

QCD Analysis of Unpolarized and Polarized Λ - Baryon Production in Leading and Next-to-Leading Order

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Abstract

We analyze experimental data for the production of Λ baryons in e^+e^- annihilation. In terms of scale dependent, QCD evolved, Λ fragmentation functions, we analyze the data for which the polarization is non-zero. We also consider the recent LEP measurements of the Λ baryon production in the Z-resonance. Such data can be used to fix these. We therefore suggest several different sets of fragmentation functions for the Λ . We point out that the present data is compatible with present data, and study the prospects of future deep-inelastic scattering experiments to discriminate between the different next-to-leading order QCD frameworks.

First next-to-next-to-leading-order extraction of fragmentation functions for Λ hyperons

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AKK Update: Improvements from New Theoretical Input and Experimental Data

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(Dated: October 22, 2018)

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I. INTRODUCTION

Global analysis of fragmentation functions to light neutral hadrons

Jun Gao¹, ChongYang Liu¹, Mengyang Li², XiaoMin Shen^{3,1}, Hongxi Xing^{2,4,5}, Yuxiang Zhao^{3,5,6,7},
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Higher-Twist Dynamics in Large Transverse Momentum Hadron Production

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Why Λ^0 ?

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Why Λ^0 ?



ChatGPT



Claude

PREPARED FOR SUBMISSION TO JHEP

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Why Λ^0 ?



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unusually long lifetime for a baryon produced in a hard interaction

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lightest baryon after the nucleons, the lightest carrying strangeness

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Why Λ^0 ?



ChatGPT



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Abstract

AKK Update: Improvements from New Theoretical Input and Experimental Data

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Conclusion: Λ production

November 1997

Valerio Bertone,^a Alessia Bongallino,^b Amedeo Chiara,^c Miguel G. Echevarria,^c Gunar Schnell^{b,d}

lightest baryon after the nucleons, the lightest carrying strangeness

polarization puzzle, baryon anomaly

not like for π or K FFs:

PACS numbers: 11.15.Bt, 12.38.-t, 12.38.Qk, 13.85.Ni

arXiv:hep-th/9711387v1 19 Nov 1997

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Truth: Λ production

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but similarly to p or $\bar{p}$

November 1997

(Dated: October 22, 2018)

I. INTRODUCTION

Higher-Twist Dynamics in Large Transverse Momentum Hadron Production

(Dated: October 28, 2018)

PACS numbers: 11.15.Bt, 12.38.-t, 12.38.Qk, 13.85.Ni

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I. INTRODUCTION

to have a closer look at lambda production beyond NLO and at EIC

(Dated: October 28, 2018)

PACS numbers: 11.15.Bt, 12.38.-t, 12.38.Qk, 13.85.Ni

Why Λ^0 ?



ChatGPT



Claude

PREPARED FOR SUBMISSION TO JHEP

First next-to-next-to-leading-order extraction of fragmentation functions for Λ hyperons

unusually long lifetime for a baryon produced in a hard interaction
lightest baryon after the nucleons, the lightest carrying strangeness
in the quark model u and d couple in a spin and isospin singlet (most probably wrong!!)
polarization puzzle, baryon anomaly ...

the truth: lambda production in proton-proton collisions does not look at all like pQCD

not like for π or K FFs: CERN ISR in mid '70s and '80s

but similarly to p or $\bar{p}$

to have a closer look at lambda production beyond NLO and at EIC

start with LHC proton-proton collisions data

Prehistory:

The vast span of human history stretching from first known use of stone tools by hominins until the invention of writing systems.

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CERN-TH/97-286
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QCD Analysis of Unpolarized and Polarized
 Λ - Baryon Production in
Leading and Next-to-Leading Order

D. de Florian^a, M. Stratmann^b, W. Vogelsang^a

^a*Theoretical Physics Division, CERN, CH-1211 Geneva 23, Switzerland*

^b*Department of Physics, University of Durham, Durham DH1 3LE, England*

Abstract

We analyze experimental data for the production of Λ baryons in e^+e^- annihilation in terms of scale dependent, QCD evolved, Λ fragmentation functions. Apart from the vast majority of the data for which the polarization of an observed Λ was not determined, we also consider the recent LEP measurements of the longitudinal polarization of Λ 's produced on the Z -resonance. Such data correspond to spin-dependent fragmentation functions for the Λ . We point out that the present data are insufficient to satisfactorily fix these. We therefore suggest several different sets of fragmentation functions, all compatible with present data, and study the prospects for conceivable future semi-inclusive deep-inelastic scattering experiments to discriminate between them. We provide the complete next-to-leading order QCD framework for all the processes we consider.

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QCD Analysis of Unpolarized and Polarized

Λ - Baryon Production in

Leading and Next-to-Leading Order

Fragmentation Functions for K_S^0 and Λ with Complete Quark

Flavour Separation

S. Albino

Institut für Theoretische Physik und Astrophysik,

Universität Würzburg, 97074 Würzburg, Germany

B. A. Kniehl and G. Kramer

II. Institut für Theoretische Physik, Universität Hamburg,

Luruper Chaussee 149, 22761 Hamburg, Germany

(Dated: November 13, 2018)

Abstract

We present new sets of next-to-leading order fragmentation functions for the production of K_S^0 and Λ particles from the gluon and from each of the quarks, obtained by fitting to all relevant data sets from e^+e^- annihilation. The individual light quark flavour fragmentation functions are constrained phenomenologically for the first time by including in the data the light quark tagging probabilities measured by the OPAL Collaboration.

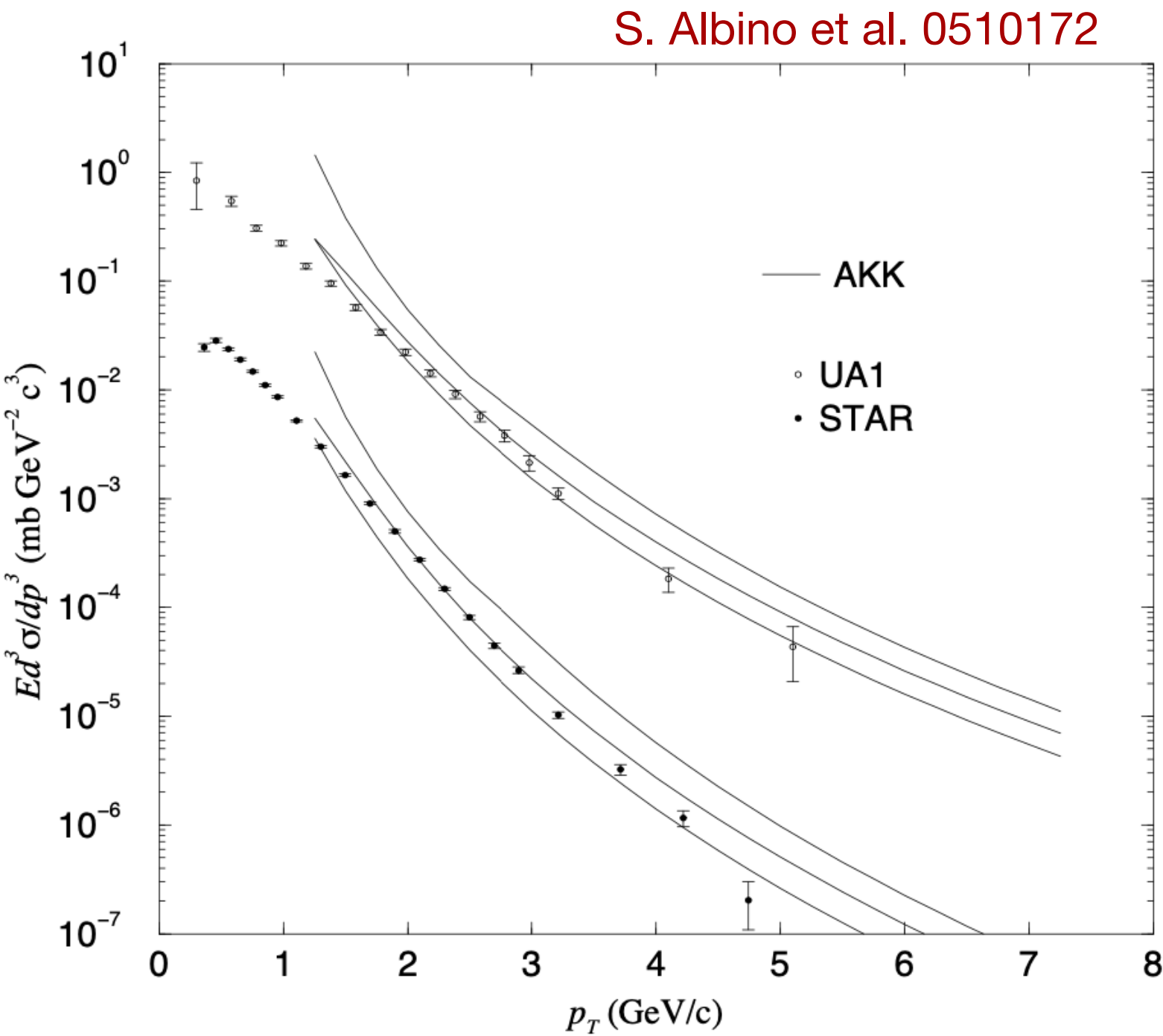
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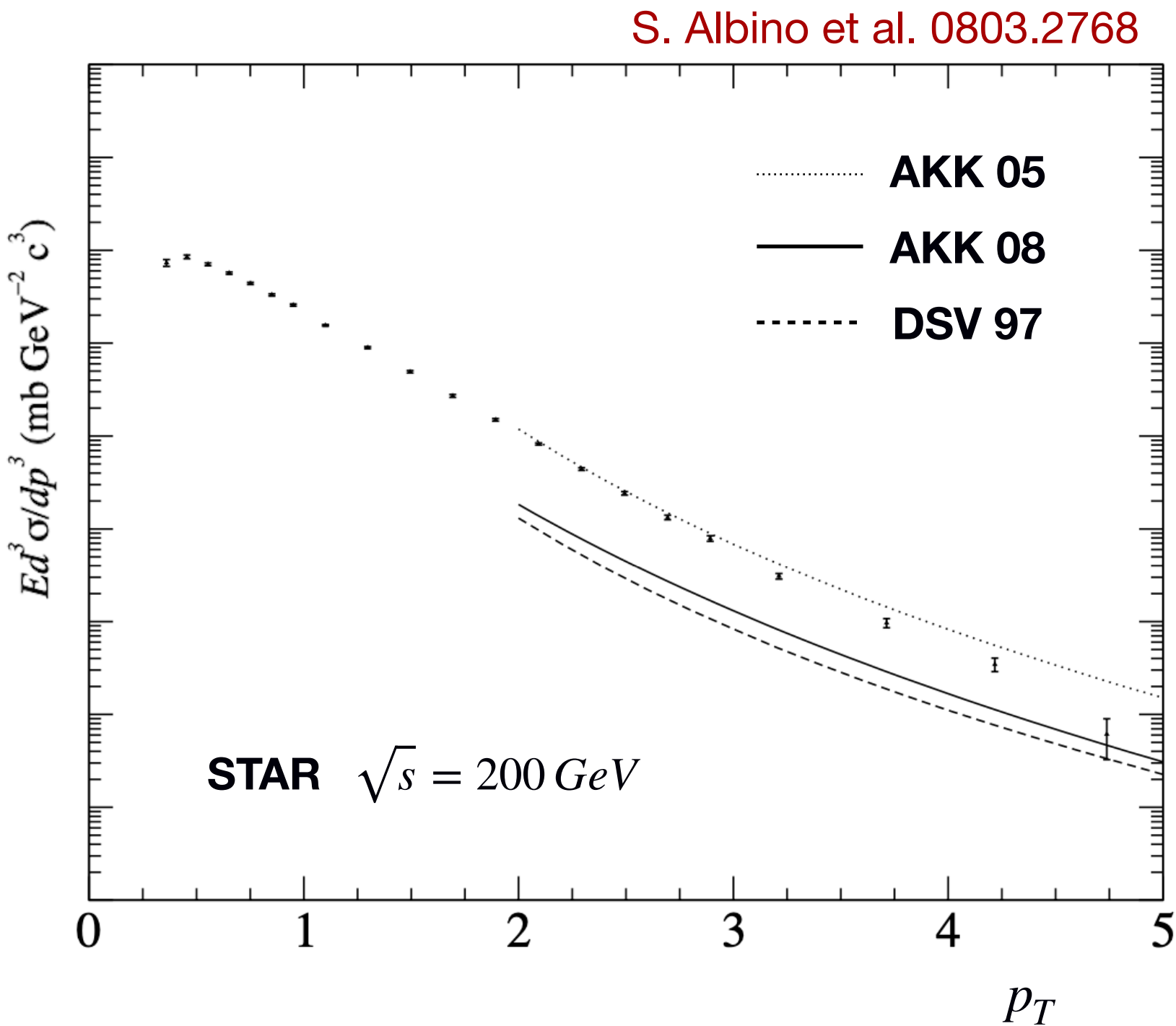
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1997 DSV set of NLO Λ^0 FFs (SIA-only)

2005 AKK extended SIA, comparison to STAR & UA1 $pp \rightarrow \Lambda^0 + X$

2008 AKK update, + CDF $p\bar{p} \rightarrow \Lambda + X$ ($\sqrt{s} = 630\text{ GeV}$)



19 Nov 1997

QCD Analysis of Unpolarized and Polarized
 Λ - Baryon Production in
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Abstract

AKK Update: Improvements from New Theoretical Input and Experimental Data

S. Albino, B. A. Kniehl, and G. Kramer
*II. Institut für Theoretische Physik, Universität Hamburg,
Luruper Chaussee 149, 22761 Hamburg, Germany*
(Dated: October 22, 2018)

We perform a number of improvements to the previous AKK extraction of fragmentation functions for $\pi^\pm$, $K^\pm$, $p/\bar{p}$, K_S^0 and $\Lambda/\bar{\Lambda}$ particles at next-to-leading order. Inclusive hadron production measurements from $pp(\bar{p})$ reactions at BRAHMS, CDF, PHENIX and STAR are added to the data sample. We use the charge-sign asymmetry of the produced hadrons in pp reactions to constrain the valence quark fragmentations. Data from e^+e^- reactions in regions of smaller x and lower $\sqrt{s}$ are added. Hadron mass effects are treated for all observables and, for each particle, the hadron mass used for the description of the e^+e^- reaction is fitted. The baryons' fitted masses are found to be only around 1% above their true masses, while the values of the mesons' fitted masses have the correct order of magnitude. Large x resummation is applied in the coefficient functions of the e^+e^- reactions, and also in the evolution of the fragmentation functions, which in most cases results in a significant reduction of the minimized χ^2 . To further exploit the data, all published normalization errors are incorporated via a correlation matrix.

13 Oct 2005

May 2008

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2025 NPC23: SIA, SIDIS & pp ratios $(\Lambda^0/K^0, 13\,TeV/7\,TeV)$

Global analysis of fragmentation functions to light neutral hadrons

Jun Gao¹, ChongYang Liu¹, Mengyang Li², XiaoMin Shen^{3,1}, Hongxi Xing^{2,4,5}, Yuxiang Zhao^{3,5,6,7}, Yiyu Zhou^{8,9,10}

¹*State Key Laboratory of Dark Matter Physics, Shanghai Key Laboratory for Particle Physics and Cosmology, Key Laboratory for Particle Astrophysics and Cosmology (MOE),*

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²*State Key Laboratory of Nuclear Physics and Technology, Institute of Quantum Matter, South China Normal University, Guangzhou 510006, China*

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⁴*Guangdong Basic Research Center of Excellence for Structure and Fundamental Interactions of Matter, Guangdong Provincial Key Laboratory of Nuclear Science, Guangzhou 510006, China*

⁵*Southern Center for Nuclear-Science Theory (SCNT), Institute of Modern Physics, Chinese Academy of Sciences, Huizhou 516000, China*

⁶*University of Chinese Academy of Sciences, Beijing 100049, China*

⁷*Key Laboratory of Quark and Lepton Physics (MOE) and Institute of Particle Physics, Central China Normal University, Wuhan 430079, China*

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⁹*Department of Physics, University of Turin, via Pietro Giuria 1, I-10125 Torino, Italy*

¹⁰*INFN, Section of Turin, via Pietro Giuria 1, I-10125 Torino, Italy* *

Fragmentation functions (FFs) are crucial non-perturbative components in quantum chromodynamics (QCD), playing a vital role in predictions and understanding of the hadronization process. In this paper, we present the FFs for K_S^0 , η , π^0 mesons, and Λ baryons in the context of global QCD analysis. The data included in the fit are from single inclusive e^+e^- annihilation (SIA), semi-inclusive deep-inelastic scattering (SIDIS) and proton-proton collisions, with kinematic cuts carefully applied to ensure validity of collinear factorization and perturbative QCD expansion. For the first time, data from SIDIS and hadron-in-jet production in SIA have been incorporated into the extraction of FFs for light-flavor neutral hadrons. Our analysis reveals that these data play a critical role in constraining the gluon distribution, and in distinguishing between different quark flavors. Pulls from different datasets are also studied by performing alternative fits with systematically subtracting groups of data from the nominal fit. For the quality of the fit, good χ^2 values are achieved for most of the datasets, and FFs are generally well constrained within the momentum fraction region (0.1,0.5). The extracted K_S^0 fragmentation functions, together with the K_S^0 FFs constructed from $K^\pm$ FFs via isospin symmetry, are used to test isospin symmetry in kaon fragmentation. Although a definitive conclusion cannot be reached yet, these studies have identified several potential measurements that can be performed at existing facilities, which may ultimately help us to arrive at a conclusive answer. With the comprehensive species of FFs extracted within the NPC framework, we are able to perform a test on the momentum sum rule with the light-flavor charged and neutral hadrons. These neutral hadrons are found to carry a relatively smaller fraction of the fragmenting parton’s momentum compared to the charged ones. The central and Hessian error sets of the fitted FFs, denoted as NPC23, are publicly available in the form of LHAPDF6 grids.

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2026 MAPFF1.0 Lambda: SIA & SIDIS @NNLO

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PREPARED FOR SUBMISSION TO JHEP

First next-to-next-to-leading-order extraction of fragmentation functions for Λ hyperons

Valerio Bertone,^a Alessia Bongallino,^b Amedeo Chiefa,^c Miguel G. Echevarría,^b Gunar Schnell^{b,d}

^aUniversité Paris-Saclay, CEA, IRFU, 91191 Gif-sur-Yvette, France

^bDepartment of Physics & EHU Quantum Center, University of the Basque Country EHU, P.O. Box 644, 48080 Bilbao, Spain

^cThe Higgs Centre for Theoretical Physics, University of Edinburgh, JCMB, KB, Mayfield Rd, Edinburgh EH9 3JZ, Scotland

^dIKERBASQUE, Basque Foundation for Science, Plaza Euskadi 5, 48009 Bilbao, Spain

E-mail: valerio.bertone@cea.fr, alessia.bongallino@ehu.eus, amedeo.chiefa@ed.ac.uk, miguel.garciae@ehu.eus, gunar.schnell@desy.de

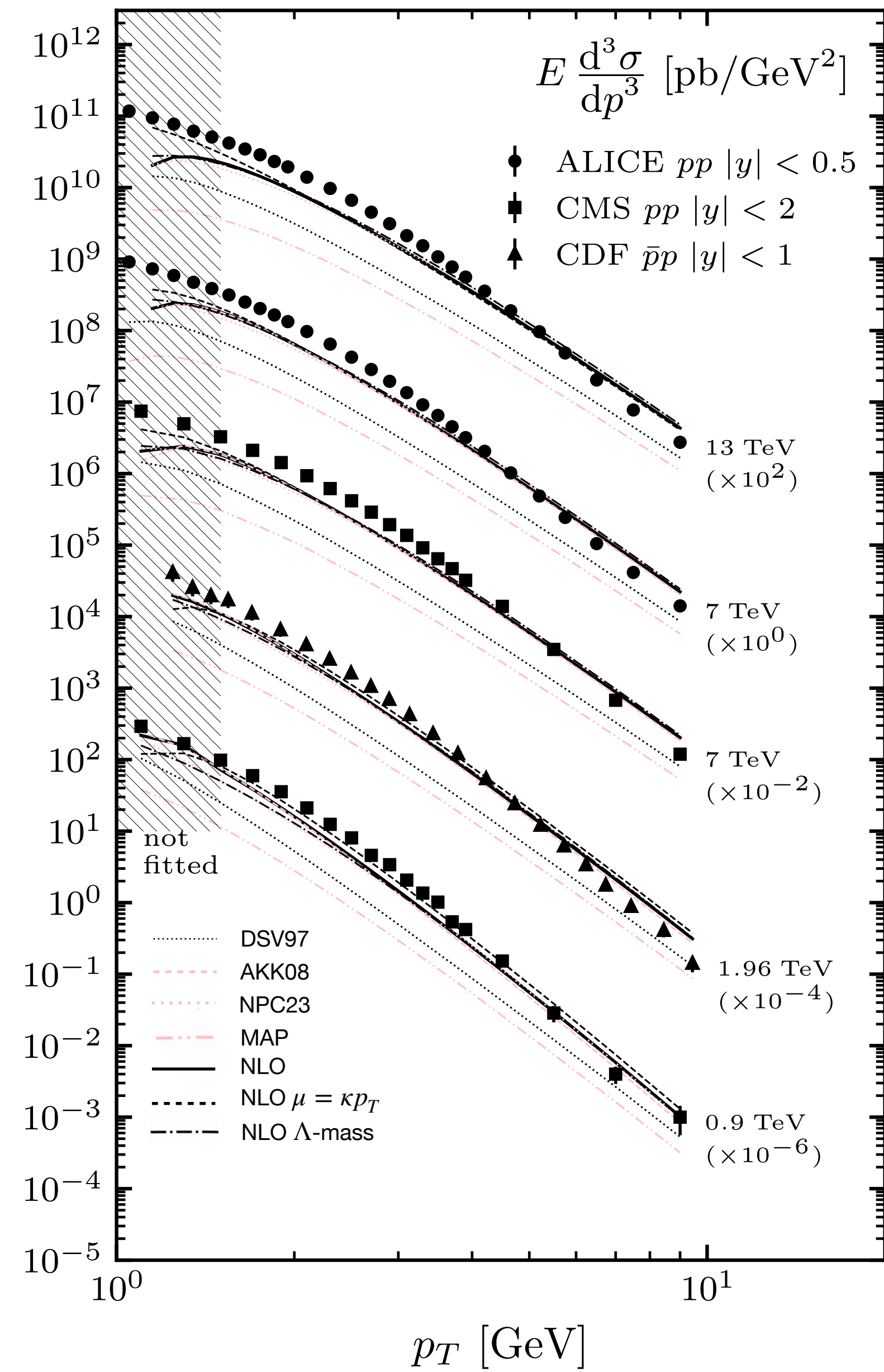
ABSTRACT: We present MAPFF1.0.Lambda, the first global analysis at next-to-next-to-leading order in perturbative QCD of the collinear unpolarised fragmentation functions of

9 Oct 2025

14v1 [hep-ph] 6 May 2026

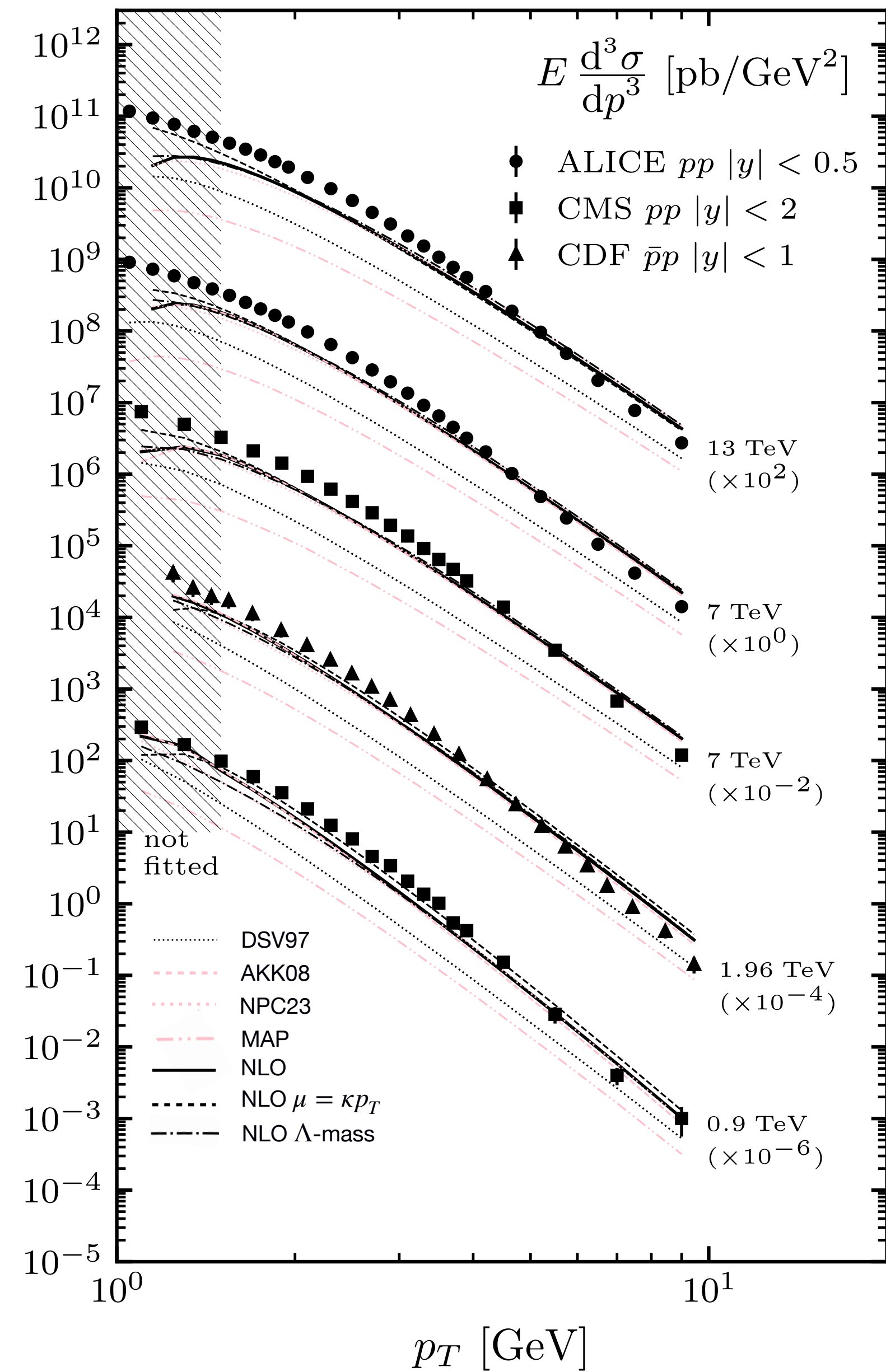
$pp \rightarrow \Lambda + X$ revisited

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p_T [GeV]

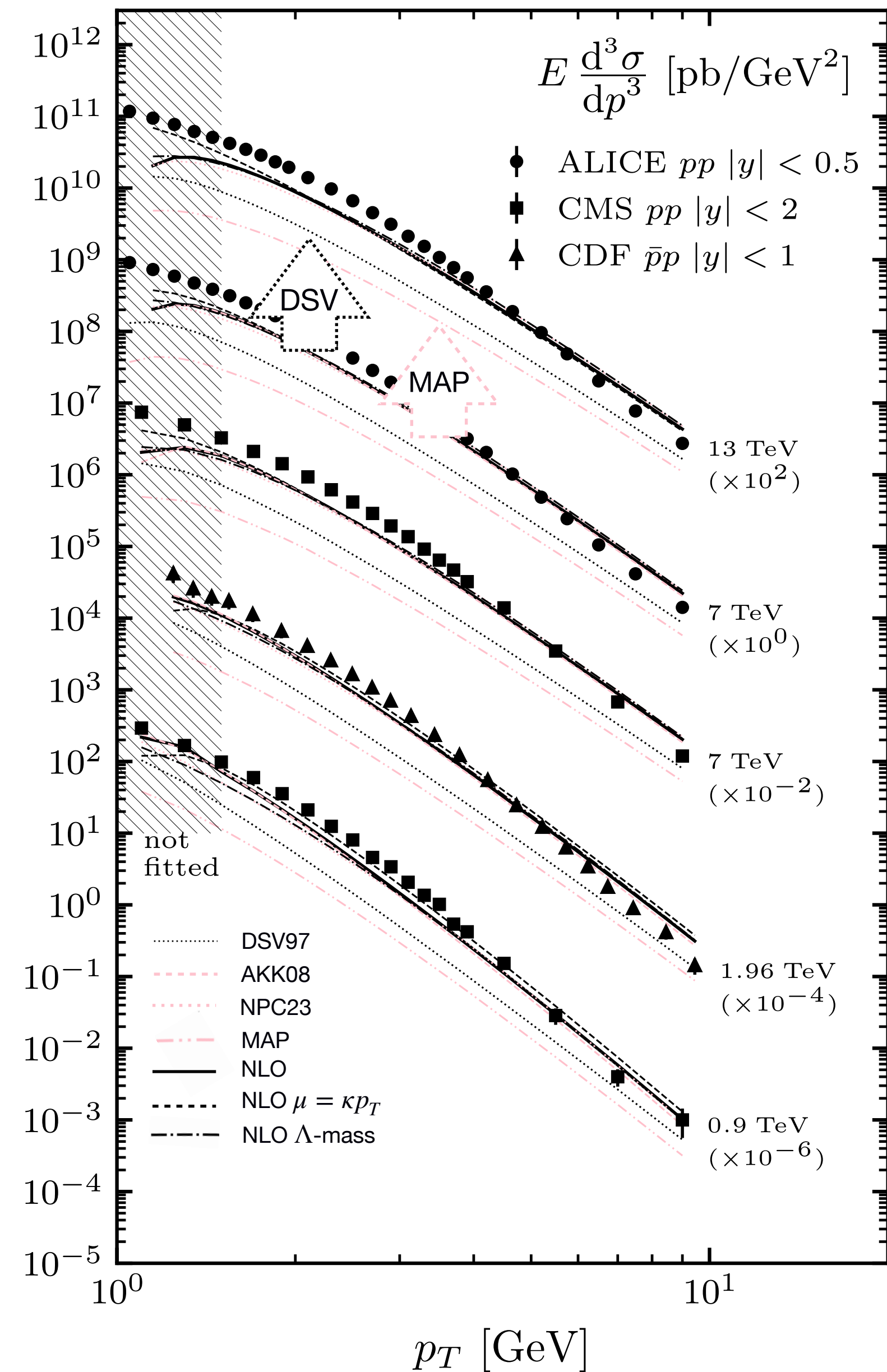
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all sets undershoot at lower pT ($\chi^2/data \sim 20$)

p_T [GeV]

$pp \rightarrow \Lambda + X$ revisited

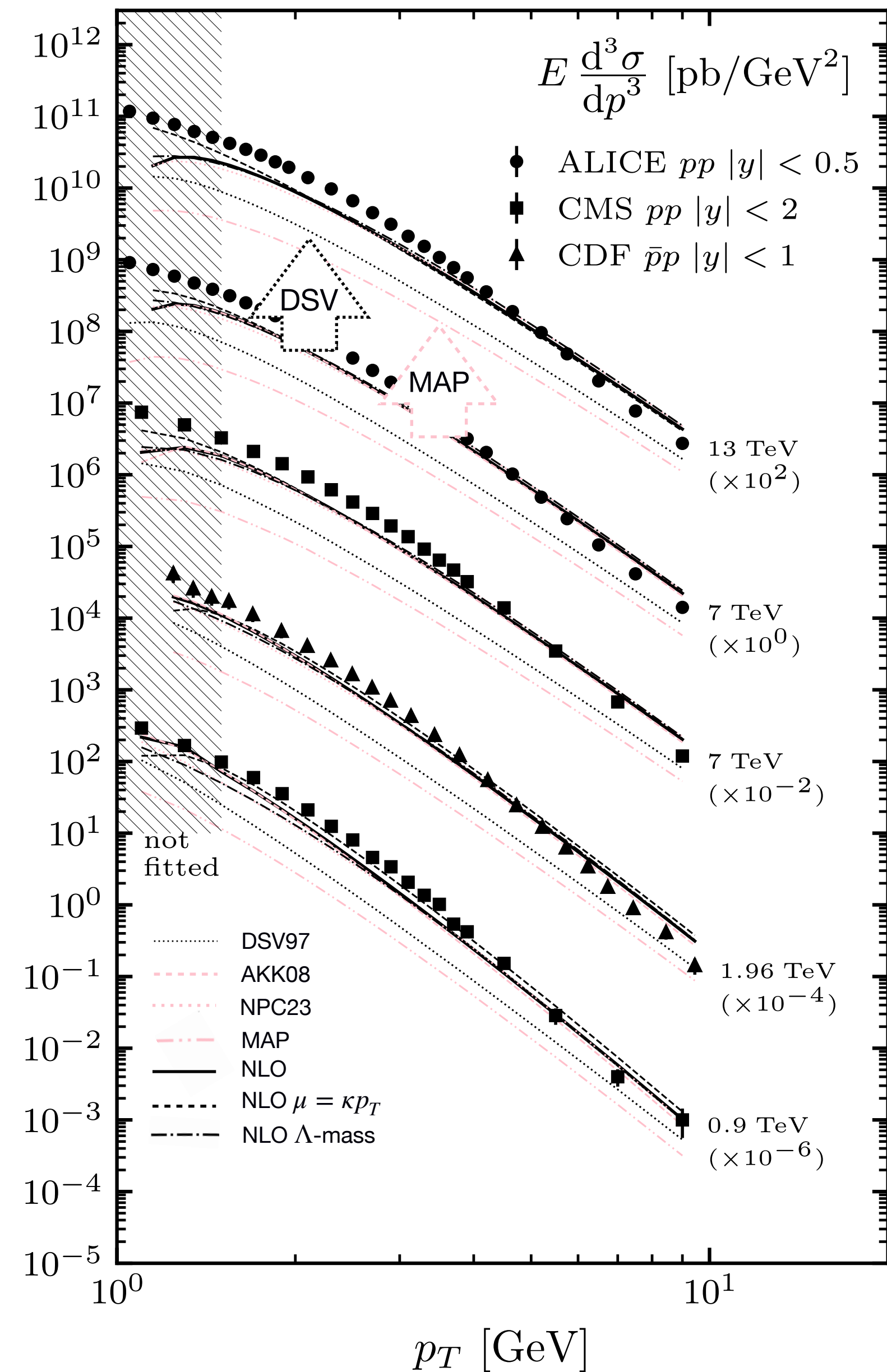


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sets with none pp data are worse

p_T [GeV]

$pp \rightarrow \Lambda + X$ revisited



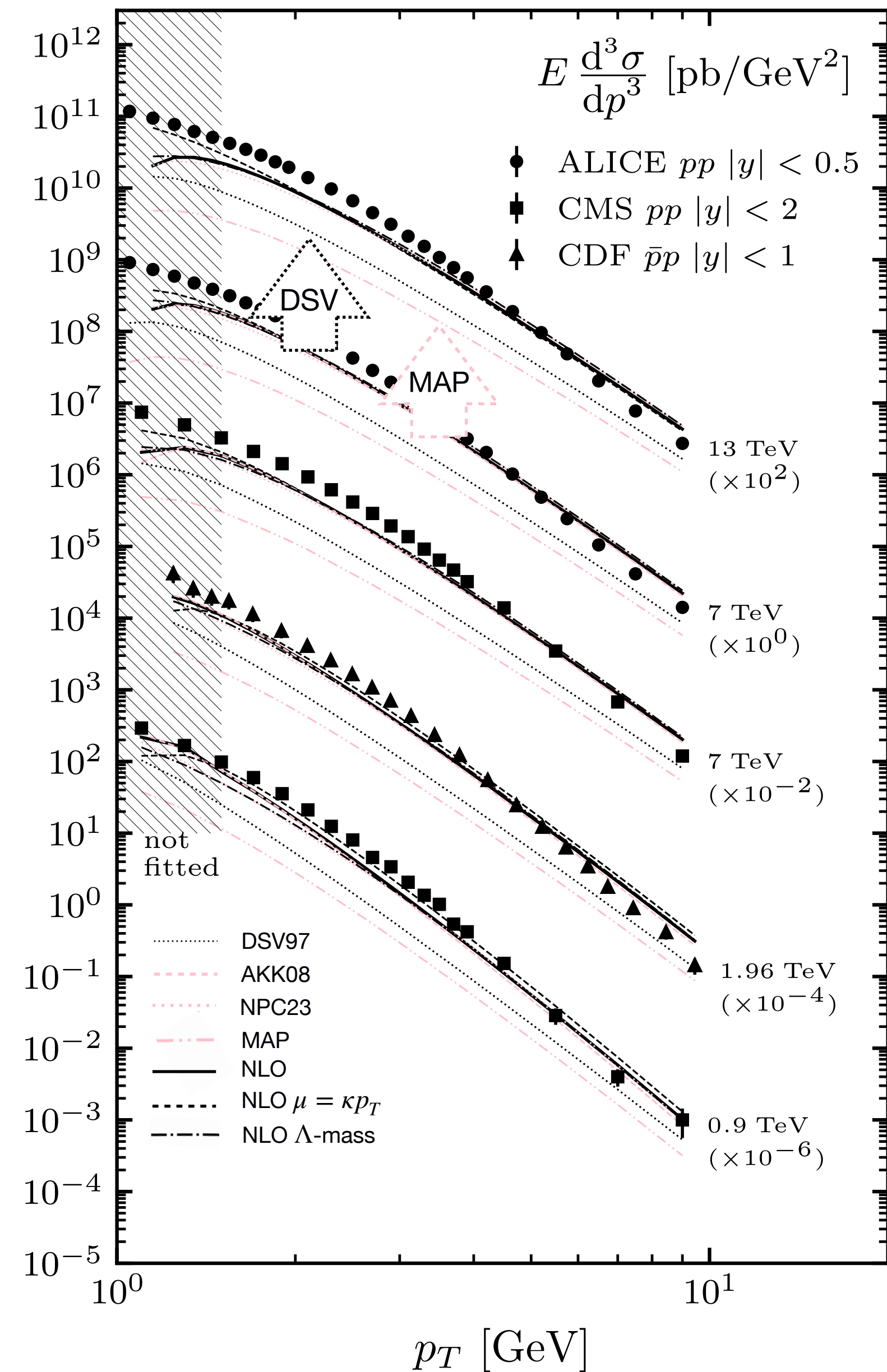
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~tension with SIA and SIDIS

p_T [GeV]

