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FCNC $q \to q'\nu\nu$ Distributions and NA62 Interpretations

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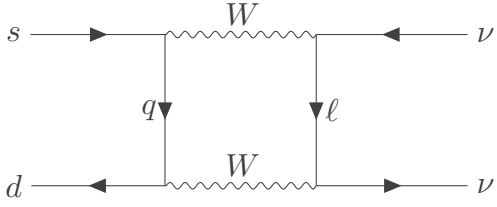
Observables: Flavour-changing neutral currents (FCNCs)

The FCNCs $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$



- FCNCs are strongly suppressed within the SM

Why?

FCNCs are forbidden at tree-level $\longrightarrow$ loop-suppression

Glashow-Iliopoulos-Maiani mechanism $\longrightarrow$ cancellation of the different quark-loops

The FCNCs $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$

- small branching ratio opens up sensitivity to indirect NP effects
- good control over hadronic uncertainties via related decays
- dedicated searches for K^+ and K_L promise new experimental input in not-so-far future

$$\mathcal{B}r(K^+ \to \pi^+ \bar{\nu}\nu)|_{SM} = (7{,}73 \pm 0{,}61) \cdot 10^{-11}$$
$$\mathcal{B}r(K_L \to \pi^0 \bar{\nu}\nu)|_{SM} = (2{,}59 \pm 0{,}28) \cdot 10^{-11}$$ [Stamou]

$$\mathcal{B}r(K^+ \to \pi^+ \bar{\nu}\nu) = 1{,}14^{+0{,}64}_{-0{,}33} \cdot 10^{-10}$$
$$\mathcal{B}r(K_L \to \pi^0 \bar{\nu}\nu) < 4{,}9 \cdot 10^{-10} @ 90\,\%\mathrm{CL}$$ [PDG]

Low-Energy-Effective-Field-Theory at Dimension Six

[Gorbahn et al., 2024]

$$\mathcal{L}^{(6)}_{s\to d\nu\nu} = \sum_{f,I,\tau} C_f^{I,\tau} O_f^{I,\tau} (+\text{h.c.})$$

→ operators written in terms of Majorana or Dirac neutrino fields with arbitrary masses

Dirac

$$O^{V,L/R\,L/R}_{ijsd} = (\bar{\nu}_{Di}\gamma_\mu P_{L/R}\nu_{Dj})(\bar{d}\gamma^\mu P_{L/R}s)$$
$$O^{S,L\,L/R}_{ijsd} = (\bar{\nu}_{Di}P_L\nu_{Dj})(\bar{d}P_{L/R}s)$$
$$O^{T,LL}_{ijsd} = (\bar{\nu}_{Di}\sigma_{\mu\nu}P_L\nu_{Dj})(\bar{d}\sigma^{\mu\nu}P_L s)$$

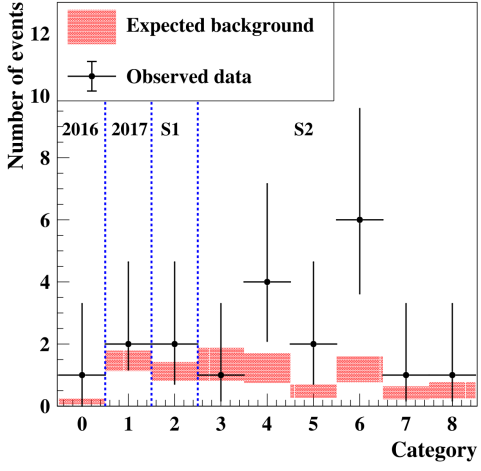
⇒ 90 in dependent complex Wilson coefficients

Majorana

$$O^{V(A),L/R}_{ijsd} = \tfrac{1}{2}(\bar{\nu}_{Mi}\gamma_\mu(\gamma_5)\nu_{Mj})(\bar{d}\gamma^\mu P_{L/R}s)$$
$$O^{S(P),L}_{ijsd} = \tfrac{1}{2}(\bar{\nu}_{Mi}(i\gamma_5)\nu_{Mj})(\bar{d}P_L s)$$
$$O^{T,L}_{ijsd} = \tfrac{1}{2}(\bar{\nu}_{Mi}\sigma_{\mu\nu}\nu_{Mj})(\bar{d}\sigma^{\mu\nu}P_L s)$$

