

Spectroscopy program at the future EIC

Justin Stevens



WILLIAM & MARY

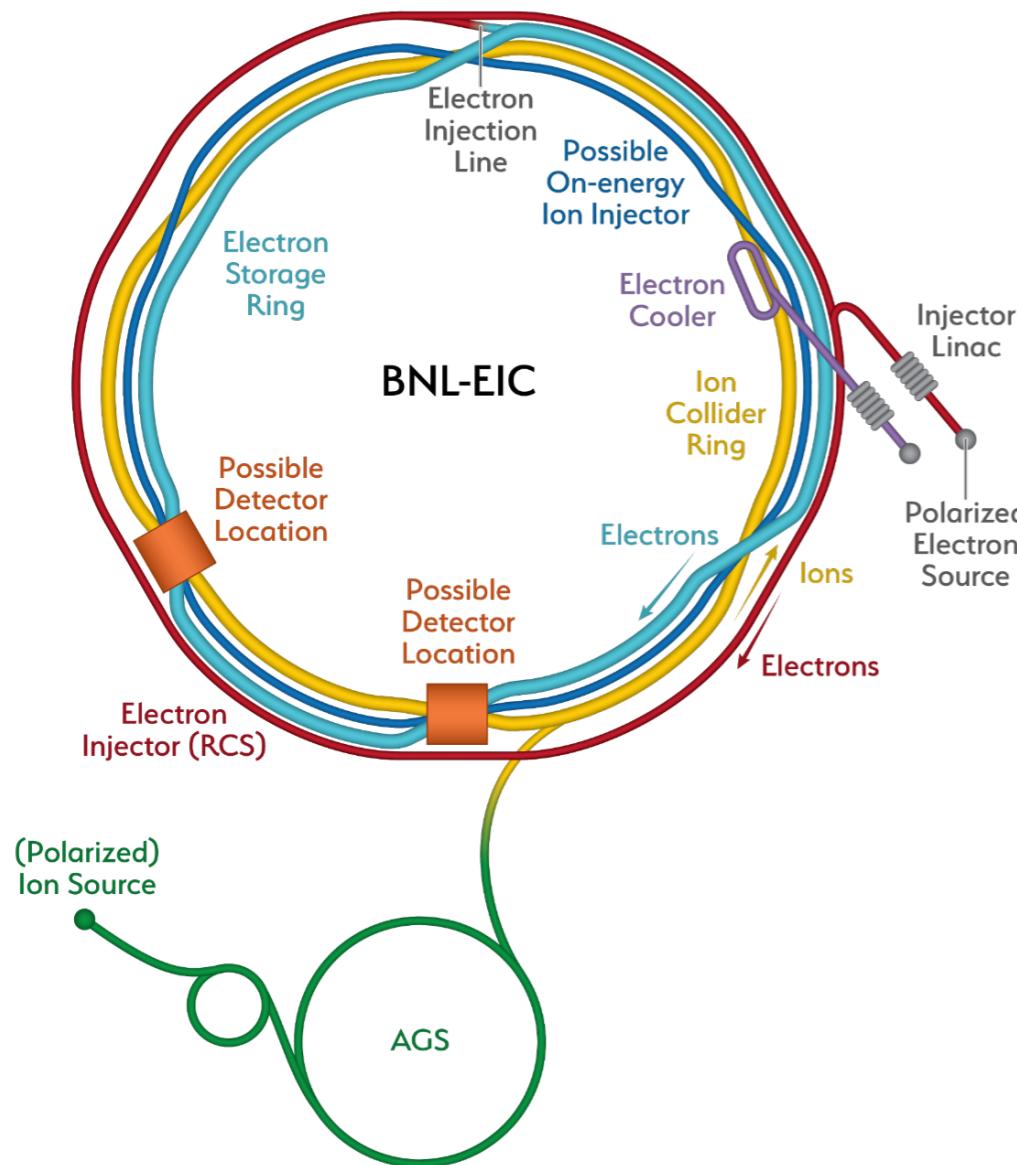
CHARTERED 1693



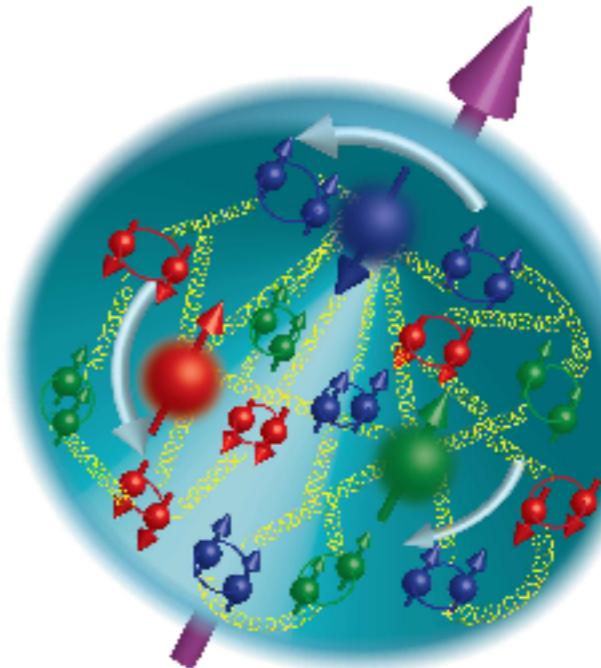
U.S. DEPARTMENT OF
ENERGY

Office of
Science

Electron Ion Collider (EIC)



- * Versatile high-luminosity, polarized e+p and e+A collider, recently launched DOE project
- * Nucleon spin and 3D structure
- * High gluon density and saturation



$$\sqrt{s} = 20 - 141 \text{ GeV}$$

$$\mathcal{L} = 10^{34} \text{ cm}^{-2}\text{s}^{-1}$$

- * Today: what can we learn about the spectrum of hadrons with the EIC?

EIC 1 year ago

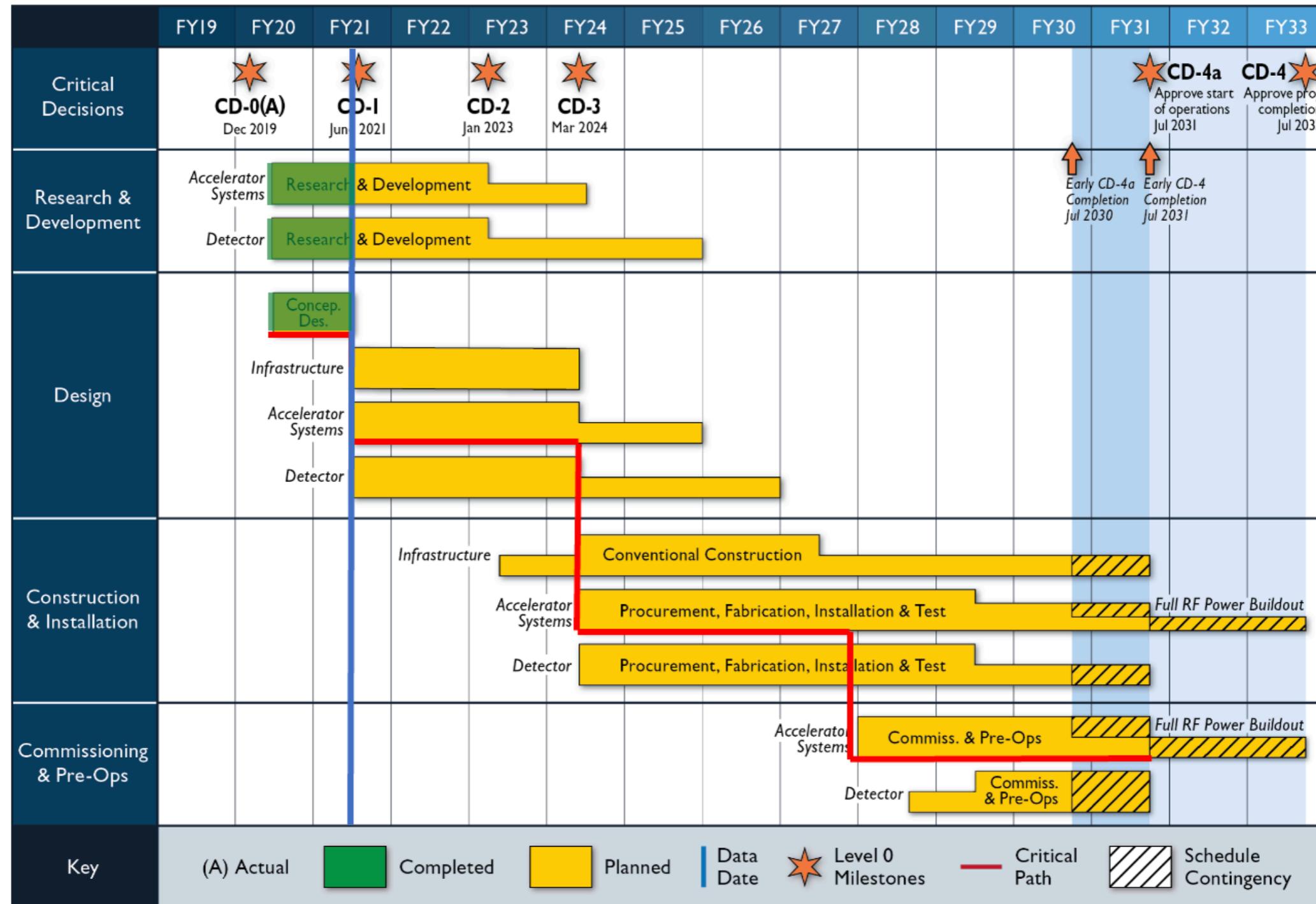
**DOE project officially launched on September 18, 2020
Joint BNL+JLab project: with CDO approval (Mission Need)**



US senator explaining hadronic physics: <https://www.youtube.com/watch?v=T0-3e0Ws8qo>

EIC today

CD1 approved (Alternative Selection and Cost Range):

