Extracting the fragmentation functions with global analyses

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in collaboration with

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Outline

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

Introduction

- Parton Distribution Functions (PDF) and Fragmentation Functions (FFs) contain the description of particles into an scattering process.
- PDF: Particles in the initial state
- FFs: Particles in a final state scattering
- Both distributions are sensitive to the data, although they are non perturbative objects $\Rightarrow$ data is necessary to understand them
- In order to know its behavior, one need to look at the nucleon substructure.

- Gauge principle is elegant and powerful nevertheless, physical theories have to stand (or fall) when it is compared with experimental results.
- Can we use perturbative QCD everywhere??

Confinement

Non perturbative hadronic structure

e.g. Lattice QCD

Asymptotic Freedom

Cross section in hard scattering processes

Perturbative methods

- Test the hadronic structure with “quanta” weakly interacting partons in the asymptotic freedom regime

If one wants to stablish a connection between theory and experiment, one needs to take care of:

1. Control of IR divergences
2. Factorization Theorems

IR Divergences

There are quantities which are independent to large distance physics, therefore one can compute them using pQCD.

Factorization

There is a lot of processes which can be factorized into universal large distance pieces and short distance pieces (it depends actually on the processes, but it is calculable)

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FFs $\left(\mathcal{D}_q^h(z,\mu)\right)$

- FFs are relevant any time a hadron is produced in High Energy Collisions.
- Non-perturbative objects to be extracted from data (like PDFs). They are scale dependent predicted by QCD.
- Describe the collinear transition of a massless parton "q" into a massless hadron "h" carrying fractional momentum "z".
- The fragmentation is independent of other colored particles.
- Needed to consistently absorb final-state collinear singularities.
- Precise FFs are needed to extract PDFs more precisely.

e+e- Single Inclusive Annihilation

The distribution is given in terms of the structure functions,

$$\frac{1}{\sigma_{tot}}\frac{d\sigma^h}{dz} = \frac{\sigma^0}{\sum_q \hat{e}_q^2}\left[2F_1^H(z,Q^2)+F_L^H(z,Q^2)\right] \qquad \sigma_{tot}=\sum_q \frac{4\pi\alpha_s^2}{s}\hat{e}_q^2\left(1+\frac{\alpha_s}{\pi}\cdots\right)$$

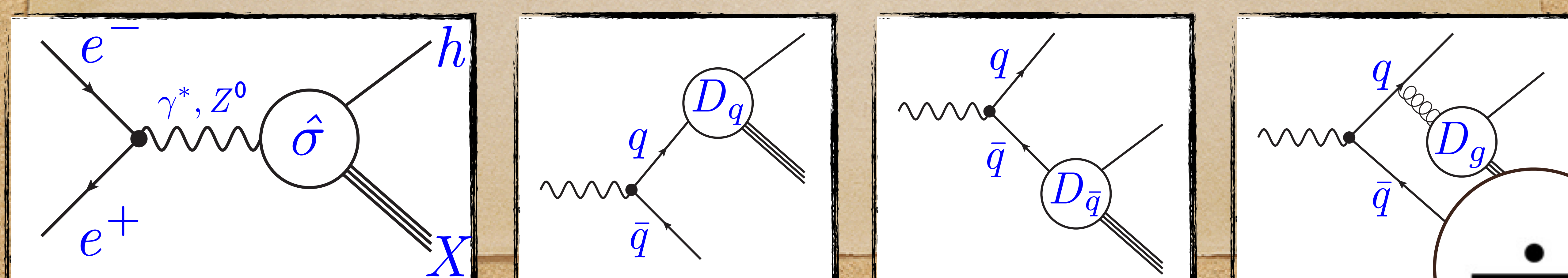
@NLO

$$2F_1^H(z,Q^2)=\sum_q \hat{e}_q^2\left\{[D_q^H(z,Q^2)+D_{\bar{q}}^H(z,Q^2)]+\frac{\alpha_s(Q^2)}{2\pi}[C_q^1\otimes[D_q^H+D_{\bar{q}}^H]+C_g^1\otimes D_g^H](z,Q^2)\right\}$$

FFs depend on energy fraction and energy scale: AP evolution

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

Not possible to separate $\mathcal{D}_q^h(z,\mu)$ and $\mathcal{D}_{\bar{q}}^h(z,\mu)$



SIDIS

Distributions for SIDIS are given by

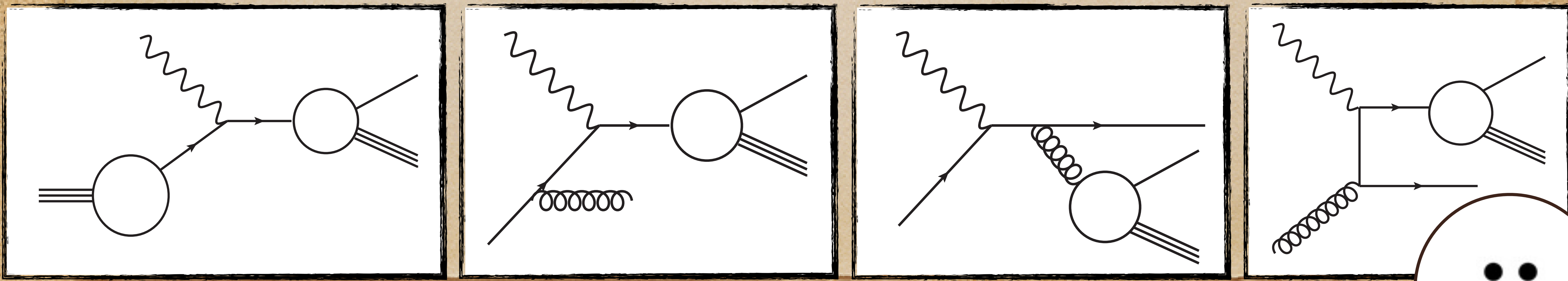
$$\frac{d\sigma^H}{dxdydz^H} = \frac{2\pi\alpha_s}{Q^2}\left[\frac{1+(1-y)^2}{y}2F_1^H(x,z_H,Q^2) + \frac{2(1-y)}{y}F_L^H(x,z_H,Q^2)\right]$$

