

# **Gluonic structure of nucleon and nuclei at RHIC and its implication at the EIC**

Alex Jentsch, Bill Schmidke, and Kong Tu  
Cold QCD group  
Sep 8, 2022

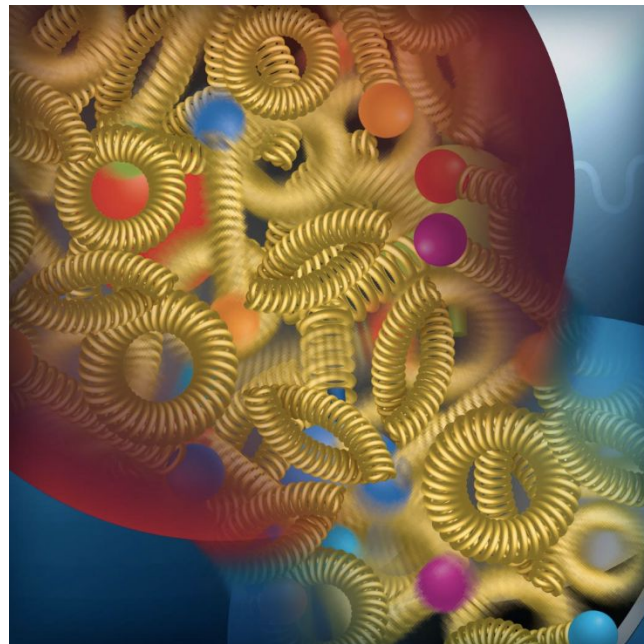
# Gluons in nucleon/nuclei at high energy

## The big questions:

- What role does gluon play in nuclear structure at high energy?
- What can gluonic structure of nucleon/nuclei tell us about *confinement*?

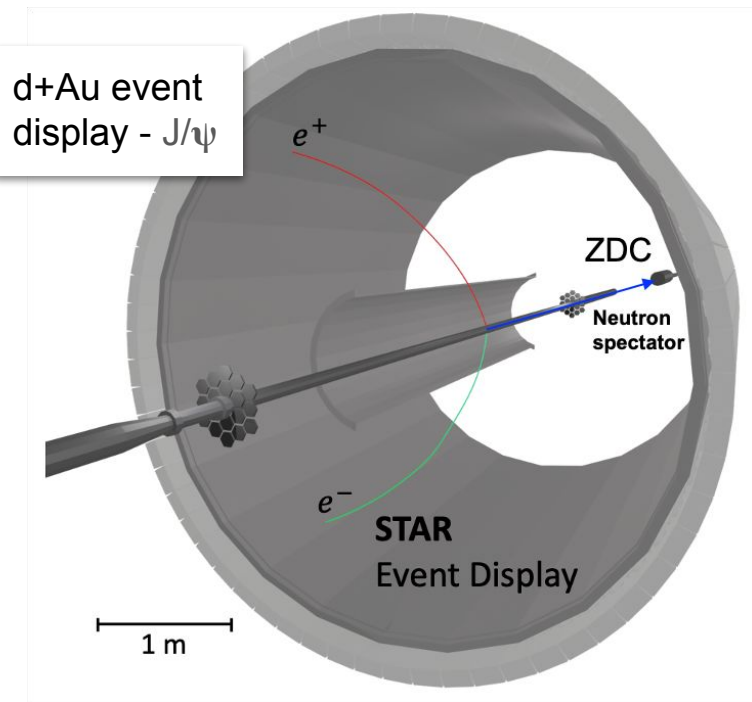
## Specific questions and directions:

- What is the gluon spatial distribution in nuclei?
- What is the correct or most relevant paradigm in describing the gluon density from low to high energy? Saturation or shadowing?
- Origin of mass?



