α_s from static energy and force @ Confinement XIII

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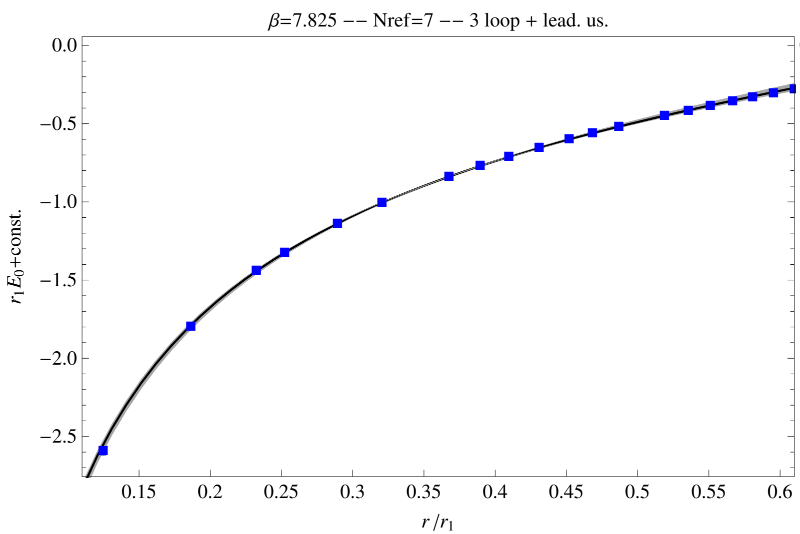
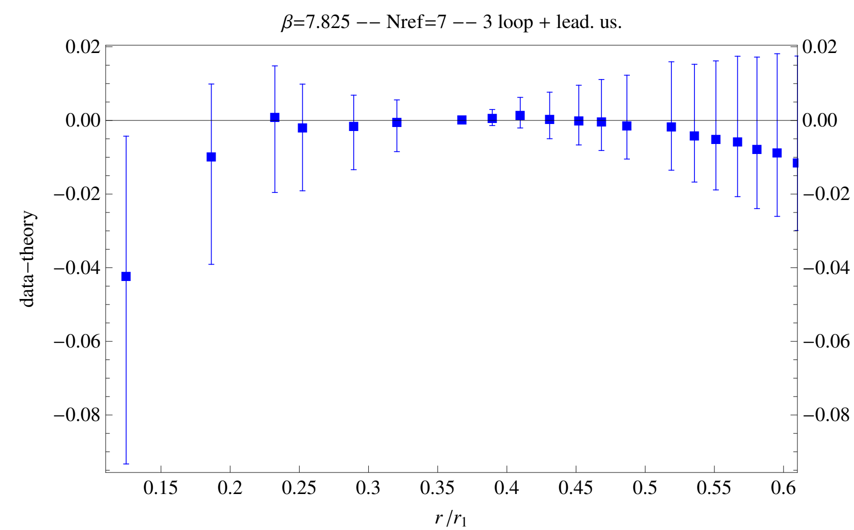
Status

Static energy vs lattice data





- Perturbation theory (N^{3}LO + RG) agrees with lattice data from 0.05 fm up to 0.14 fm.
- Using data for $\beta = 7.373, 7.596, 7.825$ one gets

$$\Lambda_{\overline{\rm MS}} = 315^{+18}_{-12}\ \text{MeV} \quad \text{which converts to} \quad \alpha_{\rm s}(M_Z, n_f = 5) = 0.1166^{+0.0012}_{-0.0008}$$

- Bazavov Brambilla Garcia Petreczky Soto Vairo PRD 90 (2014) 074038

Energy, potential, force

The static energy, E_0, is related to the potential, V_s, through: $E_0 = V_s + \Lambda_s +$ us
The perturbative expansion of V_s is affected by a renormalon ambiguity of order $\Lambda_{\rm QCD}$.
This ambiguity does not affect the slope of the potential (and the extraction of $\alpha_{\rm s}$).

