Heavy Flavor Physics and Spectroscopy

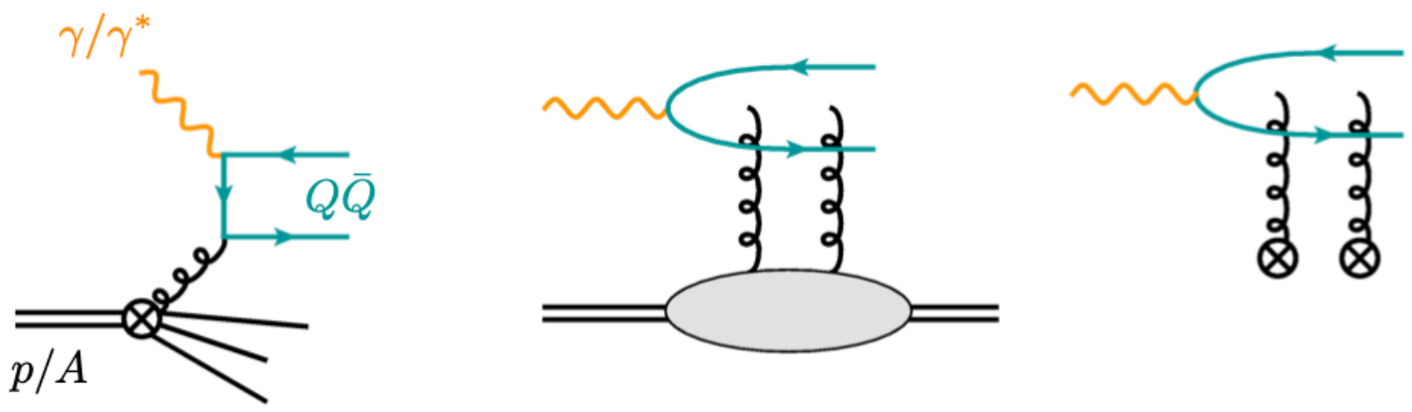
Justin Stevens

WILLIAM & MARY
CHARTERED 1693

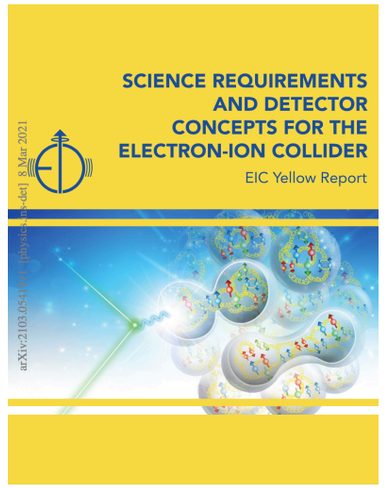
U.S. DEPARTMENT OF ENERGY | Office of Science

Overview of Yellow Report

Direct **Exclusive** **In-medium**



Processes / Topics	Inclusive	Semi-Inclusive	Jets, Heavy Quarks	Exclusive	Diffractive, Forward Tagging
Global properties & parton structure	**incl. SF**	**h, hh**	**jet, Q**	**excl. $Q\overline{Q}$**	**incl. diffraction, tagged DIS on D/He**
Multidimensional Imaging		**h**	**jet, di-jet, jet+h, Q, $Q\overline{Q}$**	**DVCS, DVMP, elast. scattering**	
Nucleus	**incl. SF**	**h, hh**	**jet, di-jet, Q, $Q\overline{Q}$**	**coh. VM, di-jet, h, hh, D/He FF**	**diffr. SF, incoh. VM, di-jet, h, hh, nucl. fragments**
Hadronization		**h, hh, jet+h**	**jet, Q, $Q\overline{Q}$**		
Other fields	**incl. SF with e^+, $\sigma^{tot}_{\gamma A}$**	**charged curr. DIS, $\sigma_{\gamma A\to hX}$**		**$\sigma^{elast}_{\gamma A}$**	**$\sigma^{diffr}_{\gamma A}$**

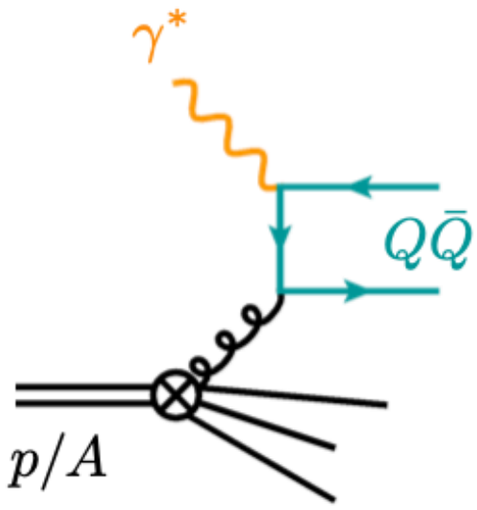


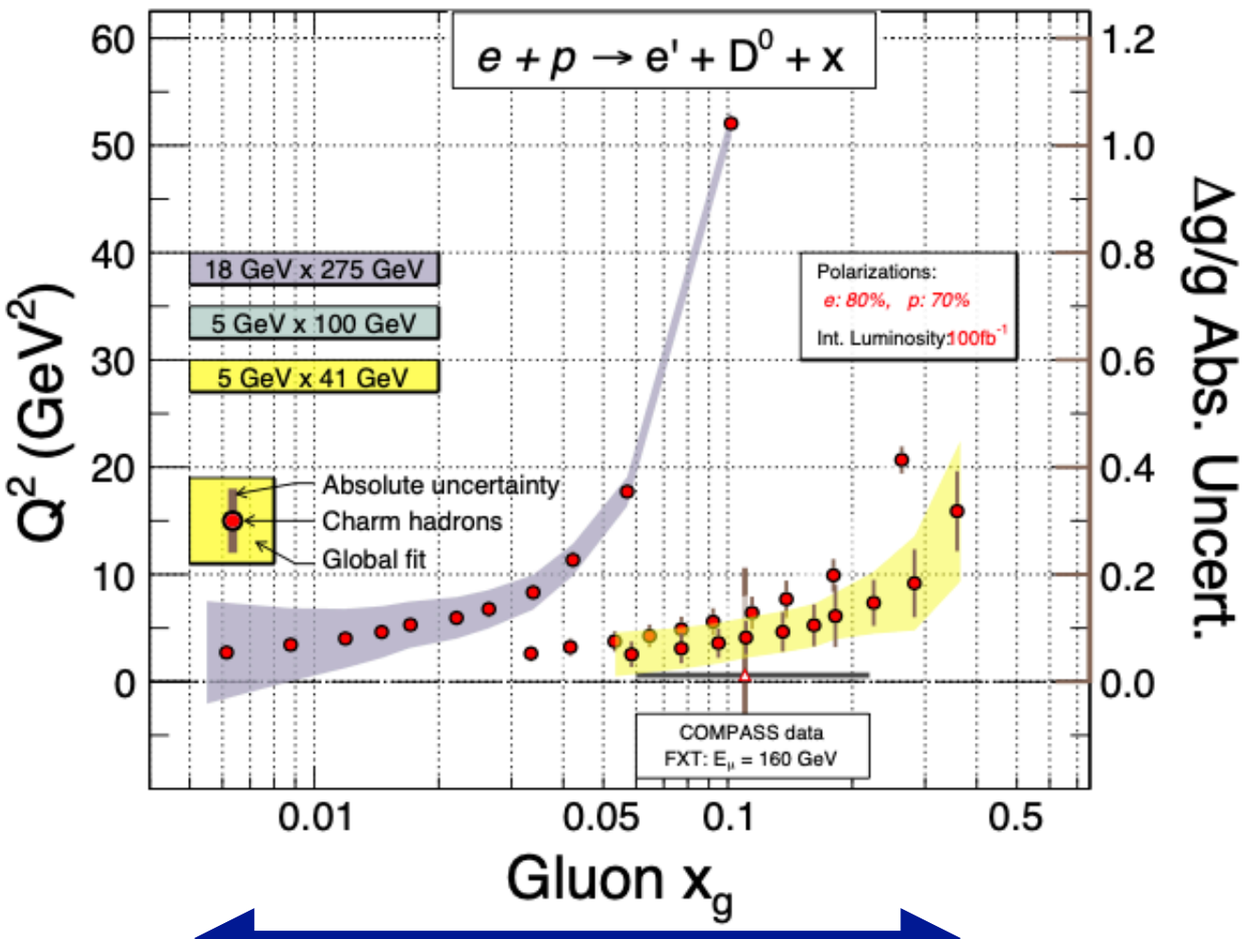
arXiv:2103.05419

- Lot's of Heavy Flavor physics! I'll try to outline some examples from the Yellow Report from the different topical areas
- Apologies if your favorite topic isn't included (see Parallel talks)

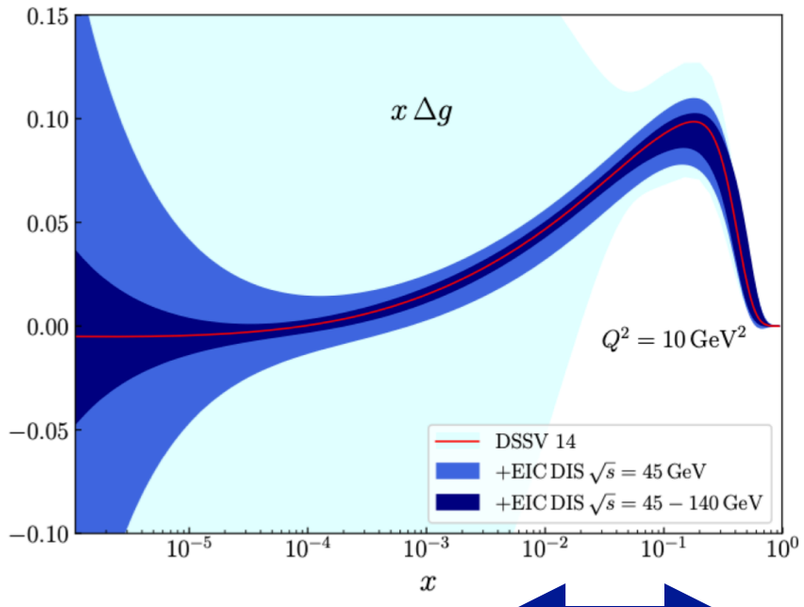
Δg through open charm

Semi-inclusive





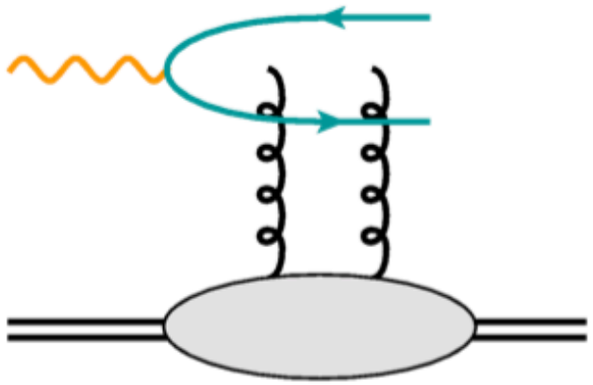
- Access Δg through A_{LL} using heavy flavor probe
- Pioneering measurements by Compass limited statistics
- Complementary to inclusive measurements in process and x_g-coverage



