NTNP kickoff meeting (virtual)
February 3rd 2023

Nuclear Theory for New Physics (NTNP)

Vincenzo Cirigliano
University of Washington

INSTITUTE for NUCLEAR THEORY

U.S. DEPARTMENT OF ENERGY | Office of Science

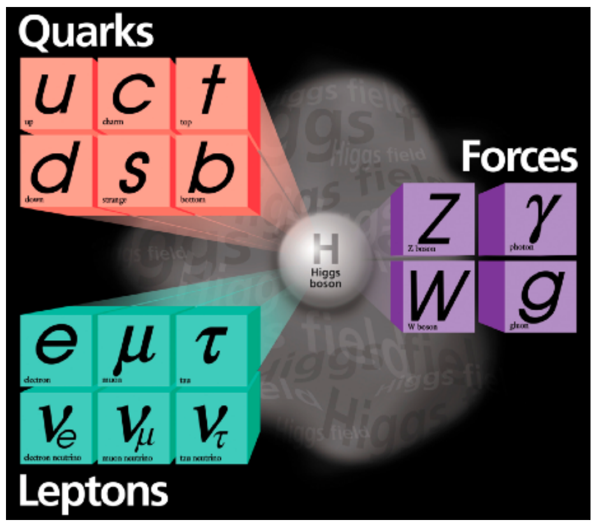
UNIVERSITY of WASHINGTON

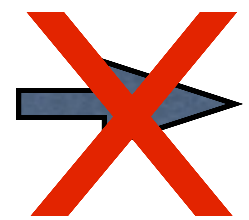
Outline

- Scientific motivation & high level goals
- Structure of the collaboration
- Three scientific thrusts
  - Precision beta decays
  - Permanent electric dipole moments
  - Lepton-nucleus scattering
- Workforce development & DEI
- NTNP @ INT / UW

The questions driving this TC

- The Standard Model is remarkably successful, but it is at best incomplete





No Baryonic Matter, no Dark Matter, no Dark Energy, no Neutrino Mass

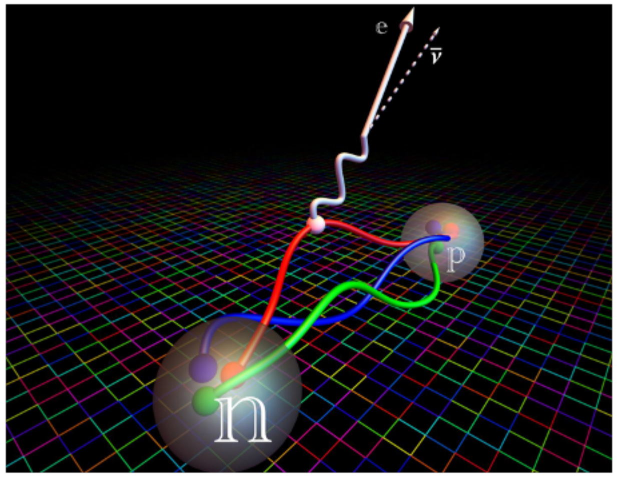
- Low-energy experiments can reveal new physics through precision measurements of SM-allowed processes or by observing SM-suppressed processes

- Nuclear physics plays an important role in the search for new physics through a "targeted program of fundamental symmetries and neutrino research that opens new doors to physics beyond the Standard Model" (2015 NSAC LRP)

High level goals

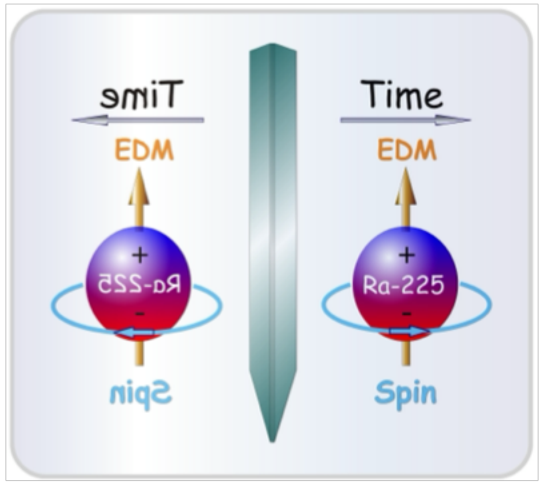
- NTNP focuses on selected aspects of the targeted program, with the goal of providing state-of-the-art predictions with quantified uncertainties.

Image credit: Evan Berkowitz



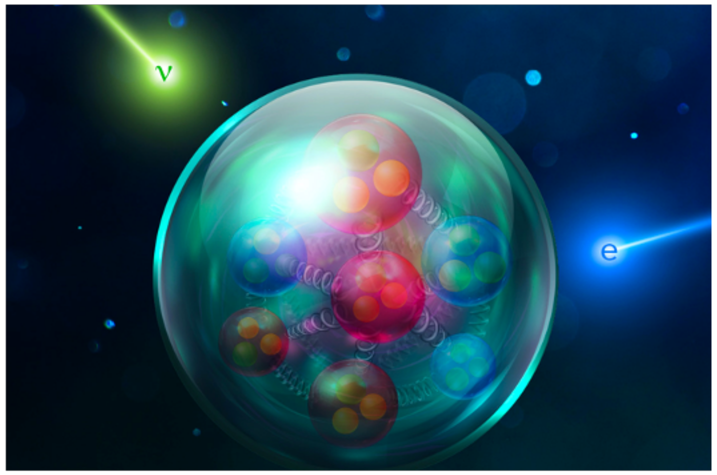
Precision studies of neutron and nuclear beta decays are exquisite probes of the electroweak interactions and can uncover new physics.
NTNP: radiative corrections to neutron & nuclear decays and implications for new physics

Image credit: R. Holt, Z. T. Lu, W. Korsch, P. Muller, J. Singh



The discovery of permanent EDMs would point to a microscopic 'arrow of time', with major implications for the origin of the baryon asymmetry.
NTNP: ab-initio calculations of Schiff moments of ^{129}Xe, ^{199}Hg, ^{225}Ra

Image credit: Jefferson Lab



Neutrino-nucleus scattering is a chief tool to learn about neutrino properties in oscillation experiments: connection to DUNE program (HEP).
NTNP: ab-initio calculations of neutrino-nucleus scattering in A=4,12,16,40

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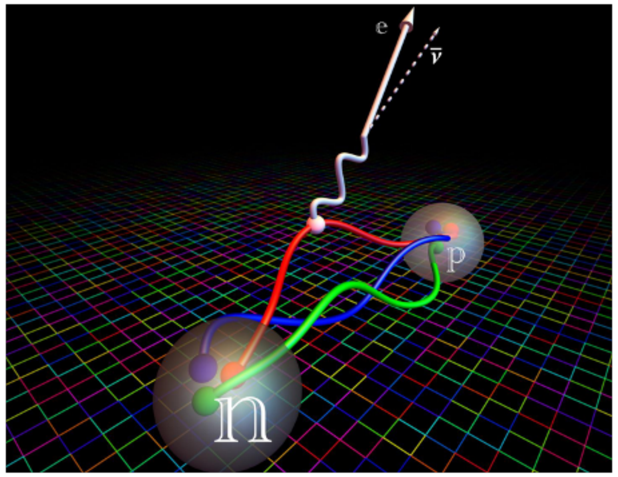

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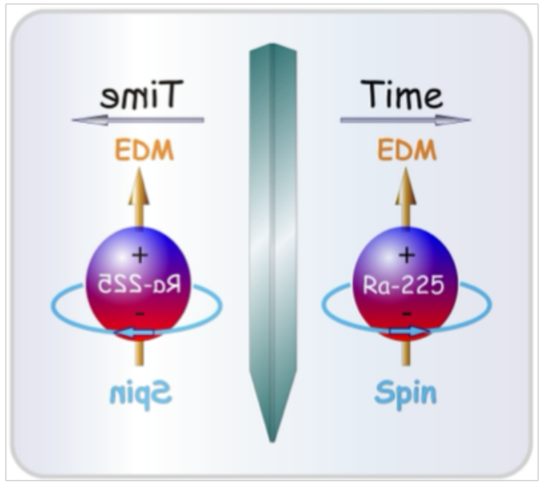

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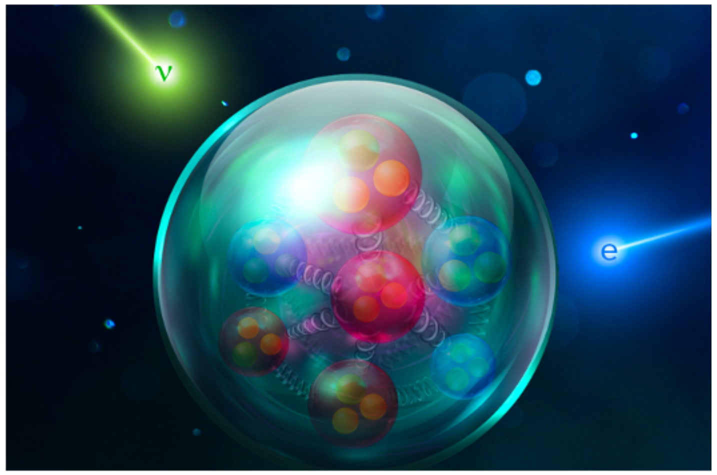

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This theoretical work is essential to turn experimental measurements into discovery tools

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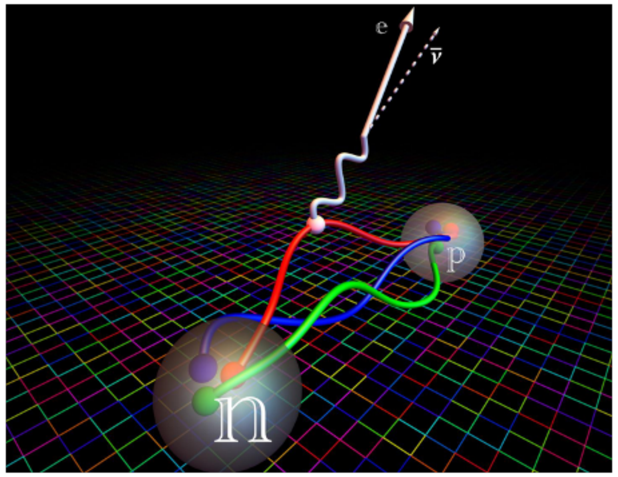

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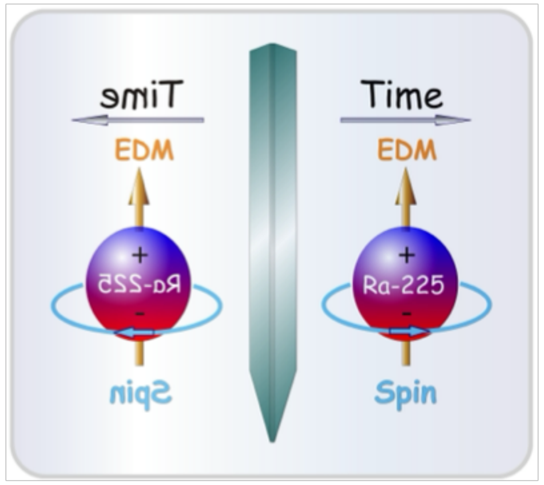

