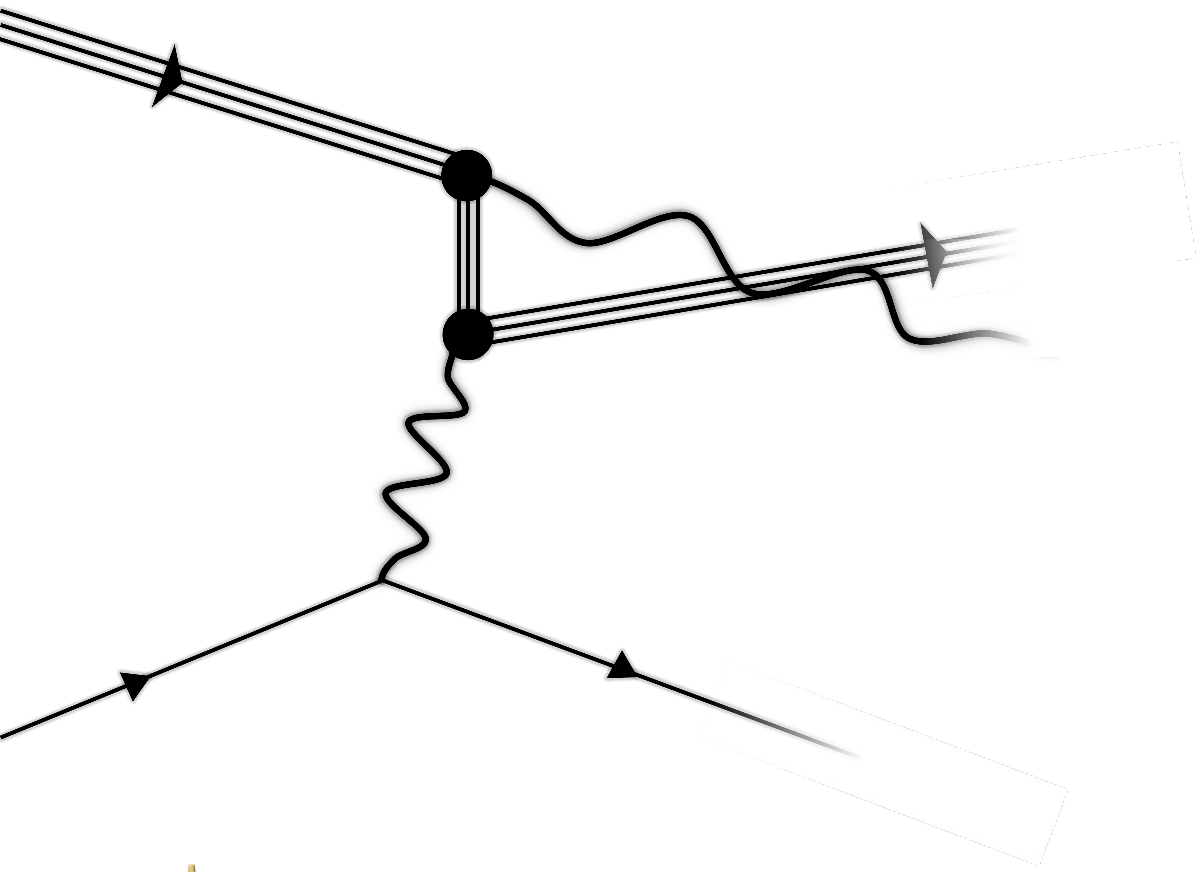

Update on Backward-Angle (u-channel) VCS and DVCS at the EIC

Zachary Sweger
University of California, Davis

Supported in part by

Forward and Backward Compton Scattering

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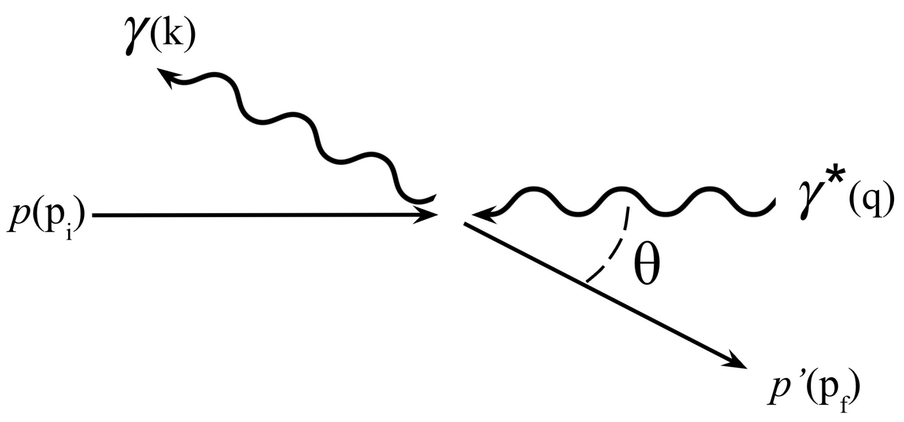
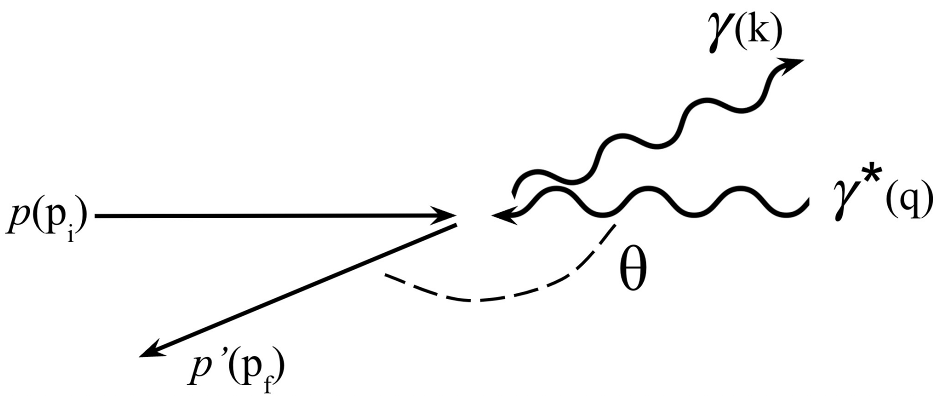
Forward Compton Scattering (COM Frame)



Glancing collision, small momentum transfer

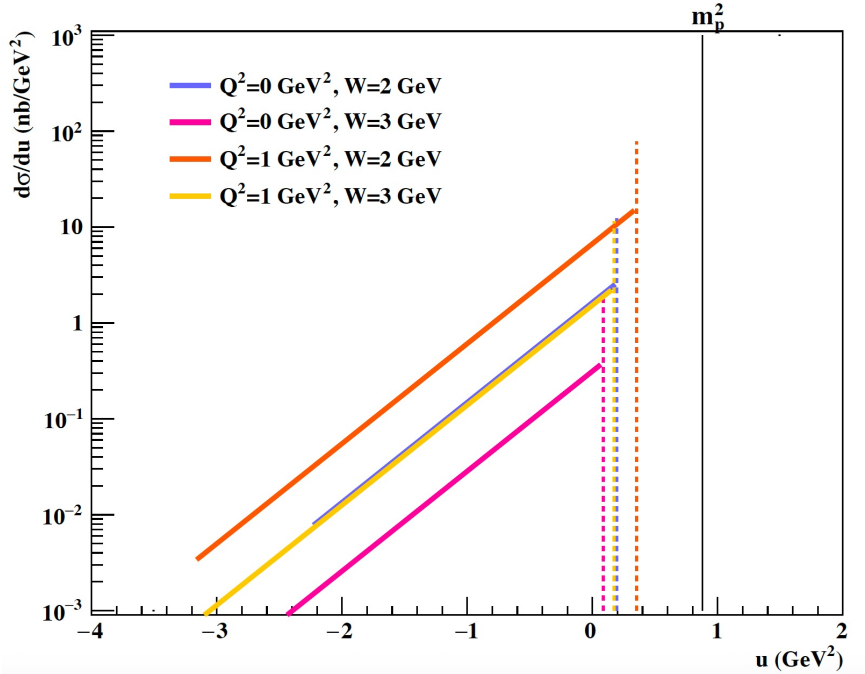
Backward Compton Scattering (COM Frame)



Backscattering, large momentum transfer

Modeling u-channel DVCS

- We presuppose a peak at backward angles ($u=u_0$) as is seen in meson production
- EIC will provide an opportunity to measure this peak if it exits, a task that is challenging in fixed-target experiments due to the softness of the photons produced



- **The strategy: exploit similarities to t-channel**

$$\frac{d\sigma}{dt}(t) \sim \exp(-B|t-t_0|) \longrightarrow \frac{d\sigma}{du}(u) \sim \exp(-D|u-u_0|)$$

- D has not been measured for backward DVCS, so for our models we test values measured for backward ω production

