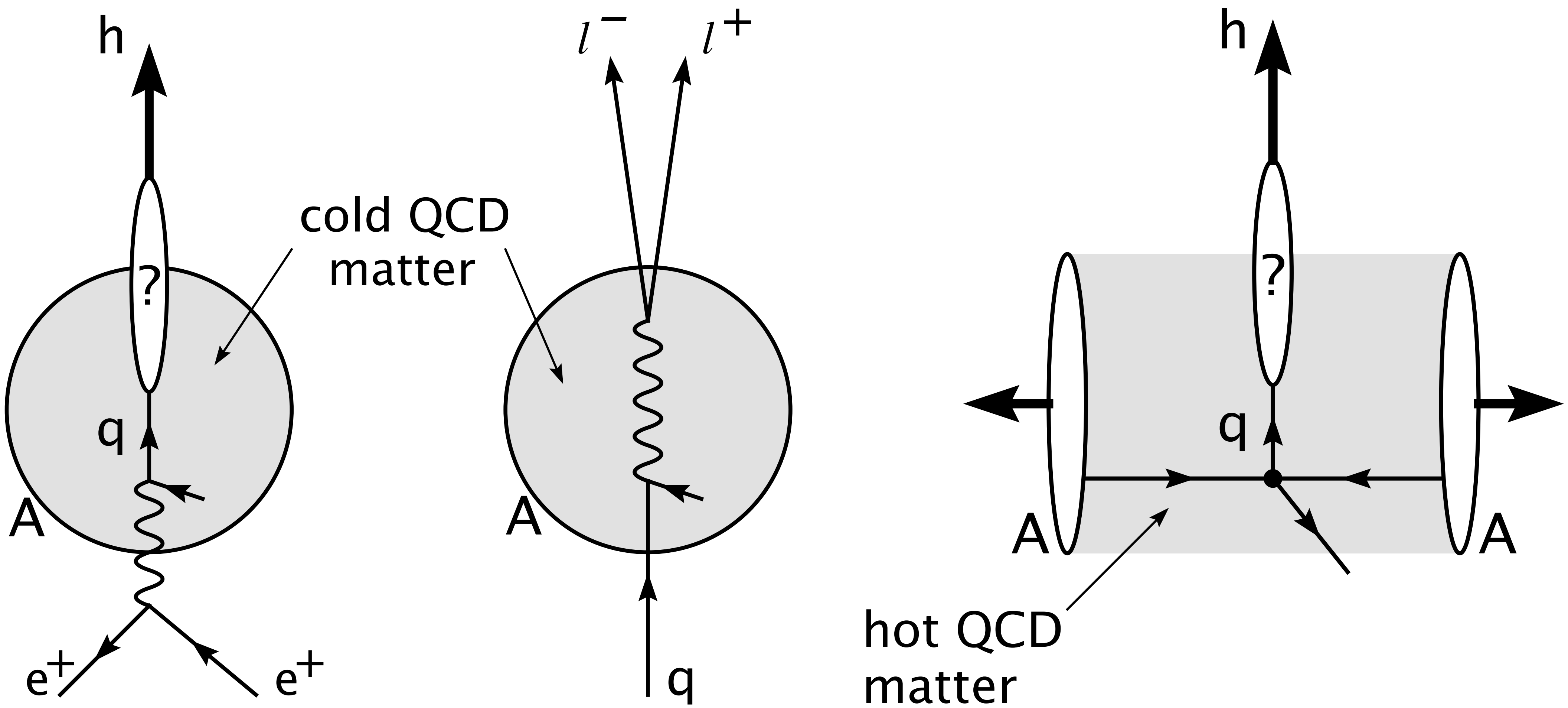
Overview of JLab hadronization data

Means to study parton propagation and fragmentation



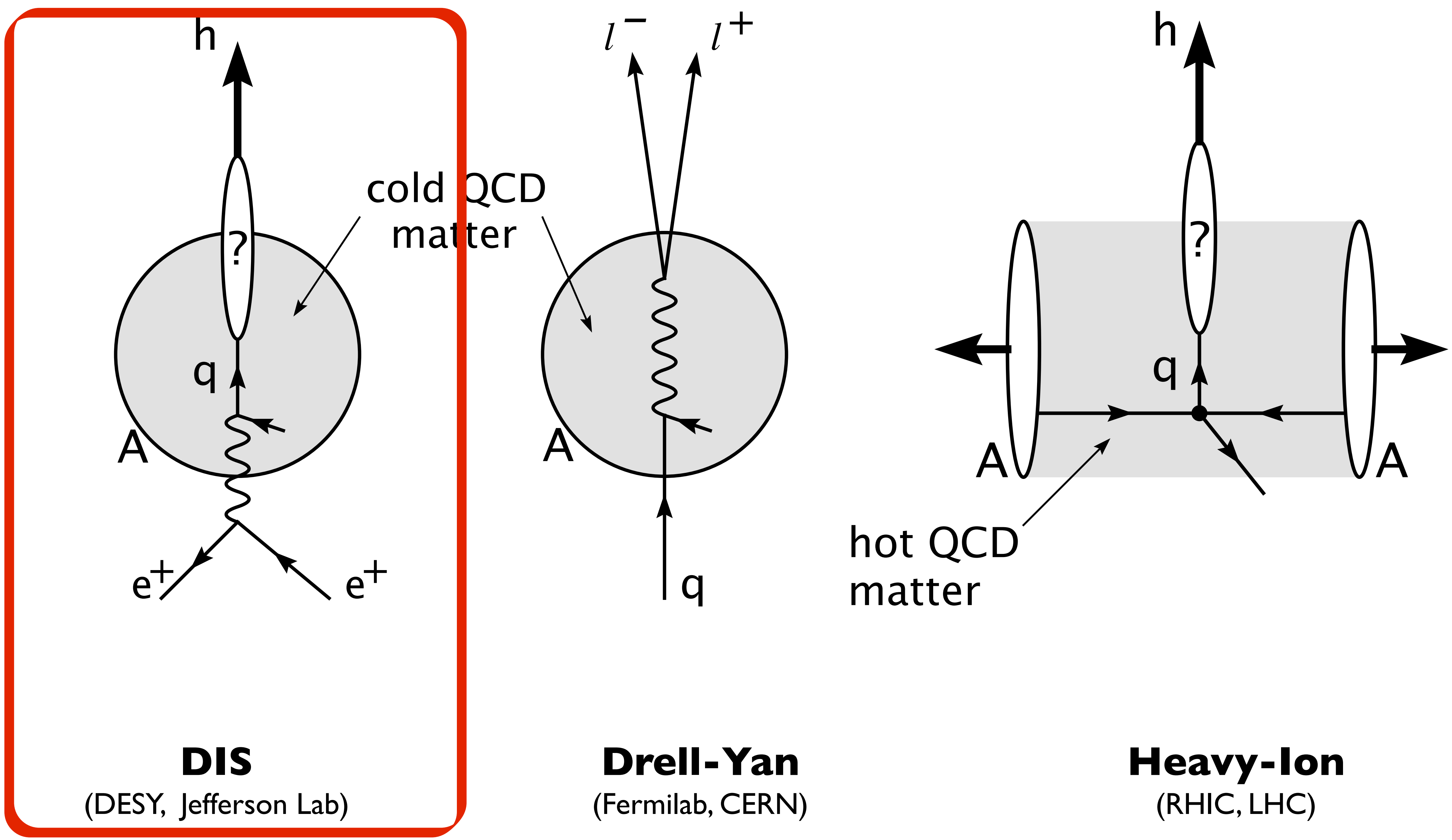
DIS
(DESY, Jefferson Lab)

Drell-Yan
(Fermilab, CERN)

Heavy-Ion
(RHIC, LHC)

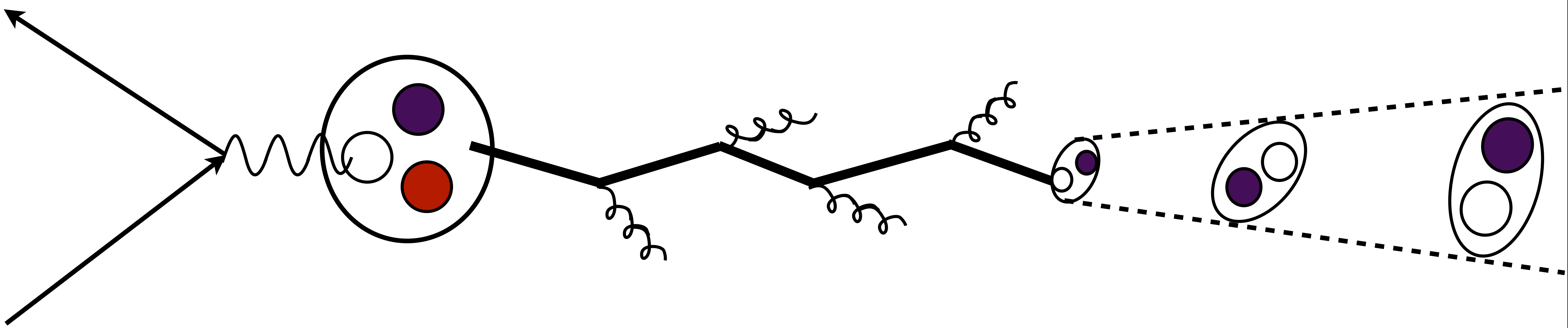
Parton Propagation and Fragmentation in QCD Matter, A.Accardi, F.Arleo, W.K. Brooks , D. D'Enterria, V.Muccifora arXiv:0907.3534v1 **[nucl-th]**

Means to study parton propagation and fragmentation

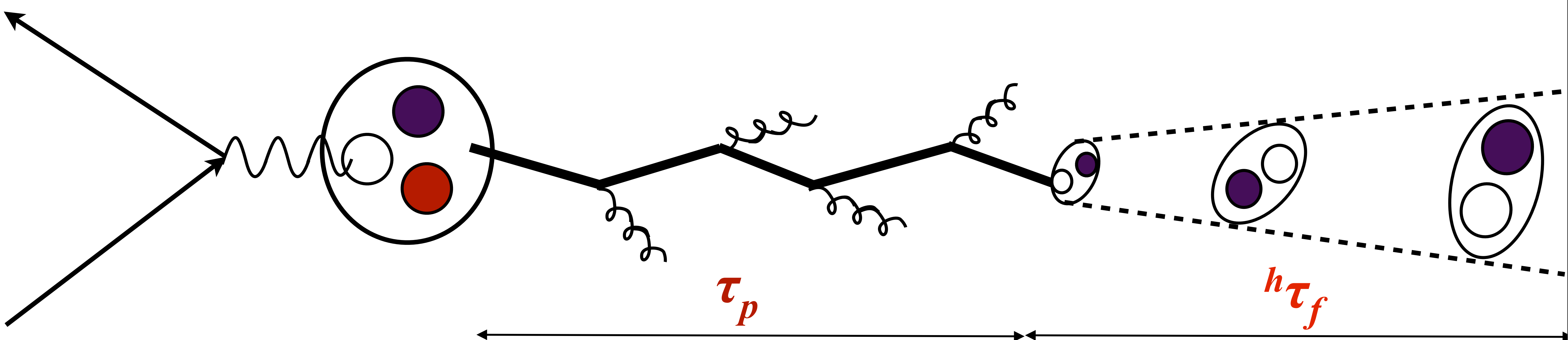


Parton Propagation and Fragmentation in QCD Matter, A.Accardi, F.Arleo, W.K. Brooks , D. D'Enterria, V.Muccifora arXiv:0907.3534v1 [nucl-th]

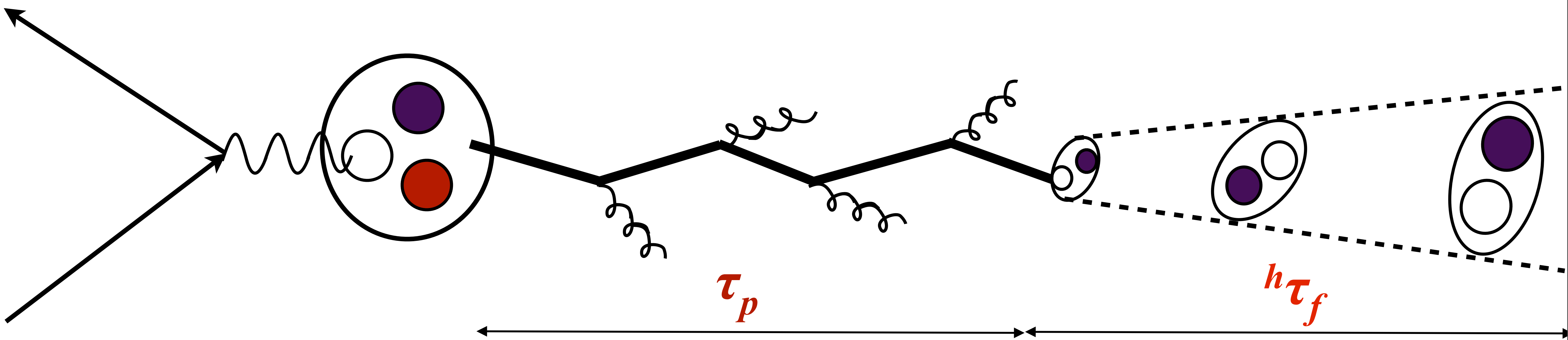
Physical picture of hadronization in DIS



Physical picture of hadronization in DIS



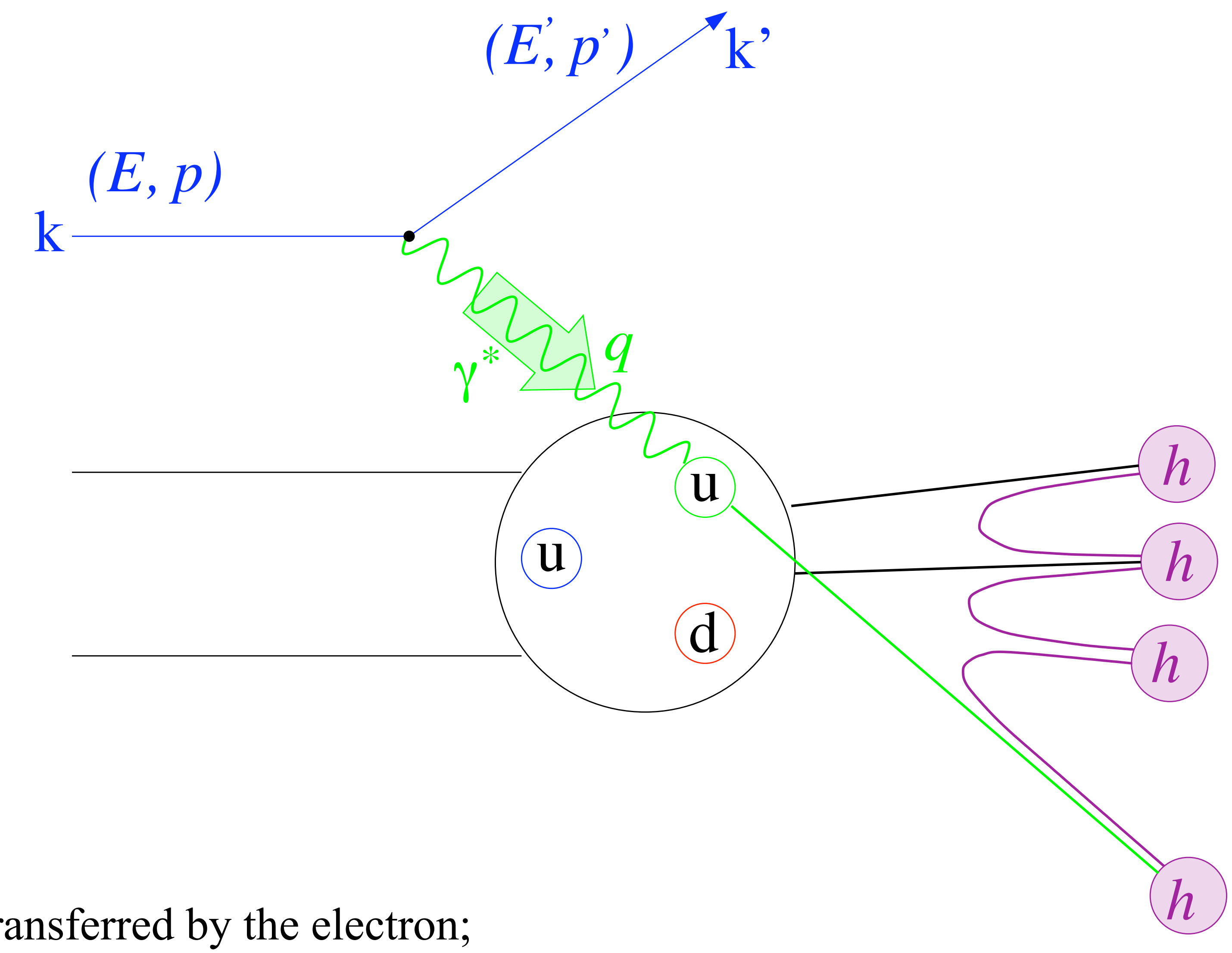
Physical picture of hadronization in DIS