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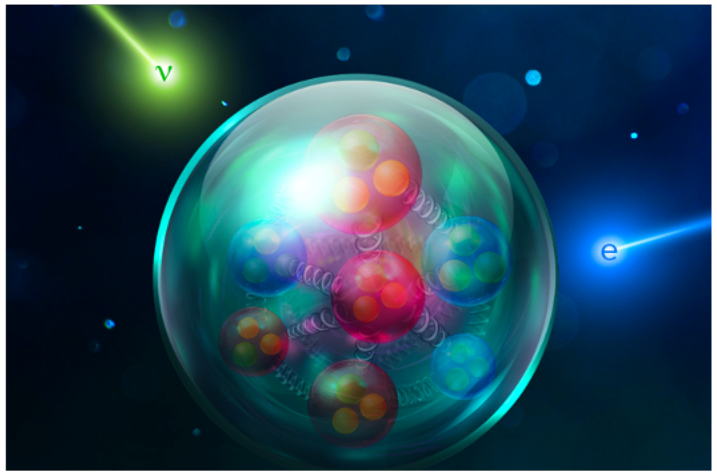

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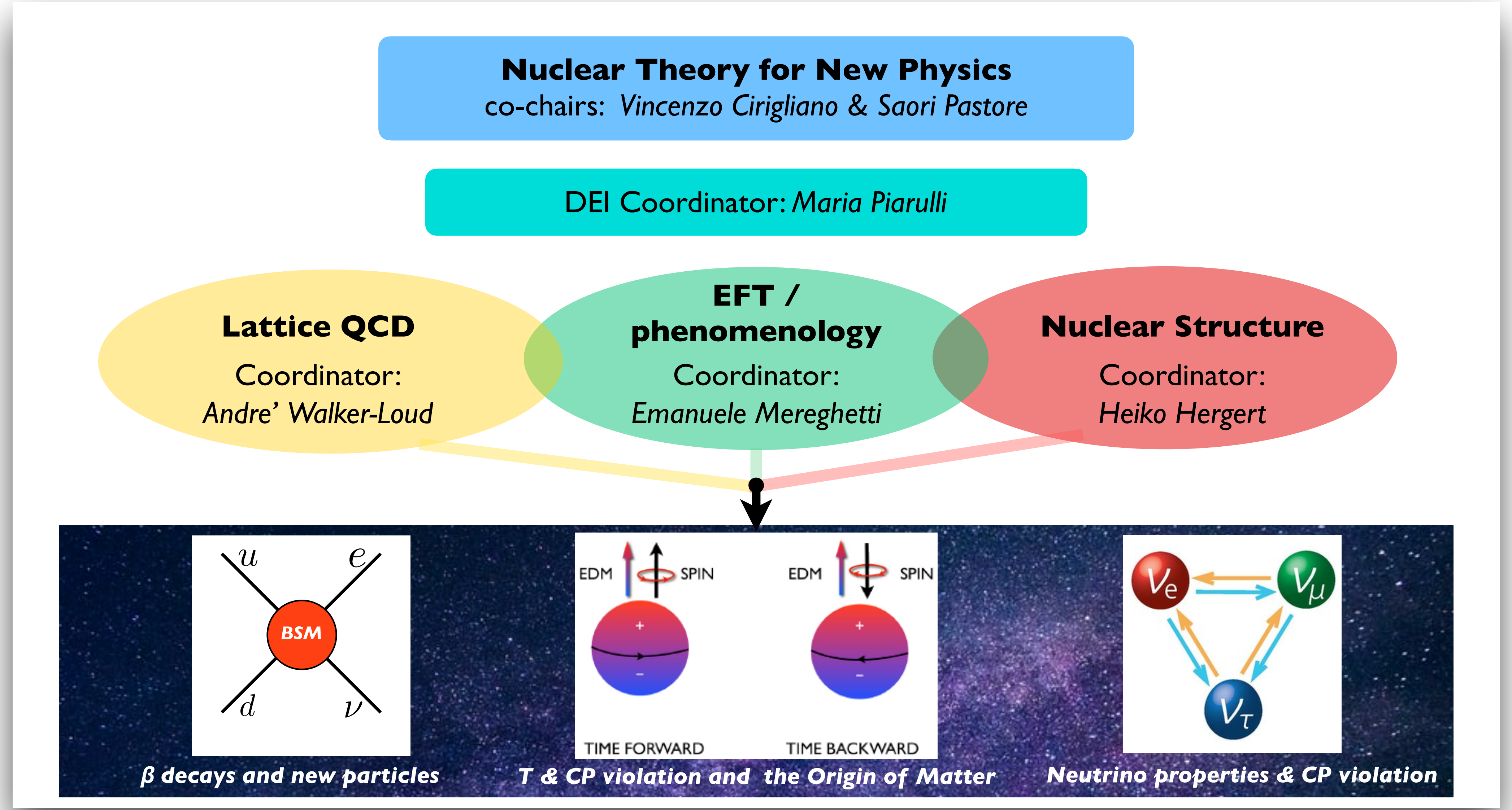
The three thrusts share challenges (multi-scale problems!), techniques, and infrastructure
Need synergy of EFT / phenomenology, lattice QCD, nuclear structure.

Structure of the collaboration

https://a51.lbl.gov/~ntnp/TC/

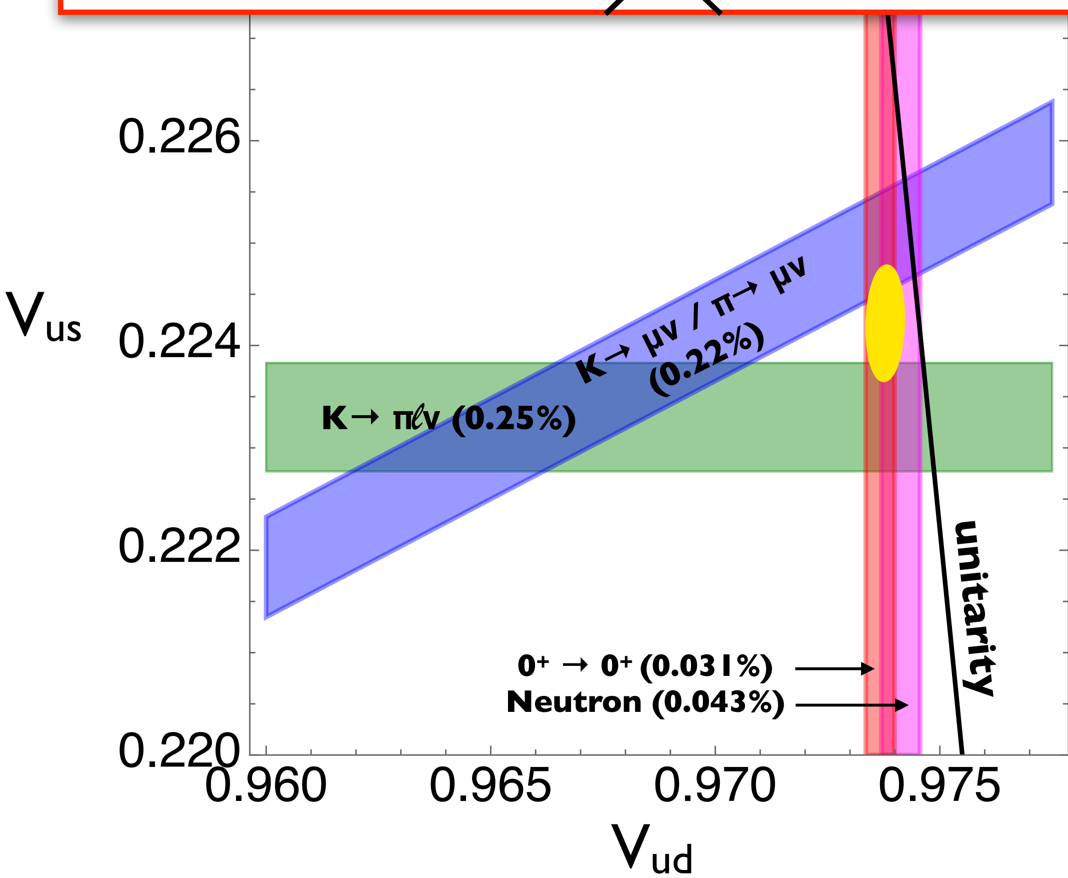


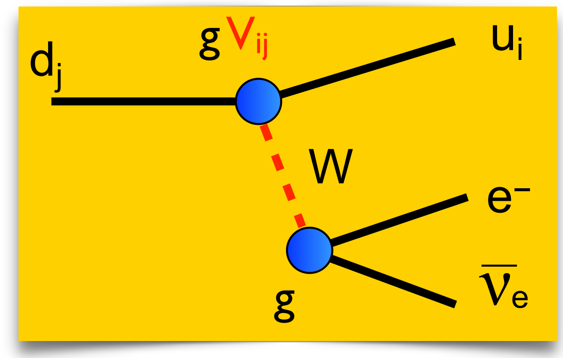
25 Senior Collaborators, 12+2 institutions

Scott Bogner and **Andrea Shindler** (MSU); **Joseph Carlson**, **Stefano Gandolfi**, and **Ingo Tews** (LANL); **Bhupal Dev** (Washington University in St Louis); **Jonathan Engel** and **Amy Nicholson** (UNC); **Gaute Hagen** (ORNL); **Wick Haxton** (UC Berkeley); **Alessandro Lovato** and **Robert Wiringa** (ANL); **S. Ragnar Stroberg** (Notre Dame); **Colin Morningstar** (CMU); **Thomas Papenbrock** and **Lucas Platter** (UT); **Michael Ramsey-Musolf** (UMass/Shanghai Jiao Tong University); **Noemi Rocco** (FNAL); **Rocco Schiavilla** (ODU/JLab).

