Re-weighting at the LHC: the p-Pb data impact

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IFIC Seminar

December 4th, 2015
Valencia, Spain

OUTLINE

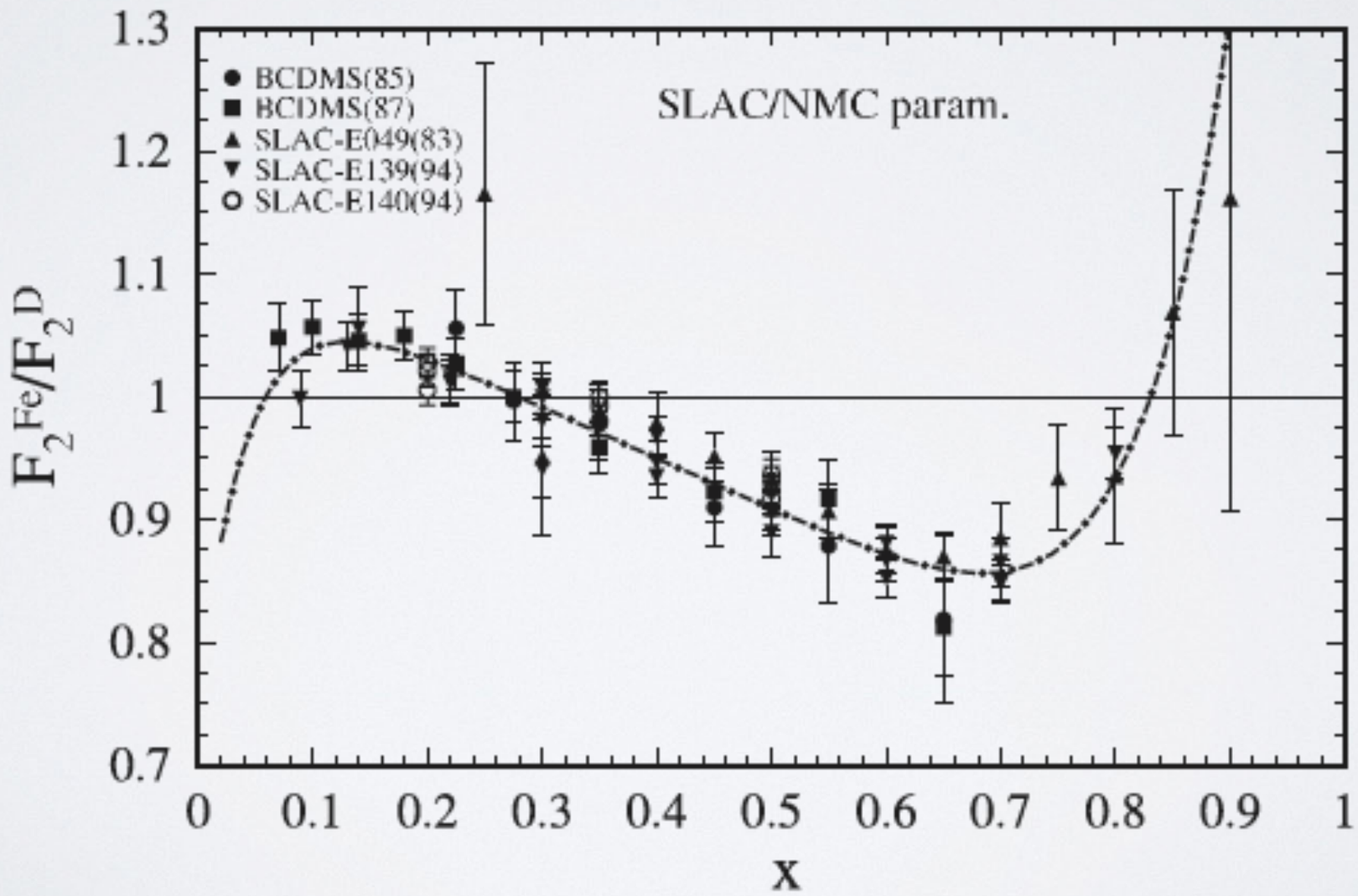
- A (brief as possible) introduction to nuclear PDFs
- What do we want with LHC data?
- Why do we care?
- How do we study it?
- (some of many) results
- Summary

Nuclear Parton Distribution Functions

In the ’80s the EMC decided to do electron-nucleus DIS experiments.

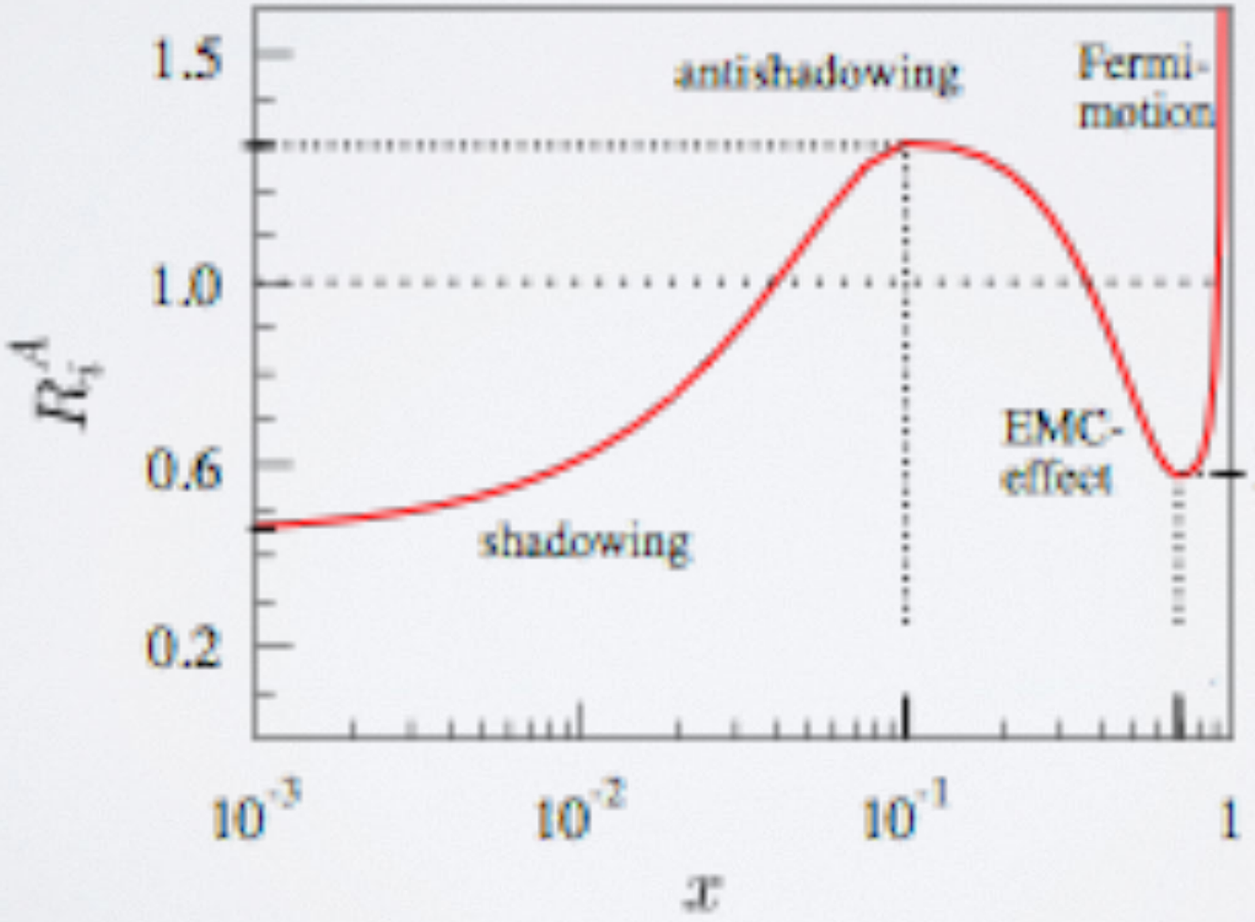
Nuclear Parton Distribution Functions

In the '80s the EMC decided to do electron-nucleus DIS experiments. And this is what they obtained:



Then either the nuclear interaction is different or we **need** something to describe this in pQCD: **nPDFs!**

- obtained the same way as proton PDFs
- obey DGLAP evolution equations
- just different parameters



State-of-the-art: NLO, Hessian uncertainties

HKN, EPS09, DSSZ, nCTEQ15?

Problem: (almost all) data from DIS at x > 10^-3

- gluons barely constrained
- extrapolations to low x not very reliable

So, **WHAT** do we want to do?

- check if data from the p-Pb Run I can help improve the picture (preferably, before the Run II results arrive)
- provide a new set of nPDFs (if possible)
- or decide if we need one right now

And, **WHY** do we want to do it?

- if we don't understand the initial state, how can we understand the measurements?
- at which point the collinear factorization stops being valid?
- p-Pb collisions are the benchmark for Pb-Pb (and QGP!!)
- future colliders using nucleus are planned/approved
- cosmic rays also have a heavy nuclei component

Then, **HOW** do we do it?

- we take data from the p-Pb run:

jets (ATLAS)
dijets (CMS)

Z (ATLAS, CMS)
W (ALICE, CMS)

charged hadrons (ALICE, CMS)
charged pions (ALICE)

- compute the observables in pQCD with different proton and nuclear PDFs

MSTW2008 : EPJC 63 (2009) 189
CT10 : PRD 82 (2010) 074024
DSSZ : PRD 85 (2012) 074028
EPS09 : JHEP 0904 (2009) 065

MCFM : JHEP 1107 (2011) 018
FR : NPB 467 (1996) 399
NPB 507 (1997) 295
NPB 507 (1997) 315

- apply the Bayesian re-weighting technique to study data/theory compatibility and/or tension

    - purely statistical methods

    - provides quantitative estimator

    - powerful time-saving tools

- ponder on what numbers and plots tell us

The Bayesian re-weighting

If we have a large ensemble of replicas describing the probability density of some data given the theory

$$< \mathcal{O} >= \frac{1}{N_{rep}} \sum_{k=1}^{N_{rep}} \mathcal{O}(f_k)$$

add new data $\vec{y}$, by Bayes' theorem:

$$\mathcal{P}_{new}(f) \propto \mathcal{P}(\vec{y}|f)\mathcal{P}_{old}(f)$$

This can be seen as each replica having a weight

$$w_k = \frac{exp^{-\chi^2_k/2\Delta}}{(1/N_{rep})\sum_{k=1}^{N_{rep}} exp^{-\chi^2_k/2\Delta}}$$

So now

$$< \mathcal{O} >_{new} = \frac{1}{N_{rep}} \sum_{k=1}^{N_{rep}} \mathcal{O}(f_k) w_k$$

And we have the quantitative estimator

$$N_{eff} = exp\left[\frac{1}{N_{rep}} \sum_{k=1}^{N_{rep}} w_k log(N_{rep}/w_k)\right]$$

Of course we don't have these replicas for the nPDFs

$$f_{S_0}, f_{S_i^+}, f_{S_i^-}$$

So, we construct them

$$f_k = f_{S_0} + \sum_{i=1}^{N_{eig}} \frac{f_{S_i^+} - f_{S_i^-}}{2} R_{i,k}$$

random, gaussian

For more info, check **JHEP 1412 (2014) 100**
and references therein

JETS BY ATLAS

- ratio pPb/pp in different rapidity windows
- pp reference removed
- forward/backward ratios taken
- systematic and statistical uncertainties in quadrature
- most forward and central information lost

ATLAS Collaboration
PLB 748 (2015) 392

JETS BY ATLAS

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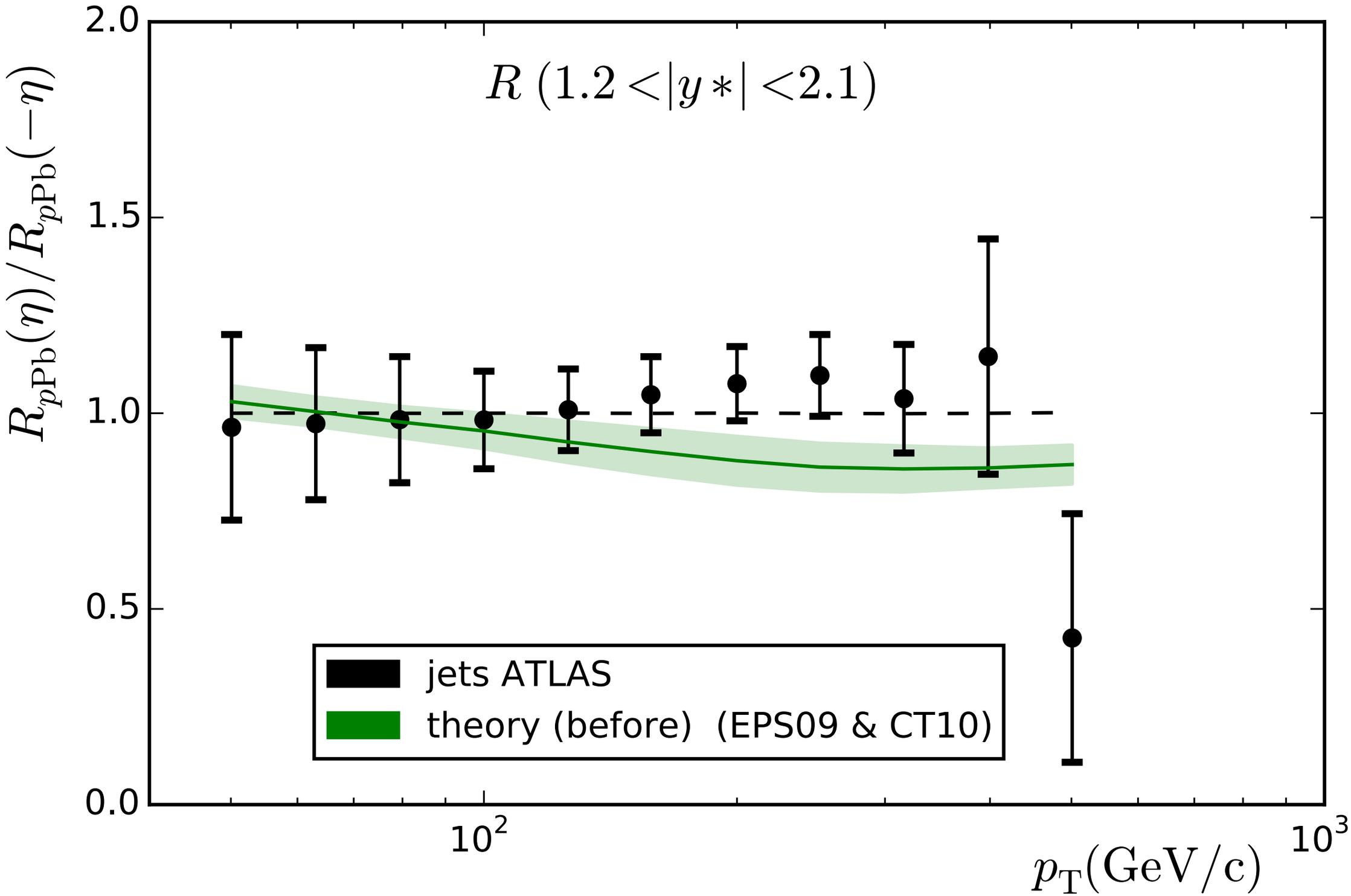

