SPC Summary on Nucleon and Nuclear Matrix Elements

- Cold Nuclear Physics [50-50 Intensity Frontier and NP]
  - Nucleon Matrix Elements, FF, and neutrino experiments
  - Hadron Interactions and Nuclei
  - Hadron Spectroscopy
  - Parton Distribution Function
- Experimental facilities
  - Present: JLab 12 GeV, RHIC, ATLAS, Fermilab
  - Future: FRIB, EIC, DUNE

Proposals

PI	Title	Status
Bhattacharya	Contribution of Theta, chromo EDM and Weinberg operators to nEDM	Continuation
Detmold	Nuclear Physics from Standard Model	Continuation
Engelhardt	Nucleon quark-gluon structure with Clover-Wilson fermion	Continuation
Gupta	Nucleon matrix elements with 2+1 flavor clover fermion	Continuation
Jin	Neutrinoless double beta decay from di-pion to di-baryon systems	New
Kronfeld	The Nucleon Axial-Vector Form Factor at the Physical Point with the HISQ Ensembles	Continuation
Lepage	Kaon electromagnetic form factor at large Q^2	New
Liang	Lattice calculaiton of nucleon form factors and EDM	Continuation
Meyer	Nucleon Physics with distillation for neutrino oscillation and CKM matrix elements	New
Murphy	Nuclear ME for neutrinoless double beta decay	New
Syritsyn	Calculation of nucleon axial form factors, proton decay amplitudes, and nucleon EDMs induced by QCD theta term and quark chromo-EDM using domain wall fermions	Continuation

Topics in Proposals

- nEDM Θ term - Bhattacharya, Liang, Syritsyn
  Chromo EDM - Bhattacharya, Syritsyn
- g_A and axial form factor – Detmold (nuclei), Gupta, Kronfeld, Liang, Syritsyn
- Scalar and tensor charges – Detmold (Nuclei), Gupta
- Electromagnetic form factors – Engelhardt, Gupta, Lepage, Liang, Syritsyn
- Quark spin, momentum and AM fractions – Liang
- TMD and OAM – Engelhardt
- Neutrinoless double β decay – Jin, Murphy
- Superallowed neutron β decay – Meyer

Samples of Progress on Projects

- Quark orbital angular momentum (direct calculation)

