

The screening spectrum of high-temperature QCD: static and non-static mesonic modes

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Introduction

Screening masses characterize the **spatial structure** of the Quark-Gluon Plasma

Length scales over which strong interaction is **screened** when a given particle is placed in the QCD thermal medium

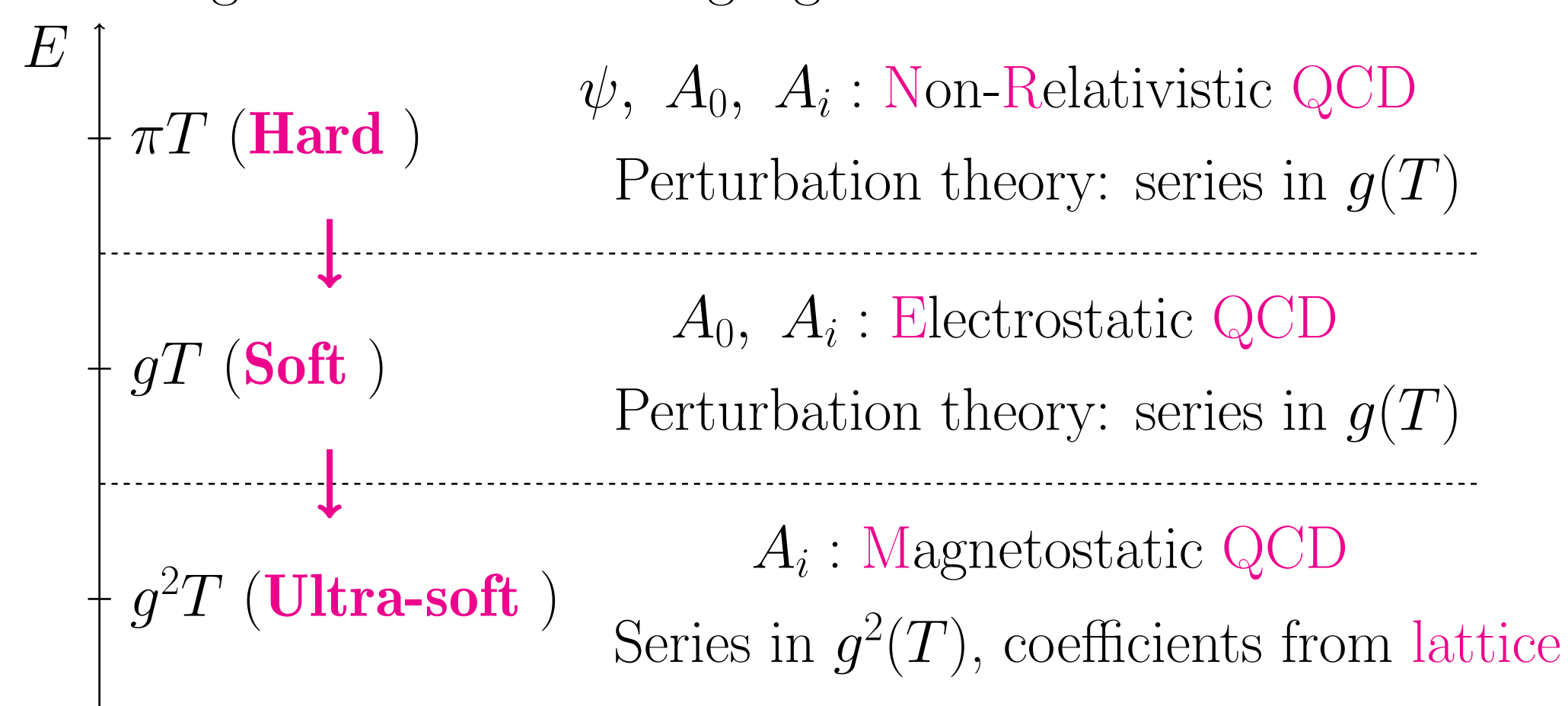
Extracted from **spatial correlators**: $\mathcal{C}_{O_\Gamma}^{(n)}(x_3) = \int_0^{L_0} dx_0 \int dx_1 dx_2 \exp\{i\omega_n x_0\} \langle O_\Gamma(x) O_\Gamma^\dagger(0) \rangle \propto_{x_3 \rightarrow \infty} \exp\{-m_{O_\Gamma}^{(n)} x_3\}$

