(Nuclear) fragmentation related measurements for an EIC

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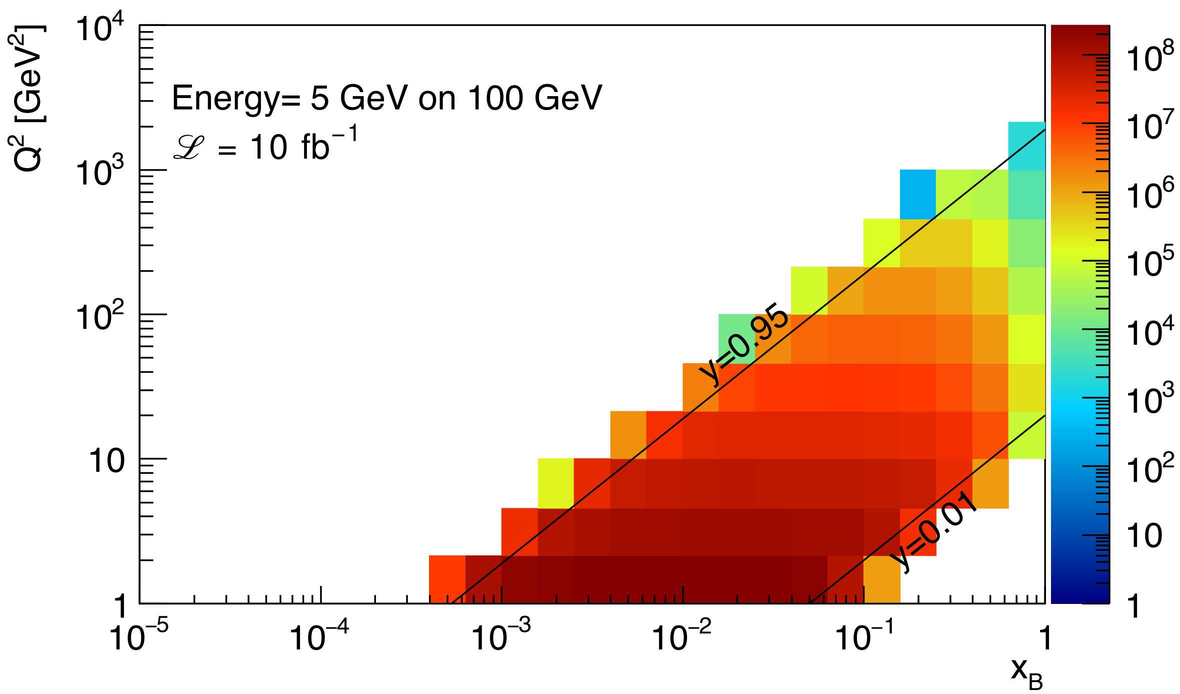
Outline

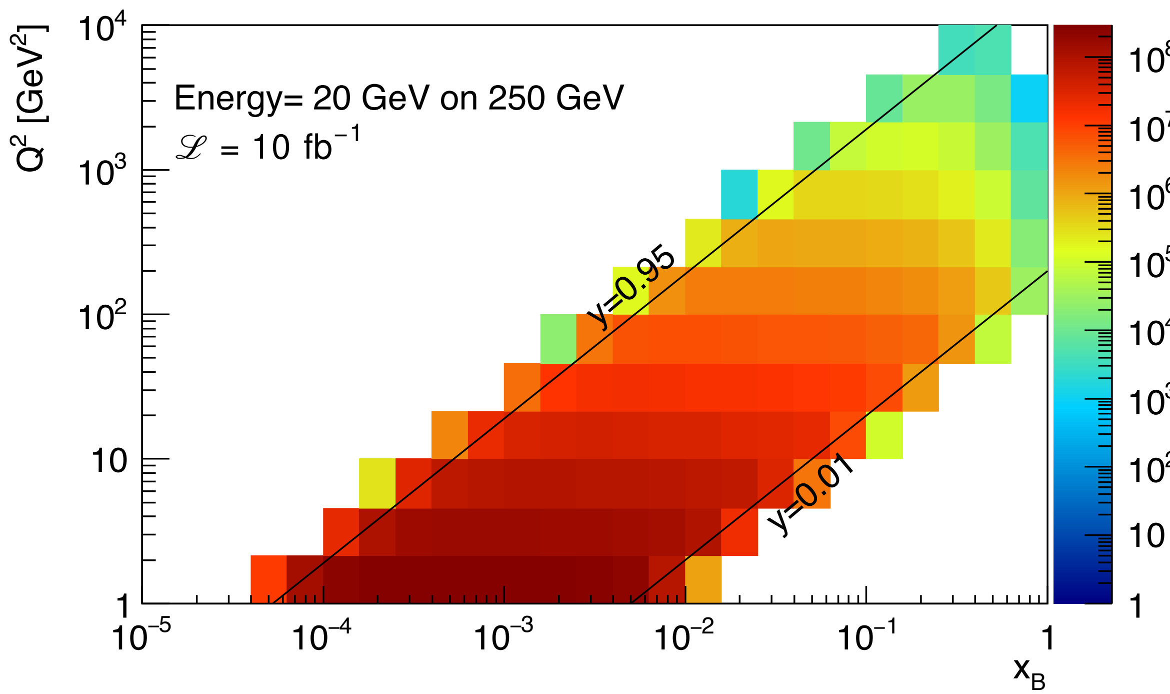
- Studies for an EIC of semi-inclusive lepton-nucleon DIS and collinear fragmentation
  [E. C. Aschenauer, I. Borsa, R. Sassot, CVH, PRD 99 (2019) 094004]

- Measurements from HERMES on nuclear targets

Study set up

- Two energy set ups: 5 GeV on 100 GeV and 20 GeV on 250 GeV
- PYTHIA-6 for event simulation
- Integrated luminosity of 10 fb^{-1}
- Kinematics: $Q^2>1$ GeV^2; $W^2>10$ GeV^2; $0.01<y<0.95$
- Finite detector resolution not considered





Hadrons

- Particle identification in pseudo-rapidity range -3.5<η<3.5

- Constraints imposed by particle identification

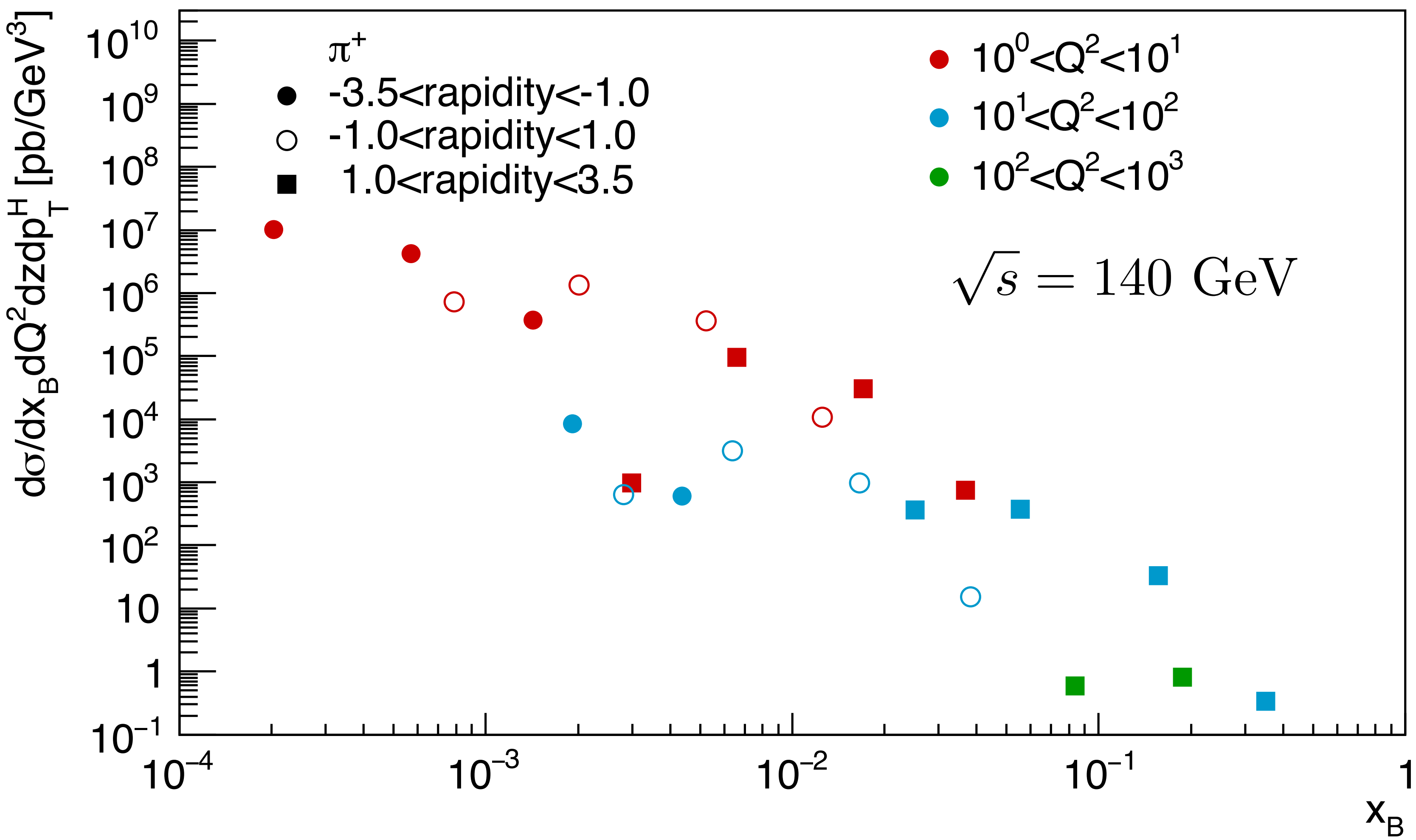
rapidity	pion momentum [GeV]	kaon momentum [GeV]	proton momentum [GeV]
$-3.5 <$ rapidity < -1.0 (RICH)	$0.5 < p_H < 5.0$	$1.6 < p_H < 5.0$	$3.0 < p_H < 8.0$
$-1.5 <$ rapidity < -1.0 (dE/dx)	$0.2 < p_H < 0.6$	$0.2 < p_H < 0.6$	$0.2 < p_H < 1.0$
$-1.0 <$ rapidity < 1.0 (DIRC and dE/dx)	$0.2 < p_H < 4.0$	$0.2 < p_H < 0.7$	$0.2 < p_H < 1.1$
		$0.8 < p_H < 4.0$	$1.5 < p_H < 4.0$
$1.0 <$ rapidity < 3.5 (RICH)	$0.5 < p_H < 50.0$	$1.6 < p_H < 50.0$	$3.0 < p_H < 50.0$
$1.0 <$ rapidity < 1.5 (dE/dx)	$0.2 < p_H < 0.6$	$0.2 < p_H < 0.6$	$0.2 < p_H < 1.0$

