Hadronization from DIS at CLAS

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DIS 2009 Conference, Madrid

April 27, 2009

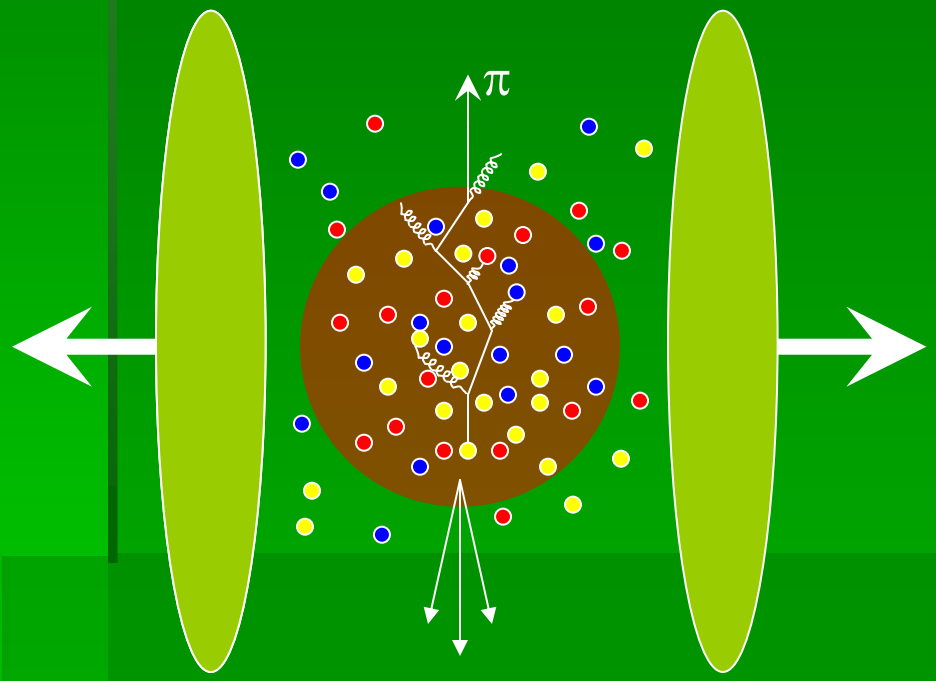
*working with Aji Daniel and the eg2 run-group.

Introduction

- Goal: measure observables of quark propagation through cold QCD matter.
- Pions: PhD work of H. Hakobyan (Yerevan)
- Kaons: work of postdoc A. Daniel (Ohio)
  - Do kaons hadronize differently than pions?
    - Heavy s-quarks could affect the hadronization.
  - K^+ and K^- attenuation ratios differ (HERMES).
    - No difference between π^+, π^- or π^0.
    - New: K^0 attenuation ratios (not done by HERMES).

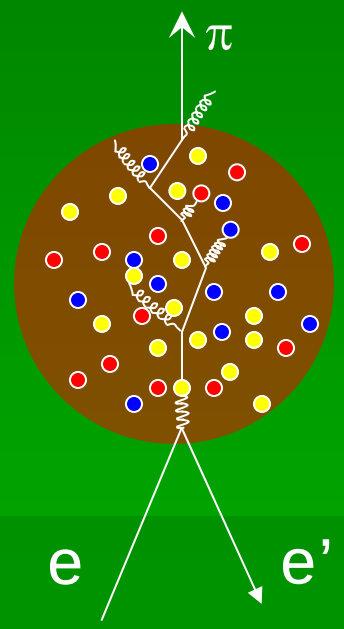
Relevance to RHIC

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

Observables

Hadronic multiplicity ratio:

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

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

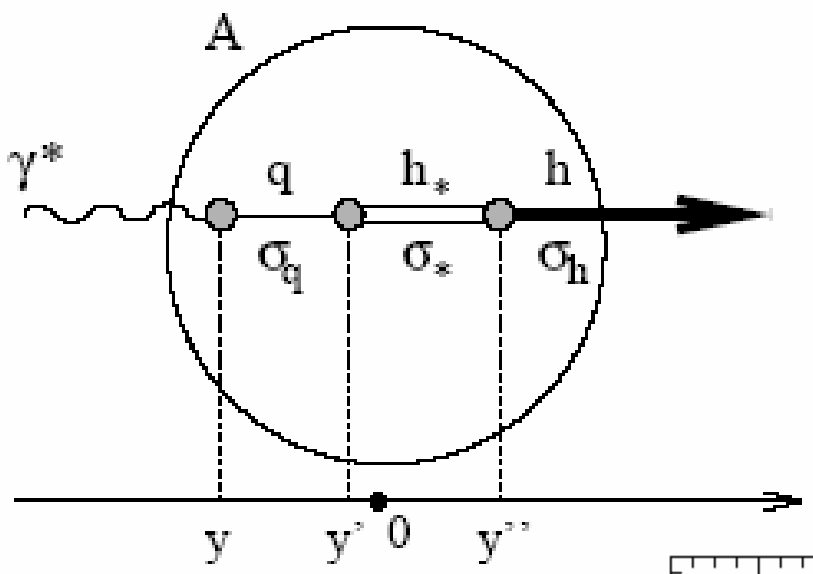
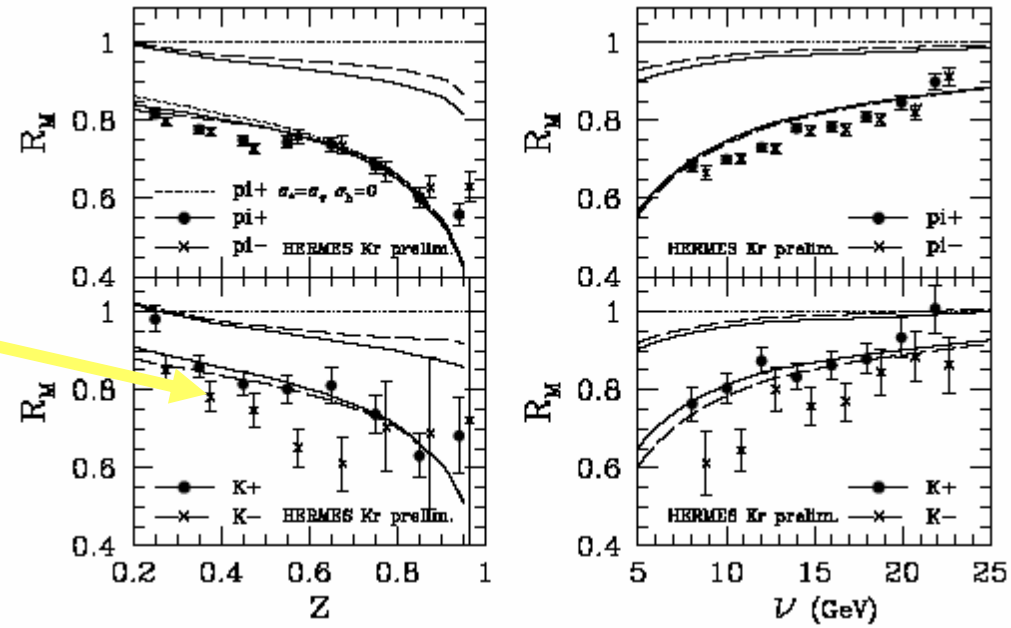
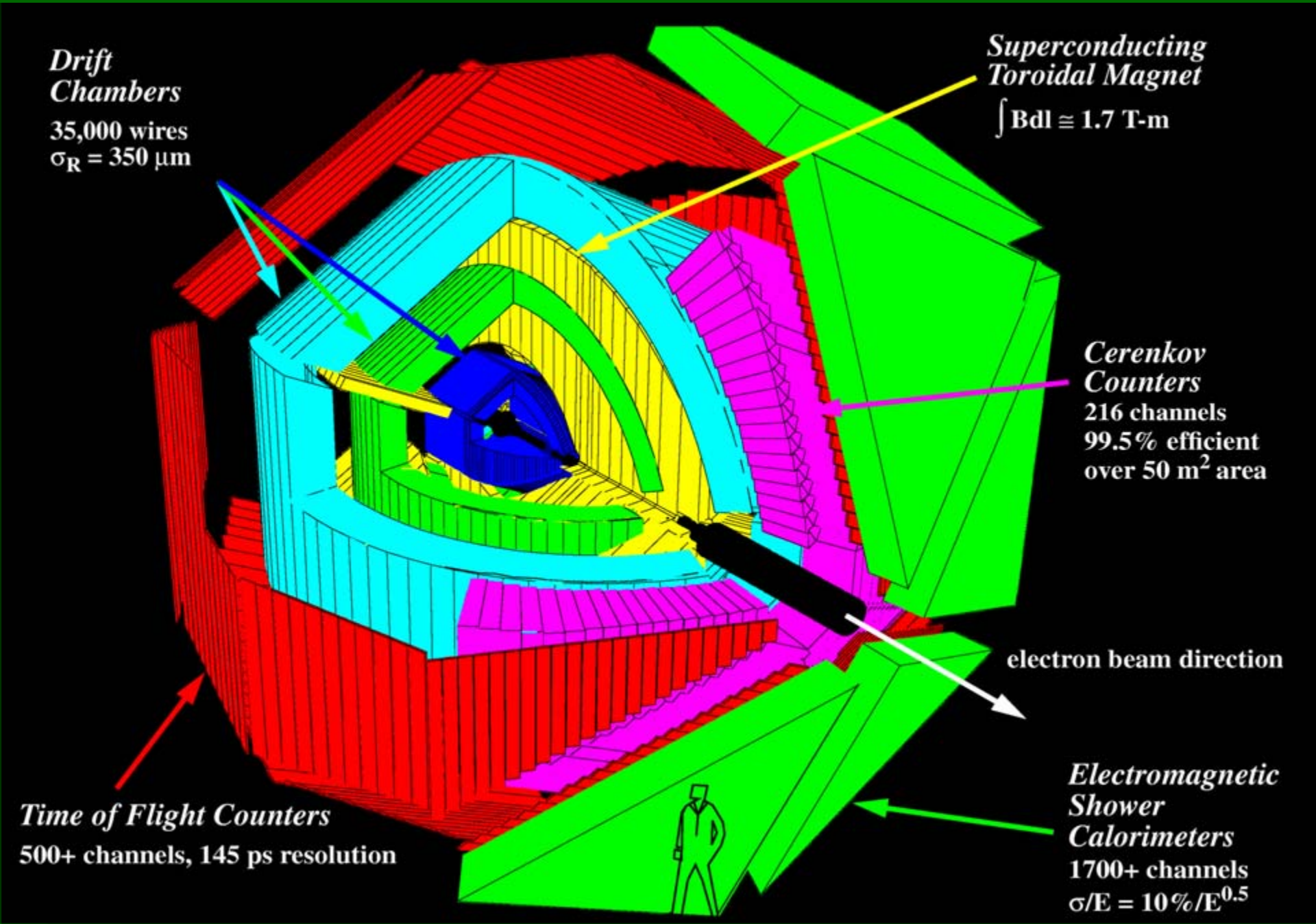


