# Atomic nuclei imaging at the Electron-Ion Collider with the ePIC experiment

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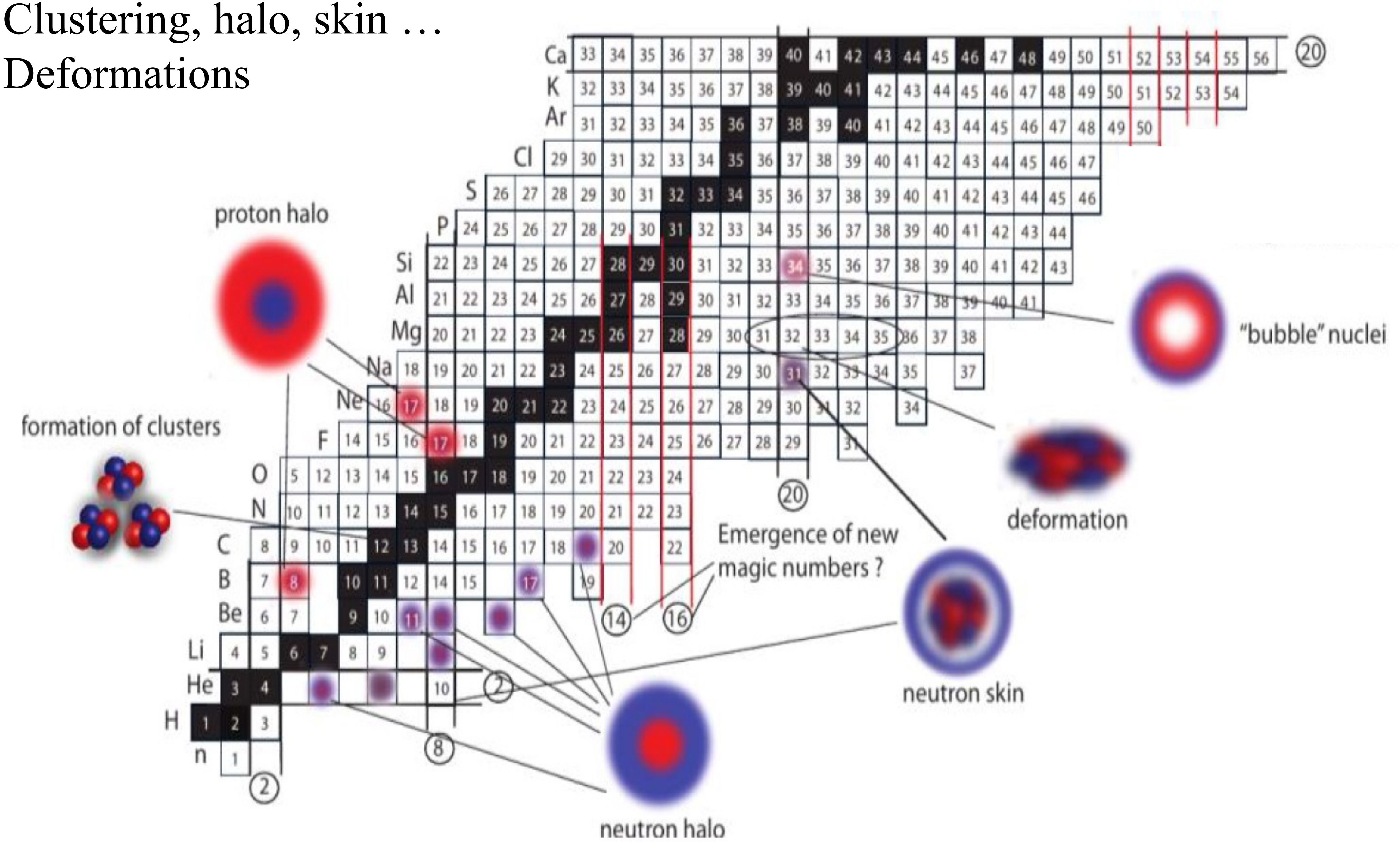
# ❖ Motivation

