KAON MULTIPLICITIES IN SIDIS FROM COMPASS

Nicolas Pierre (CEA Saclay/Johannes Gutenberg Universität Mainz)
on behalf of the COMPASS collaboration

DIS 2019 - XXVII International Workshop on Deep Inelastic scattering and related subjects

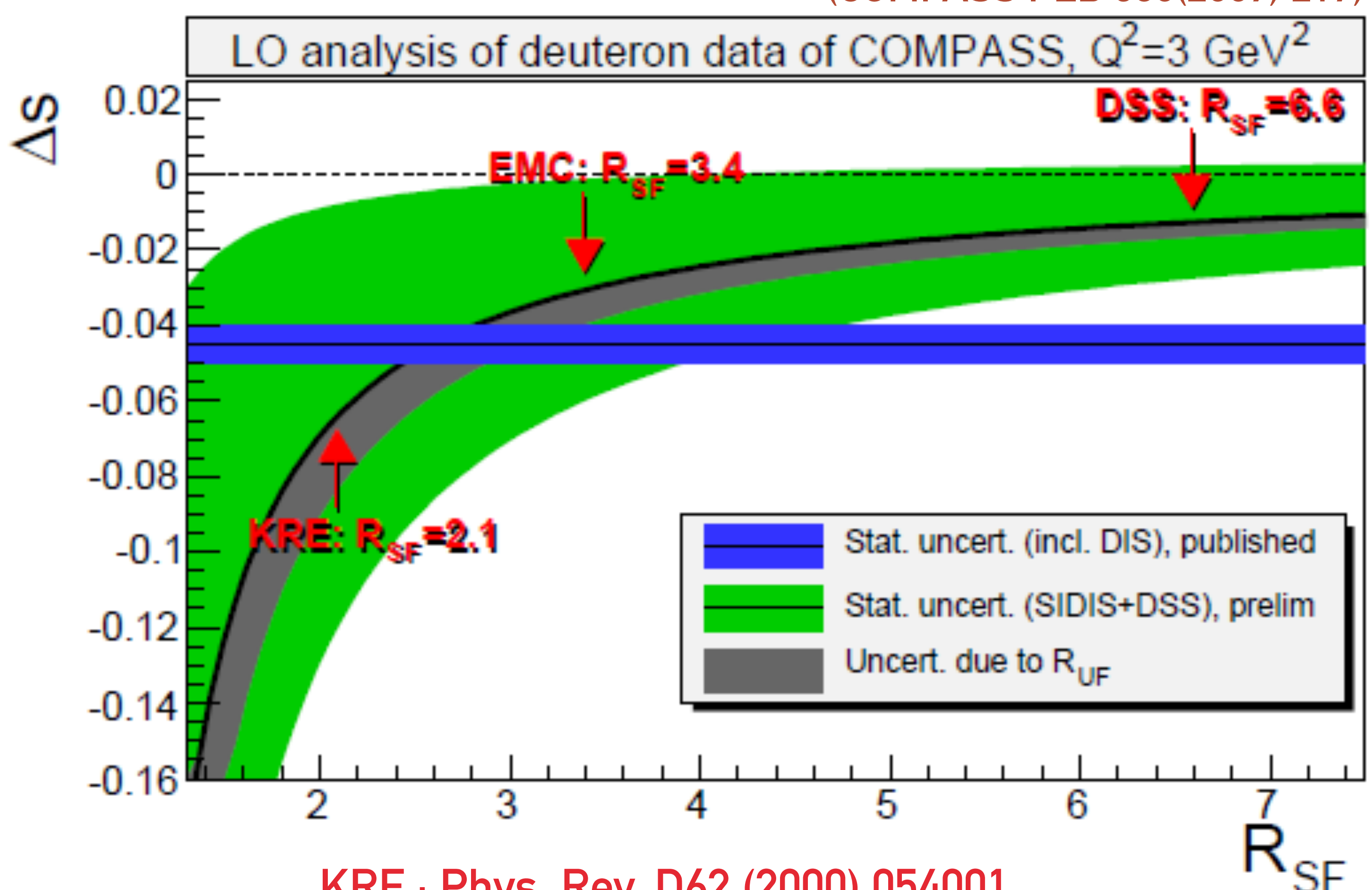
- *ΔS* form Semi-Inclusive Asymmetries strongly linked to quark fragmentation, especially the strange one, poorly known :

(COMPASS PLB 680 (2009) 217)

$$2\Delta S = f(R_{SF}), R_{SF} = \frac{\boxed{\int D_{\bar{s}}^{K^+}(z)dz}}{\boxed{\int D_u^{K^+}(z)dz}}$$

FFs

(COMPASS PLB 680(2009) 217)



Discrepancy on *ΔS* between inclusive and semi-inclusive.

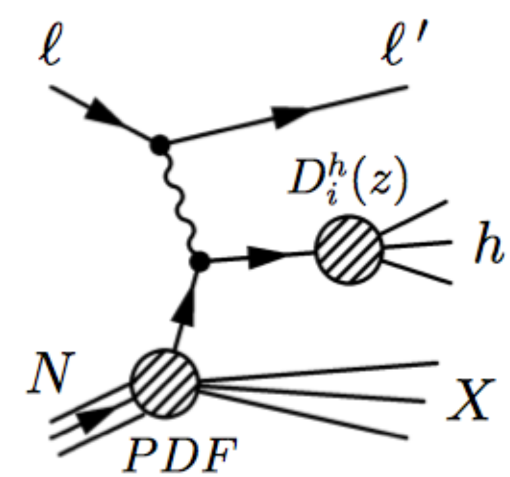
Goal is to extract better kaon fragmentation function from COMPASS data and determine R_{SF}.

KRE : Phys. Rev. D62 (2000) 054001
EMC : Nucl. Phys. B321 (1989) 541
DSS'07 : Phys. Rev. D75 (2007) 114010.

What is a SIDIS hadron multiplicity measurement ?

One can express the differential cross section for hadron production normalized to the differential inclusive DIS cross section by :

$$\frac{dM^h(x,Q^2,z)}{dz} = \frac{d^3\sigma^h(x,Q^2,z)/dxdQ^2dz}{d^2\sigma(x,Q^2)/dxdQ^2}$$



$$Q^2 = -q^2 = -(\mathrm{p}_l - \mathrm{p}_{l'})^2$$

$$x = \frac{Q^2}{2M_N(E_l - E_{l'})}$$

$$y = \frac{E_l - E_{l'}}{E_l}$$

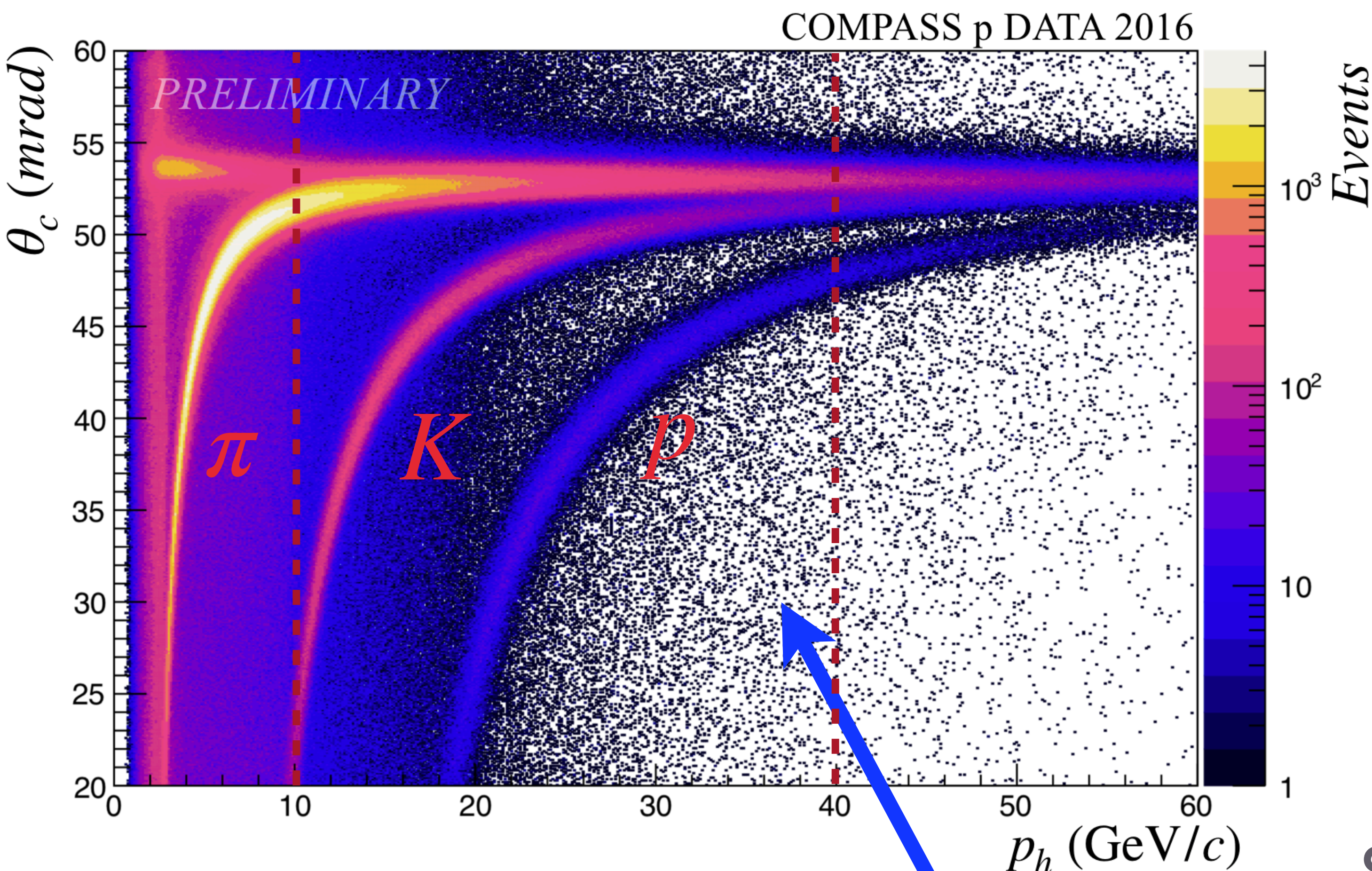
$$z = \frac{E_h}{E_l - E_{l'}}$$

This can also be expressed, in LO pQCD, as a function of Parton Distribution Functions (PDFs) and Fragmentation Functions (FFs) :

