α_s from the QCD static energy on the lattice

Xavier Garcia i Tormo

Universität Bern

(work done with Alexei Bazavov, Nora Brambilla, Péter Petreczky, Joan Soto and Antonio Vairo)

Phys. Rev. D **86**, 114031 (2012) [arXiv:1205.6155 [hep-ph]]

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Introduction

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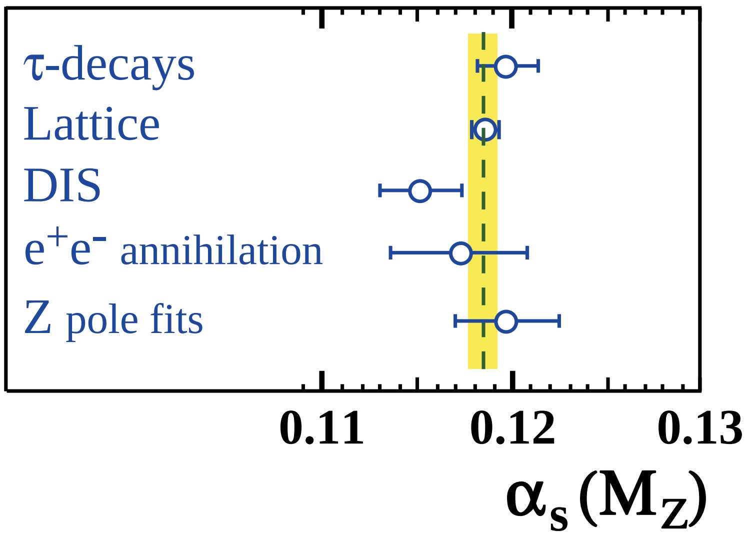
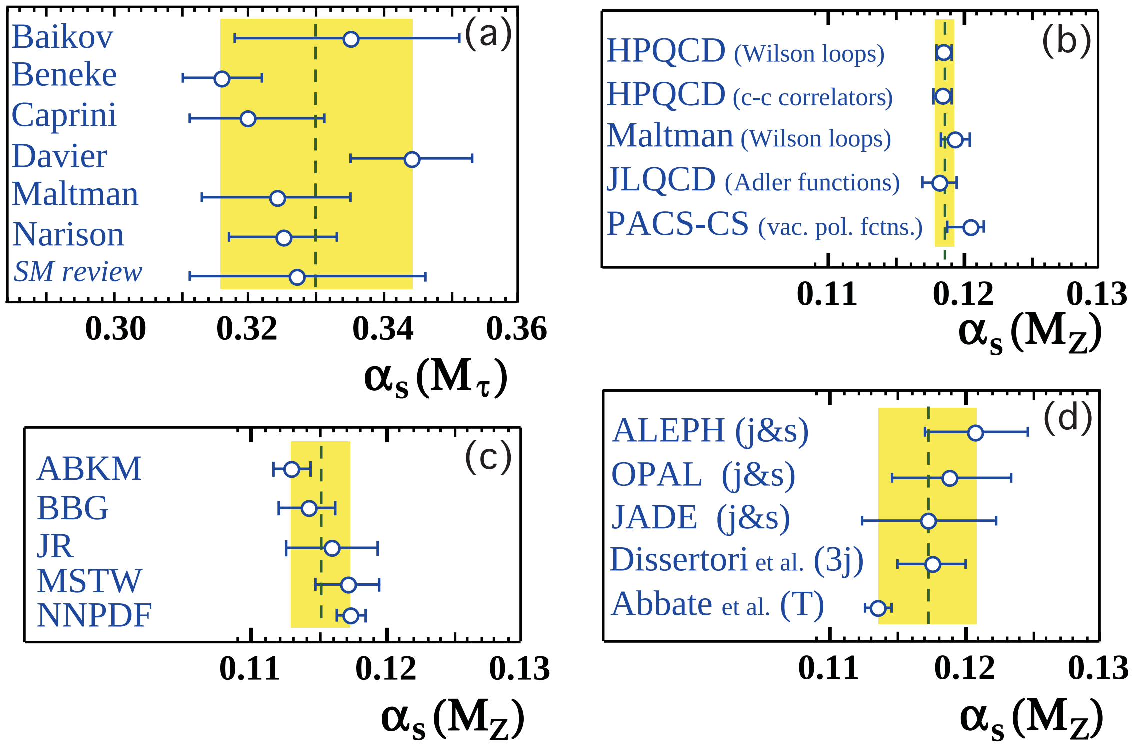
Reminder: current status of α_s world average

$$\alpha_\mathrm{s}(M_Z) = 0.1184 \pm 0.0007$$



Picture from PDG'12: J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)



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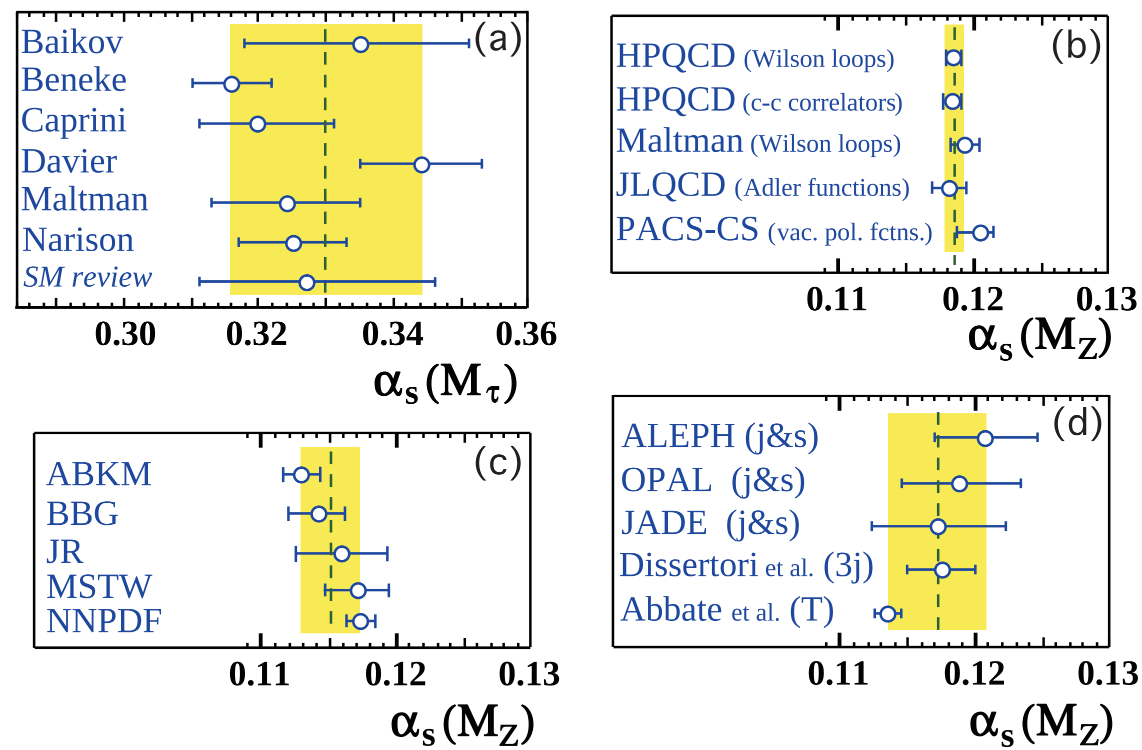
(a) τ decays (b) lattice (c) PDFs (d) e^+e^- jets



