UPDATING/ UPGRADING DSSV:

Rodolfo Sassot
Universidad de Buenos Aires

in collaboration with D. de Florian, M. Stratmann and W. Vogelsang

The Flavor Structure of the Nucleon Sea, INT Workshop, Seattle October 2nd - 17th, 2017

Outline:

Perspective: from DSSV08 … to DSSV14 … to DSSV18

DSSV08:
- main ideas/ingredients
- main results

DSSV14:
- main motivation
- main changes

DSSV18:
- main questions
- new data
- new inputs
- preliminary results

→ dijets in pp collisions and their impact on Δg

→ new FFs sets and their impact on $\Delta \overline{s}$

→ W-production data and their impact on $\Delta \overline{u}$ and $\Delta \overline{d}$

Motivation:

DSSV08

First combined DIS, SIDIS, PP global fit of pPDFs

Global fit mantra…

$$x\Delta q_i(x,Q_0^2) = N_i x^{\alpha_i}(1-x)^{\beta_i}(1+\gamma_i\sqrt{x}+\eta_i x^{\kappa_i})$$

"over-parameterized"

mellin moments: evolution & DIS

multiple mellin transform: sidis and pp

PRL **101,** 072001 (2008)

PHYSICAL REVIEW LETTERS

week ending
15 AUGUST 2008

Global Analysis of Helicity Parton Densities and their Uncertainties

Daniel de Florian and Rodolfo Sassot
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Marco Stratmann
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Werner Vogelsang
Physics Department, Brookhaven National Laboratory, Upton, New York 11973, USA

(Received 3 April 2008; published 14 August 2008)

We present a new analysis of the helicity parton distributions of the nucleon. The analysis takes into account the available data from inclusive and semi-inclusive polarized deep inelastic scattering, as well as from polarized proton-proton (p-p) scattering at RHIC. For the first time, all theoretical calculations are performed fully at next-to-leading order (NLO) of perturbative QCD, using a method that allows incorporation of the NLO corrections in a very fast and efficient way in the analysis. We find evidence for a rather small gluon polarization in the nucleon, over a limited region of momentum fraction, and for interesting flavor patterns in the polarized sea.

DOI: 10.1103/PhysRevLett.101.072001

PACS numbers: 13.88.+e, 12.38.Bx, 13.60.Hb, 13.85.Ni

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The structure of a nucleon in a helicity eigenstate is foremost described by the (anti)quark and gluon helicity parton distribution functions (PDFs), defined by

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Here, $f_j^+(x,Q^2)$ $[f_j^-(x,Q^2)]$ denotes the distribution of a parton of type j with positive [negative] helicity in a nucleon with positive helicity, having light-cone momentum fraction x of the nucleon momentum and being probed at a hard scale Q. The integral $\Delta f_j^1(Q^2) \equiv \int_0^1 \Delta f_j(x,Q^2)dx$ measures the spin contribution of parton j to the proton spin, which is one reason why there are world-wide efforts to extract the $\Delta f_j(x,Q^2)$ from experimental data.

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$$A_{LL} \equiv \frac{d\Delta\sigma}{d\sigma} \equiv \frac{d\sigma^{++} - d\sigma^{+-}}{d\sigma^{++} + d\sigma^{+-}}, \tag{2}$$

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This Letter presents the first "globa
the data from DIS, SIDIS, and RH

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072001-1

Motivation:

DSSV08

First combined DIS, SIDIS, PP global fit of pPDFs

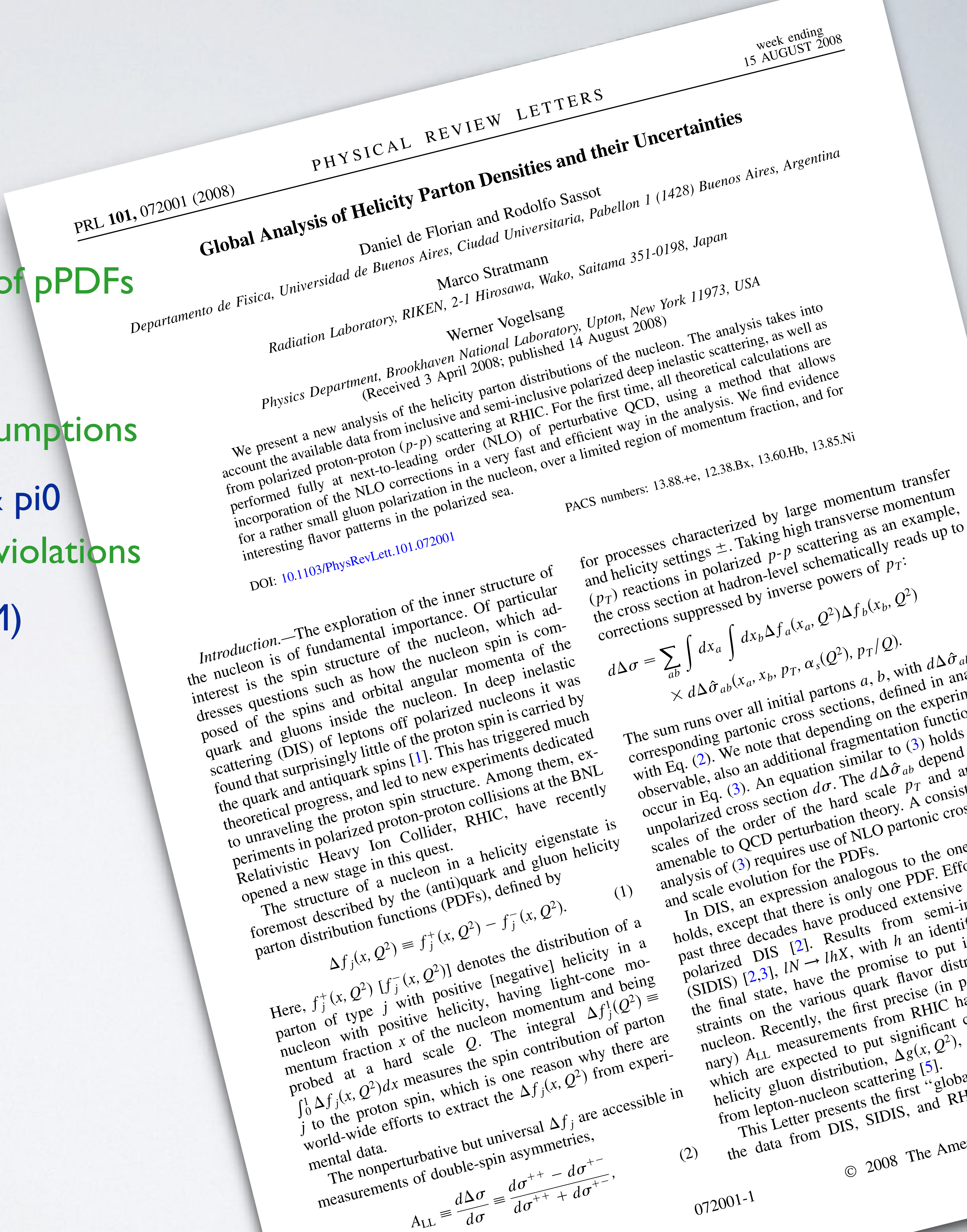
constrain $\Delta\bar{q}$ with SIDIS (DSS07 FFs)

instead of flavor symmetry assumptions

constrain Δg with RHIC run5-6 jets & pi0

instead of g_1 scaling violations

alternative error estimate approach (LM)



PRL 101, 072001 (2008) PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2008

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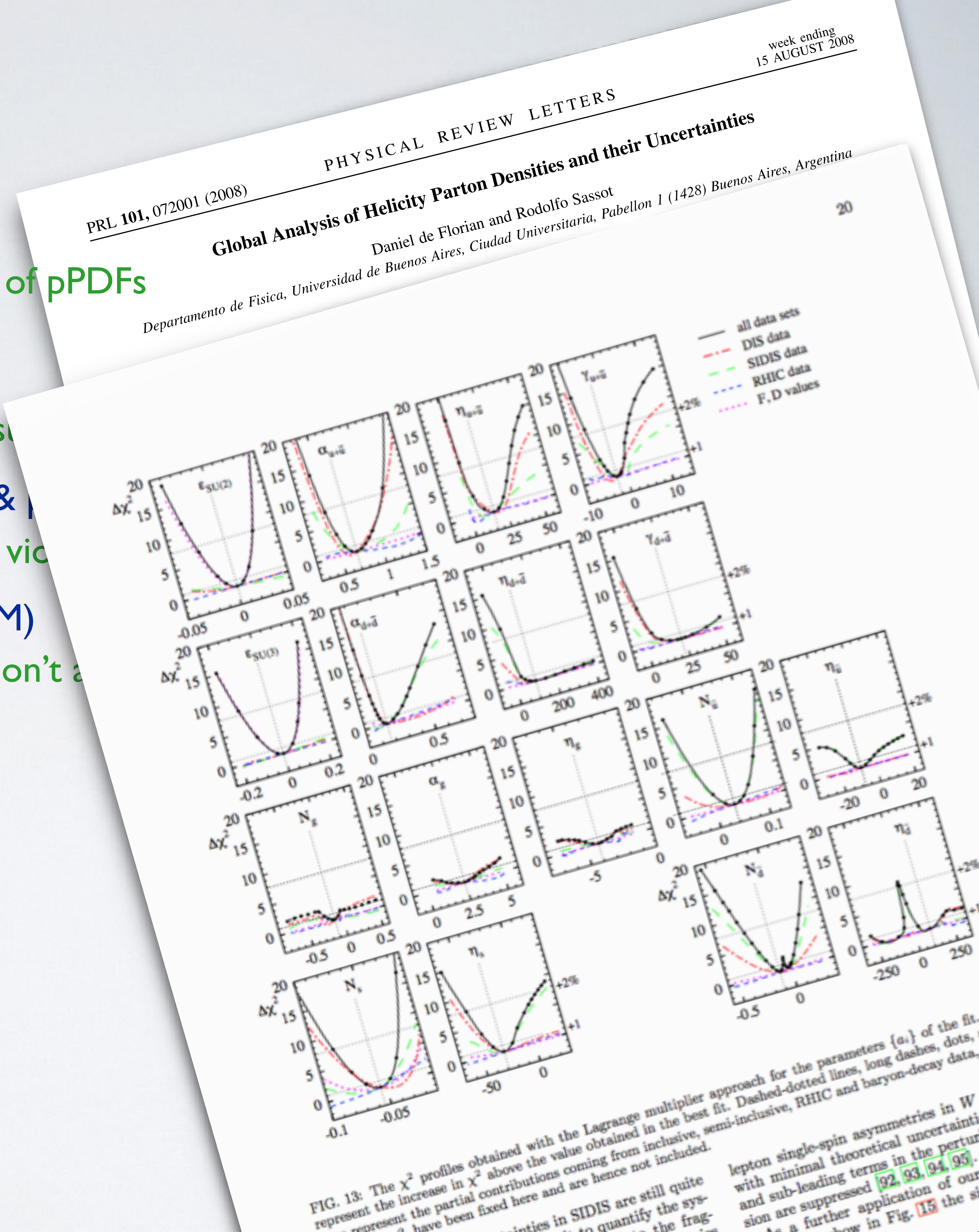

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FIG. 13: The χ^2 profiles obtained with the Lagrange multiplier approach for the parameters $\{a_i\}$ of the fit. represent the increase in χ^2 above the value obtained in the best fit. Dashed-dotted lines, long dashes, dots, represent the partial contributions coming from inclusive, semi-inclusive, RHIC and baryon-decay data, have been fixed here and are hence not included.

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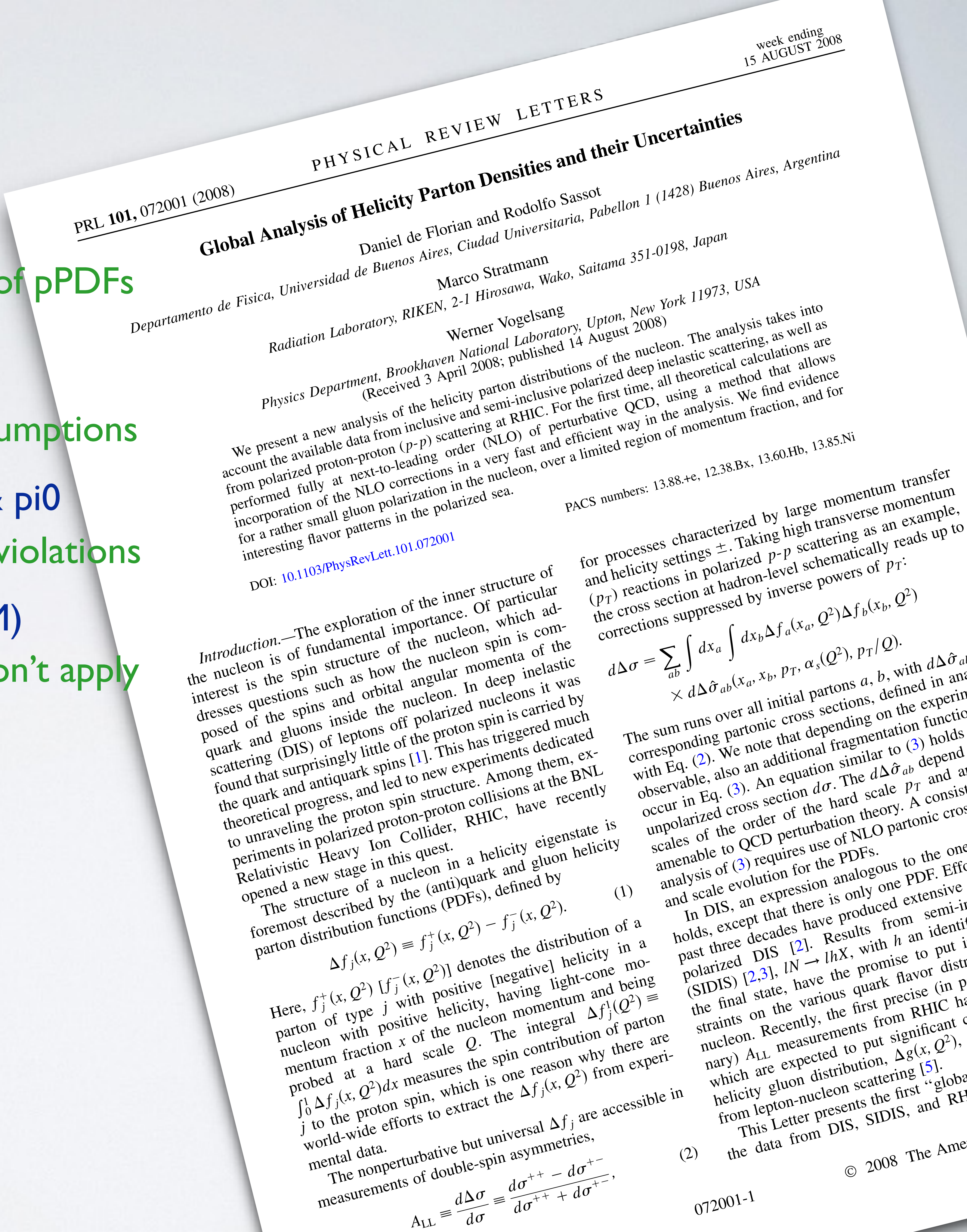
“unexpected” features:



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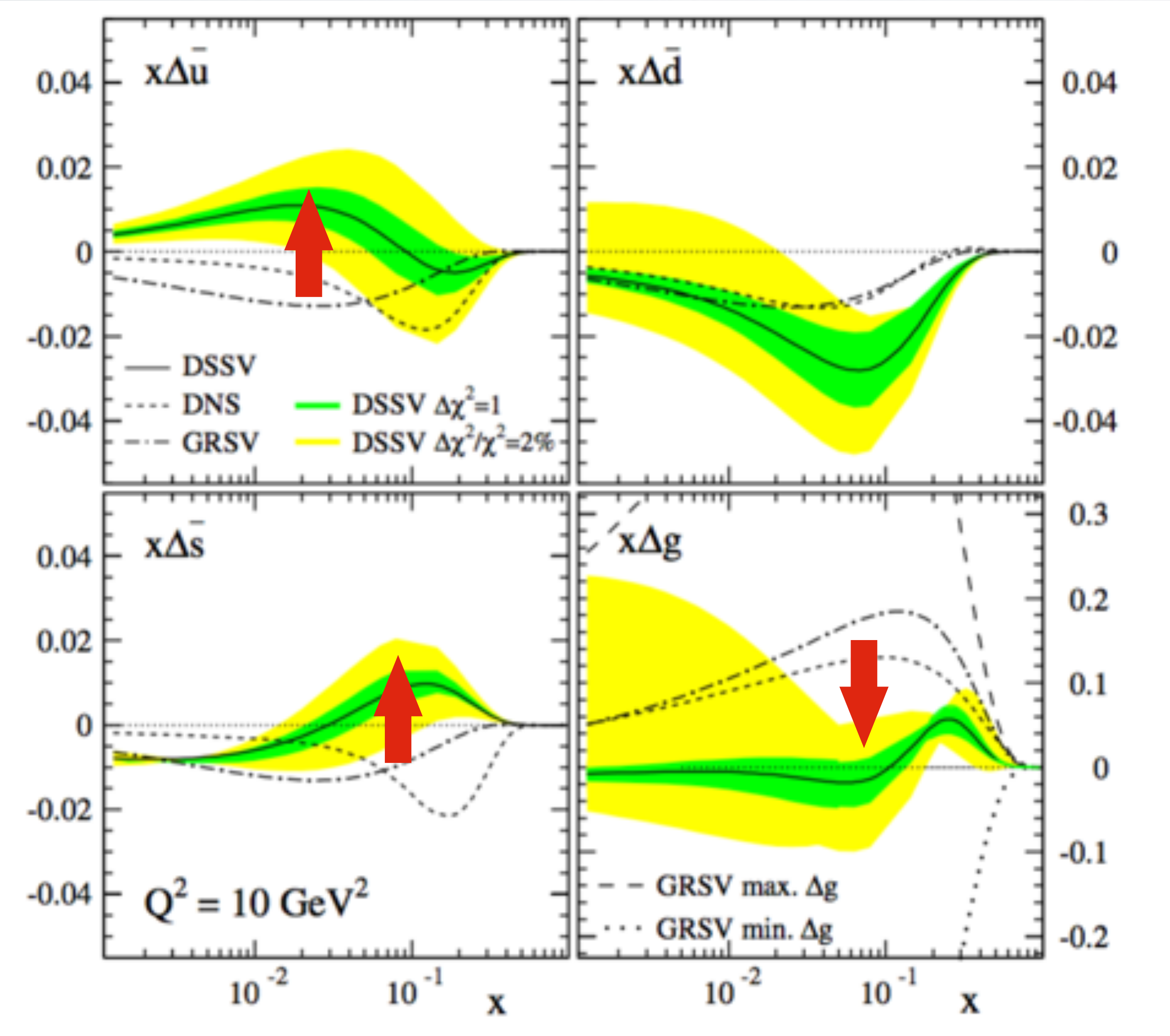

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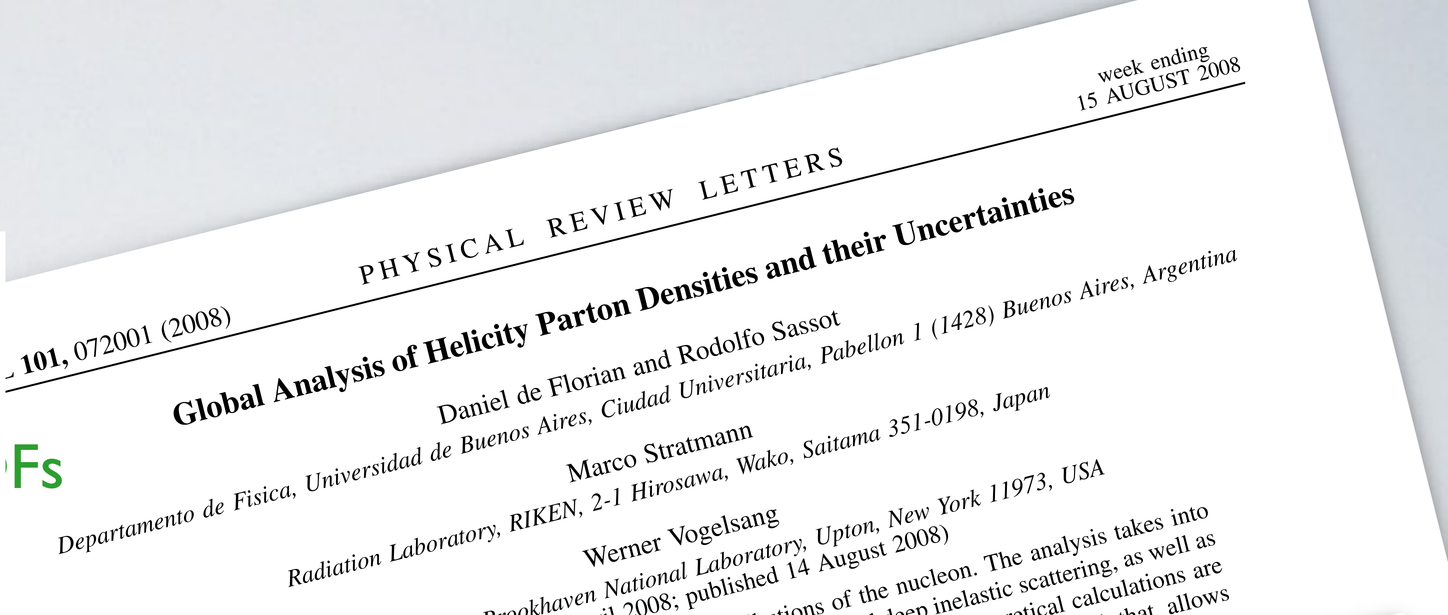

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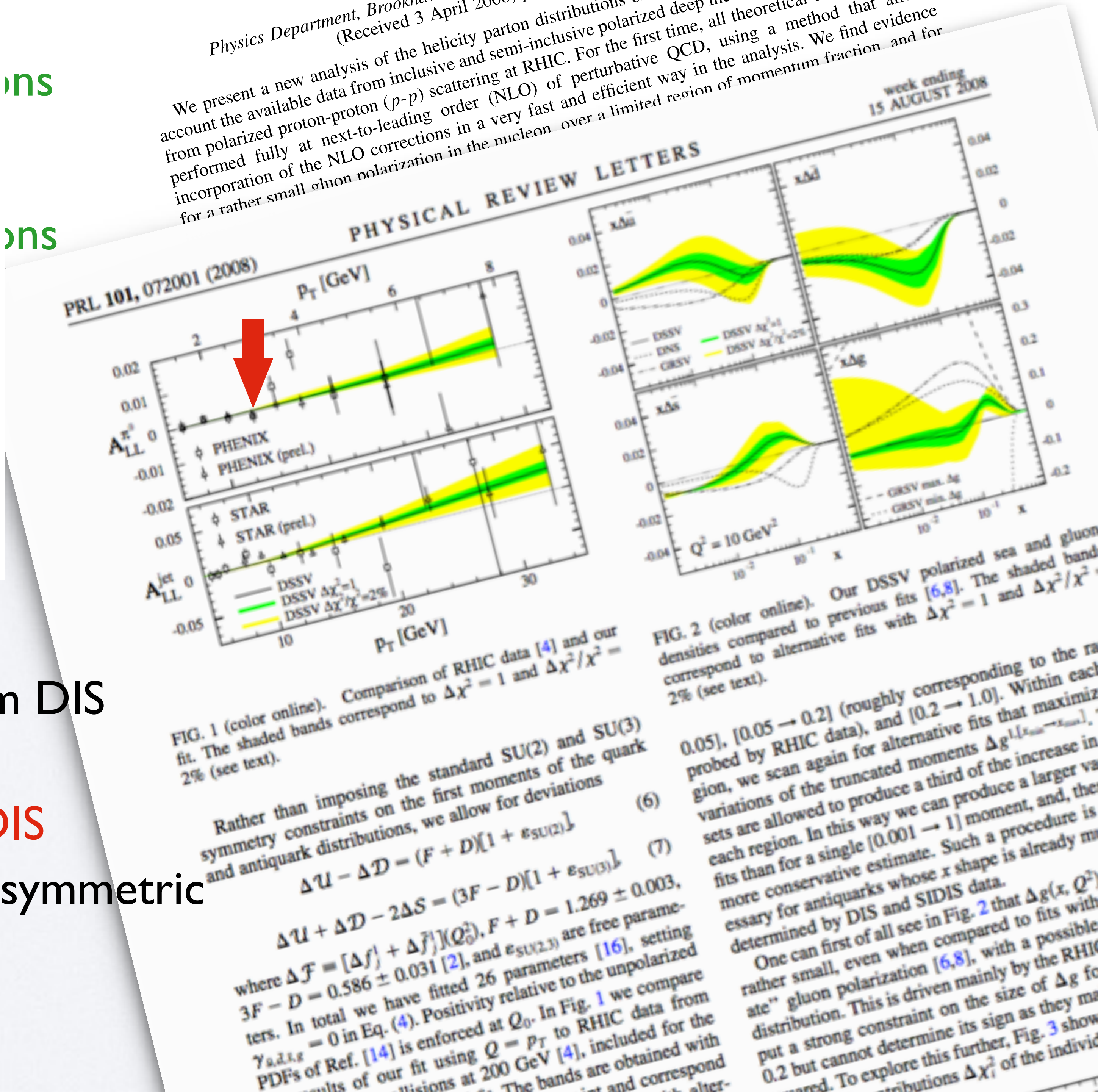


PRL 101, 072001 (2008) PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2008

FIG. 1 (color online). Comparison of RHIC data [4] and our fit. The shaded bands correspond to $\Delta\chi^2 = 1$ and $\Delta\chi^2/\chi^2 =$ 2% (see text).

