Hadronization of pions and kaons from nuclei using DIS at CLAS

K. Hicks (CLAS Collaboration)

ECT Workshop on Fragmentation

Feb. 29, 2008

Introduction

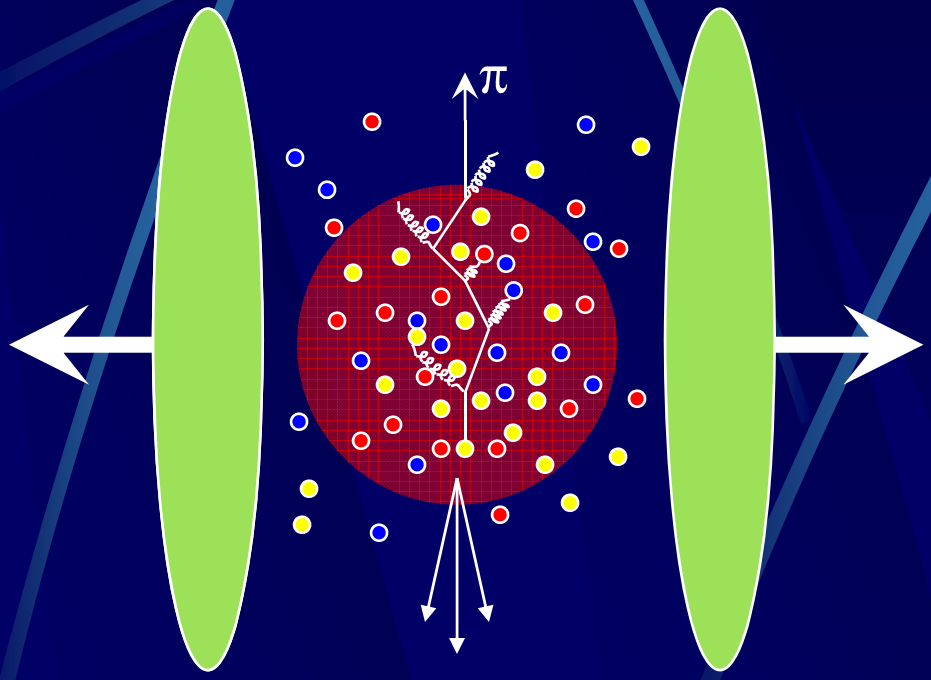
- Goal: measure observables of quark propagation through cold QCD matter.
- Primary: pions (PhD thesis of H. Hakobyan)
- Extension: kaons (Ohio postdoc A. Daniel)
  - Do kaons propagate differently from pions?
    - Do s-quarks affect the hadron propagation?
  - HERMES: K^+ and K^- attenuation ratios differ.
    - There is no difference between π^+, π^- or π^0.
    - CLAS: K^0 attenuation ratios (first time shown)

12 GeV Science Review

- 3 primary aims: GlueX, GPD, nuclear effects.
- “Precise knowledge of the hadronization process in nuclear matter is required to extract fragmentation functions [in nuclei]”
- “A better understanding of these processes would be valuable to research outside this field such as the heavy ion program at RHIC.”

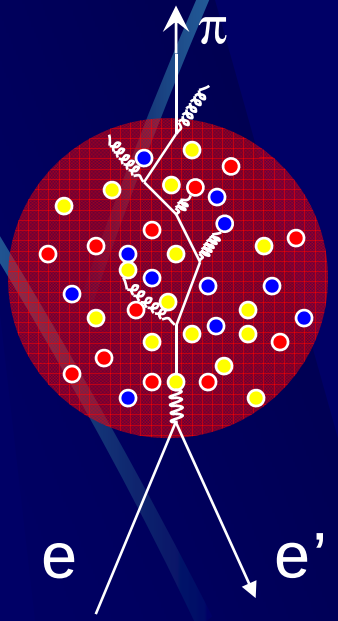
Relevance to RHIC

Relativistic Heavy-Ion Collisions



These experiments try to recreate conditions of the early universe.

Deep Inelastic Scattering



Initial quark energy is known
Properties of medium are known

Graphics by Will Brooks

Hadronization Variables

ν	energy transferred by the electron (initial energy of struck quark)
Q^2	four-momentum transferred by the electron (initial size of struck quark)
z_h	$= E_{hadron}/\nu$, fraction of struck quark energy carried by hadron; $0<z_h<1$
p_T	quark/hadron momentum transverse to virtual photon direction.

Observables

Hadronic multiplicity ratio:

$$R_M^h(z,\nu) = \frac{\left\{\frac{N_h(z,\nu)}{N_e^{DIS}(\nu)}\right\}_A}{\left\{\frac{N_h(z,\nu)}{N_e^{DIS}(\nu)}\right\}_D}$$

Transverse momentum:

$$\Delta p_T^2 \equiv \left\langle p_T^2 \right\rangle_A^{DIS} - \left\langle p_T^2 \right\rangle_D^{DIS}$$

Binning:

Q^2 (range 1.0-2.5 GeV^2)
ν (range 2.6-4.3 GeV)
z (range 0.1-1.0)

Theoretical Models

- No (dynamical) lattice calculations yet.
- Accardi et al. (nucl-th/0211011):
  - gluon radiation and absorption included.
  - good agreement with HERMES data.
  - increased *deconfinement* in nuclei.
- Many other phenomenological models.

Inside the Models

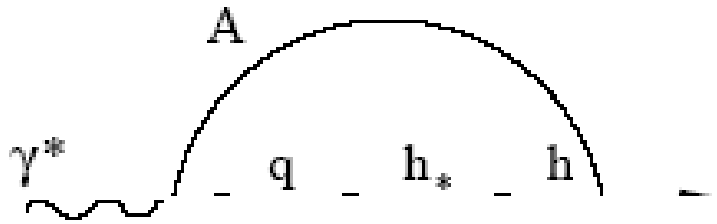
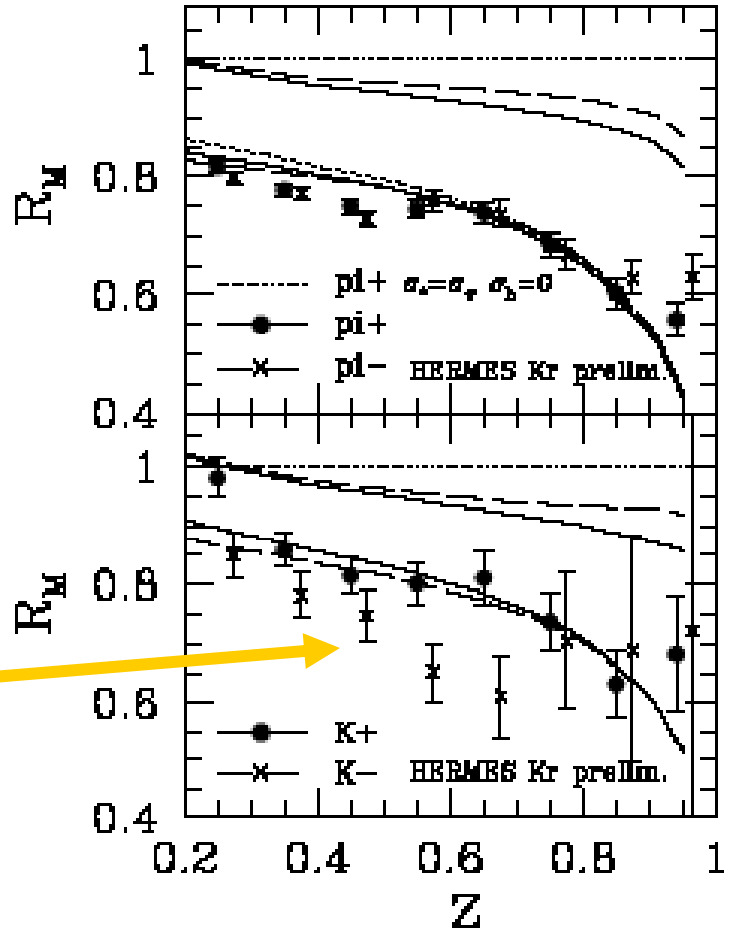
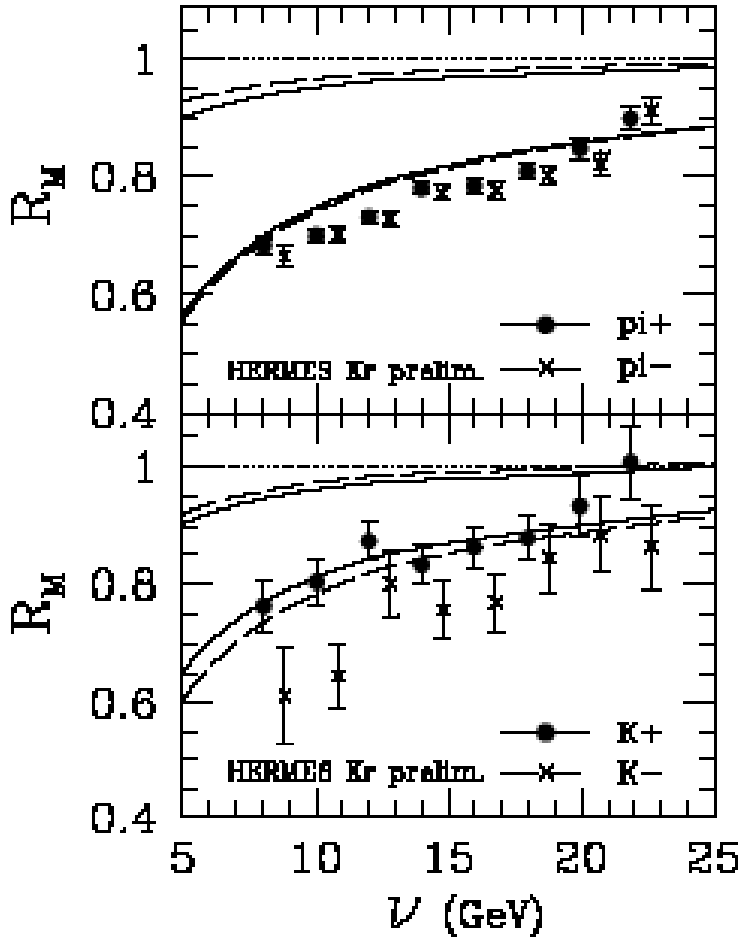