Figure 6: Nuclear attenuation of a hadron h: the virtual photon γ^* interacts with a quark q at a longitudinal coordinate y; the quark turns into a "prehadronic" state h_* at position y' and the hadron h is formed at y''. Each state interacts with the surrounding nucleons with a cross-section σ_q, σ_* and σ_h, respectively.

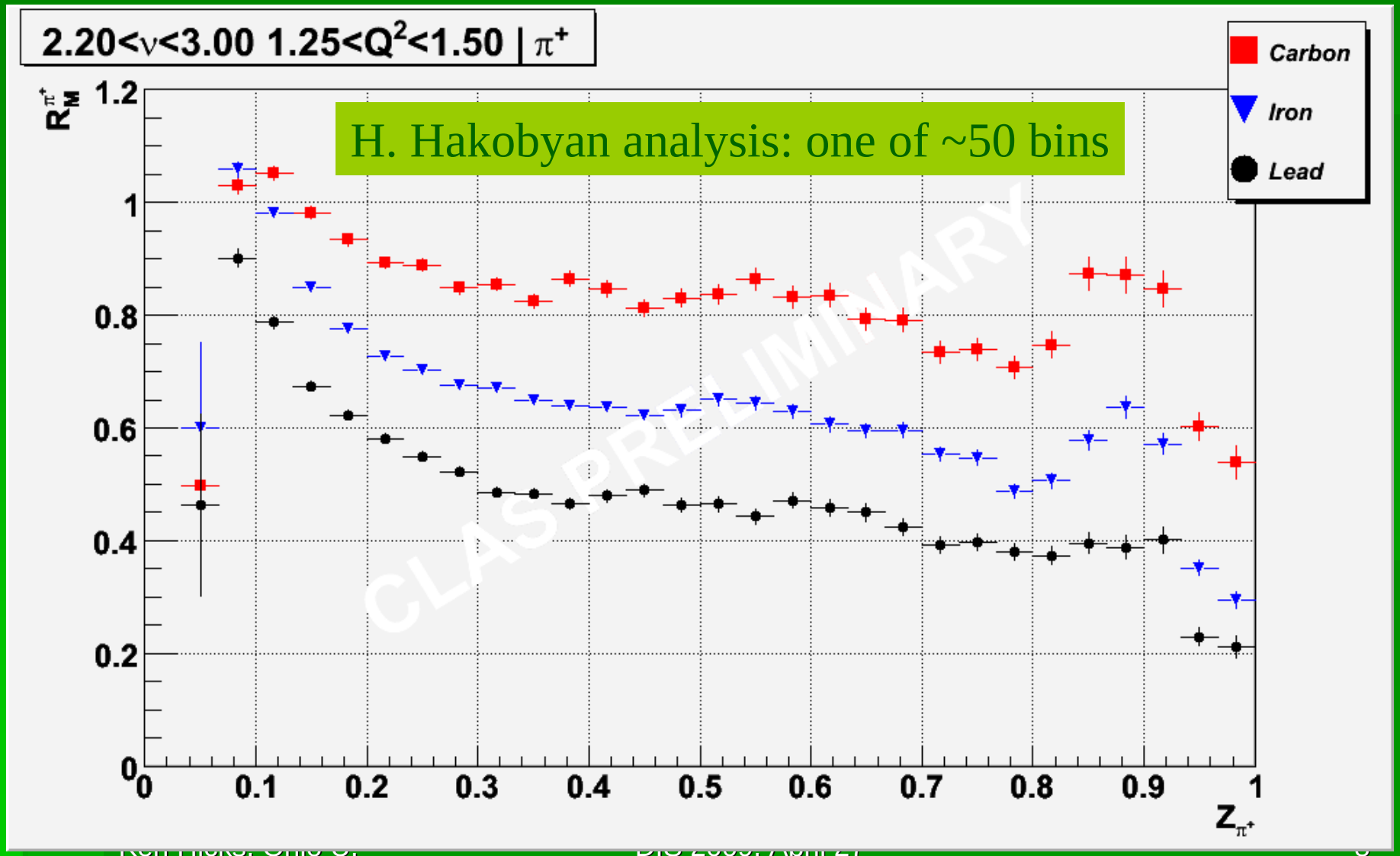
HERMES: K^+ and K^- different.



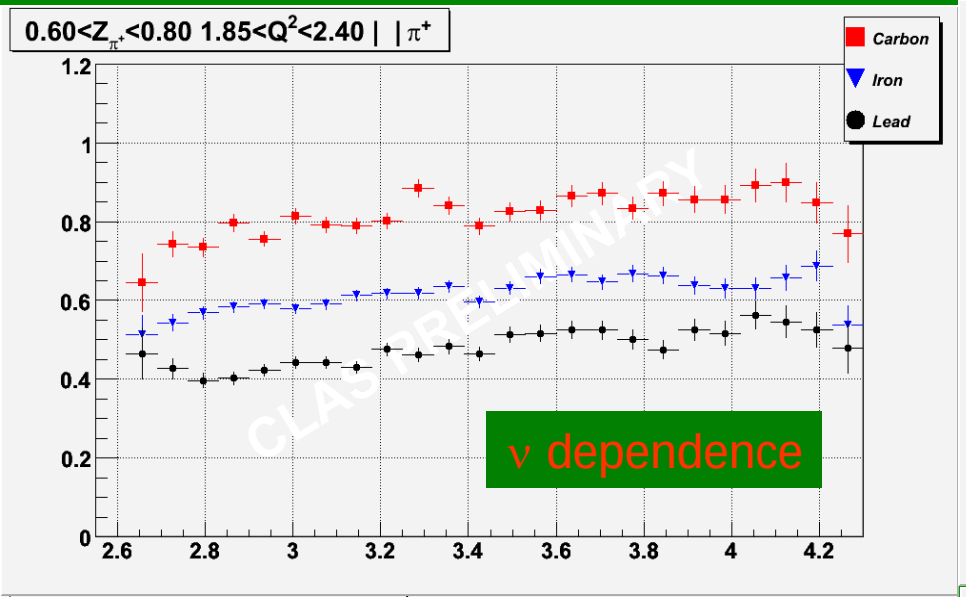
CLAS – the CEBAF Large Acceptance Spectrometer

