HADRONIC DECAYS OF THE TAU LEPTON IN THE RESONANCE CHIRAL THEORY (RχT)

$$\tau^- \to (2K\,\pi)^- \, \nu_\tau$$

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XI Spring School “Bruno Touschek”

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EURIDICE

SUMMARY:

- Hadronic decays of the τ lepton
- Tools : χPT, RχT, Large Nc (inspired)
- Motivation : Analysis of $K^+K^-\pi^-$ channel
- Recent past : $\tau^- \to (\pi\,\pi\,\pi)^- \nu_\tau$ (Gómez Dumm, Pich, Portolés '04)
- Present & immediate future : $\tau^- \to (2K\,\pi)^- \nu_\tau$
- Outlook : $\tau \to (h_1 h_2 h_3)\, \nu_\tau$

HADRONIC DECAYS OF THE τ LEPTON

(Portolés '04)

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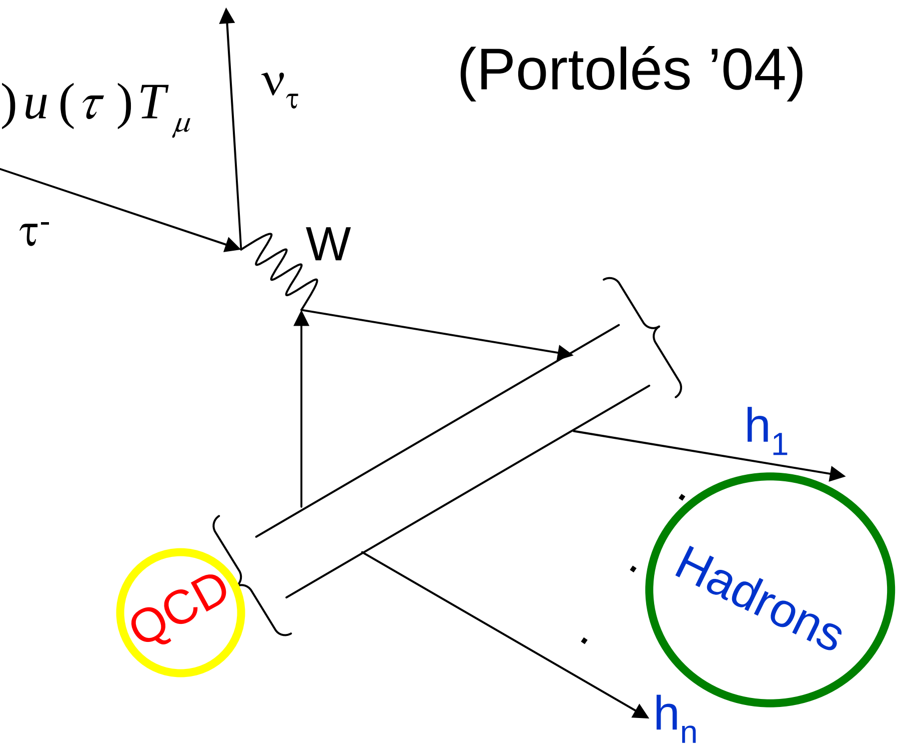

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=Σ_i(Lorentz Structure)^i $F_i(Q^2,s_j)$

$$d\Gamma = \frac{G_F^{\,2}}{4M_\tau^{\,2}} |V_{CKM}|^2 \, d\Phi^{(n+1)} \, L_{\mu\nu} T^\mu T^{\nu *}$$