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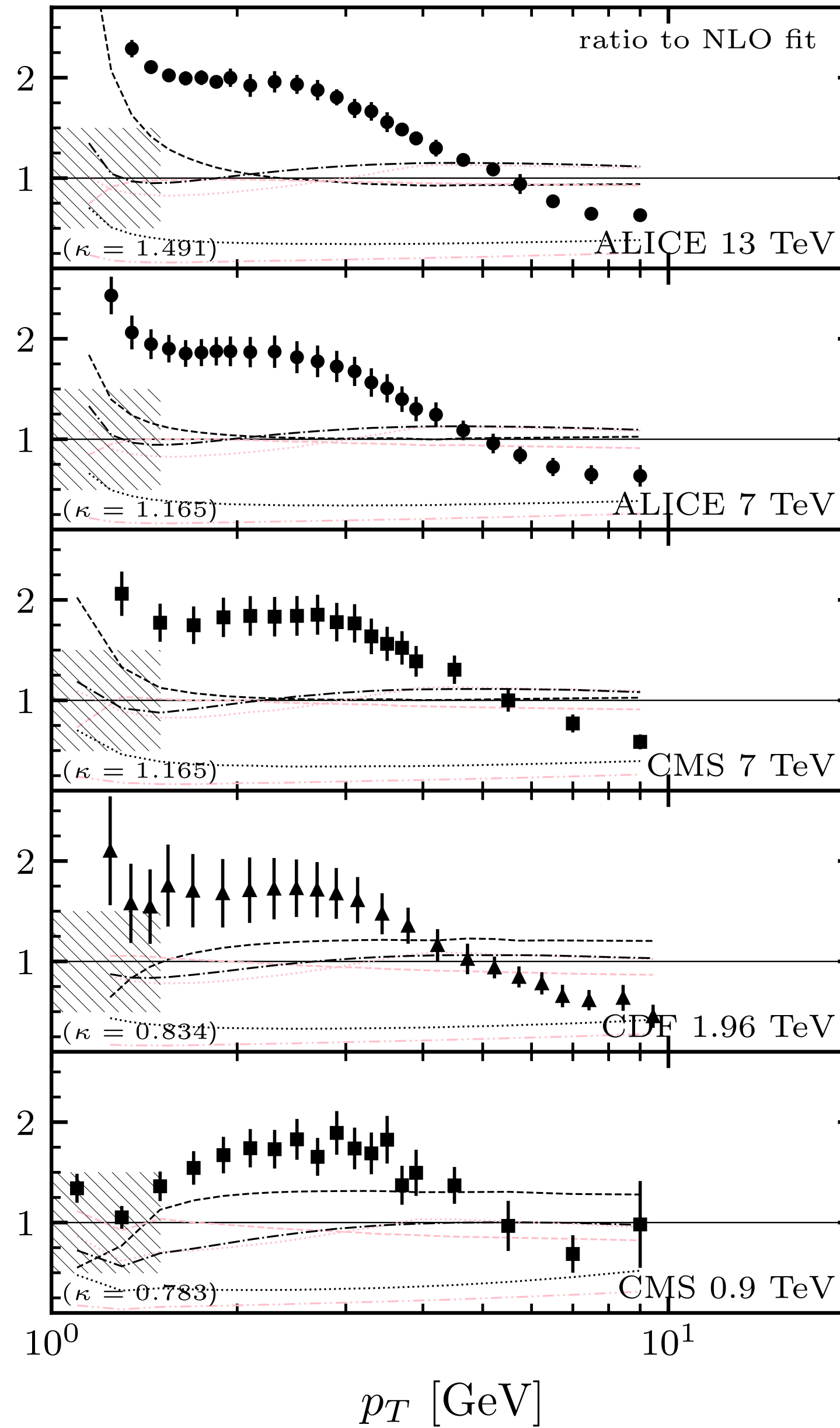
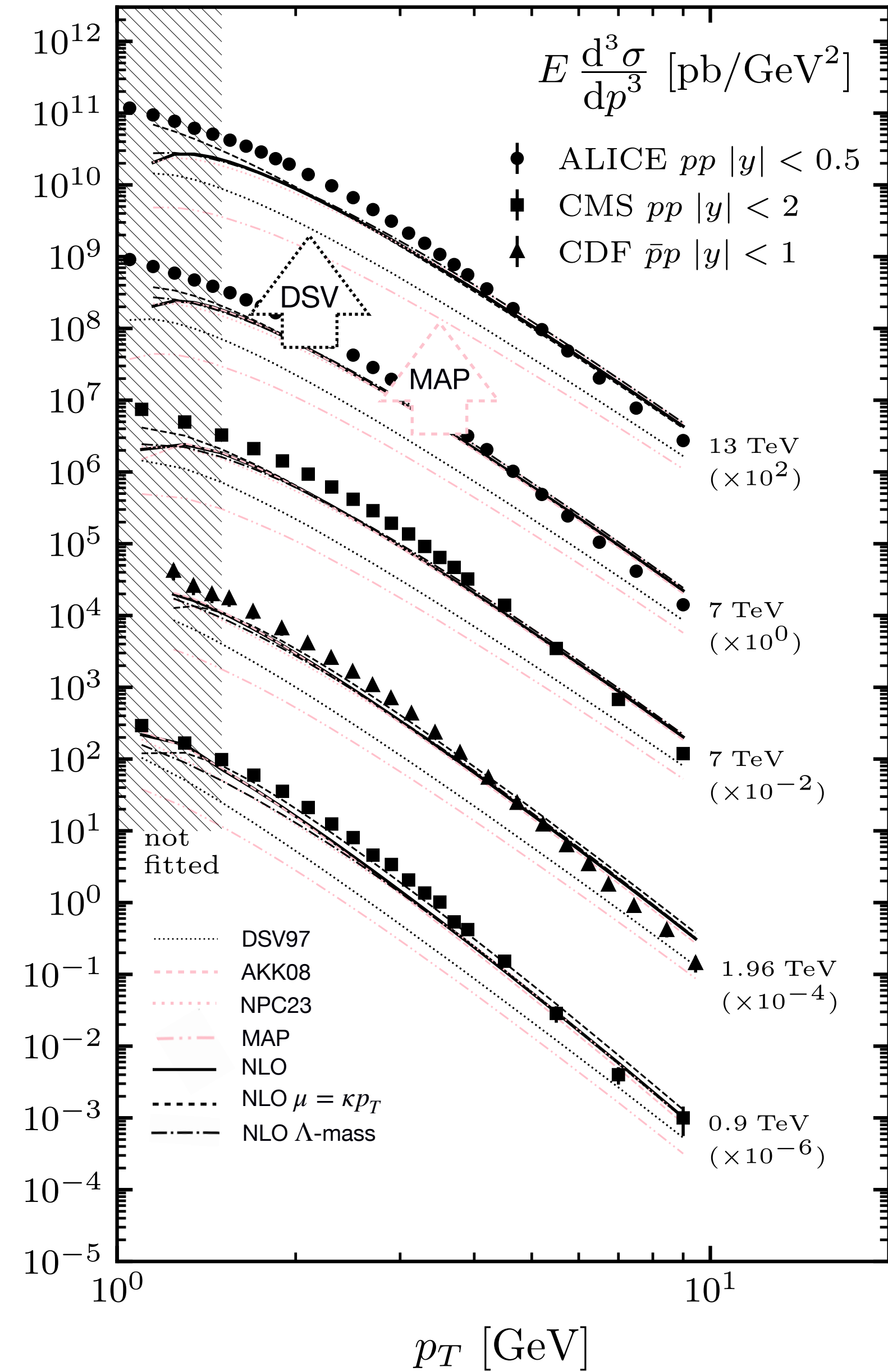
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~tension with SIA and SIDIS

difference grows with increasing $\sqrt{s}$

p_T [GeV]

$pp \rightarrow \Lambda + X$ revisited



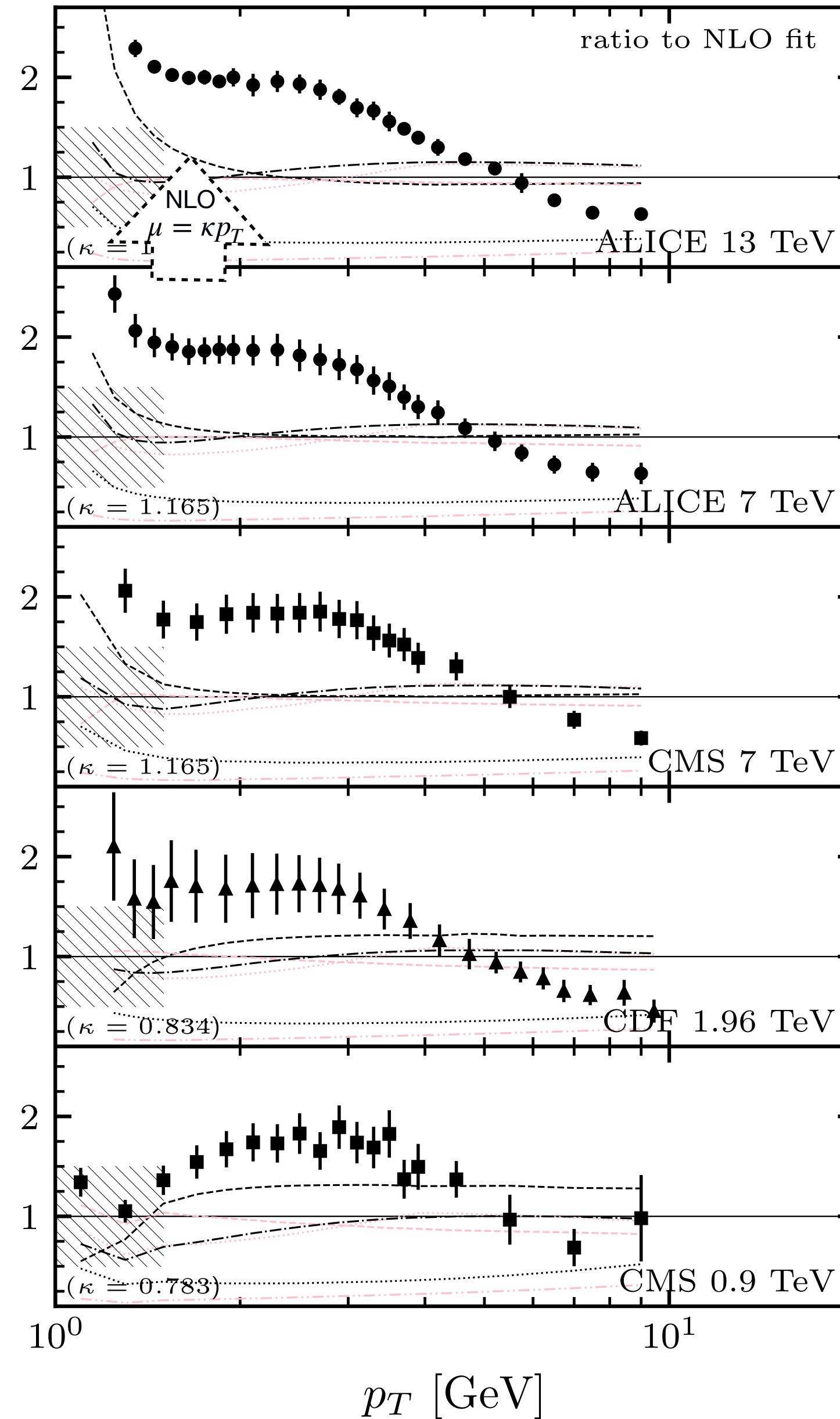
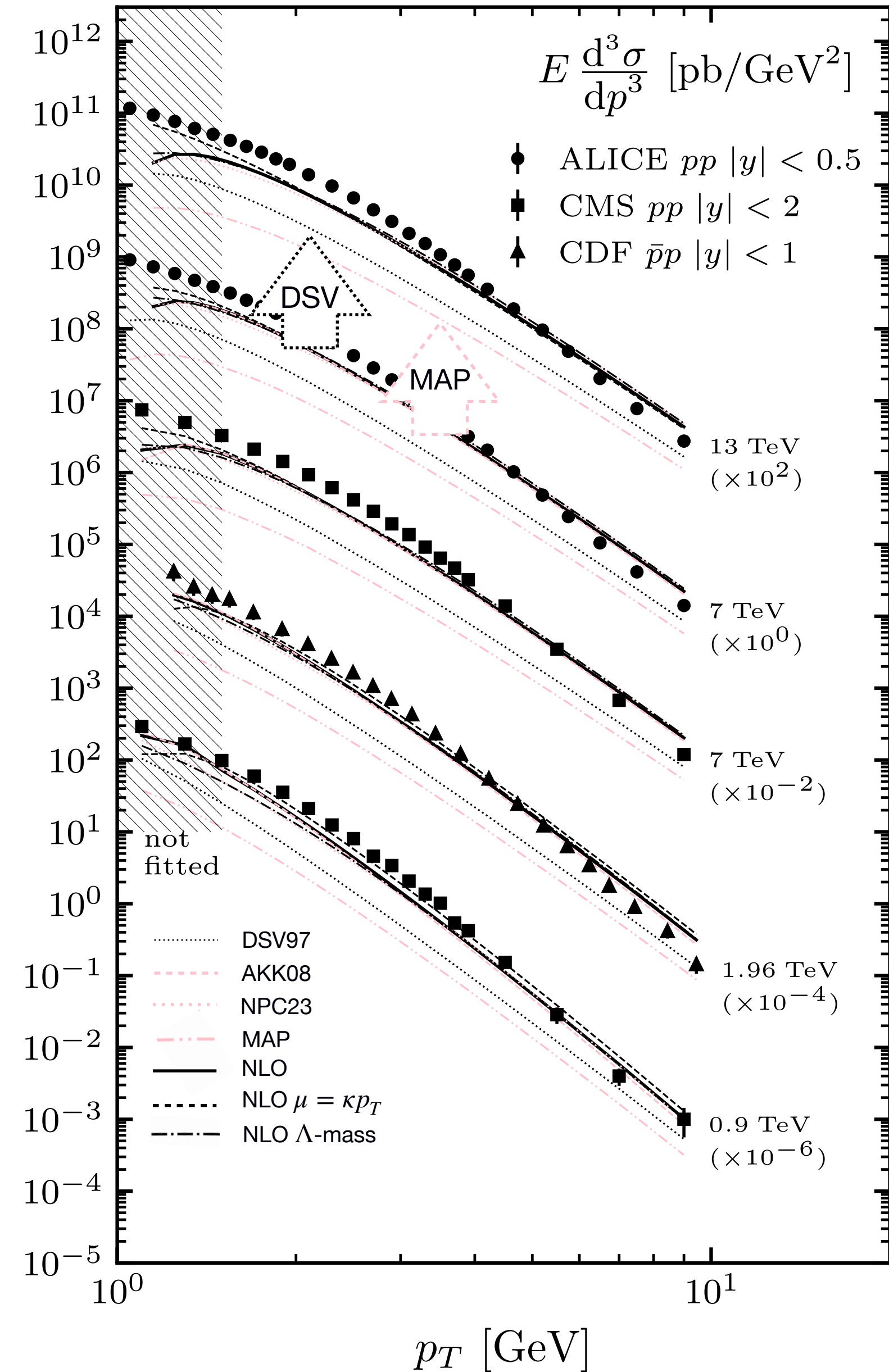
all sets undershoot at lower p_T ($\chi^2/data \sim 20$)

sets with none pp data are worse

~tension with SIA and SIDIS

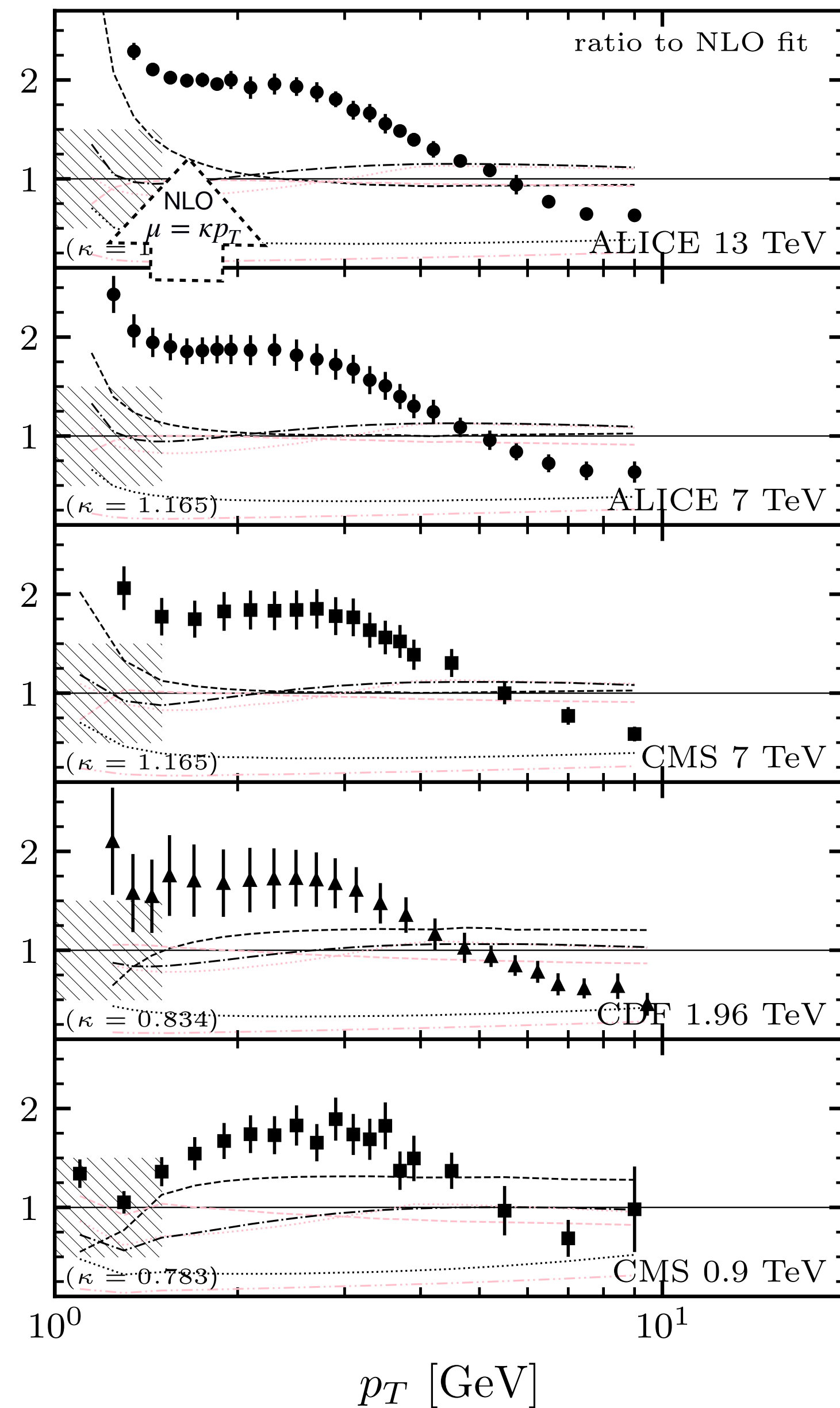
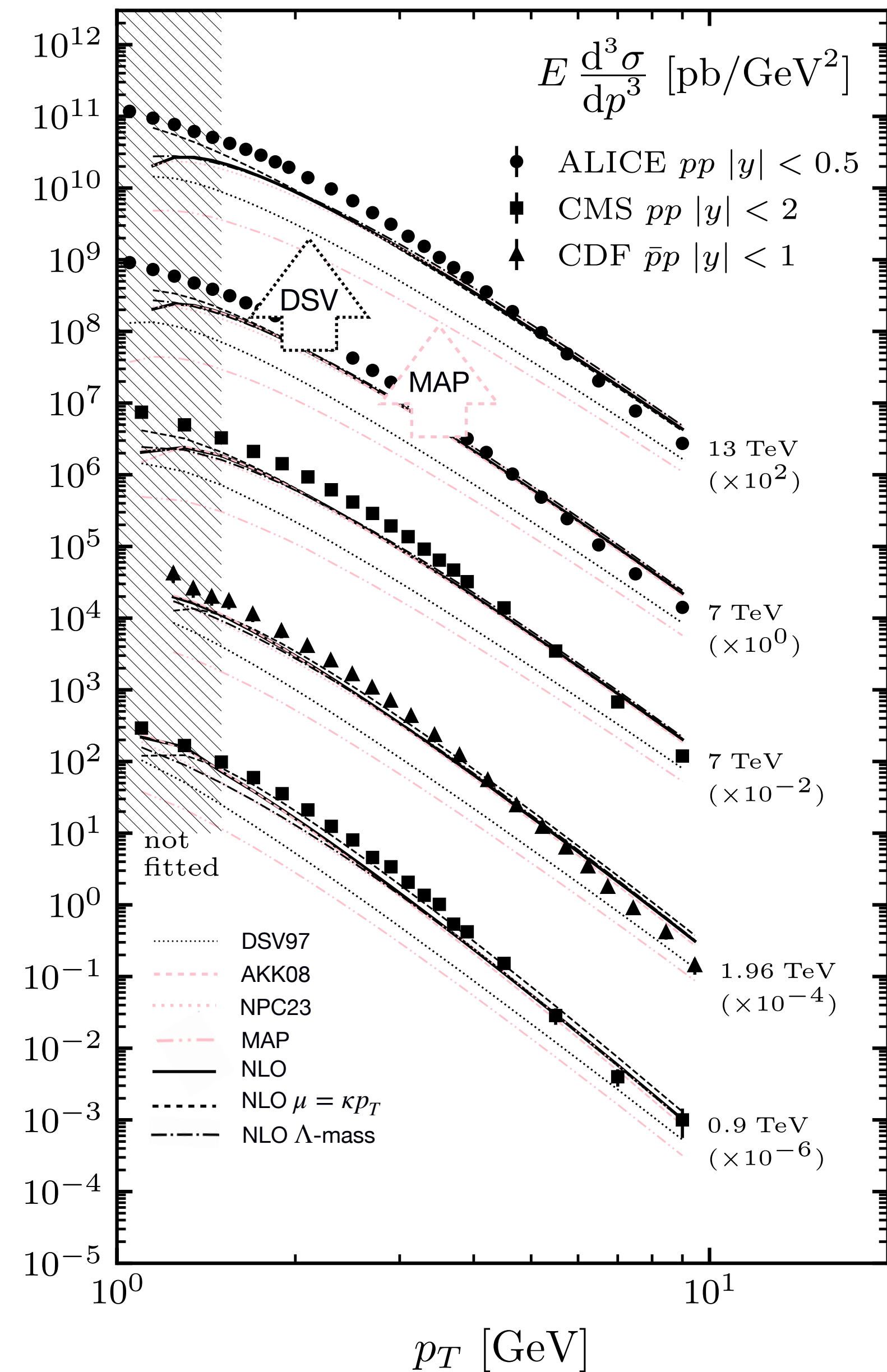
difference grows with increasing $\sqrt{s}$

$pp \rightarrow \Lambda + X$ revisited



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 difference grows with increasing $\sqrt{s}$
 factorization scale trick is not enough

$pp \rightarrow \Lambda + X$ revisited



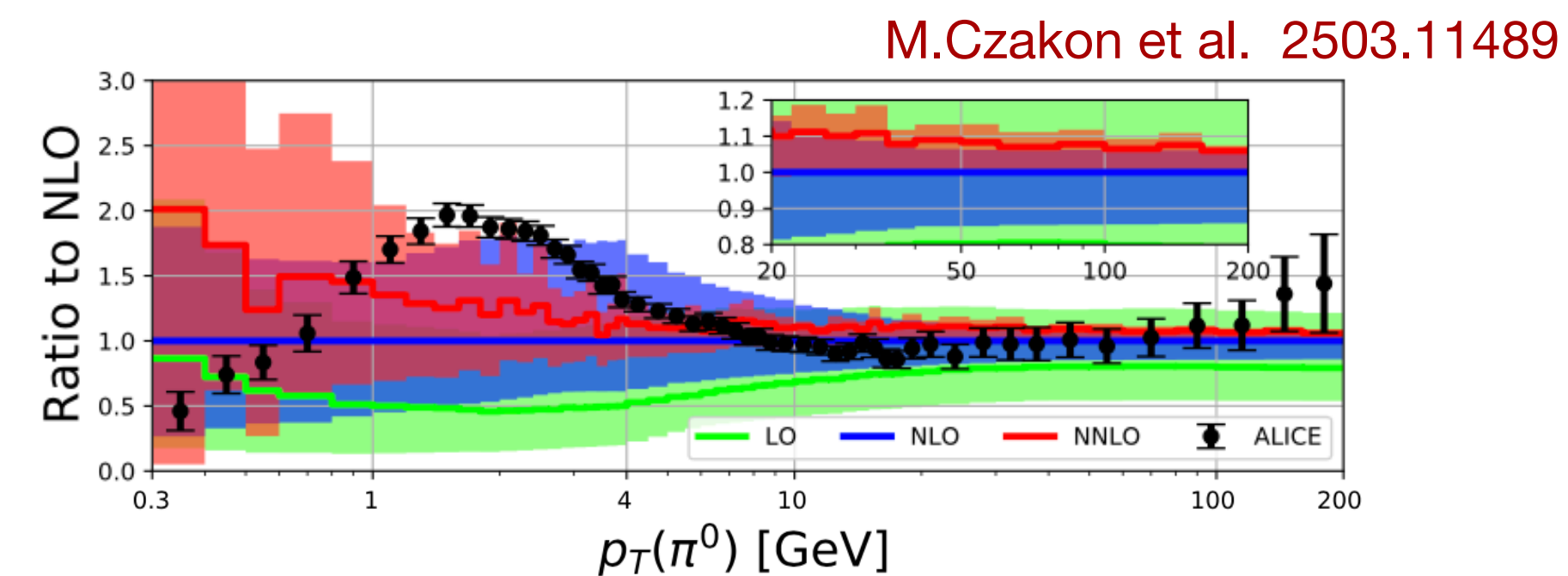
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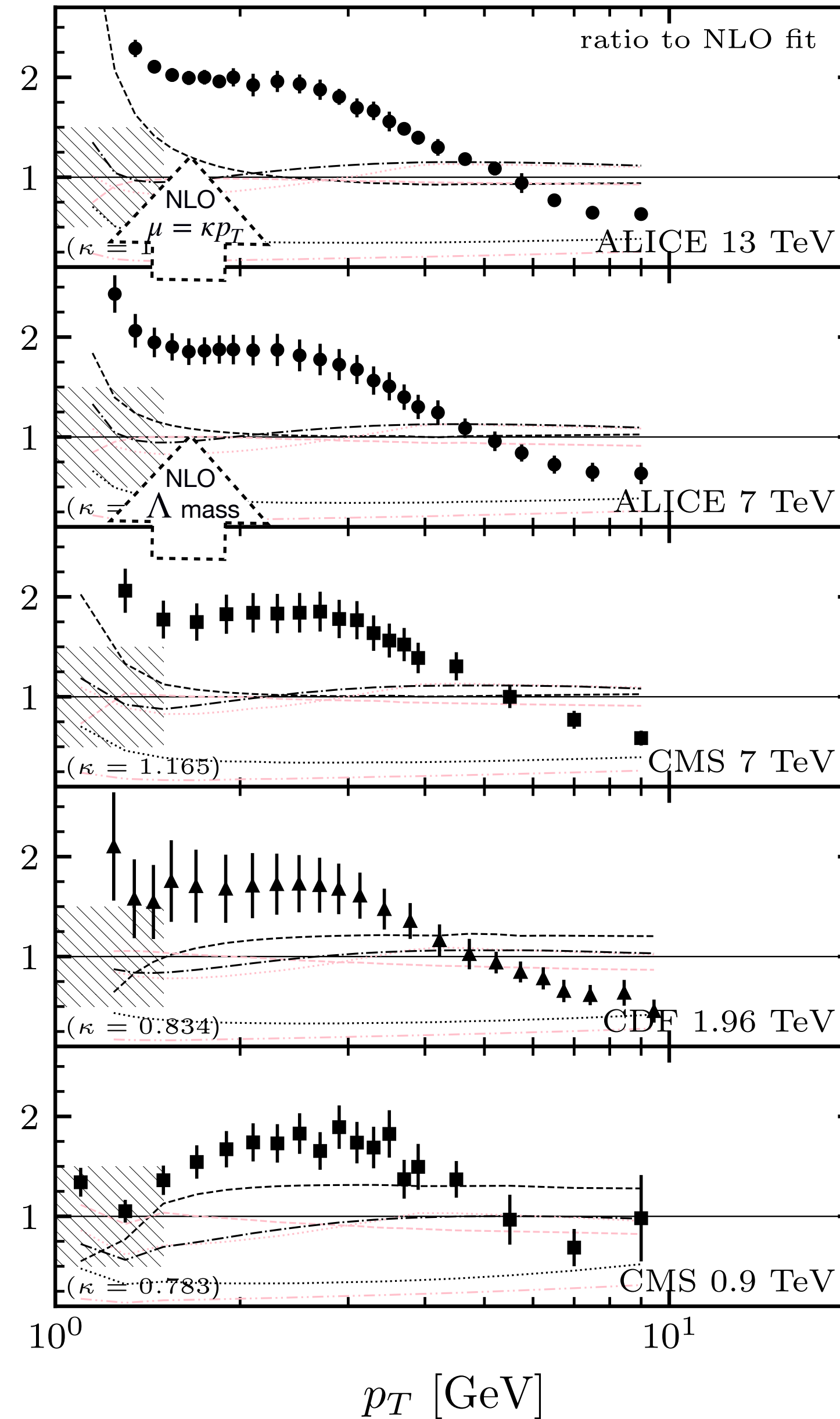
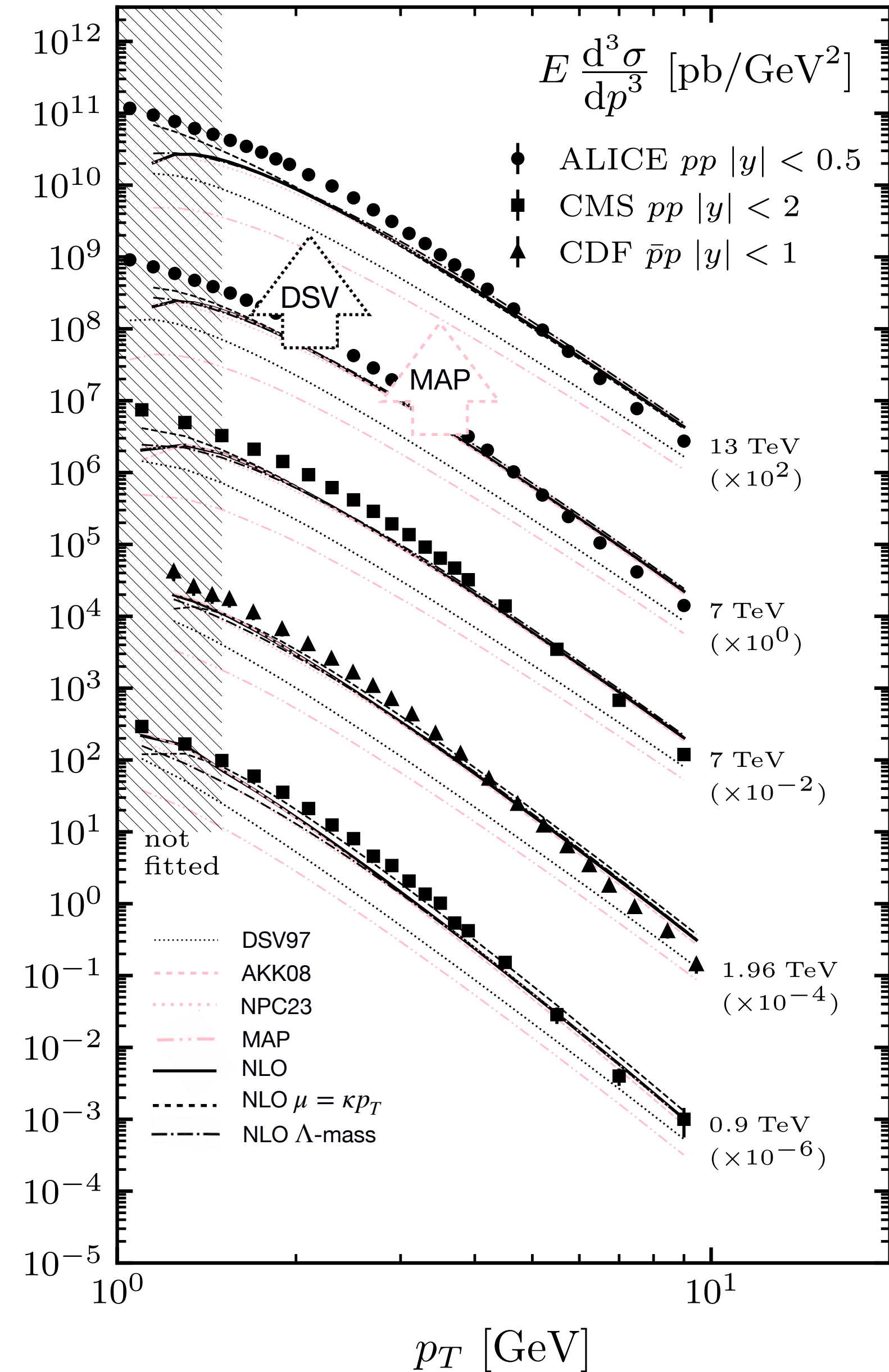
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NNLO corrections not as large

$pp \rightarrow \Lambda + X$ revisited



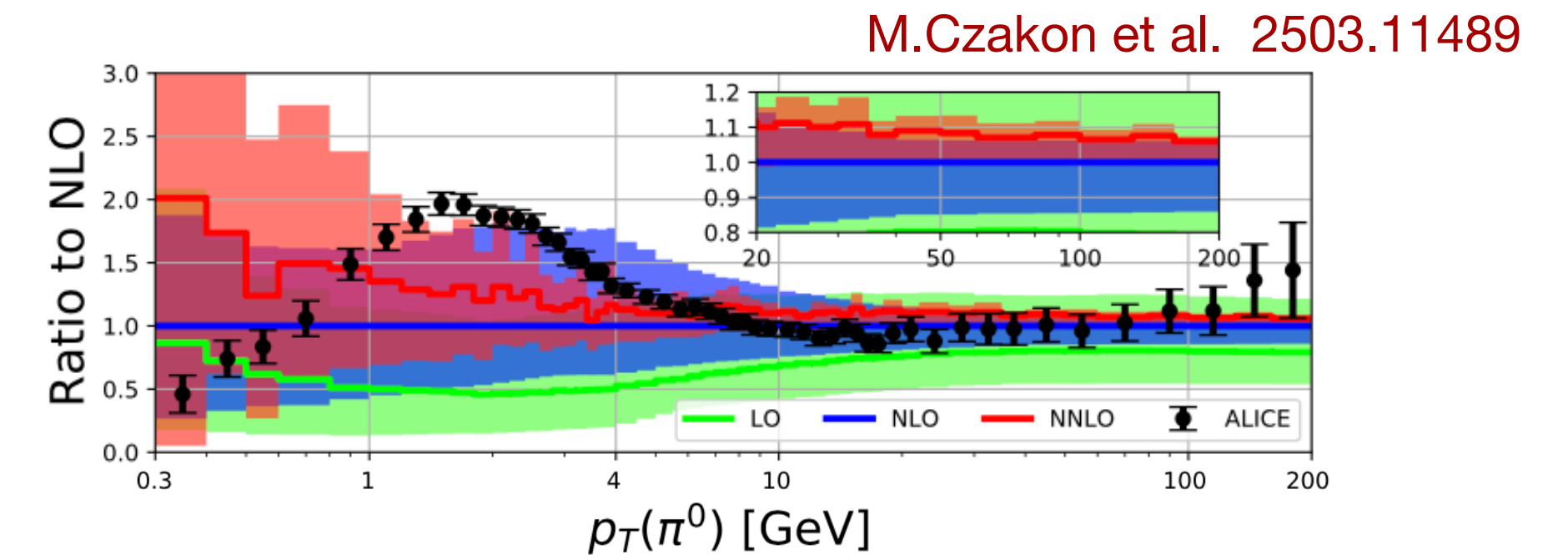
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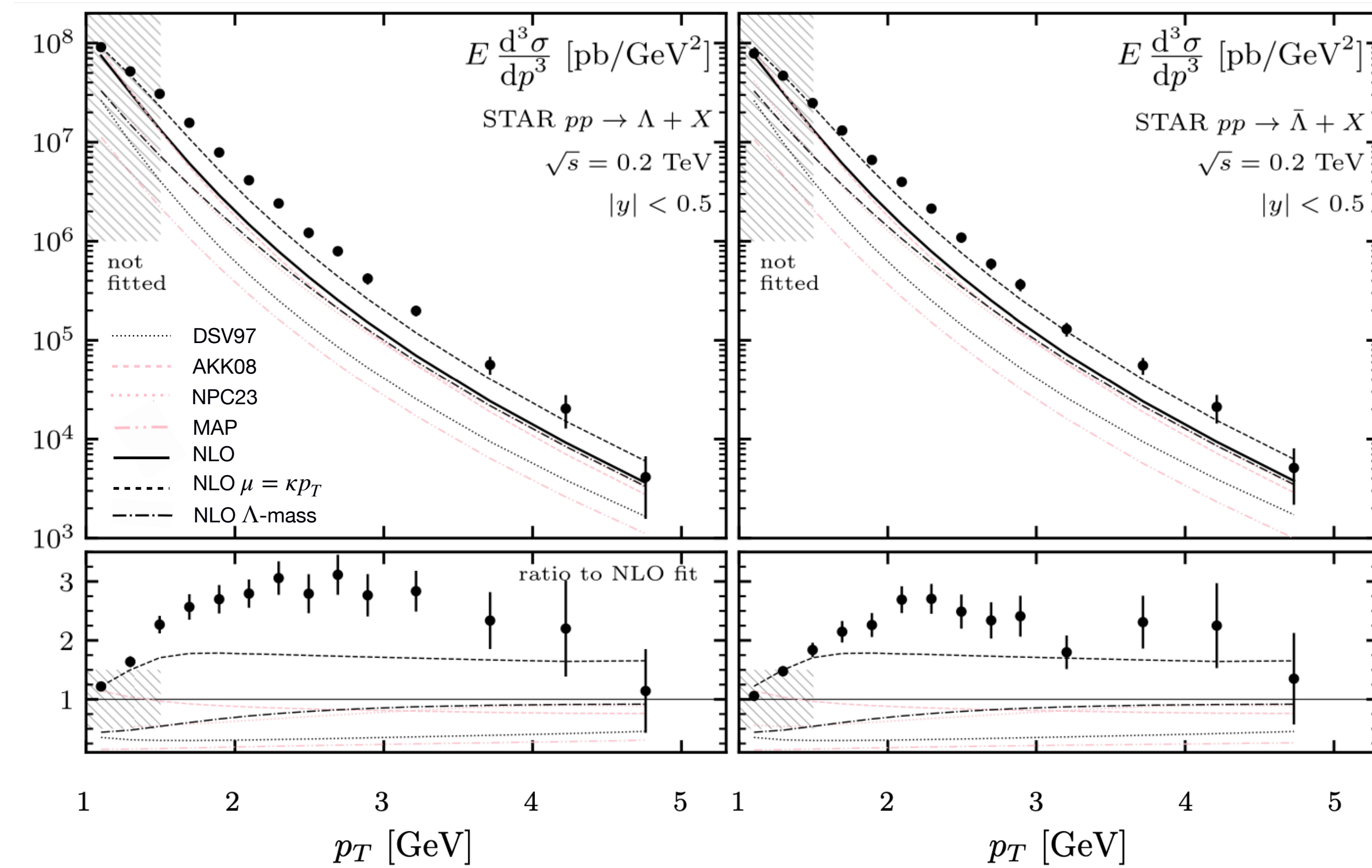


NNLO corrections not as large

hadron mass effects make it worse

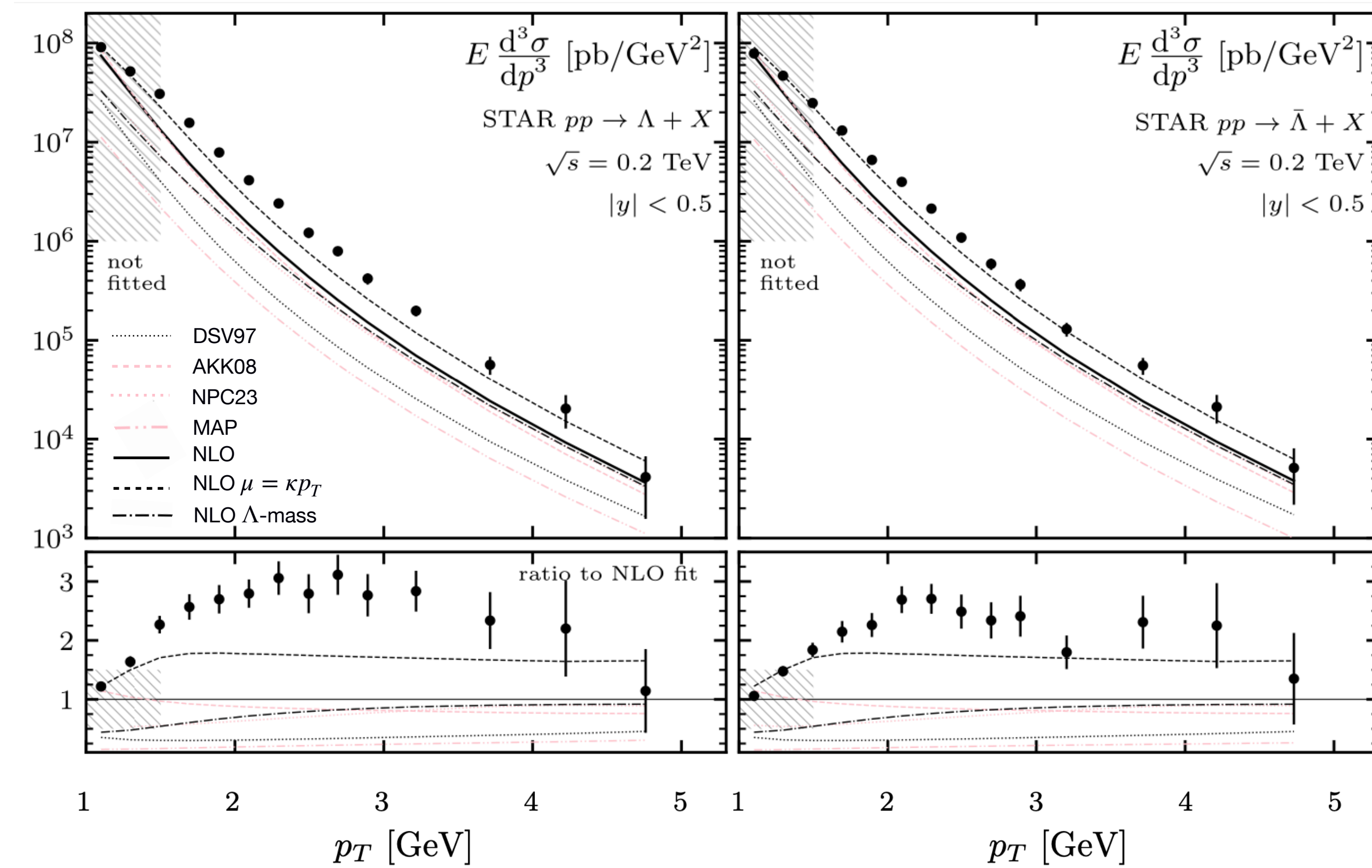
$pp \rightarrow \Lambda + X$ revisited

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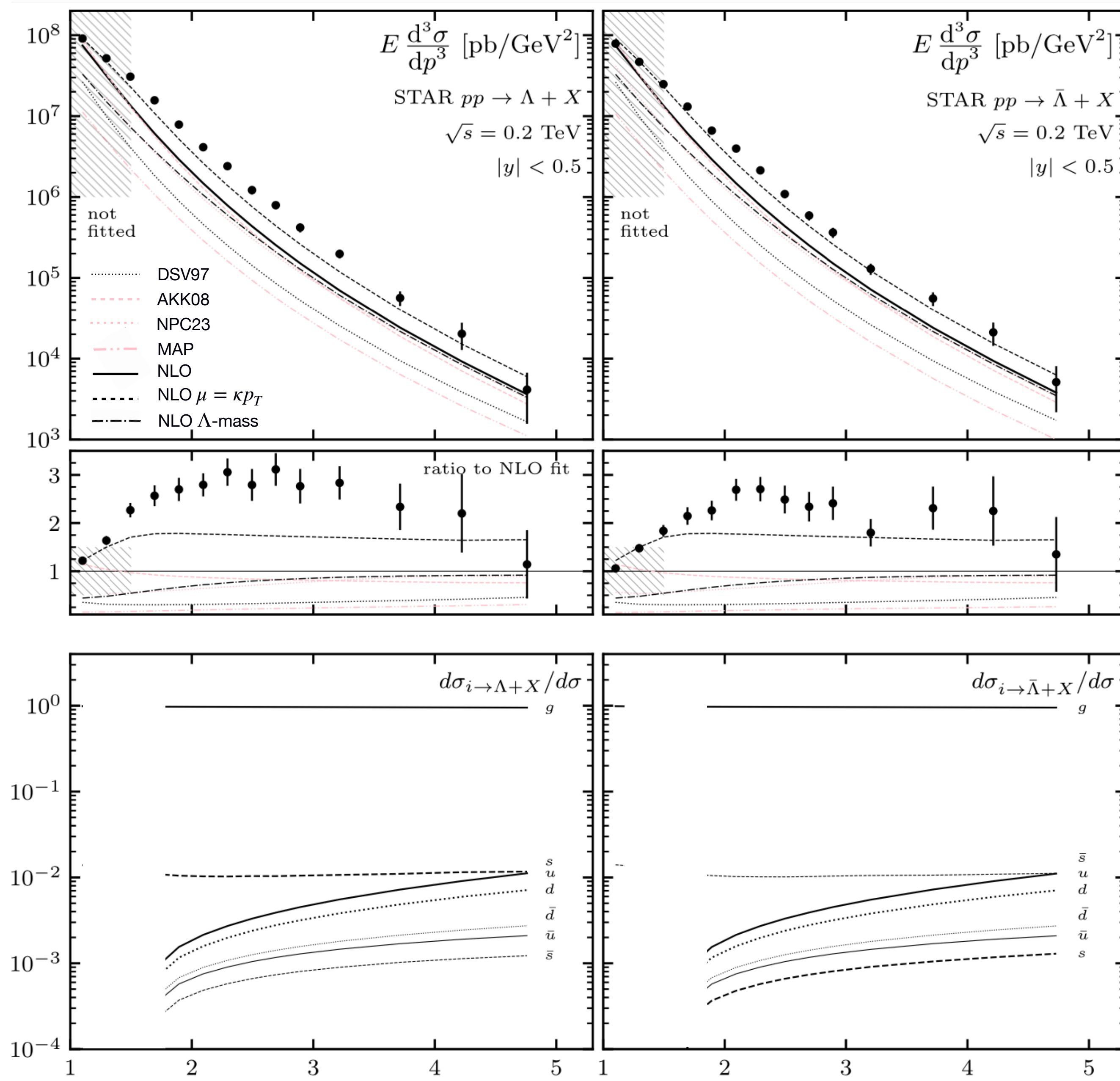
similar or worst for STAR at $\sqrt{s} = 0.2$ TeV

