Usage Report for Fiscal Year 2015

Project Title:

First principle calculation of nucleon structure and electric dipole moments

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1. Background and purpose of the project, relationship of the project with other projects

Nucleons are basic building blocks of our visible universe, and understanding how quarks and gluons interacting via Quantum Chromodynamics (QCD) give rise to their rich structure is a central focus of both theory and experiment. Quarks, while tighly bound into nucleons, can also participate in yet undiscovered interactions beyond the commonly accepted Standard Model (SM). Experimental manifestations of these interactions will strongly depend on the internal dynamics of quarks and gluons inside the nucleons.

Lattice methodologies to compute nucleon structure and nucleon electric dipole moments overlap very substantially, with the latter being essentially an extension of the former. Therefore, in our proposal we combine these two topics to save computing resources and reuse numeric data. Below we separately discuss impacts and potential outcomes of these two parts of the proposal.

2. Specific usage status of the system and calculation method

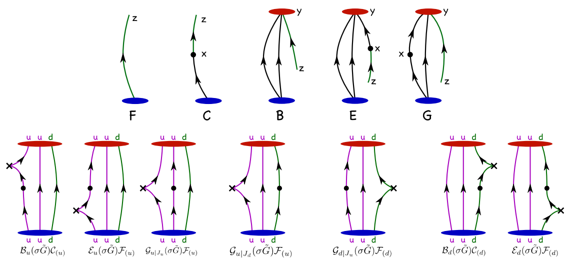
To compute "shape" of the nucleon, the form factors appear in QCD matrix elements of the quark vector current

$$\langle N(p',s')|\bar{q}\gamma_\mu q|N(p,s)\rangle_{\tilde{d}_q} = \bar{u}(p',s')\Big[\gamma_\mu F_1^q(Q^2) + \frac{i\sigma_{\mu\nu}q^\nu}{2M_N}F_2^q(Q^2) + \gamma_5\frac{\sigma_{\mu\nu}q^\nu}{2M_N}F_3^q(Q^2) + (\gamma_\mu\gamma_5 - 2M_N\gamma_5 q_\mu)F_A^q(Q^2)\Big]u(p,s)$$

by computing nucleon 3pt correlation function. The form factors F1 and F2 are related size and shape of nucleon proved electrically and magnetically, respectively. For chromo EDM, nucleon 4pt function to determine the effect of quark chromo-electric dipole moments (cEDM)

$$S_{\rm cEDM} = \int d^4x \sum_q i\tilde{d}_q\,\bar{q}(\lambda^a G^a_{\mu\nu})\sigma_{\mu\nu}\gamma_5 q$$

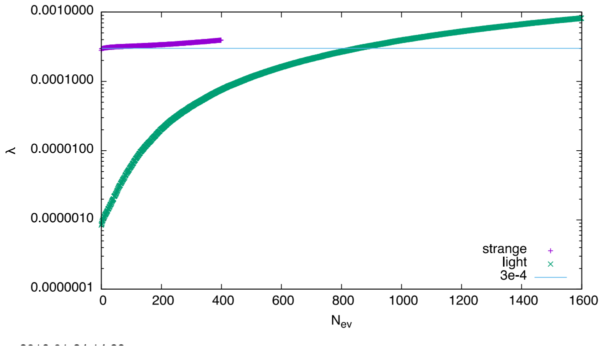
, and resulting CP-violating formfactor F3 is the resulting EDM. A schematical algorithm for the 4pt function in terms of quark diagram is shown below using so-called (doubly) sequencial source method for each of quark's vector current (dots) and cEDM interactions (crosses).



3. Result and Conclusion

For our calculation, we planed to use QCD gauge configuration ensemble with chirally-symmetric Domain Wall action generated by an international collaboration, RBC/UKQCD collaboration, including RIKEN-BNL Research Center. The target QCD ensemble is pion mass m_π=170 MeV, close to the physical m_π=135 MeV, and the lattice spacing a=0.141 fm.

In current allocation period, we have coded a statistical error reduction technique, which we called all-mode-averaging and zMobius, developed during the previous allocation, Q15252. This algorithm speeds up the computation by about one-two orders of magnitudes (estimated 160 times for physical point case), and also made efforts to optimize the code for FX-100 supercomputer. Following plot shows a computed eigenvalue by this code as a function of index of eigenmode for up, down quark (green) and for strange quark (purple).



4. Schedule and prospect for the future

In our first experience on FX-100, we successfully created a code ready for the production run. We have checked the nucleon 4pt and 3pt function code by comparing the results from 2pt with quark propagating in a weak background electromagnetic field and cEDM and found almost identical results from production code.

Fiscal Year 2015 List of Publications Resulting from the Use of the supercomputer

[Publication]

E. Shintani, T. Blum, T. Izubuchi and A. Soni, arXiv:1512.00566 [hep-lat].

E. Shintani, R. Arthur, T. Blum, T. Izubuchi, C. Jung, and C. Lehner. Phys.Rev. D91 (2015) 11, 114511

[Proceedings, etc.]

S. Syritsyn et al., PoS LATTICE 2014, 134 (2015), [arXiv:1412.3175 [hep-lat]].

S. Syritsyn, J. Phys. Conf. Ser. 640 (2015) 1, 012054