We consider **flavor non-singlet mesonic operators** $O_\Gamma = \bar{\psi} \frac{\lambda^a}{2} \Gamma \psi$ with $\omega = 0$ (**static**) $\omega = 2\pi T$, $4\pi T$ (**non-static**)

Channel	S^a	P^a	V_T^a	A_T^a	V_0^a	A_0^a	V_3^a	A_3^a
Γ	1	γ_5	$\gamma_{1,2}$	$\gamma_5 \gamma_{1,2}$	γ_0	$\gamma_5 \gamma_0$	γ_3	$\gamma_5 \gamma_3$

High Temperature Effective Field Theory

Integrate out non-static gauge fields $\rightarrow$ **3D EFT tower**



- **Static** screening masses: $2\pi T \left(1 + b_2^{(0)} \cdot g^2 + \mathcal{O}(g^3)\right)$ [1]
- **Non-static** screening mass: $2n\pi T \left(1 + b_2^{(n)} \cdot g^2 + \mathcal{O}(g^3)\right)$ [2]
- **Hyperfine splitting** in static mesons: $s_4 g^4 + \mathcal{O}(g^5)$ [3,4]

Non-perturbative lattice strategy

LQCD at High T $\rightarrow$ **Window problem**: $a \ll T^{-1} \ll M_{\text{Had}}^{-1} \ll L$
Unfeasible for $T > 1$ GeV

Solution: **go with the flow!**

Non-perturbative renormalization of the coupling [5]

$$g_{\text{SF}}^2(a\mu, g_0^2) = \bar{g}_{\text{SF}}^2(\mu), \quad a\mu \ll 1, \quad \mu = L_0^{-1} = \sqrt{2}T$$

Contact with hadronic scale at low μ , reach high μ with **non-perturbative RG running**

Finite volume effects **exponentially suppressed** with $g^2 T L$

12 temperatures, 3-4 lattice spacings each: **43** ensembles

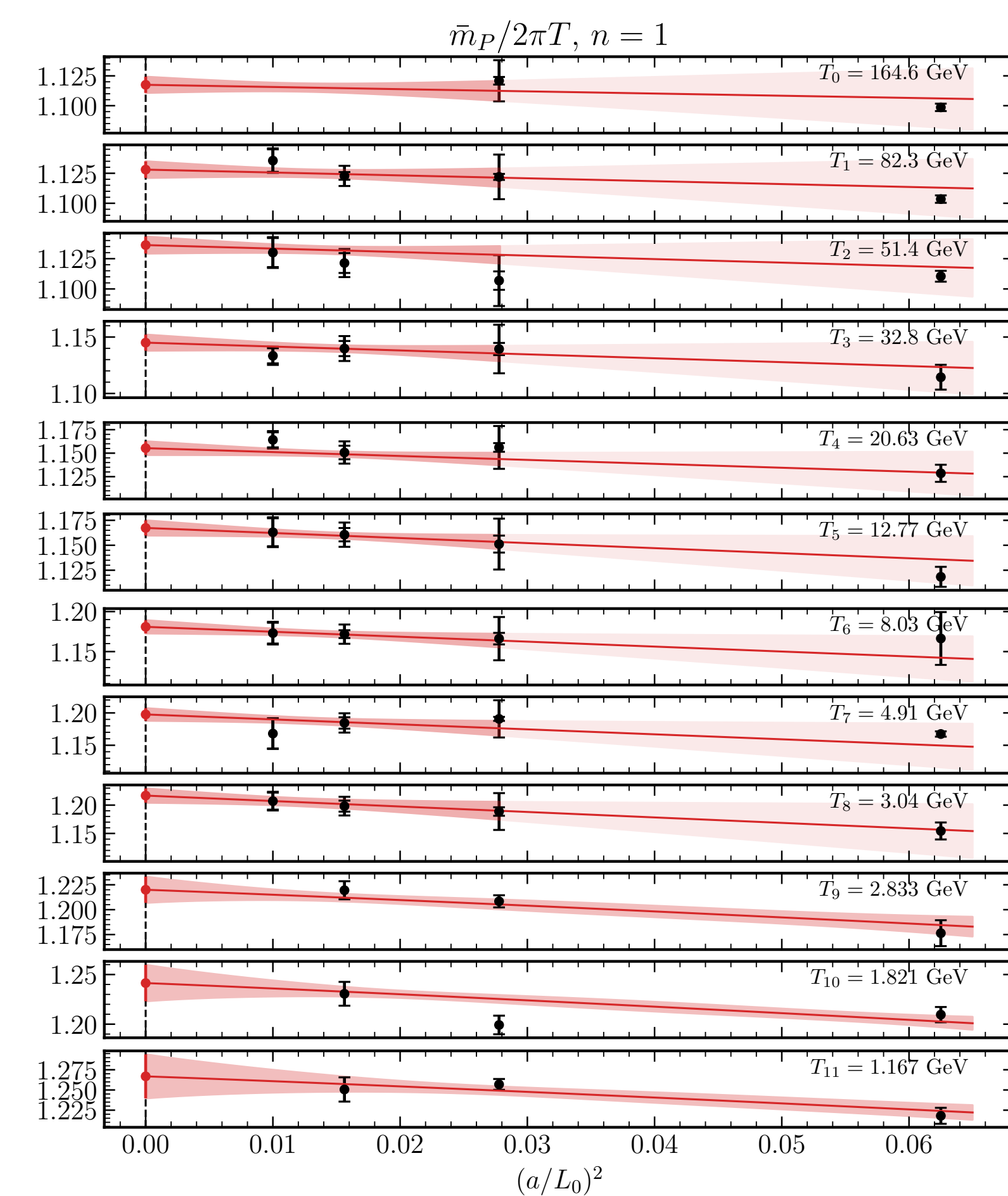
$$L_0 \times L^3, \quad L_0/a = \{4, 6, 8, 10\}, \quad L/a = 288$$

