Física del tau: Motivación

Pablo Roig
Dpto. de Física del Cinvestav, Ciudad de México

Reunión general de la RED-FAE, 10-12 de Noviembre de 2016, Pachuca, Hidalgo, México

Gabriel López Castro: $a_\mu^{HVP,LO}$	Pedro Podesta: LNV en Belle-II	Jorge Martínez: México en Belle-II

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A lo largo de la plática, indico investigación en México en esa línea mediante

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(Si no estamos, hay que pensar si nos interesa estar…)

REDFAE

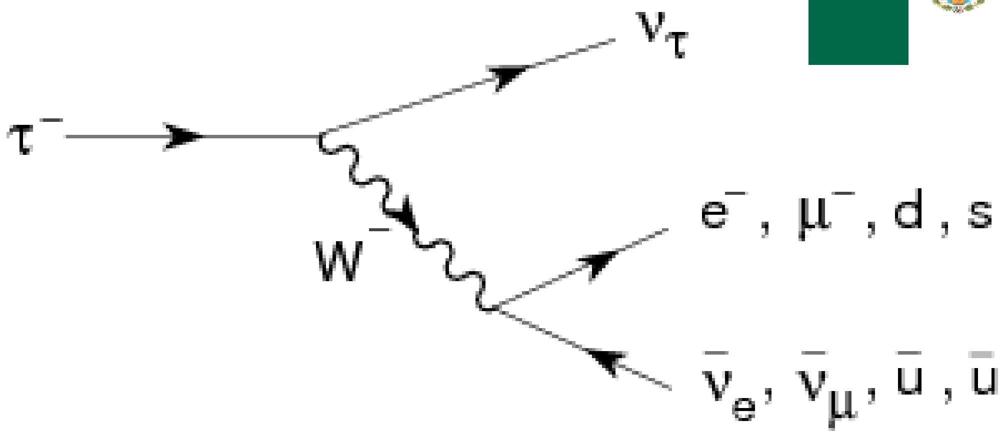
Reunión general de la RED-FAE, 10-12 de Noviembre de 2016, Pachuca, Hidalgo, México

CONTENIDOS

- + sobre las SCCs

- Otros aspectos de desintegraciones semileptónicas de taus

- Desintegraciones leptónicas de taus



+ sobre las SCCs

Non-strange V-A currents can be split into: 1st class currents $J^{PG} = 0^{++}, 0^{--}, 1^{+-}, 1^{-+}$ (σ, π, a_1, ρ)

2nd class currents $J^{PG} = 0^{+-}, 0^{-+}, 1^{++}, 1^{--}$ (a_0, η, b_1, ω)

(Weinberg'58)

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$$\mathrm{G-Parity}: G|X\rangle = e^{i\pi I_y} C|X\rangle = (-1)^I C|X\rangle$$

$$G|\bar{d}\gamma^\mu u\rangle = +|\bar{d}\gamma^\mu u\rangle \neq G|\pi^-\eta\rangle = -|\pi^-\eta\rangle$$

(Leroy-Pestieau'78)

G-parity(Isospin)-violating process ($m_u \neq m_d$, $e \neq 0$)

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Note: For efforts to discover SCCs in Nuclear Physics see Rev. Mod. Phys. 78. 991 (but they need to rely on CVC).

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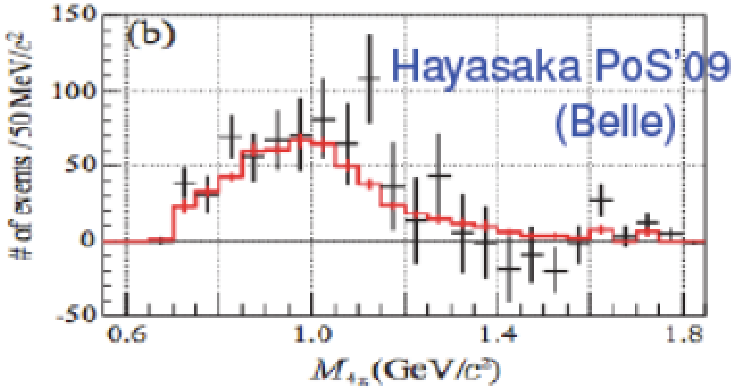

SCCs would have been discovered @ BaBar/Belle if it was not for the tough background !!

$BR^{BaBar}_{exp} < 9.9 \cdot 10^{-5}$ 95% CL

(PRD 83 (2011) 032002)

$BR^{Belle}_{exp} < 7.3 \cdot 10^{-5}$ 90% CL

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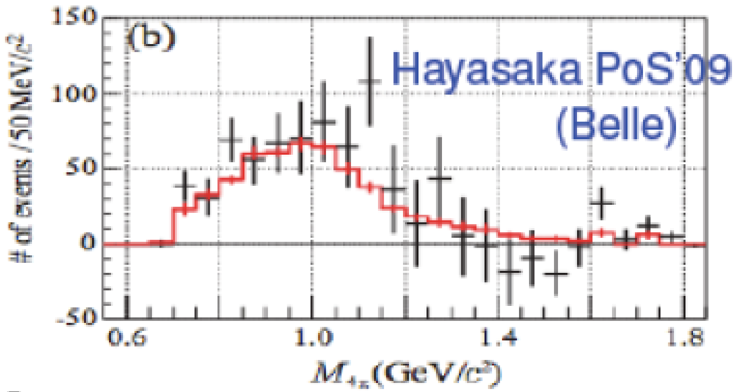

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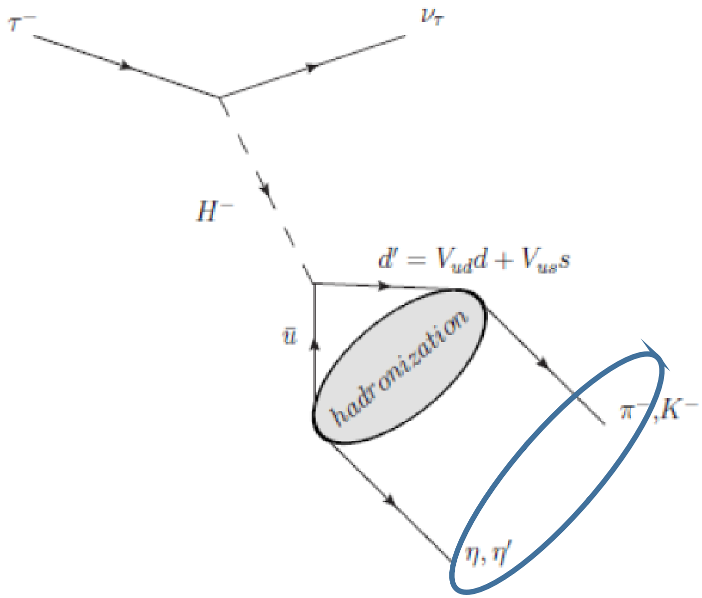

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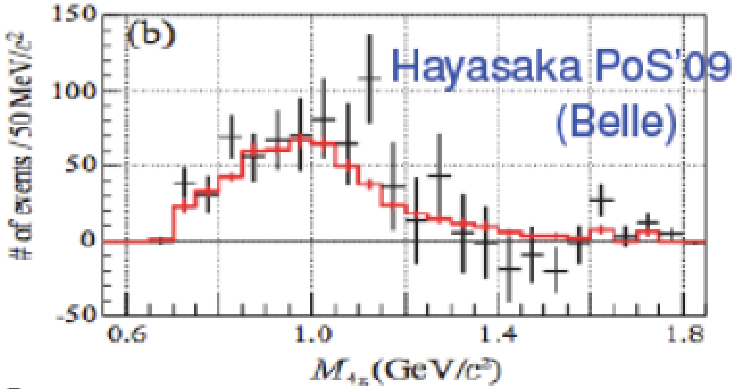

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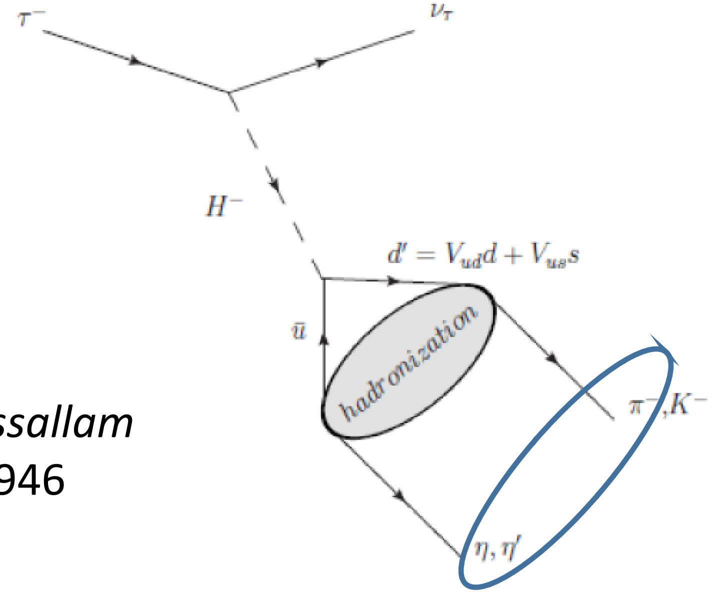
Bounds competitive with $B \to \tau\nu_\tau$ if the SFF is known (th. & exp.) with 20% accuracy!!

Descotes-Genon & Moussallam
Eur.Phys.J. C74 (2014) 2946



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Escribano, González-Solís & Roig Phys.Rev. D94 (2016) no.3, 034008

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- Analyticity+Unitarity+Chiral Expansion
- VFF: $\eta\ \pi \to \pi\ \pi$ is related to $\eta \to \pi\ \pi\ \pi$
- SFF: Dispersion relation + realistic model for phaseshift + SR constraint for inelastic region

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Input from Guo, Oller & Ruiz de Elvira
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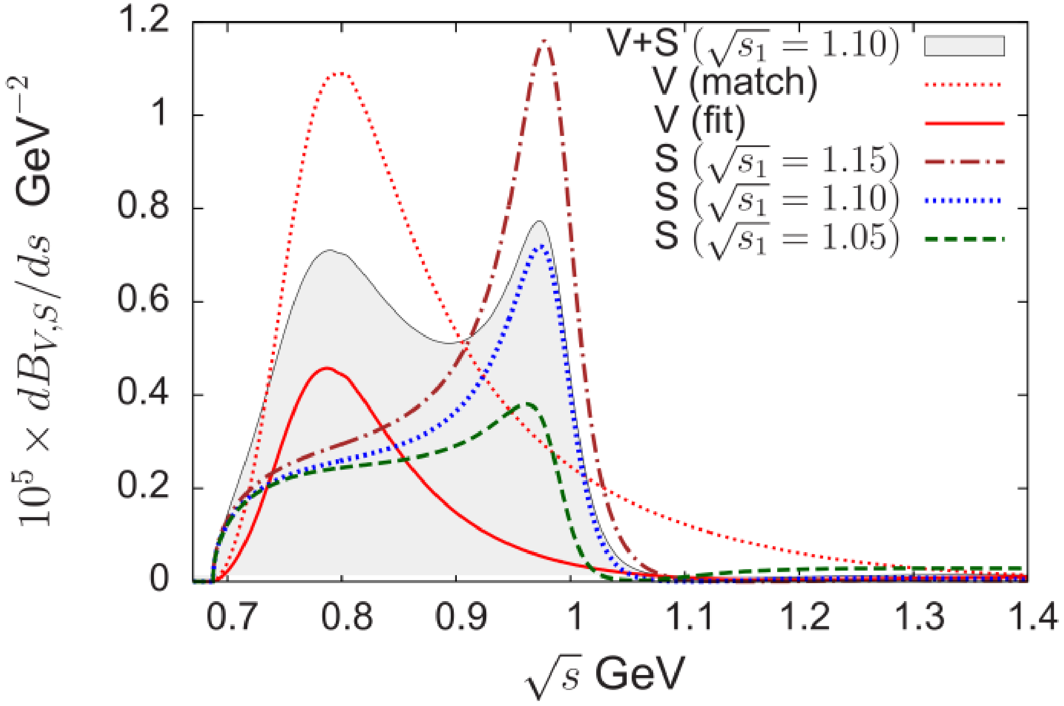

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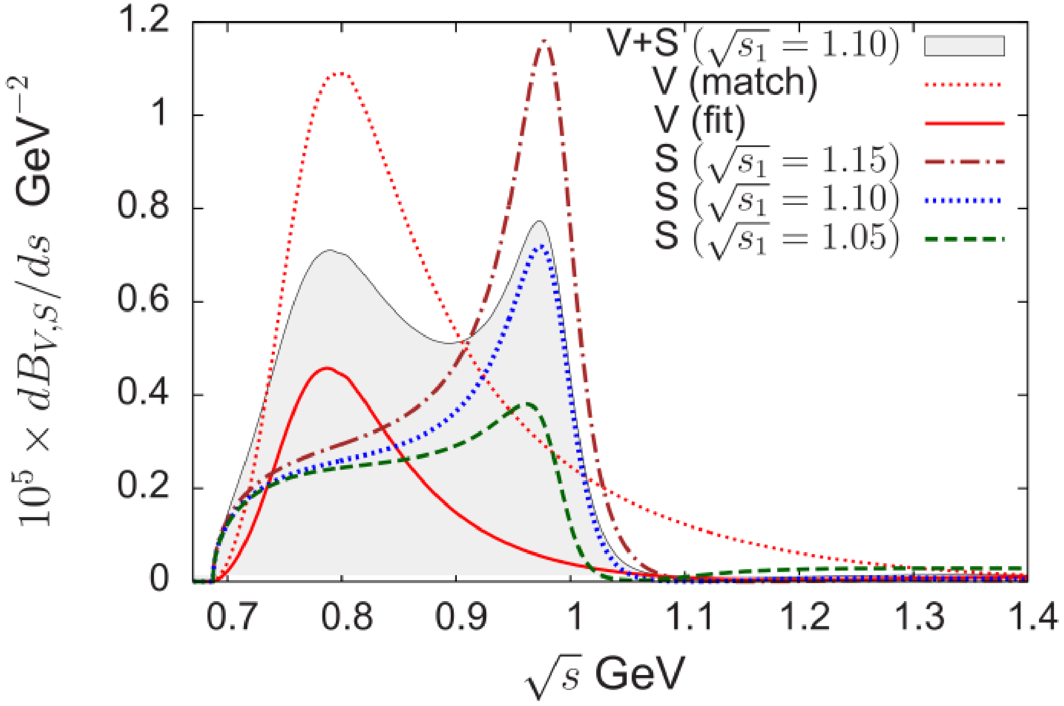

