Multiplicities of charged pion, kaon and hadrons from COMPASS

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On behalf of the COMPASS Collaboration

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Motivation: Fragmentation Functions

- Fragmentation functions (FF) describe parton fragmentation into hadron
- Relevant any time a final-state hadron is produced in high energy collisions
- Key ingredient in the flavor-separation of polarised parton distributions Δq
- Fundamental role in understanding single spin asymmetries, transversity (h_1)…
- Accessible in different processes

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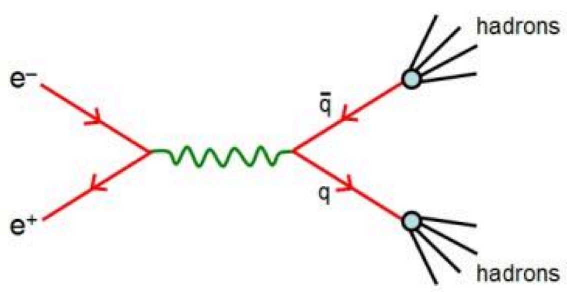
e^+e^- annihilation



- Clean process (only FFs enter)
- Very precise data (LEP/SLD, BELLE, BABAR,…)
- only sensitive to $q + \overline{q}$ FF

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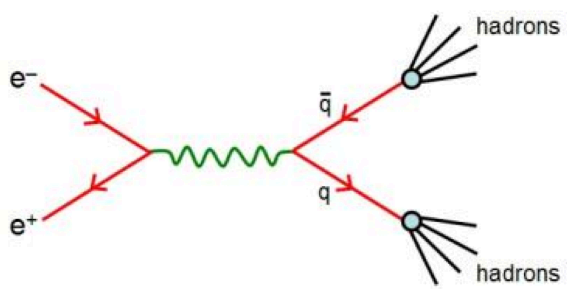

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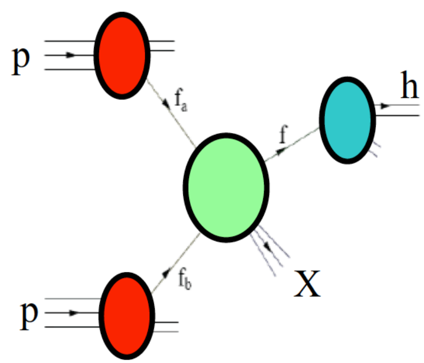

- Highly sensitive to gluon FF (high p_T hadron production)
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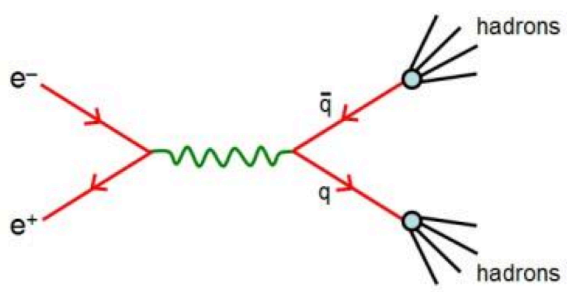

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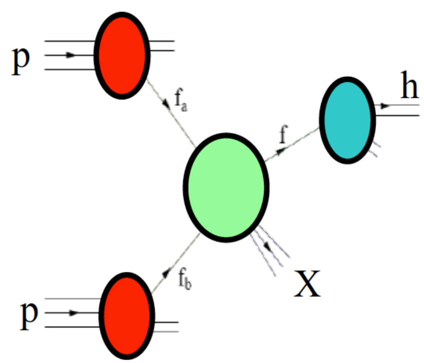

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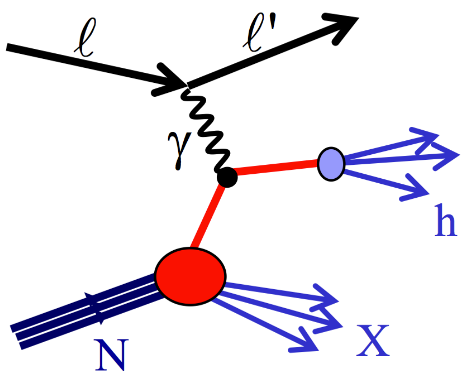
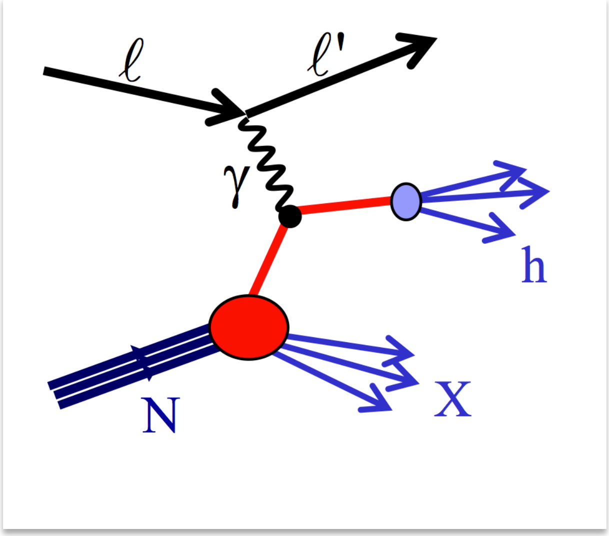
SIDIS



Semi-Inclusive DIS

SIDIS: a powerful tool to study $q \rightarrow h$ fragmentation



- Assess PDFs/FFs
- Flavor/charge separation
- wide scale coverage
- Nuclear target provide laboratory for fragmentation in nuclear medium
- Relevant for spin physics kinematic

$$\mathrm{d}\sigma^{\ell p\to\ell h X} \sim \sum_q e_q^2 f_q(x,Q^2)\cdot \mathrm{d}\sigma^{\ell q\to\ell q}\cdot D_q^h(z,Q^2)$$

Motivation, cont.

- Strange quark polarisation in the nucleon: $\int (\Delta s + \Delta\bar{s})\, dx = \Delta S$

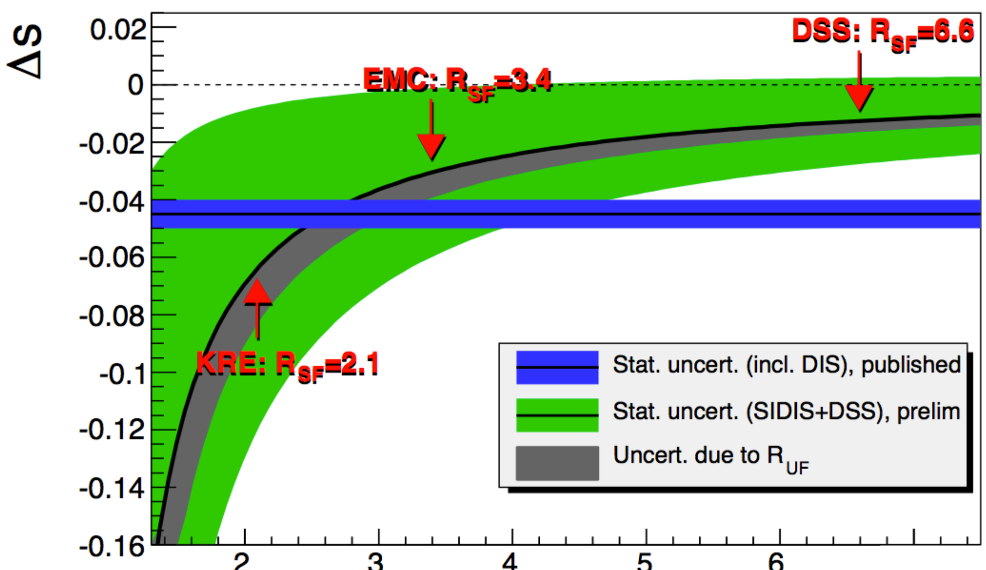
- ΔS obtained from fits to g_1 data and SIDIS π (SU(3) symmetry) is negative

