Hadron Attenuation and p_T Broadening at CLAS and HERMES

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- Motivation
- Model
  - Pythia, GiBUU, prehadronic FSI
- Results
  - EMC@100-280, Hermes@27, CLAS@5
  - Hermes: Δp_T

HIC for FAIR
Helmholtz International Center
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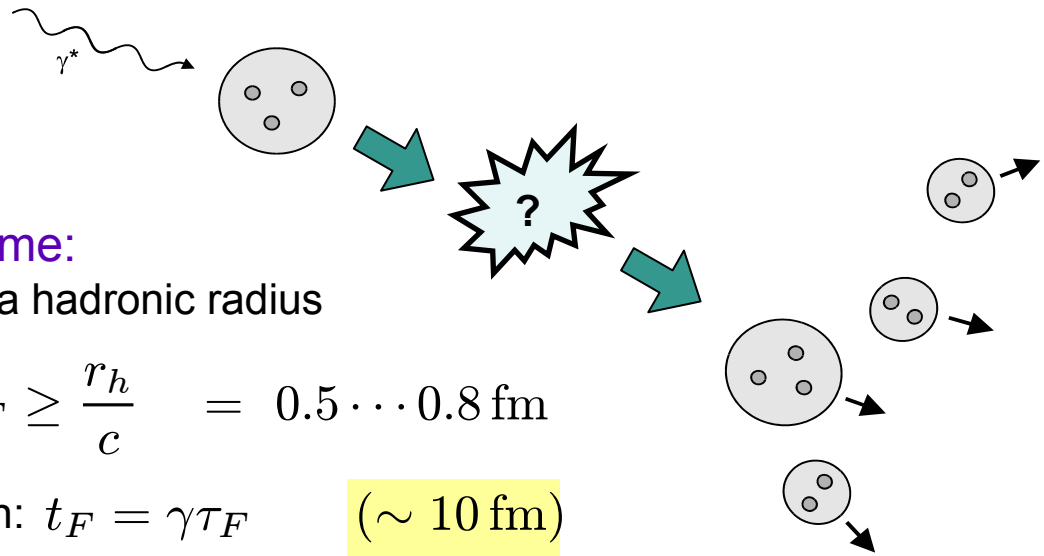
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

DPG Frühjahrstagung
Bonn, 15-19.3.2010

Motivation

- elementary reactions (eN, γN) on nucleon:



formation time:
estimation via hadronic radius

$$\tau_F \geq \frac{r_h}{c} \quad = \quad 0.5 \cdots 0.8\,\mathrm{fm}$$

time dilatation: $t_F = \gamma \tau_F$ $\quad (\sim 10\,\mathrm{fm})$

reaction products hadronize long before they reach the detector

- nuclear reactions (eA, γA @ GeV energies) :

interactions with nuclear medium during formation

→ space-time picture of hadronization $\quad \sigma^* / \sigma_H \sim t^{0,\,1,\,2,\cdots}$

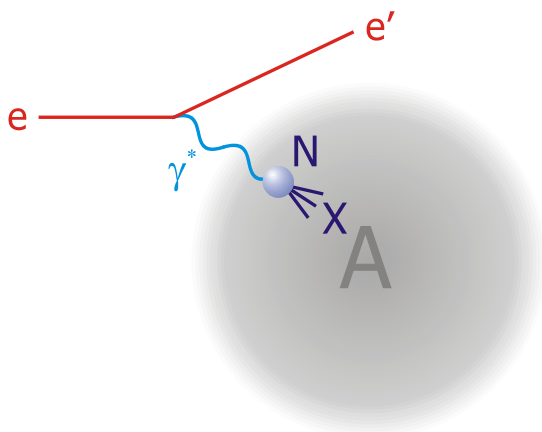
- cold nuclear matter as baseline for Heavy Ion Collisions

Model

- g^*N→X using PYTHIA

  additional:
  - binding energies
  - Fermi motion
  - Pauli blocking
  - coherence length effects