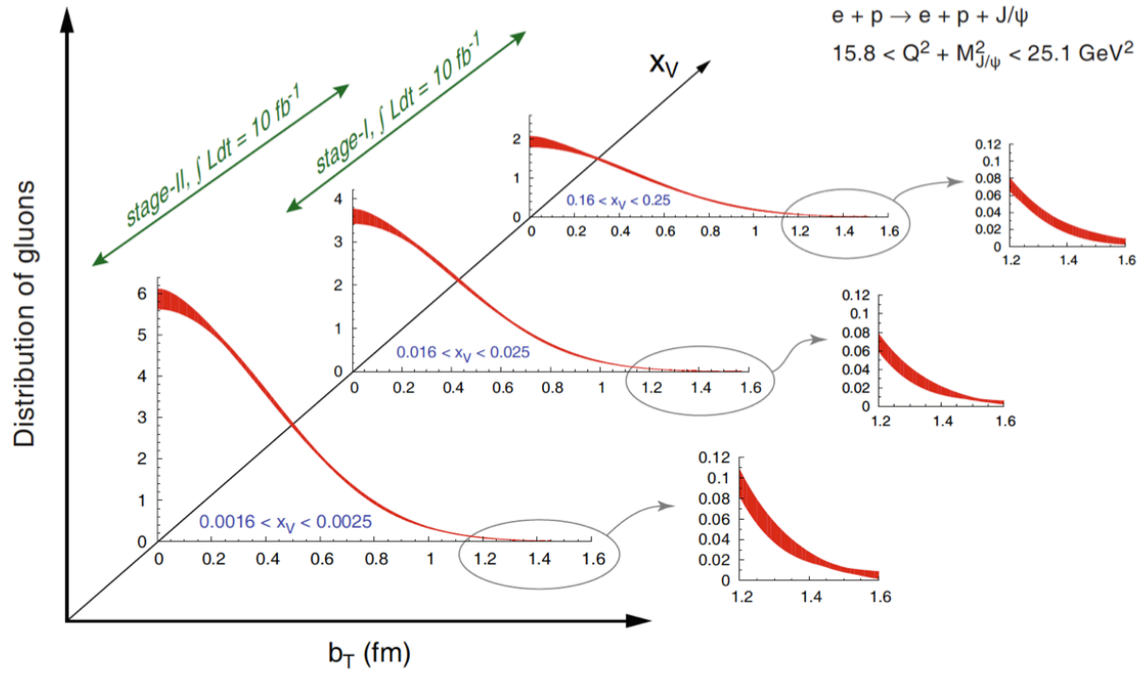
Exclusive quarkonium

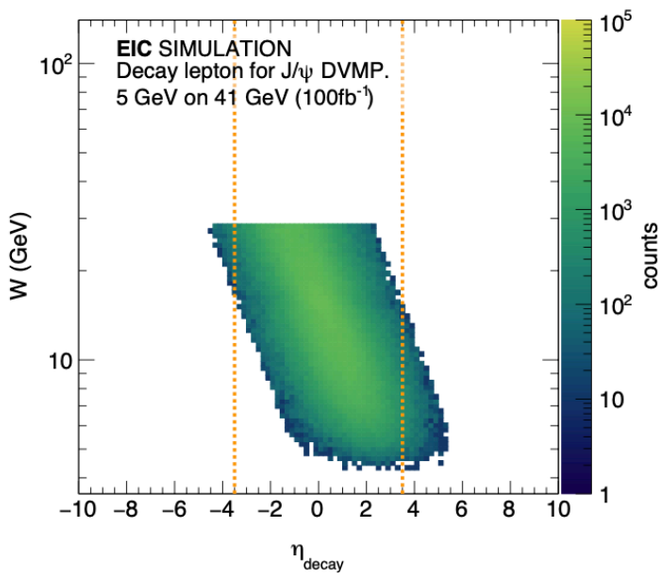
Parallel: Sylvester Joosten

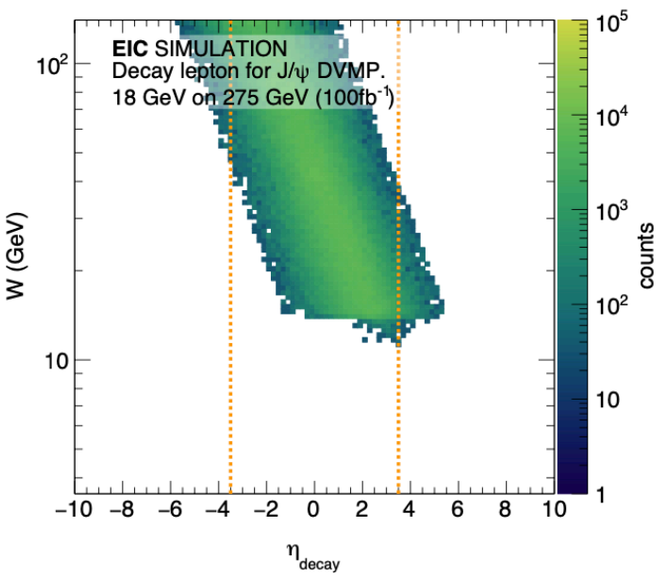
Exclusive

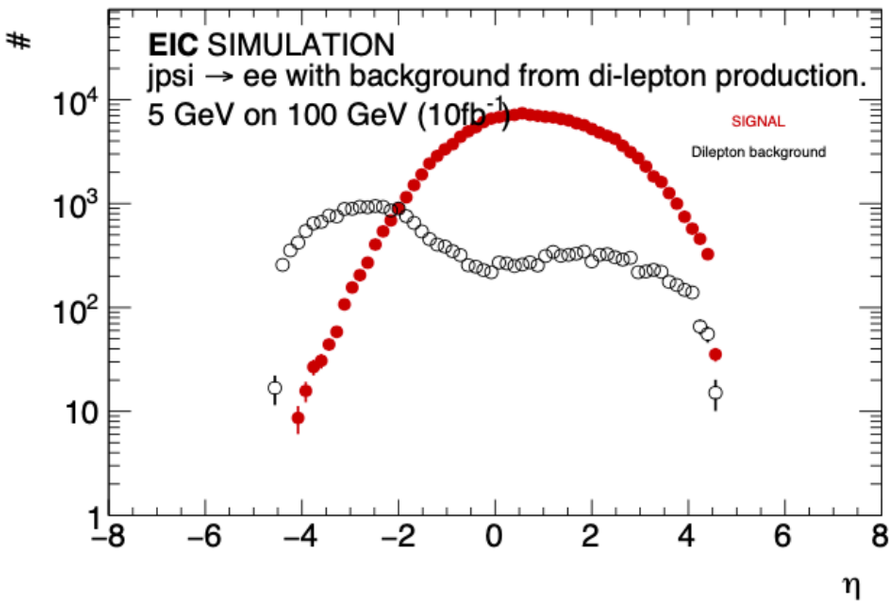


- Impact Parameter Distributions (IPD): $f(x, b_T)$ obtained from FT of dσ/dt for J/ψ with 10 fb^{-1}









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Parallel: Sylvester Joosten

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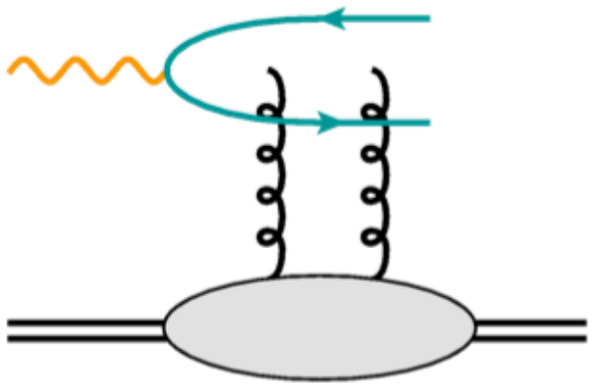
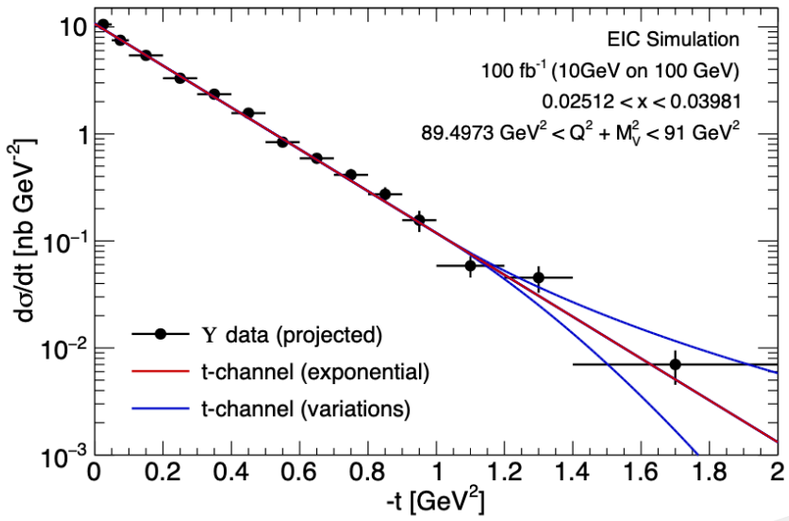
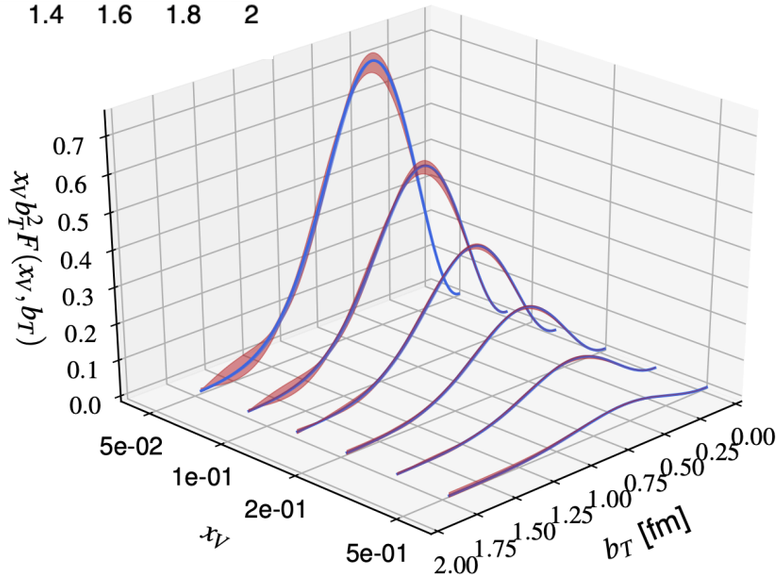


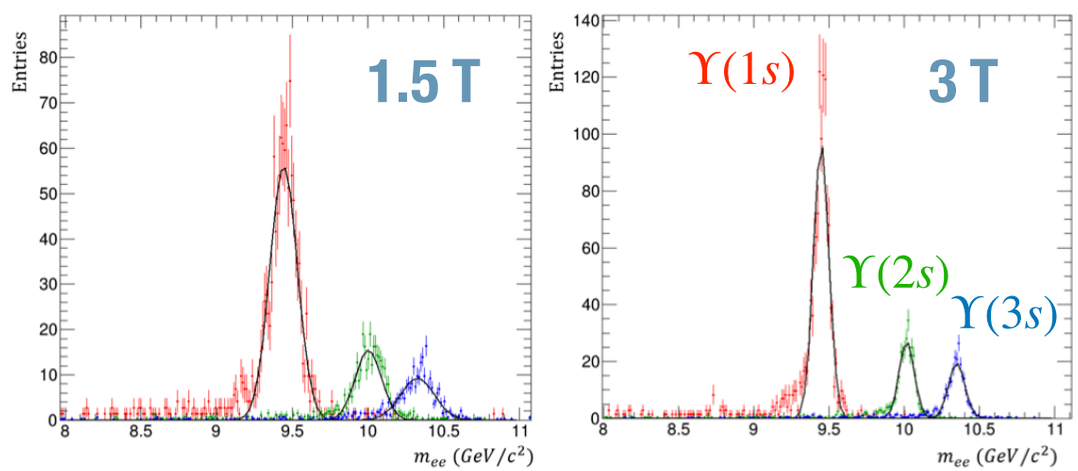


- Impact Parameter Distributions (IPD): $f(x, b_T)$ obtained from FT of dσ/dt for J/ψ with 10 fb^{-1}

- Recent work on heavier Υ shows complimentary performance with higher luminosity of 100 fb^{-1}



Υ in eA for 10 fb^{-1} /A



Exclusive quarkonium

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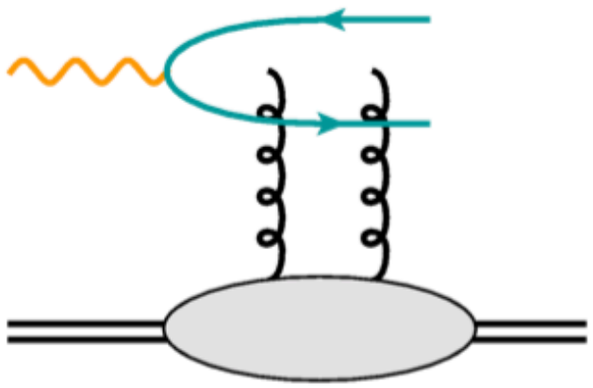

