$\alpha_S(M_Z)$ from PDF fits and collider processes

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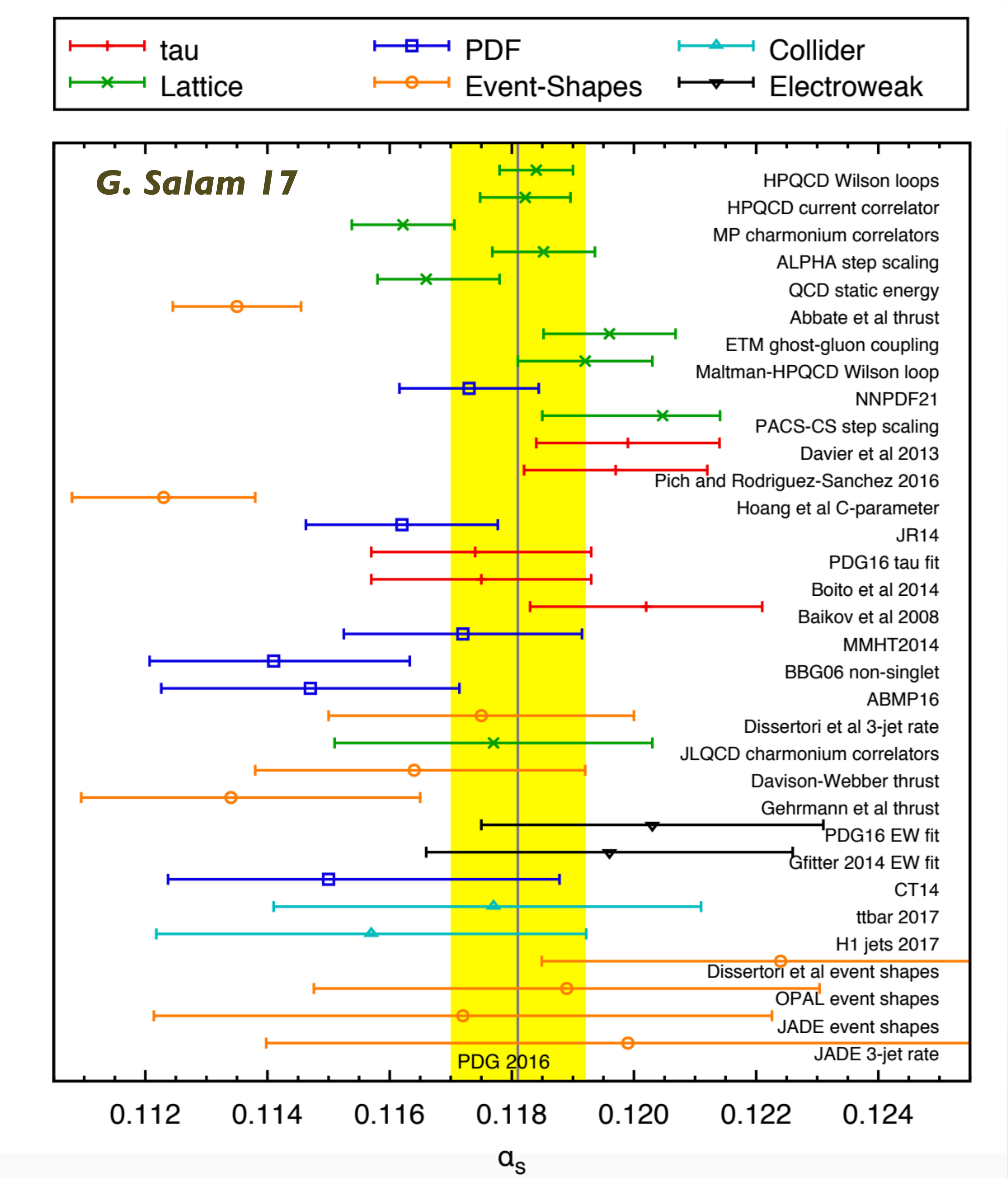
Round table on

