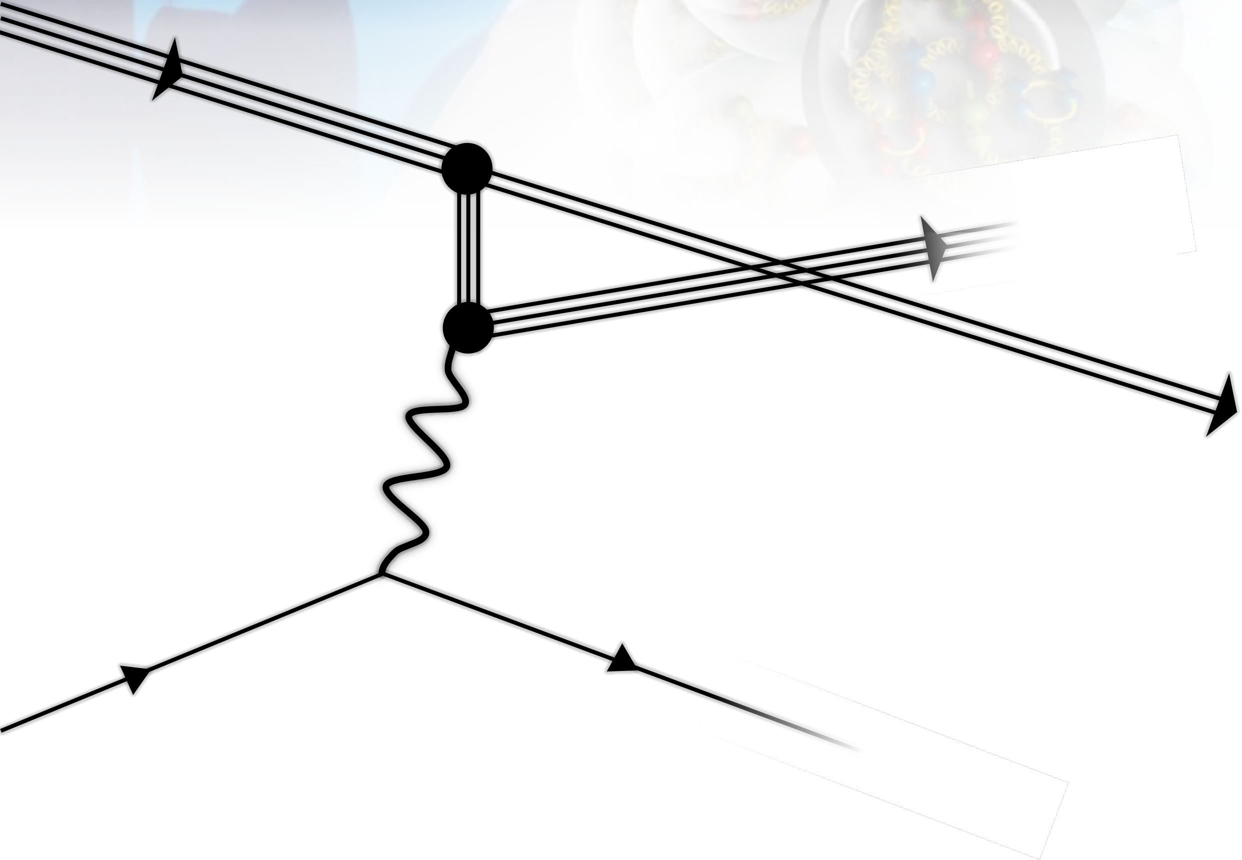
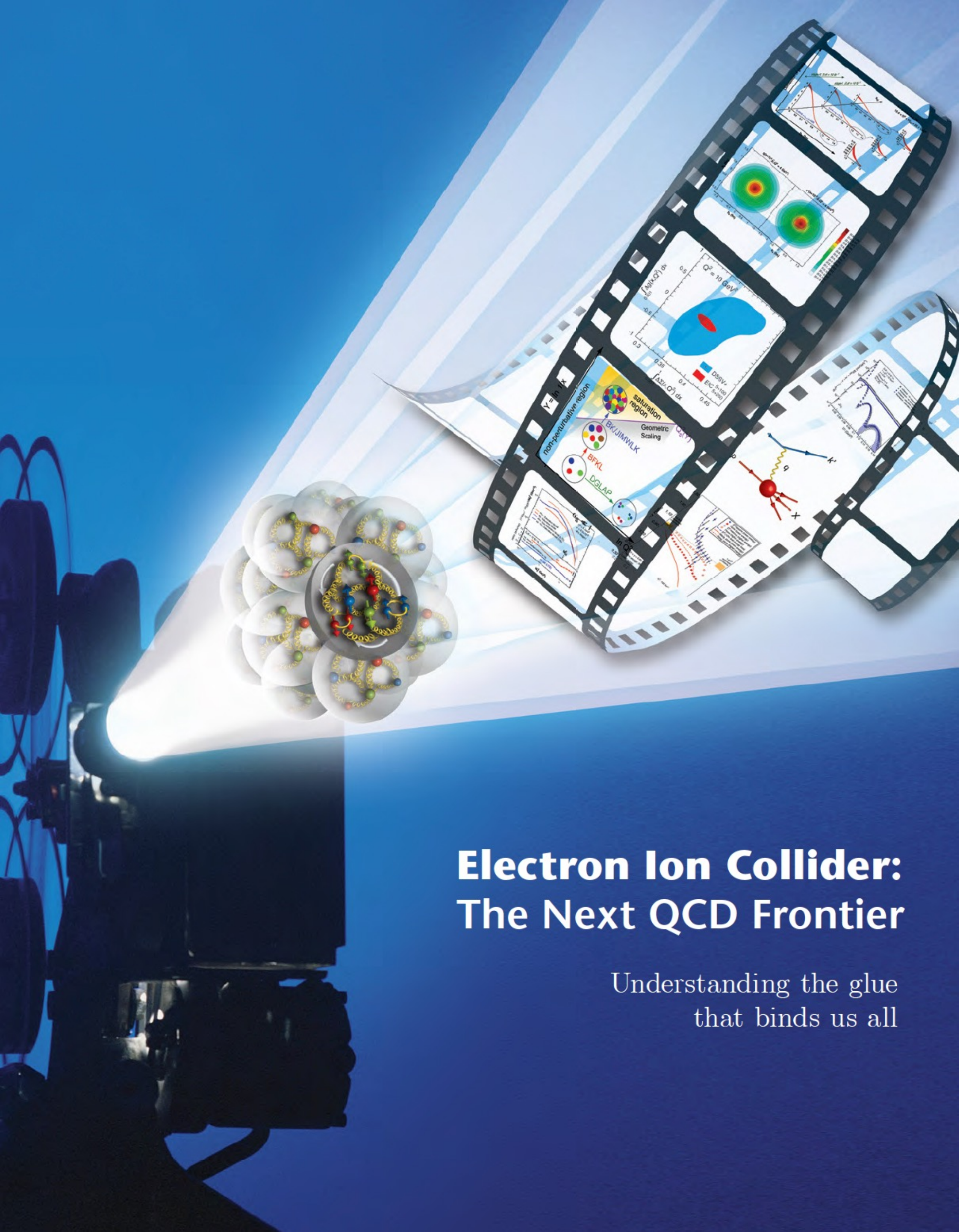


u-channel Physics at the EIC

Zachary Sweger
University of California, Davis

Supported in part by



Nuclear Imaging

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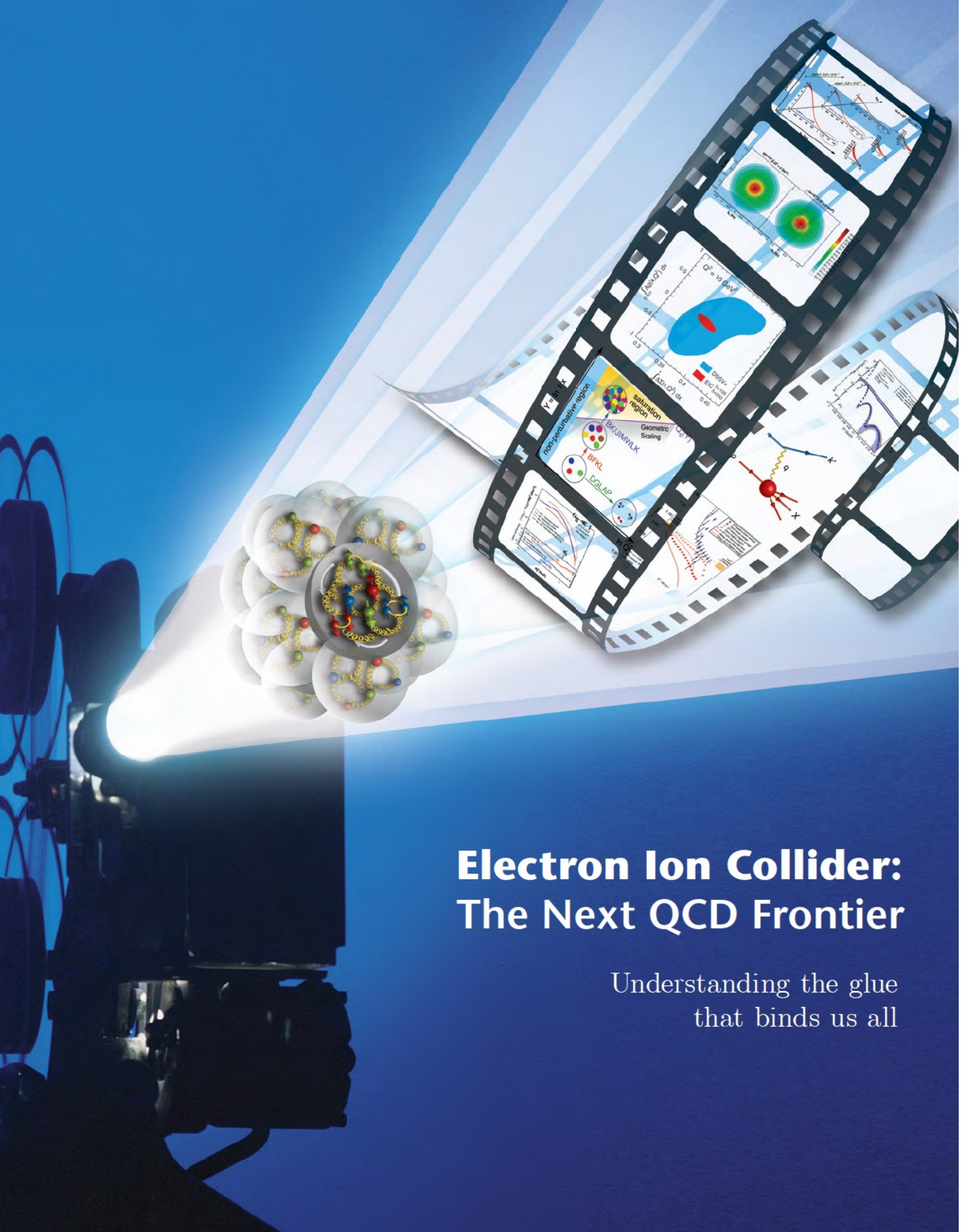

Nuclear Imaging

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- EIC will be a precision nuclear imaging machine

Nuclear Imaging

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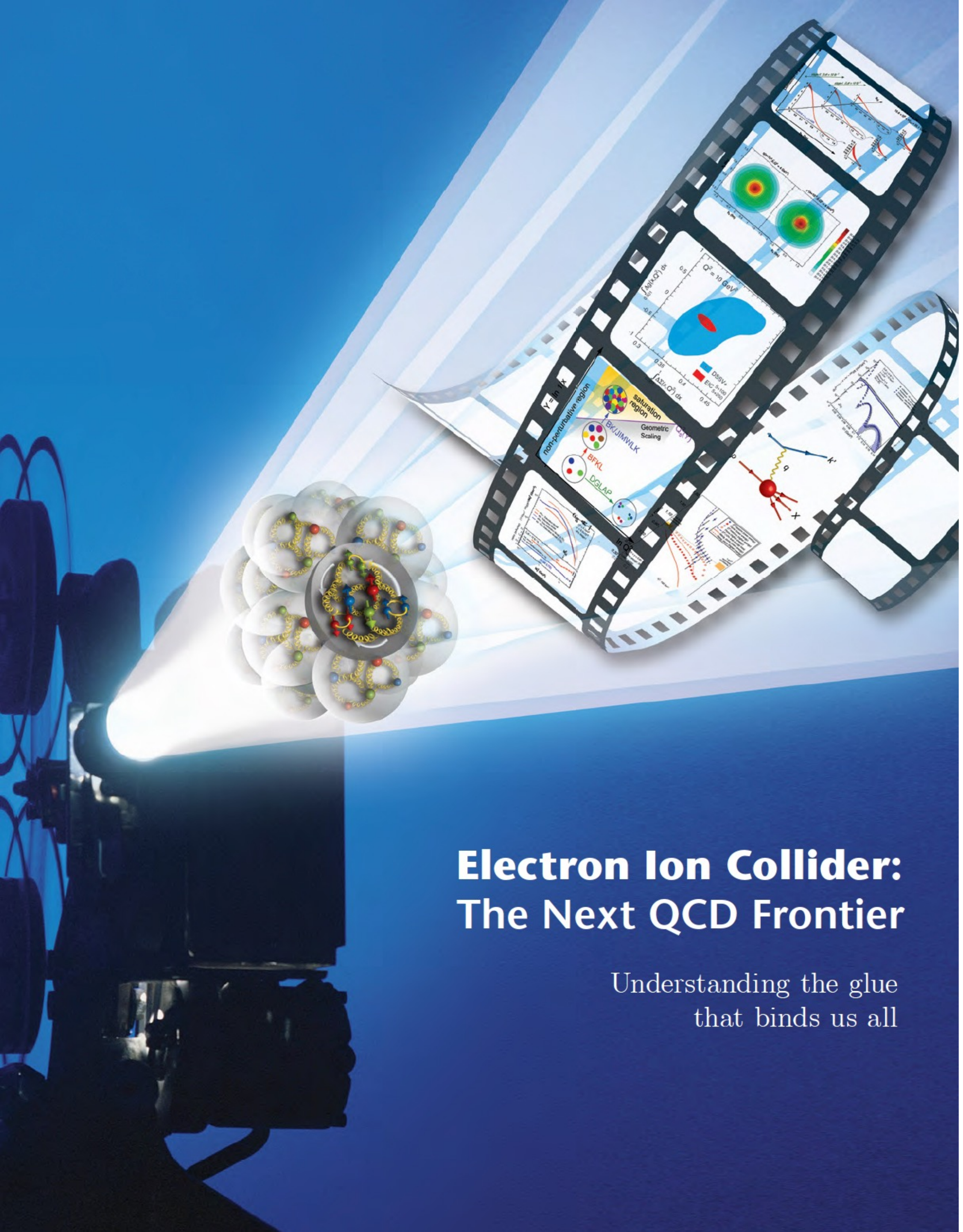

- EIC will be a precision nuclear imaging machine
- Meson production + DVCS golden channels for tomography

Nuclear Imaging

- EIC will be a precision nuclear imaging machine
- Meson production + DVCS golden channels for tomography

Tomography at the EIC

Nuclear Imaging

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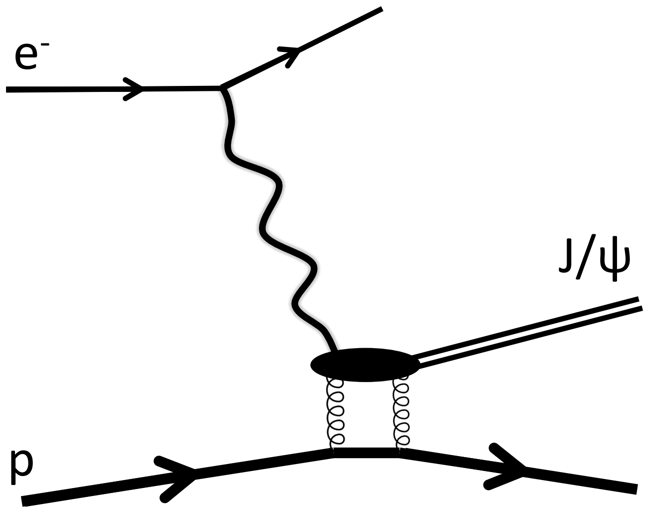
- Meson production + DVCS golden channels for tomography

Tomography at the EIC

Scattering/production



Nuclear Imaging

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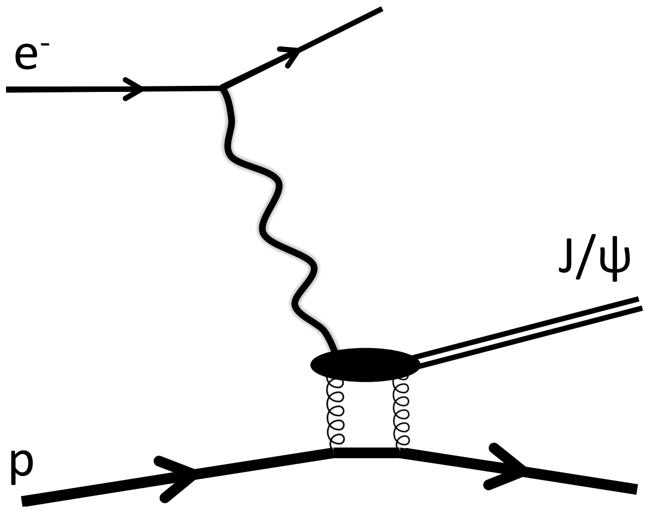
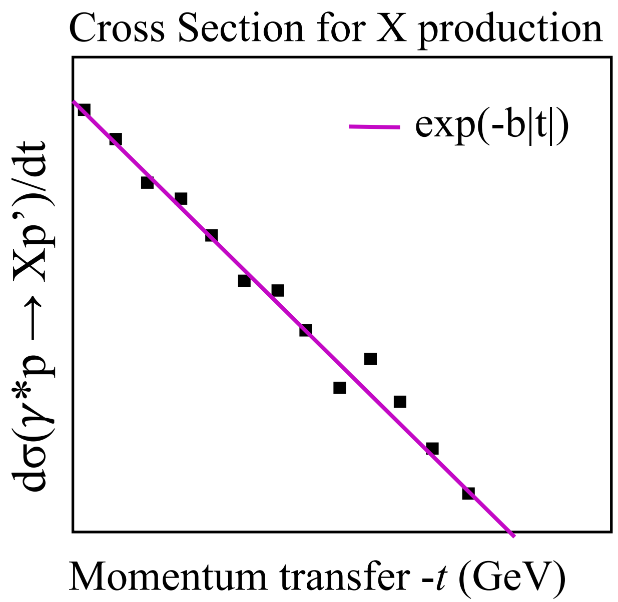
Tomography at the EIC

Scattering/production



Cross section measurement



Nuclear Imaging

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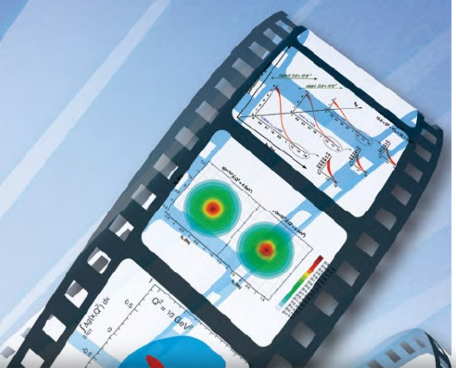

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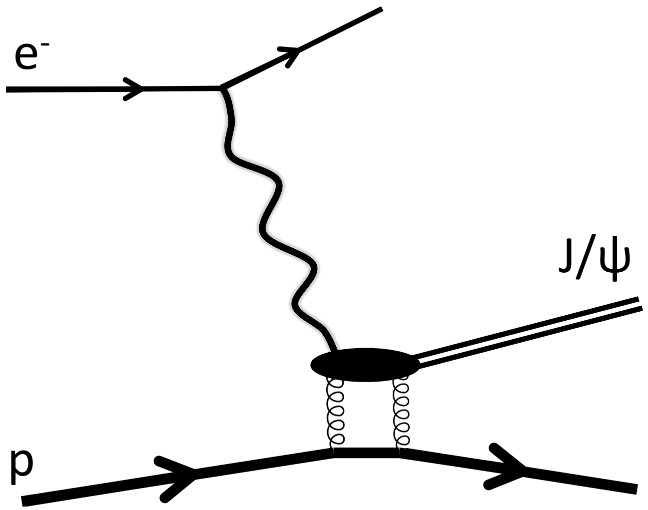
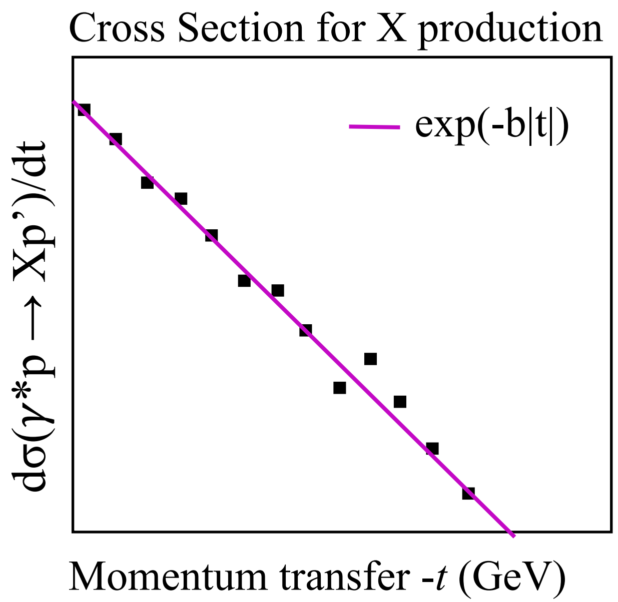
Tomography at the EIC

