Recent progress on dihadron correlations in eA scattering with CLAS

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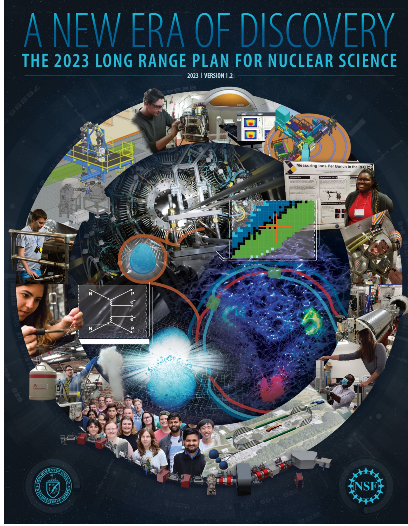
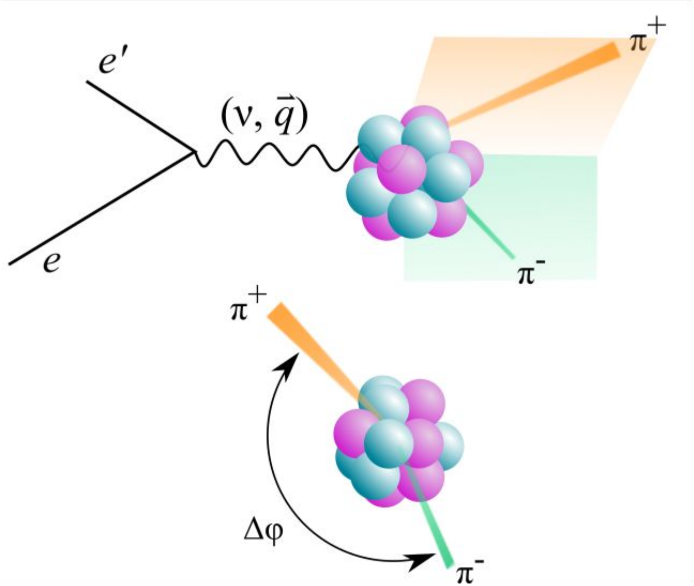
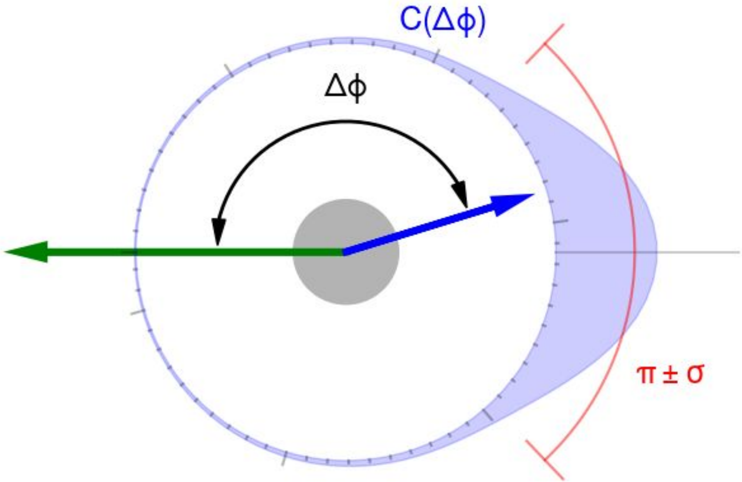
6/11/2024

CEBAF Large Acceptance Spectrometer

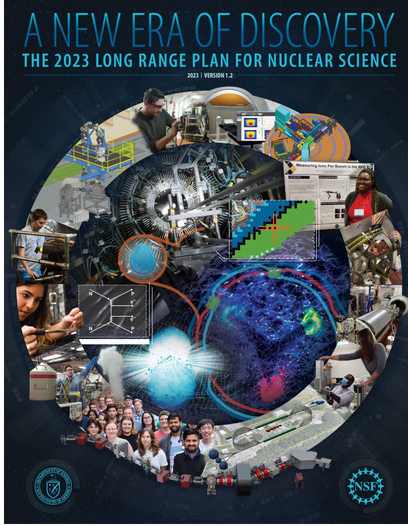
How are the various hadrons produced in a single scattering process correlated with one another…



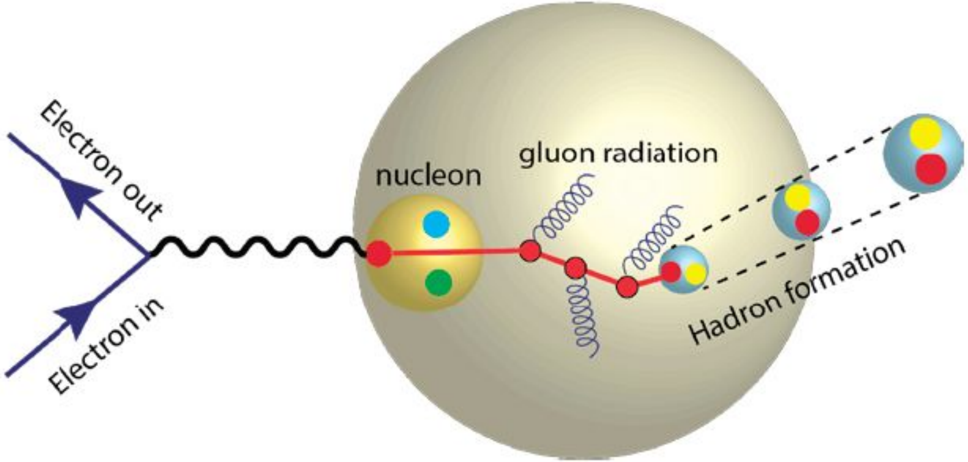




… and how does hadronization change in a dense partonic environment?

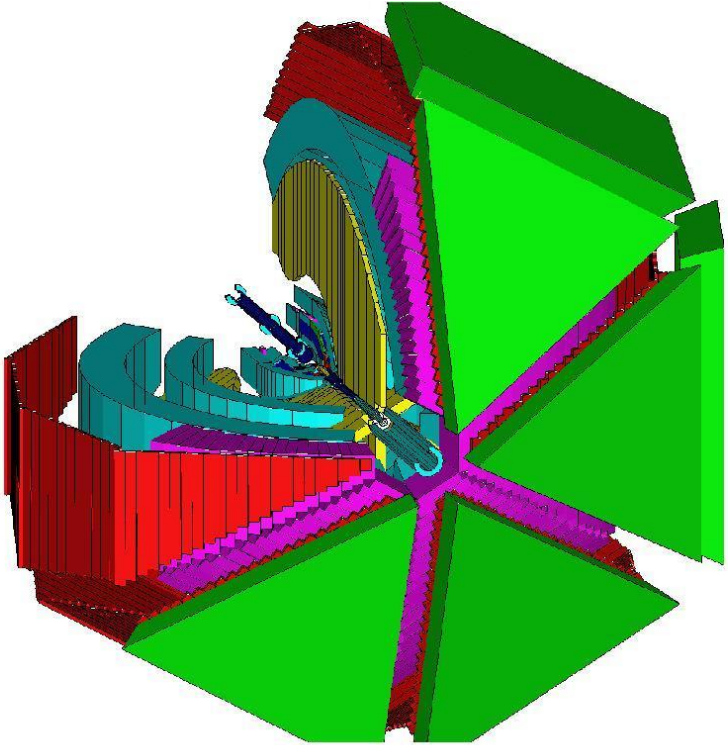


And what are the timescales of color neutralization and hadron formation?