- Minimum momentum: 0.5 GeV, imposed by 3 T magnetic field

  Magnetic field strength: compromise between loss of low-momentum hadrons and decrease in momentum resolution of high-momentum hadrons (at large rapidities)

Complementarity in rapidity

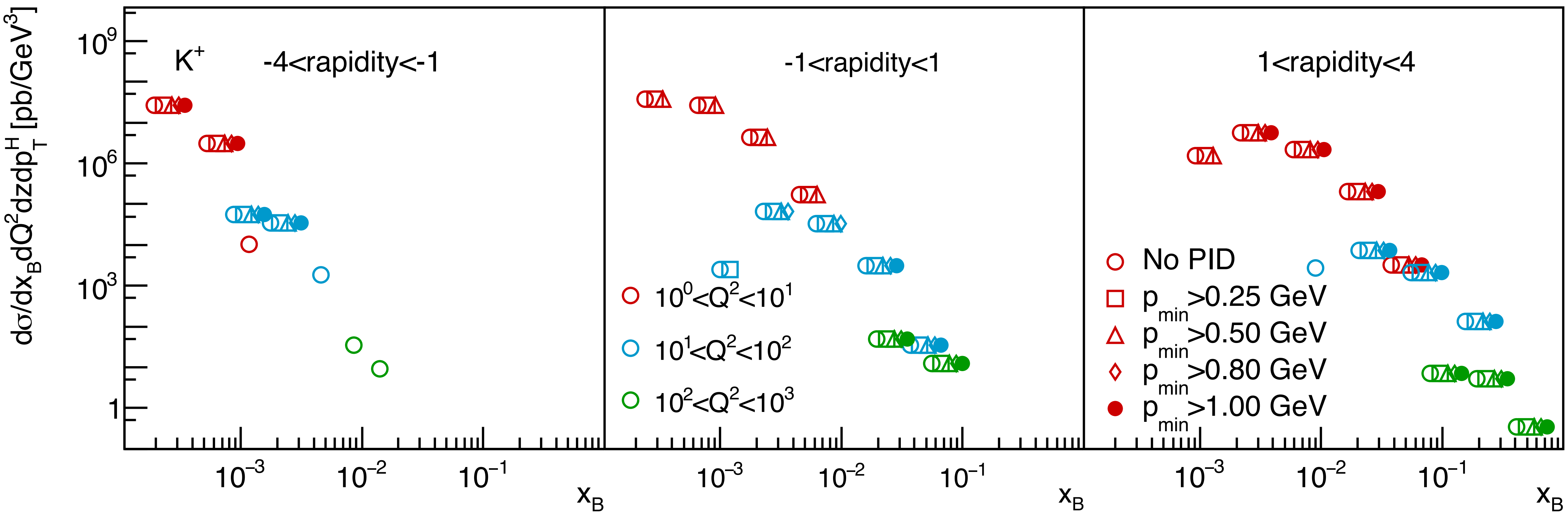
$$0.4 < z < 0.8 \text{ and } 0.2 < p_T^H < 0.5$$



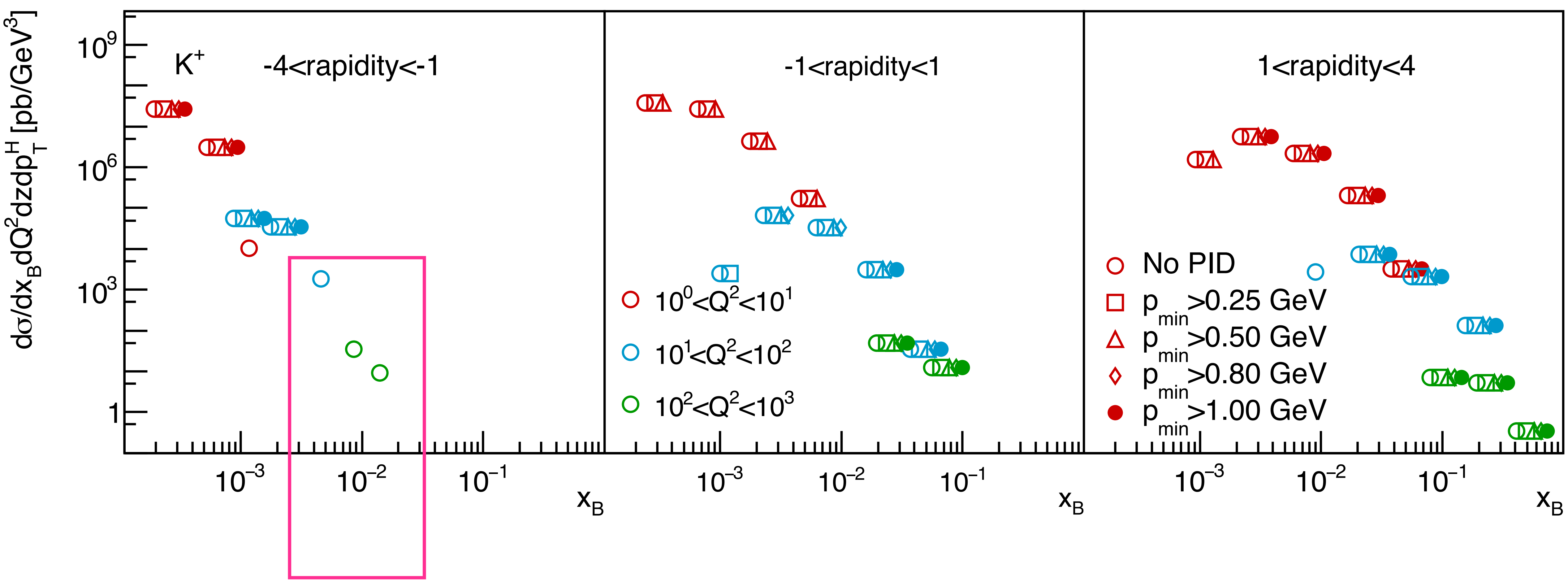
- Low Q^2 at backward rapidity; high Q^2 at forward rapidity
- Fixed Q^2: low x_B at backward rapidity; high x_B at forward rapidity

Need PID at backward, mid and forward rapidity!