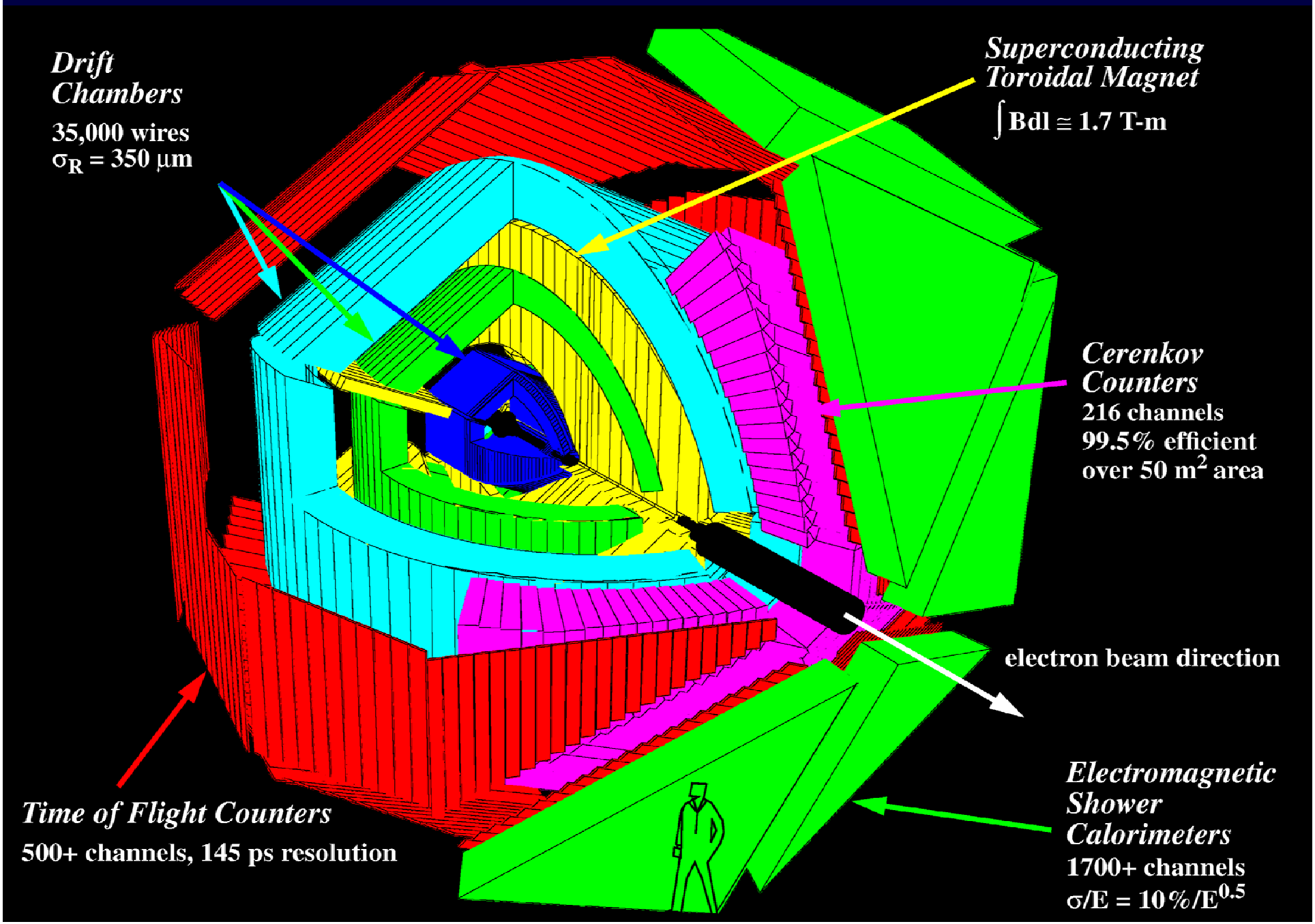
Figure 6: Nuclear attenuation of a hadron
h: the virtual photon γ* interacts with a

