Chromo-electric screening length in 2+1 flavor QCD

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What is the chromo-electric screening lenght in QCD ?

Use smeared Polyakov loop correlators to enhance the signal at large distances

PP, Sebastian Steinbeißer, Johannes Weber, work in progress

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Deconfinement and color screening

Onset of color screening is described in terms of the free energy of static quark anti-quark pair

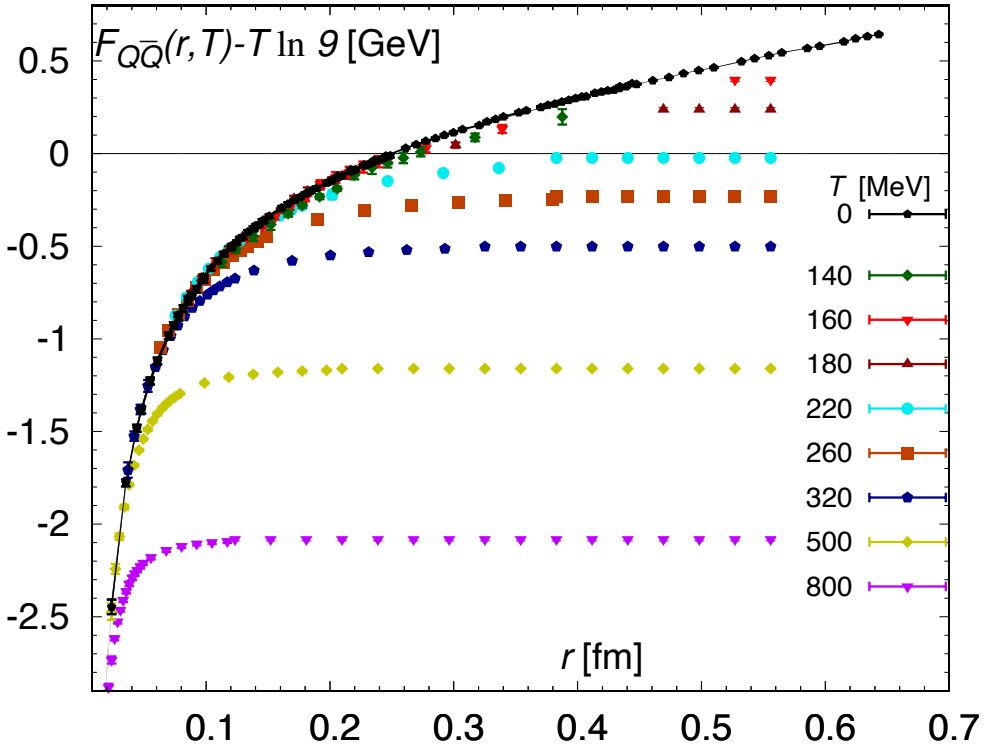
$$L(x) = \mathcal{P} \exp\left(-ig \int_0^{1/T} d\tau A_0(x,\tau)\right)$$

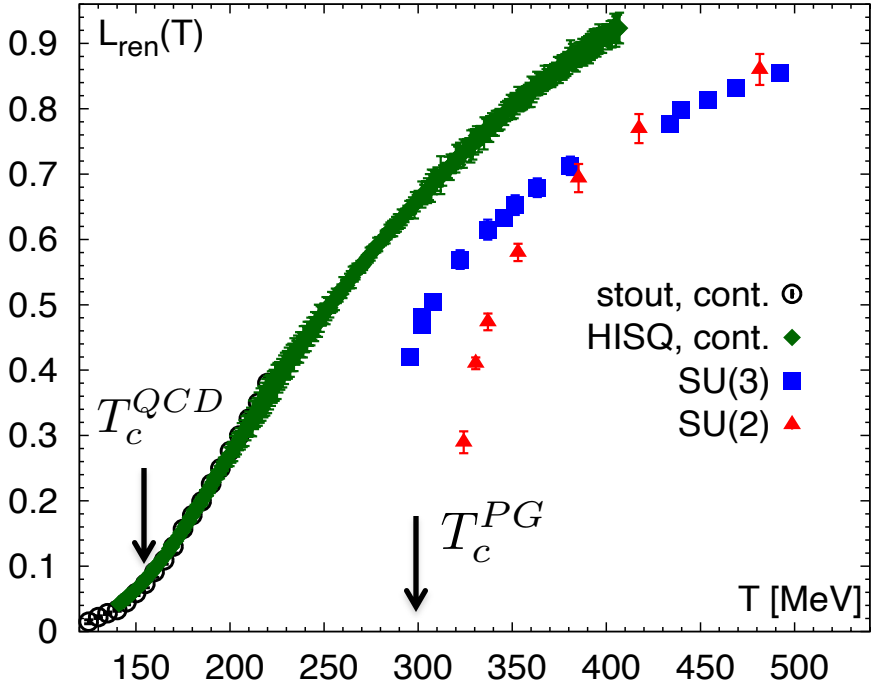
$$\exp(-F_{Q\bar{Q}}(r,T)/T) = \frac{1}{9}\langle \mathrm{tr}L(r)\mathrm{tr}L^{\dagger}(0)\rangle$$

