α_s — PDG average 2023

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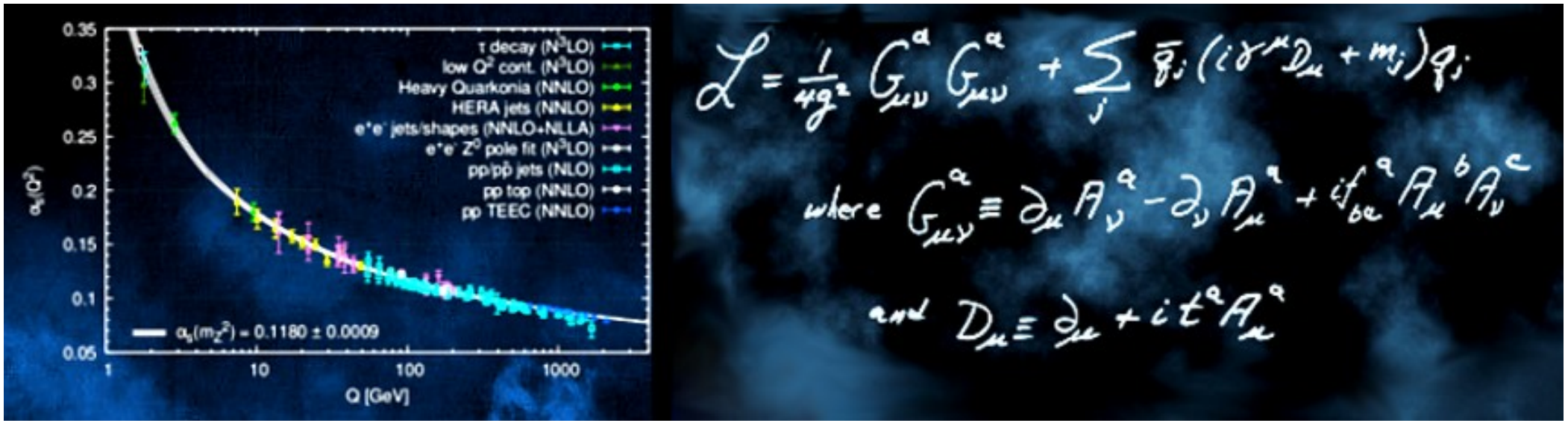
Outline

- PDG update timeline
- Criteria for inclusion in PDG α_s average
- Averaging procedure
- Average updates
- Discussion



PDG 2023/24 Timeline

Deadlines for review updates 2023/24

- 25th of May 23: Agreement about scope of review changes
- 24th of August 23: Review update delivered (by authors)
- 25th of August 23: Referees identified (by PDG)
- 20th of September 23: Referee reports sent to authors
- 11th of October 23: All referee comments addressed (by authors) & sign-off (by PDG)
- 1st of December 23: PDG online web update
- 13th of March 24: Deadline for minor updates/corrections
- 27th of March 24: Final sign-off (by PDG)
- 1st of June 24: Final PDG online update
- TBD 2024: Journal publication

Next iteration: 2025/26

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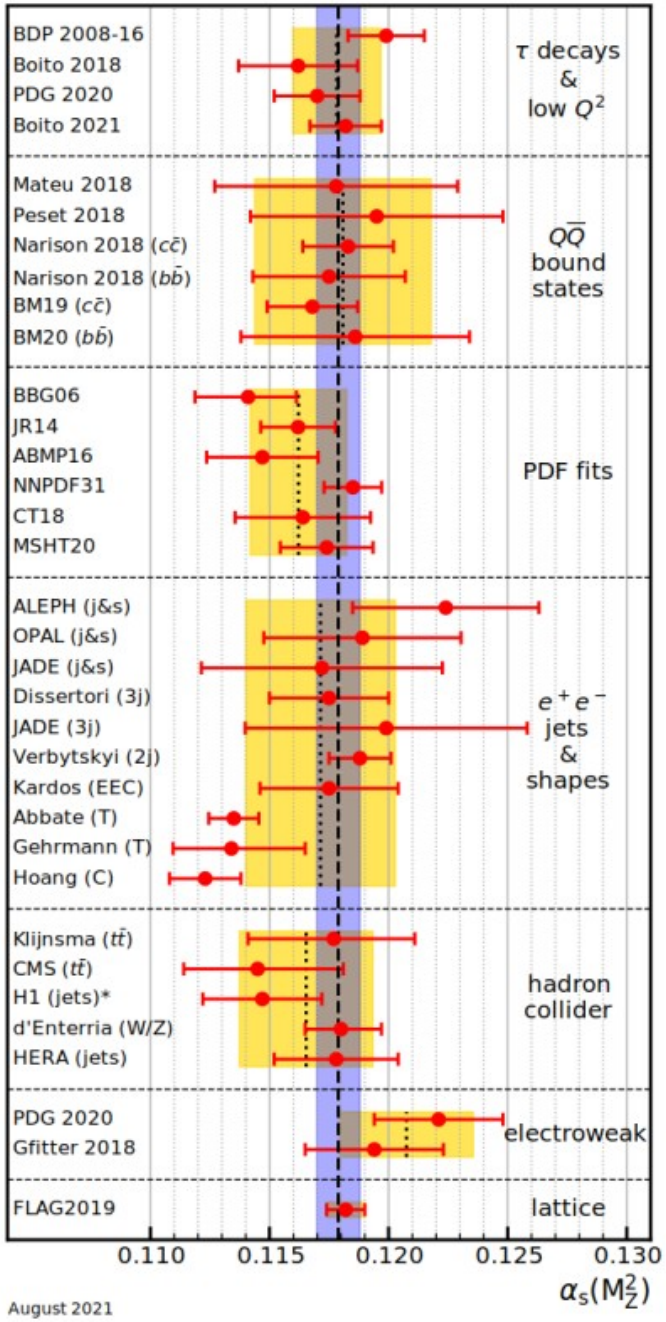
Criteria for inclusion in PDG α_s

- **Published in a peer-reviewed journal before the deadline of submitting the report**
- **Based on the most complete perturbative QCD predictions of at least NNLO accuracy**
- **Accompanied by reliable estimates of all experimental and theoretical uncertainties**