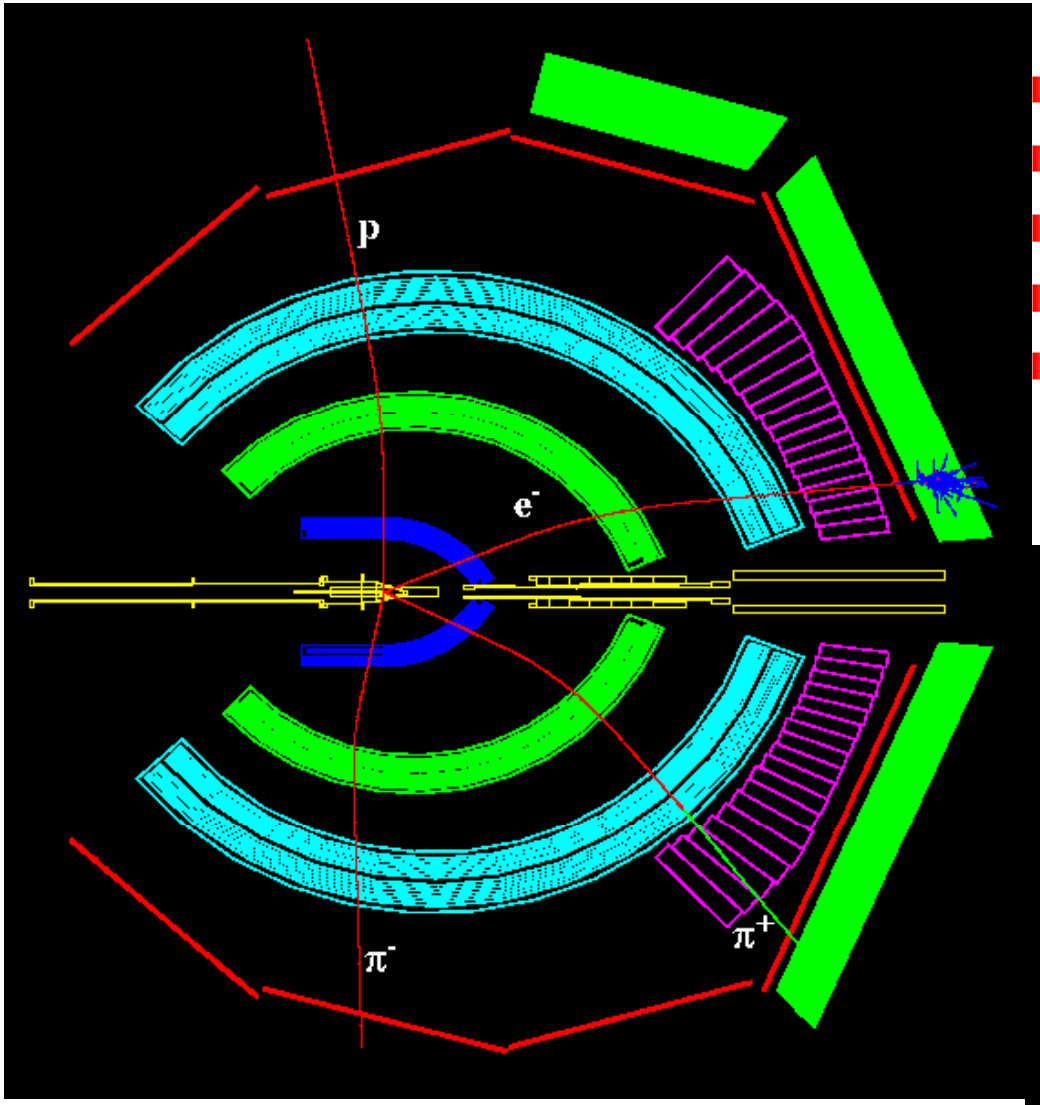




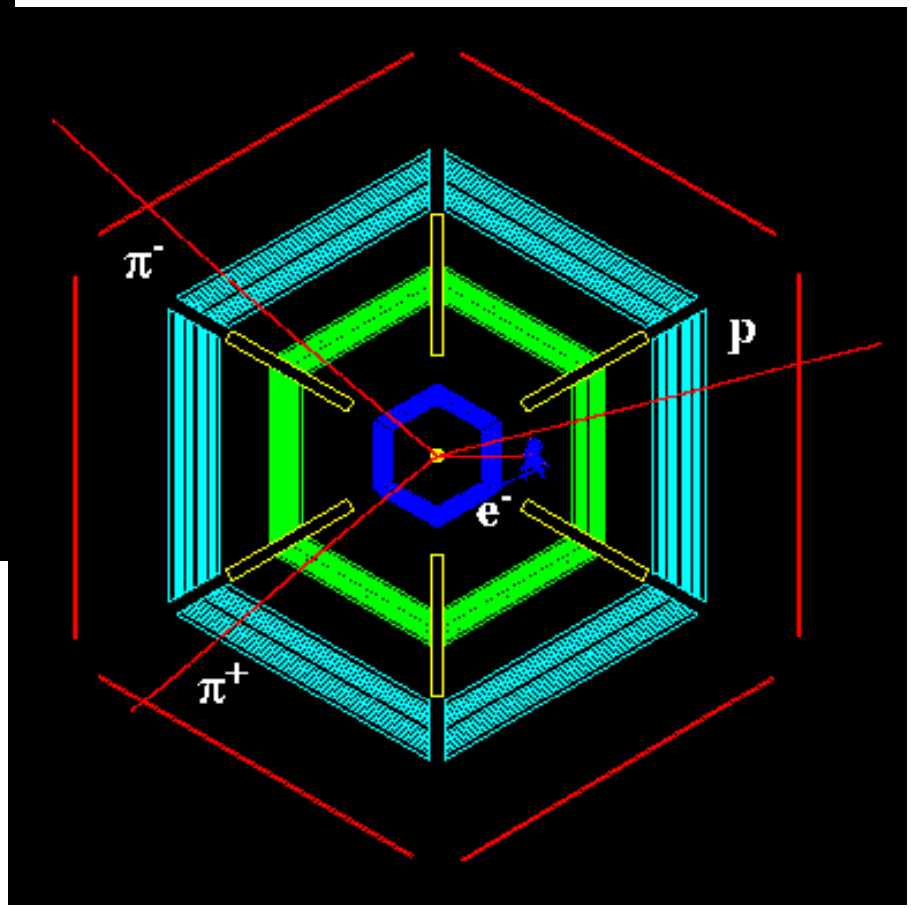
Note: K^+ different from K^-.

CLAS – the CEBAF Large Acceptance Spectrometer

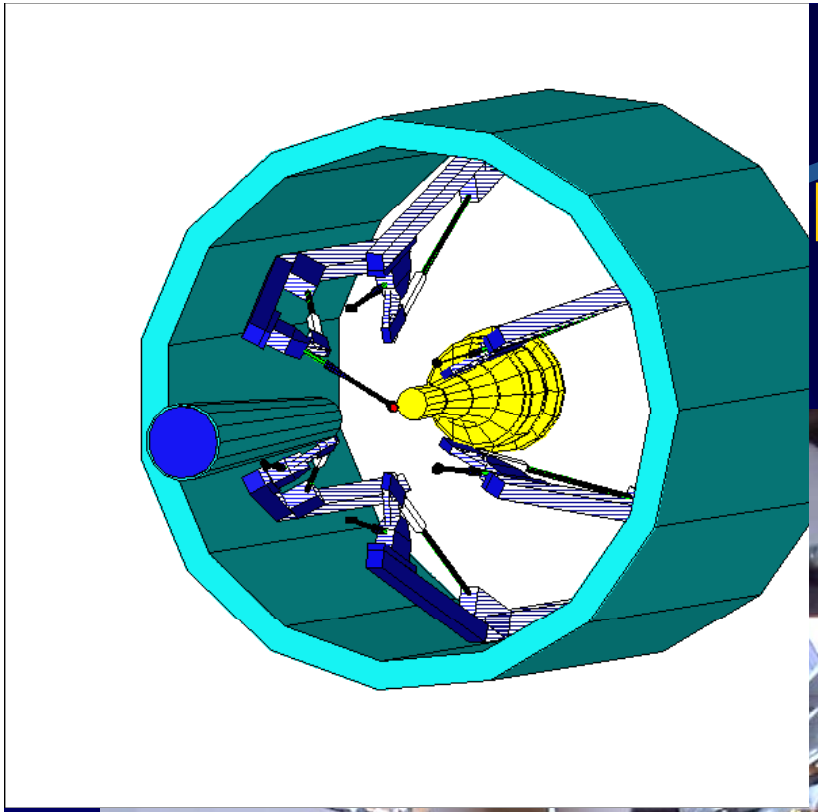




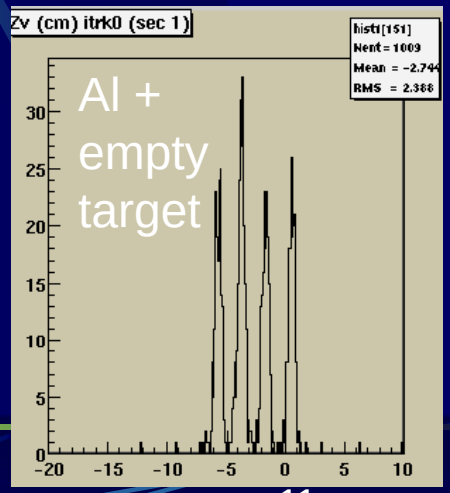
- Charged particle angles 8° - 144°
- Neutral particle angles 8° - 70°
- Momentum resolution ~0.5% (charged)
- Angular resolution ~0.5 mr (charged)
- Identification of p, π^+/π^-, K^+/K^-, e^-/e^+