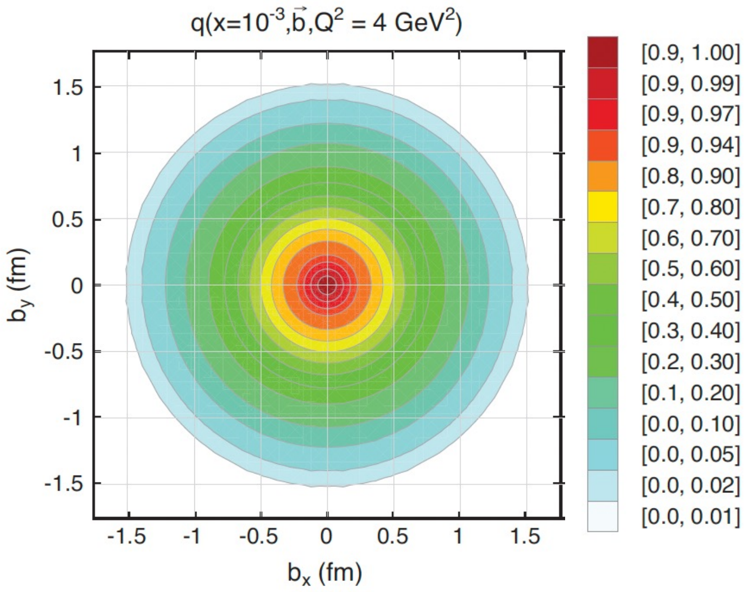
Scattering/production



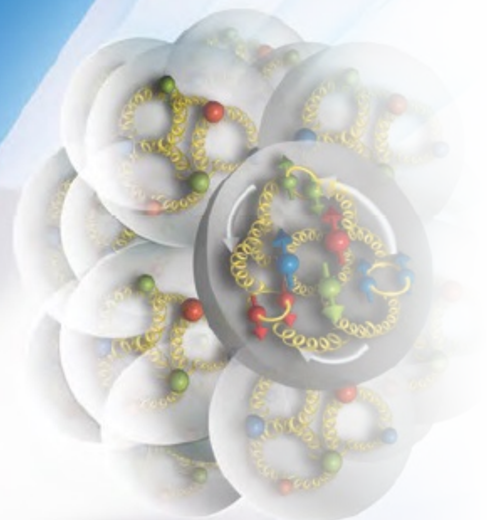
Cross section measurement

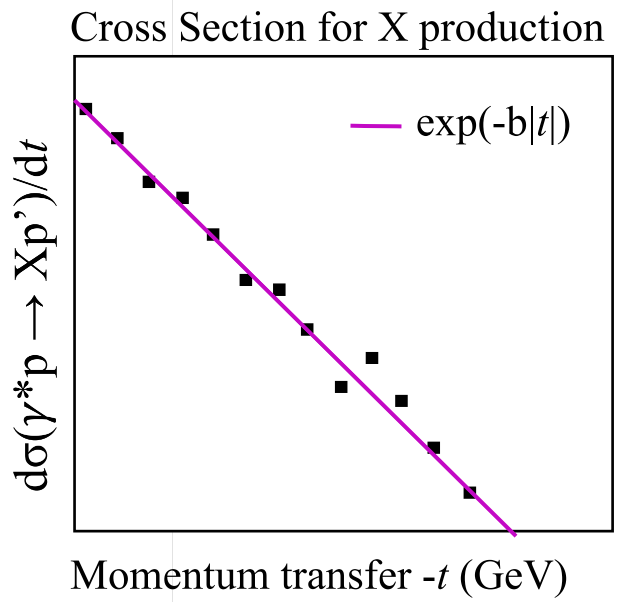


Parton density in transverse plane



Backward (u-channel) Production





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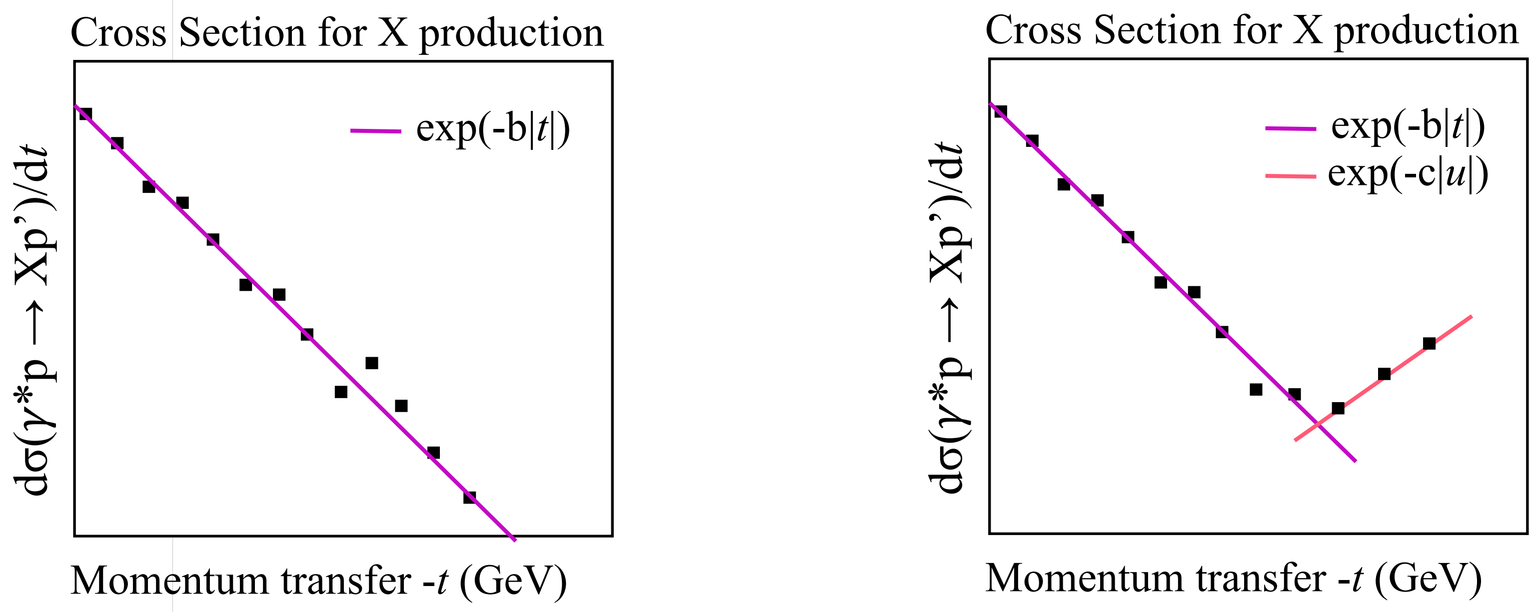
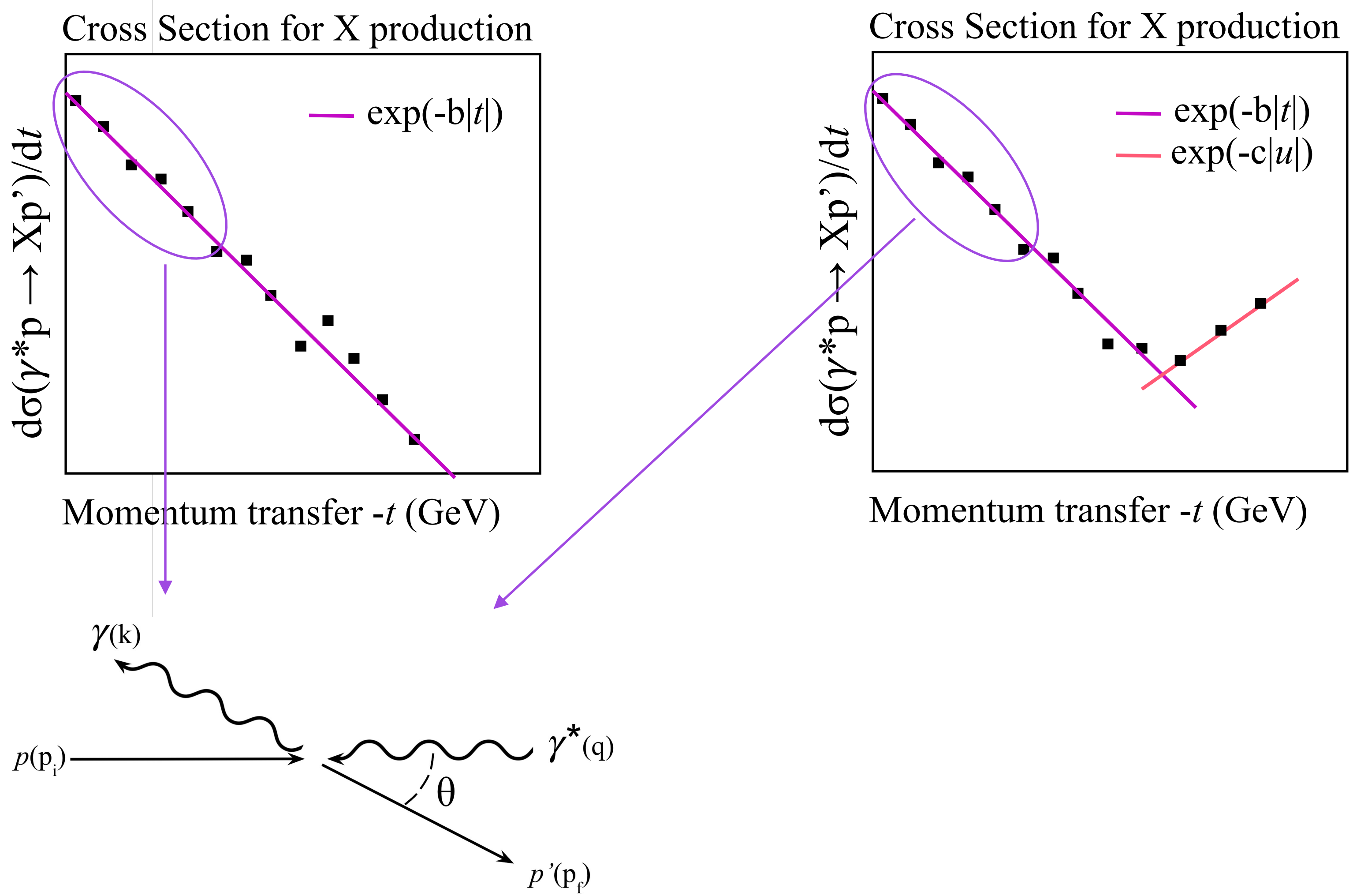
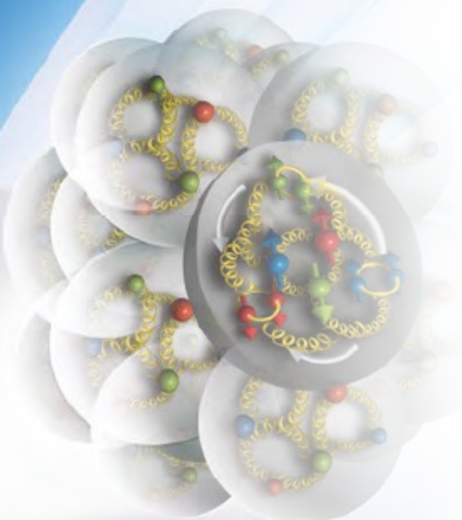


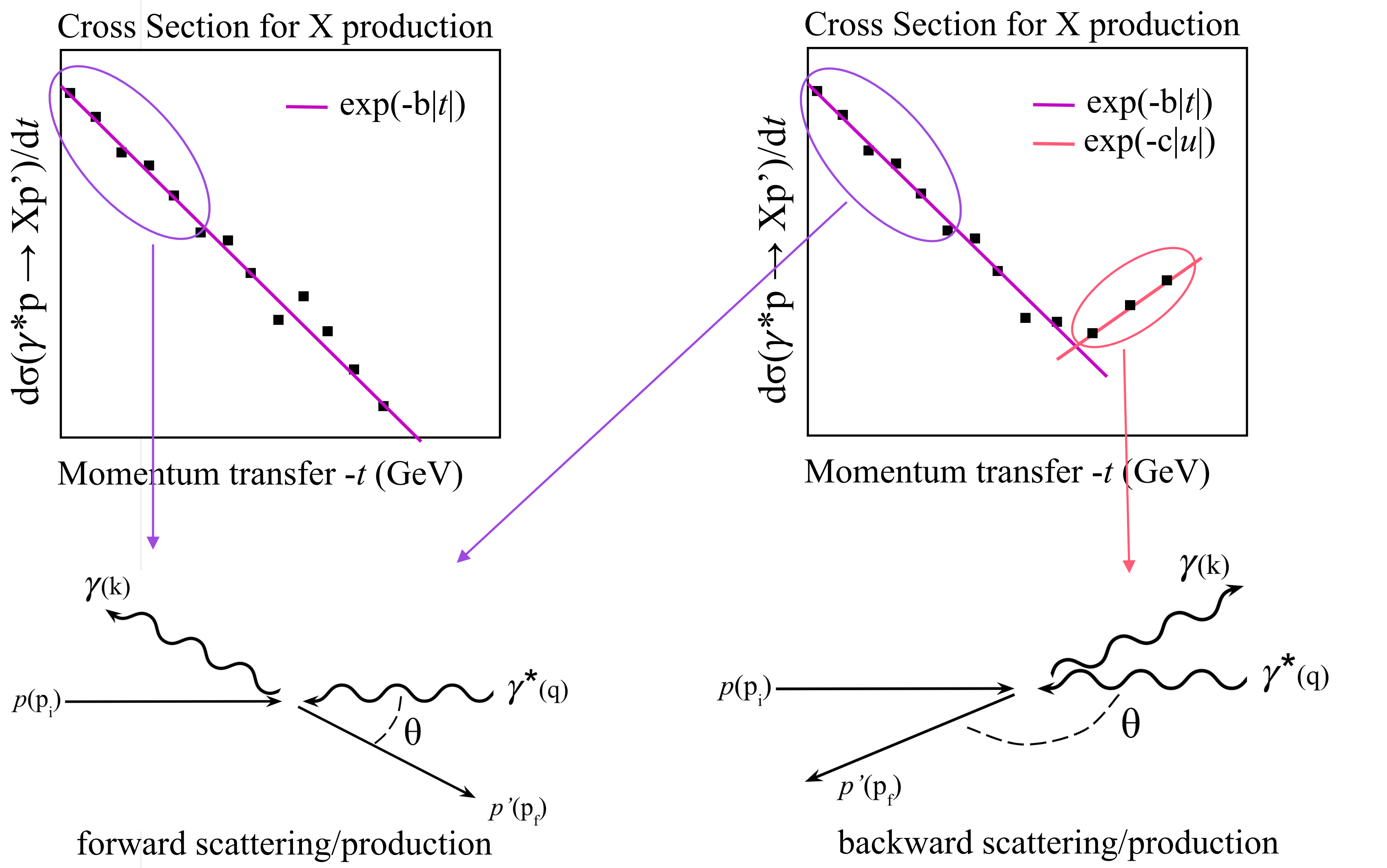
Backward (*u*-channel) Production



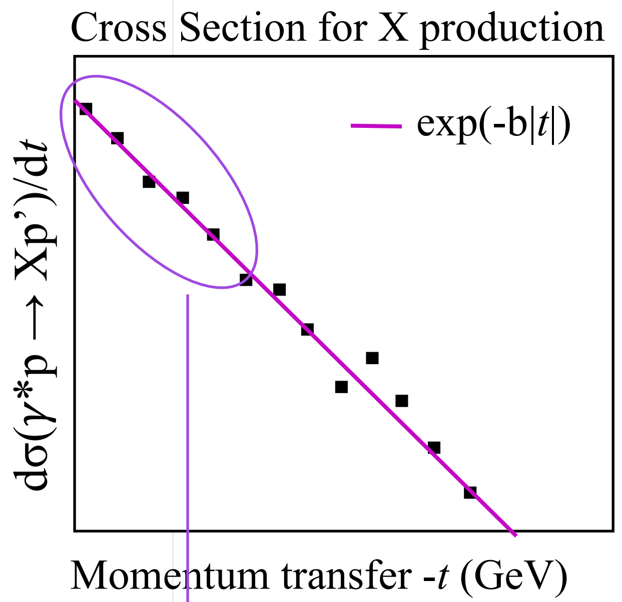
forward scattering/production

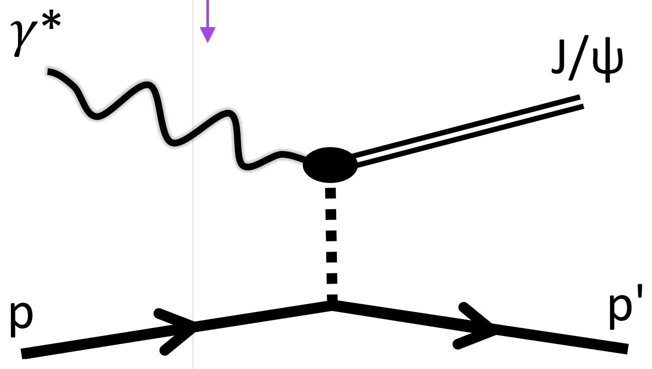
Backward (*u*-channel) Production



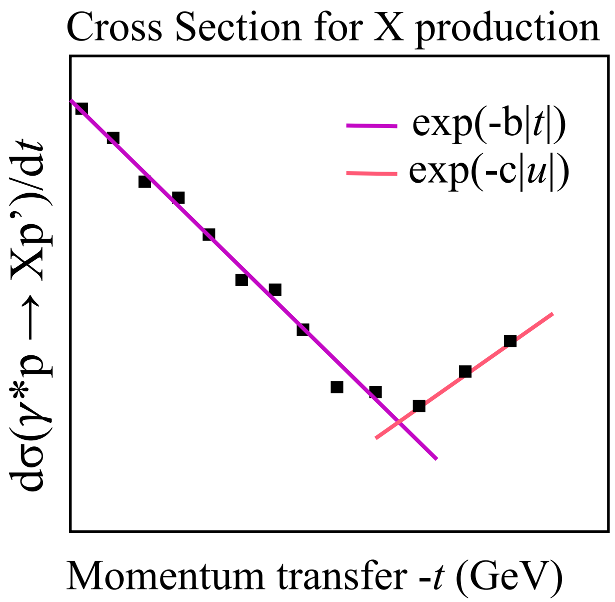


Backward (*u*-channel) Production

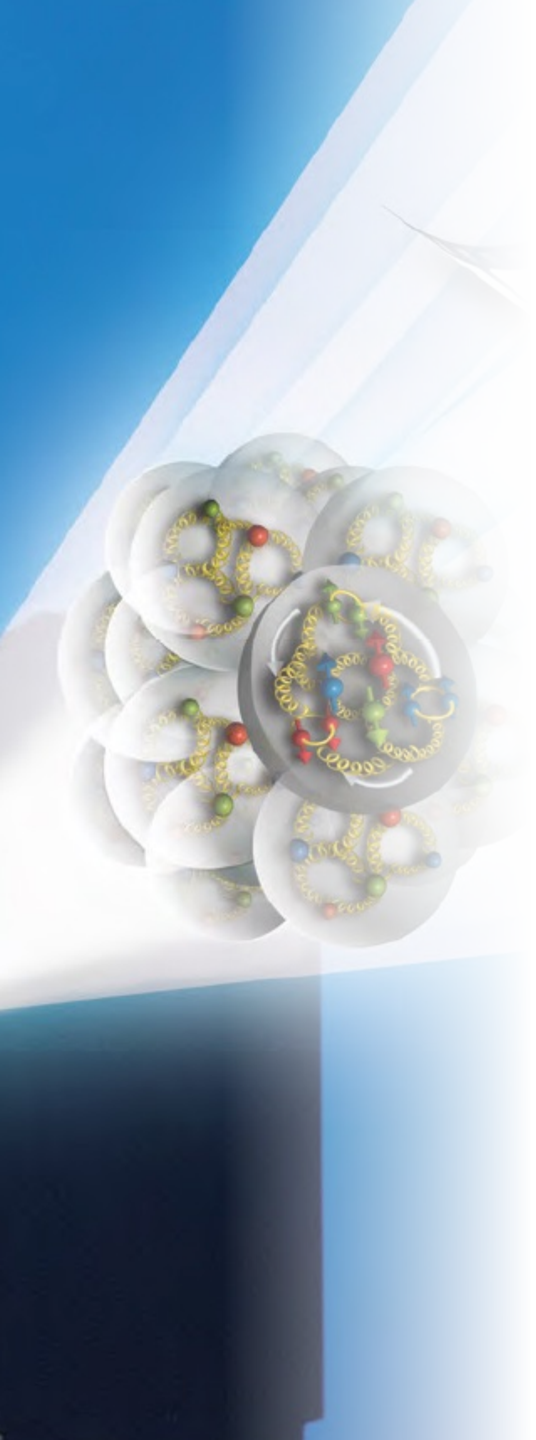


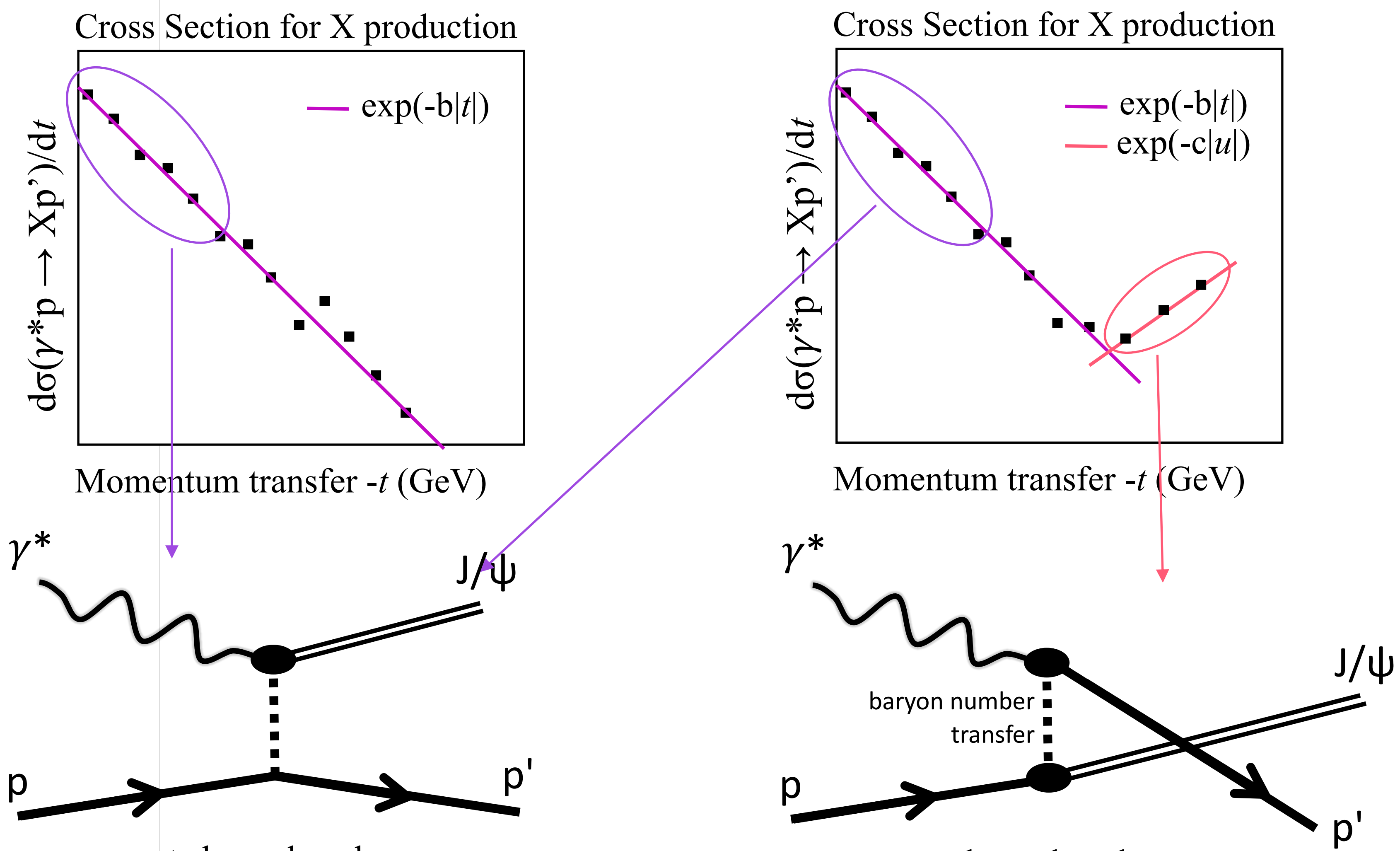


t-channel exchange



Backward (u-channel) Production





t-channel exchange

u-channel exchange

Backward (*u*-channel) Theory

Backward DVCS and Proton to Photon Transition Distribution Amplitudes

J.P. Lansberg* [ab], B. Pire[a], and L. Szymanowski [bcd]