L. Wenliang, (2017), 10.2172/1408890.

D. Cebra, Z. Sweger, X. Dong, Y. Ji, and S. R. Klein, Phys. Rev. C 106, 015204 (2022).

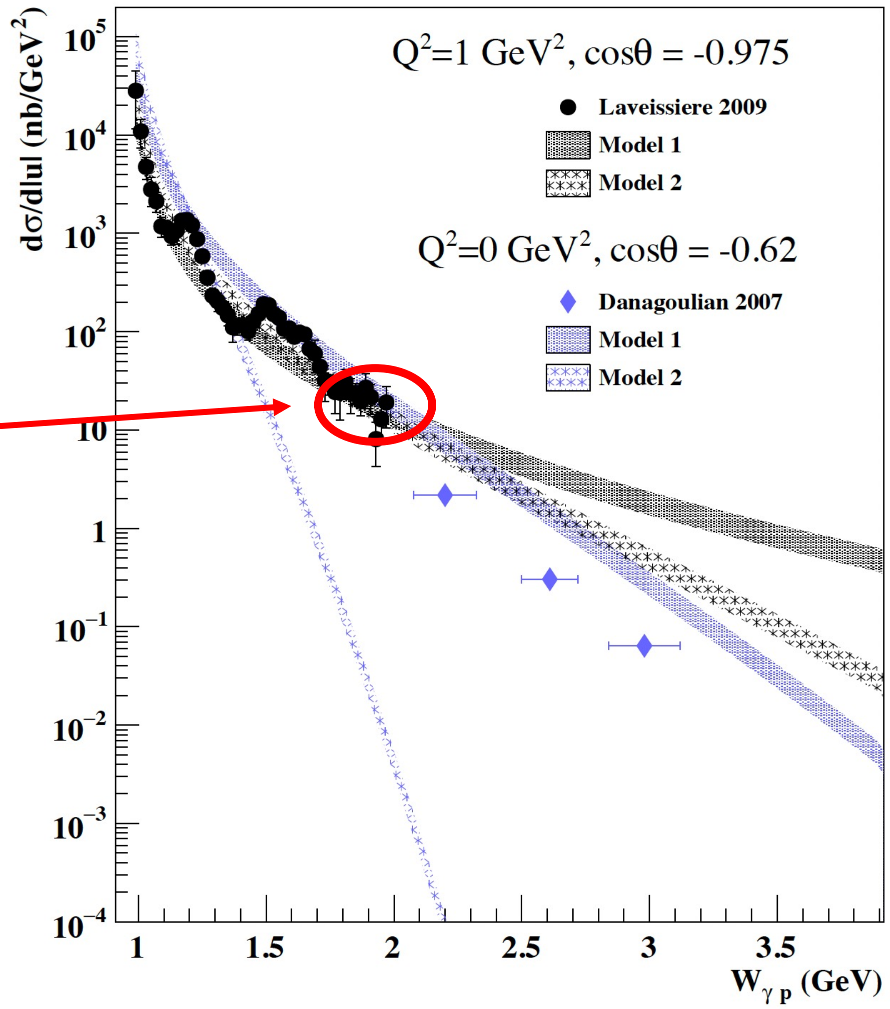
Backward DVCS Cross Section Model

- W, Q^2, and u scalings combine to yield the form:

$$\frac{d\sigma}{du}(Q^2, W, u) \approx \frac{A \exp(-D|u - u_0|)}{(W^2 - m_p^2)^2 (Q^2 + \Lambda^2)^4 / \mathrm{GeV}^8}$$

- In order to anchor the amplitude, we can fit this model to 11 VCS (Q^2=1 GeV^2) data points from JLab from 1.77<W<1.96 GeV (above strong resonances)

- Where
  - Λ^2 = 2.77 GeV^2
  - Model 1: D = 2.4 GeV^{-2}, A = 32 μb/GeV^2
  - Model 2: D = 21.8 GeV^{-2}, A = 65 μb/GeV



G. Laveissi`ere et al., Physical Review C 79 (2009), 10.1103/physrevc.79.015201.
A. Danagoulian et al. (Jefferson Lab Hall A Collaboration), Phys. Rev. Lett. 98, 152001 (2007)

Detectors of Interest For u-channel Production

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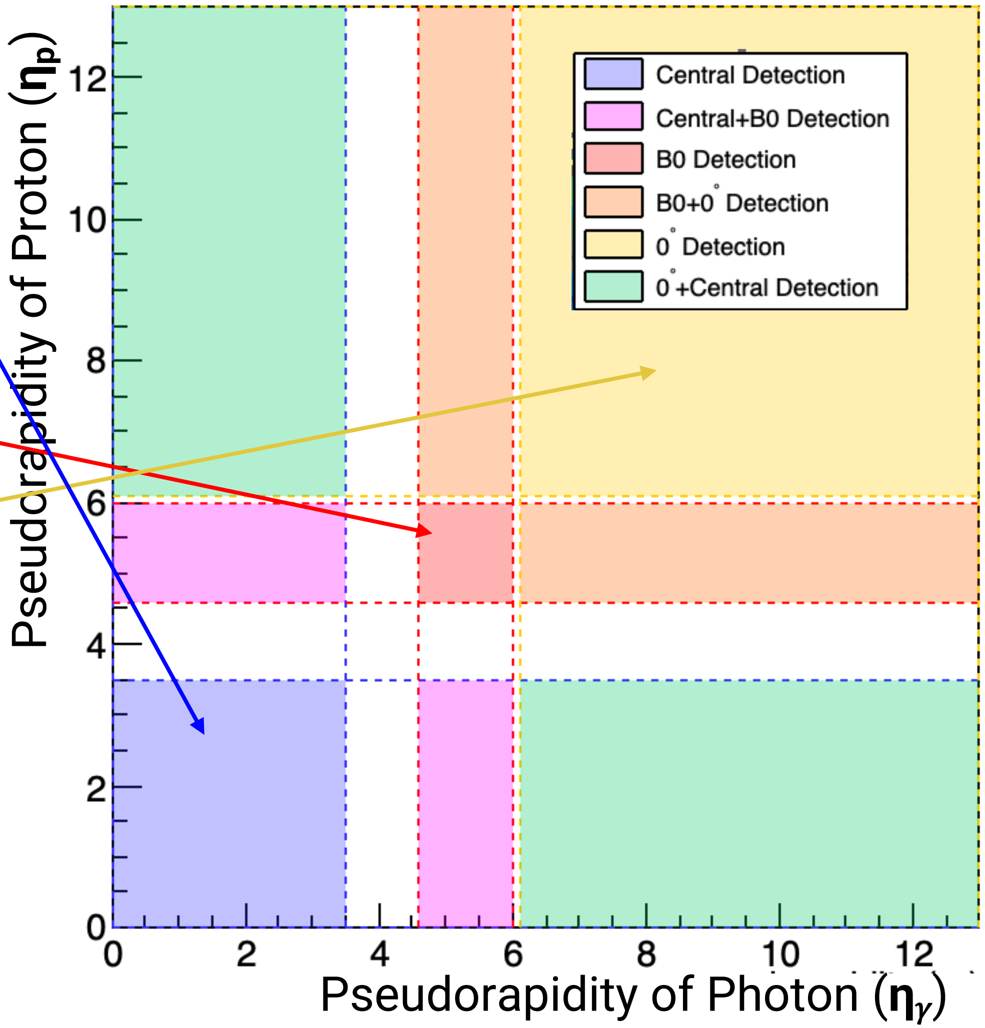
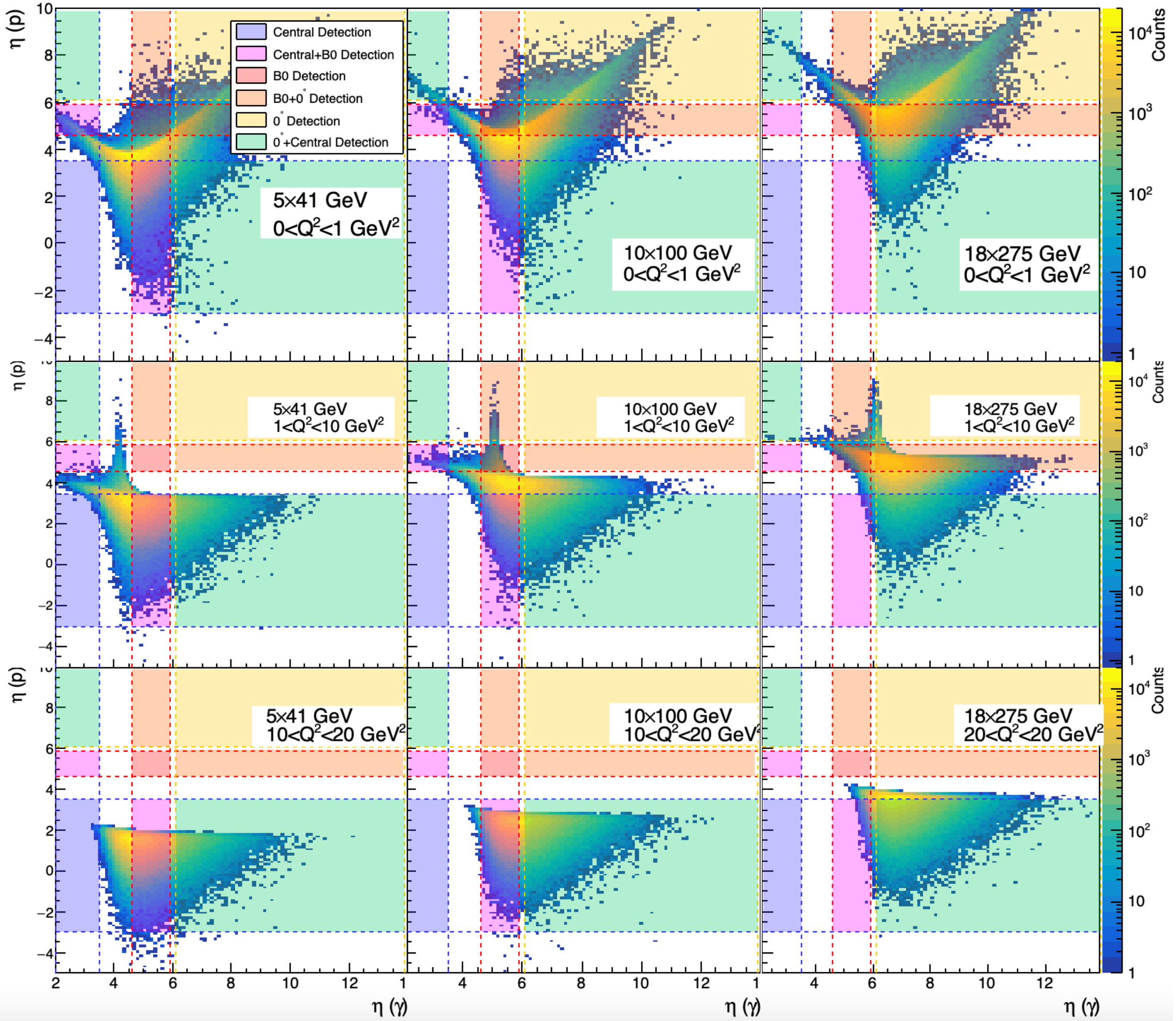
There are three detector regions of interest for backwards production