Dataset/Experimental Setup

- CLAS detector at JLab
- 5 GeV e^- beam
- Liquid deuterium target in tandem with nuclear targets*: C, Fe, and Pb
- Reduces systematic errors for A vs. D comparisons



*NIM A 592 (2008) 218– 223

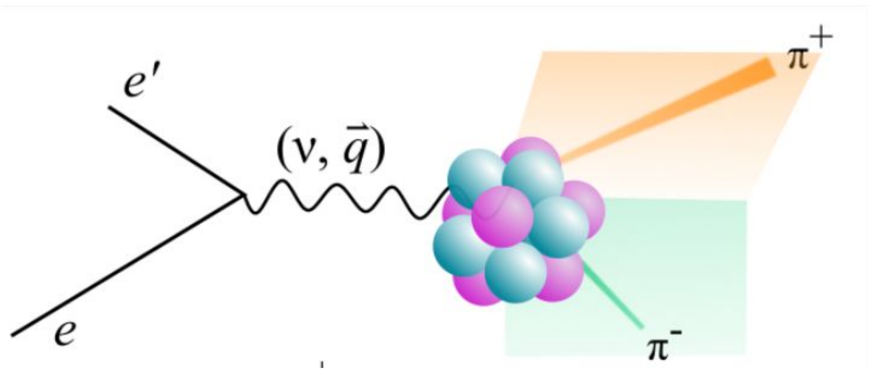
Event topologies

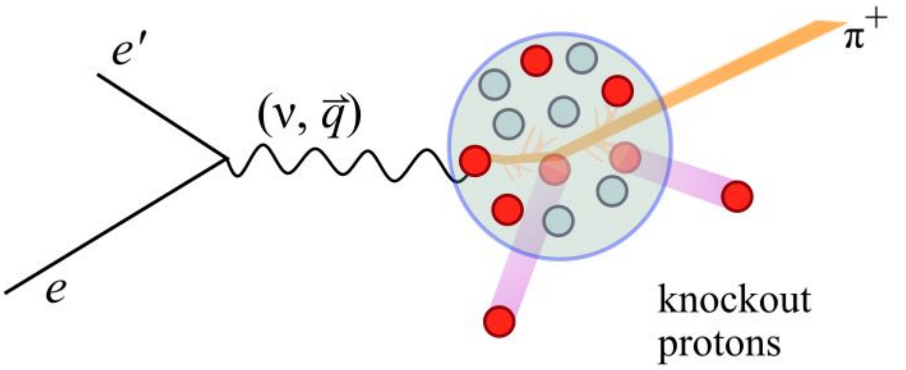
Di-pion:

- High energy π+ and low energy π-
  - Pion pair can be produced together in hard scattering, or secondary pion produced in secondary reactions

Pion+proton

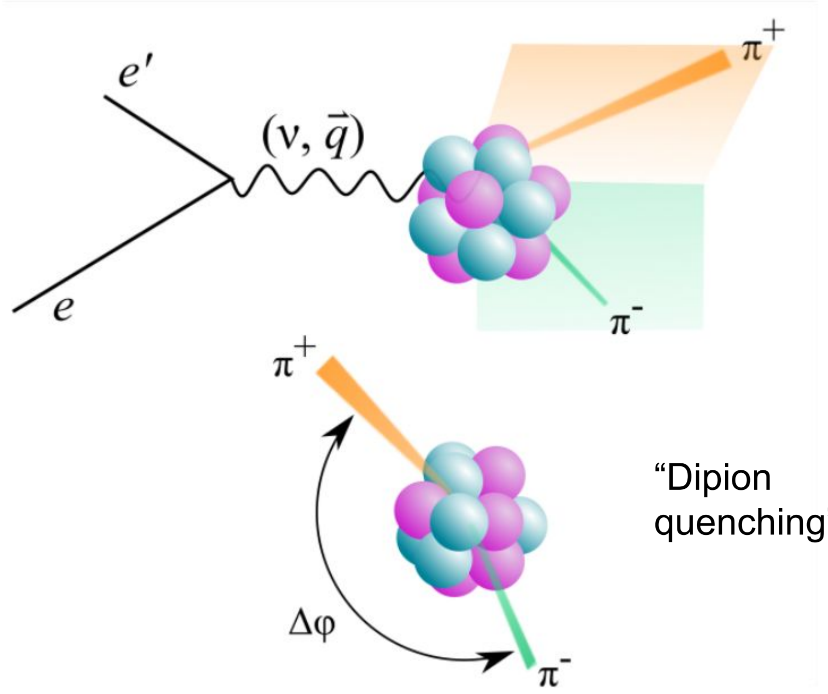
- High energy π+ and knocked-out proton
  - either the leading hadron (from the struck quark) or a cascade can knock protons out



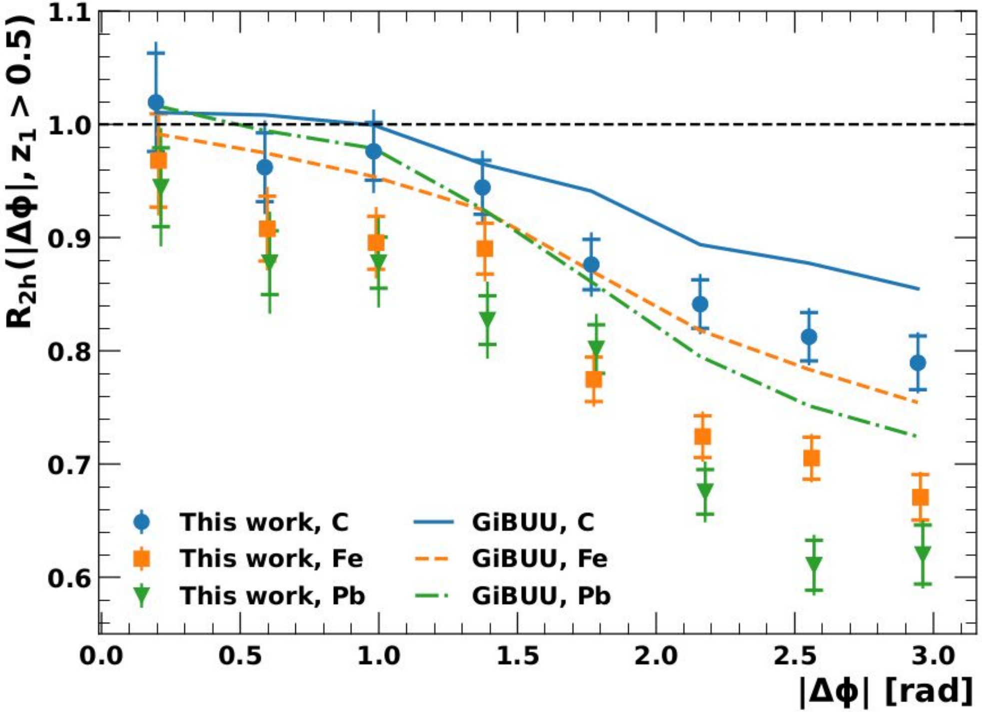


Presented at the previous JLUO meeting…

Discovery of back-to-back pion suppression in eA scattering



"Dipion quenching"



Phys. Rev. Lett. **129**, 182501

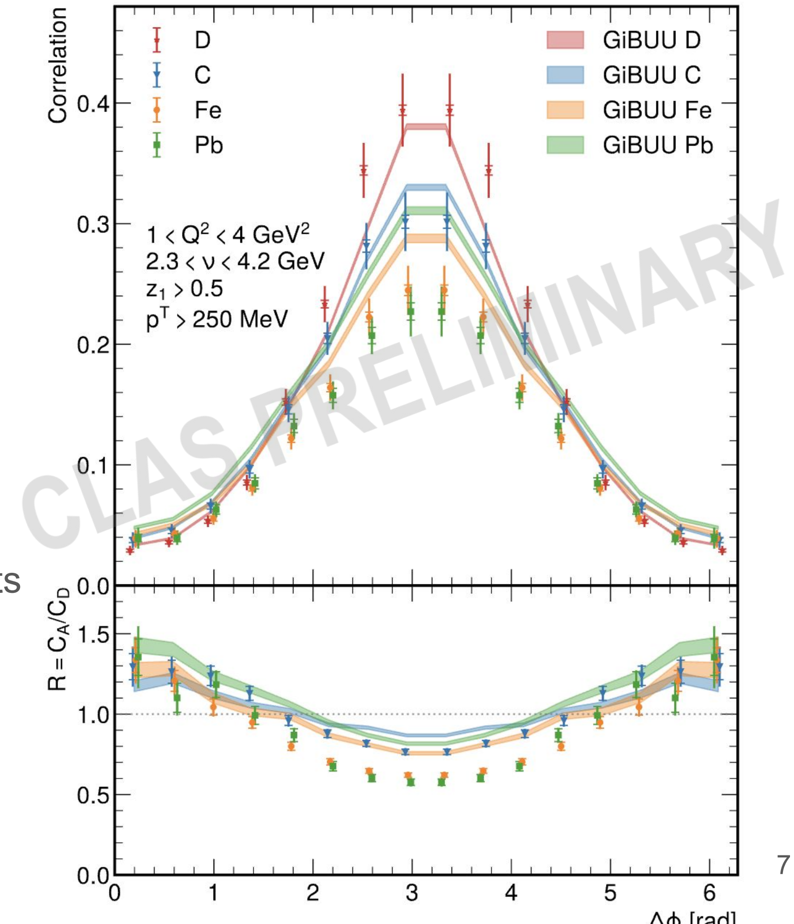
How are the various hadrons produced in a scattering process correlated with one another ?