Transition distribution amplitudes and hard exclusive reactions with baryon number transfer

B. Pire [a], K. Semenov-Tian-Shansky [b,c,*], L. Szymanowski [d]
[a] CPHT, CNRS, Ecole Polytechnique, IP Paris, 91128 Palaiseau, France

PHYSICAL REVIEW D **82,** 094030 (2010)

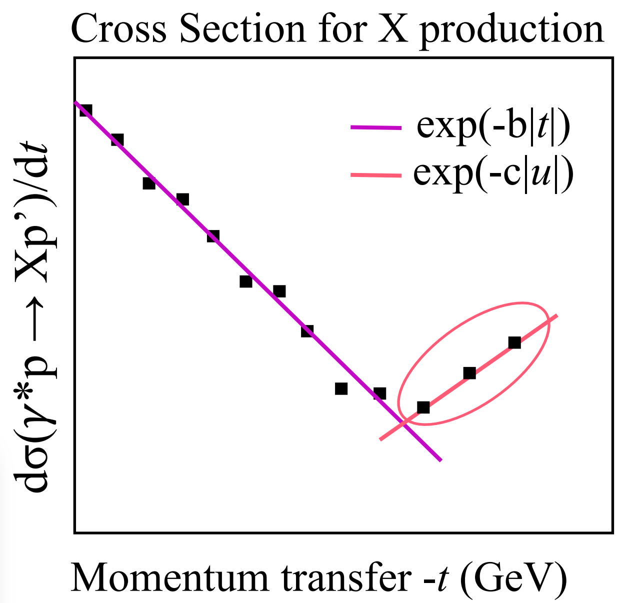
Spectral representation for baryon to meson transition distribution amplitudes

B. Pire,[1] K. Semenov-Tian-Shansky,[1,2] and L. Szymanowski[3]

Progress and Opportunities in Backward angle (*u*-channel) Physics

C. Ayerbe Gayoso[1], Ł. Bibrzycki[2], S. Diehl[3,4], S. Heppelmann[5], D.W. Higinbotham[6], G.M. Huber[7], S.J.D. Kay[7], S.R. Klein[8], J.M. Laget[6], W.B. Li[a,9,6], V. Mathieu[10,11], K. Park[12], R.J. Perry[13], B. Pire[14], K. Semenov-Tian-Shansky[15,16], A. Stanek[8], J.R. Stevens[9], L. Szymanowski[17], C. Weiss[6], B.-G. Yu[18]

[1]Mississippi State University, Starkville, MS 39762, USA
[2]Institute of Computer Science, Pedagogical University of Krakow, 30-084 Kraków, Poland



Backward (u-channel) Theory

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- Forward cross sections (through GPDs) parameterize parton distributions in transverse plane

Backward (*u*-channel) Theory

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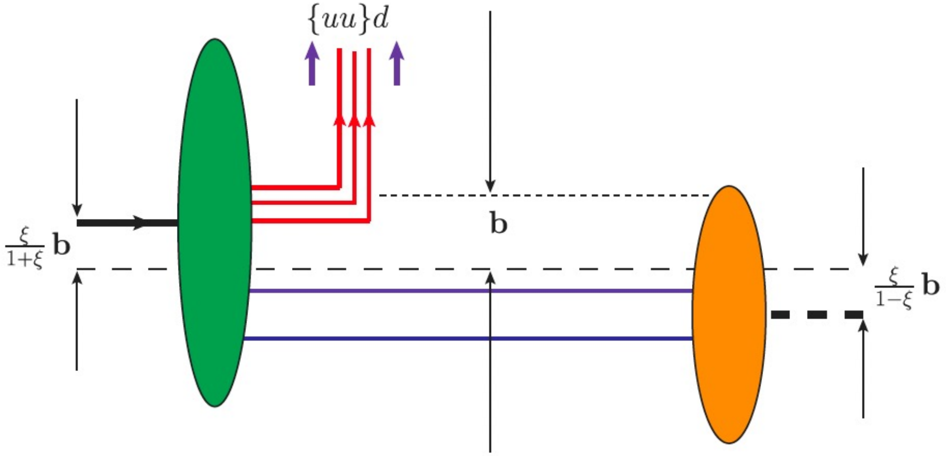

ERBL : $x_3 = w_3 - \xi \geq 0; \quad x_1 + x_2 = \xi - w_3 \geq 0;$

B. Pire, K. Semenov-Tian-Shansky, and L. Szymanowski, Phys. Rept. 940, 1 (2021), arXiv:2103.01079 [hep-ph].

- Forward cross sections (through GPDs) parameterize parton distributions in transverse plane
- Backward cross sections (through Transition Distribution Amplitudes – TDAs) parameterize quark clusters and baryon number distributions in the transverse plane

"baryon-to-meson (and baryon-to-photon) TDAs share common features both with baryon DAs and with GPDs and encode a conceptually close physical picture. They characterize partonic correlations inside a baryon and give access to the momentum distribution of the baryonic number inside a baryon. Similarly to GPDs, TDAs – after the Fourier transform in the transverse plane – represent valuable information on the transverse location of hadron constituents."

Backward (*u*-channel) Procedure

Backward Tomography at the EIC

Backward (u-channel) Procedure

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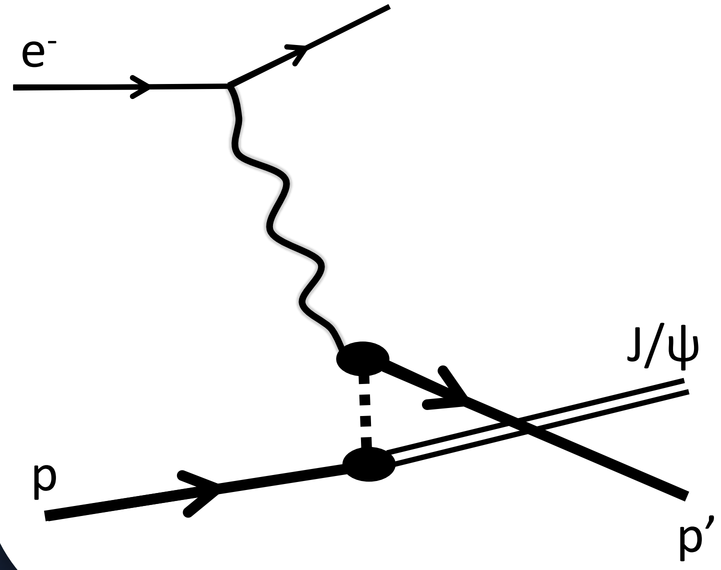
Backward Tomography at the EIC

Backward scattering/production



Backward (*u*-channel) Procedure

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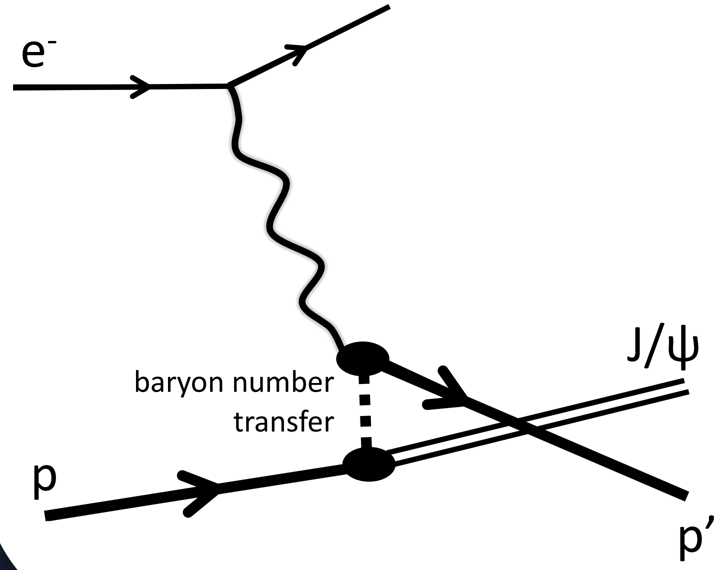

Backward (*u*-channel) Procedure

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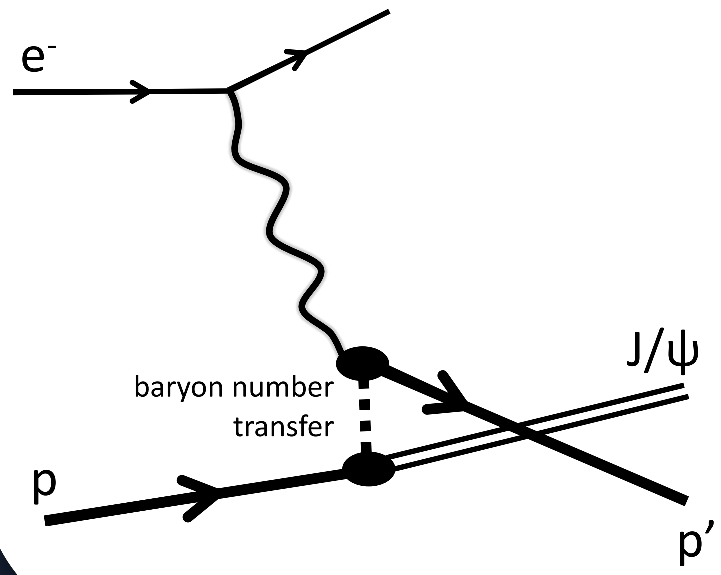
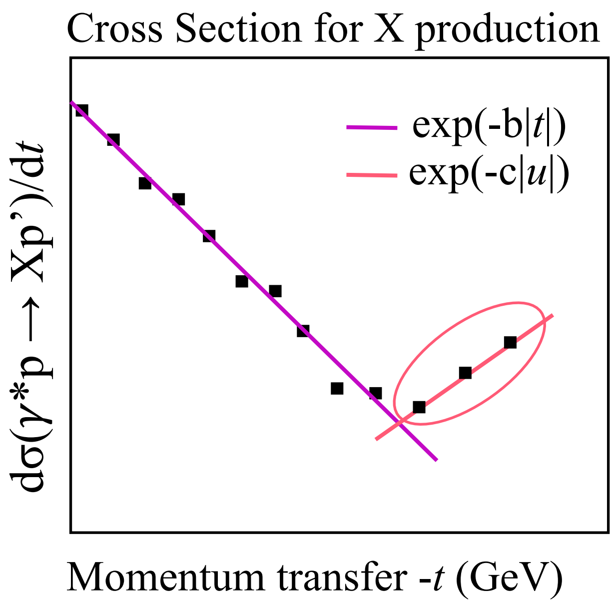


Cross section measurement



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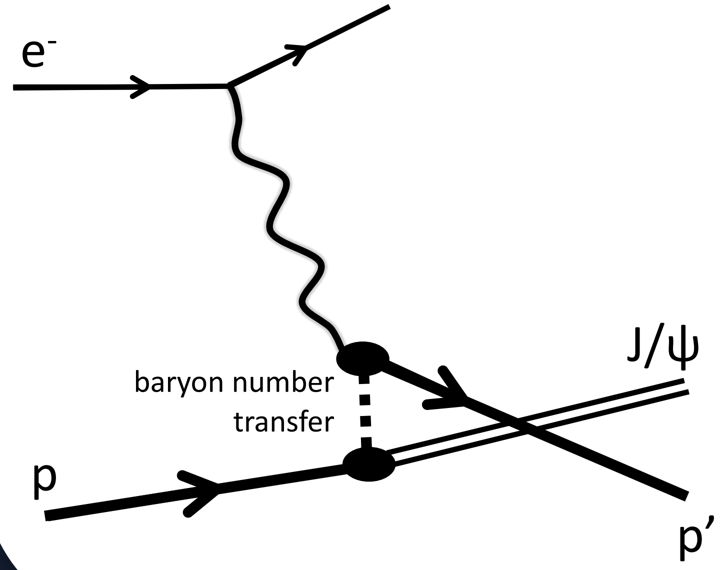
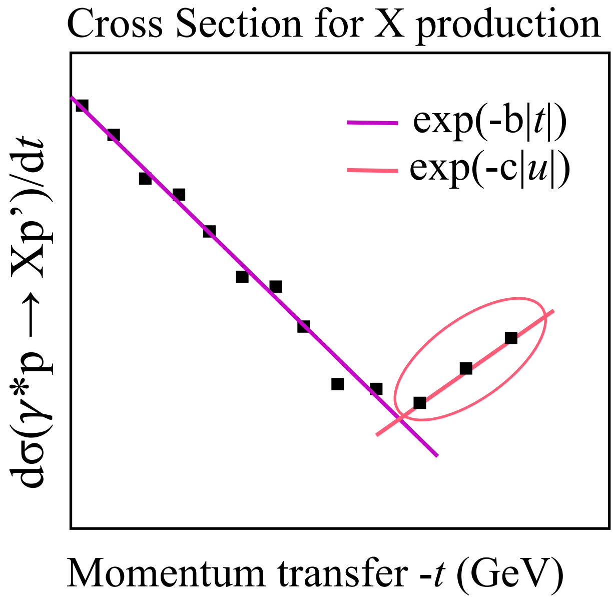
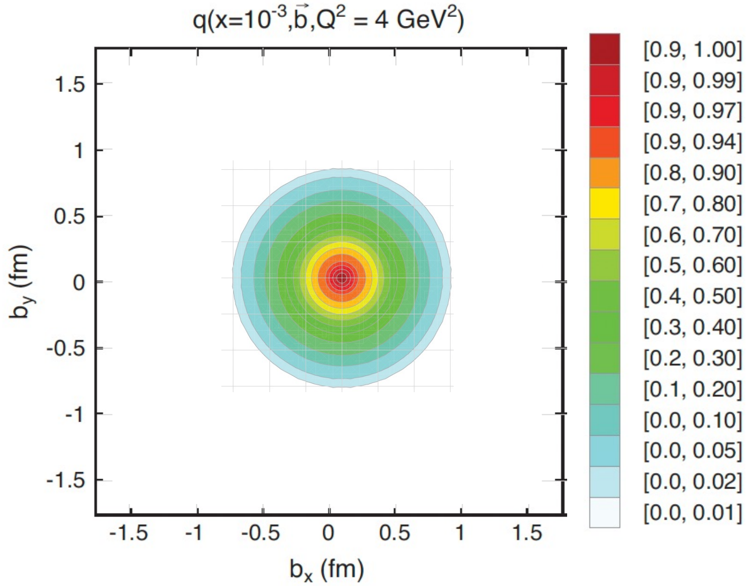
Backward scattering/production



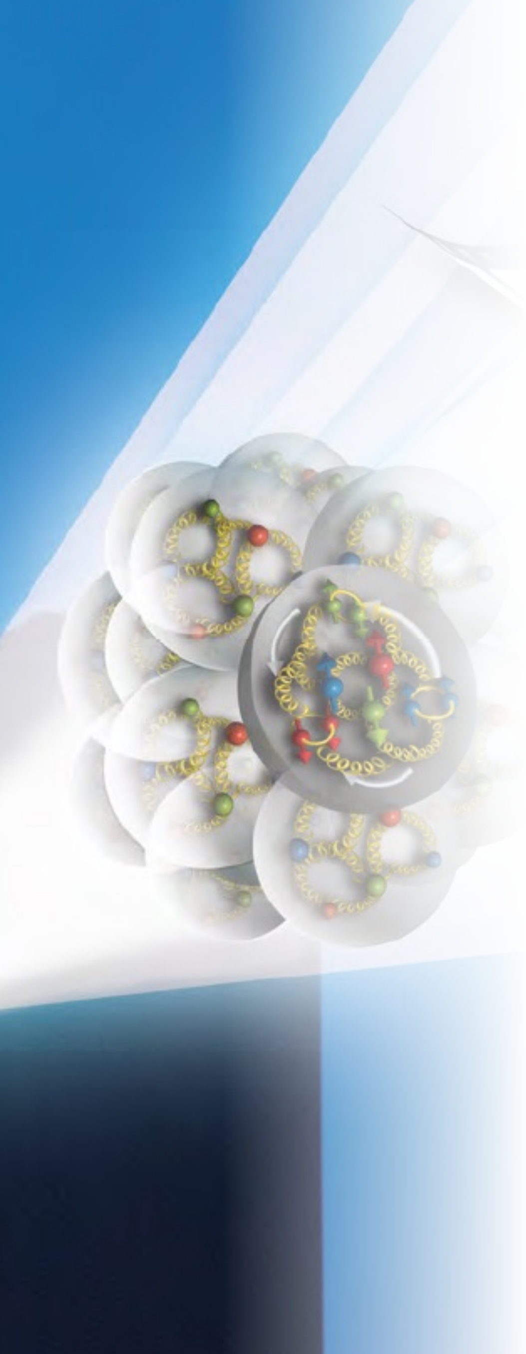
Cross section measurement



(Partonic correlations)/ (diquark clusters)/(baryon number) in transverse plane

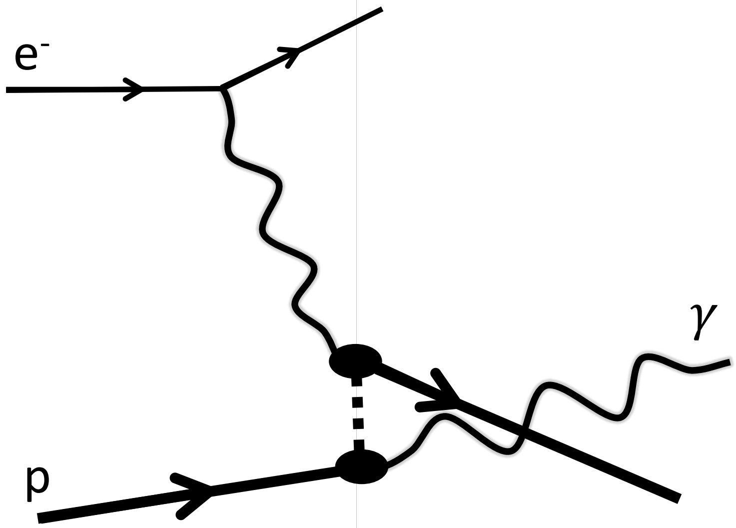


Backward (u-channel) Simulations



Backward (*u*-channel) Simulations

u-channel DVCS



Backward (*u*-channel) Simulations

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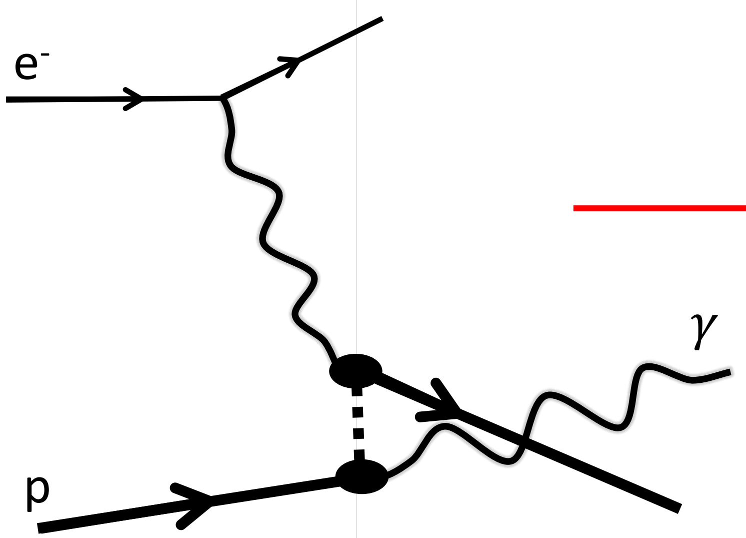
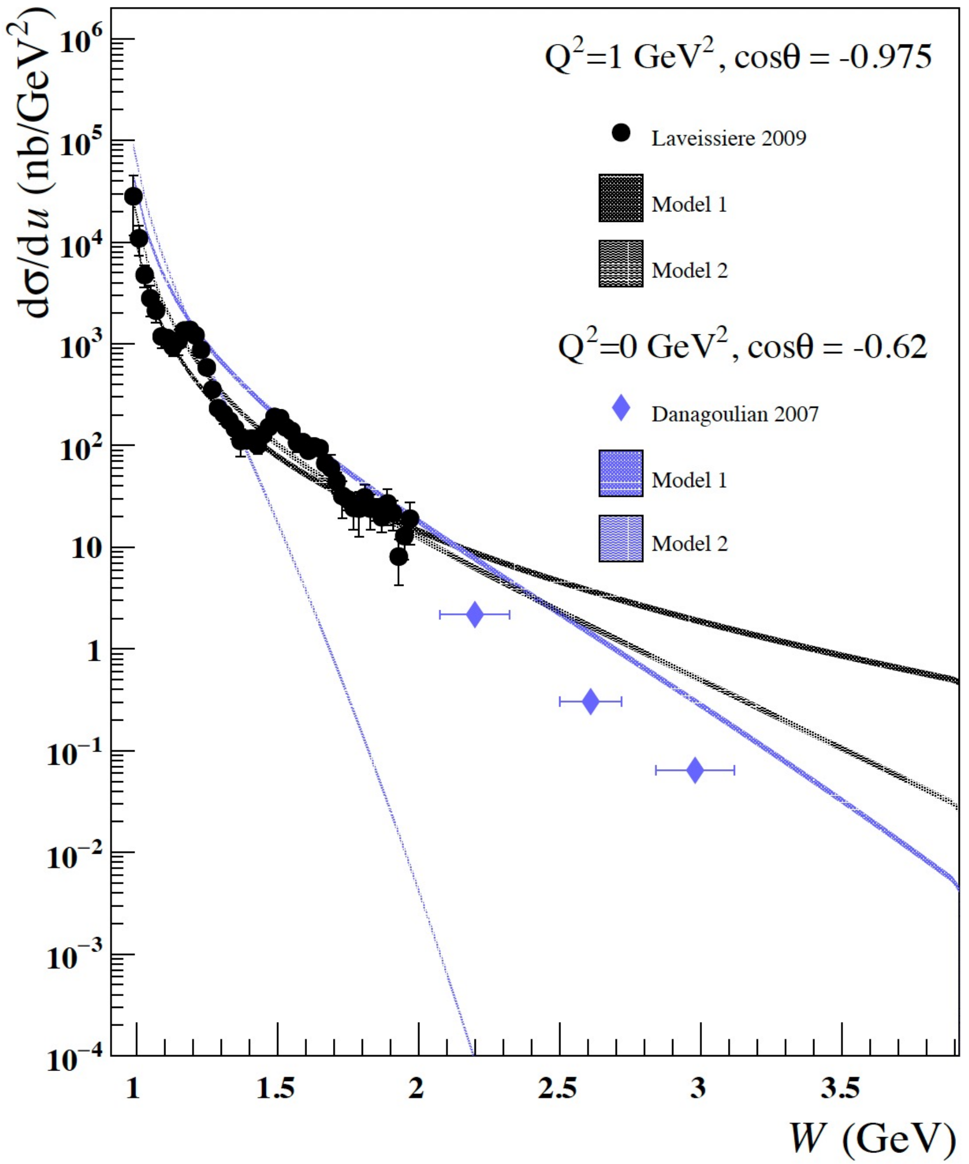
u-channel DVCS

