Key measurements for New-Physics in Flavor

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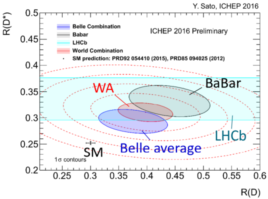
Outline

1. Intro
2. The $b \to c\tau\nu$ transitions
   - Angular analyses
   - The B_c-lifetime bound on 2HDM
3. The $b \to s\ell\ell$ decays
   - Lepton universality violating observables
   - Other observables
4. Decays of light hadrons
   - Global fit to New Physics

(Lepton universality violating) New-Physics in B decays?

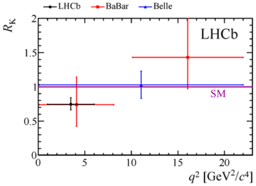
- **"$R_{D^{(*)}}$ anomaly"** in $B \to D^{(*)}\ell\nu$!



- ***Excesses*** observed at $\sim 4\sigma$ WG2 on Th.
- Other "anomalies" in $b \to (u,c)\ell\nu$
  - Inclusive *vs.* Exclusive V_{ub} and V_{cb}
- $\Lambda_{NP} \sim 2$ TeV

- **"R_K anomaly"** in $B \to K\ell\ell$ (**FCNC**)!

LHCb PRL113(2014)151601



- Tension with **SM** $\sim 2.6\sigma$ WG3 on Tue.
- Other anomalies in $b \to s\mu\mu$
  - Branching fractions
  - Angular analysis $B \to K^*\mu\mu$
- Up to 4σ in global fits Javi Virto's talk
- $\Lambda_{NP} \sim 10$ TeV

- **Anomalies addressed in many models of NP** (see e.g. V. Sudhir, J. Zupan's, S. Fajfer, ... talks)

EFT: The bottom-up approach to new physics in flavor

No evidence of new-particles at colliders up to $E \simeq 1$ TeV

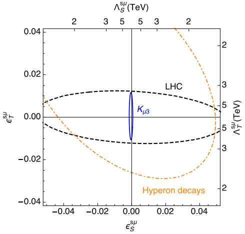
Construct the most general effective operators $\mathcal{O}_k$ built with ***all*** the SM fields and subject to the strictures of $SU(3)_c \times SU(2)_L \times U(1)_Y$

Buchmuller *et al.*'86,Grzadkowski *et al.*'10

1. **Dictionary** between low-energy flavor **observables** and high-energy (SMEFT) **Wilson coefficients**

- Complementary between **kaon decays** and LHC

$$\mathcal{L}_{\rm c.c.} \supset -\frac{G_F V_{us}}{\sqrt{2}} \Big[\epsilon_S (\bar{u}\, s)\, (\bar{e}(1-\gamma_5)\nu_e) + \epsilon_T (\bar{u}\sigma^{\mu\nu} s)\, (\bar{e}\sigma_{\mu\nu}(1-\gamma_5)\nu_e) \Big]$$



Gonzalez-Alonso and JMC, arXiv 1605.07114

2. Model-independent relations in the Wilson coefficients of the low-energy EFT
   - Caveat in HEFT's Cata&Jung PRD92(2015)no.5,055018

1. **Charged-Currents** (no RH ν):

$$\mathcal{L}_{\rm eff}^{\ell}=-\frac{G_F V_{cb}}{\sqrt{2}}[(1+\epsilon_L^{\ell})\bar{\ell}\gamma_\mu(1-\gamma_5)\nu_\ell\cdot\bar{c}\gamma^\mu(1-\gamma_5)b+\epsilon_R^{\ell}\;\bar{\ell}\gamma_\mu(1-\gamma_5)\nu_\ell\;\bar{c}\gamma^\mu(1+\gamma_5)b$$
$$+\bar{\ell}(1-\gamma_5)\nu_\ell\cdot\bar{c}[\epsilon_S^{\ell}+\epsilon_P^{\ell}\gamma_5]b+\epsilon_T^{\ell}\;\bar{\ell}\sigma_{\mu\nu}(1-\gamma_5)\nu_\ell\cdot\bar{c}\sigma^{\mu\nu}(1-\gamma_5)b]+\text{h.c.},$$

- Matching to the SMEFT

$$\mathcal{O}_{Hud}=\frac{i}{\Lambda_{\rm NP}^2}\left(\tilde{H}^\dagger D_\mu H\right)(\bar{u}_R\gamma^\mu d_R)$$

☛ **RHC is lepton universal: $\epsilon_R^{\ell}\equiv\epsilon_R+\mathcal{O}(\frac{v^4}{\Lambda_{\rm NP}^4})$ $\Rightarrow$ It cannot explain LUV in $R_{D^{(*)}}$!**