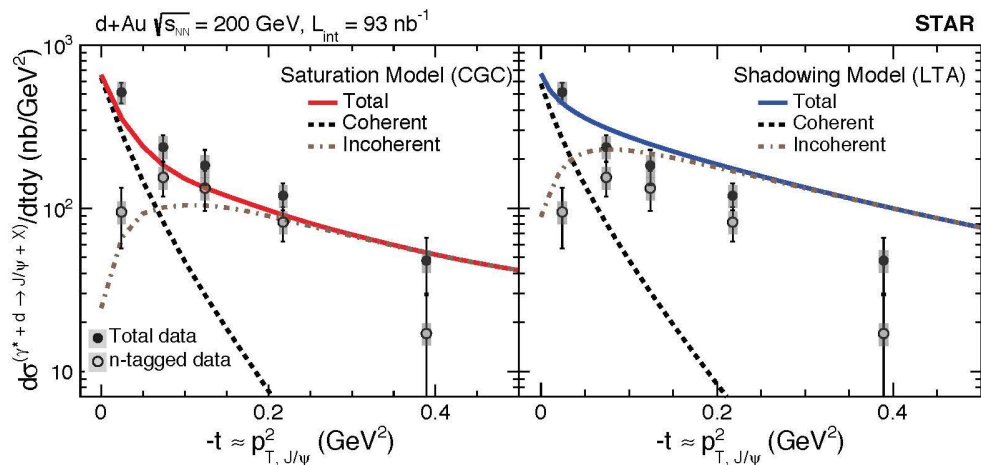
The glue that binds us all

# Unique capability of ultra-peripheral collisions at RHIC



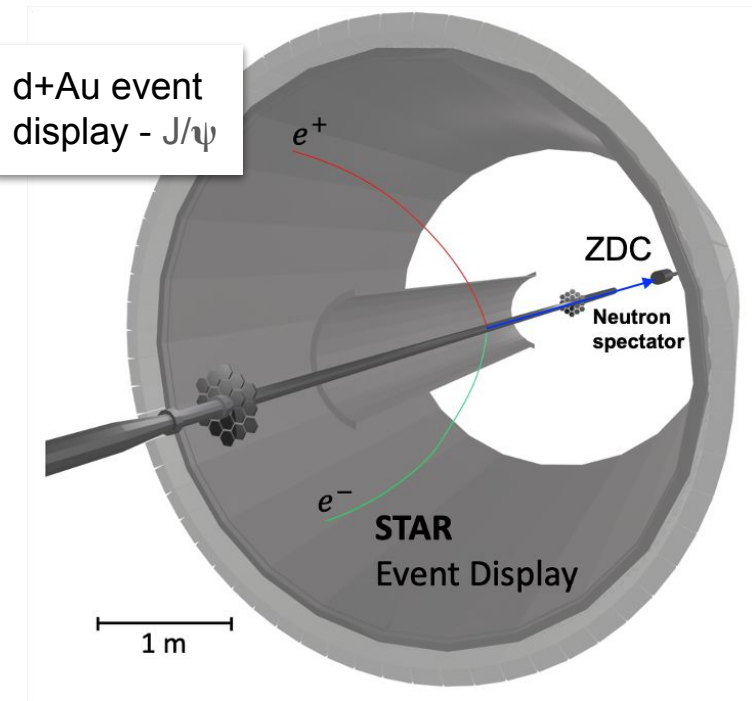
$$\gamma + p/A \rightarrow \text{VM} + p/A/X$$

- **Systems:** pp, pAu, dAu, RuRu, ZrZr, AuAu collisions at their top RHIC energies.
- **Vector-Meson:**  $\rho$ ,  $J/\psi$ , and possibly  $\phi$ .
- **Polarizations:** proton beam.
- **Forward detectors:** ZDC, RPs(?) for pAu pp runs.



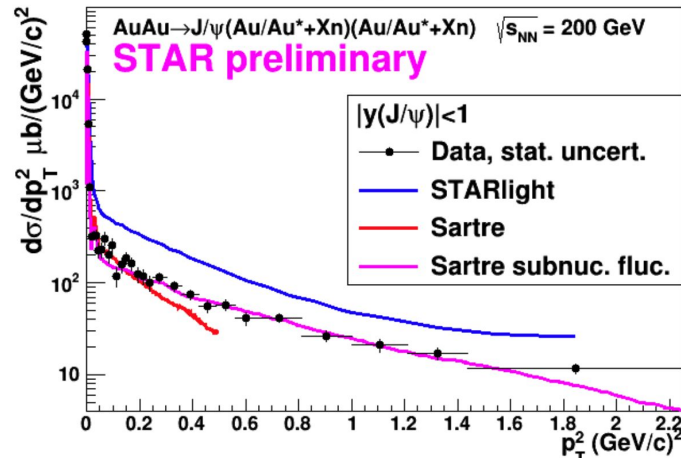
Gluon distributions measured in deuteron  
[Phys.Rev.Lett. 128 (2022) 12, 122303]