Determining the strong coupling: status and challenges

Quark Confinement and the Hadron Spectrum 2018

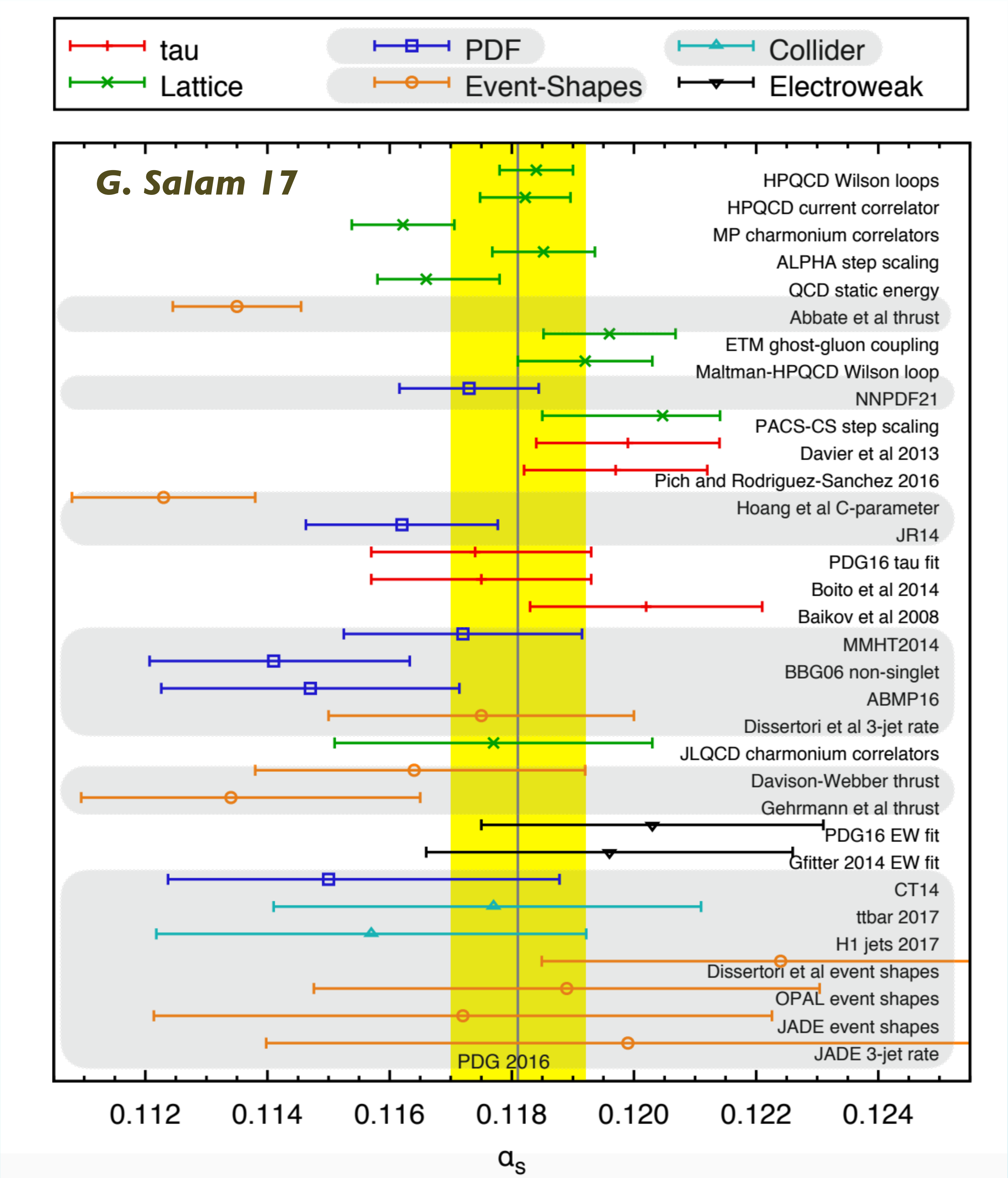
Dublin, 02/08/2018

Pinning down $\alpha_S(M_Z)$ in the LHC era



- The strong coupling is one of **fundamental parameters** of the Standard Model
- Pinning down $\alpha_S(M_Z)$ with high precision of utmost importance both from the **theory** and **phenomenology** points of view

Pinning down $\alpha_S(M_Z)$ in the LHC era



- The strong coupling is one of **fundamental parameters** of the Standard Model

- Pinning down $\alpha_S(M_Z)$ with high precision of utmost importance both from the **theory** and **phenomenology** points of view

- Here I (very) briefly discuss status of $\alpha_S(M_Z)$ determinations from **high-energy collisions**

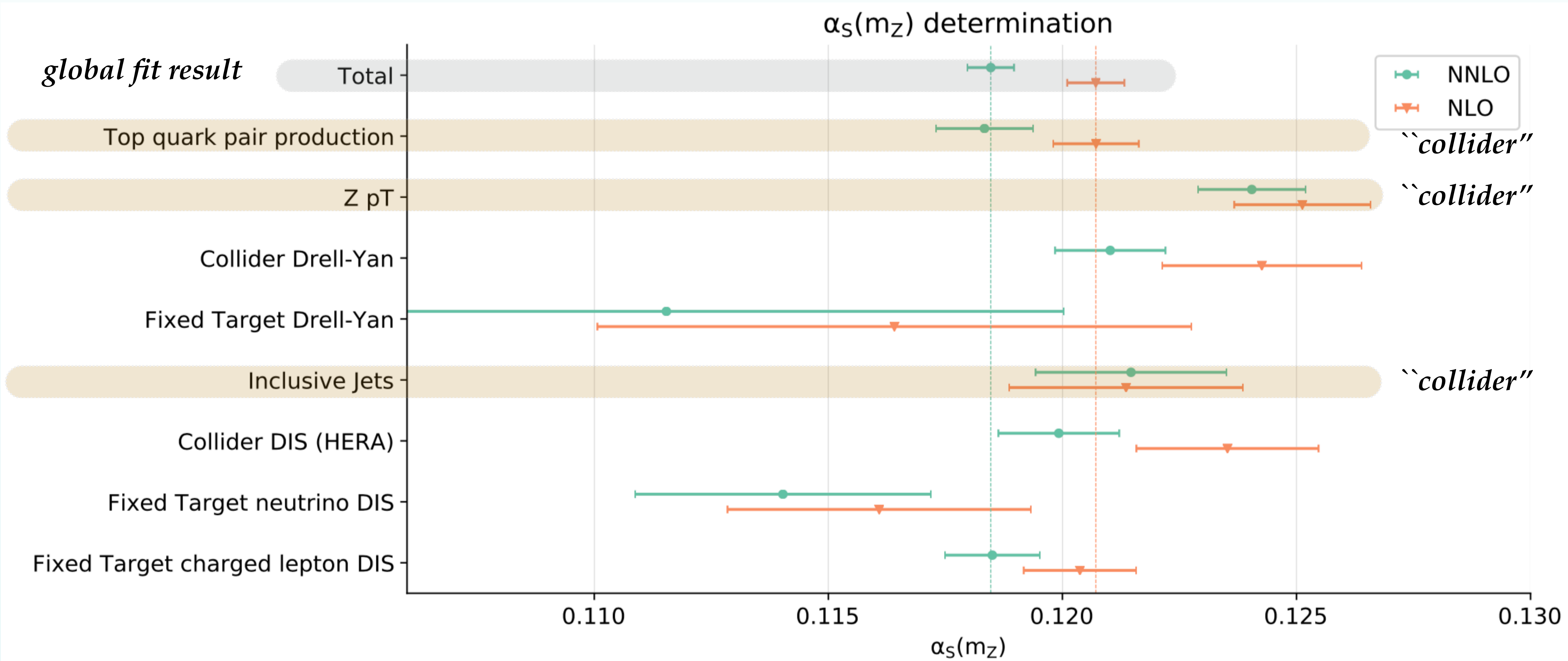
- These include **"PDFs"**, **"Collider"**, and **"Event shapes"** (see also Sven's talk)