FIG. 2 (color online). Our DSSV polarized sea and gluon densities compared to previous fits [6,8]. The shaded band correspond to alternative fits with $\Delta\chi^2 = 1$ and $\Delta\chi^2/\chi^2$ 2% (see text).

Rather than imposing the standard SU(2) and SU(3) symmetry constraints on the first moments of the quark and antiquark distributions, we allow for deviations

$$\Delta\mathcal{U} - \Delta\mathcal{D} = (F + D)[1 + \varepsilon_{SU(2)}], \quad (6)$$

$$\Delta\mathcal{U} + \Delta\mathcal{D} - 2\Delta\mathcal{S} = (3F - D)[1 + \varepsilon_{SU(3)}], \quad (7)$$

where $\Delta\mathcal{F} = [\Delta f_j^1 + \Delta \bar{f}_j^1](Q_0^2)$, $F + D = 1.269 \pm 0.003$, $3F - D = 0.586 \pm 0.031$ [2], and $\varepsilon_{SU(2,3)}$ are free parameters. In total we have fitted 26 parameters [16], setting $\gamma_{u,d,s,g} = 0$ in Eq. (4). Positivity relative to the unpolarized PDFs of Ref. [14] is enforced at Q_0. In Fig. 1 we compare results of our fit using $Q = p_T$ to RHIC data from collisions at 200 GeV [4], included for the

0.05], [0.05 → 0.2] (roughly corresponding to the ra
probed by RHIC data), and [0.2 → 1.0]. Within each
gion, we scan again for alternative fits that maximiz
variations of the truncated moments $\Delta g^{1,[x_{min}\to x_{max}]}$
sets are allowed to produce a third of the increase in
each region. In this way we can produce a larger va
fits than for a single [0.001 → 1] moment, and, the
more conservative estimate. Such a procedure is
essary for antiquarks whose x shape is already m
determined by DIS and SIDIS data.

One can first of all see in Fig. 2 that $\Delta g(x, Q^2)$
rather small, even when compared to fits with
ate" gluon polarization [6,8], with a possible
distribution. This is driven mainly by the RHI
put a strong constraint on the size of Δg fo
0.2 but cannot determine its sign as they ma

gluon polarization node driven by $A_{LL}^{\pi^0}$

instead of large and positive Δg from DIS

positive $\Delta\bar{u}$ & $\Delta\bar{s}$ polarization driven by SIDIS

instead of slightly negative and flavor symmetric

Motivation:

DSSV14

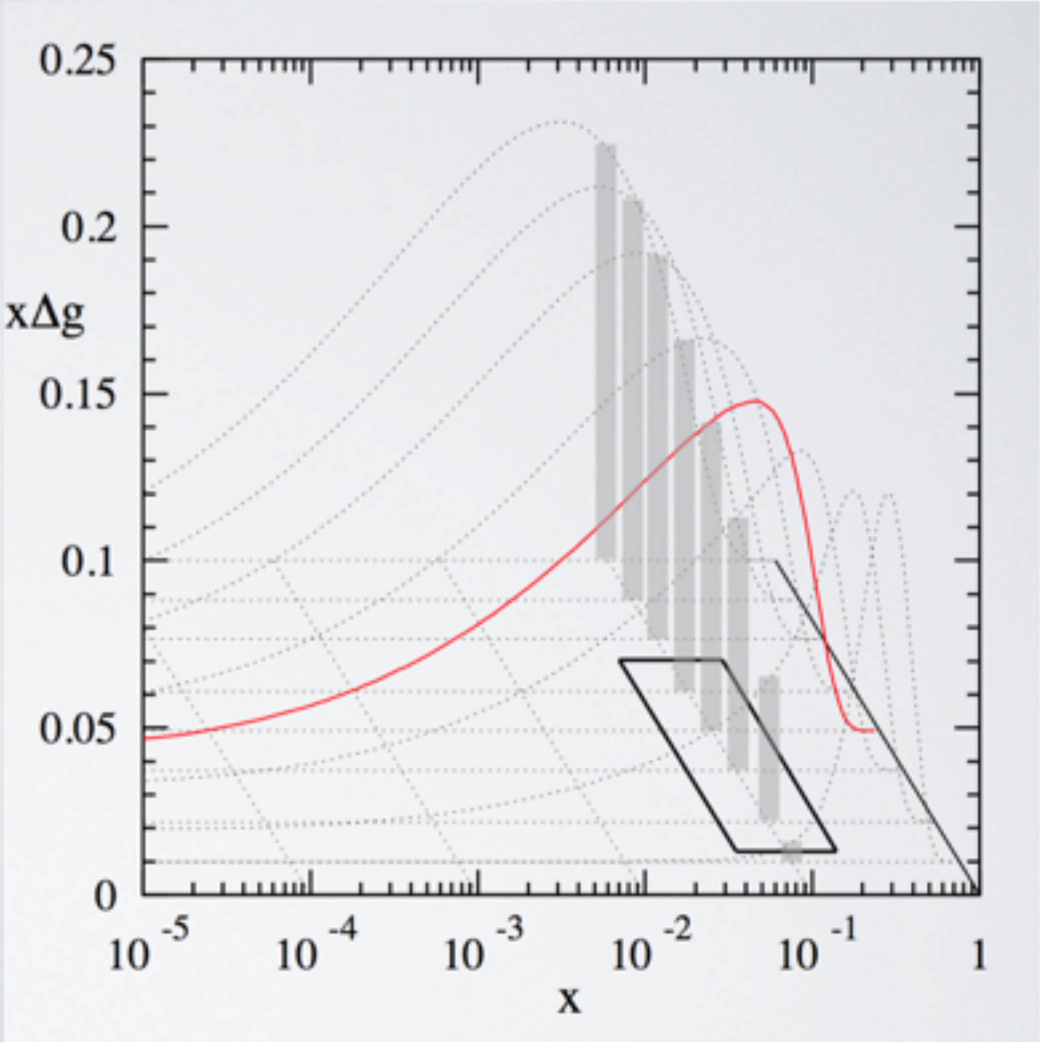
update to assess the impact of run9

STAR jet data favor larger Δg

conciliated with PHENIX pi^0 preference

(rapid Q^2 evolution)

tension?



PRL **113,** 012001 (2014)

PHYSICAL REVIEW LETTERS

week ending
4 JULY 2014

Evidence for Polarization of Gluons in the Proton

Daniel de Florian[*] and Rodolfo Sassot[†]
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We discuss the impact of recent high-statistics Relativistic Heavy Ion Collider data

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Δg in the context of a new NLO global analysis of helicity parton densities.

Global analysis and new and updated data sets.—As just described, the key ingredients to our new QCD analysis are the 2009 STAR [6] and PHENIX [7] data on the double-spin asymmetries for inclusive jet and π^0 production. At the same time, we also update some of the earlier RHIC results used in [3] and add some new DIS data sets by the COMPASS experiment. More specifically, we now utilize the final PHENIX π^0 data from run 6 at $\sqrt{s} = 200$ GeV [8] and 62.4 GeV [9], the final STAR jet results from run 5 and run 6 [10], and the recent inclusive [11] and semi-inclusive [12] DIS data sets from COMPASS. As far as the impact on Δg is concerned, the data sets [6,7] clearly dominate. The COMPASS data sets will primarily affect the quark and antiquark helicity distributions as reported in [13].

The method for our global analysis has been described in detail in [3] and will not be presented here again. It is based on an efficient Mellin-moment technique that allows one to tabulate and store the computationally most demanding parts of a NLO calculation prior to the actual analysis. In this way, the evaluation of the relevant spin-dependent pp cross sections [14] becomes so fast that it can be easily performed inside a standard χ^2 minimization analysis. As a small technical point, we note that STAR has moved to the "anti-k_t" jet algorithm [15] for their analysis of the data from the 2009 run. In order to match this feature, we use the NLO expressions derived in [16] for the polarized case. As in our previous DSSV analysis [3], standard Lagrange multiplier (LM) and Hessian techniques are employed in order to assess the uncertainties of the polarized parton distributions determined in the fit.

We adopt the same flexible functional form as in [3] to the initial

FIG. 1 (color online). Gluon helicity distributio $Q^2 = 10$ GeV^2 for the new fit, the original DSSV analy [3], and for an updated analysis without using the ne RHIC data sets (DSSV*, see text). The dotted lines pre gluon densities for alternative fits that are within the 9 limit. The x range primarily probed by the RHIC data is by the two vertical dashed lines.

tolerance and for the adopted functional for dotted-dashed curve represents the result henceforth labelled as "DSSV*"—for whi include the updates to the various RHIC da used for the original DSSV analysis [3] (das we exclude all the new 2009 data [6 COMPASS inclusive [11] and semi-incl data sets have little impact on Δg and ar DSSV* fit.

The striking feature of our new pola bution is its much larger size as comp DSSV analysis [3]. For $Q^2 = 10$ G throughout and clearly away from predominantly probe $0.05 \leq x \leq 0.2$ as is demonstrated by the alternat C.L. interval. In contrast to th the new Δg does not s [18]. It is

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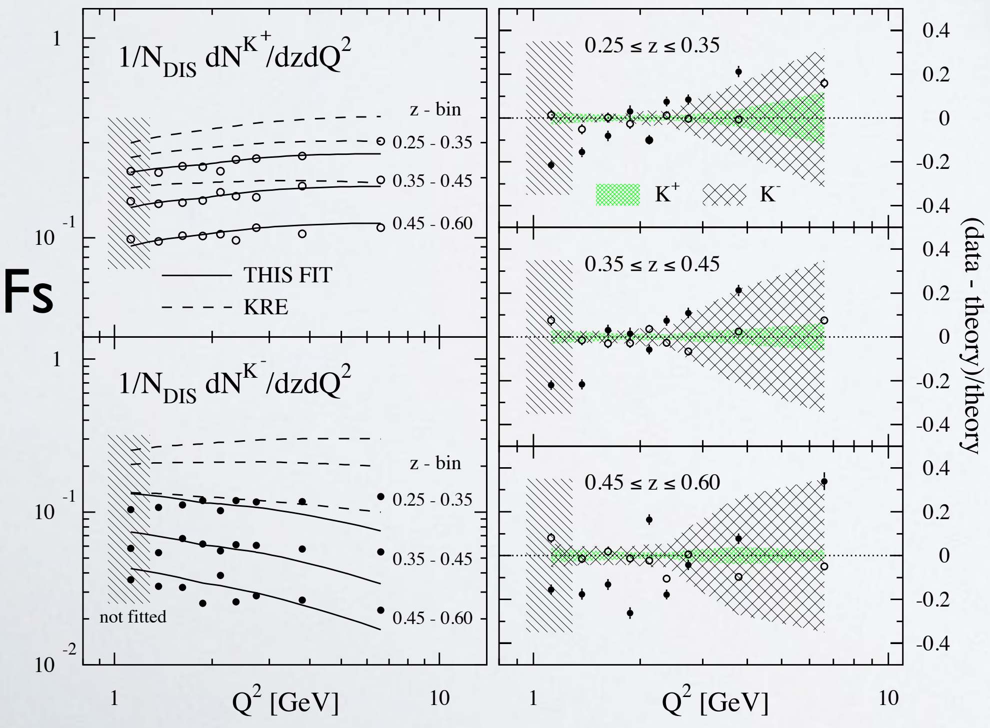
(rapid Q^2 evolution)

tension?

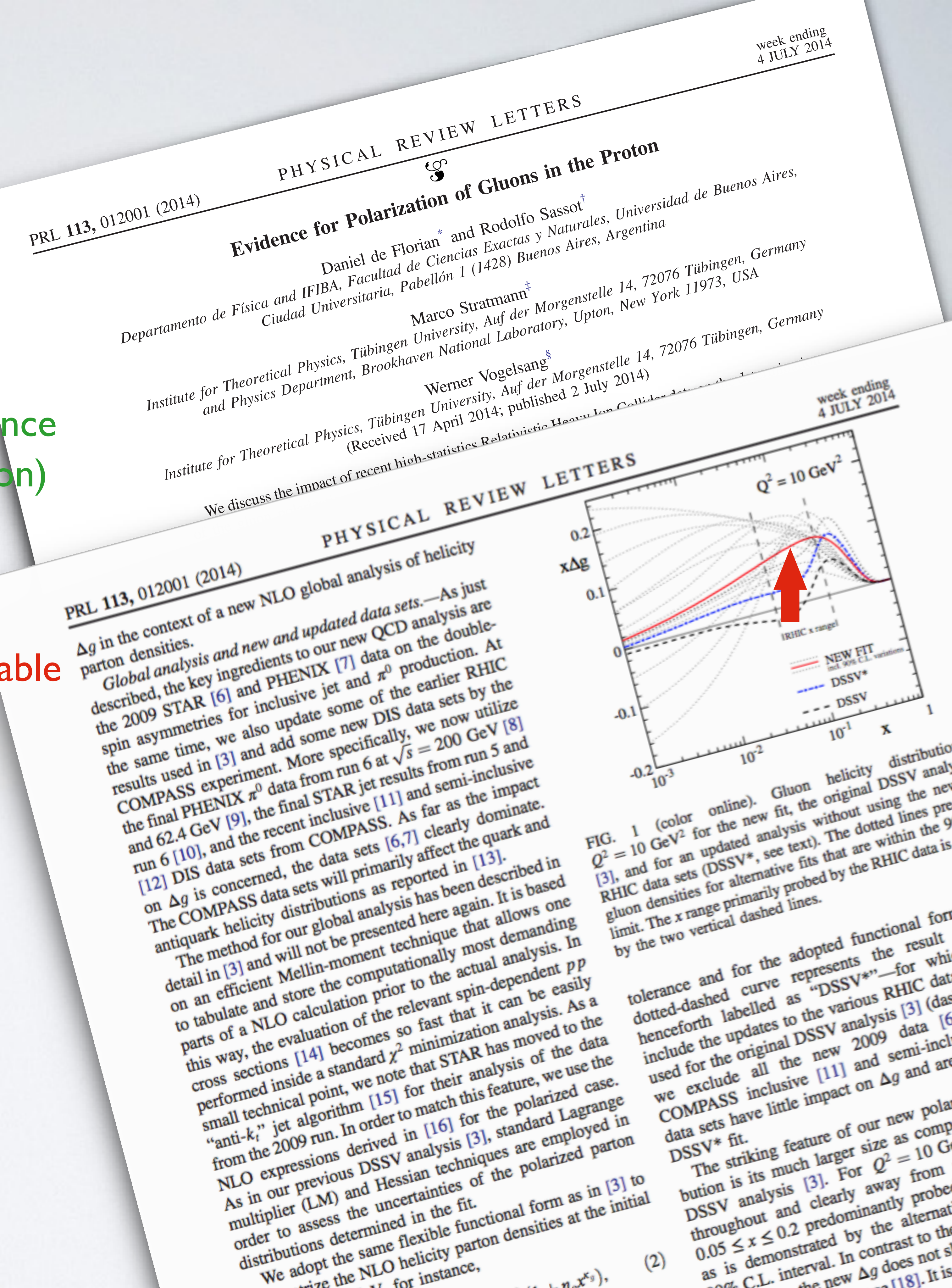
Compass SIDIS asymmetries included

SIDIS multiplicities (FFs) not yet available

Compass vs. Hermes controversy



DSS07 FFs



PRL **113,** 012001 (2014) PHYSICAL REVIEW LETTERS week ending 4 JULY 2014

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PRL **113,** 012001 (2014) PHYSICAL REVIEW LETTERS week ending 4 JULY 2014

Δg in the context of a new NLO global analysis of helicity parton densities.

Global analysis and new and updated data sets.—As just described, the key ingredients to our new QCD analysis are the 2009 STAR [6] and PHENIX [7] data on the double-spin asymmetries for inclusive jet and π^0 production. At the same time, we also update some of the earlier RHIC results used in [3] and add some new DIS data sets by the COMPASS experiment. More specifically, we now utilize the final PHENIX π^0 data from run 6 at $\sqrt{s} = 200$ GeV [8] and 62.4 GeV [9], the final STAR jet results from run 5 and run 6 [10], and the recent inclusive [11] and semi-inclusive [12] DIS data sets from COMPASS. As far as the impact on Δg is concerned, the data sets [6,7] clearly dominate. The COMPASS data sets will primarily affect the quark and antiquark helicity distributions as reported in [13].

The method for our global analysis has been described in detail in [3] and will not be presented here again. It is based on an efficient Mellin-moment technique that allows one to tabulate and store the computationally most demanding parts of a NLO calculation prior to the actual analysis. In this way, the evaluation of the relevant spin-dependent pp cross sections [14] becomes so fast that it can be easily performed inside a standard χ^2 minimization analysis. As a small technical point, we note that STAR has moved to the "anti-k_t" jet algorithm [15] for their analysis of the data from the 2009 run. In order to match this feature, we use the NLO expressions derived in [16] for the polarized case. As in our previous DSSV analysis [3], standard Lagrange multiplier (LM) and Hessian techniques are employed in order to assess the uncertainties of the polarized parton distributions determined in the fit.

We adopt the same flexible functional form as in [3] to rize the NLO helicity parton densities at the initial for instance,

$\eta_g x^{\kappa_g}),$ (2)

FIG. 1 (color online). Gluon helicity distributio $Q^2 = 10$ GeV^2 for the new fit, the original DSSV analy [3], and for an updated analysis without using the new RHIC data sets (DSSV*, see text). The dotted lines pre gluon densities for alternative fits that are within the 9 limit. The x range primarily probed by the RHIC data is by the two vertical dashed lines.

tolerance and for the adopted functional for dotted-dashed curve represents the result henceforth labelled as "DSSV*"—for whi include the updates to the various RHIC dat used for the original DSSV analysis [3] (das we exclude all the new 2009 data [6 COMPASS inclusive [11] and semi-incl data sets have little impact on Δg and are DSSV* fit.

The striking feature of our new pola bution is its much larger size as comp DSSV analysis [3]. For $Q^2 = 10$ G throughout and clearly away from $0.05 \leq x \leq 0.2$ predominantly probe as is demonstrated by the alternat 0% C.L. interval. In contrast to th the new Δg does not s [18]. It is

Motivation:

DSSV18

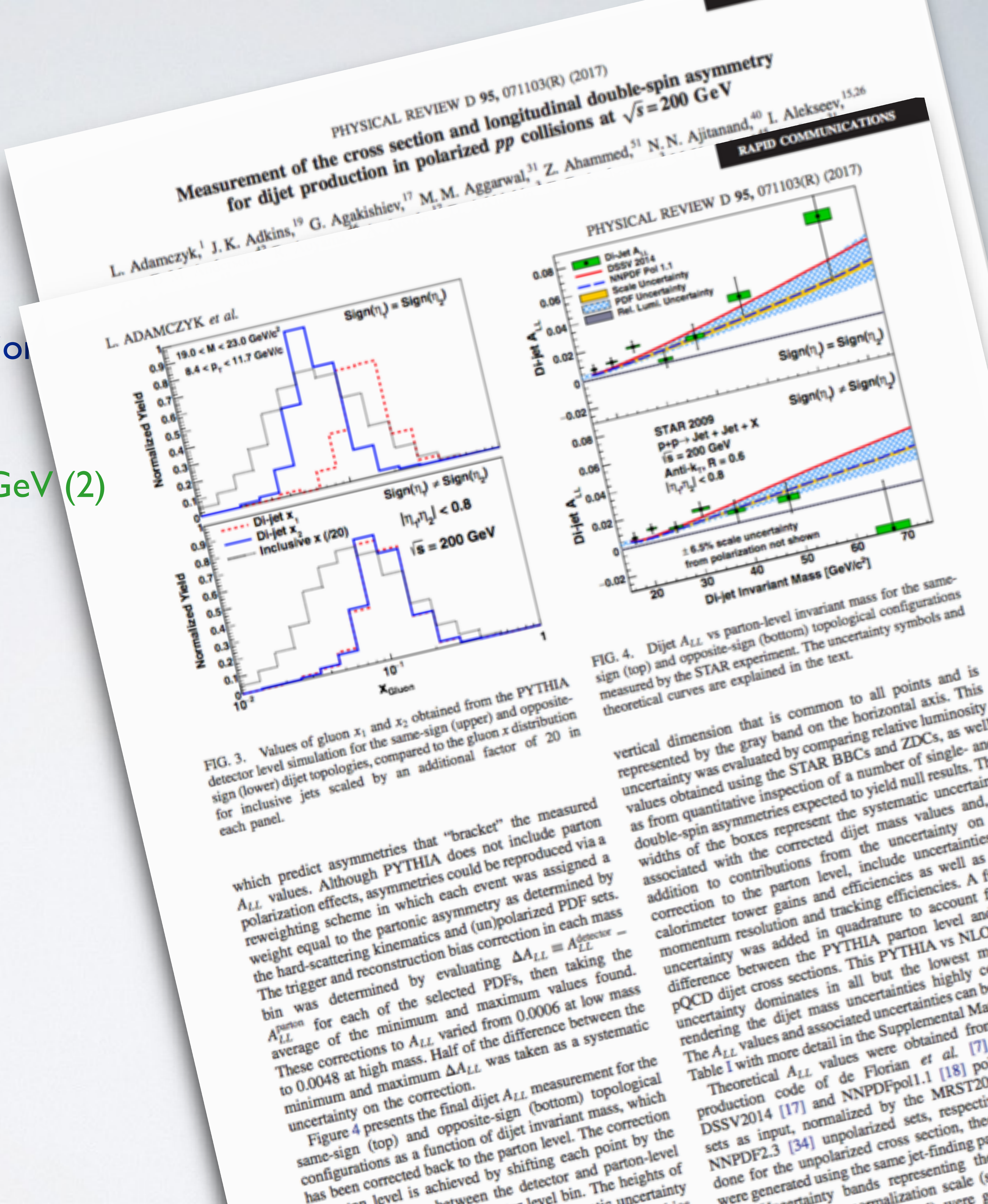
DSSV08 DSSV14

Δg : x- or Q^{2}- dependence?

remaining STAR/PHENIX tensio

preferences of new data sets?

