Pion and kaon multiplicities in Semi Inclusive Deep Inelastic Scattering at COMPASS

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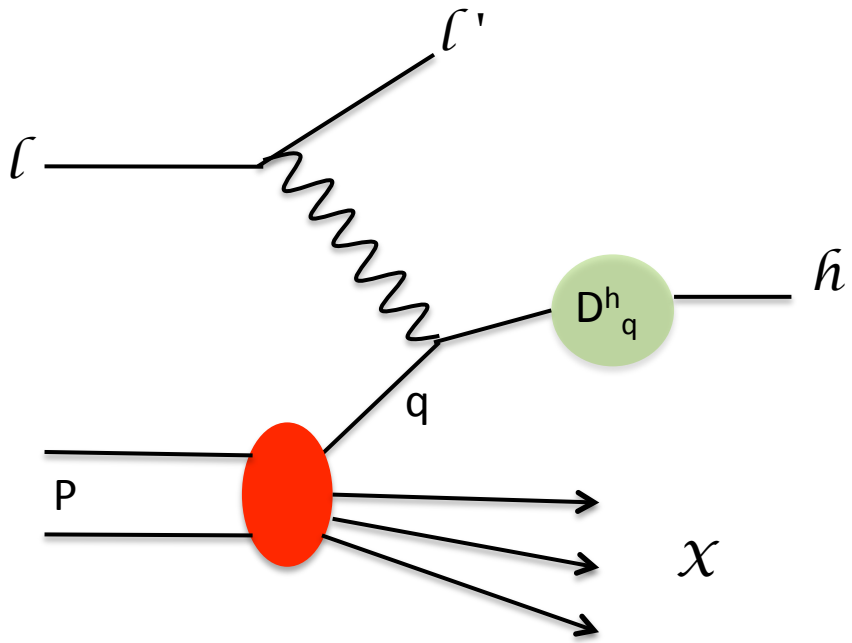
On behalf of the COMPASS collaboration

Deep Inelastic Scattering (DIS)



○ **Relevant kinematics for cross section**

Q^2 photon virtuality ⇔ resolution at which the nucleon is probed

x_B long. momentum fraction of the struck quark in the nucleon

y momentum fraction transferred by lepton to the virtual photon

Inclusive DIS : $lN \rightarrow l'X$
Semi-inclusive DIS: $lN \rightarrow l'h\,X$

○ **DIS Cross section:**

Parton Distribution functions (PDFs)

Unpolarized $\sigma^h \sim f_q(x,Q^2) \cdot D^h_q(z,Q^2)$
Polarized $\Delta\sigma^h \sim \Delta f_q(x,Q^2) \cdot D^h_q(z,Q^2)$

Fragmentation functions (FFs)

○ **Information on PDFs & FFs can be found in other processes:**
hadron-hadron collisions, e^+e^- annihilations, …

○ **Current knowledge of:**
- **PDFs: well known**
- **FFs: poorly known**

What about polarized PDFs Δf_q ?

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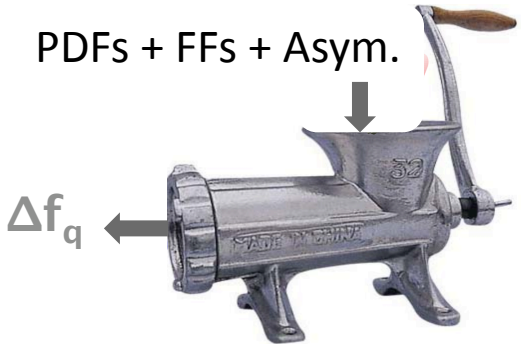
Polarized parton distributions Δf_q

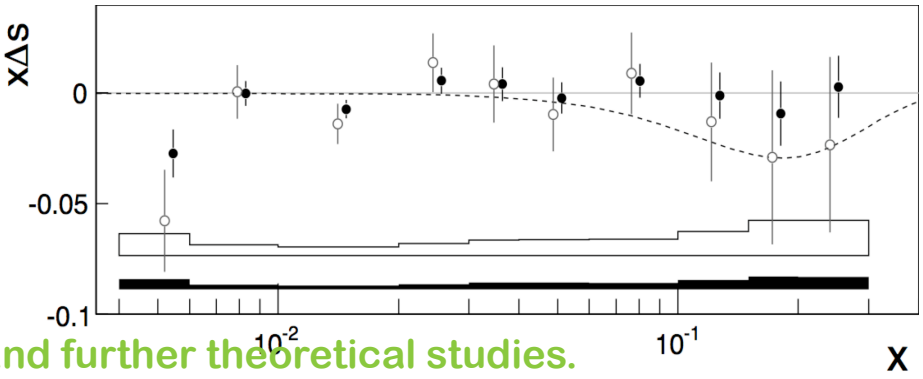
The extraction of polarized parton distributions from spin asymmetries at LO depend on FFs and PDFs



Different FFs ➡ **different results for polarized parton distributions especially for strange quark Δs**

Δs always thought to be negative from DIS data but … using SIDIS data Δs ≥ 0

puzzling result but relies on:
- **kaon fragmentation functions**
- **unpolarized PDFs (s(x) ?)**
- **…**



How well do we know FFs & s(x) ?
need more experimental data and further theoretical studies.

➡ **hadron multiplicities in Semi-inclusive Deep Inelastic Scattering**

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Why hadron multiplicities ?

Assuming Quark Parton Model, Leading Order

PDFs FFs

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

- **Gives access to non-perturbative but universal objects that enter cross sections of different processes (pp collisions, SIDIS,…):**
  - **Fragmentation functions:** $D_q^h(z,Q^2)$
  - **Parton distribution functions:** $f_q(x,Q^2)$
- **Disentangle quarks & antiquarks**
- **Allows flavor/charge separation**

- **Provides inputs to global analysis**
- **Improves the current FF parametrizations**

