1D and 2D Correlations in Nuclear DIS with EG2 Data:

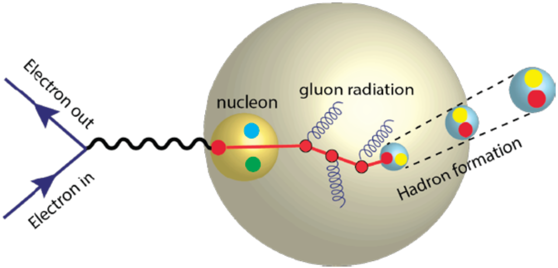
Dr. Sebouh J. Paul
on behalf of the CLAS collaboration

University of California, Riverside

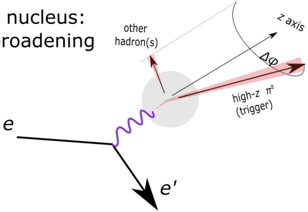
Nov 11, 2021

- Motivation
- Conditional multiplicity ratio R_{2h} in 1D binning
  - First round of review of analysis note completed
- Ongoing follow-up analysis: R_{2h} and corr. funcs in 2D binning
- Conclusions and Outlook

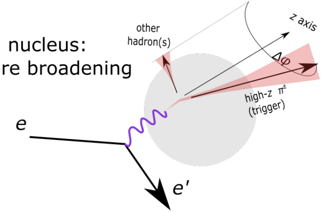
- What happens when a fast moving quark moves through a nucleus?
- Struck quark ! primary hadron
- Final-state interactions ! secondary-hadron cascade



Small nucleus:
less broadening

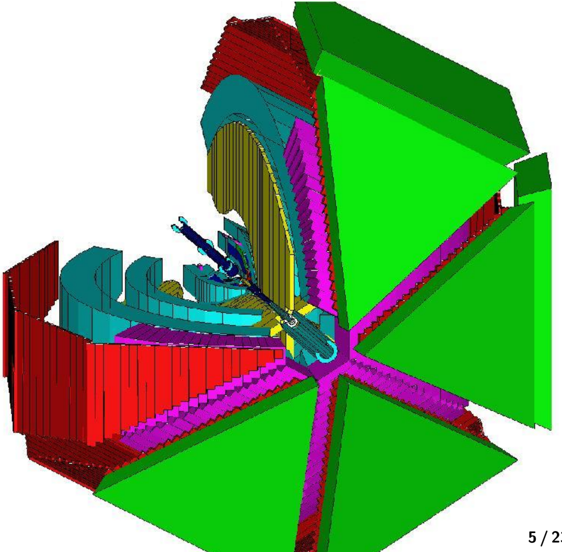


Big nucleus:
more broadening

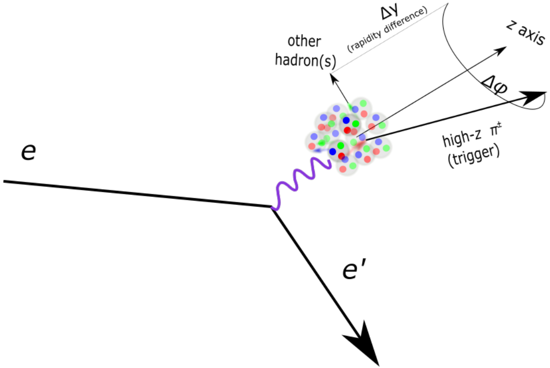


- How can nuclear effects be constrained by azimuthal correlations?
- In bigger nuclei, the hadrons encounter more material ! angle correlations smear out more.
- Sensitive to correlation effects induced by nuclear interactions.

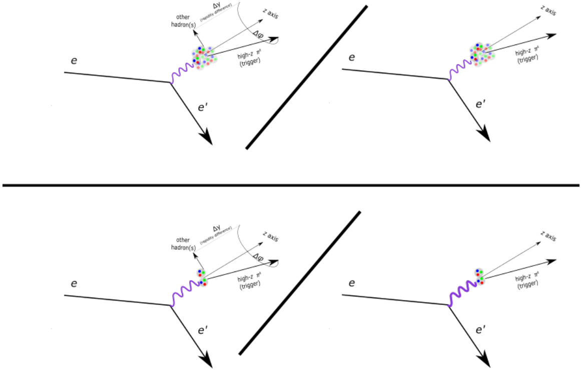
- EG2 data from CLAS6
- $E_{beam} = 5{:}014$ GeV
- deuterium target in tandem with nuclear targets: C, Fe and Pb
- **Dual-target setup minimizes systematic uncertainties for nuclear-to-deuterium ratios**



