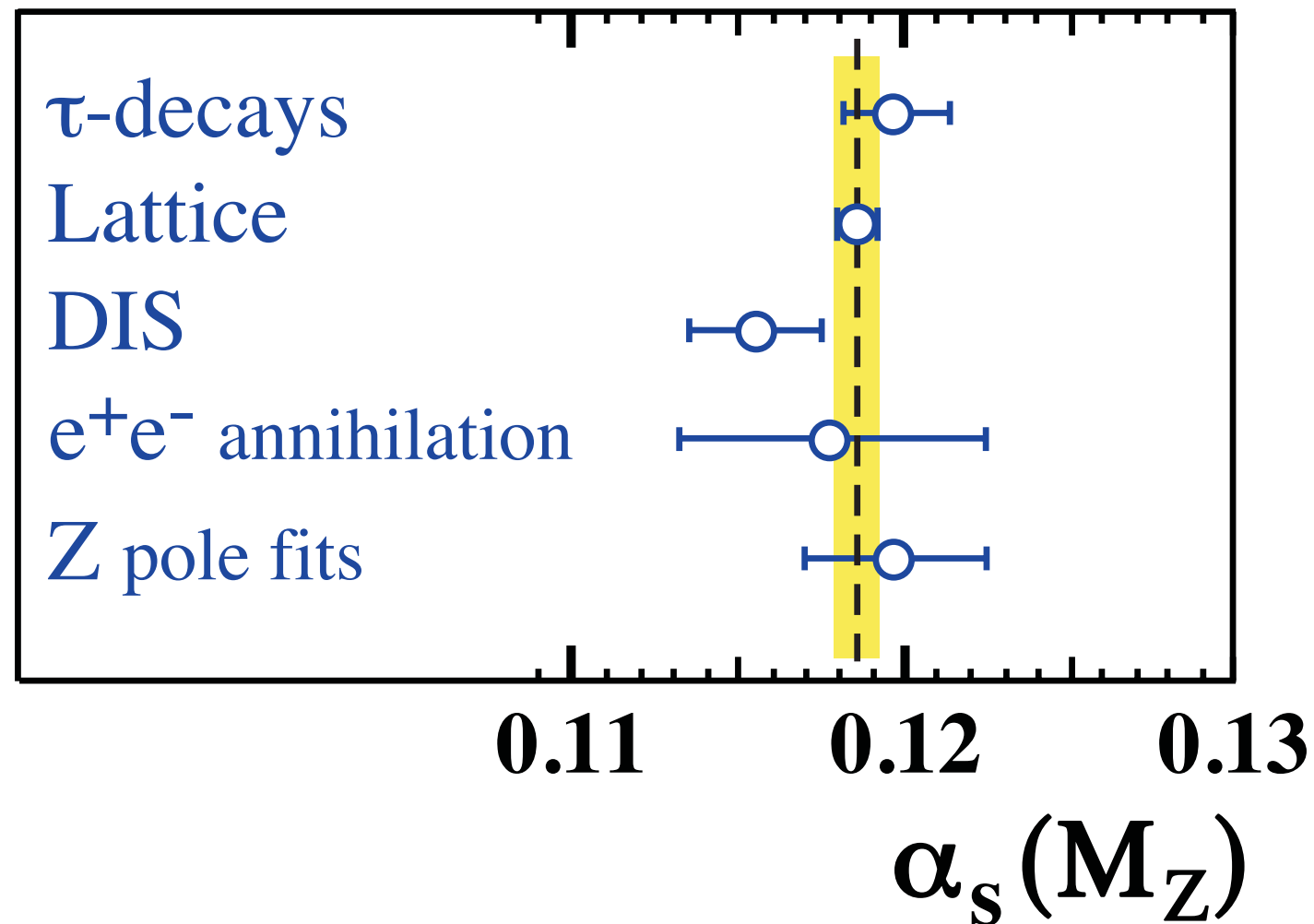


World summary

of

α_s (2015)

World Summary of α_s 2013:



$$\rightarrow \alpha_s(M_Z) = 0.1185 \pm 0.0006$$

- n.b.:
- 5 classes of measurements, each pre-averaged
 - all at least using NNLO QCD
 - using two methods to determine (pre-)averages

World Summary of α_s 2013:

used two methods to determine (pre-)averages:

– “range averaging”

average value with symmetric overall uncertainty that encompasses the central values of all individual α_s -results

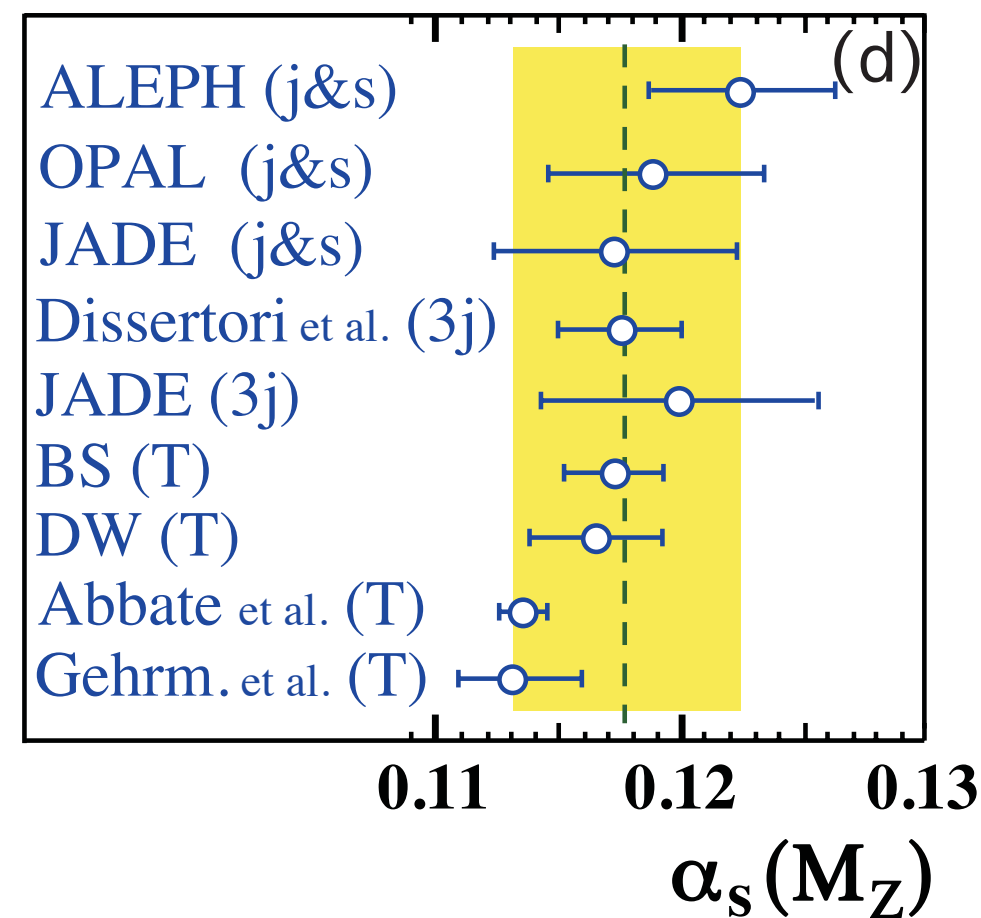
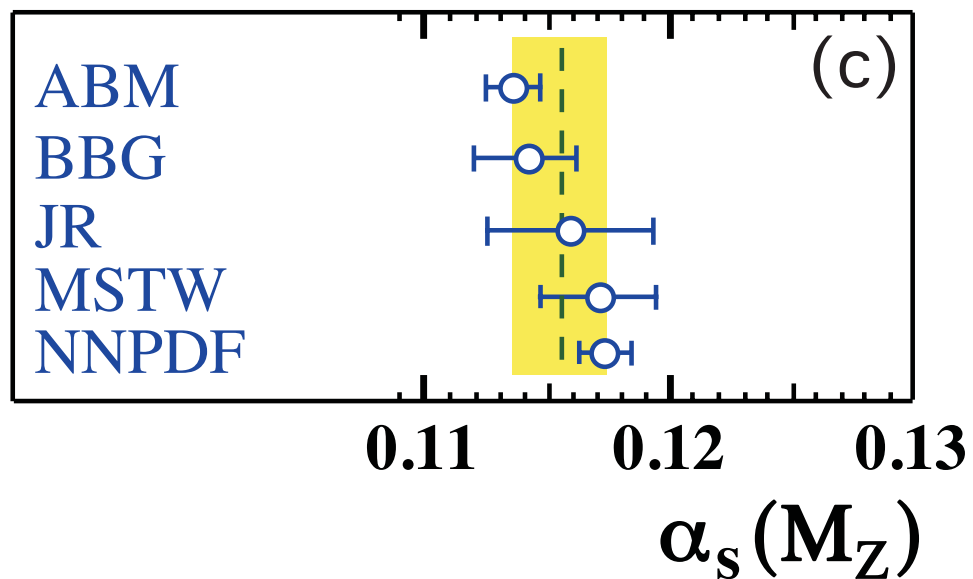
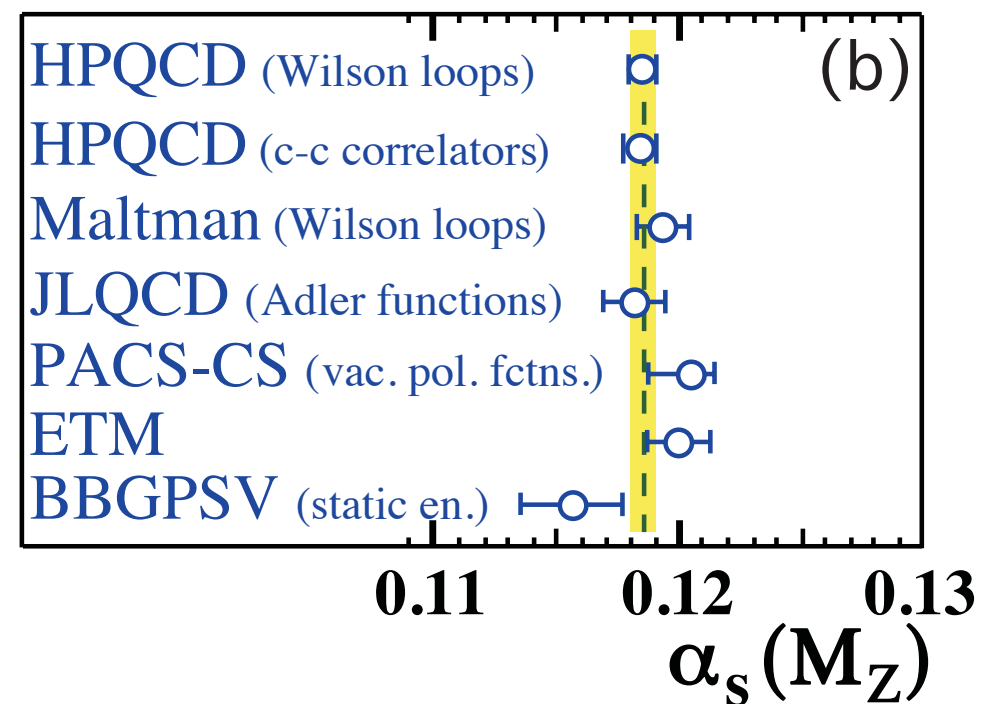
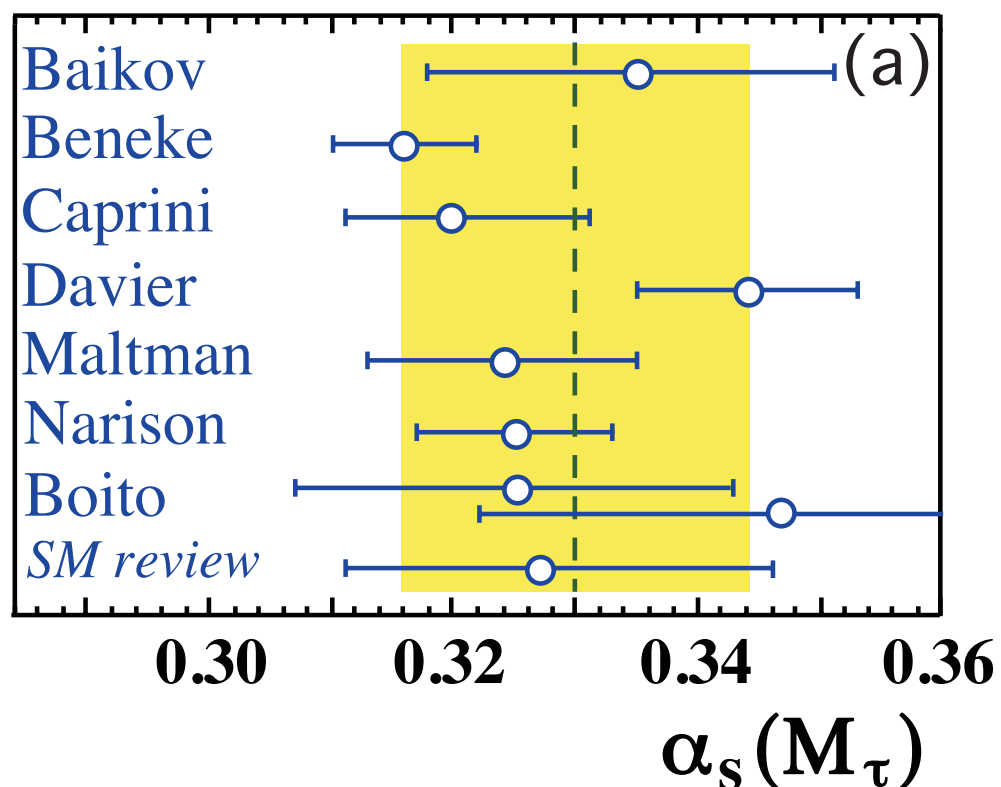
– “ χ^2 method”