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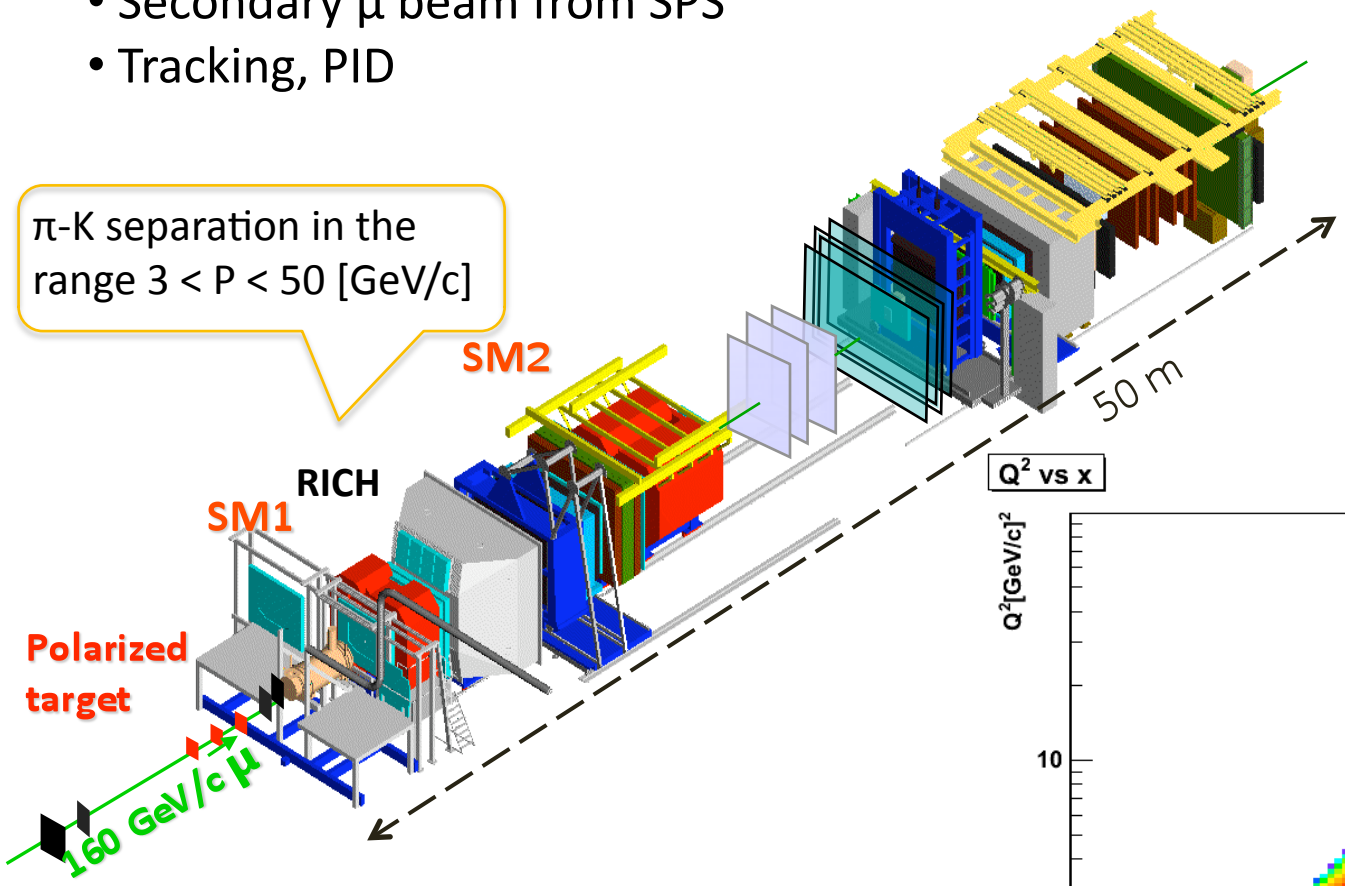
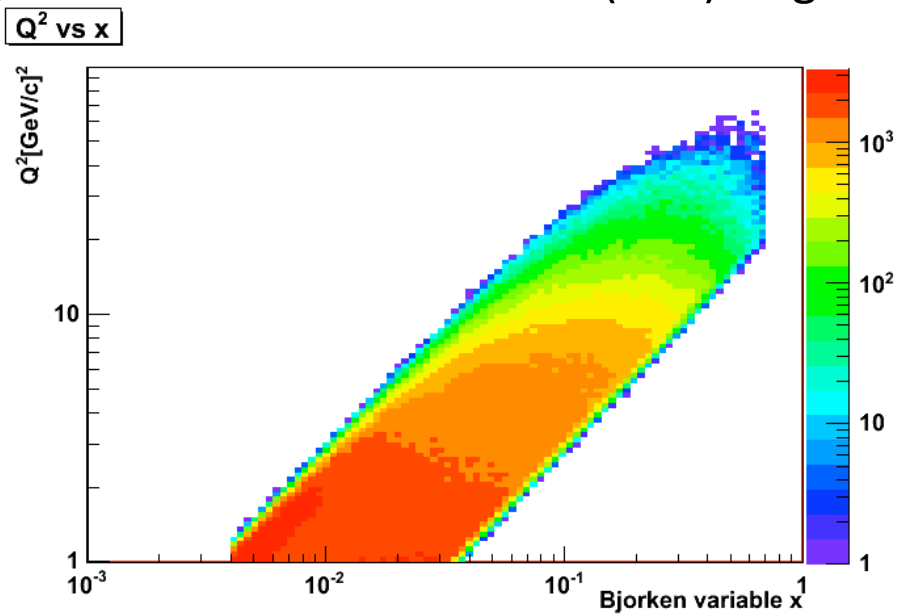
The COMPASS Experiment

Common Muon and Proton Apparatus for Structure and Spectroscopy

- Fixed target experiment at CERN
- Secondary μ beam from SPS
- Tracking, PID



2004 Data presented:
160 GeV/c μ^+ beam
Deuteron (^{6}LiD) target



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Experimental definition of hadron multiplicities& experimental cuts

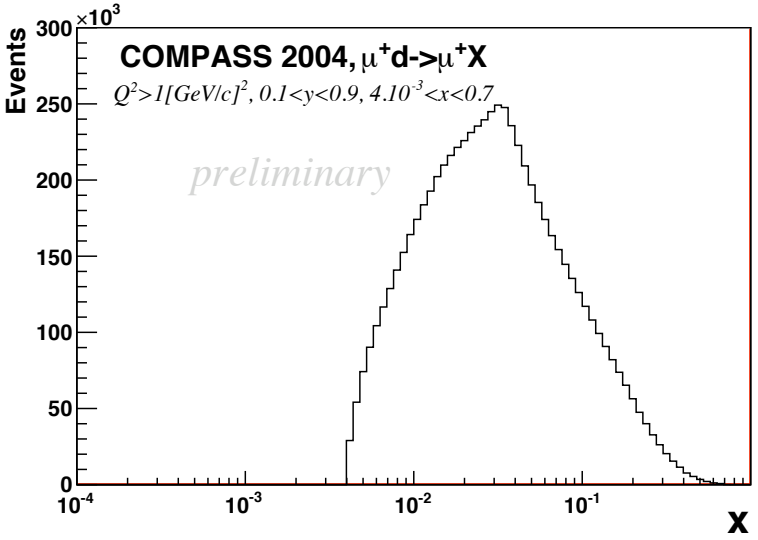
Multiplicity: Averaged number of hadrons per deep inelastic scattering event:

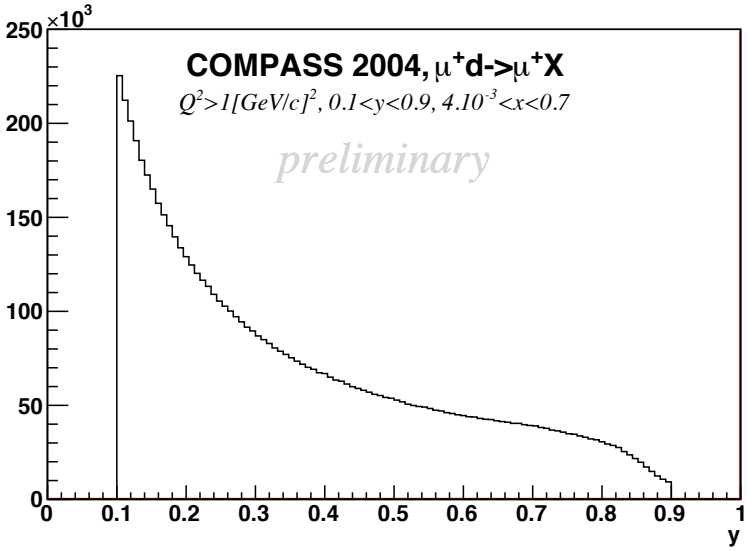
$$\frac{dM^h(x,Q^2,z)}{dz} = \frac{dxdQ^2}{d^2N^{DIS}(x,Q^2)} \cdot \frac{d^3N^h(x,Q^2,z)}{dxdQ^2dz} = \frac{\text{Hadron yields}}{\text{DIS events yields}}$$