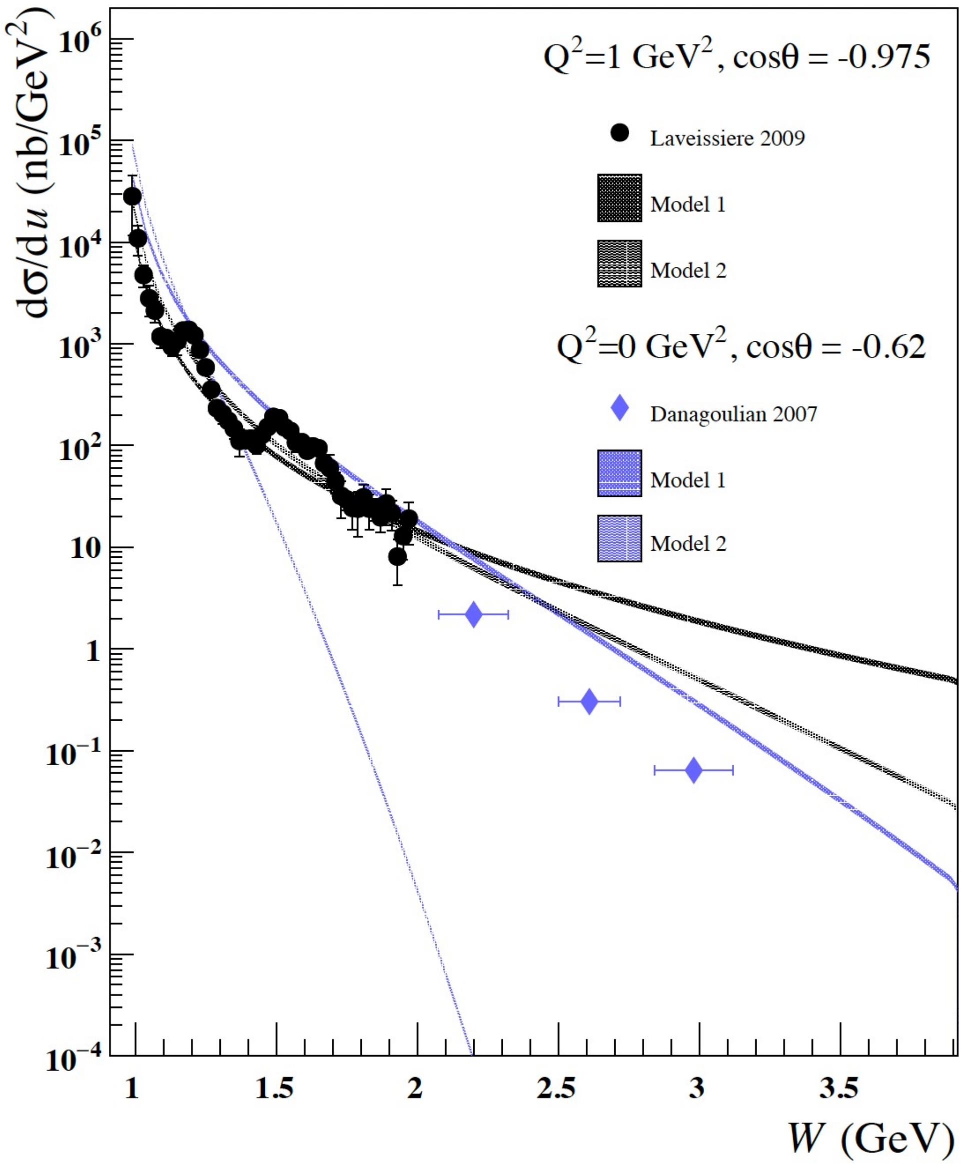


u-channel DVCS models



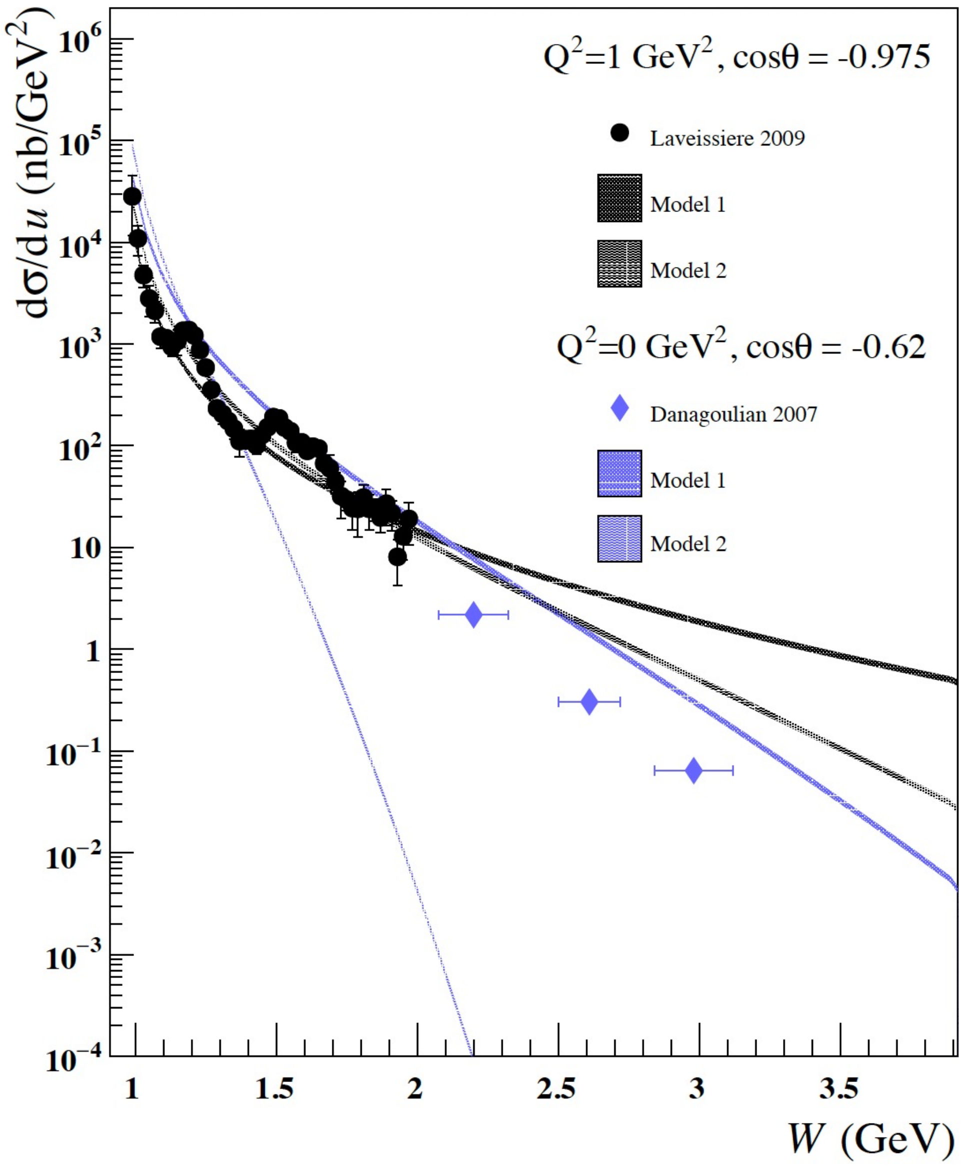
Backward (*u*-channel) Simulations

u-channel DVCS models

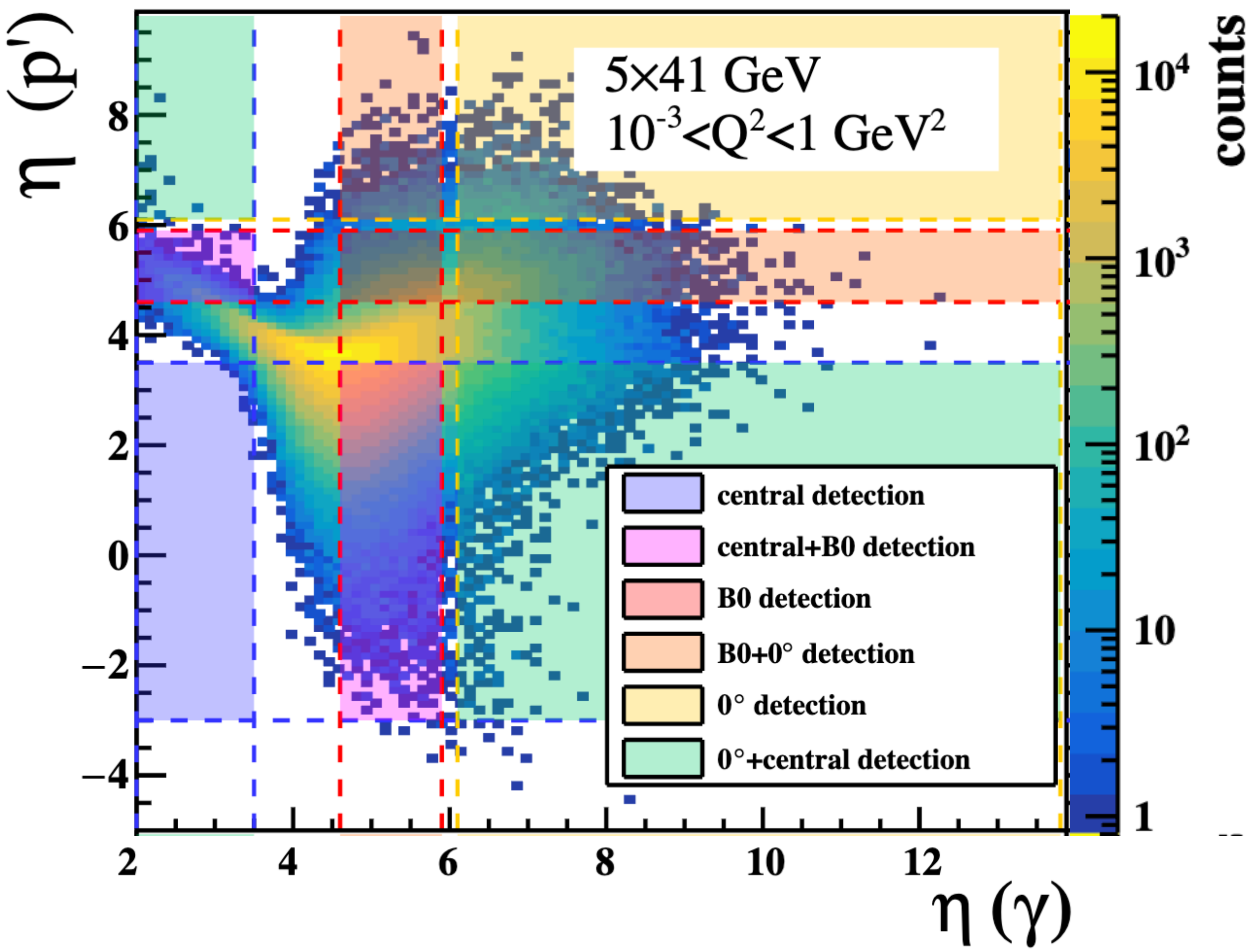


Backward (*u*-channel) Simulations

u-channel DVCS models

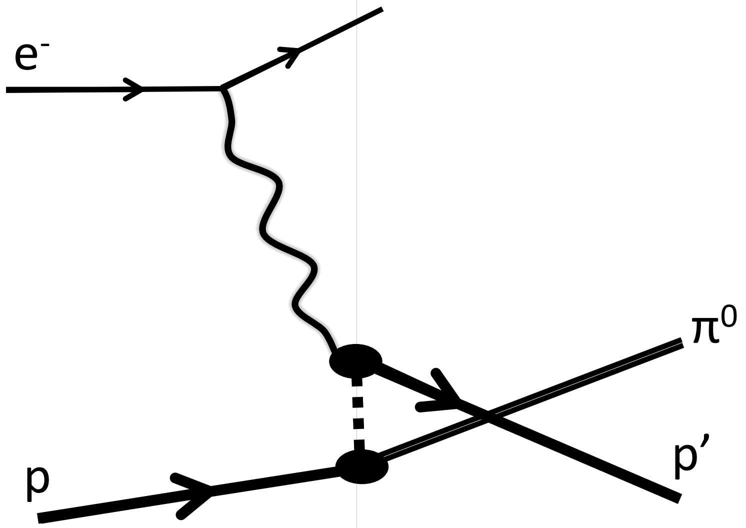


final-state particle kinematics (DVCS)



$\pi^0 \rightarrow \gamma\gamma$ Background Simulations

u-channel π^0 production



$\pi^0 \to \gamma\gamma$ Background Simulations

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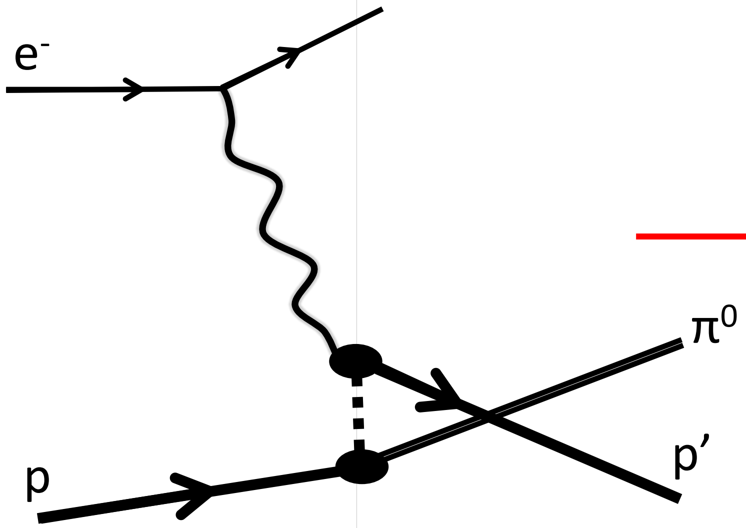
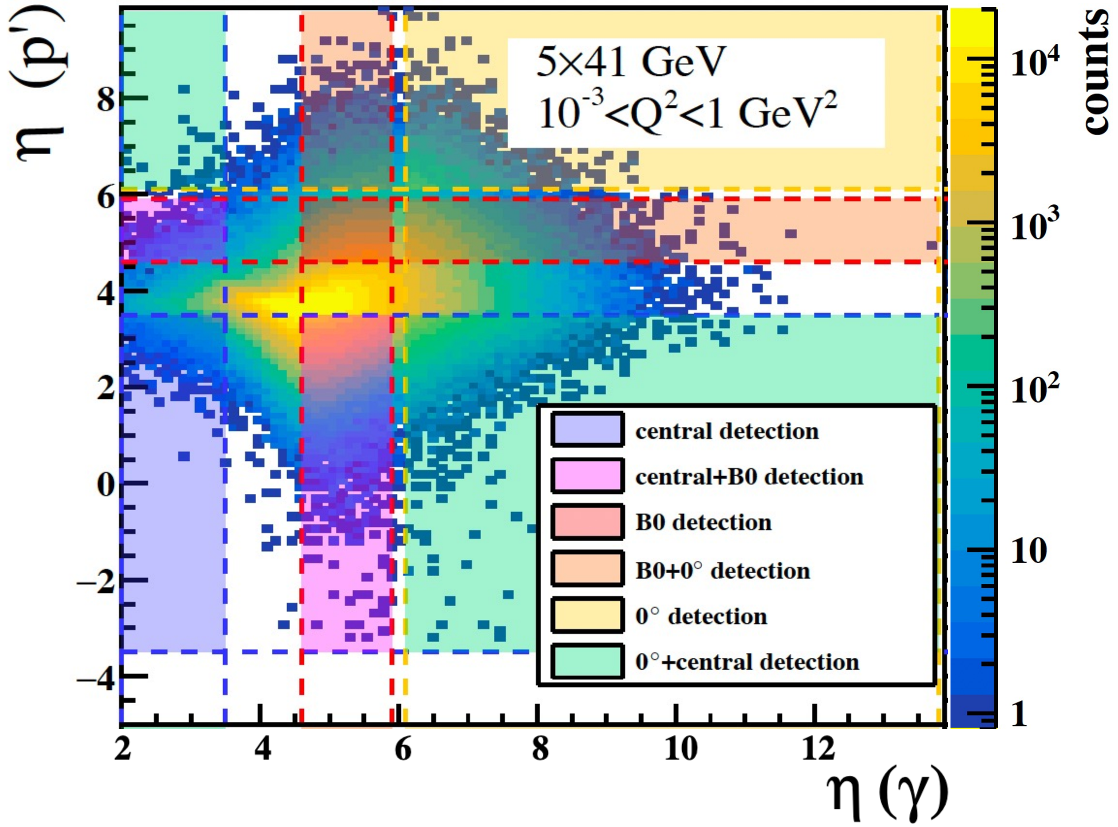
u-channel π^0 production



final-state particle kinematics (π^0)



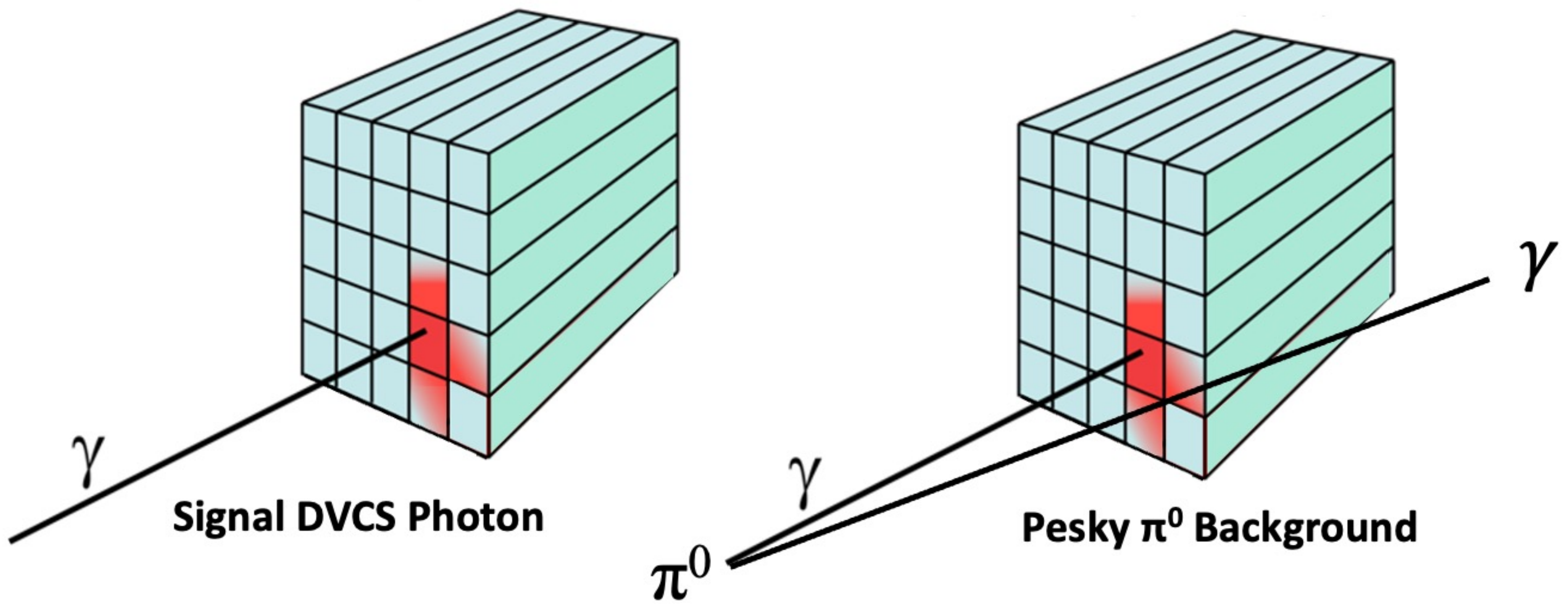
$\pi^0 \rightarrow \gamma\gamma$ Background Simulations

Conclusion from backward π^0 simulations:

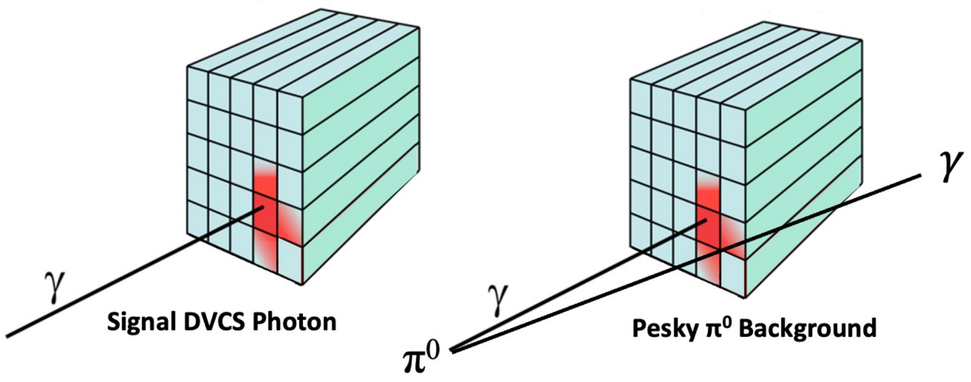
$\pi^0 \to \gamma\gamma$ Background Simulations

Conclusion from backward π^0 simulations:

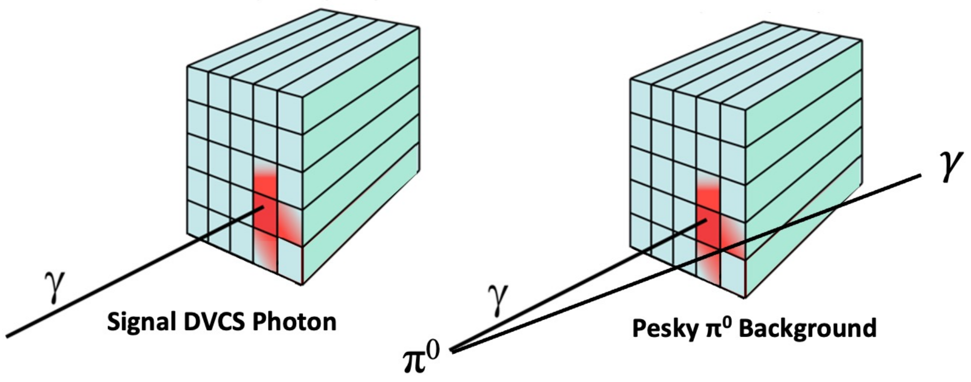
VCS background dominated by events in which one π^0 photon misses the ZDC, and the other carries majority of the energy



Reducing Background



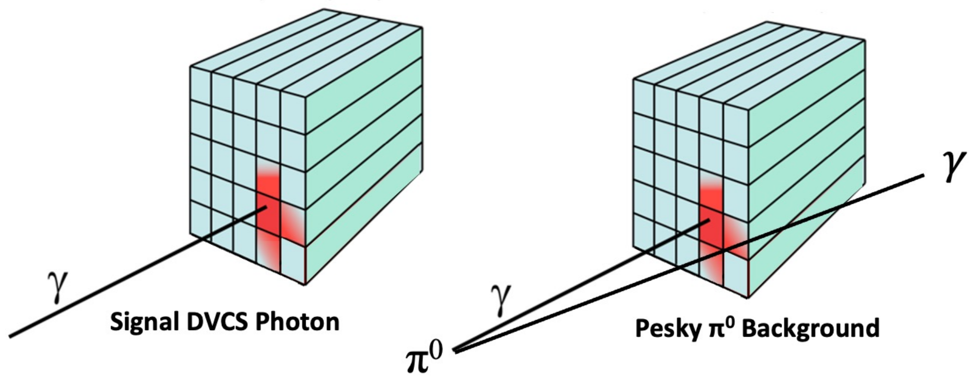
Reducing Background



apply ZDC reconstruction smearing

$$\Delta E/E \sim (2\% - 5\%)/\sqrt{E} \oplus 1\%$$

Reducing Background



apply ZDC reconstruction smearing

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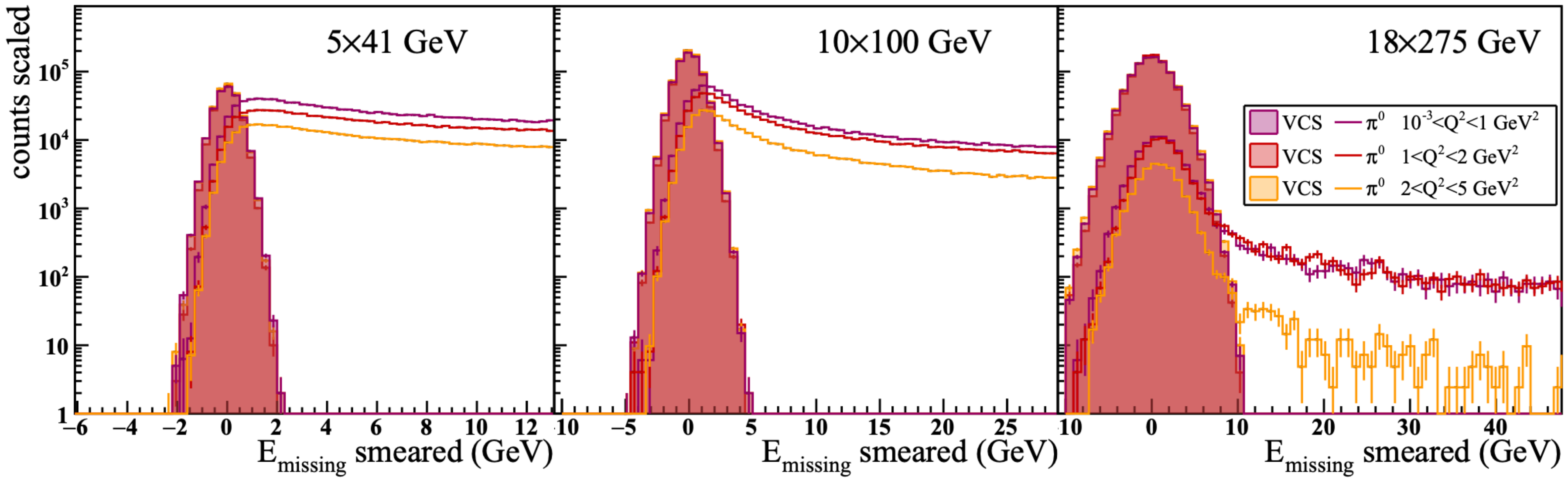

Reducing Background

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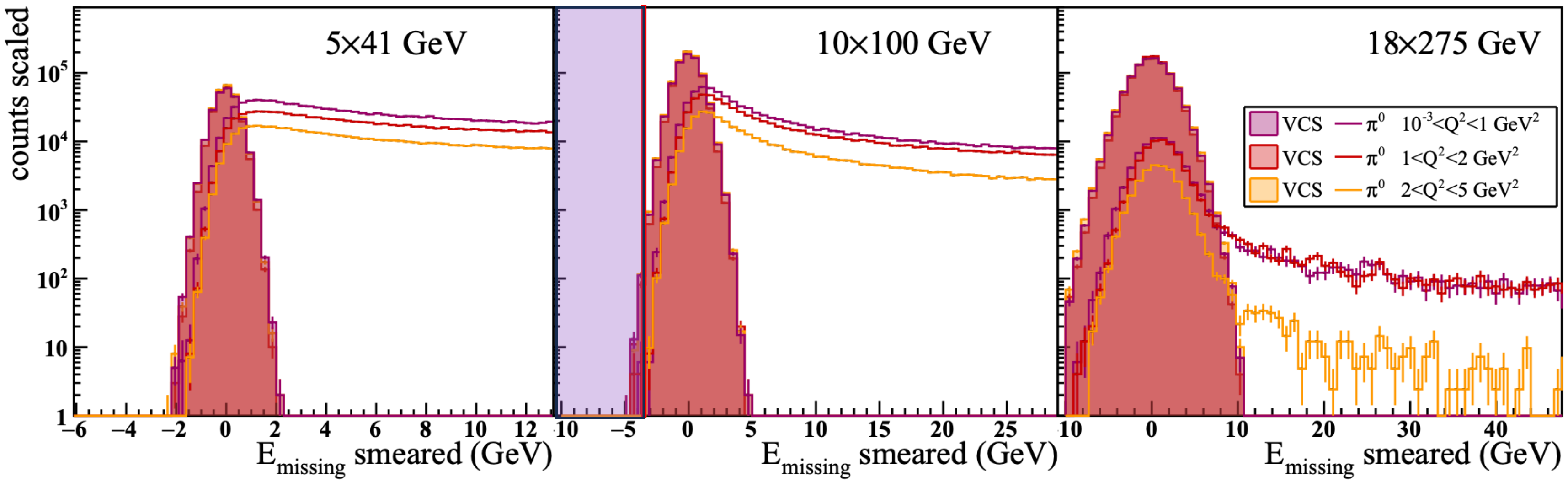
apply missing energy cuts



Reducing Background

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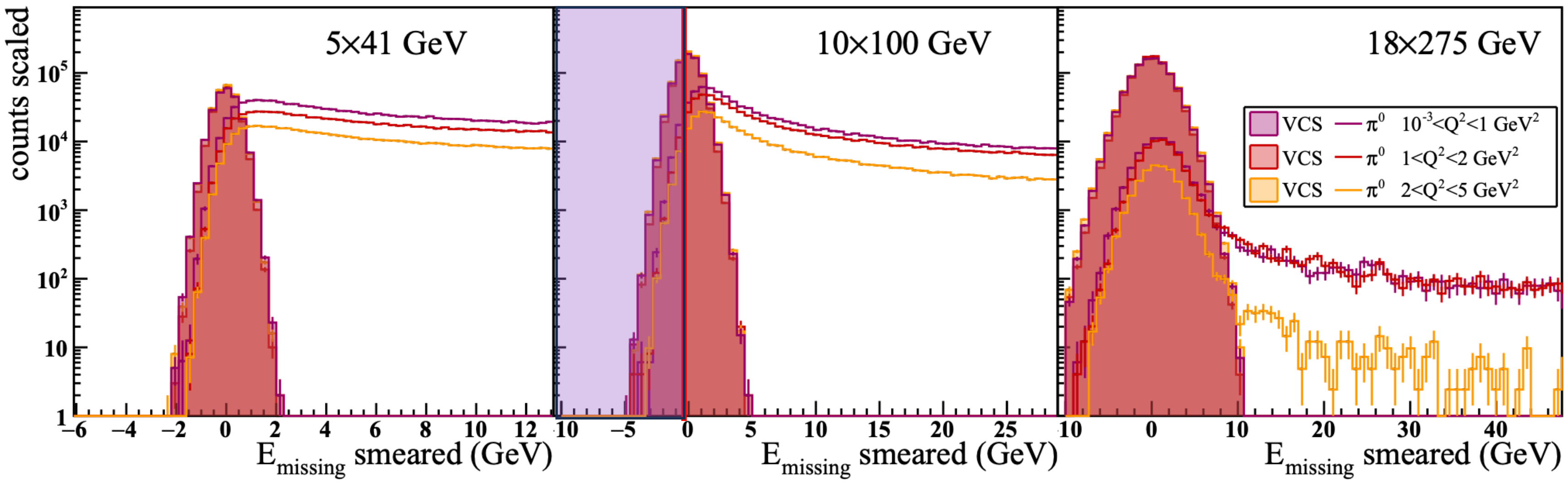
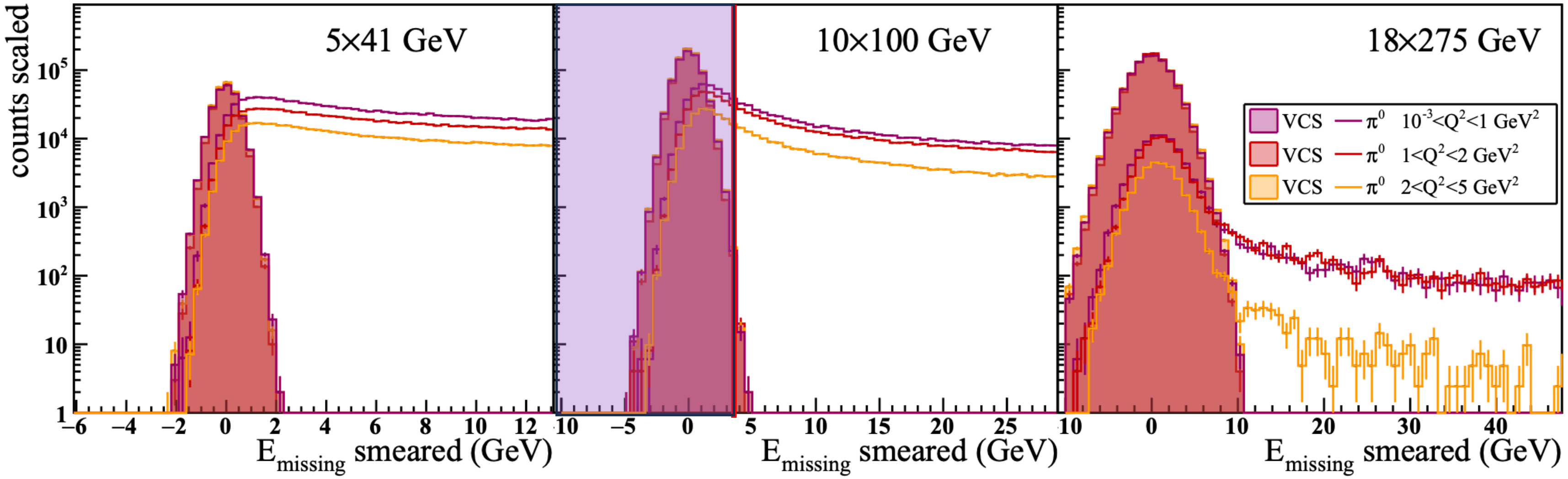
apply missing energy cuts



