Hadron attenuation in nuclei at

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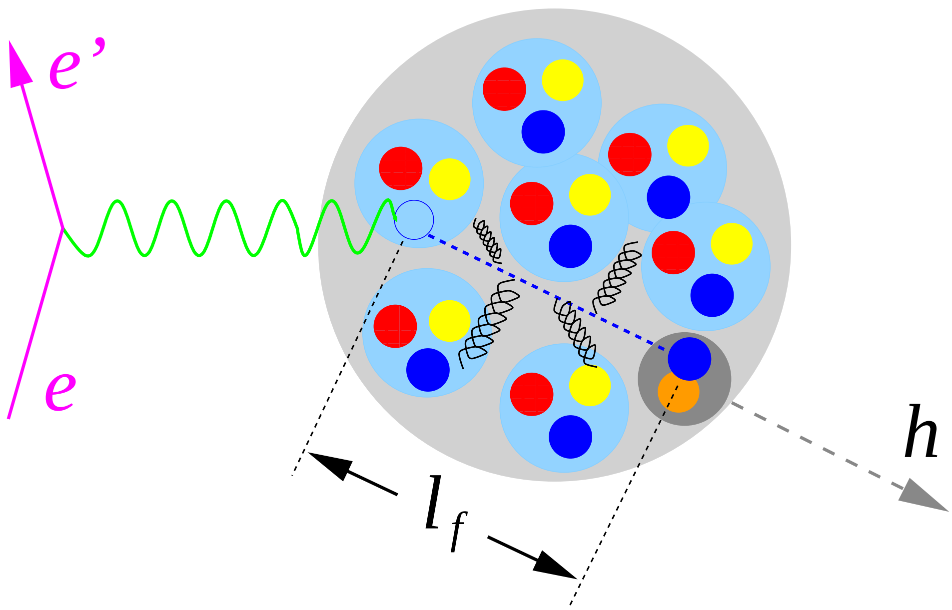
- Electroproduction on nuclei (^{14}N and D)
- Attenuation process
- Phenomenological and QCD-inspired models
- Attenuation for fast charged hadrons and pions
- Formation time's dependence on m_h
- Conclusions

Hadron production in DIS on nuclei

Nucleus as a 'passive detector' at the scale of few Fermi.



$\tau_f = c/l_f$ formation time: time between the initial hard interaction and the hadron final configuration.

Reduction of the multiplicity of the fast forward hadrons Nuclear Attenuation which increases with the size of the nucleus.

$$R_A(z_h,\nu) = \frac{\left.\frac{1}{\sigma}\frac{d^2\sigma}{dz_h\,d\nu}\right|_A}{\left.\frac{1}{\sigma}\frac{d^2\sigma}{dz_h\,d\nu}\right|_D} = \frac{\left.\frac{1}{N_e}\frac{d^2N_h}{dz_h\,d\nu}\right|_A}{\left.\frac{1}{N_e}\frac{d^2N_h}{dz_h\,d\nu}\right|_D}$$

$z = E_h/\nu$

In this measurement A=^{14}N

Models for nuclear attenuation

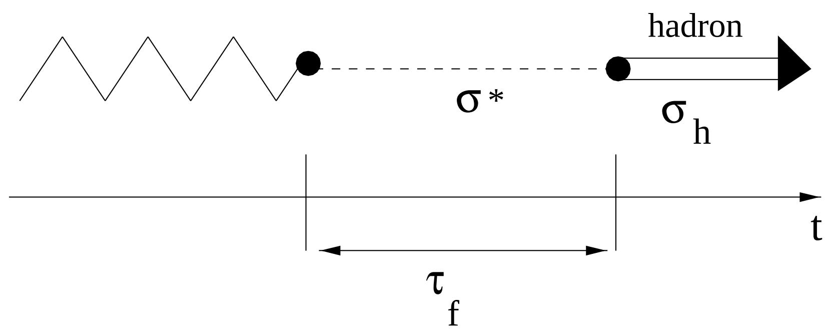
Hadron formation in DIS occurs at energy momentum scales where pQCD is not applicable:

$\rightarrow$ ONLY PHENOMENOLOGICAL MODEL available

- DIRECT PRODUCTION (one-time-scale model)

  Hadrons directly produced and interacting with typical hadronic inelastic cross section $\sigma_h \sim 20$ mb.

$$\tau_f \propto \frac{E_h}{m_h}; \quad \tau_f \propto \frac{E_q}{m_q}$$



$$R_A = 2\pi \int_0^{\infty} bdb \int_{-\infty}^{\infty} dl \rho(b,l)[P_A(b,l)]^{A-1}$$

Probability of no-interaction:

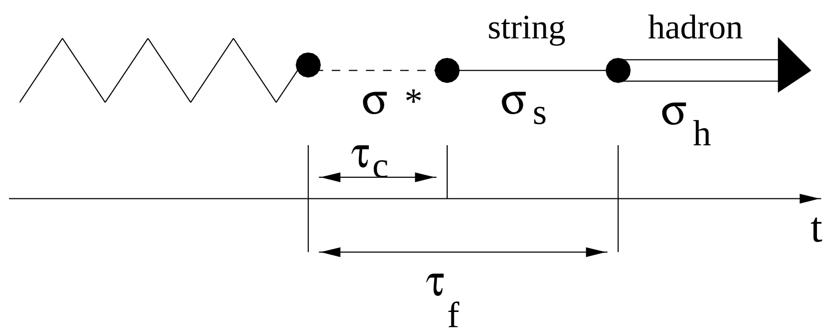
$$P_A = 1 - \sigma^* \int_l^{\infty} dl' \rho_A(b,l') P_q(l'-l) - \sigma_h \int_l^{\infty} dl' \rho_A(b,l') P_h(l'-l)$$

$\rho_A(b,l)$: normalized nuclear density

(b,l): position of the scattering

τ_f can be derived by a fit using σ^* and τ_f as free parameters

- STRING MODEL (two-time-scales τ_c, τ_f models)
  The constituents of the hadron are formed at different time τ_c, τ_f.



$$l_f - l_c = \frac{z\nu}{\kappa}$$

string constant $\kappa \approx 1\ GeV/fm$

$$R_A = 2\pi \int_0^\infty bdb \int_{-\infty}^\infty dl\rho(b,l)[P_A(b,l)]^{A-1}$$

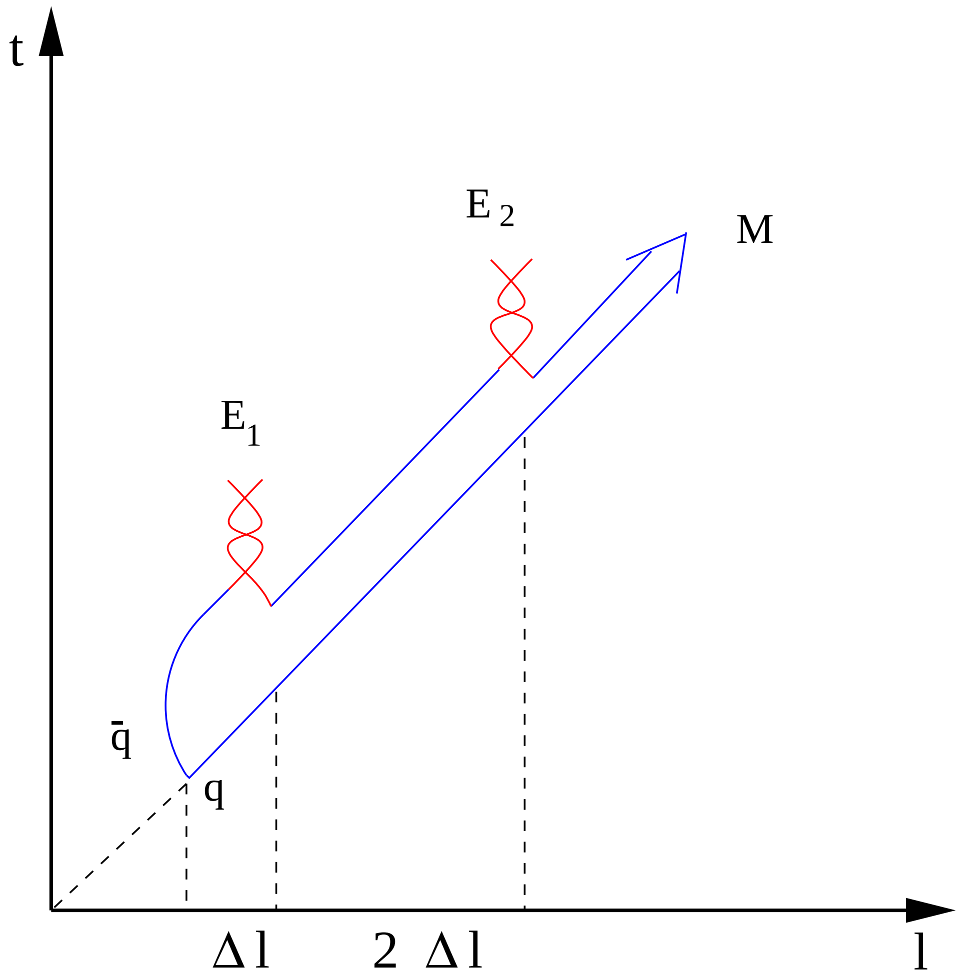
$$P_A = 1 - \sigma^* \int_l^{l_c} dl'\rho_A(b,l') - \sigma_s \int_{l_c}^{l_f} dl'\rho_A(b,l') -$$