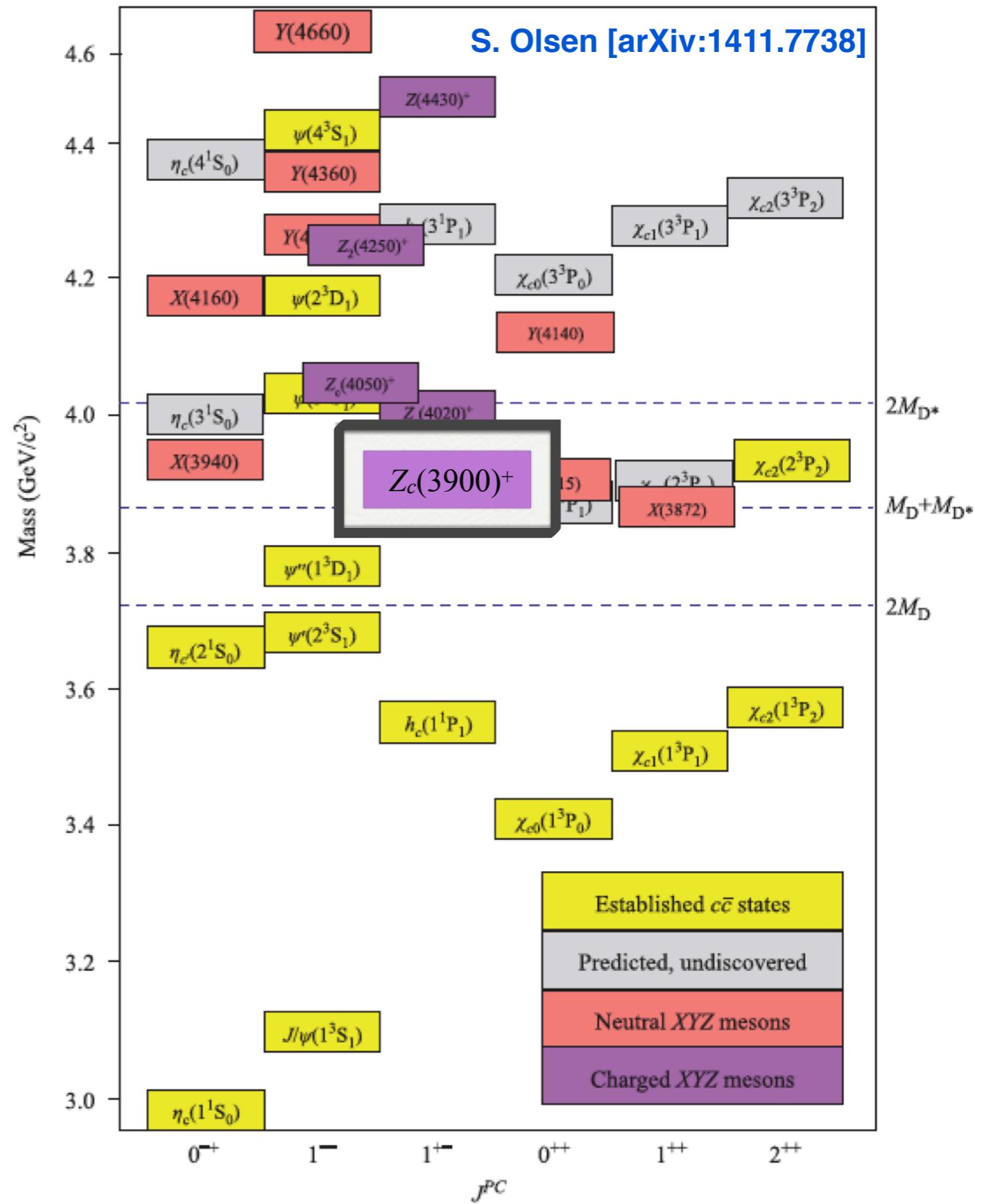
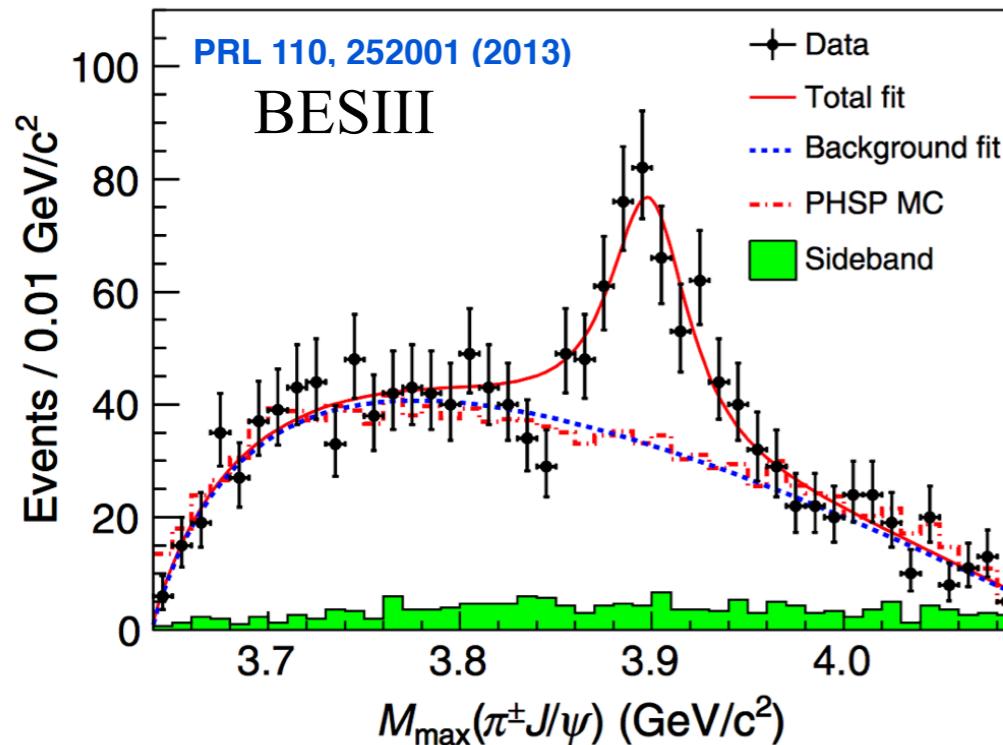


Jim Yeck at EIC UG Meeting: <https://indico.bnl.gov/event/11463/contributions/51782/>

XYZ states

- Many new states observed in the last ~decade
- Not predicted by the standard charmonium models
- Many models for interpretation: resonant states, meson molecules, re-scattering effects, etc.

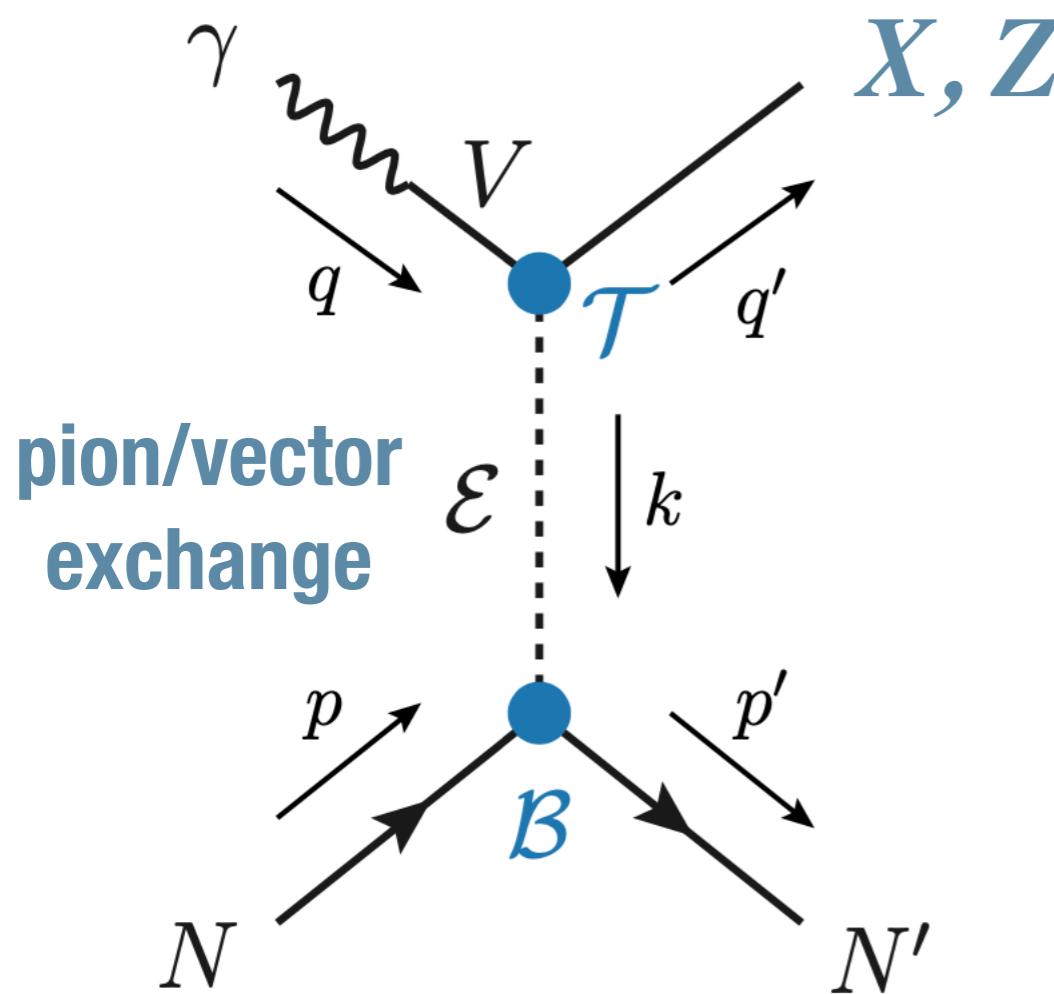
$$e^+ e^- \rightarrow \pi^+ \pi^- J/\psi \text{ (4260 MeV)}$$



Theory predictions for XYZ states

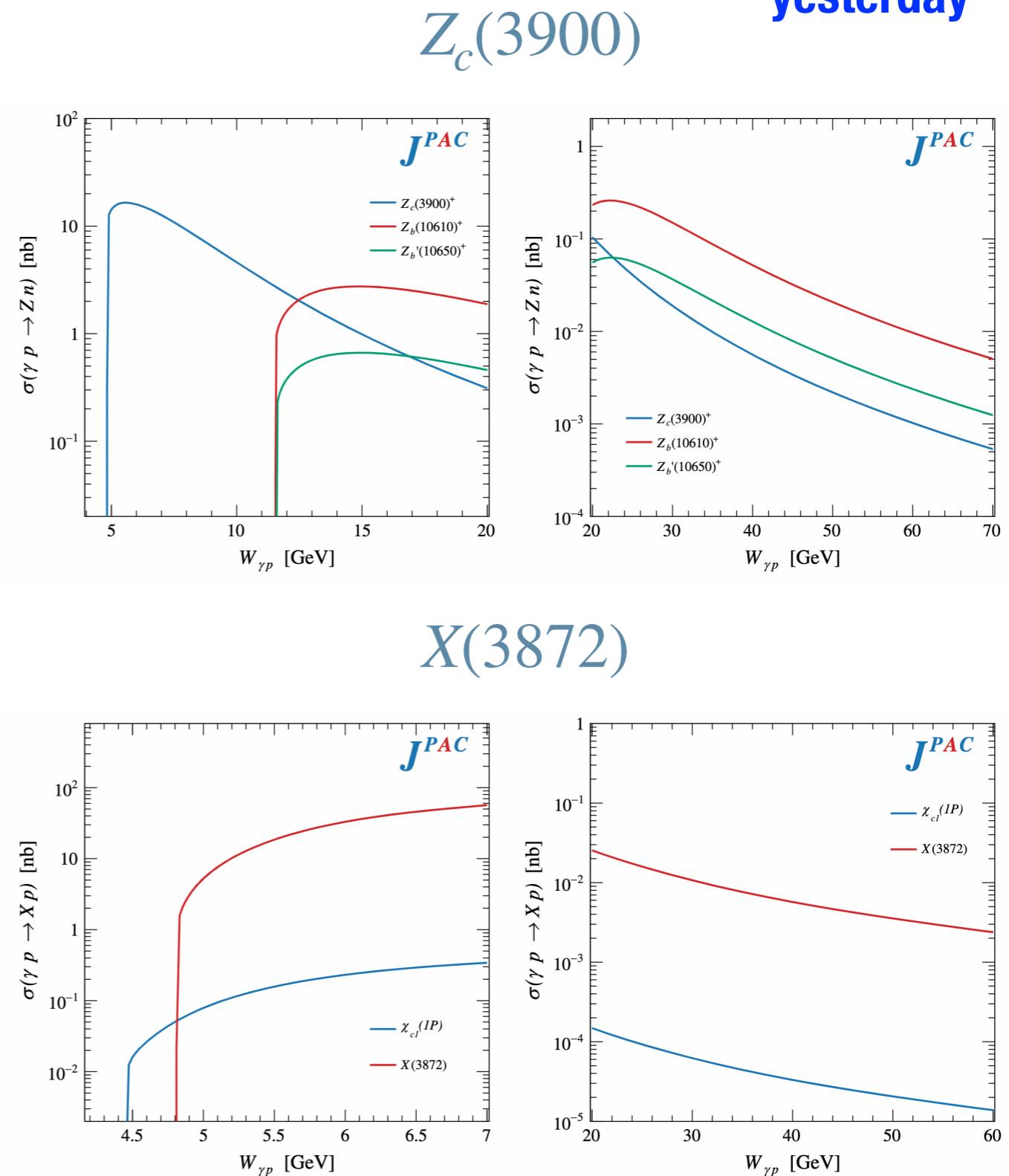
Alessandro
Pilloni's talk
yesterday

J^{PAC} : PRD 102, 114010 (2020)