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

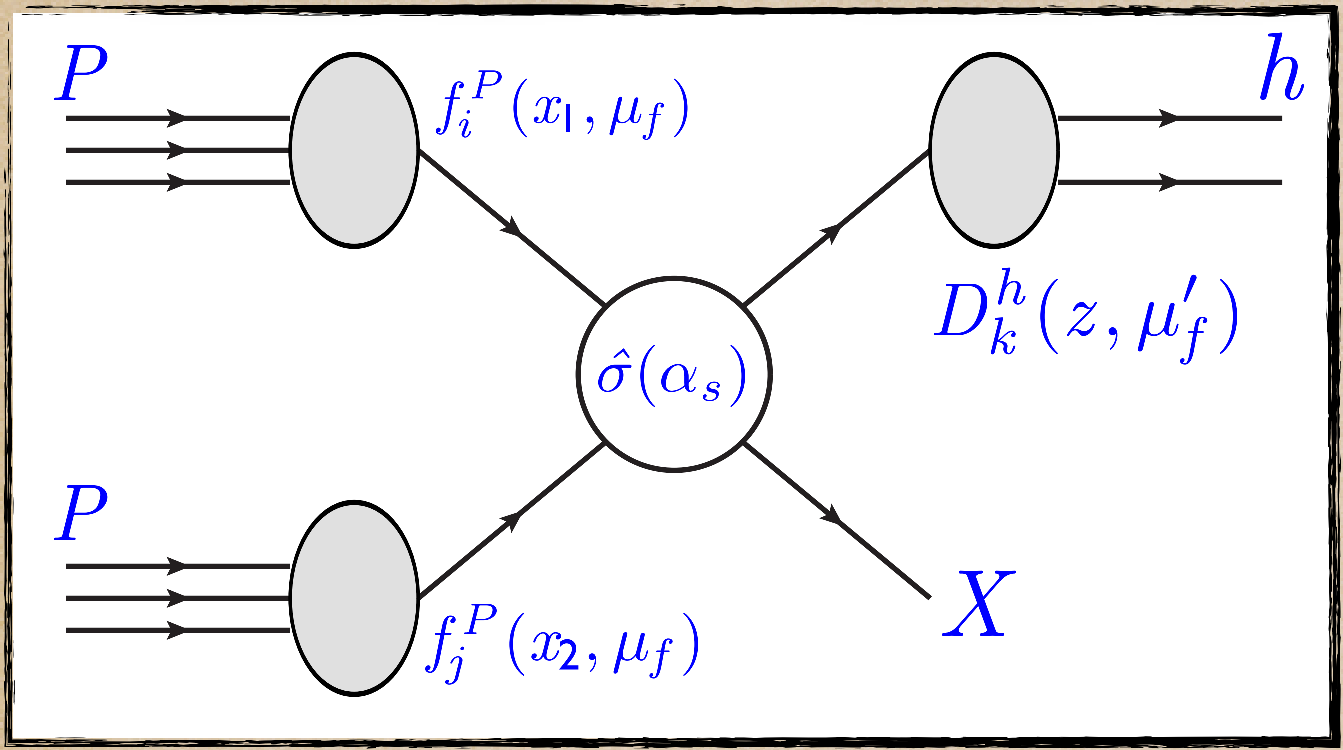
effective charge

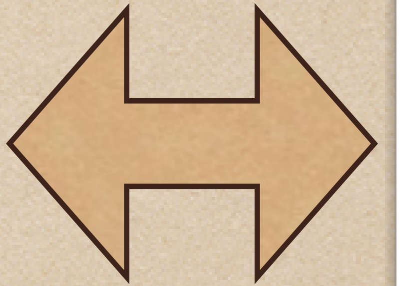
Allows charge/flavor separation.

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



Hadron-Hadron Collisions





$q\bar{q} \to g$

$qq \to q$

$qg \to g$

$qg \to q$

$gg \to q$

$gg \to g$

Transverse momentum distribution is

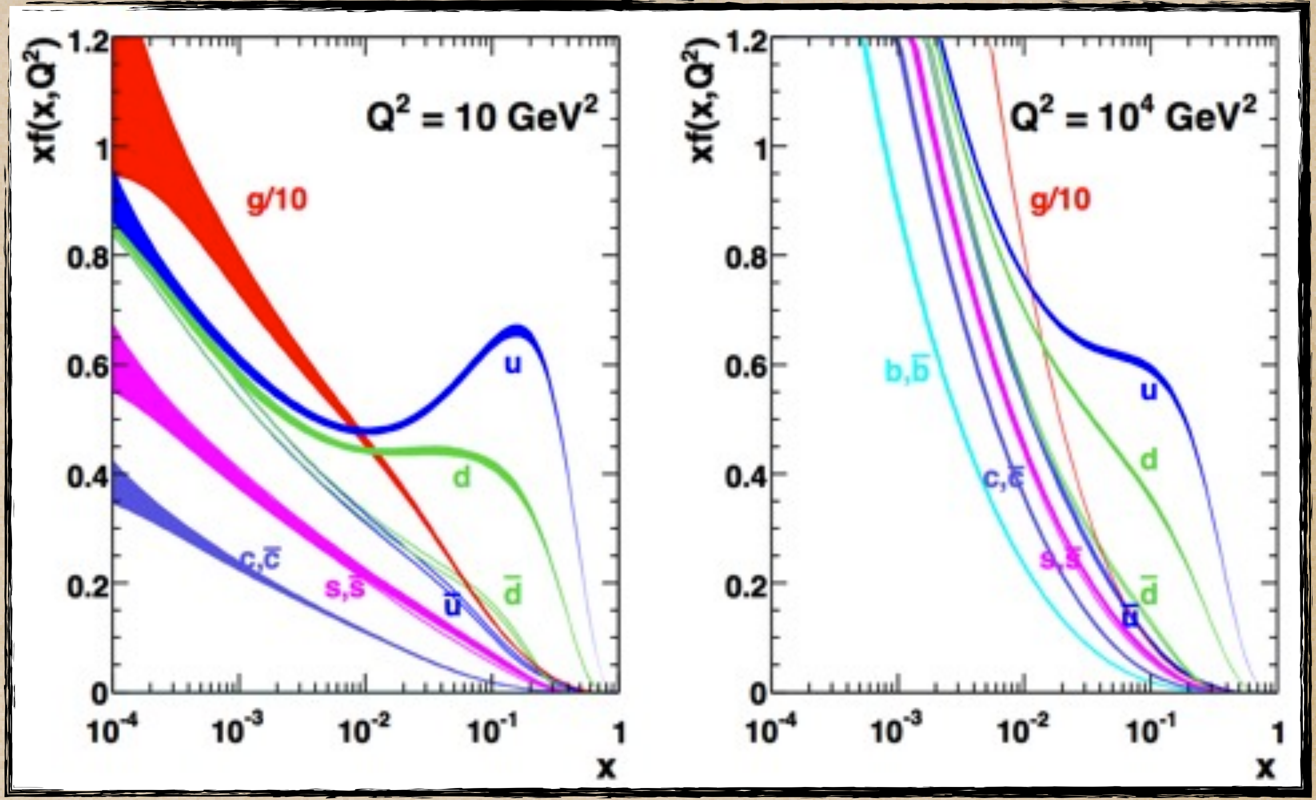
$$\frac{d\sigma(pp \to hX)}{dp_T\,d\eta} = \sum_{i,j,k} \int_0^1 dx_1 f_i^P(x_1,\mu_f) \int_0^1 f_j^P(x_2,\mu_f) \int_0^1 dz D_k^h(z,\mu'_f) \frac{d\hat{\sigma}(ij \to kX')}{dp_T\,d\eta}$$

It also allows charge/flavor separation.

It contains large contributions from gluons.

PDFs & FFs

Global analyses have improved the understanding of PDFs, such like that MSTW2008 collaboration



What about FFs ??

Processes like SIA, SIDIS and Hadron-Hadron collisions can help to understand them by doing a similar analysis. We can use a similar parametrization as the used for MSTW,

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

Global Analyses

- Constrain FFs with almost all available data.
- Check of pQCD framework
- Precise determination of the distributions

Data are taken from the experiments,

- SIA : TPC, TASSO, SLD, ALEPH, DELPHI, OPHAL
- SIDIS: HERMES, COMPASS
- Hadron-Hadron Collisions: PHENIX, STAR, BRAHMS, , UA1

