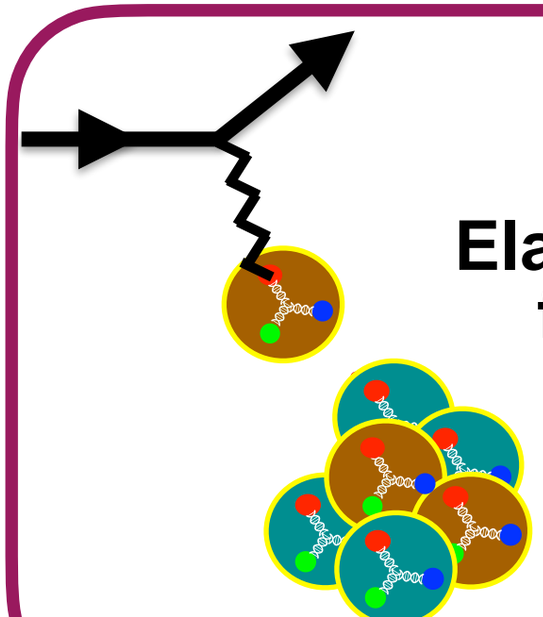
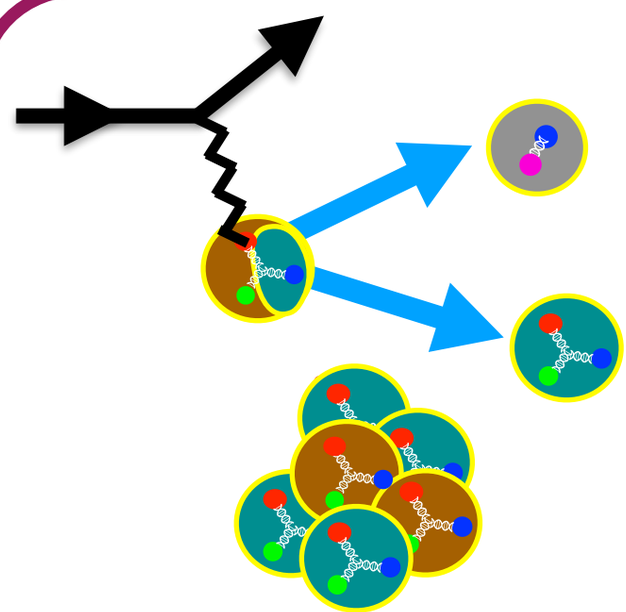
Lattice QCD and νA

LQCD can provide accurate constraints on νA cross sections at a wide range of energies with complementary strengths and weaknesses to experiment

See USQCD νA white paper: Kronfeld et al Eur. Phys. J. A 55 (2019)