Production time τ_p **- effective lifetime of the quasi-free quark .**

Formation time $^h\tau_f$ **- time required to form full sized hadron.**

SIDIS



$\mathbf{Q^2} = -q^2$ four-momentum transferred by the electron;

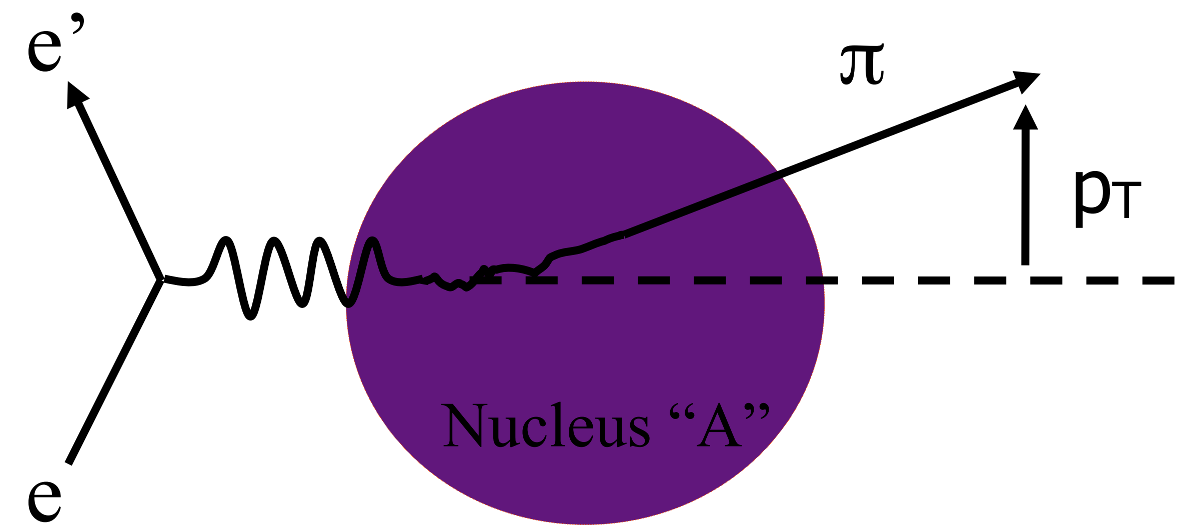
$\nu = E - E'$ energy transferred by the electron, = Initial energy of struck quark;

$\mathbf{z} = E_h/\nu$ fraction of the struck quark's initial energy that is carried by hadron;

$\mathbf{p_T}$ hadron momentum transverse to virtual photon direction;

Observable (I)

Transverse momentum broadening

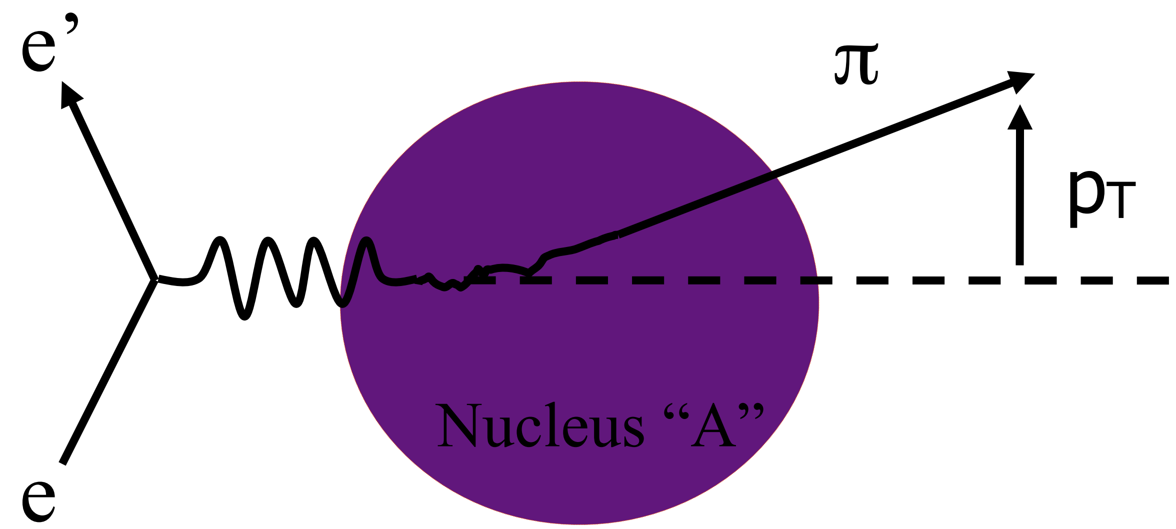


$$\Delta p_T^2 = < p_T^2 >_{\mathrm{A}} - < p_T^2 >_{\mathrm{D}}$$

$$\Delta p_T^2 = z_h^2 \Delta k_T^2$$

Observable (I)

Transverse momentum broadening



$$\Delta p_T^2 = < p_T^2 >_{\mathrm{A}} - < p_T^2 >_{\mathrm{D}}$$

$$\Delta p_T^2 = z_h^2 \Delta k_T^2$$

How long a quark can remain deconfined?

τ_p *from the shape and magnitude of* ***ΔpT^2 vs A***

Observable (2)

Hadronic multiplicity ratio

$$R_{\mathrm{A}}^{h}\left(\nu, Q^2, z, p_T, \phi\right) = \frac{\left.\frac{N_h(\nu,Q^2,z,p_T,\phi)}{N_e(\nu,Q^2)|_{\mathrm{DIS}}}\right|_{\mathrm{A}}}{\left.\frac{N_h(\nu,Q^2,z,p_T,\phi)}{N_e(\nu,Q^2)|_{\mathrm{DIS}}}\right|_{\mathrm{D}}}$$

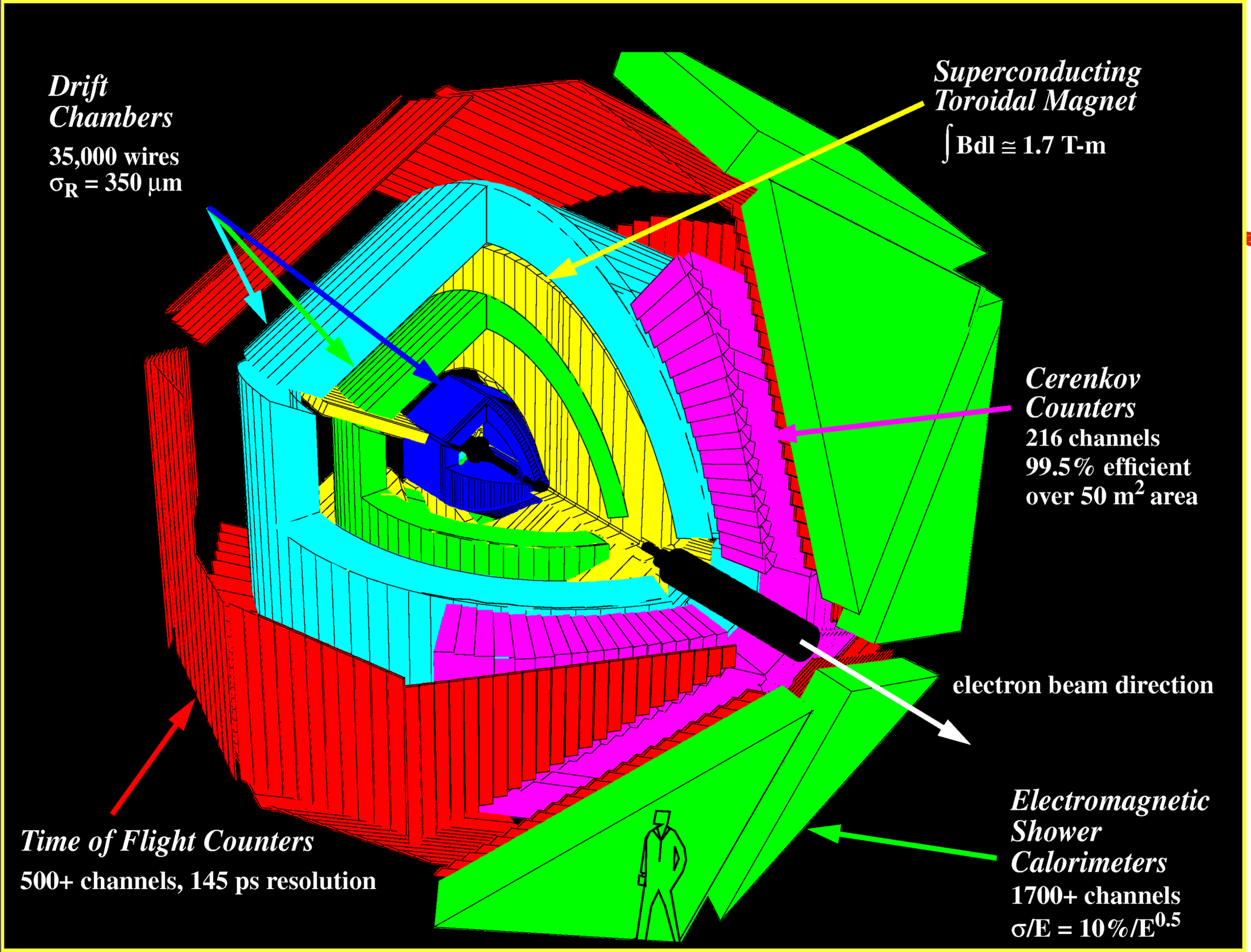
Observable (2)

Hadronic multiplicity ratio

$$R_{\mathrm{A}}^{h}\left(\nu, Q^2, z, p_T, \phi\right) = \frac{\left.\frac{N_h(\nu,Q^2,z,p_T,\phi)}{N_e(\nu,Q^2)|_{\mathrm{DIS}}}\right|_{\mathrm{A}}}{\left.\frac{N_h(\nu,Q^2,z,p_T,\phi)}{N_e(\nu,Q^2)|_{\mathrm{DIS}}}\right|_{\mathrm{D}}}$$

How long it takes to form full hadronic wave function?

$^{h}\tau_{f}$ via $\boldsymbol{R_h(Q^2, \upsilon, p_T, z_h)}$

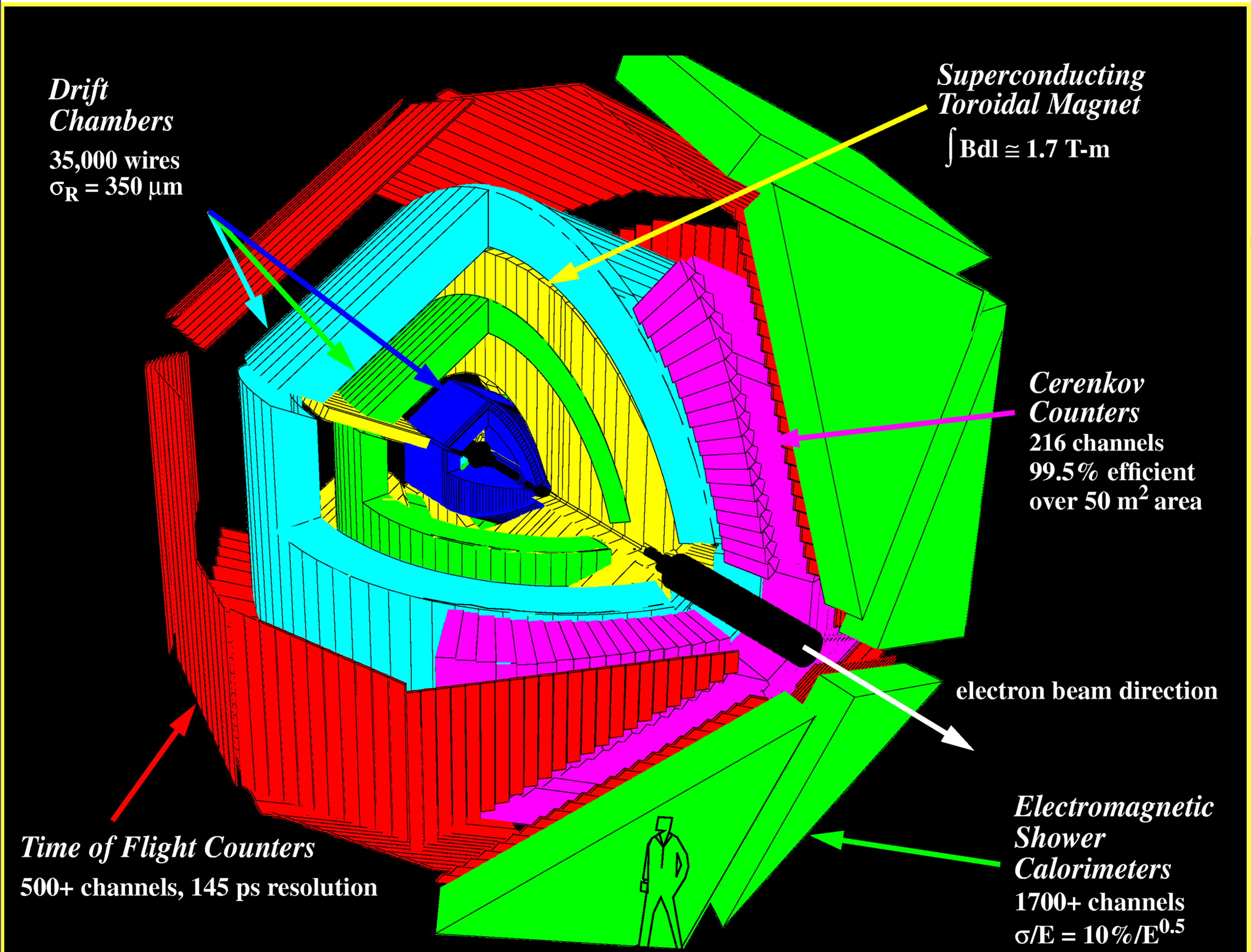


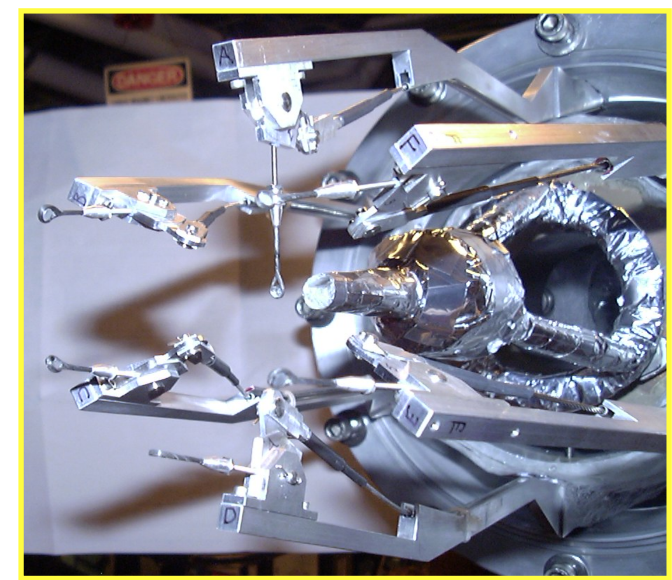
Experiment

CLAS EG2

Experiment

CLAS EG2





Two targets in the beam simultaneously:

5 GeV electron beam

D

C/Fe/Pb

Comparison of CLAS/JLab and HERMES/DESY

Comparison of CLAS/JLab and HERMES/DESY

- Beam energy 5.0 (JLab) vs 27.6 GeV (DESY)

$\nu > 2$ GeV vs $\nu > 7$ GeV
particle identification $0.3<P<5$ vs $2.5<P<15$ GeV
HERMES can detect more particles species

-Solid target in CLAS vs gas targets in HERMES

Heaviest target ^{207}Pb vs ^{131}Xe

-Luminosity in CLAS is 100 times greater than HERMES

Access to 3(4) differential binning vs 1(2) .
CLAS has good statistics at high Q^2 and $p_T{}^2$, access to more particle species

Results from HERMES and JLAB agree and compliment each other.

