Lattice study of hadronic screening masses close to the deconfinement transition

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December 14, 2010

- In colloboration with S. Datta, S. Gupta, J. Maiti, N. Mathur.
- Thanks to Mr. K. Ghadiali and Mr. A. Salve.
- Computations done on Cray X1.

Introduction

- **Goal** : Investigate the properties of hadrons at finite temperature below T_c.
- By studying $Tr(h(z)h(0)e^{-\beta\mathcal{H}})$ of various hadrons at finite temperature.
- The long distance behaviour of the above quantity gives the "screening mass"($\mu(T)$). By comparing the screening masses at finite temperature with corresponding quantities in the zero temperature spectrum.

$$C_{AB}(z) = \langle A(z)B(0)\rangle - \langle A(0)\rangle\langle B(0)\rangle \sim_{z\to\infty} b\exp\left[-\mu(T)z\right]$$

  where $\mu(T)$ is the screening length.
- In lattice with periodic boundary condition, the long distance behaviour modifies to

$$C_{AB}(z) \sim_{z\to\infty} b\left(\exp\left[-\mu(T)z\right] + \exp\left[-\mu(T)(N_Z - z)\right]\right)$$

- Screening mass is the inverse of the spatial correlation length.

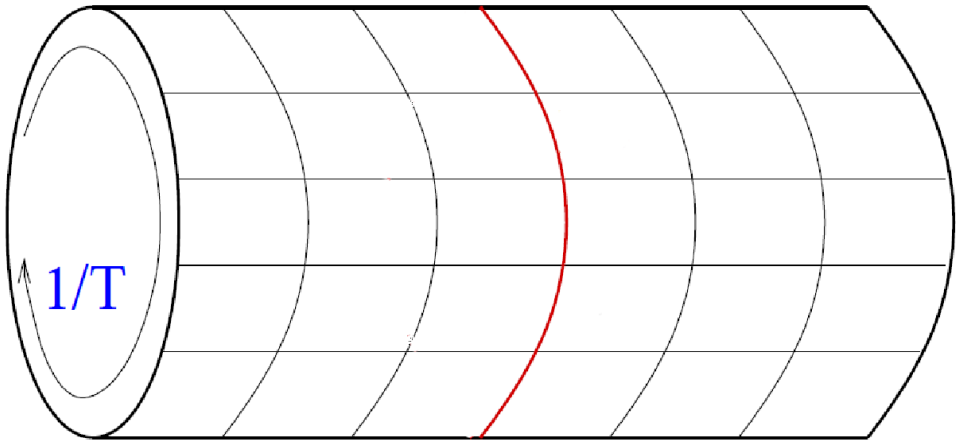
Finite temperature Lattice QCD

- The finite temperature functional integral

$$Z(T) = Tr(e^{-\beta\mathcal{H}}) = \int \mathcal{D}[\Phi] e^{-S_E[\Phi]}; \quad \beta = 1/T$$

where the integration over the (fermionic)bosonic fields is (anti-)periodic in the finite time direction.

$$S_E = S_E[U] = \int_{0,(a)pbc}^{1/T} dt \int_{\mathbb{R}^3} d^3x \mathcal{L}(U)$$

