

New extraction of fragmentation functions

Roger Hernández Pinto
Universidad de Buenos Aires

In collaboration with D. de Florán, R. Sassot and M. Stratmann

LHCPhenonet MidTerm Meeting



LHCphenonet



Outline

- Introduction/Motivation
- Constraining FFs with SIA, SIDIS and Hadron-Hadron Collisions
- Global Fits of FFs
- Conclusions

FFs: Generalities

- Non perturbative and universal objects that have to be extracted from data (like PDFs).
- Scale μ -dependence predicted by pQCD.
- Describe the collinear transition of a massless parton “q” into a massless hadron “h” carrying fractional momentum “z”.
- Fragmentation is independent of other colored particles.
- They are needed to consistently absorb final state collinear singularities.

It is possible to arrive to an unified description of all ee, ep and pp data in terms of a universal fragmentation functions ??

FFs: Properties

- bi-local operator:

$$D_z \simeq \int dy^- e^{iP^+ / zy^-} Tr \gamma^+ \langle \mathbf{0} | \psi(y^-) | hX \rangle \langle hX | \bar{\psi}(0) | \mathbf{0} \rangle$$

Collins, Soper '81, '83

no lattice formulation

- isospin and charge conjugation invariance

$$D_u^{\pi^+} = D_d^{\pi^-} = D_{\bar{u}}^{\pi^-} = D_{\bar{d}}^{\pi^+}$$

- valence enhancement

$$D_u^{\pi^+} > D_d^{\pi^+} \simeq D_s^{\pi^+}$$

- strangeness suppression

$$D_{\bar{s}}^{K^+} > D_u^{K^+}$$

$$\pi^+ = |u\bar{d}\rangle$$

$$K^+ = |u\bar{s}\rangle$$

FFs: Properties

The “valence enhancement” and “strangeness suppression” assumptions are the basis for “flavor tagging” assumptions.

Highest momentum particle in jet resembles flavor of parent quark.

• “Energy-momentum conservation”

$$\sum_h \int_0^1 z D_i^h(z, \mu) = 1$$

(a parton fragment with 100% probability into something preserving its momentum)

“mass effects” completely spoil framework of $D_i^h(z, \mu)$ for $z \lesssim 0.05 \div 0.1$ also μ -evolution has instabilities when $z \rightarrow 0$ (soft gluons). No systematic way to include mass or higher twist effect rough measure: O.K. as long as

$$\frac{p_h}{E_h} = \sqrt{1 - \frac{m_h^2}{E_h^2}} \simeq 1$$

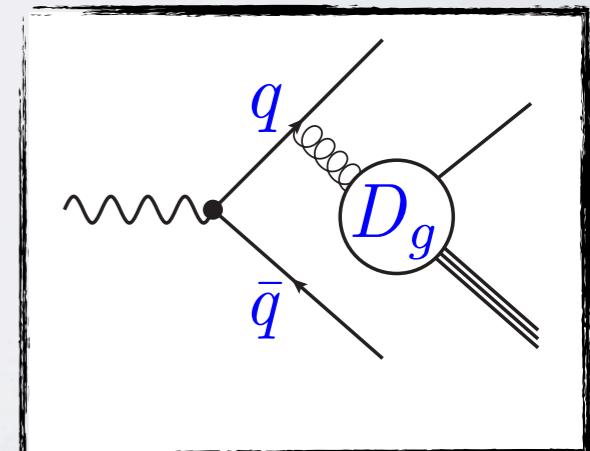
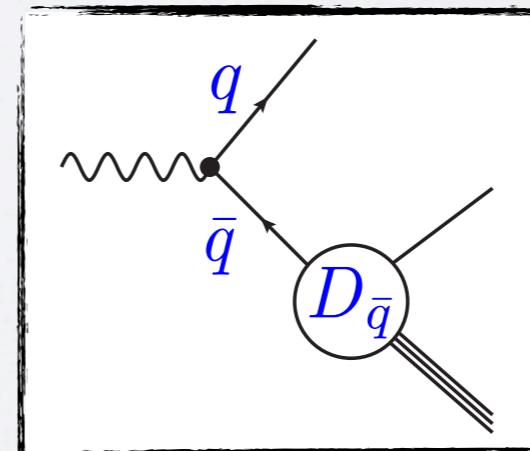
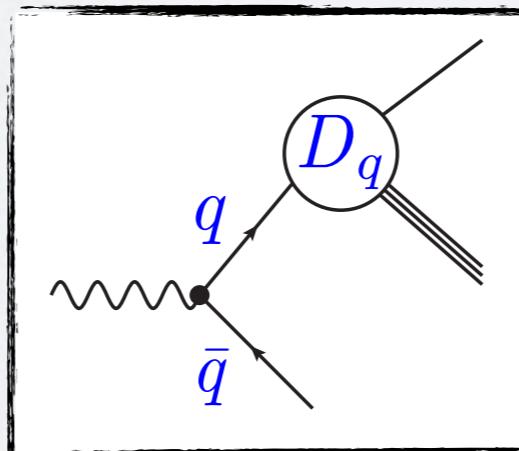
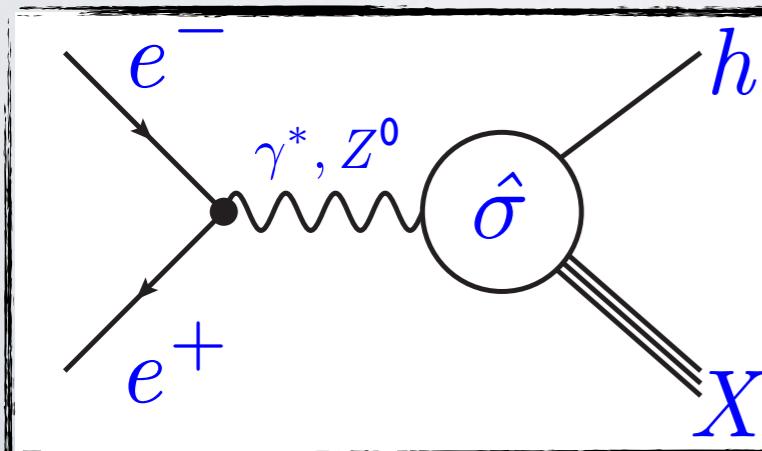
Single Inclusive Annihilation

The distribution is given in terms of the structure functions,

$$\frac{1}{\sigma_{tot}} \frac{d\sigma^h}{dz} = \frac{\sigma^0}{\sum_q \hat{e}_q^2} [2F_1^H(z, Q^2) + F_L^H(z, Q^2)]$$

$$\sigma_{tot} = \sum_q \frac{4\pi\alpha_s^2}{s} \hat{e}_q^2 \left(1 + \frac{\alpha_s}{\pi} \dots \right)$$

Total hadronic cross section



Single Inclusive Annihilation

The distribution is given in terms of the structure functions,

$$\frac{1}{\sigma_{tot}} \frac{d\sigma^h}{dz} = \frac{\sigma^0}{\sum_q \hat{e}_q^2} [2F_1^H(z, Q^2) + F_L^H(z, Q^2)]$$

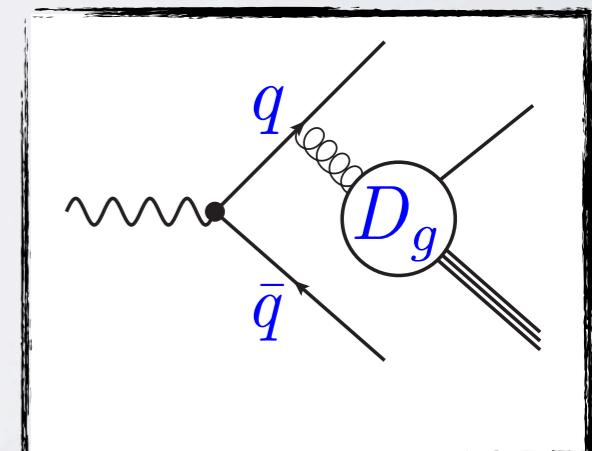
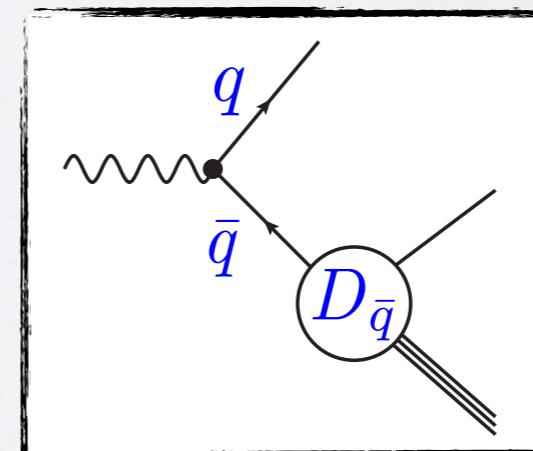
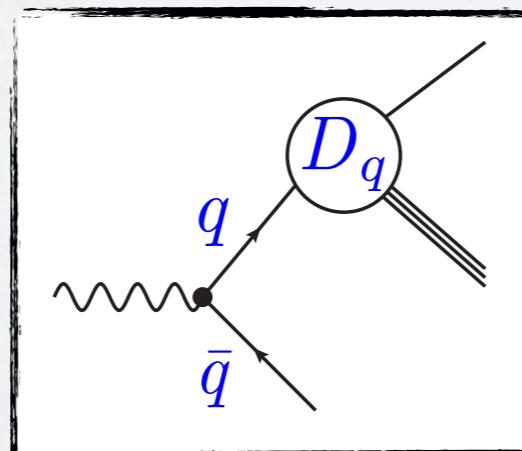
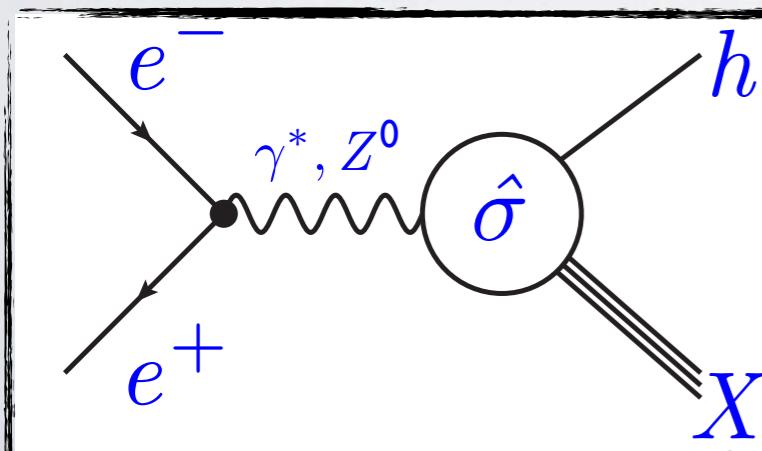
@NLO

$$2F_1^H(z, Q^2) = \sum_q \hat{e}_q^2 \left\{ [D_q^H(z, Q^2) + D_{\bar{q}}^H(z, Q^2)] + \frac{\alpha_s(Q^2)}{2\pi} [C_q^I \otimes [D_q^H + D_{\bar{q}}^H] + C_g^I \otimes D_g^H](z, Q^2) \right\}$$

$$z \equiv \frac{2P^h \cdot q}{Q^2} = \frac{2E^h}{Q}$$

where

$$\begin{aligned} s &= q = Q^2 \\ P_{e^\pm} &= (Q/2, 0, 0, \pm Q/2) \\ q &= P_{e^+} + P_{e^-} \end{aligned}$$



Single Inclusive Annihilation

The distribution is given in terms of the structure functions,

$$\frac{1}{\sigma_{tot}} \frac{d\sigma^h}{dz} = \frac{\sigma^0}{\sum_q \hat{e}_q^2} [2F_1^H(z, Q^2) + F_L^H(z, Q^2)]$$

