Estimating Parametrization and Prior Dependence for CT25 PDFs

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CTEQ-TEA (Tung Et Al.) group

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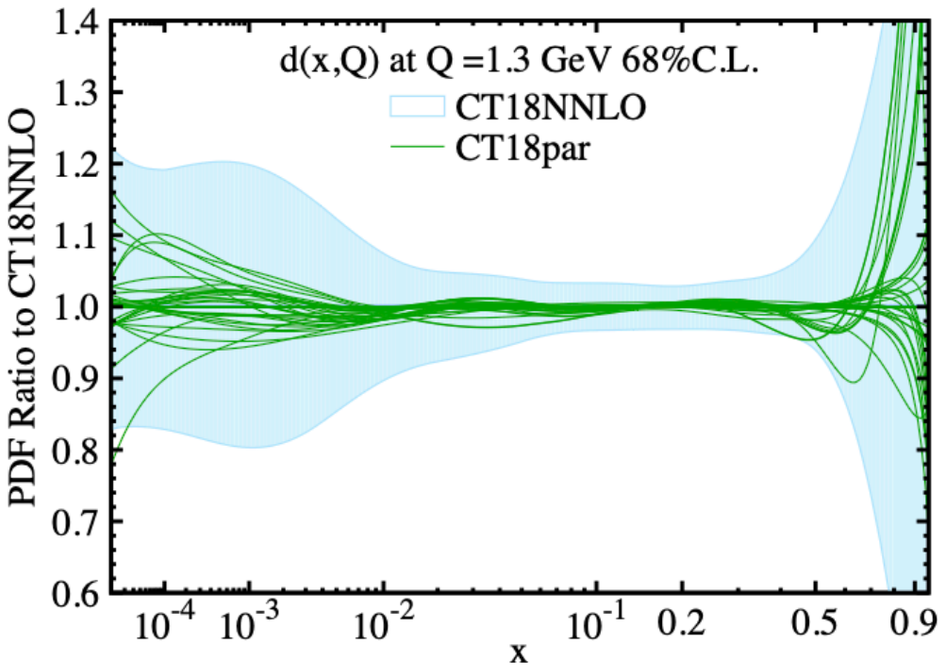
Dirección General de Asuntos del Personal Académico

Building a bottom-up uncertainty

CT18:

2-tier tolerance, based on a fixed T^2, mimicked by adding models/parametrizations



CT25:

1-tier dynamical tolerance *(D-TOL)* for many models

= **CT P**arton **C**loud

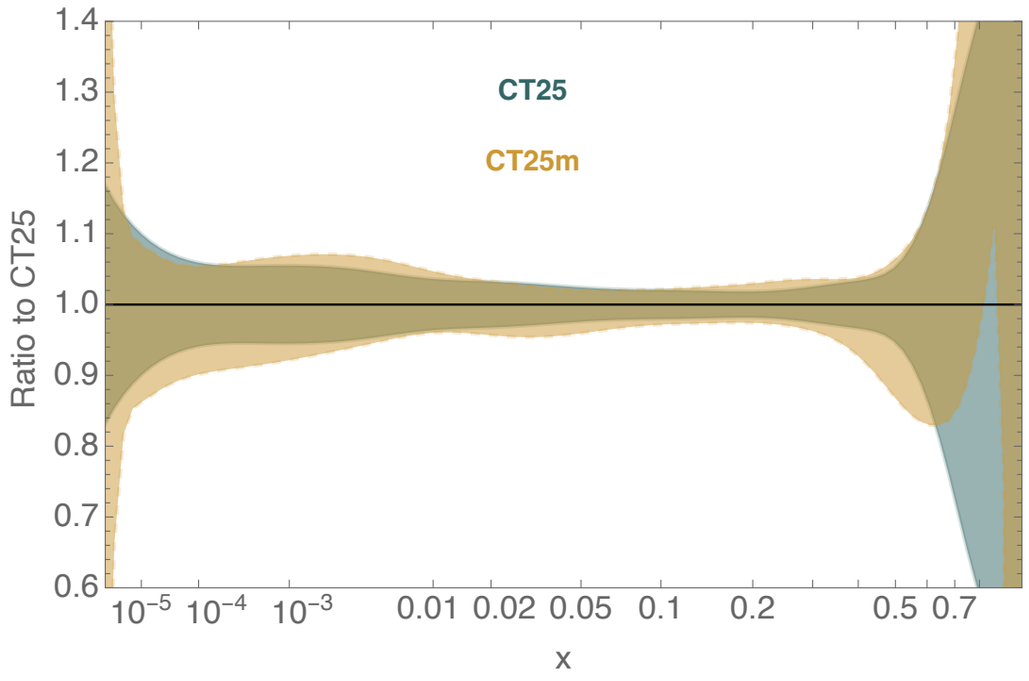
— models based on Bernstein polynomials ;

Bézier curves are WIP.

The $N_m = 8$ most diverse solutions combine into **CT25m**

— building up an emergent effective T^2.

xd (x,Q) at Q=2.0 GeV (sym.err)



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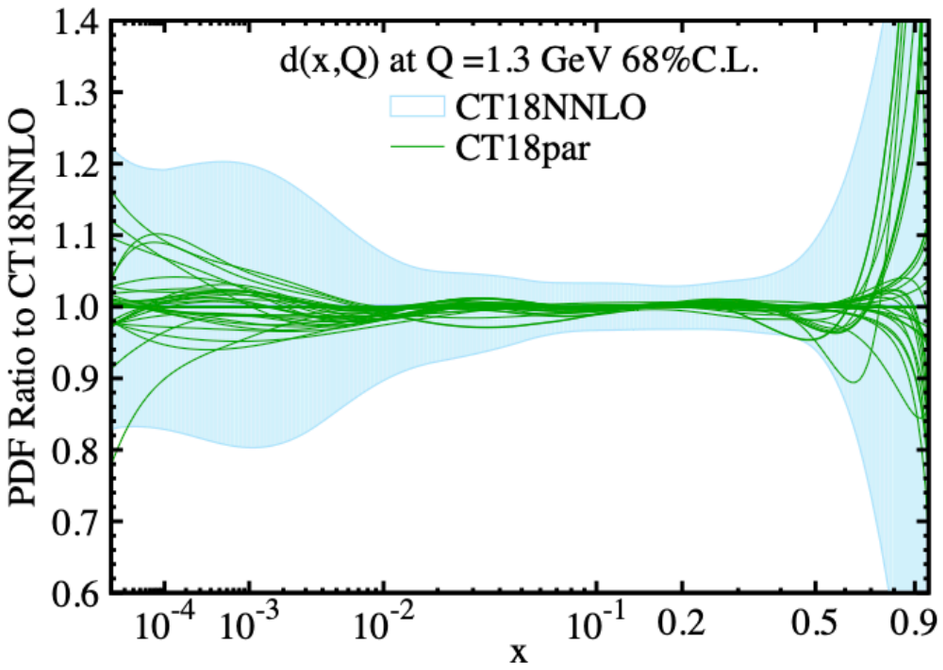