pion/vector
exchange

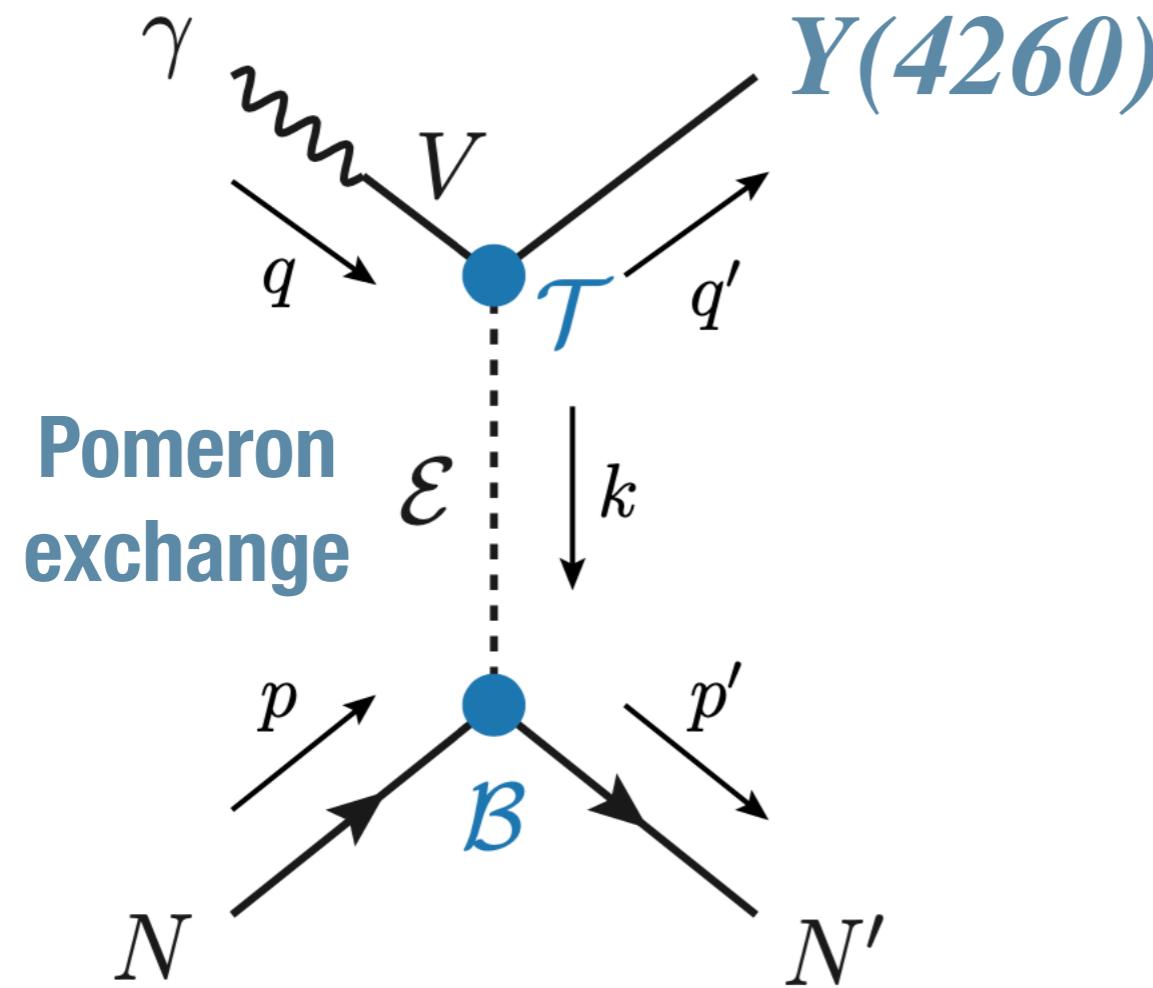
Both cross section and modeled
virtual photon flux dominated near
threshold for $Z_c(3900)$ and $X(3872)$



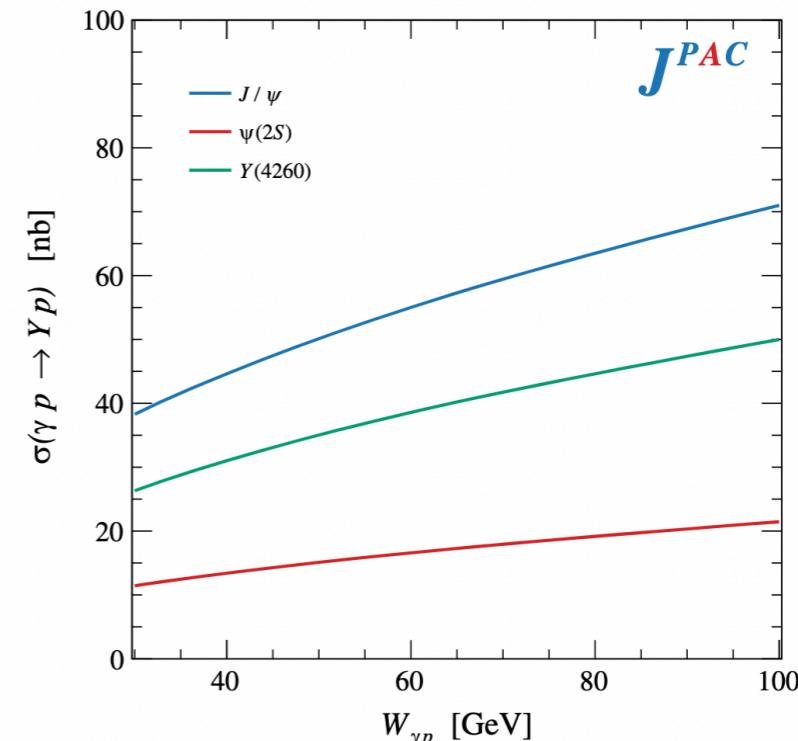
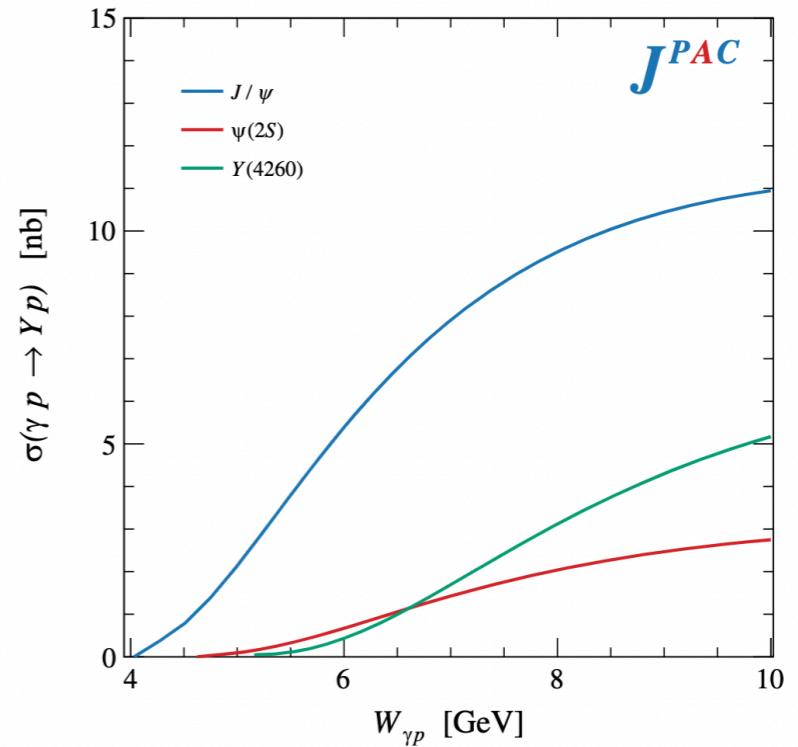
Theory predictions for XYZ states

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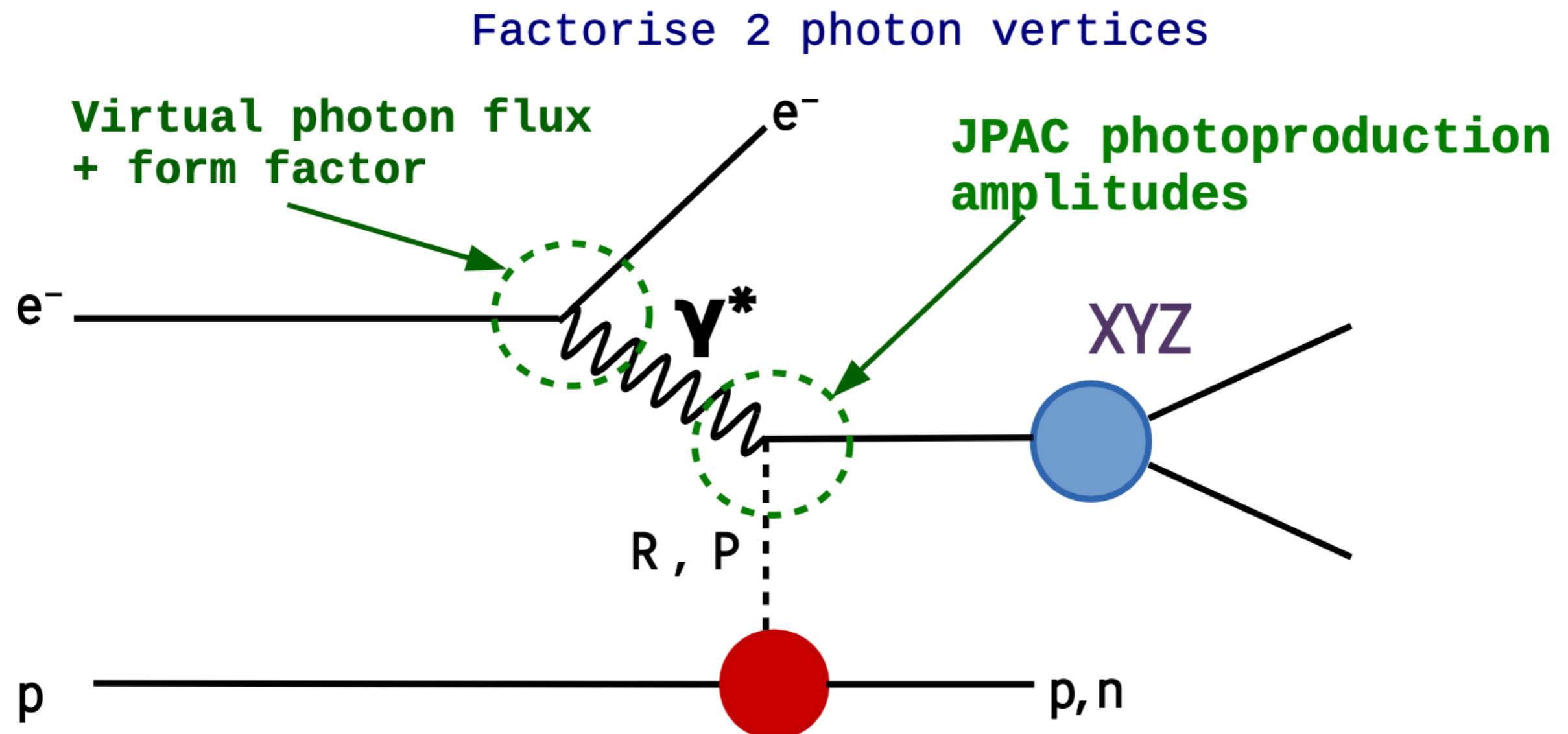