# Unique capability of ultra-peripheral collisions at RHIC



$$\gamma + p/A \rightarrow VM + p/A/X$$

- **Systems:** pp, pAu, dAu, RuRu, ZrZr, AuAu collisions at their top RHIC energies.
- **Vector-Meson:**  $\rho$ ,  $J/\psi$ , and possibly  $\phi$ .
- **Polarizations:** proton beam.
- **Forward detectors:** ZDC, RPs(?) for pAu pp runs.

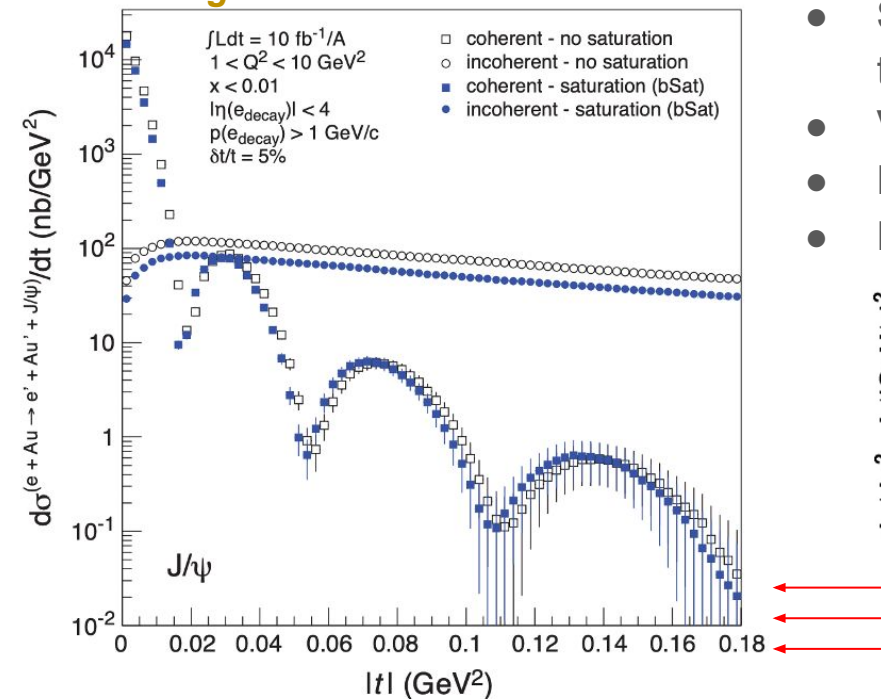


Au nucleus:  
first-time  
measurement from  
low to high  $p_T$

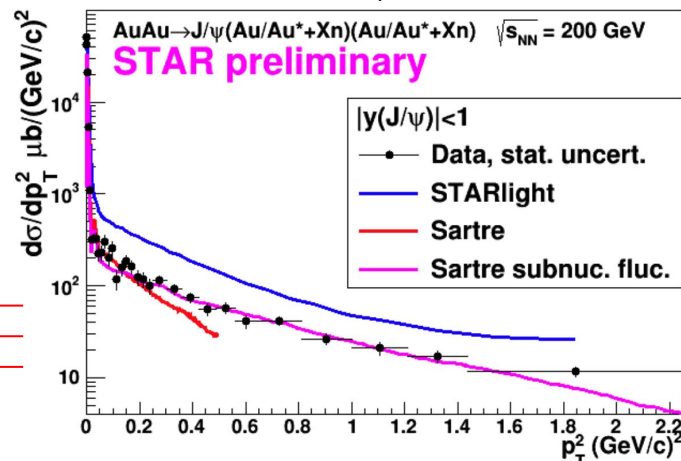
Coherent & incoherent production  $\rightarrow$  gluon spatial distributions and nucleon fluctuations

# Unique capability of ultra-peripheral collisions at RHIC

## EIC golden measurement



- **Systems:** pp, pAu, dAu, RuRu, ZrZr, AuAu collisions at their top RHIC energies.
- **Vector-Meson:**  $\rho$ ,  $J/\psi$ , and possibly  $\phi$ .
- **Polarizations:** proton beam.
- **Forward detectors:** ZDC, RPs(?) for pAu pp runs.