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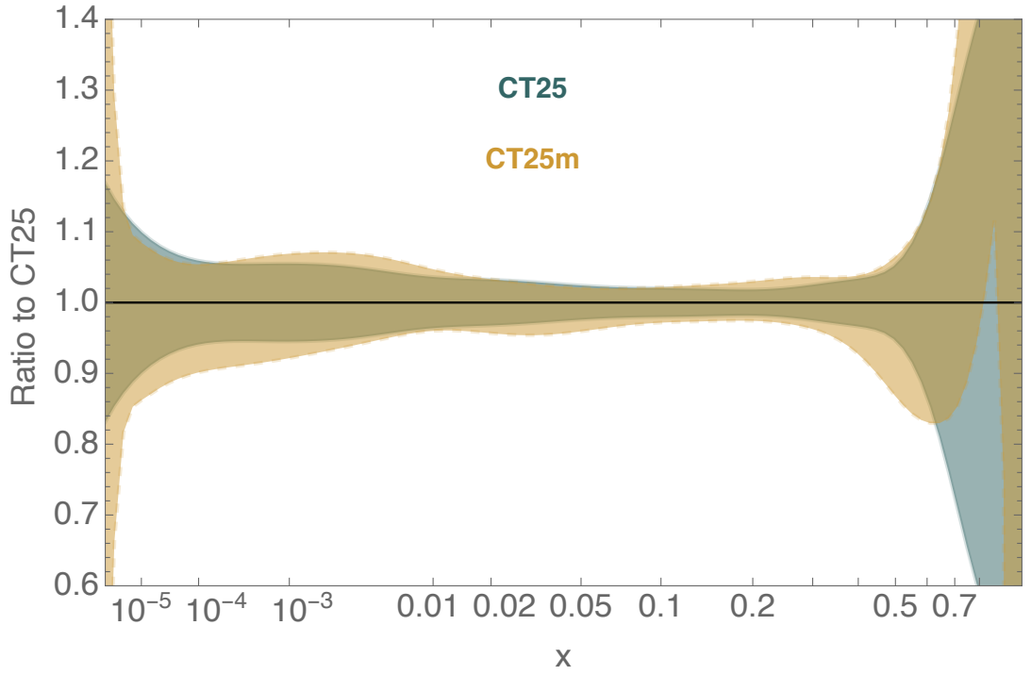

This uncertainty ensures

— agreement in data region

— larger uncertainty in extrapolation regions

CT25 selection and model uncertainty

To select the **most representative solutions**, we study:

— how they are distributed

— their χ^2 value $(\chi^2_0 + \delta\chi^2)$

I. Clustering by shapes:

Visualizing the structure of the neighborhood of χ^2_0 based on an estimator

— value of PDFs at x-vectors

— absolute shape estimator (information criterion)

[2511.07518]

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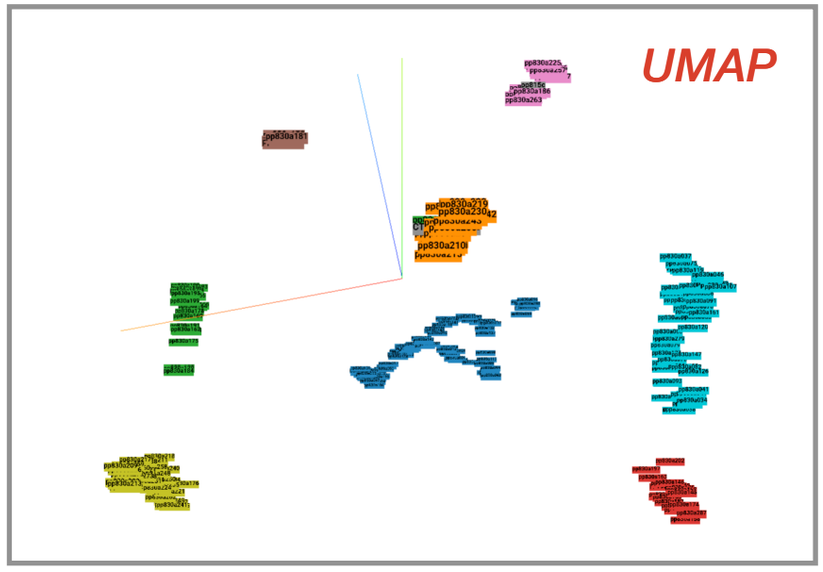
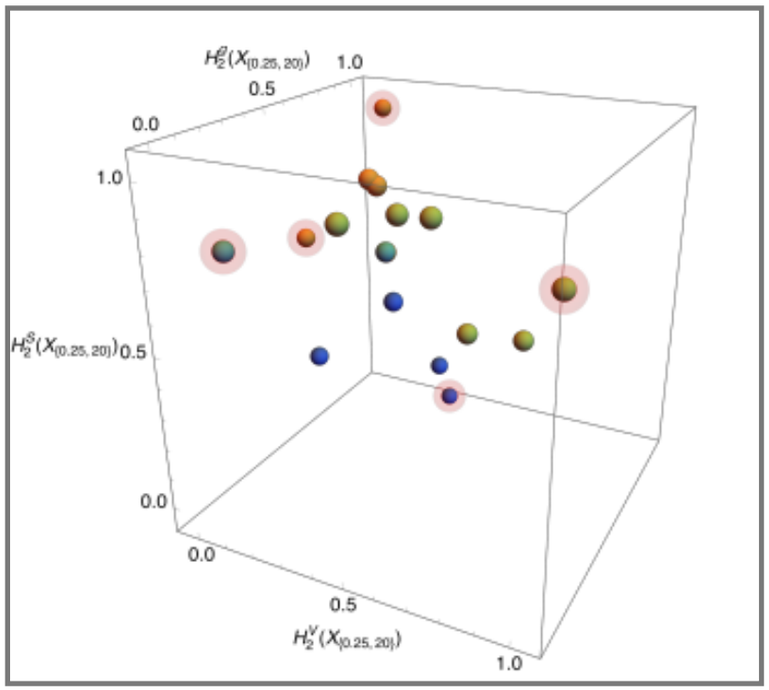


Plot by Y. Fu



Rényi space, illustrated for pion PDF

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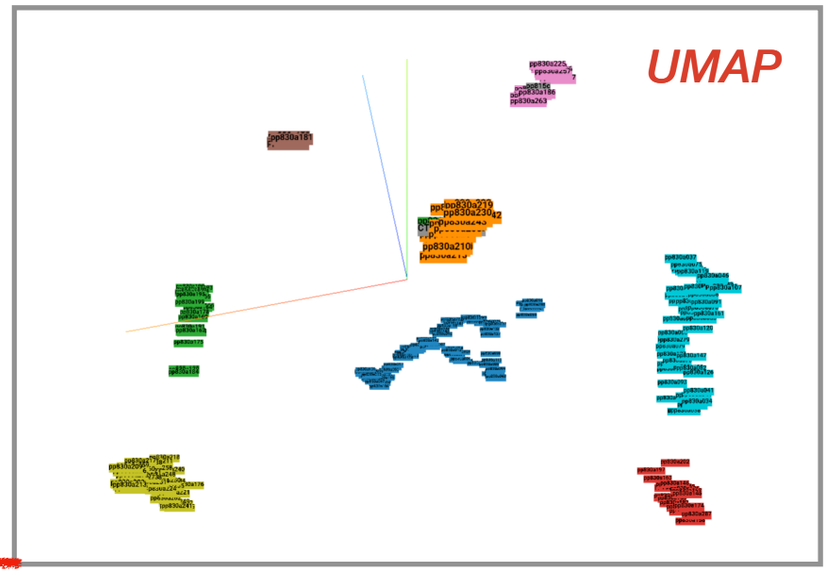