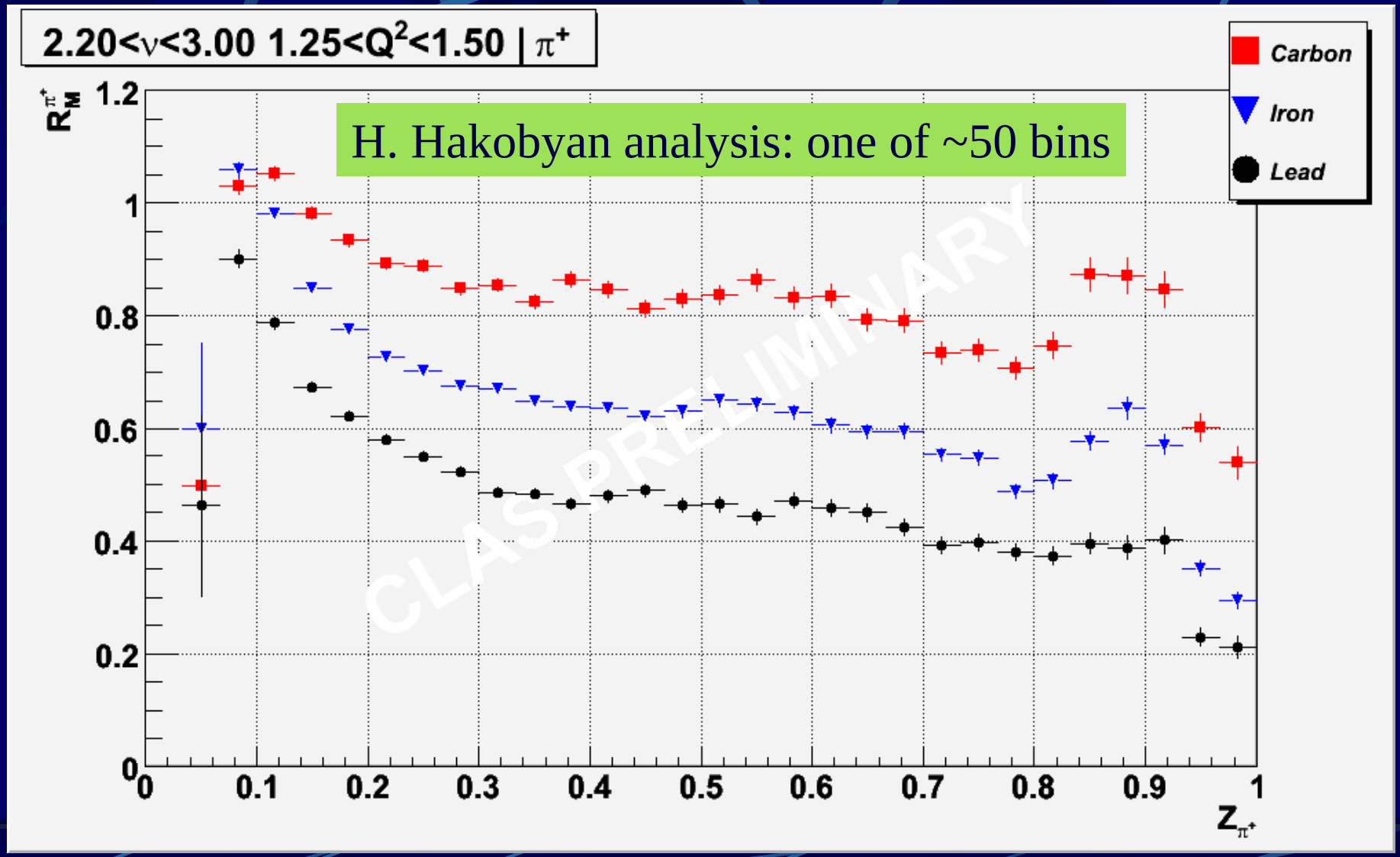
LAS EG2
Targets



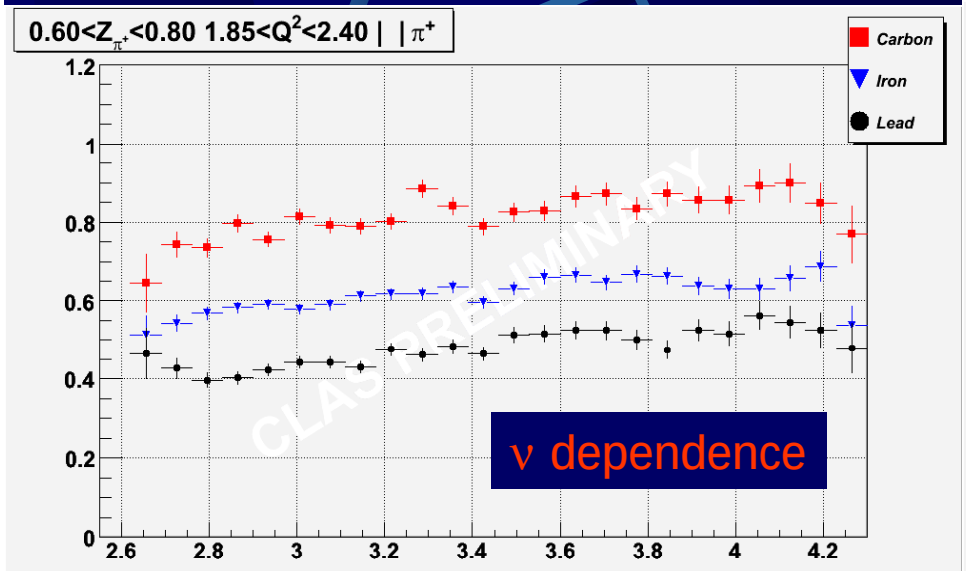
- *Two* targets in the beam simultaneously
- 2 cm LD2, upstream
- Solid target downstream
- Six solid targets:
  - -Carbon
  - -Aluminum (2 thicknesses)
  - -Iron
  - -Tin
  - -Lead

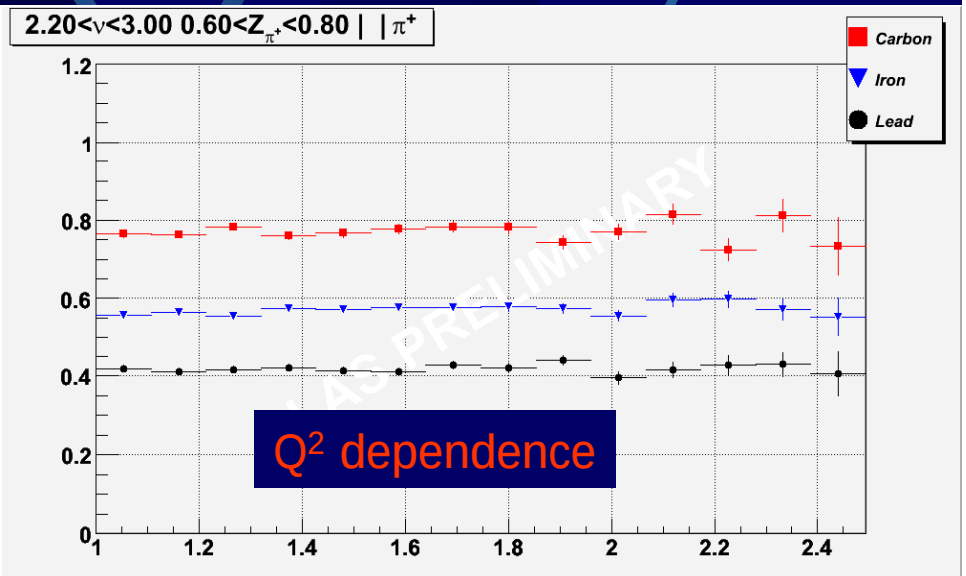


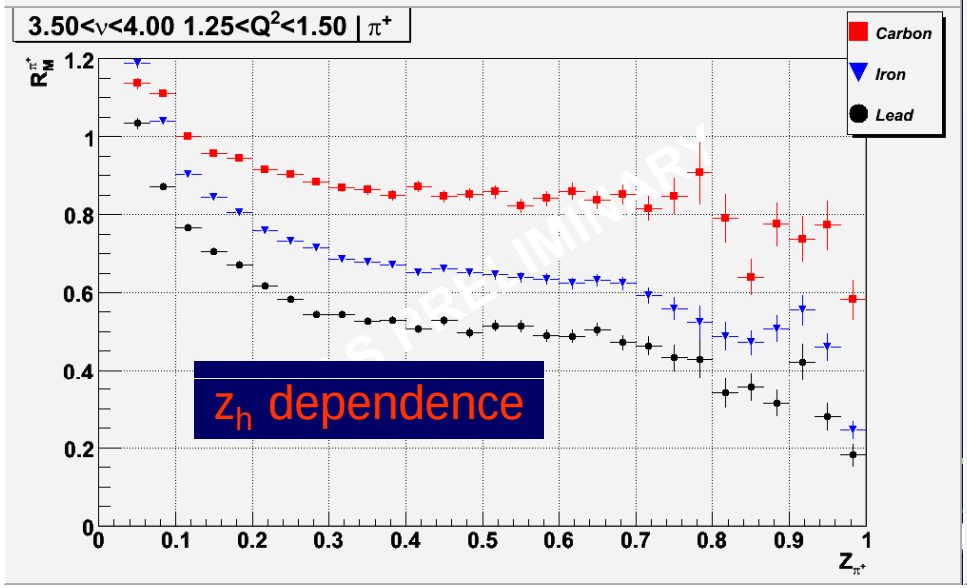
eg2: pion attenuation

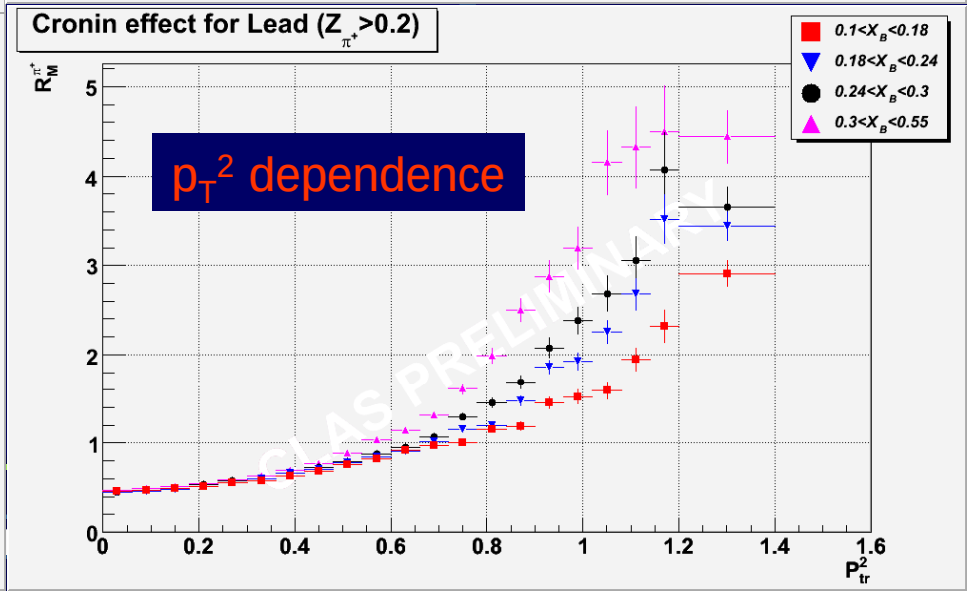


Examples of multi-variable (preliminary) CLAS data



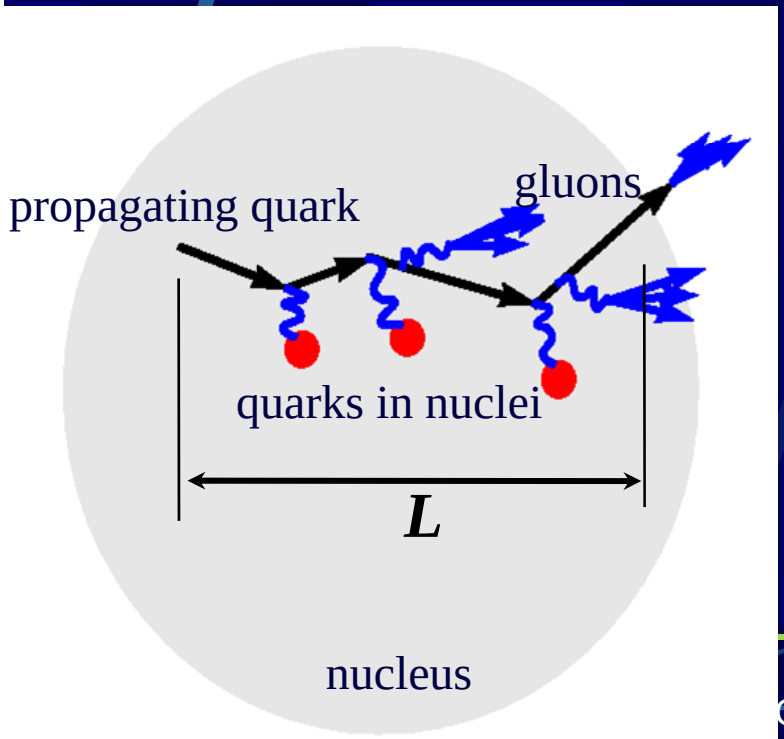






p_T Broadening and Quark Energy Loss

- Quarks lose energy by *gluon emission* as they propagate
  - In vacuum
  - Even more within a medium

