Pion and Kaon multiplicities from muon deep inelastic scattering

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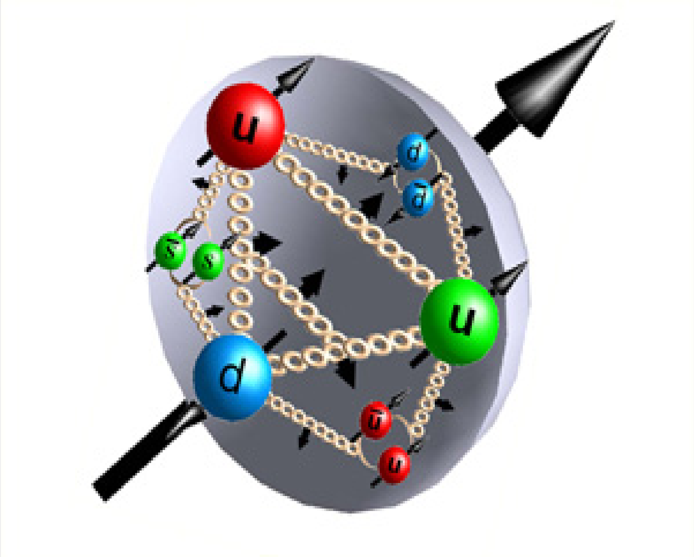
Outline

- Motivation
- The COMPASS experiment
- Results
- Conclusions

Nucleon structure

Proton structure



- 3 valence quarks
- Gluons
- Sea quarks

Spin contribution

$$S_N = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$$

where

ΔG : gluons contribution

L_z : orbital momentum

$\Delta\Sigma$: quark contribution

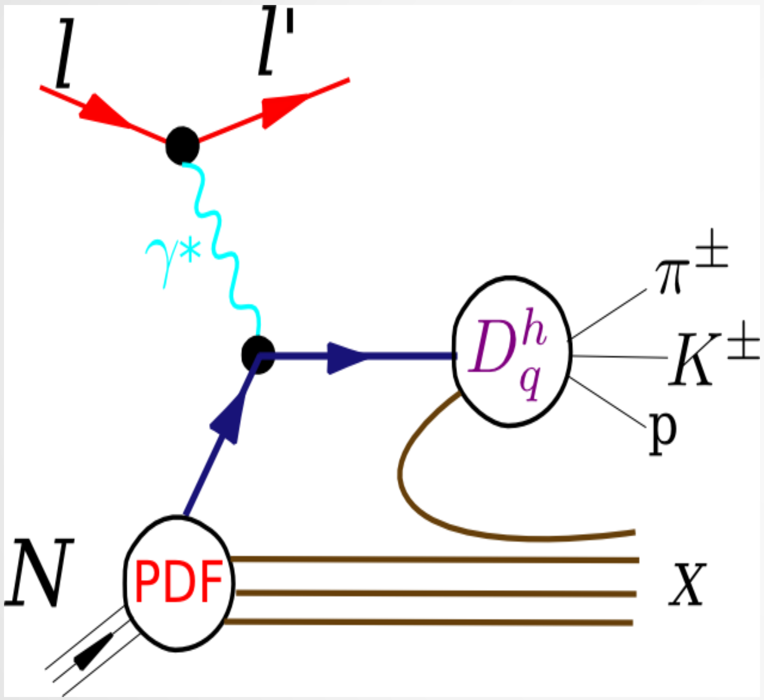
$$\Delta\Sigma = \Delta u + \Delta d + \Delta s$$

World data
PLB 647 (2007) 8-17

$\Delta\Sigma \sim 0.3$

Access to nucleon structure

Information on nucleon structure can be extracted from DIS (SIDIS) process



PDF: Parton distribution function

D_q^h : Fragmentation function

Inclusive deep inelastic scattering (DIS)	
$l\,N \rightarrow l'\,N + X$	
Kinematic variables	Q^2 : photon virtuality (γ^*) x: Bjorken scaling variable y: Inelasticity
Cross section	$\sigma \sim \mathrm{PDF}(x,Q^2)$

Semi inclusive deep inelastic scattering (SIDIS)	
$l\,N \rightarrow l'\,N\,\boldsymbol{h} + X$	
Kinematic variables	z: Fraction of energy
Cross section	$\sigma \sim \mathrm{PDF}(x,Q^2)\cdot D_q^h(z,Q^2)$

