Hadron Attenuation and p_T Broadening with GiBUU

K. Gallmeister, U. Mosel

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

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Helmholtz International Center

Institut für Theoretische Physik

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

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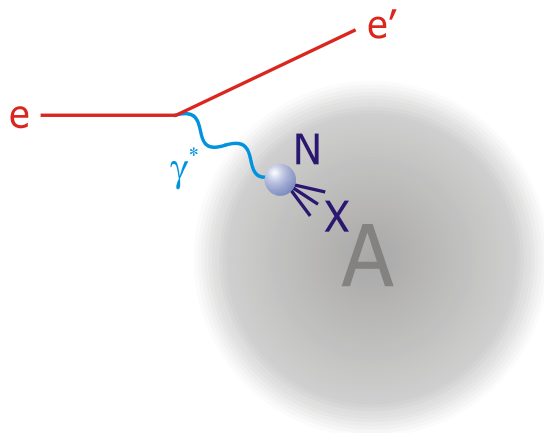
Model

- $\gamma^*N \rightarrow X$ using PYTHIA

  additional:

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

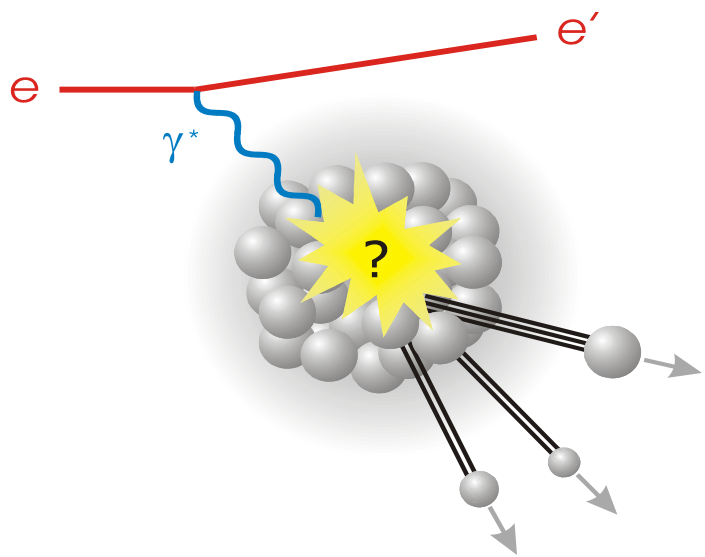
  extended for exclusive channels



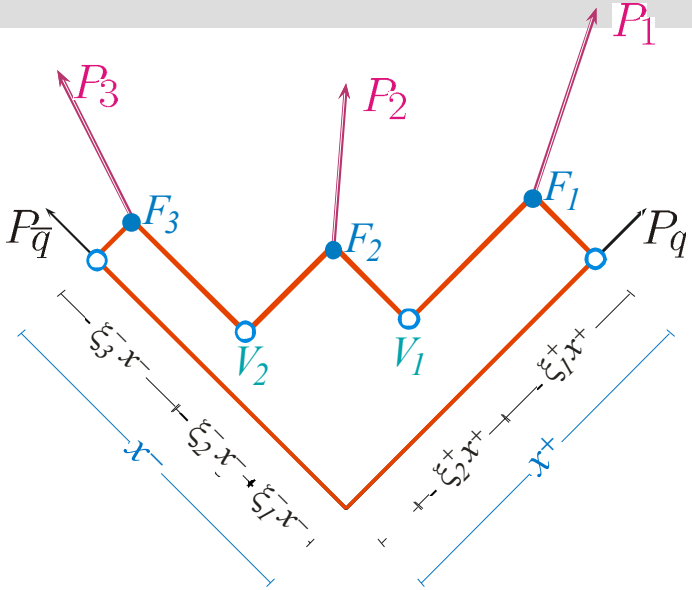
- propagation of final state X within GiBUU transport model

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

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



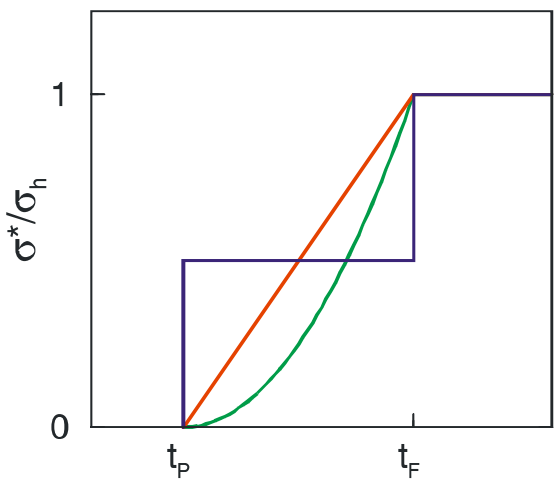
Model: Hadronization in String Model (Pythia/Jetset)

