

Quantum Computing for Heavy-Quark Fragmentation (QC4HQ)

Second quarterly report
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Progress in Second Quarter

Objective number	Milestone	FY25		FY26	
		H1	H2	H1	H2
1	Construction of Schwinger Hamiltonian; investigation of other QCD-like models				
2	State preparation and its implementation in QiskIT				
3	Construction of a SIHO appropriate to the Schwinger model in 1+1 dimensions				
4	Investigation of fragmentation in the Schwinger model using Qiskit, and the approach to the continuum limit				
5	Systematic Study of Fragmentation Functions with one heavy and one light flavor				

Studies have focused on 1+1D Nambu-Jona-Lasinio (NJL) Model for both *one flavor* and *two non-mass-degenerate flavors*



Demonstrated that two different implementations of NJL one-staggered-fermion Hamiltonian yield (largely) equivalent results

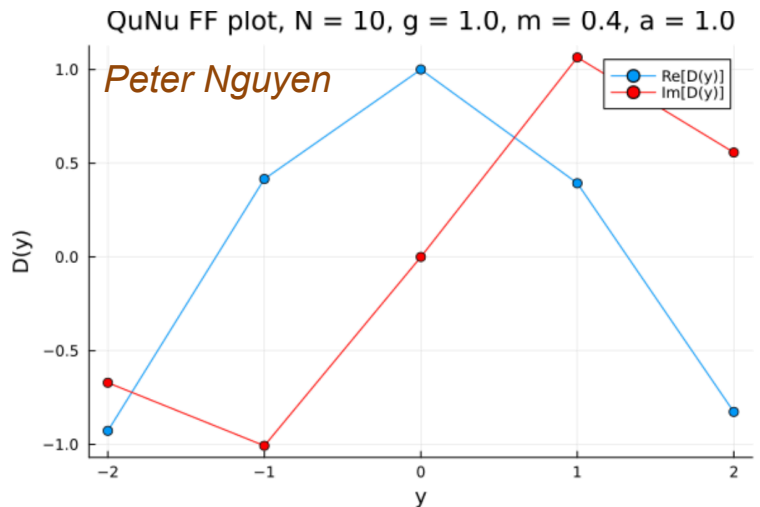


Implementing both the *Fragmentation Function* and *Parton Distribution Function* in PennyLane and using Tensor Network as a validation.

Coordinate-dependent fragmentation function for one staggered flavor obtain using a tensor network on 5 spatial sites ↔ 10 qubits.

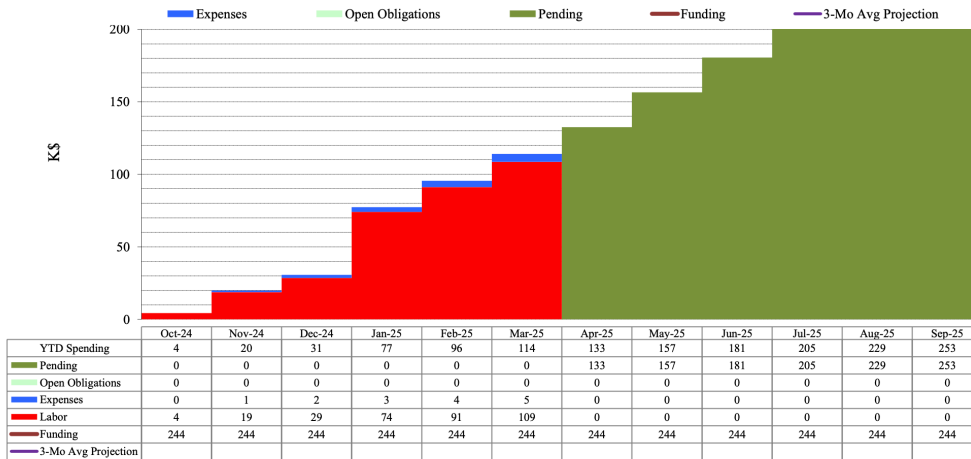
$$z D_i^h(z) = \sum_y e^{-i y n_h / z} \tilde{D}_i^h(y) \quad \text{Inverse problem}$$

Two-flavor (4 qubits/site) theory more involved through introduction of long-range interactions.



Funding

Quantum Computing for Heavy-Quark Fragmentation
D. Richards (LD2511)
WBS 1.02.LD.010 (Loaded \$k)



Funding (and progress!)
on track

Currently finishing proposal for time on IBM Quantum
under ORNL QCUP program

- Scientific case
- Estimates of number and depth of gates
- Finalizing with computations on classical computer

We will begin with the one-fermion theory, and explore how the *fragmentation function changes with the mass of the fermion*. We will then extend the study to the theory with two non-mass-degenerate theories, and explore the *fragmentation functions for the heavy-heavy, heavy-light, and light-light hadrons*. Together, these two outcomes represent a significant advance beyond that in the current literature, and position the project at the frontier of quantum simulations of QCD-inspired systems.