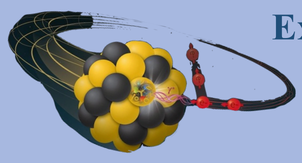

Exploring the Feasibility of Imaging Atomic Nuclei at the Electron-Ion Collider with the ePIC Experiment

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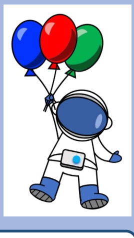


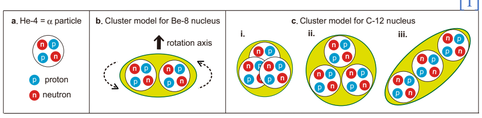
Abstract

Understanding the substructure (clustering) of atomic nuclei is crucial for gaining a comprehensive understanding of nuclear structure. Various cluster structures emerge depending on the excitation energy, the number and kinds of core clusters, and excess neutrons. In low-lying states, clusters are generally tightly bound; however, the correlation between clusters and the actual way of cluster formation is not fully charted. We have initiated feasibility studies using different measures for nuclear clustering with the ePIC detector at the Electron-Ion Collider (EIC). Using the modified BeAGLE model, we investigate the effects of clustering in $e+\,^{9}_{4}Be$, $e+\,^{12}_{6}C$ and $e+\,^{16}_{8}O$ collisions at the EIC with the aim of determining whether measurements with the ePIC detector can offer fresh insights into the phenomenon of alpha clustering within atomic nuclei.

Motivation

The rich structure of atomic nuclei:

- Clustering, halo, skin …
- Deformations; quadrupole, octupole and hexadecapole [1]



- This work presents a feasibility study on whether measurements with the ePIC detectors could give new insights into alpha clustering in atomic nuclei.
- The modified BeAGLE model is used to simulate the $^{9}_{4}Be$, $^{12}_{6}C$, and $^{16}_{8}O$ collisions.

The BeAGLE Model

The BeAGLE model [2] framework is a hybrid model that utilizes several modules;

-DPMJet model defines hadron creation and interactions with the nucleus via an intra-nuclear cascade.

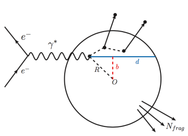
-PYTHIA-6 model, which gives the partonic interactions and subsequent fragmentation process.

-PyQM model provides the geometric density distribution of nucleons in a nucleus.

-FLUKA model describes the decay of the excited nuclear remnant.

-LHAPDF5 model and FLUKA model define the high-energy lepto-nuclear scattering.

In this model, an electron scattering event is a collision between a virtual photon (emitted by the electron) and the target nucleus.



The geometry of the collision is then characterized by examining the impact parameter (denoted as b) between the virtual photon and the nucleus.

- ✓ In this work, the centrality is defined using the model impact parameter.

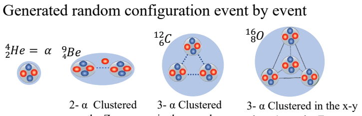
The α clustering implementation:

In $^{9}_{4}Be$, $^{12}_{6}C$, and $^{16}_{8}O$ we include the α clustering via the following scheme [3]:

a) Chose the centers of the n-α clusters with a particular configuration

b) Construct the α cluster with four nucleons

c) Generated random configuration event by event



Proposed measurements

In this work, we used the BeAGLE model to simulate the $e+\,^{9}_{4}Be$, $e+\,^{12}_{6}C$, and $e+\,^{16}_{8}O$ collisions with different initial nuclear configurations. We calculate:

- The mean energy $\langle E\rangle = \sum_{i=1}^{M} w_i E_i / \sum_{i=1}^{M} w_i$ using the ePIC detector forward acceptance of $4.6 < \eta < 5.9$
- The ratios of the mean energy between different nuclear configurations
  - ✓ Woods-Saxon
  - ✓ α-clustering in Ground State (GS)
  - ✓ α-clustering in Hoyle State (HS)

Results

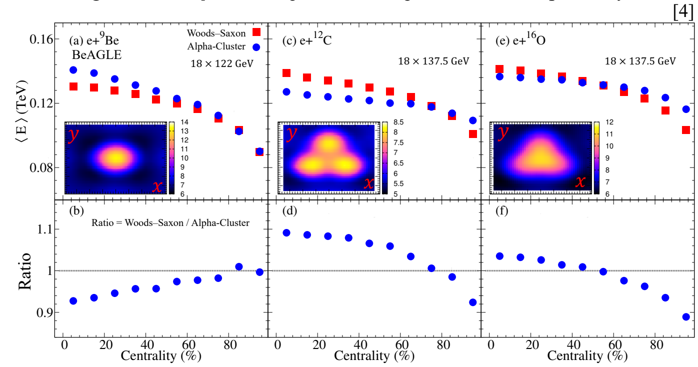
Tests of clustering effects with fixed cluster orientation

Comparisons of the neutron's mean energy $\langle E\rangle$ detected in the ePIC $B0$ detector for simulated events with and without clustering in the $e+\,^{9}_{4}Be$, $e+\,^{12}_{6}C$, and $e+\,^{16}_{8}O$ collisions, respectively.

[4]

In this current study, we are using the forward detector acceptance (i.e., $4.6 < \eta < 5.9$)

The results are for fixed orientation nuclei along the z-axis. The inset in panels (a), (c), and (e) demonstrates the initial coordinate space distribution projected to the x-y plane.



- The insets demonstrate that the nuclear distribution of clustered nuclei is integrated into the BeAGLE model and can be used to study the clustering effect on the final-state particles.
- The $\langle E\rangle$ in $B0$ is sensitive to α clustering in Be^{9}, C^{12}, and O^{16}

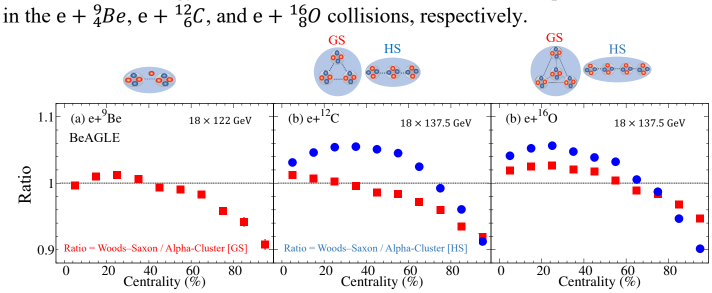
Tests of Clustering effects with random cluster orientations

Comparisons of the neutron's mean energy $\langle E\rangle$ ratios between Woods–Saxon and Alpha-Cluster cases in the $e+\,^{9}_{4}Be$, $e+\,^{12}_{6}C$, and $e+\,^{16}_{8}O$ collisions, respectively.

GS → Ground State

HS → Hoyle State

The results are for nuclei with random orientation.



- The $\langle E\rangle$ in $B0$ is sensitive to α clustering in Be^{9}, C^{12}, and O^{16}
- The $\langle E\rangle$ in $B0$ is sensitive to α clustering configuration (i.e., GS and HS)

Conclusion

We investigated the ability to use the EIC detector to study the α clustering in $^{9}_{4}\boldsymbol{Be}$, $^{12}_{6}\boldsymbol{C}$, and $^{16}_{8}\boldsymbol{O}$:

- Our proposed measurements are sensitive to α clustering and its configuration.
- Such measurements can be achieved by comparing different isotopes of $_{4}Be$, $_{6}C$, $_{8}O$

References

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