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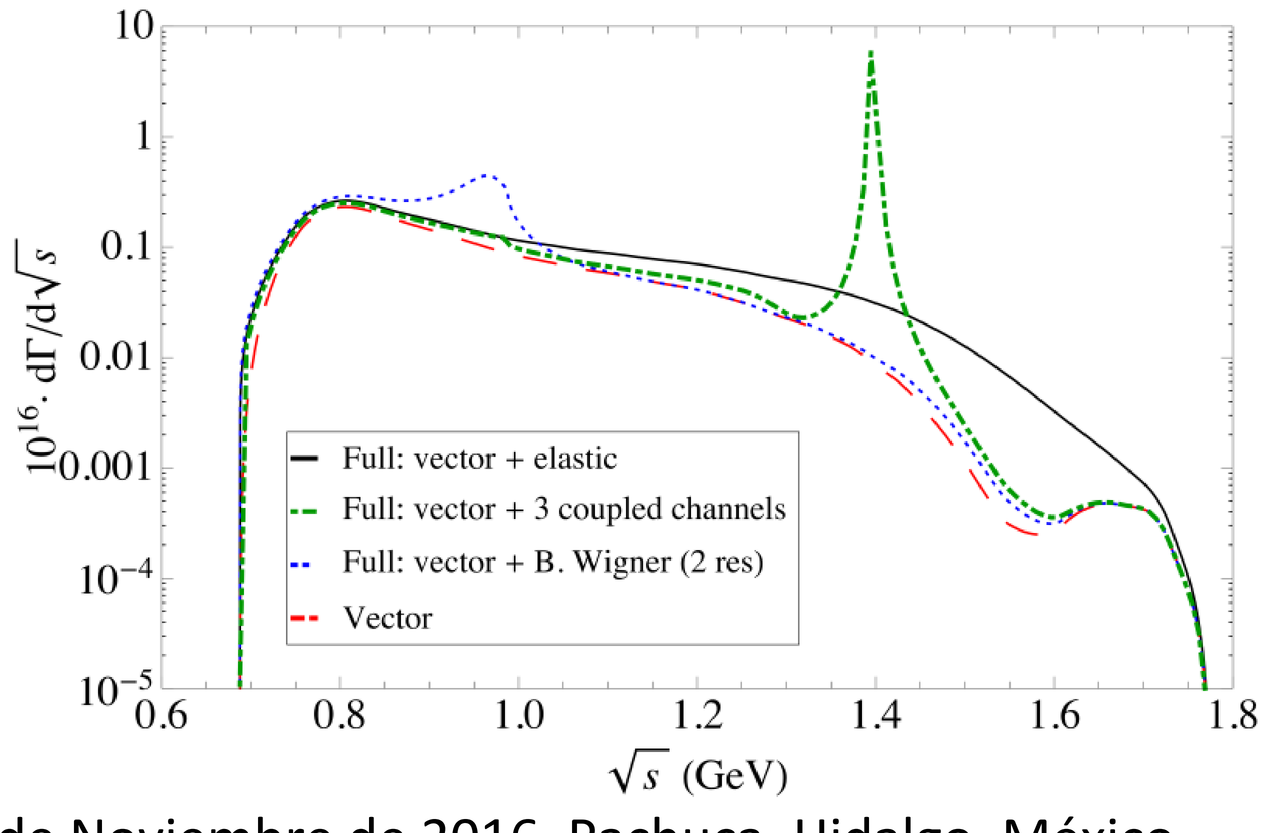

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$BR_V \times 10^5$	$BR_S \times 10^5$	$BR \times 10^5$	Reference
0.25	1.60	1.85	Tisserant, Truong [84]
0.12	1.38	1.50	Bramon, Narison, Pich [85]
0.15	1.06	1.21	Neufeld, Rupertsberger [86]
0.36	1.00	1.36	Nussinov, Soffer [87]
[0.2, 0.6]	[0.2, 2.3]	[0.4, 2.9]	Paver, Riazuddin [88]
0.44	0.04	0.48	Volkov, Kostunin [89]
0.13	0.20	0.33	Descotes-Genon, Moussallam [83]
$BR_V \times 10^5$	$BR_S \times 10^5$	$BR \times 10^5$	Our analysis
0.26 ± 0.02	1.41 ± 0.09	1.67 ± 0.09	3 coupled channels

Errors from SFF parameters not included !!

+ sobre las SCCs

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SCCs could be discovered @ Belle-II, but take care with the tough background !!

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$\tau^- \to \pi^- \eta' \nu_\tau$

Escribano, González-Solís & Roig Phys.Rev. D94 (2016) no.3, 034008

BR_V	BR_S	BR	Reference
$< 10^{-7}$	$[0.2, 1.3] \times 10^{-6}$	$[0.2, 1.4] \times 10^{-6}$	Nussinov, Soffer [90]
$[0.14, 3.4] \times 10^{-8}$	$[0.6, 1.8] \times 10^{-7}$	$[0.61, 2.1] \times 10^{-7}$	Paver, Riazuddin [91]
1.11×10^{-8}	2.63×10^{-8}	3.74×10^{-8}	Volkov, Kostunin [89]
BR_V	BR_S	BR	Our analysis
$[0.3, 5.7] \times 10^{-10}$	$[1 \times 10^{-7}, 1 \times 10^{-6}]$	$[1 \times 10^{-7}, 1 \times 10^{-6}]$	3 coupled channels

Errors dominated by $\varepsilon_{\pi\eta'}$

At least one order of magnitude suppressed with respect to $\tau \to \pi \eta \nu_\tau$!!

+ sobre las SCCs

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Much more challenging to discover SCC with η' than with η!!

+ sobre las SCCs

*An **'unexpected' background** (A. Guevara, G. López Castro & P. Roig, to appear soon)*

The Mexican members of Belle-II are studying the 'expected' backgrounds in the search for SCCs @ Belle-II (with Hayasaka-san)

Jorge Martínez: México en Belle-II

+ sobre las SCCs

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$BR^{R\chi L} = (2.7 \pm 0.8) \times 10^{-5}$

As expected, comparable to $\tau \rightarrow \pi \, \eta \, \nu_\tau$!!

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One can just cut γs above certain E (leaving windows for detecting π^0's & η's) !!

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$E_\gamma < 100$ MeV

'Unexpected' bkg killed !!

One can just cut γs above certain E (leaving windows for detecting π^0's & η's) !!

Towards the discovery of Second Class Currents in $\tau^- \to \pi^- \eta \nu_\tau$ decays @ Belle-II

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Pablo Roig

Cinvestav (Mexico City)

Otros aspectos de desintegraciones semileptónicas de taus

$\tau^- \to (\pi/K)^- \nu_\tau$ are trivial hadronically → **Lepton Universality tests**

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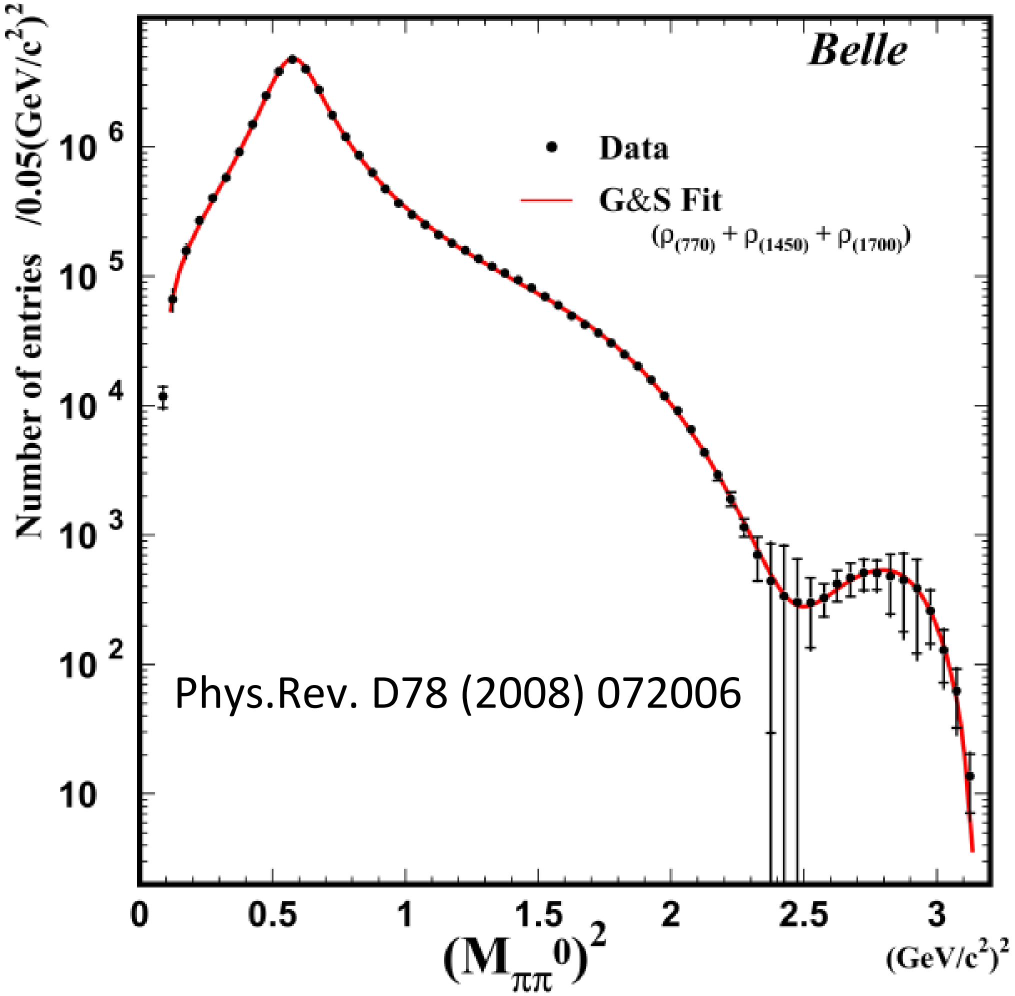
$\tau^- \to \pi^- \pi^0 \nu_\tau (\gamma)$: ρ, ρ', ρ'' **pole** parameters



Theory tools (common to 2-meson decay channels):

Dispersion relations + Chiral Constraints

Gómez-Dumm & Roig, EPJC 73, no.8, 2528 (2013)

Celis, Cirigliano & Passemar PRD 89, no 1., 013008 (2014)

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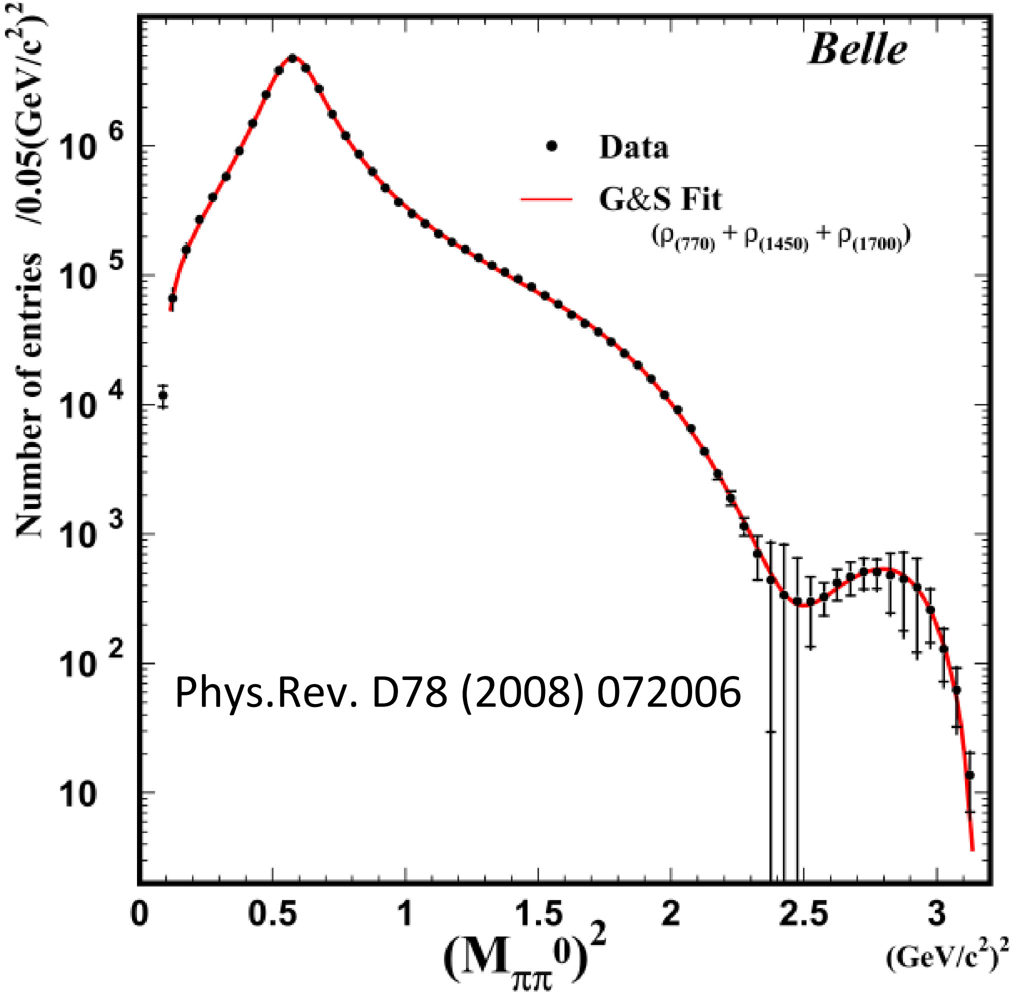
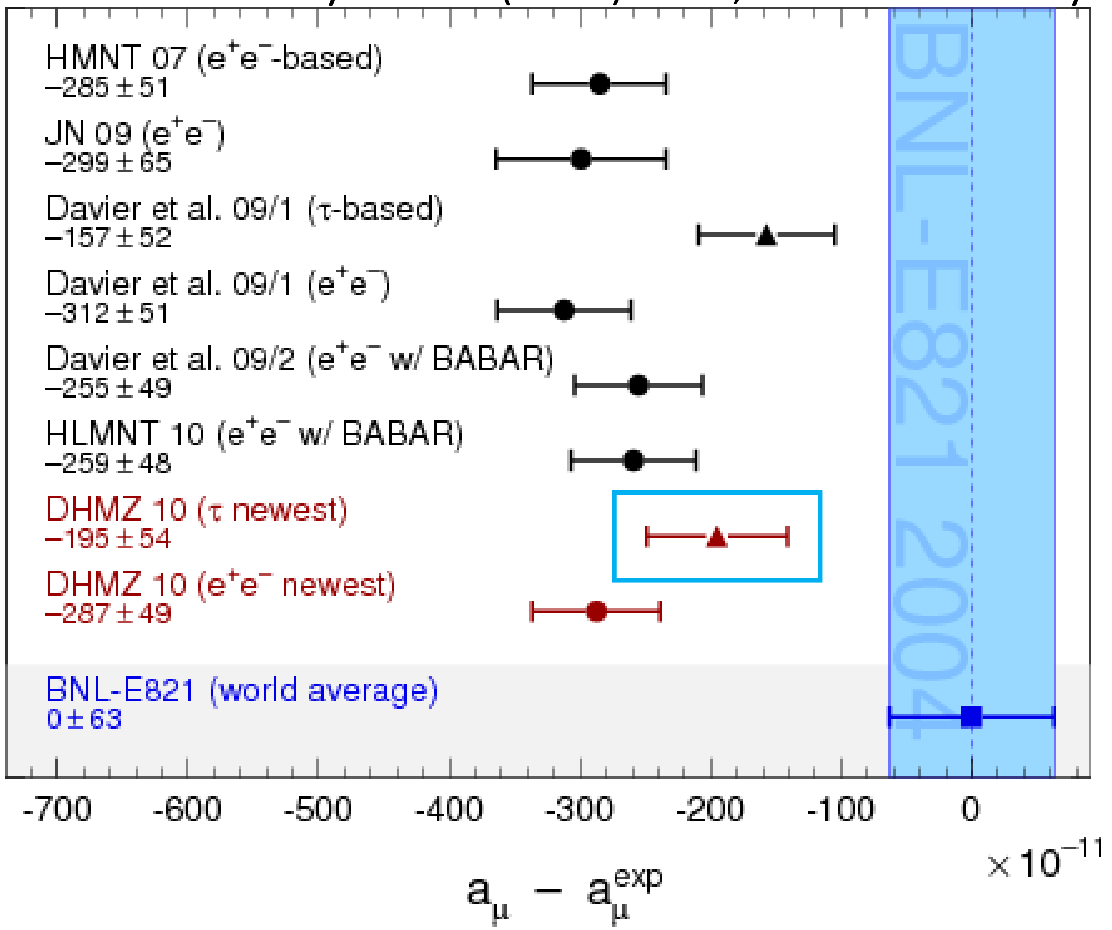
$\tau^- \to \pi^- \pi^0 \nu_\tau (\gamma)$: ρ, ρ', ρ'' **pole** parameters & Check of $e^+ e^- \to \pi^+ \pi^- (\gamma)$ for $\mathbf{a_\mu^{HVP}}$



