The η and η' mass on 2+1 flavor DWF lattices

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- Quark self loops
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Introduction

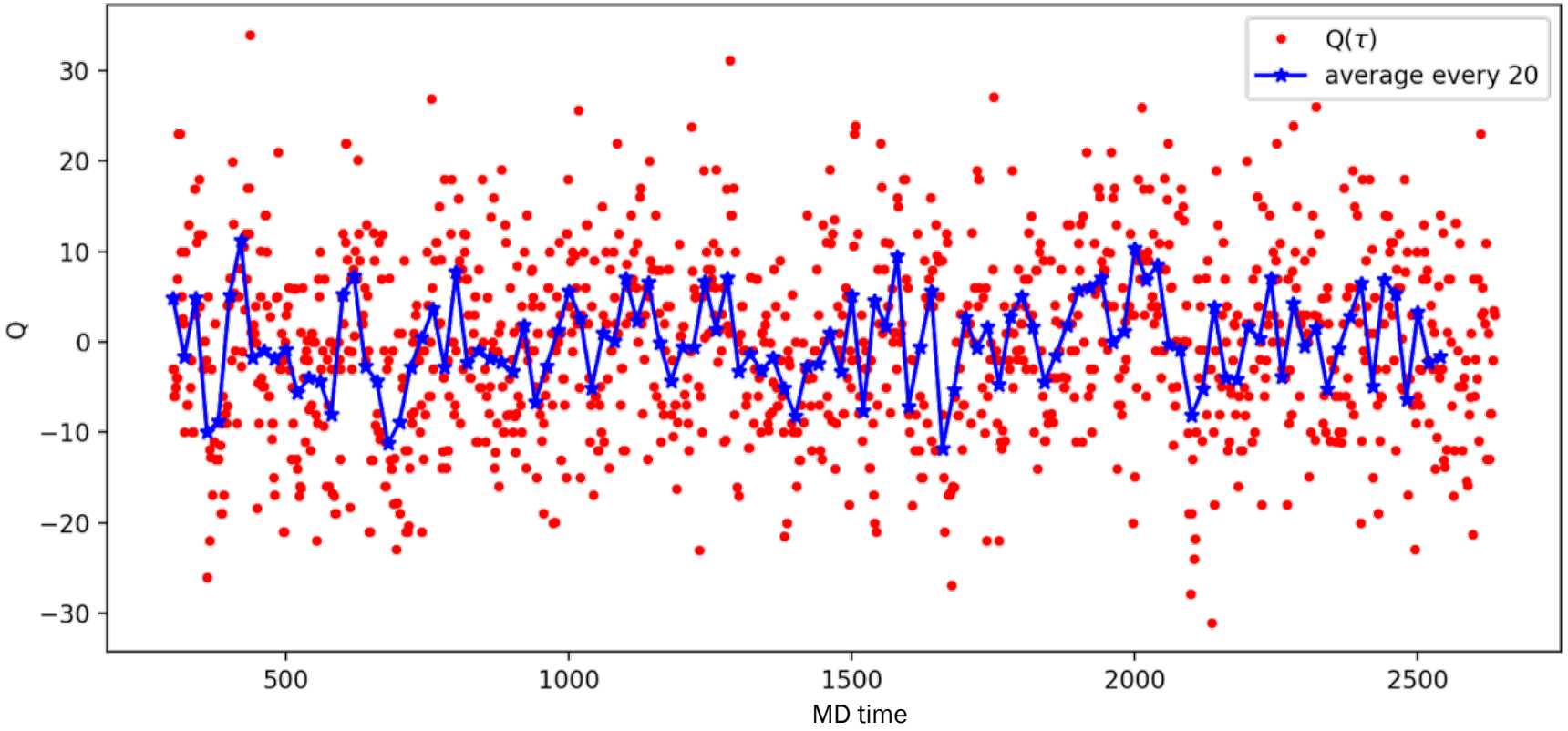
- Topological properties of the gauge configurations are crucial to the explanation of large η' mass.
- We want to investigate the source of error for η and η' measurements.
- The disconnected diagrams are calculated from quark self loops.

Lattice

- Action: IWASAKI + DSDR
- Fermion: Mobius DWF, 2 light quarks and 1 heavy quark
- Lattice size: 24^3x64x24, a^{-1} ~ 1GeV,
- β = 1.633, m_s = 0.085, m_l = 0.00107, $m_\pi \approx$ 140 MeV, $m_\pi * L \approx$ 3.36
- The measurements are done on 485 trajectories. The measurements start from 300th trajectory and are done every 4 trajectories until 2236th trajectory.

