Constraining nuclear matrix elements from lattice QCD for beyond the Standard-Model explorations

Marc Illa, for the NPLQCD Collaboration
IQuS, University of Washington

S. R. Beane, E. Chang, Z. Davoudi, W. Detmold, A. S. Gambhir, W. I. Jay, D. J. Murphy,
P. Oare, K. Orginos, A. Parreño, M. J. Savage, P. E. Shanahan, B. C. Tiburzi, M. L. Wagman, F. Winter

Searching for the nuclear electric dipole moment

E. Chang et al., Phys. Rev. Lett. **120** (2018)

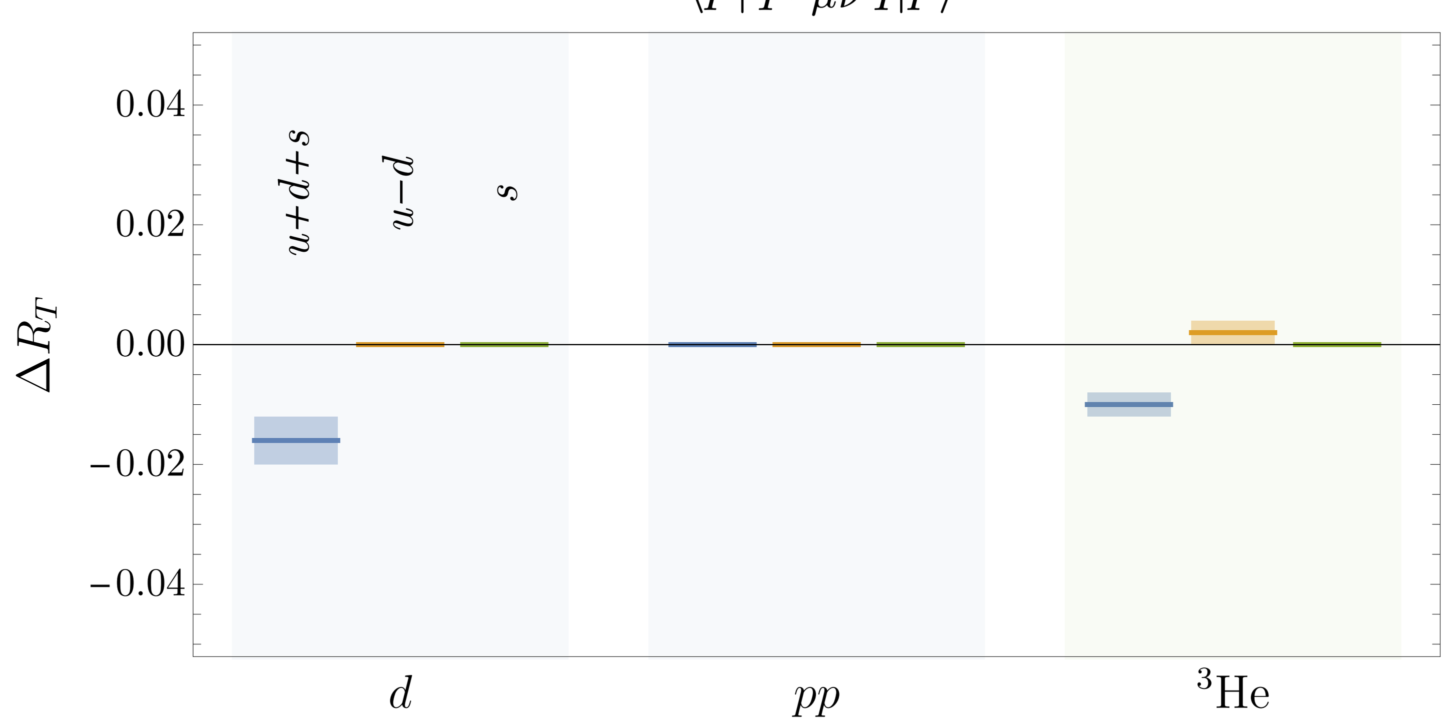
Tensor charges are involved in the quark EDM, a new source of CP violation in some beyond-SM models to solve the observed matter-antimatter asymmetry. Calculations with unphysically large values of the quark masses corresponding to m_π = 806 MeV found nuclear effects at the few-percent level.