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

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

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

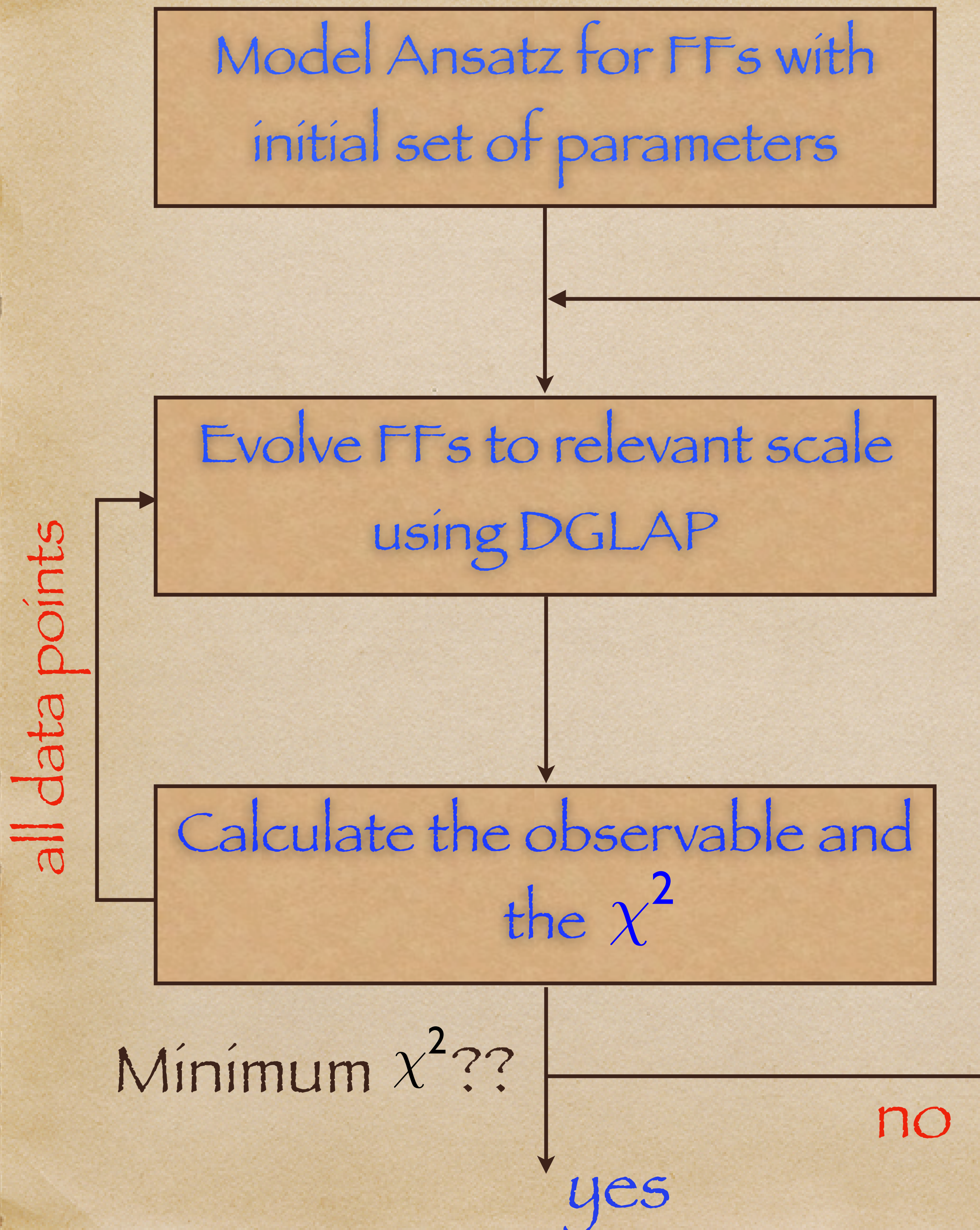
Normalization for different experiments

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

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

Allow flexible distributions for unfavored fragmentations,

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



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

33 parameters to fit

Integration using the Mellin Technique

$\otimes \rightarrow \cdot$

New grids using NLO MSTW2008 PDFs

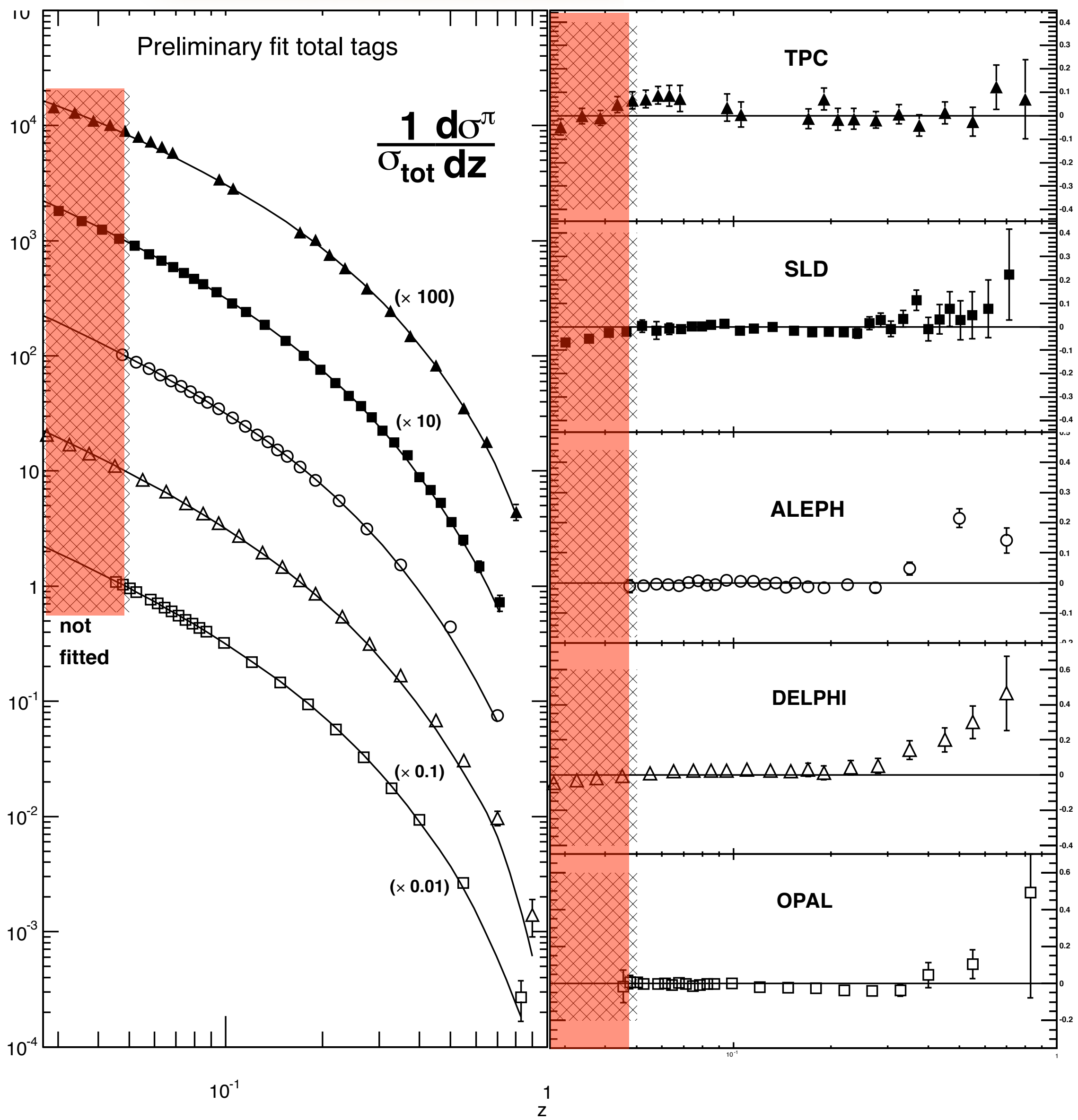
Standard χ^2 minimization (MINUIT)

