Color Screening: a View from a String Model

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Motivations

- the properties of matter at high T and density
- so far studied from the first principles only by lattice gauge theory

a limitation regarding fermions (the sign problem)

- effective string theories are no better and no worse than effective field theories

Fundamental Lessons from String Theory

$$\langle A \rangle = A_{cl} + \hbar A_1 + \hbar^2 A_2 + \cdots$$
$$= B_{cl} + \hbar' B_1 + \hbar'^2 B_2 + \cdots$$

$$A_i(a_\alpha) \quad ; \quad B_i(b_\alpha)$$
$$a_0 = \hbar' \quad ; \quad b_0 = \hbar$$

This in particular means some high order quantum corrections reduce to classical computations in a dual frame.

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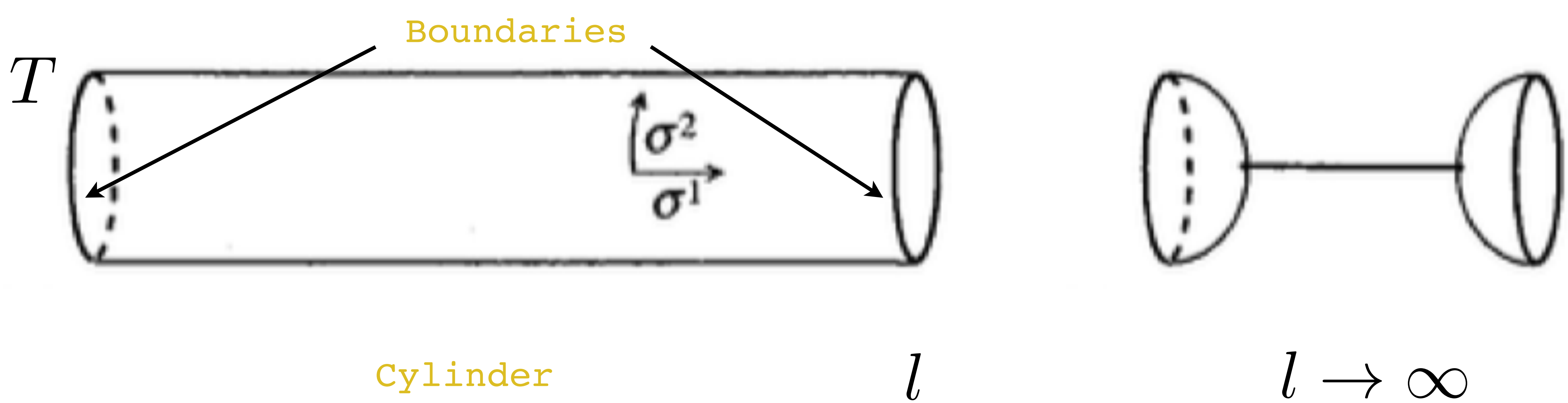
Open/Closed String Duality