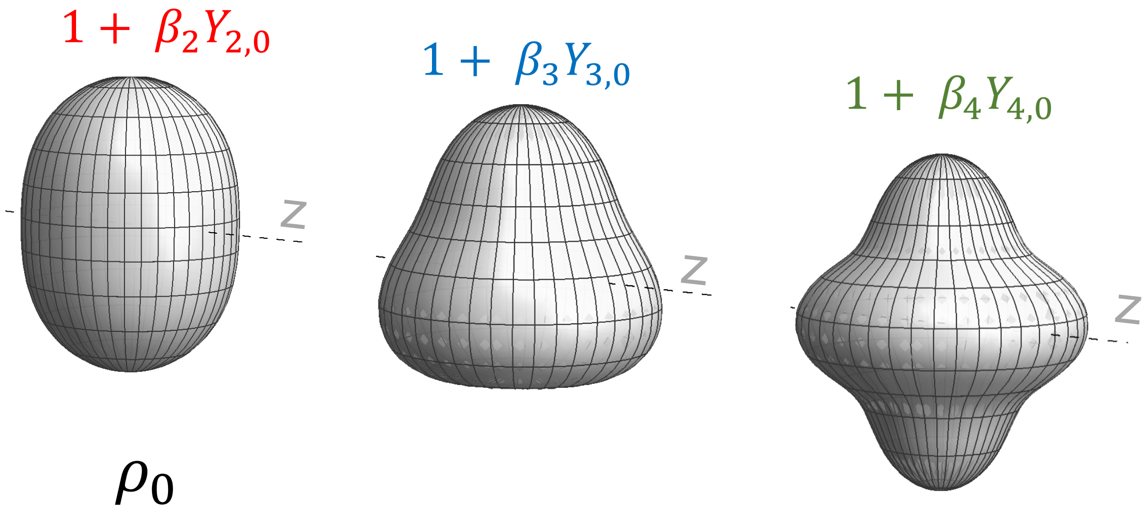
- The rich structure of atomic nuclei:
  - ✓ Clustering, halo, skin …
  - ✓ Deformations



# ❖ Motivation

The shape of the nucleus in nuclear physics is often modeled through a nucleon density profile of the Woods-Saxon $\rho(r, \theta, \phi)$.

- $Y_{n,0}$ are spherical harmonics
- $\beta_n$ are deformation parameters
  - ✓ n=2 -> Quadrupole
  - ✓ n=3 -> Octupole
  - ✓ n=4 -> Hexadecapole




$$\rho(r, \theta, \phi) = \frac{\rho_0}{1 + e^{[r - R(\theta,\phi)/a_0]}}$$

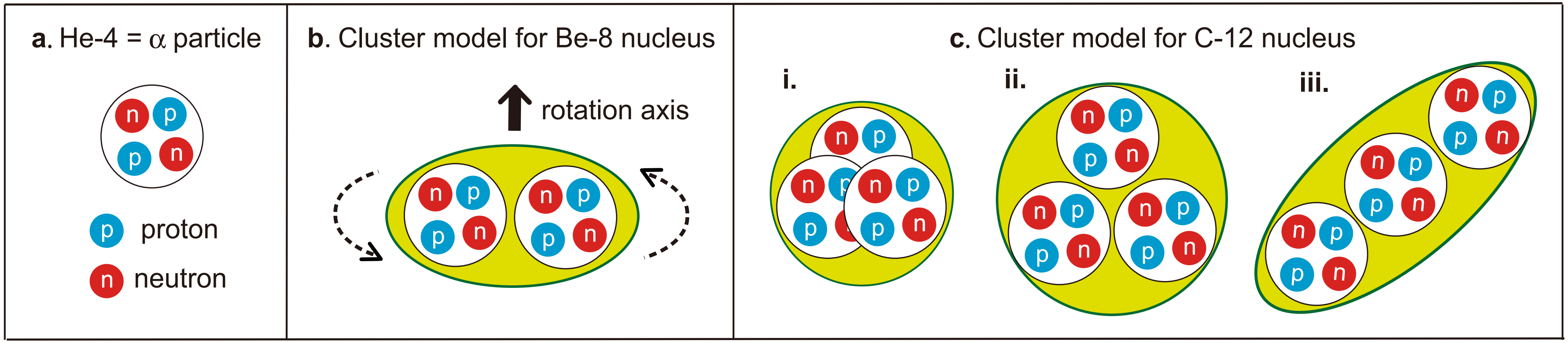
$$R(\theta, \phi) = R_0 \left(1 + \beta_2 Y_{2,0}(\theta, \phi) + \beta_3 Y_{3,0}(\theta, \phi) + \beta_4 Y_{4,0}(\theta, \phi)\right)$$

Can EIC provide additional constraints on nuclear deformation?