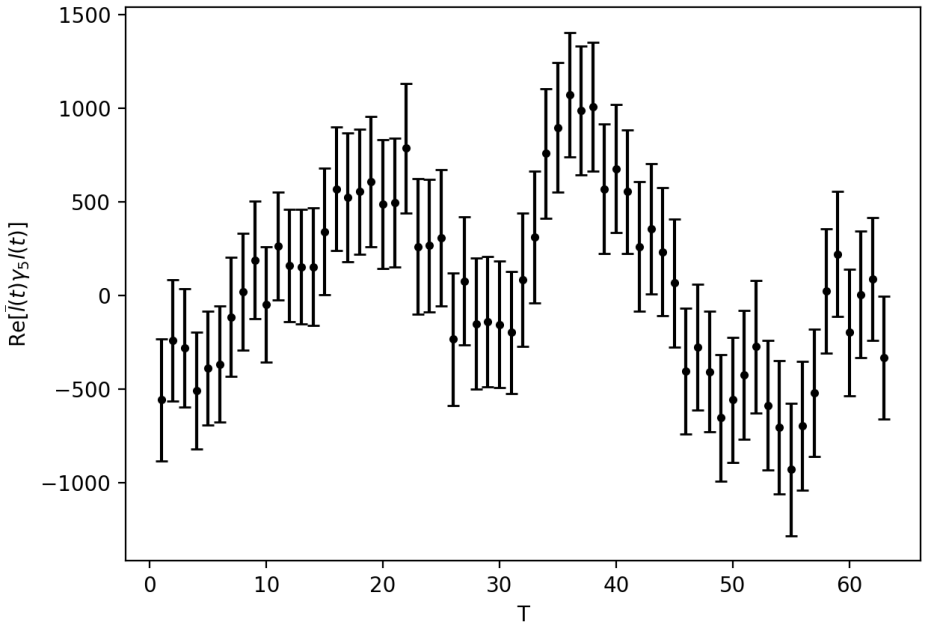
Topological charge

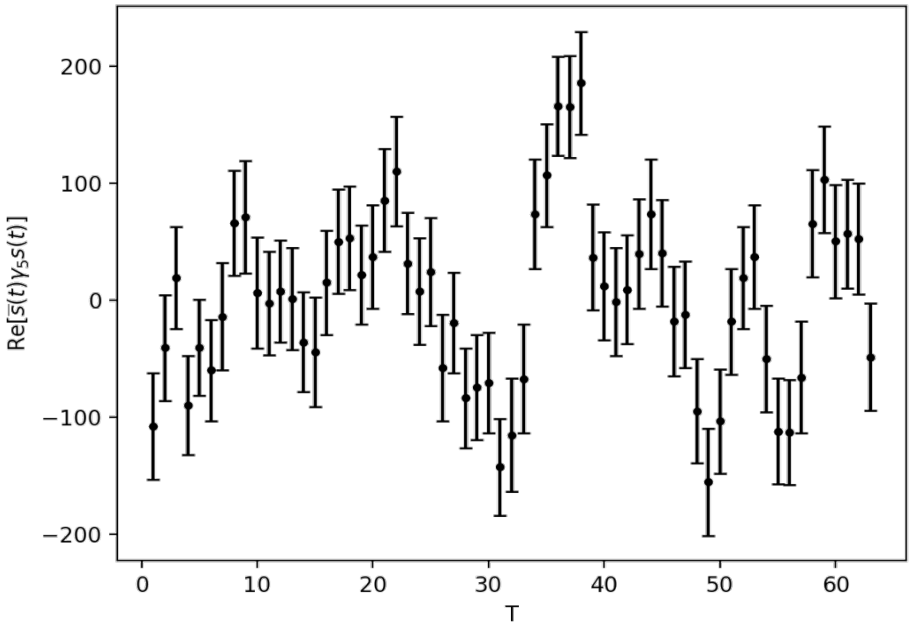
- The topological charges are measured by 5Li method[**Philippe de Forcrand *et al.* Nucl. Phys. B 1997**]