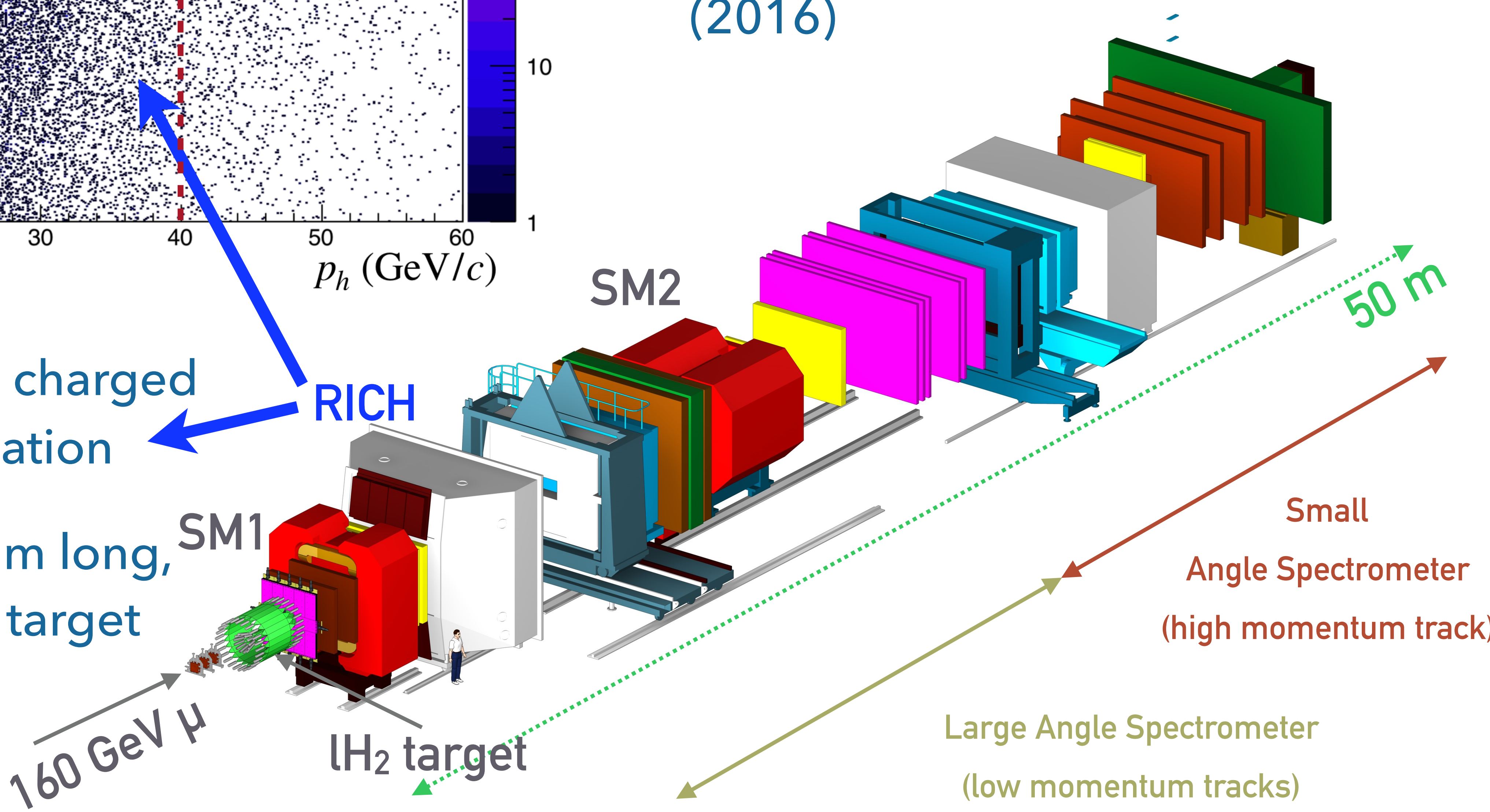
quark to hadron FFs

$$\boxed{\frac{dM^h(x,Q^2,z)}{dz} = \frac{\sum_q e_q^2 q(x,Q^2) D_q^h(z,Q^2)}{\sum_q e_q^2 q(x,Q^2)}}$$

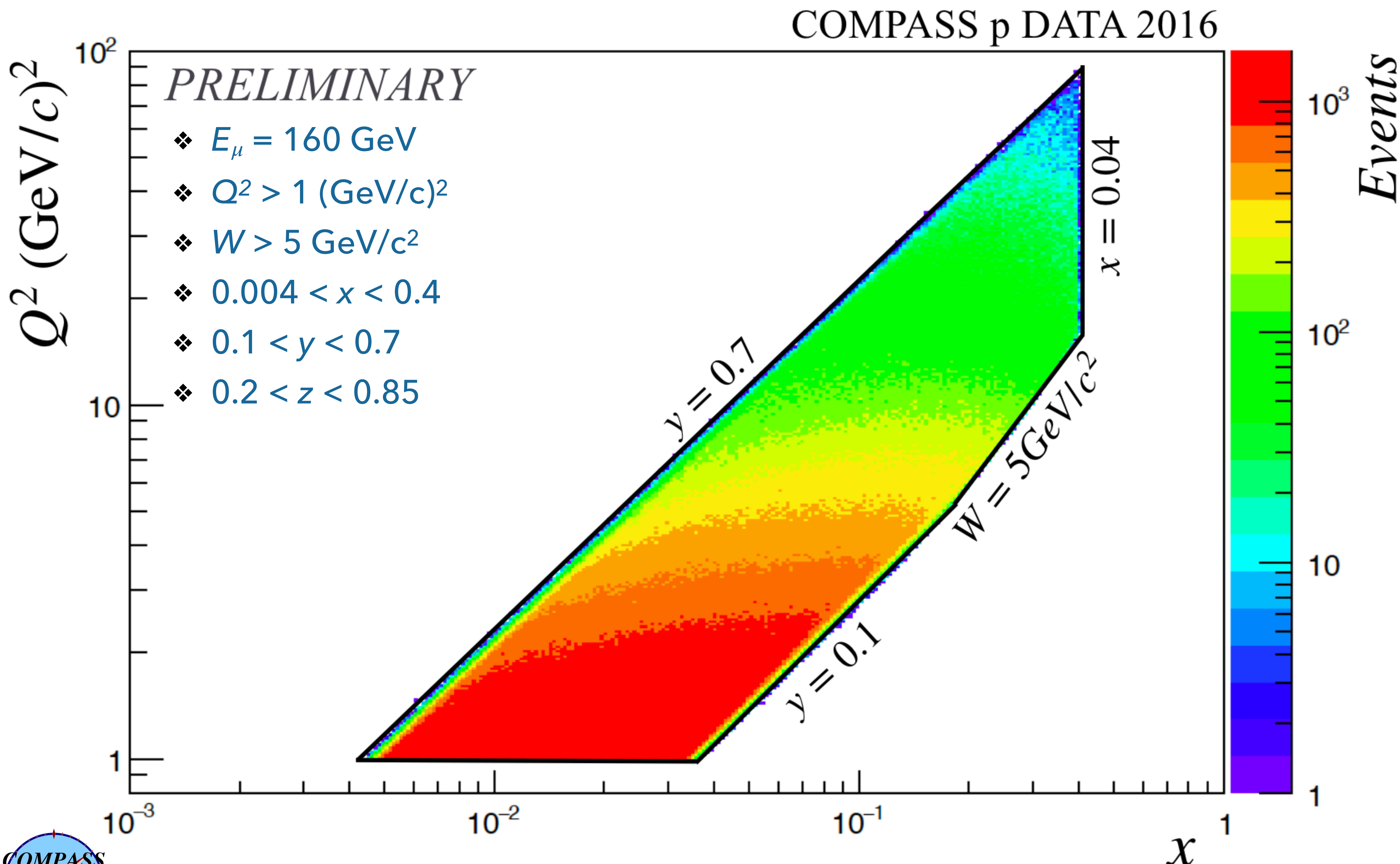
quark PDFs



- Fixed target experiment at CERN SPS
- Operates with muon or hadron beams
- This analysis : 160 GeV μ^+/μ^- beam (2016)



- RICH : excellent charged π, K, p discrimination
- This analysis : 2 m long, lH_2 pure proton target (2016)



- $E_\mu = 160$ GeV
- $Q^2 > 1$ (GeV/c)^2
- $W > 5$ GeV/c^2
- $0.004 < x < 0.4$
- $0.1 < y < 0.7$
- $0.2 < z < 0.85$

COMPASS Raw Data

- Event and particle reconstruction
- Event and particle selection
- RICH PID
- RICH unfolding

Final Multiplicities

$$\frac{dM^h(x,y,z)}{dz} = \frac{N^h(x,y,z)/\Delta z}{N^{DIS}(x,y)}$$

COMPASS Monte Carlo Simulation

Corrections

- Radiative correction
- Diffractive vector meson correction
- Electron contamination *
- Kinematic bin smearing
- Detector acceptance

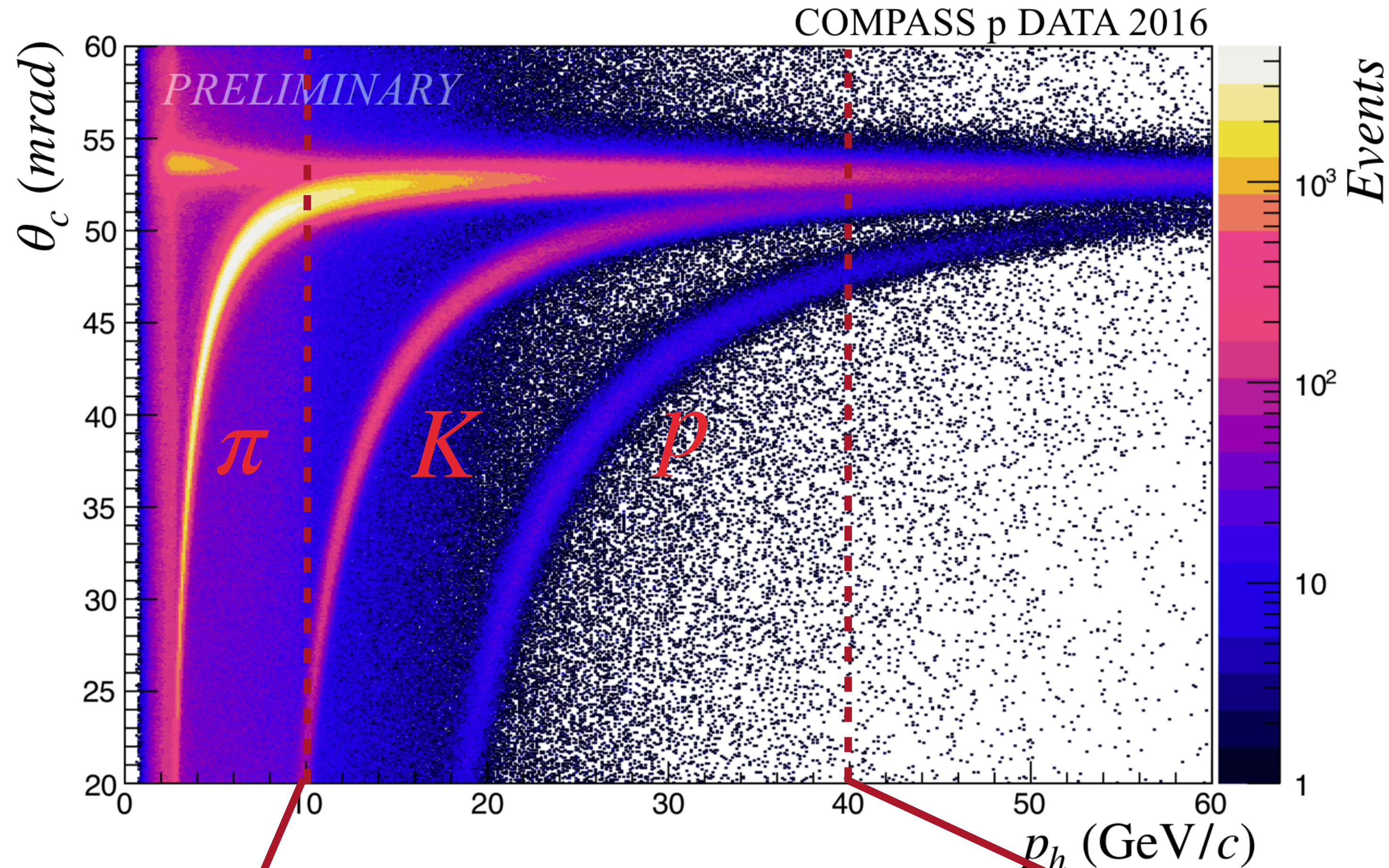
(* Because RICH discrimination btw e-/π only works at low momenta (<8 GeV), necessary for pion/unidentified hadron multiplicities)