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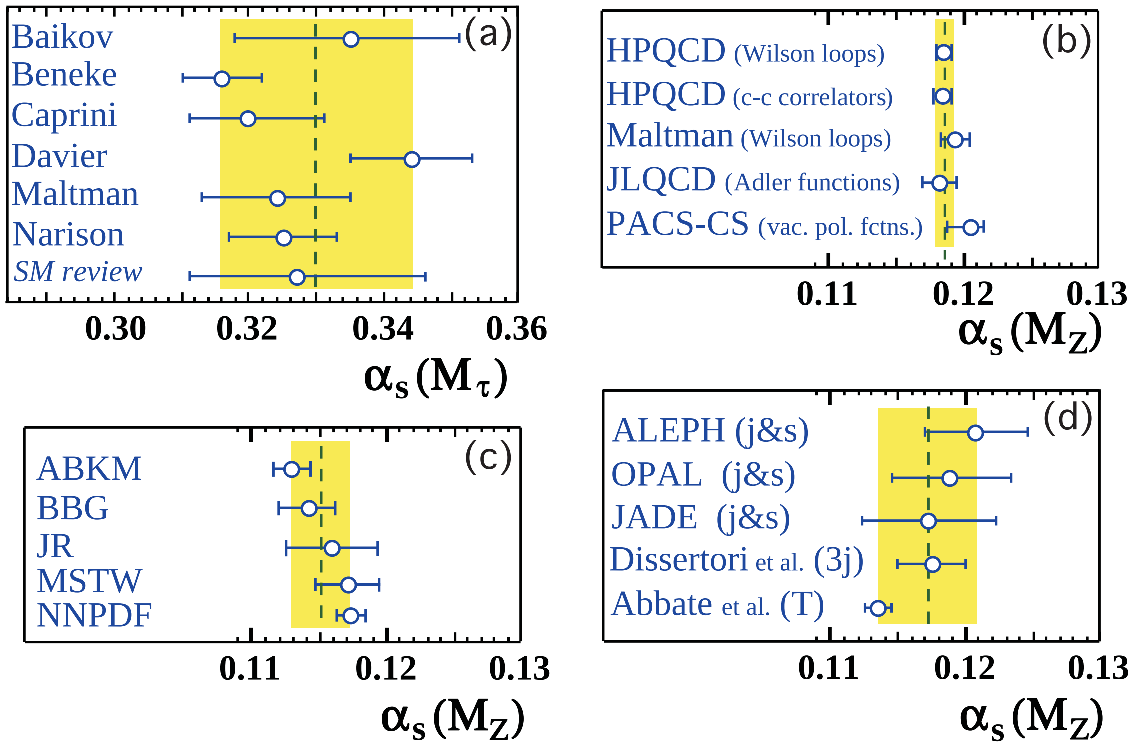

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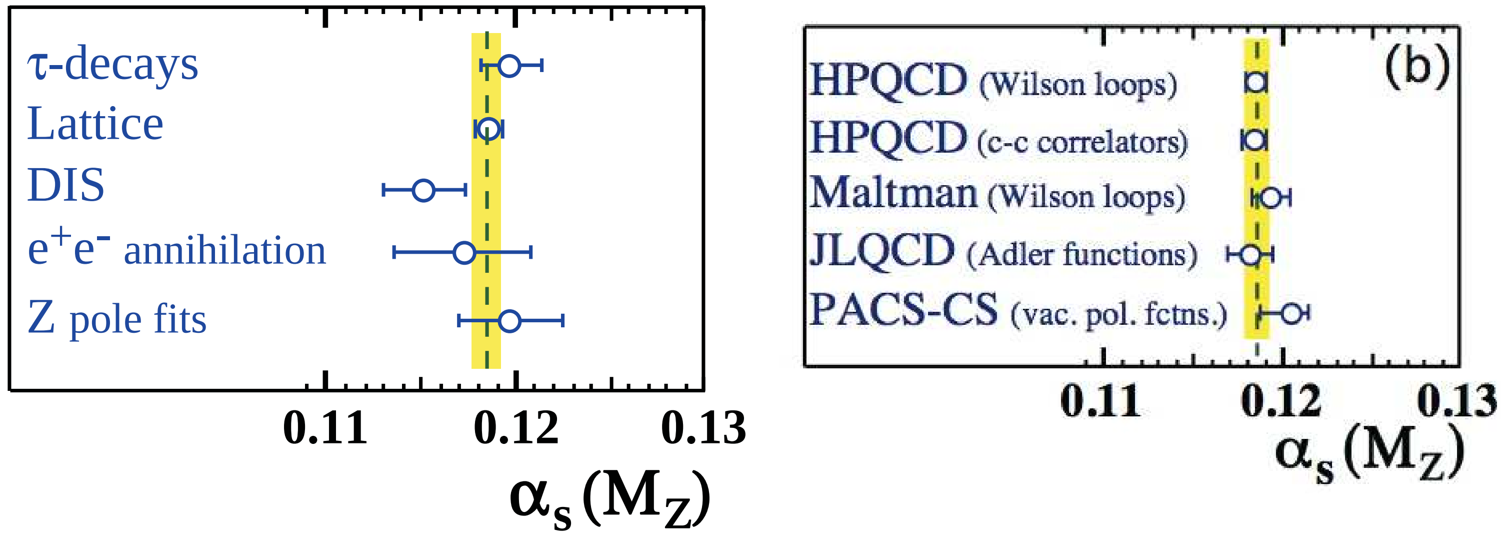
(a) τ decays (b) lattice (c) PDFs (d) e^+e^- jets