Quark self loops $\langle \bar{\psi}\gamma_5\psi \rangle$

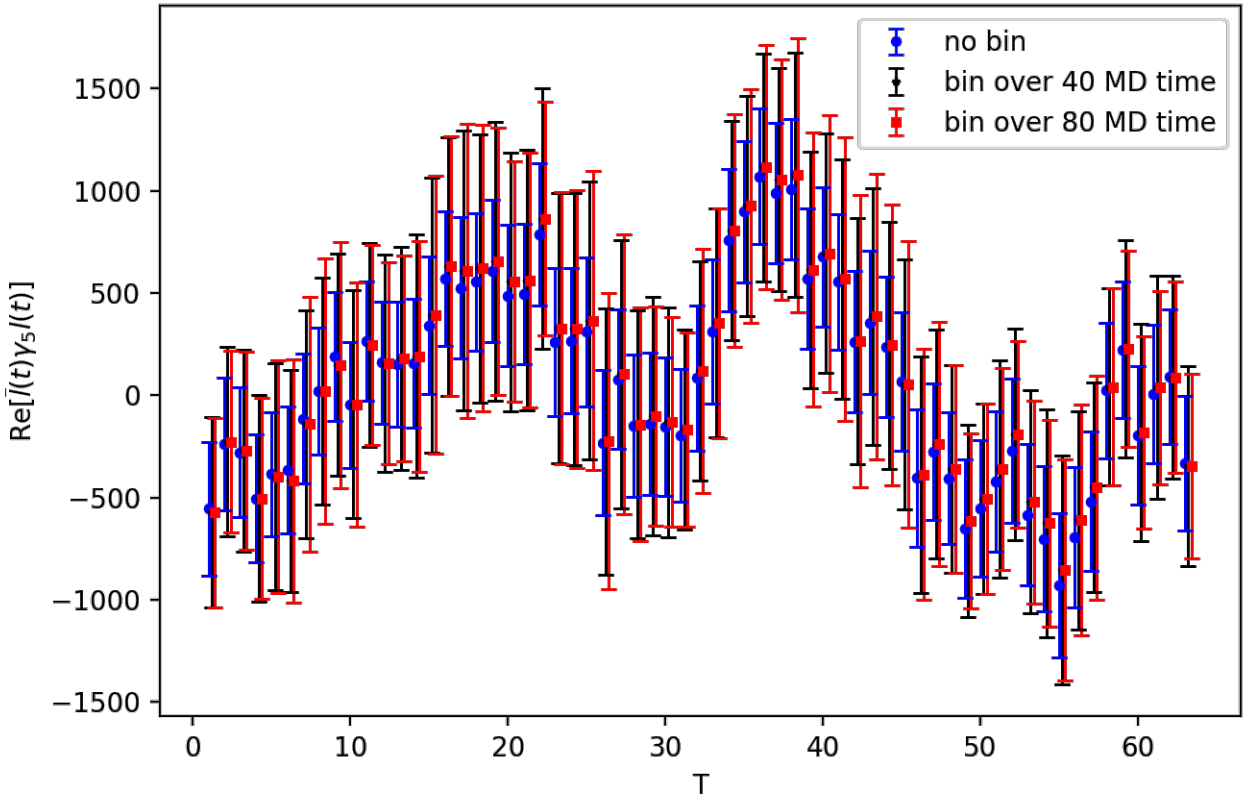
- Quark self loops are measured with wall sources(Coulomb gauge):

