Momentum Phasing for Mesons

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Thanks to Colin, Daniel, Eloy, and Robert

Challenges with phasing for the Pion

- One of the problems with applying phasing is that the interpolation operators need to have opposite phases applied to the quark and antiquark fields at source and sink
    - This means that applying a positive phasing to the quark implies that a negative phase needs to be applied to the antiquark, and vice versa
- We also need perambulators with both positive and negative phases
    - The expression used to calculate the smeared correlation function is below, taken from Daniel's notes on phasing:

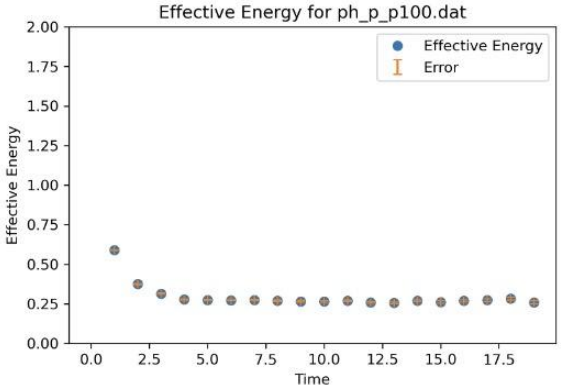
$$C_{AB}(t) = \mathrm{Tr}\left[\Phi^{A}(\zeta,t)\tau_u(\zeta,t|0)\Phi^{(B^\dagger)}(-\zeta,0)\tau_d(-\zeta,0|t)\right]$$

- Here, τ is the perambulator and ζ is the phase applied, and Φ are the meson elementals

Lattice Parameters

- We consider only local operators for the pion:
  - Pion1: $\bar{\Psi}\gamma_5\Psi$
  - Pion2: $\bar{\Psi}\gamma_4\gamma_5\Psi$
- Lattice Size: $32^3 \times 64$
- Pion Mass: 358 MeV
- 64 Eigenvectors, 350 Configurations, one time source
- Two units of phasing

Pion1-Pion1 Data



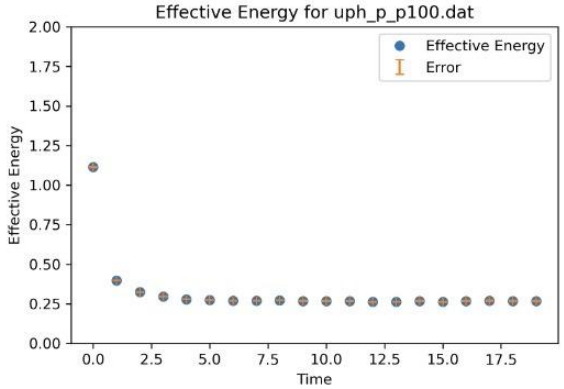
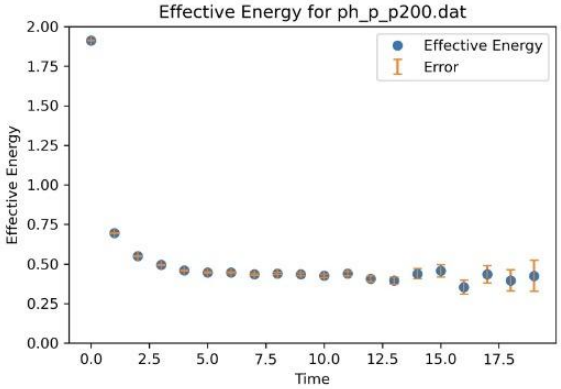


Figure 1: Mom 1 Phased (left) vs Unphased (right)



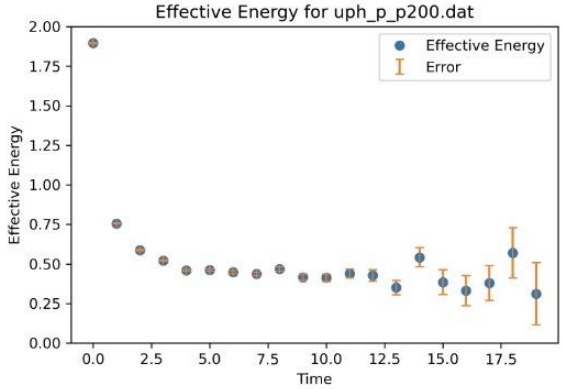


Figure 2: Mom 2 Phased (left) vs Unphased (right)

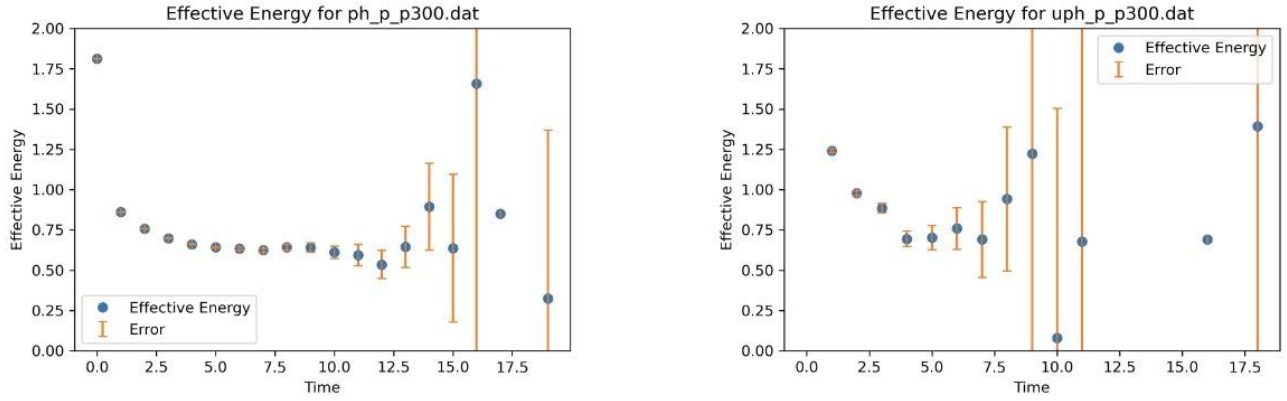


Figure 3: Mom 3 Phased (left) vs Unphased (right)

