# $\tau^- \longrightarrow \eta \pi^- \nu_\tau$

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Work in progress with S. González-Solís and R. Escribano

**Rencontres de Moriond**
**QCD and High Energy Interactions**
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- Hadronic form factors
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$\Longrightarrow$ Strong suppression in the SM: Possibility to look for NP

Experimentally, $BR \leq 9.9 \times 10^{-5}$ BaBar'11

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with $q^\mu = (p_P + p_\pi)^\mu$, $s = q^2$, and $c^V_{\pi^-\pi^0} = -\sqrt{2} = -c^V_{\pi^-\eta^{(\prime)}}$.

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$$f_-^{\pi^- P}(s) = -\frac{\Delta_{\pi^- P}}{s}\left[ \frac{c^S_{\pi^- P}}{c^V_{\pi^- P}} \frac{\Delta_{K^0K^+}}{\Delta_{\pi^- P}} f_0^{\pi^- P}(s) + f_+^{\pi^- P}(s) \right]$$

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$$\frac{d\Gamma\left(\tau^- \to \pi^- P^0 \nu_\tau\right)}{d\sqrt{s}} = \frac{G_F^2 |V_{ud} f_+^{\pi^- P}(0)|^2}{384\pi^3} \frac{(M_\tau^2 - s)^2}{M_\tau^3} \frac{\lambda^{1/2}(s, m_\pi^2, m_P^2)}{\sqrt{s}} \left(c^V_{\pi^- P}\right)^2$$

$$\left\{ 3M_\tau^2 \frac{\Delta^2_{\pi^- P}}{s^2} \frac{\Delta^2_{K^0K^+}\Big|^{QCD}}{\Delta^2_{K^0K^+}} \left| \widetilde{f}_0^{\pi^- P}(s) \right|^2 + \frac{M_\tau^2 + 2s}{s} \frac{\lambda(s, m_\pi^2, m_P^2)}{s} \left| \widetilde{f}_+^{\pi^- P}(s) \right|^2 \right\},$$

where

$$\widetilde{f}_+^{\pi^- P}(s) = \frac{f_+^{\pi^- P}(s)}{f_+^{\pi^- P}(0)}\,, \quad \widetilde{f}_0^{\pi^- P}(s) = \frac{f_0^{\pi^- P}(s)}{f_+^{\pi^- P}(0)}\,.$$

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where

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Suppression for $\eta,\eta'$

O(1)

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$\varepsilon^{\eta\pi}=0.017(2)$, $\varepsilon^{\eta'\pi}=0.004(1)$, $\theta_{\eta\eta'} \sim \theta_P(\sim -13.3°)$

Feldmann, Kroll ’02, ‘05 Ambrosino et. al ‘08

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$O(\varepsilon)$ $<O(\varepsilon^2)$: from cancellation

**Suppression of the $\pi\eta$ mode** **Strong suppression of the $\pi\eta'$ mode**

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Gasser, Leutwyler '85 Ecker et. al. '89

$$F_V^\pi(s) = \frac{M_\rho^2}{M_\rho^2 - s} - \frac{s}{96\pi^2 F^2}\left[A_\pi(s) + \frac{1}{2}A_K(s)\right]$$

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Resummation of the loop functions

$$F_V^{\pi\,(0)}(s) = \frac{M_\rho^2}{M_\rho^2\left[1 + \frac{s}{96\pi^2 F_\pi^2}\left(A_\pi(s) + \frac{1}{2}A_K(s)\right)\right] - s}$$

$$\tan\delta_1^1(s) = \frac{\Im m F_V^{\pi(0)}(s)}{\Re e F_V^{\pi(0)}(s)}$$

Boito et. al. '08

$$F_V^\pi(s) = \exp\left[\alpha_1\, s + \frac{\alpha_2}{2}\, s^2 + \frac{s^3}{\pi}\int_{s_{\mathrm{thr}}}^{\infty} ds'\, \frac{\delta_1^1(s')}{(s')^3(s' - s - i\epsilon)}\right]$$

