2024 Nuclear Theory Topical Collaborations PI Exchange Meeting
Gaithersburg, MD
May 2 2024

Nuclear Theory for New Physics (NTNP): overview and progress report

Vincenzo Cirigliano
University of Washington

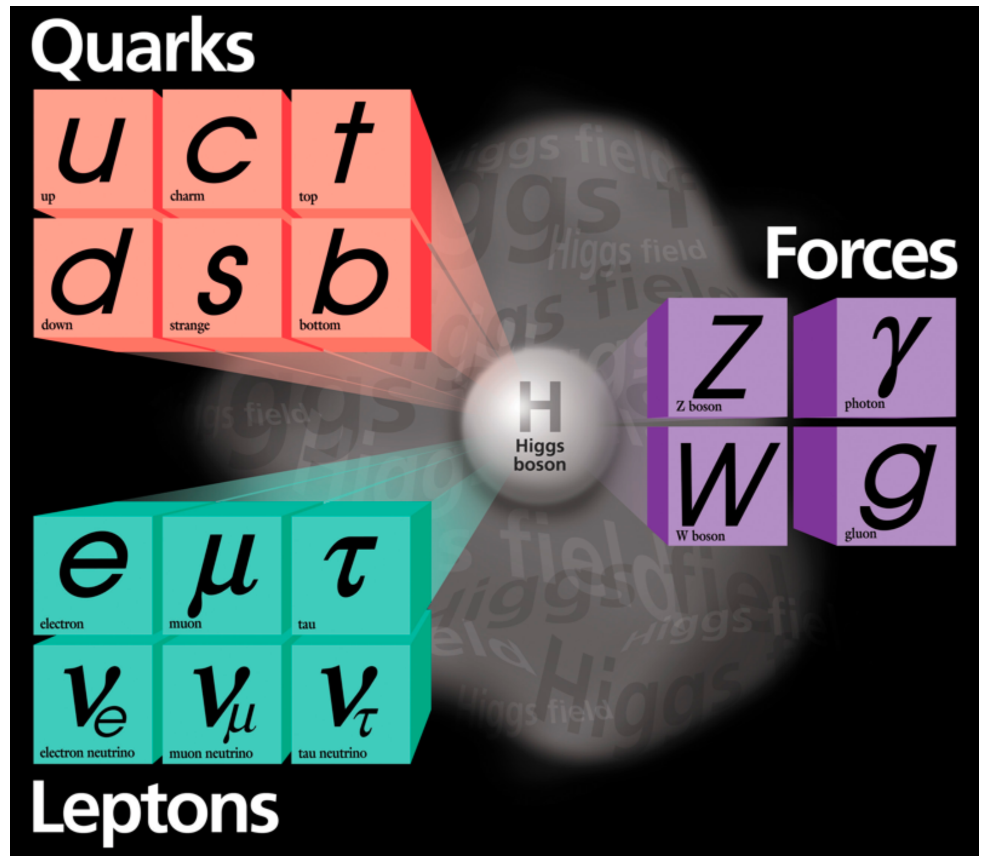
INSTITUTE for NUCLEAR THEORY

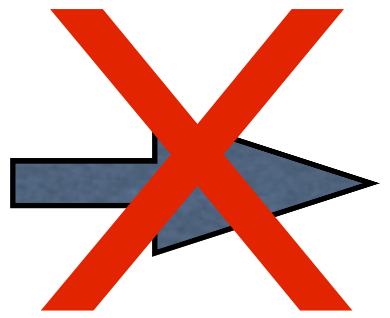
Outline

- Introduction
  - Scientific motivation & high level goals
  - Structure of the collaboration
- Workforce development
  - Bridge faculty hire & plans for 2nd bridge position
  - Postdocs and students supported & mentored through NTNP
- Scientific progress report
  - Three science thrusts
  - Progress towards objectives

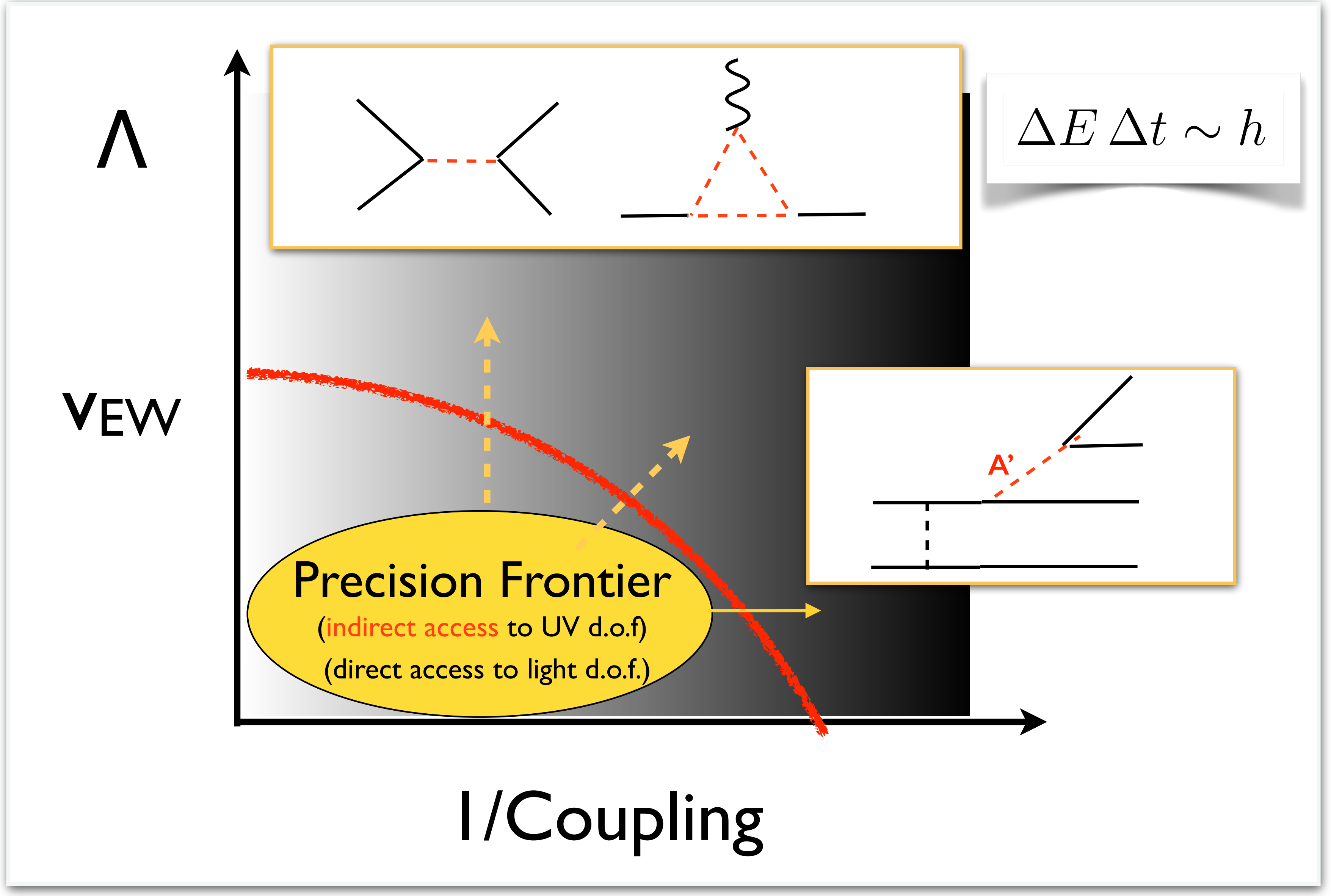
The questions driving NTNP

- 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:
  (1) precision tests of SM-allowed processes;
  (2) searches for processes that are rare of forbidden in the SM;
  (3) study of light, feebly interacting particles (neutrinos, …).

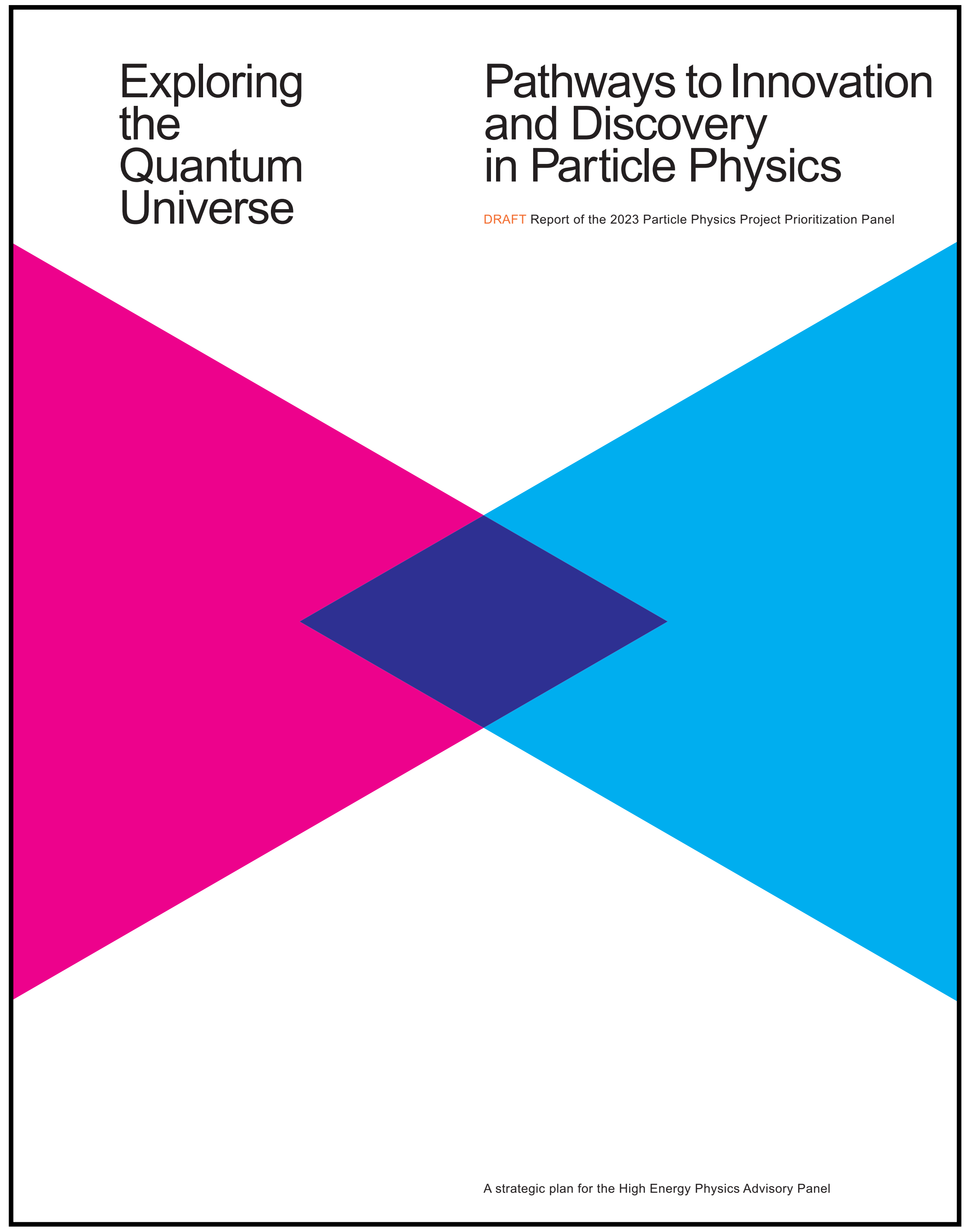


The questions driving NTNP

The precision / intensity frontier spans across Nuclear Physics and High Energy Physics

"The US program in Nuclear science includes [...] carrying out a targeted program of experiments [...] that reaches for physics beyond the Standard Model trough rare process searches and precision measurements."

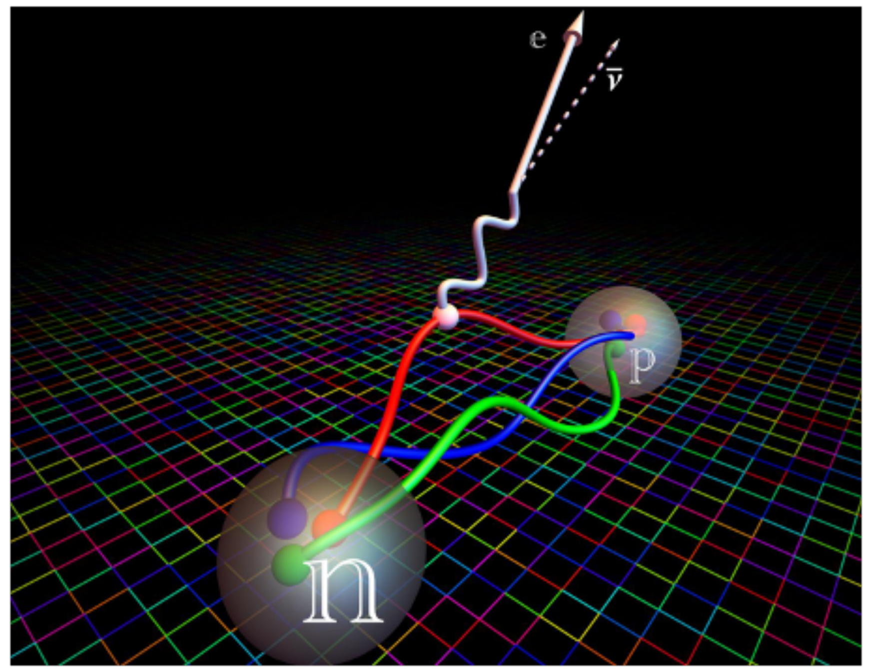
Two of the six science drivers of the 2023 P5 report are "Elucidate the Mysteries of Neutrinos" and "Pursue Quantum Imprints of New Phenomena"



High level goals of NTNP

NTNP focuses on three thrusts of the precision / intensity frontier program, with the goal of
providing state-of-the-art predictions with quantified uncertainties and assessing their phenomenological impact

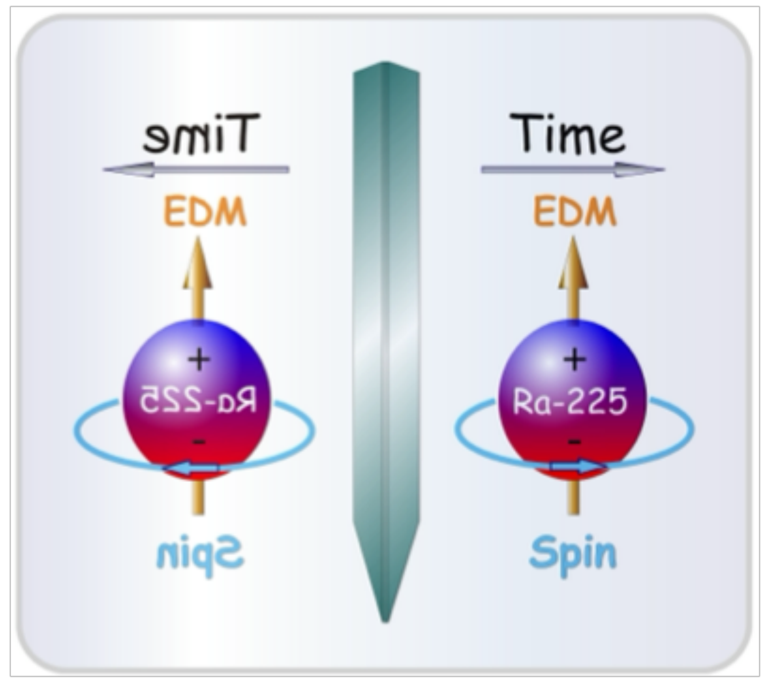
Image credit: Evan Berkowitz



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

NP experimental programs in β decays at ARUNA Labs, FRIB, LANL, NIST, ORNL

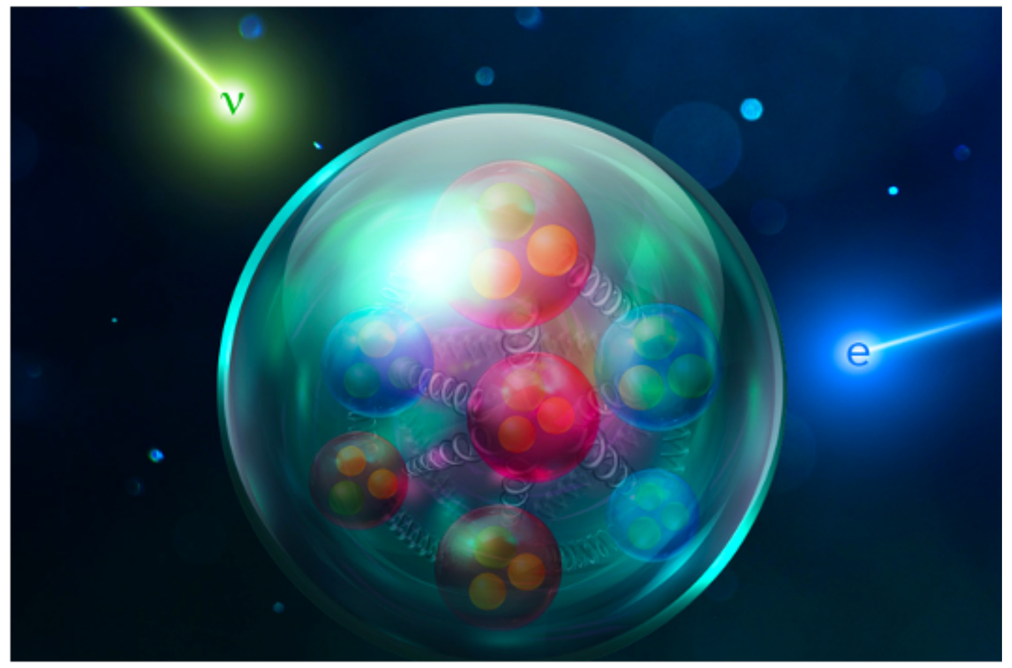
Image credit: R. Holt, Z. T. Lu, W. Korsch, P. Muller, J. Singh



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

NP EDM experiments at ANL, FRIB, LANL, UW

Image credit: Jefferson Lab



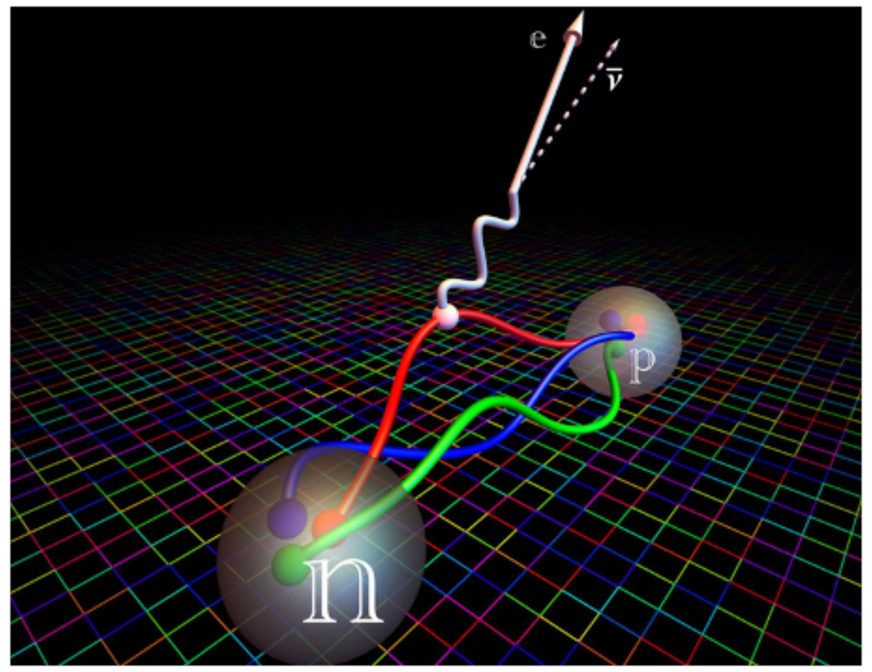
Neutrino-nucleus scattering is a chief tool to learn about neutrino properties in oscillation experiments, in particular CP-violation.
NTNP: ab-initio calculations of neutrino-nucleus scattering in A=4,12,16,40

