On the gluonic admixture in η'

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We analysed nine kinds of experimental data:

[J.L.Rosner Proceeding of Lepton Photon Conference Kyoto (1985)]

η : $\omega \to \eta\gamma$, $\phi \to \eta\gamma$, $\eta \to \gamma\gamma$

η' : $\eta' \to \omega\gamma$, $\eta' \to \rho\gamma$, $\phi \to \eta'\gamma$, $\eta' \to \gamma\gamma$

J/ψ : $J/\psi \to \eta\gamma$, $J/\psi \to \eta'\gamma$

Theoretical tools :

- Vector meson dominance model
- Decay constants for $\eta^{(\prime)}$ defined by the two mixing angle scheme

[Leutwyler hep-ph/9709408 Feldmann, Kroll and Stech Phys. Rev. D58 114006 ('98)]

$$i f_x P^\mu \equiv \langle 0 | \bar{u}\gamma^\mu\gamma_5 u + \bar{d}\gamma^\mu\gamma_5 d | \frac{u\bar{u}+d\bar{d}}{\sqrt{2}} \rangle$$

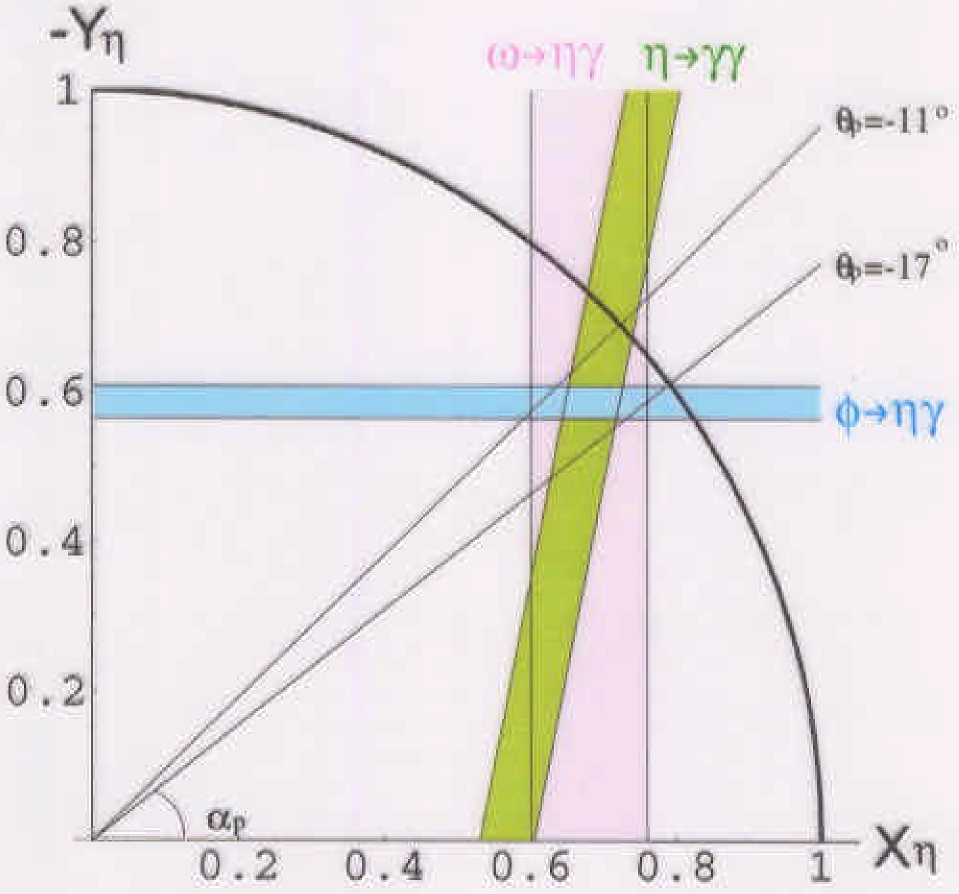
$$i f_y P^\mu \equiv \langle 0 | \bar{s}\gamma^\mu\gamma_5 s | s\bar{s} \rangle$$

$$f_x \simeq f_\pi , \quad f_y = \sqrt{2f_K^2 - f_\pi^2}$$

Result from η Process

$$-17^\circ \lesssim \theta_P \lesssim -11^\circ$$

$$X_\eta^2 + Y_\eta^2 = 1$$



$$\Gamma(\omega\to\eta\gamma) = \frac{\alpha}{24}\left(\frac{m_\omega^2 - m_\eta^2}{m_\omega}\right)^3\left(\frac{m_\omega}{f_\omega \pi^2}\right)^2\left(\frac{X_\eta}{4f_x}\right)^2$$

$$\Gamma(\eta\to\gamma\gamma) = \frac{\alpha^2}{288\pi^3} m_\eta^3\left(\frac{5X_\eta}{f_x} + \frac{\sqrt{2}\,Y_\eta}{f_y}\right)^2$$

$$\Gamma(\phi\to\eta\gamma) = \frac{\alpha}{24}\left(\frac{m_\phi^2 - m_\eta^2}{m_\phi}\right)^3\left(\frac{m_\phi}{f_\phi \pi^2}\right)^2\left(\frac{-2Y_\eta}{4f_y}\right)^2$$