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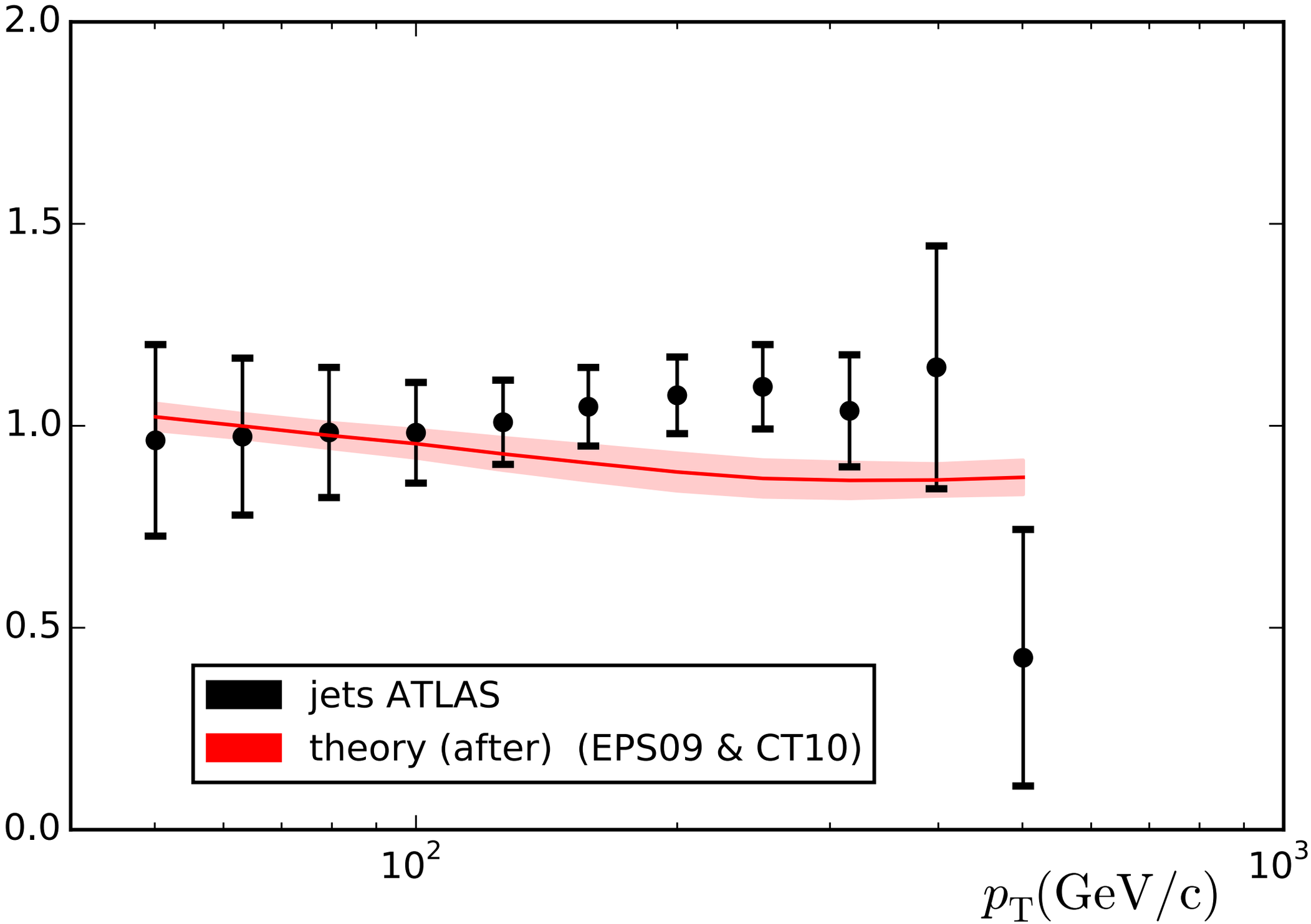

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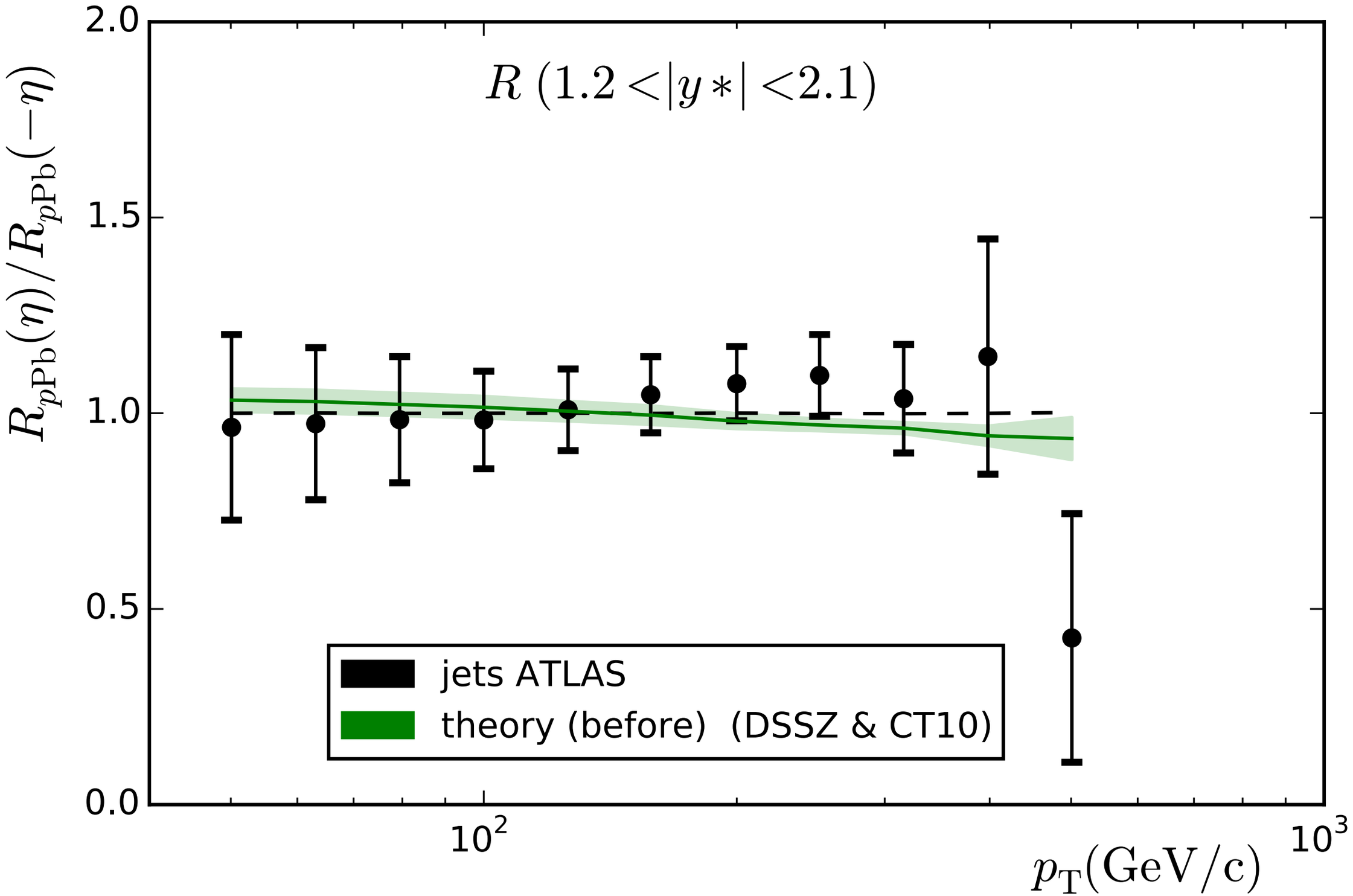

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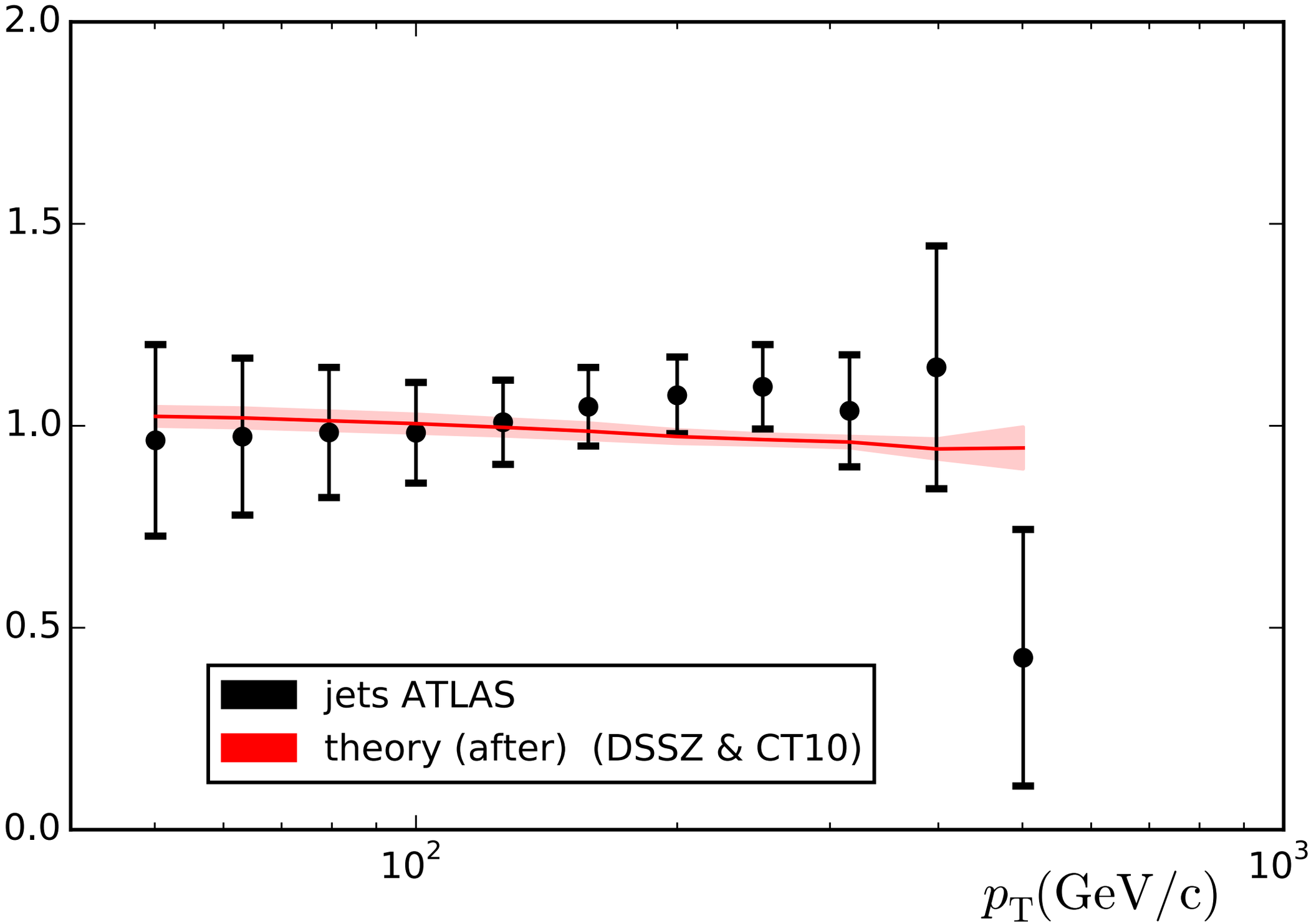
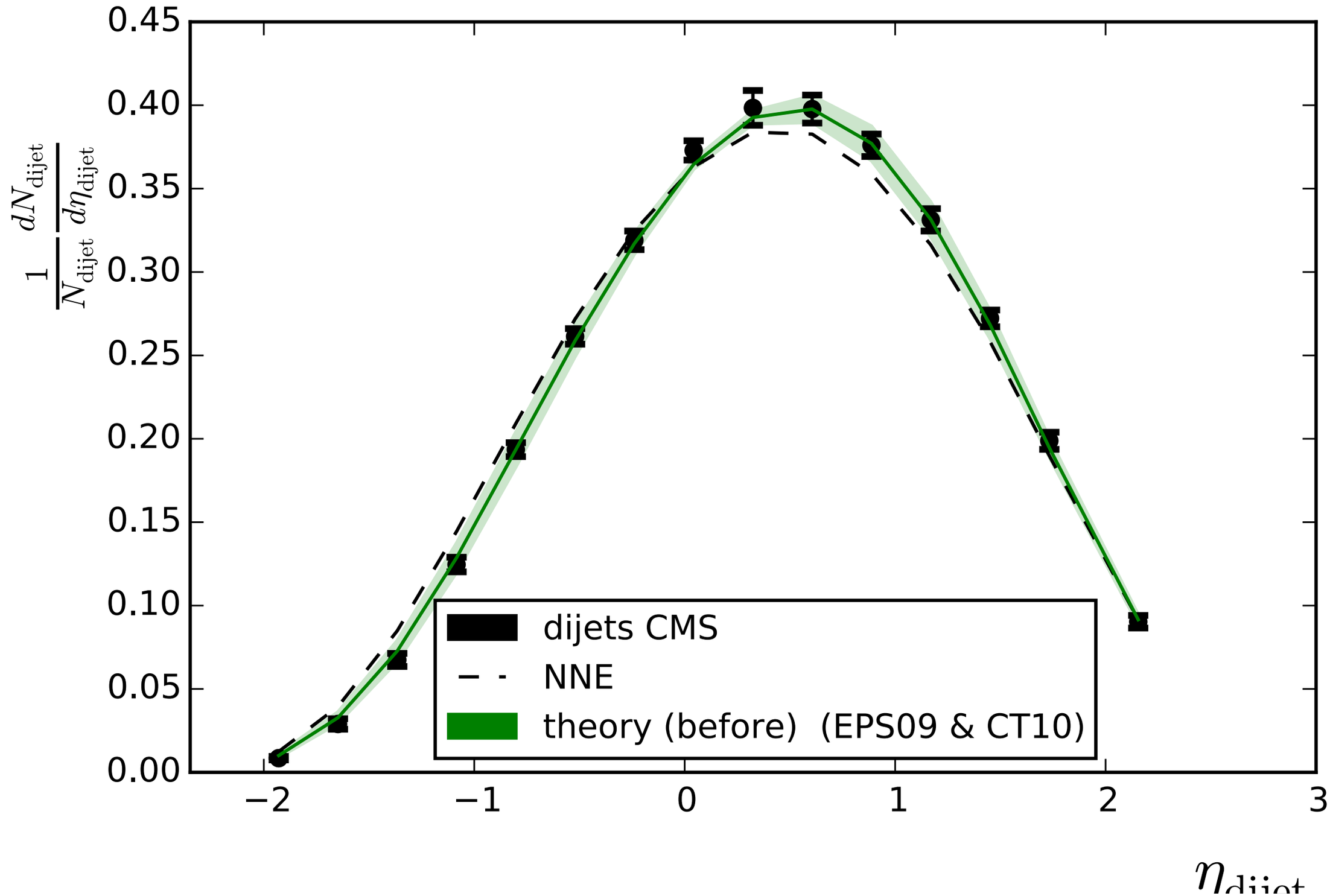


DIJETS BY CMS

CMS Collaboration
EPJC 74 (2014) 7, 2951



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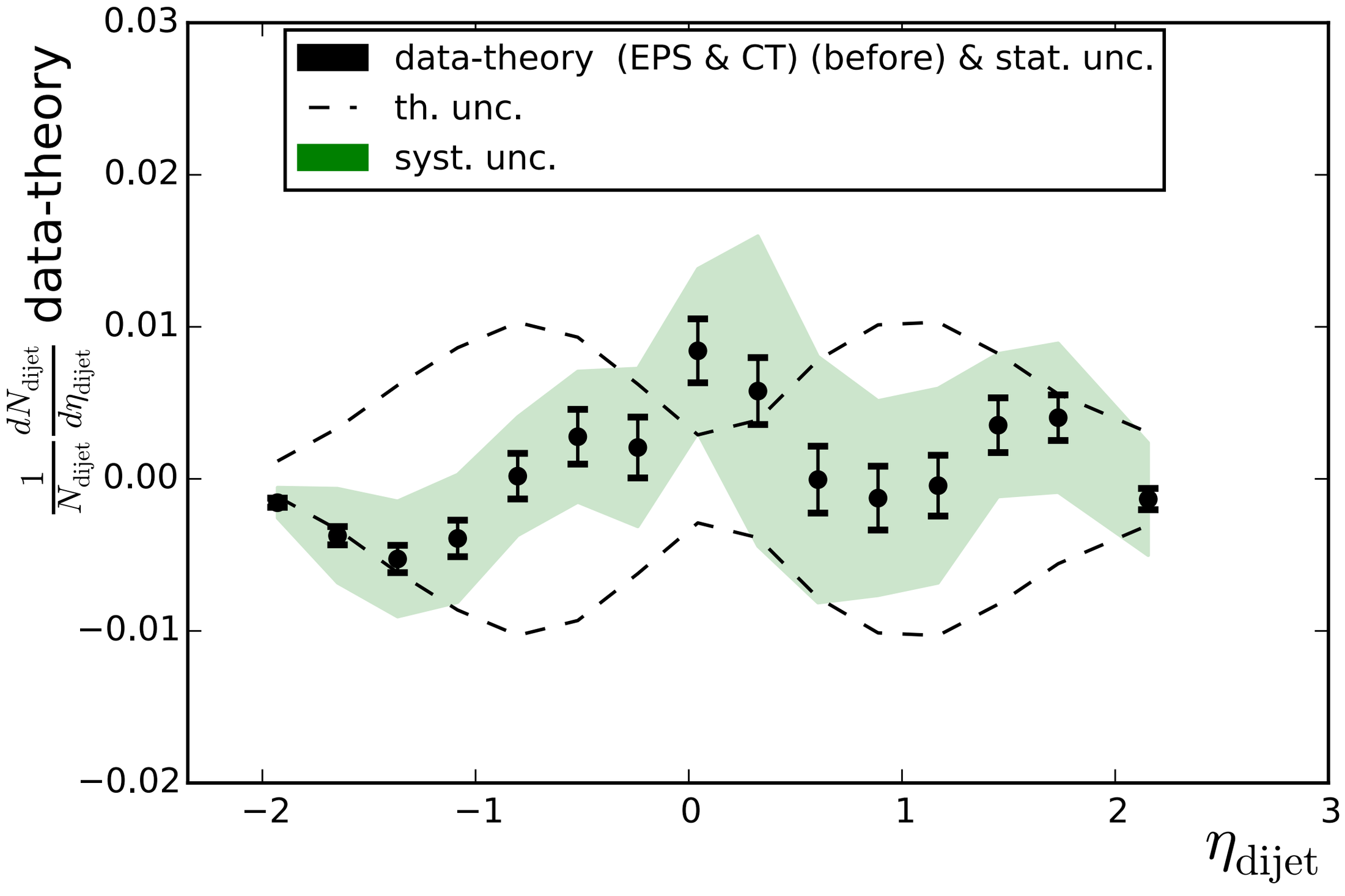