Thrust 1: precision β decays

$$\Delta_{CKM} = |V_{ud}|^2 + |V_{us}|^2 + \cancel{|V_{ub}|^2} - 1 = -15(5)\times 10^{-4}$$





- Two tantalizing 'anomalies'
- At face value point toward vertex corrections with Λ_{BSM}~10 TeV (hard to probe even at the HI-LUMI LHC)

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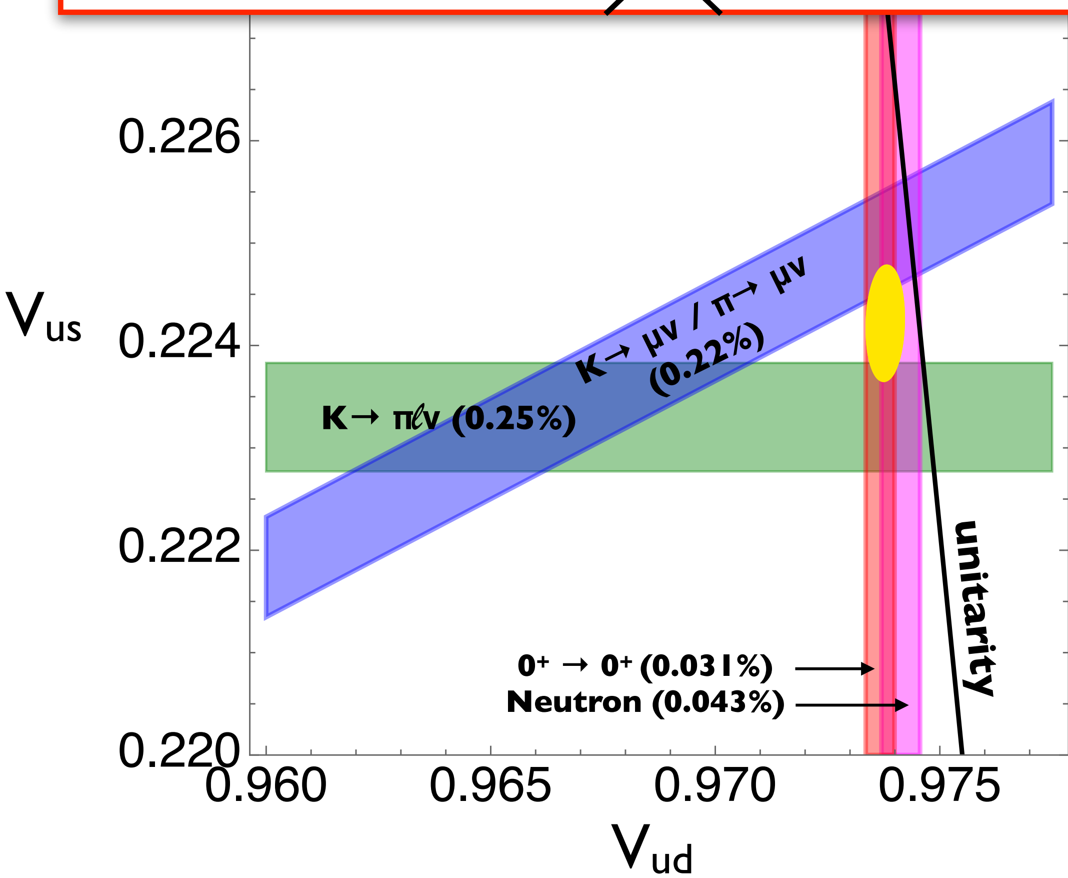
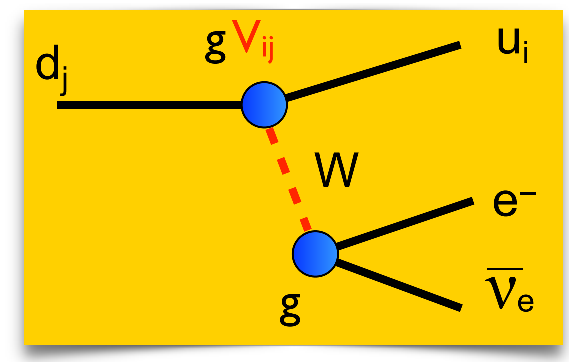


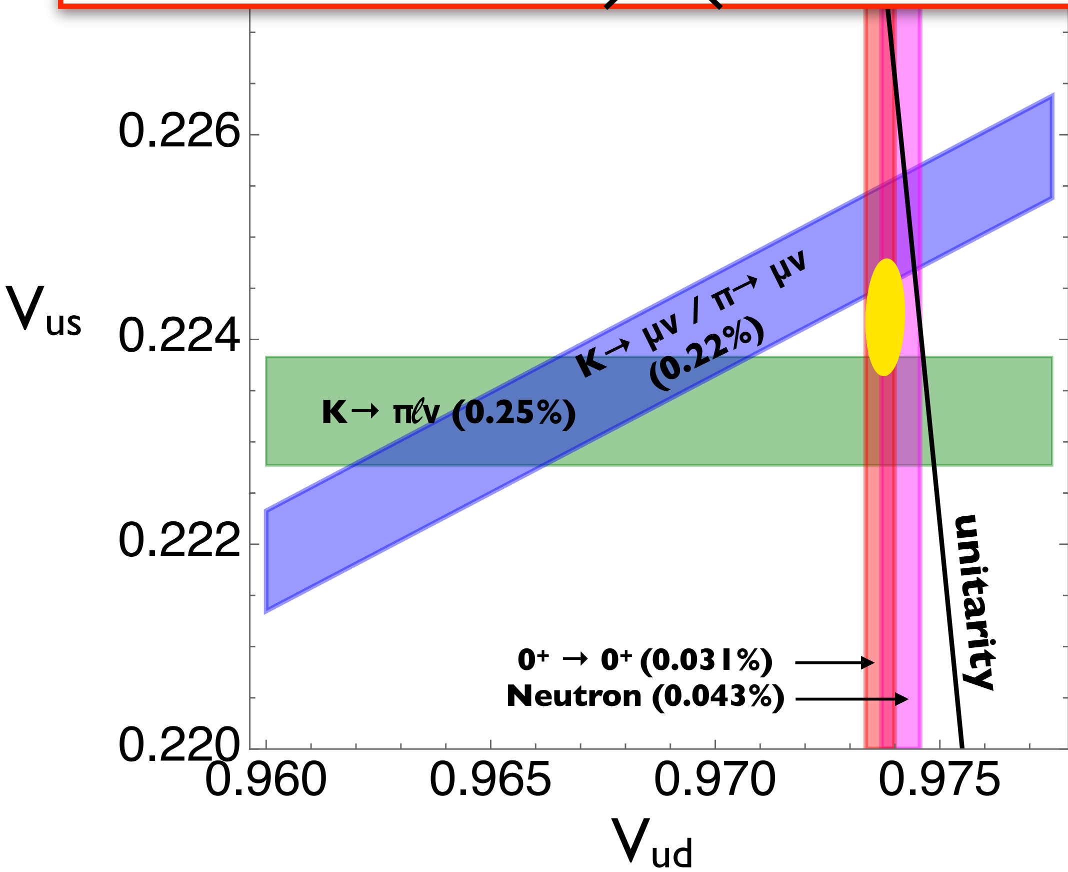


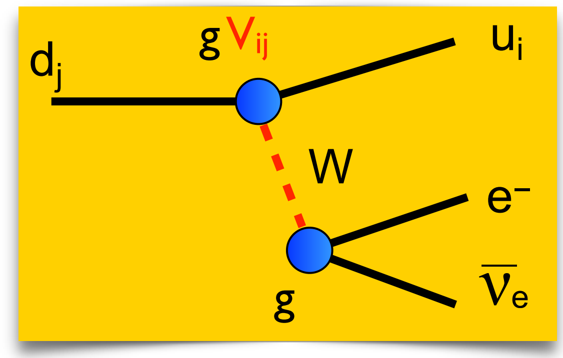
- Two tantalizing 'anomalies'
- At face value point toward vertex corrections with Λ_{BSM}~10 TeV (hard to probe even at the HI-LUMI LHC)

- NTNP objectives:
    - Radiative corrections to neutron decay in Lattice QCD (QED_M)
    - Pion-less and chiral EFT analysis of NN systems to $O(G_F\alpha)$ → input for nuclear structure
    - Radiative corrections to nuclear $0^+ \to 0^+$ decays (A=10, 14, …). Use several ab-initio many-body methods (QMC, CC, IMSRG, HOBET) → controlled uncertainty

Thrust 1: precision β decays

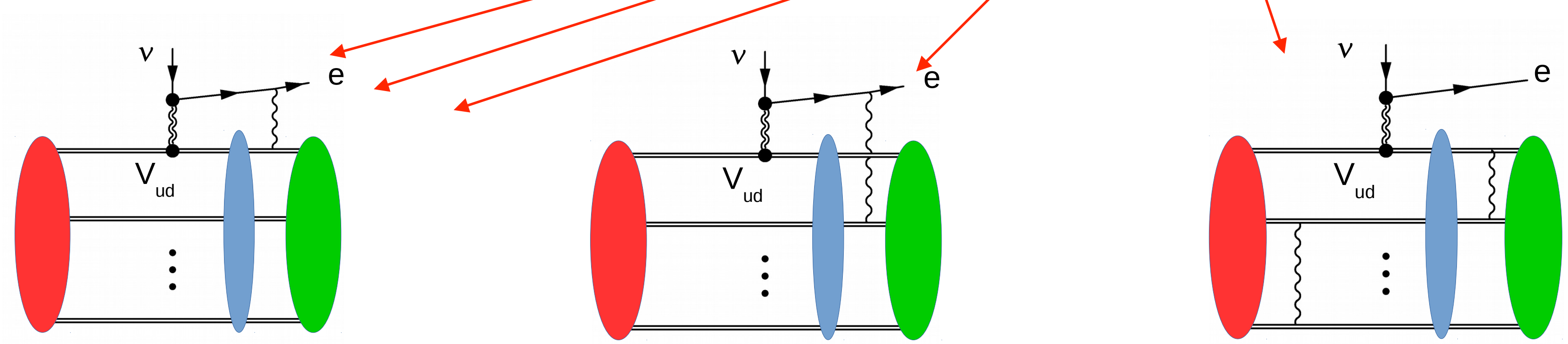
$\Delta_{CKM} = |V_{ud}|^2 + |V_{us}|^2 + \cancel{|V_{ub}|^2} - 1 = -15(5)\times 10^{-4}$





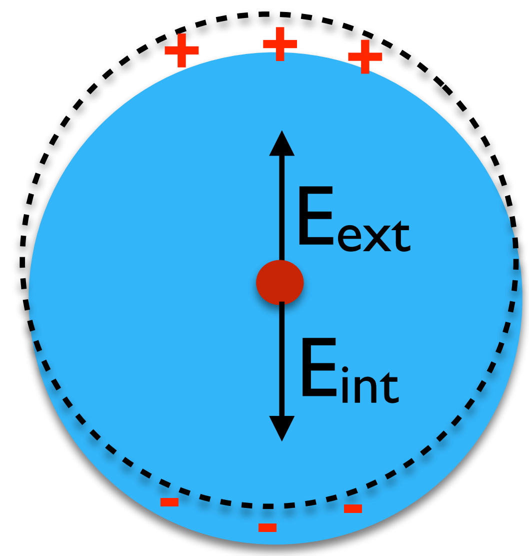
- Two tantalizing 'anomalies'
- At face value point toward vertex corrections with Λ_{BSM}~10 TeV (hard to probe even at the HI-LUMI LHC)

$$\frac{\log 2}{ft} = \frac{G_F^2 m_e^5 |V_{ud}|^2}{\pi^3}\left(1 + \Delta_R^V + \delta_R' + \delta_{NS} - \delta_C\right)$$



Thrust 2: permanent EDMs

- Permanent EDMs of nucleon, nuclei, atoms, molecules are very sensitive to new sources of CP (T) violation, probing scales up to 10^3 TeV



- Nucleon and diamagnetic atoms EDMs plagued by O(1) strong-interaction uncertainties: large dilution of physics sensitivity (e.g. to CPV couplings of the Higgs)!