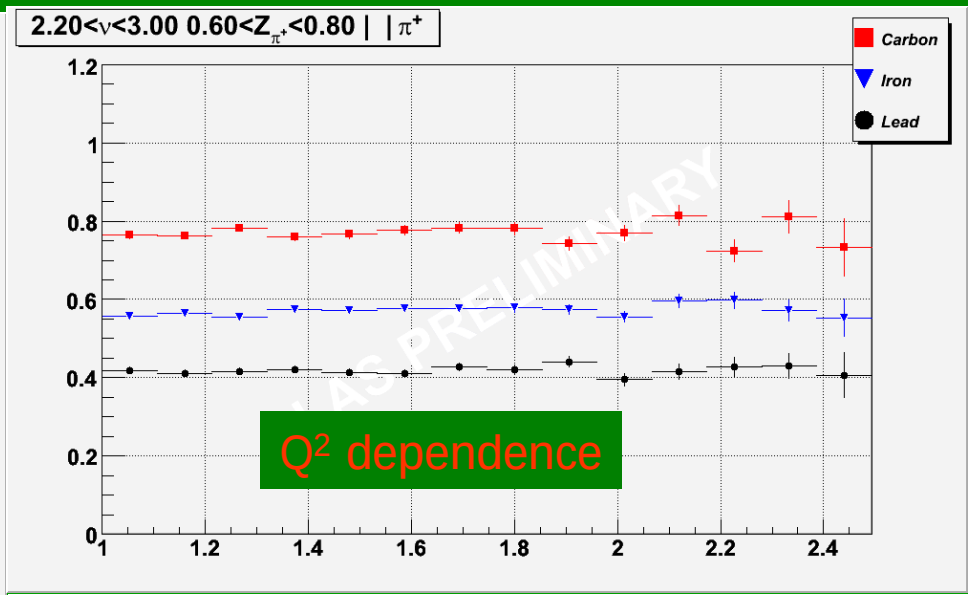


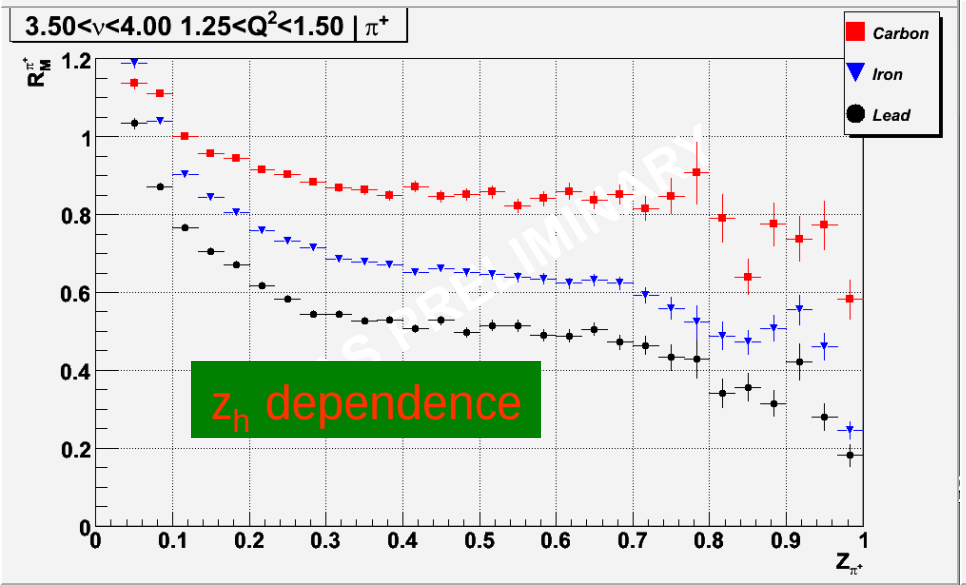
eg2: pion attenuation

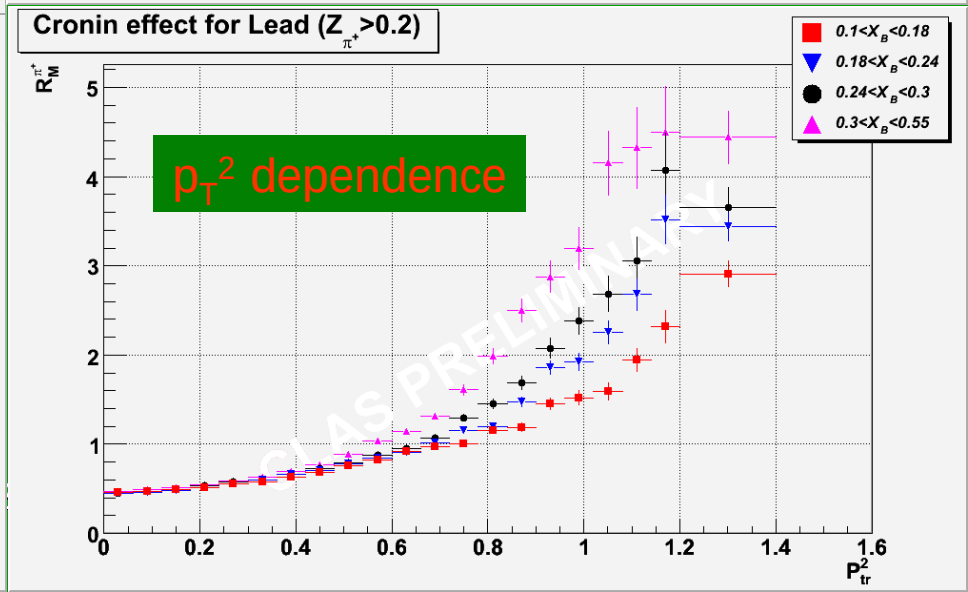


Examples of multi-variable (preliminary) CLAS data



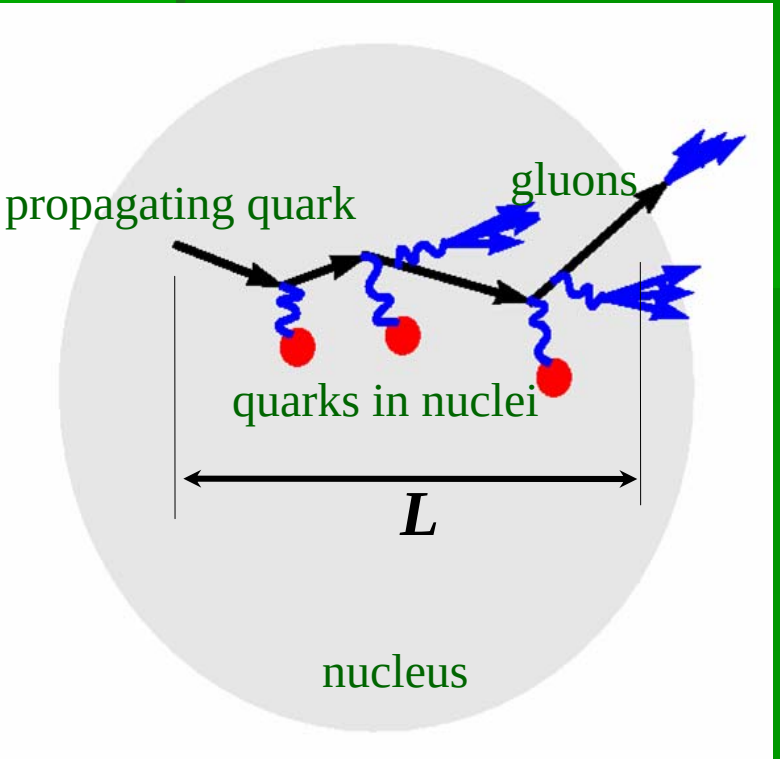






p_T Broadening and Quark Energy Loss

- Quarks lose energy by *gluon emission* as they propagate within a medium