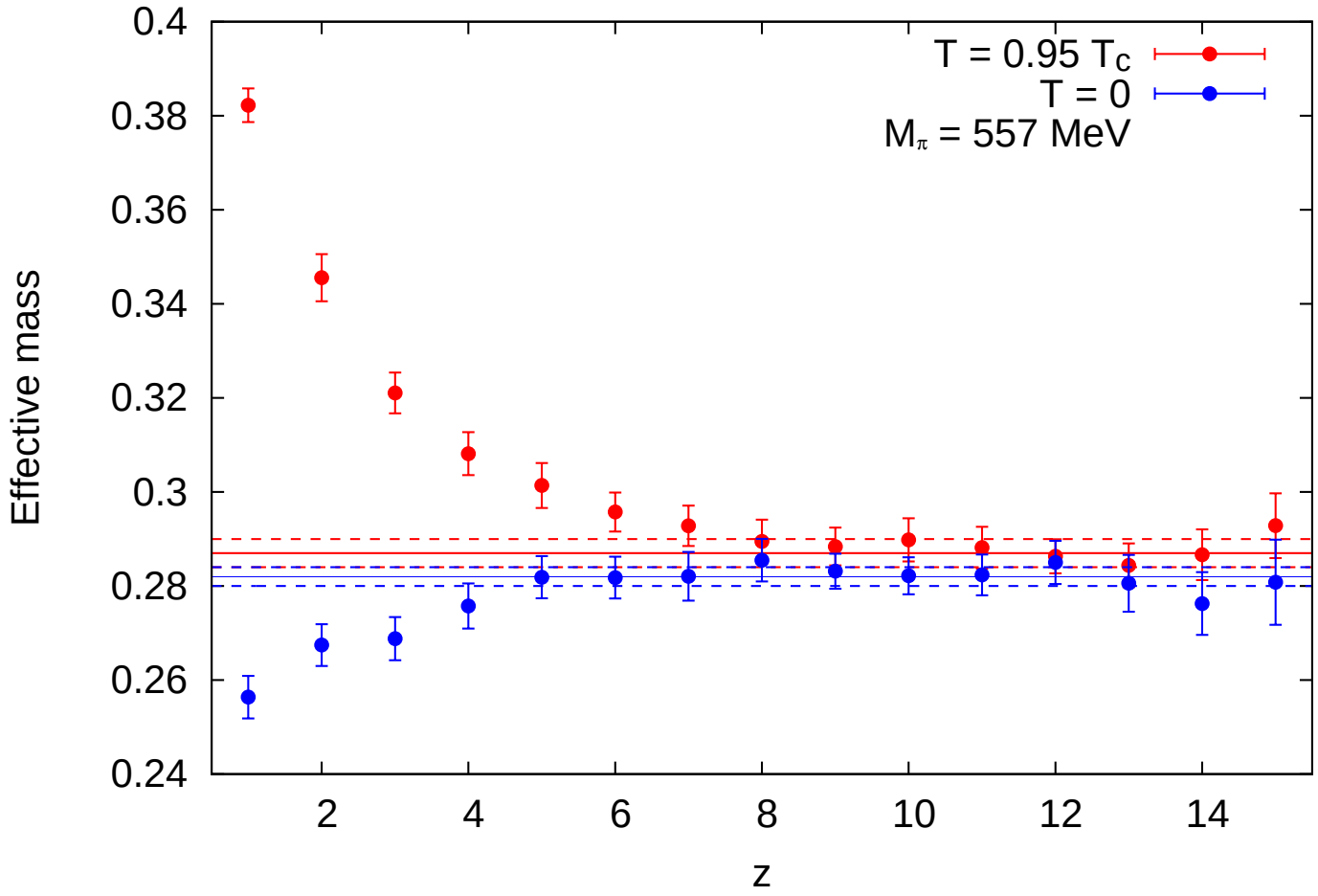


What we do?

- Quenched approximation : No quark loops.
- Improved Wilson fermion with clover action used.
- $T = 0.95\,T_c$, $a^{-1} = 2.05\,GeV$, $L_T = 4$ and $T = 0$ at same cut-off.
- Constructed different hadron correlators for different π masses ranging from $650\,MeV$ to $350\,MeV$.
- Pseudoscalar, vector, scalar mesons and nucleon are being investigated in this work.