$pp \rightarrow \Lambda + X$ revisited



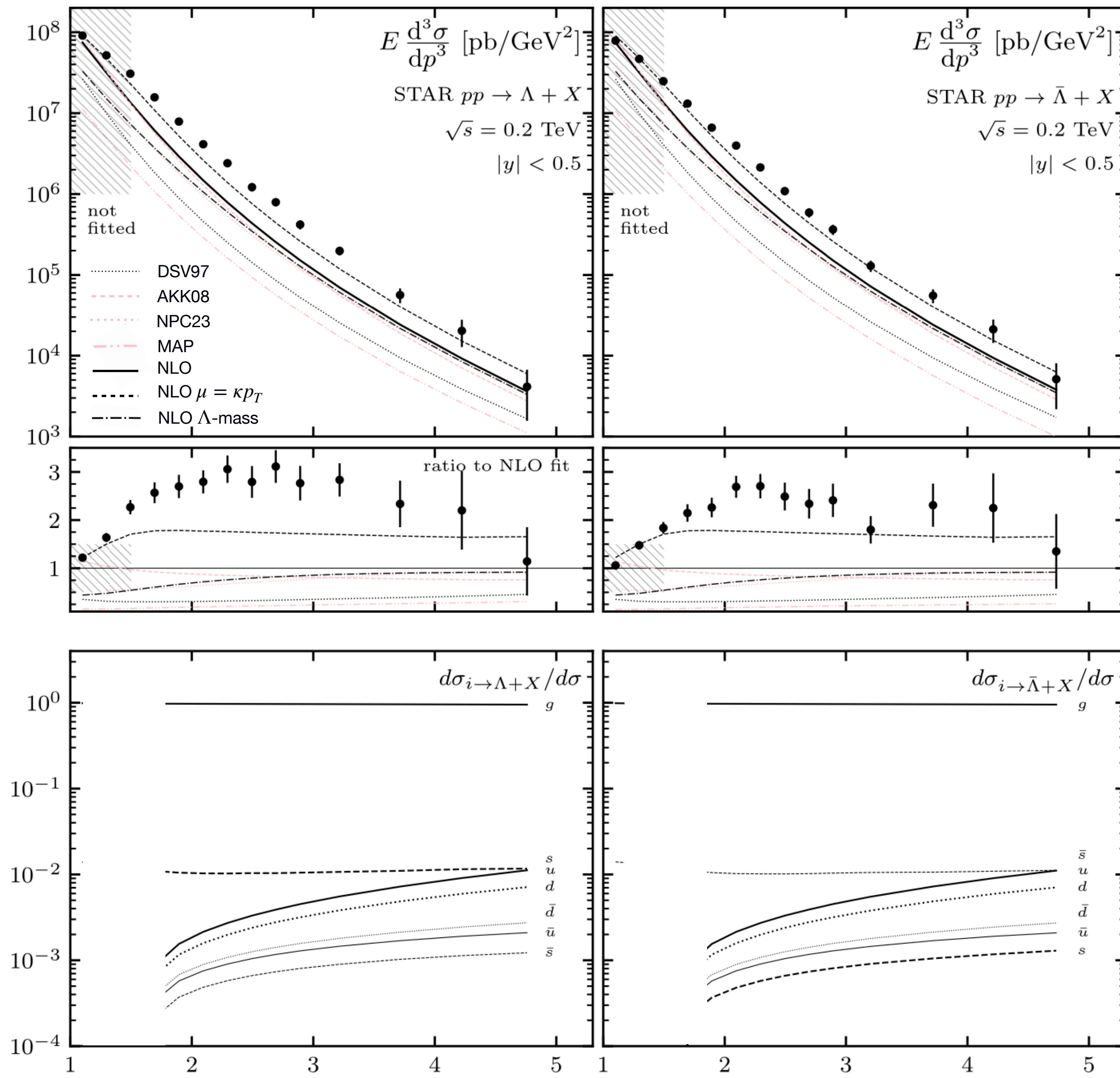
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$pp \rightarrow \Lambda + X$ revisited



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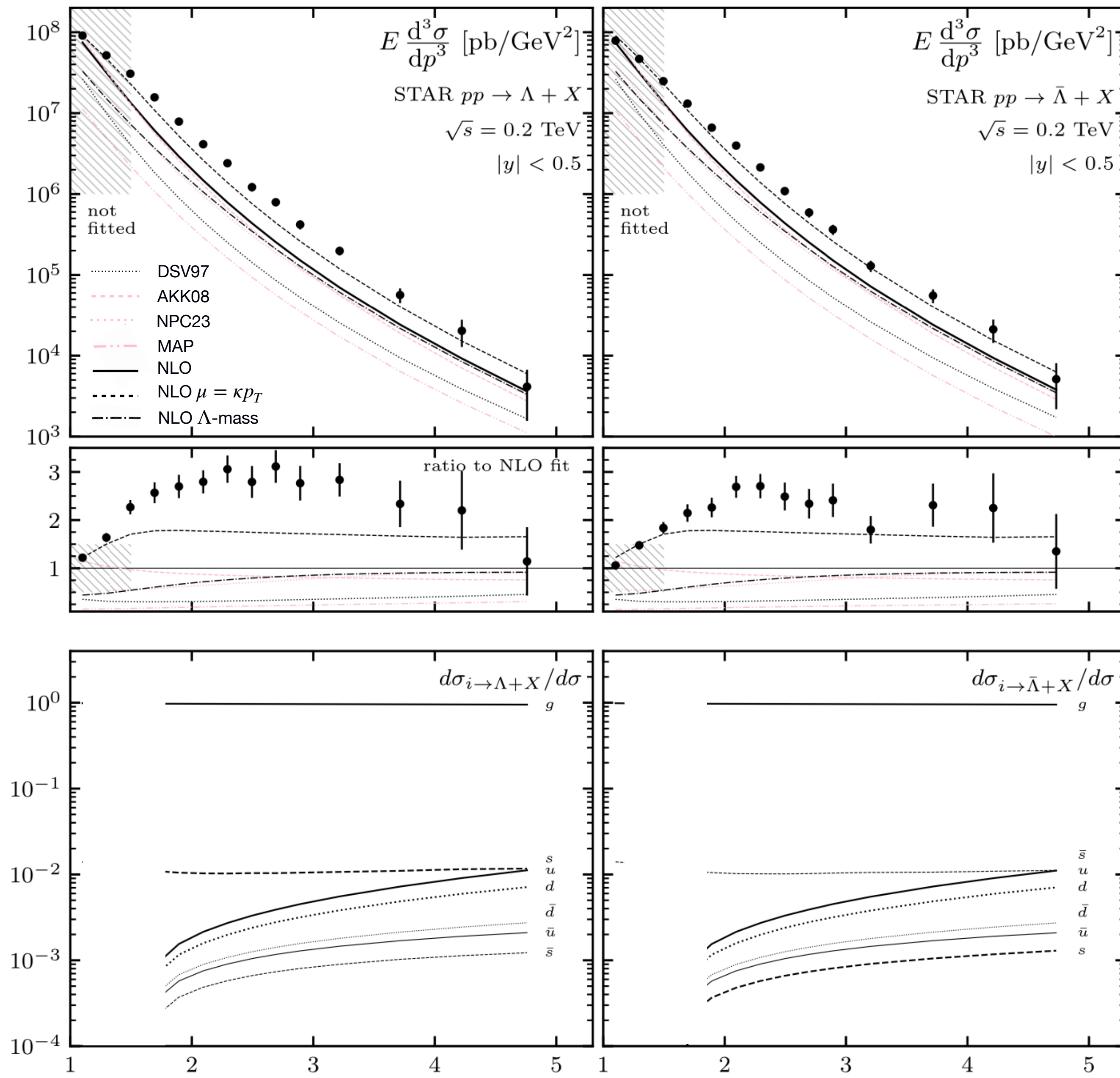


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$pp \rightarrow \Lambda + X$ revisited

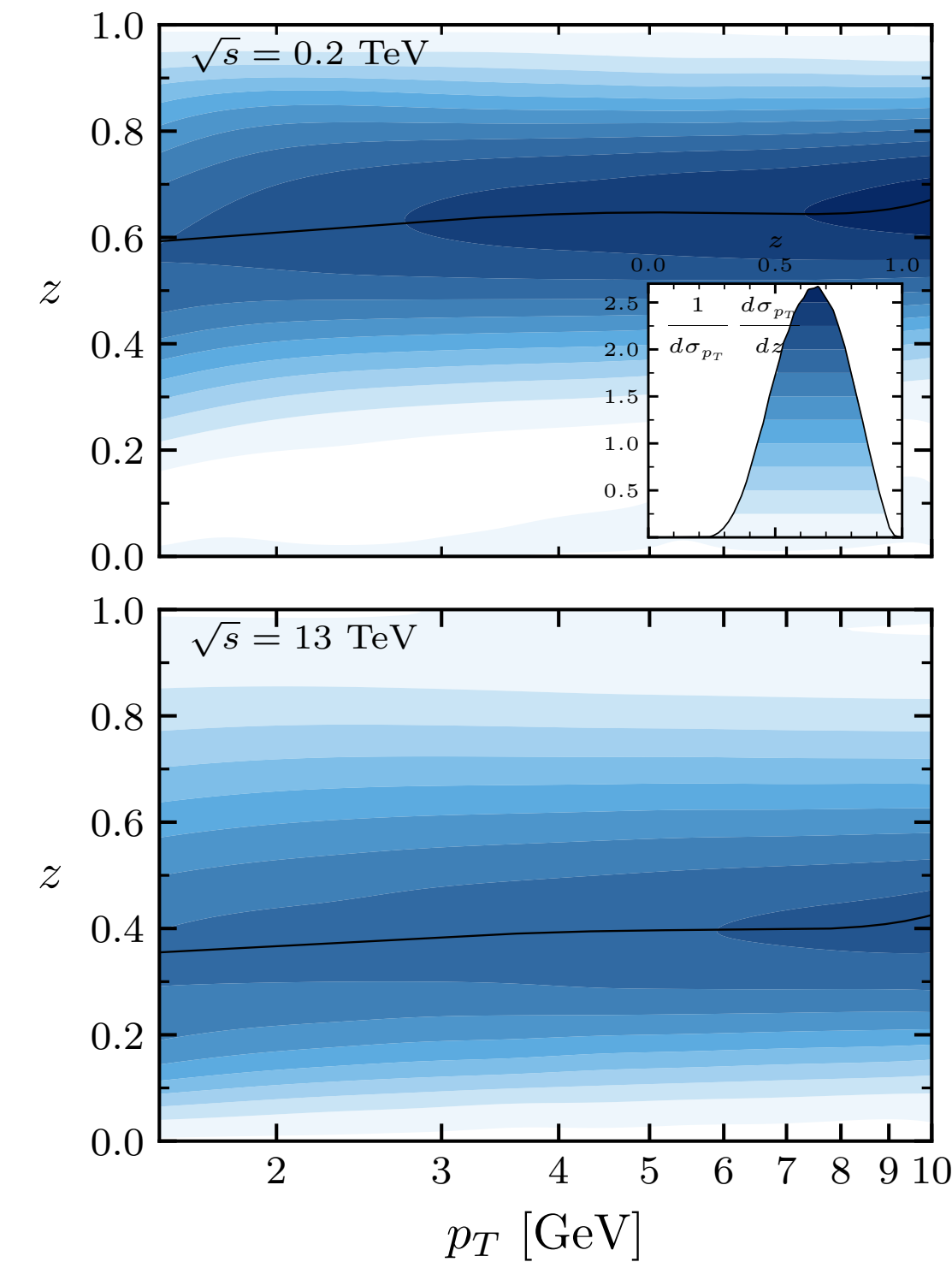


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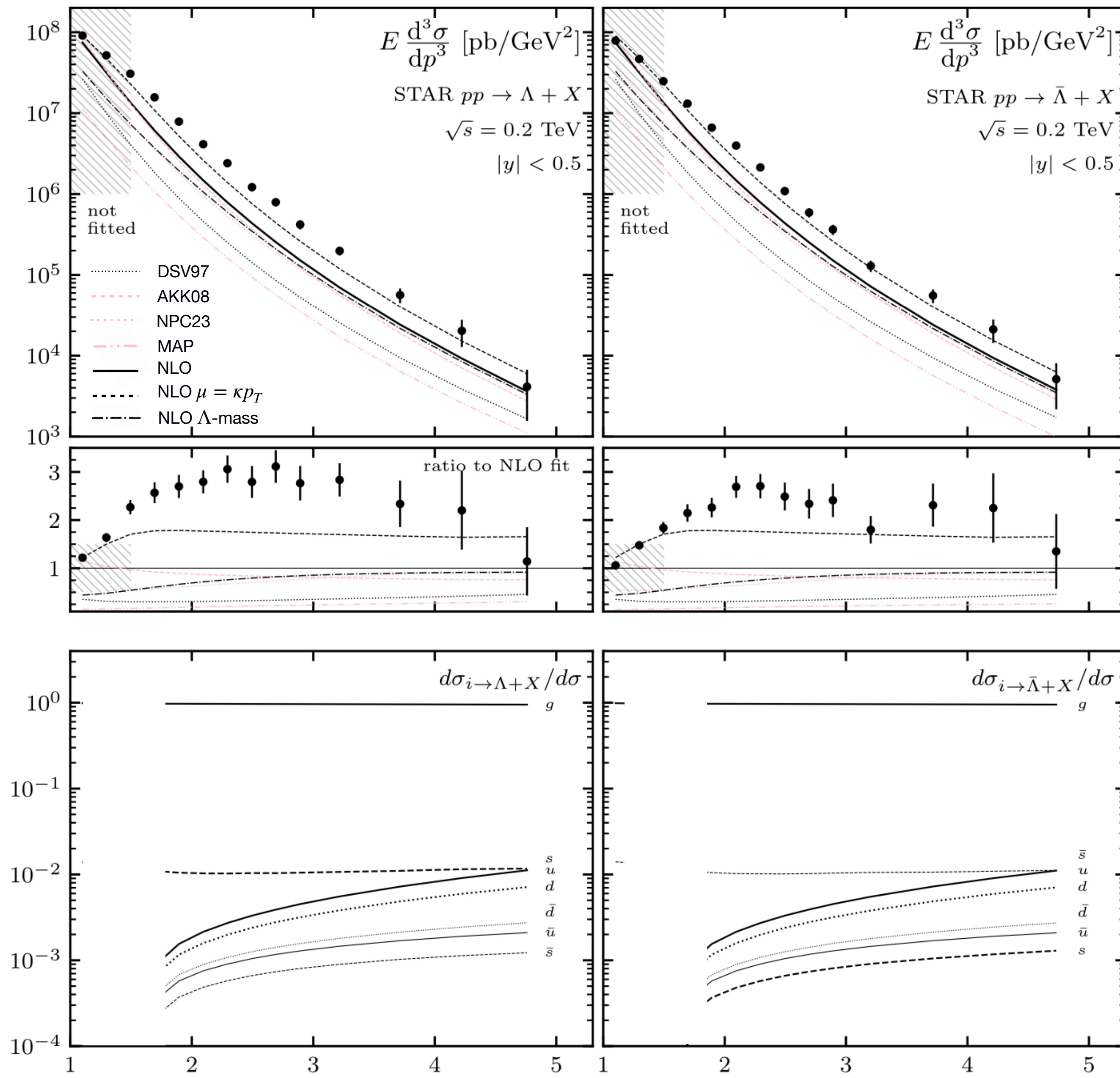
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at a similar z



$pp \rightarrow \Lambda + X$ revisited



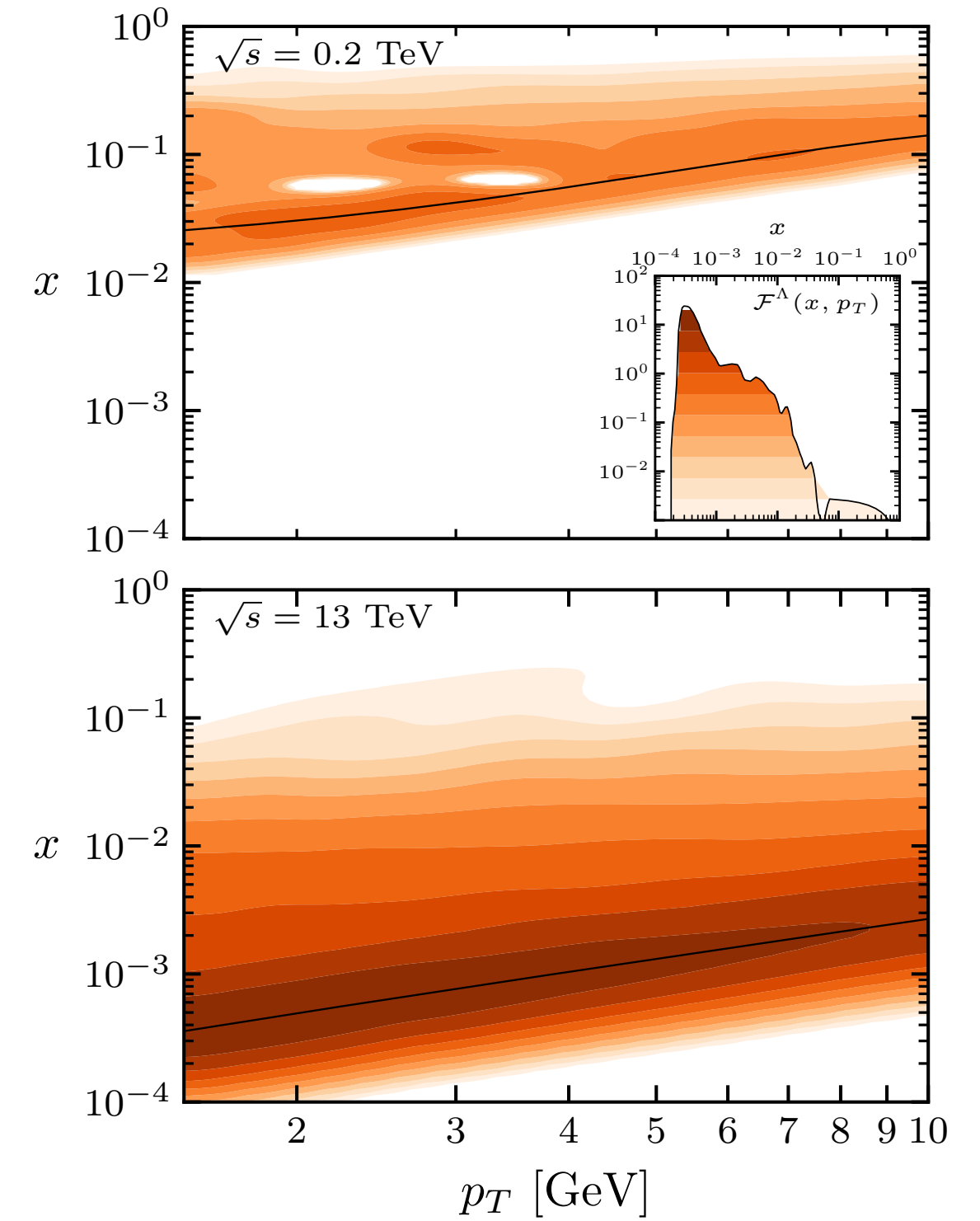
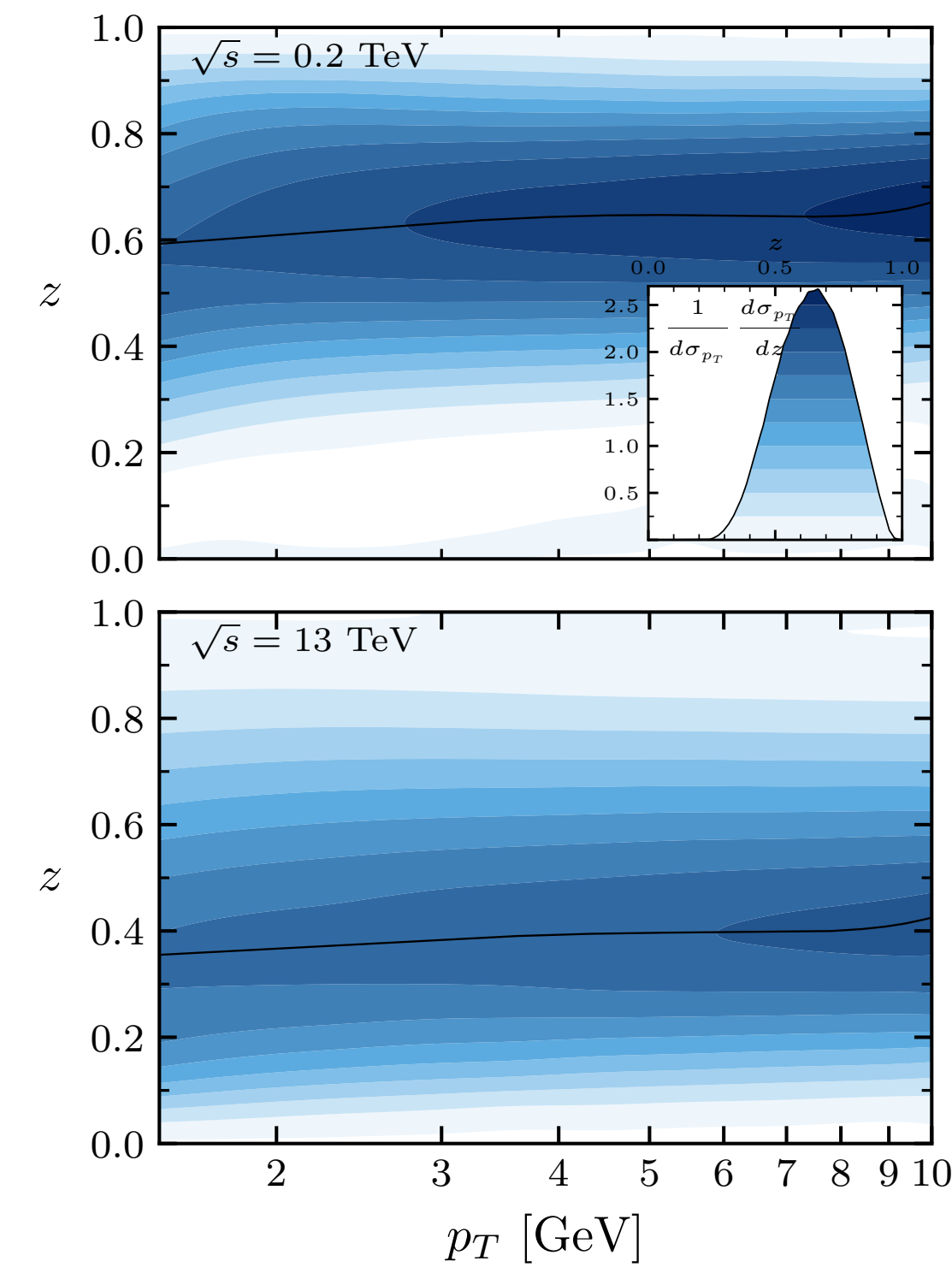
similar or worst for STAR at $\sqrt{s} = 0.2$ TeV

cannot be absorbed into FFs

dominated by D_g^Λ

at a similar z

at safe x



non-perturbative effects?

non-perturbative effects?

~higher twists/power corrections?

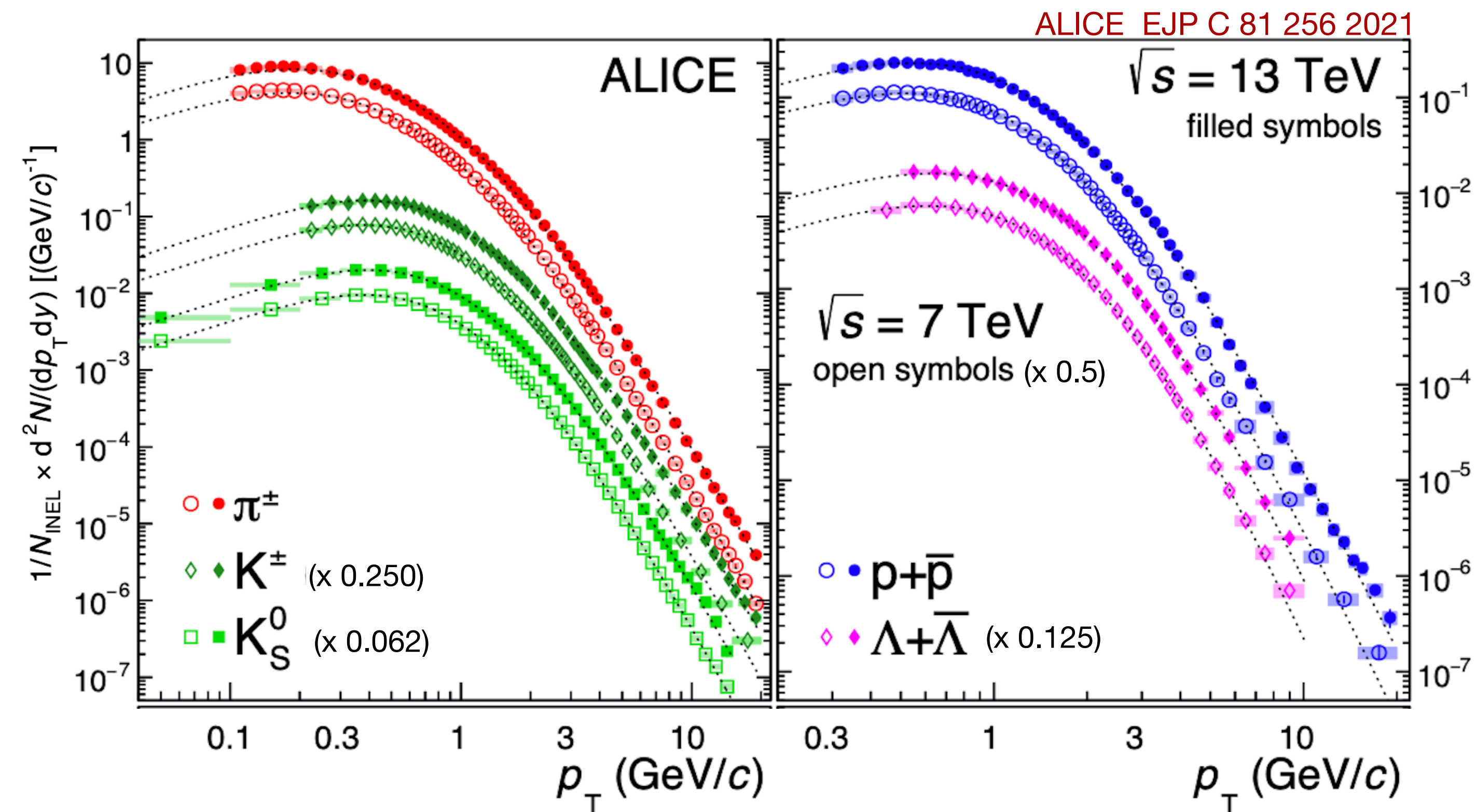
non-perturbative effects?

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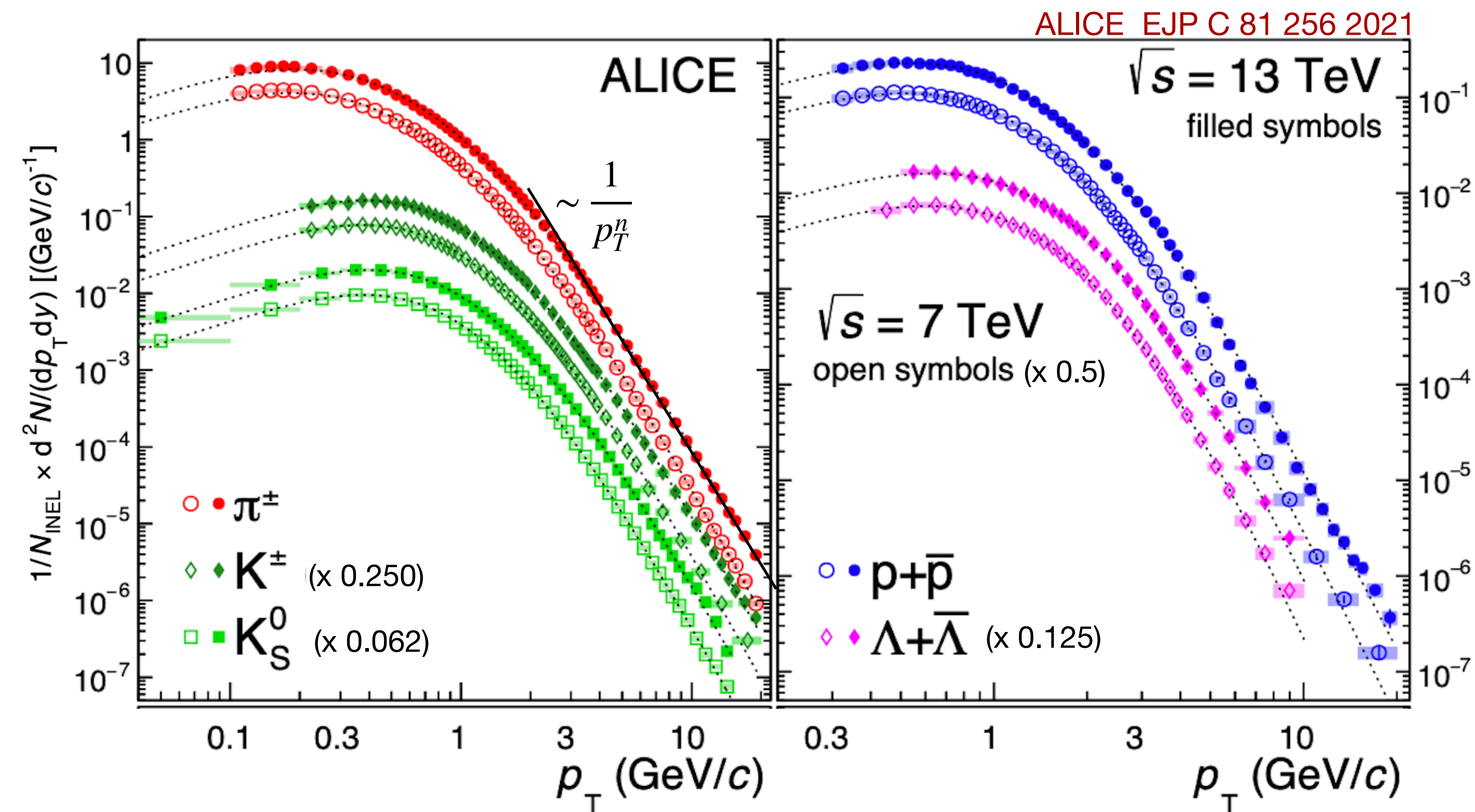
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missing logarithmic resummation?