Phys.Rev. D78 (2008) 072006

Davier, Michel et al. Eur.Phys.J. C71 (2011) 1515, Erratum: Eur.Phys.J. C72



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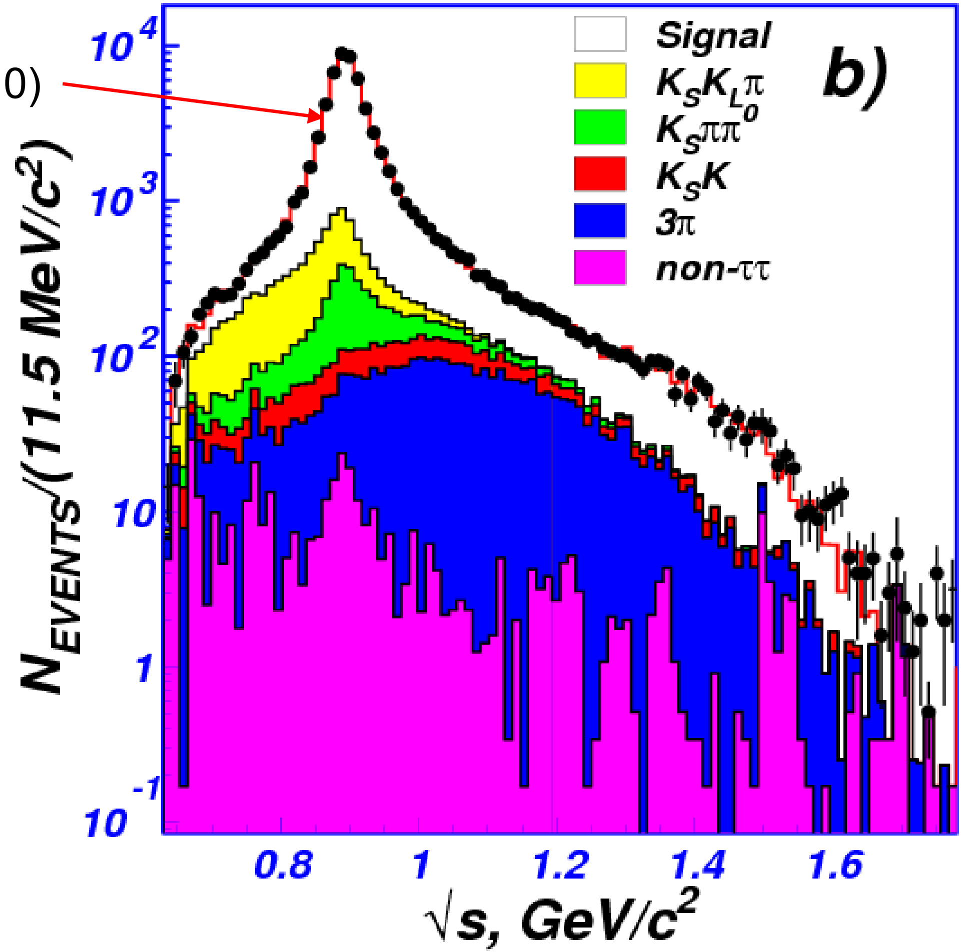
$\tau^- \to (K\pi)^- \nu_\tau$: K*, K*' **pole** parameters and unitarity tests

Belle Collaboration (Epifanov, D. et al.) Phys.Lett. B654 (2007) 65-73

$K^*(892)+K^*_0(800)+K^*(1410)$



Otros aspectos de desintegraciones semileptónicas de taus

$\tau^- \to (\pi/K)^- \nu_\tau$ are trivial hadronically → **Lepton Universality tests**

$\tau^- \to \pi^- \pi^0 \nu_\tau$ (γ): ρ, ρ', ρ'' **pole** parameters & Check of $e^+ e^- \to \pi^+ \pi^-$ (γ) for $\mathbf{a_\mu^{HVP}}$

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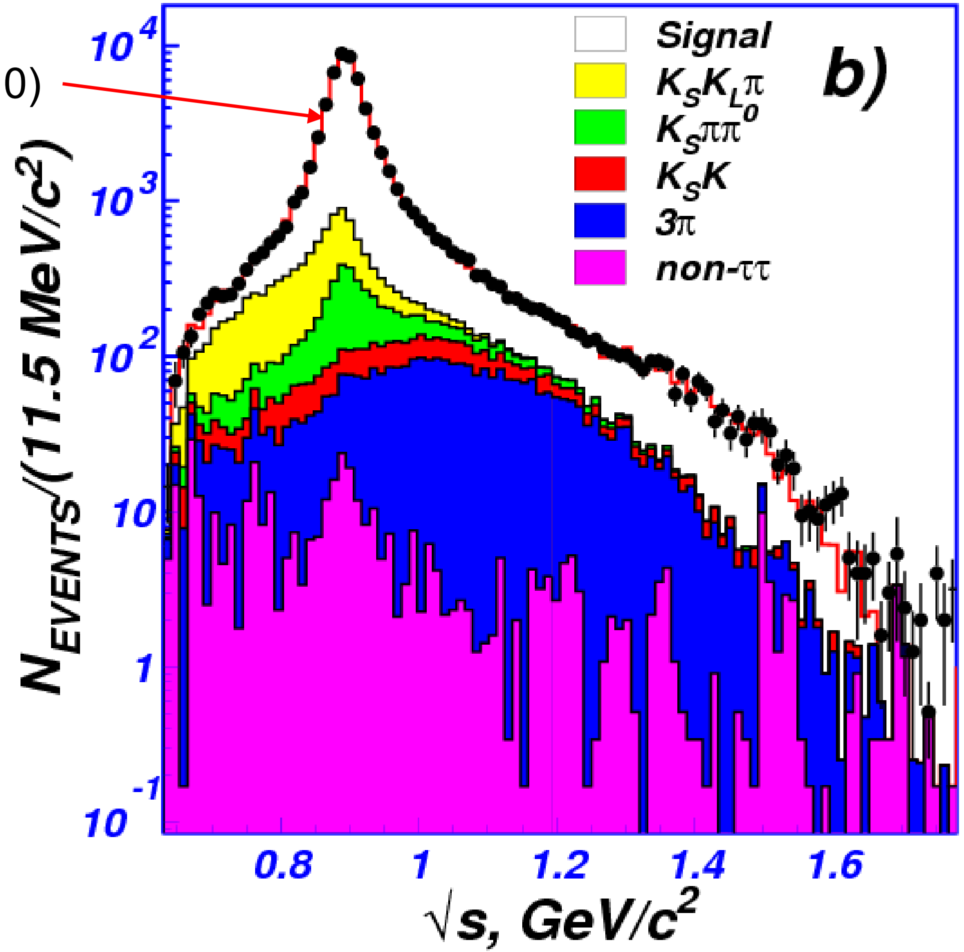

Theory tools (2-meson decay channels):

Dispersion relations + Chiral Constraints

Boito, Escribano & Jamin EPJC 59, 821 (2009); JHEP 1009, 031 (2010)

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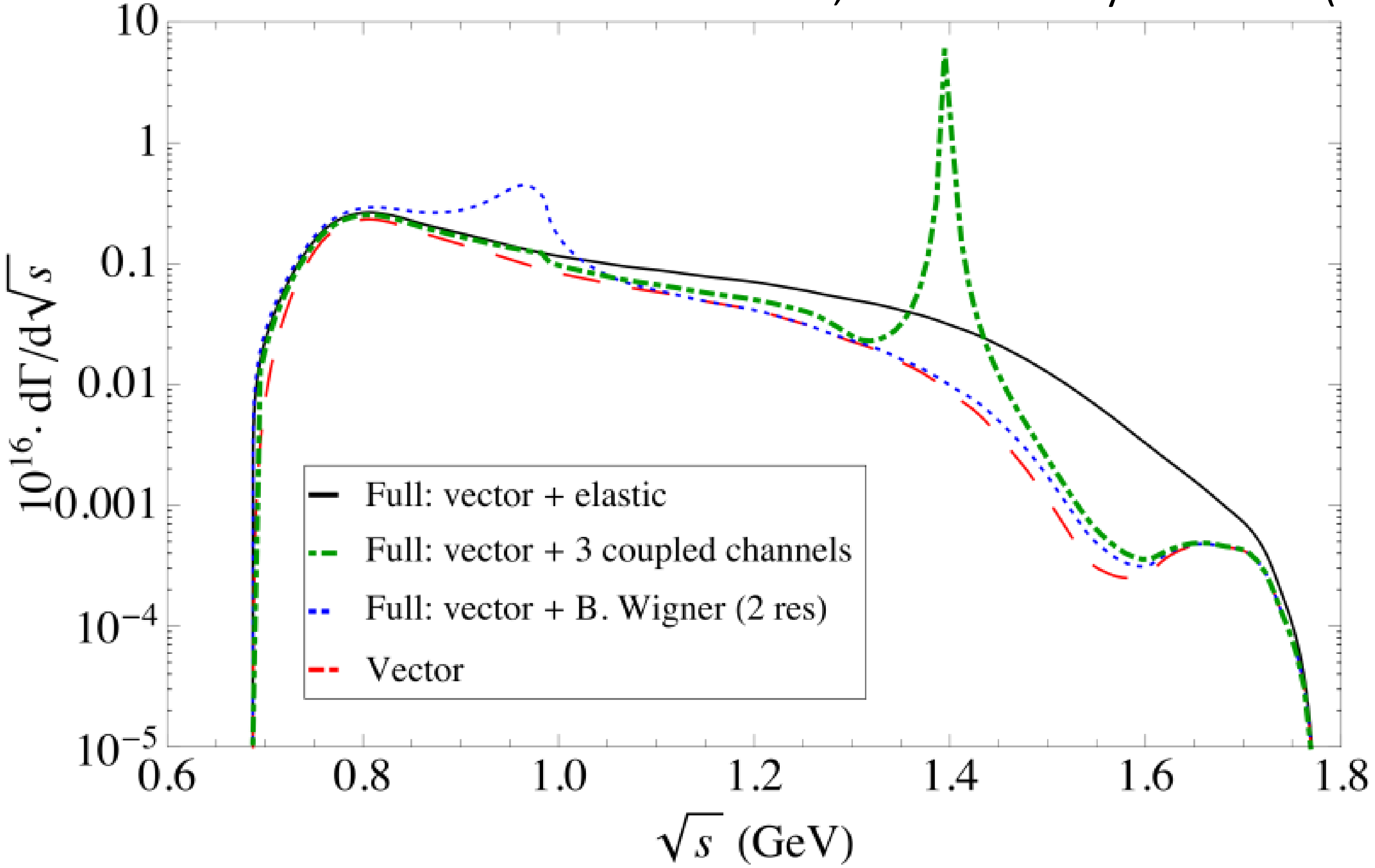
Escribano, Rafel et al. Phys.Rev. D94 (2016) no.3