# ❖ Motivation

➢ What can we learn about the nuclear shape and structure (α clustering)

✓ Can α particles be the building block of some nuclei?
✓ No direct experimental evidence has ever been provided.

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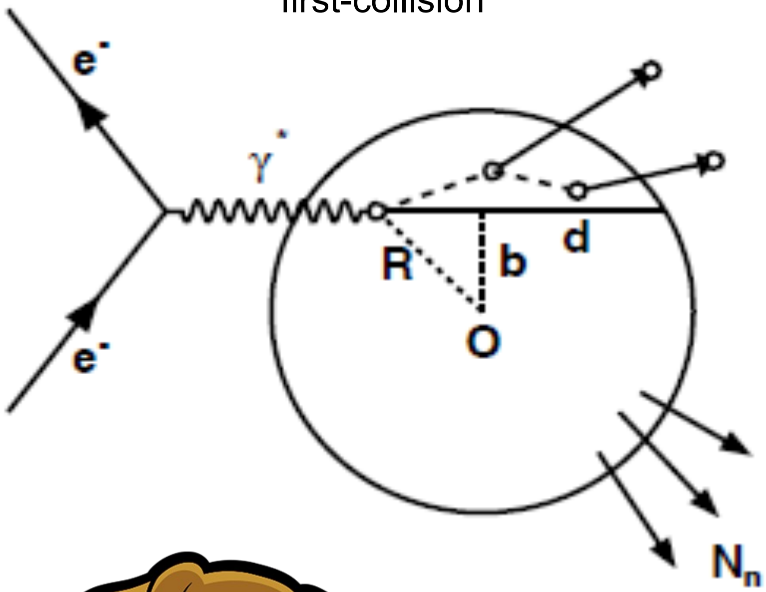
Can EIC answer this long-standing question?

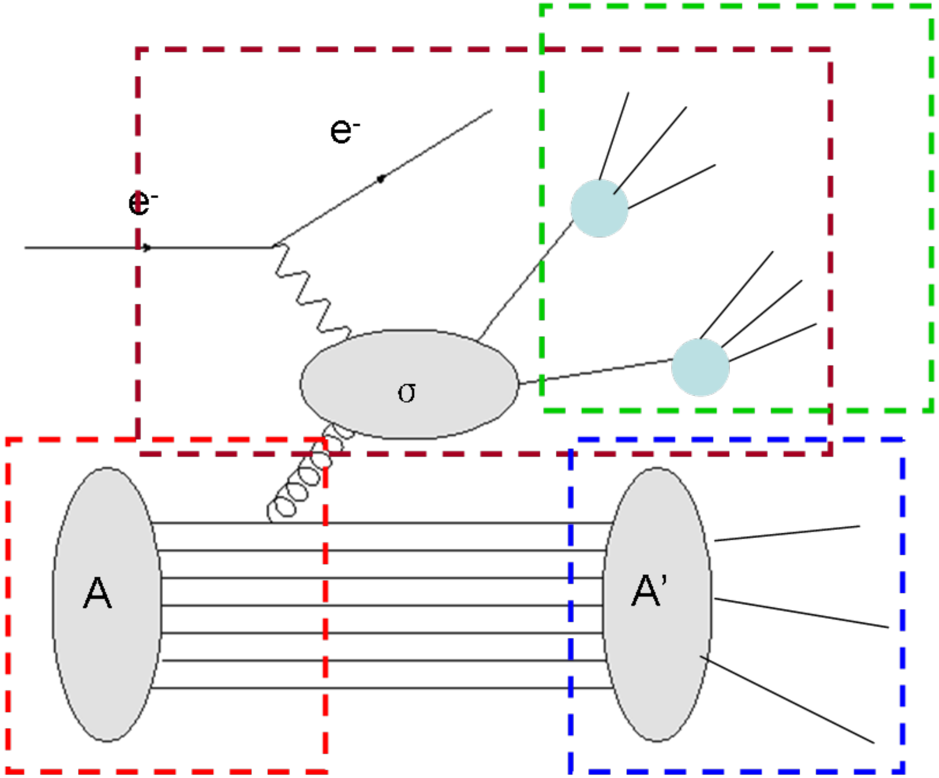
# ❖ The BeAGLE model:

$d \equiv \int dz\, \rho/\rho_0$

PRD 106, 012007 (2022)

from $Z_{first\text{-}collision} \to \infty$




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.