- *nb* the categorisation is ambiguous: **PDF fits** already include a lot of **collider data**

- **Not a review,** just to trigger discussion!

PDFs + collider determinations

Modern global PDF fits include a wide variety of **lepton-proton and proton-proton collider data**, including several processes that provide a **direct handle on the strong coupling**



NNPDF 18

Based on around **4000 data points** from **O(15) different processes**, in all of them using **exact NNLO theory**

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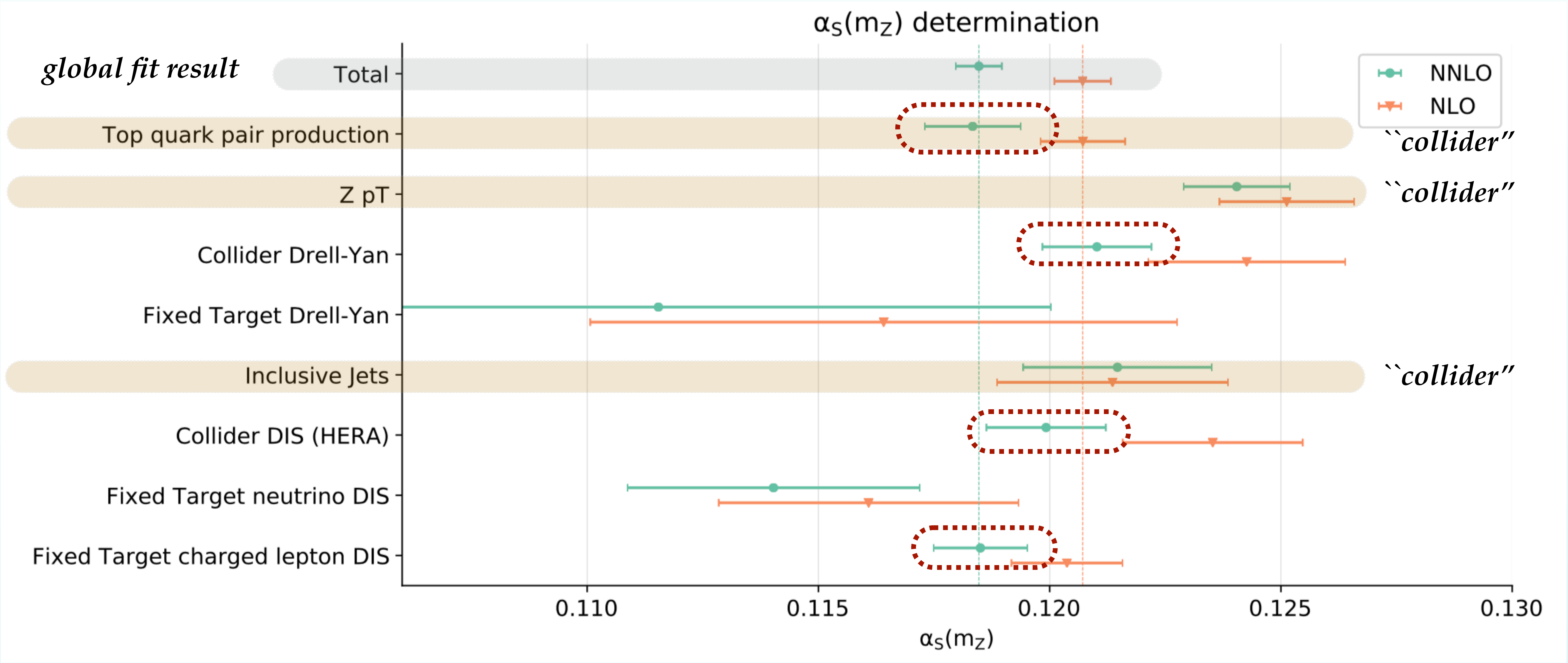