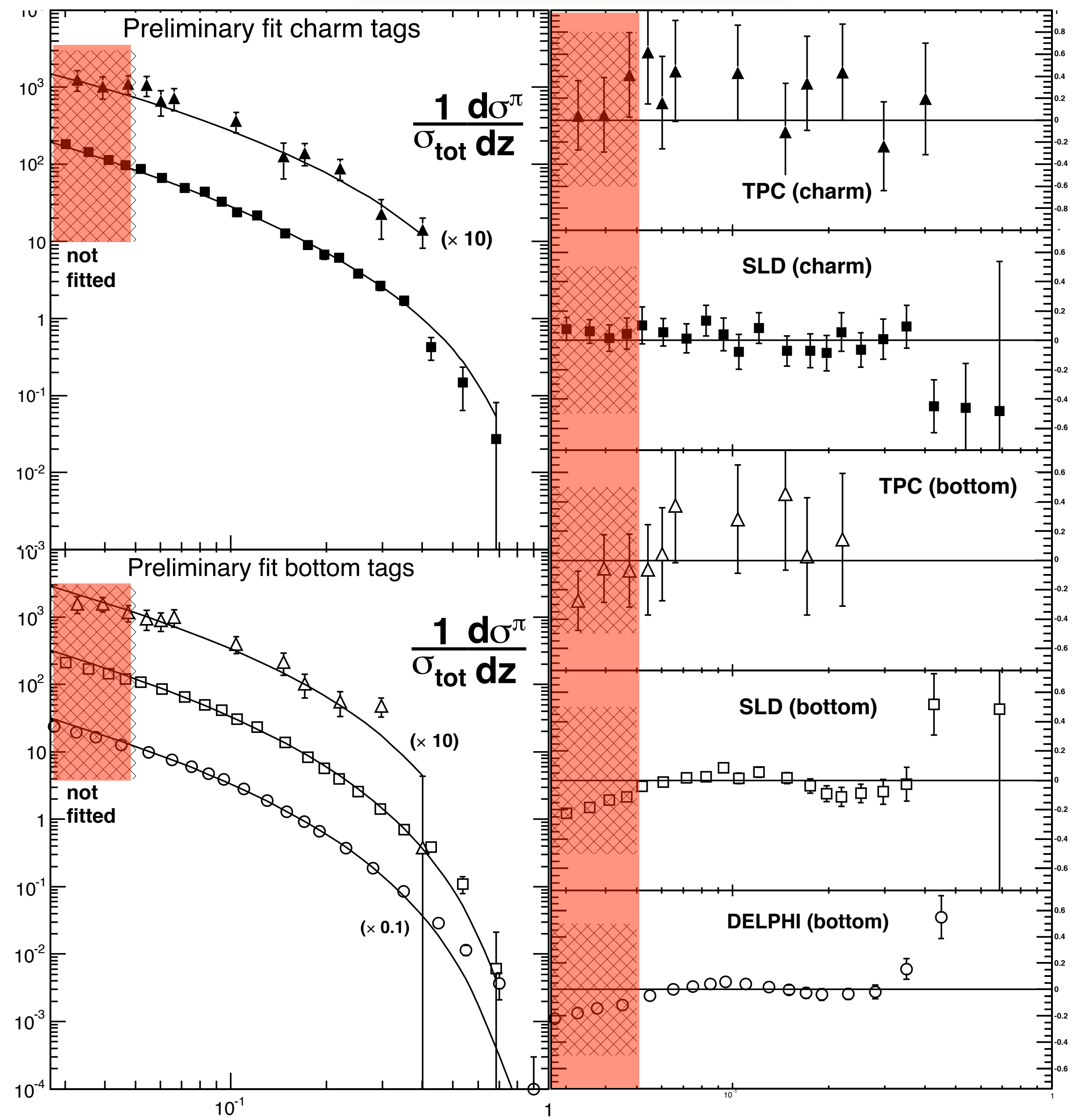
Results

e+e- Fit

Preliminary

Preliminary

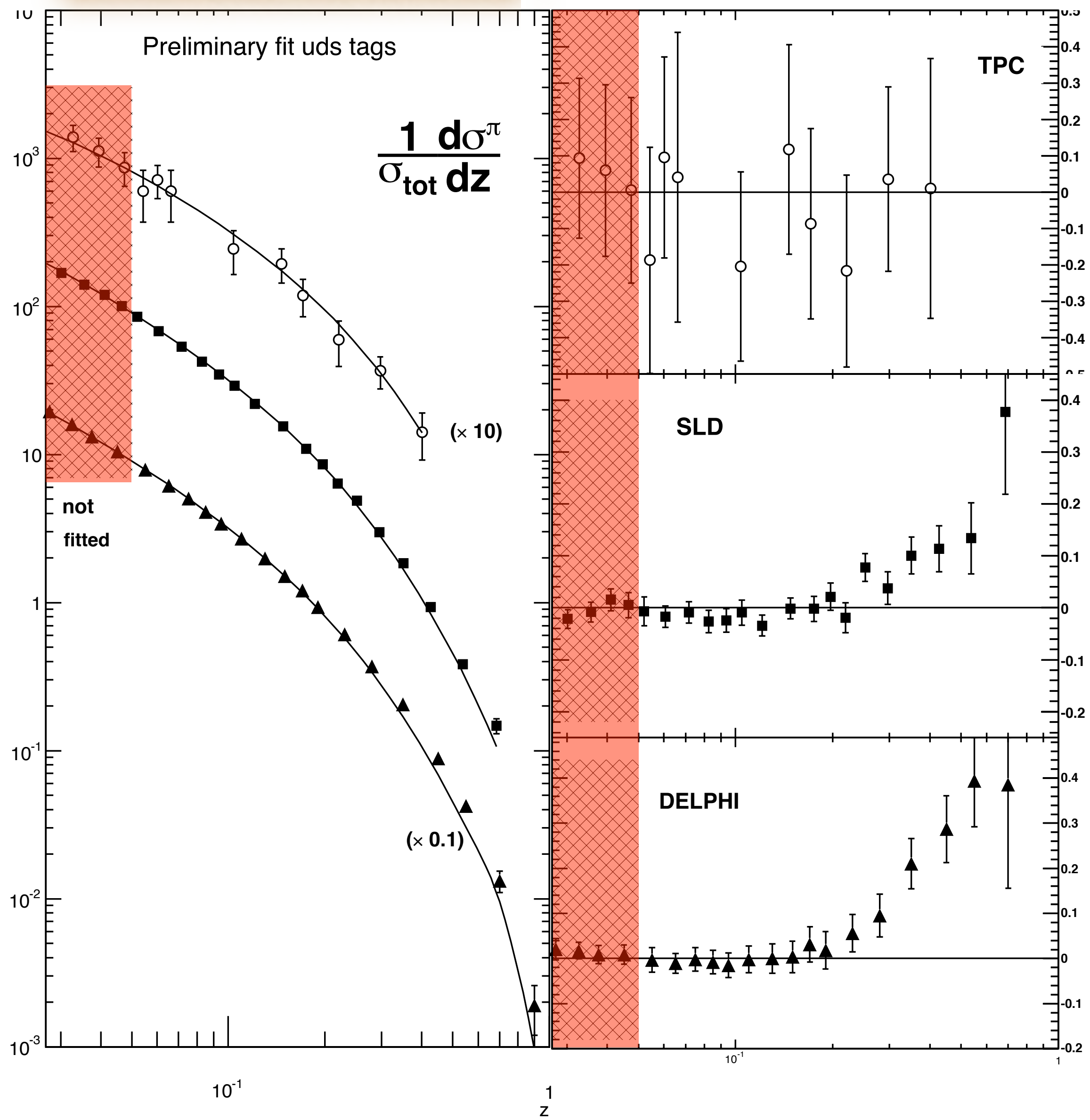


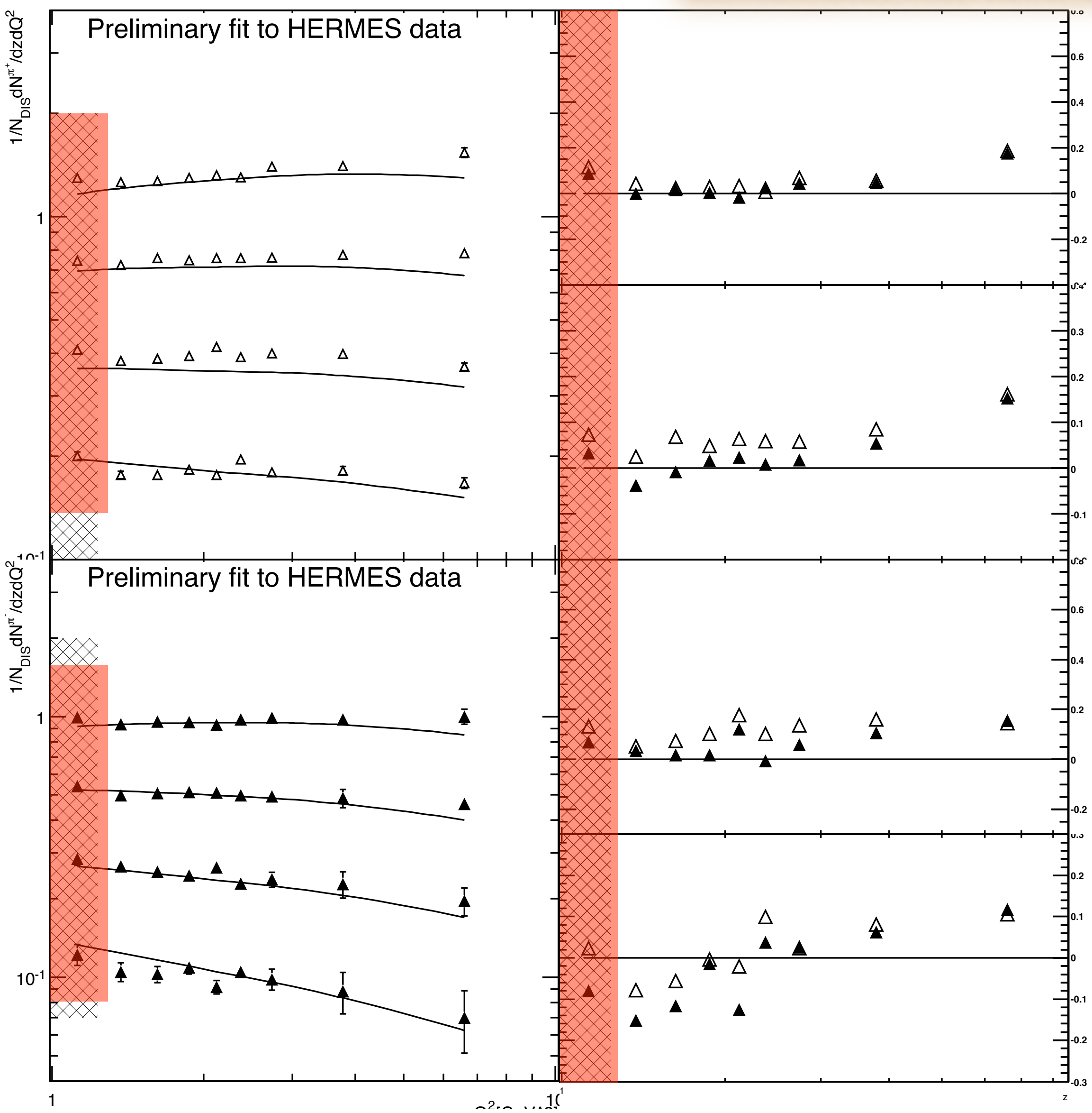


