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World Summary of α_s (2015)

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Abstract. This is a **preliminary** update of the measurements of α_s and the determination of the world average value of $\alpha_s(M_Z^2)$ presented in the 2013/2014 edition of the Review of Particle Properties [1].

A number of studies which became available since late 2013 provide new results for each of the (previously 5, now) 6 subclasses of measurements for which pre-average values of $\alpha_s(M_Z^2)$ are determined. In the following, we list those new results which are used to determine the new average values of α_s, i.e. which are based on at least complete $NNLO$ perturbation theory and are published in peer-reviewed journals, as well as those which are used for demonstrating asymptotic freedom (although being based on NLO only) :

- updated results from τ-decays [2] [3] [4], based on a re-analysis of ALEPH data and on complete N^3LO perturbation theory,
- more results from unquenched lattice calculations, [5][6],
- further results from world data on structure functions, in $NNLO$ QCD [7],
- from e^+e^- hadronic event shapes (C-parameter) in soft collinear effective field theory ($NNLO$) [8],
- α_s determinations at LHC, from data on the ratio of inclusive 3-jet to 2-jet cross sections [9], from inclusive jet production [10], from the 3-jet differential cross section [11], and from energy-correlations [12], all in NLO QCD, plus one determination in complete $NNLO$, from a measurement of the $t\bar{t}$ cross section at $\sqrt{s} = 7$ TeV [13];
- and finally, an update of α_s from a global fit to electroweak precision data [14].

All measurements available in subclasses of τ-decays, lattice results, structure functions and from e^+e^--annihilation are summarized in figure 1.

With the exception of lattice results, most results within their subclass are strongly correlated, however to an unknown degree, as they largely use the same data sets. The large scatter between many of these measurements, sometimes with only marginal or no agreement within the given errors, indicate the presence of additional systematic uncertainties from theory or caused by details of the analyses. In such cases, a pre-average value is determined,

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with a symmetric, overall uncertainty that encompasses the central values of all individual determinations ('*range averaging*'). For the subclass of lattice results, the average value determined in Ref. [5] is taken over. For the subclasses of hadron collider results and electroweak precision fits, only one result each is available in full $NNLO$, so that no pre-averaging can be applied. Note, however, that more measurements of top-quark pair production at LHC are meanwhile available, indicating that on average, a larger value of $\alpha_s(M_Z^2)$ is likely to emerge in the future; see also [15]. The resulting subclass averages are indicated in figure 1, and are summarized in table 1.

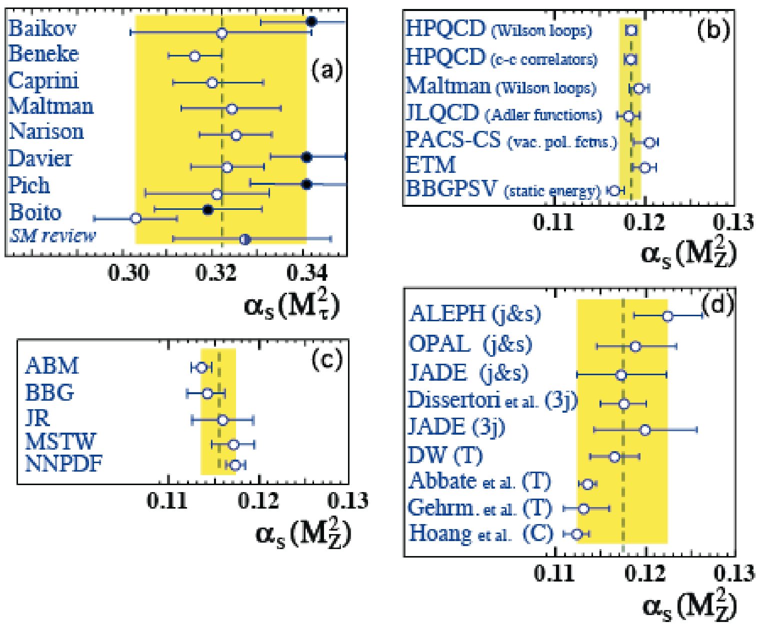

Figure 1. Summary of determinations of α_s from hadronic τ-decays (a), from lattice calculations (b), from DIS structure functions (c) and from e^+e^- annihilation (d). The shaded bands indicate the pre-average values explained in the text, to be included in the determination of the final world average of α_s. In a), full circles are results obtained using CIPT, and open circles using FOPT expansions, see text.