$$L_{ren} = \exp(-F_Q(T)/T)$$

$$F_{Q\bar{Q}}(r \to \infty, T) = 2F_Q(T)$$

TUMQCD, PRD 98 (2018) 054511





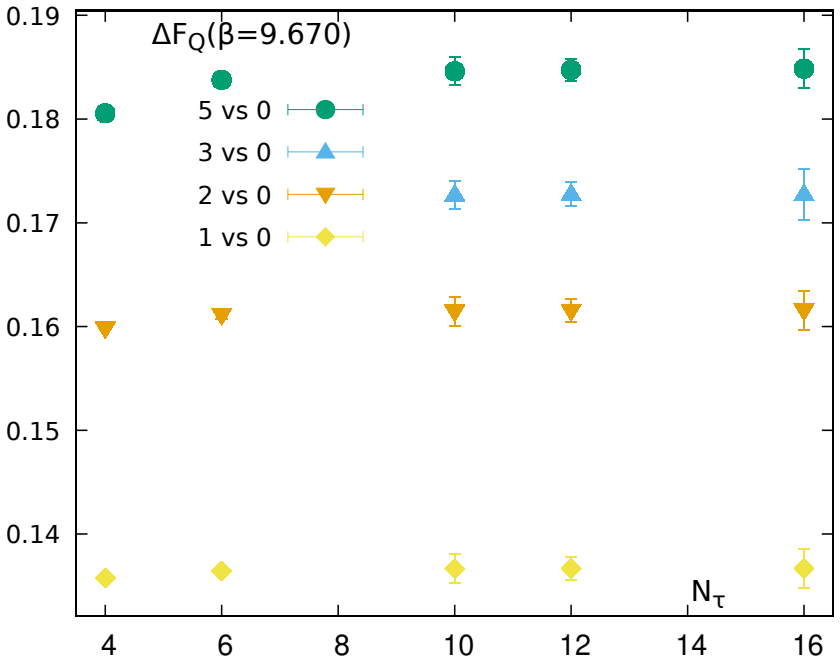
What is the screening mass (length) ? Challenge : poor signal for large separations