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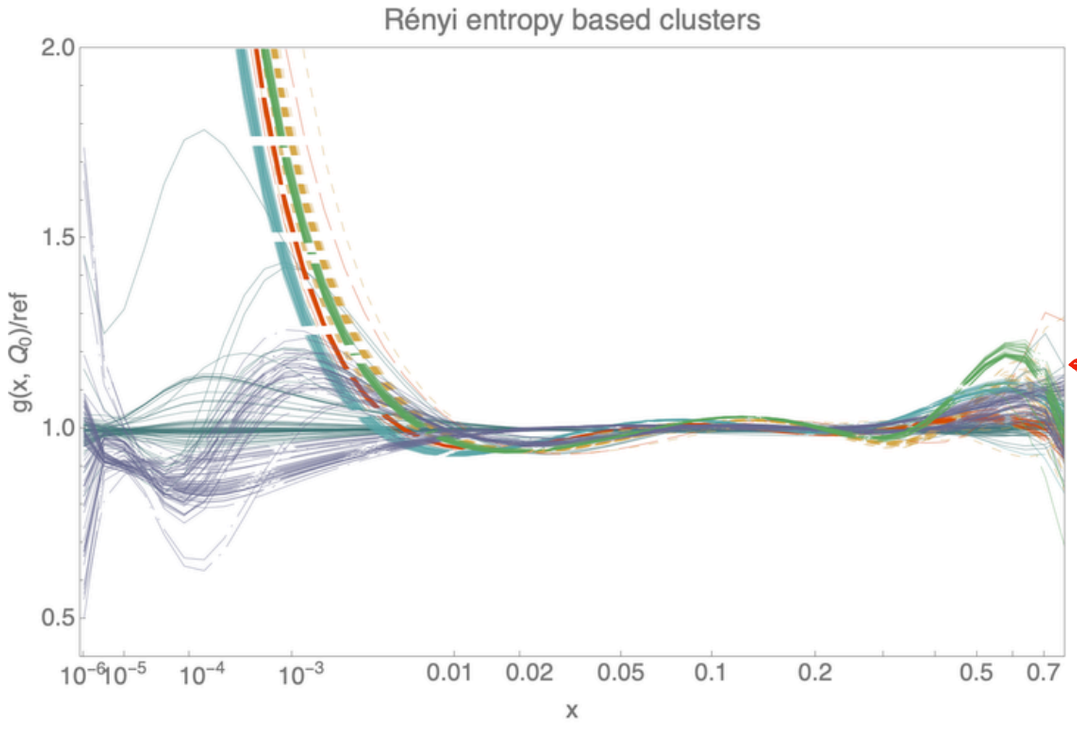

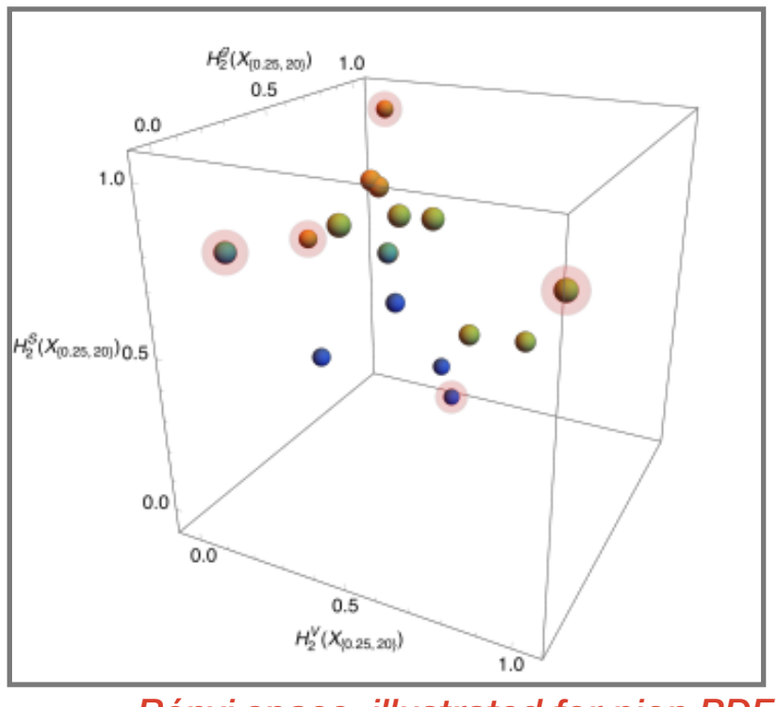

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CT25 selection and model uncertainty

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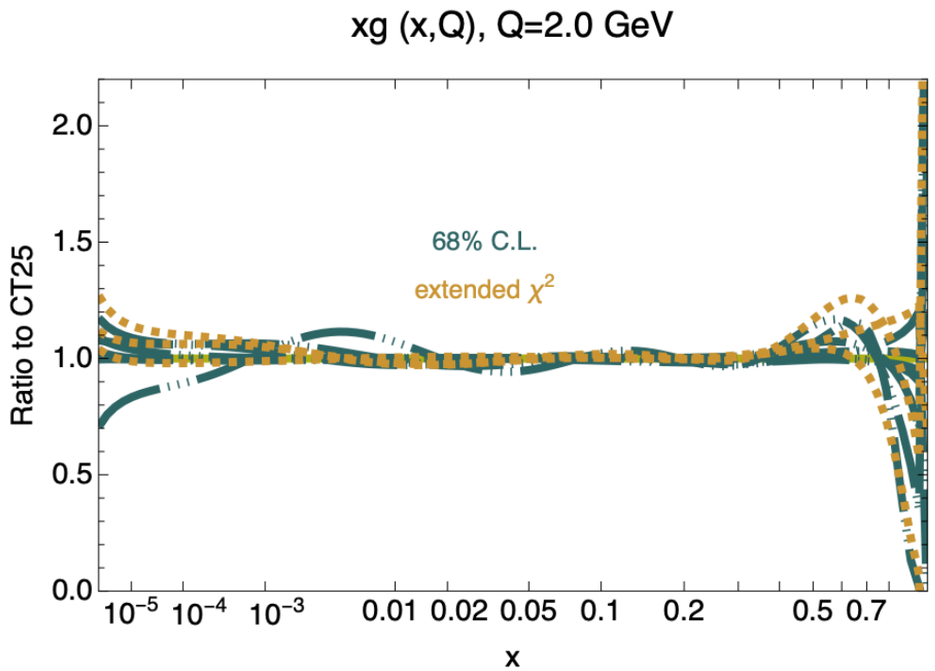
— explore the set of χ^2 paraboloids (landscape)

— select the solution with best χ^2 per cluster



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III: Building the uncertainty:

Building the Hessian uncertainty accounting for both aleatoric and epistemic sources