- Many measurements dominated by systematic uncertainties, and many correlated inputs
- Some recent precise determinations noticeably different than the average



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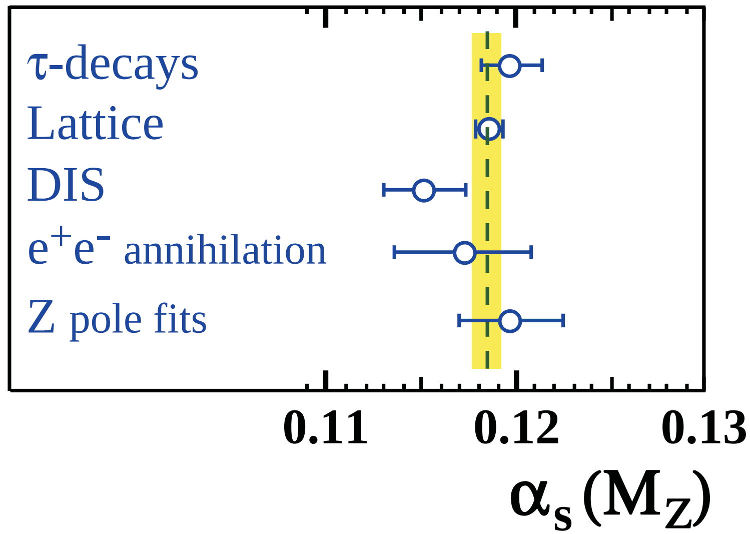
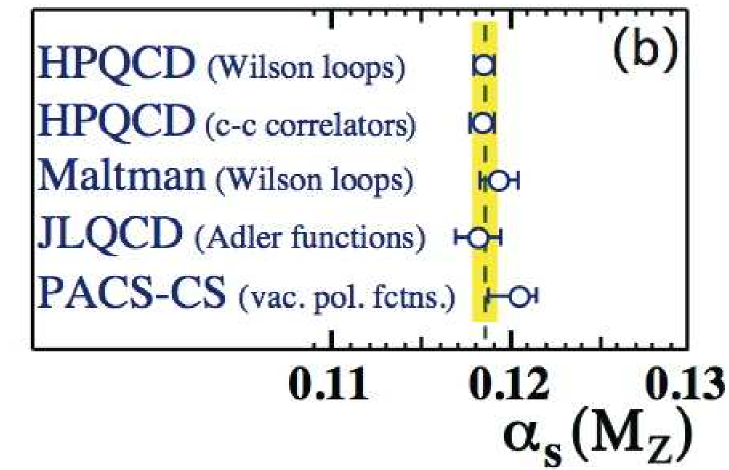
Overall uncertainty largely determined by the precise lattice result





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Overall uncertainty largely determined by the precise lattice result

We provide a new, independent determination from the static energy on the lattice

Static energy in QCD

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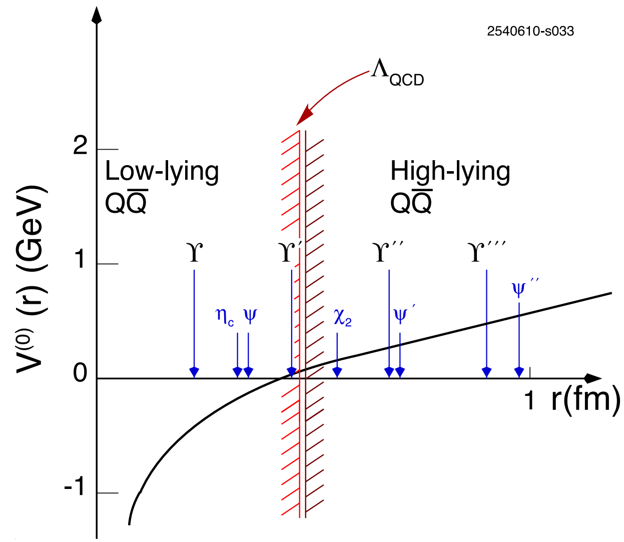

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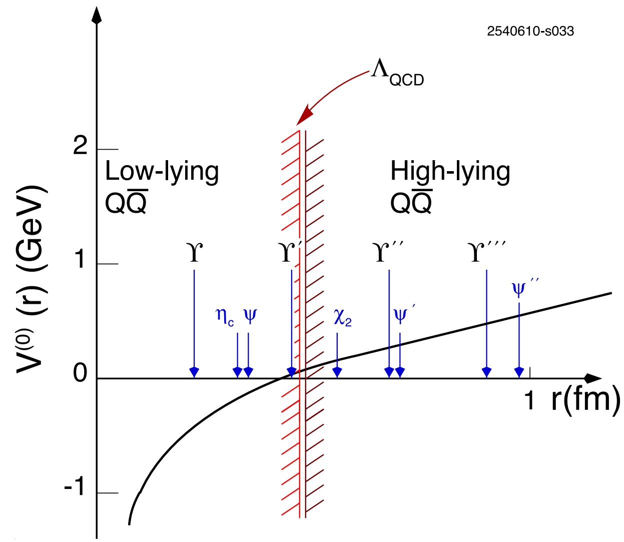

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Short-distance part $\longleftrightarrow$ Long-distance part