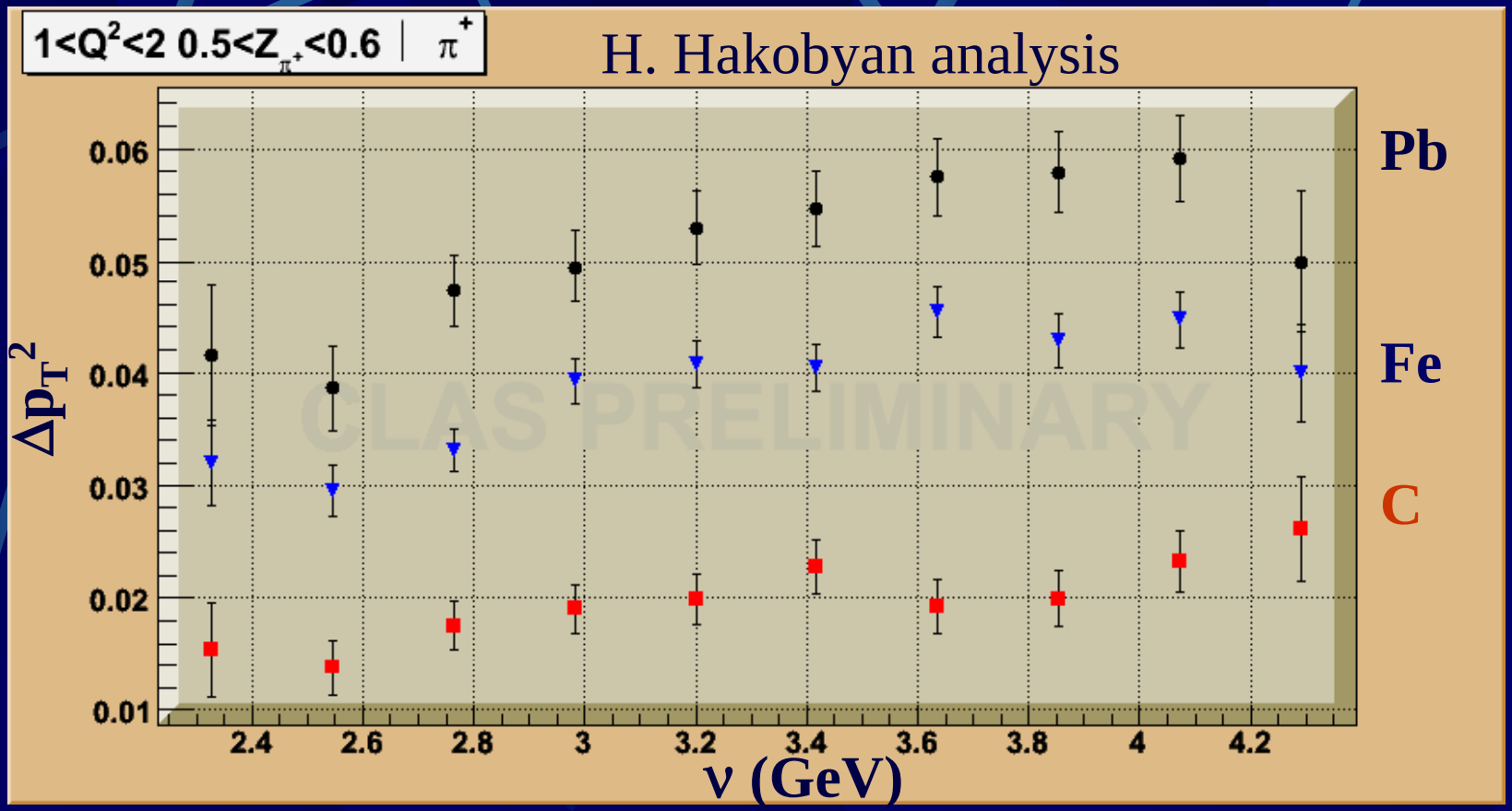


- This energy loss is manifested by Δp_T^2
- Δp_T^2 is a signature of the *production time* τ_p
- $\Delta E \sim L$ dominates in QED
- $\Delta E \sim L^2$ dominates in QCD?

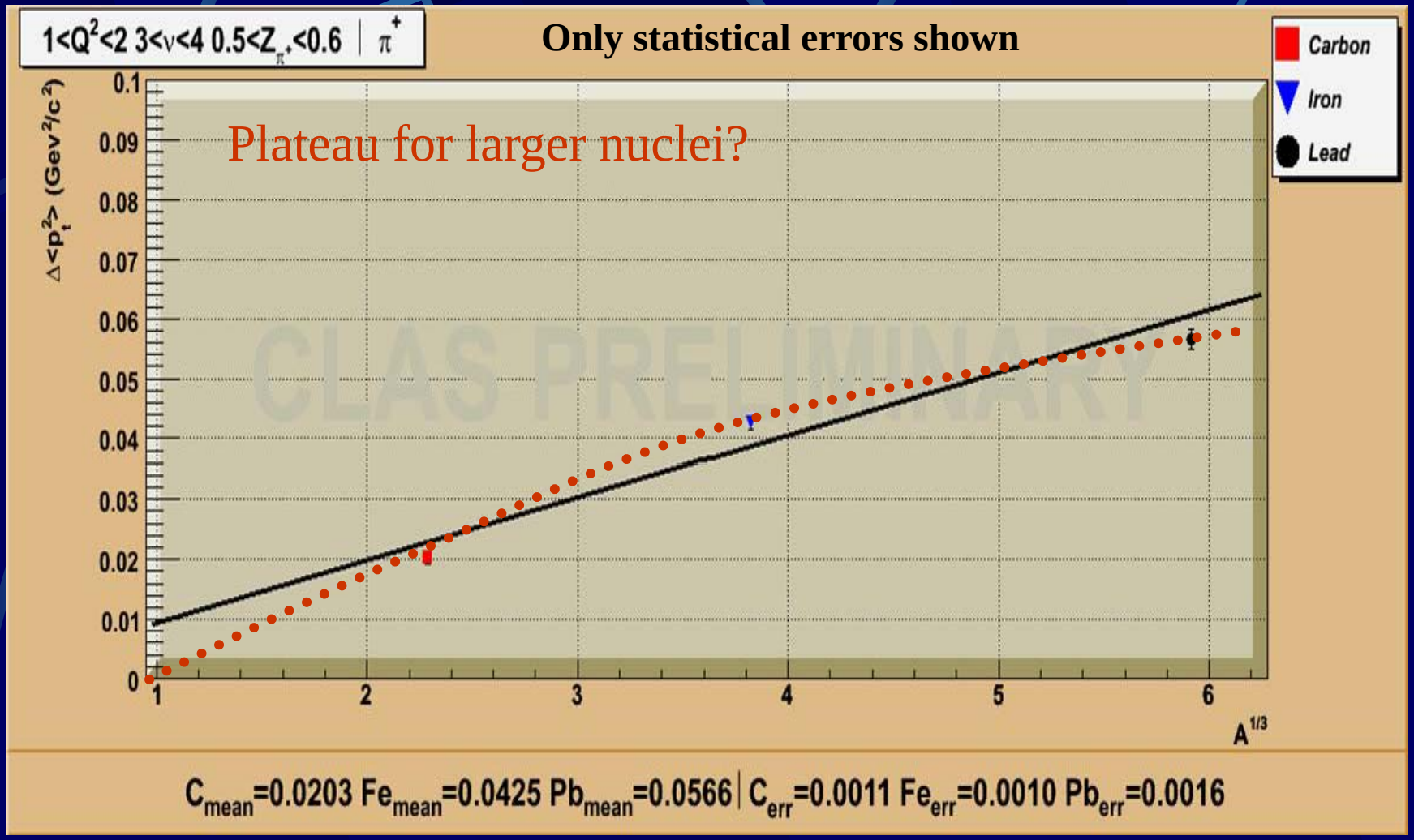
$$dE/dx \approx \frac{\alpha_s}{\pi} N_c \langle p_T^2 \rangle_L$$