noticed since CERN ISR



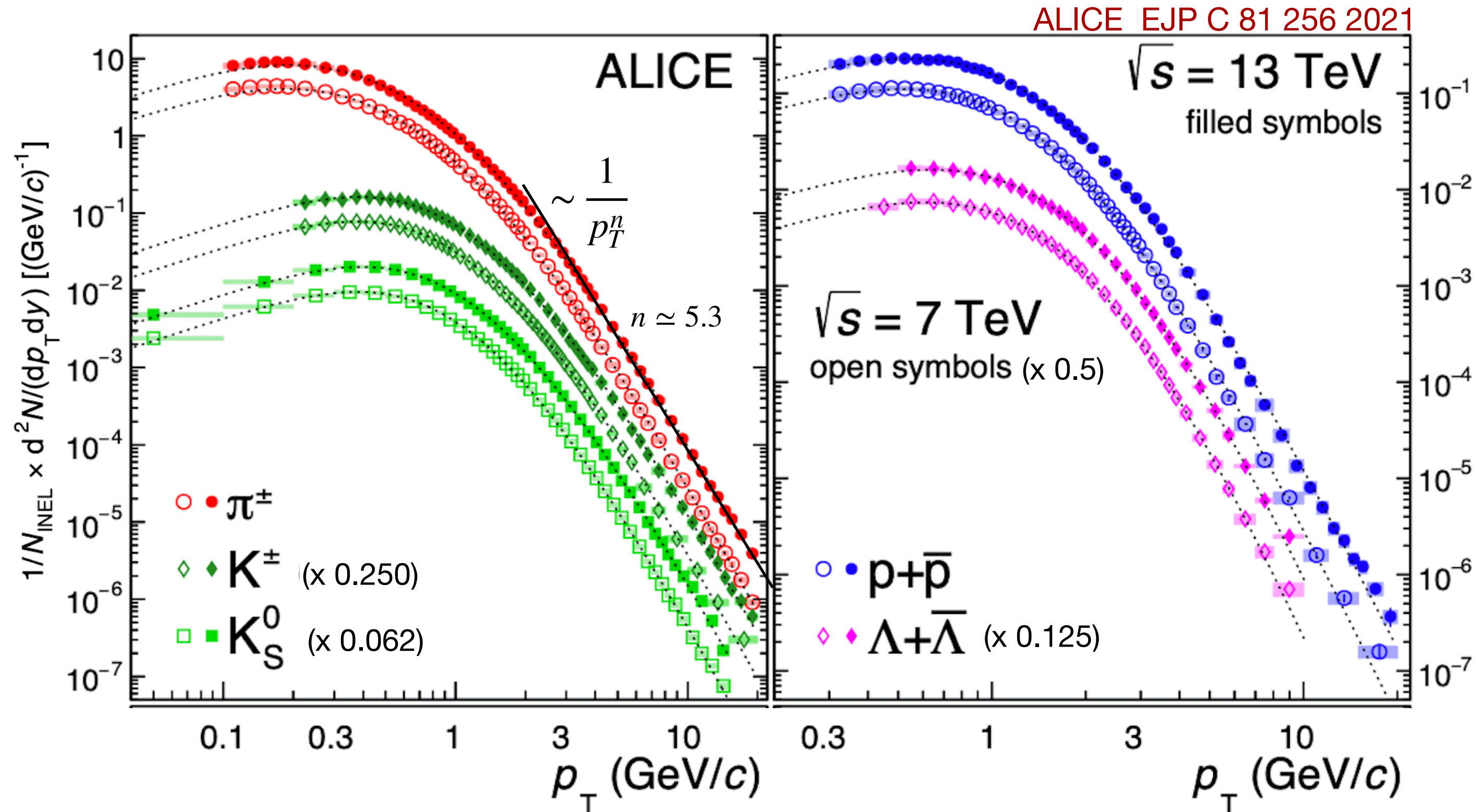
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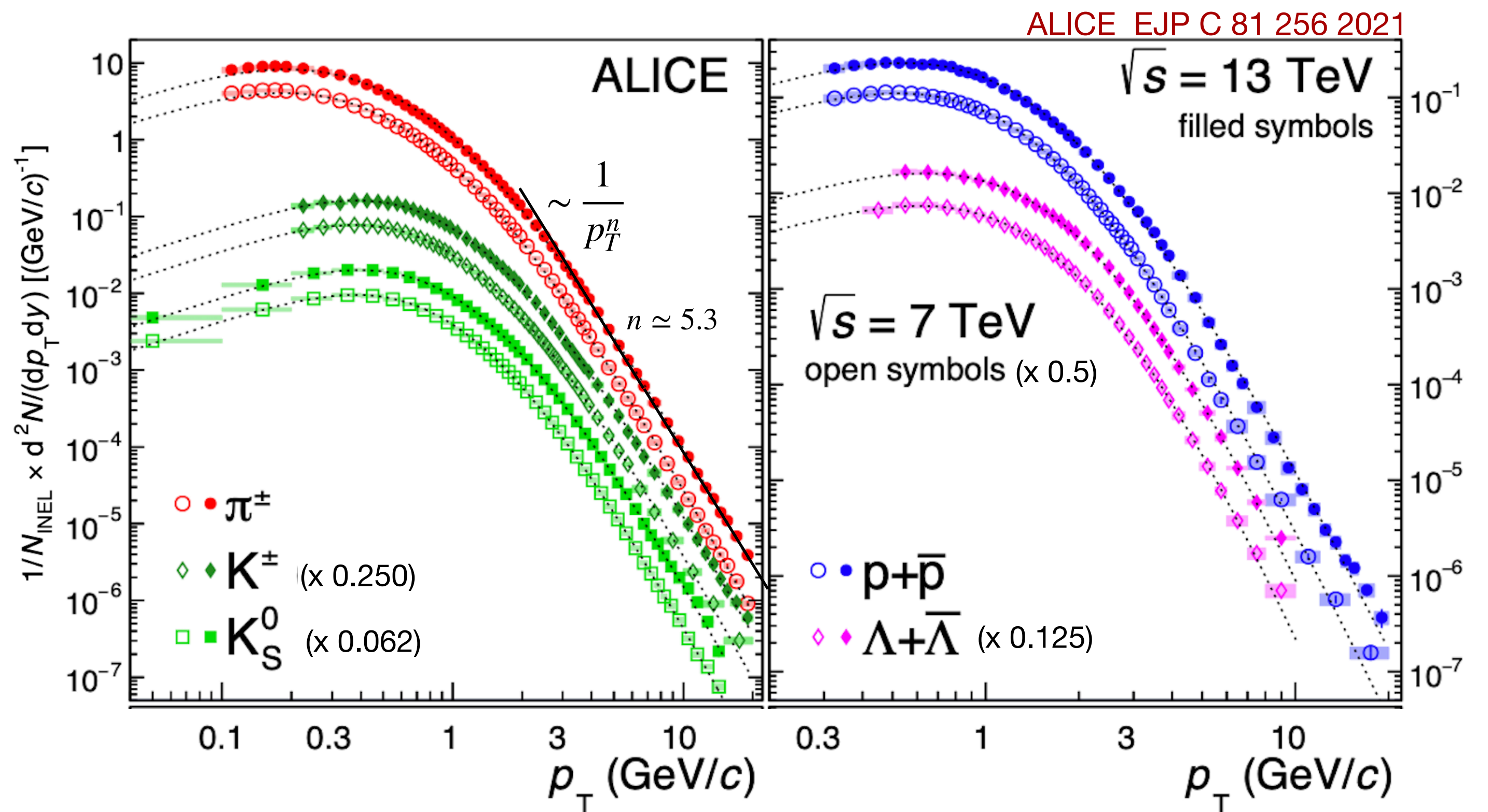
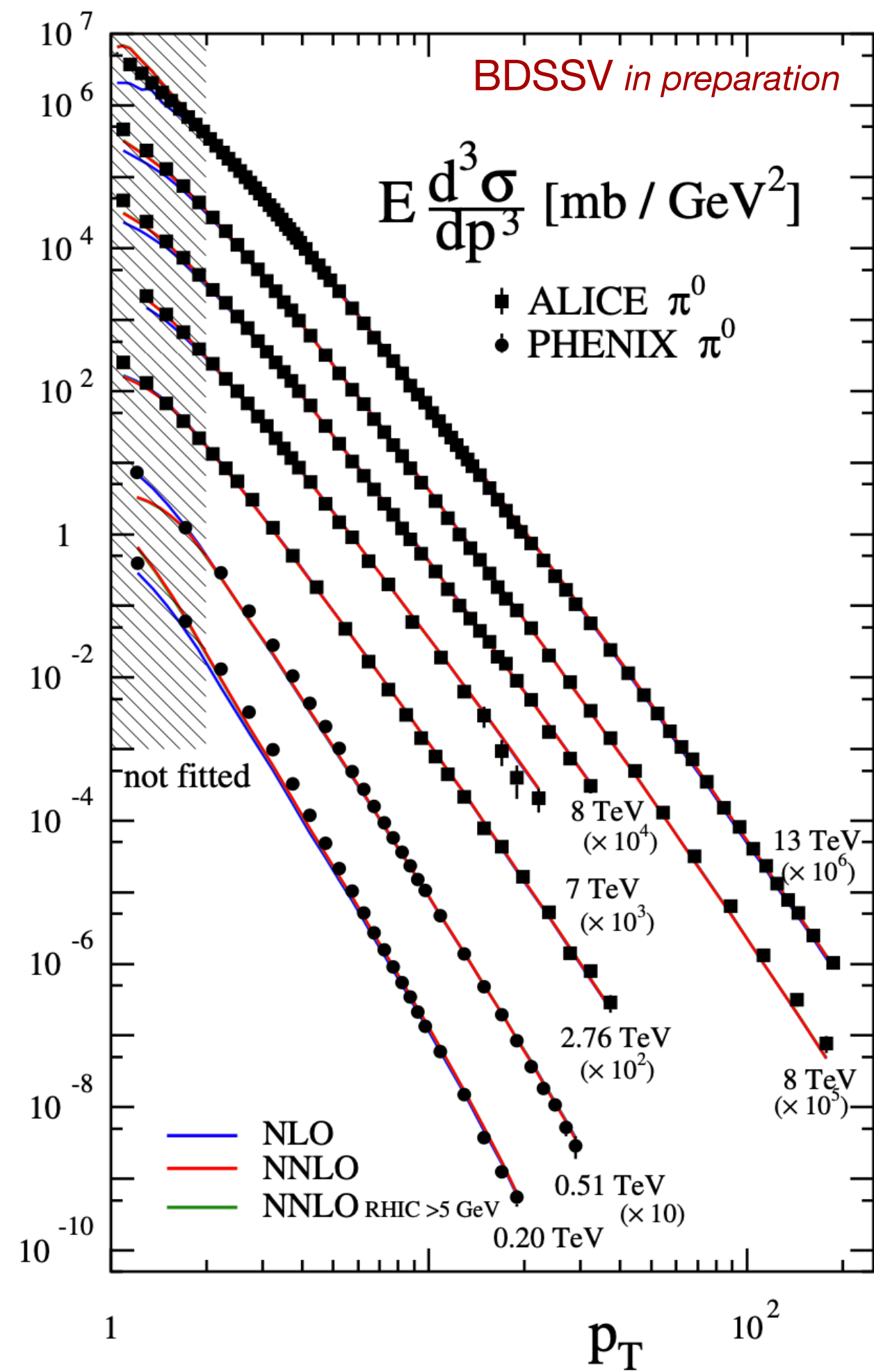
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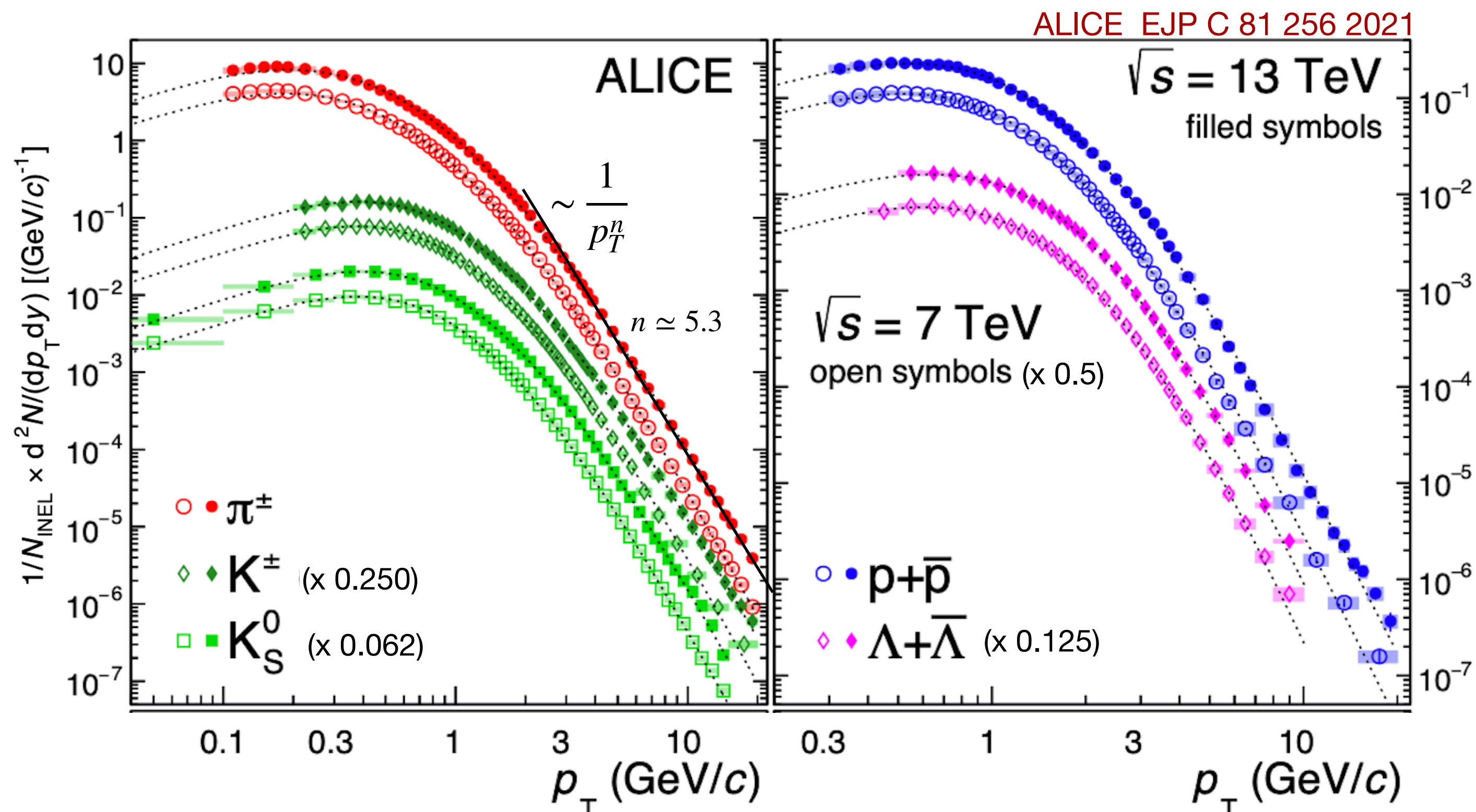
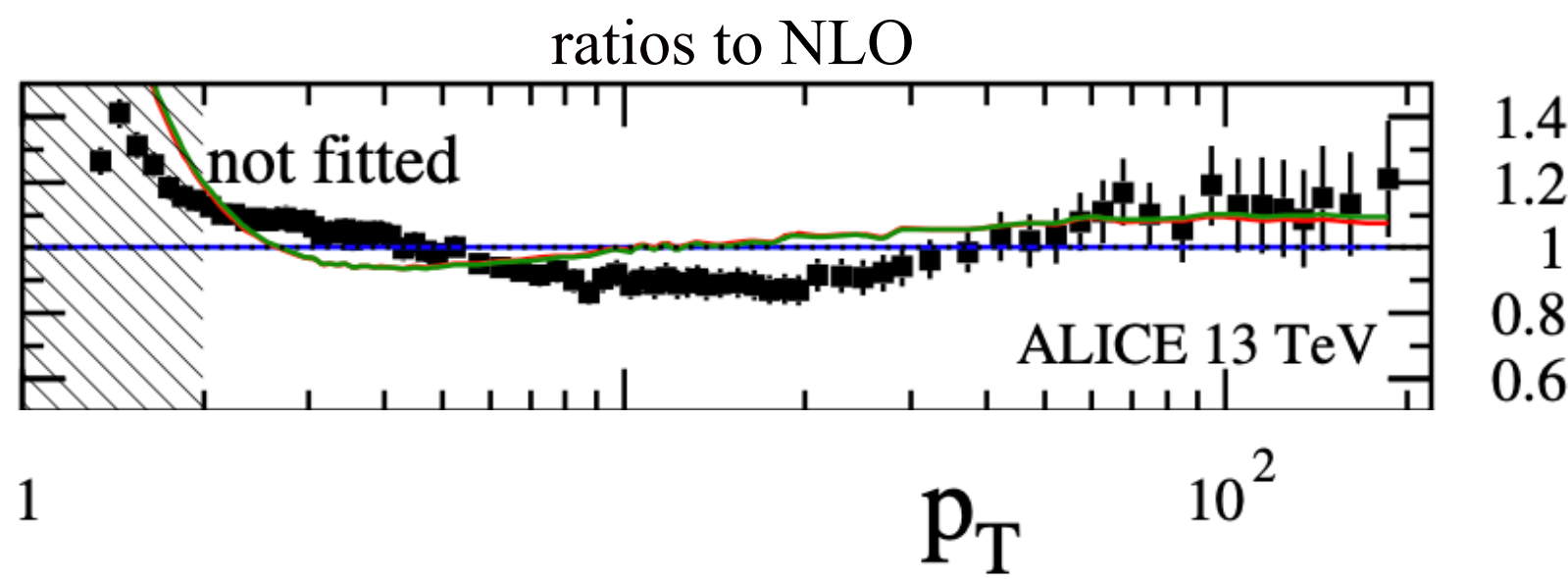
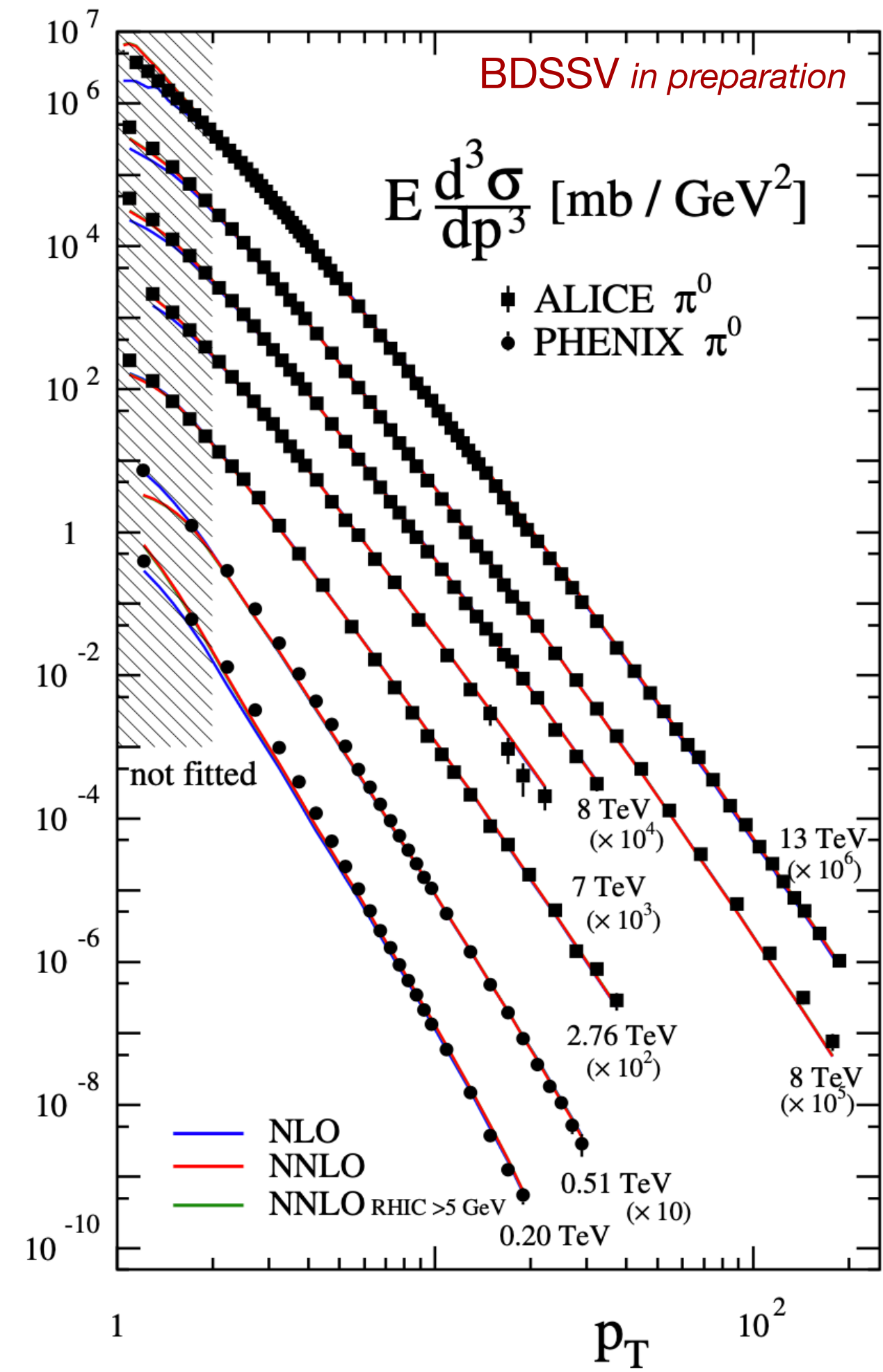
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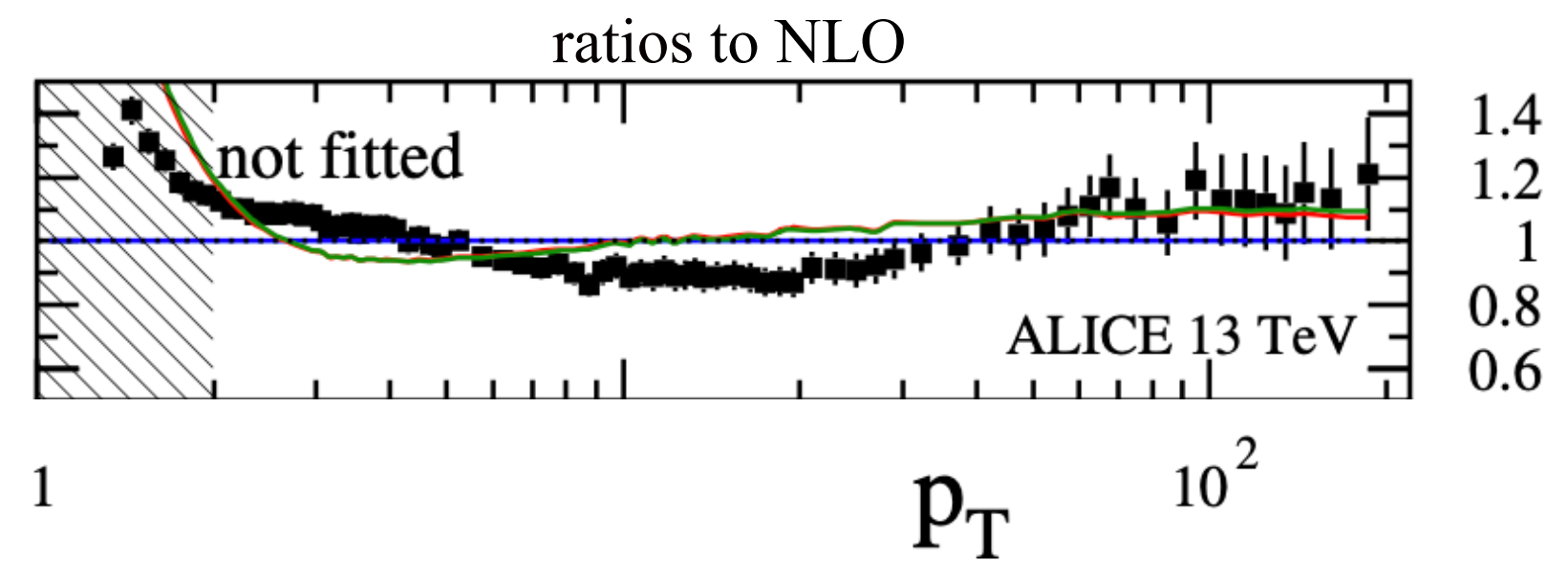
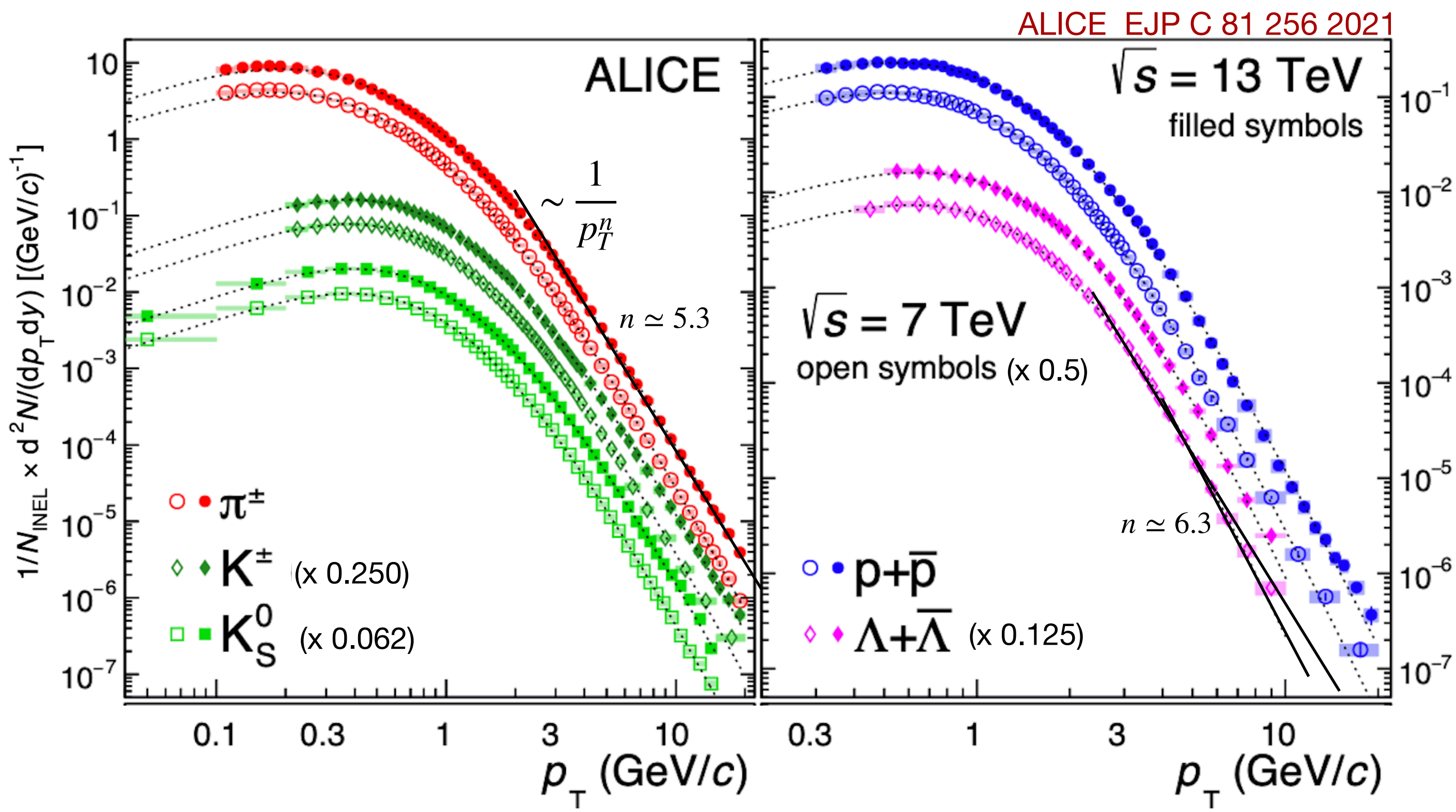
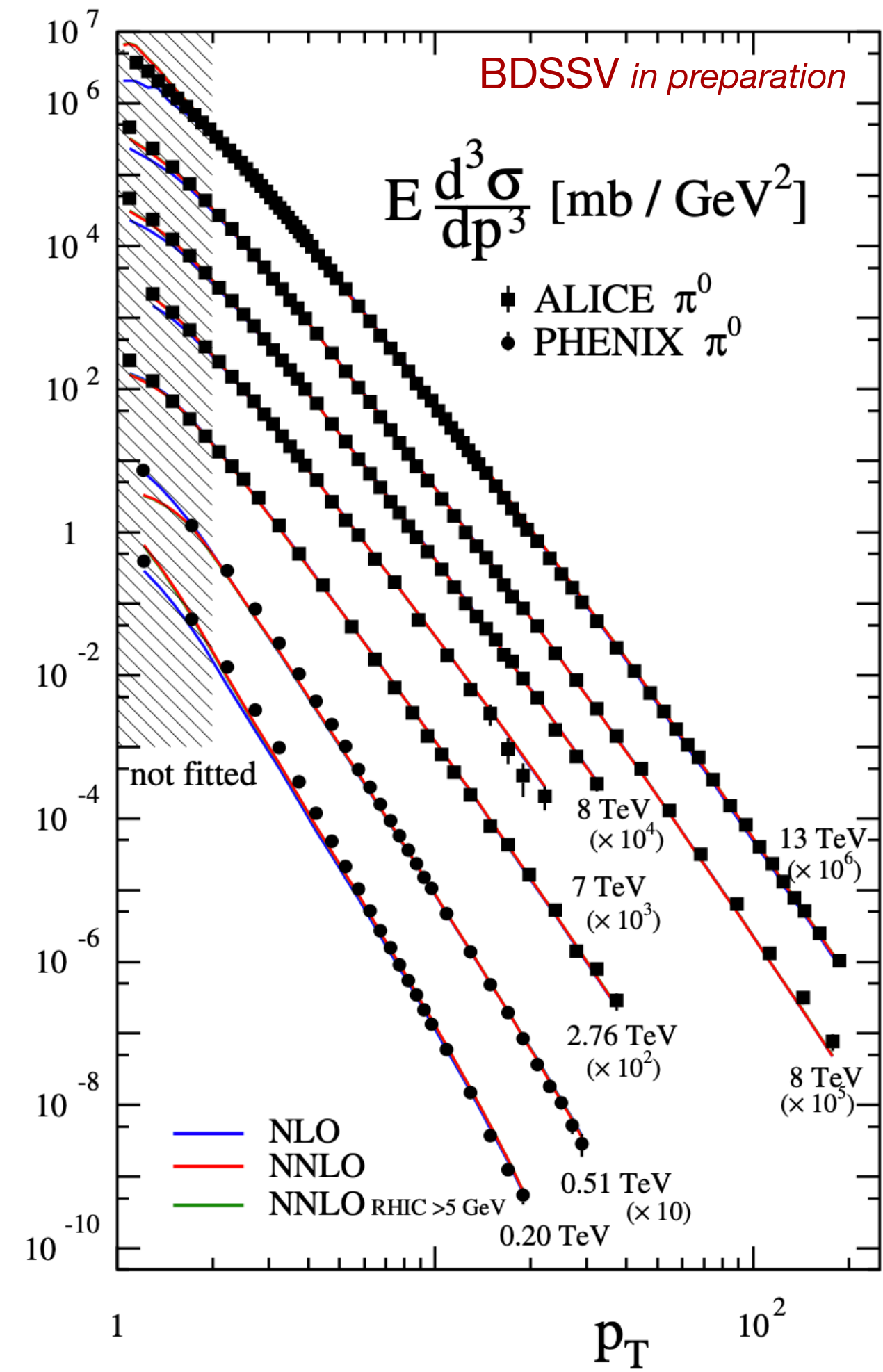
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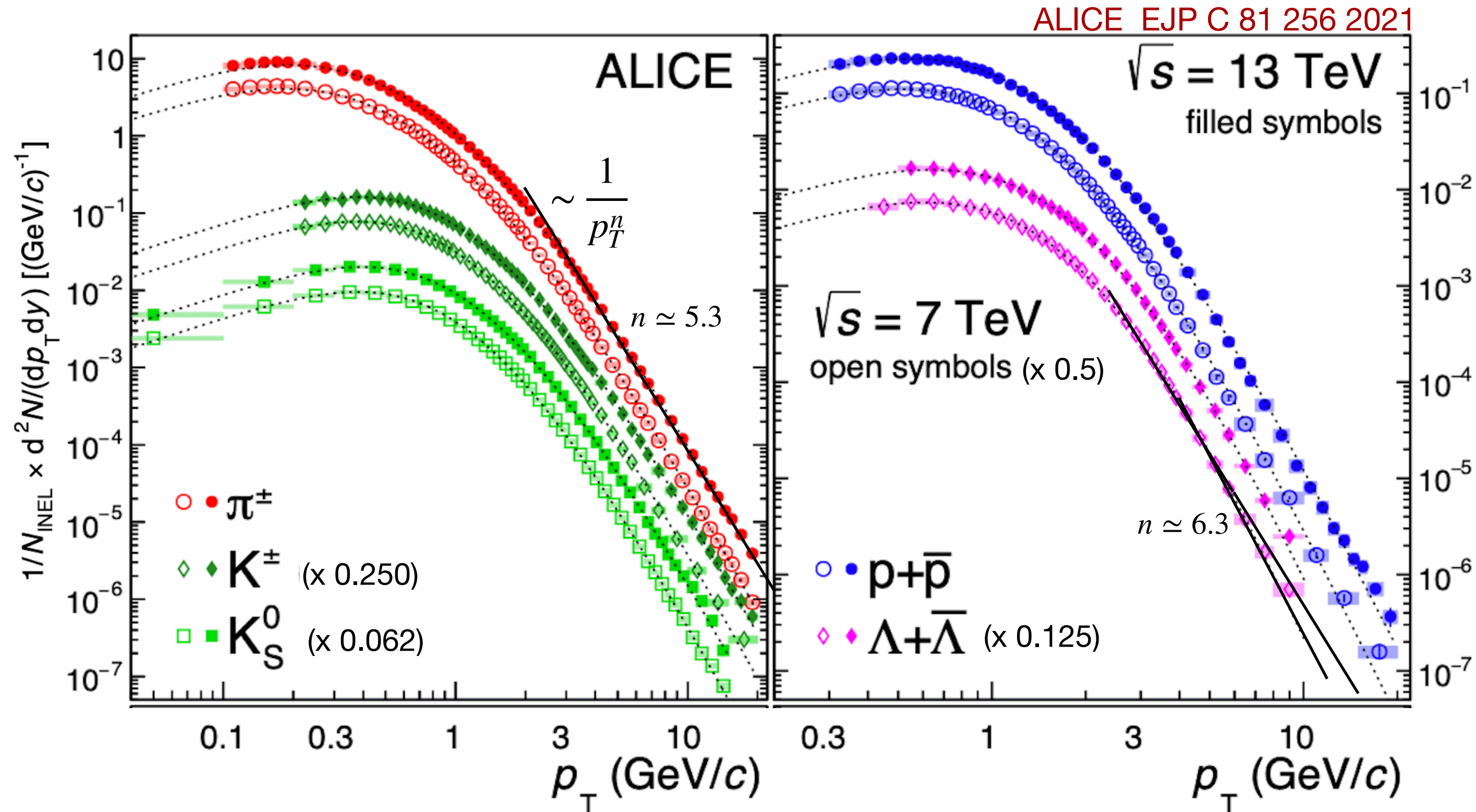
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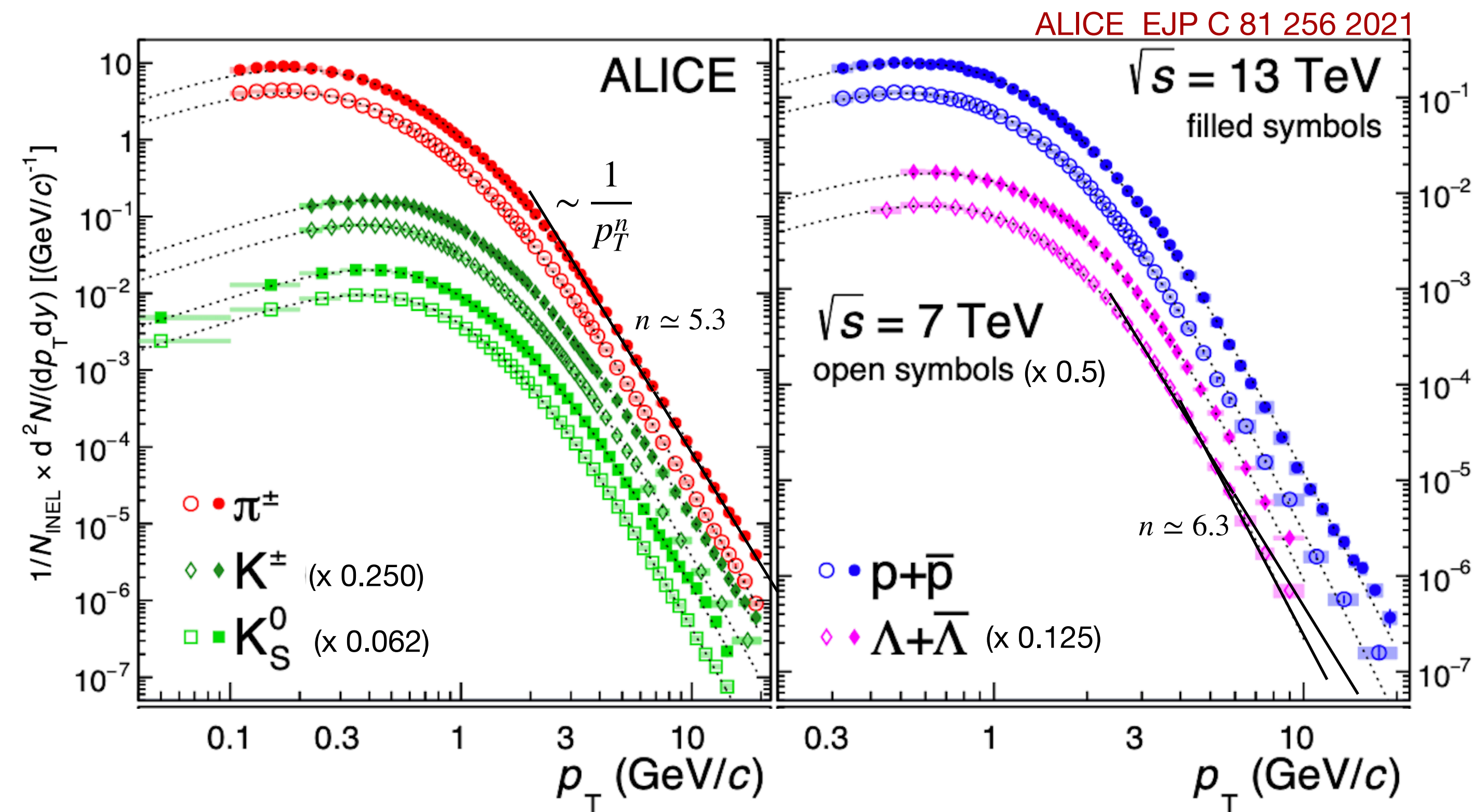
S. Brodsky, R. Farrar PRL 31 1153 1973
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“ x_T scaling”

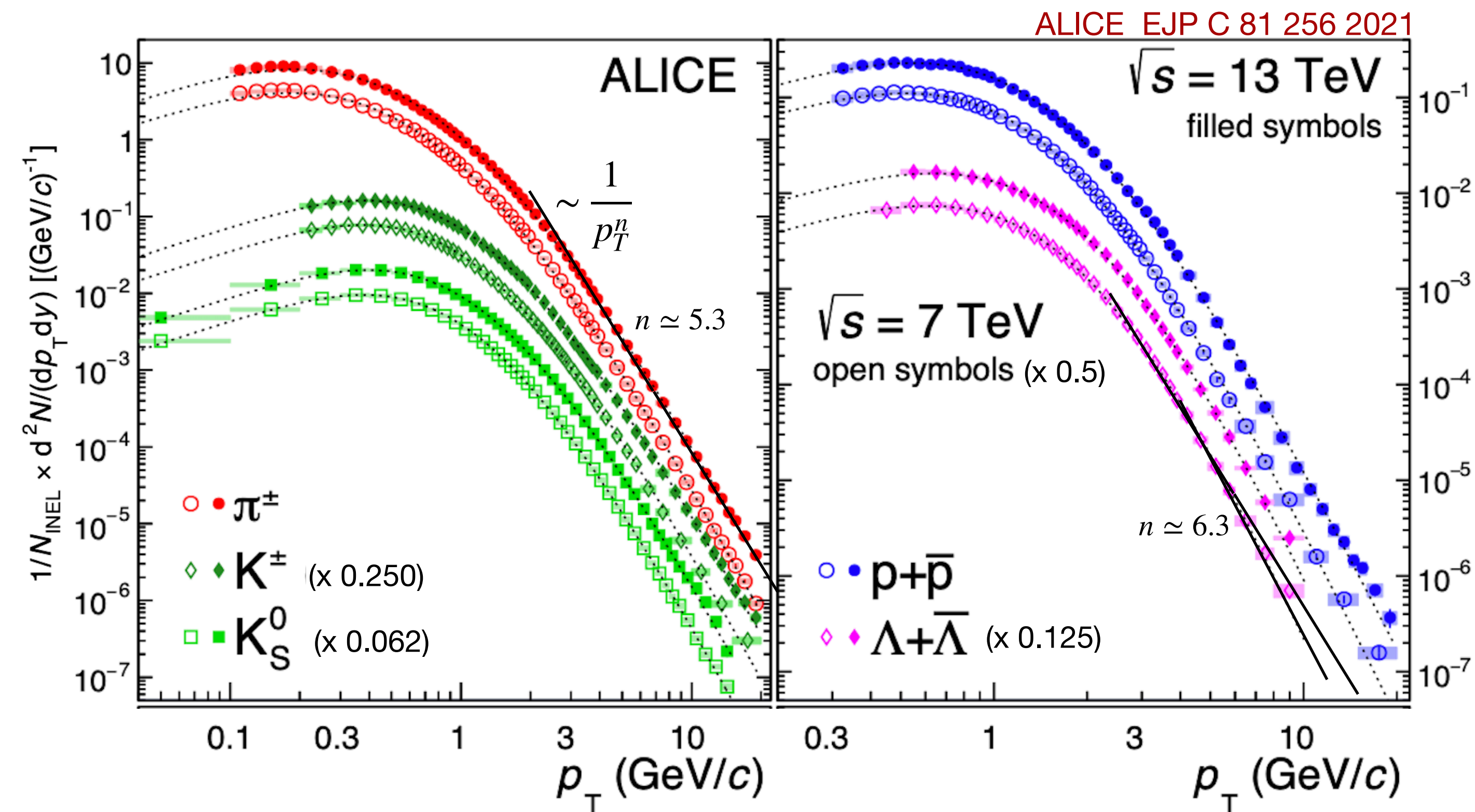
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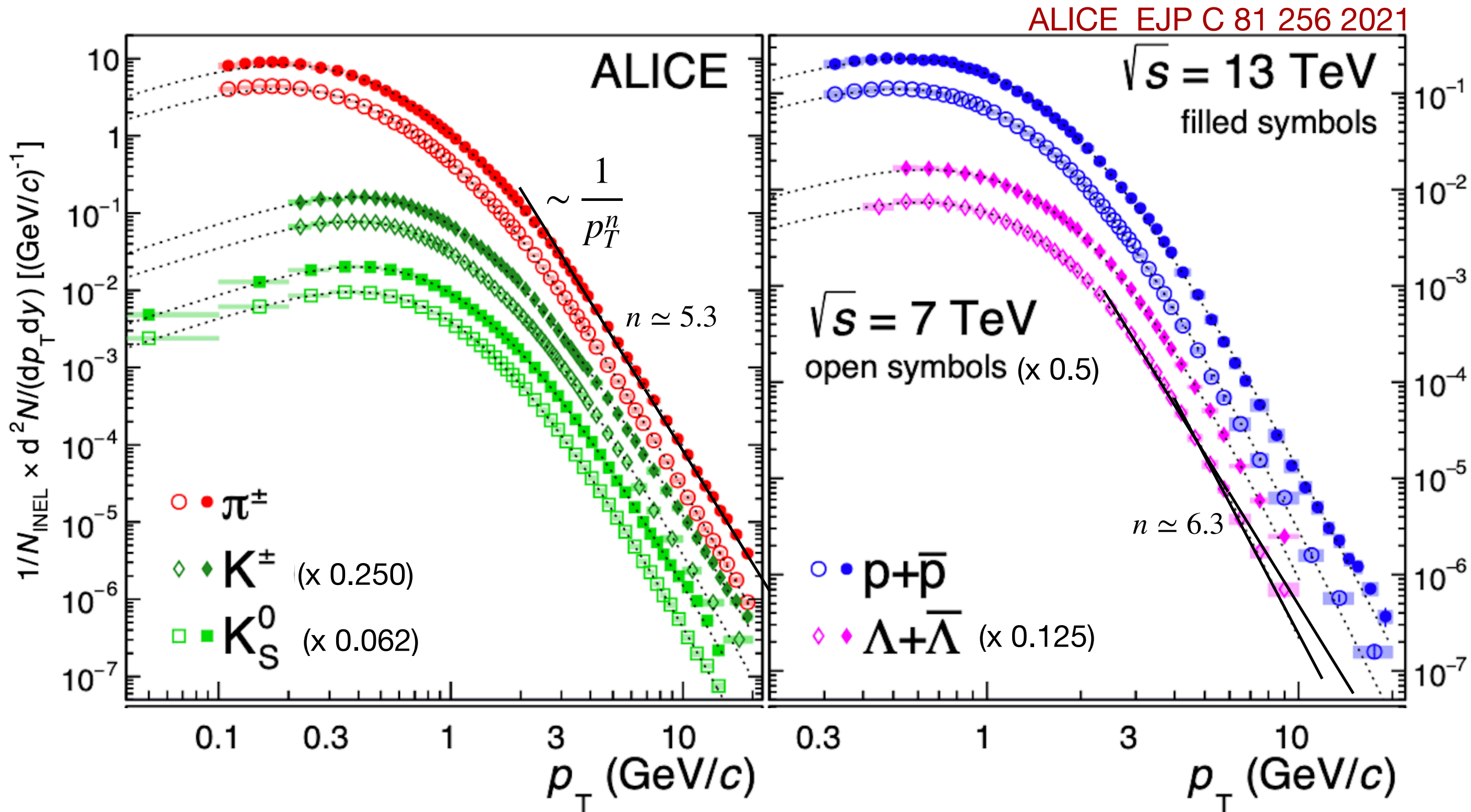
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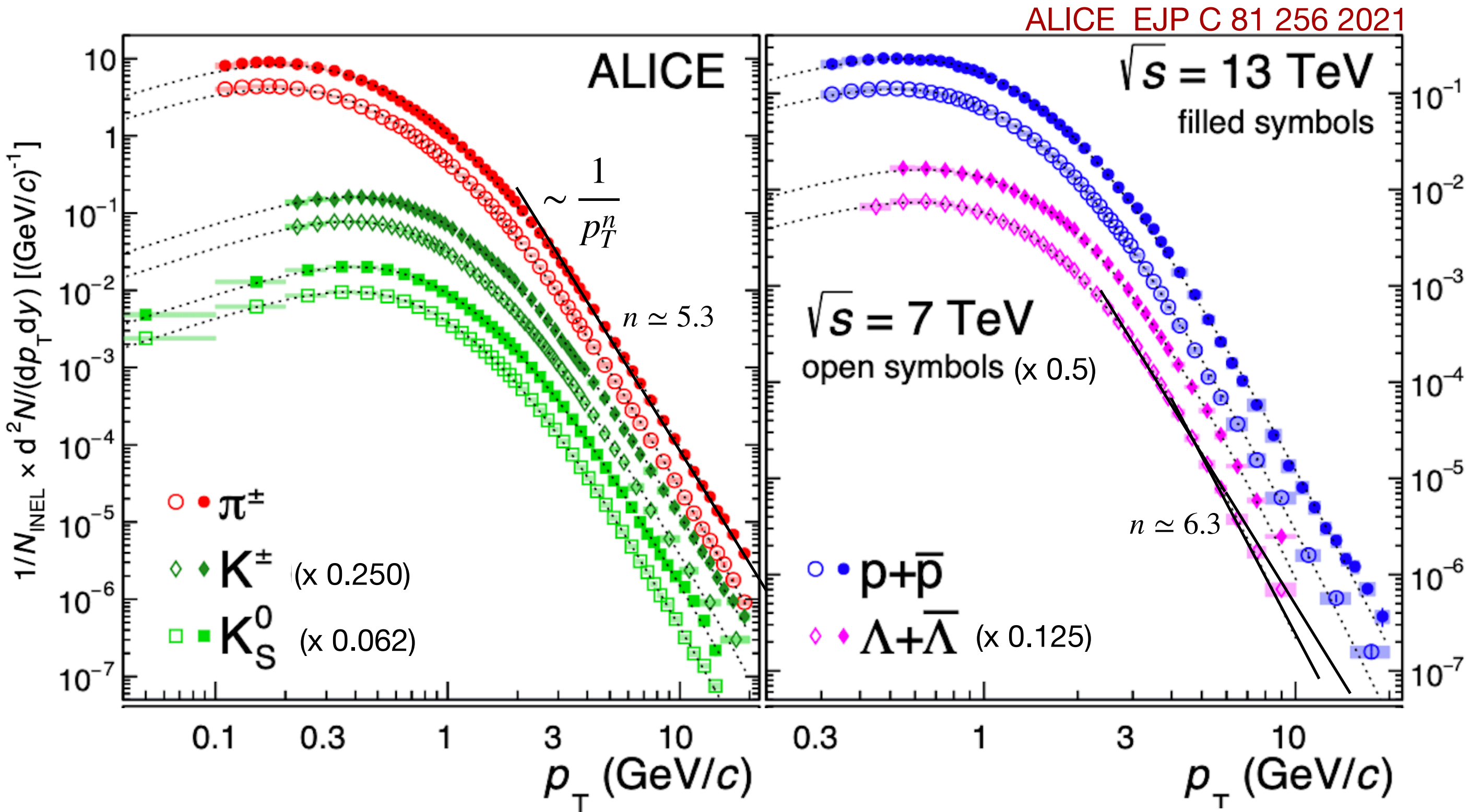
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$$2 \longrightarrow 2 \quad n = 4$$