PDG averages 2022

PDG α_s averaging in 6 groups



τ hadronic decay widths & spectral functions

heavy quarkonia decays

global fits of proton structure & α_s

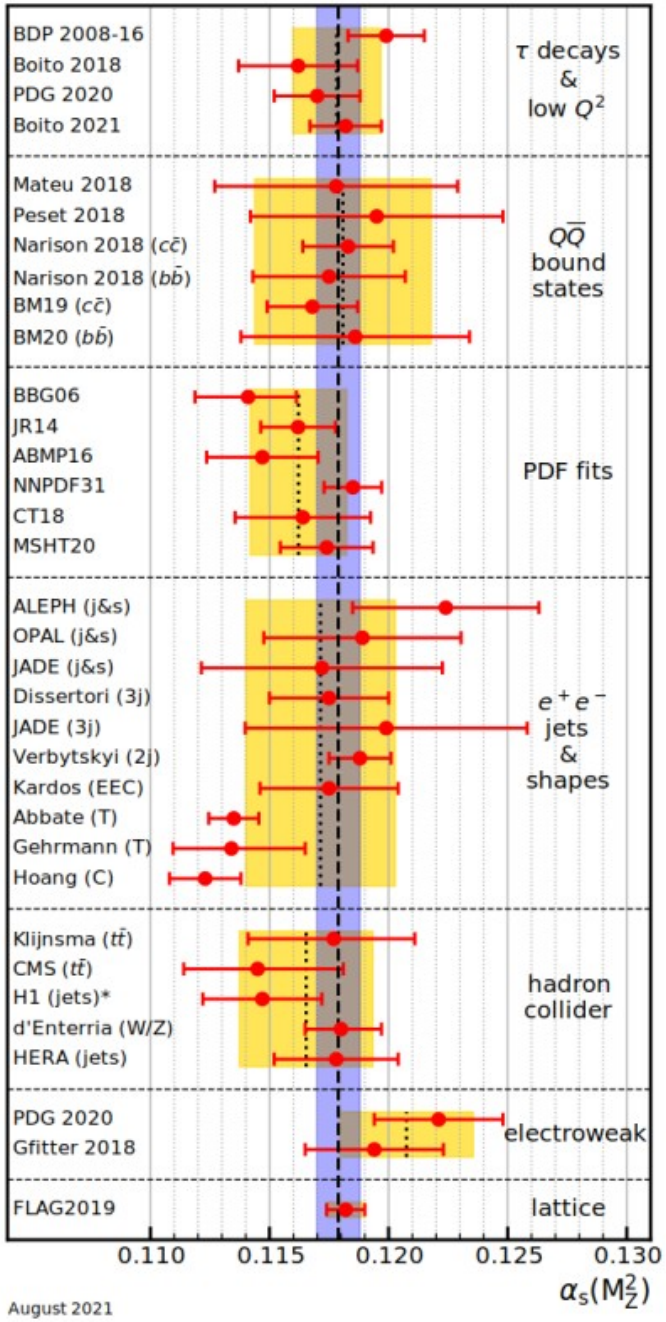
event shapes & jet rates in e^+e^-

observables from hh collisions & DIS

electroweak fits

FLAG 2019 estimate from lattice calculations

PDG α_s averaging in 6 groups



One entry (red point) might be already an average, e.g. the first one BDP 2008-16.

Uncertainties might be combined from info in relevant publication(s), if total not explicitly given.

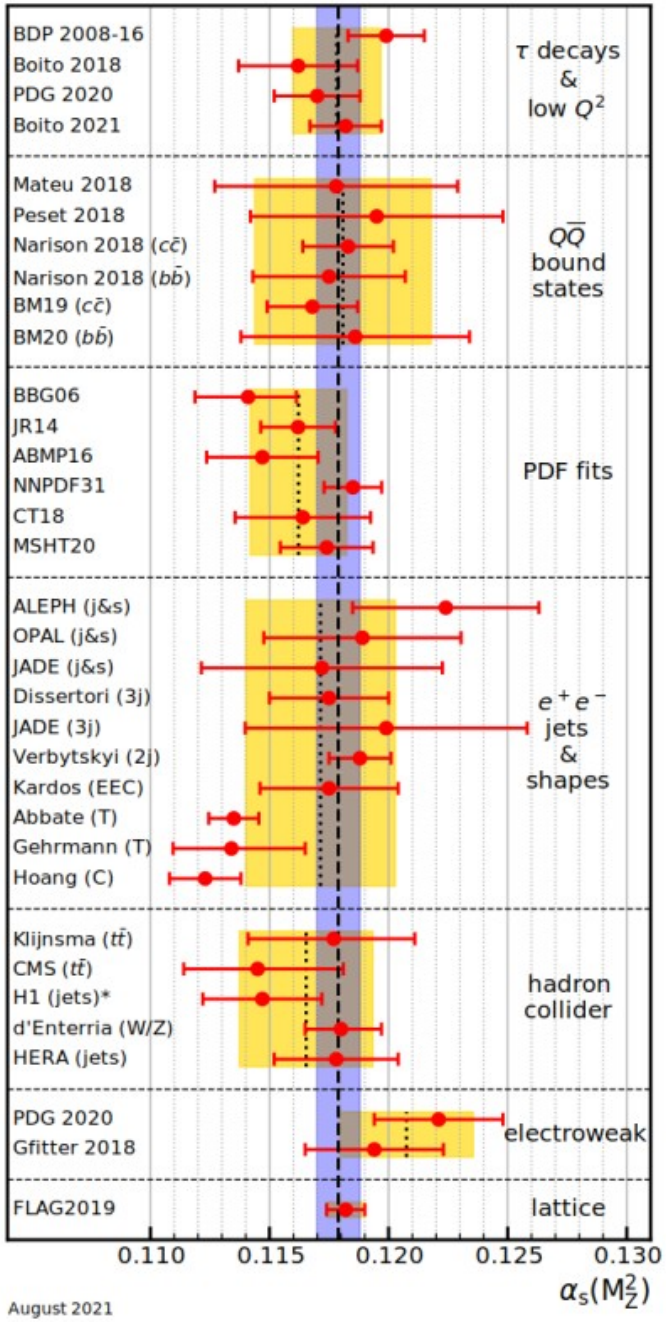
For each field determine unweighted average of central value and uncertainty
→ black dotted lines & yellow area.

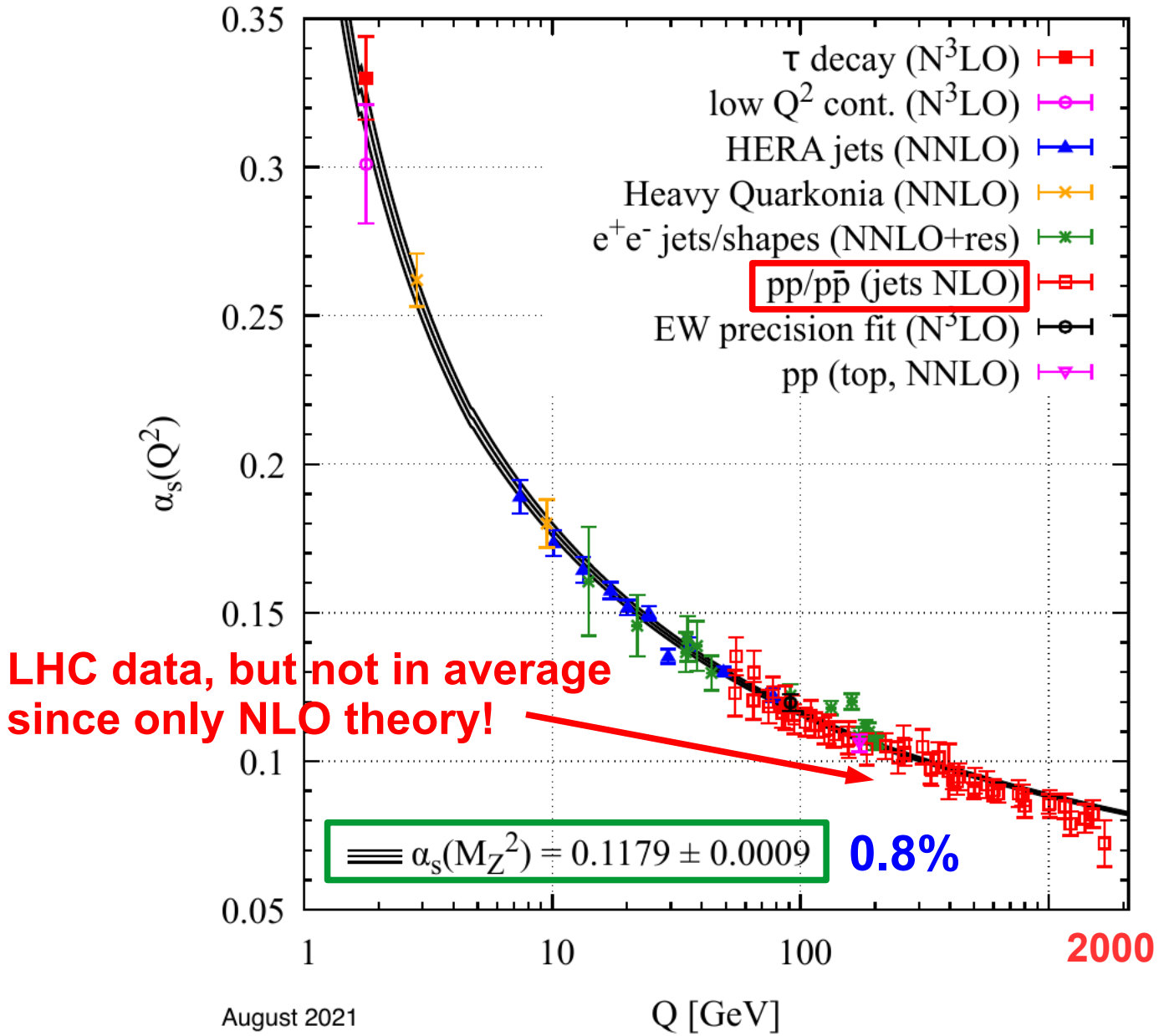
Non-lattice average derived from field averages by X^2-averaging method (if X^2/ndof too small, increase correlation until X^2/ndof ~ 1)