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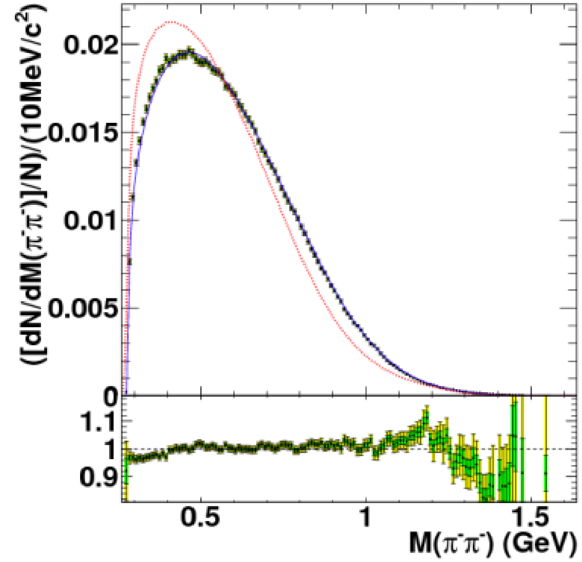
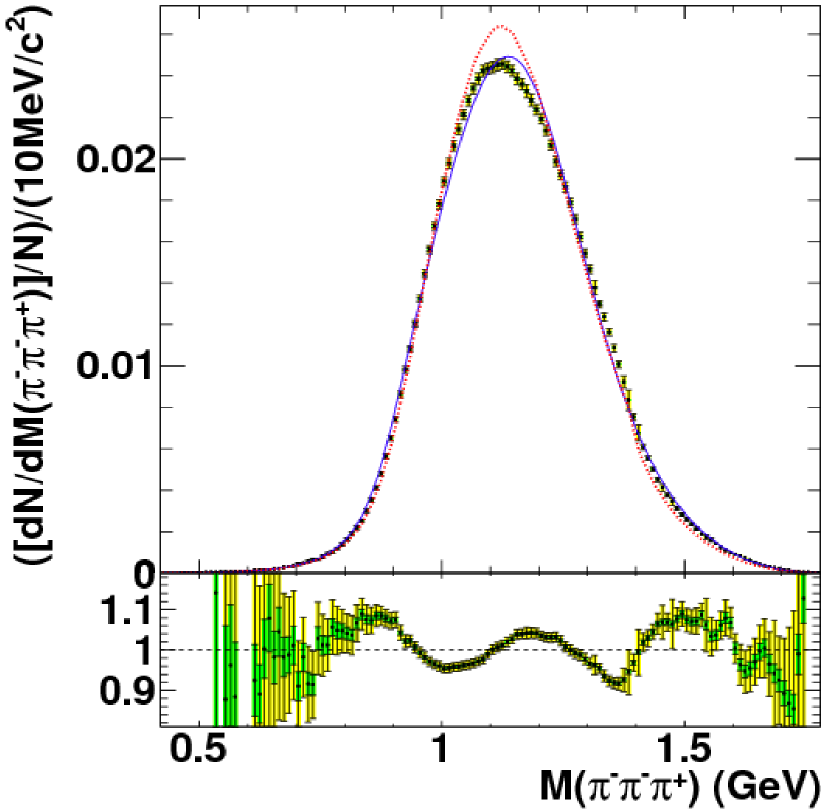
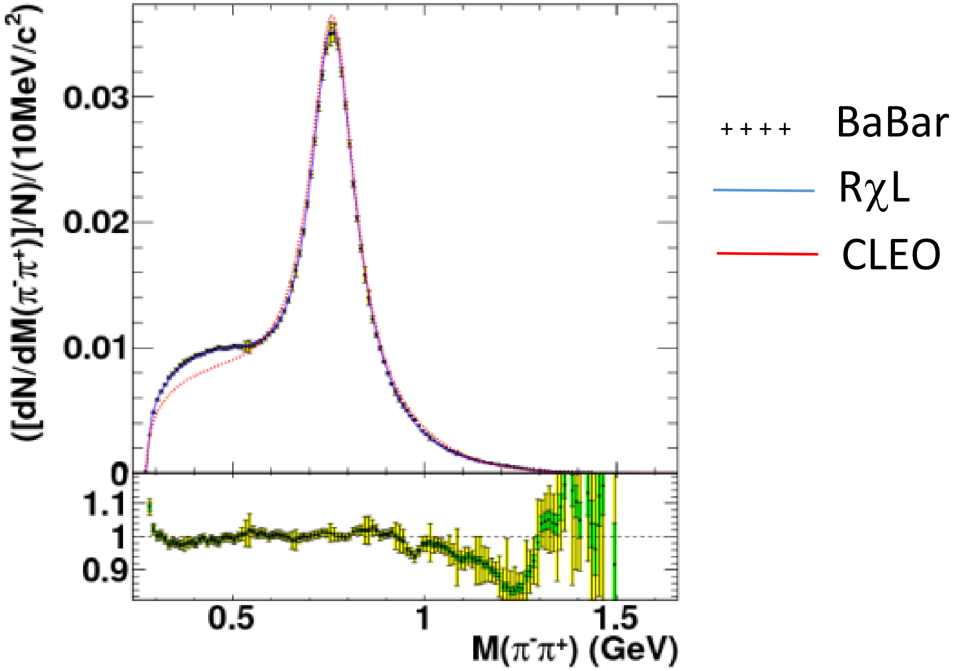
Nugent, I.M. et al. Phys.Rev. D88 (2013) 093012







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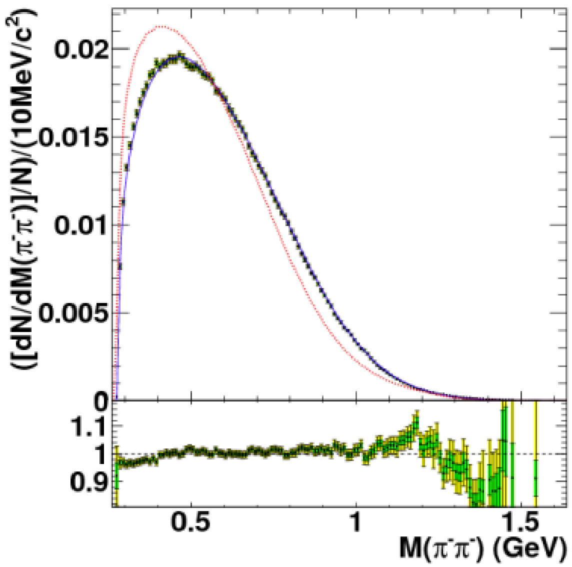

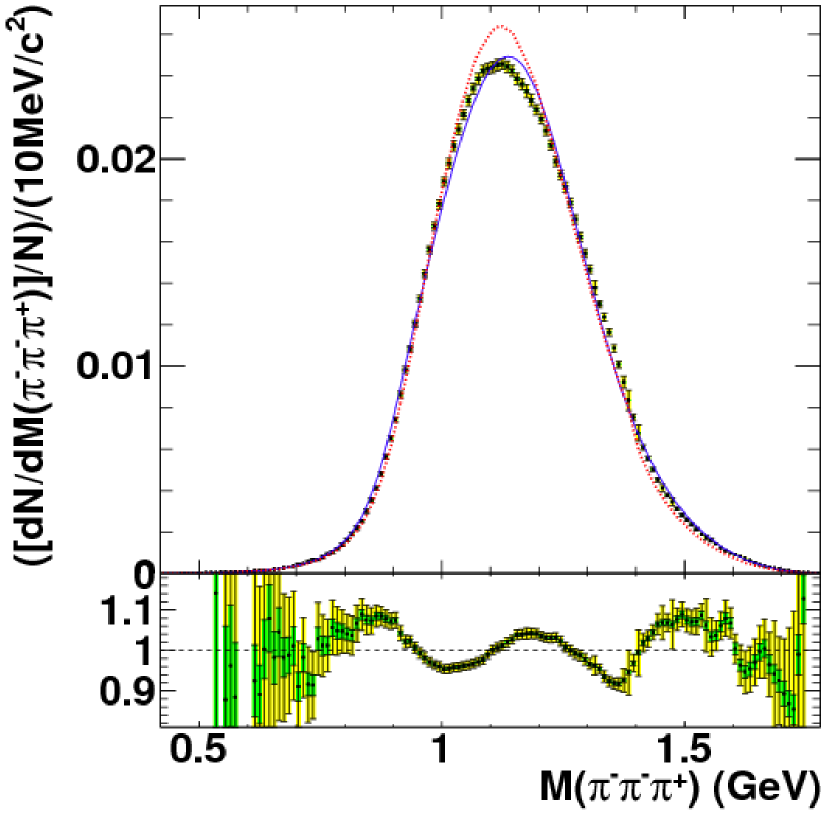

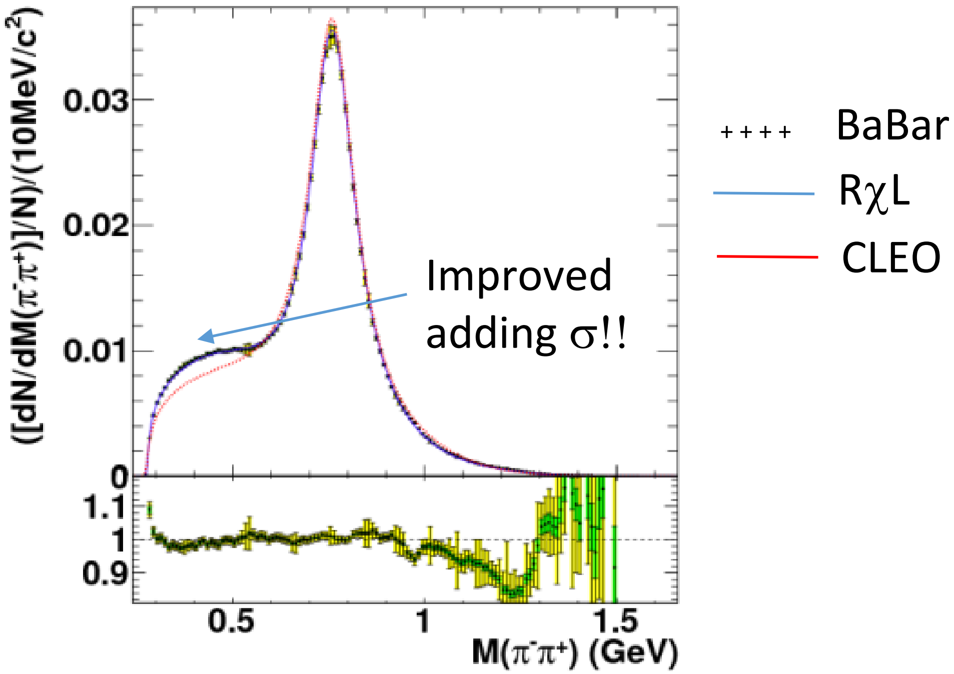

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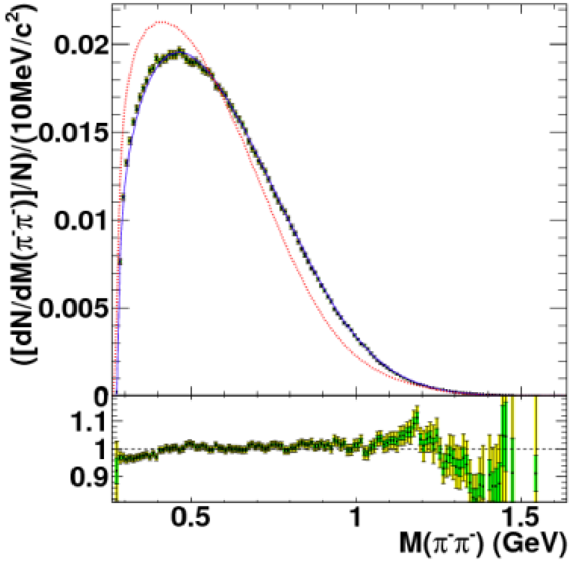

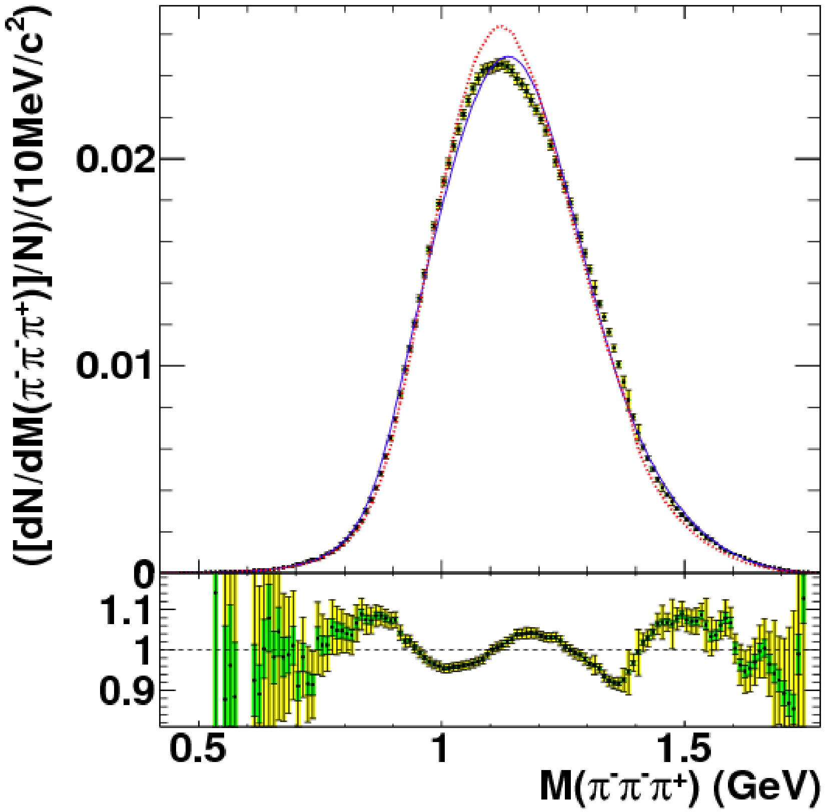

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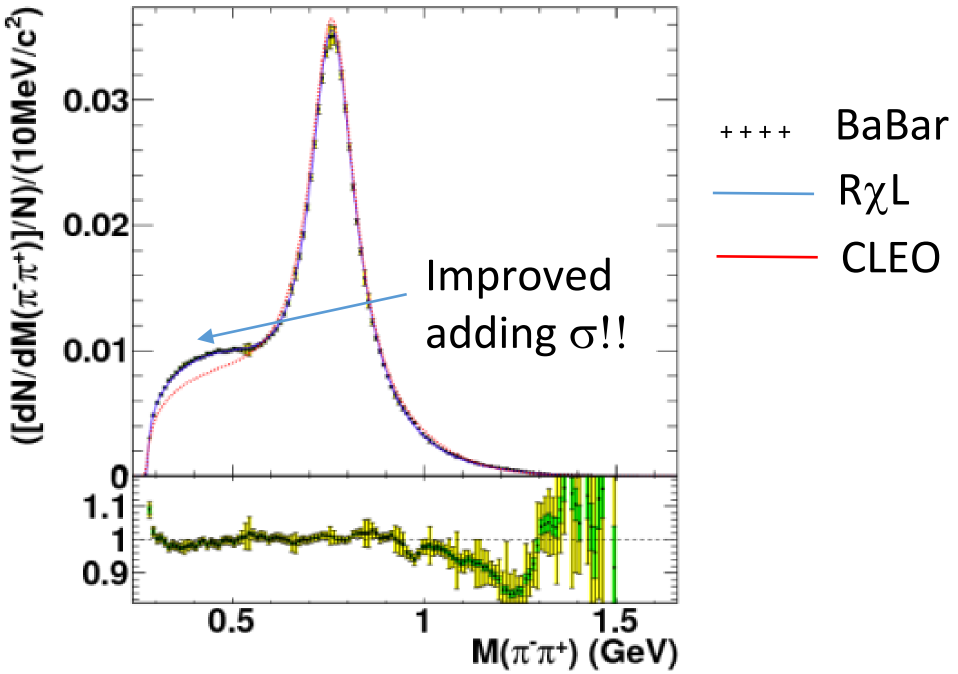