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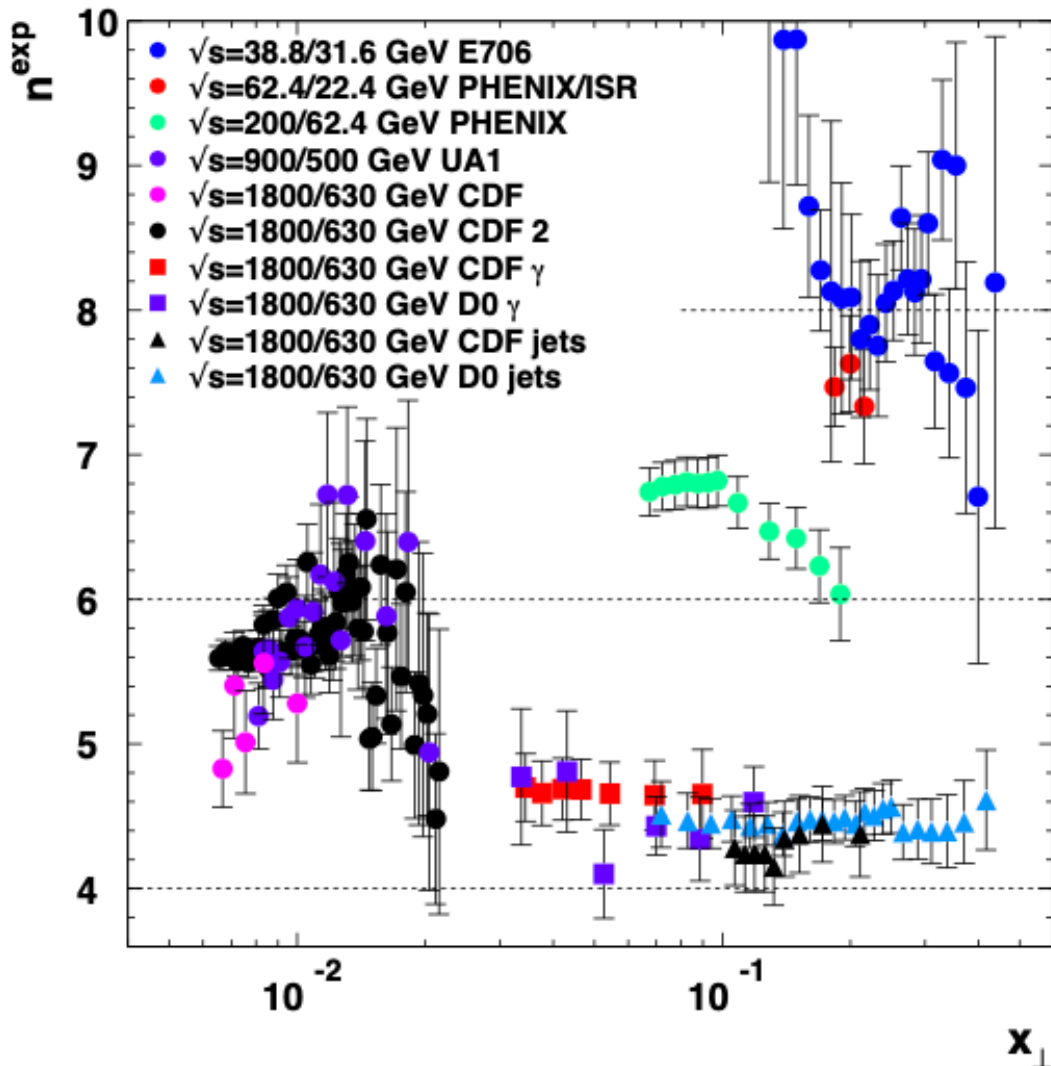


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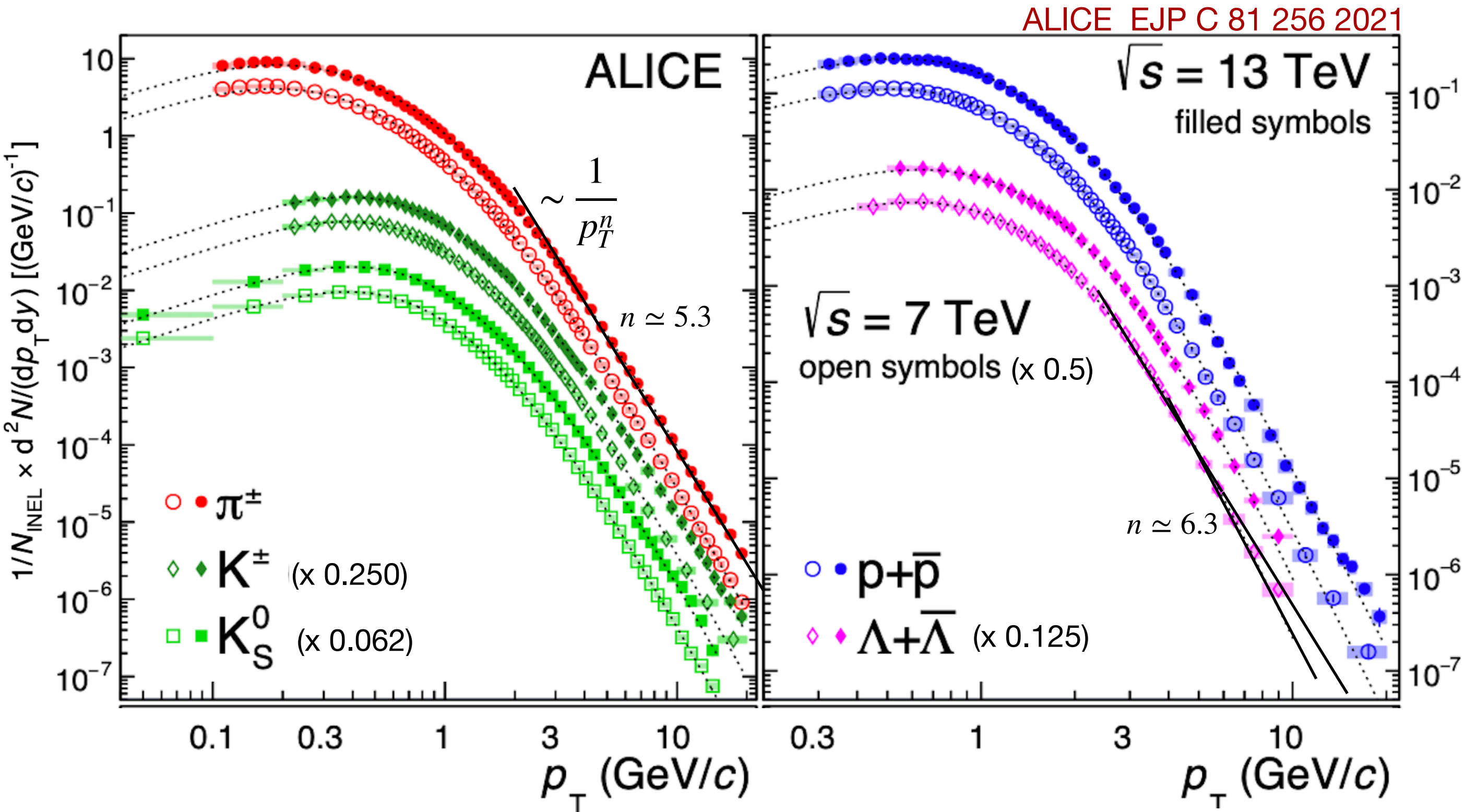
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R. Ball et al. EJP C 86 281 2016

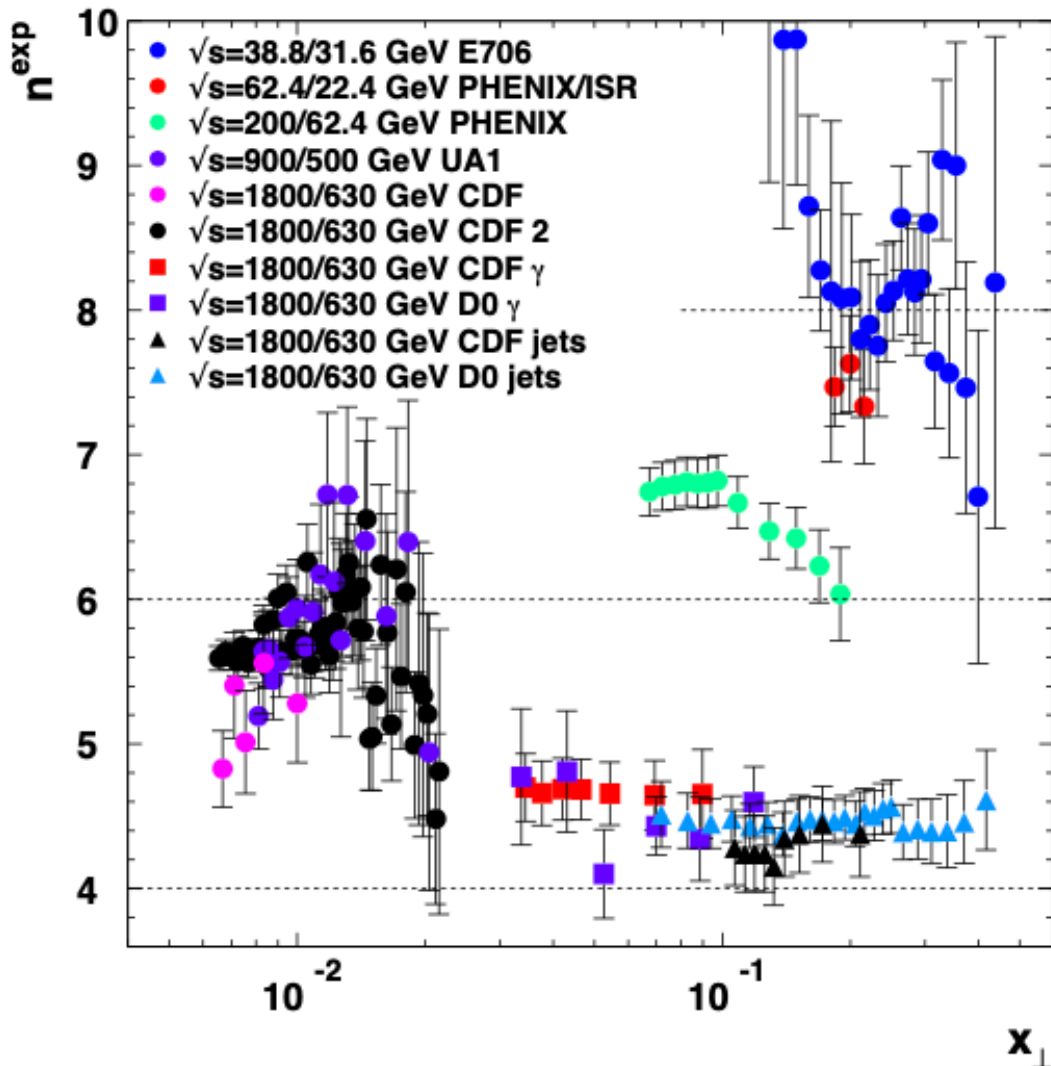


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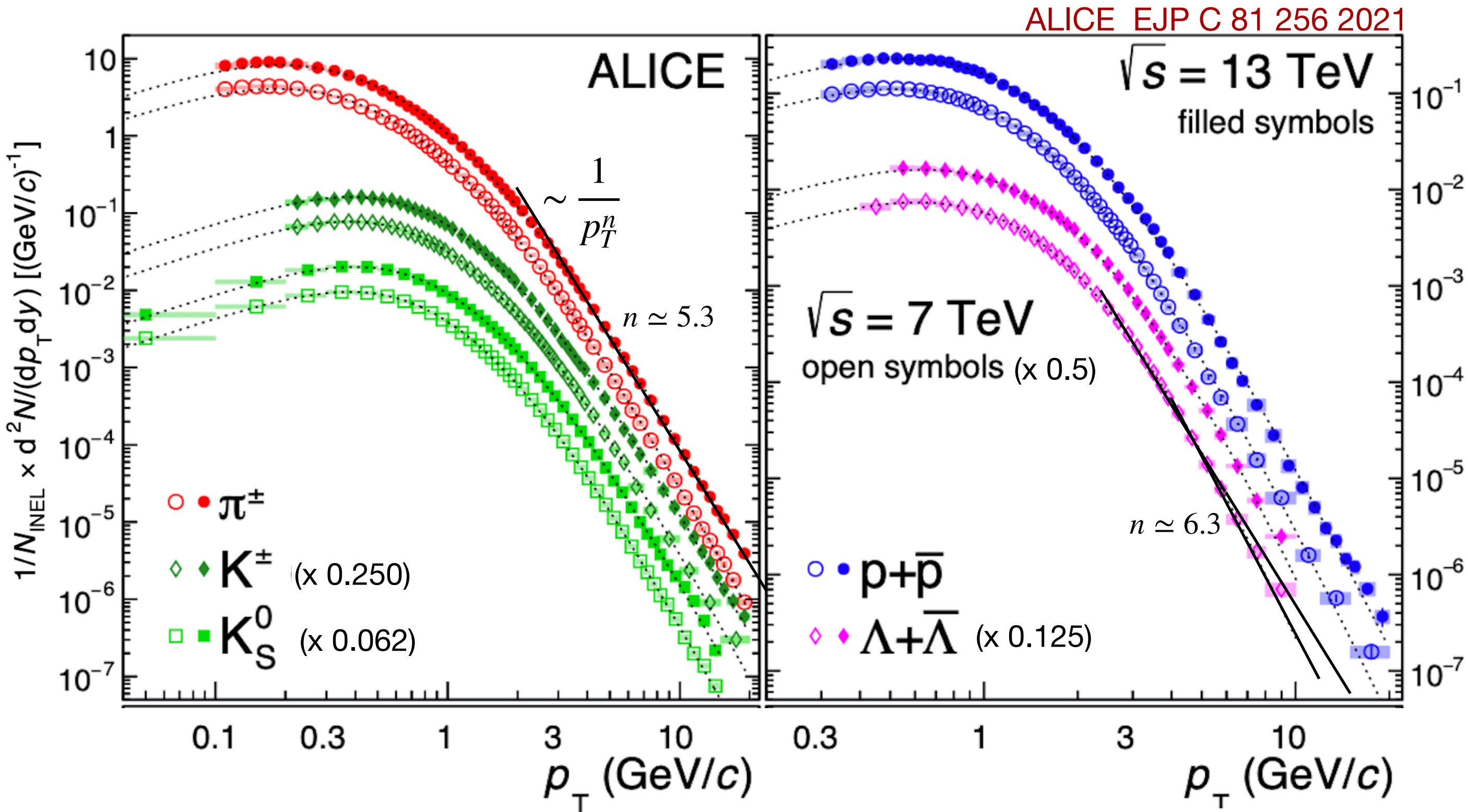
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multiple parton/color interactions

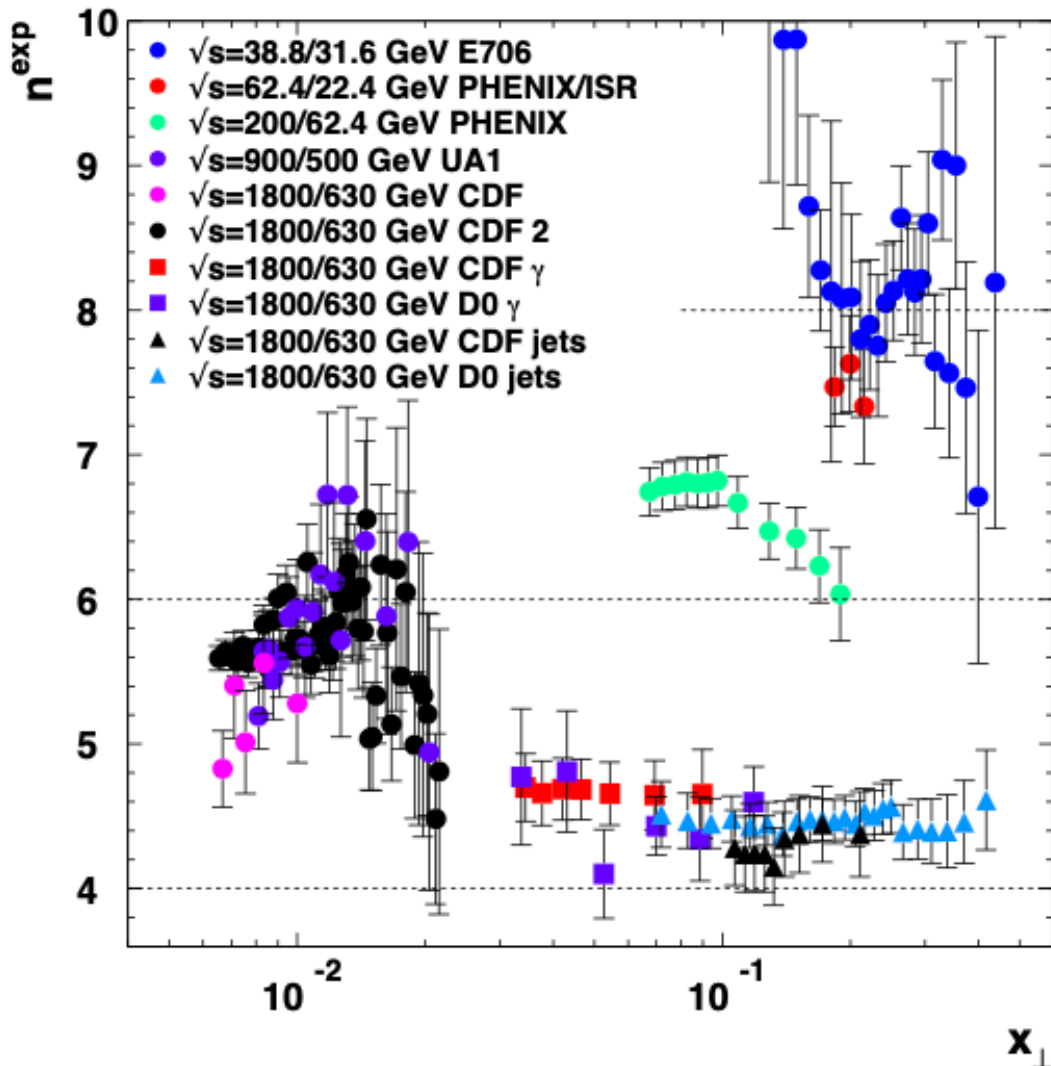


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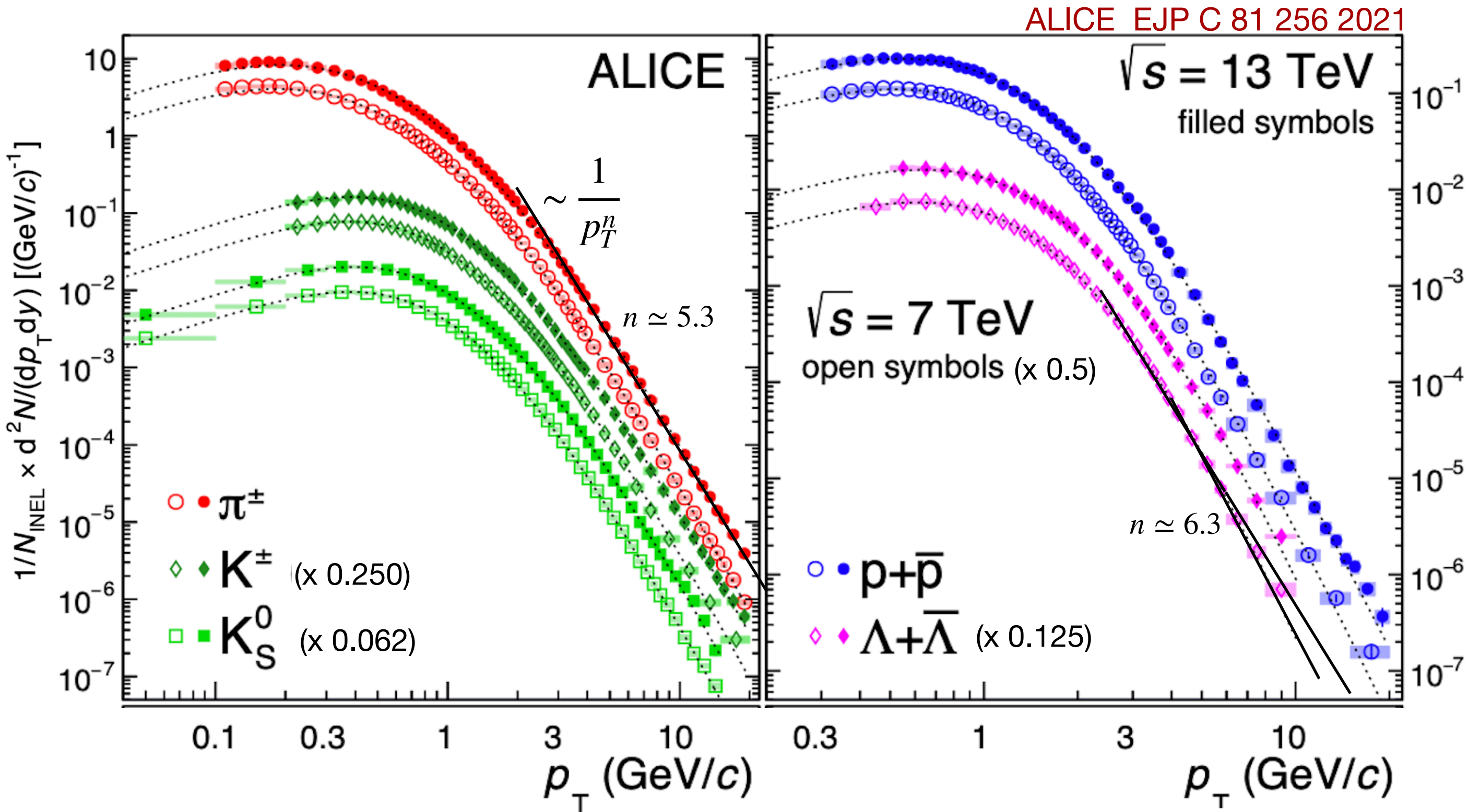
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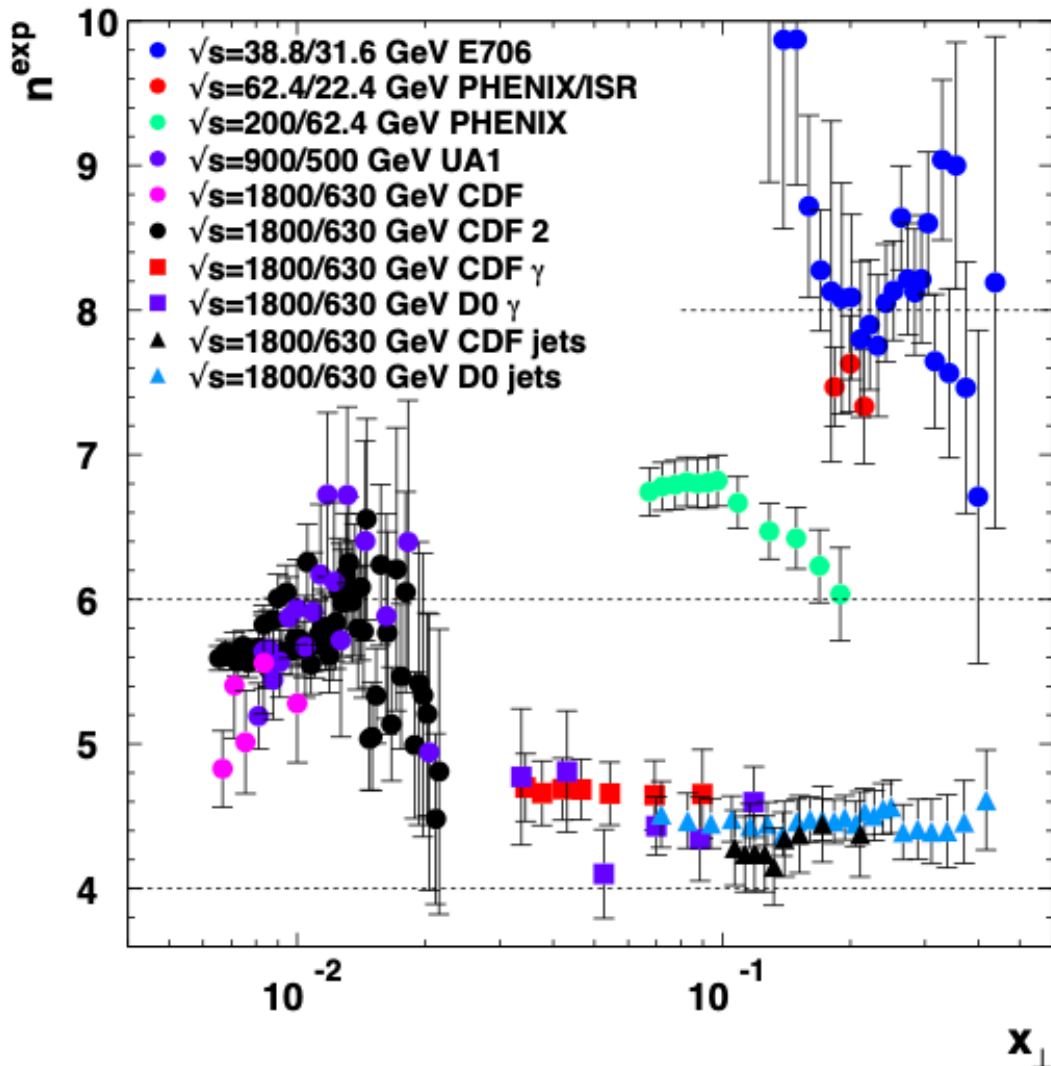


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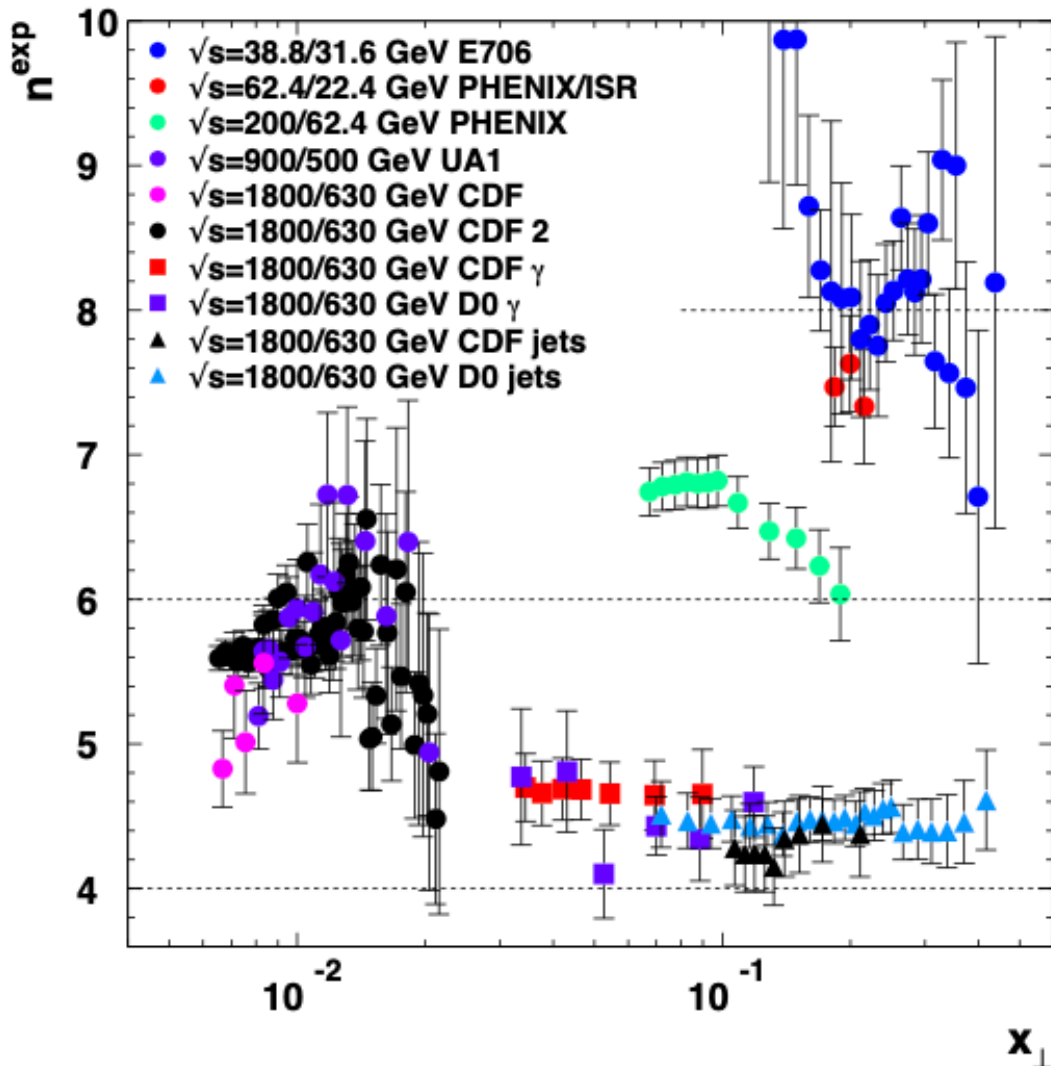
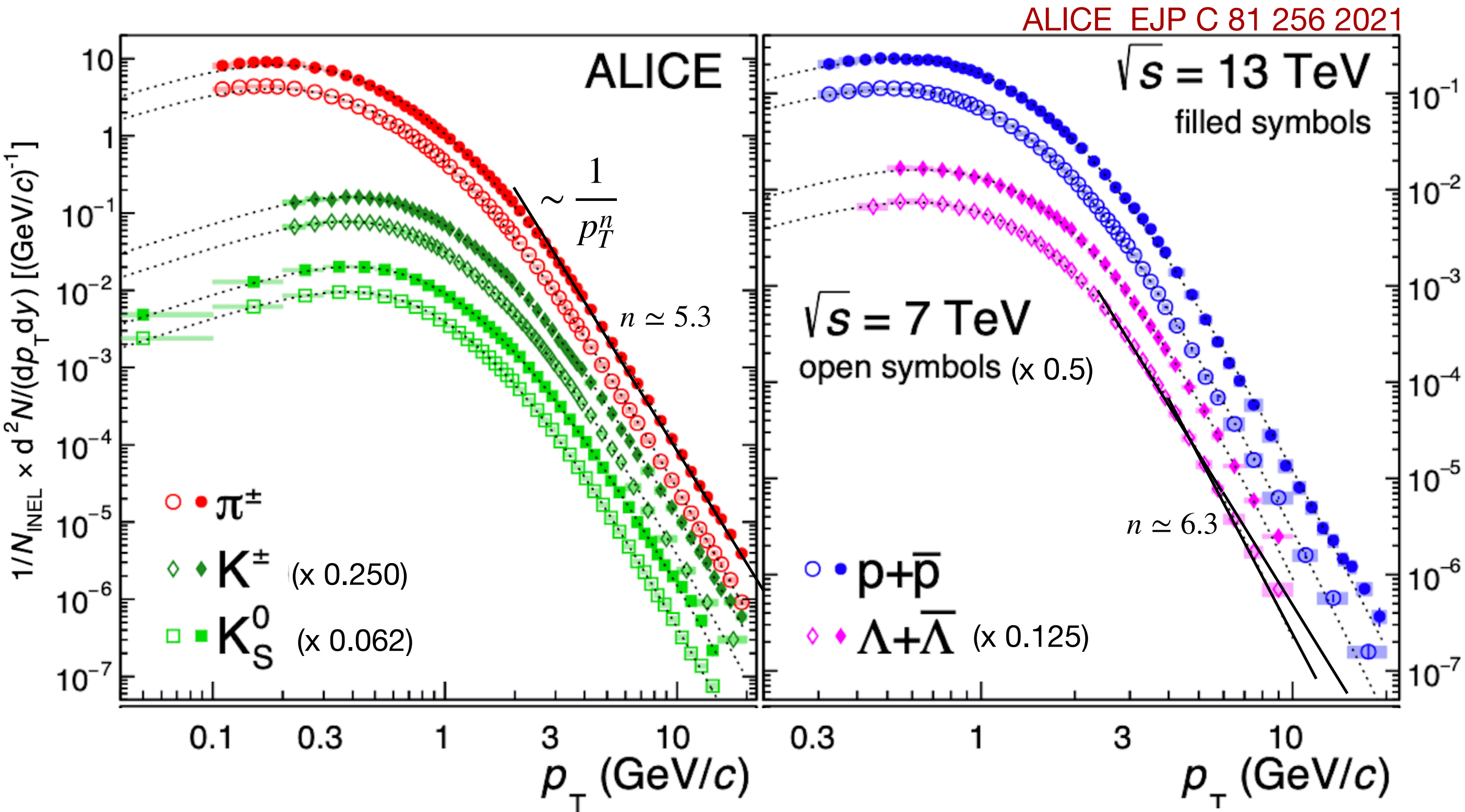
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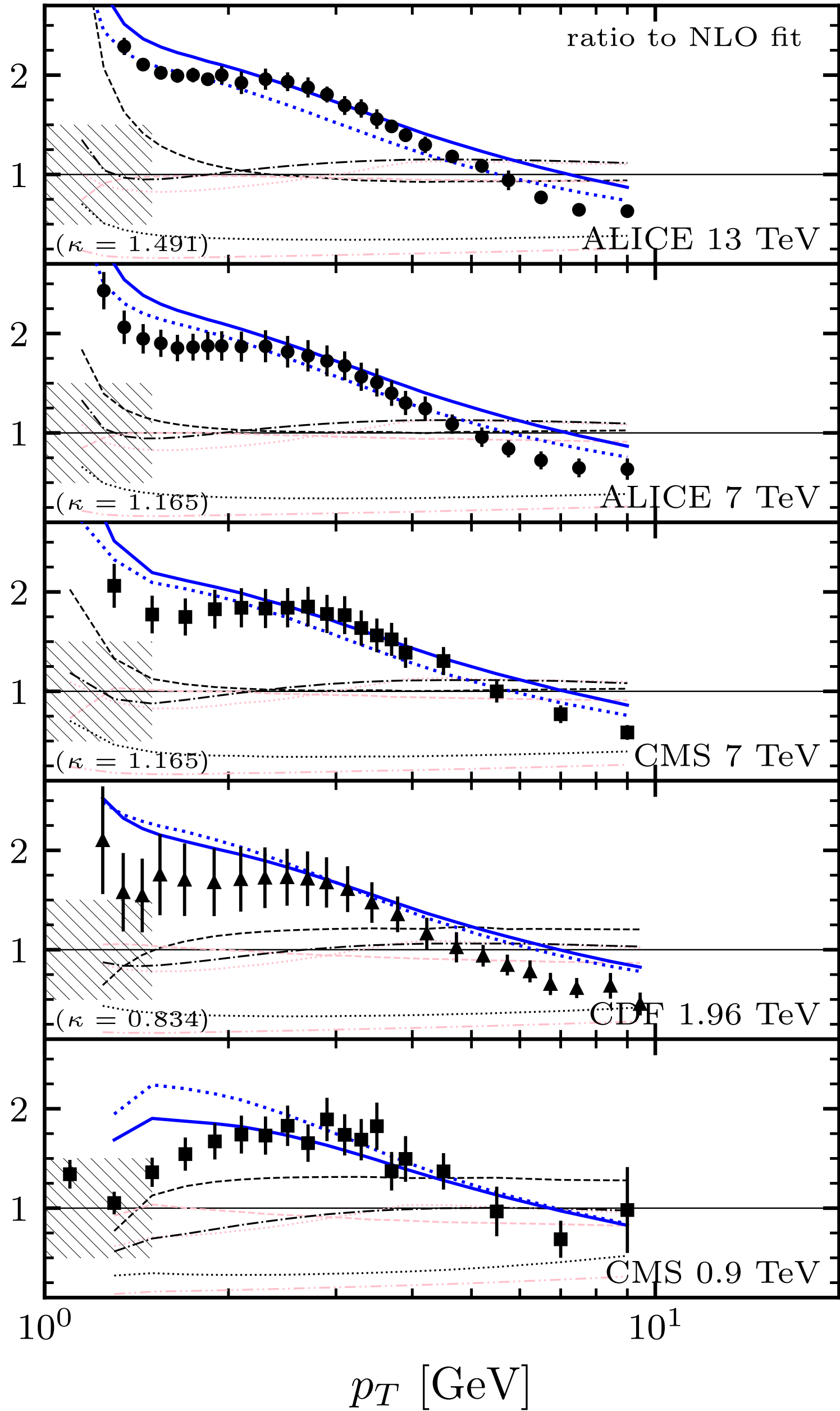
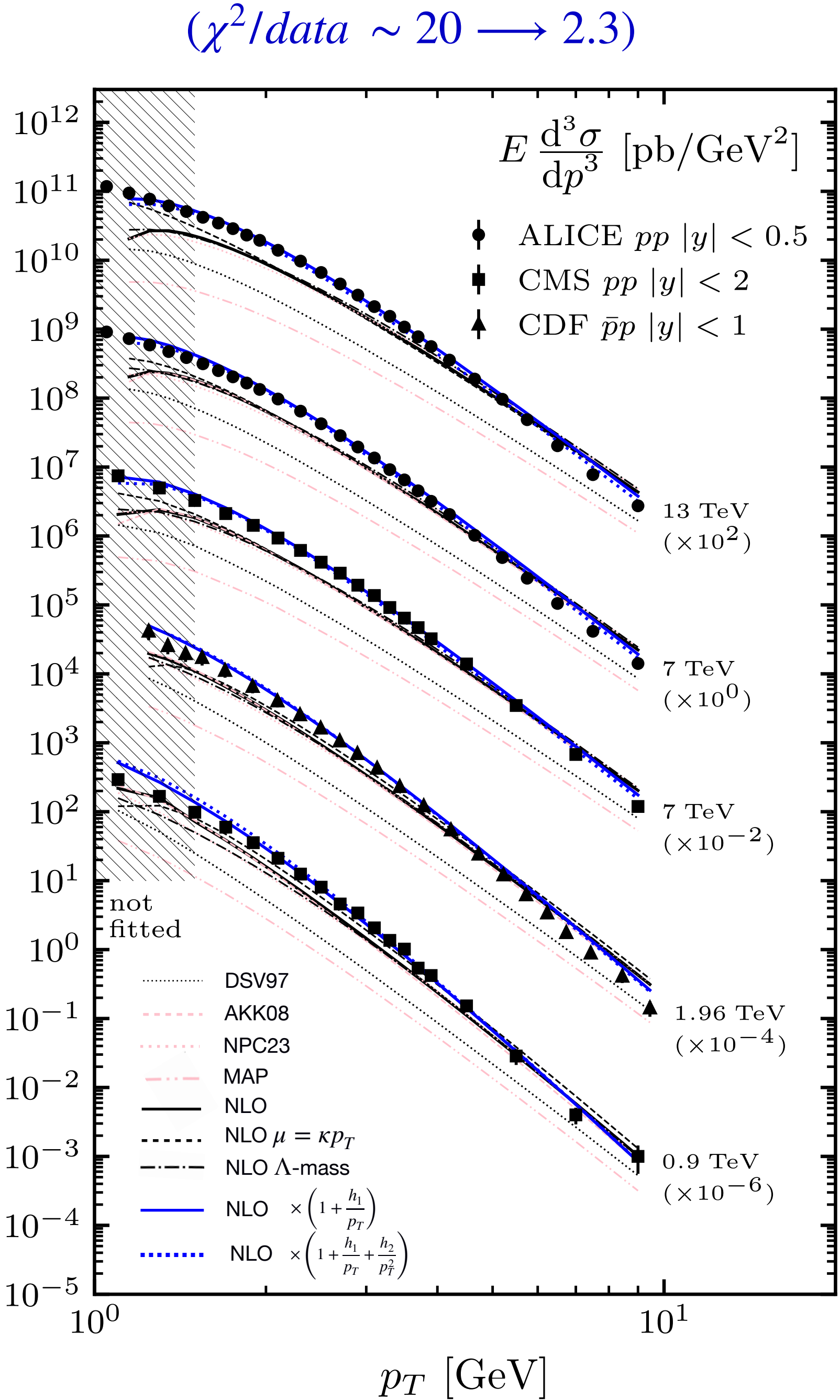
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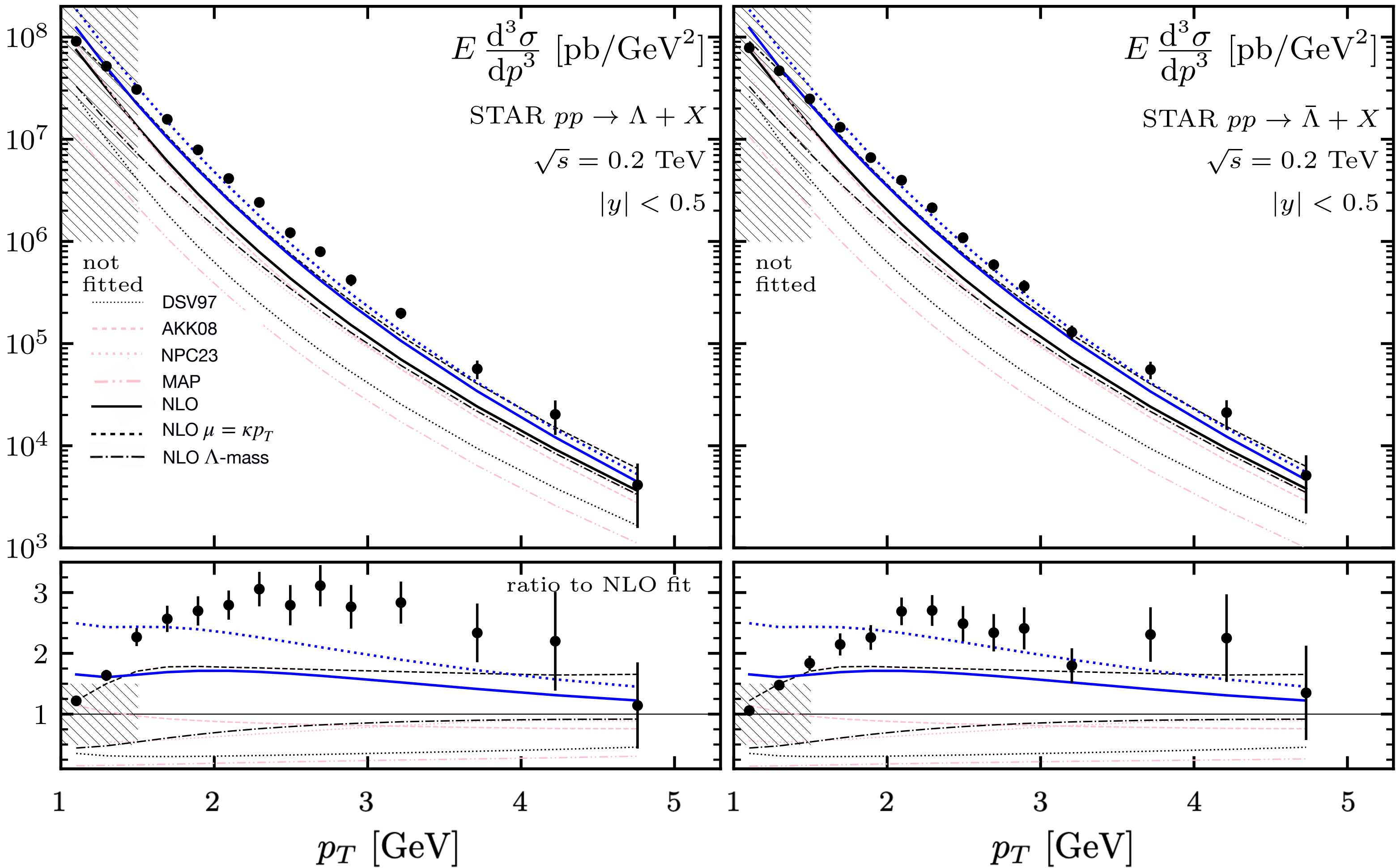
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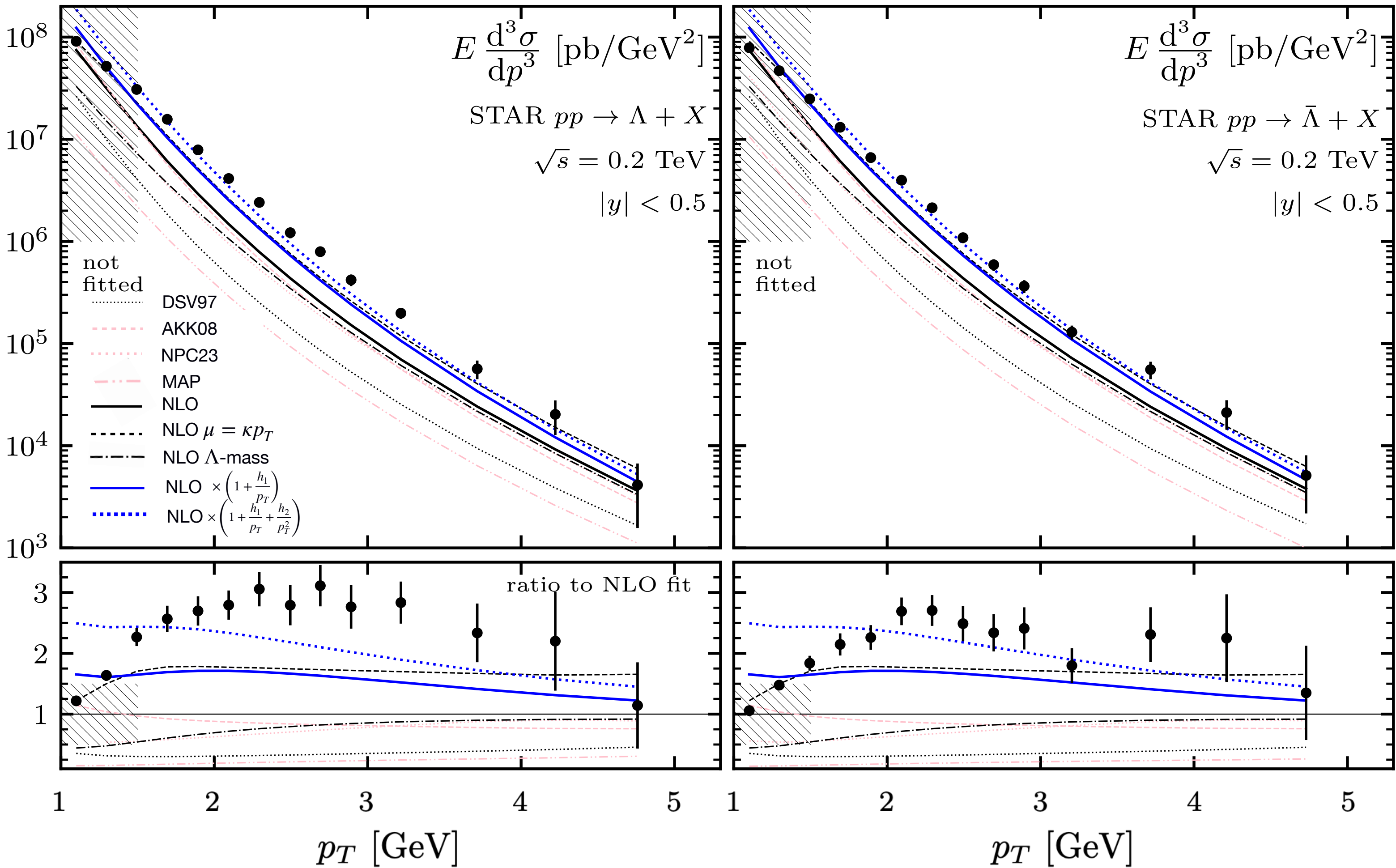
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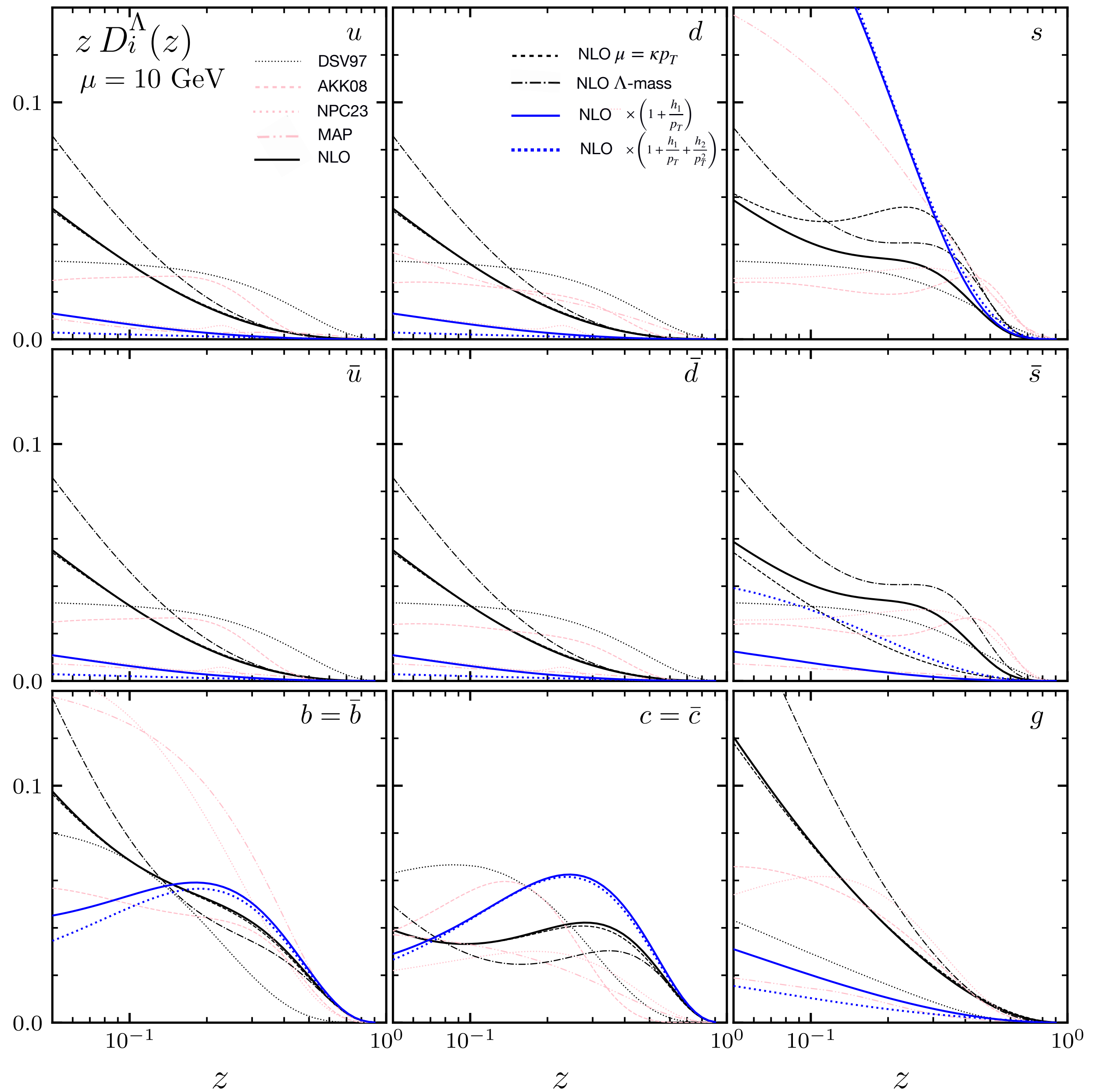
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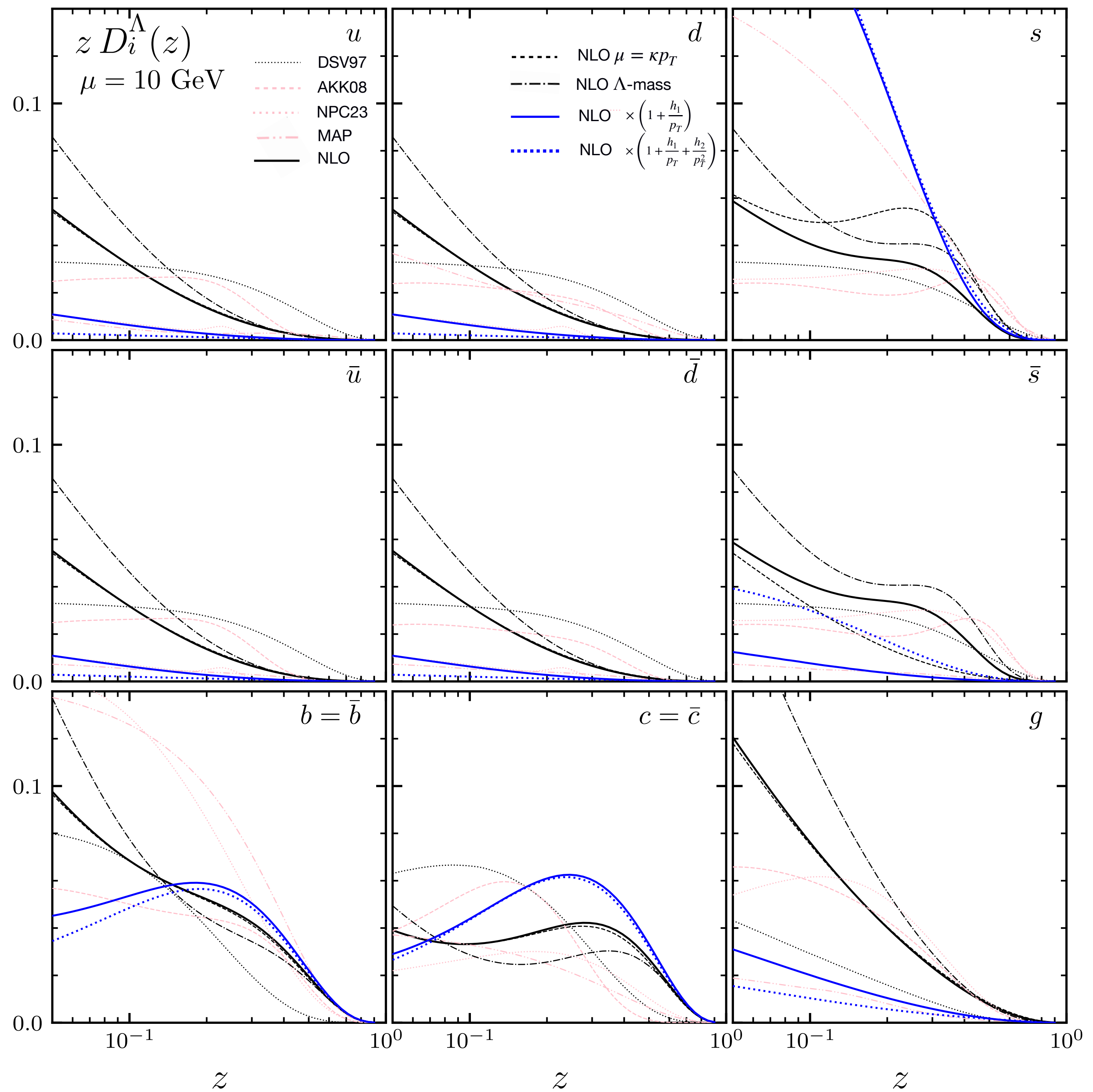