Derive final result from unweighted average of non-lattice average and FLAG estimate
→ black dashed line & purple area

FLAG 2019 estimate from lattice calculations

PDG α_s average 2022





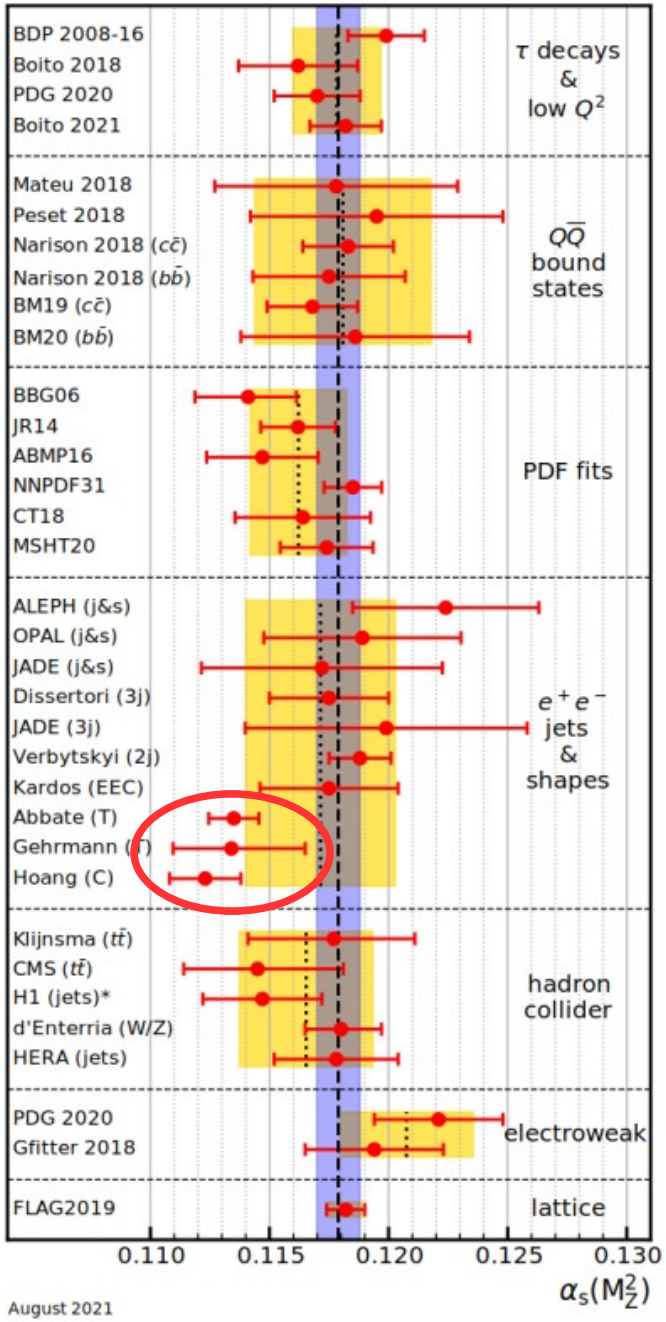
LHC data, but not in average since only NLO theory!

PDG´92: 2.4%

PDG, PTEP (2022) 083C01.