$Y(4260)$ production increases with
energy like other vectors



Event generator: elSpectro

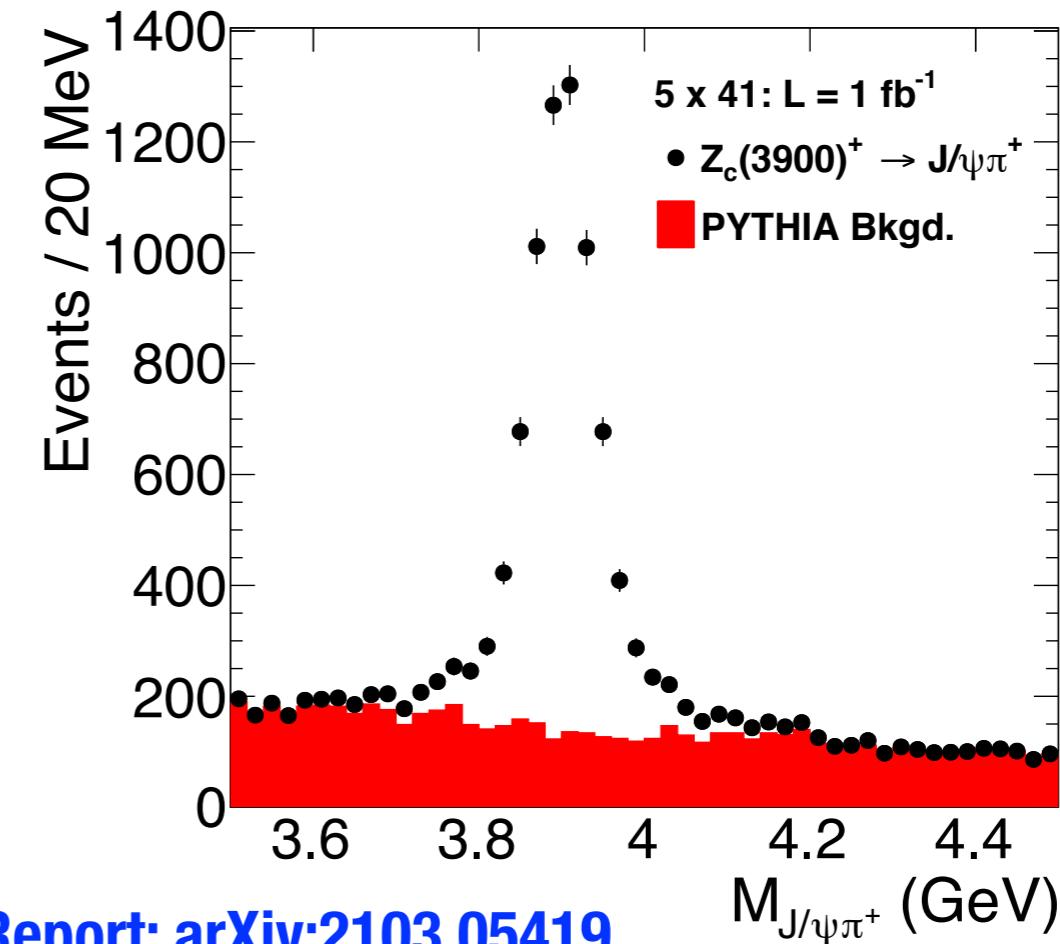
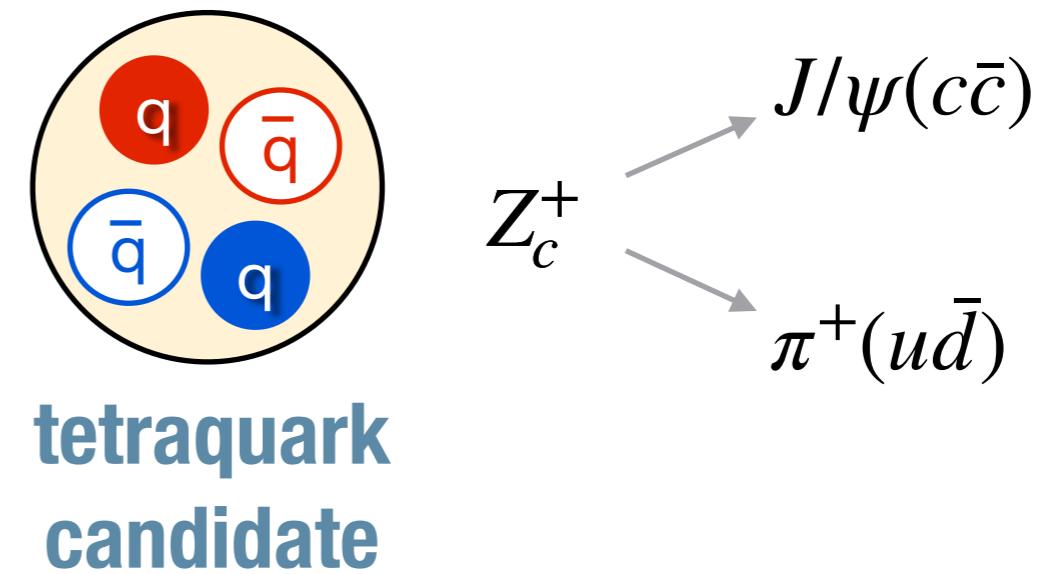
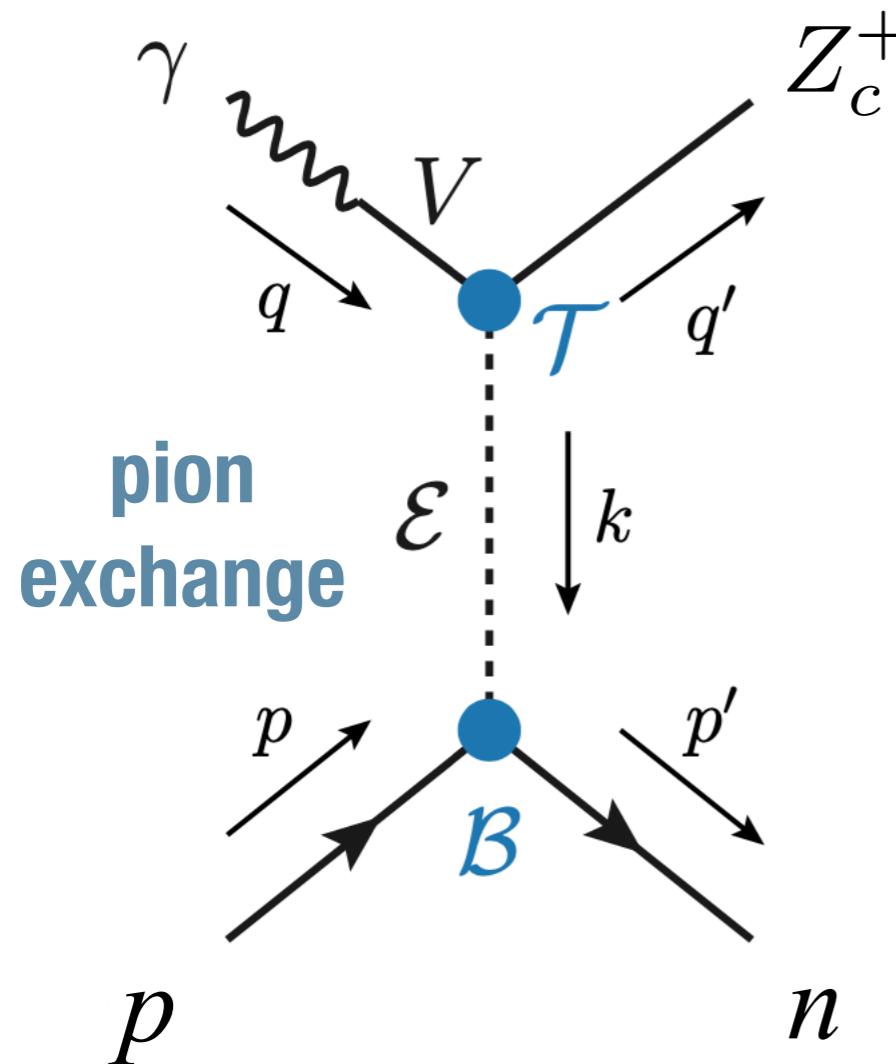
Derek Glazier



Generator available on GitHub: <https://github.com/dglazier/elSpectro>

Exclusive: $Z_c^+(3900)$ at an EIC

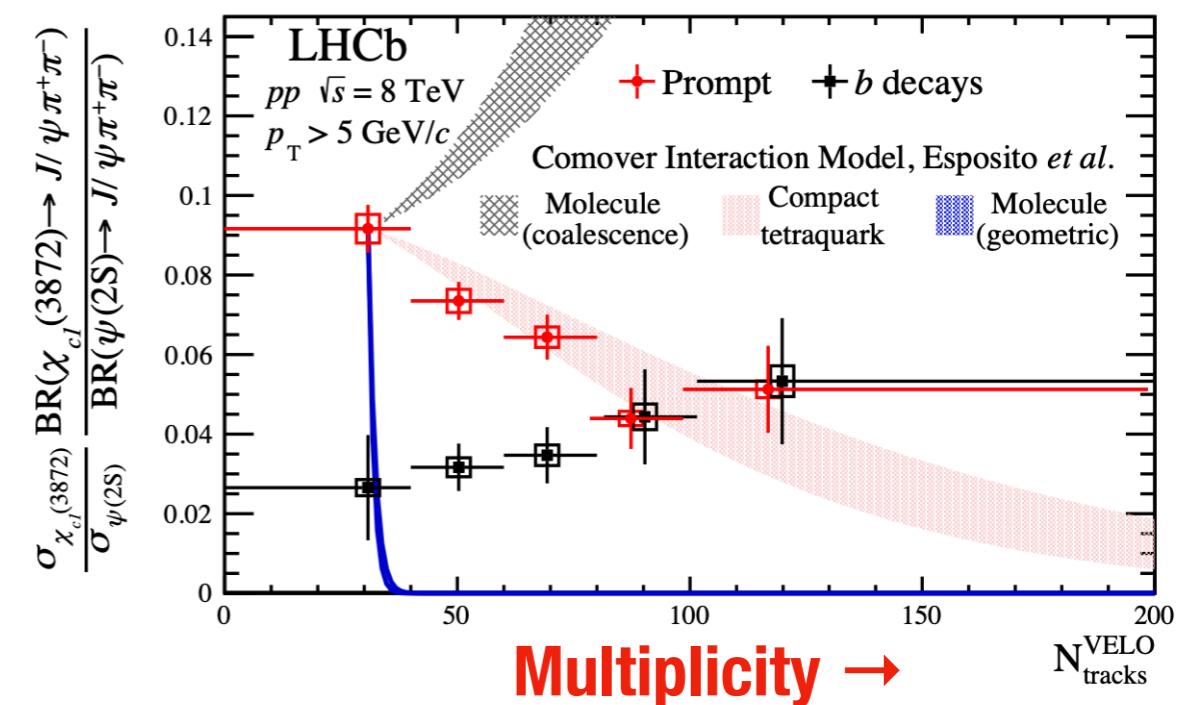
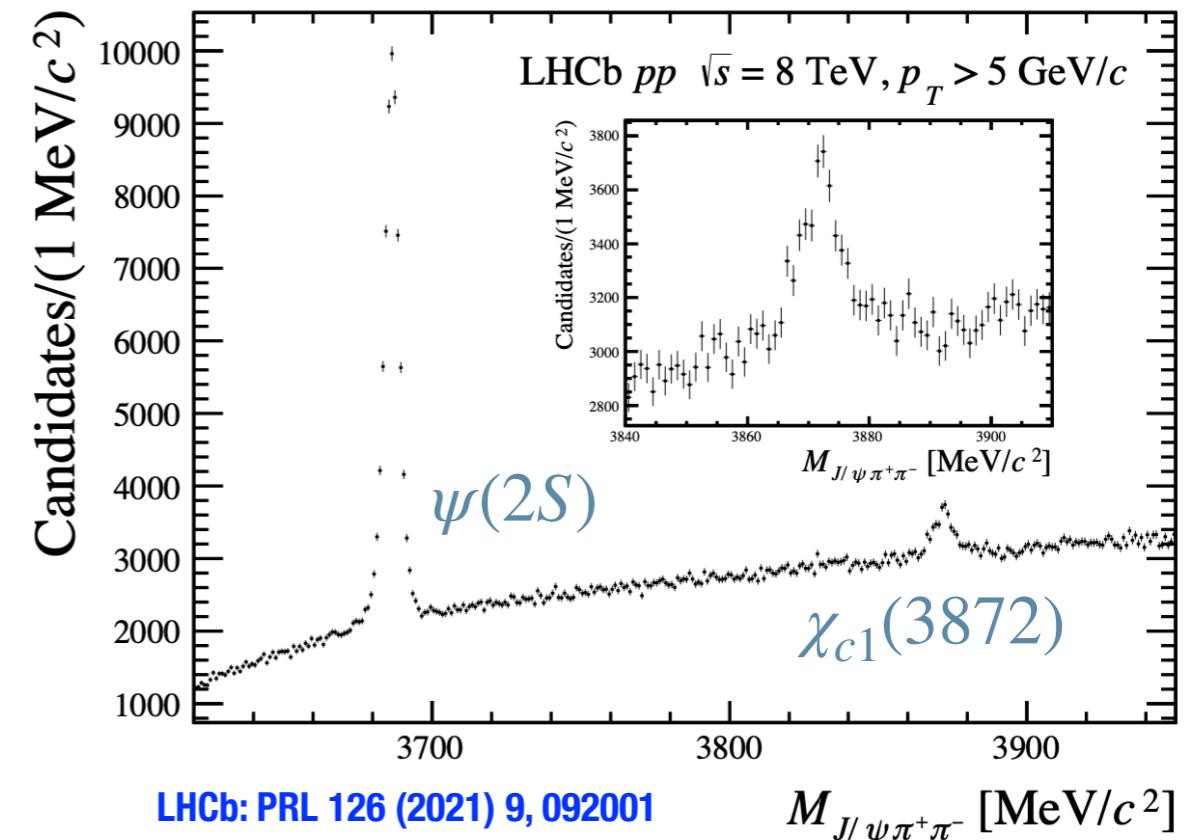
 : PRD 102, 114010 (2020)