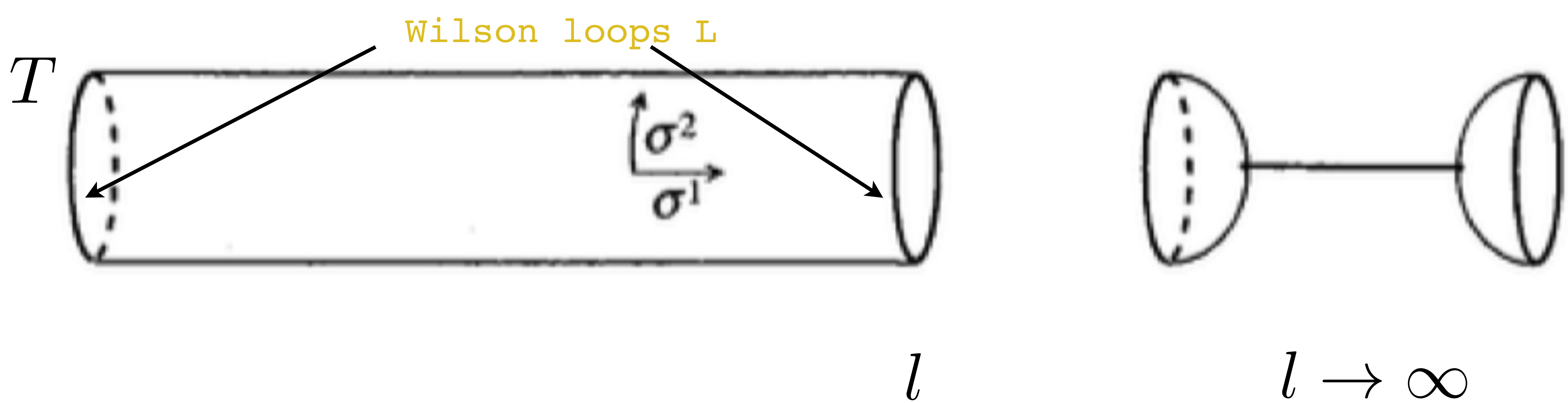


At short distances - open strings stretched between two loops

At long distances - closed strings

The mass ratio $M^2 = 4m^2$

What is going on in the QCD picture



At short distances - singlet/antitriplet channel, with m_D the Debye mass

At large distances - the relation $M = 2m_D$ and exponential fall off

$$\langle\, L^\dagger(0)L(l)\,\rangle \sim \exp\{-Ml\}$$

The model: effective 5d string theory

A Nambu-Goto string in the background of

5-dimensional Euclidean metric (the ansatz) and U(1) gauge field

$$ds^2 = e^{\mathbf{s}r^2} \frac{R^2}{r^2} \Big(f dt^2 + d\vec{x}^2 + f^{-1} dr^2 \Big) , \qquad A = (A_t(r), 0, \ldots, 0) \, .$$

It is a one-parameter deformation of the AdS black hole (charged).

We use the saddle point approximation, so

$$\langle \, L^\dagger L \, \rangle = \sum_m w_m e^{-S_m}$$

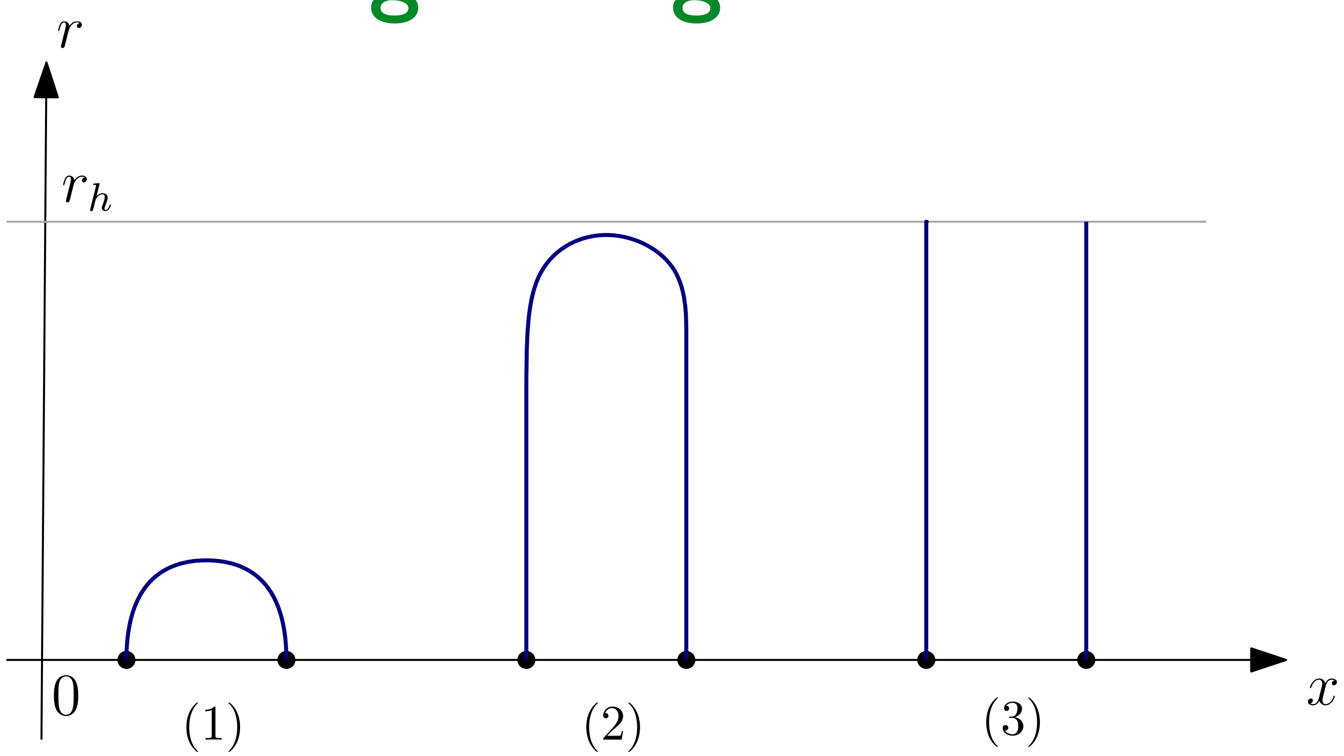
with w_m relative weights.