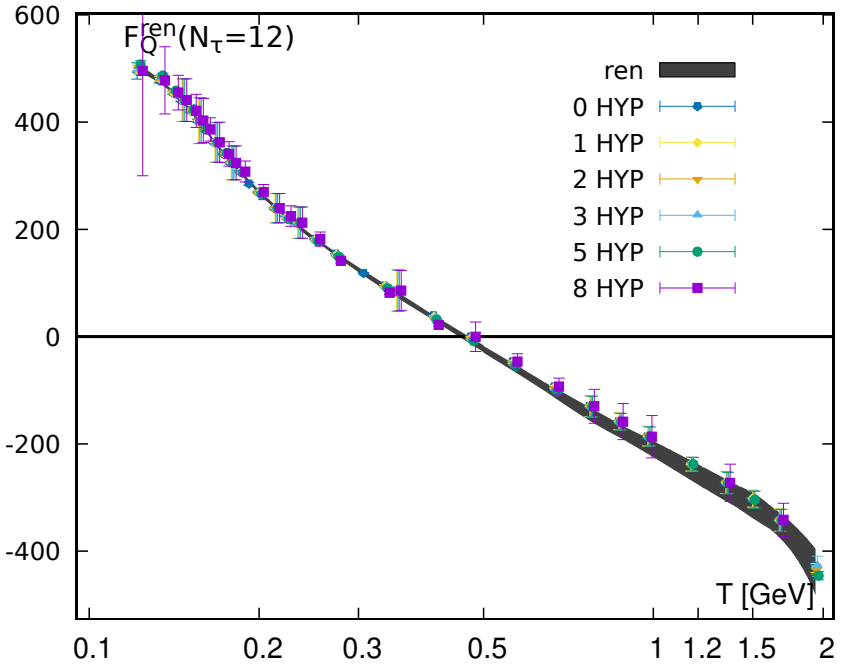
Smeared Polyakov loops

Use several steps of HYP smearing, *h=0,1,2,3,5, 8* on gauge configurations to improve the noise

2+1 flavor QCD, HISQ action, $m_l = m_s/20 \leftrightarrow m_\pi = 160$ MeV, $N_\sigma \times N_\tau$ lattices with $N_\tau = 4,\ 6,\ 8,\ 10,\ 12$ and 16, $N_\sigma/N_\tau = 4$ or 6 $\quad T = 155 - 6000$ MeV

$$\Delta F_Q = F_Q^h - F_Q^{h'}$$

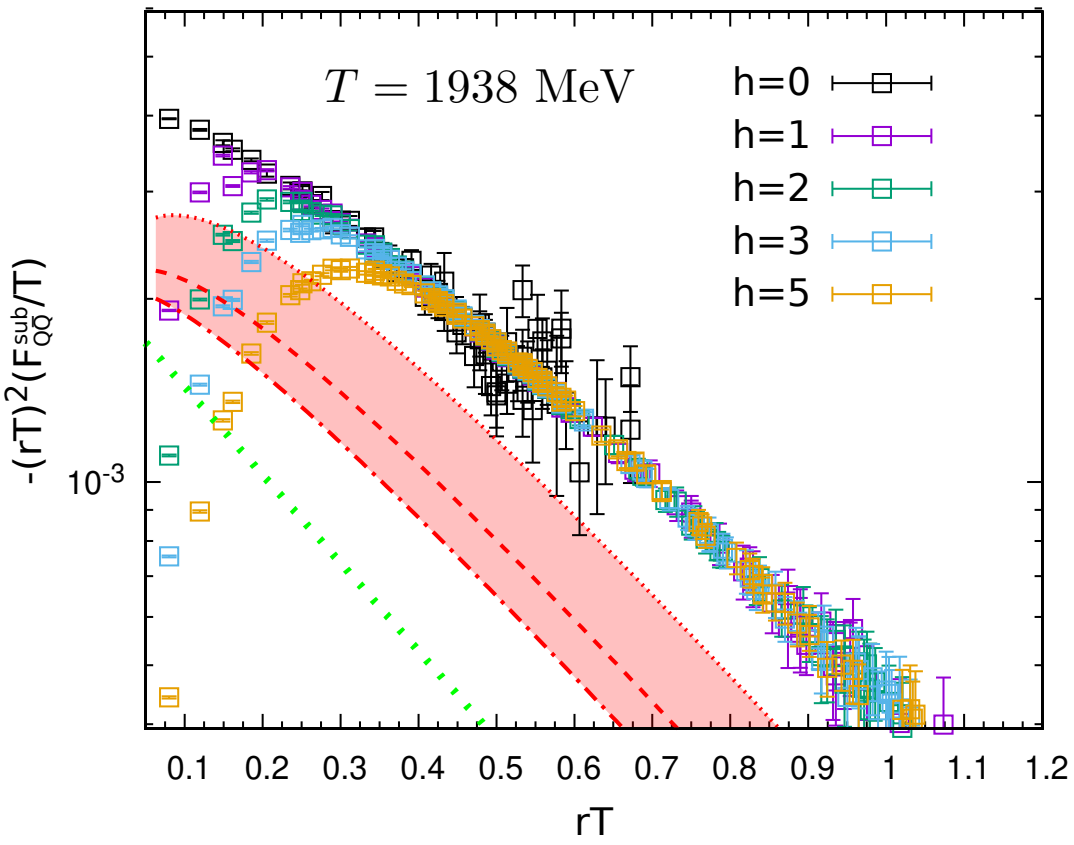




HYP smearing only causes a T-independent shift of F_Q, the T-depenence is not affected by smearing for $N_\tau > 4$