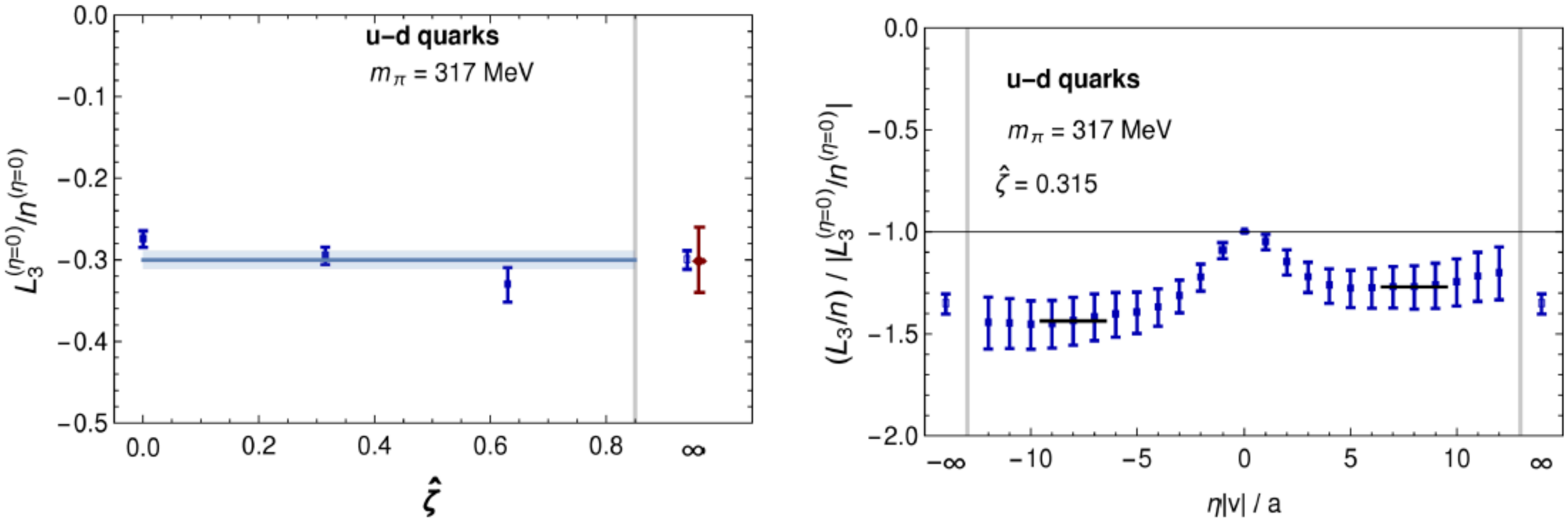


Figure 3: Quark orbital angular momentum as a function of $\hat{\zeta}$ compared to the Ji sum rule result (left) and as a function η normalized by the Ji sum rule (absolute) value (right).

M. Engelhardt et al., PoS SPIN2018, 047 (2019)

Quark Spin Compoments $\overline{\text{MS}}$ (2 GeV)

g_A	Δ(u+d) CI	Δ(u/d) DI	Δs	Δu	Δd	Δu-Δd (g_A^3)	ΔΣ
C. Alexandrou	0.598 (24)(6)	-0.077 (15)(5)	-0.042 (10)(2)	0.830 (26)(4)	-0.386 (16)(6)	1.216 (31)(7)	0.402 (34)(10)
χ QCD	0.580 (16)(30)	-0.070 (12)(15)	-0.035 (6)(7)	0.847 (18)(32)	-0.407 (16)(18)	1.254 (16)(30)	0.405 (25)(37)
PNDME	0.575 (24)(30)	-0.118 (14)	-0.053 (8)	0.777 (25)(30)	-0.438 (18)(30)	1.218 (25)(30)	0.286 (62)(72)
NPPDFpol1.1 (Q^2=10 GeV^2)			-0.10 (8)	0.76 (4)	-0.41 (4)	1.17 (6)	0.25 (10)
DSSV (Q^2=10 GeV^2)			-0.012 +(56)-(62)	0.793 +(28)-(34)	-0.416 +(35)-(25)	1.209 +(45)-(42)	0.366 +(62)-(42)

C. Alexandrou et al., N_F=2, twisted mass fermion, , m_π = 131 MeV, one lattice

χ QCD, N_F=2+1, Overlap on DWF, m_π = 170, 290, 330 MeV, 5 - 6 valence quarks for each of the three lattices

PNDME, N_F=2+1, Clover on HISQ, 4 lattice spacings, m_π = 135, 220, 315 MeV

Expt. g_A^3 = 1.2723(23); CallLat: g_A^3 = 1.271(13) N. Hasan et al., g_A^3 = 1.265(49) [1903.06487]

