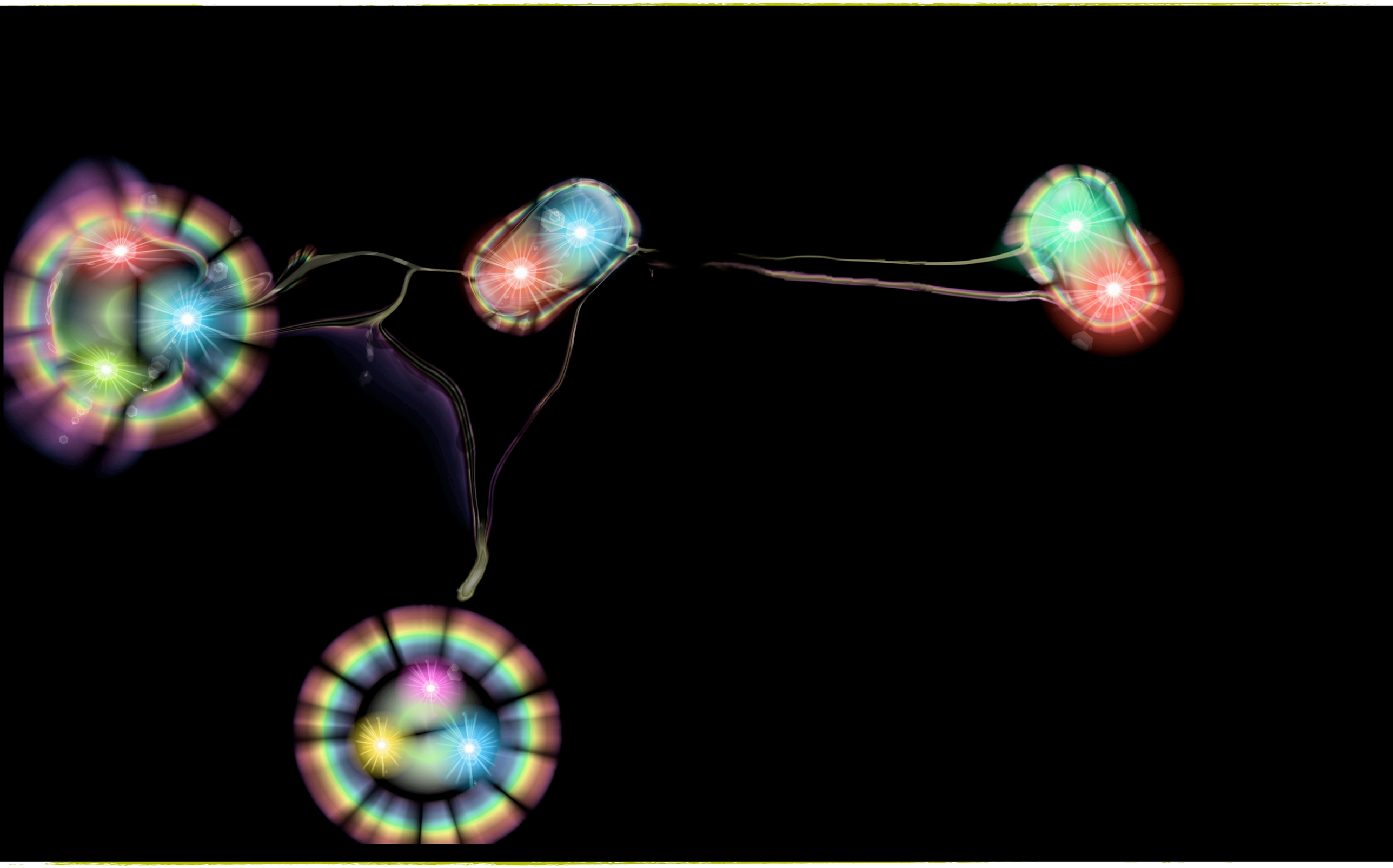
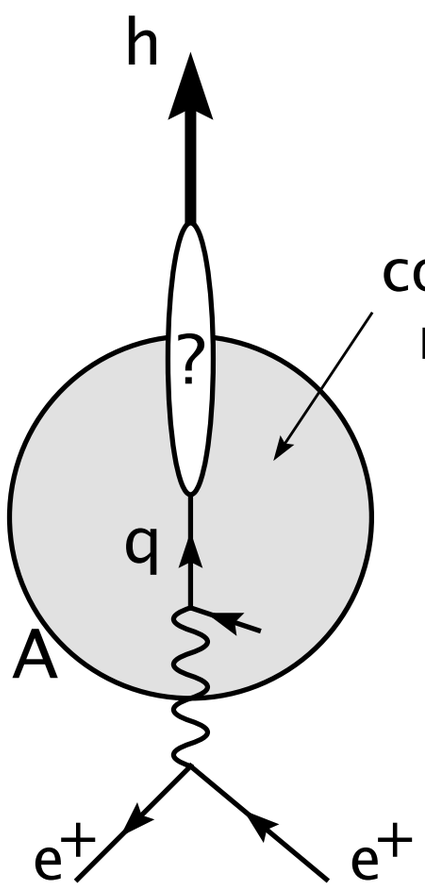
Overview of hadronization data at CLAS

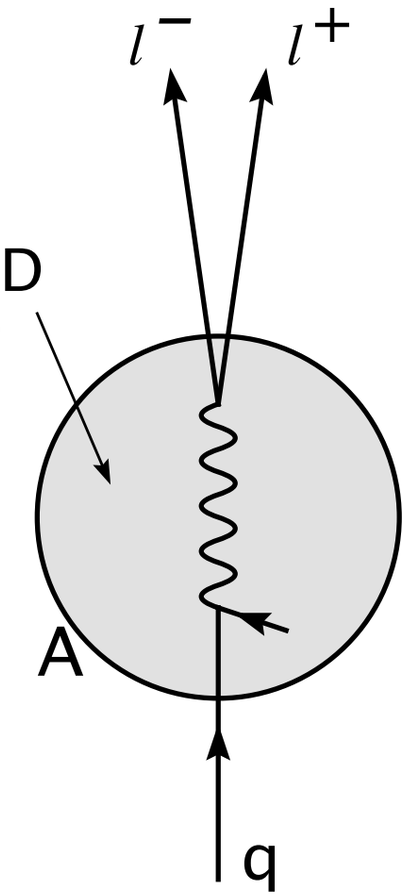


Taisiya Mineeva

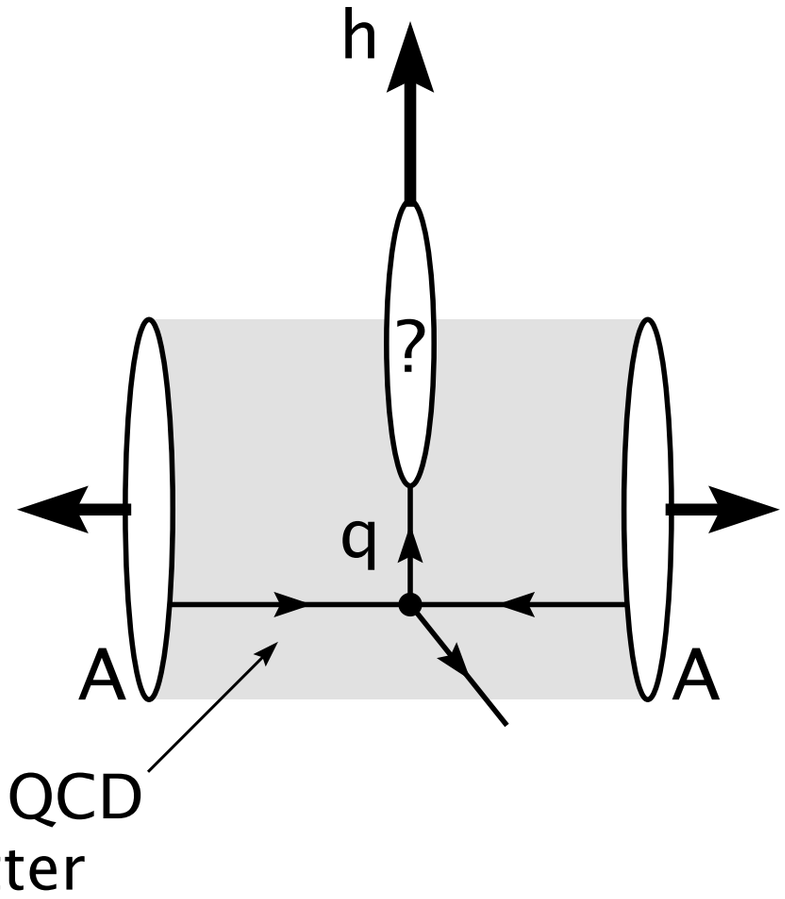
Means to study parton propagation and fragmentation



DIS
(DESY, Jefferson Lab)



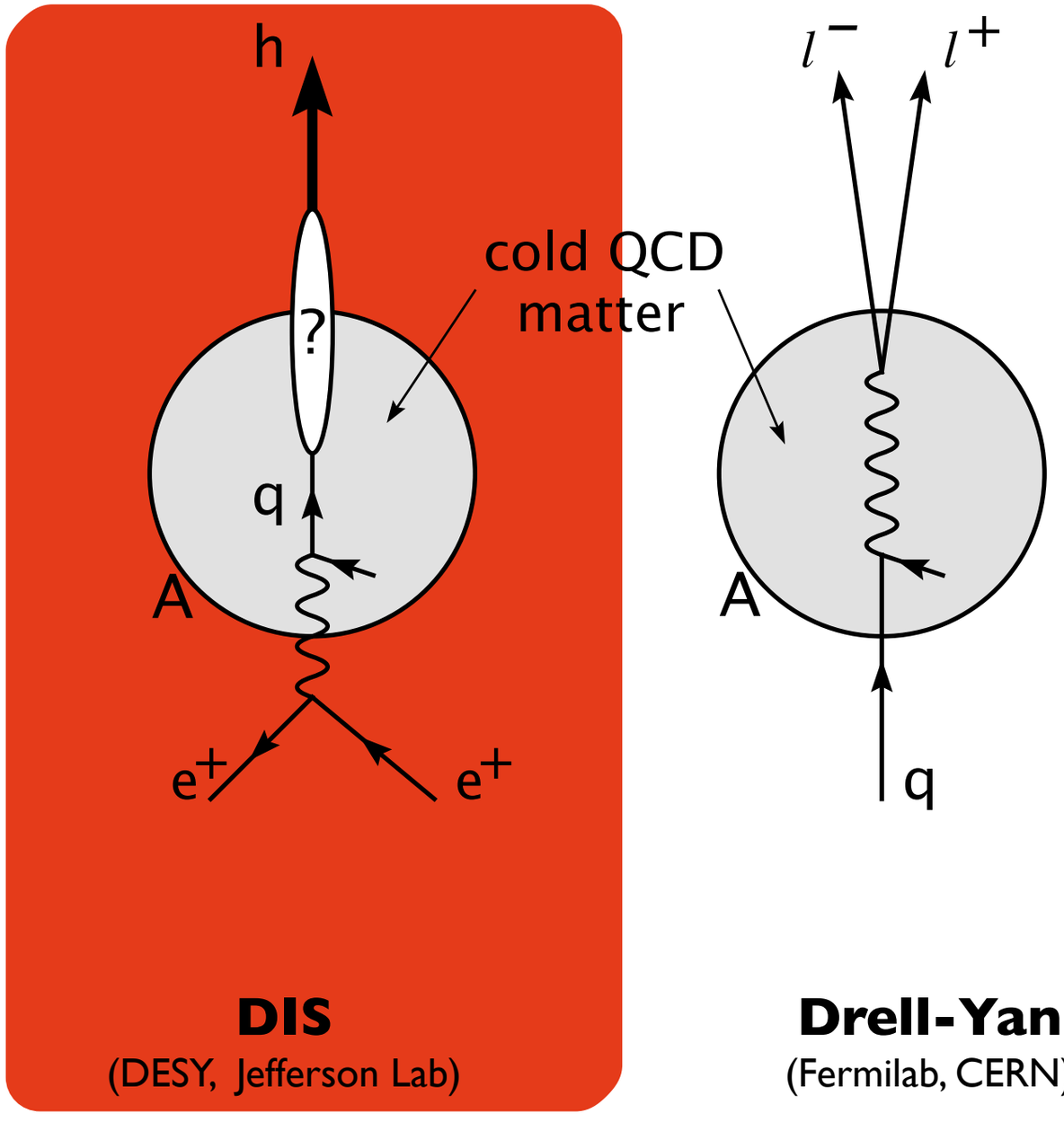
Drell-Yan
(Fermilab, CERN)