CLAS EG2 statistics

$$\sum_{events} \approx 5B \Rightarrow \sum_{e-} \approx 130M$$

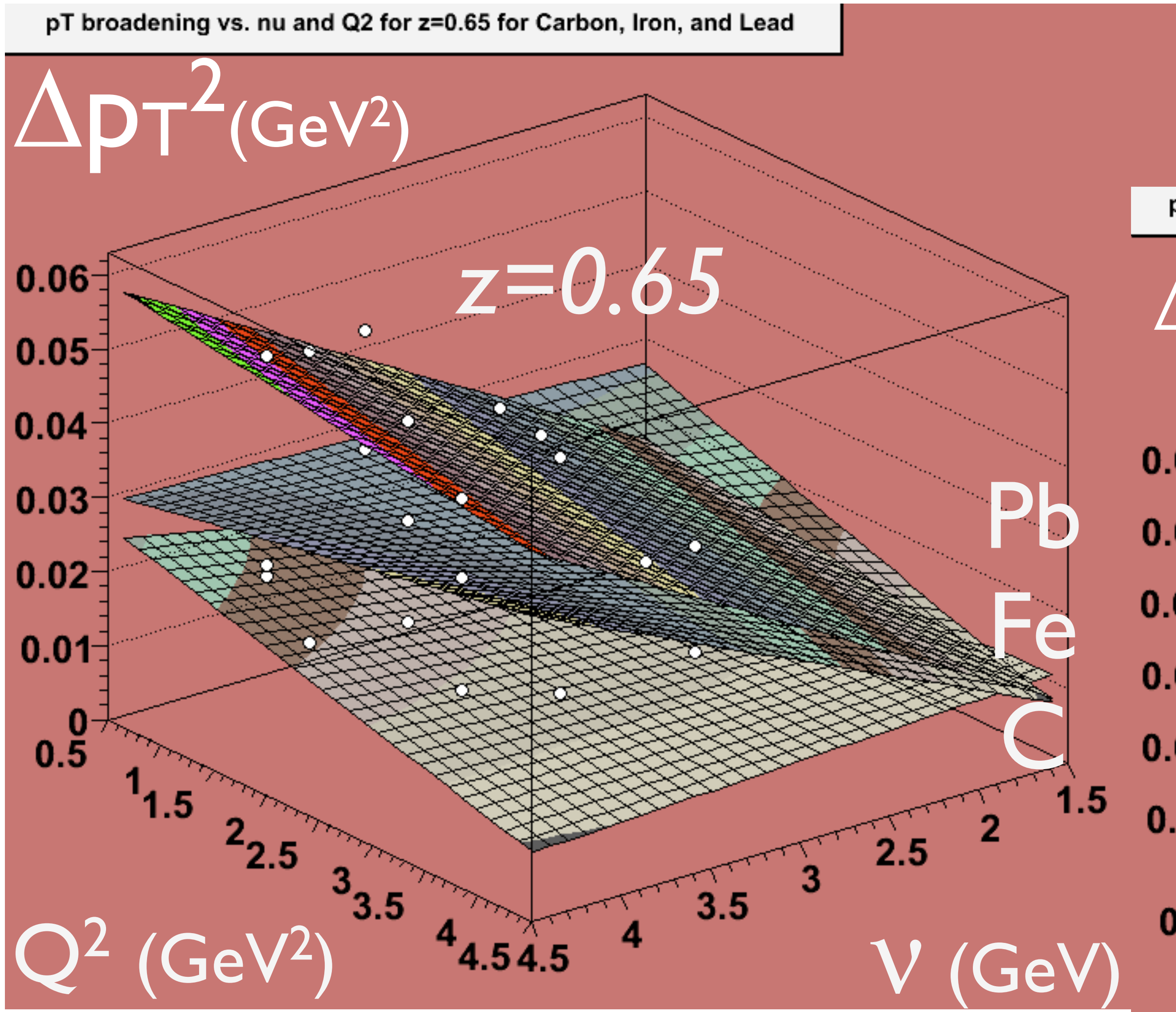
π^+	6.60M
π^-	2.85M
π^0	2.05M
K_s^0	32K
η	300K

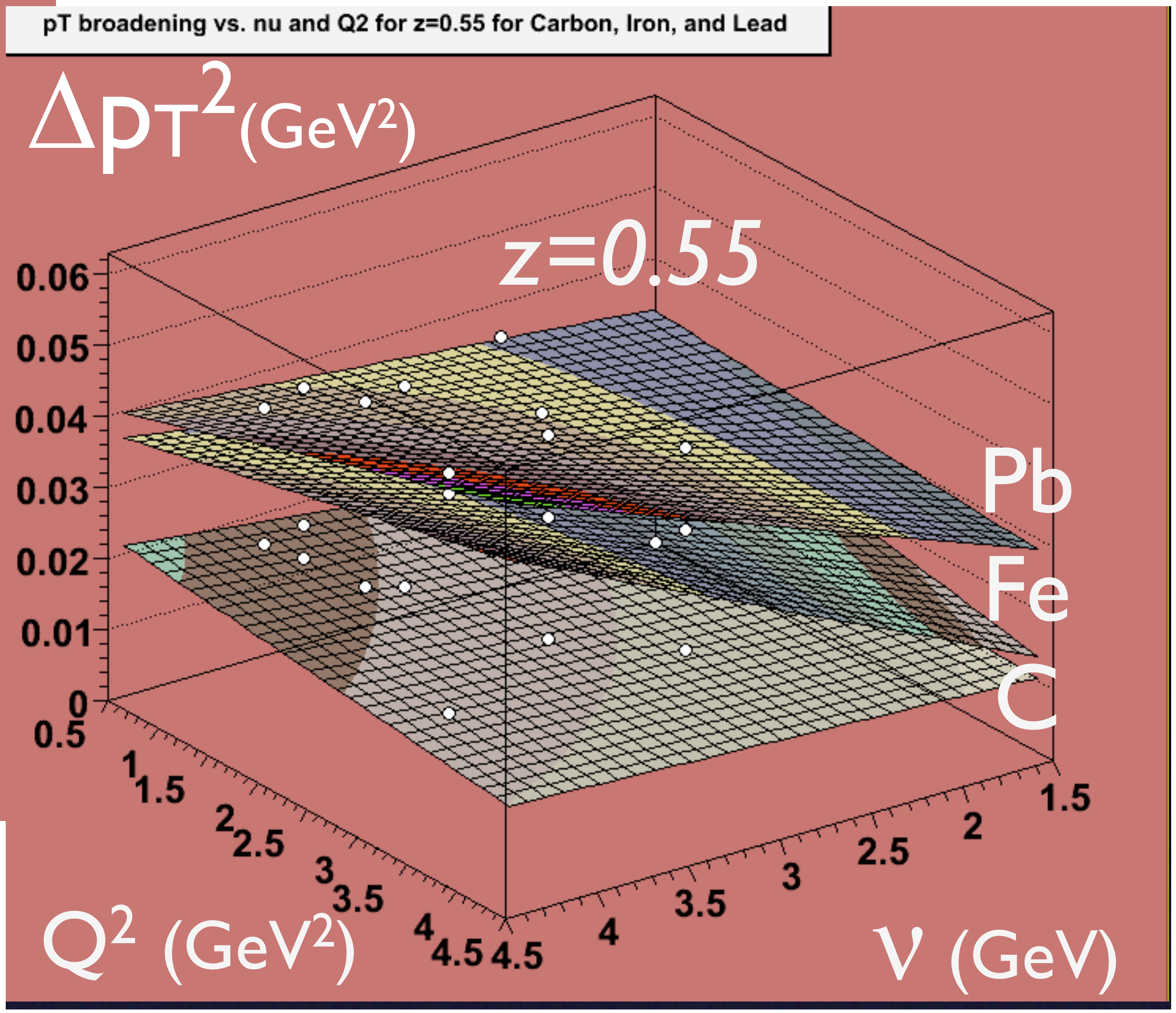
Sufficient statistics to analyze more channels..

Transverse momentum broadening

Transverse momentum broadening(1)

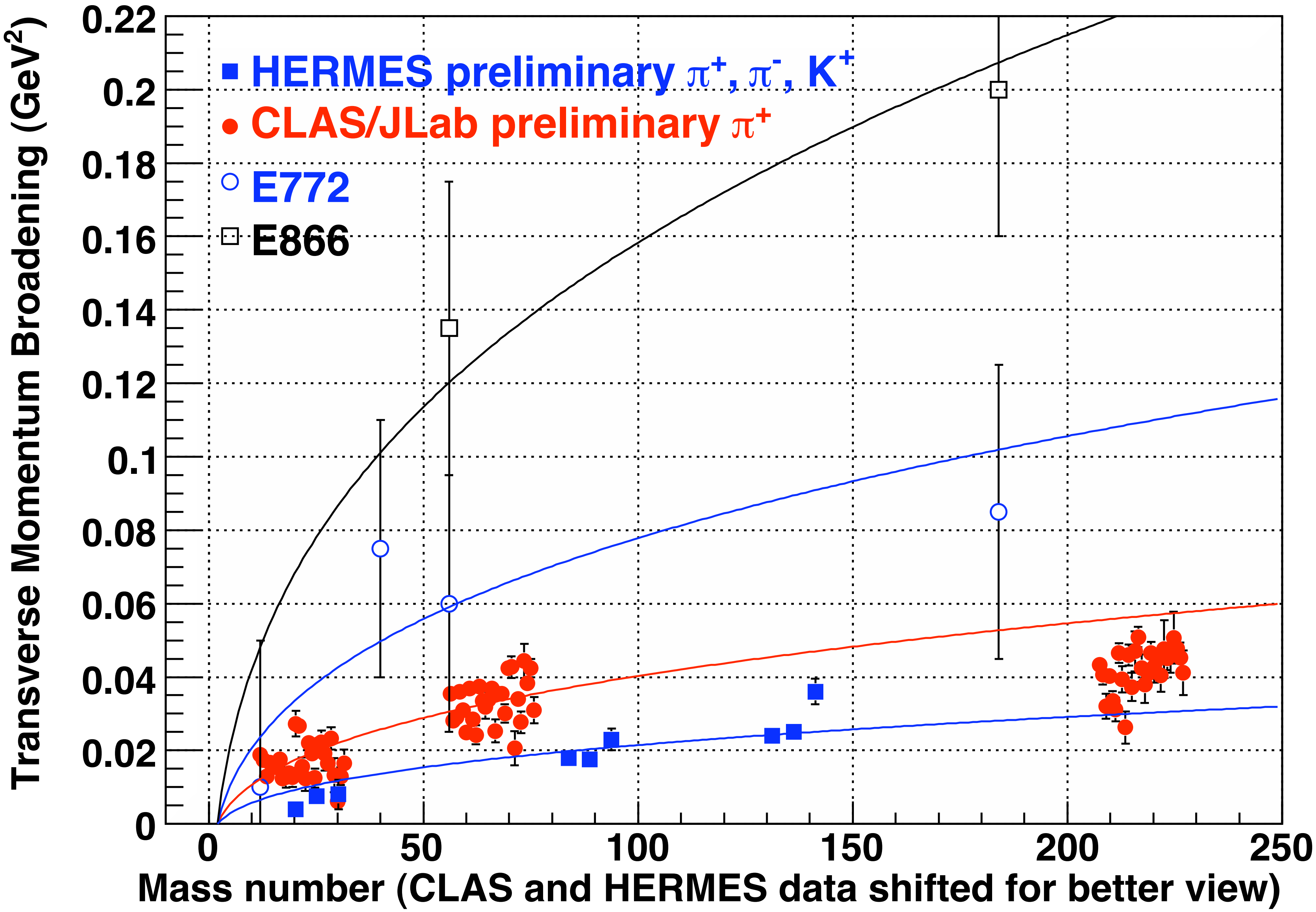
π^+





27 bins in ν, Q^2, z for each of 3 targets

Transverse momentum broadening(2)



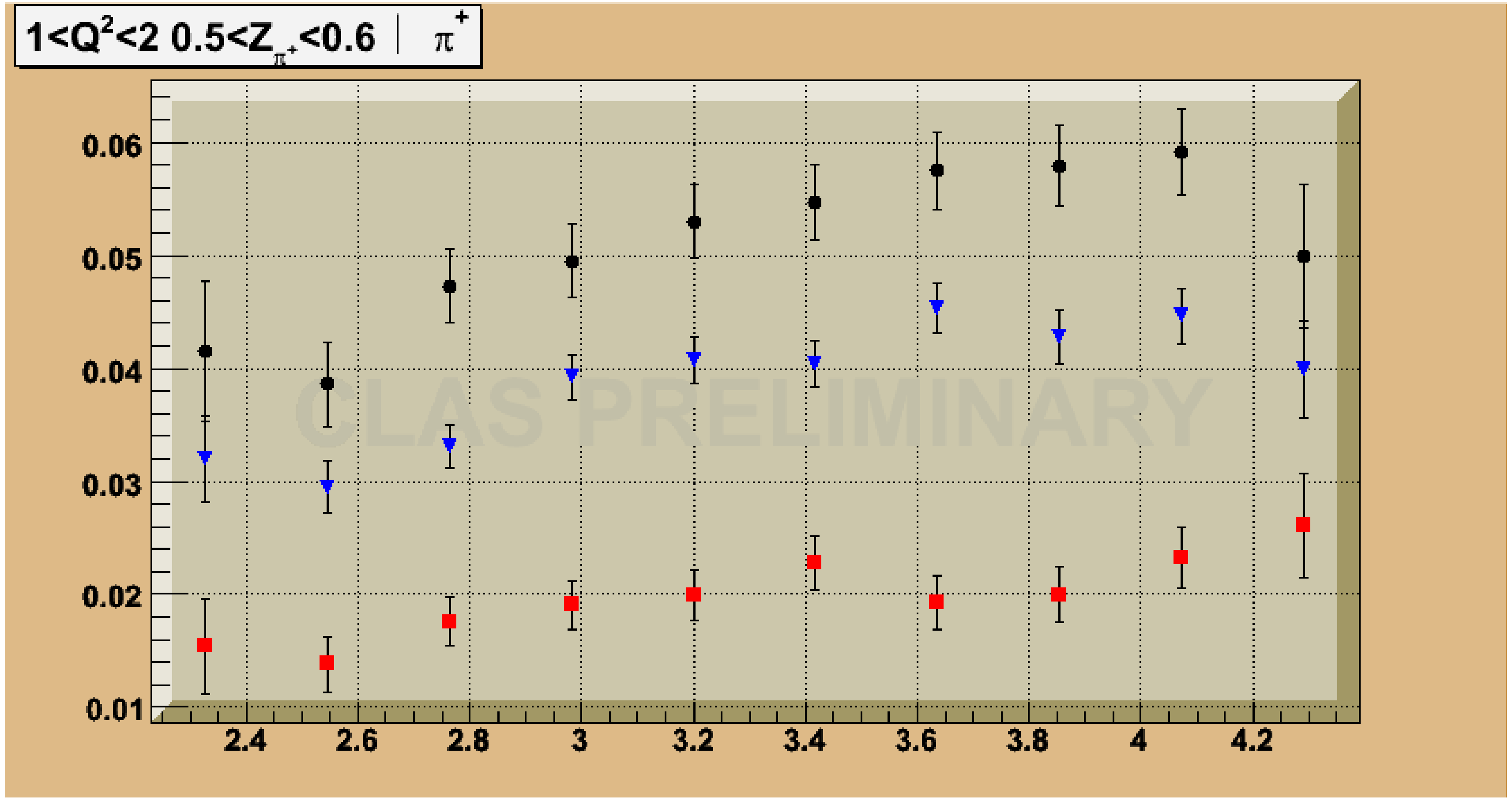
π^+

W.Brooks, H.Hakobyan arxiv.0907.4606

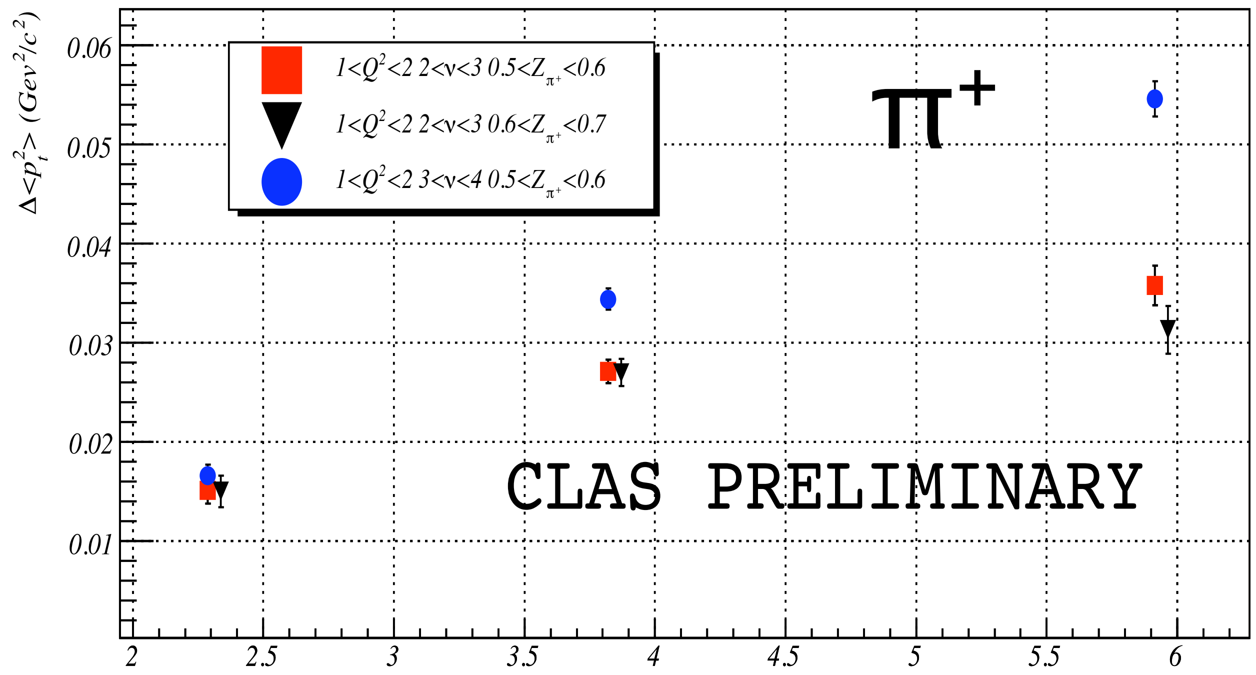
Transverse momentum broadening(2)