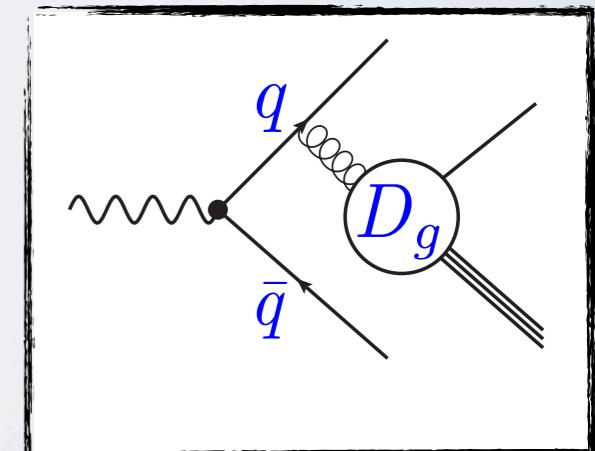
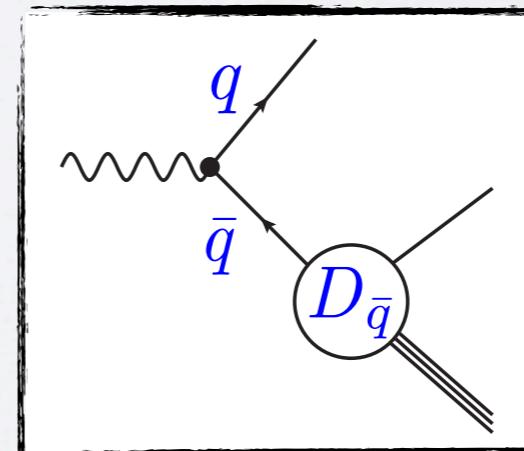
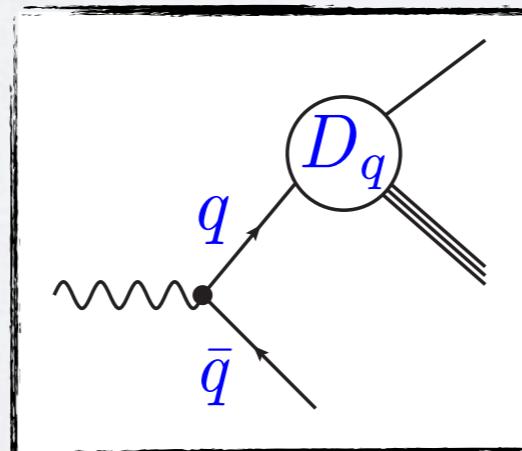
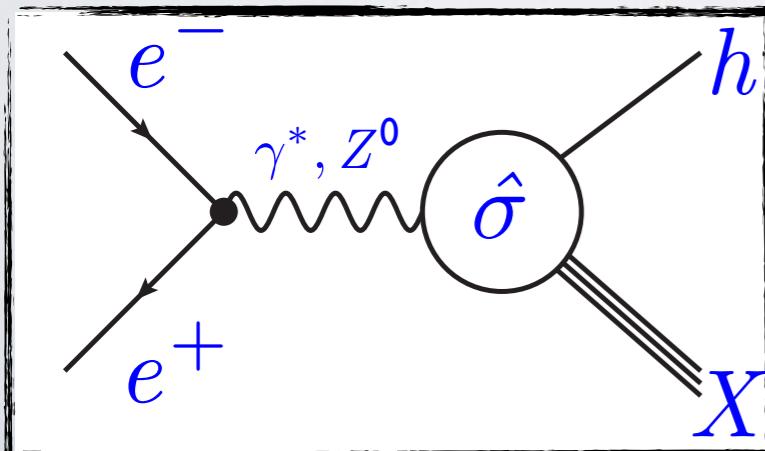
@NLO

$$2F_1^H(z, Q^2) = \sum_q \hat{e}_q^2 \left\{ [D_q^H(z, Q^2) + D_{\bar{q}}^H(z, Q^2)] + \frac{\alpha_s(Q^2)}{2\pi} [C_q^I \otimes [D_q^H + D_{\bar{q}}^H] + C_g^I \otimes D_g^H](z, Q^2) \right\}$$

Altarelli, Ellis, Martinelli, Pi '79

Furmanski, Petronzio '82

@NNLO: Rijken, van Neerven '96, '97



Single Inclusive Annihilation

The distribution is given in terms of the structure functions,

$$\frac{1}{\sigma_{tot}} \frac{d\sigma^h}{dz} = \frac{\sigma^0}{\sum_q \hat{e}_q^2} [2F_1^H(z, Q^2) + F_L^H(z, Q^2)]$$

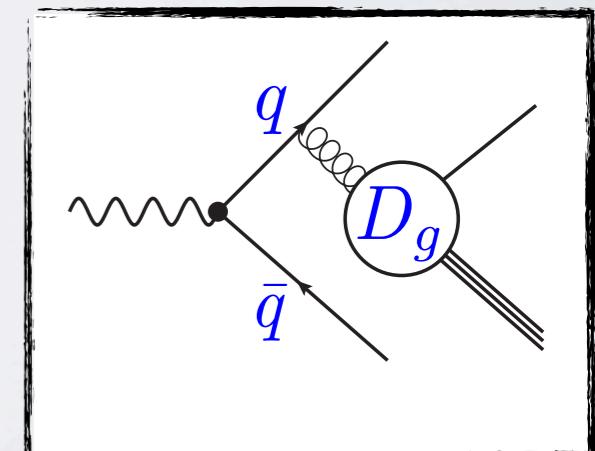
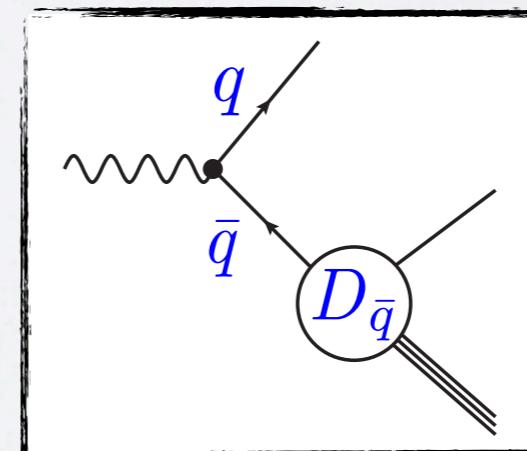
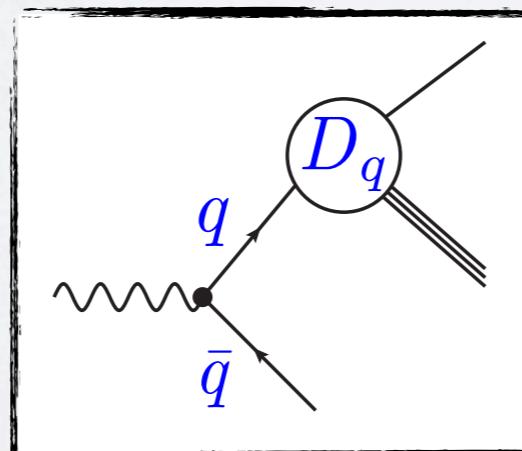
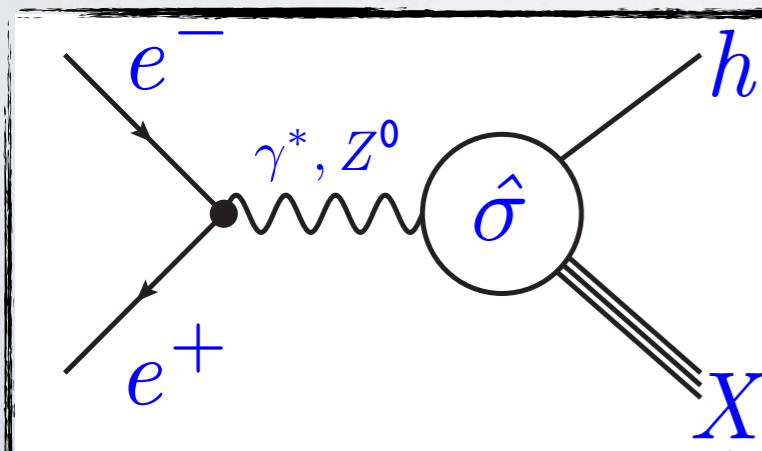
@NLO

$$2F_1^H(z, Q^2) = \sum_q \hat{e}_q^2 \left\{ [D_q^H(z, Q^2) + D_{\bar{q}}^H(z, Q^2)] + \frac{\alpha_s(Q^2)}{2\pi} [C_q^I \otimes [D_q^H + D_{\bar{q}}^H] + C_g^I \otimes D_g^H](z, Q^2) \right\}$$

FFs depend on energy fraction and energy scale: AP evolution

$$\frac{d}{d \ln Q^2} \mathbf{D}^H = [\hat{P} \otimes \mathbf{D}^H](z, Q^2)$$

Not possible to separate $D_q^h(z, \mu)$ and $D_{\bar{q}}^h(z, \mu)$



SIDIS

Distributions for SIDIS are given by

$$\frac{d\sigma^H}{dxdydz^H} = \frac{2\pi\alpha_s}{Q^2} \left[\frac{1 + (1 - y)^2}{y} 2F_1^H(x, z_H, Q^2) + \frac{2(1 - y)}{y} F_L^H(x, z_H, Q^2) \right]$$

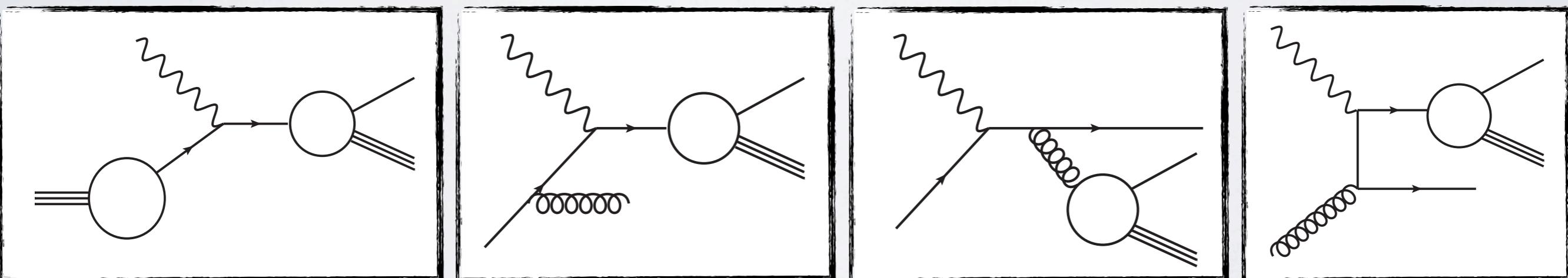
@LO $2F_1^H(x, z_H, Q^2) = \sum_{q, \bar{q}} \hat{e}_q^2 \cdot q(x, Q^2) D_q^H(z_H, Q^2)$

effective charge

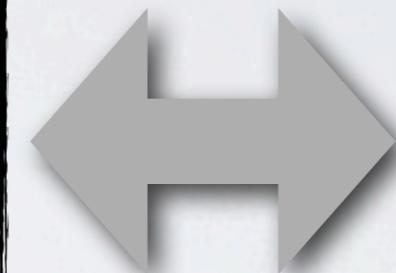
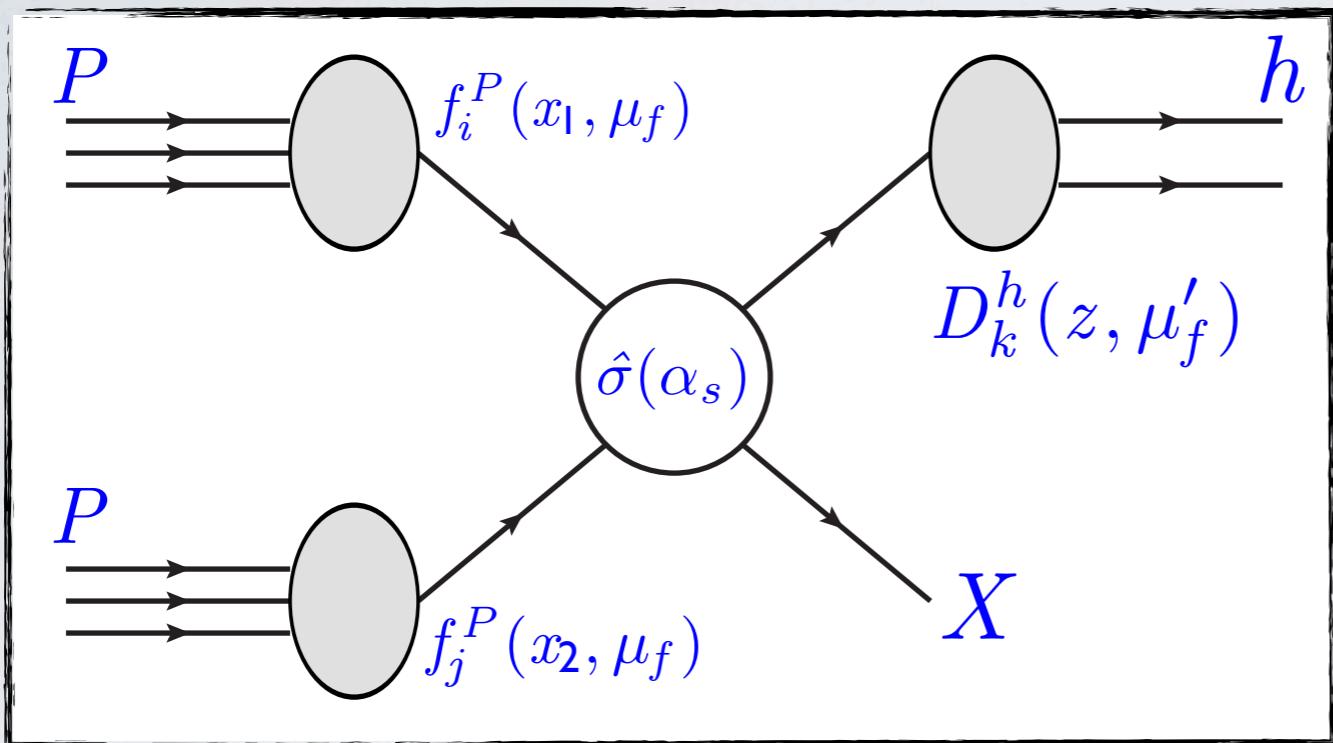
Allows charge/flavor separation.