e+e- Fit & Hermes

Preliminary

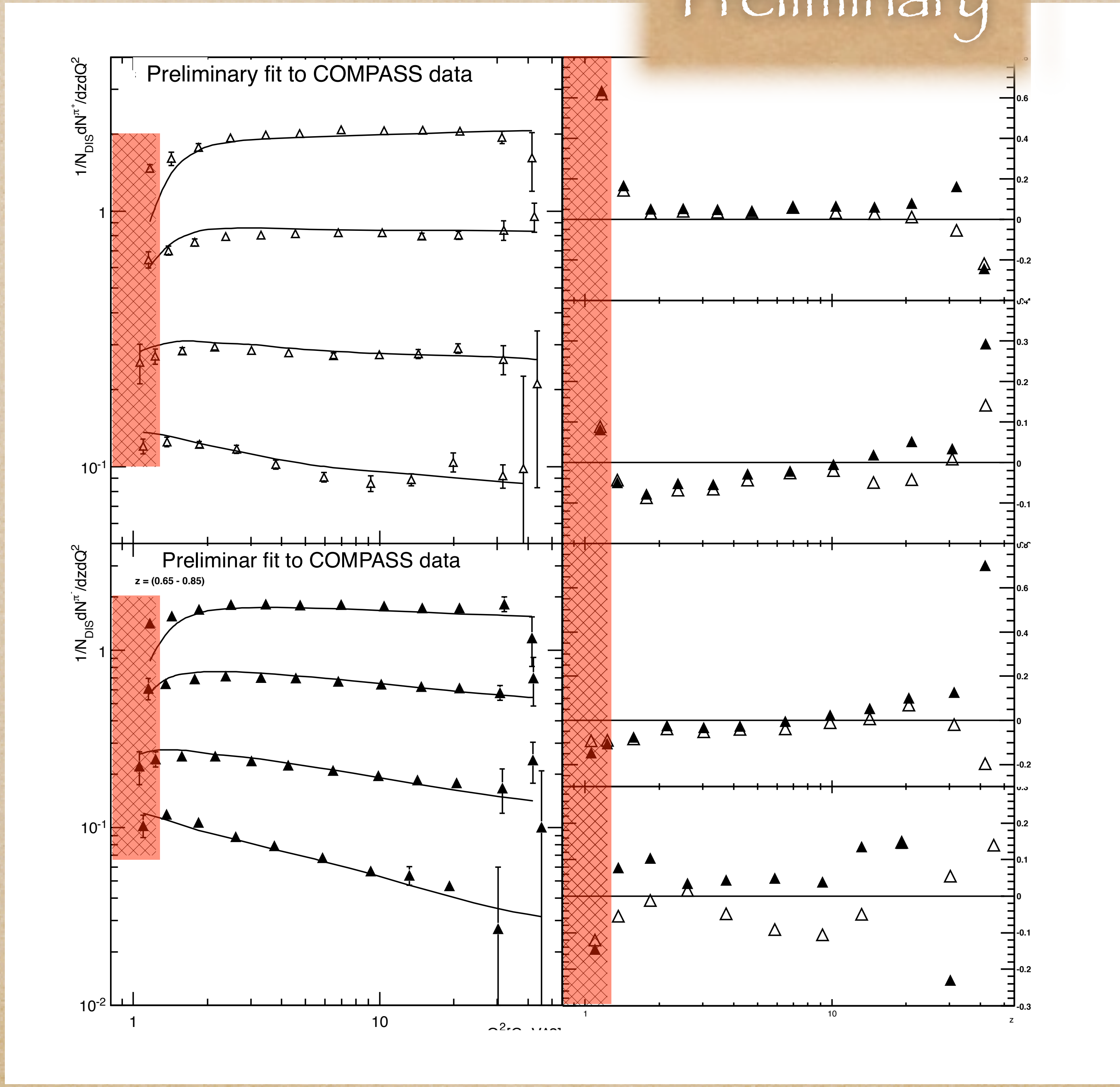
Preliminary





COMPASS

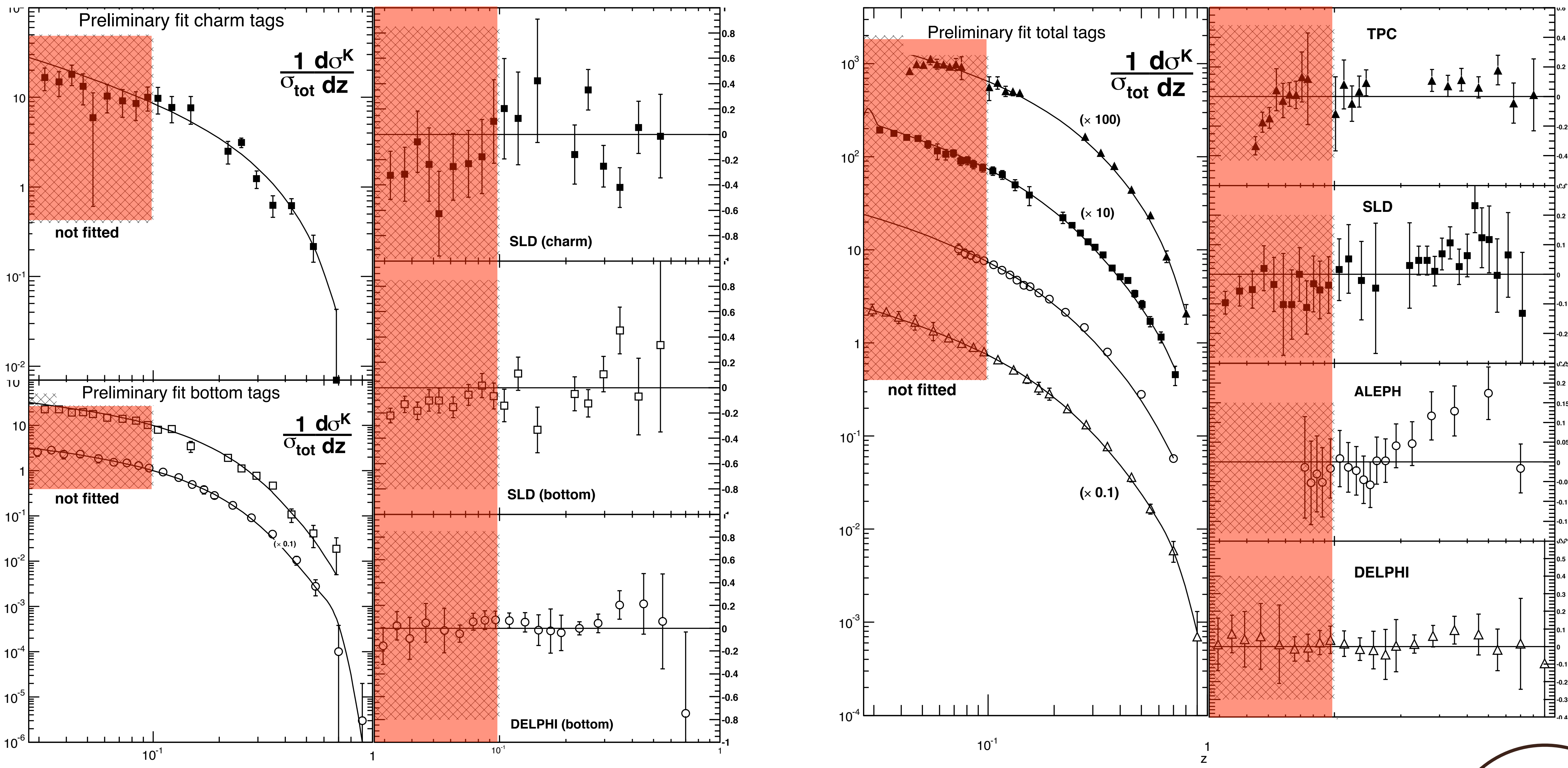