$N_f = 3$ $\mathcal{O}(a)$ -improved Wilson Fermions at the chiral limit

T [GeV]	$\bar{g}_{\text{SF}}^2(\mu)$
T_0 165(6)	1.01636
T_1 82.3(2.8)	1.11000
T_2 51.4(1.7)	1.18446
T_3 32.8(1.0)	1.26569
T_4 20.6(6)	1.3627
T_5 12.8(4)	1.4808
T_6 8.03(22)	1.6173
T_7 4.91(13)	1.7943
T_8 3.04(8)	2.0120

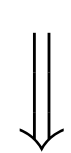
T [GeV]	$\bar{g}_{\text{GF}}^2(\mu)$
T_9 2.83(7)	2.7359
T_{10} 1.82(4)	3.2029
T_{11} 1.167(23)	3.8643

From the lattice to the continuum



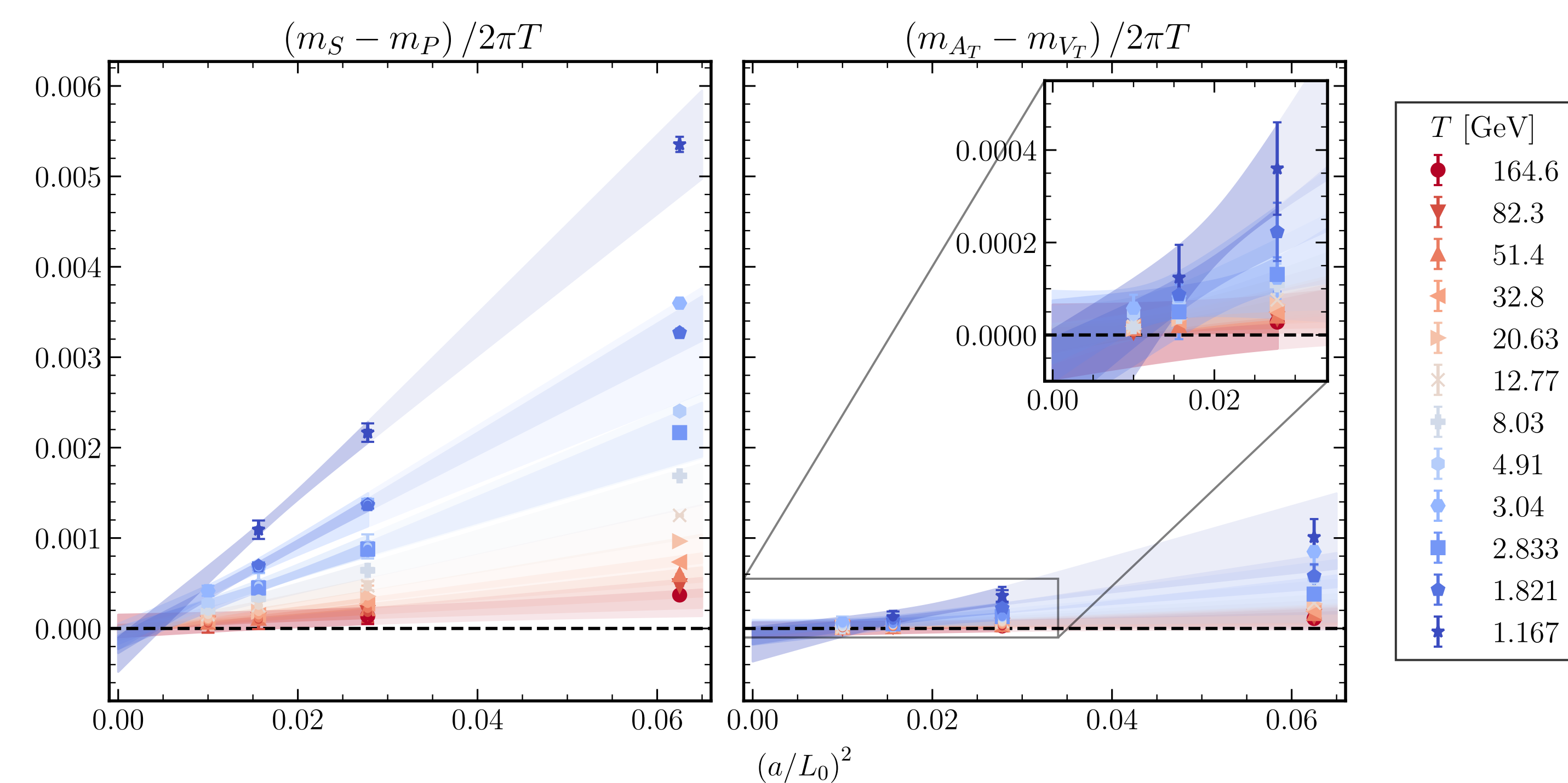
- **Screening masses** obtained from a single state fit in **effective mass plateau**

- Repeat for all lattice spacings (3-4), temperatures (12), mesonic channels (8), Matsubara sectors (3)



- **Continuum limit**: remove lattice artifacts with combined extrapolation to $a \rightarrow 0$

Chiral and $U(1)_A$ symmetry



$U(1)_A$ restored $\Rightarrow m_S = m_P$

Chiral symmetry restored $\Rightarrow m_{A_T} = m_{V_T}$

Symmetries **broken** at $a \neq 0$ (Wilson fermions) but recovered in the continuum

Features of the spectrum

- **Precision** varies from $\sim 0.1\%$ up to $\sim 5\%$ (different Signal-to-Noise in correlators)