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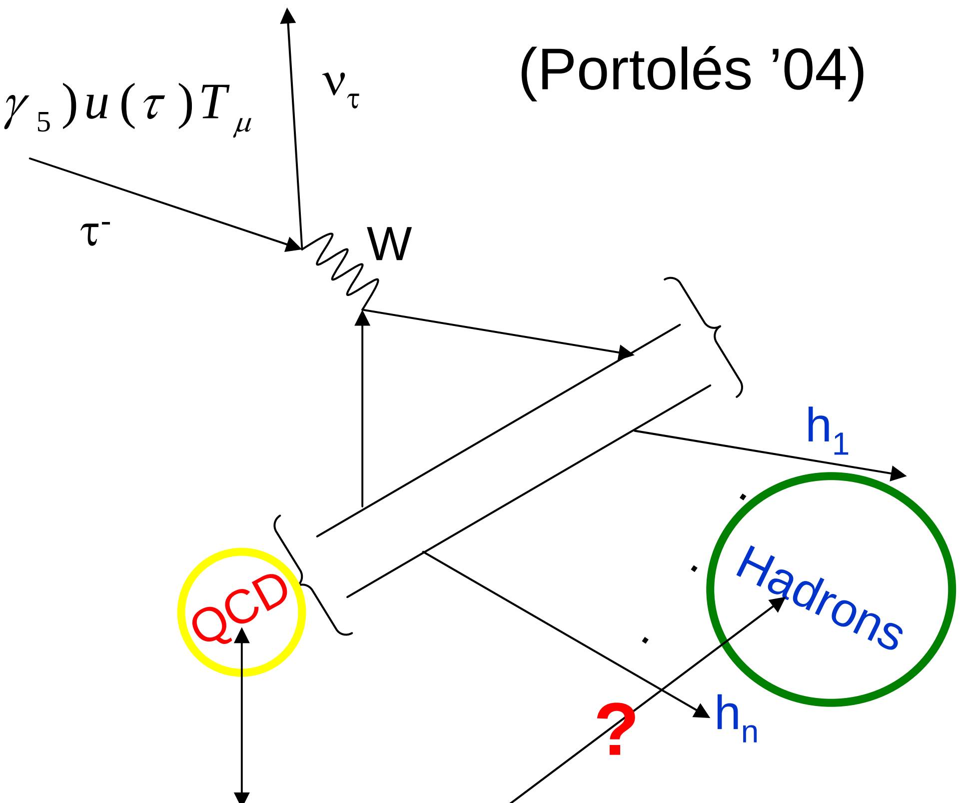

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$$\mathcal{L}_{QCD} = \mathcal{L}_{QCD}\,(q_i, G_\mu^a; g_s, m_i)$$

$\tau^- \to (2K\pi)^- \nu_\tau$ in RχT

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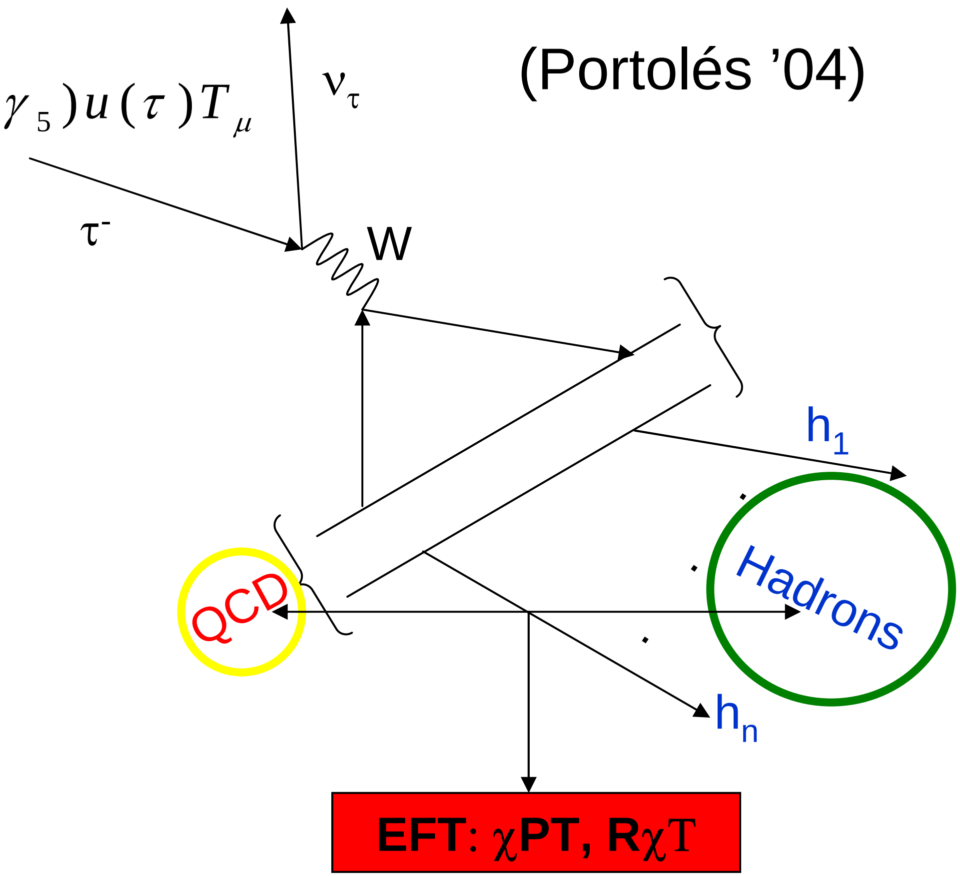