Quark-Antiquark Case

Correlator:

$$\langle\, L^\dagger \, L \,\rangle$$

String configurations:



We fit it to

$$F_{q\bar{q}} = -\frac{\alpha_{q\bar{q}}}{l} e^{-ml}$$

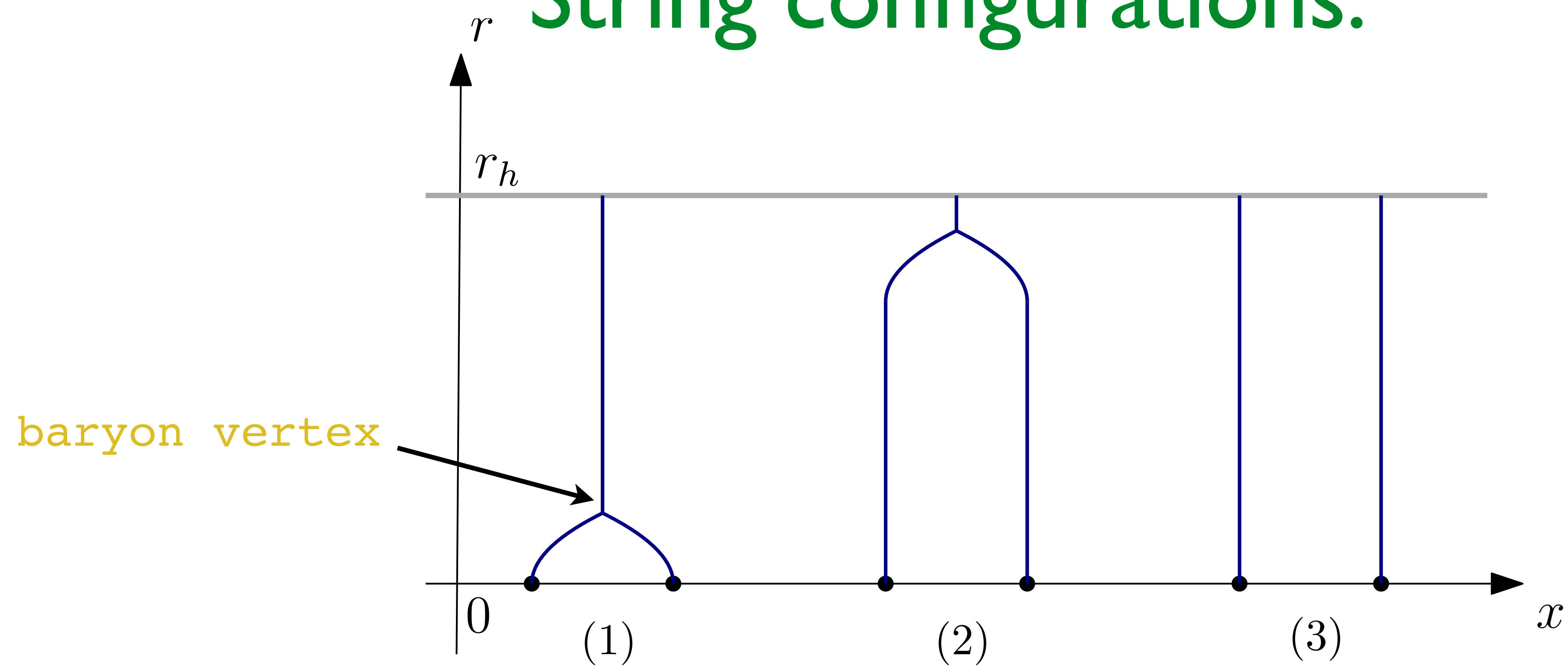
$$m = \frac{1}{4\pi^3}\Gamma^4\left(\tfrac{1}{4}\right)\sqrt{\mathbf{s}}\left(\frac{1}{\sqrt{h}}e^{h} - \sqrt{\pi}\,Erfi(\sqrt{h}\,) + \mathbf{w}\frac{T}{\sqrt{\mathbf{s}}}\right) \quad \text{with} \quad h = \mathbf{s} r_h^2$$

Quark-Quark Case

Correlator:

$$\langle\, L\, L\, \rangle$$

String configurations:



We fit it to
$$F_{qq} = -\frac{\alpha_{qq}}{l} e^{-m' l}$$

We get $m = m'$, if a free parameter (due to the baryon vertex) is

$$\mathbf{k} = -0.1$$

Sample Models

- $$f(r) = 1 - \left(\frac{r}{r_h}\right)^4$$ It allows $$T = \frac{1}{\pi r_h}$$ Andreev-Zakharov