Strange quark polarization Δs

Strangeness contribution to spin

$$\Delta s = \int_{x_{min}}^{x_{max}} s(x) + \bar{s}(x)\, dx$$

From inclusive measurements

PLB 647 (2007) 8-17

$\Delta s = -0.08 \pm 0.02 \pm 0.02$

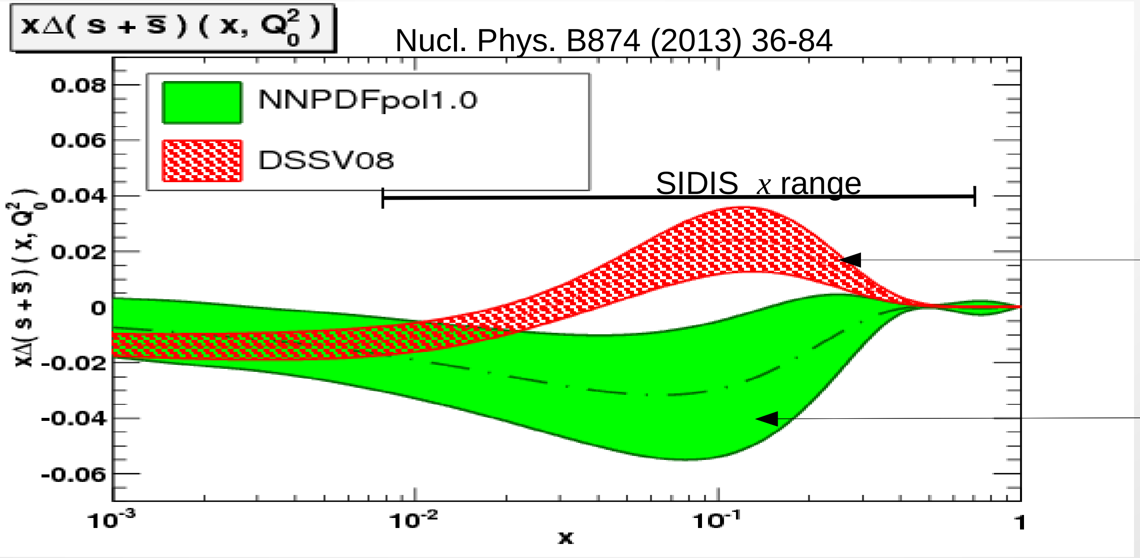
with *SU3* asymmetry assumed

From semi inclusive measurements

PLB 693 (2010) 227-235

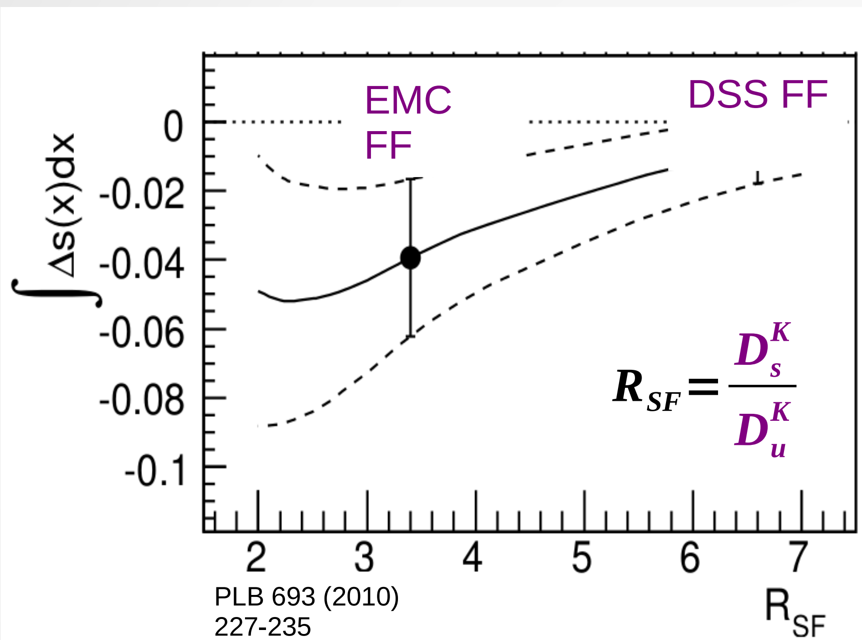
$\Delta s = -0.02 \pm 0.02 \pm 0.02$

in a limited x range



Strange quark polarization (Δs) and D_q^K in SIDIS

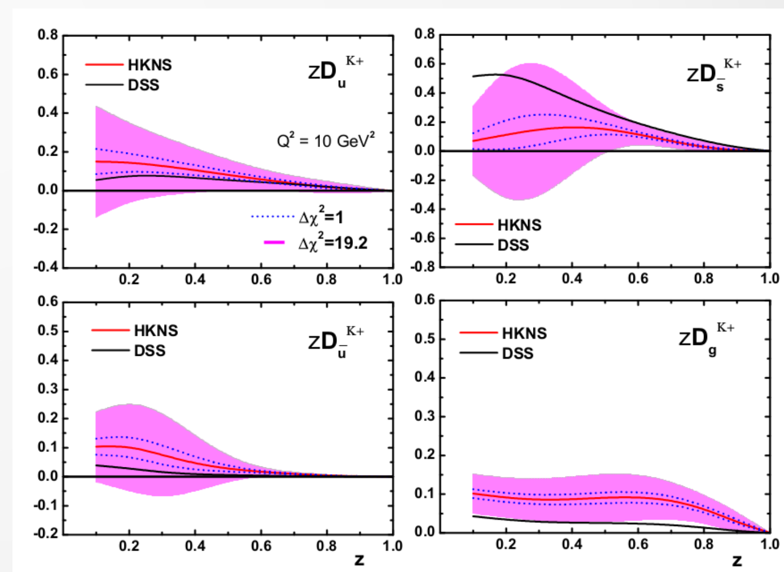
$\Delta s(x)$ extracted from SIDIS data depends on the choice of FFs



FF parametrization: HKNS, DSS, AKK,..

Disagreement among themselves

- Different assumptions
- Different set of data points to fit



More SIDIS data are needed to better constrain FF.

Fragmentation functions D_q^h

- Probability that a parton q fragments into a hadron h carrying a fraction z of energy

$$z = \frac{E_h}{E} \qquad \text{(with } E = E' - E_{Beam}\text{)}$$

- Present in high energy process where hadrons are identified as a final state
- Universal → can be extracted from global fits on different observables

