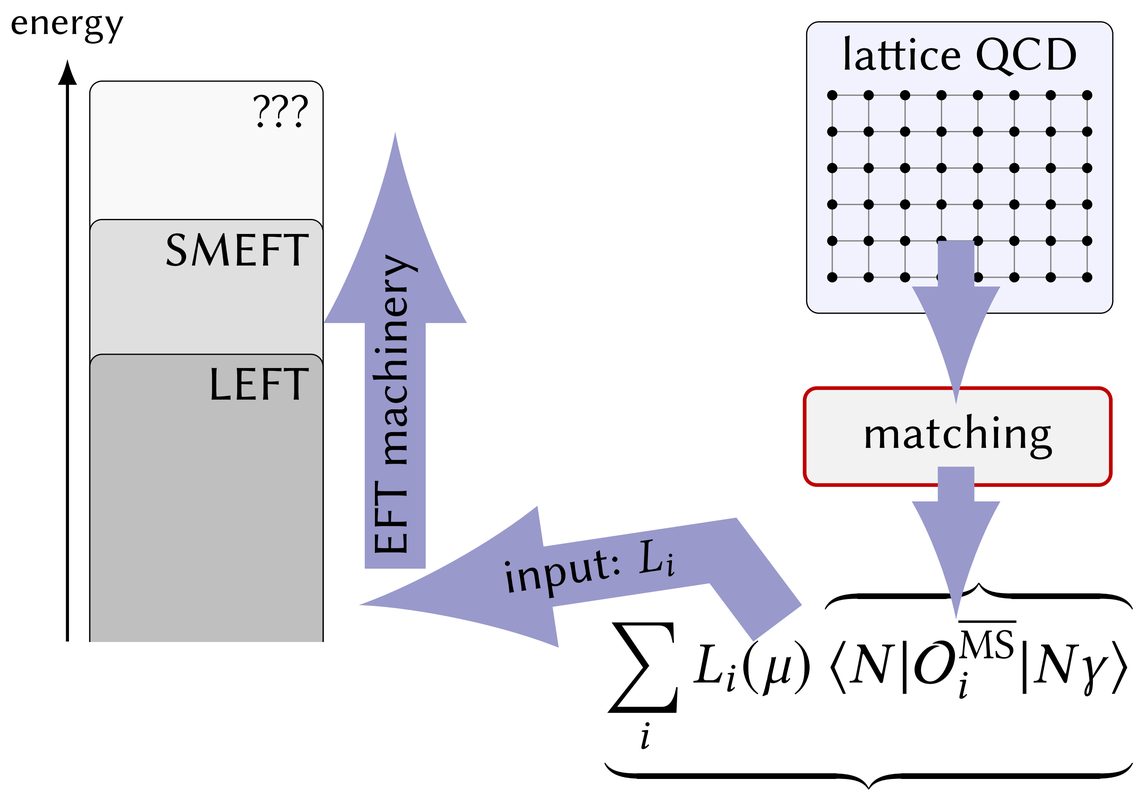
Low-energy traces of heavy new physics

Indirect searches for new physics

- The Standard Model (SM) of particle physics is one of the greatest achievments but fails to explain e.g. the dominance of matter over antimatter
- New SM particles might be too heavy to produce directly in particle accelerators from $E = mc^2$
- Instead, they can appear virtually through quantum corrections and lead to footprints in low-energy observables 👣
- These indirect searches require precision calculations, which are agnostic w.r.t. the underlying theory at higher energies



EFT machinery

- The SM can be extended to an EFT valid below the scale $\Lambda_{\rm NP}$ of new physics

$$\mathcal{L}_{\rm SMEFT} = \mathcal{L}_{\rm SM} + \sum_{d\geq 5} \frac{1}{\Lambda_{\rm NP}^{d-4}} \sum_i C_i O_i$$