— combine the solutions using MetaPDF algorithm

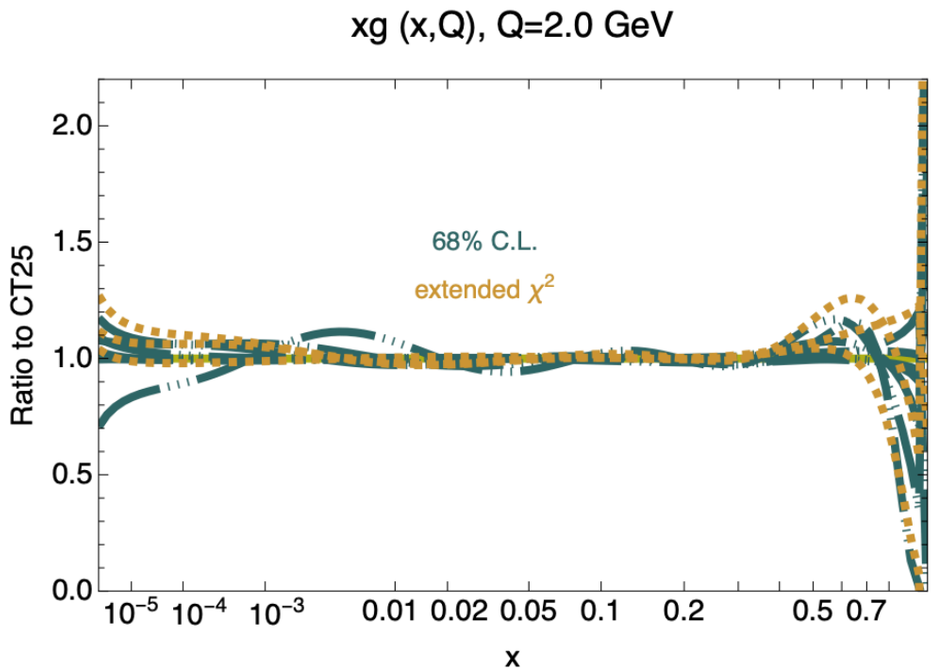
[1401.0013]

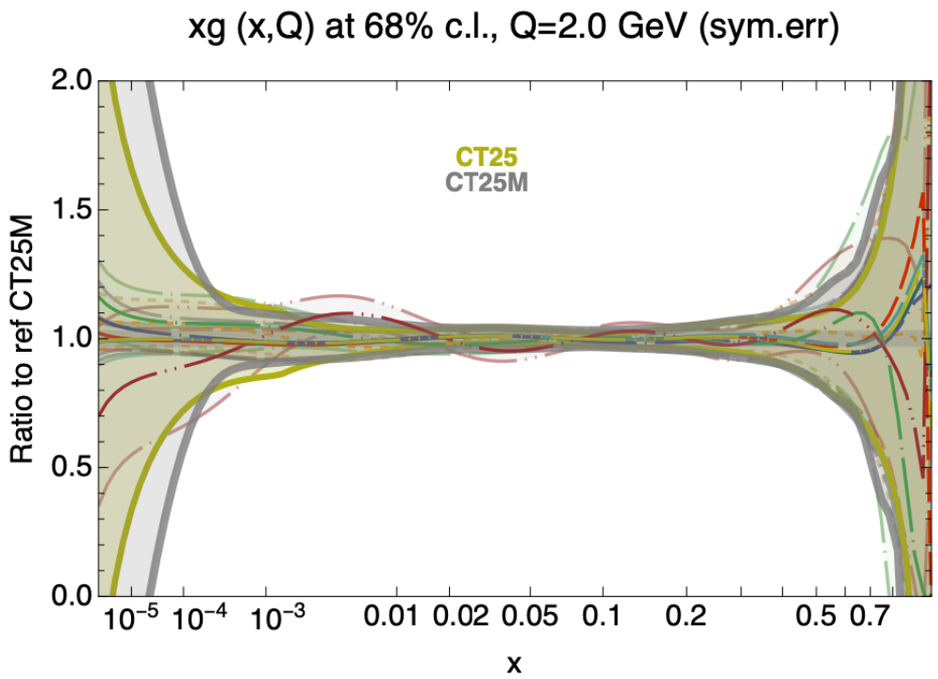
Statistically justified by de Finetti's theorem.

[2505.13594]

Implementation-wise, follows the META combination of the PDF4LHC.

[2203.05506]





CTEQ-TEA Parton Cloud

A growing repository of 300+ global fits

CT25m NNLO

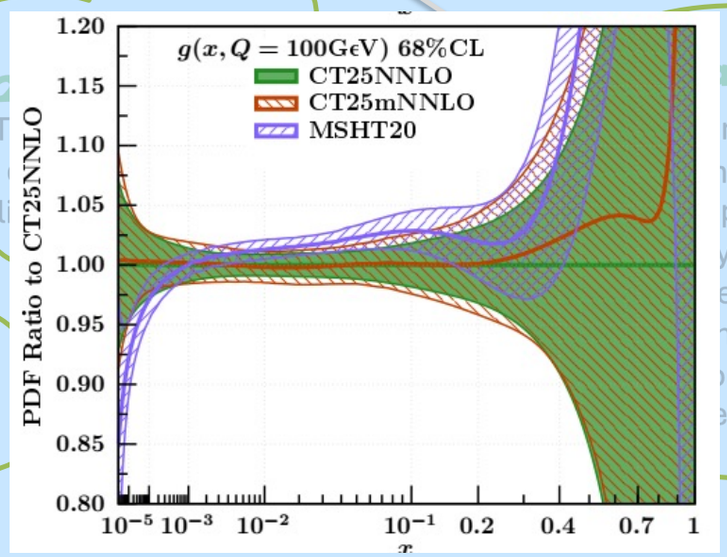
- general-purpose sym. Hessian set for LHC studies, 68% CL
- a META combination of 8 D-TOL ensembles based on distinct PDF parametrizations
- includes a CT18X input ensemble with a negative small-x gluon
- comparable with PDF4LHC21

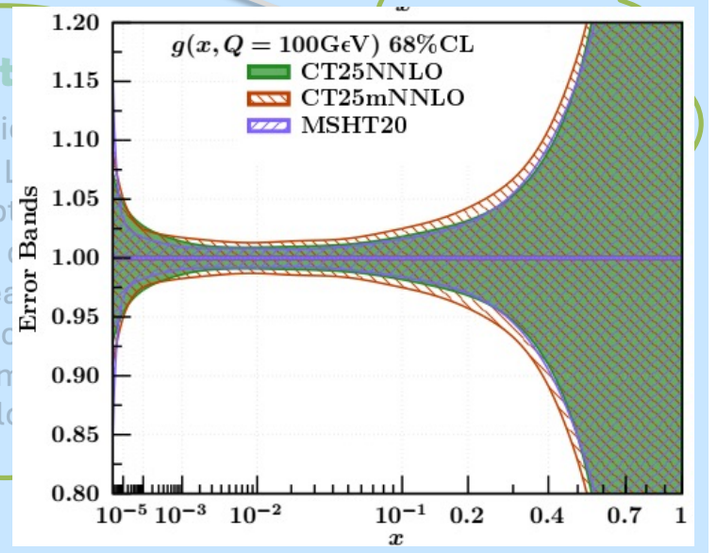
CT25 NNLO

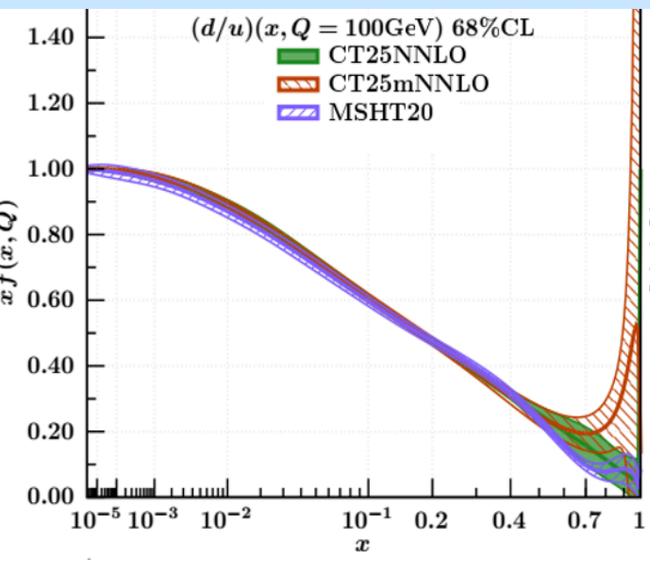
- general-purpose Hessian, 68% CL
- one PDF parametrization choice
- -asymmetric dynamical tolerance (D-TOL)
- supersedes CT18 series;
- -comparable with MSHT20
- on cteq-tea.gitlab.io

