

# Physics Opportunities with Heavy Quarkonia at EIC

Topical Workshop, Center for Frontiers in Nuclear Science CFNS, Stony Brook University, 25-27 Oct, 2021 (virtual)

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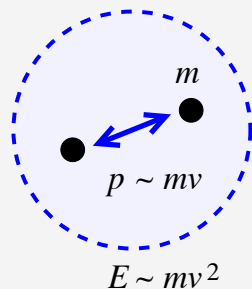


- Welcome
- Context and objectives
- Plan of meeting



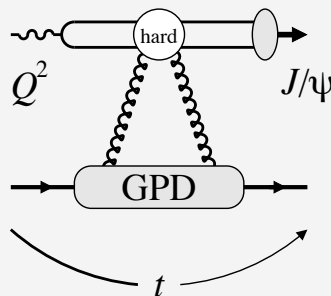
## Heavy quarkonia structure

- Multiscale systems
- Small size on hadronic scale  $\leftrightarrow$  QCD
- Unique probe of gluodynamics
- Theoretical approaches: LQCD, NRQCD, QCD sum rules, instantons, holography



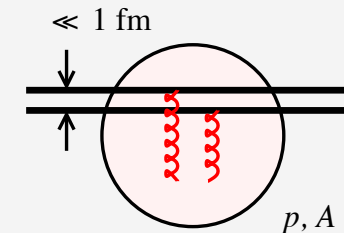
## Heavy quarkonia production

- QCD factorization
- Processes: Inclusive and exclusive, pp/AA vs ep/eA, small-x vs near-threshold
- HQ structure: Wave functions, LDMEs, universality
- Open questions



## Probe of initial-state gluons

- Color dipole probes gluon field
- Nucleon: Gluon PDFs, GPDs  $\leftrightarrow$  form factor, local gluon operators  $\leftrightarrow$  EM tensor
- Nuclei: Shadowing, diffraction, saturation

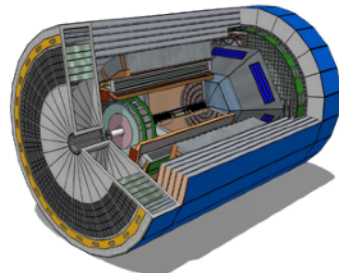
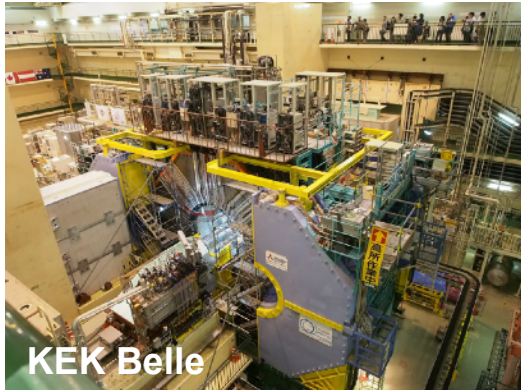
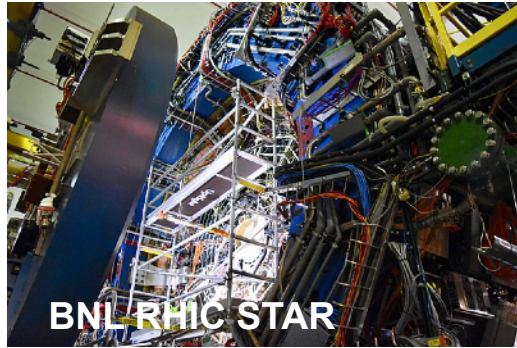


## Probe of final-state medium

- Heavy-ion collisions: Hot medium, QGP
- Extensively studied in theory experiment

## Heavy quarkonia spectroscopy

- XYZ states: Challenge conventional understanding
- Open questions: Universality, channel couplings  $\leftrightarrow$  decays, near-threshold effects
- Future: Move from spectroscopy to structure



EIC Project detector schematic

## **pp/AA collisions at LHC, RHIC, Tevatron**

Extensive measurements of inclusive quarkonium production, jets, nuclear modifications

## **Ultrapерipheral $\gamma\gamma/\gamma A$ collisions at LHC, RHIC**

High-energy photoproduction in diffractive/exclusive processes

## **$e^+e^-$ facilities BaBar, Belle, BES**

Heavy quarkonium spectroscopy, XYZ states

## **$ep/\gamma p$ collisions at HERA**

$J/\psi$  production in diffractive/exclusive processes, also  $\Upsilon$

## **$ep/\gamma p$ in fixed-target experiments**

$J/\psi$  production at SLAC, Cornell, FNAL, CERN

JLab12 GlueX results; CLAS12, Hall C planned

## **$ep/\gamma p/eA/\gamma A$ at electron-ion collider EIC**

CM energy 20-100 GeV/N, luminosity  $\sim 10^{33}$ - $10^{34}$  cm<sup>-2</sup>s<sup>-1</sup>

First eA collider!