Leading π^+, subleading π^-

Our observable: correlation function

$$C(\Delta\phi) = C_0 \frac{1}{N_{eh}} \frac{dN_{ehh}}{d\Delta\phi}$$

- Δφ is the difference in azimuth
- N_{eh} is the number of events with scattered electron and a "leading hadron" ($z=E_h/\nu>0.5$)
- N_{ehh} is the number of "subleading hadrons" in those events
- C_0 is the normalization factor (use same value for all targets)
- **First** measurement of this observable in *eA* scattering
    - Only possible due to CLAS's large acceptance



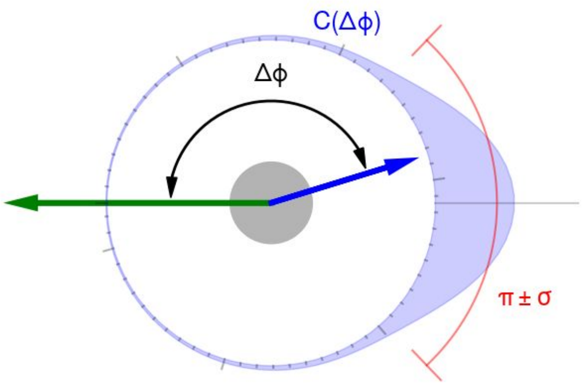
*Results to be submitted for publication in PRC next week

Derived quantities: RMS widths and broadenings

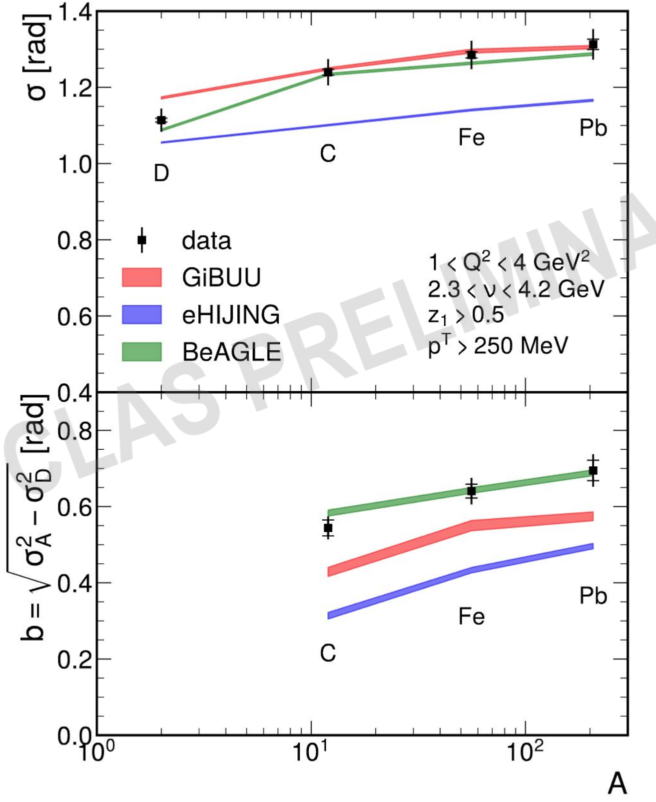
RMS width:

$$\sigma = \sqrt{\frac{\int_0^{2\pi} d\Delta\phi\, C(\Delta\phi)(\Delta\phi-\pi)^2}{\int_0^{2\pi} d\Delta\phi\, C(\Delta\phi)}}$$

Broadening: $b = \sqrt{\sigma_A^2 - \sigma_D^2}$



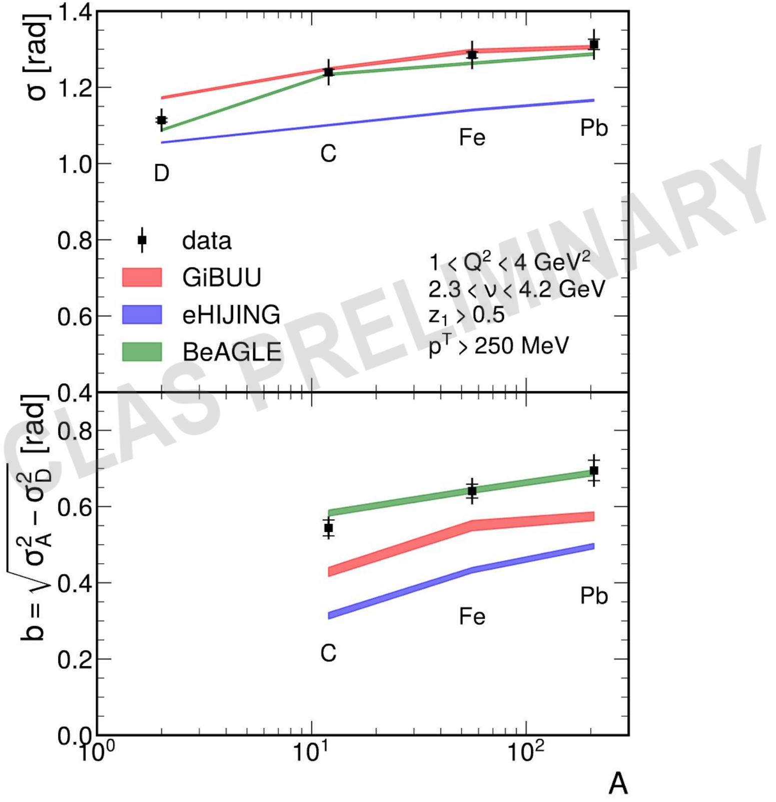
Leading π^+, subleading π^-



Derived quantities: RMS widths and broadenings

- RMS widths and broadening increase with larger nuclei
- Most of these models are new, developed for the EIC rather than JLab energies, yet predict this trend correctly