  $\Delta S = -0.8 \pm 0.01 \pm 0.02$ PLB 647 (2007) 8

- SIDIS *K* data prefer zero or positive value at moderate x values

  $\Delta S = -0.01 \pm 0.01 \pm 0.01$ PLB 693 (2010) 227

- However impact of SIDIS *K* data strongly depends upon the choice of strange quark FF D_S^K



$$R_{SF} = \frac{\int D_{\bar{s}}^{K^+}(z)\mathrm{d}z}{\int D_u^{K^+}(z)\mathrm{d}z}$$

PLB 680 (2009) 217

Hadron Multiplicity

- Hadron Multiplicities are defined as observed number of hadrons in a number of DIS events

$$\frac{\mathrm{d}M^h(x,Q^2,z)}{\mathrm{d}z} = \frac{\mathrm{d}^3\sigma^h(x,Q^2,z)/\,\mathrm{d}x\,\mathrm{d}Q^2\,\mathrm{d}z}{\mathrm{d}^2\sigma(x,Q^2)/\,\mathrm{d}x\,\mathrm{d}Q^2}$$

quark FFs

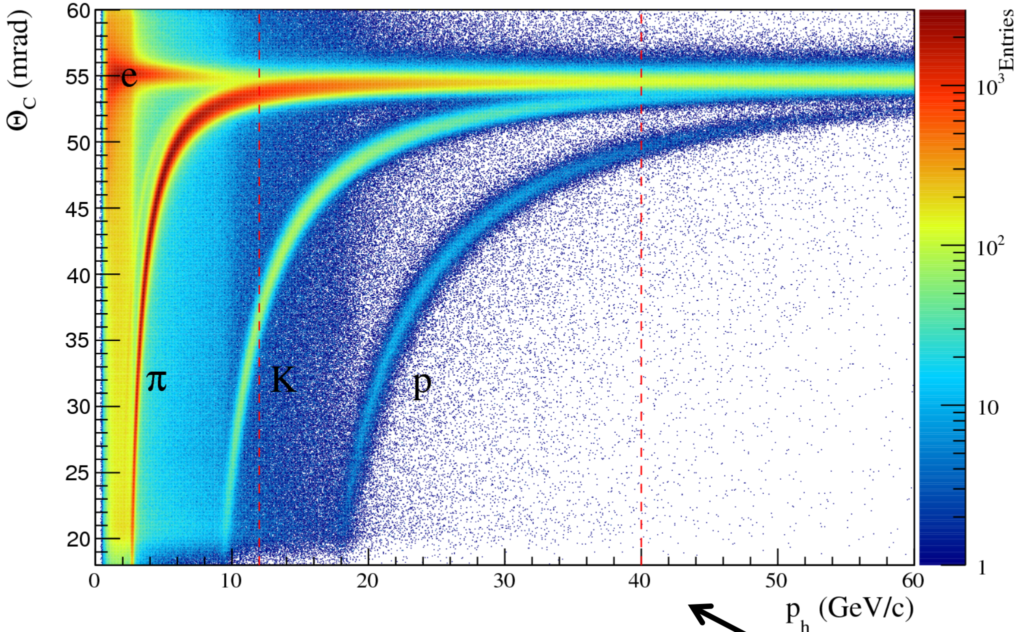
$$= \frac{\sum_q e_q^2 f_q(x,Q^2) D_q^h(z,Q^2)}{\sum_q e_q^2 f_q(x,Q^2)}$$

quark PDFs

Experimentally measured multiplicity must be corrected for many effects as

- Spectrometer acceptance
- PID efficiency and purity
- Radiative effects
- Diffractive vector meson production

