Probing the Structure of Exotic Hadrons at the EIC

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EIC @ Snowmass

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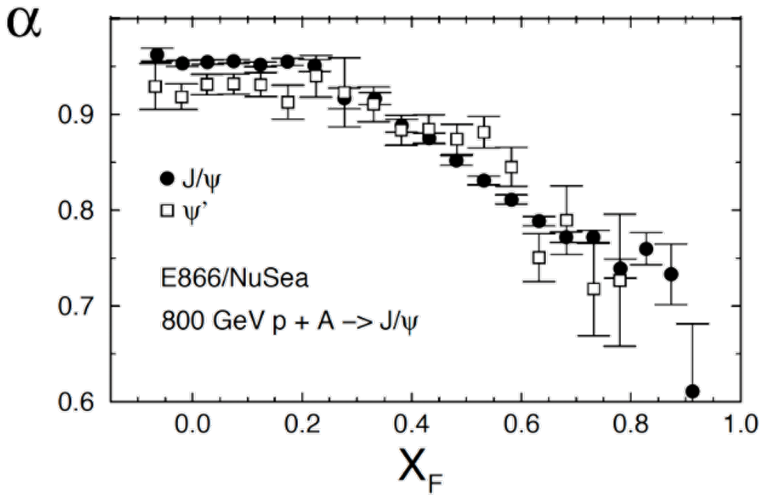
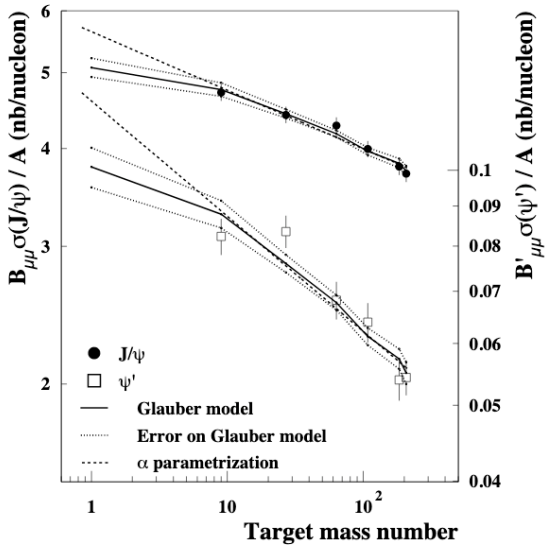
Quarkonia Interactions Inside the Nucleus

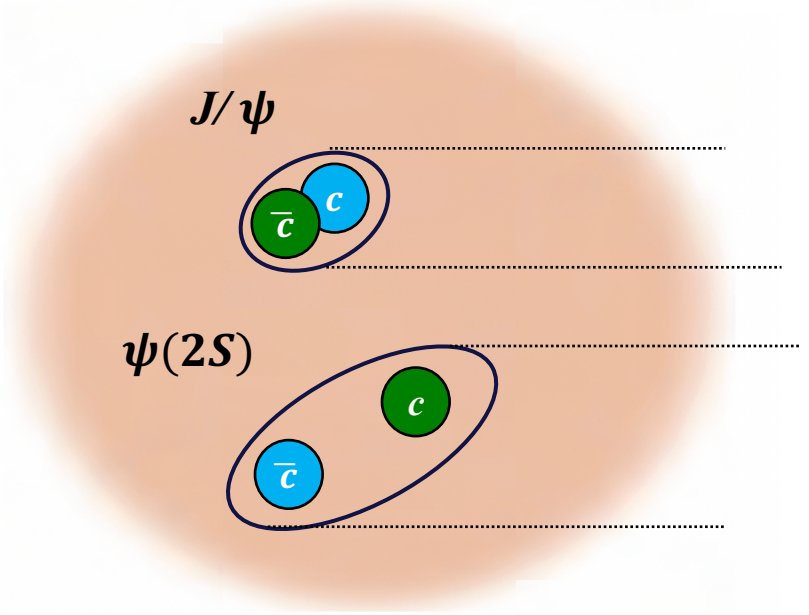
- At the EIC, hadronization inside the nucleus becomes an important effect (Vitev, 1912. 10965)
- Quarkonia is subject to breakup as it crosses the nucleus – suppression due to disruption of the $Q\bar{Q}$ pair