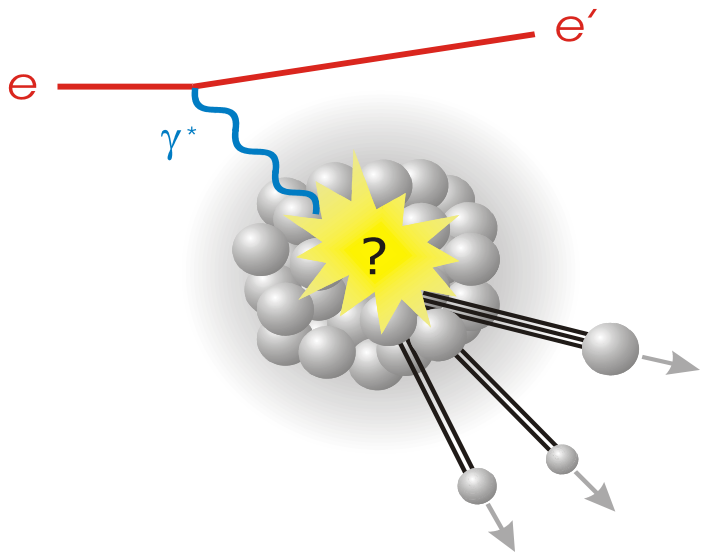
  extended for exclusive channels



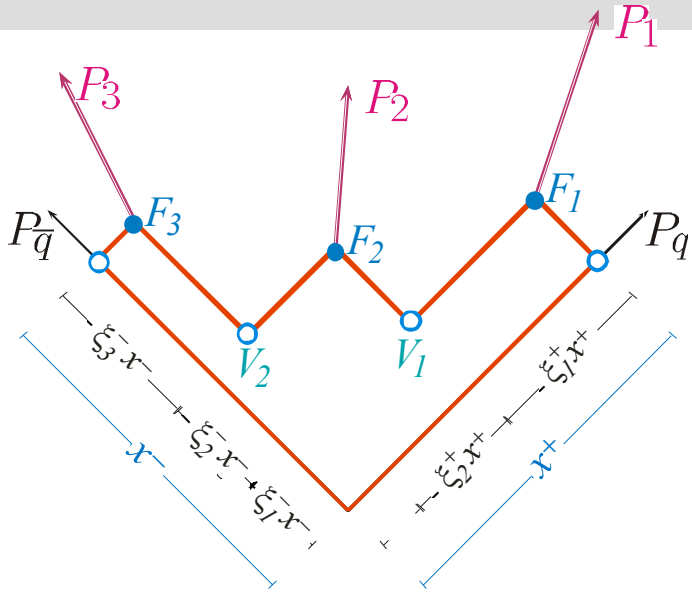
- propagation of final state X within GiBUU transport model

  http://gibuu.physik.uni-giessen.de

  - elastic/inelastic scatterings (coupled channels)
  - experimental acceptance



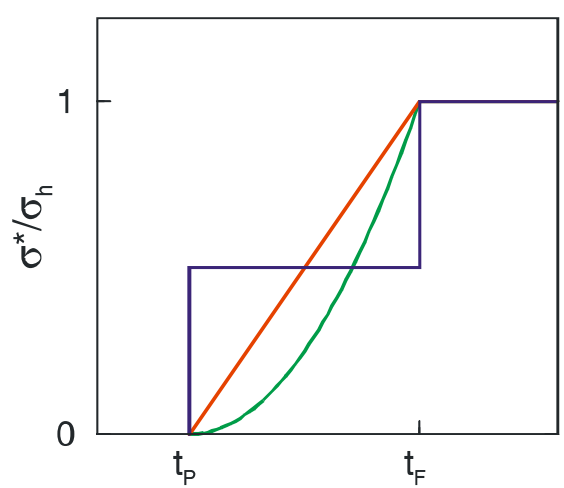
Model: Hadronization in String Model (Pythia/Jetset)