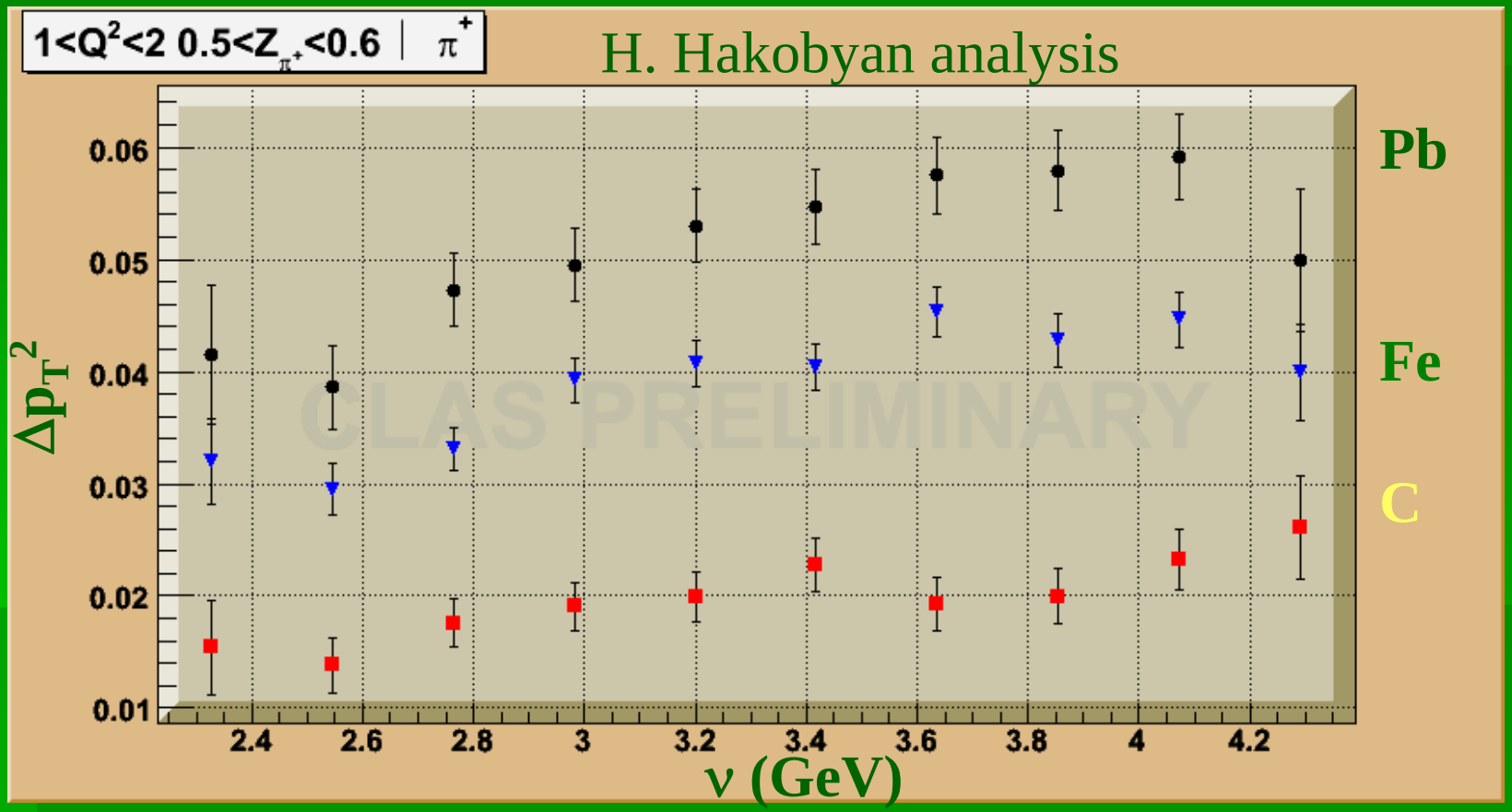
- This energy loss is manifested by Δp_T^2
- Δp_T^2 gives the *production time* τ_p

- $\Delta E \sim L$ dominates in QED
- $\Delta E \sim L^2$ dominates in QCD?

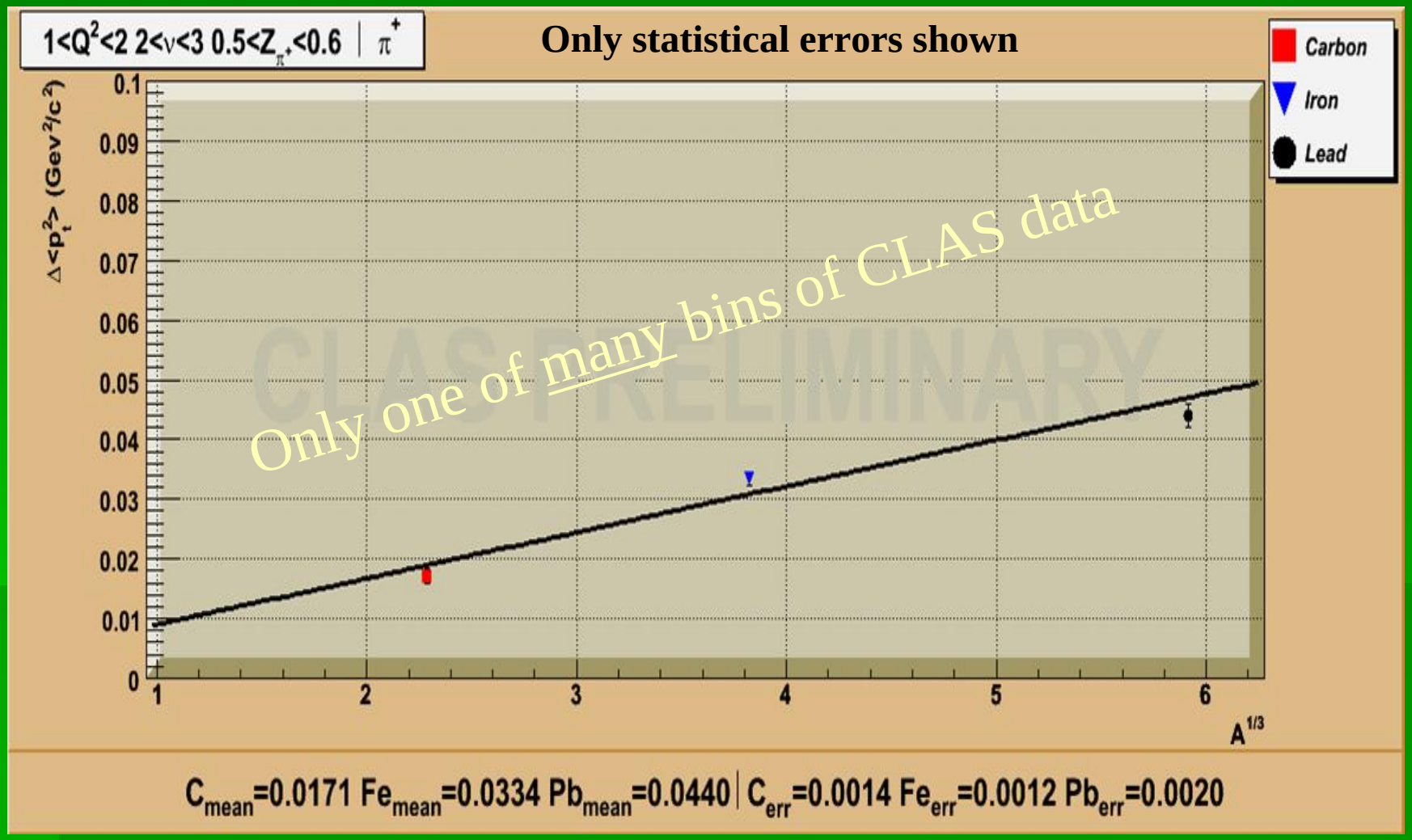
$$dE/dx \approx \frac{\alpha_s}{\pi} N_c \langle p_T^2 \rangle_L$$