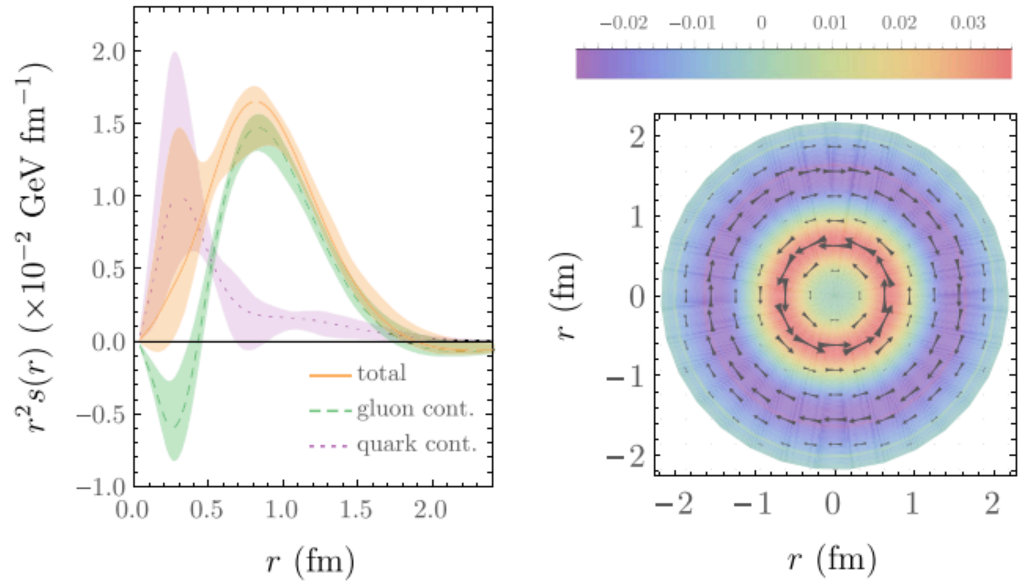
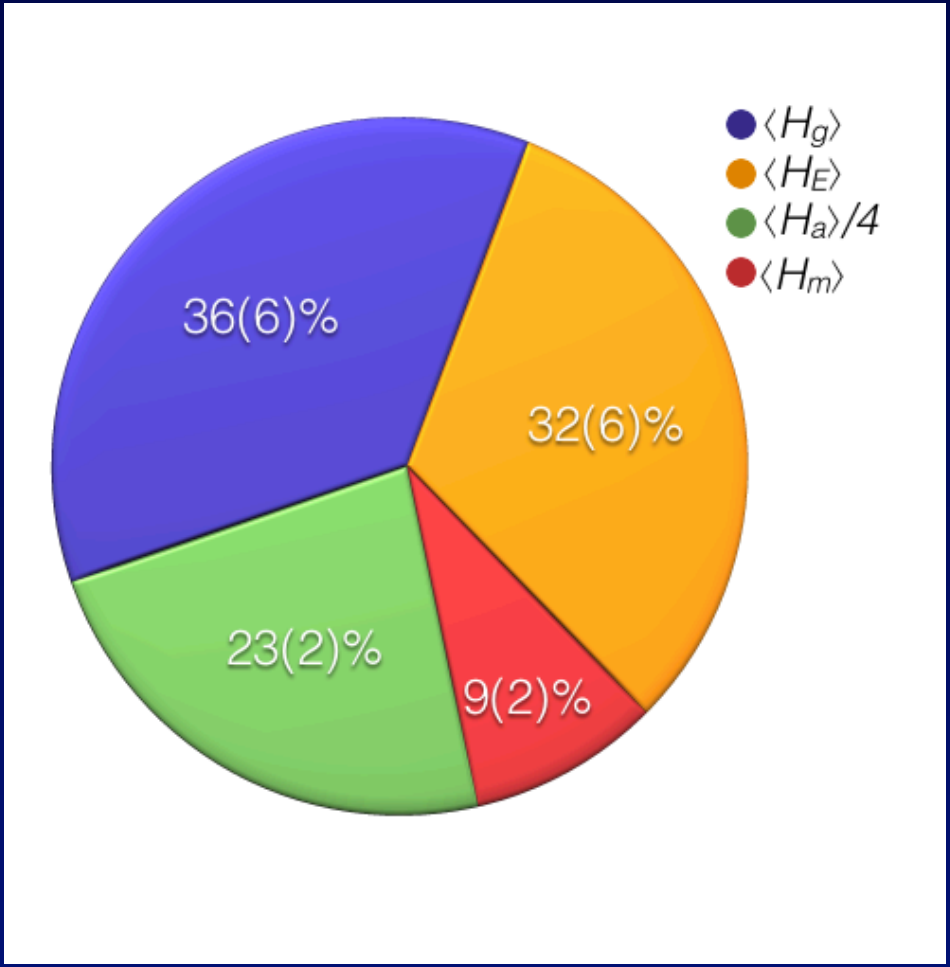


