Viable Inputs for the Flavor White Paper

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We Need PHYSICS Inputs (w/ Plots) Based on Green Texts & Discussions

- Remainder of FCNC decay modes
- Inputs for the global CKM fit
- Tau and low multiplicity observables
- Charm/Strange physics
- BSM from flavor physics

Remainder of FCNC decay modes

- ☑ Di-tau modes
- ☑ Di-neutrino modes (invisible)
- ☒ Radiative mode (e.g. Λ_b -> Λ /pK + γ)
- ☒ Electron modes for RK and RK* (systematic dominated)

Inputs for the global CKM fit
CP Invariant Observables

- |Vub|, |Vcb|:
  - 1) Inclusive & exclusive **B->$X_{c,u}$lv** decay rates
  - 2) W->cb decays (see later talks)
  - 3) Bc->τν decays
- |Vts|, |Vtd|: from Δ_d & Δ_s (B0 and Bs oscillation time, reprojection?)
- |Vus|: currently 0.2% from K decays. (Ideal limit from Tera-Z: 4E-4??)

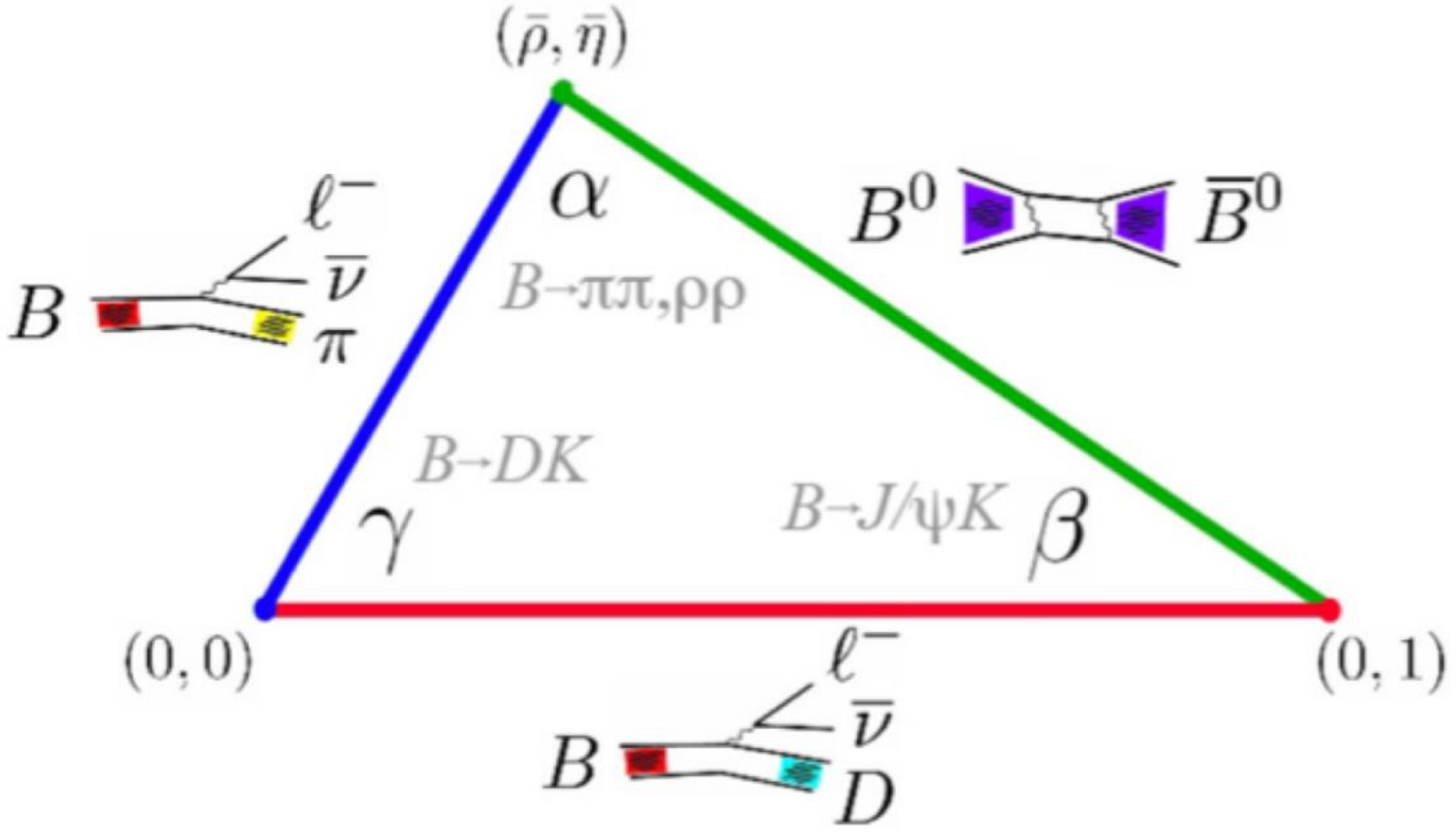
See the TALK

Using tau measurements and OPE, no lattice QCD

$$\frac{R(\tau \to X_{\text{strange}}\,\nu)}{|V_{us}|^2} = \frac{R(\tau \to X_{\text{non-strange}}\,\nu)}{|V_{ud}|^2} - \delta R_{\tau,\text{SU3 breaking}},$$

$\tau \to X_s \nu$

Inputs for the global CKM fit
The Angles



The TALK

Observable/experiments	CurrentW/A	Belle II (50 /ab)	HL-LHC	FCC-*ee*
CKM inputs				
γ (uncert., rad)	$1.296^{+0.087}_{-0.101}$	1.136 ± 0.026	1.136 ± 0.006	1.136 ± 0.004
$\lvert V_{ub} \rvert$ (precision)	5.9%	2.5%	1%	1%
Mixing-related inputs				
$\sin(2\beta)$	0.691 ± 0.017	0.691 ± 0.008	0.691 ± 0.003 (stat.)	0.691 ± 0.005
ϕ_s (mrad)	-15 ± 35	n/a	-18 ± 3	-18 ± 2
Δm_d (ps^{-1})	0.5065 ± 0.0020	Same	Same	Same
Δm_s (ps^{-1})	17.757 ± 0.021	Same	Same	Same
$a^d_{\mathrm{fs}}(10^{-4},$ precision)	23 ± 26	-7 ± 15	-7 ± 2	-7 ± 2
$a^s_{\mathrm{fs}}(10^{-4},$ precision)	-48 ± 48	n/a	0.3 ± 3	0.3 ± 2

Inputs for the global CKM fit
The Angles

- α : b -> uud, e.g. B->ππ (0.4°), best precision from **B->ρρ**
- β: b->ccs/ mixing, e.g. B-> J/ψ K, rescale FCC?