weighted average treating individual uncertainties as being uncorrelated and of Gaussian nature.

If overall $\chi^2 < 1/\text{d.o.f.}$, an overall correlation coefficient is introduced and adjusted such that $\chi^2 = 1/\text{d.o.f.}$

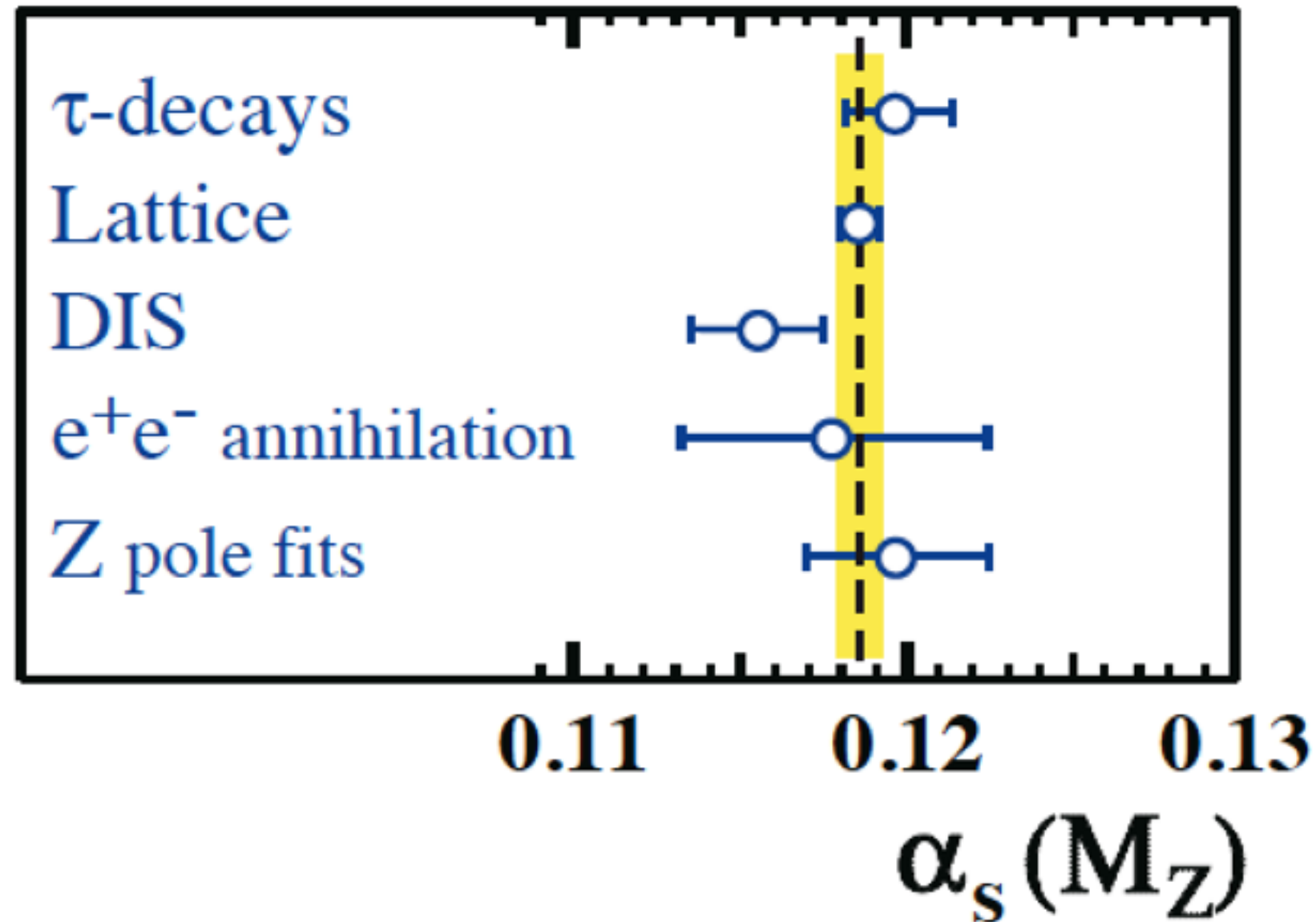
If overall $\chi^2 > 1/\text{d.o.f.}$, all uncertainties are enlarged by a common factor such that $\chi^2 = 1/\text{d.o.f.}$

World Summary of α_s 2013:



(e) Z-pole fits: $\alpha_s(M_Z) = 0.1197 \pm 0.0028$

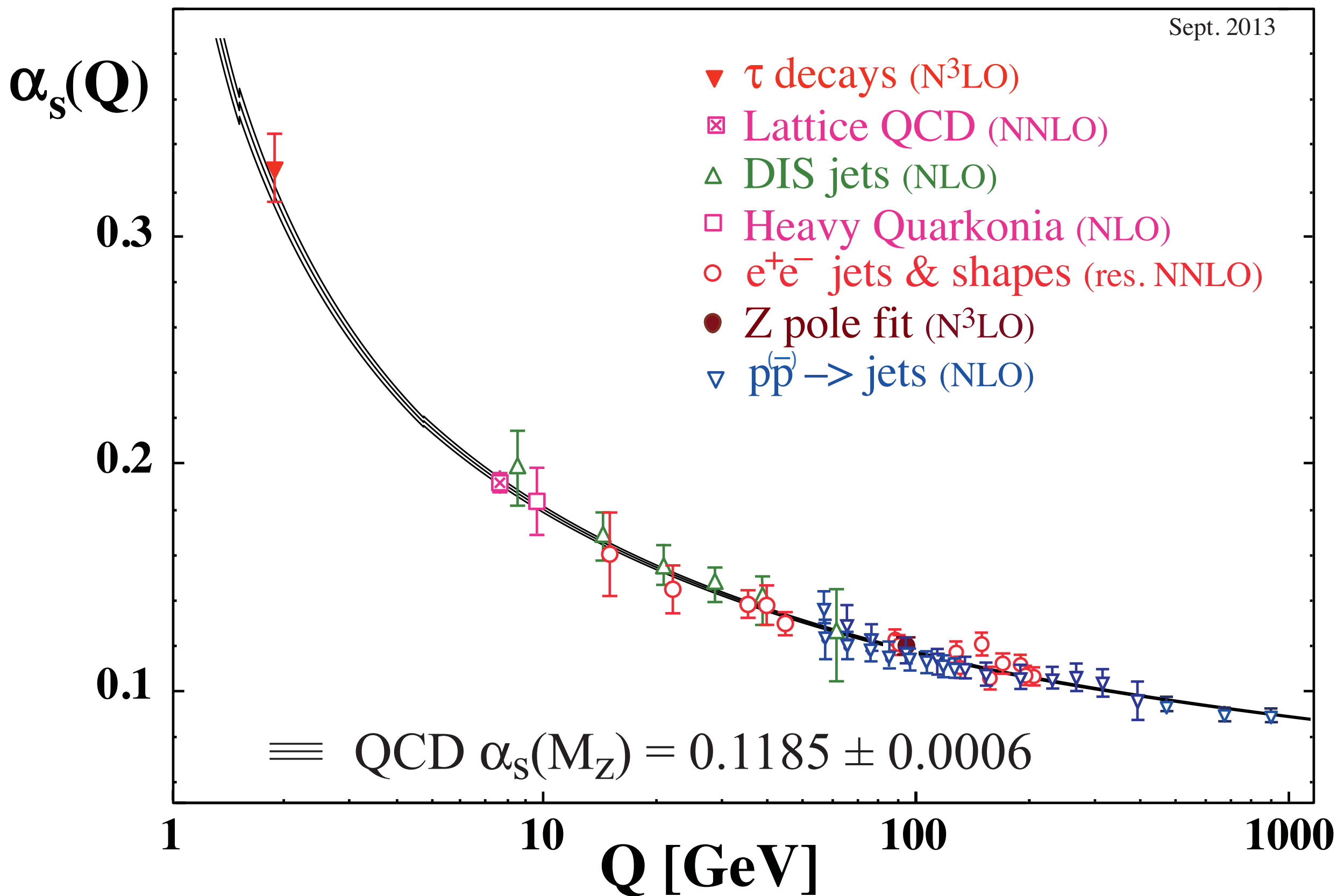
World Summary of α_s 2013:



$$\alpha_s(M_Z) = 0.1185 \pm 0.0006$$

without lattice: $\alpha_s(M_Z) = 0.1183 \pm 0.0012$

World Summary of α_s 2013:



new measurements/results added for 2015 summary :

- update results from τ -decays (in $N^3\text{LO}$)

(Davier et al., Eur.Phys.J. C74 (2014) 3, 2803; Boito et al., Phys.Rev. D91 (2015) 3, 034003)

- more results from unquenched lattice calculations

(FLAG collab., Eur.Phys.J. C74 (2014) 2890; Brambilla et al., Phys.Rev. D90 (2014) 7, 074038)

- more α_s from world data of structure functions (in NNLO)

(MMHT, arXiv:1506.05682 [hep-ph])

- α_s from hadron collider (in NNLO) (CMS collab., Phys. Lett. B 728 (2013) 496;)

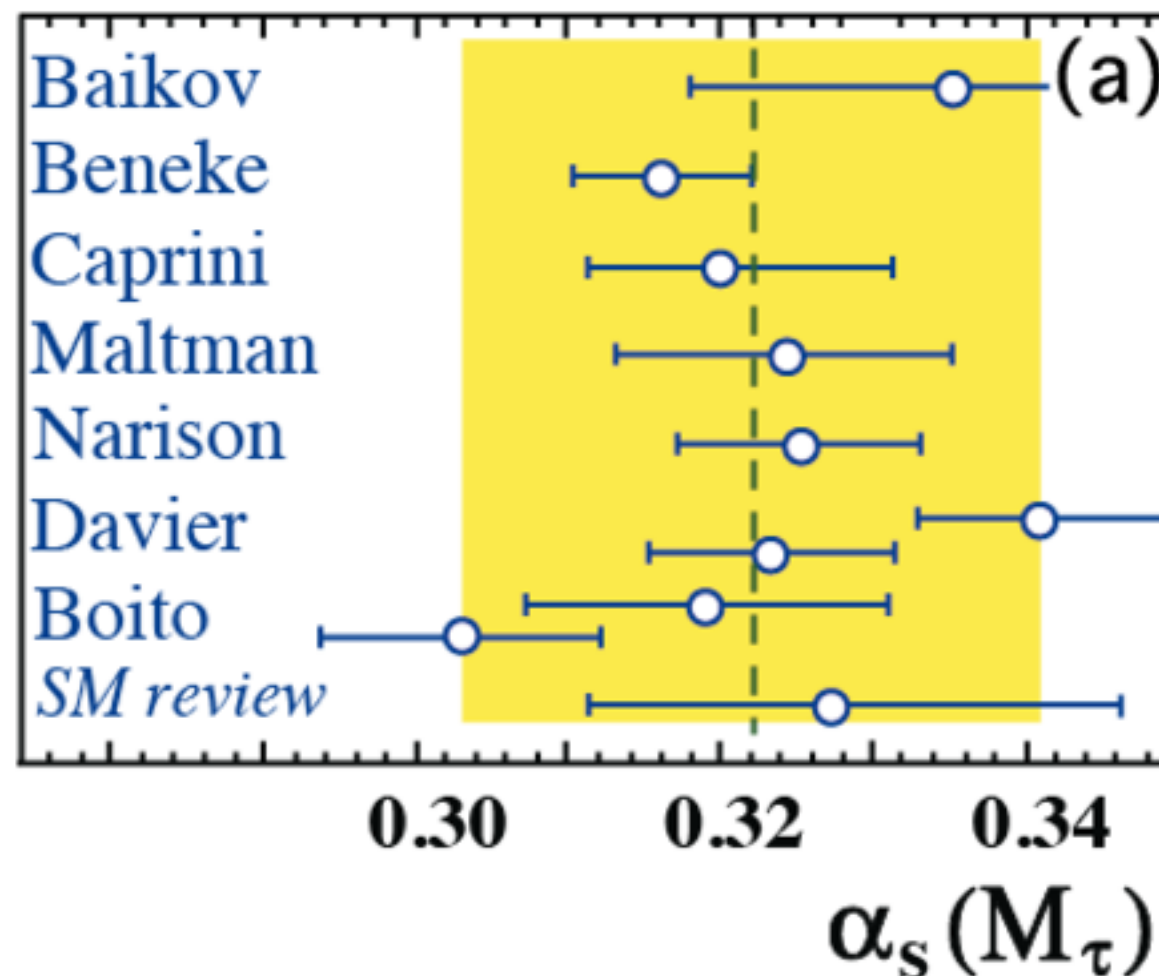
(in NNLO) (CMS collab., Eur. Phys. J. C 75 (2015) 186; Eur. Phys. J. C 75 (2015) 288)

- $e^+ e^-$ hadronic event shape (C) in soft collinear effective field theory (NNLO)

(Hoang et al., Phys. Rev. D 91, 094018 (2015))

α_s from τ -decays

- complete N3LO prediction (Baikov, Chetyrkin, Kühn; arXiv:0801.1821)
- strong theor. activities, all based on ~same (ALEPH) datasets
- large dependence on details of perturbative expansion:
FOPT vs. CIPT; some dependence on nonpert. corrections