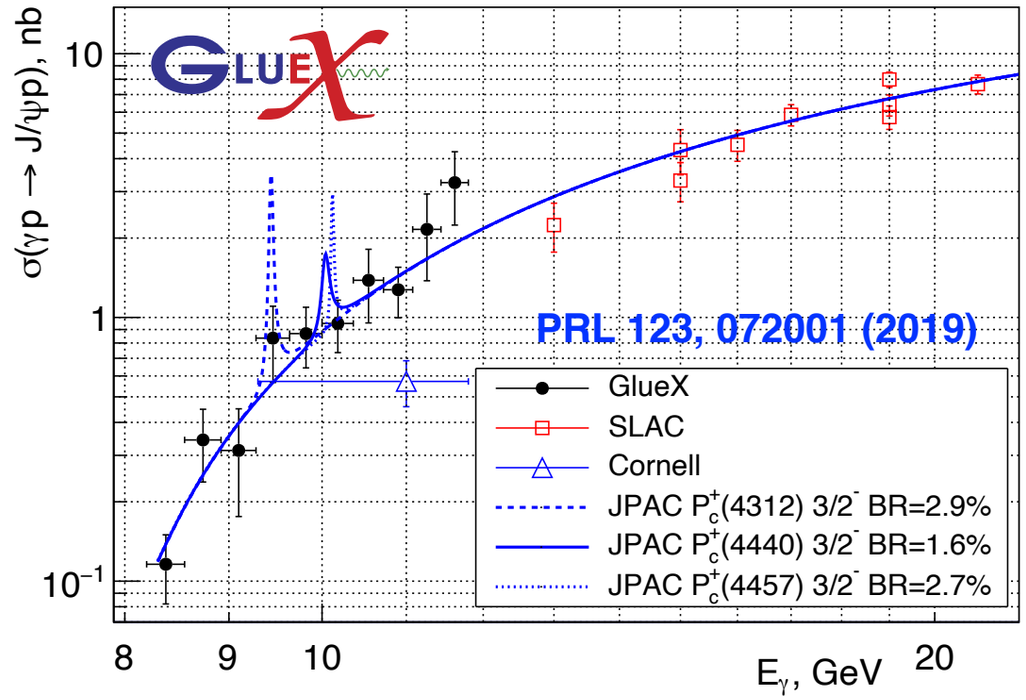

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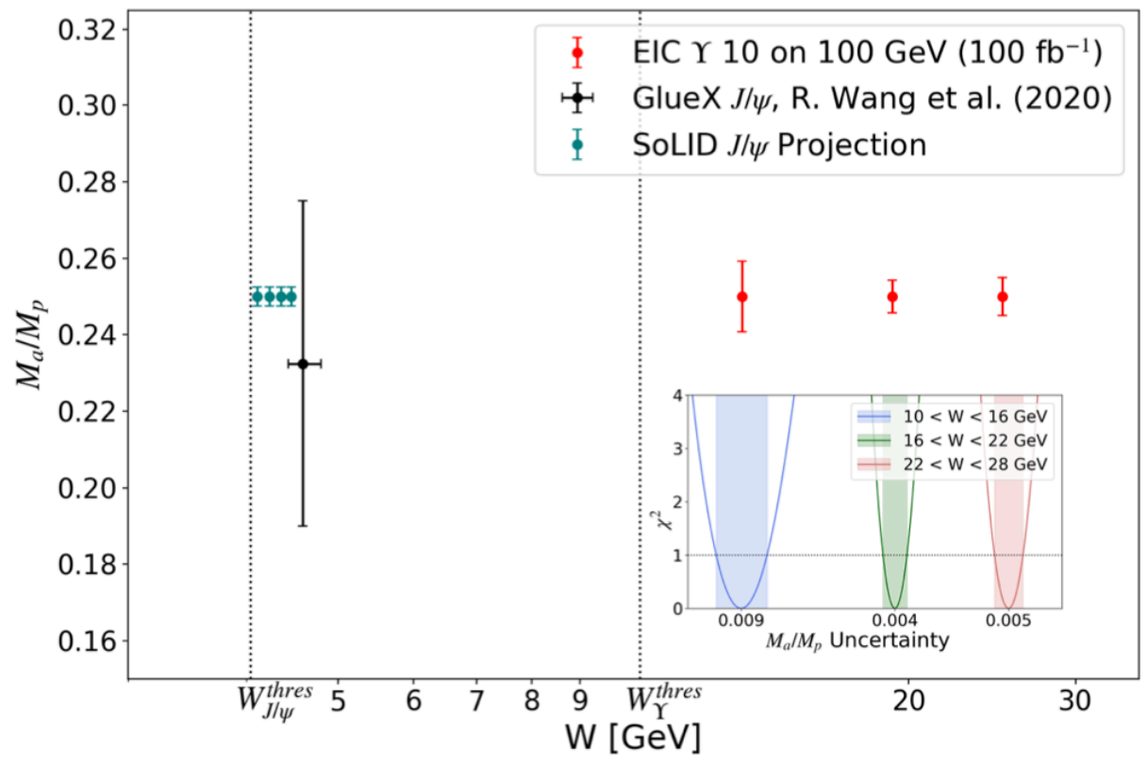
- Recent work on heavier ϒ shows complimentary performance with higher luminosity of 100 fb^{-1}

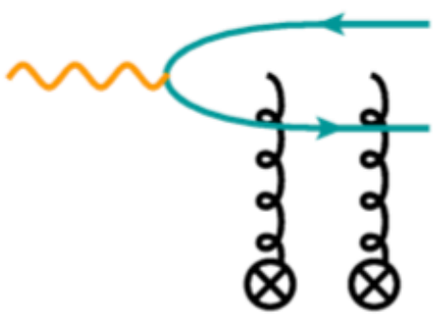
- Threshold photoproduction of VMs: trace anomaly, origin of proton mass (recent workshop)



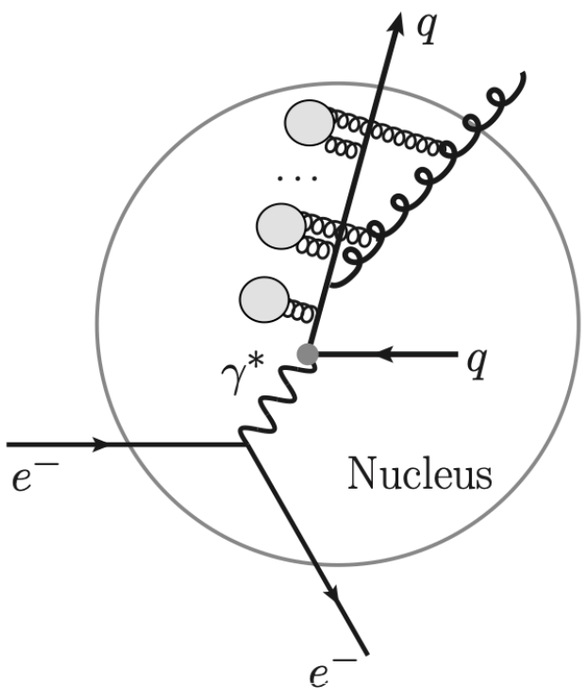
Hadronization in-medium

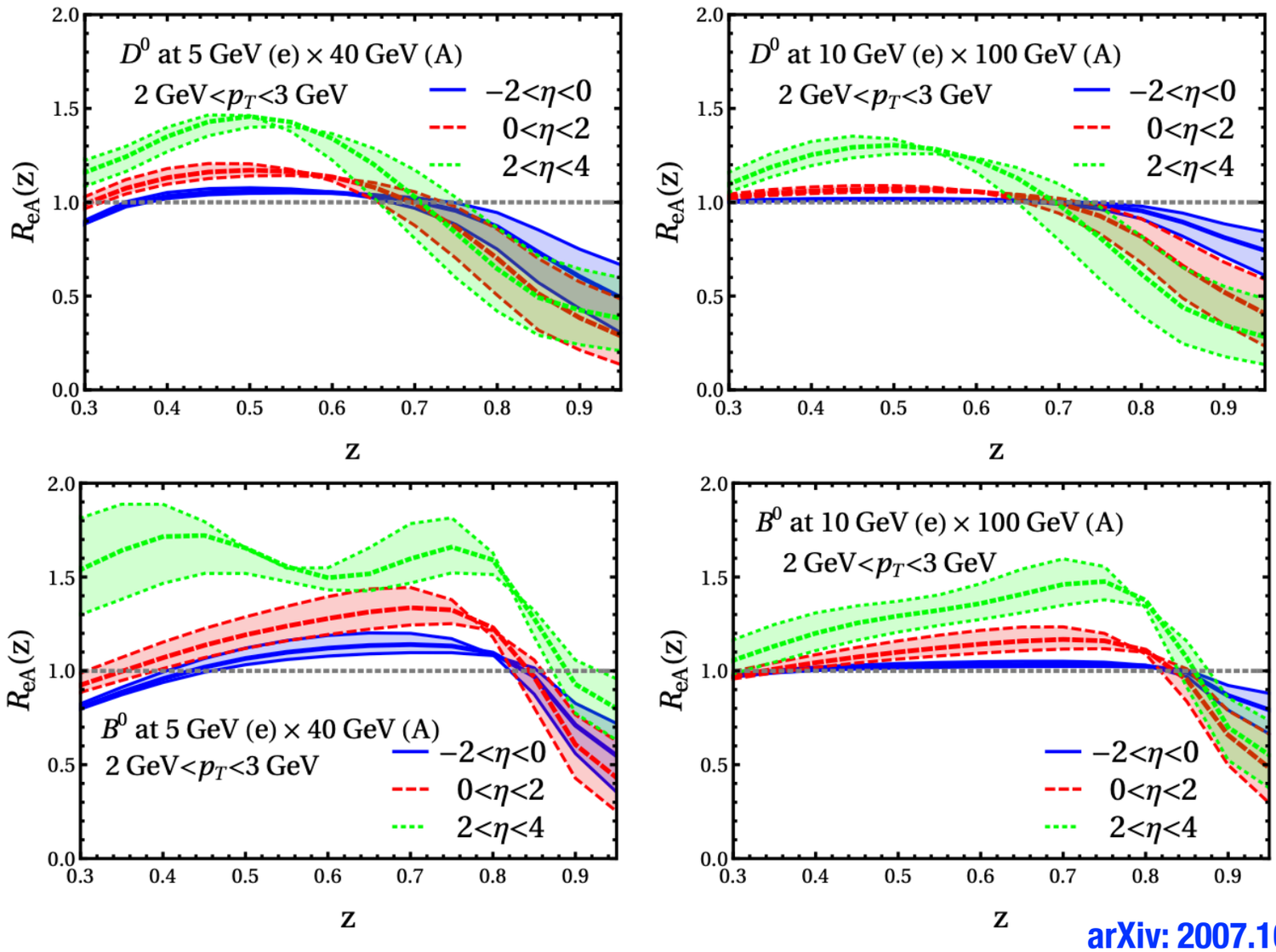
Parallel: Ivan Vitev

In-medium



$$R_{eA}^{h}(p_T,\eta,z) = \frac{N^{h}(p_T,\eta,z)}{N^{\text{inc}}(p_T,\eta)}\Big|_{\text{e+Au}} \Big/ \frac{N^{h}(p_T,\eta,z)}{N^{\text{inc}}(p_T,\eta)}\Big|_{\text{e+p}}$$