Λ^0 FFs



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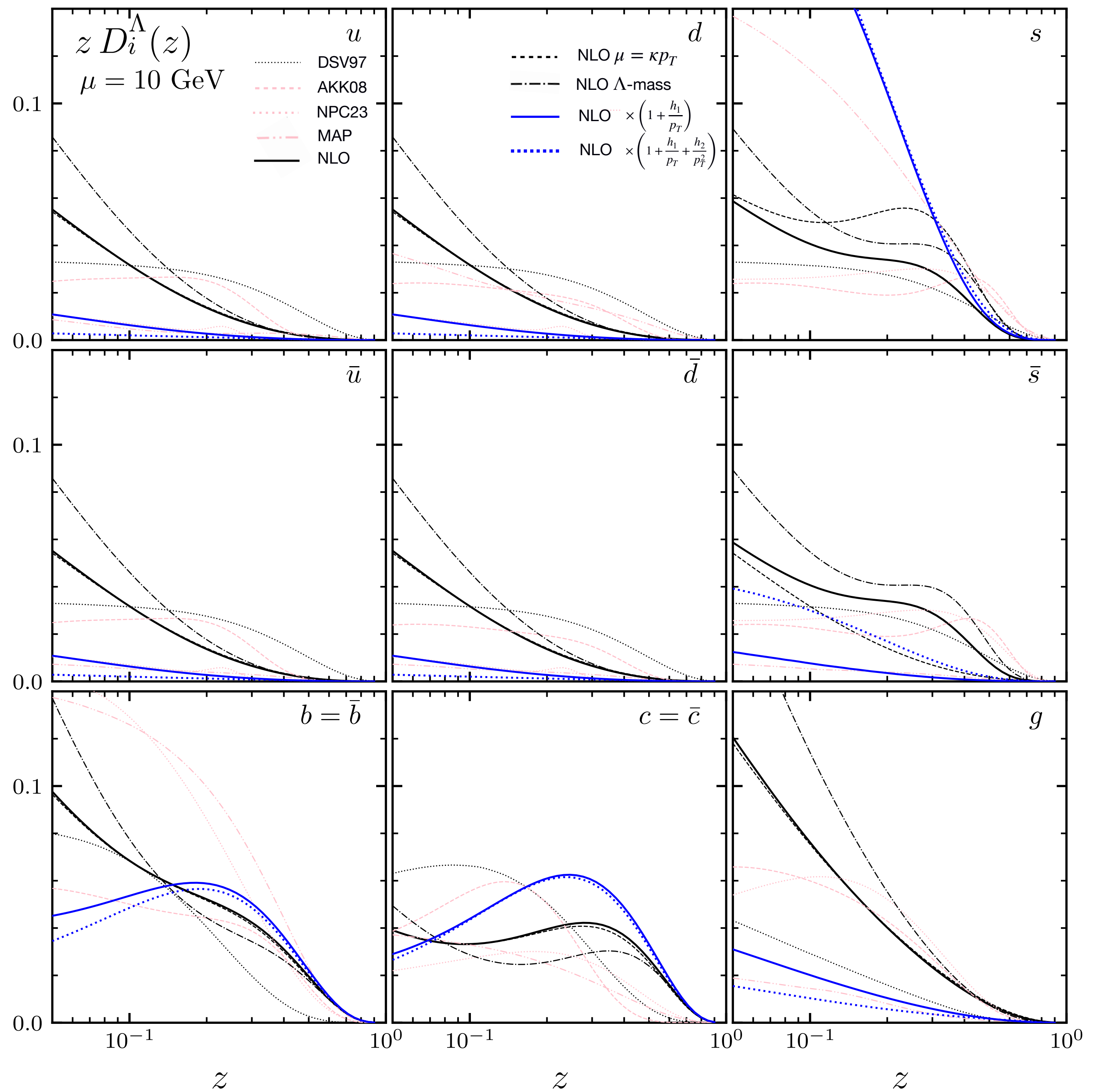
$$D_i^\Lambda(z, \mu_0) = N_i z^{\alpha_i} (1-z)^{\beta_i} [1 + \gamma_i (1-z)^{\delta_i}] \quad \mu_0 = 1 \text{ GeV}$$



Λ^0 FFs

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$$D_{u+\bar{u}}^\Lambda(z, \mu_0) = D_{d+\bar{d}}^\Lambda(z, \mu_0) \quad D_{s+\bar{s}}^\Lambda(z, \mu_0) \quad D_g^\Lambda(z, \mu_0)$$

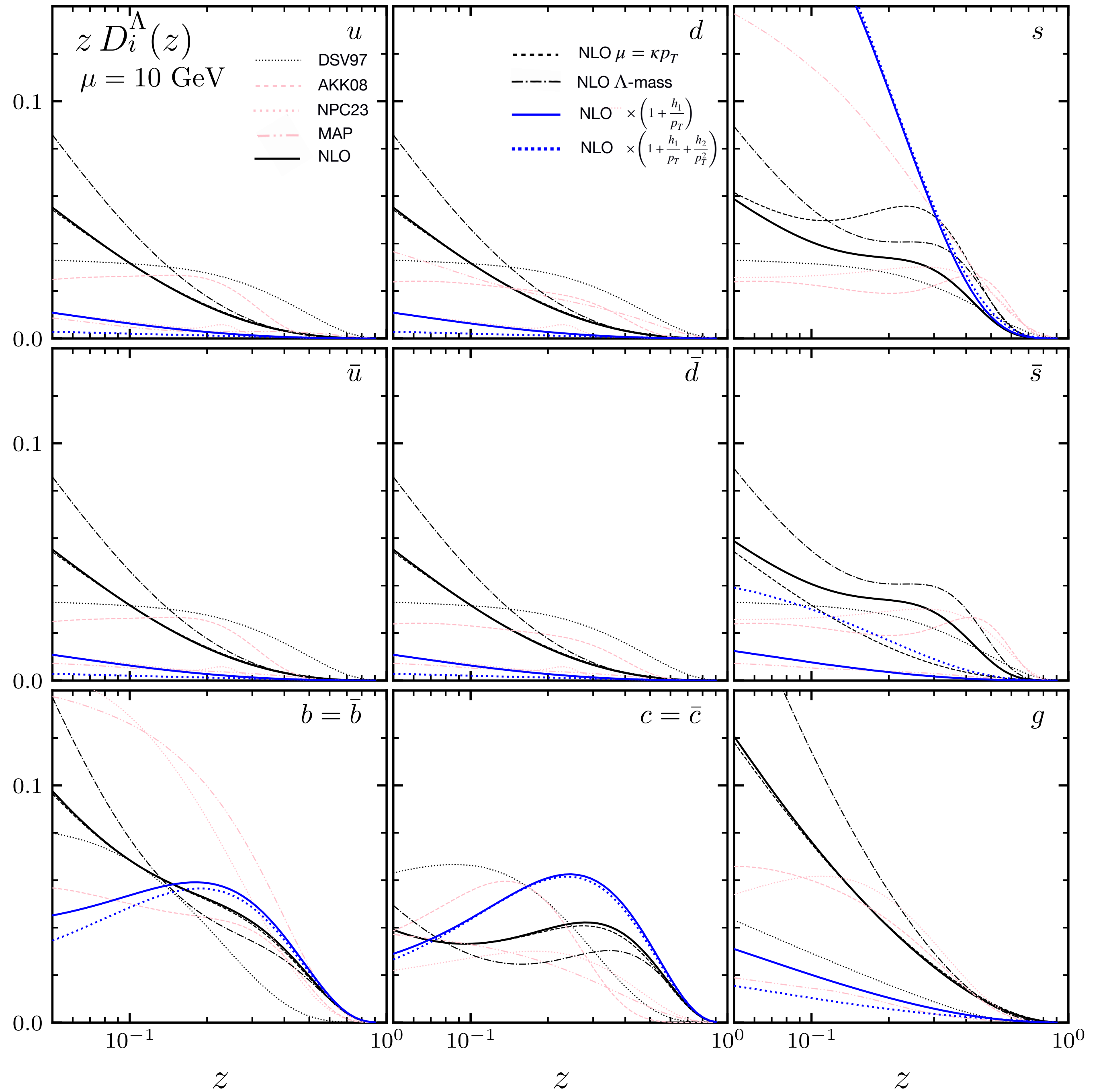


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$$D_{\bar{u}}^\Lambda(z, \mu_0) = D_{\bar{d}}^\Lambda(z, \mu_0) = \left(\frac{1}{2} + \Upsilon_l \right) D_{u+\bar{u}}^\Lambda(z, \mu_0)$$



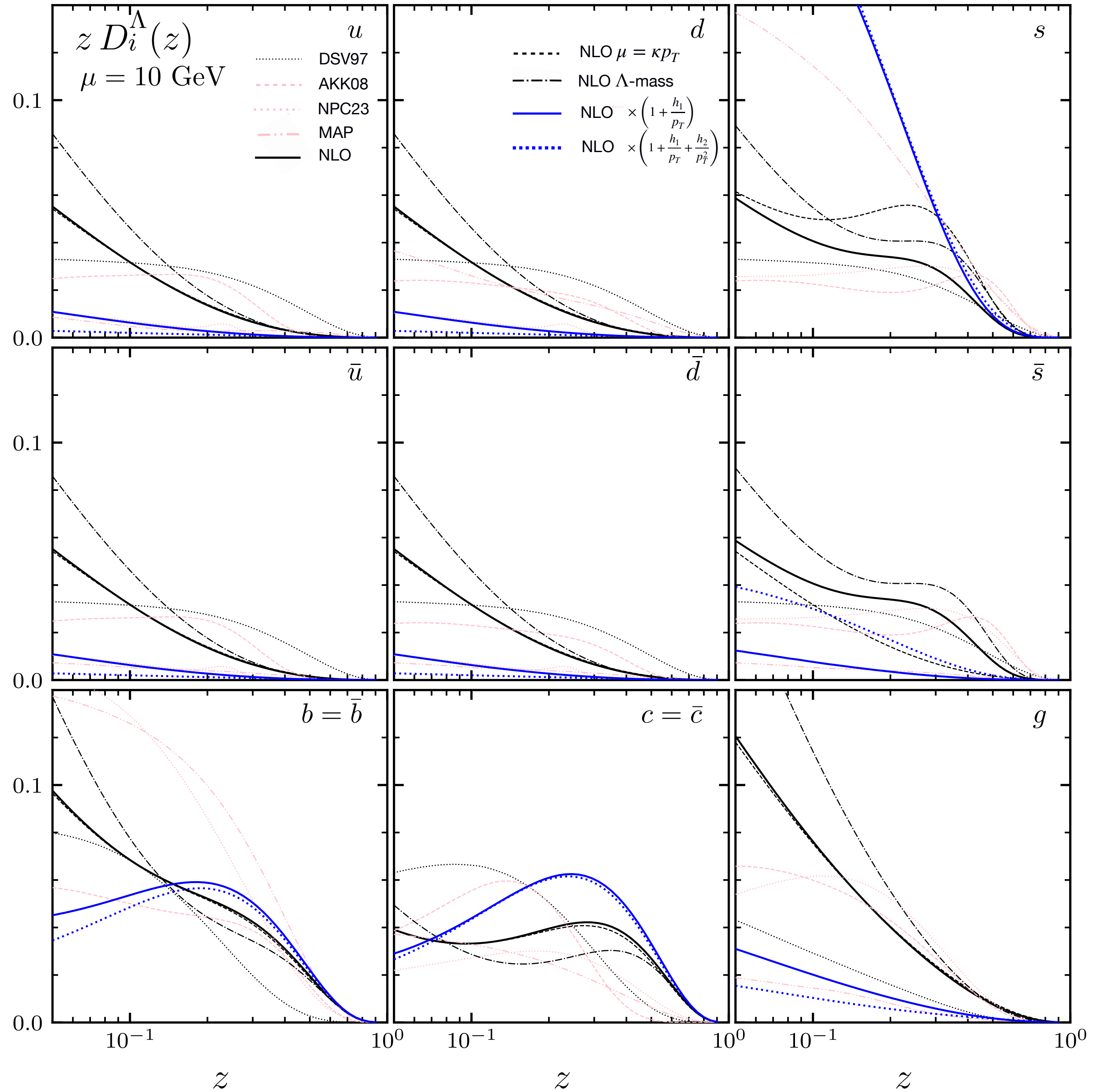
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$$D_i^\Lambda(z, \mu_0) = N_i z^{\alpha_i} (1-z)^{\beta_i} [1 + \gamma_i (1-z)^{\delta_i}] \quad \mu_0 = 1 \text{ GeV}$$

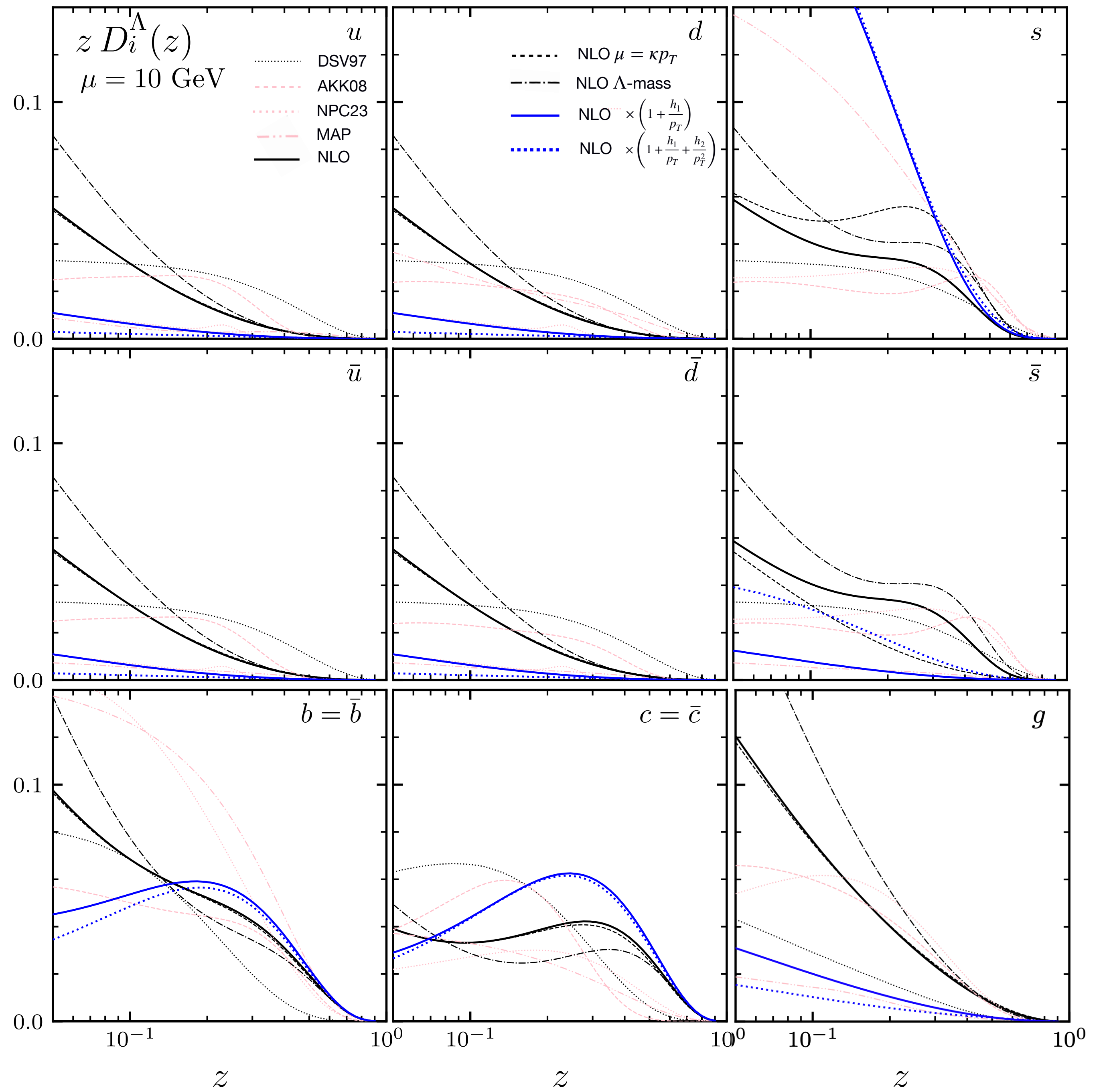
$$D_{u+\bar{u}}^\Lambda(z, \mu_0) = D_{d+\bar{d}}^\Lambda(z, \mu_0) \quad D_{s+\bar{s}}^\Lambda(z, \mu_0) \quad D_g^\Lambda(z, \mu_0)$$

$$D_{\bar{u}}^\Lambda(z, \mu_0) = D_{\bar{d}}^\Lambda(z, \mu_0) = \left(\frac{1}{2} + \Upsilon_l \right) D_{u+\bar{u}}^\Lambda(z, \mu_0)$$

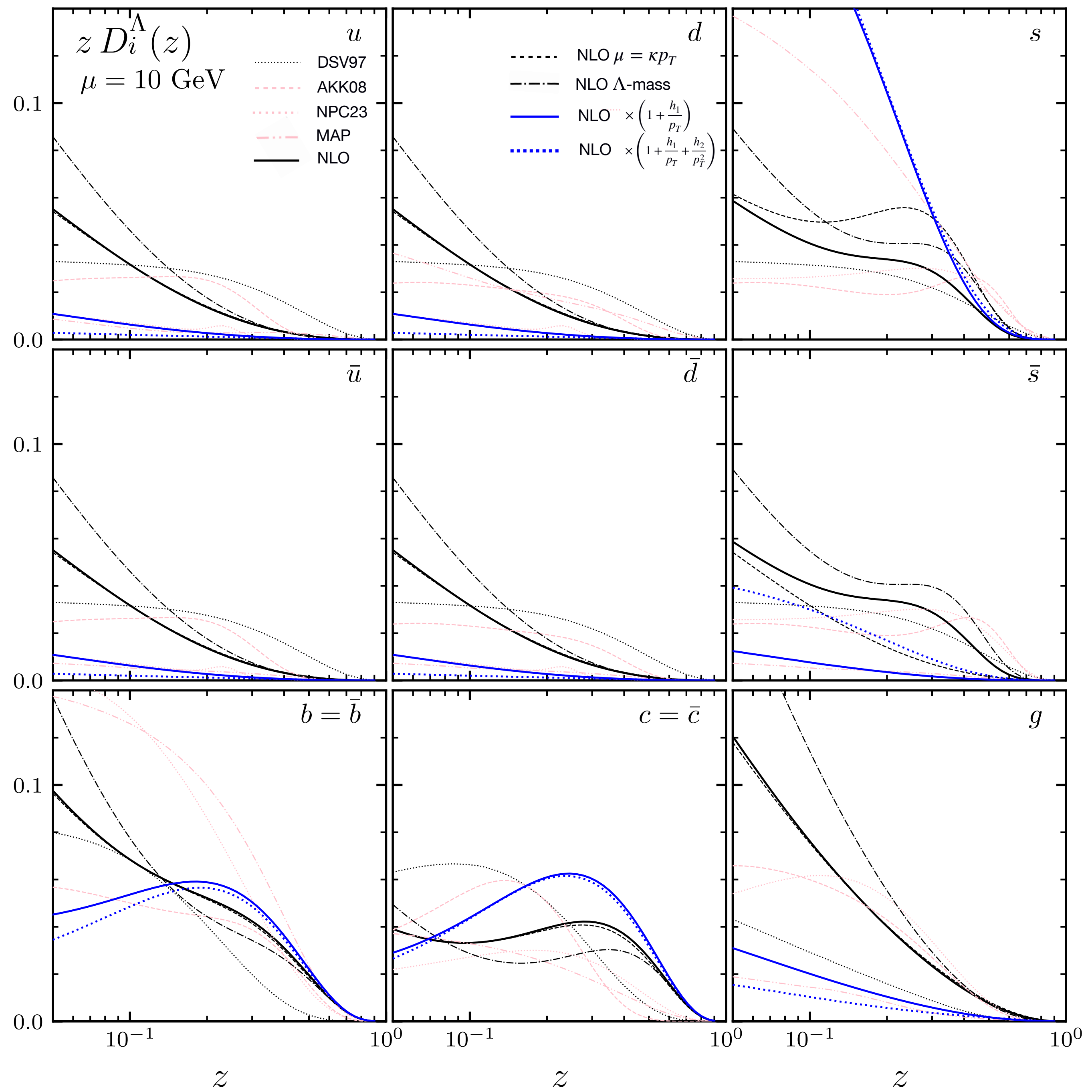
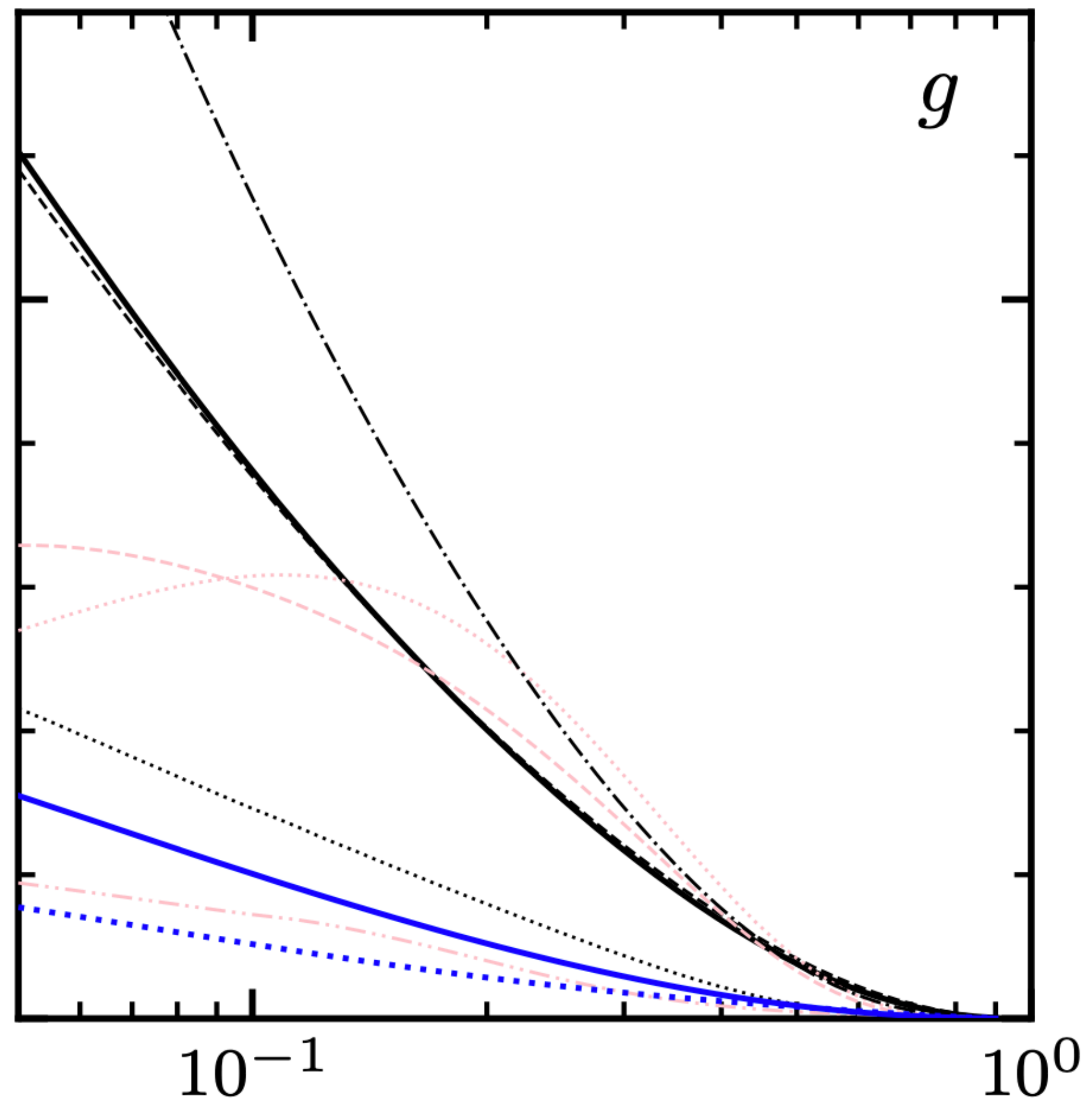
$$D_{\bar{s}}^\Lambda(z, \mu_0) = \left(\frac{1}{2} + \Upsilon_s \right) D_{s+\bar{s}}^\Lambda(z, \mu_0)$$



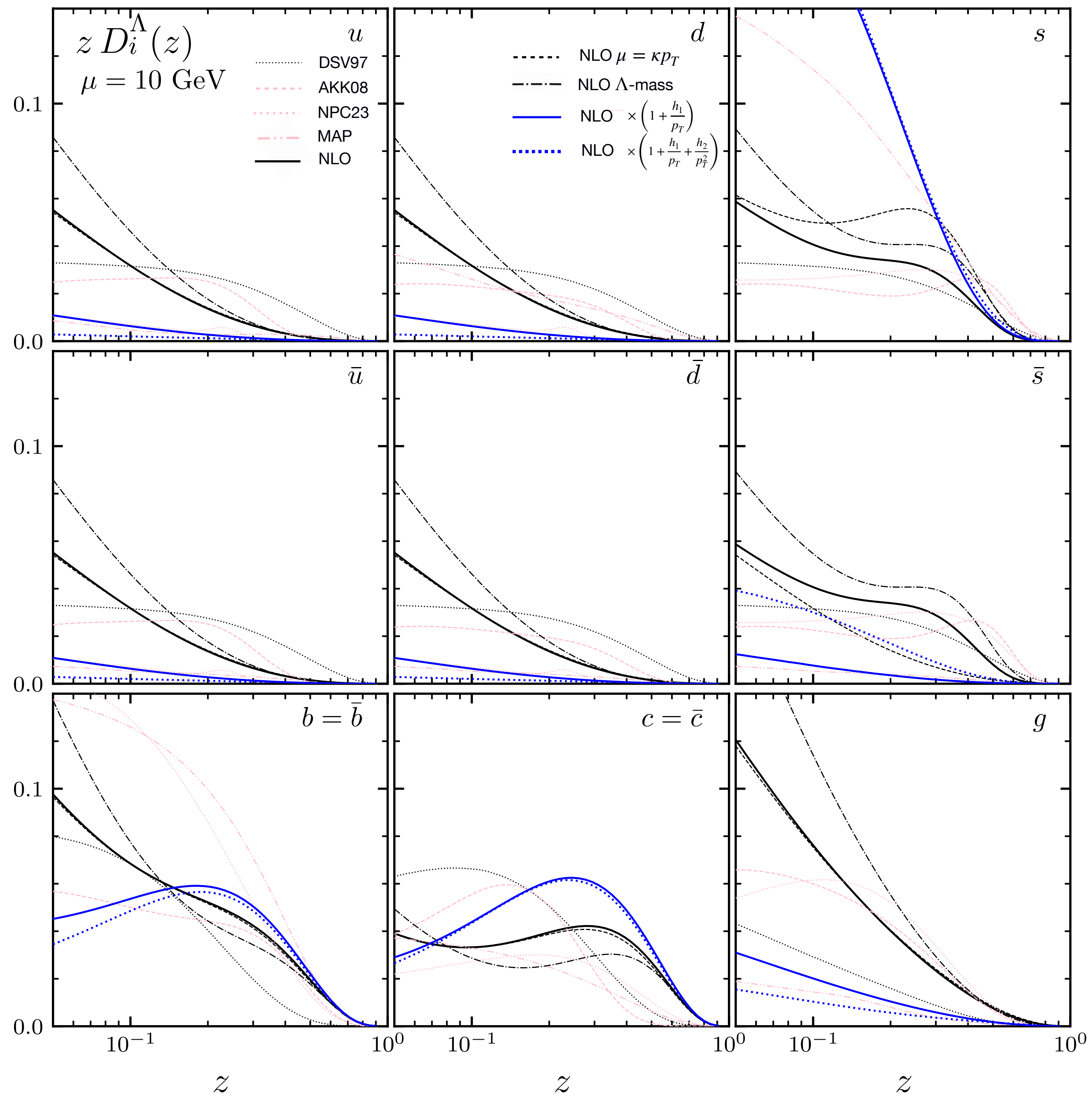
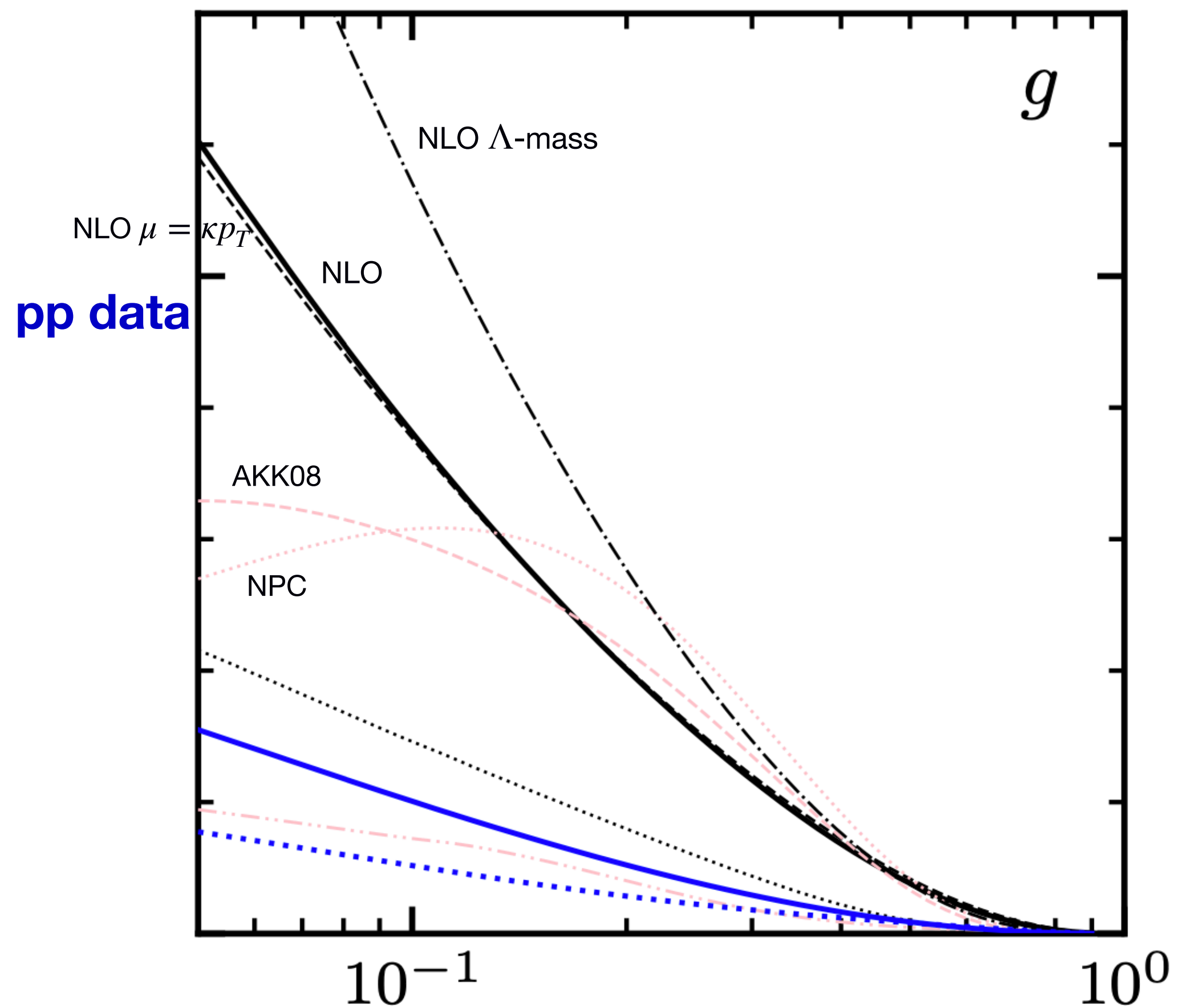
Λ^0 FFs