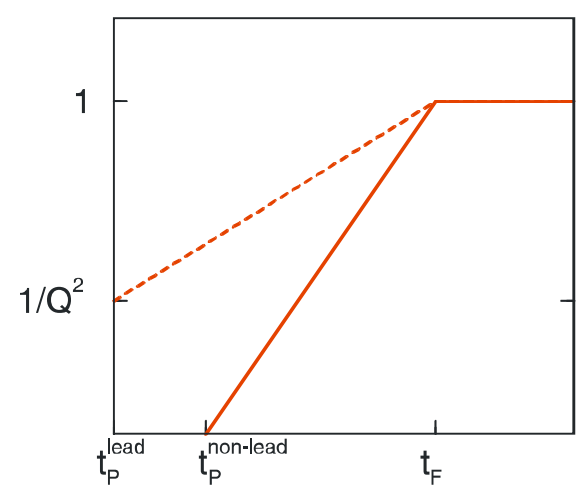


- 3 times/points per particle:
  - „Production 1“ String-Break
  - „Production 2“ String-Break
  - „Formation“ Line Meeting
- leading vs. non-leading

CT

- XS evolution scenarios:





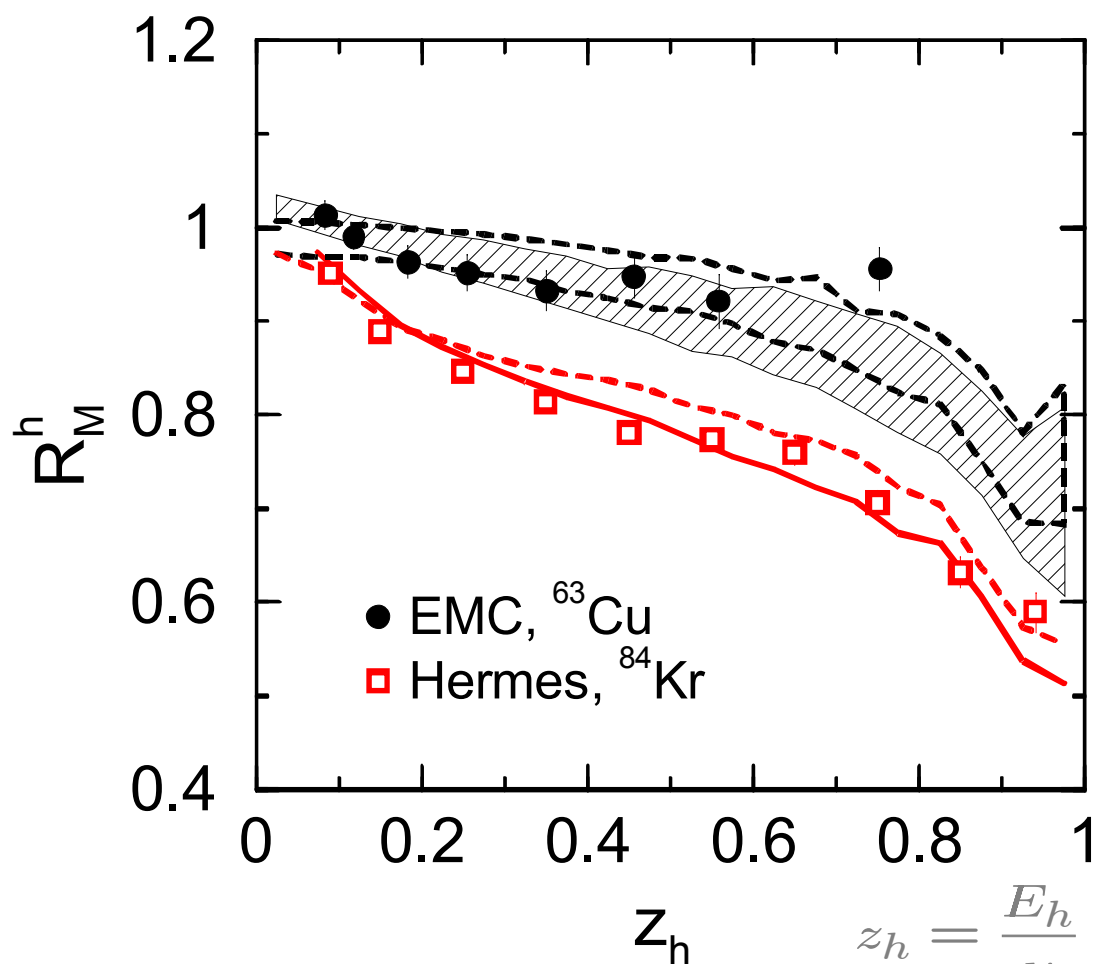
Results: EMC & Hermes

$$\frac{\sigma^*}{\sigma_h} = \frac{r_{\rm lead}}{Q^2} + \left(1 - \frac{r_{\rm lead}}{Q^2}\right)\left(\frac{t - t_P}{t_F - t_P}\right)$$

!

