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Interplay of α_s, m_t and gluon parameterization in CT PDF extractions

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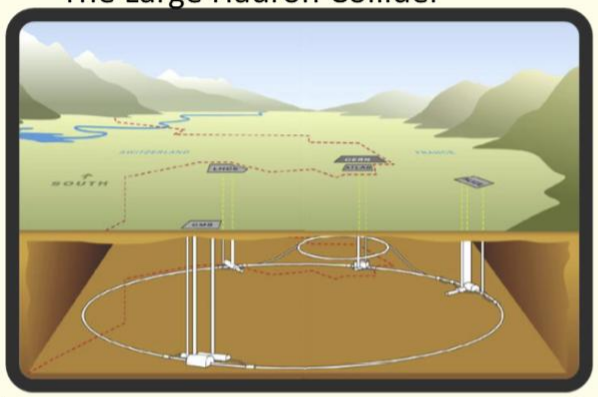
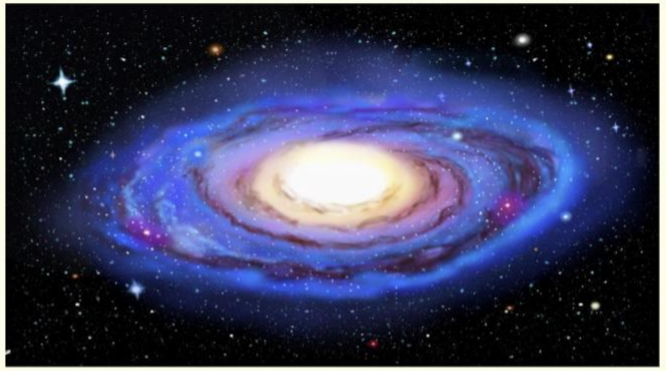
The subatomic Universe

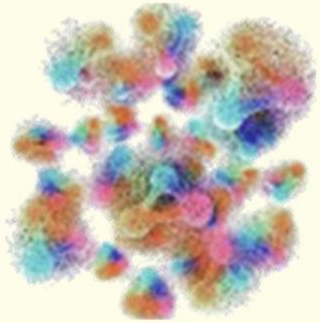
The Large Hadron Collider



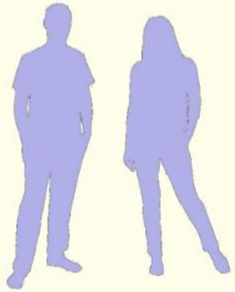
Milky Way



$$= \qquad \sim 10^{21}$$



Quarks and gluons



Human

Colliders, our most powerful microscopes, explore the rich world of subatomic particles and fundamental forces

Introduction

Experiments involving hadronic bound states:

Experimental data $\pm$ uncertainties vs. theoretical predictions

In deep inelastic scattering: exp. data $\pm$ unc. vs. $\int_x^1 \frac{d\hat{x}}{\hat{x}} f\left(\frac{x}{\hat{x}}, \mathrm{Q}^2\right) C(\hat{x}, \mathrm{Q}^2)$

$C(x, \mathrm{Q}^2)$ can be computed using perturbative QCD

$f\left(x, Q^2\right)$ are non-perturbative objects, that need to be extracted from the experimental data

Perform a fit of $f\left(x, Q^2\right)$ by performing a minimization in the PDF parameter space

Loss function for minimization: χ^2

Introduction

α_s and m_t are input parameters in PDF fits

They are highly correlated with the gluon PDF

As such, their input values can be expected to have a large effect on the resulting PDF

And consequently, a large effect on the quality of the resulting fit

Furthermore, correlated constraints on α_s and m_t affect projections for stability of electroweak vacuum [arXiv:2401.08811]

Question: how do the PDFs (and the fit quality) change upon varying these input parameters?