Yellow Report: arXiv:2103.05419

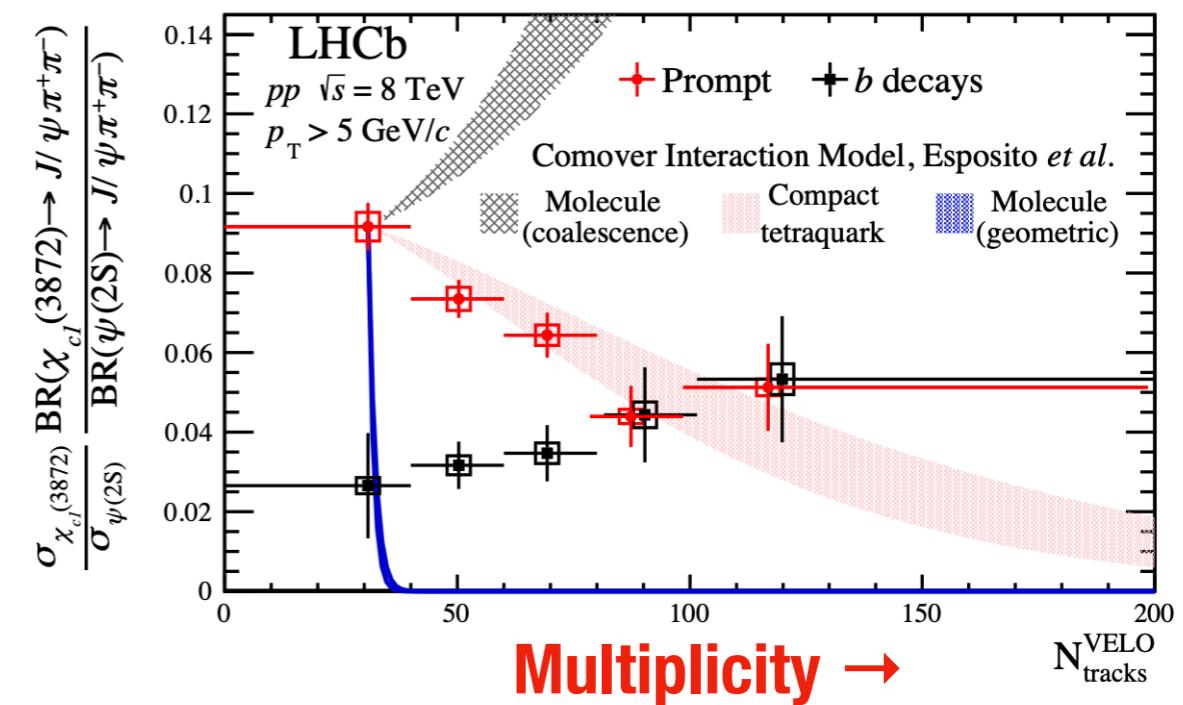
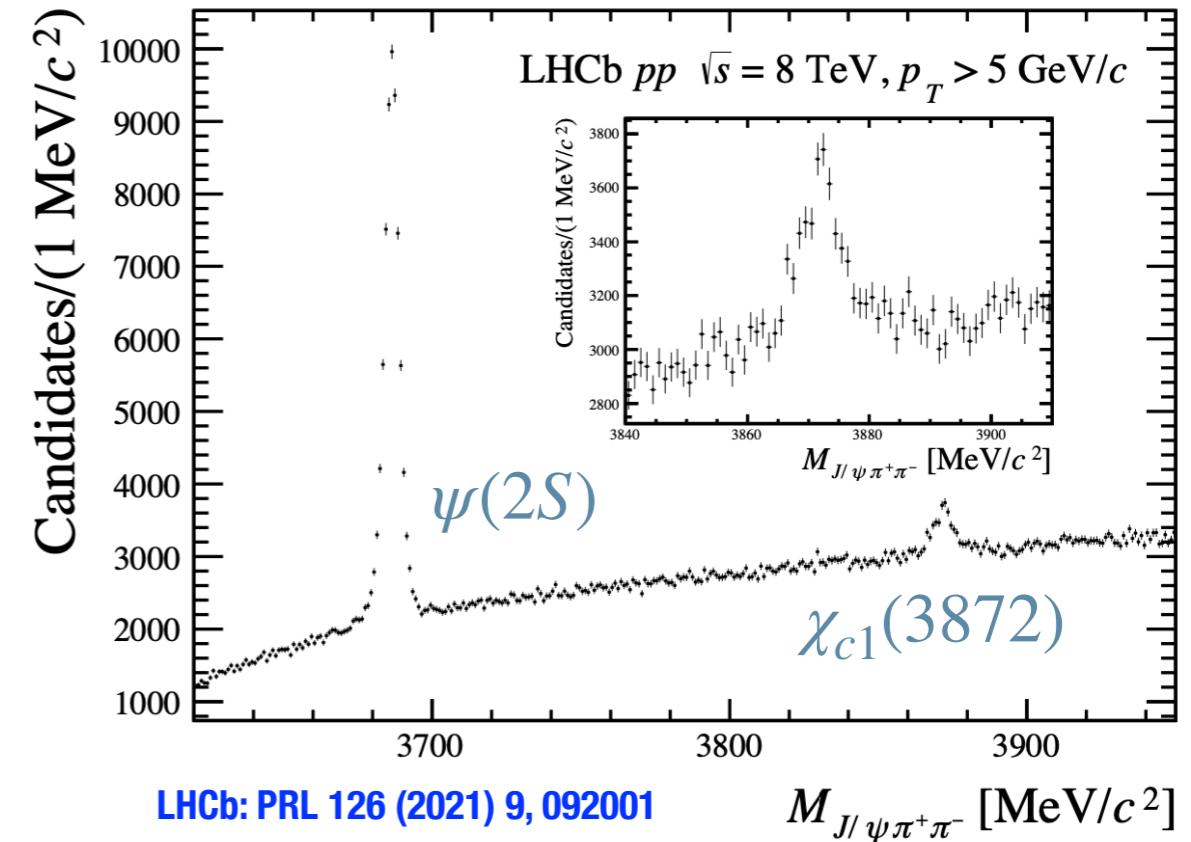
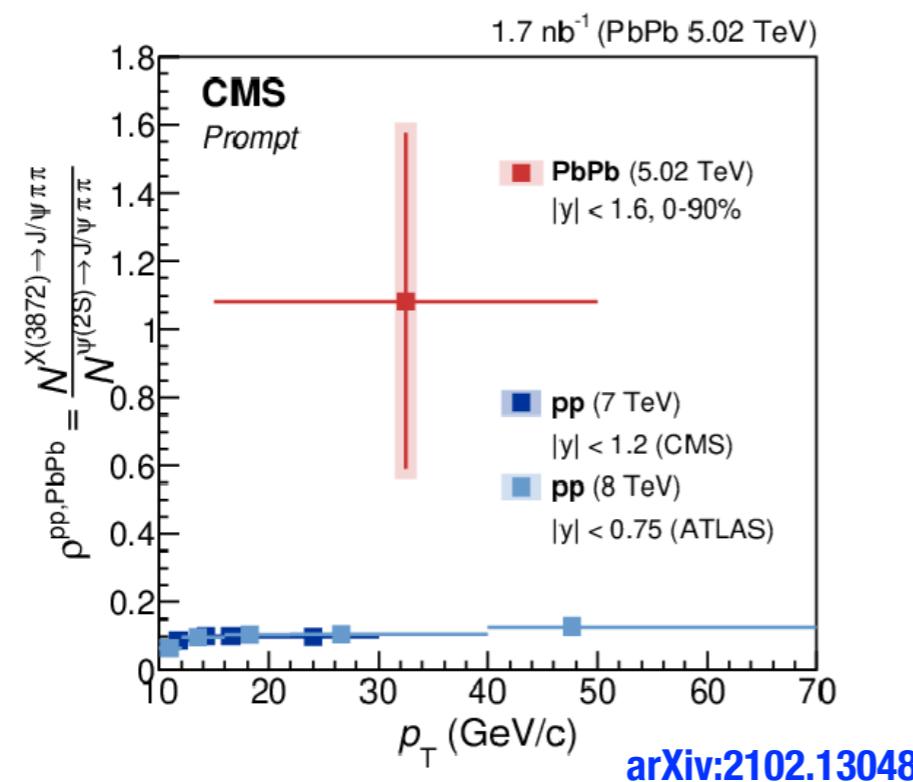
In-medium: unconventional mesons $\chi_{c1}(3872)$

- Recent LHCb results in pp show prompt $\chi_{c1}(3872)$ decreases with multiplicity

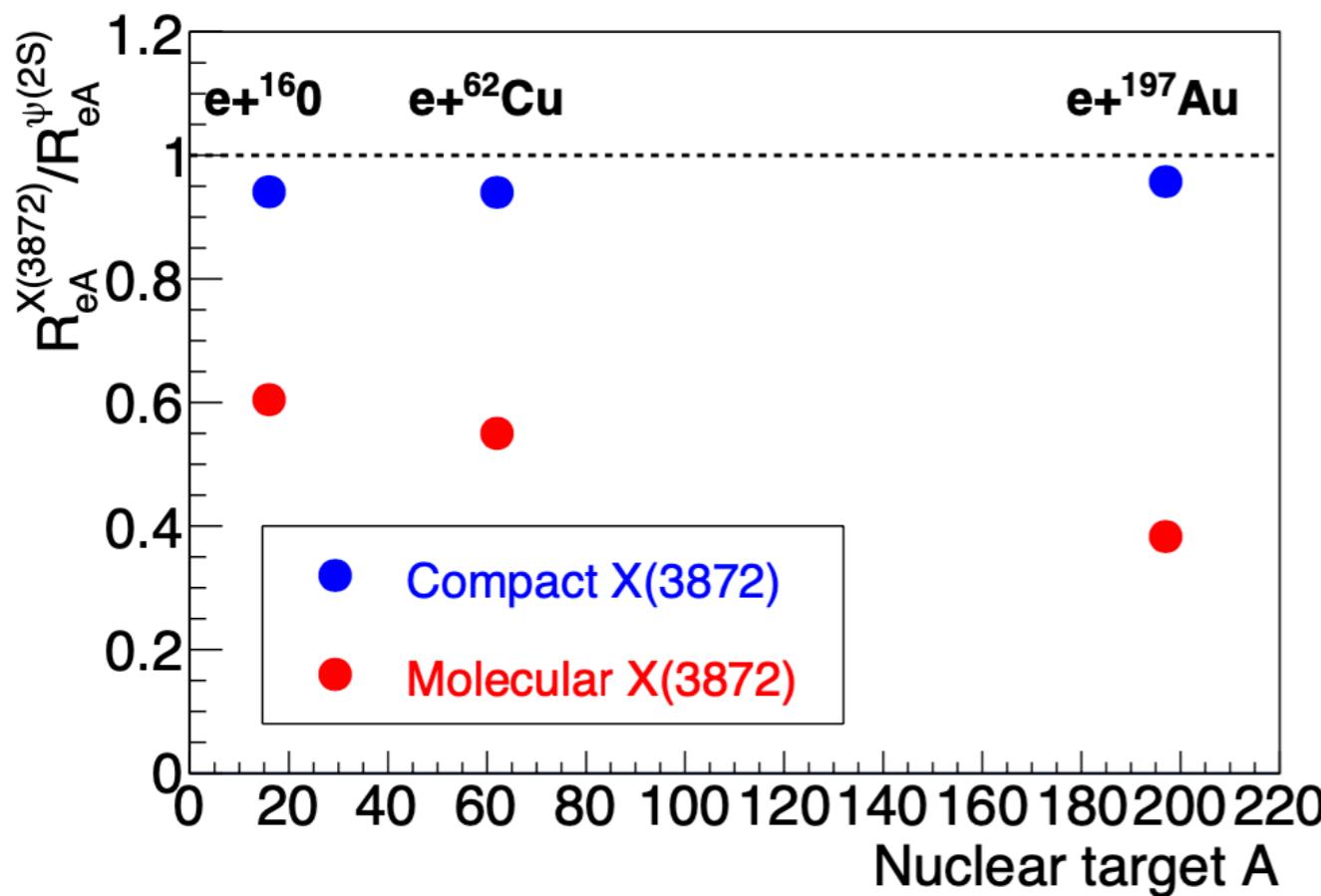
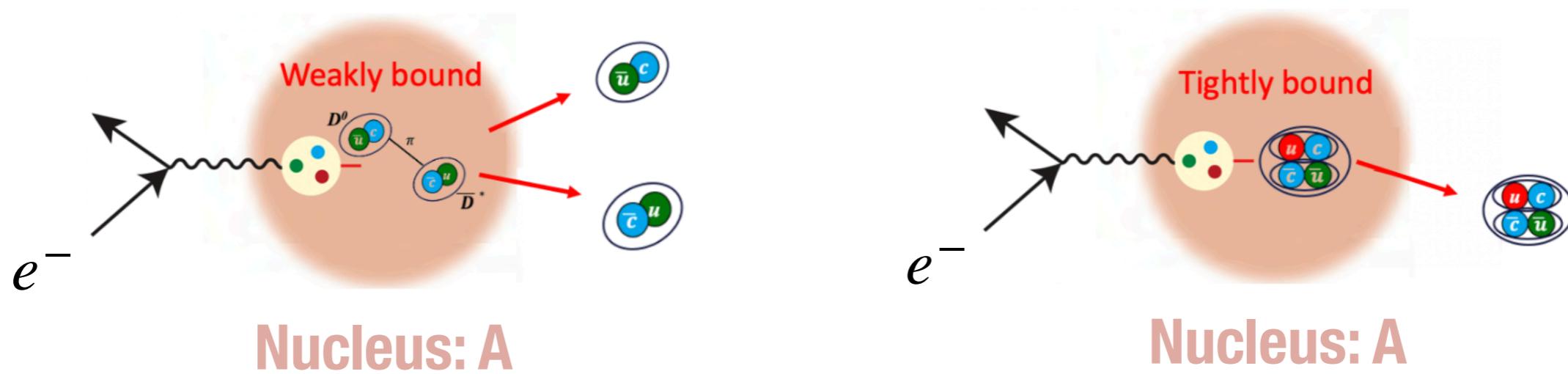