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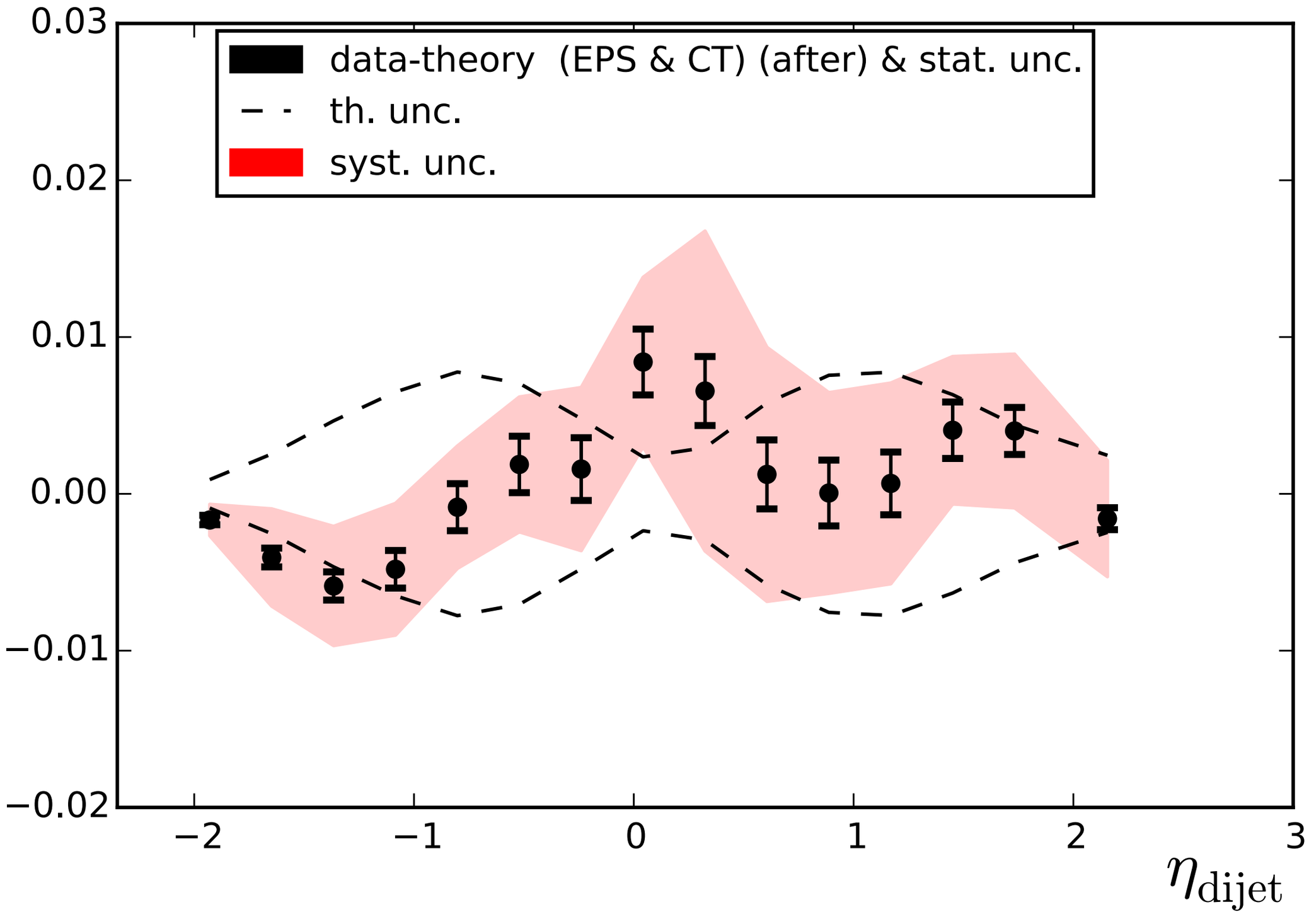

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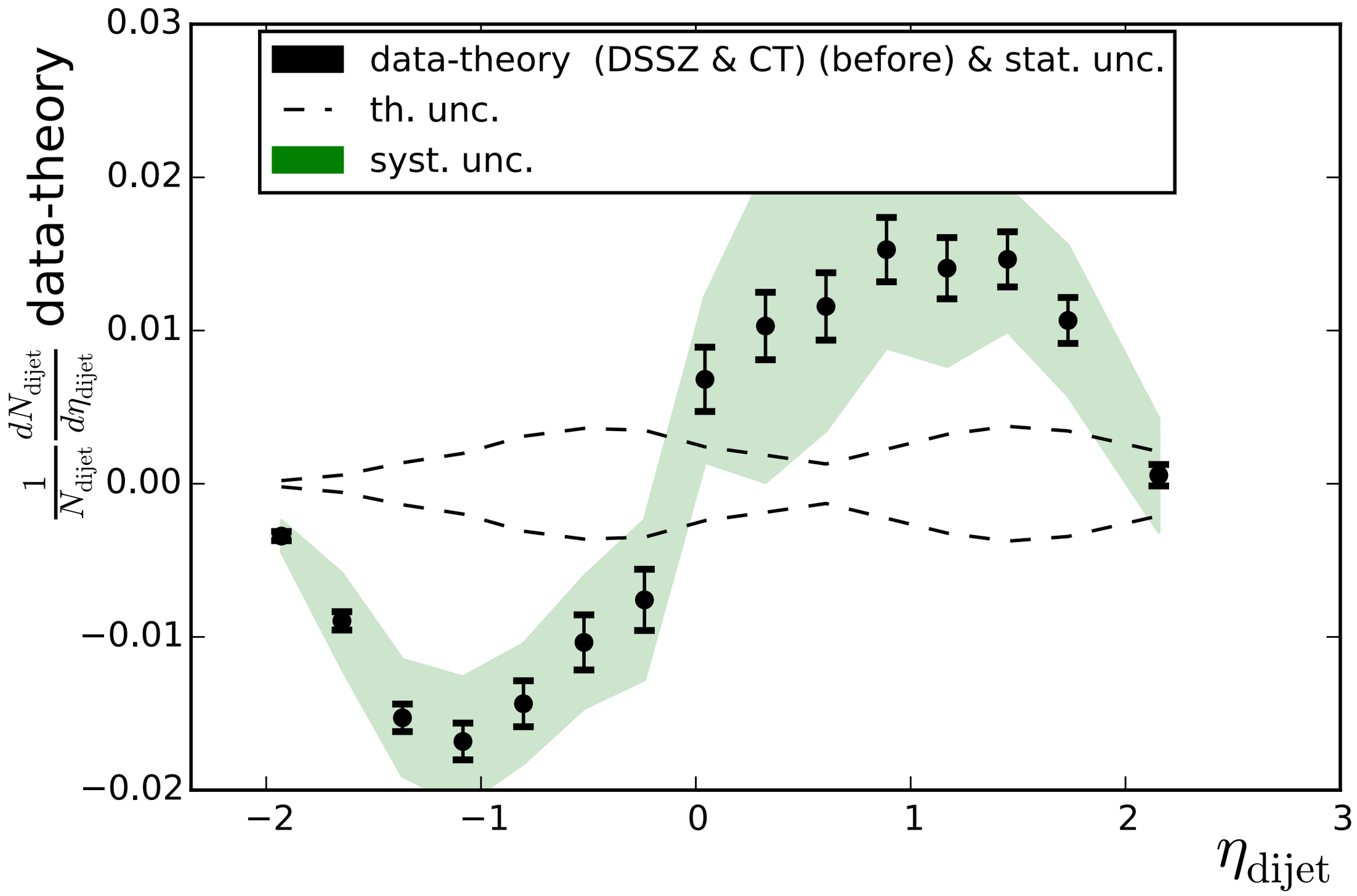

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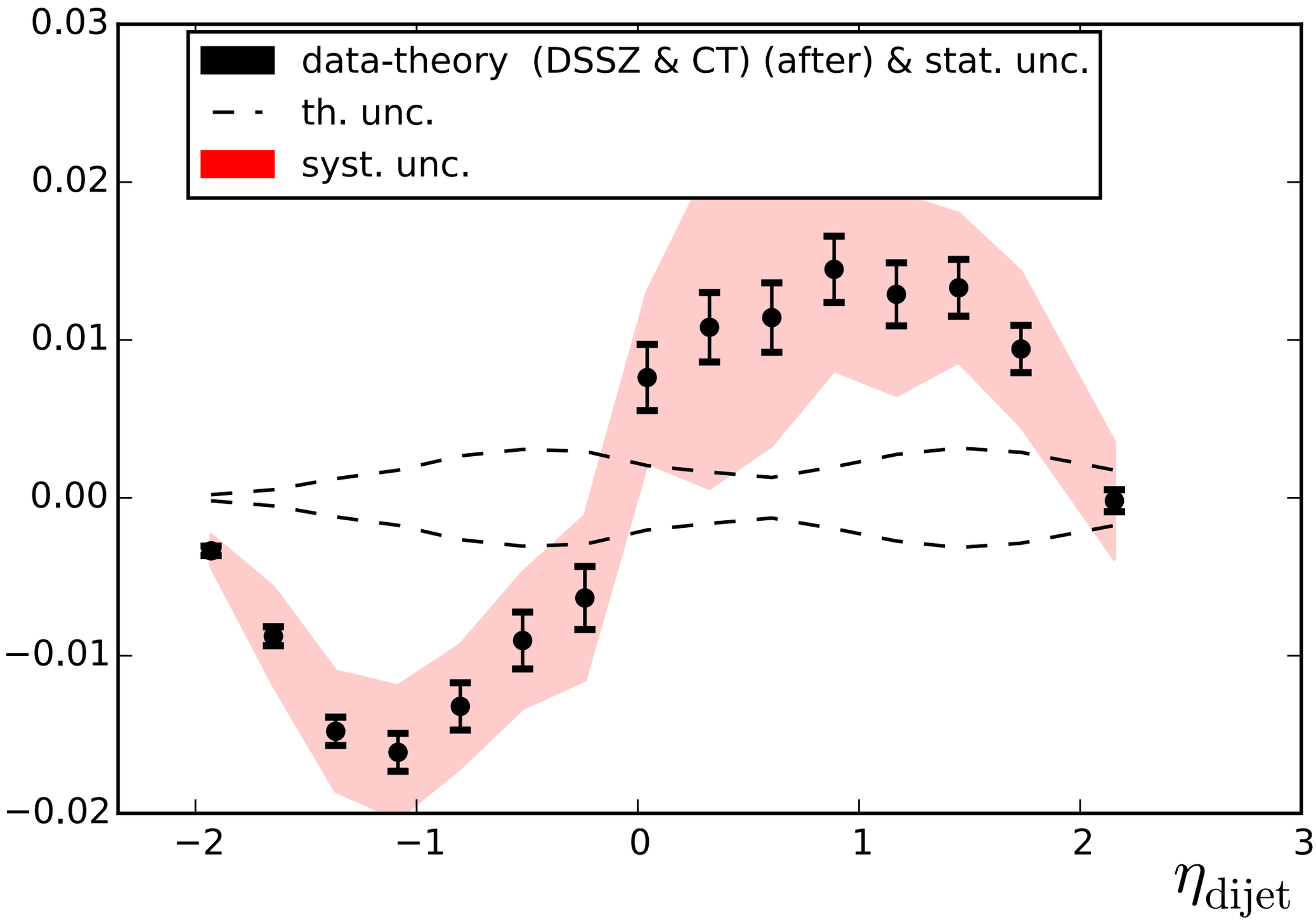
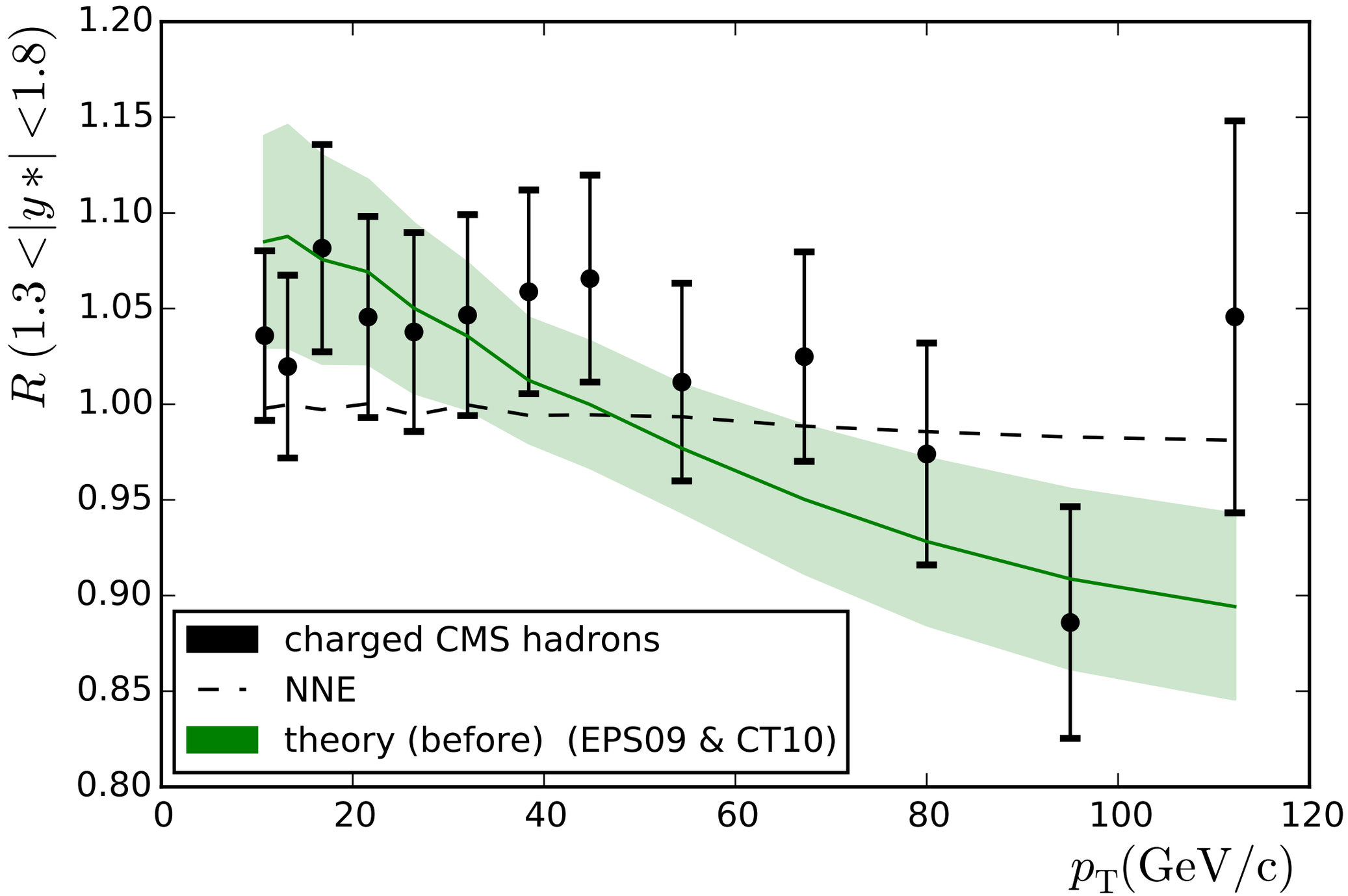