HEP / NP experimental programs in lepton-nucleus scattering — JLab & DUNE

High level goals of NTNP

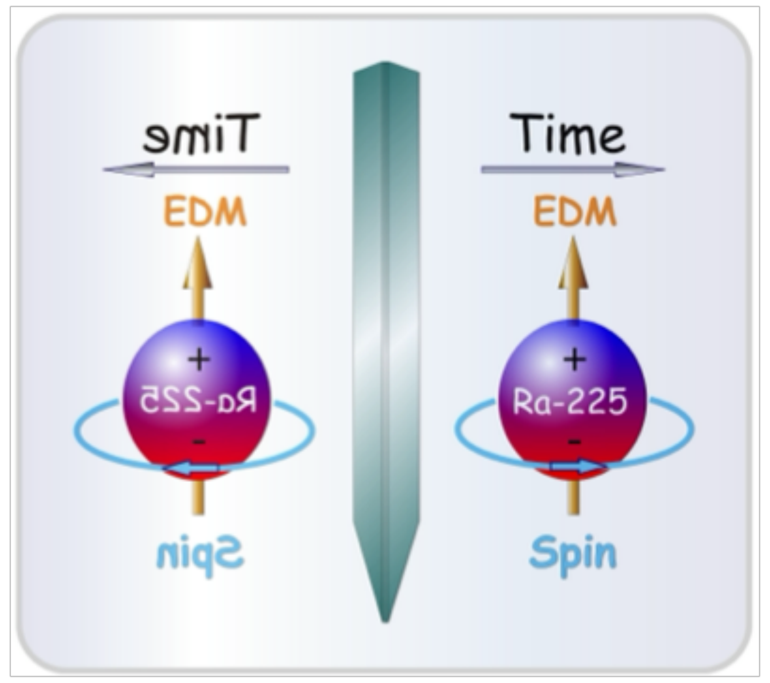
NTNP focuses on three thrusts of the precision / intensity frontier program, with the goal of
providing state-of-the-art predictions with quantified uncertainties and assessing their phenomenological impact

Image credit: Evan Berkowitz



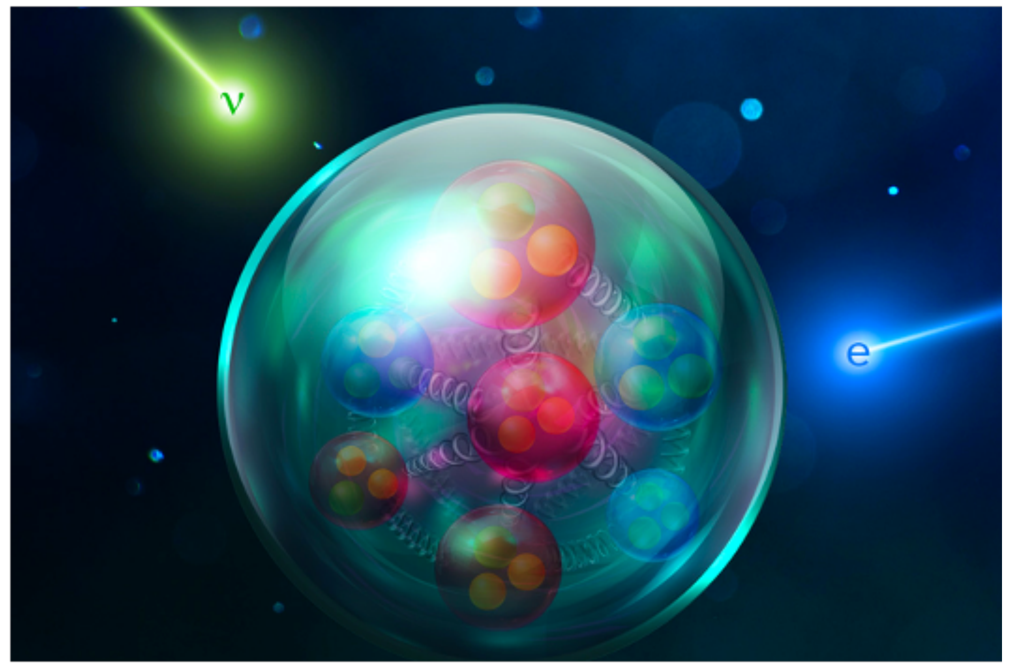
Precision studies of neutron and nuclear beta decays are exquisite probes of the electroweak interactions and can uncover new physics.
NTNP: radiative corrections to neutron & nuclear decays and implications for new physics

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



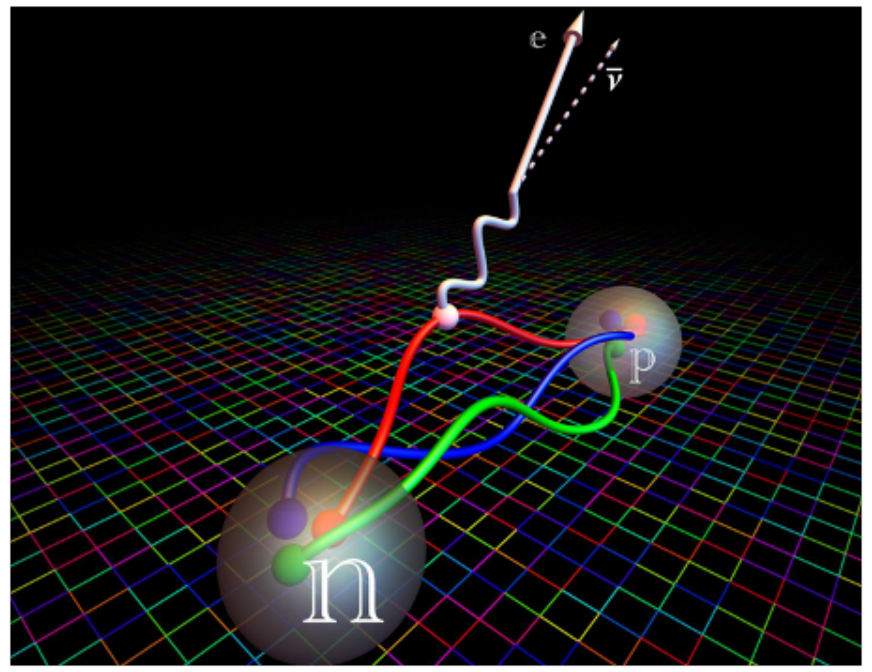
Neutrino-nucleus scattering is a chief tool to learn about neutrino properties in oscillation experiments, in particular CP-violation.
NTNP: ab-initio calculations of neutrino-nucleus scattering in A=4,12,16,40

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

High level goals of NTNP

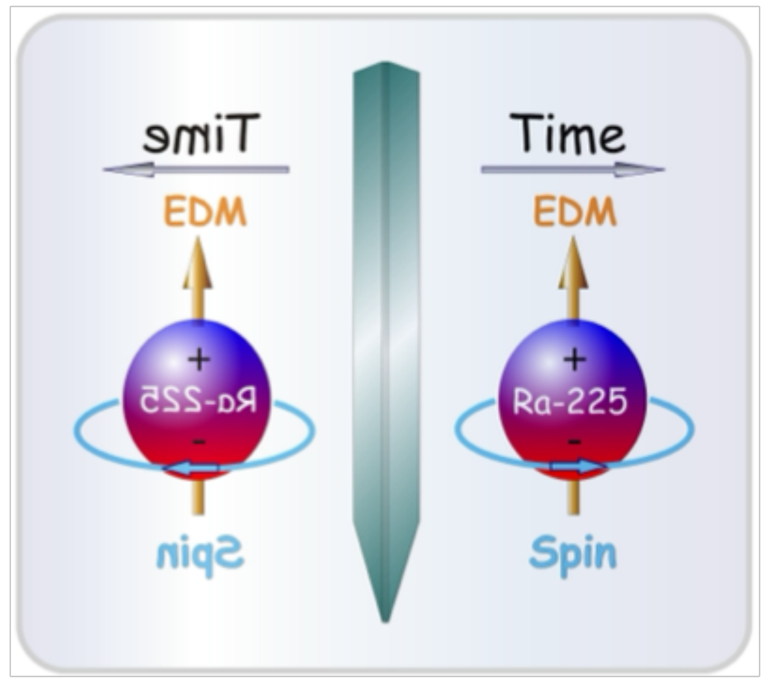
NTNP focuses on three thrusts of the precision / intensity frontier program, with the goal of
providing state-of-the-art predictions with quantified uncertainties and assessing their phenomenological impact

Image credit: Evan Berkowitz



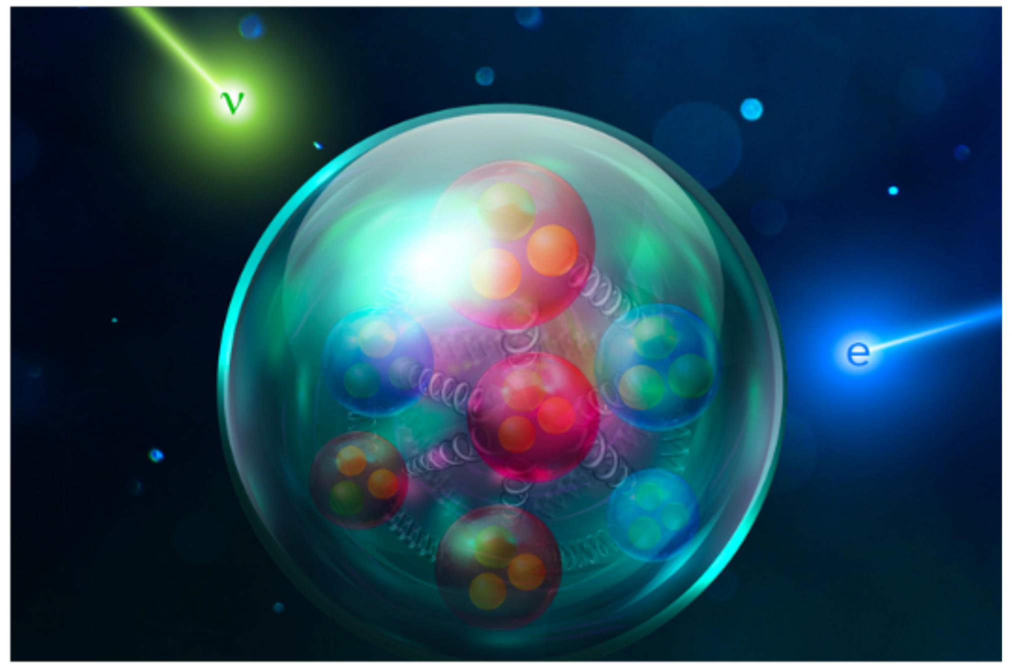
Precision studies of neutron and nuclear beta decays are exquisite probes of the electroweak interactions and can uncover new physics.
NTNP: radiative corrections to neutron & nuclear decays and implications for new physics

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

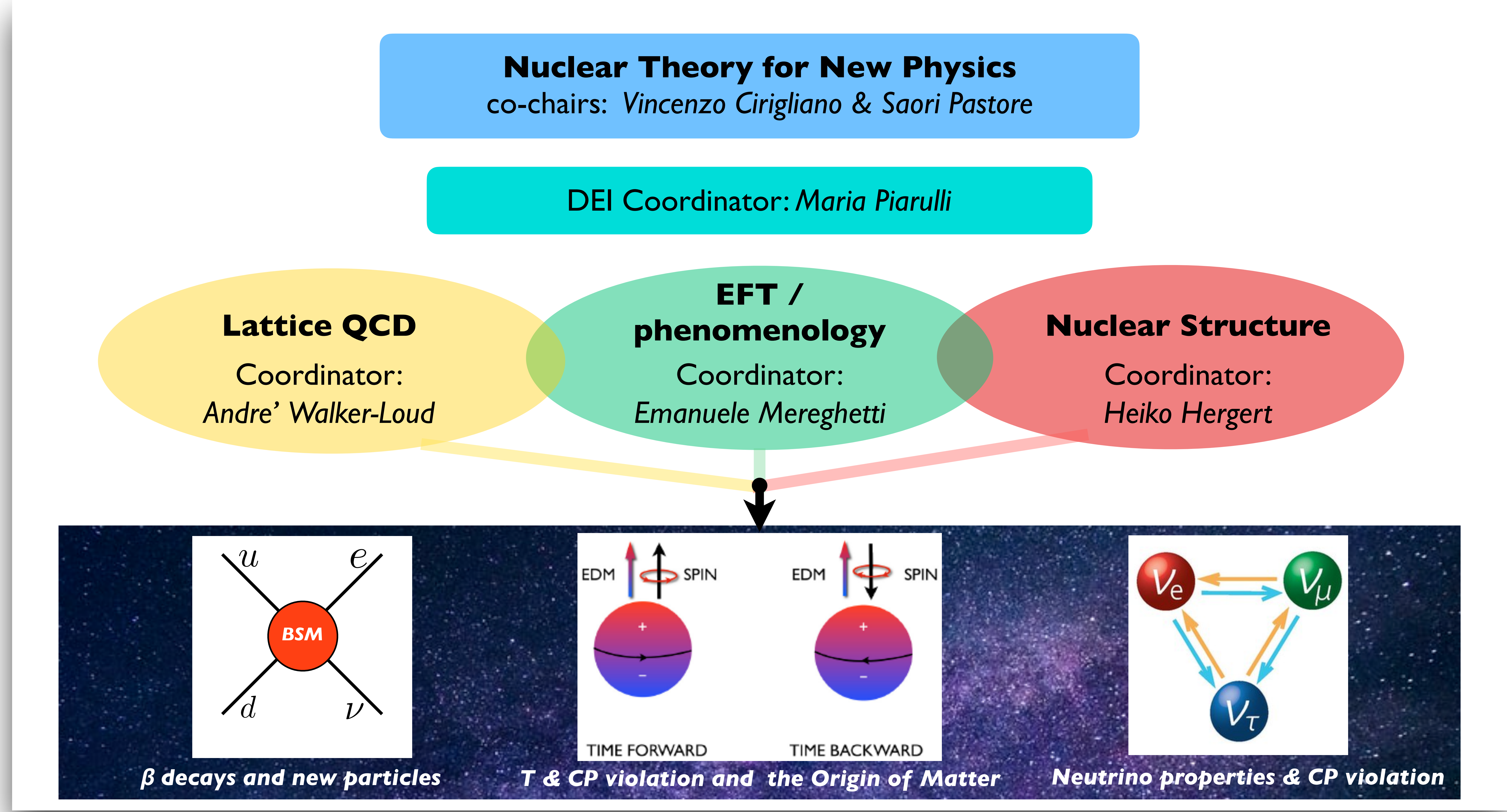


Neutrino-nucleus scattering is a chief tool to learn about neutrino properties in oscillation experiments, in particular CP-violation.
NTNP: ab-initio calculations of neutrino-nucleus scattering in A=4,12,16,40

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/



10 Universities, Institute for Nuclear Theory, 6 National Laboratories
28 Senior Collaborators + 2 5-year fellows (FRIB-TA+UW & INT)
10 Postdocs, 8 Graduate Students

Faces of NTNP

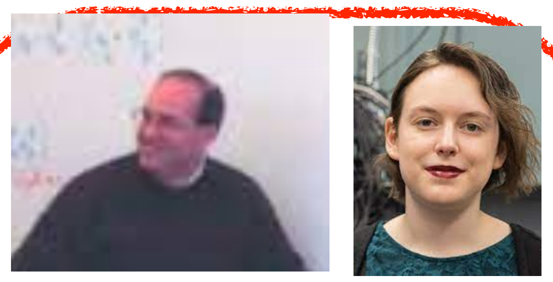
UW/INT
Vincenzo Cirigliano
Wouter Dekens
Chien-Yeah Seng
Ayala Glick-Magid
Maria Dawid

FNAL
Noemi Rocco

ANL
Alessandro Lovato
Anna McCoy
Robert Wiringa

MSU (& FRIB)
Scott Bogner
Heiko Hergert

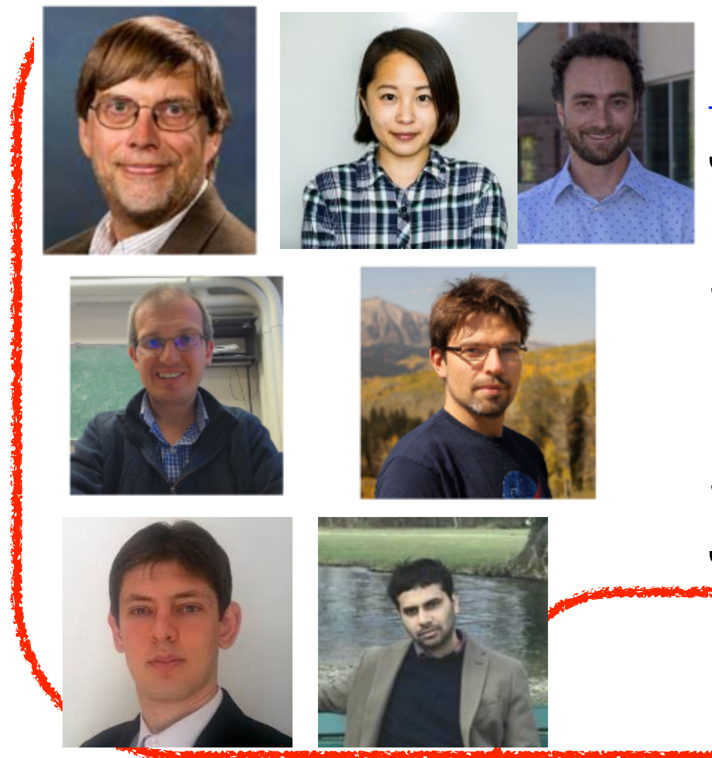
Notre Dame
Ragnar Stroberg



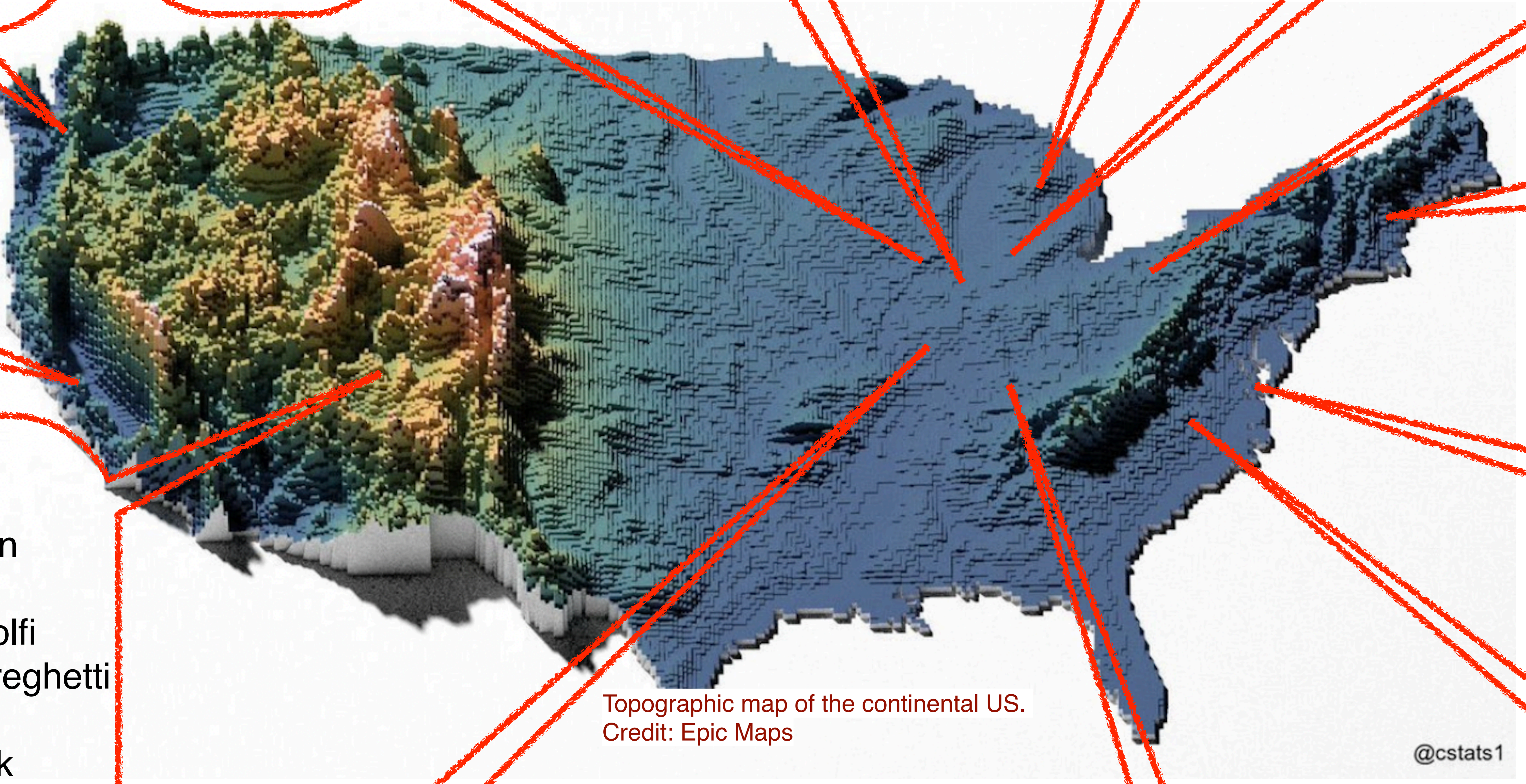
Carnegie Mellon University
Colin Morningstar
Sarah Skinner

UC Berkeley/LBNL
Wick Haxton
André Walker-Loud
Andrea Shindler
Lukáš Gráf
Zack Hall

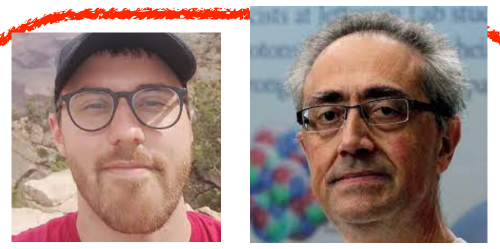
UMass Amherst
Michael Ramsey-Musolf
Leon Friedrich



LANL
Joseph Carlson
Kaori Fuyuto
Stefano Gandolfi
Emanuele Mereghetti
Ingo Tews
Sasha Tomalak
Jacky Kumar



Topographic map of the continental US.
Credit: Epic Maps



ODU/JLab
Alex Gnech
Rocco Schiavilla

Wash. U. St Louis
Bhupal Dev
Saori Pastore
Maria Piarulli
Anna McCoy
Lorenzo Andreoli
Sam Novario
Jason Bub
Garrett King
Graham Chambers-Wall

ORNL / University of Tennessee
Gaute Hagen
Thomas Papenbrock
Lucas Platter
Evan Combes

UNC Chapel Hill
Jon Engel
Amy Nicholson
Zack Hall
Joeseph Moscoso

Workforce Development

Workforce development

- NTNP fosters workforce development in multiple ways, by
  - Providing welcoming and inclusive environment for all the participating researchers — adopted collaboration-wide code of conduct
  - Sponsoring two bridge faculty positions — implementing procedures to attract broad pool of candidates
  - Training, mentoring, and supporting the next generation of nuclear theorists: the majority of allocated funds support graduate students and postdocs
  - Facilitating discussions and scientific collaborations across sub-fields of nuclear theory — collaboration meetings & cross-cutting projects

Code of conduct

NTNP | Home | science | people | meetings | Code of Conduct

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.