E866, PRL 84 (2000) 3256-3260



NA50, EPJC 48 329 (2006)





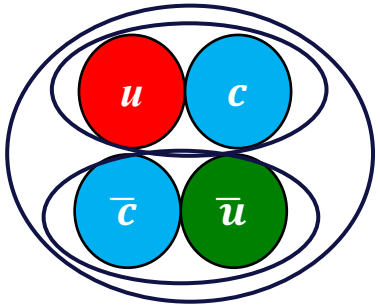
- Larger (weakly bound) states sample a larger volume of the nucleus while passing through – larger absorption cross section Arleo, Gossiaux, Gousset, Aichelin PRC 61 (2000) 054906
- Explains trends observed in fixed target data at FNAL, SPS
- As expected, fails at RHIC (hadronization occurs outside nucleus) PHENIX PRL 111 202301 (2013)

Study Exotic Hadron Structure at the EIC

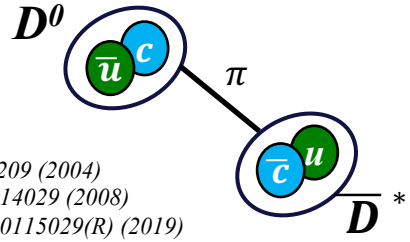
- The structure of exotic quarkonia states such as X(3872) is not known:

Compact Tetraquark
(relatively tightly bound)

Diquark-diantiquark
PRD 71, 014028 (2005)
PLB 662 424 (2008)



Hadronic Molecule
(weakly bound)



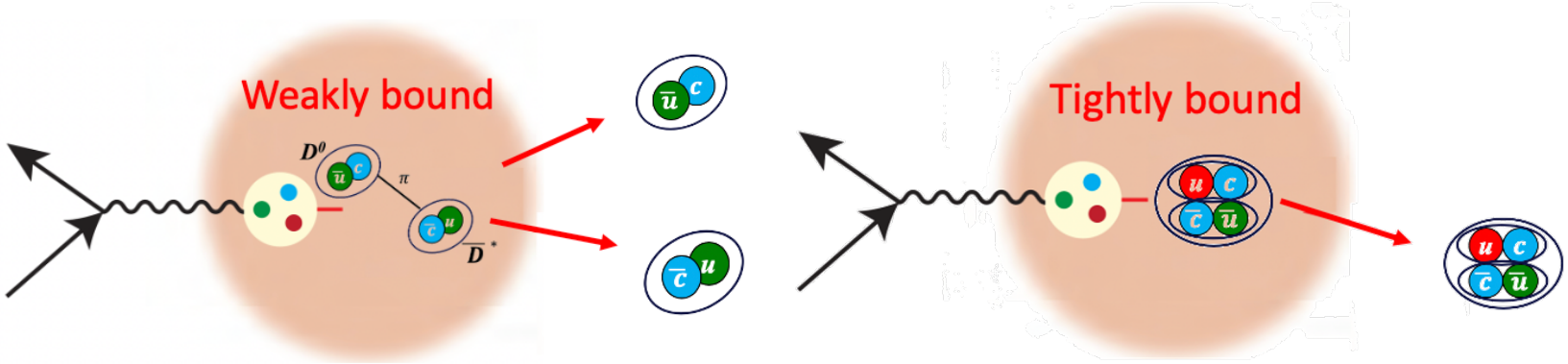
PLB 590 209 (2004)
PRD 77 014029 (2008)
PRD 100 0115029(R) (2019)