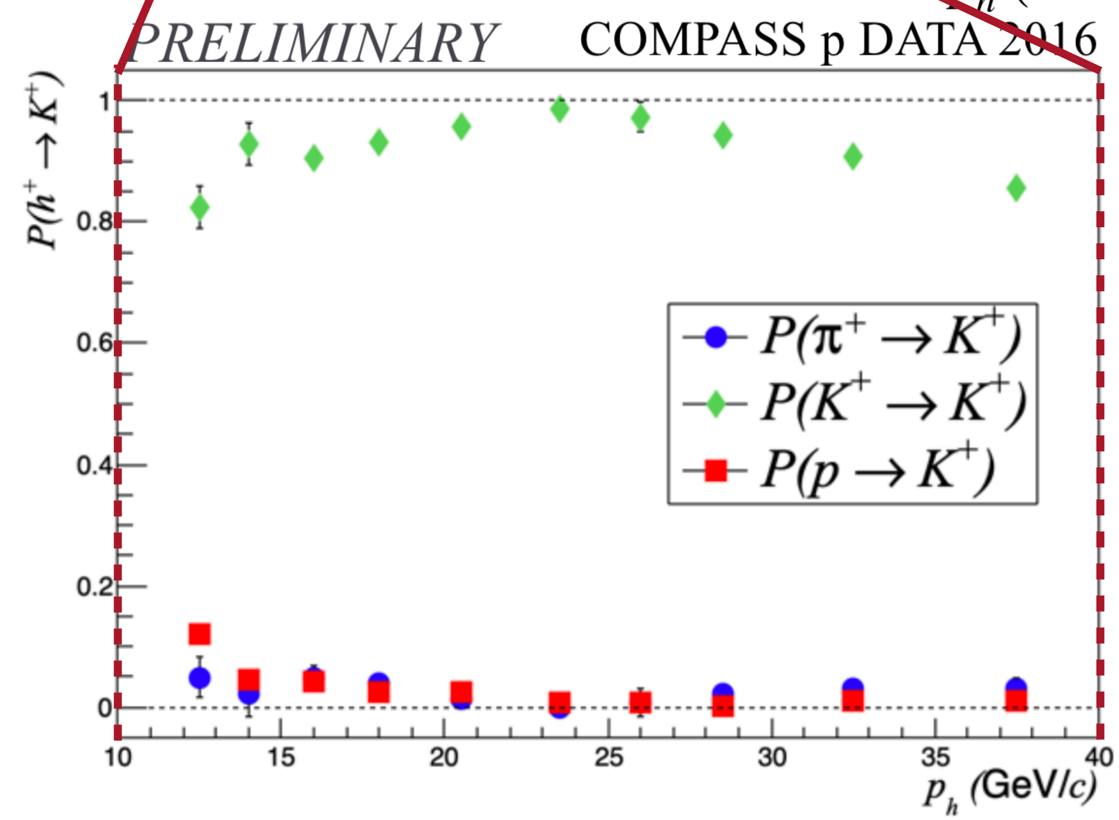
❖ Particle identification uses likelihoods based on the number and distribution of detected photons in RICH associated to a charged particle

❖ Purity of the charged hadron sample depends on the probabilities P of correct identification and misidentification

❖ The charged hadron yield is corrected using these probabilities by unfolding :

$$\begin{bmatrix} I_\pi \\ I_K \\ I_p \end{bmatrix} = M^{\pm} \begin{bmatrix} T_\pi \\ T_K \\ T_p \end{bmatrix} = \begin{bmatrix} P(\pi \to \pi) & P(\pi \to K) & P(\pi \to p) \\ P(K \to \pi) & P(K \to K) & P(K \to p) \\ P(p \to \pi) & P(p \to K) & P(p \to p) \end{bmatrix} \begin{bmatrix} T_\pi \\ T_K \\ T_p \end{bmatrix}$$





Correction for the limited geometrical acceptance, reconstruction and detector inefficiencies as well as resolutions.

Reconstructed multiplicities

Kinematic bin determined using reconstructed values

$$A(x,y,z) = \frac{M^h_{rec}}{M^h_{gen}} = \frac{N^h_{rec}(x_{rec}, y_{rec}, z_{rec})/N^{DIS}_{rec}(x_{rec}, y_{rec})}{N^h_{gen}(x_{gen}, y_{gen}, z_{gen})/N^{DIS}_{gen}(x_{gen}, y_{gen})}$$

Generated multiplicities

Kinematic bin determined using generated values

MC technical features :

- Events are generated with the DJANGOH generator (LEPTO + radiative events, SOPHIA for low energy hadronic final state, LUND MODEL, ARIADNE for parton cascade, http://wwwthep.physik.uni-mainz.de/~hspiesb/djangoh/djangoh.html).
- JETSET package for parton hadronization with COMPASS high-p_T tuning.
- Spectrometer simulated using TGEANT based on GEANT4.

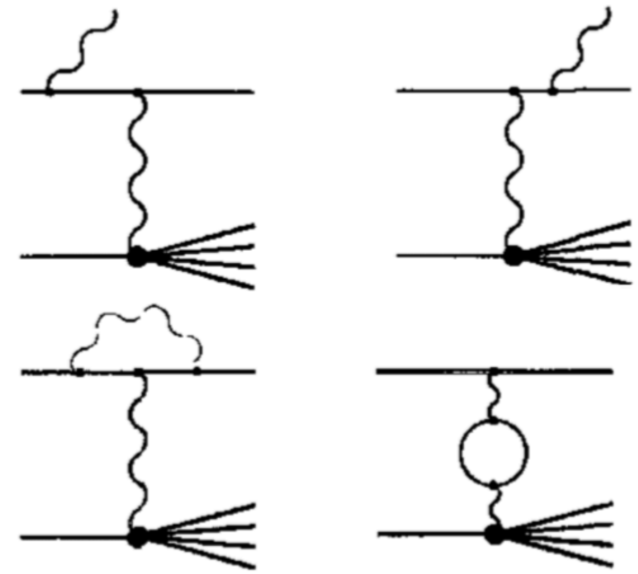
This research is part of the Blue Waters sustained-petascale computing project, which is supported by the National Science Foundation (awards OCI-0725070 and ACI-1238993) and the state of Illinois. Blue Waters is a joint effort of the University of Illinois at Urbana-Champaign and its National Center for Supercomputing Applications. This work is also part of the "Mapping Proton Quark Structure using Petabytes of COMPASS Data" PRAC allocation supported by the National Science Foundation (award number OCI 1713684).

New way of computing radiative corrections including z dependence.

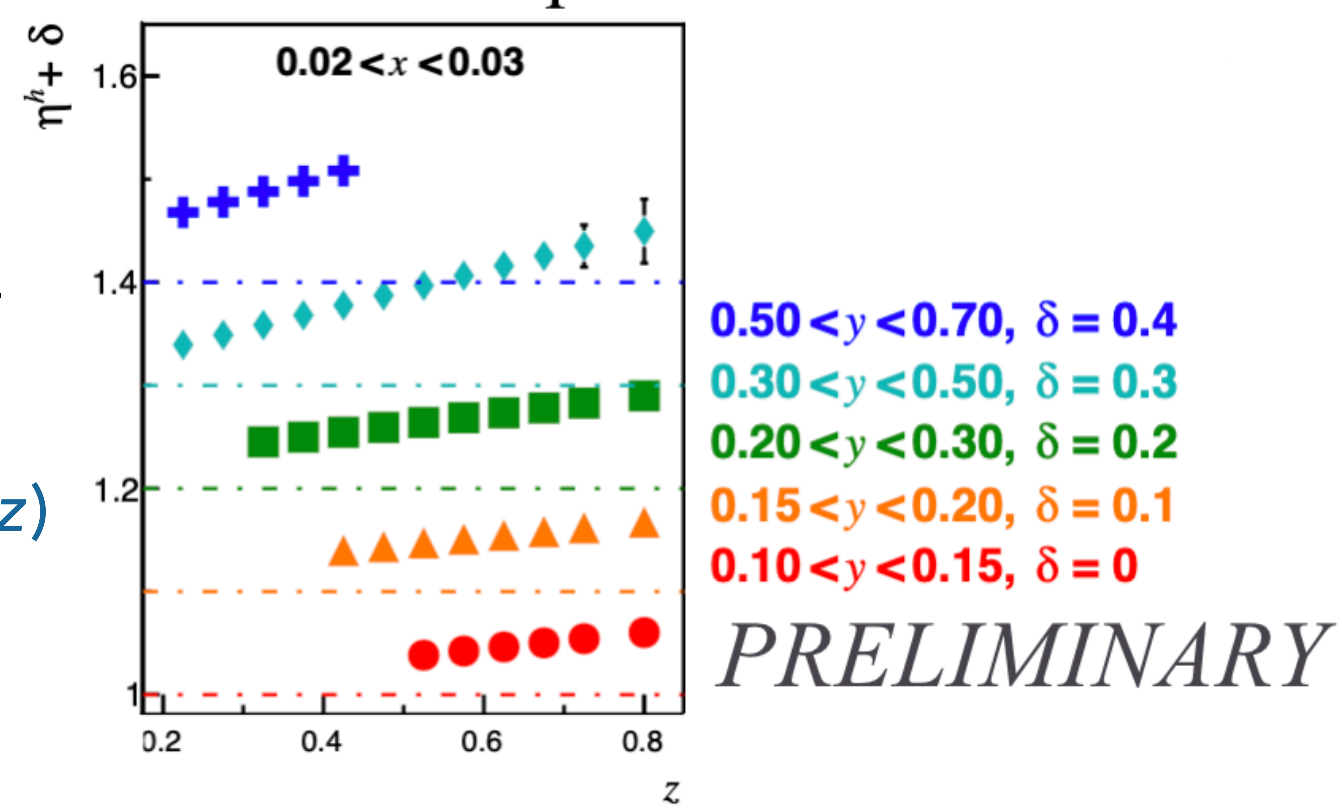
Use of the DJANGOH generator to compute (x,y,z) radiative corrections (H. Spiesberger, N. Pierre)

Radiative processes considered :

- ❖ Initial and final state radiation
- ❖ Vertex correction
- ❖ Vacuum polarisation



COMPASS p DATA 2016



Correction factors are applied directly to multiplicities :

$$\eta^h(x,y,z) = \frac{N^h_{BORN}(x,y,z)/N^h_{BORN+Corrections}(x,y,z)}{N^{DIS}_{BORN}(x,y)/N^{DIS}_{BORN+Corrections}(x,y)}$$

Corrections going from 0% (low y and low z) to 20% (high y and high z).

Presence of hadrons from diffractive vector mesons in the data ⇒ No parton hadronization.

Correction factor to the pion and kaon yield is determined using DJANGOH (SIDIS) and HEPGEN++ (Diffractive processes) Monte-Carlo, with each sample normalized using their respective luminosities.