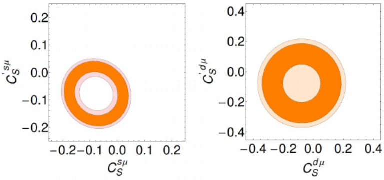
Bernard, Oertel, Passemar & Stern PLB638(2006)480, Alonso, Grinstein and JMC JHEP 1510 (2015) 184

2. **Flavor Changing Neutral Currents**:

- Constraints *LR* operators: from **6** to **2**
  - ★ **No tensor operators!**

Alonso, Grinstein, JMC, PRL113(2014)241802

- Important consequences in $B_s\to\mu\mu$



☛ **Only $\mathcal{O}_{9,10}^{(\prime)}$ can explain LUV in R_K!**

Alonso, Grinstein, JMC, PRL113(2014)241802 (see also Hiller&Schmaltz'14,...)

The $b \to c\tau\nu$ decays

New physics in τ decays?

- New physics..
  - could **look different** in different $\tau \to X\nu$ decay channels
  - should **appear universally** in all $Y \to Z\tau(\to X\nu)$ decays
- Leptonic τ decays: **Michel parameters**

A. Pich PPNP75(2014)41

Bounds on the $g^V_{\epsilon\omega}$ couplings, assuming that (non-standard) W-exchange is the only relevant interaction. The τ-decay (μ-decay) limits are at 95% CL (90% CL). Numbers within parentheses use μ-decay data through cross-channel identities.

	$\lvert g^V_{RR}\rvert$	$\lvert g^V_{LR}\rvert$	$\lvert g^V_{RL}\rvert$	$\lvert g^V_{LL}\rvert$
$\mu \to e$	<0.0004	<0.023	<0.017	>0.999
$\tau \to \mu$	<0.017 (0.003)	<0.12	<0.14 (0.023)	>0.983
$\tau \to e$	<0.017 (0.002)	<0.13	<0.13 (0.017)	>0.983

  - 4-lepton **(pseudo)scalar** interactions less constrained
- Hadronic τ decays: **Lepton universality ratios**

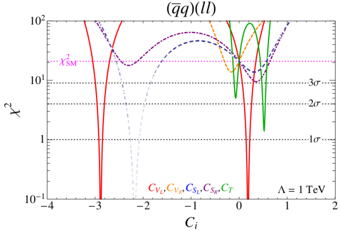
$$R_{\tau/P} \equiv \frac{\Gamma(\tau^- \to \nu_\tau P^-)}{\Gamma(P^- \to \mu^- \bar{\nu}_\mu)} = \left|\frac{g_\tau}{g_\mu}\right|^2 \frac{m_\tau^3}{2 m_P m_\mu^2} \frac{(1 - m_P^2/m_\tau^2)^2}{(1 - m_\mu^2/m_P^2)^2} \left(1 + \delta R_{\tau/P}\right)$$

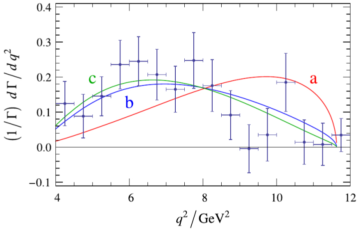
$$\delta R_{\tau/\pi} = (0.16 \pm 0.14)\%$$

  - New physics constrained at **subpercent level** in hadronic modes

Fits to new physics

- The $R_{D^{(*)}}$ and **spectrum** do not provide enough discriminating power





Freytsis *et al.*, PRD92(2015)no.5,054018; also Sasaki *et al.* PRD91(2015)no.11, 114028, ...

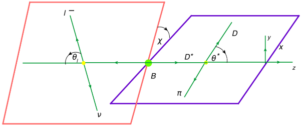
- Looking for LUR in **new decay modes**
  - **Semileptonic $B_c \to J/\Psi\ell\nu$ decays** **Lytle *et al.* Wed. WG2 (arXiv: 1605.05645) and C. Bozzi Th. WG2**
  - $\Lambda_b \to \Lambda_c^{(*)}\ell\nu$ S. Meinel @ HC2NP–Tenerife
  - $B_s \to D_s^{(*)}\ell\nu$ A. Bhol, EPL106(2014)31001

- Measure new observables

Look at the full kinematic (angular) distributions!