@NLO

*Altarelli et al.'79;
Furmanski, Petronzio'82;
de Florian, Stratmann, Vogelsang'98*



Hadron-Hadron Collisions



$q\bar{q} \rightarrow g$
$qq \rightarrow q$
$qg \rightarrow g$
$qg \rightarrow q$
$gg \rightarrow q$
$gg \rightarrow g$

Transverse momentum distribution is

$$\frac{d\sigma(pp \rightarrow hX)}{dp_T d\eta} = \sum_{i,j,k} \int_0^1 dx_1 f_i^P(x_1, \mu_f) \int_0^1 f_j^P(x_2, \mu_f) \int_0^1 dz D_k^h(z, \mu'_f) \frac{d\hat{\sigma}(ij \rightarrow kX')}{dp_T d\eta}$$

It also allows charge/flavor separation.

It contains large contributions from gluons.

Global QCD analysis

Goal: provide NLO (and LO) FFs for π^\pm , K^\pm

New data is coming from CERN Experiments and from all other around the world, but there are some issues:

- NLO expressions for ep and, in particular, pp are very lengthy and difficult to handle in fits

Analysis collaboration uses technology of spin off and experience from global fitters:

- Mellin Technique to handle exact NLO expressions in the fit.
- fast and well-tested DGLAP evolution codes.
- vast array of NLO calculations of ep and pp at hand.

Data selection

We include on the fits the following set of data:

- SIA : all LEP, SLD, TASSO TPC and BELLE e+e- “w/o flavor tagging”
- SIDIS: HERMES and COMPASS for ep
- Hadron-Hadron Collisions: PHENIX, STAR, BRAHMS, and from Alice Experiment for pp data

Global Analysis method

Parametrization

$$\mathcal{D}_i^H(z, Q_0^2) = N_i z^{\alpha_i} (1-z)^{\beta_i} [1 + \gamma_i (1-z)^{\delta_i}]$$

at scale

$$Q_0^2 = 1 \text{ GeV}^2 \quad u, d, s, g$$

$$Q_0^2 = m_Q^2 \quad c, b$$

Normalization for different experiments

Allowing for possible breaking of $SU(3)$ of sea and $SU(2)$ in favored distributions,

$$\mathcal{D}_{d+\bar{d}}^{\pi^+} = N \mathcal{D}_{u+\bar{u}}^{\pi^+} \quad \mathcal{D}_s^{\pi^+} = \mathcal{D}_{\bar{s}}^{\pi^+} = N' \mathcal{D}_{\bar{u}}^{\pi^+}$$

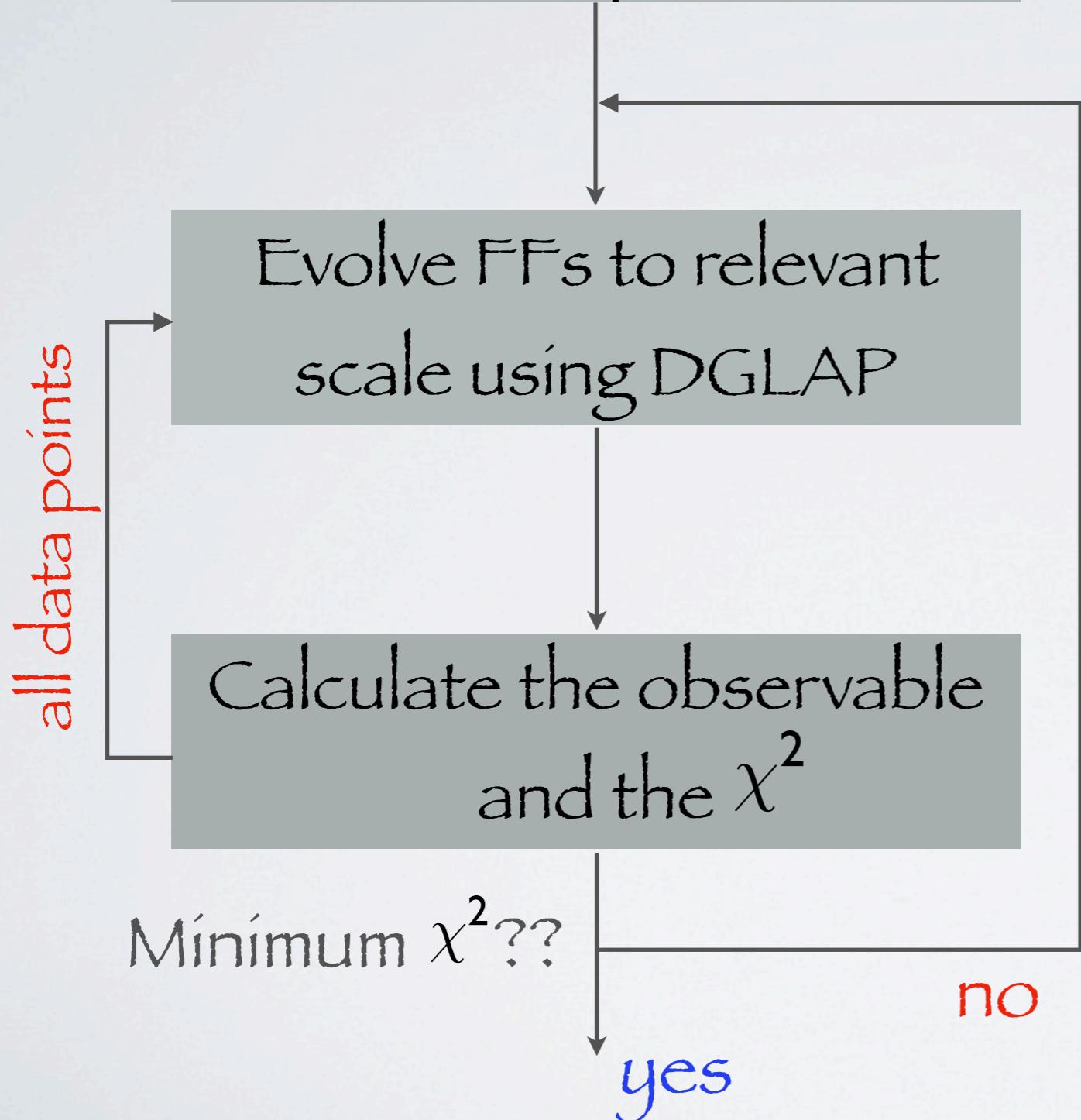
Allow flexible distributions for unfavored fragmentations,

$$\mathcal{D}_{\bar{u}}^{\pi^+} = N_{ud} (1-z)^{\epsilon_{ud}} \mathcal{D}_d^{\pi^+} \quad \mathcal{D}_{\bar{u}}^{K^+} = N_{us} (1-z)^{\epsilon_{us}} \mathcal{D}_s^{K^+} = \mathcal{D}_d^{K^+} = \mathcal{D}_{\bar{d}}^{K^+}$$

Model Ansatz for FFs with
initial set of parameters

$$D_i^H(z, Q_0^2) = N_i z^{\alpha_i} (1-z)^{\beta_i} [1 + \gamma_i (1-z)^{\delta_i}]$$

33 parameters to fit

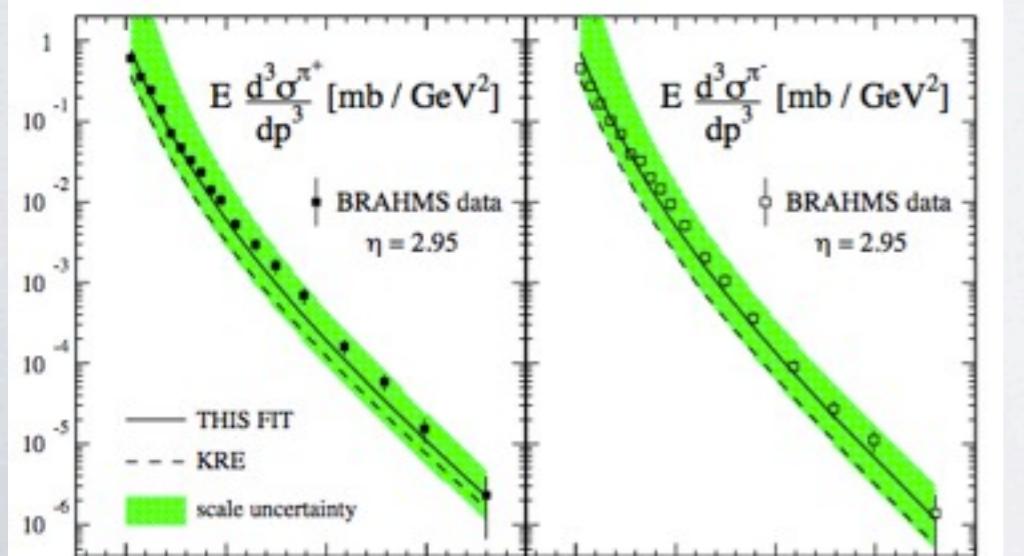
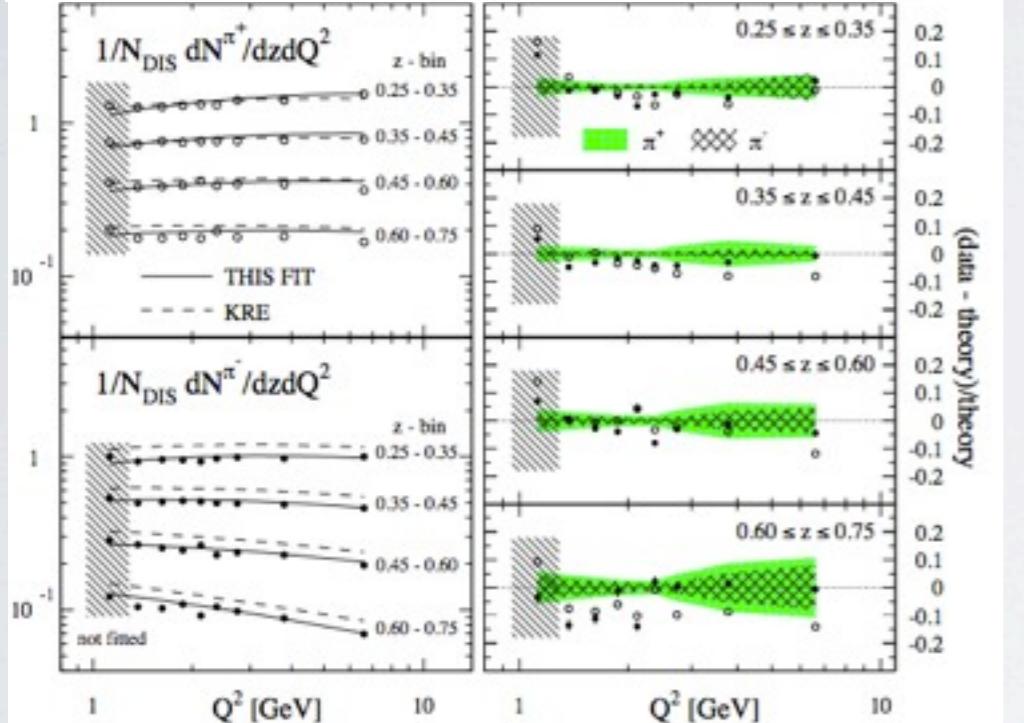
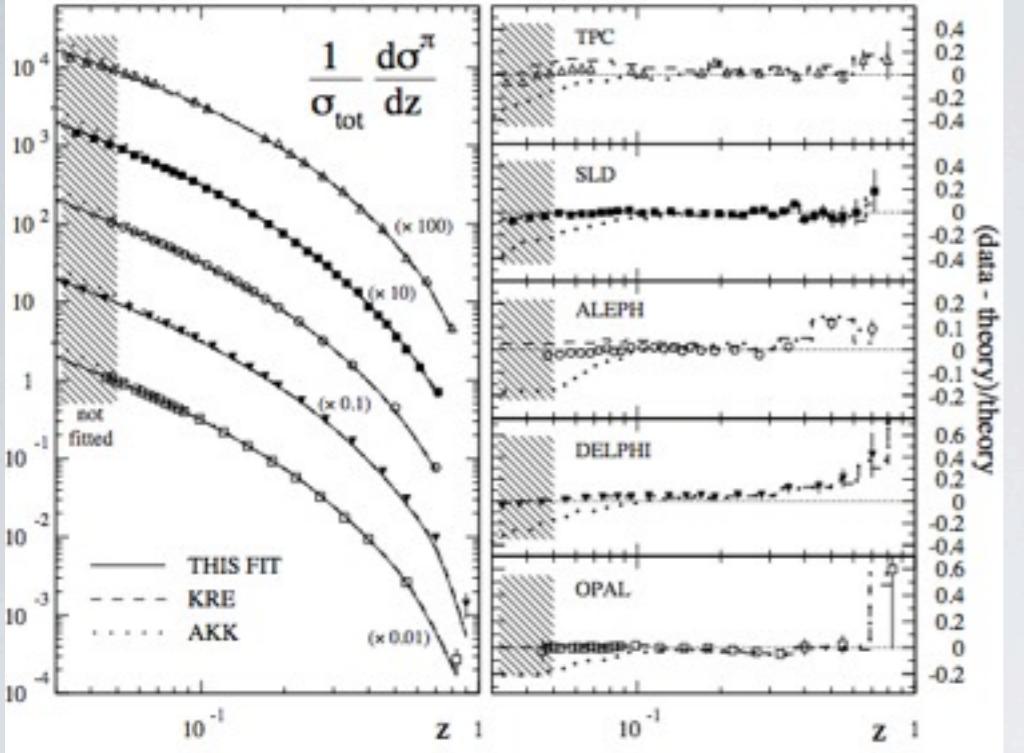