The analysis

As a first step, the fitting package is interfaced with PineAPPL

MATRIX framework interfaced with PineAPPL is run to produce theory predictions, up to NNLO accuracy in QCD, for top quark pair distributions

This foregoes the use of K-factors and allows the computation of cross sections to NNLO accuracy in an efficient manner

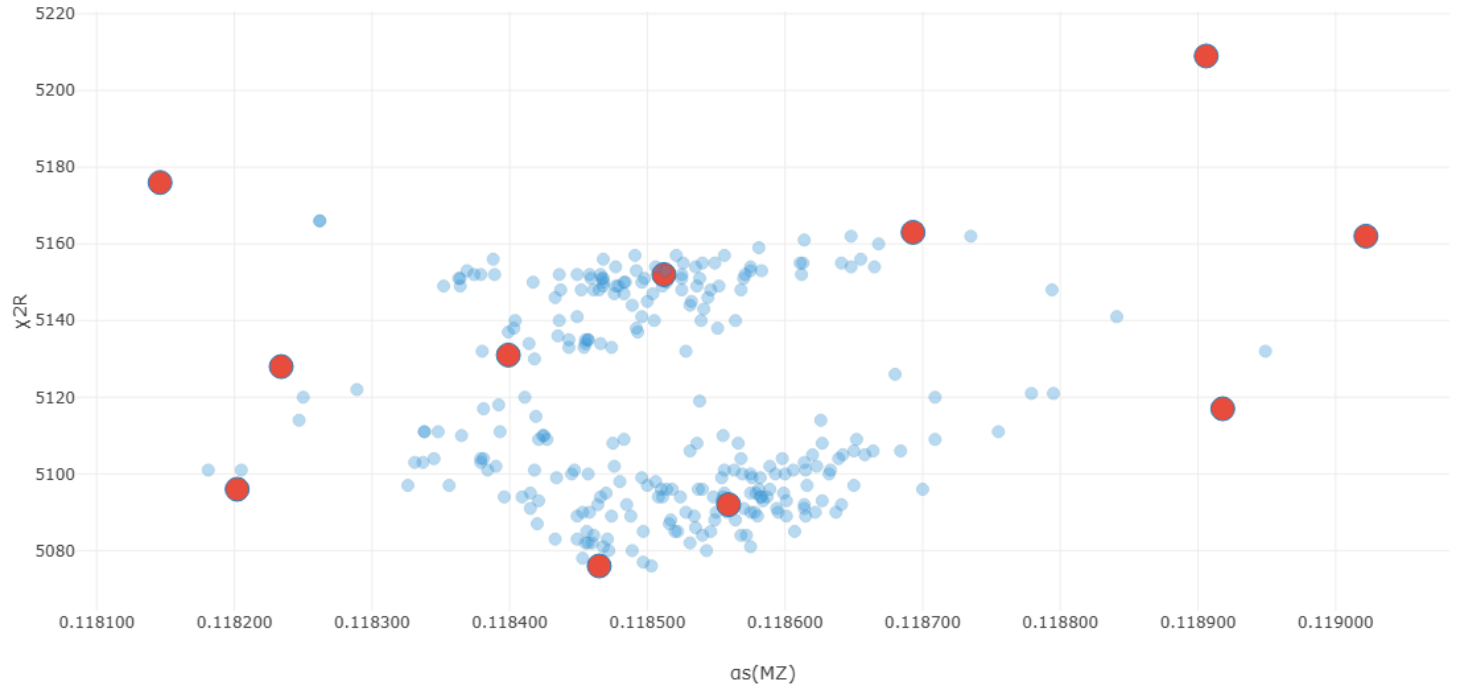
Grids are produced for m_t values of 170, 171.25, 172.5, 173.75 and 175 GeV