Heavy-Ion
(RHIC, LHC)

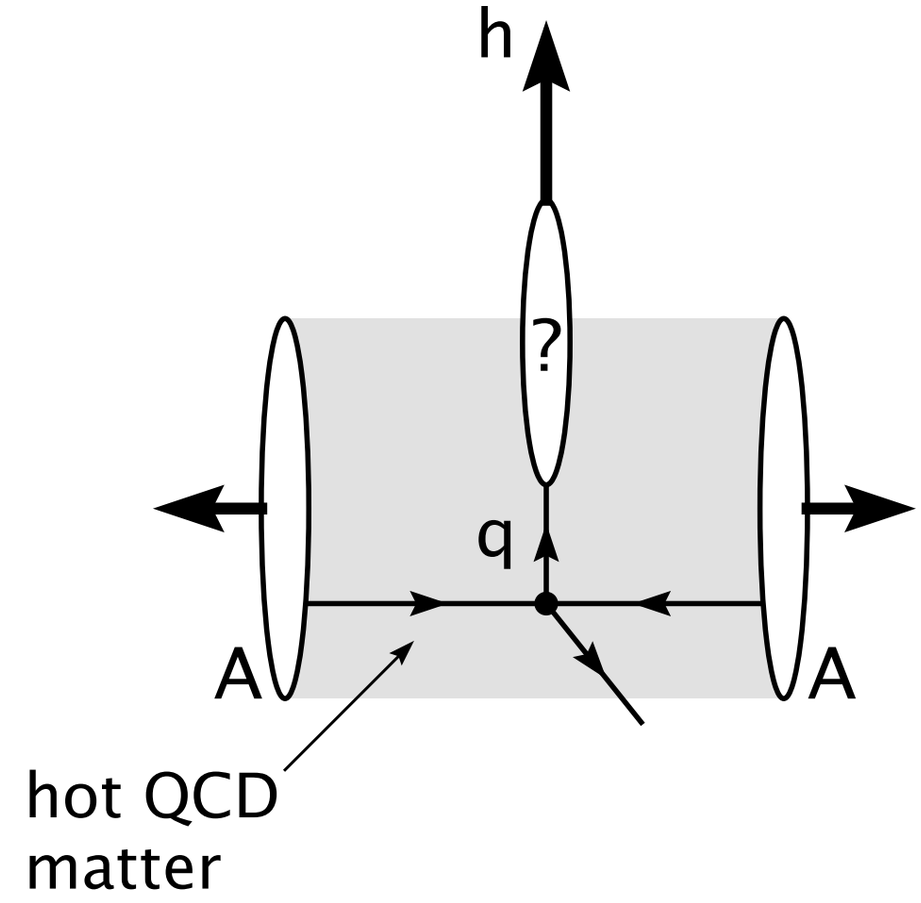
Parton Propagation and Fragmentation in QCD Matter, A.Accardi, F.Arleo, W.K. Brooks , D. D'Enterria, V.Muccifora arXiv:0907.3534v1 [nucl-th]

Means to study parton propagation and fragmentation



DIS
(DESY, Jefferson Lab)

Drell-Yan
(Fermilab, CERN)



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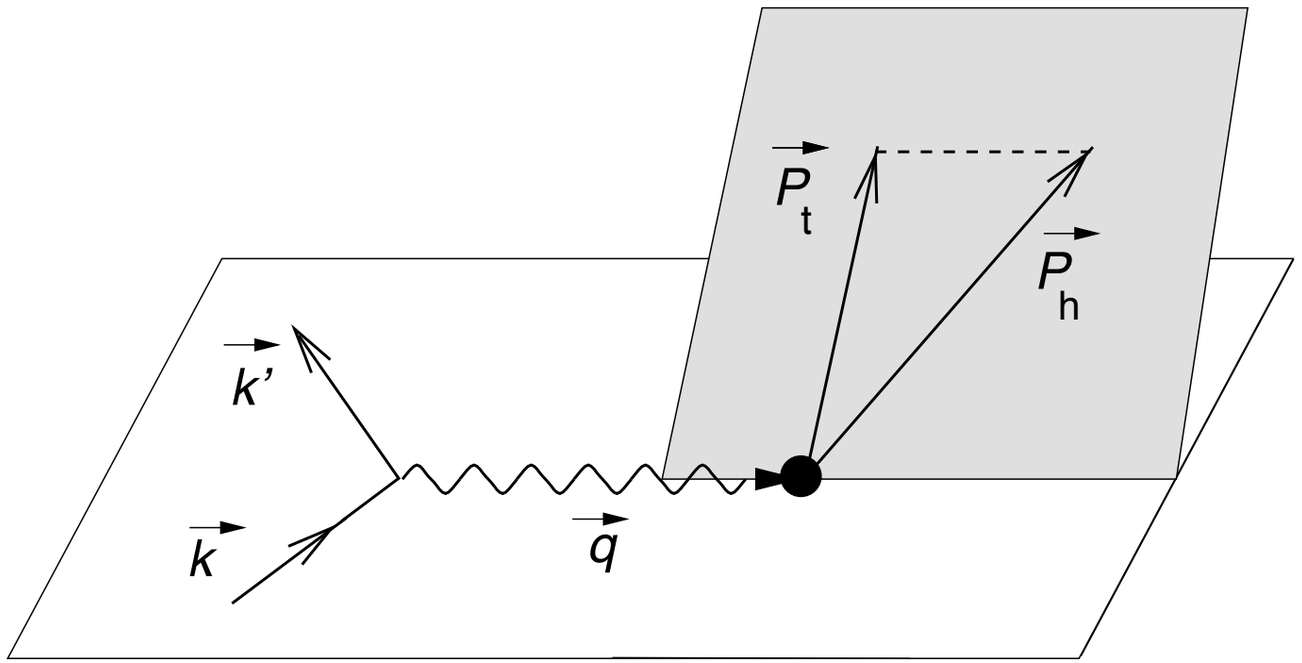
Parton Propagation and Fragmentation in QCD Matter, A.Accardi, F.Arleo, W.K. Brooks , D. D'Enterria, V.Muccifora arXiv:0907.3534v1 [nucl-th]

SIDIS



Q^2 = $-q^2$ four-momentum transferred by the electron;

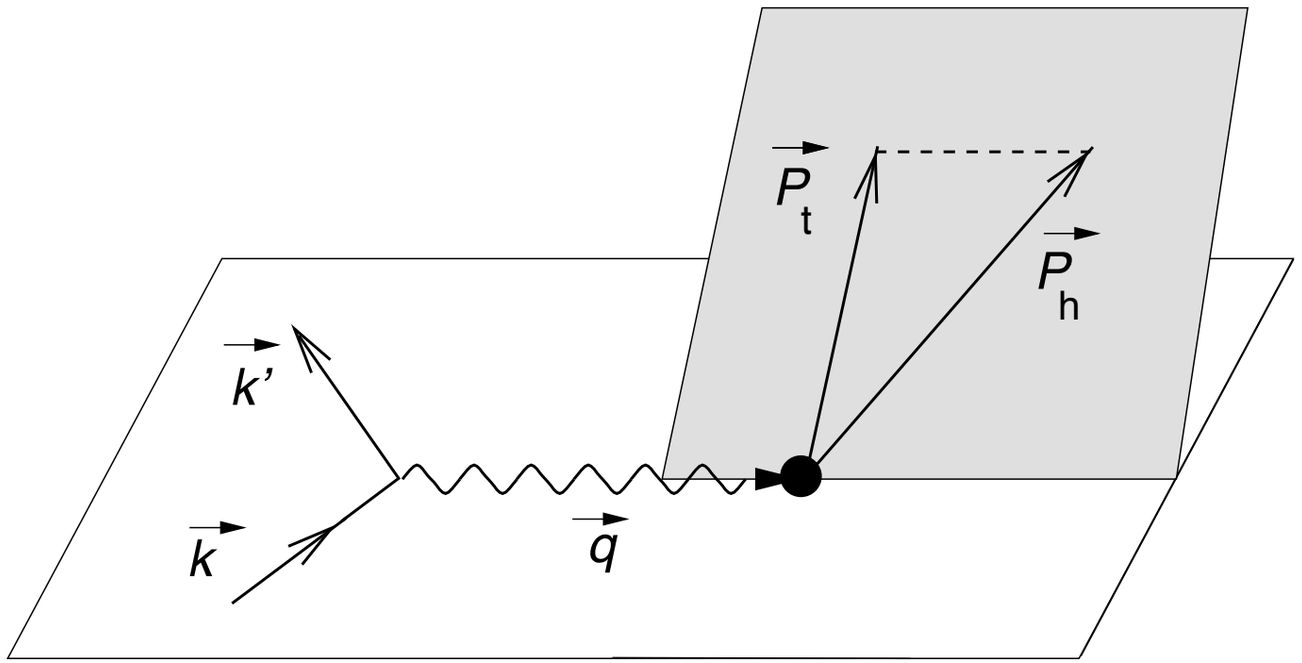
ν = $E-E'$ (lab) energy transferred by the electron;

z = E_h/ν fraction of initial quark energy carried by hadron;

p_T hadron momentum transverse to γ^* direction;

φ angle between leptonic and hadronic planes

SIDIS



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z = E_h/ν fraction of initial quark energy carried by hadron;

p_T hadron momentum transverse to γ^* direction;

φ angle between leptonic and hadronic planes

- CLAS/DIS kinematics: $Q^2>1$ GeV^2, $W>2$ GeV ; $0.1<x<0.55$, $y<0.85$

Transverse momentum broadening

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

Connects to partonic phase

- in-medium partonic multiple scattering
- medium stimulated gluon emission
- quark energy loss
- average transport coefficient