$$\sigma_h \int_{l_f}^\infty dl'\rho_A(b,l')$$

τ_f can be derived by a fit using σ^* and τ_f as free parameters

- GLUON BREMSSTRAHLUNG MODEL

(B.Kopeliovich et al)



$E_1 \simeq \xi \Delta l$

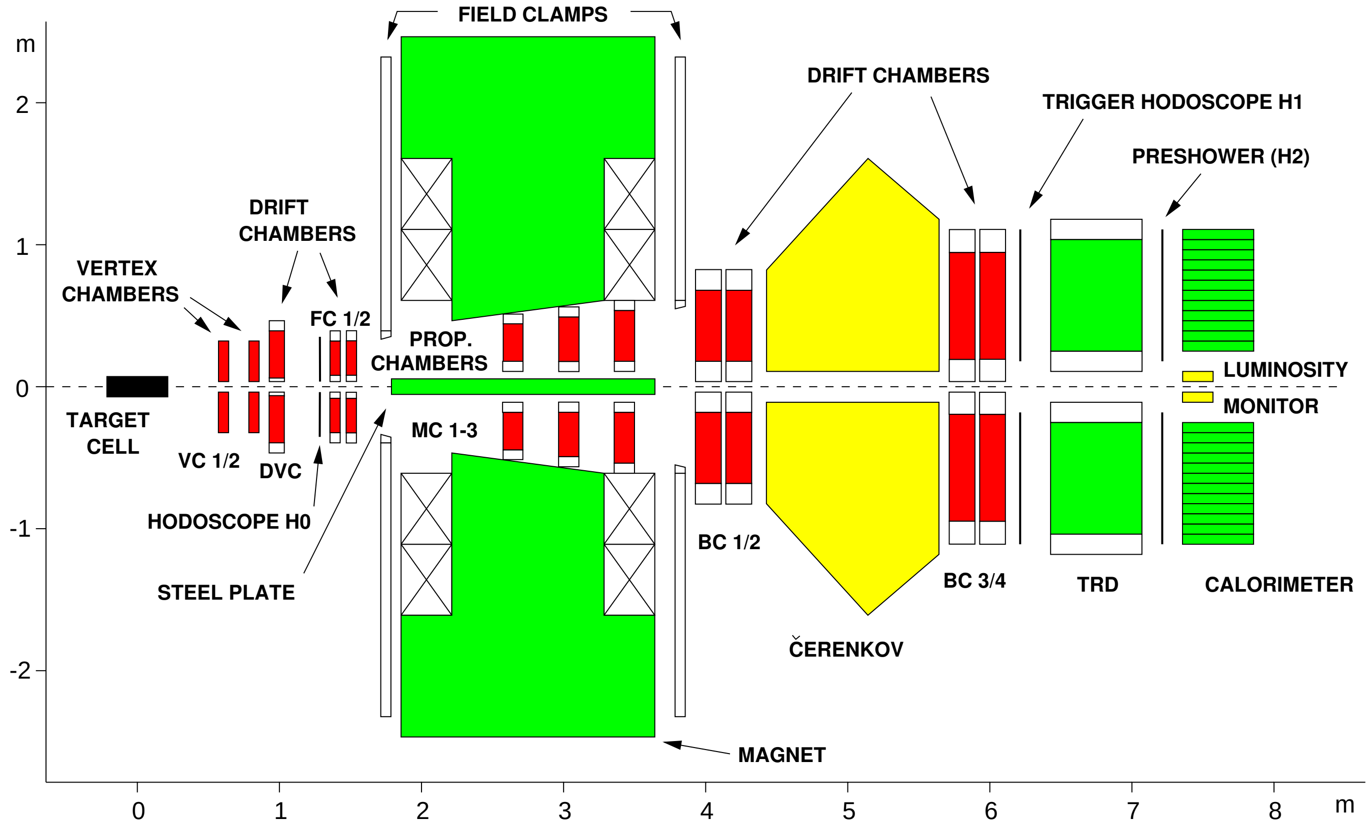
$E_2 \simeq \xi 2 \Delta l$

$-\xi = \frac{dE}{dl} \sim 1\ GeV/fm$

QCD inspired model for "leading-meson" (high z) formation and subsequent rescattering.