Mixtures
exotic + conventional states

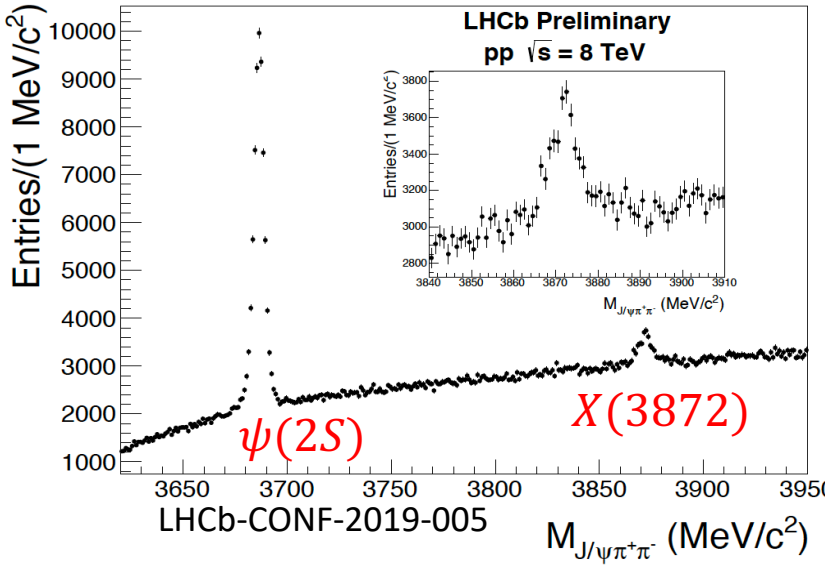
$$X = a\,|c\bar{c}\rangle + b\,|c\bar{c}q\bar{q}\rangle$$

PLB 578 365 (2004)
PRD 96 074014 (2017)

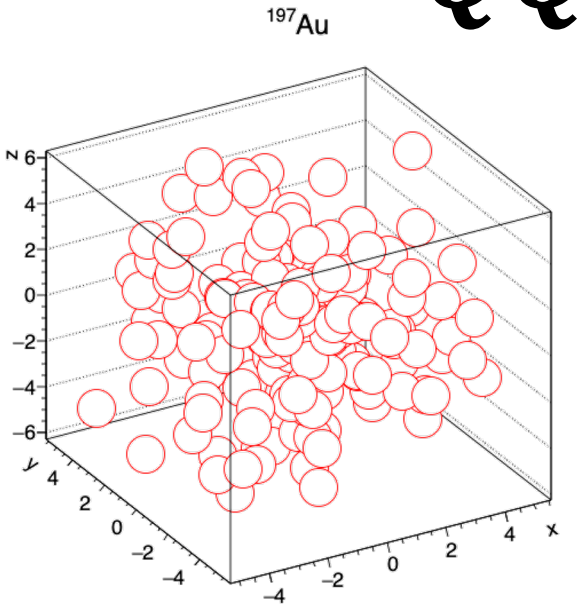
- Breakup of X(3872) and other exotics in nuclei should depend on radius
- Therefore, exotic structure can be studied by measuring suppression in eA collisions:



conventional $\psi(2S)$ and exotic X(3872) accessible through $J/\psi\pi^+\pi^-$ decays