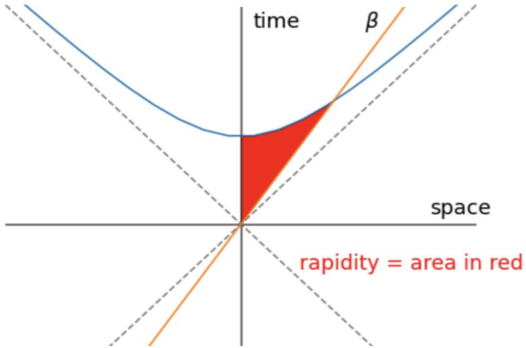
Leading π^+, subleading π^-

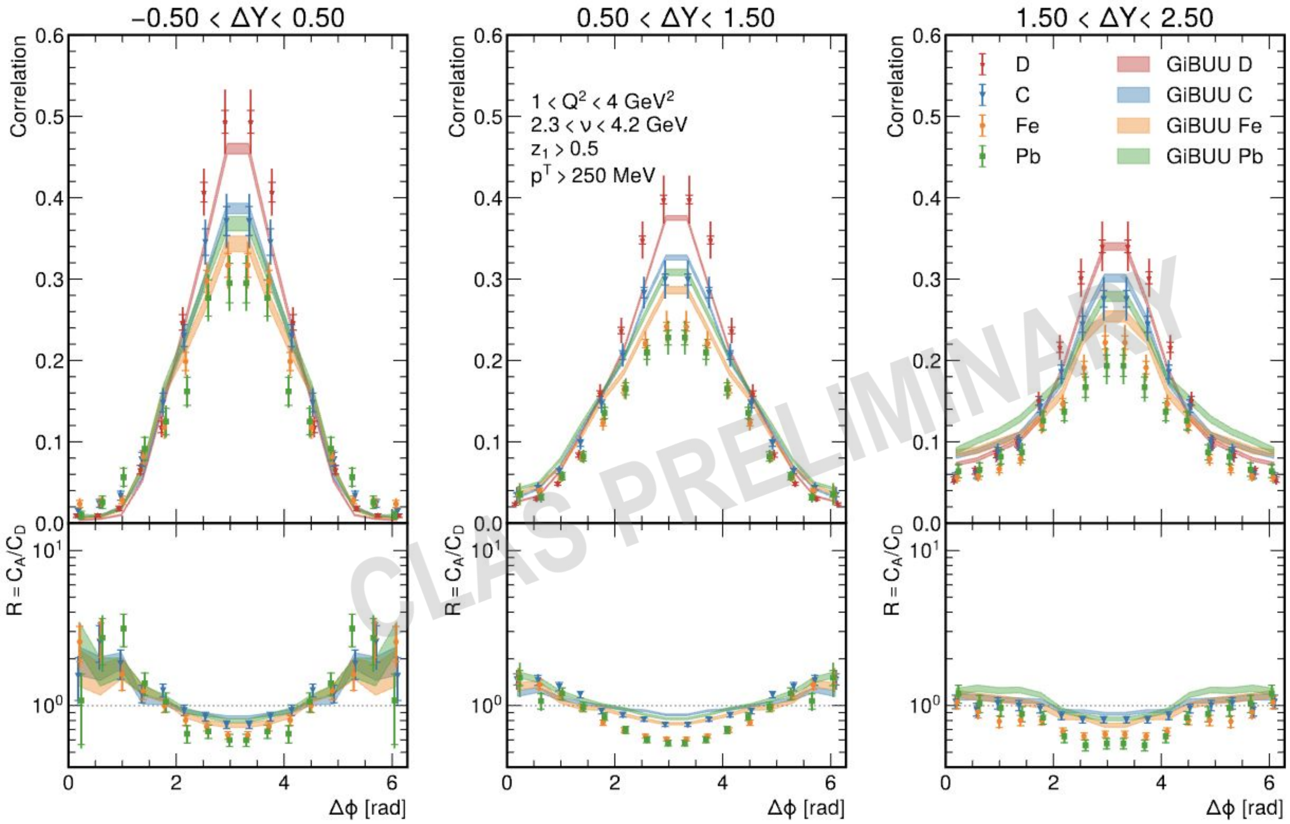


Multidimensional measurements

- Correlation functions can be measured in bins of multiple variables, such as
  - rapidity difference, $\Delta Y = Y_1 - Y_2$
  - transverse momentum of the leading hadron, p_T^1
  - subleading hadron p_T^2

$$Y = \frac{1}{2}\ln\frac{E_h + p_{z,h}}{E_h - p_{z,h}}$$

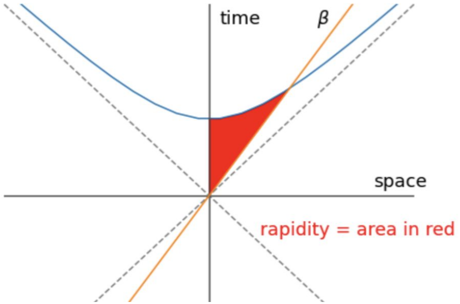


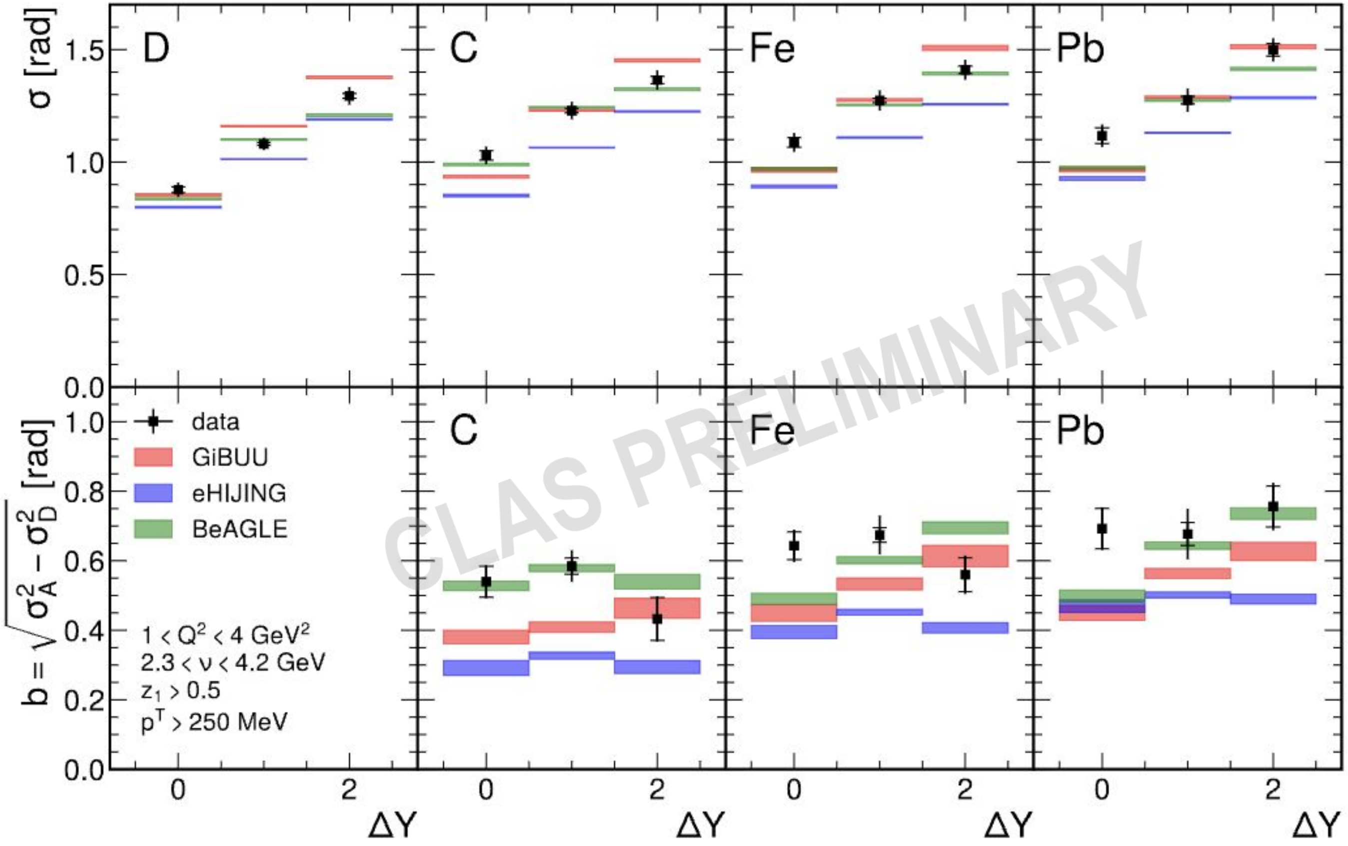


Multidimensional measurements

- Widths and broadenin can also be evaluated these bins

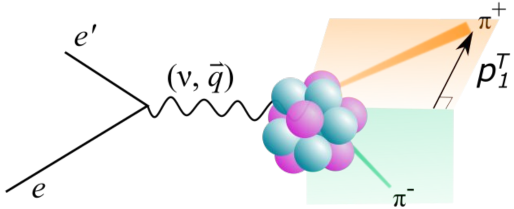
$$Y = \frac{1}{2} \ln \frac{E_h + p_{z,h}}{E_h - p_{z,h}}$$