- Central Region (endcap & barrel): $|\eta| < 3.5$
  - ✓ Charged-particle tracking
  - ✓ Electromagnetic calorimetry
- B0 Magnets: $4.6 < \eta < 6.0$
  - ✓ Charged-particle tracking
  - ? Electromagnetic calorimetry
- Zero-degree Detection: $\eta > 6.215–5.991$
  - ✓ Roman Pots: Charged-particle tracking
  - ✓ ZDC: Electromagnetic calorimetry



Backward DVCS Acceptances

- Used Model 1 with W > 2 GeV
- Low collision energies: photon lands in B0 and ZDC
- ZDC is critical at high energies
- At low Q^2 proton is often in B0
- At high Q^2, proton is almost exclusively in central detector region



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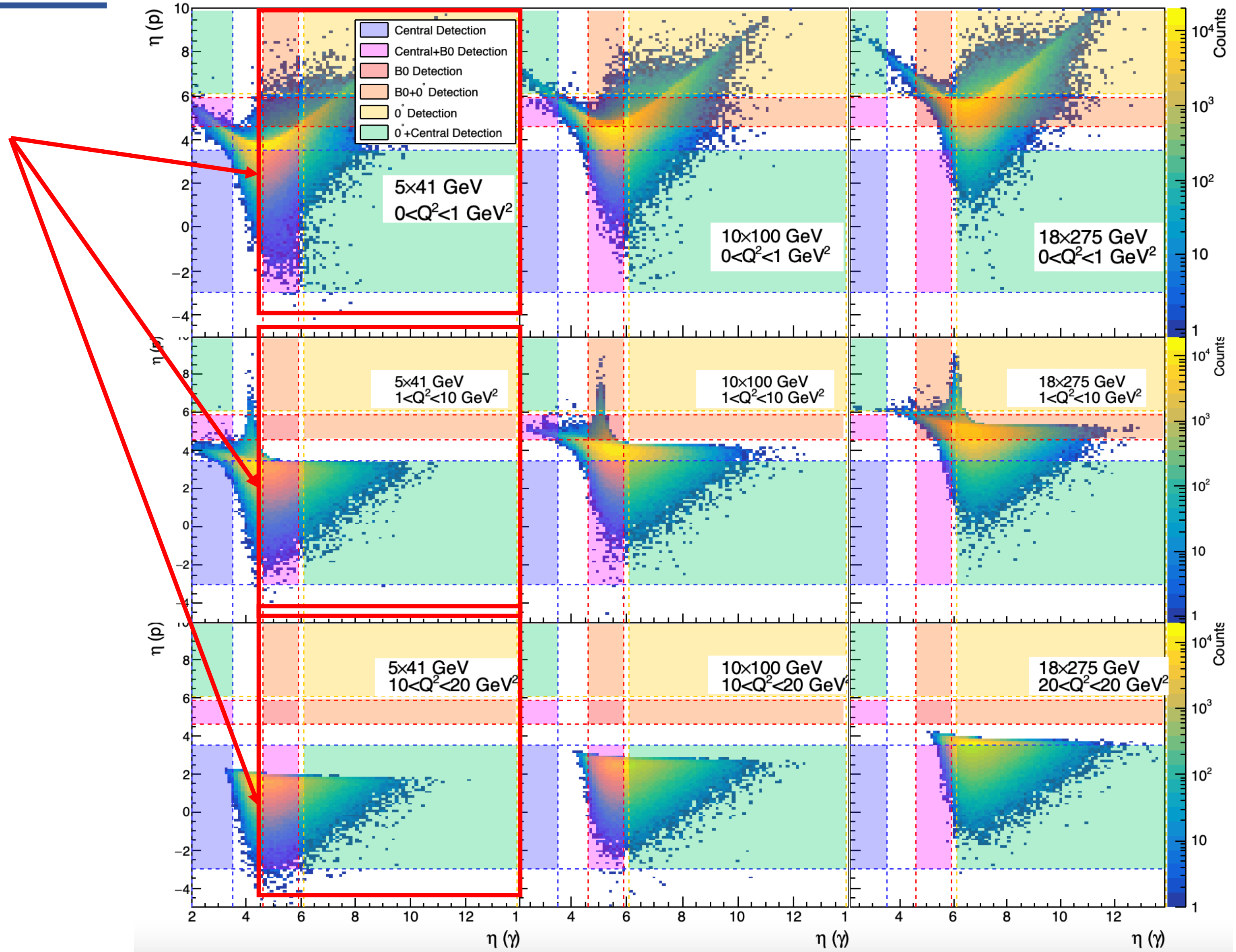

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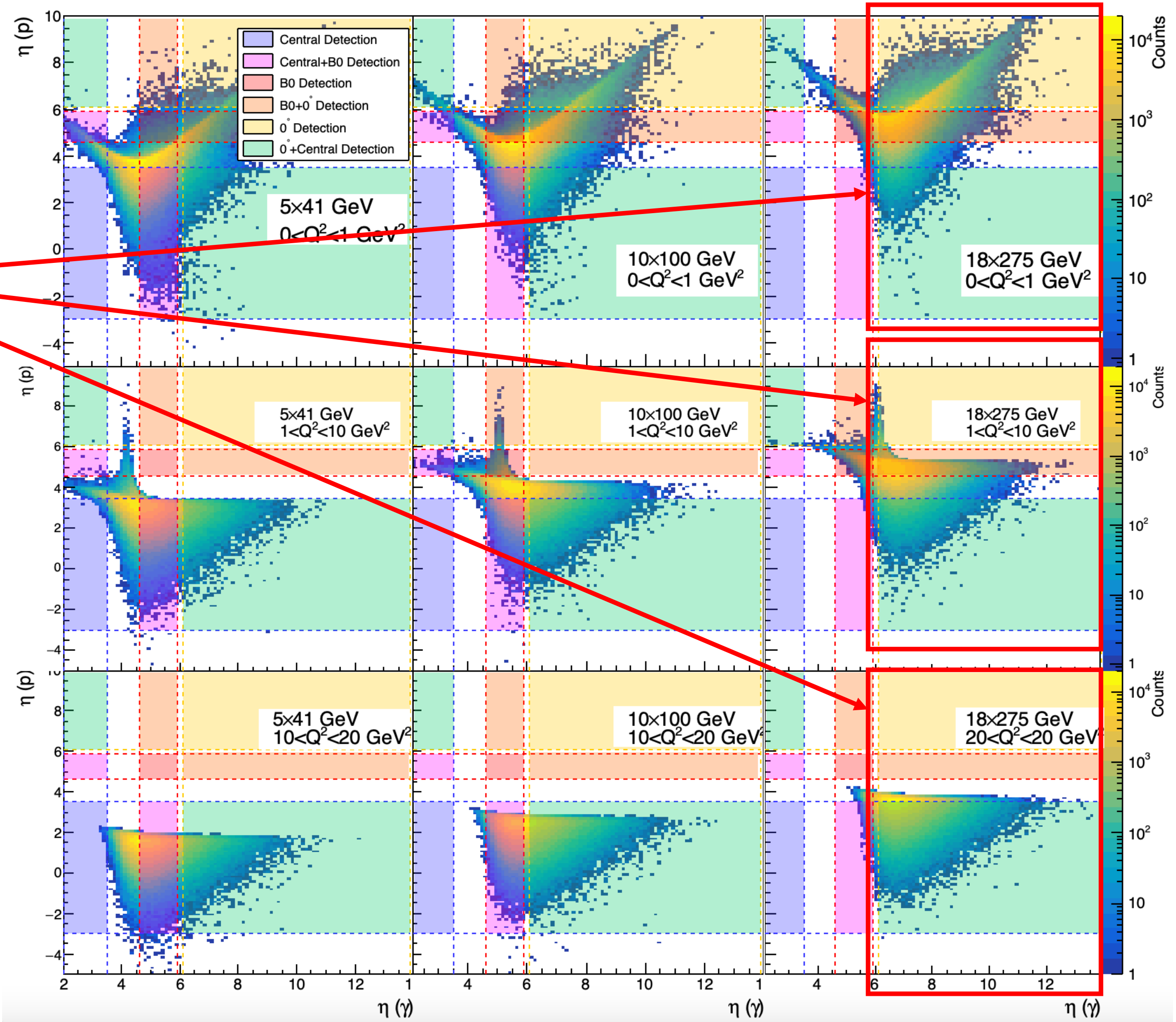