Free energy of static quark anti-quark with smearing

$$F^{sub}_{Q\bar{Q}}(r,T) = F_{Q\bar{Q}}(r,T) - 2F_Q(T)$$



- HYP smearing largely improves the signal at large r for $F_{Q\bar{Q}}(r,T)$
- There is an overlap region for different smearing levels
- There is no distortion for $r > 0.4/T$ where screening sets in
- The lattice results are significantly larger than the LO and NLO perturbative result for $0.4 < rT < 0.8$

Correlators of real and imaginary part of the Polyakov loop

$$C_{PL}(r,T) = C^R_{PL}(r,T) + C^I_{PL}(r,T),$$

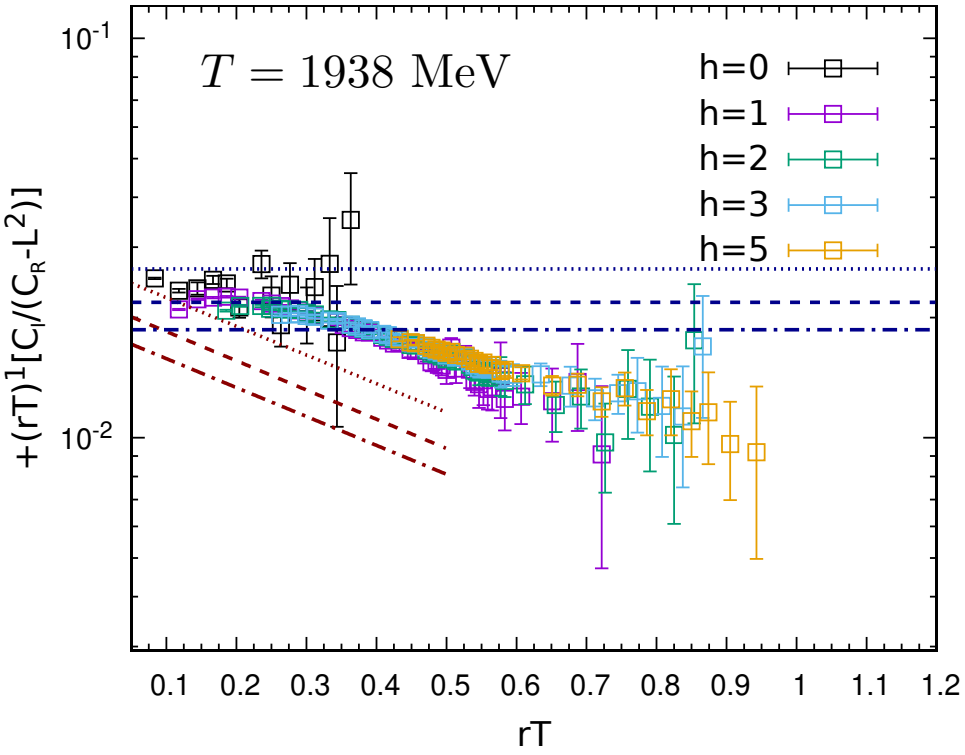
$$C^R_{PL}(r,T) = \langle \mathrm{Re}L(r) \cdot \mathrm{Re}L(0) \rangle, C^I_{PL}(r,T) = \langle \mathrm{Im}L(r) \cdot \mathrm{Im}L(0) \rangle.$$

LO perturbative result:

$$C^R_{PL}(r,T) = 1 + 2F^{(0)}_Q + g^4 \frac{N^2-1}{8N^2} \left(\frac{e^{-m_D r}}{4\pi r T} \right)^2, \; C^I_{PL}(r,T) = g^6 \frac{N^2-1}{8N^2} \frac{N^2-4}{12N} \left(\frac{e^{-m_D r}}{4\pi r T} \right)^3$$