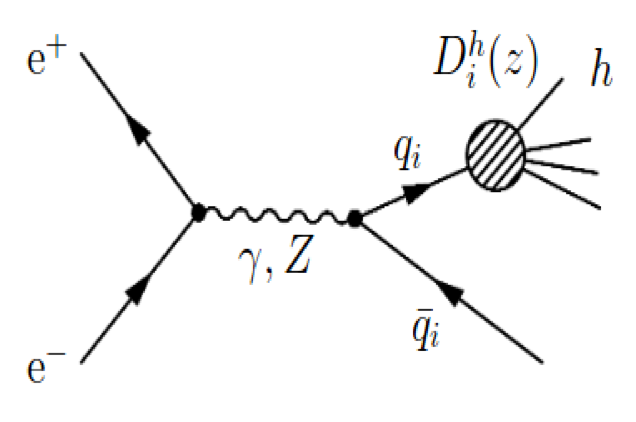
Access to **FFs**

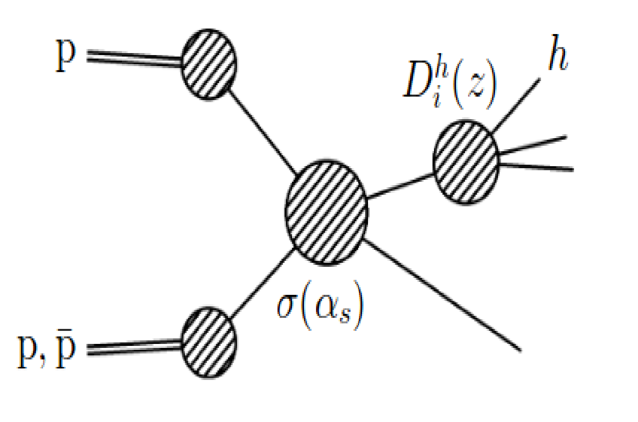
Access to **FFs** is possible via high-energy reactions

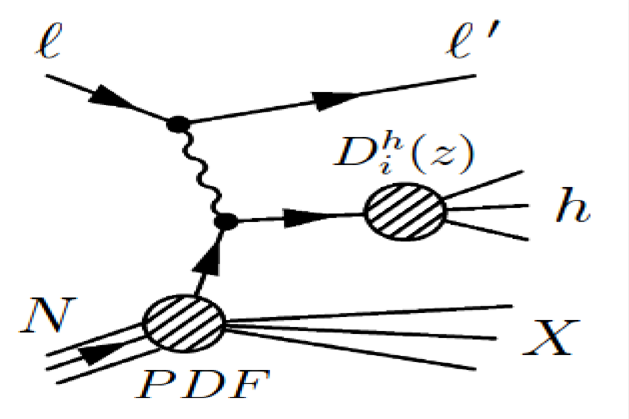
e^+e^- annihilation
(into hadrons)
(Belle & BABAR)
- High precision data
- No dependence on PDF
- Access to singlet combination only
  $(D_\Sigma = D^h_{\bar{u}} + D^h_d + D^h_s + \ldots)$

Hadron-hadron collision
(RHIC, Fermi Lab, ..)
- High precision data
- Flavor/charge separation
- Sensitive to gluon FF
- Dependence on PDF

Lepton-hadron collision
(COMPASS, HERMES, JLab)
- High precision data
- Flavor/charge separation
- Access larger z
- Study of hadronization process
- Dependence on PDF







Fragmentation functions from SIDIS

FFs are accessible trough hadron multiplicities (M^h) in a SIDIS process (hadron yields produced per DIS events)

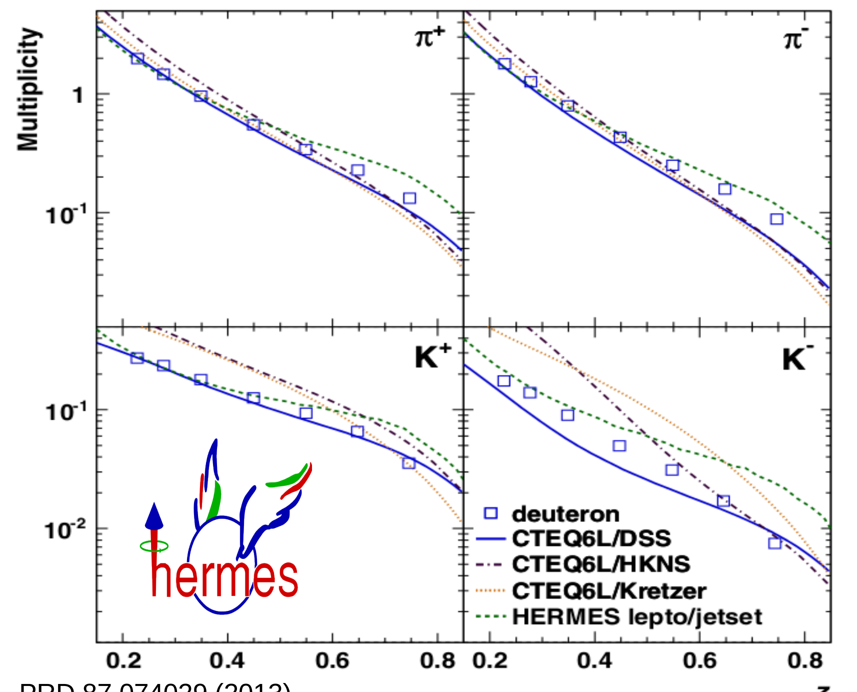
$$M^h(x, Q^2, z) = \frac{d\sigma^h{}_{SIDIS}/dz}{\sigma_{DIS}} = \frac{\Sigma_q e^2{}_q q(x, Q^2) D_q^h(z, Q^2)}{\Sigma_q e^2{}_q q(x, Q^2)}$$

- Hadron multiplicities depend on the product PDF x ***FFs***
  Up and down unpolarized PDF well known