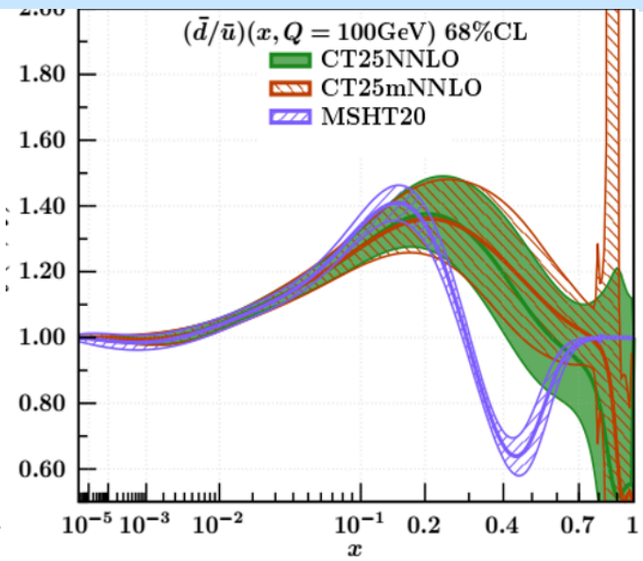
CT25 α_s series

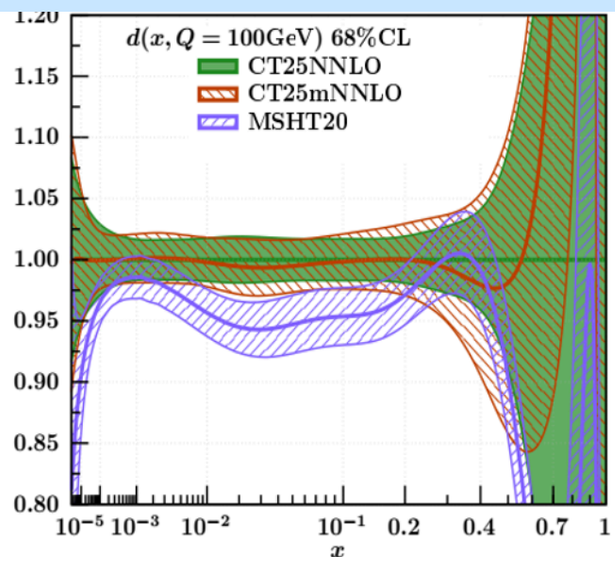
- based on α_s determination in 2512.23792
- on cteq-tea.gitlab.io

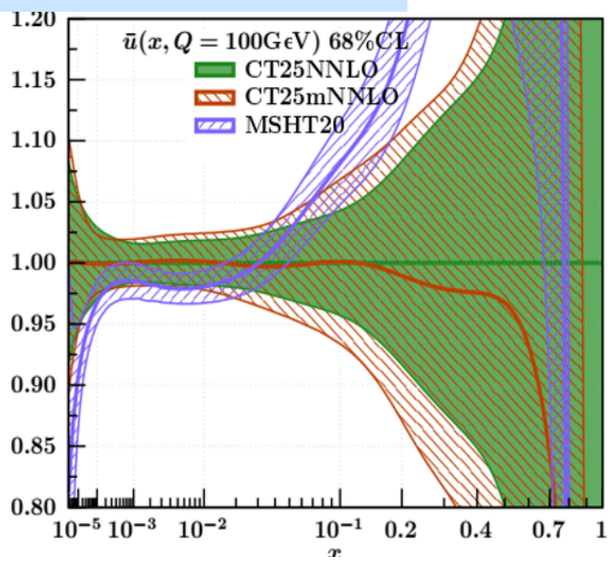












CT25 flat prior

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CT25pd NNLO

- As CT25, based only on proton and deuteron data
- baseline for nuclear PDFs

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- based on α_s determination in 2512.23792
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- general-purpose sym. Hessian s
for LHC studies, 68% CL
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ensembles based on distinct PDF
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- includes a CT18X input ensemble with a negative small-x gluon
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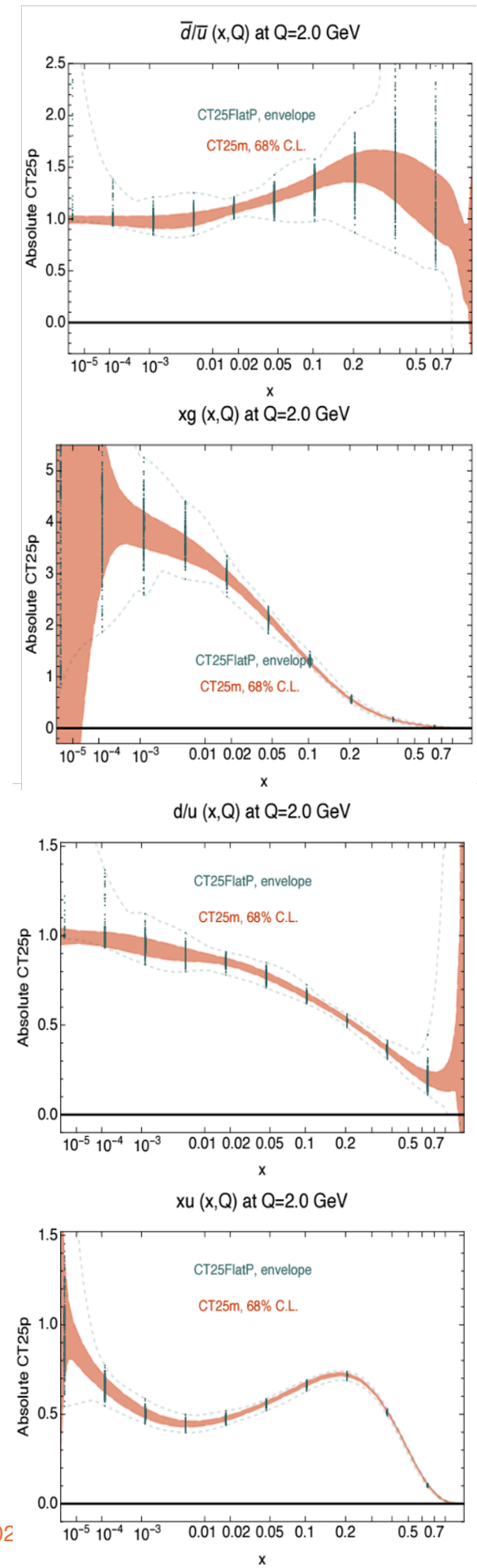
CT25FlatP NNLO

- Flat PDF prior for reweighting with LHC data
-350 equally acceptable fits to proton-only data
- estimate aleatoric and epistemic PDF uncertainties
- Error computed as an envelope



Proton-only data and ~150 *as-good*, pruned central solutions on top of CT25-like and small-x (with negative gluon at Q_0) behavior. Less flavor-separation power.