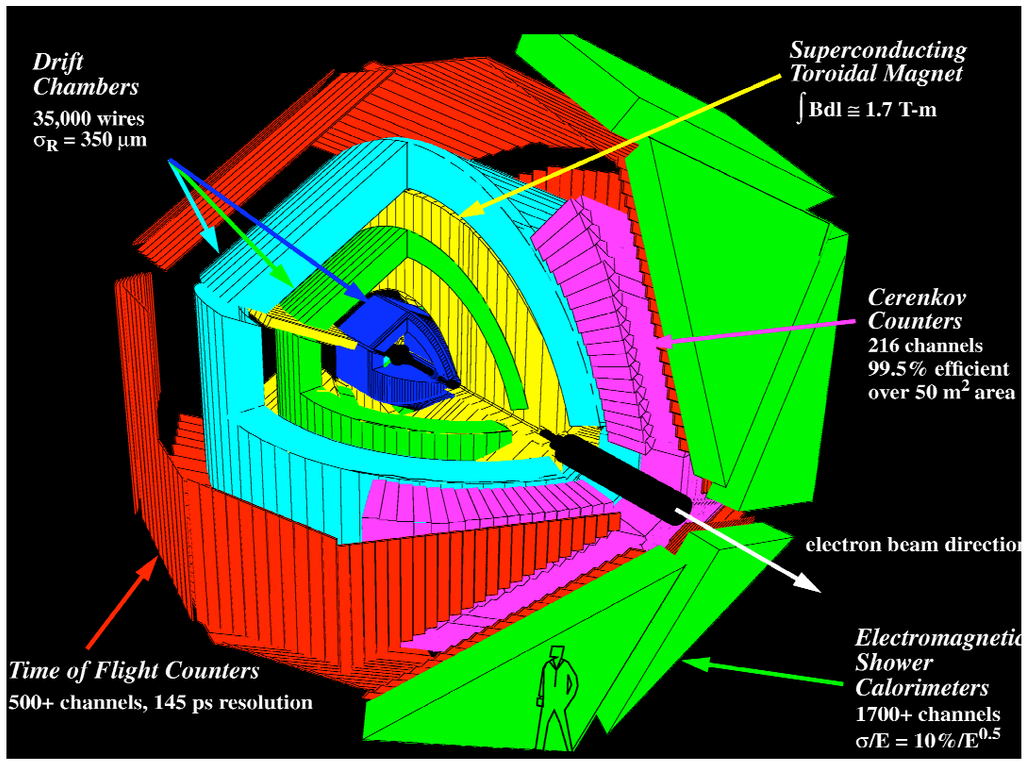
Hadronic multiplicity ratio

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

Connects to hadronic phase

- hadron formation times and mechanisms
- in-medium cross sections

Experiment



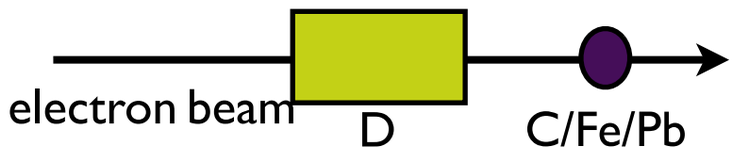
CEBAF Large Acceptance Spectrometer

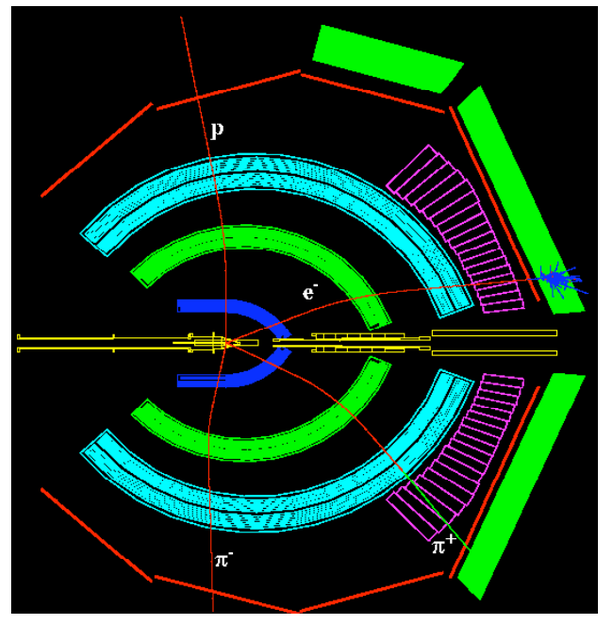
- Charged particles angles 8°-144°
- Neutral particles angles 8°-70°
- Identification of e^+/e^-,γ, p,n, $\pi+/\pi^-$,K^+/K^-

CLAS EG2

- Electron Beam 5.014 GeV
- Luminosity (1.3-2)10^{34} 1/s•cm^2
- Targets ^{2}H,^{12}C,^{56}Fe,^{207}Pb

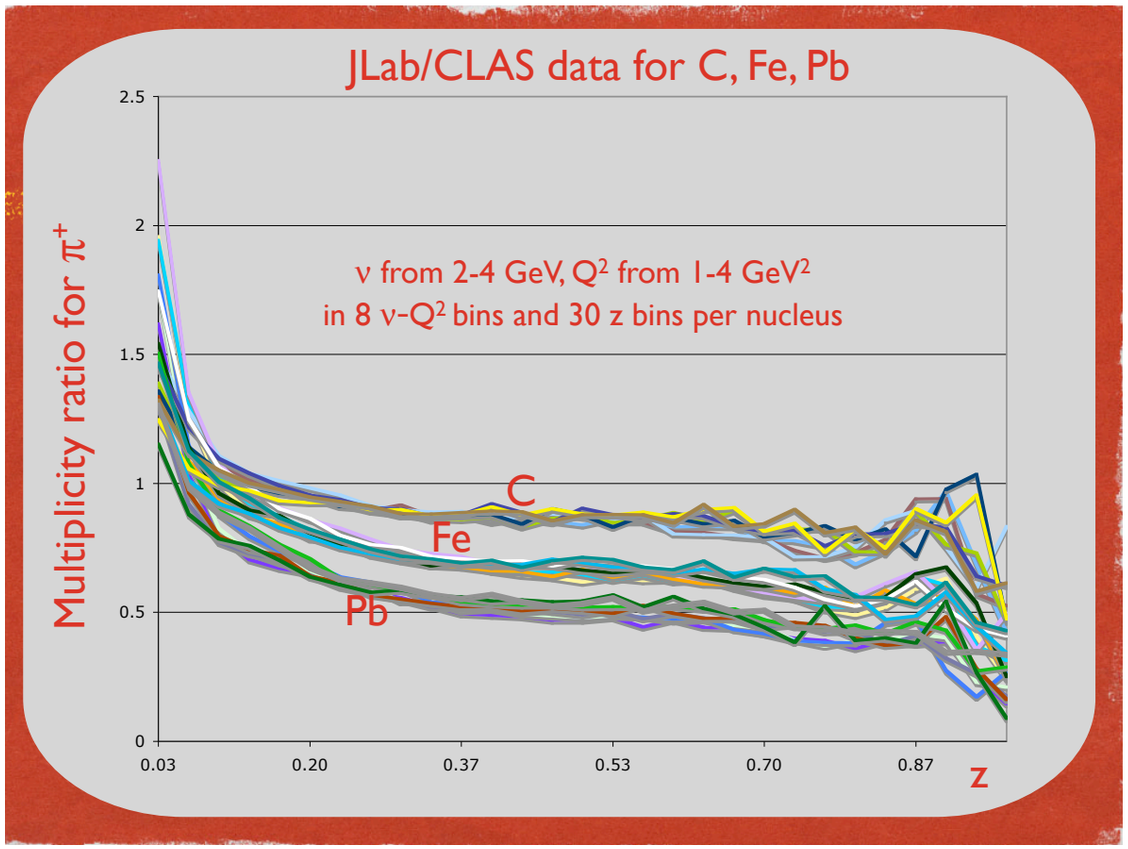
Two targets in the beam simultaneously



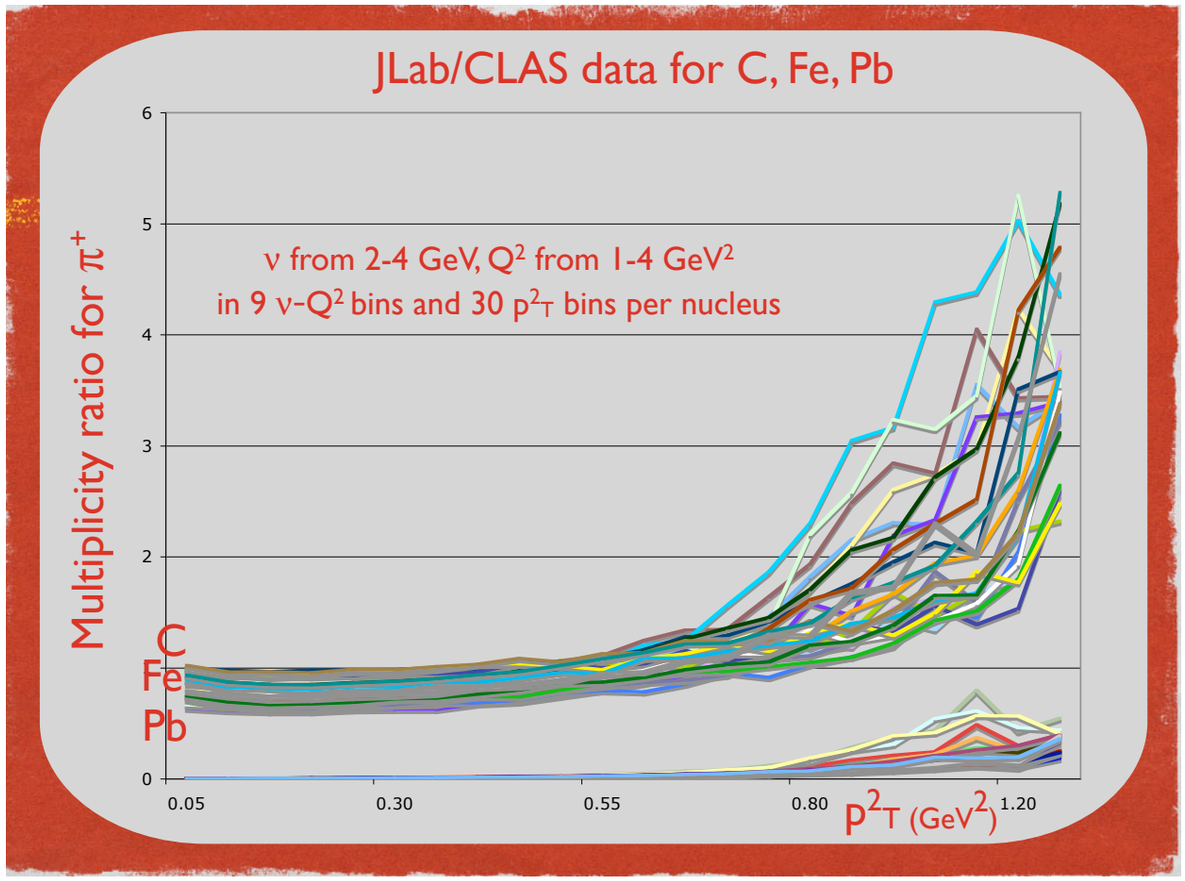


Hadron Attenuation

Hadron Attenuation | π^+



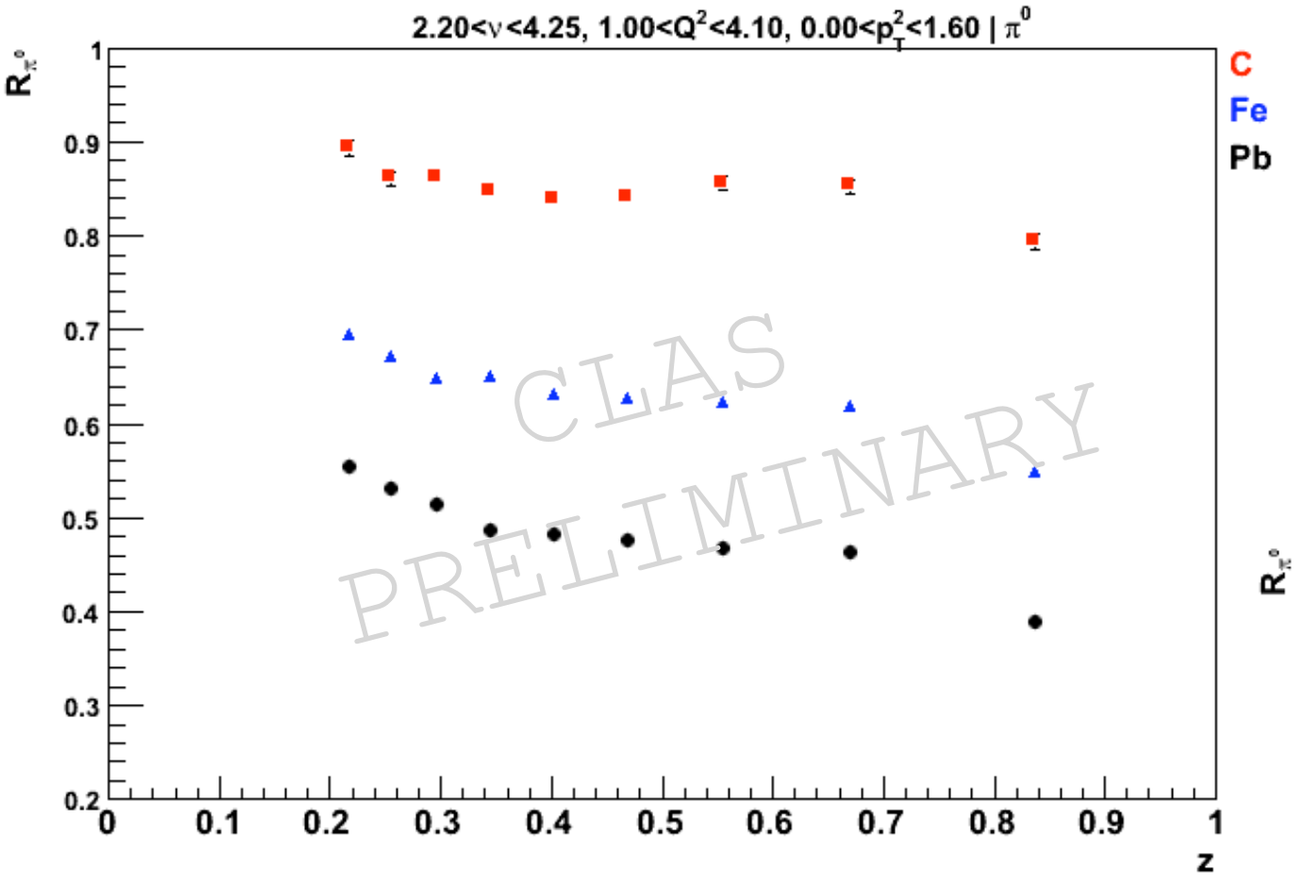
Example of 3D multivariable slices of preliminary CLAS data on π^+