- EDMs of diamagnetic atoms controlled by the nuclear Schiff moment (S)

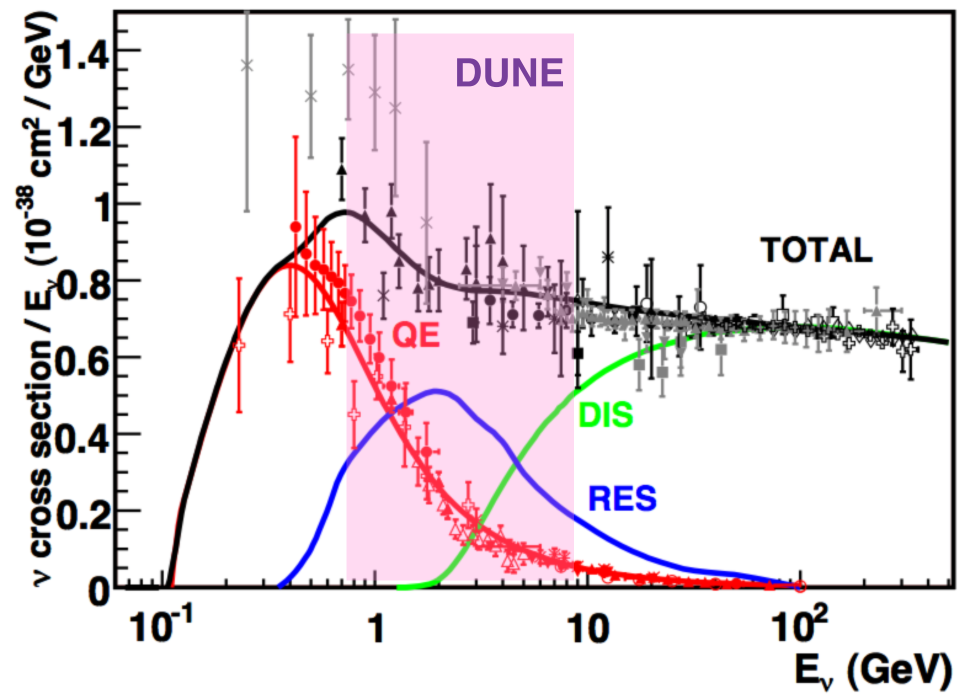
$$S = \sum_{i\neq 0} \frac{\langle \Phi_0 | S_z | \Phi_i \rangle \langle \Phi_i | V_{TVPV} | \Phi_0 \rangle}{E_0 - E_i} + \text{c.c.}$$

$$\vec{S} = \frac{e}{10} \sum_{p=1}^{Z} \left(r_p^2 - \frac{5}{3} \langle r^2 \rangle_{\text{ch}} \right) \vec{r}_p \quad + \ldots$$

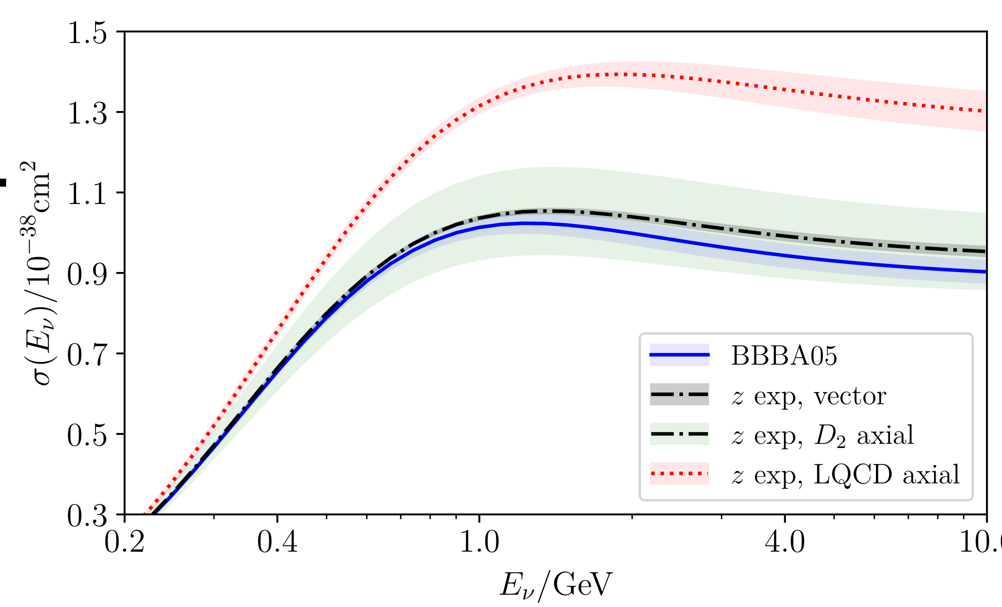
- NTNP objectives:
    - First calculations of nuclear Schiff moments with ab-initio methods: VS-IMSRG for ^{129}Xe, ^{199}Hg and IM-GCM for ^{225}Ra
    - Uncertainty estimate by studying convergence pattern in various expansions (chiral potentials, many body calculation)

Thrust 3: neutrino-nucleus scattering

- The success of neutrino oscillations experiments (such as DUNE) requires knowing neutrino-nucleus cross sections at few % level over a broad range of energies (flux determination, ν energy reconstruction , …)



- NTNP objectives: First-principles calculations of inclusive and exclusive cross sections
  - Lattice QCD input on single-nucleon form factors (elastic and not)
  - EFT-based nuclear interactions and currents: retain key many-body correlations
  - Validation: use multiple many-body methods for A=4,12,16,40 & JLAB data on electron scattering



Workforce development & DEI

- NTNP will foster workforce development in multiple ways, by
  - Providing welcoming and inclusive environment for all the participating researchers
  - Facilitating discussions and scientific collaborations across sub-fields of nuclear theory
  - Training and supporting the next generation of nuclear theorists: the majority of allocated funds will support graduate students and postdocs
  - Sponsoring two bridge junior faculty positions, one at Carnegie Mellon University and one at Old Dominion University

NTNP @ INT / UW: people

NTNP will leverage expertise and "ecosystem" of the INT & UW Nuclear Theory groups

INT

Vincenzo Cirigliano
Senior Fellow, Professor

Maria Dawid
PhD student

Wouter Dekens,
Research Assistant Professor

UW Nuclear Theory

Ayala Glick-Magid
Postdoctoral Researcher

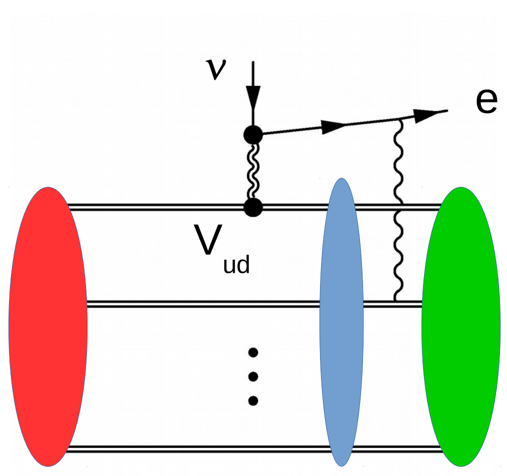
Chien-Yeah Seng
FRIB Theory Fellow

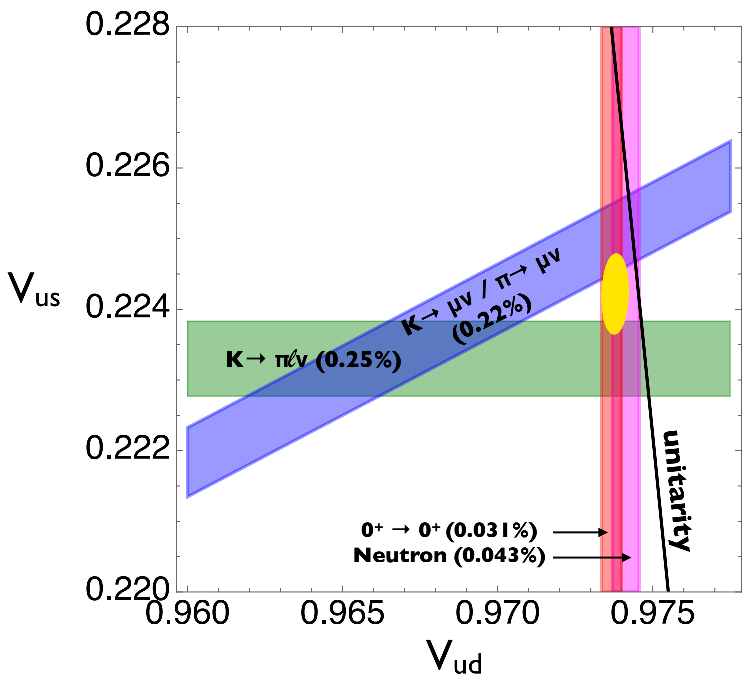
Expertise: EFTs from BSM to nuclear physics; radiative corrections; BSM phenomenology

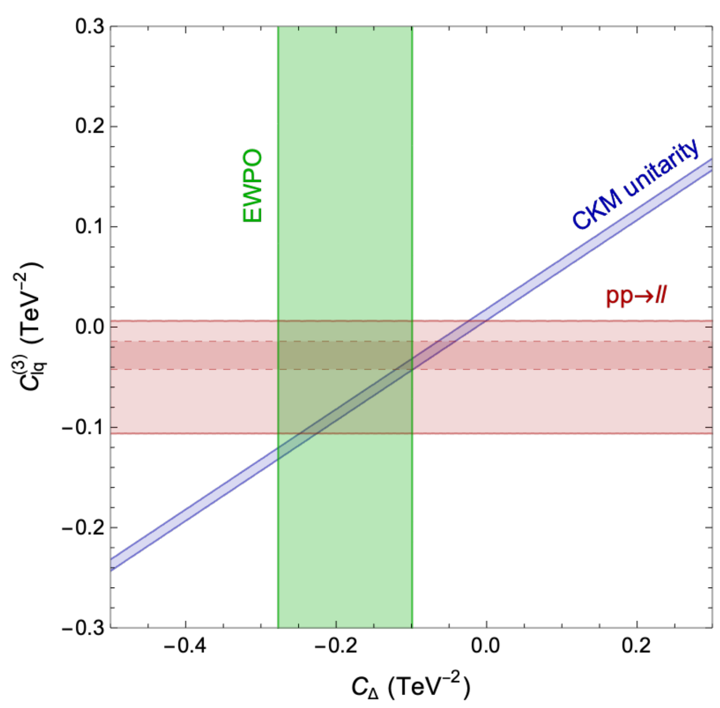
NTNP @ INT / UW: research

- We will focus primarily on the beta decay thrust
  - Radiative corrections to neutron decay
  - EFT for A=2 systems to $O(G_F\alpha)$
  - Construct the two-body transitions operators for δ_C and δ_{NS}, in chiral EFT
  - Connection to "precision electroweak measurements" & BSM implications

Institutions involved: LANL, UCB, UMass, UTK, UW, WUSTL







In the next 40 minutes

- Report from DEI coordinator
- Planning and status of bridge faculty positions
- Report from institutional PIs

Thank you!

T. D. Lee in a drawing by Bruno Touschek

Bruno Touschek (1921-1978)

Code of Conduct for the NTNP Collaboration:

The NTNP collaboration requires all members to act in a professional manner that is **welcoming to all colleagues and free from discrimination, harassment, or retaliation**. Members should respect one another and work to create a positive, inclusive, and diverse environment that supports scientific progress. We will use open and deliberate processes in communicating research opportunities with all members.