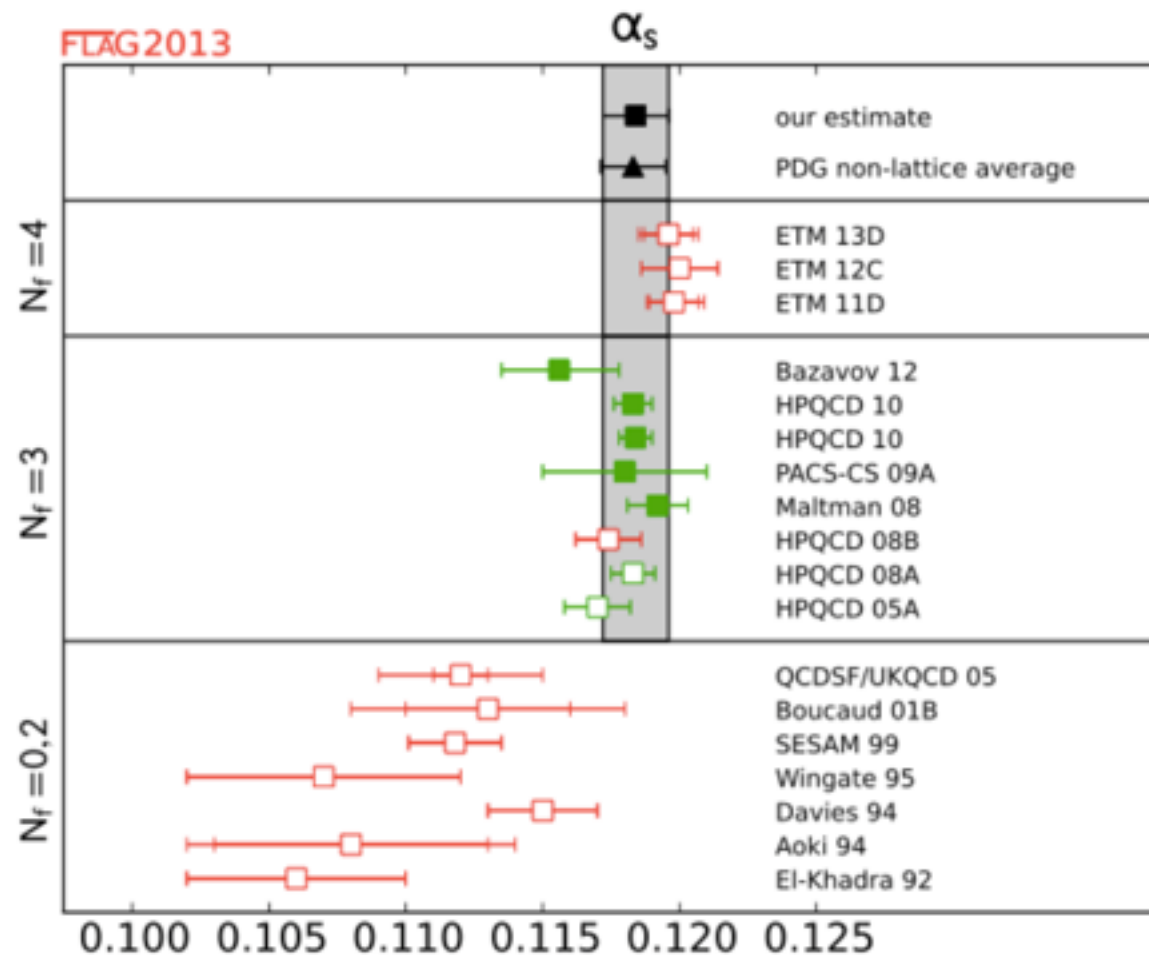
} note: same new ALEPH data, large systematics between different authors!

- averaging and summarising: $\alpha_s(M_\tau) = 0.322 \pm 0.019$
 $\rightarrow \alpha_s(M_Z) = 0.1187 \pm 0.0023$

α_s from lattice QCD

summary from FLAG collaboration, 2013:

- The importance of quality criteria is seen in our estimate of α_{strong}



- FLAG estimate has conservative error (not all FLAG agrees)
- PDG total average takes all lattice results at face value
- PDG without lattice agrees with FLAG

FLAG estimate:

$$\alpha_{\overline{MS}}^{(5)}(M_Z) = 0.1184(12)$$

(2013) PDG average

$$\alpha_{\overline{MS}}^{(5)}(M_Z) = 0.1185(5)$$

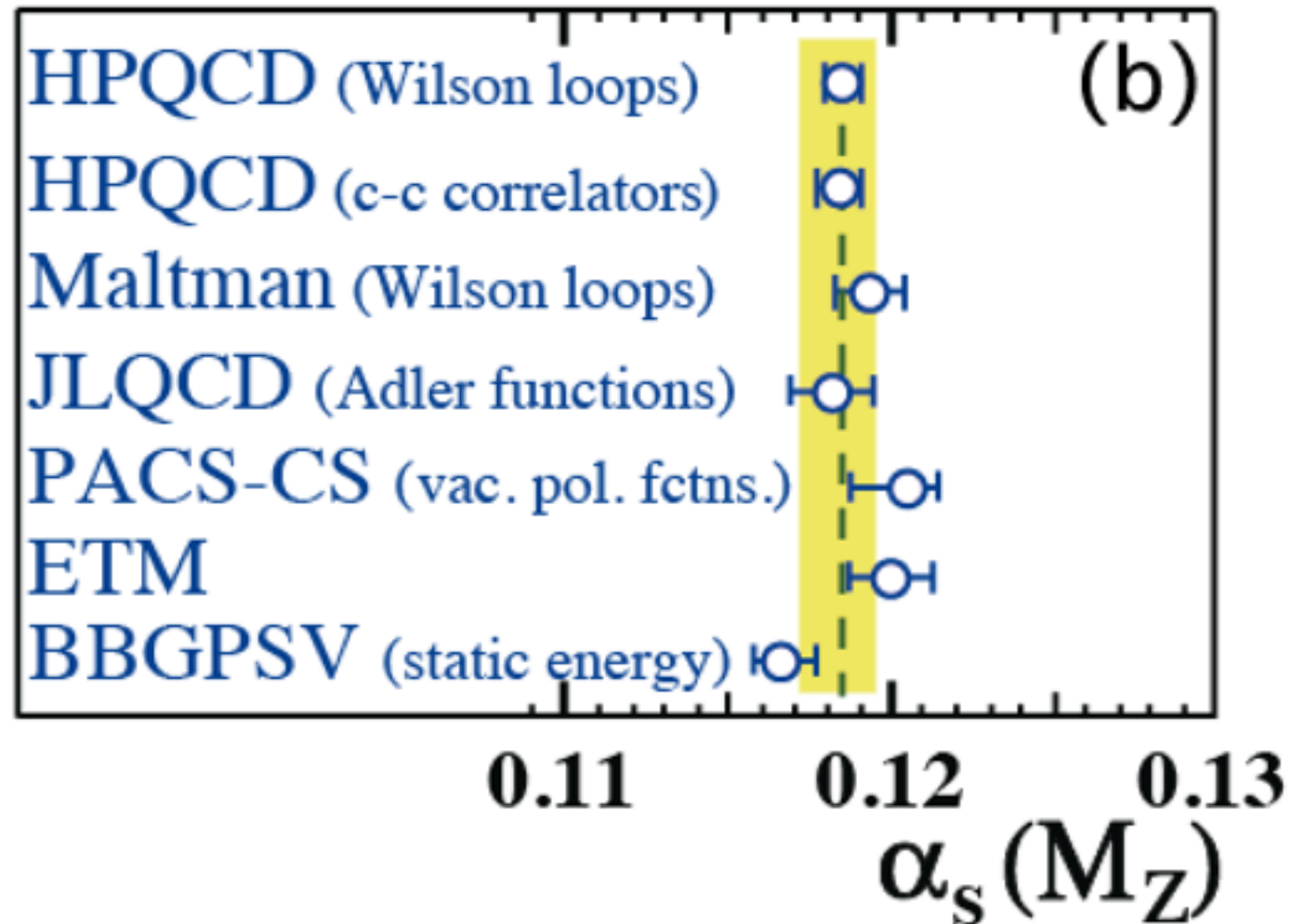
(2013) PDG average (non lattice)

$$\alpha_{\overline{MS}}^{(5)}(M_Z) = 0.1183(12)$$

slide from: Anastasios VLADIKAS

α_s from lattice QCD

our RPP summary 2015:



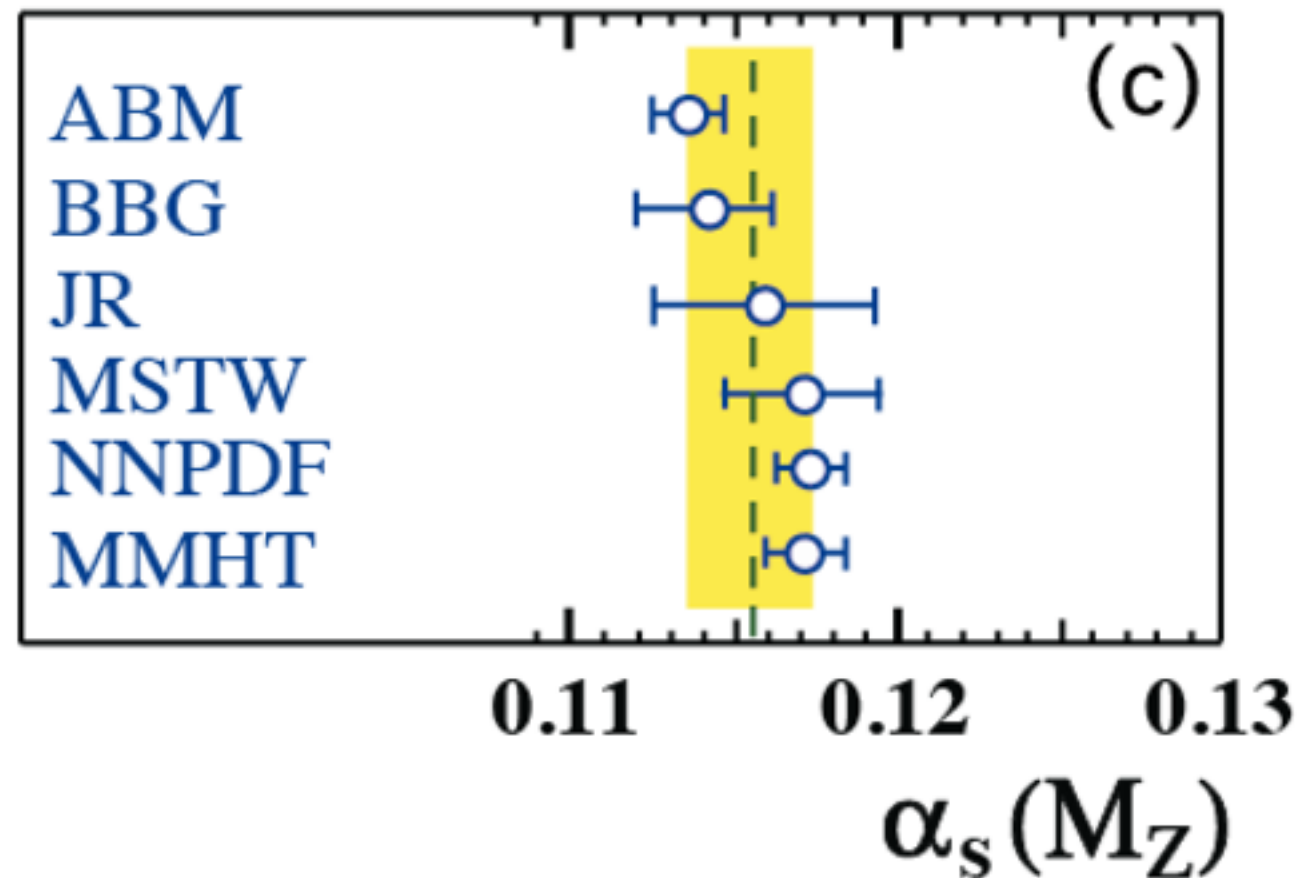
shown: FLAG summary, $\alpha_s(M_Z) = 0.1184 \pm 0.0012$