π^+

Δp_T vs ν

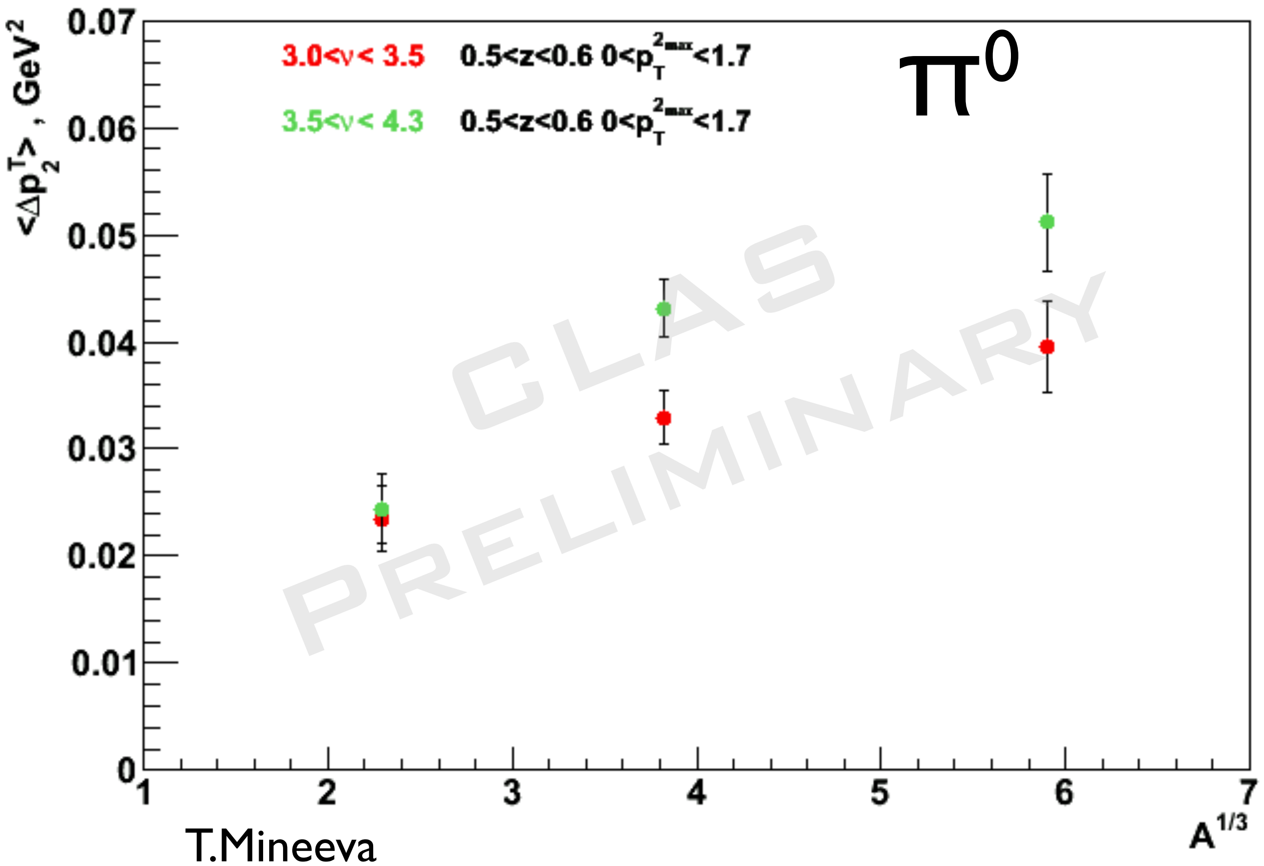


Transverse momentum broadening(3)

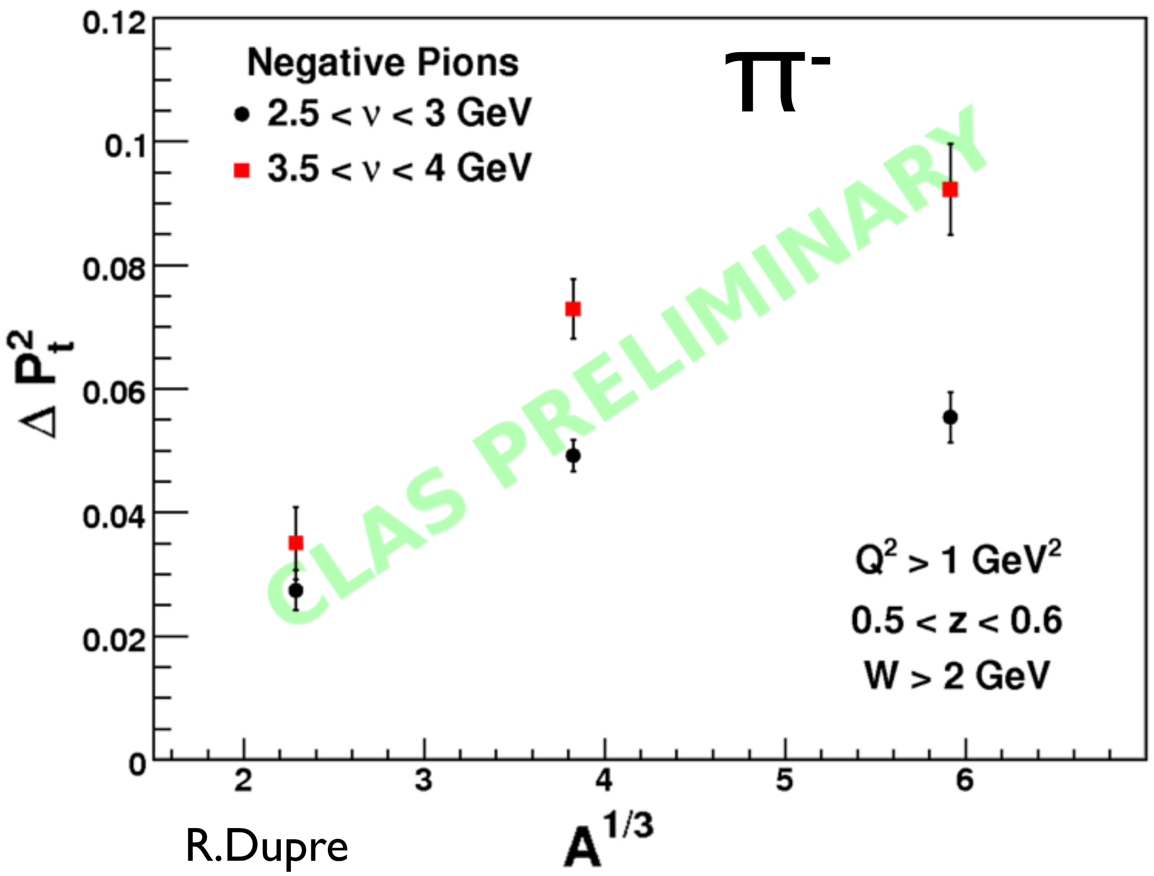


H.Hakobyan

-not acceptance corrected
-statistical errors only



T.Mineeva



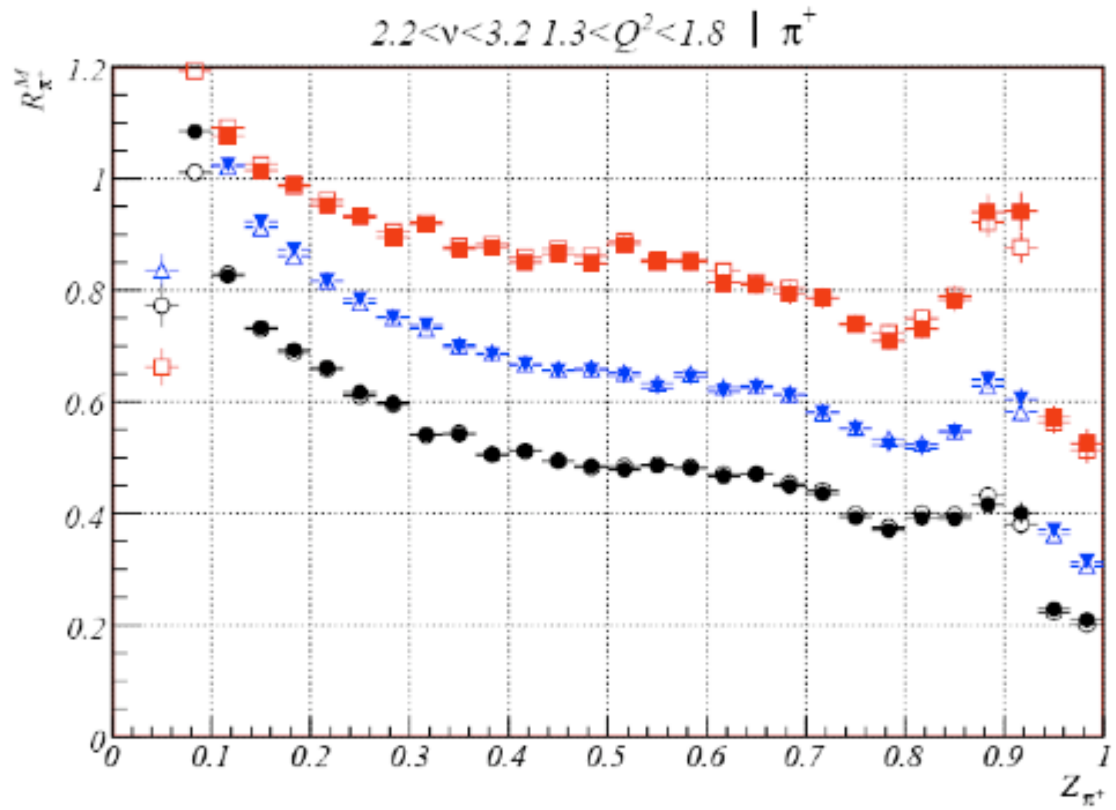
R.Dupre

Hadron attenuation

Hadron attenuation (1)

R_h vs z

π^+



Hadron attenuation (1)

R_h vs z

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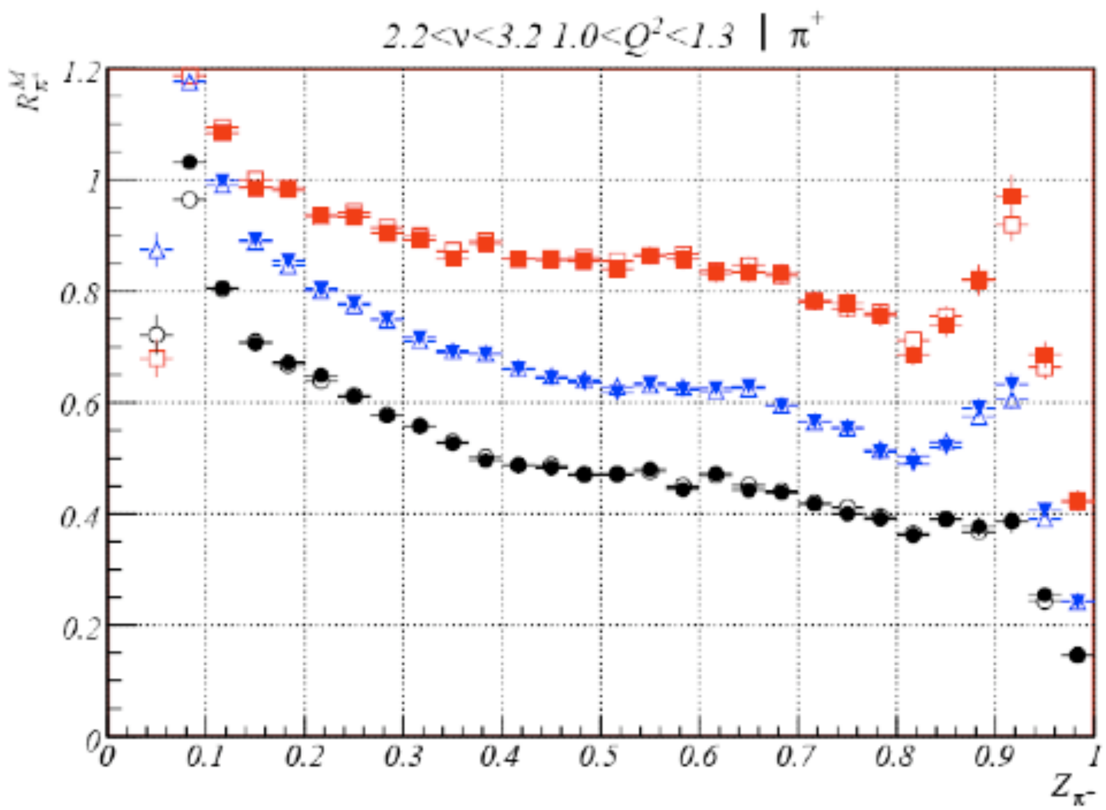

Hadron attenuation (1)

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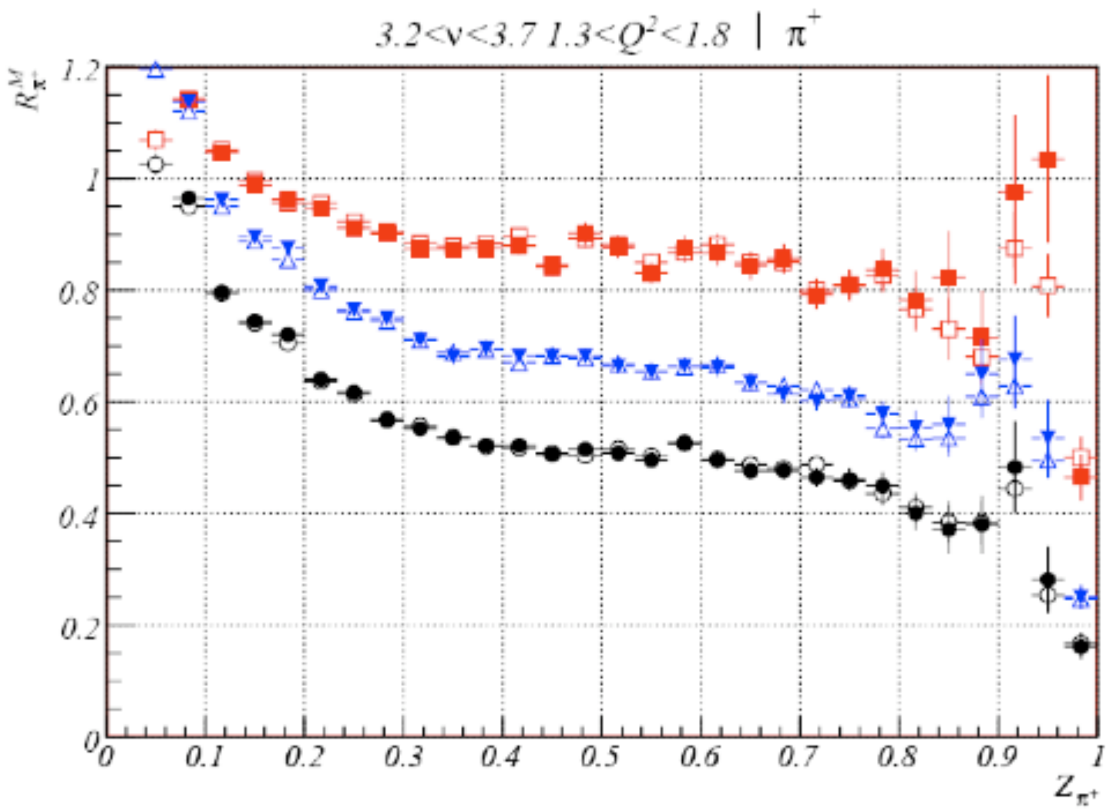