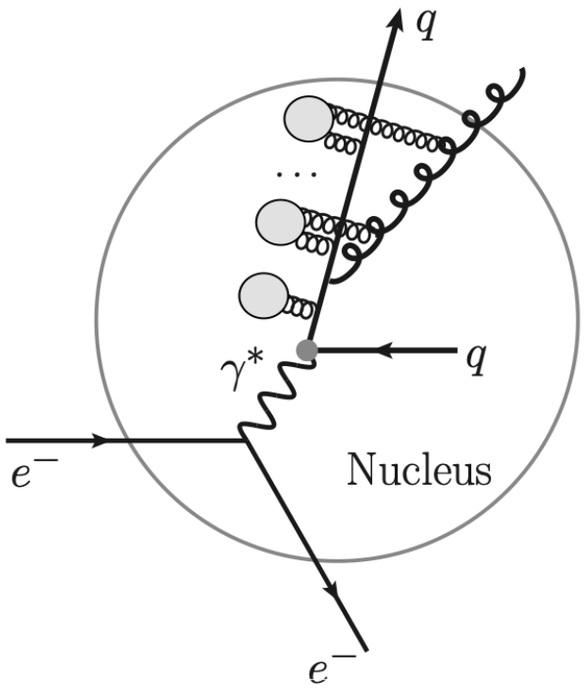




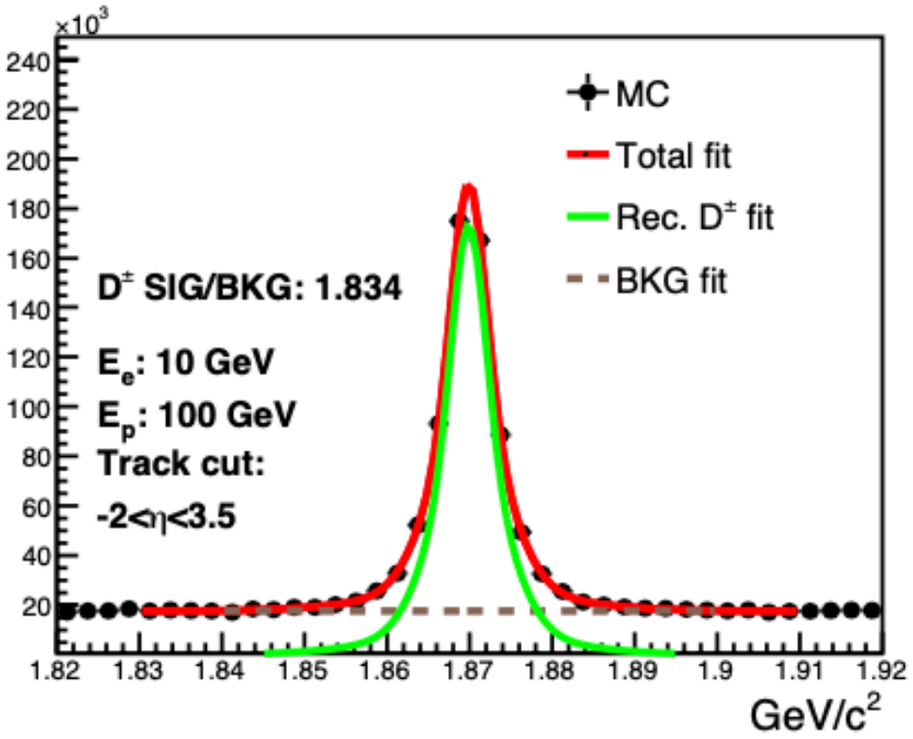
arXiv: 2007.10994

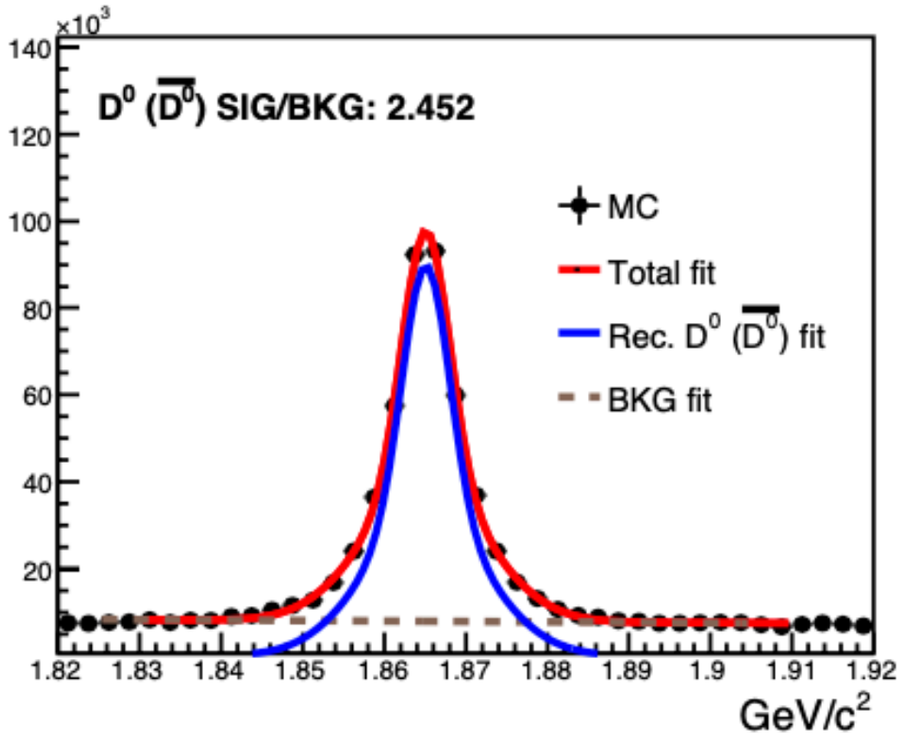
Hadronization in-medium

Parallel: Ivan Vitev



- Example simulations of forward silicon vertex tracker demonstrate D, B signal extraction
- Projections show flavor dependence of hadronization accessible through π, D, B and precision differential measurements are possible with full luminosity

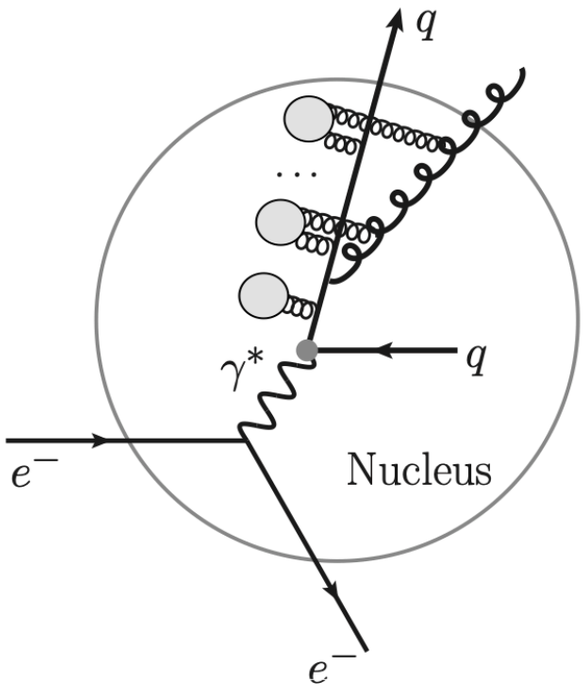




arXiv: 2009.02888

Hadronization in-medium

Parallel: Ivan Vitev



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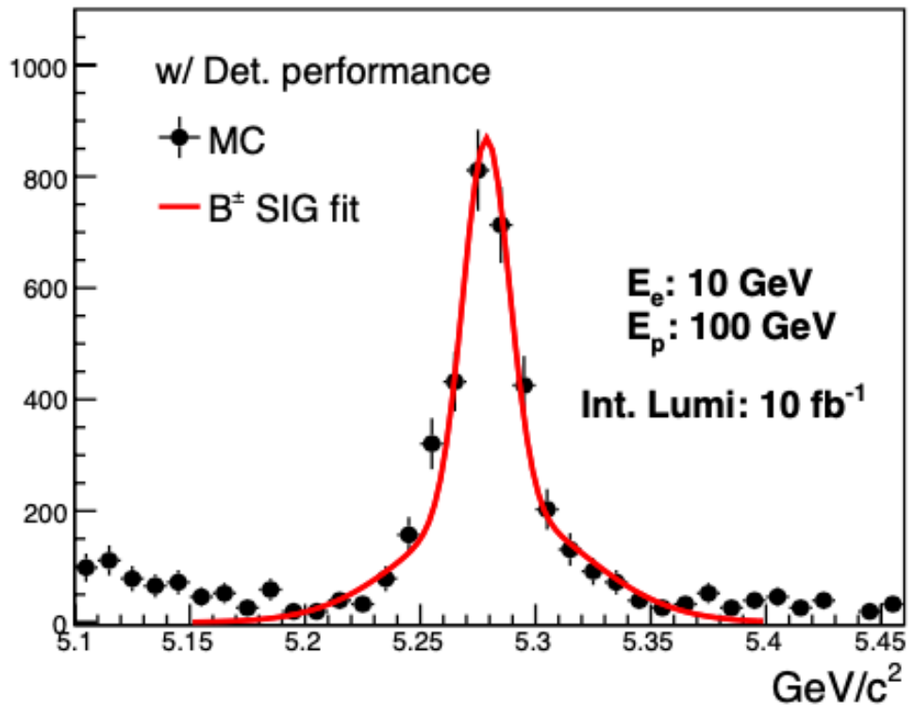

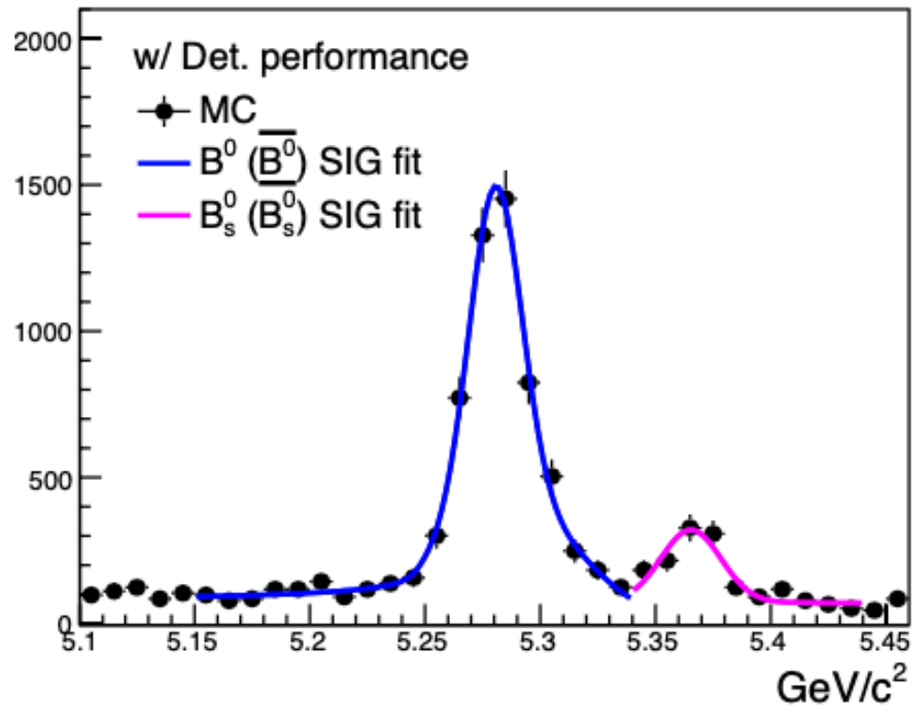

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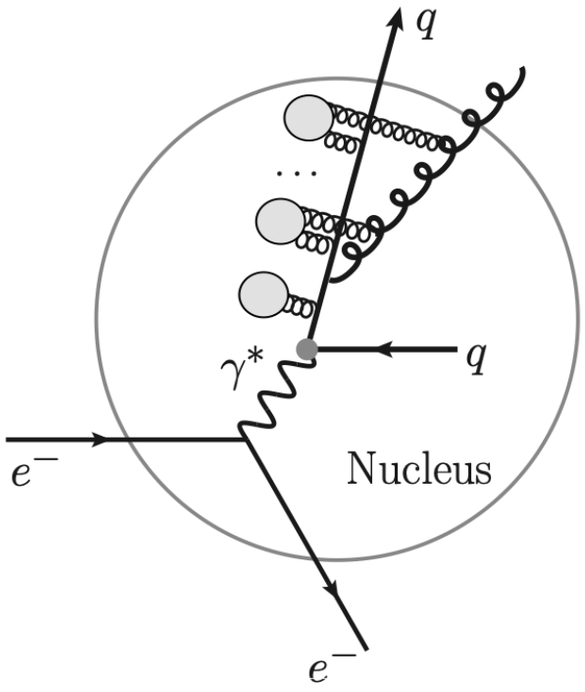