PDG update 2023

PDG α_s average 2022 → 2023



- remove CIPT → red. uncertainty
- add result, update result

- add 1 result

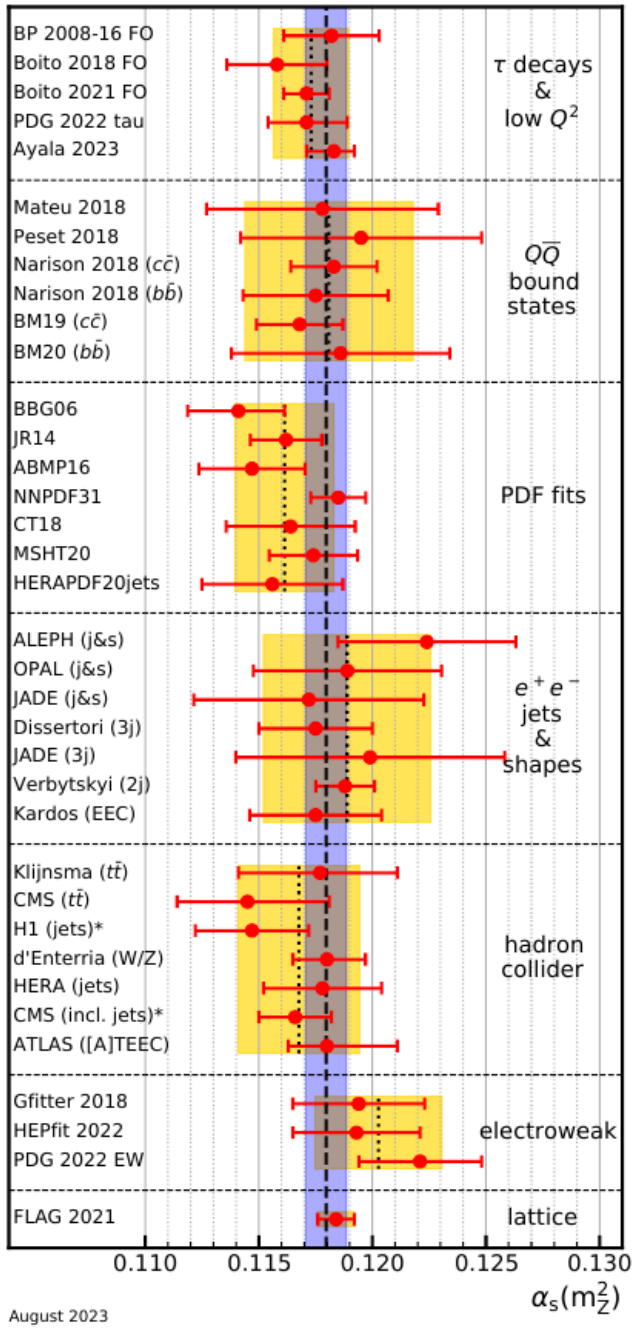
2022 → 2023

- remove results with analytic hadronisation corrections

- add 2(3) results

- add 1 result

- update FLAG result

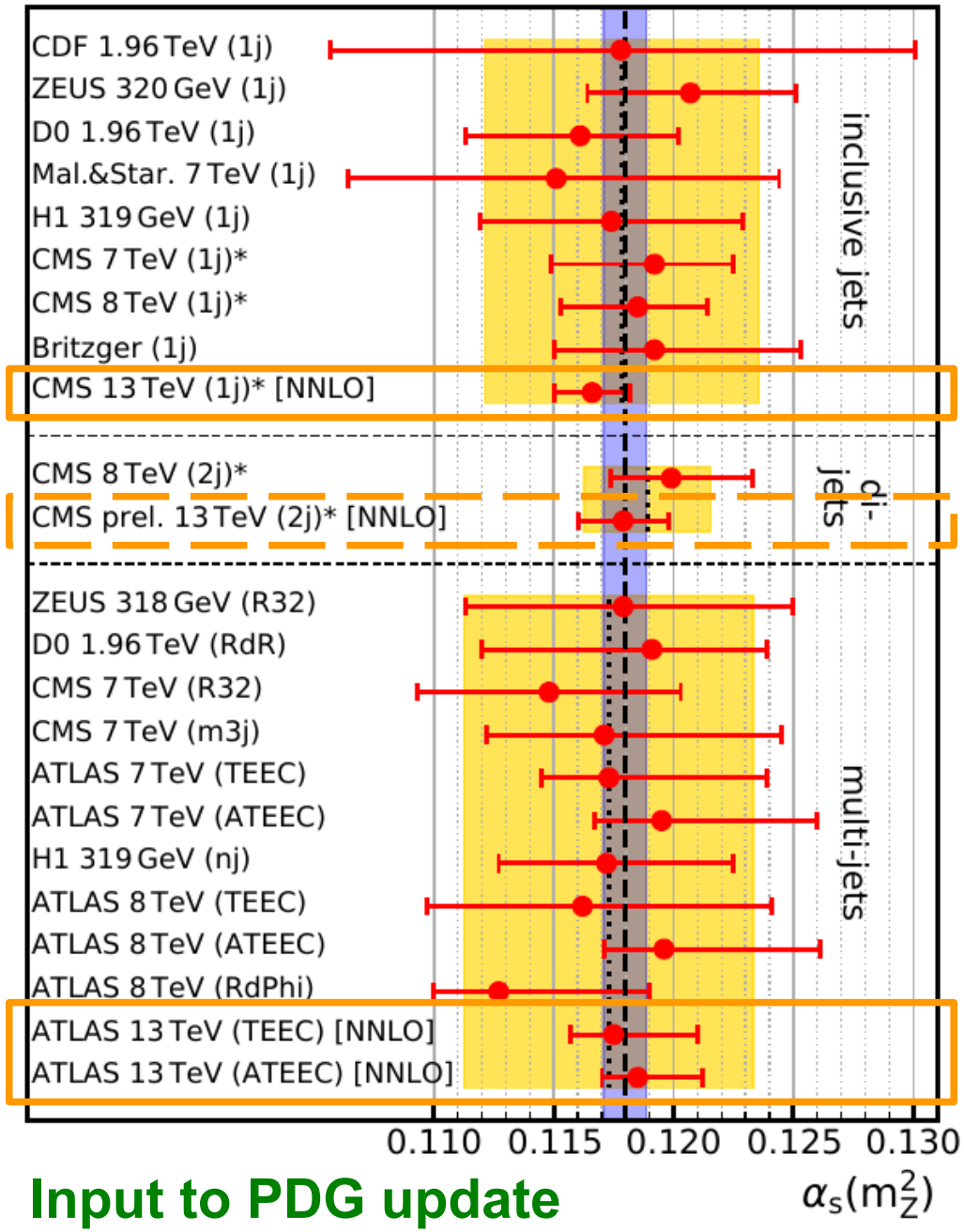


Most prominent changes

- τ decay widths
  - two perturbative calculations used, both valid
    - fixed-order perturbation theory (FOPT)
    - contour-improved perturbation theory (CIPT)
  - finite difference between the two, $\alpha_s^{CIPT} > \alpha_s^{FOPT}$, started long debate; → included in uncertainty estimate
  - now found that CIPT cannot be combined with standard OPE to estimate non-perturbative effects → removed for now
- e^+e^- event shapes (thrust, C parameter)
  - analytical hadronisation corrections possible
  - but outliers with respect to MC estimated hadronisation corrections
  - now found that use of analytical model based on 2-jet configuration needs modification for 3-jet limit where α_s was extracted → removed for now

See QCD review at PDG2023 online for details and references.

$\alpha_s(m^2_Z)$ from jet data



2023: new at NNLO!

Input to PDG update

PDG 2023 α_s averages

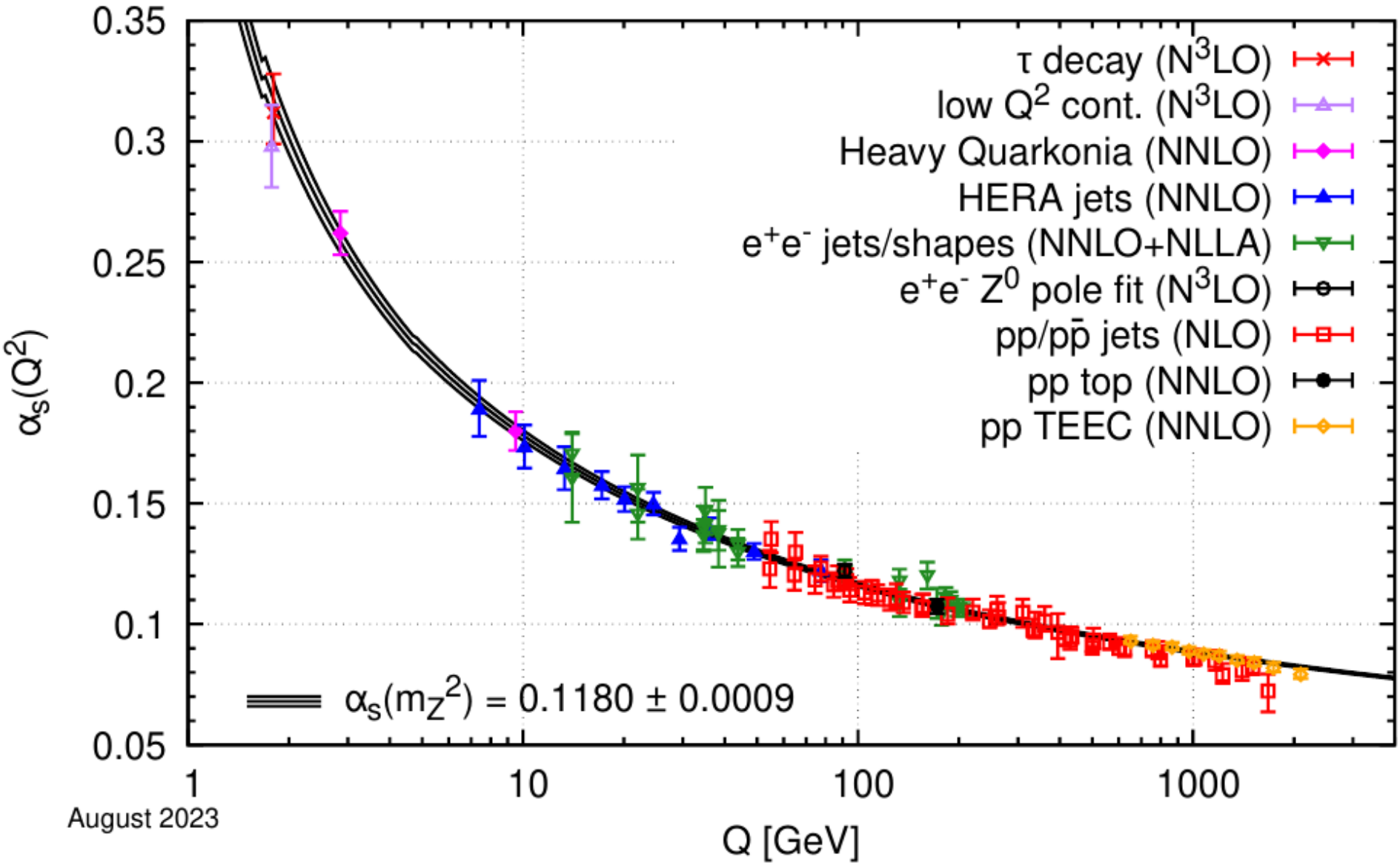
averages per sub-field	unweighted	weighted	unweighted without subfield
τ decays & low Q^2	0.1173 ± 0.0017	0.1174 ± 0.0009	0.1177 ± 0.0013
$Q\bar{Q}$ bound states	0.1181 ± 0.0037	0.1177 ± 0.0011	0.1175 ± 0.0011
PDF fits	0.1161 ± 0.0022	0.1168 ± 0.0014	0.1179 ± 0.0011
e^+e^- jets & shapes	0.1189 ± 0.0037	0.1187 ± 0.0017	0.1174 ± 0.0011
hadron colliders	0.1168 ± 0.0027	0.1169 ± 0.0014	0.1177 ± 0.0011
electroweak	0.1203 ± 0.0028	0.1203 ± 0.0016	0.1171 ± 0.0011
PDG 2023 (without lattice)	0.1175 ± 0.0010	0.1178 ± 0.0005	n/a