$Q\bar{Q}$ Propagation through Nuclei



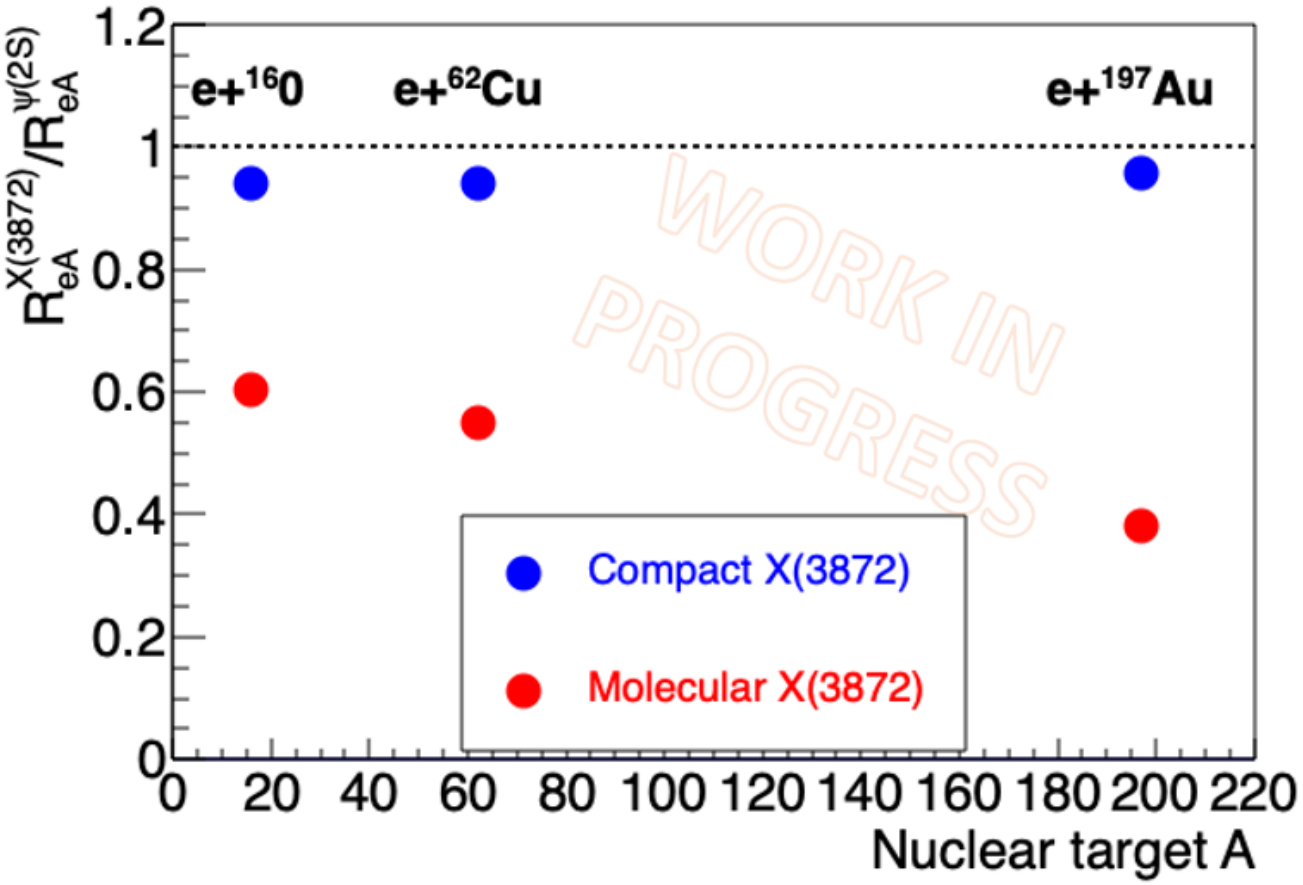
- In Monte Carlo simulation, populate a Glauber nucleus, using parameters from PHOBOS model: arXiv:1408.2549
- Randomly select starting point for $Q\bar{Q}$ pair
- Propagate $Q\bar{Q}$ along z axis

- Following model of Arleo *et al.* in Phys Rev C, 61 054906 (2000), expand $Q\bar{Q}$ radius as a function of time:

$$r_{c\bar{c}}(\tau) = \begin{cases} r_0 + v_{c\bar{c}}\ \tau & \text{if } r_{c\bar{c}}(\tau) \leq r_i \\ r_i & \text{otherwise} \end{cases}$$

- Calculate radius-dependent cross section: $\sigma_{(c\bar{c})_1 N} = \sigma_{\psi N}(s) \cdot (r_{c\bar{c}}/r_{\psi})^2$
- If the state comes within a distance of $\sqrt{\sigma_{c\bar{c}}/\pi}$ to a nucleon, consider it disrupted.
- Three cases: $\psi(2S)$ with radius 0.87 fm, compact X(3872) with radius 1 fm, molecular X(3872) with radius 7 fm

Relative modification of X(3872)/ $\psi(2S)$ at EIC



$$\frac{R_{eA}^{X(3872)}}{R_{eA}^{\psi(2S)}} = \frac{\sigma_{eA}^{X}}{\sigma_{eA}^{\psi}} \Big/ \frac{\sigma_{ep}^{X}}{\sigma_{ep}^{\psi}}$$