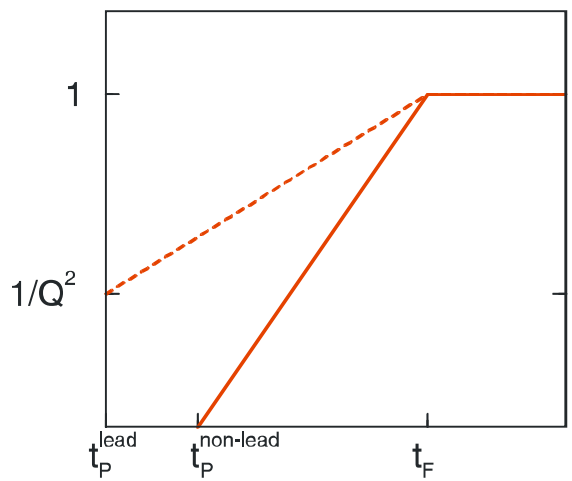


- 3 times/points per particle:
  - „Production 1“ String-Breaking
  - „Production 2“ String-Breaking
  - „Formation“ Line Meeting
- leading vs. non-leading

CT

- XS evolution scenarios:





Model: Transport (GiBUU)

GiBUU: Gießen + Boltzmann-Uehling-Uhlenbeck

$$\frac{\mathrm{d}f^X}{\mathrm{d}t} = \frac{\partial f^X}{\partial t} + \frac{\partial H}{\partial \vec{p}}\frac{\partial f^X}{\partial \vec{r}} - \frac{\partial H}{\partial \vec{r}}\frac{\partial f^X}{\partial \vec{p}} = I_{\mathrm{coll}}(f^X, f^a, f^b, \cdots)$$