STAR dijets: run9 200 GeV (2)



PHYSICAL REVIEW D 95, 071103(R) (2017)

Measurement of the cross section and longitudinal double-spin asymmetry for dijet production in polarized pp collisions at $\sqrt{s} = 200$ GeV

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FIG. 3. Values of gluon x_1 and x_2 obtained from the PYTHIA detector level simulation for the same-sign (upper) and opposite-sign (lower) dijet topologies, compared to the gluon x distribution for inclusive jets scaled by an additional factor of 20 in each panel.

FIG. 4. Dijet A_{LL} vs parton-level invariant mass for the same-sign (top) and opposite-sign (bottom) topological configurations measured by the STAR experiment. The uncertainty symbols and theoretical curves are explained in the text.

which predict asymmetries that "bracket" the measured A_{LL} values. Although PYTHIA does not include parton polarization effects, asymmetries could be reproduced via a reweighting scheme in which each event was assigned a weight equal to the partonic asymmetry as determined by the hard-scattering kinematics and (un)polarized PDF sets. The trigger and reconstruction bias correction in each mass bin was determined by evaluating $\Delta A_{LL} \equiv A_{LL}^{\mathrm{detector}} - A_{LL}^{\mathrm{parton}}$ for each of the selected PDFs, then taking the average of the minimum and maximum values found. These corrections to A_{LL} varied from 0.0006 at low mass to 0.0048 at high mass. Half of the difference between the minimum and maximum ΔA_{LL} was taken as a systematic uncertainty on the correction.

Figure 4 presents the final dijet A_{LL} measurement for the same-sign (top) and opposite-sign (bottom) topological configurations as a function of dijet invariant mass, which has been corrected back to the parton level. The correction

vertical dimension that is common to all points and is
represented by the gray band on the horizontal axis. This
uncertainty was evaluated by comparing relative luminosity
values obtained using the STAR BBCs and ZDCs, as well
as from quantitative inspection of a number of single- an
double-spin asymmetries expected to yield null results. Th
widths of the boxes represent the systematic uncertain
associated with the corrected dijet mass values and,
addition to contributions from the uncertainty on
correction to the parton level, include uncertaintie
calorimeter tower gains and efficiencies as well as
momentum resolution and tracking efficiencies. A f
uncertainty was added in quadrature to account f
difference between the PYTHIA parton level an
pQCD dijet cross sections. This PYTHIA vs NLO
uncertainty dominates in all but the lowest m
rendering the dijet mass uncertainties highly c
The A_{LL} values and associated uncertainties can b
Table I with more detail in the Supplemental Ma

Theoretical A_{LL} values were obtained fro
production code of de Florian et al. [7]
DSSV2014 [17] and NNPDFpol1.1 [18] po
sets as input, normalized by the MRST20
NNPDF2.3 [34] unpolarized sets, respecti
done for the unpolarized cross section, the
were generated using the same jet-finding p

Motivation:

DSSV18

Δg : x- or Q^{2}- dependence?

DSSV08

DSSV14

remaining STAR/PHENIX tension

preferences of new data sets?

STAR dijets: run9 200 GeV (2)

prel. run12 510 GeV (1)

prel. run9 200 GeV (3)

prel. run12 510 GeV (2)

prel. run13 510 GeV (2)

Recent STAR Jet Results of the High-Energy Spin Physics Program at RHIC

Figure 3: Dijet double-spin asymmetry A_{LL} for the 2012 data at $\sqrt{s}$= 510 GeV, along with a comparison to DSSV14 and NNPDFpol1.1. Both the data and the global fits are consistent, supporting a positive gluon polarization.

Motivation:

DSSV18

DSSV08 DSSV14

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remaining STAR/PHENIX tensio

preferences of new data sets?

➡ STAR dijets: run9 200 GeV (

prel. run12 510 GeV (

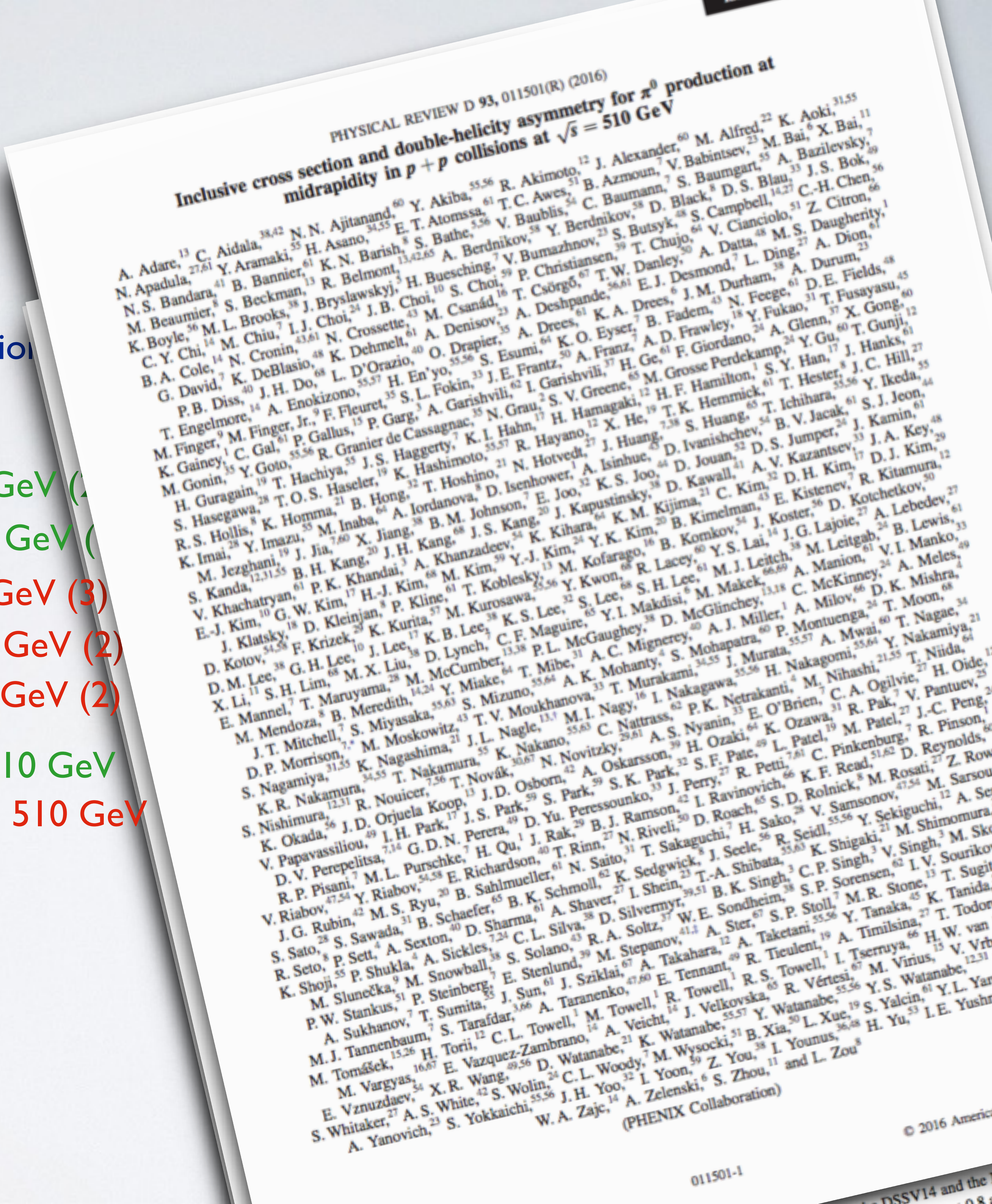
prel. run9 200 GeV (3)

prel. run12 510 GeV (2)

prel. run13 510 GeV (2)

➡ PHENIX pi0 run12-13 510 GeV

STAR jets prel. run12-13 510 GeV



PHYSICAL REVIEW D 93, 011501(R) (2016)

Inclusive cross section and double-helicity asymmetry for π^0 production at midrapidity in $p+p$ collisions at $\sqrt{s} = 510$ GeV

(PHENIX Collaboration)

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011501-1

Motivation:

DSSV18

DSSV08 DSSV14

Δg : x- or Q^2- dependence?

remaining STAR/PHENIX tensio

preferences of new data sets?

STAR dijets: run9 200 GeV

prel. run12 510 GeV

prel. run9 200 GeV (

prel. run12 510 GeV (

prel. run13 510 GeV (2

PHENIX pi0 run12-13 510 GeV

STAR jets prel. run12-13 510 GeV

COMPASS p&d DIS "legacy"

Physics Letters B 753 (2016) 18–28

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The spin structure function g_1^p of the proton and a test of the Bjorken sum rule

Physics Letters B 769 (2017) 34–41

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Final COMPASS results on the deuteron spin-dependent structure function g_1^d and the Bjorken sum rule

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Motivation:

DSSV18

Δg : x- or Q^2- dependence? DSSV08 DSSV14

remaining STAR/PHENIX tensio

preferences of new data sets?

STAR dijets: run9 200 GeV

prel. run12 510 GeV

prel. run9 200 GeV (

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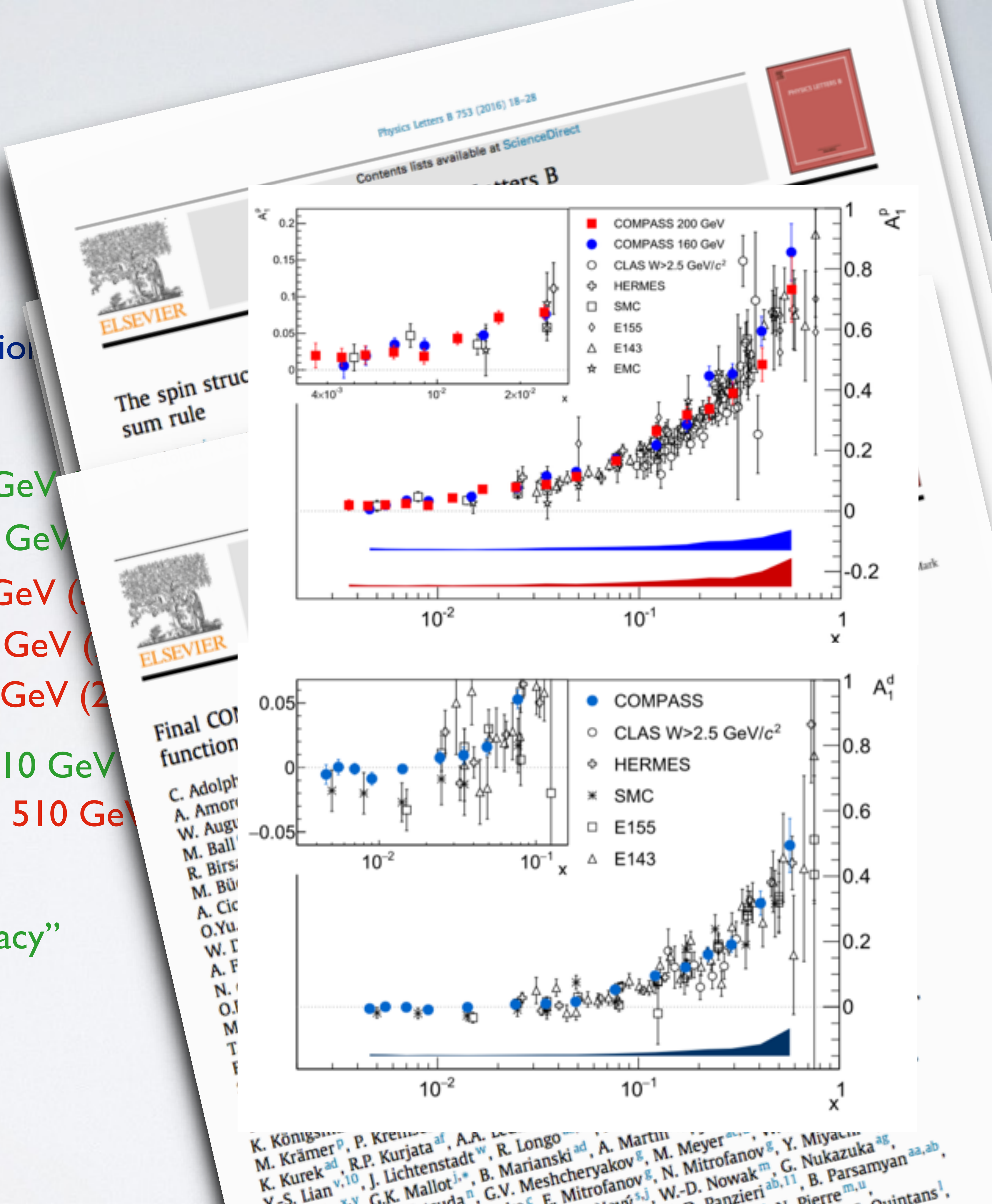
prel. run13 510 GeV (2

PHENIX pi0 run12-13 510 GeV

STAR jets prel. run12-13 510 GeV

COMPASS p&d DIS “legacy”



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prel. run13 510 GeV (2

PHENIX pi0 run12-13 510 GeV

STAR jets prel. run12-13 510 Ge

COMPASS p&d DIS “legacy”

CLAS HALL-A p&n&d DIS

NNPDF3.0 $F_1(x,Q^2)$ $F_1^{SIDIS}(x,Q^2)$ $\alpha_s(Q^2)$

PHYSICAL REVIEW C **90**, 025212 (2014)

Precision measurements of g_1 of the proton and of the deuteron with 6 GeV electrons

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Troy, New York 12180-3590, USA

Motivation:

DSSV18

DSSV08 DSSV14

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COMPASS p&d DIS "legacy"

CLAS HALL-A p&n&d DIS

NNPDF3.0 $F_1(x,Q^2)$ $F_1^{SIDIS}(x,Q^2)$ $\alpha_s(Q^2)$

instead of MRST04!!!

PHYSICAL REVIEW C **90**, 025212 (2014)

Precision measurements of g_1 of the proton and of the deuteron with 6 GeV electrons

Y. Prok,[1,2,*] P. Bosted,[3,2] N. Kvaltine,[4] K. P. Adhikari,[1] D. Adikaram,[1] M. Aghasyan,[5] M. J. Amaryan,[1] M. D. Anderson,[6] S. Anefalos Pereira,[7] H. Avakian,[2] H. Baghdasaryan,[4] J. Ball,[8] N. A. Baltzell,[9,10] M. Battaglieri,[11] A. S. Biselli,[12] J. Bono,[13] W. J. Briscoe,[14] J. Brock,[2] W. K. Brooks,[15,2] S. Bültmann,[1] V. D. Burkert,[2] C. Carlin,[2] D. S. Carman,[2] A. Celentano,[11] S. Chandavar,[16] L. Colaneri,[17,18] P. L. Cole,[19] M. Contalbrigo,[5] O. Cortes,[19] D. Crabb,[4] V. Crede,[20] A. D'Angelo,[17,18] N. Dashyan,[21] R. De Vita,[11] E. De Sanctis,[7] A. Deur,[2] C. Djalali,[10] G. E. Dodge,[1] D. Doughty,[22,2] R. Dupre,[23,9] A. El Alaoui,[9,†] L. El Fassi,[9,‡] L. Elouadrhiri,[2] G. Fedotov,[10,24] S. Fegan,[11] R. Fersch,[3,§] J. A. Fleming,[25] T. A. Forest,[19] M. Garçon,[8] B. Garillon,[23] N. Gevorgyan,[21] Y. Ghandilyan,[21] G. P. Gilfoyle,[26] F. X. Girod,[2] K. L. Giovanetti,[27] J. T. Goetz,[16] W. Gohn,[28,‖] R. W. Gothe,[10] K. A. Griffioen,[3] B. Guegan,[23] N. Guler,[1,¶] K. Hafidi,[9] C. Hanretty,[4,#] N. Harrison,[28] M. Hattawy,[23] K. Hicks,[16] D. Ho,[29] M. Holtrop,[30] Y. Ilieva,[10,14] D. G. Ireland,[6] B. S. Ishkhanov,[24] E. L. Isupov,[24] S. Jawalkar,[3] X. Jiang,[31] H. S. Jo,[23] K. Joo,[28] N. Kalantarians,[4] C. Keith,[2] D. Keller,[4,16] M. Khandaker,[19,32] A. Kim,[33] W. Kim,[33] A. Klein,[1] F. J. Klein,[34] S. Koirala,[1] V. Kubarovsky,[2,35] S. E. Kuhn,[1] S. V. Kuleshov,[15,36] P. Lenisa,[5] K. Livingston,[6] H. Y. Lu,[10] I. J. D. MacGregor,[6] N. Markov,[28] M. Mayer,[1] B. McKinnon,[6] D. Meekins,[2] T. Mineeva,[28] M. Mirazita,[7] V. Mokeev,[2,24] R. A. Montgomery,[7,**] H. Moutarde,[8] A Movsisyan,[5] E. Munevar,[2] C. Munoz Camacho,[23] P. Nadel-Turonski,[2] S. Niccolai,[23] G. Niculescu,[27] I. Niculescu,[27] M. Osipenko,[11] A. I. Ostrovidov,[20] L. L. Pappalardo,[5] R. Paremuzyan,[21,††] K. Park,[2,10] P. Peng,[4] J. J. Phillips,[6] J. Pierce,[2] S. Pisano,[7,23] O. Pogorelko,[36] S. Pozdniakov,[36] J. W. Price,[37] S. Procureur,[8] D. Protopopescu,[6] A. J. R. Puckett,[28] B. A. Raue,[13,2] D. Rimal,[13] M. Ripani,[11] A. Rizzo,[17,18] G. Rosner,[6] P. Rossi,[7,2] P. Roy,[20] F. Sabatié,[8] M. S. Saini,[20] C. Salgado,[32] D. Schott,[14,13] R. A. Schumacher,[29] E. Seder,[28] Y. G. Sharabian,[2] A. Simonyan,[21] C. Smith,[2] G. Smith,[6] D. I. Sober,[34] D. Sokhan,[23] S. S. Stepanyan,[33] S. Stepanyan,[2] I. I. Strakovsky,[14] S. Strauch,[10] V. Sytnik,[15] M. Taiuti,[11] W. Tang,[16] S. Tkachenko,[4] M. Ungaro,[2,28] B. Vernarsky,[29] A. V. Vlassov,[36] H. Voskanyan,[21] E. Voutier,[38] N. K. Walford,[34] D. P. Watts,[25] L. B. Weinstein,[1] N. Zachariou,[10] L. Zana,[25,30] J. Zhang,[2] B. Zhao,[3] Z. W. Zhao,[4] and I. Zonta[17,18]

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[7] *INFN, Laboratori Nazionali di Frascati, I-00044 Frascati, Italy*
[8] *CEA, Centre de Saclay, Irfu/Service de Physique Nucléaire, F-91191 Gif-sur-Yvette, France*
[9] *Argonne National Laboratory, Argonne, Illinois 60439, USA*
[10] *University of South Carolina, Columbia, South Carolina 29208, USA*
[11] *INFN, Sezione di Genova, I-16146 Genova, Italy*
[12] *Fairfield University, Fairfield Connecticut 06824, USA*
[13] *Florida International University, Miami, Florida 33199, USA*
[14] *The George Washington University, Washington, DC 20052, USA*
[15] *Universidad Técnica Federico Santa María, Casilla 110-V Valparaíso, Chile*
[16] *Ohio University, Athens, Ohio 45701, USA*
[17] *INFN, Sezione di Roma Tor Vergata, I-00133 Rome, Italy*
[18] *Universita' di Roma Tor Vergata, I-00133 Rome, Italy*
[19] *Idaho State University, Pocatello, Idaho 83209, USA*
[20] *Florida State University, Tallahassee, Florida 32306, USA*
[21] *Yerevan Physics Institute, 375036 Yerevan, Armenia*
[22] *Christopher Newport University, Newport News, Virginia 23606, USA*
[23] *Institut de Physique Nucléaire ORSAY, Orsay, France*
[24] *Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, 119234 Moscow, Russia*
[25] *Edinburgh University, Edinburgh EH9 3JZ, United Kingdom*
[26] *University of Richmond, Richmond, Virginia 23173, USA*
[27] *James Madison University, Harrisonburg, Virginia 22807, USA*
[28] *University of Connecticut, Storrs, Connecticut 06269, USA*
[29] *Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA*
[30] *University of New Hampshire, Durham, New Hampshire 03824-3568, USA*
[31] *Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*
[32] *Norfolk State University, Norfolk, Virginia 23504, USA*
ook National University, Daegu 702-701, Republic of Korea
ity of America, Washington, D.C. 20064, USA
Troy, New York 12180-3590, USA

Motivation:

DSSV18

$\Delta\bar{q}$: bias from DSS07 FFs ?
consistency with W data ?

$\pi^{\pm}$ FFs update DSS14
$K^{\pm}$ FFs update DSS17
$h^{\pm}$ FFs update DSS18

PHYSICAL REVIEW D **91**, 014035 (2015)

Parton-to-pion fragmentation reloaded

Daniel de Florian[*] and R. Sassot[†]

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Universidad de Buenos Aires, Ciudad Universitaria, Pabellón 1, (1428) Buenos Aires, Argentina

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PHYSICAL REVIEW D **95**, 094019 (2017)

Parton-to-kaon fragmentation revisited

Daniel de Florian

Facultad de Ciencias Físico-Matemáticas, Universidad
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Departamento de Física and IFIBA, Facultad de Ciencias Exactas y Naturales,
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(Received 22 February 2017; published 26 May 2017)

We revisit the global QCD analysis of parton-to-kaon fragmentation functions at next-to-leading-order accuracy using the latest experimental information on single-inclusive kaon production in electron-positron annihilation, lepton-nucleon deep-inelastic scattering, and proton-proton collisions. An excellent description of all data sets is achieved, and the remaining uncertainties in parton-to-kaon fragmentation functions are estimated and discussed based on the Hessian method. Extensive comparisons to the results from our previous global analysis are made.

DOI: 10.1103/PhysRevD.95.094019

I. INTRODUCTION AND MOTIVATION

Parton-to-hadron fragmentation functions (FFs) parametrize how quarks and gluons that are produced in hard interactions at high energies confine themselves into hadrons measured and identified in experiment [1]. This information is beyond the reach of perturbative quantum chromodynamics (pQCD) and must therefore be inferred from the wealth of data on identified hadron production under the theoretical assumption that the relevant nonperturbative dynamics of FFs factorizes in a universal way from the calculable hard partonic cross sections [2] up to corrections which can be usually neglected.

Precise parton-to-kaon FFs are usually considered as
key ingredient to probe the strangeness content of t
nucleon and are expected to be of crucial importance
further constraining the corresponding momentum di
butions at a future electron-ion collider (EIC) thro
charged kaon production in semi-inclusive deep-inel
scattering (SIDIS) [4]. This is especially the case fo
helicity dependent strangeness parton distributions
$\Delta\bar{s}$ [5,6], largely because of the complete lack o
experimental constraints from neutrino-induced,
weak deep-inelastic structure function measurem
that are routinely utilized in all extractions of u
parton distribution functions (PDFs); see, e.g., [8
the discussions below, it should be kept in mi
unpolarized strangeness PDF is also less well
than the light sea quarks; see, e.g., [8].