Final average including lattice (FLAG2021):

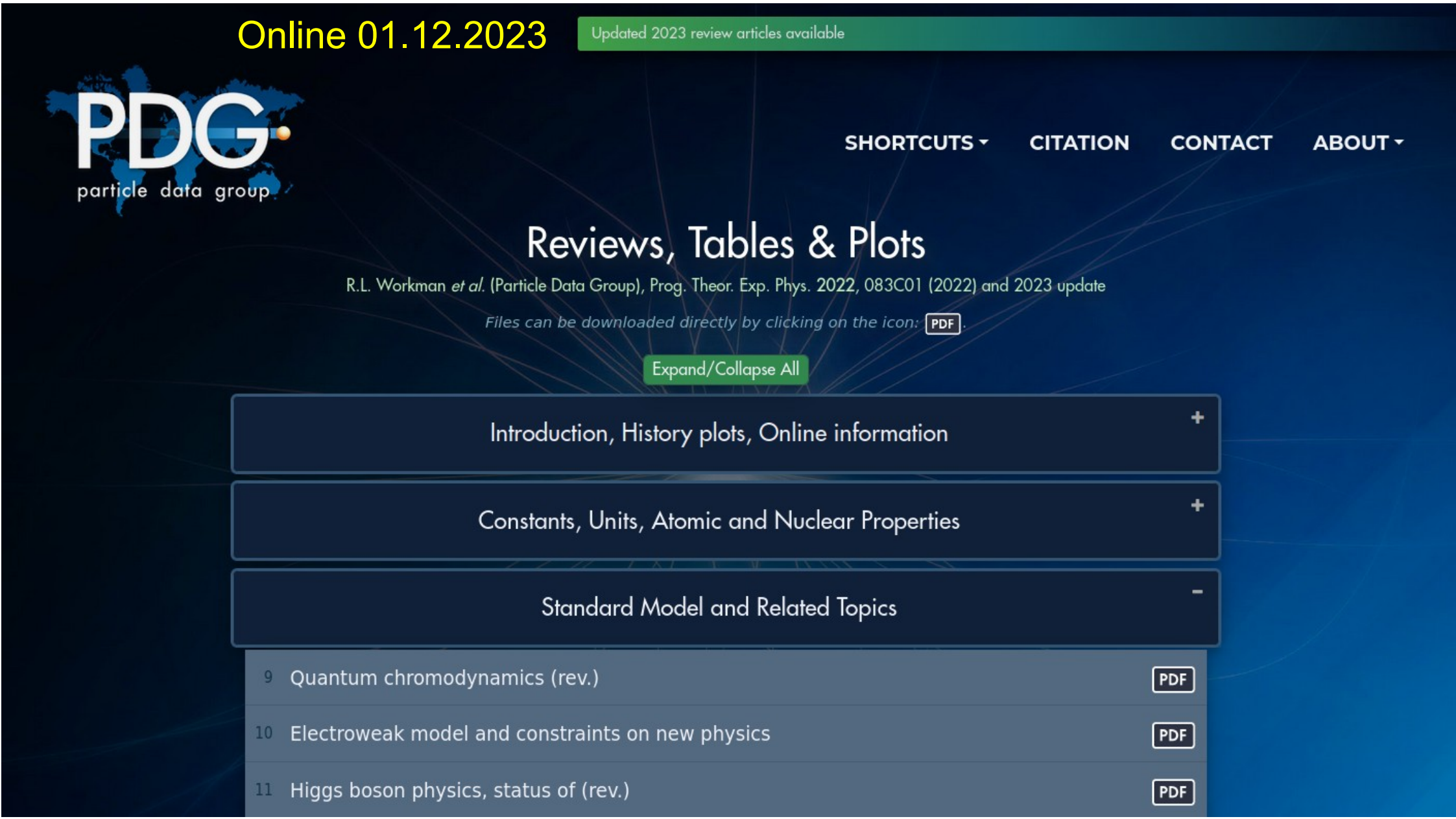
$$\alpha_s(m_Z^2) = 0.1180 \pm 0.0009$$

rel. uncertainty: 0.76%

PDG 2023 α_s running



PDG 2023 online updates



https://pdg.lbl.gov/2023/reviews/contents_sports.html

Discussion

- Some suggestions for sub-field updates from yesterday's discussion
  - Global PDF fits
  - Hadron collider observables incl. simultaneous PDF fit
  - Final-state observables
    - Independent of PDFs
    - Together with e^+e^-?
- Unweighted → weighted averages?
- Discussion

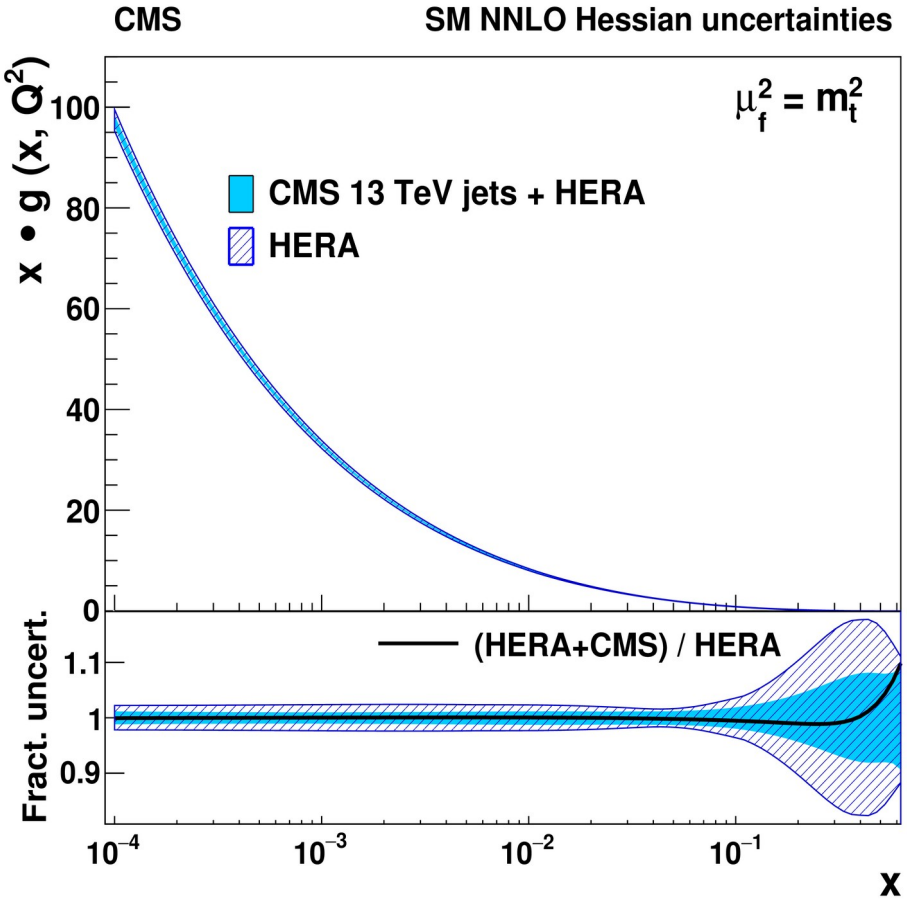
Backup Slides

Inclusive jets: α_s & PDFs

Simultaneous fit of α_s & PDFs possible combining HERA DIS & CMS jet data using xFitter Tool