Influence of PID and magnetic field

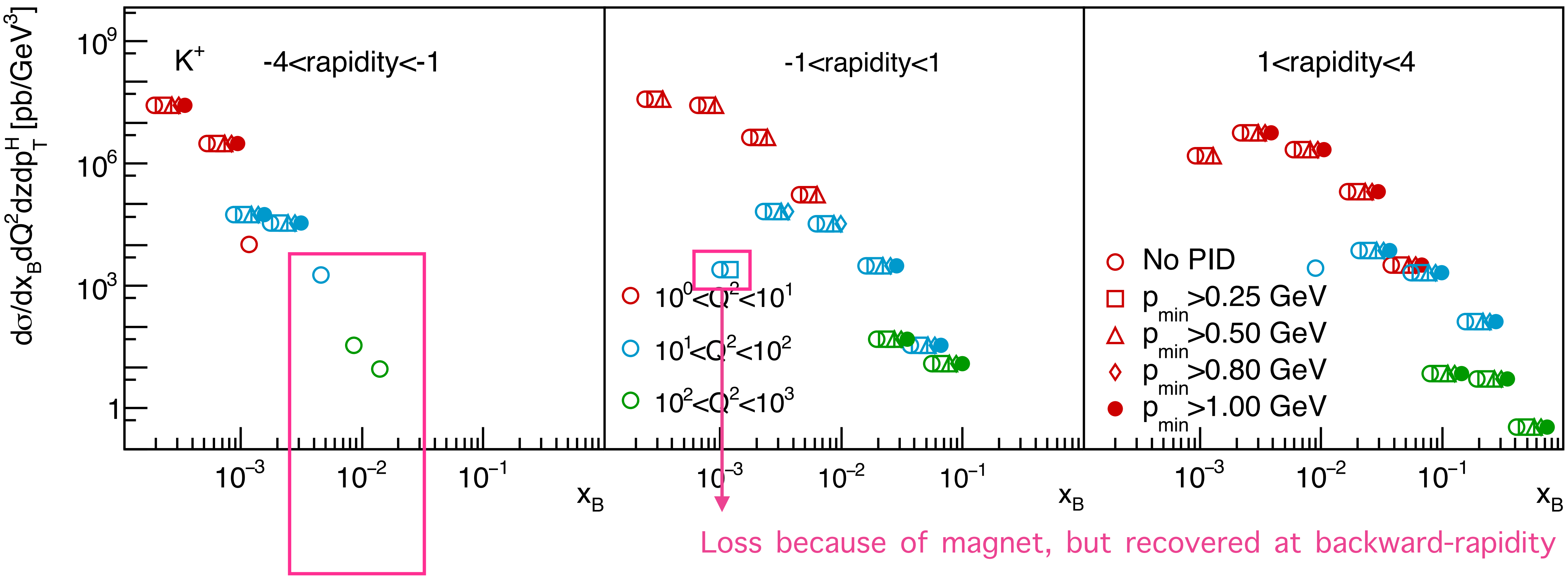


Influence of PID and magnetic field



Loss because of PID, but recovered at mid-rapidity

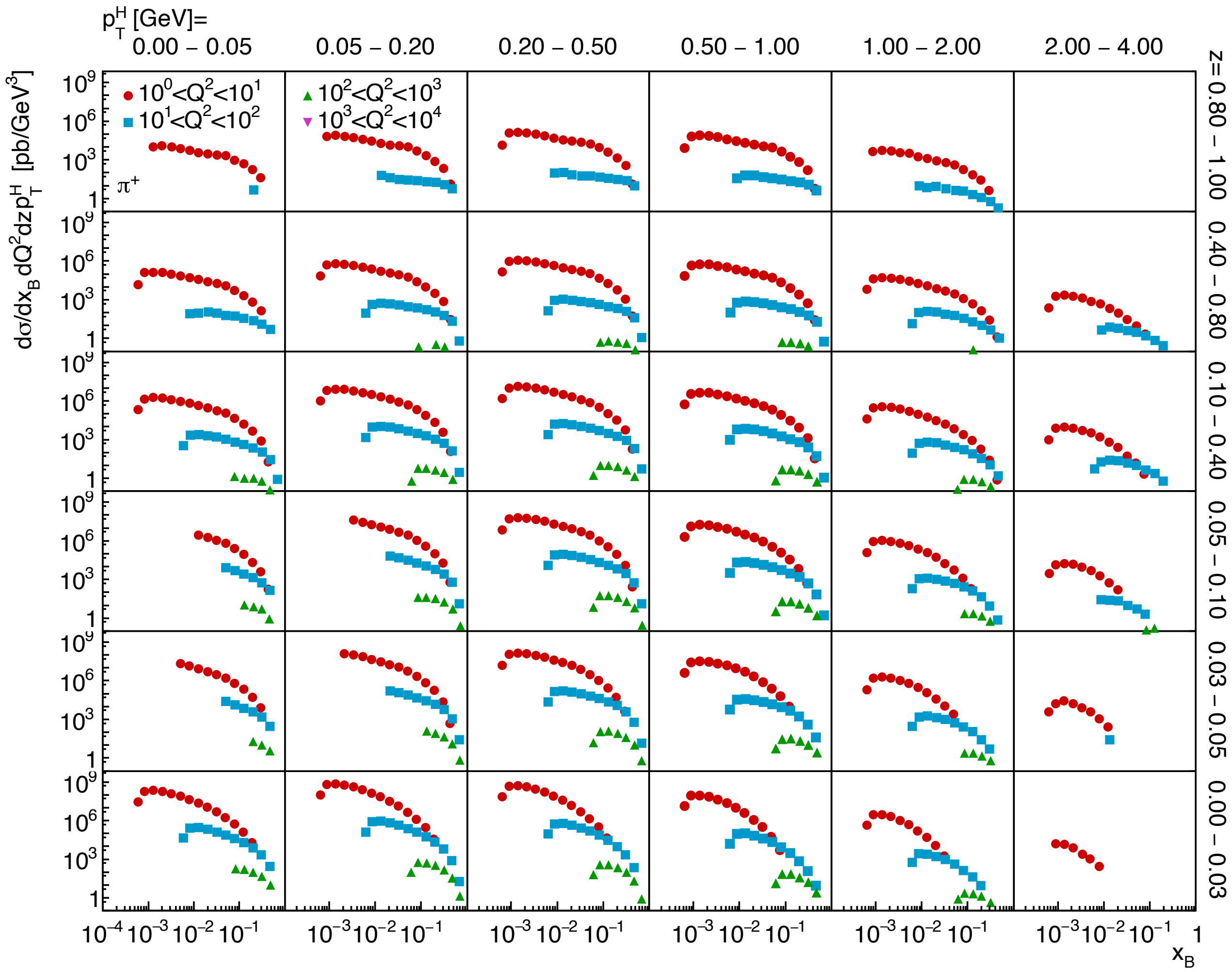
Influence of PID and magnetic field



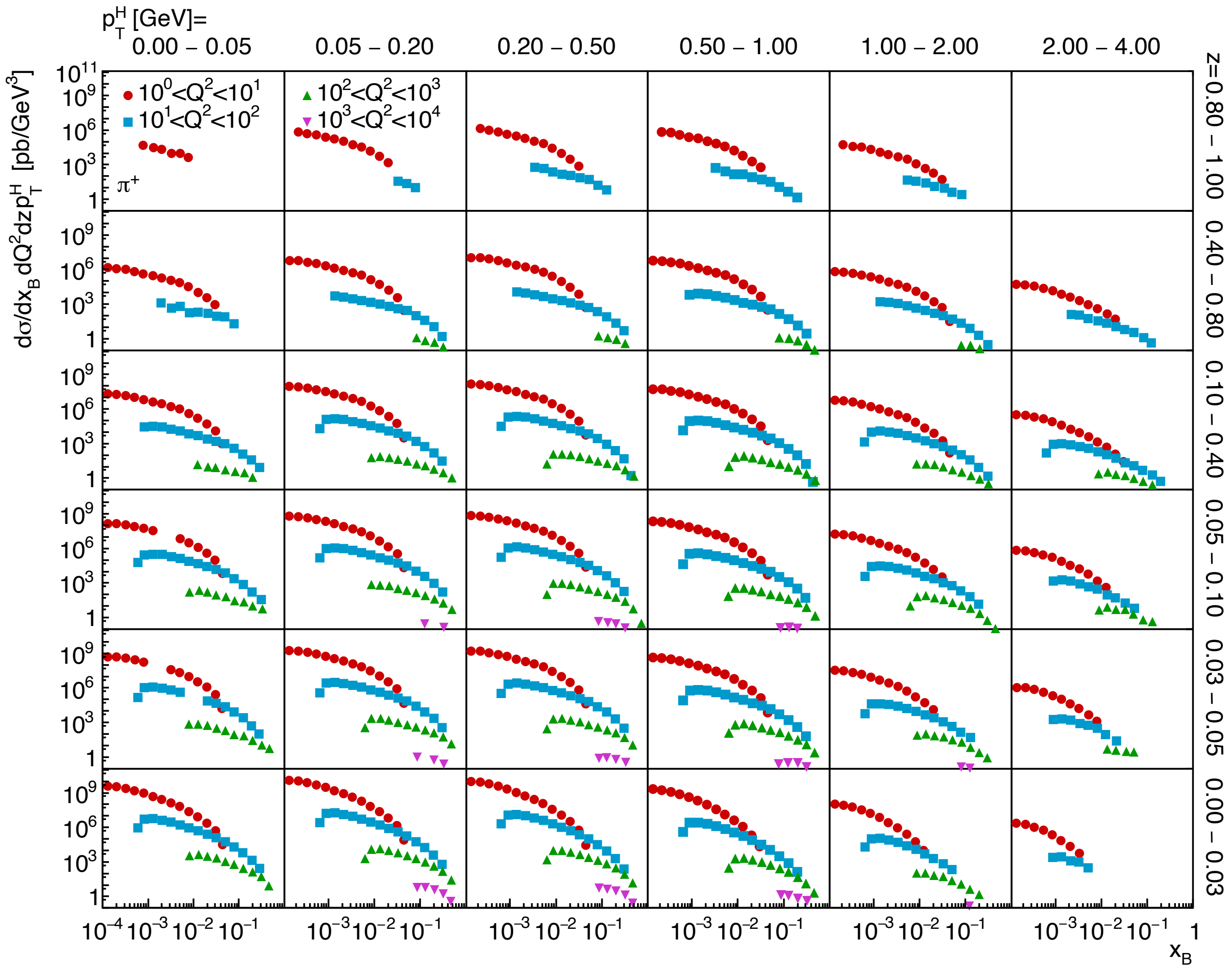
Loss because of magnet, but recovered at backward-rapidity

Loss because of PID, but recovered at mid-rapidity

Covered kinematic region

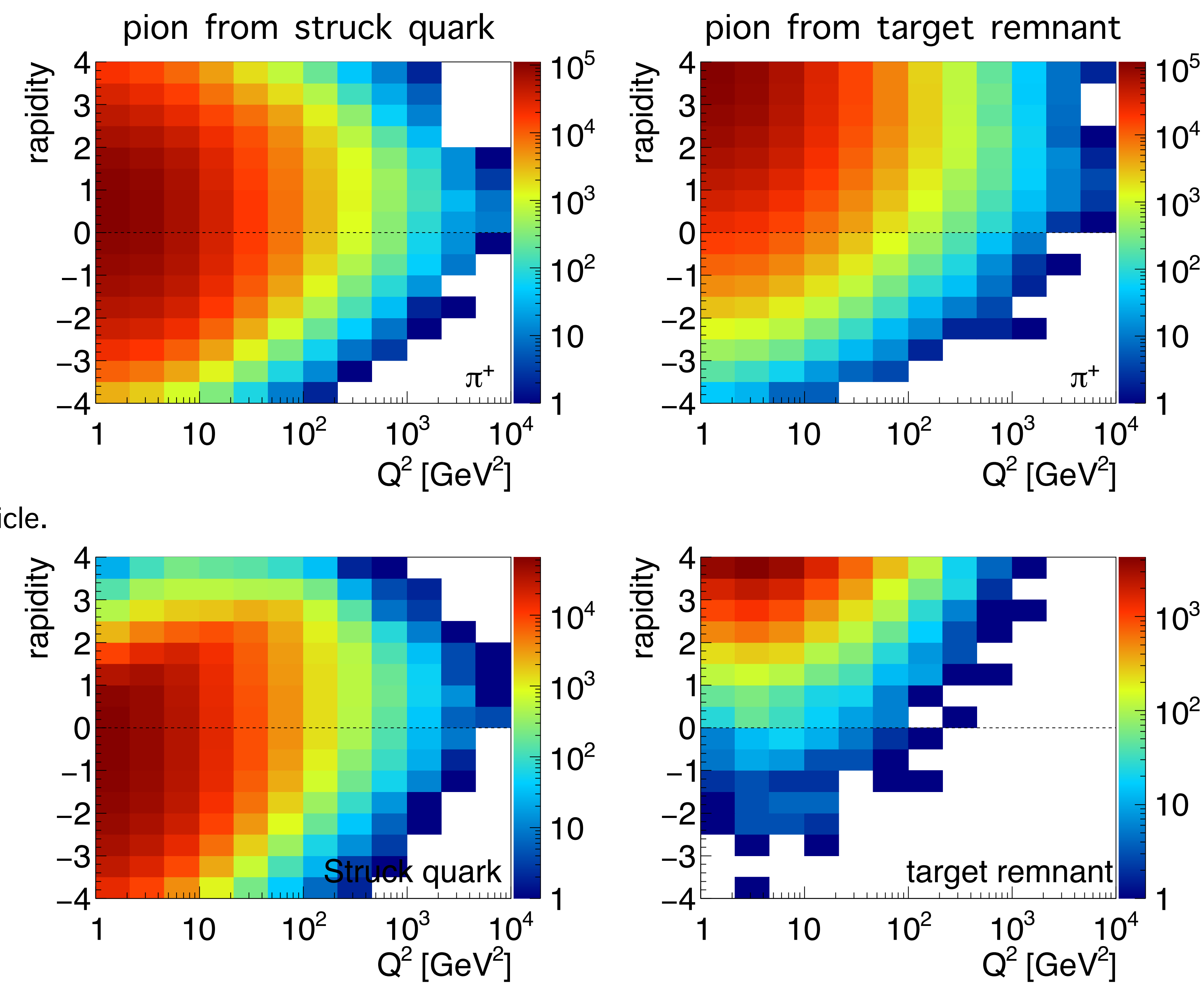


$\sqrt{s} = 45$ GeV



$\sqrt{s} = 140$ GeV

Current and target fragmentation



process $\gamma^* q \to q$

Struck quark:
KS=11 or 12, parent particle: KS=21.