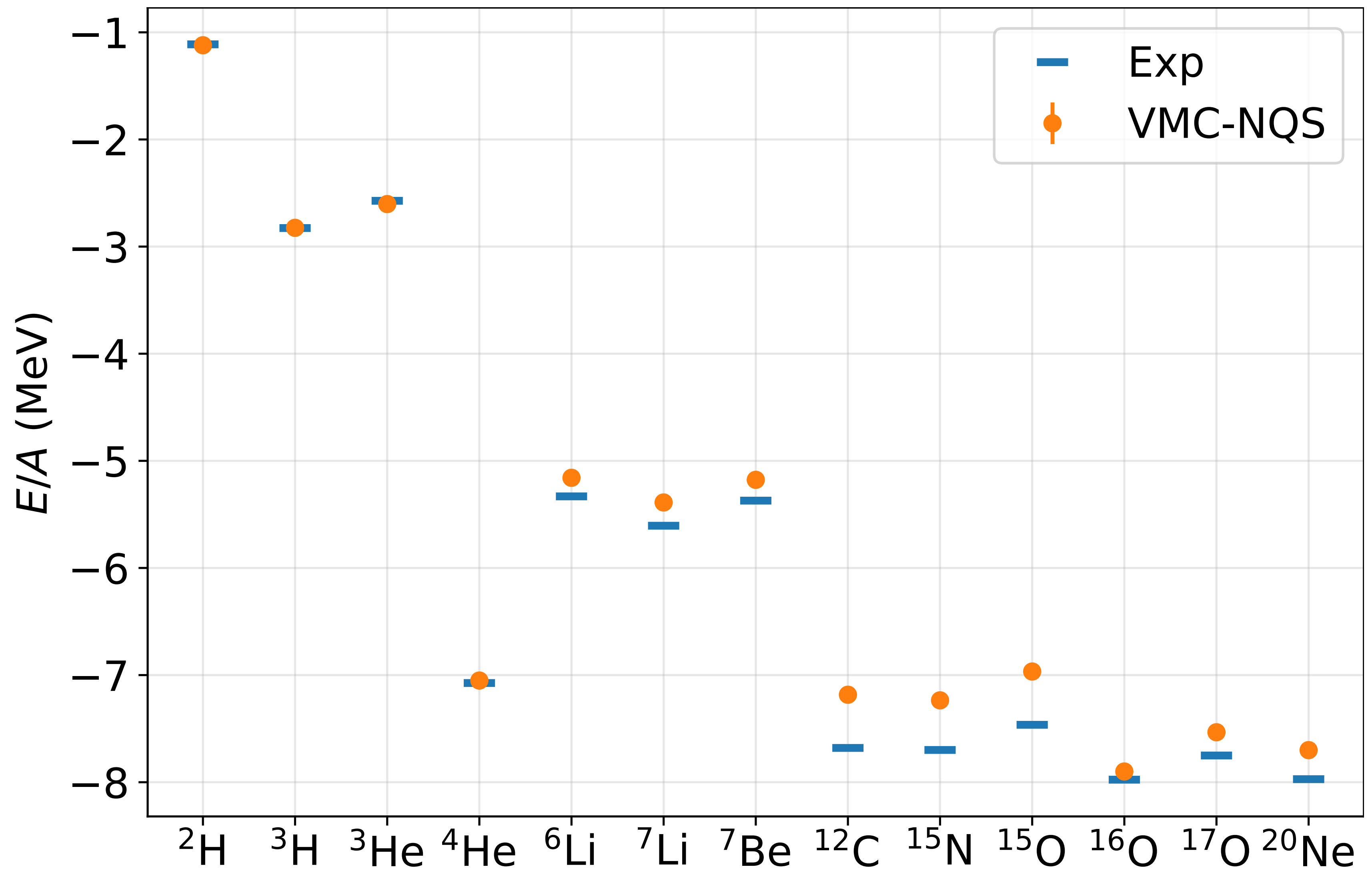
Bridge position 1: Alex Gnech

- Alex Gnech joined Old Dominion University / JLAB in January 2024

  - Current research
    - Implementation of the electroweak currents in the Neural Network Quantum State approach (NQS) (with A. Lovato)
    - Derivation of Time-Reversal-Violating operators in chiral EFT (with A. Clark, PhD Student at ODU)
    - Calculation of response functions of light nuclei using the Lorentz Integral Transform

  - Future plans
    - Calculation of pion electroproduction on light nuclei using Short Time Approximation (with L. Andreoli et al.)
    - Calculation of superallowed beta-decays using the NQS in pionless EFT

2308.16266



Ground state nuclear energies in LO pion-less EFT with NQS

= Beta decay

= EDMs

= νN scattering

Bridge position 2

- Originally planned search at Carnegie Mellon University did not go through (change of dean)
- With program manager concurrence, we had an internal ‘call’ to probe interest of other NTNP institutions
- Three institutions expressed strong interest in hosting the position
- We will collect appropriate support letters and make a concrete proposal to DOE by September 2024

Junior investigators

Grad Students	Institution	PRIMARY AREA
Jason Bub	Washington University, St. Louis	NS
Graham Chambers-Wall	Washington University, St. Louis	NS
Evan Combes	University of Tennessee Knoxville	EFT
Maria Dawid	University of Washington	EFT
Zack Hall	University of North Carolina Chapel Hill and LBNL	LQCD
Garrett King	Washington University, St. Louis	NS
Joseph Moscoso	University of North Carolina Chapel Hill	LQCD
Sarah Skinner	Carnegie Mellon University	LQCD

Postdocs	Institution	PRIMARY AREA
Lorenzo Andreoli	Washington University, St. Louis	NS
Leon Friedrich	UMass Amherst	EFT
Ayala Glick-Magid	University of Washington, Seattle	NS
Lukáš Gráf	University of California Berkeley	EFT
Peter Gysbers	Michigan State University	NS
Jacky Kumar	Los Alamos National Laboratory	EFT
Sam Novario	Washington University, St. Louis	NS
* Thomas Richardson	University of California Berkeley	EFT/LQCD
* Noah Steinberg	Argonne National Laboraory and Fermilab	NS
Sasha Tomalak	Los Alamos National Laboratory	EFT

5-year Fellows	Institution	PRIMARY AREA
Wouter Dekens	Institute for Nuclear Theory	EFT
Chien Yeah Seng	University of Washington & FRIB	NS

NTNP directly supports a number of students and postdocs

By leveraging other resources, NTNP also provides an 'ecosystem' that facilitates collaboration and growth

8 graduate students, 10 postdocs, 2 5-year fellows

LEGEND:

= Partially or fully supported by NTNP

EFT = Effective Field Theory

LQCD = Lattice QCD

NS = Nuclear Structure

* = Onboarding next year

Collaboration meetings

Meetings of the NTNP Collaboration

- 2024 May 15-17 In Person Meeting at Wash. U.
- 2023 Jun.1-2, In Person Meeting at the INT
- 2023 Feb. 3 Kick Off Meeting with DOE

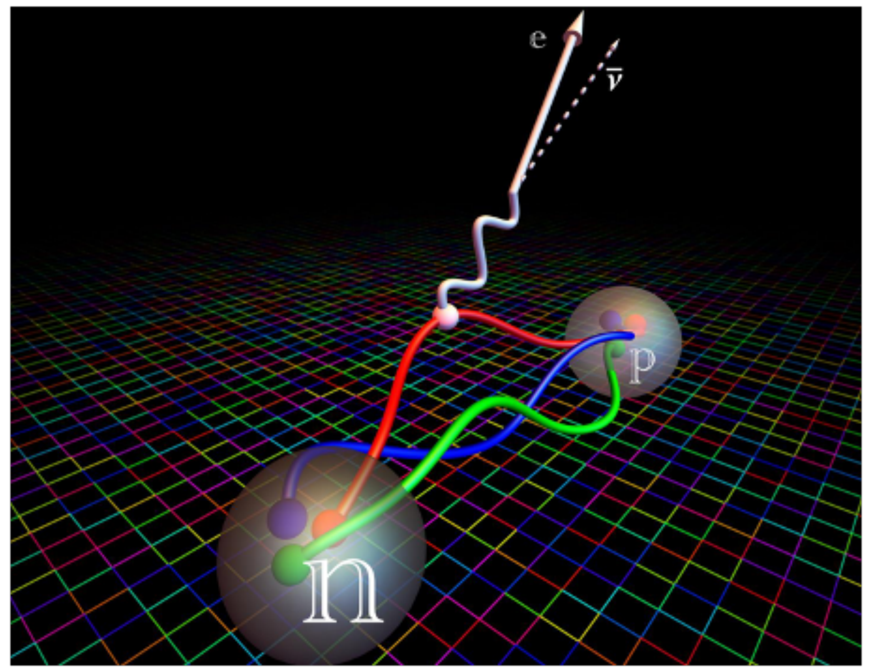
- Opportunity to share results, plan, and educate
- Schedule for upcoming May 15-17 meeting @ WashU St. Louis: majority of talks by junior members of the collaboration
- Leverage cost and infrastructure — INT (2023) and McDonnell Center @ WashU (2024)

	Wednesday, May 15, 2024	Thursday, May 16, 2024	Friday, May 17, 2024
9:15-10:00	Vincenzo Cirigliano "Overview of the collaboration and report on the DOE review"	Alex Gnech "Bayesian analysis of muon capture on the deuteron in chiral effective field theory"	Andrea Shindler "An update on lattice QCD calculations of the neutron EDM"
10:00-10:45	Oleksandr Tomalak "Effective field theory for radiative corrections to neutron decay"	Jason Bub "Bayesian Uncertainty Quantification in EFTs"	Noemi Rocco TBA
10:45-11:15	**Coffee Break**	**Coffee Break**	**Coffee Break**
11:15-12:00	Zack Hall "Non-monotonic Finite Volume Corrections to gA"	Peter Gysbers TBA	Lorenzo Andreoli "Lepton-Nucleus scattering in the STA"
12:00-1:30	**Lunch**	**Lunch**	**Closing Remarks/Lunch**
1:30-2:15	Maria Dawid "One-loop analysis of beta decays in SMEFT"	Ayala Glick-Magid "Precision beta decay"	
2:15-3:00	Chien-Yeah Seng "Progress in delta_NS calculation"	Garrett King "Electroweak structure and reactions with QMC methods"	
3:00-3:30	**Coffee Break**	**Coffee Break**	
3:30-4:15	Wouter Dekens "Radiative corrections to nuclear beta decays in EFT"	Abraham Flores "Preparing Quantum Monte Carlo Methods for the Next Generation of Computers"	
4:15-5:00	**Open Mic**	Wick Haxton "Mu-to-e Conversion"	
5:00-5:30		**Open Mic**	
5:30-8:00	**Social Dinner** Urban Chestnut Brewing Company 4465 Manchester Road		

= 5-yr Fellow
= Postdoc
= Student

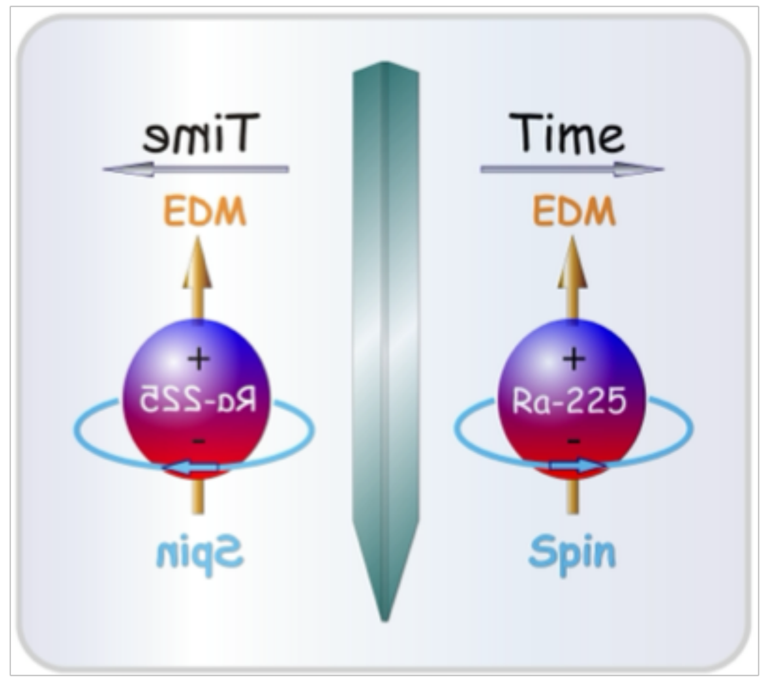
Scientific thrusts
and
progress towards objectives

Image credit: Evan Berkowitz



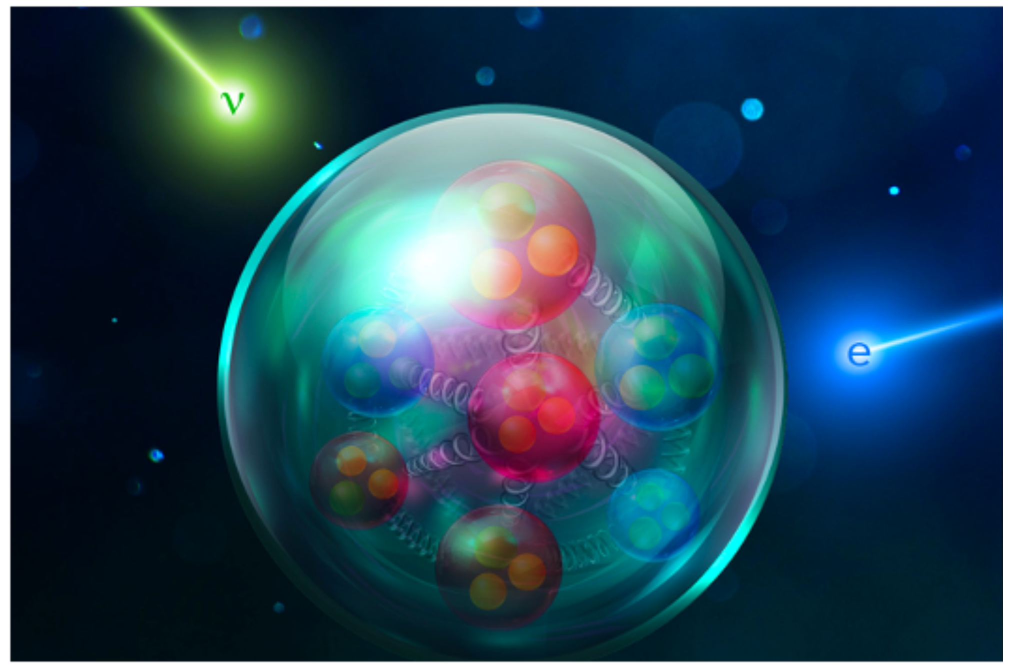
Precision beta decays

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



Nuclear EDMs

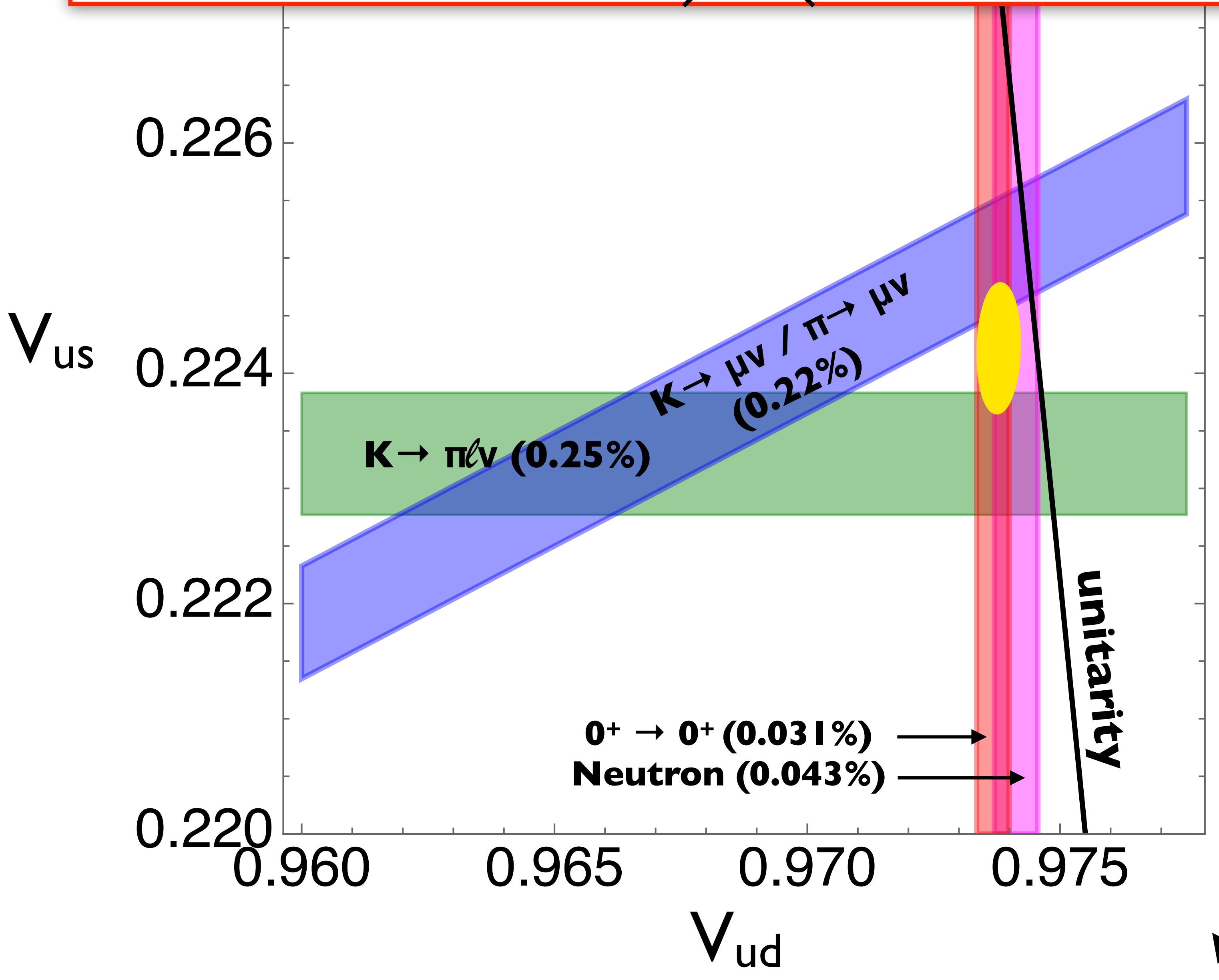
Image credit: Jefferson Lab

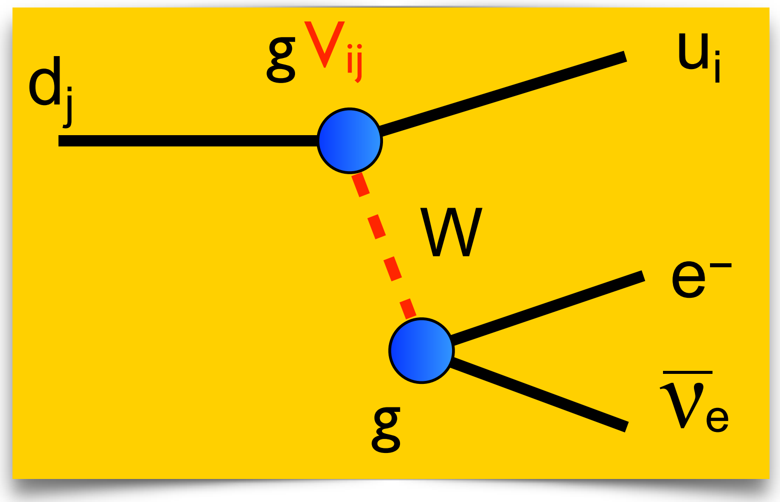


Neutrino-nucleus scattering

Thrust I: precision β decays

$\Delta_{CKM} = |V_{ud}|^2 + |V_{us}|^2 + \cancel{|V_{ub}|^2} - 1 = -15(5)\times10^{-4}$