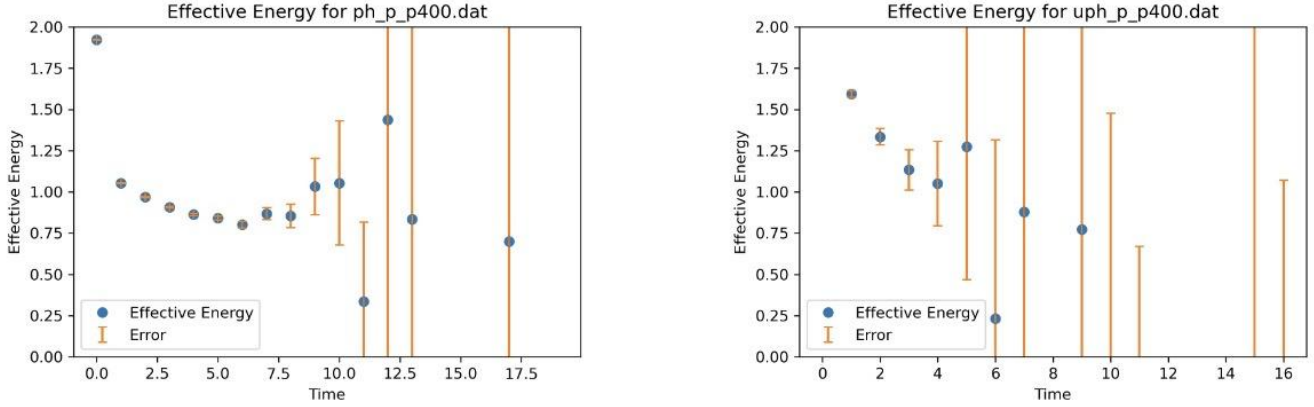


Figure 4: Mom 4 Phased (left) vs Unphased (right)

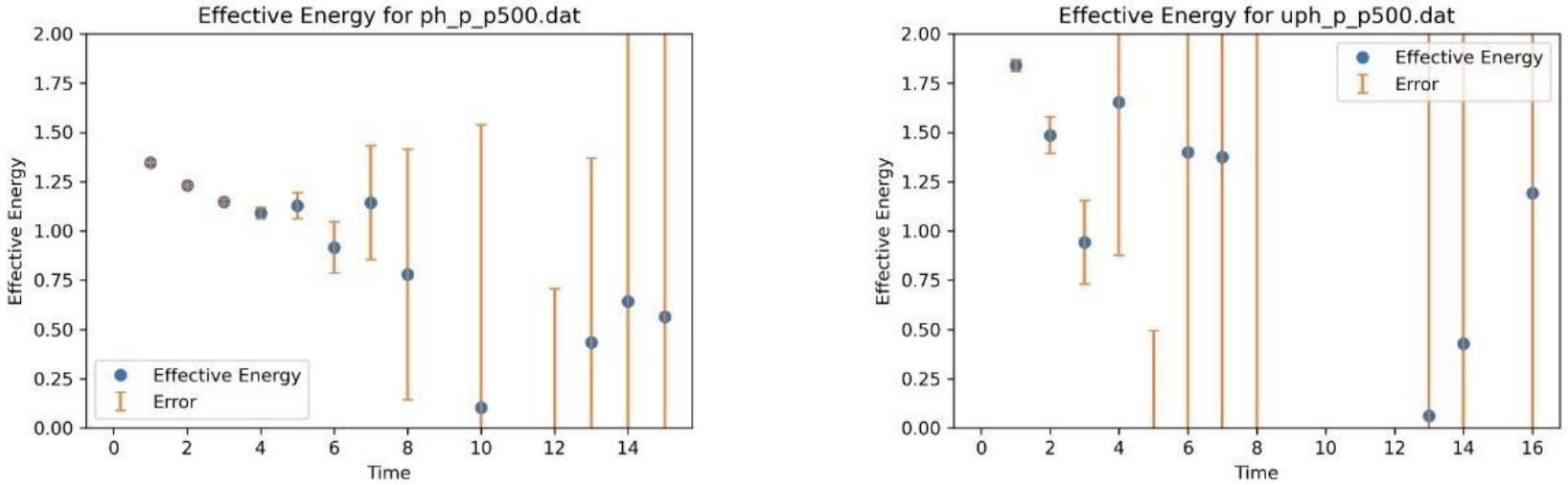
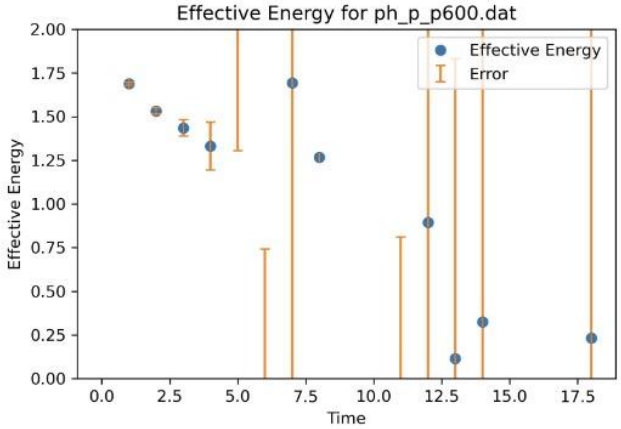
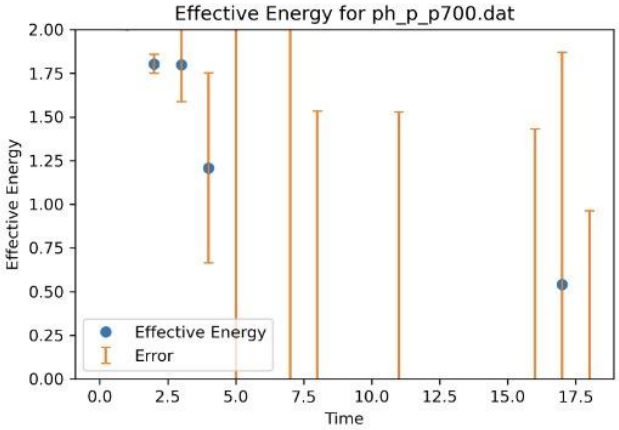