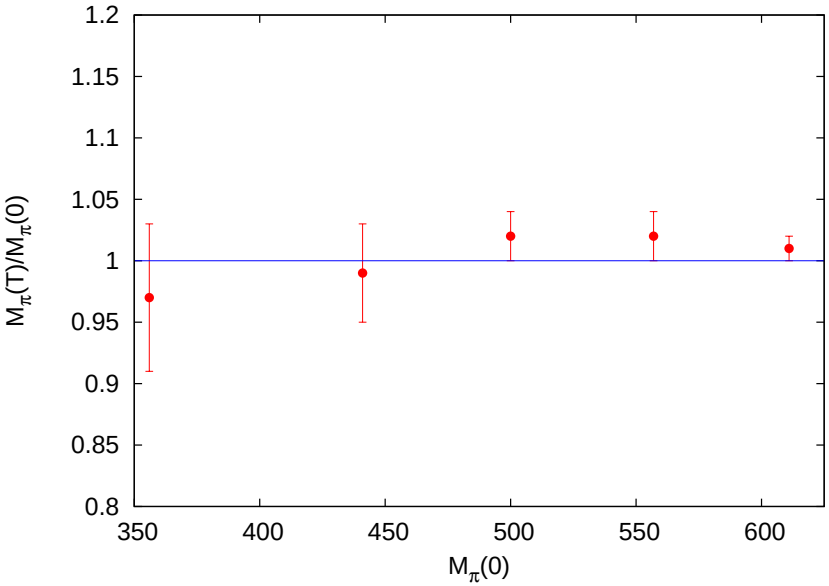
π-meson effective masses : Temperature dependence

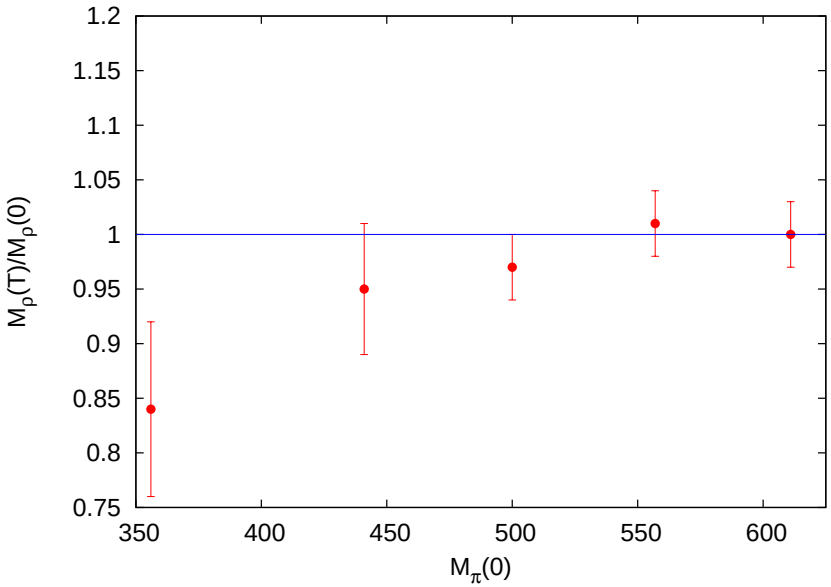
$$\mu = \log\left(\frac{C(z+1)}{C(z)}\right)$$



$$C(z) = A\cosh(m(N_Z/2 - z))$$

π- and ρ- meson fit masses





No significant temperature dependence was found in the π- meson screening masses. The ρ- meson screening masses is found to show some statistical insignificant deviations from the zero temperature at lower M_π.

Scalar meson correlators

- Long distance behaviour of bosonic correlation function is

$$\lim_{z \to \infty} C_{ii}(z) = A\{e^{-E_1 z} + e^{-E_1(\beta - z)}\} + \mathcal{O}\{\text{excited states}\}$$

- Scalar correlator takes negative values.
- Quenched χPT : The operator has significant overlap with two states: a) the η-π ghost states , b) the scalar meson, a_0.