Belle, BaBar e^+e^-, Final Hermes & Compass SIDIS, pp

NNPDF3.0 based variant of DSS

Motivation:

DSSV18

$\Delta\bar{q}$: bias from DSS07 FFs ?

consistency with W data ?

$\pi^{\pm}$ FFs update DSS14

$K^{\pm}$ FFs update DSS17

$h^{\pm}$ FFs update DSS18

STAR run11-12 Ws:

PHYSICAL REVIEW D **91,** 014035 (2015)

Parton-to-pion fragmentation reloaded

Daniel de Florian* and R. Sassot†

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PHYSICAL REVIEW D **95,** 094019 (2017)

Parton-to-kaon fragmentation revisited

Daniel de Florian

PRL **113,** 072301 (2014) PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2014

Measurement of Longitudinal Spin Asymmetries for Weak Boson Production in Polarized Proton-Proton Collisions at RHIC

PRL **113,** 072301 (2014) PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2014

FIG. 4 (color online). Longitudinal single-spin asymmetry A_L for $W^{\pm}$ production as a function of lepton pseudorapidity η_e in comparison to theory predictions (see text for details).

up antiquark polarization $\Delta\bar{u}$, which is not currently well constrained [16,17] as can be seen by the large uncertainty in the theoretical prediction there. While consistent within the theoretical uncertainty, the large positive values for $A_L^{W^-}$ indicate a preference for a sizable, positive $\Delta\bar{u}$ in the range $0.05 < x < 0.2$ relative to the central values of the DSSV08 and LSS10 fits. Global analyses from both DSSV++ [36] and neural network PDF [37] have extracted the antiquark polarizations, using our preliminary measurement from the 2012 data set. These analyses quantitatively confirm the enhancement of $\Delta\bar{u}$ and the expected reduction in the uncertainties of the helicity-dependent PDFs compared to previous fits without our data.

The $W^{\pm}$ double-spin asymmetry, shown in Fig. 5, is sensitive to the product of quark and antiquark polarizations, and has also been proposed to test positivity constraints using a combination of A_L and A_{LL} [38]. The measured double-spin asymmetries are consistent with the theoretical predictions and in conjunction with $A_L^{W^{\pm}}$ satisfy the positivity bounds within the current uncertainties.

A similar profile likelihood procedure is used to determine the single-spin asymmetry A_L^{Z/γ^*} for Z/γ^* production with $|\eta_e| < 1.1$, $E_T^e > 14$ GeV, and $70 < m_{e^+e^-} < 110$ GeV$/c^2$. A_L^{Z/γ^*} is sensitive to the combination of u, $\bar{u}$, d, and $\bar{d}$ polarizations. The measured asymmetry $A_L^{Z/\gamma^*} = -0.07^{+0.14}_{-0.14}$ is consistent, within the large uncertainty, with theoretical predictions using the different helicity-dependent PDFs A_L^{Z/γ^*}(DSSV08) = −0.07 and A_L^{Z/γ^*}(LSS10) = −0.02.

In summary, we report new measurements of the parity-violating single-spin asymmetry A_L and parity-conserving double-spin asymmetry A_{LL} for $W^{\pm}$ production as well as the first measurement of A_L for Z/γ^* production in longitudinally polarized proton collisions by the STAR

Motivation:

DSSV18

$\Delta\bar{q}$: bias from DSS07 FFs ?
consistency with W data ?

$\pi^{\pm}$ FFs update DSS14
$K^{\pm}$ FFs update DSS17
$h^{\pm}$ FFs update DSS18

STAR run11-12 Ws:

PHENIX run11-13 Ws:

PHYSICAL REVIEW D 91, 014035 (2015)

Parton-to-pion fragmentation reloaded

Daniel de Florian* and R. Sassot†

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PHYSICAL REVIEW D 95, 094019 (2017)

Parton-to-kaon fragmentation revisited

Daniel de Florian

PRL 113, 072301 (2014) PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2014

Measurement of Longitudinal Spin Asymmetries for Weak Boson Production in Polarized Proton-Proton Collisions at RHIC

RAPID COMMUNICATIONS

PHYSICAL REVIEW D 93, 051103(R) (2016)

Measurement of parity-violating spin asymmetries in W± production at midrapidity in longitudinally polarized $p+p$ collisions

RAPID COMMUNICATIONS

MEASUREMENT OF PARITY-VIOLATING SPIN ... PHYSICAL REVIEW D 93, 051103(R) (2016)

FIG. 2. Asymmetry results from the combined 2011 and 2012 data sets for $|\eta| < 0.35$ (black circles) and the 2013 data (red squares) separated into two equal η bins between −0.35 and 0.35. The green line and shaded region shows a theoretical calculation with the NNPDFpol1.1 PDF sets [14], while the DSSV14 calculation [31].

W^+ (W^-), for $|\eta| < 0.5$. The W^- difference a larger $\Delta\bar{u}$ contribution in the covered $x \sim 0.16$ range, when compared with the central value of the DSSV 14 PDF fit calculation.

In summary, for high p_T e^- and e^+ from $W^\pm$ and Z boson decays, PHENIX measured the single-spin asymmetries with more than 27 times higher statistics and better polarization compared to 2009 [9]. These new results and the STAR data [11] will help constrain the antiquark PDFs in a global analysis. Asymmetries calculated from global fits based on previous measurements, such as DSSV14 and NNPDFpol1.1, are consistent with our data. The use of the electroweak interaction provides an independent tool to extract quark and antiquark helicity contribution. The data presented here are complementary to previous SIDIS measurements and bring the field one step closer to elucidation of the proton-spin puzzle [1].

We thank the staff of the Collider-Accelerator and Physics Departments at Brookhaven National Laboratory and the staff of the other PHENIX participating institutions for their vital contributions. We acknowledge support from the Office of Nuclear Physics in the Office of Science of the Department of Energy, the National Science Foundation, Abilene Christi University Research Council, Research Foundation of SUN and Dean of the College of Arts and Sciences, Vander Ministry of Education, Culture, Sp and the Japan Society for

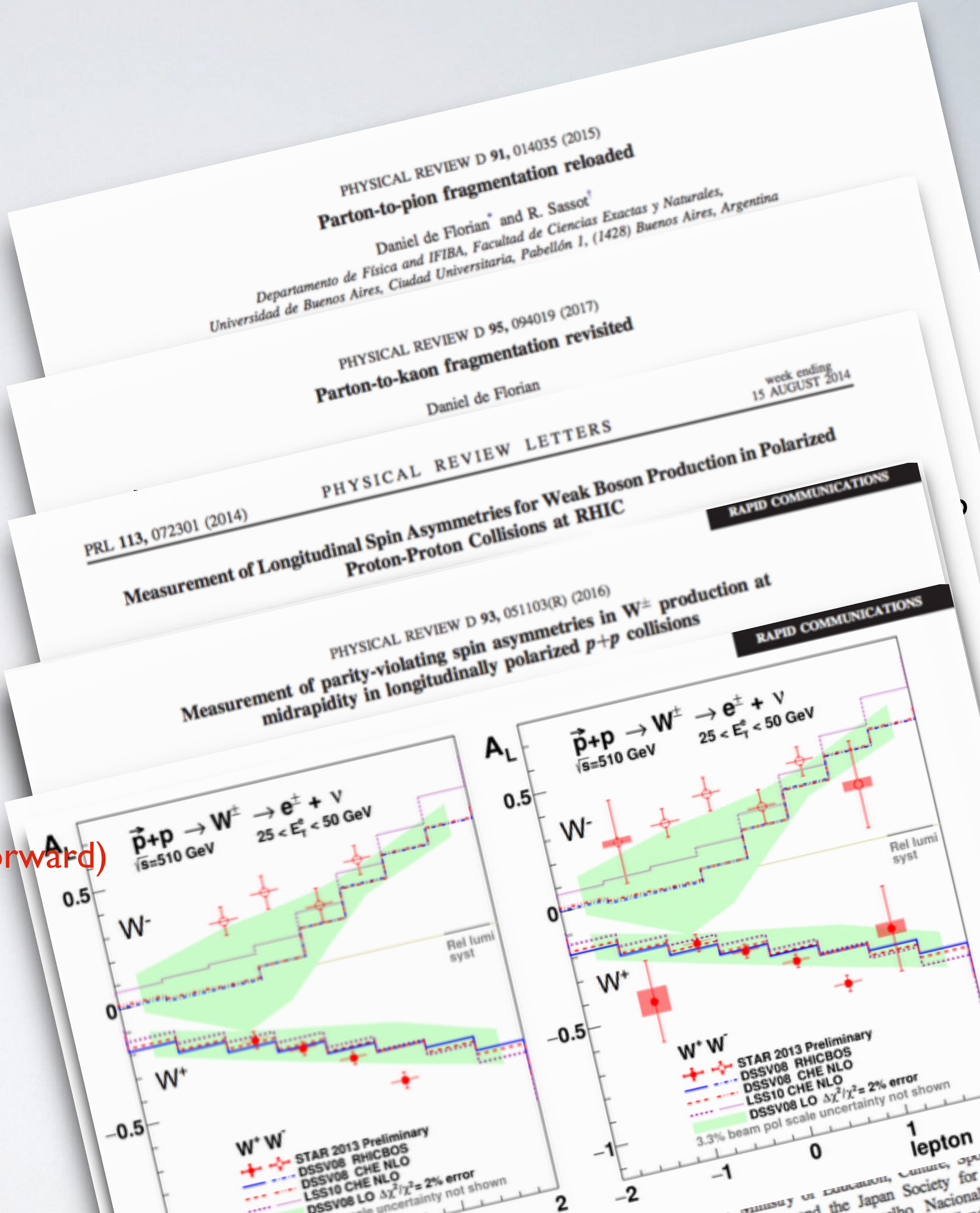
Motivation:

DSSV18

$\Delta\overline{q}$: bias from DSS07 FFs ?
consistency with W data ?

$\pi^{\pm}$ FFs update DSS14
$K^{\pm}$ FFs update DSS17
$h^{\pm}$ FFs update DSS18

STAR run11-12 Ws:
PHENIX run11-13 Ws:
prel. STAR run13
prel. STAR run13 (near forward)



PHYSICAL REVIEW D 91, 014035 (2015)

Parton-to-pion fragmentation reloaded

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PHYSICAL REVIEW D 95, 094019 (2017)

Parton-to-kaon fragmentation revisited

Daniel de Florian

PRL 113, 072301 (2014) PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2014

Measurement of Longitudinal Spin Asymmetries for Weak Boson Production in Polarized Proton-Proton Collisions at RHIC

RAPID COMMUNICATIONS

PHYSICAL REVIEW D 93, 051103(R) (2016)

Measurement of parity-violating spin asymmetries in W± production at midrapidity in longitudinally polarized p+p collisions

RAPID COMMUNICATIONS

Motivation:

DSSV18

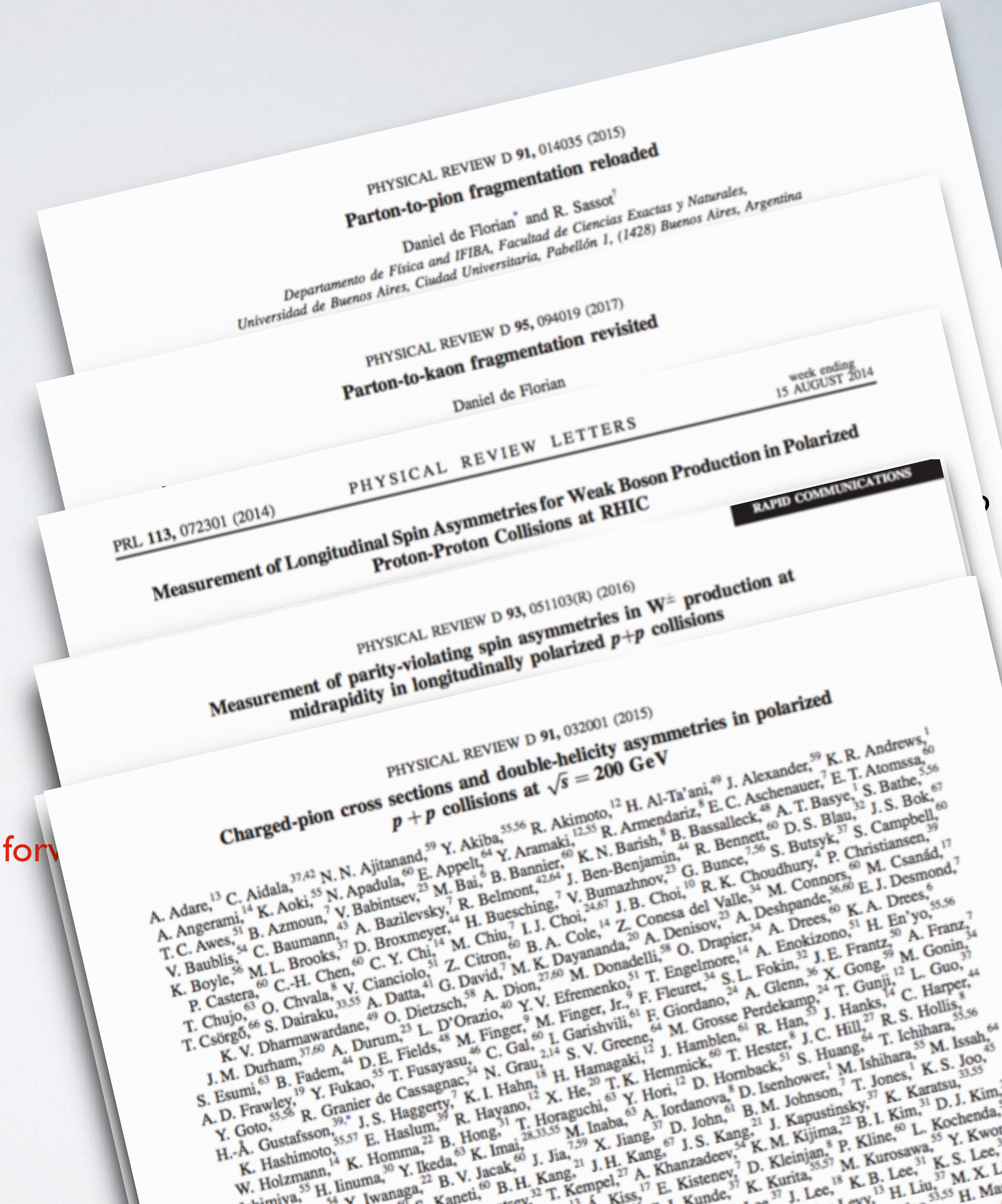
$\Delta\bar{q}$: bias from DSS07 FFs ?
consistency with W data ?

- $\pi^{\pm}$ FFs update DSS14
$K^{\pm}$ FFs update DSS17
$h^{\pm}$ FFs update DSS18

- STAR run11-12 Ws:
PHENIX run11-13 Ws:
prel. STAR run13
prel. STAR run13 (near for

- PHENIX run9 $A_{LL}^{\pi^{\pm}}$

anything else "relevant" before EIC?



PHYSICAL REVIEW D **91,** 014035 (2015)

Parton-to-pion fragmentation reloaded

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PHYSICAL REVIEW D **95,** 094019 (2017)

Parton-to-kaon fragmentation revisited

Daniel de Florian

PRL 113, 072301 (2014) PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2014

Measurement of Longitudinal Spin Asymmetries for Weak Boson Production in Polarized Proton-Proton Collisions at RHIC

RAPID COMMUNICATIONS

PHYSICAL REVIEW D **93,** 051103(R) (2016)

Measurement of parity-violating spin asymmetries in $W^{\pm}$ production at midrapidity in longitudinally polarized $p+p$ collisions

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PHYSICAL REVIEW D **91,** 032001 (2015)

Charged-pion cross sections and double-helicity asymmetries in polarized $p+p$ collisions at $\sqrt{s}=200$ GeV

A. Adare,[13] C. Aidala,[37,42] N. N. Ajitanand,[59] Y. Akiba,[55,56] R. Akimoto,[12] H. Al-Ta'ani,[49] J. Alexander,[59] K. R. Andrews,[1]
A. Angerami,[14] K. Aoki,[55] N. Apadula,[60] E. Appelt,[64] Y. Aramaki,[12,55] R. Armendariz,[8] E. C. Aschenauer,[7] E. T. Atomssa,[60]
T. C. Awes,[51] B. Azmoun,[7] V. Babintsev,[23] M. Bai,[6] B. Bannier,[60] K. N. Barish,[8] B. Bassalleck,[48] A. T. Basye,[1] S. Bathe,[5,56]
V. Baublis,[54] C. Baumann,[43] A. Bazilevsky,[7] R. Belmont,[42,64] J. Ben-Benjamin,[44] R. Bennett,[60] D. S. Blau,[32] J. S. Bok,[67]
K. Boyle,[56] M. L. Brooks,[37] D. Broxmeyer,[44] H. Buesching,[7] V. Bumazhnov,[23] G. Bunce,[7,56] S. Butsyk,[37] S. Campbell,[60]
P. Castera,[60] C.-H. Chen,[60] C. Y. Chi,[14] M. Chiu,[7] I. J. Choi,[24,67] J. B. Choi,[10] R. K. Choudhury,[4] P. Christiansen,[39]
T. Chujo,[63] O. Chvala,[8] V. Cianciolo,[51] Z. Citron,[60] B. A. Cole,[14] Z. Conesa del Valle,[34] M. Connors,[60] M. Csanád,[17]
T. Csörgő,[66] S. Dairaku,[33,55] A. Datta,[41] G. David,[7] M. K. Dayananda,[20] A. Denisov,[23] A. Deshpande,[56,60] E. J. Desmond,[7]
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S. Esumi,[63] B. Fadem,[44] D. E. Fields,[48] M. Finger,[9] M. Finger, Jr.,[9] F. Fleuret,[34] S. L. Fokin,[32] J. E. Frantz,[50] A. Franz,[7]
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Y. Goto,[55,56] R. Granier de Cassagnac,[34] N. Grau,[2,14] S. V. Greene,[64] M. Grosse Perdekamp,[24] T. Gunji,[12] L. Guo,[37]
H.-Å. Gustafsson,[39,*] J. S. Haggerty,[7] K. I. Hahn,[18] H. Hamagaki,[12] J. Hamblen,[61] R. Han,[53] J. Hanks,[14] C. Harper,[44]
K. Hashimoto,[55,57] E. Haslum,[39] R. Hayano,[12] X. He,[20] T. K. Hemmick,[60] T. Hester,[8] J. C. Hill,[27] R. S. Hollis,[8]
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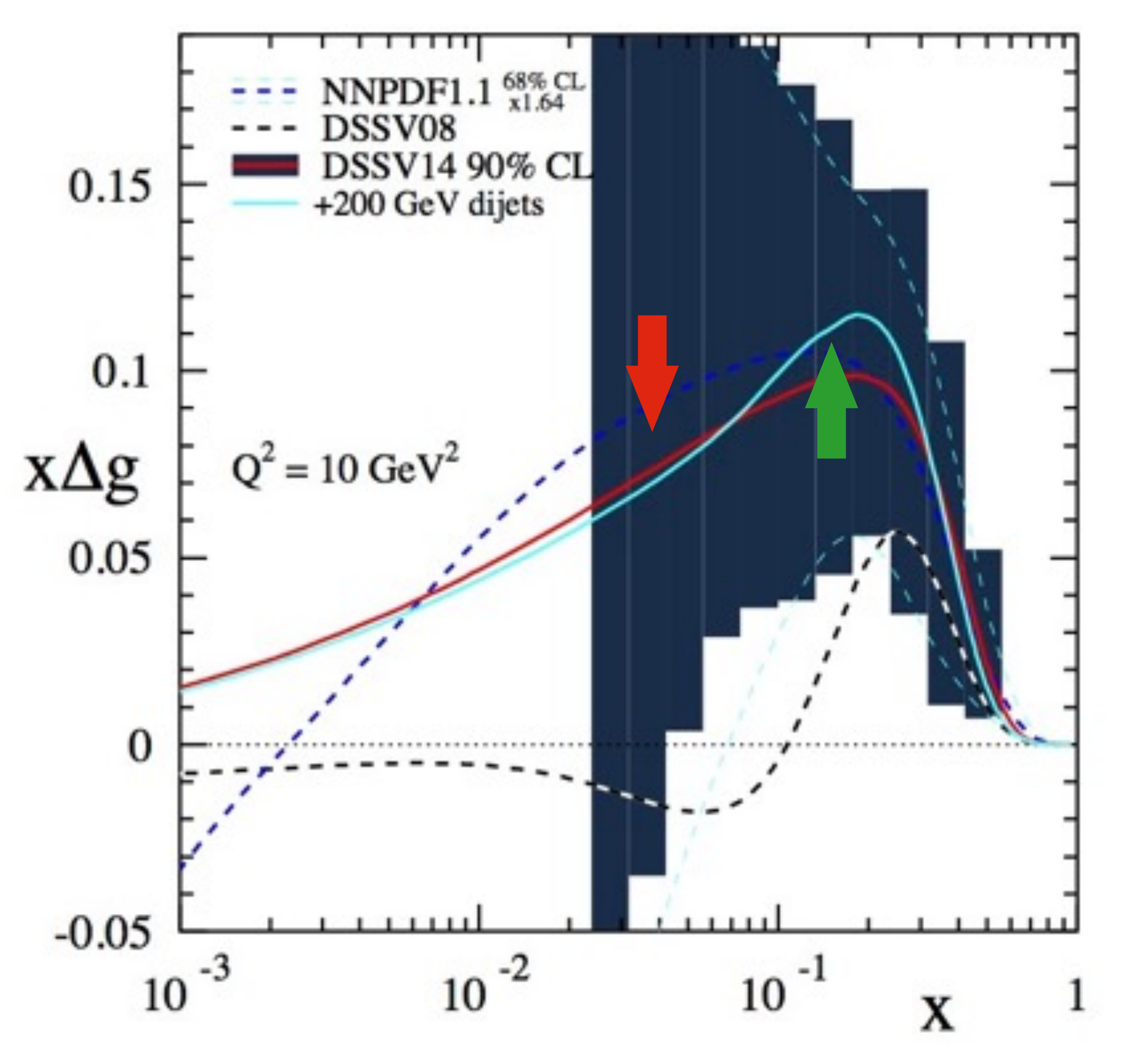
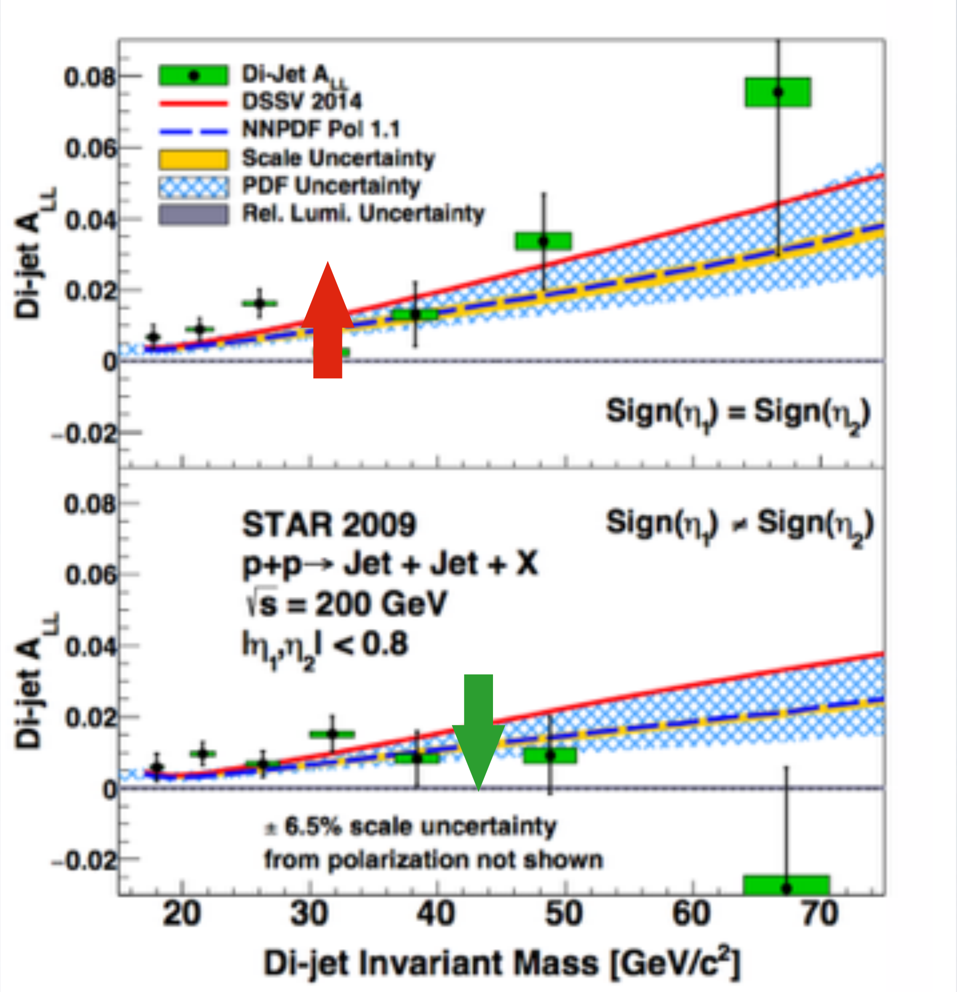
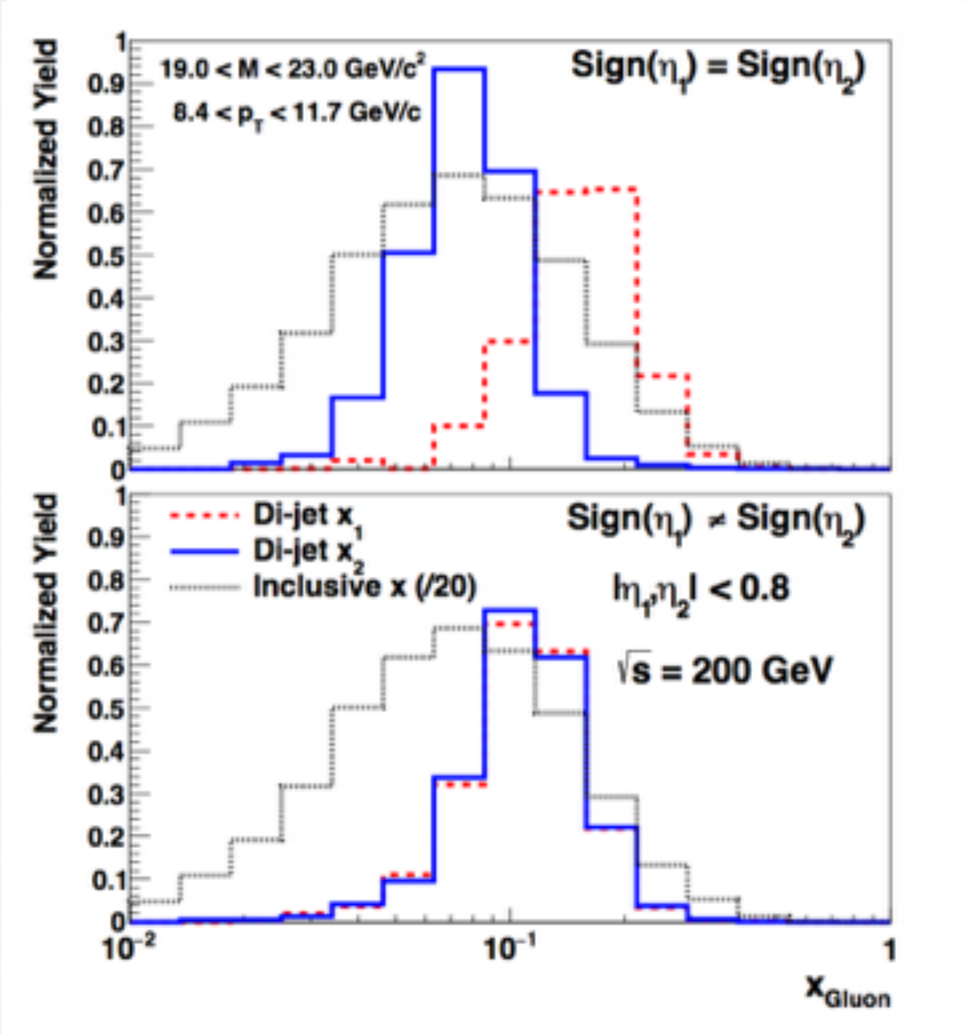
Y. Iwanaga,[22] B. V. Jacak,[60] J. Jia,[7,59] X. Jiang,[37] D. John,[61] B. M. Johnson,[7] T. Jones,[1] K. S. Joo,[45]