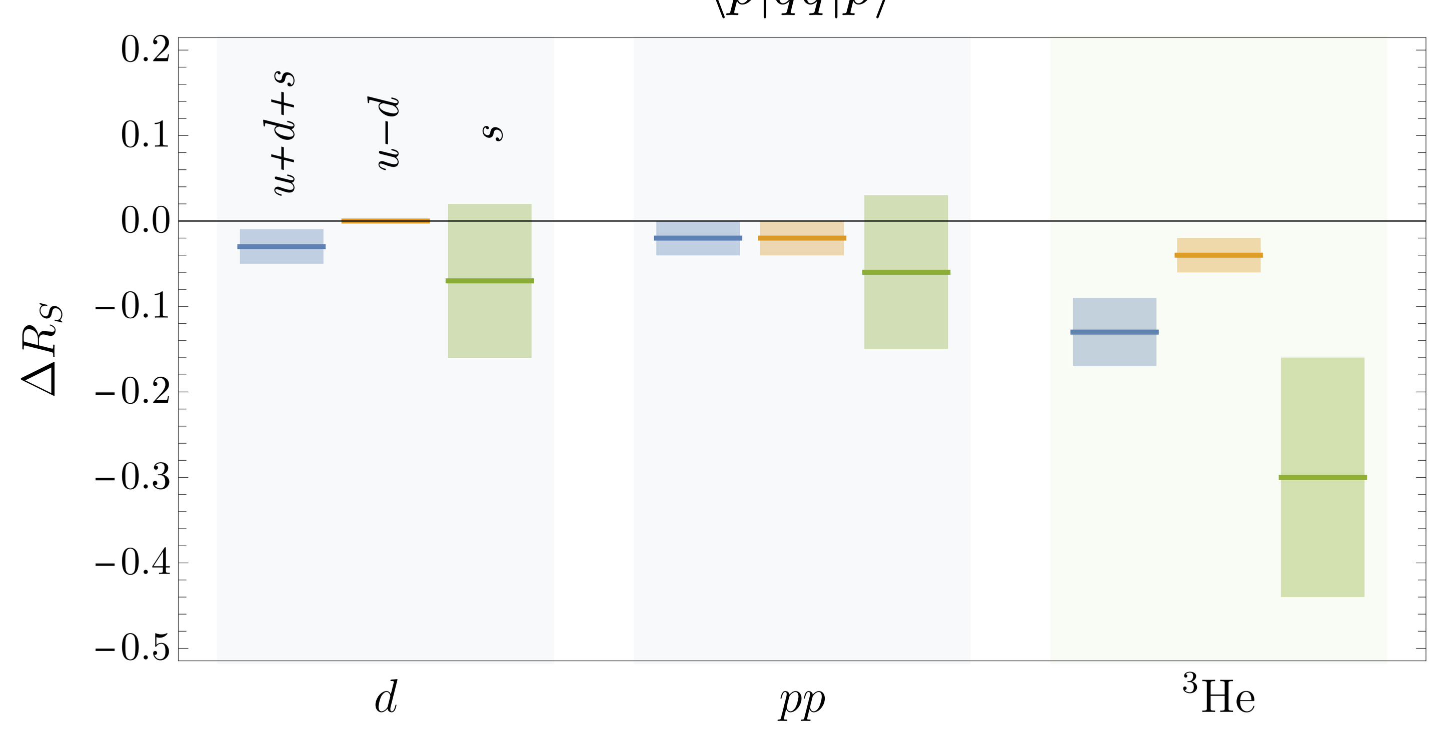
Dark matter detection

E. Chang et al., Phys. Rev. Lett. **120** (2018)

Some operators mediating interactions between dark matter and quarks involve local quark bilinear operators. Nuclear effects in these spin-independent interactions were observed to be as large as 10%, providing an indication of the significant level of uncertainty in the scalar matrix elements in isotopes of relevance to experiments.

$$R_T = \frac{\langle Z,N|\bar{q}\sigma_{\mu\nu}q|Z,N\rangle}{\langle p|\bar{q}\sigma_{\mu\nu}q|p\rangle} \qquad \Delta R_X = R_X - R_X^{\rm NSN} \qquad R_S = \frac{\langle Z,N|\bar{q}q|Z,N\rangle}{\langle p|\bar{q}q|p\rangle}$$