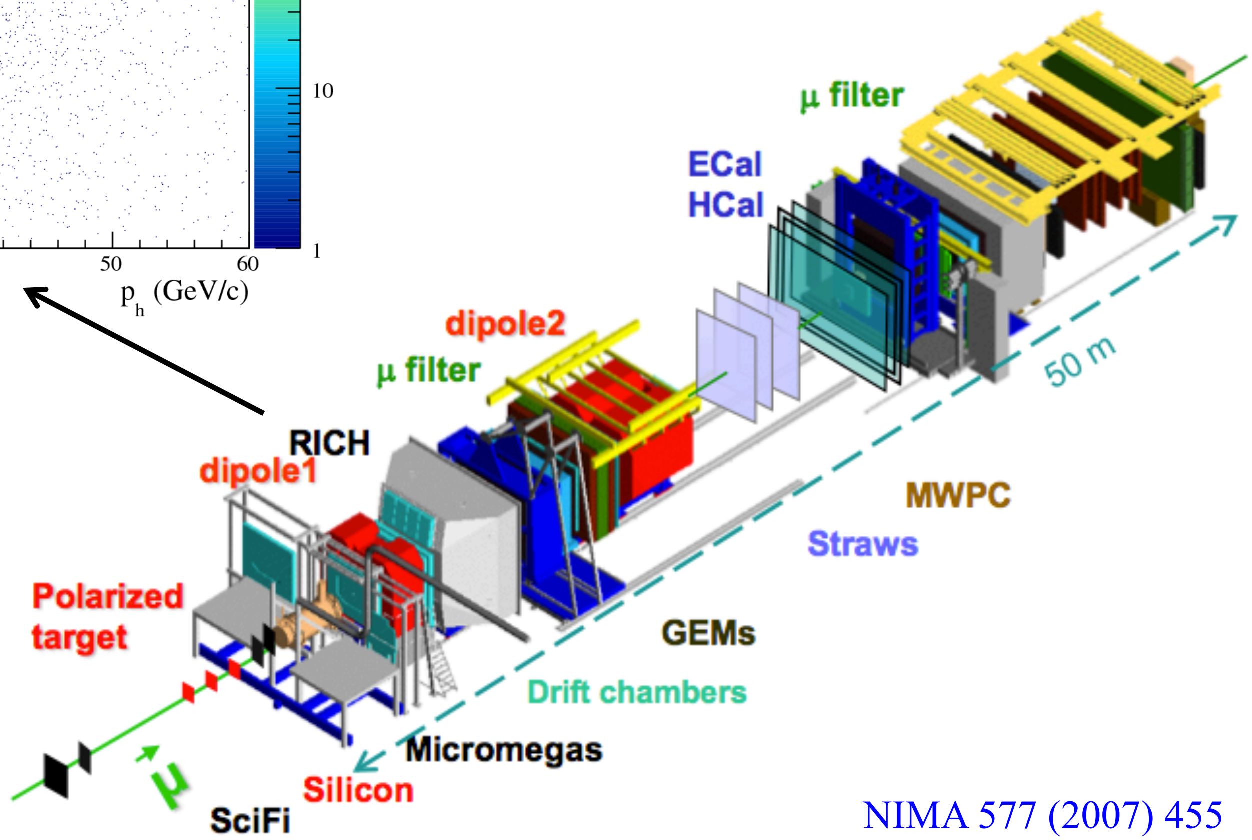
COMPASS Spectrometer



- Fixed-target
- Polarised muon beam & polarised targets p&d

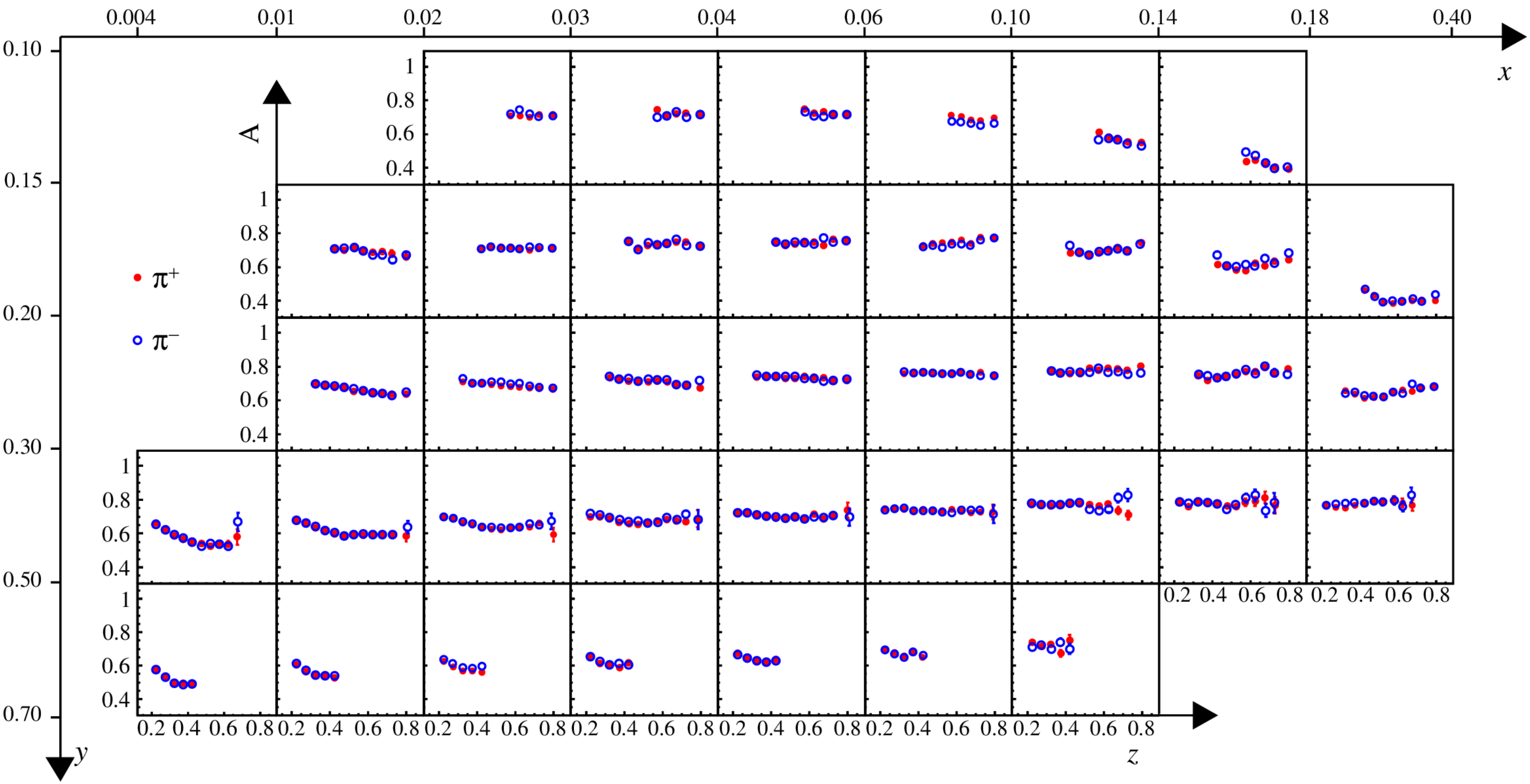
Excellent discrimination between π, K, p using RICH

This analysis:
160 GeV μ^+ beam
1.2 m long polarised ^{6}LiD isoscalar target (2006)