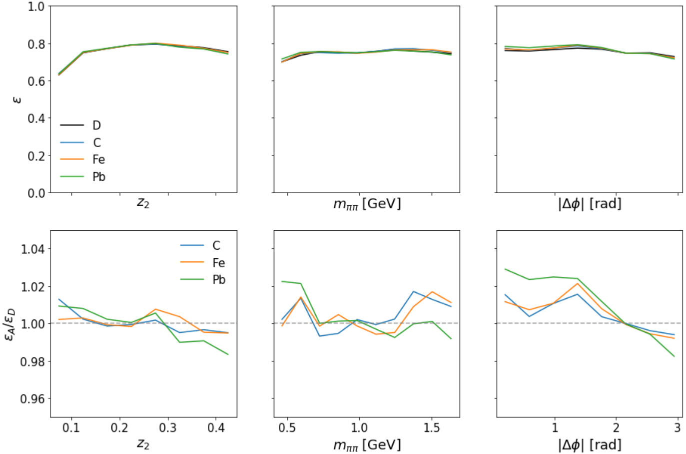
- We look at events with a scattered electron, a high-z pion (trigger) and another pion (associated)
- Results use the virtual-photon coordinate system
  - : di erence in azimuthal angle
  - y: di erence in rapidity ($y = \frac{1}{2} \ln \frac{E+p_z}{E \quad p_z}$)



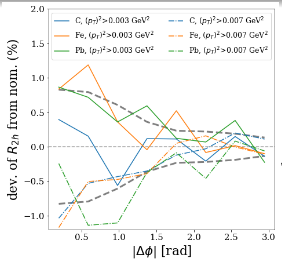
- A/D ratio of secondary pions per trigger:
- $R_{2h}(z_2) = \frac{N_h^A(z_2;z_1 > 0:5)=N_h^A(z_1 > 0:5)}{N_h^D(z_2;z_1 > 0:5)=N_h^D(z_1 > 0:5)}$
- Acceptance effects cancel out within 2% in ratio (see next slide).
- Analysis note on R_{2h} in 1D binnings: received and responded to first round of review earlier this month.

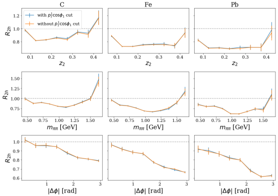


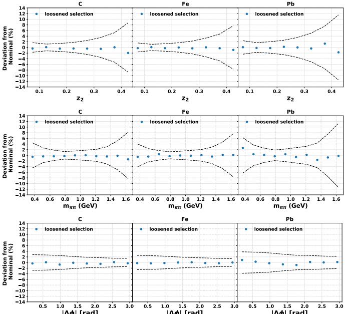
- Several tests have shown that acceptance cancels out within 2% :
  - sector-by-sector comparison
  - MC with no physics signal ! $R_{2h} = 1$
  - Data-driven mixed-event test
- Based on reviewers' feedback, we added the following additional test.
- Generated events with Pythia, weighted by Omnifold.
- $(h_2) = \frac{\sum_{i \in \text{events}} w_i j \text{recon:}(e;h_1;h_2)}{\sum_{i \in \text{events}} w_i j \text{recon:}(e;h_1);\text{gen:}(h_2)}$
- $_A = _D$ 1:00 0:02 (accounted for in syst. uncertainty)



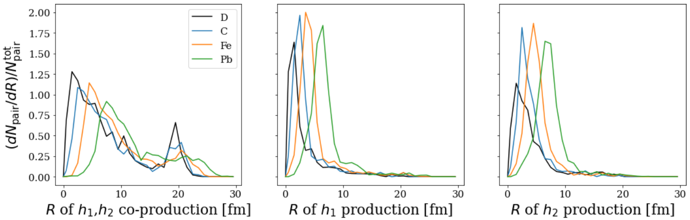
- min p_T cut for both pions
- maximum p_x cut (* frame) for trigger pion (reduces low-mass e^-e^+ background)
- More conservative systematic errors from vertex selection and acceptance than previously assigned.
- Overall, minor changes to the results. **Our double-ratio observable is rather robust**







- A transport model incorporating FSI, absorption, and production mechanisms with elastic and inelastic channels
- includes pre-hadronic degrees of freedom
- may be produced in the same internal interaction as one another, or separately
- surface bias: hadrons produced in interior of nuclei more likely to be absorbed



$N_h(z_2, z_1 > 0.3) - N_h(z_1 > 0.3)$

$N_h(z_2, z_1 > 0.3) = N_h(z_1 > 0.3)$

$N_h(z_2, z_1 > 0.5) - N_h(z_1 > 0.5)$

$$R_{2h}(z_2) = \frac{N_h^A(z_2; z_1 > 0.5)/N_h^A(z_1 > 0.5)}{N_h^D(z_2; z_1 > 0.5)/N_h^D(z_1 > 0.5)}$$

- Qualitatively similar to GiBUU model
- Nuclear dependence is clearly visible in our data
- No abrupt behavior at (770) mass.
- Back-to-back suppression observed for nuclear data
- Plan to publish these three plots in a PRL paper.