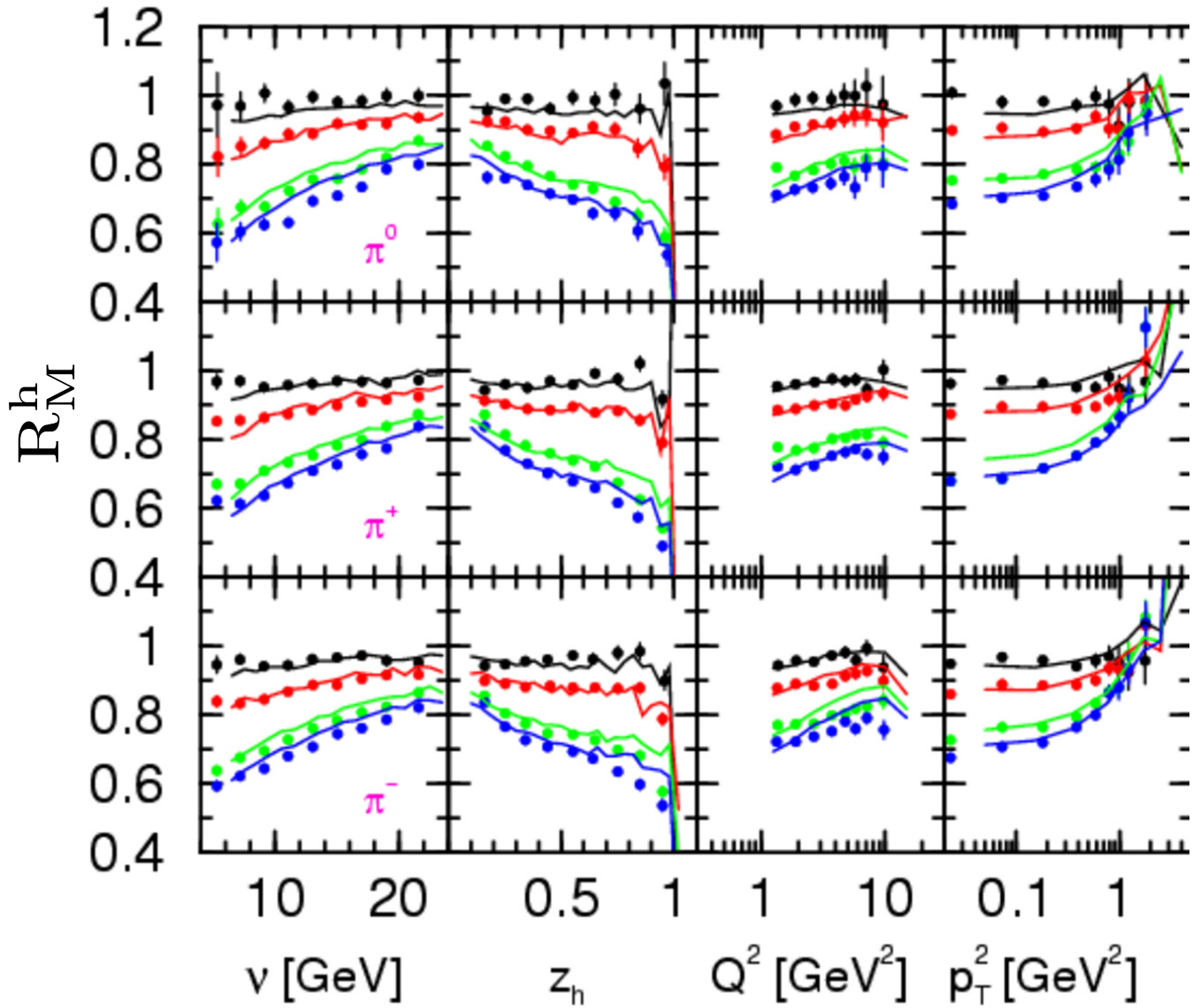
EMC@100...280 GeV
and
Hermes@27 GeV
described simultanously