NIMA 577 (2007) 455

Acceptance

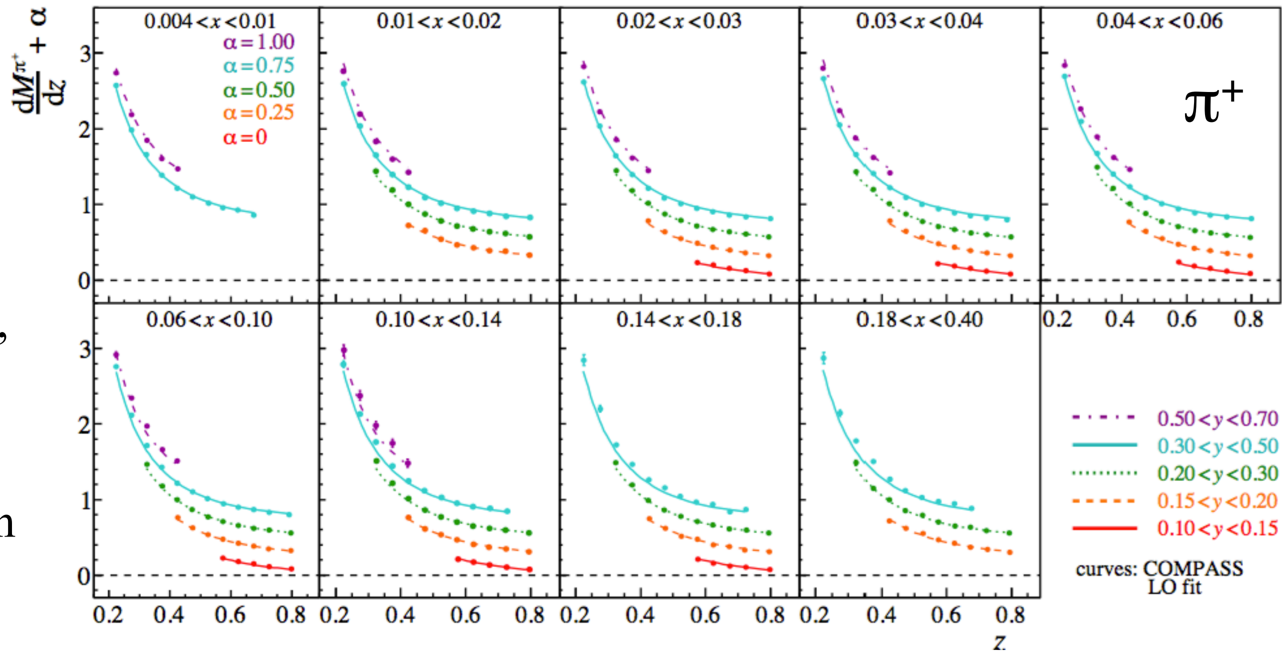


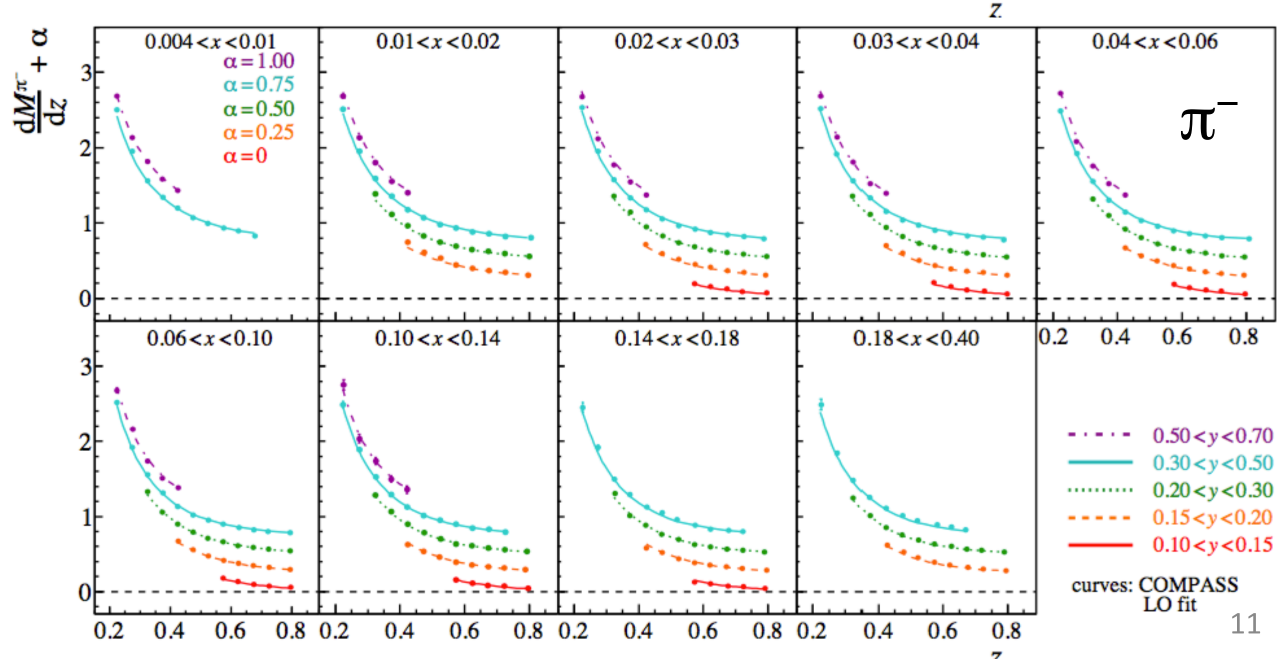
- ✧ Multidimensional evaluation of acceptance to avoid model dependencies
- ✧ High and flat acceptance in all kinematic bins, about 60-80%, uncertainty about 5%
- ✧ Little kinematic dependence except at high x

Charged pion multiplicity results

3-D kinematic binning in *x*, *y*, and *z*

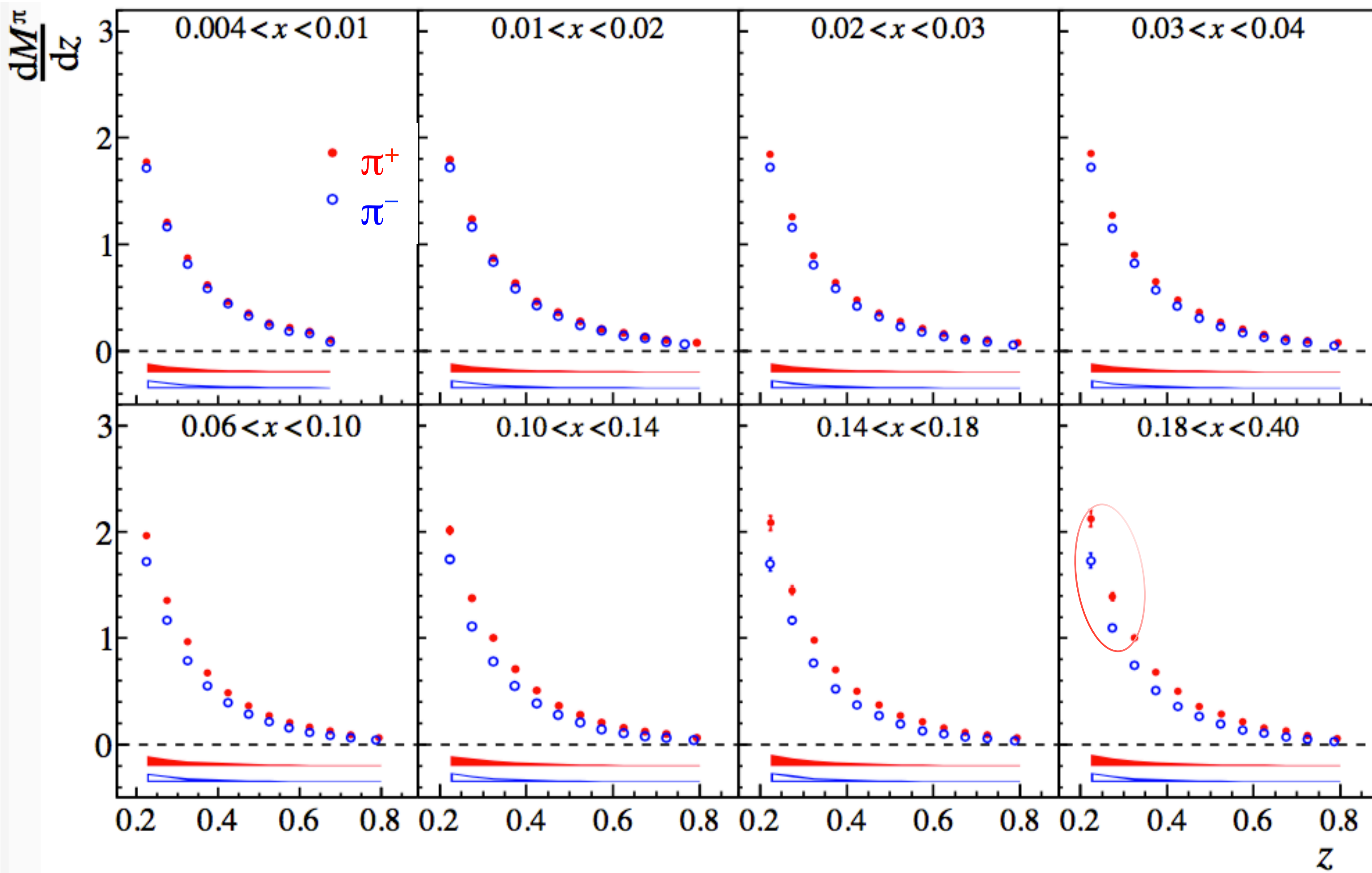
- ✧ 317 kinematic bins
- ✧ Practically no y dependence, strong z dependence
- ✧ curves: COMPASS LO pQCD fit: Results agree with world FFs
- ✧ DSS++ fit of FFs used preliminary data (only 189 kinematic bins)
- ✧ Paper accepted by PLB, arXiv:1604.02695





Charged pion multiplicity results

2-D projection in *x*,*z*



hep-ex:1604.02695

accepted by PLB.