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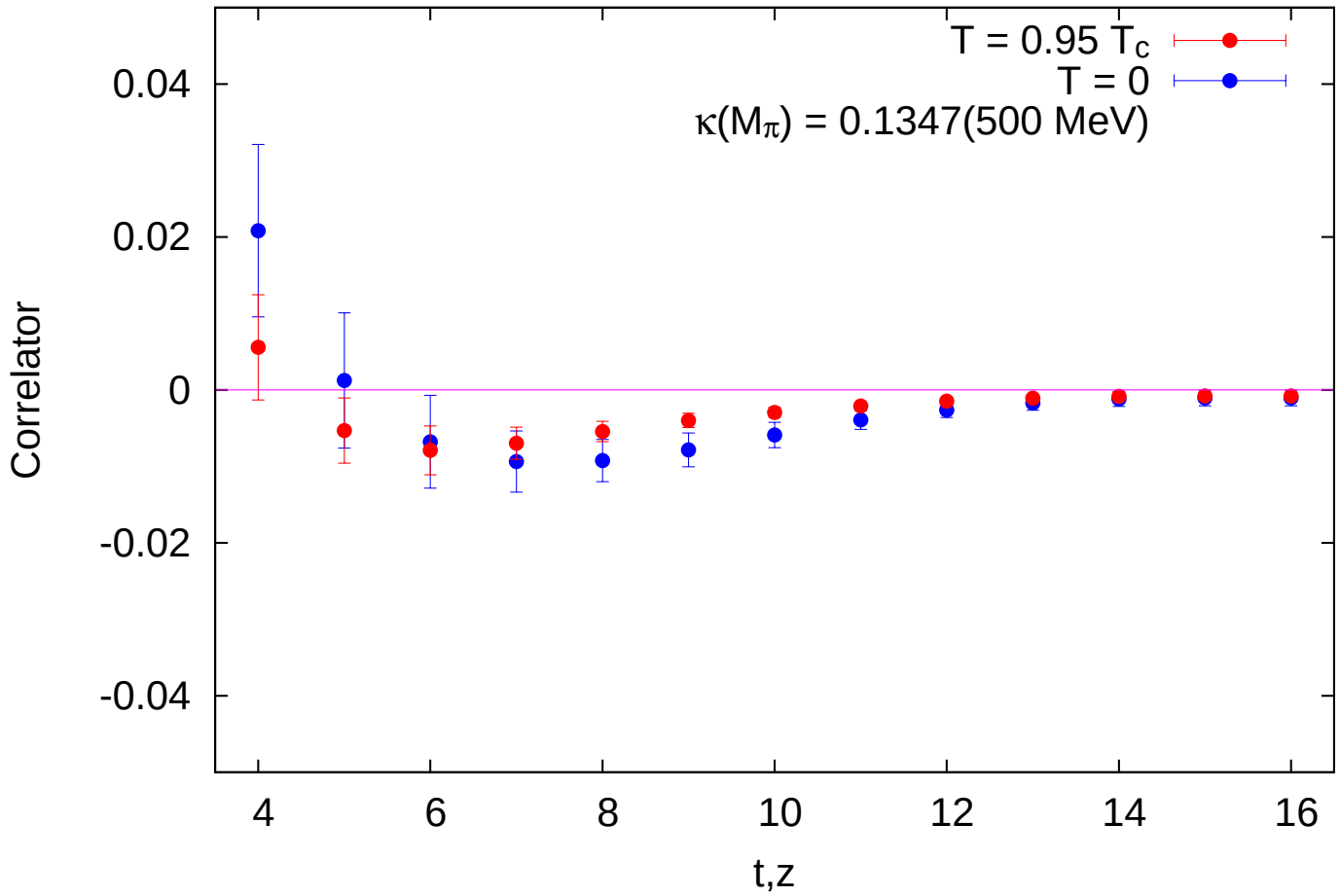
- Quenched χPT : The modified leading form of the scalar screening correlator is given by