Hadron attenuation (1)

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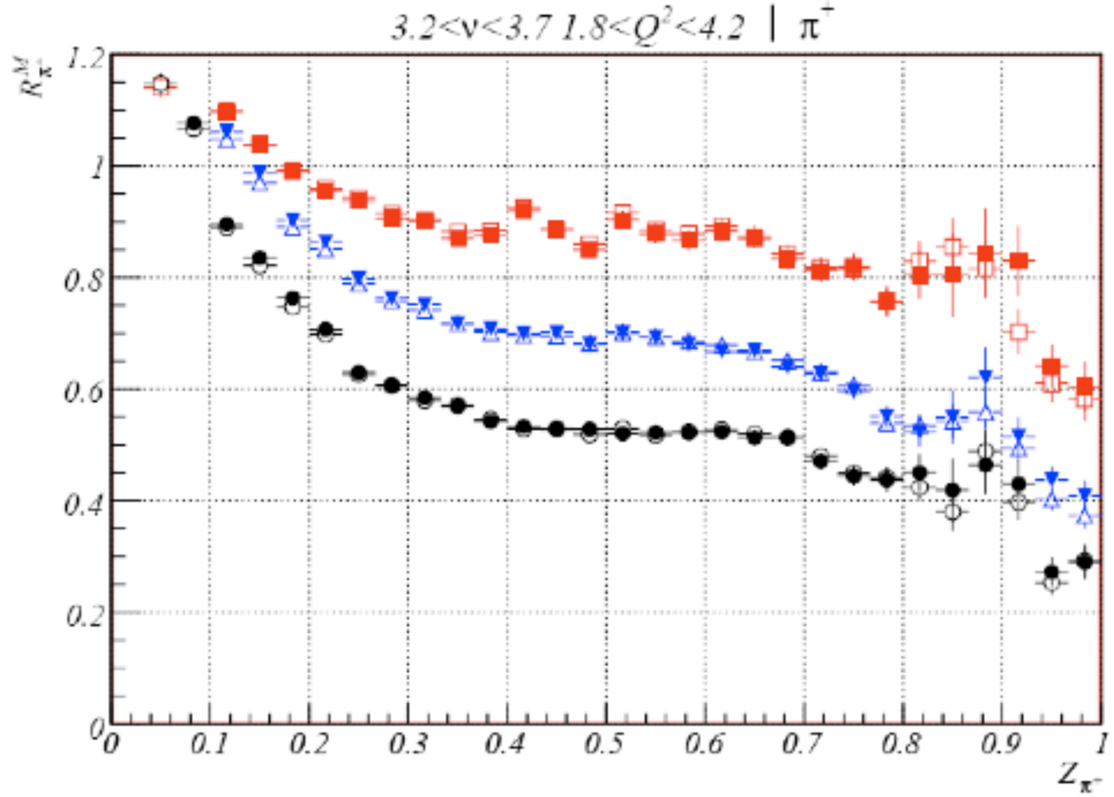
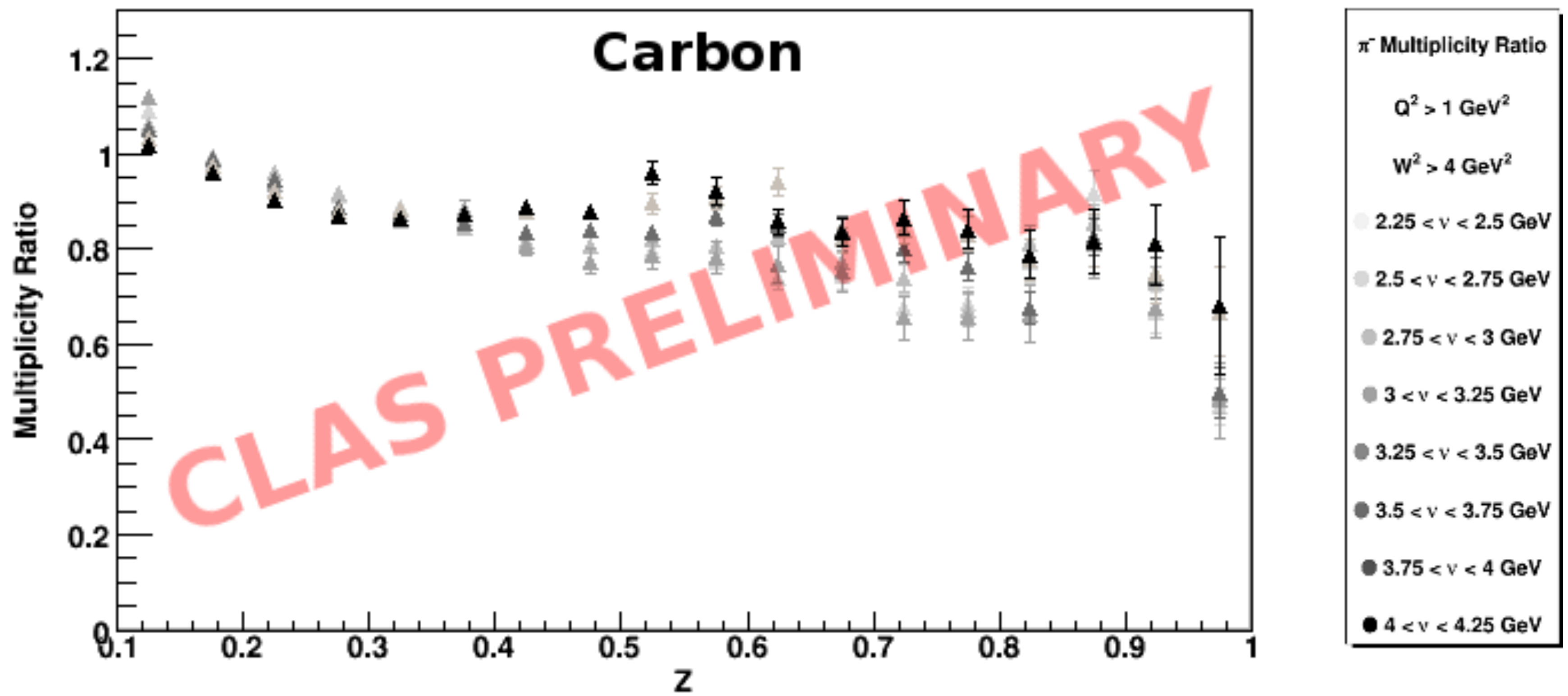


Hadron attenuation (1)

R_h vs z

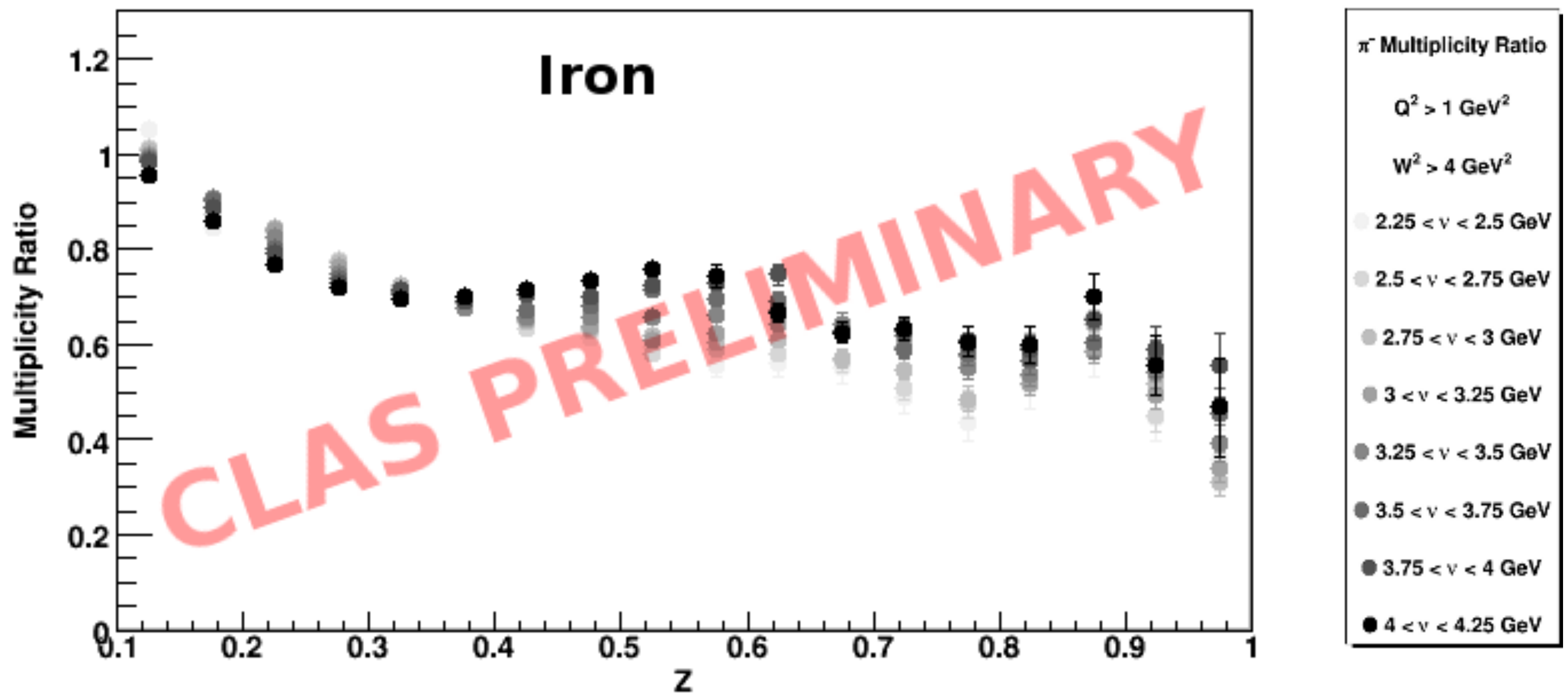
π^-



Hadron attenuation (1)

R_h vs z

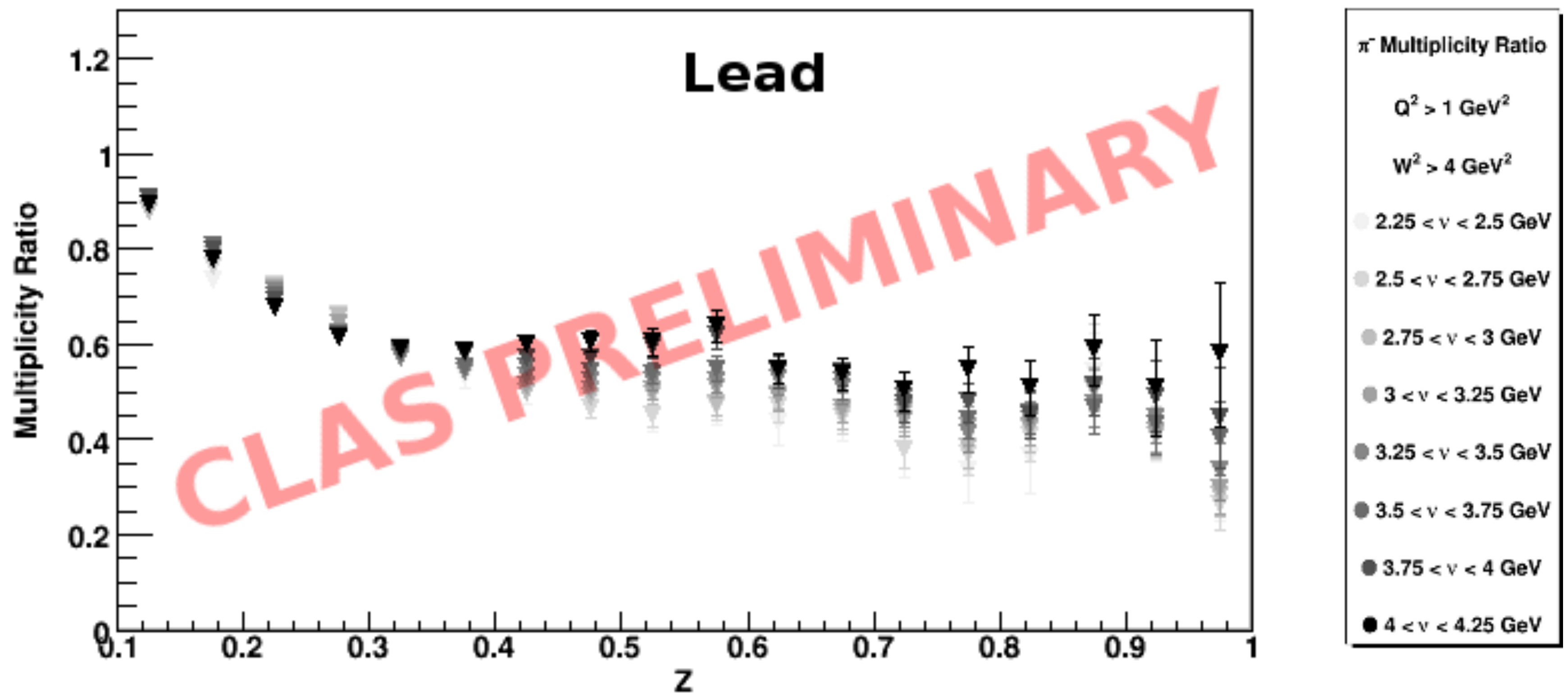
π^-



Hadron attenuation (1)

R_h vs z

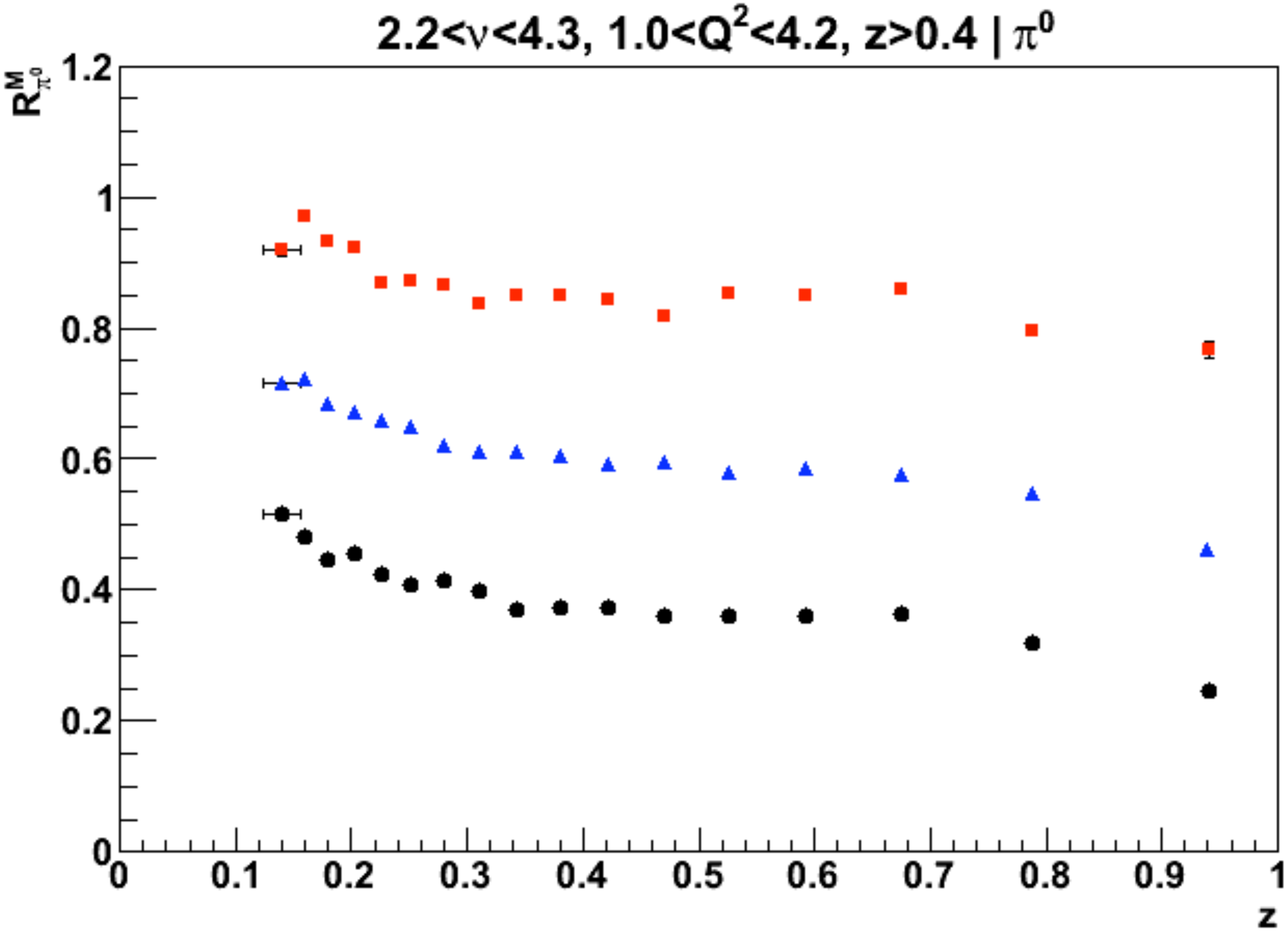
π^-



Hadron attenuation (1)