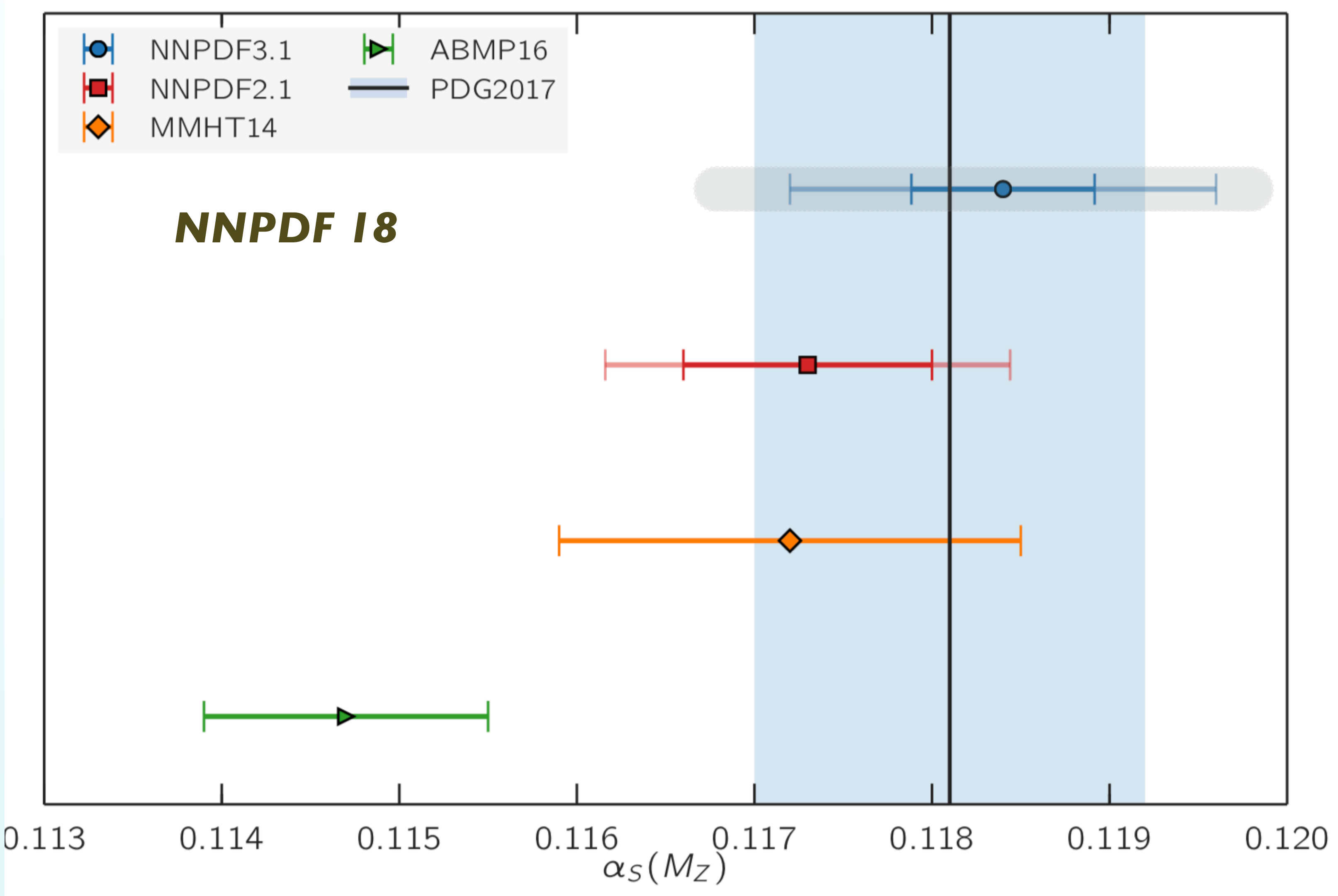
NNPDF 18

Based on around **4000 data points** from **O(15) different processes**, in all of them using **exact NNLO theory**

Note that a **PDG-like value of $\alpha_S(M_Z)$ is preferred** by the majority of the most sensitive processes in the fit

PDFs + collider determinations

NNPDF3.1: $\alpha_s^{\rm NNLO}(m_Z) = 0.1185 \pm 0.0005^{\rm exp} \pm 0.0001^{\rm meth} \pm 0.0011^{\rm th}$