Medium-stimulated loss calculation by BDMPS

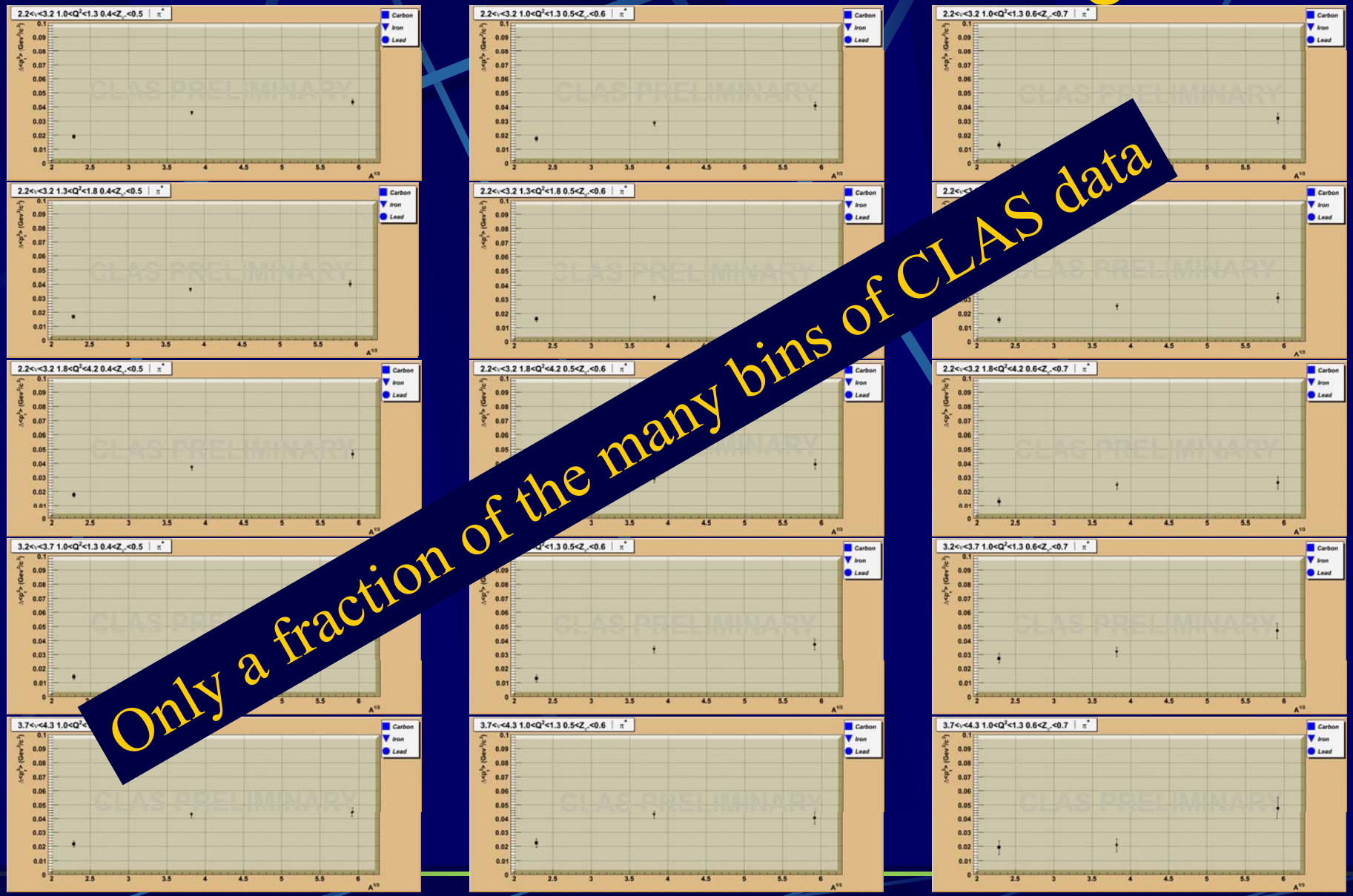
eg2: pion p_T broadening



A-dependence of Δp_T^2



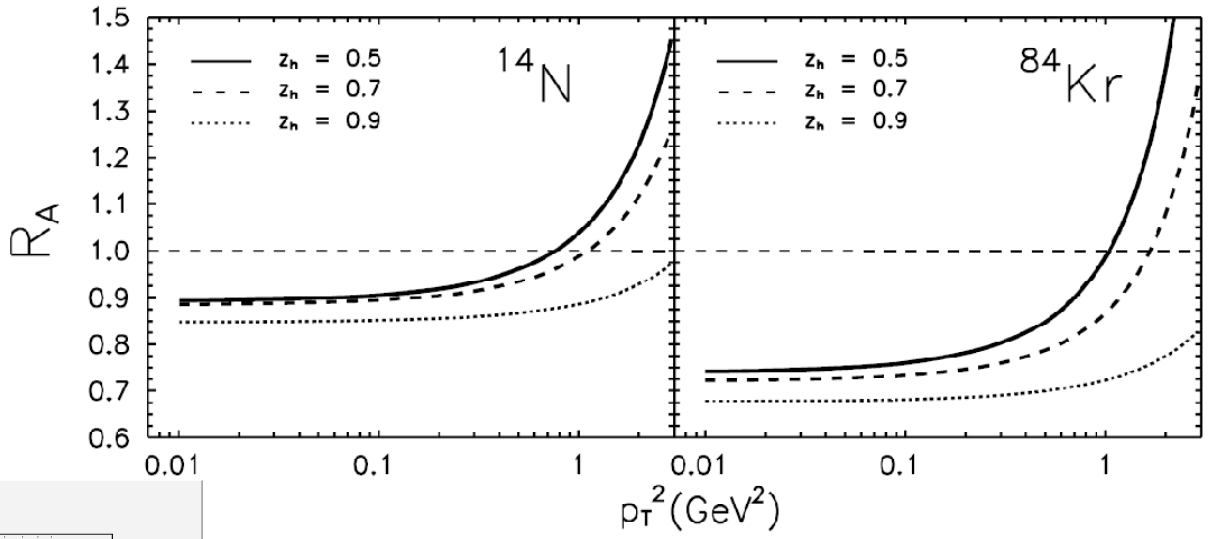
CLAS data: binning



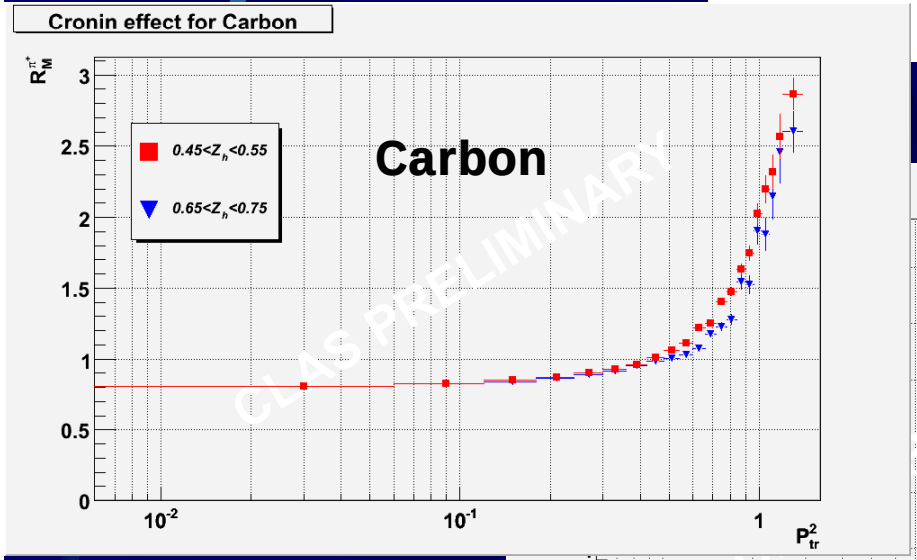
Cronin Effect

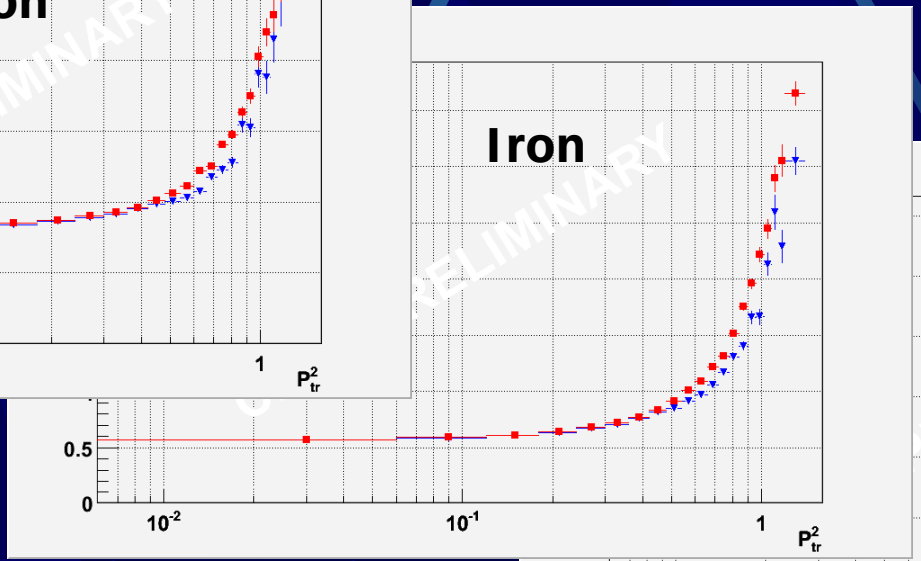
Theoretical *prediction:*

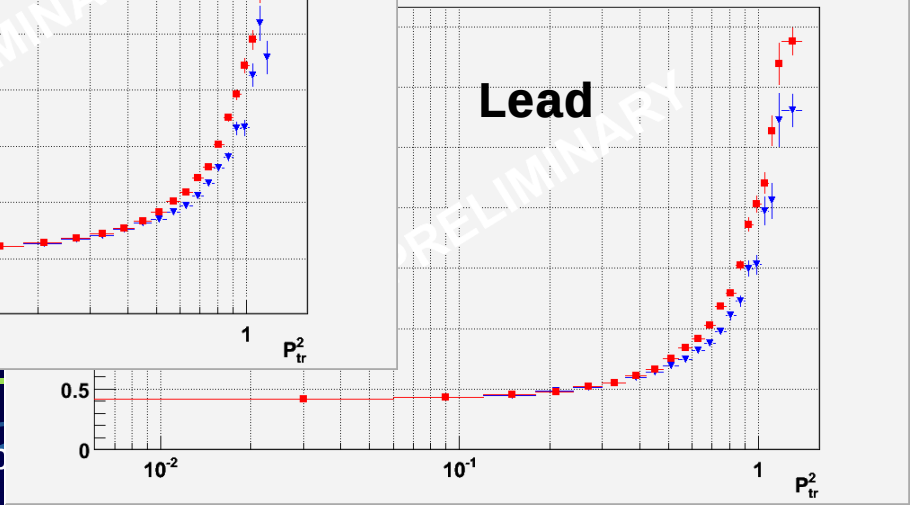
B.Z. Kopeliovich et al. / Nuclear Physics A 740 (2004) 211–245