Medium-stimulated loss calculation by BDMPS

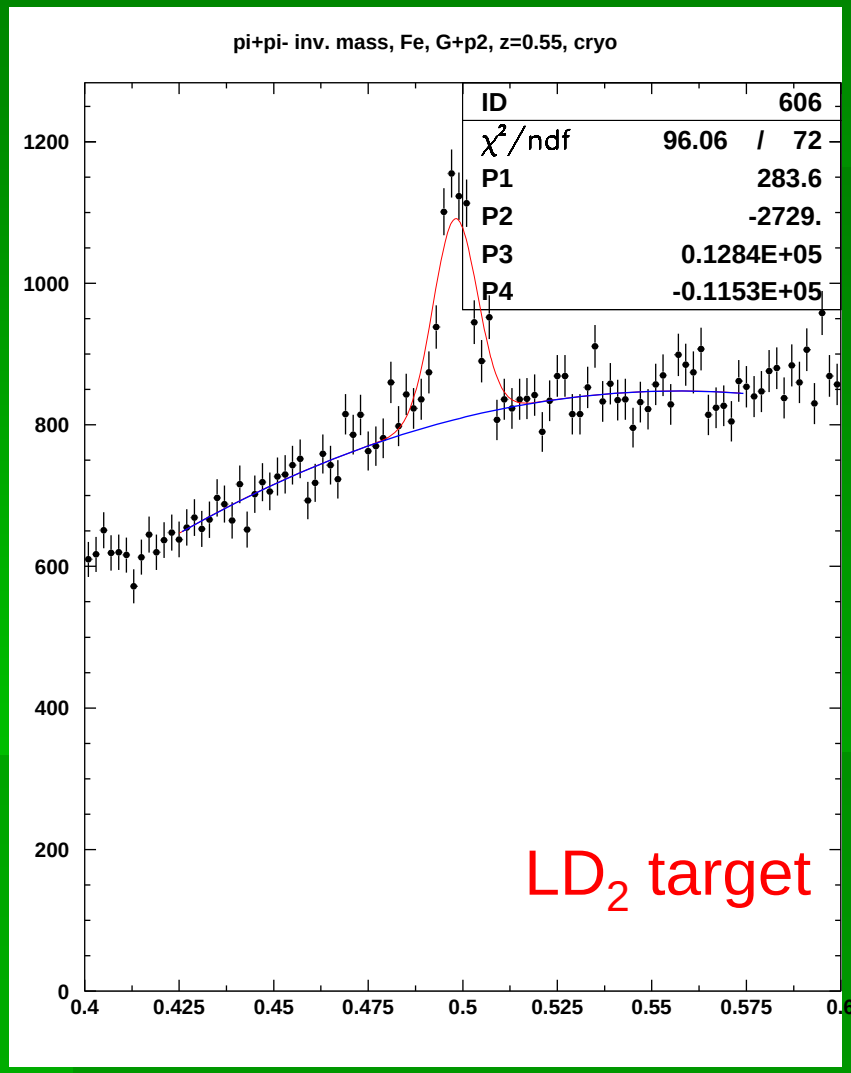
eg2: pion p_T broadening

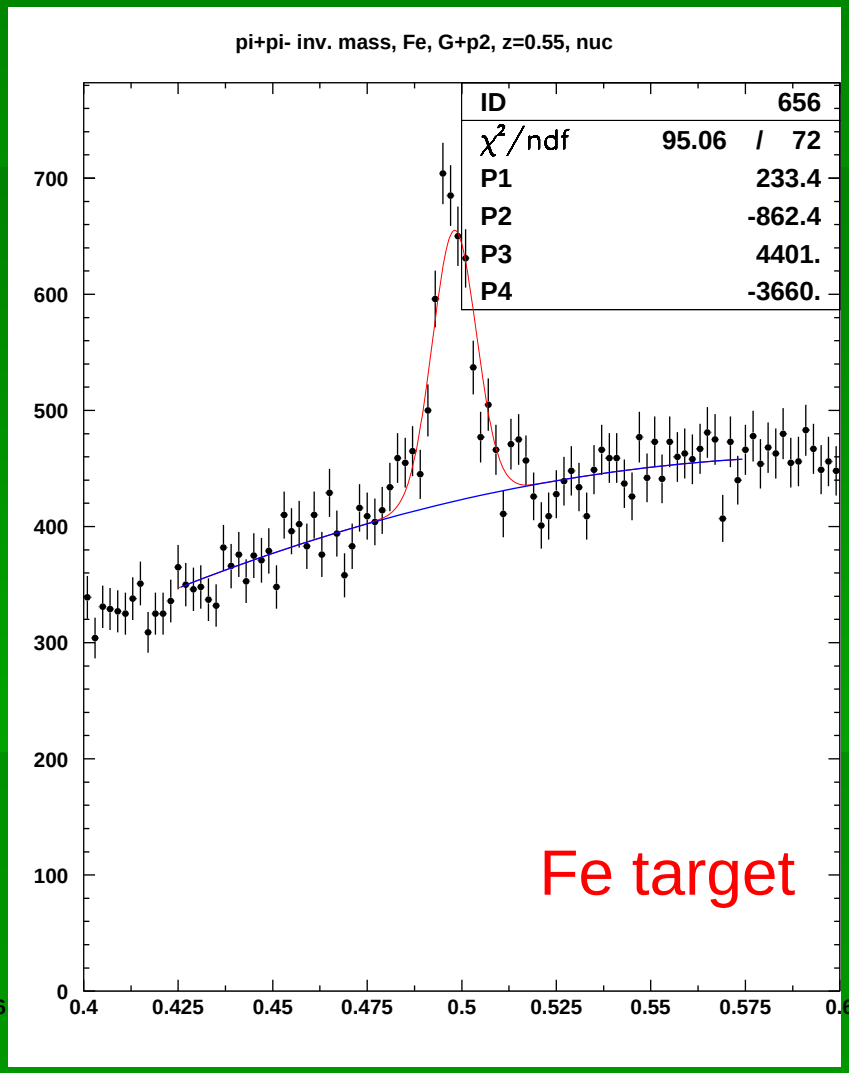


A-dependence of Δp_T^2



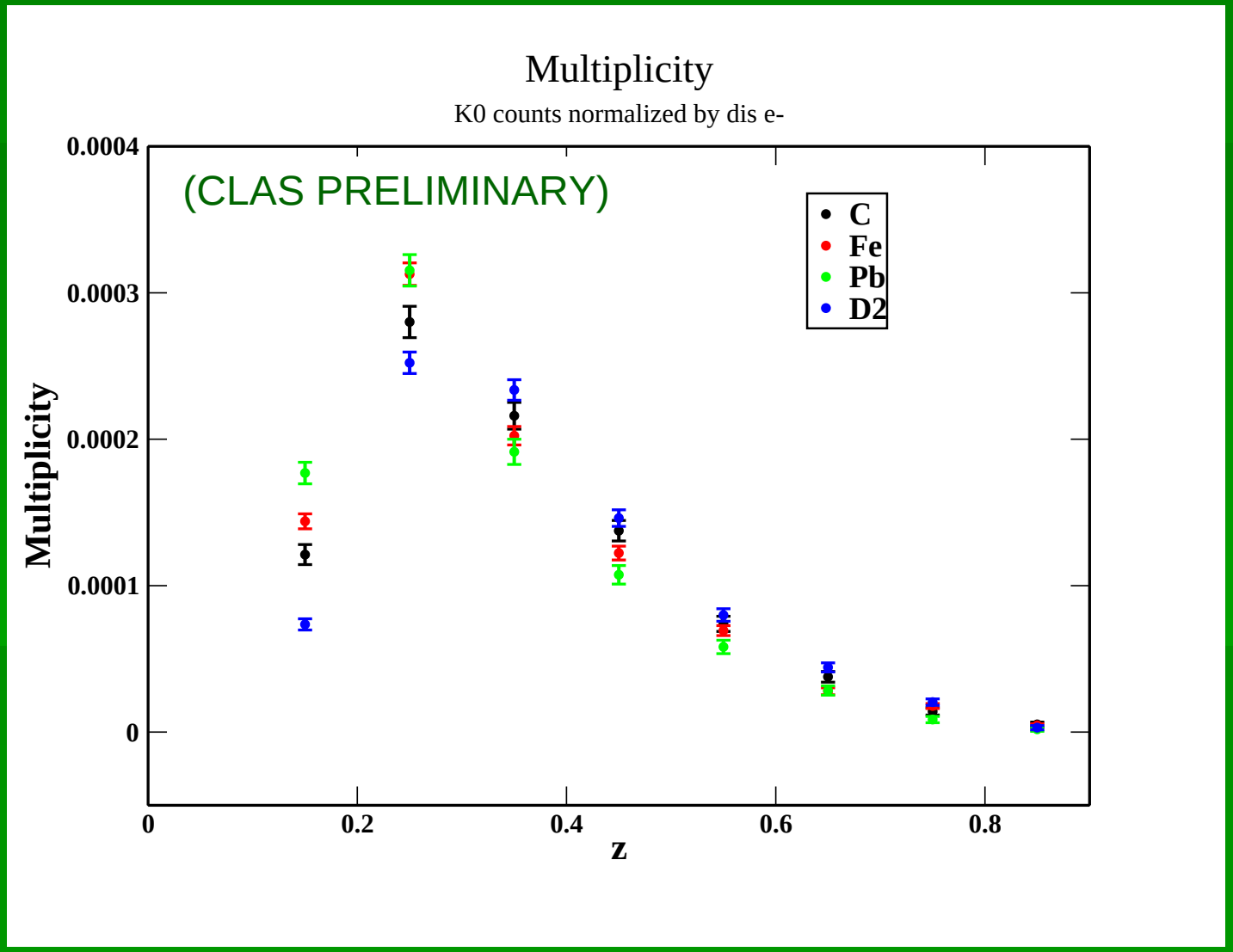
K^0 from $M(\pi^+\pi^-)$ at z=0.55



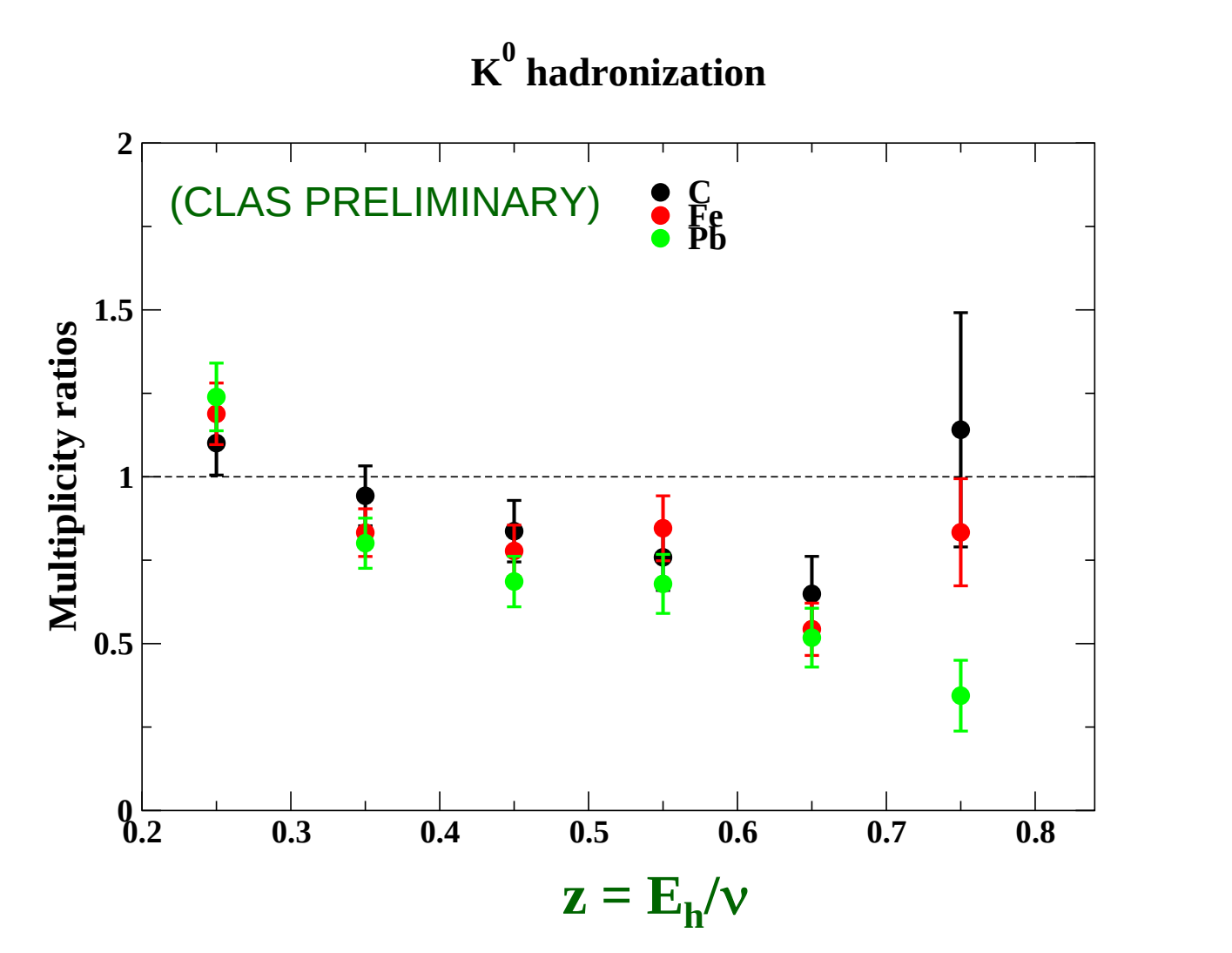


$M(\pi^+\pi^-)$ [GeV]