Side note: computational cost of producing the grids ~ 300k core hours

The analysis

For α_s, we consider the values of 0.116, 0.117, 0.118, 0.119 and 0.12

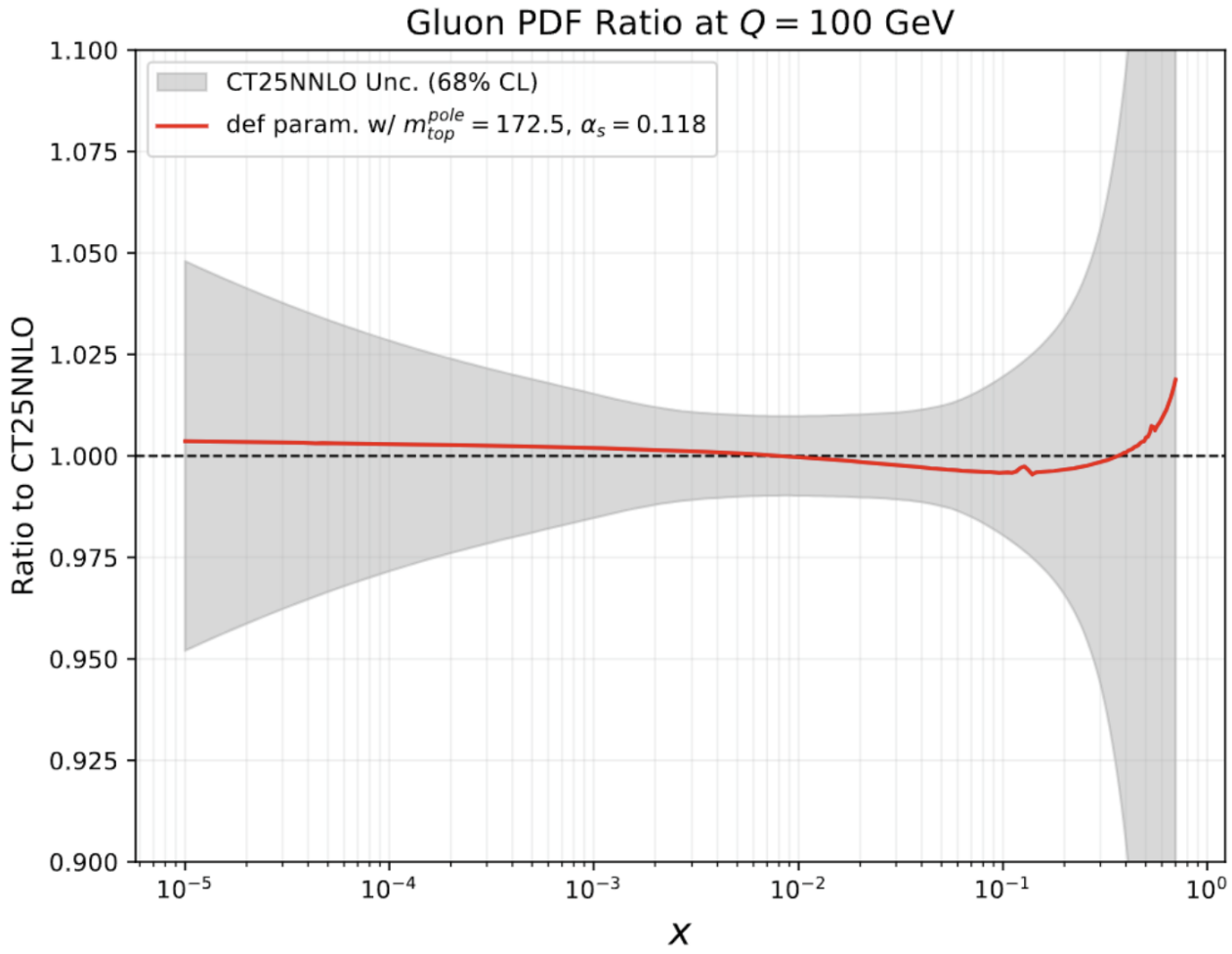
For parameterizations, we consider the default CT parameterization and 11 other parameterizations from the 287 considered in [arXiv:2512.23792]