✧ Small charge asymmetry due to u-quark dominance

Pion multiplicity sum

For the isoscalar target, when expressed at LO the sum is:

$$M^{\pi^+ + \pi^-} = D_{fav} + D_{unf} - \frac{2(s+\bar{s})}{5(u+\bar{u}+d+\bar{d})+2(s+\bar{s})}(D_{fav} - D_{unf}) \boxed{\approx D_{fav} + D_{unf}}$$

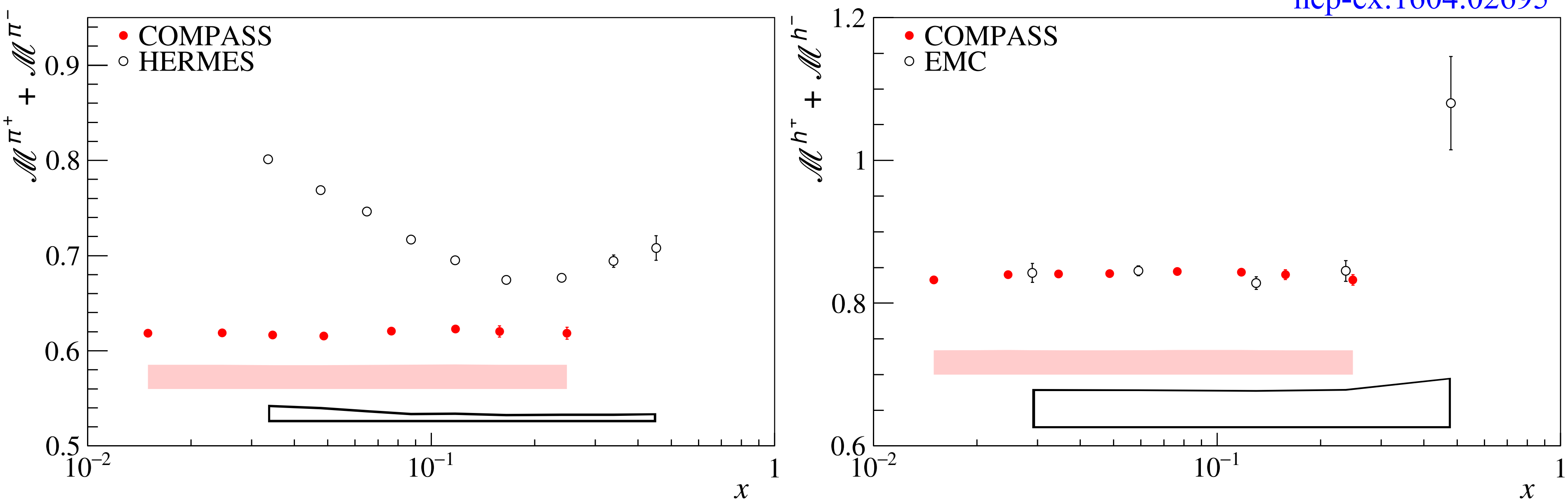
z-dependent term

⇒ z integrated sum is expected to be almost flat vs. x

pions:

Charged hadrons:

hep-ex:1604.02695

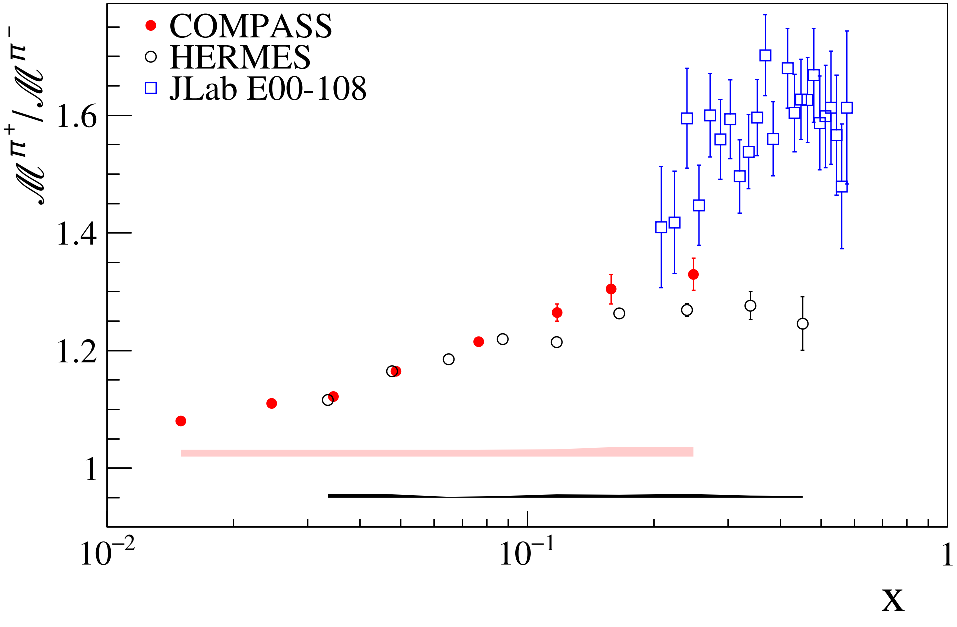


no x-dependence observed neither in COMPASS nor in EMC data as expected from LO predictions, at variance with HERMES data (lower energy)

π^+/π^- multiplicity ratio

- Interesting observable (π^+/π^-, h^+/h^-) because of cancellation of most of experimental systematic uncertainties
- Good agreement between COMPASS and EMC for charged hadrons, similar kinematic ranges covered by both experiments
- Reasonable agreement between COMPASS and HERMES results despite the discrepancy observed in the sum

pions:



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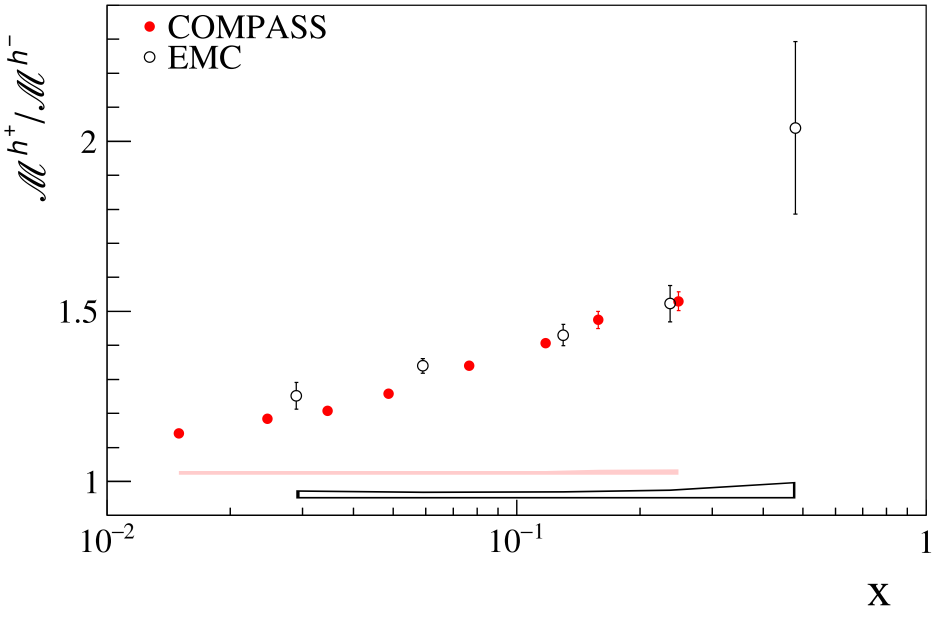
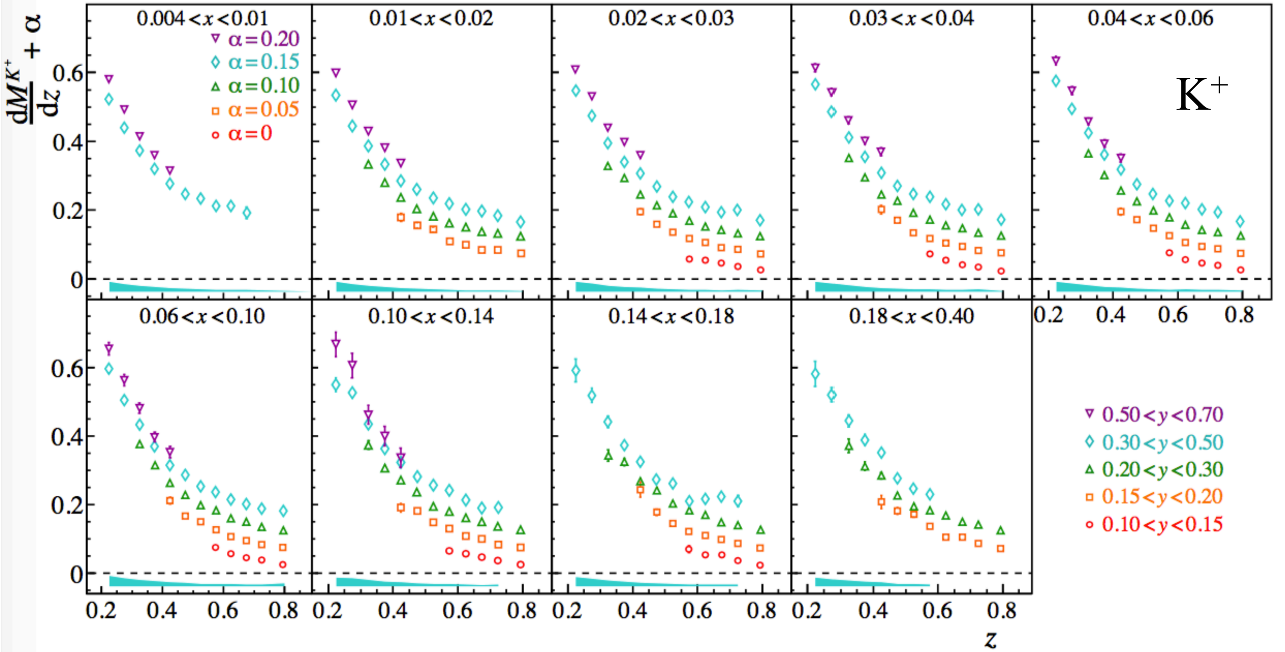
hep-ex:1604.02695