R_h vs z

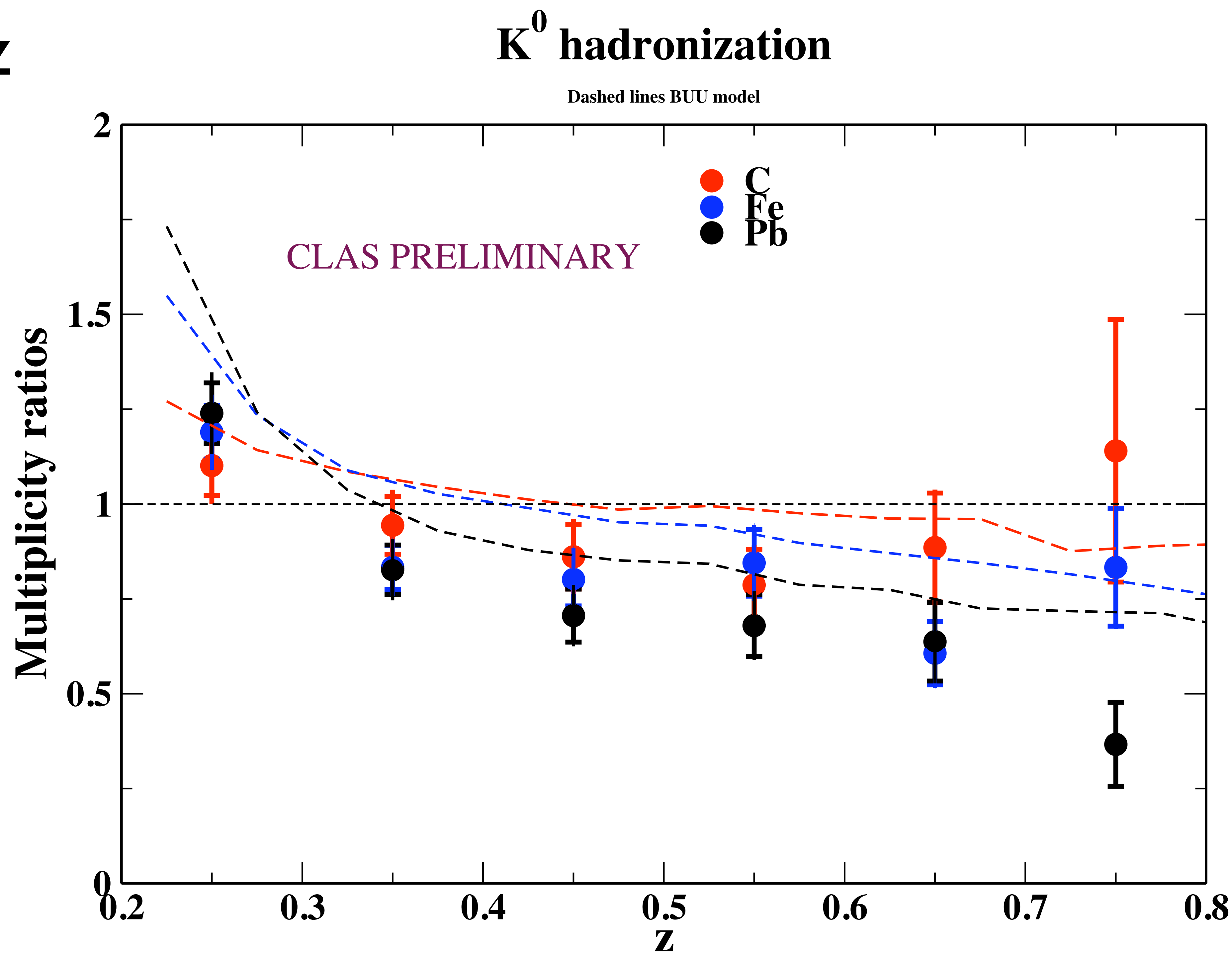
π^0



Hadron attenuation (1)

R_h vs z

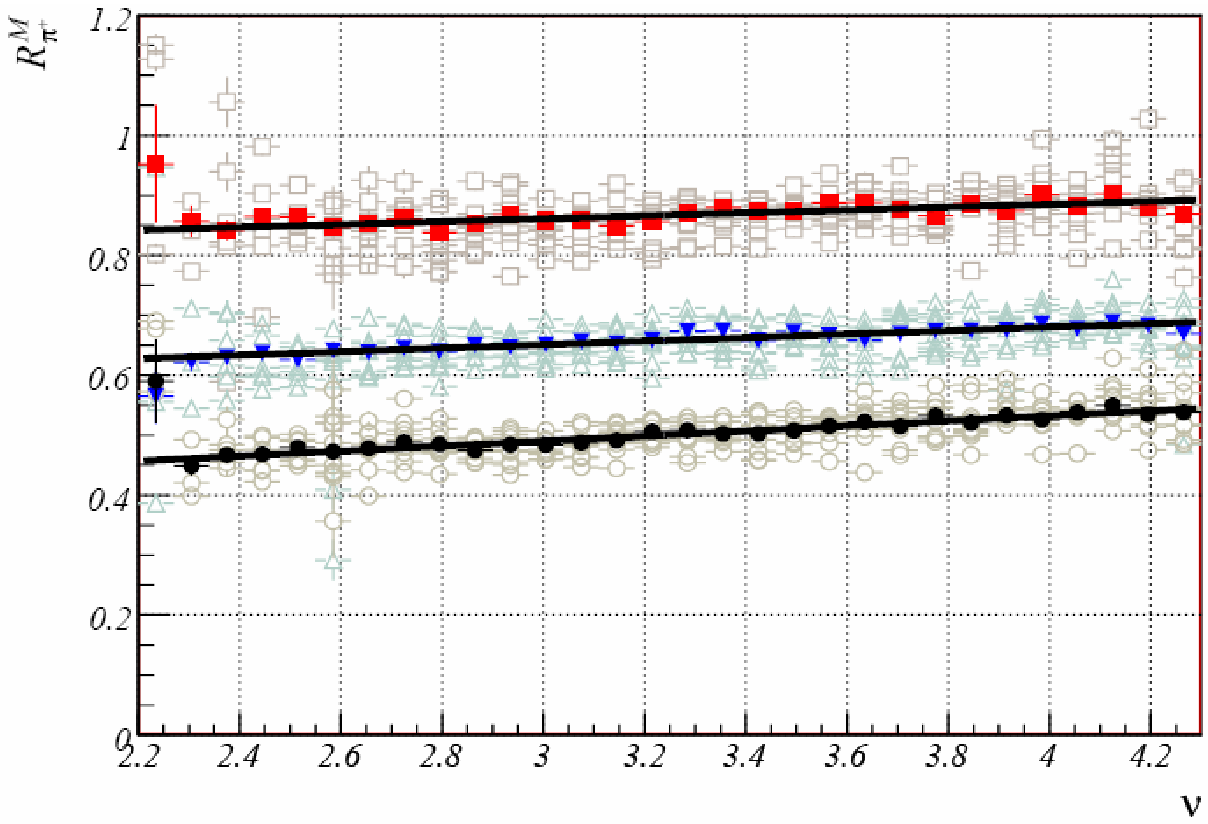
K^0

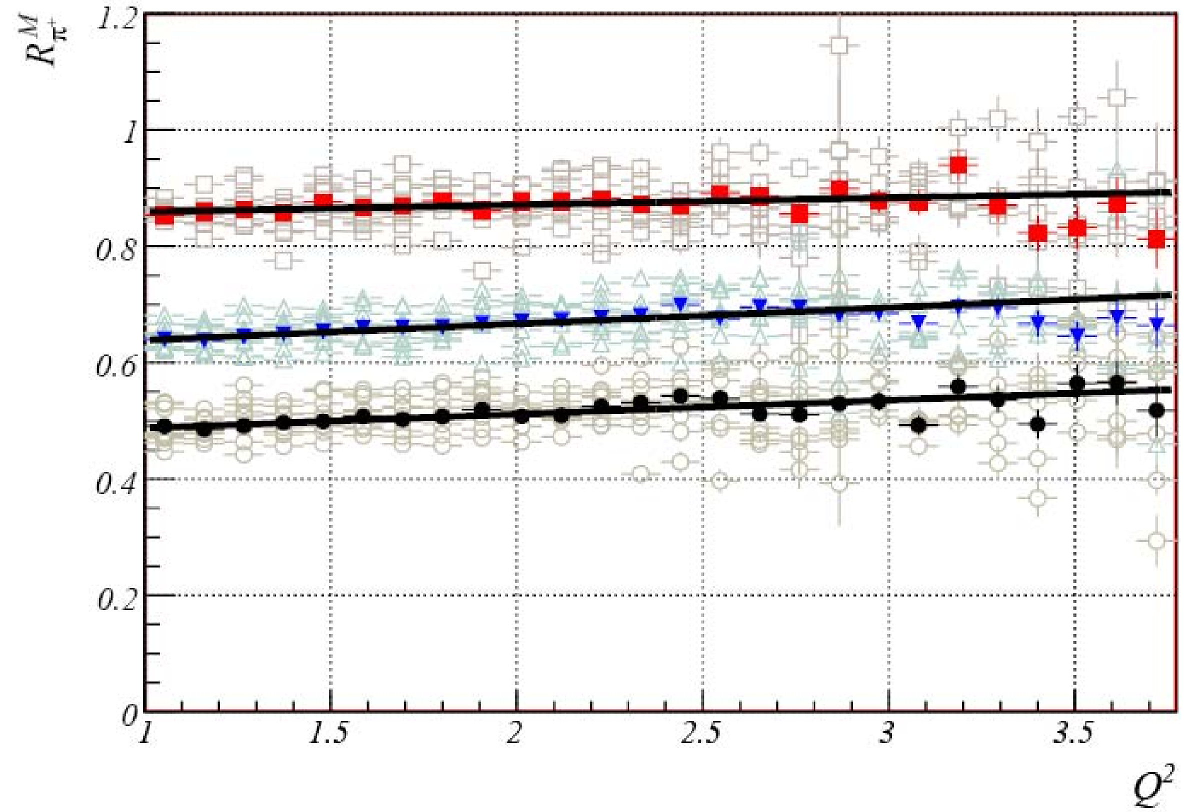


A.Daniel

Hadron attenuation (1)