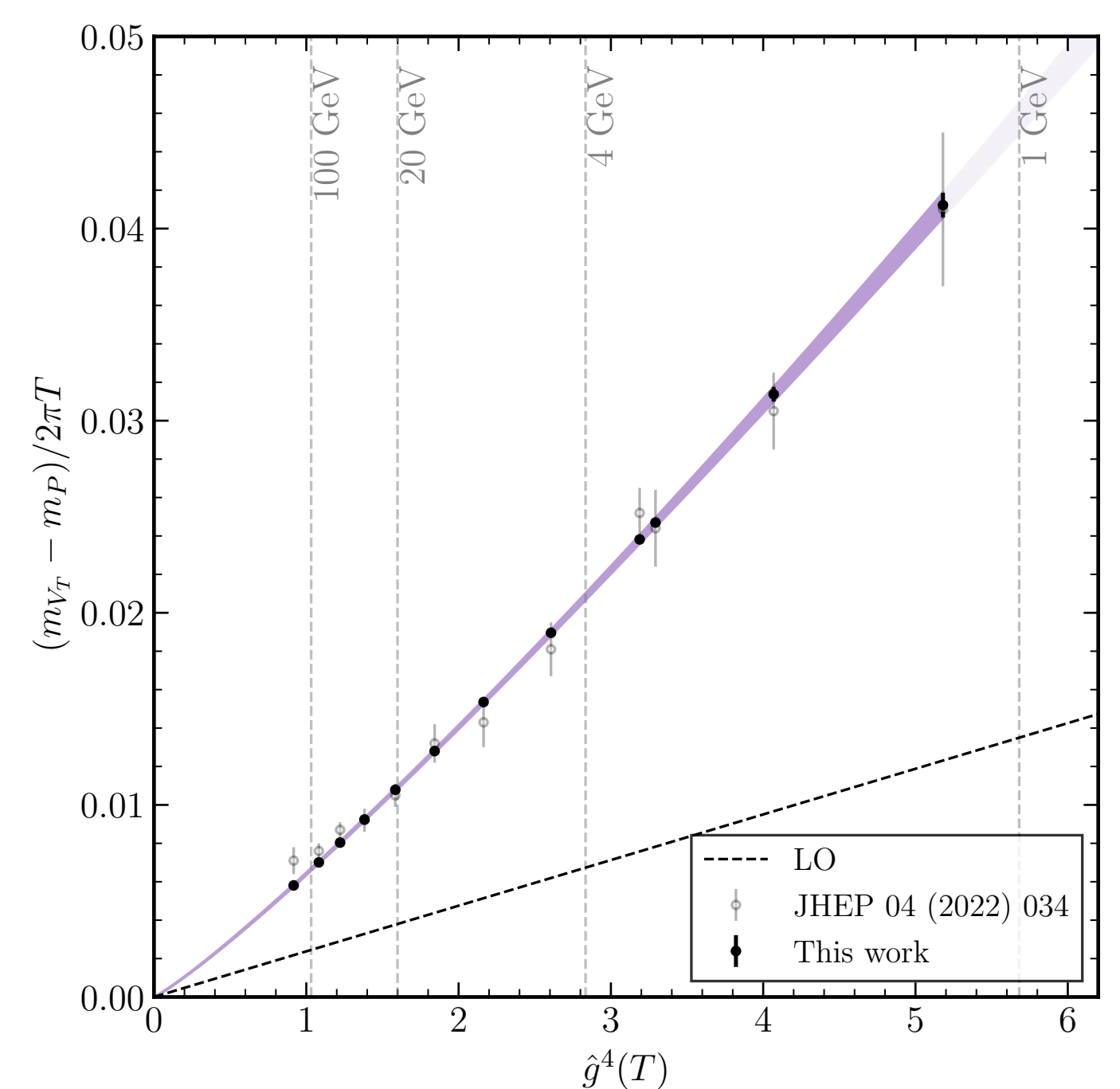
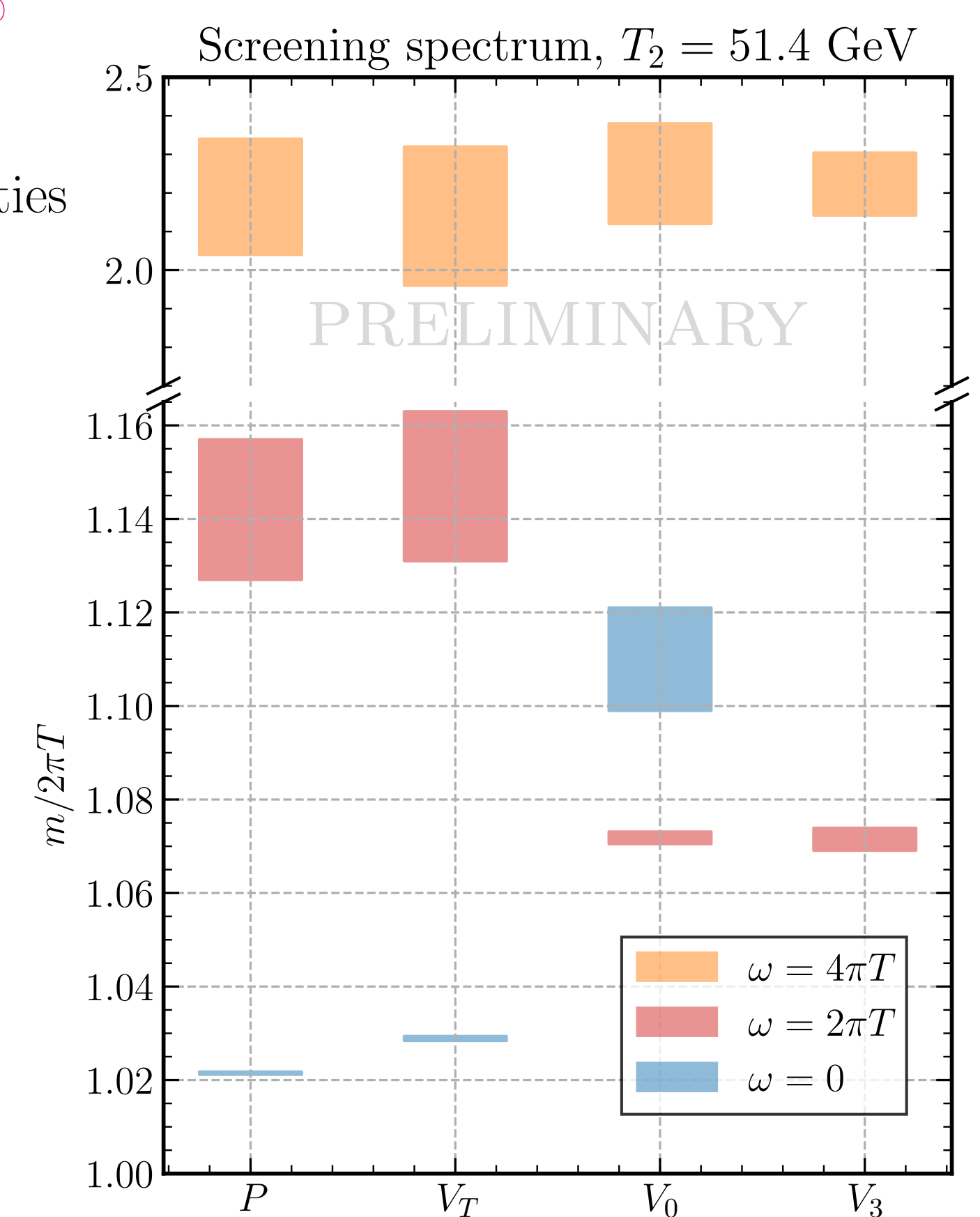