(if done as in previous RPP: $\alpha_s(M_Z) = 0.1185 \pm 0.0005$)

α_s from DIS structure functions

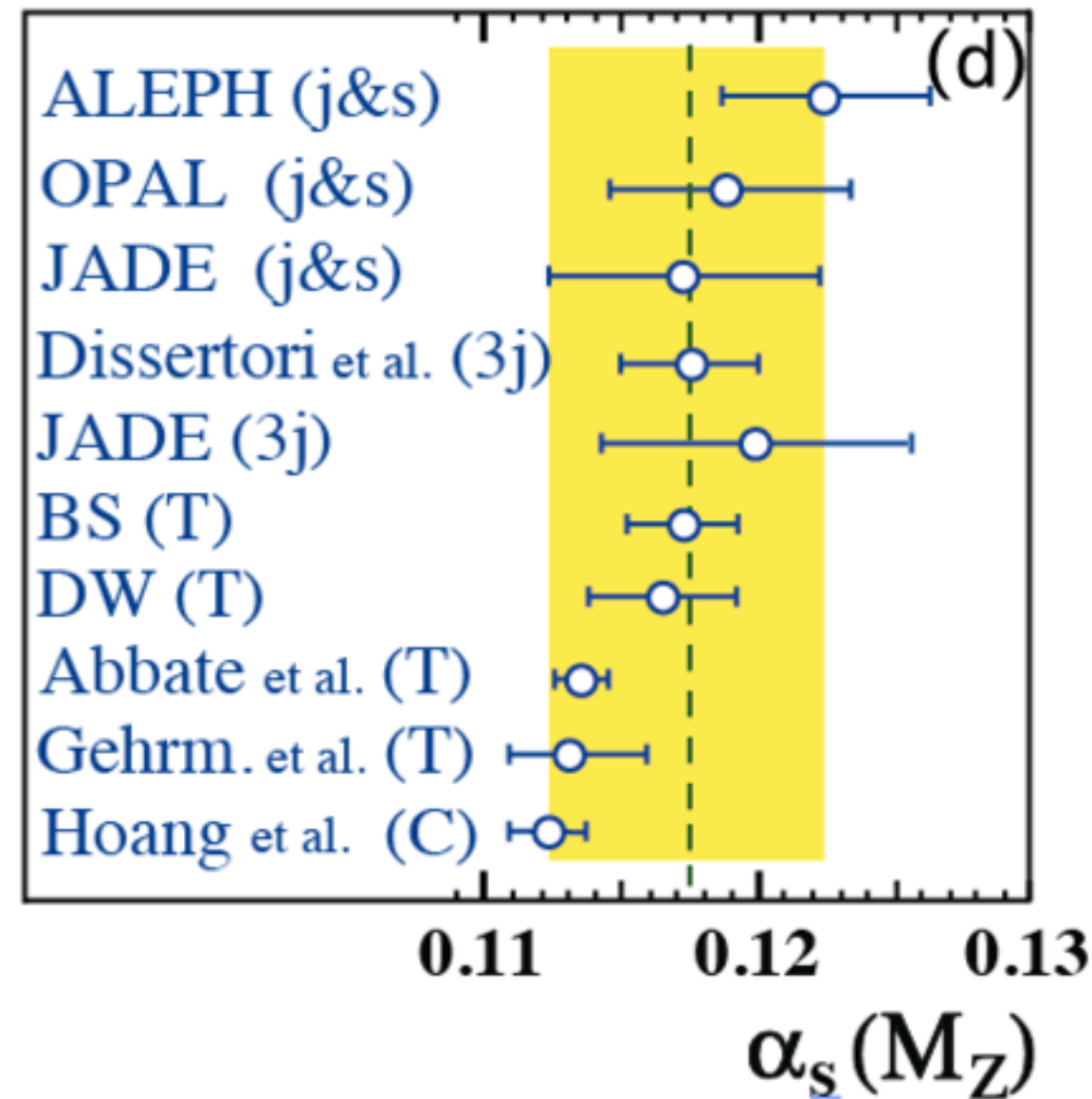
- determination of parton densities from DIS; QCD in NNLO (up to N³LO);
- MSTW/NNPDF/MMHT: include hadron collider jet data (in order to constrain gluon at large x)

n.b.: all use similar (sub-)sets of data



→ $\alpha_s(M_Z) = 0.1154 \pm 0.0020$ (same as in 2013)

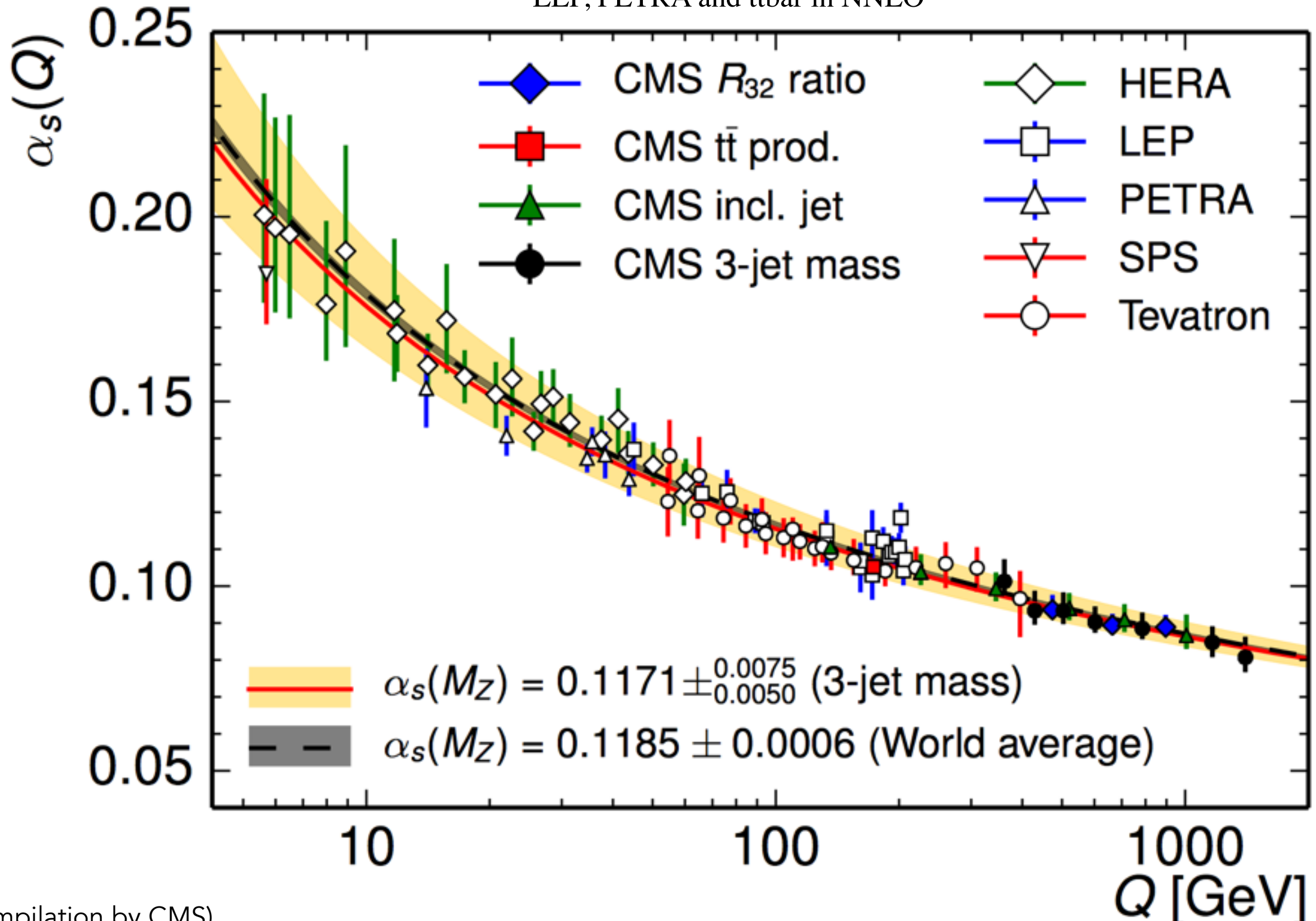
α_s from jets and event shapes in e^+e^- annihilation