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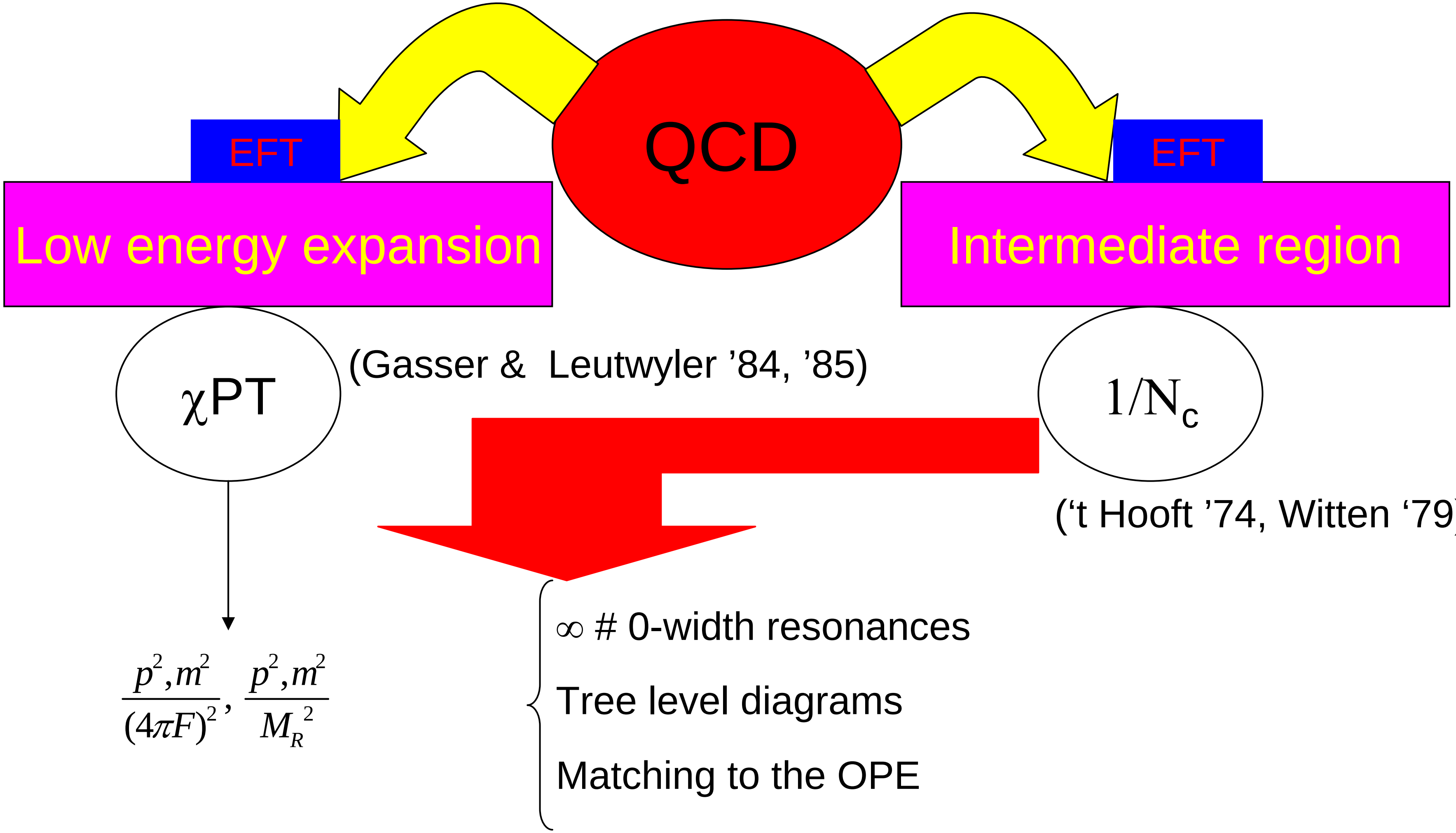
TOOLS: EFFECTIVE FIELD THEORIES