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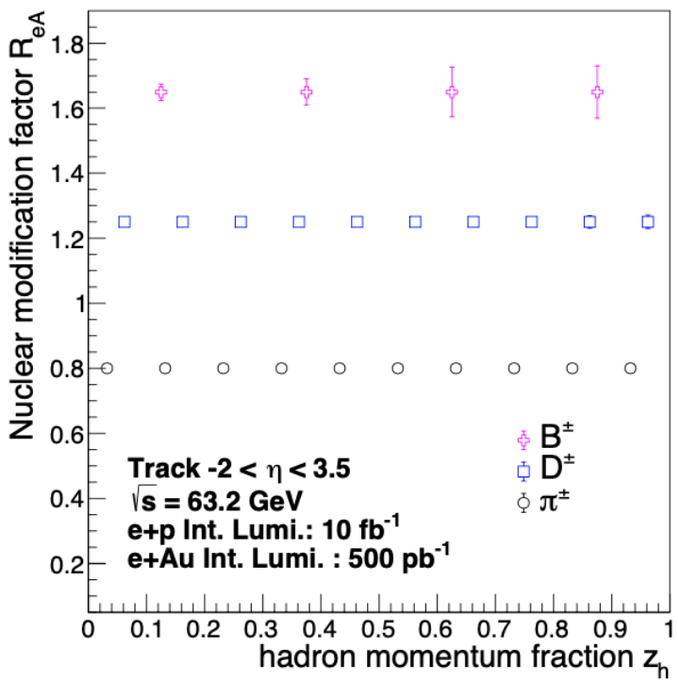
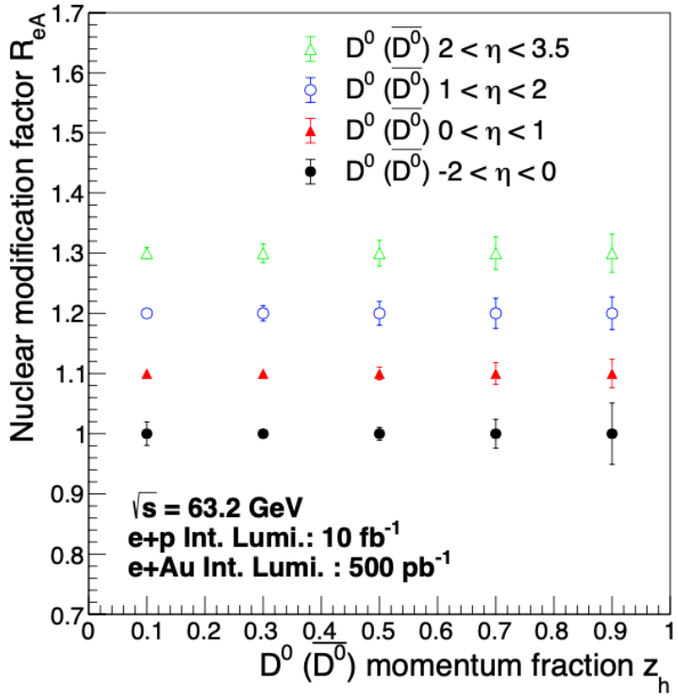
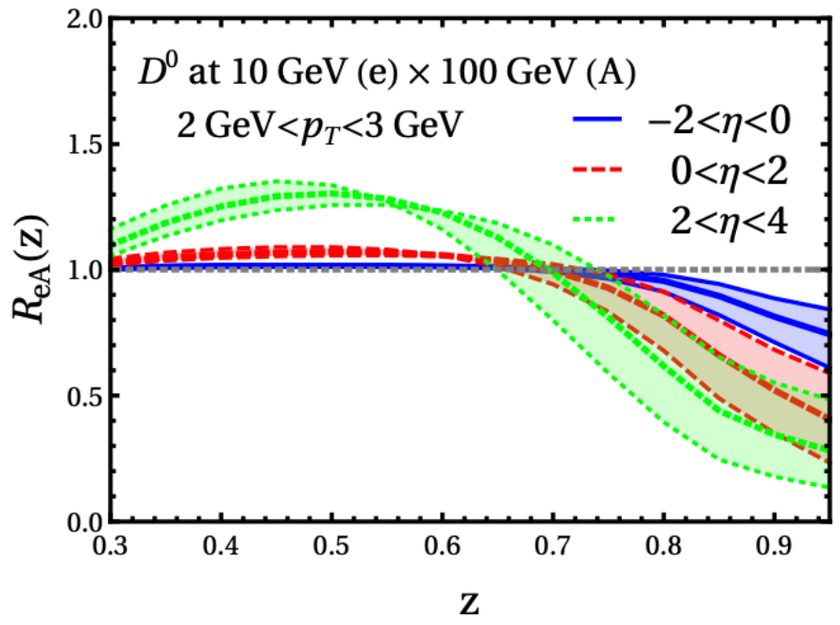
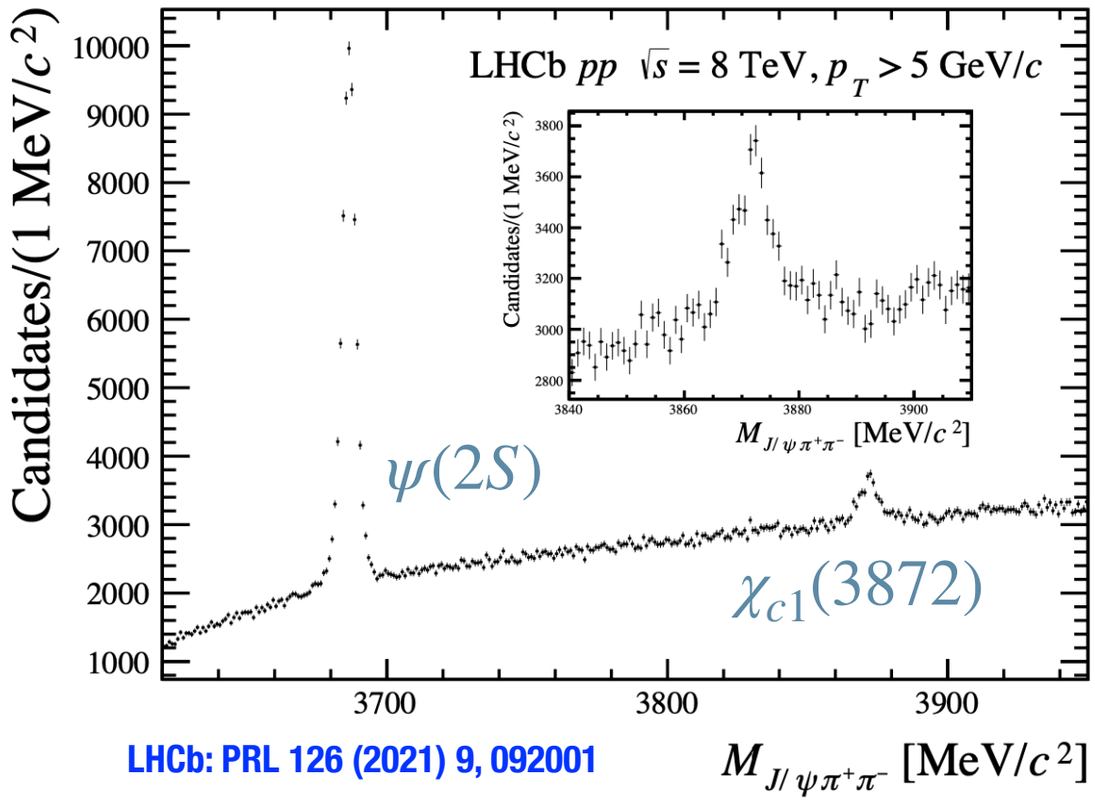