Any inappropriate actions or statements based on individual characteristics such as age, race, ethnicity, sexual orientation, gender identity, gender expression, marital status, nationality, political affiliation, ability status, educational background, or any other characteristic protected by law **will not be tolerated.** This includes, but is not limited to, inappropriate or intimidating behavior and language, unwanted jokes or comments, unwanted touching or attention, offensive images, photography without permission, and stalking. Harassment related to political, religious, etc. issues is also prohibited. If a participant observes inappropriate comments or actions and personal intervention seems appropriate and safe, they should be considerate of all parties before intervening.

Any violations of this code of conduct should be reported to the spokespersons, diversity coordinator and/or members of the NTNP Executive Committee. Responses to violations may include verbal warning, notification of the pertinent HR departments and/or appropriate authorities, and expulsion from the NTNP Collaboration. Retaliation for complaints of inappropriate conduct will not be tolerated.

This policy is not intended to replace or supersede institutional codes of conduct or sexual harassment policies, and borrows wording from the American Physical Society code of conduct for meetings.

Commitment to Diversity, Equity, and Inclusion:

As the NTNP collaboration,

- we are committed to promoting and sustaining a diverse, equitable, welcoming, and inclusive workforce and culture;
- we believe that a diverse and inclusive group helps us to better achieve our scientific goals, and makes us a stronger and more effective team;
- we are dedicated to creating a safe and inclusive space for all members, and to actively seeking out and engaging with diverse perspectives and voices in our discussions and decision-making processes.

As part of our commitment to diversity, equity, and inclusion,

- we require that applications for bridge faculty positions funded by NTNP include a statement describing the applicant's experience and commitment to these values;
- we will actively recruit candidates from underrepresented groups in physics and broadly advertise all the NTNP positions using several platforms including the National Society of Black Physicists, the National Society of Hispanic Physicists, the Society of Indigenous Physicists, and the Women in Physics Society.

NTNP Bridge Position Status at ODU

- Search is underway for bridge position at (tenure-track) assistant professor level in areas relevant to the TC research program (expected start date Fall 2023)
- Position will be converted to a joint one within the JLab Theory Center after the three-year bridge funding ends
- Joint ODU/JLab search committee with 4 members from each institution
- Application deadline was Jan 31, 2023, but later applications will also be reviewed
- R. Schiavilla (sole ODU TC member presently) at half time starting in December 2023 (phased retirement) and fully retired by July 2025

NTNP Bridge Position Status at CMU

- Goal: begin search for NTNP bridge position in lattice QCD this fall
- Assistant professor (tenure-track) to begin fall 2024
- Three years of bridge funding pays half salary
- Department members in subatomic physics (experiment and theory) agreed this position is priority for next subatomic hire
- Department head supports this position, but must be voted on by the department
- Department head will bring up vote later this spring after current search well underway (now interviewing for bio-physics position)
- Mellon College of Science dean must approve (she is aware of this award and upcoming bridge position request)
- Dean approval is last major hurdle (Dean communicates with Provost, etc.)

TC Nuclear Theory for New Physics - LANL members

J. Carlson

S. Gandolfi

E. Mereghetti

I. Tews

Expertises:

1. Quantum Monte Carlo (VMC, GFMC, AFDMC) methods, chiral EFT interactions and currents, electromagnetic and weak nuclear probes, neutrino-nucleus scattering

1. Chiral EFT for low-energy BSM searches, connections of fundamental symmetry program with colliders and high-energy phenomenology

TC - NTNP Thrusts

- BETA-2
  - Develop EFT formalism for A=2 systems to O(GF α)
  - Construct the two-body transitions operators for δ_C and δ_{NC}, including higher-order effects in chiral and pionless EFT

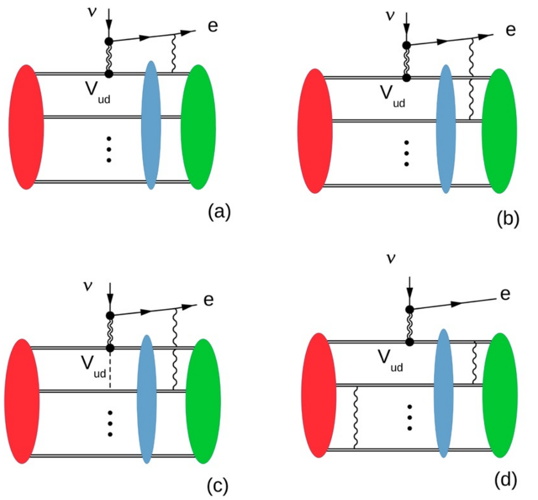
Participating Institutions: LANL, UMass, UTK, UW

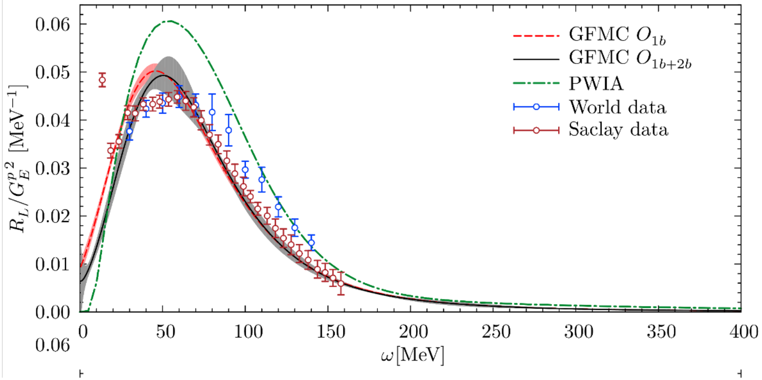
- BETA-3
  - Calculation of δ_C and δ_{NC} in low-A systems with QMC methods

Participating Institutions: ANL, LANL, ND, UCB, UNC, WashU

- XSEC-4 and 5: nu-A scattering
  - Electroweak cross sections in 40 Ca

Participating Institutions: ANL, LANL, ODU, WashU





NTNP@UTK

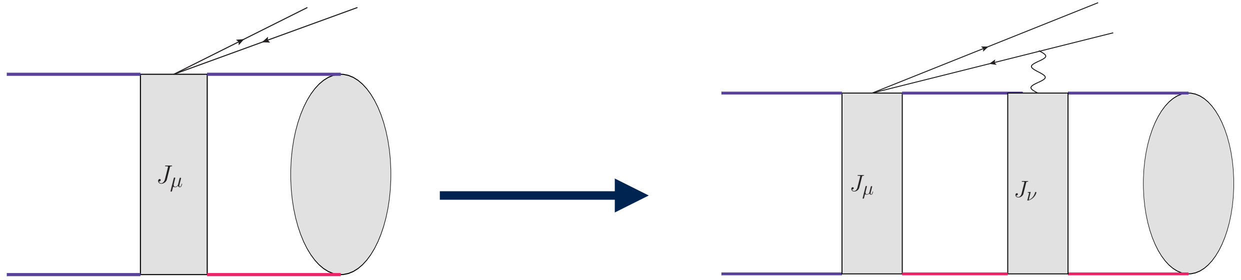
Lucas Platter & Thomas Papenbrock
University of Tennessee, Knoxville

see G. Hagen's (ORNL) talk for involvement in

Radiative Corrections

Important for future electroweak studies

- Start with few-body systems (pp-fusion, muon-capture)



- Uncertainty from radiative correction in pp-fusion not well understood but important for stellar models

Thrust BETA2

Goal

- Use controlled low-energy expansion (effective field theory)
- Understand relevance and scaling of radiative corrections (energy-dependence , A-dependence)
- Lay ground for systematic understanding in larger A systems (radiative corrections in superallowed beta-decay)

U Mass Nuclear Theory

- Team Leader: MJRM

- Post-docs/senior researchers:
    - Jaber Balal Habashi
    - Leon Friedrich
    - Supriya Senapati
    - Jia Zhou (emeritus)

NTNP

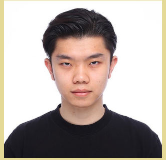



- Ph.D. Students
    - Manuel Diaz
    - Justin Fagnioni
    - Dyson Kennedy
    - Kafei Ning
    - Tianyang Shen
    - Sebastian Urrutia-Quiroga






- Undergraduate Student
    - Haochen Wang (Hampshire College)



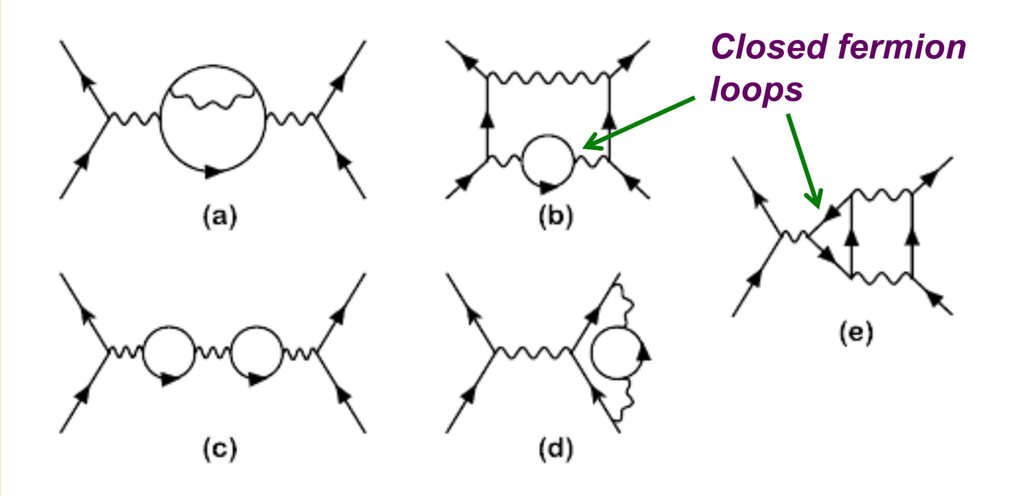
Electroweak Radiative Corrections

- *PV electron scattering and…*
  - *NNLO (two-loop) Moller: closed fermion loops*
  - *NNLO charged current (β-decay): closed fermion loops*
  - *NNLO PV semileptonic (^{12}C elastic, SoLID…)*
  - *NNLO bosonic loops*
  - *Synergy with precision e^+e^- (Milan group)*

- *Electroweak boxes*
  - *Neutron β-decay: $W\gamma$ box*
  - *Nuclear β-decay: $W\gamma$ box*
  - *PVES: $Z\gamma$ box*
  - *EDM: $\gamma\gamma$ box*

NNLO EW Radiative Corrections

First phase = Closed fermion loops: gauge invariant



1. *PV Moller: Du, Freitas, Patel, MJRM [1912.08220] Phys. Rev. Lett. 126 (2021) 131801*
2. *Beta Decay: Du, Fagnioni, Friedrich, MJRM, Zhou [NTNP]*
3. *PVES: Semileptonic closed fermion loops*
4. *Second phase: Bosonic loops*

NNLO EWRC: CC & PVES

- *Calculations are highly technical, computationally intensive, requiring significant workforce to ensure redundancy (cross checks)*

- *Time investment is high, number of publications relatively low → participants' research portfolios must have additional research projects to enhance career advancement prospects*