- γ: B->DK, rescale FCC?
- β_s: from Bs-> J/ψ ϕ, known
- A_{SL}: rescale FCC?
- |Vts Vtd sin(β+ βs)|: see strange physics

Tau & Low-Multiplicity

Measurement	Current [?]	FCC [86]	Tera-Z Prelim. [88]	Comments
Lifetime [sec]	$\pm 5 \times 10^{-16}$	$\pm 1 \times 10^{-18}$		from 3-prong decays, stat. limited
BR($\tau \to \ell\nu\bar{\nu}$)	$\pm 4 \times 10^{-4}$	$\pm 3 \times 10^{-5}$		0.1× the ALEPH systematics
m(τ) [MeV]	± 0.12	$\pm 0.004 \pm 0.1$		$\sigma(p_{\text{track}})$ limited
BR($\tau \to 3\mu$)	$< 2.1 \times 10^{-8}$	$\mathcal{O}(10^{-10})$	same	bkg free
BR($\tau \to 3e$)	$< 2.7 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
BR($\tau^{\pm} \to e\mu\mu$)	$< 2.7 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
BR($\tau^{\pm} \to \mu ee$)	$< 1.8 \times 10^{-8}$	$\mathcal{O}(10^{-10})$		bkg free
BR($\tau \to \mu\gamma$)	$< 4.4 \times 10^{-8}$	$\sim 2 \times 10^{-9}$	$\mathcal{O}(10^{-10})$	$Z \to \tau\tau\gamma$ bkg , $\sigma(p_\gamma)$ limited
BR($\tau \to e\gamma$)	$< 3.3 \times 10^{-8}$	$\sim 2 \times 10^{-9}$		$Z \to \tau\tau\gamma$ bkg, $\sigma(p_\gamma)$ limited
BR($Z \to \tau\mu$)	$< 1.2 \times 10^{-5}$	$\mathcal{O}(10^{-9})$	same	$\tau\tau$ bkg, $\sigma(p_{\text{track}})$ & $\sigma(E_{\text{beam}})$ limited
BR($Z \to \tau e$)	$< 9.8 \times 10^{-6}$	$\mathcal{O}(10^{-9})$		$\tau\tau$ bkg, $\sigma(p_{\text{track}})$ & $\sigma(E_{\text{beam}})$ limited
BR($Z \to \mu e$)	$< 7.5 \times 10^{-7}$	$10^{-8} - 10^{-10}$	$\mathcal{O}(10^{-9})$	PID limited
BR($Z \to \pi^+\pi^-$)			$\mathcal{O}(10^{-10})$	$\sigma(\vec{p}_{\text{track}})$ limited, good PID
BR($Z \to \pi^+\pi^-\pi^0$)			$\mathcal{O}(10^{-9})$	$\tau\tau$ bkg
BR($Z \to J/\psi\gamma$)	$< 1.4 \times 10^{-6}$		$10^{-9} - 10^{-10}$	$\ell\ell\gamma$+$\tau\tau\gamma$ bkg
BR($Z \to \rho\gamma$)	$< 2.5 \times 10^{-5}$		$\mathcal{O}(10^{-9})$	$\tau\tau\gamma$ bkg, $\sigma(p_{\text{track}})$ limited