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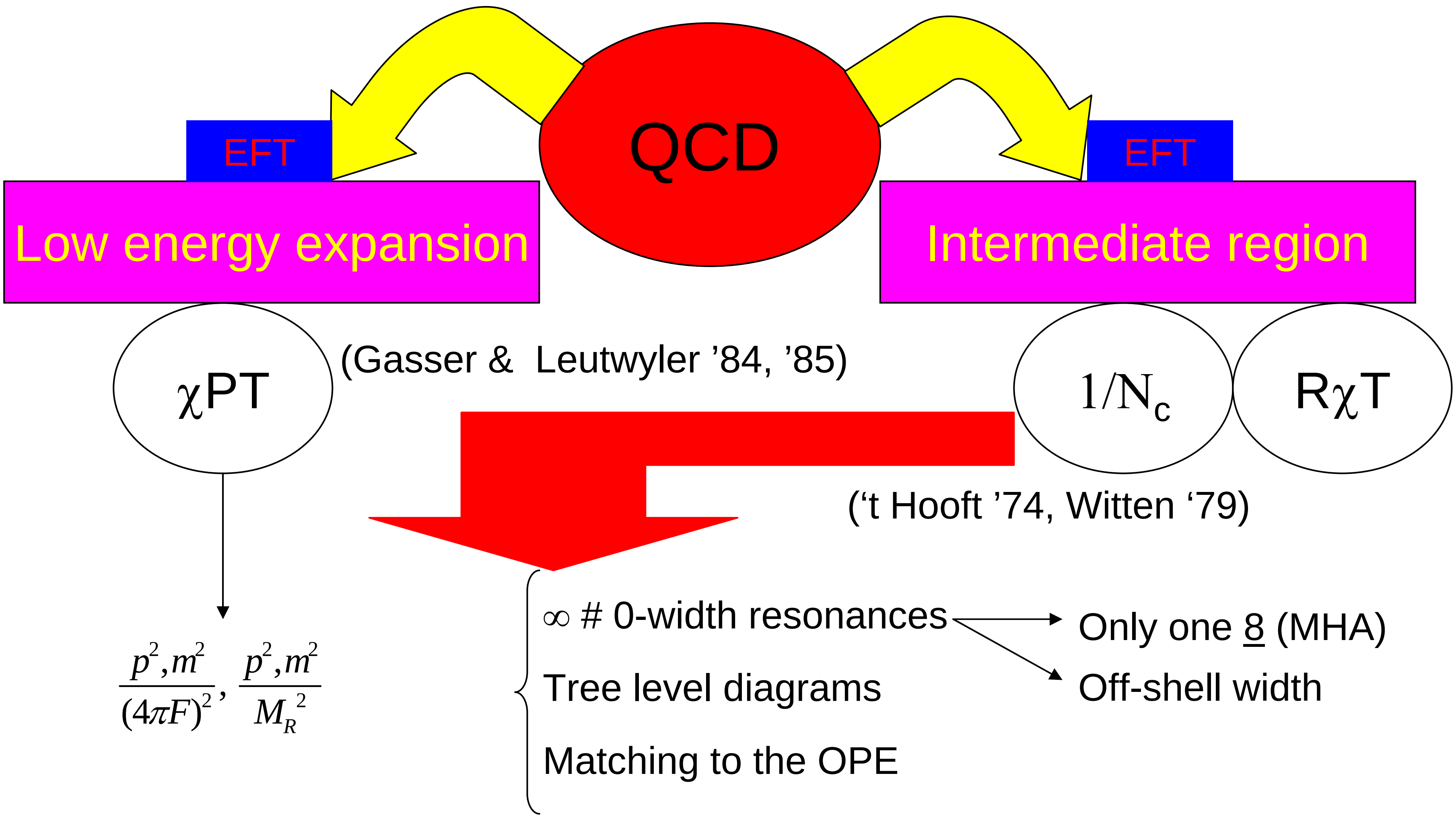