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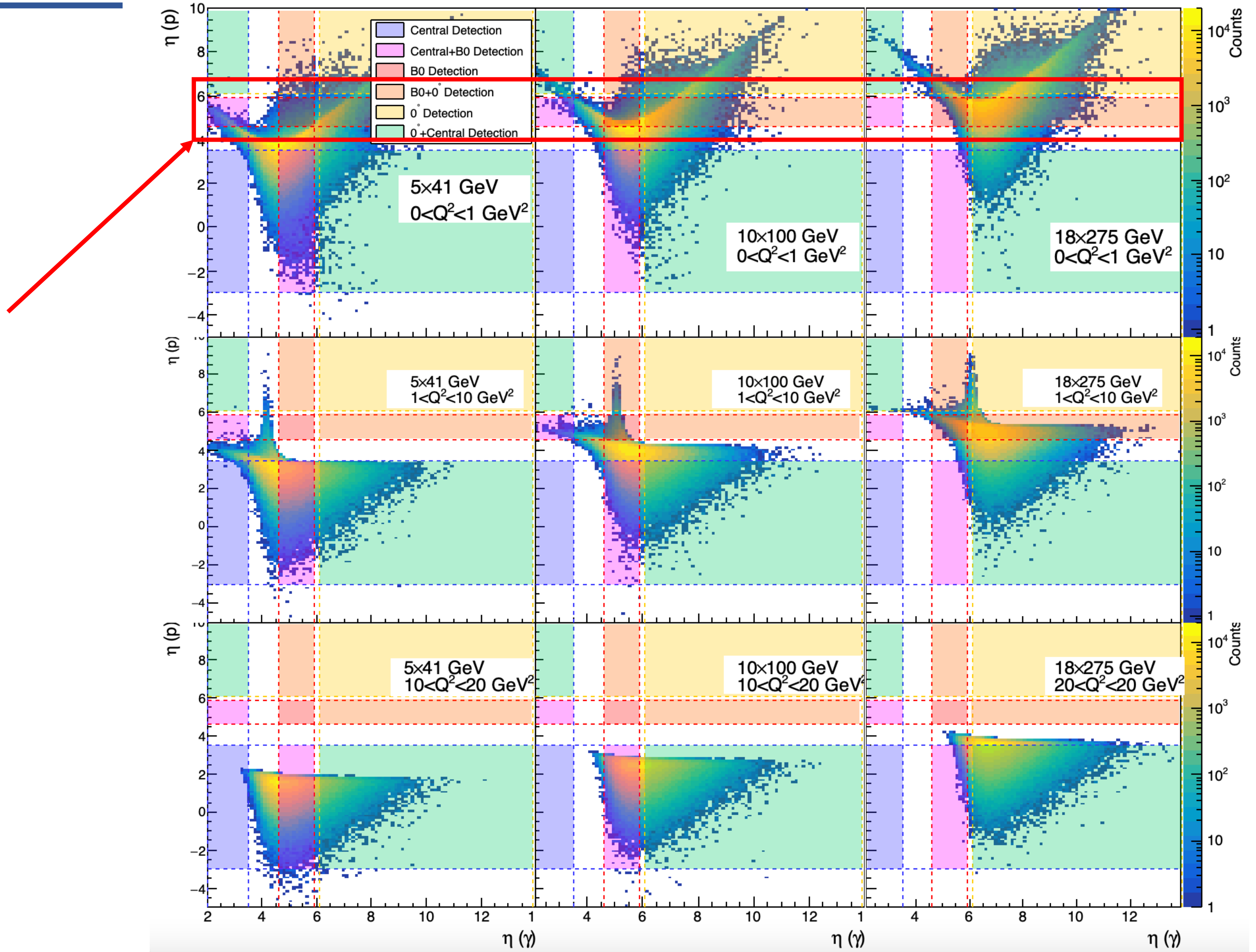

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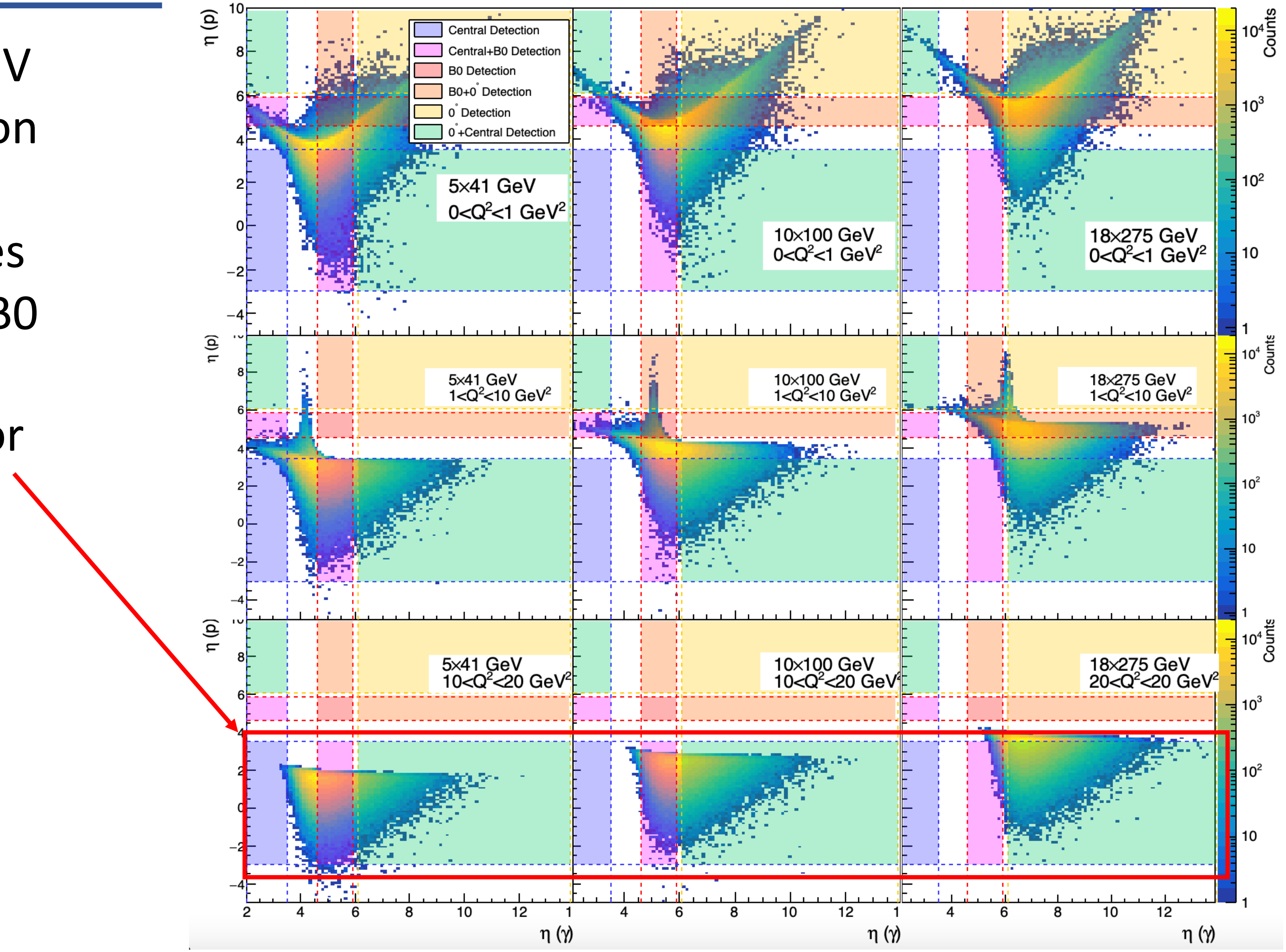
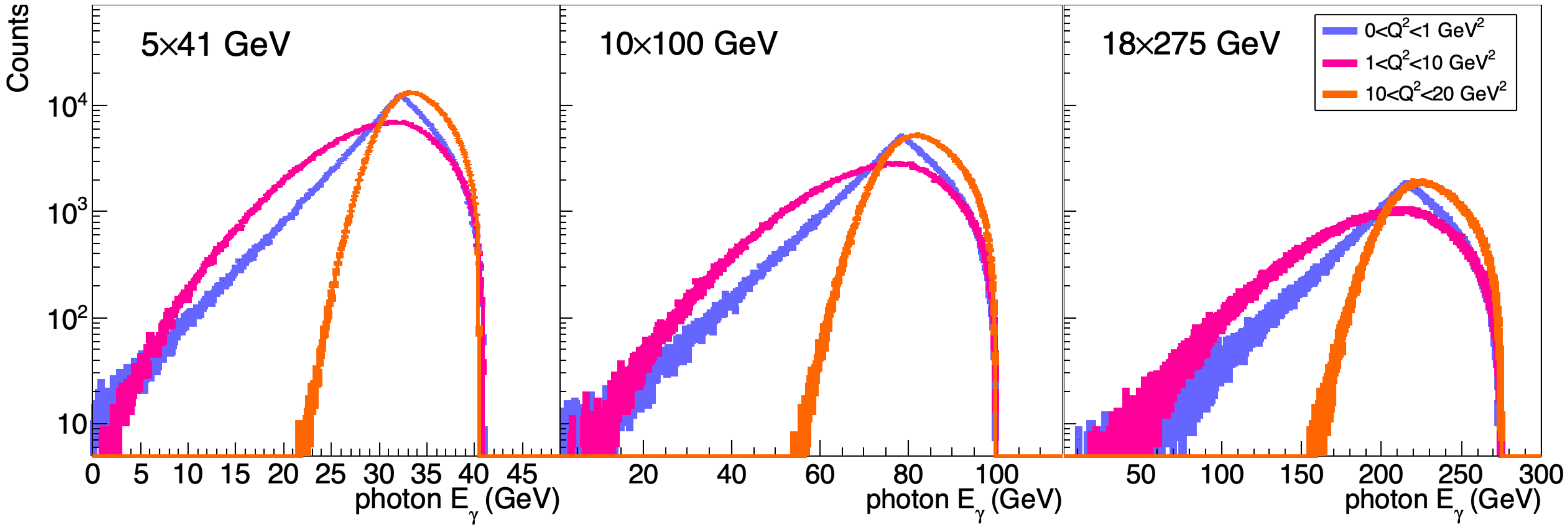
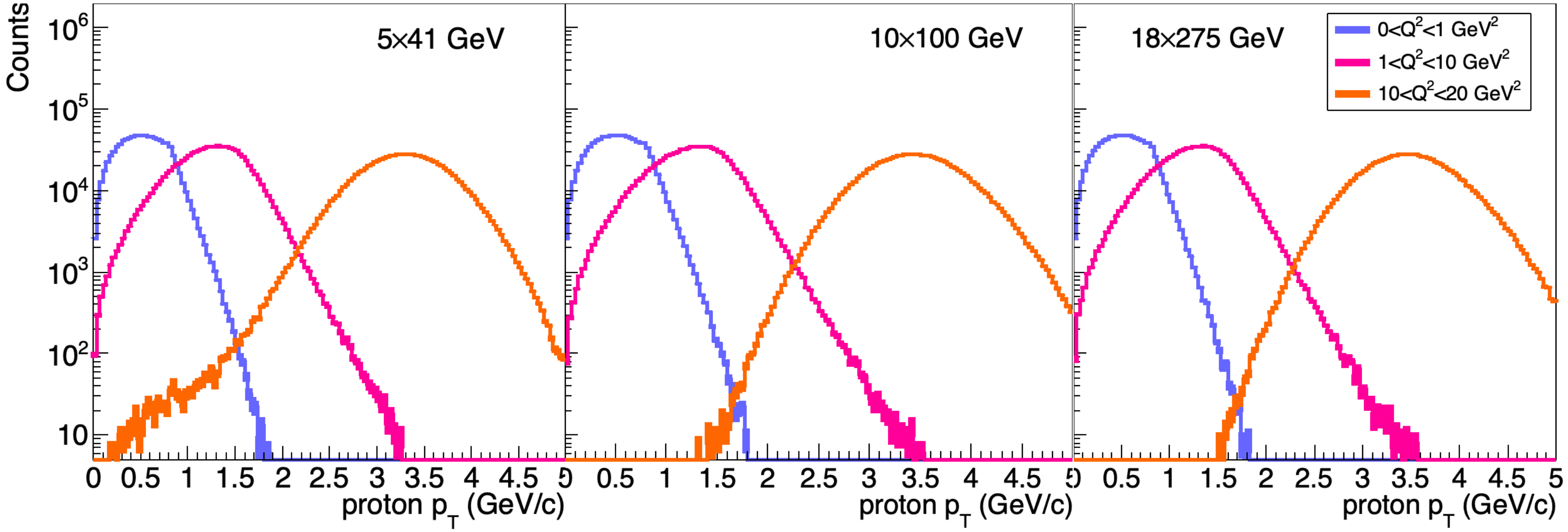