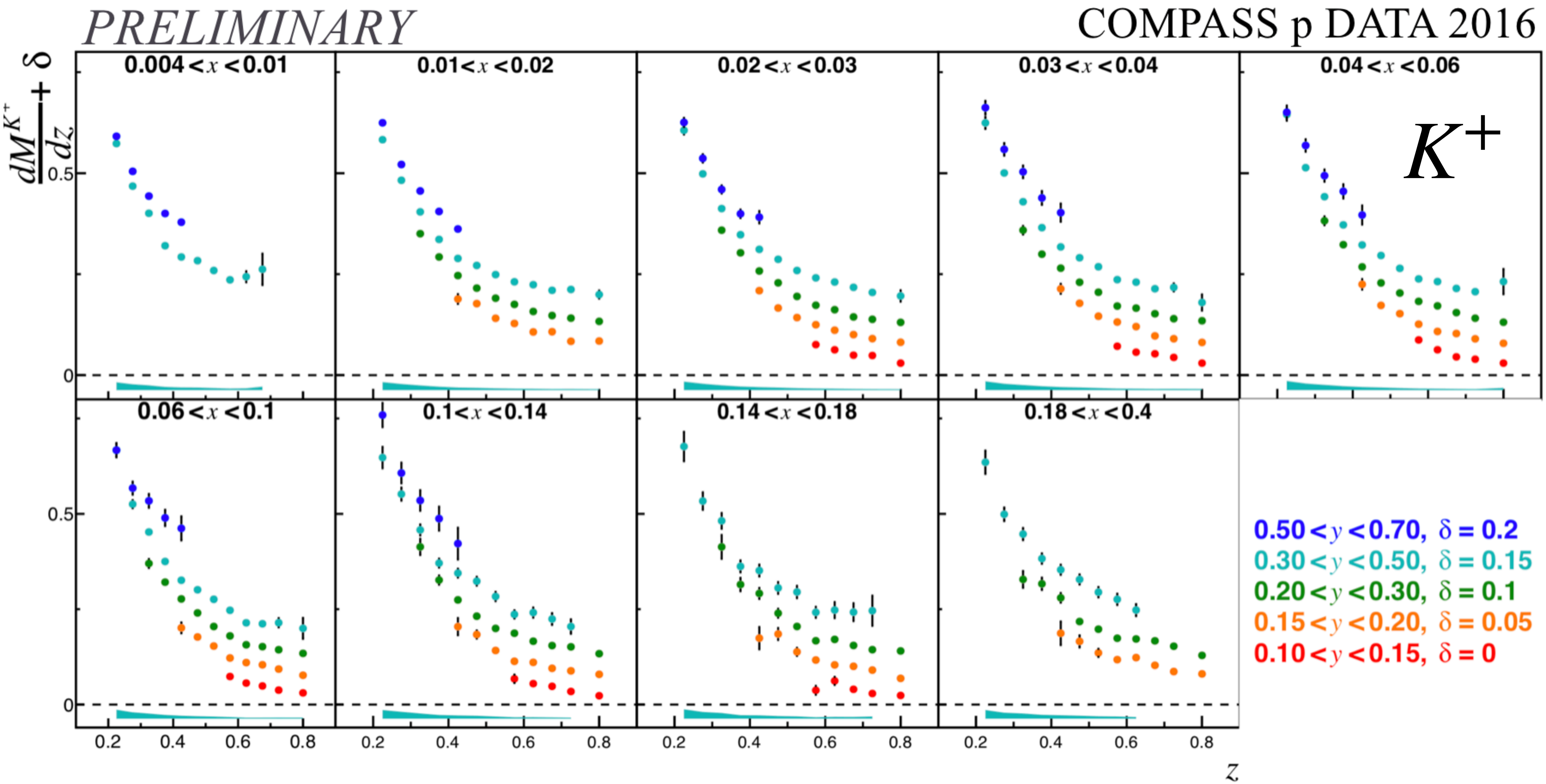
Correction for the number of kaons and the number of DIS events are :

$$f_{\Phi}^{K}(x,y,z) = \frac{N^{K}_{\Phi,HEPGEN++}(x,y,z)}{N^{K}_{\Phi,HEPGEN++}(x,y,z) + N^{K}_{DJANGOH}(x,y,z)}$$

$$f_{\Phi}^{DIS}(x,y,z) = \frac{N^{DIS}_{\Phi,HEPGEN++}(x,y,z)}{N^{DIS}_{DJANGOH}(x,y,z) + N^{DIS}_{\rho^0,HEPGEN++}(x,y,z) + N^{DIS}_{\Phi,HEPGEN++}(x,y,z)}$$

$$C^{K}_{DVM}(x,y,z) = \frac{1 - f^{K}_{\Phi}(x,y,z)}{1 - f^{DIS}_{\Phi}(x,y,z)}$$

The corrections are < 10% in most bins except low x, mid z where it can reach ~ 20%.



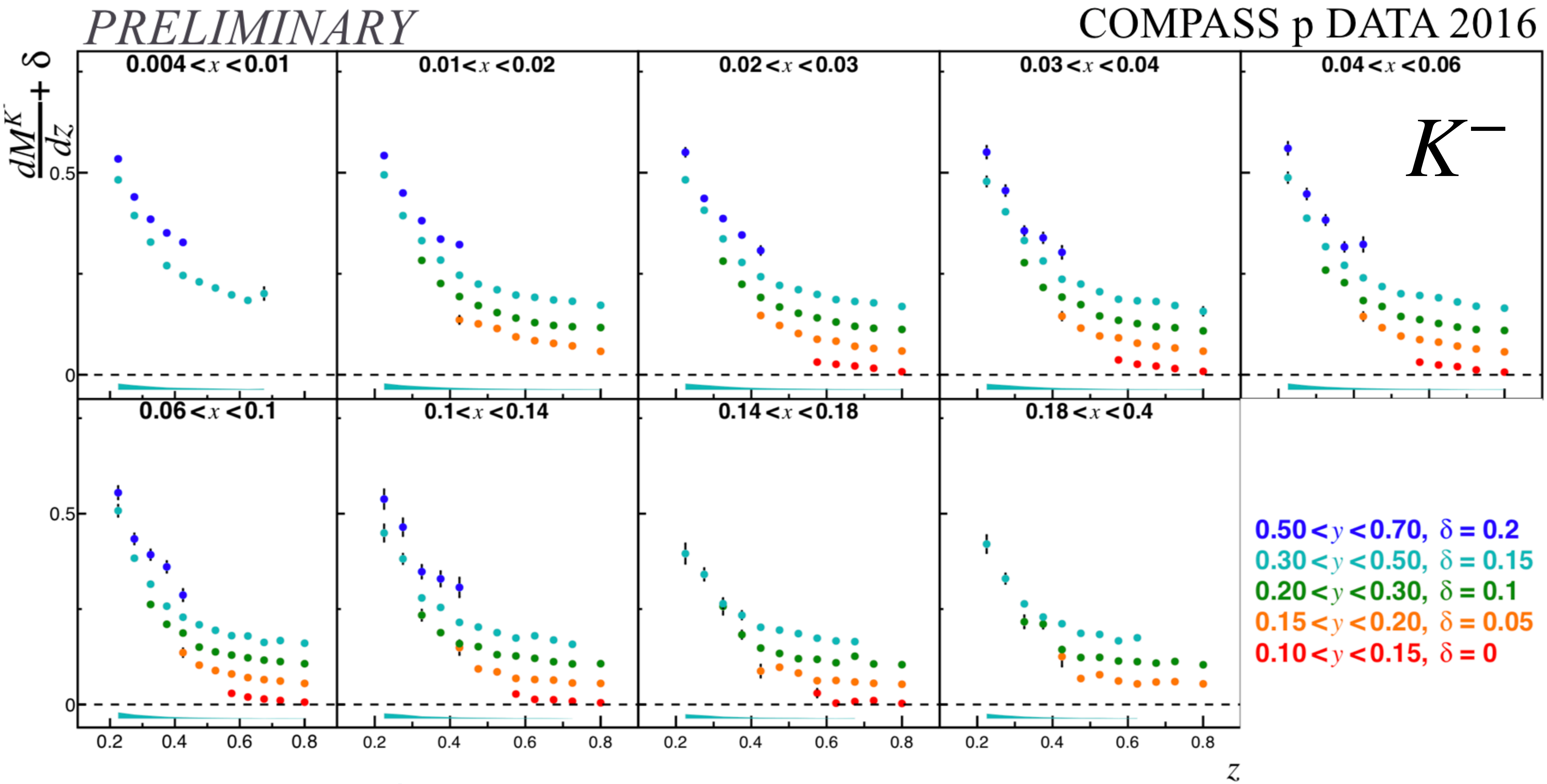
<u>Systematic studies :</u>

Acceptance : 10%

RICH PID/Efficiency for $K^{\pm}$: 0.1% (low *y*) - 7% (high *y*)

Diffractive VM correction : 6% max (low *x*, mid *z*)

x, *y*, *z* 3D-binning
300 kinematic bins
Strong *z*-dependance



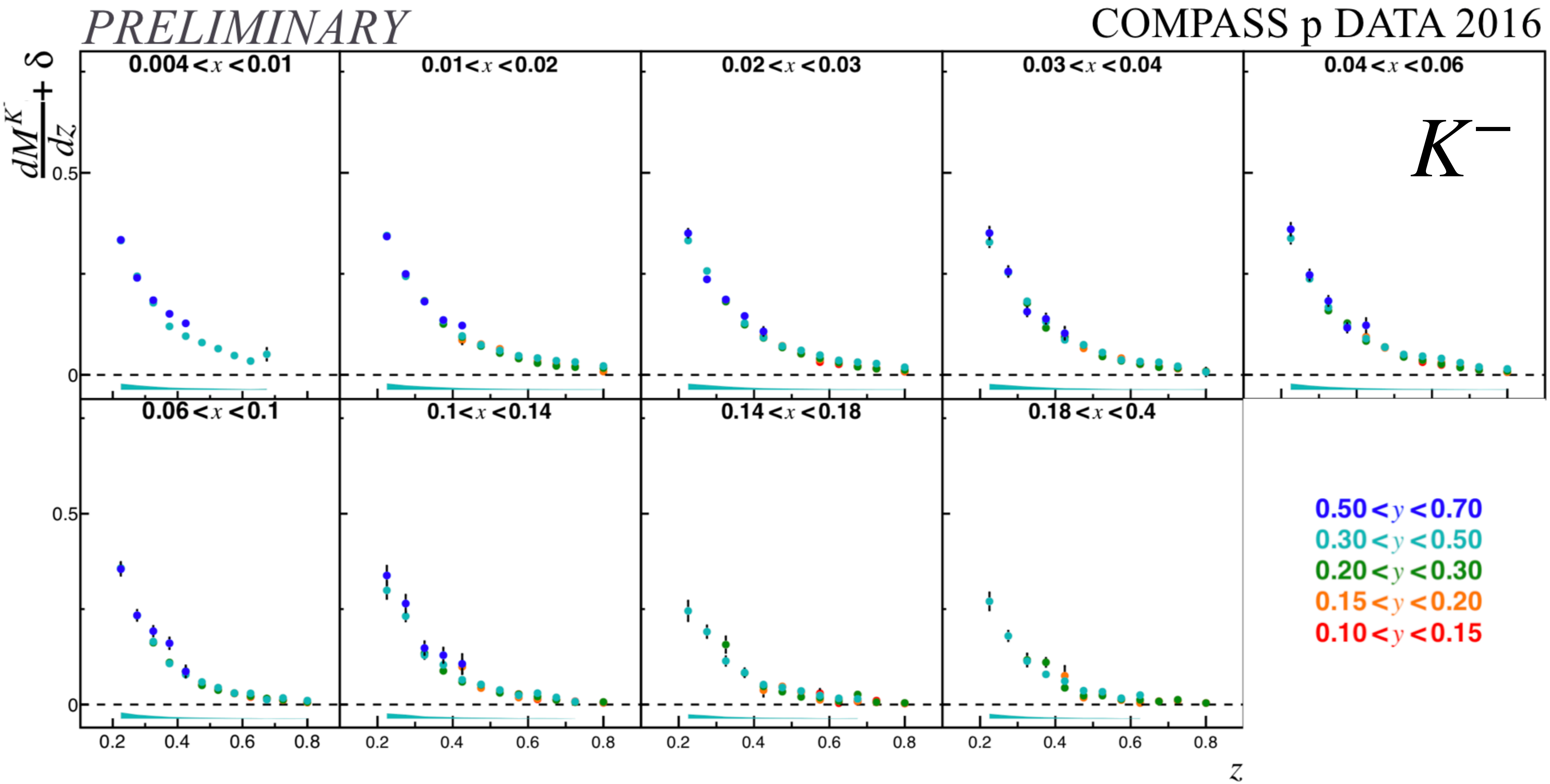
Systematic studies :

Acceptance : 10%

RICH PID/Efficiency for $K^\pm$: 0.1% (low y) - 7% (high y)