Impact on Δg

STAR run9 200 GeV dijets:

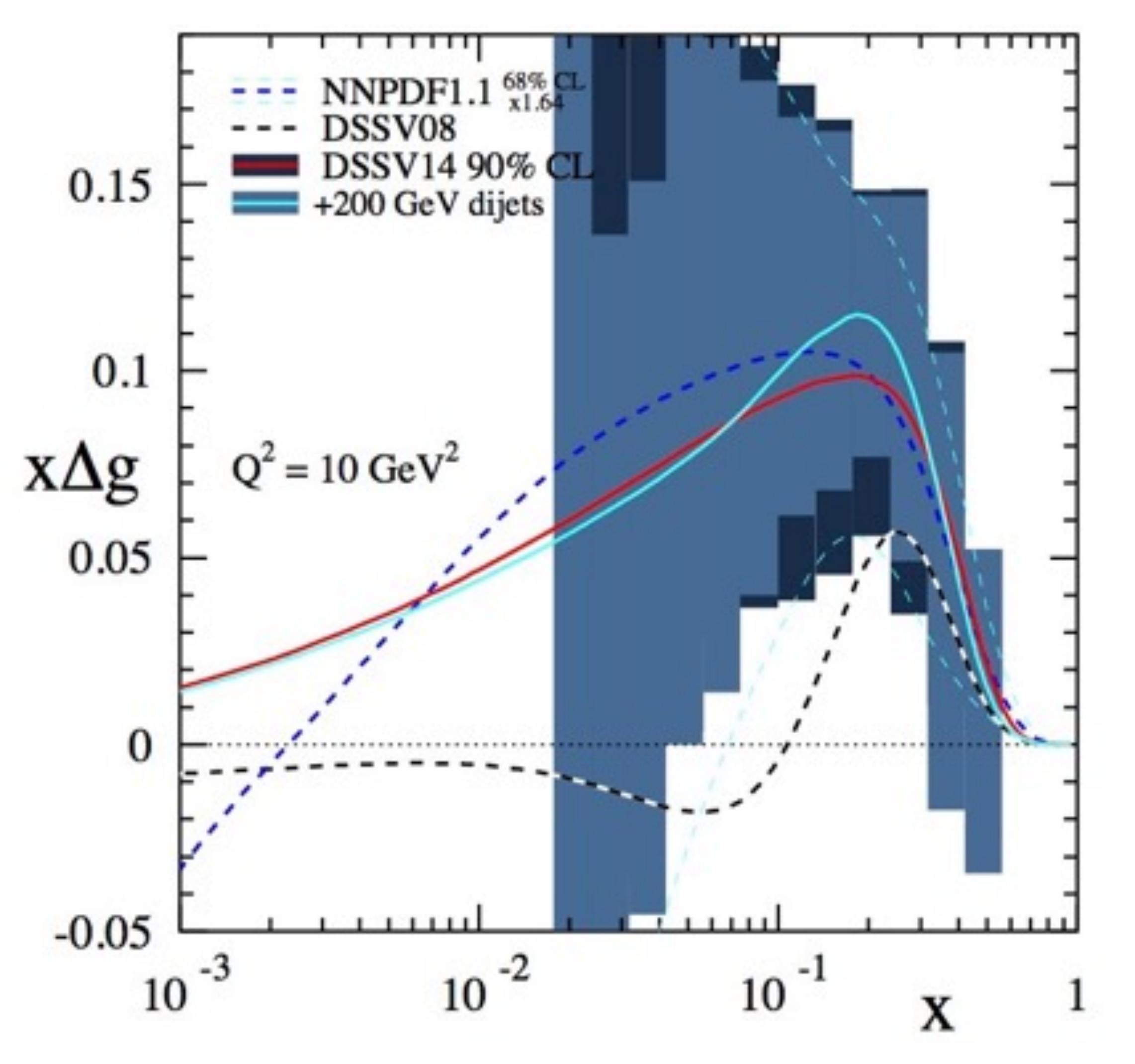


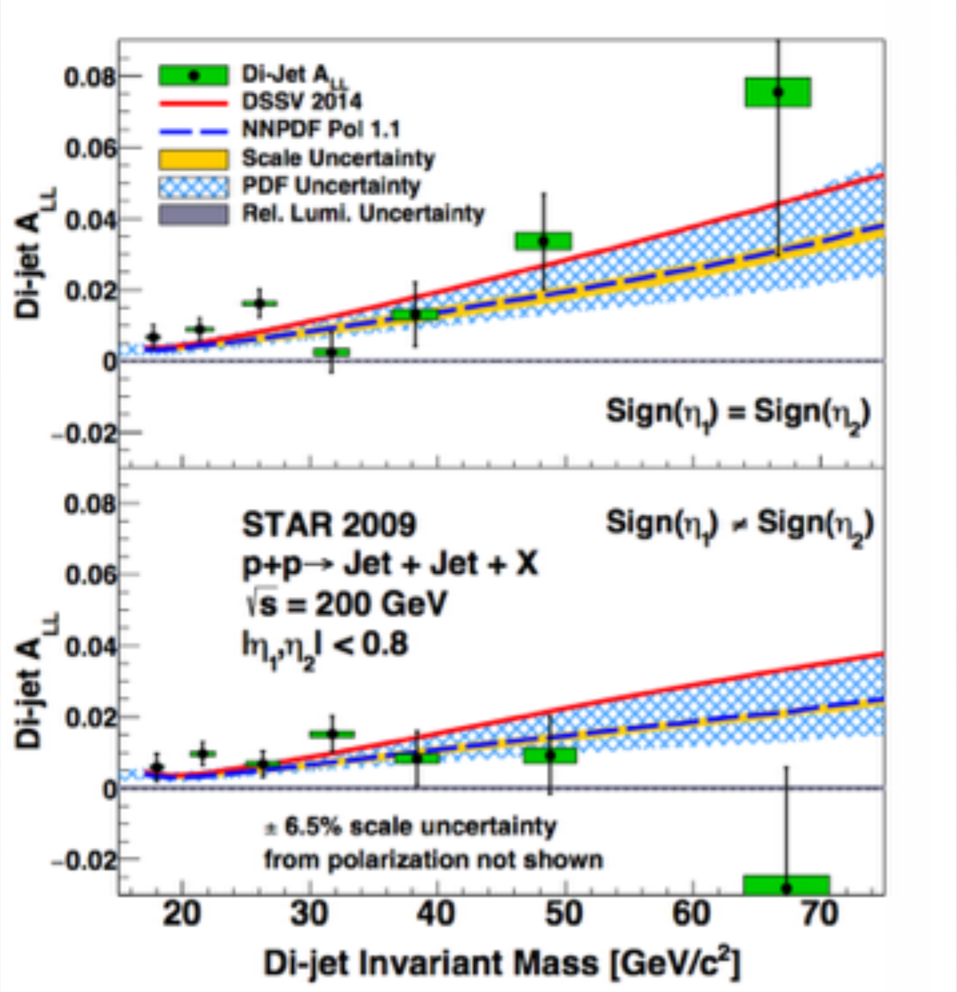


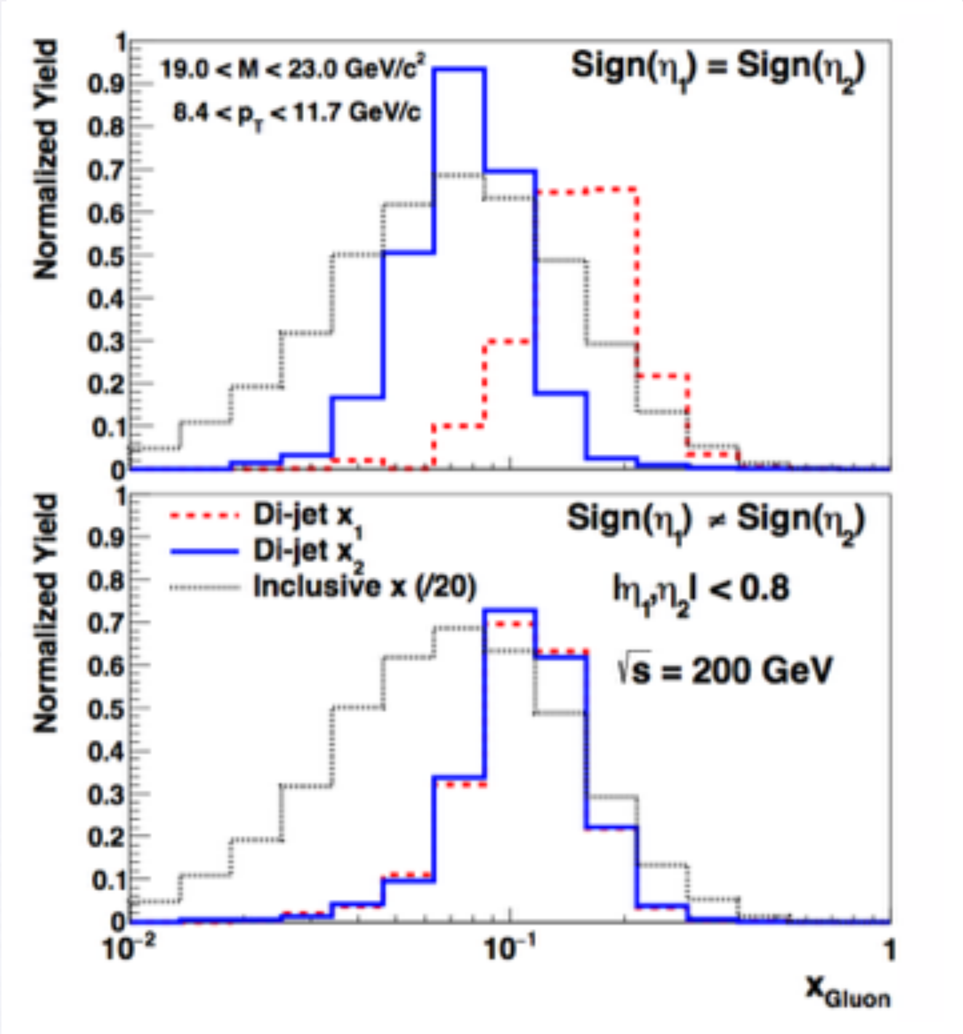


Impact on Δg

STAR run9 200 GeV dijets:







Impact on Δg

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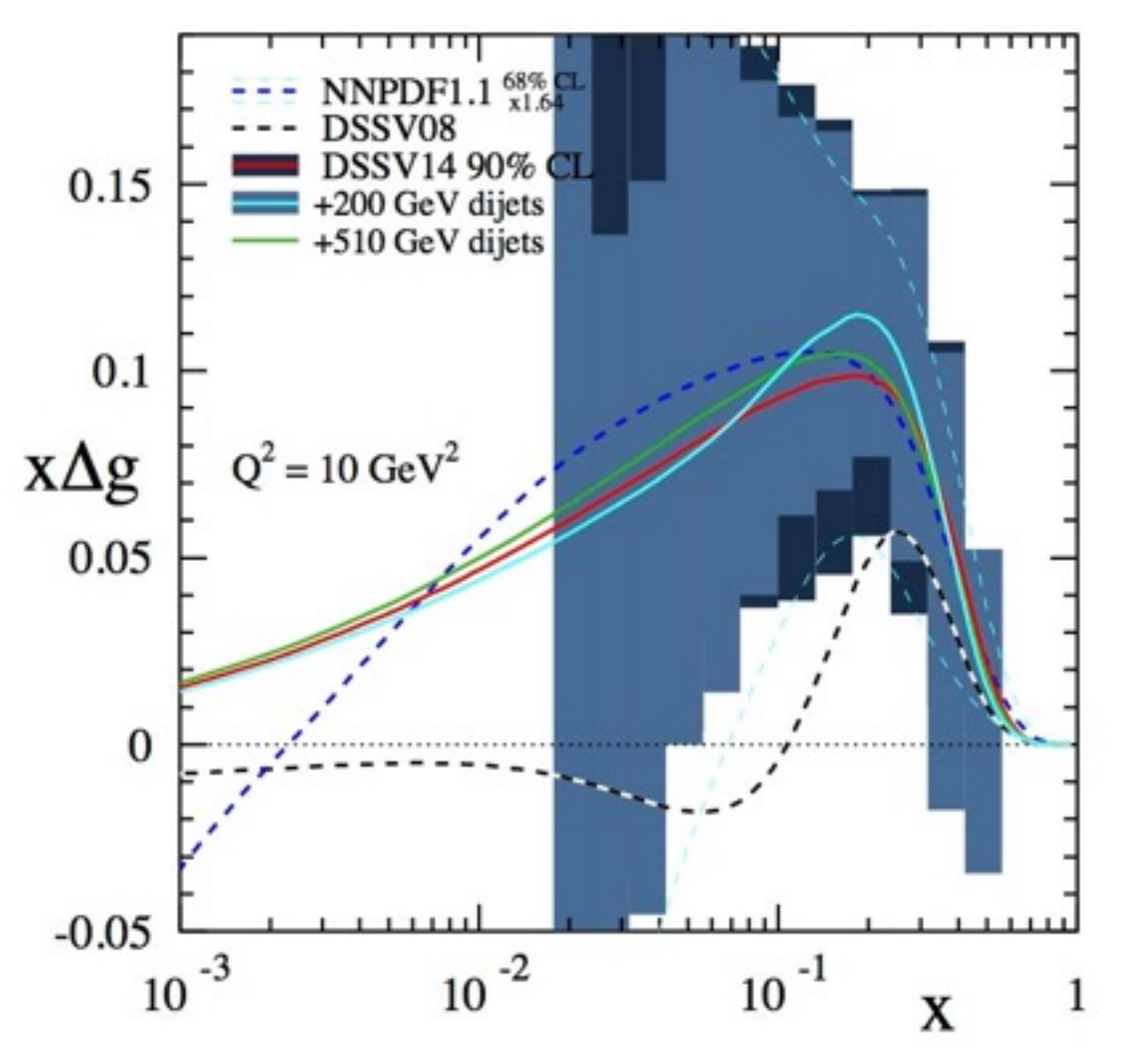
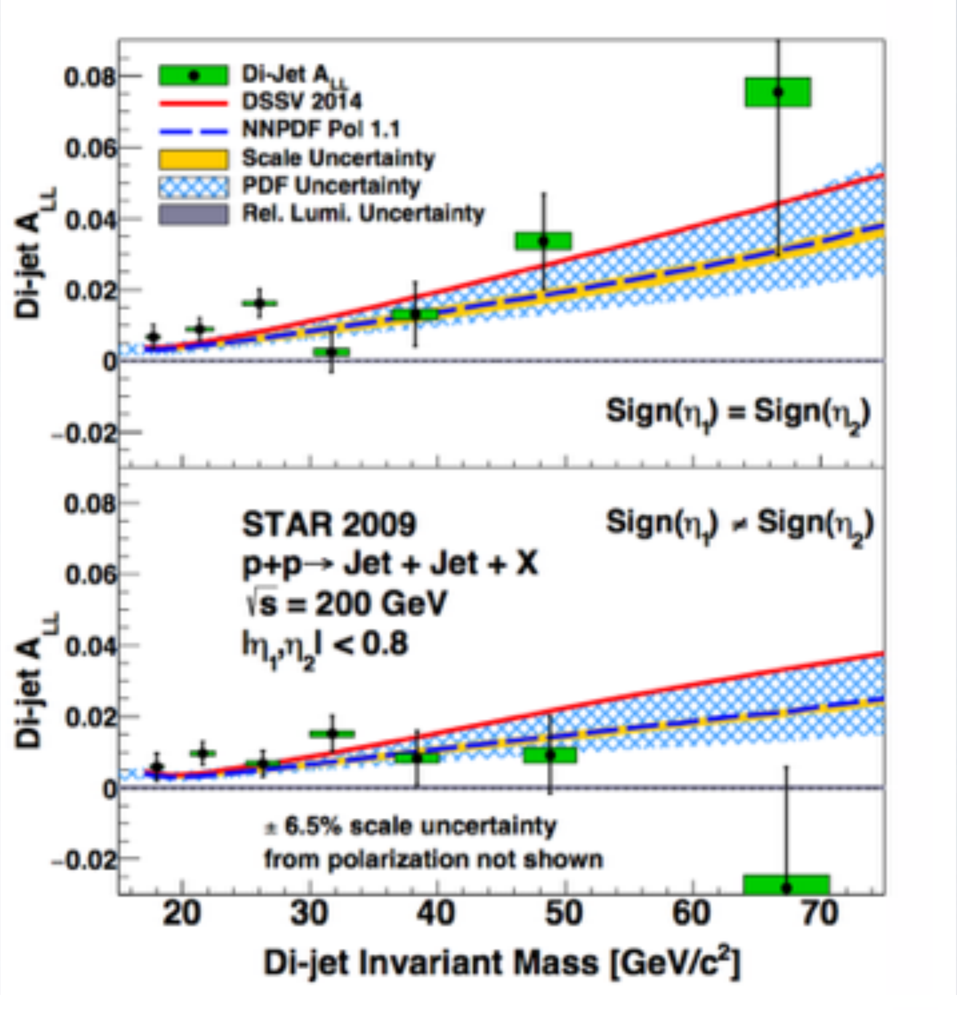
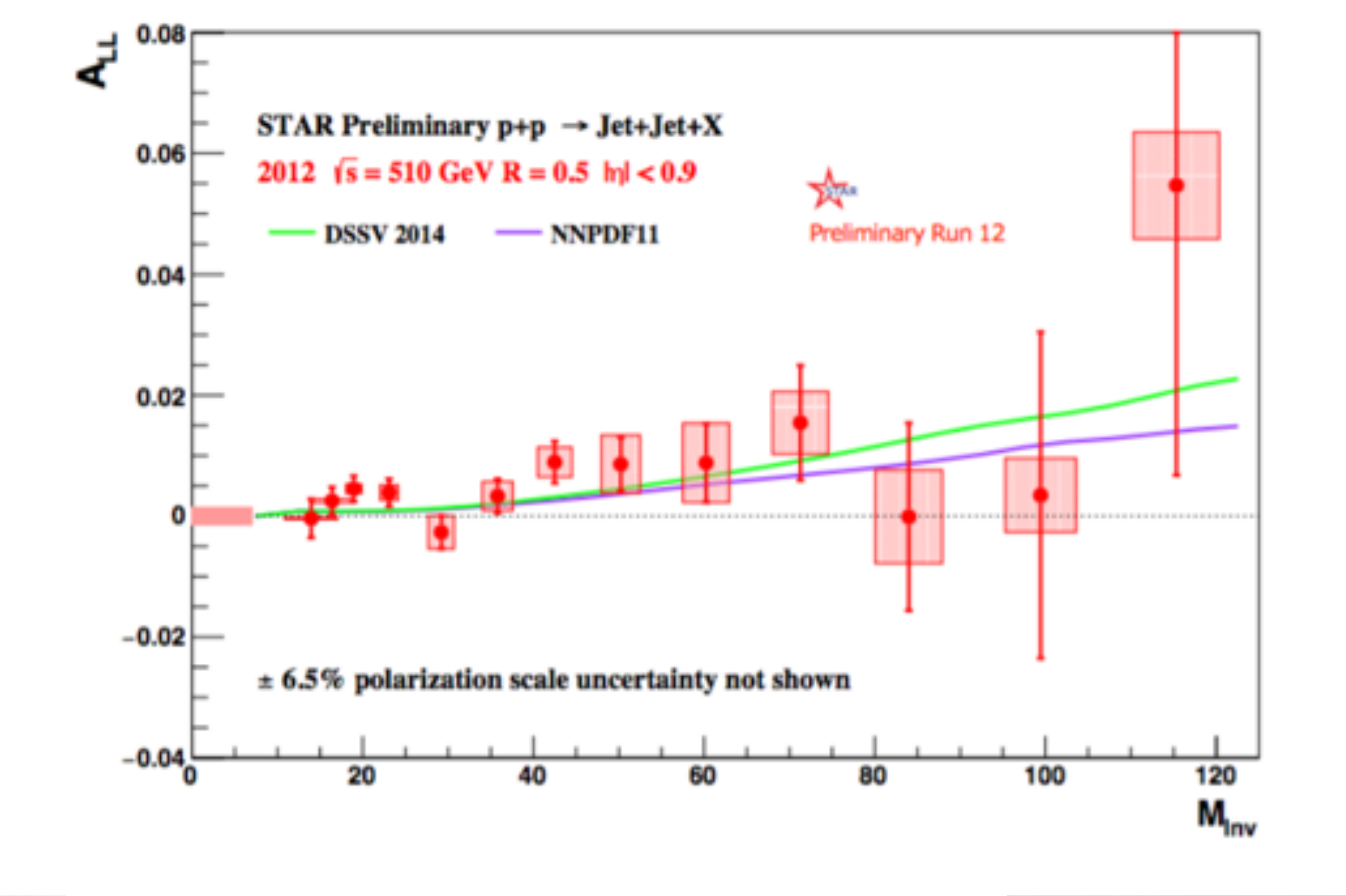
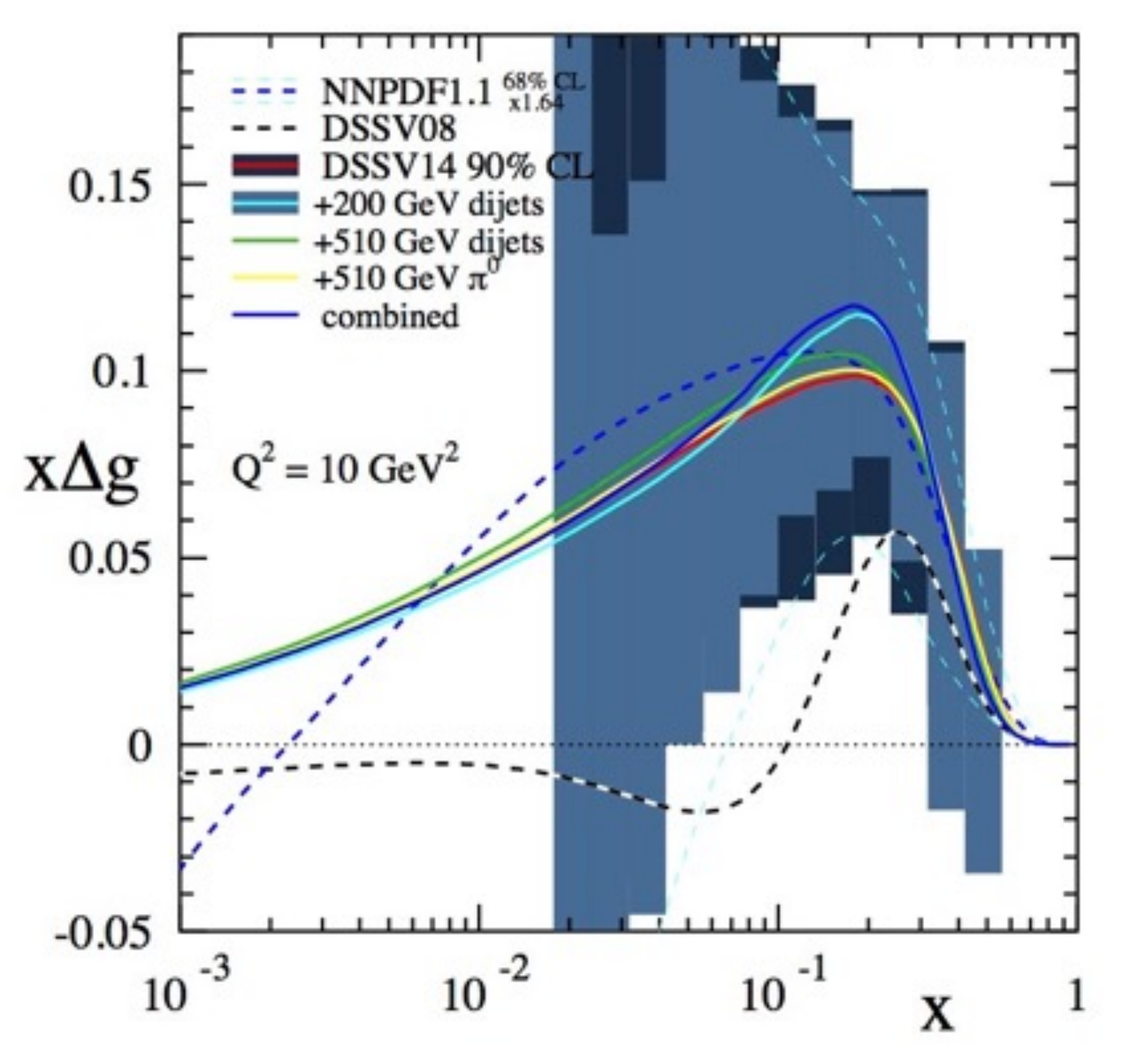