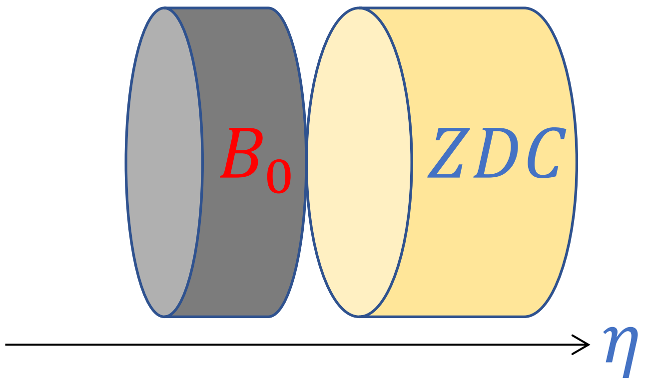
Nuclear evaporation ( gamma dexcitation/nuclear fission/fermi break up ) treated by DPMJet

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

❖ The detector's acceptance:

**Caption text**

| Detector | Acceptance | Notes |
|---|---|---|
| Zero-Degree Calorimeter (ZDC) | $\theta < 5.5$ mrad ($\eta > 6$) | About 4.0 mrad at $\phi \sim \pi$ |
| B0 Detector | $5.5 < \theta < 20.0$ mrad ($4.6 < \eta < 5.9$) | Silicon tracking + EM preshower |