A first approach: Full angular analysis of the $B \to D^{(*)}\tau\nu$

- Many angular observables as functions of helicity amplitudes (like $B \to K^{(*)}\mu\mu$!)



$$\frac{d^4\Gamma}{dq^2 d\cos\theta_l d\cos\theta_{D^*} d\chi} = \frac{9}{32\pi} NF\{\cos^2\theta_{D^*}(V_1^0 + V_2^0 \cos 2\theta_l + V_3^0 \cos\theta_l) + \sin^2\theta_{D^*}(V_1^T + V_2^T \cos 2\theta_l + V_3^T \cos\theta_l)$$
$$+ V_4^T \sin^2\theta_{D^*} \sin^2\theta_l \cos 2\chi + V_1^{0T} \sin 2\theta_{D^*} \sin 2\theta_l \cos\chi + V_2^{0T} \sin 2\theta_{D^*} \sin\theta_l \cos\chi$$
$$+ V_5^T \sin^2\theta_{D^*} \sin^2\theta_l \sin 2\chi + V_3^{0T} \sin 2\theta_{D^*} \sin\theta_l \sin\chi + V_4^{0T} \sin 2\theta_{D^*} \sin 2\theta_l \sin\chi\},$$

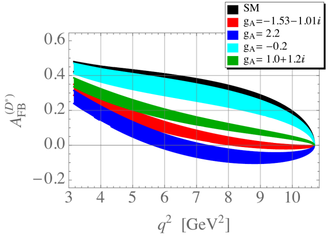
$$V_1^0 = 2\left[\left(1 + \frac{m_l^2}{q^2}\right)(|\mathcal{A}_0|^2 + 16|\mathcal{A}_{0T}|^2) + \frac{2m_l^2}{q^2}|\mathcal{A}_{tP}|^2 - \frac{16 m_l}{\sqrt{q^2}} \mathrm{Re}[\mathcal{A}_{0T}\mathcal{A}_0^*]\right],$$

$$V_2^0 = 2\left(1 - \frac{m_l^2}{q^2}\right)[-|\mathcal{A}_0|^2 + 16|\mathcal{A}_{0T}|^2],$$
$$V_3^0 = -8\mathrm{Re}\left[\frac{m_l^2}{q^2}\mathcal{A}_{tP}\mathcal{A}_0^* - \frac{4m_l}{\sqrt{q^2}}\mathcal{A}_{tP}\mathcal{A}_{0T}^*\right]$$

...

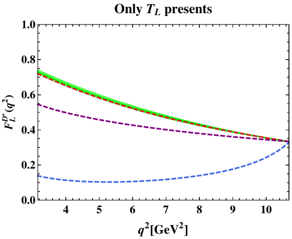
Duraisamy *et al.*, PRD90, 074013 (2014)

- Leptonic forward-backward asymmetry



Becirevic *et al.*, arXiv:1602.03030.

- Longitudinal polarization of the D^*



Duraisamy *et al.*, PRD90, 074013 (2014)

- **However** the τ's lifetime is $\sim 10^{-13}$ s
  - It is not *observed* but *reconstructed* from decay products with **missing neutrinos**! (kinematics might be reconstructed from 3-prong τdecays) Bozzi's talk Th. WG2

- **Alternatively**, kinematic distributions of the **observable** τ decay products!
  - Maximize the coverage of the τ's lifetime

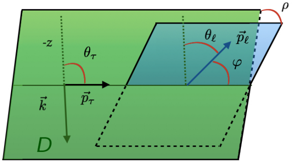
Channel	$\tau \to \mu\nu\nu$	$\tau \to e\nu\nu$	$\tau \to \pi\nu$	$\tau \to \rho\nu$	$\tau \to 3\pi\nu$	TOTAL
$\mathcal{B}$	17.4%	17.8%	10.82%	25%	9%	$\sim$ 80%

  - **Different τ decay modes are subject to very different backgrounds!**
  - Two different strategies in the literature
    - **Analytical:** Nierste *et al.* PRD78,015006 '08 (BD-$\pi\nu$), Alonso, Kobach & JMC, PRD94 (2016) no.9, 094021 ($BD^{(*)}$-$\ell\nu\nu$), Alonso, JMC & Westhoff, in preparation ($BD^{(*)}$-$\pi\nu$ or $\rho\nu$)
    - **Montecarlo:** Hagiwara *et al.* PRD89, 094009 (2014) (BD-$3\pi\nu$), Bordone *et al.* EPJC76 (2016) no.7, 360 (BD-$\ell\nu\nu$), Ligeti *et al.* arXiv:1610.02045 ($BD^*(\to D\pi)$-$\ell\nu\nu, \ldots$)

Test **new physics** and understand better **systematics**!