2-gluon exchange

3-gluon exchange



data with r/a < #HYP are cut away

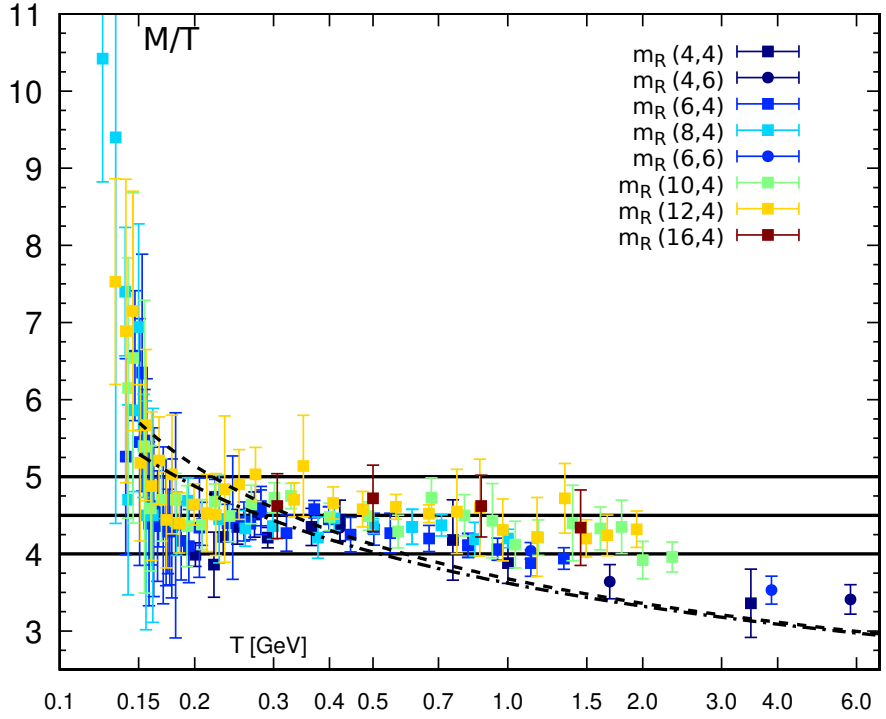
- HYP smearing largely improves the signal at large r for $F_{Q\bar{Q}}(r,T)$
- There is an overlap region for different smearing levels
- The lattice results agree with LO result for result for $rT < 0.4$ but are above the LO result at large distances

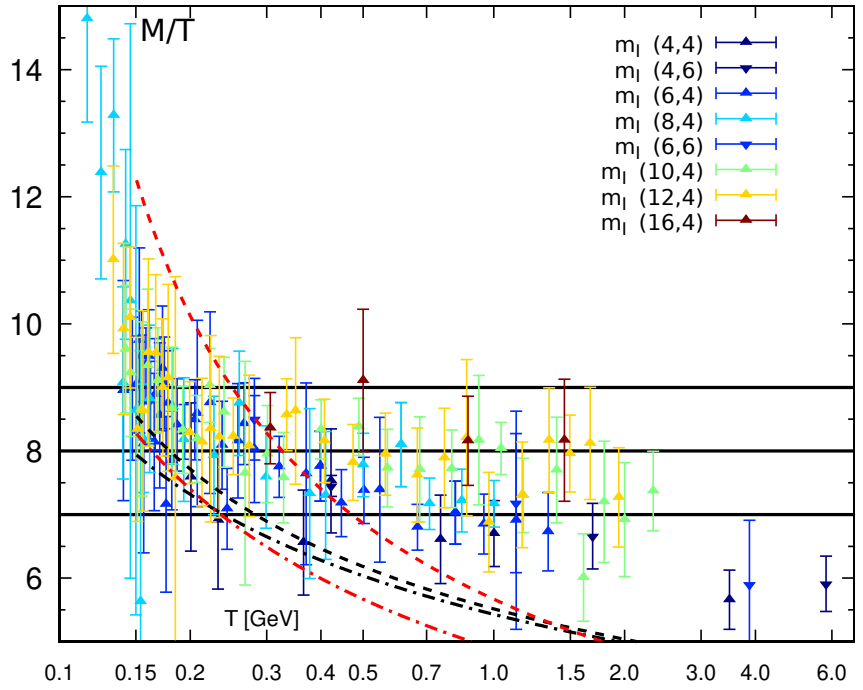
Electric screening masses from the Polyakov loop correlators

The large distance behavior of the correlation functions is governed by screening masses:

$$C_R(r,T) \sim \exp(-m_R(T)r)/r,\ C_I \sim \exp(-m_I(T)r)/r$$

In the weak coupling picture $m_I/m_R \simeq 3/2$ and $m_R \simeq 2m_D, m_I \simeq 3m_D$