adjust parameters

Integration using the
Mellin Technique
 $\otimes \rightarrow \cdot$

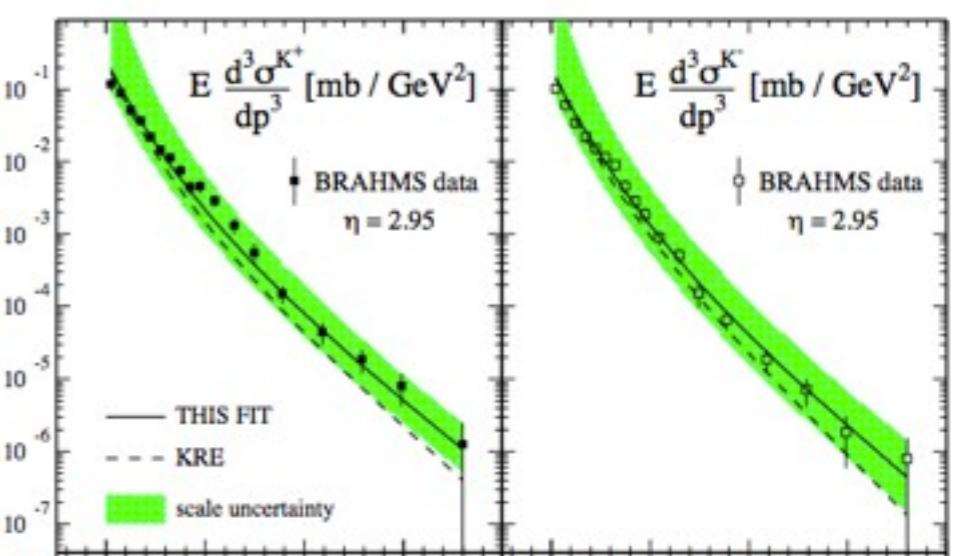
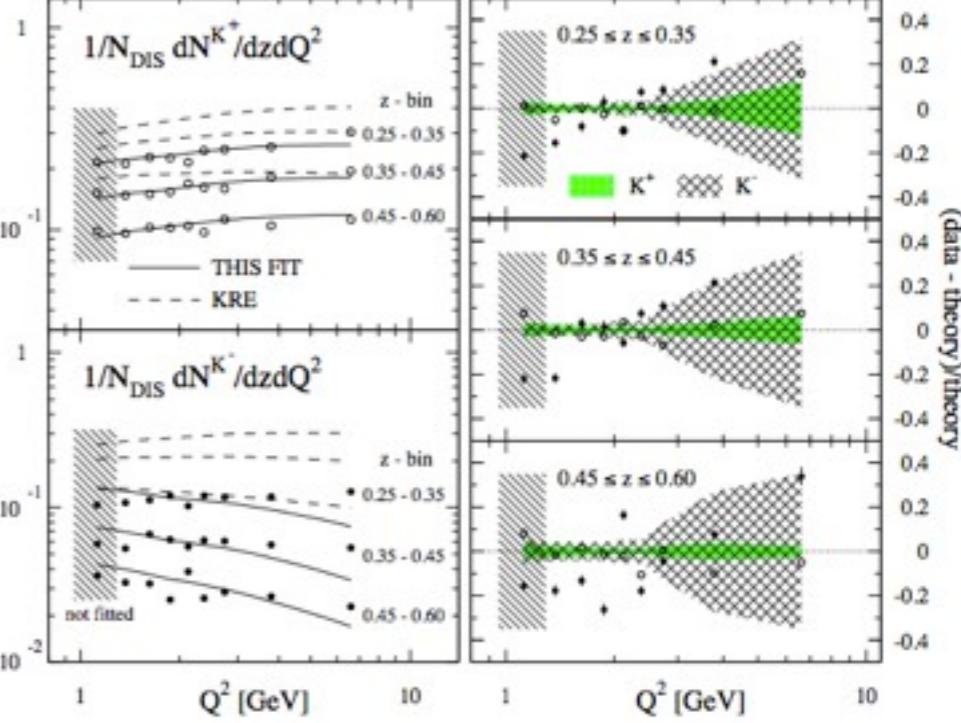
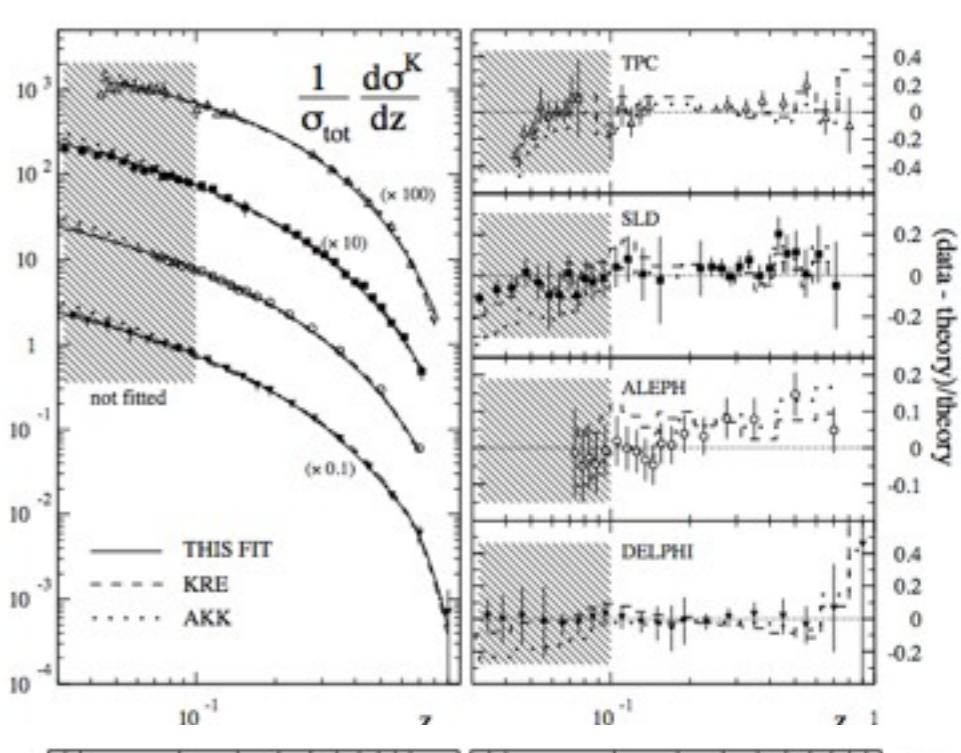
New grids using NLO
MSTW2008 PDFs

Standard χ^2 minimization
(MINUIT)



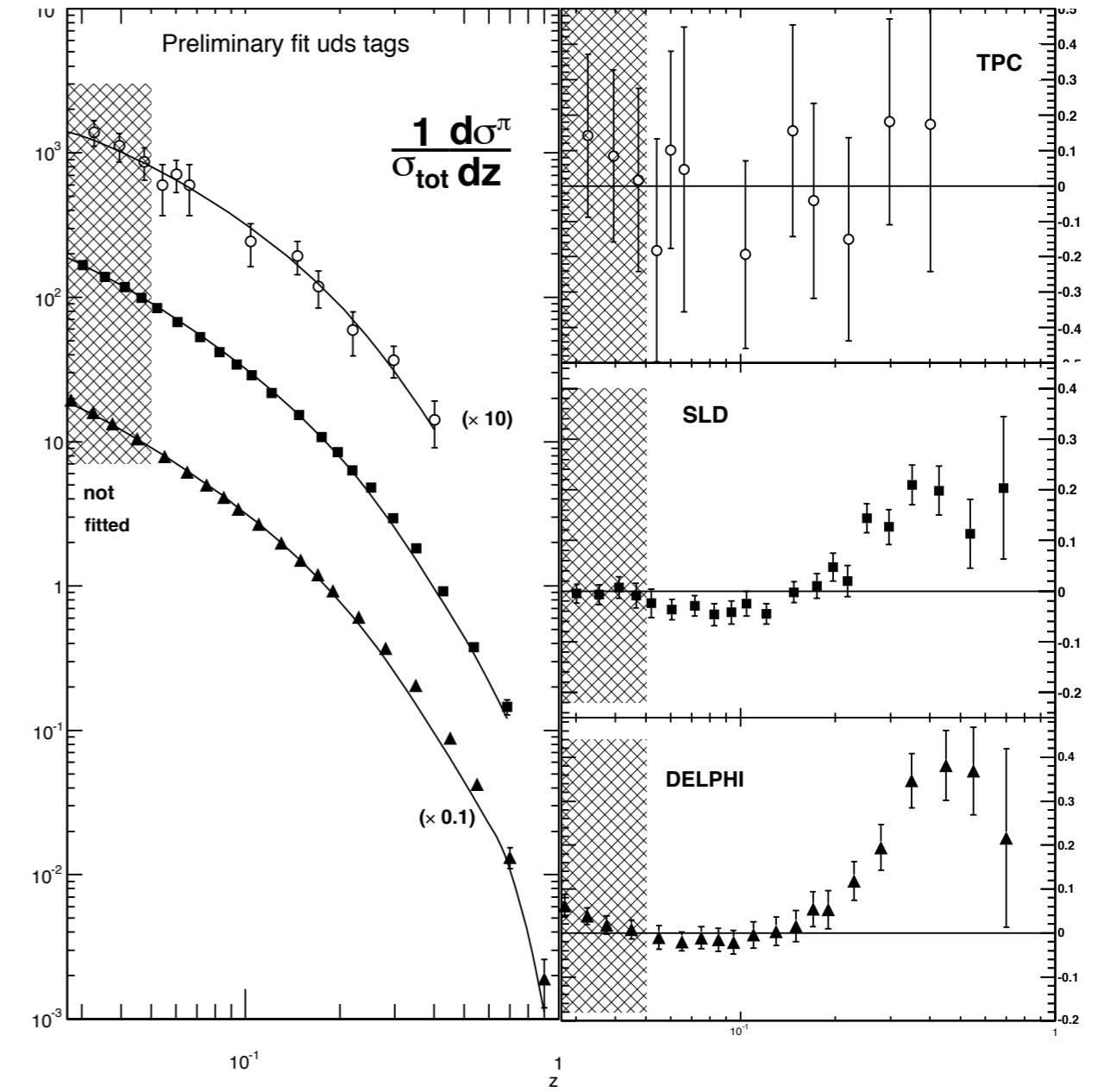
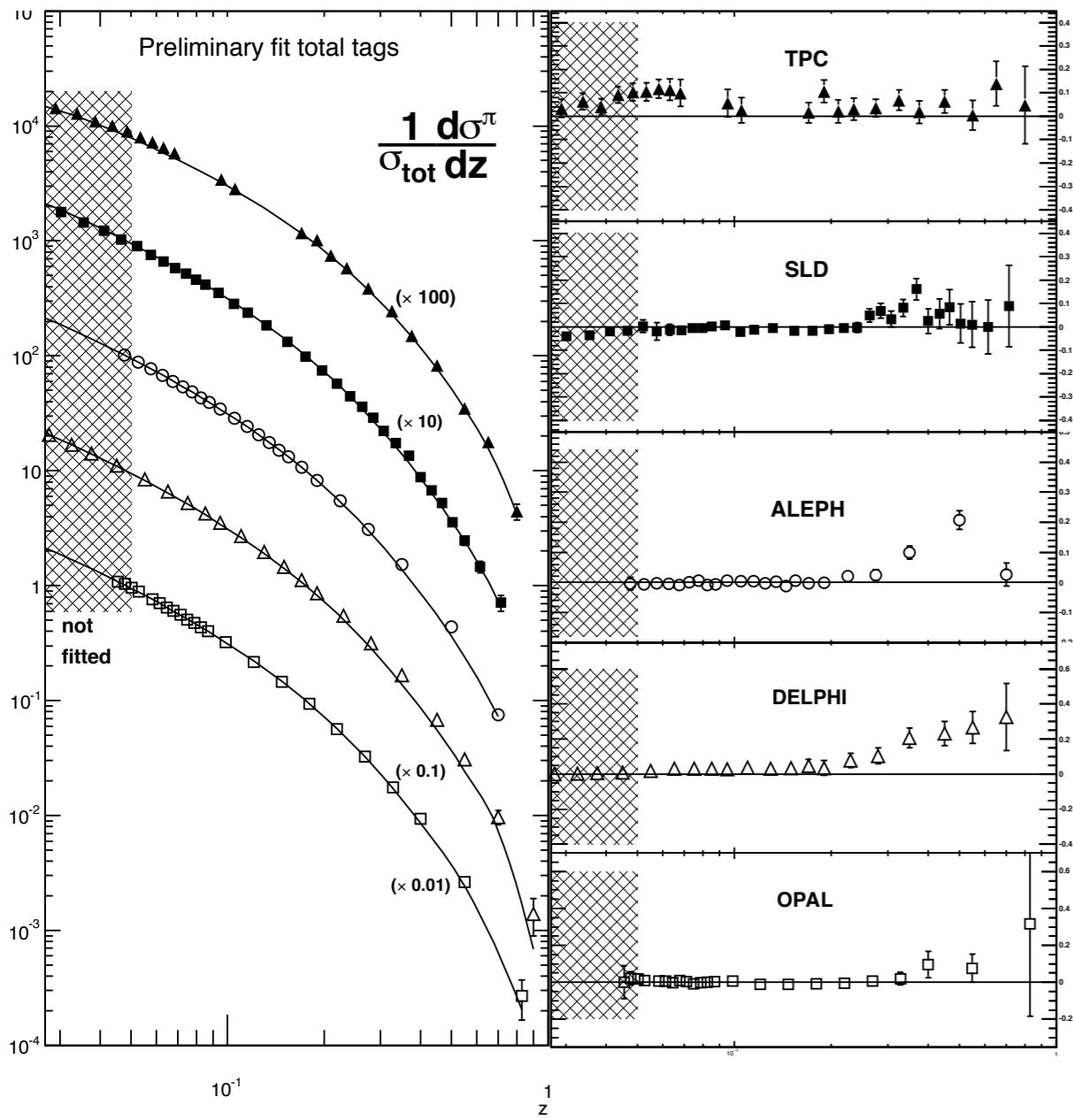
DSS
FIT