1 particle phase space densities

full coupled channel

- Hamiltonian $H = H(f^X, f^a, f^b, \cdots)$

  hadronic mean fields + potentials

- Solved with „testparticle ansatz“

$$f^X = \sum_{i=1}^{n \times N^X} \delta(\vec{r} - \vec{r}_i)\,\delta(p - p_i)$$

local ensemble method
= local collisions

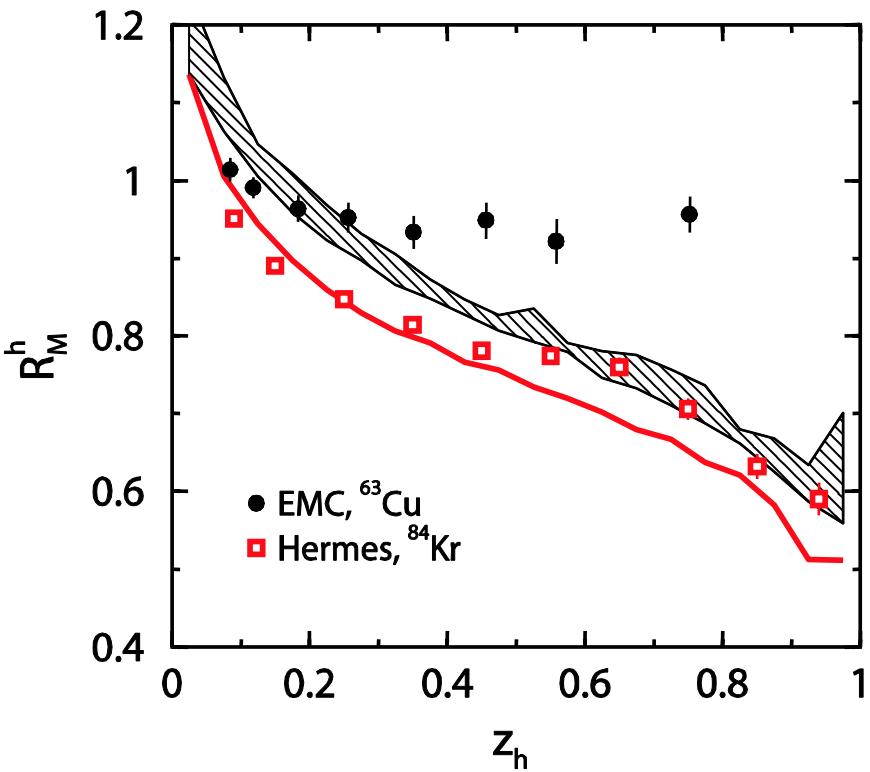
- 61 baryons, 21 mesons

Results: EMC & Hermes

- constant cross section

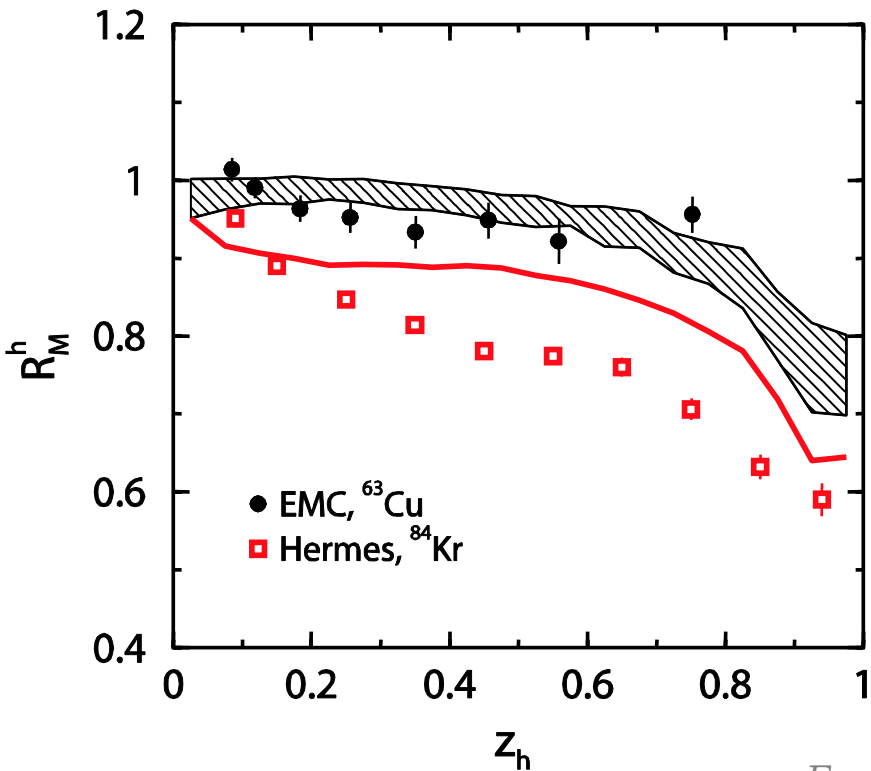
$$t = t_P \cdots t_F :$$

$$\sigma^* = 0.5\,\sigma_H$$



- quadratic increase

$$\sigma^* = \left(\frac{t - t_P}{t_F - t_P}\right)^2 \sigma_H$$



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

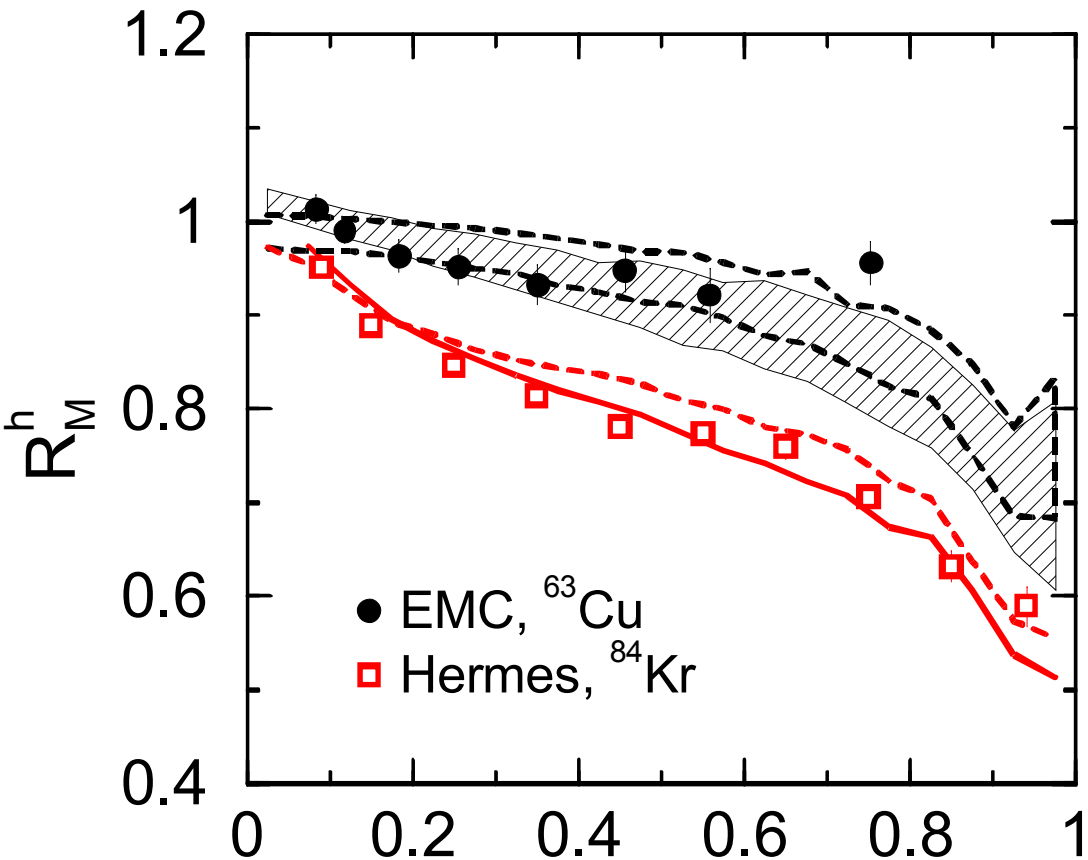
Results: EMC & Hermes

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

!