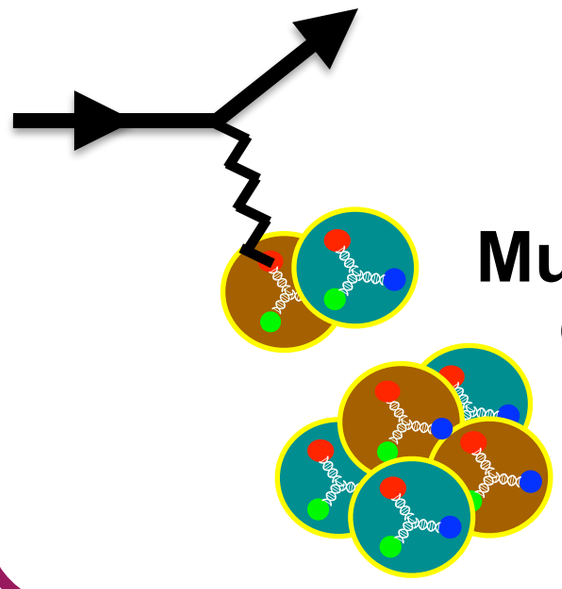


Elastic nucleon form factors

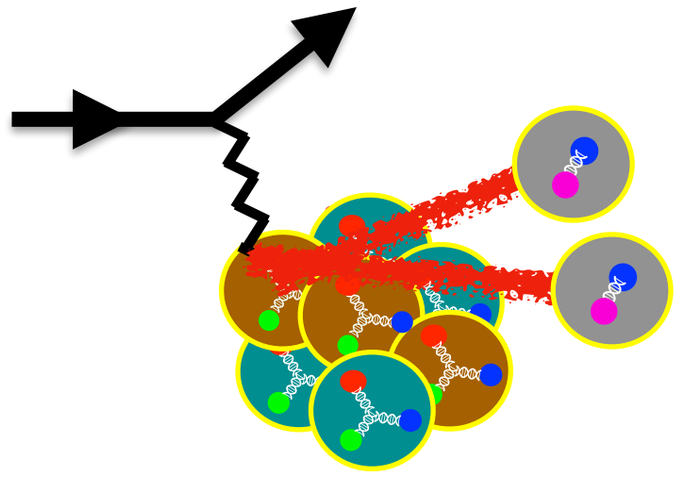


$N,\ \pi,\ \Delta$

transition form factors

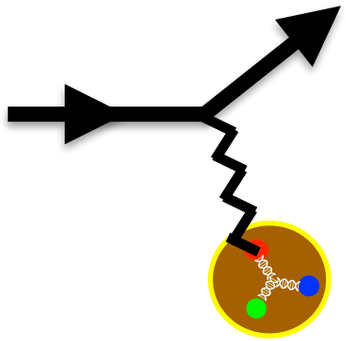


Multi-nucleon currents



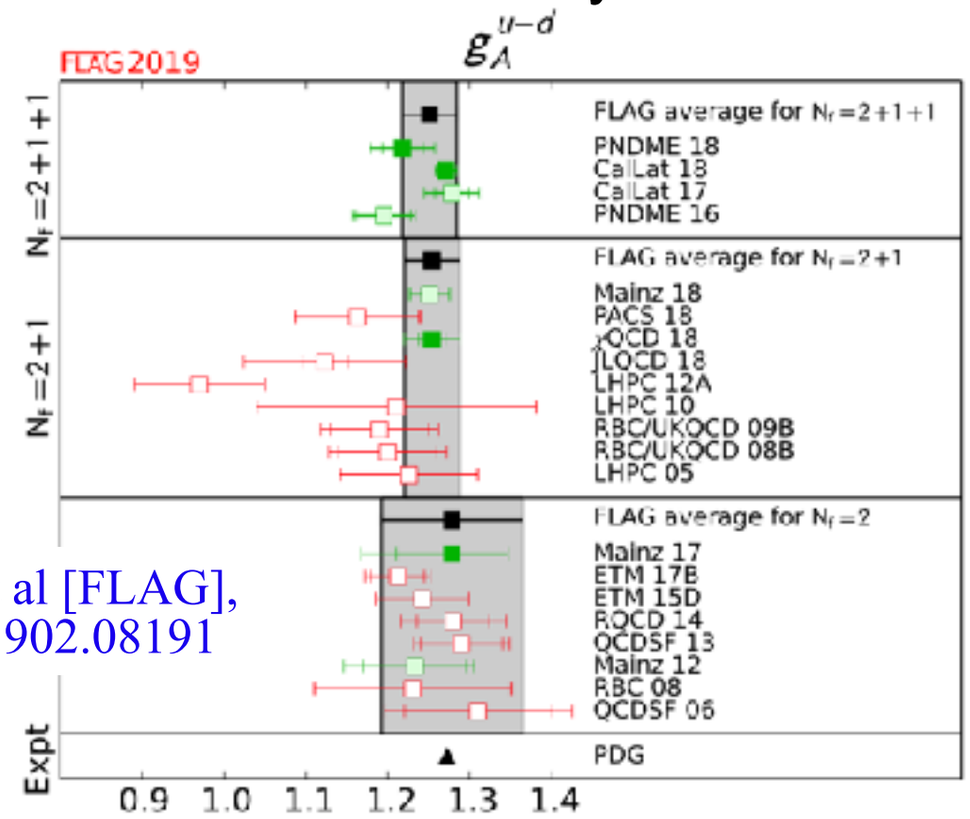
Nucleon / nuclear PDFs

Lattice QCD possibilities



Elastic nucleon form factors

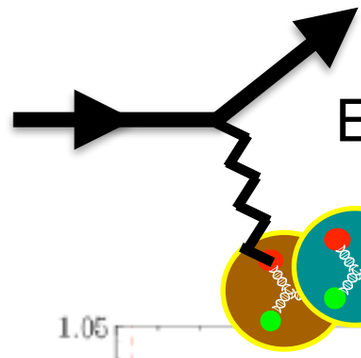
Complete QCD predictions of nucleon axial charge with percent-level uncertainties achieved by LQCD community