$$\rightarrow \alpha_s(M_Z) = 0.1174 \pm 0.0051$$

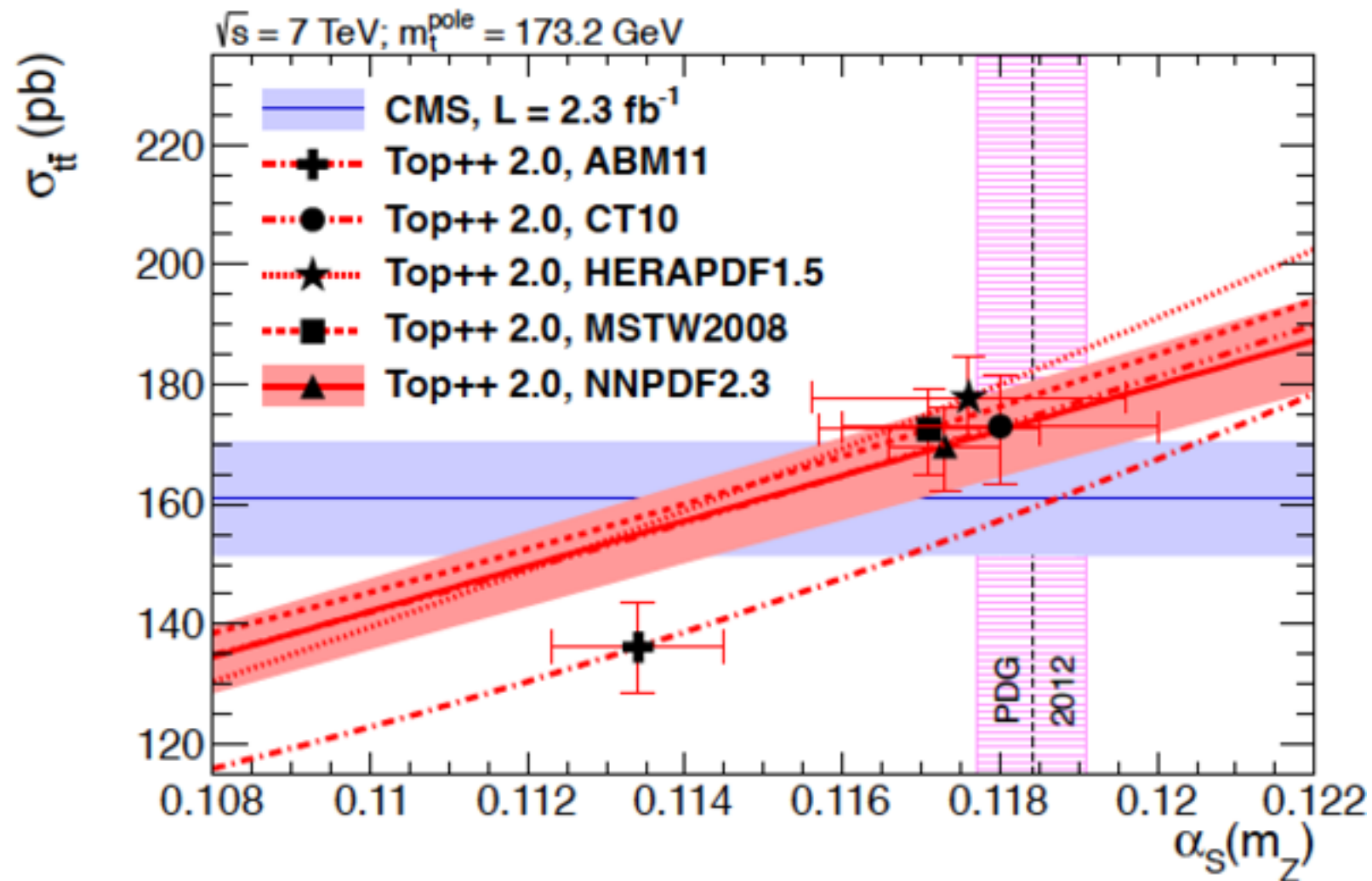
α_s results from hadron collider data

all hadron collider and HERA results in NLO
LEP, PETRA and $t\bar{t}$ in NNLO



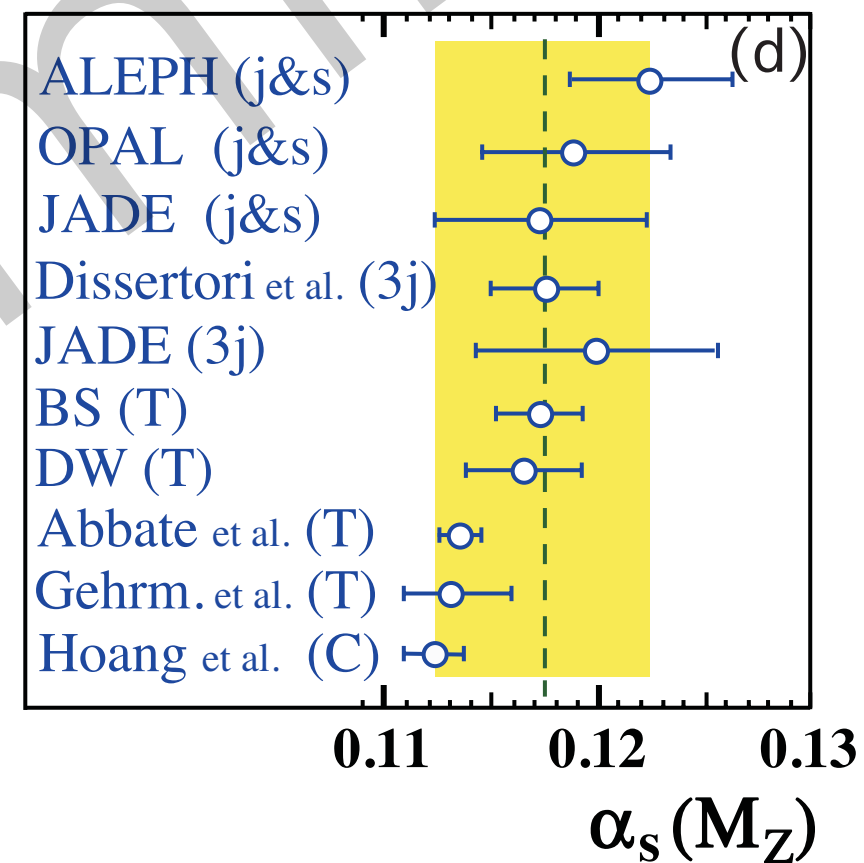
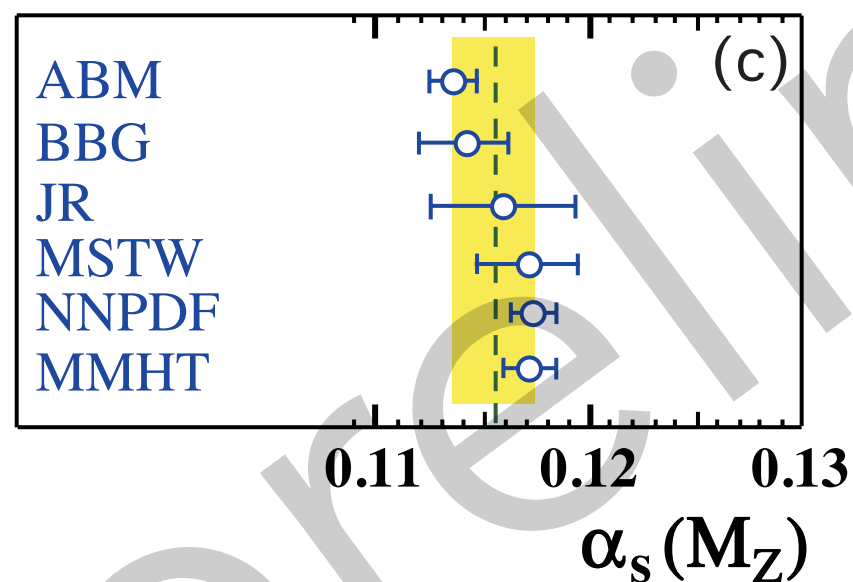
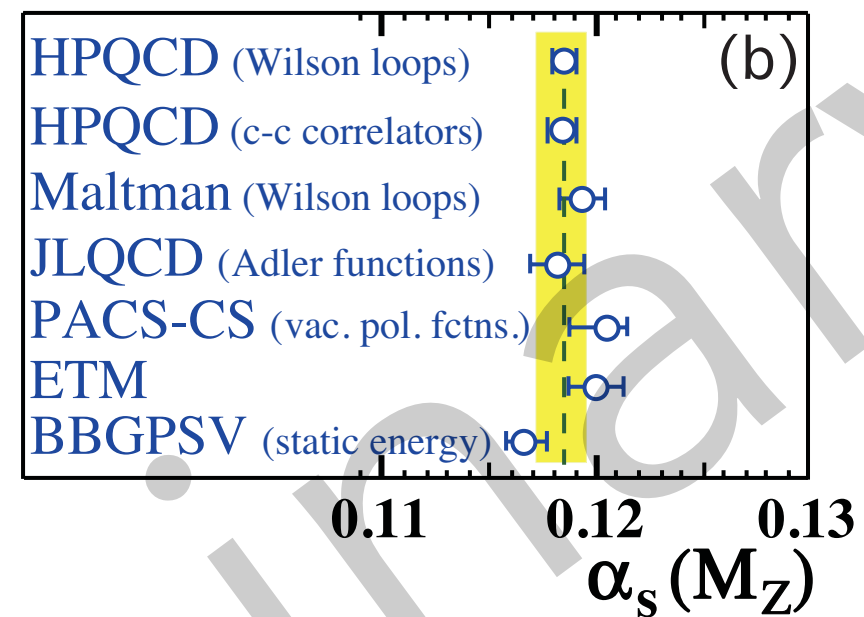
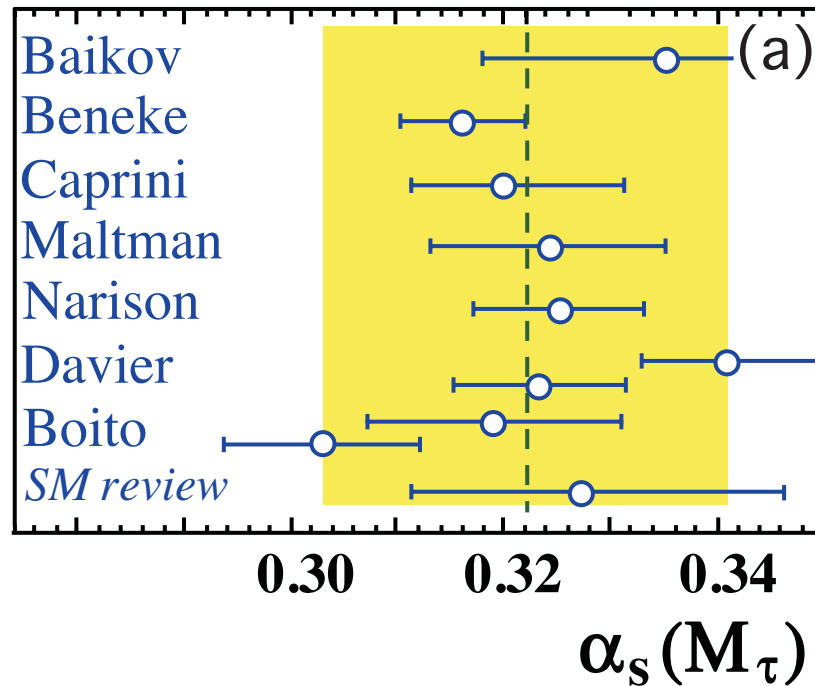
(compilation by CMS)