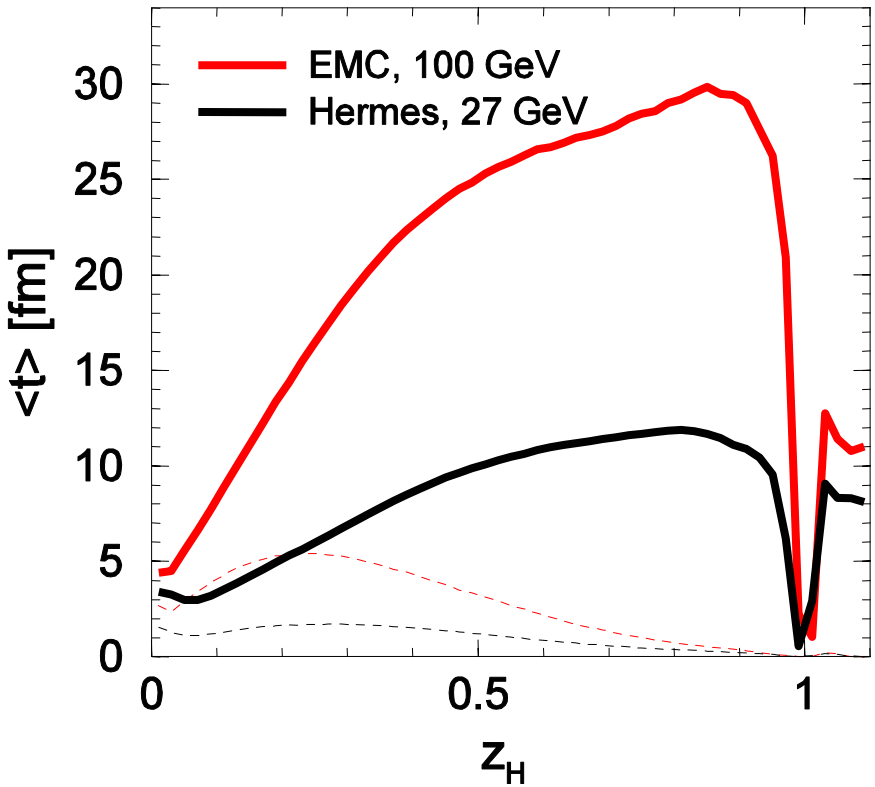
EMC@100...280 GeV
and
Hermes@27 GeV
described simultanously

pedestal value?
…small effect!