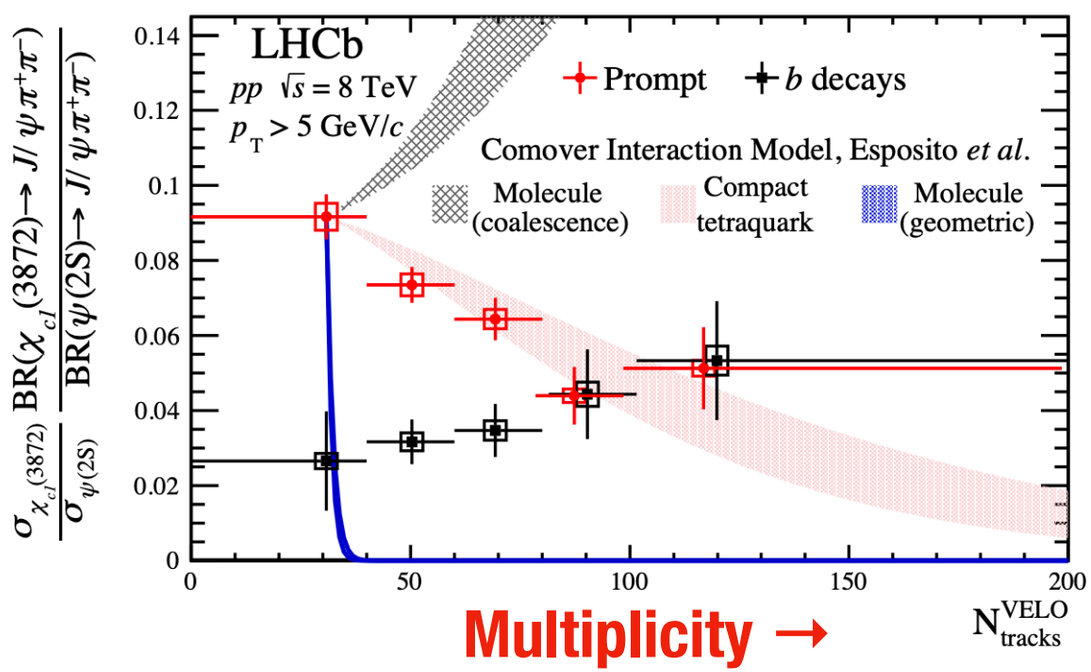


In-medium: unconventional mesons $\chi_{c1}(3872)$

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

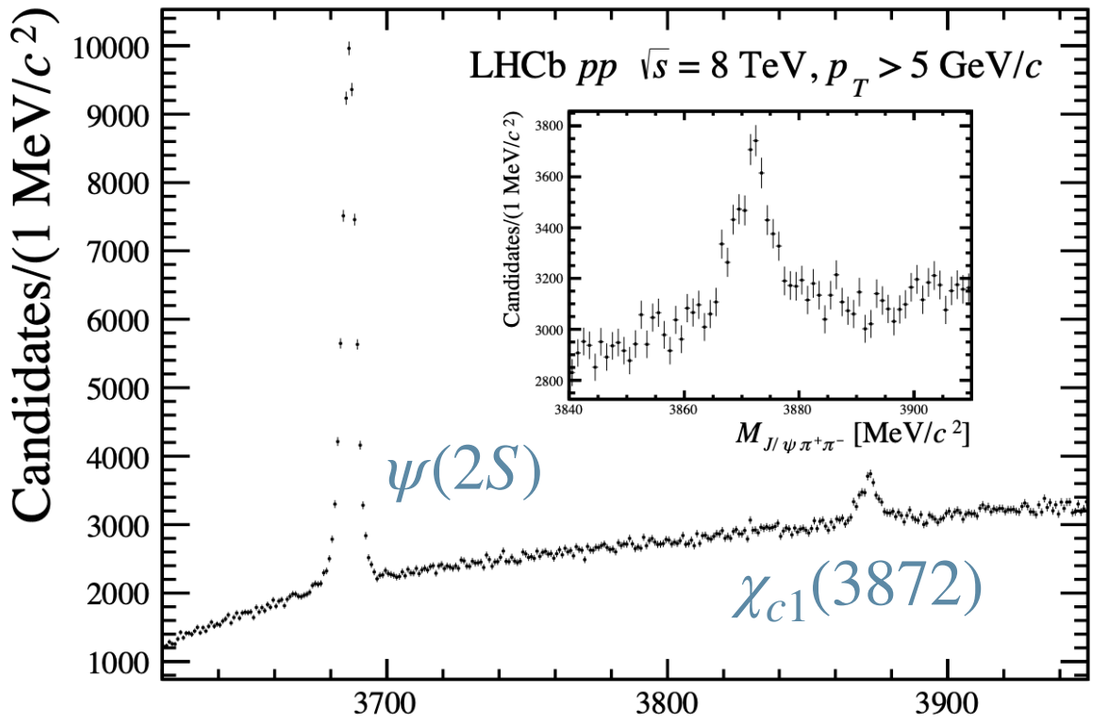


LHCb: PRL 126 (2021) 9, 092001



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 $\psi(2S)$



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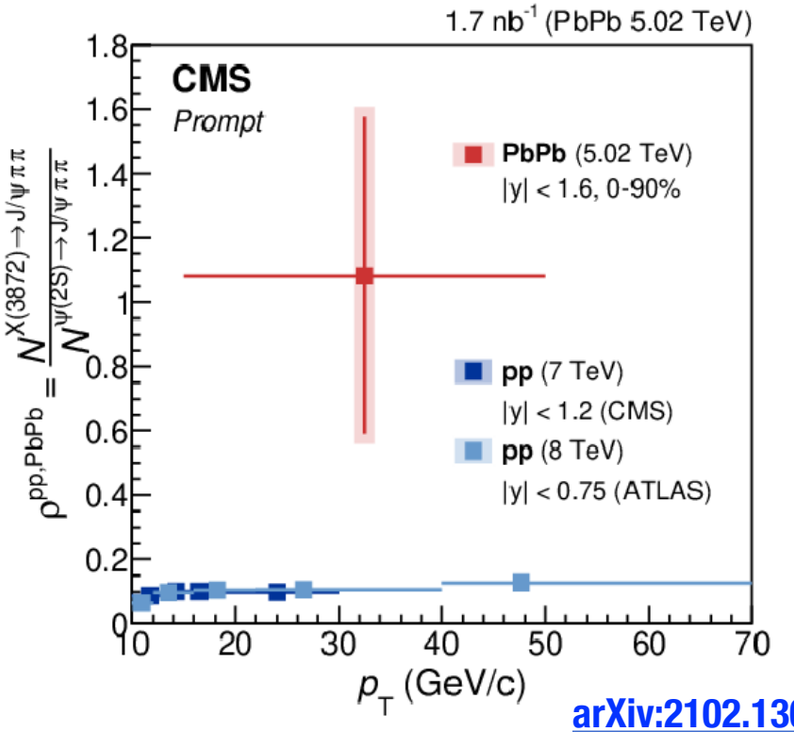
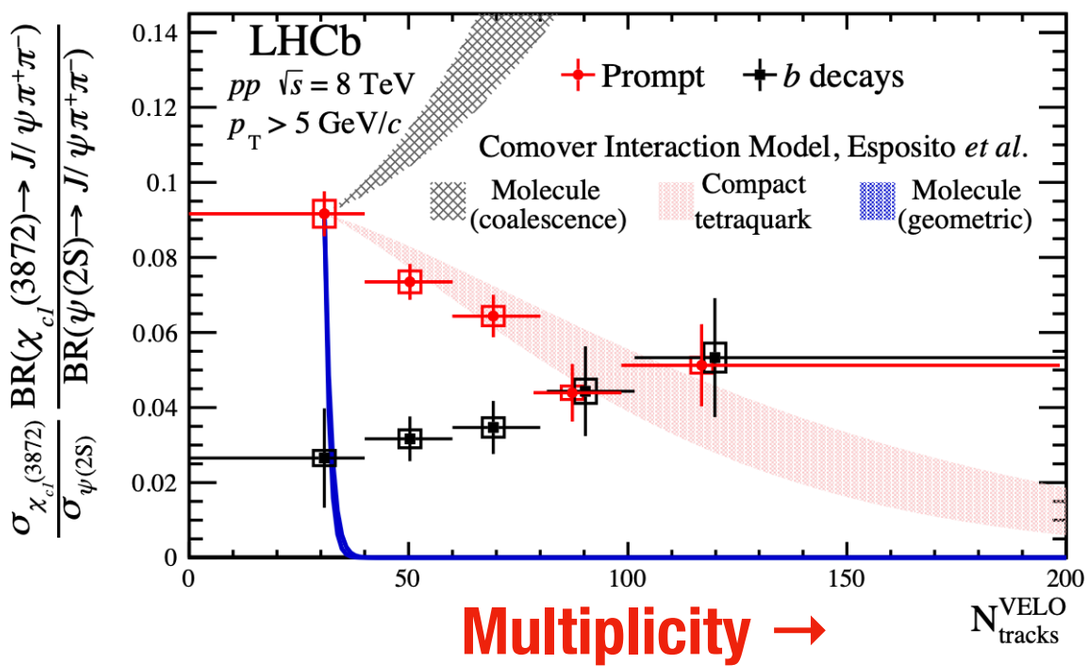
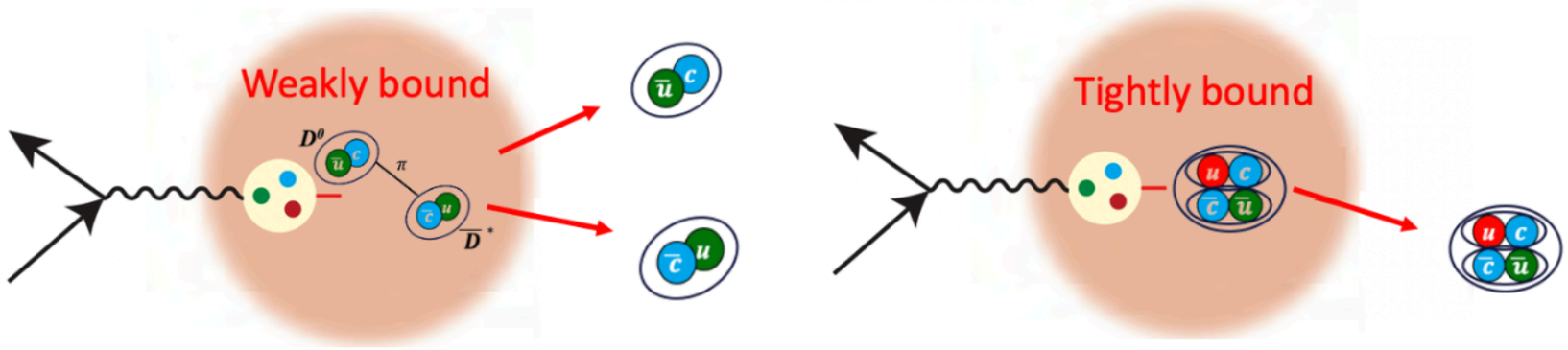