- $$f(r) = 1 - \frac{1 - \left(1 + \frac{3}{2}\mathbf{s}r^2\right) e^{-\frac{3}{2}\mathbf{s}r^2}}{1 - \left(1 + \frac{3}{2}h\right) e^{-\frac{3}{2}h}}$$ Kiritsis et al

in fact due to the consistency condition $$\beta^f = \frac{1}{w}\left(\beta^G_{tt} - f\beta^G_{ii}\right) = 0$$

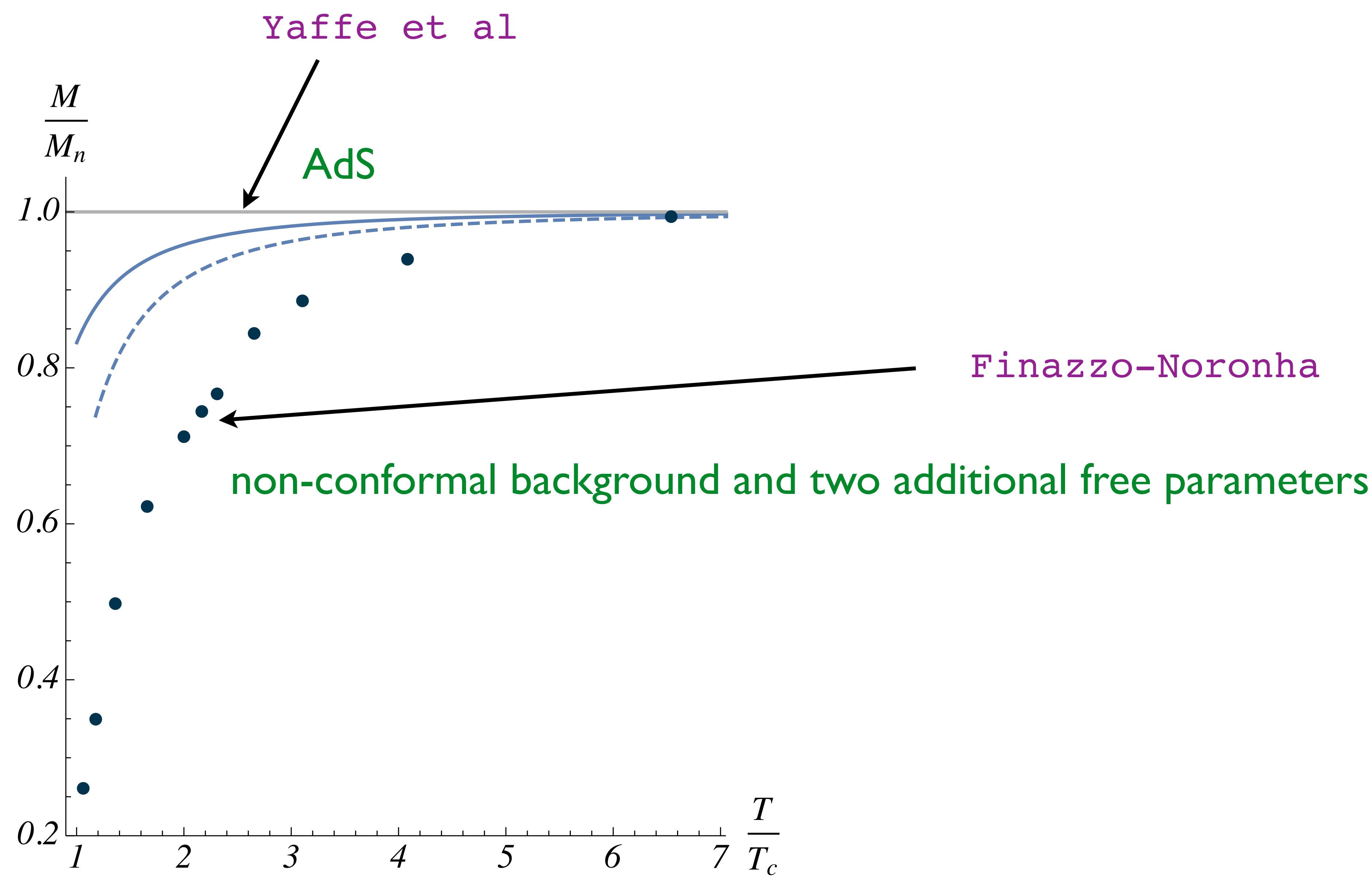
- $$f(r) = 1 - A\left(1 - (1 + 2\mathbf{s}r^2)e^{-2\mathbf{s}r^2}\right) - B\left(1 - \left(1 + \frac{3}{2}\mathbf{s}r^2\right)e^{-\frac{3}{2}\mathbf{s}r^2}\right)$$