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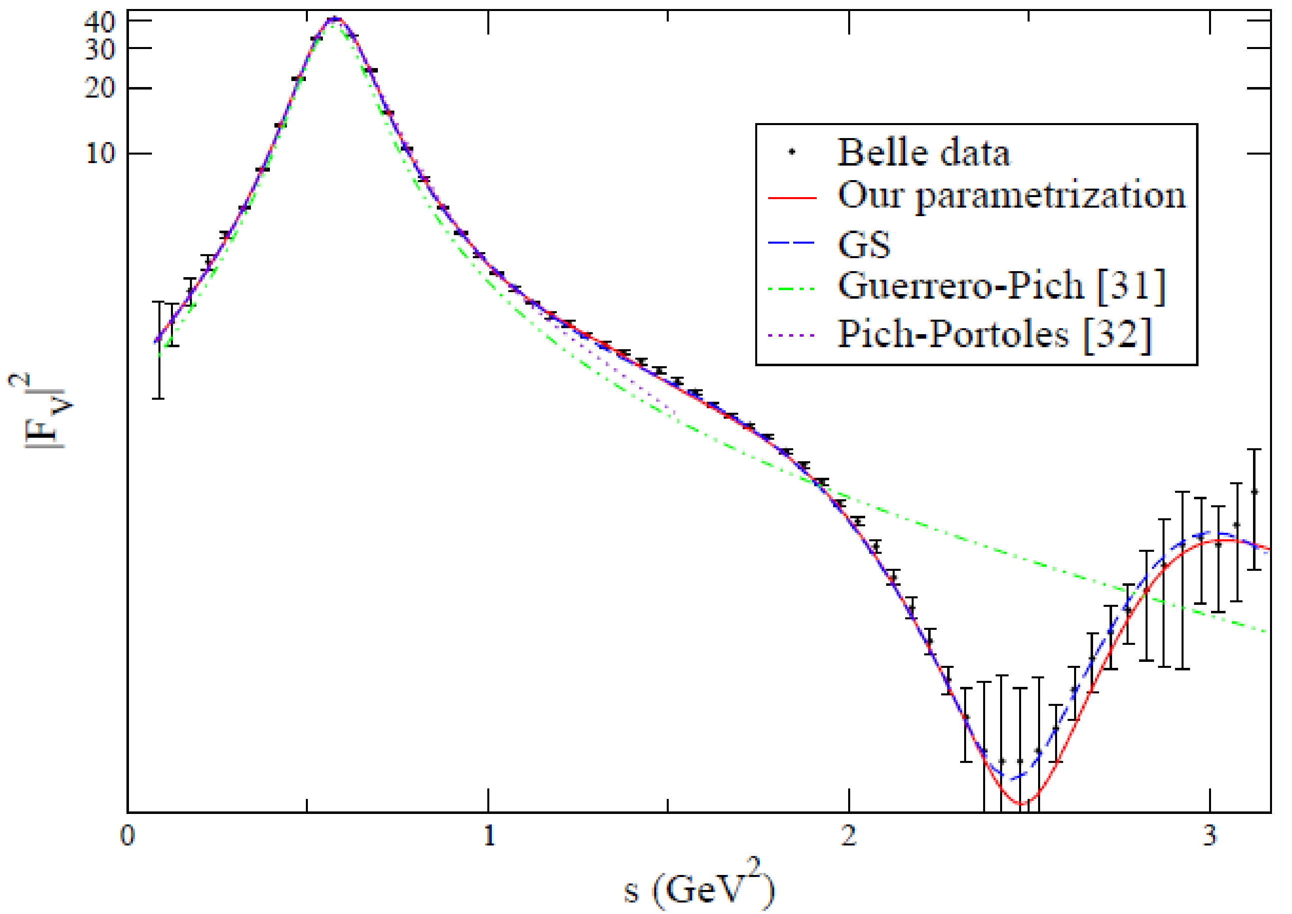

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Further suppression
$O(\varepsilon)$