CMS result for $\alpha_s(M_Z)$ at NNLO: $\alpha_s(m_Z^2) = 0.1166 \pm 0.0016(\text{fitall}) \pm 0.0004(\text{scl})$

Reduced uncertainties of gluon PDF

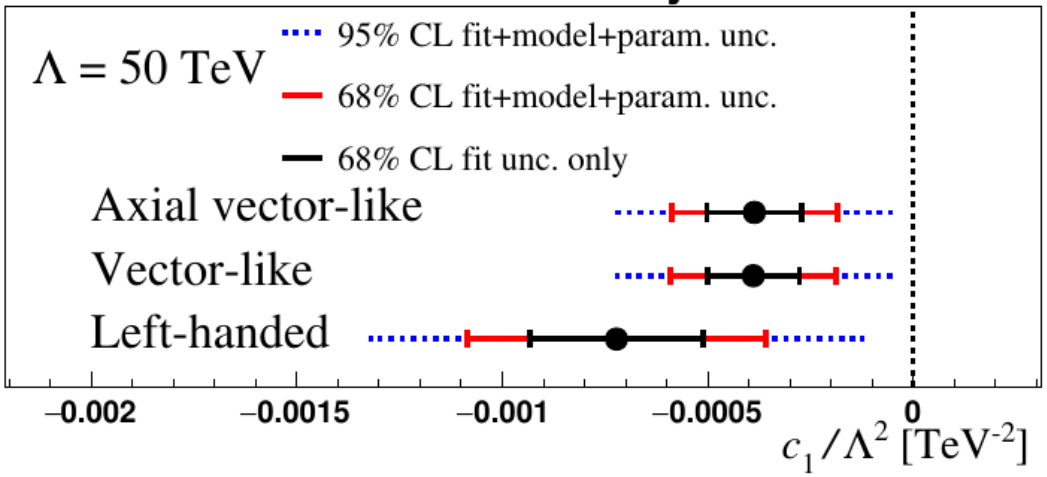


CMS, JHEP02 (2922) 142 & JHEP12 (2922) 035.

Also NLO fit of α_s & PDFs & CI

Data compatible with SM → exclusion limits

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \frac{2\pi}{\Lambda^2} \sum_{n \in \{1,3,5\}} c_n O_n. \qquad \textbf{EFT}$$



Transverse energy-energy correlation

$$\frac{1}{\sigma}\frac{d\Sigma^{\mathrm{asym}}}{d\cos\phi} = \frac{1}{\sigma}\frac{d\Sigma}{d\cos\phi}\bigg|_{\phi} - \frac{1}{\sigma}\frac{d\Sigma}{d\cos\phi}\bigg|_{\pi-\phi}$$

Asymmtry

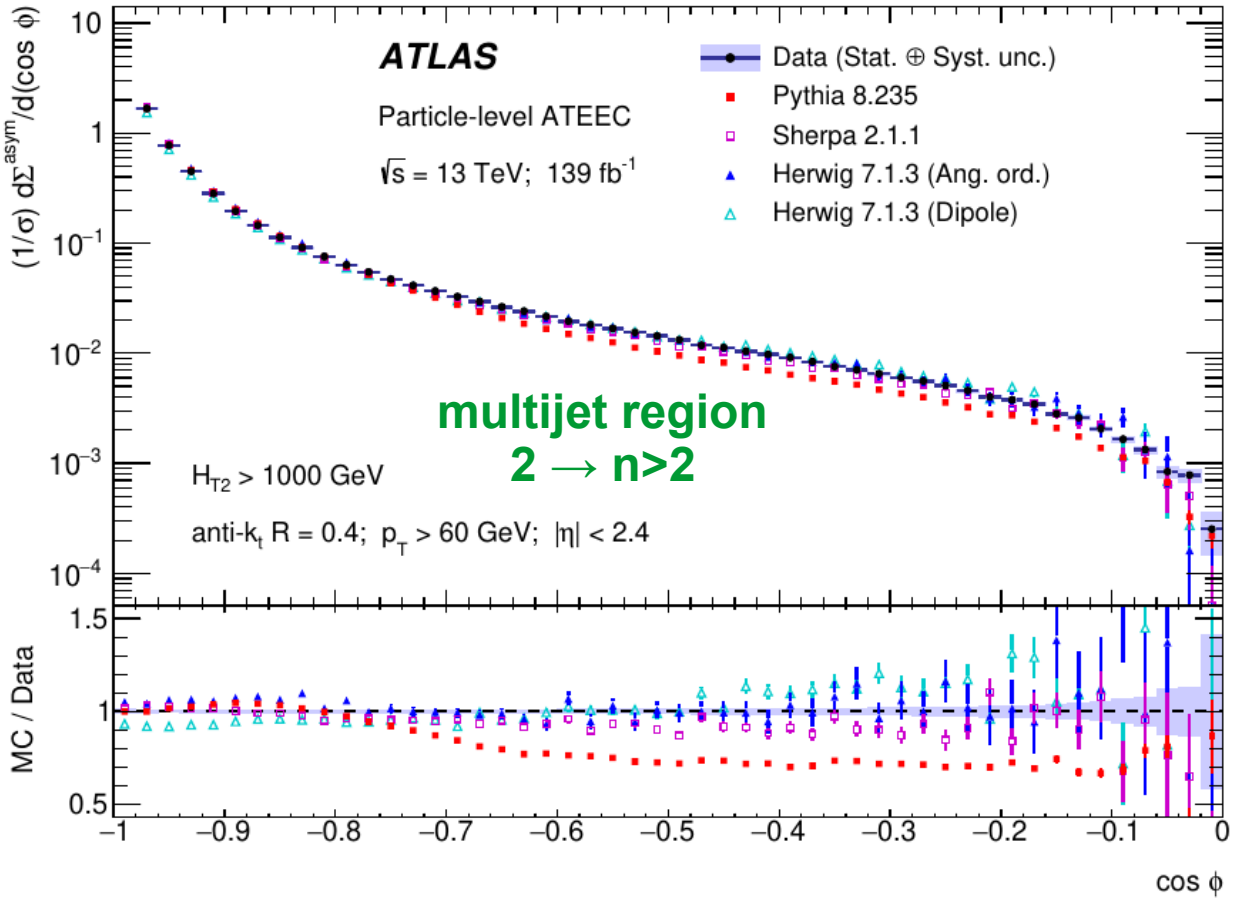
$$\mathrm{ATEEC} \propto \alpha_s$$

NNLO

$$\alpha_s(m_Z) = 0.1175 \pm 0.0006\ (\mathrm{exp.})^{+0.0034}_{-0.0017}\ (\mathrm{theo.})$$

$$\alpha_s(m_Z) = 0.1185 \pm 0.0009\ (\mathrm{exp.})^{+0.0025}_{-0.0012}\ (\mathrm{theo.})$$

Normalised



ATLAS, JHEP 07 (2023) 085.