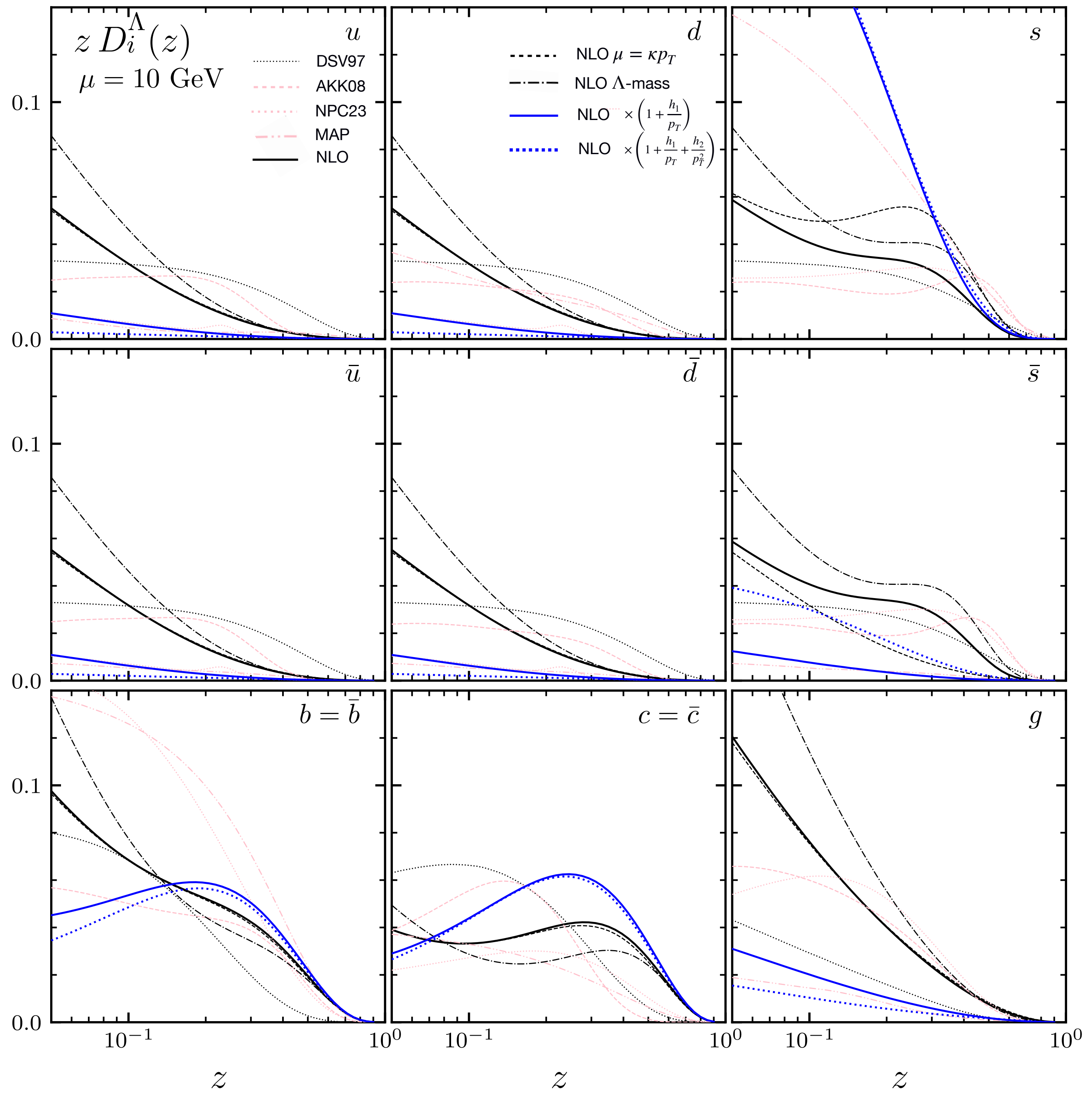
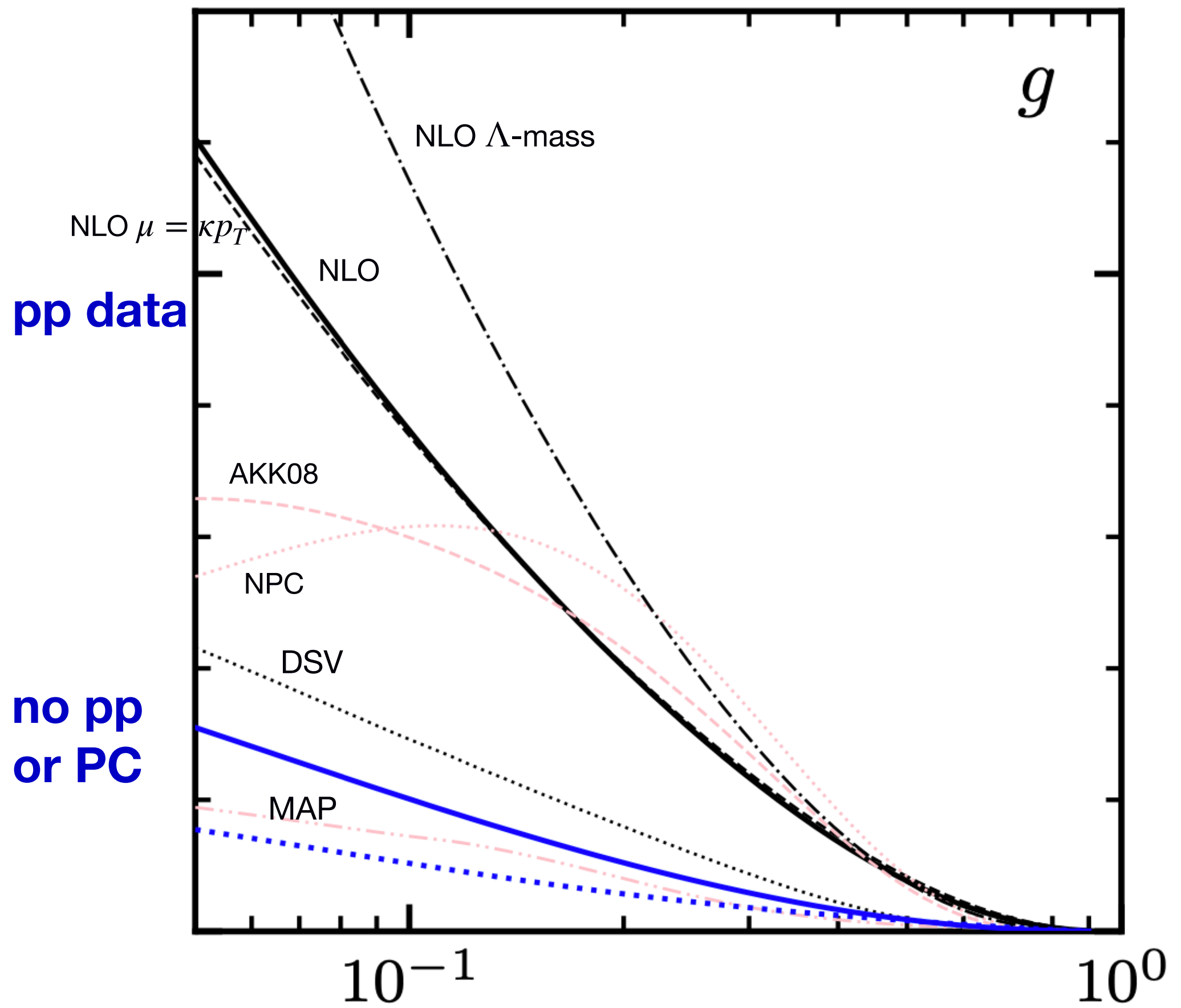
Λ^0 FFs



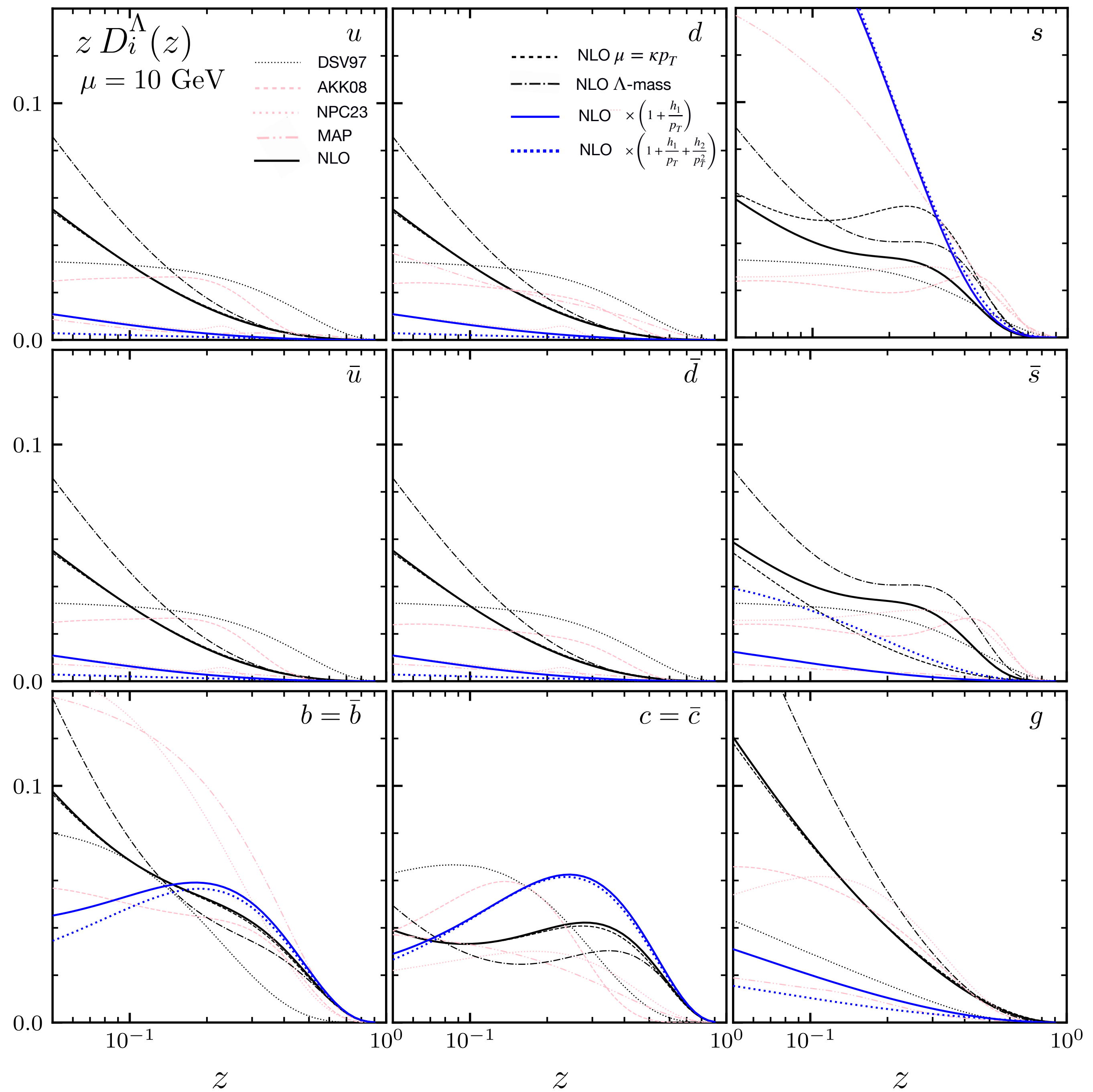
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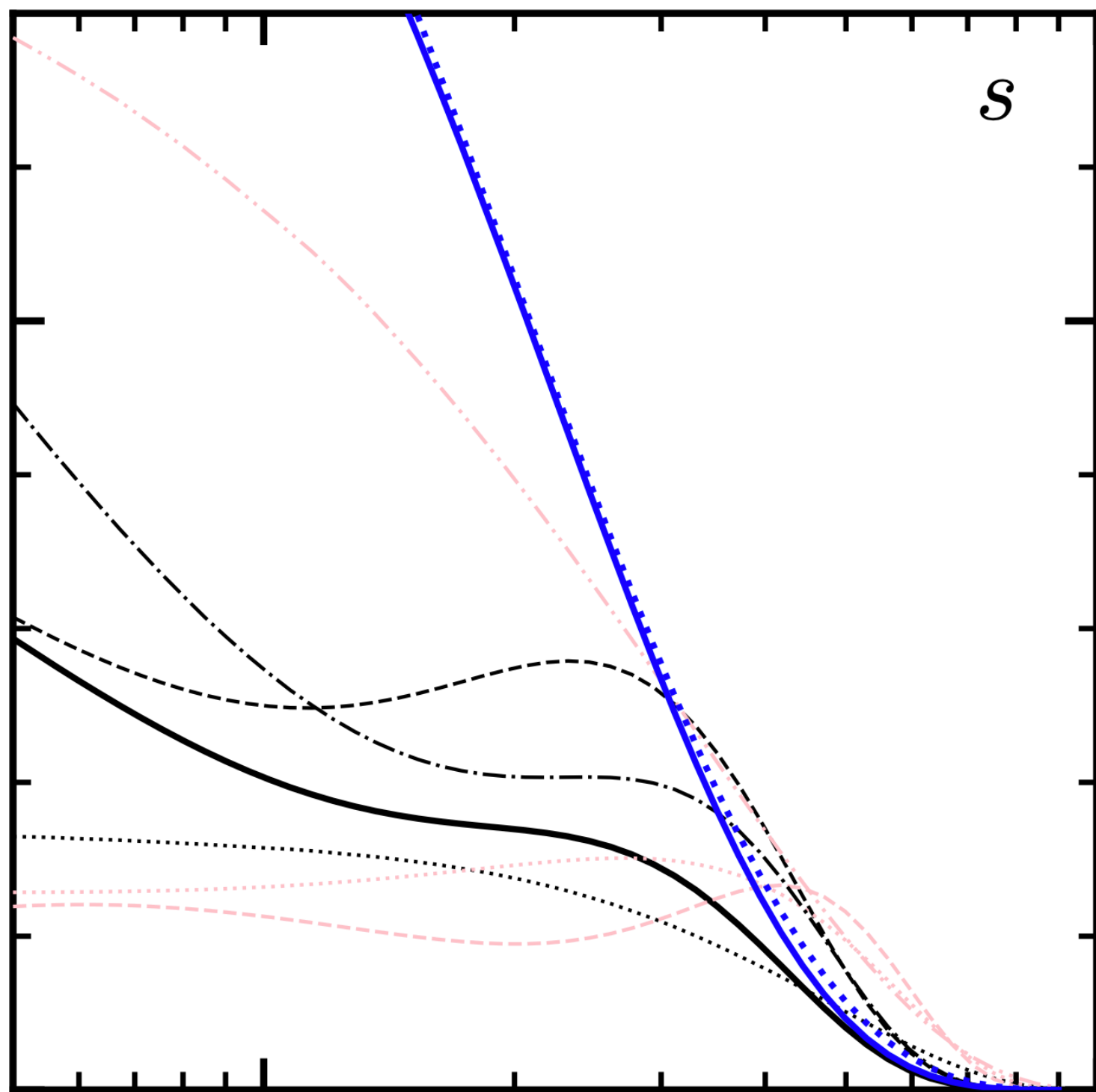
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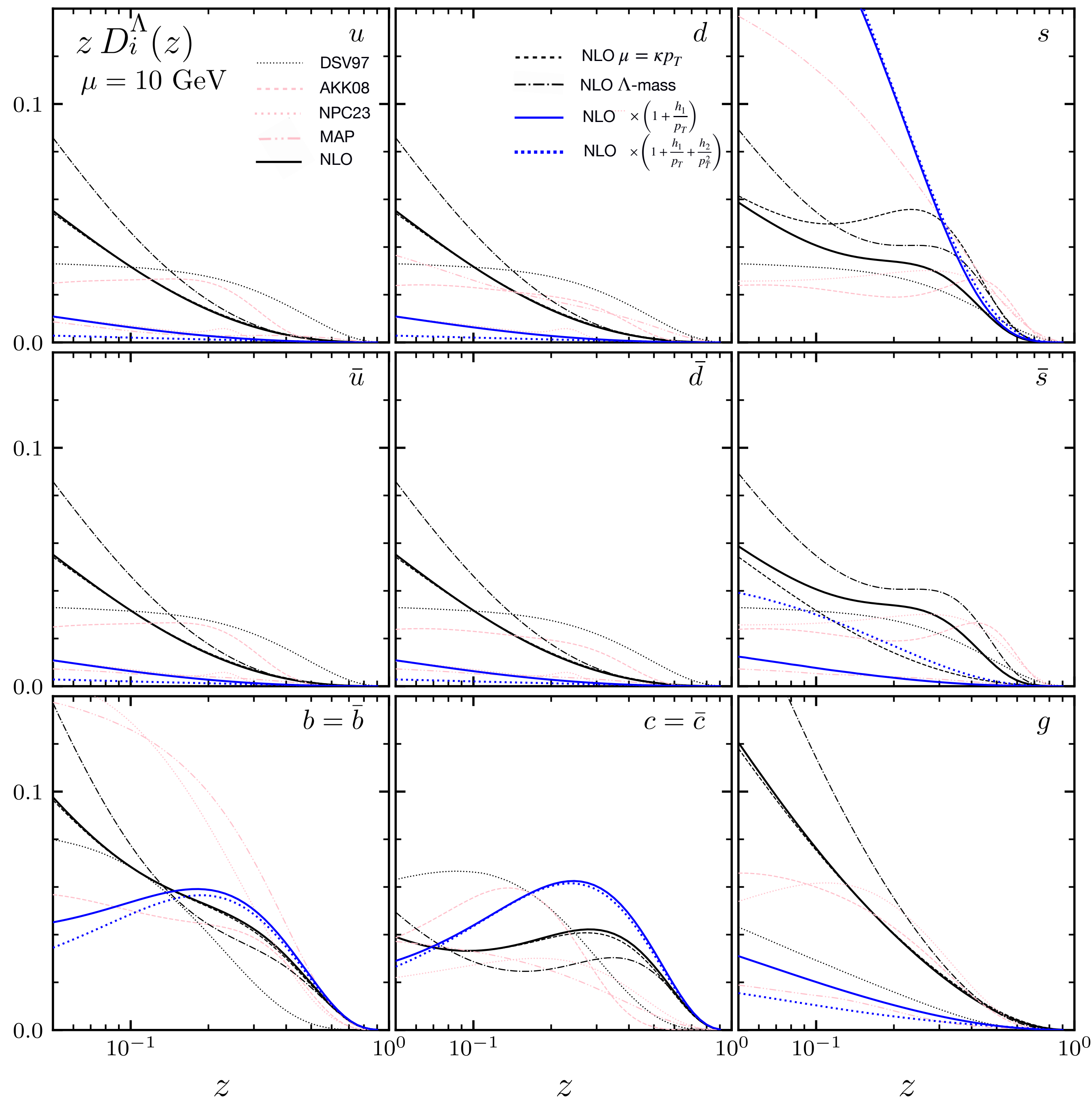
Λ^0 FFs



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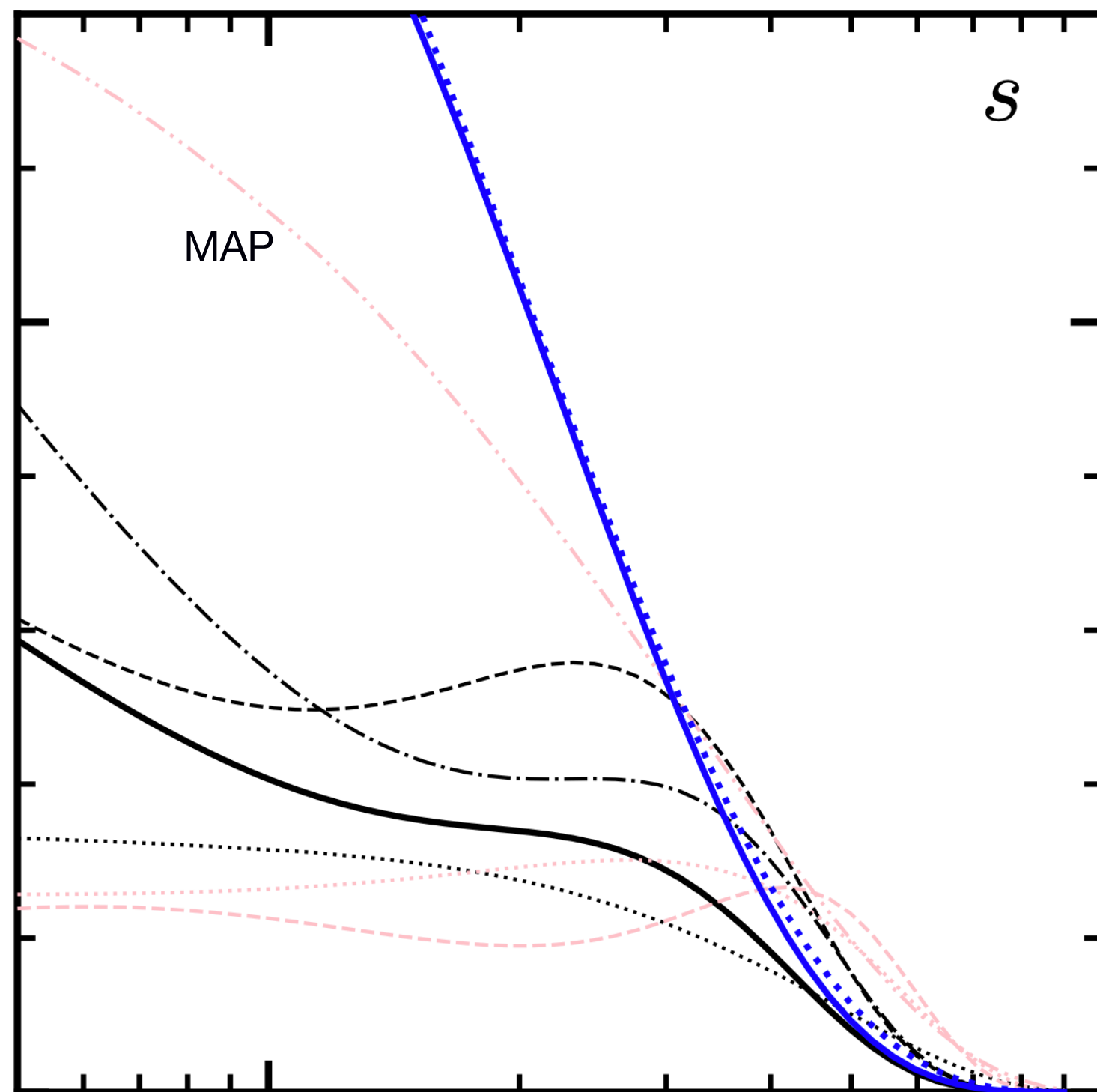


large uncertainty

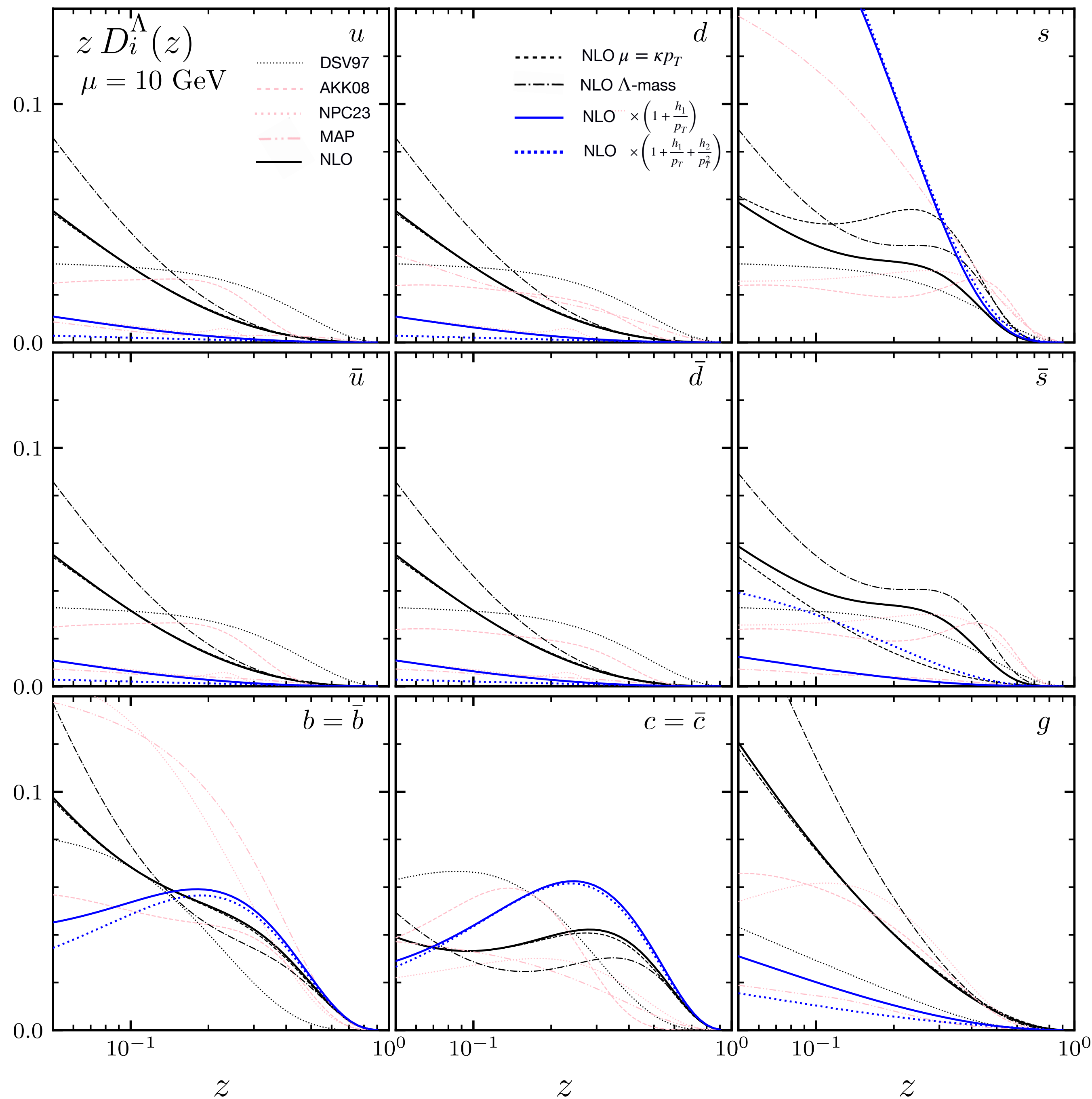


Λ^0 FFs

no pp
or PC

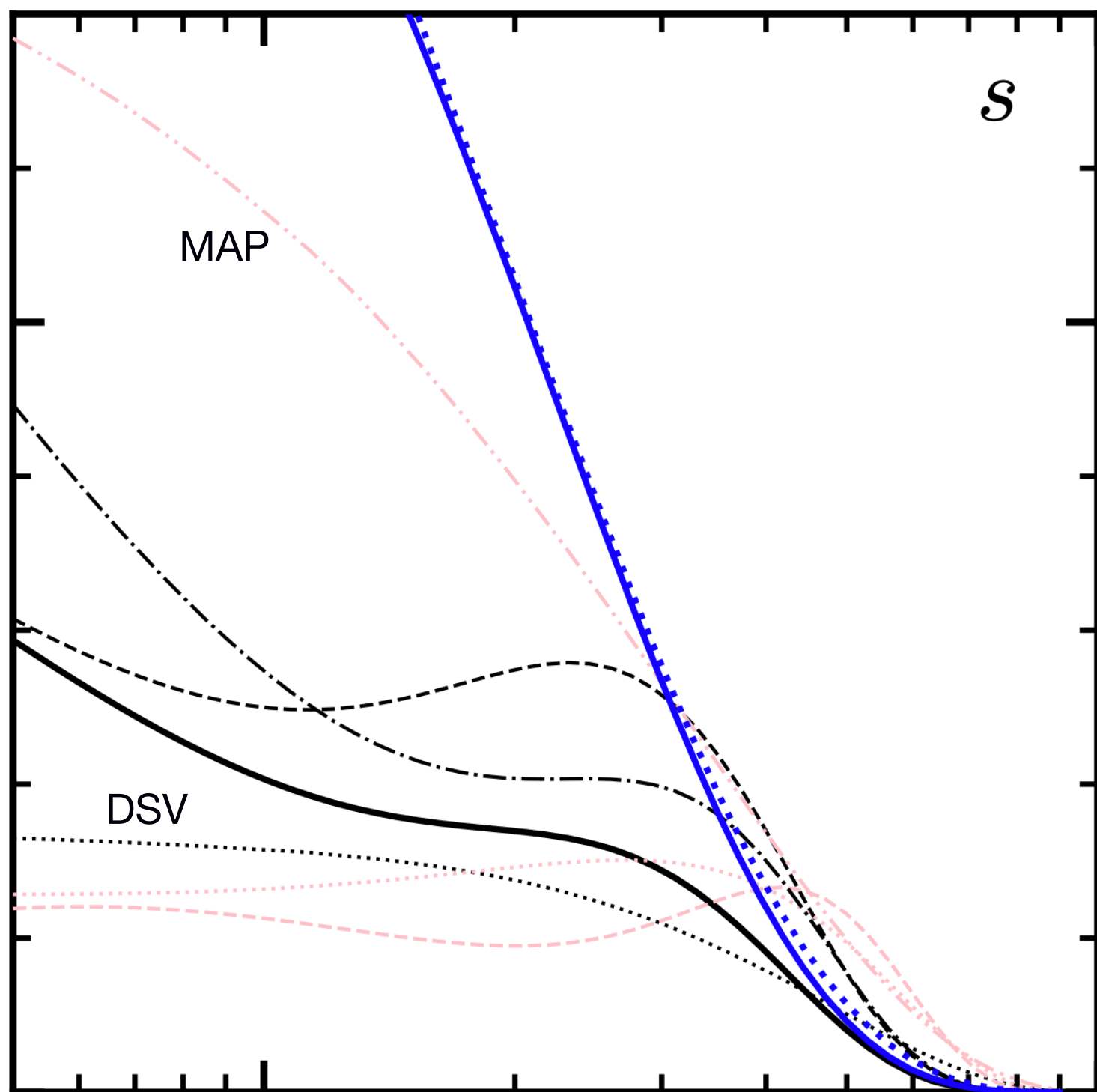


large uncertainty
sets based on SIDIS (or with PC) favor large D_s^Λ

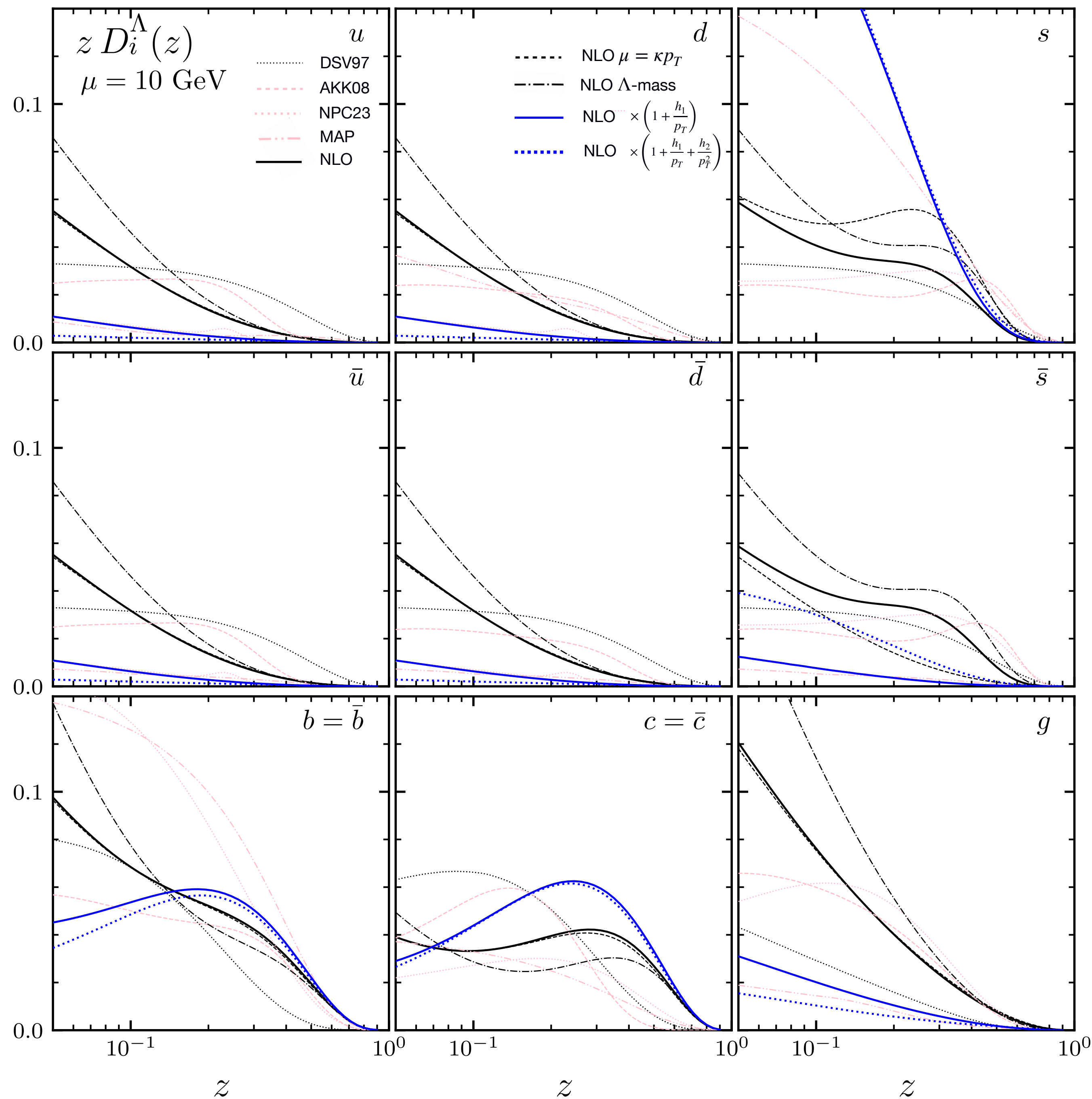


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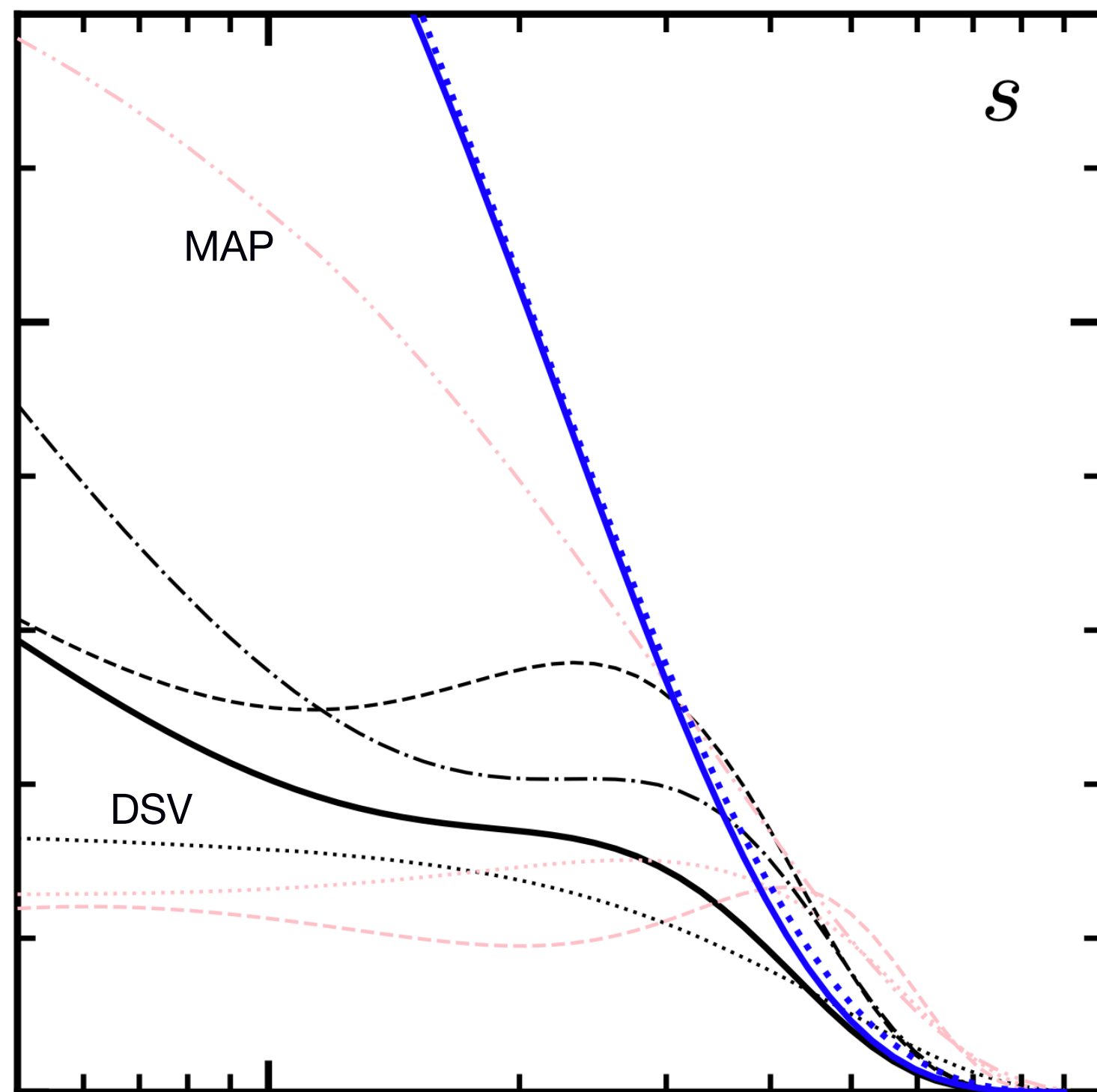