The $N_s = 350$ solutions form an envelop known as **CT25FlatP**

— building up a prior for those predictions that need be free of deuteron biases.

Conclusions

CT25 is a family of 4

with two sets considering **epistemic uncertainty** through the choice of **parametrization**

— CT25m and CT25FlatP

exploration of the **space of solutions**

— defining its *boundaries* (CT25m) and populating the *landscape* (CT25FlatP)

Usage of CT25 epistemic-inclusive sets:

☑ CT25m: extrapolation regions, both large- and small-x, important for BSM searches

☑ CT25FlatP: studies that need to be free of deuteron-related biases — Drell-Yan,…

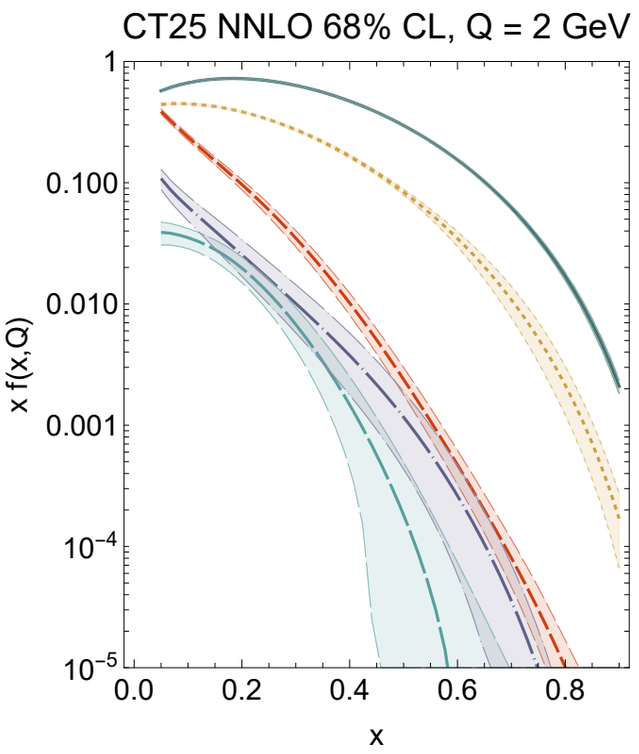
— LHC profiled analyses,…

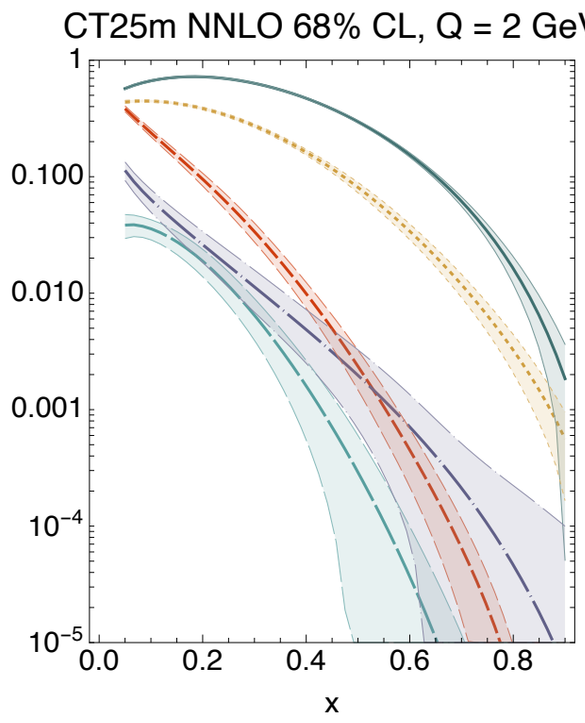
Backup

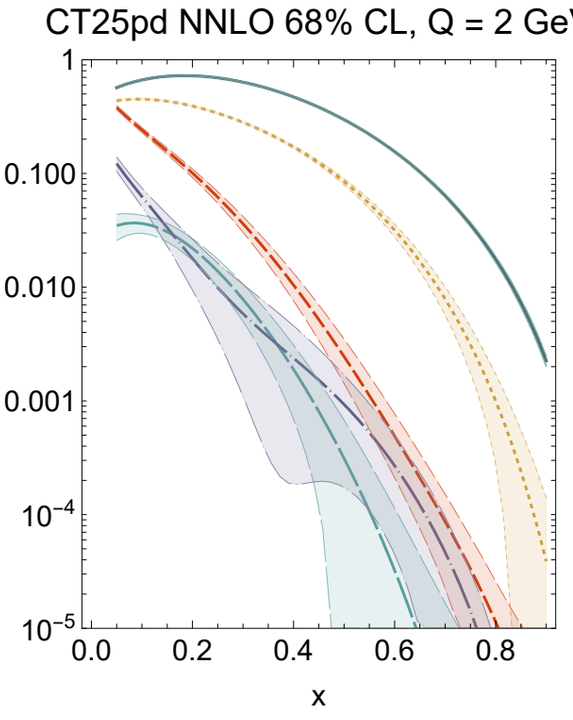
CT25 is a family of 4

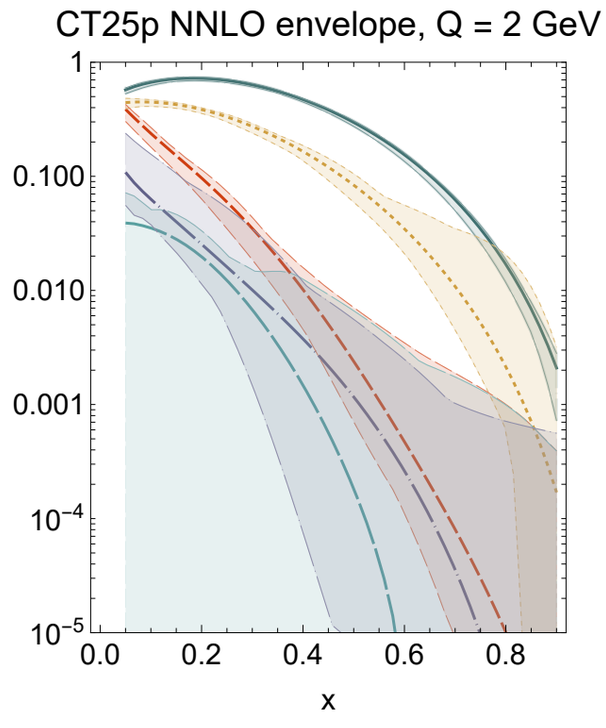
The large-x behavior for the sea is not well determined.

Each set reflects different non-perturbative inputs,
either from PDF model or choice on inclusion of deuteron data.