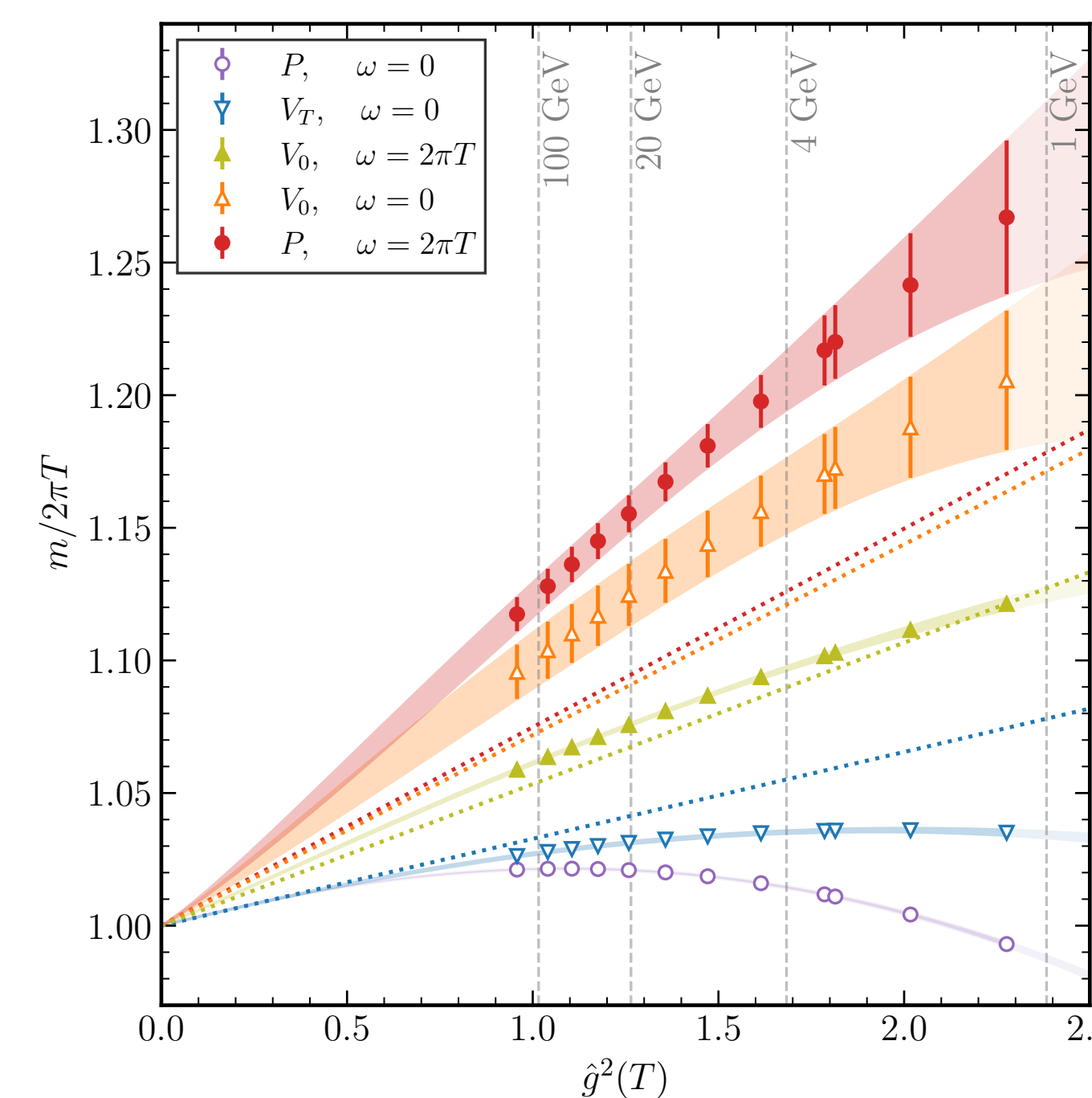
- $m_{V_0}^{(n)} \sim m_{V_3}^{(n)}$ at $n \neq 0$ due to Ward identities (current conservation)

