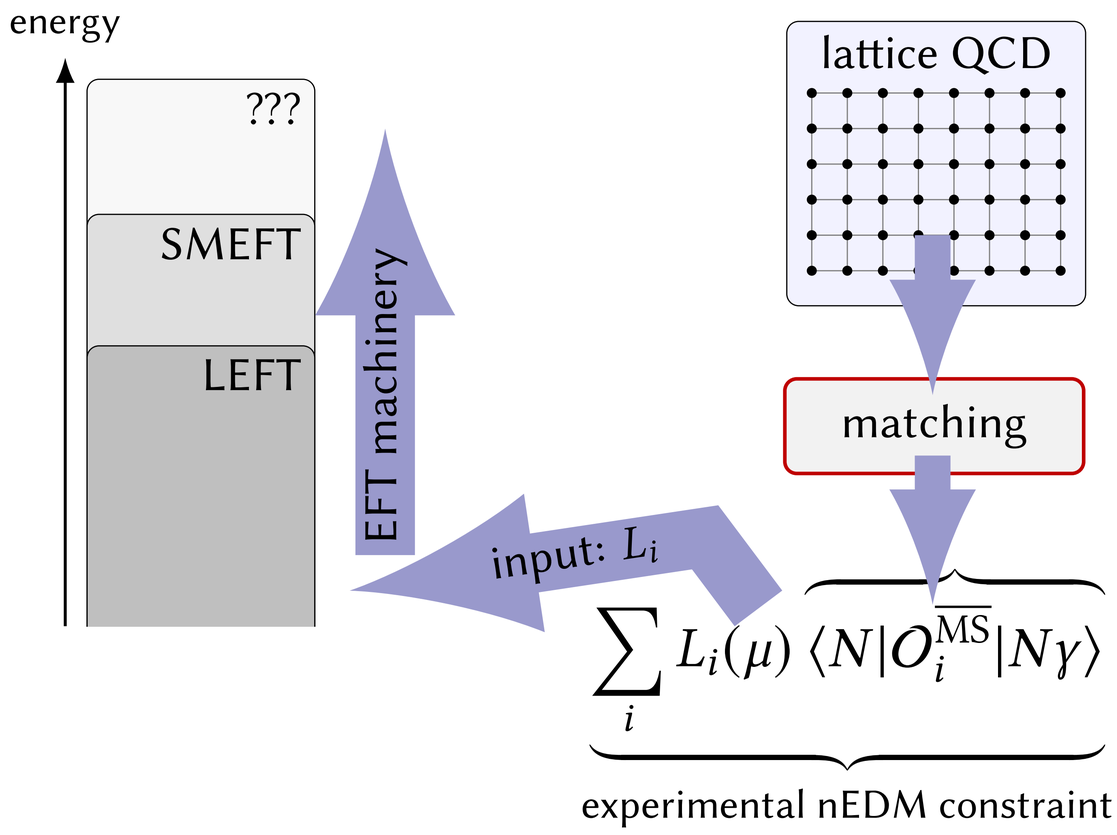
Low-energy traces of heavy new physics

Indirect searches for new physics

- The Standard Model (SM) of particle physics is incomplete
- If new particles are too heavy, we cannot produce them directly in particle accelerators, since we may not reach the required energy $E = mc^2$
- Indirect searches can still detect footprints of new particles through the influence of their quantum corrections
- This requires precision calculations at low energies, which are agnostic w.r.t. UV theory



EFT machinery

- The SM can be extended to an EFT (SMEFT), valid below the scale of new physics
- The LEFT describes physics below $\Lambda_{\rm EW} \approx 100$ GeV

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

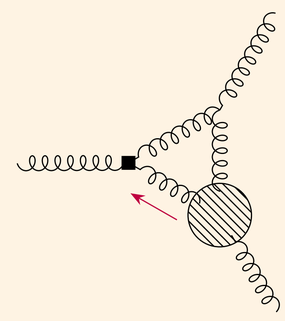
- Renormalization group & matching allows to evolve theory parameters to different energies
- Ultimate goal: translating low-energy experimental results into information on unknown more fundamental theories 🧐
- We have developed a renormalization scheme for the LEFT based on the 't Hooft–Veltman scheme, but preserving chiral symmetry: (2310.13051)
- EFT calculations can be done in a geometric formalism, which simplifies loop calculations (2310.19883)

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

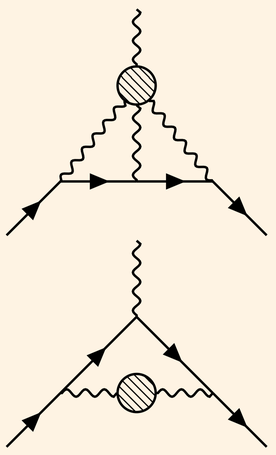
The gradient-flow formalism for CP violating observables

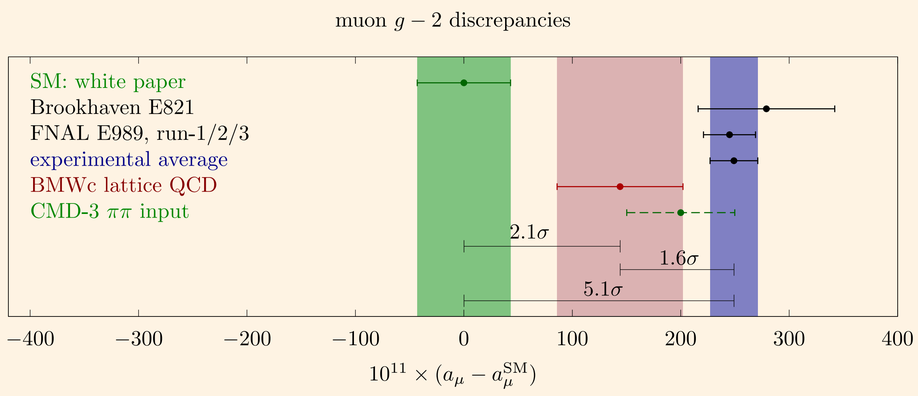
- Hadronic EDMs are non-perturbative quantities $\Longrightarrow$ we require matrix elements from lattice QCD
- The EFT tower requires results given in $D = 4 - 2\epsilon$ space-time dimensions. However, lattice QCD is tied to integer dimensions 😢
- We are involved in the translation between lattice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



Muon g-2

- Tension between measured value and SM prediction could indicate presence of new physics
- Requires control over hadronic uncertainties
- Our group is involved in the determination of the hadronic light-by-light and hadronic vacuum polarization contributions: (2208.08993), (2302.12264), (2308.04217)





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