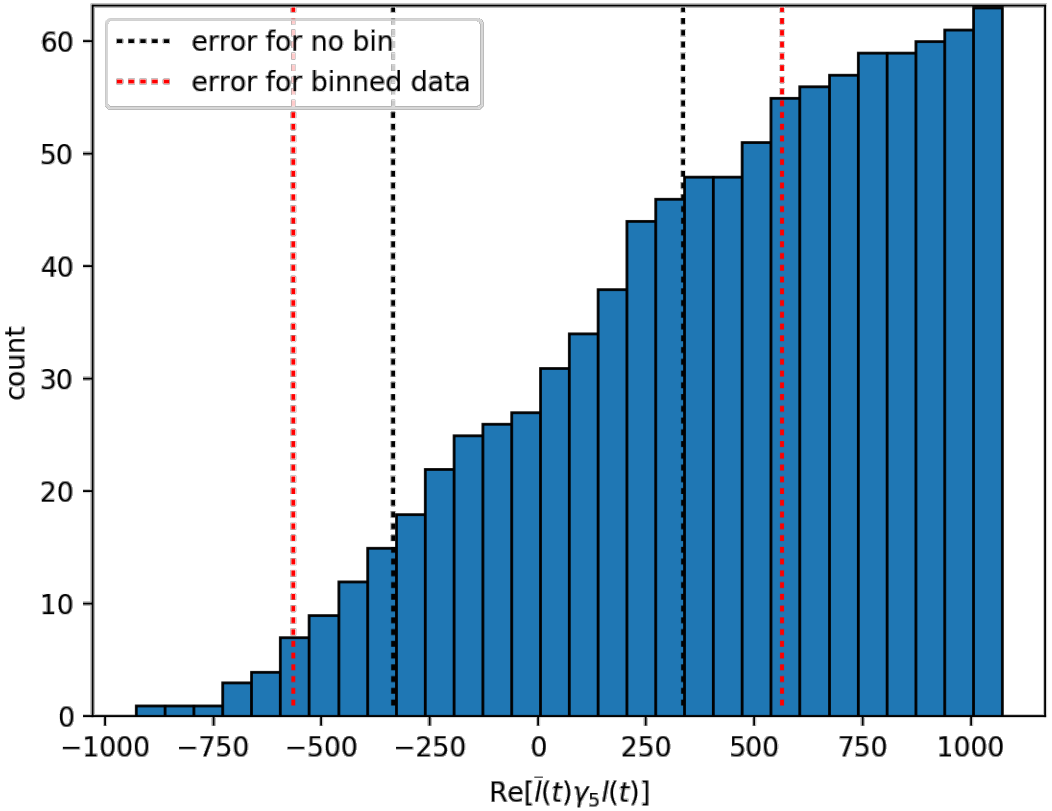




Quark self loops $\langle \bar{\psi}\gamma_5\psi \rangle$

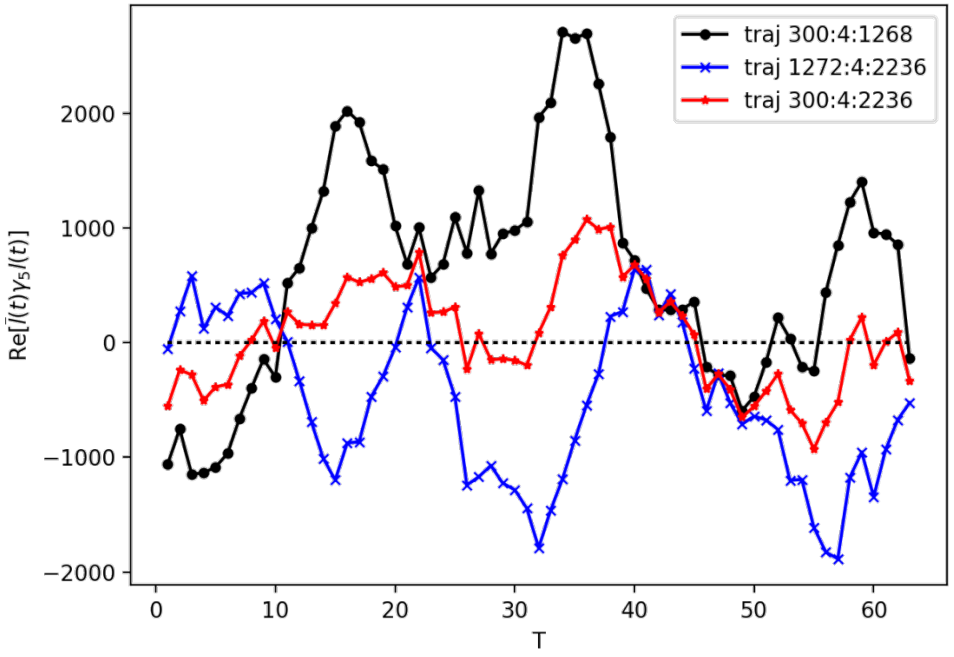
- Estimation of errorbars:

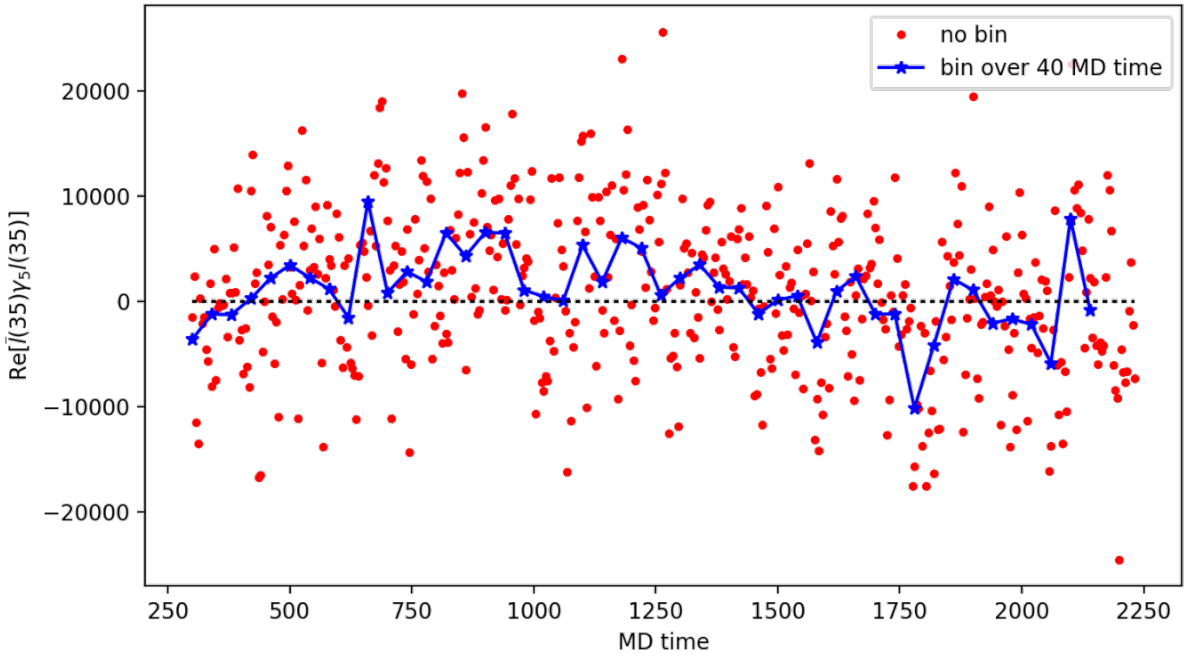




Long autocorrelation of quark self loops

- There are large fluctuations yet there is long correlation in MD time.





Diffusion model

- Consider correlation function in MD time:

$$C(t, t_0, \tau) \equiv \langle B(t, \tau_0 + \tau) B(t_0, \tau_0) \rangle$$

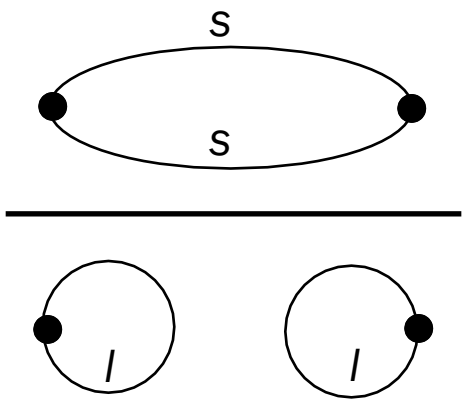
- here $B = Q$ or $\bar{\psi}\gamma_5\psi$. It's found that it satisfies the following diffusion equation[**Greg McGlynn and Robert D. Mawhinney Phys. Rev. D 2014**]:

$$\frac{\partial}{\partial \tau} C(t, t_0, \tau) = \frac{\partial}{\partial t}\left(D \frac{\partial}{\partial t} C(t, t_0, \tau)\right) - \frac{1}{\tau_{\mathrm{tunn}}} C(t, t_0, \tau)$$

- Fitting results:

	Q	$\bar{\psi}\gamma_5\psi$
D	0.095(9)	0.16(14)
τ_{tunn}	7.85(58)	8.52(80)

η' and η



- With approximate SU(3) flavor symmetries:

$$|\eta\rangle = \frac{1}{\sqrt{6}}\left(\bar{u}\gamma_5 u + \bar{d}\gamma_5 d - 2\bar{s}\gamma_5 s\right) \quad (Octet)$$

$$|\eta'\rangle = \frac{1}{\sqrt{3}}\left(\bar{u}\gamma_5 u + \bar{d}\gamma_5 d + 2\bar{s}\gamma_5 s\right) \quad (Singlet)$$