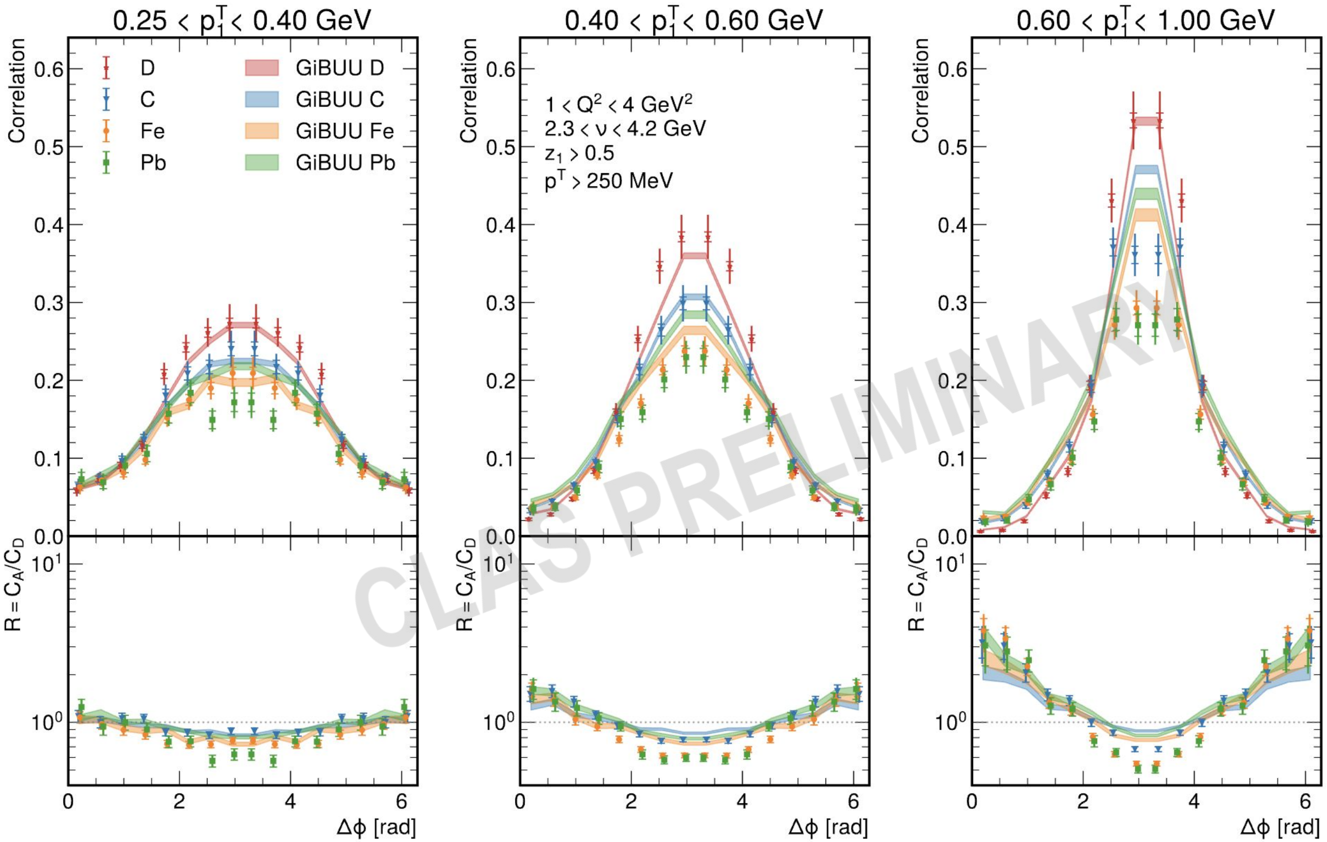




Multidimensional measurements

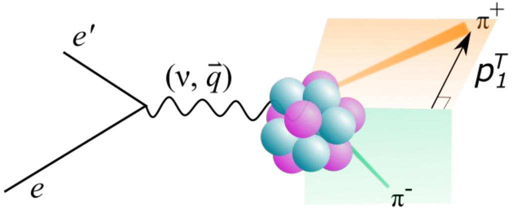
- Correlation functions get narrower as p_1^T gets larger

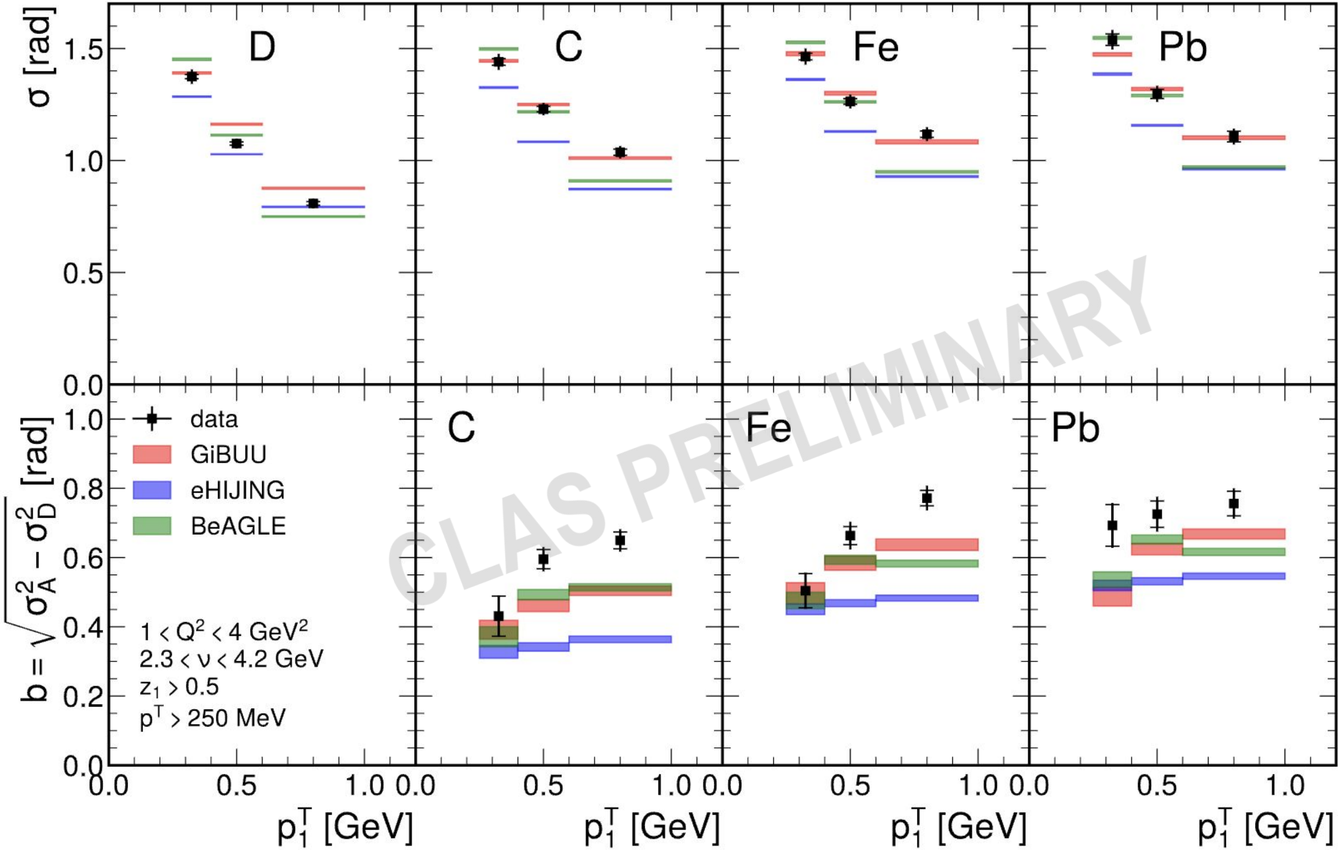




Multidimensional measurements

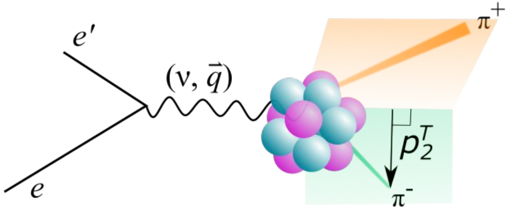
- Correlation functions get narrower as p_1^T gets larger
- And this is reflected in the widths