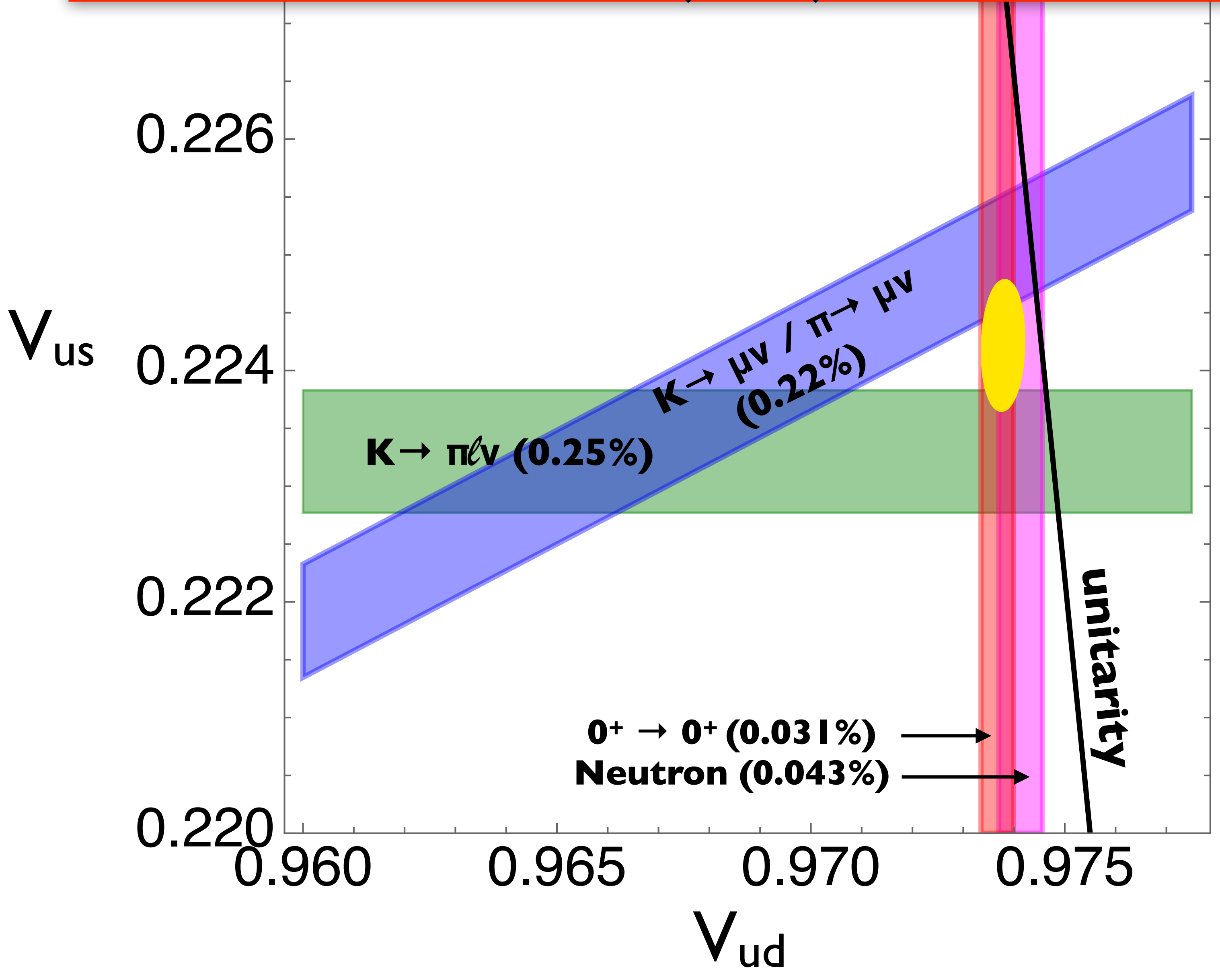
- Two tantalizing ‘anomalies’
- At face value point toward BSM vertex corrections with Λ_{BSM}~10 TeV (hard to probe even at the HI-LUMI LHC)

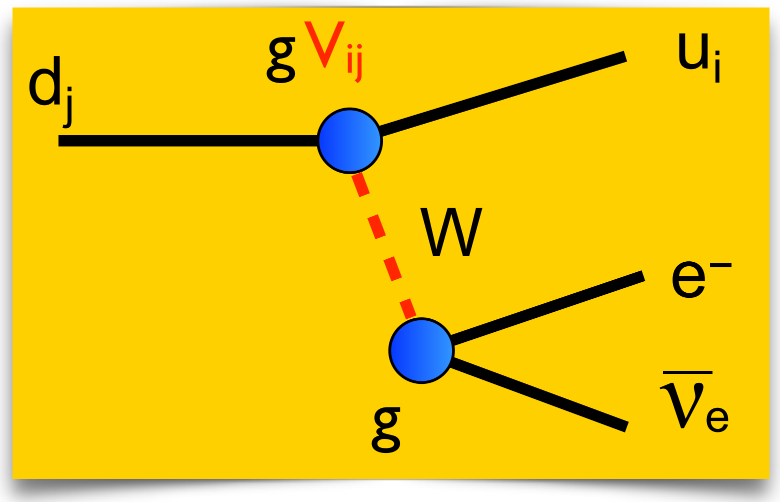
$$\Gamma = G_F^2 \times |V_{ij}|^2 \times |M_{\rm had}|^2 \times (1+\Delta_R) \times F_{\rm kin}$$

Meaningful test requires EM radiative corrections with controlled uncertainties (~0.03% precision in V_{ud}!)

Thrust I: precision β decays

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



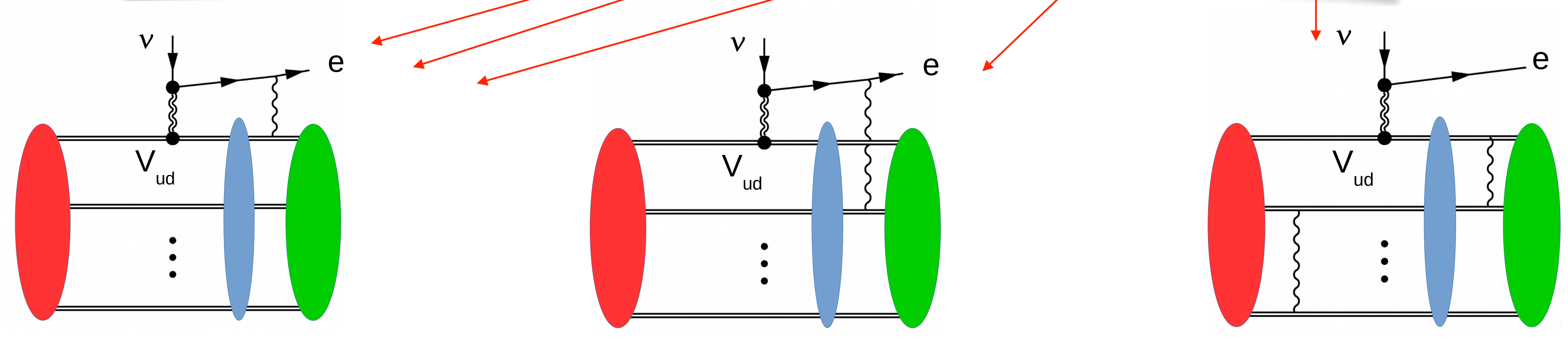


- Two tantalizing 'anomalies'
- At face value point toward BSM vertex corrections with Λ_{BSM}~10 TeV (hard to probe even at the HI-LUMI LHC)

Example of nuclear superallowed decays ($0^+ \to 0^+$)

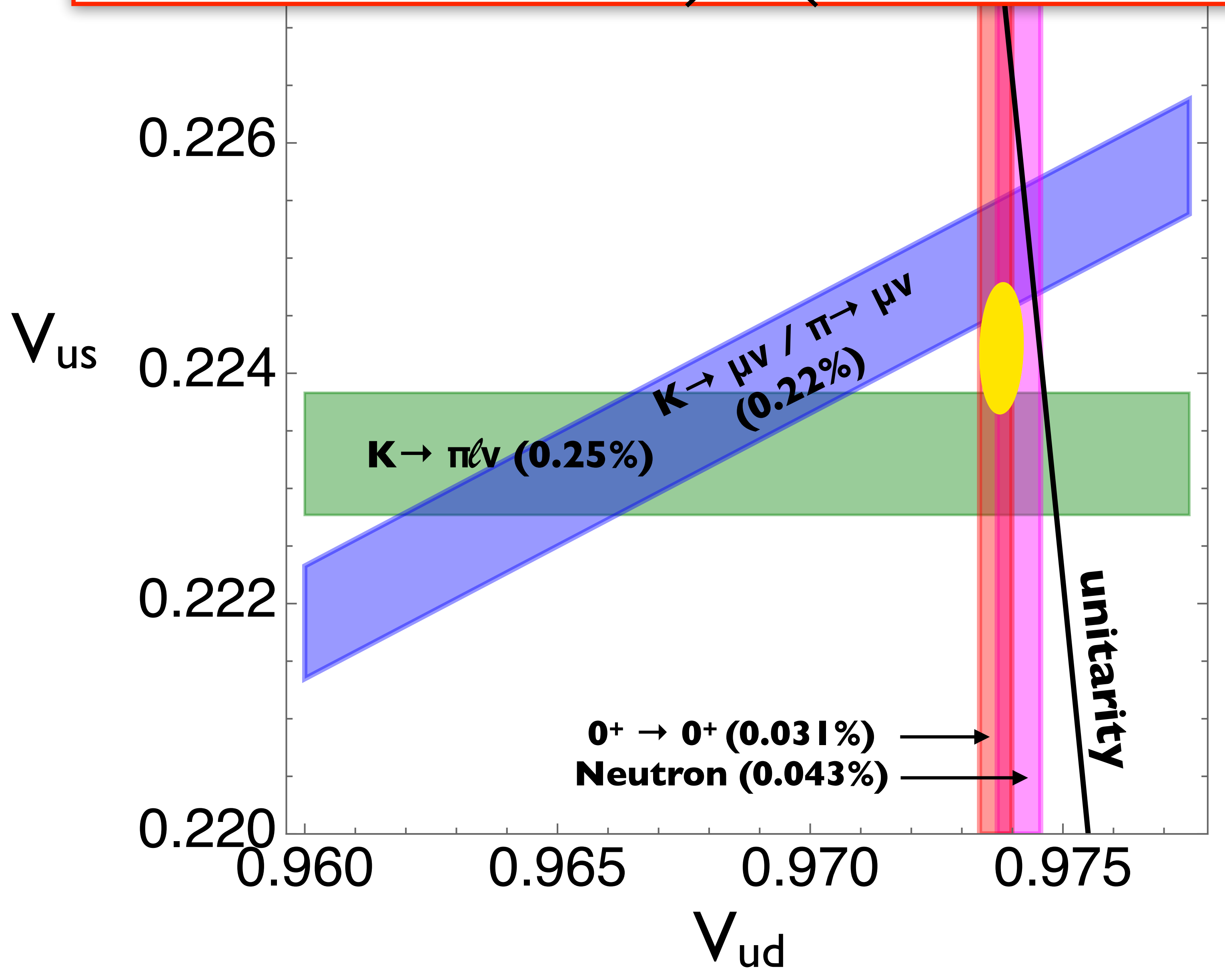
$$\frac{\log 2}{ft} = \frac{G_F^2 m_e^5 |V_{ud}|^2}{\pi^3}\left(1 + \Delta_R^V + \delta_R' + \delta_{NS} - \delta_C\right)$$

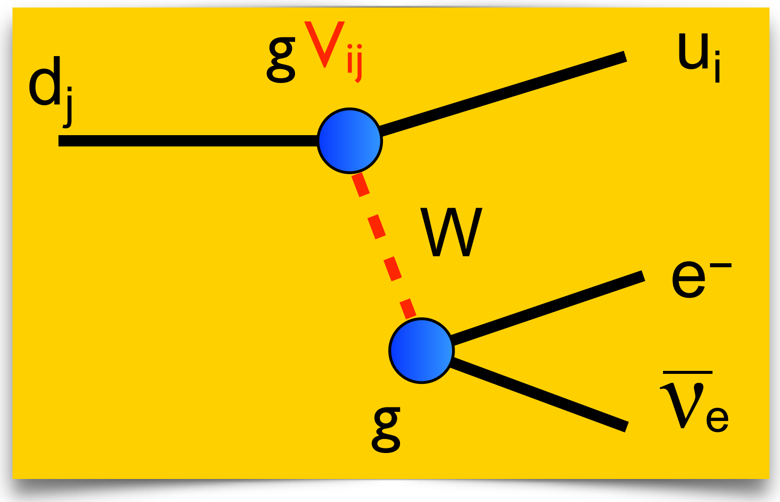
$$V_{ud}^{0^+\to 0^+} = 0.97367(11)_{\rm exp}(13)_{\Delta_R^V}(27)_{\rm NS}[32]_{\rm total}$$



Thrust 1: precision β decays

$\Delta_{CKM} = |V_{ud}|^2 + |V_{us}|^2 + \cancel{|V_{ub}|^2} - 1 = -15(5)\times10^{-4}$



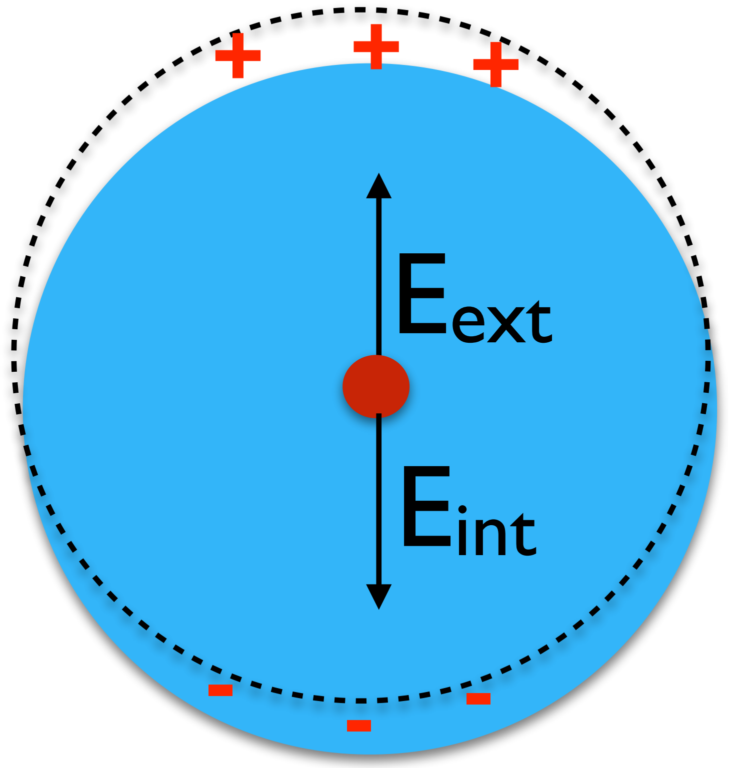


- Two tantalizing 'anomalies'
- At face value point toward BSM vertex corrections with Λ_{BSM}~10 TeV (hard to probe even at the HI-LUMI LHC)

- NTNP objectives:
  - BETA-1: Radiative corrections to neutron decay in EFT and Lattice QCD
  - BETA-2: Effective Field Theory (EFT) analysis of NN systems to $O(G_F\alpha)$ → input for nuclear structure
  - BETA-3: Radiative corrections to nuclear $0^+ \to 0^+$ decays (A=10, 14, 18, …) with multiple ab-initio many-body methods
  - BETA-4: Implications for new physics

Thrust 2: permanent EDMs

- Permanent EDMs of nucleon, nuclei, atoms, (radioactive) 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 & radioactive molecules (exciting opportunities at FRIB) controlled by the nuclear Schiff moment

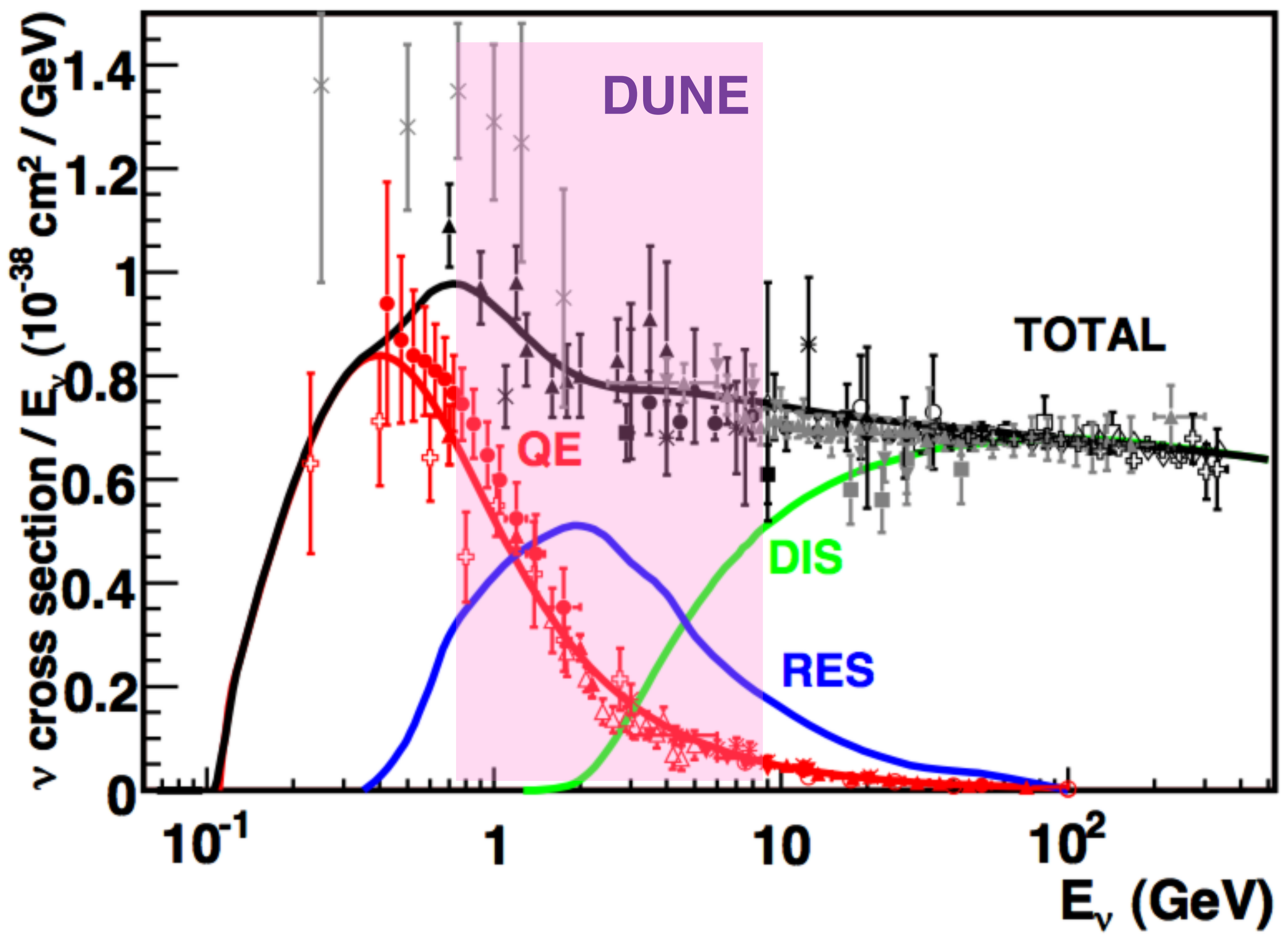
$$S = \sum_{i \neq 0} \frac{\langle \Phi_0 | S_z | \Phi_i \rangle \langle \Phi_i | V_{TVPV} | \Phi_0 \rangle}{E_0 - E_i} + \text{c.c.}$$