- The LEFT describes physics below $\Lambda_{\rm EW} \approx 100$ GeV

$$\mathcal{L}_{\rm LEFT} = \mathcal{L}_{\rm QED+QCD} + \sum_i L_i O_i$$

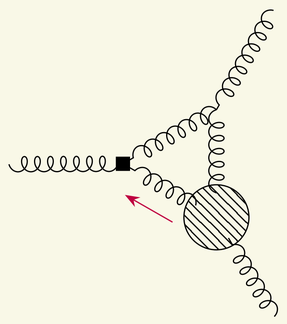
- The number of operators O_i in each EFT grows with the dimension d and can be calculated with algebraic methods (Hilbert series)
- Goal: translate low-energy data to high energies, using matching and renormalization-group running 🧐
- We have developed a suitable scheme for the LEFT, preserving chiral symmetry (2310.13051)

CP and lepton-flavor violation

- Baryon asymmetry $\Longrightarrow$ we need more CP violation than the one we have in the SM (CKM phase + possible θ-term)
- The SM predicts lepton-flavor conservation, i.e. processes such as $\mu \to e\gamma$ are forbidden
- From an EFT perspective, we study the implications that experiments at PSI have on New Physics models:
  - We are interested in hadronic effects in the processes $\mu \to e\gamma$ (1810.05675) and $\mu \to 3e$, measured by the MEG and Mu3e collaborations
  - The nEDM collaboration gives the best upper bound on the neutron electric dipole moment, a CP-violating observable, see the gradient-flow section

The gradient-flow formalism for CP violating observables

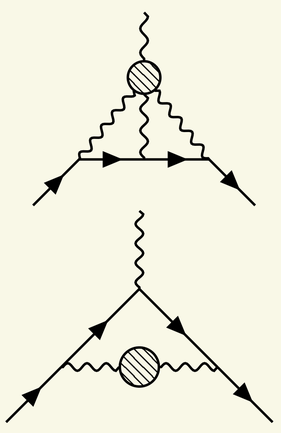
- Hadronic EDMs are non-perturbative quantities $\Longrightarrow$ we require matrix elements from lattice QCD
- The EFT tower requires results given in $D = 4 - 2\epsilon$ space-time dimensions. However, lattice QCD is tied to integer dimensions 😢
- We are involved in the translation between lattice scheme (gradient flow) and EFT-tower scheme (minimal subtraction): (2111.11449), (2304.00985), (2308.16221)

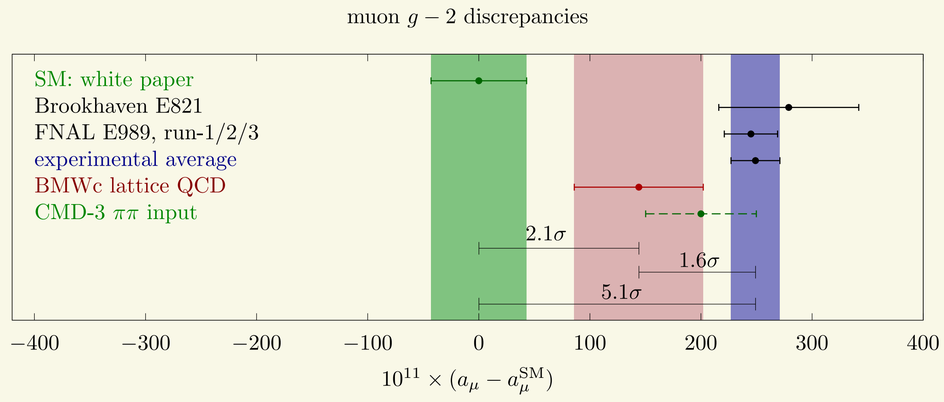


- We also get the LEFT renormalization group equations for free! 🤩

Muon g-2

- Current SM prediction unclear🤬: discrepancies between lattice simulations and the dispersive approach which uses e^+e^- data
- We aim to lower uncertainties in the hadronic light-by-light and hadronic vacuum polarization contributions: (2208.08993), (2302.12264), (2308.04217), (2402.14060), (2410.11946)





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