$B \to D^{(*)}\tau^-(\to \ell^- \bar{\nu}_\ell \nu_\tau)\bar{\nu}_\tau$

Alonso, Kobach, JMC, arXiv: 1602.07671



- **Integrate analytically τ angular phase-space:** (nontrivial)

$$\frac{d^3\Gamma_5}{dq^2\, dE_\ell\, d(\cos\theta_\ell)} = \mathcal{B}[\tau_\ell]\, \frac{G_F^2 |V_{cb}|^2 \eta_{\rm EW}^2}{32\pi^3} \frac{|\vec{k}|}{m_B^2} \left(1 - \frac{m_\tau^2}{q^2}\right)^2 \frac{E_\ell^2}{m_\tau^3} \times \left[I_0(q^2, E_\ell) + I_1(q^2, E_\ell)\cos\theta_\ell + I_2(q^2, E_\ell)\cos\theta_\ell^2\right]$$

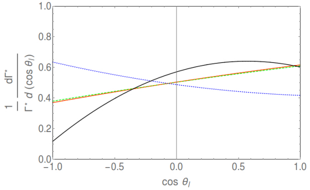
  - $\cos\theta_\ell$ defined as for the normalization mode (w.r.t recoiling $D^{(*)}$ in the q rest frame)
  - $I_{0,2}(q^2, E_\ell)$ accessed in $R_{D^{(*)}}$
  - $I_1(q^2, E_\ell)$ accessible only with a FB leptonic asymmetry!

$$\frac{d^2 A_{FB}(q^2, E_\ell)}{dq^2\, dE_\ell} = \left(\int_0^1 d(\cos\theta_\ell) - \int_{-1}^0 d(\cos\theta_\ell)\right) \frac{d^3\Gamma_5}{dq^2\, dE_\ell\, d(\cos\theta_\ell)}$$

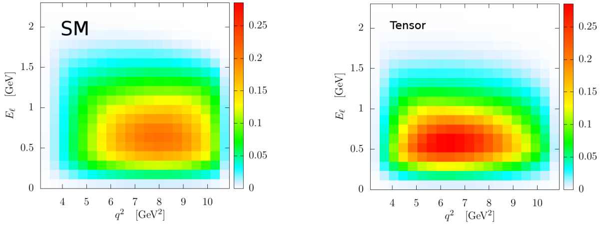
$$R_{FB}^{(*)} = \frac{1}{\mathcal{B}[\tau_\ell]} \frac{1}{\Gamma_{\rm norm.}} A_{FB},$$

- Angular distributions can help to discriminate signal *vs.* normalization

	R_{D^*}	R^*_{FB}
SM	0.252(4)	0.0310(7)
Current	0.333	0.0410
Scalar	0.315	0.0363
Tensor	0.346	−0.0377
Expt.	0.322(18)(12)	–



- E_ℓ and double $(E_\ell,\ q^2)$ spectra can also be studied



Ligeti *et al.* arXiv:1610.02045

$B \to D^{(*)}\tau^-(\to \pi^-\nu_\tau)\bar{\nu}_\tau$: $\tau^- \to \pi^-\nu_\tau$ as a τ polarimeter

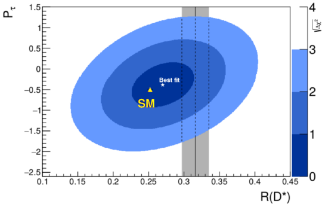
$$\frac{d^2\Gamma_4}{dq^2 dE_\pi} = \frac{\mathcal{B}[\tau_\pi]\, m_\tau^2}{|\vec{p}_\tau|(m_\tau^2 - m_\pi^2)} \frac{d\Gamma_B}{dq^2}\left[1 + \xi(E_\pi,\, q^2)\frac{dP_L}{dq^2}\right], \quad \xi(E_\pi, q^2) = \frac{1}{\beta_\tau}\left(2\frac{E_\pi}{E_\tau} - 1\right)$$

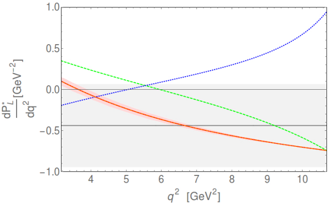
Tanaka&Watanabe, PRD82, 034027 (2010)

Slope in E_π of $d\Gamma_4 \Rightarrow$ **Longitudinal Polarization**

$$\frac{dP_L}{dq^2} = \frac{d\Gamma_{B,+}/dq^2 - d\Gamma_{B,-}/dq^2}{d\Gamma_B/dq^2}$$

- Applied to the BD^* channel by **Belle**





Belle, arXiv: 1608.06391, K. Adamczyk's talk Th. WG2

$B \to D^{(*)}\tau^-(\to \pi^-\nu_\tau)\bar{\nu}_\tau$: $\tau^- \to \pi^-\nu_\tau$ as a τ polarimeter