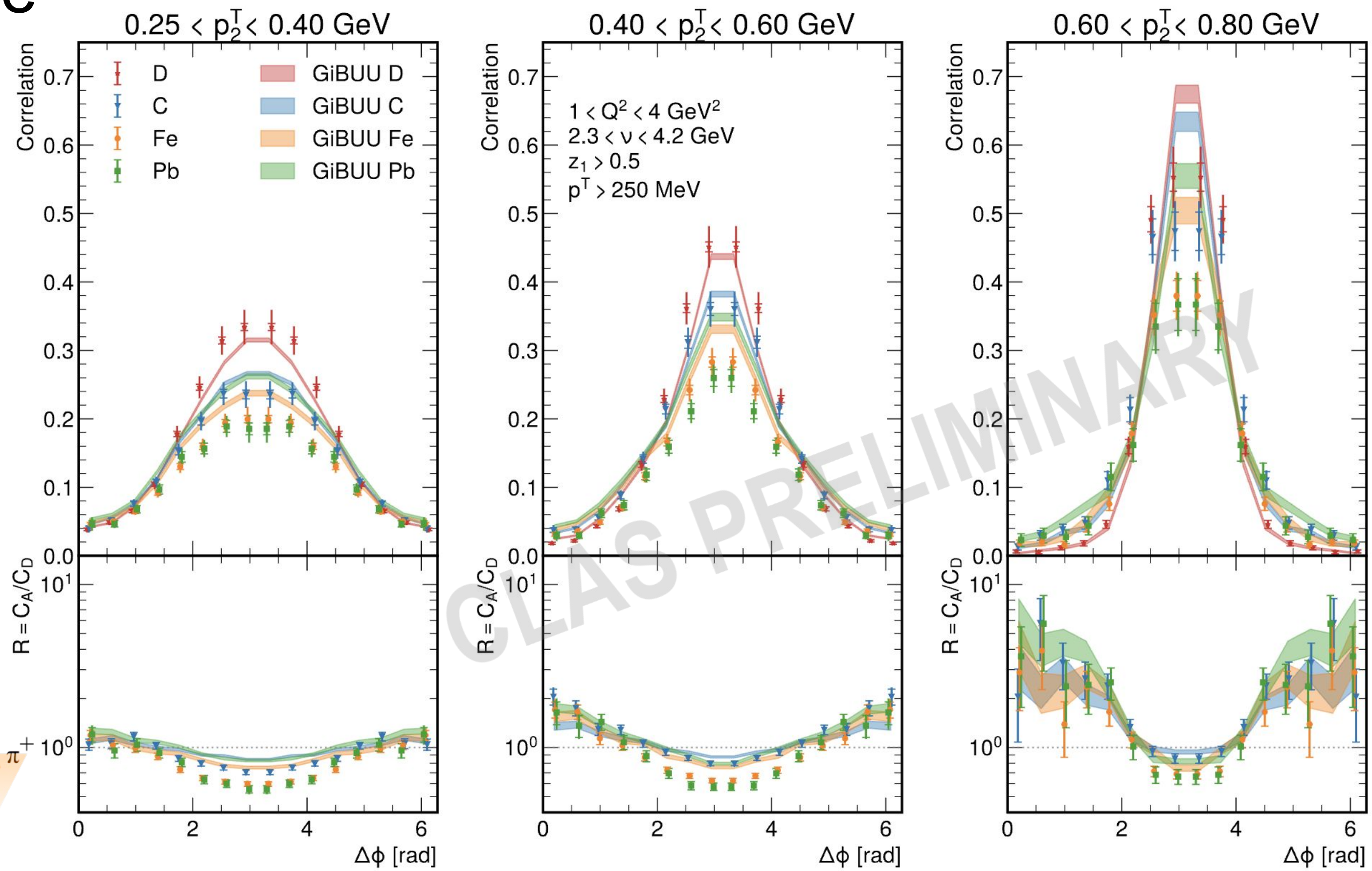




p_2^T dependence

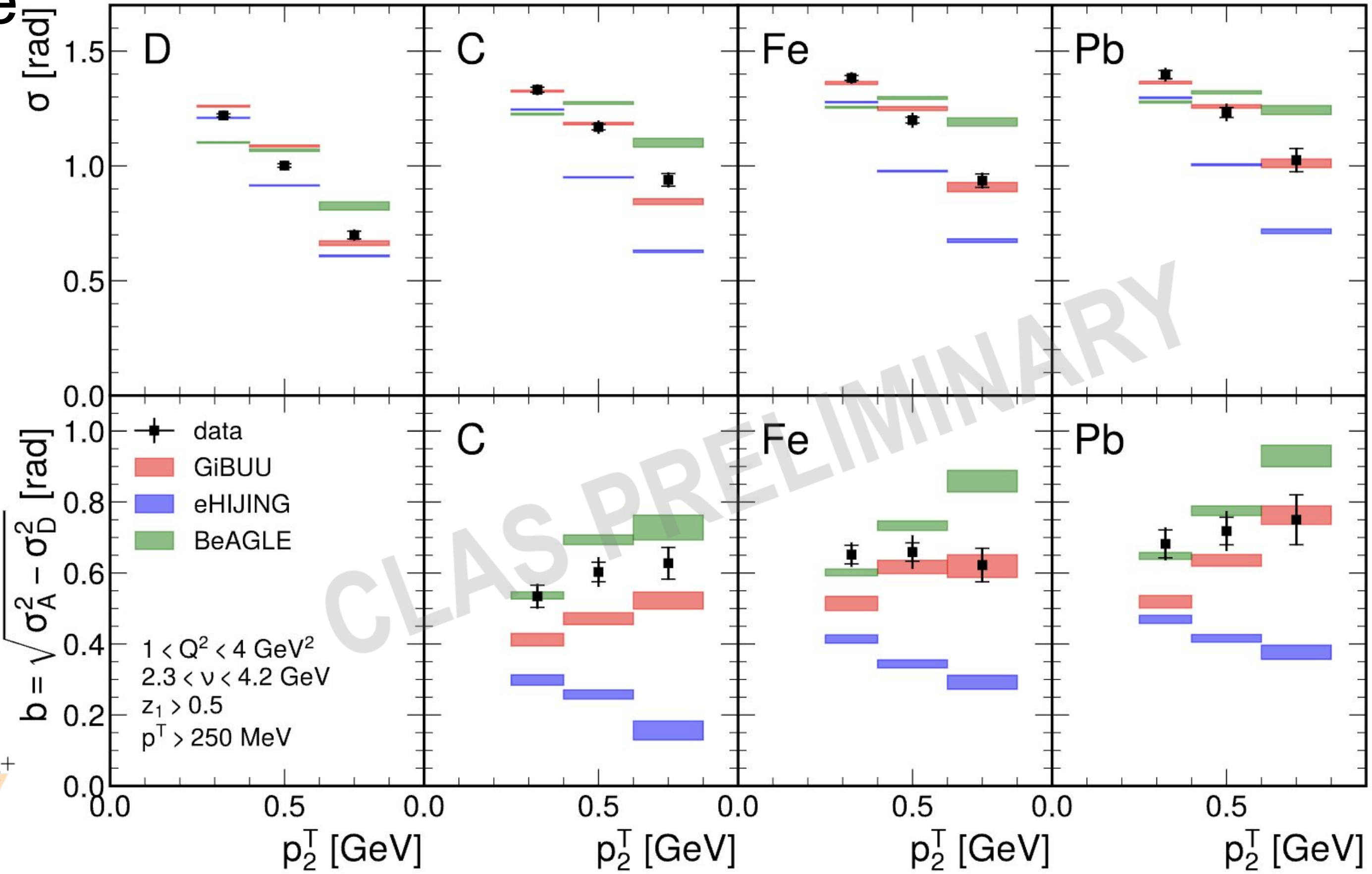
- Similar trend to the p_1^T dependence

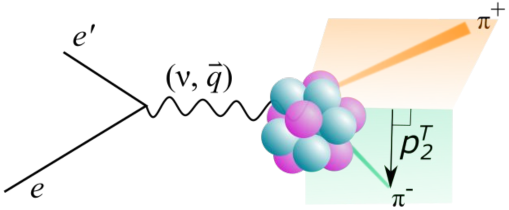




p_2^T dependence

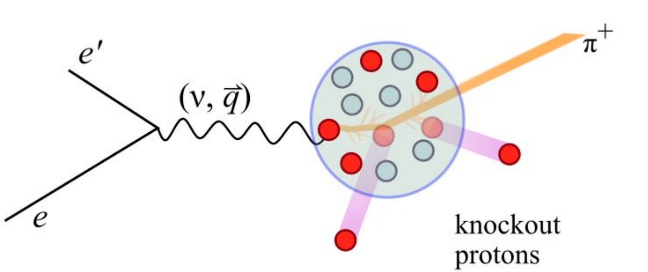
- Models predict different trends in the broadening vs p_2^T, which demonstrates the discriminating power of these measurements