- $m_P^{(n)} \sim m_{V_T}^{(n)}$ at $n \neq 0$: suppression of **spin-dependent interactions** in non-static sectors?

Temperature dependence:

Study continuum data as function of 5-loop $\overline{\text{MS}}$ coupling at $\mu = 2\pi T$: $\hat{g}^2(T)$

$$\frac{m}{2\pi T} = \overbrace{b_0^{(n)} + b_2^{(n)} \hat{g}^2(T) + b_3^{(n)} \hat{g}^3(T) + b_4^{(n)} \hat{g}^4(T)}^{\text{fit parameters}} + \underbrace{s_4 \hat{g}^4(T) + s_5 \hat{g}^5(T) + s_6 \hat{g}^6(T)}_{\text{fit parameters}}$$



Sizeable differences with 1 loop PT in all channels
 $\mathcal{O}(g^5)$ in hyperfine splitting receives **non-perturbative** contributions [3,4]

Conclusions

Static and **non-static** properties of hot QCD can be computed **non-perturbatively** up to $T \sim 160$ GeV with **sub-percent** or **percent** precision, respectively

Comparison with PT shows **discrepancies** in the whole temperature range

Some sensible quantities (hyperfine splitting) point to the presence of relevant **non-perturbative** contributions

Want to read more?



References

- [1] Laine and Vepsalainen 2004
- [2] Brandt et al. 2014
- [3] Cè et al.* 2025
- [4] Bala et al. 2025
- [5] Bruno et al. 2017

$\rightarrow$ Talk by M. Bressiani, EoS

$\rightarrow$ Poster by G. Catumba, EFT

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