CMS: α_s from $t\bar{t}$ cross section at $\sqrt{s}=7$ TeV (in NNLO + NNLL)



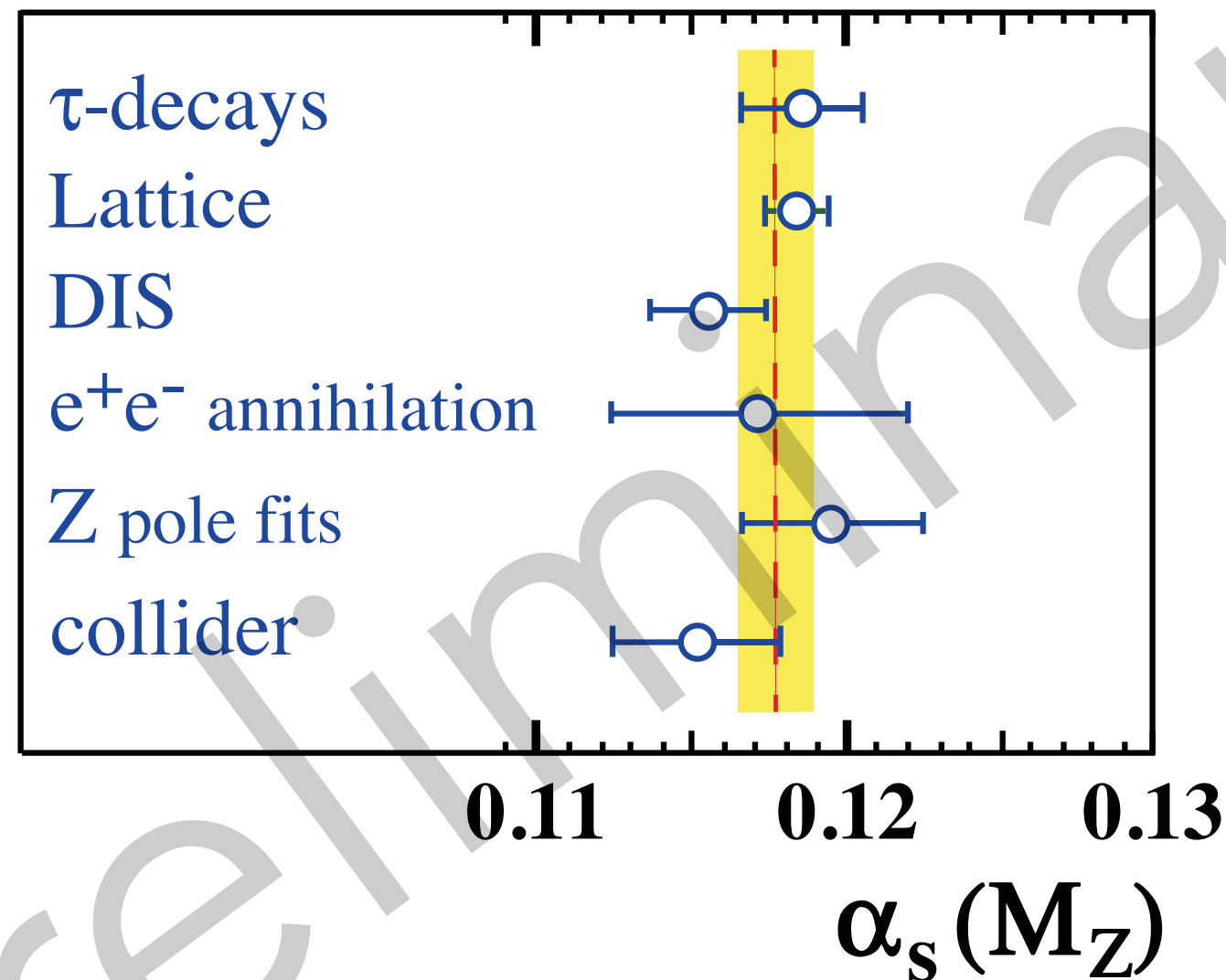
	Most likely $\alpha_s(m_Z)$ value	Uncertainty		
		Total	From δm_t^{pole}	From δE_{LHC}
ABM11	0.1187	+0.0027 -0.0027	+0.0010 -0.0010	+0.0006 -0.0006
CT10	0.1151	+0.0034 -0.0034	+0.0012 -0.0013	+0.0007 -0.0007
HERAPDF1.5	0.1143	+0.0024 -0.0024	+0.0010 -0.0010	+0.0006 -0.0006
MSTW2008	0.1144	+0.0031 -0.0032	+0.0012 -0.0013	+0.0007 -0.0008
NNPDF2.3	0.1151	+0.0033 -0.0032	+0.0013 -0.0013	+0.0008 -0.0008

2015 summary of α_s



- (e) hadron collider (ttbar): $\alpha_s(M_Z) = 0.1151^{+0.0033}_{-0.0032}$
 (f) e.w. precision fit (GFitter): $\alpha_s(M_Z) = 0.1196 \pm 0.0030$