Assuming that the resulting pre-averages are largely independent of each other, the final world average value is determined as the weighted average of the different input values. An initial uncertainty of the central value is calculated treating the uncertainties of all measurements as being uncorrelated and of Gaussian nature, and the overall χ^2 to the central value is determined. If the initial value of χ^2 is smaller than the number of degrees of freedom, an overall, a-priori unknown correlation coefficient is introduced and determined by requiring that the total χ^2/d.o.f. equals unity. Applying this procedure to the values listed in table 1 results in a **preliminary** new world average of

$$\alpha_s(M_Z^2) = 0.1177 \pm 0.0013 \ .$$

Table 1. Pre-average values of subclasses of measurements of $\alpha_s(M_Z^2)$. The value from τ-decays was converted from $\alpha_s(M_\tau^2) = 0.322 \pm 0.019$, using the QCD 4-loop β-function plus 3-loop matching at the charm- and bottom-quark pole masses.

Subclass	$\alpha_s(M_Z^2)$
τ-decays	0.1187 ± 0.0023
lattice QCD	0.1184 ± 0.0012
structure fuctions	0.1154 ± 0.0020
e^+e^- [jets & shps]	0.1174 ± 0.0051
hadron collider	$0.1151^{+0.0028}_{-0.0027}$
ew precision fits	0.1196 ± 0.0030

This value is in reasonable agreement with that from 2013/2014, which was $\alpha_s(M_Z^2) = 0.1185 \pm 0.0006$, however at a somewhat decreased central value and with an overall uncertainty that has doubled. These changes are mainly due to the following reasons:

- the uncertainty of the lattice result, now taken from the estimate made by the FLAG group, is more conservative than that used in the previous review, leading to a larger final uncertainty of the new world average, and to a reduced fixing power towards the central average value;
- the decreased pre-average value of $\alpha_s(M_Z^2)$ from τ-decays, due to the most recent re-evaluations and their unexplained, increased inconsistency with respect to each other;
- the relatively low value of α_s from the new sub-class of hadron collider results, which currently consists of only one measurement of the $t\bar{t}$ cross section at $\sqrt{s} = 7$ TeV, and which appears to be "lowish" if compared to further measurements at higher $\sqrt{s}$ [15].

Note that pending revisions of the procedures applied may still change the results shown in table 1 and the final world average value which therefore are regarded to be **preliminary**.

While there is still room for improved measurements and treatments of systematic uncertainties, the data and results, especially when including measurements which are available at *NLO* only, consistently demonstrate and prove asymptotic freedom and the running of α_s, as predicted by QCD, up to energies beyond 1 TeV, see figure 2.

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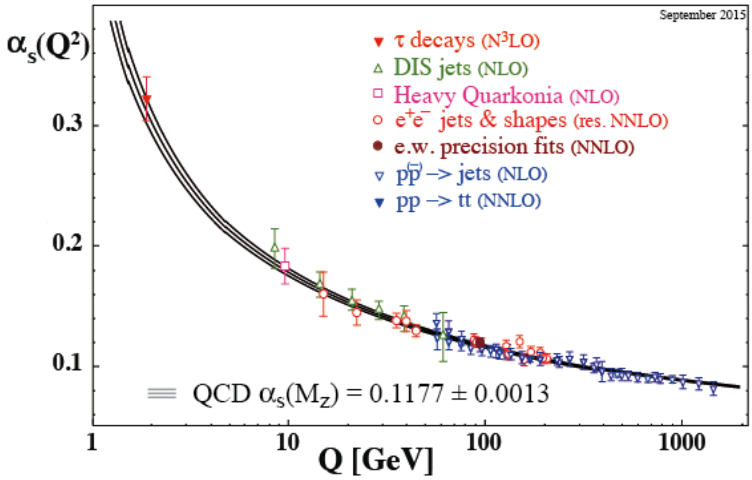

Figure 2. Summary of measurements of α_s as a function of the energy scale Q. The respective degree of QCD perturbation theory used in the extraction of α_s is indicated in brackets (NLO: next-to-leading order; NNLO: next-to-next-to leading order; res. NNLO: NNLO matched with resummed next-to-leading logs; N^3LO: next-to-NNLO).

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