Highly virtual quark reaches its mass shell by the emission of gluons. It is *time* and *energy* dependent.

HERMES '97



$$E_{e^+beam} = 27.5\ GeV$$

$40 < \theta < 220$ mrad, $0.004 < x_{Bj} < 0.8$, $0.2 < Q^2 < 20\ GeV^2$

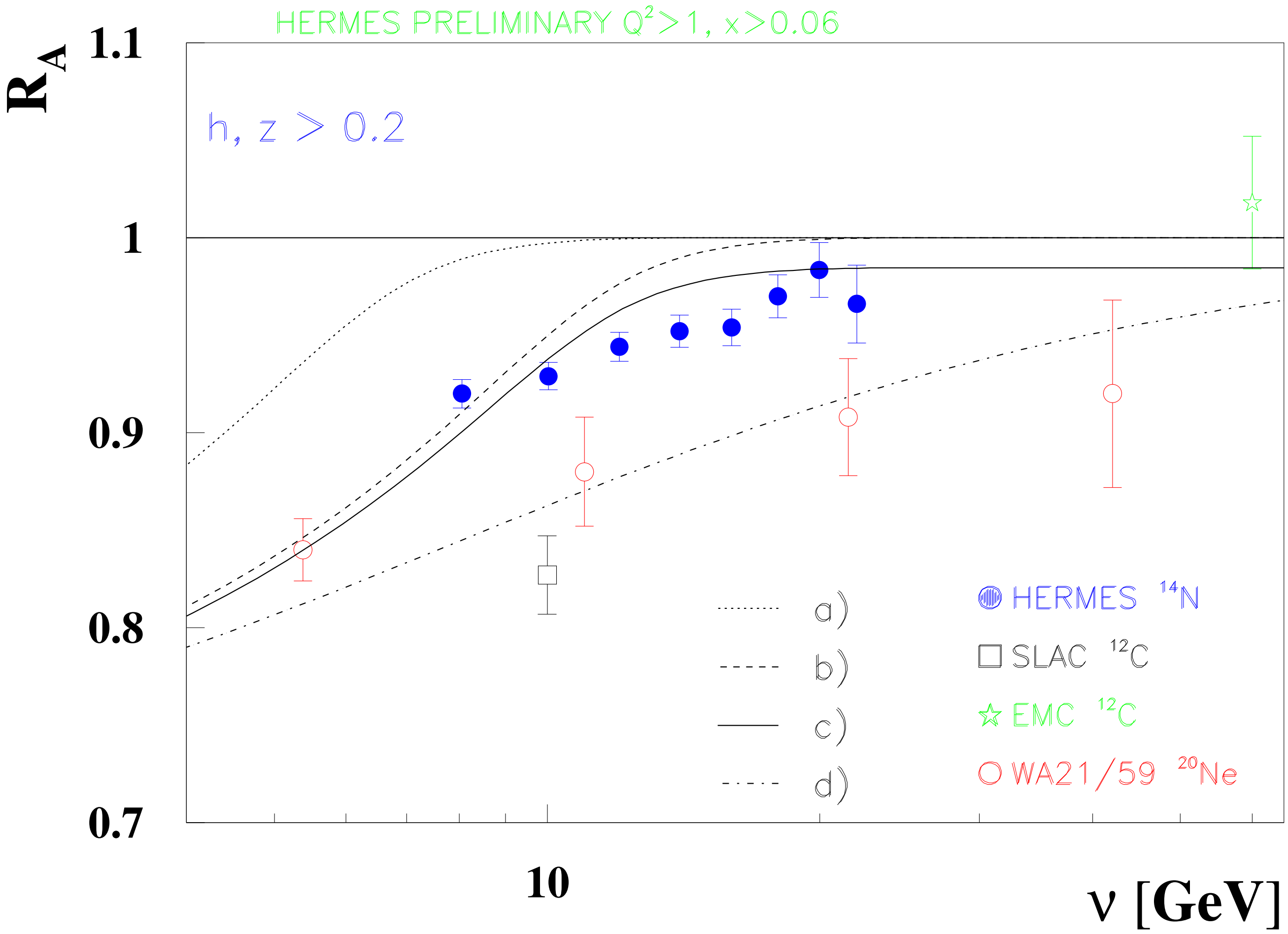
Internal D and ^{14}N storage cell gas targets ($\sim 10^{15}\ nucl/cm^2$)

