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

Probing the sea quark content of the proton with SIDIS data

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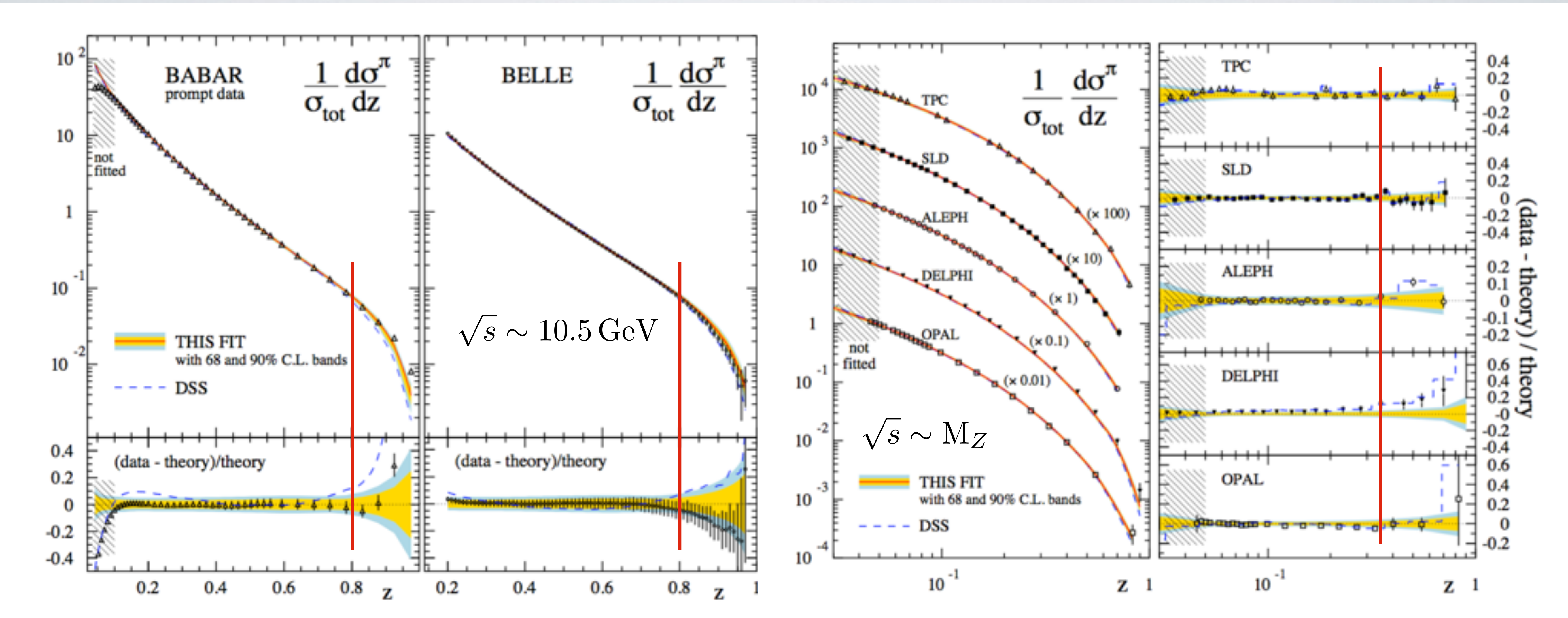
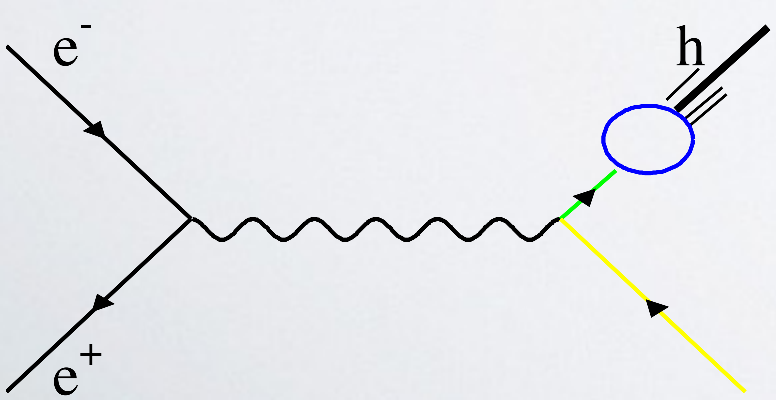
Universidad de Buenos Aires

in collaboration with I. Borsa and M. Stratmann
1708.01630

Motivation:

significant progress in final state hadron measurements

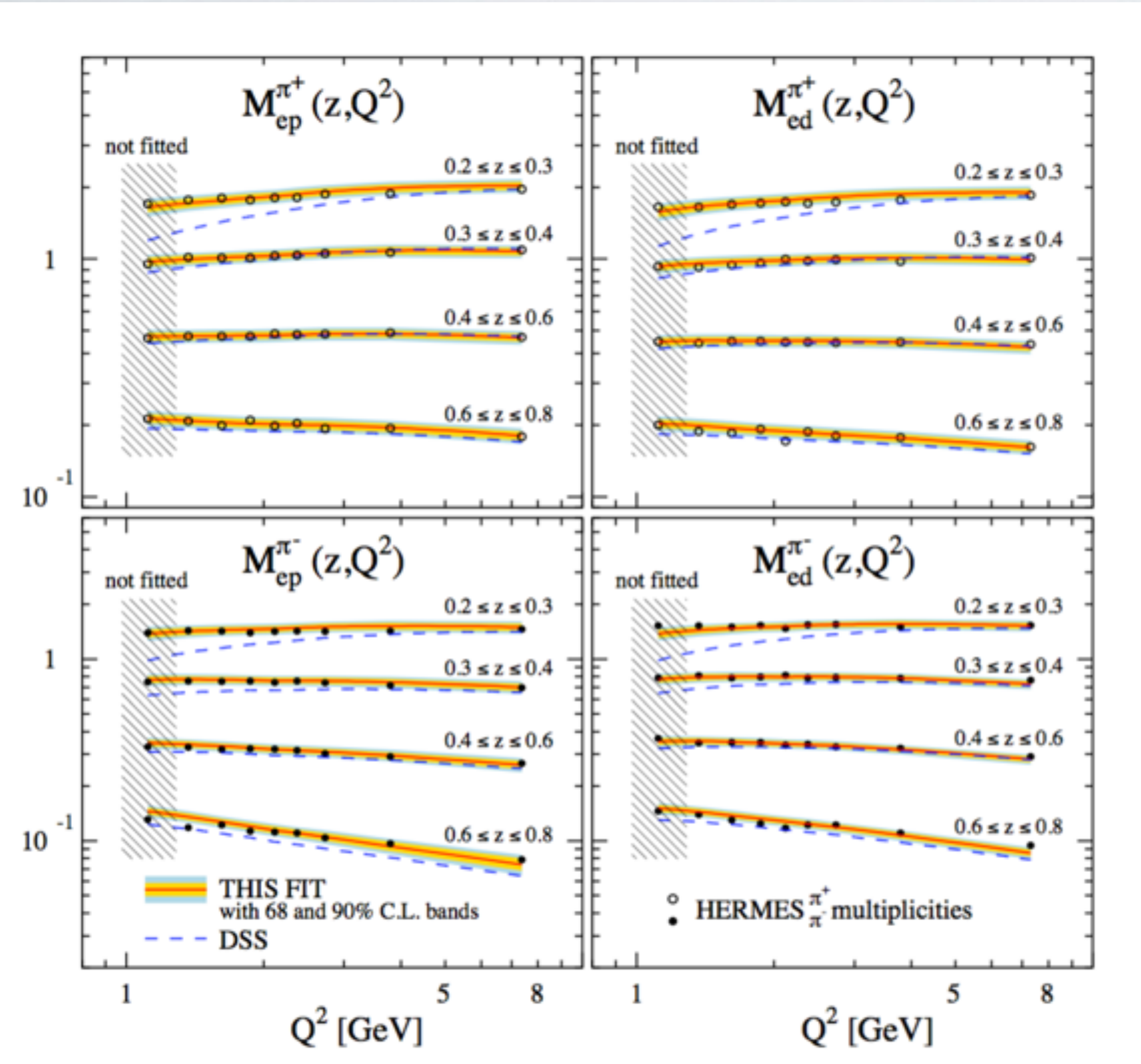


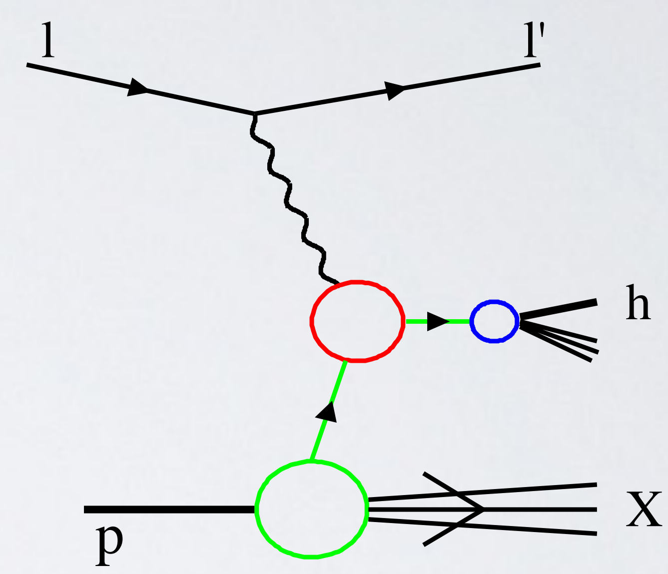


$$\frac{d\sigma}{dz}(e^+e^- \longrightarrow hX) = c_q(z) \otimes [D_q(z,Q^2) + D_{\bar{q}}(z,Q^2)]$$
$$+ c_g(z) \otimes D_g(z,Q^2)$$

Motivation:

significant progress in final state hadron measurements





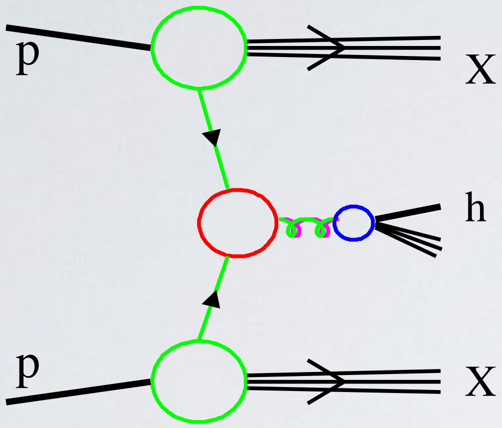
$$M^{\pi^\pm}_{e,p(d)} \equiv \frac{d\sigma^{\pi^\pm}/dx\,dQ^2\,dz}{d\sigma/dx\,dQ^2}$$

$$\frac{d\sigma^\pi}{dxdzdQ^2} = c_{if}(x,z) \otimes f_i(x,Q^2) \otimes D^\pi_f(z,Q^2)$$

