

Discussion – SM constraints

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Kaons @ CERN
September 12th, 2023

Why kaon physics?

- What is the best way to **visualize** the impact of precision measurements in constraining new physics models? Two types:
 - to sell Kaon physics to the wider community (flavour and non-flavour)
 - to understand which measurement we expect to have the biggest impact? (On what?)
- What **mass scales** could be reached?, or:
- Should we look at **multi-dimensional fits**? Two types:
 - SMEFT
 - CKM fit

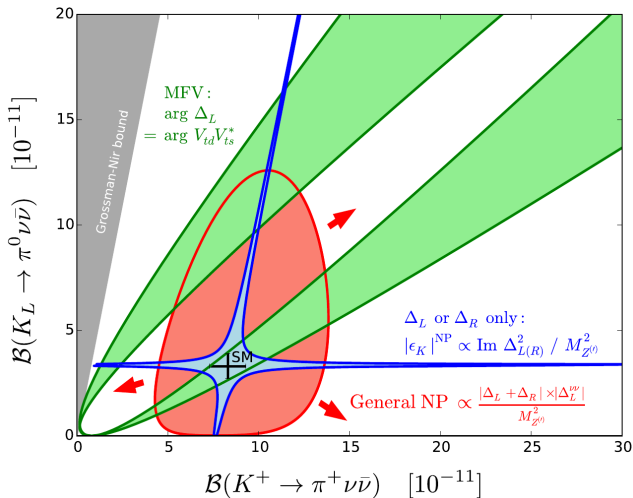
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Rare K decays: charged vs. neutral mode



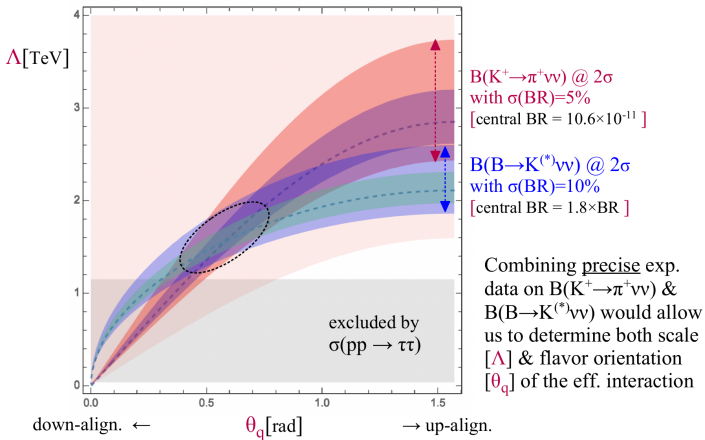
[Buras, Buttazzo, Kneijens 1507.08672]

SMEFT

G. Isidori – The BSM potential of rare kaon decays

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► Effective-theory approach



HIKE: Kaon Global fit

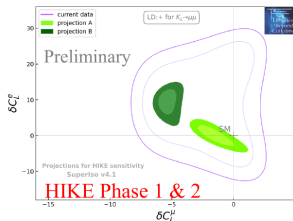
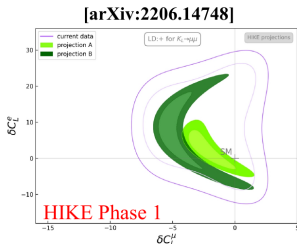
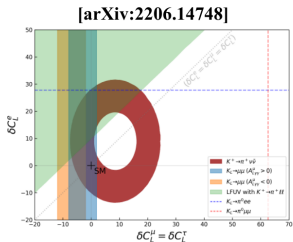
Global fits to set of kaon measurements, in the framework of lepton universality.
Effect on Wilson coefficients for NP scenarios with only left-handed quark currents.

$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} \lambda_t^{sd} \frac{\alpha_e}{4\pi} \sum_k C_k^\ell O_k^\ell$$

$$C_k^\ell = C_{k,SM}^\ell + \delta C_k^\ell$$

$$O_L^\ell = (\bar{s} \gamma_\mu P_L d) (\bar{\nu}_\ell \gamma^\mu (1 - \gamma_5) \nu_\ell)$$

[CERN Physics Beyond Colliders Document in preparation, and paper in preparation by D’Ambrosio, Mahmoudi, Neshatpour]



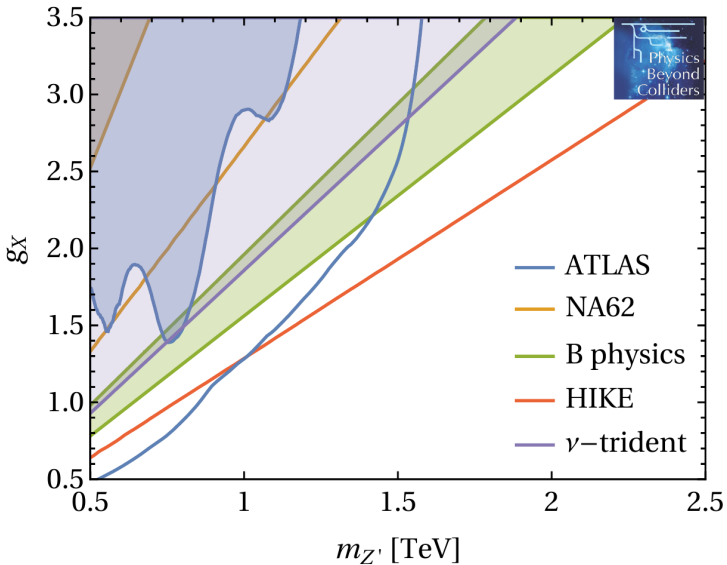
Bounds from individual observables.
Coloured regions are 68%CL measurements
Dashed lines are 90%CL upper limits