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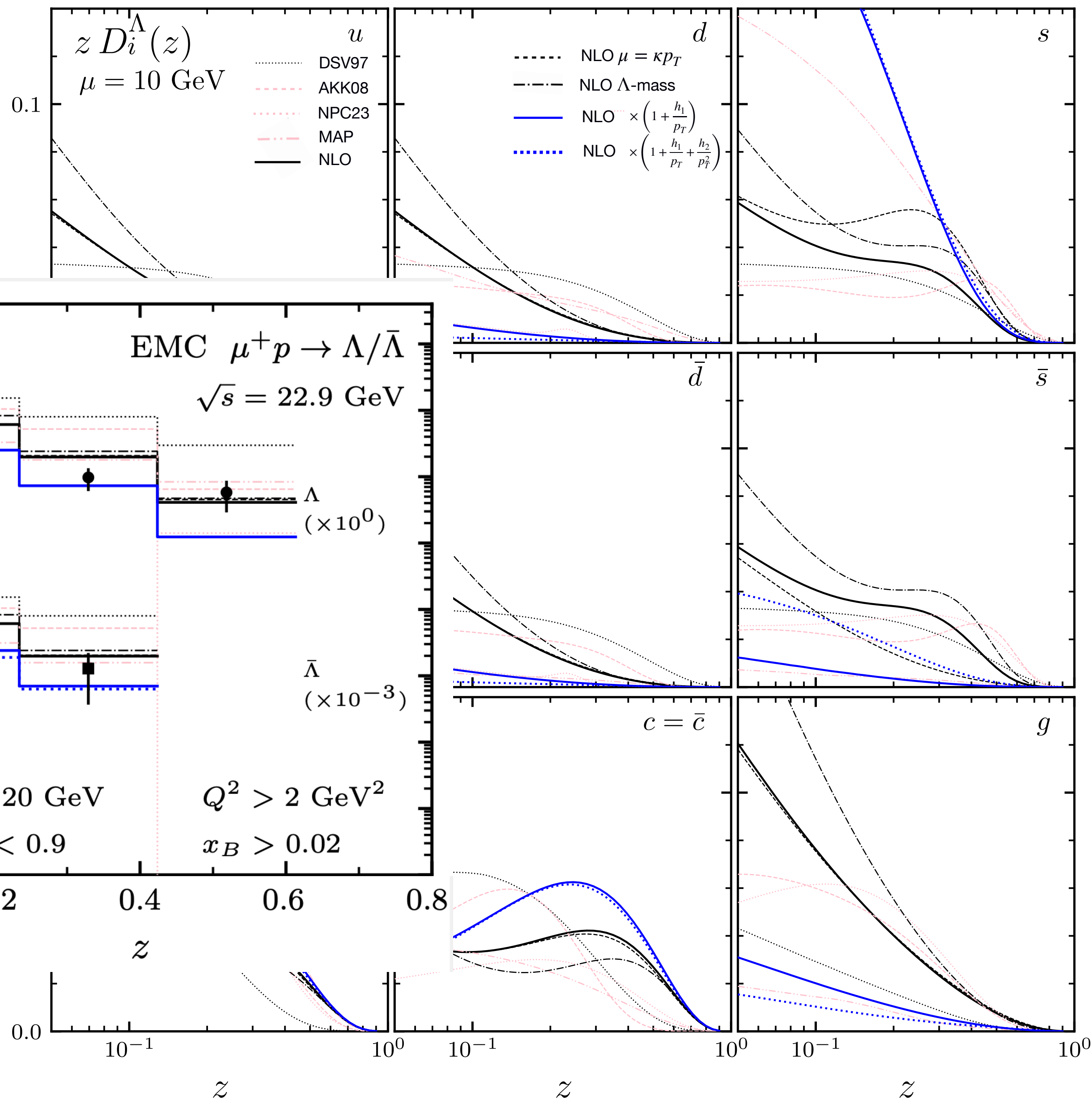


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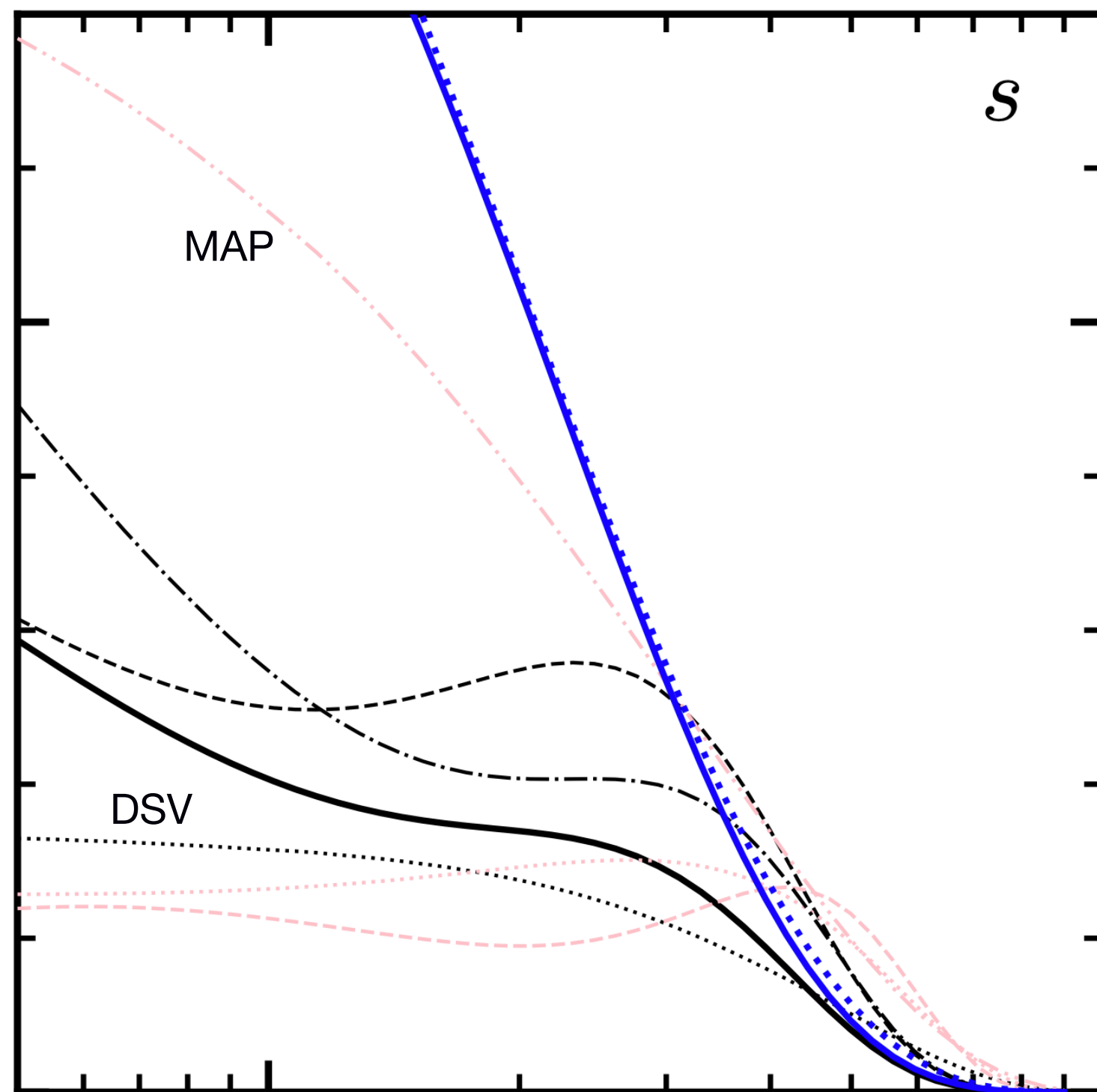


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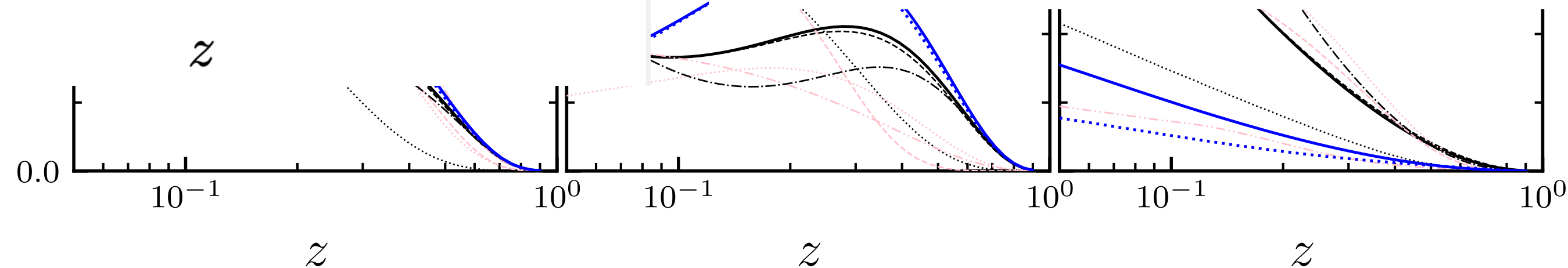
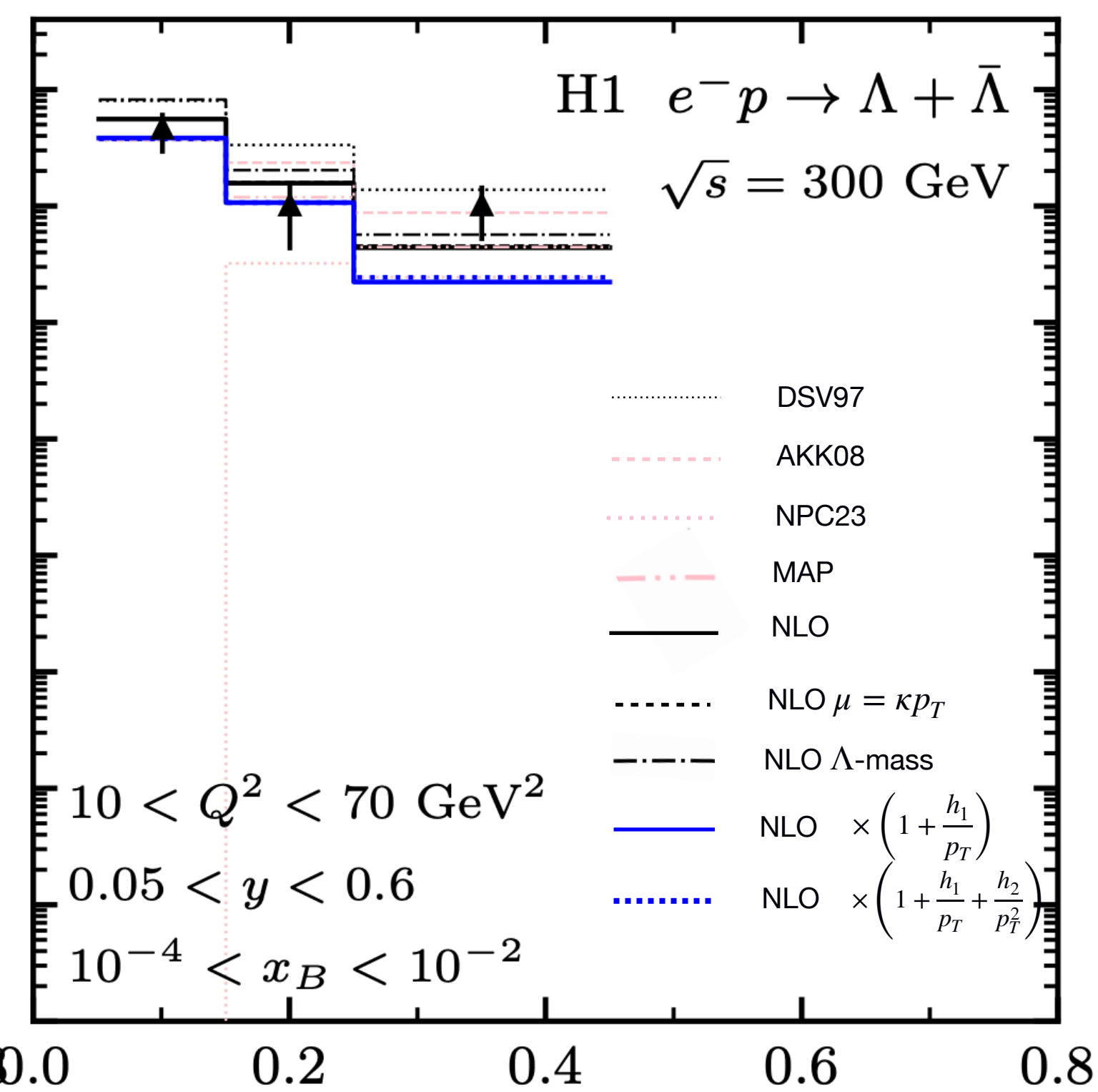
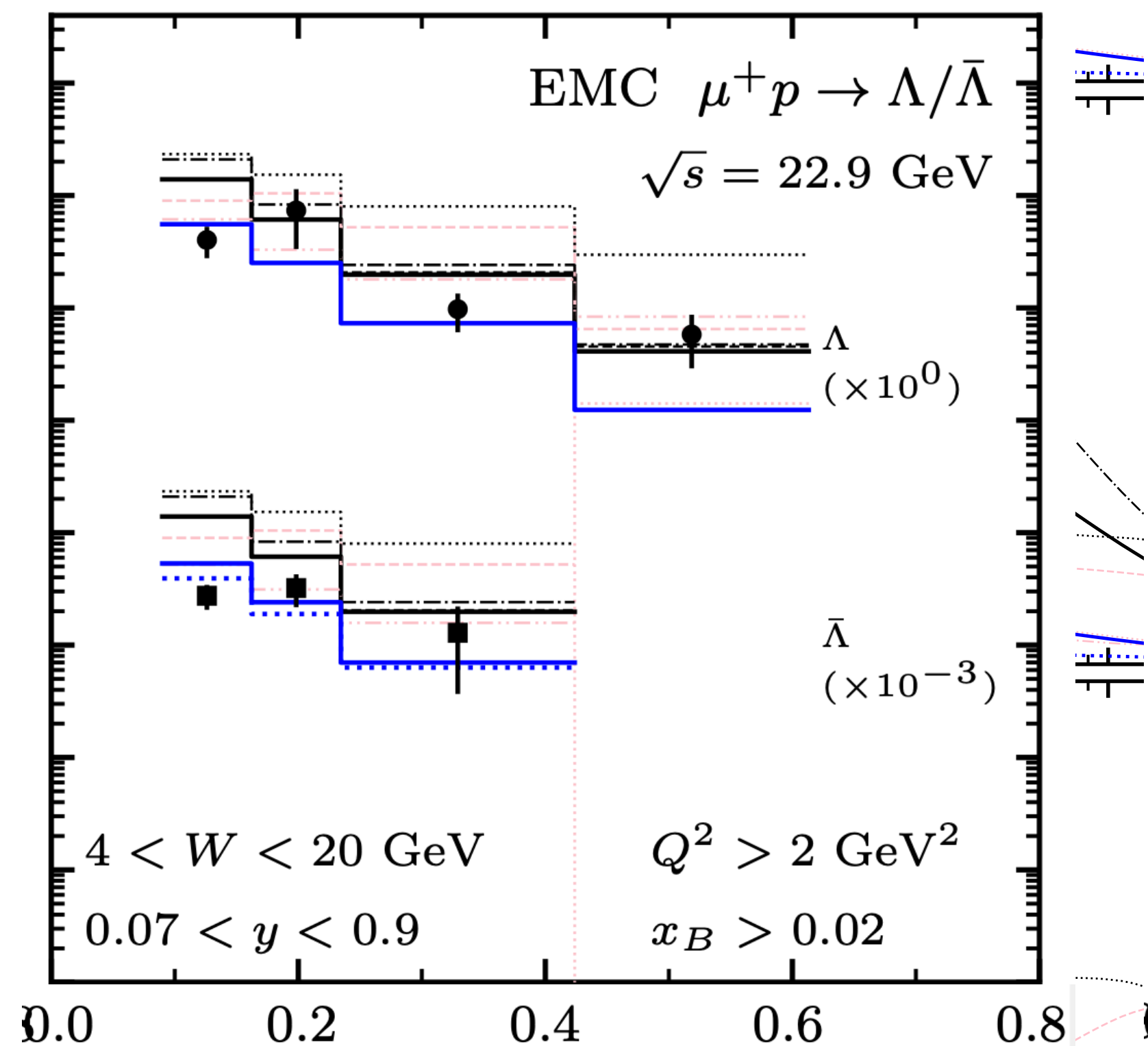
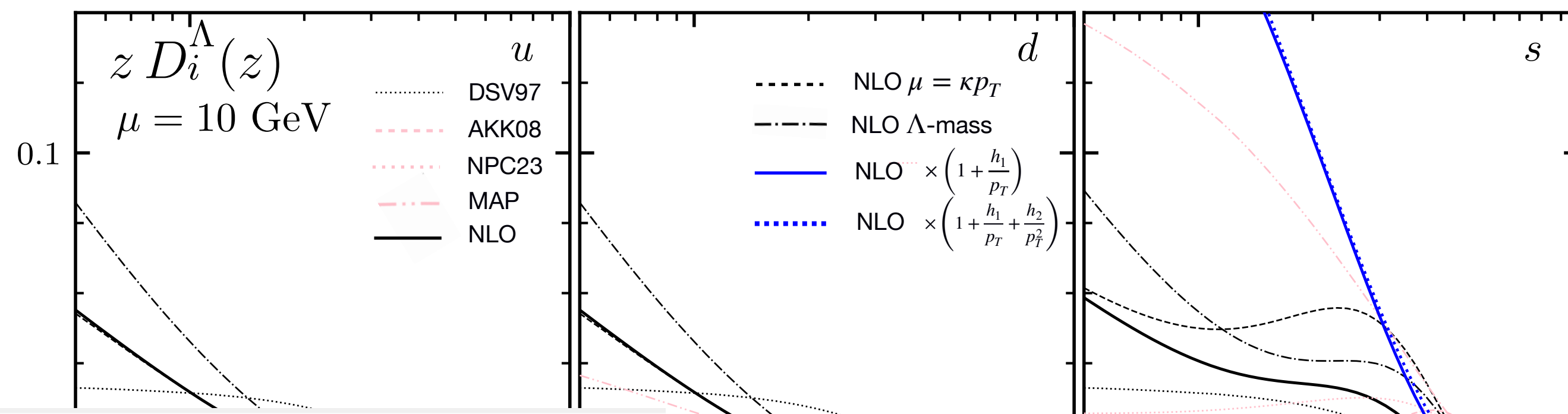


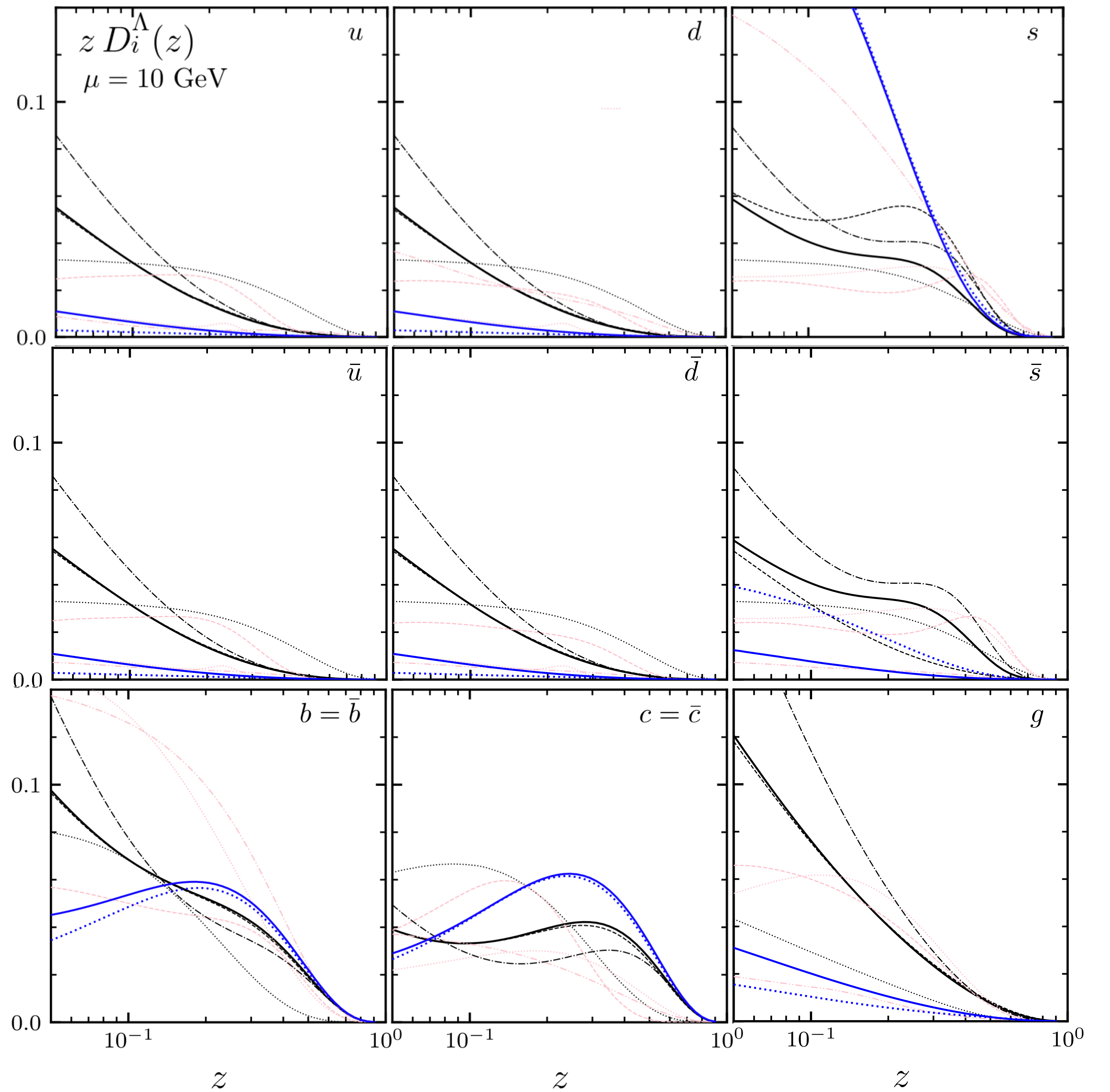
Λ^0 FFs

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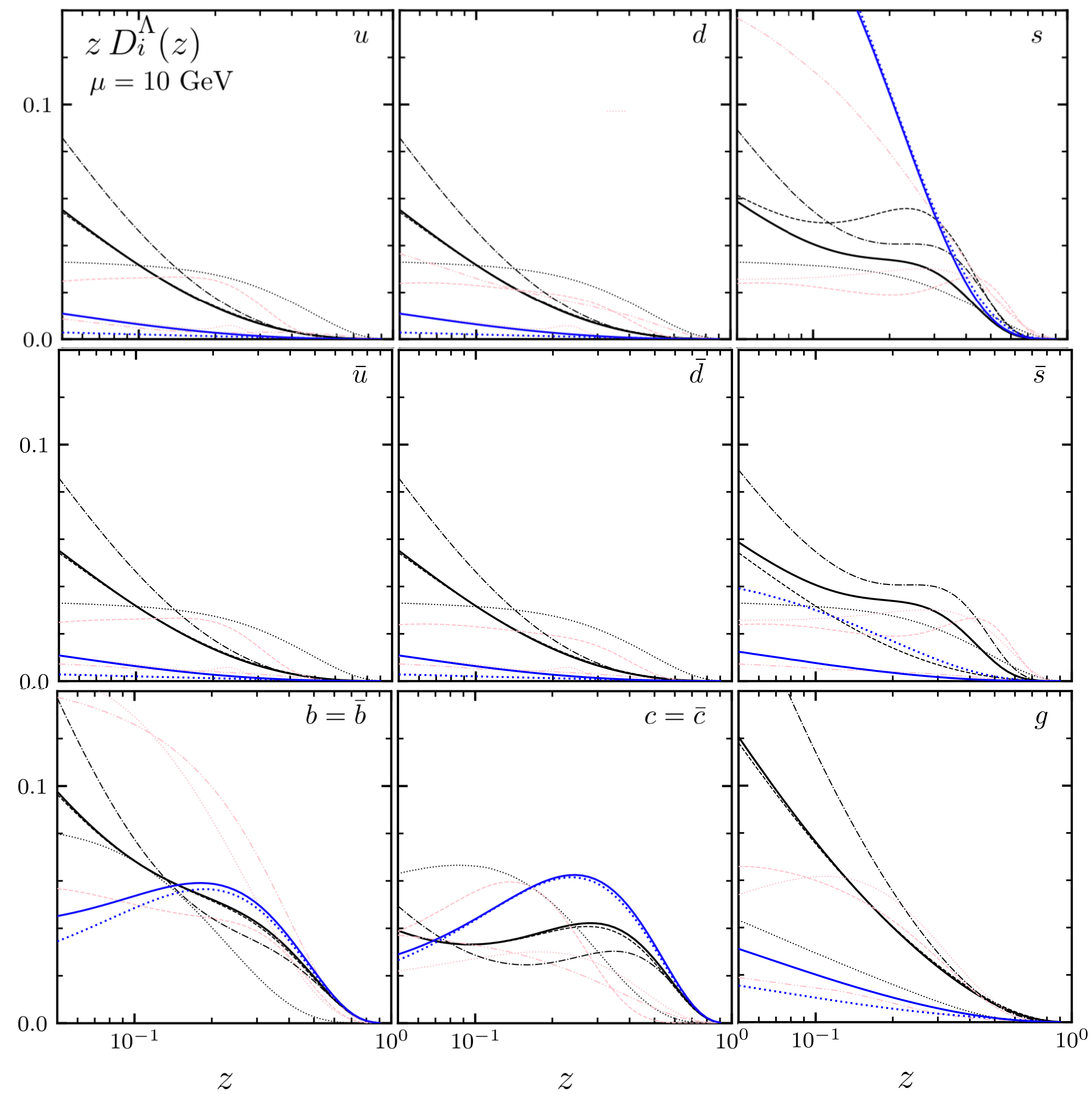


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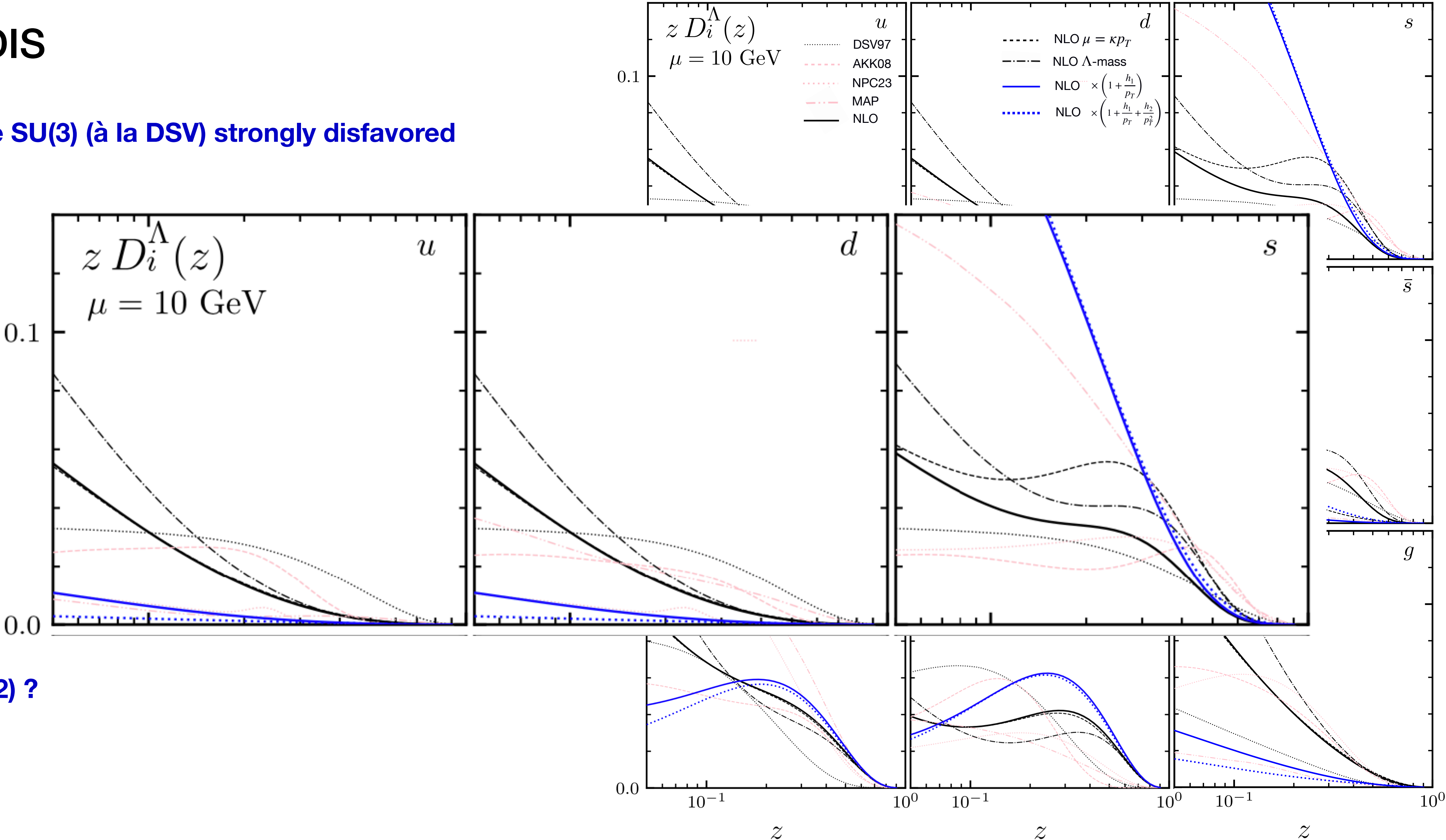


SIDIS



SIDIS

naive SU(3) (à la DSV) strongly disfavored

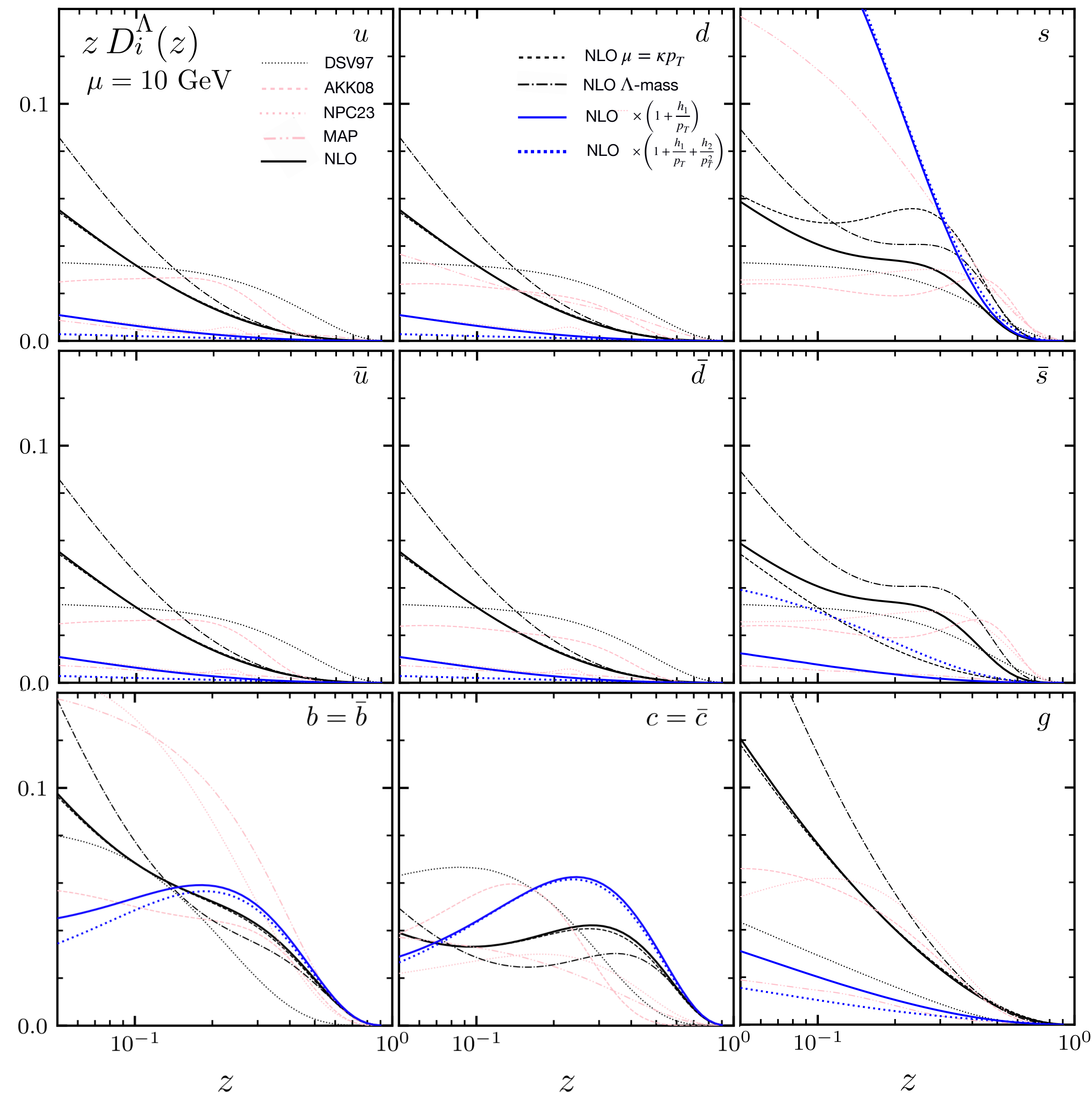


SU(2) ?

SIDIS

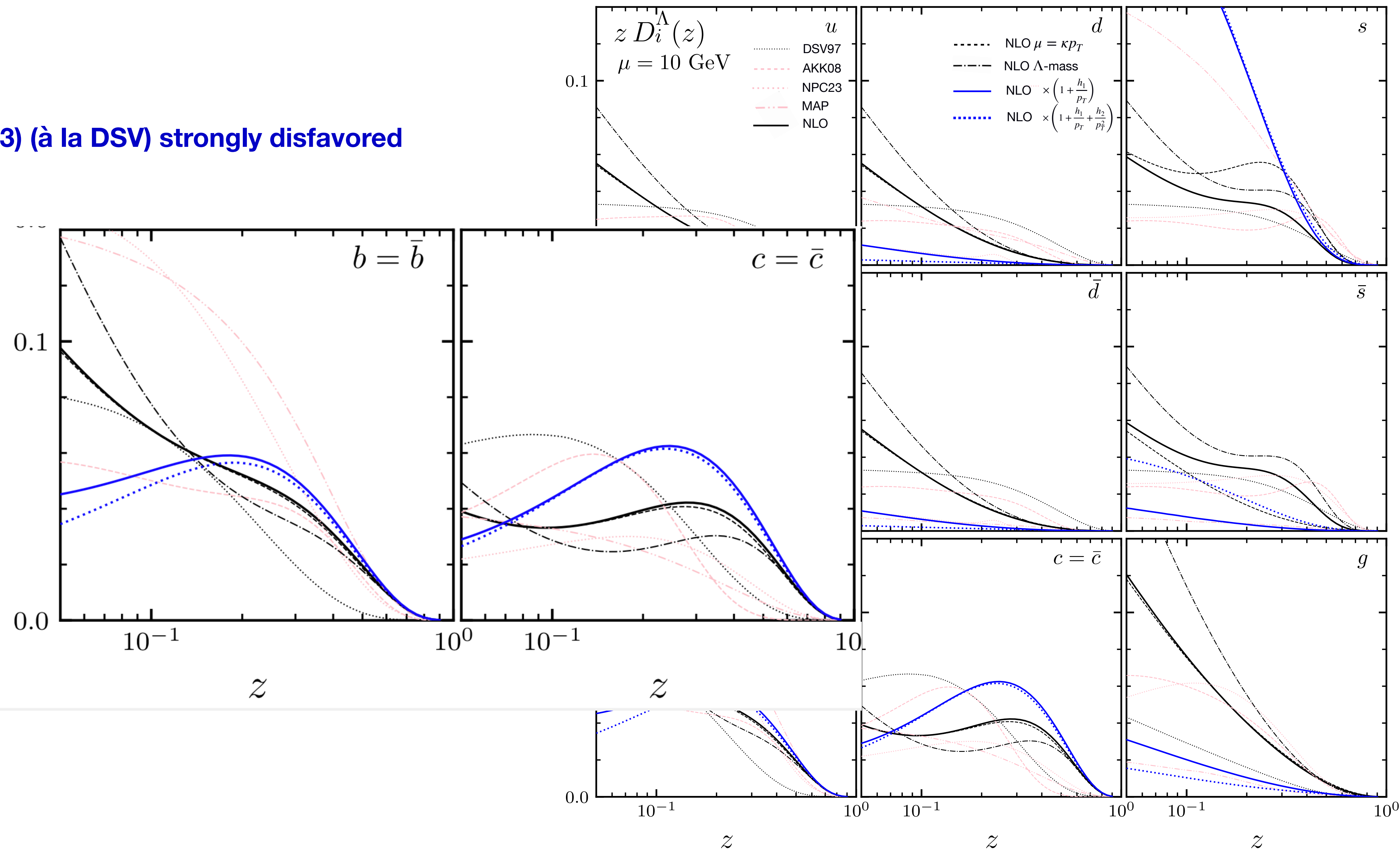
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SU(2) ?



SIDIS

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SU(2) ?

to be continued...

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uncertainties: Montecarlo Error Sampling

to be continued...

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NNLO: exact NNLO evolution, SIA and SIDIS, pp k-factors

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EIC impact study

to be continued...

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NNLO: exact NNLO evolution, SIA and SIDIS, pp k-factors

EIC impact study

polarization

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work in progress...

arXiv:hep-ph/9711387v1 19 Nov 1997

QCD Analysis of Unpolarized and Polarized
 Λ - Baryon Production in
Leading and Next-to-Leading Order

D. de Florian^a, M. Stratmann^b, W. Vogelshe

^aTheoretical Physics Division, CERN, CH-1211 Geneva 23

^bDepartment of Physics, University of Durham, Durham L

Abstract

We analyze experimental data for the production of Λ baryons in terms of scale dependent, QCD evolved, Λ fragmentation functions. The majority of the data for which the polarization is measured we also consider the recent LEP measurements of Λ production on the Z -resonance. Such data correct the previous results. We point out that the previous fragmentation functions for the Λ . We suggest several different functions to fix these. We therefore suggest several different functions compatible with present data, and study the prospect of deep-inelastic scattering experiments to discriminate between the complete next-to-leading order QCD framework for

23 May 2008

November 1997

PREPARED FOR SUBMISSION TO JHEP

First next-to-next-to-leading-order extraction of
fragmentation functions for Λ hyperons

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AKK Update: Improvements from New Theoretical Input and Experimental Data

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II. Institut für Theoretische Physik, Universität Hamburg
Luruper Chaussee 149, 22761 Hamburg, Germany
(Dated: October 22, 2018)

We perform a number of improvements to the previous AKK extraction of fragmentation functions for $\pi^\pm$, $K^\pm$, $p/\bar{p}$, K_S^0 and $\Lambda/\bar{\Lambda}$ particles at next-to-leading order. Including measurements from $pp(\bar{p})$ reactions at BRAHMS, CDF, PHENIX and STAR sample. We use the charge-sign asymmetry of the produced hadrons in p and $\bar{p}$ collisions to fix the valence quark fragmentation functions. Data from e^+e^- reactions in regions of low x_F are added. Hadron mass effects are treated for all observables and, for the first time, the hadron mass used for the description of the e^+e^- reaction is fitted. The baryons' fragmentation functions are only around 1% above their true masses, while the values of the mesons' fragmentation functions are of the correct order of magnitude. Large x resummation is applied in the coefficient functions for $q\bar{q}$ and gg reactions, and also in the evolution of the fragmentation functions, which leads to a significant reduction of the minimized χ^2 . To further exploit the data, all errors are incorporated via a correlation matrix.

I. INTRODUCTION

11 Feb 2010

Global analysis of fragmentation functions to light neutral hadrons
Jun Gao¹, ChongYang Liu¹, Mengyang Li², XiaoMin Shen^{3,1}, Hongxi Xing^{2,4,5}, Yuxiang Zhao^{3,5,6,7},
¹State Key Laboratory of Dark Matter Physics, Shanghai Key Laboratory for Particle Physics and Cosmology (MOE),
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²State Key Laboratory of Nuclear Physics and Technology, Institute of Quantum Matter,
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Guangdong Basic Research Center of Excellence for Structure and Fundamental Interactions of Matter,
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⁷Key Laboratory of Quark and Lepton Physics (MOE) and Institute of Particle Physics,
Central China Normal University, Wuhan 430079, China
⁸Key Laboratory of Atomic and Subatomic Structure and Quantum Control (MOE),
Guangdong-Hong Kong Joint Laboratory of Quantum Matter, Guangzhou 510006, China
⁹Department of Physics, University of Turin, via Pietro Giuria 1, I-10125 Torino, Italy
¹⁰INFN, Section of Turin, via Pietro Giuria 1, I-10125 Torino, Italy
Fragmentation functions (FFs) are crucial non-perturbative components in quantum chromodynamics (QCD), playing a vital role in predictions and understanding of the hadronization process. In this paper, we present the FFs for K_S^0 , η , π^0 mesons, and Λ baryons in the context of global analysis. The data included in the fit are from single inclusive e^+e^- annihilation (SIA), inclusive deep-inelastic scattering (SIDIS) and proton-proton collisions, with kinematic cuts applied to ensure validity of collinear factorization and perturbative QCD expansion. For the first time, data from SIDIS and hadron-in-jet production in SIA have been incorporated into the extraction of FFs for light-flavor neutral hadrons. Our analysis reveals that these data play a crucial role in constraining the gluon distribution, and in distinguishing between different quark fragmentation functions. FFs from different datasets are also studied by performing alternative fits to the data. The extracted K_S^0 fragmentation functions are generally well constrained by the data, while the η and π^0 fragmentation functions are still poorly constrained. The Λ fragmentation functions are also studied by performing alternative fits to the data. The extracted Λ fragmentation functions are generally well constrained by the data, while the $\bar{\Lambda}$ fragmentation functions are still poorly constrained.

Higher-Twist Dynamics in Large Transverse Momentum Hadron Production

François Arleo,¹ Stanley J. Brodsky,² Dae Sung Hwang,³ and Anne M. Sickles⁴

¹Laboratoire d'Annecy-le-Vieux de Physique Théorique (LAPTH), UMR5108, Université de Savoie, CNRS, BP 110, 74941 Annecy-le-Vieux cedex, France

²SLAC National Accelerator Laboratory, Stanford University, Stanford, California 94309, USA

³Department of Physics, Sejong University, Seoul 143-747, Korea

⁴Brookhaven National Laboratory, Upton, New York 11973, USA

(Dated: October 28, 2018)

A scaling law analysis of the world data on inclusive large- $p_\perp$ hadron production in hadronic collisions is carried out. A significant deviation from leading-twist perturbative QCD predictions at next-to-leading order is reported. The observed discrepancy is largest at high values of $x_\perp = 2p_\perp/\sqrt{s}$. In contrast, the production of prompt photons and jets exhibits the scaling behavior which is close to the conformal limit, in agreement with the leading-twist expectation. These results bring evidence for a non-negligible contribution of higher-twist processes in large- $p_\perp$ hadron production in hadronic collisions, where the hadron is produced directly in the hard subprocess rather than by gluon or quark jet fragmentation. Predictions for scaling exponents at RHIC and LHC are given, and it is suggested to trigger the isolated large- $p_\perp$ hadron production to enhance higher-twist processes.

PACS numbers: 11.15.Bt, 12.38.-t, 12.38.Qk, 13.85.Ni