9 \pm 0.7)^\circ$	$(39.7 \pm 0.7)^\circ$

Freeing the overlapping parameters

$$\frac{\Gamma(\eta'\to\gamma\gamma)}{\Gamma(\pi^0\to\gamma\gamma)}=\frac{1}{9}\left(\frac{m_{\eta'}}{m_\pi}\right)^3\left(5\mathrm{X}_{\eta'}+\sqrt{2}\frac{f_q}{f_s}Y_{\eta'}\right)^2$$

$$\frac{\Gamma(\eta'\to\rho\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{C_{NS}}{\cos\phi_V}\cdot 3\left(\frac{m_{\eta'}^2-m_\rho^2\,m_\omega}{m_\omega^2-m_\pi^2\,m_{\eta'}}\right)^3 X_{\eta'}^2$$

$$\frac{\Gamma(\eta'\to\omega\gamma)}{\Gamma(\omega\to\pi^0\gamma)}=\frac{1}{3}\left(\frac{m_{\eta'}^2-m_\omega^2\,m_\omega}{m_\omega^2-m_\pi^2\,m_{\eta'}}\right)^3\left[C_{NS}X_{\eta'}+2\frac{m_s}{\bar{m}}C_s\cdot\tan\phi_V\cdot Y_{\eta'}\right]^2$$

Not enough constraint to leave free C_{NS} and C_S

We add to the fit:

$$\frac{\Gamma(\omega\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)},\frac{\Gamma(\rho\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)},\frac{\Gamma(\phi\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)}$$

Fit result

FCN= 1.406759 FROM MINOS STATUS=SUCCESSFUL 187 CALLS 277 TOTAL
EDM= 0.34E-06 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT PARAMETER			PARABOLIC	MINOS ERRORS	
NO.	NAME	VALUE	ERROR	NEGATIVE	POSITIVE
1	z2	0.11720	0.41464E-01	-0.41484E-01	0.41463E-01
2	PHIP	40.056	0.97108	-0.94271	1.0031
3	CNSP	0.86965	0.31043E-01	-0.31096E-01	0.31044E-01
4	CSPA	0.79071	0.47577E-01	-0.44712E-01	0.50965E-01

	Fit with free C_{NS} C_S	Paper	Escribano
z^2	0.12 ± 0.04	0.14 ± 0.04	$(0.04 \pm 0.09)^{\circ}$
ϕ_p	$(40.1 \pm 1.0)^{\circ}$	$(39.7 \pm 0.7)^{\circ}$	$(41.4 \pm 1.3)^{\circ}$
C_{NS}	0.87 ± 0.03		0.86 ± 0.03
C_S	0.79 ± 0.05		0.78 ± 0.05

Fit result

FCN= 1.406759 FROM MINOS STATUS=SUCCESSFUL 187 CALLS 277 TOTAL

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EXT	PARAMETER		PARABOLIC	MINOS ERRORS	
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4	CSPA	0.79071	0.47577E-01	-0.44712E-01	0.50965E-01

	Fit with free C_{NS} C_S	Paper	Escribano
z^2	0.12 ± 0.04	0.14 ± 0.04	$(0.04 \pm 0.09)^\circ$
ϕ_p	$(40.1 \pm 1.0)^\circ$	$(39.7 \pm 0.7)^\circ$	$(41.4 \pm 1.3)^\circ$
C_{NS}	0.87 ± 0.03		0.86 ± 0.03
C_S	0.79 ± 0.05		0.78 ± 0.05

↔ **Perfect agreement**

Fit results

Gluonium still at 3σ

Fit with free C_{NS} C_S		Paper	Escribano
Z^2	0.12 ± 0.04	0.14 ± 0.04	$(0.04 \pm 0.09)^\circ$
ϕ_p	$(40.1 \pm 1.0)^\circ$	$(39.7 \pm 0.7)^\circ$	$(41.4 \pm 1.3)^\circ$
C_{NS}	0.87 ± 0.03		0.86 ± 0.03
C_S	0.79 ± 0.05		0.78 ± 0.05