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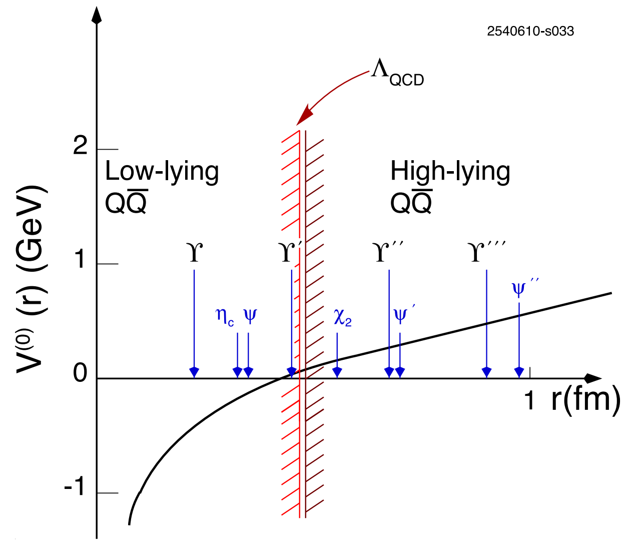

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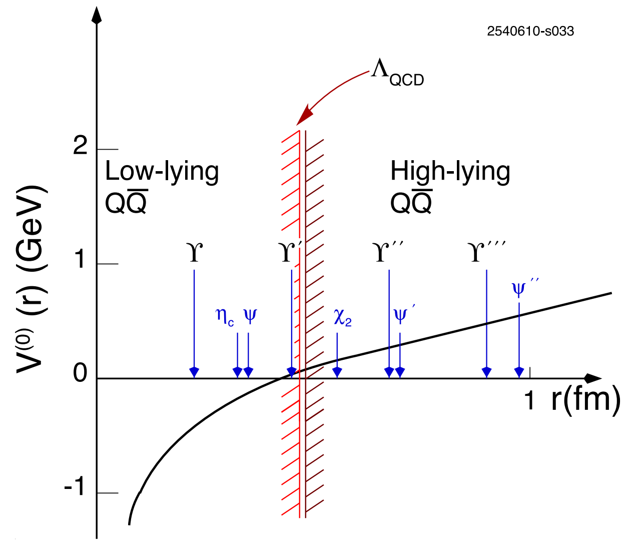

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Perturbation theory

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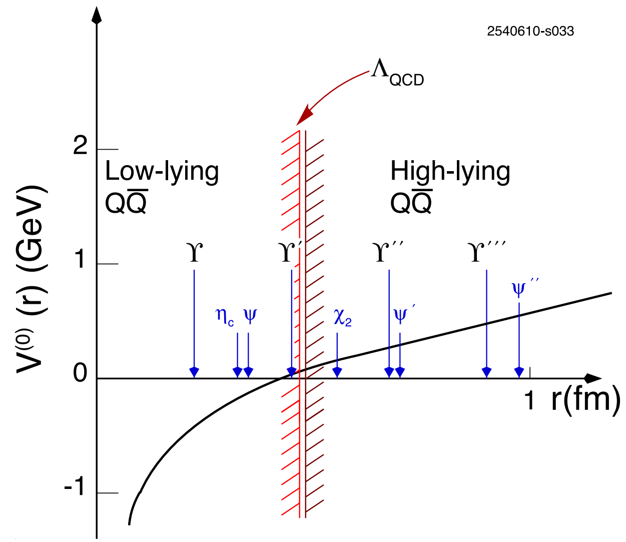

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Short-distance part $\downarrow$ Perturbation theory

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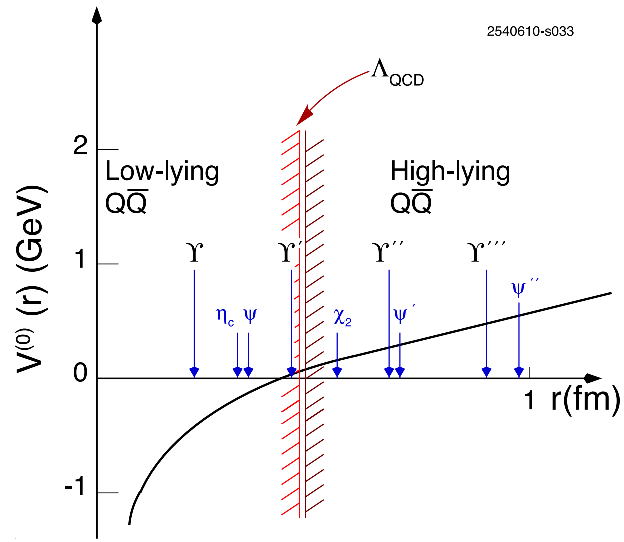

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Lattice data

$E_0(r)$ recently calculated on the lattice in 2+1 flavor QCD

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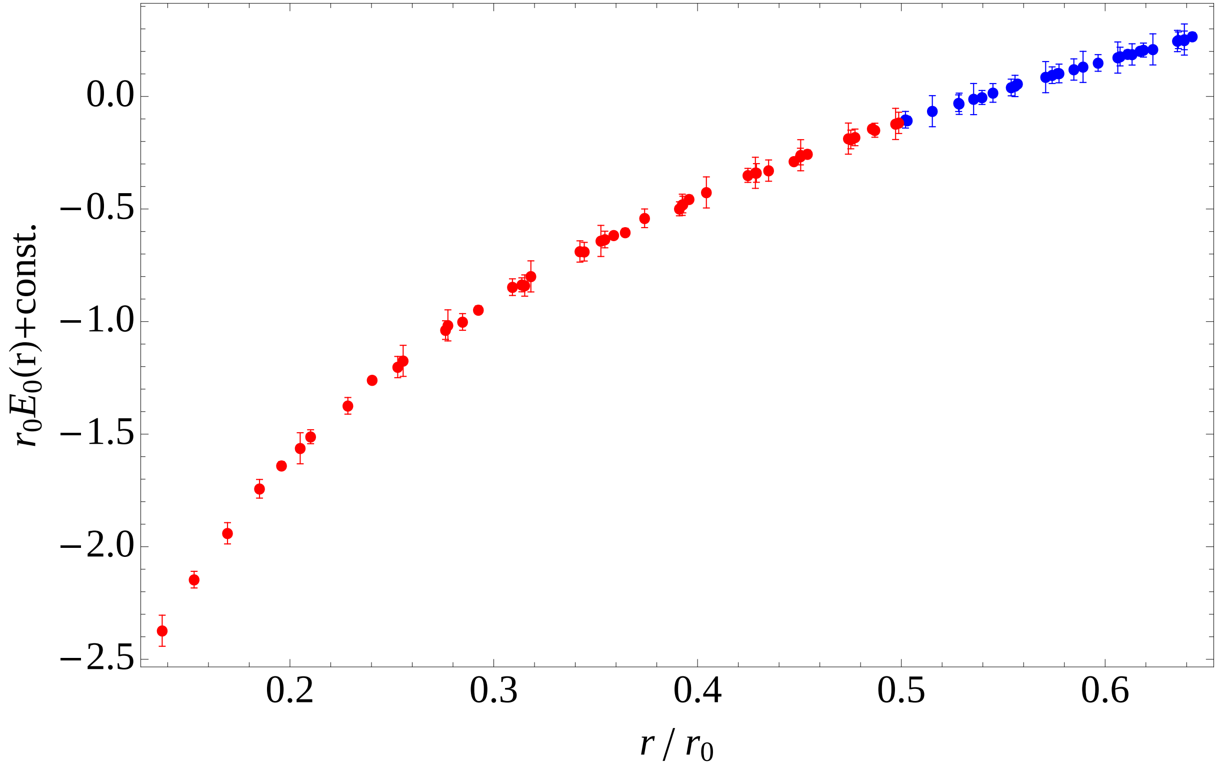