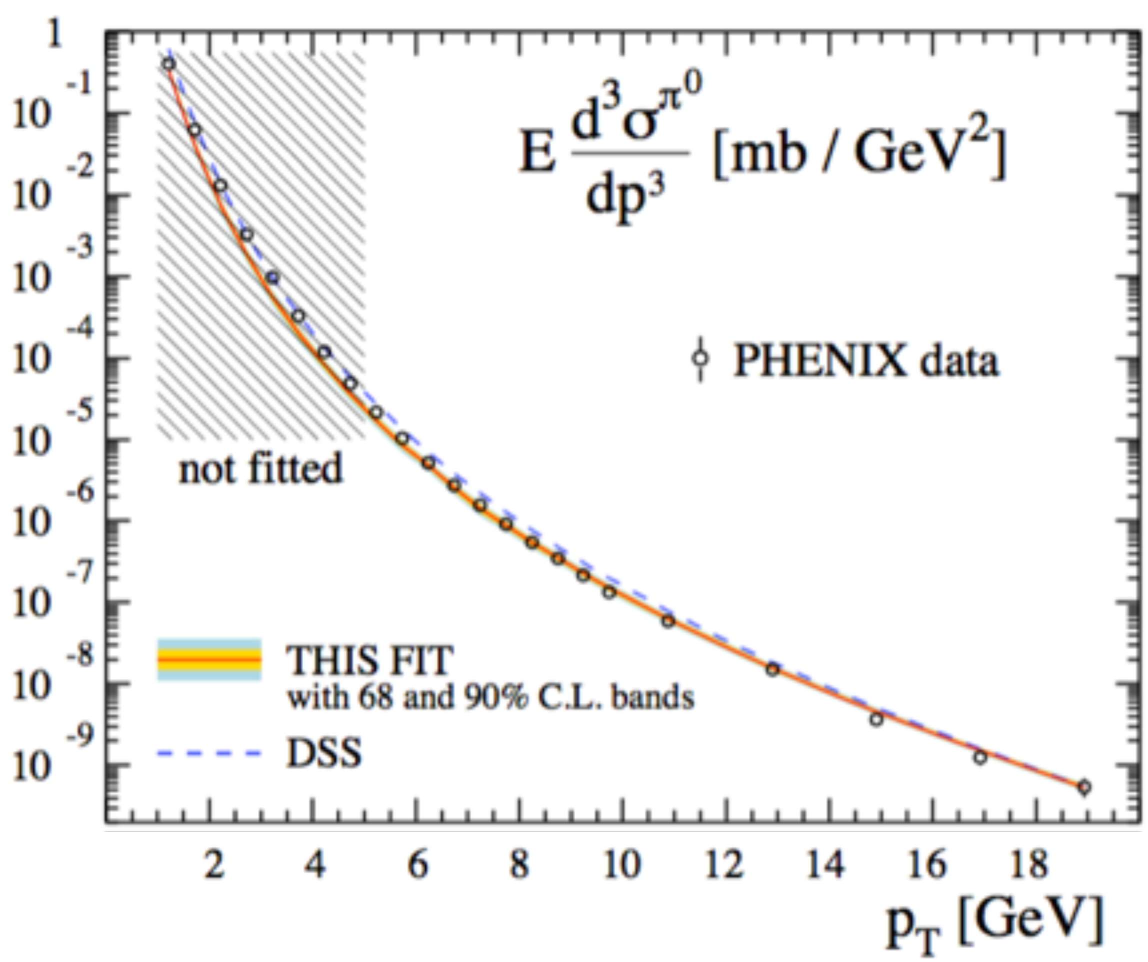
$$\frac{d\sigma}{dxdQ^2} = c_i(x) \otimes f_i(x,Q^2)$$

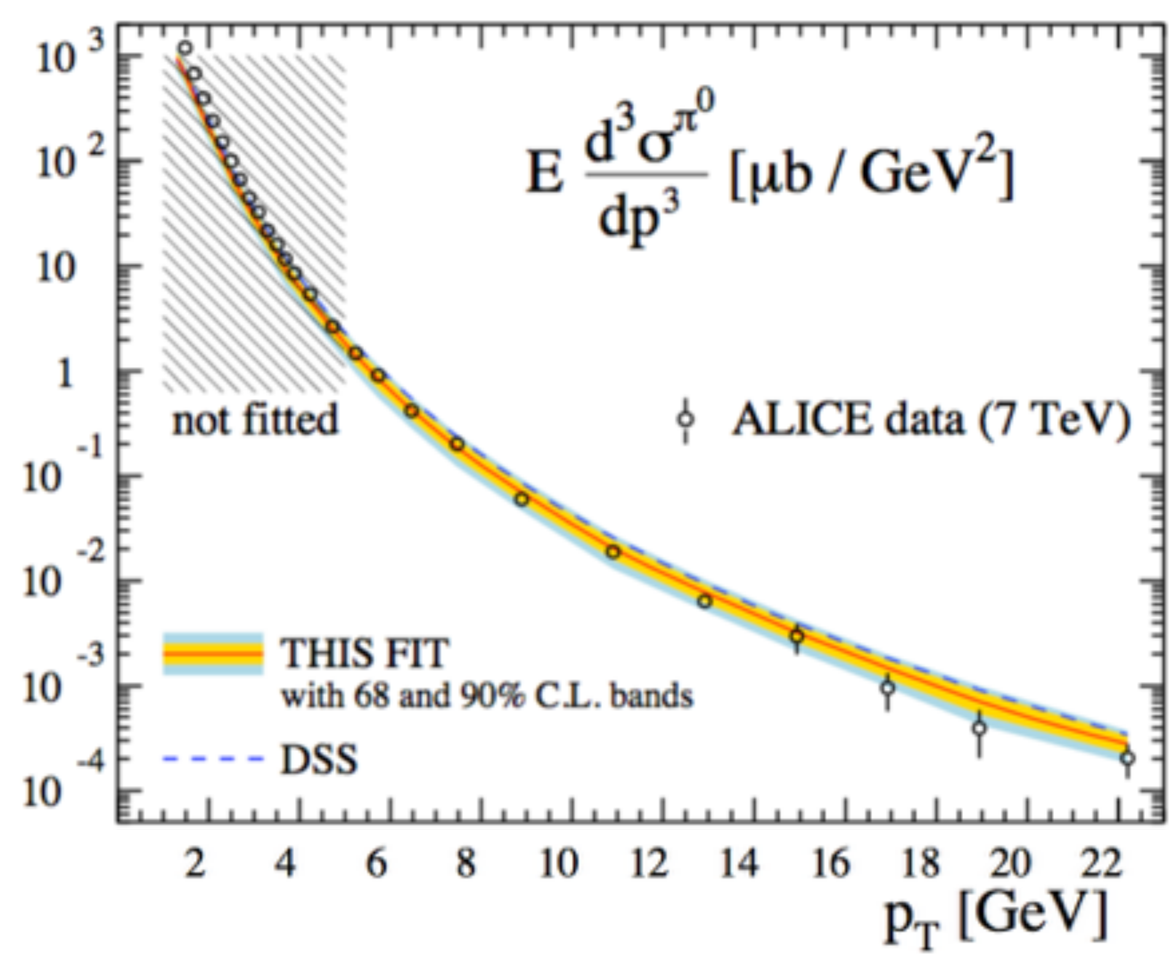
Motivation:

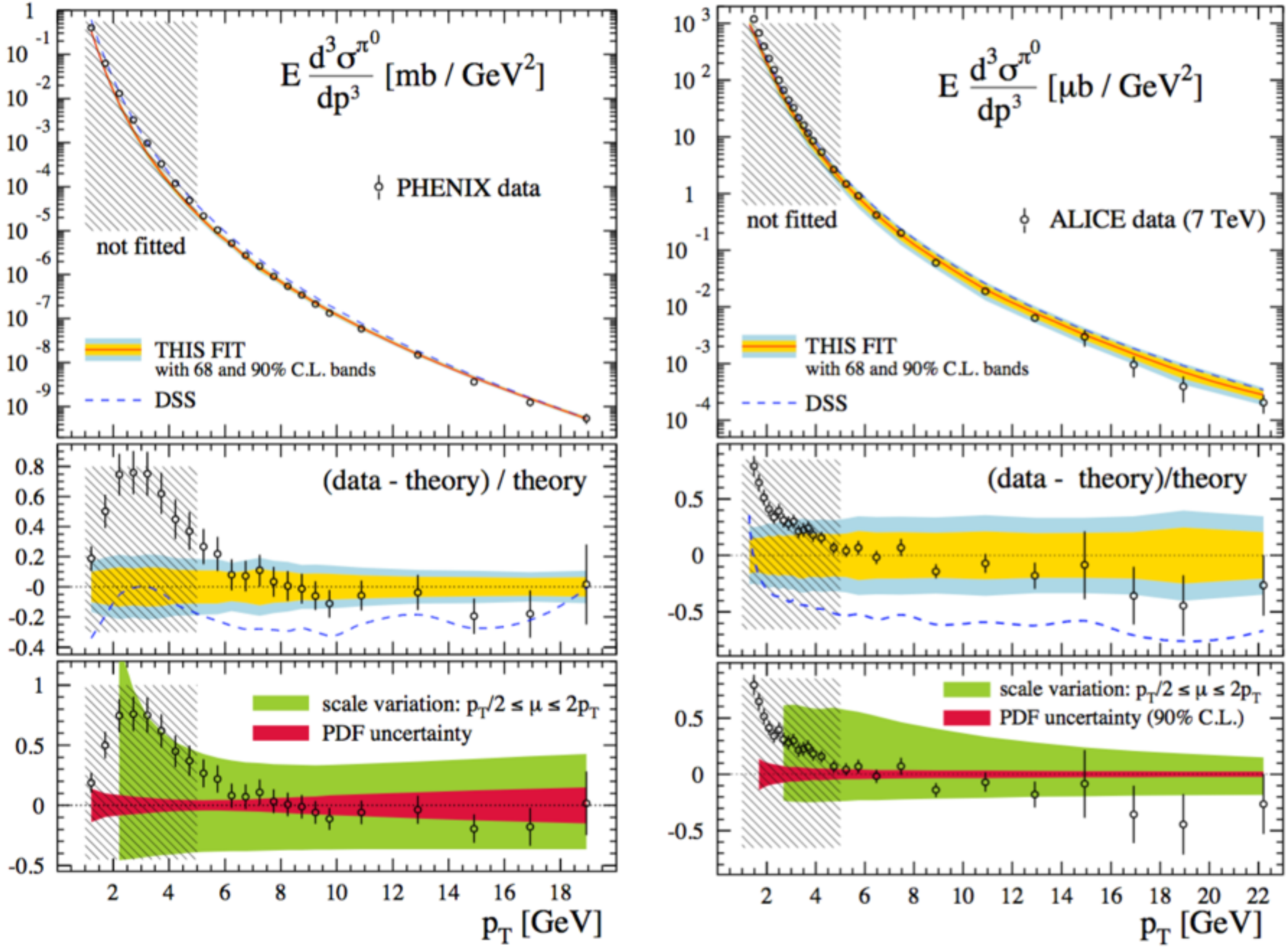
significant progress in final state hadron measurements