Kinematics of Final-State Particles

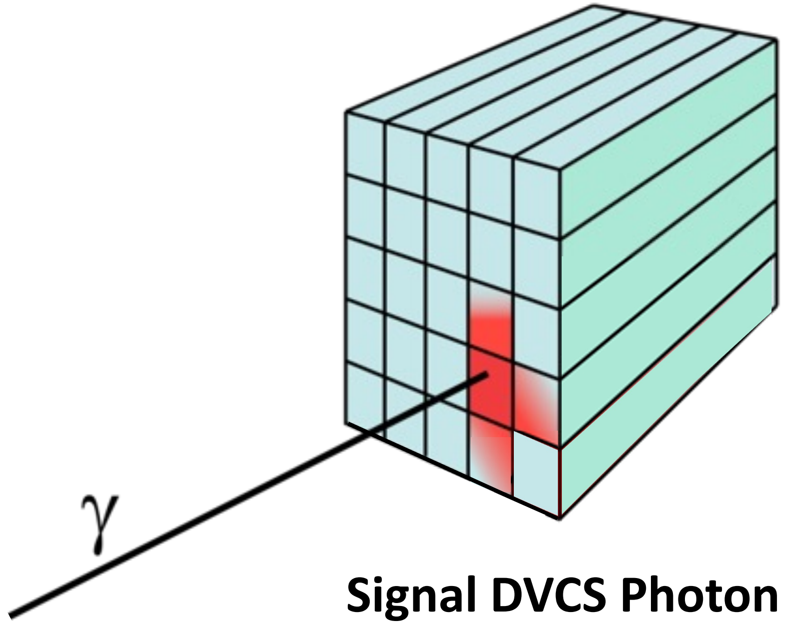
- Final-state photons in B0 and ZDC between 10 and 275 GeV
- Low-Q^2 events have low-pT protons
- Need to focus on detecting these due to large cross section

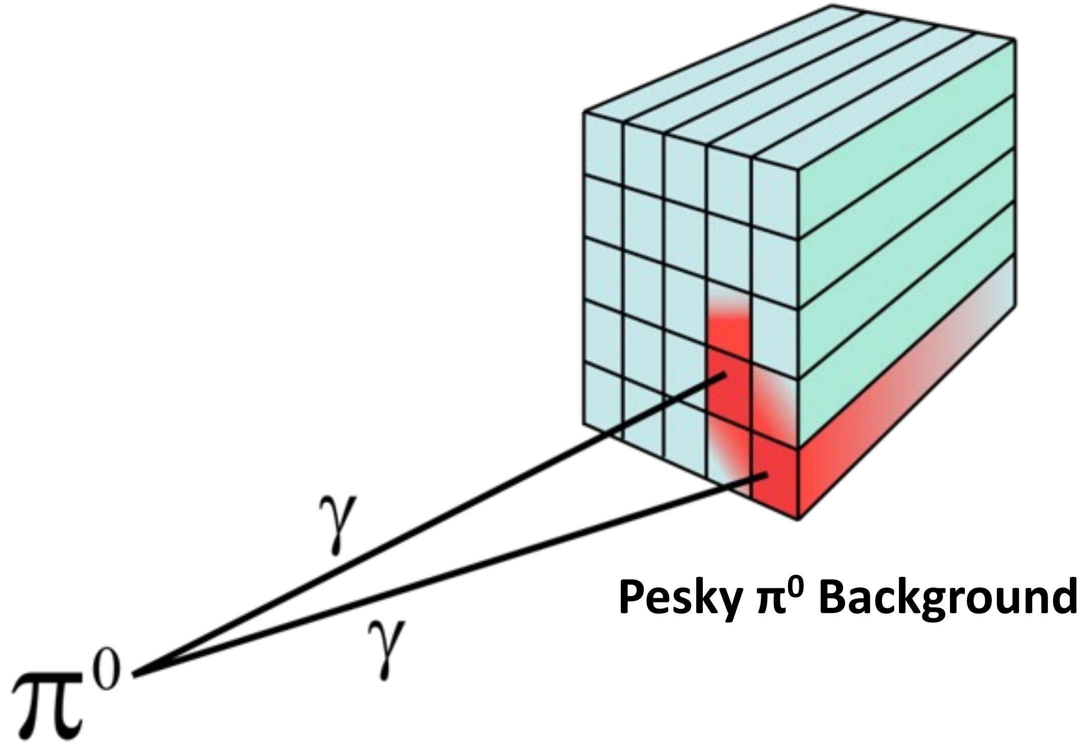




Primary Challenge: π^0 Background

- Backward π^0s expected ~100-1000 stronger than backward CS
- Need to resolve one CS photon from two π^0 photons
- ZDC made of PbWO4 towers with 2cm transverse size
- ZDC ~35m downstream of IP