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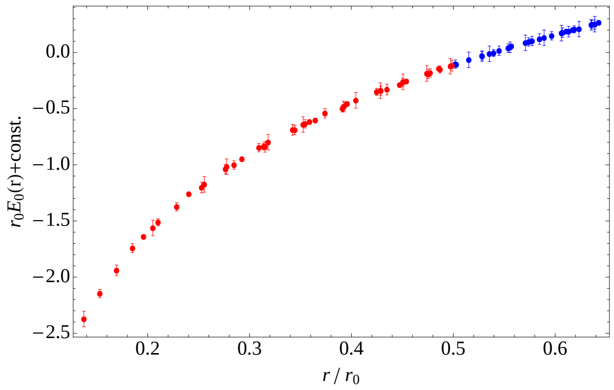

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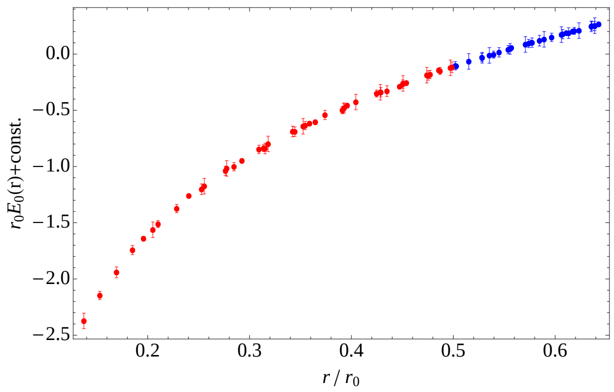

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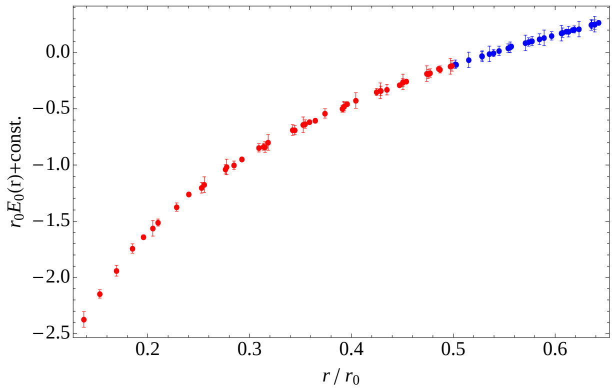

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Energy calculated in units of r_0 Sommer'93

$$r^2 \frac{dE_0(r)}{dr}|_{r=r_0} = 1.65$$

Calculation for a wide range of gauge couplings.
$(\beta = 6.664, 6.740, 6.800, 6.880, 6.950, 7.030, 7.150, 7.280$;
corresponds to lattice spacings $3.994/r_0 \leq a^{-1} \leq 6.991/r_0)$

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- Replace r by improved distance $r_I = (4\pi C_L(r))^{-1}$

  Necco Sommer'01

$$C_L(r) = \int \frac{d^3k}{(2\pi)^3} D_{00}(k_0 = 0, \vec{k}) e^{i\vec{k}\vec{r}}$$

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  Aubin *et al.*'04, Booth *et al.*'92

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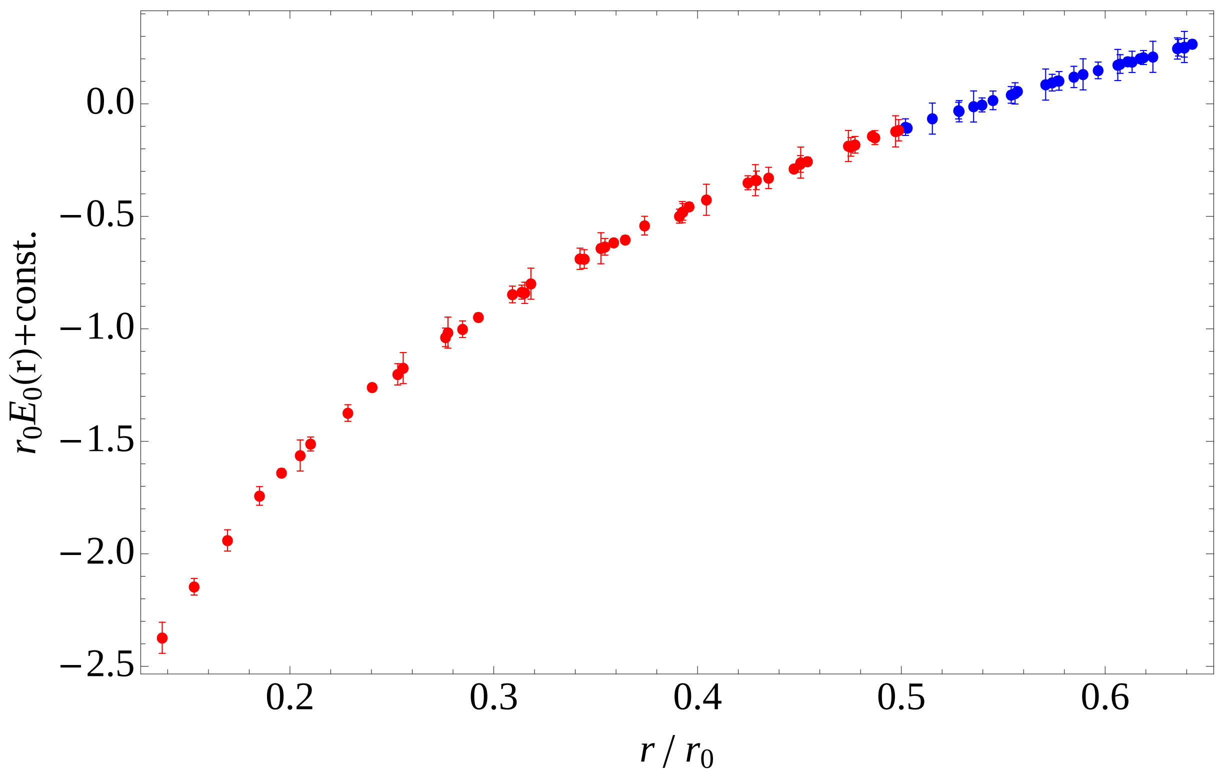
Both methods lead to the same results, within errors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−0.5
−1.0
−1.5
−2.0
−2.5
0.2
0.3
0.4
0.5
0.6
$r_0 E_0(\mathrm{r})$+const.
r / r_0