TOOLS : χPT

(Gasser & Leutwyler '84, '85)

$$\phi(x)=\begin{pmatrix} \frac{\pi^0}{\sqrt{2}}+\frac{\eta_8}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}}+\frac{\eta_8}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -\frac{2\eta_8}{\sqrt{6}} \end{pmatrix}$$

$$u(x)=\exp\left(\frac{i\phi(x)}{\sqrt{2}F}\right),\quad \mathrm{u}_\mu = i\left[u^\dagger(\partial_\mu - ir_\mu)u - u(\partial_\mu - il_\mu)u^\dagger\right]$$

$$\chi = 2B_0(s+ip),\quad \chi_\pm = u^\dagger \chi u^\dagger \pm u\chi u$$

$$f_\pm^{\mu\nu} = uF_L^{\mu\nu}u^\dagger \pm u^\dagger F_R^{\mu\nu} u$$

$$L^{(2)}{}_\chi = \frac{F^2}{4}\langle u_\mu u^\mu + \chi_+\rangle$$

$$L^{(4)}{}_\chi = L_1\langle u_\mu u^\mu\rangle^2 + \ldots + L_4\langle u_\mu u^\mu\rangle\,\langle\chi_+\rangle + \ldots + L_7\langle\chi_-\rangle^2 + \ldots - iL_9\langle f_+^{\mu\nu}u_\mu u_\nu\rangle + \ldots$$

$L^{(4)}{}_{\chi,\,WZW}$ in the odd-intrinsic parity sector

TOOLS : RχT

(Ecker, Gasser, Pich, De Rafael '89)

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Antisymmetric tensor formalism

$$V_{\mu\nu}(x) = \begin{pmatrix} \frac{\rho^0}{\sqrt{2}} + \frac{\omega_8}{\sqrt{6}} & \rho^+ & K^{*+} \\ \rho^- & -\frac{\rho^0}{\sqrt{2}} + \frac{\omega_8}{\sqrt{6}} & K^{*0} \\ K^{*-} & \bar{K}^{*0} & -\frac{2\omega_8}{\sqrt{6}} \end{pmatrix}_{\mu\nu}$$

$$L_{VAP} = \sum_{i=1}^{5} \lambda_i O^i(V_{\mu\nu}, A^{\mu\nu}, \phi) = \lambda_1 \langle [V_{\mu\nu}, A^{\mu\nu}] \chi_- \rangle + \ldots$$

(Gómez Dumm, Pich, Portolés '04)

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(Ruiz-Femenia, Pich, Portolés '03)

$$L_{VPPP} = \sum_{i=1}^{5} \frac{g_i}{M_V} O^i(V_{\mu\nu}, \phi) = \frac{g_4}{M_V} \varepsilon_{\mu\nu\alpha\beta} \langle \left\{ V^{\mu\nu}, u^\alpha u^\beta \right\} \chi_- \rangle + \ldots$$