Diffractive VM correction : 6% max (low x, mid z)

x, y, z 3D-binning
300 kinematic bins
Strong z-dependance



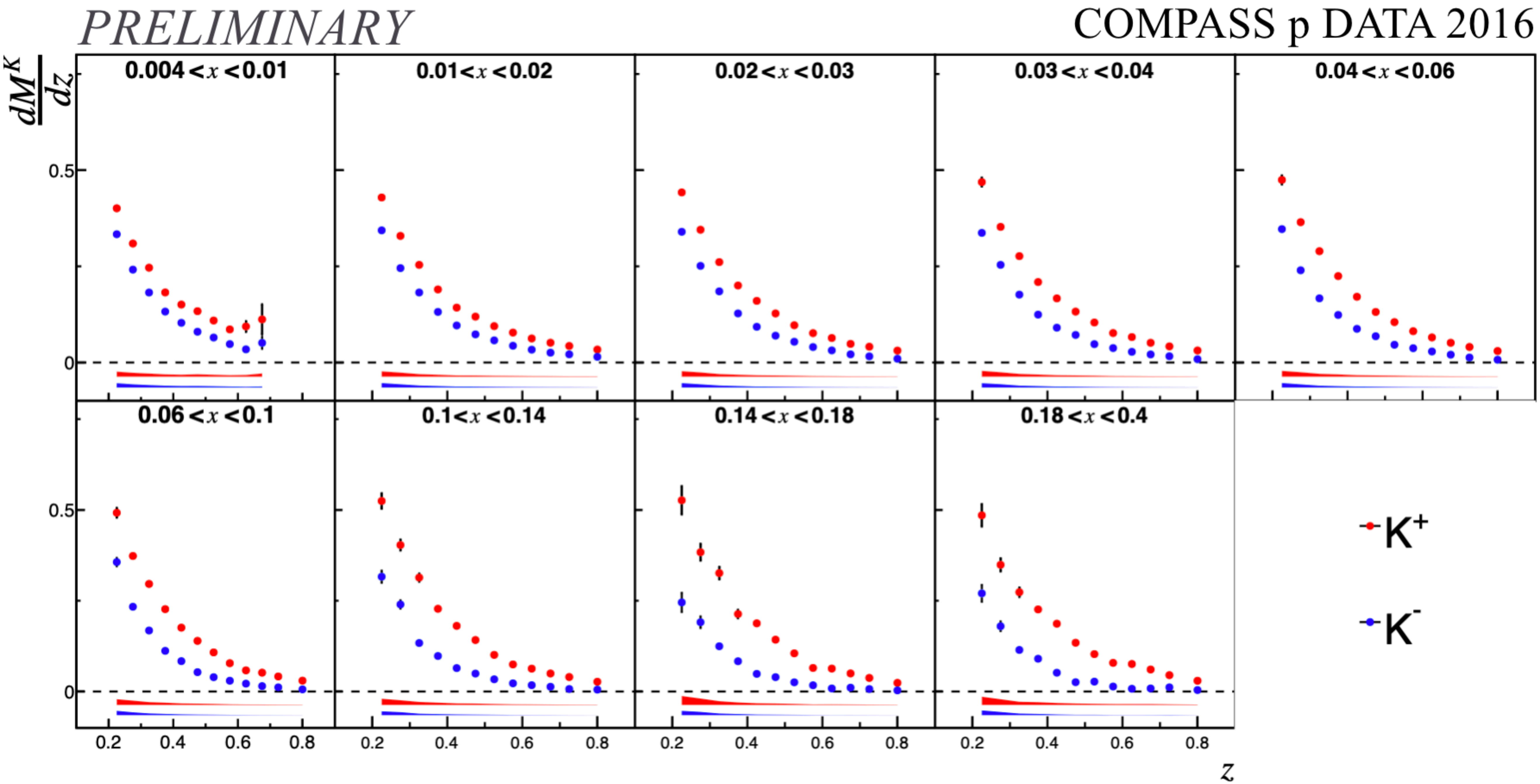
<u>Systematic studies :</u>

Acceptance : 10%

RICH PID/Efficiency for $K^{\pm}$: 0.1% (low *y*) - 7% (high *y*)

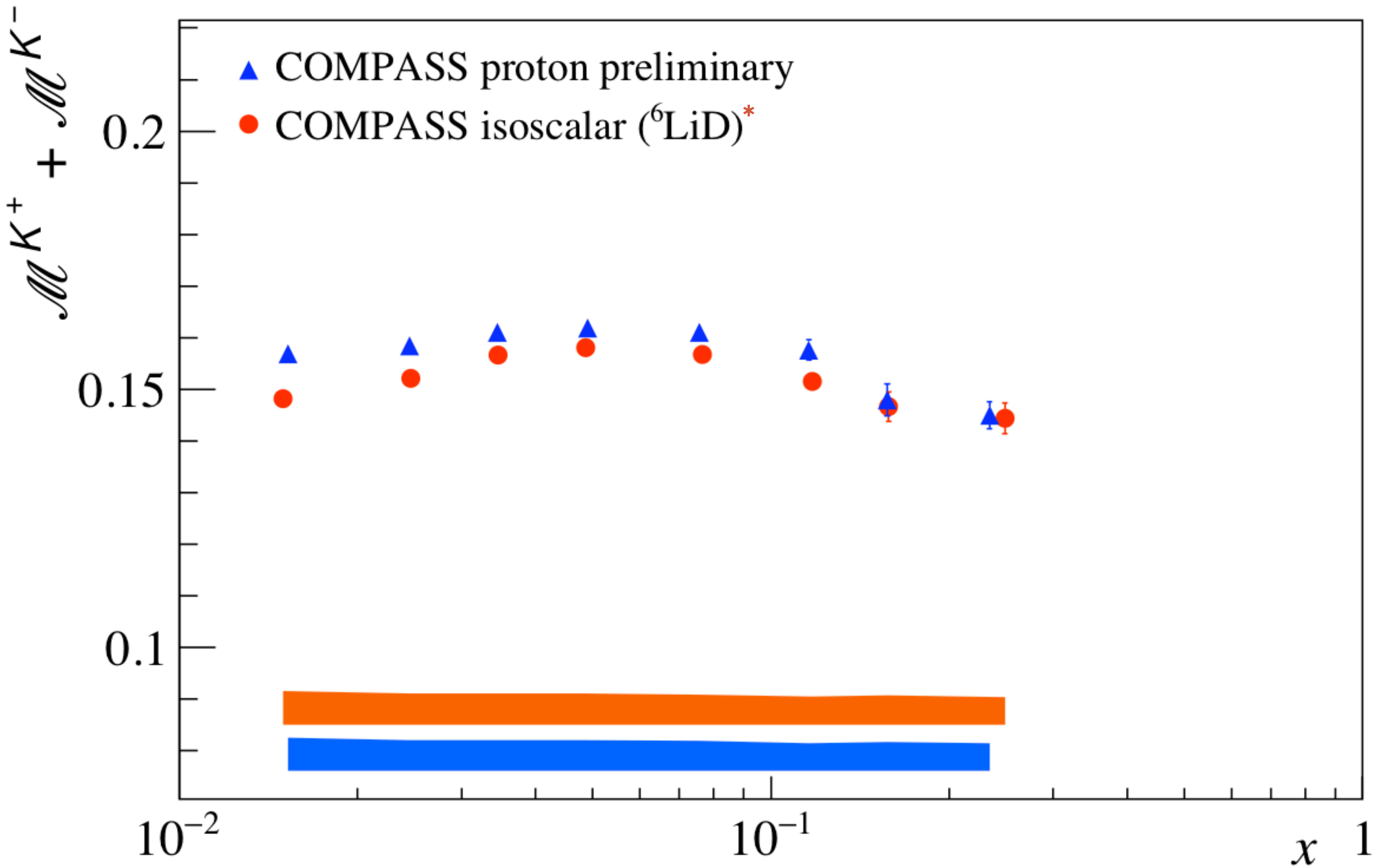
Diffractive VM correction : 6% max (low *x*, mid *z*)

x, *y*, *z* 3D-binning
300 kinematic bins
Strong *z*-dependance



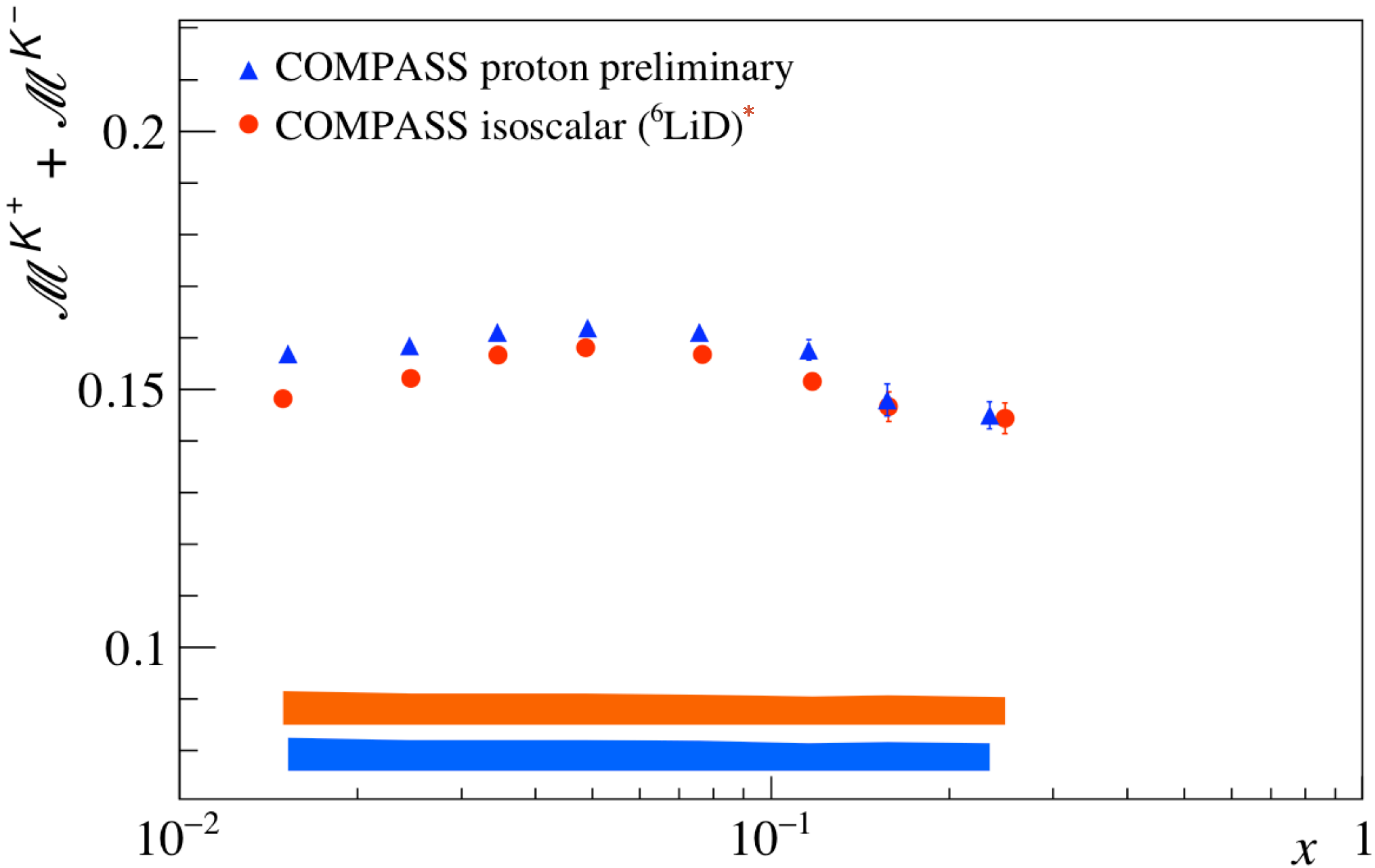
$$\left\langle \frac{dM^K(x,y,z)}{dz} \right\rangle_y = \left\langle \frac{N^h(x,y,z)/\Delta z}{N^{DIS}(x,y)} \right\rangle_y$$