Tracking: 57 tracking planes, $\frac{\delta P}{P} \simeq 1\%$, $\delta\theta < 0.6\ mrad$

PID: $efficiency > 99\%$, contamination $< 0.5\%$

(NIM A417 (1998) 230)

Hadron Attenuation Ratio *vs* ν



a) 2-time scale model $\sigma_h = 20\ mb$, $\sigma_s = 0\ mb$, $\sigma^* = 0\ mb$

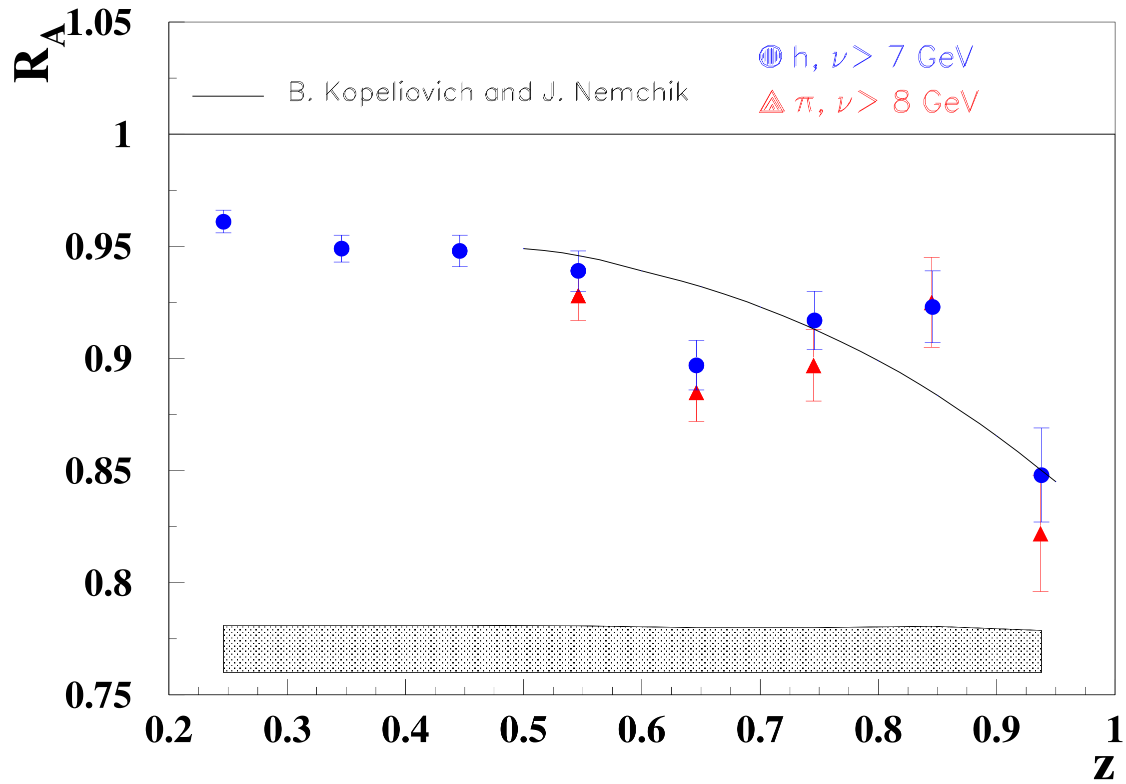
b) 2-time scale model $\sigma_h = \sigma_s = 20\ mb$, $\sigma^* = 0\ mb$