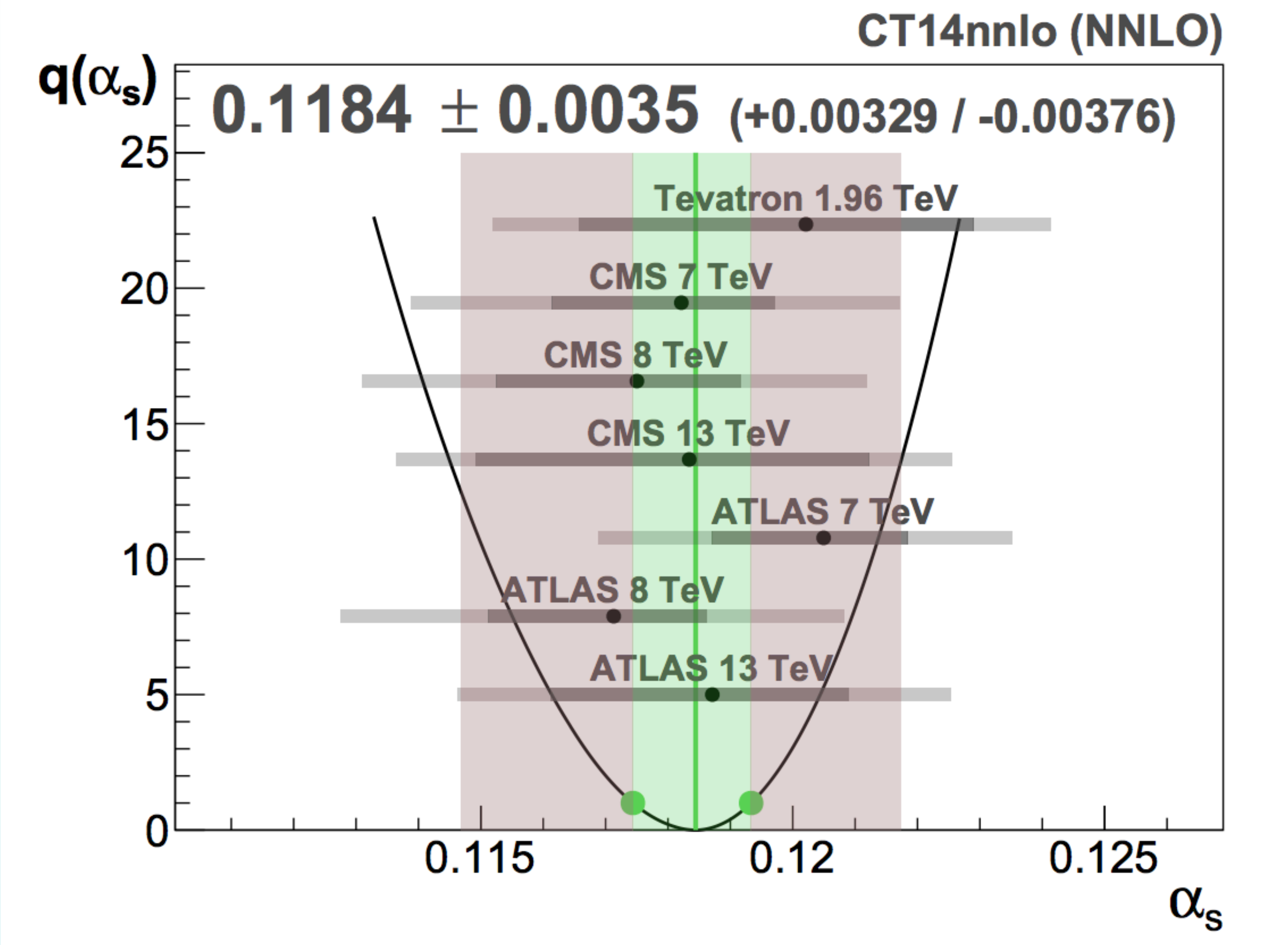
Uncertainty dominated by MHOUs, estimated as (NNLO-NLO)/2

Competitive (and compatible) with current PDG average

Limitations and Challenges

- No systematic way to **account for theory errors from MHOUs** in the fitted $\alpha_S(M_Z)$ - but see encouraging preliminary results in the backup
- Dependence on **methodological settings**: *e.g.* parametrisation, definition of PDF uncertainties
- Dependence on **theoretical settings**, *e.g.* differences in **heavy quark treatment** dominate spread between NNPDF3.1/MMHT14 and ABM16

PDFs + collider determinations



Klijnsma et al 17, also CMS 13

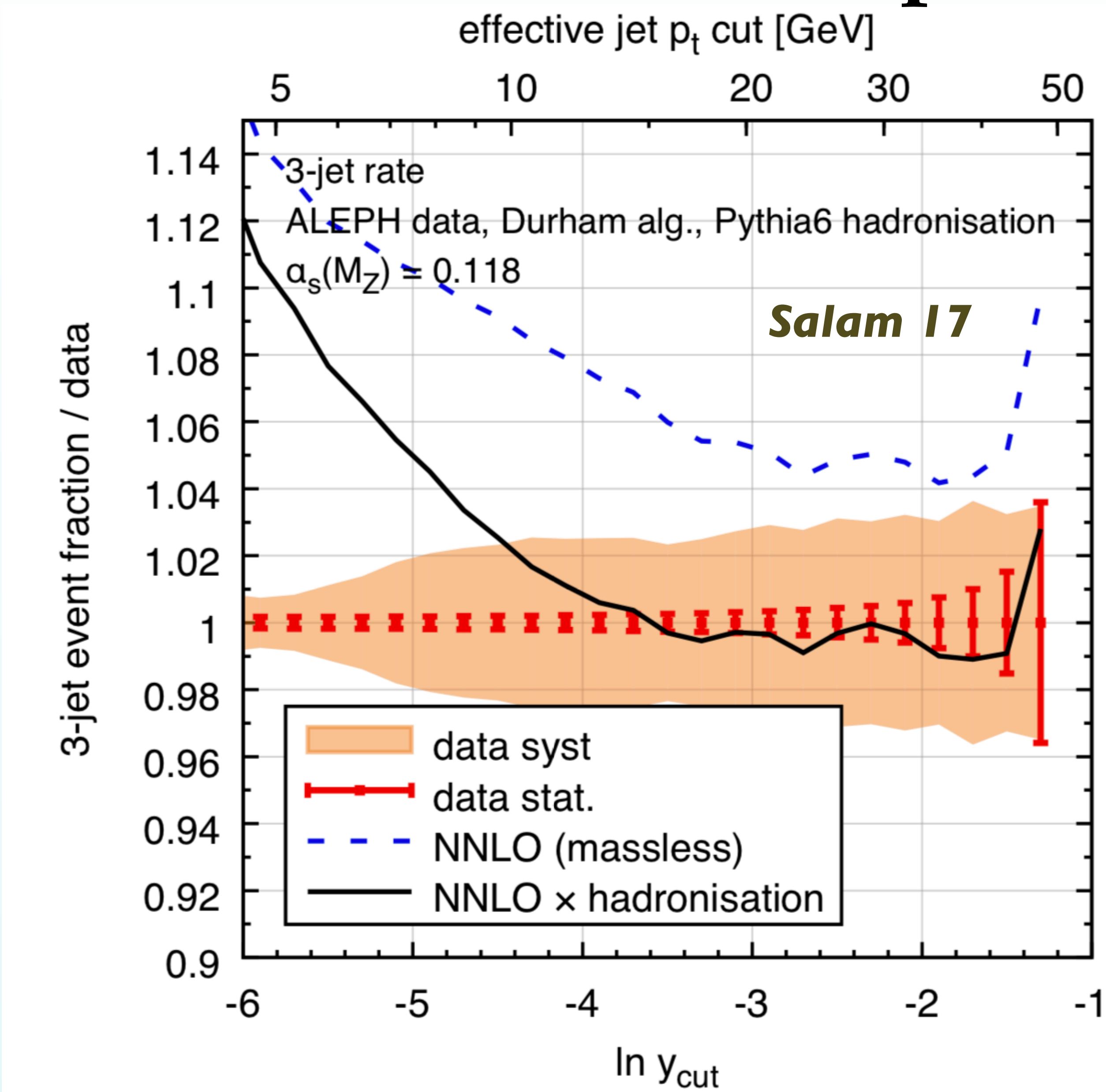
Direct determination of $\alpha_S(M_Z)$ from top quark pair inclusive cross-sections