Figure 5: Mom 5 Phased (left) vs Unphased (right)





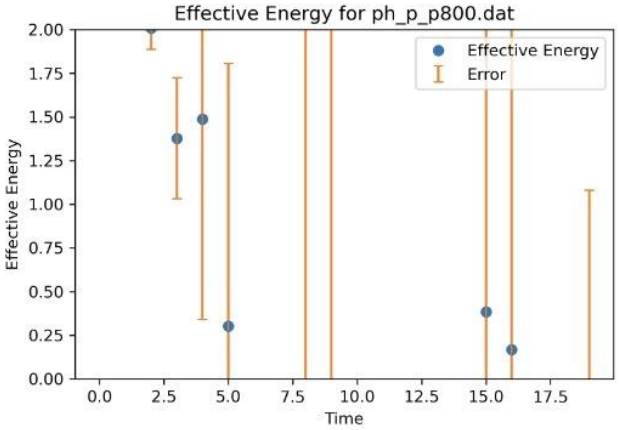
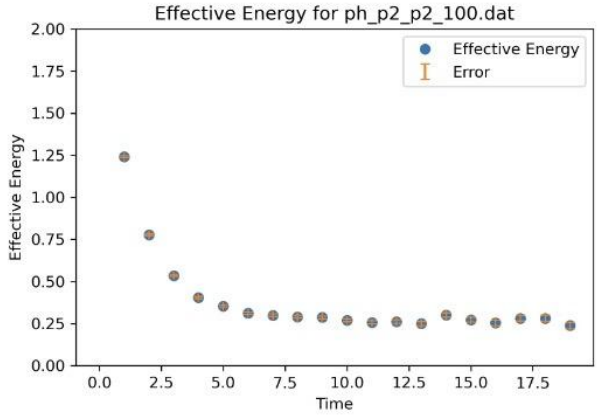


Figure 6: Mom 6,7, and 8 Phased

Pion2-Pion2 Data



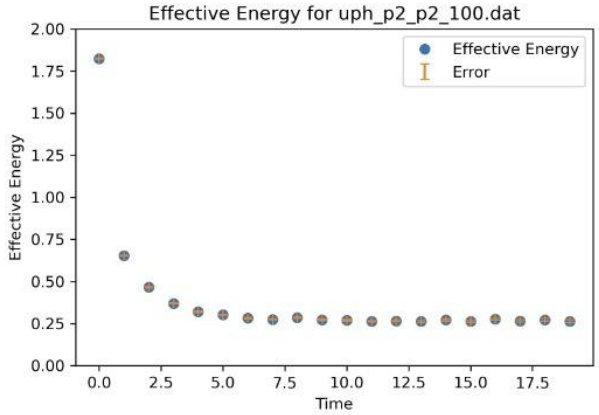
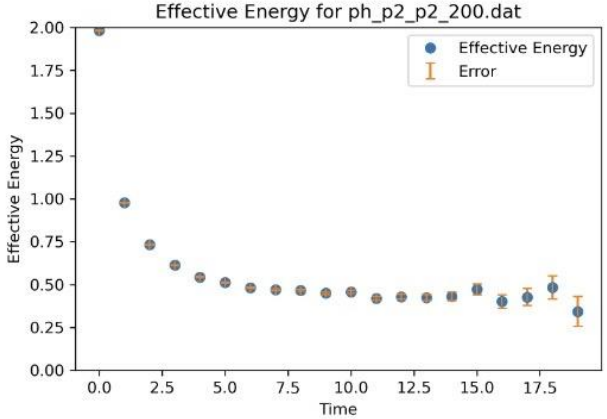


Figure 7: Mom 1 Phased (left) vs Unphased (right)



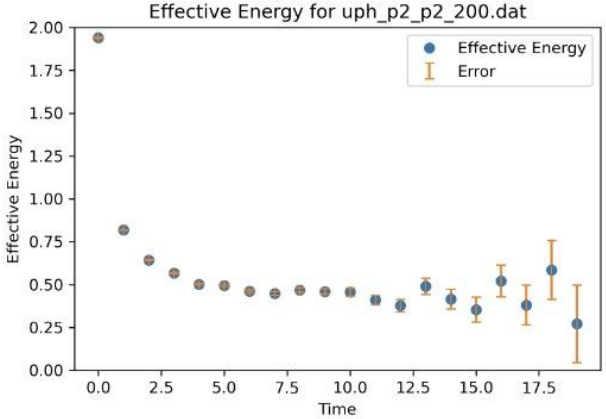


Figure 8: Mom 2 Phased (left) vs Unphased (right)