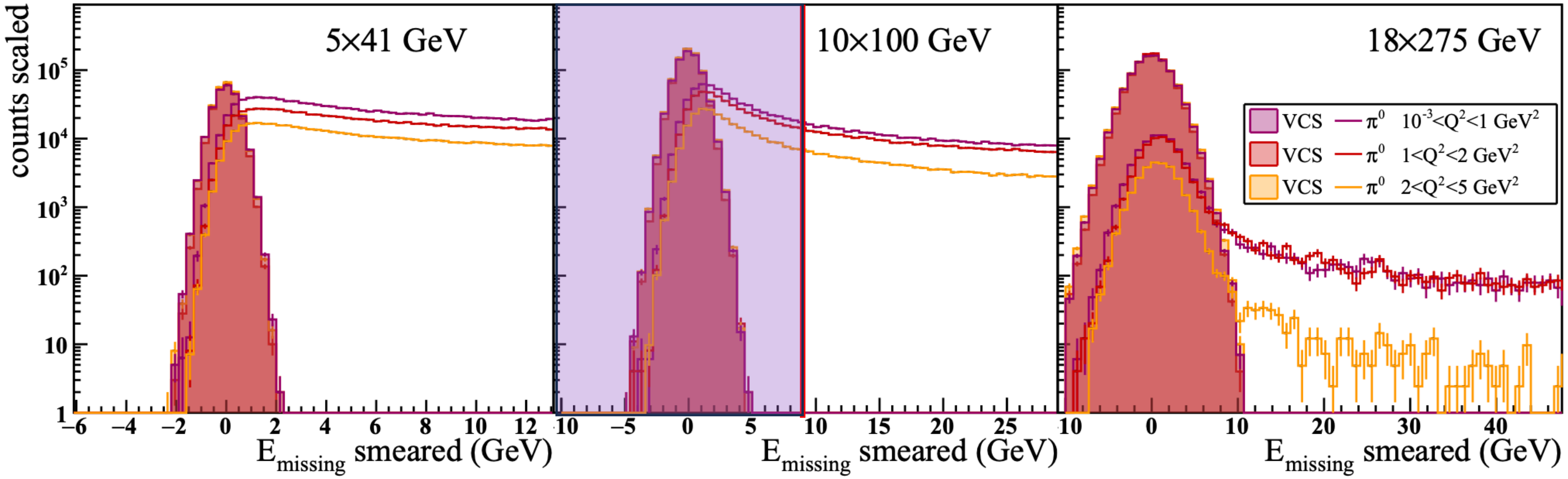
Reducing Background

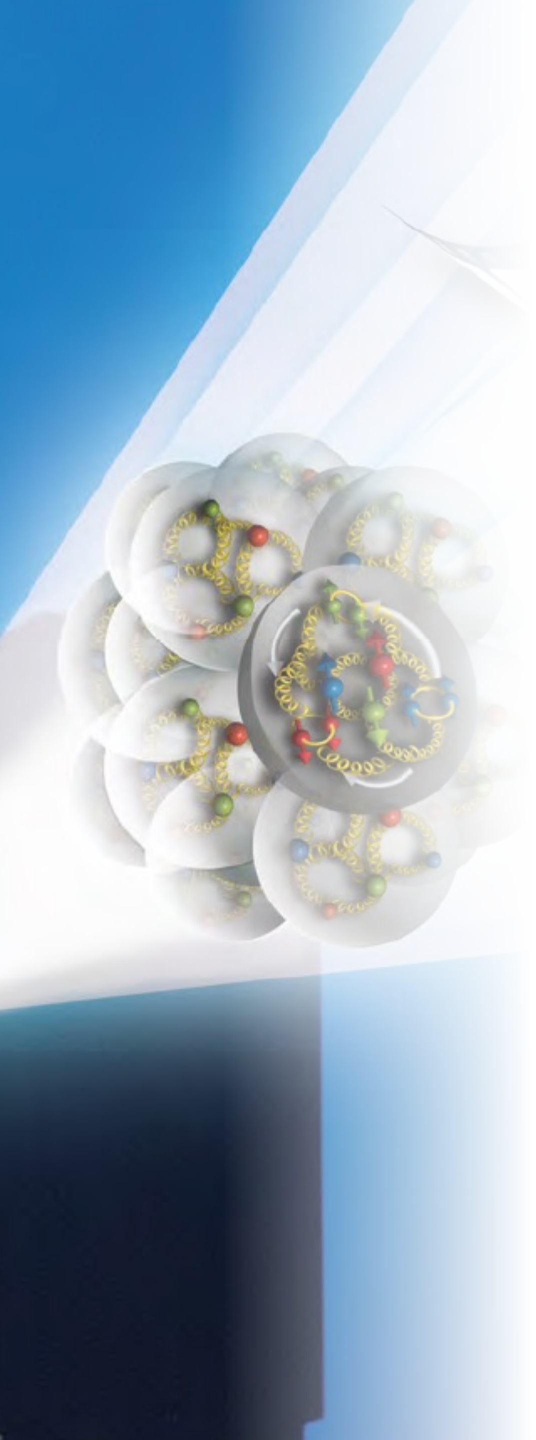
apply missing energy cuts



Reducing Background

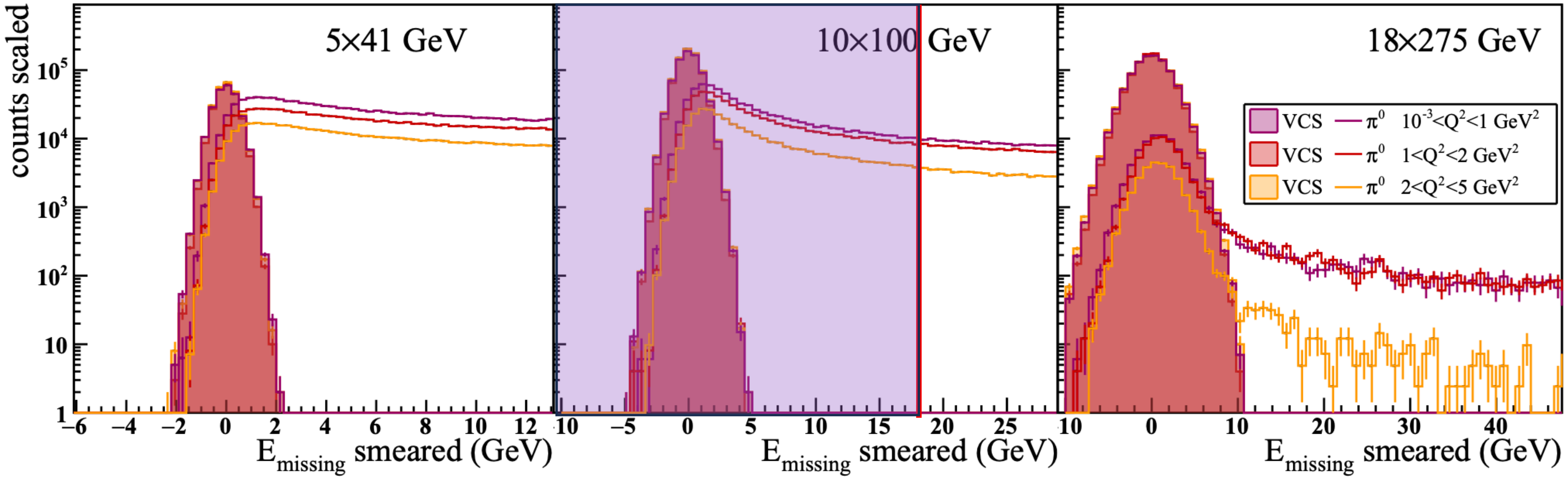
apply missing energy cuts



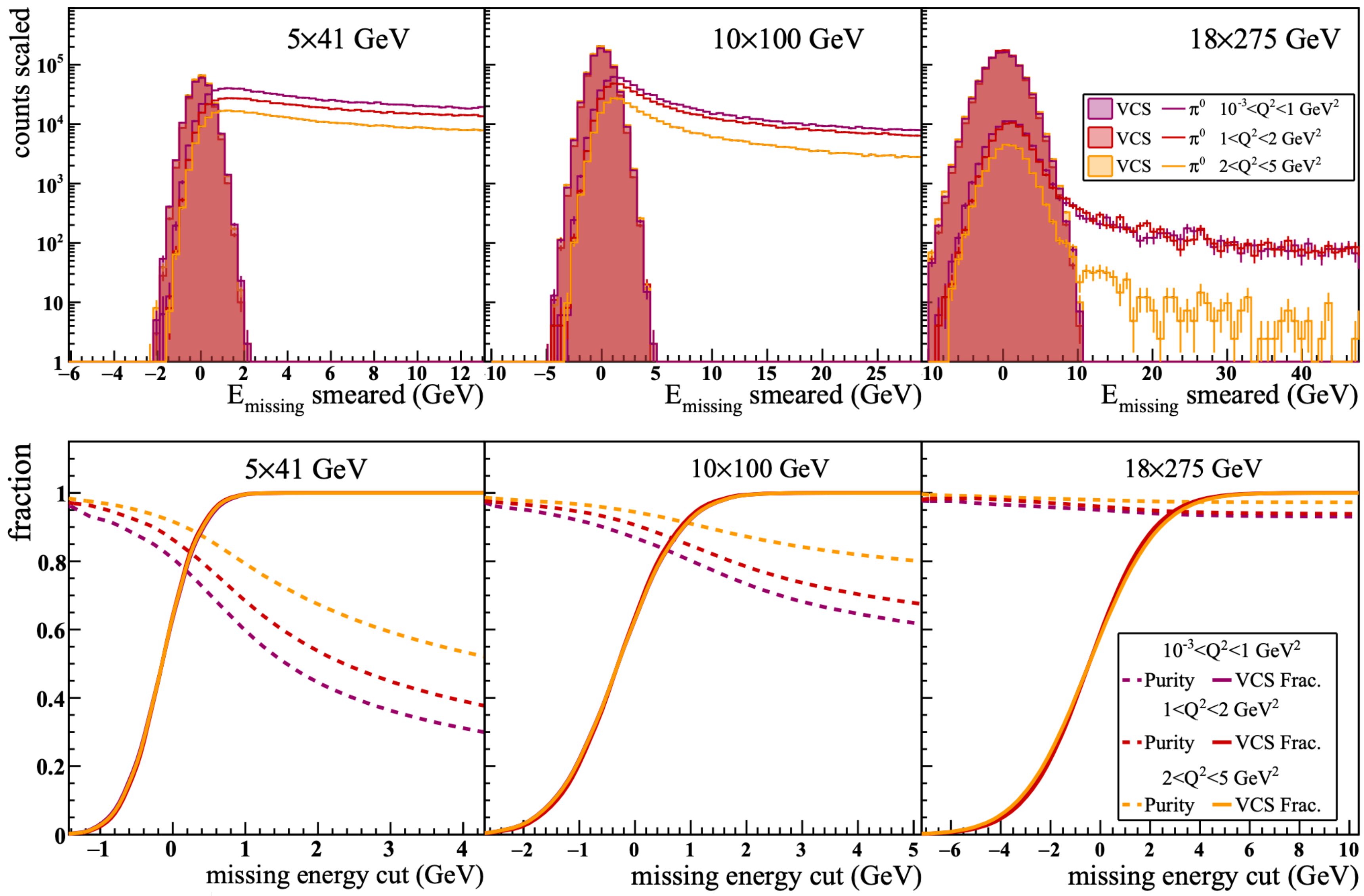


Reducing Background

apply missing energy cuts



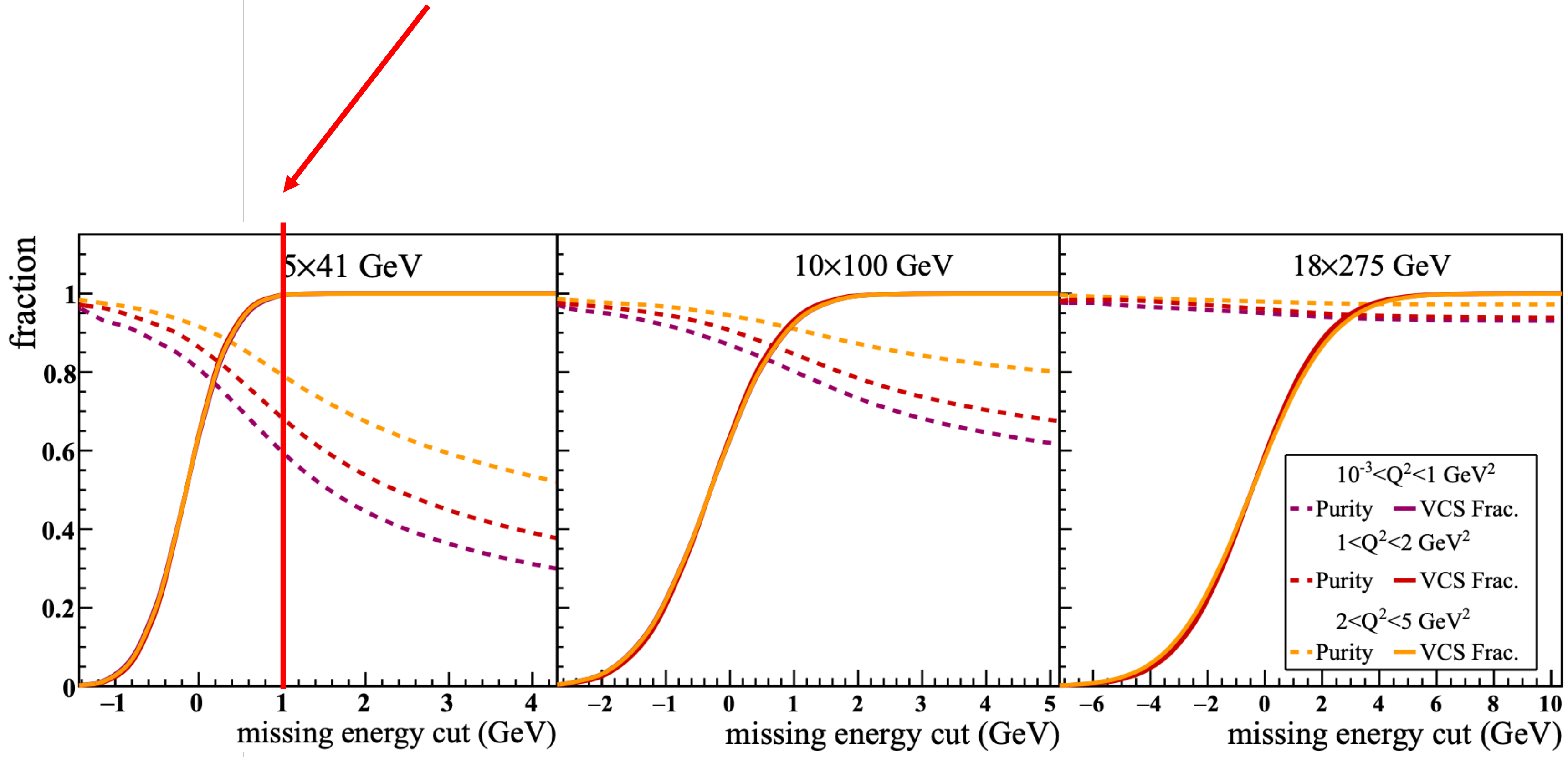
Reducing Background



Reducing Background

Missing energy cuts to collect entire VCS sample

- 5×41 GeV: $E_{missing} < 1$ GeV → ~70% purity



Reducing Background

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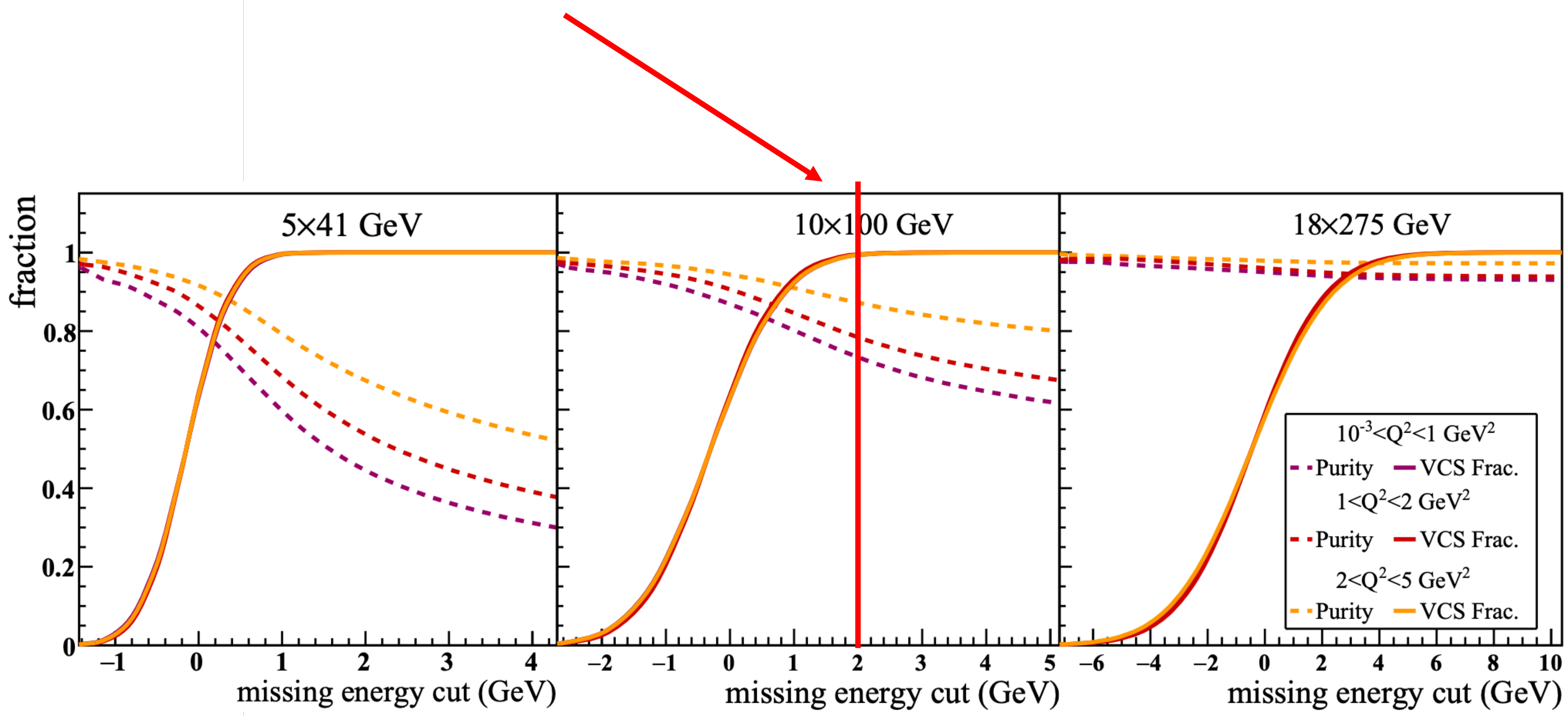
Missing energy cuts to collect entire VCS sample

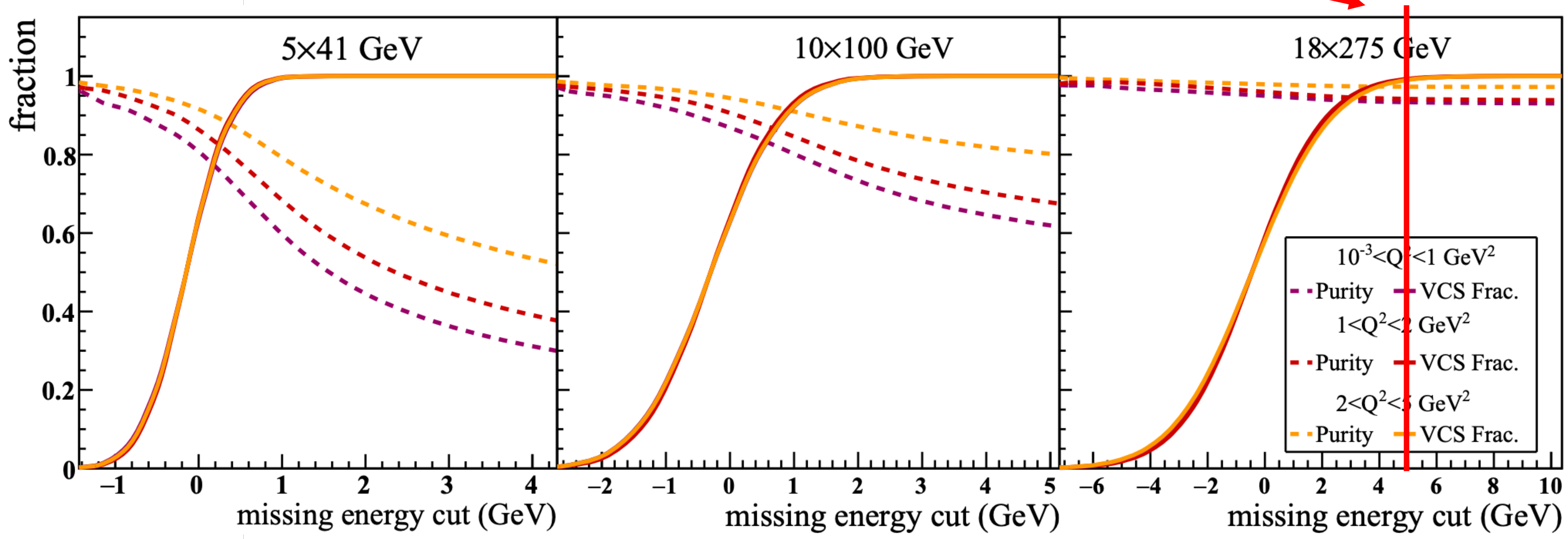
- 5×41 GeV: $E_{missing} < 1$ GeV → ~70% purity
- 10×100 GeV: $E_{missing} < 2$ GeV → ~80% purity



Reducing Background

Missing energy cuts to collect entire VCS sample

- 5×41 GeV: $E_{missing} < 1$ GeV → ~70% purity
- 10×100 GeV: $E_{missing} < 2$ GeV → ~80% purity
- 18×275 GeV: $E_{missing} < 5$ GeV → ~95% purity



Reducing Background

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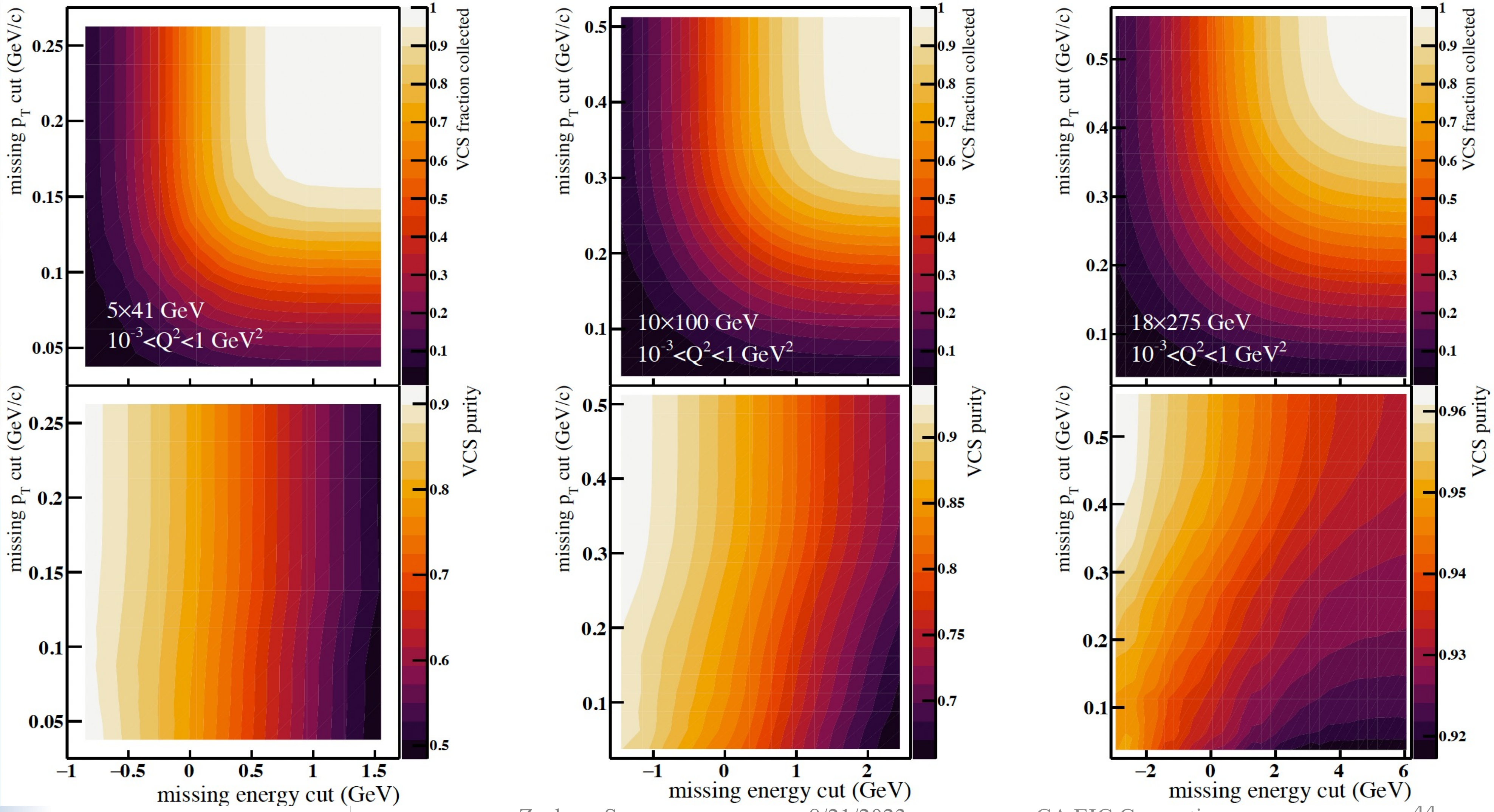

Reducing Background

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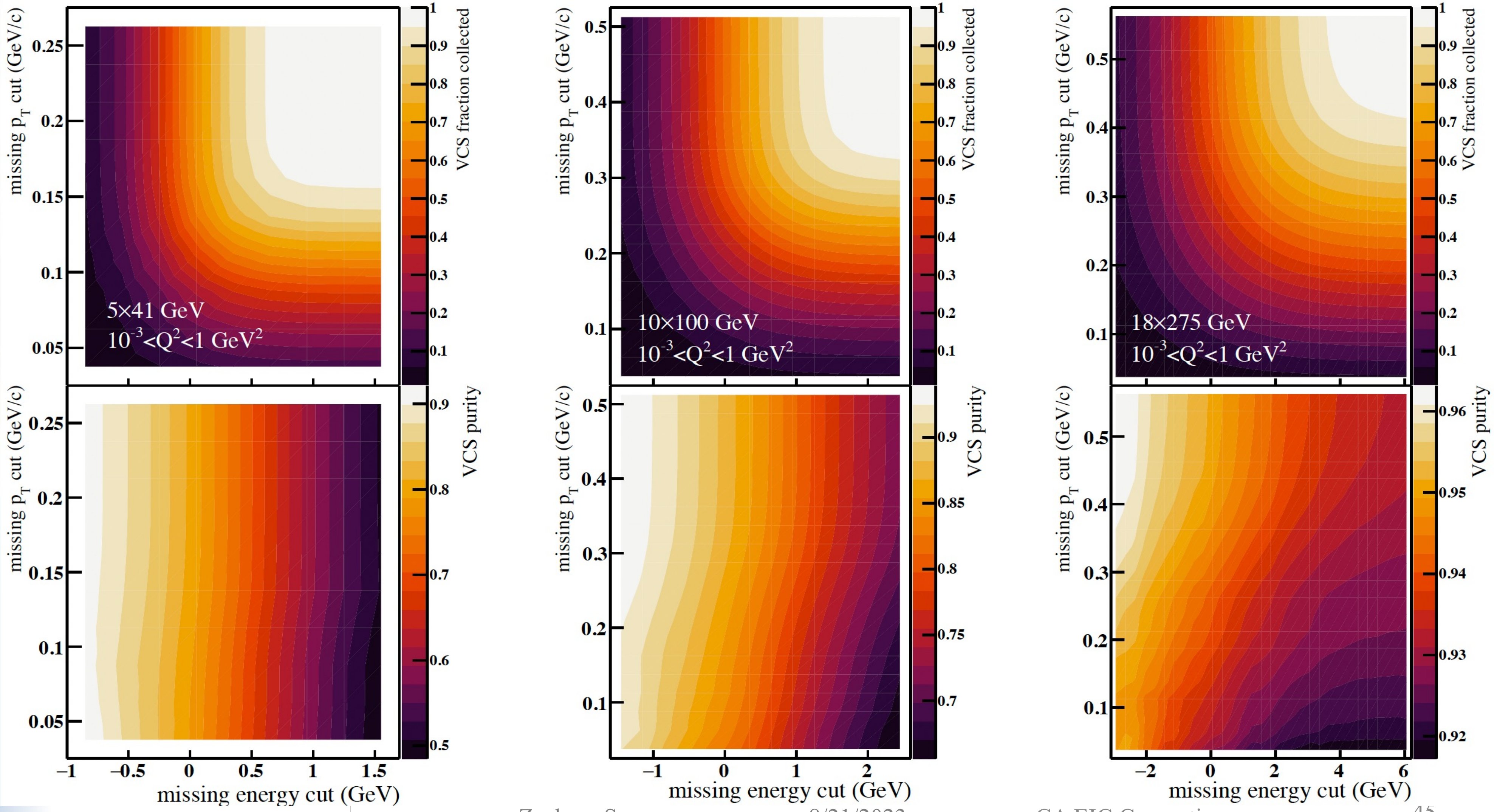
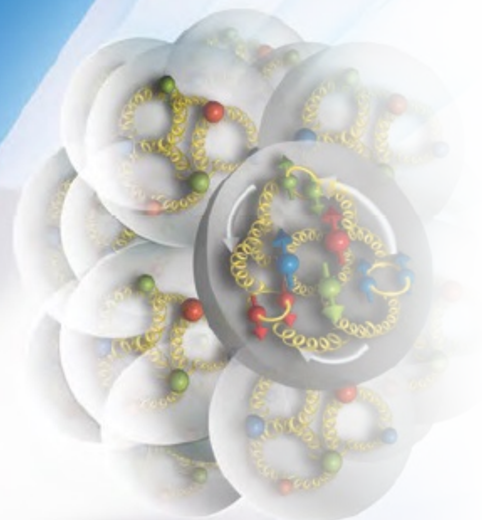
Conclusion: missing p_T cuts do not additionally improve sample purity



Backward VCS Paper on ArXiv!

Backward VCS Paper on ArXiv!