Strange Physics

One prominent example: KS ->μμ

Γ_{11}	$\mu^+\mu^-$	*S1*	$< 2.1 \times 10^{-10}$

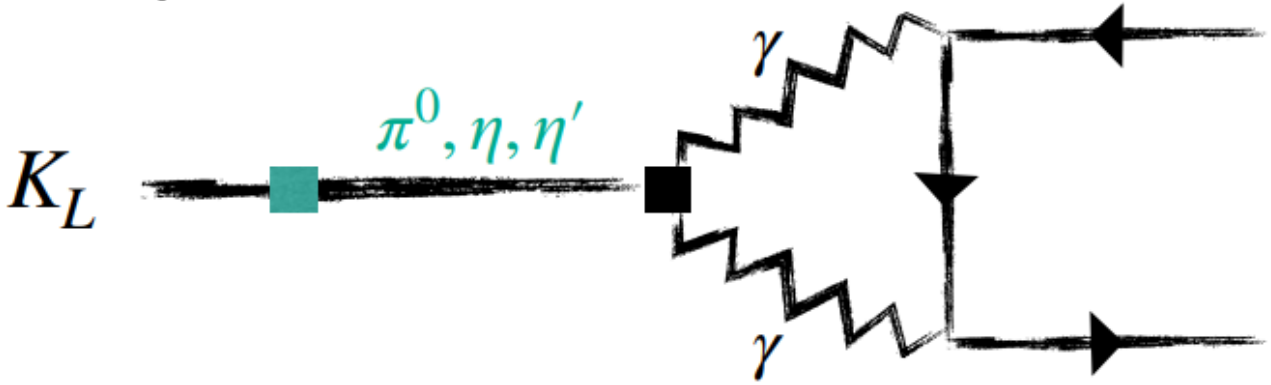
LD SD

$$\mathcal{B}(K_S \to \mu^+\mu^-)_{\rm SM} \approx (4.99 + 0.19) \times 10^{-12}$$
$$= (5.18 \pm 1.50 \pm 0.02) \times 10^{-12}$$

Two orders of magnitude away! Decay length ~ 3 cm.
Syst. dominated @ LHCb, challenging even at future K factories.