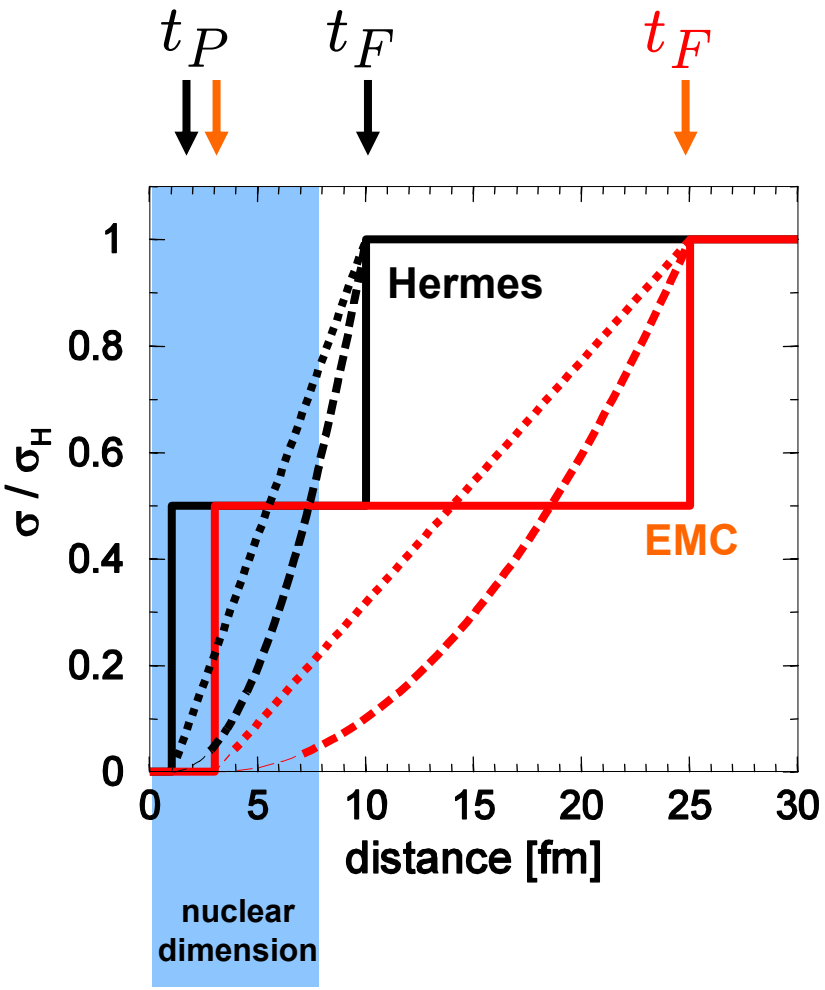
$$z_h = \frac{E_h}{\nu}$$

Times

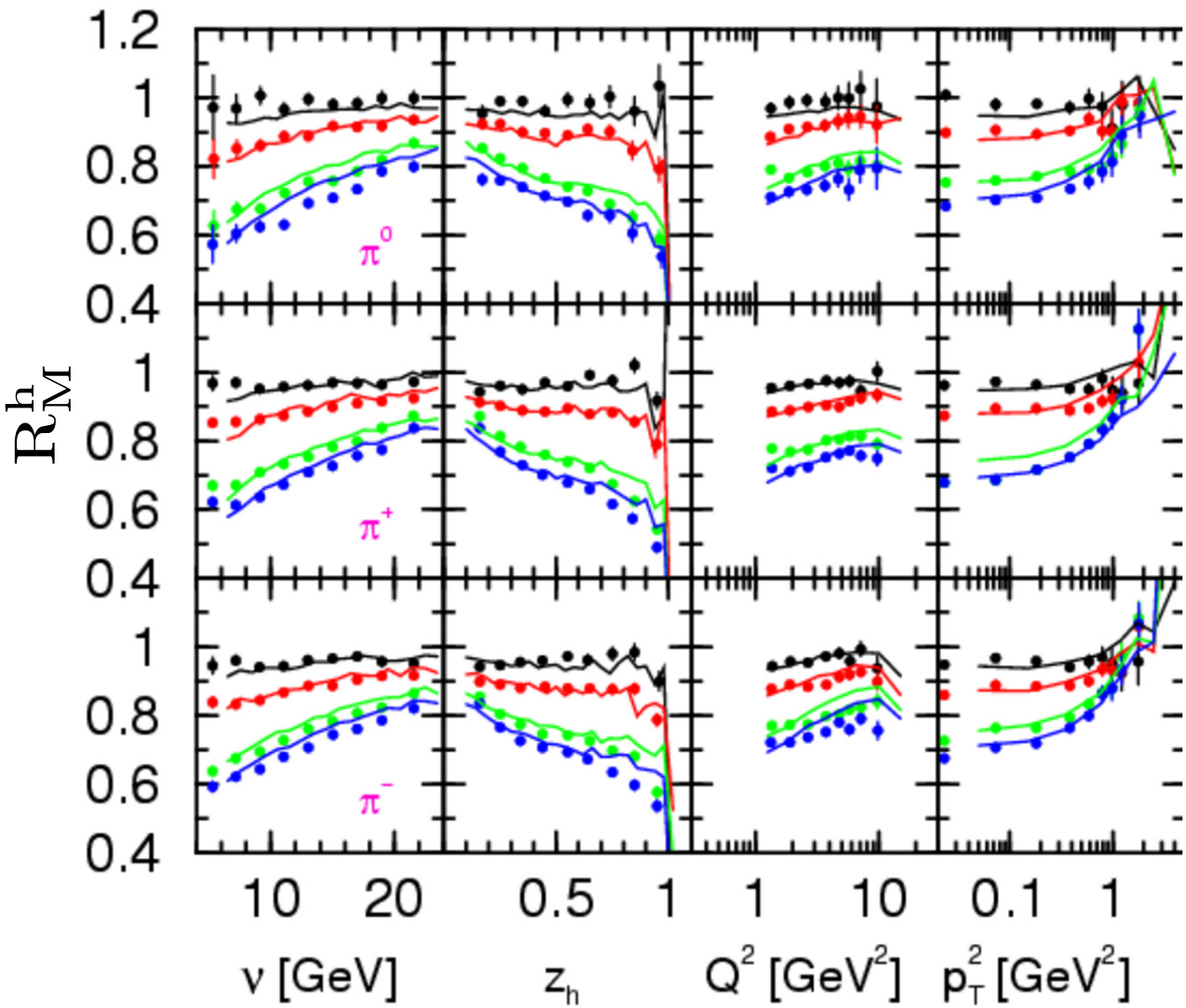


here: averaged times

in code: individual times



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