Probes reaction mechanism







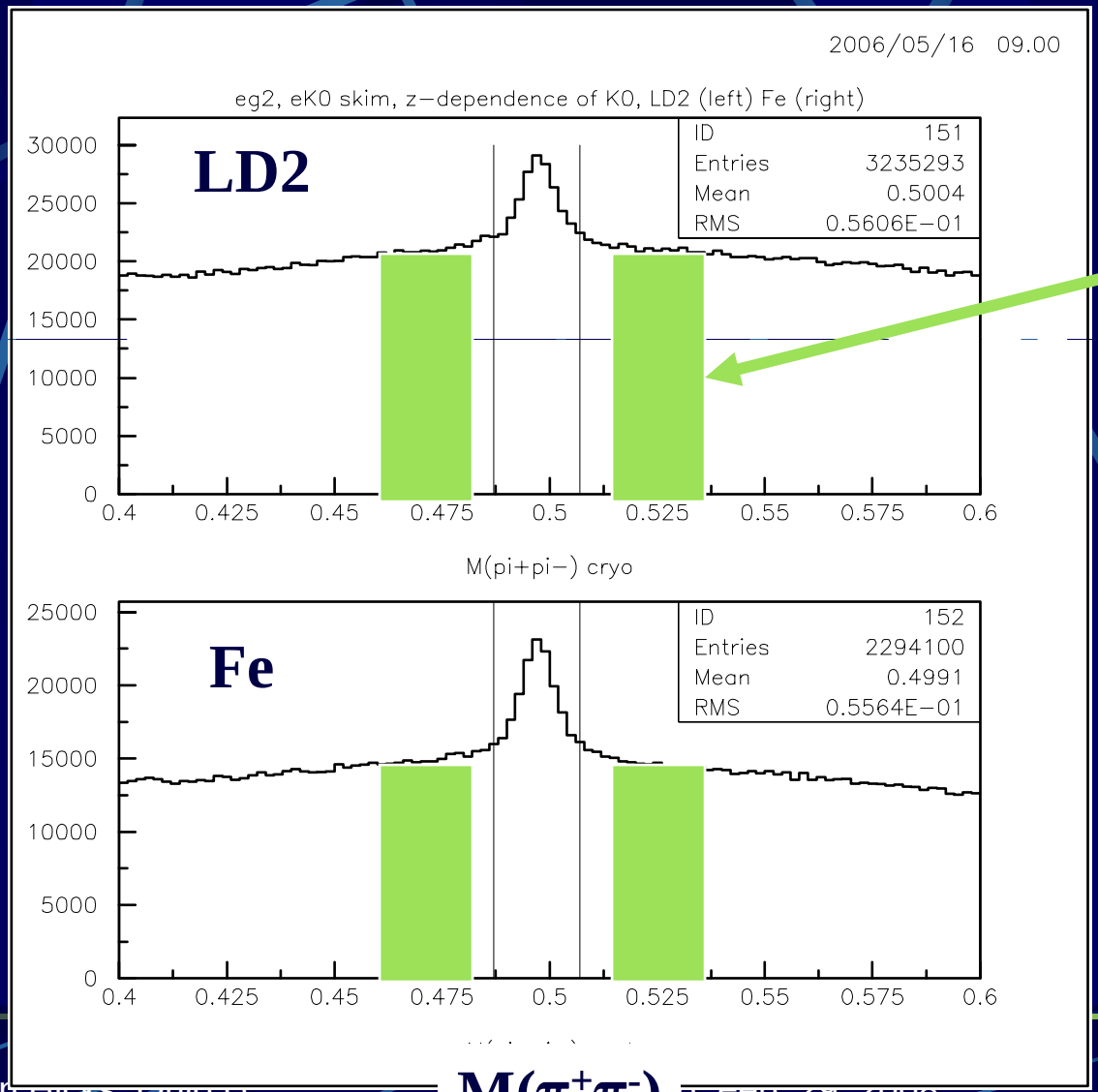
CLAS preliminary data
z=0.5 and 0.7

12 GeV Anticipated Data

Examples of Experimental Data and Theoretical Predictions

Bins in yellow accessible at 5 GeV at CLAS

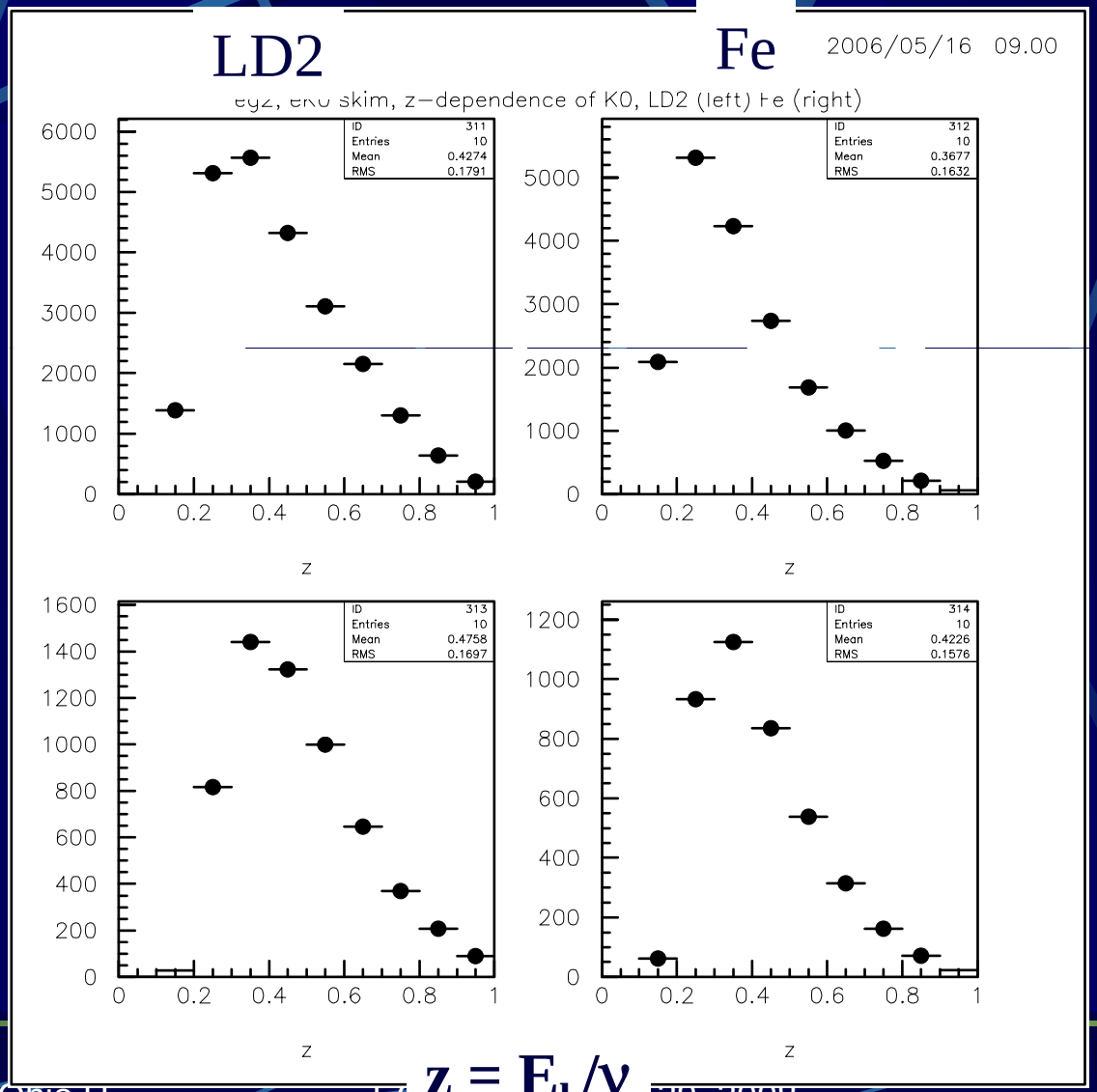
K^0 from $M(\pi^+\pi^-)$



Sidebands used to subtract background

$M(\pi^+\pi^-)$

z-dependence of K^0 peak

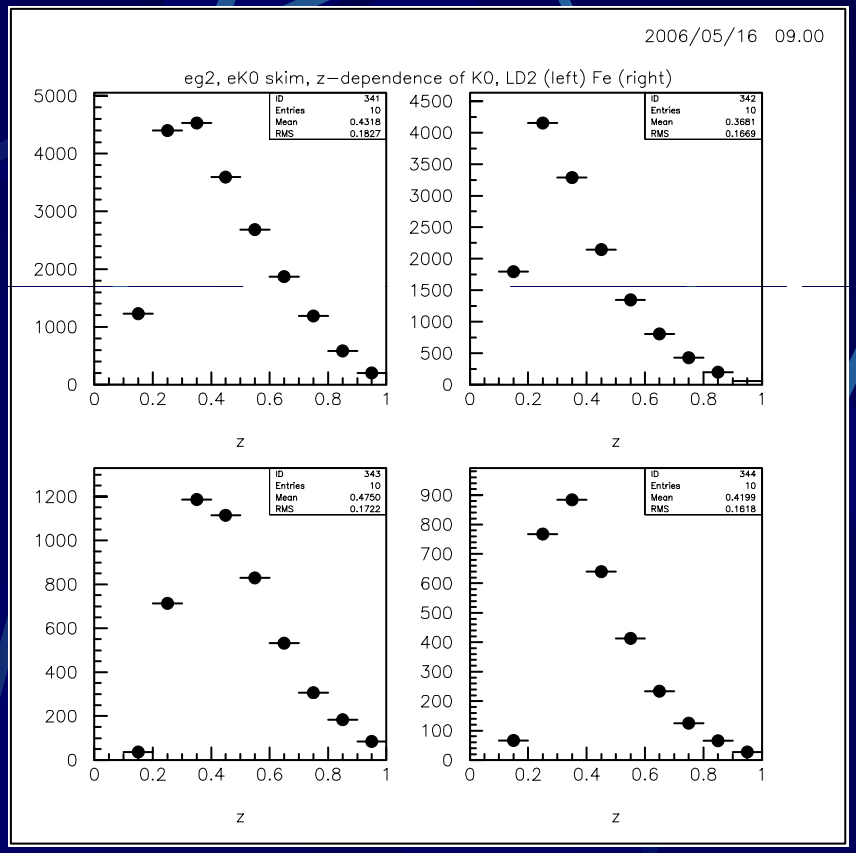


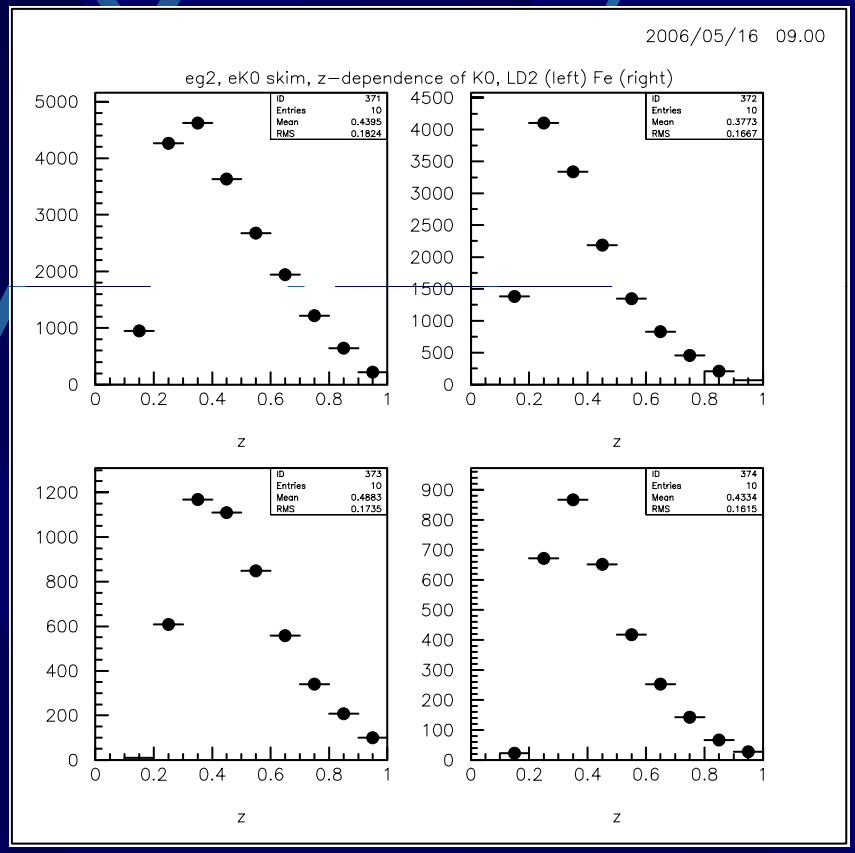
All events

