



## SPC Perspective: High Energy Physics

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USQCD All Hands' Meeting 2024

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# What counts as High Energy Physics today?

2023 P5 Report <https://www.usparticlephysics.org/>

Historical definition: for PI's funded by DOE or NSF, does your funding come from HEP or NP?

"Dual Use": Sometimes that means that quantities computed in lattice QFT are of interest in both HEP and NP experiments: e.g. DUNE and EIC.

Sometimes, PI's funded by NP can make significant contributions to HEP priorities and vice versa.

Examples where traditional NP expertise will be important for HEP programs

SBN/Dune: form factors and PDF's of nuclei (Ar).

Dark Matter Direct Detection: nuclear sigma terms.

LHC: Can BSM physics be hiding in data-driven PDF's used by experiments?



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the  
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Elucidate the Mysteries  
of Neutrinos

Reveal the Secrets of  
the Higgs Boson



Explore  
New  
Paradigms  
in Physics

Search for Direct Evidence  
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Pursue Quantum Imprints  
of New Phenomena



Illuminate  
the  
Hidden  
Universe

Determine the Nature  
of Dark Matter

Understand What Drives  
Cosmic Evolution

# Current HEP projects on USQCD Resources: Pursue Quantum Imprints of New Phenomena

Large- $Q^2$  Kaon Form Factors with Physical Quark Masses, X. Gao (PI)

New preprint: [arXiv:2404.04412 \[hep-lat\]](https://arxiv.org/abs/2404.04412)

Semileptonic B decays with vector final state, A. Lytle (PI)

Lattice 2023: [arXiv:2403.03959 \[hep-lat\]](https://arxiv.org/abs/2403.03959)

New ensembles for precision light-meson decay constants, S. Gottlieb (PI)

K to pi pi decay calculation at physical point with PBC, M. Tomii (PI)

Published: [arXiv:2306.06781 \[hep-lat\]](https://arxiv.org/abs/2306.06781)

QCD+QED studies, L. Jin (PI)

Muon g-2 HVP from four flavors of sea quarks using HISQ, M. Lynch (PI)



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# Current HEP projects on USQCD Resources: Reveal the Secrets of the Higgs Boson Search for Direct Evidence of New Particles

Novel phases and emerging fixed points in SU(2) gauge systems, A. Hasenfratz (PI)

This was a new proposal. No update yet.

From BSM to  $\alpha_s$  in QCD at the Z-pole, J. Kuti (PI)

[LATTICE 2023 Parallel Talk](#)

No-perturbative beta-function of eight-flavor SU(3) gauge theory, C. Peterson

[LATTICE 2023 Parallel Talk](#)

Gradient flow renormalization scheme, A. Hasenfratz (PI)

[LATTICE 2023 Parallel Talk by O. Witzel](#)



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# Proposed HEP projects on USQCD Resources: Pursue Quantum Imprints of New Phenomena

Semileptonic B decays with vector final state, A. Lytle (PI, cont)

K to pi pi decay calculation at physical point with PBC, M. Tomii (PI, cont)

Updating previous calculation with finer lattice spacing.

QCD+QED studies, L. Jin (PI, cont)

New ensembles for precision light-meson decay constants, A. Bazazov (PI, cont)

Since 2020, important for determining 1<sup>st</sup> row CKM unitarity.

Nucleon EDMs by QCD theta term and 4-quark CP interactions with DWF, S. Syritsyn (PI)

Radiative corrections to beta decays, T. Bhattacharya (PI)

Omega Baryon Scale Setting and HPV Observables, A. Grebe (PI)



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# Proposed HEP projects on USQCD Resources: Reveal the Secrets of the Higgs Boson Search for Direct Evidence of New Particles

From BSM to  $\alpha_s$  in QCD at the Z-pole, J. Kuti (PI, cont)

Plans to improve matching to 3-loop PT plus new calculations at strong coupling

Non-perturbative beta-function of eight-flavor SU(3) gauge theory, C. Peterson (PI, cont)

No clear inflection point in beta function for  $g^2 < 20$ . Plan to increase  $g^2$  to continue searching for inflection point. Also plans to compute  $g^2$  in QCD.

**GTF Note:** As C. Monahan mentioned yesterday. Improved accuracy in QCD running coupling and quark masses essential for future LHC precision. BSM running coupling studies in conformal window are much harder but have shown the way to improve accuracy in QCD.



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# Dual use projects on USQCD Resources: Reveal the Secrets of the Higgs Boson Search for Direct Evidence of New Particles

In 2022, CDF announced a final value for W boson mass, using all Tevatron data up to 2011, that disagreed with EW global fit.

Recently, [ATLAS finalized](#) their analysis of the W boson mass, using only LHC Run 1 data up to 2011, that agreed with EW global fit.

These are very hard, decade long analyses. Understanding PDF uncertainties are important to reconciling these two measurements.

Wagman has USQCD project to compute Collins-Soper kernel, which counts as NP for SPC. The Collins-Soper kernel, is a key ingredient in transverse-momentum resummation for Drell-Yan processes, which are the production mechanism for W and Z at the LHC.

An example of what C. Monahan said yesterday about importance of precise PDFs to achieve precision goals at future runs of LHC.