D. de Florian et al.
PRD 75, 114010 (2007)



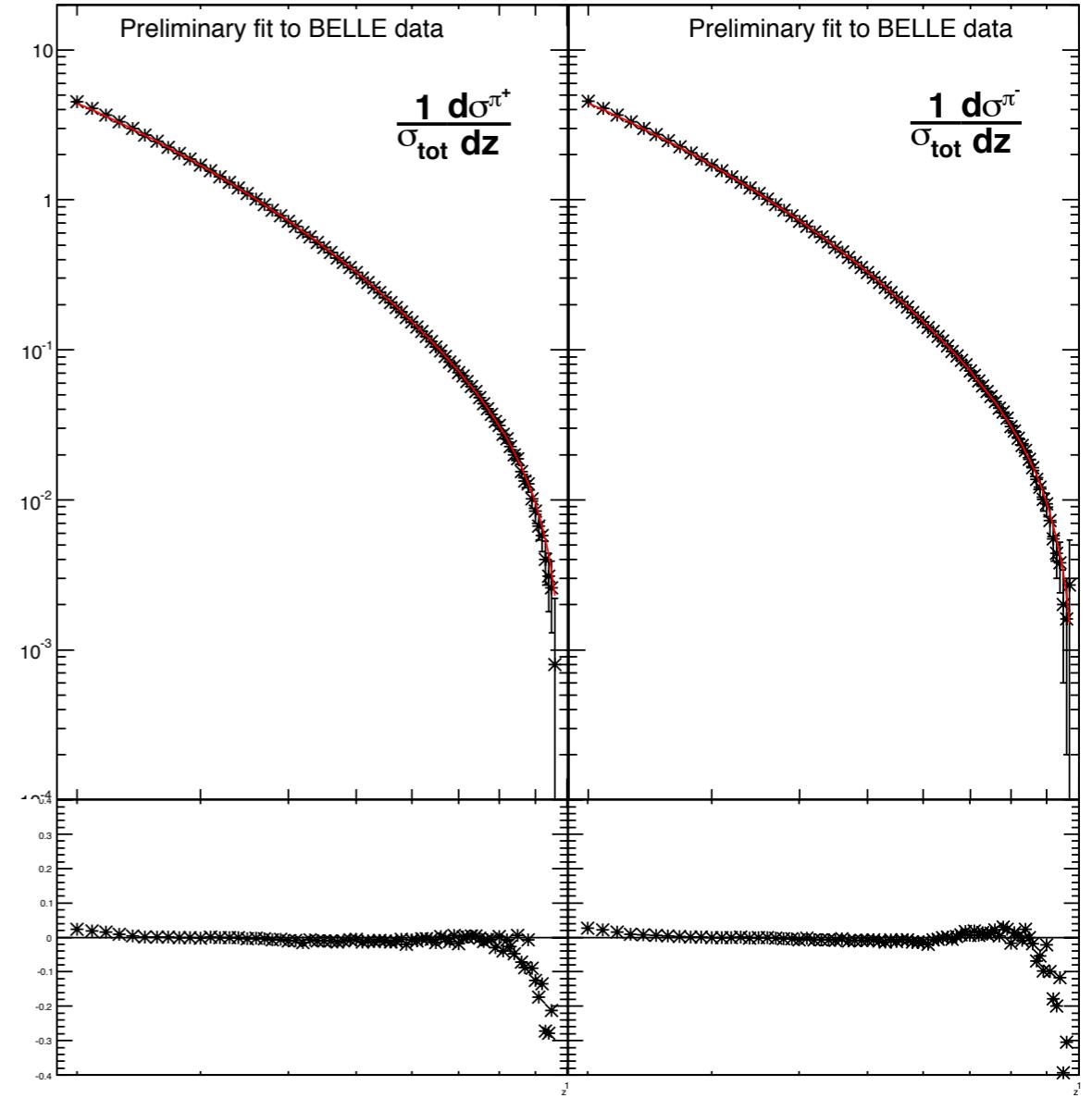
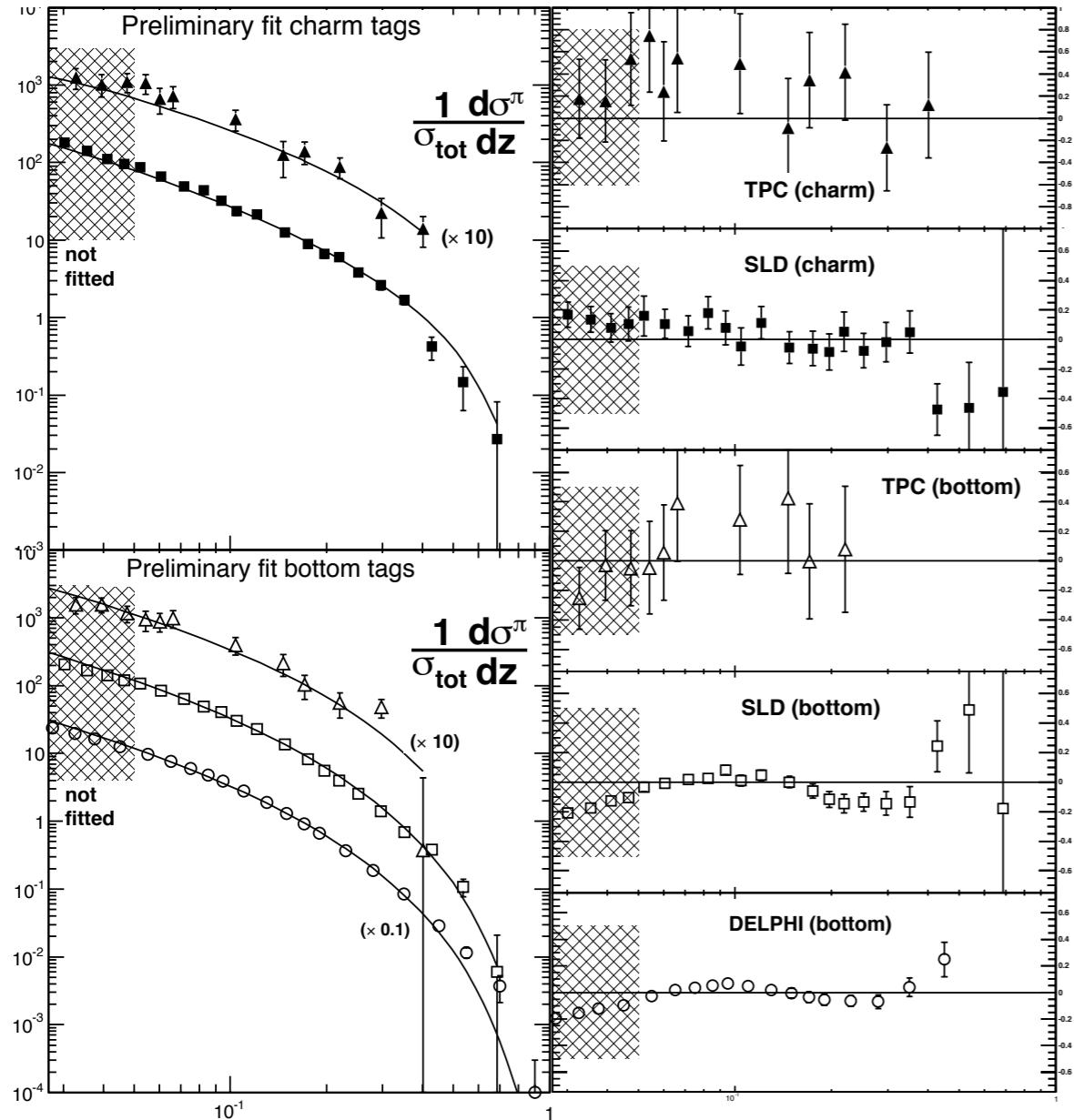
π