The PDG(98) Averages

$Br(\omega \to \eta\gamma) = (6.5 \pm 1.0) \times 10^{-4}$

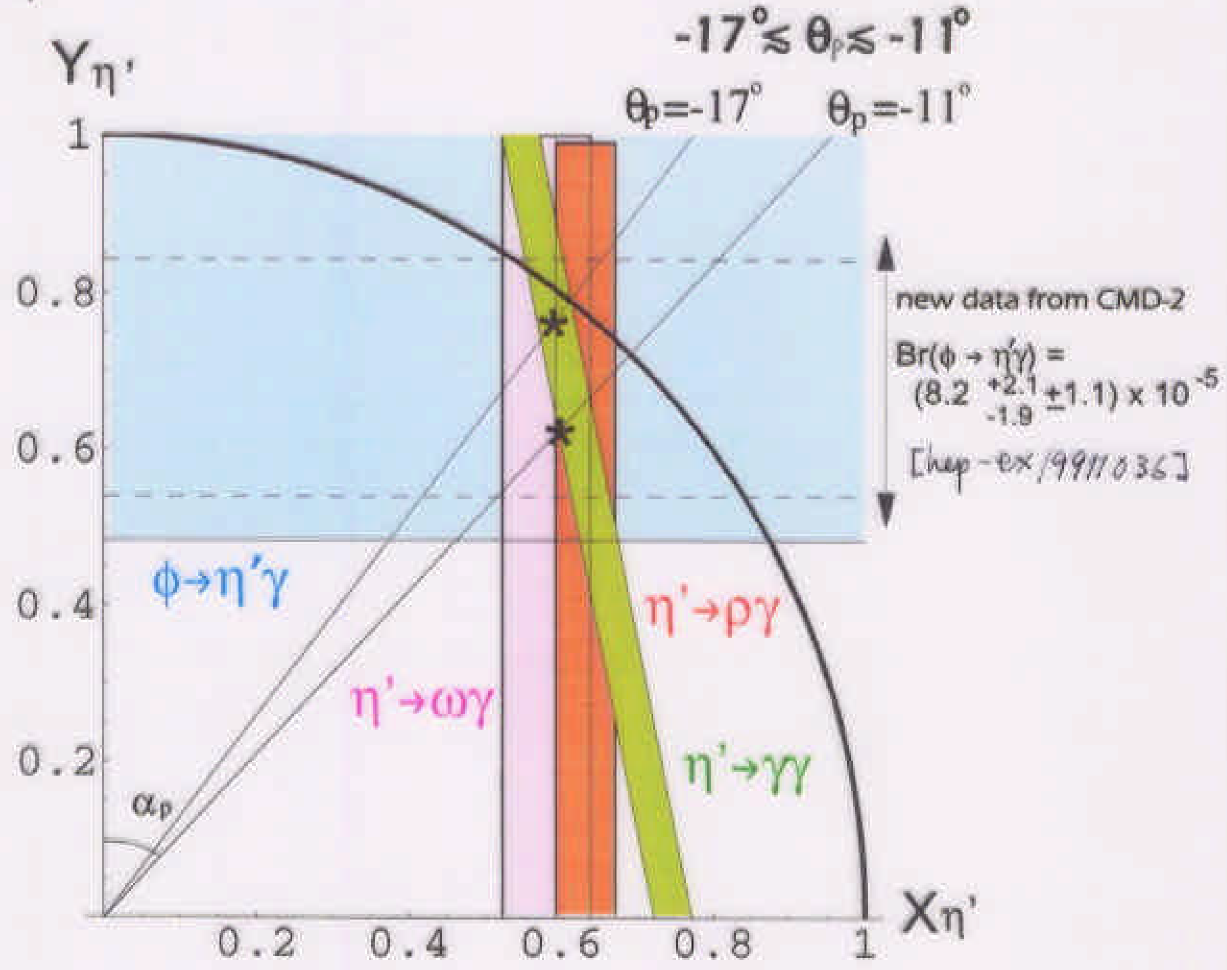
$\Gamma(\eta \to \gamma\gamma) = (0.46 \pm 0.04)$ KeV