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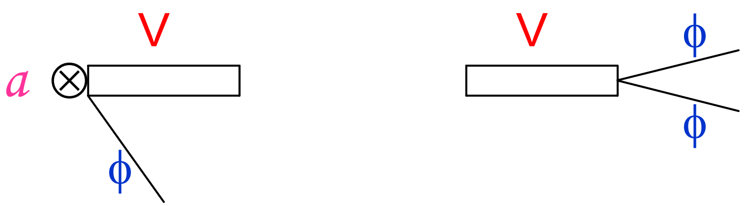

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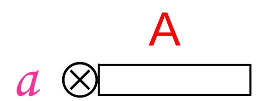

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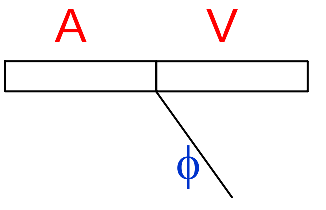

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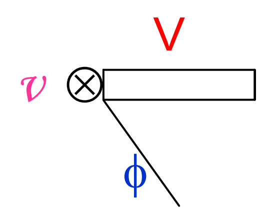

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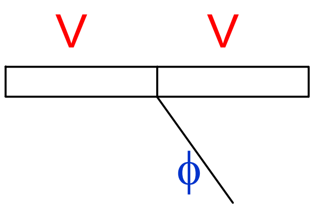

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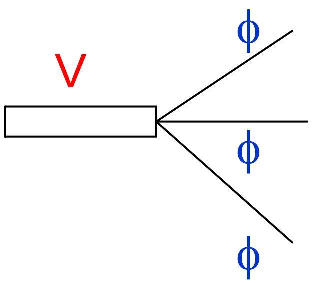

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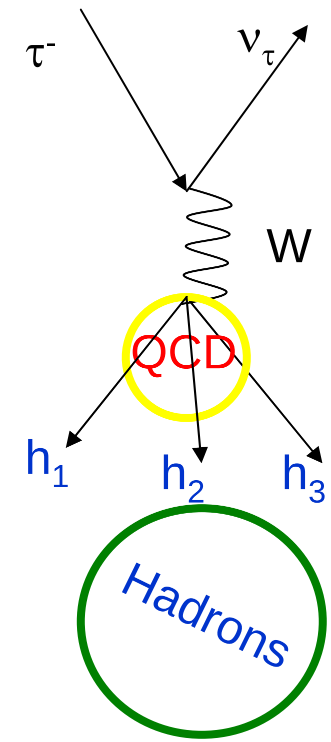

$$\tau^- \to h_1(p_1) h_2(p_2) h_3(p_3) \nu_\tau$$

$$(p_1+p_2+p_3)^\mu = Q^\mu, \; V_{1\mu} = \left(g_{\mu\nu} - \frac{Q_\mu Q_\nu}{Q^2} \right)(p_2-p_1)^\nu, \; V_{2\mu} = \left(g_{\mu\nu} - \frac{Q_\mu Q_\nu}{Q^2} \right)(p_3-p_1)^\nu$$

$$T_\mu = V_{1\mu} F_1 + V_{2\mu} F_2 + Q_\mu F_P + i \varepsilon_{\mu\nu\rho\sigma} p_1^{\,\nu} p_2^{\,\rho} p_3^{\,\sigma} F_V$$

$$\frac{d\Gamma}{dQ^2} = \frac{G_F^{\,2} |V_{CKM}|^2}{128(2\pi)^5 M_\tau^{\,3}} \int ds dt \; f\left(I_{0^-}, I_{1^+}, I_{1^-} \right)$$

(Kühn, Santamaría ’90)

(Gómez-Cadenas, González-García, Pich ’90)

$\tau^- \to (2K\pi)^- \nu_\tau$ in RχT

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$\tau^- \to K^+K^-\pi^- \nu_\tau$ CLEO VERSION

(F. Liu '03, CLEO-III '04)

$$F_V = -\frac{1}{2\sqrt{2}\pi^2 F^3}\sqrt{R_B}\sum_i BW_i$$

$$BW_{V,A}(x = s_i, Q^2) = \frac{M_{V,A}{}^2}{M_{V,A}{}^2 - x - iM_{V,A}\Gamma_{V,A}(x)}$$