- Event-selection
  - Cerenkov Counter (for high-momentum $^{+}$ id)
  - Vertex selection
  - min-p_T cut (binning only)
- Hadron identi cation
- Acceptance-cancellation
- The following were negligible:
  - Coulomb corrections
  - Luminosity
  - Electron ID
  - Time-dependent e ects
  - Target thickness
  - Trigger e ciency

C(; y) complimentary measurement to R_{2h}

Probability, given one hadron's (; y), of nding another hadron some (, y) away

Related to same-event yield $S_{uncorr} = \frac{1}{N_{trig}} \frac{dN_{pair}}{d \quad d \quad y}$

Includes single-particle and pair acceptance corrections (see next two slides)

Analogous to galactic correlation function used in cosmology

Unlike R_{2h}, corr. funcs need corrections for single particle acceptance of secondary pion.

Determined using MC.

Fortunately, the e ciency is weakly dependent on and y.

acceptance correction is $S = S_{uncorr} = (h_2)$

An event-mixing method is used for the pair-acceptance corrections.

Correlation function $C(\; ; \; y)$ is the ratio of same-event yield to mixed-event yie

$M = \frac{1}{N_{mix}^{tot}} \frac{dN_{mix}}{d \quad d \quad y}$

This method was used previously in CLAS12 and tested with an independent, MC-based correction, providing similar results*

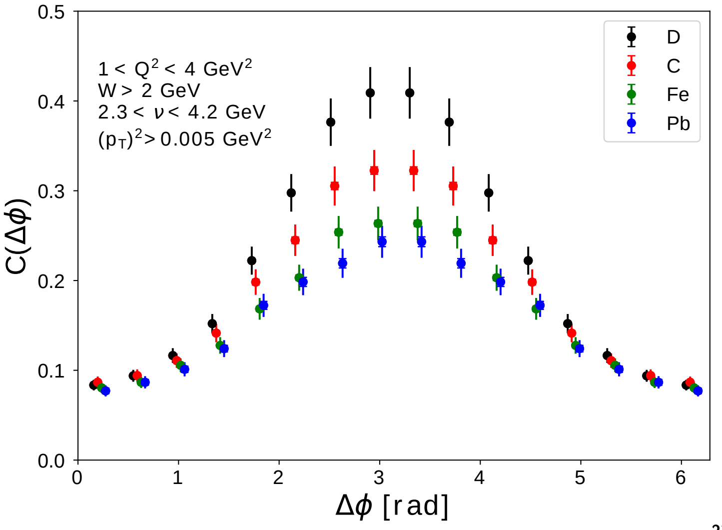
*S. Paul \Long-range two-particle correlations in DIS with CLAS12", DIS 2021.

Correlation function is the ratio of the same- and mixed-event yields

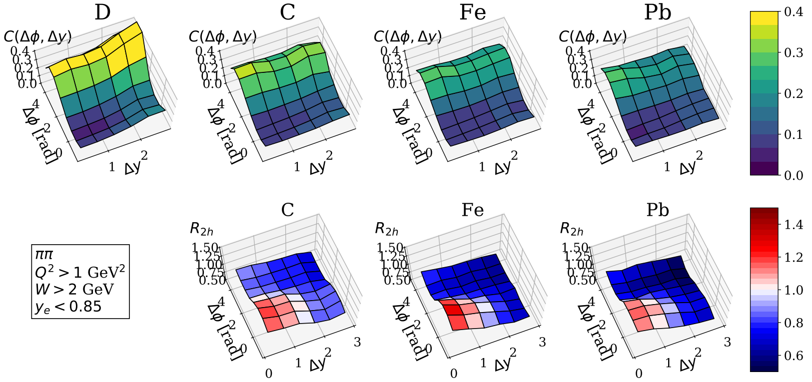
dependent on both and y

Example shown for deuteron

- Correlation function flattens and widens as a function of Δ
- Fully-corrected (acceptance from MC, mixed-events correction data-driven).
- Larger systematic uncertainties than in ratio measurements, but gives more information.



- correlation functions more smeared out for nuclei.
- enhancement at Δ Δy 0, not seen in 1d plot



- Plan to publish 1D-binned R_{2h} results in PRL after reviews are completed
  - 1D-binned R_{2h} results show nuclear dependence of R_{2h}, suppression for back-to-back pairs.
  - GiBUU model reproduces most of the qualitative features of the data, just as in recent charged-pion paper.
- On-going follow-up analysis with multi-dimensional binning underway
  - 2D bins show enhancement where both and y are small; suppression every where else.
  - Correlation functions complement D/A ratio measurements, and show smearing for heavier nuclei.
- Similar analyses are planned for p pairs.