this comes from the U(1) gauge field

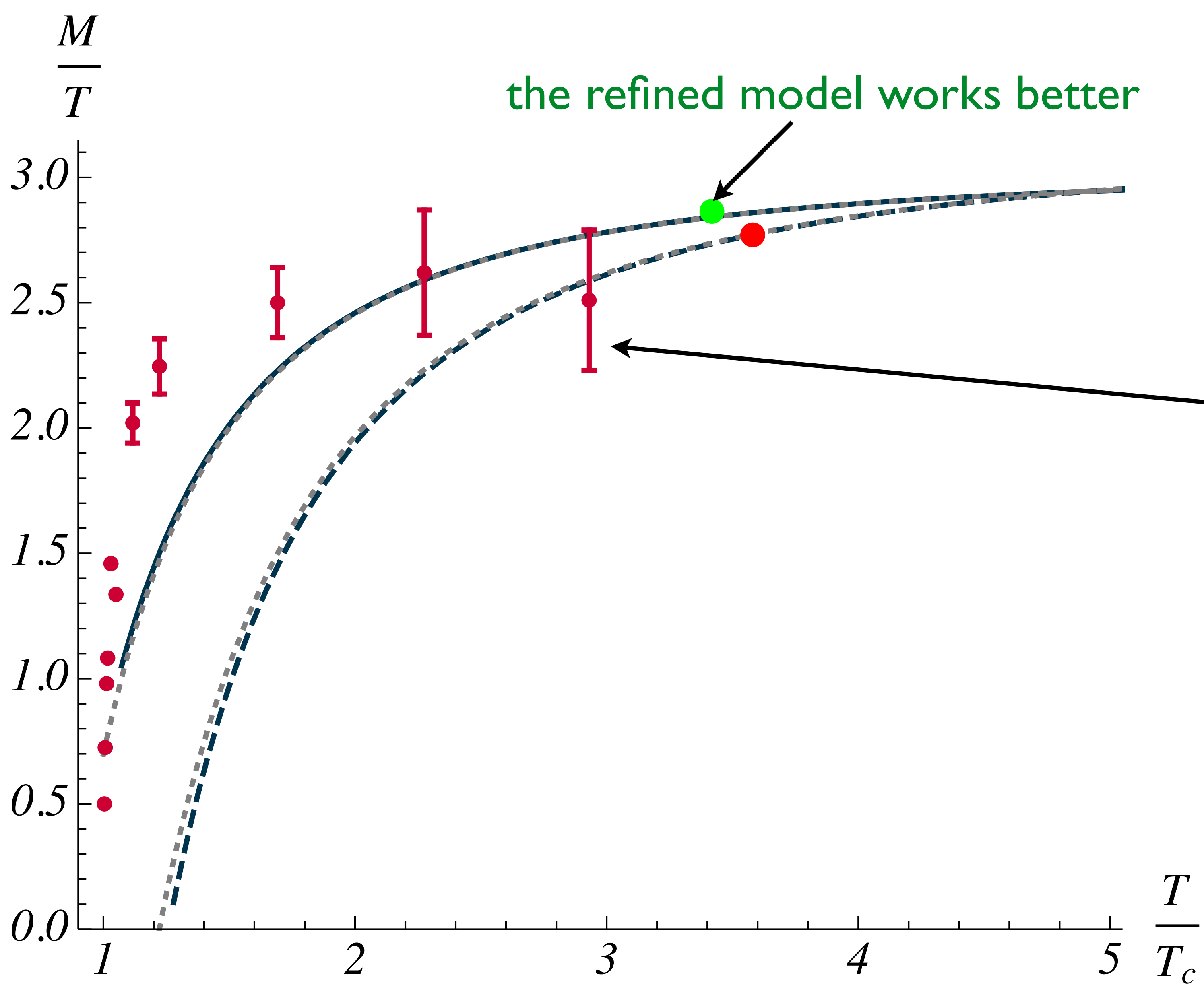
$$A_t(r) = \mu + c\left(1 - e^{-\mathbf{s}r^2/2}\right)$$ with $$A_t(0) = \mu\,, \quad A_t(r_h) = 0$$

