Finite Temperature Transitions in QCD

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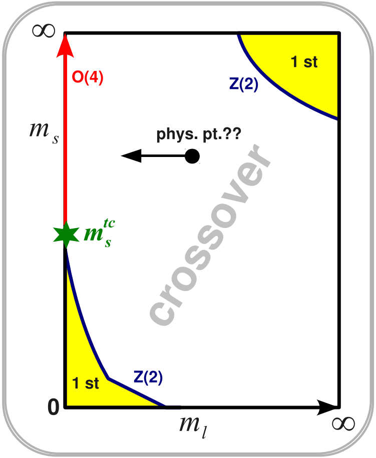
Deconfinement & Chiral transitions



★ **Deconfinement**: $m_l,\ m_s \to \infty$

- symmetry: $Z(3)$
- nature: first order
- order parameter: Polyakov loop

★ **Chiral**: $m_l \to 0$, $m_s \to \infty$

- symmetry: 3-d $O(4)$
- nature: second order
- order parameter: $\bar{\psi}\psi$

★ **Crossover**: $m_l,\ m_s \to$ physical

- symmetry: none
- order parameter: none

★ **Unified picture of Deconfinement & Chiral transitions ???**

- **meaning of pseudo-critical temperatures**
- **quantify the width of the crossover region**

One possible strategy: use $O(4)$ scaling properties

★ **If** physical quark masses lie within the $O(4)$ scaling window

$$\frac{T}{V} \ln \mathcal{Z} = f_s(t,h) + f_{reg}(T, m_l, m_s)$$

★ Scaling part: $f_s(t,h) = h^{1+1/\delta} f_M(z)$

- χSB: $h \propto m_l$
- thermal: $t \propto T - T_c$
- scaling: $z = t\, h^{-1/\beta\delta}$

Chiral

chiral susceptibility

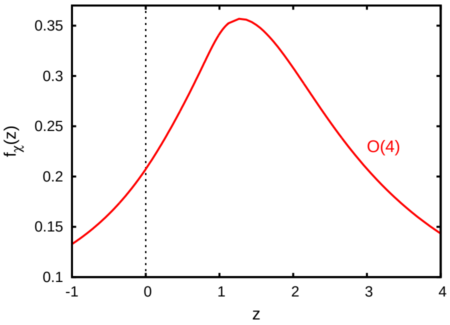
$$\chi_{h,h} = h^{1/\delta - 1} f_\chi(z) + reg.$$

Deconfinement

specific heat

$$\chi_{t,t} = h^{-\alpha/\beta\delta} f_M^{(2)}(z) + reg.$$

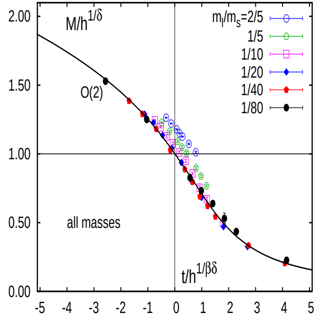
Pseudo-critical temperature: an example

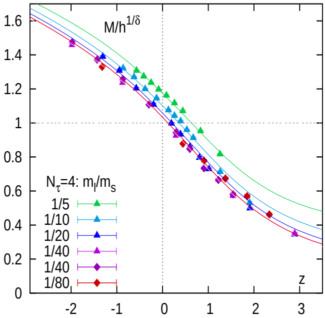


- $\chi_h = h^{1/\delta-1} f_\chi(z)$
- $z = t\, h^{-1/\beta\delta}$

$$T_{pc}(h) = T_c \left(1 + z_p\, \boldsymbol{c}\, h^{1/\beta\delta}\right)$$

Pseudo-critical temperature: an example



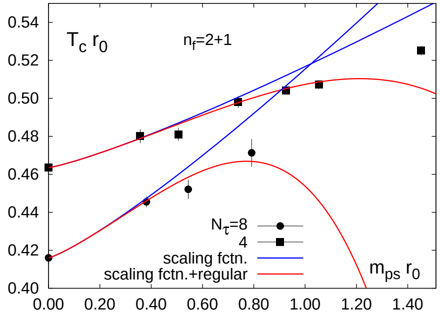


★ scaling for: $m_\pi \lesssim$ **150 MeV**

- scaling violation: $f_{reg}(T, m_l) = a_t m_l \left(\frac{T - T_c}{T_c}\right) + b_1 m_l$

Ejiri *et. al.*, PRD 80, 094505 (2009)

Pseudo-critical temperature: an example



Pseudo-critical temperature & crossover

- **2** relevant parameters (***h***, ***t***): **3** susceptibilities

★ $\chi_{h,h} = h^{\frac{1-\delta}{\delta}} f_\chi(z)$: chiral susceptibility

★ $\chi_{h,t} = h^{\frac{\beta-1}{\beta\delta}} f'_G(z)$: infection pt. of $\bar{\psi}\psi$

- $\chi_{t,t} = h^{-\frac{\alpha}{\beta\delta}} f_M^{(2)}(z) + reg.$: c_V; inflection pt. of ϵ, $\chi_I^{(2)}$
  - small μ_I, no explicit χSB by μ_I
  - 1 derivative w.r.t t $\equiv$ 2 derivatives w.r.t μ_I

$$t \sim (T - T_c) + \kappa_I \left(\frac{\mu_I}{T}\right)^2$$

★ $\chi_{t,t,t} = h^{-\frac{(1+\alpha)}{\beta\delta}} f_M^{(3)}(z)$: $\chi_I^{(6)}$; inflection pt. of c_V, $\chi_I^{(4)}$

Kaczmarek *et. al.*, PRD 83, 014504 (2011); J. Engels & F. Karsch, in preparation.

Pseudo-critical temperature & crossover

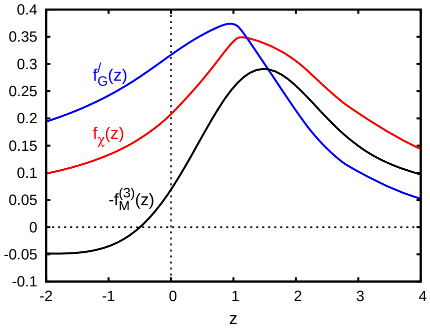
★ **3** susceptibilities

★ $\chi_{h,h} = h^{\frac{1-\delta}{\delta}} f_\chi(z)$

★ $\chi_{h,t} = h^{\frac{\beta-1}{\beta\delta}} f'_G(z)$

★ $\chi_{t,t,t} = h^{-\frac{(1+\alpha)}{\beta\delta}} f_M^{(3)}(z)$

$$T_{pc}(h) = T_c \left(1 + z_p\ c\ h^{1/\beta\delta}\right)$$



At most 3 T_{pc}

★ **well-defined & quantifiable**