Target remnant:
KS=11 or 12, nucleon as parent particle.

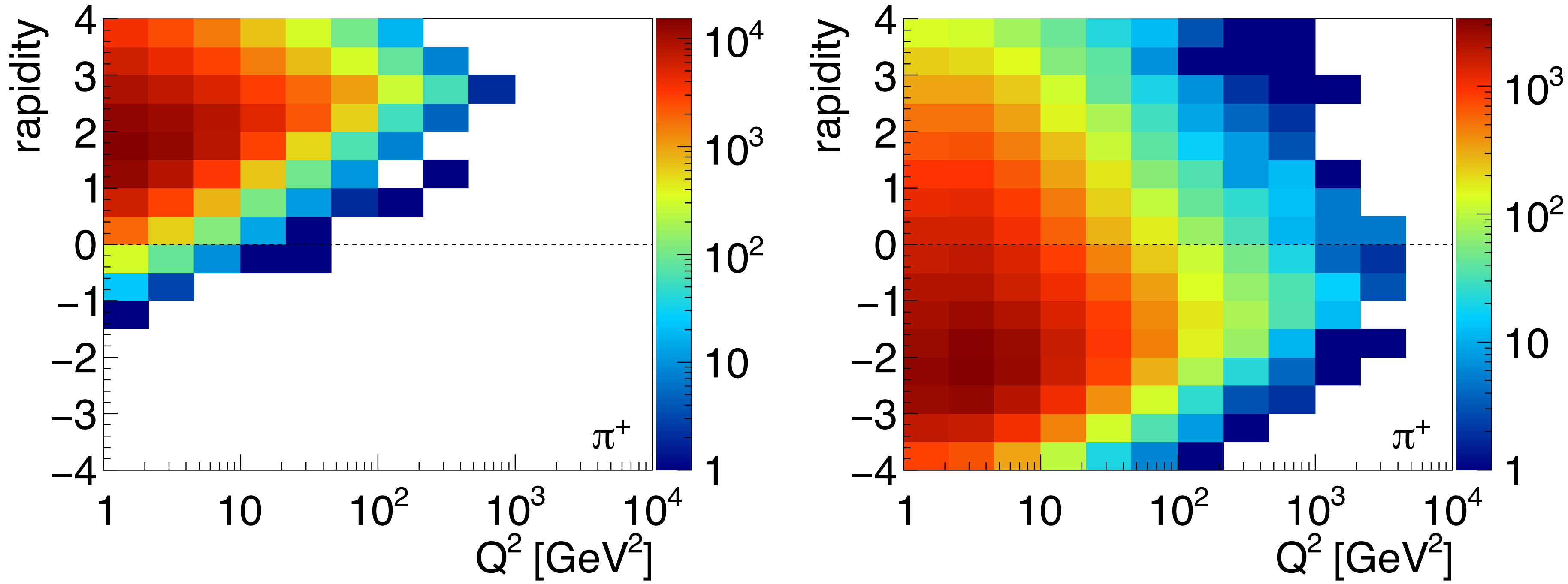
Large coverage in rapidity:
improved separation current and target fragmentation

Current and target fragmentation: W^2 dependence

process $\gamma^* q \to q$

Struck quark:
KS=11 or 12, parent particle: KS=21.

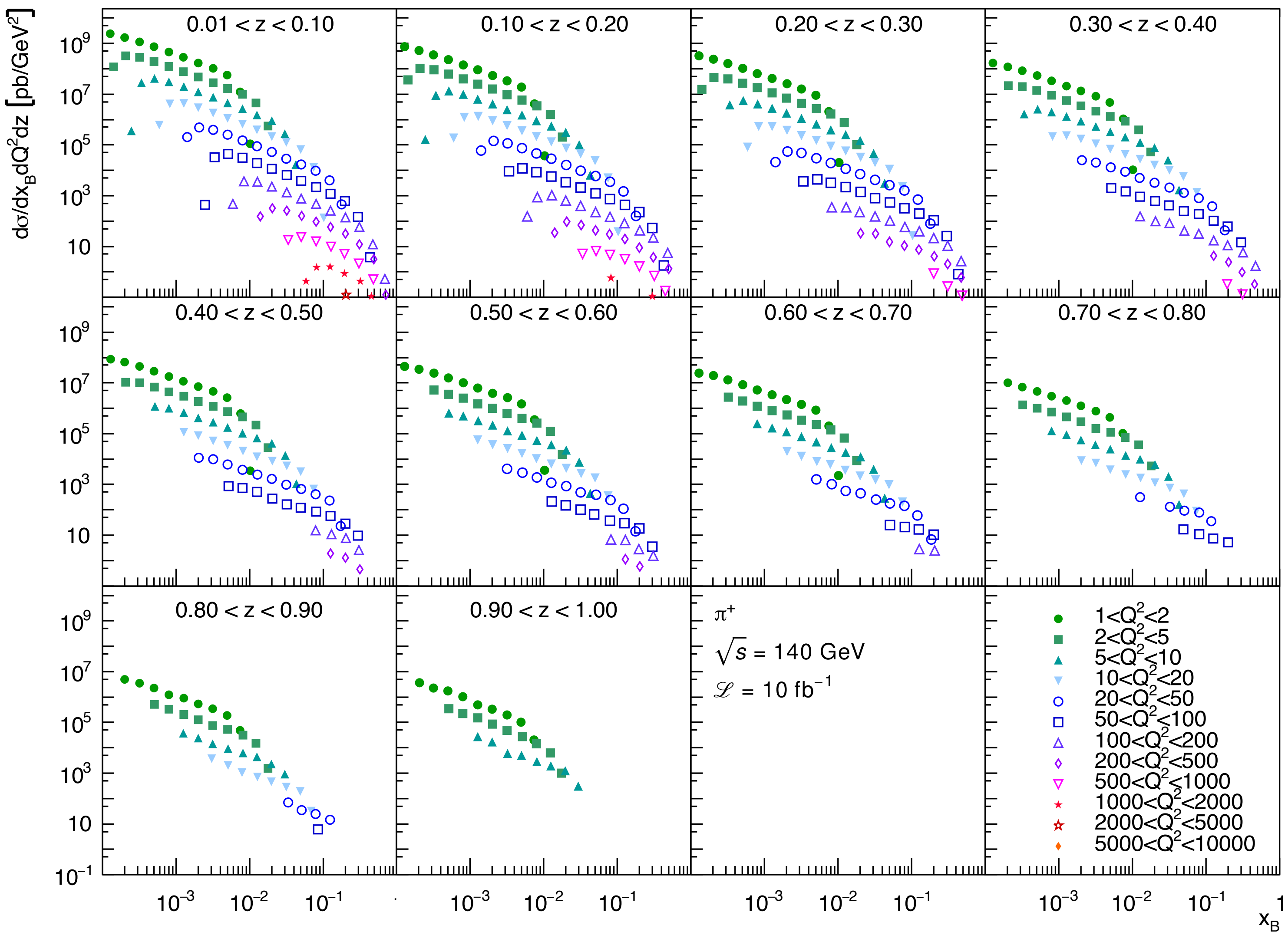
pion from struck quark



200 GeV^2<W^2<300 GeV^2 16000 GeV^2<W^2<18000 GeV^2

Strong W^2 dependence

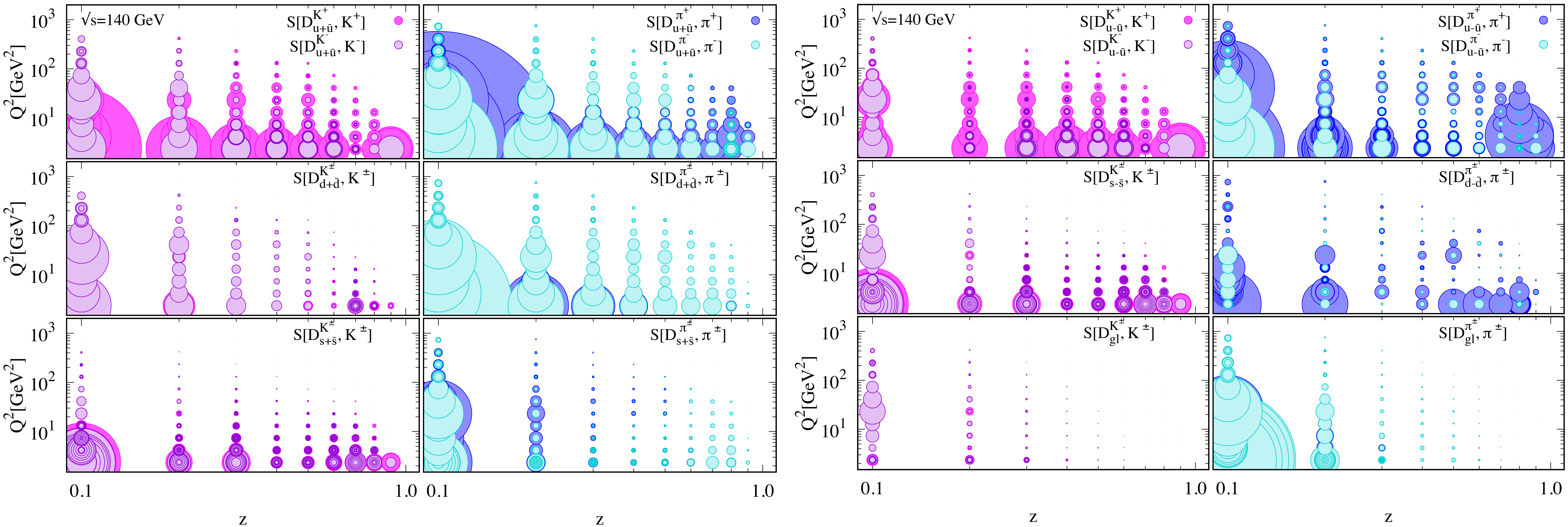
Impact of EIC data on extraction of fragmentation functions