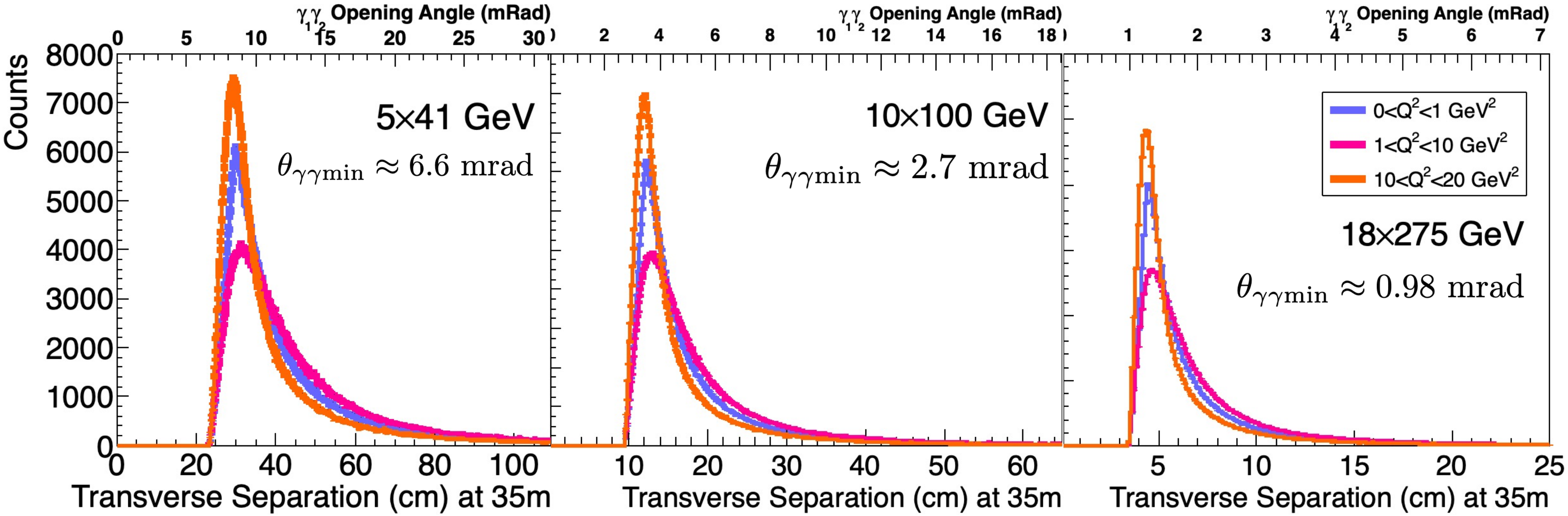




π^0 Background Photon Separation

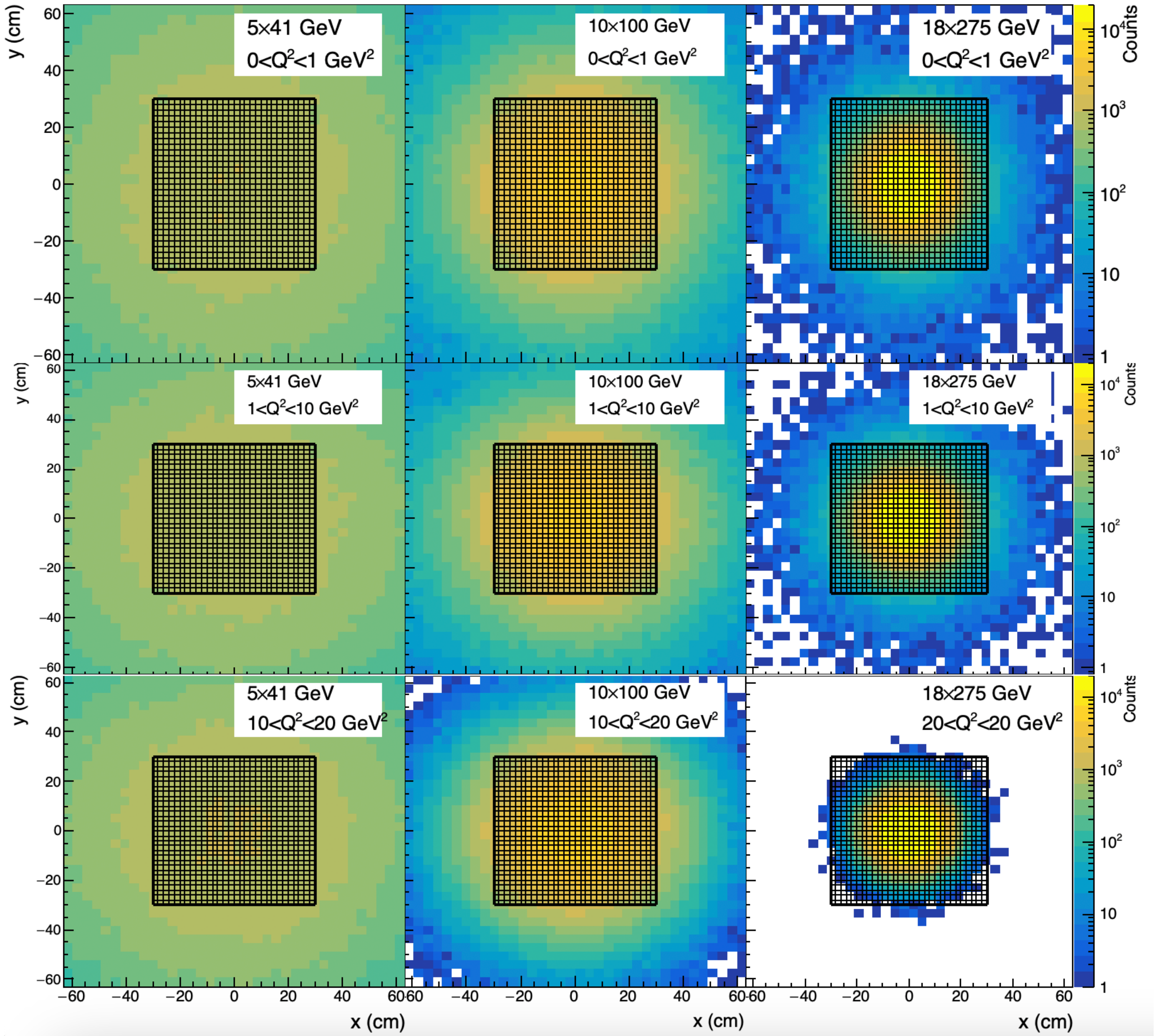
- I generated π^0s with the same kinematics as predicted DVCS photons
- Photons were well-separated
- Photons from π^0s merging in the same tower will not be the main issue

- Theoretical minimum opening angle: $\theta_{\gamma\gamma\text{min}} \approx 2\,\text{arctan}(m_{\pi^0}/E_p)$



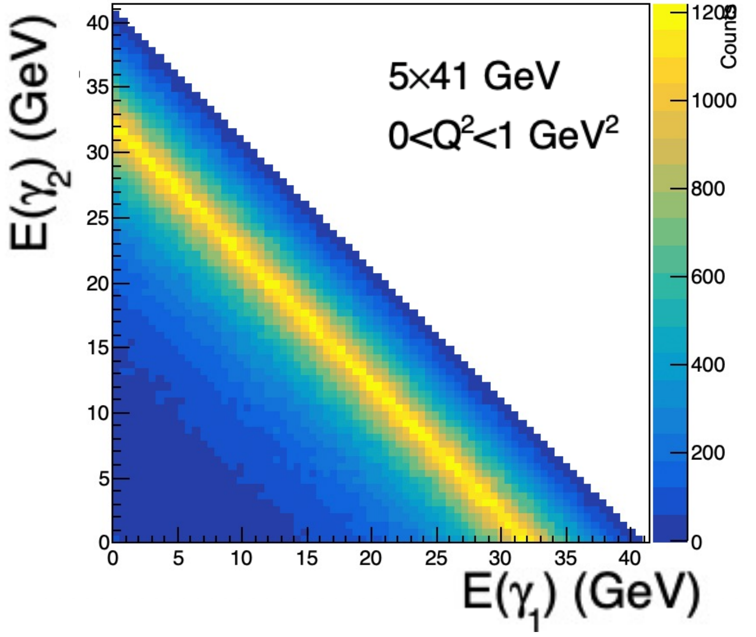
$\pi^0 \rightarrow \gamma\gamma$ CoM Distribution

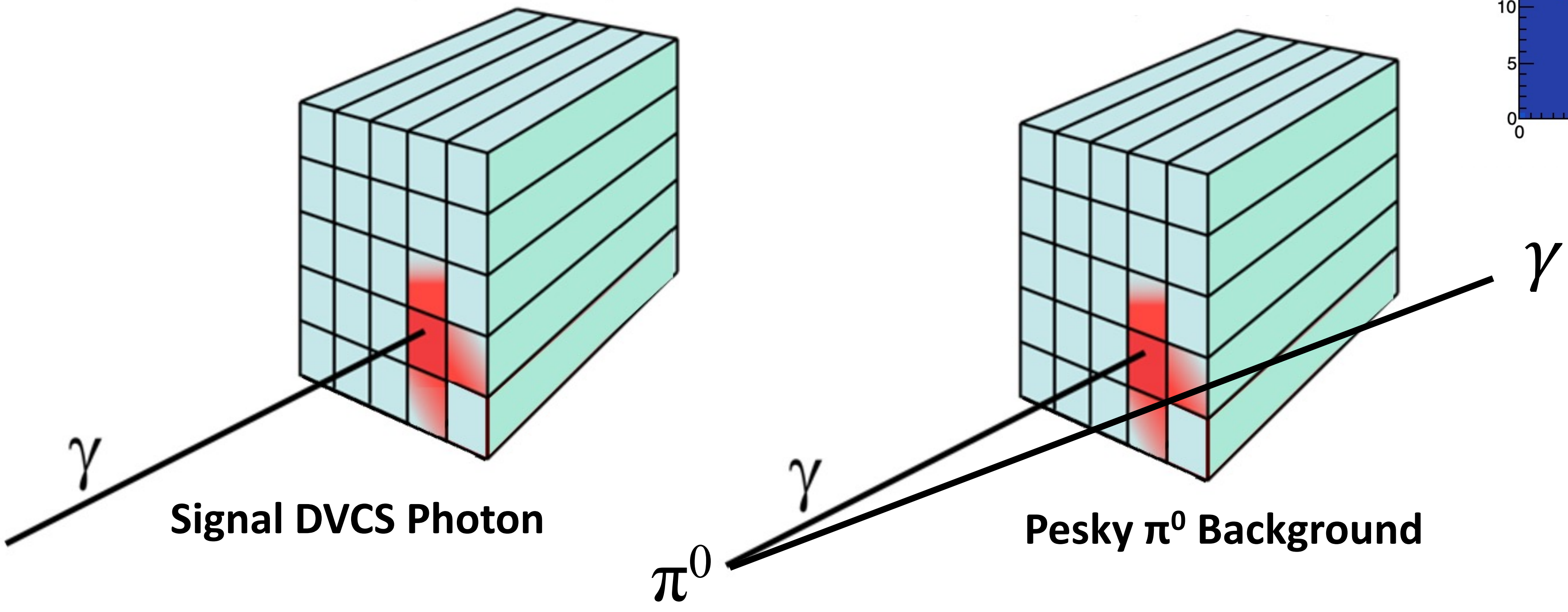
- The figure at right shows CoM distribution of $\gamma\gamma$ pairs from π^0s with the same kinematics as DVCS photons
- Overlaid on 60x60cm ZDC w/ 2x2cm towers
- At low energy and Q^2, the CoM is broad and often misses ZDC
- Taken with the previous slide, this gives an important conclusion



True Cause of $\pi^0 \rightarrow \gamma\gamma$ Background

Conclusion: the background will be dominated by events in which one of the π^0 photons carries most of the energy and the other misses the ZDC entirely. Depending on the high-energy resolution, this may easily be mistaken for backward DVCS. We need full backward π^0 simulations.





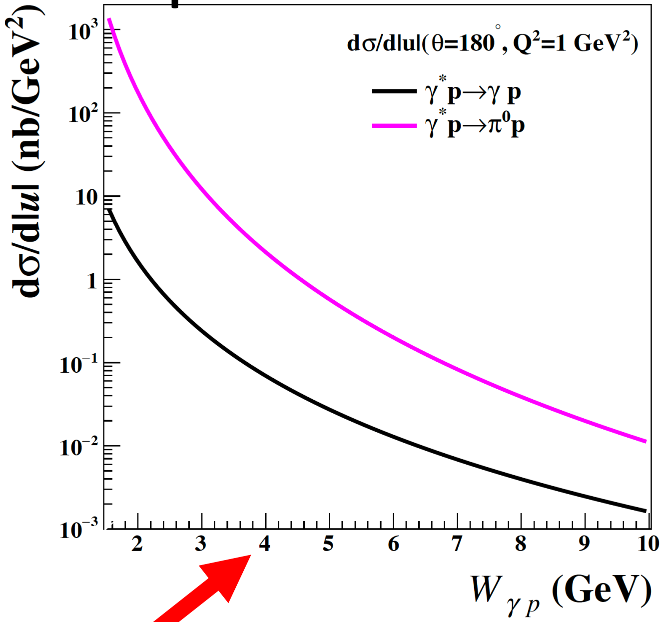
Backward π^0 Model

- Backward π^0 model has similar form

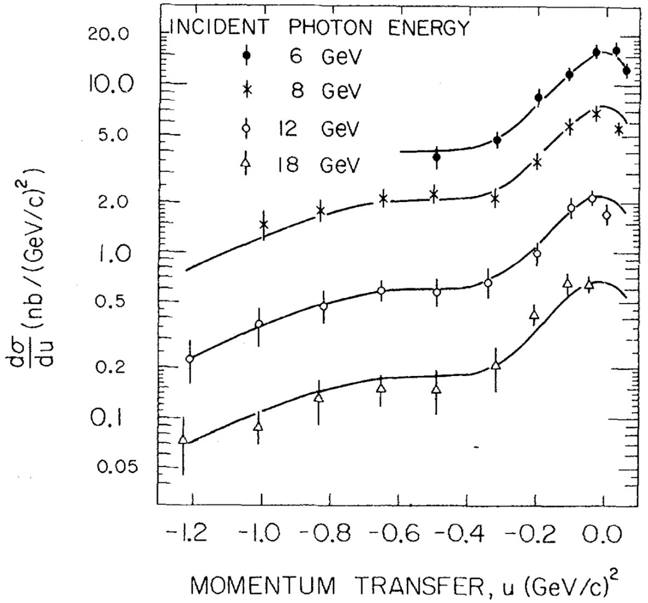
$$\frac{d\sigma}{du}(Q^2, W, u) \approx \frac{A\exp(-D|u-u_0|)}{(W^2-m_p^2)^{2.8}(Q^2+\Lambda^2)^4/\mathrm{GeV}^8}$$