Andreev

✦ How it works: closed string channel

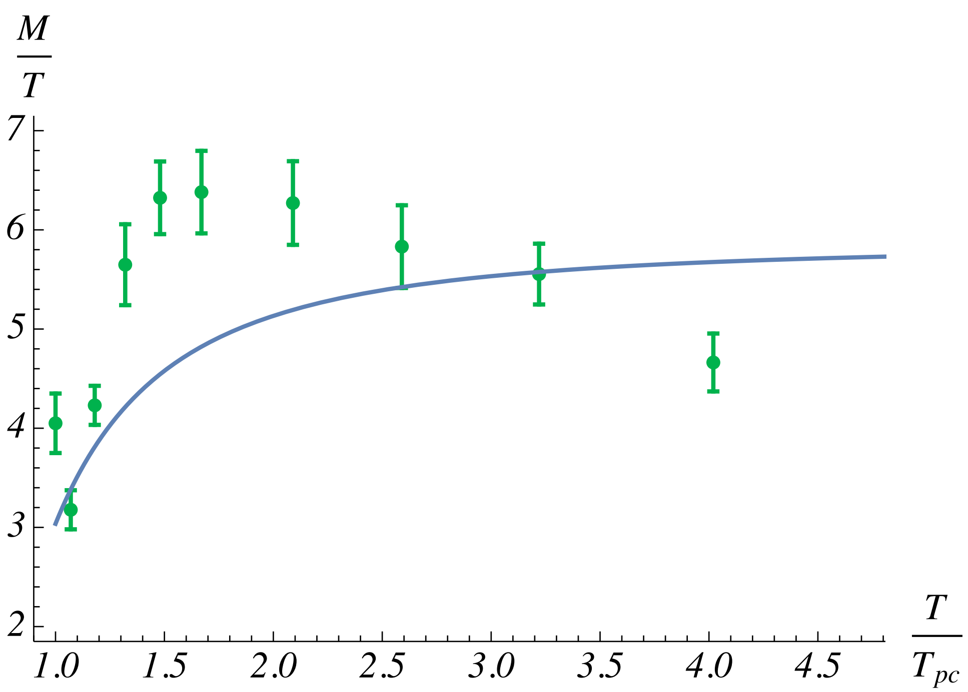


✦ How it works: pure SU(3) gauge theory

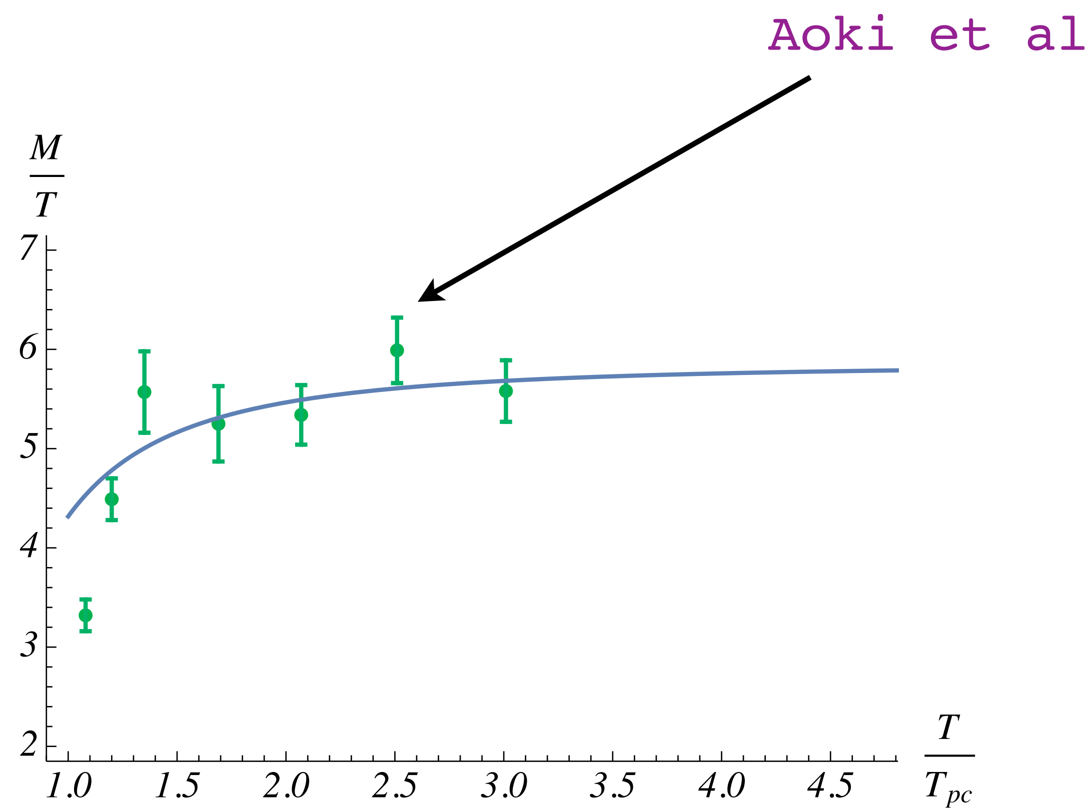


near the phase transition the classical (string) approximation becomes bad