$1.0<Q^2<2.0$ GeV^2 cut

$z = E_h/\nu$

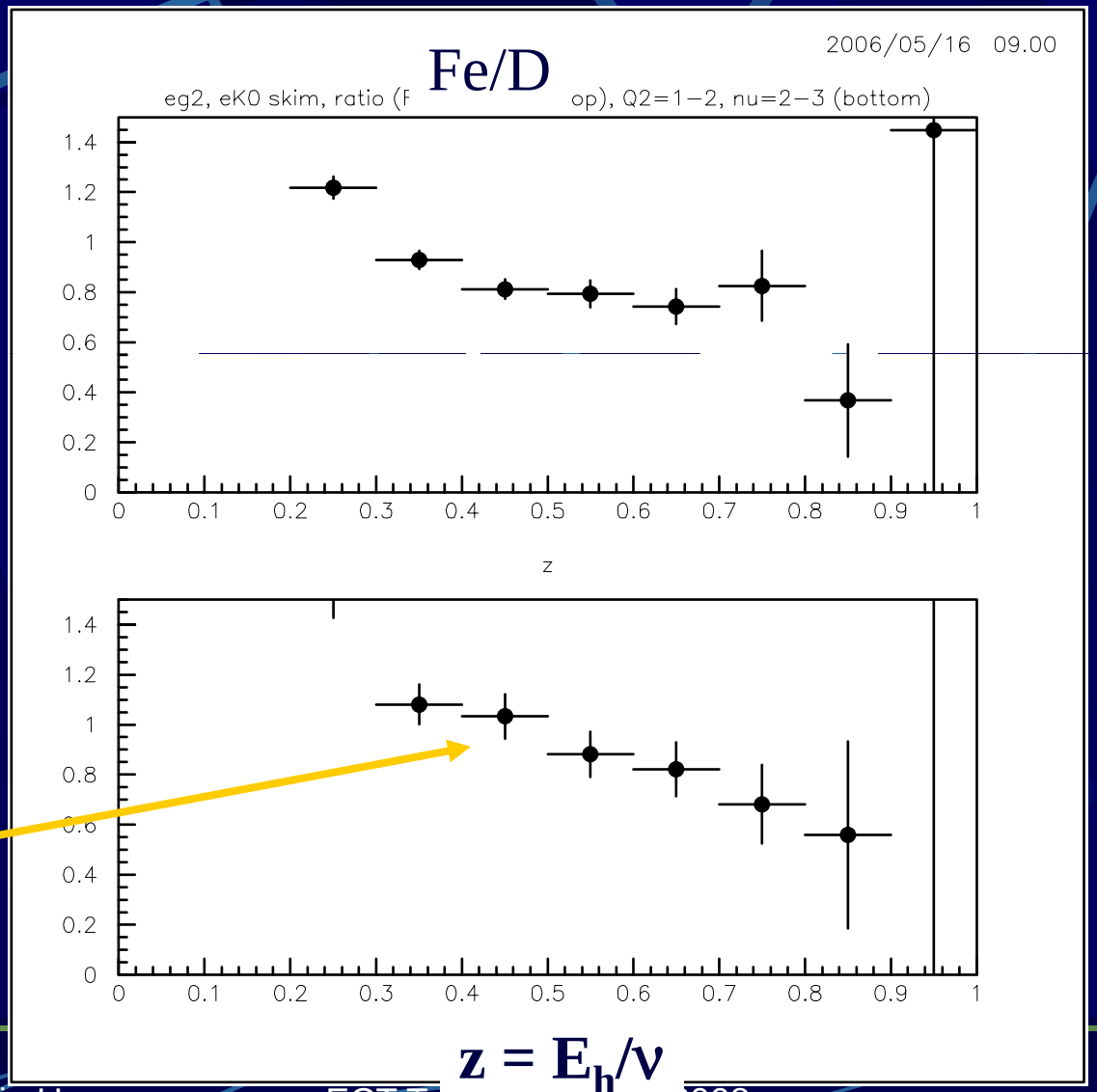
Sidebands





(Same ordering as before)

K^0 Multiplicity Ratio



All events

Note the smaller attenuation than for π's.

$1.0<Q^2<2.0$
$2.0<\nu<3.0$

Summary

- There is good statistical precision of the pion data at 5 GeV.
  - Hadronization ratios and Δp_T^2.
  - Cronin Effect looks interesting (preliminary)
- There is modest statistical precision for the K^0 data at 5 GeV.
  - Can we learn how the s-quark hadronizes?