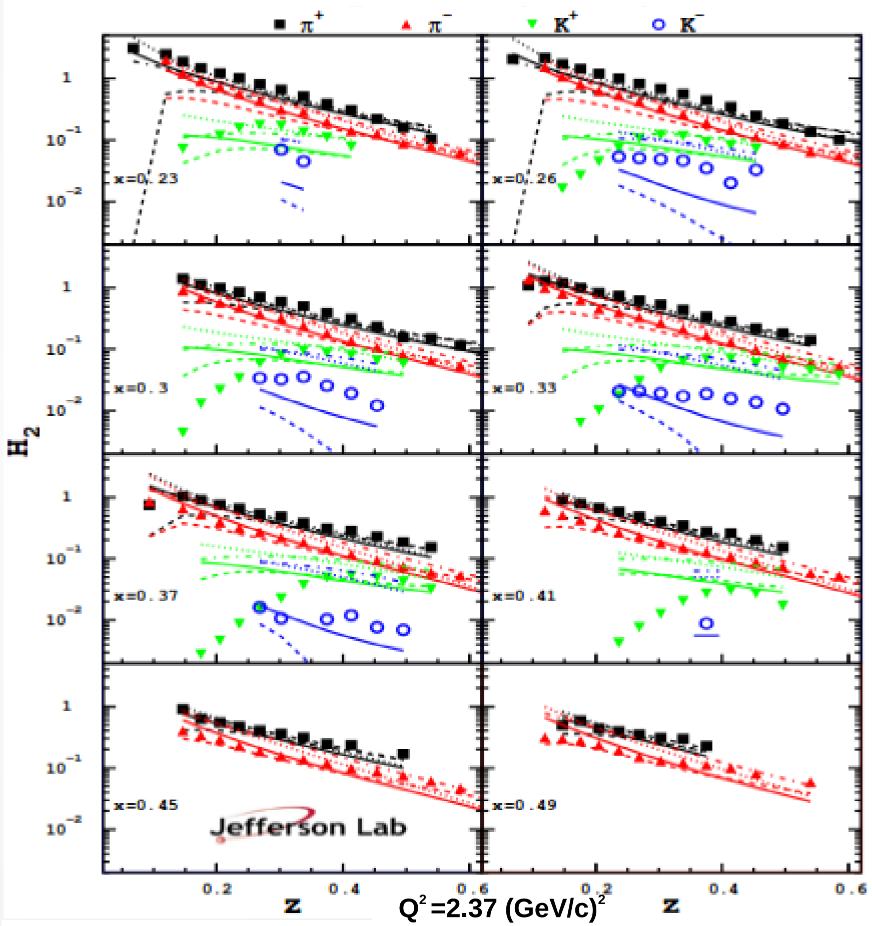
- Flavor separation

$$D_u^h, D_{\bar{u}}^h, D_d^h, D_{\bar{d}}^h, D_s^h, D_{\bar{s}}^h, \ldots$$

Recent results (FFs global effort)



2nd Workshop on Probing Strangeness in Hard Processes
Nov 11-13 2013
M. Osipenko



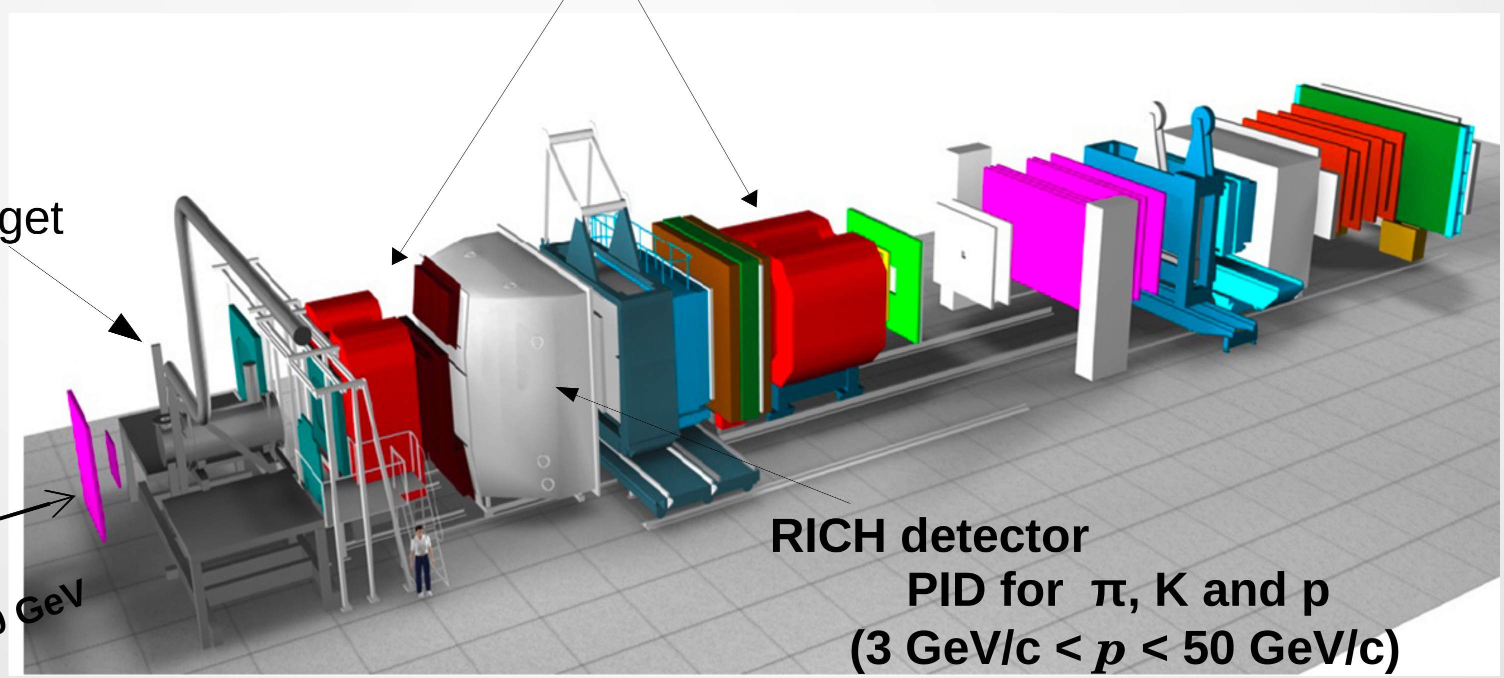
Solid → DSS LO
Dashed → DSS NLO
Dotted → Kretzer LO
Dot-dashed → Kretzer NLO

$\pi\pm$ multiplicities at low-medium z bins are reasonable well described by DSS fit in HERMES case.
$K\pm$ multiplicities description not optimal

COMPASS spectrometer

COmmon **M**uon **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

- Fixed target at CERN
- ^{6}LiD target (2006)
- Two stage spectrometer
- Tracking and particle identification
- High acceptance