⇒ 48 in dependent complex Wilson coefficients

NA62 measurement of $K^+ \to \pi^+ \nu\bar{\nu}$



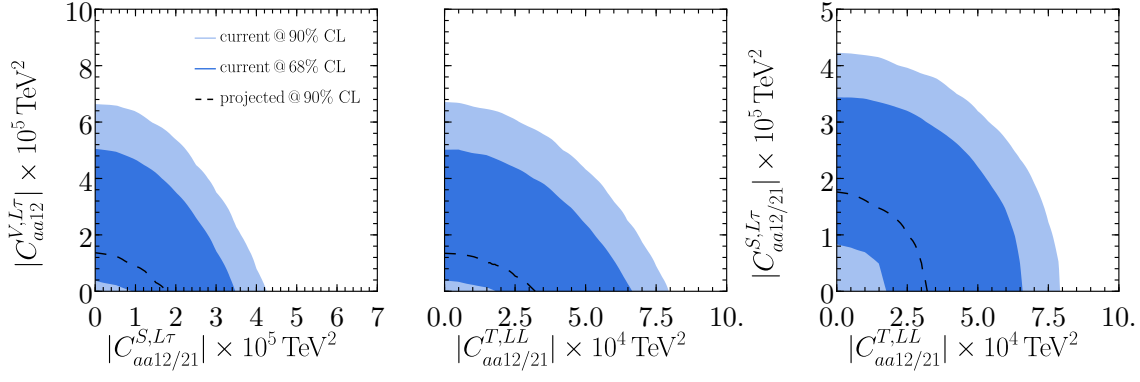
- categories include old (2016,2017) and new momentum binned data (S1,S2)
- first sensitivity to kinematic distributions

$\Rightarrow$ new input to constrain NP tensor and scalar interactions

[Cortina Gil, 2021]

Results: NP Sensitivities and Correlations

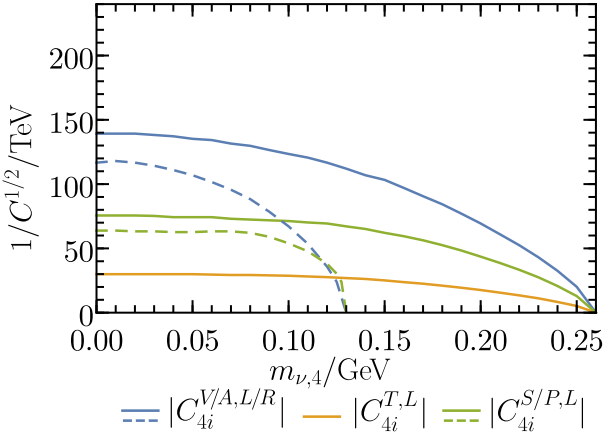
SM Diracs plus one NP operator → probing scales of $\mathcal{O}(100\,\mathrm{TeV})$



Results: Sensitivities to Massive Sterile Neutrinos

SM Majoranas plus one massive 4th neutrino $\rightarrow$ probing scales of $\mathcal{O}(100\,\mathrm{TeV})$

- considering masses within the kinematically allowed region
- final states with one (solid) or two (dashed) 4th neutrinos



Conclusion

- studied impact of a massive sterile neutrino on the invisible mass spectrum
- model-independent constraints on various New Physics scenarios
- currently sensitive to New Physics up to $\mathcal{O}(100\,\mathrm{TeV})$

  $\Rightarrow$ strong motivation for future kaon programs

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- studied impact of a massive sterile neutrino on the invisible mass spectrum
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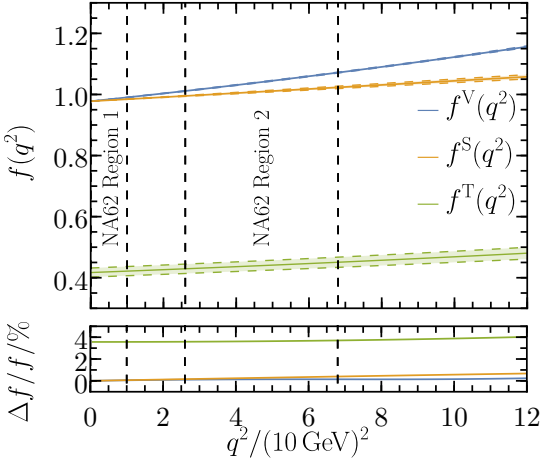
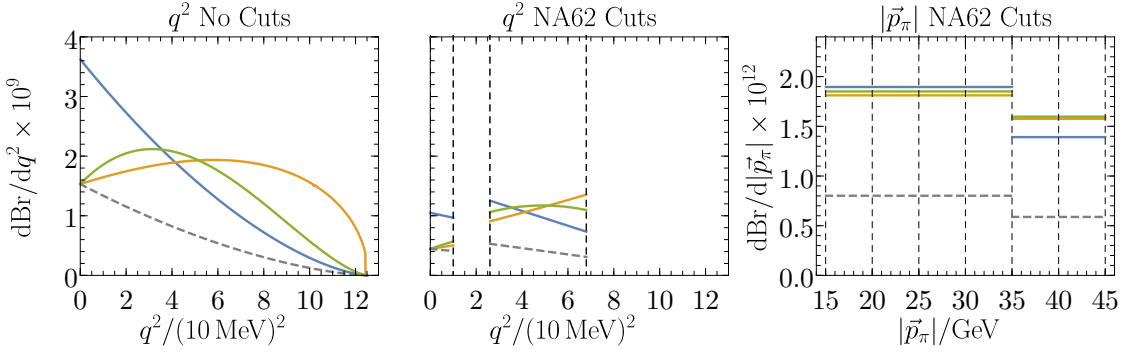
Outlook