Perfect agreement

Fit results

Cl… at 3σ

TO BE CONTINUED

Fit wi… s		Paper	Escribano
Z^2	0.12 ± 0.04	0.14 ± 0.04	$(0.04 \pm 0.09)^\circ$
ϕ_p	$(40.1 \pm 1.0)^\circ$	$(39.7 \pm 0.7)^\circ$	$(41.4 \pm 1.3)^\circ$
C_{NS}	0.87 ± 0.03		0.86 ± 0.03
C_S	0.79 ± 0.05		0.78 ± 0.05

↔ **Perfect agreement**

The $\eta' \to \gamma\gamma/\pi^0 \to \gamma\gamma$ constraint

Removing this constraint we obtain:

Fit with free C_{NS} C_S no $P \to \gamma\gamma$ constraint		Fit with free C_{NS} C_S		Escribano
Z^2	0.09 ± 0.06	Z^2	0.12 ± 0.04	$(0.04 \pm 0.09)^\circ$
ϕ_P	$(40.2 \pm 1.0)^\circ$	ϕ_P	$(40.1 \pm 1.0)^\circ$	$(41.4 \pm 1.3)^\circ$
C_{NS}	0.86 ± 0.03	C_{NS}	0.87 ± 0.03	0.86 ± 0.03
C_S	0.79 ± 0.05	C_S	0.79 ± 0.05	0.78 ± 0.05

The $\eta' \to \gamma\gamma / \pi^0 \to \gamma\gamma$ constraint

Removing this constraint we obtain:

Fit with free C_{NS} C_S no $P\to\gamma\gamma$ constraint		Fit with free C_{NS} C_S		Escribano
z^2	0.09 ± 0.06	z^2	0.12 ± 0.04	$(0.04 \pm 0.09)^\circ$
ϕ_p	$(40.2 \pm 1.0)^\circ$	ϕ_p	$(40.1 \pm 1.0)^\circ$	$(41.4 \pm 1.3)^\circ$
C_{NS}	0.86 ± 0.03	C_{NS}	0.87 ± 0.03	0.86 ± 0.03
C_S	0.79 ± 0.05	C_S	0.79 ± 0.05	0.78 ± 0.05

The $P\to\gamma\gamma$ **constraint is important!! It moves the central value and reduce the error (Here someone is cheating..)**

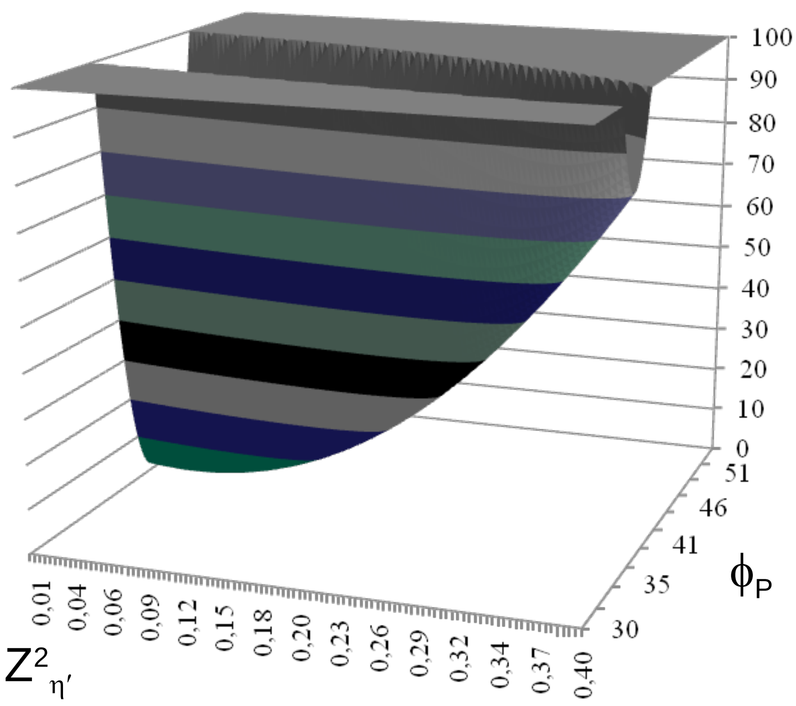
Fitting the Width
(using KLOE and last SND results)