Preliminary



e+e- Fit

Preliminary

Preliminary



e+e- & Hermes

Preliminary

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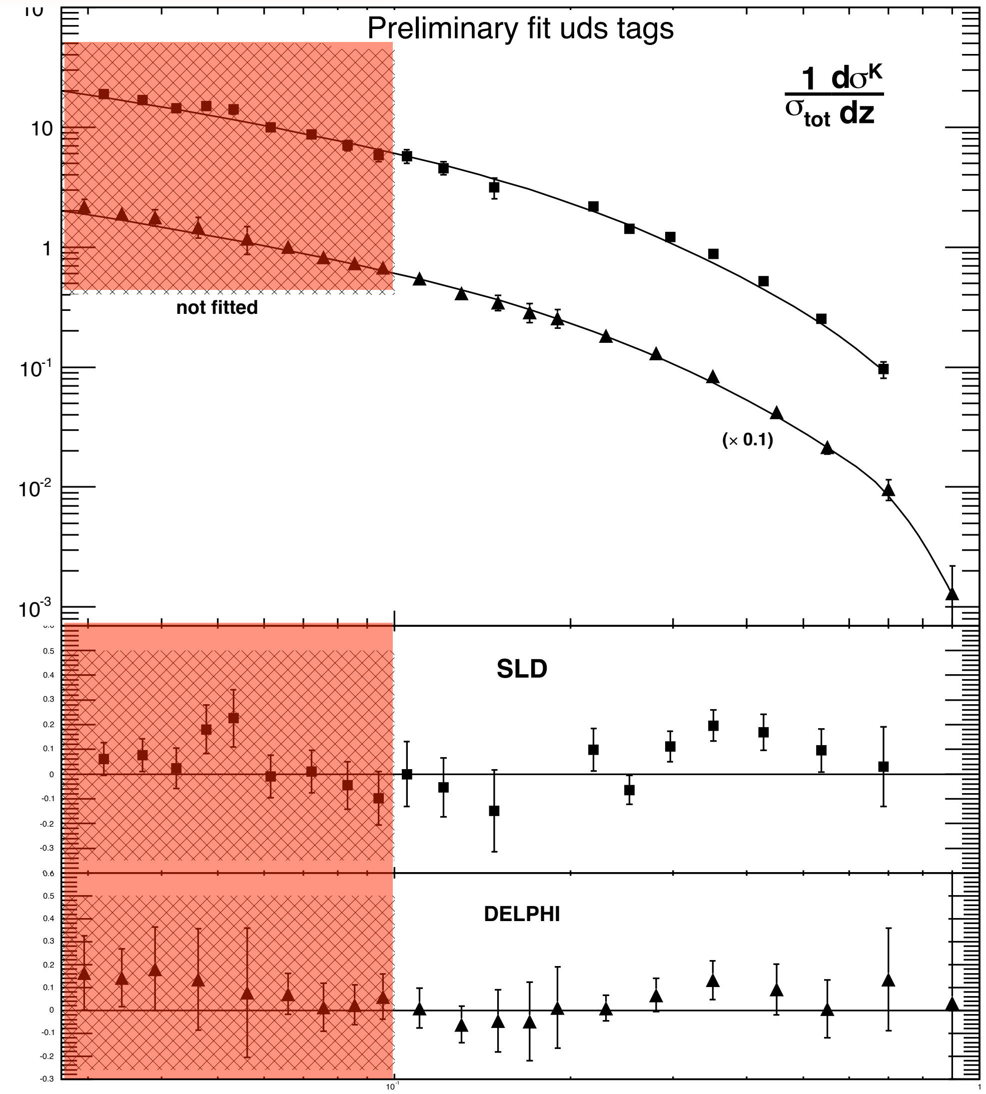
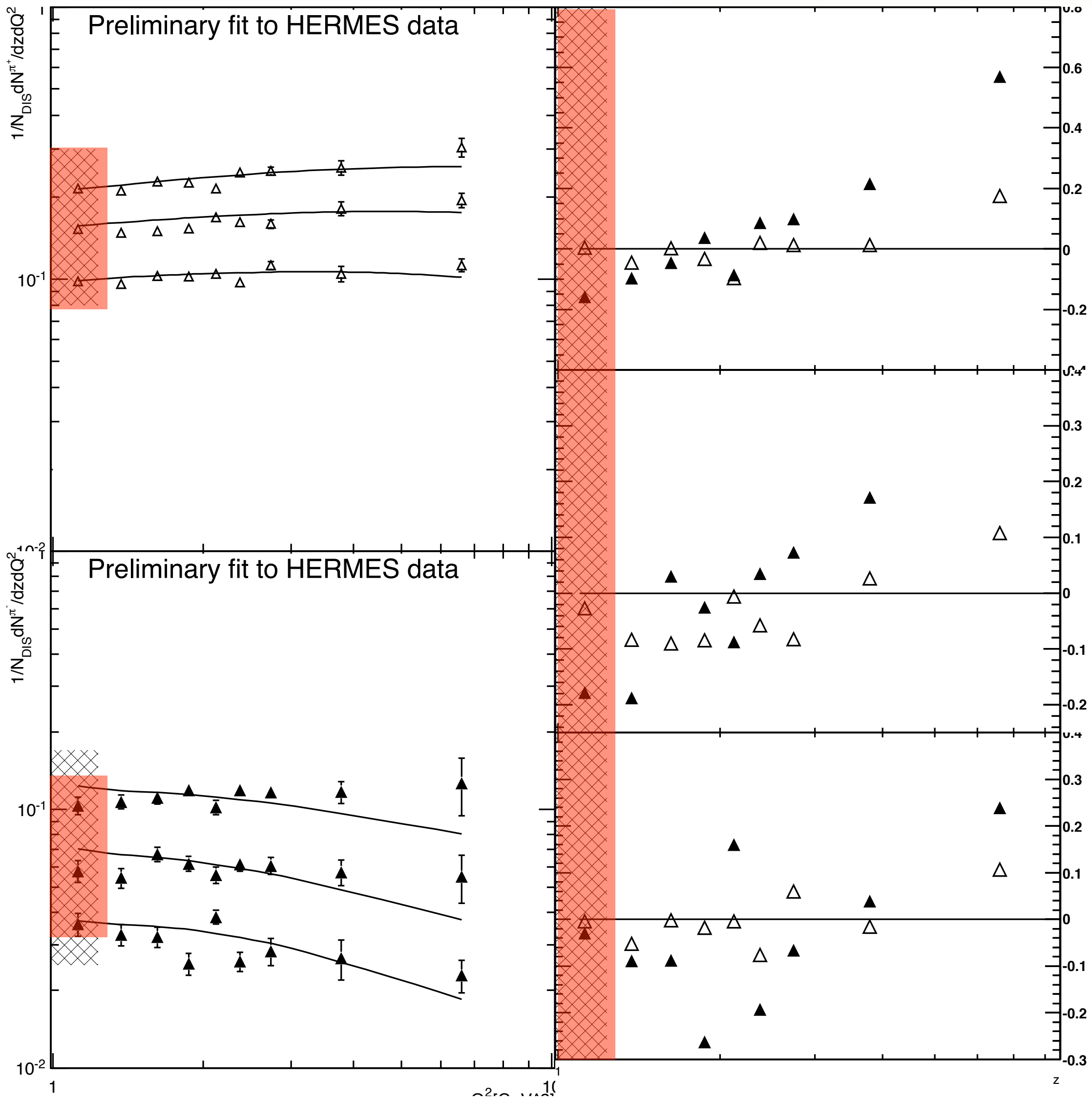
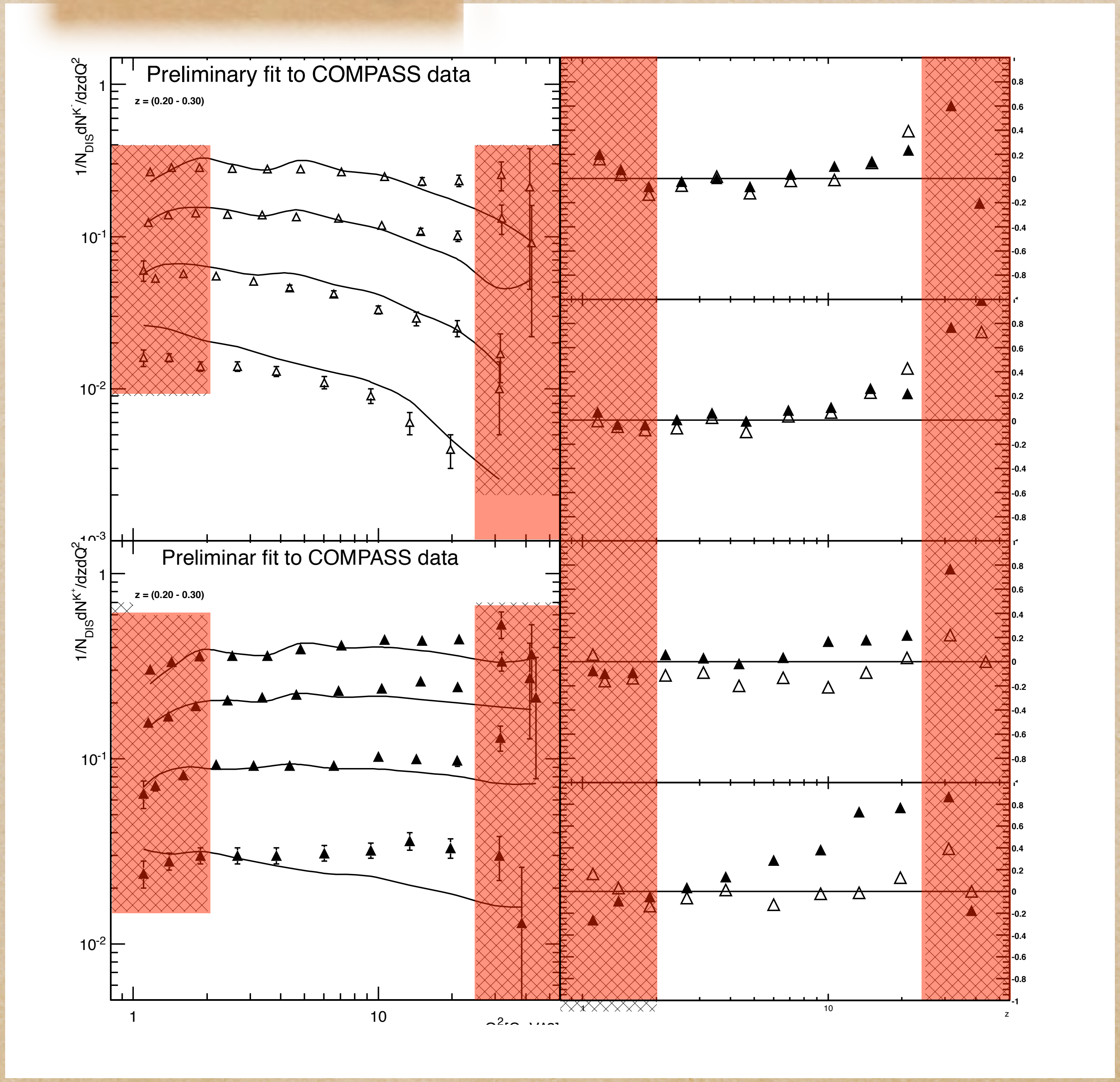
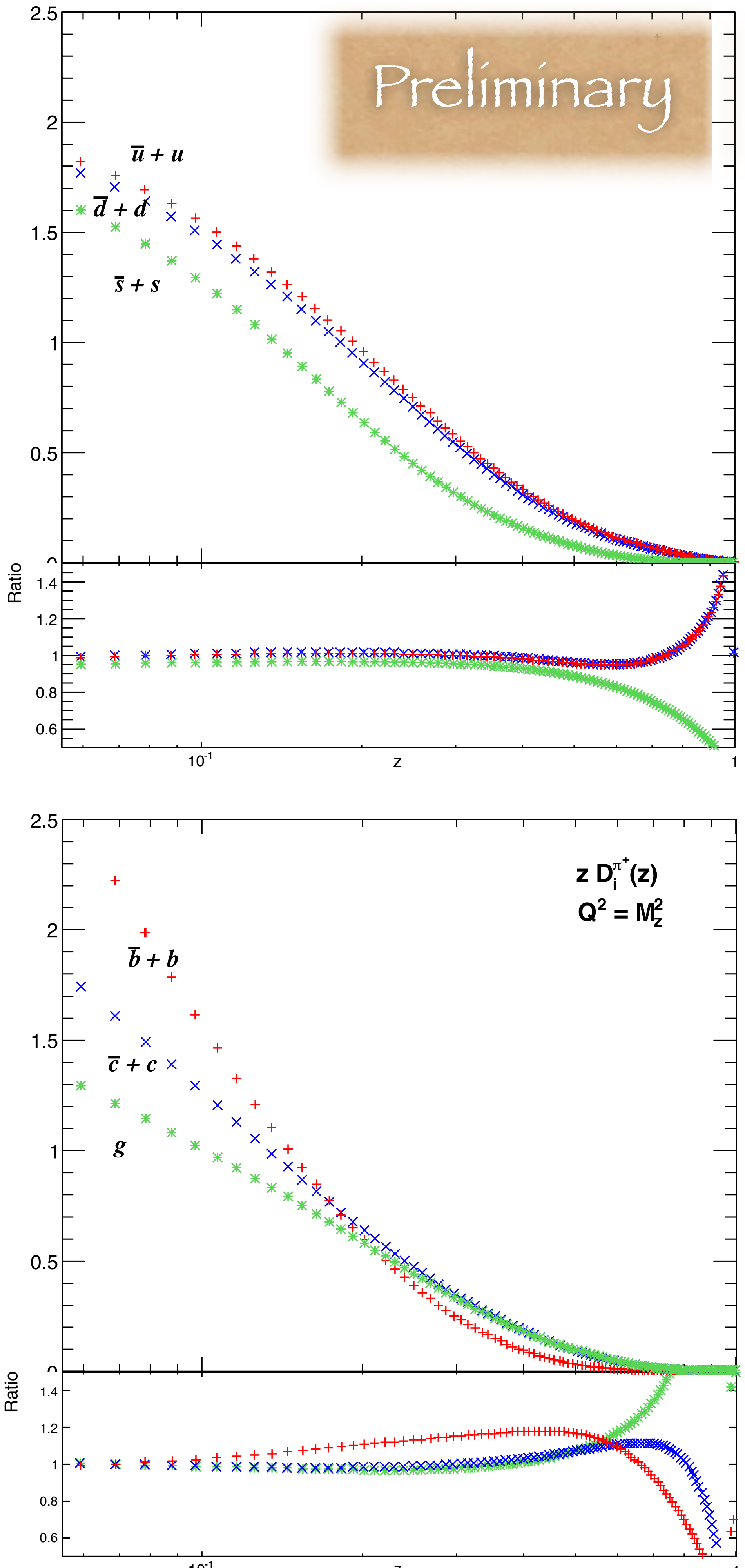