CHARGED HADRONS BY CMS



CMS Collaboration, CMS-PAS-HIN-12-017

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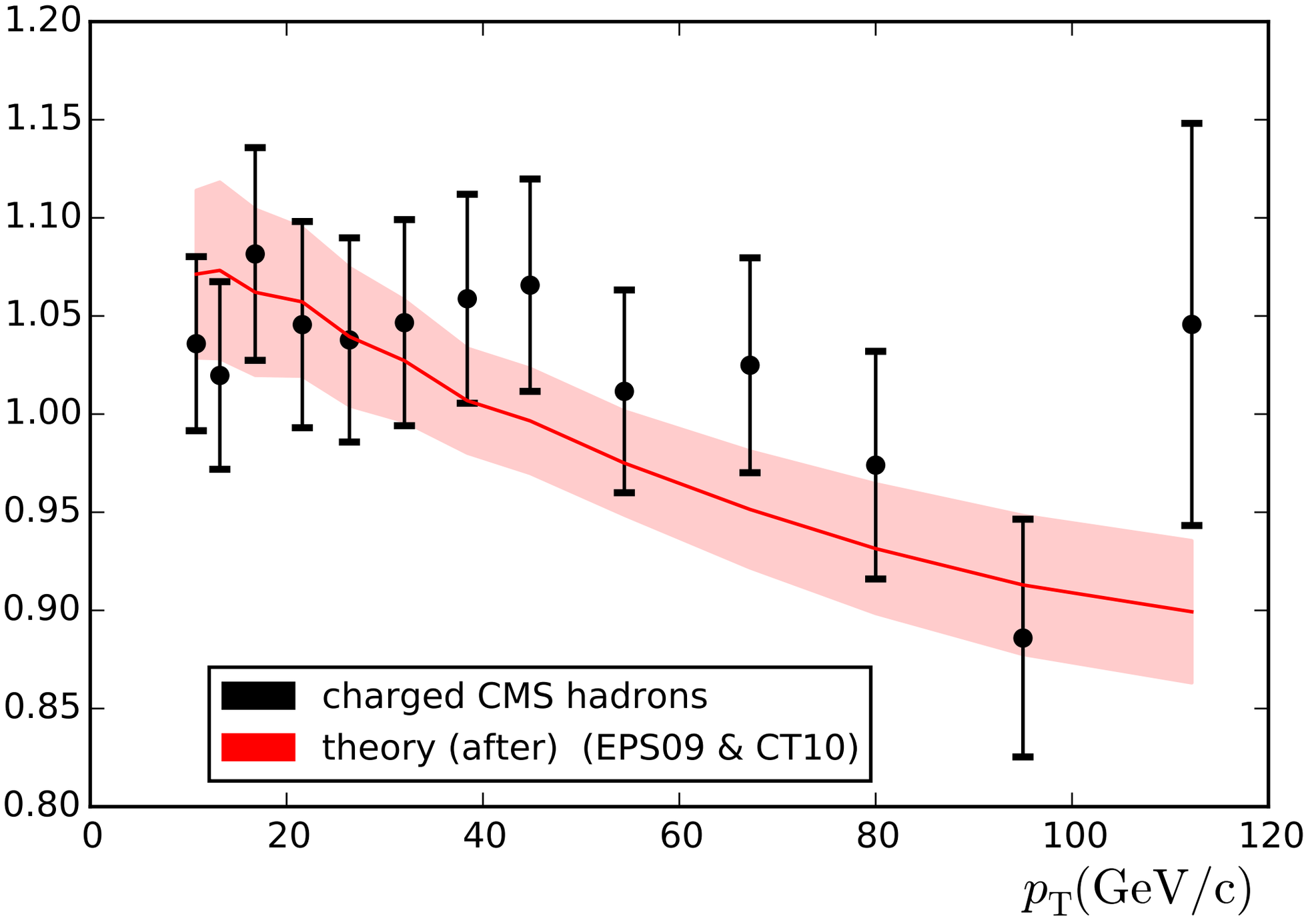

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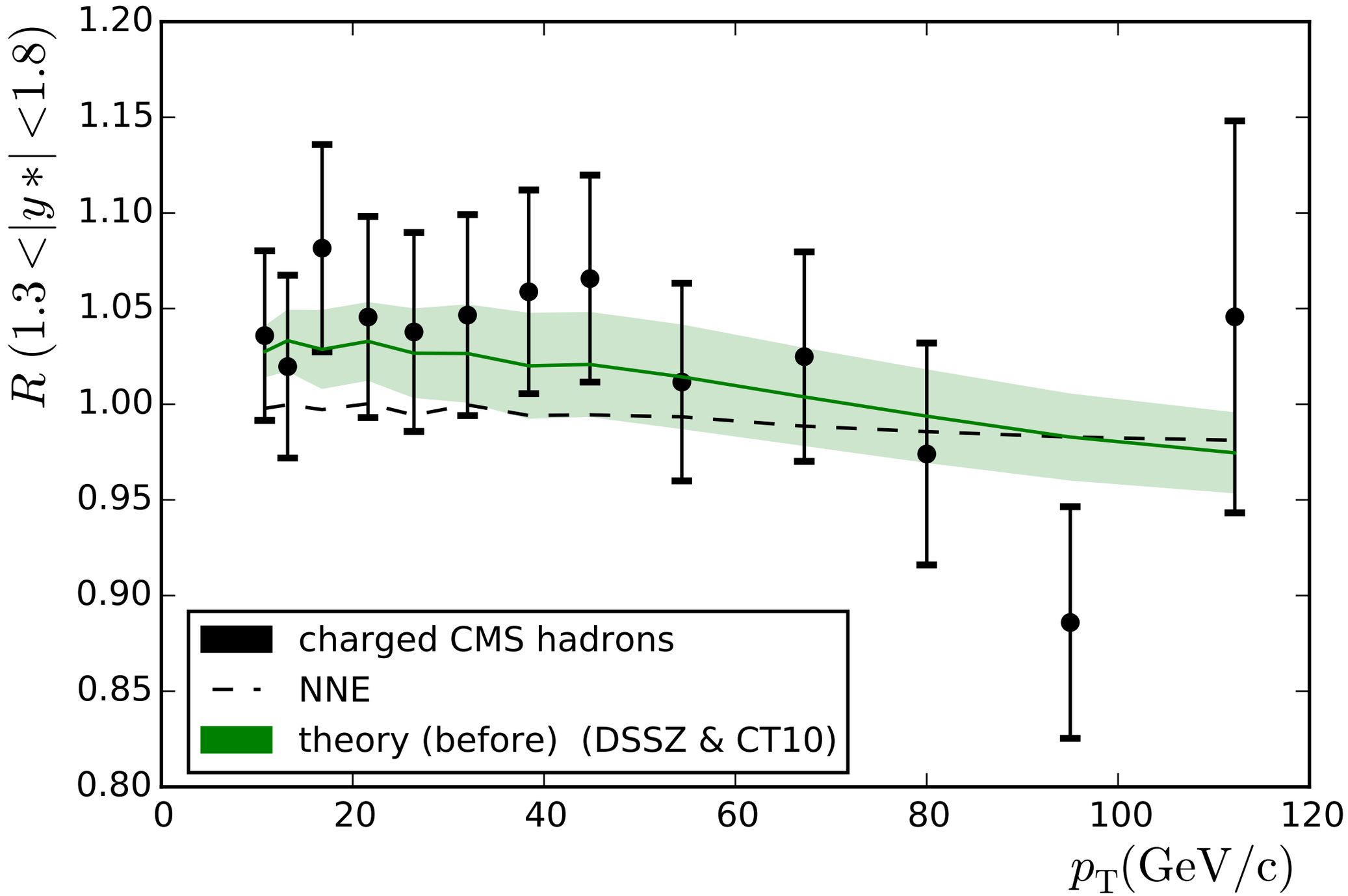

CMS Collaboration, CMS-PAS-HIN-12-017

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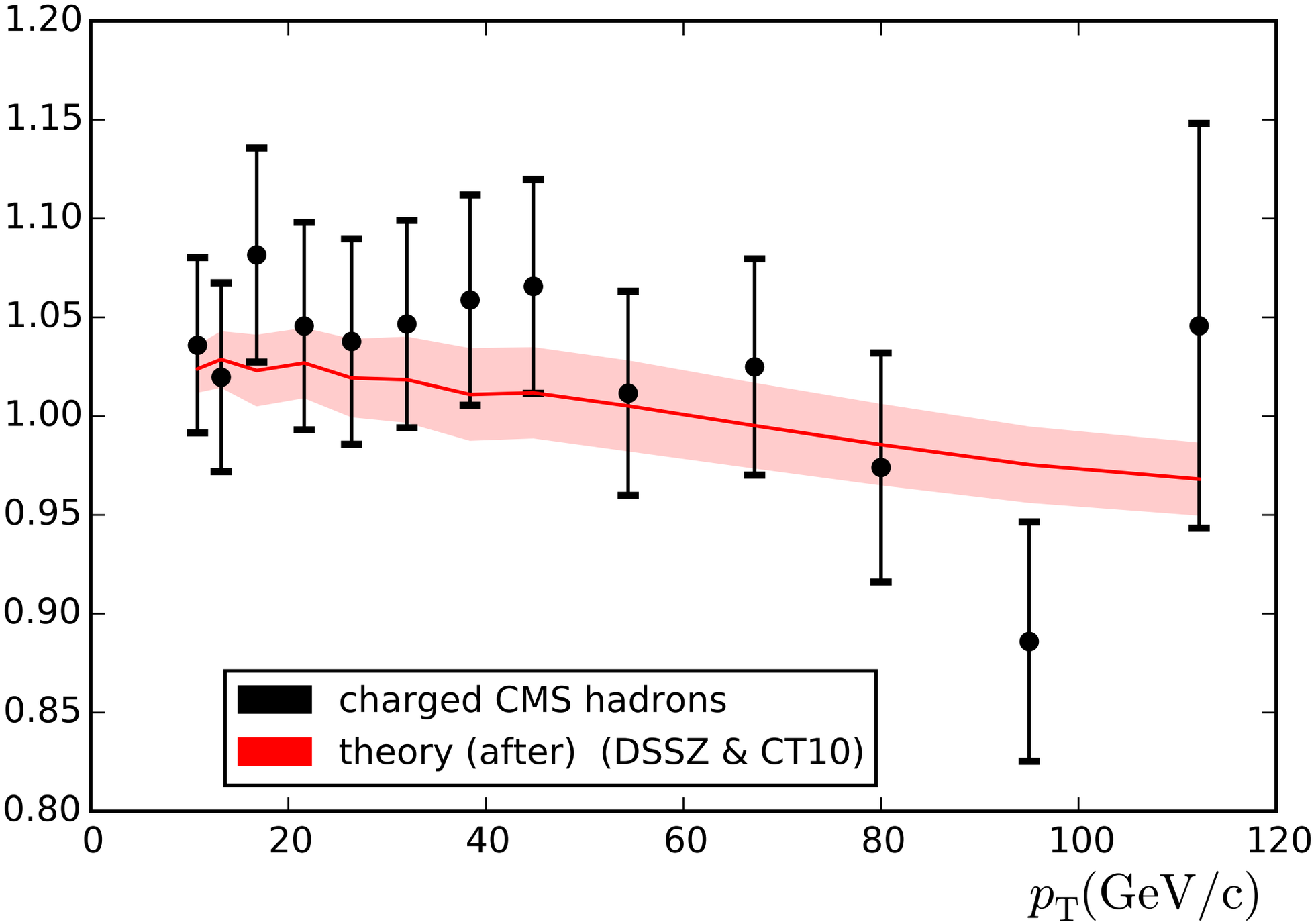

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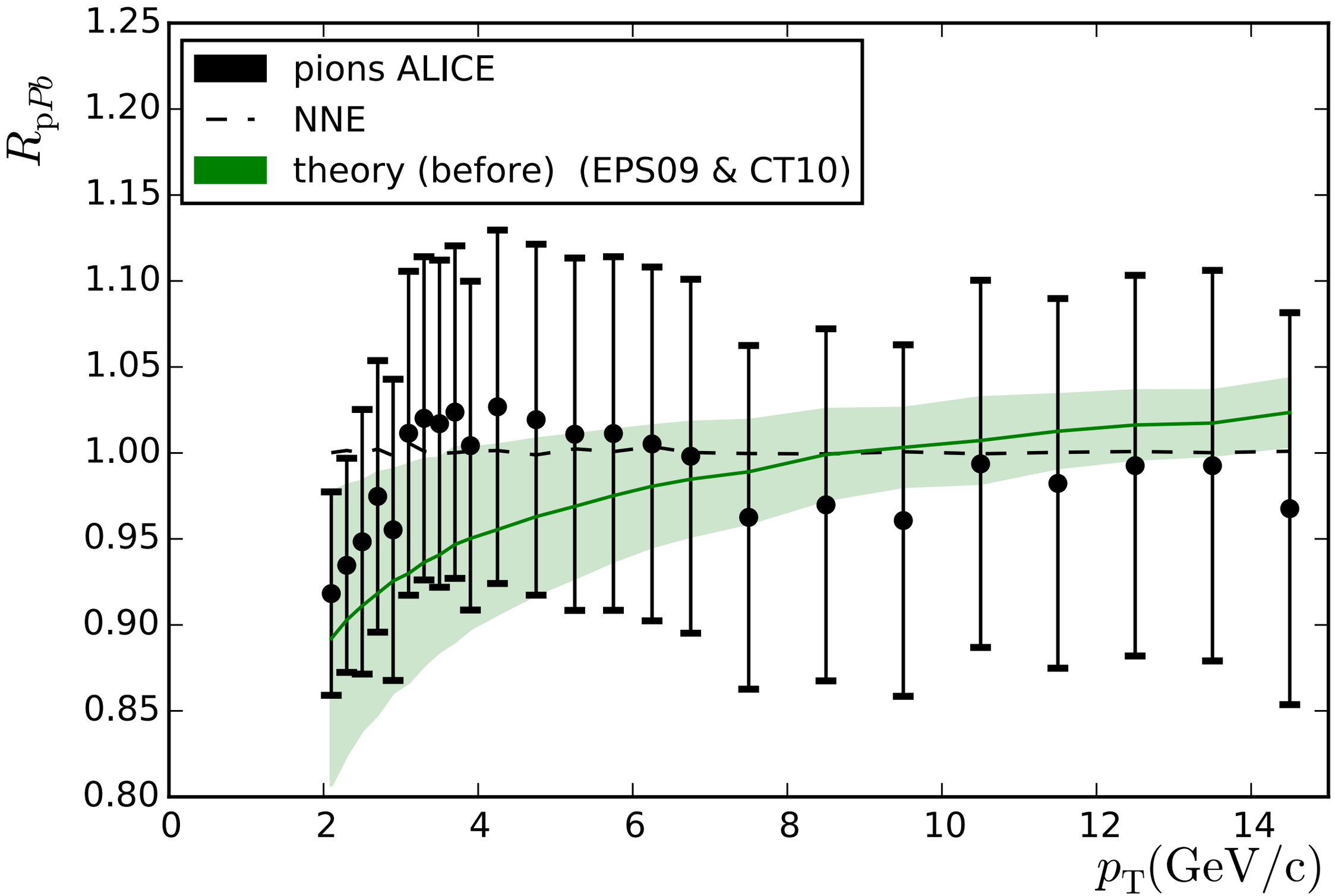
PIONS BY ALICE