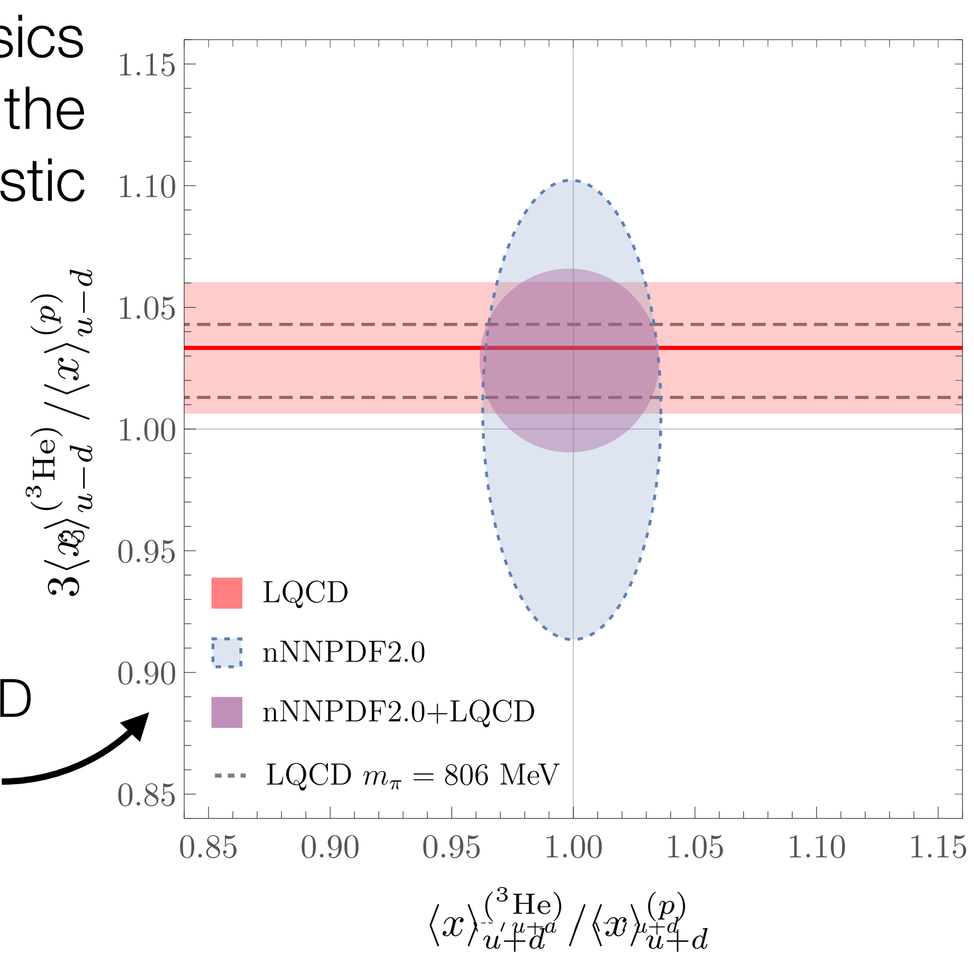
Nuclear targets are critical to many fundamental experiments that are being used to search for previously unknown aspects of physics. Interpreting the results of these experiments with fully controlled uncertainties necessitates a better theoretical understanding of nuclear targets. Large-scale numerical calculations using lattice QCD will allow us to address this challenge and achieve a quantitative connection between the Standard Model and nuclear phenomenology.

Momentum fraction of light nuclei

W. Detmold et al., Phys. Rev. Lett. **126** (2021)

Lattice QCD is expected to quantitatively elucidate the QCD origin of important aspects of nuclear structure, such as the EMC effect, i.e., the difference between the parton distributions of a nucleus and those of the constituent nucleons. Measurements of nuclear PDFs are expected to improve the flavor separation of proton PDFs and thereby reduce the effect of what is currently a leading uncertainty in searches for new physics in p-p collisions at the LHC and in deep-inelastic scattering experiments.