$Br(\phi \to \eta\gamma) = (1.26 \pm 0.06) \times 10^{-2}$

Result from η' Process

Maximum 26 % of gluonium in η'

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



$$\Gamma(\eta'\to\omega\gamma) = \frac{\alpha}{8}\left(\frac{m_{\eta'}^2 - m_\omega^2}{m_{\eta'}}\right)^3 \left(\frac{m_\omega}{f_\omega \pi^2}\right)^2 \left(\frac{X_{\eta'}}{4f_x}\right)^2$$

$$\Gamma(\eta'\to\rho\gamma) = \frac{\alpha}{8}\left(\frac{m_{\eta'}^2 - m_\rho^2}{m_{\eta'}}\right)^3 \left(\frac{m_\rho}{f_\rho \pi^2}\right)^2 \left(\frac{3X_{\eta'}}{4f_x}\right)^2$$

$$\Gamma(\eta'\to\gamma\gamma) = \frac{\alpha^2}{288\pi^3} m_{\eta'}^3 \left(\frac{5X_{\eta'}}{f_x} + \frac{\sqrt{2}\,Y_{\eta'}}{f_y}\right)^2$$

$$\Gamma(\phi\to\eta'\gamma) = \frac{\alpha}{24}\left(\frac{m_\phi^2 - m_{\eta'}^2}{m_\phi}\right)^3 \left(\frac{m_\phi}{f_\phi \pi^2}\right)^2 \left(\frac{-2Y_{\eta'}}{4f_y}\right)^2$$

The PDG(98) Averages

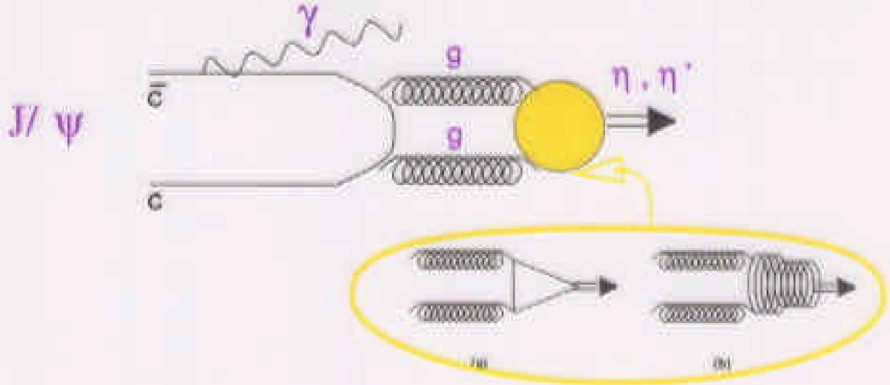
$Br(\eta' \to \omega\gamma) = (3.0 \pm 0.30) \times 10^{-2}$

$Br(\eta' \to \rho\gamma) = (3.0 \pm 0.13) \times 10^{-1}$

$Br(\phi \to \eta'\gamma) = (1.2^{+0.7}_{-0.5}) \times 10^{-4}$

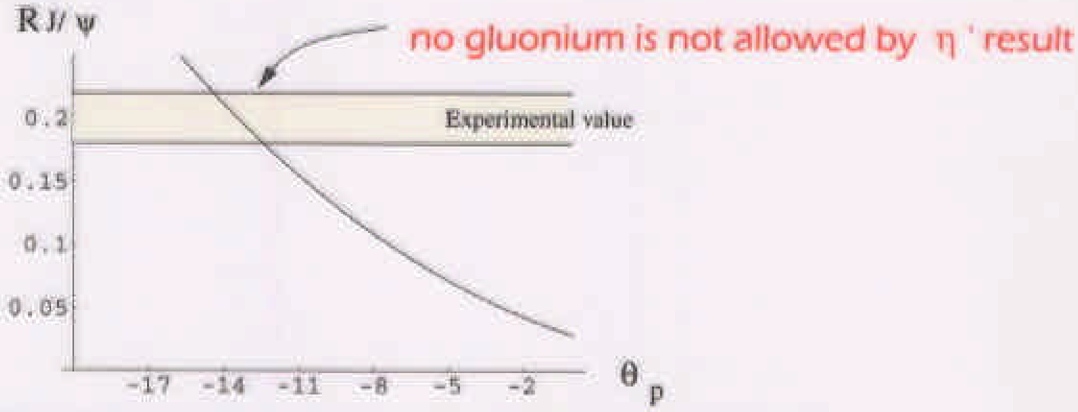
$\Gamma(\eta \to \gamma\gamma) = (4.27 \pm 0.16)$ KeV