ALICE Collaboration, EPJC 74 (2014) 9, 3054

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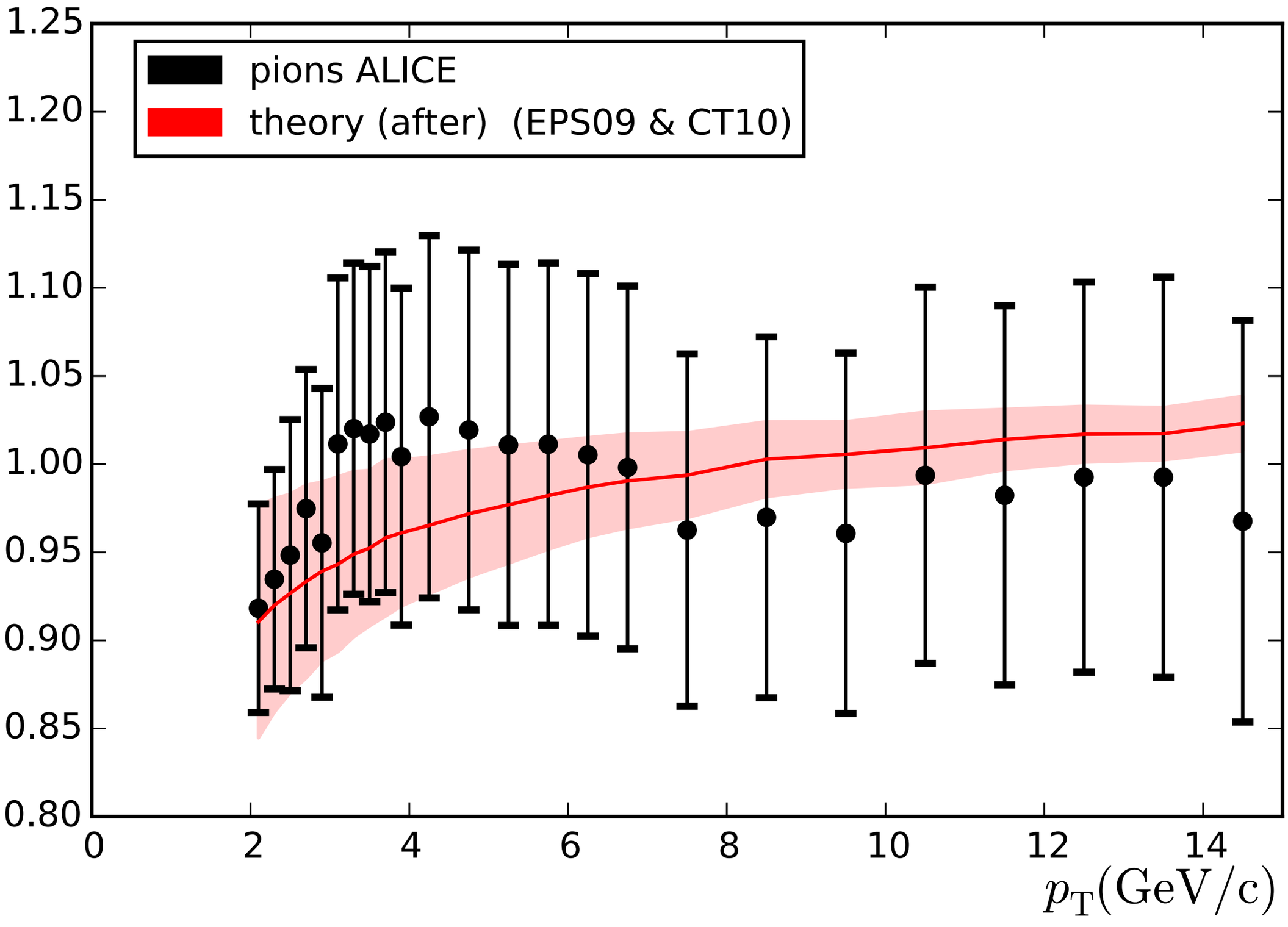

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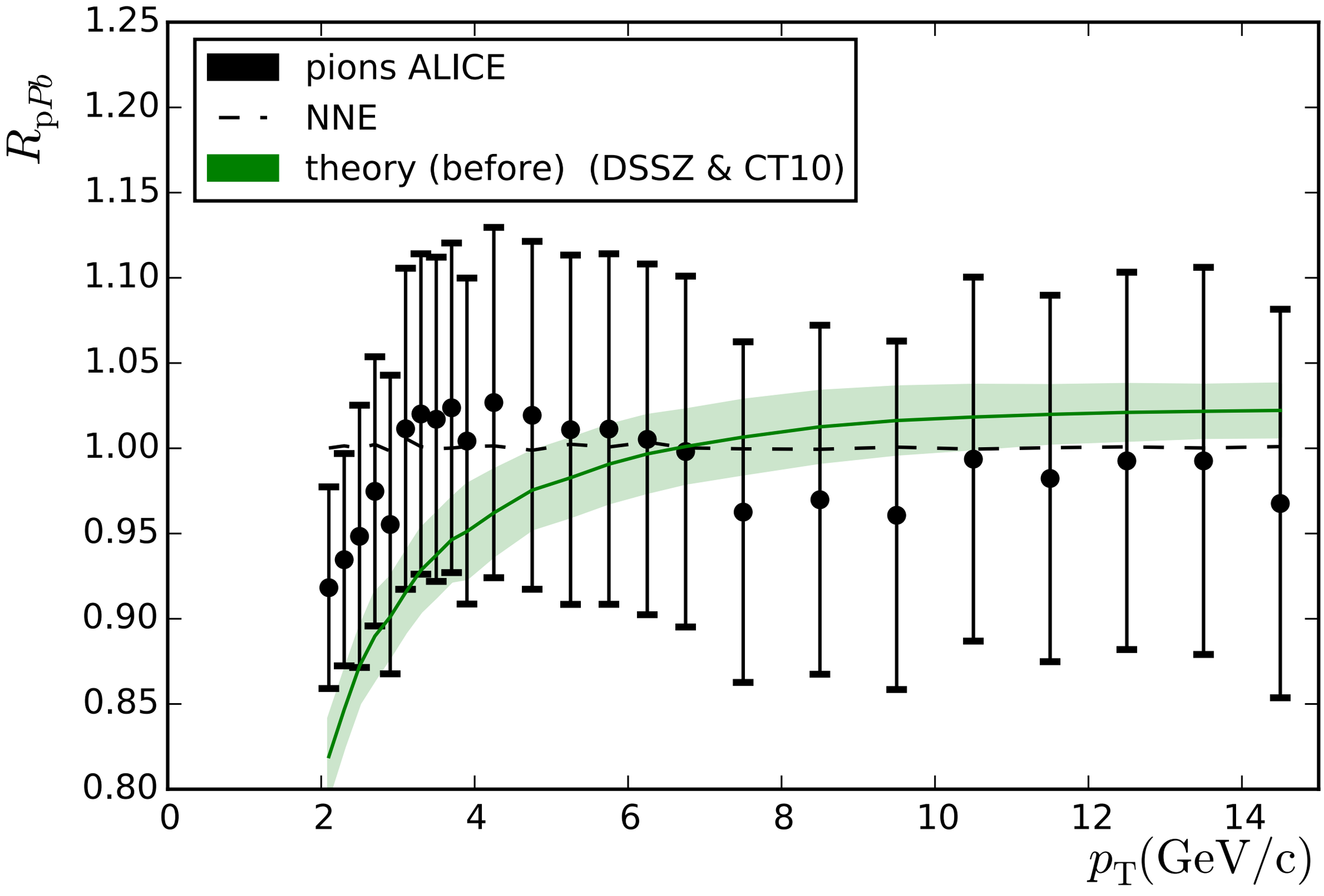

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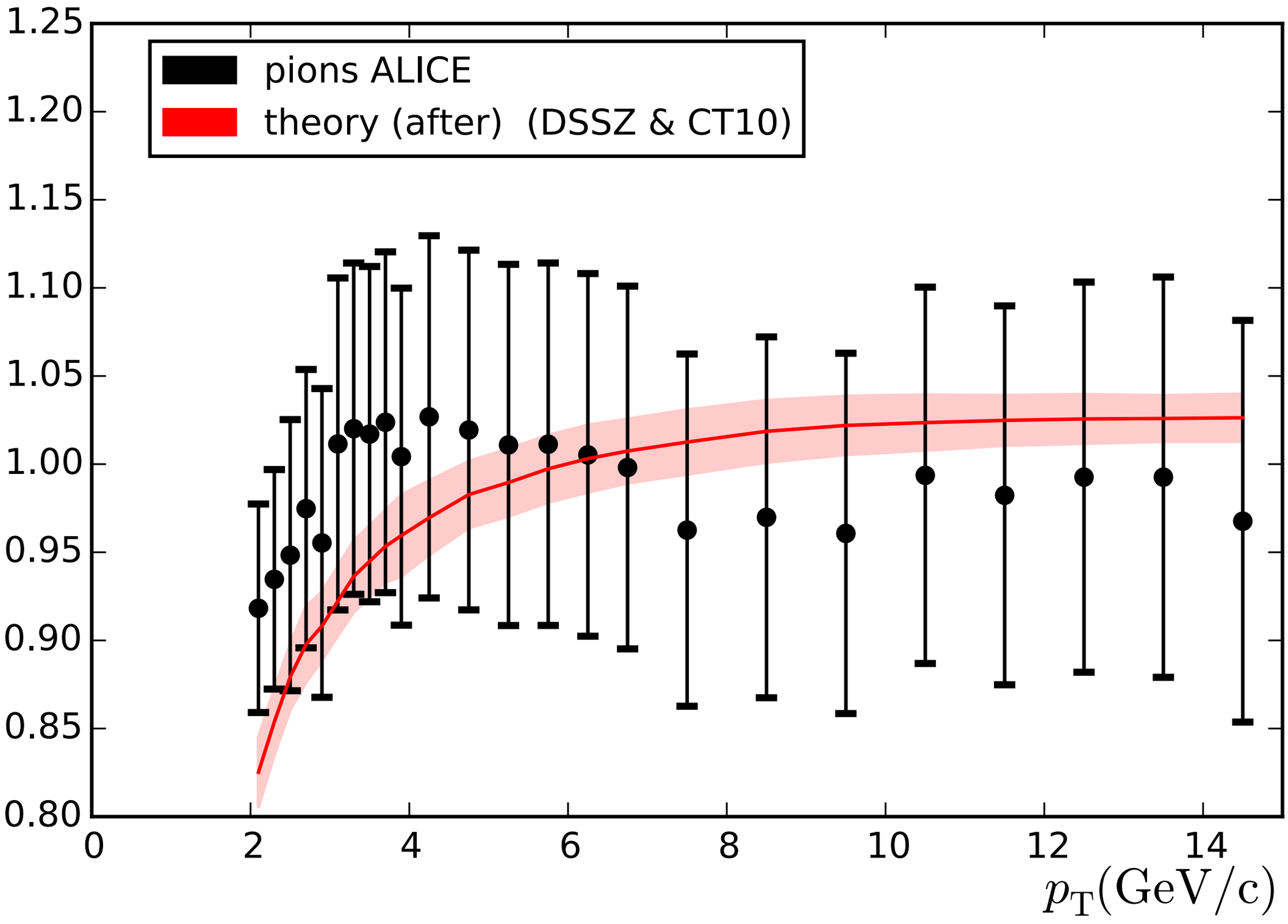

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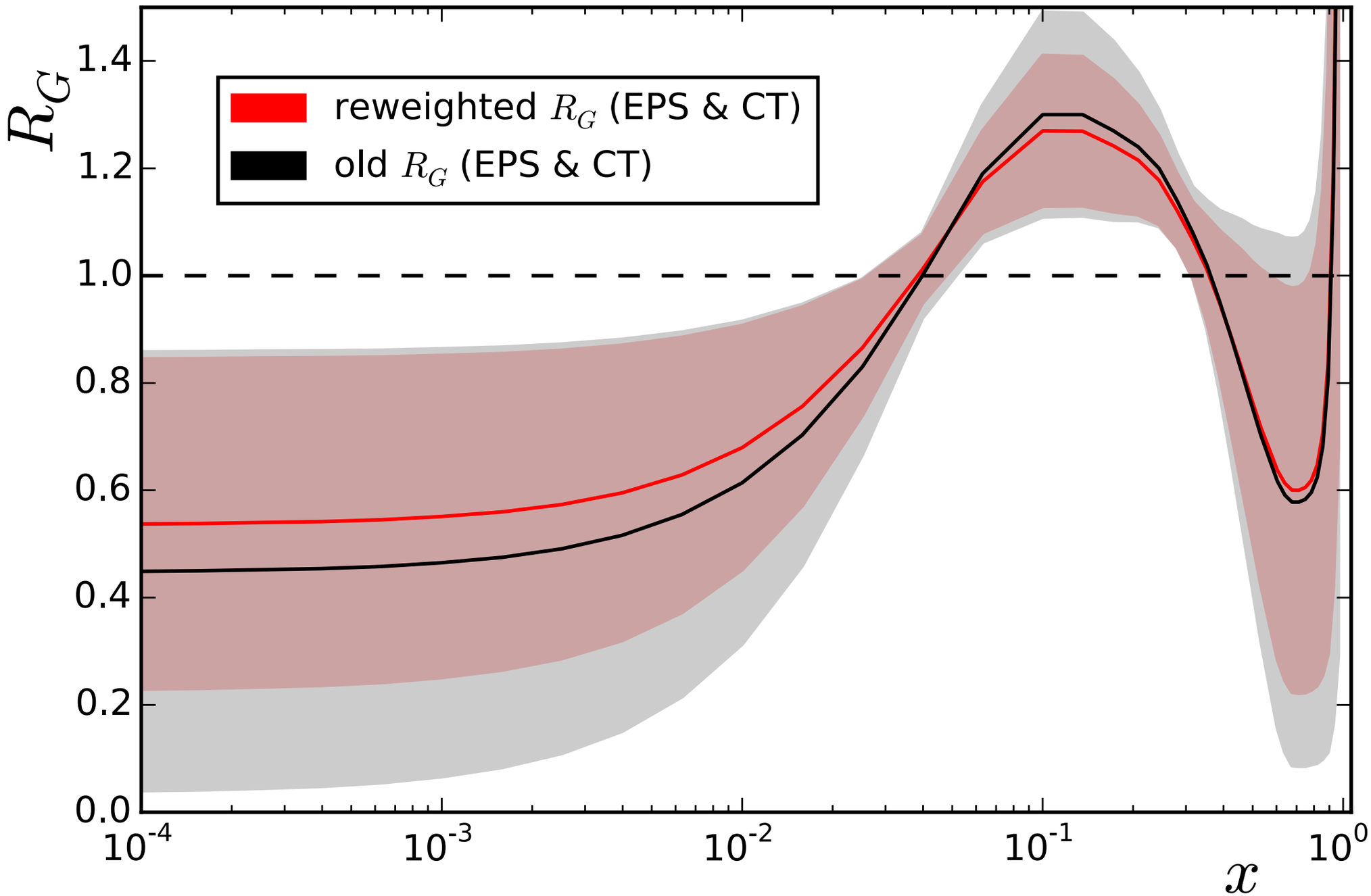
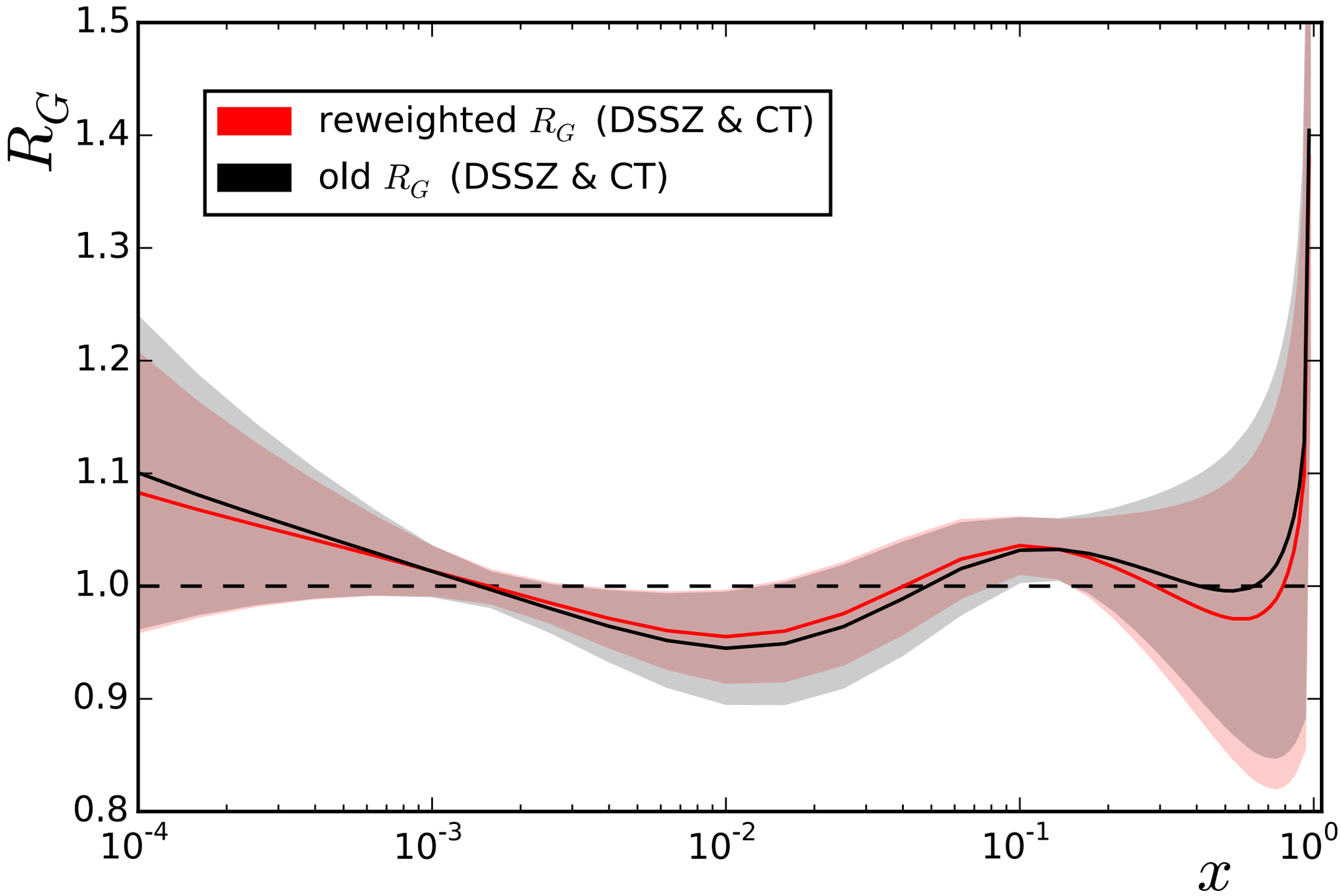
GLUON