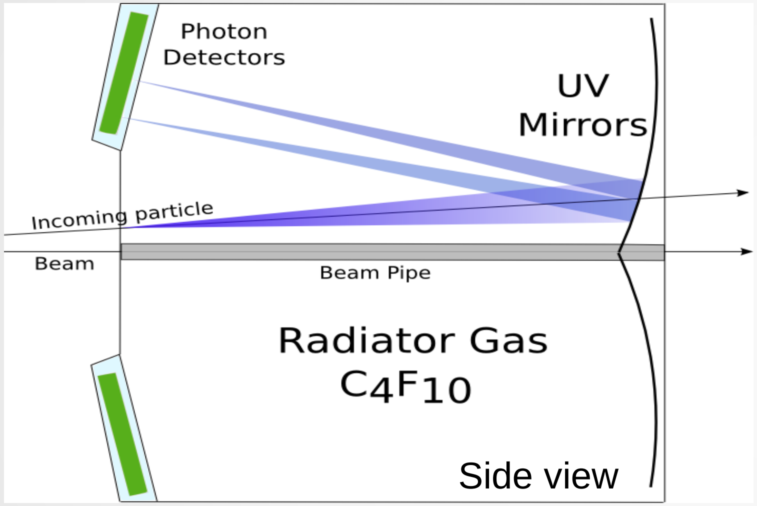


Particle identification (PID)

RICH detector

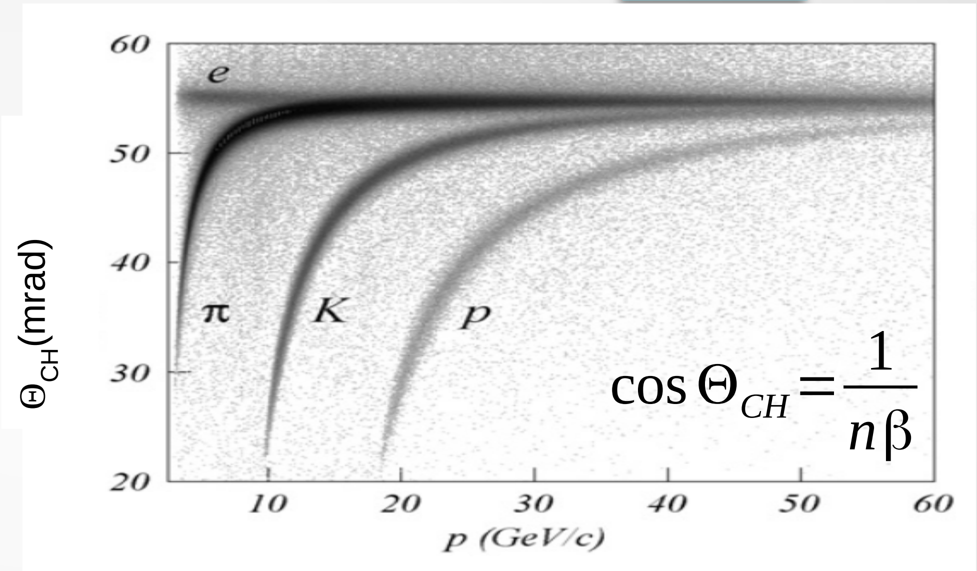
(Ring-**I**maging **Ch**erenkov)

$v_h > c/n$ → Cherenkov radiation



Photon detection: MAPMT and MWPC coated with CsI

- Separate π, K and p in a high-intensity environment
- Covers full spectrometer acceptance
- Mirror system ~ 22 m^2
- Photon detection system: MWPC + MAPMT



$$\cos\Theta_{CH} = \frac{1}{n\beta}$$

Particle identification algorithm

- Photon trajectory reconstruction → Θ_{CH} measured
- Maximum likelihood estimator
  - 5 mass hypothesis (e, μ, π, K and p)
  - Background hypothesis
- Maximum of 6 likelihood → good hypothesis

Multiplicities at COMPASS

- Kinematic domain
  - $Q^2 > 1$ GeV^2
  - $0.004 < x_{Bj} < 0.7$
  - $0.1 < y < 0.7$
  - $0.2 < z < 0.85$
  - $10 < P_h < 40$ (GeV/c)

DIS events ~ 7.9×10^6
Hadrons events ~ 4.8×10^7

3 weeks of data taken in 2006

- Multidimensional binning : x_{Bj} , y and z (relevant variables)
  - Extract raw multiplicities from data
    Correct for PID efficiencies (for identified hadrons)
  - Geometric acceptance of the spectrometer and reconstruction efficiency estimated via MC
  - Correct real data

Experimental multiplicities

For each bin (x_{Bj}, y, z):

1. Get number of DIS events (N_{DIS})
2. Get number of hadrons (N_h,N_π,N_K and N_p)

   The hadron identification relies on the RICH detector performance

   → Correct number of identified hadrons by detector inefficiencies

$$\begin{pmatrix} N_\pi \\ N_K \\ N_p \end{pmatrix} = \begin{pmatrix} \epsilon_I(\pi^\pm \Rightarrow \pi^\pm) & \epsilon_M(\pi^\pm \Rightarrow K^\pm) & \epsilon_M(\pi^\pm \Rightarrow p^\pm) \\ \epsilon_M(K^\pm \Rightarrow \pi^\pm) & \epsilon_I(K^\pm \Rightarrow K^\pm) & \epsilon_M(K^\pm \Rightarrow p^\pm) \\ \epsilon_M(p^\pm \Rightarrow \pi^\pm) & \epsilon_M(p^\pm \Rightarrow K^\pm) & \epsilon_I(p^\pm \Rightarrow p^\pm) \end{pmatrix}_{(P,\theta)} \begin{pmatrix} T_\pi \\ T_K \\ I_p \end{pmatrix}$$