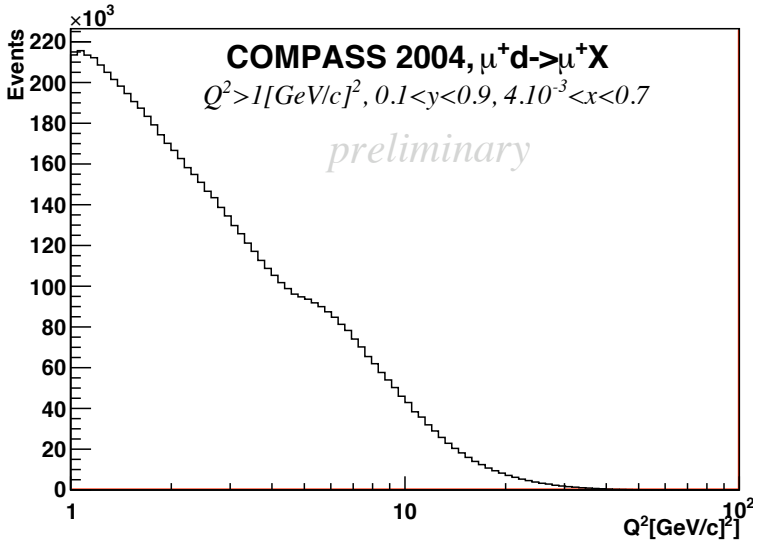
- **DIS events cuts:**
  - **$Q^2 > 1$ [GeV/c]^2**
  - **y: [0.1,0.9]**
  - **W > 7 GeV**
  - **x: [0.004, 0.7]**

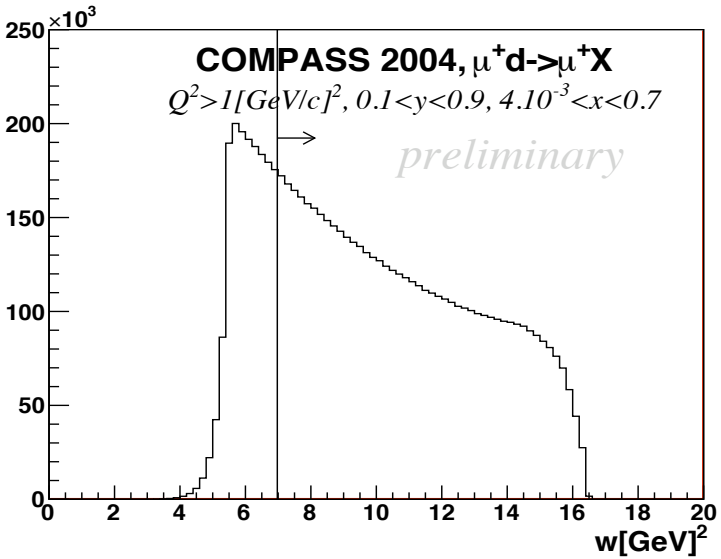
- **Hadron candidate cuts:**
  - **z: [0.2, 0.85] to avoid target fragmentation region and exclusive processes**
  - **P < 50 GeV/c to ensure π-K separation**

Kinematical distributions of DIS events









From hadron yields to final hadron multiplicities

- **Radiative corrections (< 15%)**

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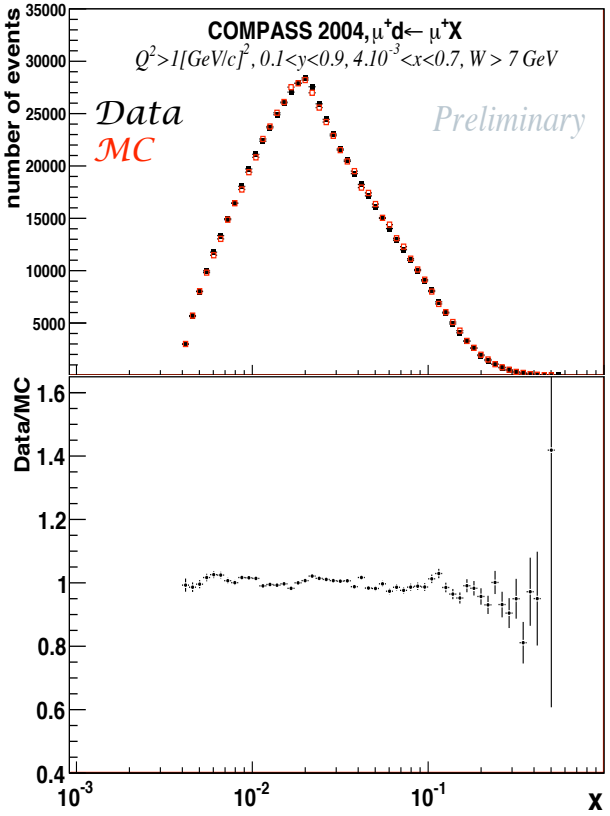
- Acceptance correction:
  - Production of large MC sample (~10^7 events)
    - ✓ using full Monte Carlo simulation of DIS process
      (LEPTO, GEANT3, COMPASS event reconstruction)

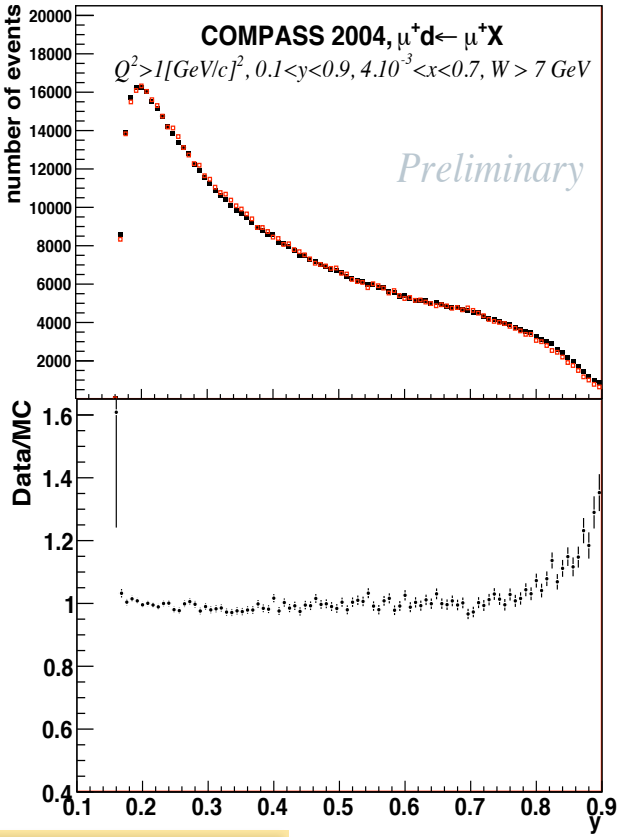
    - ✓ using fragmentation parameters in MC optimized for COMPASS data
  - detection efficiency
  - Kinematical smearing