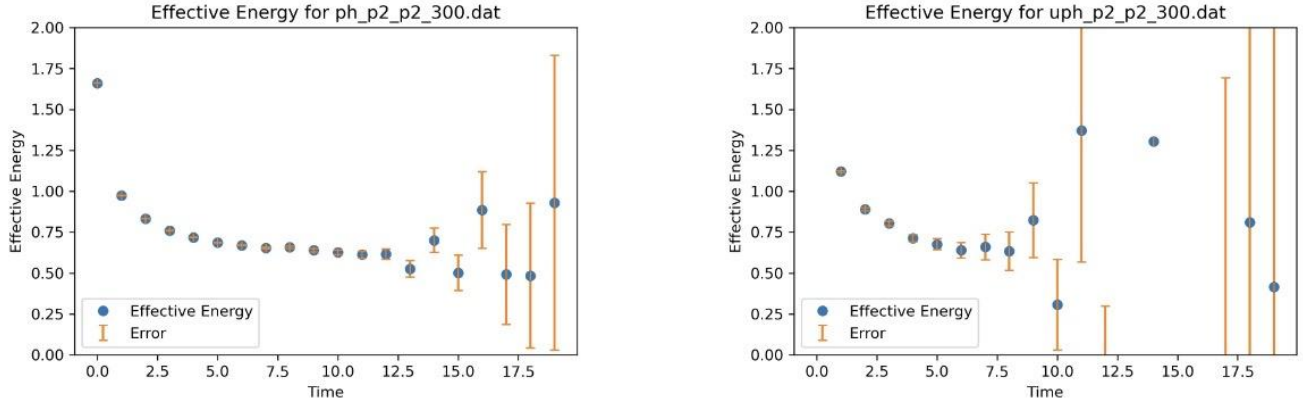


Figure 9: Mom 3 Phased (left) vs Unphased (right)

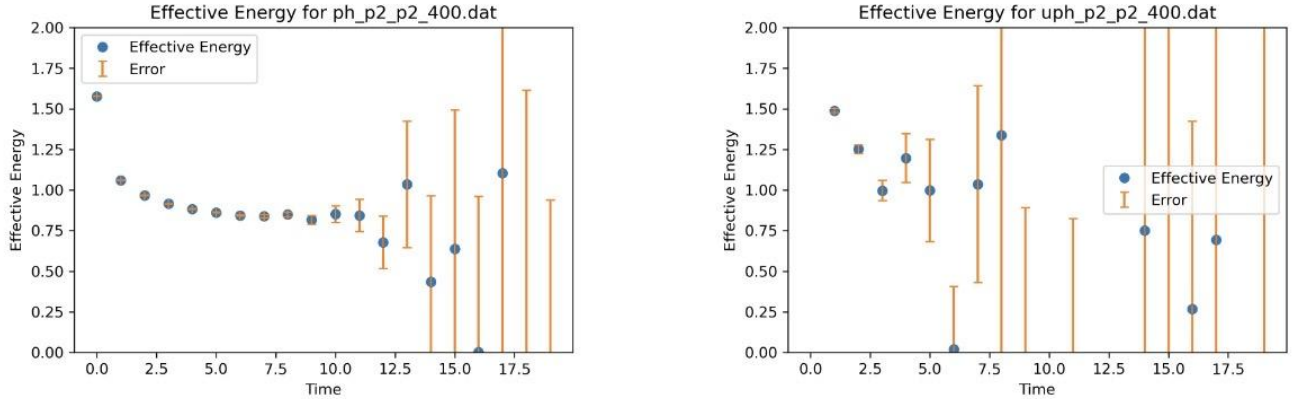
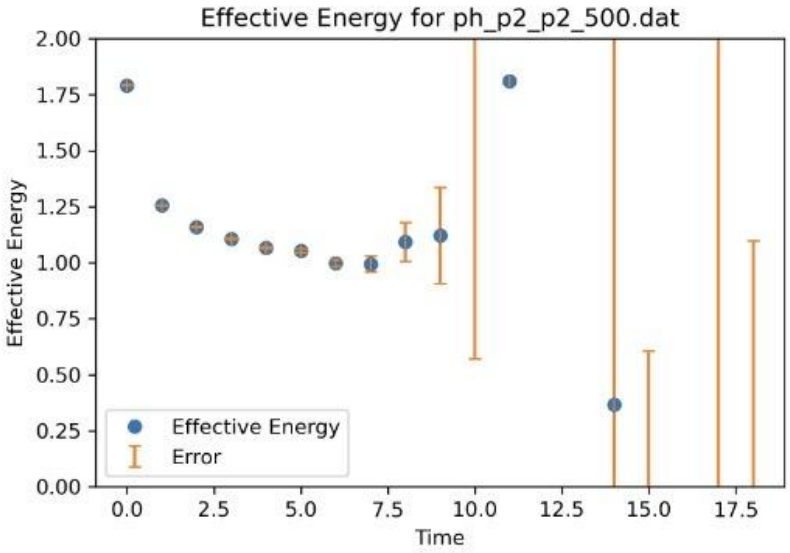


Figure 10: Mom 4 Phased (left) vs Unphased (right)