- *U Mass strategy:*

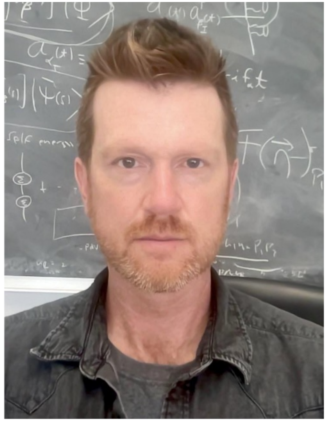
  - *Build a team (Friedrich, Fagnoni, Wang)*
  - *Exploit synergies with HEP: electroweak physics in e^+e^- (FCC-ee, ILC, CEPC) → new collaboration with Milan group (A. Vicini)*

TC Nuclear Theory for New Physics - MSU/ND Members

FRIB / MSU

U Notre Dame

Heiko Hergert



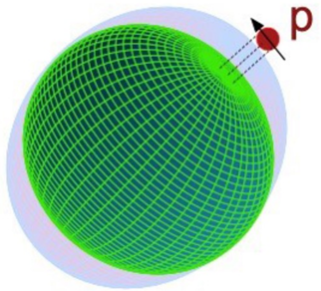
Scott Bogner

Ragnar Stroberg

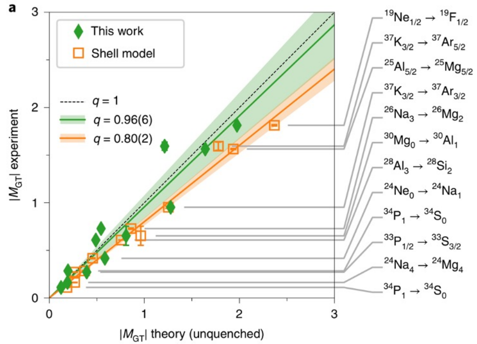
Expertise: Quantum many-body theory, EFTs, Renormalization Groups (IMSRG, …), nuclear forces, nuclear structure, high-performance computing

TC - NTNP Thrusts - MSU/ND

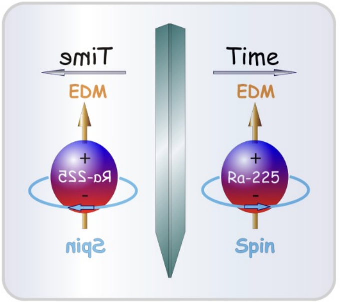
- Cross-cutting work
  - Extension of ab initio frameworks (IMSRG, …) to odd nuclei
  - Developing formats and workflows for applications of one-body, two-body and higher transition operators
  - Participating Institutions: MSU, ND, UNC, ORNL, LANL, UW, WUSTL, …
- BETA-3
  - Multi-method surveys and precision calculations of radiative corrections
  - Participating Institutions: MSU, ND, ORNL, …
- EDM-3
  - Precision calculations of nuclear Schiff moments
  - Participating Institutions: MSU, ND, UNC, …



credit: J.M. Allmond (ORNL)



P. Gysbers et al., Nature 15, 428 (2019)



credit: P. Müller (ANL)

TC Nuclear Theory for New Physics

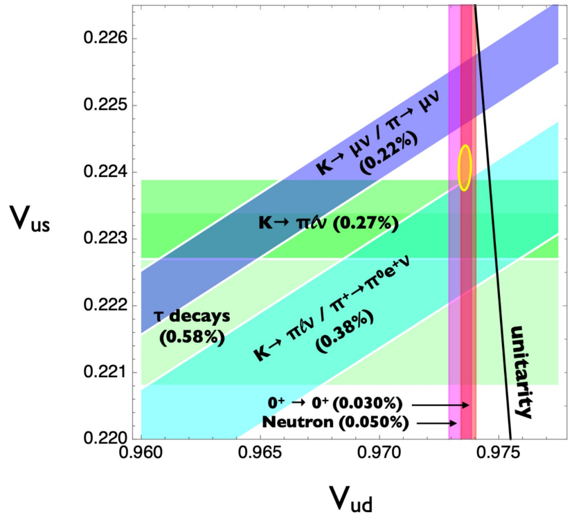
OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Expertise:
Coupled-cluster theory for atomic nuclei and infinite nuclear matter nuclear forces and two-body currents, effective field theory, weak decays and transitions, lepton nucleus scattering and response functions

TC - NTNP Thrusts

$$\Delta_{\mathrm{CKM}} \equiv |V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 - 1$$

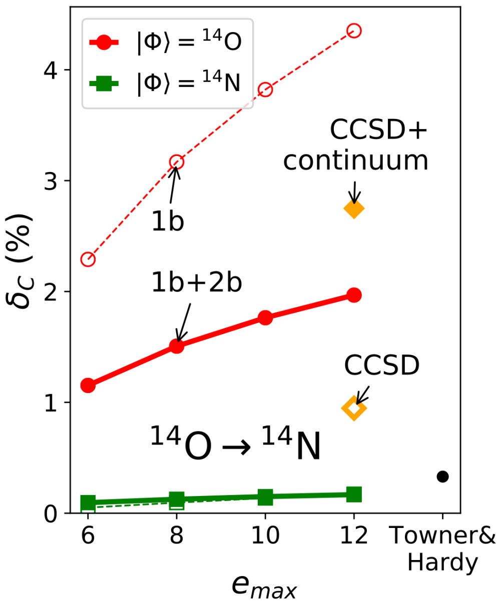


Searches for new physics:

$$\frac{\log 2}{ft} = \frac{G_F^2 m_e^5 |V_{ud}|^2}{\pi^3}(1 + \Delta_R^V + \delta_R' + \boxed{\delta_{NS} - \delta_C})$$

$$\delta_C = 1 - |M_F|^2/2$$

Status of the challenge:



S. R. Stroberg, Particles 2021, 4, 521 (2021)

- Analyze results and develop formulas for extrapolations to infinite model spaces
- Perform ab-initio computations of the superallowed beta decay of ^{14}O and other nuclei
- Quantify all theory uncertainties

Participating institutions: ANL, LANL, ND, ODU, ORNL, UTK, WUSTL

Nuclear Schiff Moments and Atomic EDMs

J. Engel*, H. Hergert, R. Stroberg

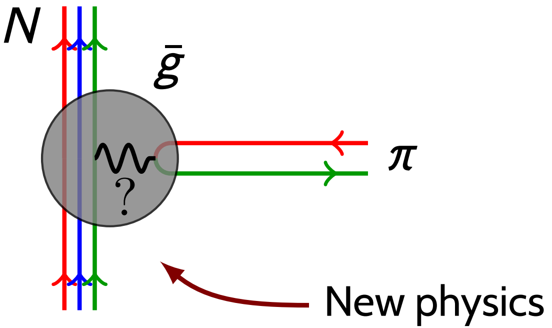
UNC*, MSU, ND

February 3, 2023

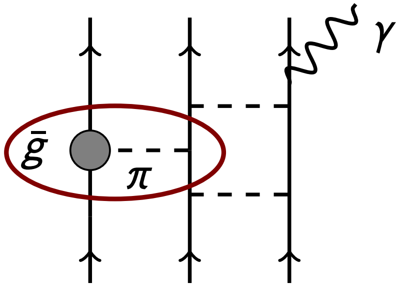
How Atoms Can Get EDMs

Standard-Model *CP* violation is weak; an additional undiscovered source is needed to explain the matter/antimatter imbalance.

The source can work its way into nuclei through CP-violating πNN vertices (in chiral EFT)…



…leading to a nuclear EDM from a *CP*-violating *NN* interaction:



How Atoms Can Get EDMs

Atoms get EDMs from nuclei. But electronic shielding replaces nuclear dipole operator with "Schiff operator,"

$$S \sim \sum_p r_p^2 \vec{r}_p$$

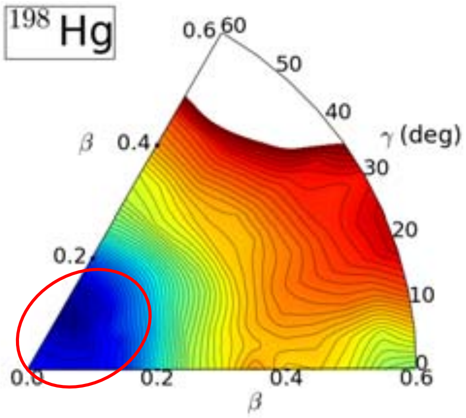
making the relevant nuclear quantity the Schiff moment $\langle \vec{S} \rangle$.

Job of nuclear-structure theory:
Compute dependence of $\langle S \rangle$ on the CP-violating πNN vertices.

Three of the most important nuclei: ^{199}Hg, ^{129}Xe, ^{225}Ra

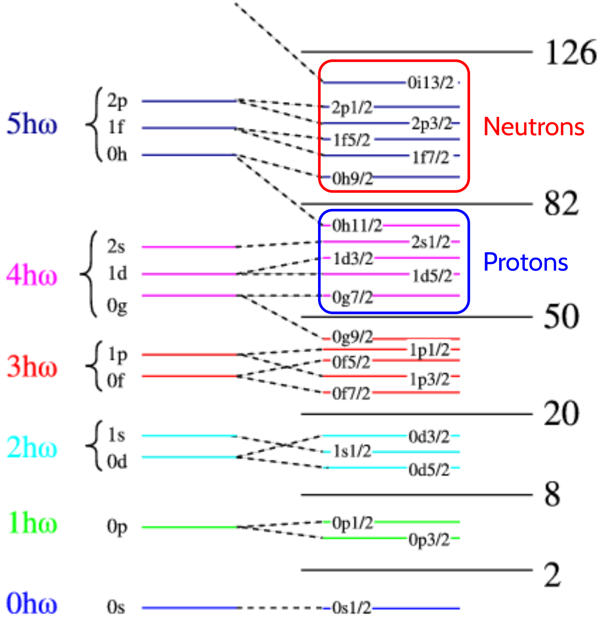
^{199}Hg and ^{129}Xe: Soft and Complicated

^{198}Hg has a very soft oblate minimum.



Prassa et al., EPJ Web Conf. **252** 02007 (2021).

Shell-Model Representation

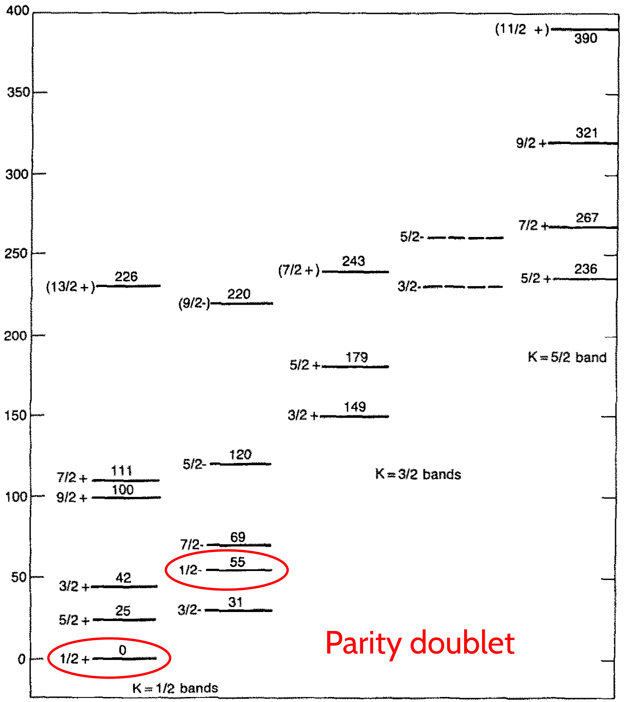


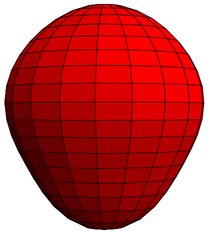
We're using the valence-space IMSRG to construct an *ab initio* shell-model interaction that includes the CP-violating part.