- Quantitative behavior compatible with Hermes
- Attenuation depends on nuclear size
- Increase of hadrons at low z, attenuation at high z
- Bears resemblance to Cronin effect at high p_T^2

Analysis by H.Hakobyan

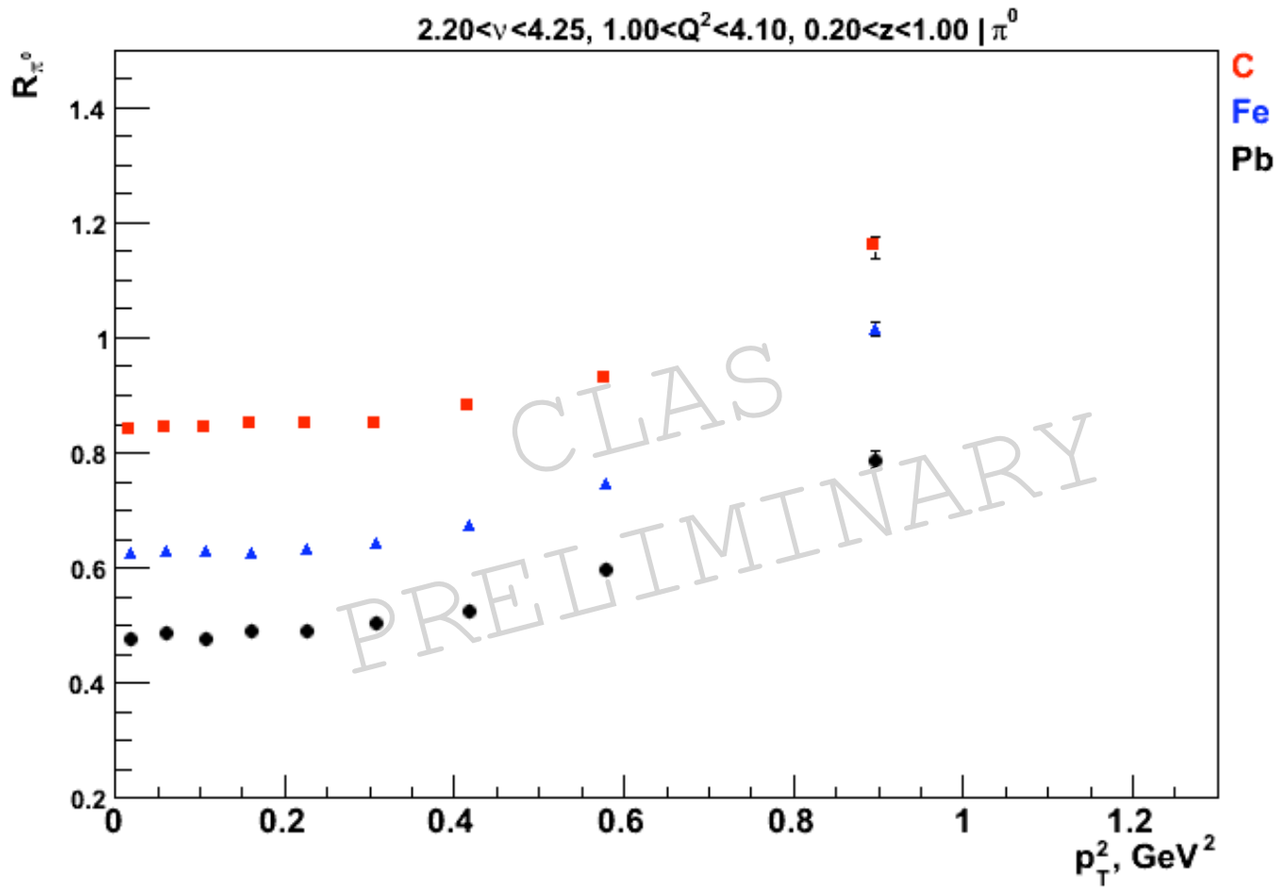
Hadron Attenuation | π^0



1D preliminary CLAS data on π^0

2D and 3D π^0 analysis are on the way

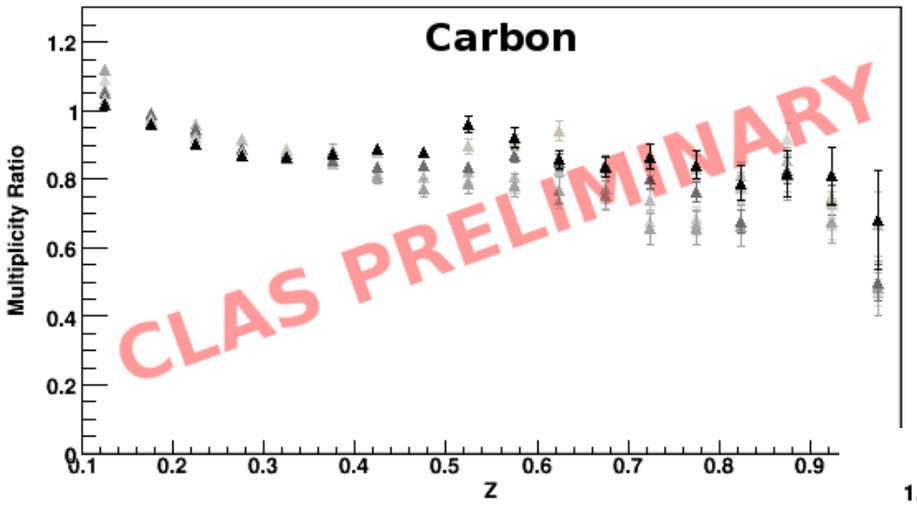
access to eta meson multiplicities



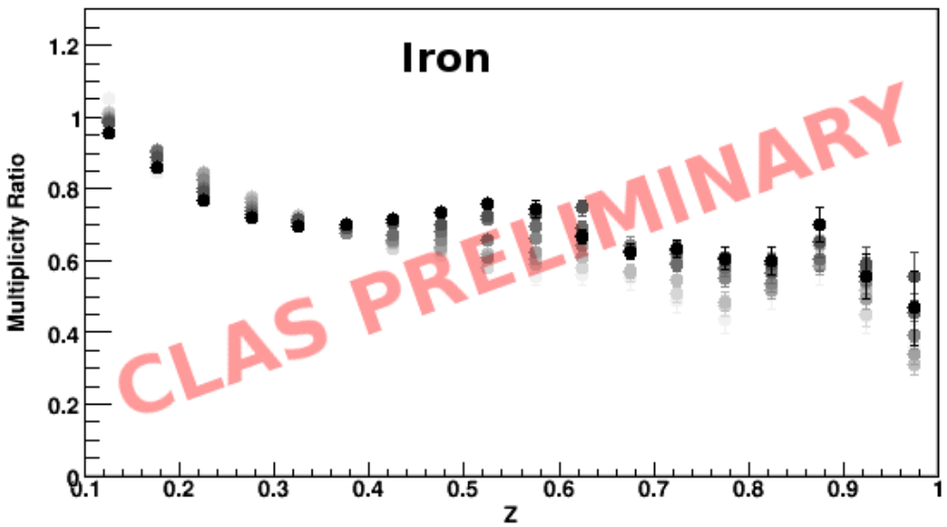
- Results are not corrected for acceptance and radiative effects
- Include statistical errors only

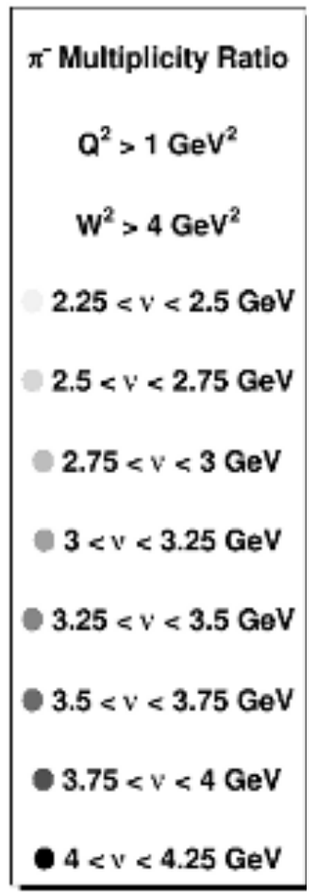
Analysis by T.Mineeva

Hadron Attenuation | π^-

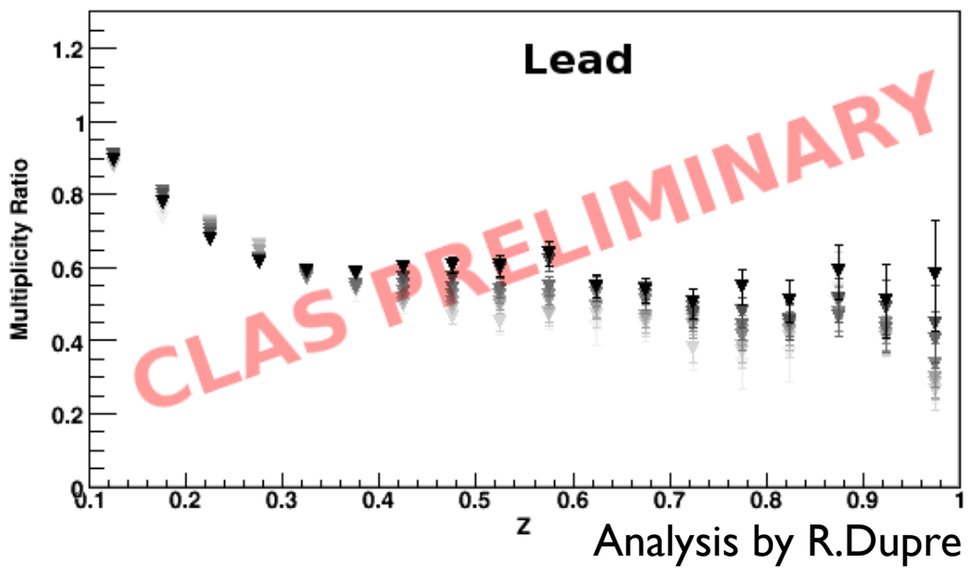


Example of 2D preliminary CLAS data on π^-



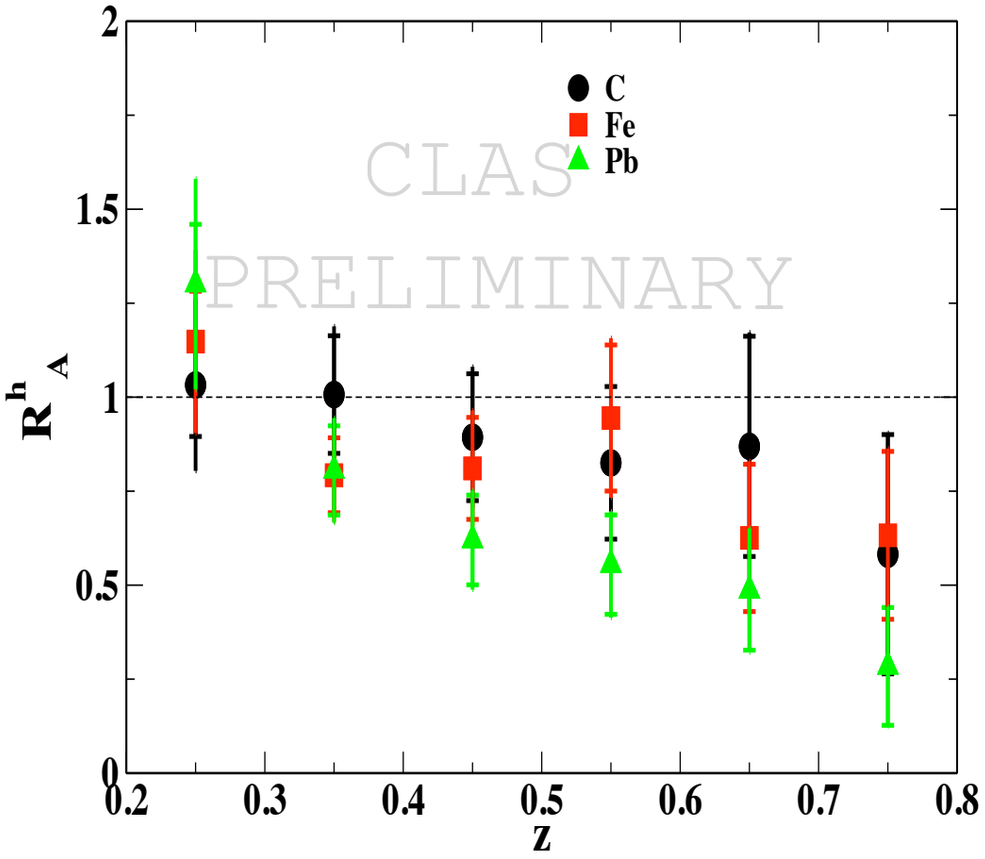


- Results are not corrected for acceptance and radiative effects
- Include statistical errors only