Monte Carlo description of data for DIS variables

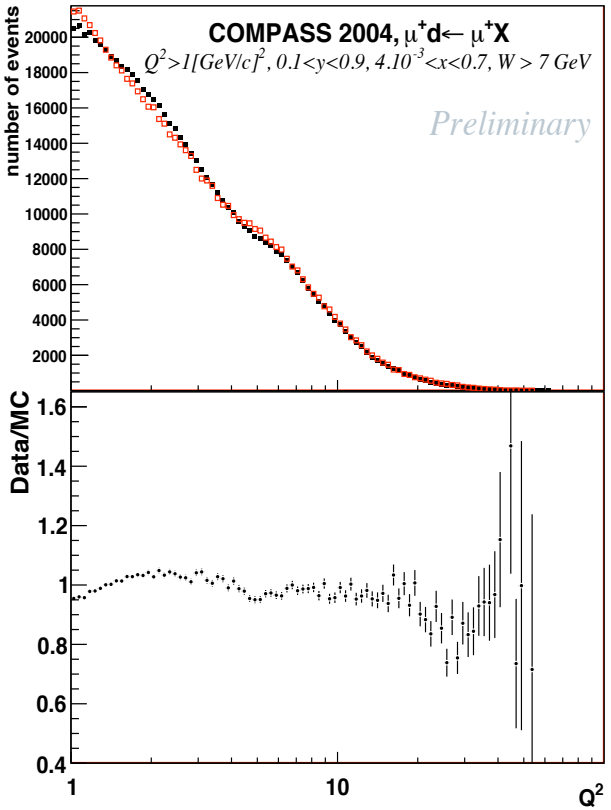
$x_{Bjorken}$



y



Q^2



Good decscription of data by Monte Carlo for inclusive variables

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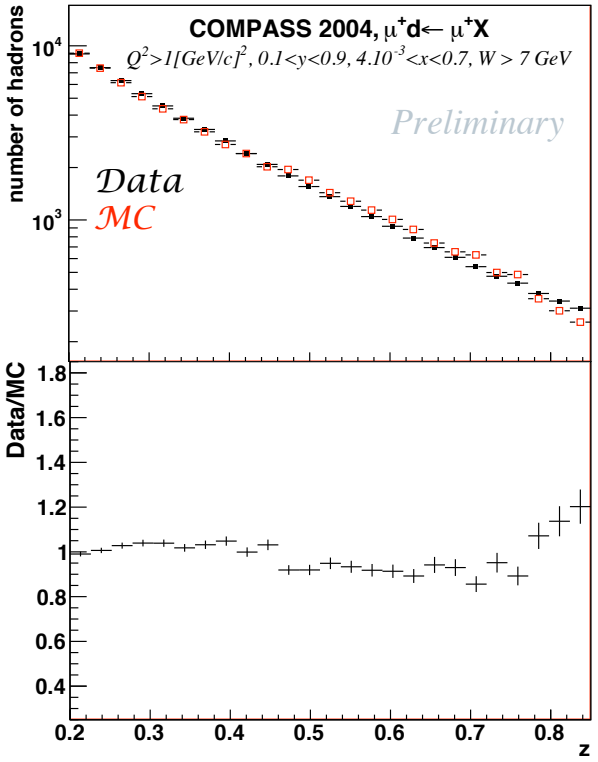
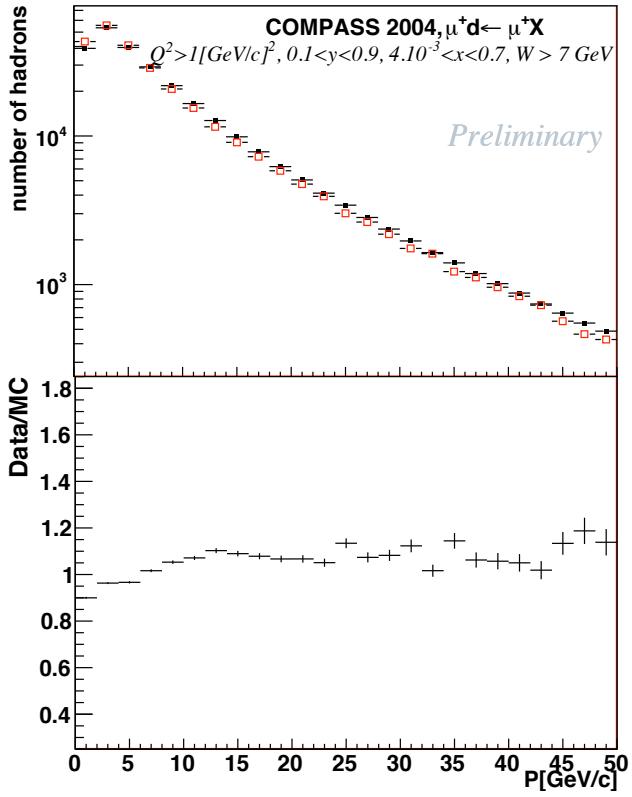
Monte Carlo description of data for SIDIS variables

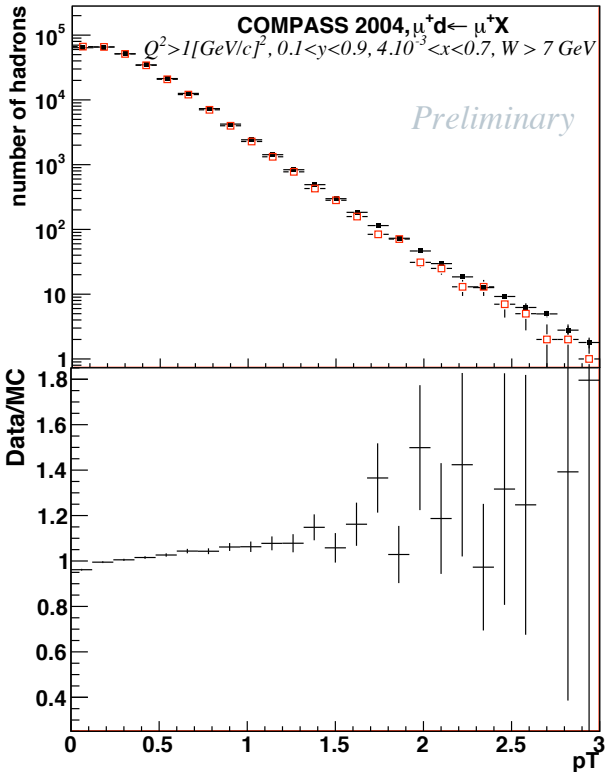
Fractional energy z



Momentum



Transverse momentum



Good decscription of data by Monte Carlo for semi-inclusive variables

From hadron yields to final hadron multiplicities

- Radiative corrections (< 15%)