- Q2 scaling of cross section comes from JLab Hall A: https://journals.aps.org/prc/pdf/10.1103/PhysRevC.69.045203
- W and u scalings come from SLAC photoproduction data: https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.23.725

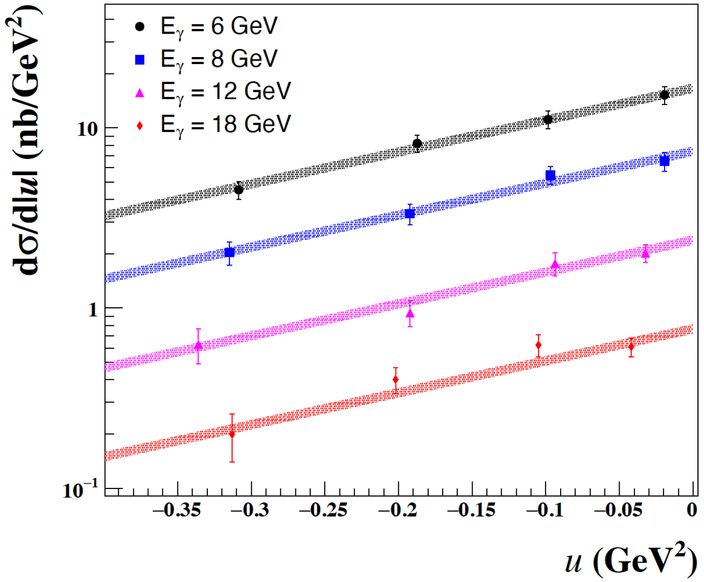
Comparison of cross sections



SLAC Data



Model Comparison



Backward π^0 Simulation Results

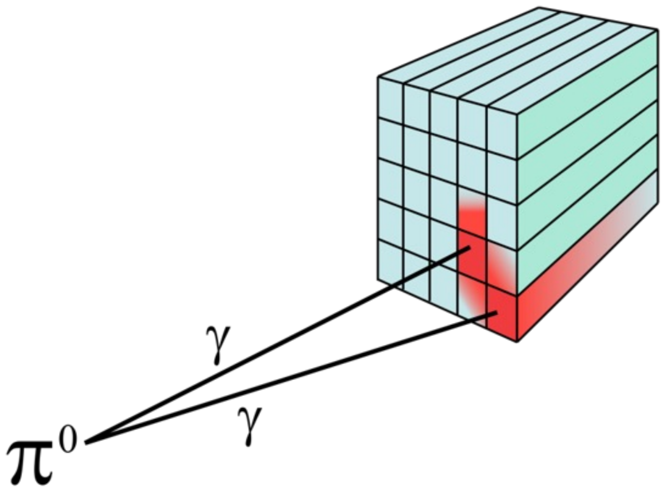
- Remember backward π^0 cross section around 100× larger than backward DVCS cross section

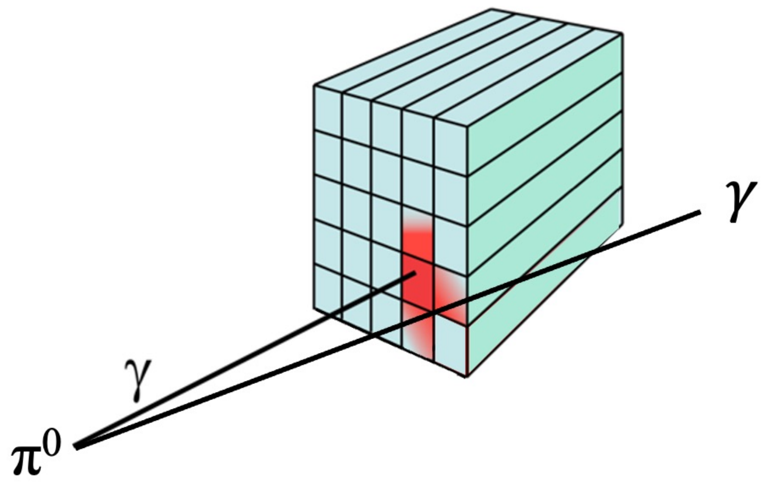
π^0 Both Photons in ZDC Acceptance

	5×41	10×100	18×275
$0<Q^2<1$ GeV^2	13%	72%	99%
$1<Q^2<10$ GeV^2	11%	69%	98%
$10<Q^2<20$ GeV^2	15%	79%	99%

π^0 Single-Photon in ZDC Rates

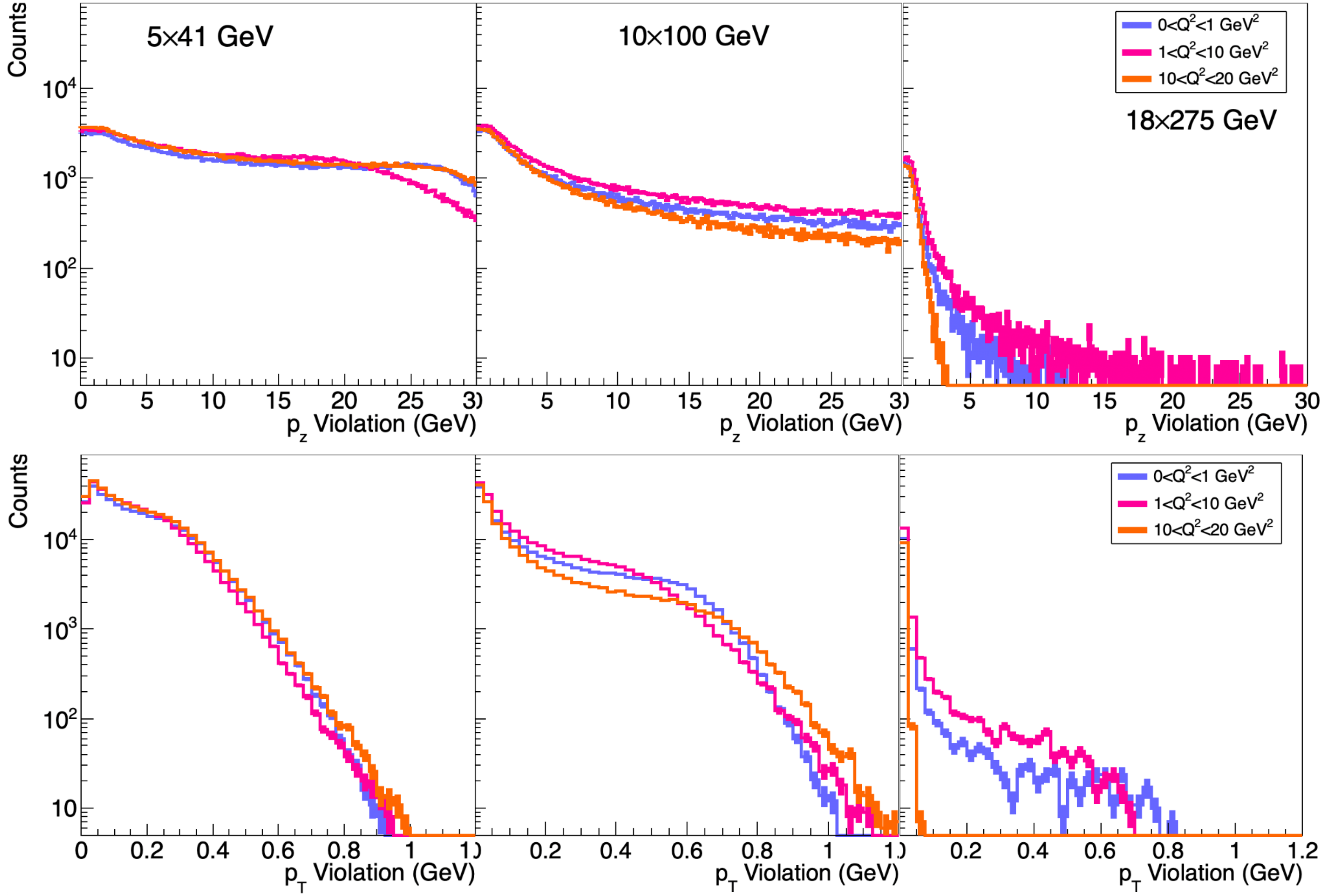
	5×41	10×100	18×275
$0<Q^2<1$ GeV^2	34%	21%	1%
$1<Q^2<10$ GeV^2	35%	24%	2%
$10<Q^2<20$ GeV^2	38%	18%	1%