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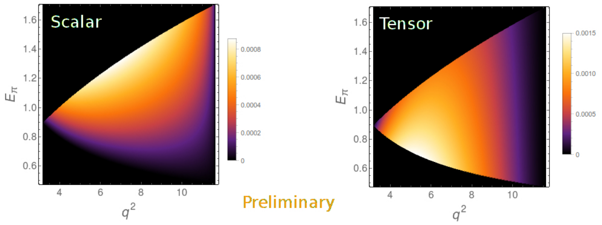
$$\frac{dP_L}{dq^2} = \frac{d\Gamma_{B,+}/dq^2 - d\Gamma_{B,-}/dq^2}{d\Gamma_B/dq^2}$$

- **Scalar** and **Tensor** modify $d^2\Gamma_4$ up to 50% in some regions of phase-space

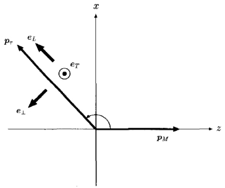


Alonso, JMC & Westhoff, to appear

More $B \to D^{(*)}\tau\nu$ observables from *FB* asymmetries

PRELIMINARY: Alonso, JMC & Westhoff to appear

- Decay rate into a τ polarized along a given direction $\hat{s}$



Tanaka Z. Phys. C 67, 321

$$d\Gamma_B(\hat{s}) = d\Gamma + \tfrac{1}{2} d\Gamma \left(dP_L\, \hat{z}' + dP_\perp\, \hat{x}' + dP_T\, \hat{y}' \right) \cdot \hat{s}$$

- dP_L measured by Belle
- dP_T (T-odd): Not accessible without τ **direction**
- $dP_\perp$ **accessible from the pionic** ***FB*** **asymmetry!**

- **Master formula for the** ***BD*** **mode**

$$\frac{d^2\Gamma_{FB}^{N_X}}{dq^2\, dE_\pi} = -\frac{\mathcal{B}[\tau_\pi]\, m_\tau^2}{|\vec{p}_\tau|^3} \frac{d\Gamma_B}{dq^2} \left(\xi_{FB}^X(E_\pi, q^2) \frac{dA_{FB}}{dq^2} + \xi_\perp(E_\pi, q^2) \frac{dP_\perp}{dq^2} \right)$$

- $\xi_{FB,\perp}^X(q^2, E_X)$ depend on the decay channel $\tau \to X\nu_\tau$

☛ ***FB*** **asymmetries allows us to measure 3-body decay observables** A_{FB} **and** $P_\perp$**!**

The lifetime of the B_c meson and new physics

- **4** Wilson coefficients can explain R_{D^*} anomalies: ϵ_L, ϵ_S, ϵ_P, ϵ_T
  - **2HDM** with discrete symmetries:

$$\epsilon_S \simeq \epsilon_P \simeq \xi^b \xi^\ell \frac{m_b\, m_\ell}{m^2_{H^\pm}}$$

- BD^* depends on ϵ_P Browder's talk
- $B_c \to \tau\nu$ **also** receives a **chiral enhanced** contribution from ϵ_P!

$$\mathrm{Br}(B_c^- \to \tau \bar{\nu}_\tau) = \tau_{B_c^-} \frac{m_{B_c} m_\tau^2 f_{B_c}^2 G_F^2 |V_{cb}|^2}{8\pi} \left(1 - \frac{m_\tau^2}{m_{B_c}^2}\right)^2 \left|1 + \epsilon_L + \frac{m_{B_c}^2}{m_\tau (m_b + m_c)} \epsilon_P\right|^2$$

The constraint from the B_c lifetime

- **QCD:** "Most of the B_c lifetime comes from $\bar{c} \to \bar{s}$ ($\sim 65\%$) and $b \to c$ ($\sim 30\%$) transitions"

Bigi PLB371 (1996) 105, Beneke *et al.* PRD53(1996)4991, Kiselev *et al.* NPB585 (2000) 353

☛ **BR**$(B_c \to \tau\nu) \leq 30\%$ **(accounting conservatively for errors)**

Alonso, Grinstein&JMC, arXiv: 1611.06676 (see also Xin-Qiang Li *et al.*, JHEP 1608 (2016) 054)

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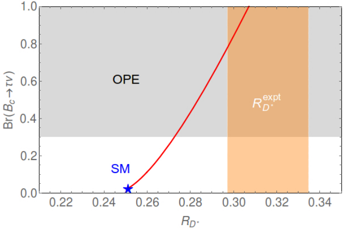


Alonso, Grinstein&JMC, arXiv: 1611.06676

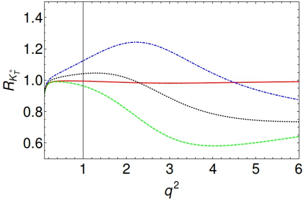
> τ_{B_c} makes **highly implausible ANY** "scalar solution" (e.g. 2HDM) to the R_{D^*} anomaly!