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$\tau^- \rightarrow K^+K^-\pi^- \nu_\tau$ **CLEO VERSION**

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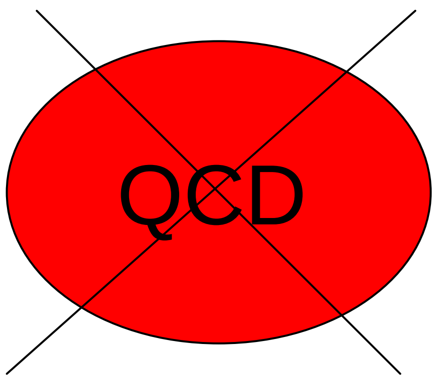
R_B = 1.80±0.53



$\tau^- \to (2K\pi)^- \nu_\tau$: STATUS

(Gómez Dumm, Pich, Portolés, P.R. in progress)

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- Asymptotic behaviour of form factors
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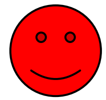
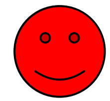
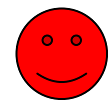
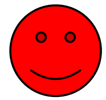
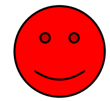
$\tau^- \to (2K\,\pi)^-\,\nu_\tau$: STATUS

(Gómez Dumm, Pich, Portolés, P.R. in progress)

- Computation finished 
- Asymptotic behaviour of form factors 
- Analysis of existing data 
- Implementation in the SHERPA Monte-Carlo 

$\tau^- \to (2K\,\pi)^- \,\nu_\tau$: **STATUS**

(Gómez Dumm, Pich, Portolés, P.R. in progress)

- Computation finished 
- Asymptotic behaviour of form factors 
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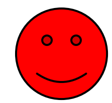
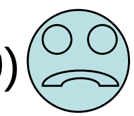
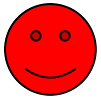
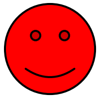
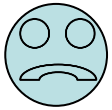
- Implementation in the SHERPA Monte-Carlo 
  - ➢Off-shell width for $a_1(1260)$ 
  - ➢All 3-meson τ decay channels
  - ➢Analysis of LHC, BABAR, BELLE and BES data

$\tau^- \to (2K\,\pi)^- \, \nu_\tau$: STATUS

(Gómez Dumm, Pich, Portolés, P.R. in progress)

- Computation finished 
- Asymptotic behaviour of form factors 
- Analysis of existing data 
- Implementation in the SHERPA Monte-Carlo 
  - Off-shell width for $a_1(1260)$ 
  - All 3-meson τ decay channels
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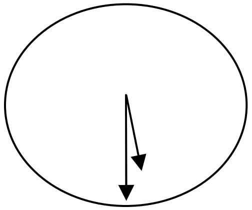


SHERPA

(**S**imulation of **H**igh **E**nergy **R**eactions of **PA**rticles)