- current fragmentation
- pion and kaon production
- based on unfolded EIC pseudo-data
- Methodology:
  - generate set of FF replicas according to uncertainty of existing data
  - weights take into account degree of agreement between replica and new EIC data
  - recalculate new FF
  - NLO accuracy
- statistical uncertainties of pseudo-data and PDF uncertainty when reweighing the FFs

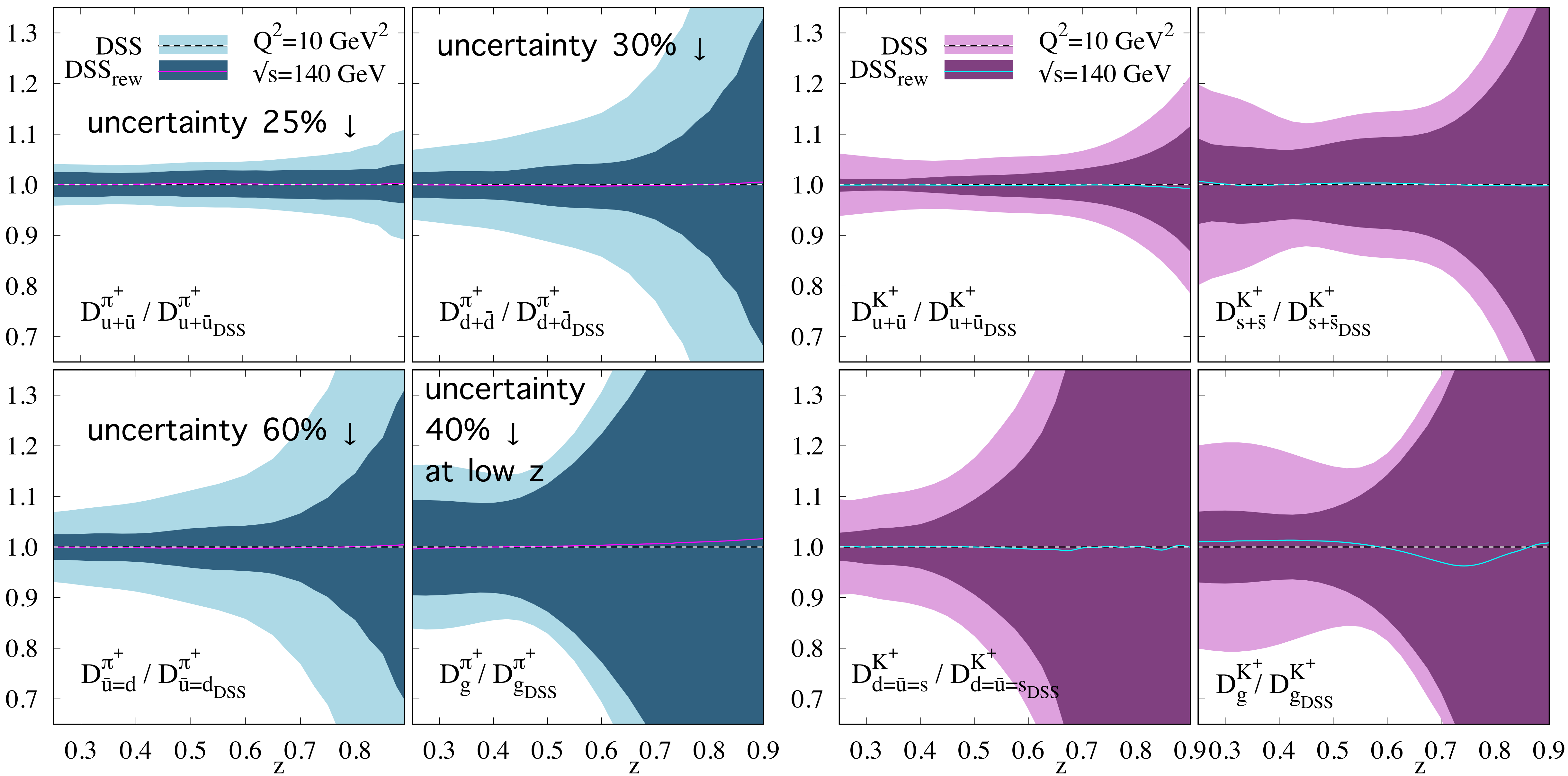
Impact of EIC data on FFs: kinematic coverage

Sensitivity coefficients: correlation FF and cross section, scaled with statistical uncertainties



$$\sqrt{s} = 140\ \mathrm{GeV}$$

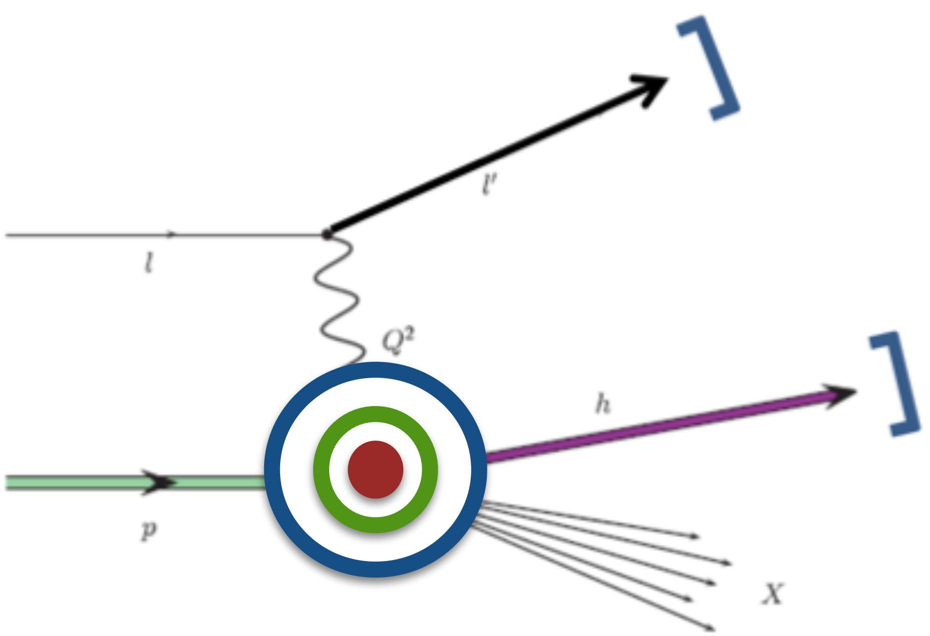
Impact of EIC data on FFs



Large reduction for kaons, but much more rigid functional form: careful with interpretation of reduced uncertainties, especially for unfavoured FFs!

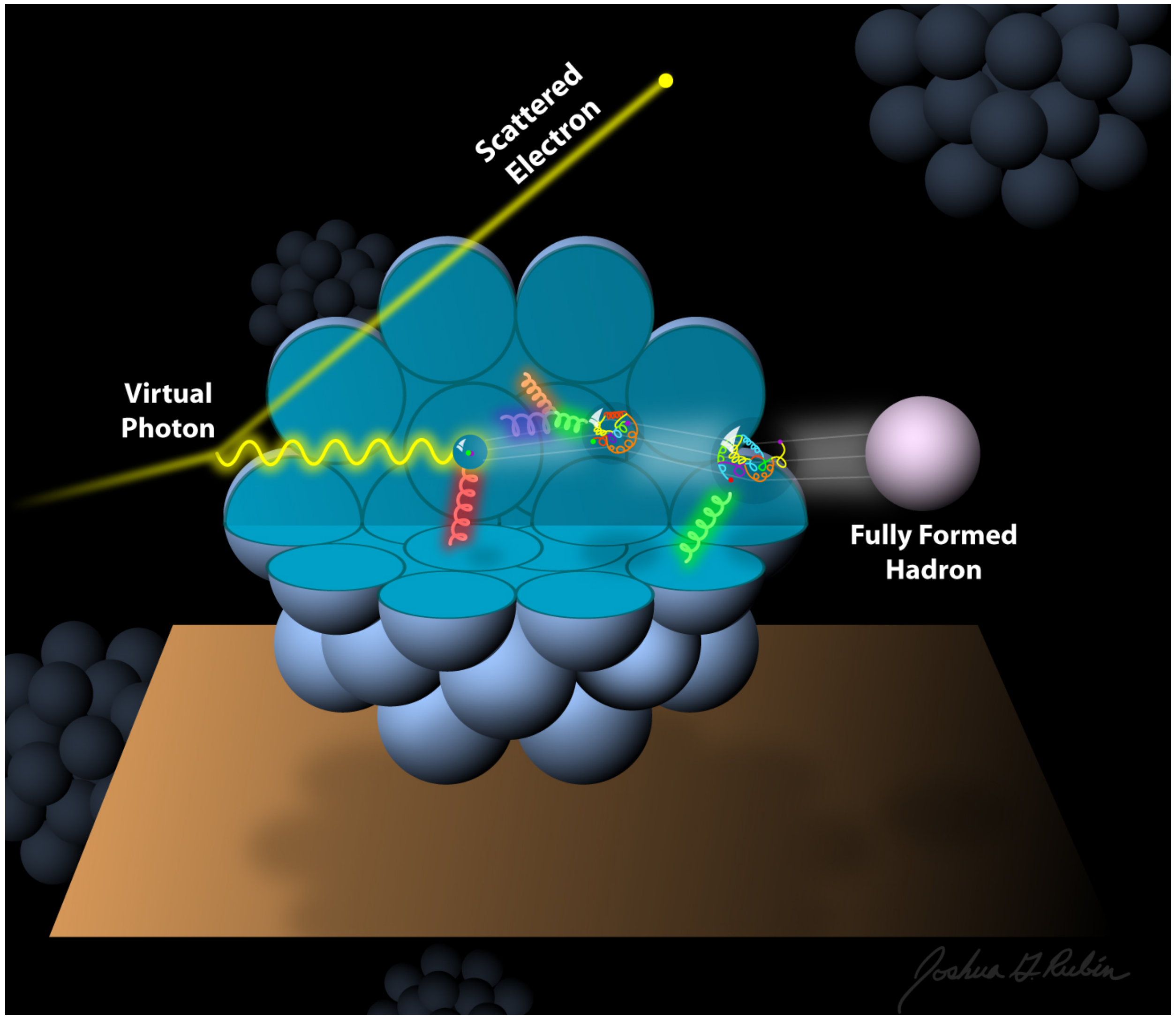
High z region: reflection of PDF uncertainties, which grow with z for fixed x_B and Q^2