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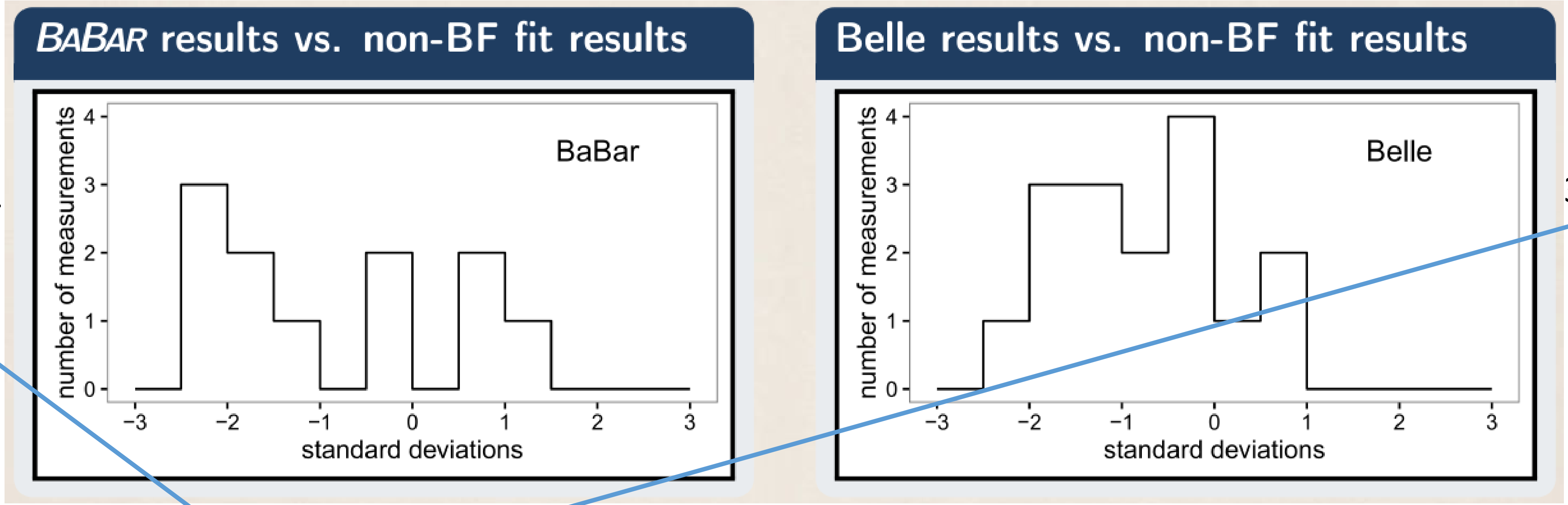
Improved **BR** measurements to test **Unitarity**

A. Lusiani, HFAG Status, TAU'16

1.58 ±0.13 ±0.12

Phys.Rev.Lett. 100 (2008) 011801



3.29 ±0.17 ±0.20

Phys.Rev. D81 (2010) 113007

BABAR and Belle $\mathcal{B}(\tau \rightarrow K^- K^- K^+ \nu_\tau)$ results (times 10^{-5})

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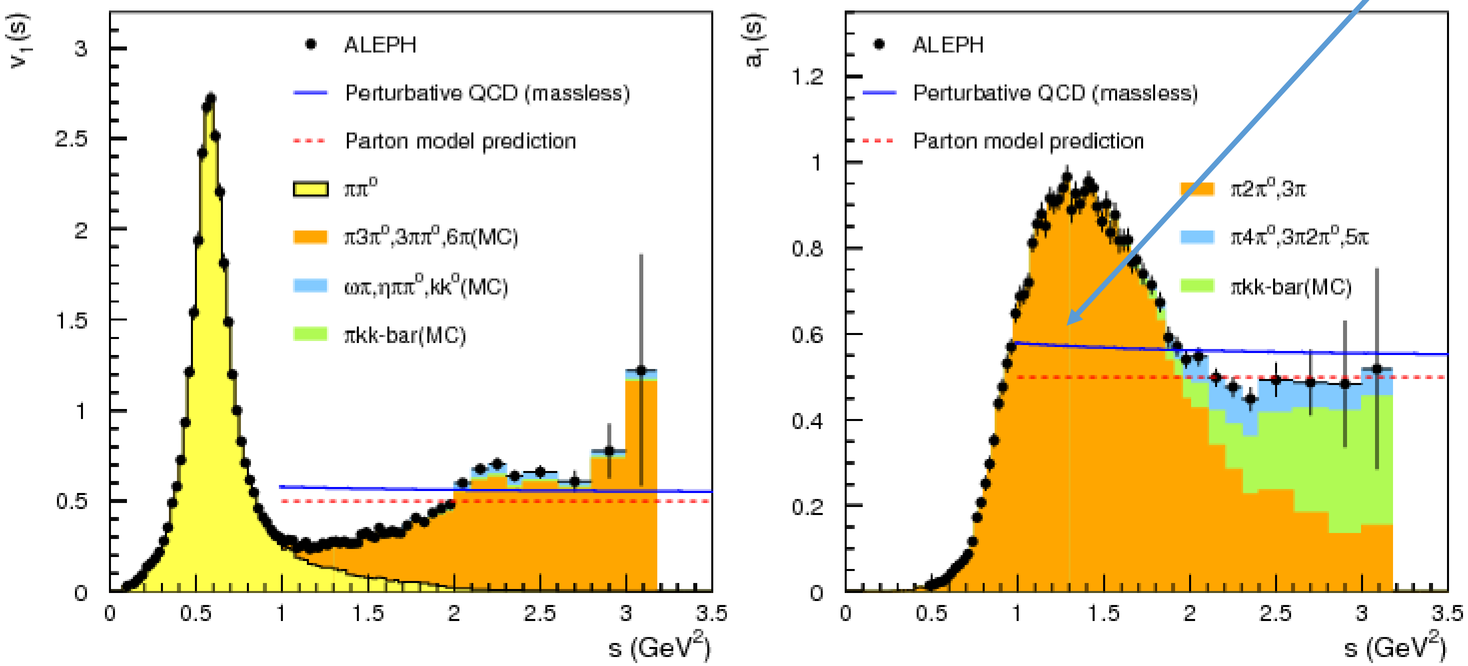
Better **non-strange spectral functions**

Davier, Michel et al. Eur.Phys.J. C74 (2014) no.3



DV's

$\alpha_s(M_Z^2)$

$$R_\tau^{\exp} = \frac{\Gamma[\tau^- \to \nu_\tau + \mathrm{hadrons}]}{\Gamma[\tau^- \to e^- \bar{\nu}_e \nu_\tau]} = 3.6280(94)$$

$$R_\tau^{V+A} = 3|V_{ud}|^2 S_{\mathrm{EW}} \left[1 + \delta^{(0)} + \delta^{\mathrm{NP}}_{V+A}\right]$$

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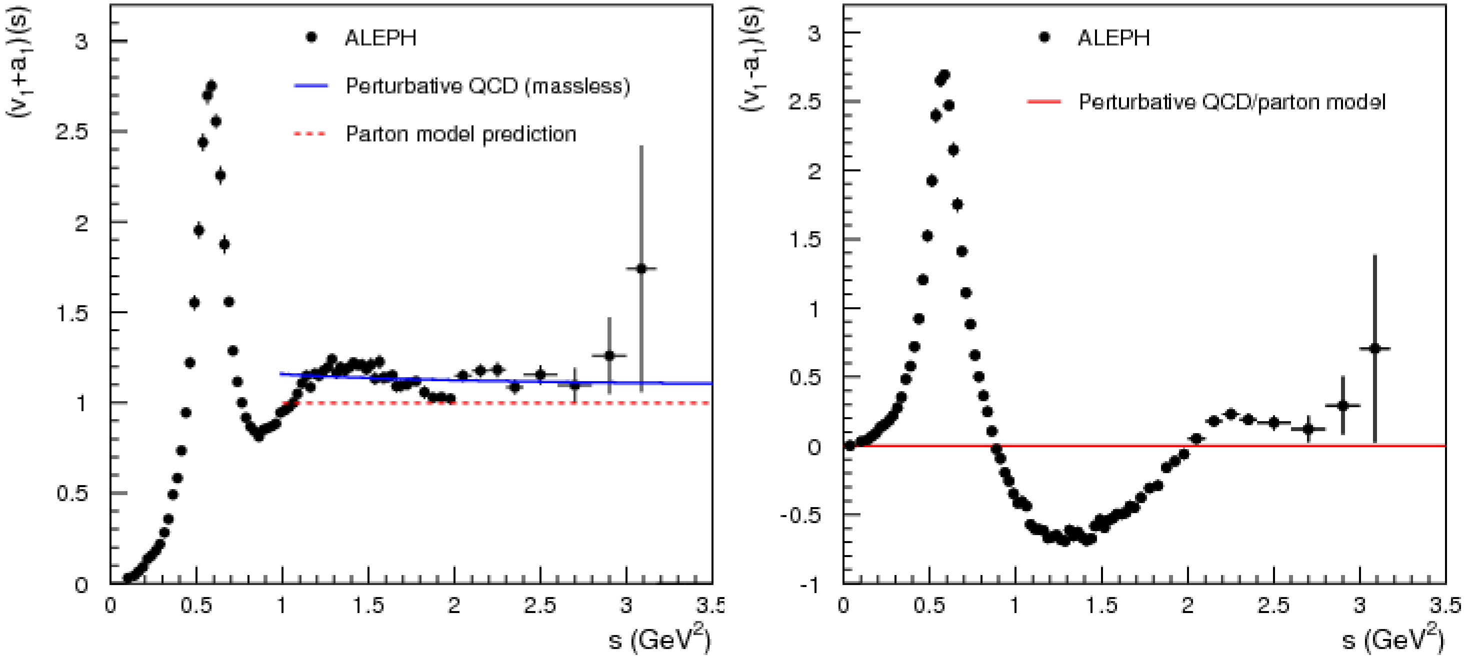

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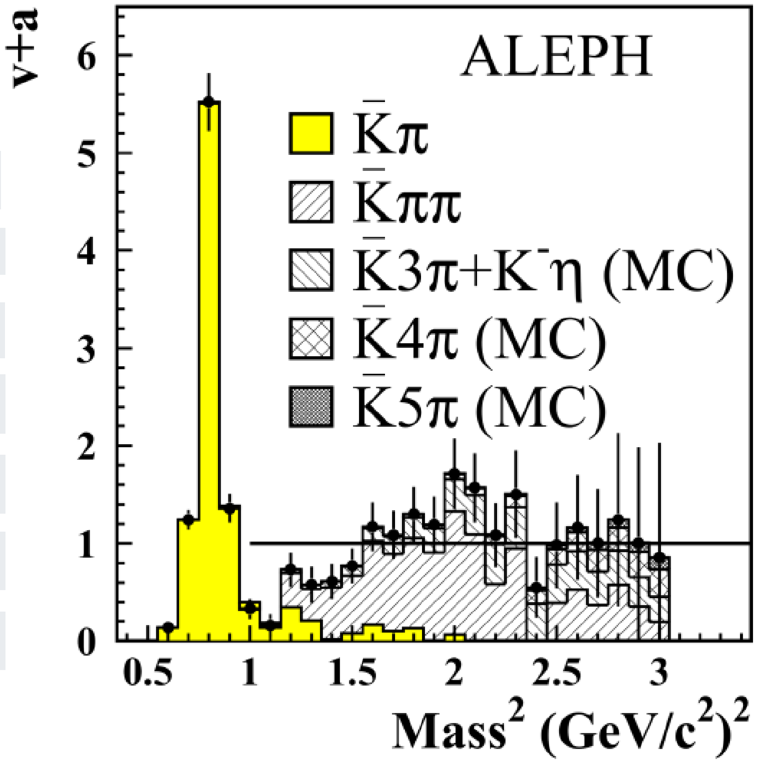
HFAG '16 errors on main strange BRs (%)

$\pi^- \bar{K}^0 \pi^0 \pi^0 \nu_\tau$ (ex. K^0)	0.0234 ± 0.0231
$K^- 2\pi^0 \nu_\tau$ (ex. K^0)	0.0640 ± 0.0220
$K^- 3\pi^0 \nu_\tau$ (ex. K^0, η)	0.0428 ± 0.0216
$K^- \pi^0 \nu_\tau$	0.4327 ± 0.0149
$K^- \pi^- \pi^+ \pi^0 \nu_\tau$ (ex. K^0, ω, η)	0.0410 ± 0.0143
$\pi^- \bar{K}^0 \nu_\tau$	0.8386 ± 0.0141
$\pi^- \bar{K}^0 \pi^0 \nu_\tau$	0.3812 ± 0.0129



Miss-ID between π's & K's

$m_s(m_s)$ & V_{us}

$$\delta R_\tau = \frac{R_{\tau,V+A}}{|V_{ud}|^2} - \frac{R_{\tau,S}}{|V_{us}|^2}$$

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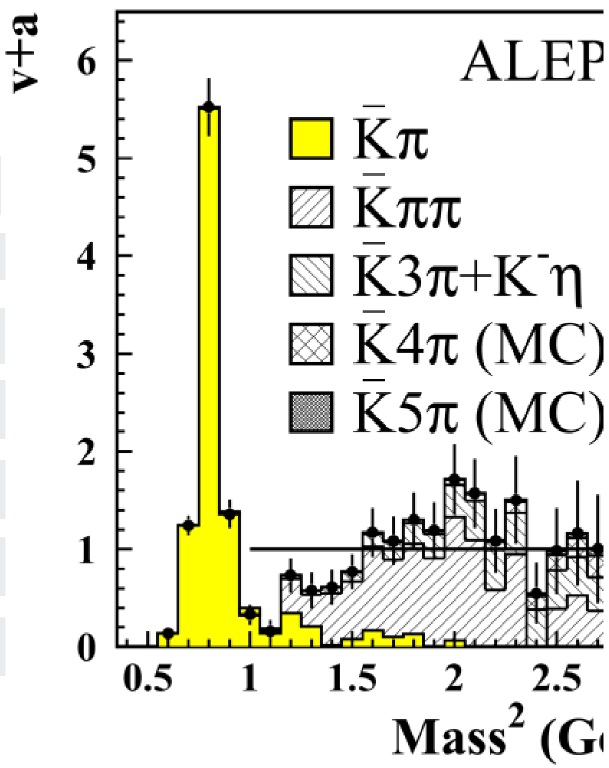