Allows careful estimates of theory uncertainties in particular from MHOUs

Limitations and Challenges

- Does not fully account for **correlations** between **PDFs** (treated as external input), the **fitted collider data**, and the **resulting $\alpha_S(M_Z)$**
- By construction, cannot be competitive with global fit, since only based on a **subset of all available data** - but perhaps this could be offset by the superior robustness of a **single-process determination**?

Event shapes in e^+e^- collisions



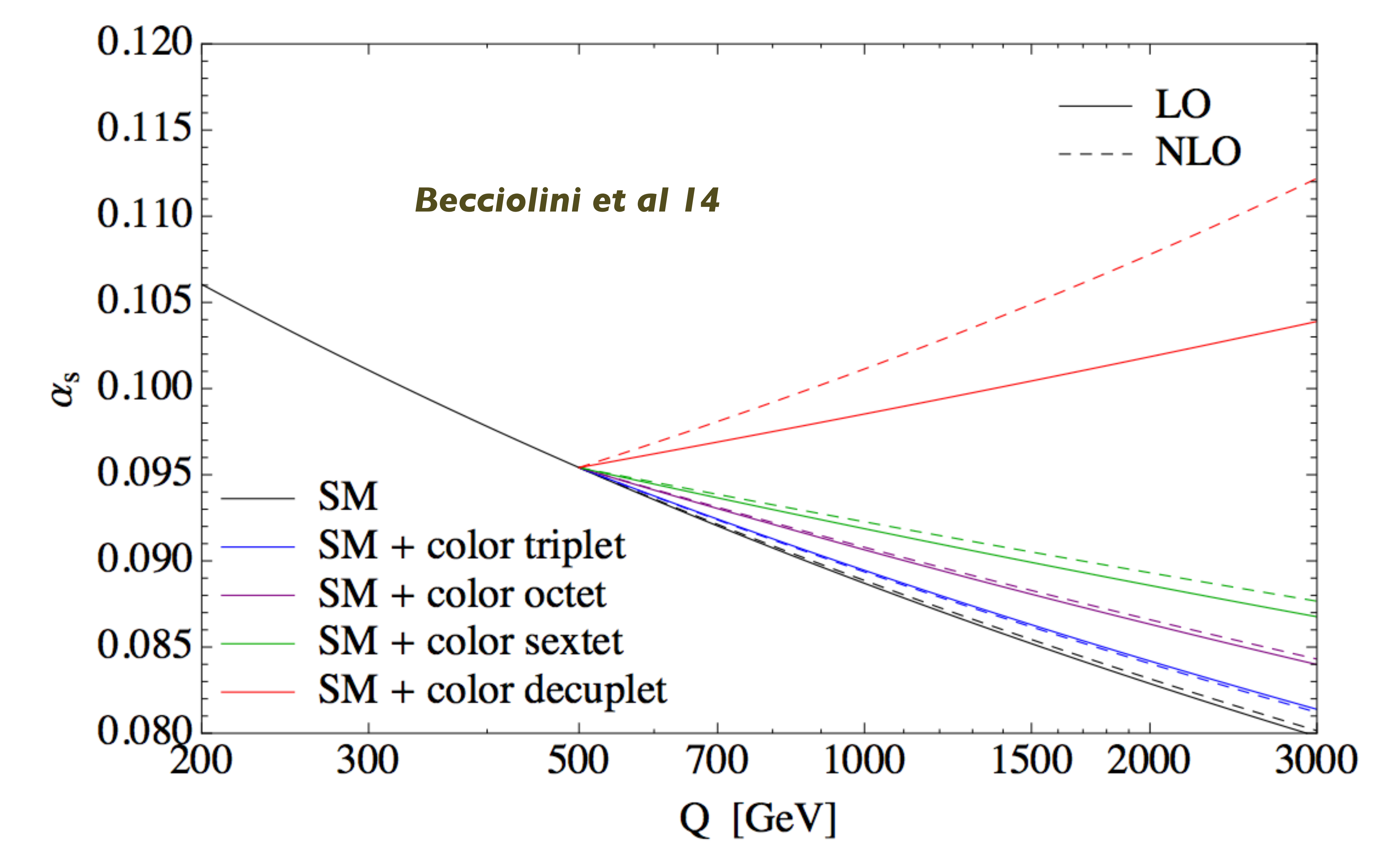
0.1135 ± 0.0011	Thrust (SCET NNLO+N^{3}LL+anlhad)
0.1123 ± 0.0015	C-parameter (SCET NNLO+N^{3}LL+anlhad)

