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Study of heavy flavor hadronization in eA collision via BeAGLE simulation

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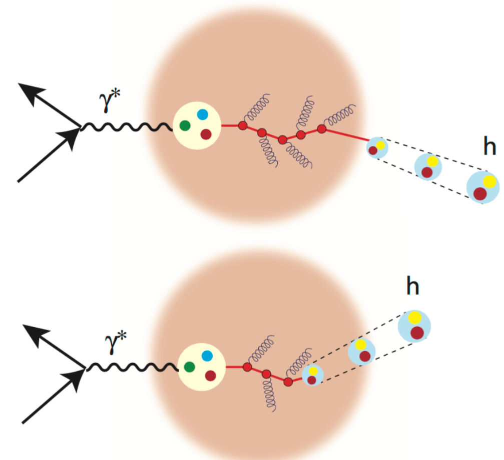
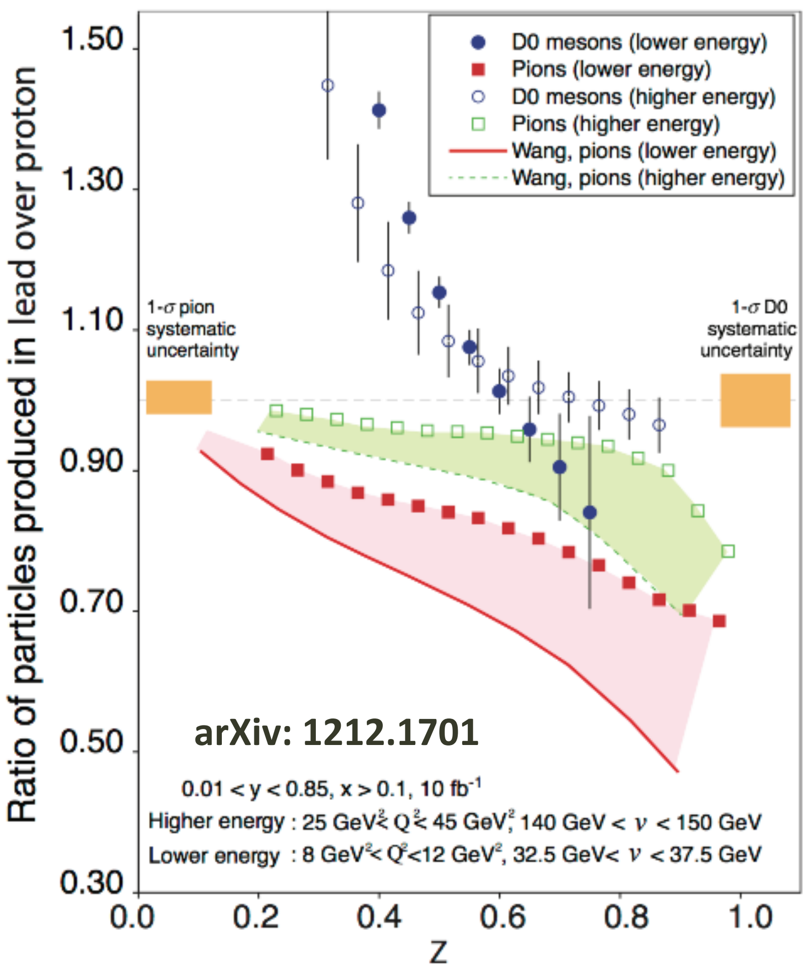
EIC RNC meeting, 06/21/2022

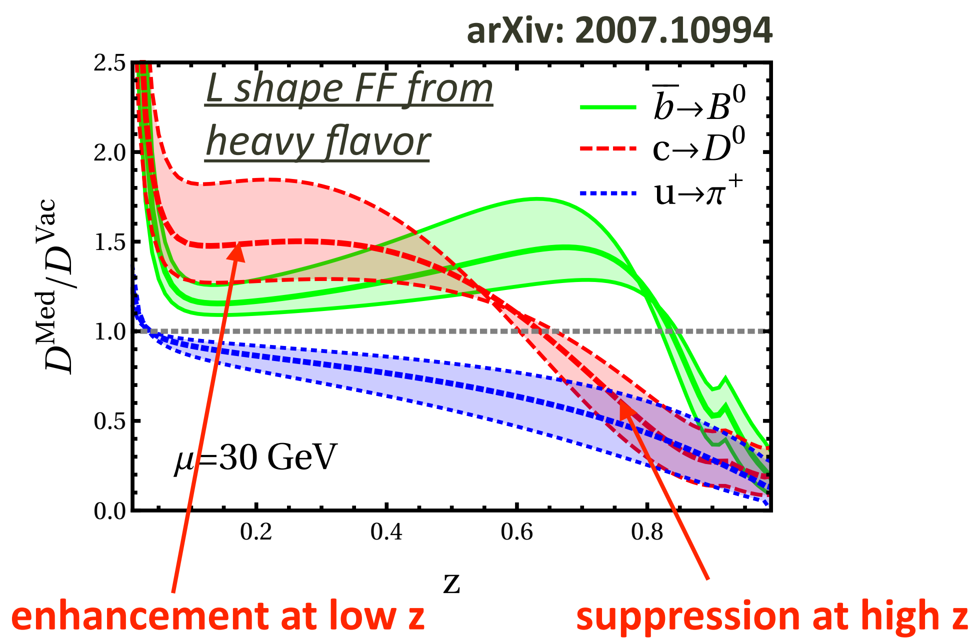
Motivation

- Study nuclear modification of (light and heavy) hadrons in different eA system
  - Hadronization scale
  - Energy loss mechanism inside nucleus

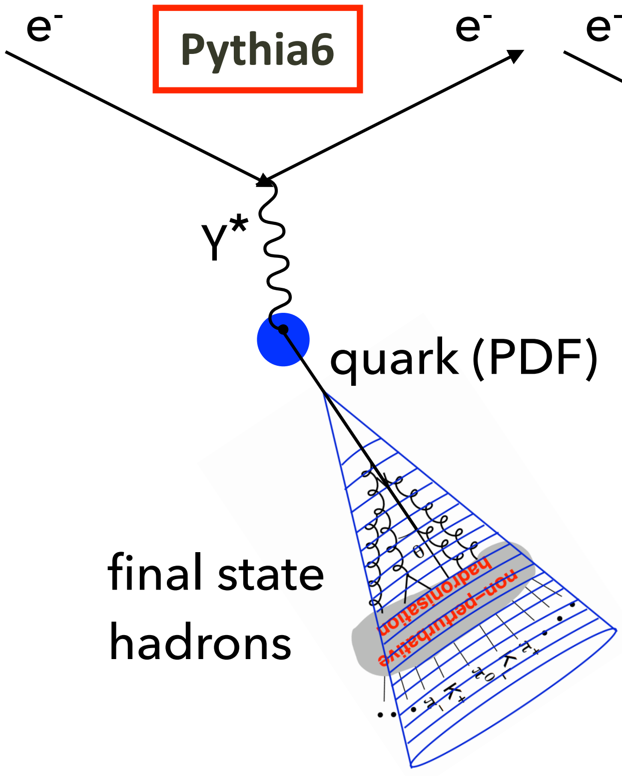


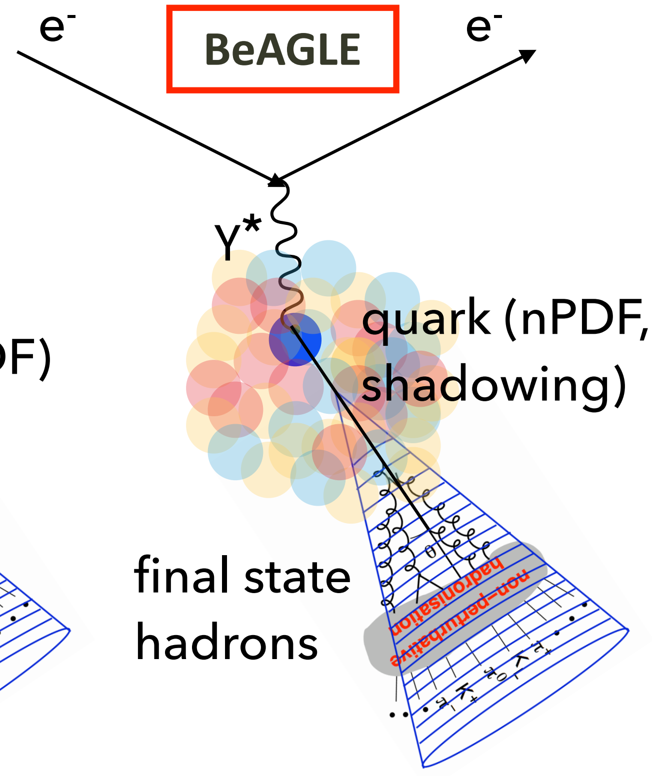
Would be interesting to also look at Λ_c (Eloss on parton level or hadron level or mixed?)





Nuclear modification in e+A events generated by BeAGLE





Fractional energy of the final state hadron z: $z = \frac{P\cdot p}{P\cdot q} \overset{\text{lab}}{=} \frac{E_h}{\nu}$

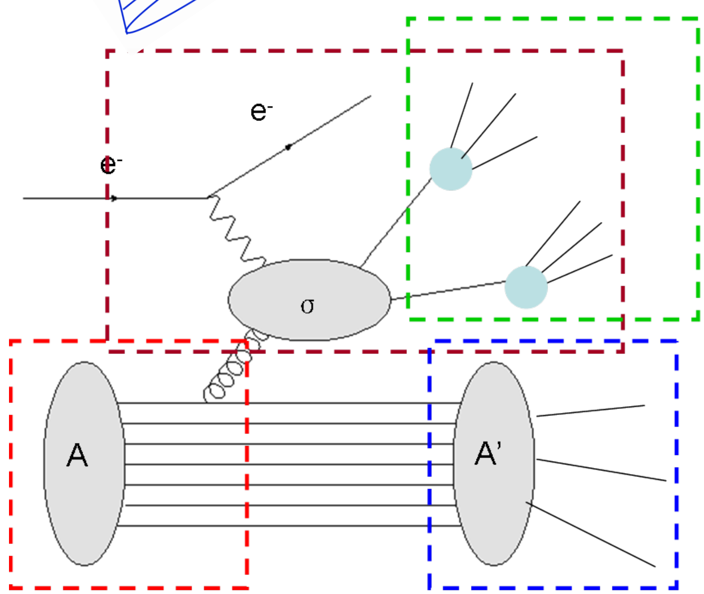
$$R_{eA}(x, Q^2, z) = \frac{\left(\frac{N^h(x,Q^2,z)}{N^e(x,Q^2)}\right)_{e+A}}{\left(\frac{N^h(x,Q^2,z)}{N^e(x,Q^2)}\right)_{e+p}}$$

Cancel out nPDF effect

- PythiaeRHIC (Pythia6) for ep collisions
- BeAGLE for eA collisions
  - **nPDF effect handled by Pythia**

wiki page

arXiv:2204.11998



A hybrid model consisting of DPMJet and PYTHIA with nPDF EPS09.

Nuclear geometry by DPMJet and nPDF provided by EPS09.

Parton level interaction and jet fragmentation completed in PYTHIA.

Nuclear evaporation (gamma dexcitation/nuclear fission/fermi break up) treated by DPMJet

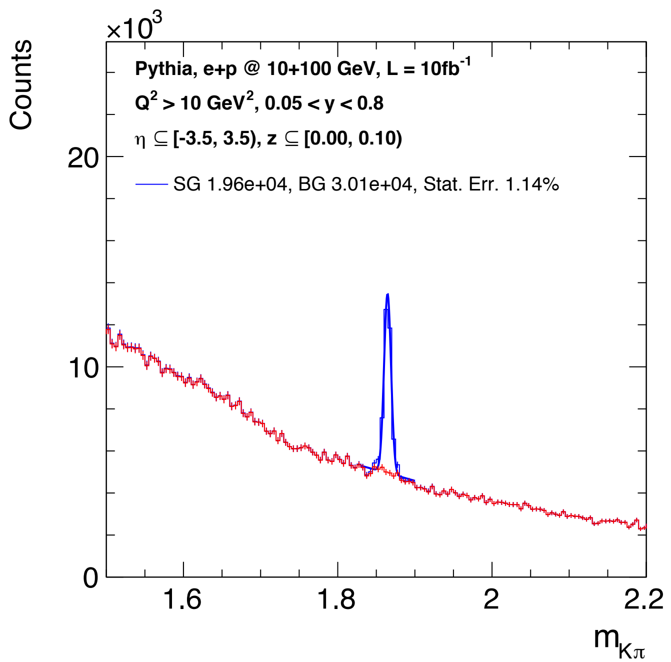
Energy loss effect from routine by Salgado&Wiedemann to simulate the nuclear fragmentation effect in cold nuclear matter

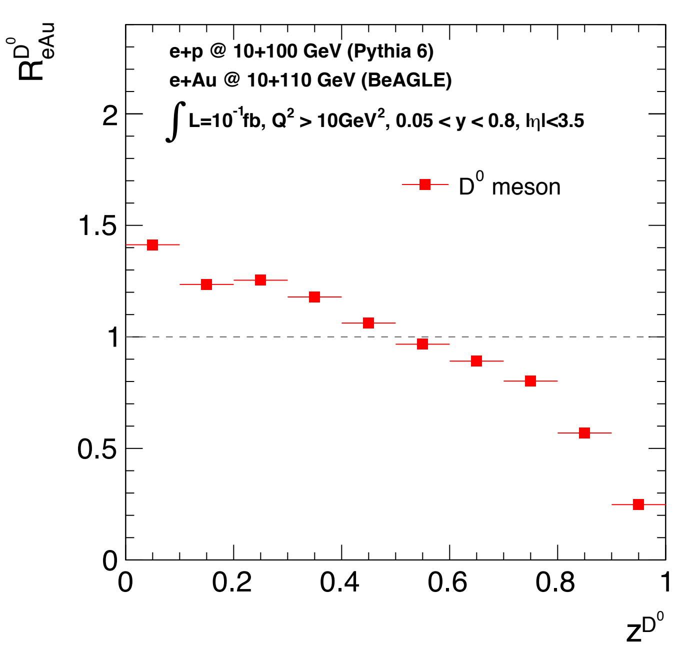
Fast simulation and ATHENA smearing

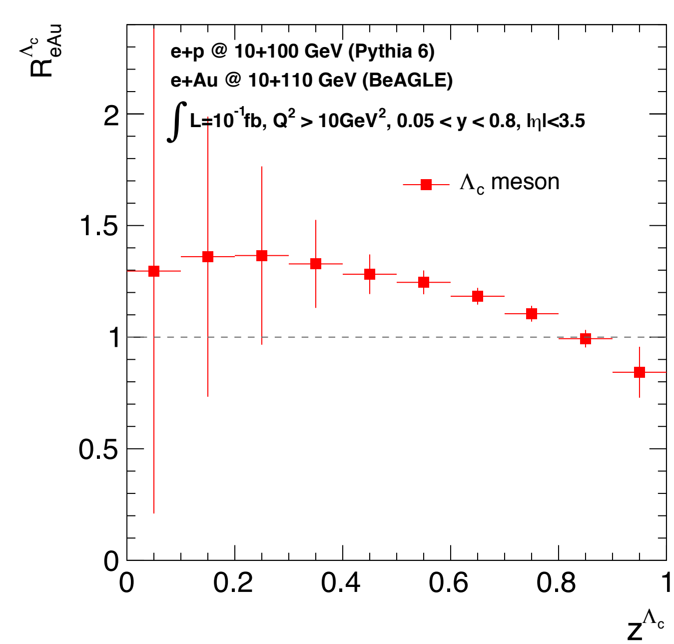
- Single track smearing benchmarked by ATHENA single particle simulation
  - Momentum and vertex position of each track smeared by the correponding resolution from full simulation
  - Primary vertex smearing from multi-track fitting (Matt Kelsey's study)
  - Reconstruct D^0 and Λ_c and calculate projected statistical uncertainty

Fractional energy of the final state hadron z: $z = \frac{P \cdot p}{P \cdot q} \overset{\text{lab}}{=} \frac{E_h}{\nu}$

$$R_{eA}(x, Q^2, z) = \frac{\left(\frac{N^h(x,Q^2,z)}{N^e(x,Q^2)}\right)_{e+A}}{\left(\frac{N^h(x,Q^2,z)}{N^e(x,Q^2)}\right)_{e+p}}$$







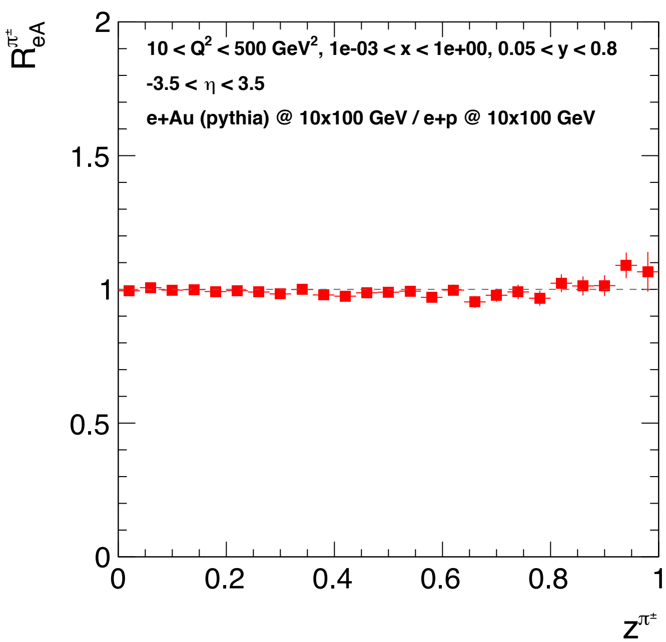
Revisiting the definition of multiplicity ratio and z

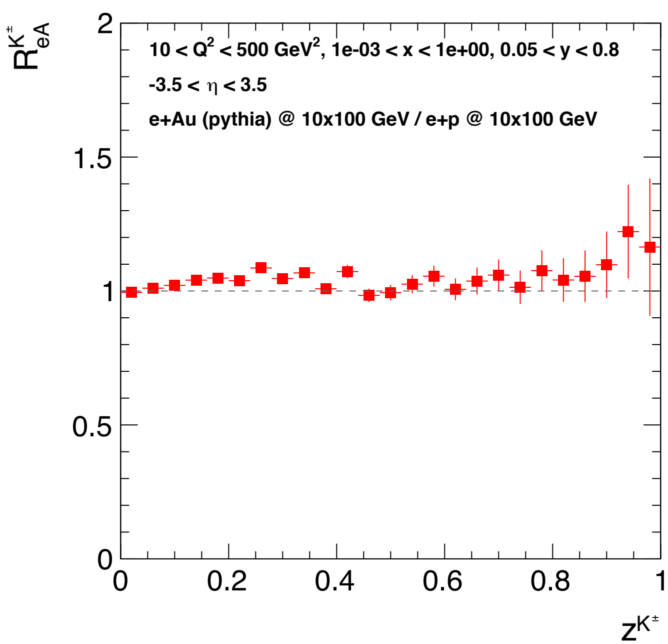
- Minimize intial state effect with double ratio
  - Works well for light flavor hadrons

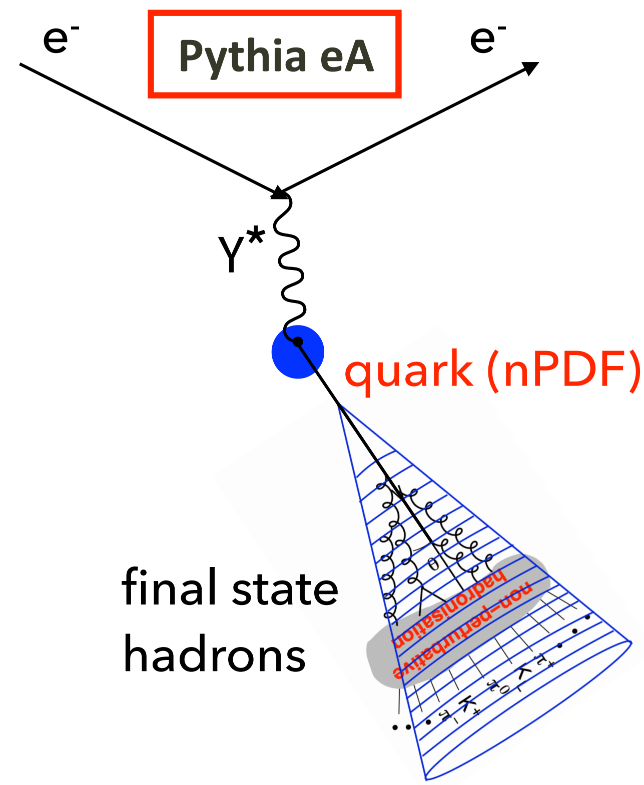
$$R_{eA}(x,Q^2,z) = \frac{\left(\frac{N^h(x,Q^2,z)}{N^e(x,Q^2)}\right)_{e+A}}{\left(\frac{N^h(x,Q^2,z)}{N^e(x,Q^2)}\right)_{e+p}} = \frac{\frac{N^h(x,Q^2,z)_{e+A}}{N^h(x,Q^2,z)_{e+p}}}{\frac{N^e(x,Q^2)_{e+A}}{N^e(x,Q^2)_{e+p}}}$$

Fractional energy of the final state hadron z: $z = \frac{P\cdot p}{P\cdot q} \overset{\text{lab}}{=} \frac{E_h}{\nu}$

Cancel out nPDF effect

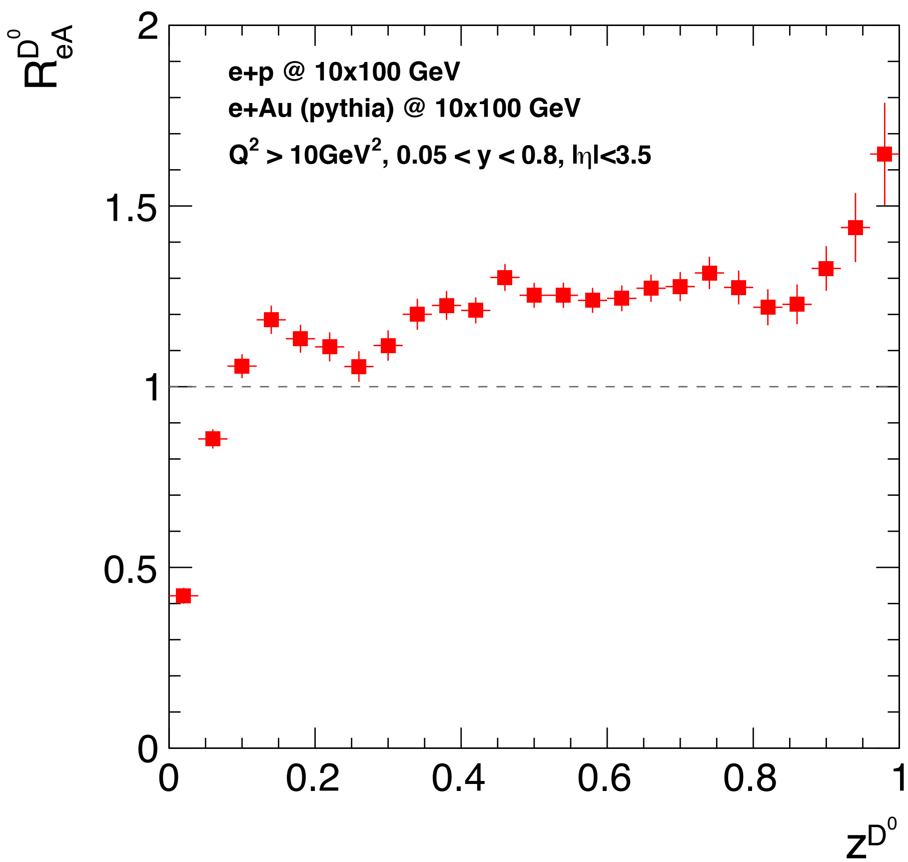


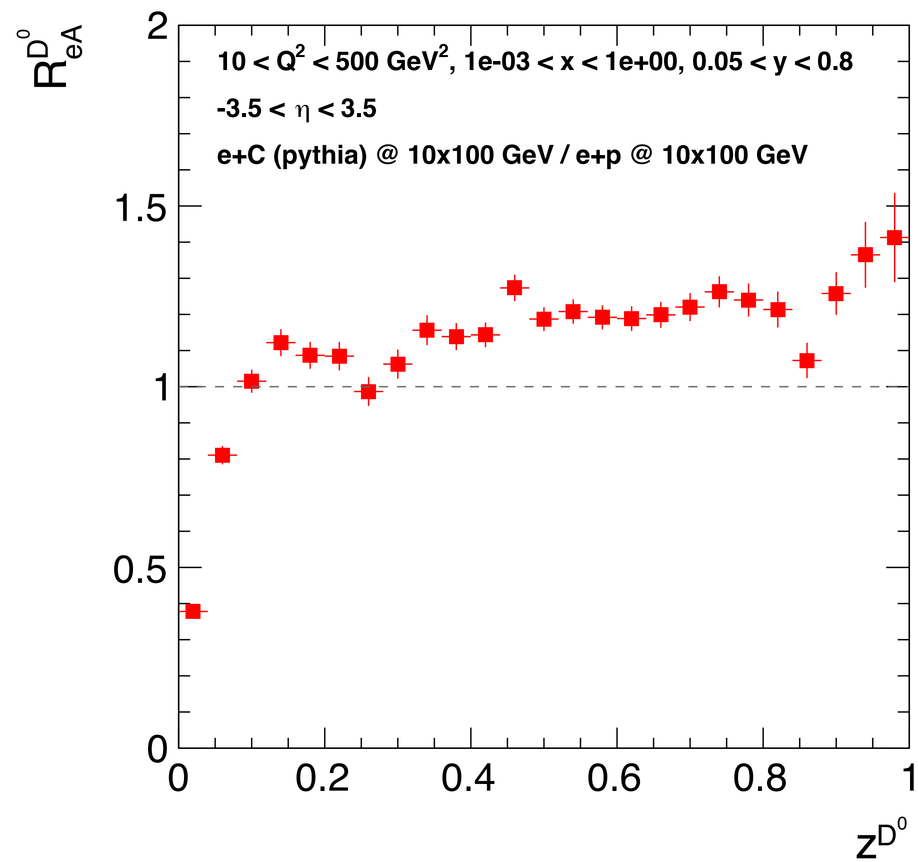




nPDF for different nuclei

- Minimize intial state effect with double ratio
  - Works well for light flavor hadrons
  - Does not work as well for charm hadrons
  - eAu vs eC: different effect from different nuclei nPDF

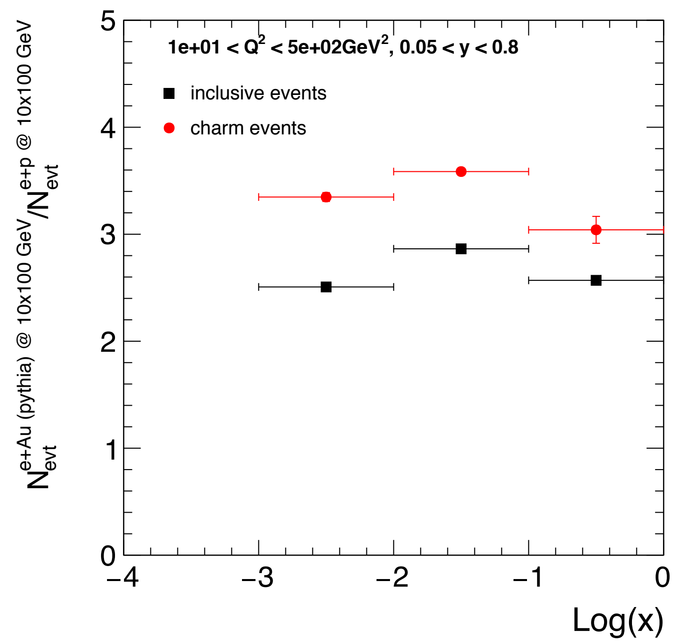


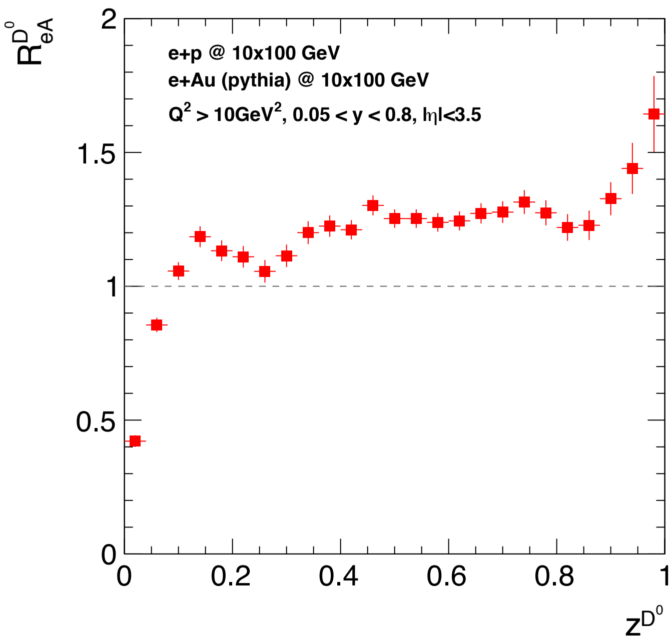


Revisiting the definition of multiplicity ratio and z

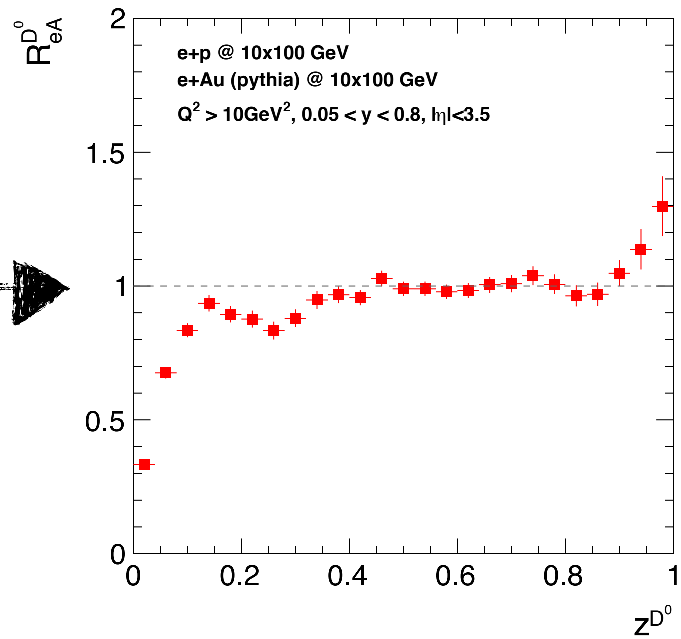
- Minimize intial state effect with double ratio
  - nPDF has different effect on inclusive DIS cross section and charm cross section

$$R_{eA}(x,Q^2,z) = \frac{\left(\frac{N^h(x,Q^2,z)}{N^{c\bar{c}}(x,Q^2)}\right)_{e+A}}{\left(\frac{N^h(x,Q^2,z)}{N^{c\bar{c}}(x,Q^2)}\right)_{e+p}} = \frac{\frac{N^h(x,Q^2,z)_{e+A}}{N^h(x,Q^2,z)_{e+p}}}{\boxed{\frac{N^{c\bar{c}}(x,Q^2)_{e+A}}{N^{c\bar{c}}(x,Q^2)_{e+p}}}} \neq \frac{\frac{N^h(x,Q^2,z)_{e+A}}{N^h(x,Q^2,z)_{e+p}}}{\boxed{\frac{N^e(x,Q^2)_{e+A}}{N^e(x,Q^2)_{e+p}}}}$$



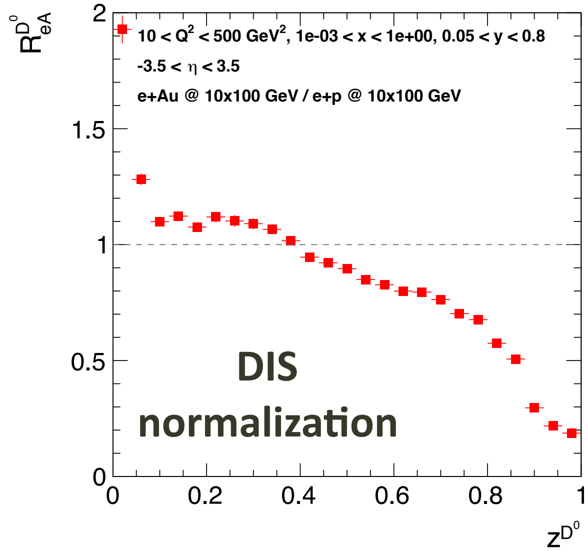


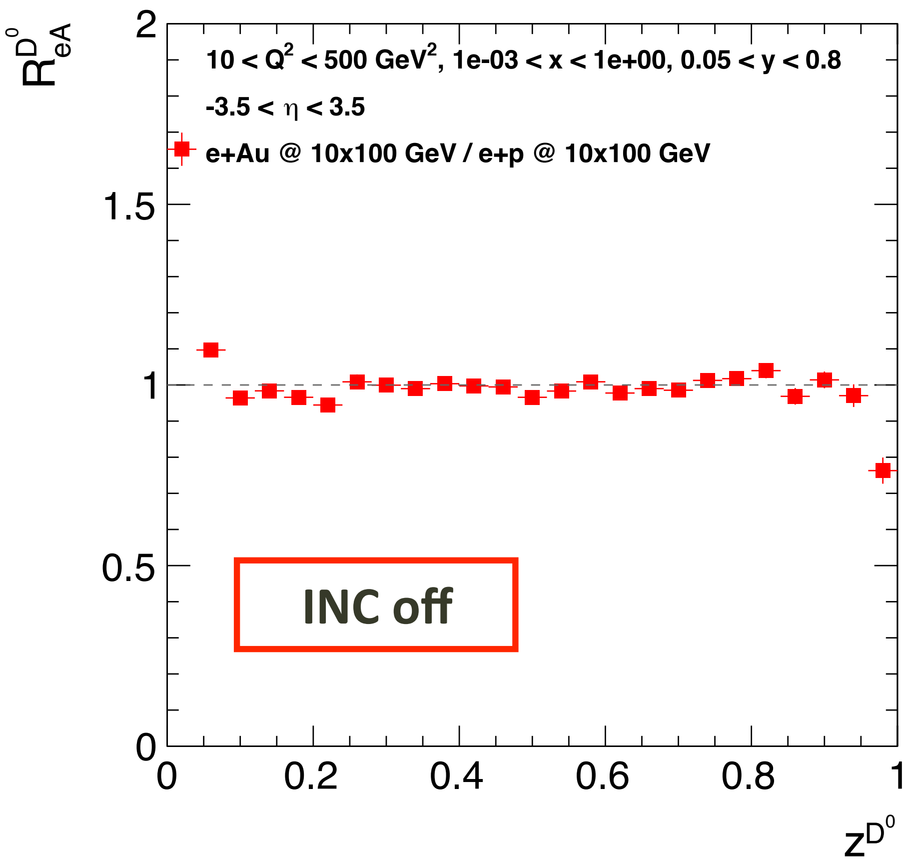
Replacing N_{DIS} by N_{charm}

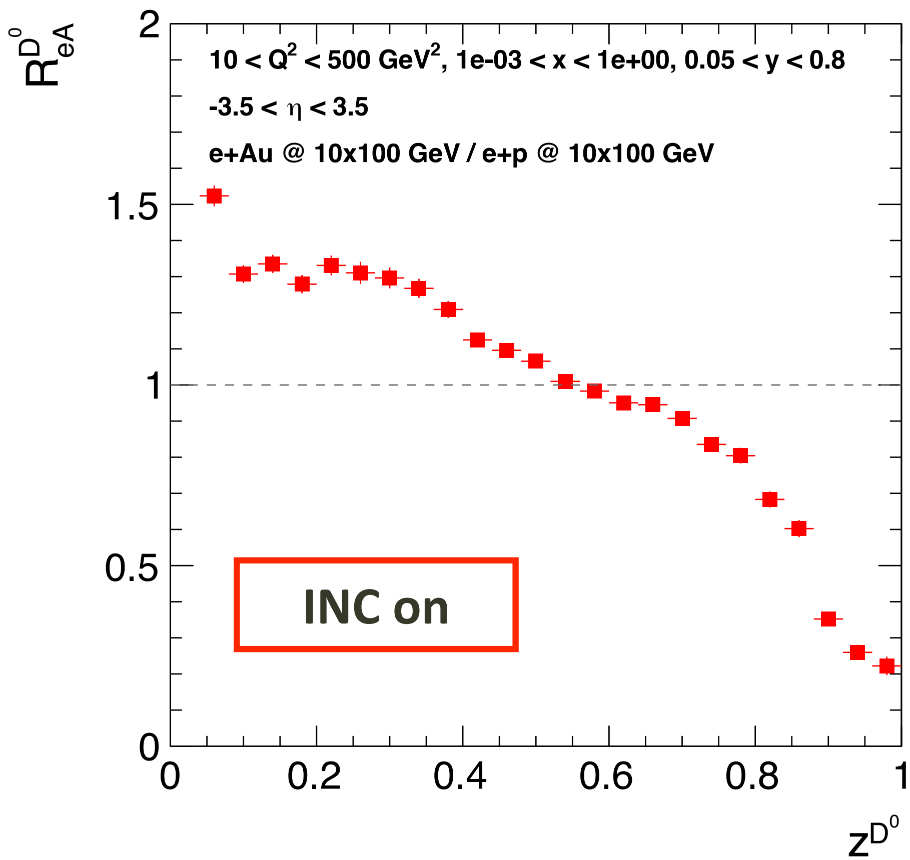


BeAGLE e+Au

- Using new normalization for charm hadrons
  - No energy loss effect in this BeAGLE version
  - Turning Intra-Nuclear Cascade (INC) on and off

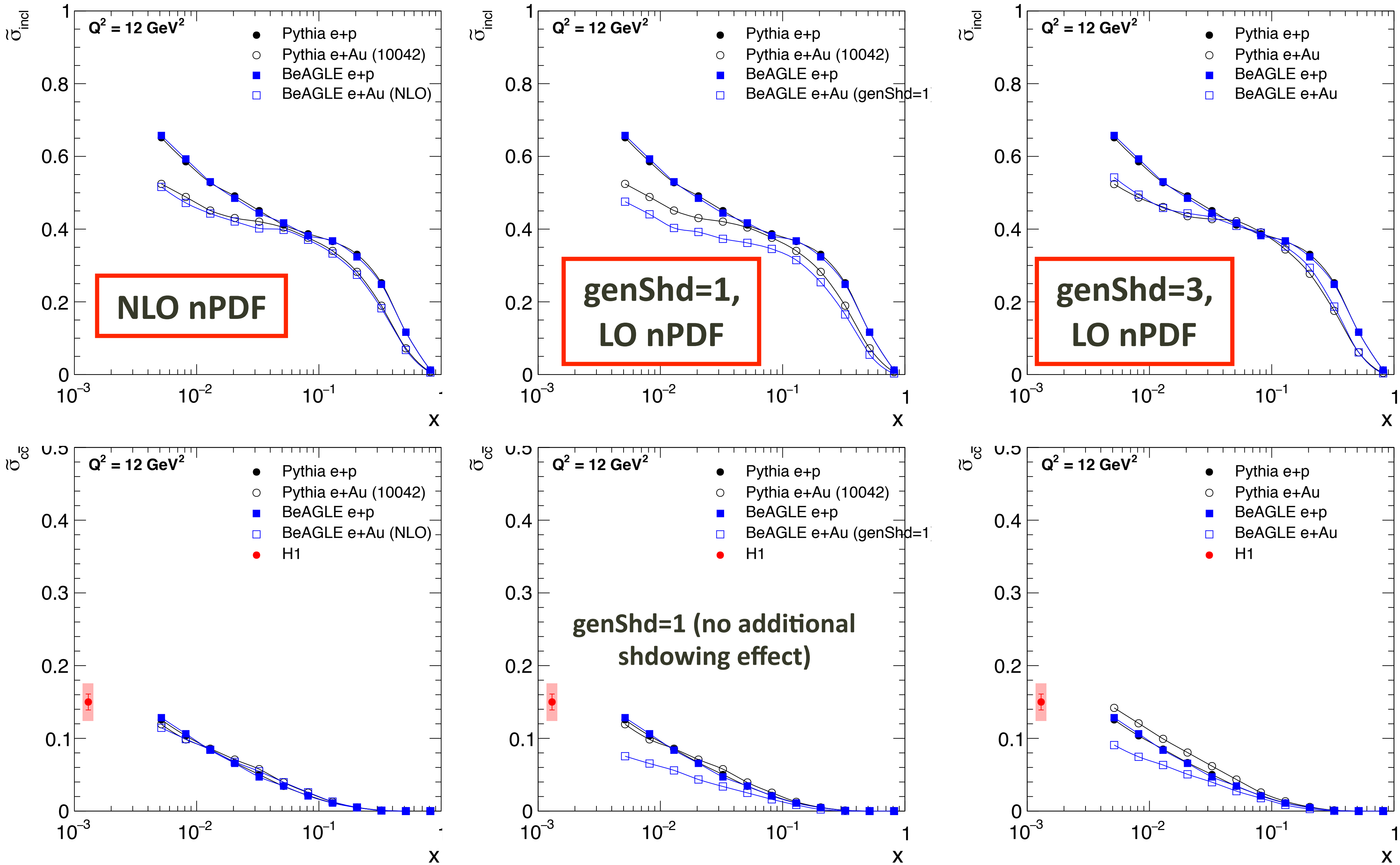






Cross-section comparison between BeAGLE and Pythia6

- Consistent cross-section when using the same nPDF input



Summary

- Revisited the multiplicity ratio observable
  - Using charm cross-section to normalize looks more reasonable
- More investigation on the final state effect avaiable in BeAGLE
  - Collision geometry
  - Intra-Nuclear Cascade (INC) effect
  - Energy loss model: PyQM (https://arxiv.org/pdf/2203.16665.pdf)

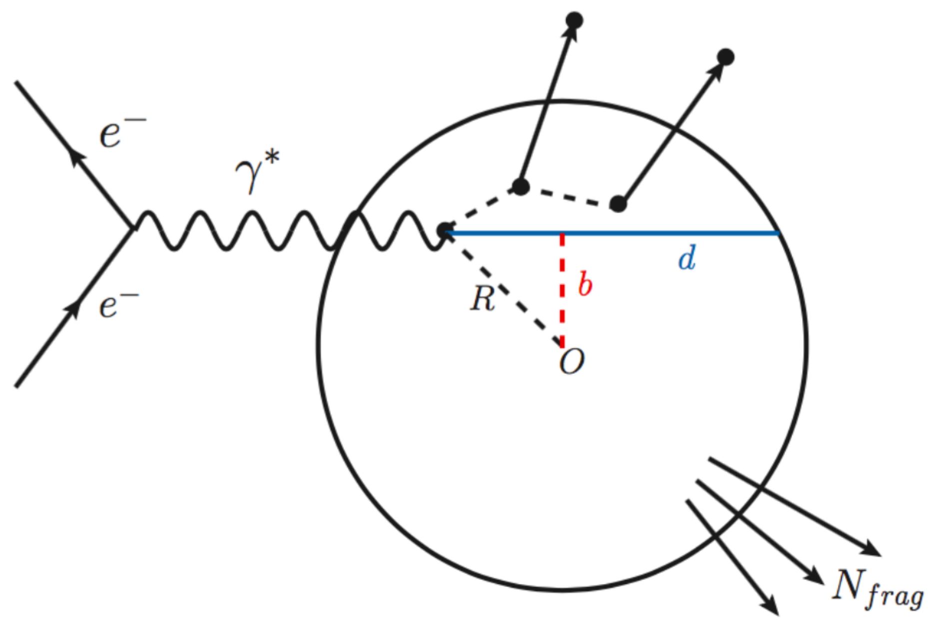


FIG. 11. Relevant quantities to describe the collision geometry. The effective interaction length, d, is the distance between the photon-nucleon interaction point and the edge of the nucleus in the direction of the virtual photon, weighted by the nuclear density. The variable b is the impact parameter between d and the center of the nucleus.