Nominal CT25 — D-Tol
CT25m — includes model uncertainty
CT25pd — deuteron corrections (less data)
CT25p_flat — flat prior w/o deuteron data

Characteristics of the clusters

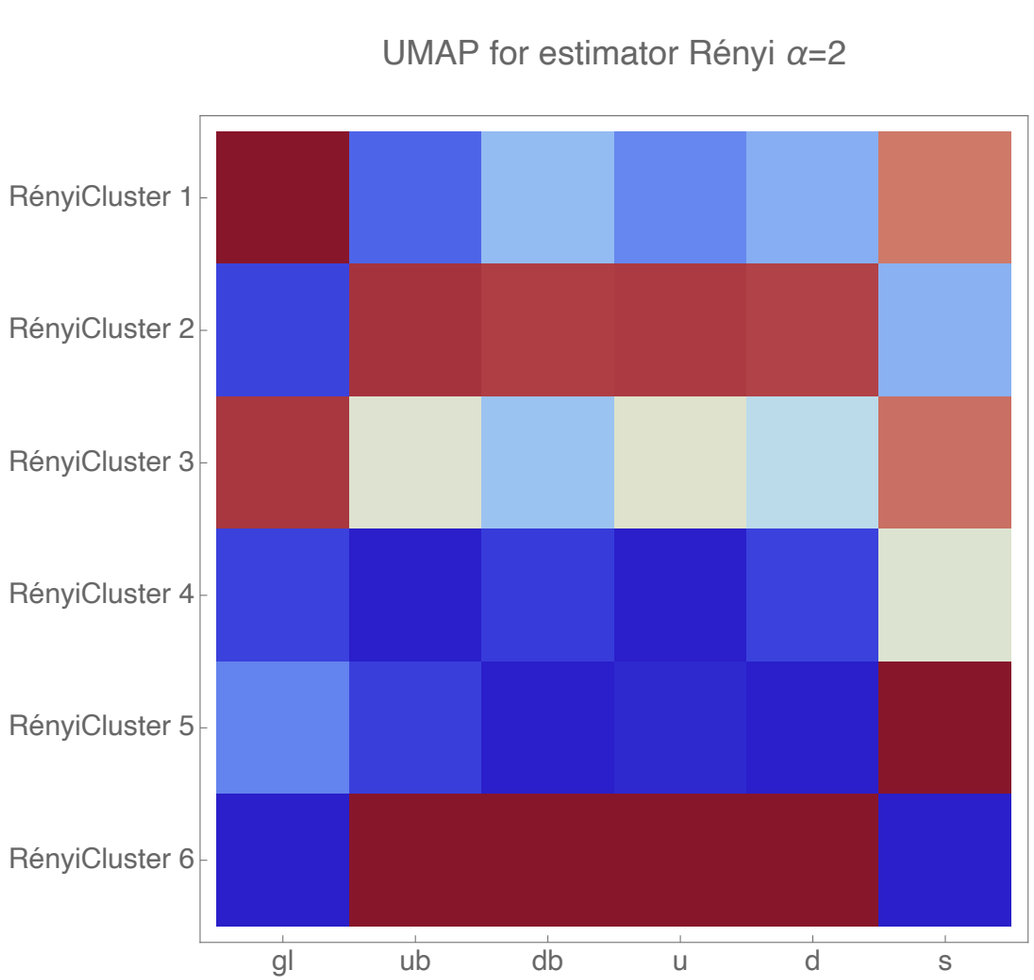
Rényi entropy: as an absolute shape estimator

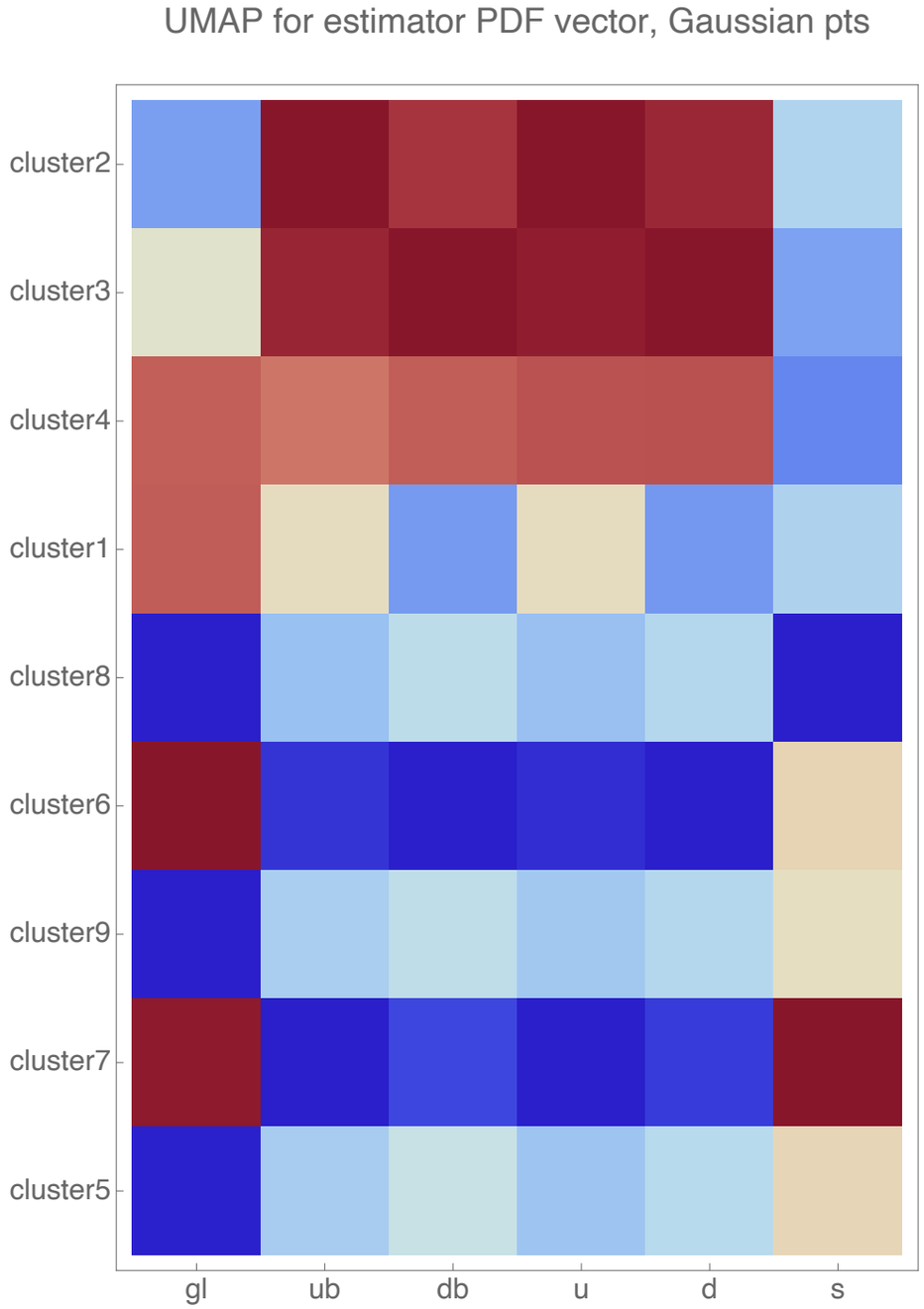
How bumpy (certain) is a solution on $x \in [0,1]$*?*