True number of id hadrons

RICH probability matrices $\epsilon(P,\theta)$

RICH matrices are extracted from real data

P : particle momentum

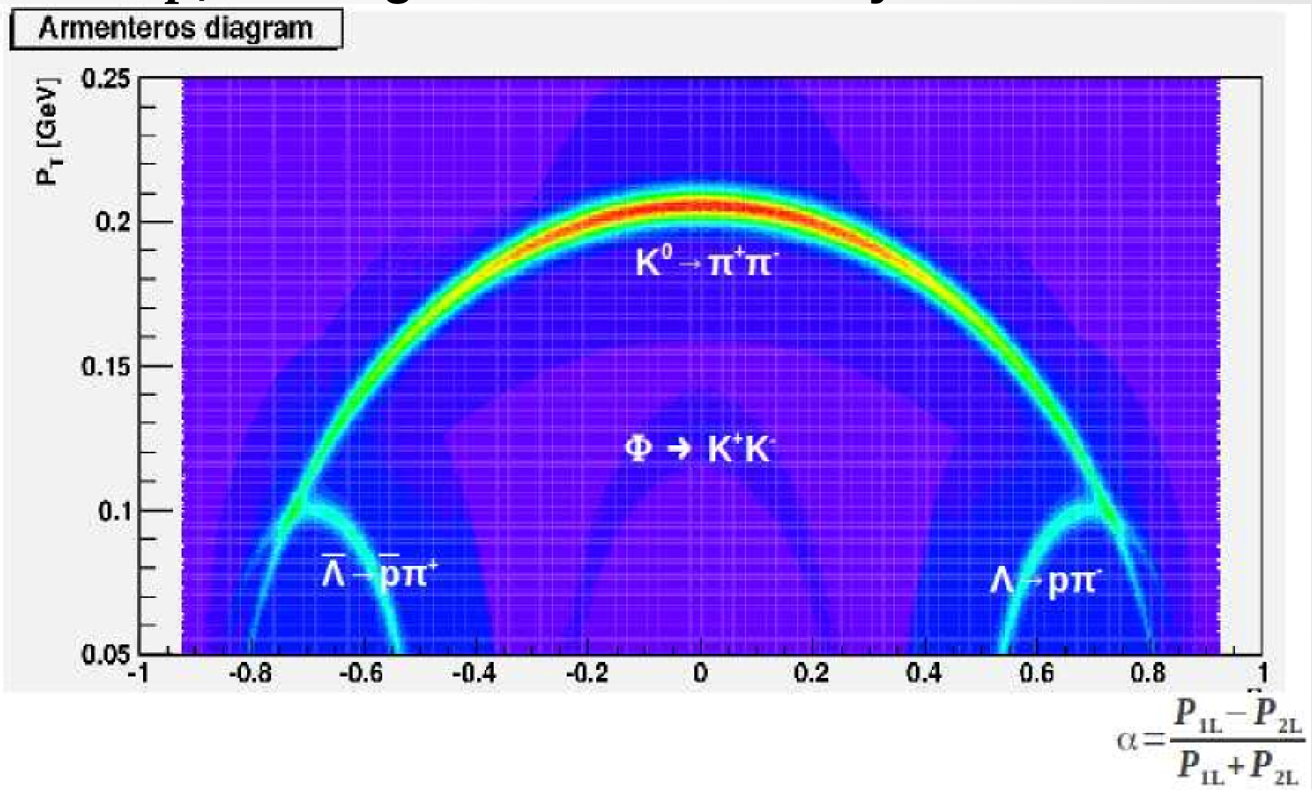
θ : incident angle at RICH entrance

$$\vec{T}_h = \epsilon^{-1} \vec{I}_h$$

RICH probability matrices determiantion

- **Use pure samples of π, K and p, coming from known decays**

  - $K^0 \rightarrow \pi^+\pi^-$
  - $\Phi \rightarrow K^+K^-$
  - $\Lambda \rightarrow \pi^- p$ $(\bar{\Lambda} \rightarrow \pi^+ \bar{p})$



<u>Analysis features</u>

- Dependence on P (momentum) and θ (incident angle at RICH entrance)
- Different RICH response for $h+$ and $h-$

→ 40 matrices

Acceptance

Correction for geometric acceptance of the spectrometer and reconstruction efficiency

- LEPTO generator: DIS events with hadrons as final state (generated SIDIS events)

$$M^h_{gen}(x_{Bj}, y, z)$$

- Reconstruct LEPTO SIDIS events using COMPASS spectrometer simulation (GEANT3)