R vs ν π^+ R vs Q^2

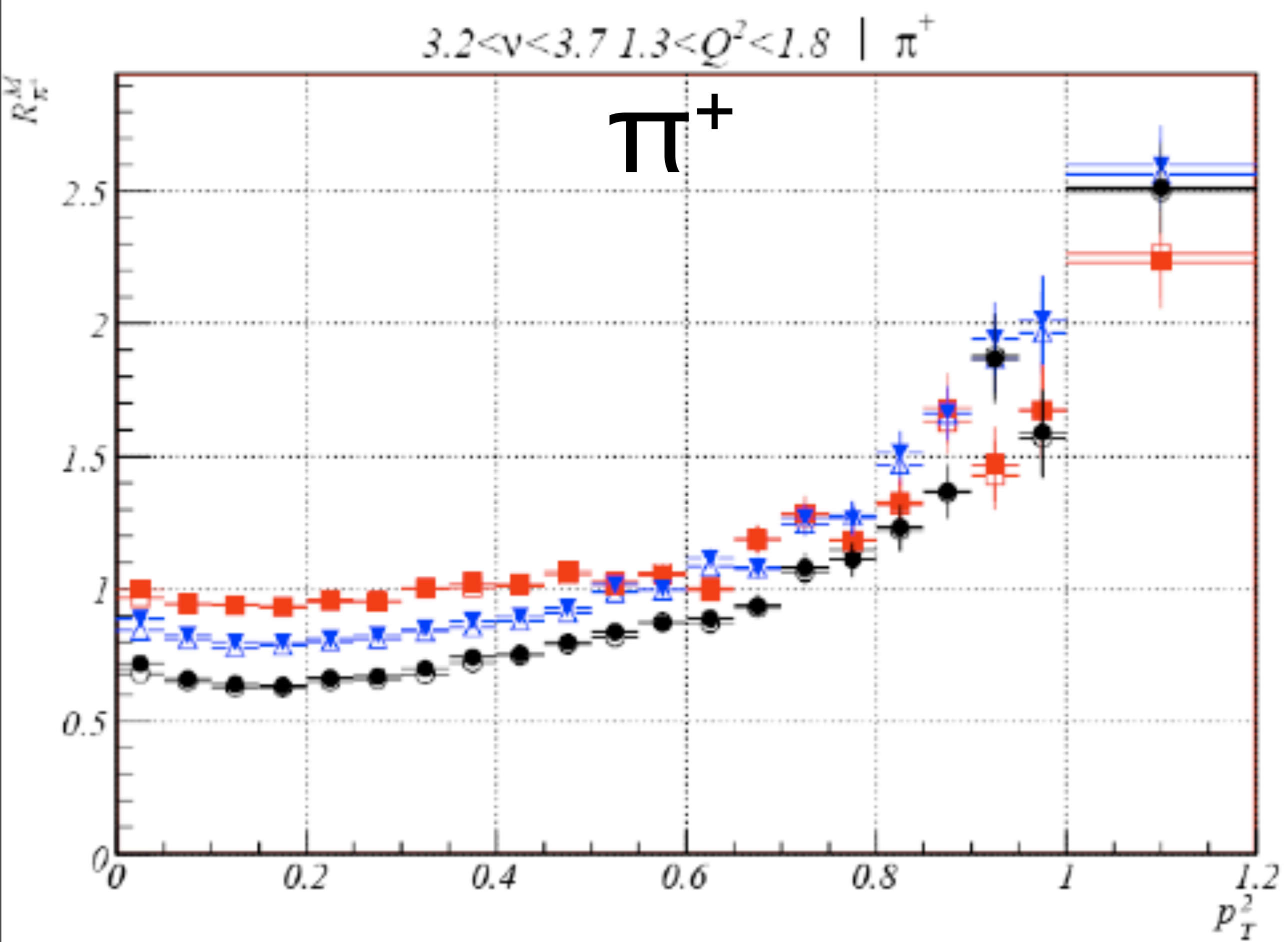


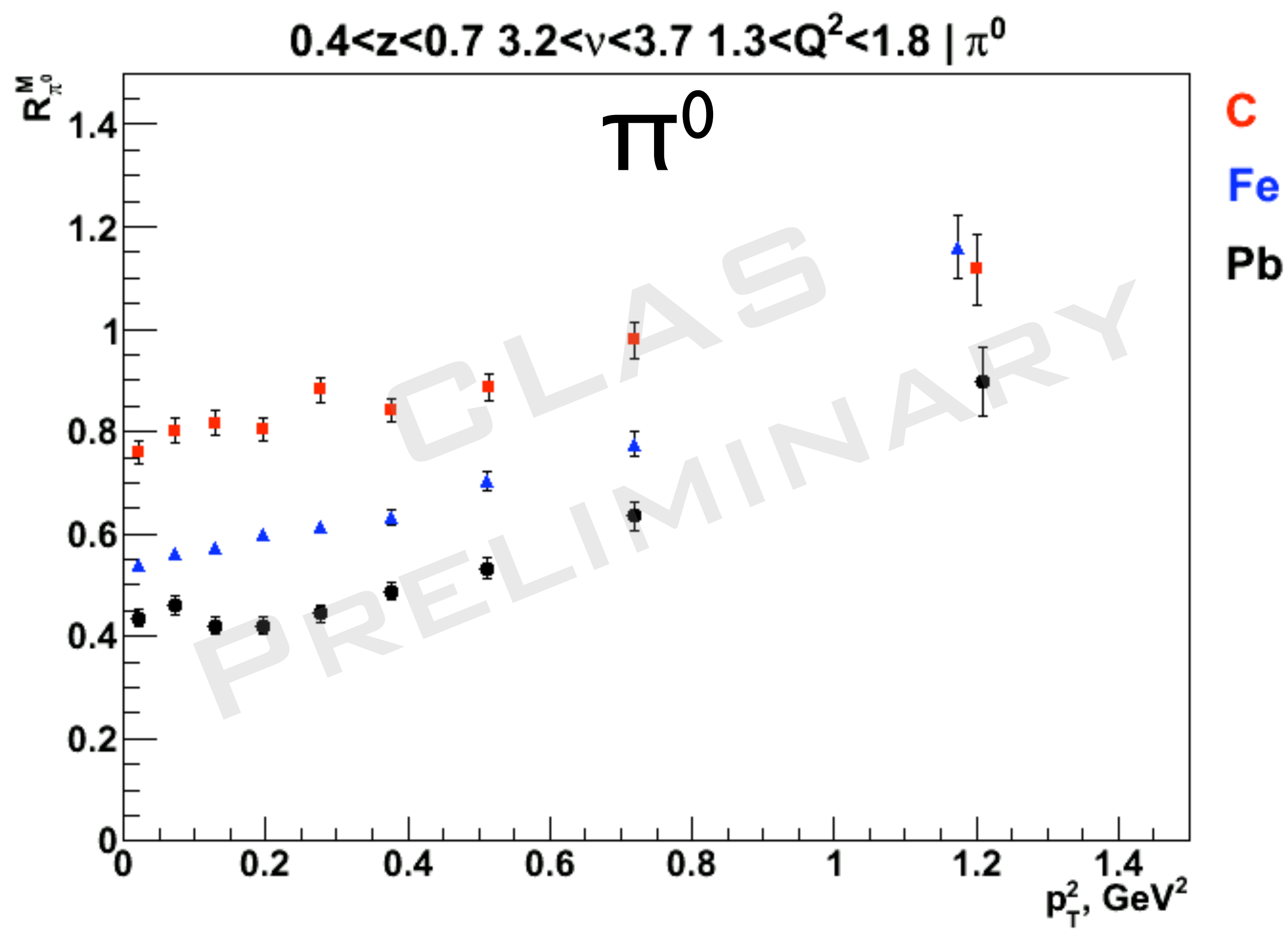


Acceptance corrected, no radiative correction

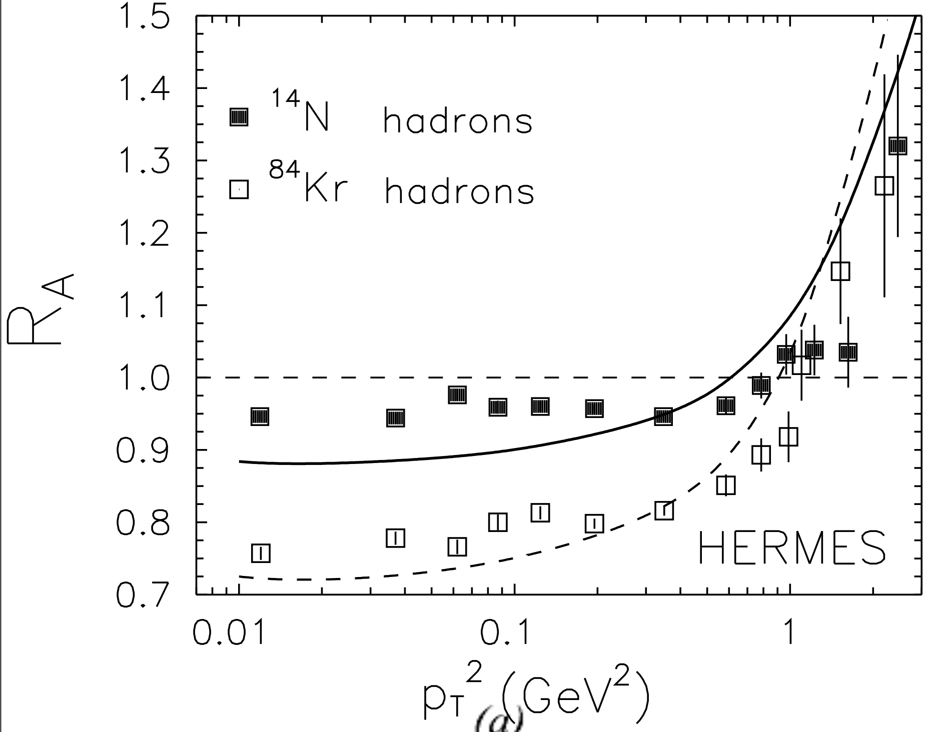
Hadron attenuation (1)

Cronin effect in 0.4<z<0.7

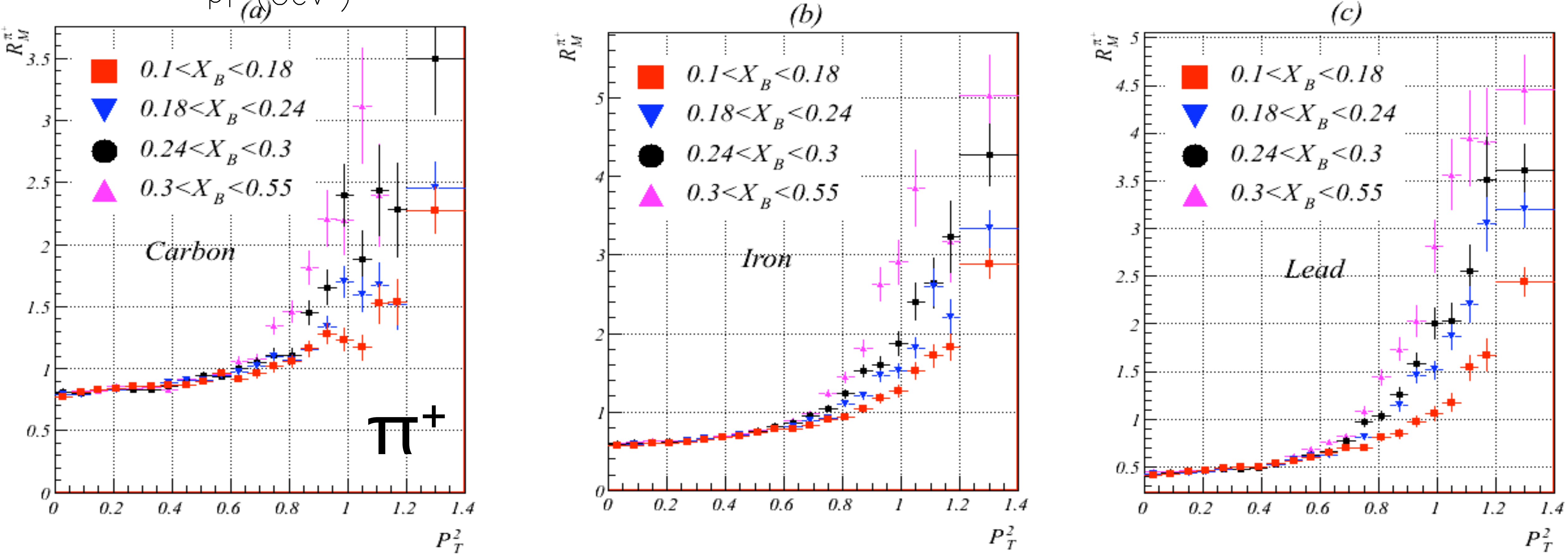




Hadron attenuation (1)



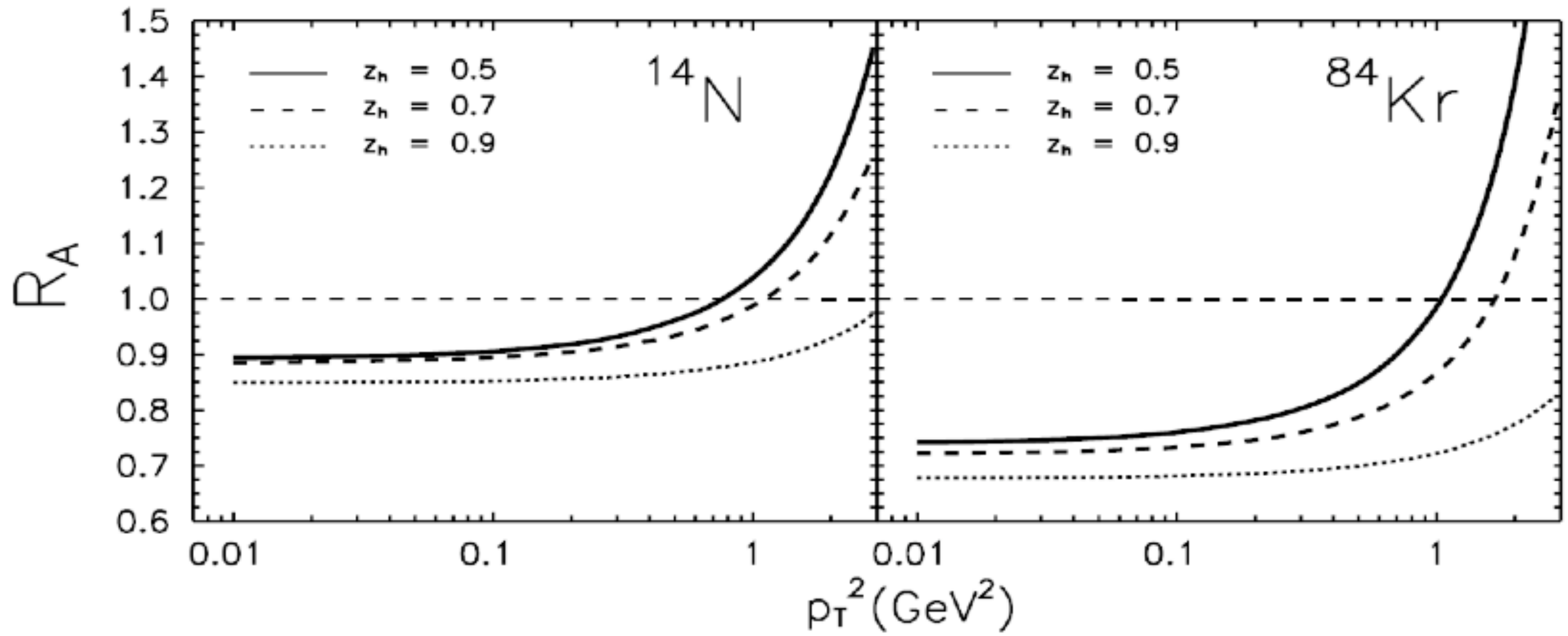
Cronin dependance on xB



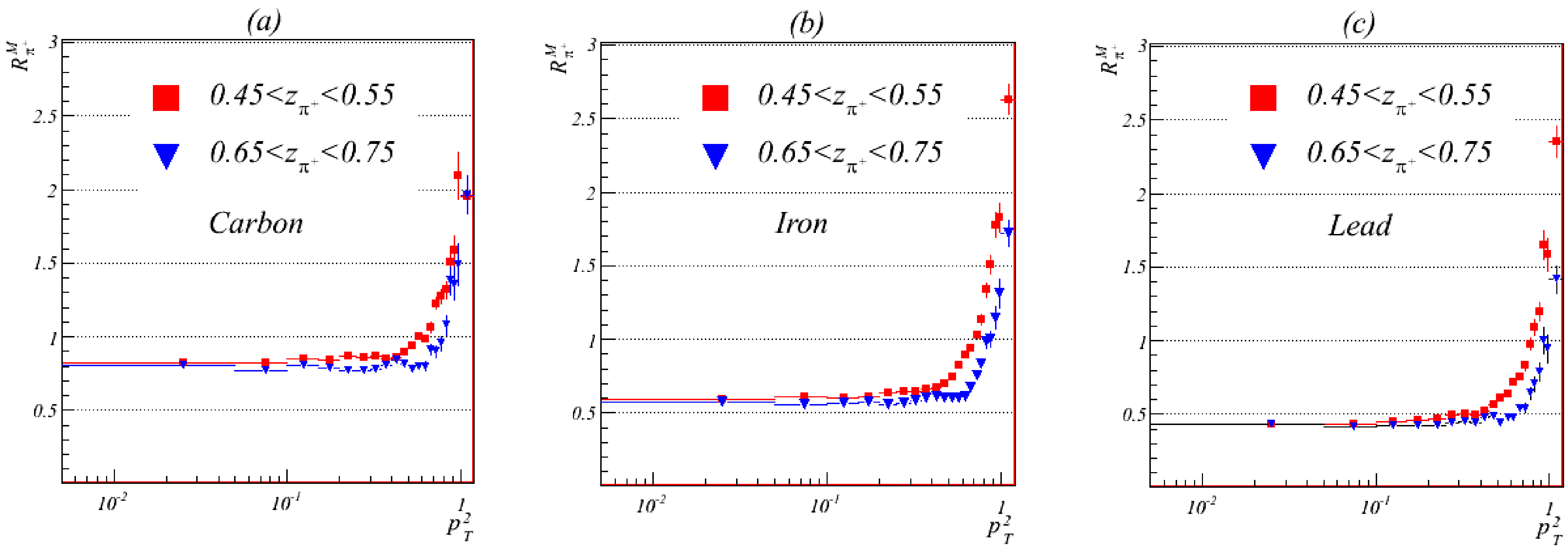
Hadron attenuation (I)

Cronin effect vs z

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



π^+

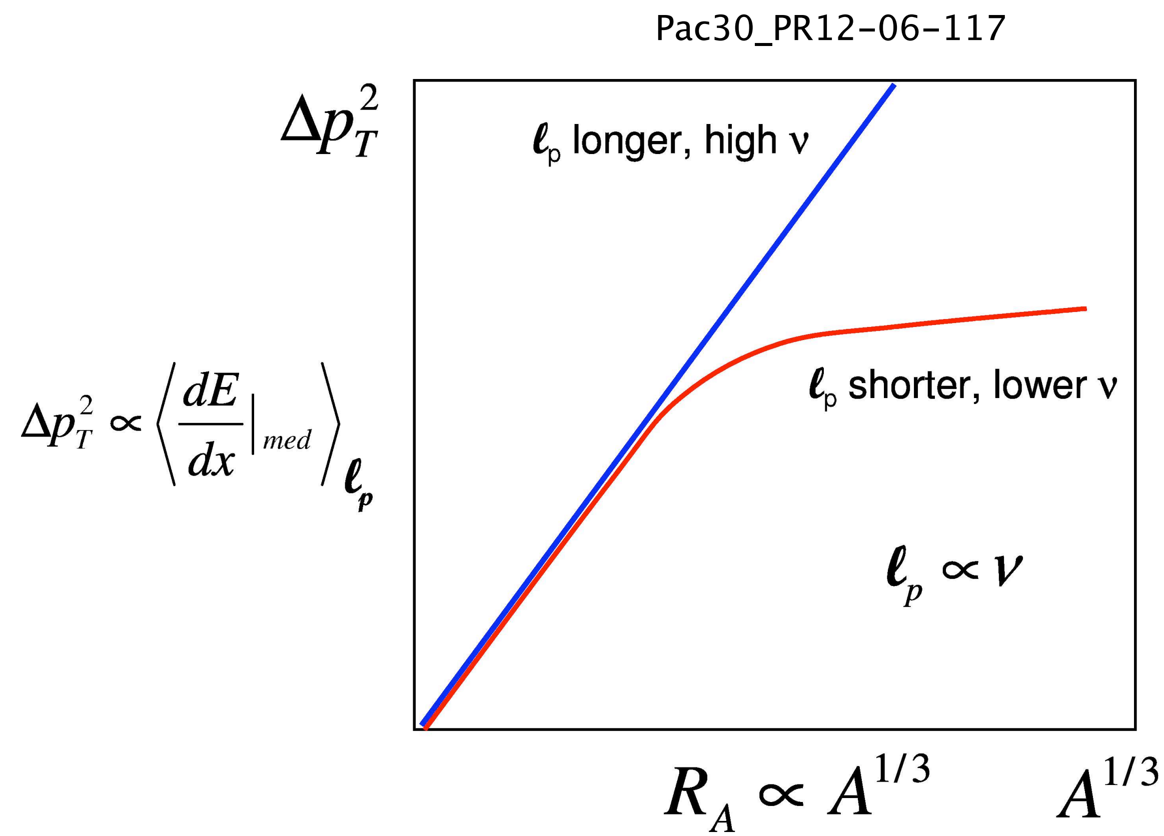


Future in EIC

EIC offers Elab= 100-2000 GeV, 10<ν<1600 GeV

.long parton live time -> ***high dpt***

hadron formation outside of nuclear medium



Future in EIC

Δp_T observables (1)

-Quark energy loss

attenuation is suppressed, pure energy loss

heavy quark energy loss (D,B)

Δp_T observables (1)

-Quark energy loss

attenuation is suppressed, pure energy loss
heavy quark energy loss (D,B)