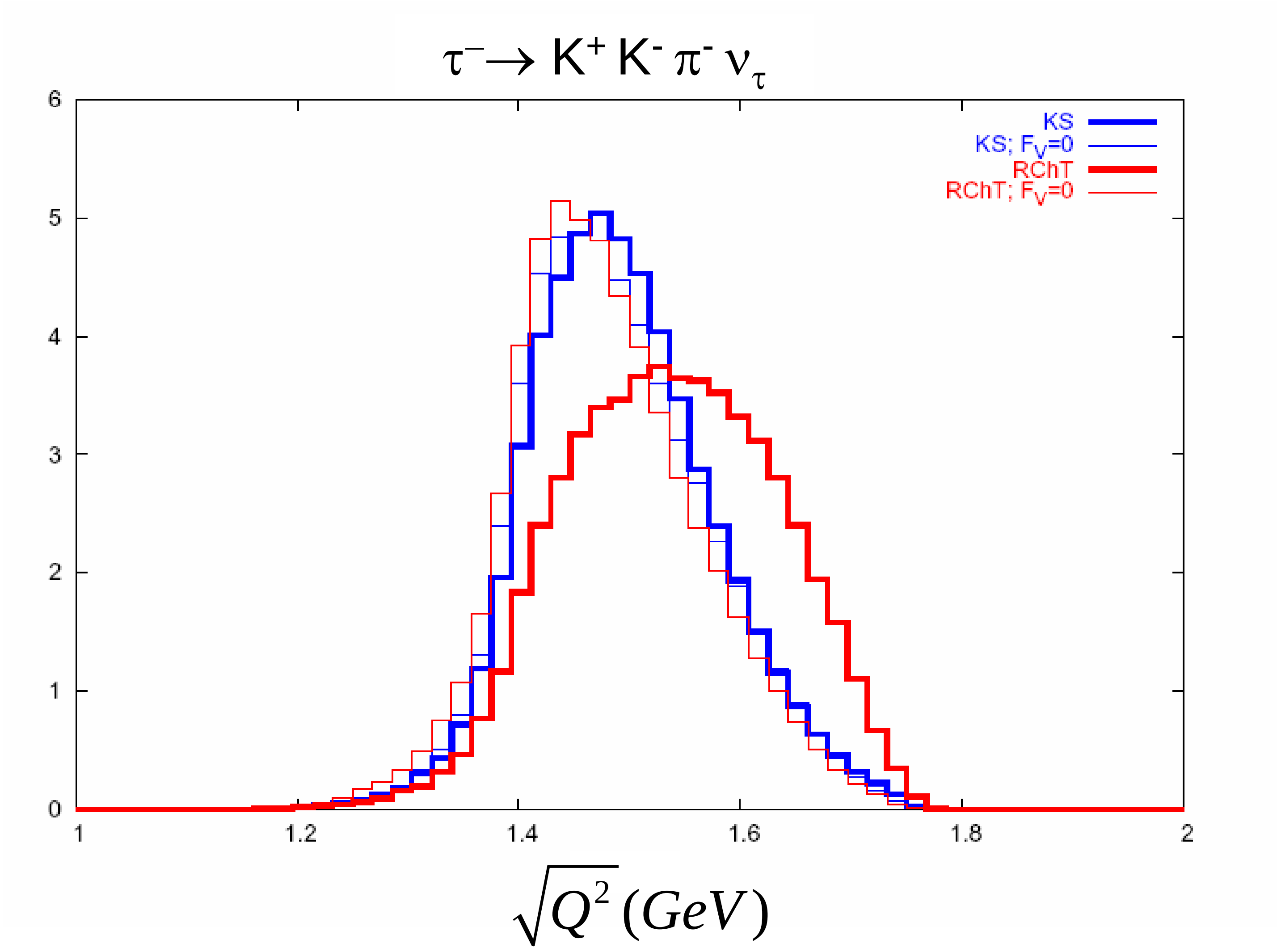
- Institute for Theoretical Physics at TU Dresden (Germany)

- Group Leader : Frank Krauss
- Tevatron + LHC

- http://www.physik.tu-dresden.de/~krauss/hep

Insertion of our matrix elements for hadronic tau decays

RESULTS


$\tau^- \to K^+ K^- \pi^- \nu_\tau$
KS
KS; F_V=0
RChT
RChT; F_V=0
6
5
4
3
2
1
0
1
1.2
1.4
1.6
1.8
2
$\sqrt{Q^2}\,(GeV)$

CONCLUSIONS

- Recent analyses of $\tau^- \to K^+K^-\pi^- \nu_\tau$ data by CLEO-III using TAUOLA have shown noticeable inconsistencies.
- We have studied this decay in RχT with a **Large N$_C$**-inspired model guided by QCD.
- Our results have been implemented in **SHERPA** (**LHC** and **TEVATRON**).
- **LHC**, **BABAR**, **BELLE**, **BES**…are promising facilities to test our predictions.