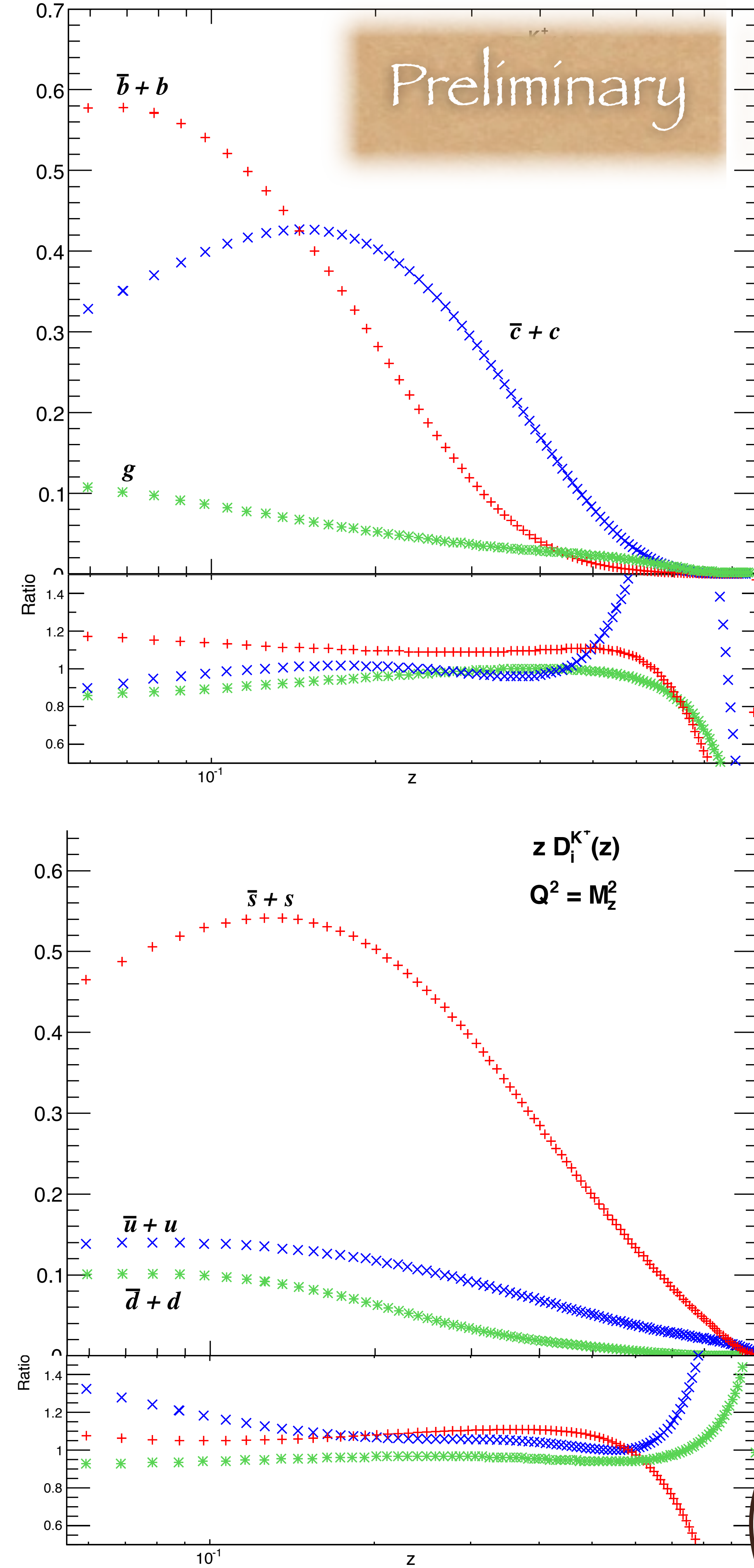


COMPASS

Preliminary




Preliminary
ū + u
d̄ + d
s̄ + s
Ratio
z
b̄ + b
c̄ + c
g
z D_i^{π+}(z)
Q² = M_z²


Preliminary
b̄ + b
c̄ + c
g
Ratio
z
z D_i^{K+}(z)
Q² = M_z²
s̄ + s
ū + u
d̄ + d

Conclusions & 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 when SIDIS and Hadron-Hadron collisions are considered in the global fit.

- Better understanding of Kaon FFs.
- Study of theoretical uncertainties with more data.

Thank you...