- Experimentally **very clean measurements**
- Perturbative calculations available up to high orders and with **resummation included**
- Most accurate determinations (from SCET) **far from the PDG average**

Limitations and Challenges

- Sensitive to modelling of **hadronisation** and related **non-perturbative** effects
- Getting a 1% error on α_S**(M_Z)** from a measurement where **NP effects** range between 5% to 15% ! requires very careful understanding of NP phenomena

Beyond M_Z: the running coupling in bSM scenarios



- Collider measurements of $\alpha_S(Q)$ **in the TeV scale** are sensitive to **new bSM coloured sectors in a model-independent way**

- Experiments should provide both **direct measurements of** α_S**(Q)** (from top, jets, Z pT) as well as the resulting extrapolation down to M_Z assuming the **QCD running**

Beyond M_Z: the running coupling in bSM scenarios

Determination from the inclusive multi jet cross-sections at 8 TeV

CMS 16

$H_{T,2}/2$ (GeV)	MSTW2008: $\Delta\alpha_s(M_Z) \times 1000$				
	$\alpha_s(M_Z)$	exp	PDF	NP	scale
300–420	0.1157	± 15	± 14	± 19	$^{+53}_{-0}$
420–600	0.1153	± 11	± 14	± 18	$^{+57}_{-0}$
600–1000	0.1134	± 13	± 16	± 19	$^{+52}_{-0}$
1000–1680	0.1147	± 29	± 17	± 18	$^{+63}_{-11}$
300–1680	0.1150	± 10	± 13	± 15	$^{+50}_{-0}$

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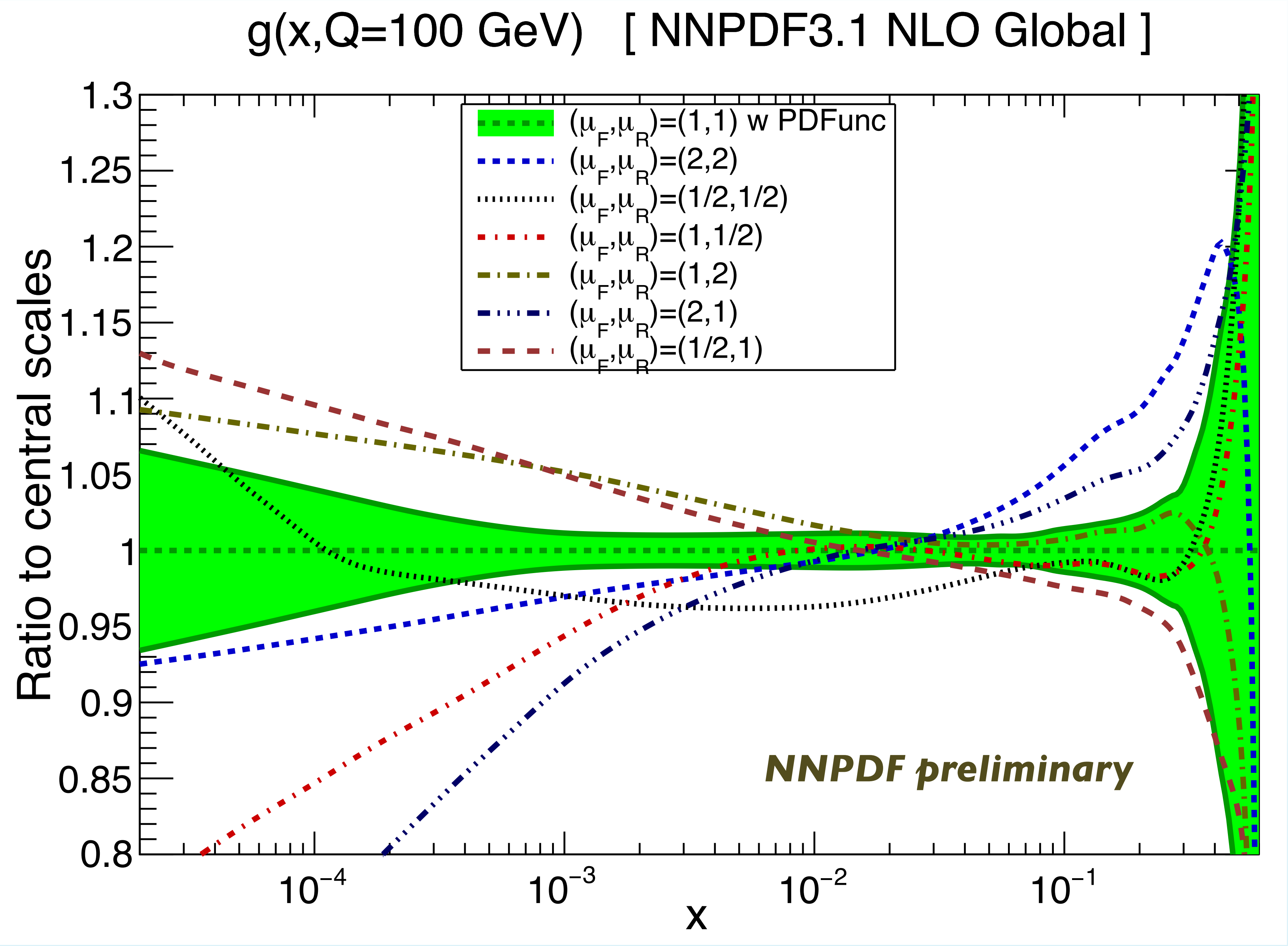
Additional material