In-medium: unconventional mesons $\chi_{c1}(3872)$

- Recent LHCb results in pp show prompt $\chi_{c1}(3872)$ decreases with multiplicity
- First observation of prompt $\chi_{c1}(3872)$ in PbPb at CMS not suppressed relative to $\psi(2S)$

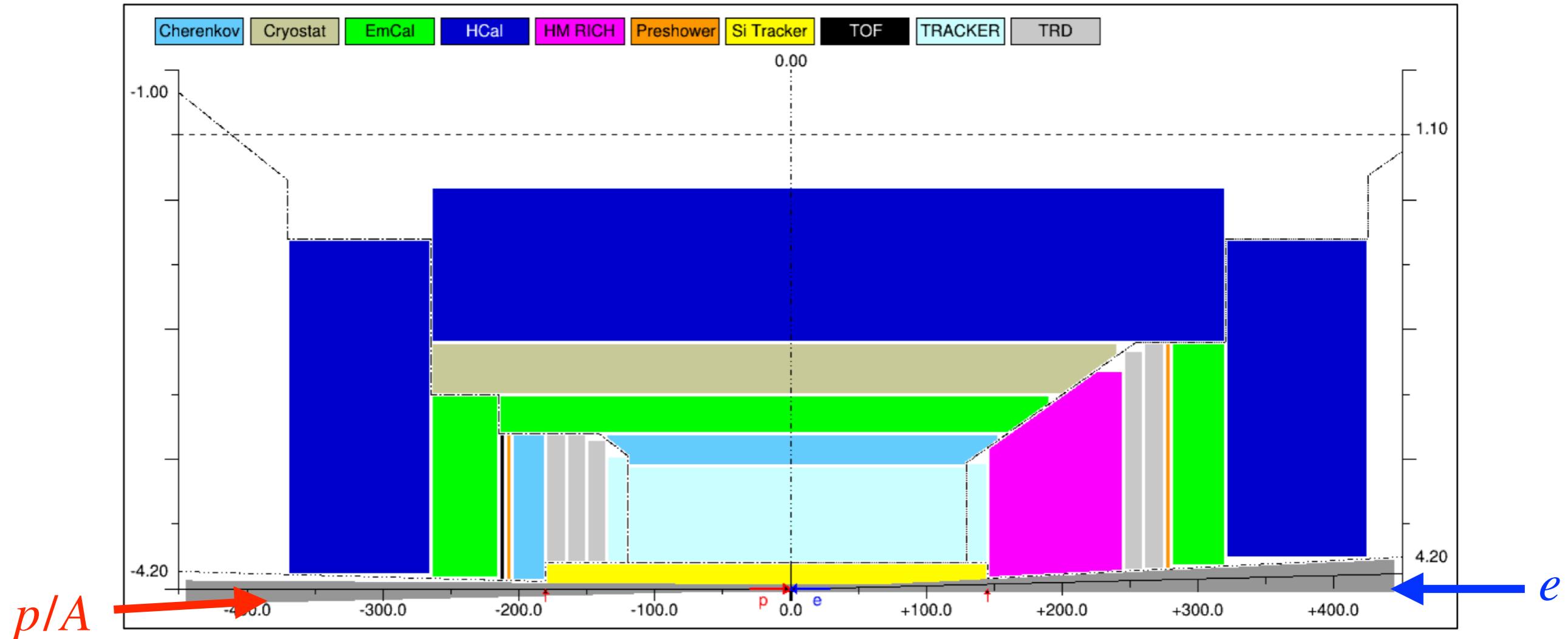


In-medium effects for spectroscopy



- * Dependence on breakup of $X(3872)$ in nuclei?
- * Little suppression expected for compact tetraquark configuration
- * Expect suppression of molecular (large size) configuration

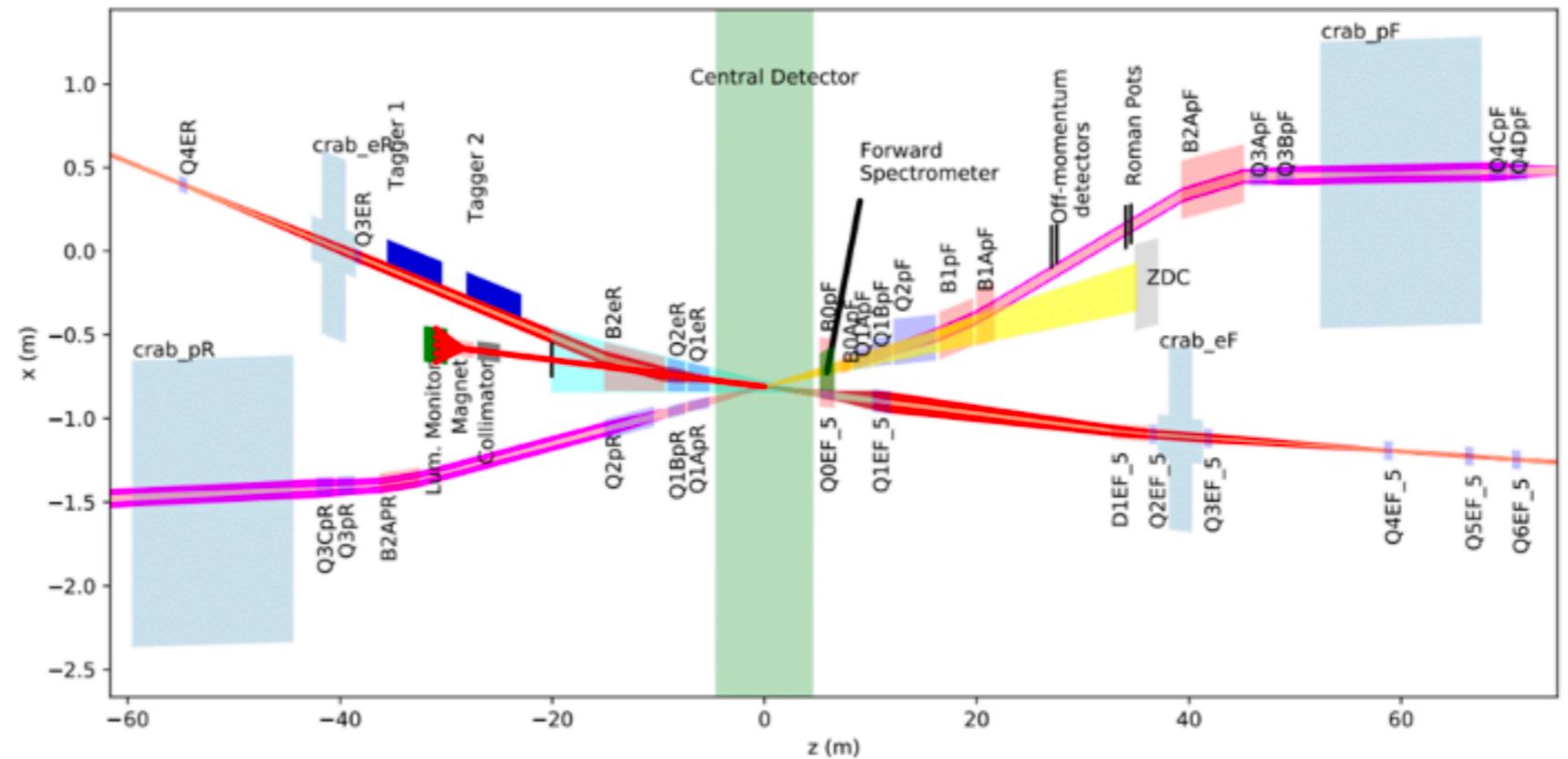
- Defined detector requirements (including spectroscopy)



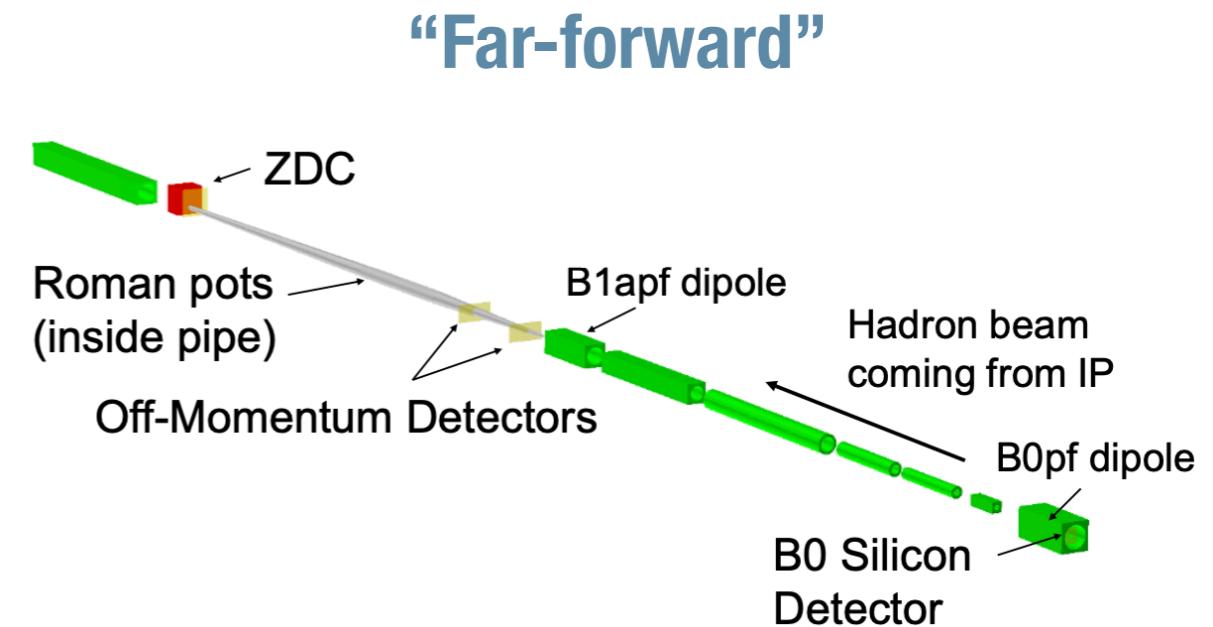
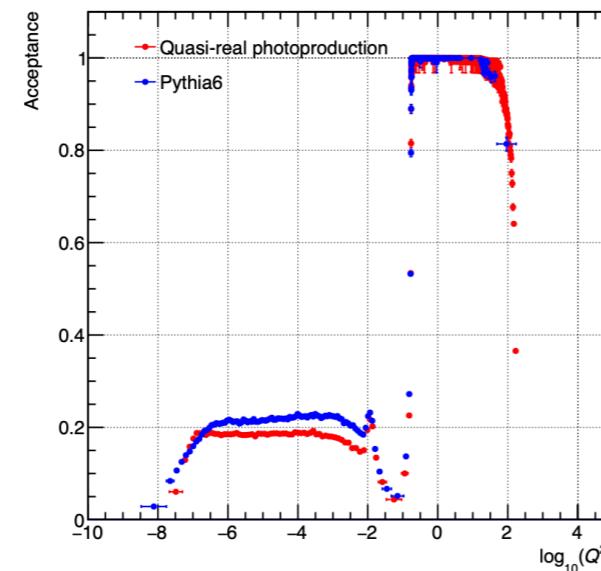
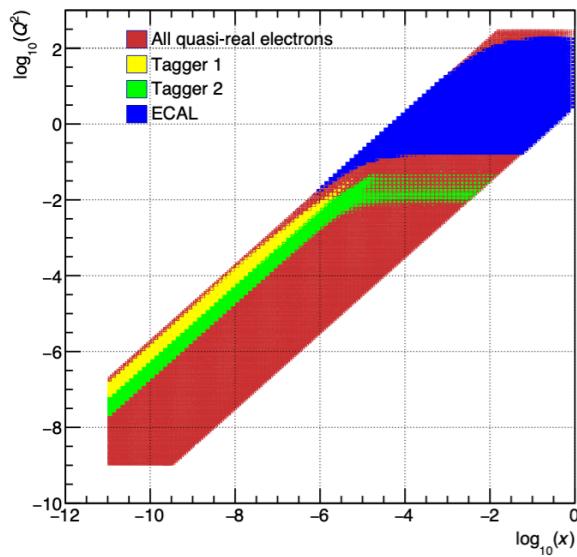
Asymmetric central detector concepts due to asymmetric beam energies: “complete” coverage for $|y| < 3.5$