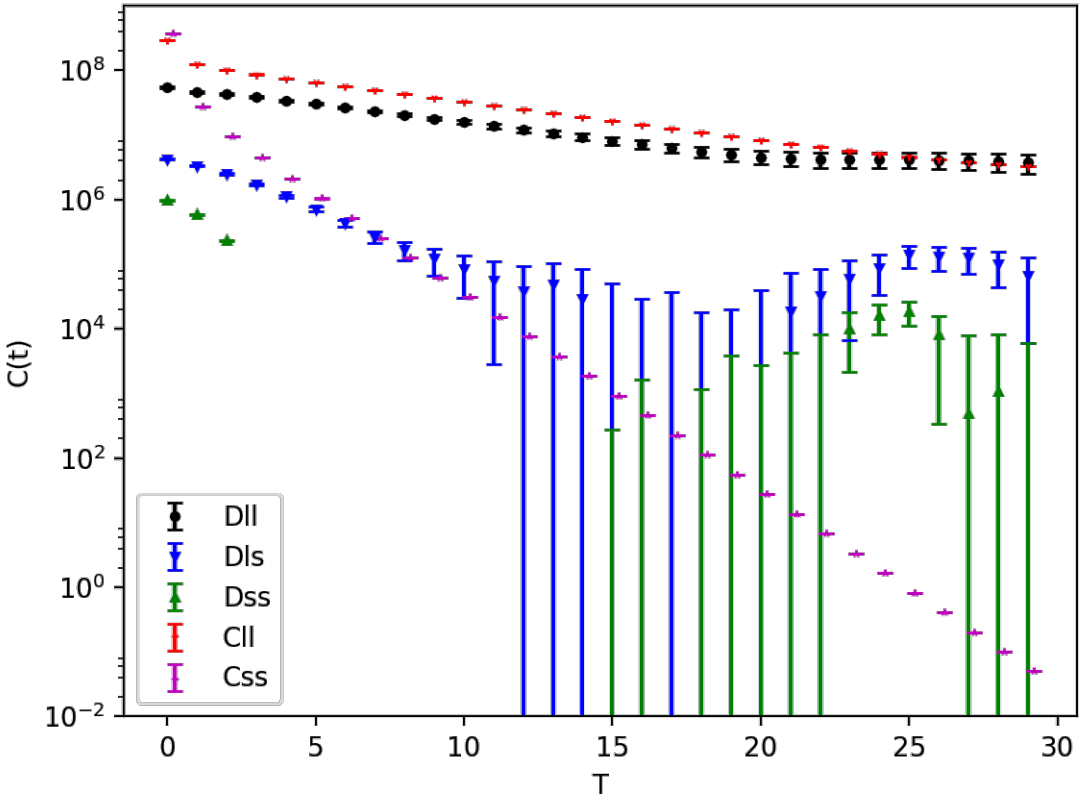
- With $|l\rangle = \frac{1}{\sqrt{2}}\left(\bar{u}\gamma_5 u + \bar{d}\gamma_5 d\right)$ and $|s\rangle = \bar{s}\gamma_5 s$[**Norman. H. Christ *et al.* Phys. Rev. Lett 2010**]:

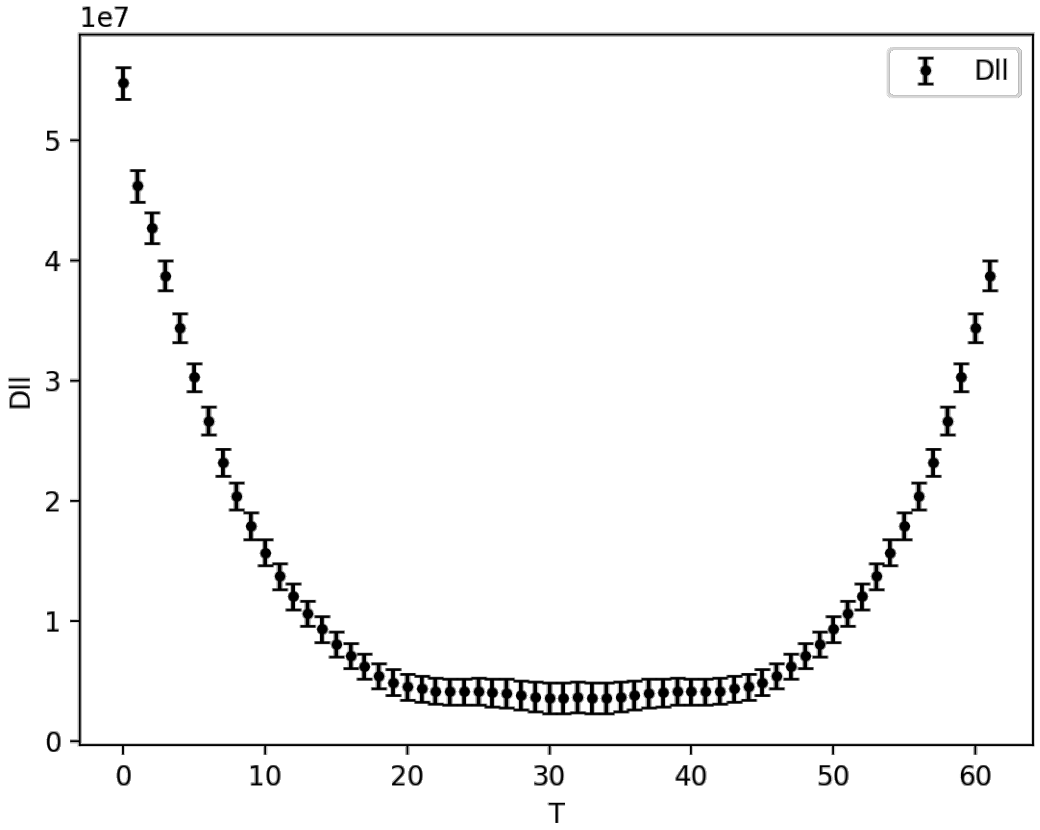
$$\begin{pmatrix} \langle l(t)l^\dagger(0)\rangle & \langle s(t)l^\dagger(0)\rangle \\ \langle l(t)s^\dagger(0)\rangle & \langle s(t)s^\dagger(0)\rangle \end{pmatrix} = \begin{pmatrix} C_{ll} - 2D_{ll} & -\sqrt{2}D_{ls} \\ -\sqrt{2}D_{ls} & C_{ss} - D_{ss} \end{pmatrix}$$

- We expect: $|\eta\rangle = \cos\theta|l\rangle - \sin\theta|s\rangle$ and $|\eta'\rangle = \sin\theta|l\rangle + \cos\theta|s\rangle$

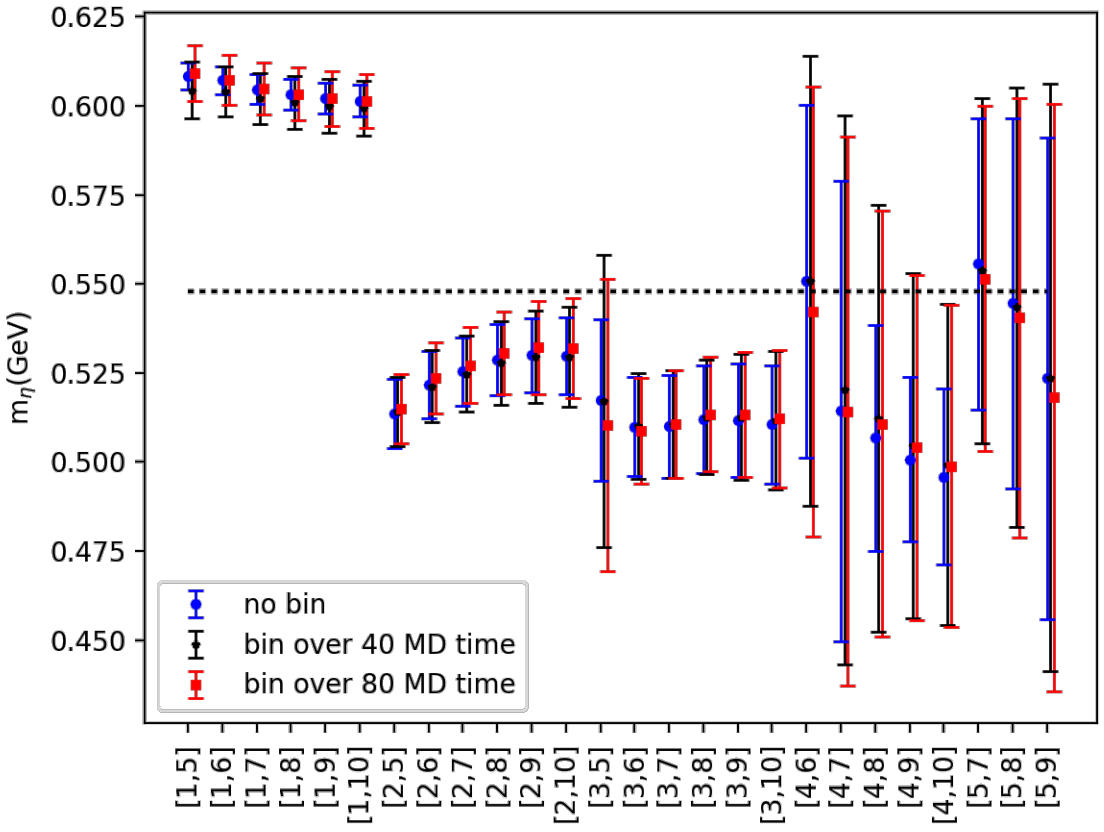
Correlators:

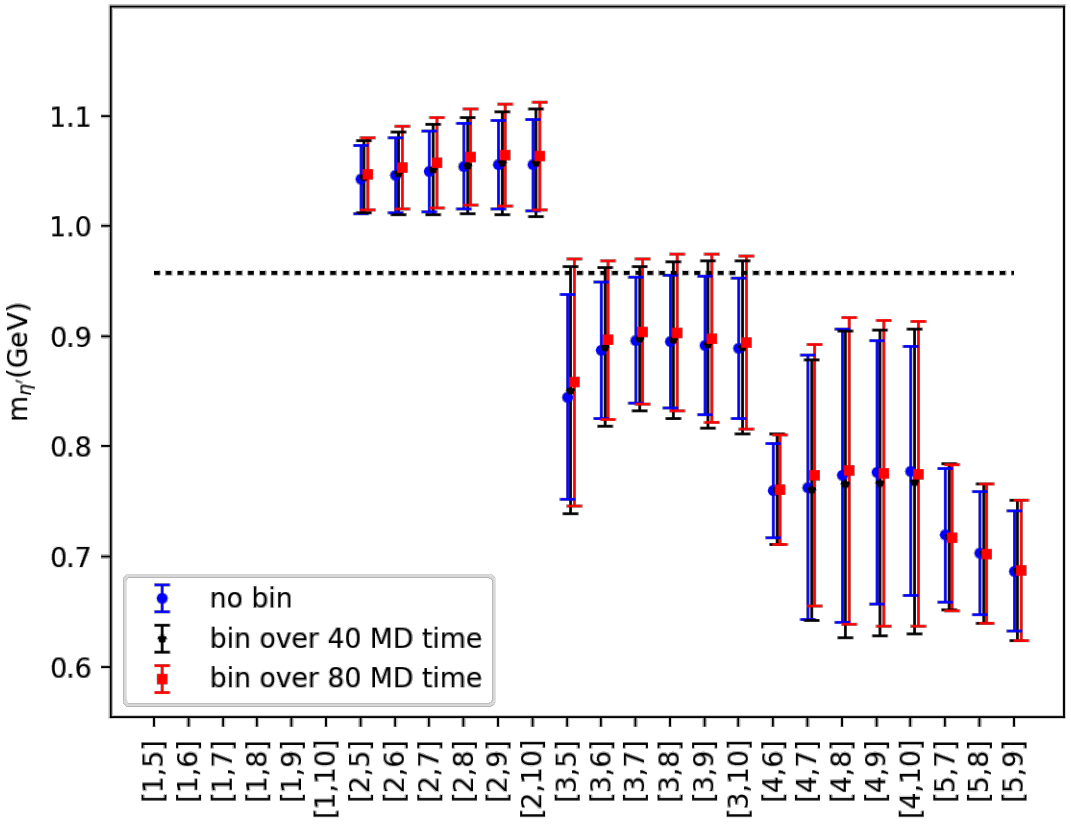
$$\mathscr{C}(t) = \begin{pmatrix} \mathscr{C}_{ll} & \mathscr{C}_{ls} \\ \mathscr{C}_{sl} & \mathscr{C}_{ss} \end{pmatrix} = \begin{pmatrix} C_{ll} - 2D_{ll} & -\sqrt{2}D_{ls} \\ -\sqrt{2}D_{ls} & C_{ss} - D_{ss} \end{pmatrix}$$





Fitting Results





Conclusion and outlook

- The quark self loops have long autocorrelation and our results suggest that there are large topological objects.
- The η' and η results agree with experimental results when measured on some ranges but more data are needed.
- We can use eigenvectors to investigate the specific distribution of instantons in future.

Thank you!