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

- NTNP objective:
    - EDM-3: First calculations of nuclear Schiff moments with ab-initio methods: VS-IMSRG for ^{129}Xe, ^{199}Hg and IM-GCM & CC for ^{225}Ra

Thrust 3: neutrino-nucleus scattering

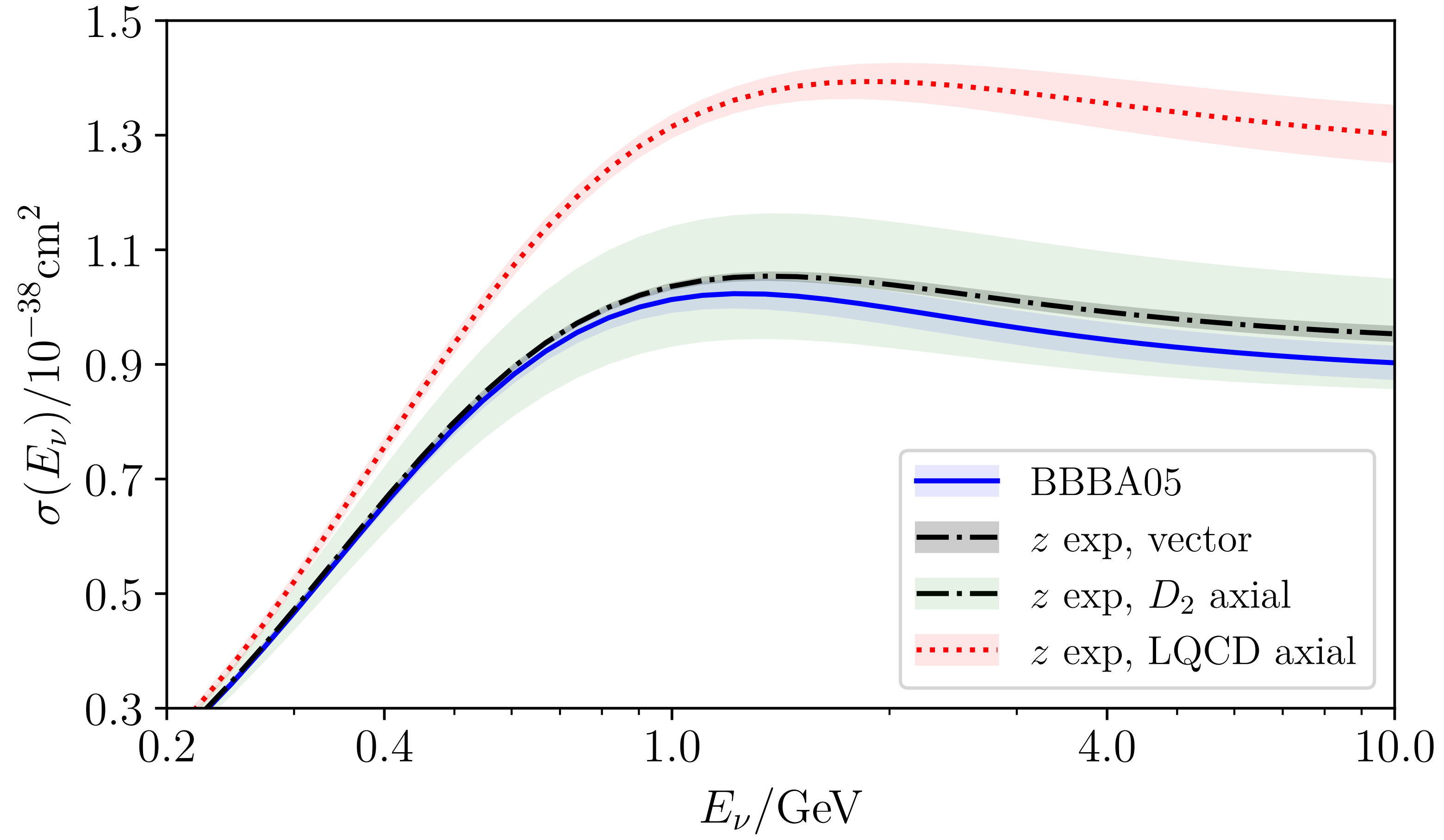
J. Formaggio, G. P. Zeller, 1305.7513 [



- 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
  - XSEC-1 and XSEC-2: Lattice QCD input on single-nucleon form factors (elastic and not)
  - XSEC-4 and XSEC-5: Use multiple many-body methods for A=4,12,16,40 to compute inclusive and exclusive cross-section (& JLAB data on electron scattering for validation)

A. Meyer, A. Walker-Loud, C. Wilkinson, 2201.01839



Progress towards objectives

Year-1

BETA-2 Develop EFT formalism for A=2 systems to $O(G_F\alpha)$ [LANL *, UMass, UTK, UW]

Year-2

BETA-1 Two loop calculation of electroweak corrections to charged-current processes [UMass *]

BETA-3 Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]

XSEC-1 Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]

Year-3

BETA-1 Calculation of $n \to pe\bar{\nu}$ to $O(G_F\alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]

BETA-2 EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]

BETA-3 Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]

EDM-3 VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]

XSEC-2 First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]

Year-4

BETA-3 Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]

XSEC-4 Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]

Year-5

BETA-3 Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]

BETA-4 Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]

EDM-3 IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]

XSEC-4 Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]

XSEC-5 Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

← Milestones from final proposal

Progress towards objectives

Year-1	**BETA-2**	Develop EFT formalism for A=2 systems to $O(G_F\alpha)$ [LANL *, UMass, UTK, UW]
Year-2	**BETA-1**	Two loop calculation of electroweak corrections to charged-current processes [UMass *]
	BETA-3	Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]
	XSEC-1	Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]
Year-3	**BETA-1**	Calculation of $n \to pe\bar{\nu}$ to $O(G_F\alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]
	BETA-2	EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]
	BETA-3	Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]
	EDM-3	VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]
	XSEC-2	First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]
Year-4	**BETA-3**	Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]
	XSEC-4	Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]
Year-5	**BETA-3**	Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]
	BETA-4	Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]
	EDM-3	IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]
	XSEC-4	Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]
	XSEC-5	Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

- Work underway on our three major thrusts:
  12 research articles, 3 reviews, 42+ talks
- In the rest of this talk and in the 3 research talks:
  - Accomplishments & progress so far
  - On track to reach milestones for current and future years

= Beta decay
= EDMs
= νN scattering

Precision β decays

Year-1	**BETA-2**	Develop EFT formalism for A=2 systems to $O(G_F\alpha)$ [LANL *, UMass, UTK, UW]
Year-2	**BETA-1**	Two loop calculation of electroweak corrections to charged-current processes [UMass *]
	BETA-3	Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]
	XSEC-1	Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]
Year-3	**BETA-1**	Calculation of $n \to pe\bar{\nu}$ to $O(G_F\alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]
	BETA-2	EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]
	BETA-3	Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]
	EDM-3	VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]
	XSEC-2	First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]
Year-4	**BETA-3**	Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]
	XSEC-4	Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]
Year-5	**BETA-3**	Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]
	BETA-4	Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]
	EDM-3	IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]
	XSEC-4	Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]
	XSEC-5	Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

Heavier upfront load on beta decays

Precision β decays

Year-1	**BETA-2**	Develop EFT formalism for A=2 systems to $O(G_F\alpha)$ [LANL *, UMass, UTK, UW]
Year-2	**BETA-1**	Two loop calculation of electroweak corrections to charged-current processes [UMass *]
	BETA-3	Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]
	XSEC-1	Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]
Year-3	**BETA-1**	Calculation of $n \to pe\bar{\nu}$ to $O(G_F\alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]
	BETA-2	EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]
	BETA-3	Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]
	EDM-3	VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]
	XSEC-2	First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]
Year-4	**BETA-3**	Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]
	XSEC-4	Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]
Year-5	**BETA-3**	Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]
	BETA-4	Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]
	EDM-3	IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]
	XSEC-4	Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]
	XSEC-5	Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

See talk by Emanuele Mereghetti

Precision β decays

Year-1 **BETA-2** Develop EFT formalism for A=2 systems to $O(G_F\alpha)$ [LANL *, UMass, UTK, UW]

Year-2 **BETA-1** Two loop calculation of electroweak corrections to charged-current processes [UMass *]

BETA-3 Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]

XSEC-1 Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]

Year-3 **BETA-1** Calculation of $n \to pe\bar{\nu}$ to $O(G_F\alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]

BETA-2 EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]

BETA-3 Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]

EDM-3 VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]

XSEC-2 First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]

Year-4 **BETA-3** Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]

XSEC-4 Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]

Year-5 **BETA-3** Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]

BETA-4 Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]

EDM-3 IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]

XSEC-4 Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]

XSEC-5 Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

→ Developed software and file formats to deploy EFT transition operators in multiple ab-initio methods

In synergistic work, developed new emulators for enhanced UQ capabilities

Precision β decays

Year-1	**BETA-2**	Develop EFT formalism for A=2 systems to $O(G_F\alpha)$ [LANL *, UMass, UTK, UW]
Year-2	**BETA-1**	Two loop calculation of electroweak corrections to charged-current processes [UMass *]
	BETA-3	Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]
	XSEC-1	Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]
Year-3	**BETA-1**	Calculation of $n \to pe\bar{\nu}$ to $O(G_F\alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]
	BETA-2	EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]
	BETA-3	Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]
	EDM-3	VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]
	XSEC-2	First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]
Year-4	**BETA-3**	Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]
	XSEC-4	Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]
Year-5	**BETA-3**	Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]
	BETA-4	Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]
	EDM-3	IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]
	XSEC-4	Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]
	XSEC-5	Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

24

→ See talk by Andre' Walker-Loud

Precision β decays

Year-1
- **BETA-2** Develop EFT formalism for A=2 systems to $O(G_F \alpha)$ [LANL *, UMass, UTK, UW]

Year-2
- **BETA-1** Two loop calculation of electroweak corrections to charged-current processes [UMass *]
- **BETA-3** Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]
- **XSEC-1** Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]

Year-3
- **BETA-1** Calculation of $n \to pe\bar{\nu}$ to $O(G_F \alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]
- **BETA-2** EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]
- **BETA-3** Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]
- **EDM-3** VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]
- **XSEC-2** First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]

Year-4
- **BETA-3** Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]
- **XSEC-4** Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]

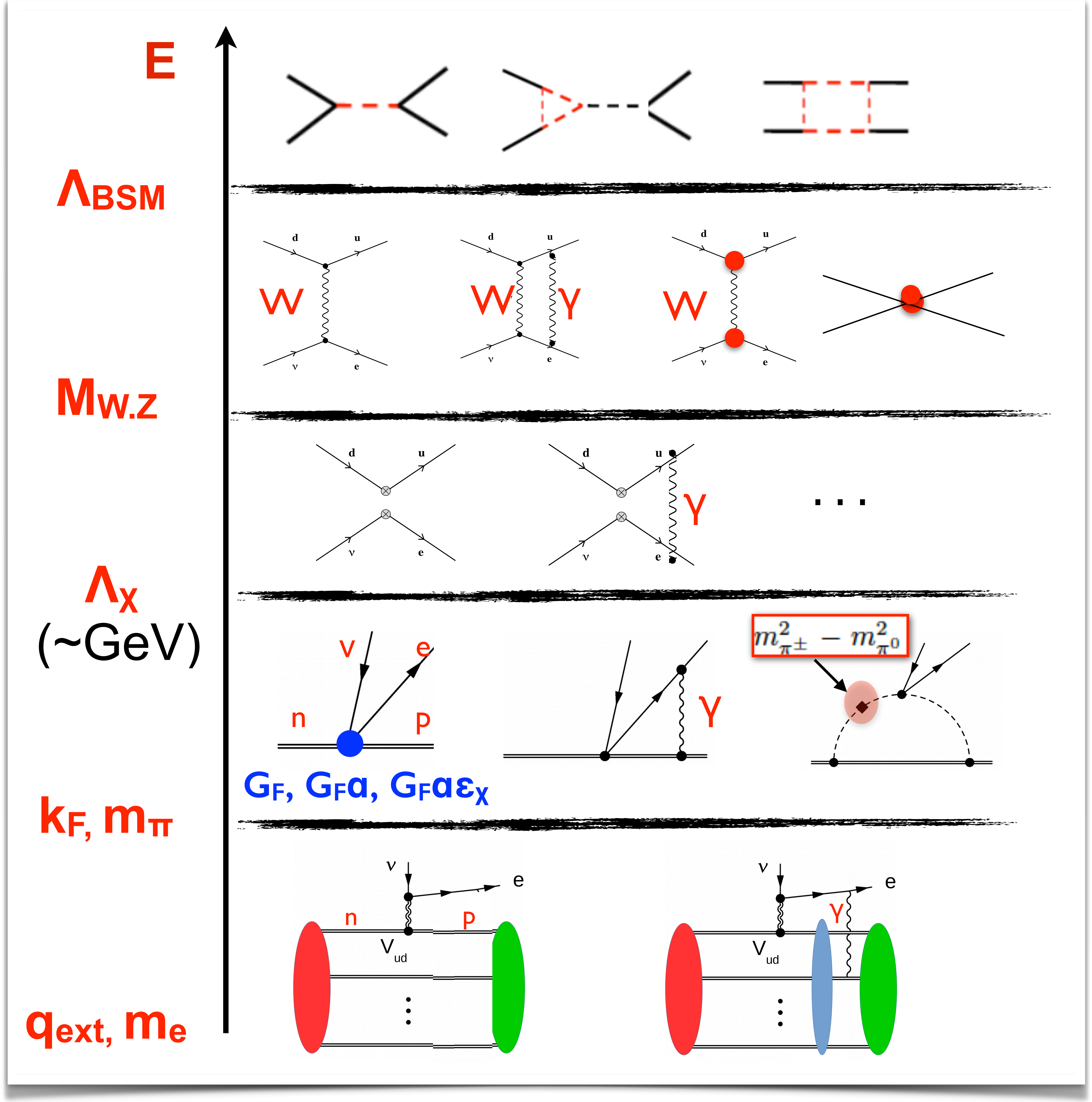
Year-5
- **BETA-3** Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]
- **BETA-4** Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]
- **EDM-3** IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]
- **XSEC-4** Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]
- **XSEC-5** Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

In this talk:

- EFT framework for radiative corrections to β decays of neutron and nuclei
- Connection of β decays to electroweak precision tests and BSM physics

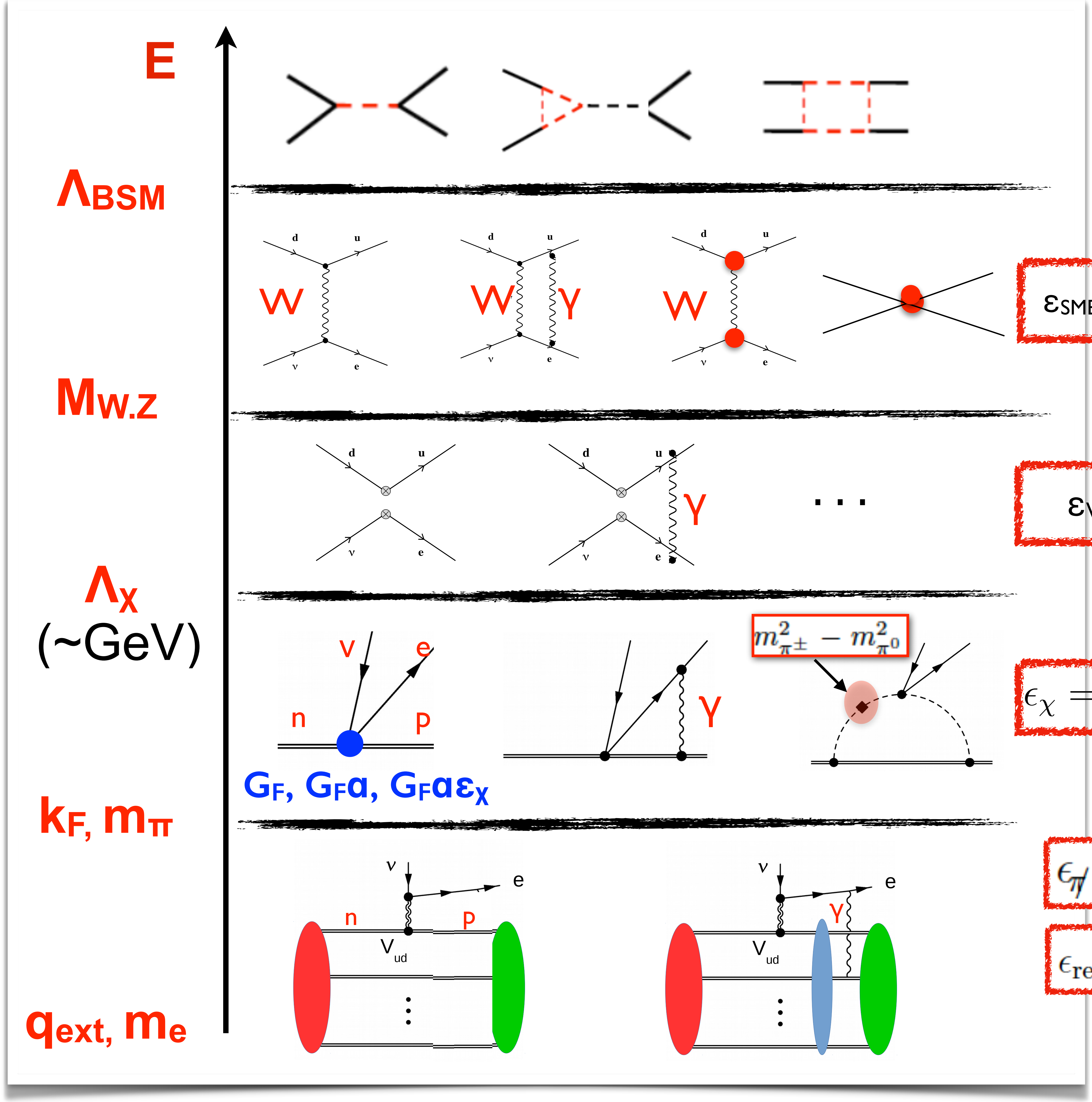
EFTs for β decays: from BSM to nuclei

Widely separated scales: Λ_{BSM}, M_W, Λ_χ, m_π, m_e ~ q_{ext} ⇒ Tackle the problem through a tower of EFTs



EFTs for β decays: from BSM to nuclei

Widely separated scales: Λ_{BSM}, M_W, Λ_χ, m_π, $m_e \sim q_{ext}$ ⇒ Tackle the problem through a tower of EFTs