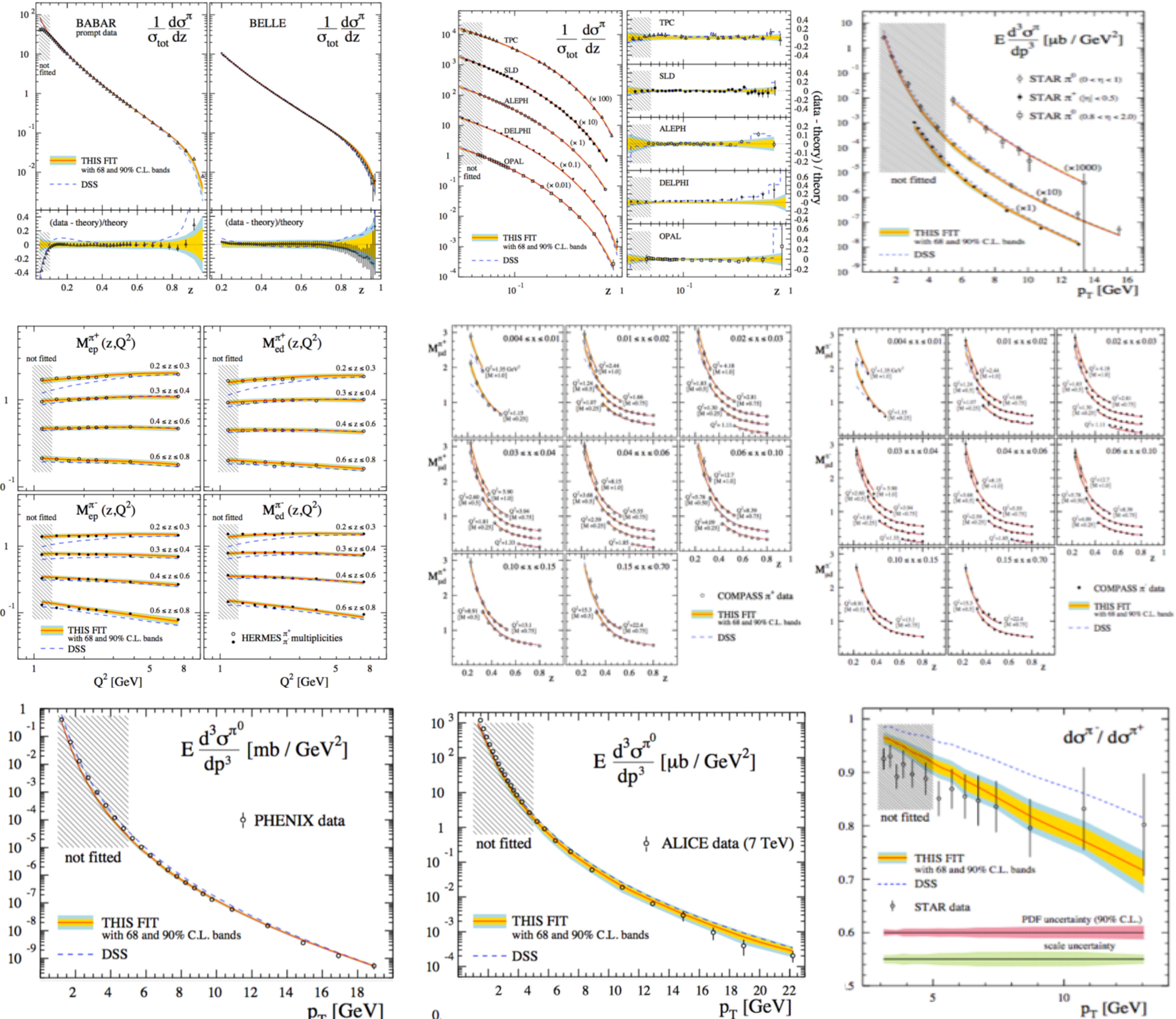
$$\frac{d\sigma}{d\eta dp_T} \sim f_i(x_1, p_T^2) \otimes f_j(x_2, p_T^2) \otimes C_{ijk} \otimes D_k^h(z, p_T^2)$$







$E \frac{d^3\sigma^{\pi^0}}{dp^3}$ [mb / GeV^2]
PHENIX data
not fitted
THIS FIT
with 68 and 90% C.L. bands
DSS
(data - theory) / theory
scale variation: $p_T/2 \le \mu \le 2p_T$
PDF uncertainty
p_T [GeV]
$E \frac{d^3\sigma^{\pi^0}}{dp^3}$ [μb / GeV^2]
ALICE data (7 TeV)
not fitted
THIS FIT
with 68 and 90% C.L. bands
DSS
(data - theory)/theory
scale variation: $p_T/2 \le \mu \le 2p_T$
PDF uncertainty (90% C.L.)
p_T [GeV]



predictive power for

SIA

SIDIS

pp

~ 1000 data

$\chi^2/d.o.f \sim 1.18$

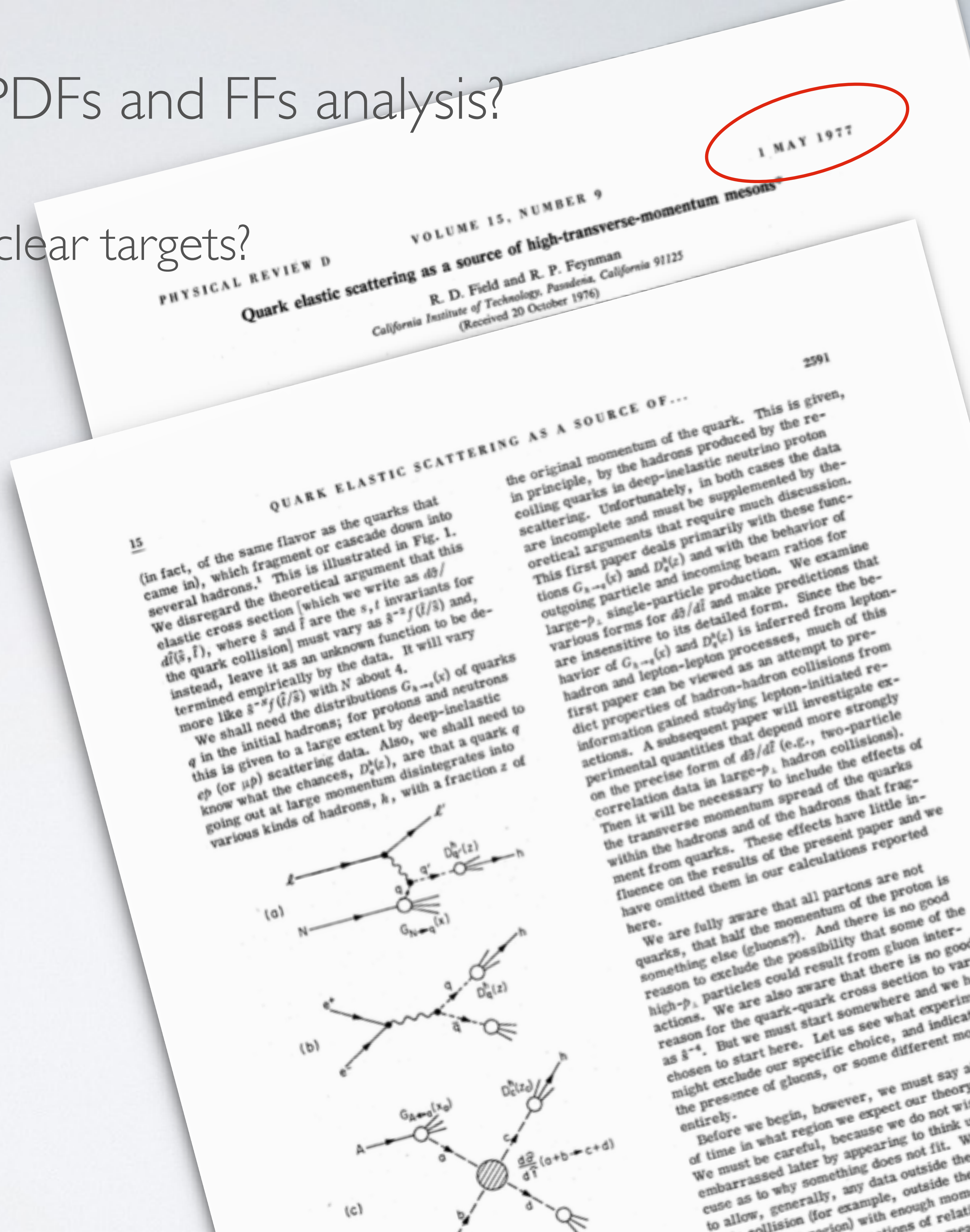
a case for a combined PDFs and FFs analysis?

flavor separation without nuclear targets?

isospin symmetry?

nuclear effects in d?

nuclear effects in A?



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Quark elastic scattering as a source of high-transverse-momentum mesons*

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(Received 20 October 1976)

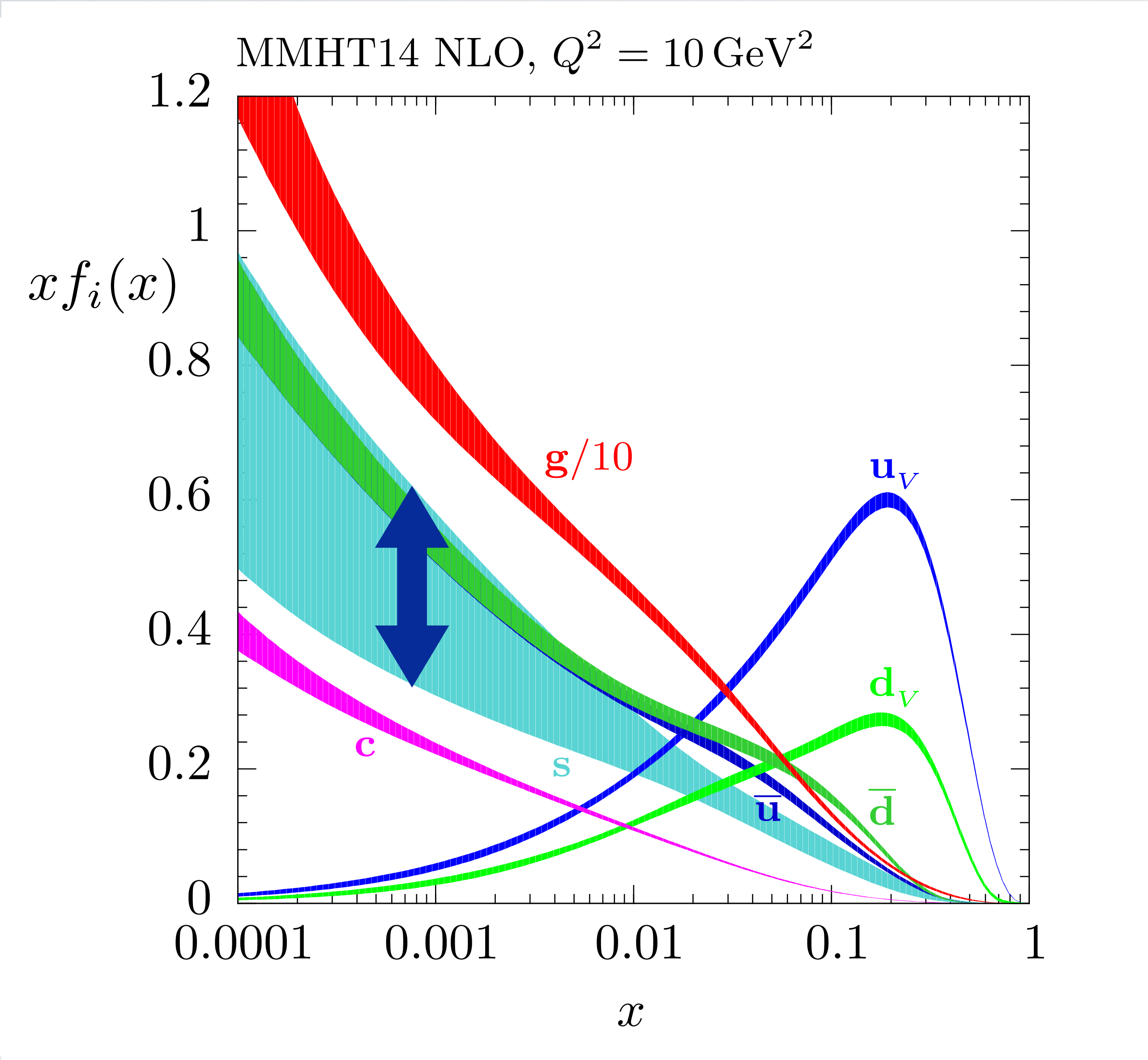
(in fact, of the same flavor as the quarks that came in), which fragment or cascade down into several hadrons.[1] This is illustrated in Fig. 1. We disregard the theoretical argument that this elastic cross section [which we write as $d\hat{\sigma}/d\hat{t}(\hat{s},\hat{t})$, where $\hat{s}$ and $\hat{t}$ are the s,t invariants for the quark collision] must vary as $\hat{s}^{-2}f(\hat{t}/\hat{s})$ and, instead, leave it as an unknown function to be determined empirically by the data. It will vary more like $\hat{s}^{-N}f(\hat{t}/\hat{s})$ with N about 4.