Static energy in perturbation theory

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Virtual emissions that change the color state of the pair (*Ultrasoft gluons*)

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$$E_0^{\mathrm{N^3LO}}(r) = -\frac{C_F \alpha_s(1/r)}{r}\left\{1 + 17.4\,\frac{\alpha_s(1/r)}{4\pi} + 863\left(\frac{\alpha_s(1/r)}{4\pi}\right)^2 + \left[1421 \ln\frac{3\alpha_s(1/r)}{2} + 53945\right]\left(\frac{\alpha_s(1/r)}{4\pi}\right)^3\right\}$$

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E_0 known at *3 loop +sub-leading ultrasoft log res.* (N^3LL)

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Agreement with lattice improves when perturbative order is increased

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In that ϱ range, use reduced χ^2 as weight of fit values $r_0\Lambda_{\overline{\rm MS}}$ and take the average. This gives our central value for $r_0\Lambda_{\overline{\rm MS}}$

Accuracy	$r_0\Lambda_{\overline{\rm MS}}$
tree level	0.395
1 loop	0.848
2 loop	0.636
N^{2}LL	0.756
3 loop	0.690
3 loop + lead. us. res.	0.702

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N$^{3(2)}$LL accuracy: $\alpha_{\rm s}^{1+[3(2)+n]}\ln^n\alpha_{\rm s}$ with $n\geq 0$
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Take 3 loop + lead. us. res. as our best result

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Cross-check: redo full analysis with energy normalized in units of r_1

$$r^2 \frac{dE_0(r)}{dr}\Big|_{r=r_1} = 1$$

Gives compatible results

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Cross-check: redo full analysis with energy normalized in units of r_1

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Gives compatible results (comes from the same lattice data set in terms of r/a. But error analysis for the normalization of the energy for each lattice spacing is different in the two cases)

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which corresponds to

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$$\rightarrow \quad \alpha_s\left(M_Z, n_f = 5\right) = 0.1156^{+0.0021}_{-0.0022}$$

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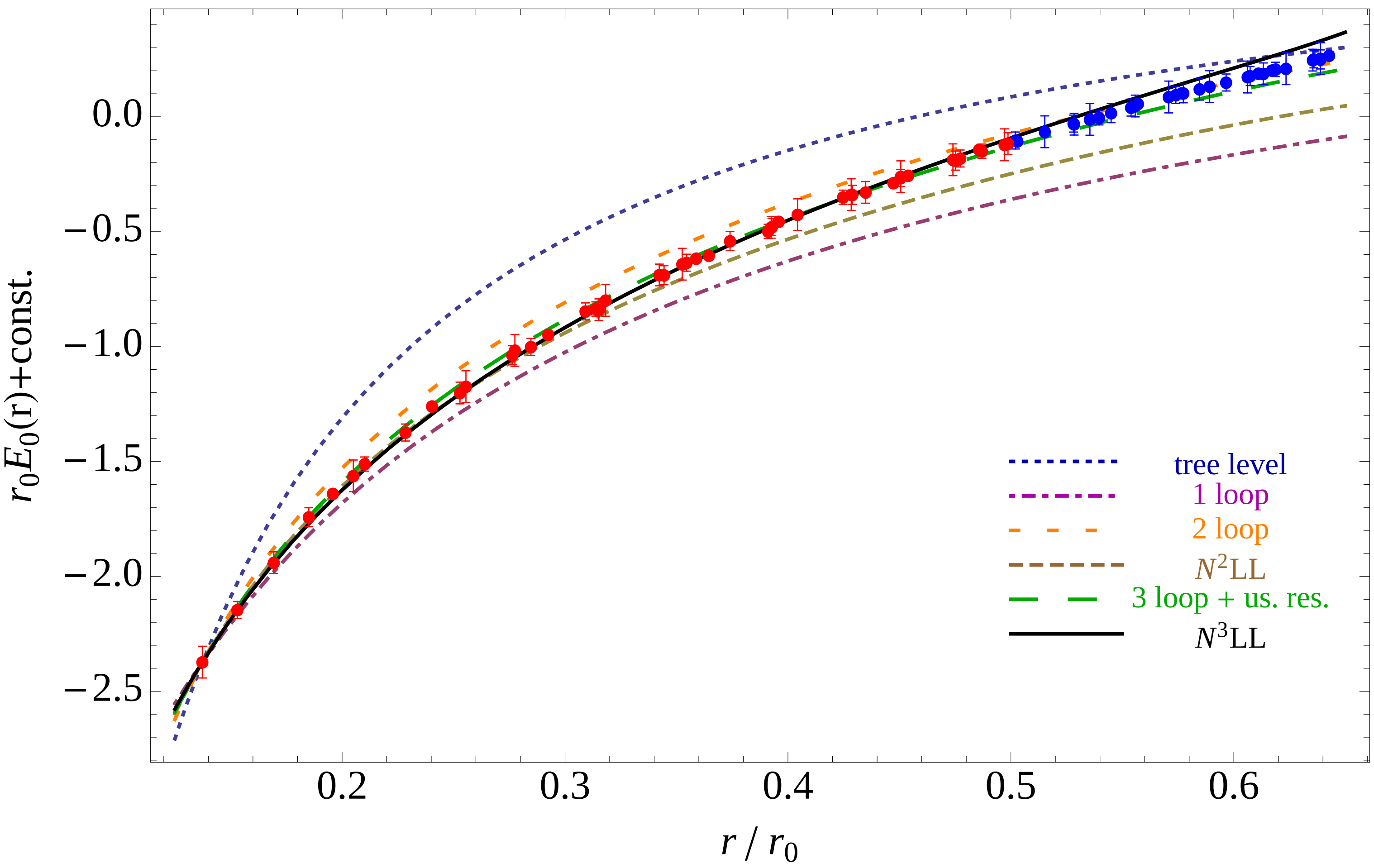