Hadronisation in nuclei: results from HERMES



- targets=unpolarised D, Ne, Kr, Xe
- hadrons=charged pions, kaons, protons and antiprotons

Probing space-time evolution of hadronisation



- Energy loss of parton by medium-induced gluon radiation

- Energy loss of (pre-)hadrons
  - absorption
  - rescattering (small)

- Partonic and hadronic processes: different signature

  → probe space-time evolution of hadron formation

- PDFs modified by nuclear medium

Multiplicity ratios

- Multiplicities of Ne, Kr, Xe compared to D:

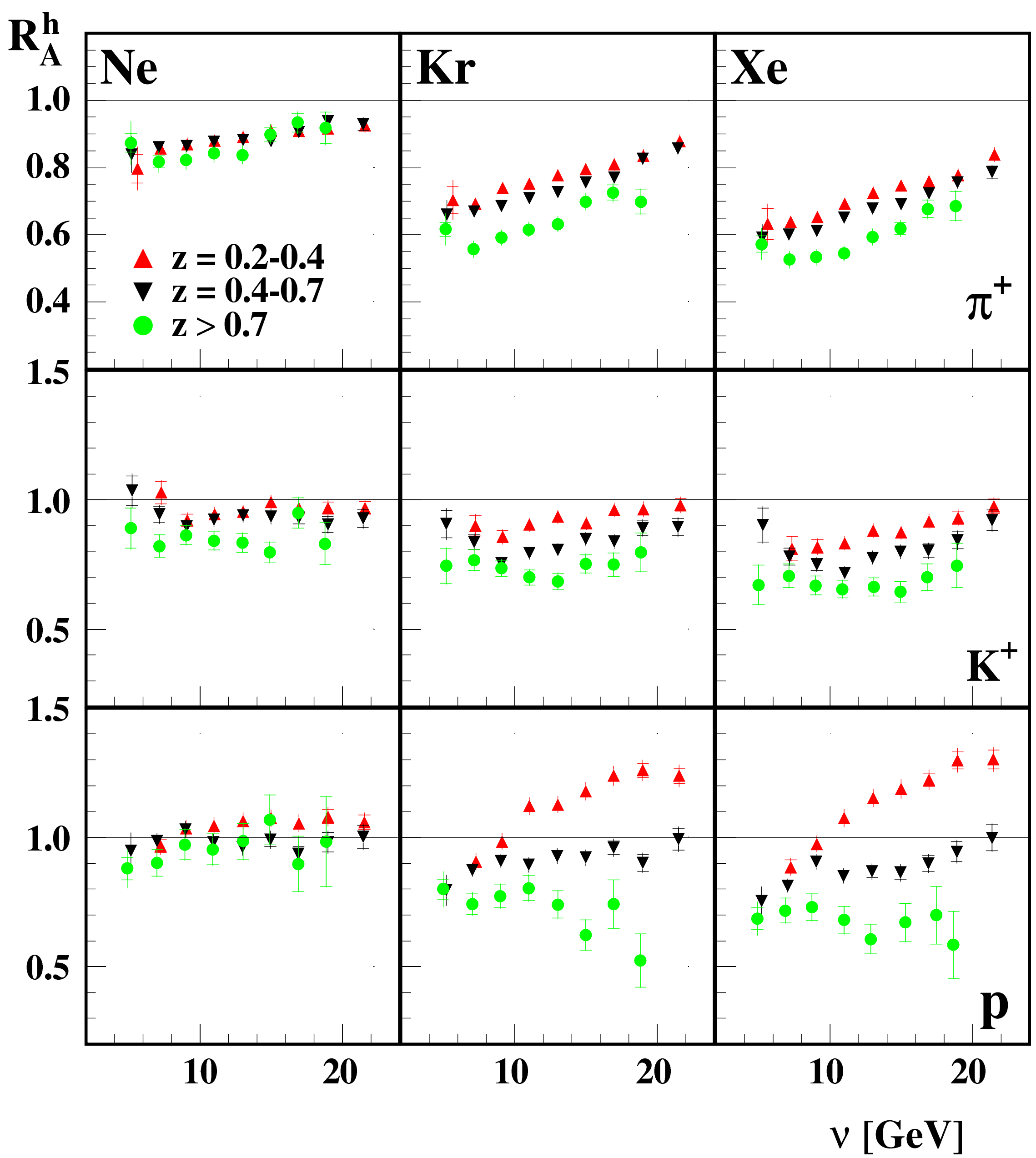
$$R_A^h = \frac{\left(\frac{N^h}{N_{DIS}}\right)_A}{\left(\frac{N^h}{N_{DIS}}\right)_D}$$

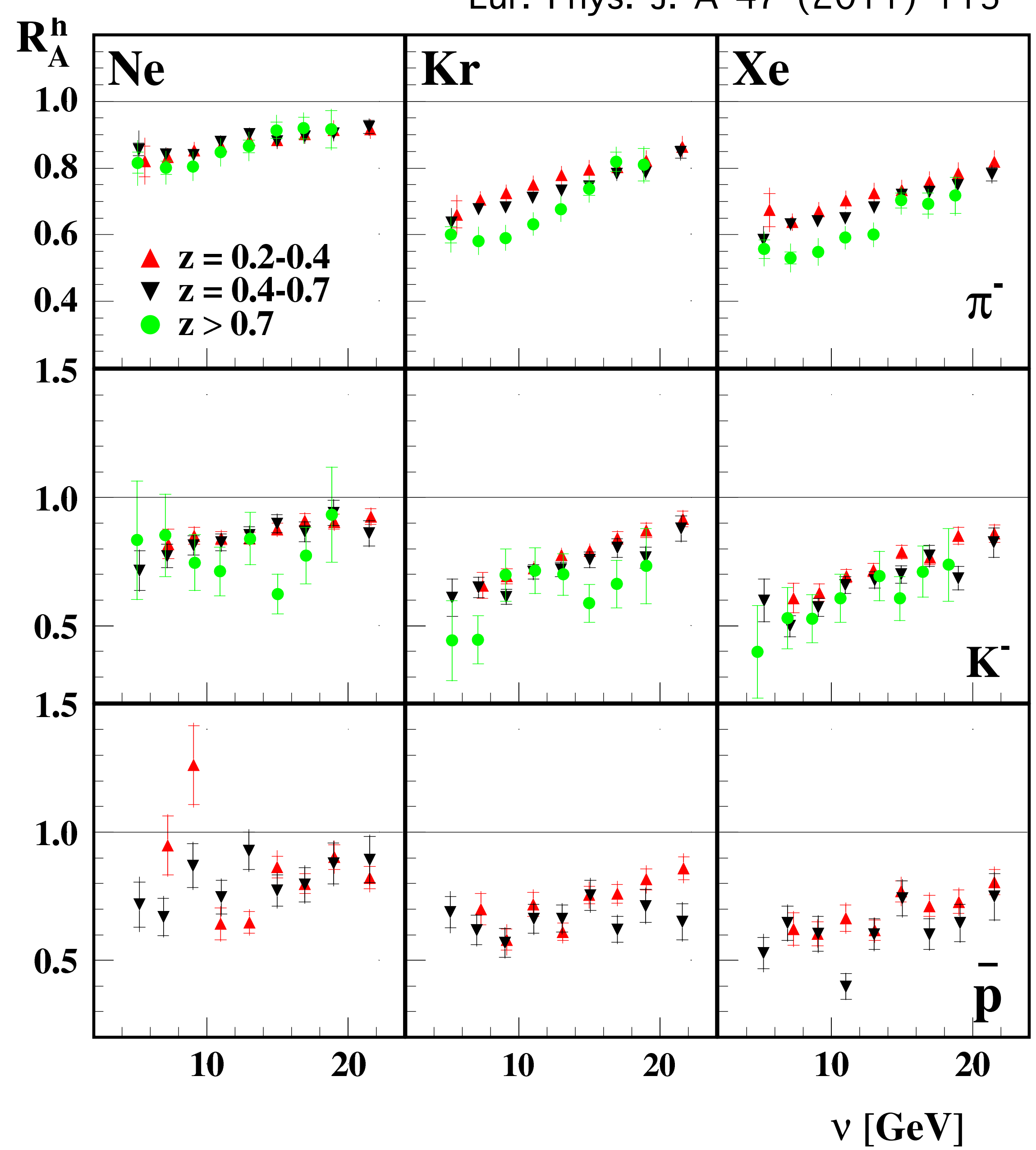
- Approximate cancelation of
  - QED radiative effects
  - limited detector acceptance and resolution

- Two-dimensional extraction ($\boldsymbol{\nu}$,z); ($P_{h\perp}$,z)

Results ($\boldsymbol{\nu}$,z)