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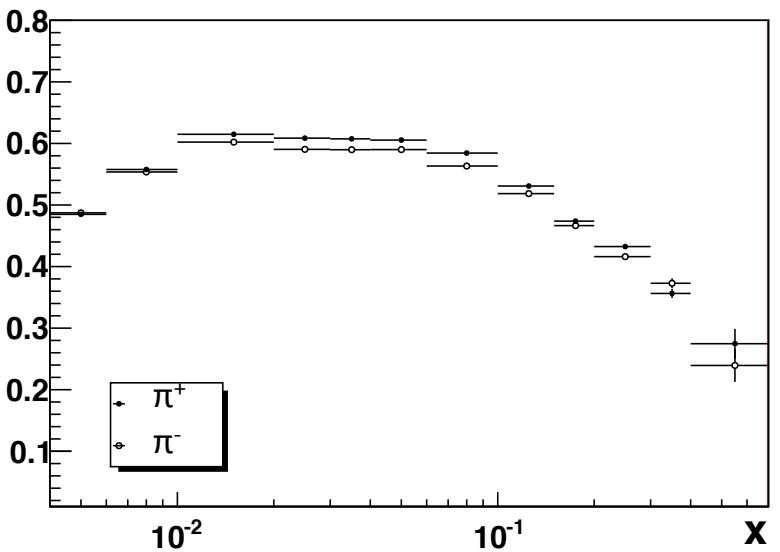
  - Kinematical smearing

- Analysis performed in bins of (x,z) and (Q2,z)
  - acceptance in bin i :

$$\epsilon_i = \frac{M^{rec}_{MC,i}}{M^{gen}_{MC,i}}$$



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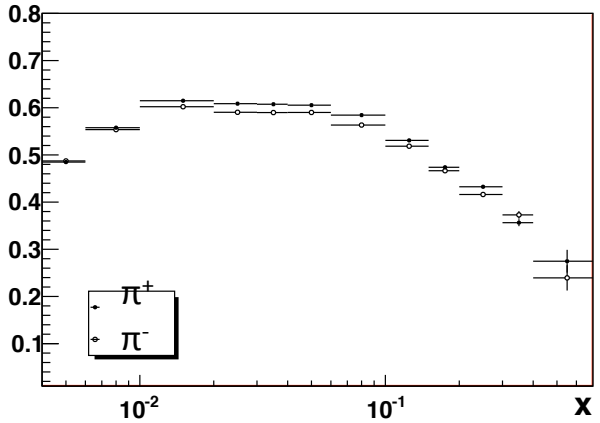
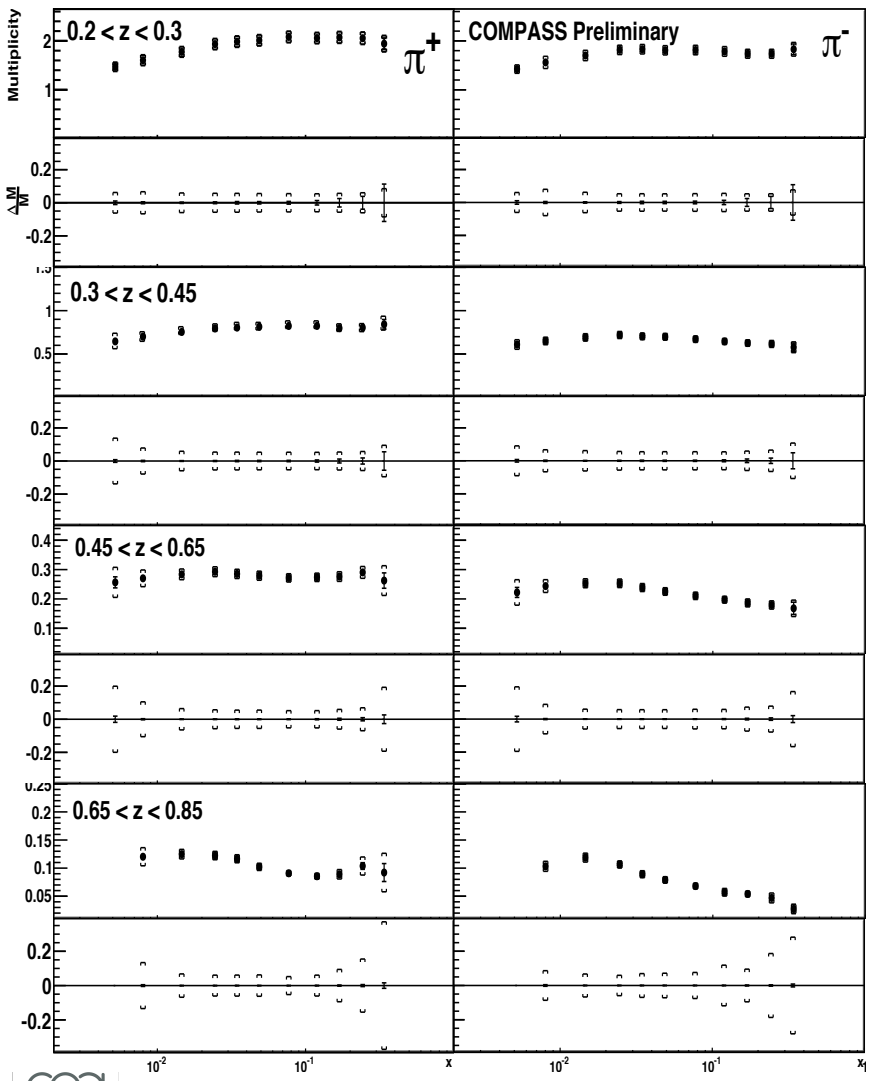
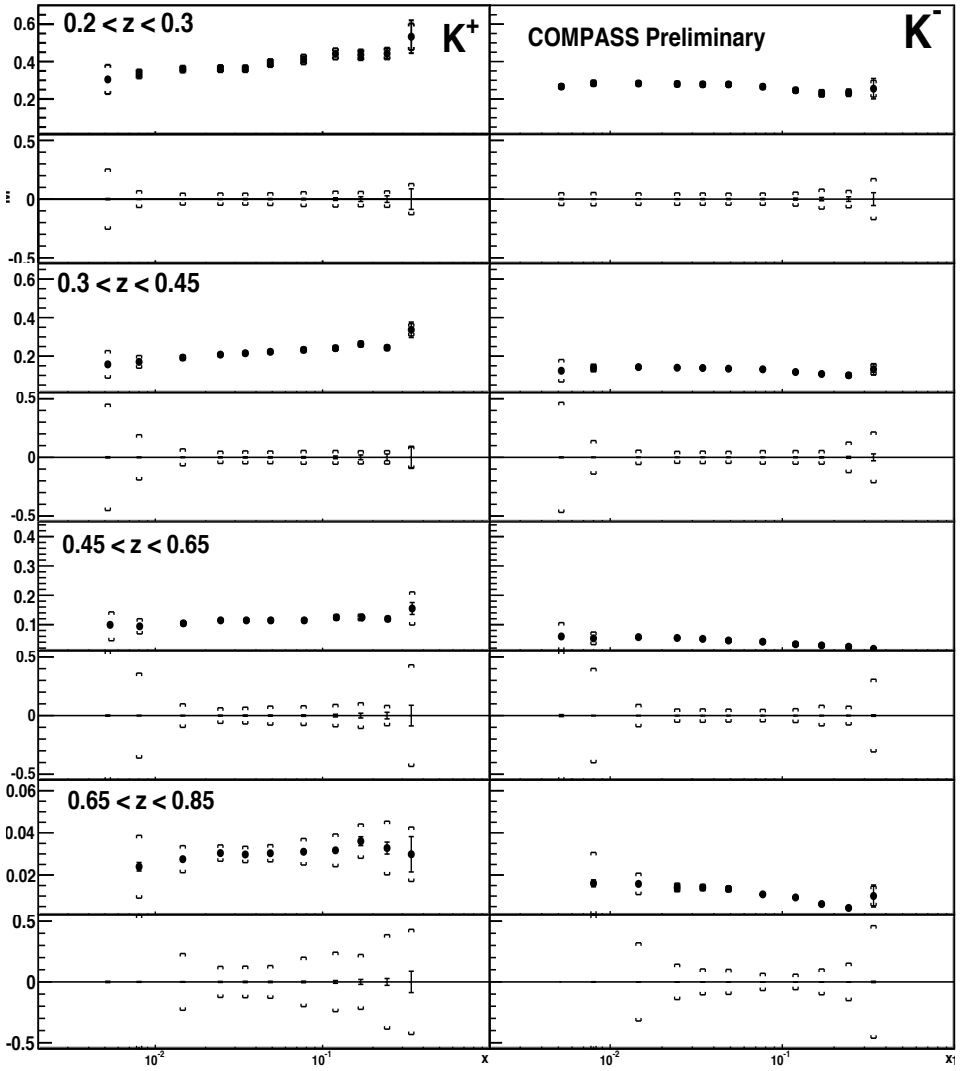