$$M^h_{rec}(x_{Bj}, y, z)$$

- Acceptance

$$A(x_{Bj}, y, z) = \frac{M^h_{rec}(x_{Bj}, y, z)}{M^h_{gen}(x_{Bj}, y, z)}$$

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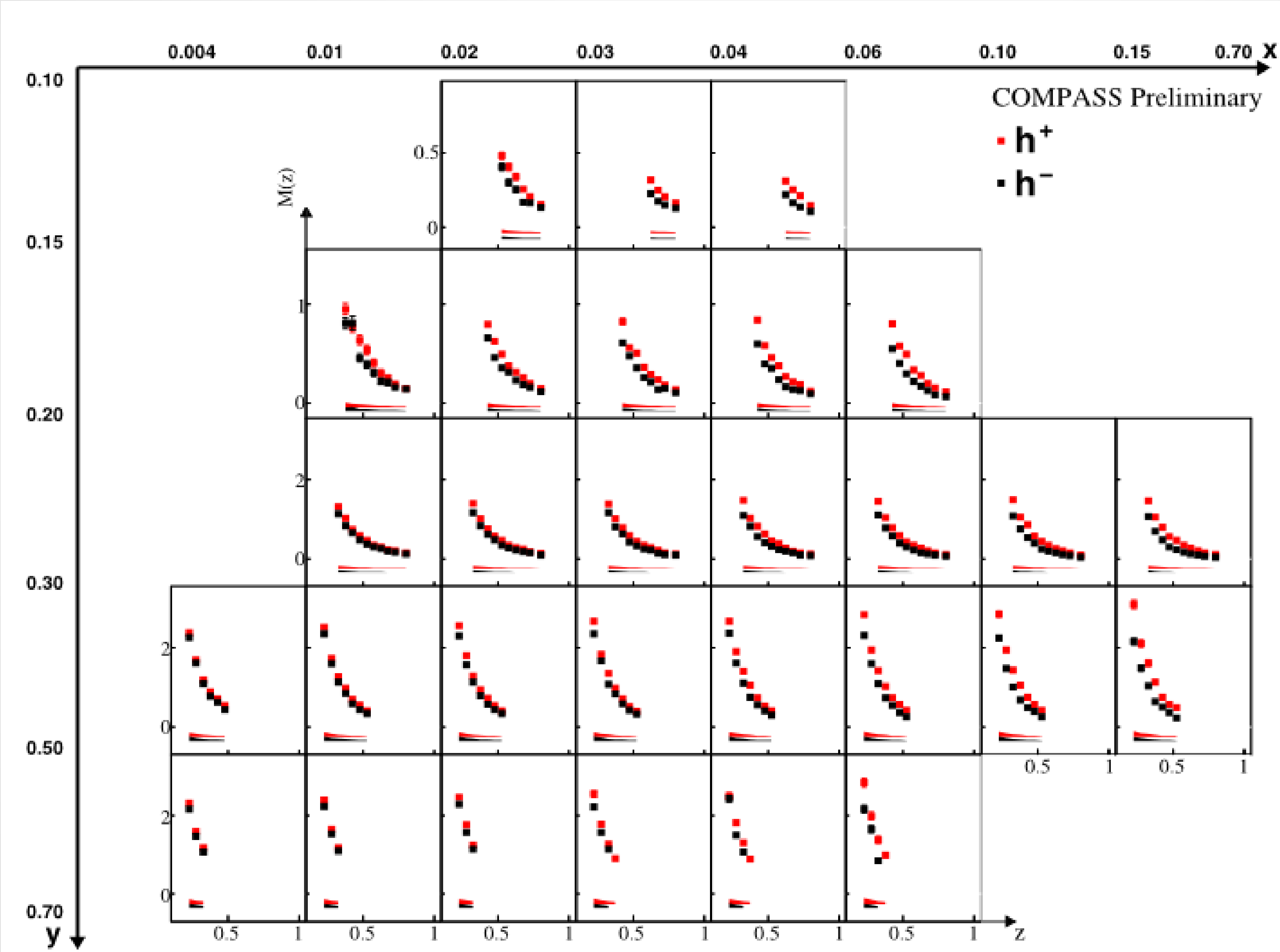
  - $0.004 < x_{Bj} < 0.7$
  - $0.1 < y < 0.7$

DIS events ~ 7.9×10^6
Hadrons events ~ 4.8×10^7

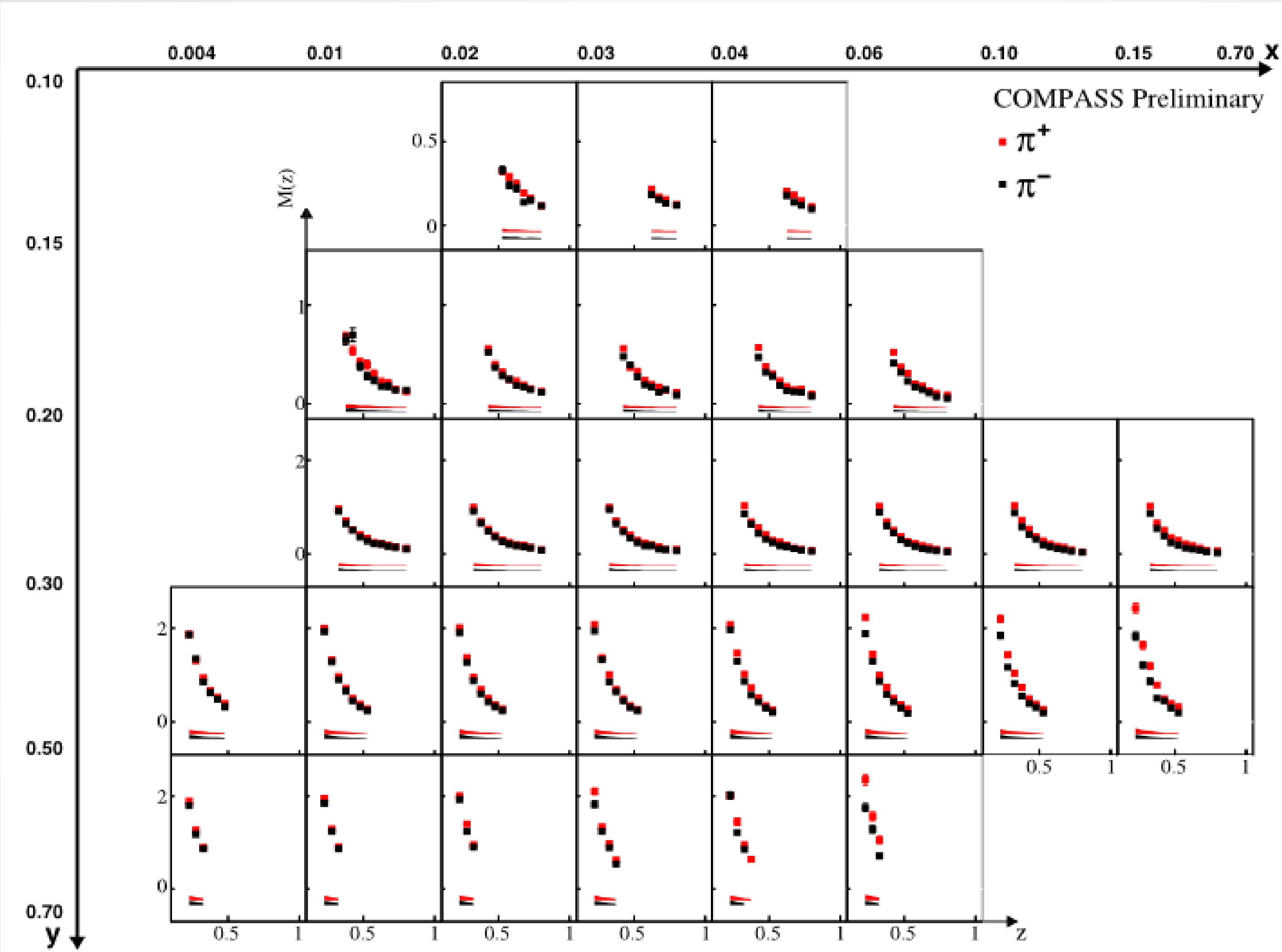
$$M^h(x_{Bj}, y, z) = \frac{M^h_{\exp}(x_{Bj}, y, z)}{A(x_{Bj}, y, z)}$$