e+e- fits



π

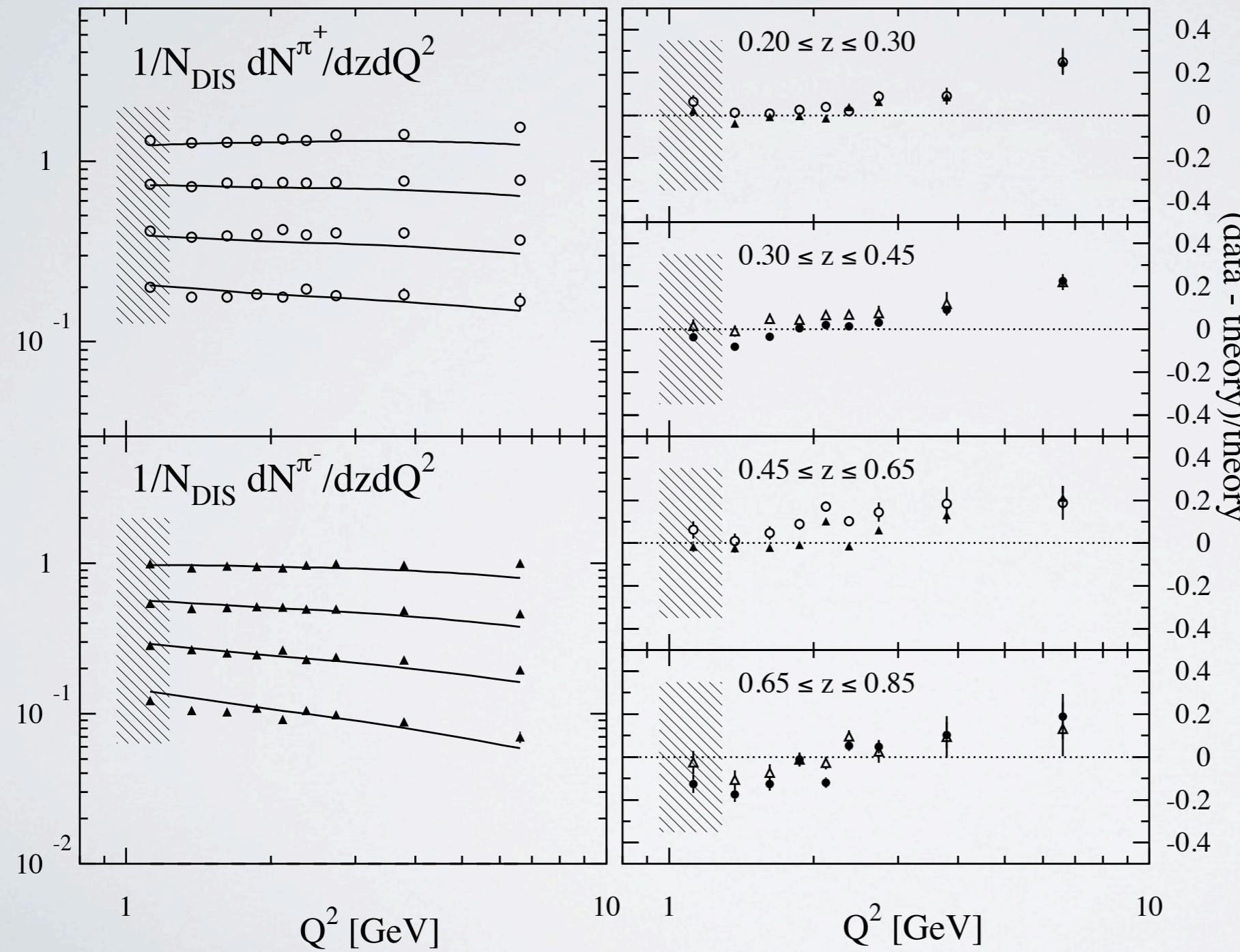
e+e- fits



Looks O.K. for the new BELLE data

π

ep fits

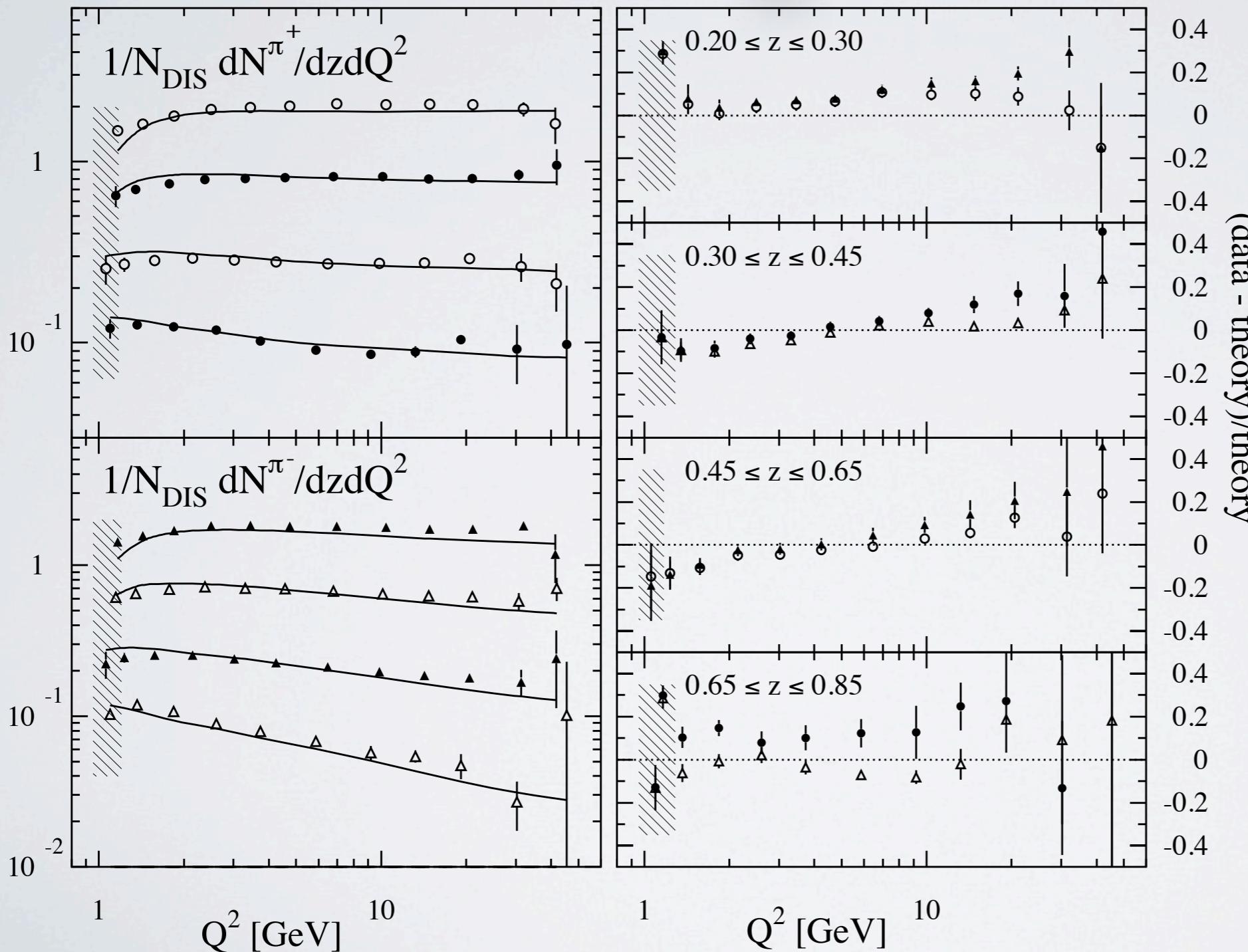


fit is still O.K.
for SIDIS

discrepancies
around 20% at most

π

ep fits

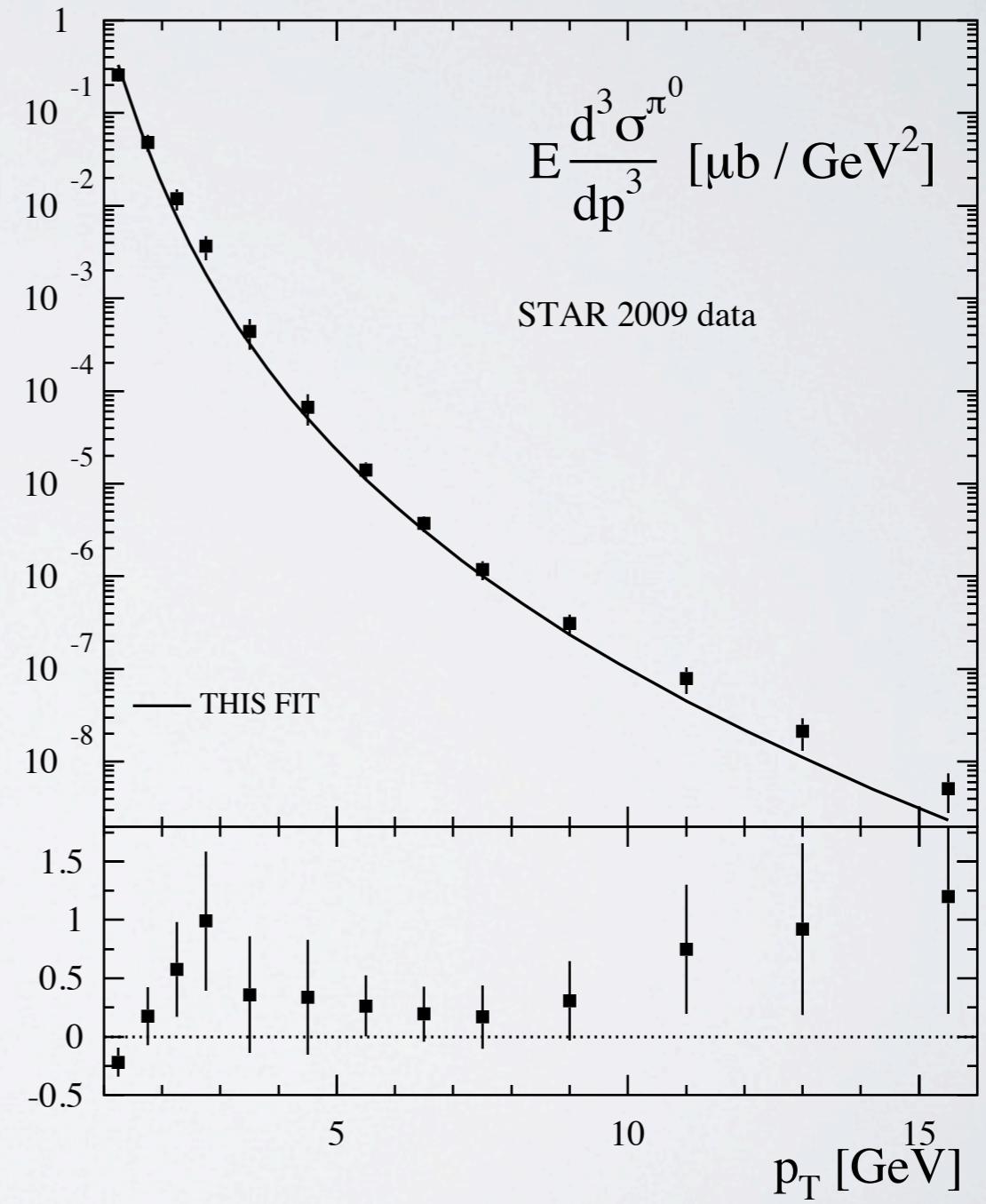
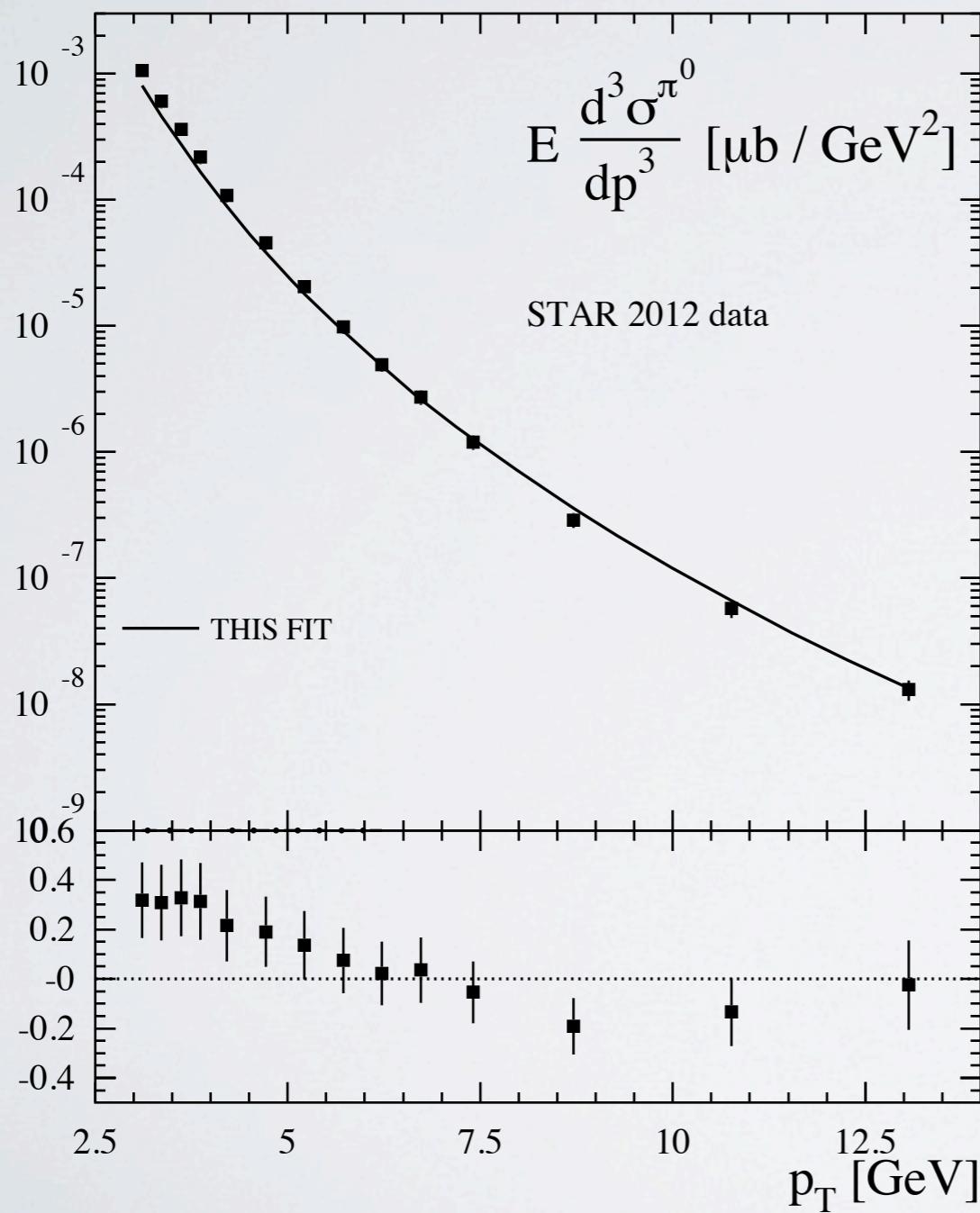