The $b \to s\ell\ell$ decays

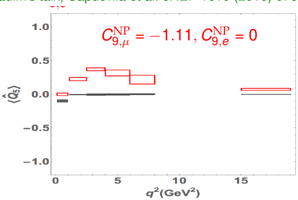
Lepton Universality in $b \to s\ell\ell$

- **Theory:** Plenty of LUR's in the $B_{(s)} \to K^*(\Phi)\ell\ell$ angular analysis!

Jäger and JMC, PRD93(2016)no.1,014028

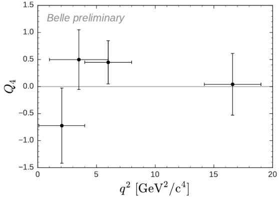


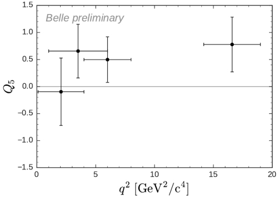
Quim's talk, Capdevila *et al.* JHEP 1610 (2016) 075



- **Experiment:** New results from Belle in angular observables!

S. Wehle's talk





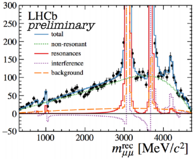
Eagerly waiting for the new LHCb data on $R_{K^{(*)}}$ and R_Φ (other angular observables?)

Paula Alvarez's talk

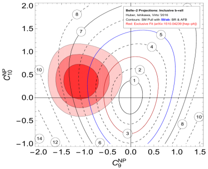
Angular analyses of $B_{(s)} \to K^*(\Phi)\mu\mu$ and radiative

Nature and **size** of hadronic corrections still a **controversial** topic

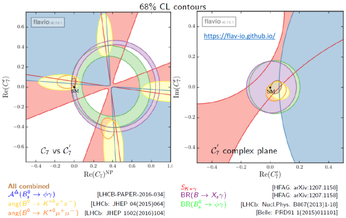
- **New** experimental information and **prospects**
  - Phases and fudge factors of resonances
    Ponci's talk $(B \to K\mu\mu)$
  - Future interplay with $B \to X_s\ell\ell$ at Belle2
    Virto's talk



Resonance
$\rho(770)$
$\omega(780)$
$\phi(1020)$
J/ψ
$\psi(2S)$
$\psi(3770)$
$\psi(4040)$
$\psi(4160)$
$\psi(4415)$



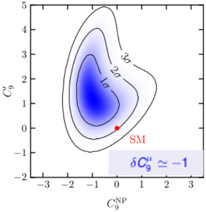
- Radiative and $B \to K^*ee$ at very low q^2 very clean! Jäger and JMC, PRD93(2016)no.1,014028
  - New data on BR$(B_s \to \Phi\gamma)$ and $\mathcal{A}_\Delta$!
    Arantxa Oranguren's and Polci's talk
  - Stringent constraints on $C_7^{(\prime)}$
    Paul & Straub arXiv:1608.02556



What about the high q^2 region?

No satisfactory (model-independent) solution (yet?)

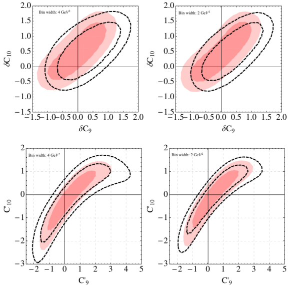
- FFs in **LQCD+OPE** Wingate's talk



  - Some analyses obtain large **RHC**

    Rusa Mandal's talk

- Duality violation Braß *et al.* arXiv:1606.00775



- **New ideas:** Analyse $B_s^* \to \ell\ell$ and $\ell\ell \to B_s^* \to B_s\gamma$! B. Grinstein and JMC PRL116(2016)no.14,141801
  - **Cleanest** (non-LUR) observables sensitive to C_9
    - ★ Matrix elements of local quark currents are described by **decay constants**
    - ★ $m_{B_s}^2 \sim 30$ GeV^2 well above charm resonances (use **OPE!**)
  - **Very challenging experimentally**
    - ★ BR$\sim 10^{-11}$ not far from $B_s \to \mu\mu$; X-sections receive resonant enhancement $\sigma \sim 10$ fb
    - ★ Might be useful in the charm sector Khodjamirian *et al.* JHEP 1511 (2015) 142

New physics in semileptonic decays of light hadrons

New-physics in light quark charged-current transitions?