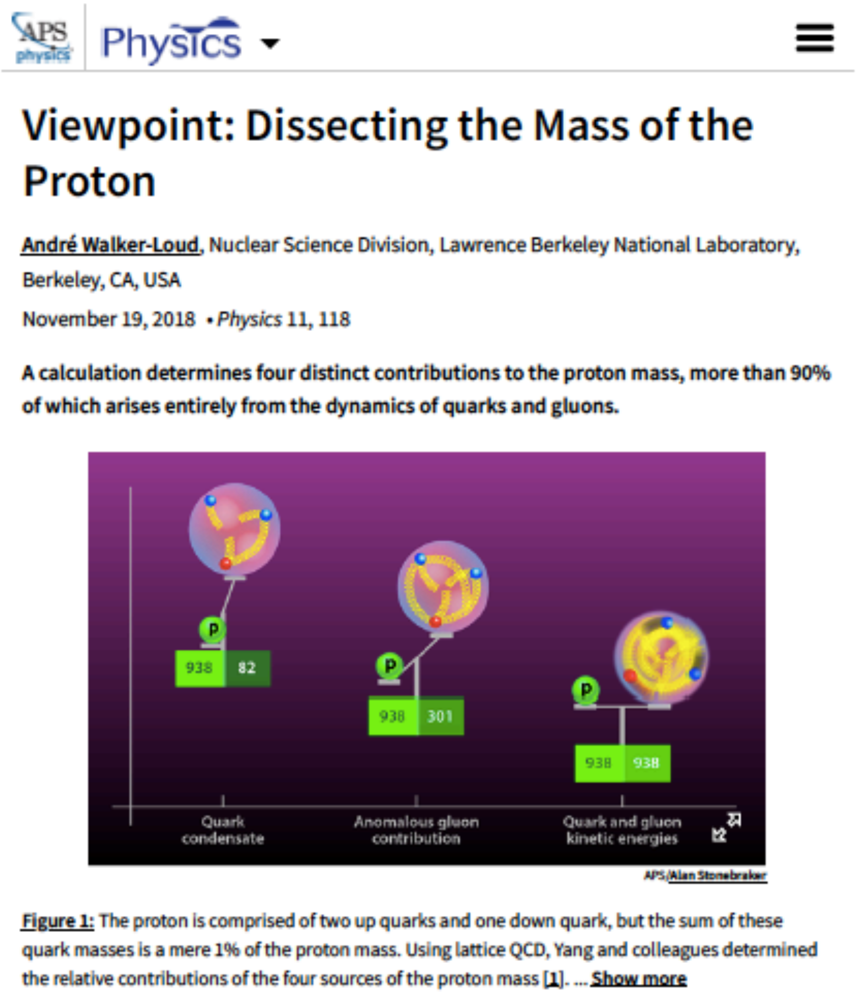
FIG. 3. (Left) Quark (purple) and gluon (green) shear distributions in the proton determined from modified z-expansion fits to the LQCD GFFs in the $\overline{\text{MS}}$ scheme at $\mu = 2$ GeV, as well as the total shear (orange) defined as their sum. (Right) Tangential forces in the proton. The color coding and arrows represent the tangential shear vector field defined in Ref. [4].

P.E. Shanahan and W. Detmold
Pressure distribution and shear forces in the proton
PRL 112, 072003 (2019) – Editor’s suggestion

Proton Mass Decomposition from the QCD Energy Momentum Tensor

Y. Yang et al, PRL, 121, 212001 (2018)





Viewpoint: Dissecting the Mass of the Proton

André Walker-Loud, Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

November 19, 2018 • *Physics* 11, 118

A calculation determines four distinct contributions to the proton mass, more than 90% of which arises entirely from the dynamics of quarks and gluons.