Color transparency?
…small effect!



$$z_h = \frac{E_h}{\nu}$$

Hermes@27: A.Airapetian et al., NPB780(2007)1



Pions

$^2d_1$

$^4He_2$

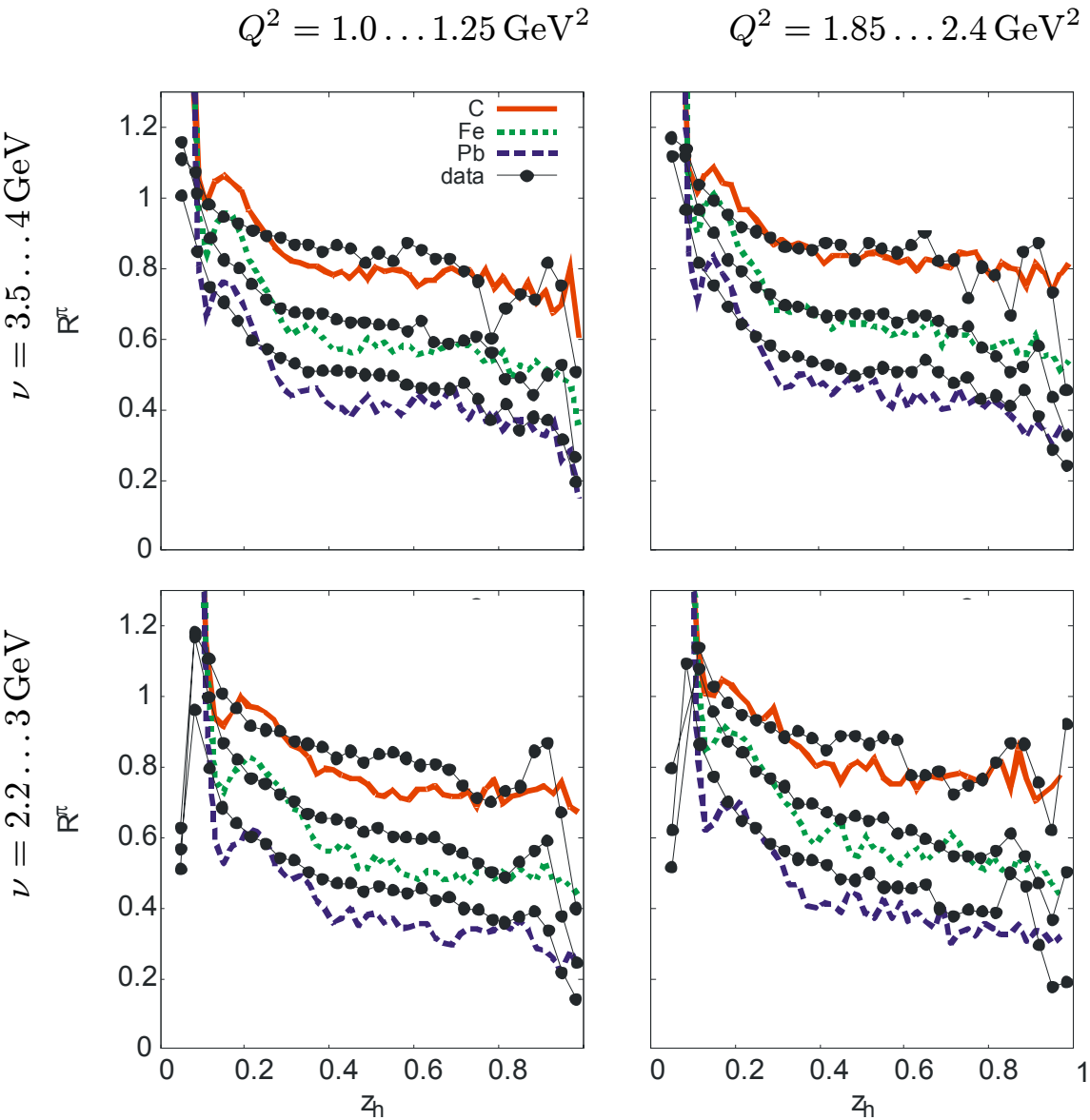
$^{20}Ne_{10}$

$^{84}Kr_{36}$

$^{131}Xe_{54}$

no diffractive

CLAS@5, π^+ : selected (ν,Q^2) bins



Data:

- CLAS preliminary
- no error bars shown

Calculations:

- not tuned !!!
- no Fermi Motion (W<2 GeV possible)
- no potentials

As good as at higher energies !