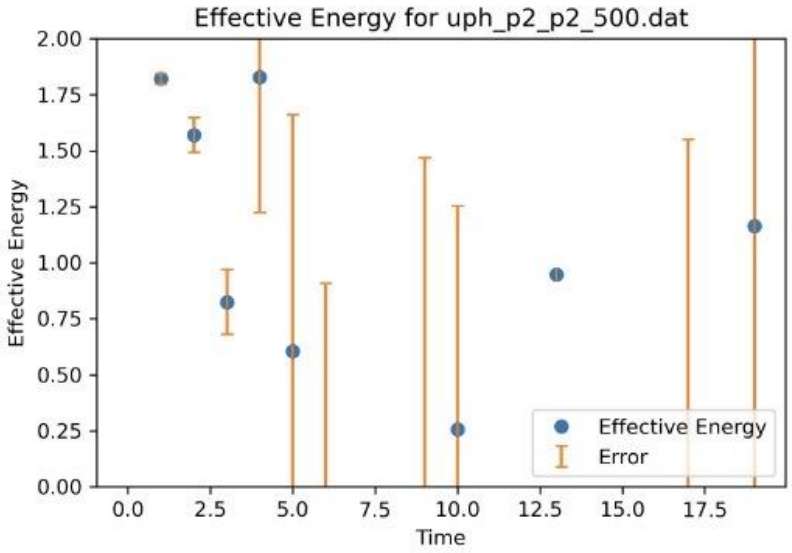
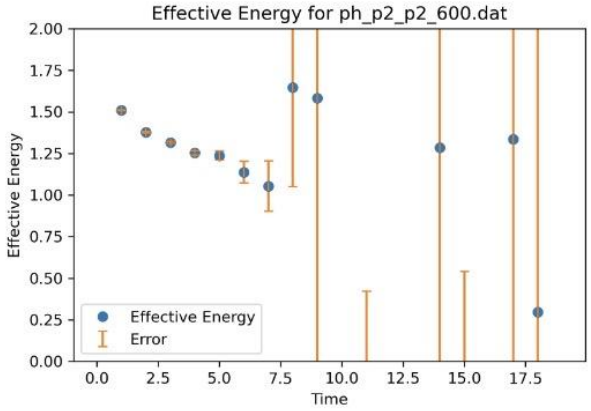
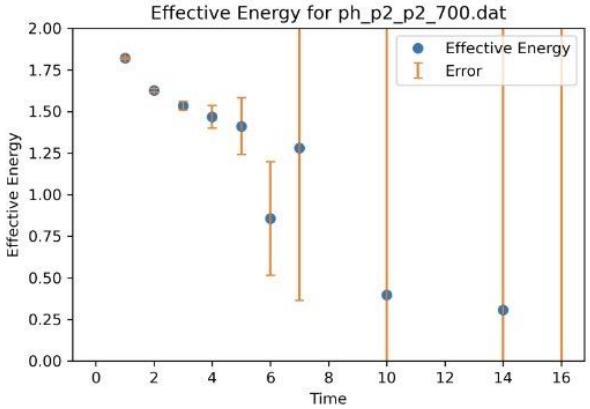


Figure 11: Mom 5 Phased (left) vs Unphased (right)





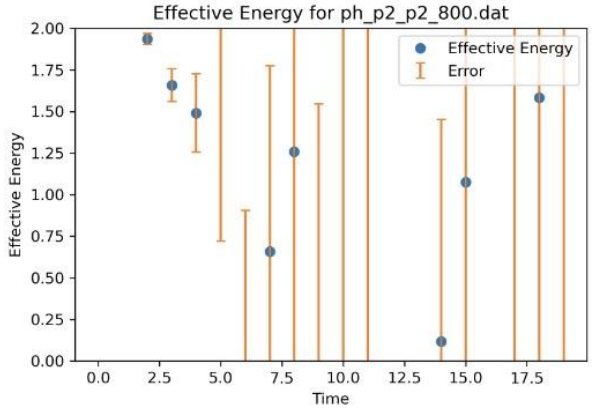
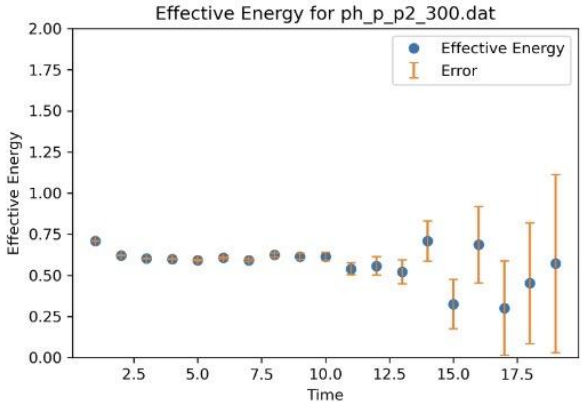


Figure 12: Mom 6,7, and 8 Phased

Cross Correlators (pion1-pion2 and pion2-pion1)



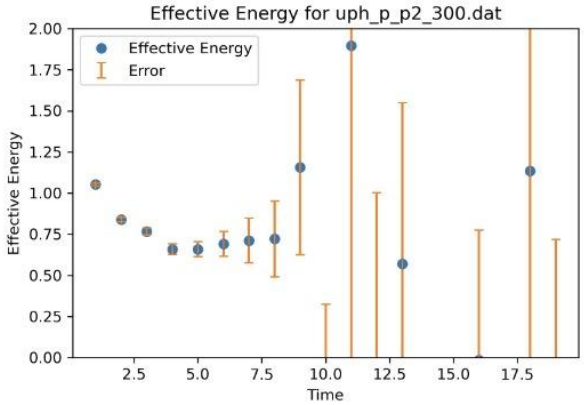
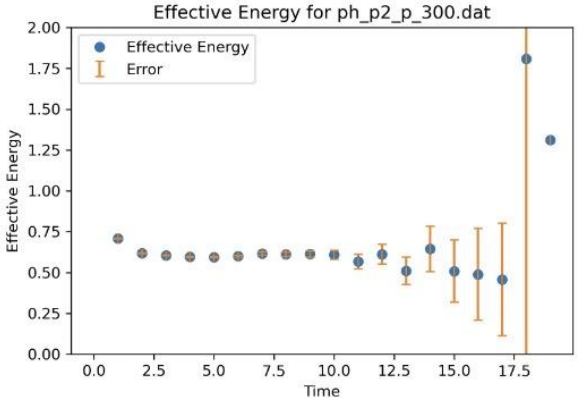