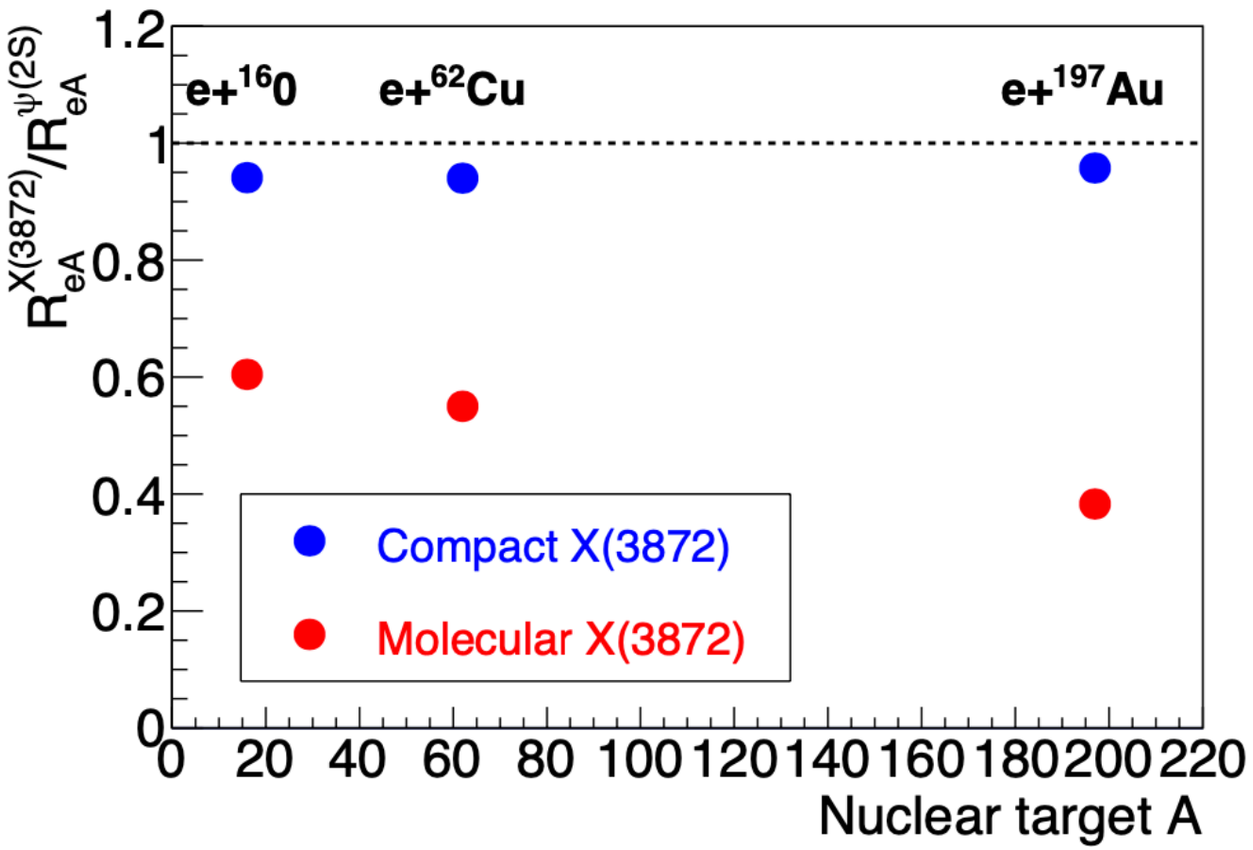
arXiv:2102.13048



Multiplicity →

In-medium effects for spectroscopy



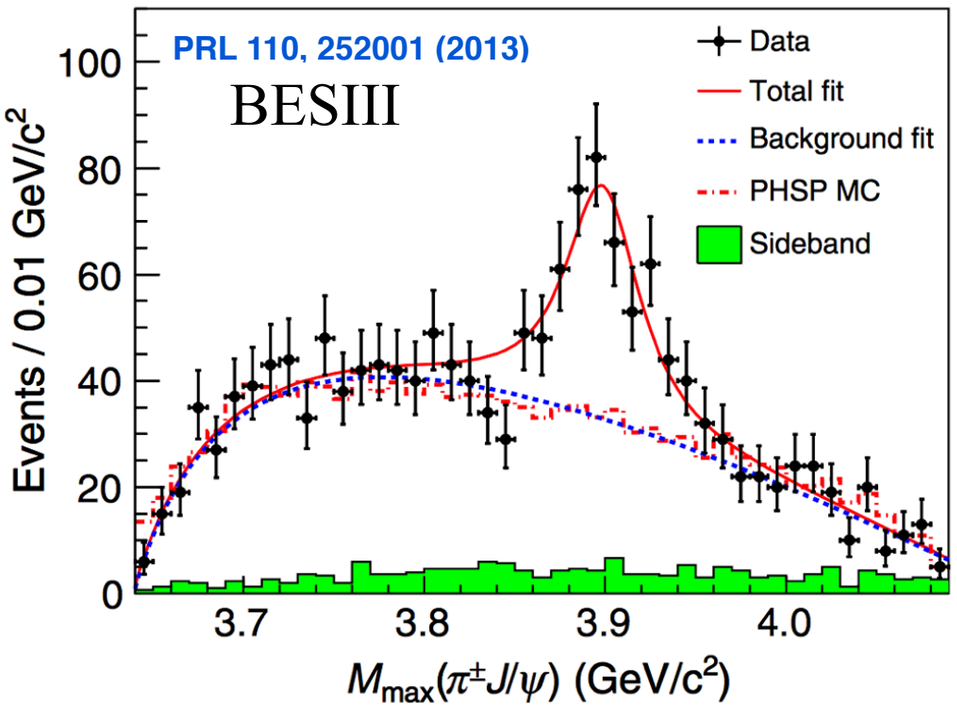


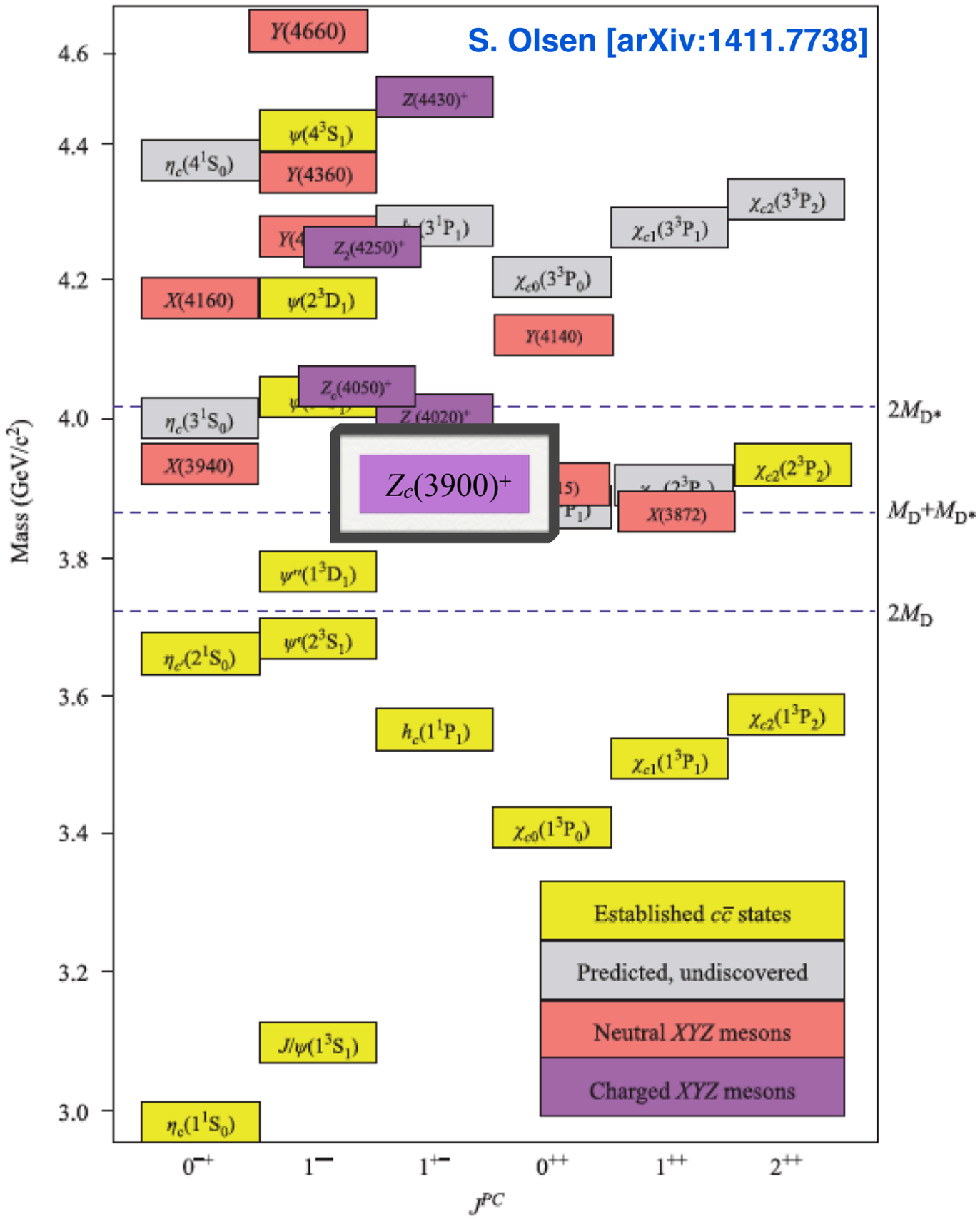
- Dependence on breakup of X(3872) in nuclei?
- Little suppression expected for compact tetraquark configuration
- Expect suppression of molecular (large size) configuration

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.

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



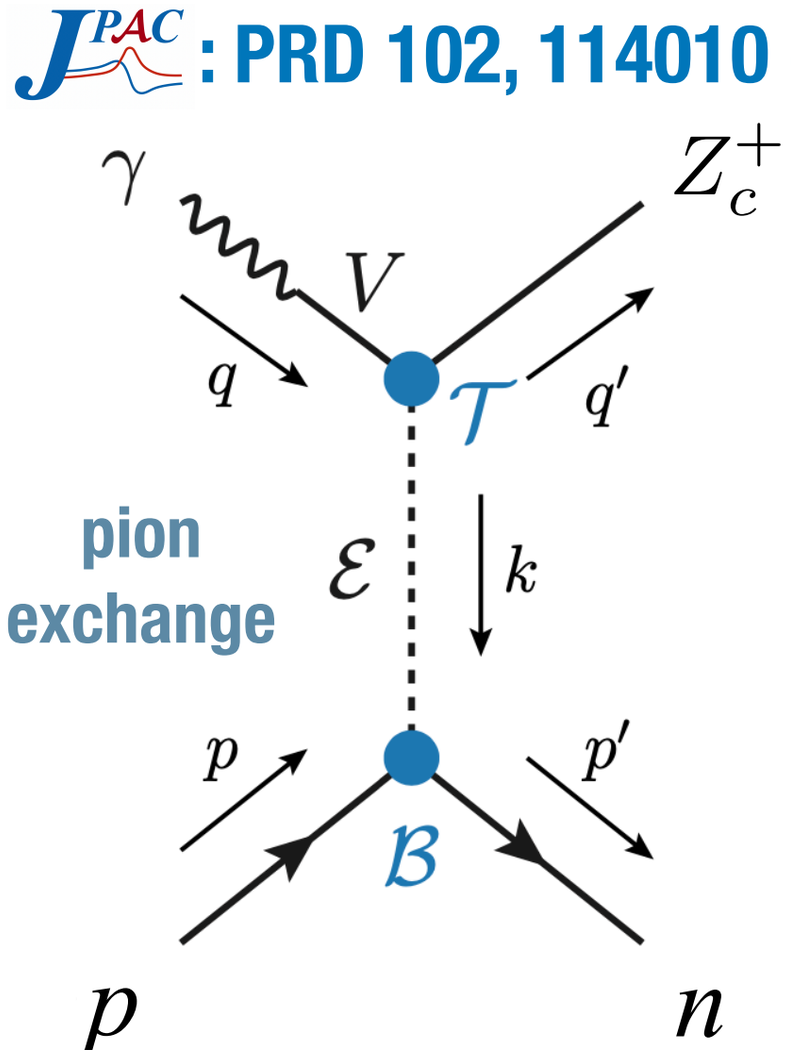


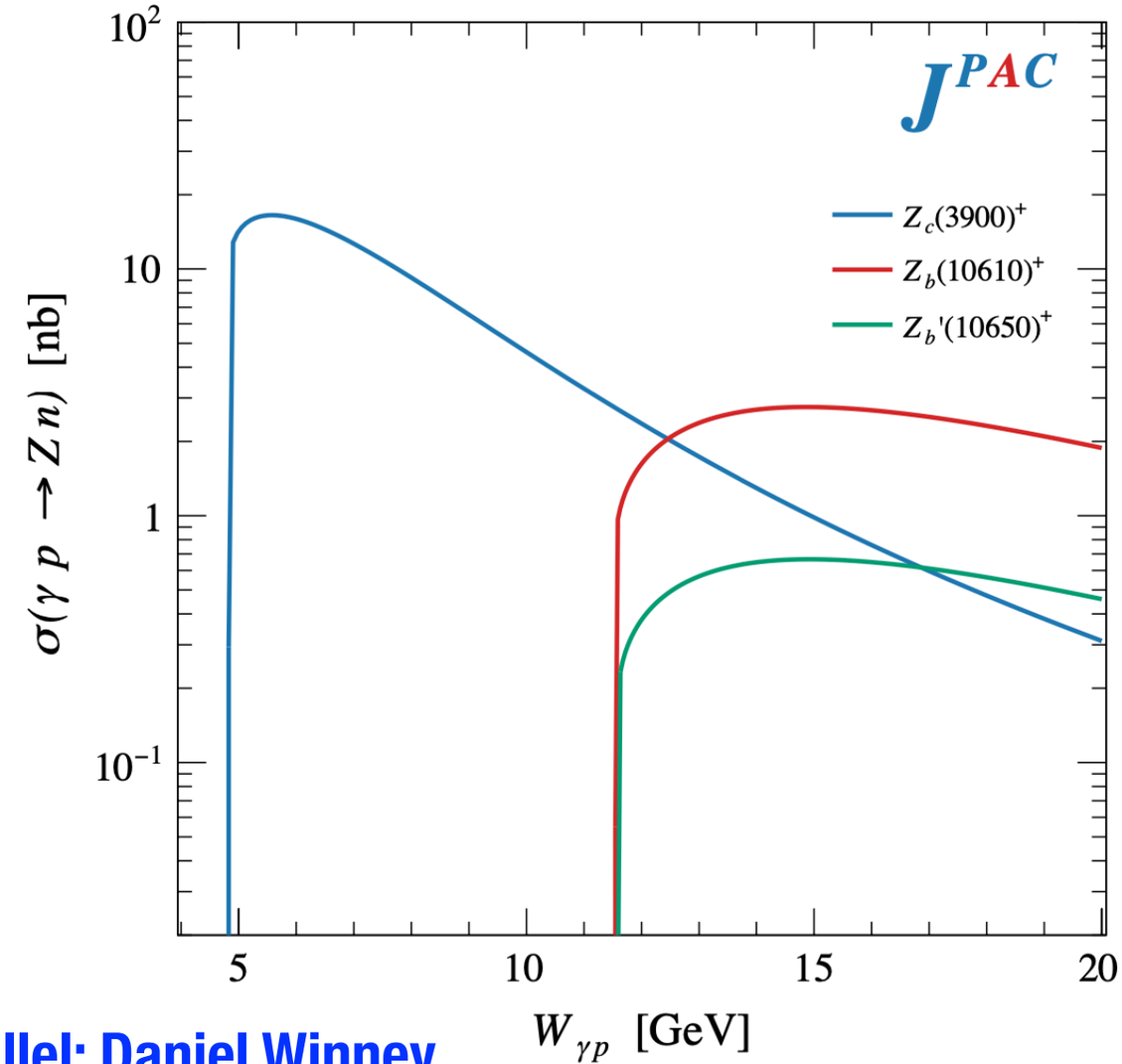
$Z_c^+(3900)$ at an EIC

- Plenty more data to come from BESIII, Belle II, LHC, PANDA, etc. on the timeline of the EIC

- Alternative production mechanism to probe exotic hadrons, critical to resolve underlying structure

JPAC: PRD 102, 114010 (2020)