- looking into similar studies of the K_L mode
- SMEFT or specific UV models $\longrightarrow$ correlations between different operators

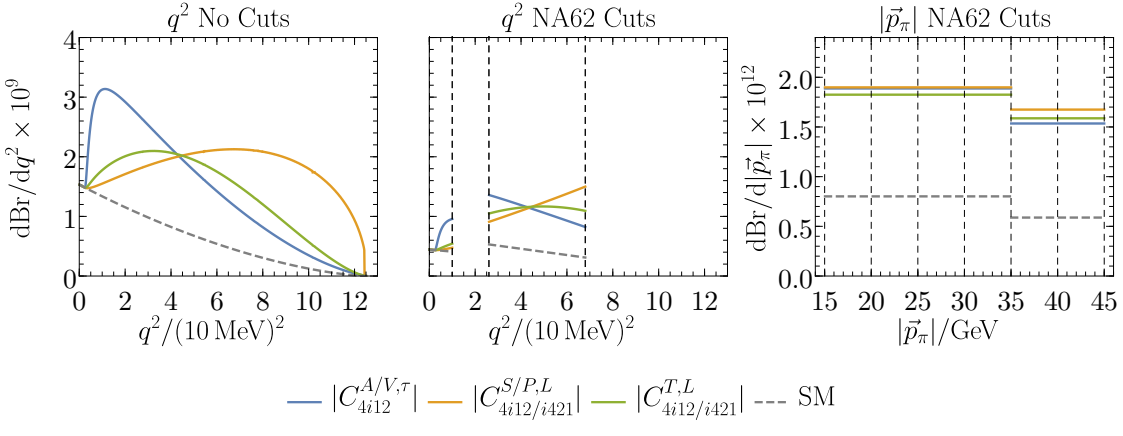
Backup: q^2 dependent uncertainties



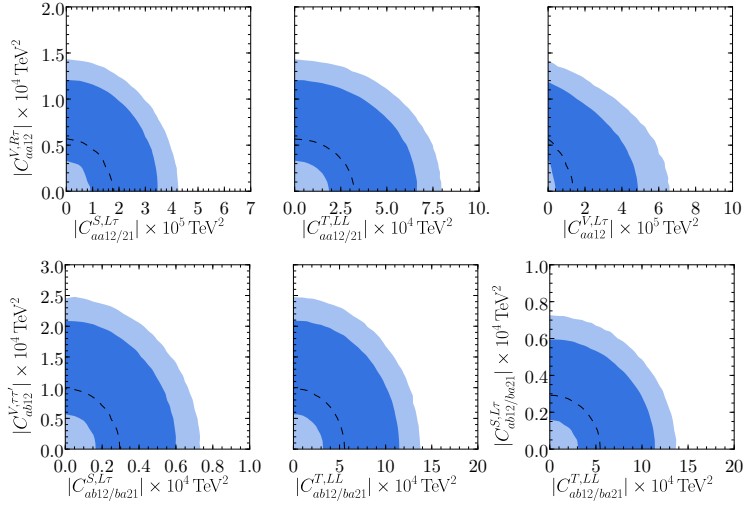
Backup: Differential distributions of 3 massless neutrinos



Backup: Differential distributions of 3 massless Majorana neutrinos plus one massive 4th-generation Majorana neutrino $m_{\nu,4} = 50\,\mathrm{MeV}$



Backup: Dirac Correlations



Backup: Majorana Correlations