Pions

$^2d_1$

$^4He_2$

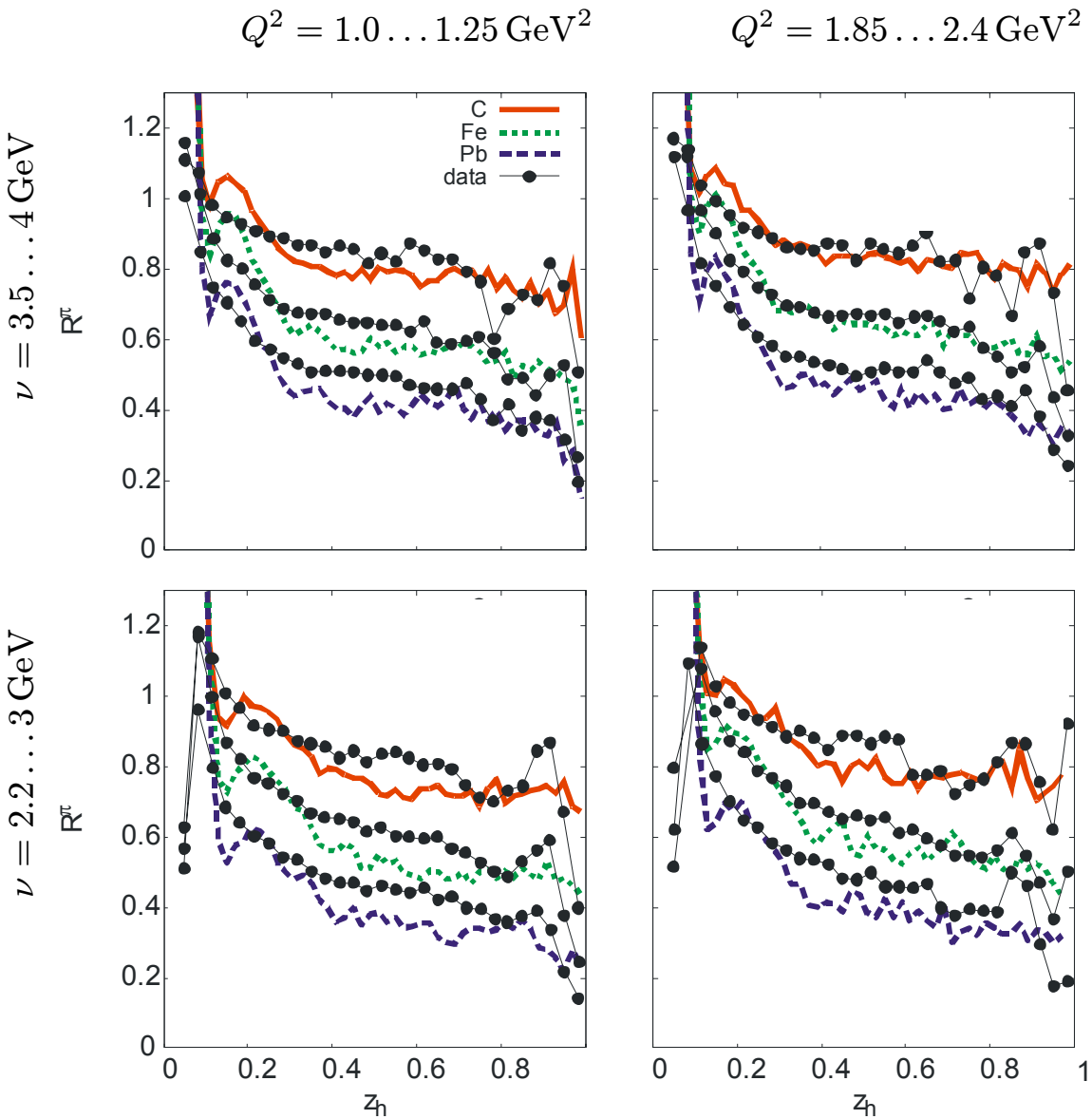
$^{20}Ne_{10}$

$^{84}Kr_{36}$

$^{131}Xe_{54}$

no diffractive

CLAS@5, π^+ : selected (ν,Q^2) bins



Data:

- CLAS preliminary
- no error bars shown

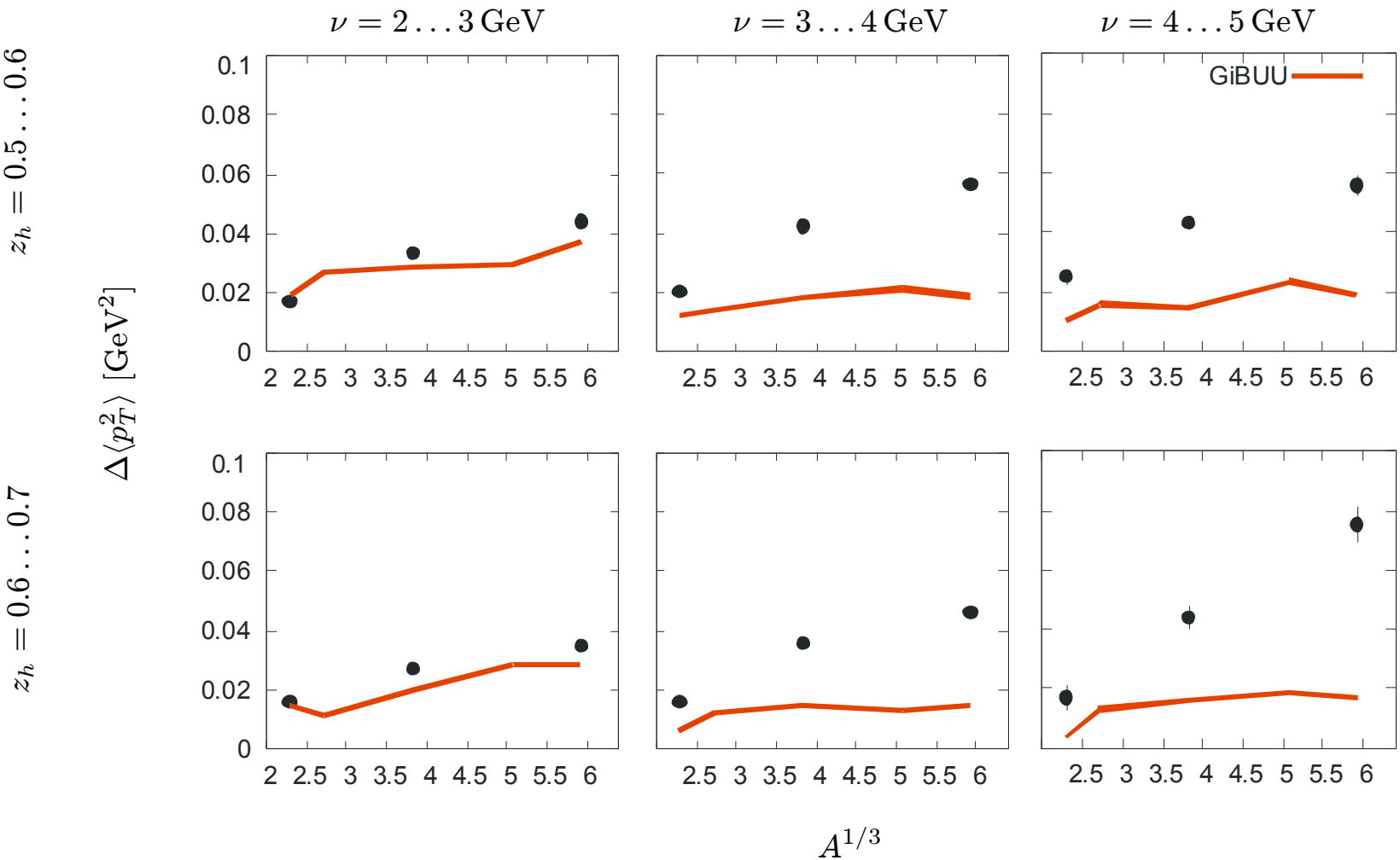
Calculations:

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

As good as at higher energies !

pT – Broadening: JLAB@5, π^+

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



Hermes@27: p_T Broadening

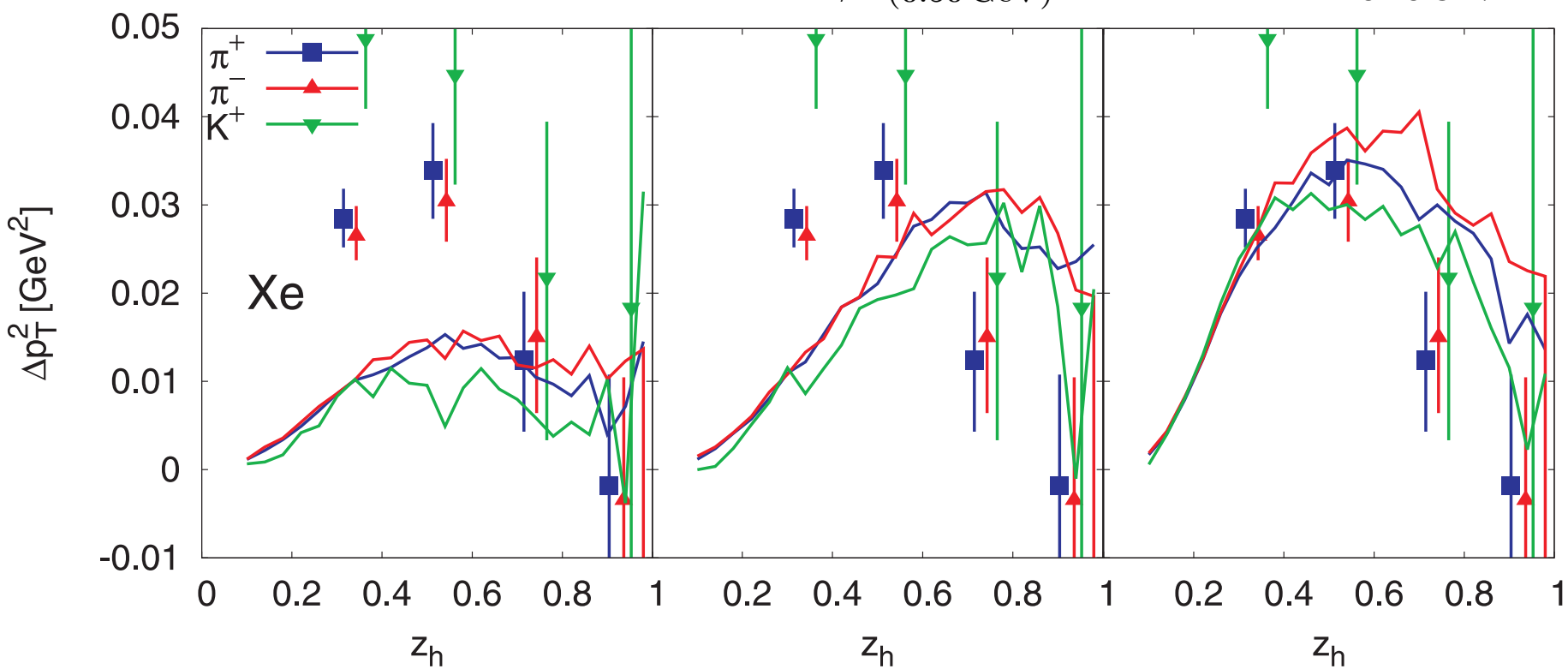
$$\Delta p_T^2 = \langle p_T^2 \rangle_A - \langle p_T^2 \rangle_D$$