✦ How it works: gauge theory with two flavors



$$T_{pc} = 262\,\mathrm{MeV}$$



$$T_{pc} = 357\,\mathrm{MeV}$$

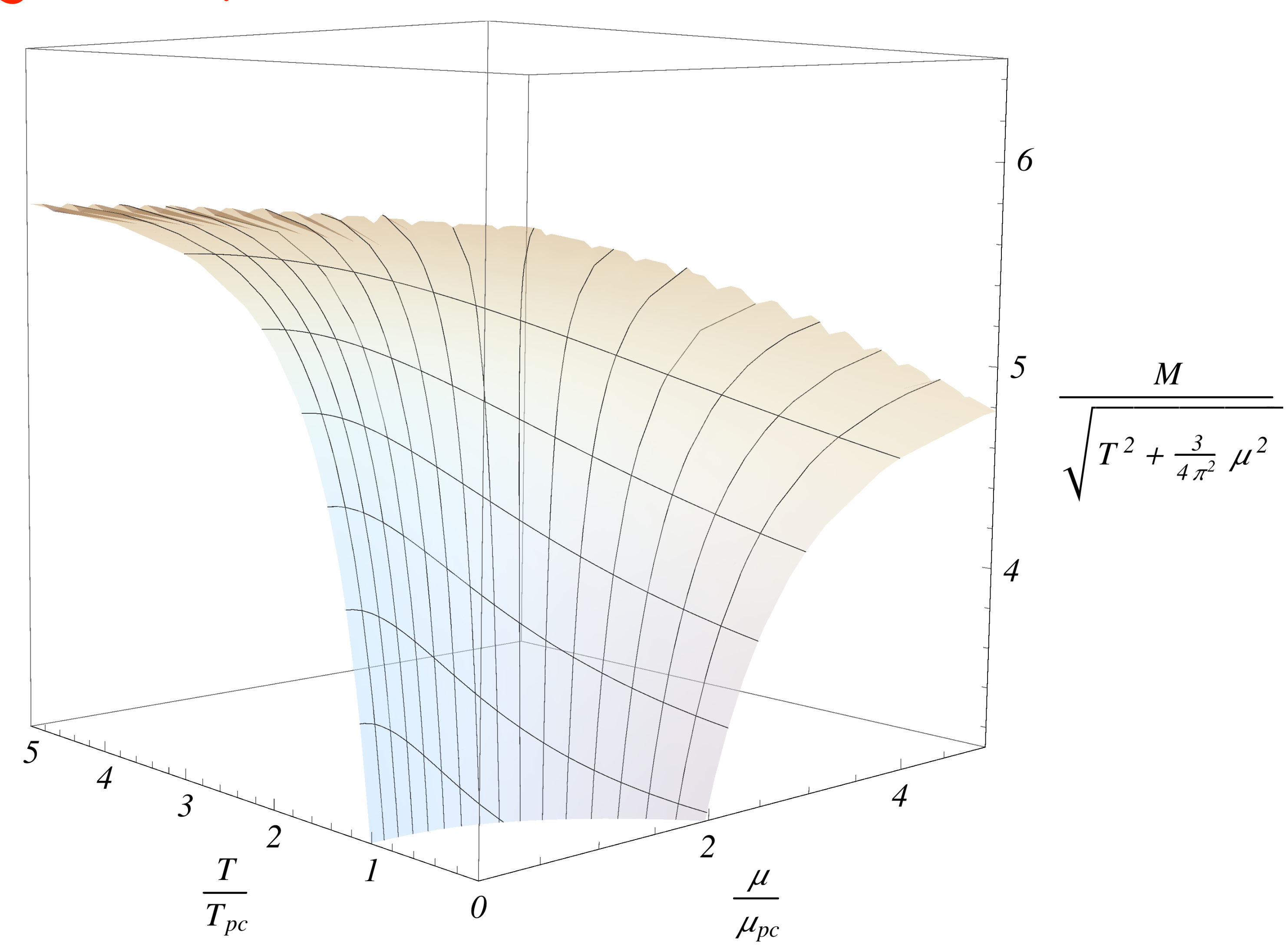
How it works: non-zero baryonic chemical potential