It may be eliminated from the perturbative series

- either by subtracting a (constant) series in $\alpha_{\rm s}$ to V_s and reabsorb it in a redefinition of the residual mass Λ_s,
- or by considering the force:

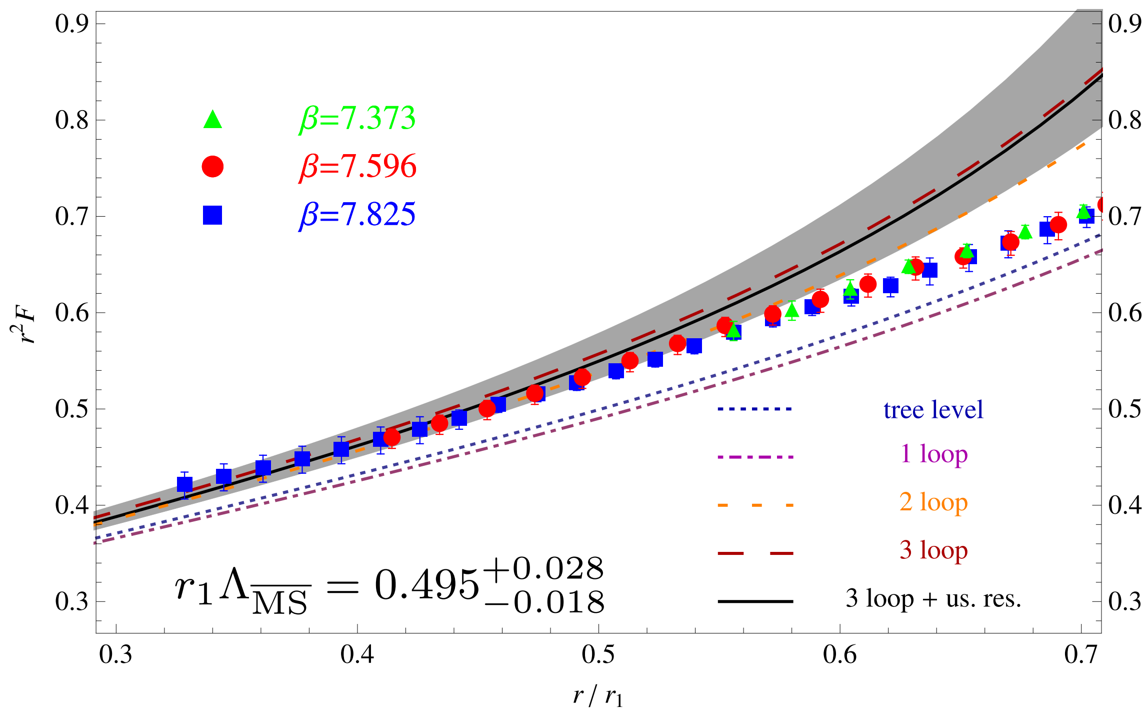
$$F(r, \alpha_{\rm s}(\nu)) = \frac{d}{dr} E_0(r, \alpha_{\rm s}(\nu))$$

  - The force $F(r, \alpha_{\rm s}(1/r))$ could be directly compared with lattice,
  - or integrated and compared with the static energy

$$E_0(r) = \int_{r_*}^{r} dr' \, F(r', \alpha_{\rm s}(1/r'))$$

up to an irrelevant constant fixed by the overall normalization of the lattice data.

Force vs lattice data



- Bazavov Brambilla Garcia Petreczky Soto Vairo PRD 90 (2014) 074038

Perspectives

- Not all of the presently available perturbative information has been used:

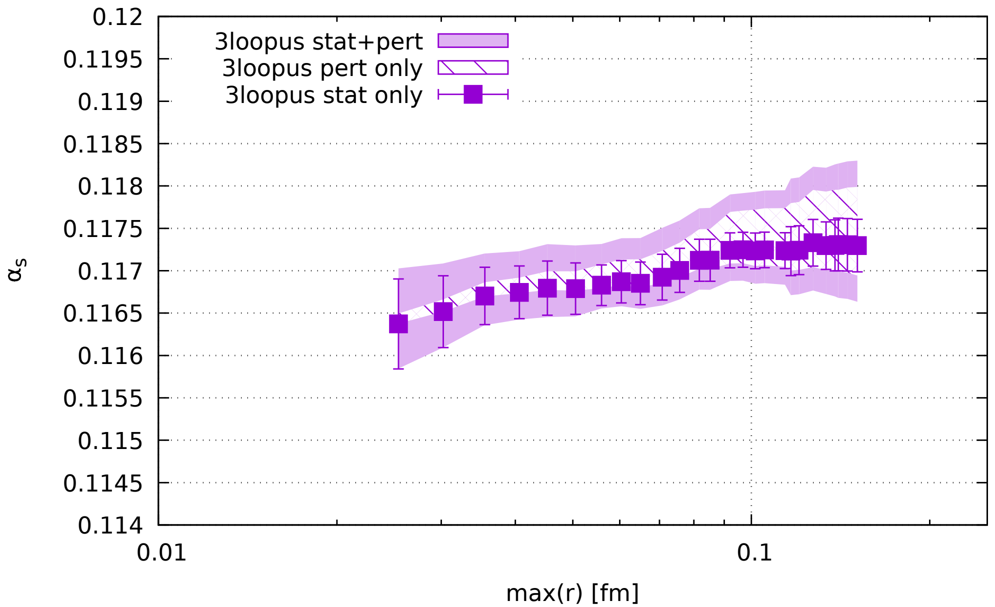
  N^3LL, finite mass effects, ...

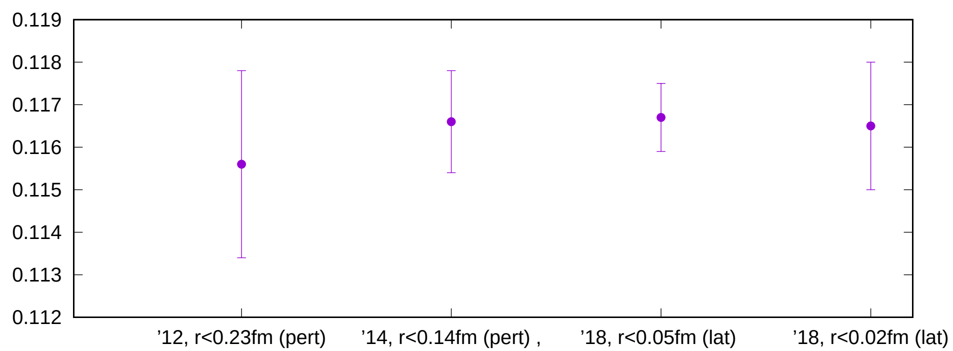
  because the data are not sensitive to it.

- Also the data do not seem sensitive to short-range nonperturbative effects (e.g., condensates $\sim r^3\langle E(0)^2\rangle$, or correlators $\sim r^2 \int dt\langle E(t)E(0)\rangle$).

- Can data at shorter distances, in 2+1+1 lattices, from different observables complement or extend our present knowledge of α_s from the QCD potential?

α_s from the static energy at very short distances

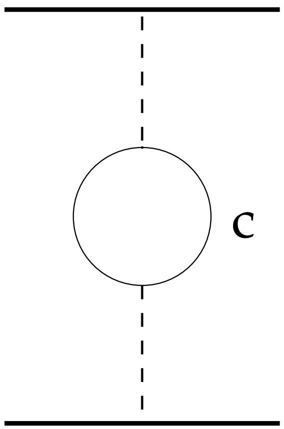




- Bazavov Brambilla Garcia Petreczky Soto Vairo Weber (2018)