Figure 13: Mom 3 Phased (left) vs Unphased (right) (Pion1-Pion2)



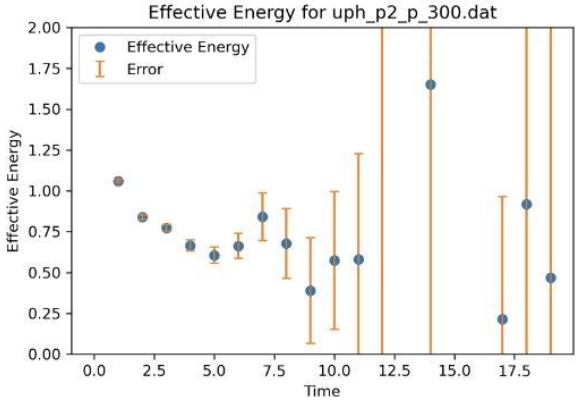
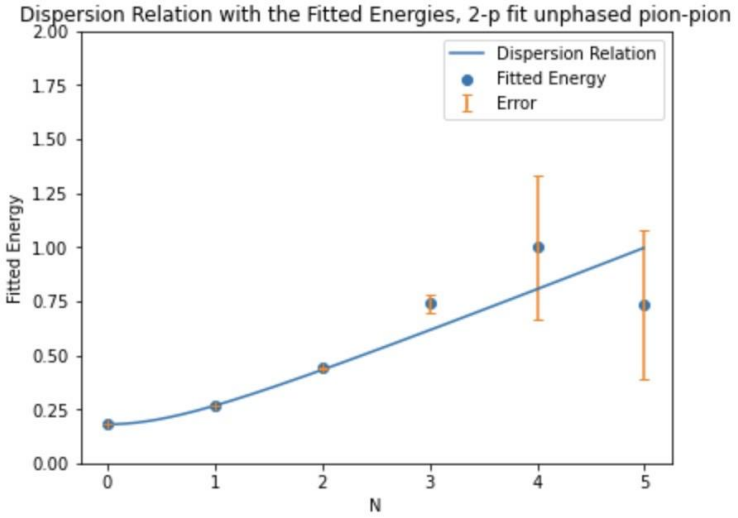


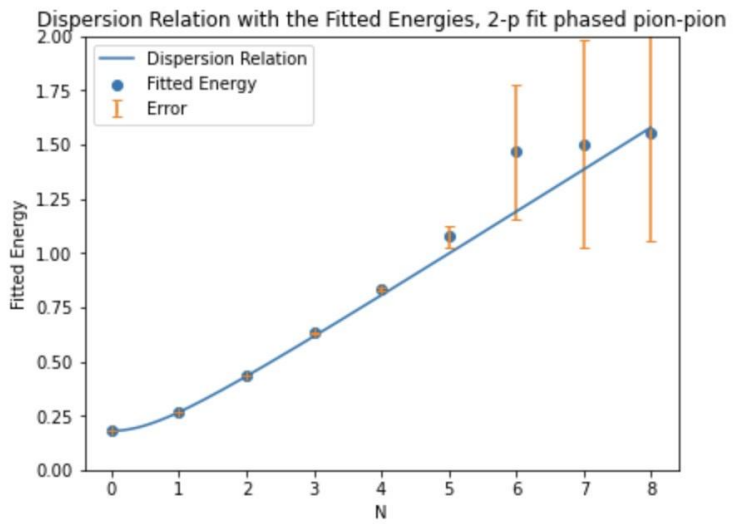
Figure 14: Mom 3 Phased (left) vs Unphased (right) (Pion2-Pion1)

Plotting fitted energies on the dispersion relation using lsqfit package

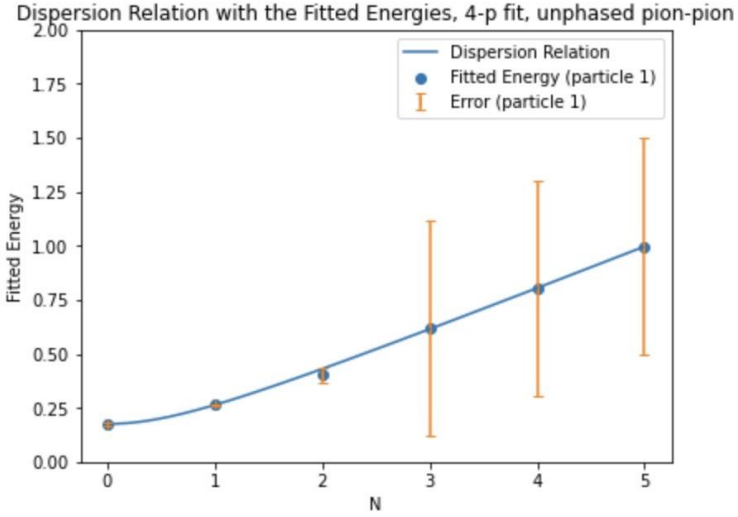
Pion1 Data

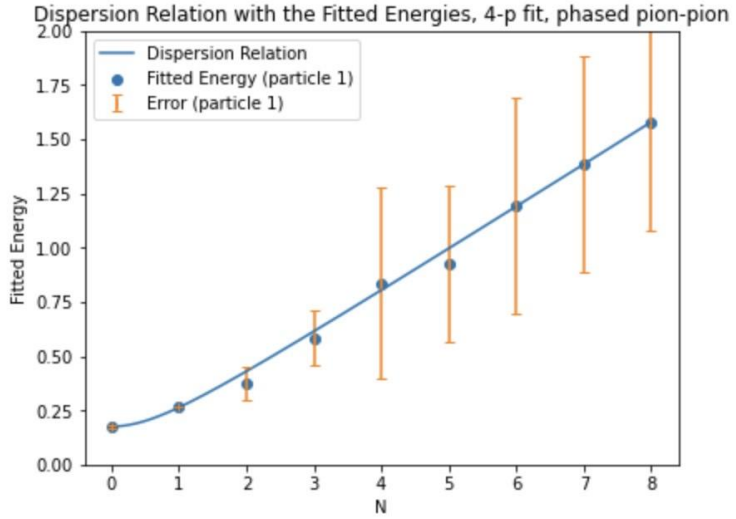
Single particle (two parameter) fits to the data