x,z binning (*y*-averaged)
212 kinematic bins
Strong *z*-dependance



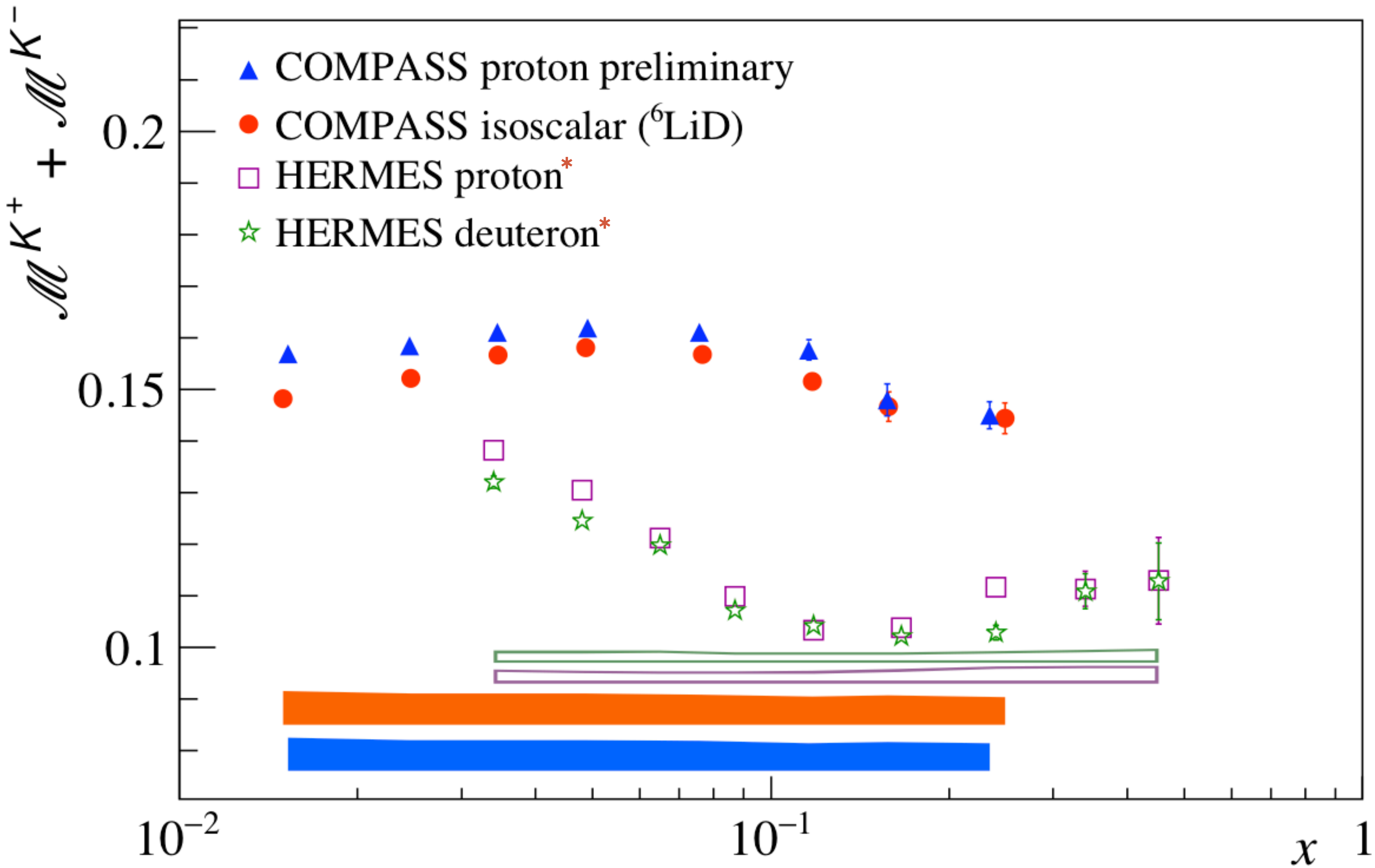
$$\mathcal{M}^{K^+} + \mathcal{M}^{K^-} = \int_{0.2}^{0.85} \left\langle \frac{dM^{K^+}(x,y,z)}{dz} \right\rangle_y dz + \int_{0.2}^{0.85} \left\langle \frac{dM^{K^-}(x,y,z)}{dz} \right\rangle_y dz$$

*PLB 767 (2017) 133



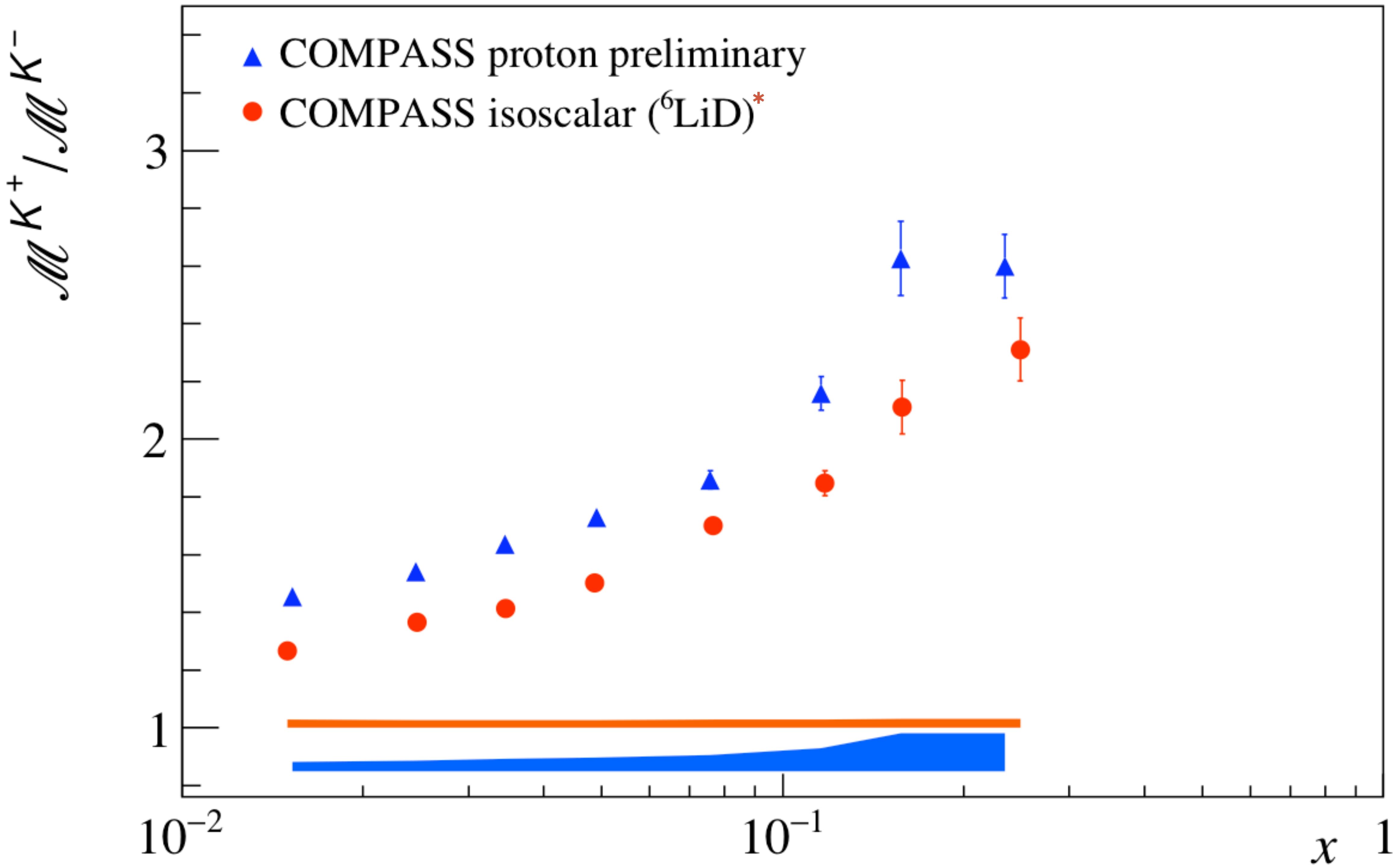
Results of kaon sum for proton target expected to be 5% above our results for isoscalar target from LO estimations (different PDF combinations involved).

*PLB 767 (2017) 133



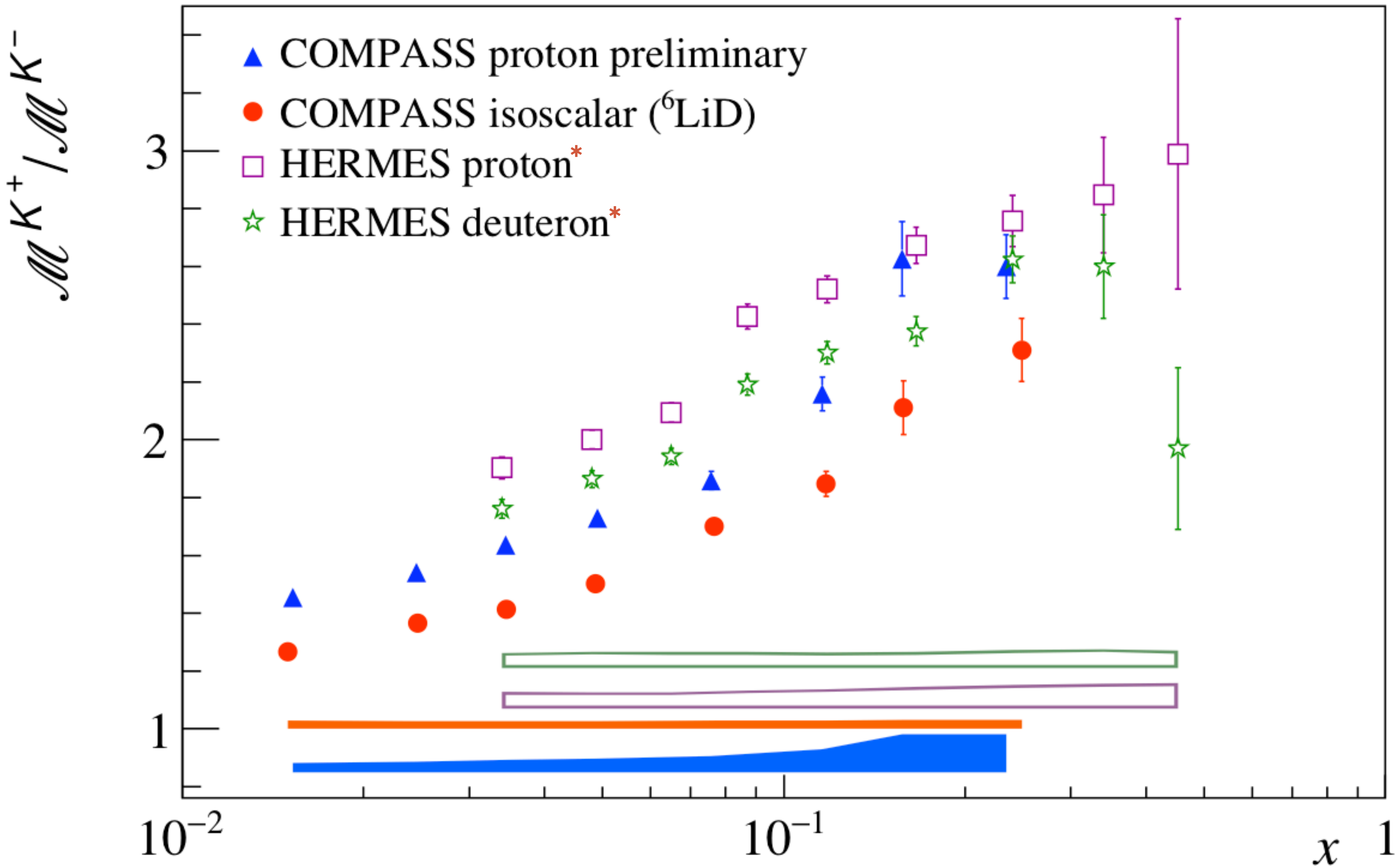
Discrepancy with HERMES results for proton target, already seen with results for isoscalar/deuteron target (but perhaps can be explained *cf. M. Stolarski talk*).

*PRD 89 (2014) 097101



Results of kaon ratio for proton target expected to be 10% above our results for isoscalar target from LO estimations (different PDF combinations involved).