Result from J/ψ Process



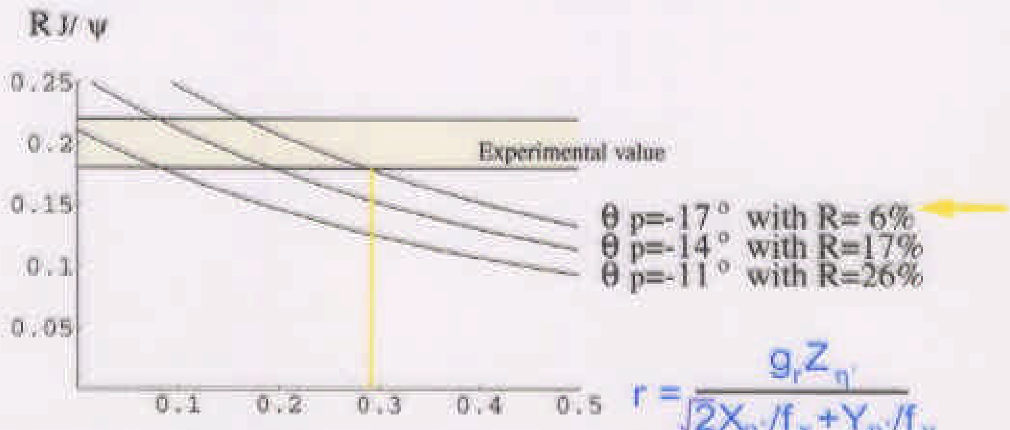
$$R_{J/\psi} = \frac{\Gamma(J/\psi \to \eta\gamma)}{\Gamma(J/\psi \to \eta'\gamma)} = \left(\frac{1-m_\eta^2/m_{J/\psi}^2}{1-m_{\eta'}^2/m_{J/\psi}^2}\right)^3 \left(\frac{\sqrt{2}X_\eta/f_x - (-Y_\eta)/f_y}{\sqrt{2}X_{\eta'}/f_x + Y_{\eta'}/f_y + g_r Z_{\eta'}}\right)^2$$

J/ψ decays also demand gluonium!



Result by asuuming $g_r Z_\eta = 0$ (no gluonium)

Maximum 20% of amplitude comes from gluonium!



$$r = \frac{g_r Z_{\eta'}}{\sqrt{2}X_{\eta'}/f_x + Y_{\eta'}/f_y}$$

Contribution of gluonium to $J/\psi \to \eta' \gamma$ amplitude

Notation

$$|\eta\rangle = X_\eta|\frac{u\bar{u}+d\bar{d}}{\sqrt{2}}\rangle + Y_\eta|s\bar{s}\rangle$$

$$|\eta'\rangle = X_{\eta'}|\frac{u\bar{u}+d\bar{d}}{\sqrt{2}}\rangle + Y_{\eta'}|s\bar{s}\rangle + Z_{\eta'}|gluonium\rangle$$

We have normalization conditions:

$$\begin{cases} X_\eta^2 + Y_\eta^2 = 1 \\ X_{\eta'}^2 + Y_{\eta'}^2 + Z_{\eta'}^2 = 1 \end{cases}$$

$X_{\eta^{(\prime)}}, Y_{\eta^{(\prime)}}$ and $Z_{\eta^{(\prime)}}$ are related to the pseudoscalar mixing angle θ_p by

$$X_\eta = \cos\alpha_p, \quad Y_\eta = -\sin\alpha_p$$

$$X_{\eta'} = \sin\alpha_p\cos\phi, \quad Y_{\eta'} = \cos\alpha_p\cos\phi, \quad Z_{\eta'} = \sin\phi$$

where

$$\alpha_p = \theta_p - \theta_I + \frac{\pi}{2} \qquad (\theta_I = \tan^{-1}\frac{1}{\sqrt{2}})$$

Conclusion

We have examined the gluonic compontent of η'
and the contibutions to the process $gg \to \eta'$.
By analysing the latest experimental data on
the radiative light meson decays,
we have observed that the maximum 26% of
the gluonic component of η' is possible at $\theta_P = -11^\circ$.
Our constraint on θ is $-17^\circ \lesssim \theta_P \lesssim -11^\circ$.
Futher investigation would be done once the data
from DAΦNE comes out.
We have aslo studied J/ψ decays.
Combining the results from analysis of
light meson decays,
we found that J/ψ decays also demand gluonium in η'.
In a case when we choose $\theta_P = -17^\circ$
with 6% of gluonium in η',
we have obsereved that the 20% of the amplitude
of $J/\psi \to \eta' \gamma$ comes from glunium.