Strange Physics

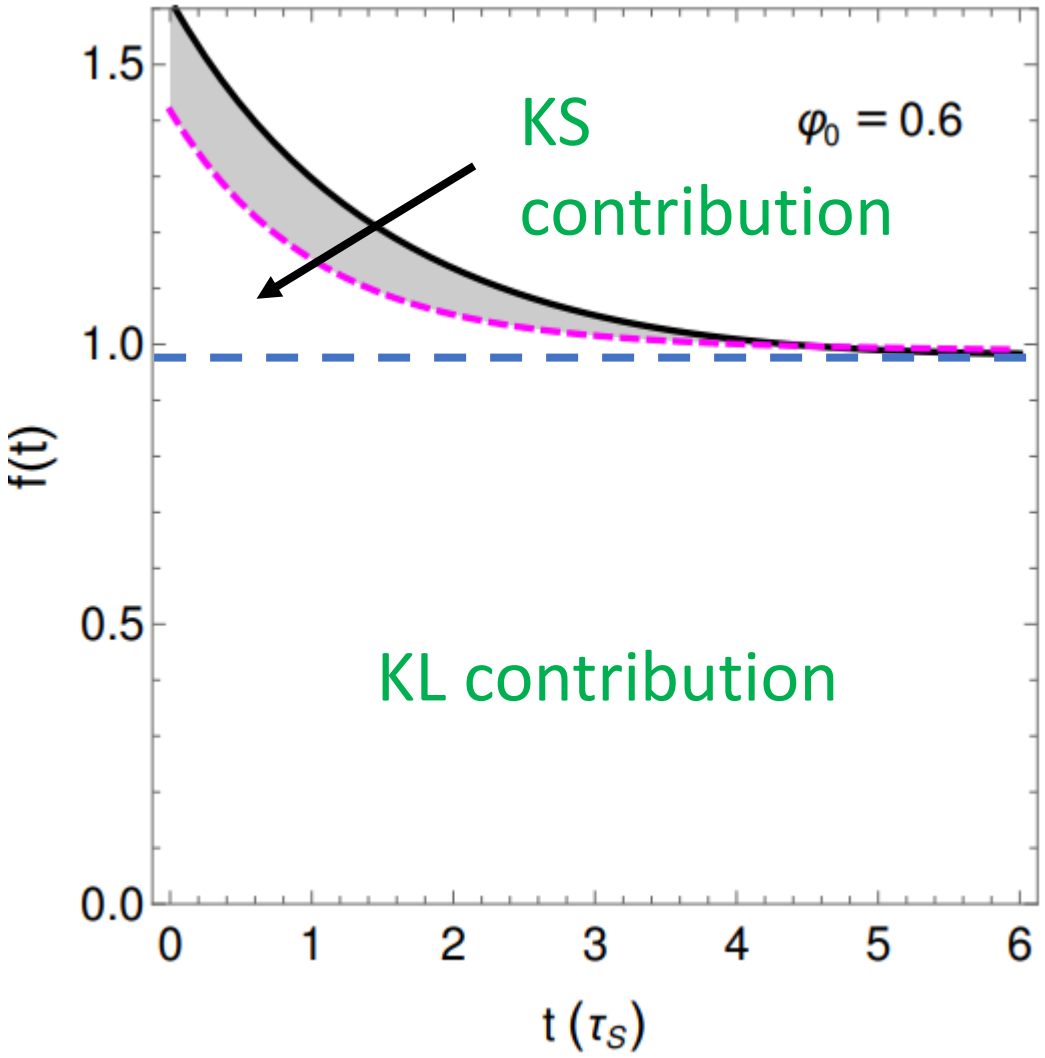
Dominated by KL decays with long-distance contributions



Statistics require O(10^{13}) neutral K0's
Possible for a Tera-Z+:

- QCD K0 in general jets (~1 in each Z-> qq)
- Z->ss to hard K0's
- b/c decay to K0's in Z->bb/cc

Need to measure precise lifetime, transition from KS to KL



Strange Physics

If the strange can be “tagged”, $D = \dfrac{N_{K^0} - N_{\overline{K}^0}}{N_{K^0} + N_{\overline{K}^0}}$ is non zero, can be used to measure CPV in the short distance KS-> μμ amplitude

$$\mathcal{B}(K_S \to \mu^+\mu^-)_{\ell=0} = \frac{\beta_\mu \tau_S}{16\pi m_K} \left| \frac{G_F}{\sqrt{2}} \frac{2\alpha_{em}}{\pi \sin^2\theta_W} m_K m_\mu \times Y(x_t) \times f_K \times V_{ts}V_{td}\sin\theta_{ct} \right|^2$$

$$\approx 1.64 \cdot 10^{-13} \times \left| \frac{V_{ts}V_{td}\sin\theta_{ct}}{(A^2\lambda^5\bar{\eta})_{\text{best fit}}} \right|^2 ,$$

BSM Physics: Light States from Flavor

- From tau decays: see Anson's talk later
- From B decays: Ongoing
- New ideas?