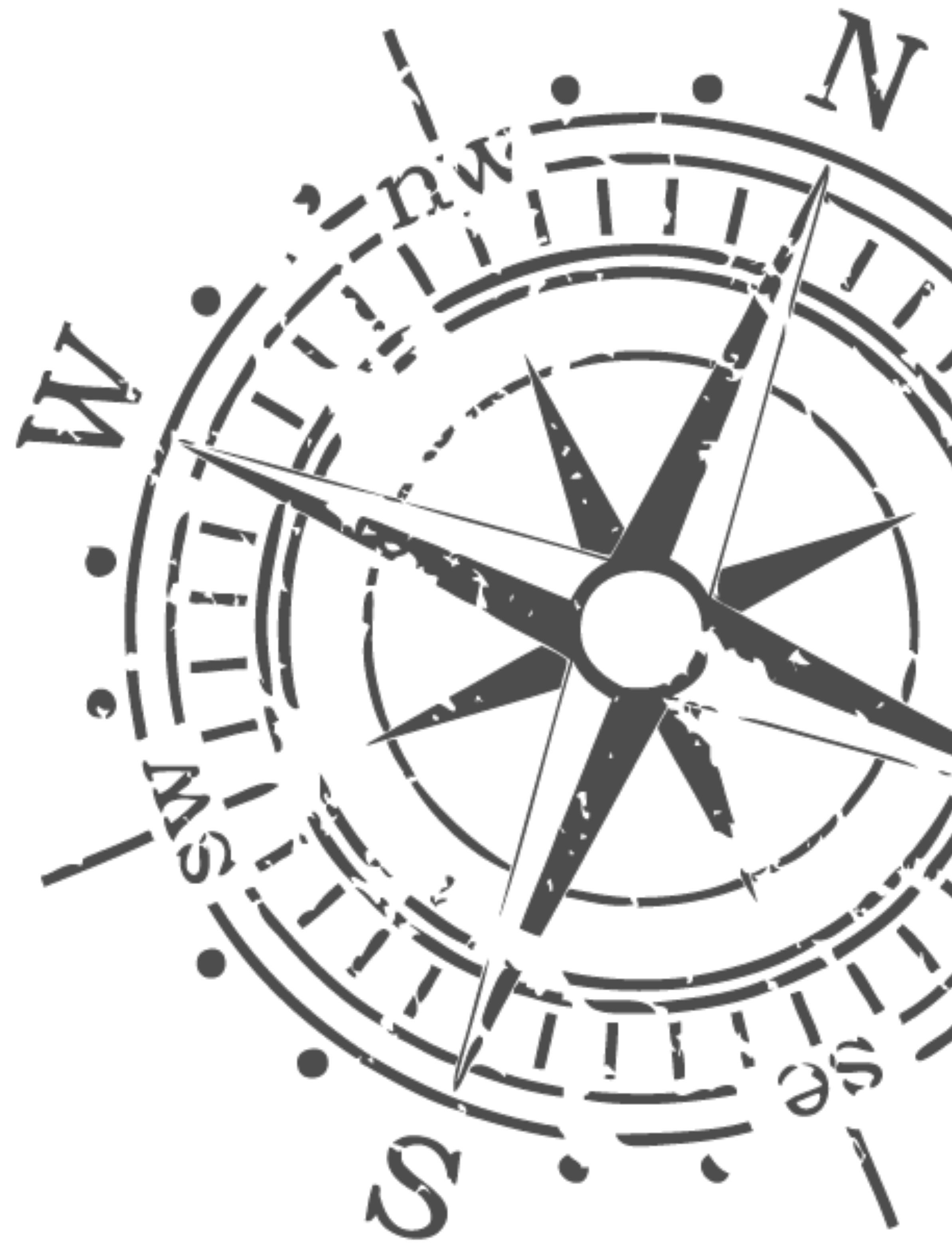
*PLB 767 (2017) 133



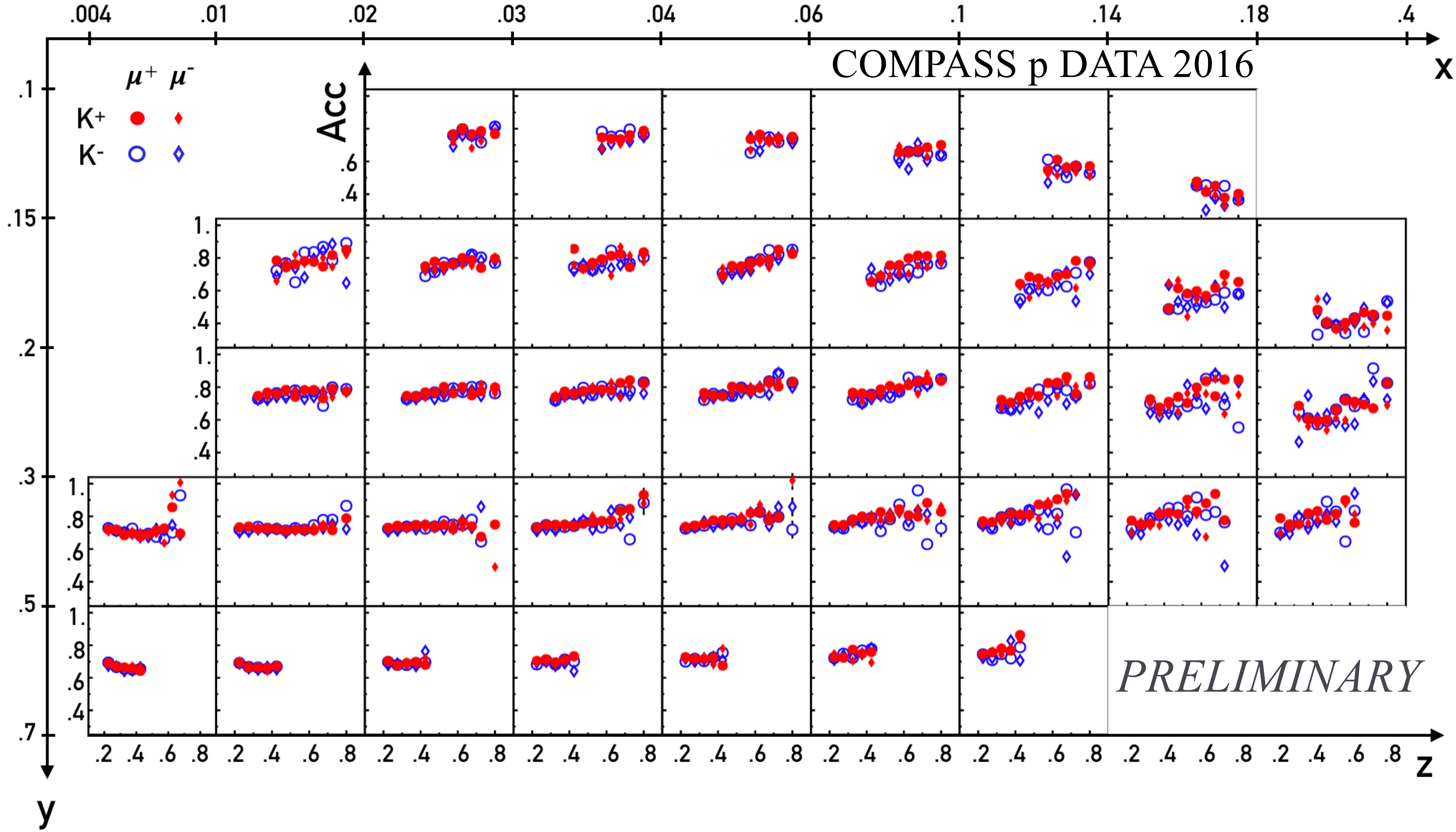
Discrepancy with HERMES results for proton target, already seen with results for isoscalar/deuteron target (but perhaps can be explained *cf. M. Stolarski talk*).

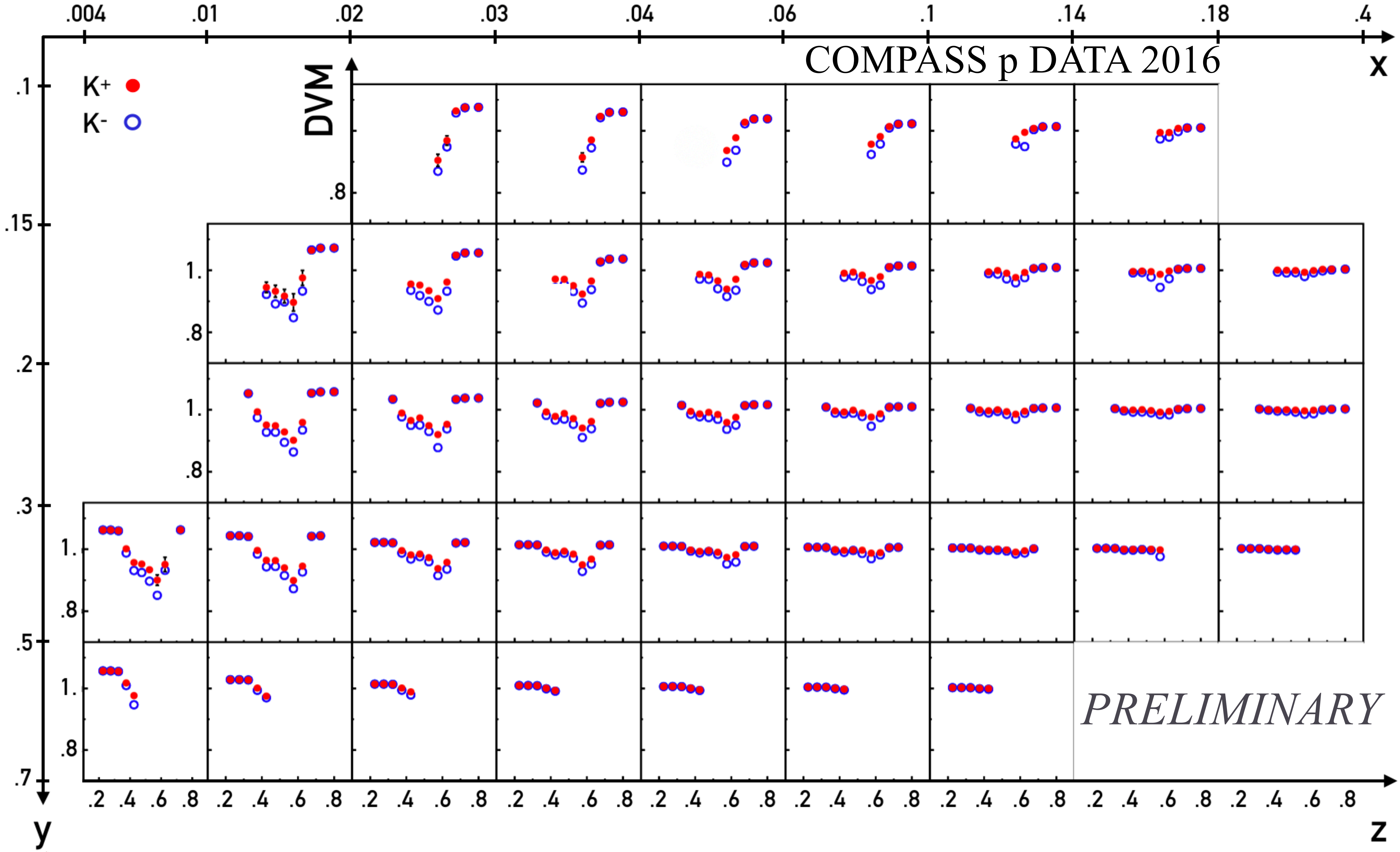
*PRD 89 (2014) 097101

- Charged kaon multiplicities were measured from COMPASS 2016 data with a pure proton lH_2 target and 160 GeV μ^+ and μ^- beam.
- Multiplicities were measured in 300 3-D kinematic bins of x, y and z.
- Preliminary proton results agree with COMPASS results with isoscalar ^6LiD target.
- Large discrepancy with respect to HERMES $K^\pm$ results obtained with a proton target.
- Outlook/In progress :
  - Finalizing pions, protons.
  - Use the full statistic of 2016 and 2017 data (using ~1/4th at the moment).