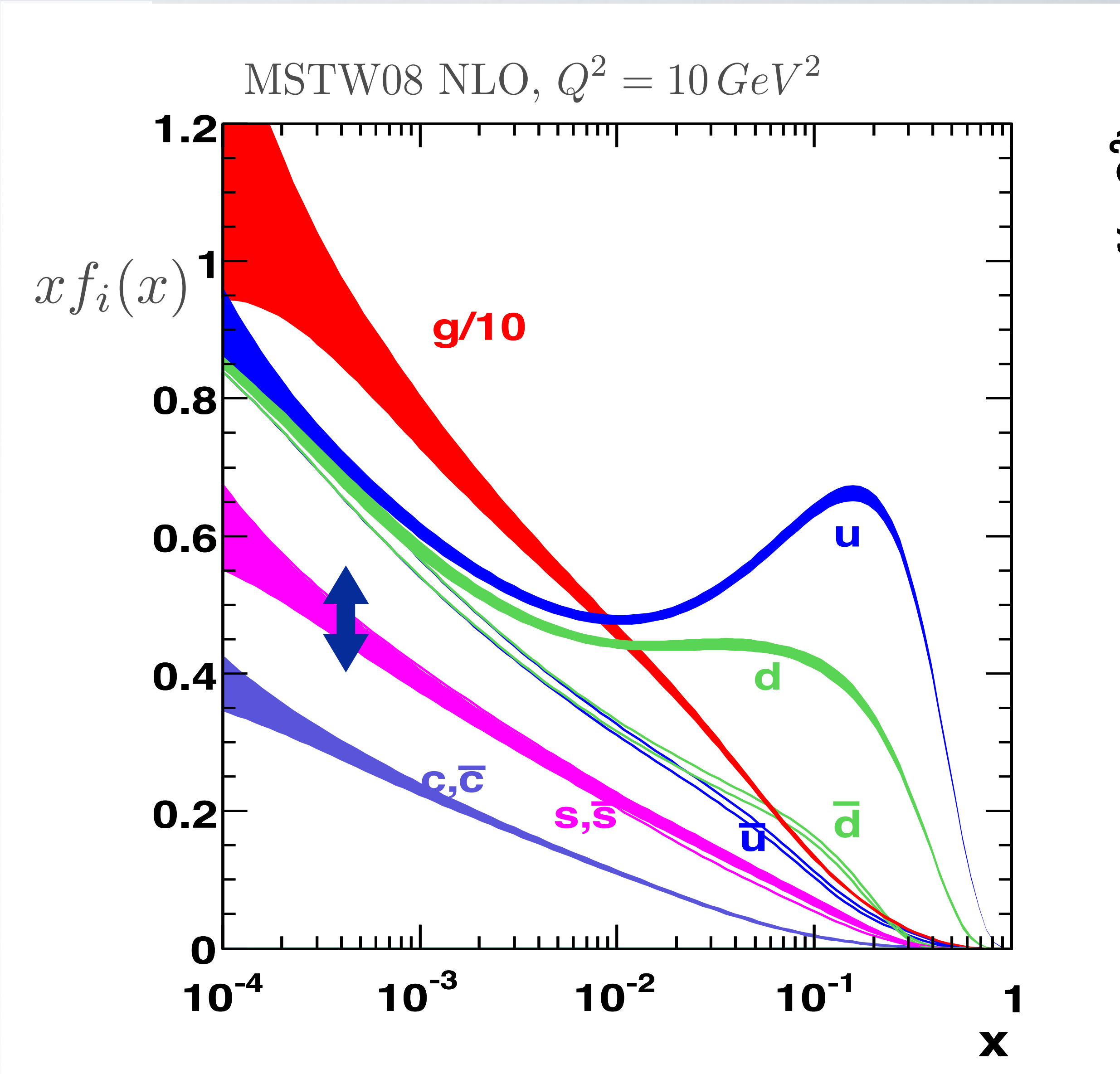
We shall need the distributions $G_{h\to q}(x)$ of quarks q in the initial hadrons; for protons and neutrons this is given to a large extent by deep-inelastic ep (or μp) scattering data. Also, we shall need to know what the chances, $D_q^h(z)$, are that a quark q going out at large momentum disintegrates into various kinds of hadrons, h, with a fraction z of the original momentum of the quark. This is given, in principle, by the hadrons produced by the recoiling quarks in deep-inelastic neutrino proton scattering. Unfortunately, in both cases the data are incomplete and must be supplemented by theoretical arguments that require much discussion. This first paper deals primarily with these functions $G_{h\to q}(x)$ and $D_q^h(z)$ and with the behavior of outgoing particle and incoming beam ratios for large-$p_\perp$ single-particle production. We examine various forms for $d\hat{\sigma}/d\hat{t}$ and make predictions that are insensitive to its detailed form. Since the behavior of $G_{h\to q}(x)$ and $D_q^h(z)$ is inferred from lepton-hadron and lepton-lepton processes, much of this first paper can be viewed as an attempt to predict properties of hadron-hadron collisions from information gained studying lepton-initiated reactions. A subsequent paper will investigate experimental quantities that depend more strongly on the precise form of $d\hat{\sigma}/d\hat{t}$ (e.g., two-particle correlation data in large-$p_\perp$ hadron collisions). Then it will be necessary to include the effects of the transverse momentum spread of the quarks within the hadrons and of the hadrons that fragment from quarks. These effects have little influence on the results of the present paper and we have omitted them in our calculations reported here.

We are fully aware that all partons are not quarks, that half the momentum of the proton is something else (gluons?). And there is no good reason to exclude the possibility that some of the high-$p_\perp$ particles could result from gluon interactions. We are also aware that there is no good reason for the quark-quark cross section to var as $\hat{s}^{-4}$. But we must start somewhere and we h chosen to start here. Let us see what experim might exclude our specific choice, and indica the presence of gluons, or some different mo entirely.

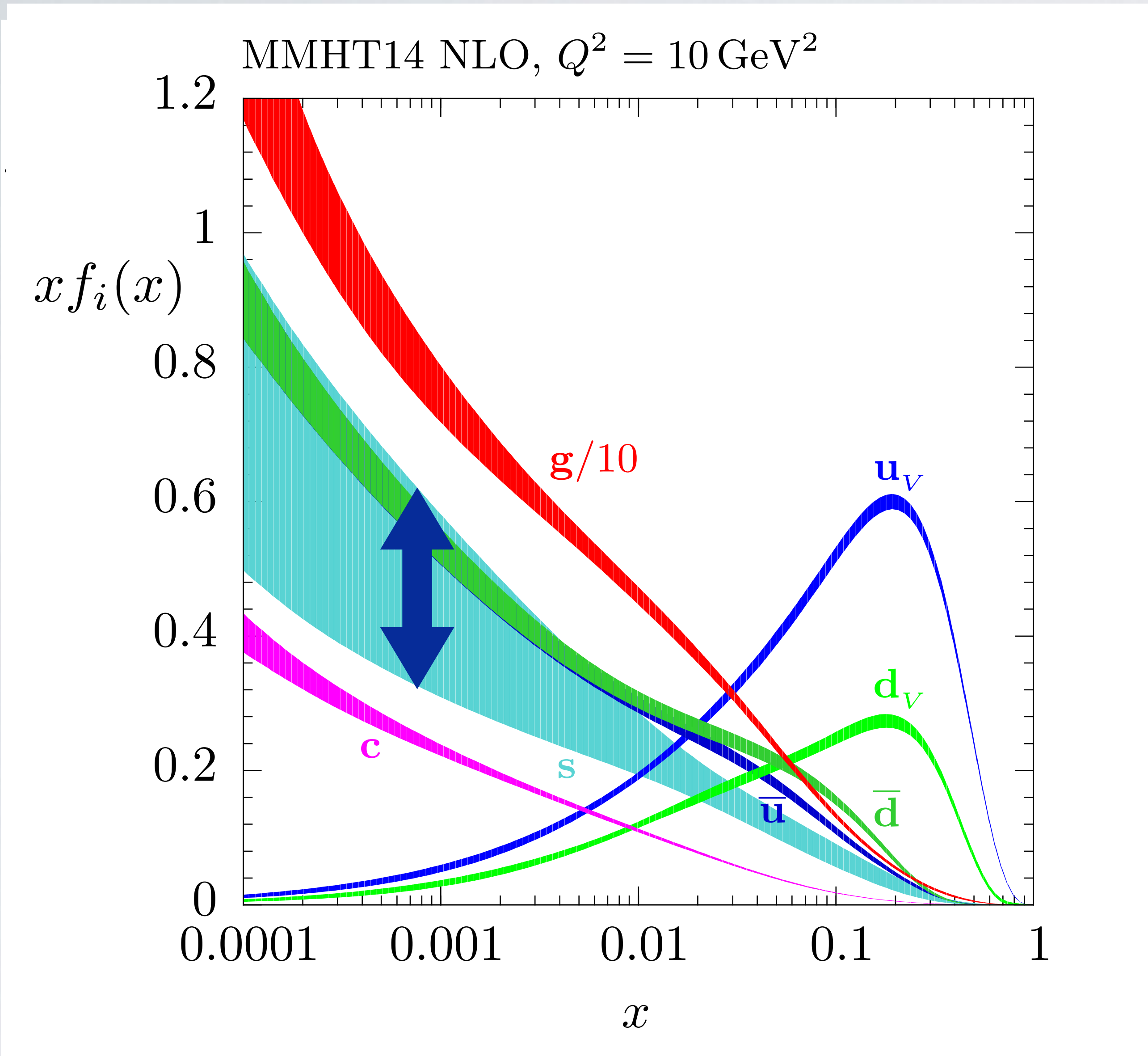
Before we begin, however, we must say a of time in what region we expect our theor We must be careful, because we do not wi embarrassed later by appearing to think cuse as to why something does not fit. W to allow, generally, any data outside th collision (for example, outside the with enough mo