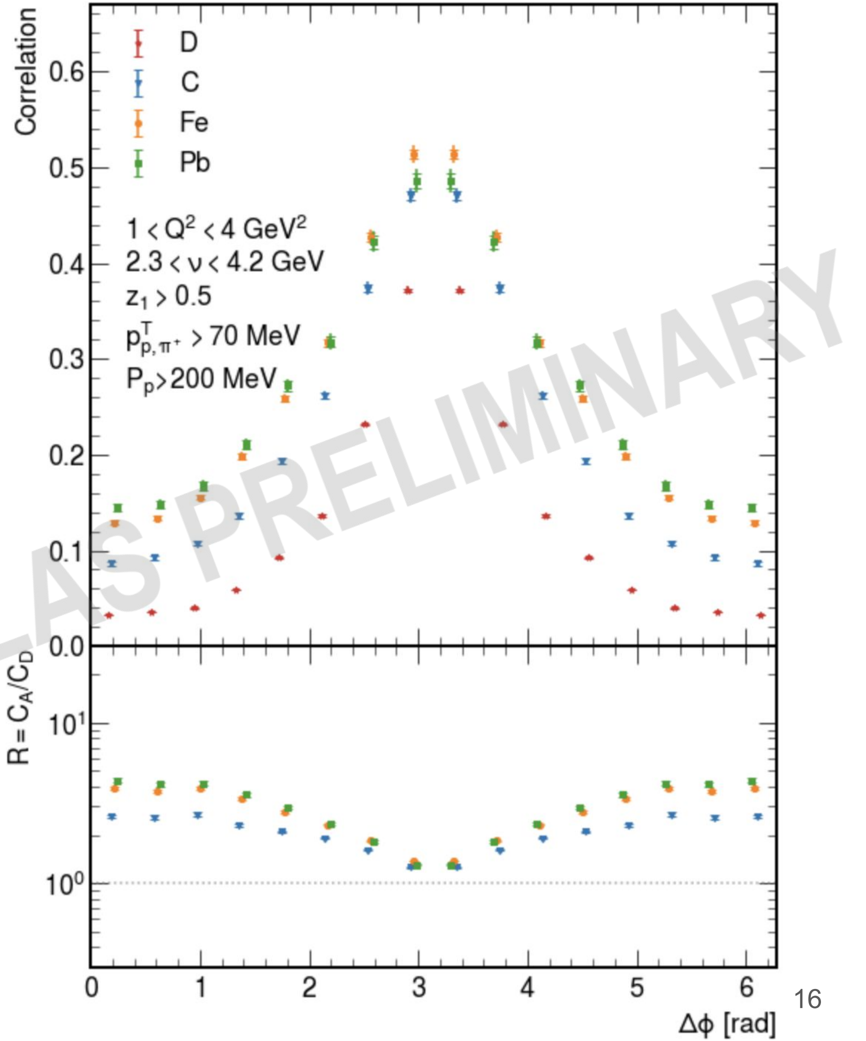




Results for the pion-proton analysis

- Similar to di-pion analysis…,
  - Peak is at Δφ=π,
  - Wider correlation functions for nuclear than for deuterium
- But unlike di-pion case…
  - Taller peaks for nuclear than for deuterium…



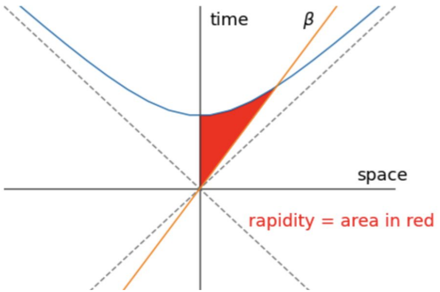


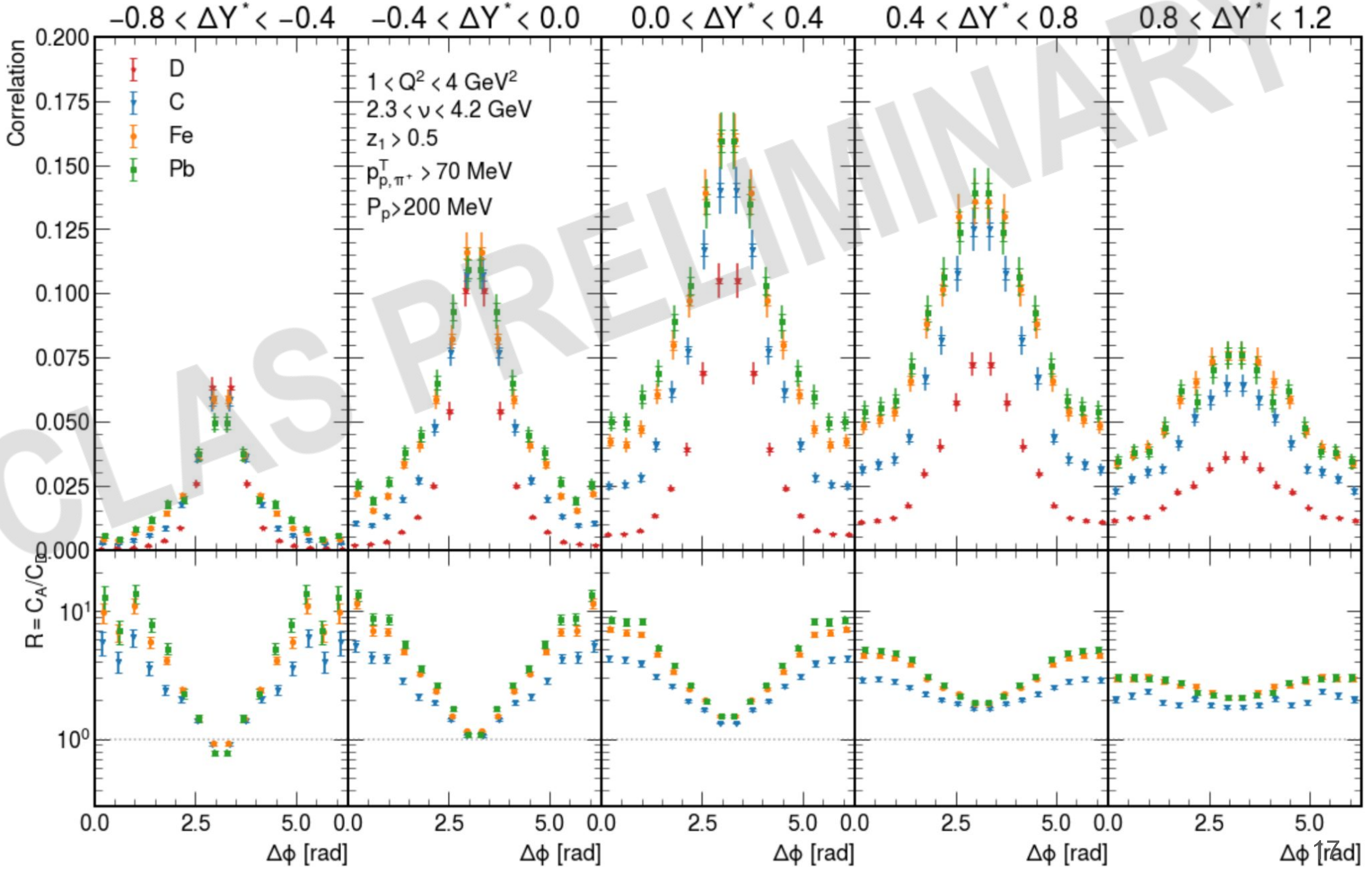
Multidimensional πp results:

$$\Delta Y^* = Y_{\pi^+} - Y_p - (Y_{\mathrm{cm}} - Y_{\mathrm{lab}})$$

$$Y = \frac{1}{2}\ln\frac{E_h + p_{z,h}}{E_h - p_{z,h}}$$

- Peak heights largest at low |ΔY*|
- Wider correlation functions for larger positive ΔY*
- Nuclear data has larger peak heights than deuterium for most ΔY* bins, especially at large positive ΔY*