- Defined detector requirements (including spectroscopy)

**Complete detectors
are ~100 m with
far-forward and
backward regions**



“Far-backward”: low- Q^2 tagger

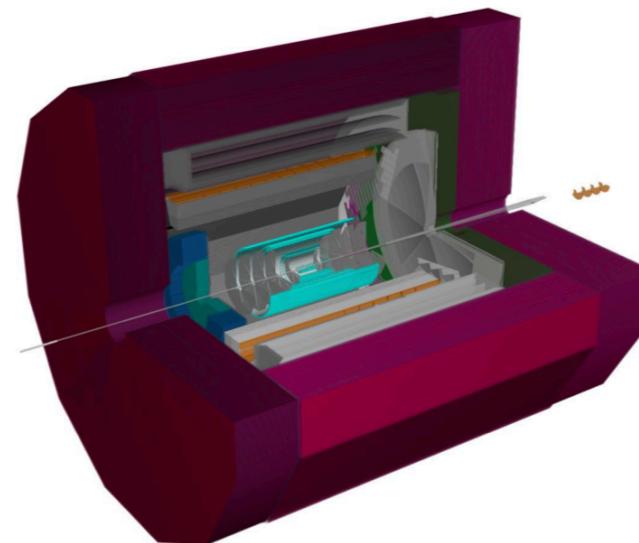


Detector proposals

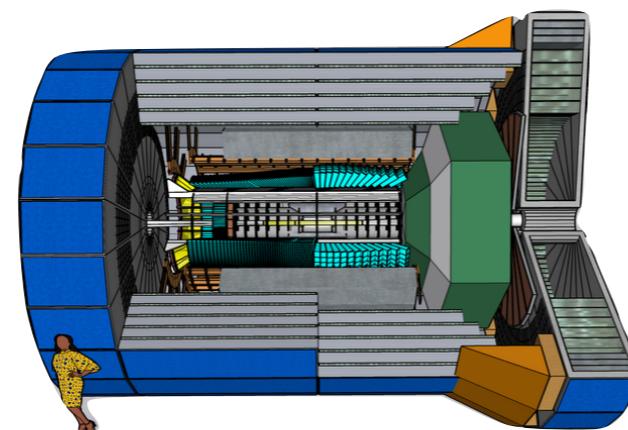
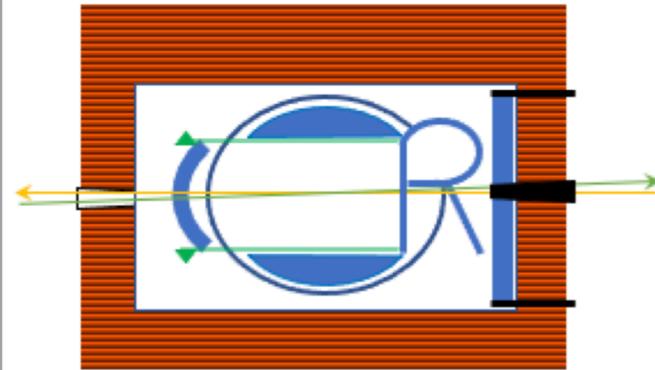
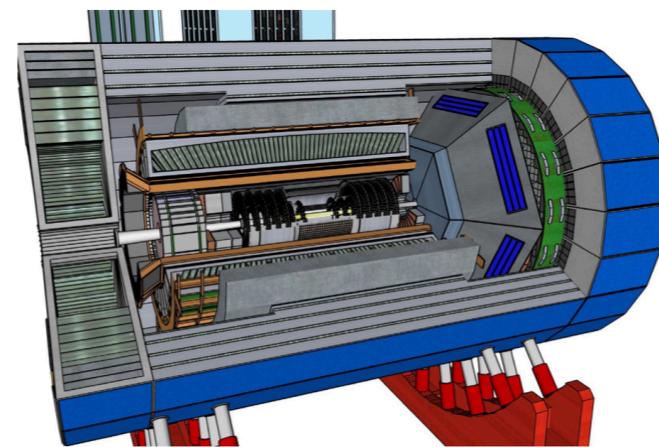
Proposals will be submitted
to DOE this December 2021



ATHENA



ECCE



- * New 3T solenoid magnet

- * Plan installation at IP6

<https://sites.temple.edu/eicatip6/>

- * Re-use BaBar/sPHENIX
1.5 T solenoid

- * Installation at IP6 or IP8

<https://www.ecce-eic.org>

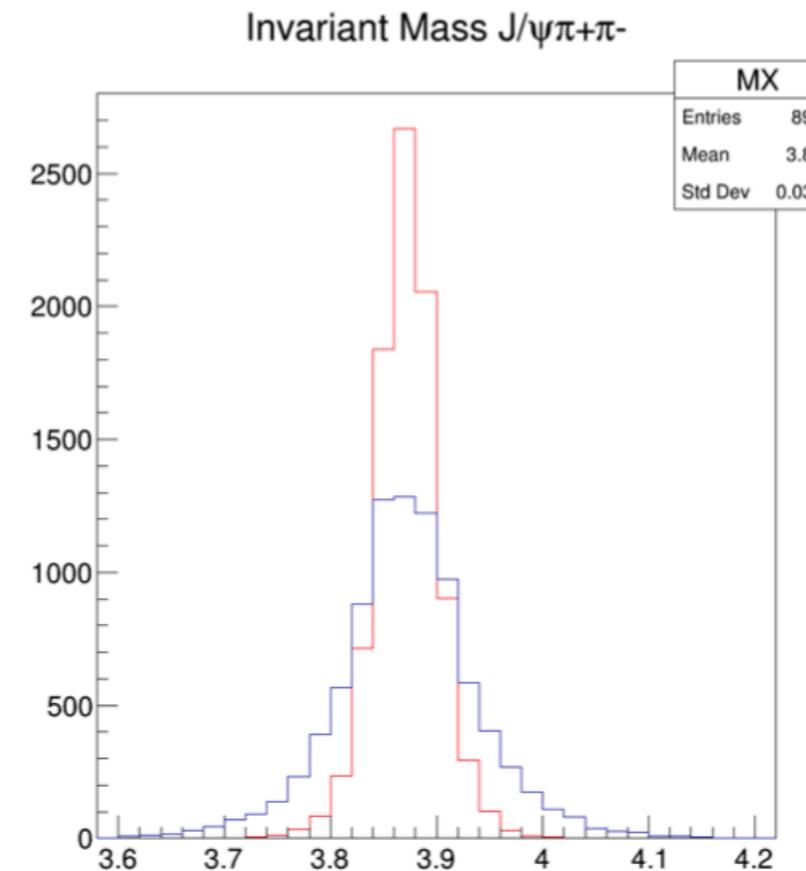
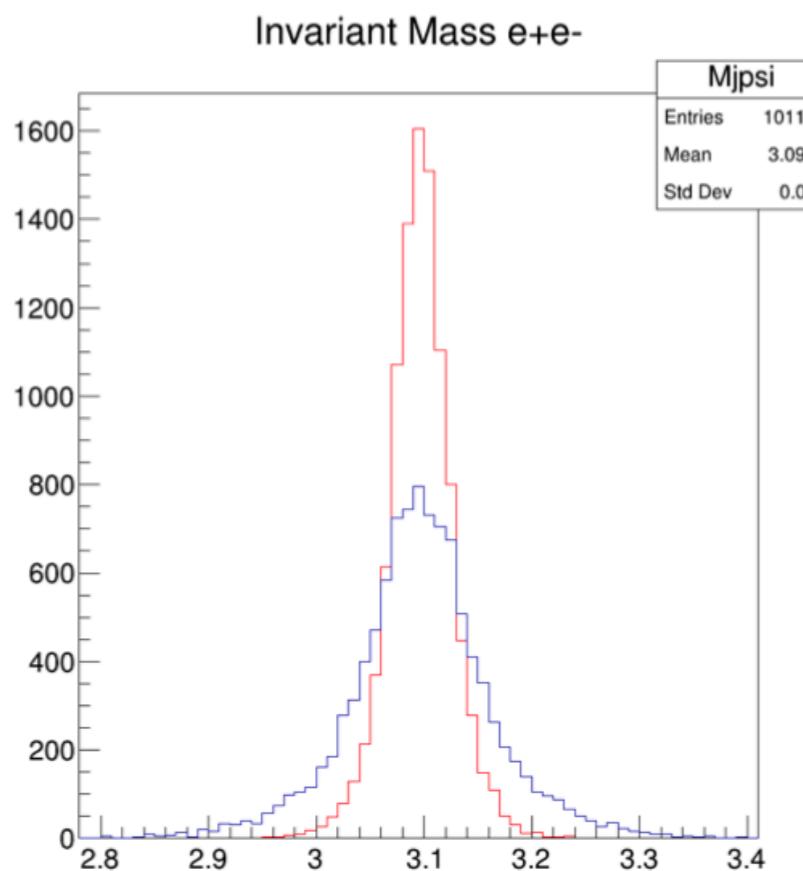
- * Compact concept

- * Installation at IP8

<https://eic.jlab.org/core/>

Detector requirements for spectroscopy

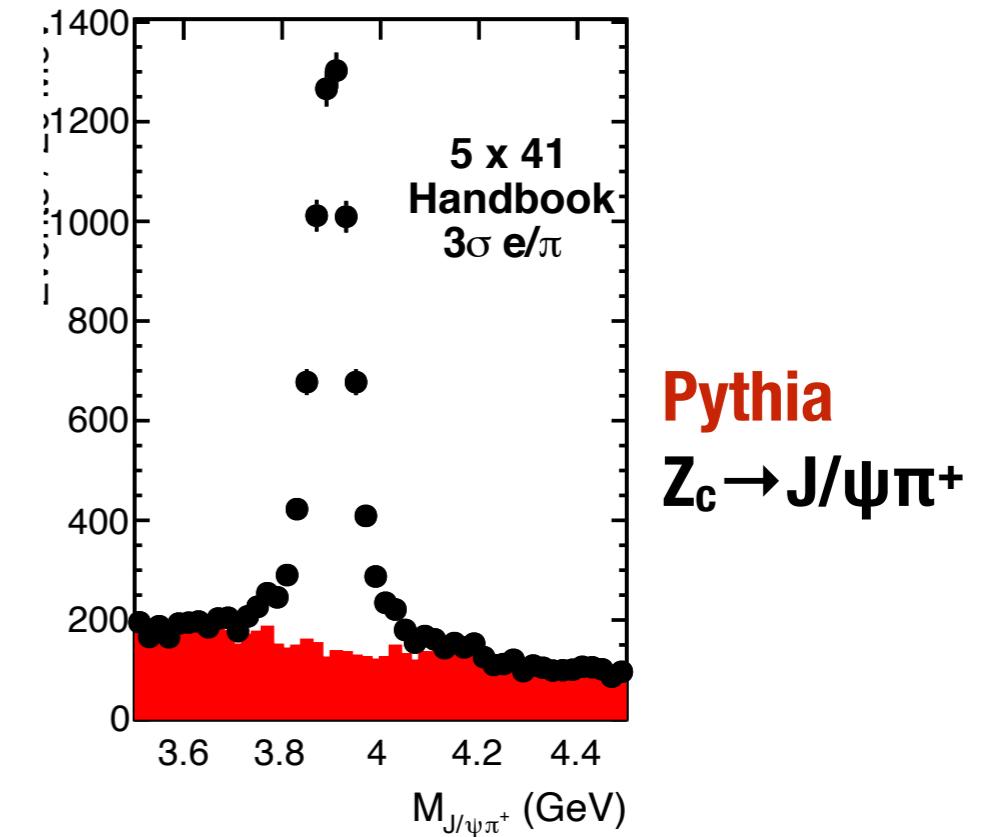
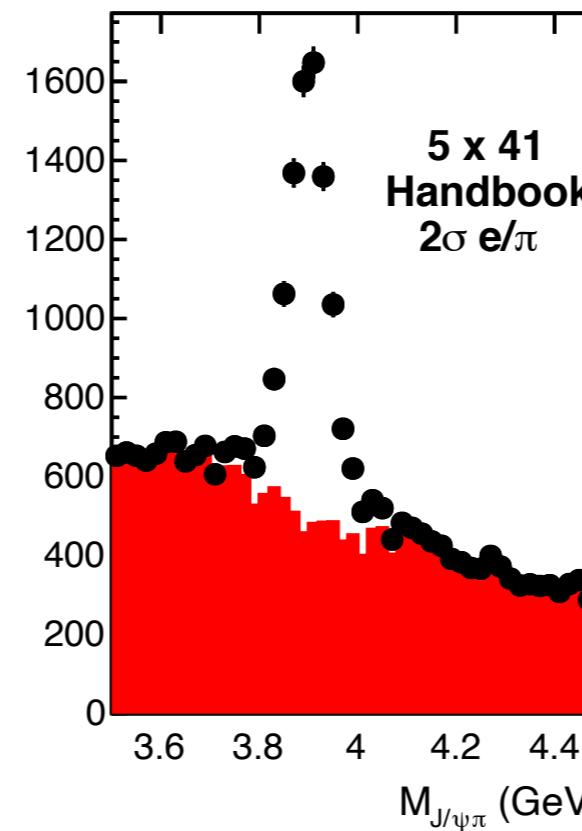
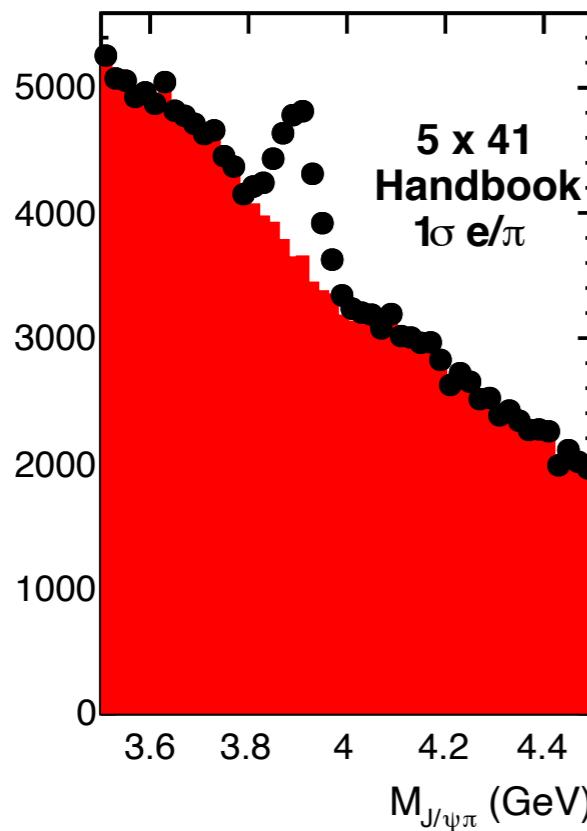
- * **Mass resolution** critical for both:
 - * Background reduction (J/ψ or ψ' selection)
 - * Identifying narrow states and determining widths