1. **Experimental data:** $K_{\ell 2}$ and $K_{\ell 3}$ boast an extremely rich database

   Cecucci's, Moulson's talks, FlaviaNet Kaon Working Group, Antonelli *et al.* EPJC69, 399 (2010)

2. **Hadronic matrix elements:** Flagship quantities in χPT and LQCD

   FLAG collaboration, Simula's talk

3. Radiative and isospin-breaking corrections understood!

   Cirigliano *et al.* Rev.Mod.Phys. 84 (2012) 399

LUR's predicted at the sub-permille level!

$$R_P = \frac{\Gamma(P_{e2(\gamma)})}{\Gamma(P_{\mu 2(\gamma)})}$$

$$R_\pi^{\rm SM} = 1.2352(1) \times 10^{-4} \qquad R_\pi = 1.2344(30) \times 10^{-4}$$

$$R_K^{\rm SM} = 2.477(1) \times 10^{-5} \qquad R_K = 2.488(9) \times 10^{-5}$$

Cirigliano & Rosell PRL99 (2007) 231801

A Global NP analysis of the light-quark meson decay data is called for!

$K_{\ell 3}$

- Neglecting contributions $\mathcal{O}(\frac{v^4}{\Lambda_{\rm NP}^4})$ (terms quadratic in ϵ_i^2)

$$\Gamma(K_{\ell 3(\gamma)}) = \overbrace{\frac{G_F^2 m_K^5}{192\pi^3}}^{\text{Measured in } \mu \text{ decay}} C\, S_{\rm EW}\, \underbrace{|\tilde{V}_{us}^{\ell}|^2}_{\left(1+\epsilon_L^{s\ell}+\epsilon_R^{s}-\tilde{v}_L\right) V_{us}^{\rm SM}} f_+(0)^2\, \overbrace{I_K^{\ell}(\lambda_{+,0},\, \epsilon_S^{s\ell},\, \epsilon_T^{s\ell})}^{\text{Phase-space Int.}}\, \underbrace{\left(1+\delta^c+\delta_{\rm em}^{c\ell}\right)^2}_{\text{Rad. and isosp. corr.}}$$

- $f_+(0)$, δ^c and $\delta_{\rm em}^{c\ell}$ th. inputs (LQCD and χPT)
- $\epsilon_{S,T}^{s\ell}$ accessible through the spectra/angular distribution

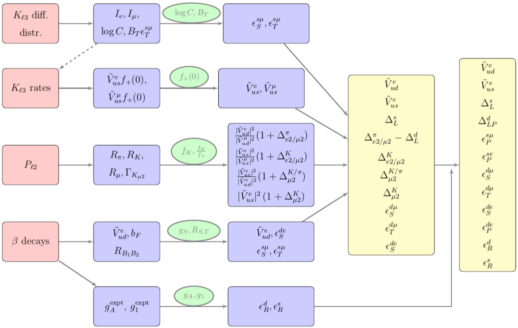
Interference with SM is $\propto m_\ell$!

- K_{e3} spectra is SM-like! (sensitivity to $|\epsilon_{S,T}^{se}|^2$)
- $K_{\mu 3}$ sensitive $\Rightarrow$ Simultaneous fit of $\lambda_{+,0}$, $\epsilon_S^{s\mu}$, $\epsilon_T^{s\mu}$

- $|\tilde{V}_{us}^{\ell}|$ only accessible through CKM unitarity and LUV tests
  - Less NP-polluted for K_{e3}
  - Cross-contamination from NP in μ decays

Flowchart of data, theoretical inputs and outputs of the fit

M. Gonzalez-Alonso & JMC, arXiv:1605.07114, JHEP in print

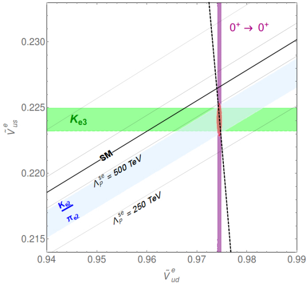


- Nuclear, neutron and hyperon β decay data essential!
  - Nuclear decays provide the most precise determination of $|\tilde{V}_{ud}^e|$ Hardy's talk
  - Axial nucleon/hyperon couplings important probes of **RHC**
    $g_1(0) = (1 - 2\epsilon_R^s) g_1(0)^{\rm QCD}$
  - Hyperon decays very sensitive to **tensor currents** Chang *et al.* PRL114 (2015) no.16, 161802
  - ...
- **Very old data base:** Plenty of room for improvement at LHCb and NA62!