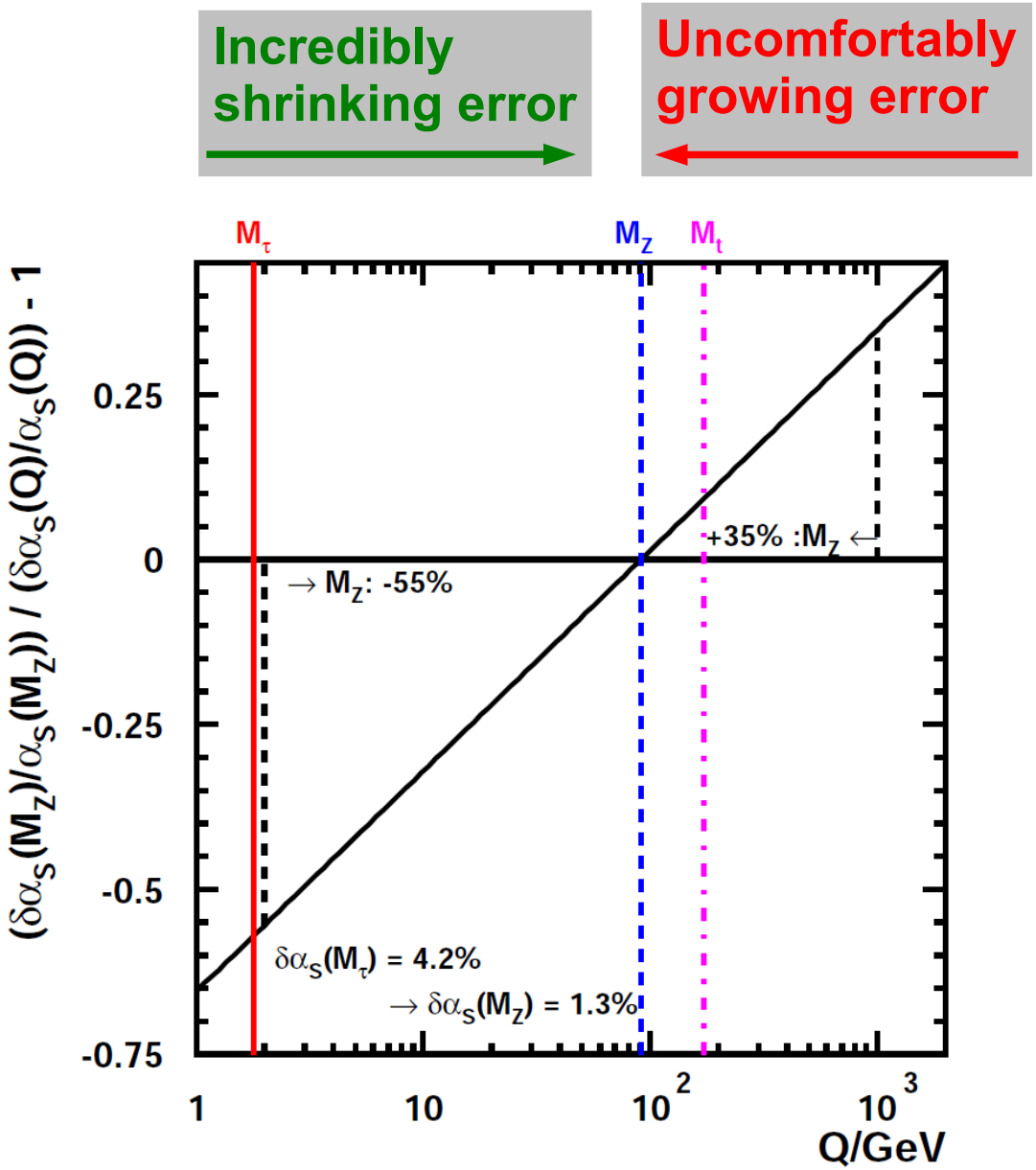
Jets and α_s

Two goals for α_s:

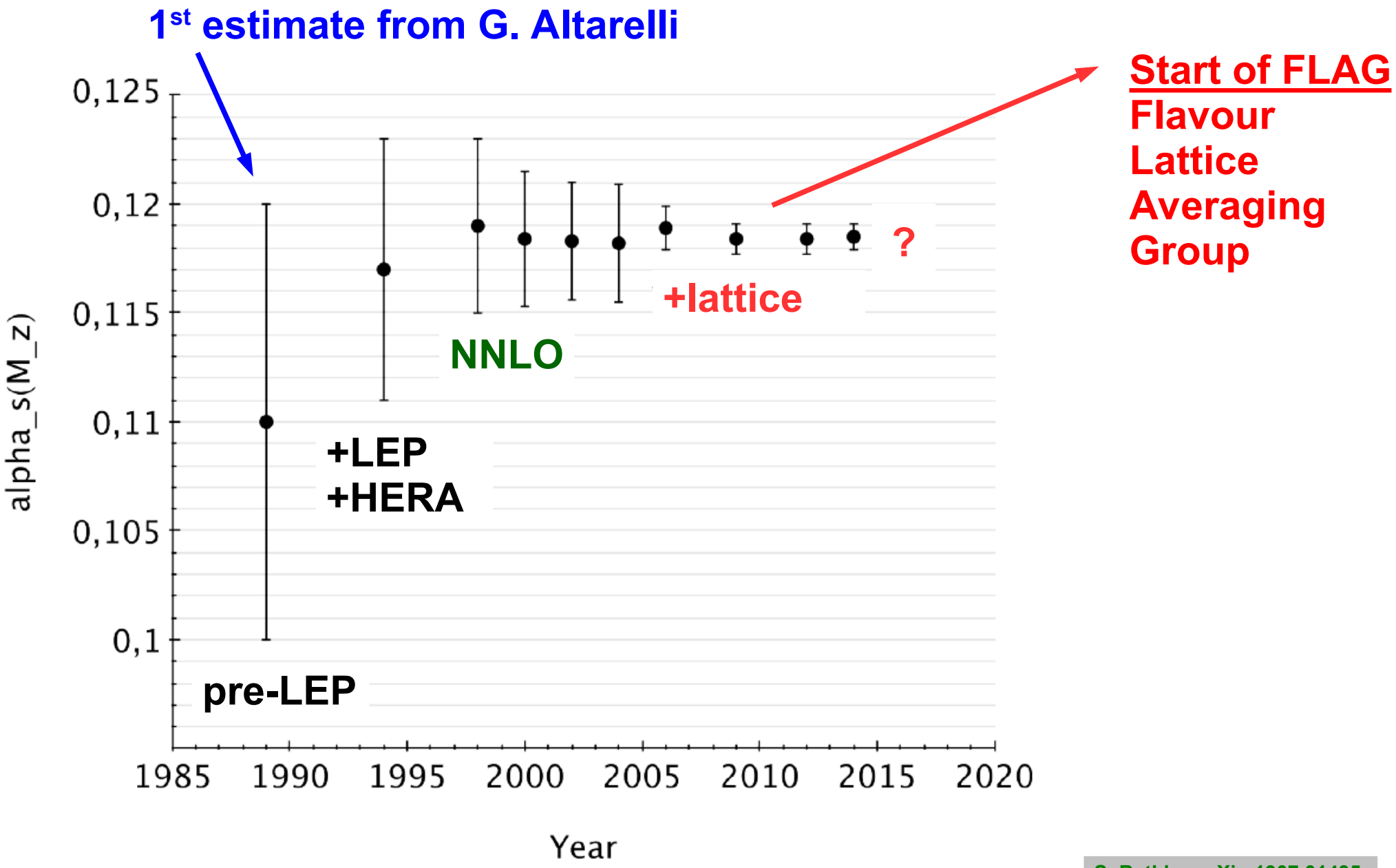
1. Measure the running of $\alpha_s(Q)$ up to the highest scales possible
→ looked after $\alpha_s(Q)$!
2. Measure $\alpha_s(M_Z)$ as precisely as possible
→ find phase space with small uncertainties:
20 – 200 GeV, central rapidity