R_G
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
reweighted R_G (EPS & CT)
old R_G (EPS & CT)
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
x

GLUON


reweighted R_G (DSSZ & CT)
old R_G (DSSZ & CT)
R_G
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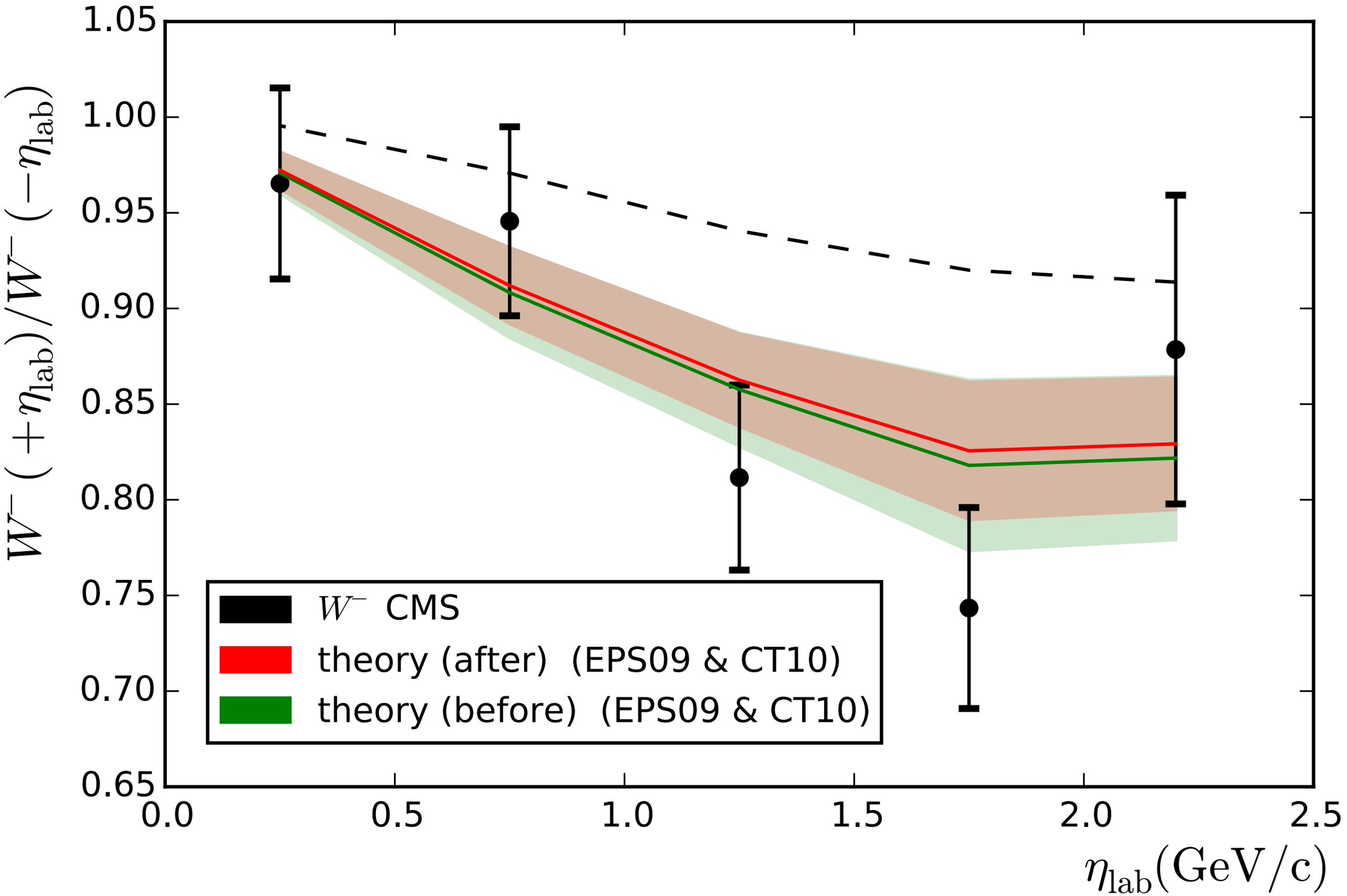
1.4
1.3
1.2
1.1
1.0
0.9
0.8
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
x

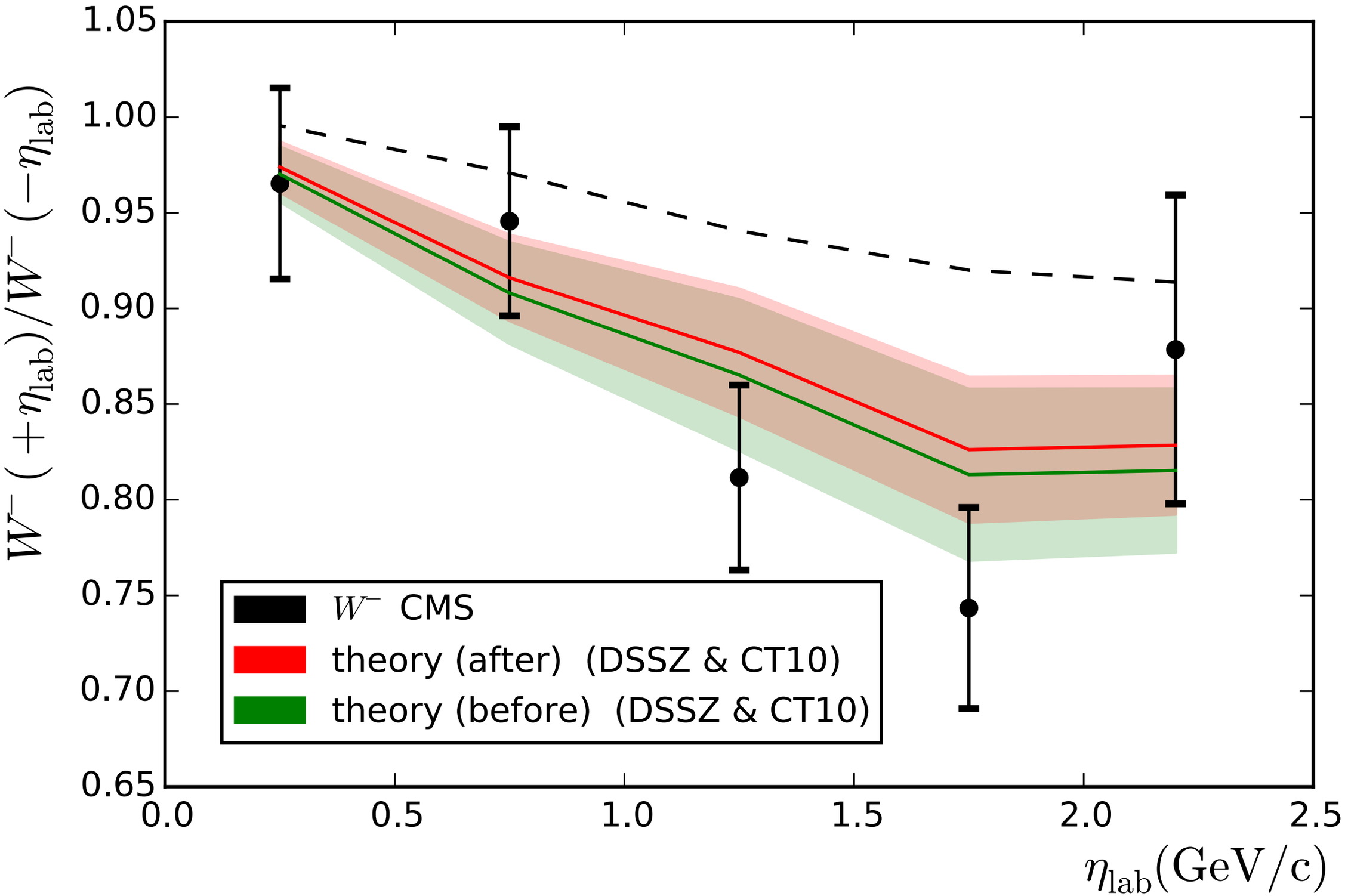
W'S BY CMS

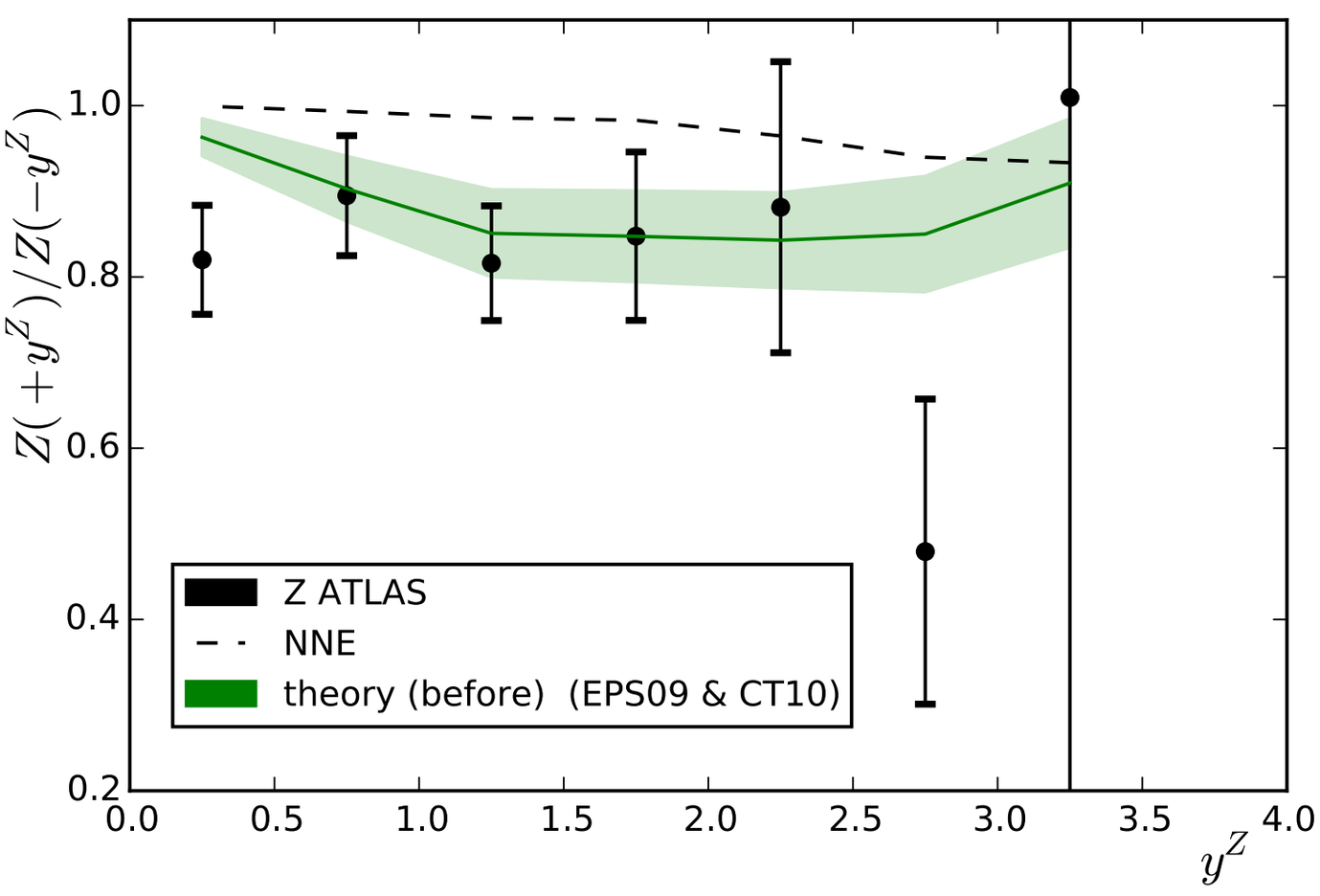
CMS Collaboration,
arXiv:1503.05825 [hep-ex].



W'S BY CMS

CMS Collaboration,
arXiv:1503.05825 [hep-ex].