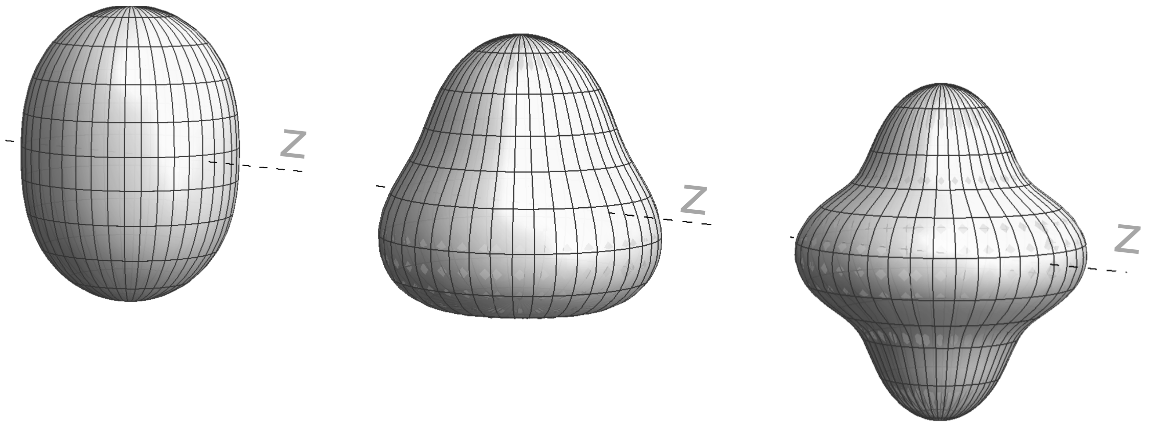

➢ In this current study, we are using: ZDC and $B_0$ detectors

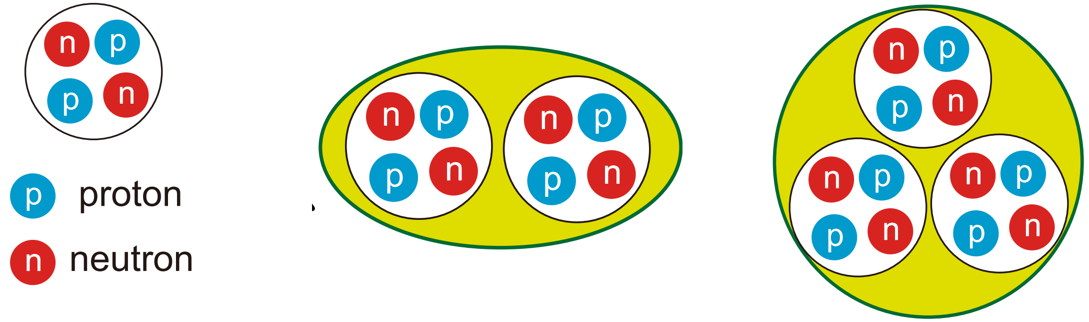
# ❖ Motivation

➢ EIC can be a unique tool for understanding the nuclear structure?

✓ Understanding the nuclear deformation

✓ Understanding the α clustering



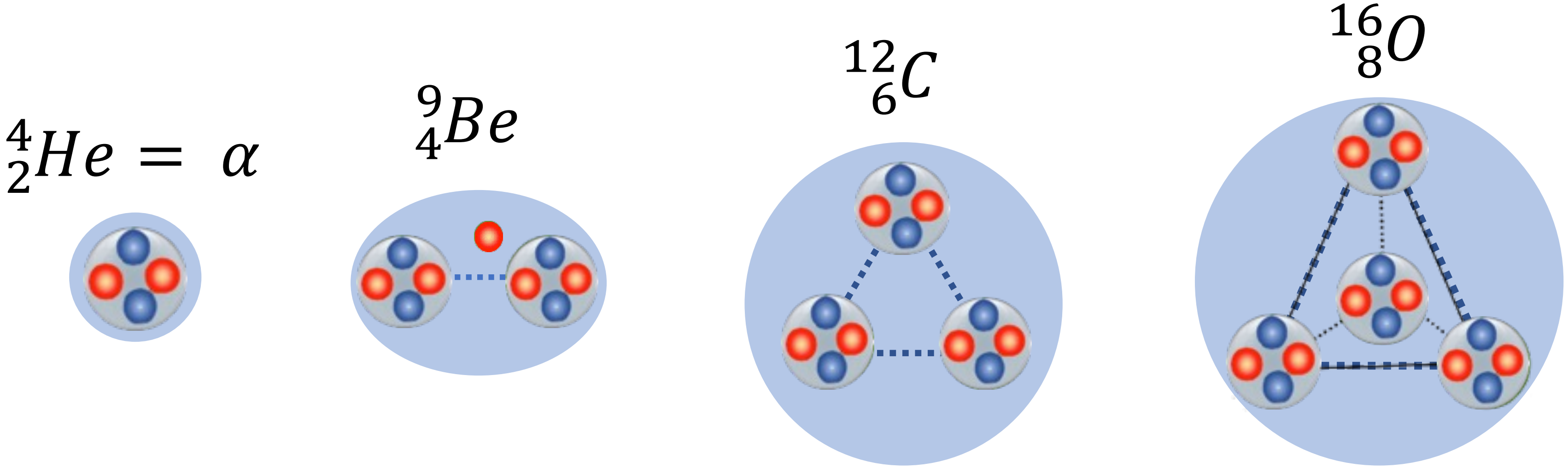




$He^{4} = \alpha\ particle$ $Be^{8} = 2\ \alpha\ particles$ $C^{12} = 3\ \alpha\ particles$

We are putting additional efforts into the simulation in these avenues:

- ➢ Using the BeAGLE model
  - ✓ Modifying the nucleus information in the model

# ❖ The α clustering

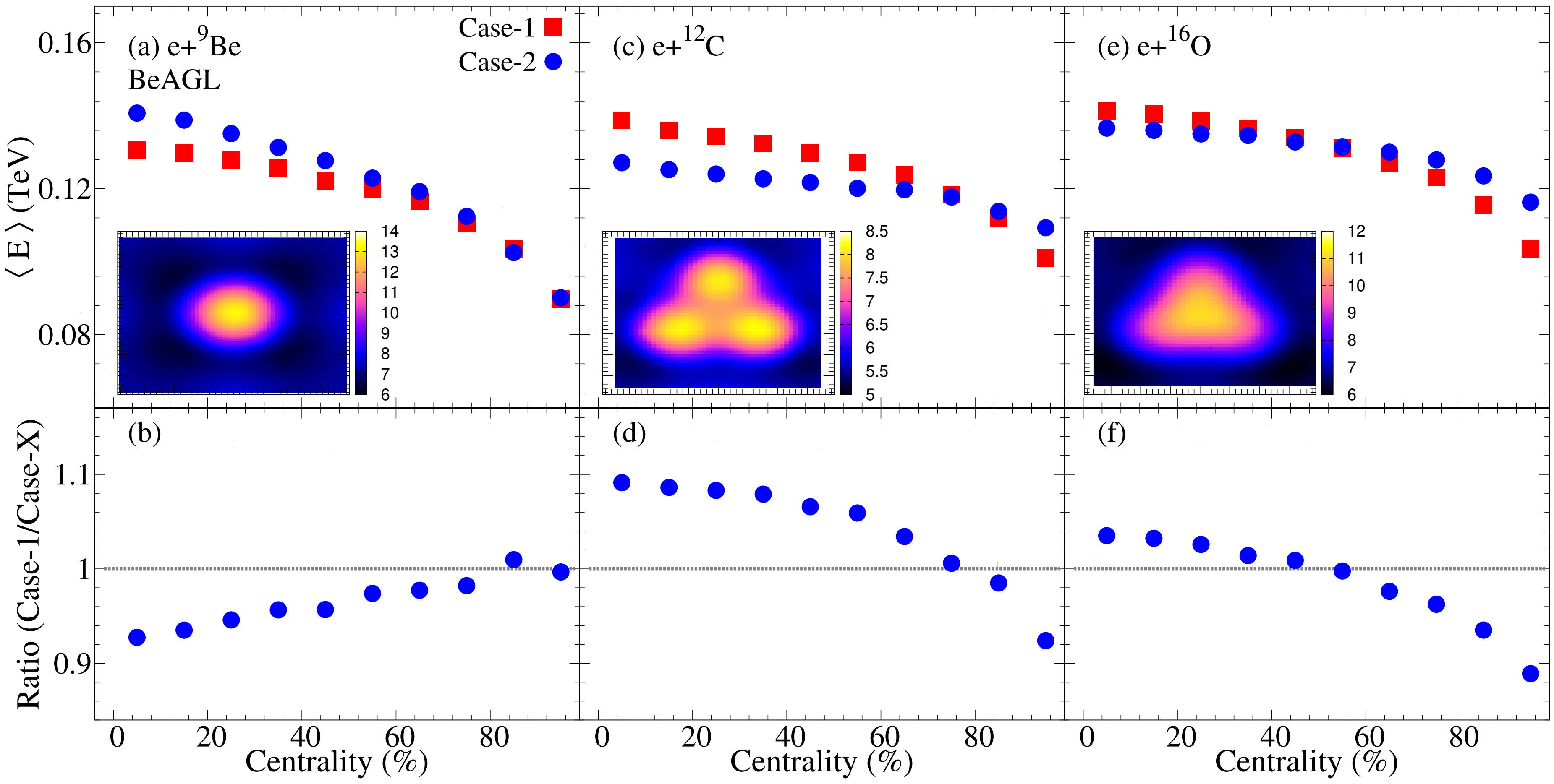



- The α clustering in $^{9}_{4}Be$, $^{12}_{6}C$, and $^{16}_{8}O$
- Fixed and random orientation
- The BeAGLE model is updated to consider the α clustering

# ❖ The α clustering

- ➢ Neutrons at forward rapidity
- ➢ Fixed orientation

➢ Shadowing is On




The $\langle E \rangle$ in $B_0$ is sensitive to α clustering in $Be^9$, $C^{12}$, and $O^{16}$