Two particle (four parameter) fits to the data

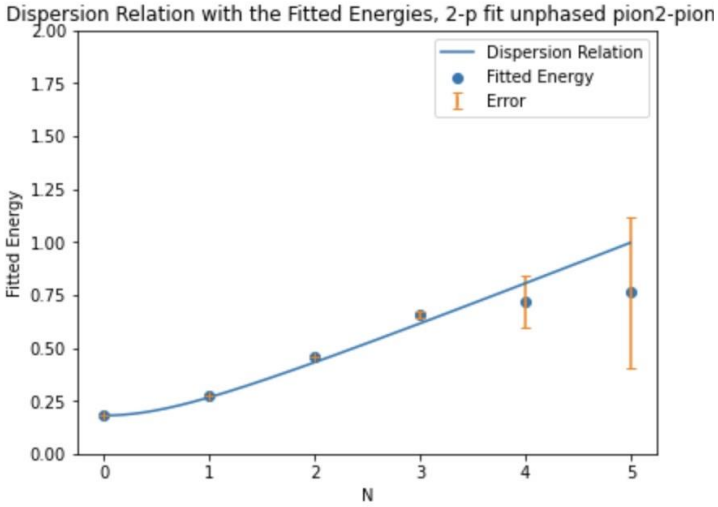


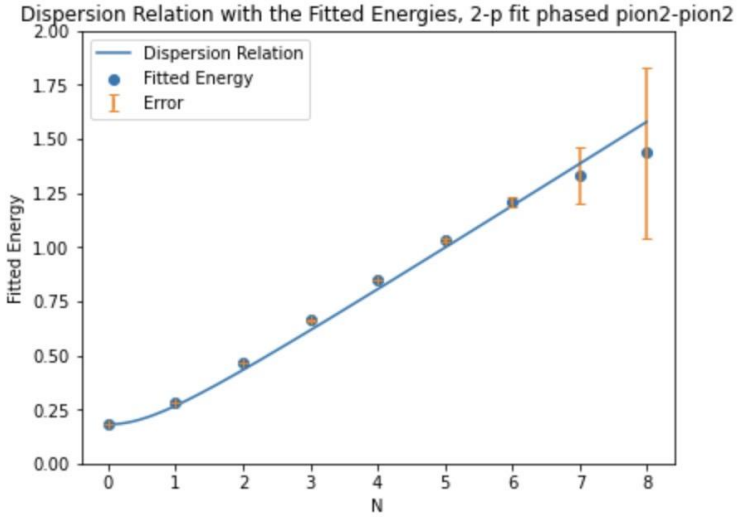


$$p = \frac{2\pi N}{L}$$

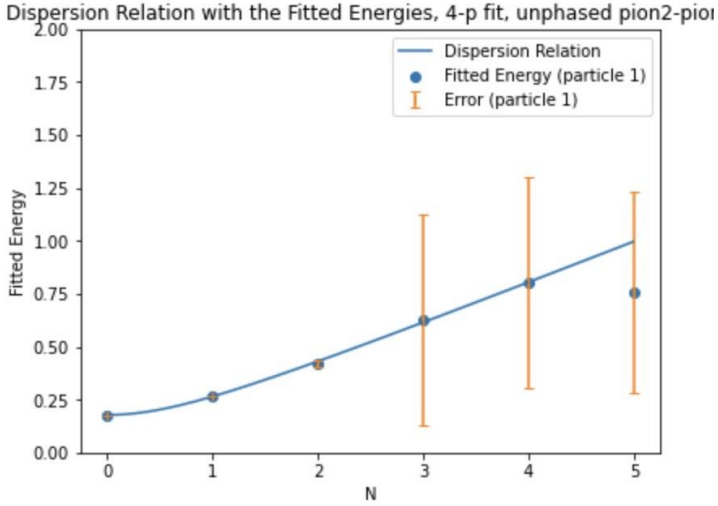
Pion2 Data

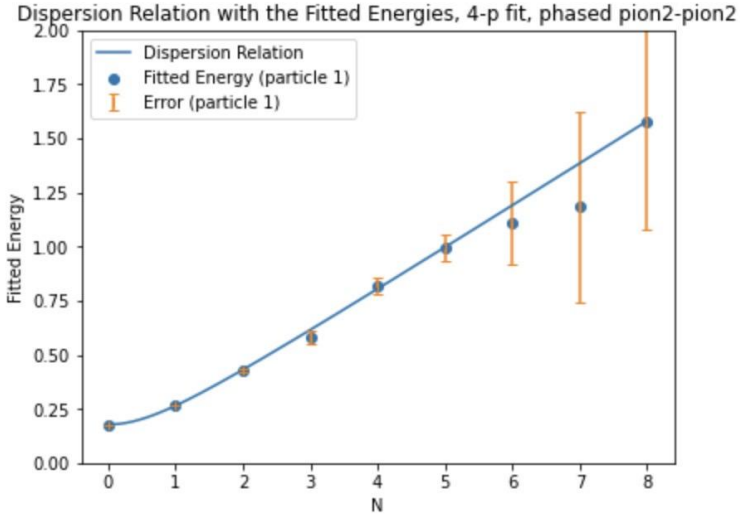
Single particle (two parameter) fits to the data