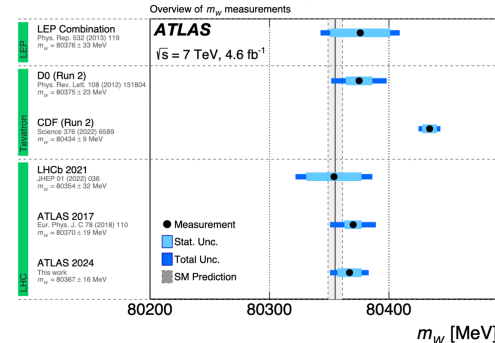
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# Other Projects by USQCD Members

The HEP science program by USQCD members is much larger than USQCD resources alone can accommodate.



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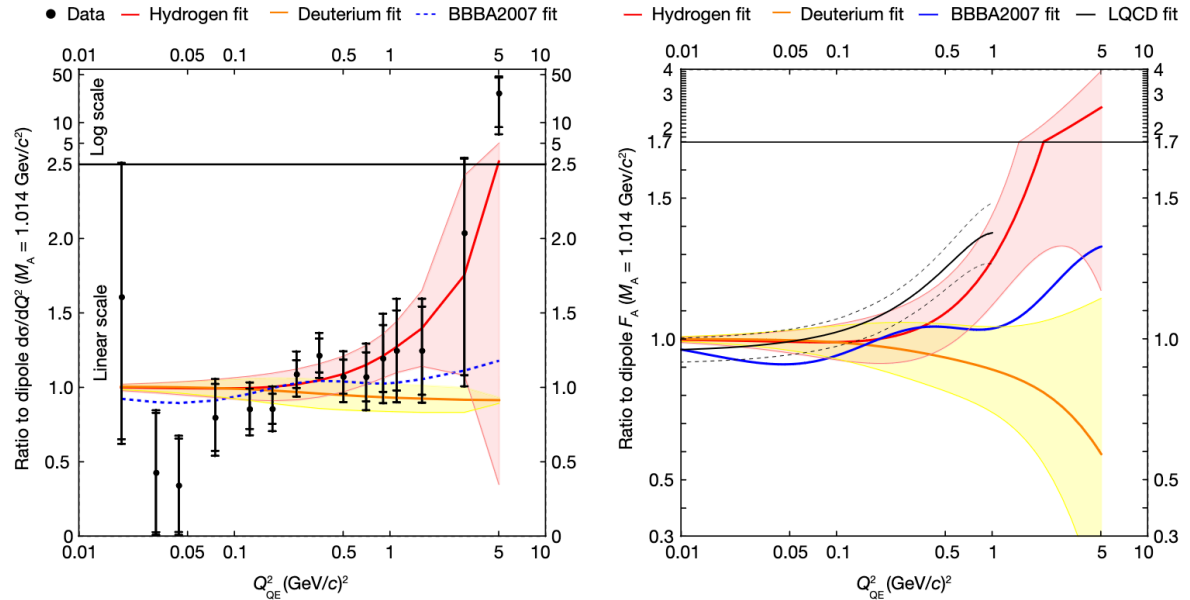
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**Elucidate the Mysteries of Neutrinos:** on-going work to compute axial form factors on one to few nuclei systems and Delta to N-pi and N-pi-pi transition form factors.

Recent publication in Nature by Minerva Collaboration of proton axial form factor, with comparison to LQCD fit by H.-W. Lin.

New era in precision neutrino scattering experiments. Dipole form factor hypothesis no longer sufficient.

Next generation SBND starting operation using LArTPC.





## Other Projects by USQCD Members

Current thinking by model builders is **Composite Higgs** scenarios require near-conformal gauge theories.

LSD Collaboration updated studies of near-conformal SU(3) Nf=8 theory [arXiv:2305.03665 \[hep-lat\]](#) and [arXiv:2306.06095 \[hep-lat\]](#).

LSD is also exploring whether SMG occurs in massless SU(3) Nf=8 theory. Related to work of A. Hasenfratz and C. Peterson.

It would be nice to study near-conformal theories using radial quantization on  $\mathbb{R} \times \mathbb{S}^{D-1}$ . The Quantum Finite Elements (QFE) Collaboration is making steady progress towards this goal using two recent class B proposals by studying critical 3-D Ising model.

[arXiv:2311.01100 \[hep-lat\]](#)

[LATTICE 2023 talk by R. Brower](#), [LATTICE 2023 talk by E. Owen](#)

E. Owen Ph.D. Thesis



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## Other Projects by USQCD Members

Non-Abelian Dark Forces could lead to **Composite Dark Matter** as either dark glueballs, dark pions or dark baryons.

First order finite temperature phase transitions could produce detectable gravity waves. Dark baryons could form dark nuclei.

[arXiv:2312.07836 \[hep-lat\]](#), K. Cushman Ph.D. Thesis.  
[LATTICE 2023 Proceedings by V. Ayyar](#)

More speculatively, efforts continue to develop the Euclidean Dynamical Triangulation (EDT) formalism of quantum gravity, which would impact **Cosmic Evolution** at the earliest times.

New results by J. Laiho and collaborators show algorithmic improvements that enable calculations on finer lattices, approaching semiclassical Euclidean de Sitter space in the continuum limit.

[arXiv:2309.12257 \[hep-lat\]](#)



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# Request for Assistance

Many of the topics covered here will be covered in the upcoming LQCD Infrastructure DOE review next month.

I will be covering BSM topics and others will cover the rest of HEP.

If you think I misrepresented your work or want to make me aware of new work, particularly outside of USQCD Type A proposals, please let me know so I can include it in my talk or direct it to the relevant presenter.



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