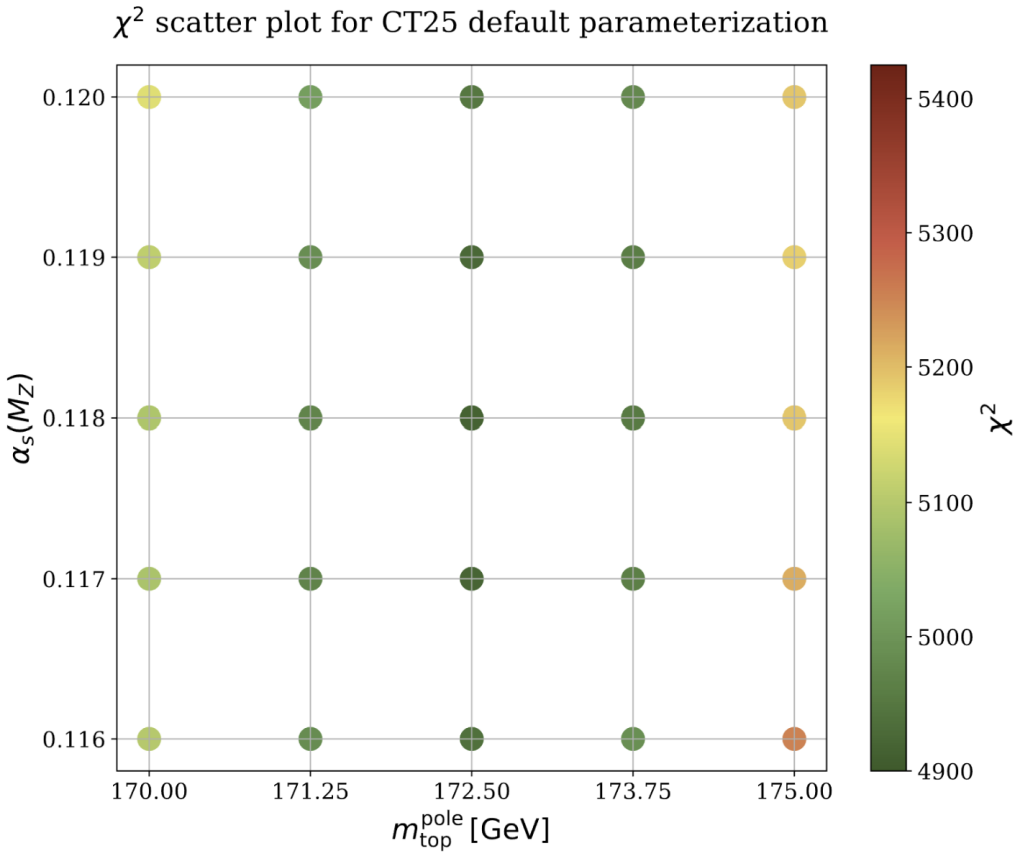
The analysis

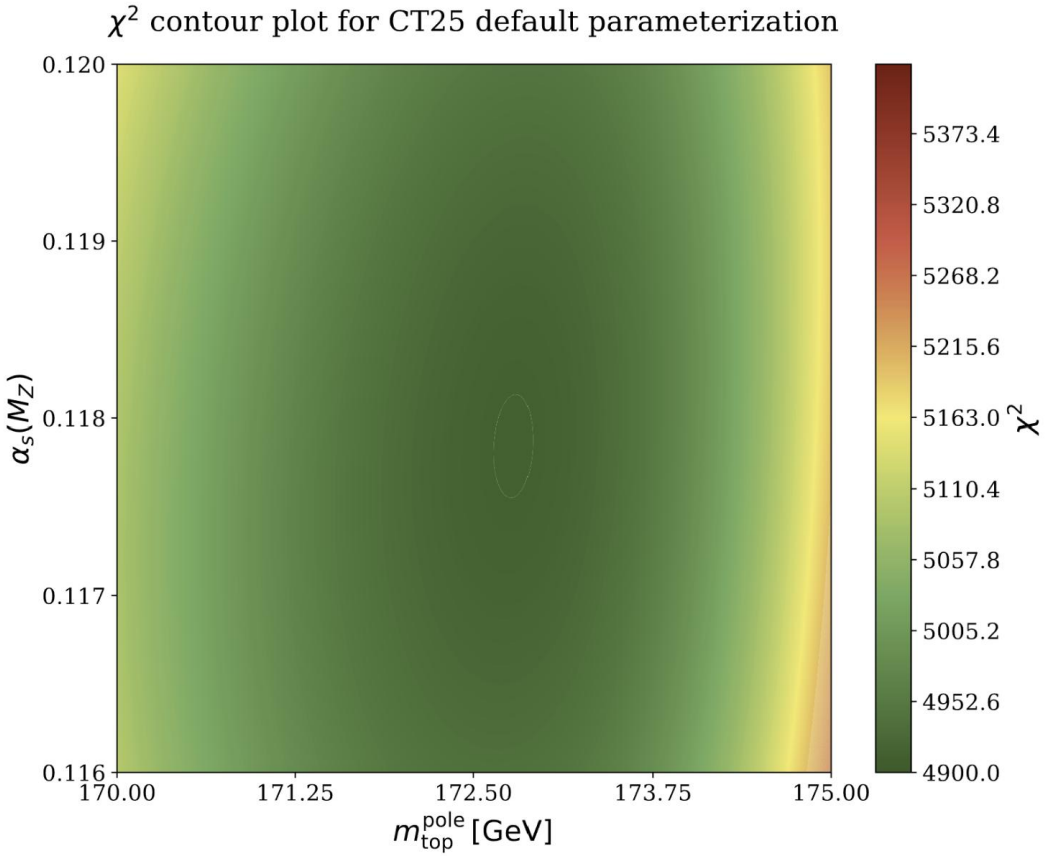
Finally, 300 (5x5x12) fits are run

Only the central PDFs are produced

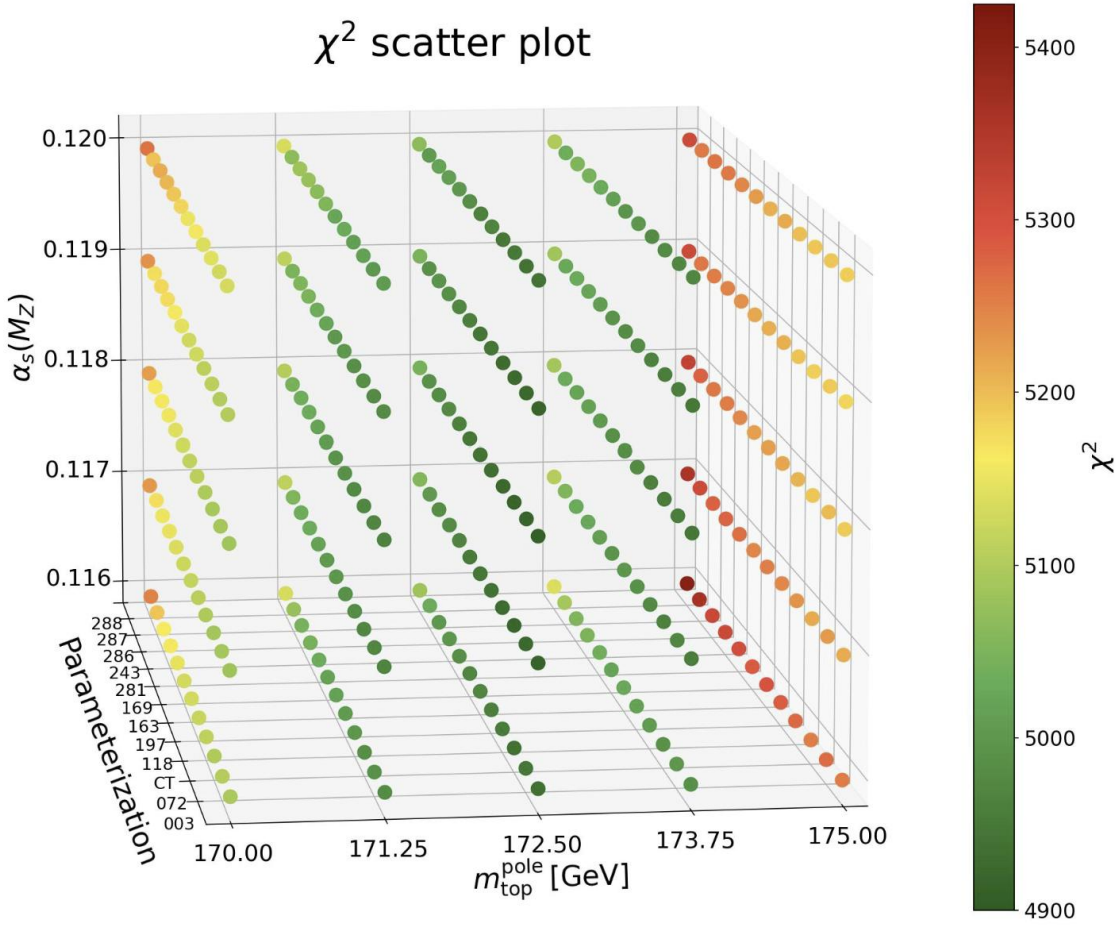


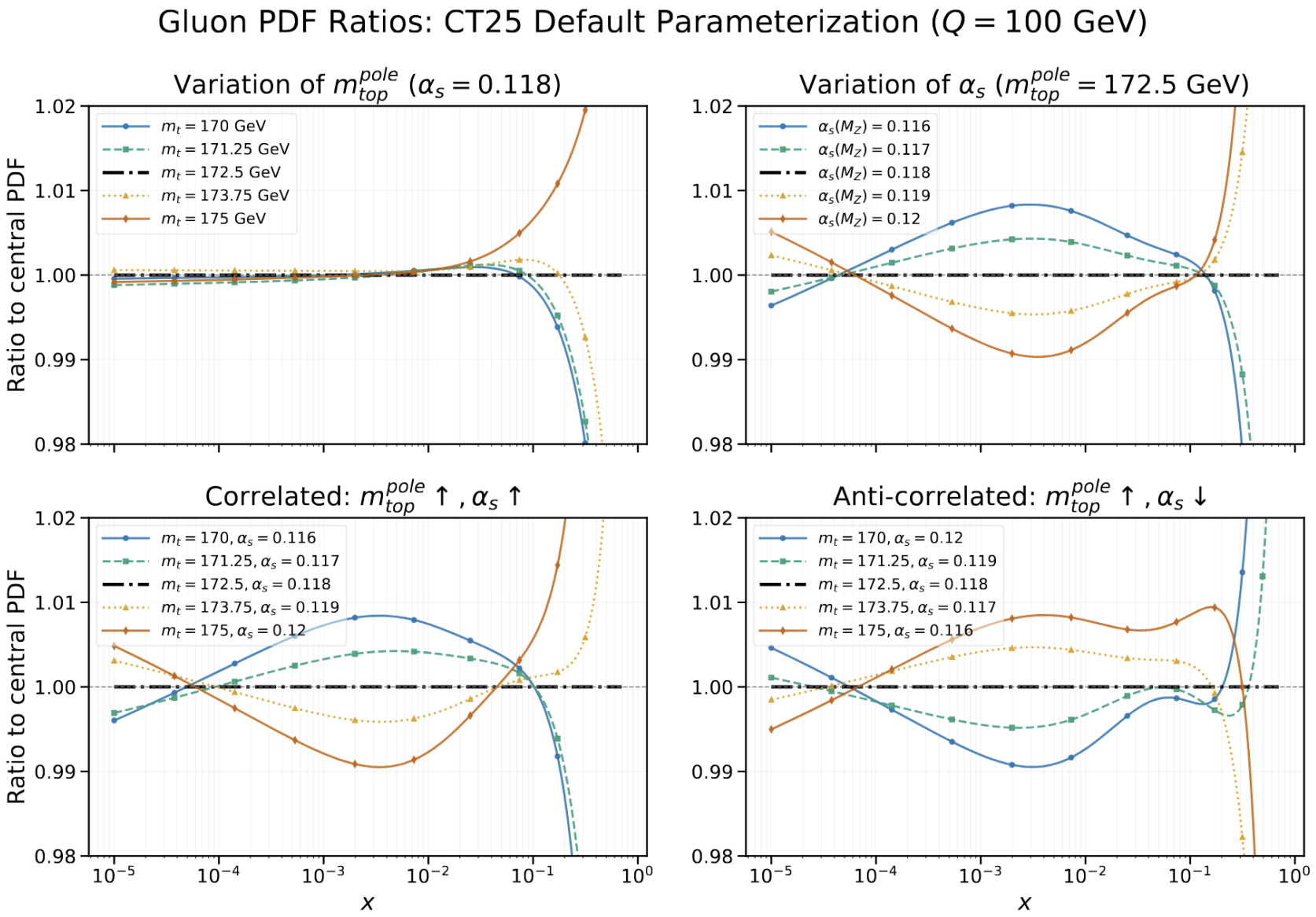
Results: default CT parameterization





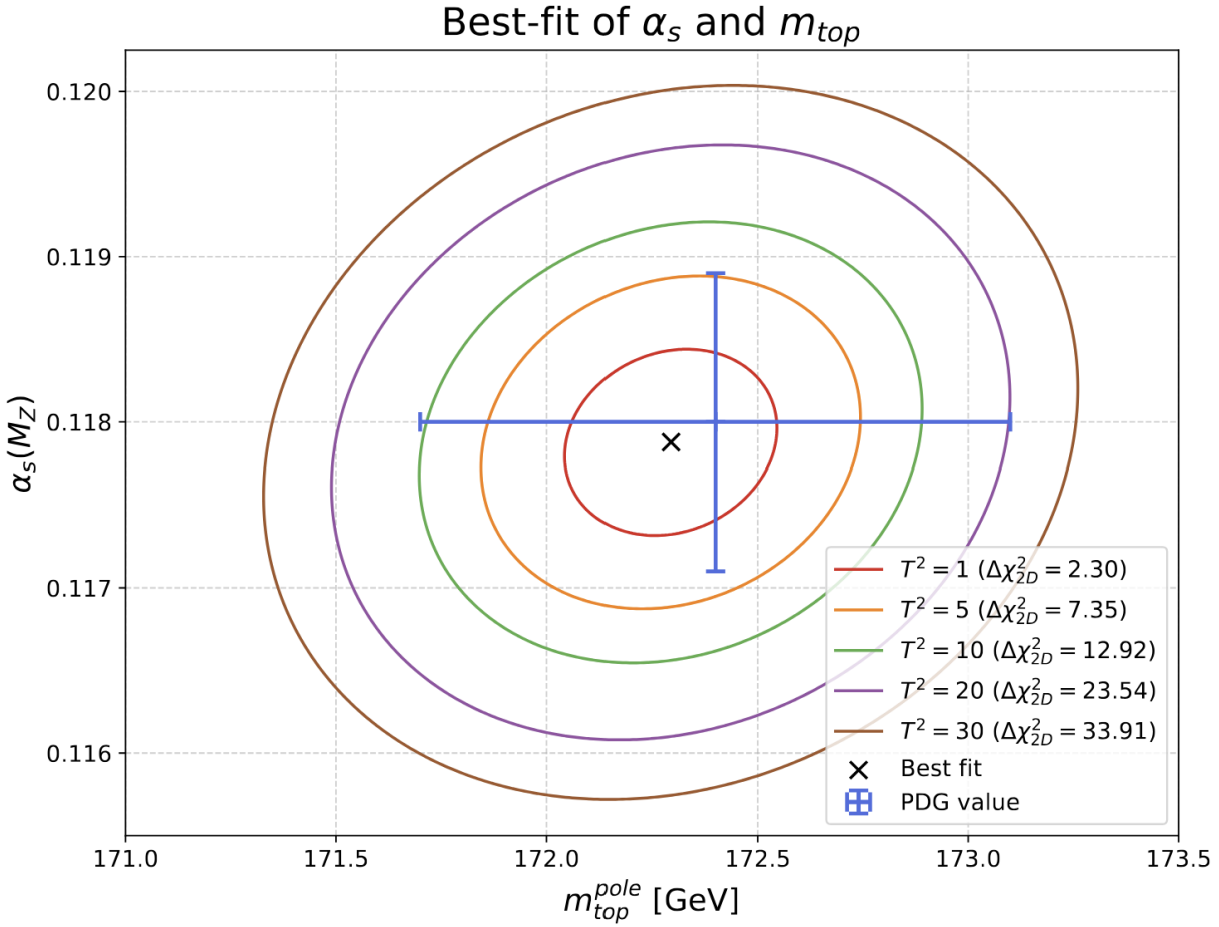
Results: all parameterizations





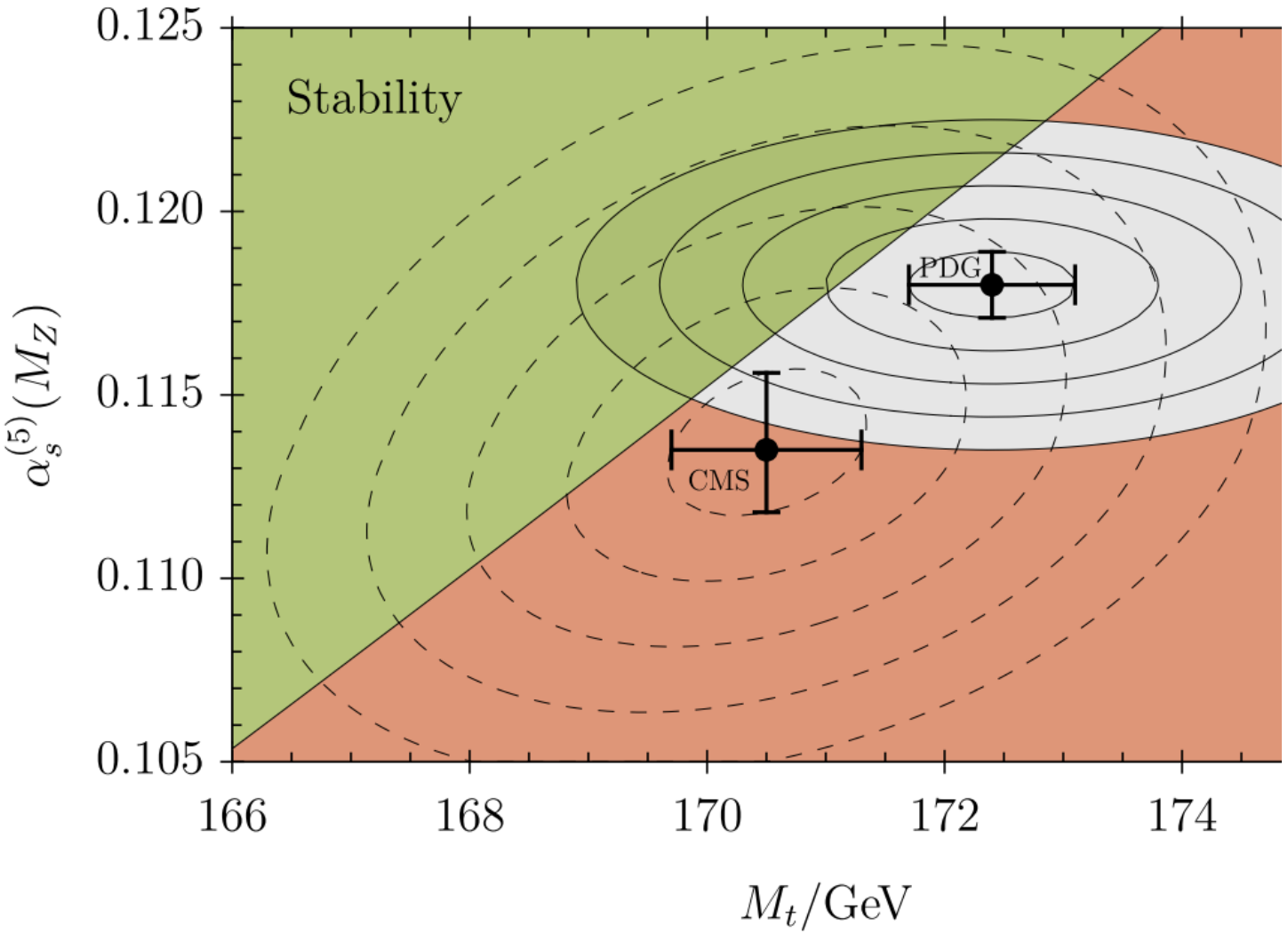