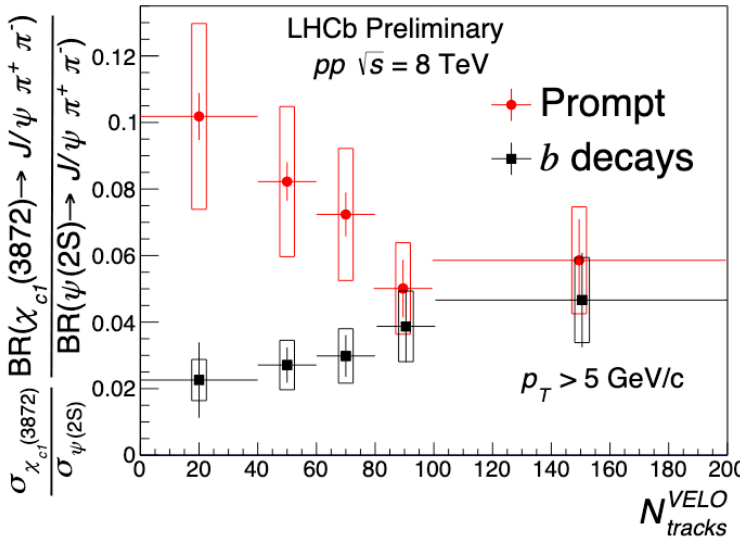
- Little difference in suppression between model of compact X(3872) and $\psi(2S)$, as expected.
- Large difference between model of molecular X(3872) and $\psi(2S)$.

- **The EIC has the potential to provide decisive discrimination between exotic structure models.**
  - **X(3872) is only an example, technique can be applied to other exotics as well.**
    - **This work is supported by LANL Lab Directed R&D**

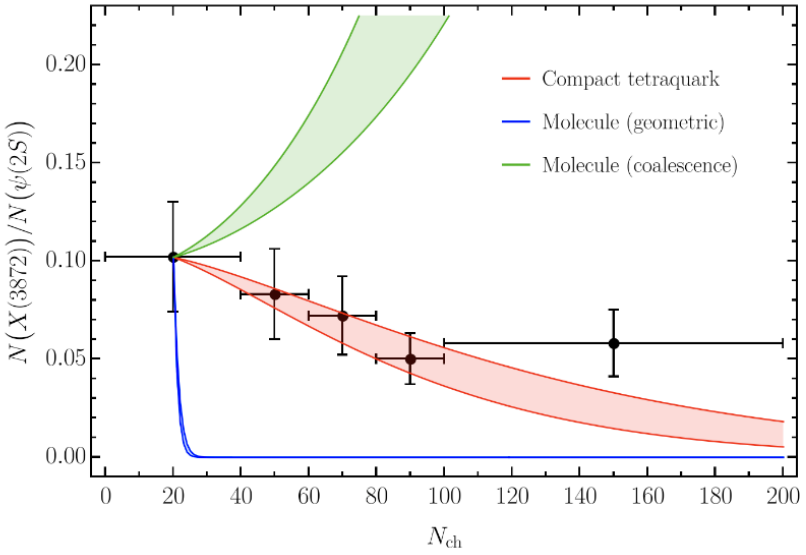
BACKUP

Interactions of exotics with QCD medium

LHCb-CONF-2019-005



Esposito et al, 2006.15044



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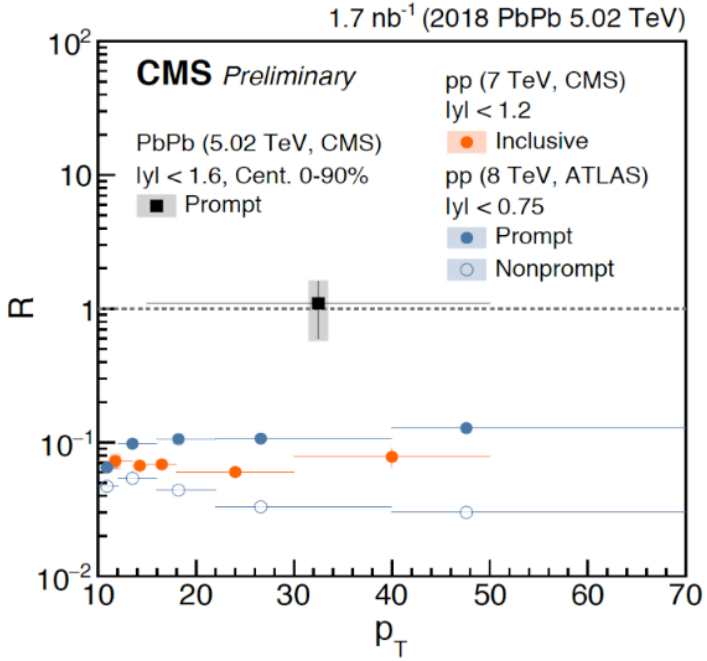

$$R = 1.10 \pm 0.51\ (\text{stat.}) \pm 0.53\ (\text{syst.})$$