$\varepsilon_{SMEFT} = (M_W/\Lambda_{BSM})^2$

$\varepsilon_W = (\Lambda_\chi/M_W)^2$

$\epsilon_\chi = \{k_F, m_{\pi,K}\}/\Lambda_\chi$

$\epsilon_{\not\pi} = q_{ext}/m_\pi$

$\epsilon_{recoil} = q_{ext}/\Lambda_\chi$

BSM

↓ *Perturbative matching*

Standard Model Effective Field Theory

↓ *Perturbative matching*

Fermi Theory + QCD + QED

↓ *Non-perturbative matching: Lattice QCD, dispersion relations, data, …*

Chiral Perturbation Theory

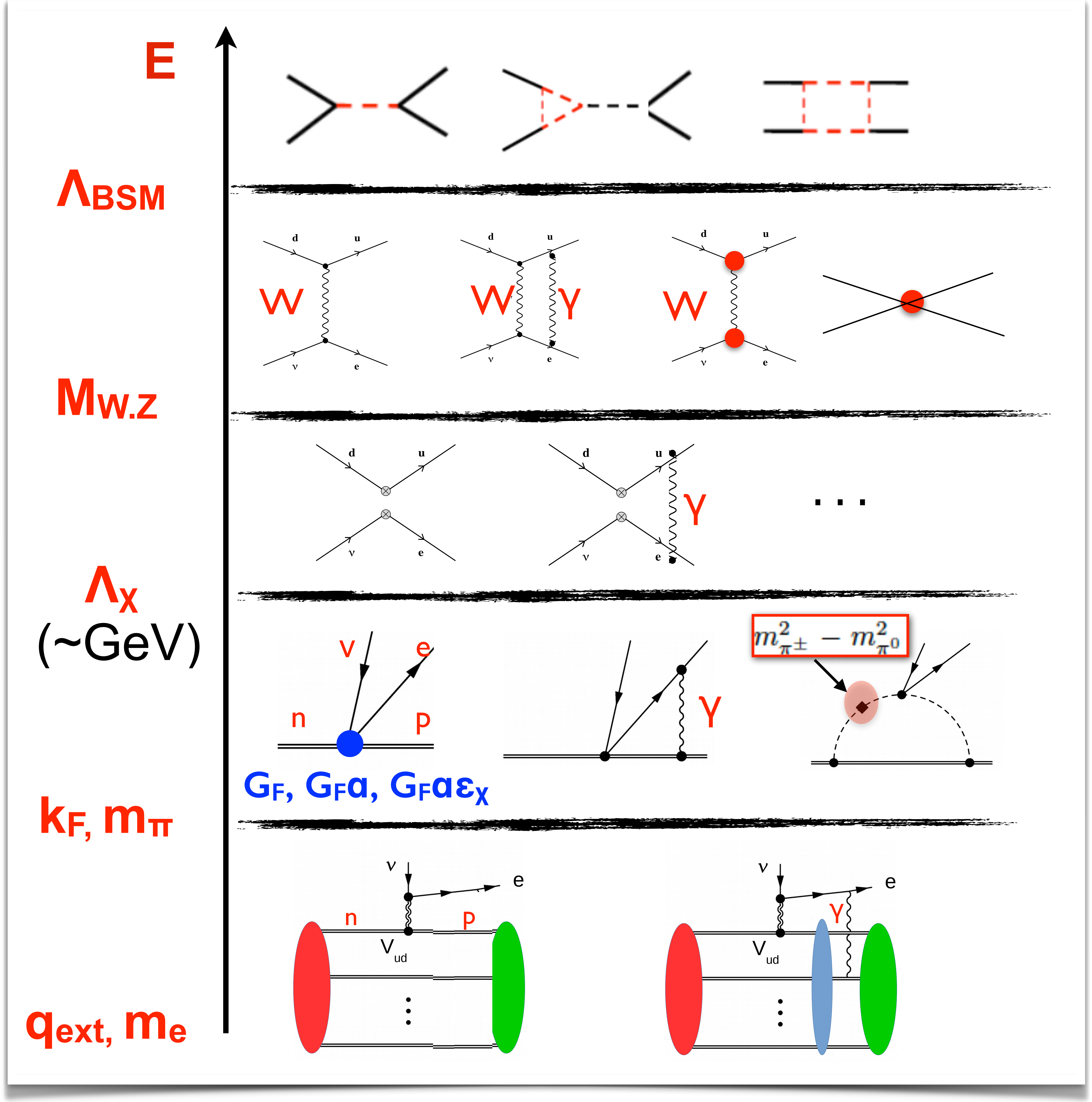
↓ *Integrate out pions*

Chiral & pion-less EFT

The EFT expands amplitudes in ε's and re-sums large logarithms $\sim \alpha^{n+m} (\ln(\varepsilon))^n$

EFTs for β decays: from BSM to nuclei

Widely separated scales: Λ_{BSM}, M_W, Λ_χ, m_π, $m_e \sim q_{ext}$ ⇒ Tackle the problem through a tower of EFTs



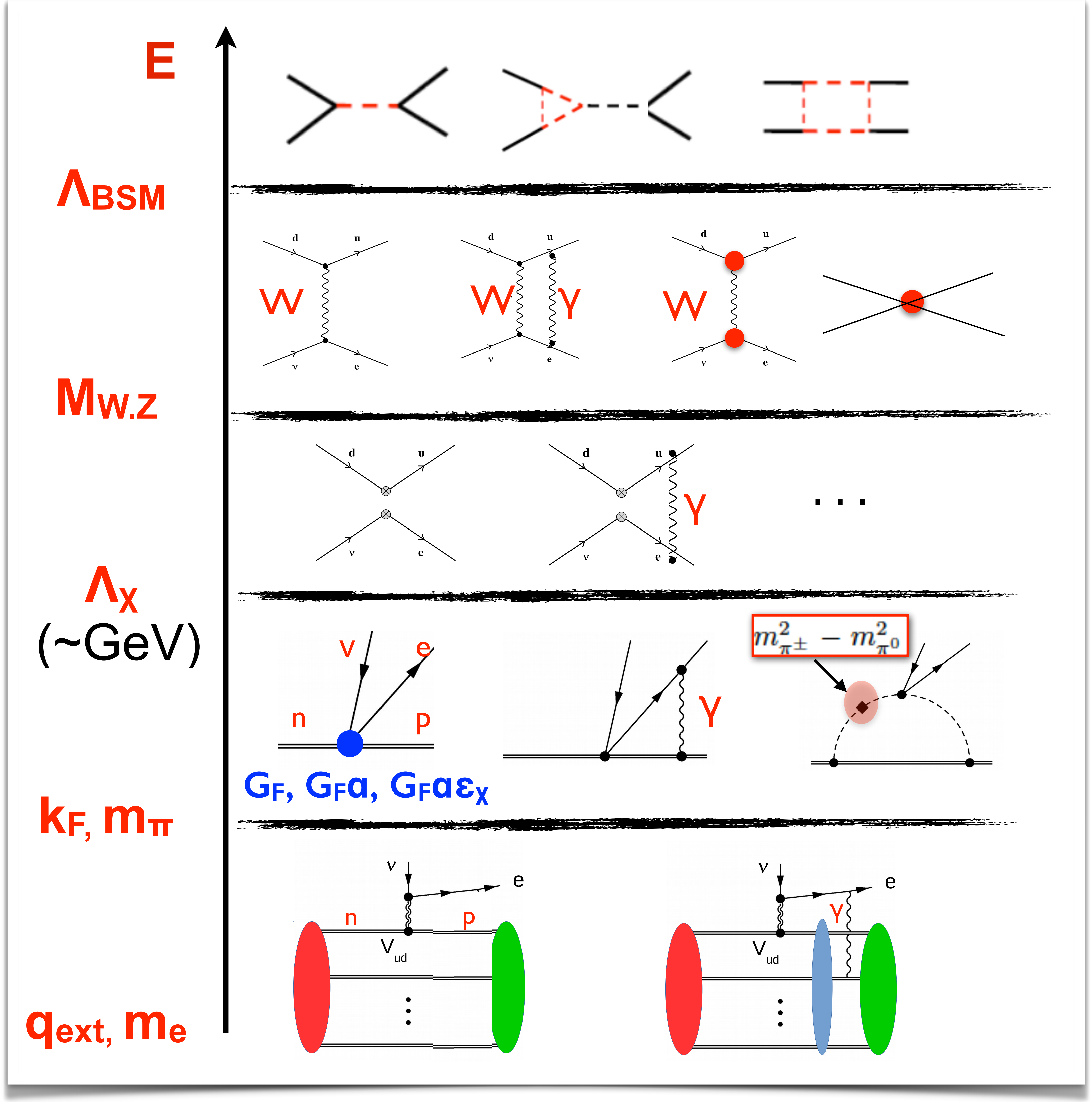
- Within NTNP we developed the EFT framework for one- and multi-nucleon systems (talk by E. Mereghetti)

- Neutron decay
  - EFT analysis including next-to-leading logarithms and seamless interface to Lattice QCD input
  - → Next generation neutron experiments will achieve a competitive extraction of V_{ud} with fully controlled theoretical uncertainties
- Nuclear decays
  - New (simpler) way to compute the nuclear-structure dependent corrections δ_{NS}
  - New NN contact interactions at $O(G_F \alpha \epsilon_\chi)$
  - Collaboration with nuclear structure groups in NTNP will enable rich phenomenology in the future

2306.03138, 2405.xxxxx, ...

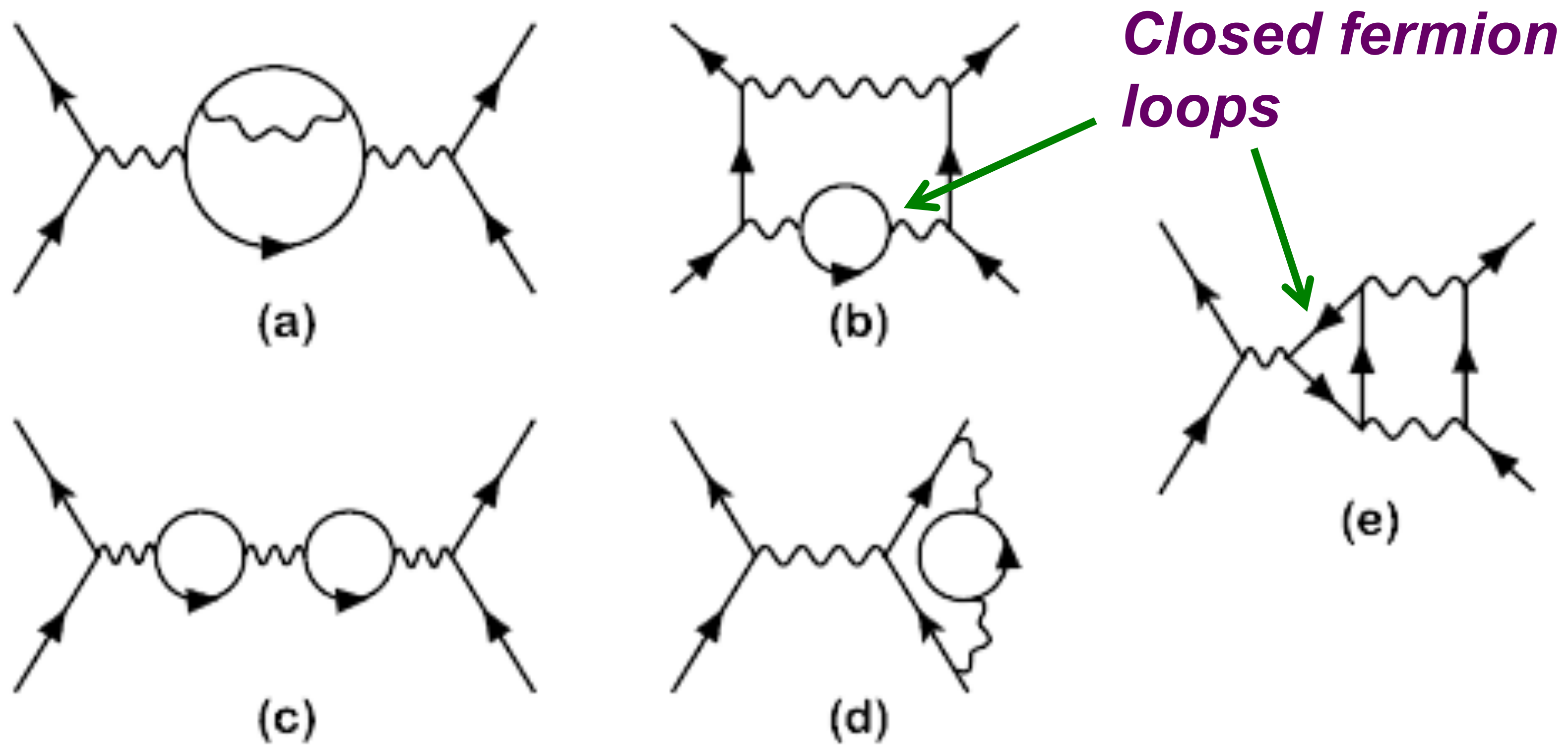
EFTs for β decays: from BSM to nuclei

Widely separated scales: Λ_{BSM}, M_W, Λ_χ, m_π, $m_e \sim q_{ext}$ ⇒ Tackle the problem through a tower of EFTs



- Improving precision at each step:

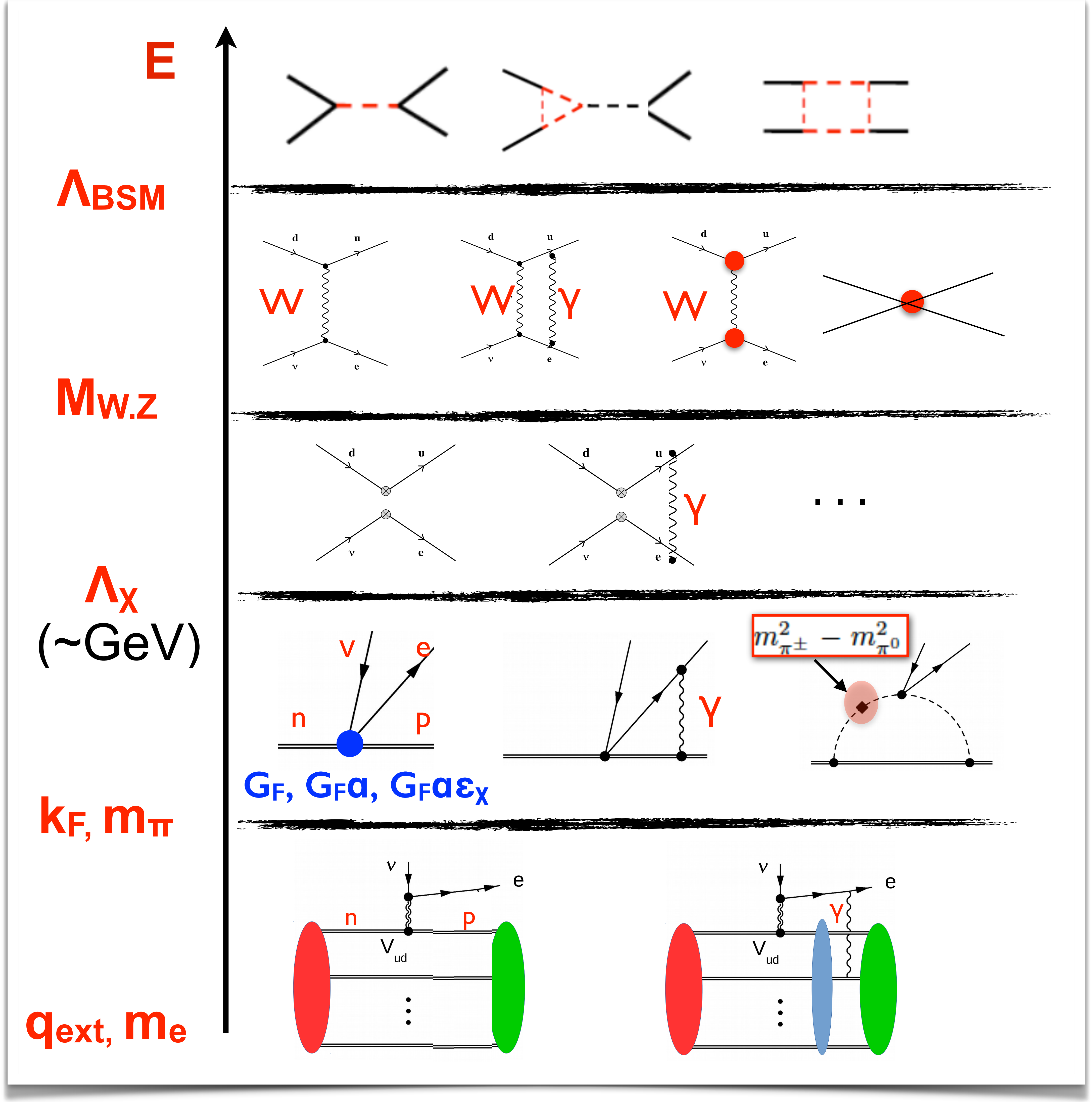
Two-loop perturbative matching calculation to capture n_f-enhanced terms $\sim n_f (\alpha/\pi)^2$



M. Ramsey-Musolf, L. Friedrich, J. Fagnoni, UMass Amherst

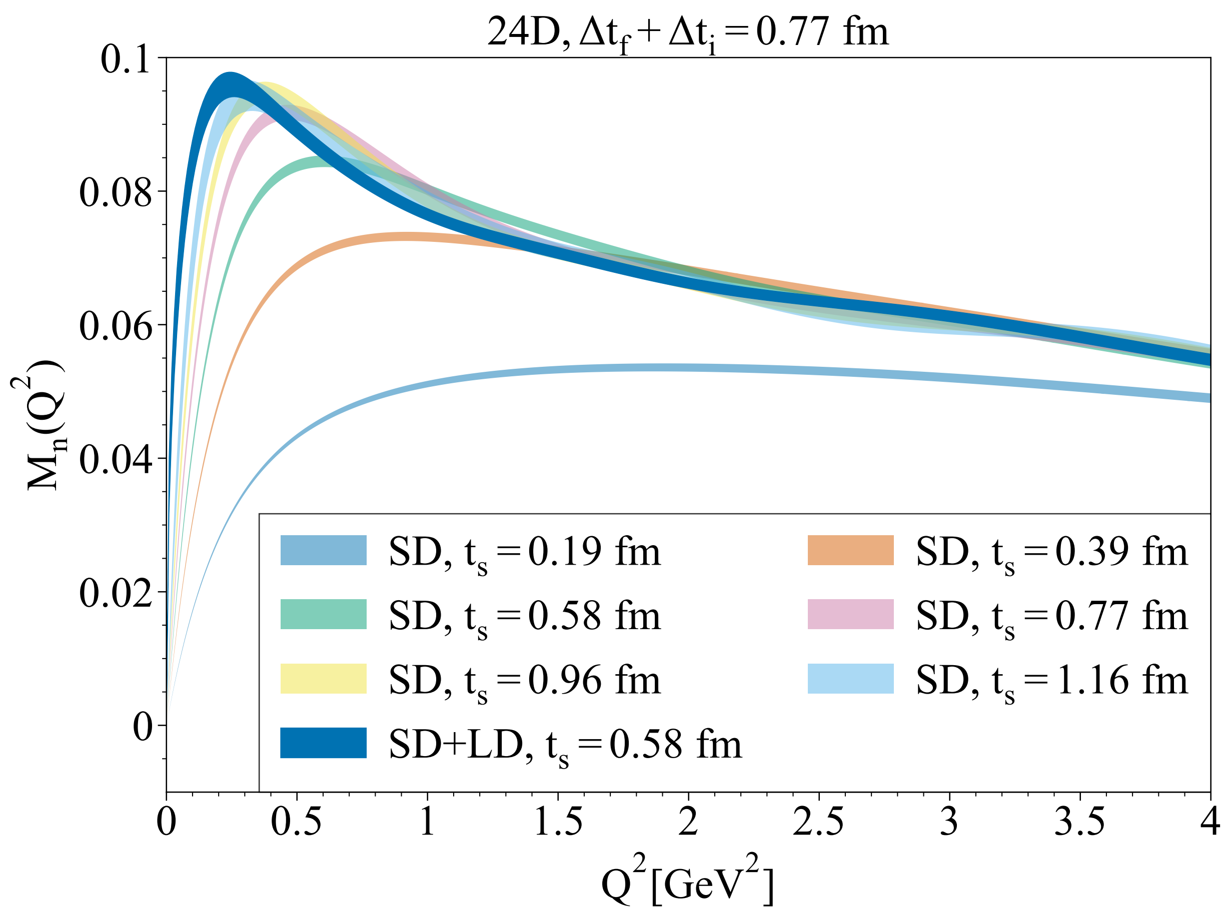
EFTs for β decays: from BSM to nuclei

Widely separated scales: Λ_{BSM}, M_W, Λ_χ, m_π, $m_e \sim q_{ext}$ ⇒ Tackle the problem through a tower of EFTs

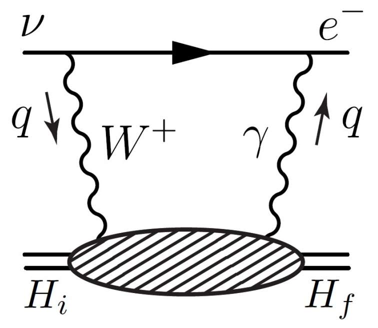


- Improving precision at each step:

- Hybrid EFT + dispersive analysis for neutron decay
- Lattice QCD for vector coupling to $O(G_F\alpha)$:



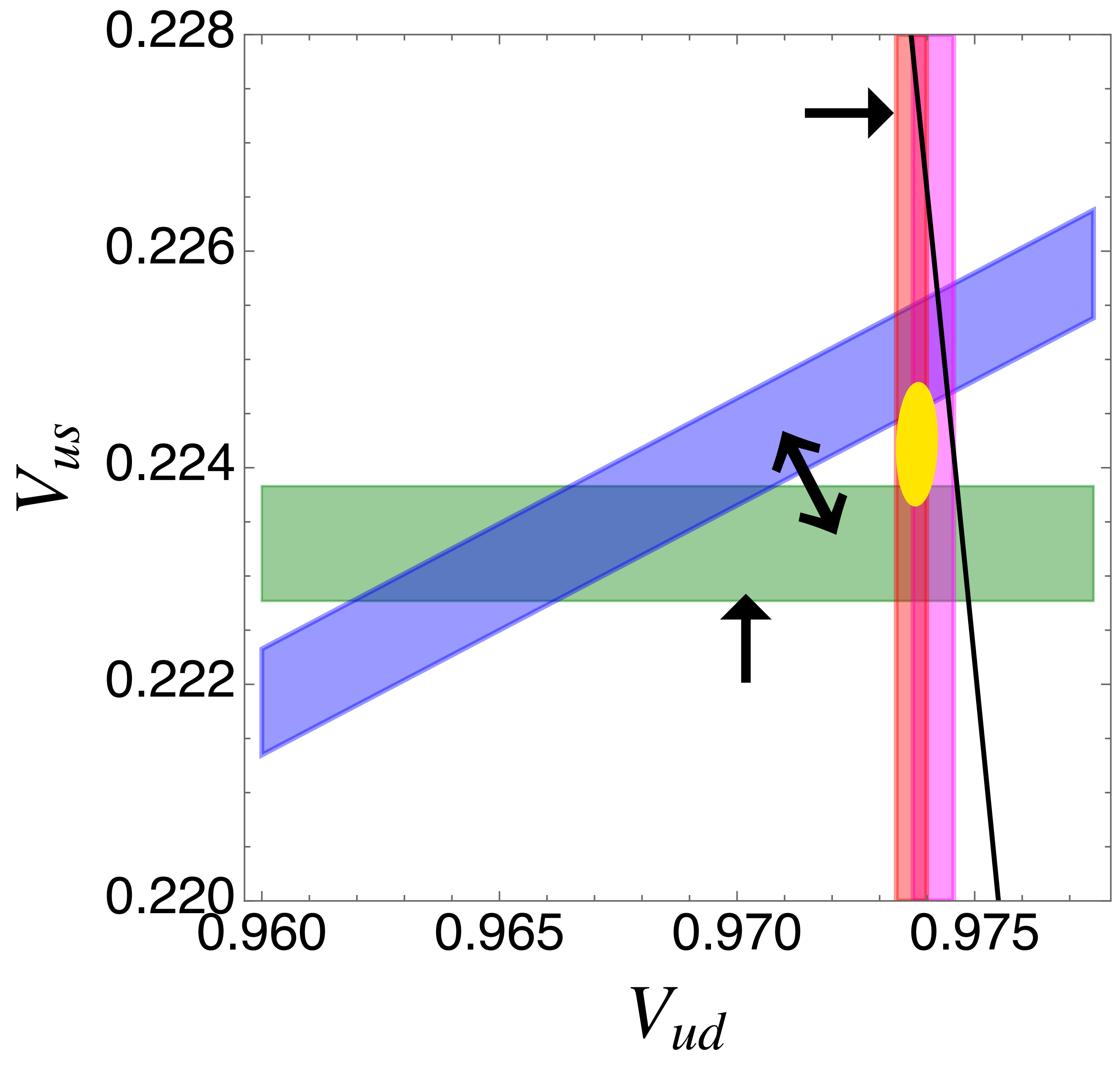
Lattice QCD calculation within uncertainty of dispersive result 2308.16755

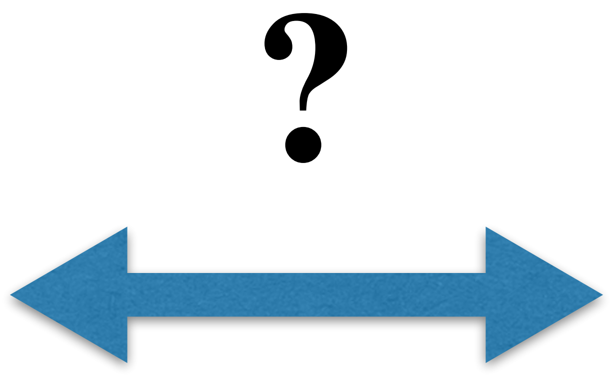


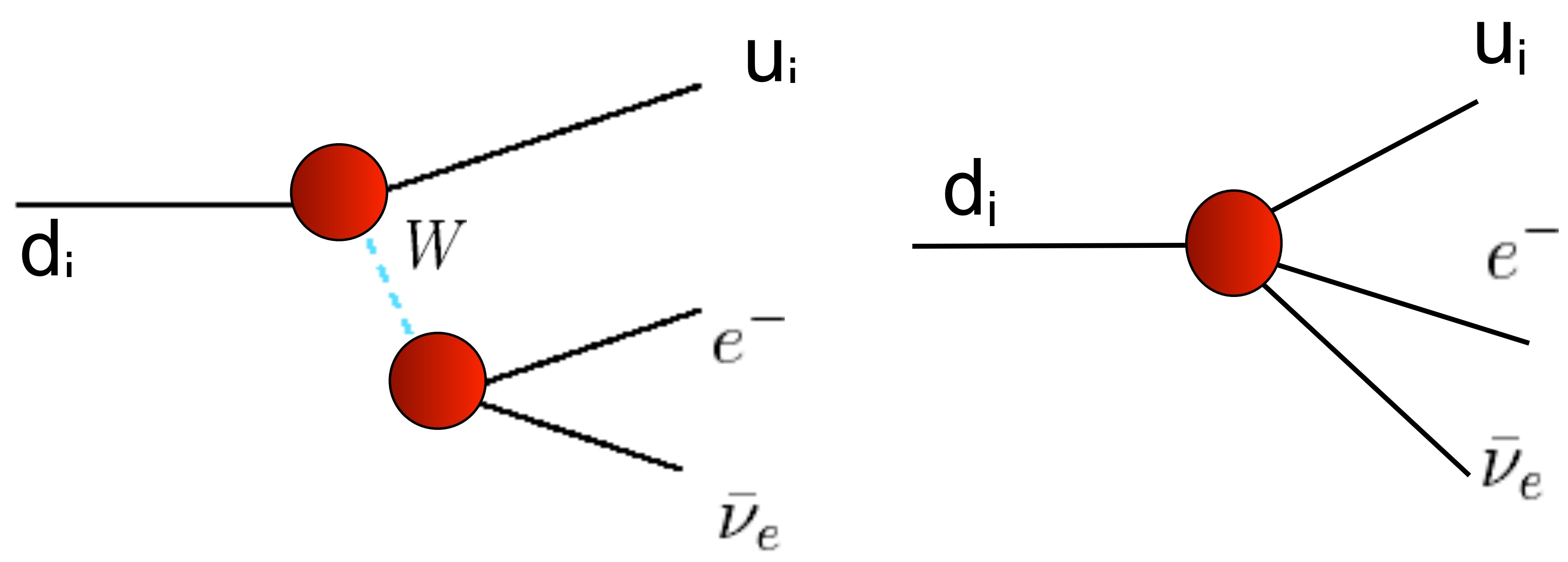
C.Y. Seng with collaborators outside NTNP

2308.16755
2309.16893
2403.08976

β decays and BSM physics

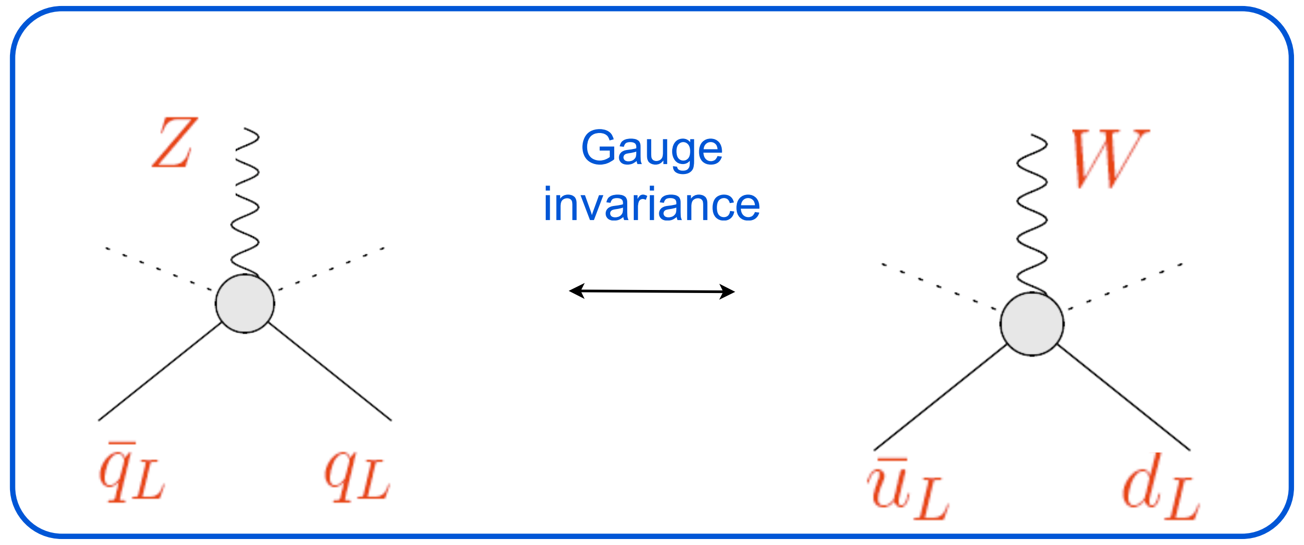




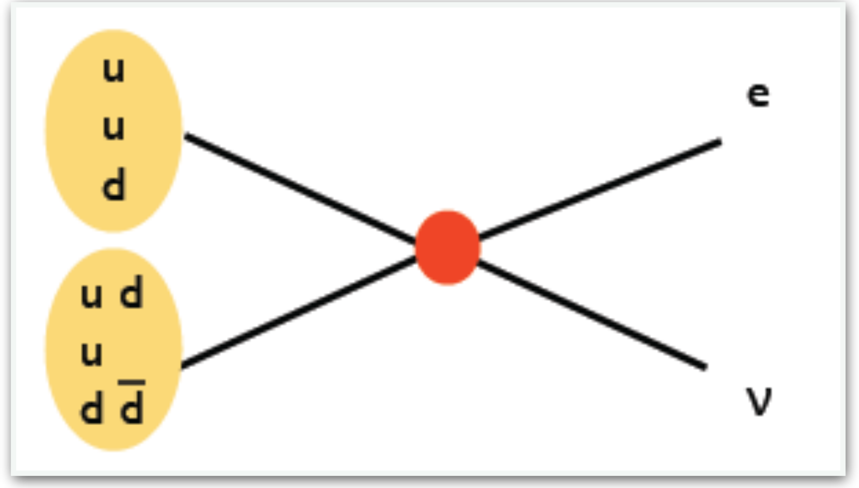


- New physics contributing to β decays also affects
  - Precision electroweak observables
  - Drell-Yan processes at colliders

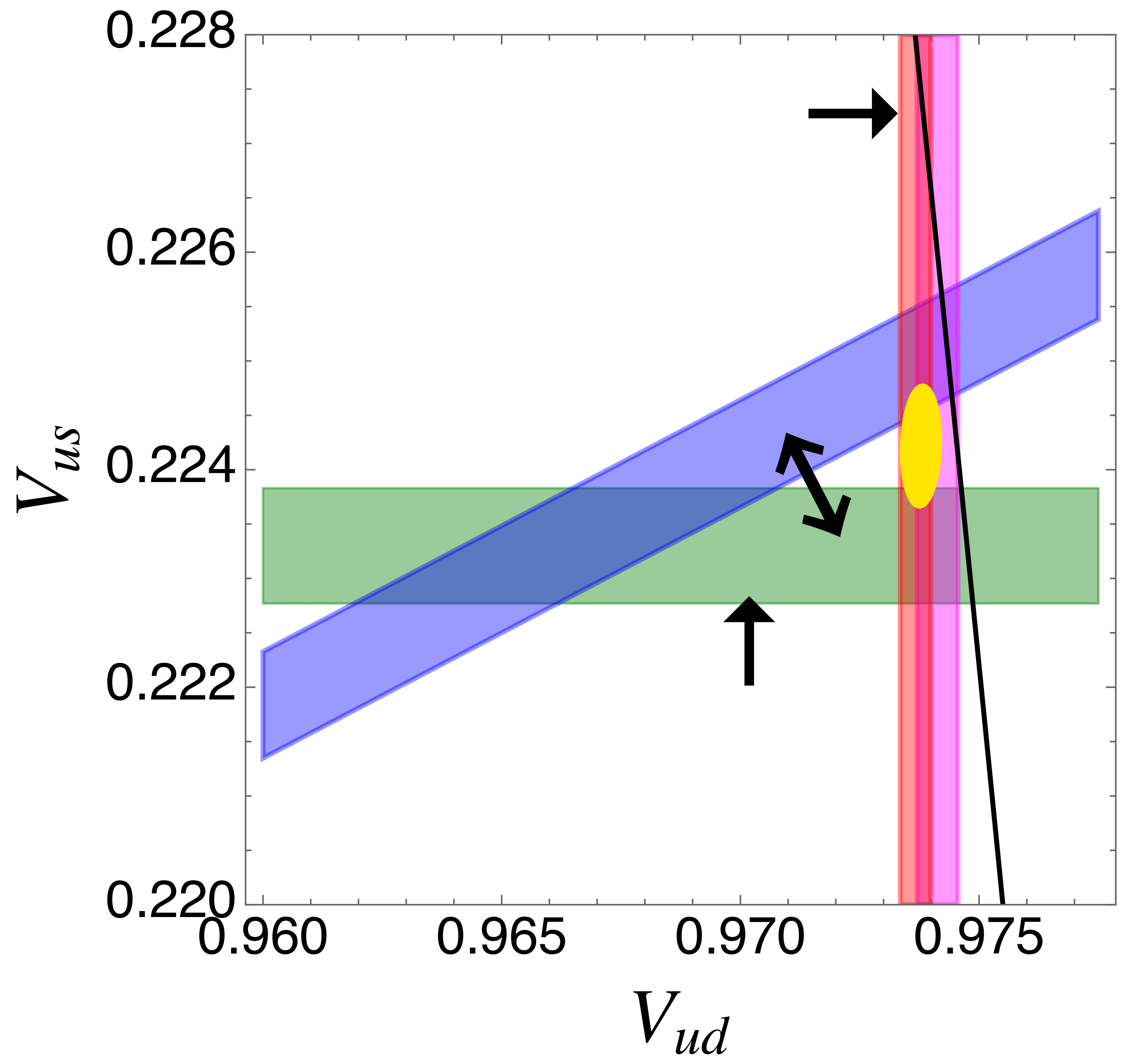
Z-pole observables

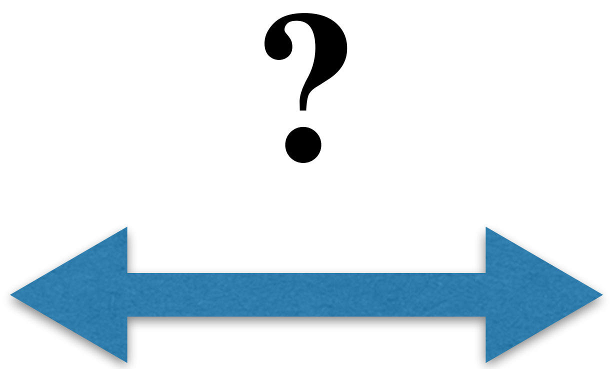


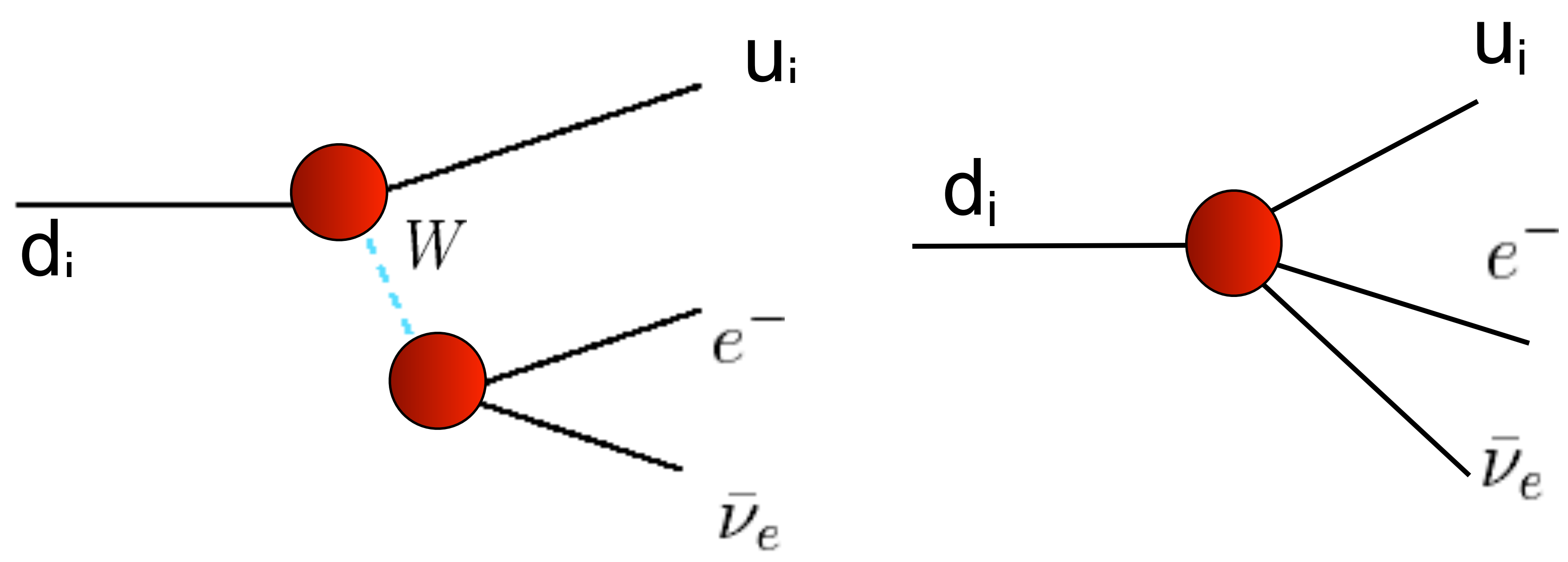
LHC: pp → eν + X

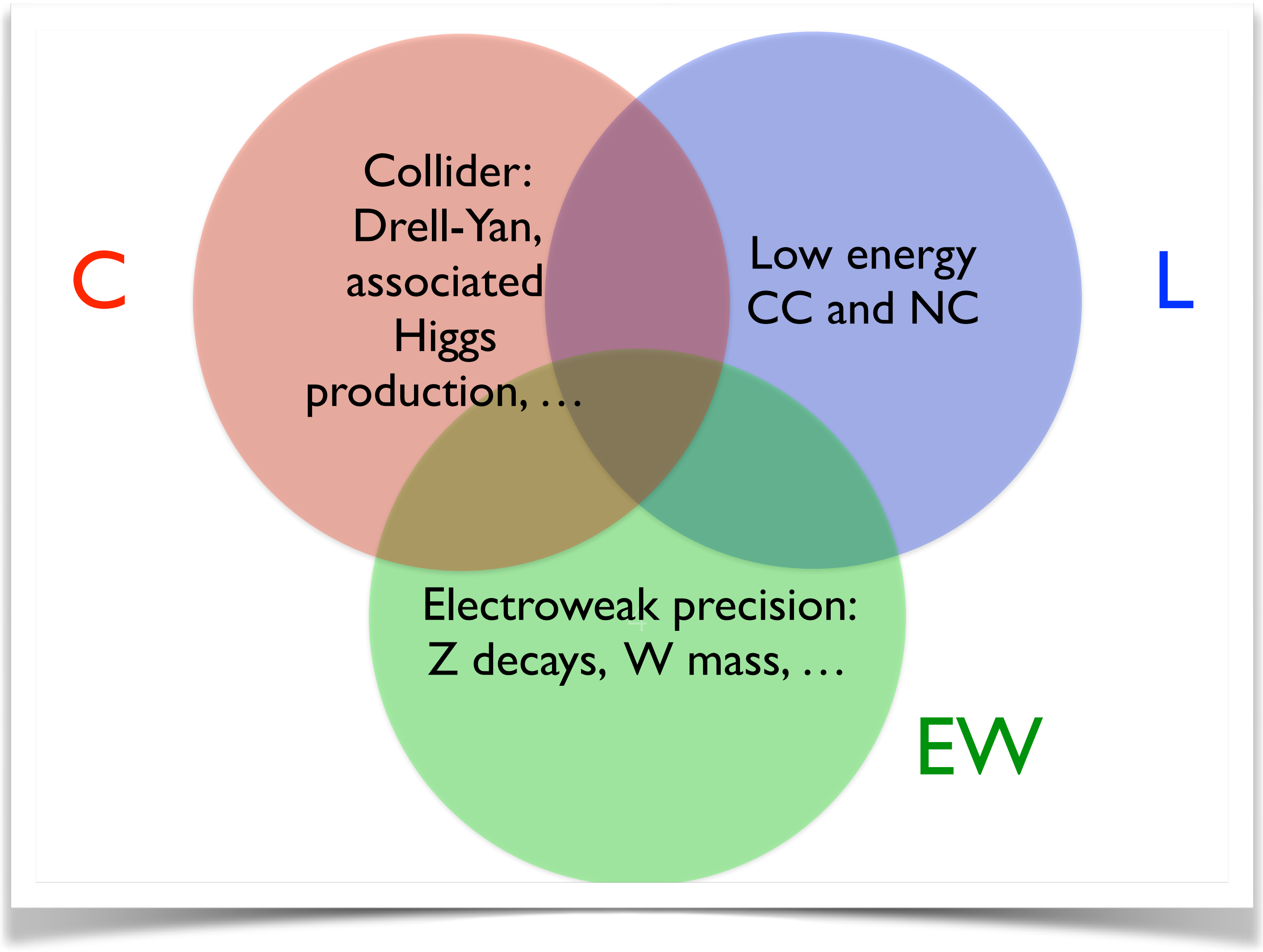


β decays and BSM physics









VC, W. Dekens, J. De Vries, E. Mereghetti, T. Tong, JHEP 03 (24) 33, arXiv: 2311.00021