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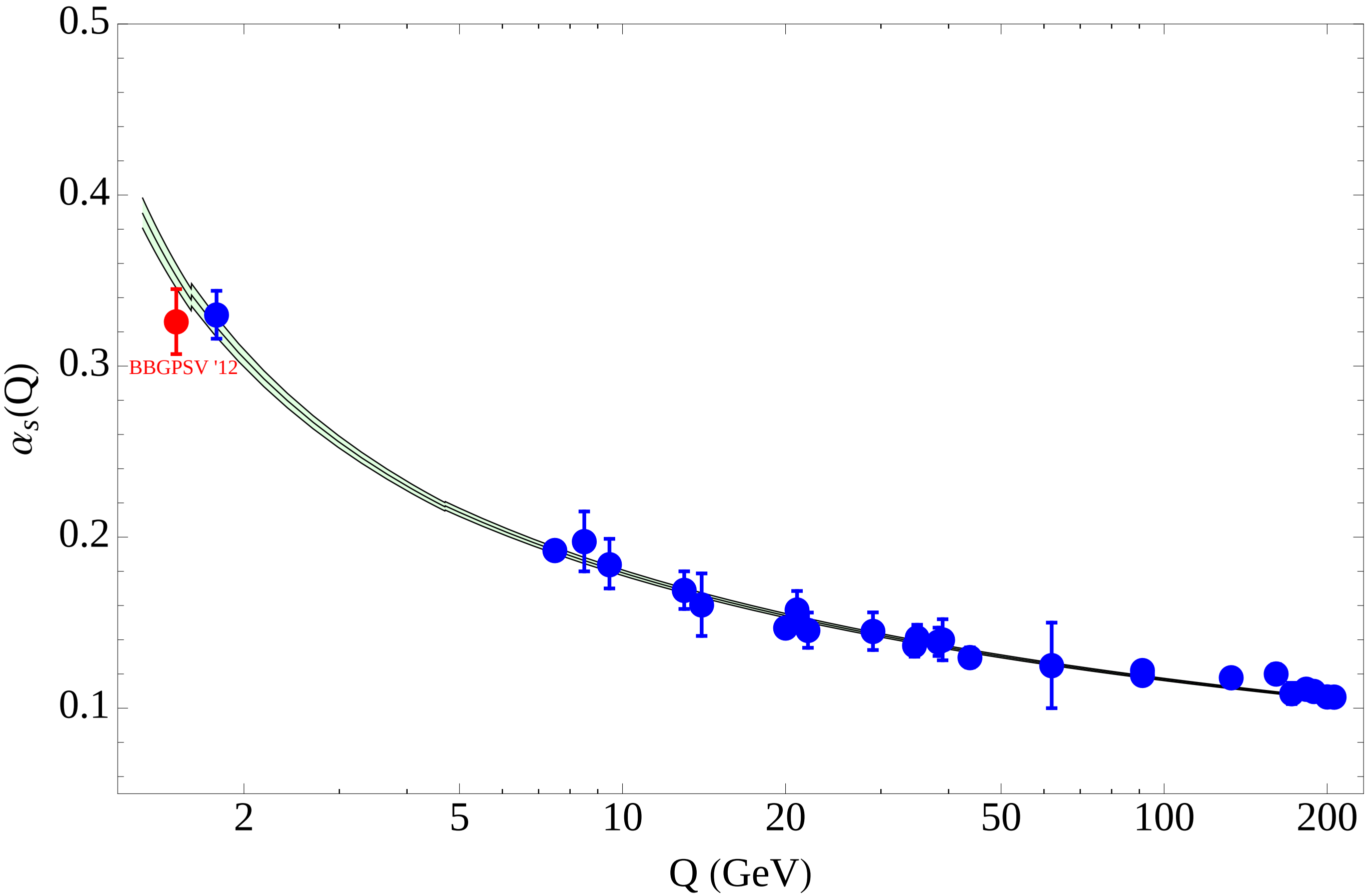
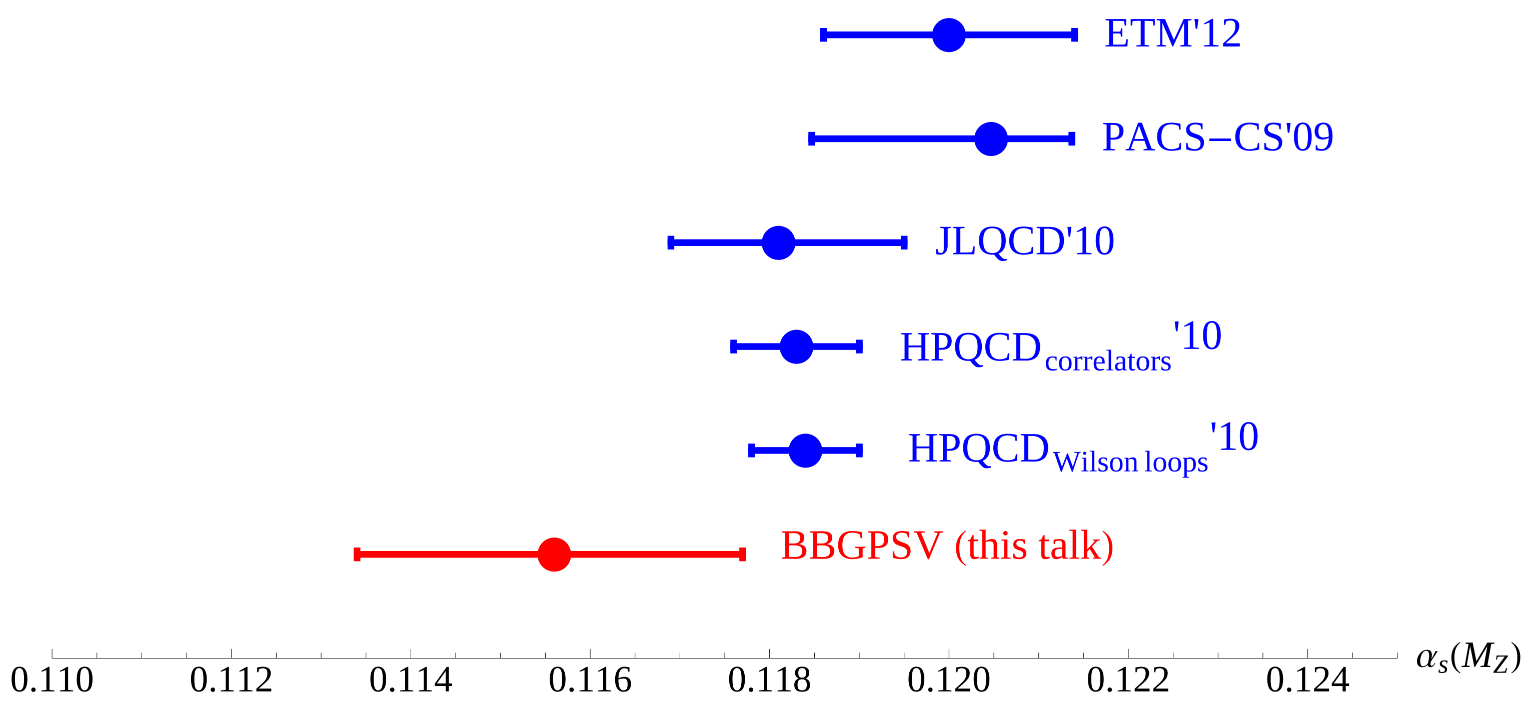
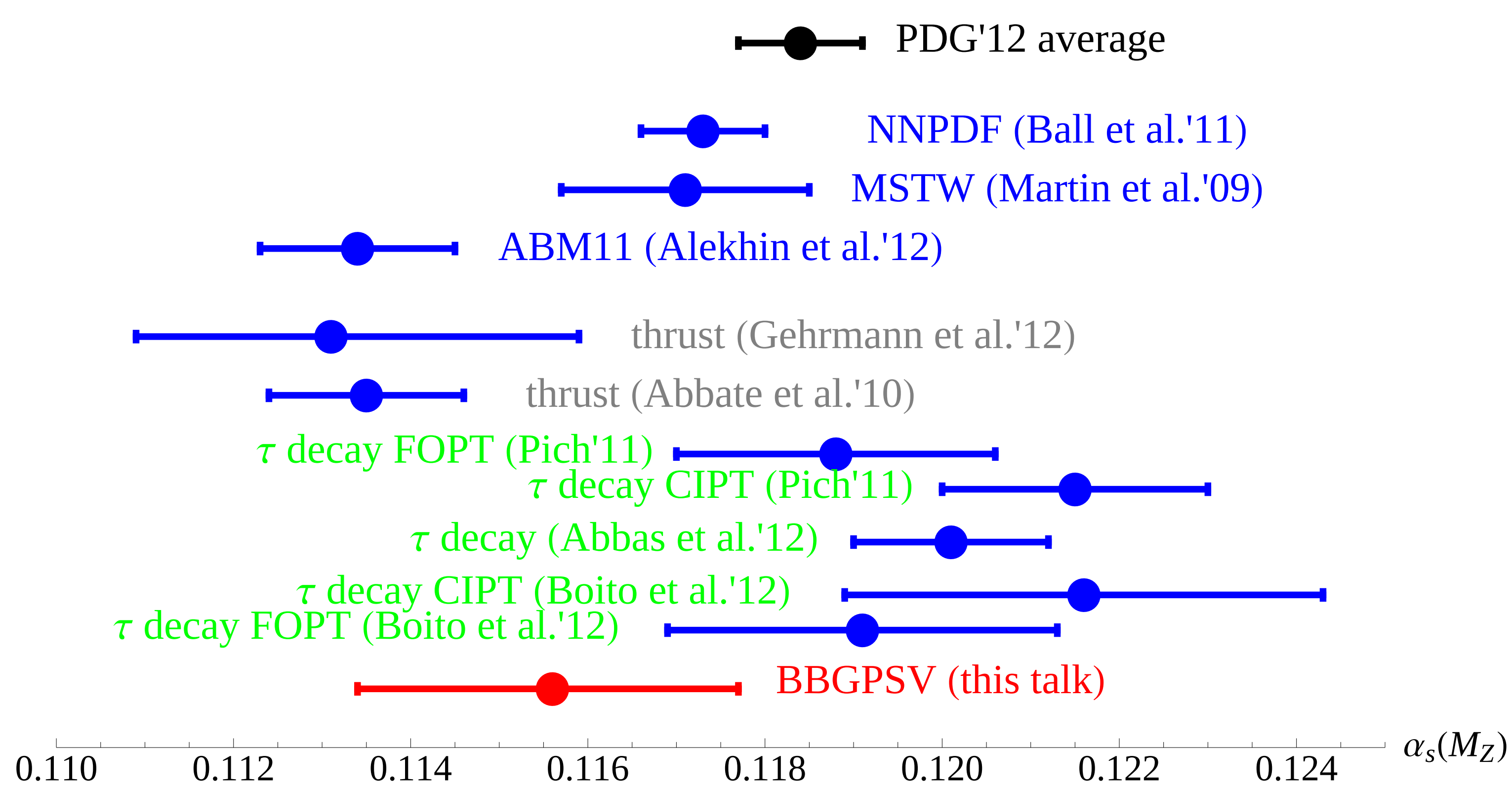


Determinations entering the world average Bethke'09 This result

Comparison with other recent lattice determinations



Comparison with a few recent determinations using other techniques



Conclusions

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- Updated analysis (in the near future), also including lattice data at shorter distances. Reduced error for our α_{s} extraction is conceivable