Results: how do the PDFs change

Results: α_s & m_t extraction



- $T^2 = 1$: $\alpha_s = 0.1179 \pm 0.0006$, $m_{top} = 172.29 \pm 0.25\text{GeV}$
- $T^2 = 5$: $\alpha_s = 0.1179 \pm 0.0010$, $m_{top} = 172.29 \pm 0.45\text{GeV}$
- $T^2 = 10$: $\alpha_s = 0.1179 \pm 0.0013$, $m_{top} = 172.29 \pm 0.60\text{GeV}$
- $T^2 = 20$: $\alpha_s = 0.1179 \pm 0.0018$, $m_{top} = 172.29 \pm 0.81\text{GeV}$
- $T^2 = 30$: $\alpha_s = 0.1179 \pm 0.0022$, $m_{top} = 172.29 \pm 0.97\text{GeV}$

CT α_s study: $\alpha_s = 0.1183^{+0.0023}_{-0.0020}$ [arXiv:2512.23792]



From [arXiv:2401.08811]

Our extraction falls in the meta-stable region (near the PDG value)

Confidence level depends on the choice of tolerance

Conclusions

PDF parameterizations seem to affect fit quality almost equally for any combination of α_s and m_t

Effect on fit quality by m_t is greater than the effect on fit quality by α_s

Simultaneous extraction of α_s and m_t yields 0.1179 and 172.29 GeV respectively

Results compatible with PDG world average (even when considered with a tolerance of 1)

Backup

PineAPPL: an interpolation grid library

$$\frac{d\sigma}{d\mathcal{O}} = \int_x^1 \frac{d\hat{x}}{\hat{x}} f\left(\frac{x}{\hat{x}}, \mathrm{Q}^2\right) C(\hat{x}, \mathrm{Q}^2)$$

based on piece-wise Lagrange polynomials

pre-compute over an interpolation basis, thus creating an array of weights which can be contracted with an array of PDF values at the interpolation nodes to obtain the final value of the observable

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