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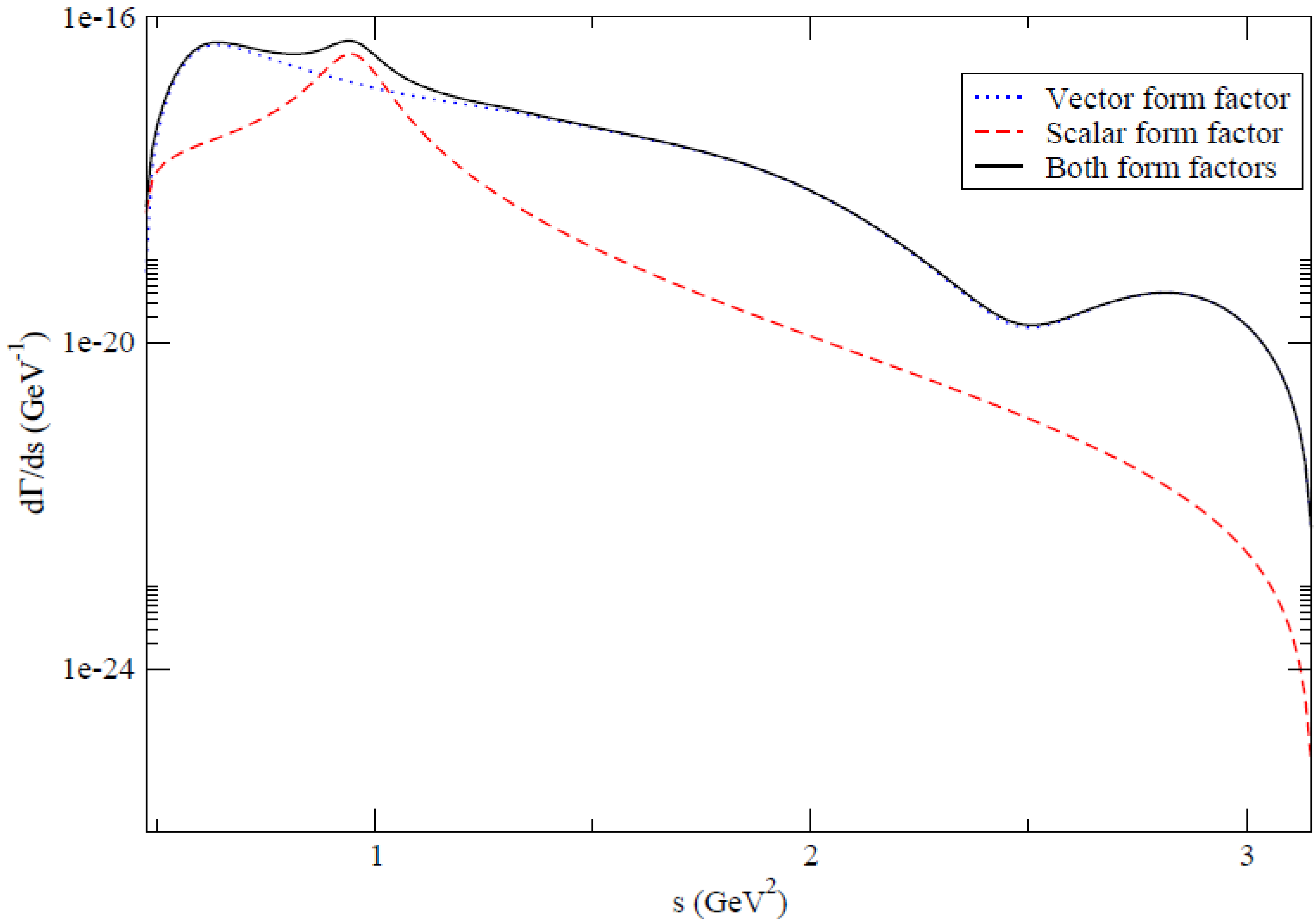
Scalar resonance [a0(980)] width:

$$1/(M_S^2 - s) \longrightarrow 1/(M_S^2 - s - iM_S\Gamma_S(s))$$

$$\Gamma_{a_0}(s) = \Gamma_{a_0}\left(\frac{s}{M_{a_0}^2}\right)^{\frac{3}{2}} \frac{\lambda^{1/2}\left(1, \frac{m_\eta^2}{s}, \frac{m_\pi^2}{s}\right)}{\lambda^{1/2}\left(1, \frac{m_\eta^2}{M_{a_0}^2}, \frac{m_\pi^2}{M_{a_0}^2}\right)}\theta\left[s - (m_\eta + m_\pi)^2\right]$$

# Predictions

## $\tau^- \longrightarrow \eta \pi^- \nu_\tau$



# Predictions

$$BR(\tau^- \longrightarrow \eta\pi^-\nu_\tau)\cdot 10^5$$

| | Vector | Scalar | Both |
|---|---|---|---|
| Tisserant & Truong ‘87 | 0.25 | 1.60 | 1.85 |
| Pich ‘87 | 0.12 | 1.38 | 1.50 |
| Neufeld & Rupertsberger ‘95 | 0.15 | 1.06 | 1.21 |
| Nussinov & Soffer ‘08 | 0.36 | 1.00 | 1.36 |
| Paver & Riazuddin ‘10 | [0.2,0.6] | [0.2,2.3] | [0.4,2.9] |
| Volkov & Kostunin ‘12 | 0.44 | 0.04 | 0.48 |
| Descotes-Genon, Kou & Moussallam (preliminary, TAU’12) | 0.11 | $0.37^{+0.30}_{-0.25}$ | $0.48^{+0.30}_{-0.25}$ |
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$$BR(\tau^- \longrightarrow \eta\pi^-\nu_\tau)\cdot 10^5$$

| | Vector | Scalar | Both |
|---|---|---|---|
| Tisserant & Truong '87 | 0.25 | 1.60 | 1.85 |
| Pich '87 | 0.12 | 1.38 | 1.50 |
| Neufeld & Rupertsberger '95 | 0.15 | 1.06 | 1.21 |
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⇒ Error estimated using Belle data corrected by em effects (Flores et. al.06) and other parametrizations ±0.02

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➡ Error from $\varepsilon^{\eta\pi}$ : $\pm0.2$