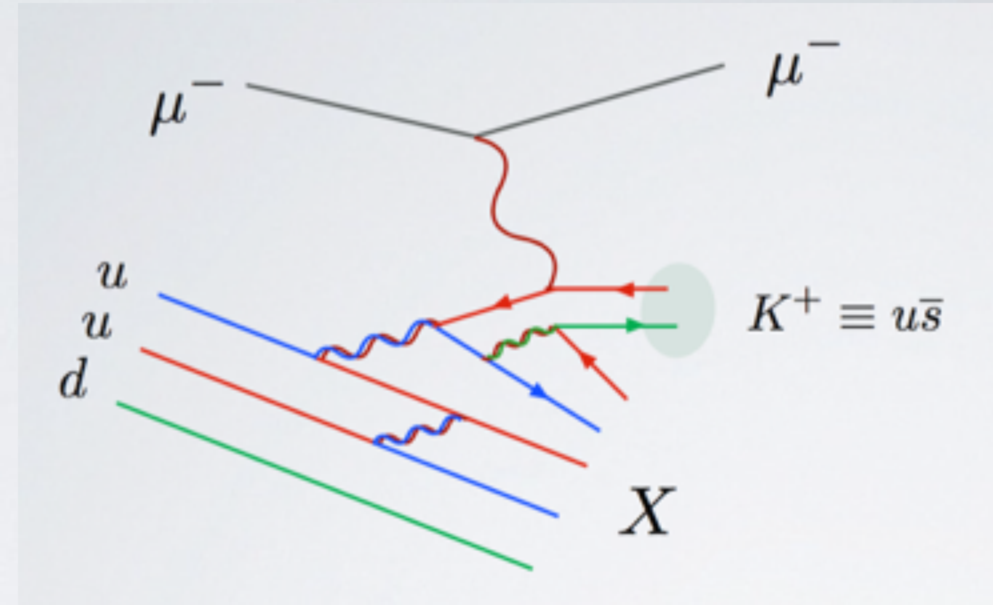
are PDFs that good?

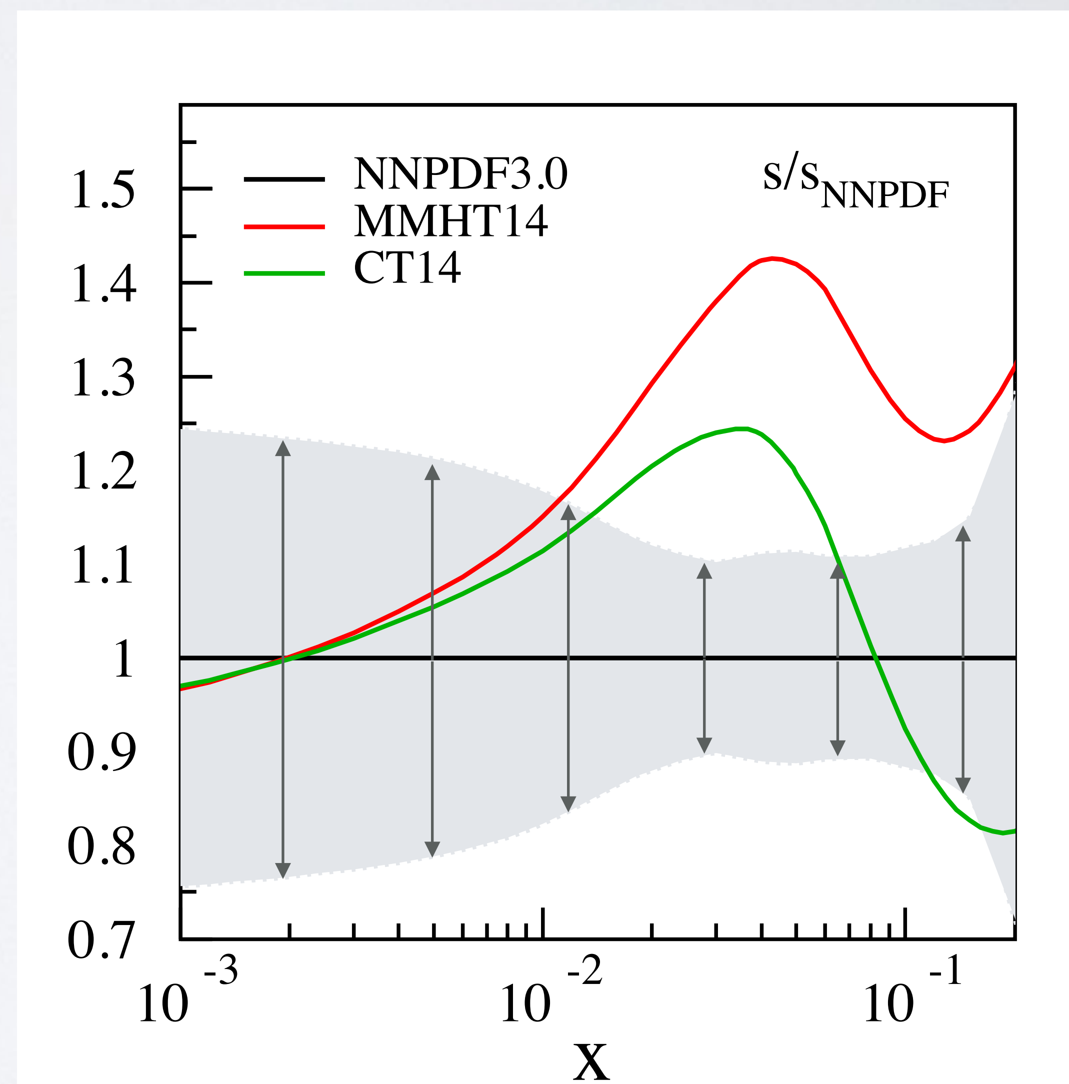




are PDFs that good?







$D^{K^\pm}(z, Q^2)$
(1194 data)

$\chi^2_{\mathrm{MMHT14}} = 1271.7$

$\chi^2_{\mathrm{CT14}} = 1185.3$ $\Delta\chi^2 \sim 254$!!!

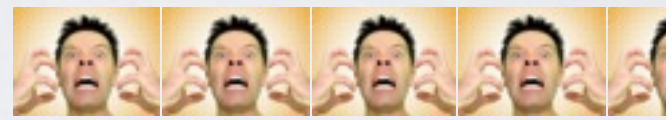
$\chi^2_{\mathrm{NNPDF3.0}} = 1017.2$

combined PDFs and FFs extraction

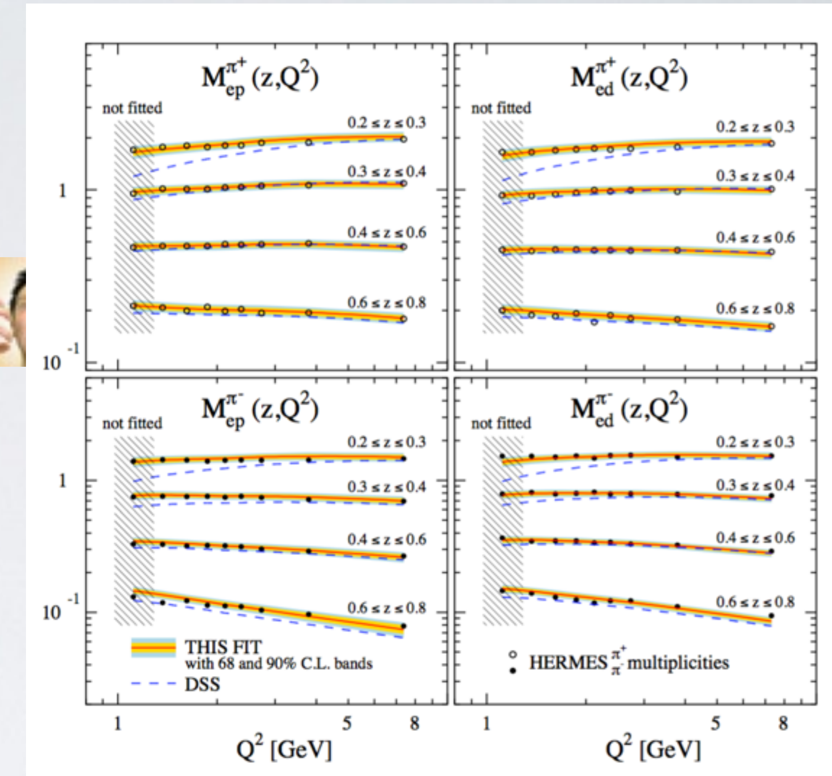
number/type data

number parameter/unknowns

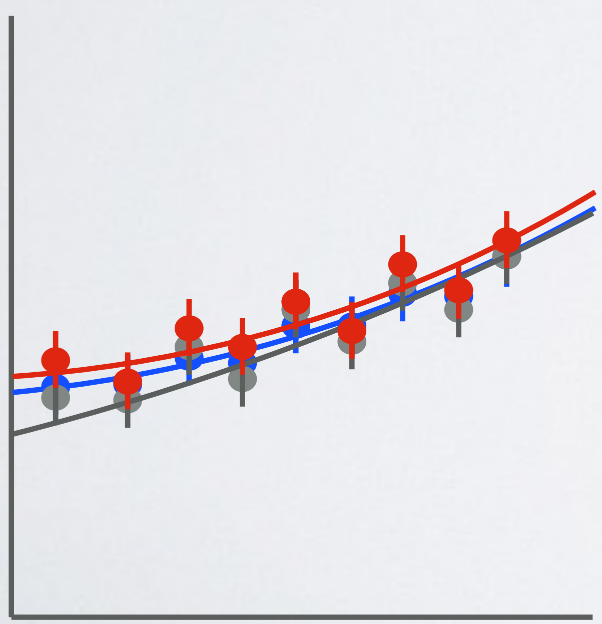
topography



contamination



PDFs reweighting: **1012.0836**



$$f_i(x) \quad w(\chi^2)$$
$$f_i(x) \quad w(\chi^2)$$
$$f_i(x) \quad w(\chi^2)$$
$$\vdots$$
$$1000 \ times$$

$$f_i^{best}(x) = \frac{1}{N_{rep}} \sum f_i(x)$$

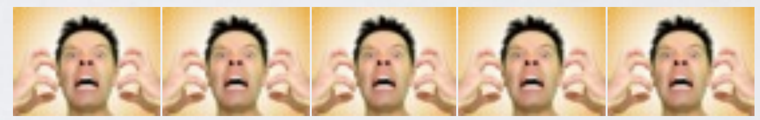
$$f_i^{reweight}(x) = \frac{1}{N_{rep}} \sum w f_i(x)$$