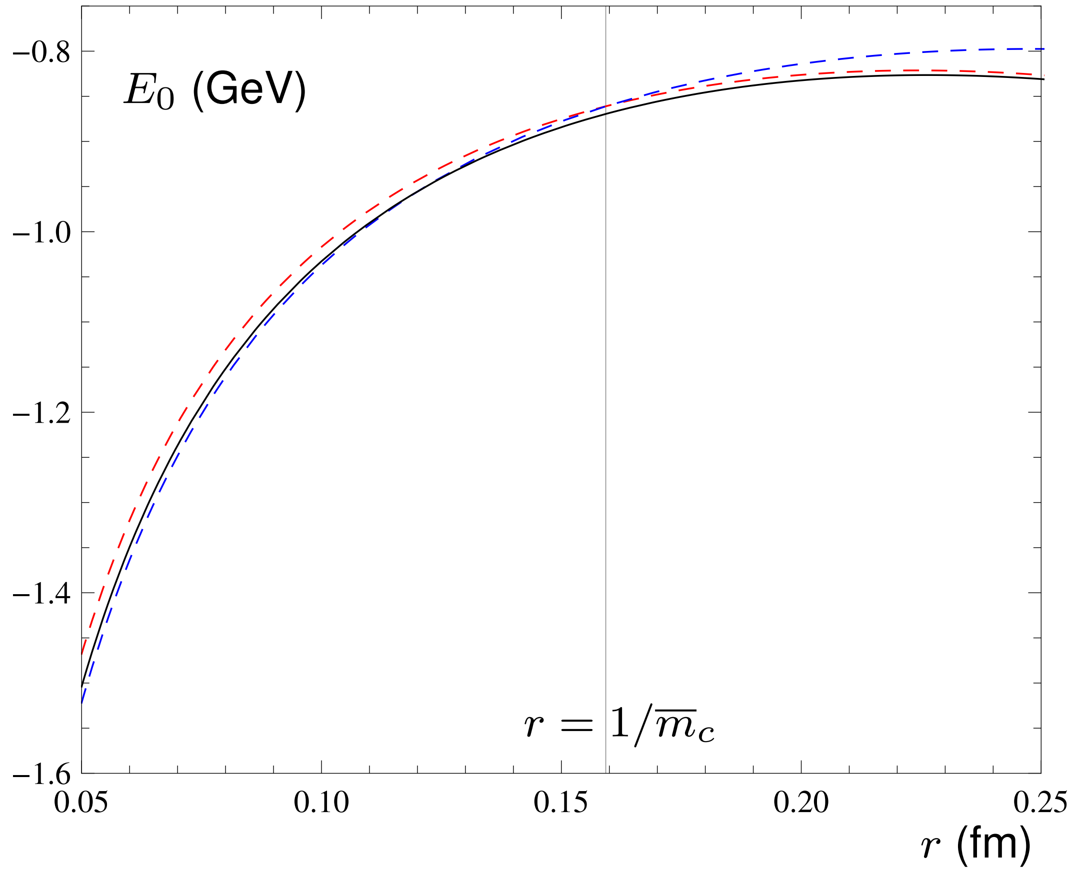
Charm mass effects

- $m_c \gg \Lambda_{\rm QCD}$
  Charm-mass effects happen at a perturbative scale.
- $m_c \approx$ 1.5 GeV $\approx$ 0.13 fm
  The charm mass affects
  * bottomonium physics: $m_b v_b \sim m_c$
  * 2+1+1 lattice computations of the static energy at short distances.
- Charm mass effects in the static energy are well known:



○ Eiras Soto PLB 491 (2000) 101

Charm mass effects in the static energy



blue dashed: c massless ($n_l = 4$)

red dashed: c infinitely heavy ($n_l = 3$)

black: $E^{(n_l=4)} + \delta E$

$\overline{m}_c = 1.237$ GeV

α_s from the force

It is possible to compute the force directly from the lattice:

$$F(r) = -\lim_{T\to\infty} \frac{\left\langle \mathrm{Tr}\,\mathrm{P}\,\hat{\mathbf{r}}\cdot g\mathbf{E}(t,\mathbf{r})\,\exp\left\{ig\oint_{r\times T} dz^\mu\, A_\mu\right\}\right\rangle}{\left\langle \mathrm{Tr}\,\mathrm{P}\exp\left\{ig\oint_{r\times T} dz^\mu\, A_\mu\right\}\right\rangle}$$

- Vairo MPLA 31 (2016) 1630039