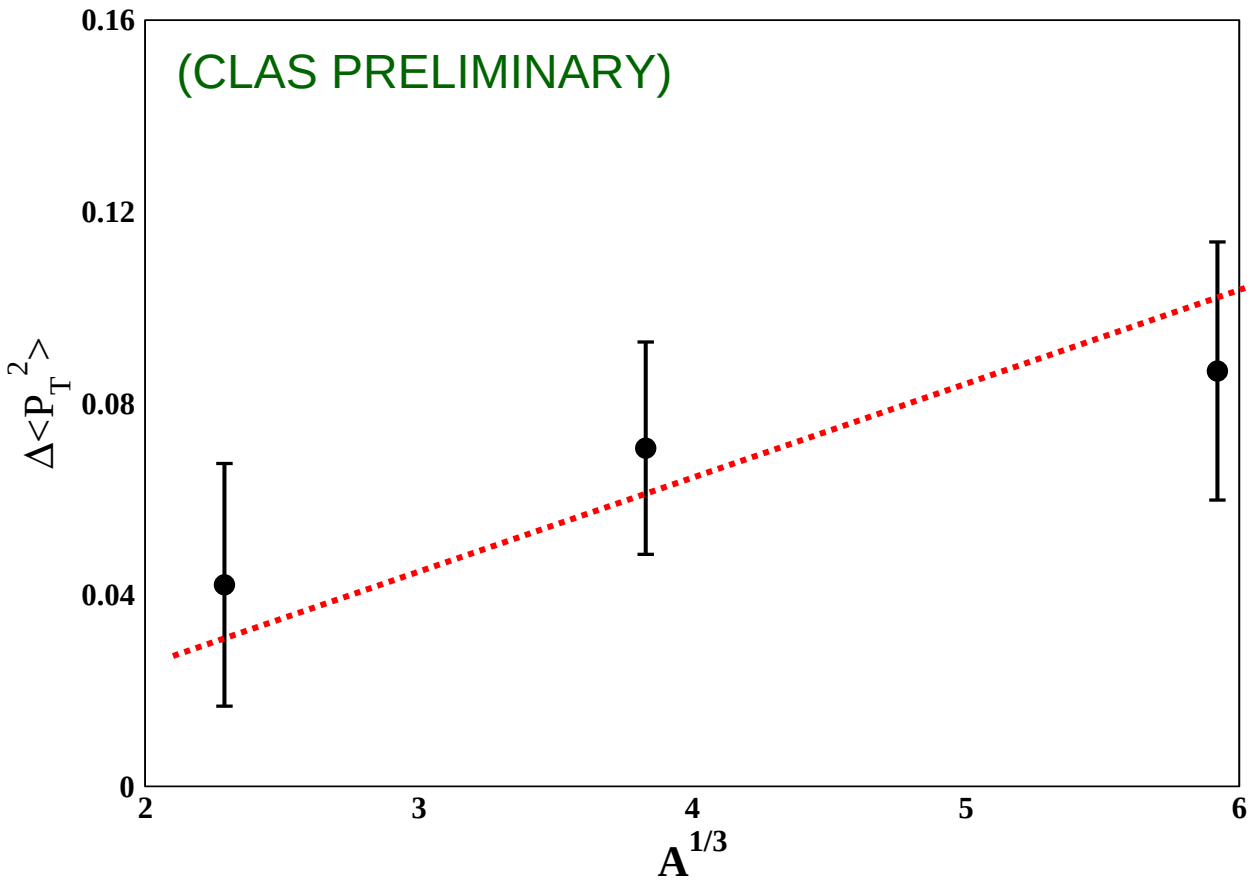
z-dependence of K^0 peak



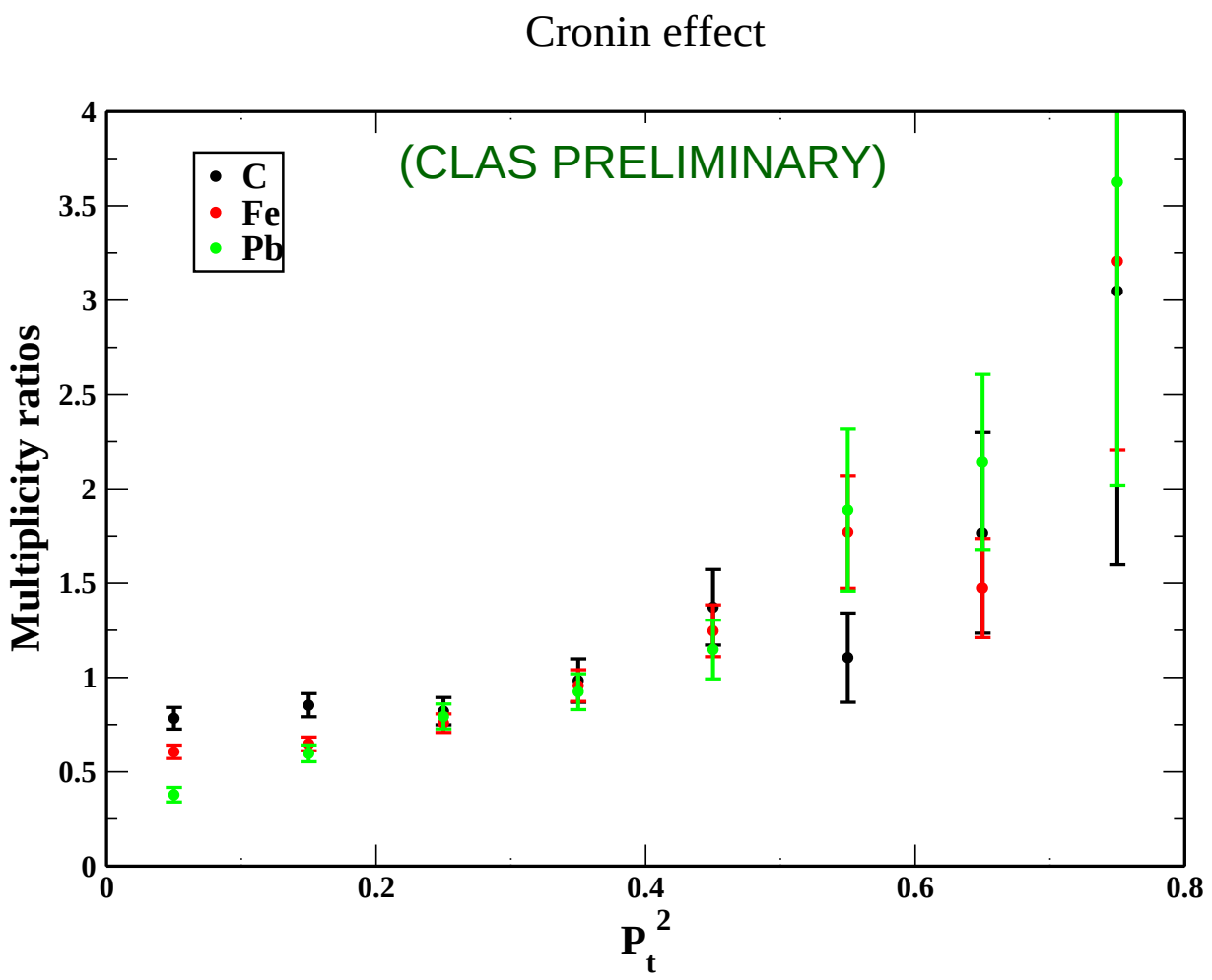
K^0 Multiplicity Ratio



K^0 broadening of $<p_t^2>$



K^0 Cronin Effect



12 GeV Anticipated Data

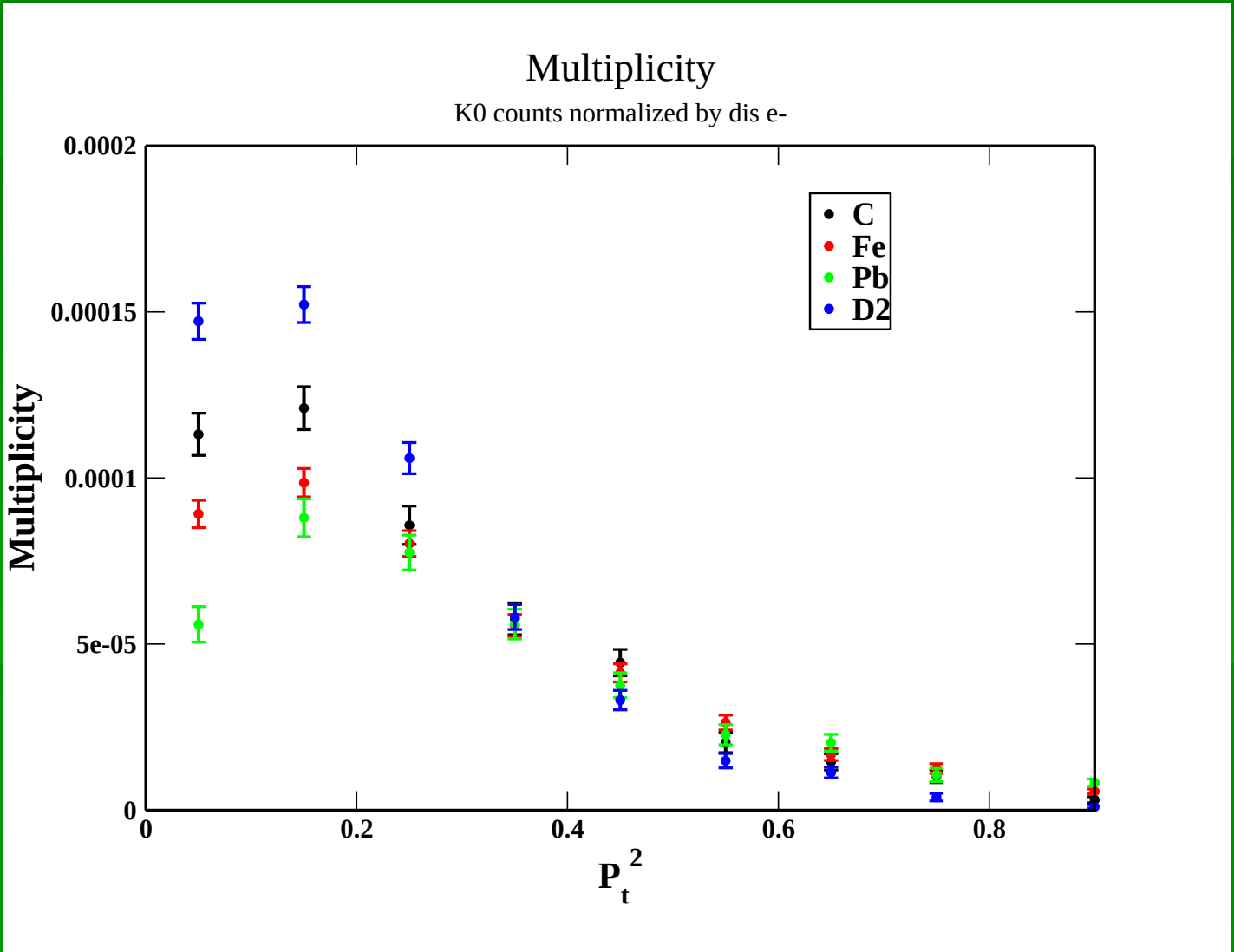
Examples of Experimental Data and Theoretical Predictions

Bins in yellow accessible at 5 GeV at CLAS

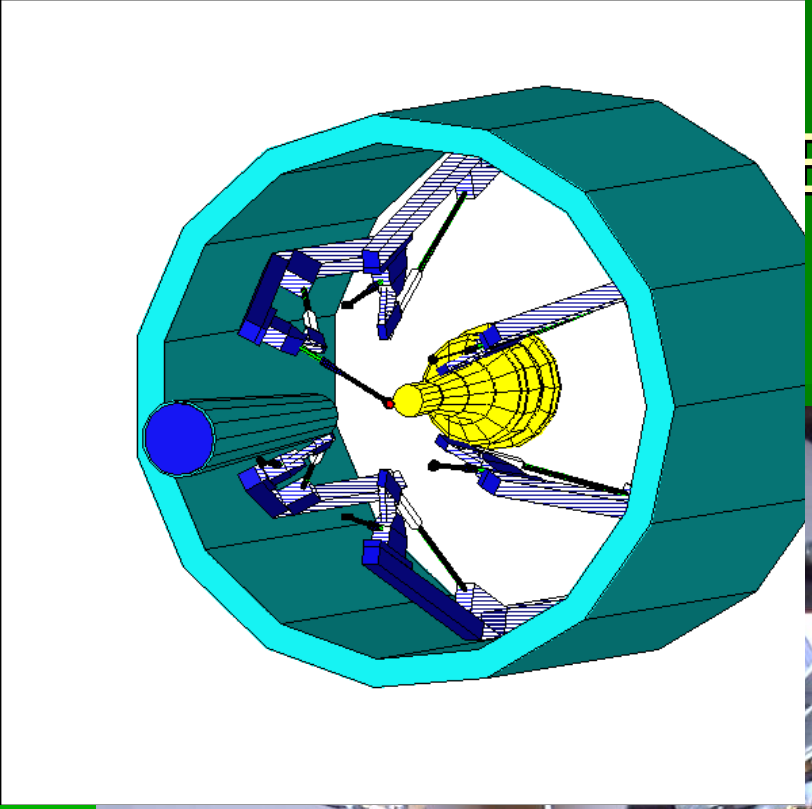
Summary

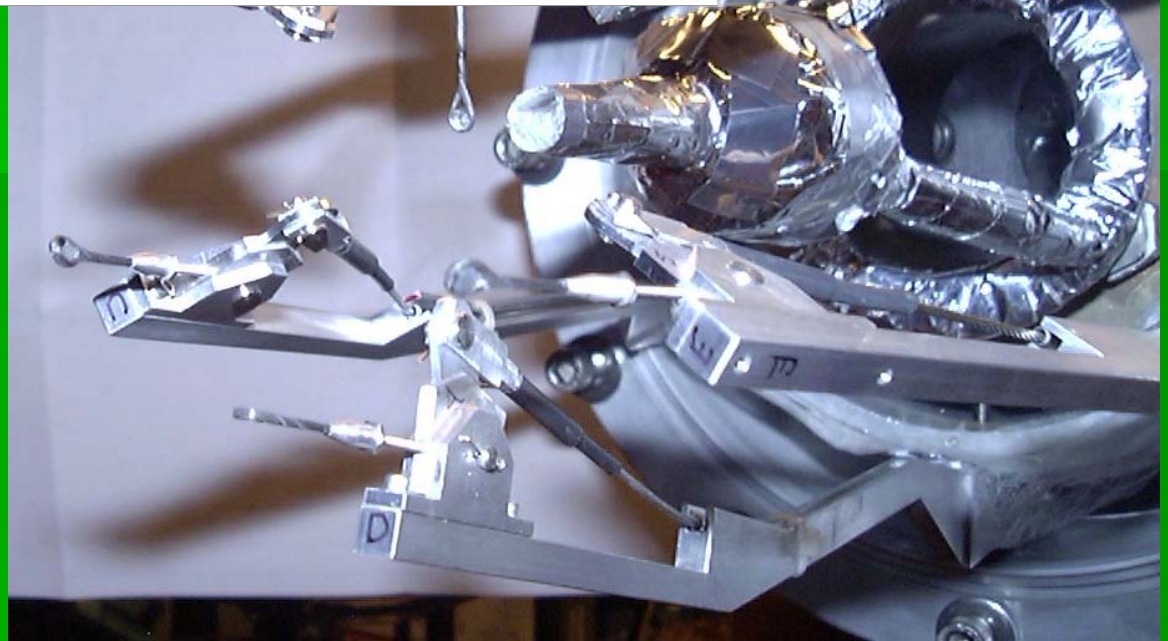
- There is good statistical precision of the pion data at 5 GeV.
  - Hadronization ratios, Δp_T^2, and Cronin effect.
  - Results are still preliminary but nearly final.
- There is modest statistical precision for the K^0 data at 5 GeV.
  - From these data, we hope to learn about the quark mass dependence of hadronization.
- The JLab 12 GeV upgrade creates new possibilities to study quark-matter propagation.