Results of the fit

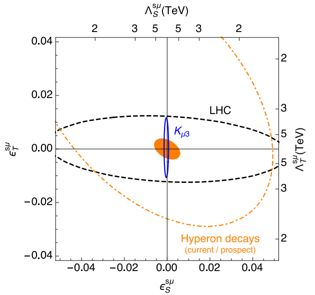
$$\begin{pmatrix} \tilde{V}^e_{ud} \\ \tilde{V}^e_{us} \\ \Delta^s_L \\ \Delta^d_{LP} \\ \epsilon^{de}_P \\ \epsilon^d_R \\ \epsilon^{se}_P \\ \epsilon^{s\mu}_P \\ \epsilon^s_R \\ \epsilon^{s\mu}_S \\ \epsilon^{s\mu}_T \\ \epsilon^{de}_S \end{pmatrix} = \begin{pmatrix} 0.97451 \pm 0.00038 \\ 0.22408 \pm 0.00087 \\ 1.1 \pm 3.2 \\ 1.9 \pm 3.8 \\ 4.0 \pm 7.8 \\ -1.3 \pm 1.7 \\ -0.4 \pm 2.1 \\ -0.7 \pm 4.3 \\ 0.1 \pm 5.0 \\ -3.9 \pm 4.9 \\ 0.5 \pm 5.2 \\ 1.4 \pm 1.3 \end{pmatrix} \times 10^\wedge \begin{pmatrix} 0 \\ 0 \\ -3 \\ -2 \\ -6 \\ -2 \\ -5 \\ -3 \\ -2 \\ -4 \\ -3 \\ -3 \end{pmatrix}, \quad \rho = \begin{pmatrix} 1. & 0. & 0. & 0.01 & 0.01 & 0. & 0. & 0. & 0. & 0. & 0. & 0.82 \\ - & 1. & -0.12 & 0. & 0. & 0. & 0.04 & 0.04 & 0. & -0.26 & 0. & 0. \\ - & - & 1. & 0. & 0. & 0. & 0. & 0.03 & 0. & 0. & 0.72 & 0. \\ - & - & - & 1. & 0.9995 & -0.87 & 0.09 & 0.09 & 0. & 0.04 & 0. & 0.01 \\ - & - & - & - & 1. & -0.87 & 0.09 & 0.09 & 0. & 0.04 & 0. & 0.01 \\ - & - & - & - & - & 1. & 0. & 0. & 0. & 0. & 0. & 0. \\ - & - & - & - & - & - & 1. & 0.9993 & -0.98 & -0.01 & 0. & 0. \\ - & - & - & - & - & - & - & 1. & -0.98 & -0.01 & 0.02 & 0. \\ - & - & - & - & - & - & - & - & 1. & 0. & 0. & 0. \\ - & - & - & - & - & - & - & - & - & 1. & 0. & 0. \\ - & - & - & - & - & - & - & - & - & - & 1. & 0. \\ - & - & - & - & - & - & - & - & - & - & - & 1. \end{pmatrix}.$$

- Re-interpretation of *Classic* $|V_{ud}|$-$|V_{us}|$ plot



M. Gonzalez-Alonso & JMC, arXiv:1605.07114, JHEP in print

- Interplay kaons, hyperons and LHC



M. Gonzalez-Alonso & JMC, NA62 Phyics Handbook

Conclusions

1. **The $b \to c\tau\nu$ decays**
   - **Angular analyses** and **new decay modes** will settle this issue
   - The **lifetime** of the B_c meson makes **highly implausible** 2HDMs interpretations
   - **Lack of time:**
     - ★ NP in $B \to D^{(*)}\ell\nu$ (angular) observables and $|V_{cb}|$ Tayduganov's talk, Colangelo *et al.*arXiv:1611.07387,...
     - ★ EW mixing and interplay with colliders Ferruglio *et al.* arXiv:1606.00524, Faroughy *et al.* PLB764(2017)126
2. **The $b \to s\ell\ell$ decays**
   - **Lepton Universality ratios**
   - **New interesting data on charm and radiative**
   - **Lack of time:**
     - ★ LFV; $b \to s\tau\tau$ very enhanced in models aligning R_K and $R_{D^{(*)}}$ with flavor
3. **(Semi)leptonic decays of light quarks**
   - Boasts an exquisite data base and good theoretical understanding
   - **Global fits to NP** $\to$ Reinterpretation of $|V_{us}|$-$|V_{ud}|$ plot, interplay with colliders,...
   - **Lack of time:**
     - ★ Extensions to global fits to (semi)leptonic charm meson decays Fajfer's talk
     - ★ Rare kaon and hyperon decays (LHCb upcoming program in strange physics!)