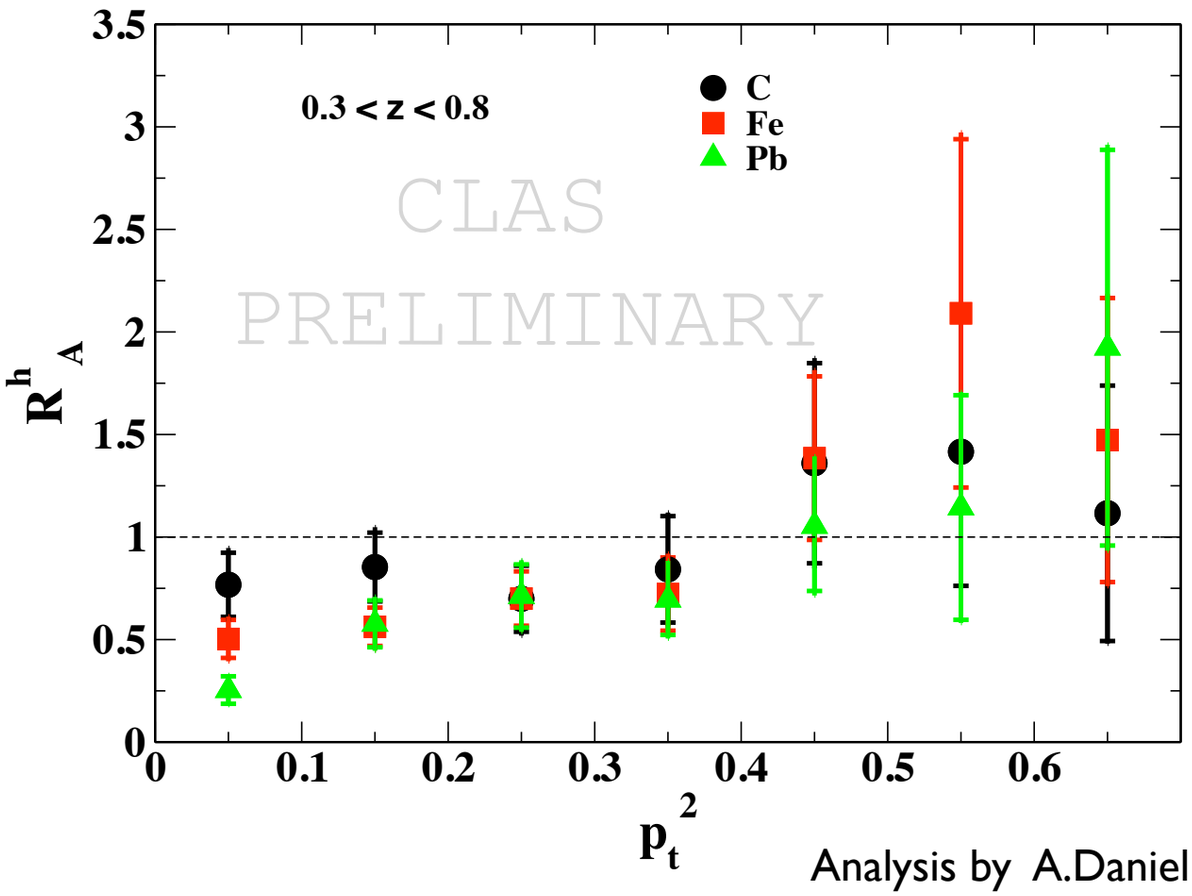


Analysis by R.Dupre

Hadron Attenuation | K^0_S



1D preliminary CLAS data on K^0

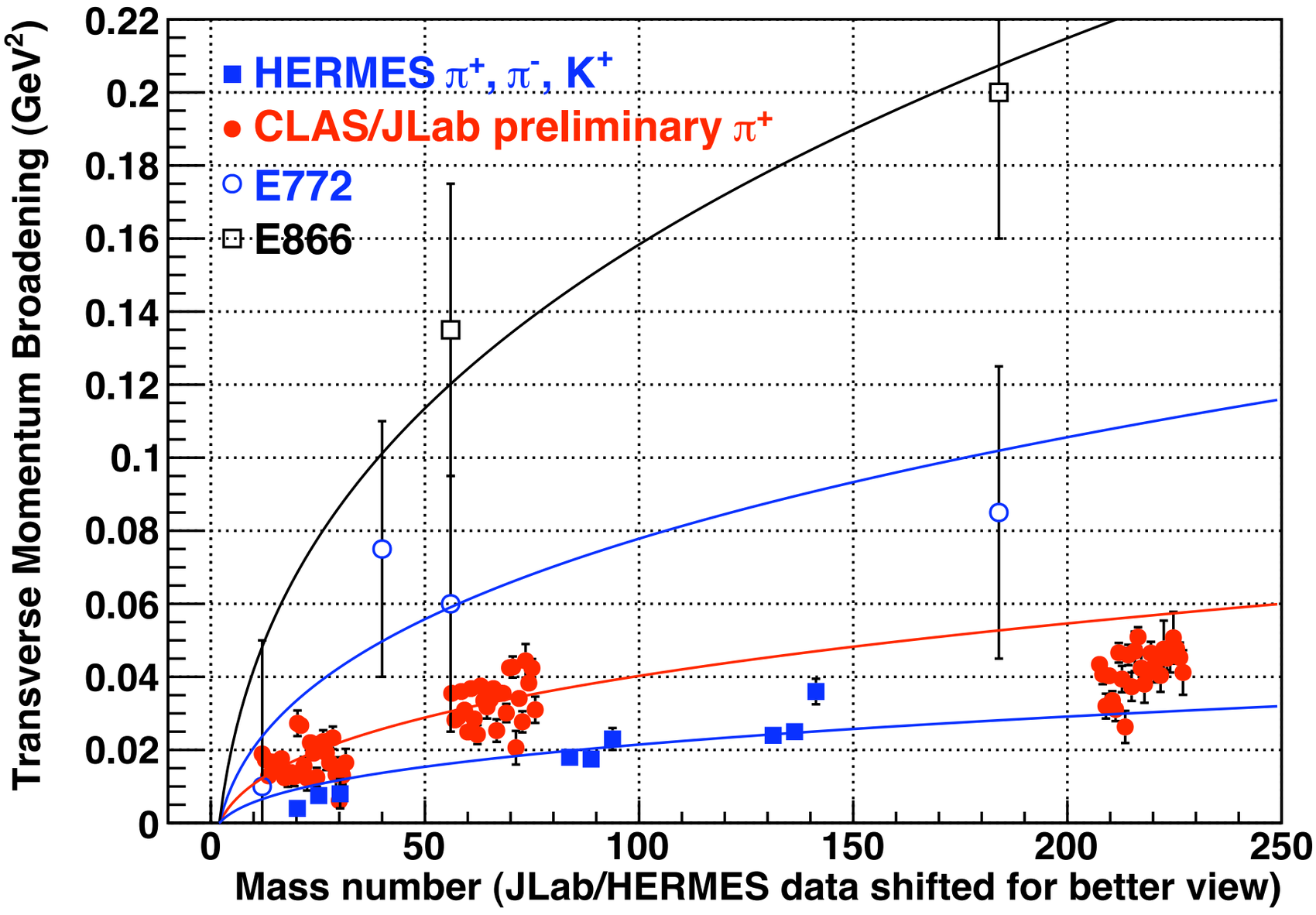


- Results are corrected for acceptance
- Include estimation of radiative effects in systematic uncertainties
- Errors are statistical and systematical

Analysis by A.Daniel

p_T Broadening

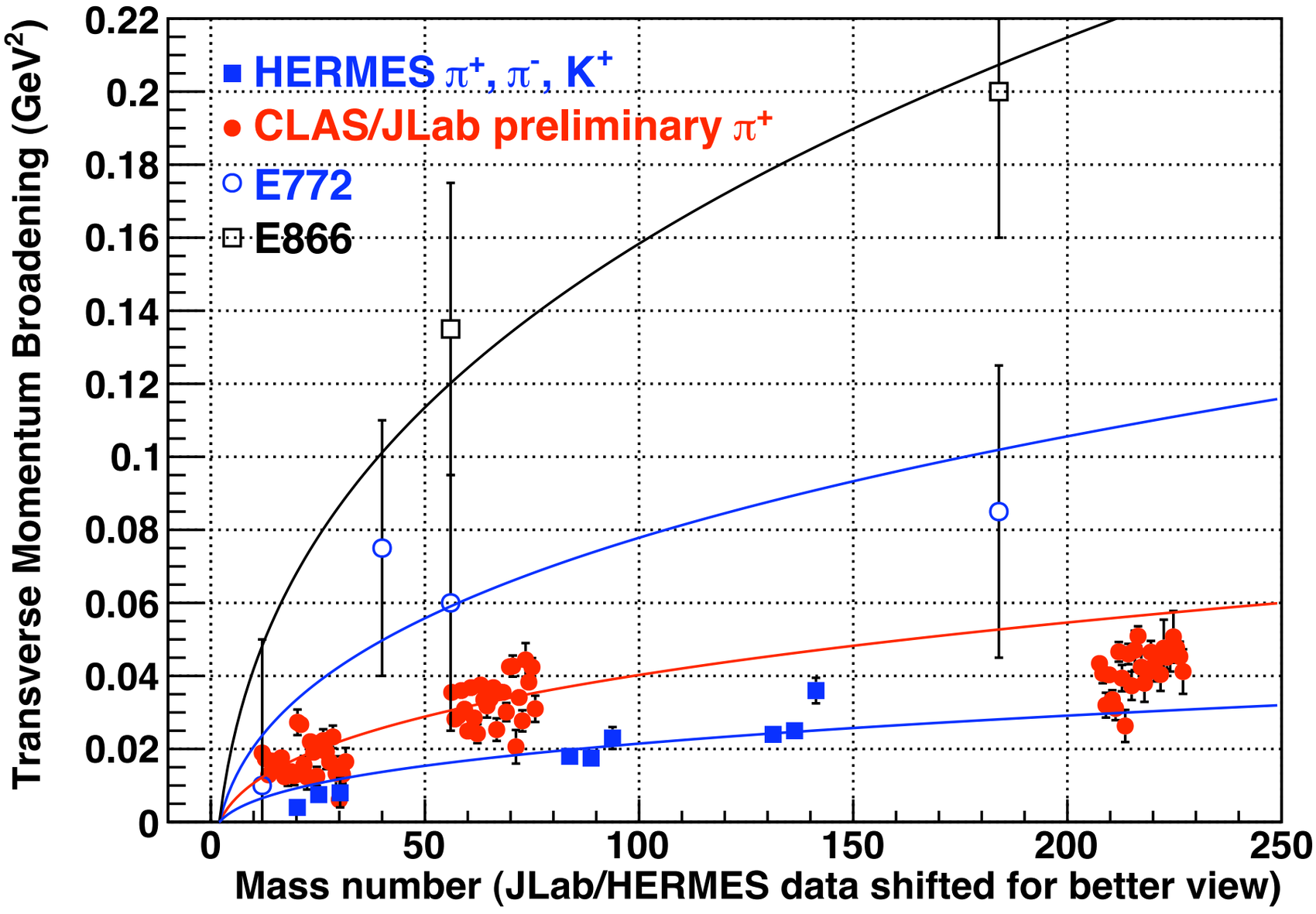
Drell-Yan and DIS comparison



W.Brooks, H.Hakobyan arxiv.0907.4606

P_T BROADENING | π^+

Drell-Yan and DIS comparison



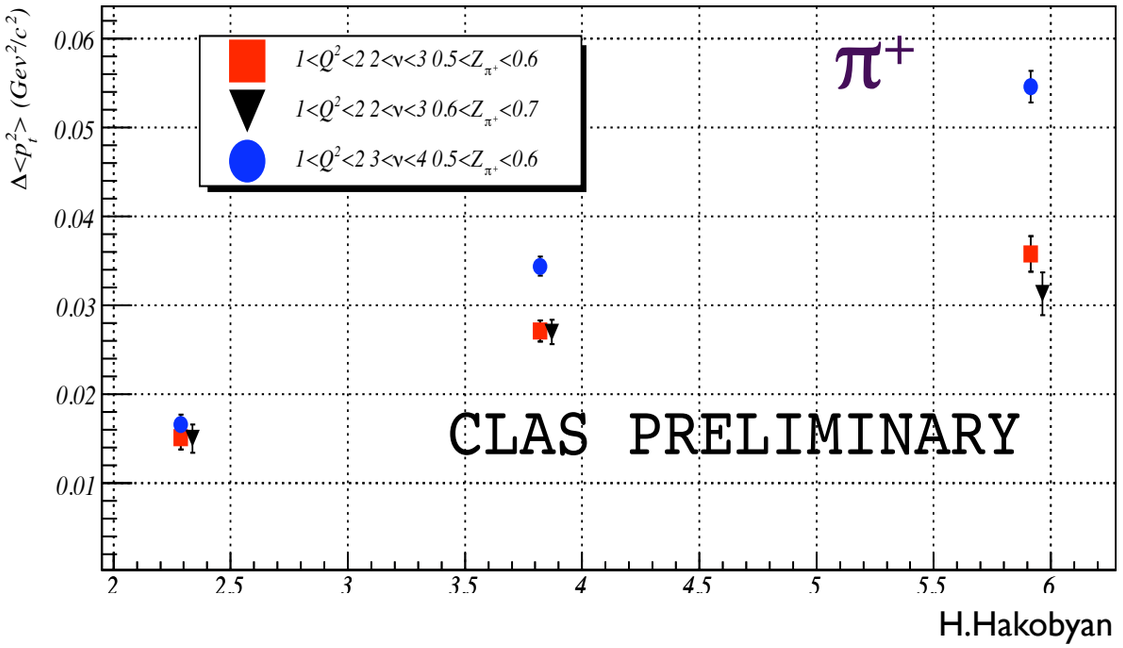
$$\Delta p_T^2 \approx z_h^2 \Delta k_T^2$$

CLAS
0.4 < z < 0.7

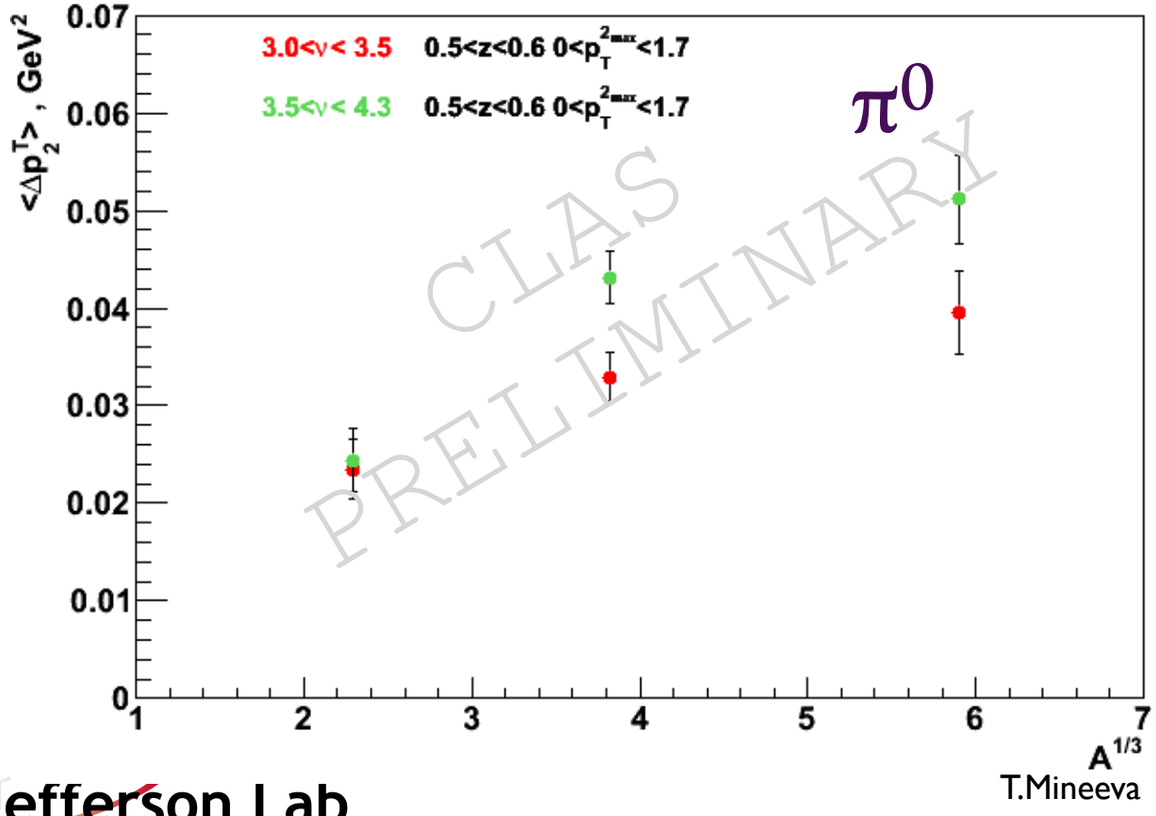
HERMES
z>0.2

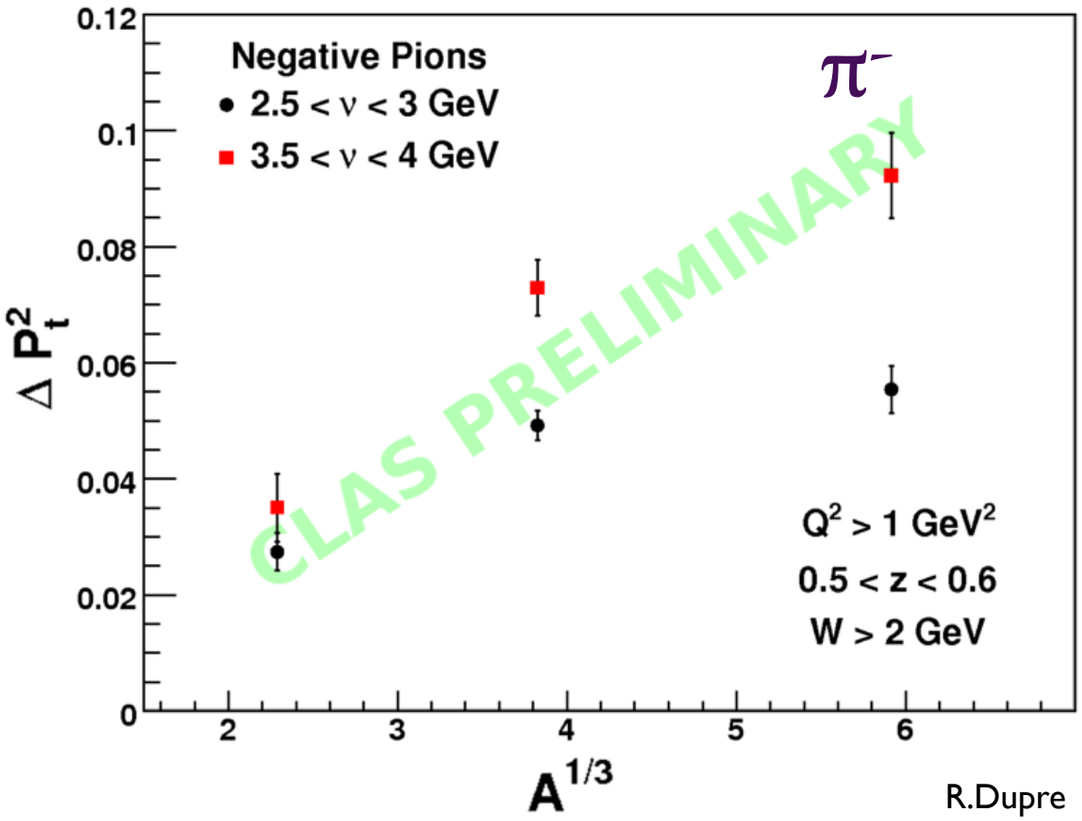
W.Brooks, H.Hakobyan arxiv.0907.4606

P_T BROADENING | π^+ π^0 π^-



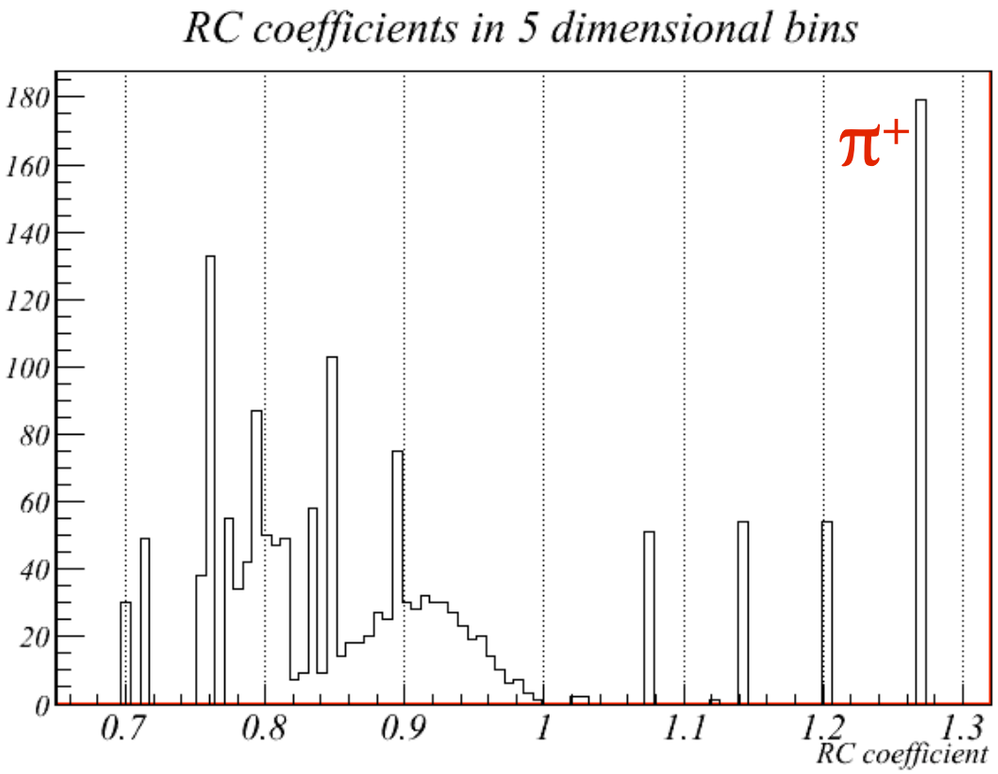
- Results are not corrected for acceptance, radiation
- Include statistical errors only
- π^0 requires a further study of resolution effects



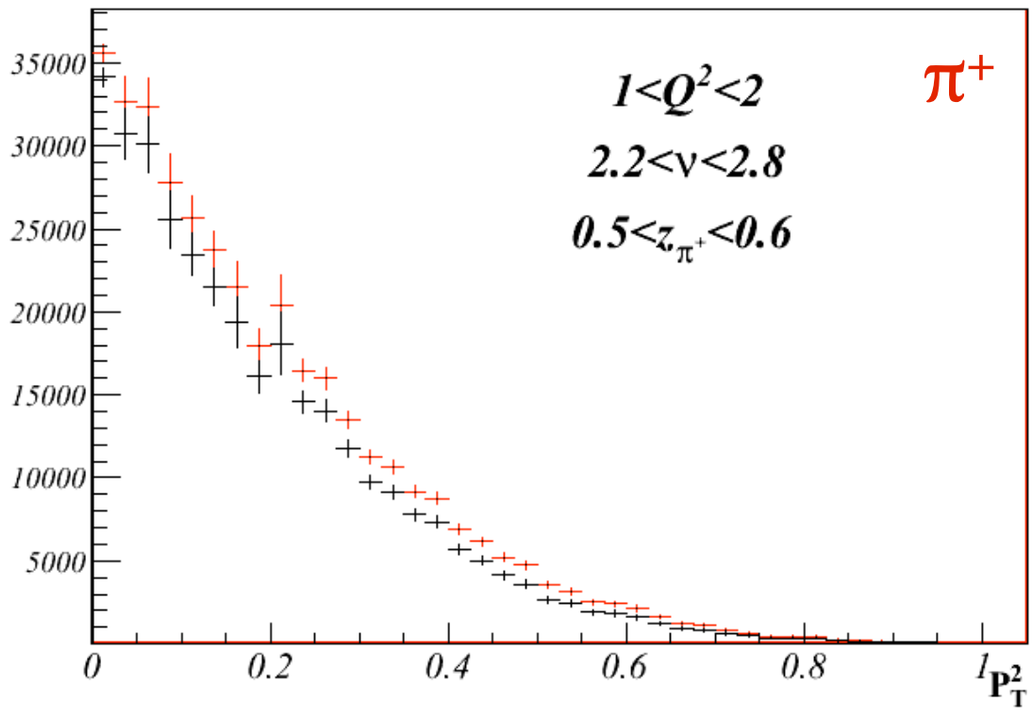


Radiative Corrections

HAPRAD_CPP = HAPRAD(2) + Modified structure fnc from fit(x, Q^2, z, p_T, φ) to CLAS data



Distribution of the RC coefficients calculated for 3(Q^2)x3(ν)x3(z)x60(p_T)xφ(12) equidistant points



p_T^2 without radiative correction (red) and the same with radiative correction (black)

HAPRAD_CPP code: https://github.com/usm-data-analysis/HAPRAD_cpp

Radiative Effects in the Processes of Hadron Electroproduction. I.Akushevich, N.Shumeiko, A.Soroko. Eur. Phys. J. C10, 681-687 (1999).

Lowest order QED radiative corrections to five-fold differential cross section of hadron leptoproduction. Phys. Lett. B 672 35-44 (2009).

H.Hakobyan

FUTURE

Near term data

- LHC jet quenching; comparison of PbPb vs pp at $\sqrt{s}$ = 2.76 TeV/nucleon
- FNAL E906: 120 GeV Drell-Yan; partonic energy loss extraction

Near decade data

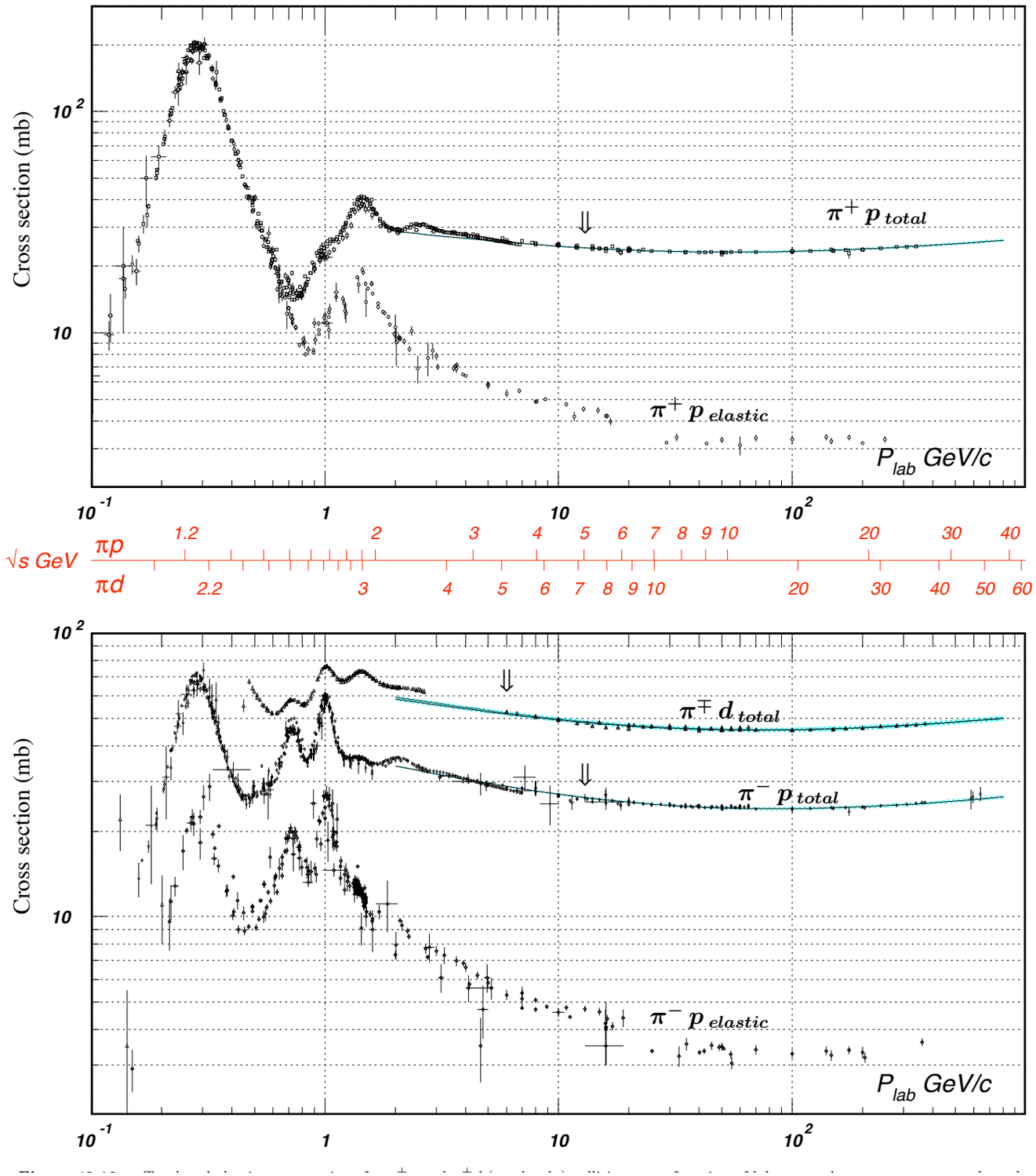
- CLAS@12GeV : $2 < \nu < 9$ GeV; $2 < Q^2 < 9$ GeV^2 ; 10x more luminosity.
  Approved experiment: http://www.jlab.org/exp_prog/proposals/06/PR12-06-117.pdf
- EIC: $100 < E_{lab} < 2000$GeV; $10 < \nu < 1600$ GeV;
  hadron formation outside nuclear medium.

https://eic.jlab.org/wiki/index.php/EA_Parton_propagation_and_fragmentation

Conclusion

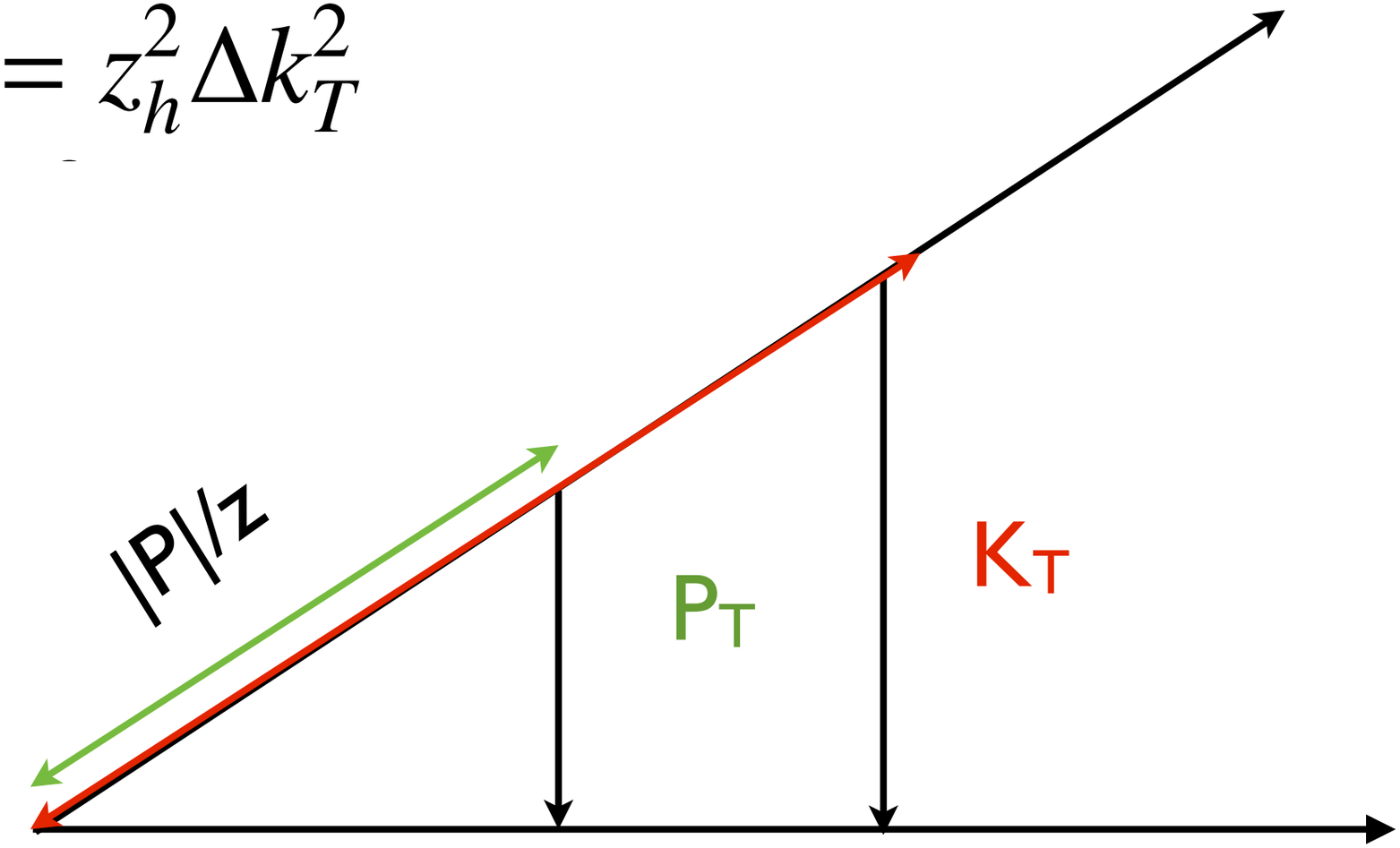
- Preliminary results on multi variable extraction of multiplicities and transverse momentum broadening for π^+ π^0 π^-
- First world data on K^0 multiplicities
- Good consistency of CLAS data set with HERMES results
- Need theoretical framework to extract partonic and hadronic scales in nuclear medium
- CLAS12 gives access to flavor dependence and further multidimensional analysis

Additional Slides


Cross section (mb)
10^2
10
10^{-1}
1
10
10^2
$\pi^+ p_{total}$
$\pi^+ p_{elastic}$
P_{lab} GeV/c
√s GeV
πp
πd
1.2
2
3
4
5
6
7
8
9
10
20
30
40
2.2
3
4
5
6
7
8
9
10
20
30
40
50
60
$\pi^\mp d_{total}$
$\pi^- p_{total}$
$\pi^- p_{elastic}$

z-scaling of Δp_T^2

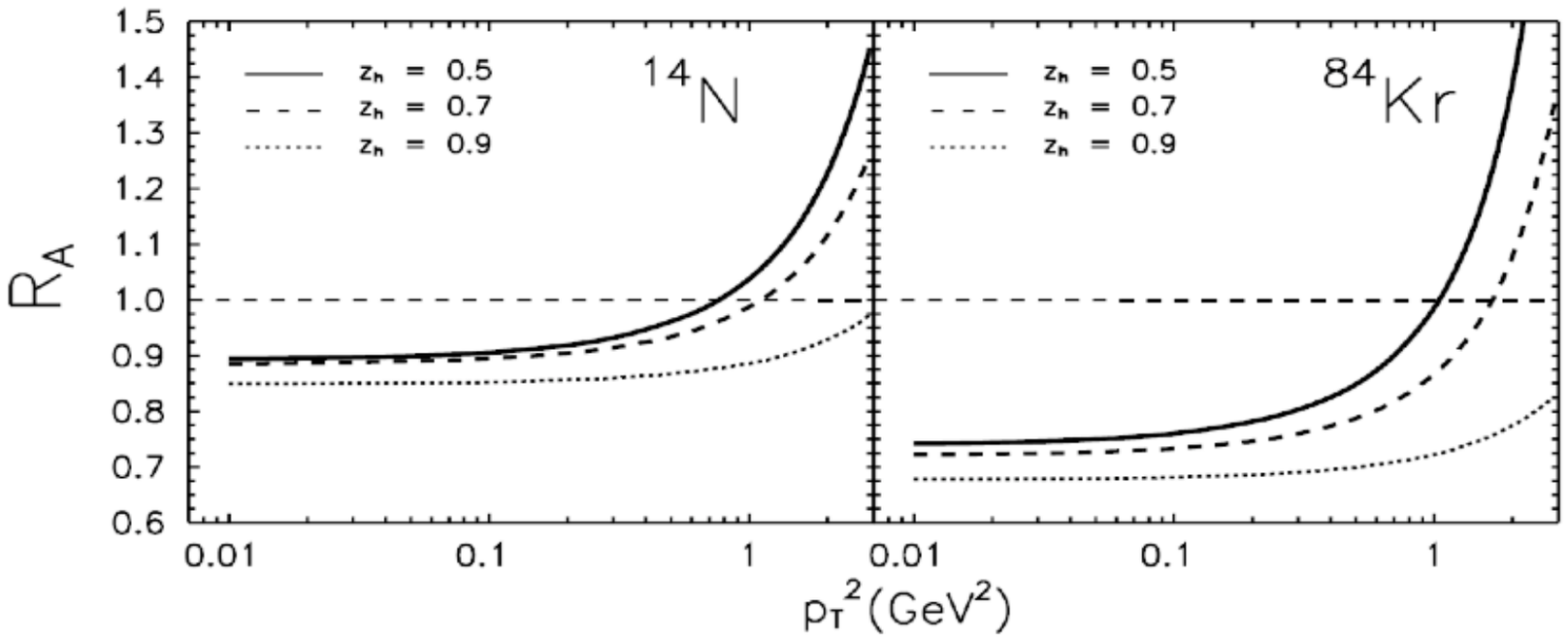
$$\Delta p_T^2 = z_h^2 \Delta k_T^2$$

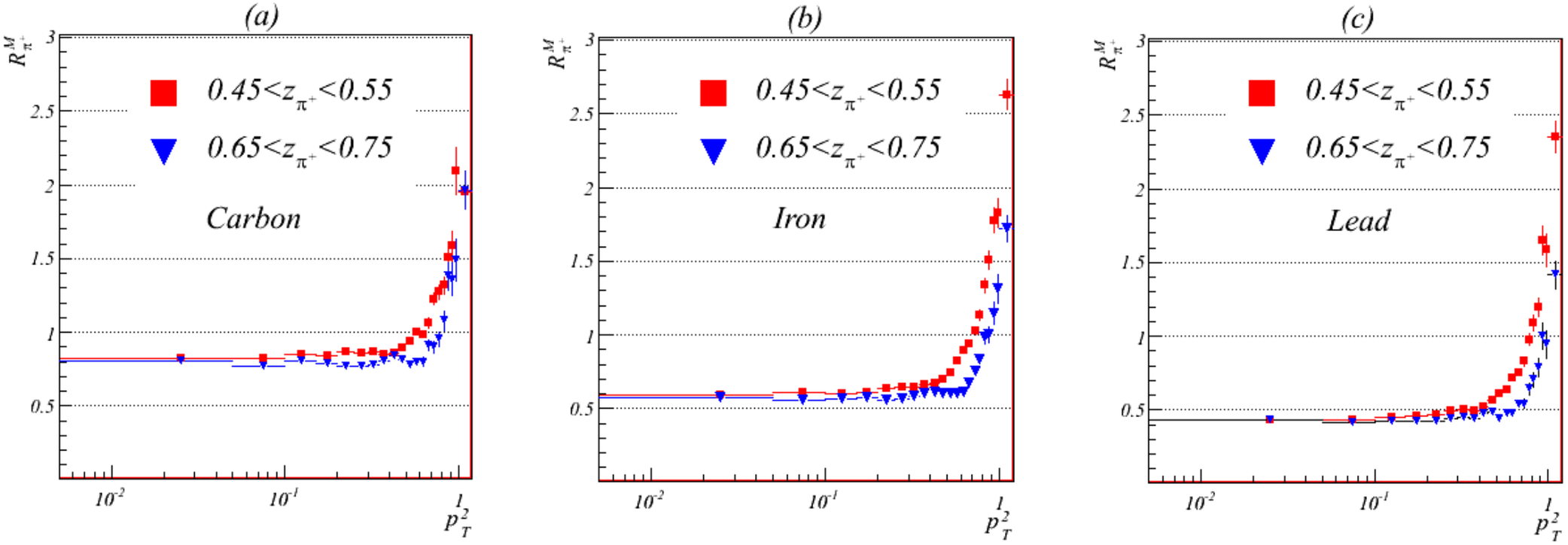


Hadron Attenuation | π^+

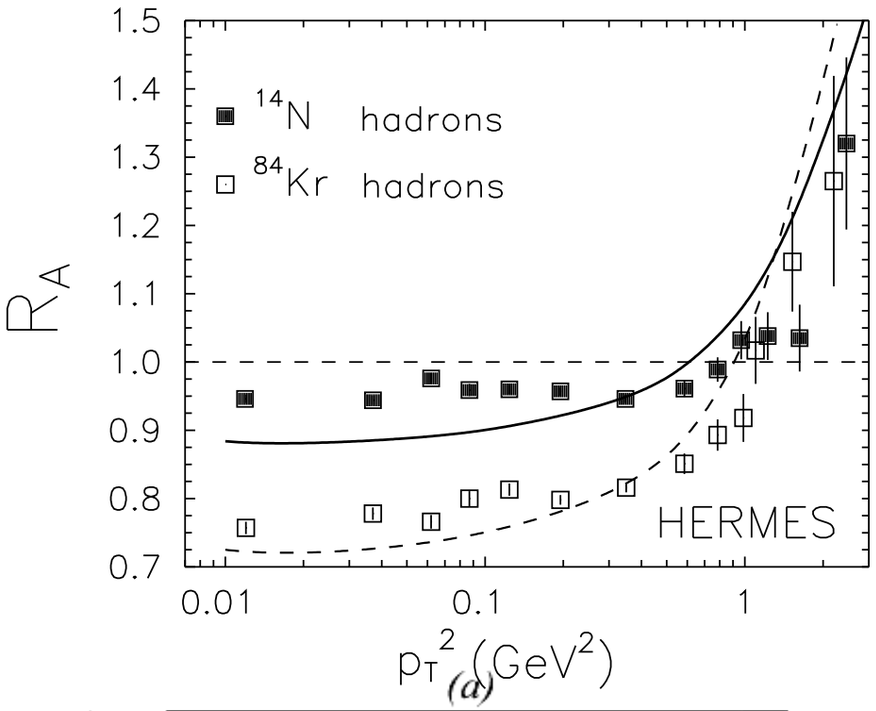
Cronin effect

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

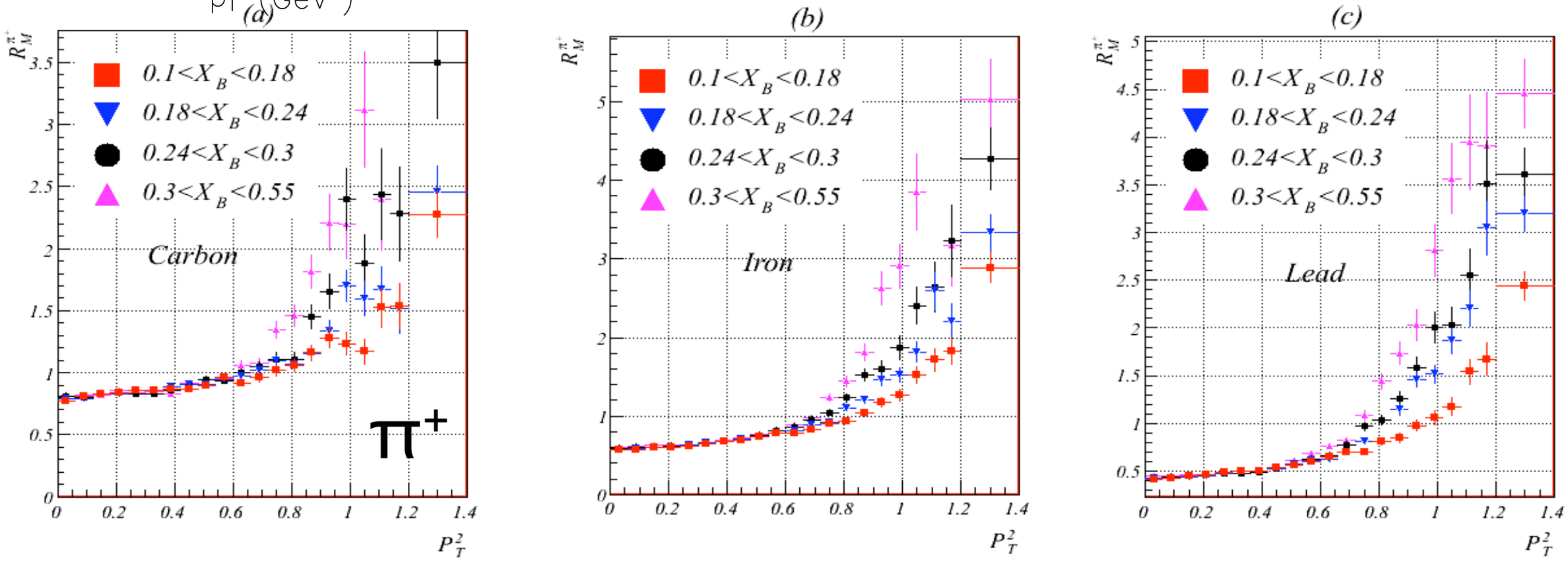




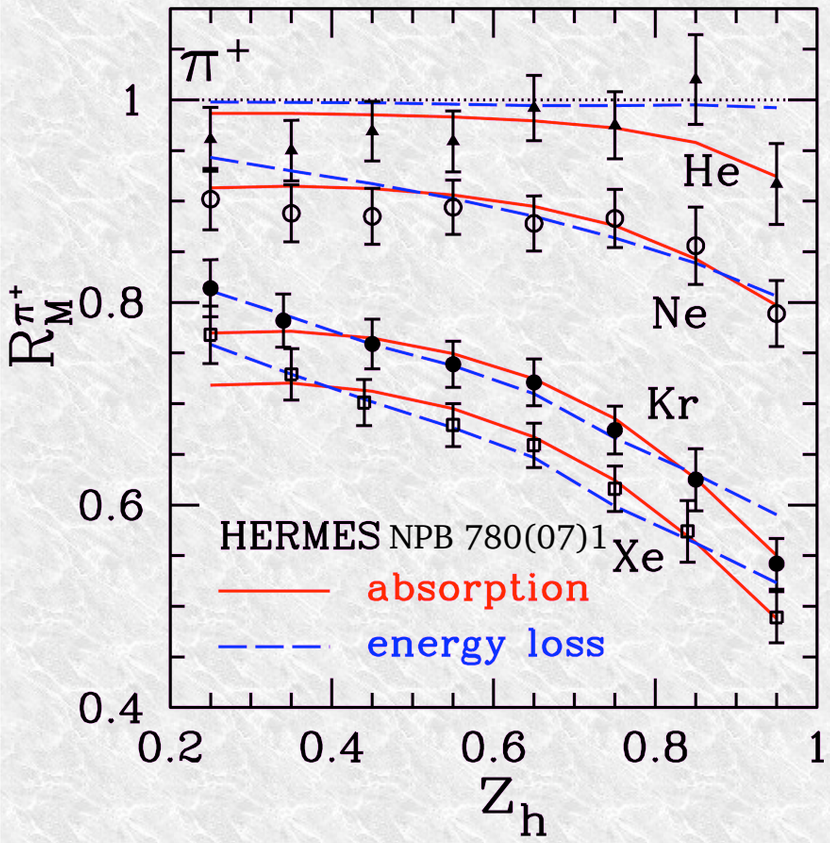
Hadron attenuation (1)



Cronin dependance on xB



1) Hadron quenching vs. z_h



Red: **absorption model**

$(\sigma_p = 0.65\,\sigma_h)$

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

Blue: **energy loss model**
with SW quenching weights

$(\hat{q} = 0.6\ \mathrm{GeV}^2/\mathrm{fm})$

[A.A., Acta.Phys.Hung. '06 & PRC '07]

Both describe the data:
no info on parton lifetime