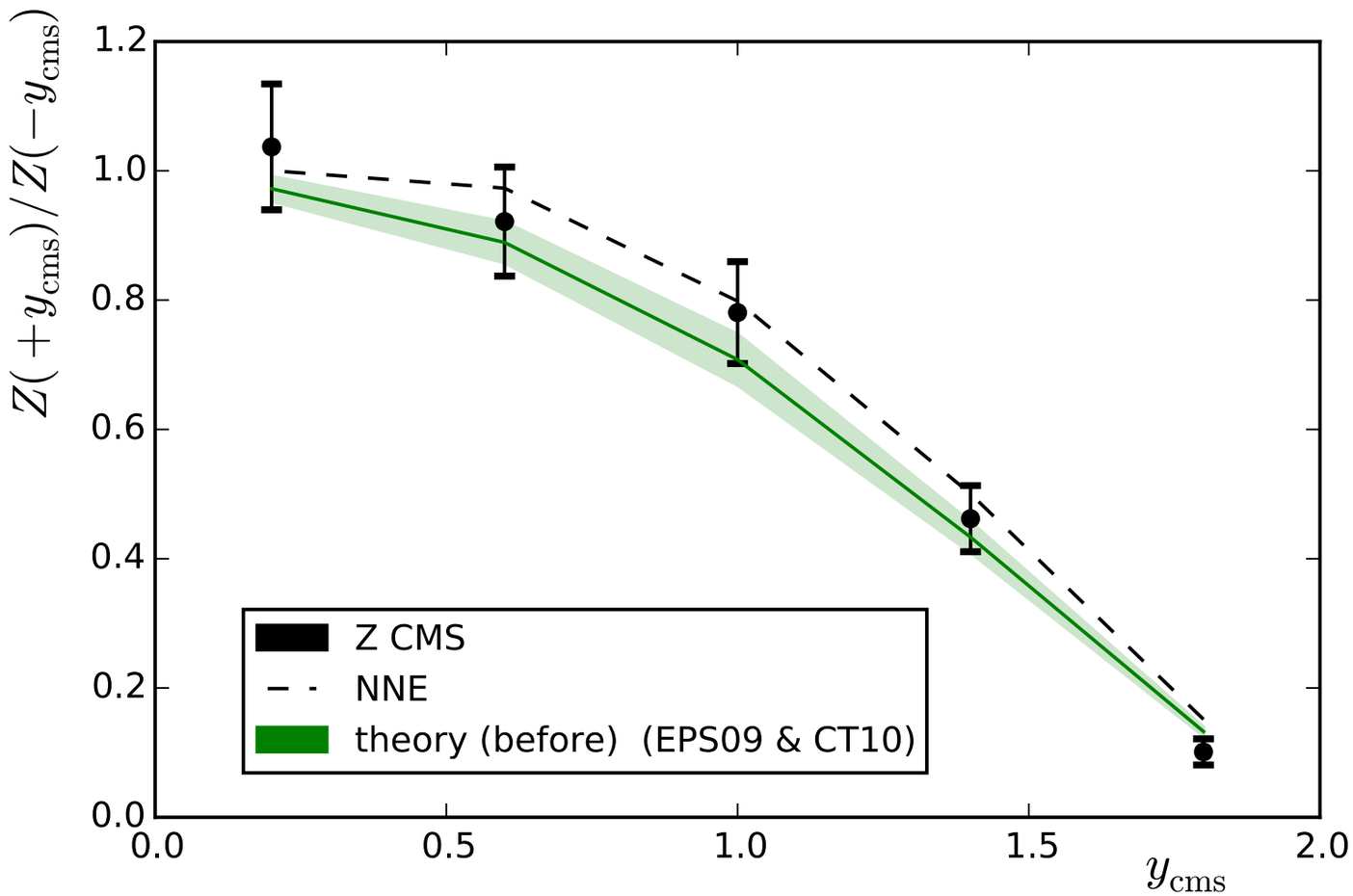


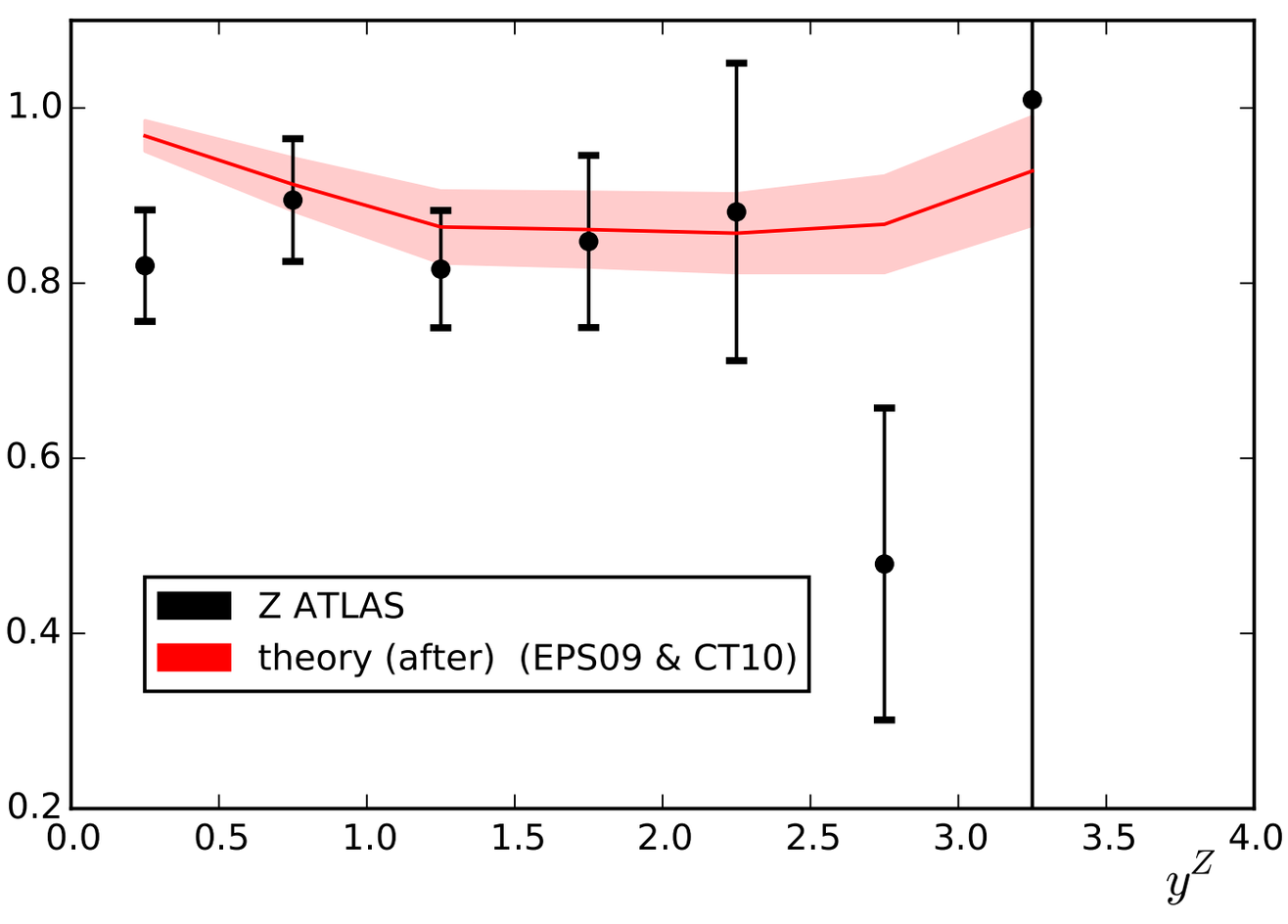
Z BY CMS

CMS collaboration
CMS-PAS-HIN-15-002

Z BY ATLAS

ATLAS collaboration
arXiv:1507.06232 [hep-ex]





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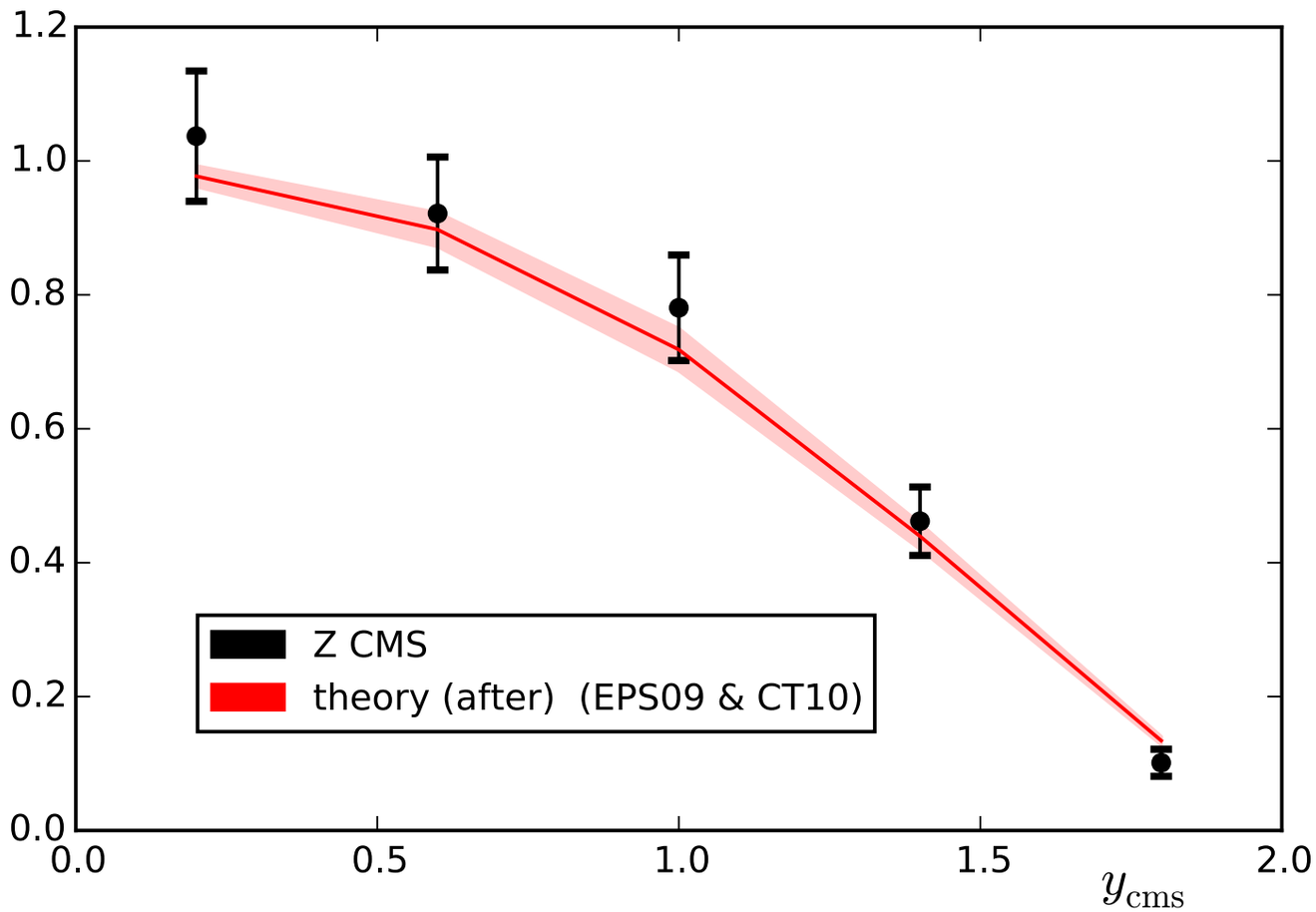

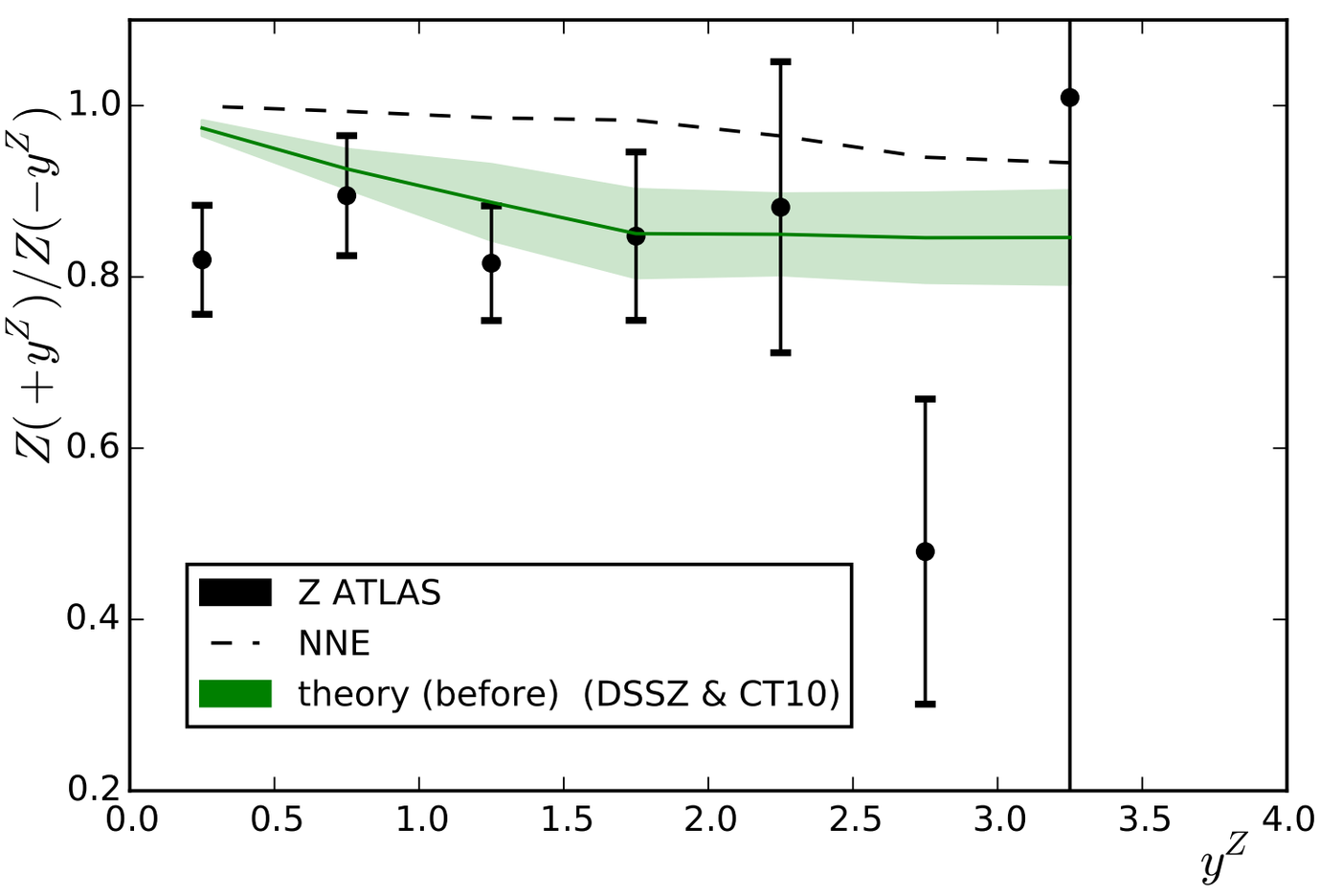

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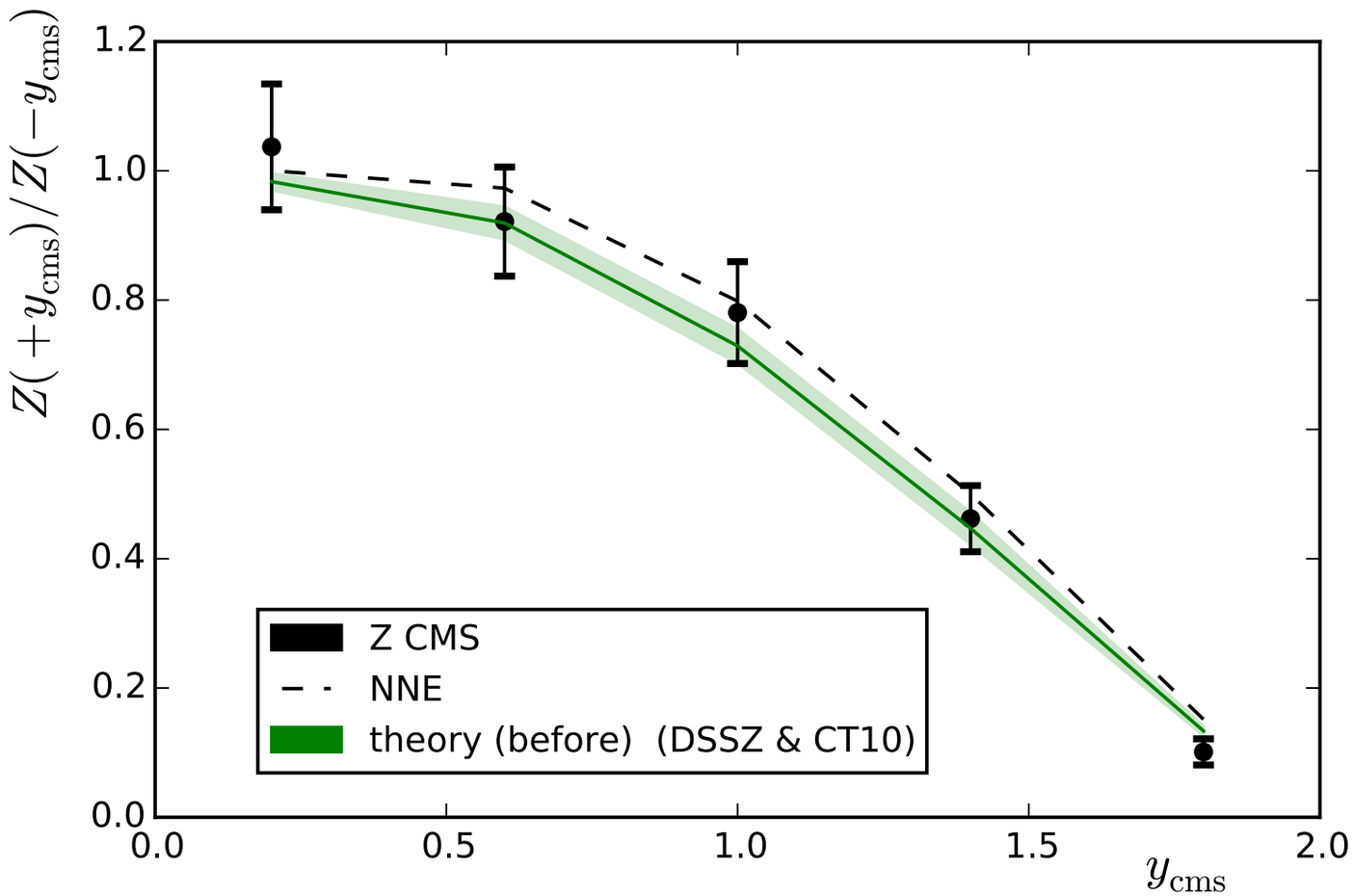