Typically 2x better
Resolution with 3T

Detector requirements for spectroscopy

- ✳ Other background reduction requirements
 - ✳ exclusivity: tagging low- Q^2 electron and recoil proton/neutron
 - ✳ e/π separation appears to be critical



Summary

- * Observation of “exotic” states in heavy quarkonium are challenging our understanding of the hadron spectrum and QCD
- * Plenty more data to come from BESIII, Belle II, LHC, PANDA, etc. on the timeline of the EIC
- * EIC provides an alternative production mechanism to probe exotic hadrons, with detector requirements being defined now!
- * Exclusive event generator (**eISpectro**) provides realistic cross sections and rate estimates for evaluating detector concepts
- * Detector proposals are being developed **now** and requirements for the spectroscopy program are being considered

Upcoming CFNS workshop in Early 2022:
“Exotic heavy meson spectroscopy and structure with EIC”

Supported by DE-SC0018224



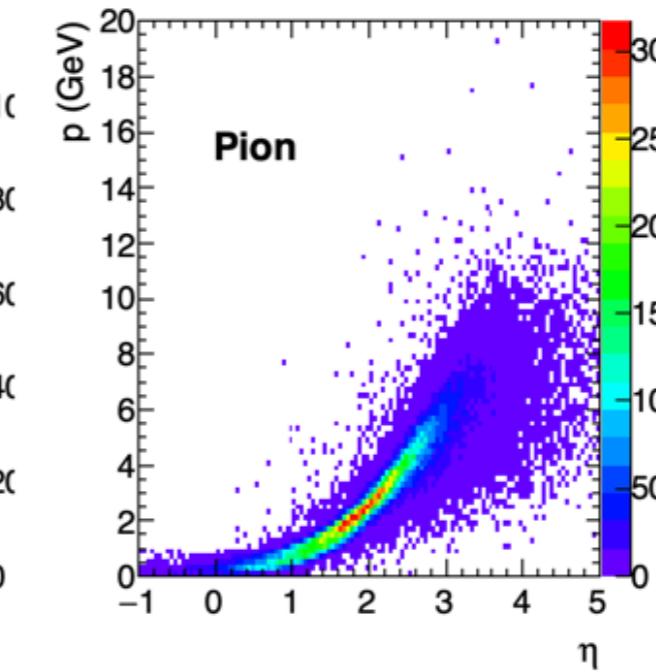
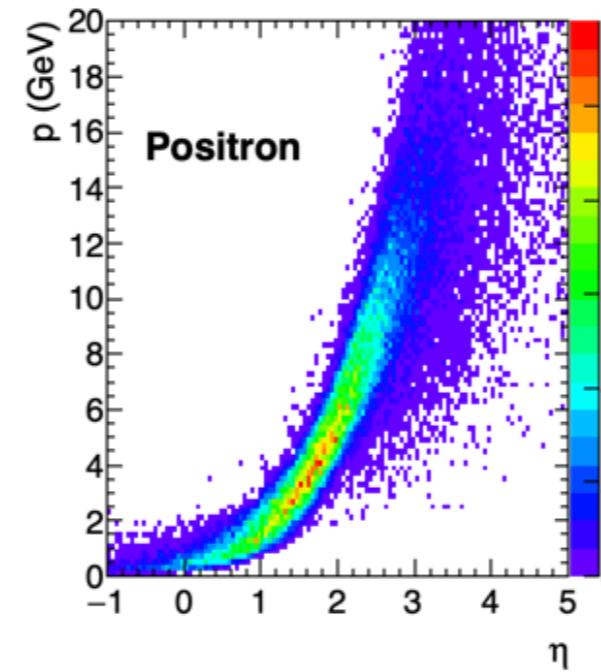
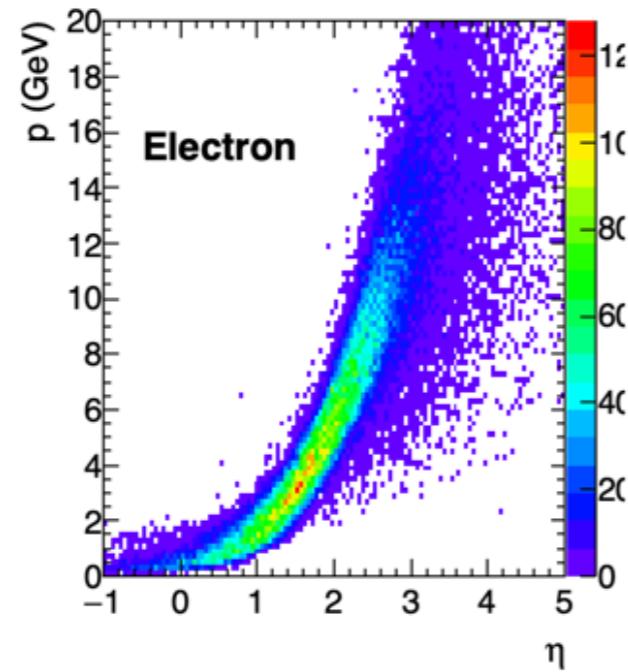
Backup

elSpectro generator: Z_c^+ , π exchange

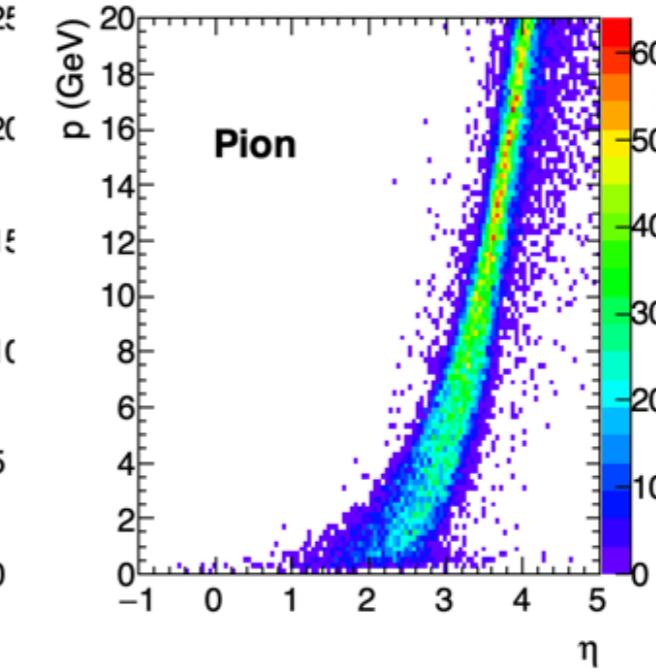
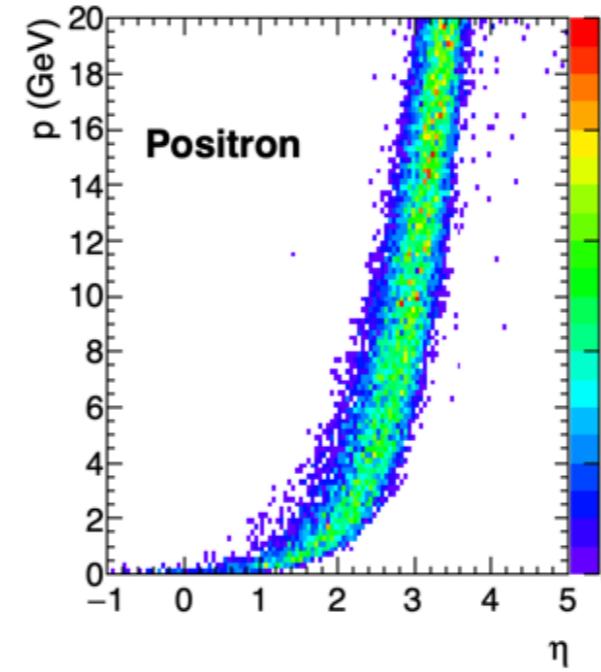
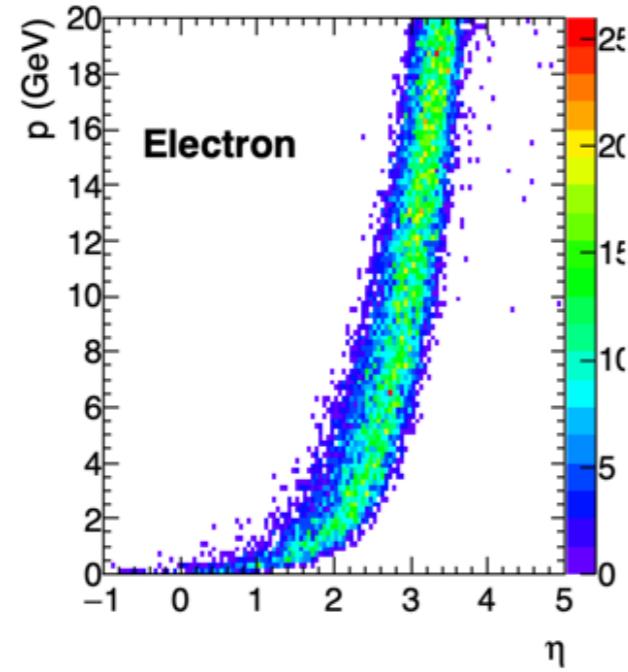
$Z_c^+ \rightarrow J/\psi\pi^+$ $J/\psi \rightarrow e^+e^-$ **Parallel: Derek Glazier**

**Beam
energies**

5 x 41



18 x 275



**Decays boosted to forward η (lower acceptance, degraded mass resolution)
lower energy proton beam energies beneficial**

US Snowmass Process

Letter of Interest: Hadron Spectroscopy at the Electron Ion Collider

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LOI: https://www.snowmass21.org/docs/files/summaries/RF/SNOWMASS21-RF7_RF0-090.pdf