Backup Slides

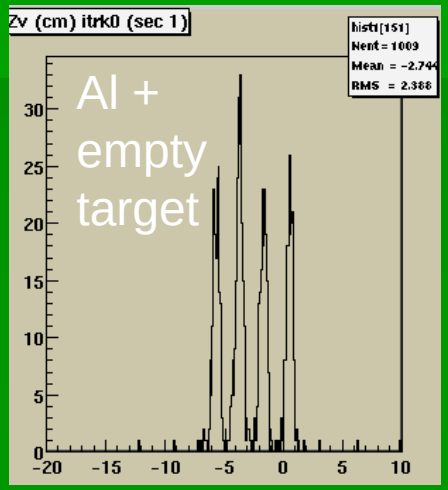


EG2





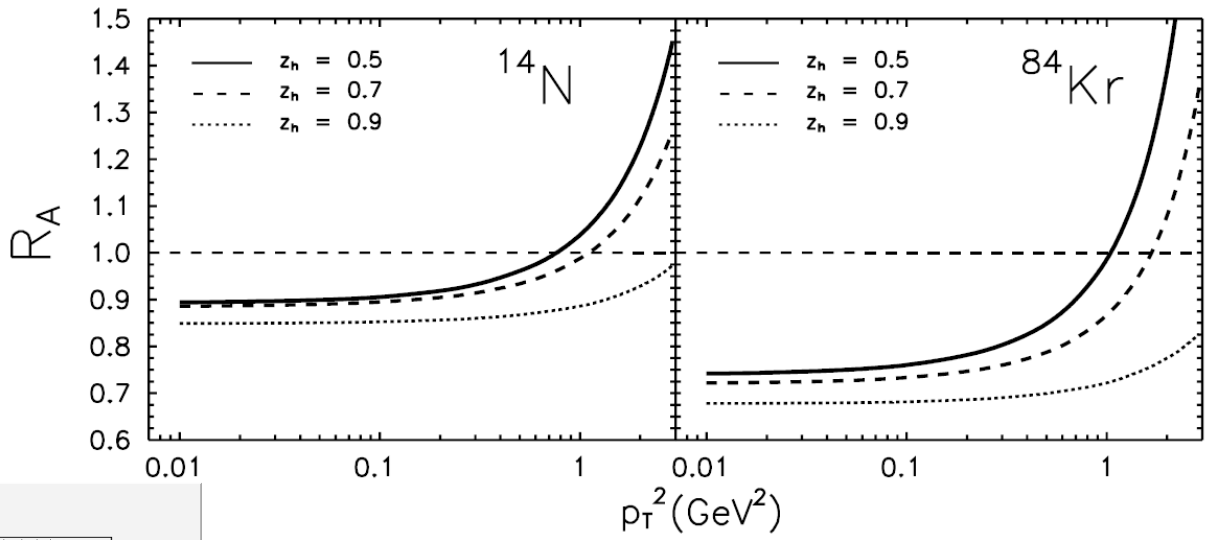
- *Two* targets in the beam simultaneously
- 2 cm LD2, upstream
- Solid target downstream
- Six solid targets:
  - -Carbon
  - -Aluminum (2 thicknesses)
  - -Iron
  - -Tin
  - -Lead



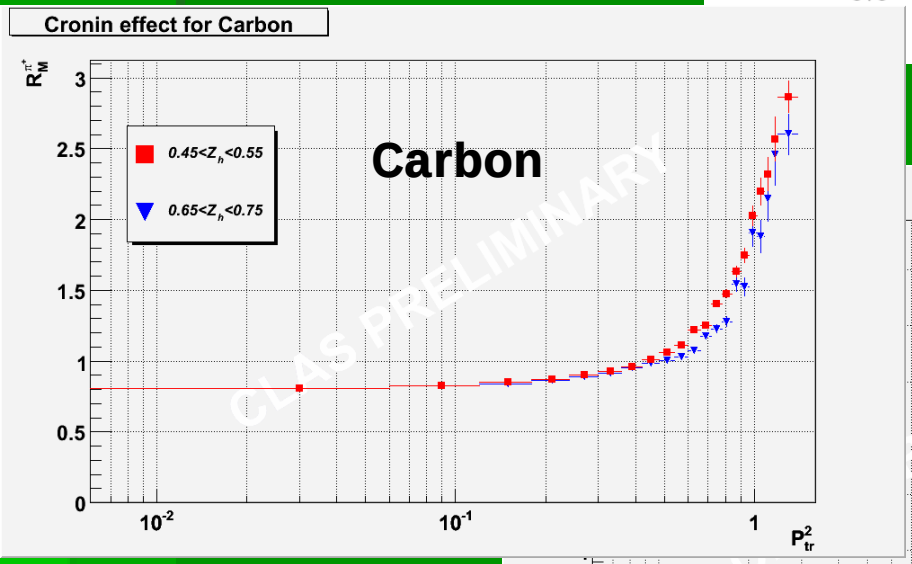
Cronin Effect

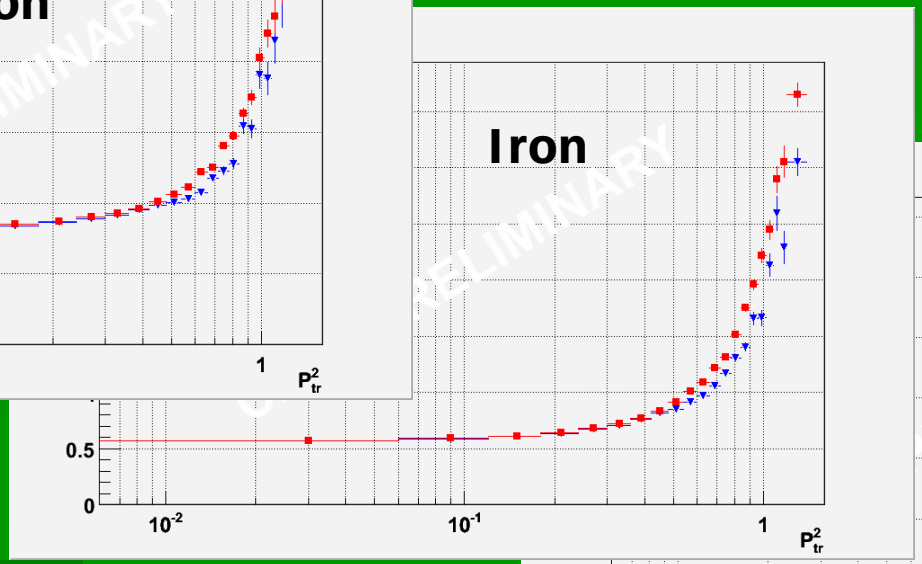
Theoretical *prediction:*

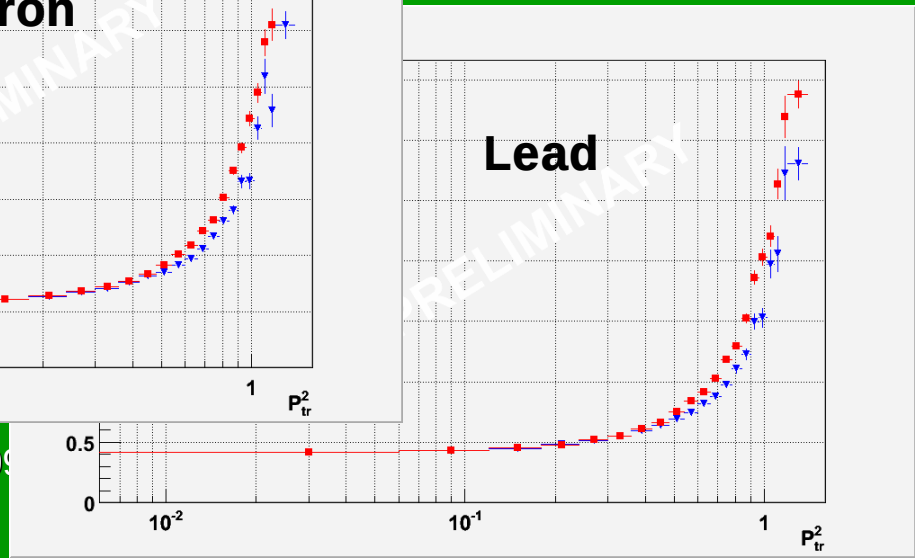
B.Z. Kopeliovich et al. / Nuclear Physics A 740 (2004) 211–245



Probes reaction mechanism







CLAS preliminary data
z=0.5 and 0.7