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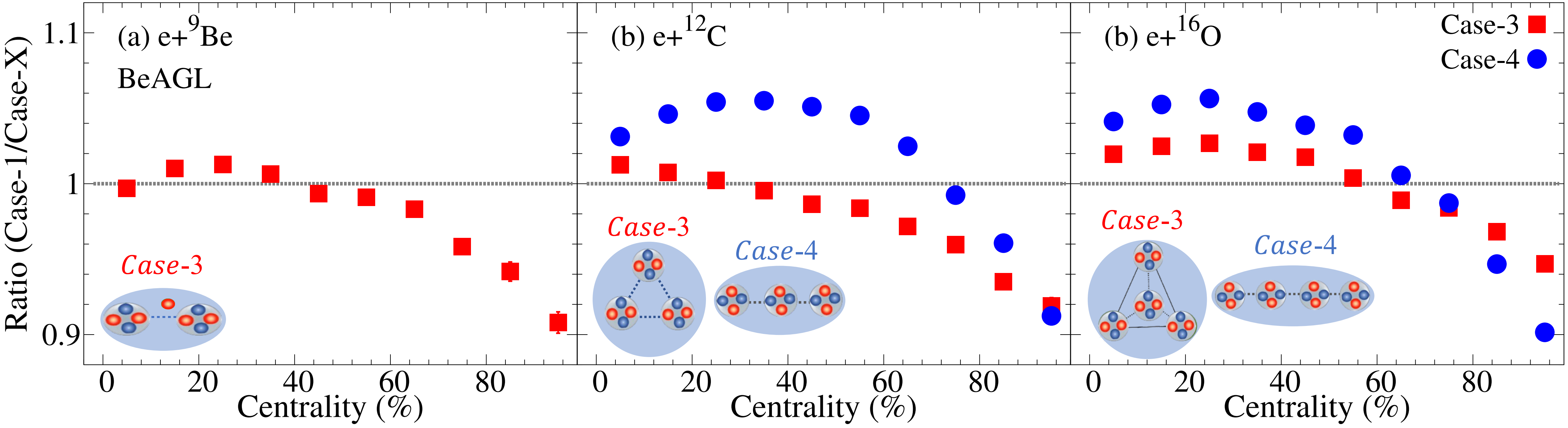
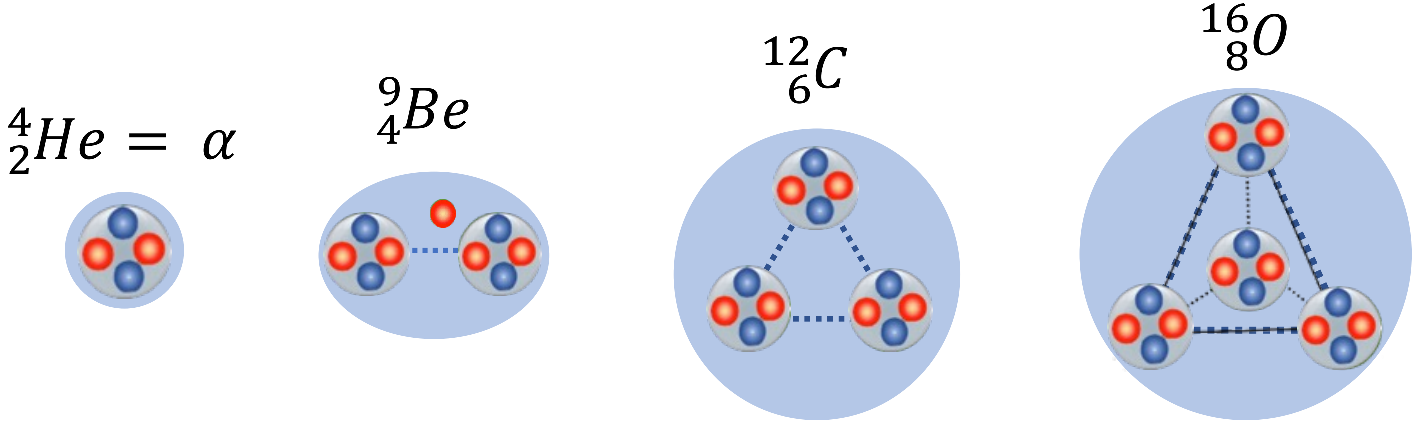



The $\langle E \rangle$ in $B_0$ is sensitive to α clustering in $Be^9$, $C^{12}$, and $O^{16}$

# ❖ Conclusions

We investigated the ability to use the forwarded rapidity detectors to investigate the α clustering in ${}^{9}_{4}Be$, ${}^{12}_{6}C$, and ${}^{16}_{8}O$:




- For fixed and random orientations;
  - ✓ Characteristic patterns are observed because of α-clustering
  - ✓ The $\langle E \rangle$ in $B_0$ is sensitive to α clustering, and its configuration

**Thank You**