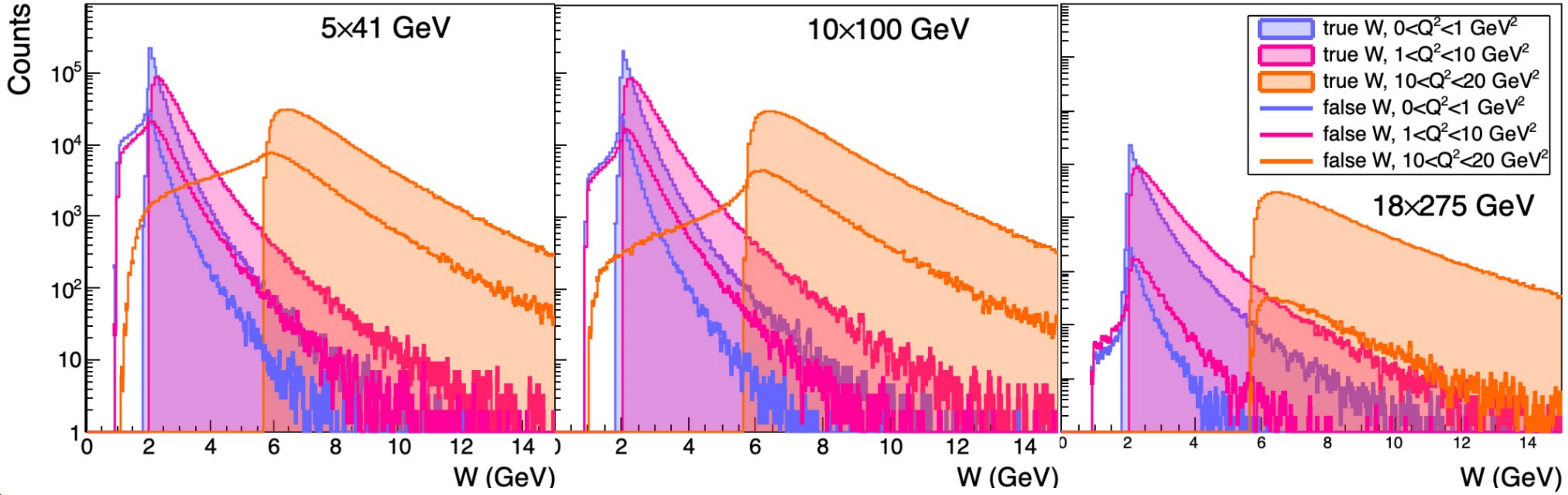
Momentum Non-conservation for Single Hit

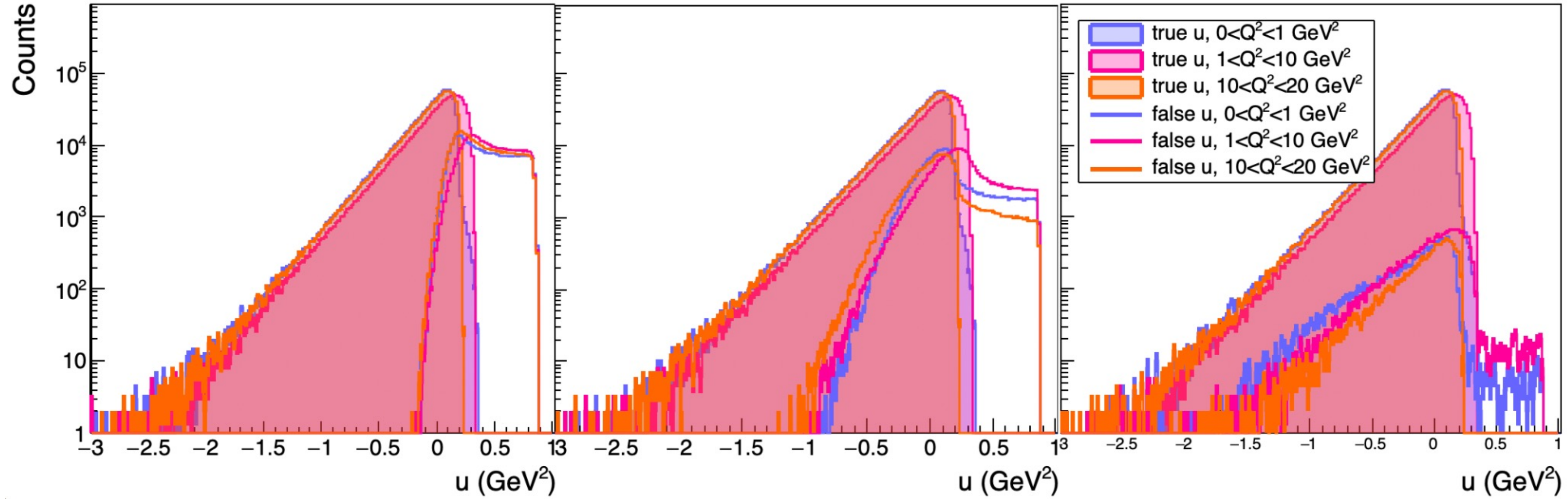
- If we think single-photon from π^0 is actually DVCS, this is amount of non-conservation observed:



Comparison of DVCS Kinematics with False Signal Kinematics

- The following plots are reconstructed kinematics for background and signal events





Conclusions and Outlook

- Early backward DVCS simulations demonstrate importance of B0 and ZDC calorimetry especially for high-energy photons.
- Backward π^0 production will be dominant background
- We've built models of both backward DVCS and π^0 production
- π^0 production will be ~100x stronger than backward DVCS, but will only be mistaken for backward DVCS when only one photon is detected
- In this case, conservation cuts will reduce background
- Detector simulations of both of these processes are crucial, especially in the ZDC
- I plan to submit new samples of DVCS and π^0 production for next simulation campaign

Thank you for your attention!

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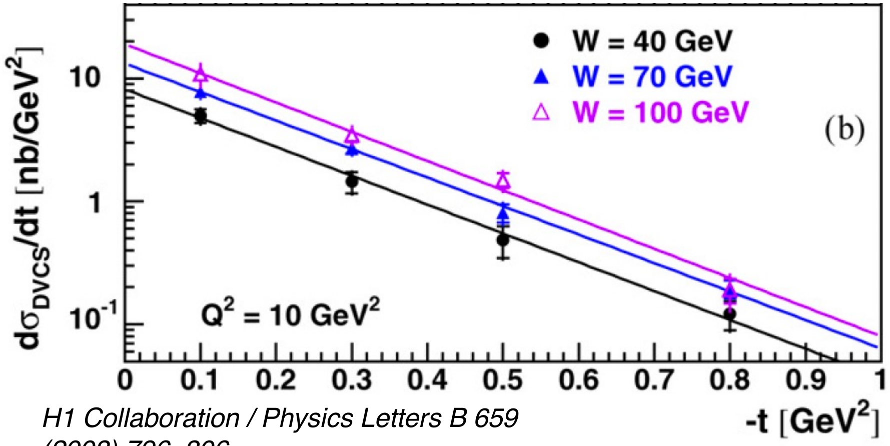
Backup Slides

A u-channel Peak?



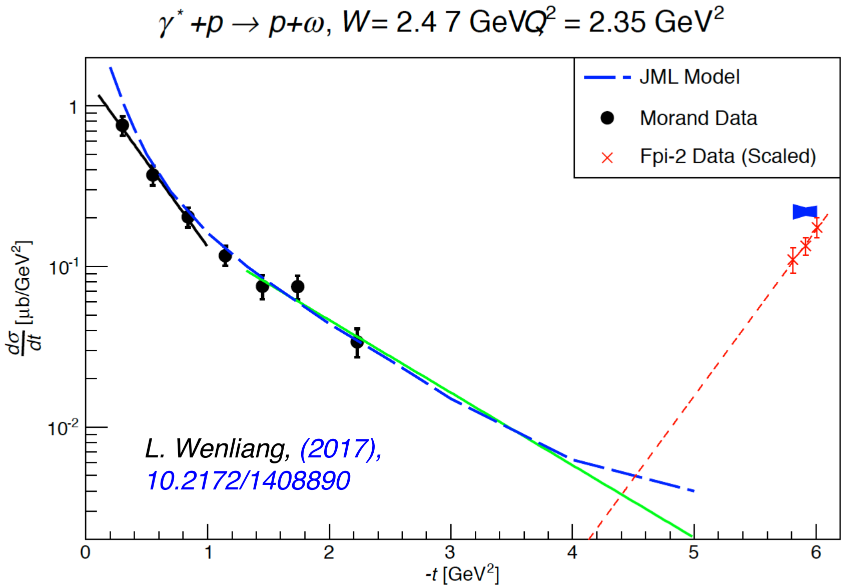
H1 Collaboration / Physics Letters B 659 (2008) 796–806

Typical Description of DVCS cross section

- Cross section at fixed Q^2 and W is typically modeled using an exponential: $e^{-b|t|}$
- This cross section encodes information about the proton GPDs in impact-parameter space
- So why care about cross section at very high $|t|$?

Non-trivial Behavior at High t

- Photon production (CS) cross sections should not be wildly different from vector-meson production
- Cross sections for mesons have exponential drop-off with $|t|$, BUT also an exponential rise at the highest $|t|$ values
- This is from u-channel contributions which may also be expected in (D)VCS



Meaning of u-channel Cross Section

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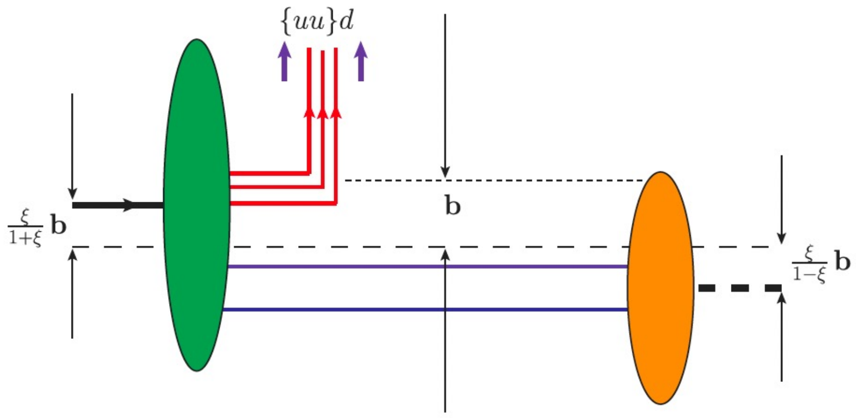

B. Pire, K. Semenov-Tian-Shansky, and L. Szymanowski, Phys. Rept. 940, 1 (2021), arXiv:2103.01079 [hep-ph].

Backward DVCS cross section → partonic correlations and baryon number?

- Forward DVCS maps parton distributions within proton
- Recent (2021) work by Pire et al. works to formulate a similarly meaningful interpretation of the backward cross section
- They argue backward reactions provide access to the location in impact parameter space of di-quark and three-quark (shown at right) clusters

"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."