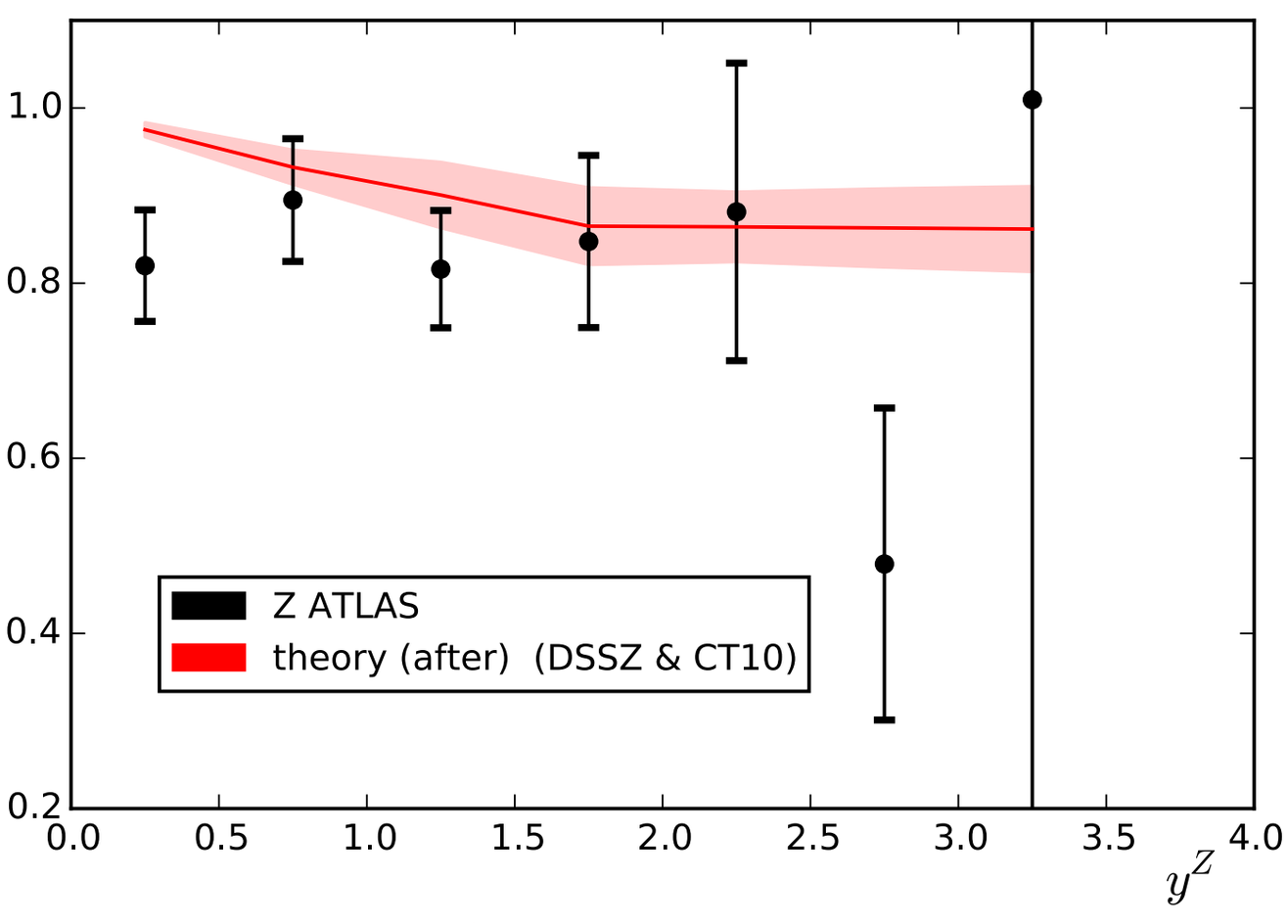

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ATLAS collaboration
arXiv:1507.06232 [hep-ex]

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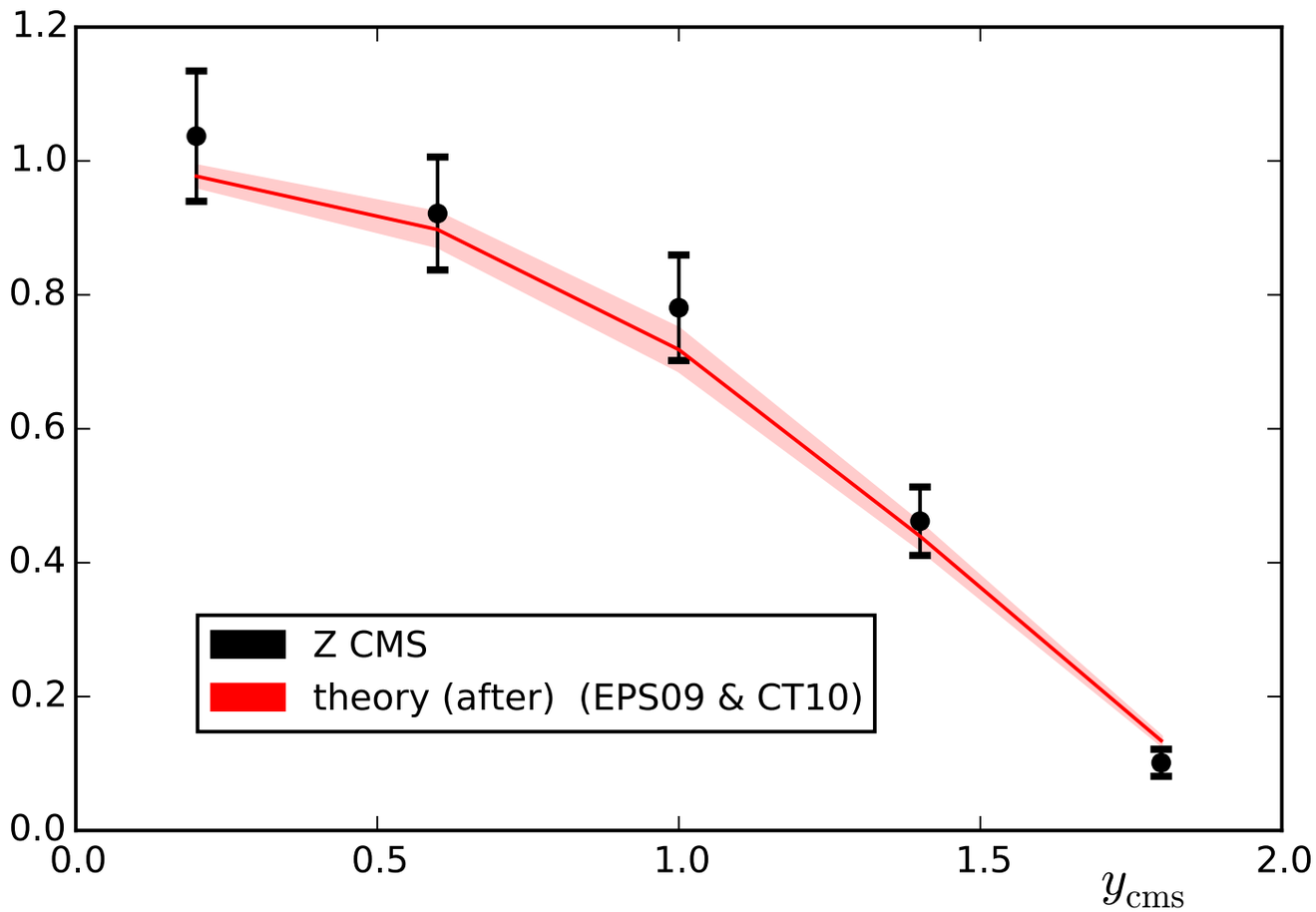
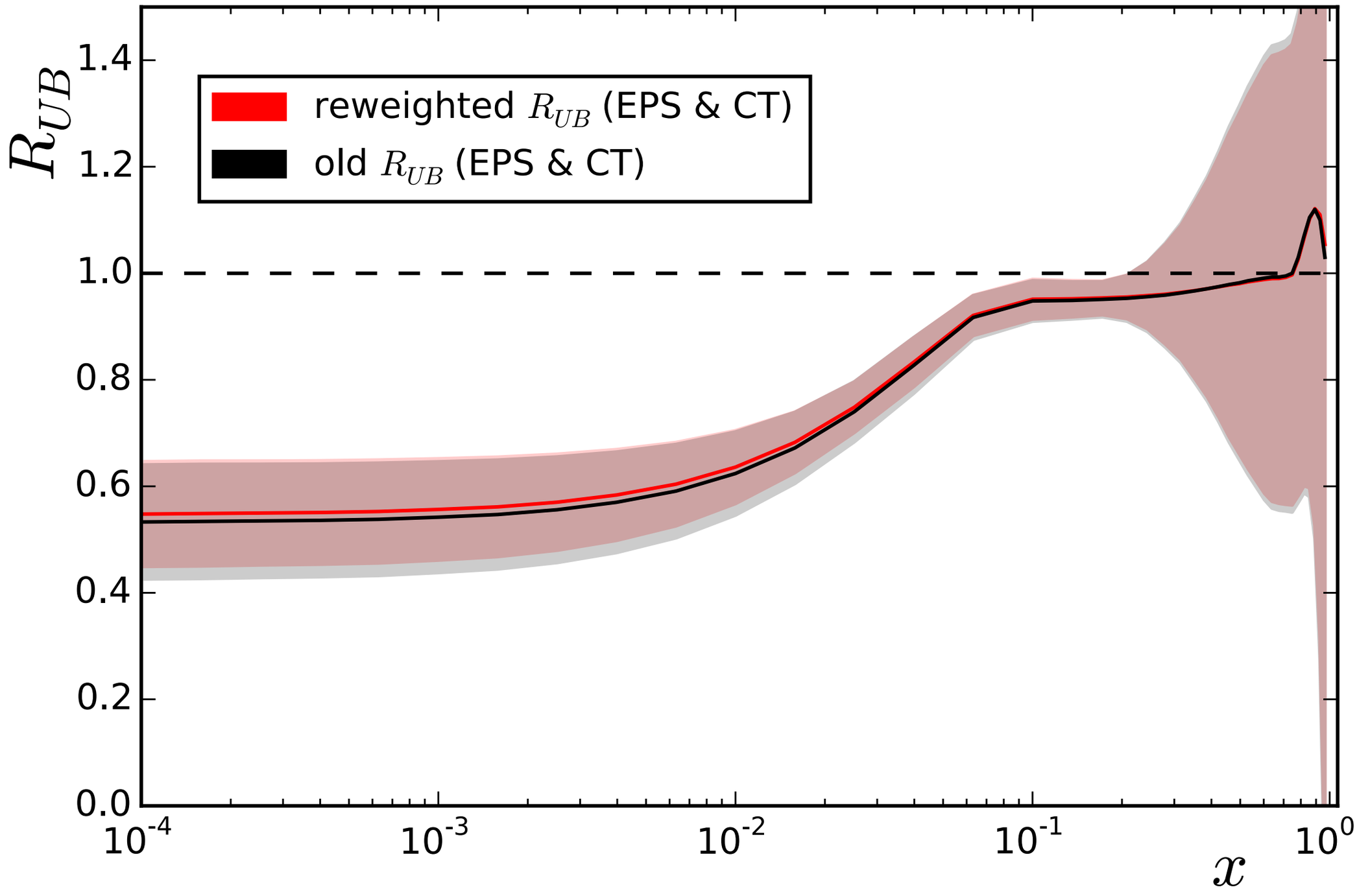
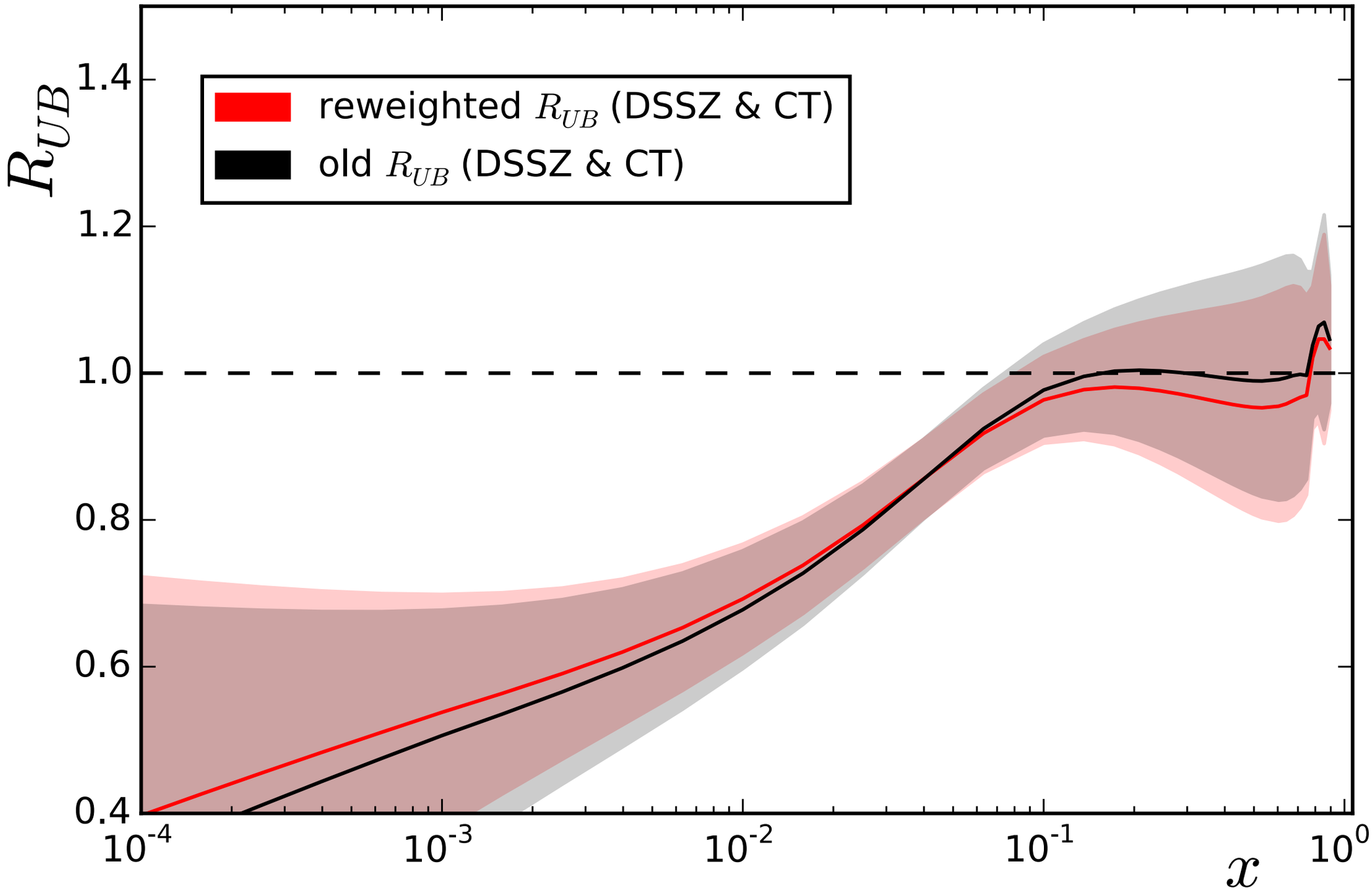
CMS collaboration
CMS-PAS-HIN-15-002



SEA QUARKS


reweighted R_{UB} (EPS & CT)
old R_{UB} (EPS & CT)
R_{UB}
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
x

SEA QUARKS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R_{UB}
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0.8
0.6
0.4
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
x

IN NUMBERS

PDF+nPDF	X^2	$X^2_{\text{re-weighted}}$
CT10+DSSZ	1.074	1.016
CT10+EPS09	0.674	0.632
CT10 only	1.425	——
MSTW2008+DSSZ	0.876	0.826
MSTW2008+EPS09	0.649	0.583
MSTW2008 only	1.138	——

SUMMARY

- We analyzed p-Pb data from LHC with four combinations of proton and nuclear PDFs
- The impact seems rather small due to the systematic uncertainties
- The trend is a flatter gluon, less shadowing and anti-shadowing
- W bosons and dijets call for a new fit with flavour separation