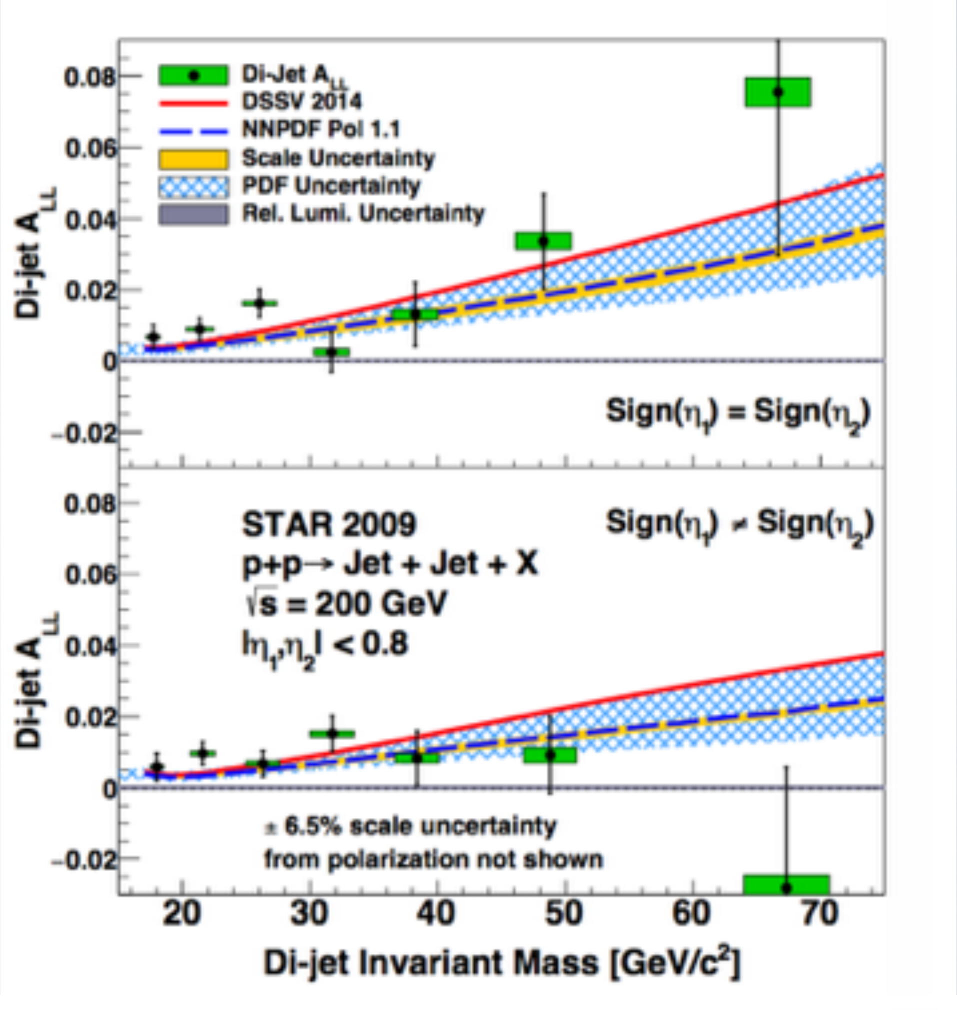


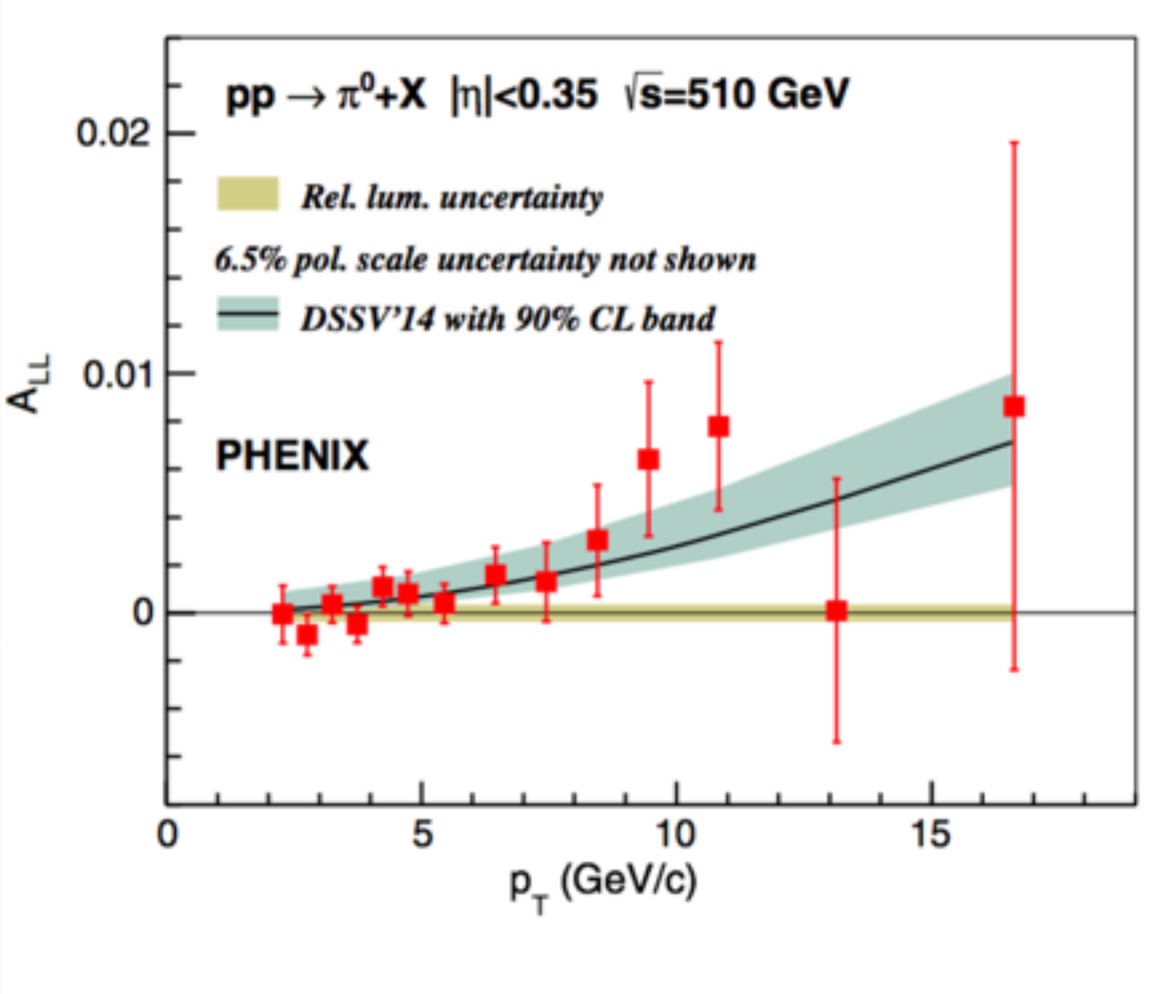


Impact on Δg

STAR run9 200 GeV dijets:



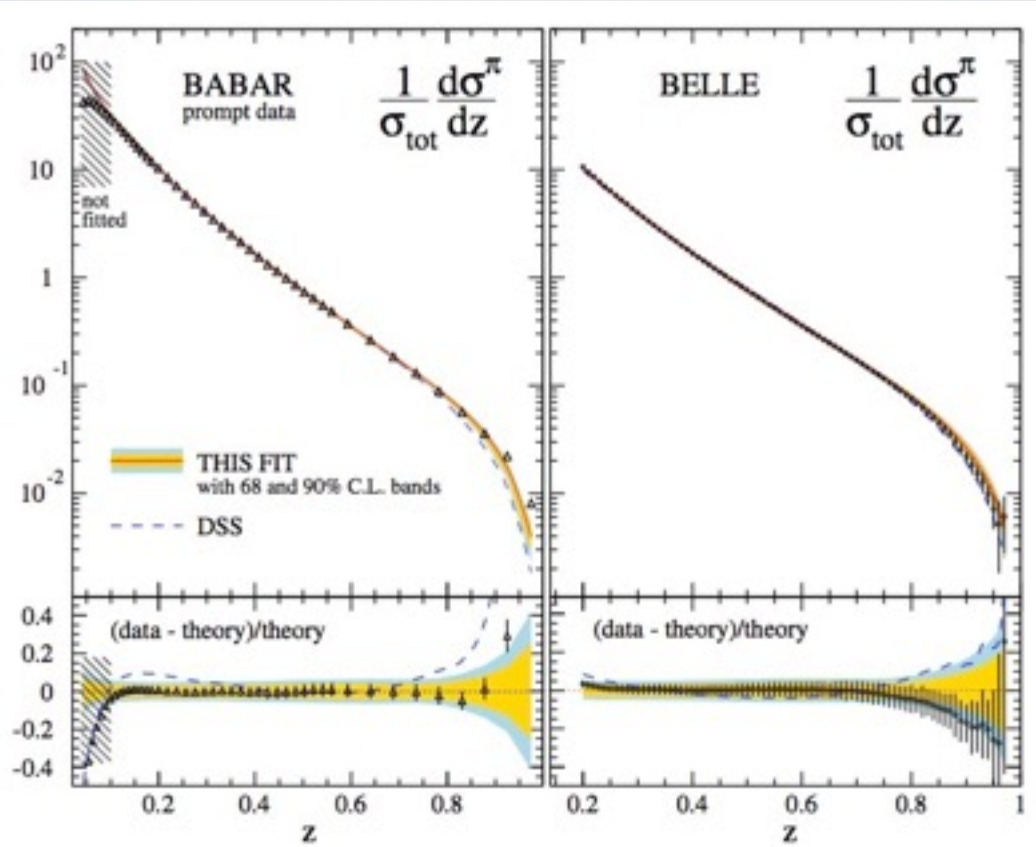


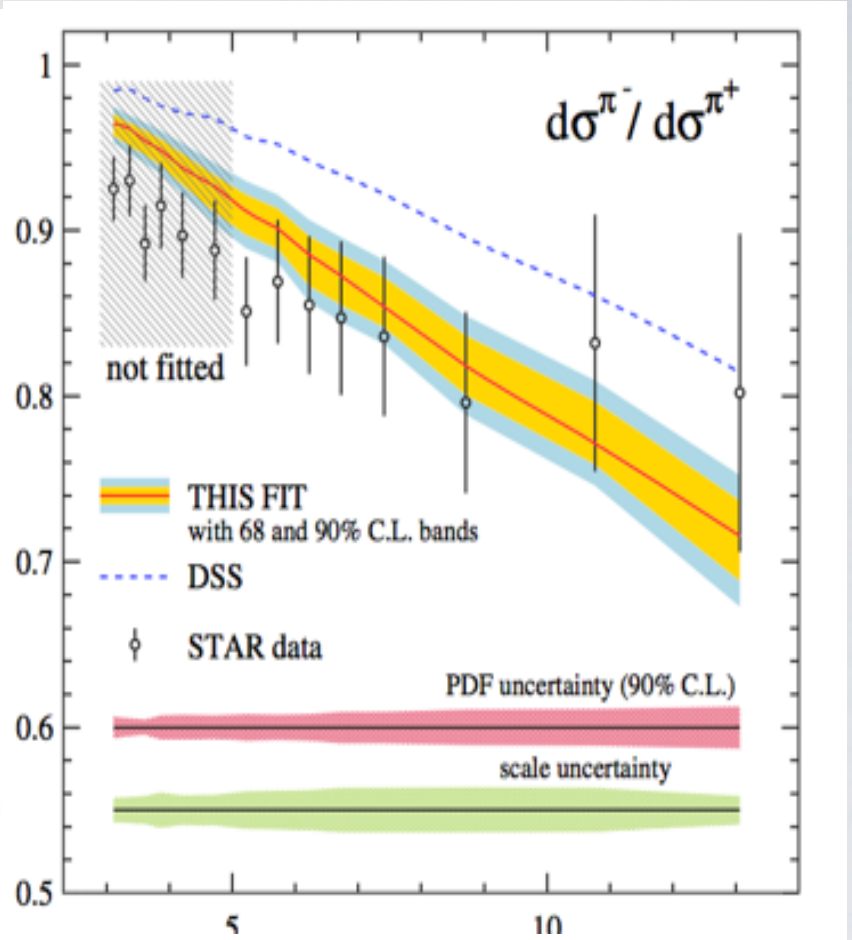


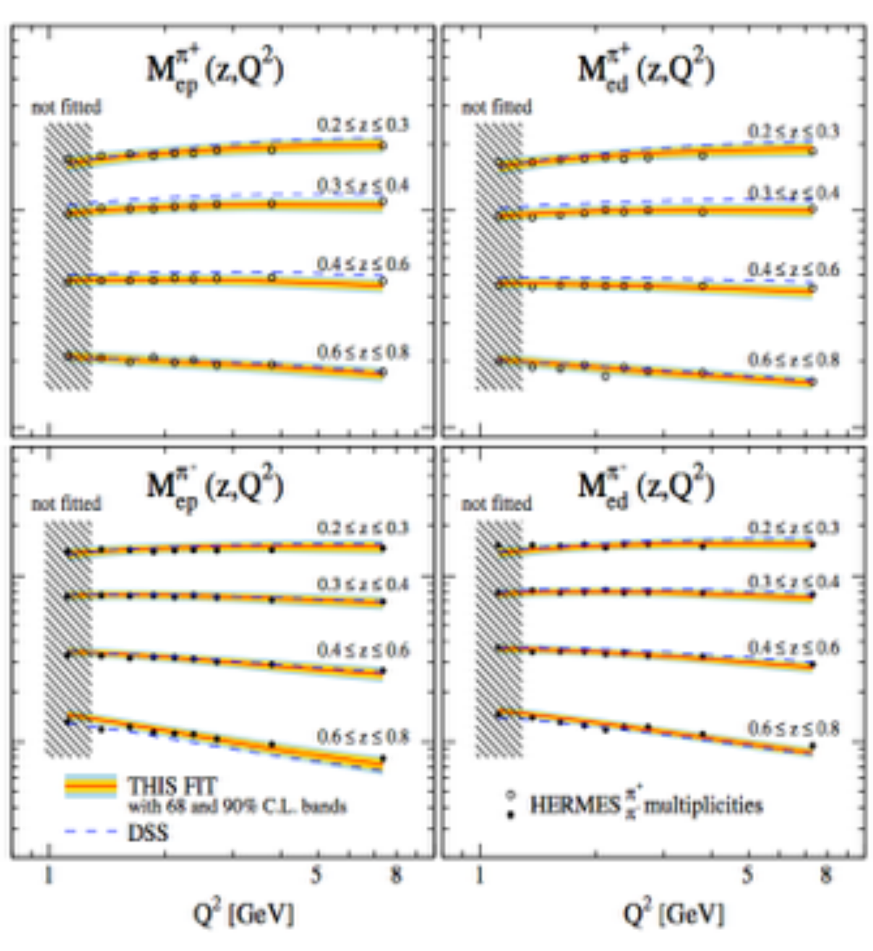
Impact on $\Delta\bar{q}$

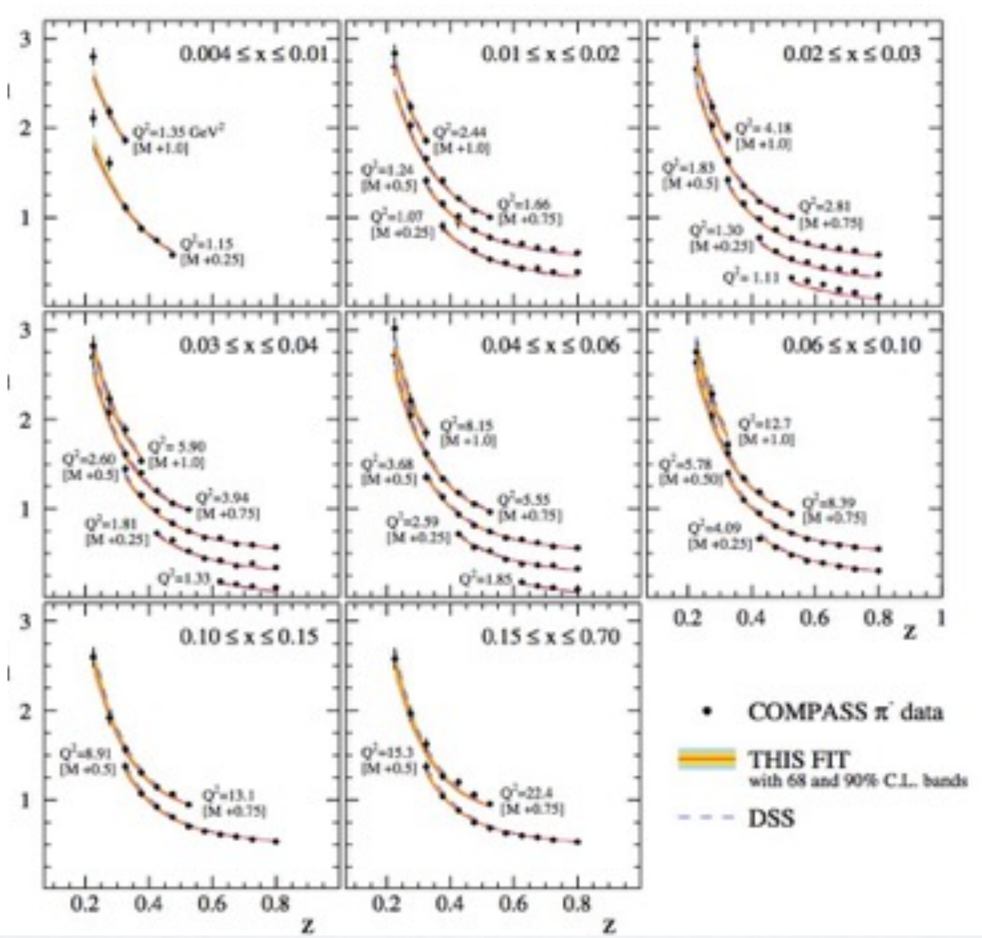
DSS FFs updates:

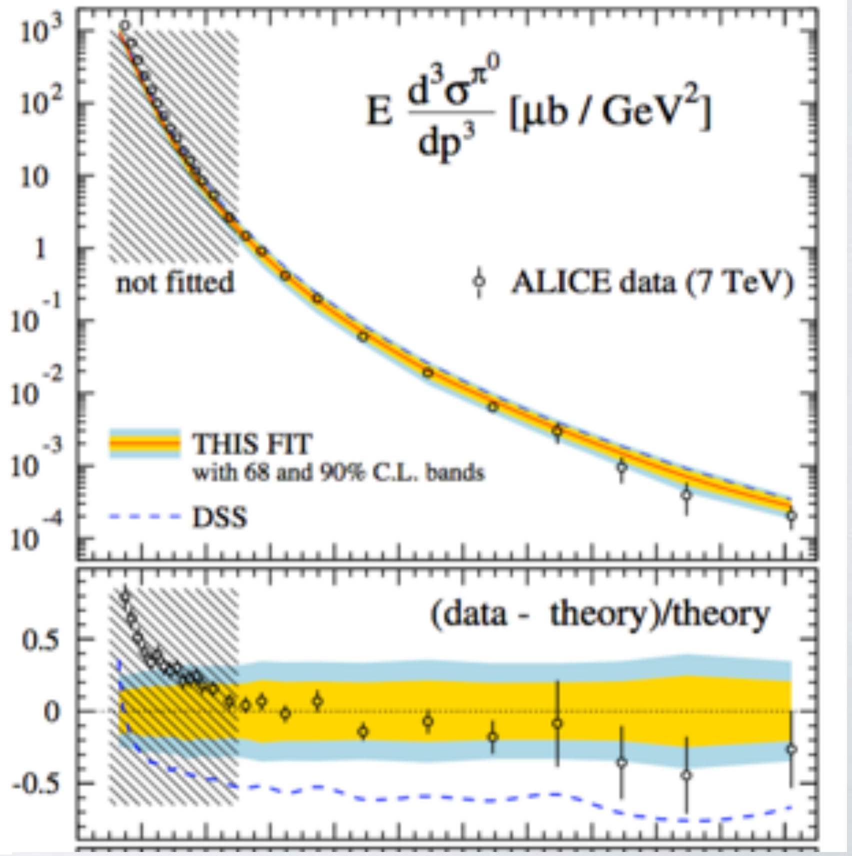
pions:







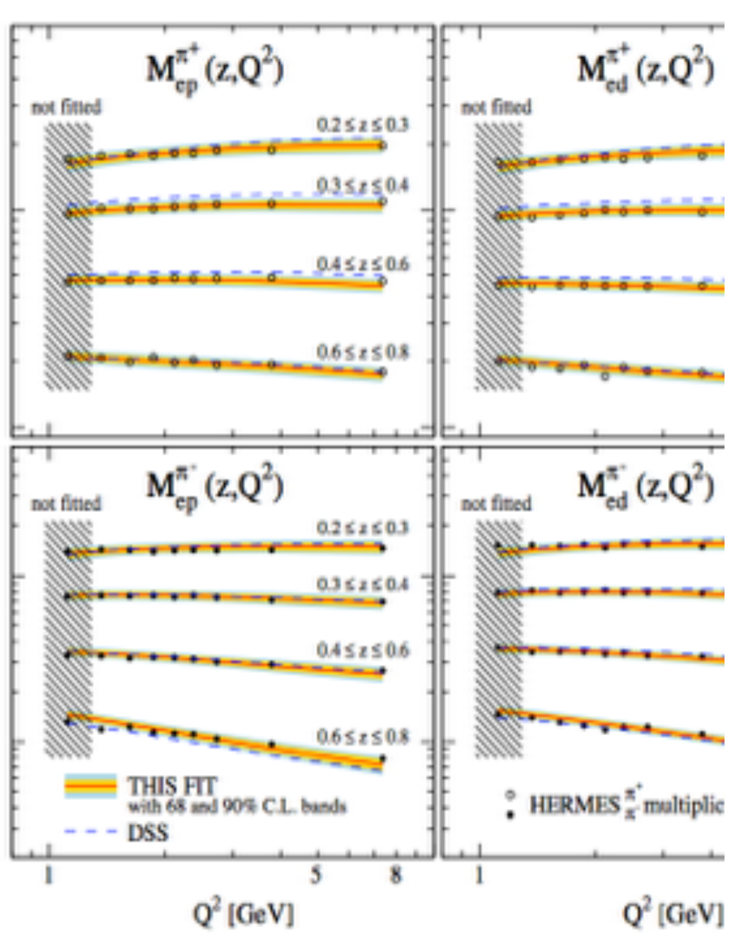


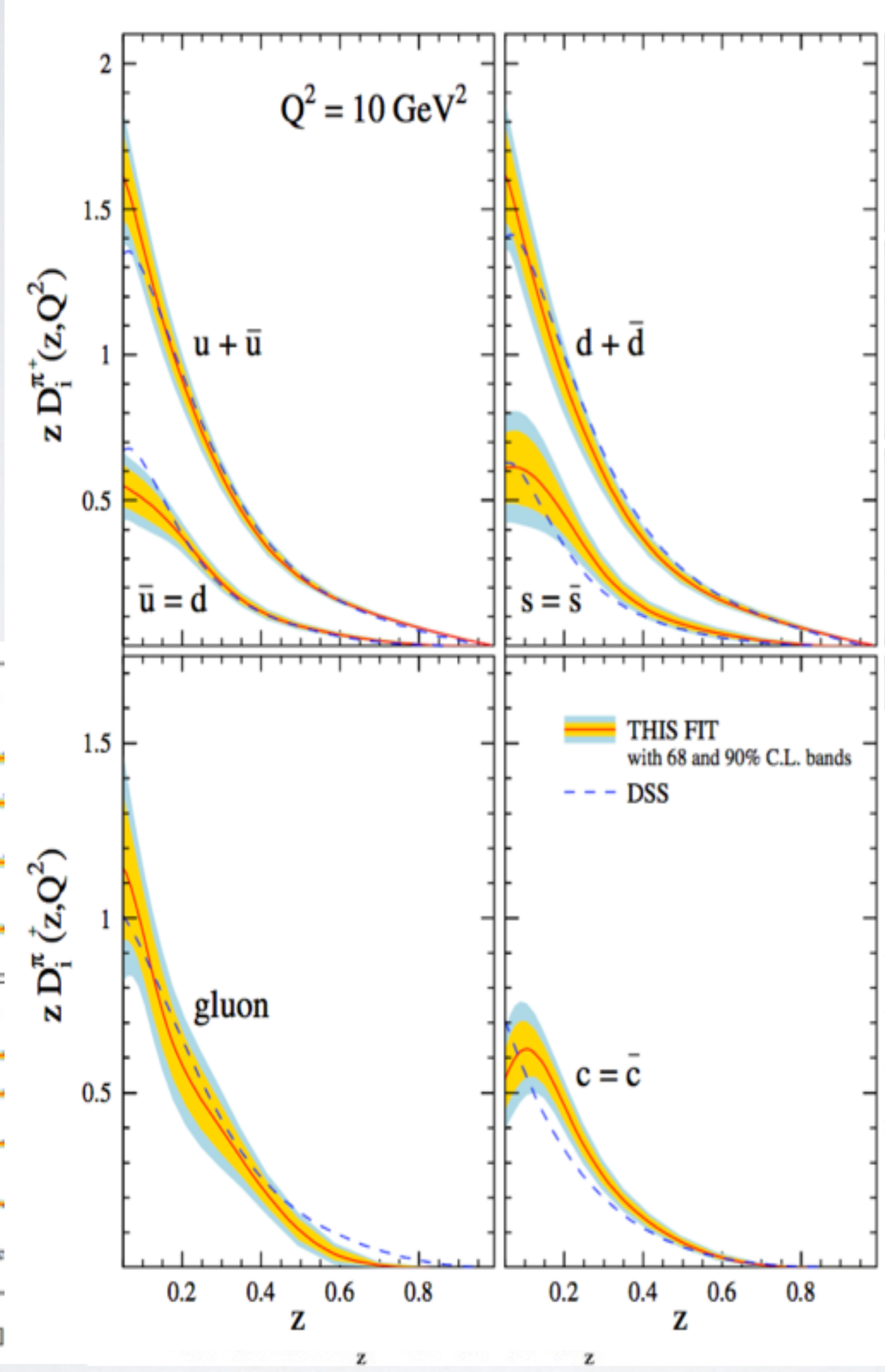


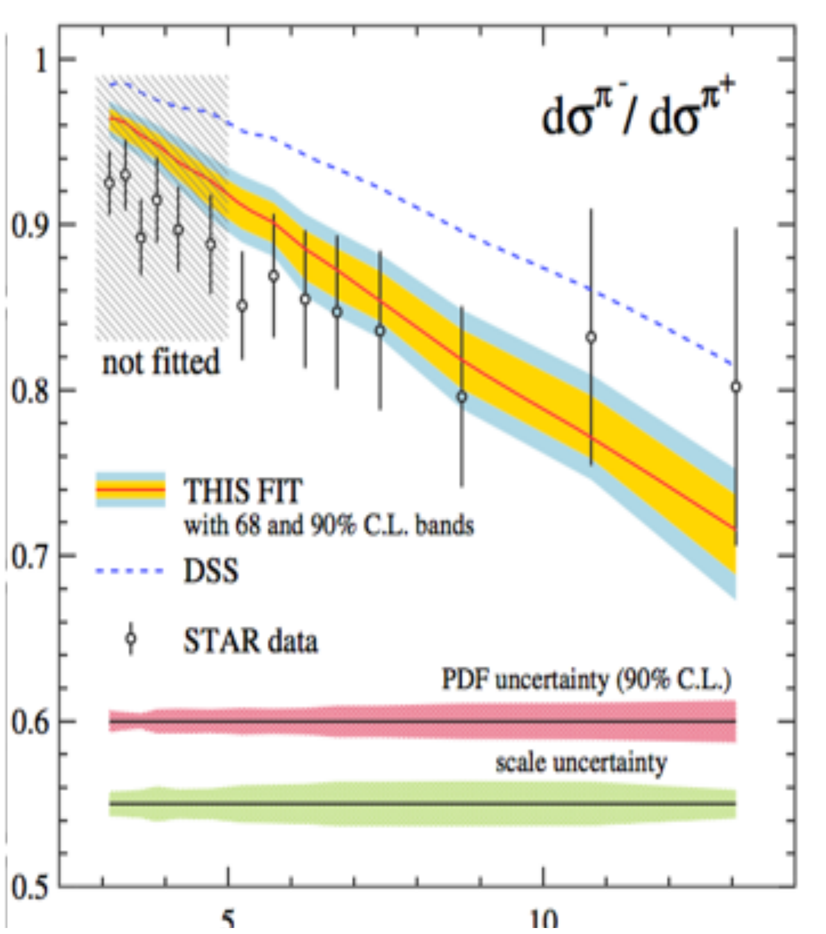
Impact on $\Delta\bar{q}$

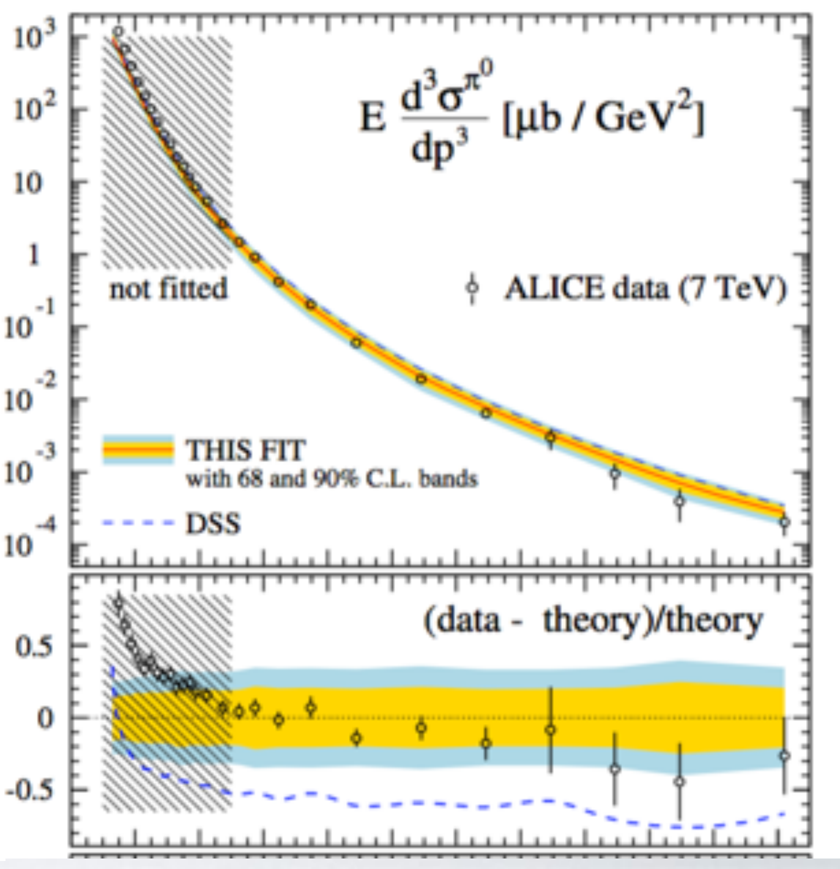
DSS FFs updates:

pions:





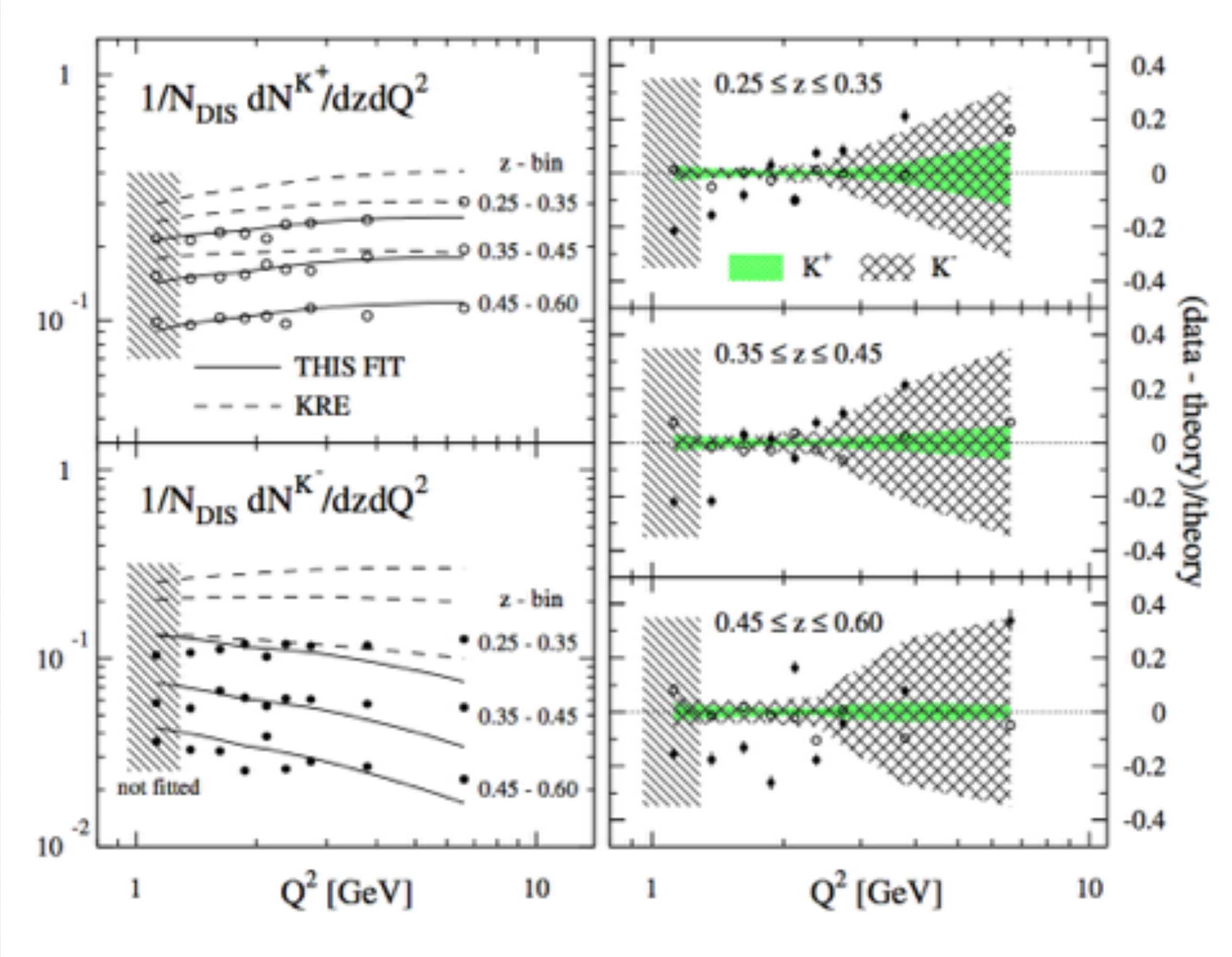


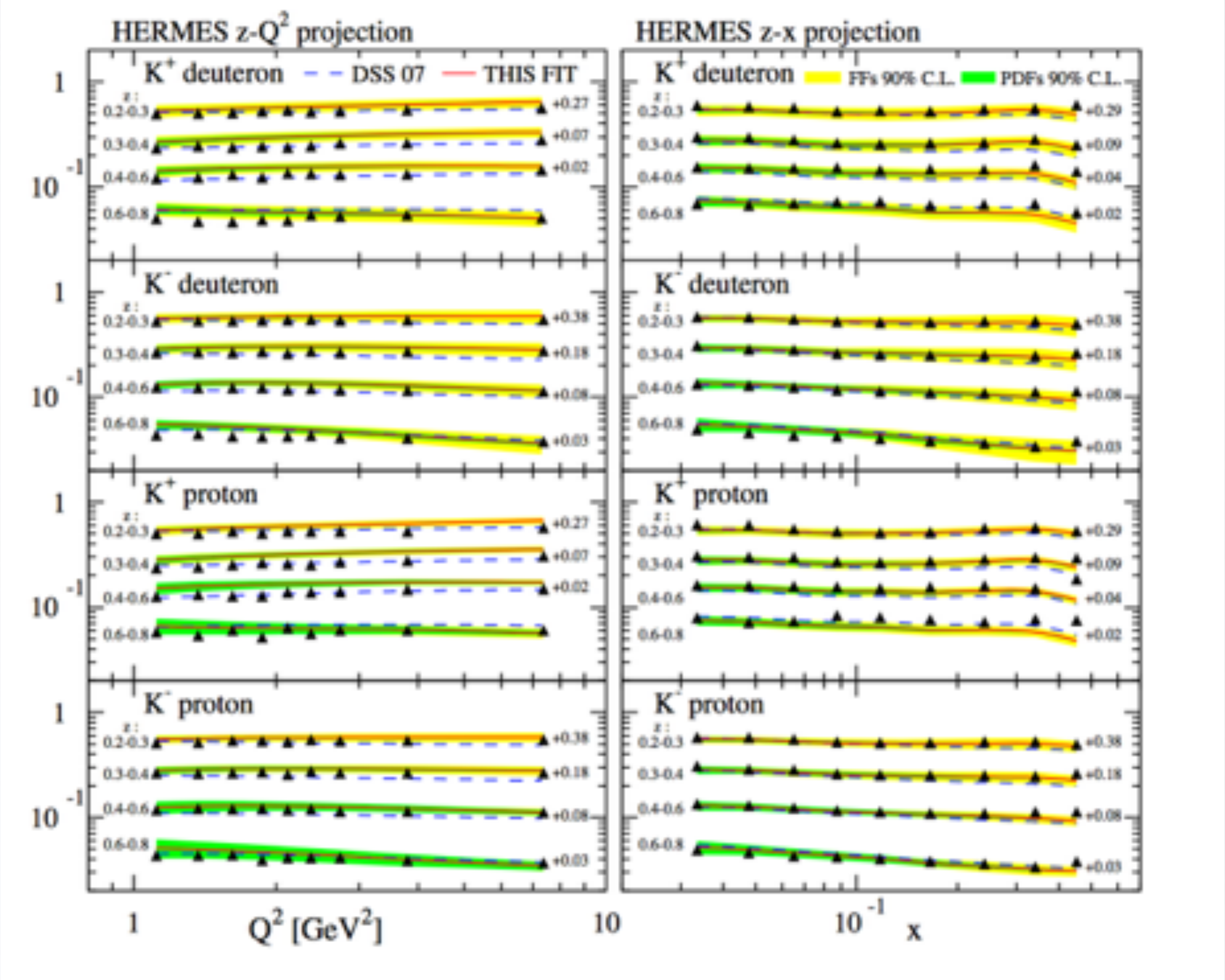


Impact on $\Delta\bar{q}$

DSS FFs updates:

kaons:

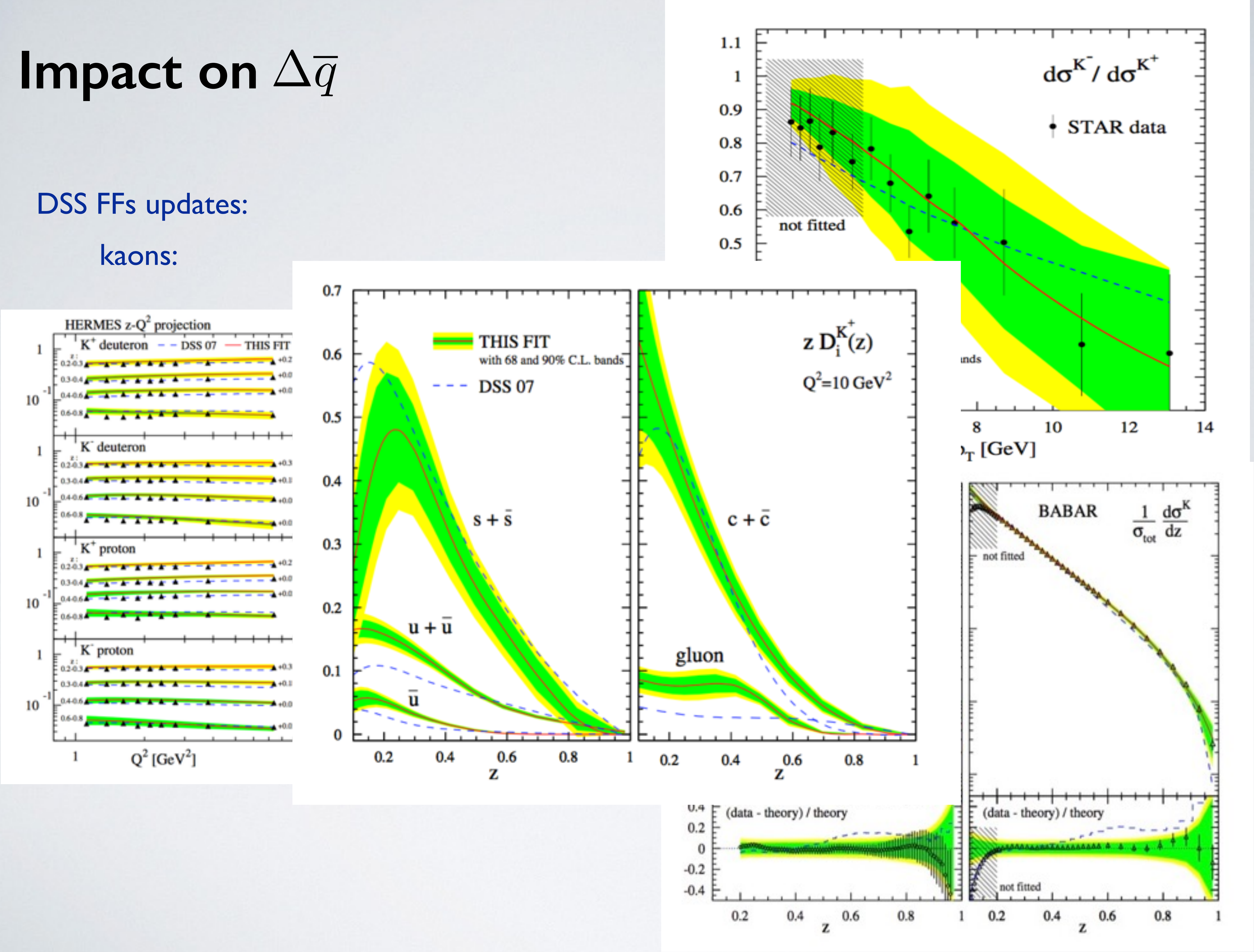




Impact on $\Delta\bar{q}$

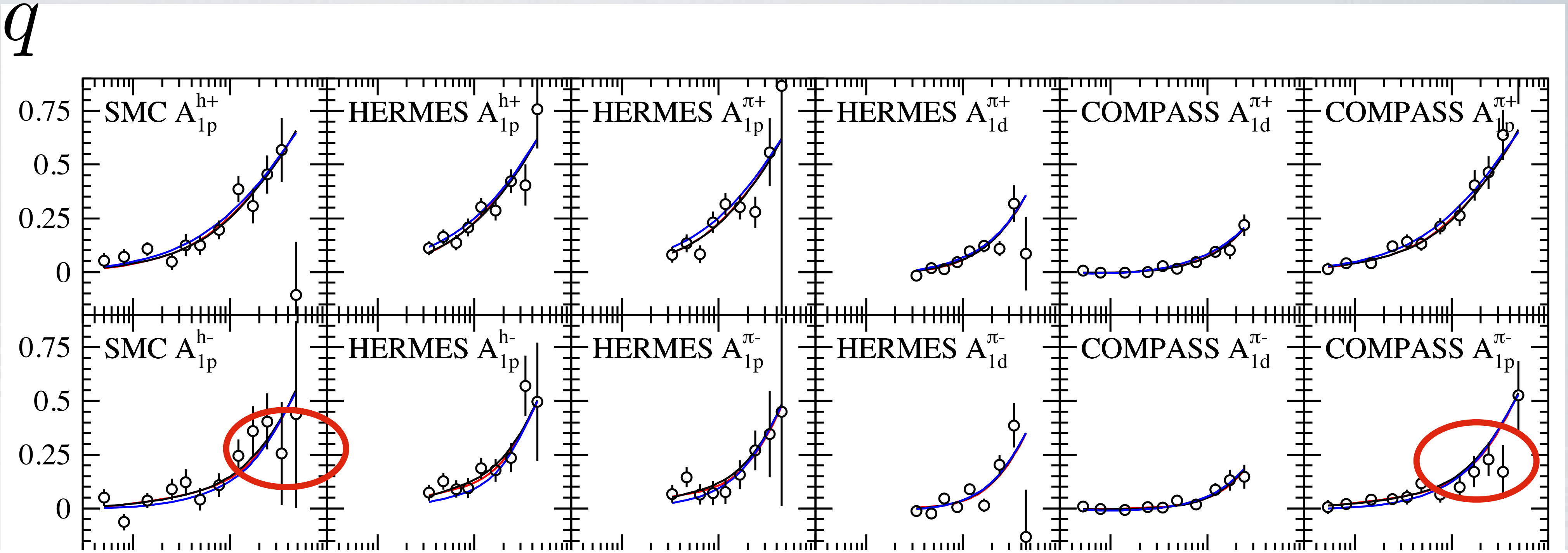
DSS FFs updates:

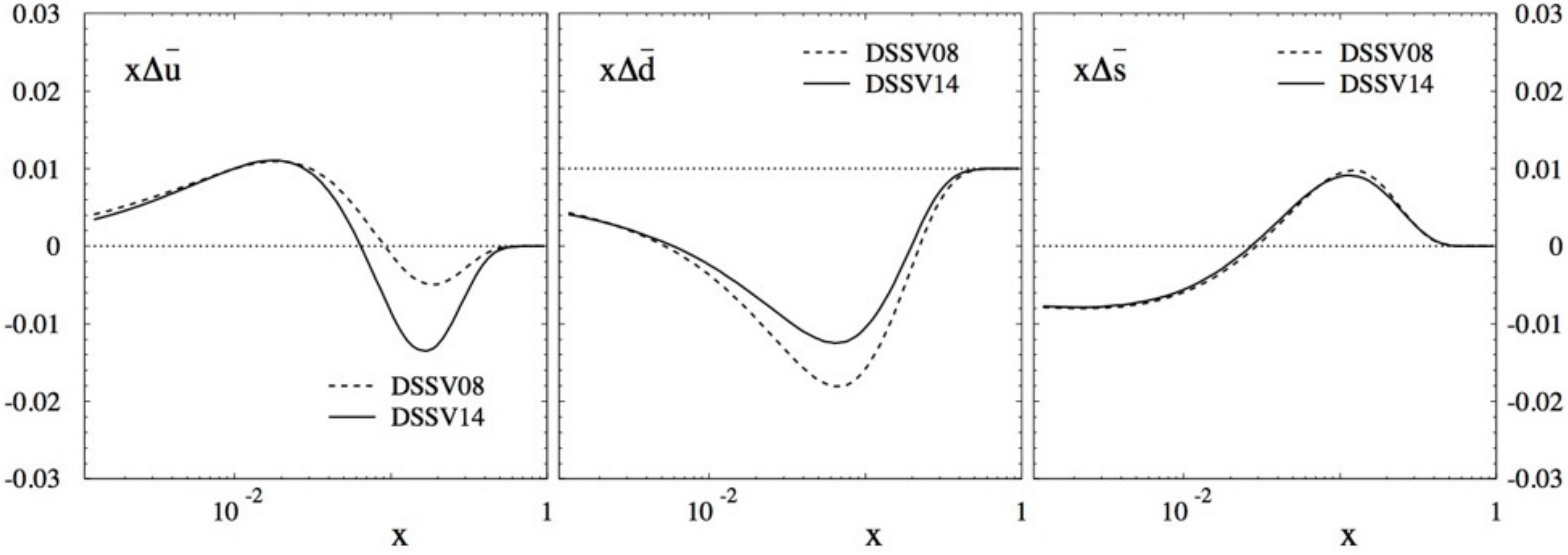
kaons:



Impact on $\Delta\bar{q}$

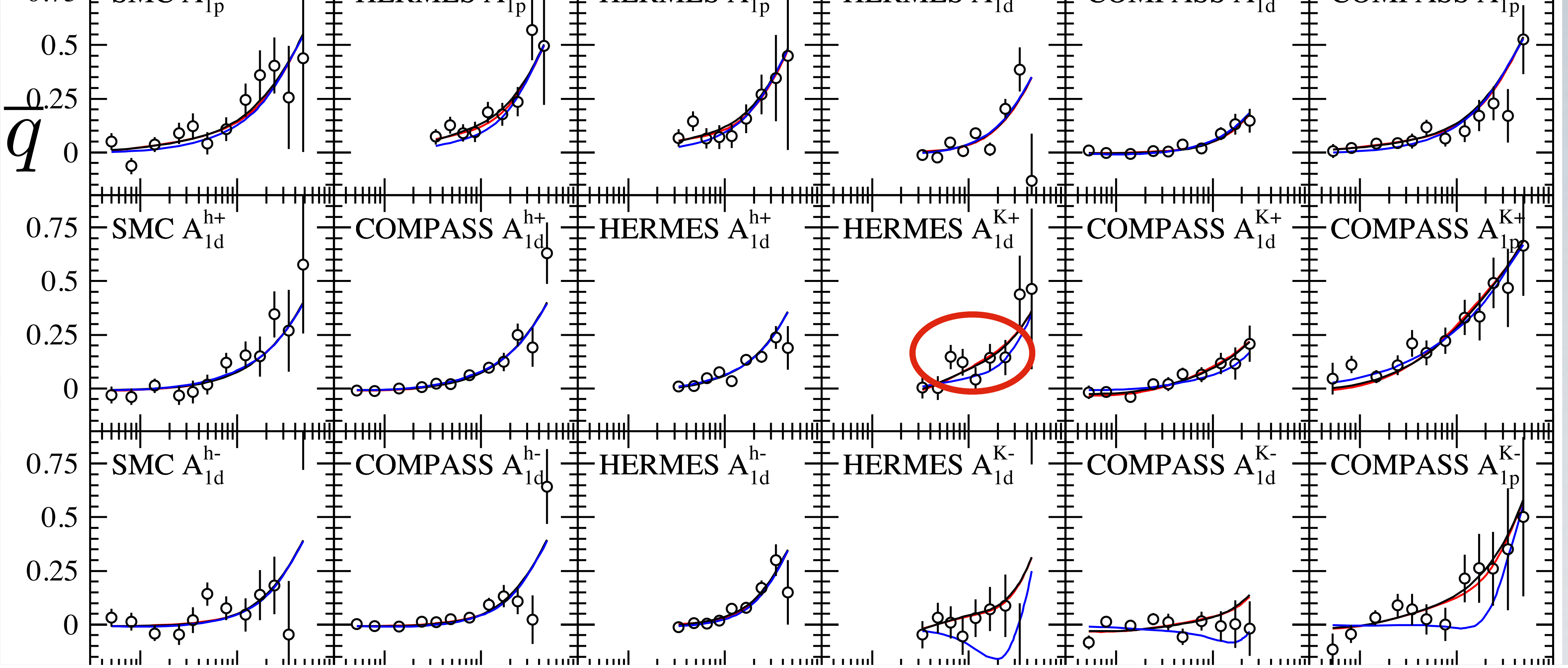
DSS FFs updates:

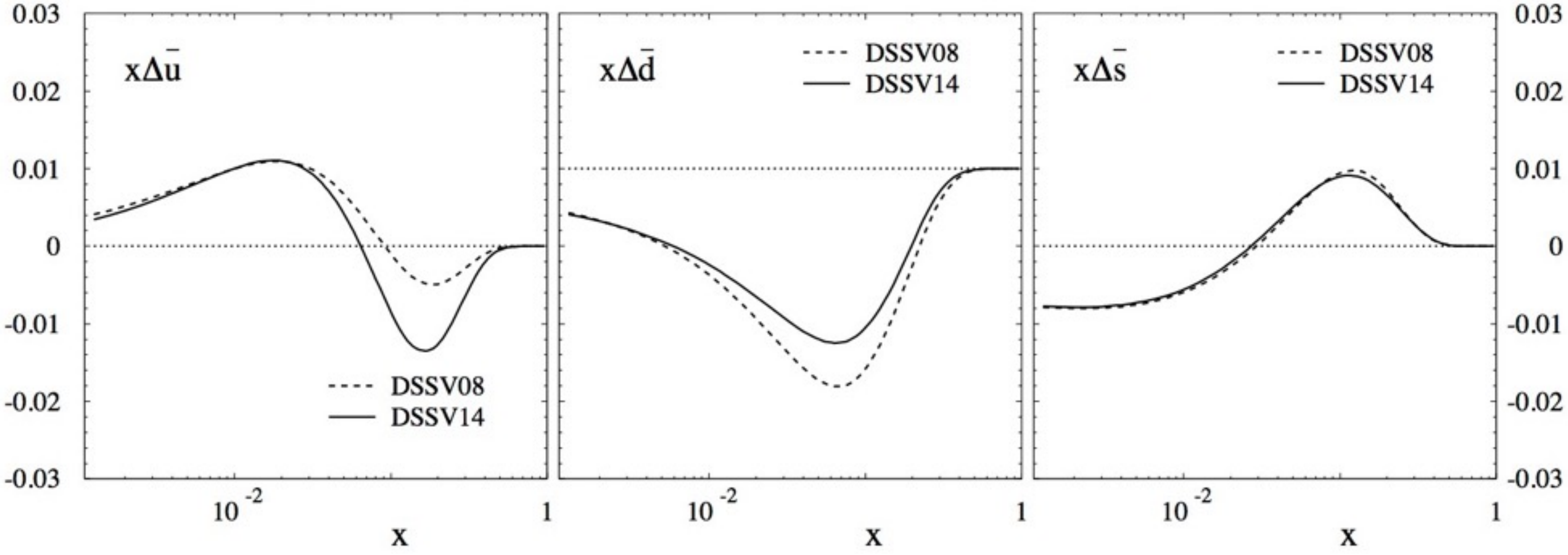




Impact on $\Delta\bar{q}$

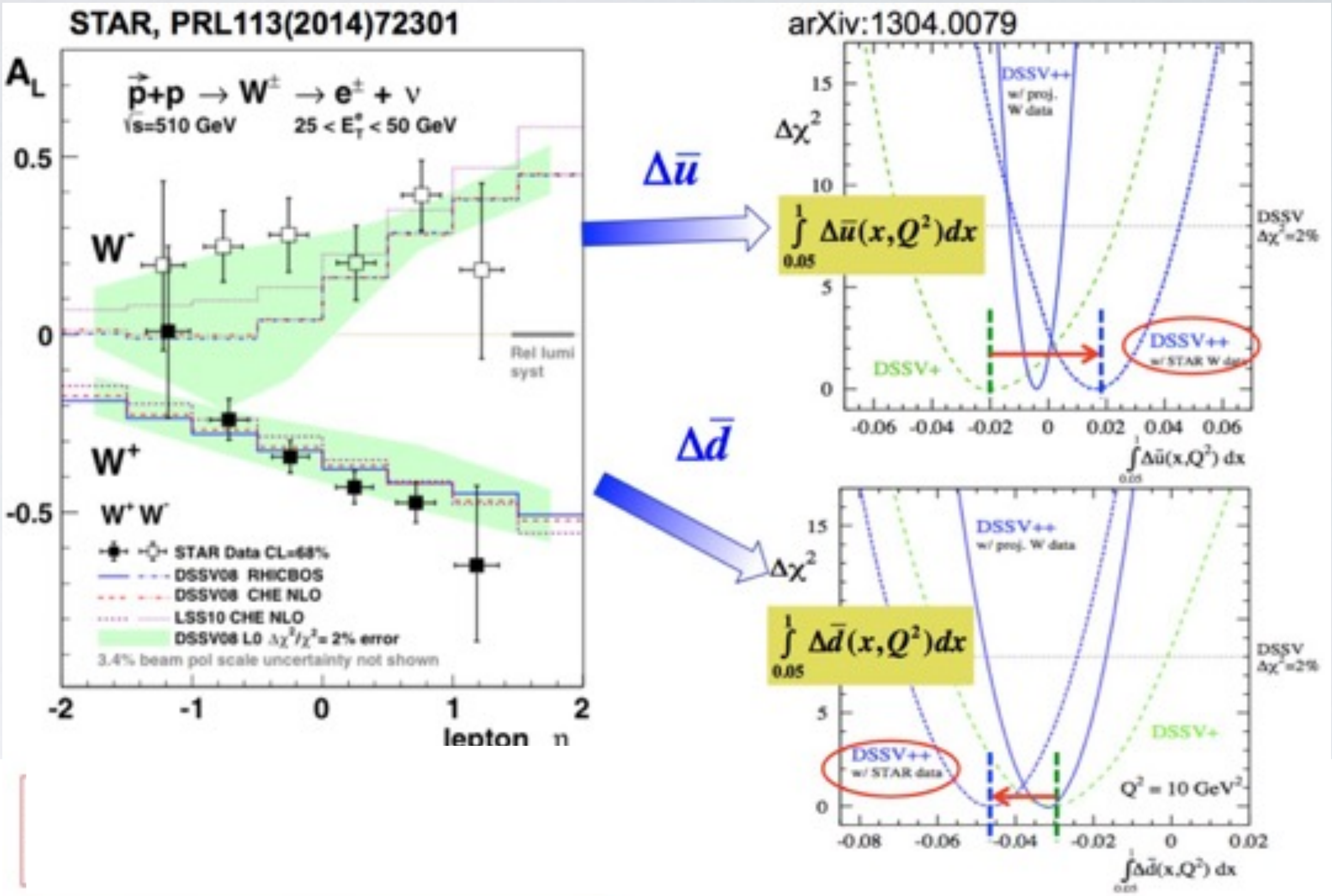
DSS FFs updates:

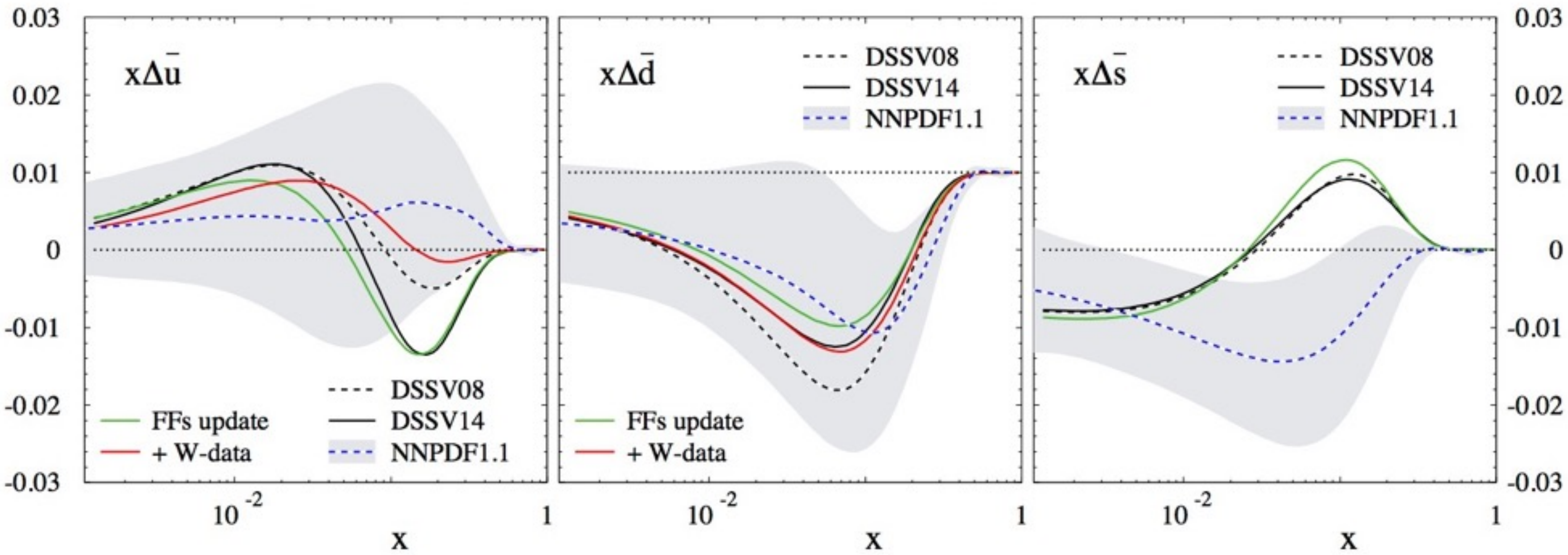




Impact on $\Delta\bar{q}$

DSS FFs updates:
W-data upgrade:

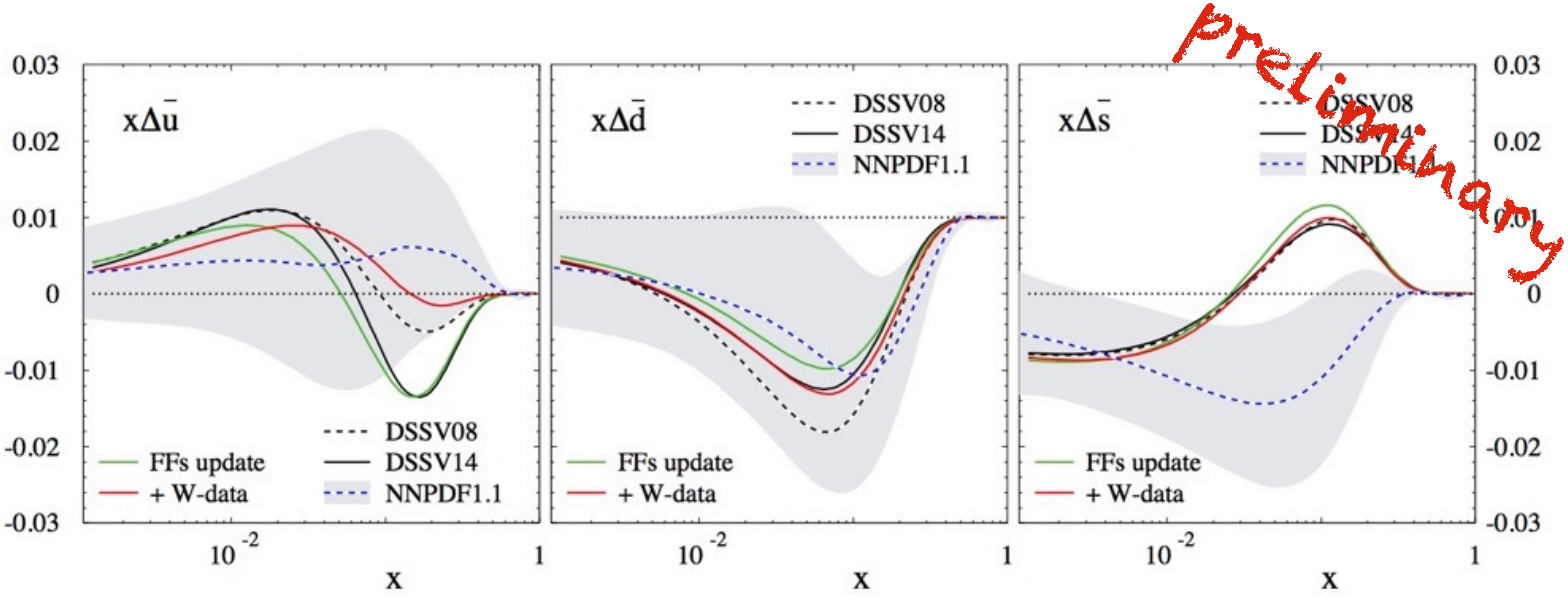




Impact on $\Delta\bar{q}$

DSS FFs updates:

W-data upgrade: anything left? W/Z?



Summary:

update of DSSV ongoing, plenty of new data, improved input FFs PDFs

gluon polarization slightly larger, much better constrained

dijets unveil the shape of Δg

jet and hadro-production in pp collisions **agree**

updated FFs have a **negligible effect on sea quarks best fits**

$\Delta\overline{u}$ & $\Delta\overline{d}$ in good shape, $\Delta\overline{s}$ **still a puzzle**