Good agreement
with COMPASS

Data range is going
up to 40-50 GeV

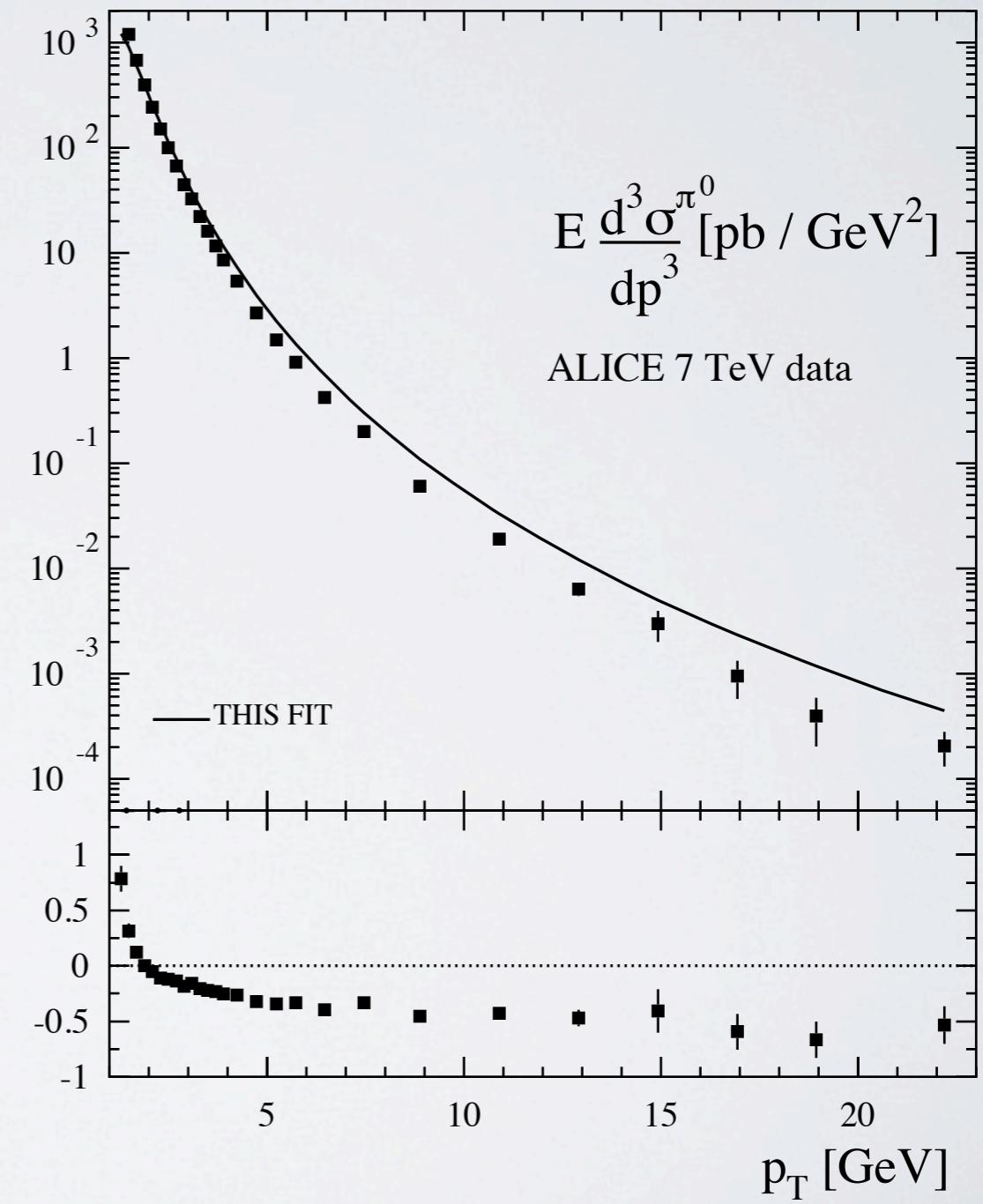
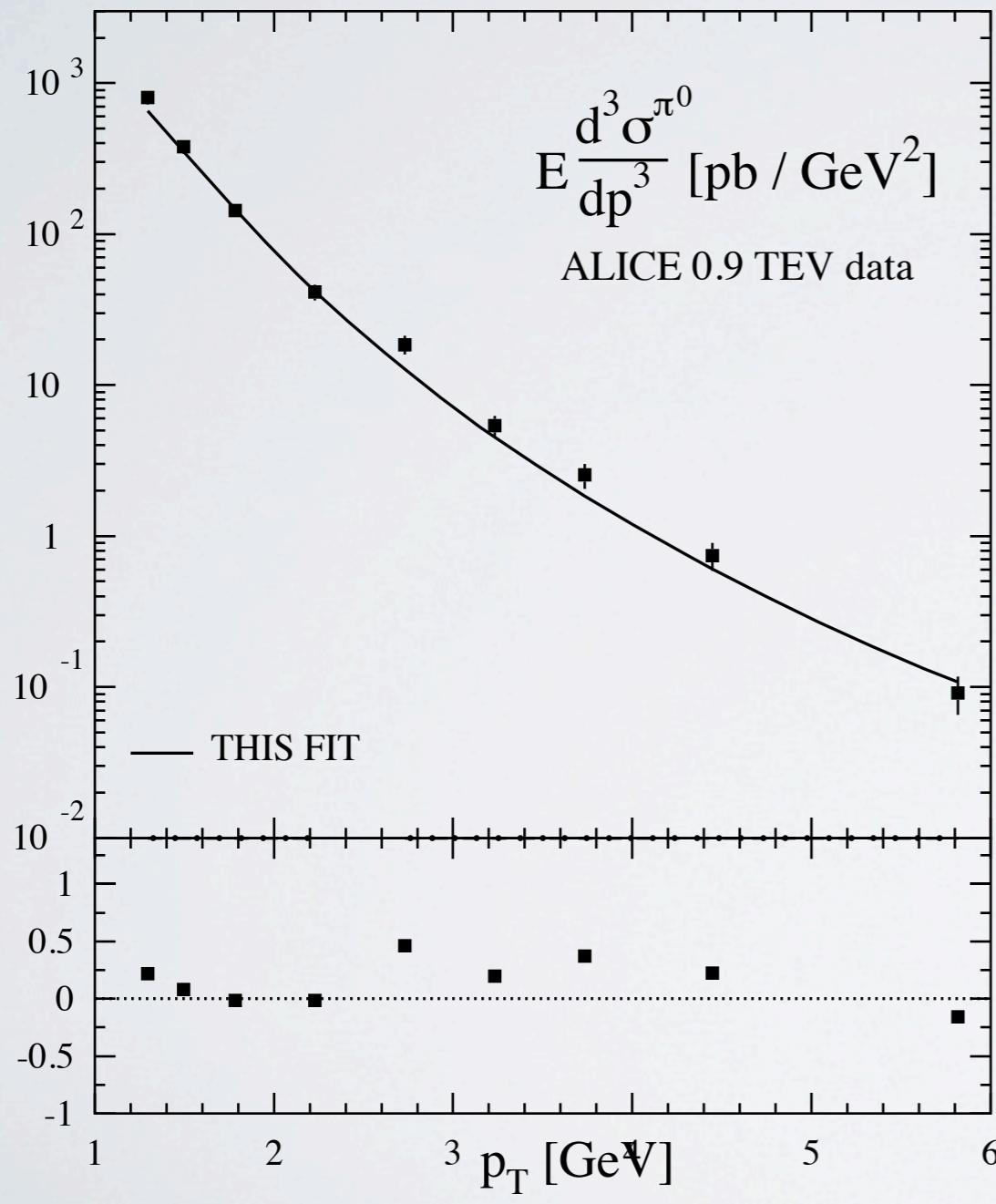
π