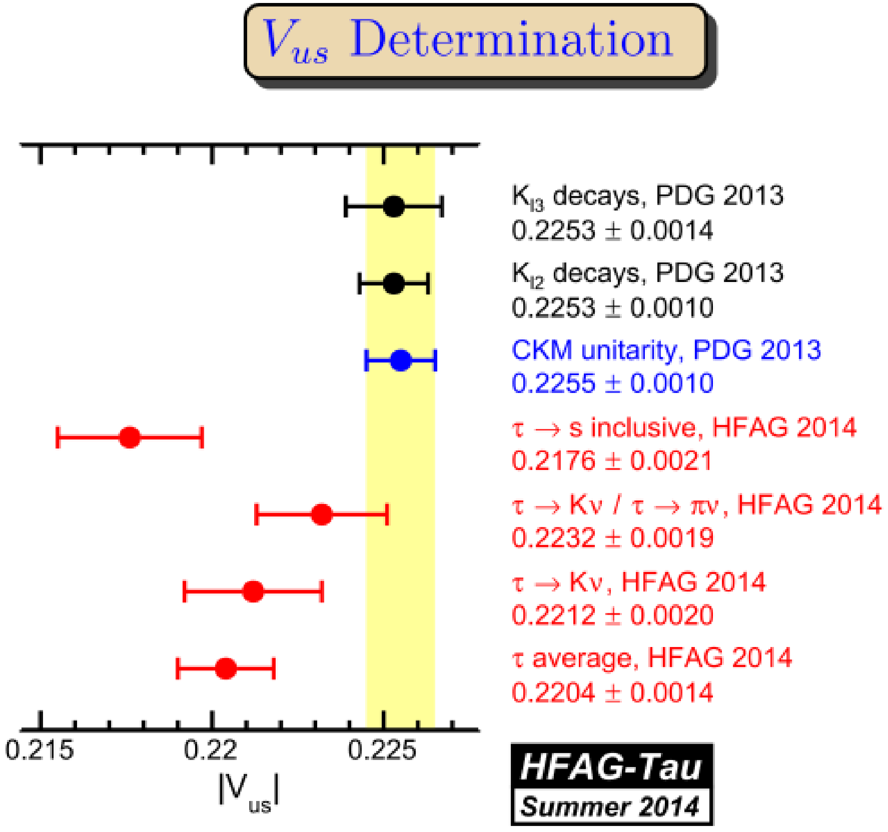

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TAUOLA for Belle-II

Jorge Martínez: México en Belle-II

LNV @ Belle-II

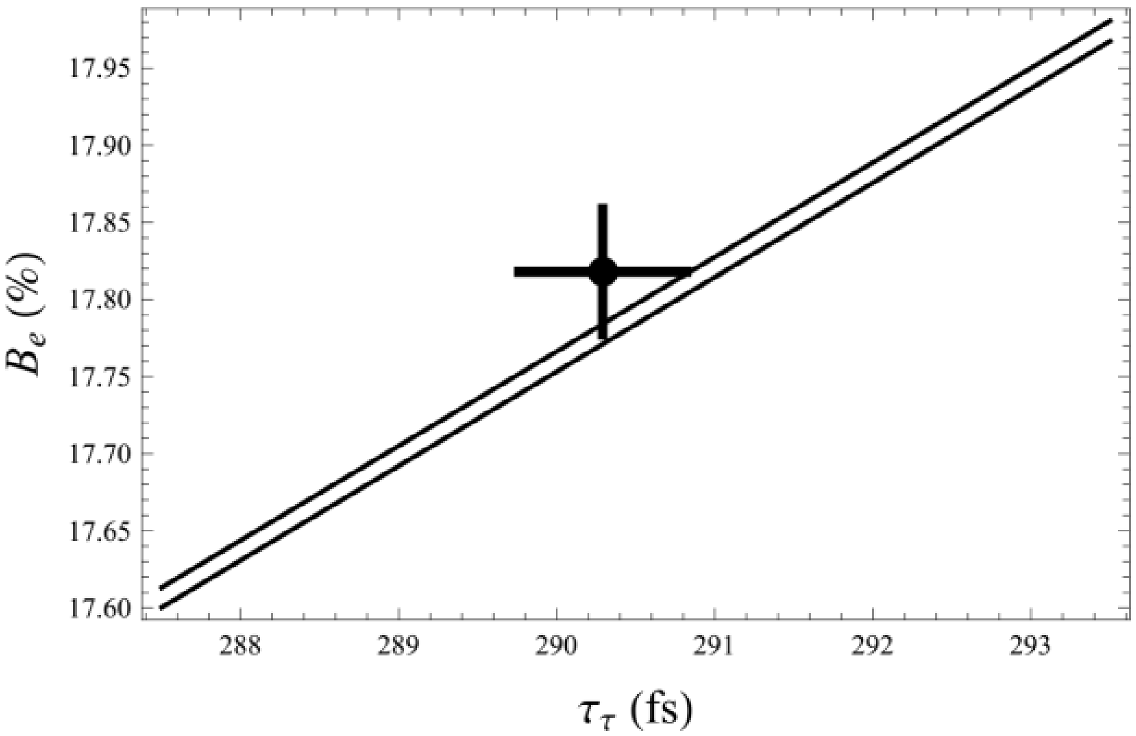
Pedro Podesta: LNV en Belle-II

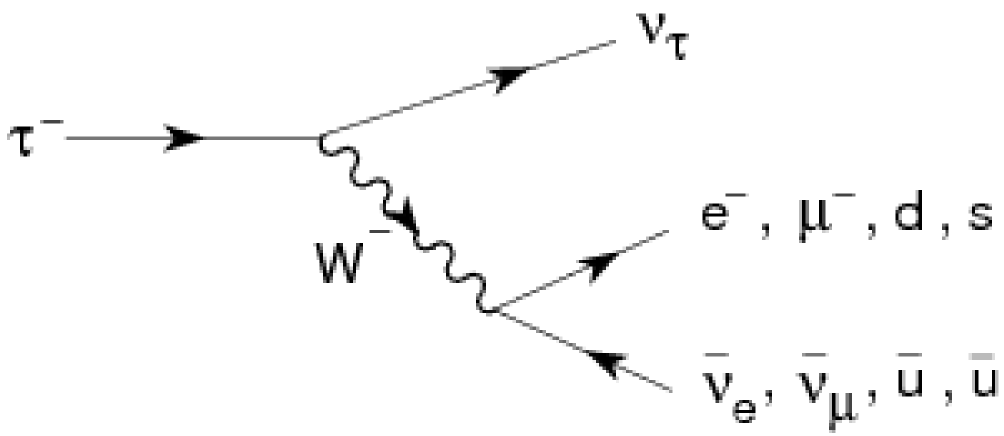
Desintegraciones leptónicas de taus

Pich, A. Prog.Part.Nucl.Phys. 75 (2014) 41-85

$$\Gamma_{\ell\to\ell'} \equiv \Gamma[\ell^- \to \ell'^- \bar{\nu}_{\ell'} \nu_\ell(\gamma)] = \frac{G_{\ell'\ell}^2 m_\ell^5}{192\pi^3} f\left(m_{\ell'}^2/m_\ell^2\right) \left(1+\delta_{\rm RC}^{\ell'\ell}\right)$$

$$B_e = \frac{B_\mu}{0.972559 \pm 0.000005} = \frac{\tau_\tau}{(1632.9 \pm 0.6) \times 10^{-15}\,\mathrm{s}}$$





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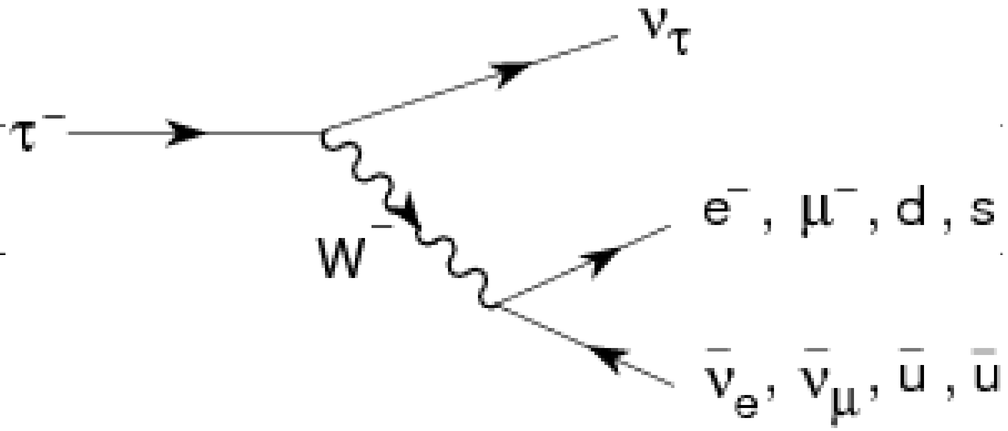
Pich, A. Prog.Part.Nucl.Phys. 75 (2014) 41-85

	$\Gamma_{\tau\to\mu}/\Gamma_{\tau\to e}$	$\Gamma_{\pi\to\mu}/\Gamma_{\pi\to e}$	$\Gamma_{K\to\mu}/\Gamma_{K\to e}$	$\Gamma_{K\to\pi\mu}/\Gamma_{K\to\pi e}$	$\Gamma_{W\to\mu}/\Gamma_{W\to e}$
$\|g_\mu/g_e\|$	1.0018 (14)	1.0021 (16)	0.9978 (20)	1.0010 (25)	0.996 (10)

	$\Gamma_{\tau\to e}/\Gamma_{\mu\to e}$	$\Gamma_{\tau\to\pi}/\Gamma_{\pi\to\mu}$	$\Gamma_{\tau\to K}/\Gamma_{K\to\mu}$	$\Gamma_{W\to\tau}/\Gamma_{W\to\mu}$
$\|g_\tau/g_\mu\|$	1.0011 (15)	0.9962 (27)	0.9858 (70)	1.034 (13)

	$\Gamma_{\tau\to\mu}/\Gamma_{\mu\to e}$	$\Gamma_{W\to\tau}/\Gamma_{W\to e}$
$\|g_\tau/g_e\|$	1.0030 (15)	1.031 (13)



$$R_{P\to e/\mu} \equiv \frac{\Gamma[P^-\to e^-\bar{\nu}_e(\gamma)]}{\Gamma[P^-\to \mu^-\bar{\nu}_\mu(\gamma)]} = \left|\frac{g_e}{g_\mu}\right|^2 \frac{m_e^2}{m_\mu^2}\left(\frac{1-m_e^2/m_P^2}{1-m_\mu^2/m_P^2}\right)^2 (1+\delta R_{P\to e/\mu})$$

Desintegraciones leptónicas de taus

Michel '50, Bouchiat & Michel '57
Kinoshita & Sirlin '57, '57

$\ell^- \to \ell'^- \bar{\nu}_{\ell'} \nu_\ell$

(See also A. Pich PPNP '14)

$\mathcal{P}_\ell$

$$\omega \equiv (m_\ell^2 + m_{\ell'}^2)/2m_\ell$$

$$x \equiv E_{\ell'}/\omega$$

$$x_0 \equiv m_{\ell'}/\omega$$

$$\frac{d^2\Gamma_{\ell\to\ell'}}{dx\, d\cos\theta} = \frac{m_\ell\, \omega^4}{2\pi^3} G_{\ell'\ell}^2 \sqrt{x^2 - x_0^2} \left\{ F(x) - \frac{\xi}{3} \mathcal{P}_\ell \sqrt{x^2 - x_0^2} \cos\theta\, A(x) \right\}$$

$$F(x) = x(1-x) + \frac{2}{9}\rho\left(4x^2 - 3x - x_0^2\right) + \eta\, x_0(1-x)\,,$$

$$A(x) = 1 - x + \frac{2}{3}\delta\left(4x - 4 + \sqrt{1 - x_0^2}\right).$$

Desintegraciones leptónicas de taus

Michel '50, Bouchiat & Michel '57
Kinoshita & Sirlin '57, '57

$\ell^- \to \ell'^- \bar{\nu}_{\ell'} \nu_\ell$

(See also A. Pich PPNP '14)

$\mathcal{P}_\ell$

$\omega \equiv (m_\ell^2 + m_{\ell'}^2)/2m_\ell$

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Michel parameter

Low-E parameter

$(\xi', \xi'', \eta'', \alpha', \beta')$

(if $P_{l'}$ is known)

These can be determined knowing $\mathcal{P}_\ell$

In the **SM** $\rho=\delta=3/4$, $\eta=0$, $\xi=1$.

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Low-E parameter

$(\xi',\, \xi'',\, \eta'',\, \alpha',\, \beta')$

(if $P_{l'}$ is known)

These can be determined knowing $\mathcal{P}_\ell$

In the **SM** ρ=δ=3/4, η=0, ξ=1.

For **massless neutrinos**, $\Gamma_{\ell\to\ell'} = \frac{\widehat{G}_{\ell'\ell}^2 m_\ell^5}{192\pi^3} f\left(m_{\ell'}^2/m_\ell^2\right)\left(1 + \delta_{\rm RC}^{\ell'\ell}\right)$, $\quad \widehat{G}_{\ell'\ell} \equiv G_{\ell'\ell}\sqrt{1 + 4\,\eta\, \frac{m_{\ell'}}{m_\ell}\, \frac{g(m_{\ell'}^2/m_\ell^2)}{f(m_{\ell'}^2/m_\ell^2)}}$,

$$f(x) = 1 - 8x + 8x^3 - x^4 - 12x^2 \log x \qquad \delta_{\rm RC}^{\ell'\ell} = \frac{\alpha}{2\pi}\left[\frac{25}{4} - \pi^2 + \mathcal{O}\left(\frac{m_{\ell'}^2}{m_\ell^2}\right)\right] + \cdots \qquad g(z) = 1 + 9z - 9z^2 - z^3 + 6z(1+z)\log z$$

Desintegraciones leptónicas de taus

Michel '50, Bouchiat & Michel '57
Kinoshita & Sirlin '57, '57

$\ell^- \to \ell'^- \bar{\nu}_{\ell'} \nu_\ell$

(See also A. Pich PPNP '14)

	$\mu^- \to e^- \bar{\nu}_e \nu_\mu$	$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$	$\tau^- \to e^- \bar{\nu}_e \nu_\tau$	$\tau^- \to \ell^- \bar{\nu}_\ell \nu_\tau$
ρ	0.74979 ± 0.00026	0.763 ± 0.020	0.747 ± 0.010	0.745 ± 0.008
η	0.057 ± 0.034	0.094 ± 0.073	—	0.013 ± 0.020
ξ	$1.0009 {}^{+0.0016}_{-0.0007}$	1.030 ± 0.059	0.994 ± 0.040	0.985 ± 0.030
$\xi\delta$	$0.7511 {}^{+0.0012}_{-0.0006}$	0.778 ± 0.037	0.734 ± 0.028	0.746 ± 0.021

→ In **radiative leptonic lepton decays**, the photon carries information about spin state of daughter lepton. As a result, **two additional Michel-like parameters** can be extracted *(more on this in the EFT section)*.

→ $L \to l\, \nu_L\, \nu_l\, \gamma$ @ NLO shows a tension with the BaBar '15 measurement of **3.5 σ** (Fael, Mercolli & Passera '15)

$\tau \to e \gamma \bar{\nu}_e \nu_\tau$

It can be **check**ed with $\tau \to 3e\, 2\nu$!!

→ In the case of the **5-lepton lepton decays**, the current accuracy in **MP** determination (from μ decays) can be improved using tau decays @Belle-II ([10,20]% → [3,5]%). (D. Epifanov, past KEKFF & B2TIP Workshops)

Hardest **background for LFV L → l l' l'** decays: they must be described accurately in Belle's TAUOLA (D. Epifanov).

Alain Flores-Tlalpa, Gabriel López-Castro, PR JHEP 1604 (2016) 185

LFV en desintegraciones de taus

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After the discovery of ν oscillations, flavor violation only remains unmeasured in the charged lepton sector.