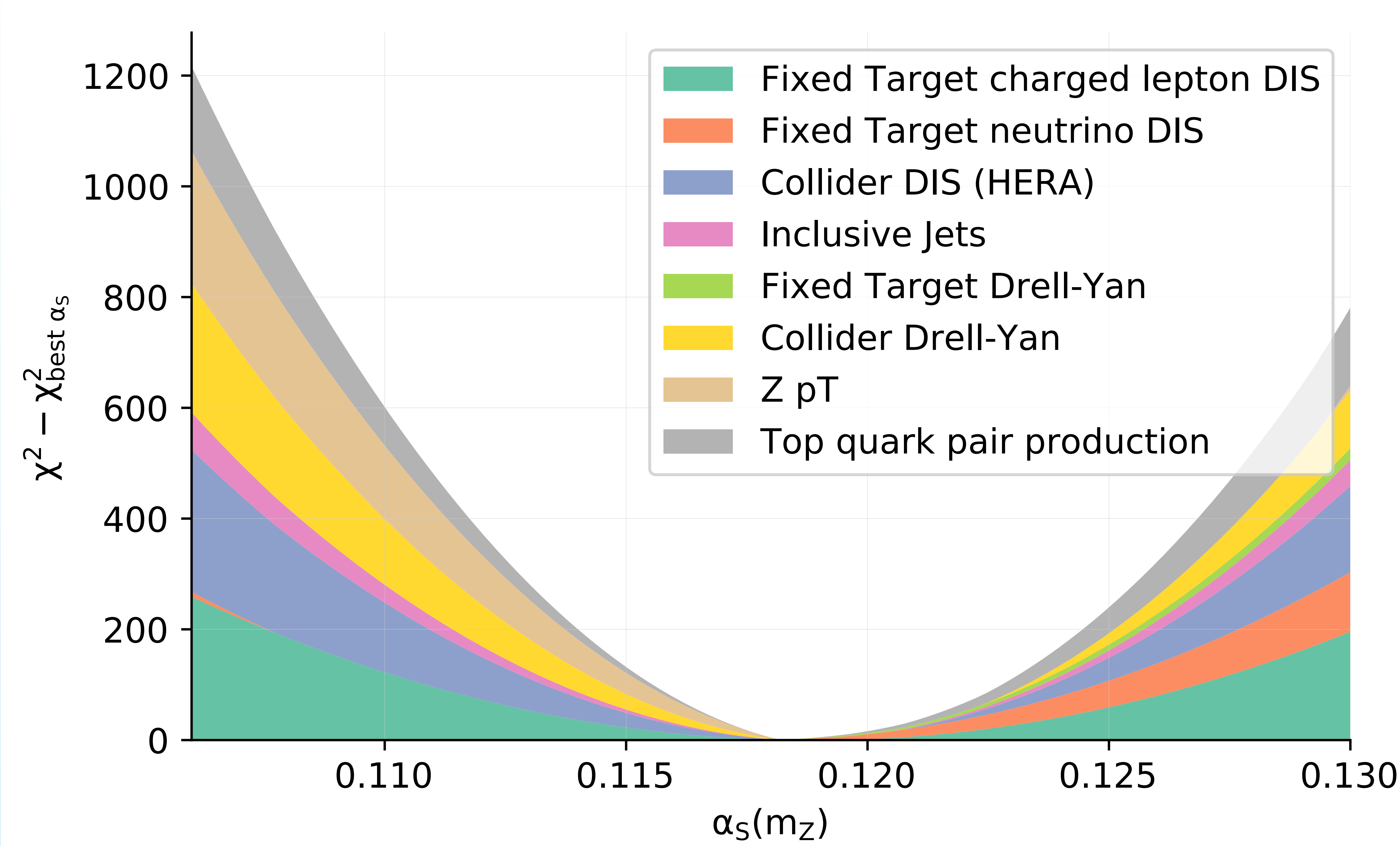
Global PDF fits with MHOU estimates



A determination of $\alpha_S(M_Z)$ from a global PDF fit taking into account MHOUs is now within reach

- At NLO, **MHOUs are comparable if not larger** than nominal PDF errors in the global fit
- Can be estimated by means of **fits with scale-varied theories**
- Construct a **combined exp+th covariance matrix** which allows to **propagate MHOUs** from the theory calculations to the fitted PDFs

Impact of individual processes



- Even processes with few data points can provide stringent constraints on the fitted $\alpha_S(Q)$ value
- For instance, the **O(100) points from Z p_T** data dominate over the **O(1000) points from HERA data**