pp fits



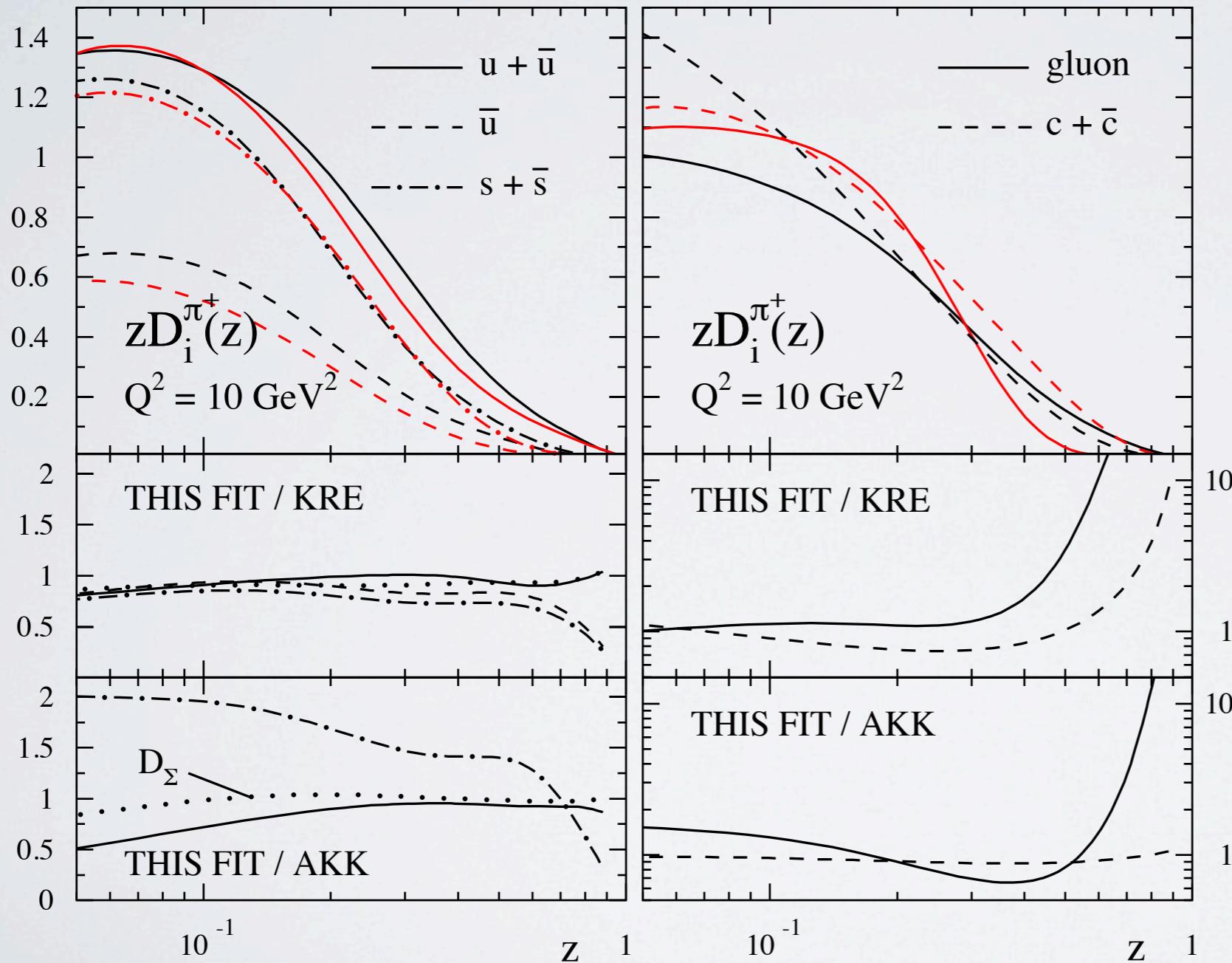
π

pp fits



π

FFs profiles

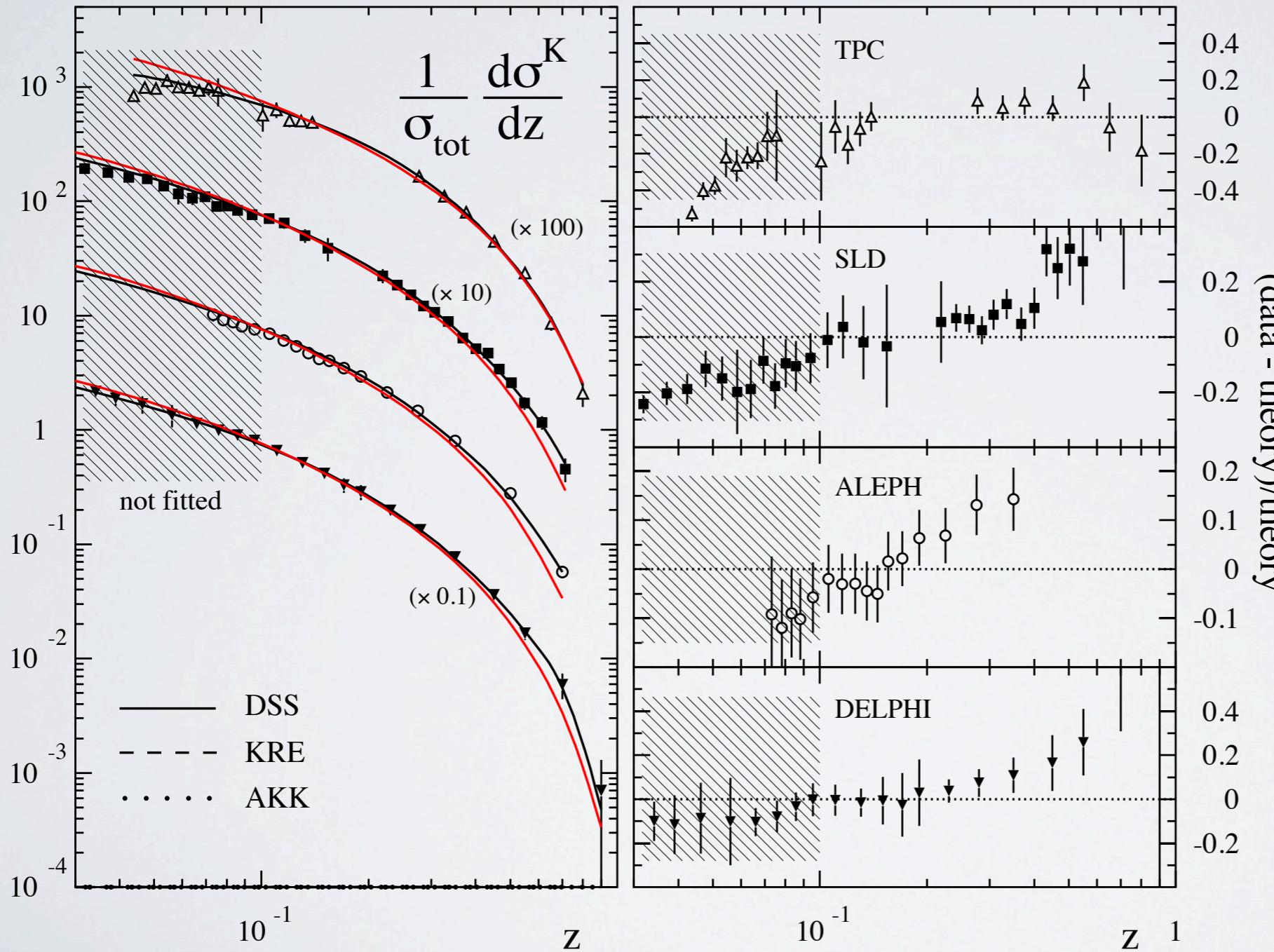


Small deviations for
u and s FFs

Differences in the c
and gluon
fragmentation
functions

K

e+e- fits

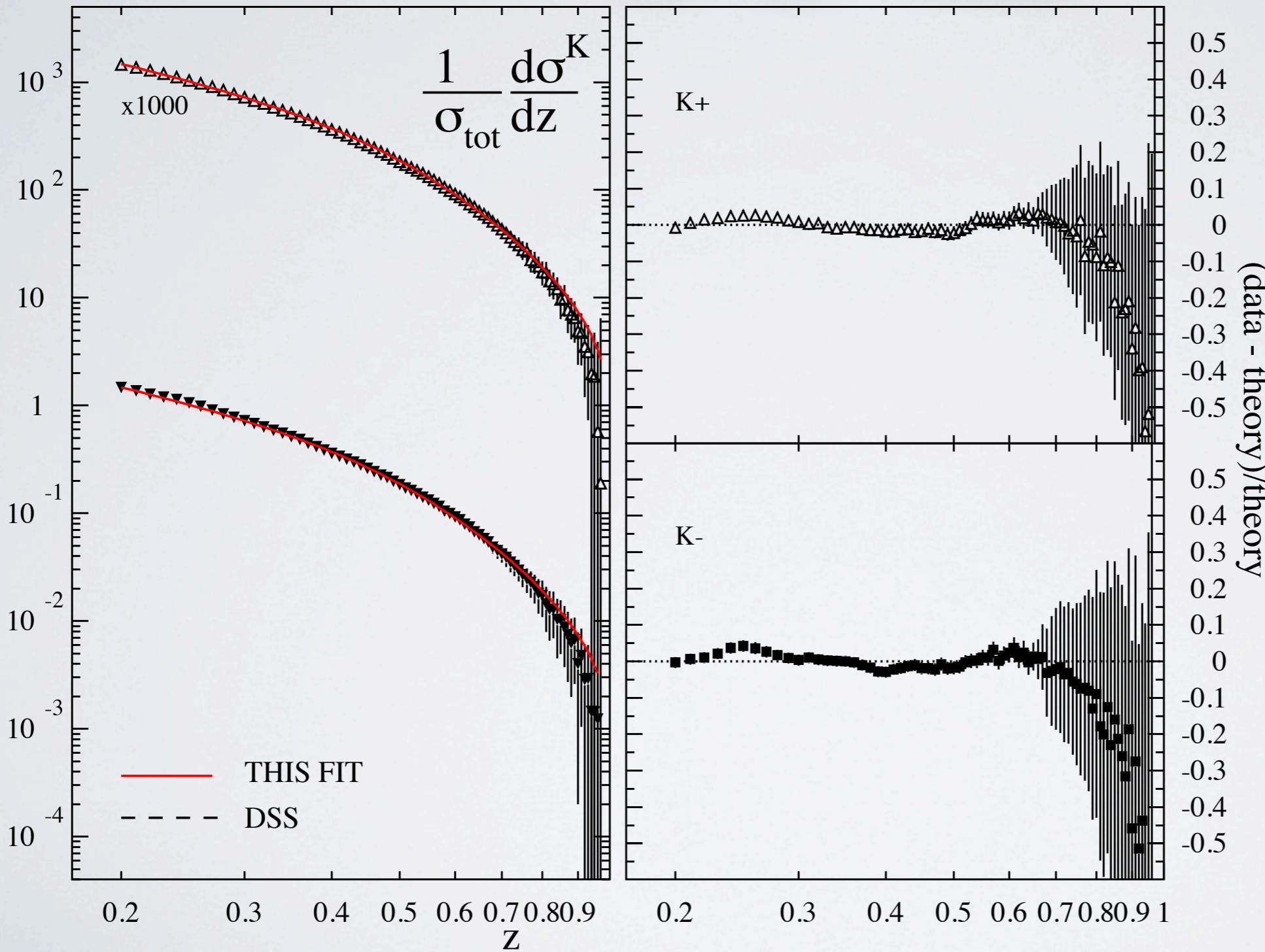


More complicated fit
for kaons

tension with
DELPHI increases

K

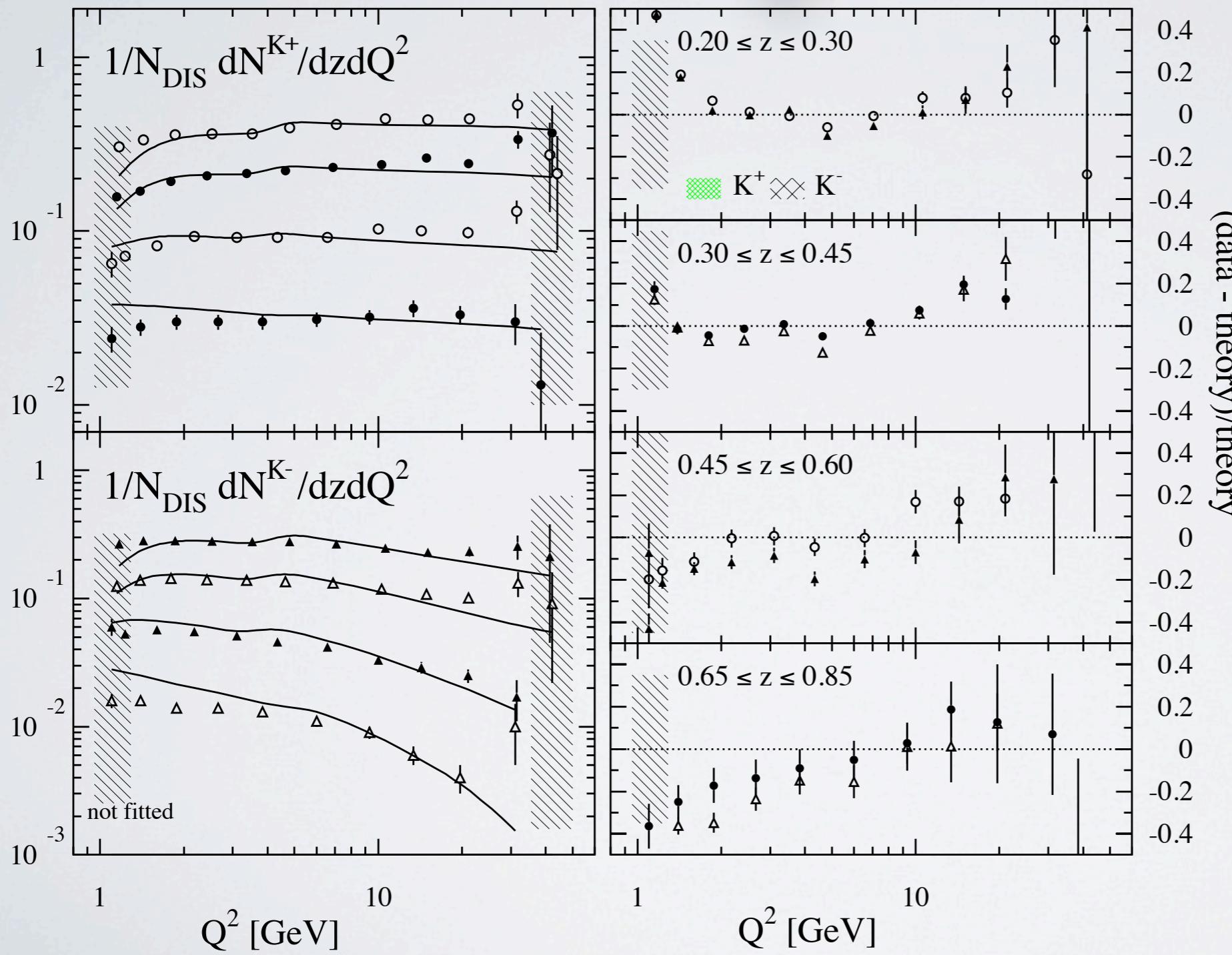
e+e- fits



But, we have a
good
agreement with
the BELLE
data

K

ep fits



There is a tension
for K^- data in the
COMPASS data set

discrepancies can
be of the order of
40%

Conclusions and Perspectives

- FFs are an important tool for describing observables within pQCD.
- NLO (LO) FFs can be extracted precisely only when global analyses are implemented.
- Charge/Flavor separation can be achieved only when SIDIS and Hadron-Hadron collisions are considered in the global fit.
- The fit for pions and kaons have a good agreement with almost all the new experimental results.
- Better understanding of Kaon FFs.
- Study of theoretical uncertainties.

THANK YOU...