$$C(z) = A(e^{-m_{a_0} z} + e^{-m_{a_0}(N_Z - z)}) - B(1 + M_\pi z)e^{-2Mz}$$

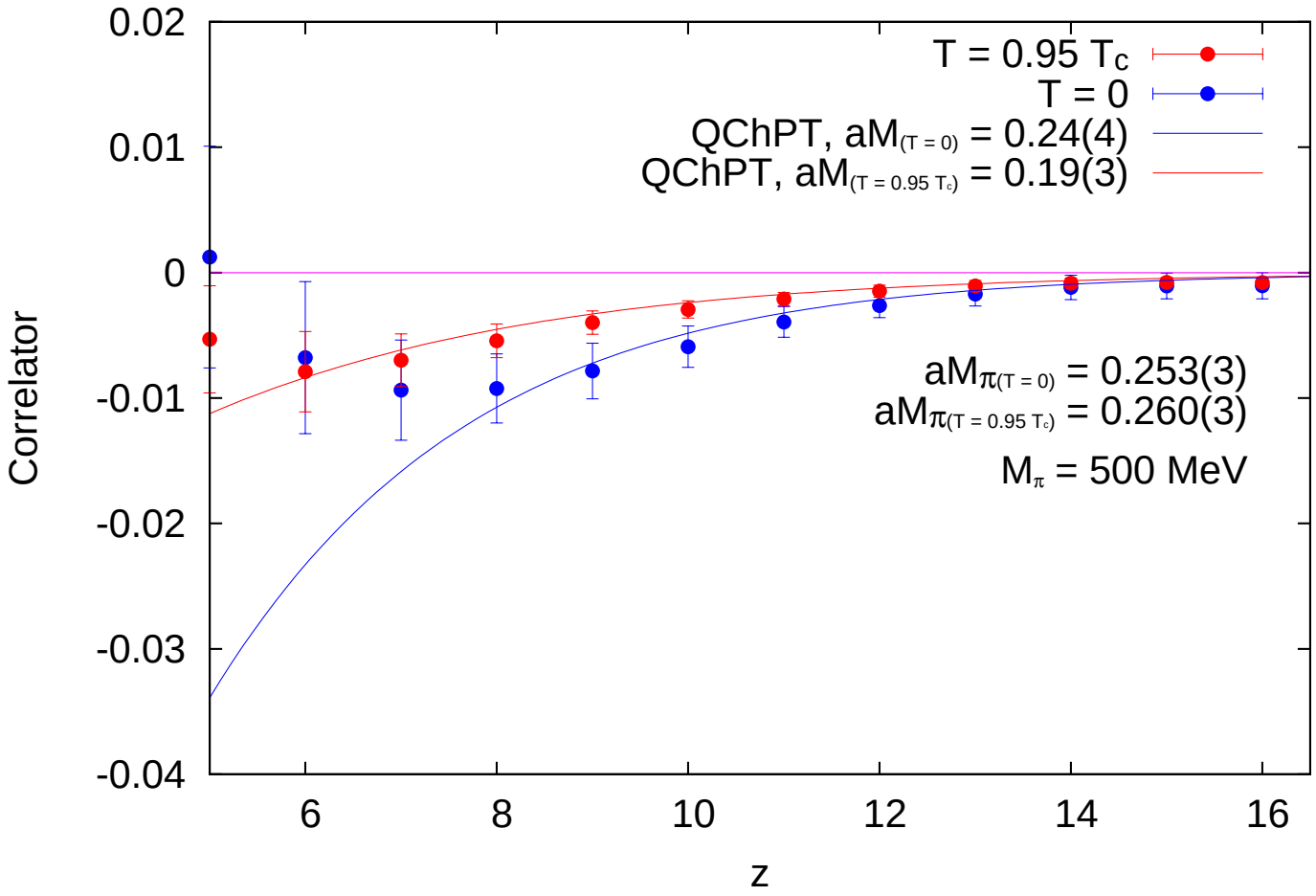
[Bardeen. et. al. 2001], [N. Mathur, et. al. 2006]

- Larger M_π, ghost term couples less to the scalar channel.