Eur. Phys. J. A 47 (2011) 113

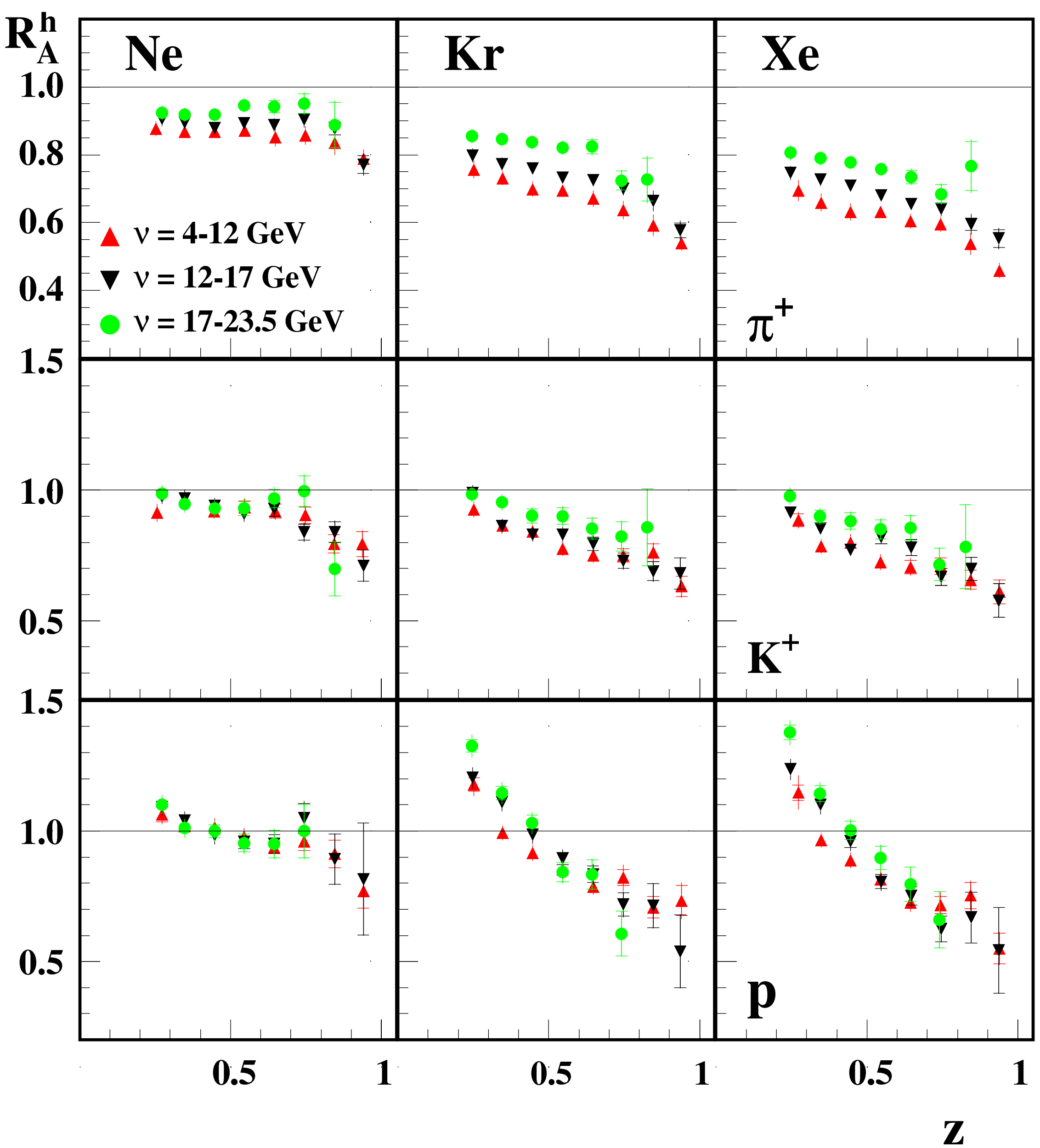




- Decrease of R_A^h with increasing A
- Increase of R_A^h with increasing $\boldsymbol{\nu}$

- $\pi^\pm$ and K^- similar behaviour
- K^+ (@higher z) flatter
- p large increase of $R_A^h > 1$ @ low z

Results (z,$\boldsymbol{\nu}$)



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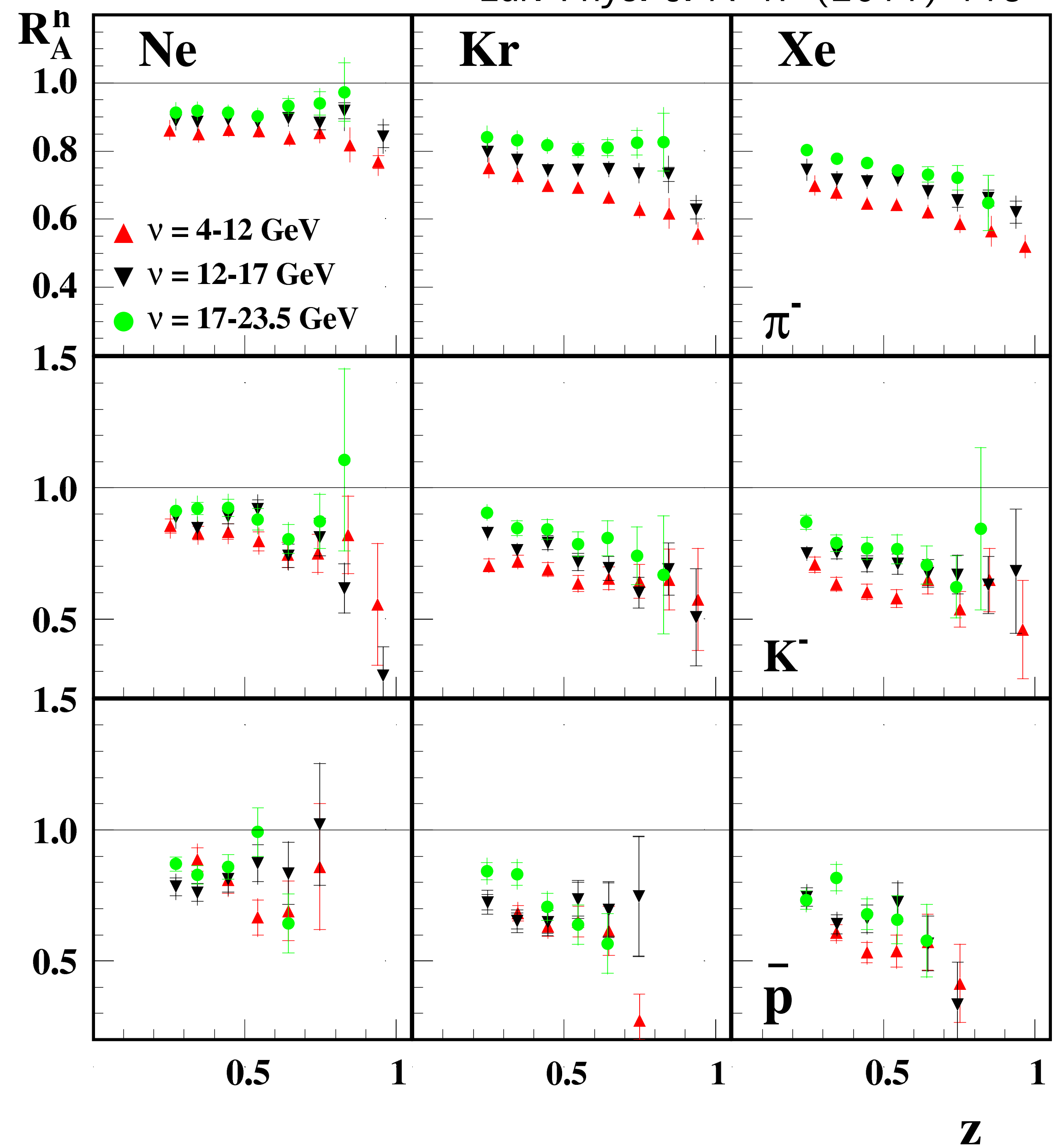

- Decrease of R_A^h with increasing z
- @ highest z: hadronic absorption

- $\pi^{\pm}$ and K^- similar behaviour
- p R_A^h >> 1 @ low z for Kr and Xe
- K^+ R_A^h reaching 1 at low z: $\pi p \longrightarrow K\Lambda$

Results ($P_{h\perp}$,z)

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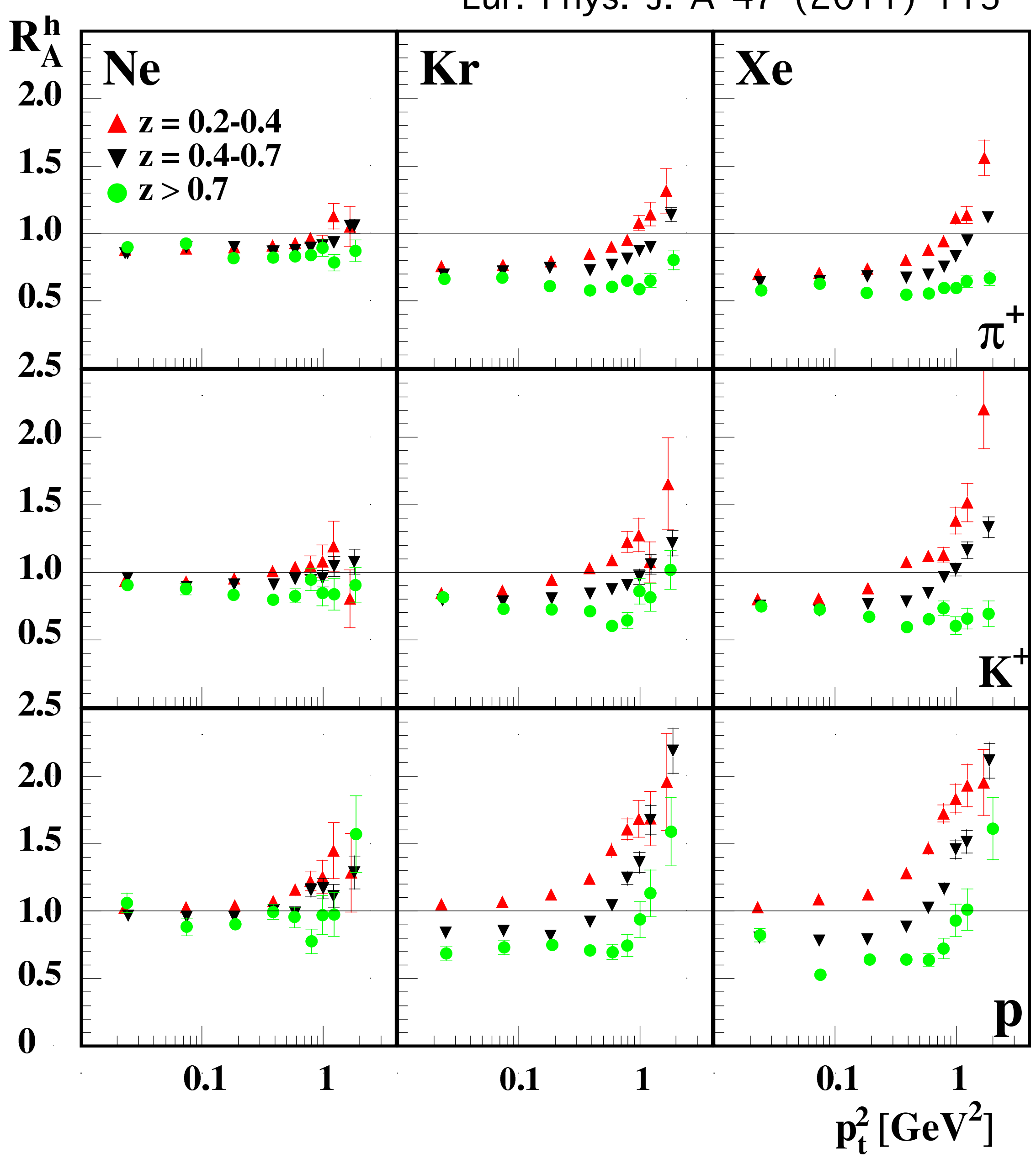