## Scientific program and community

Scientific program and machine designs developing since late 1990s

Major milestones: 2015 EIC White Paper, 2015 NSAC Long-Range Plan; 2017 US National Academy of Sciences Study

Formation and organization of international user community  
>1200 scientists, 250 institutions [\[Webpage\]](#)

## DOE EIC Project

CD0 and site selection at Brookhaven National Lab in 2019

CD1 achieved in 2021 [\[Webpage\]](#)

CD4 and operations expected in 2030+

Framework for international participation being set up

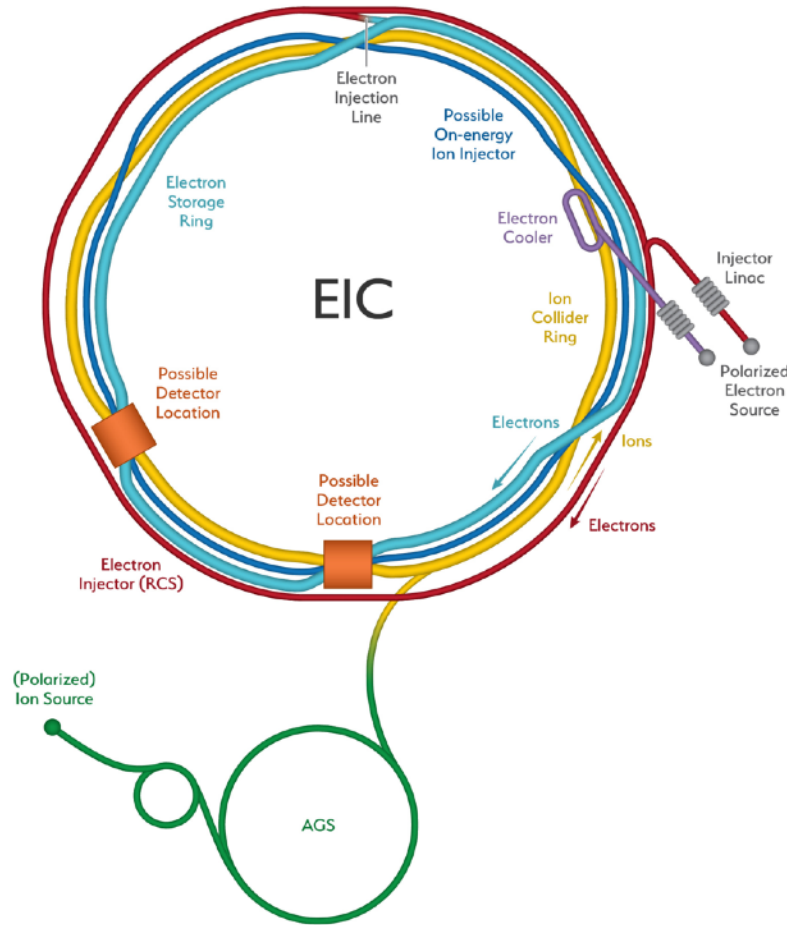
Project hosted/managed jointly by BNL and JLab

## Current developments

EIC Yellow Report Physics-Detector studies completed 2021 [\[2103.05419\]](#)

Call for Collaboration Proposals for EIC detectors (1 Dec, 2021) [\[Webpage\]](#)

Community exploring possibilities/options for second detector/IR



## Objectives

- Review physics of heavy quarkonium structure, production, and use as probe of gluonic structure and hot/dense matter
- Assess experimental requirements for heavy quarkonium measurements at EIC, lessons from previous experiments, and available solutions
- Connect pp/AA and ep/eA communities, theory and experiment

} Based on Yellow Report, but going beyond...

## Agenda

Heavy quarkonium structure: LQCD, NRQCD

**Mon 25 Oct**

Heavy quarkonium production in QCD: Factorization, pp and ep, small-x and near-threshold

Heavy quarkonium as probe of gluonic structure of initial state: PDFs/GPD, diffraction, nuclear shadowing

**Tue 26 Oct**

Heavy quarkonium as probe of hot/dense matter: Effective theories, open quantum systems, transport theory

Detector requirements for quarkonium measurements at EIC: Exclusive/inclusive, coverage, resolution

**Wed 27 Oct**

Lessons from other experiments: HERA, LHCb

Status of heavy quarkonium capabilities of EIC detector proposals

**Format:** Summary presentations 25+5 mins, topical discussion at end of sessions

Past CFNS Workshop “Opportunities with heavy flavor at EIC”, 4-6 Nov 2020, 140 participants [\[Webpage\]](#):  
Reviewed all heavy flavor physics, including open HF, jets — many interesting ideas and connections.  
Present workshop focuses specifically on heavy quarkonia

Upcoming CFNS Workshop “Exotic heavy meson spectroscopy and structure with EIC”, early 2022, dates TBD:  
Will focus specifically on exotic heavy quarkonium spectroscopy, XYZ states