Scalar correlators : Temperature dependence

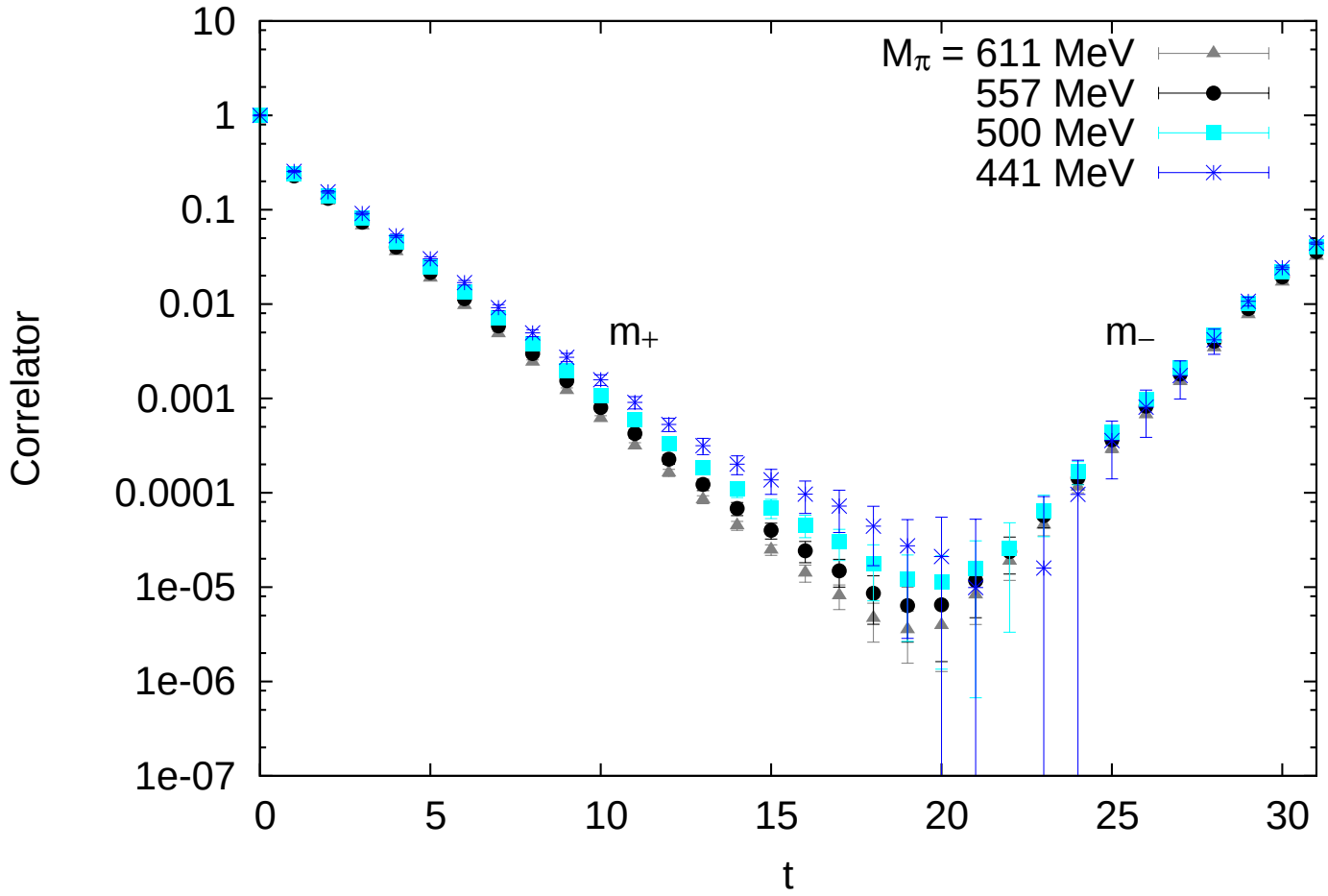


Scalar correlators : Temperature dependence



Nucleon correlators : Zero