ND PI Ragnar Stroberg at ND and UNC postdoc David Kekejian working on this.

^{225}Ra and Other Light Actinides

Octupole Physics and DFT





Deformed density

The two states in the parity doublet, projections from an octupole-deformed state, are the whole story here.

We will use the In-Medium GCM, which takes octupole deformed state as starting point, adds other physics through IMSRG flow.

JE + MSU PI Heiko Hergert and UNC student will work on this.

Milestones, Etc.

- ^{199}Hg and ^{129}Xe

  Y1: Construction of code for including CP-violating interaction and Schiff operator in valence-space IMSRG. Preliminary Schiff moment for ^{199}Hg.

  Y2: Complete results for both ^{199}Hg and ^{129}Xe, including analysis of uncertainties from chiral EFT and many-body approximations.

- ^{225}Ra

  Y4: Extension of In-Medium GCM to odd nuclei. Preliminary Schiff moment for ^{225}Ra.

  Y5: Complete results for ^{225}Ra, including analysis of uncertainties from chiral EFT and many-body approximations.

Nuclear Theory for New Physics

kickoff meeting, 3 February 2023

André Walker-Loud

Who are we?

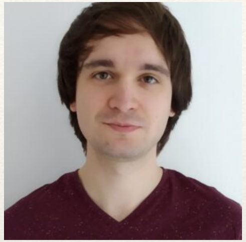
Faculty/Staff

Wick Haxton
UC Berkeley/LBNL

André Walker-Loud
LBNL/UC Berkeley

Andrea Shindler
Visiting Associate Prof.
@ UC Berkeley

Postdocs



Lukas Graf
UC Berkeley/N3AS

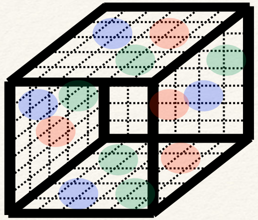
Ken McElvain
UC Berkeley

Evan Rule
UC Berkeley/N3AS

Grad Students

Zack Hall
UNC Chapel Hill
DOE SCGSR @ LBNL

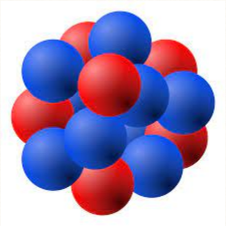
What is our focus?



Lattice QCD

In collaboration with:
Colin Morningstar
Amy Nicholson

Nuclear Effective Theory



- QED corrections to neutron β-decay
  LQCD+QED corrections to g_A
  → LQCD+QED calculation of neutron decay amplitude
- ν-N cross section
  LQCD/pheno discrepancy
  N-to-Δ inelastic with novel method
  NN corrections (?)
- Neutron EDM
  pioneering new method to compute neutron EDM

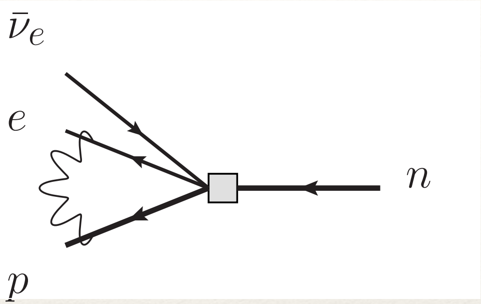
- QED corrections to light nuclear β-decay
- Nuclear EDMs
- Connecting nuclear structure to LQCD through HOBET

- Connect Lattice QCD to nuclear Effective (Field) Theory
  - →Wick, Ken, Evan (HOBET), Lukas
  - →Emanuele, Vincenzo, Michael (N, NN EFT and BSM)
    - → Scott, Joe, Stefano, Gaute, Heiko, Alessandro, Thomas, Saori, Maria, Lucas, Noemi, Ragnar, Ingo, Bob

Backup

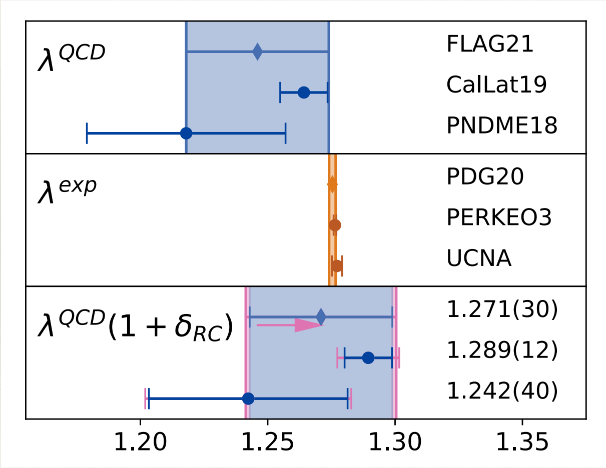
QED corrections to neutron β-decay

- Recent work uncovered an O(2%) QED correction to g_A, (previously estimated at 0.2%)
  Cirigliano, de Vries, Hayen, Mereghetti, Walker-Loud, PRL 129 (2022)



- Limiting factor comparing experiment and LQCD to constrain BSM right-handed currents

- LQCD + QED can be used to determine this correction



- Given that this term was missed with other theory methods, and QED corrections need to be controlled at 10^{-4} level, could there be other hadronic corrections important for gV and therefore a determination of V_{ud}?

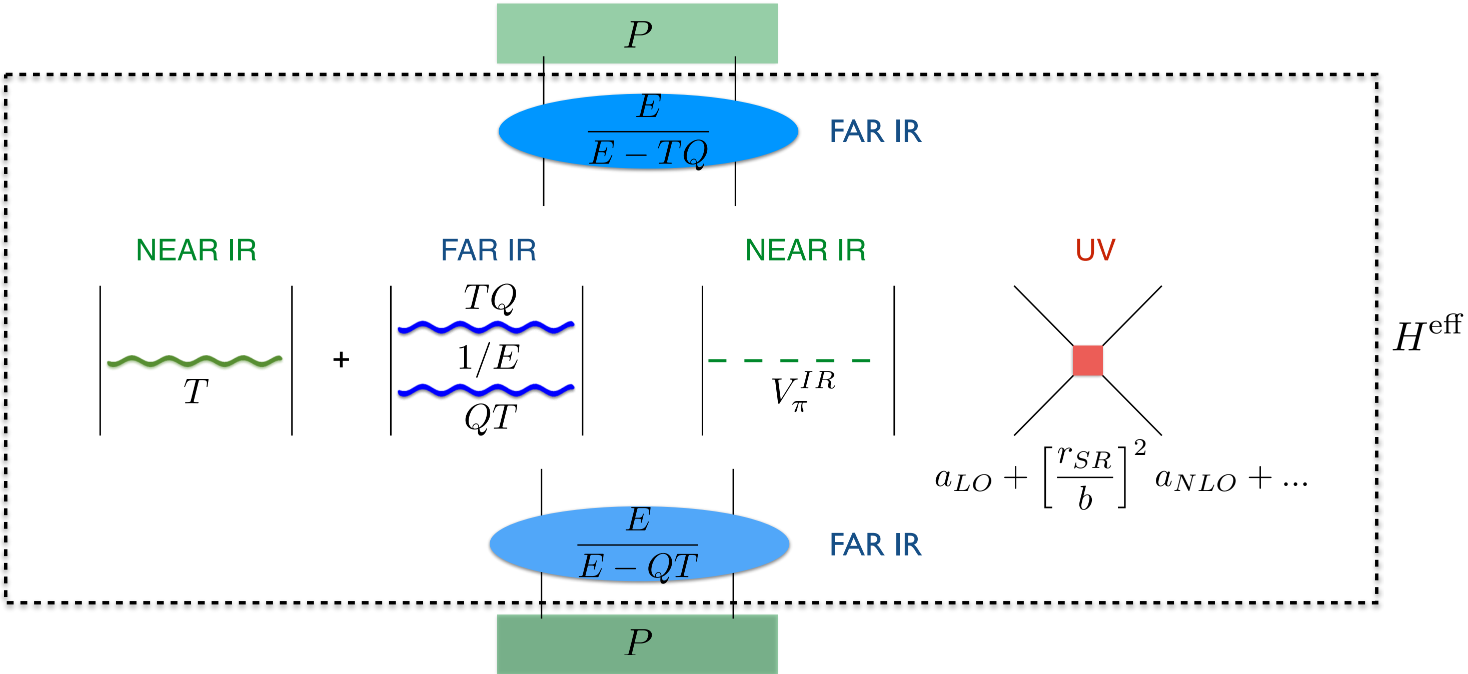
- We need a fully non-perturbative LQCD+QED calculation of neutron β-decay to validate the more recent dispersive determinations (or uncover larger corrections)

Harmonic Oscillator Based Effective Theory (HOBET)

ET developed from potential theory:
then abstracted in terms of HO
ladder operators $\Rightarrow$ no reference to SR potential remains

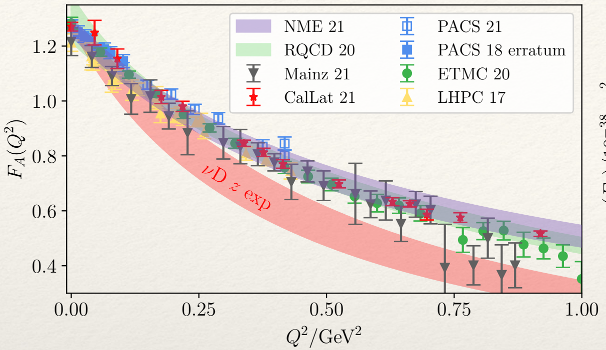
$$H^{\mathrm{eff}} = G_{TQ}\left[T + T\frac{Q}{E}T + V + VG_{QH}QV\right]G_{QT}$$

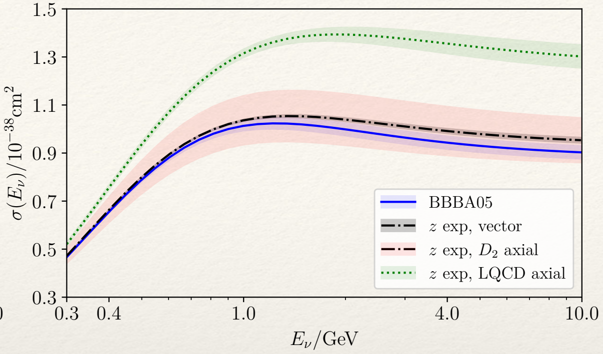
$$V + V\;G_{QH}\;QV \rightarrow \begin{cases} V_\delta & \text{pionless} \\ V_\pi^{\mathrm{IR}} + V_\delta & \text{pionful} \end{cases}$$