In lattice gauge theory, take small μ and expand M in $\frac{\mu^2}{T^2}$

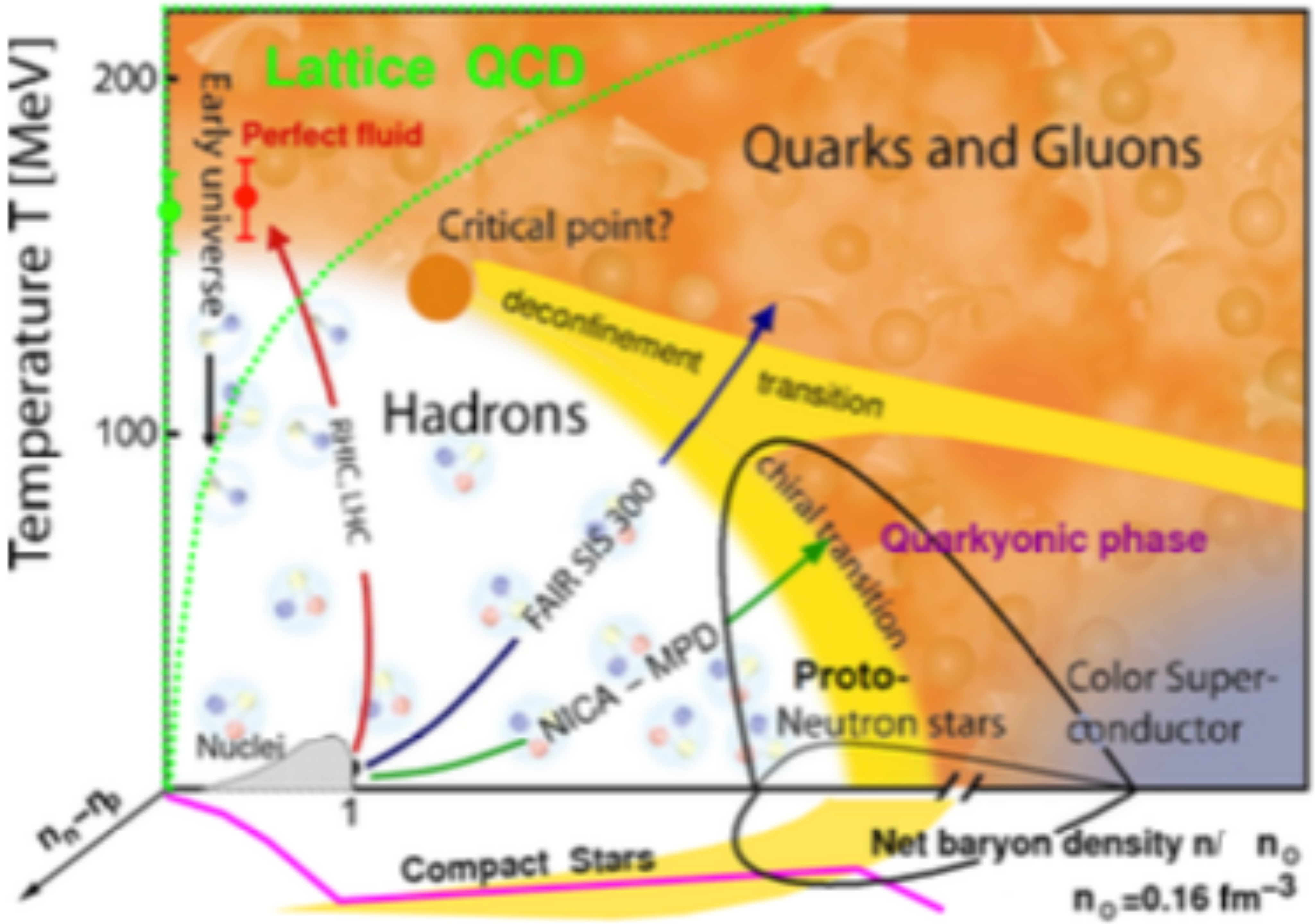
$$M(T,\mu) = \sum_{n=0} M_{2n}(T)\left(\frac{\mu^2}{T^2}\right)^n$$

In this way it is possible to compute a few terms only.

The effective string theory allows more



Why we need it



It is difficult not to agree with this

"In my opinion, string theory in general may be too ambitious. We know too little about string dynamics to attack the fundamental questions of the right vacua, hierarchies, to choose between anthropic and misanthropic principles etc. The lack of control from the experiment makes going astray almost inevitable. I hope that gauge/string duality somewhat improves the situation. There we do have some control, both from experiment and from numerical simulations. Perhaps it will help to restore the mental health of string theory."

A.M. Polyakov