(public at 5pm today)



Modeling Backward-Angle (u-channel) Virtual Compton Scattering at an Electron-Ion Collider

Zachary Sweger, Saeahram Yoo, Ziyuan Zeng, and Daniel Cebra
Department of Physics and Astronomy, University of California, Davis, California 95616, USA

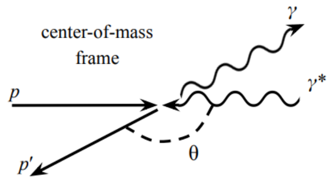
Spencer R. Klein, Yuanjing Ji, and Xin Dong
Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

Minjung Kim
Department of Physics, University of California, Berkeley, California 94720, USA
(Dated: August 21, 2023)

High-energy backward (u-channel) reactions can involve very large momentum transfers to the target baryons, shifting them by many units of rapidity. These reactions are difficult to understand in conventional models in which baryon number is carried by the valence quarks. Backward Compton scattering is an especially attractive experimental target, because of its simple final state. There is currently limited data on this process, and that data is at low center-of-mass energies. In this paper, we examine the prospects for studying backward Compton scattering at the future Electron-Ion Collider (EIC). We model the cross-section and kinematics using the limited data on backward Compton scattering and backward meson production, and then simulate Compton scattering at EIC energies, in a simple model of the ePIC detector. Generally, the proton is scattered toward mid-rapidity, while the produced photon is in the far-forward region, visible in a Zero Degree Calorimeter (ZDC). We show that the background from backward π^0 production can be rejected using a high-resolution, well-segmented ZDC.

I. INTRODUCTION

Backward (u-channel) Compton scattering (CS) occurs when a photon scatters backwards from a proton, with a large momentum transfer between the two as shown in Fig. 1a. This is in stark contrast to the more common t-channel process which dominates the CS cross section.



(a)

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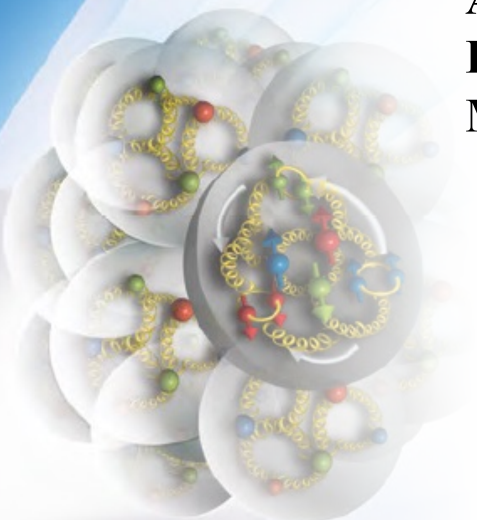
All California EIC Consortium Members



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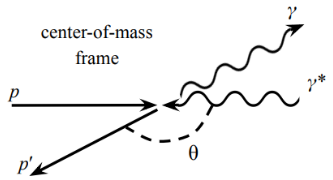

(a)

Backward (u-channel) Simulations

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Summary of u-channel studies to-date

Phys. Rev. C 106, 015204 (2022)

Process	optimal collision energies	requires	acceptance rate: without B0 EMCal	acceptance rate: with B0 EMCal
ω	10×100 GeV	ZDC	1.3%	41%
	18×275 GeV	B0 EMCal	6%	63%
ρ	10×100 GeV	B0 tracker	49%	
π^0	18×275 GeV	ZDC	65%	68%
DVCS	18×275 GeV	ZDC B0 EMCal	75%	81%

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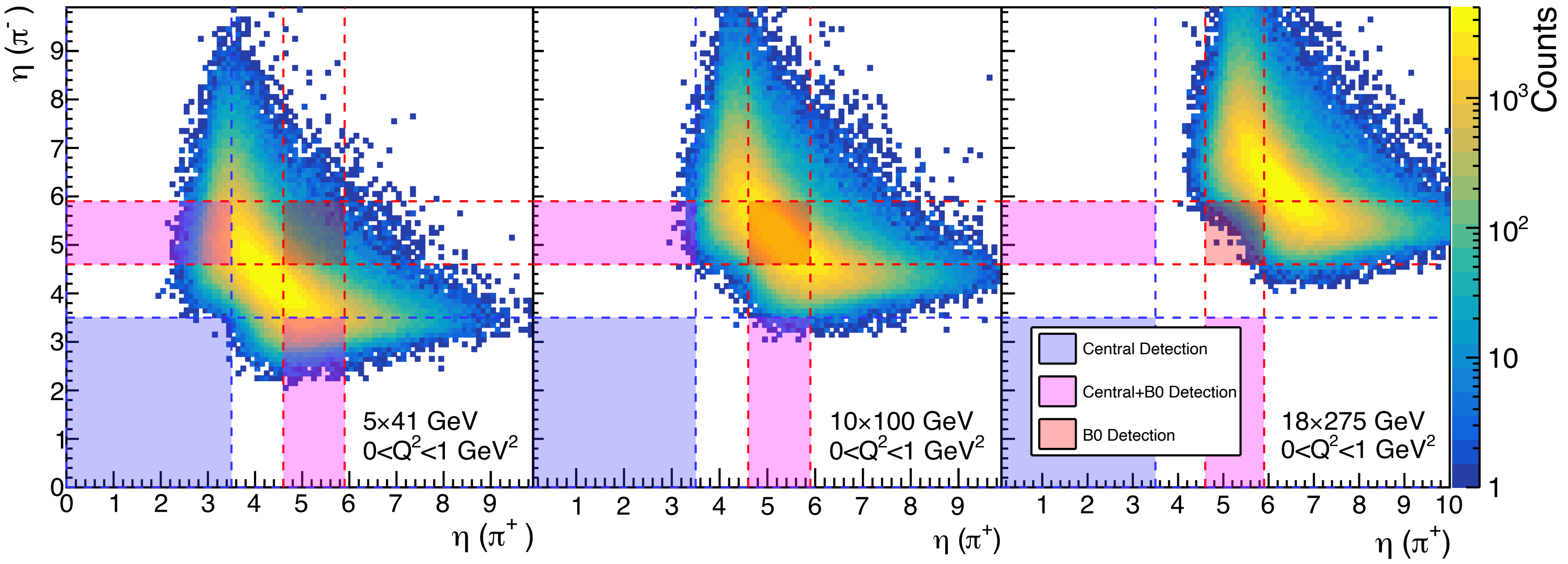

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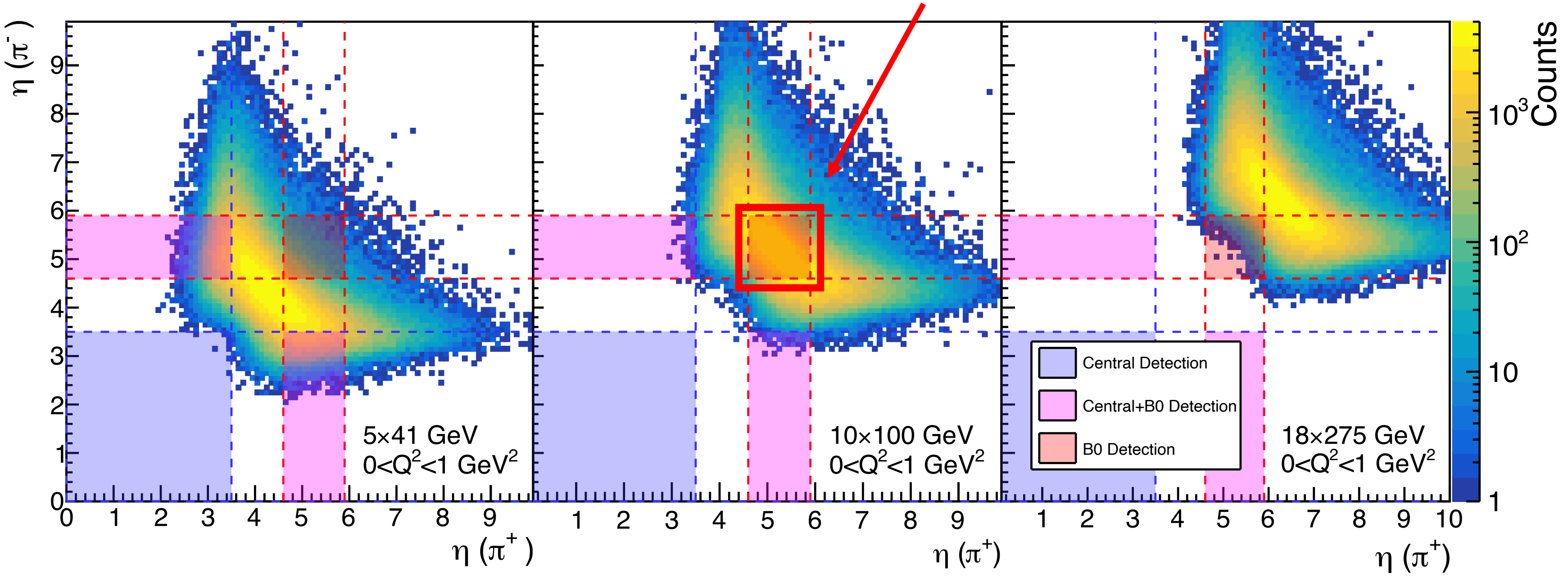

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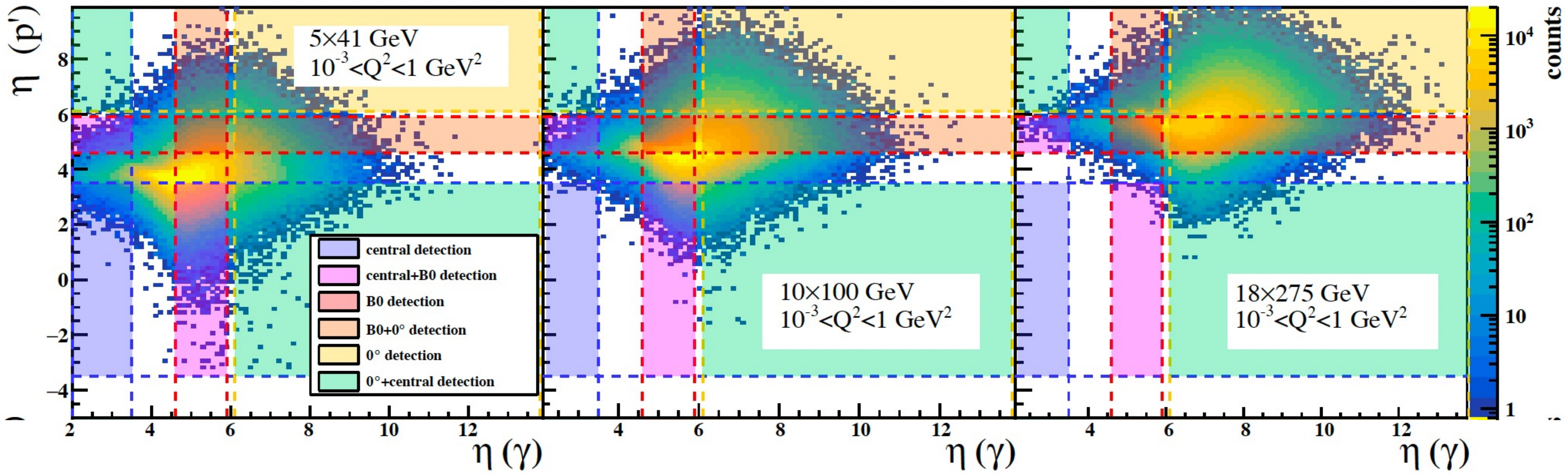

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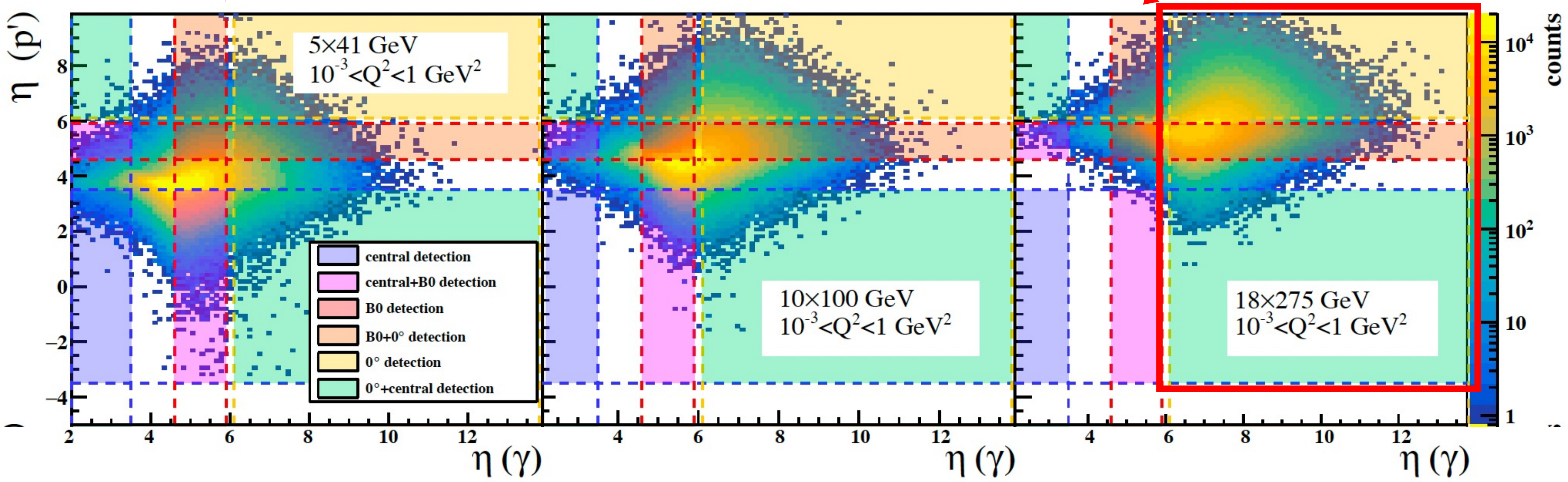

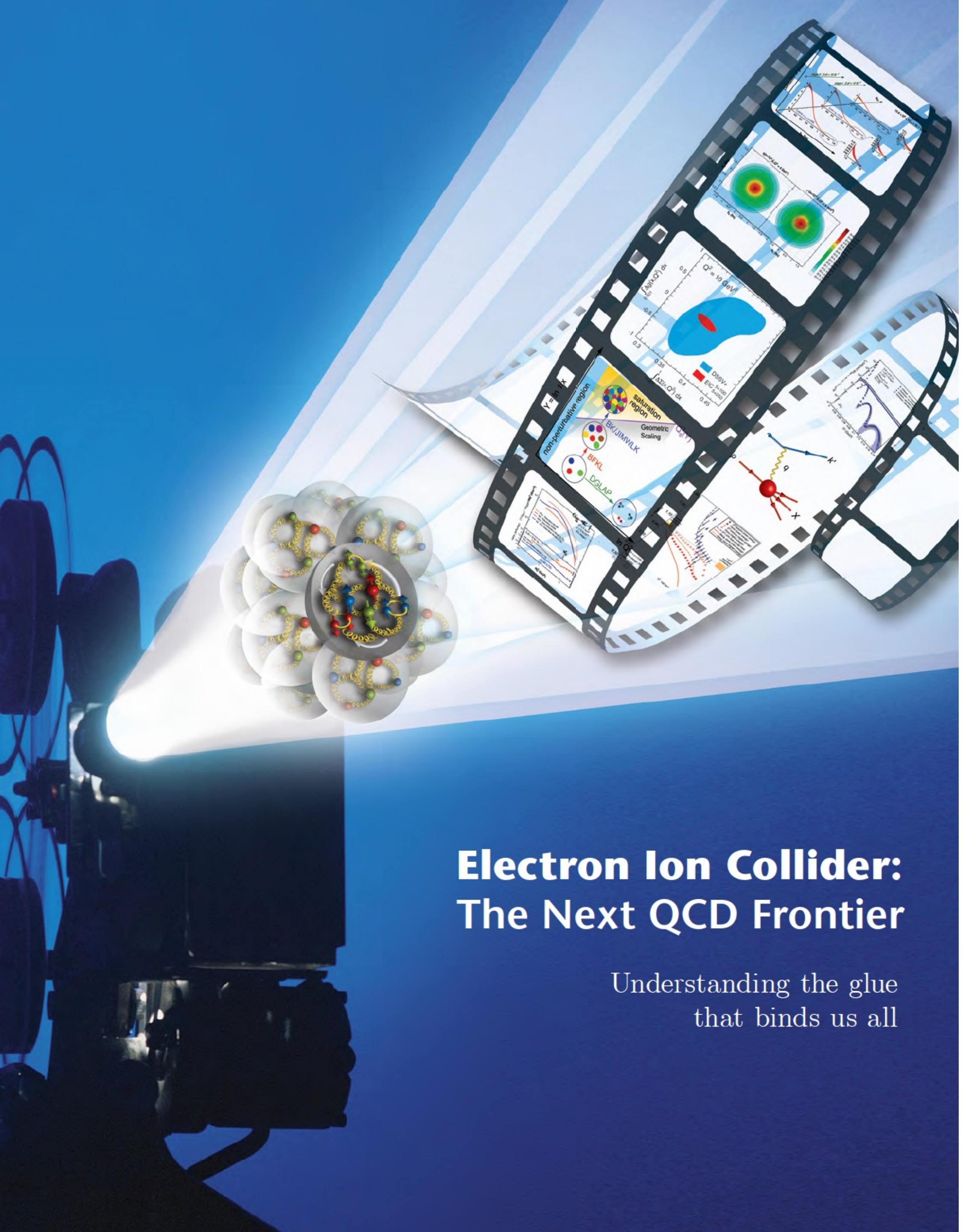

Conclusions

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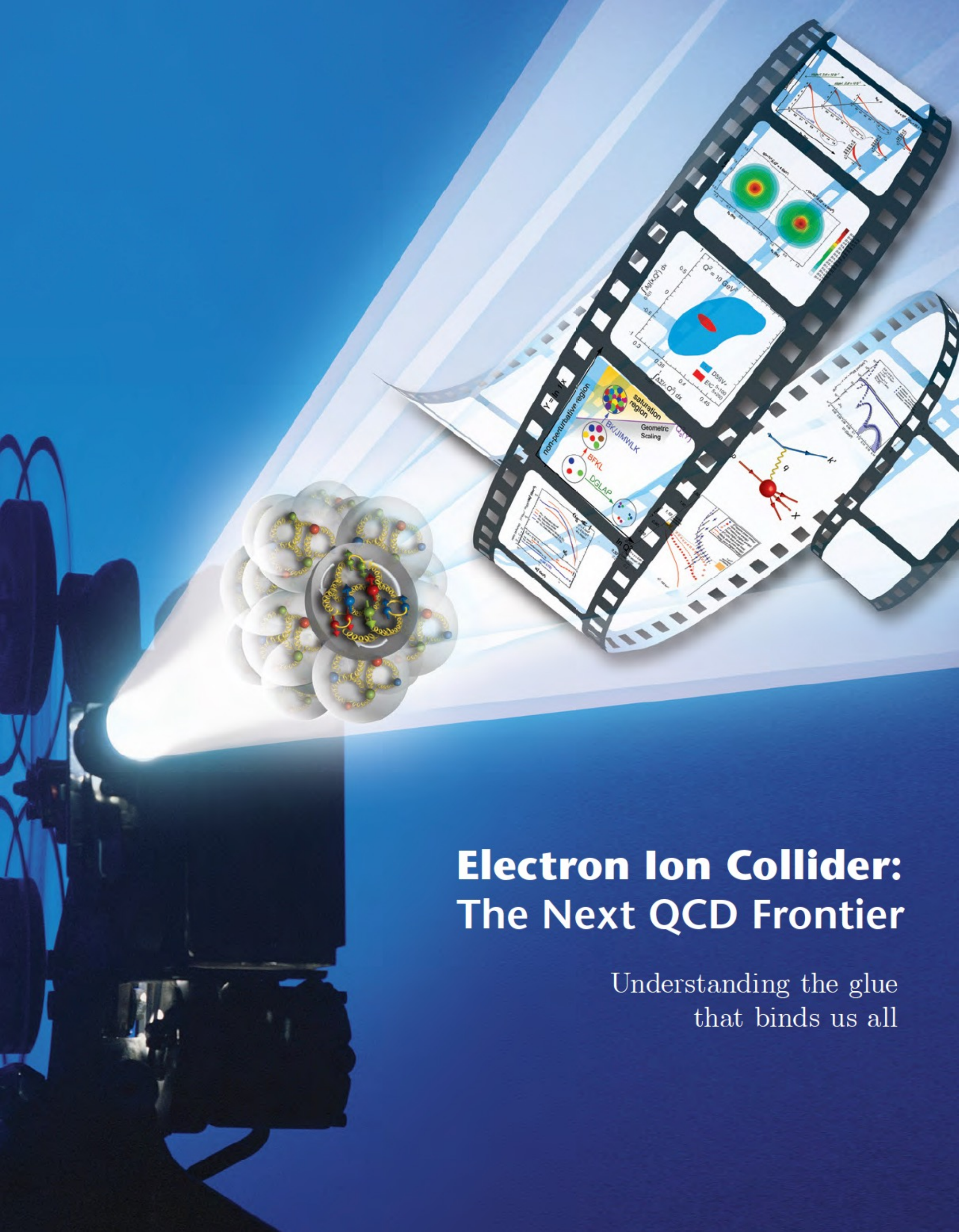