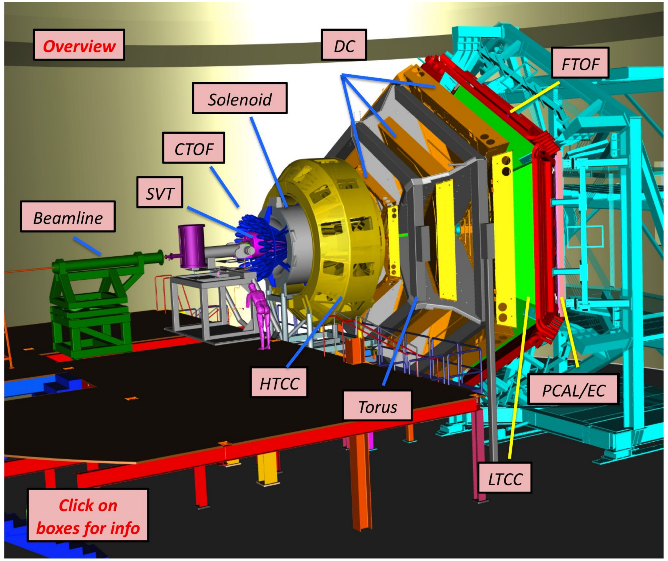




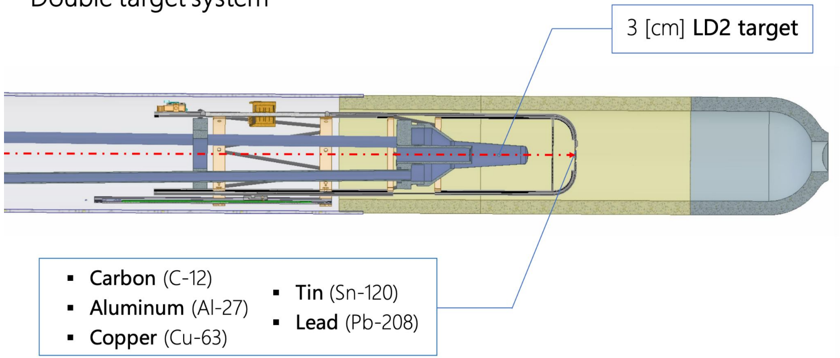
Follow-up measurements with upgraded CLAS12 (Run Group E)

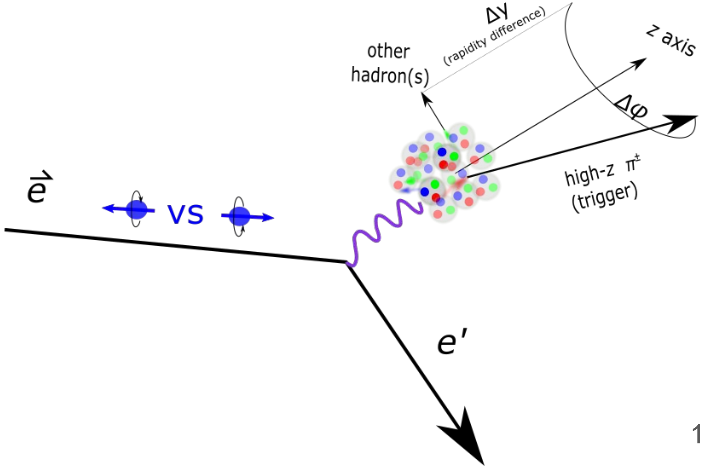
These di-hadron measurements can be extended using recent measurements with

- Higher luminosity
- Higher beam energy
- Polarized electron beam
  - Can measure beam-spin asymmetries
- Larger variety of targets



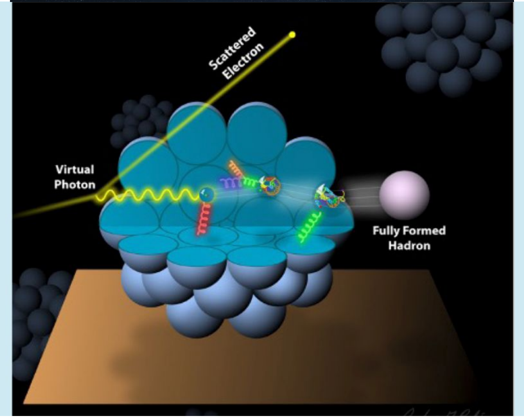
Double target system





Summary

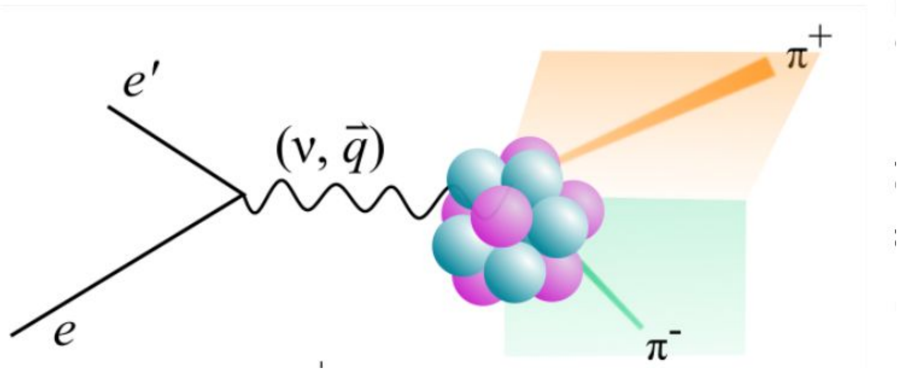
- Di-hadron correlations offer unique insights into how hadronization is affected by the presence of nuclear material
- A recent experiment with CLAS12 will extend these measurements with even higher precision, and introduces a polarization as a new probe.
- Current and future analyzes will seek to answer some of the questions raised in the new LRP
  - How are the various hadrons produced in a single scattering process correlated with one another and how does hadronization change in a dense partonic environment?
  - What are the timescales of color neutralization and hadron formation?



Backup

Di-Pion Event Selection

- Electron with DIS kinematics
  - Q^2>1 GeV^2
  - W>2 GeV
  - 2.3<ν<4.2 GeV
- Leading π+
  - $z=E_h/\nu>0.5$
  - Identified with
    - TOF only (P<2.7 GeV)
    - TOF+Cerenkov (P>2.7 GeV)
- Sub-leading π-
  - TOF cuts for identification
  - P>350 MeV
- Both hadrons:
  - pT>250 MeV



Pion-Proton Event selection

- Electron with DIS kinematics
  - $Q^2 > 1$ GeV^2
  - W>2 GeV
  - 2.3<ν<4.2 GeV
- Leading π+
  - $z = E_h/\nu > 0.5$
  - Identified with
    - TOF only (P<2.7 GeV)
    - TOF+Cerenkov (P>2.7 GeV)
- Proton
  - TOF cuts
  - 0.2<P<2.8 GeV
- Both hadrons:
  - pT>70 MeV