Aoki et al [FLAG], arXiv:1902.08191

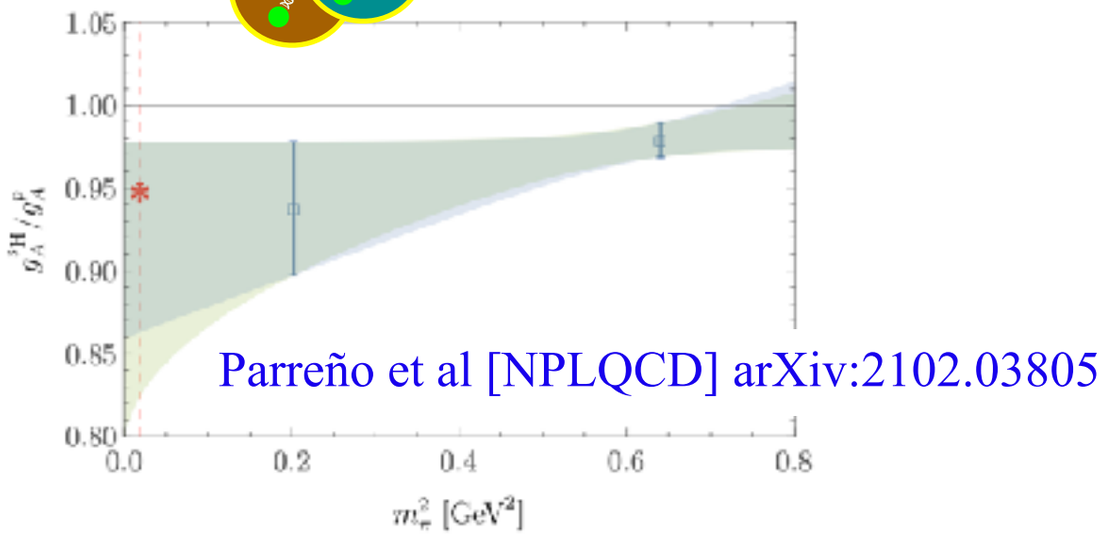
Form factor calculations more challenging due to Npi excited-state contamination, calculations have reached physical quark masses and are studying remaining systematics

See talk by A. Meyer



Multi-nucleon currents

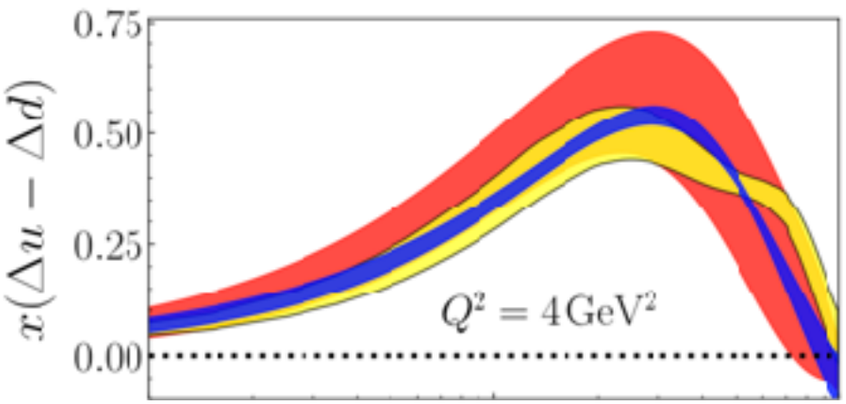
Exploratory calculations underway, systematics still under study