Hermes@27: p_T Broadening

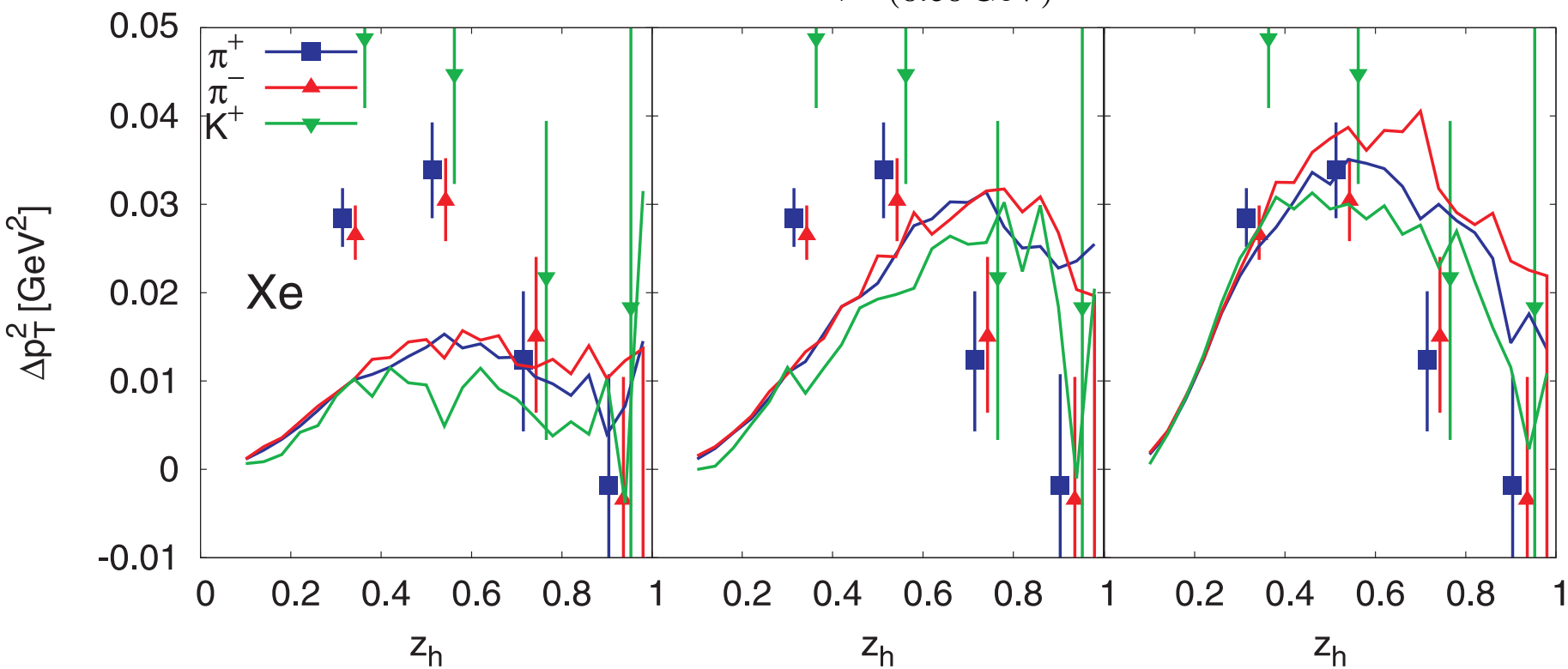
$$\Delta p_T^2 = \langle p_T^2 \rangle_A - \langle p_T^2 \rangle_D$$

Default:

normal attenuation

In-Medium modifications:

$$\langle k_T^2 \rangle_{Xe} = (0.44\,\mathrm{GeV})^2 \rightarrow (0.50\,\mathrm{GeV})^2 \qquad (\sigma_p)_{Xe} = 0.36\,\mathrm{GeV} \rightarrow 0.40\,\mathrm{GeV}$$



data: Y.van Haarlem et al., arXiv:0704.3712 [hep-ex]