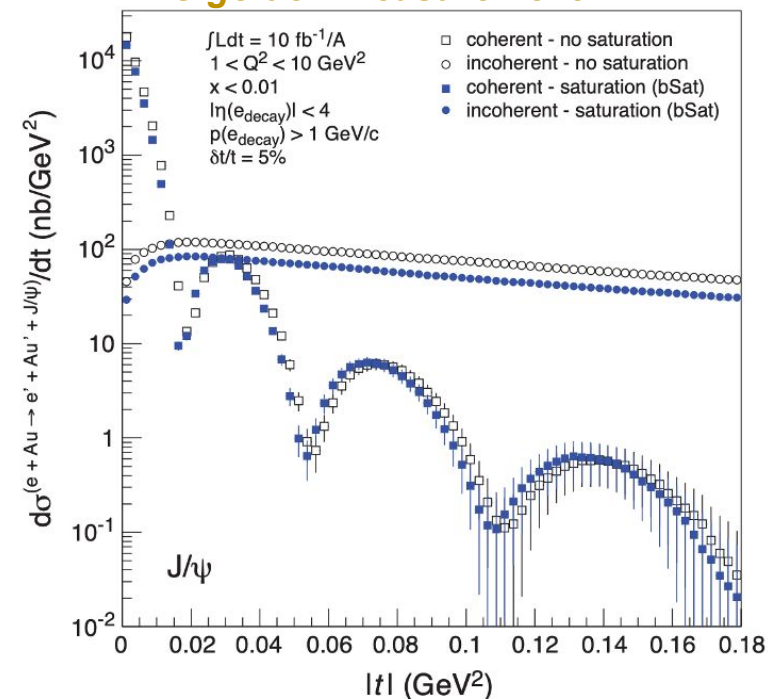
Au nucleus:  
first-time  
measurement from  
low to high  $p_T$

Understand RHIC data is the key!

Coherent & incoherent production → gluon spatial distributions and nucleon fluctuations

# Unique capability of ultra-peripheral collisions at RHIC

## EIC golden measurement



Understand RHIC data is the key!

- **Systems:** pp, pAu, dAu, RuRu, ZrZr, AuAu collisions at their top RHIC energies.
- **Vector-Meson:**  $\rho$ ,  $J/\psi$ , and possibly  $\phi$ .
- **Polarizations:** proton beam.
- **Forward detectors:** ZDC, RPs(?) for pAu pp runs.

Tools:

- System/target dependence, VM species dependence, polarization dependence, separation of coh/incoh., etc.

Goal:

- An **unified picture** of the gluonic structure from nucleon to heavy nuclei at RHIC energies, **refined models** to projections at the EIC based on RHIC data, and (clearly identify) **challenges/opportunities** for the EIC

# Plans

## Must-haves:

- High-luminosity AuAu, pAu, and pp runs for Run 23-25 - as scheduled.
- Forward capabilities of STAR, dedicated triggers, etc.
- People-power, software support, etc for analyzing the data.
- **Training next-generation scientists for the EIC physics based on RHIC data.**

## Directions:

1.  $J/\psi$  photoproduction in Au and proton, compared with inclusive jet photoproduction in Au and p;
2.  $J/\psi$  near-threshold and/or sub-threshold production in p and Au;
3.  $J/\psi$  photoproduction in polarized proton;
4. **Exploratory study, photoproduction of  $\phi$ , which is difficult at the EIC;**
5. ...

**EIC will extend in detector coverages, kinematic phase spaces, precisions, etc.**  
**Both RHIC & EIC are necessary to understand the big questions.**