  - Corrected data multiplicity in bin i: $M_{corrected,i} = \frac{M_{data,i}}{\epsilon_i}$

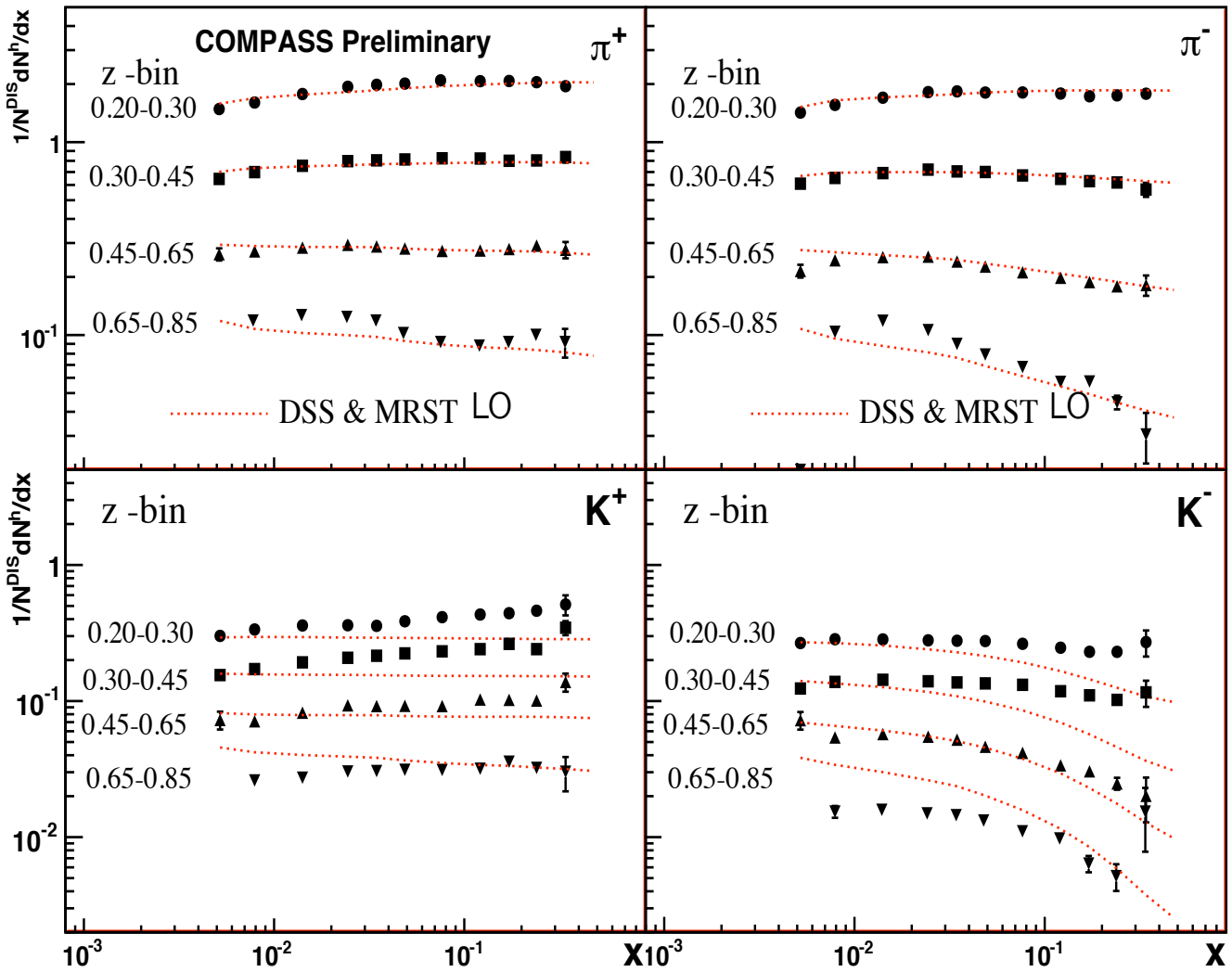
Results : 2D (x,z) Multiplicities for $\pi^{\pm}$ & $K^{\pm}$