Hermes@27: p_T Broadening

$$\Delta p_T^2 = \langle p_T^2 \rangle_A - \langle p_T^2 \rangle_D \qquad \text{and} \qquad R_A(p_T)$$

Default:

normal attenuation

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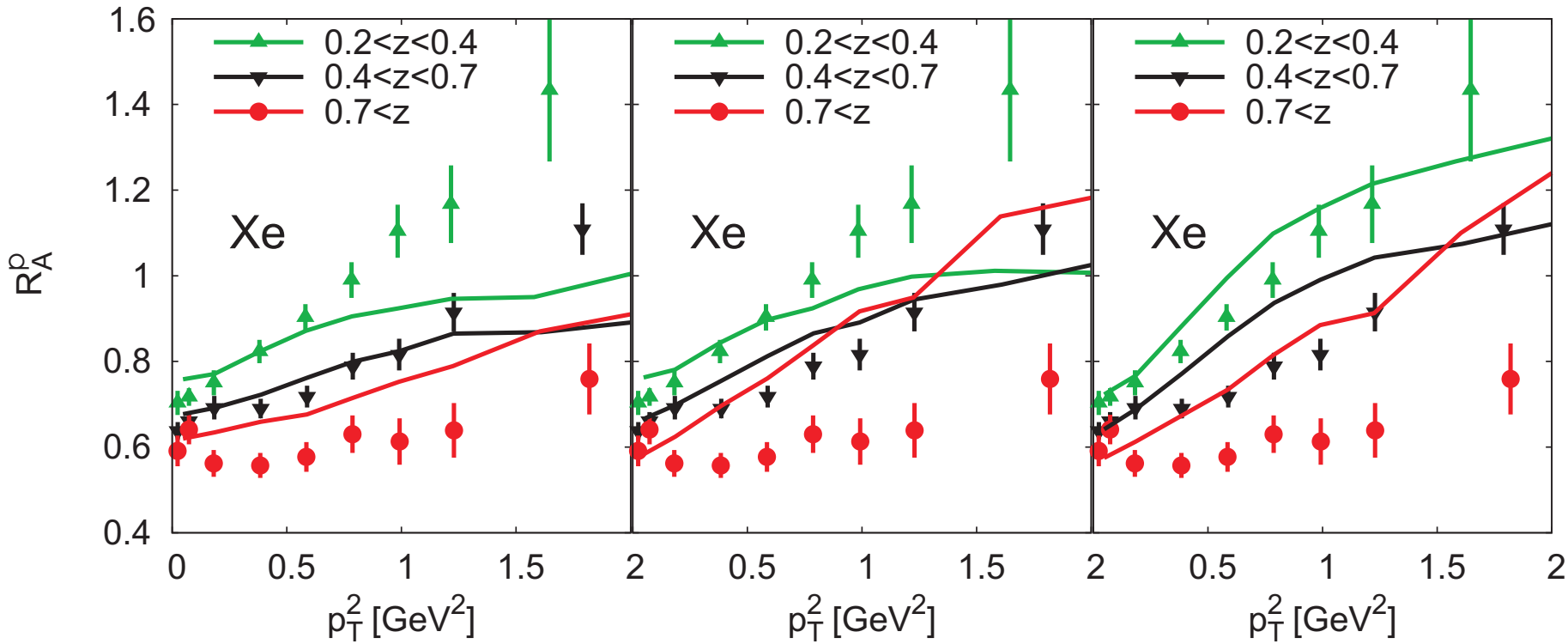

data: A.Airapetian et al., NPB 780 (2007) 1

Conclusions

- GiBUU:
  - coupled channel transport code (semi classical)
  - from some MeV to tens of GeV (Pythia v6.4 for high energy)
  - multi purpose: p, π, γ^*, ν – induced reactions
    Heavy Ion Collisions

- pre-hadron cross section: linear in time
  (EMC,Hermes,CLAS)

- Transverse momentum broadening
  - attenuation leads to broadening
  - medium modification of fragmentation parameters ???