First lattice QCD constraint on nuclear PDFs

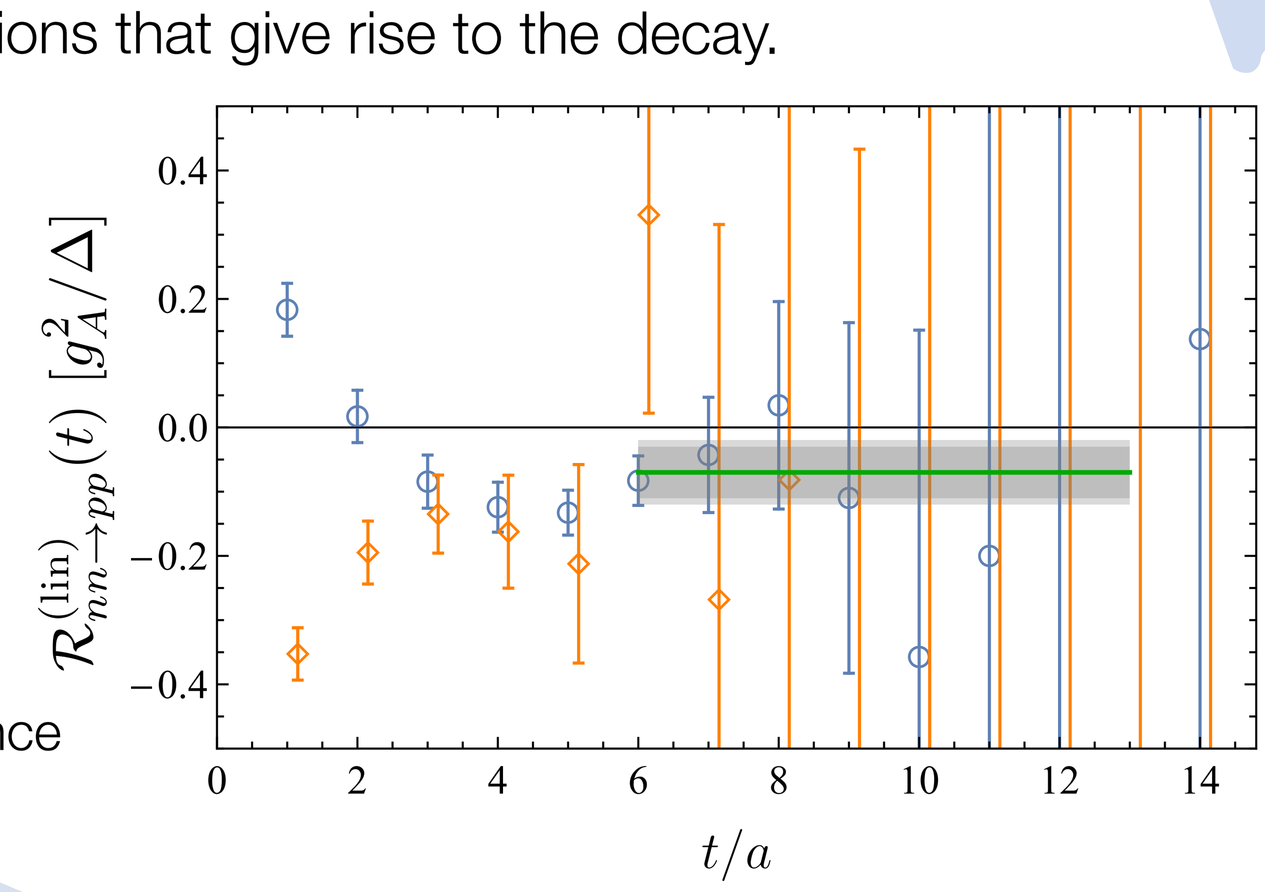


Neutrinoful and neutrinoless double-β decays

P. E. Shanahan et al., Phys. Rev. Lett. **119** (2017); B. C. Tiburzi et al., Phys. Rev. D **96** (2017)

Neutrinoful double-β decays of nuclei are the rarest subatomic processes observed experimentally. They serve as intricate tests of our understanding of the physics of the weak interactions of nuclei and enable probes of deficiencies in that understanding. The neutrinoless decay mode requires lepton number violation and that neutrinos are Majorana particles. For both decays, critical components in determining the decay rate are the nuclear matrix elements of the interactions that give rise to the decay.

Short-distance contribution



QUANTUM SCIENCE CENTER
UNIVERSITY of WASHINGTON
IQuS
NERSC
BSC Barcelona Supercomputing Center
USQCD
PRACE
OAK RIDGE National Laboratory
NPLQCD

For more information, scan here: