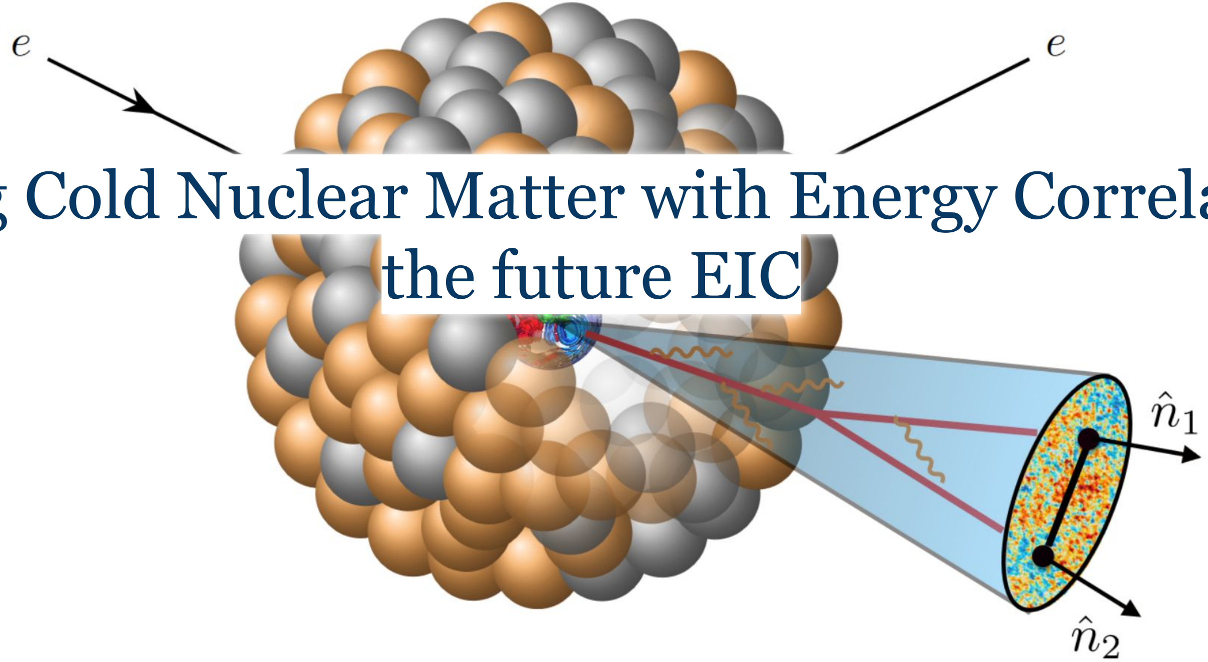

Imaging Cold Nuclear Matter with Energy Correlators at the future EIC

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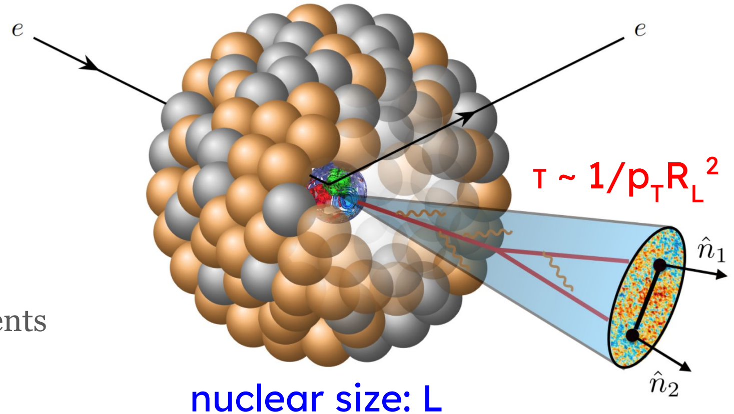
Energy correlators

- Jet-substructure observables can probe the interactions between jets and cold nuclear matter as a function of scale
  - Two-point energy correlator (energy-energy correlator):

$$\langle \mathcal{E}^n \mathcal{E}^n \rangle = \sum_{ij} \int dR'_L \left(\frac{p_{T,i}\, p_{T,j}}{p^2_{T,\mathrm{jet}}} \right)^{\overset{\text{weight power}}{n}} \underset{\text{angular distance}}{\delta(R'_L - R_L)}$$

$$R_L = \sqrt{(\eta_j - \eta_i)^2 + (\phi_j - \phi_i)^2}$$

  - Scale quantified by R_L, the angular distance between jet constituents
  - Higher $R_L \leftrightarrow$ earlier splitting/modification onset
  - Choice of "weight power" n



- "Imaging" the nuclear structure; the formation time of the splitting is smaller than the nucleus size

$$R_L > \frac{1}{\sqrt{p_T L}}$$

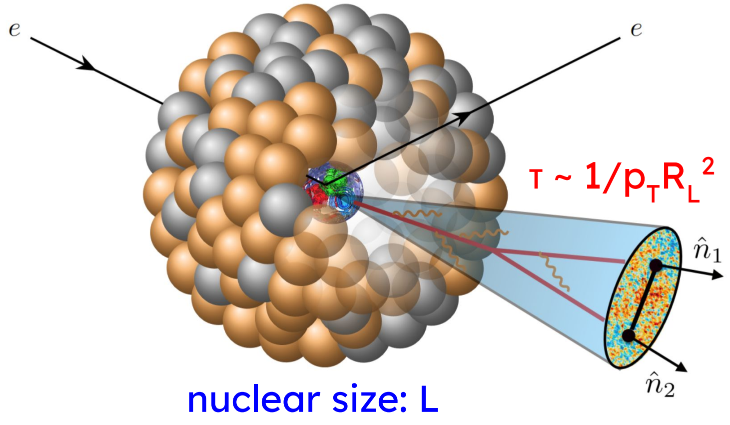
- Sensitive to only final state effects; comparing against many e+A species is powerful

Important parameters

Energy correlators dependent on several parameters:

qhat, jet p_T, jet η, nucleus size, weight power

- Probability of medium induced emissions (how strong the medium is at modifying the traversing jet) $\sim \hat{q}L^2$
  - qhat of nuclear medium
- Effective path length (how long it's in the medium)
  - Nuclear size in the nucleus rest frame $L \sim r_0 A^{1/3}$
  - Formation time of splitting $\tau \sim \frac{1}{p_T R_L^2}$
  - Jet η in lab frame
    - larger η → nucleus and jet co-move → longer path length
- Weight power



In this study we explore each of these dependencies…

eHIJING and simulating EIC conditions

- eHIJING (electron-Heavy-Ion Jet Interaction Generator) simulates jet evolution in DIS events from nuclear modification effects
  - Initial interaction modeled by PYTHIA8
  - EPPS16 nPDF input, isospin effects, EMC, (anti-)shadowing effects
  - Parton shower experiences medium modifications:
    - p_T broadening via multiple collisions with small x gluons
    - Parton splitting included
    - Hadronization
  - Benchmarked against HERMES fixed-target

- Settings used for EIC conditions
  - qhat controlled by input K-factor. K=4 ↔ qhat=0.02 GeV^2/fm
  - 10 on 100 GeV for all e+p/A species
  - 4E8 events per species, ~10^{-1} fb luminosity
  - ep chosen as baseline

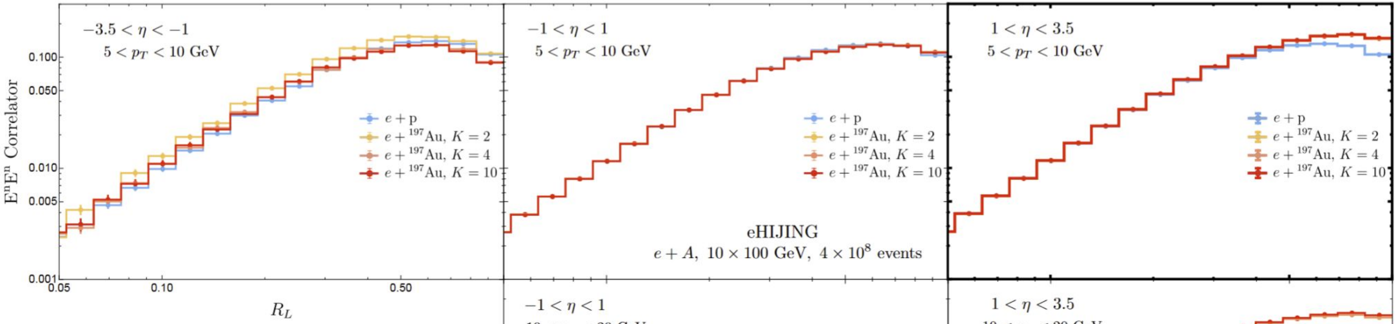
Collision Species and Energies Supported by the EIC				
Nuclei species A	e+A Beam Energies (GeV)			
proton	18 on 275	10 on 100	5 on 100	5 on 41
deuterium / ^{3}He / ^{4}He	18 on 110	10 on 110		5 on 41
C / ^{40}Ca / Cu	18 on 110	10 on 110		5 on 41
Au	18 on 110	10 on 110		5 on 41

Modification observed in EEC

➤ Calculation

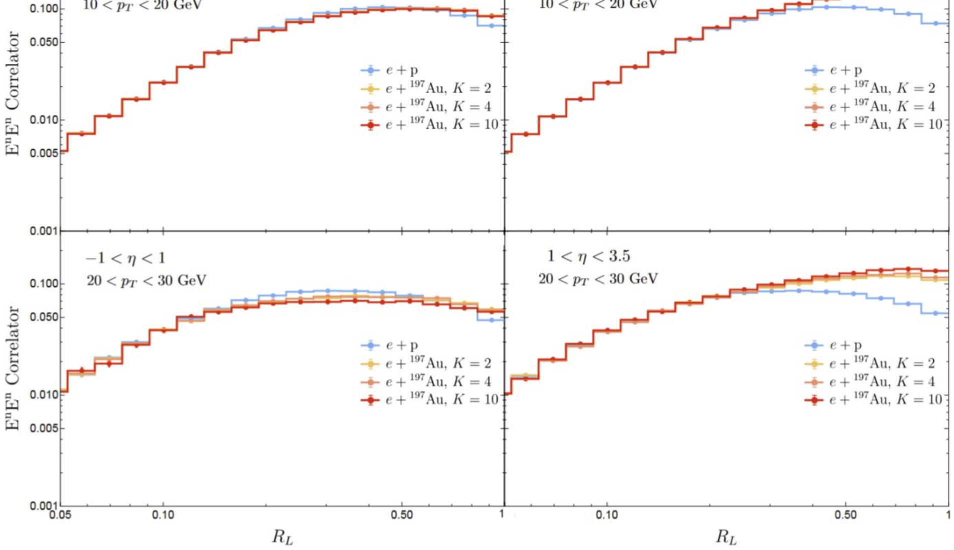
$$\alpha \cdot \langle \mathcal{E}^n \mathcal{E}^n \rangle$$

Relative normalization factor α forces e+A and e+p to match at low R_L



➤ Modification visible in e+A compared to e+p at default qhat

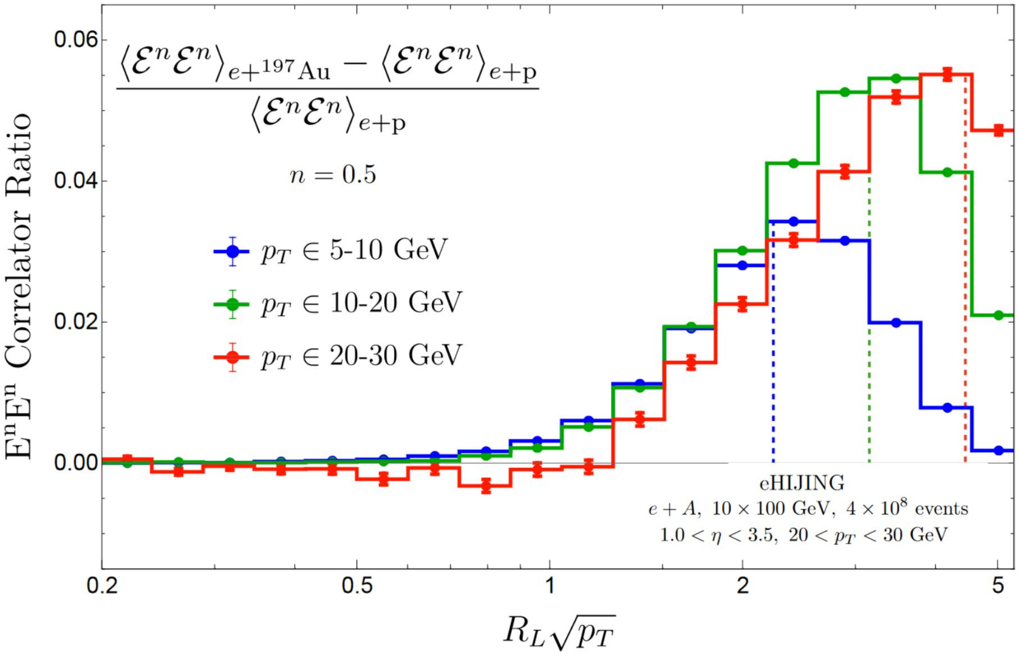
- Enhanced at high R_L (early splitting → inside the nucleus)
- No modification at small at low R_L (late splitting → outside the nucleus)
- Onset of the modification reflects the nuclear size
- Enhanced at higher p_T and forward η - we select this bin to study



➤ 10^{-1} fb luminosity - EIC will have high precision for EEC measurements

Jet p_T dependence

- e+Au case subtracted by e+p baseline
- "Turn-on" of modification occurs when e+A deviates from e+p baseline
  - Turn-on happens at a characteristic length scale given by the formation time of the shower τ
  - $\tau \sim \dfrac{1}{p_T R_L^2}$
  - Scaling the x-axis to $R_L$sqrt(p_T) causes the turn-ons coincide across p_T bins
- Strength of modification enhanced for higher p_T jets
- Peak maximum comes from the edge effect of using finite jet radius R=1
  - Dashed lines drawn → sqrt(lower p_T bound) * jet R

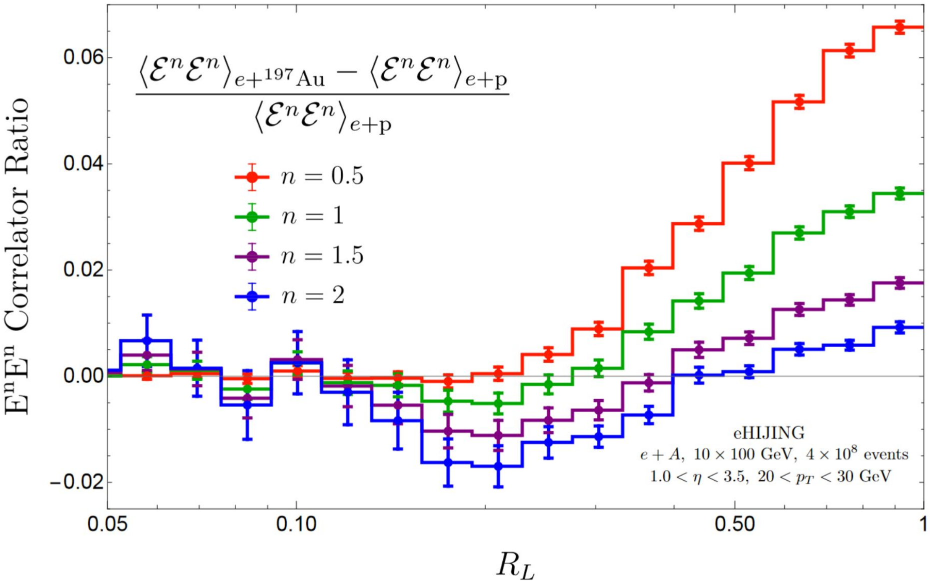


Weight power comparison

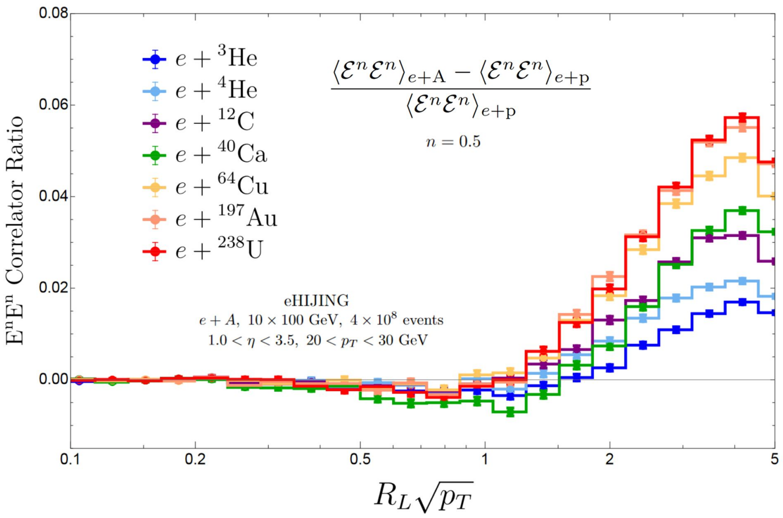
$$\langle \mathcal{E}^n \mathcal{E}^n \rangle = \sum_{ij} \int dR'_L \left(\frac{p_{T,i}\, p_{T,j}}{p^2_{T,\mathrm{jet}}} \right)^{n} \delta(R'_L - R_L)$$

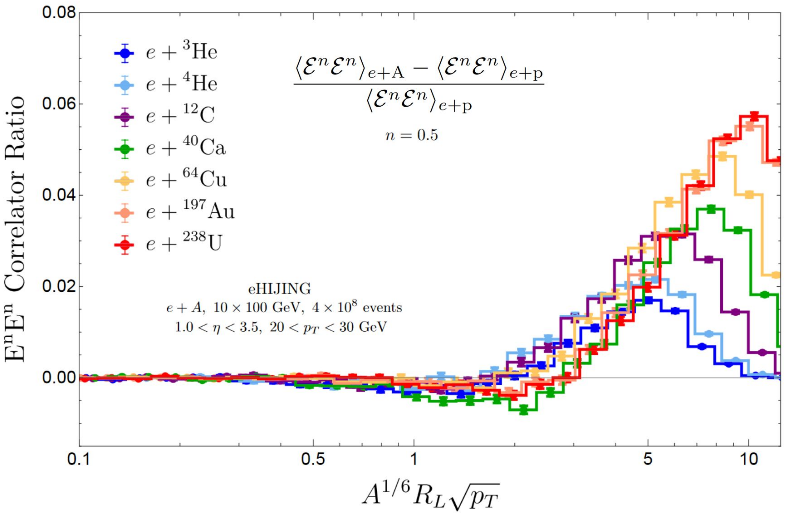
weight power

- Modification size varies for different weight powers n
  - Smaller n tends to give larger enhancement in at high R_L
- We use n=0.5 as it gives high modification values
- More clearly differentiates nuclei species and jet p_T



Nuclear size dependence



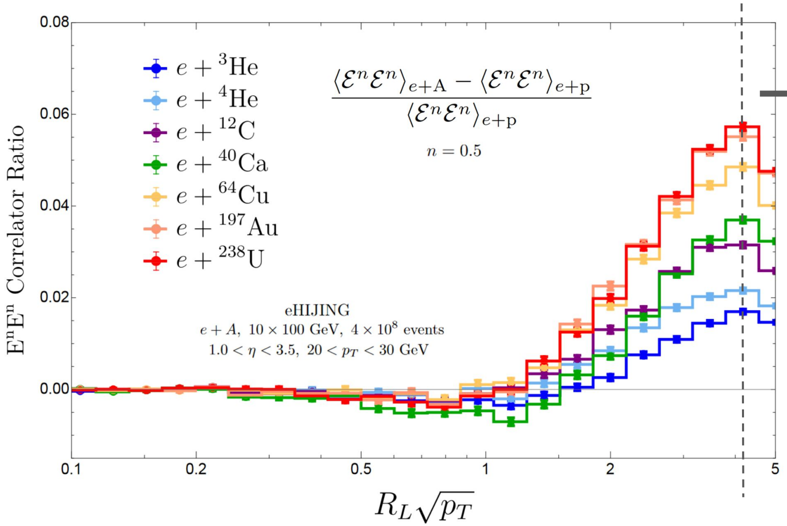


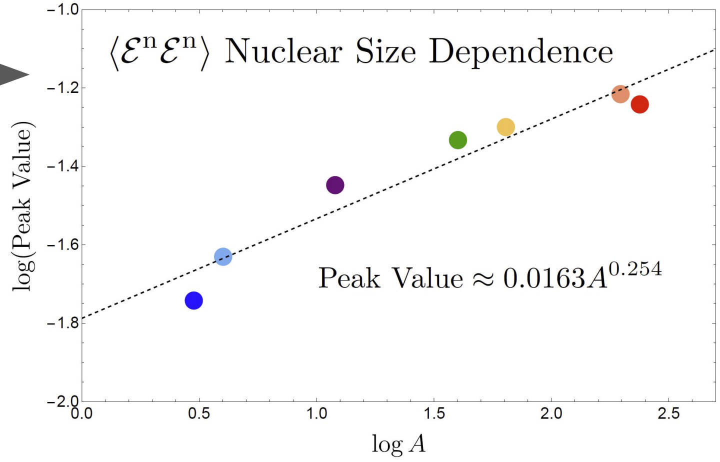
- Modification size different across nuclei
  - Curves ordered such that larger enhancement is seen for larger nuclei
  - Corresponds with larger effective path length

- Scaling the x-axis by $A^{1/6}$ (RHS) causes the turn-on points to better coincide
  - The onset angle is given by

$$\theta_R \sim \frac{1}{\sqrt{EL}} \sim \frac{1}{\sqrt{p_T A^{1/3}}} \sim \frac{1}{A^{1/6}\sqrt{p_T}}$$

Nuclear size dependence





- A more qualitative description of observed modification
  - Size of modification $\propto$ peak height of LHS curve = RHS point
  - Log-log plot on RHS used to determine power of modification's relationship with atomic mass A
- RHS plot shows a nearly linear relationship
  - Nuclear modification of jet follows power 0.25 from this fit
  - We need to investigate more what this means

Significance for the EIC

- Energy correlators will have excellent sensitivity for studying nuclear structure at the EIC
  - Energy correlators will be measured with high precision given the EIC's high luminosity
  - Modification due to cold nuclear matter effects and transport phenomena can be clearly seen
  - There is a clear nuclear size dependent trend
  - Benefits from EIC's ability to run a variety of e+A species at high luminosity