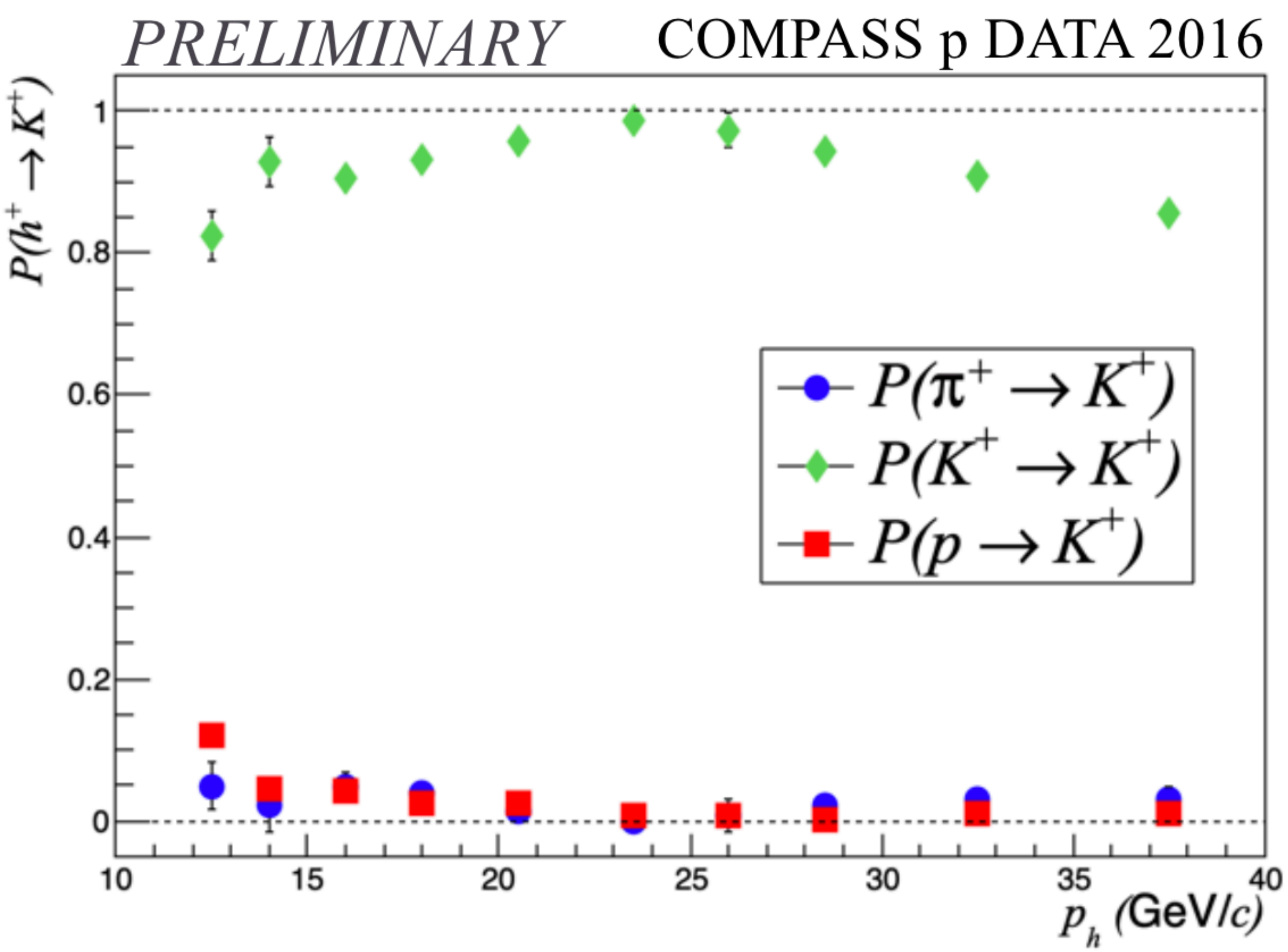


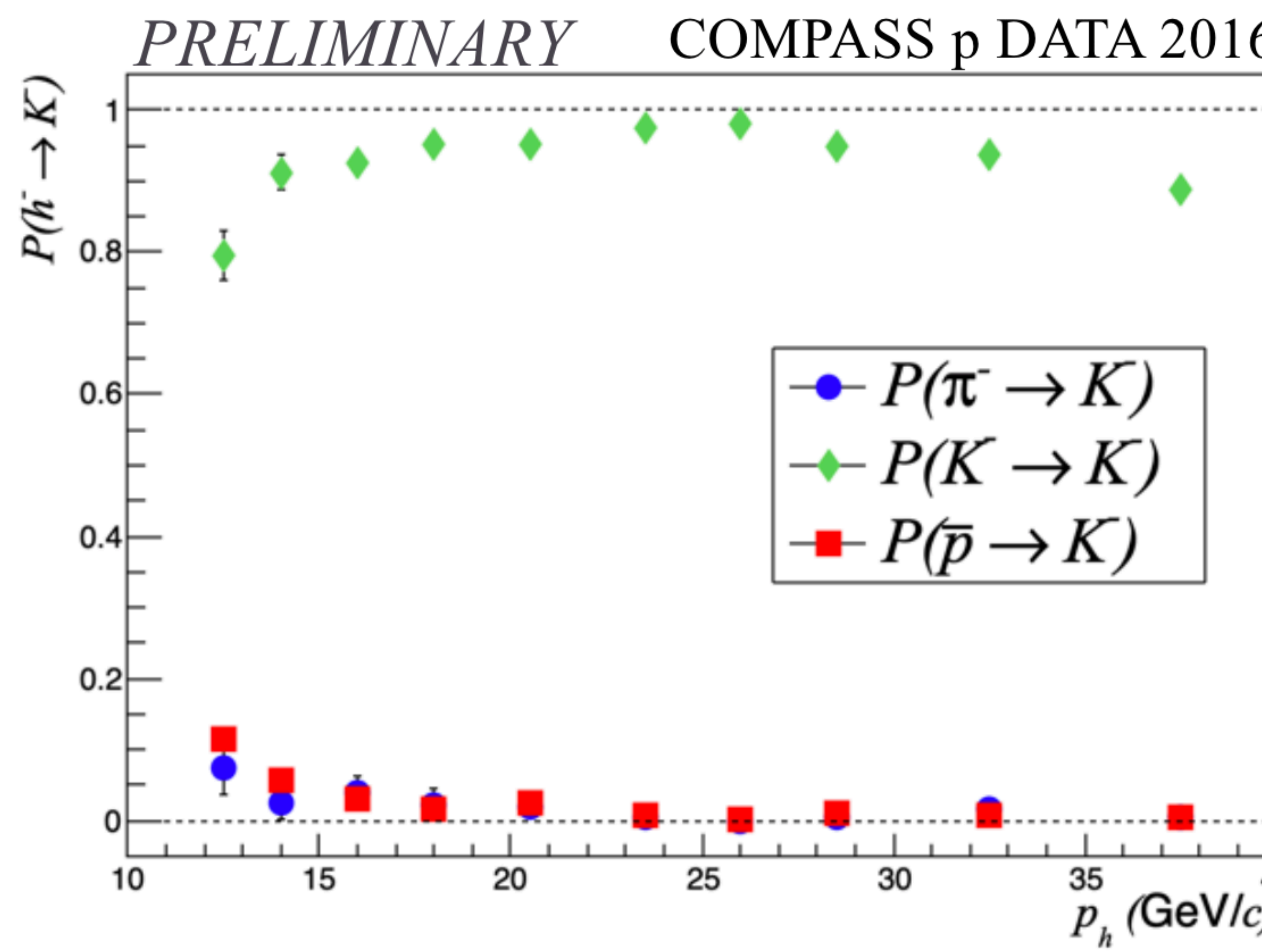

BACKUP

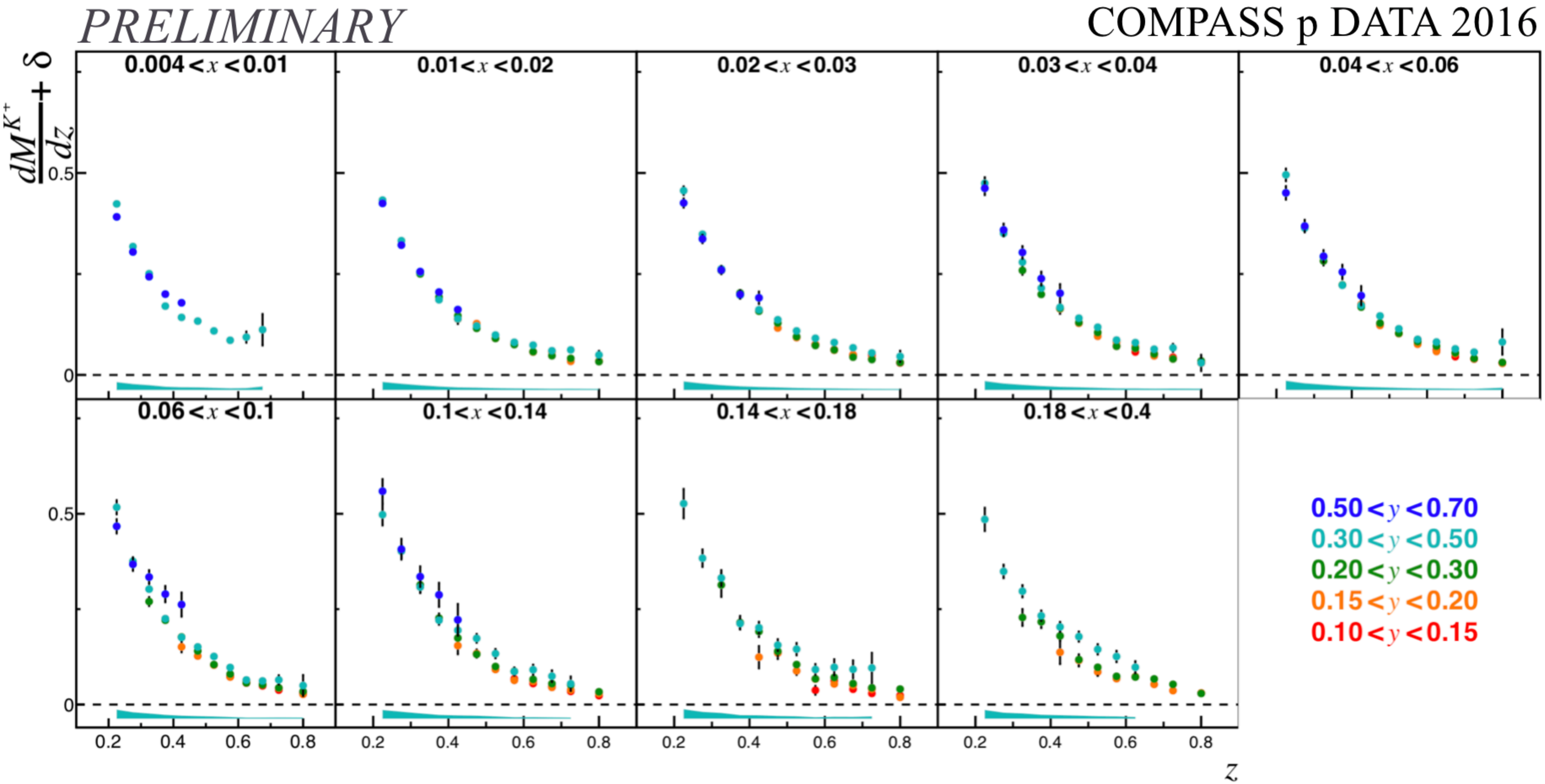

COMPASS p DATA 2016
x
.004 .01 .02 .03 .04 .06 .1 .14 .18 .4
y
.1 .15 .2 .3 .5 .7
z
.2 .4 .6 .8
Acc
1. .8 .6 .4
μ^+ μ^-
K+
K-
PRELIMINARY


.004
.01
.02
.03
.04
.06
.1
.14
.18
.4
x
COMPASS p DATA 2016
K+
K-
DVM
.1
.15
.2
.3
.5
.7
y
1.
.8
.2 .4 .6 .8
z
PRELIMINARY

RICH EFFICIENCIES - K^+ AND K^-







x, y, z 3D-binning
300 kinematic bins
Strong *z*-dependance