$$\chi^2(\mathrm{FFs(PDFs)})$$

combined PDFs and FFs extraction

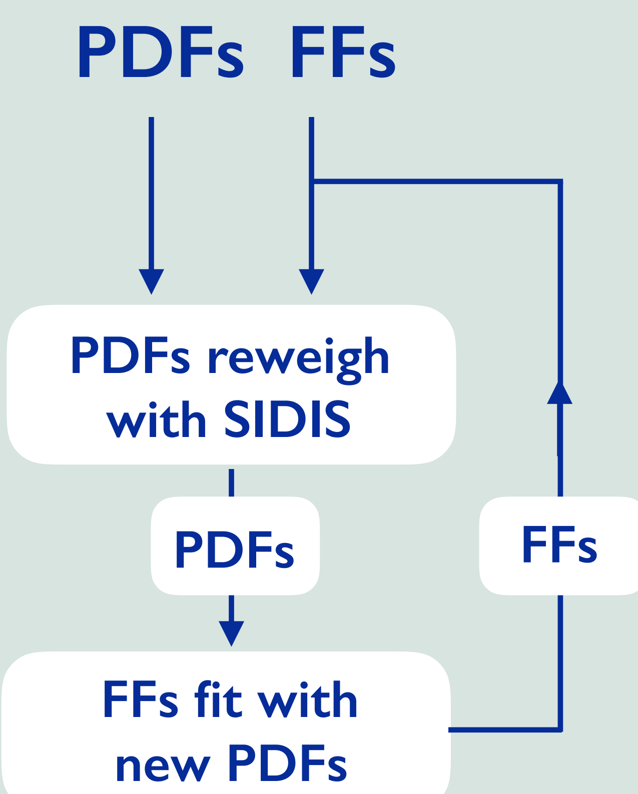
number/type data 

number parameter/unknowns 

topography 

contamination

iterative FFs & PDFs determination:

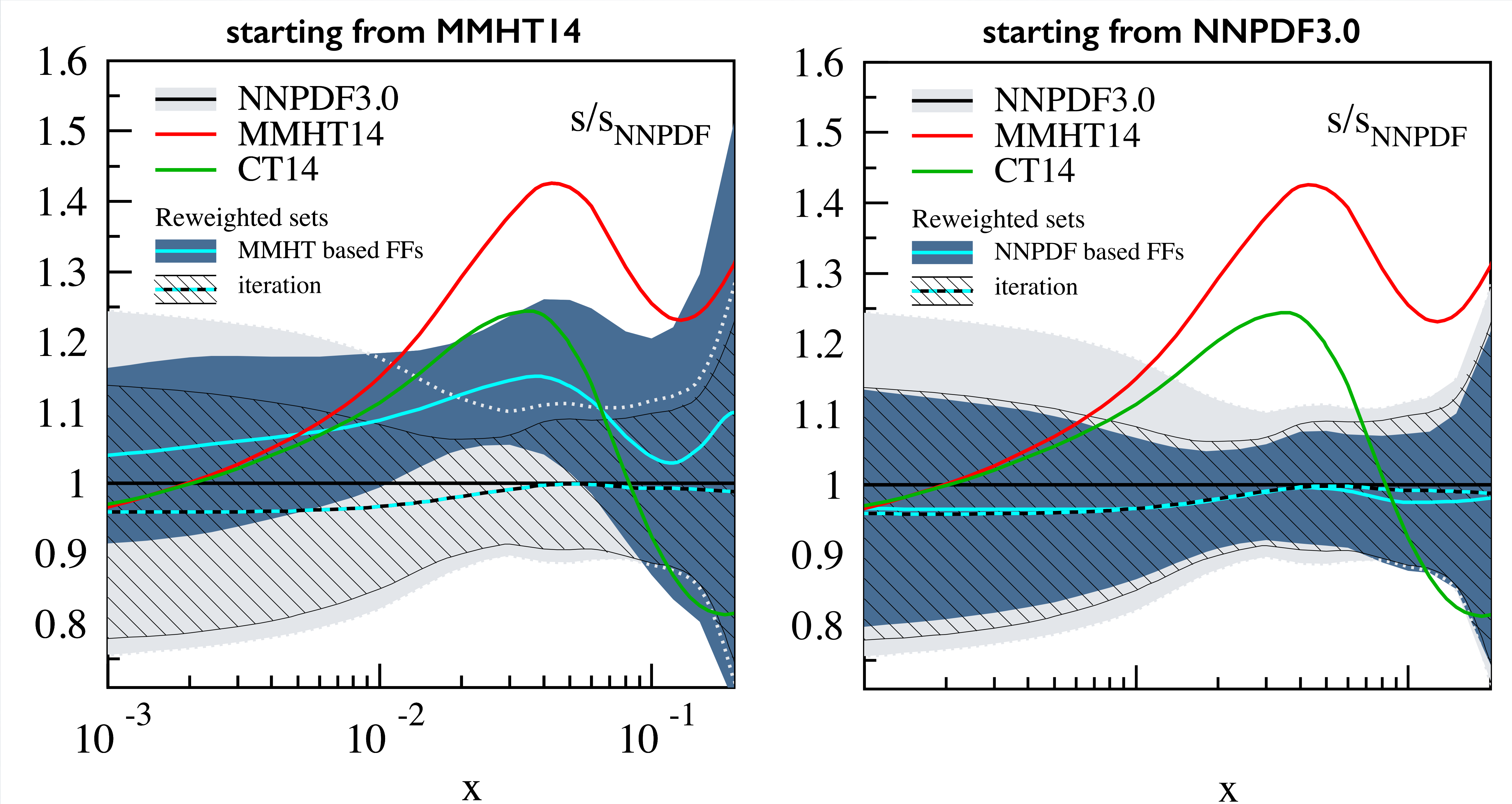


convergence?

and very fast!

robust!