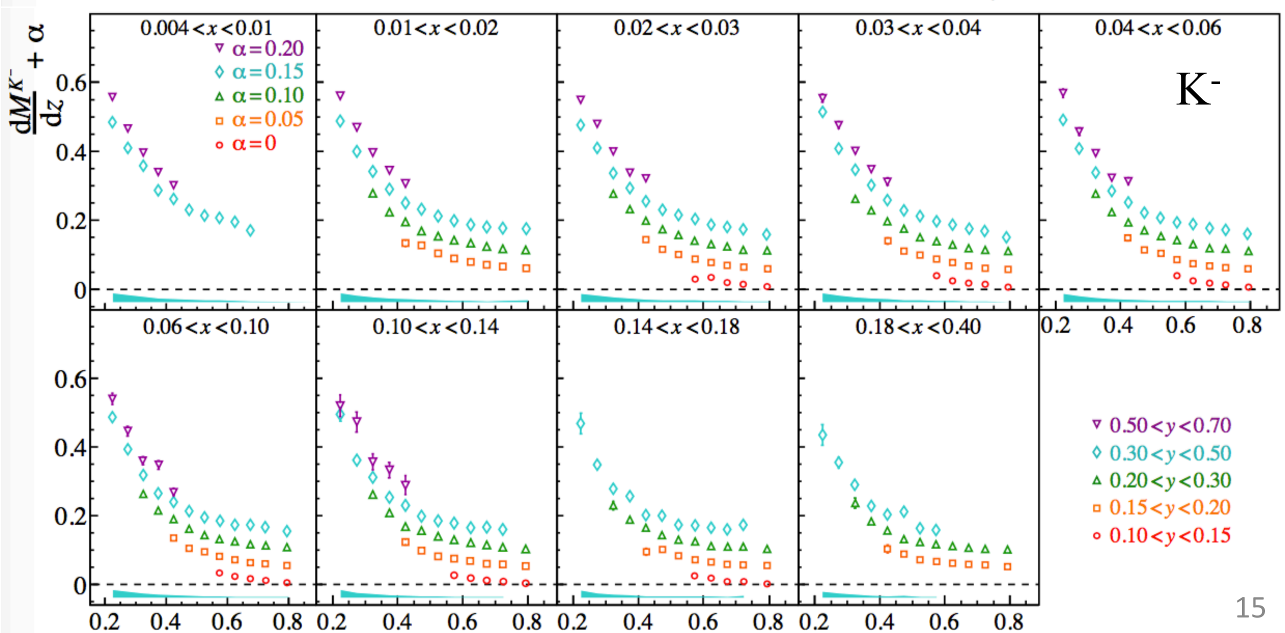


Charged Kaon multiplicity results

3-D kinematic binning
in *x*, *y*, and *z*

- 317 kinematic bins
- Strong z dependence as expected
- Paper submitted to PLB.
  hep-ex:1608.06760
- Valuable inputs for NLO QCD analyses foreseen in the near future





Kaon multiplicity sum

For the isoscalar target, when expressed at LO the sum is:

$$M^{K^+ + K^-} \approx \frac{Q D_Q^K + S D_S^K}{5Q + 2S}$$

non-strange: $Q = u + d + \bar{u} + \bar{d}$

$D_Q^K = 4D_{fav}^K + 6D_{unf}^K$

strange: $S = s + \bar{s}$, D_S^K

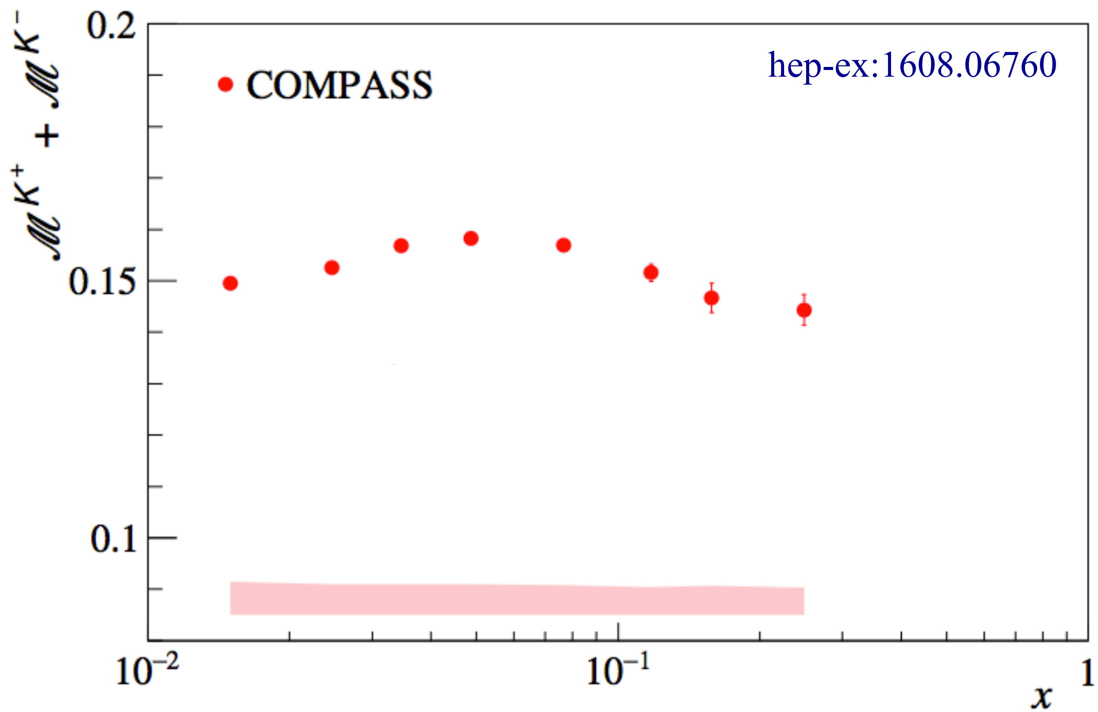
→ Separate strange and non-strange contributions