Parreño et al [NPLQCD] arXiv:2102.03805

Nucleon / nuclear PDFs

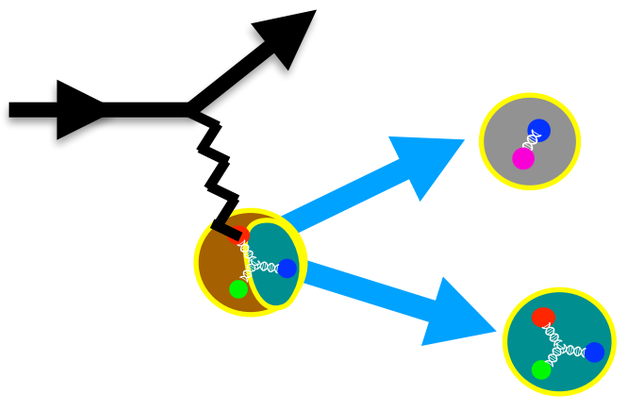
Global fits to lattice + experiment are increasing precision (especially isovector)



Bringewatt et al [JAM], arXiv:2010.00548

Lattice QCD possibilities

Resonant form factors



LQCD calculations of electroweak pion production amplitudes are possible (but hard)

Leinweber, Draper, Woloshyn PRD 48 (1993) Alexandrou et al, PRD 77 (2008)

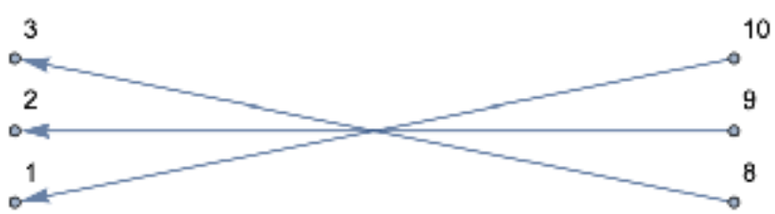
Formalism for relating calculable finite-volume matrix elements to physical amplitudes exists

Baroni, Briceño, Hansen, Ortega-Gama, PRD 100 (2018)

Review: Briceño, Dudek, Young, Rev. Mod. Phys. 90 (2018)

QCD results can be used as inputs to tune nuclear many-body calculations

— requires cooperation between QCD + nuclear theory + event generators



Adding more nucleons to LQCD simulations is exponentially costly, adding more pions is not (but it can still get complicated)

Michael Wagman, NuSTEC 2021

Complementarity with experiment

Easy for LQCD

Matrix elements of local operators with spacelike momenta

Flavor dependence

(neutrons ~ protons)

Spin dependence

(axial ~ vector)

Pions

Hard for LQCD

Real-time scattering amplitudes above multi-particle production thresholds

Large baryon number

LQCD can't predict high-energy nuclear x-secs on it's own

LQCD can provide inputs to nuclear models that complement experiment and validate models of transition between EFT and pQCD