LFV en desintegraciones de taus

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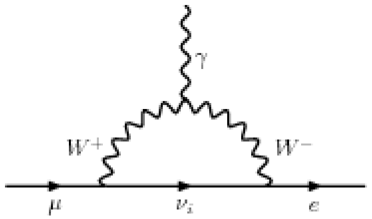

$B(\mu \to e\gamma) \lesssim 10^{-54}$ Marciano-Sanda '77, Bilenky-Petcov-Pontecorvo '77, Cheng-Li '77

LFV en desintegraciones de taus

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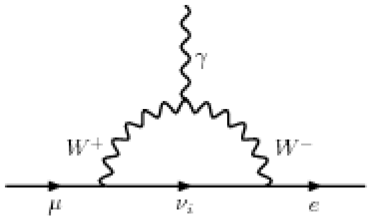


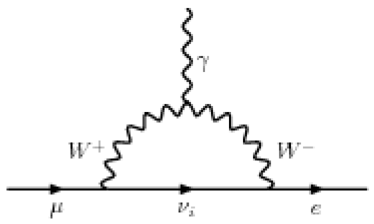
$B(\mu \to e\gamma) \lesssim 10^{-54}$ Marciano-Sanda '77, Bilenky-Petcov-Pontecorvo '77, Cheng-Li '77

$B(\mu^+ \to e^+\gamma) \leq 5.7 \times 10^{-13}$

4.2

LFV en desintegraciones de taus

After the discovery of ν oscillations, flavor violation only remains unmeasured in the charged lepton sector.

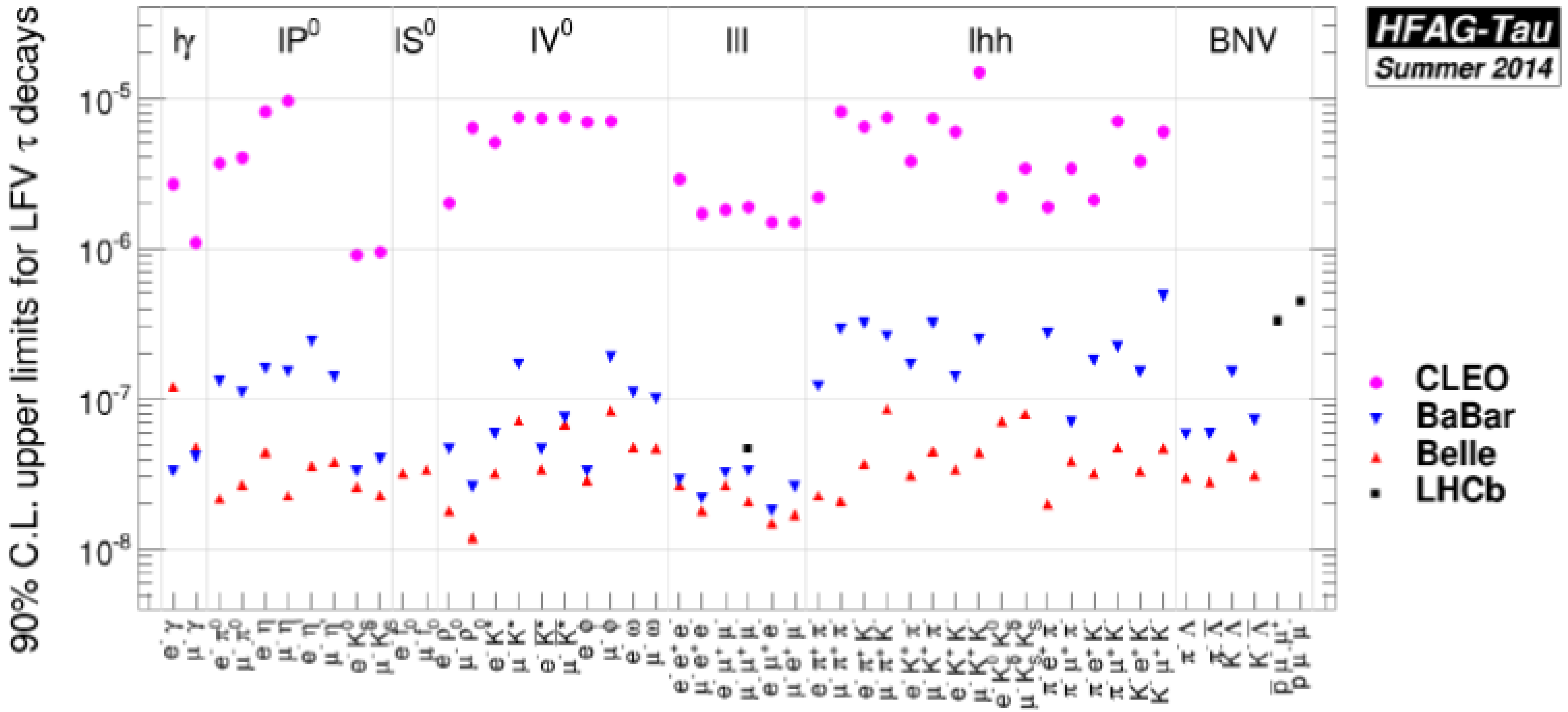


$B(\mu \to e\gamma) \lesssim 10^{-54}$ Marciano-Sanda ‘77, Bilenky-Petcov-Pontecorvo ‘77, Cheng-Li ‘77

MEG’s present upper bound: $B(\mu^+ \to e^+\gamma) \leq 5.7 \times 10^{-13}$ (5.7 → 4.2)

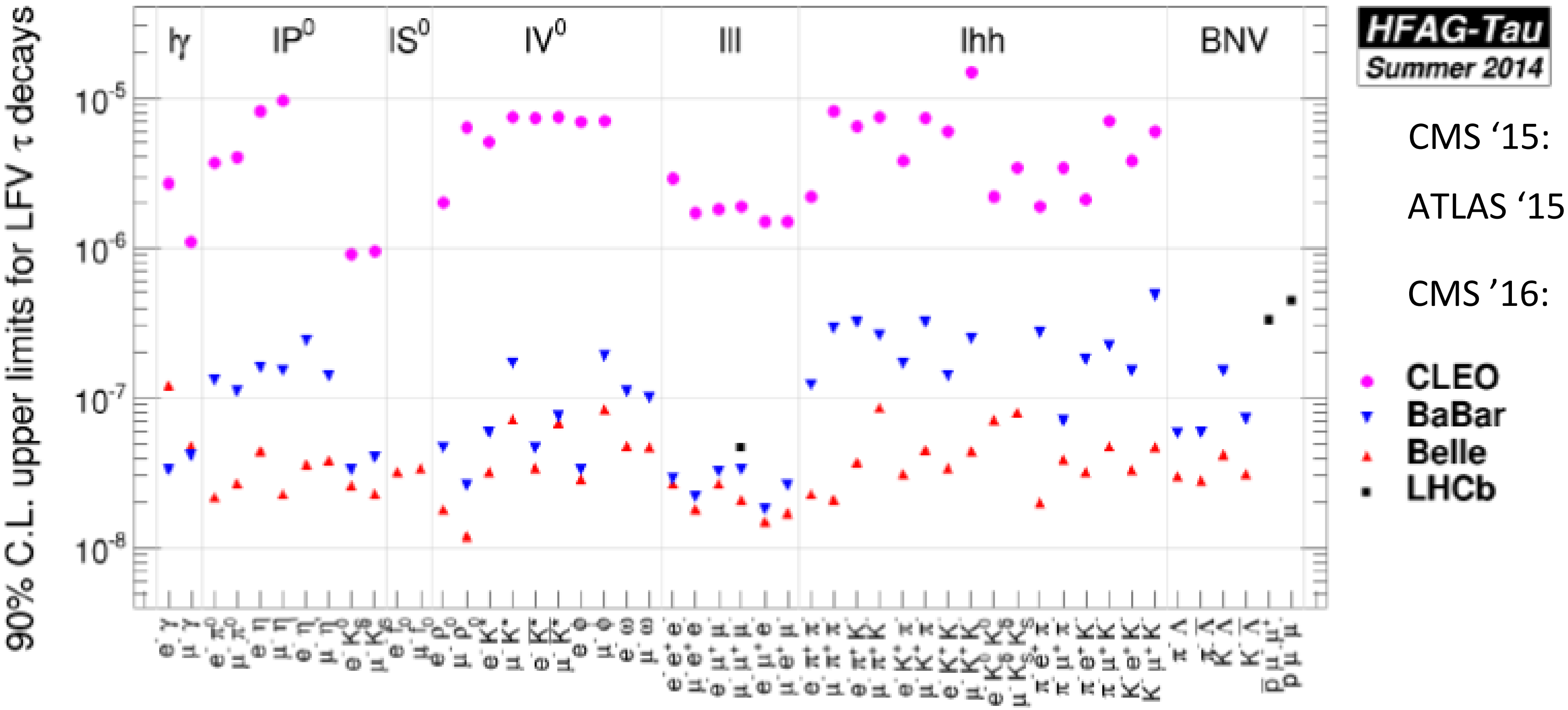
Hunt of New Physics at MEG, MEGA, SINDRUM (II), Mu2e, Mu3e, COMET, PRISM, Belle-II, ATLAS & CMS, …

LFV en desintegraciones de taus



And 2 orders of magnitude improvement expected for Belle-II !!

LFV en desintegraciones de taus



¿Posible conexión?

CMS '15: $BR(H \to \tau\mu) = (0.84^{+0.39}_{-0.37})\,\%$

ATLAS '15: $BR(H \to \tau\mu) < 1.85\%$ at 95% CL

CMS '16: $BR(H \to \tau\mu) = (-0.76 \pm 0.81)\,\%$

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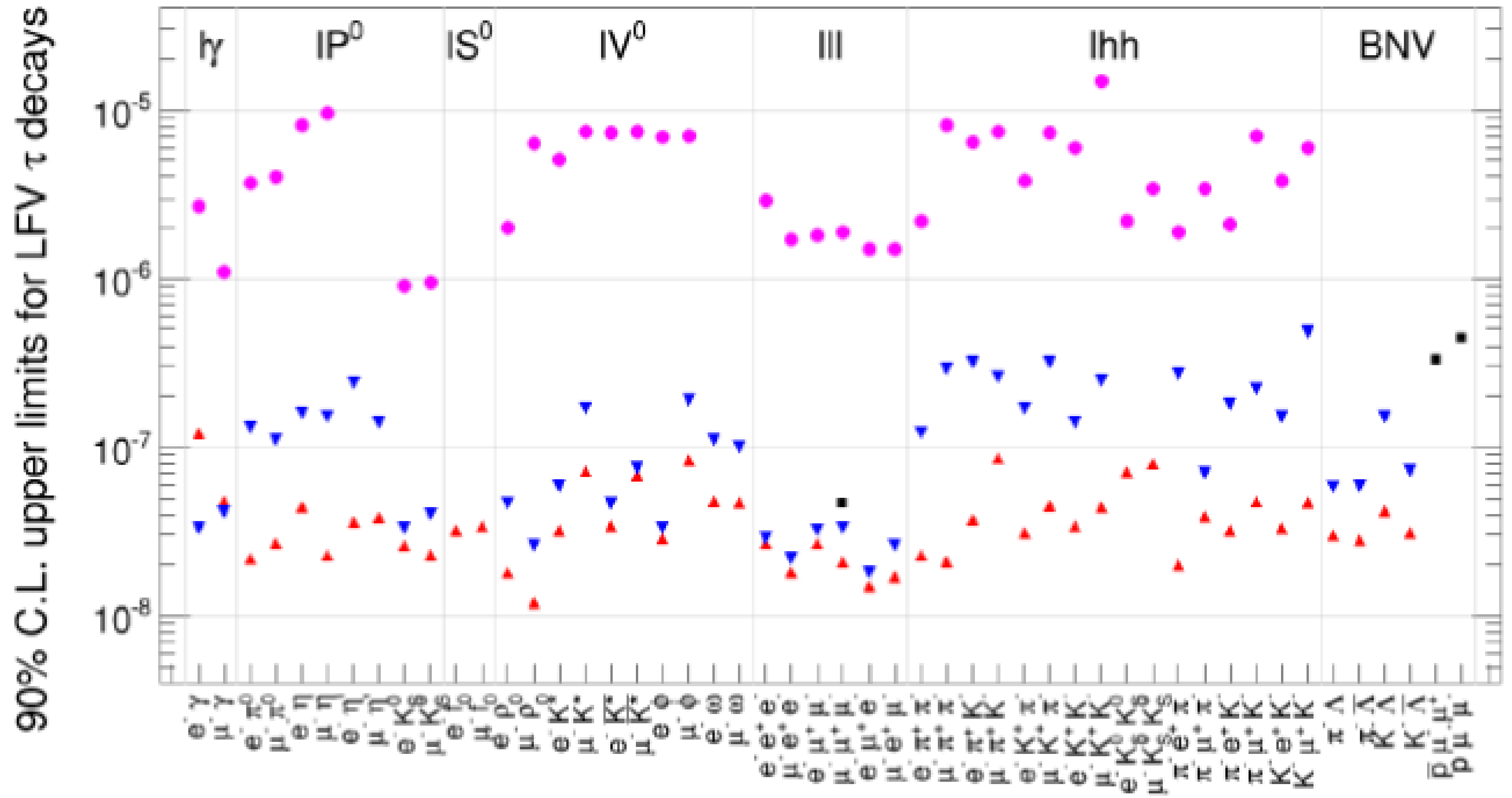
LFV en desintegraciones de taus



HFAG-Tau Summer 2014

- CLEO
- BaBar
- Belle
- LHCb

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And 2 orders of magnitude improvement expected for Belle-II !!