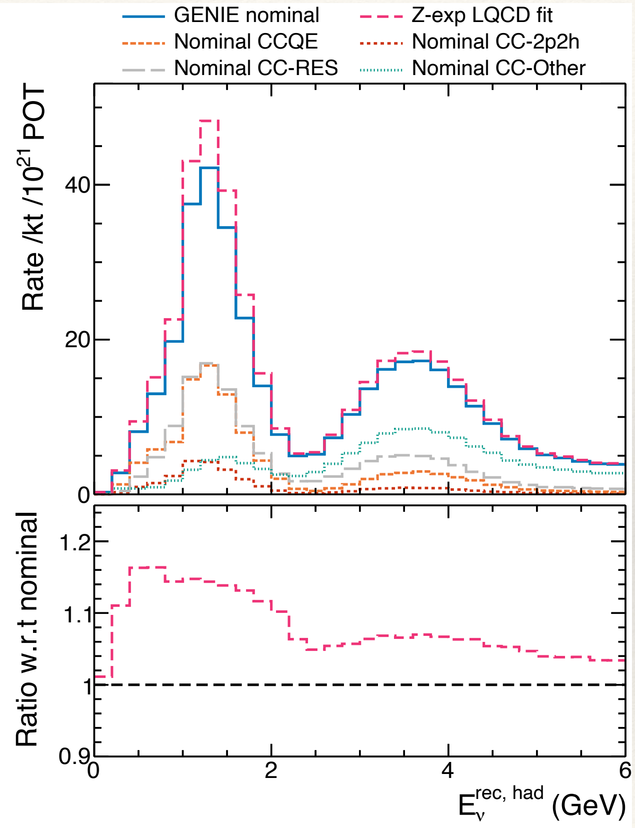


ν-N cross section

Meyer, Walker-Loud, Wilkinson
Ann. Rev. Nucl. Part. Sci. 72 (2022)



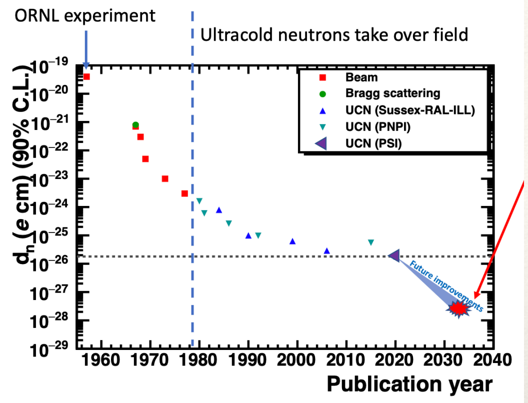




- Lattice QCD determination of $F_A(Q^2)$ is inconsistent with older phenomenological extraction
- results in 30% increase in ν-N cross section
- Energy dependent change in DUNE near/far detector
- Use novel method (stochastic Laplacian Heaviside) to
  - solidify LQCD determination
  - Explore inelastic N-to-Δ transitions - next most important contribution to ν-A

neutron EDM

Shindler:
Eur.Phys.J.A 57 (2021) 4, 128



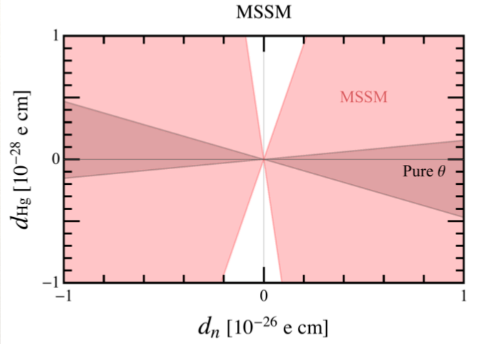
$$|d_n| < 1.8 \times 10^{-26}\ e\ \mathrm{cm}\ (90\%\ \mathrm{C.L.})$$

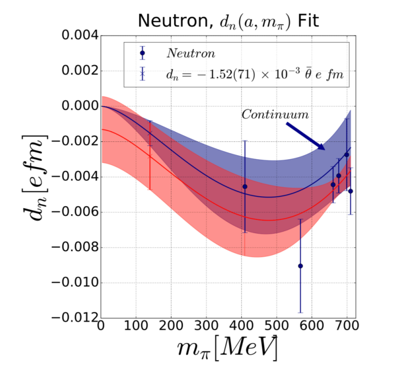
Abel et al.:
Phys.Rev.Lett. 124 (2020) 8, 081803

$$(d_n)_{\mathrm{SM}=(1-6)\times 10^{-32} e} \quad \mathrm{cm}$$

Alcorcon et al.:
2022 Snowmass Summer Study

$$\begin{aligned} d_n = \quad & - \quad (1.5 \pm 0.7) \cdot 10^{-3} \bar{\theta} e\ \mathrm{fm} \\ & - \quad (0.2 \pm 0.01) d_u + (0.78 \pm 0.03) d_d + (0.0027 \pm 0.016) d_s \\ & - \quad (0.55 \pm 0.28) e\tilde{d}_u - (1.1 \pm 0.55) e\tilde{d}_d + (50 \pm 40) \mathrm{MeV} e\tilde{d}_G \end{aligned}$$





Dragos, Luu, Shindler, de Vries, Yousif:
Phys.Rev.C 103 (2021) 1

- 6 orders of magnitudes of background-free window for BSM discovery
- Lattice QCD provides the only theoretically robust way to determine hadronic matrix elements -> only way to interpret experimental results and disentangle all CP violating sources
- Need a portfolio of EDM experiments. Single EDM experiment not sufficient even if the LEC are correlated in a given model
- Use new method based on the GF to overcome the major hurdle (renormalization) that has prevented in the past any lattice EDM calculation -> first results on the θ term
- Goal —> Calculate all relevant contributions to the neutron EDM from the theta term and from BSM physics

TC Nuclear Theory for New Physics - ANL/FNAL members

A. Lovato

R. B. Wiringa

N. Rocco

Expertises:

Quantum Monte Carlo, machine-learning methods, nuclear forces, electroweak transitions, lepton-nucleus scattering, nuclear matter.

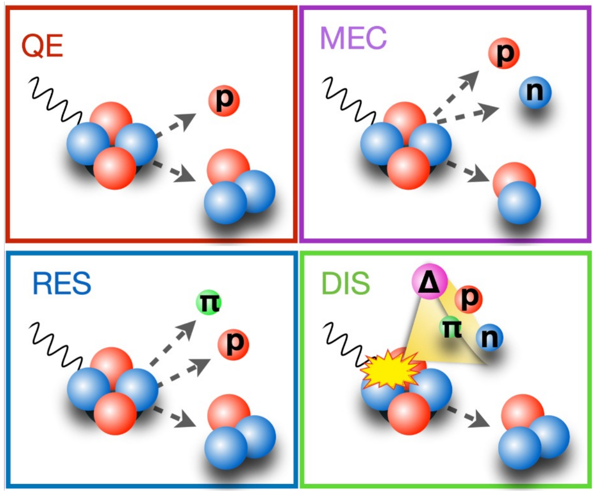
Expertises:

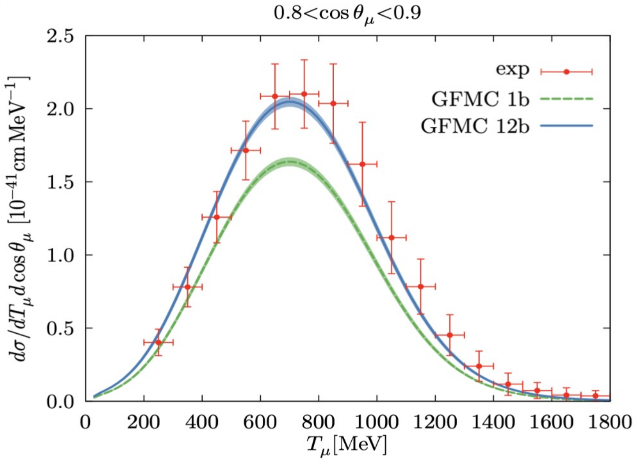
Quantum Monte Carlo, lepton-nucleus scattering, machine-learning methods, neutrino event generators.

TC - NTNP Thrusts

- nu-A scattering
  - QMC (GFMC and AFDMC) calculations of neutrino-nucleus cross sections with controlled uncertainties (aided by artificial neural networks);
  - QMC calculations of spectral functions, spatial-density, and momentum distributions — interface with neutrino event generators;
  - Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering (LQCD inputs)

Participating Institutions: ANL, LANL, ODU, WashU (N. Rocco FNAL)





TC Nuclear Theory for New Physics - WashU members

Webpage: Quantum Monte Carlo group

Expertise:

Quantum Monte Carlo, many-nucleon interactions and currents, EFTs, nuclear electroweak properties, nuclear matter, lepton-nucleus scattering, UQ

Webpage: Dev's group

Expertise:

Neutrino theory and phenomenology, BSM physics at neutrino experiments, light dark sector physics, flavor anomalies

Washington University in St. Louis
Arts & Sciences

Department of Physics

McDonnell Center for the Space Sciences

Quantum Monte Carlo Group for Nuclear Physics

https://physics.wustl.edu/quantum-monte-carlo-group

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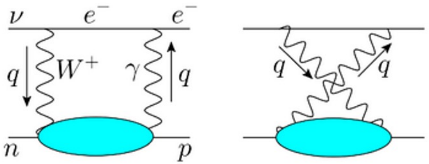
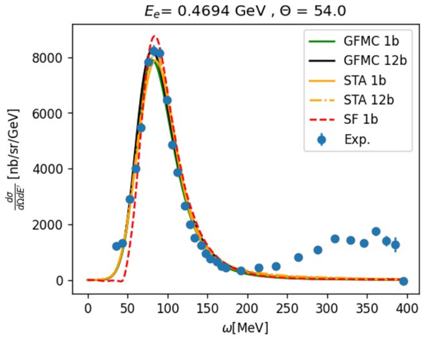
Dr. Andreoli: Universities Research Association's Visiting Scholars Program (2022)
J. Bub: Summer BAND Fellowship (2022)
G. King: DOE/NNSA Stewardship Science Graduate Fellowship (2021)
Dr. Anna McCoy: FRIB Theory Fellow (Sep 2022)

TC - NTNP Thrusts



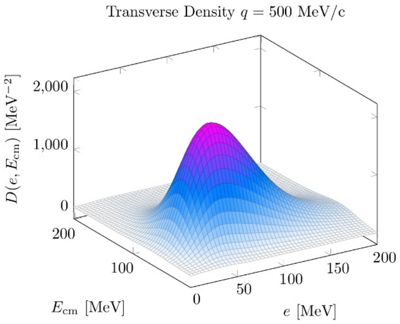
- Beta decay
  - QMC (VMC, GFMC, AFDMC) calculations of δ_C and δ_{NC} in light and medium mass nuclei

Participating Institutions: ANL, LANL, ND, UCB, UNC, WashU



- nu-A scattering
  - Calculations of nu-A and e-A cross sections, responses, and response densities with ab initio methods based on factorization schemes (Short-time Approximation, Spectral function) supplemented by QMC methods (VMC, AFDMC)

Participating Institutions: ANL, LANL, ODU, WashU + Noemi Rocco (FNAL)



TC - NTNP Aknoweldgments

We are really excited to start this Topical Collaboration on Nuclear Theory for New Physics!

U.S. DEPARTMENT OF ENERGY | Office of Science

Webpage

https://a51.lbl.gov/~ntnp/TC/