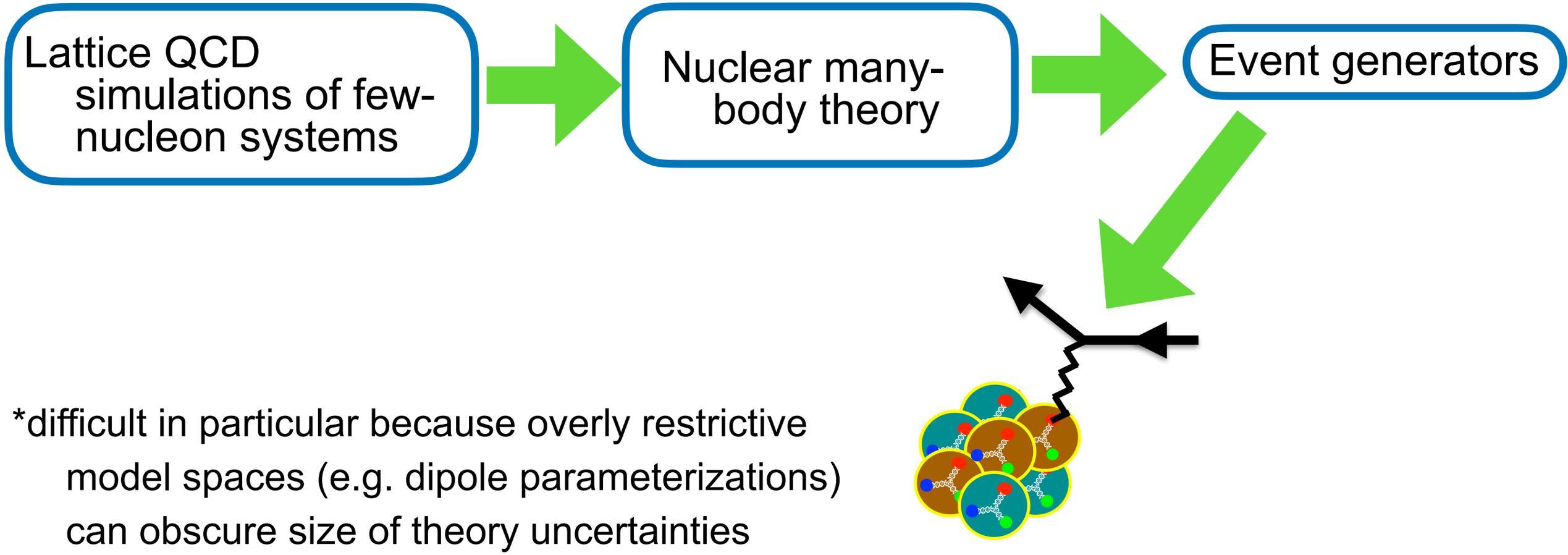
From QCD to nuA

We need a theory pipeline from QCD to nuA x-sec with quantified uncertainties

We need clearly identified theory goals* if we want theory community to get organized
(and apply for petascale / exascale computing resources…)

“nucleon axial and pseudoscalar form factors at 1 GeV with XYZ% uncertainty”

“deuteron axial current two-pion production amplitude at 1 GeV with ABC% uncertainty”



*difficult in particular because overly restrictive model spaces (e.g. dipole parameterizations) can obscure size of theory uncertainties

Michael Wagman, NuSTEC 2021

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Event Generators for Accelerator-Based Neutrino Experiments

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Pedro A. N. Machado (Theoretical Physics Department, Fermilab) [pmachado@fnal.gov]
Noemi Rocco (Theoretical Physics Department, Fermilab) [nrocco@anl.gov]

Snowmass 2021 LoI: Nucleon Form Factors for Neutrino Physics

Taku Izubuchi,[a,b] Christoph Lehner,[a,c] Aaron S. Meyer,[a,*] Shigemi Ohta[b,d,e], Sergey Syritsyn[b,f]

QCD theorists want to help

Lattice-QCD Calculations Supporting Neutrino-Oscillation Experiments

Fermilab Lattice and MILC Collaborations

Theoretical predictions of Neutrino-nucleus Interactions

Contact Information:

Rajan Gupta (Los Alamos National Laboratory) [rajan@lanl.gov]:
Stefano Gandolfi (Los Alamos National Laboratory) [stefano@lanl.gov]:

Connecting QCD to neutrino-nucleus scattering

Joseph Carlson[1], Chia Cheng Chang (張家丞)[2,3,4], William Detmold[5], Joshua Isaacson[6], William Jay[6], Gurtej Kanwar[5], Andreas Kronfeld[6], Huey-Wen Lin[7], Yin Lin (林胤)[5,8], Keh-Fei Liu[9], Alessandro Lovato[10,11], Pedro Machado[6], Aaron S. Meyer[12], Saori Pastore[13], Noemi Rocco[6,10], Phiala Shanahan[5], and Michael Wagman[6]

Lattice Calculation of Neutrino-Nucleon Cross Section

Keh-Fei Liu[1] (liu@g.uky.edu), Terrence Draper[1], Jian Liang[1], G. Wang[1], Yi-Bo Yang[2], and Yong Zhao[3]

Michael Wagman, NuSTEC 2021