SPC Summary on Nucleon and Nuclear Matrix Elements

- Cold Nuclear Physics
  - Nucleon Matrix Elements
  - Parton Distribution Function and Moments
  - Hadron Spectroscopy
  - Hadron Interactions and Nuclei
- Experimental facilities
  - Present: JLab 12 GeV, RHIC, ATLAS, Fermilab
  - Future: FRIB, EIC

All Hands Meeting
JLab, Apr. 20-21, 2018
### Proposals

<table>
<thead>
<tr>
<th>PI</th>
<th>Title</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhattacharya</td>
<td>Contribution of Theta, chromo EDM and Weinberg operators to nEDM</td>
<td>Continuation</td>
</tr>
<tr>
<td>Detmold</td>
<td>Nuclear Physics from Standard Model</td>
<td>Continuation</td>
</tr>
<tr>
<td>Engelhardt</td>
<td>Nucleon quark-gluon structure with Clover-Wilson fermion</td>
<td>Continuation</td>
</tr>
<tr>
<td>Gupta</td>
<td>Nucleon matrix elements with 2+1 flavor clover fermion</td>
<td>Continuation</td>
</tr>
<tr>
<td>Kronfeld</td>
<td>The Nucleon Axial-Vector Form Factor at the Physical Point with the HISQ Ensembles</td>
<td>Continuation</td>
</tr>
<tr>
<td>Liang</td>
<td>Lattice calculation of nucleon EDM and hadronic tensor</td>
<td>Continuation, New</td>
</tr>
<tr>
<td>Shanahan</td>
<td>Gluon GPDs of the nucleon</td>
<td>Continuation</td>
</tr>
<tr>
<td>Sufian</td>
<td>Proton charge radius and neutral current FF</td>
<td>New</td>
</tr>
<tr>
<td>Syritsyn</td>
<td>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</td>
<td>Continuation</td>
</tr>
<tr>
<td>Yang</td>
<td>Proton Spin Decomposition with Non-perturbative renormalization</td>
<td>Continuation</td>
</tr>
</tbody>
</table>
Topics in Proposals

- nEDM $\Theta$ term - Bhattacharya, Liang, Syritsyn
  Chromo EDM - Bhattacharya, Syritsyn
- $g_A$ and axial form factor – Engelhardt, Gupta, Kronfeld, Syritsyn, Yang
- Scalar and tensor charges – Detmold (Nuclei), Gupta
- Electromagnetic form factors – Engelhardt, Gupta, Sufian, Syritsyn
- Quark spin, momentum and AM fractions – Engelhardt, Yang
- TMD – Engelhardt
- Glue GPDs – Shanahan, Yang
Samples of Progress on Projects

- $g_A$ -- 1.195(33)(20) [PNDME, 1606.07049, PRD (2016)]
  1.278(21)(26) [CalLat, 1704.01114],
  -- talk by Boram Yoon

- $g_A$ form factor

R. Gupta et al. (PNDME), 1705.06834, PRD (2017)

M. Engelhardt (PI) – separate u and d contribution to axial form factor
nEDM with the $\Theta$ term


$$F_3 = \hat{F}_3 - 2\alpha_5 F_2$$

Note: $Q \sim \sqrt{V}$

S. Syritsyn (PI) -- $24^3 \times 64$ DWF, $a = 0.114$ fm, $m_\pi = 330$ MeV

J. Liang (PI) -- $24^3 \times 64$ DWF, $a = 0.114$ fm, $m_\pi = 330$ MeV

- Chromo-EDM: T. Bhattacharya, S. Syritsyn
Electromagnetic Form Factors

FIG. 3: (Top) The data for the renormalized isovector form factors $G_E(Q^2)/g_V$ (left) and $G_M(Q^2)/g_V$ (right) from twelve clover-on-HISQ calculations and the Kelly parameterization of the experimental data plotted versus $Q^2$ in units of GeV$^2$. (Bottom) The clover-on-clover data.

R. Gupta (PI) Error of charge radii? Need disconnected insertion.
Electromagnetic Form Factors of the Disconnected insertions

R. Sufian et al, 1705.05849, PRD (2017)

~ 1/3 of the discrepancy of $<r^2>_E$ in proton charge radius puzzle.
Sizable for neutron charge radius.
Nuclear modification of scalar, axial, and tensor charges from lattice QCD
-- E. Chang et al. (NPLQCD), 1712.03221, PRL (2018)

First lattice QCD study of the gluonic structure of light nuclei
-- F. Winter et al. (NPLQCD), 1709.00395, PRD (2017)

$M_\pi \sim 450 \text{ MeV}$

$M_\pi \sim 806 \text{ MeV}$

Nuclear modification of scalar, axial, and tensor charges from lattice QCD
-- E. Chang et al. (NPLQCD), 1712.03221, PRL (2018)
Highlights of the Year

December 18, 2017 • Physics 10, 137

Physics looks back at its favorite stories from 2017.

Y. Yang et al, PRL 118, 102001 (2017), 1609.05837
More Challenges...

R. Gupta et al. (PNDME), 1705.06834, PRD (2017)

J. Liang et al. (χ QCD) 1612.04388, PRD (2017)

FIG. 13. Plot of the ratio $(Q^2 + M^2) \tilde{G}_P/Q^2)/(4M^2 \tilde{G}_A/Q^2)$ versus $Q^2$ for the eight ensembles. Validity of the pion pole-dominance hypothesis, given in Eq. (11), requires that this ratio is unity for all $Q^2$. Our data show significant deviations, especially for $Q^2 \lesssim 0.2$ GeV$^2$. 