2015 summary of α_s

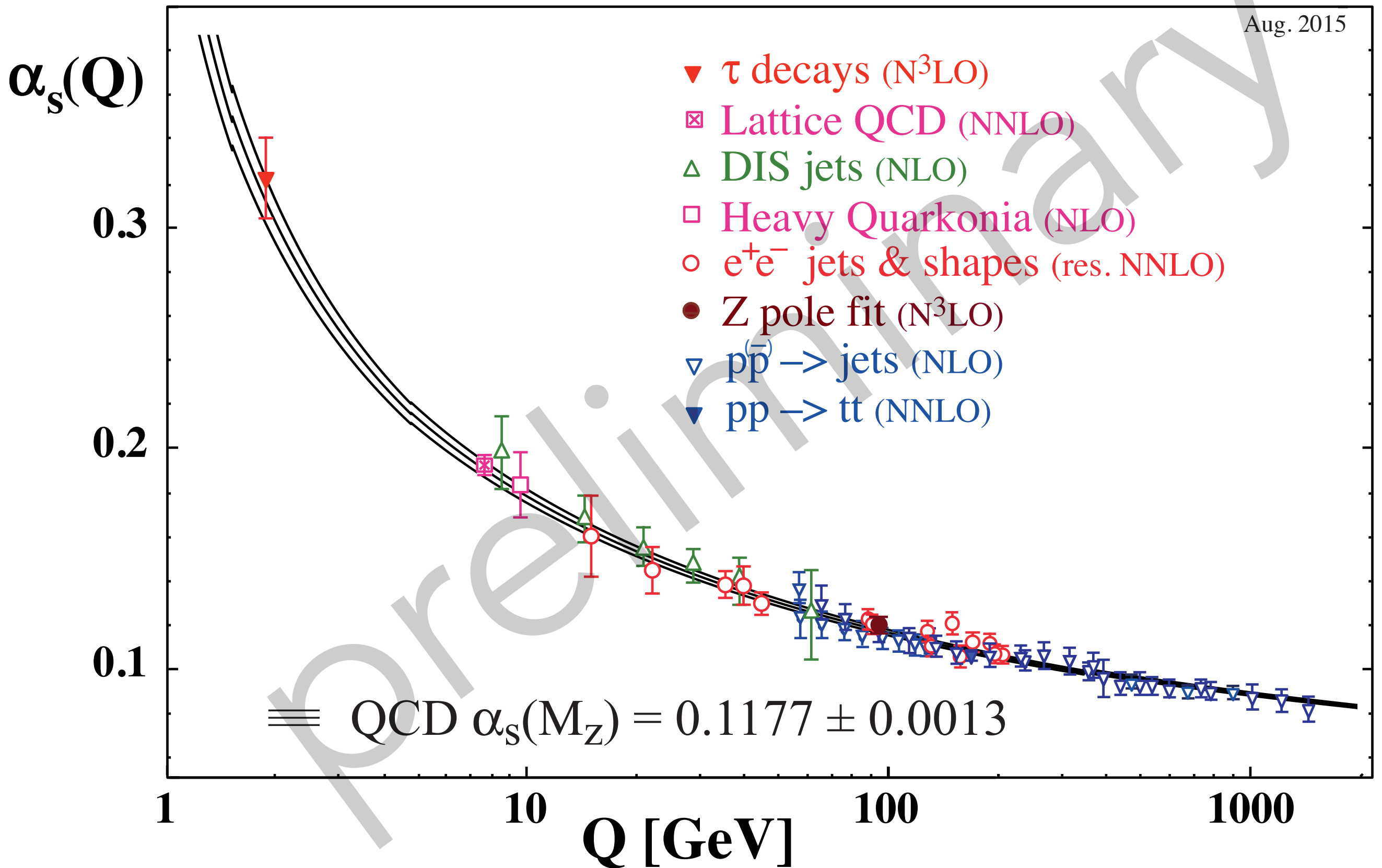


$$\alpha_s(M_Z) = 0.1177 \pm 0.0013$$

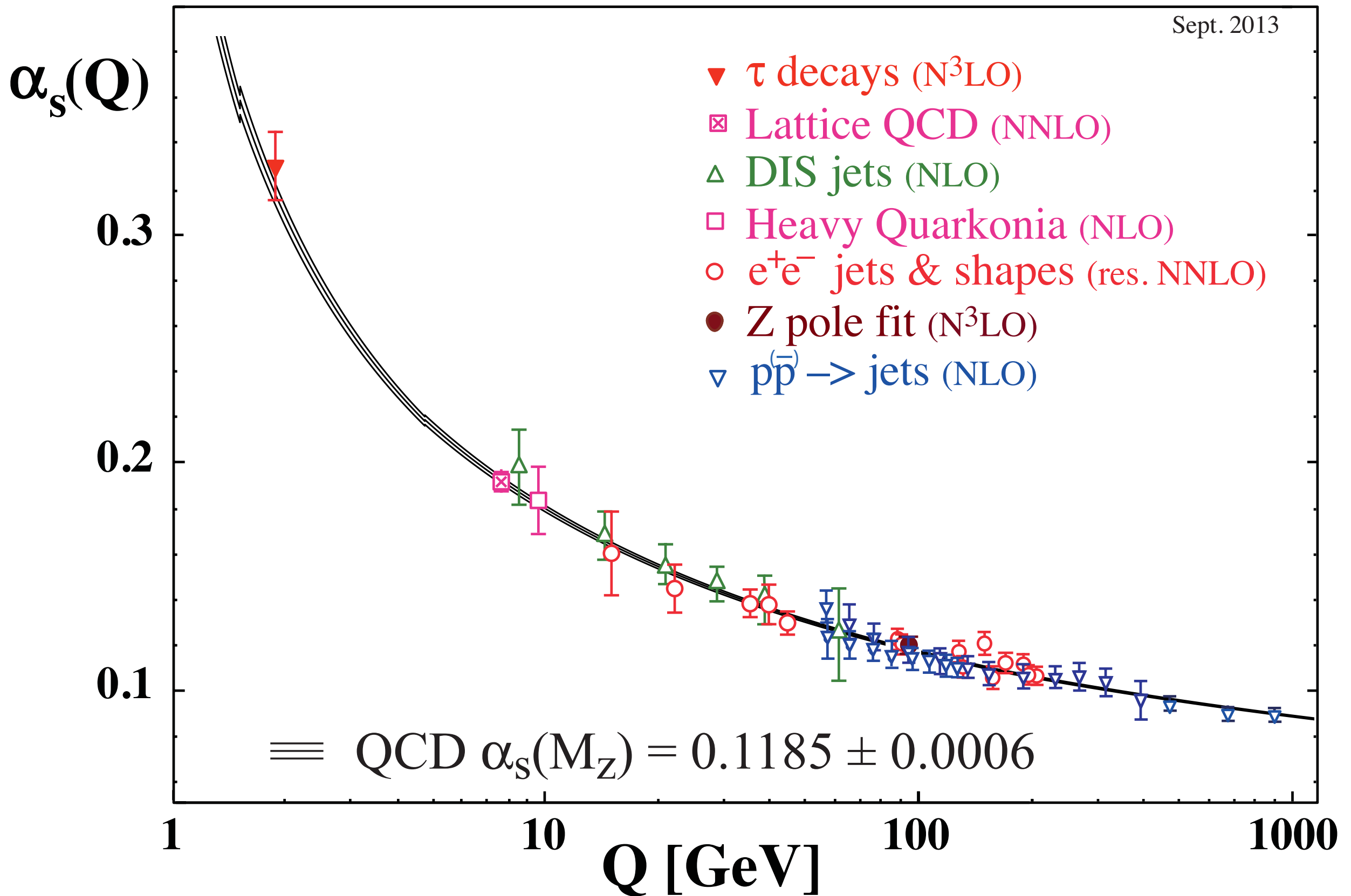
without lattice: $\alpha_s(M_Z) = 0.1170 \pm 0.0018$

w/2013 RPP lattice: $\alpha_s(M_Z) = 0.1183 \pm 0.0006$

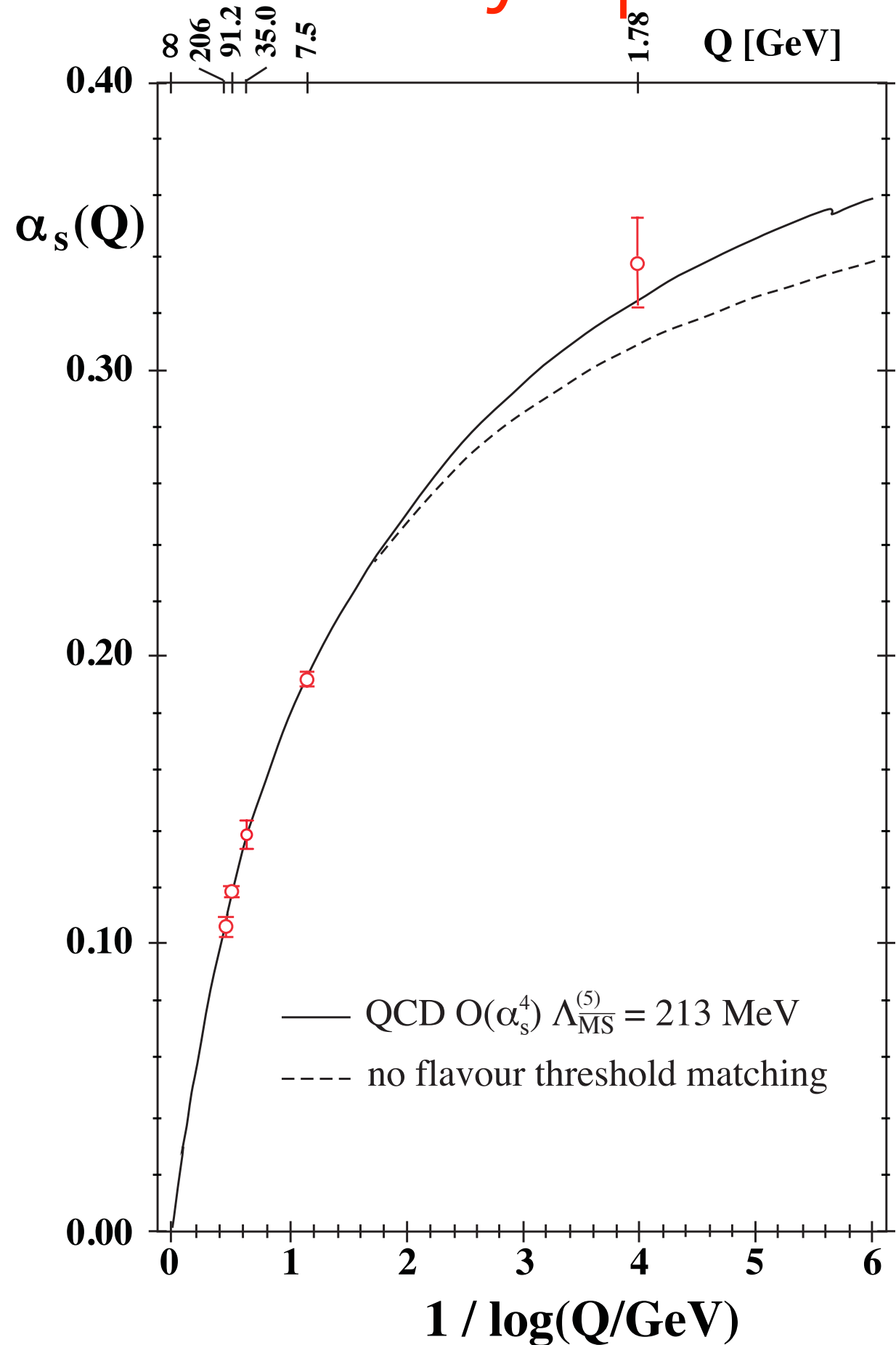
2015 summary of running α_s



2013 summary of running α_s



evidence for asymptotic freedom:



known issues:

all subclasses do have known and unresolved issues:

- α_s from τ -decays: FOPT vs CIPT; technical systematics
 - α_s from lattice: overall size of uncertainties
 - α_s from DIS: unsolved issues between author groups (PDFs)
 - α_s from e^+e^- annihilation: analytic vs. classical treatment of (nonperturbative) hadronisation effects
 - α_s from hadron colliders: so far, only one determination in NNLO (already known to be a fluctuation to the low side)
 - α_s from hadron colliders: (NLO) treatment of top-threshold?
 - α_s from e.w. precision data: correct only in strict SM
- no convergence since 2013 review (just contrary ...) !!

wrap-up:

- new **preliminary** value of world $\alpha_s(M_Z) = 0.1177 \pm 0.0013$
- change from 2013 value ($\alpha_s(M_Z) = 0.1185 \pm 0.0006$) mainly due to:
 - decreased weight (increased error) of lattice results
 - decreased central value from τ -decays
 - result from new class (hadron collider, $t\bar{t}$ x-section), with only one published result, however known to be systematically low
- known but unresolved issues for almost all classes
- no convergence of issues in sight
 - however –
- even within conservative uncertainties, Asymptotic Freedom and in general, **QCD is in excellent shape !**