Better in:
- JEC uncertainty
- PDF uncertainty
- Evolution to M_Z

Worse in: NP effects



$\alpha_s(M_Z)$ world average versus time



S. Bethke, arXiv:1907.01435.

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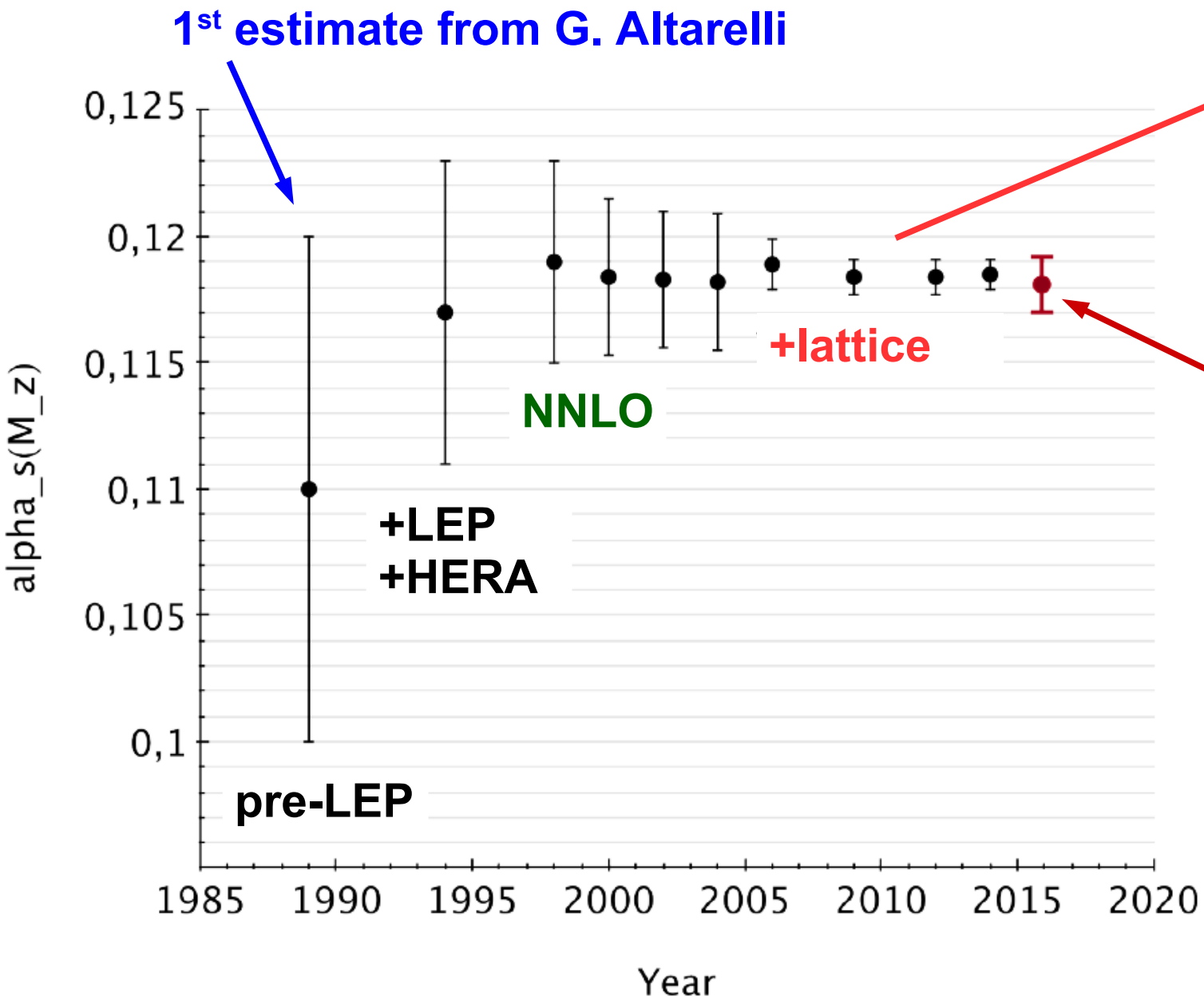


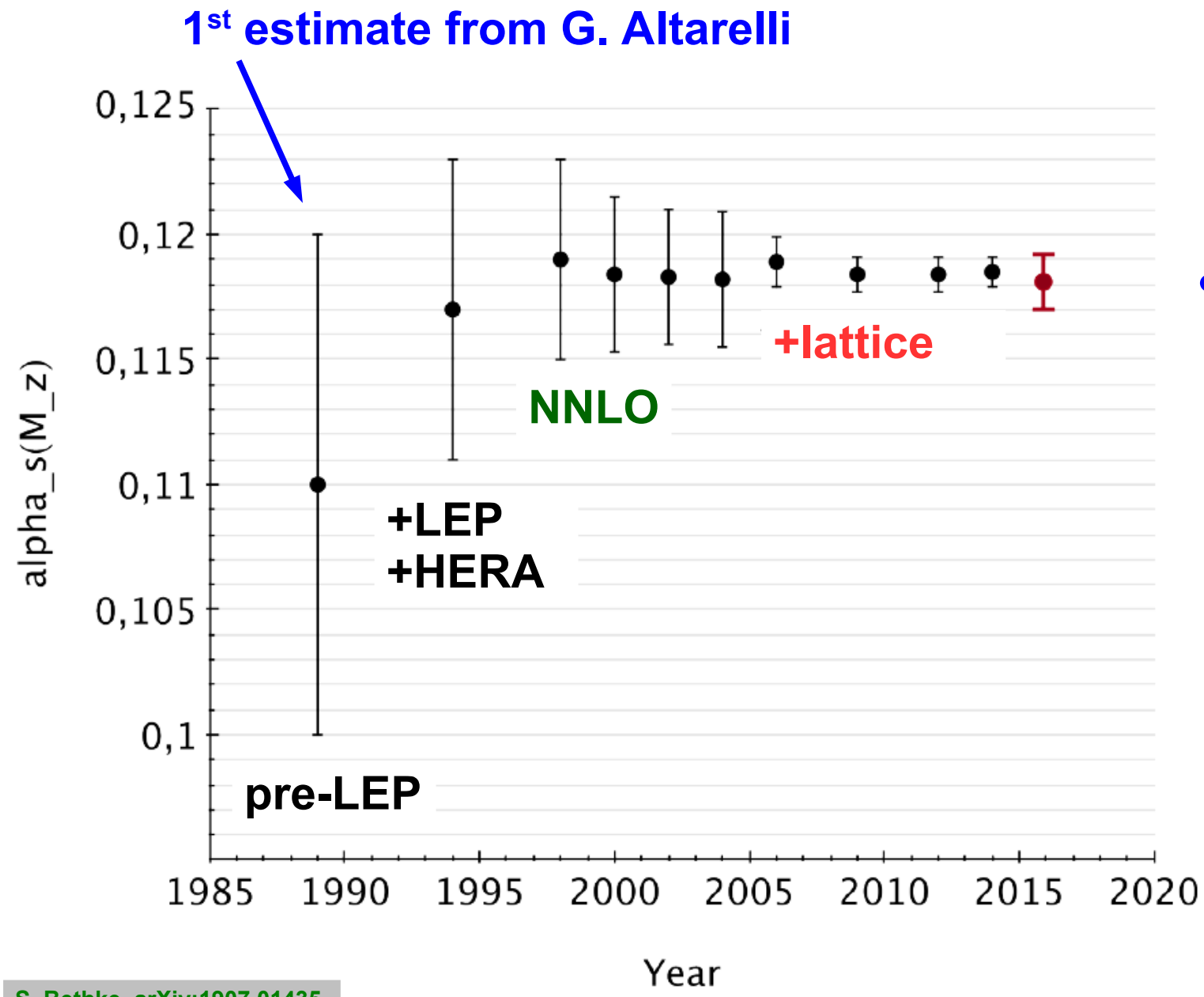
Start of FLAG
Flavour
Lattice
Averaging
Group

PDG 2016

Revised validation of lattice methods & uncertainties

S. Bethke, arXiv:1907.01435.

$\alpha_s(M_Z)$ world average versus time



PDG 2022

Still large theoretical uncertainty from (PDF + α_s) on Higgs x sections

In particular tTH & gg-Fusion: 7-13%

S. Bethke, arXiv:1907.01435.

CERN YR, LHC Higgs xs WG.