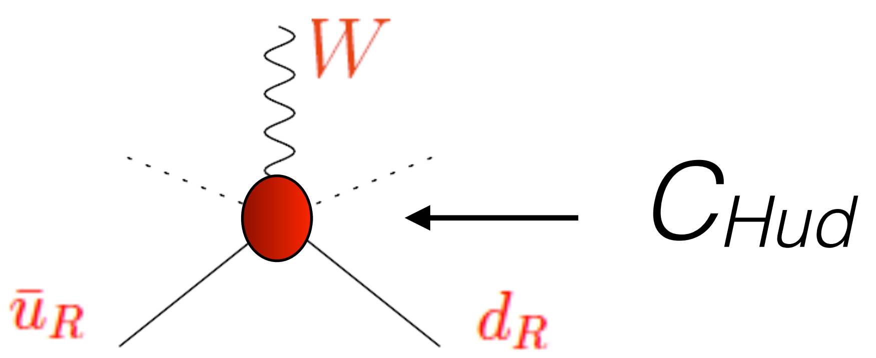
- New physics contributing to β decays also affects
  - Precision electroweak observables
  - Drell-Yan processes at colliders

- Need the 'CLEW' framework to analyze the impact of β decays on new physics!

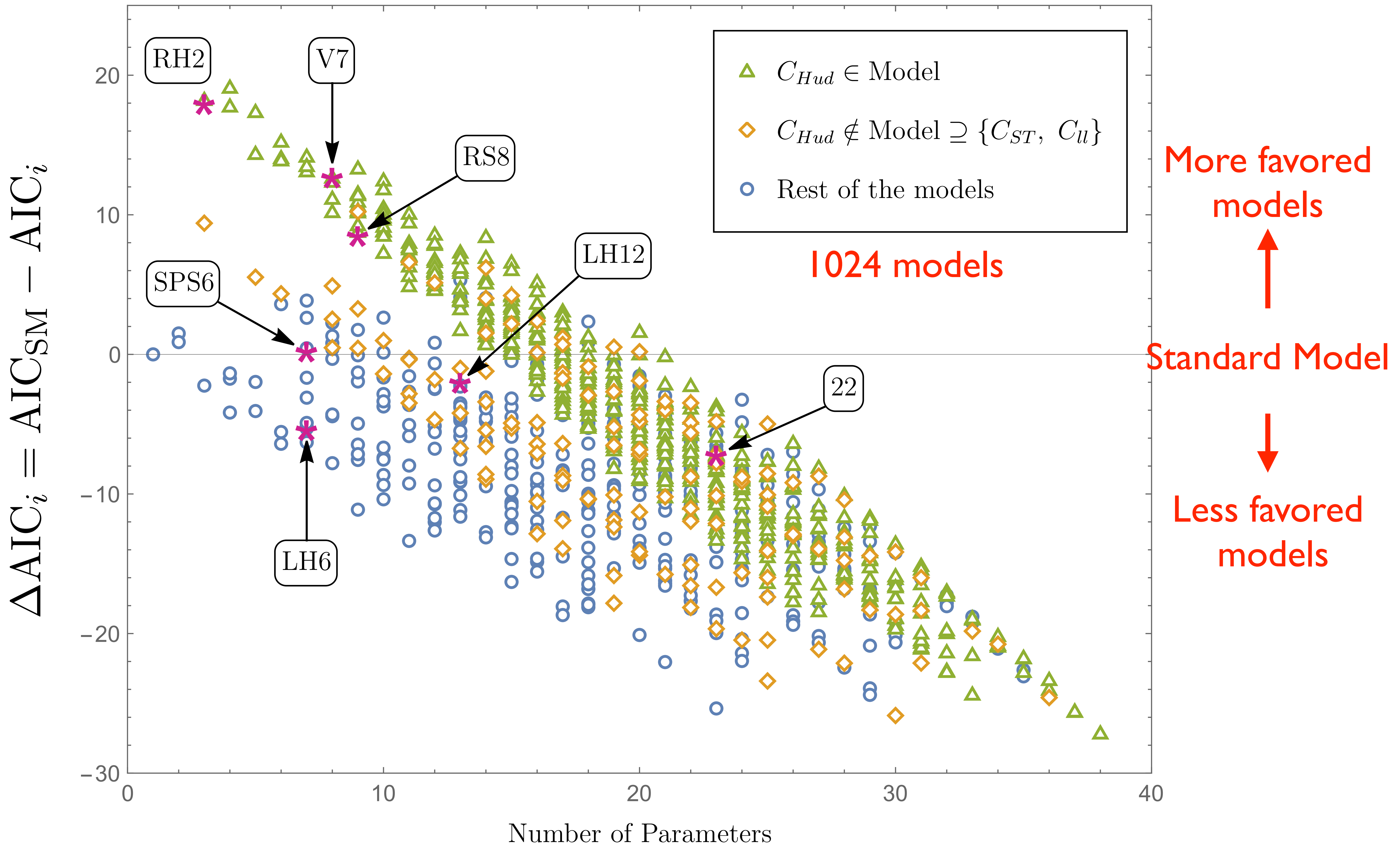
β decays and BSM physics

- Performed 'CLEWed' analysis within SMEFT. Scanned model space by 'turning on' certain classes of effective couplings

- Akaike Information Criterion favors models with Right-Handed Charged Currents of quarks (V+A)



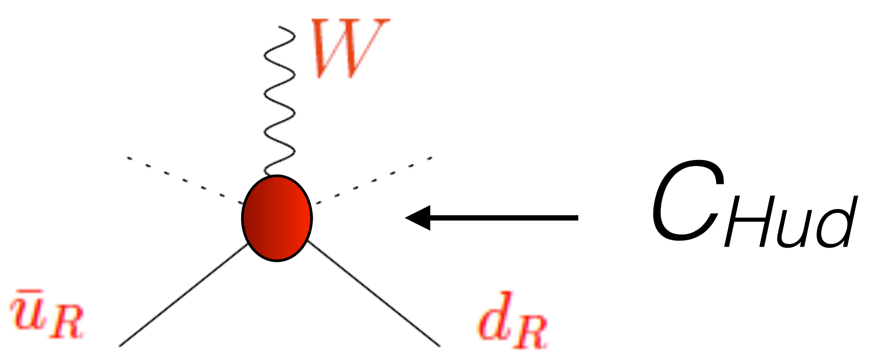
VC, W. Dekens, J. De Vries, E. Mereghetti, T. Tong, JHEP 03 (24) 33, arXiv: 2311.00021



β decays and BSM physics

- Performed 'CLEWed' analysis within SMEFT. Scanned model space by 'turning on' certain classes of effective couplings

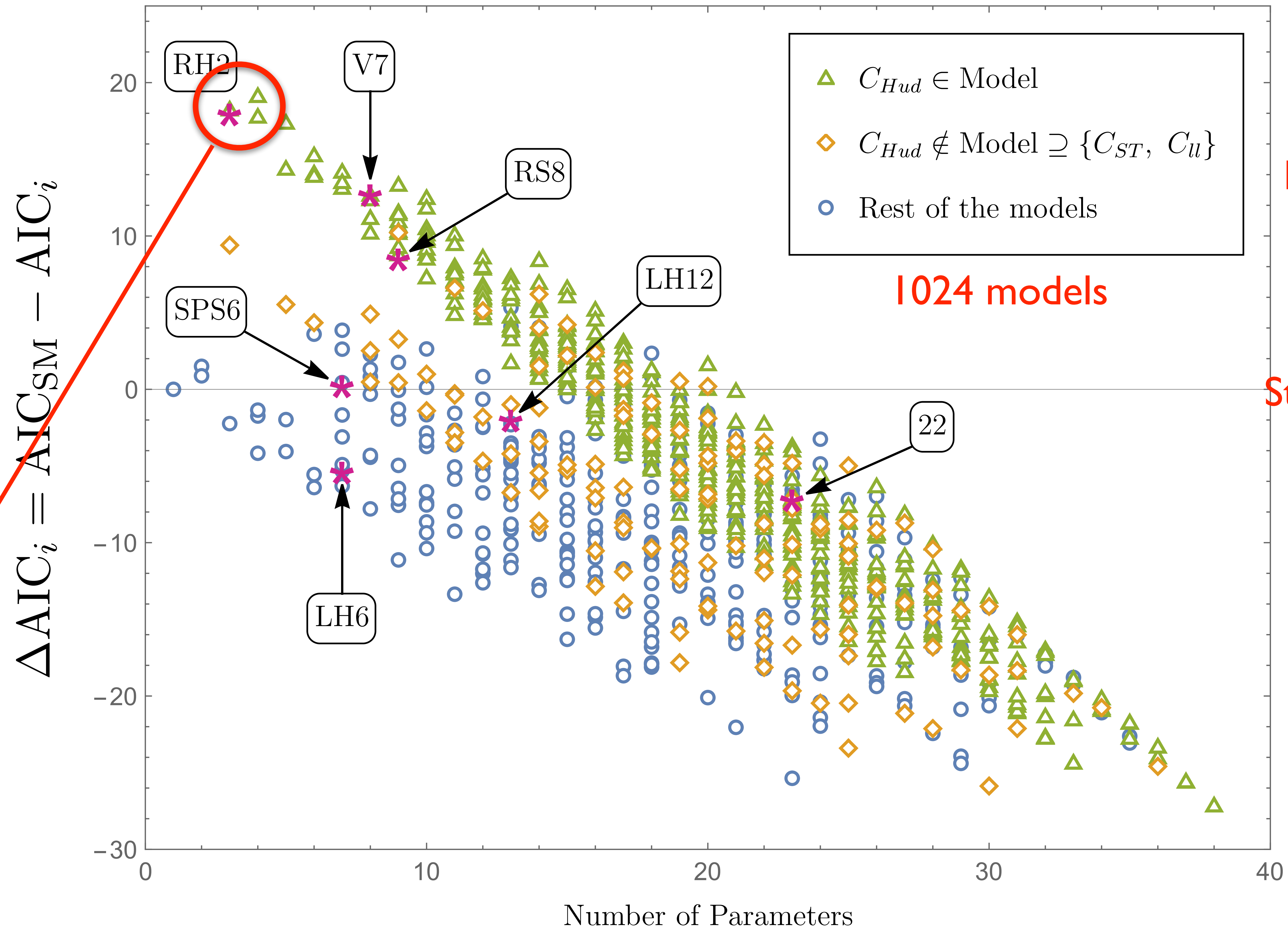
- Akaike Information Criterion favors models with Right-Handed Charged Currents of quarks (V+A)



- Best fit to CLEW data: two RH CC vertex corrections and the S parameter.

CKM anomaly not ruled out by other data!

VC, W. Dekens, J. De Vries, E. Mereghetti, T. Tong,
JHEP 03 (24) 33, arXiv: 2311.00021



More favored models

Standard Model

Less favored models

CP violation and EDMs

Year-1 **BETA-2** Develop EFT formalism for A=2 systems to $O(G_F\alpha)$ [LANL *, UMass, UTK, UW]

Year-2 **BETA-1** Two loop calculation of electroweak corrections to charged-current processes [UMass *]

BETA-3 Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]

XSEC-1 Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]

Year-3 **BETA-1** Calculation of $n \to pe\bar{\nu}$ to $O(G_F\alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]

BETA-2 EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]

BETA-3 Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]

EDM-3 VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]

XSEC-2 First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]

Year-4 **BETA-3** Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]

XSEC-4 Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]

Year-5 **BETA-3** Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]

BETA-4 Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]

EDM-3 IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]

XSEC-4 Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]

XSEC-5 Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

→

- Infrastructure is in place, exploratory work in VS-IMSRG* and IM-GCM** already underway
- On track to reach this milestone

*VS-IMSRG = Valence-Space In Medium Similarity Renormalization Group

** IM-GCM = In Medium Generator Coordinate Method

Lepton-nucleus scattering

Year-1

BETA-2 Develop EFT formalism for A=2 systems to $O(G_F\alpha)$ [LANL *, UMass, UTK, UW]

Year-2

BETA-1 Two loop calculation of electroweak corrections to charged-current processes [UMass *]

BETA-3 Compute δ_C in superallowed β decays in VS-IMSRG and IM-GCM. [MSU *, ND]

XSEC-1 Compute with controlled uncertainties in LQCD the nucleon elastic form factors [UCB *, CMU]

Year-3

BETA-1 Calculation of $n \to pe\bar{\nu}$ to $O(G_F\alpha)$ in Lattice QCD+QED [CMU, LANL, UCB *, UW]

BETA-2 EFT analysis of radiative corrections to few-body systems [LANL, UTK *, UW]

BETA-3 Calculation of δ_C, δ_{NS} in low-A systems with various methods – benchmarking [ANL, LANL, ND, UCB, UNC, WUSTL *]

EDM-3 VS-IMSRG results with uncertainties for Schiff moments of ^{199}Hg and ^{129}Xe. [MSU, ND, UNC *]

XSEC-2 First Lattice QCD results for the $N \to \Delta$ transition induced by electro-weak currents [CMU *, UCB]

Year-4

BETA-3 Ab initio calculations of δ_C for relevant medium-mass nuclei with multiple methods [ANL, LANL, ND, ODU, ORNL, UTK *, WUSTL *]

XSEC-4 Calculations of inclusive electroweak cross sections in $A = 4, 12, 16$ with QMC methods supplemented by factorization schemes (Short-Time-Approximation and Spectral Function formalism). [ANL *, LANL, ODU, WUSTL]

Year-5

BETA-3 Ab initio calculations of δ_{NS} in low- and medium-mass nuclei [ANL, LANL, ODU, ORNL, WUSTL *, UTK *]

BETA-4 Phenomenology of beta decays and CKM unitarity with quantified uncertainties [LANL, UMass, UW *]

EDM-3 IM-GCM Schiff moment result for ^{225}Ra, with uncertainty analysis [MSU, ND, UNC *]

XSEC-4 Electroweak cross sections in ^{40}Ca. [ANL, LANL *, ODU, WUSTL]

XSEC-5 Determination of theoretical uncertainties in calculations of inclusive and exclusive cross sections induced by lepton scattering. [ANL *, LANL, ODU, WUSTL]

See talk by Andre' Walker-Loud for progress on the lattice QCD front

See talk by Saori Pastore for progress on the nuclear structure front

Summary and outlook

The NTNP collaboration addresses multi-scale problems to maximize the discovery potential of experiments at the precision / intensity frontier

β decays as probes of new physics

- Controlled uncertainties with EFT + ab-initio nuclear structure
- CKM unitarity test: are we uncovering right-handed currents?

EDMs as probes of new sources CP violation

- First ab-initio calculations of nuclear Schiff moments
- Impact on EDM searches with diamagnetic atoms and radioactive molecules

Lepton-nucleus scattering

- Lattice QCD + many-body methods → precise microscopic description of cross sections
- Key input for the interpretation of neutrino oscillation experiments

The NTNP collaboration fosters the development of a much-needed workforce to attack these multi-scale problems (2023 NSAC LRP)

- One bridge position filled and one in the works
- We provide an environment for exchange and growth, across sub-discipline boundaries, for both junior and senior researchers

Thank you!

T. D. Lee in a drawing by
Bruno Touschek

Bruno Touschek
(1921-1978)

Backup

Publications

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

Electric Dipole Moments in 5+3 Weak Effective Theory
Jacky Kumar, Emanuele Mereghetti
[arXiv:2404.00516]
Abstract

Hybrid analysis of radiative corrections to neutron decay with current algebra and effective field theory
Chien-Yeah Seng
[arXiv:2403.08976]
Abstract

Testing effective field theory with the most general neutron decay correlations
Chien-Yeah Seng
Phys. Rev. D 109, 073007 (2024) [arXiv:2403.05714]
Abstract

Bayesian analysis of muon capture on deuteron in chiral effective field theory
A. Gnech, L.E. Marcucci, M. Viviani
Physical Review C 109(3), 035502 [arXiv:2305.07568]
Abstract

One-loop analysis of beta decays in SMEFT
Maria Dawid, Vincenzo Cirigliano, Wouter Dekens
Submitted to JHEP [arXiv: 2402.06723]
Abstract

Recent progress in the electroweak structure of light nuclei using quantum Monte Carlo methods
Garrett B. King, Saori Pastore
[arXiv:2402.06602]
Abstract

Pseudo-neutrino versus recoil formalism for 4-body phase space and applications to nuclear decay
Chien-Yeah Seng
Phys.Rev.C109,035501(2024) [arXiv:2312.08630]
Abstract

Non-relativistic nuclear reduction for tensor couplings in dark matter direct detection and muon-to-electron conversion
Ayala Glick-Magid
[arXiv:2312.08339]
Abstract

Anomalies in global SMEFT analyses: a case study of first-row CKM unitarity
Vincenzo Cirigliano, Wouter Dekens, Jordy de Vries, Emanuele Mereghetti, Tom Tong
JHEP 03 (2024) 033 [arXiv:2311.00021]
Abstract

Superallowed nuclear beta decays and precision tests of the Standard Model
Mikhail Gorchtein, Chien-Yeah Seng
Ann.Rev.Nucl.Part.Sci. 74 (2024) 23-47 [arXiv:2311.00044]
Abstract

Data-driven reevaluation of ft values in superallowed β decays
Chien-Yeah Seng, Mikhail Gorchtein
Phys. Rev. C 109, 045501 (2024) (Editors' Suggestion) [arXiv:2309.16893]
Abstract

Lattice QCD Calculation of Electroweak Box Contributions to Superallowed Nuclear and Neutron Beta Decays
Peng-Xiang Ma, Xu Feng, Mikhail Gorchtein, Lu-Chang Jin, Keh-Fei Liu, Chien-Yeah Seng, Bi-Geng Wang, Zhao-Long Zhang
[arXiv:2308.16755]
Abstract

The Standard Model theory of neutron beta decay
Mikhail Gorchtein, Chien-Yeah Seng
Universe 2023, 9(9), 422 [arXiv:2307.01145]
Abstract

Quark mass difference effects in hadronic Fermi matrix elements from first principles
Chien-Yeah Seng, Vincenzo Cirigliano, Xu Feng, Mikhail Gorchtein, Luchang Jin, Gerald A. Miller
Phys.Lett.B 846 (2023) 138259 [arXiv:2306.10199]
Abstract

Effective field theory for radiative corrections to charged-current processes I: Vector coupling
Vincenzo Cirigliano, Wouter Dekens, Emanuele Mereghetti, Oleksandr Tomalak
Phys.Rev.D 108 (2023) 5, 053003 [arXiv:2306.03138]
Abstract