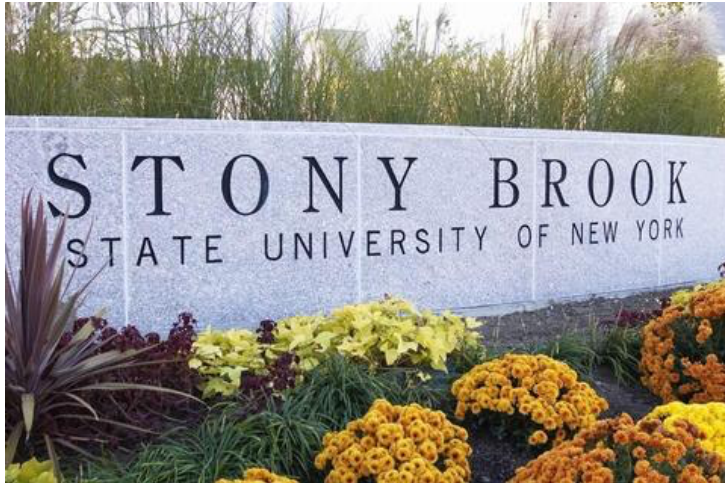


# Exotic heavy meson spectroscopy and structure with EIC

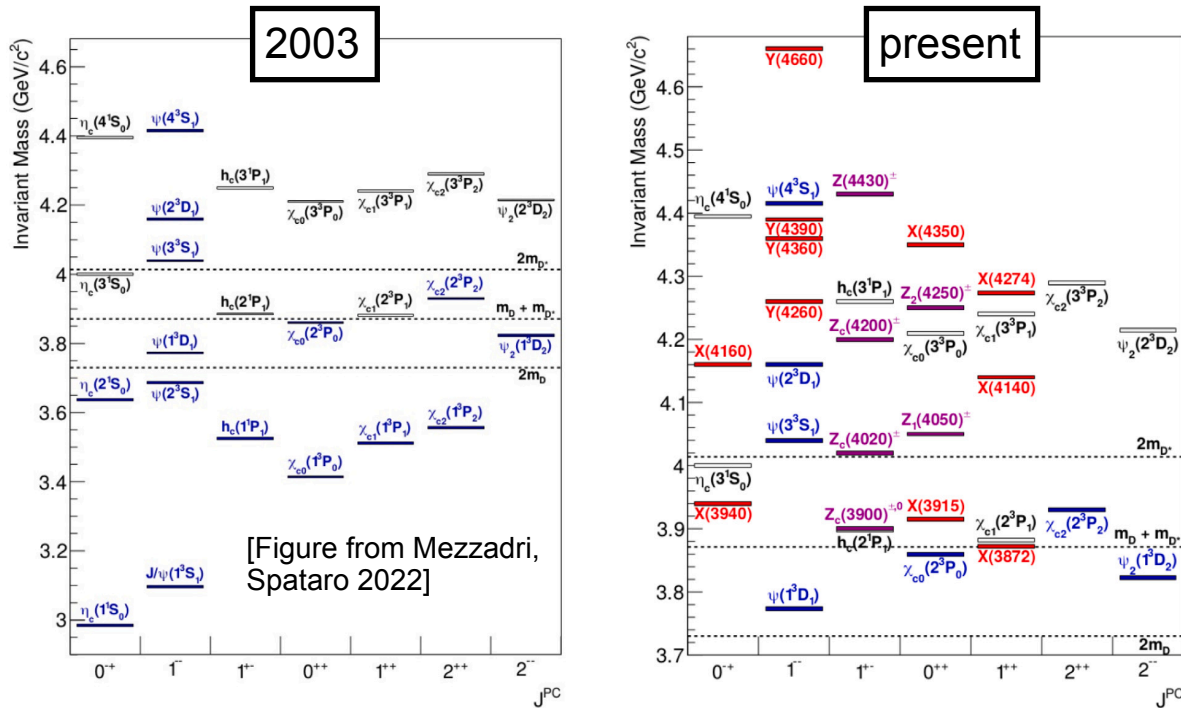
Topical Workshop, Center for Frontiers in Nuclear Science CFNS, Stony Brook University, 15-18 Aug 2022 (hybrid)

Derek Glazier, Astrid Hiller Blin, Jin Huang, Alessandro Pilloni, Justin Stevens, Adam Szczepaniak, Christian Weiss (Organizers)



- **Welcome**
- **Context and objectives**
- **EIC status**
- **Plan of meeting**





## Experiments

$e^+e^-$  + ISR: BaBar, Belle, CLEO, BES

$pp$ : LHCb, ATLAS, CMS

$\bar{p}p$ : GSI PANDA

$AA$  ultraperipheral  $\gamma\gamma$ : LHC

$\mu p / e p$  fixed-target: COMPASS, CEBAF upgrade?

$e p / e A$  collider: EIC ←

## Questions

Universality of resonances: Independence of production mechanism, observation in several channels?

Properties of states: Quantum numbers, decay modes, BRs?

Structure and dynamics: Molecules, tetraquarks, hybrids, ...  
QCD-based concepts? Effective dynamics?

Near-threshold phenomena?

## Theory

Heavy quarkonia involve multiple dynamical scales  
 $m \gg mv \gg mv^2$ , generate rich structure

EFT-type approaches: NRQCD

Production is “hard” process, QCD factorization

- Review status and plans for exotic heavy quarkonium experiments and theory
- Assess prospects for exotic heavy quarkonium production with EIC and their impact
- Discuss path forward for exotic heavy quarkonium measurements with EIC

## Specific challenges in XYZ production at EIC

Production rates: X and Z photo/electroproduction is non-diffractive process with quantum number exchange. Cross sections are generally small at high energies. Compare with near-threshold  $J/\psi$  and  $\Upsilon$  production at EIC.