Projections assumptions:

- A:** central value for existing measurements kept the same + SM expectation used for measurement with upper bounds
- B:** central value of all observables is projected to the best-fit points obtained from fits to existing data

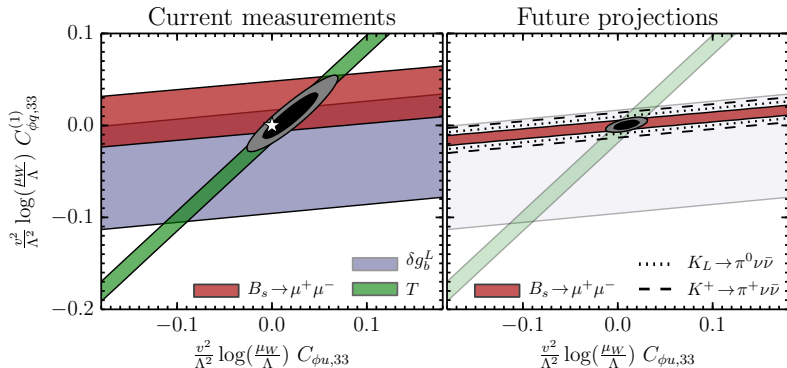
Z'

$$g_\mu^V = g_\tau^V = -g_X, m_T = 2.0 \text{ TeV}, \sin(\theta_R) = 0.5$$



ttZ couplings

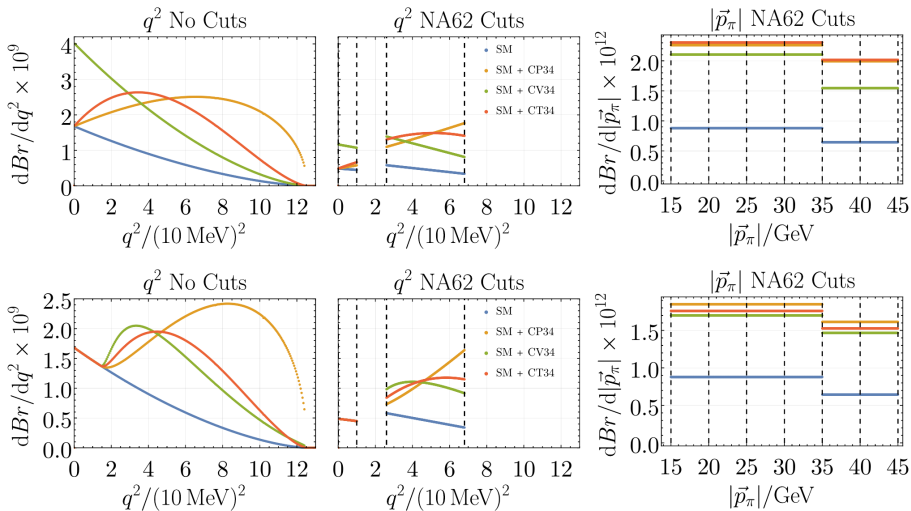
- $(H^\dagger i \overleftrightarrow{D}_\mu^a H)(\bar{Q}_{L,3} \gamma^\mu \sigma^a Q_{L,3}), (H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{Q}_{L,3} \gamma^\mu Q_{L,3}), (H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{t}_R \gamma^\mu t_R)$



[Brod, Greljo, Stamou, Uttayarat 1408.0792]

Differential rates

- $(\bar{L}_L N_R)\epsilon(\bar{Q}_L d_R)$ [Gorbahn, Moldanarazova, Seija, Stamou, Tabet, W.I.P.]



What is needed for a successful kaon program?

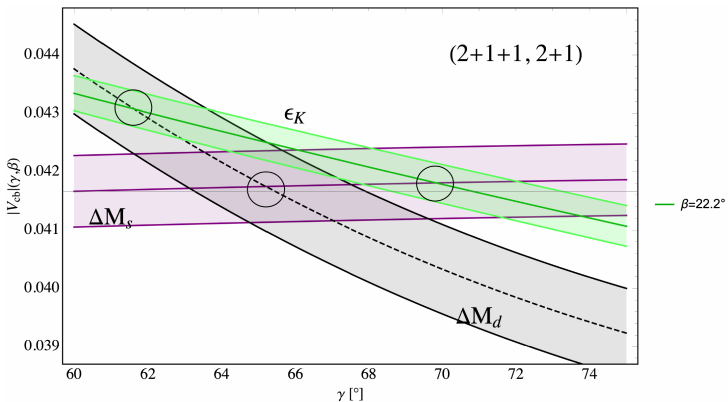
- What is the current theory error for:
 - $K \rightarrow \pi\nu\bar{\nu}$?
 - $K \rightarrow \mu^+\mu^-$?
 - $K \rightarrow \pi\ell^+\ell^-$?
 - ϵ'/ϵ ?
 - $K_{\ell 2}, K_{\ell 3}$?
- What is the ultimate theory error for these modes?
- What about parametric uncertainties?

$$K \rightarrow \pi \ell^+ \ell^-$$

- Test different operators – scalar, vector, tensor
 - (sign of) a_S ?
 - Differential spectrum?

$$\text{Br}(K_L \rightarrow \pi^0 \ell^+ \ell^-) = (C_{\text{dir}}^\ell \pm C_{\text{int}}^\ell |a_S| + C_{\text{mix}}^\ell |a_S|^2 + C_{\gamma\gamma}^\ell) \times 10^{-12}$$

Ratios as tests for NP



[Buras 2307.15737]