EDMs and CP violation

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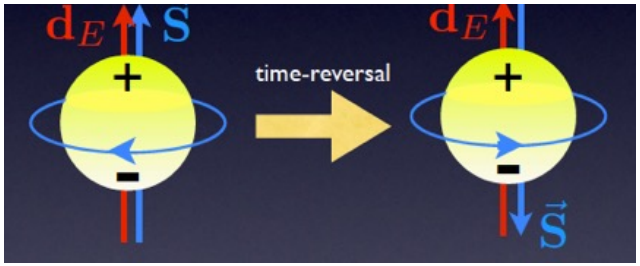
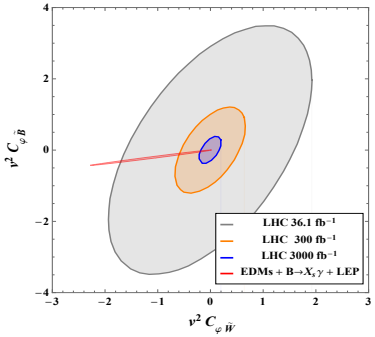
July 20, 2022

LA-UR-22-27106

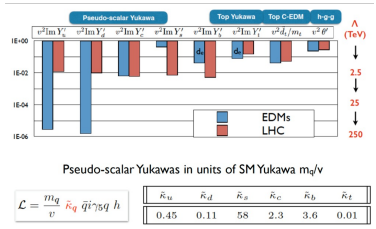
Why EDMs?



- CP violation in excess of Standard Model contribution must exist.
  - SM can't create the baryon asymmetry
- If BSM CP-violation couples to the baryons or charged leptons
  - EDMs much larger than the tiny SM contribution.
- **Opportunity for rapid improvement in the next decade.**
- Arise at a very high scale if at one-loop
  - Electron EDM 10^{-29} *e* cm 48 TeV
  - Quark EDM 10^{-29} *e* cm 130 TeV
  - Quark cEDM 10^{-29} cm 250 TeV
  - Gluon cEDM 10^{-29} cm/100 MeV 260 TeV
- Often complementary to accelerator searches.



Cirigliano *et al.*, PRL 123, 051801 (2019)



Cirigliano *et al.*, PRD 94 (2016) 016002

Needs combination of theory and experiments

- Experimental result = (Fundamental Physics) * (Hadronic matrix elements)
- Hadronic matrix elements very poorly known

$$d_n = -(0.0015 \pm 0.0007)\ e\,\vartheta\ \text{fm}$$
$$-(0.20 \pm 0.01)d_u + (0.78 \pm 0.03)d_d + (0.0027 \pm 0.016)d_s$$
$$-(0.55 \pm 0.28)e\tilde{d}_u - (1.1 \pm 0.55)e\tilde{d}_d \pm (50 \pm 40)e\,w\ \text{MeV}$$

$$\bar{g}_0 = (5 \pm 10)\left(\tilde{d}_u + \tilde{d}_d\right)\ \text{fm}^{-1}$$

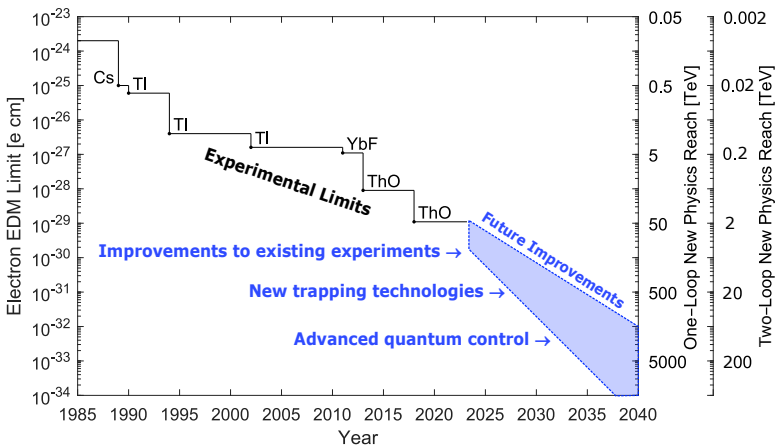
$$\bar{g}_1 = (24^{+40}_{-10})\left(\tilde{d}_u - \tilde{d}_d\right)\ \text{fm}^{-1}$$

Green indicates lattice results

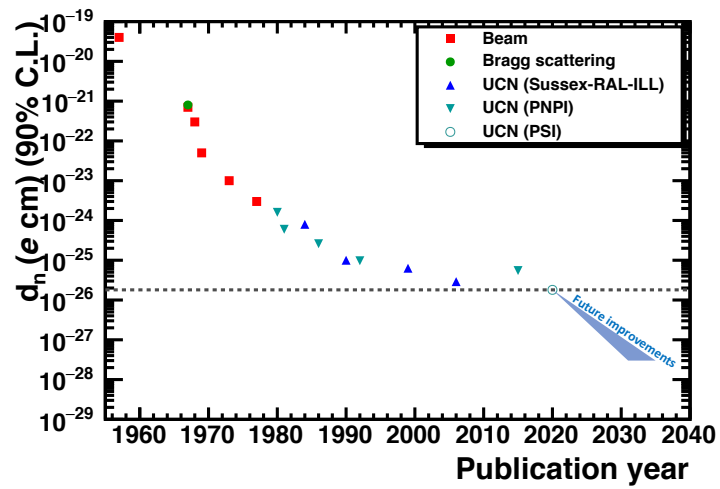
Need multiple systems

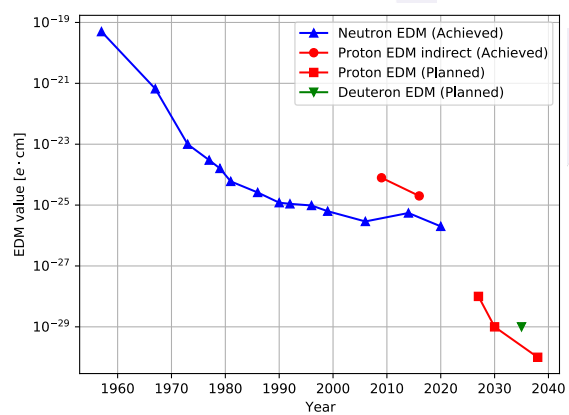
- More than one low-energy CPV quantity: d_n, d_p, g_0, g_1, d_e, C_S, C_P, C_T, …
- Need EDM of more than one system
  - Neutron EDM: d_n
  - Proton EDM: d_p
  - Nuclear/Diamagnetic atoms/molecules EDM (^{199}Hg, ^{129}Xe, ^{225}Ra): d_n, d_p, g_0, g_1
  - Paramagnetic atoms and molecules (ThO, HfF^+) EDM: d_e, C_S, C_P, C_T, …
- Interest and expertise among the HEP, NP, and AMO communities; as well as in quantum sensing and other disciplines.

Improvement Over Time: Rapid progress expected



AMO





Proton

Summary

- EDMs one of the best short-term insight into BSM theories
- Needs multiple systems and interdisciplinary science
- Proton storage ring a window of opportunity for HEP