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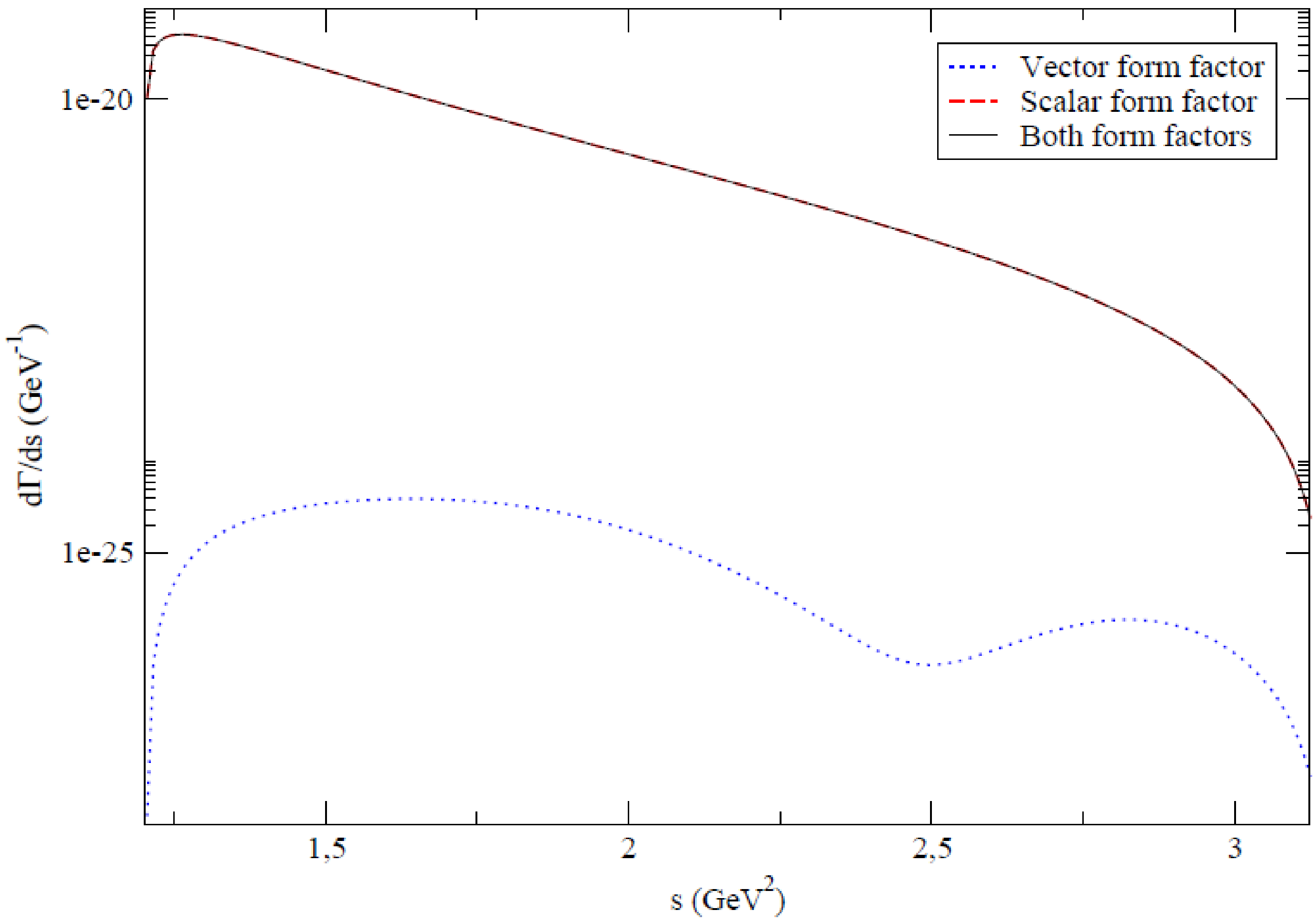

# Predictions

# $BR(\tau^- \longrightarrow \eta' \pi^- \nu_\tau)$

| | Vector | Scalar | Both |
|---|---|---|---|
| Nussinov & Soffer '09 | $<10^{-7}$ | $[0.2,1.3]\cdot 10^{-6}$ | $[0.2,1.4]\cdot 10^{-6}$ |
| Paver & Riazuddin '11 | $[10^{-9}, 3\cdot 10^{-8}]$ | $[6\cdot 10^{-8}, 2\cdot 10^{-7}]$ | $[6\cdot 10^{-8}, 2\cdot 10^{-7}]$ |
| Volkov & Kostunin '12 | $1.1\cdot 10^{-8}$ | $2.6\cdot 10^{-8}$ | $3.7\cdot 10^{-8}$ |
| Our prediction (preliminary) | $\sim 0$<br>$O(\varepsilon^4)$ | $\sim 10^{-8}$ | $\sim 10^{-8}$ |

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## $\Longrightarrow$Strong suppression in the SM: Possibility to look for NP

## Experimentally, $BR \leq 9.9\text{x}10^{-5}$ BaBar'11