temperature, even parity channel

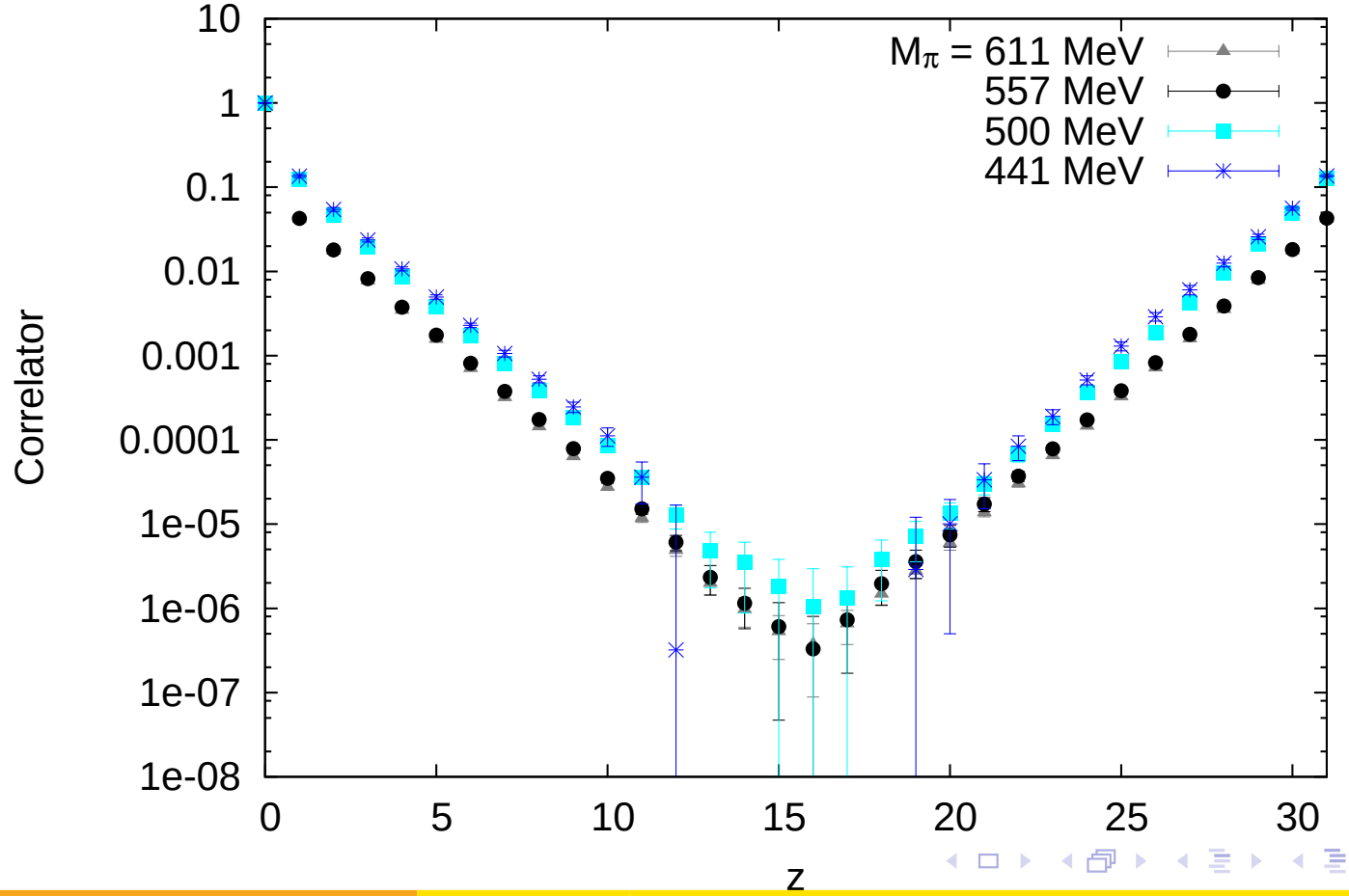
$$\langle \mathcal{N}(t)\bar{\mathcal{N}}(0)\rangle = B_+ e^{-m_+ t} - B_- e^{-m_-(N_T - t)}$$