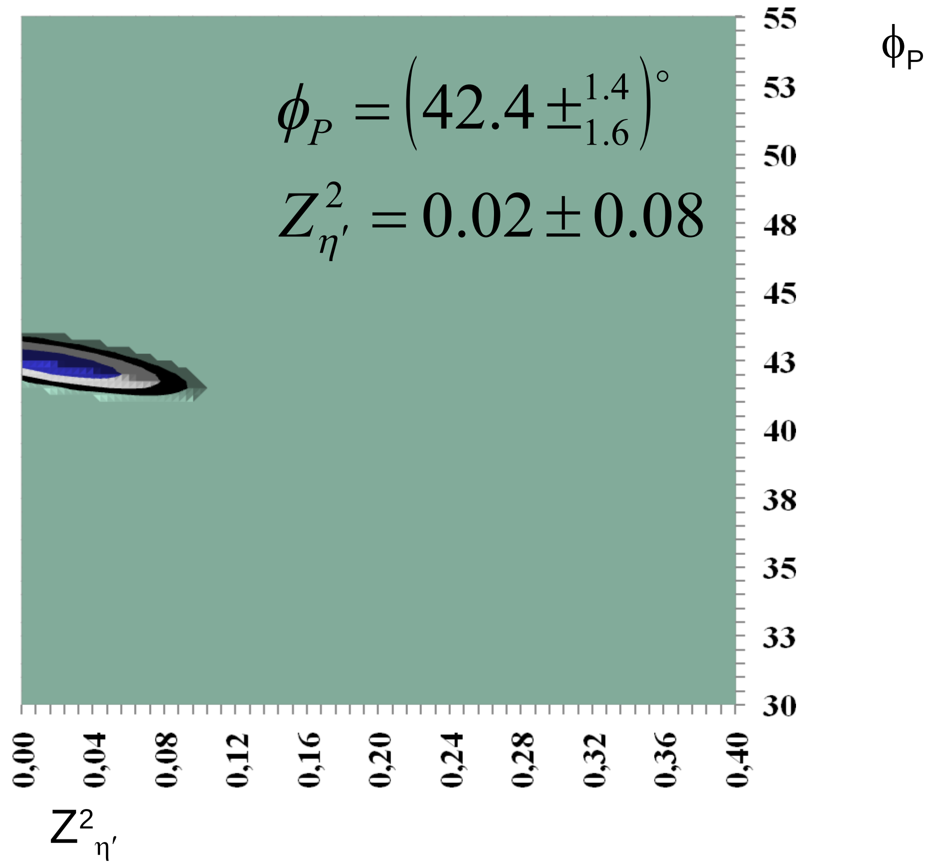
Slide from Camilla

We fit as Escribano - constraints from partial width
with our method - only cosϕ_P, cosϕ_G left free
We find the following results to compare with Rafel's ones

Escribano fit

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





Conclusions and outlook

- All the objections to our paper have been rejected by the check performed;
- To complete the study we have to implement 4 further constraints and fit with all free parameters;

- From the preliminary study we can say:
  - The gluonium is at 3σ whatever we use for the overlapping parameters or include them in the fit;
  - The $P \to \gamma\gamma$ is proved to be an important constraint: increases the gluonium component and reduces the error by 33%
  - The fit to the Γ's looks promising
- We would like to write a short answer to Escribano and Thomas at the end of the work.