Disentanglement of x and z





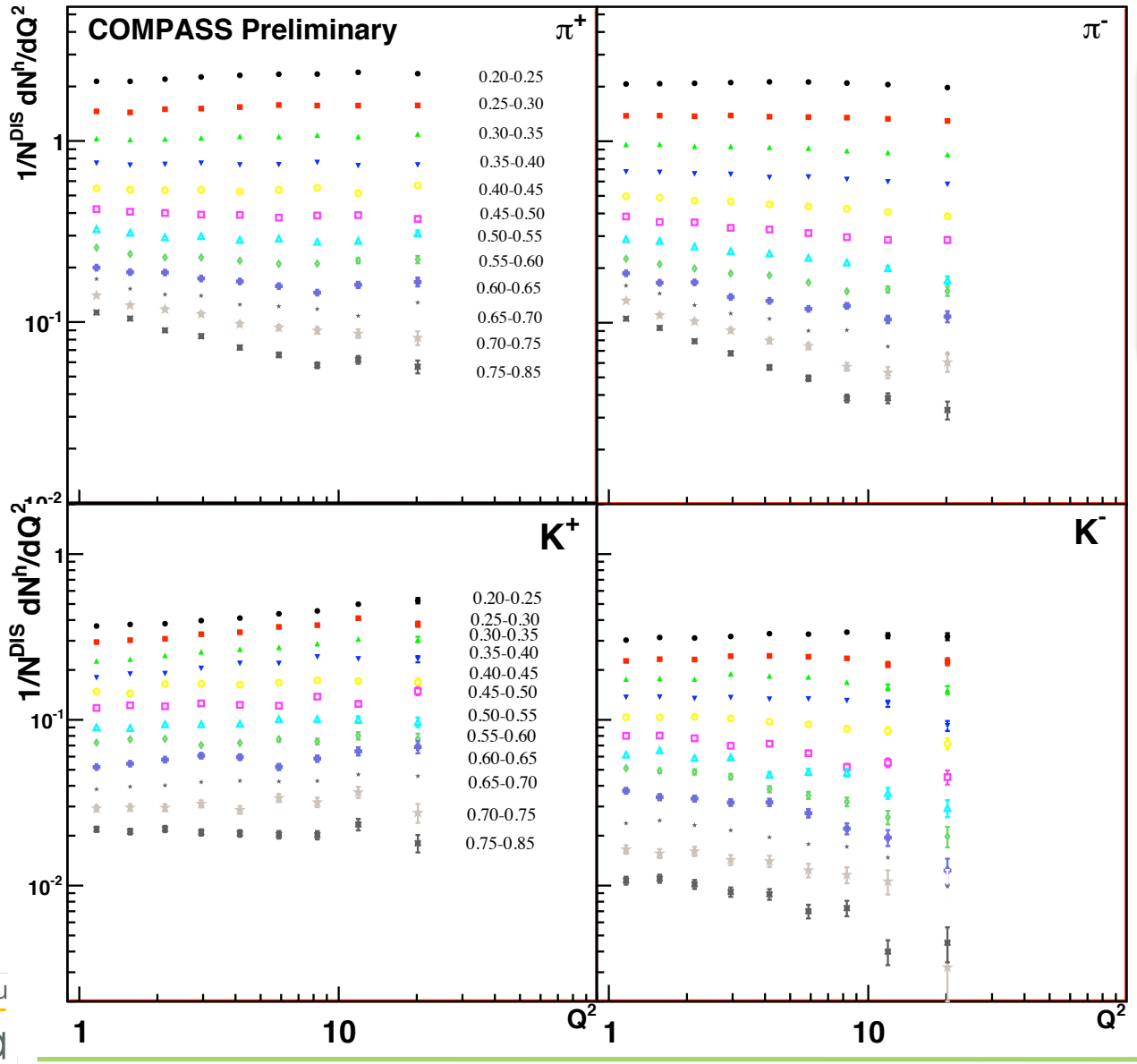
Comparison with predictions : 2D (x,z) multiplicities



- Good agreement with DSS+MRST04 for $\pi^{\pm}$ (except at high z)
- large deviations from prediction for $K^{\pm}$ at high x

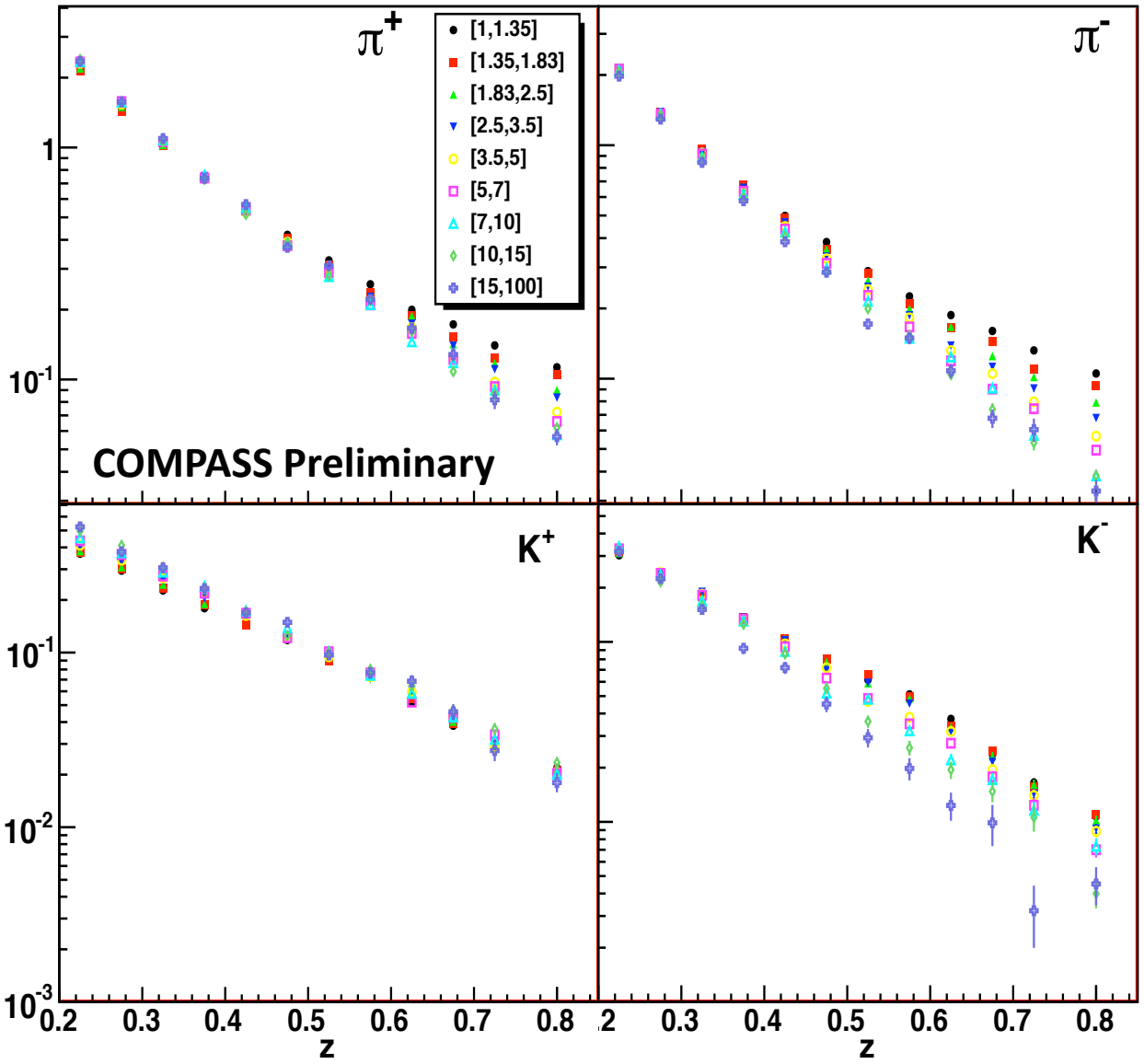
-Model uncertainty ?
-unpolarized strange quark distribution s(x) ?
-Higher orders contributions?