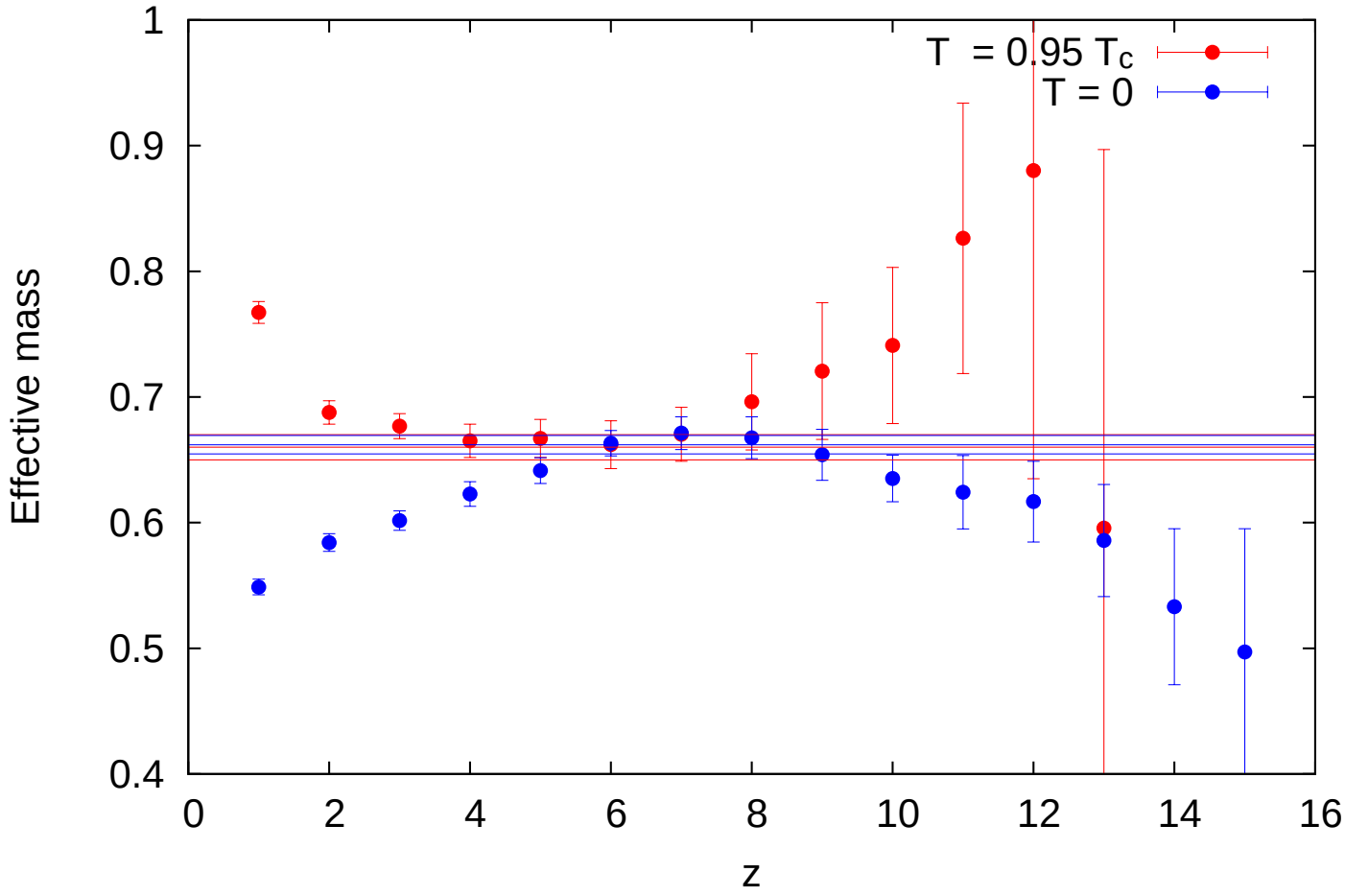
Nucleon correlators : Finite temperature, even parity channel

The long distance behaviour of nucleon screening correlator at finte temperature is not the same.

- The difference in boundary conditions imposed.
- Matsubara frequency for fermion modes.



Nucleon effective masses : Temperature dependence, even parity channel



Conclusion

- We study hadronic screening lengths at high temperature in the hadronic phase. Screening masses found to be close to ($T = 0$) particle masses.
- Interesting trends of finite temperature effects observed in some channels. But the effect is not statistically significant at the moment. Future investigations will focus on these in detail.
- No significant temperature dependence was observed in π- meson screening masses.
- ρ- meson screening masses were observed to show some statistically insignificant signatures of deviation from the zero temperature physics towards lower M_π.
- We have the first observation of the η-π ghost states at finite temperature. Interesting changes were observed in the behaviour of the scalar correlator from zero temperature.
- We also have studied nucleon channels. Expected large distance(time) behaviour was observed in the screening (temporal) correlators. The nucleon screening masses were found to be matching with zero temperature results.