✧ At high x → S ≈ 0 → access D_Q^K

✧ $D_Q^K = 5M^{K+ + K-} = 0.7$

✧ $D_Q^K = 0.43$ in DSS analysis

Kaon results suggest larger non-strange than in DSS (PRD 75 114010)



Kaon multiplicity sum

For the isoscalar target, when expressed at LO the sum is:

$$M^{K^++K^-} \approx \frac{QD_Q^K + SD_S^K}{5Q+2S}$$

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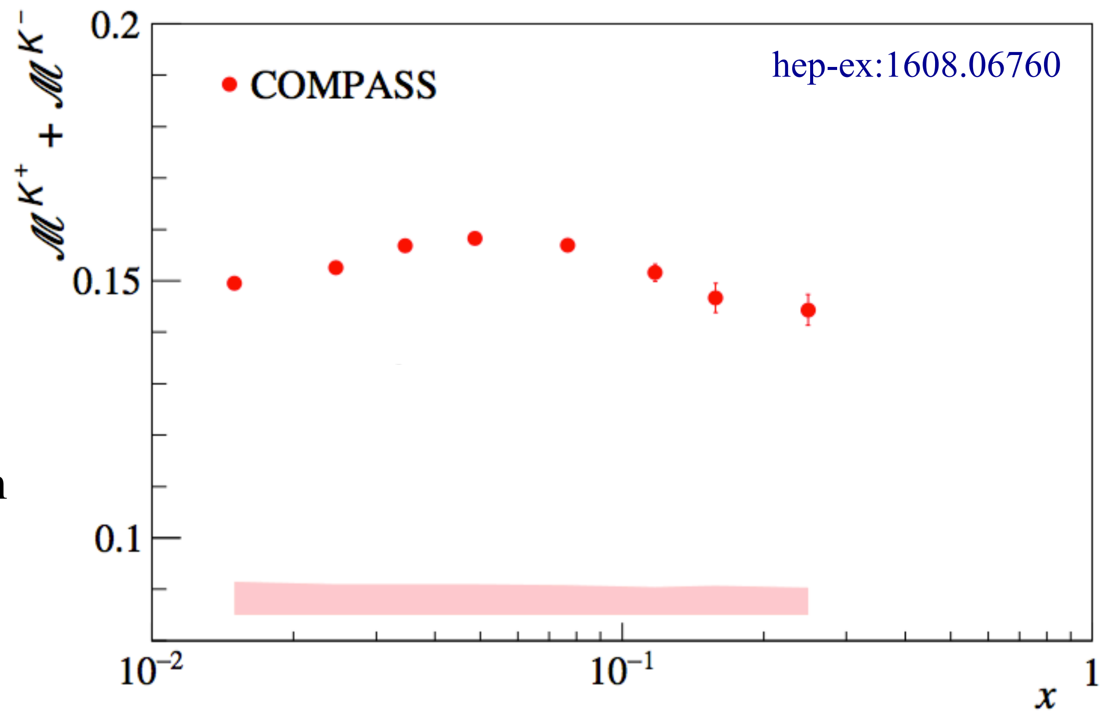
✧ At low x → SD_S^K may be significant

With DSS D_{str}/D_{fav}, one expects a rise in the M^{K++K-} towards low x (DSS ~ 50% increase)



✧ Strong increase of M^{K++K-} towards low x is not observed

✧ Results suggest lower D_{str}/D_{fav} than in the DSS parameterisation

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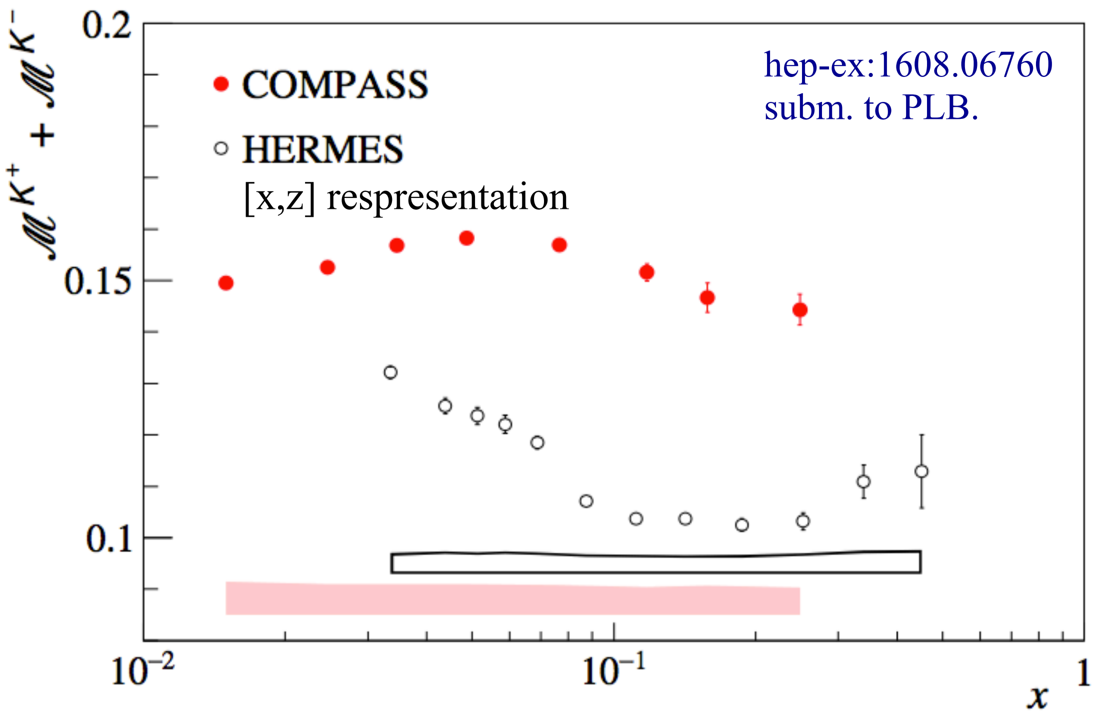
COMPASS vs. HERMES

Significant discrepancies observed:

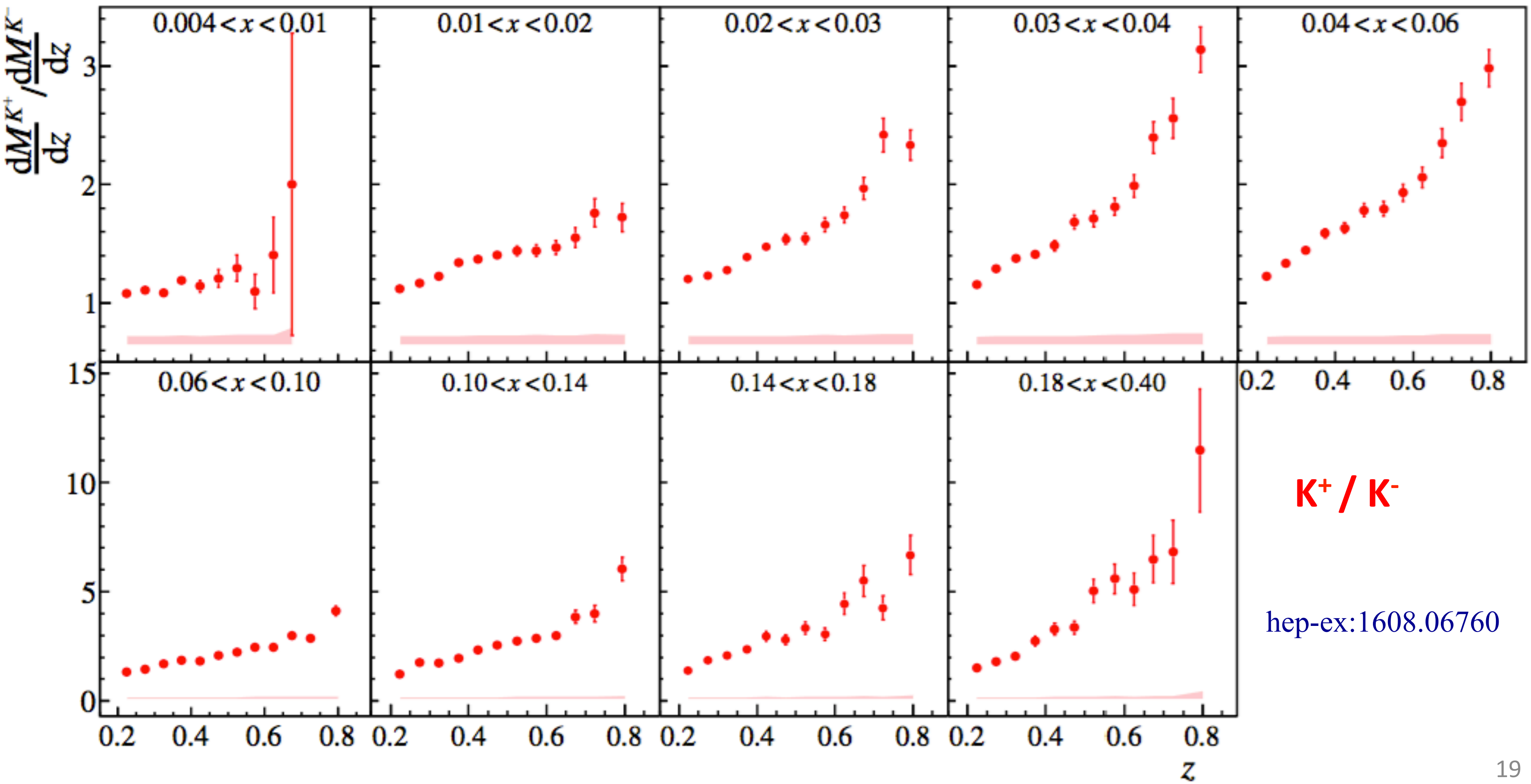
- shape of the sum at low x
- value of the sum at high x



Kaon multiplicity ratio

2-D projection in *x*, and *z*

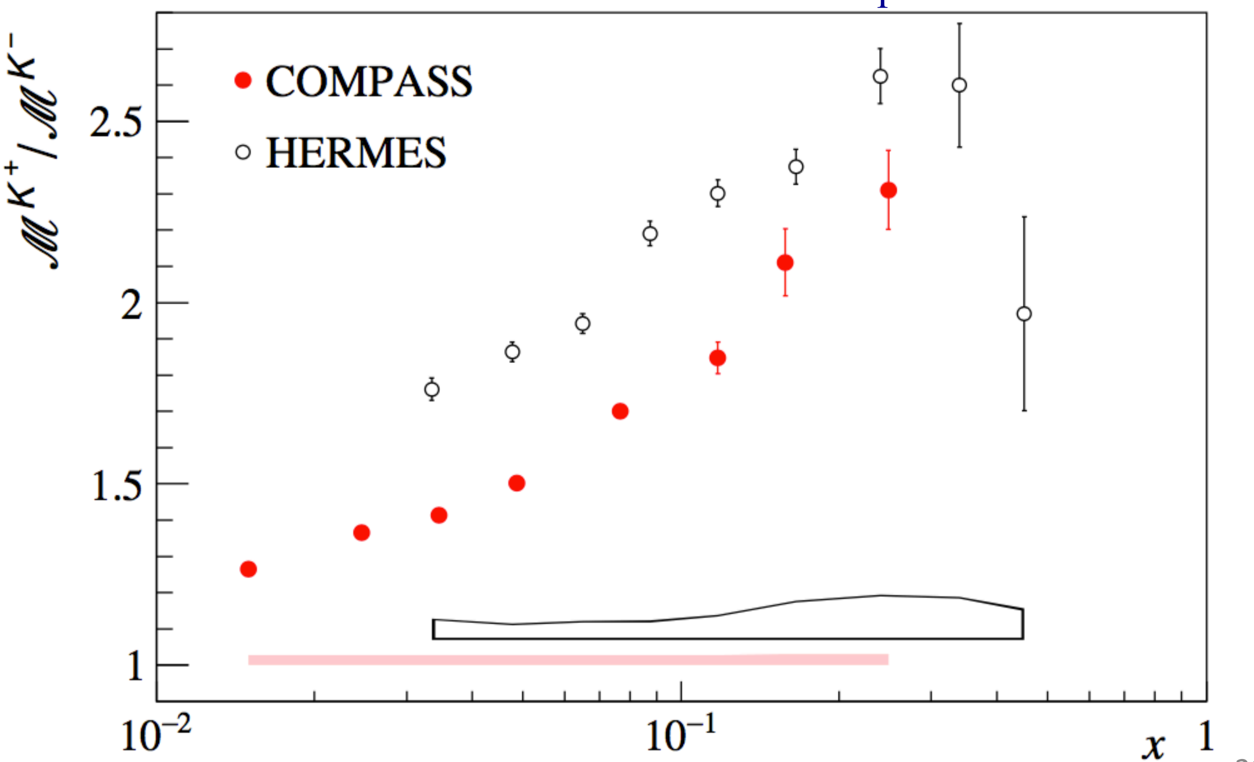
- ✧ K^+/K^- is interesting to study due to significant cancellation of systematic uncertainties
- ✧ Larger ratio at large z reflects favoured fragmentation dominance in K^+



Kaon multiplicity ratio, COMPASS vs. HERMES

- The ratio K^+/K^- is interesting to study due to significant cancellation of systematic uncertainties
- Significant discrepancy between COMPASS and HERMES is observed in contrast with the pion case (π^+/π^-) where a good agreement was found
- NLO QCD fits of FFs will help

hep-ex:1608.06760



Summary

- Charged pion, kaon and hadron multiplicities were measured at COMPASS using data collected with an isoscalar ^{6}LiD target and 160 GeV μ^{+} beam in 2006

  - in a wide kinematic domain
  - in 3-D kinematic binning in x,y and z
  - Paper on charged pion and hadron multiplicities accepted by PLB
    hep-ex:1606.03725, CERN-EP-2016-095
  - Paper on charged kaon multiplicities submitted to PLB
    hep-ex:1608.06760, CERN-EP-2016-206

- Visible tensions between COMPASS and HERMES (lower energy) results
- Favored and unflavored FF extracted from LO fits to COMPASS $\pi^{\pm}$ multiplicities only are in good agreement with results from global fits

Backup

RICH efficiency/purity

- COMPASS RICH detector is able to detect π , K and p starting from 3, 9 and 18 GeV/c respectively, up to about 50 GeV/c
- A 3x3 efficiency-purity matrix is obtained from data based on decays of K^0, Φ and Λ
- The analysis region was limited to a momentum range where K identification is stable, namely 13-40 GeV/c
- In the selected range, efficiency of K id if very high at the same time, miss-identification of π as K is very low.
- In order to minimize possible systematic effects, π and h multiplicities were extracted in the same momentum range as K