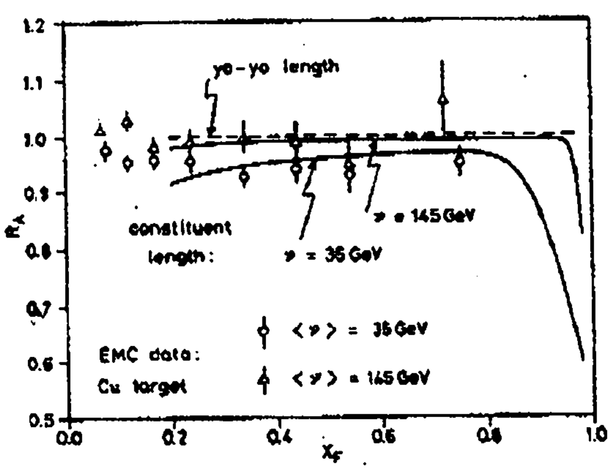
c) 2-time scale model $\sigma_h = \sigma_s = 20\ mb$, $\sigma^* = 0.75\ mb$

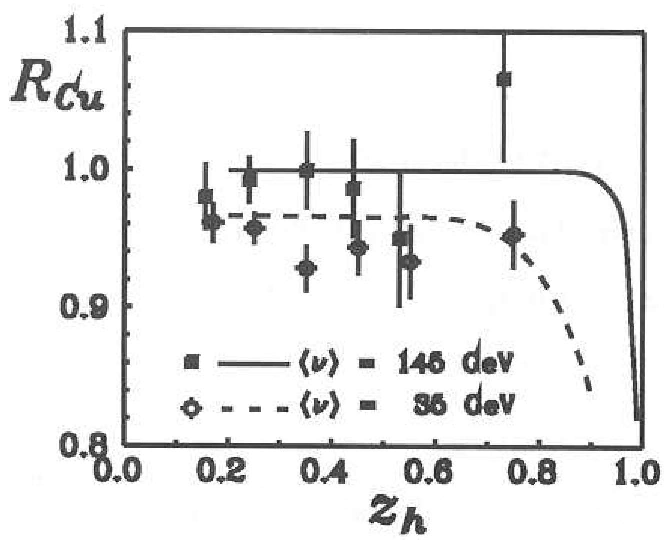
d) 1-time scale model $\tau_h \sim E_h$

- Significant hadron attenuation at low ν.
- Accuracy of HERMES data adequate to constrain model predictions.