Results : 2D (Q^2,z) Multiplicities for $\pi^{\pm}$ & $K^{\pm}$



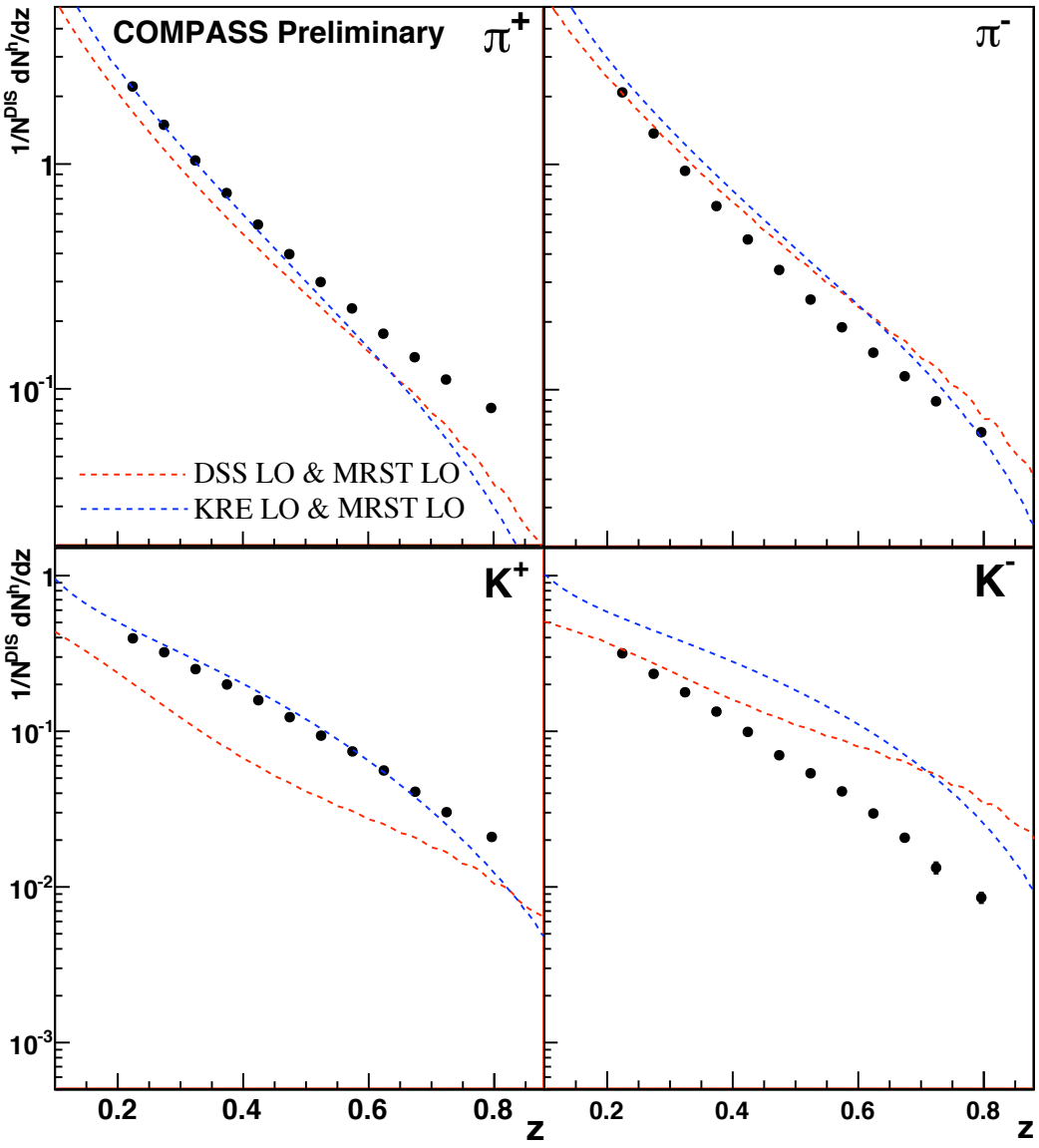
- High statistics
- Fine z binning
- Strong Q^2 dependence for negative hadtons (π^- & K^-)

Results : 2D (z,Q^2) Multiplicities for $\pi^{\pm}$ & $K^{\pm}$



- Q^2 dependence more pronounced for negative hadrons (π^- & K^-)

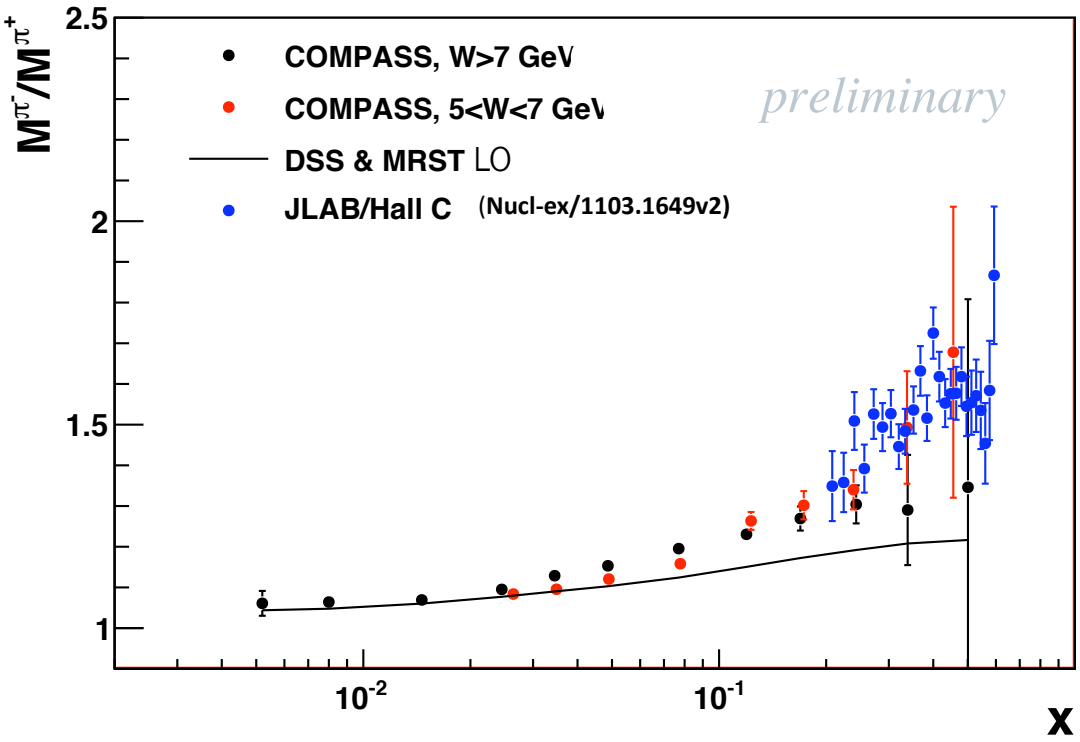
Results : 1D z Multiplicities for $\pi^{\pm}$ & $K^{\pm}$



- π^+ & π^- multiplicities in agreement with predictions (DSS+MRST) & (KRE+MRTS)
- deviations at high z for $\pi^{\pm}$
- poor agreement with DSS for K^+
- Large deviations for K^-

Model uncertainty ?
Higher orders ?

Ratio M^{π^+}/M^{π^-} versus x



- Some systematic effects cancel in the ratio M^{π^+}/M^{π^-}
- gives access to ratio of fragmentation functions

Summary

- $\pi^{\pm}$ and $K^{\pm}$ multiplicities as a function of (x,z) and (Q2,z) from muon-deuteron(LiD) deep inelastic scattering measured at COMPASS

- Data will be used:
  - for direct LO extraction of quark fragmentation functions
  - for direct LO extraction of unpolarized Parton distribution functions
    → the strange distribution s(x) from kaon's multiplicities

  - To test the LO assumption of factorization

- Data can significantly contribute to knowledge of the hadronization process

Backup

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Comparison HERMES/COMPASS