Parallel: Daniel Winney

$Z_c^+(3900)$ at an EIC

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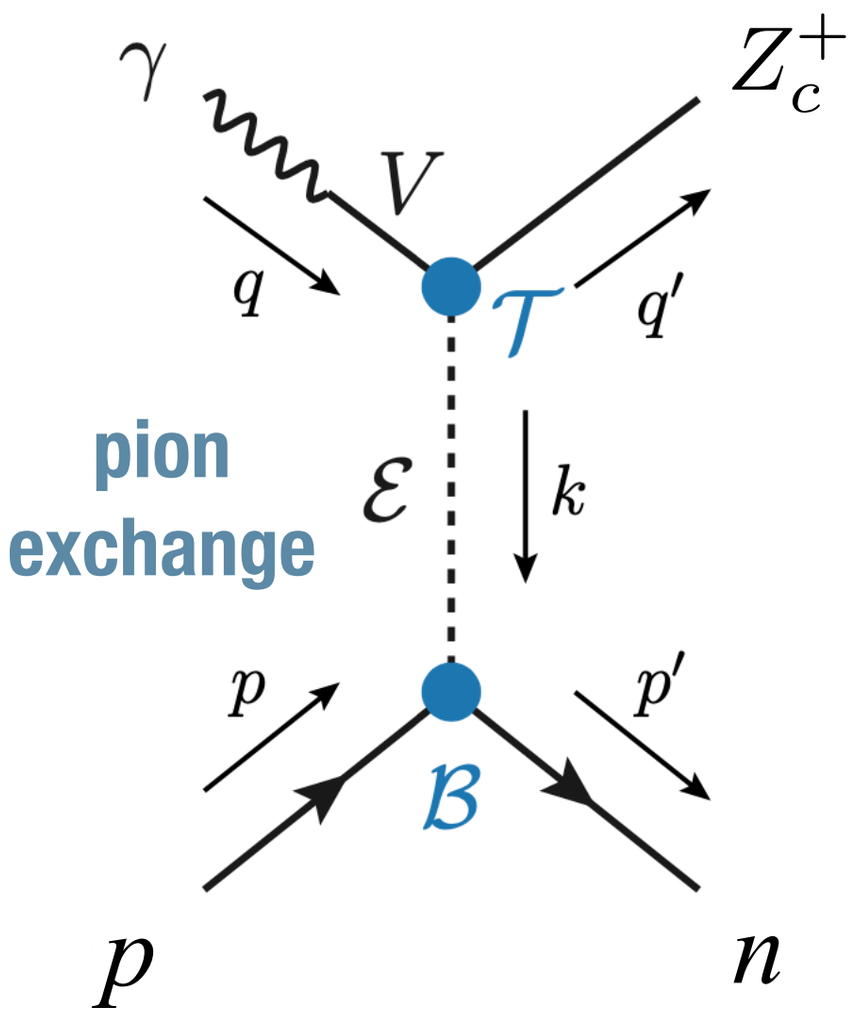
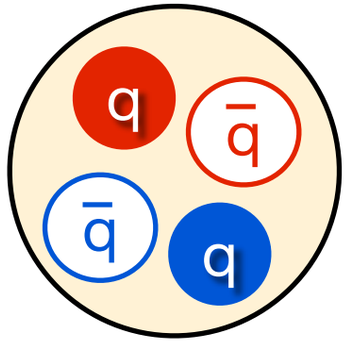
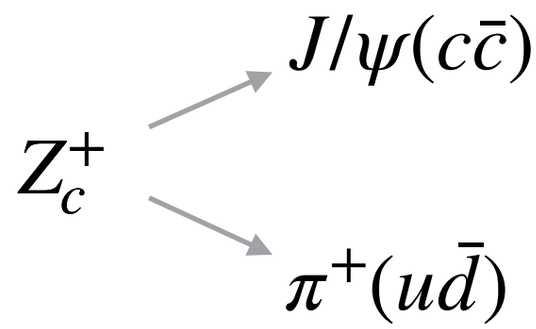
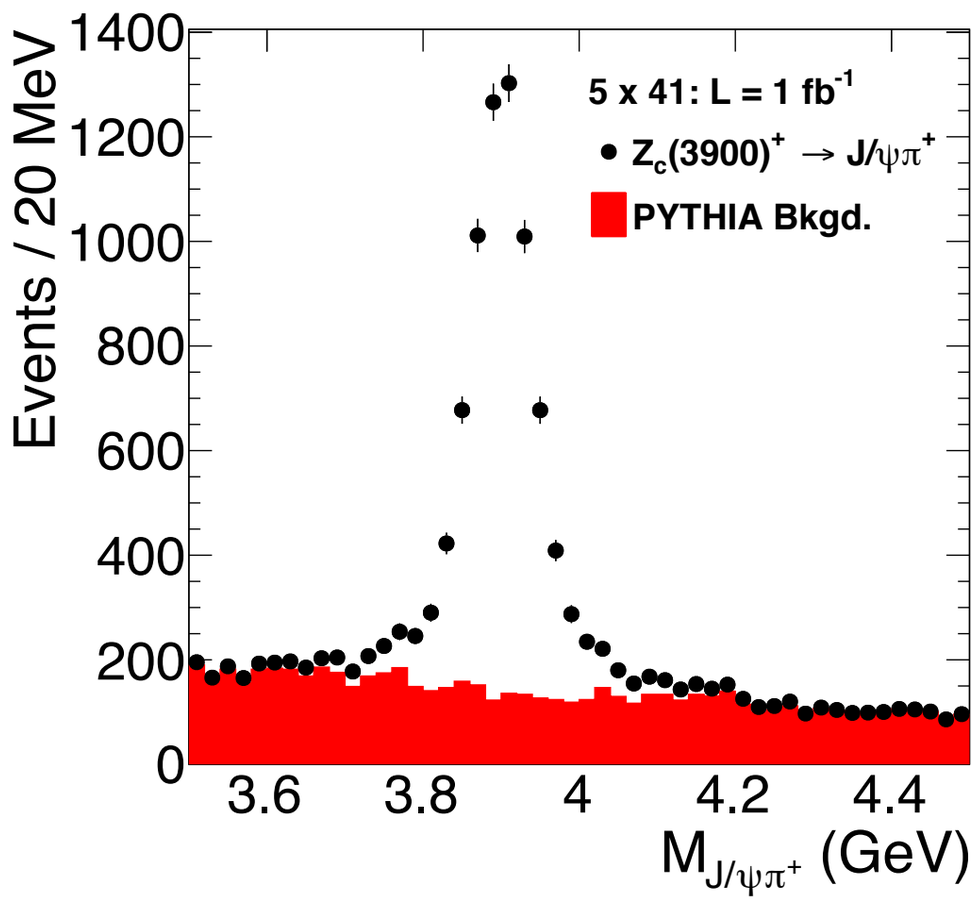




tetraquark candidate





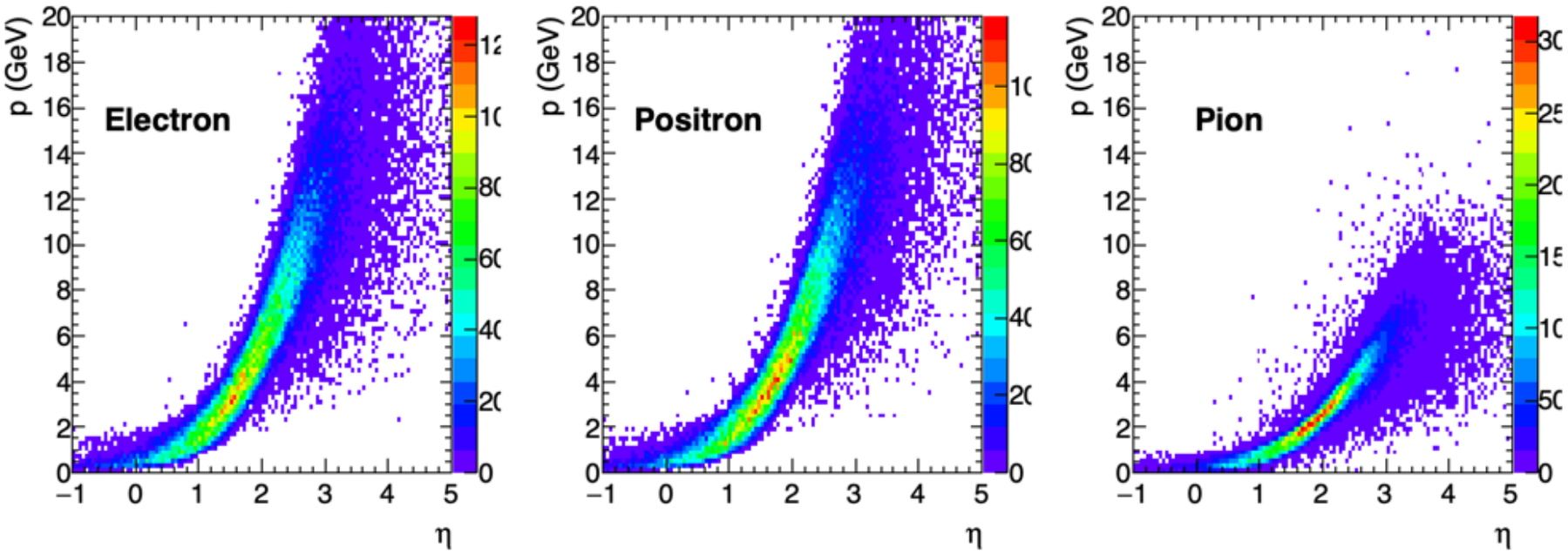
elSpectro generator: Z_c, π exchange

$$Z_c^+ \to J/\psi\pi^+ \quad J/\psi \to e^+e^-$$

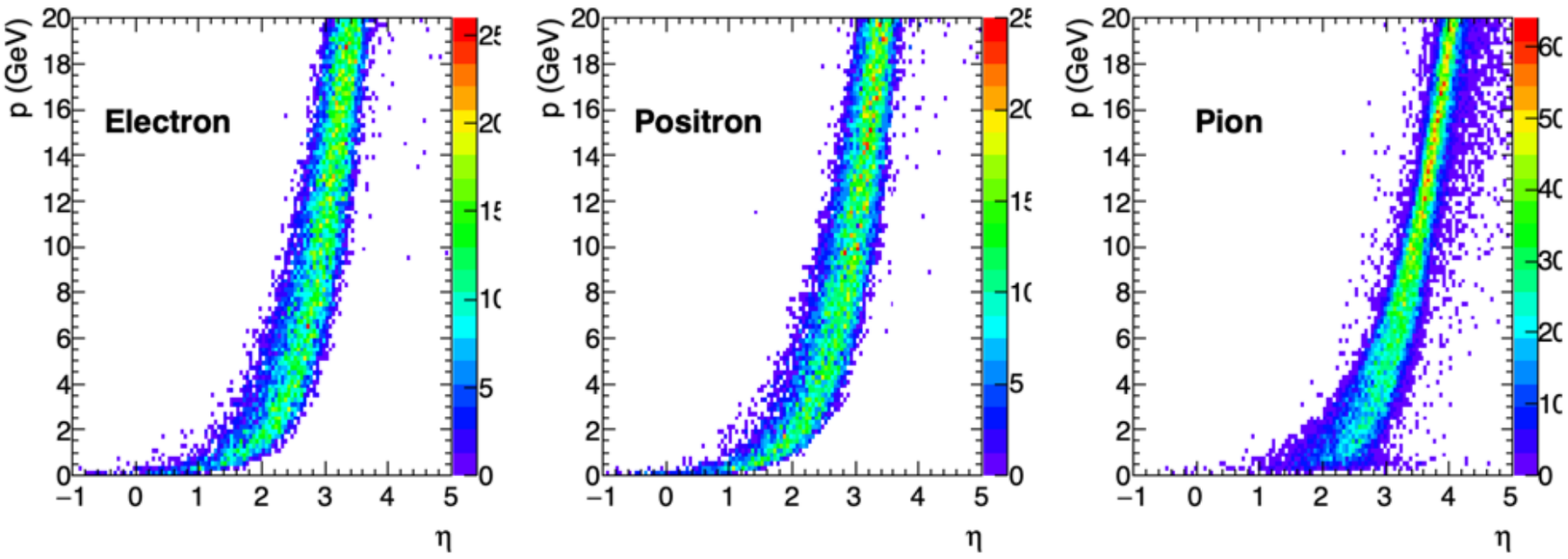
Parallel: Derek Glazier

Beam energies

5 x 41



18 x 275



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

Summary and speculation

- Heavy flavor physics is ubiquitous throughout the EIC program: 3D nucleon structure, hadronization, spectroscopy, etc.
  - Many measurements require the full luminosity 10 or 100 fb^{-1}
- What unique/complementary features can a 2nd IR provide?
  - High luminosity at low CM energies: enhanced access for threshold production useful for spectroscopy
  - Complementarity in kinematic coverage for particle ID and tradeoffs in resolution/low momentum thresholds in tracking technology
  - Crossing angle and forward ion acceptance?
- Looking forward to hearing more about the 2nd IR concepts and applications to heavy flavor and spectroscopy!

Supported by DE-SC0018224

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