Attenuation Ratio $vs\ z = \frac{E_h}{\nu}$

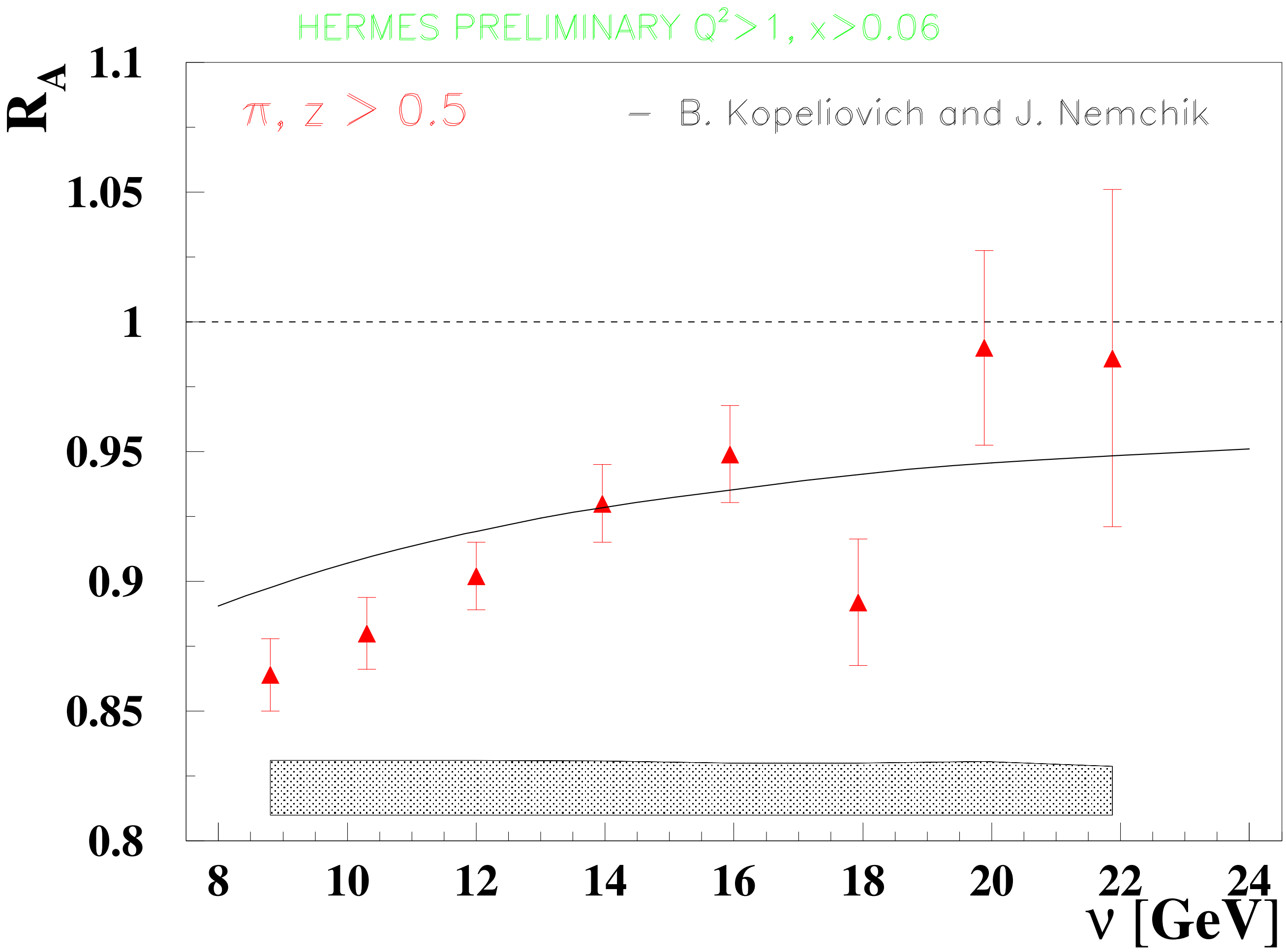






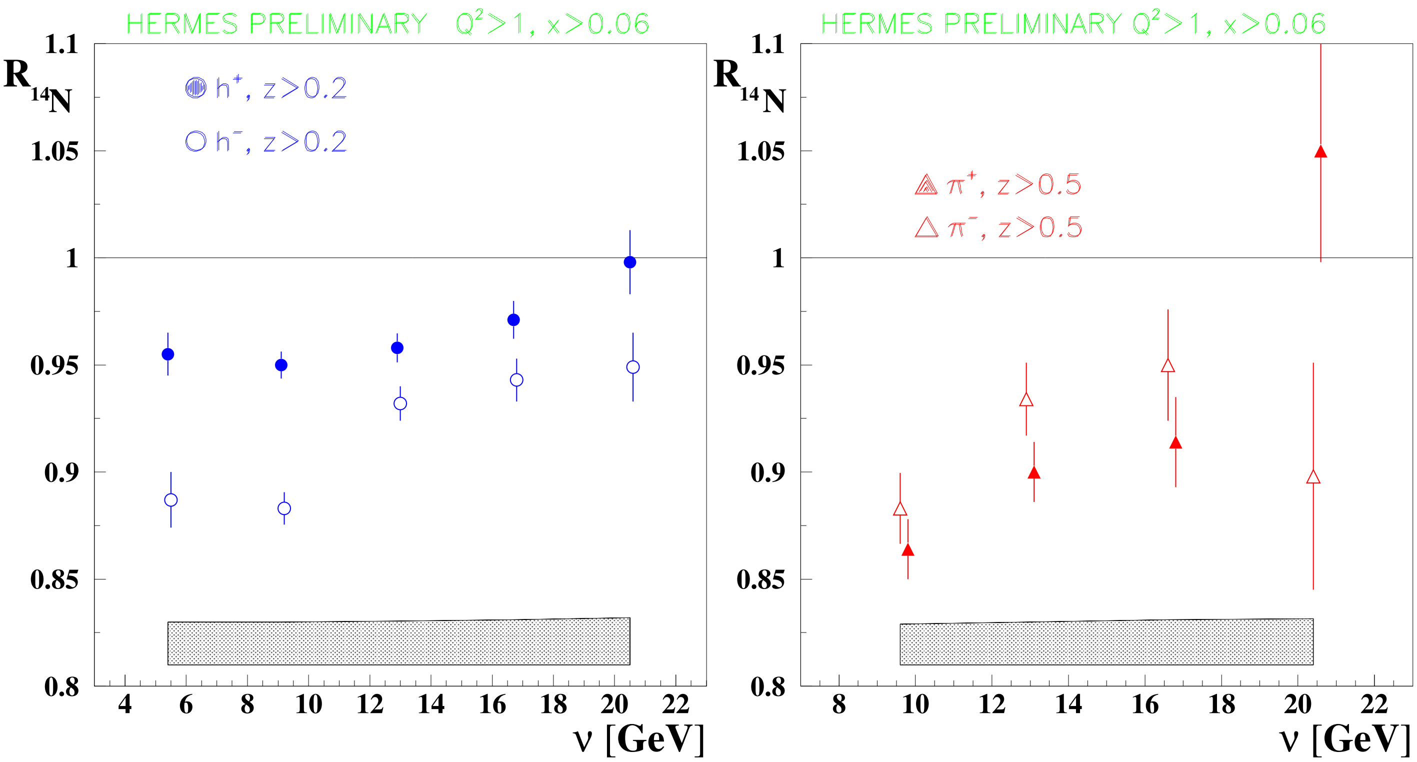
- Significant attenuation of fast forward hadrons
- Good agreement with the *gluon-bremsstrahlung model.* Disagreement with other models
- HERMES data provide information in the unexplored region $z > 0.8$ where the model predictions strongly differ
- Significant improvement in the statistical accuracy

Pion Attenuation Ratio *vs* ν



- First measurement of pion attenuation
- Significant attenuation of fast forward pions at low ν.

Attenuation Ratio *vs* ν



- Comparison between $h^+(\pi^+, K^+, p)$ and $h^-(\pi^-, K^-, \bar{p})$: for the first time a possible dependence on the m_h.
  Protons seem to be less attenuated $\Rightarrow$ longer formation time.
- No significant difference between π^+ and π^- $\Rightarrow$ the space-time hadronization for the pion is almost charge-independent.
- RICH detector will provide τ_f for π, K and p separately

Conclusions

HERMES has shown, for the first time, data in a new region of the kinematical plane where model predictions strongly differ:

- Significant nuclear attenuation of fast hadrons and, for the first time, pions has been found by semi-inclusive electroproduction in ^{14}N.

- First measurement in the high z region. Qualitative agreement with the gluon bremsstrahlung model prediction.

- First observation of a possible dependence of the nuclear attenuation on the hadron mass.