combined PDFs and FFs extraction

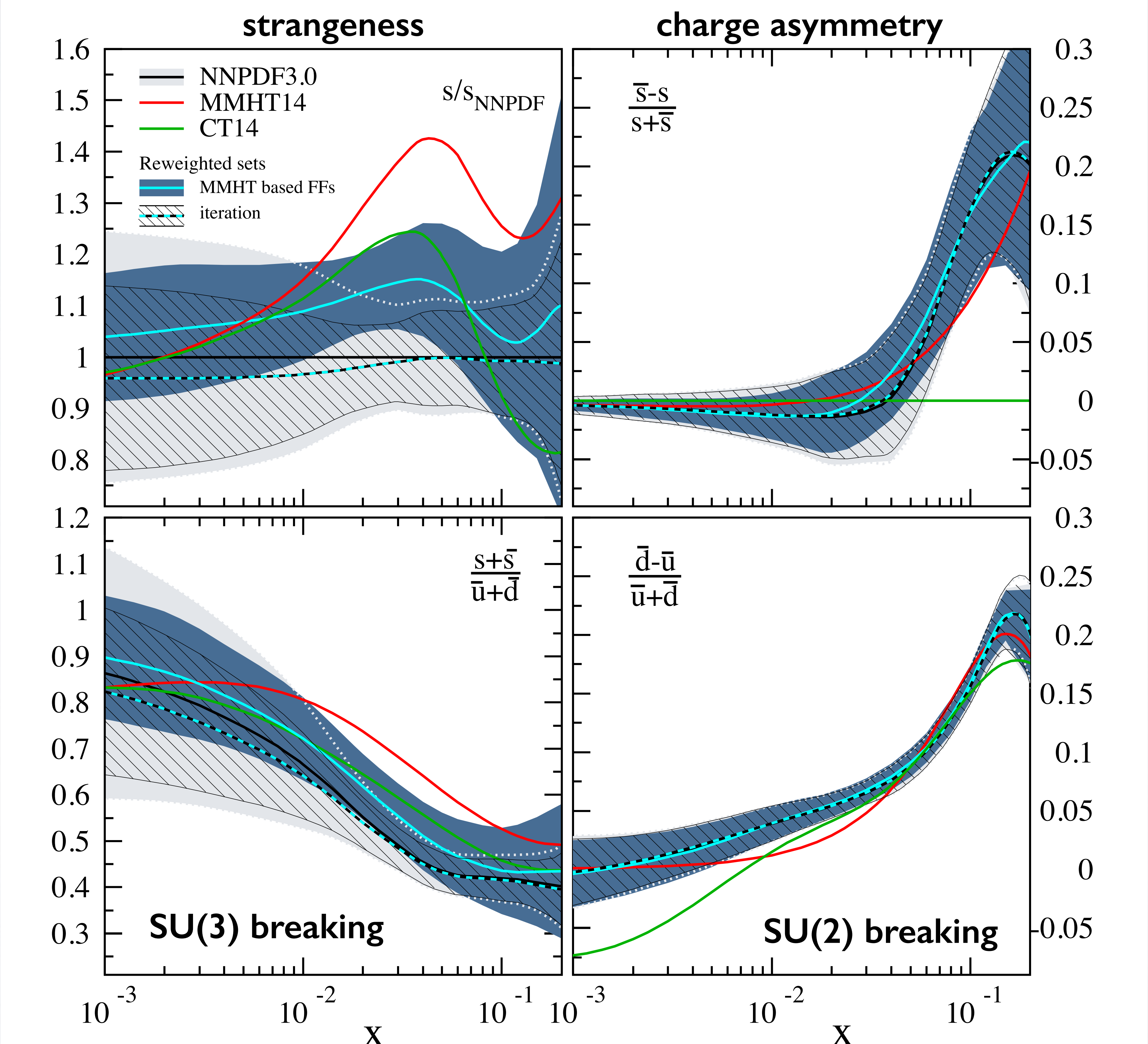


$\chi^2_{FF} =$ 1271.7 | 1041.3 | 1002.3

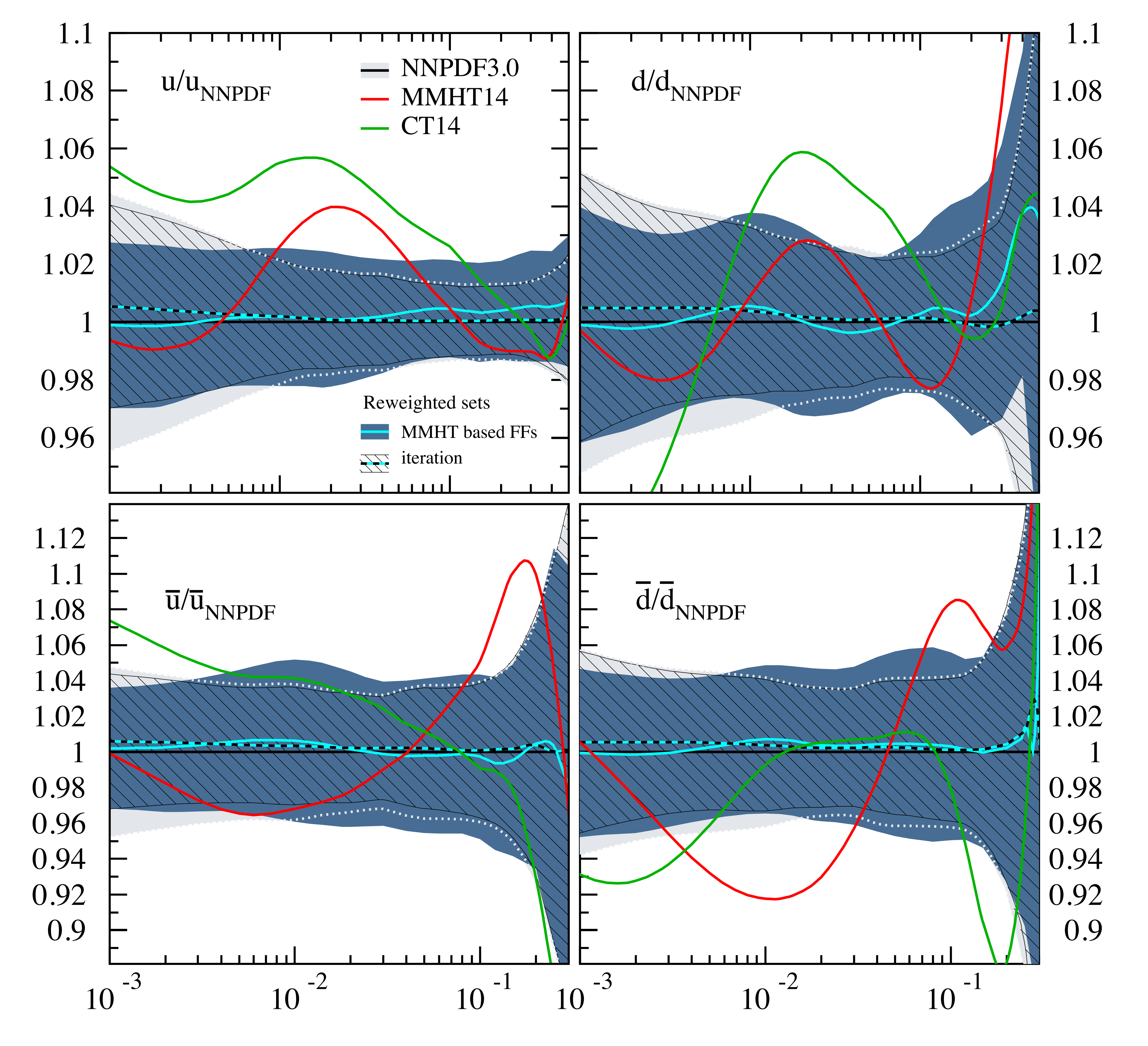
1017.2 | 1005.3 | 1000.6

similar results with CT14 replicas

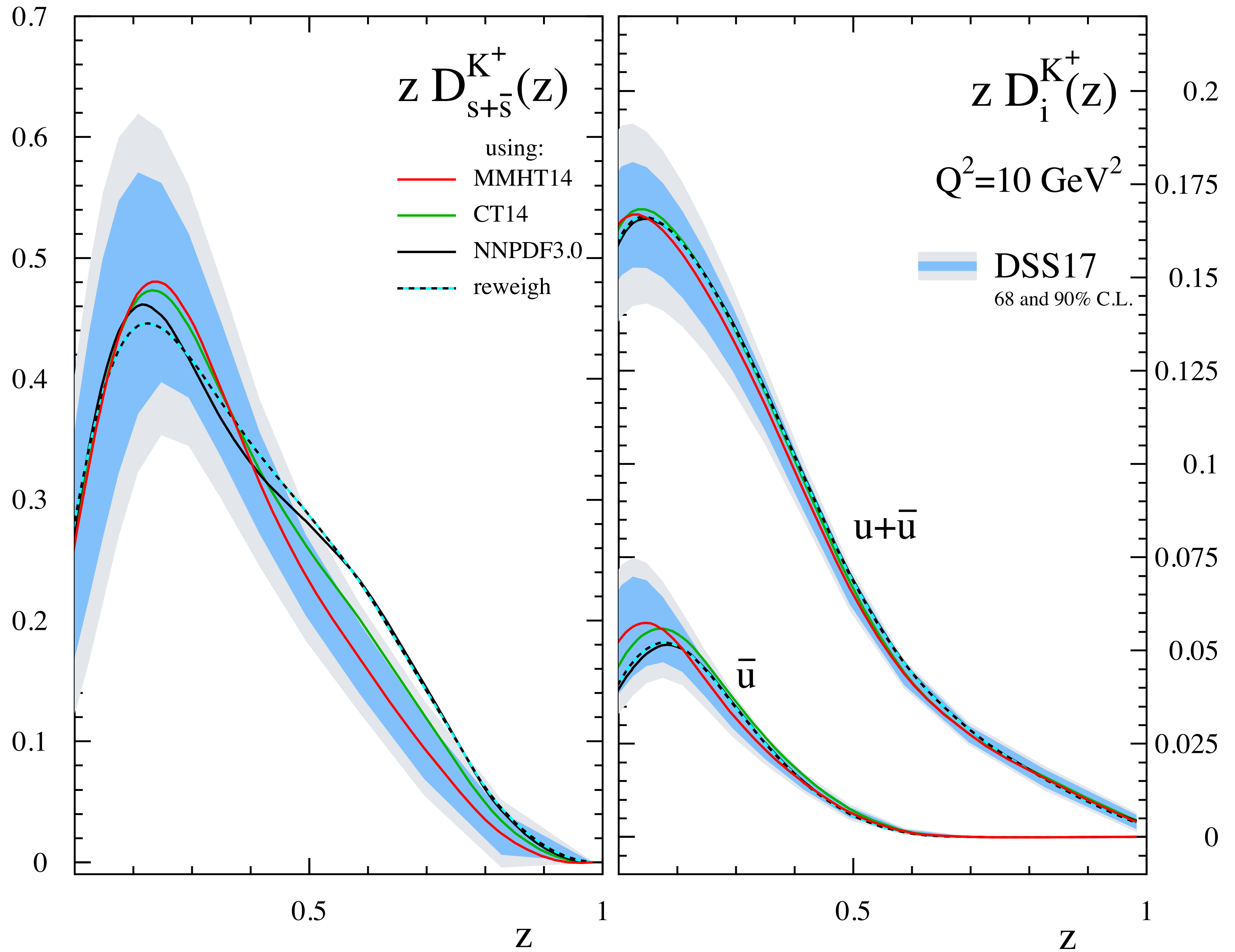
combined PDFs and FFs extraction



combined PDFs and FFs extraction



optimized FFs



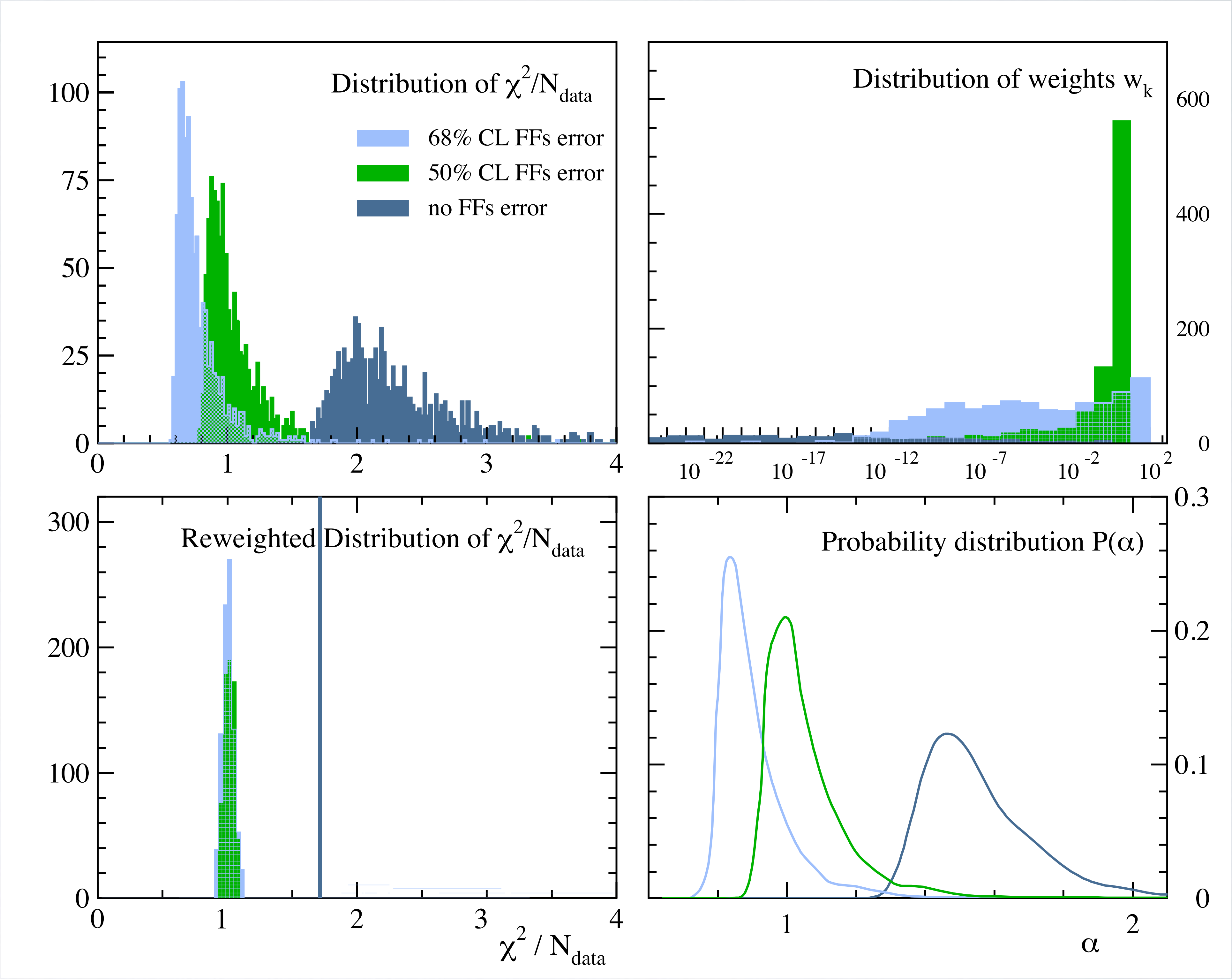
reweighting esoterica:

consistency checks:

 # surviving replicas

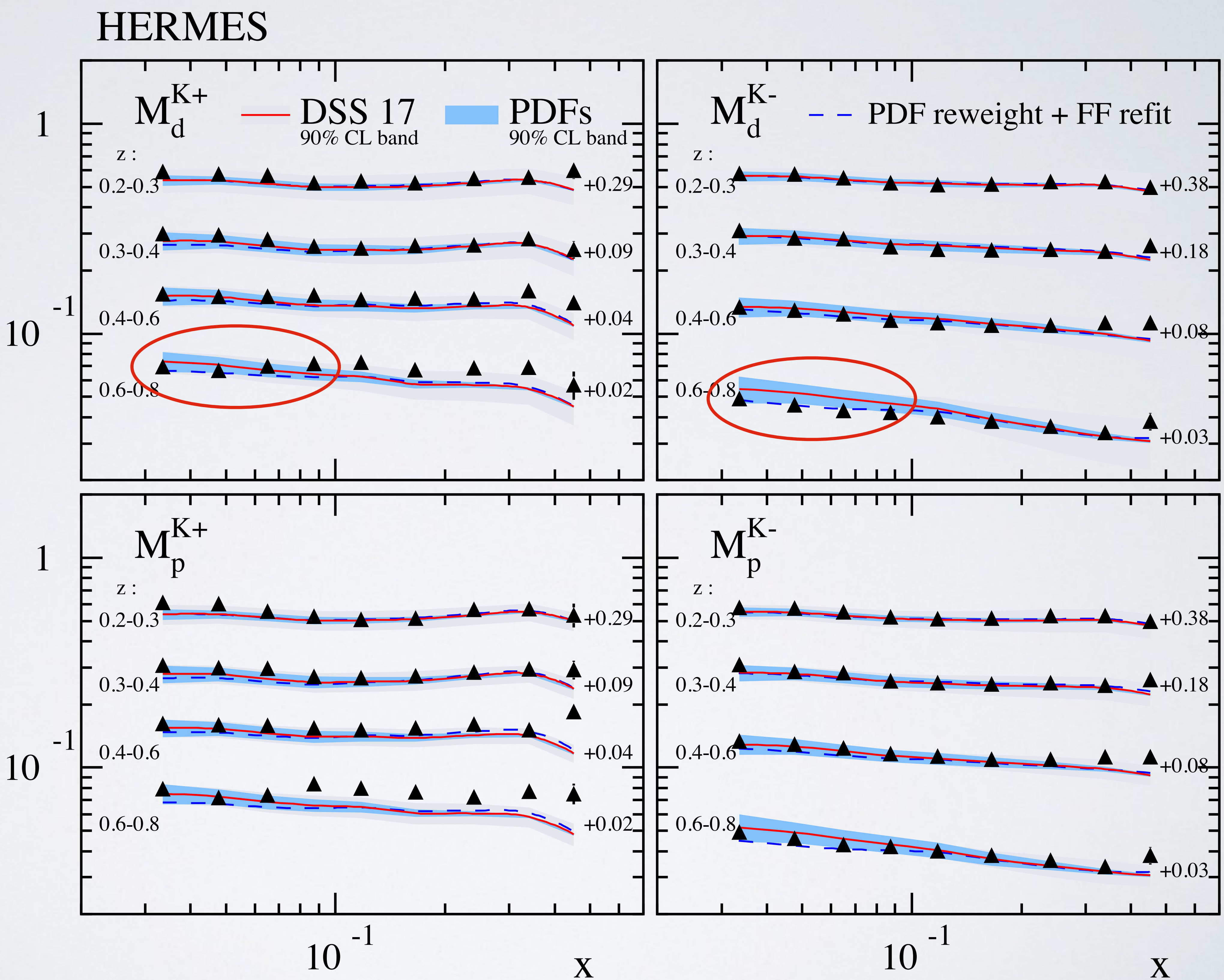
distribution of w

double counting

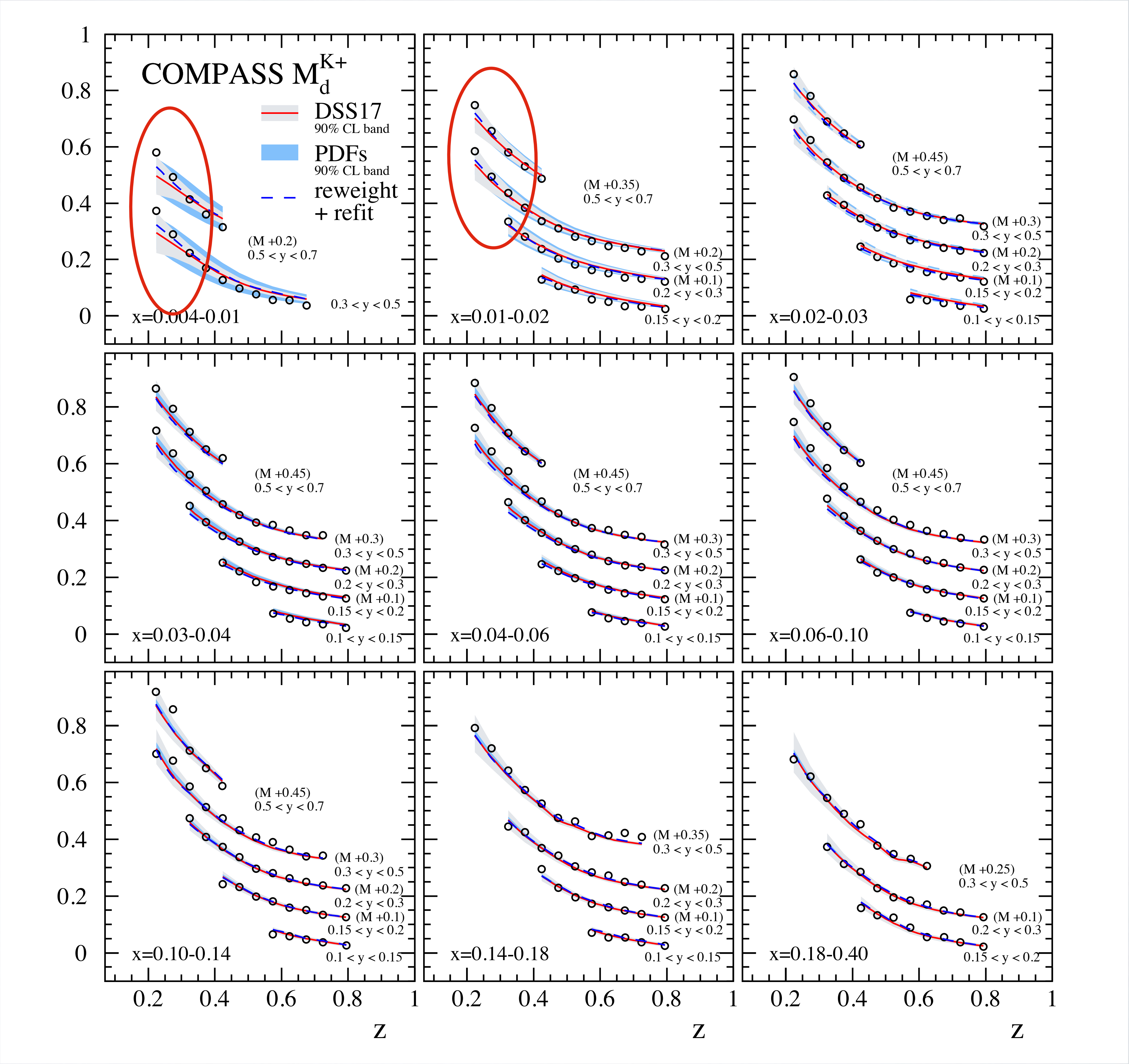


SIDIS revisited:

low-x (low-Q^2)



SIDIS revisited:

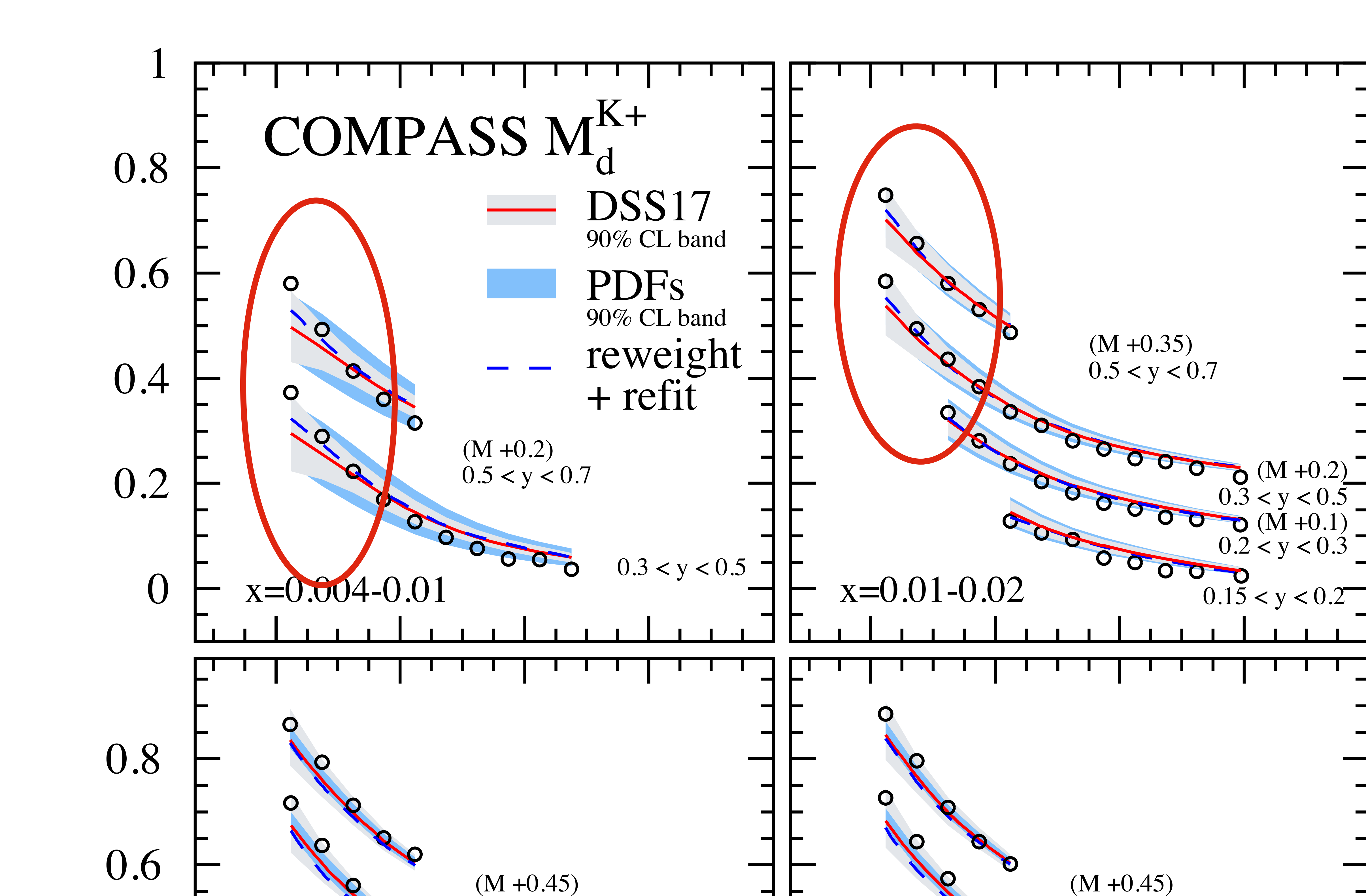


SIDIS revisited:

550.9

467.6

434.5



Summary:

FFs are coming on age: from **rough pictures** to **precision tools**

not yet as precise as current PDFs, but still can be **useful**

as **fundamental** as PDFs in the pQCD description

combined analysis **PDFs & FFs works**

key to **flavor separation** without nuclear targets?