Production mechanisms in  $ep$ : Little understood, theoretical models?

Detection and reconstruction: Momentum/angle distributions in collider? Resolution requirements? Backgrounds?

## Novel capabilities at EIC compared to previous XYZ experiments

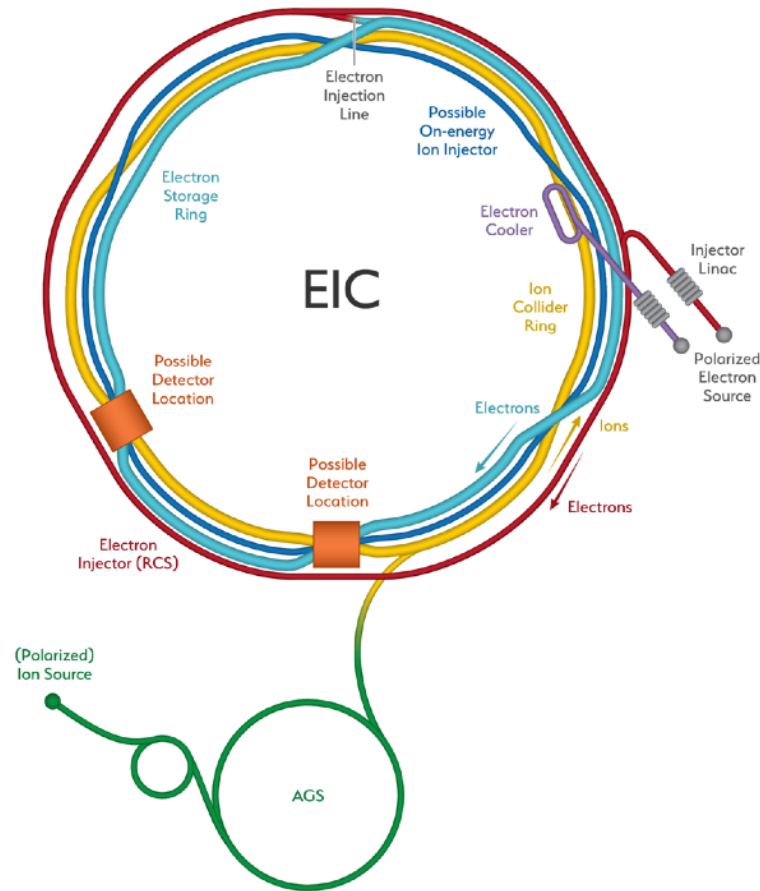
Electroproduction:  $Q^2$  dependence  $\rightarrow$  L + T amplitudes, resolution scale for structure

Photoproduction with low- $Q^2$  tagger

Far-forward detection: Exclusive processes, fragmentation

Polarized electron and proton beams

*Can we use them for XYZ physics?*



ep(pol), eA(light, pol), eA(heavy)  
CM energy  $s^{1/2} = 20\text{-}100(140)$  GeV  
Luminosity  $\sim 10^{33}\text{-}10^{34}$  cm<sup>-2</sup> s<sup>-1</sup>

## 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

CD-0 and site selection at Brookhaven National Lab in 2019

CD-1 achieved in 2021 [\[Webpage\]](#)

Planning for CD-2/3A in 2024, CD-4 + operations probably  $\sim 2034$  [\[Update\]](#)

Framework for international participation being set up

Project hosted/managed jointly by BNL and JLab

## Recent developments

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

Proposals for EIC Detector-1 evaluated 2022 [\[Webpage\]](#)

Formation of joint EPIC detector collaboration on-going [\[Update\]](#)

Community exploring possibilities/options for 2nd IR + detector

## **XYZ experimental programs: Status, plans**

**Mon 15 Aug**

B. Grube, M. Mikhasenko, A. Pompili, G. Mezzadri, B. Fulsom, S. Dobbs + Discussion

## **XYZ production: Theory, estimates**

**Tue 16 Aug**

A. Hiller Blin, D. Winney, F.-K. Guo, V. Mathieu, J. Silva-Castro, W. Schäfer, E. Braaten + Discussion

## **Quarkonium/XYZ structure and interactions: Theory, models**

**Wed 17 Aug**

X. Wang, N. Brambilla, M. Durham, S. Dawid, W. Smith, E. Santopinto, R. Lebed + Discussion

## **Quarkonium/XYZ at EIC: Detector, capabilities, estimates**

**Thu 18 Aug**

J. Huang, J. Stevens, B. Surrow, W. Zha, D. Glazier, X. Li, M. Boer, A. Jentsch, S. Gardner, Zh. Shi + Discussion

Format: Presentations + Discussion (coordinated + open)

CFNS Workshop “Opportunities with heavy flavor at EIC”, 4-6 Nov 2020, 140 participants [\[Webpage\]](#):  
Covered all heavy flavor physics, including open HF, jets. Many interesting ideas and connections.

CFNS Workshop “Physics opportunities with heavy quarkonia at EIC”, 25-27 Oct 2021, 132 participants [\[Webpage\]](#):  
Covered “non-exotic” heavy quarkonium physics, including production, structure, interactions with medium

JLab Workshop “Hadron spectroscopy with a CEBAF energy upgrade”, 16-17 Jun 2022 [\[Webpage\]](#):  
Discussed possible light+heavy spectroscopy measurements with CEBAF energy upgrade