- Quark-gluon correlation function

X.Guo, J.Qiu Phys Rev D vol61 096003

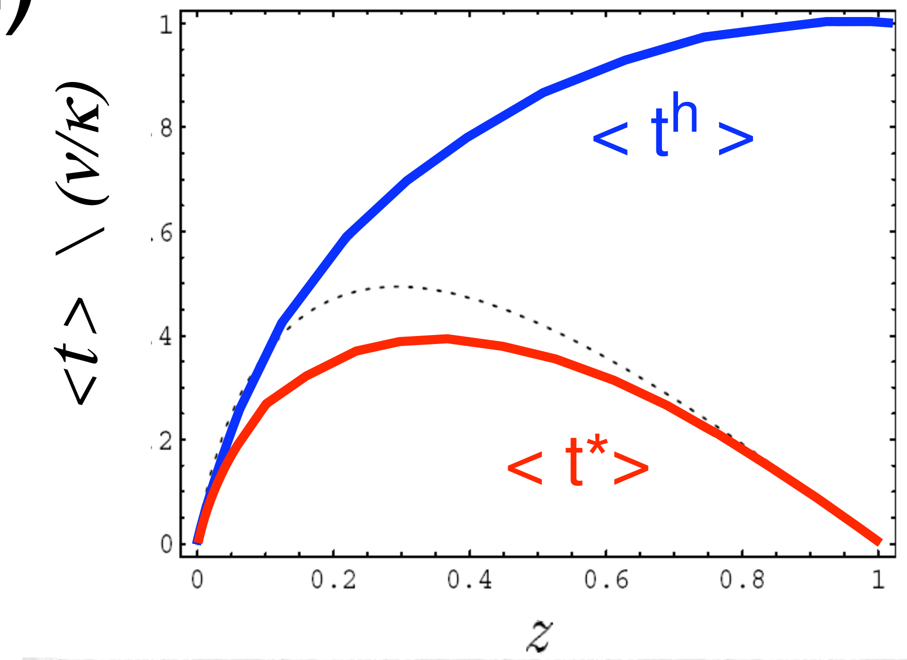
$$T^A_{qF}(x,Q^2)=\lambda^2 A^{1/3} q^A(x,Q^2)$$

$$\Delta\langle l_T^2\rangle_{1/3} = \frac{4\pi^2\alpha_s(Q^2)}{3} A^{1/3}\lambda^2 \frac{\sum_q e_q^2 q^A(x_B,Q^2) D_{q\to\pi}(2,z_{\min})}{\sum_q e_q^2 q^A(x_B,Q^2)}.$$

Future in EIC

Δp_T observables(2)

[Accardi et al., NPA 761(05)67]



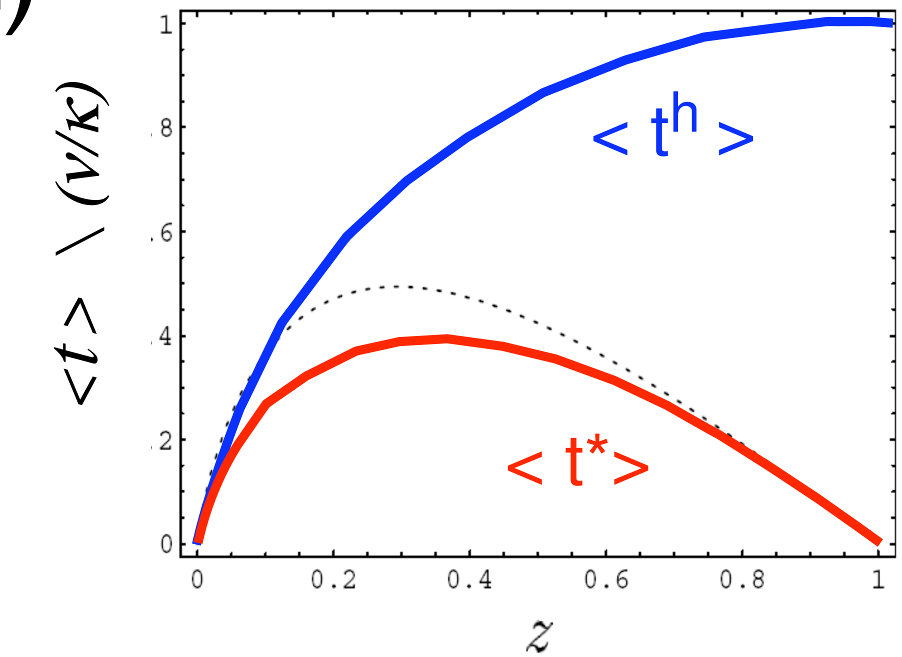
-Medium modification of DGLAP

A.Accardi *et al* arvix 0808.0656

Future in EIC

Δp_T observables(2)

[Accardi et al., NPA 761(05)67]



-Medium modification of DGLAP

A.Accardi *et al* arvix 0808.0656

- Quark and gluon saturation

B.Z Kopeliovich arxiv.1001.4281v1

$$Q^2_{qA}(b,E) = \Delta p^2_T(b,E),$$

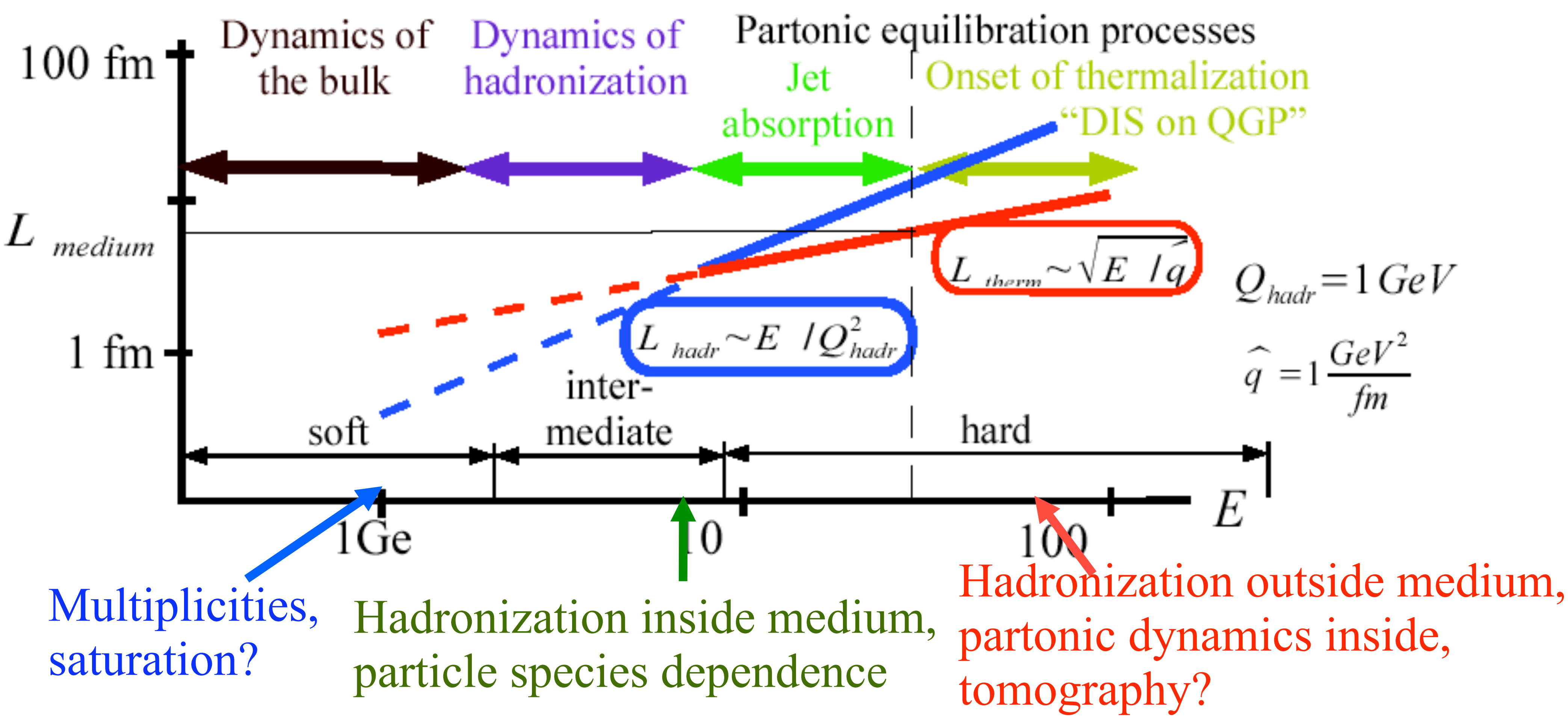
$$Q^2_{qA}(b,E) = 2C_q(E, r_T = 1/Q_{qA})T_A(b).$$

$$\Delta p^2_T = 2T_A(b)\left.\frac{d\sigma^N_{\bar{q}q}(r_T)}{dr^2_T}\right|_{r_T=0} = 2T_A(b)C_q(E, r_T = 0).$$

Summary

Extraction of Δp_T^2 ***(Q2, υ, A***) and ***Rh(Q2, υ, pT, zh)*** from JLab data provides an access to the characteristic time scales of fragmentation and hadronization distances.

Prospectives in the EIC can encompass study of pure partonic energy loss, quark gluon saturation, nuclear modification function, quark gluon correlation, and many more ...



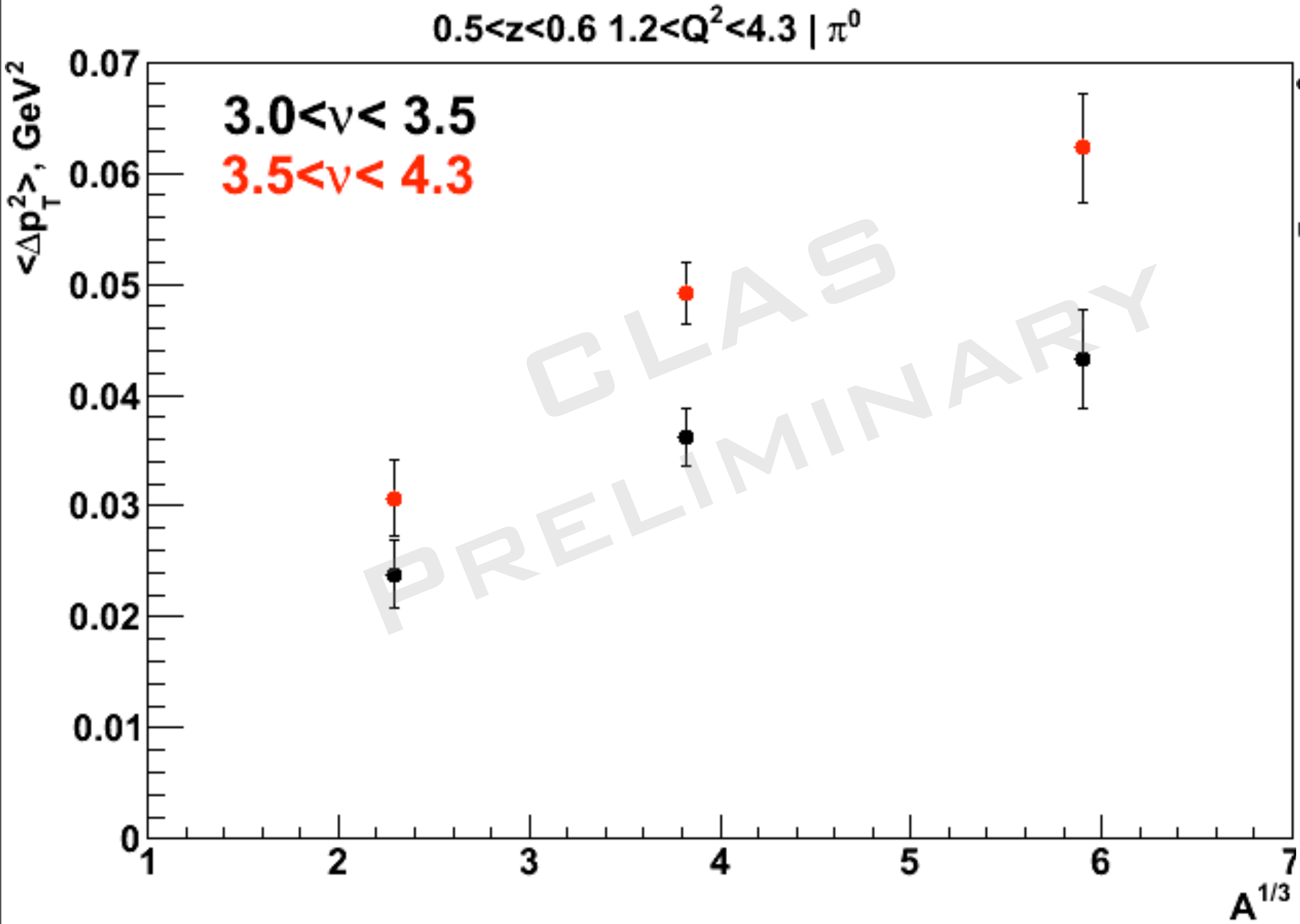
N.Armesto hard probes summer school Torino 2005

Future in EIC

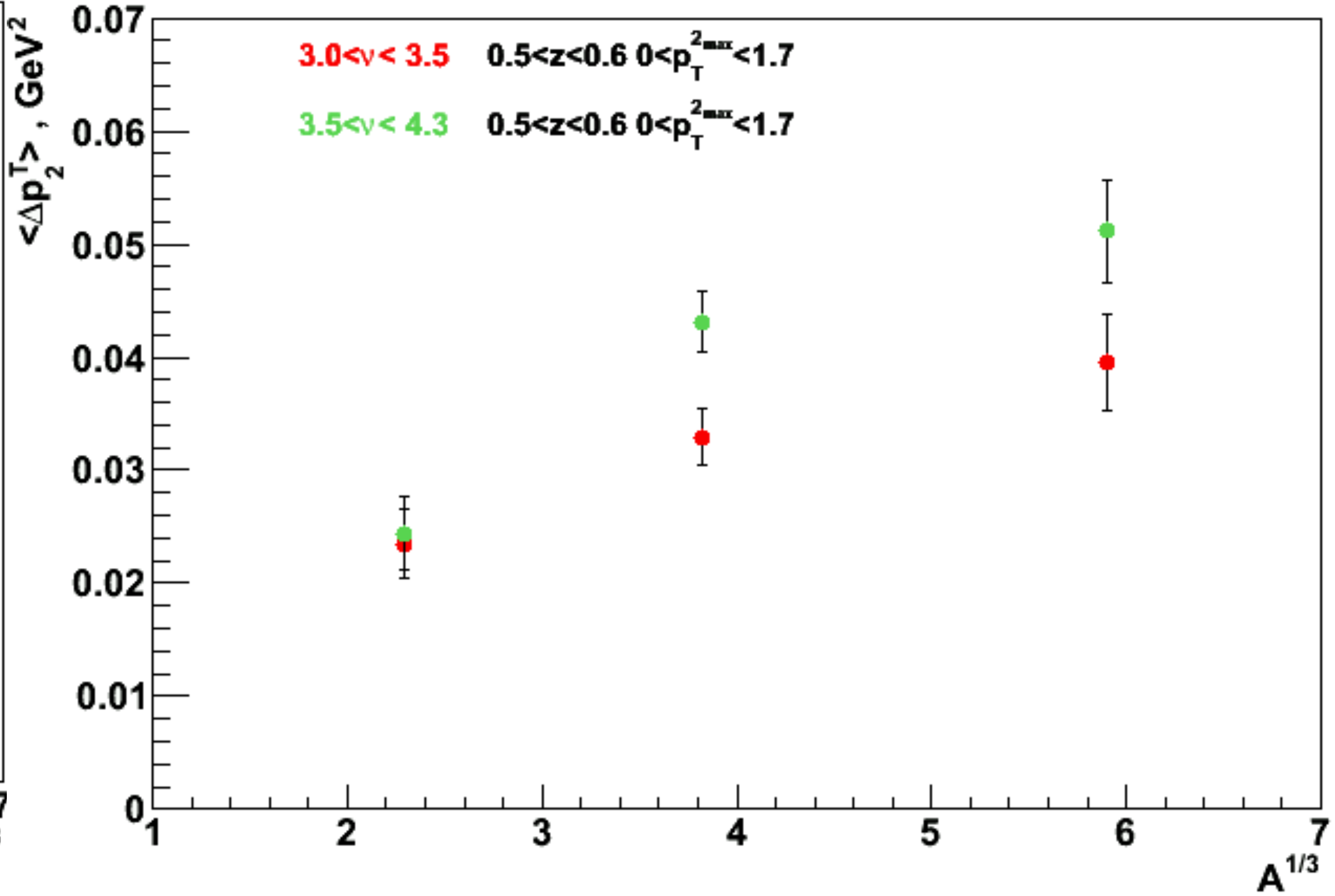
Multiplicity ratio observables:

- broadening in R for mesons vs baryons (nuclear modification of baryons vs mesons)

Transverse momentum broadening



$0<p_T^2<7.0$ GeV



$0<p_T^2<1.7$ GeV

z-scaling of Δp_T^2

$$\Delta p_T^2 = z_h^2 \Delta k_T^2$$