No quantitative agreement between the lattice and the perturbative results but the lattice Results are consistent with the picture of chromo-electric gluon exchange picture:

$m_I/m_R \simeq 1.75$

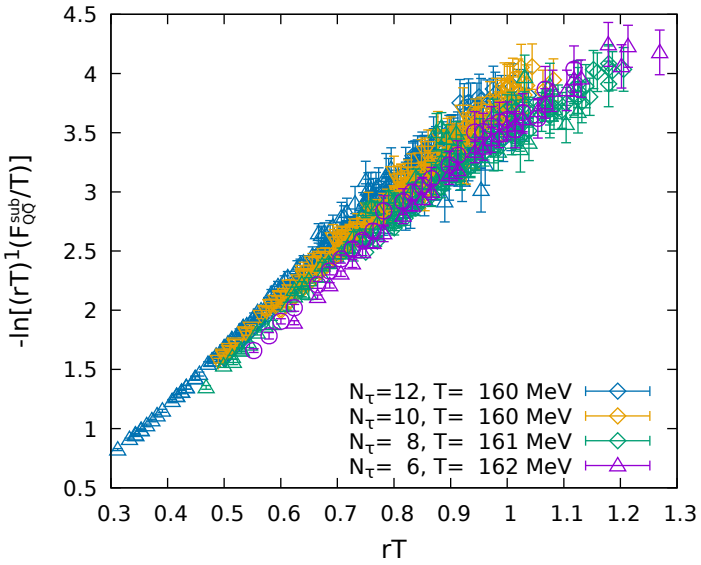
Conclusions

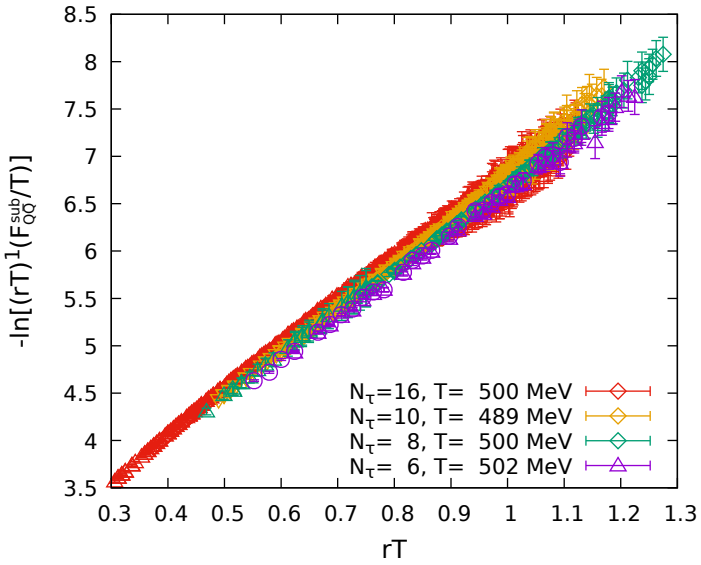
- HYP smearing largely improves the signal in the Polyakov loop and Polyakov loop correlators and the distortion due to smearing can be controlled
- The free energy of static $Q\bar{Q}$ obtained on the lattice for $0.4 < rT < 0.8$ is significantly larger than the NLO perturbative prediction
- The correlator of the imaginary part of the Polyakov loop is well described by LO perturbative result for $rT < 0.4$, but is larger than the LO result for $rT > 0.4$
- We determined the screening masses for the correlator of the real and imaginary part of the Polyakov loop and found $m_R/T \simeq 4.5$ and $m_I/T \simeq 8$ corresponding to screening length of $(0.38 - 0.44)T^{-1}$; Similar results in

  Borsanyi et al, JHEP 04 (2015) 138

  Datta, Gupta PRD67 (2003) 054503 (for the ratio of the screening masses in quenched QCD)

Back-up


-ln[(rT)^1(F_QQ^sub/T)]
rT
N_τ=12, T= 160 MeV
N_τ=10, T= 160 MeV
N_τ= 8, T= 161 MeV
N_τ= 6, T= 162 MeV


-ln[(rT)^1(F_QQ^sub/T)]
rT
N_τ=16, T= 500 MeV
N_τ=10, T= 489 MeV
N_τ= 8, T= 500 MeV
N_τ= 6, T= 502 MeV