- Increase of R_A^h with increasing $P_{h\perp}$:
  - partonic and/or hadronic interactions
- $\pi^\pm$ and K^+ no broadening @ highest z
  $\longrightarrow$ $P_{h\perp}$ broadening at partonic level
- Stronger increase of R_A^h with increasing $P_{h\perp}$ for protons

Results (z,$P_{h\perp}$)

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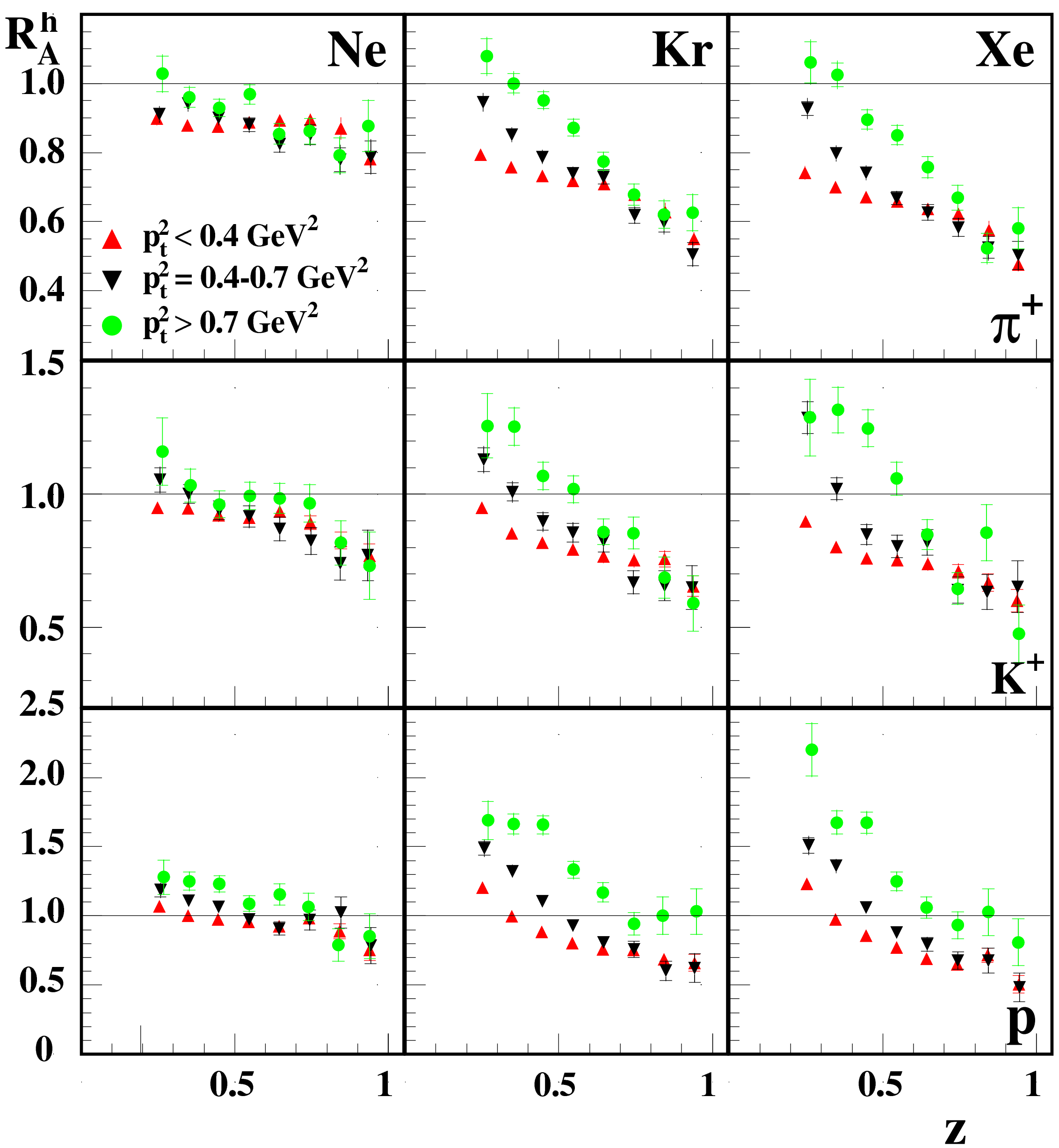

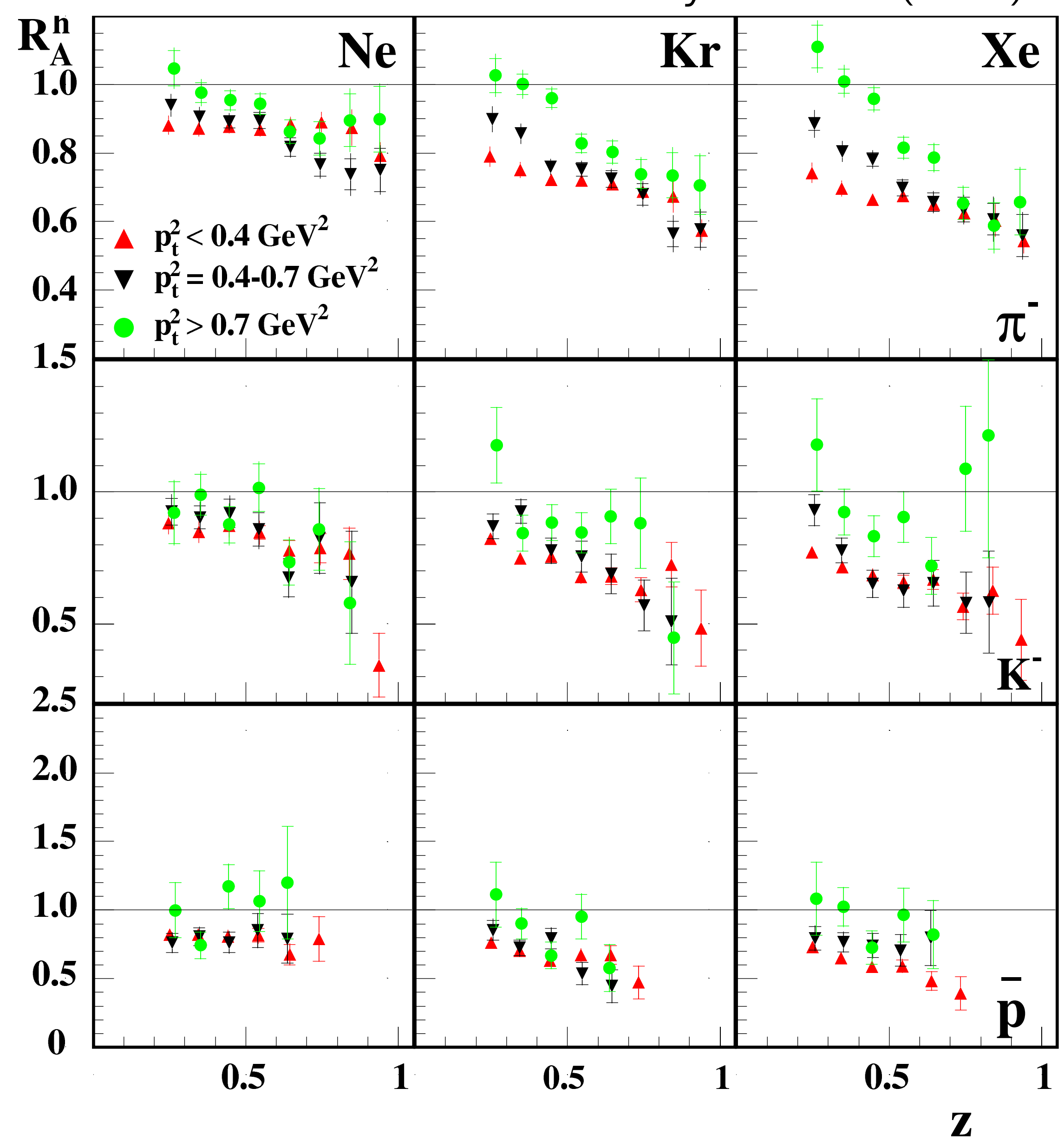

- Decrease of R_A^h with increasing z, stronger at large $P_{h\perp}$
- $\pi^\pm$ and K^+@ highest z, independent of $P_{h\perp}$
- Increase of R_A^h >1 at low z stronger at high $P_{h\perp}$

Summary

- EIC has substantial impact on reduction of FF uncertainties
- Large (PID) detector coverage in rapidity necessary:
  - complementarity of rapidity regions in kinematic coverage
  - disentanglement current and target fragmentation
- Impact of limited detector resolution needs to be studied

- Measurements on nuclear targets allow to study hadronisation process: studies for EIC needed