- Geometric acceptance of the spectrometer and reconstruction efficiency
- Correct real data

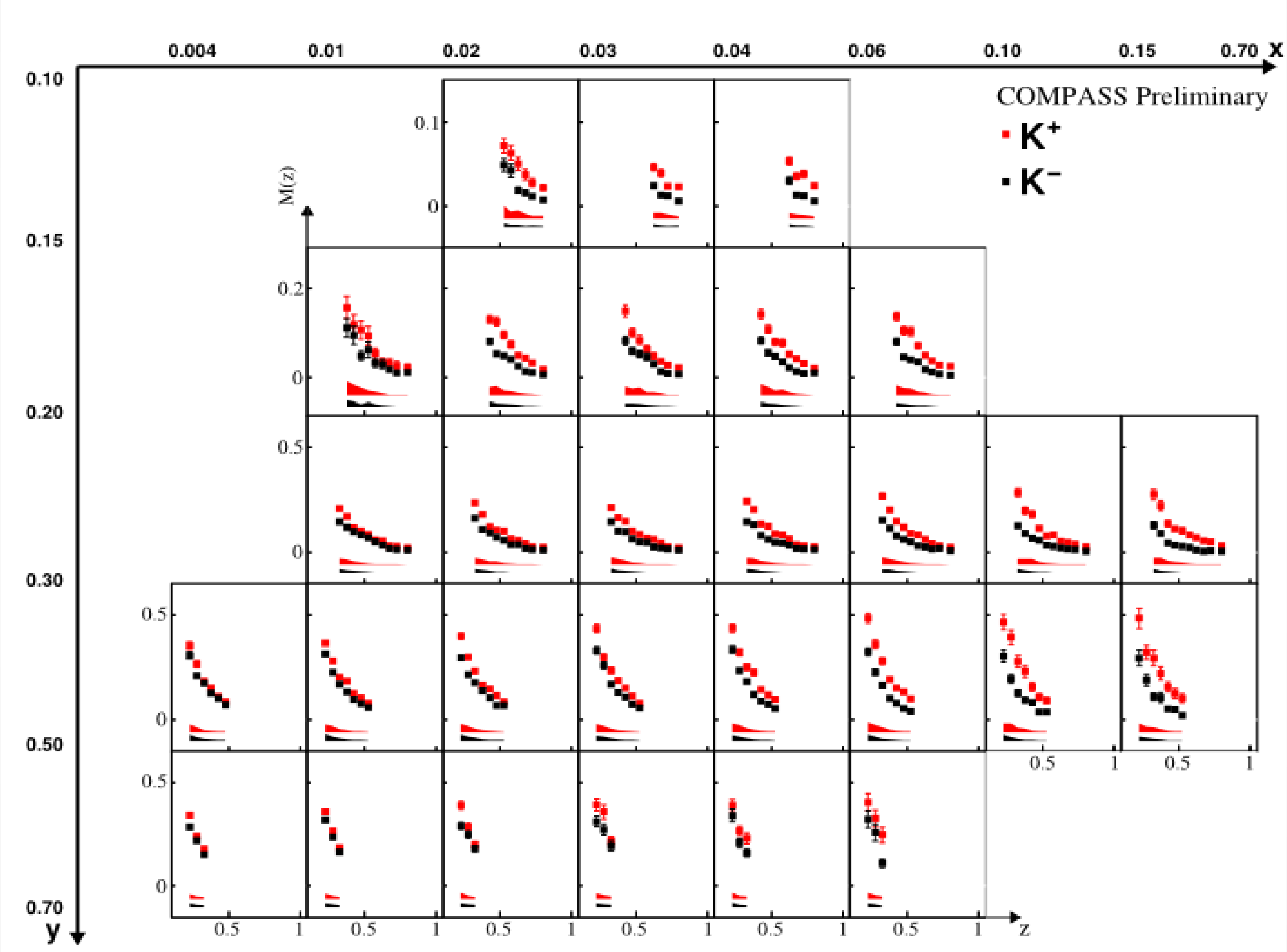
Unidentified hadron Multiplicities



π multiplicities



K multiplicities



Summary & Outlook

- Preliminary π and K multiplicities have been extracted in a multidimensional binning (x_{Bj},y,z) from SIDIS process ($\mu d \rightarrow \mu' h + X$) for 2006 COMPASS data (^{6}LiD target)
- Improvement on the RICH particle identification process → reduction in the systematic errors
- The COMPASS π multiplicities will be included in a new global fit to extract FF
- An analysis to study the contamination from exclusive vector mesons (ρ and Φ) is on-going
- Final π multiplicity soon ready (broad kinematical range)
- More work needed for the final K multiplicity
- P_T^2 dependent π and K multiplicities in (x, Q^2, z) bins analysis is on-going