Se espera que LFV pueda ayudar a resolver alguno de los problemas del SM

Gabriel López Castro: $a_\mu^{HVP,LO}$	Pedro Podesta: LNV en Belle-II	Jorge Martínez: México en Belle-II

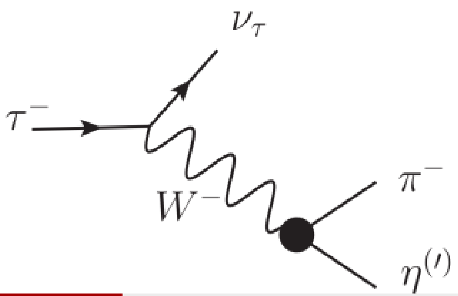
Física del tau: Motivación

Pablo Roig
Dpto. de Física del Cinvestav, Ciudad de México

Reunión general de la RED-FAE, 10-12 de Noviembre de 2016, Pachuca, Hidalgo, México

ADDITIONAL MATERIAL

Towards the discovery of Second Class Currents in $\tau^- \to \pi^- \eta \, \nu_\tau$ decays @ Belle-II



$$\overset{q^2 \ll M_W^2}{=} \frac{G_F}{\sqrt{2}} V_{ud} \bar{u}(p_{\nu_\tau}) \gamma^\mu (1-\gamma^5) u(p_\tau) \langle \pi^- \eta^{(\prime)} | \bar{d} \gamma^\mu (1 - \underbrace{\cancel{\gamma^5}}_{0^-,1^+ \nrightarrow 0^+,1^-}) u | 0 \rangle$$

$$\leftrightarrow \quad \Delta_{PQ} = M_P^2 - M_Q^2$$

$$\langle \pi^- \eta^{(\prime)} | \bar{d} \gamma^\mu u | 0 \rangle = \left[(p_{\eta^{(\prime)}} - p_\pi)^\mu + \frac{\Delta_{\pi^-\eta^{(\prime)}}}{s} q^\mu \right] C^V_{\pi\eta^{(\prime)}} F_+^{\pi\eta^{(\prime)}}(s) + \frac{\Delta^{QCD}_{K^0K^+}}{s} q^\mu C^S_{\pi^-\eta^{(\prime)}} F_0^{\pi^-\eta^{(\prime)}}(s)$$

Matrix element & decay width

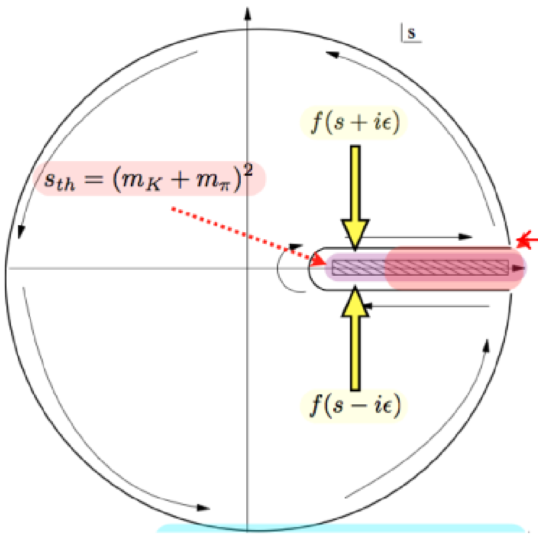
$$\frac{d\Gamma\left(\tau^- \to \pi^- \eta^{(\prime)} \nu_\tau\right)}{d\sqrt{s}} = \frac{G_F^2 M_\tau^3}{24\pi^3 s} S_{EW} |V_{ud}|^2 |F_+^{\pi^-\eta^{(\prime)}}(0)|^2 \left(1 - \frac{s}{M_\tau^2}\right)^2$$

$$\left\{ \left(1 + \frac{2s}{M_\tau^2}\right) q^3_{\pi^-\eta^{(\prime)}}(s) |\widetilde{F}_+^{\pi^-\eta^{(\prime)}}(s)|^2 + \frac{3\Delta^2_{\pi^-\eta^{(\prime)}}}{4s} q_{\pi^-\eta^{(\prime)}}(s) |\widetilde{F}_0^{\pi^-\eta^{(\prime)}}(s)|^2 \right\}$$

$$\widetilde{F}_{+,0}^{\pi^-\eta^{(\prime)}}(s) = \frac{F_{+,0}^{\pi^-\eta^{(\prime)}}(s)}{F_{+,0}^{\pi^-\eta^{(\prime)}}(0)}, \qquad F_+^{\pi^-\eta^{(\prime)}}(0) = -\frac{C^S_{\pi^-\eta^{(\prime)}}}{C^V_{\pi^-\eta^{(\prime)}}} \frac{\Delta^{QCD}_{K^0K^+}}{\Delta_{\pi^-\eta^{(\prime)}}} F_0^{\pi^-\eta^{(\prime)}}(0)$$

Pablo Roig **Cinvestav (Mexico City)**

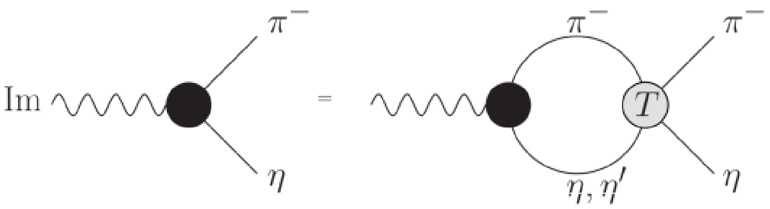
Towards the discovery of Second Class Currents in $\tau^- \to \pi^- \eta \nu_\tau$ decays @ Belle-II



Other cuts $(K\bar{K}, \pi\eta' \ldots)$

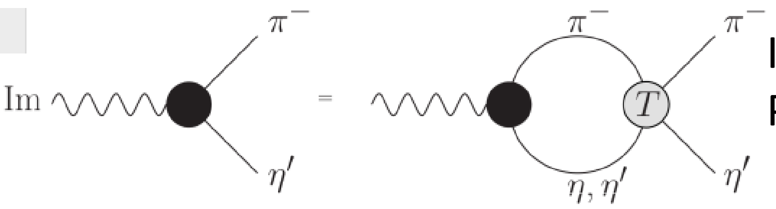
$$F_0^i(s) = \frac{1}{\pi}\sum_{j=1}^{2}\int_{s_i}^{\infty} ds' \frac{\Sigma_j(s')F_0^j(s')T_0^{i\to j}(s')^\star}{(s'-s-i\varepsilon)}$$

Coupled channels for the SFF



$$F_0^{\pi\eta}(s) = \frac{1}{\pi}\int_{s_{th1}}^{\infty} ds' \frac{\sigma_{\pi\eta}(s')F_0^{\pi\eta}(s')T^*_{\pi\eta\to\pi\eta}(s')}{s'-s-i\varepsilon} + \frac{1}{\pi}\int_{s_{th2}}^{\infty} ds' \frac{\sigma_{\pi\eta'}(s')F_0^{\pi\eta'}(s')T^*_{\pi\eta'\to\pi\eta}(s')}{s'-s-i\varepsilon}$$

S.Gonzàlez-Solís | TAU'16

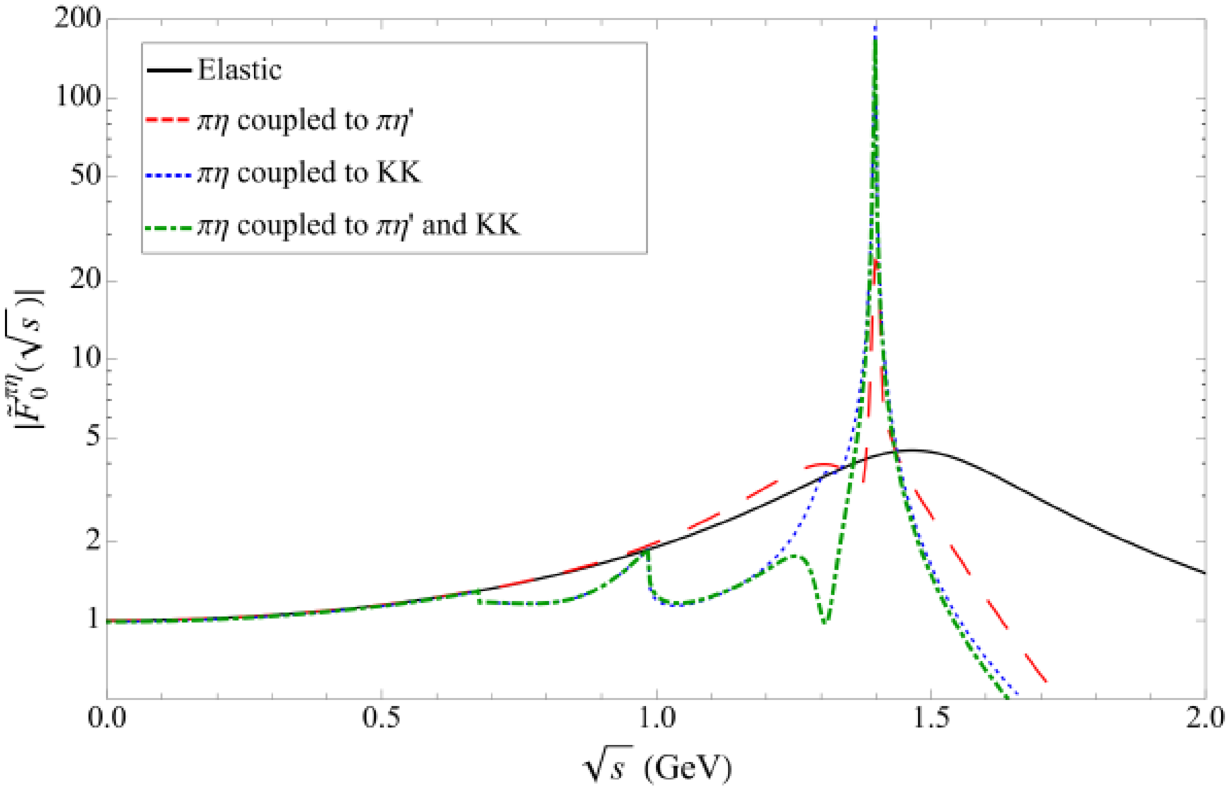


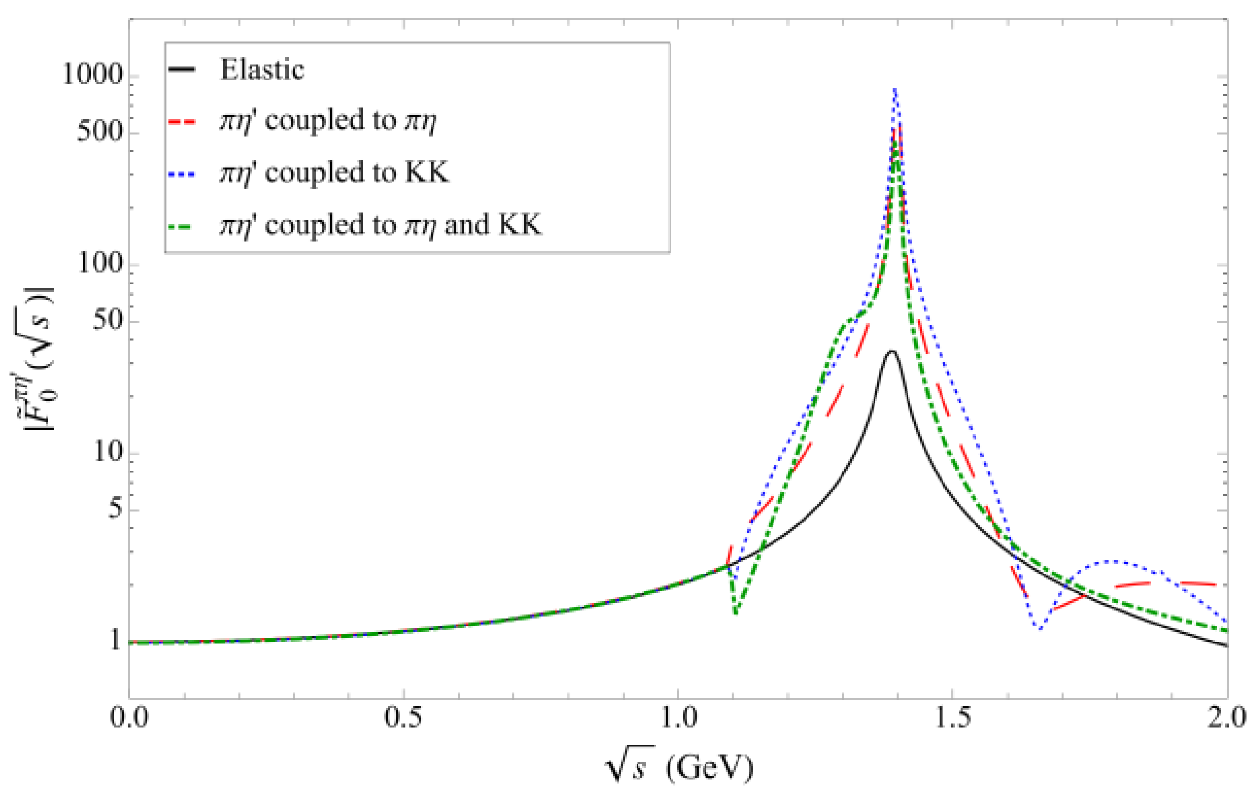
Input from Guo, Oller & Ruiz de Elvira Phys. Rev. D 86, 054006 (2012)

$$F_0^{\pi\eta'}(s) = \frac{1}{\pi}\int_{s_{th1}}^{\infty} ds' \frac{\sigma_{\pi\eta}(s')F_0^{\pi\eta}(s')T^*_{\pi\eta\to\pi\eta'}(s')}{s'-s-i\varepsilon} + \frac{1}{\pi}\int_{s_{th2}}^{\infty} ds' \frac{\sigma_{\pi\eta'}(s')F_0^{\pi\eta'}(s')T^*_{\pi\eta'\to\pi\eta'}(s')}{s'-s-i\varepsilon}$$

Towards the discovery of Second Class Currents in $\tau^- \to \pi^- \eta \nu_\tau$ decays @ Belle-II

Main physical effect: Coupling of $\pi\eta$ & KK channels on $\pi\eta$ SFF !!





Pablo Roig

Cinvestav (Mexico City)

Towards the discovery of Second Class Currents in $\tau^- \to \pi^- \eta \nu_\tau$ decays @ Belle-II

- π^0-η-η' mixing (P. Kroll, Mod. Phys. Lett. A20, 2667 (2005))

$$\begin{pmatrix} \pi^0 \\ \eta \\ \eta' \end{pmatrix} = \begin{pmatrix} 1 & \varepsilon_{\pi\eta} c\theta_{\eta\eta'} + \varepsilon_{\pi\eta'} s\theta_{\eta\eta'} & \varepsilon_{\pi\eta'} c\theta_{\eta\eta'} - \varepsilon_{\pi\eta} s\theta_{\eta\eta'} \\ -\varepsilon_{\pi\eta} & c\theta_{\eta\eta'} & -s\theta_{\eta\eta'} \\ -\varepsilon_{\pi\eta'} & s\theta_{\eta\eta'} & c\theta_{\eta\eta'} \end{pmatrix} \cdot \begin{pmatrix} \pi_3 \\ \eta_8 \\ \eta_0 \end{pmatrix}$$

where $\varepsilon_{\pi\eta^{(\prime)}}$ and $\theta_{\eta\eta'}$ are the π^0-$\eta^{(\prime)}$ and η-η' mixing angles

- $\pi - \eta - \eta'$ mixing: Next-to-leading order prediction in Res. ChPT

$$F_+^{\pi^-\eta^{(\prime)}}(0) = -\frac{C^S_{\pi^-\eta^{(\prime)}}}{C^V_{\pi^-\eta^{(\prime)}}} \frac{\Delta^{QCD}_{K^0K^+}}{\Delta_{\pi^-\eta^{(\prime)}}} F_0^{\pi^-\eta^{(\prime)}}(0)$$

$$\left.\begin{aligned} F_+^{\pi^-\eta^{(\prime)}}(0) &= \varepsilon_{\pi\eta^{(\prime)}} \\ F_0^{\pi^-\eta^{(\prime)}}(0) &= c_0^{\pi^-\eta^{(\prime)}} \frac{M_S^2 + \Delta_{\pi^-\eta^{(\prime)}}}{M_S^2} \end{aligned}\right\} \quad \begin{aligned} \varepsilon_{\pi\eta} &= 9.8(3) \cdot 10^{-3} \\ \varepsilon_{\pi\eta'} &= 2.5(1.5) \cdot 10^{-4} \end{aligned}$$