APS/Alan Stonebraker

Figure 1: The proton is comprised of two up quarks and one down quark, but the sum of these quark masses is a mere 1% of the proton mass. Using lattice QCD, Yang and colleagues determined the relative contributions of the four sources of the proton mass [1]. ... Show more

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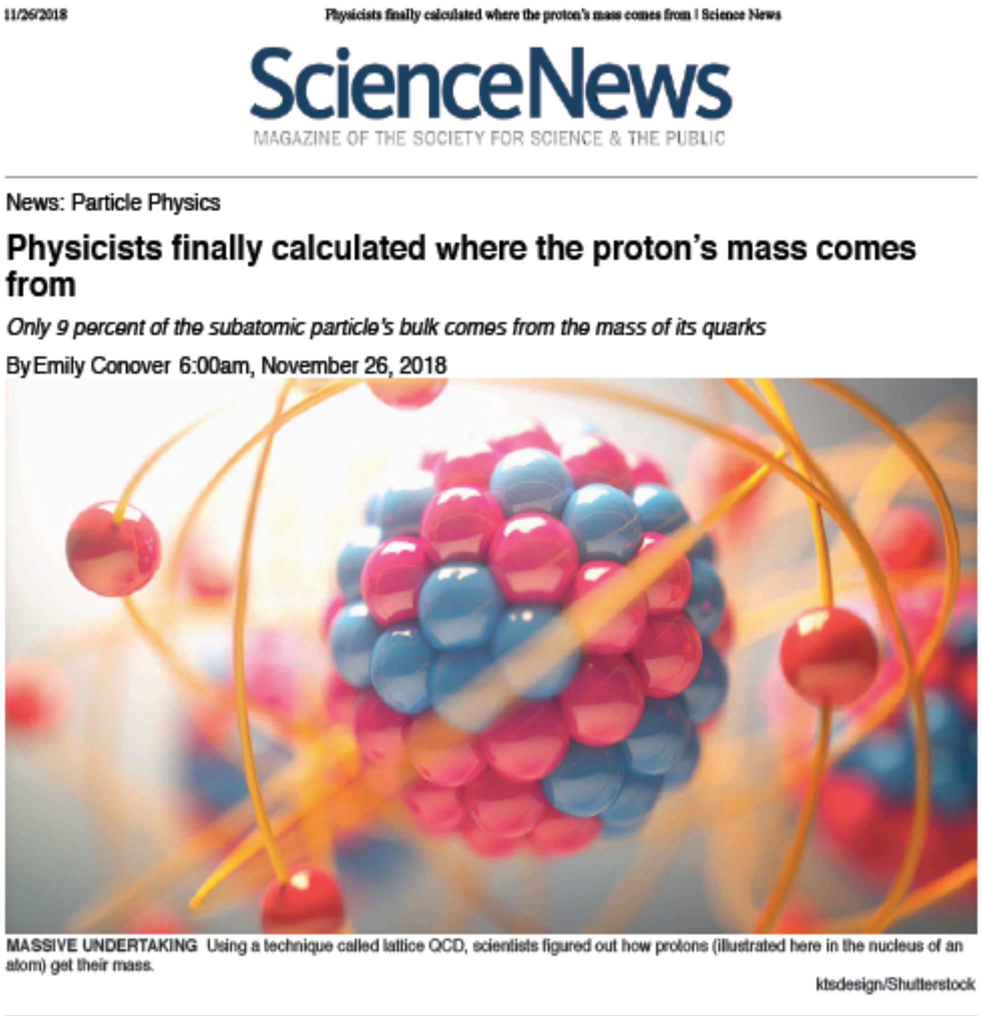

11/26/2018 Physicists finally calculated where the proton's mass comes from | Science News

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

News: Particle Physics

Physicists finally calculated where the proton's mass comes from

Only 9 percent of the subatomic particle's bulk comes from the mass of its quarks

By Emily Conover 6:00am, November 26, 2018

MASSIVE UNDERTAKING Using a technique called lattice QCD, scientists figured out how protons (illustrated here in the nucleus of an atom) get their mass.

ktsdesign/Shutterstock