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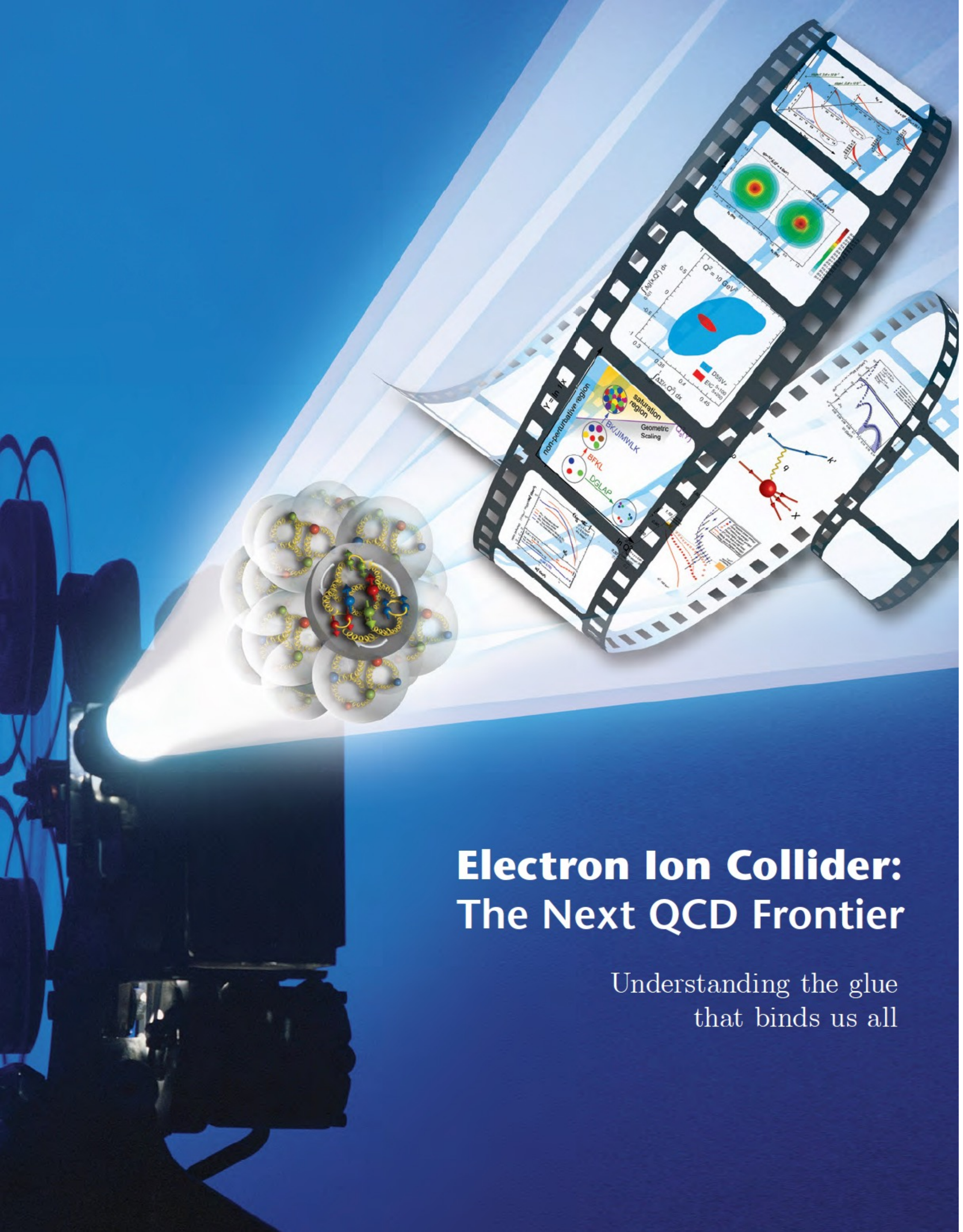

Conclusions

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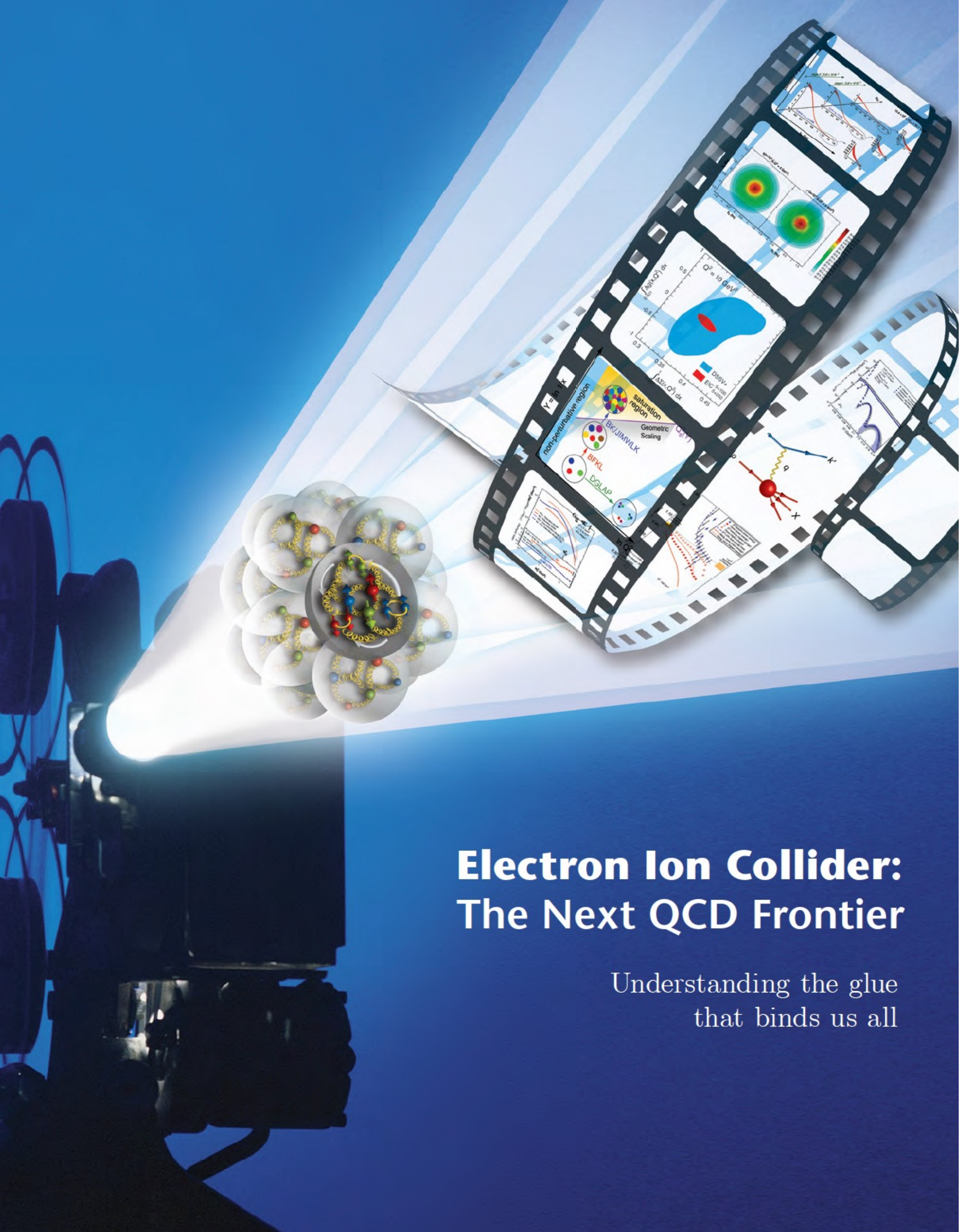
- Impact-parameter-space interpretation of u-channel is rich and rapidly developing



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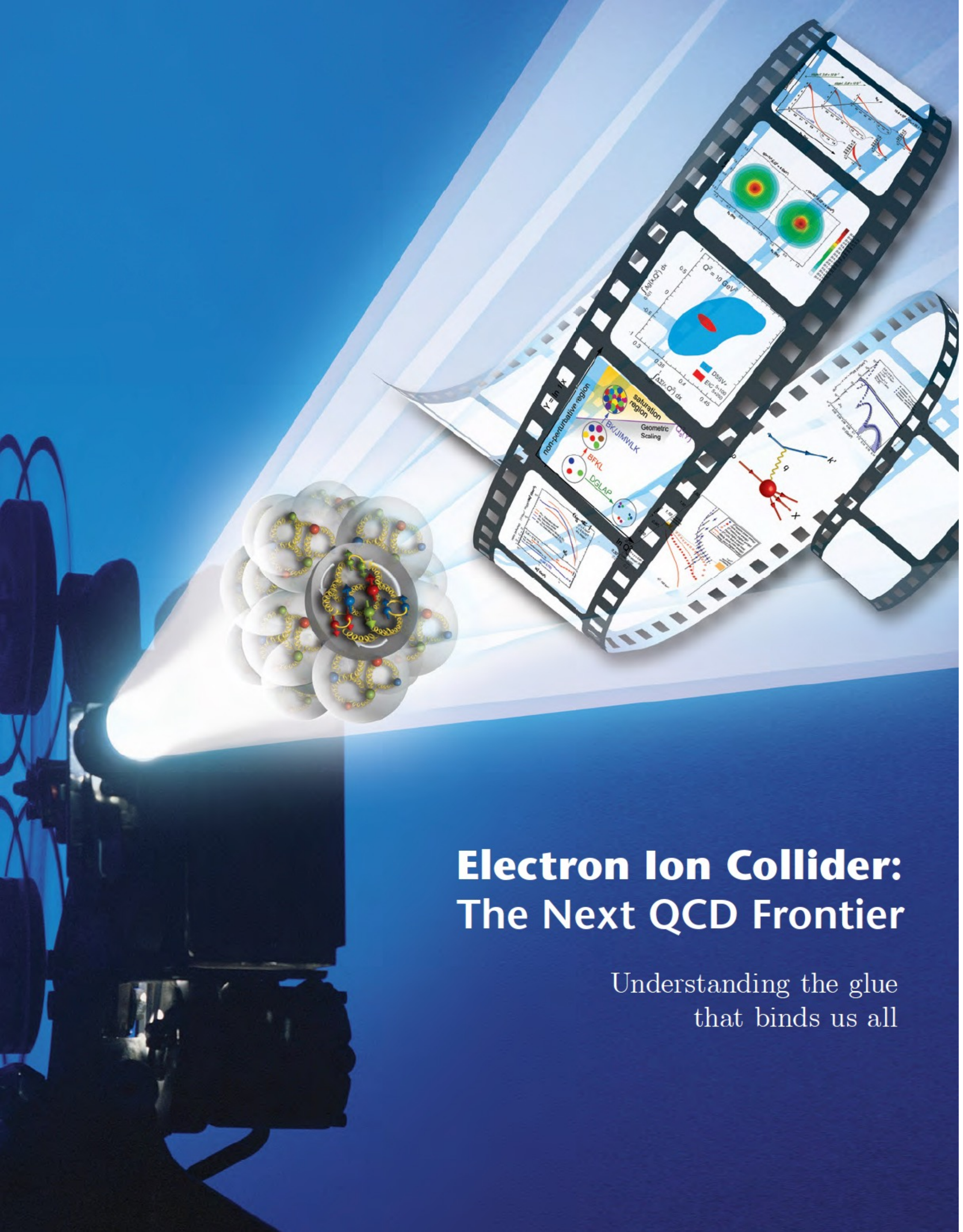

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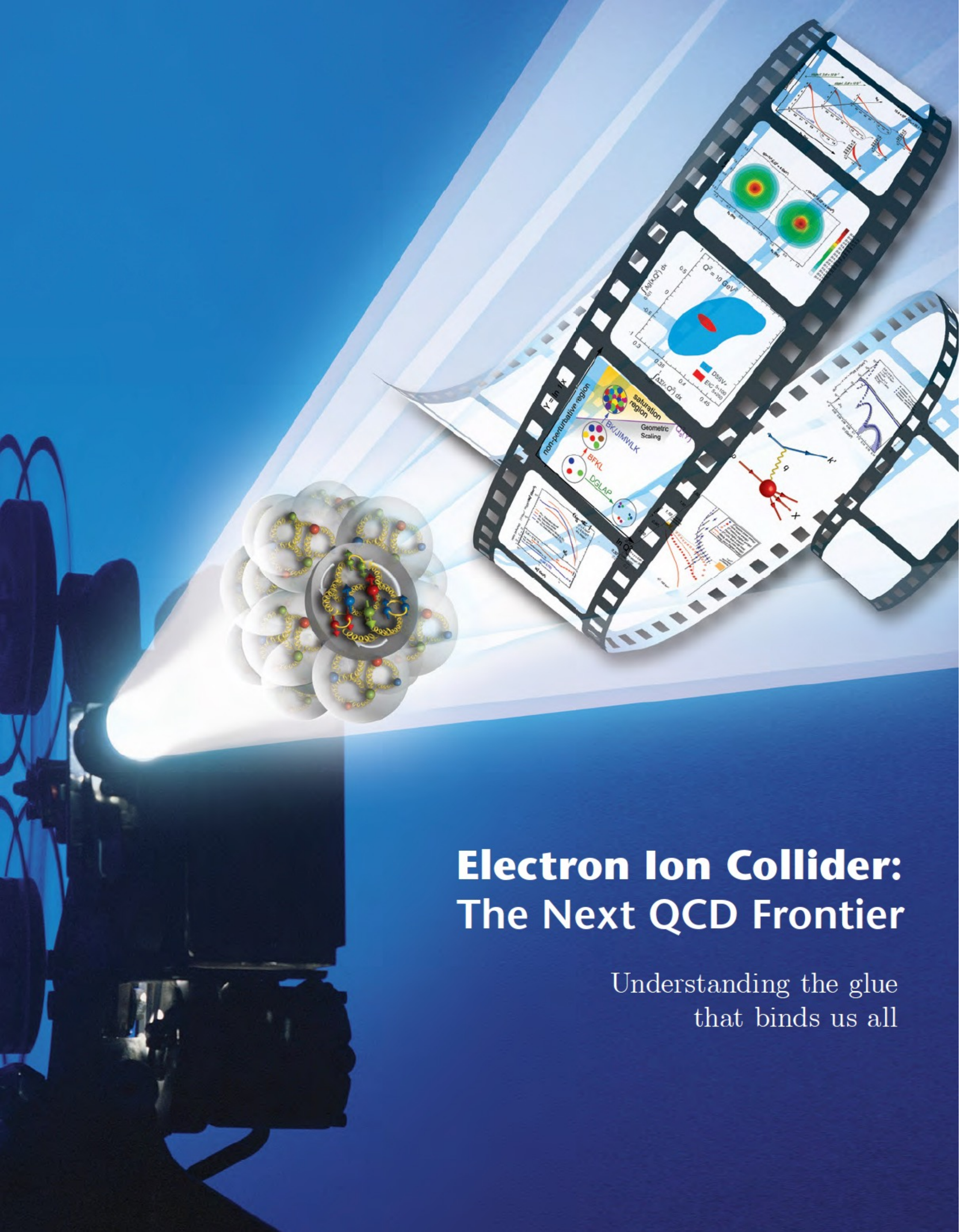

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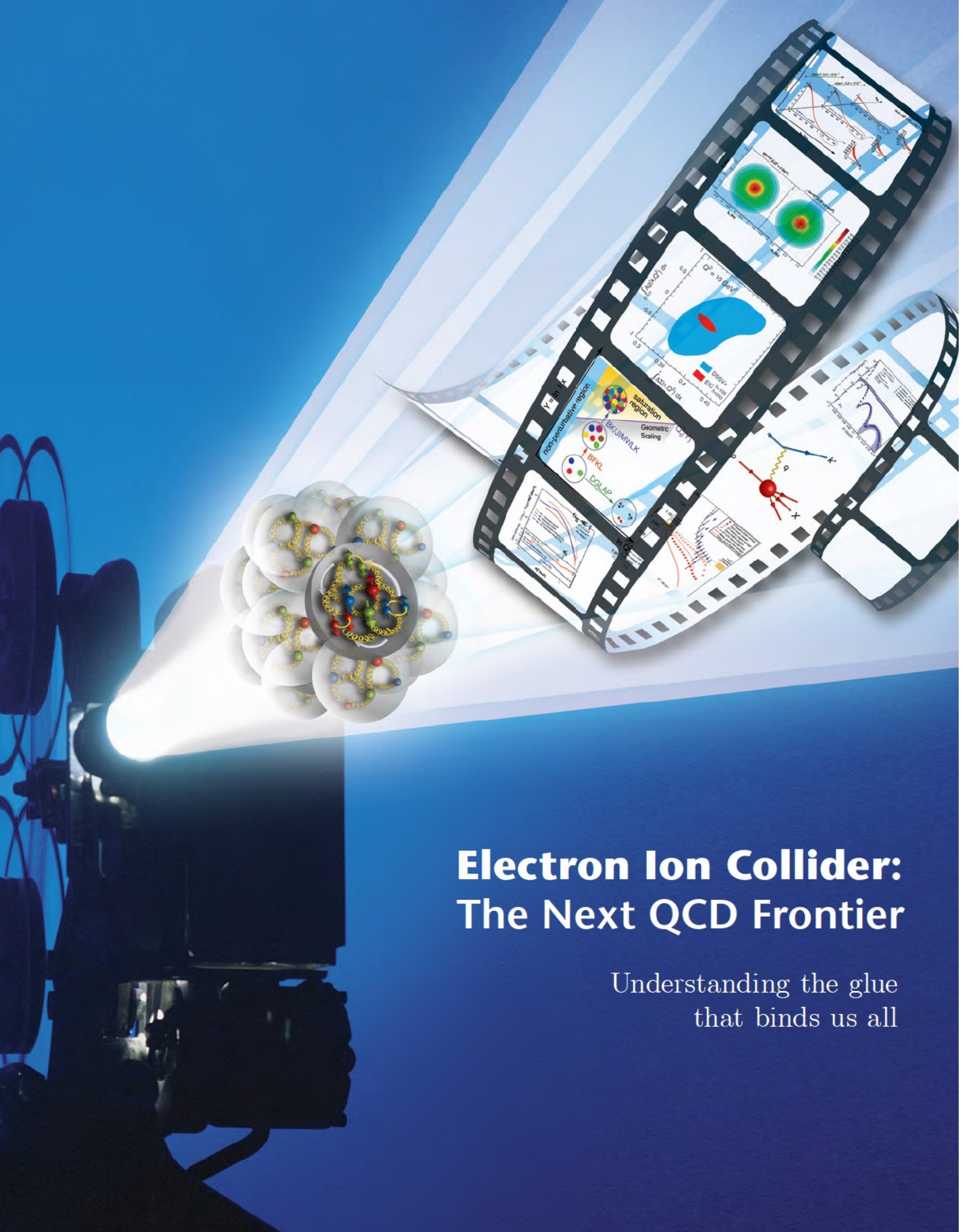

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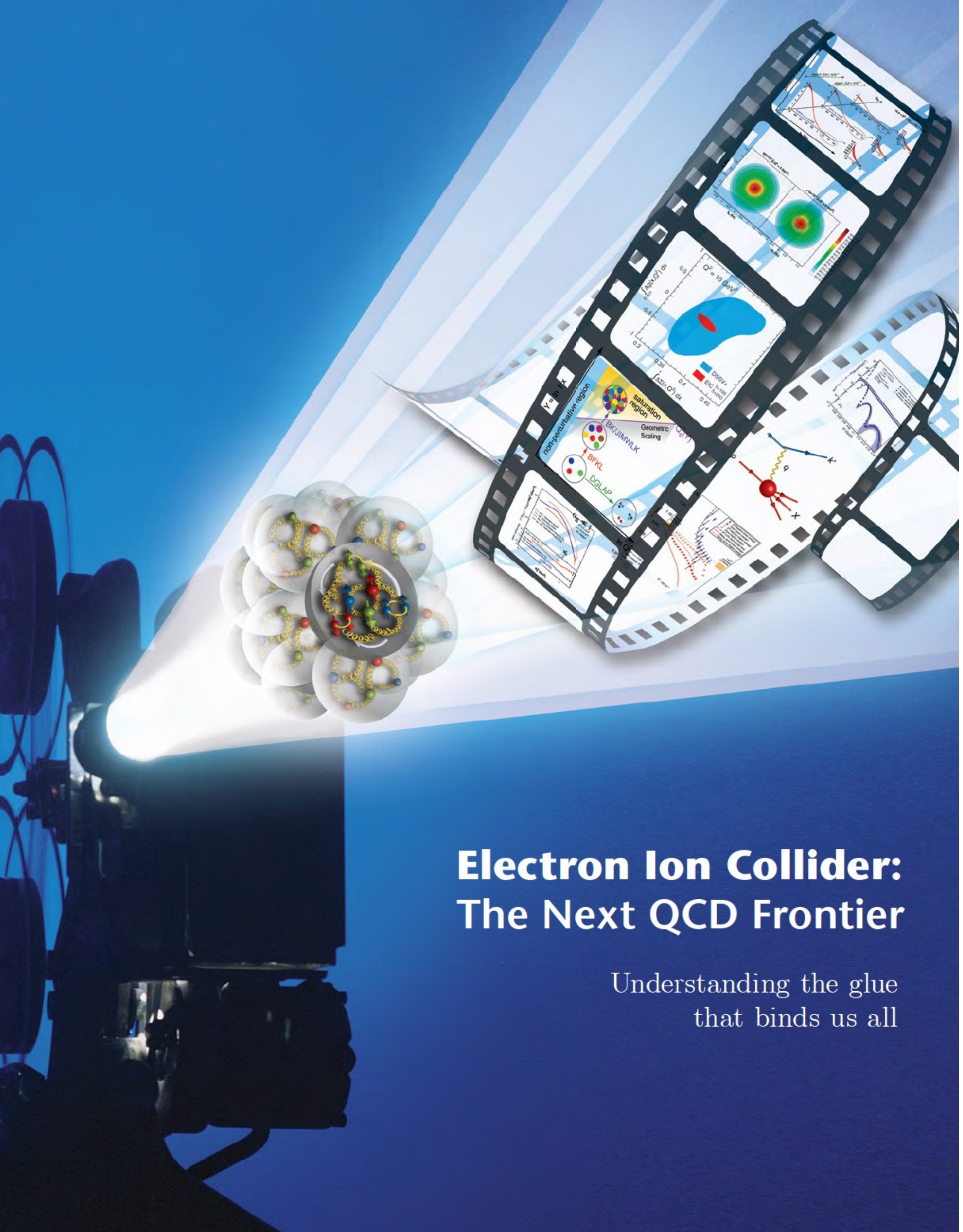

Conclusions

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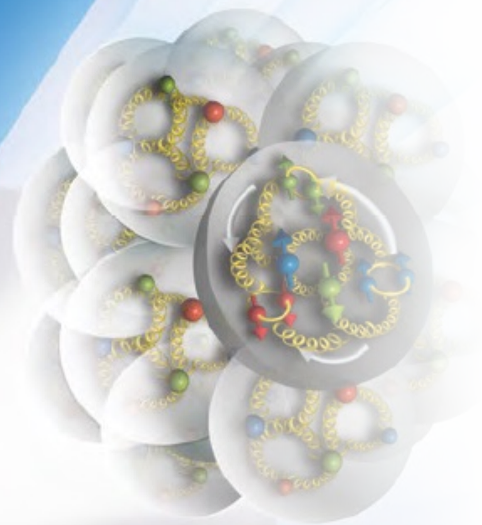
  - ❑ J/ψ studies
  - ❑ ϕ studies
  - ❑ Full ePIC simulations & reconstruction



Thank you for your attention!

zwsweger@ucdavis.edu

Backward VM paper: Phys. Rev. C 106, 015204 (2022)
Backward VCS paper: search “ArXiv Sweger Klein Compton” 30 minutes from now!