Two particle (four parameter) fits to the data



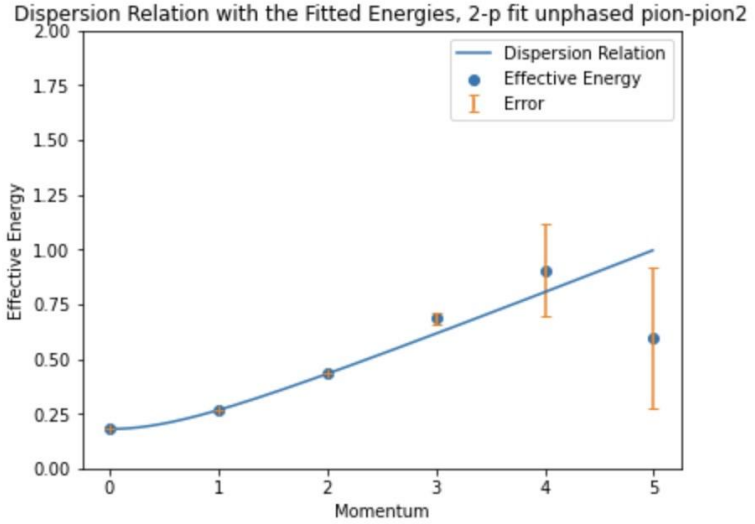


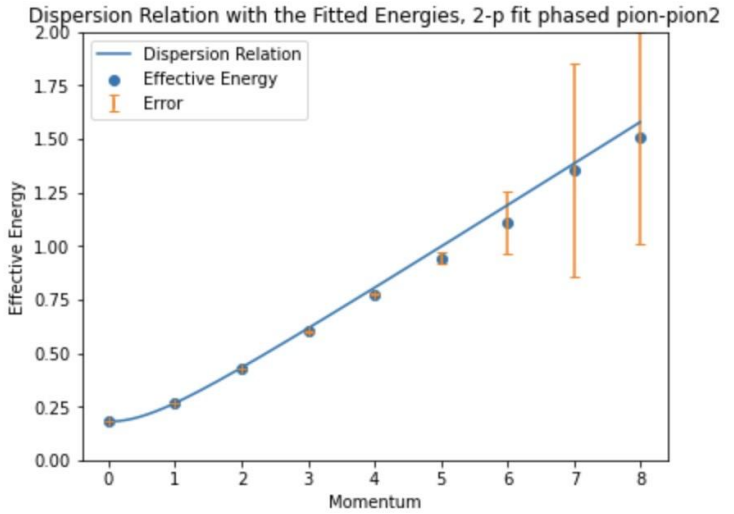
$$p = \frac{2\pi N}{L}$$

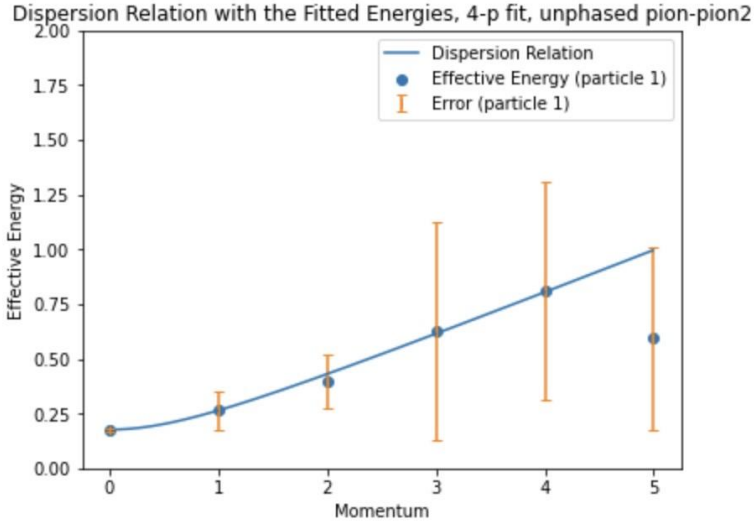
Summary

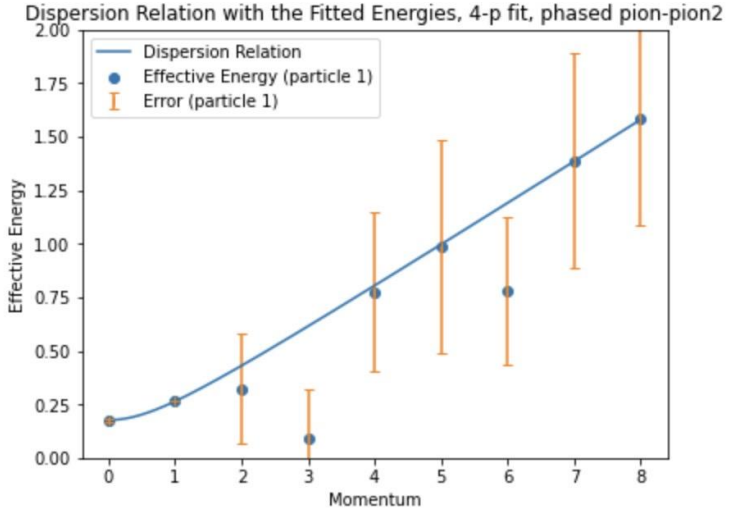
- Demonstrated effectiveness of phasing using local interpolating operators
- Currently analyzing four time sources per configuration to increase statistics
- Next Steps:
  - Extend the analysis to nonlocal operators and using variational method
  - Charges for moving pion
- Next Project:
  - Gluon and valence PDF of the pion
  - Quark distribution amplitudes
  - Pion form factor at higher momentum
  - …

Unphased pion-pion2 data vs phased pion-pion2 data









Unphased pion2-pion data vs phased pion2-pion data