Default:

normal attenuation

In-Medium modifications:

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



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

Hermes@27: p_T Broadening

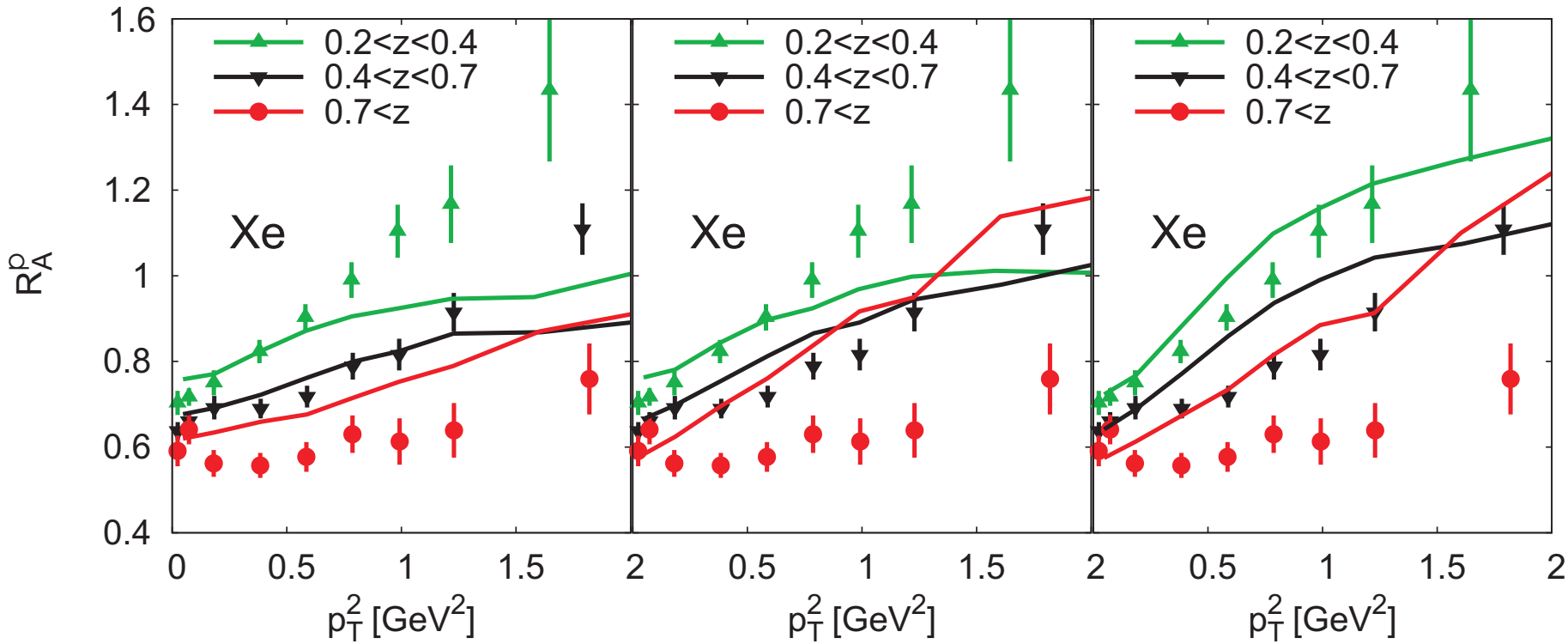
$$\Delta p_T^2 = \langle p_T^2 \rangle_A - \langle p_T^2 \rangle_D \qquad \text{and} \qquad R_A(p_T)$$

Default:

normal attenuation

In-Medium modifications:

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



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 **???**
- **funding:**

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