Patterns of entropy per flavor varies cluster to cluster

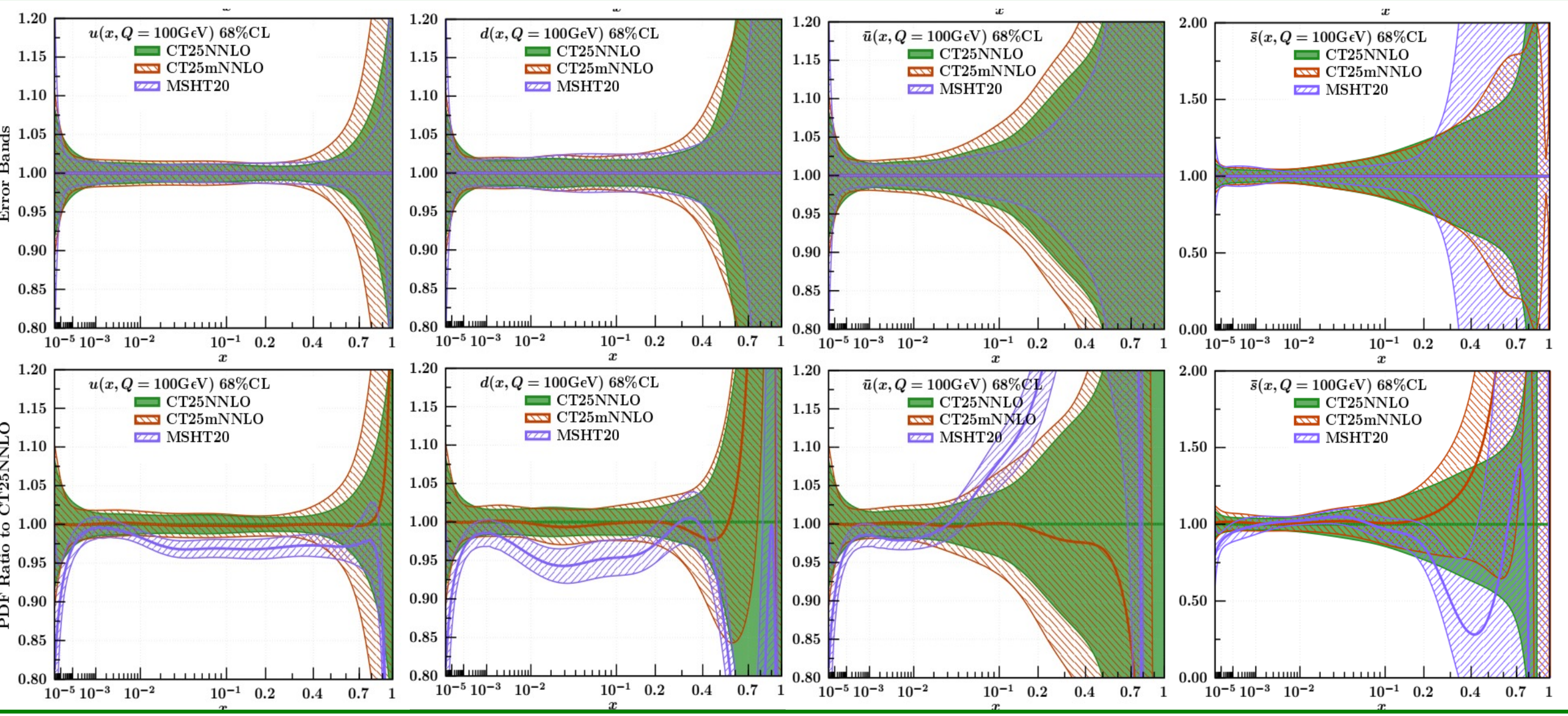
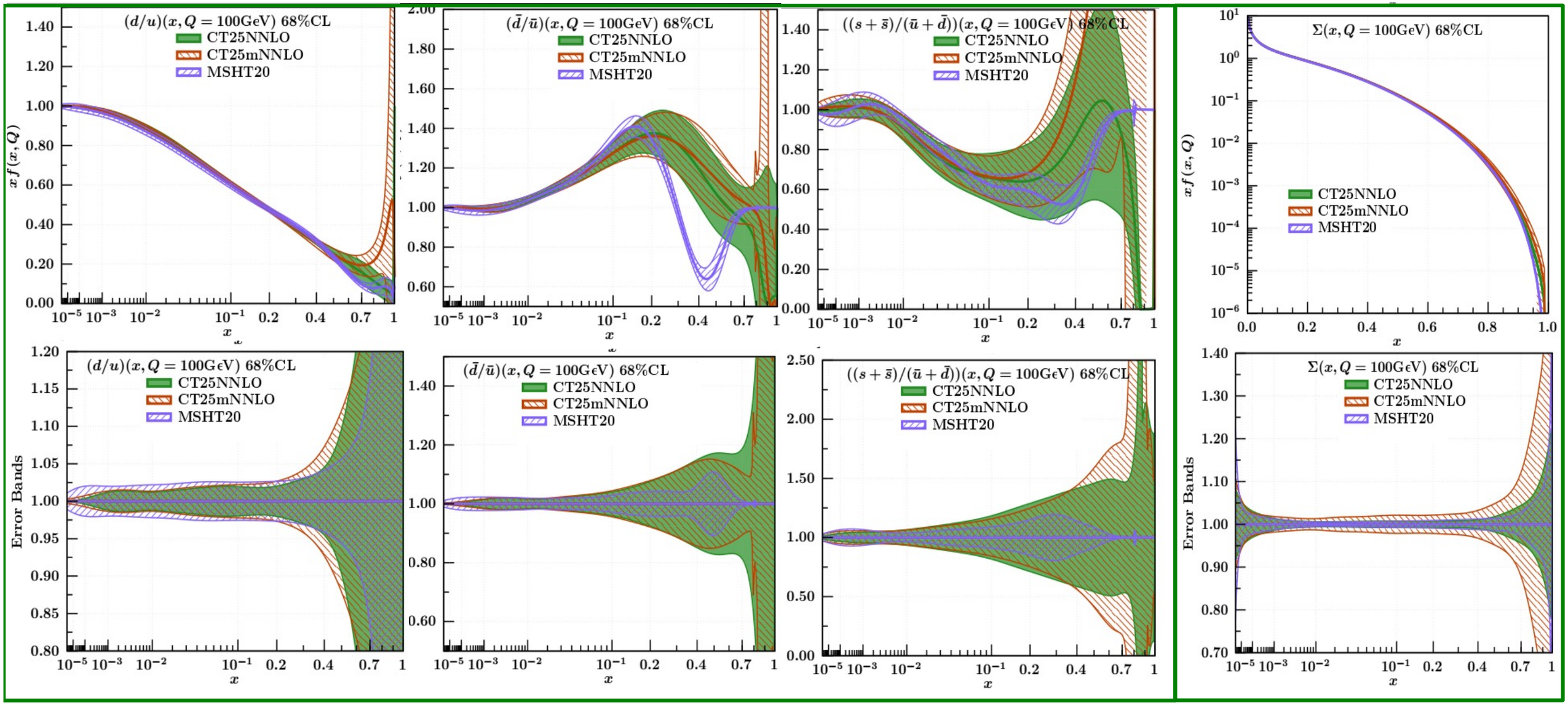
— 9 clusters with PDF vector as estimator

— 6 clusters with Rényi entropy as estimator





CT25m vs CT25 and MSHT20 PDFs, (anti)quark sector



CT25m vs CT25 and MSHT20 PDFs, ratios and quark singlet